

# THE ARCTIC AND GLOBAL CHANGE

*Multidisciplinary approach and international efforts  
at Ny-Ålesund, Svalbard*

Proceedings from the Fourth Ny-Ålesund Seminar

Ravello, Italy, 5-6 March 1998

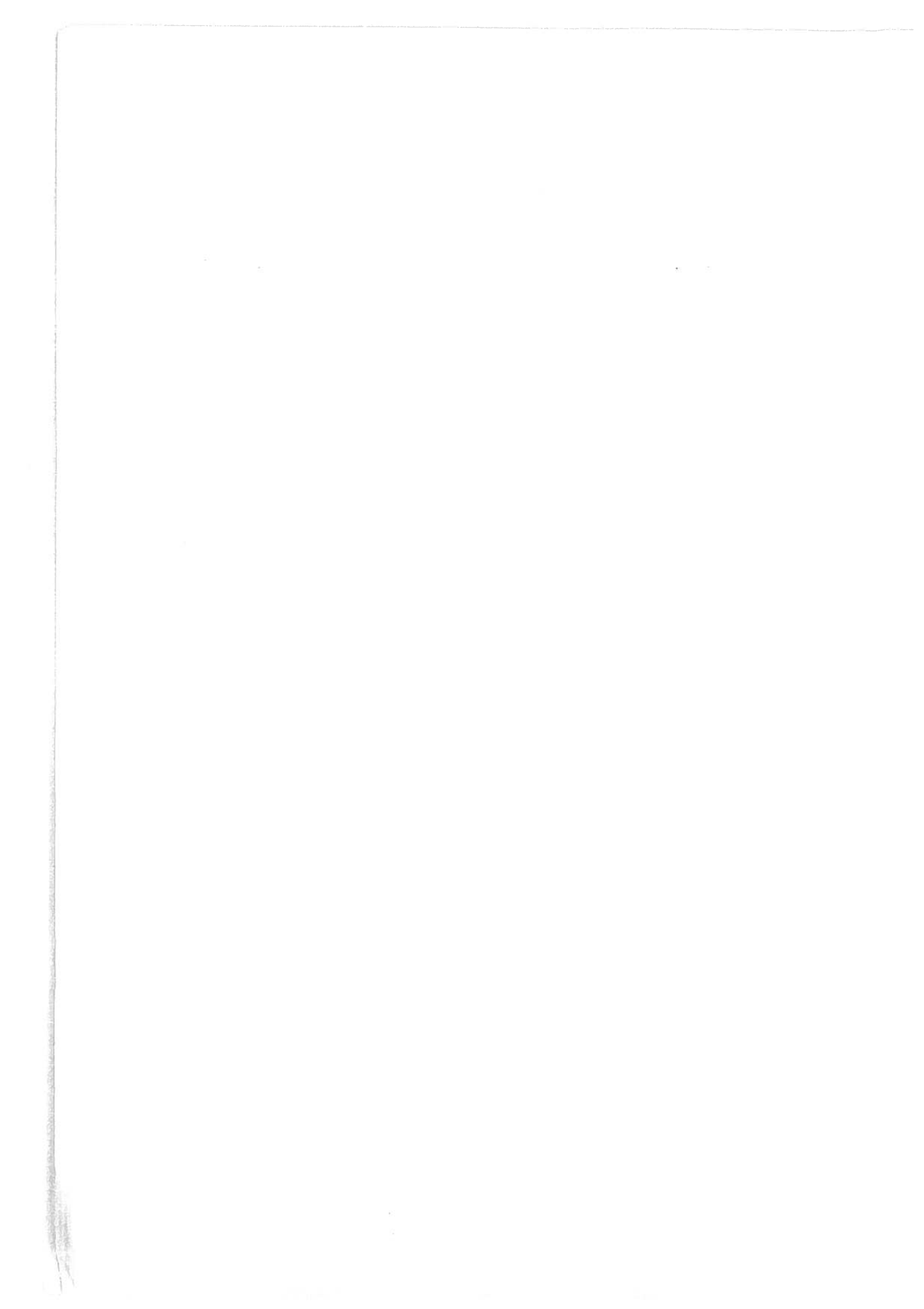
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## Contents

Preface	3
List of oral and <i>poster</i> presentations	5
Atmospheric Science	9
Geophysics and Geodesy	91
Biology and Biodiversity	117
Marine Science	171
Appendix A - Programme	199
Appendix B - List of Participants	205



## Preface

The Ny-Ålesund Seminar Series was conceived by NySMAC (**Ny-Ålesund Science Managers Committee**) as a means of bringing together research scientists involved in programmes running at Ny Ålesund or having an interest in that area. The first Seminar was held in Potsdam, Germany, in May 1995, and included talks which covered all current research disciplines; physical, atmospheric, earth and biological sciences. The Second Seminar was devoted to biological Science and particularly to ecology. It was held in Cambridge in UK in February 1996. The subject of the Third Seminar, held in Kjeller, Norway, April 1997 was atmospheric research in Ny-Ålesund.

The Fourth Seminar, *The Arctic and Global Change - Multidisciplinary approach and international efforts at Ny-Ålesund, Svalbard*, is organised in Ravello, Italy in March 1998. The main purpose of this seminar is to present and discuss the relationships between various scientific fields in the Arctic, for example atmospheric and marine science, biology and biodiversity, climatology, glaciology, geophysics and geodesy. A second main objective is to discuss making the observations at Ny-Ålesund available for comparative studies involving data acquired from other locations and in modelling studies.

Global change research can be carried out more effectively in the polar areas than in most other regions of the Earth. This is due to the remoteness of the polar areas, and their relatively low levels of human impacts. Nevertheless, these regions, and the Arctic in particular, may undergo severe environmental modification due to pollutants in the atmosphere and in the oceans, which are transported from the sub-arctic regions, and due to uncontrolled human exploitation.

With its extreme northern location, good infrastructure and accessibility, the international scientific station at Ny-Ålesund represents a unique opportunity to promote co-operation between research programmes related to the study of global change. Some national programmes have been operating for many years and other nations are developing new arctic research programmes. We believe that a discussion of the results obtained until now will contribute to identify advantages and possibilities to establish new international joint ventures in Ny-Ålesund.

On behalf of the organizing committee:

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## List of oral and poster presentations

### Atmospheric Science

		Page
Allegrini, I., Beine, H.J., Ianniello A., Hillamo R., Masia P., Sparapani R. (LSF)	PHYSICO-CHEMICAL PROPERTIES OF AEROSOLS COLLECTED IN POLAR ATMOSPHERE	11
Allegrini I., Beine H.J., Ianniello A., Sparapani R. (LSF)	A COMPARISON OF NO <sub>2</sub> MEASUREMENTS IN THE ARCTIC	17
Argentini S., Santoleri R., Georgiadis T., Colacino M.	ITALIAN PARTICIPATION IN THE ARTIST PROJECT	21
Beine H.J.	PHOTOCHEMISTRY IN THE ARCTIC TROPOSPHERE	27
Beine H.J., Dahlback A., Ørbæk J.B.	J(NO <sub>2</sub> ) AT NY-ÅLESUND: MEASUREMENTS AND MODEL CALCULATIONS	31
Bojkov B.R., Beine H.J.	ON THE COMPARISON OF OZONE MEASUREMENTS IN THE LOWER TROPOSPHERE	35
Ciccioli P., Brancaleoni E., Frattoni M., Mabilia R.,	OCCURRENCE OF OXYGENATED VOLATILE ORGANIC COMPOUNDS (OVOC) IN THE ARCTIC AND ANTARCTIC REGIONS AND THEIR POSSIBLE RELEVANCE ON OZONE FORMATION	37
Dimmer C., Simmonds P.G., Nickless G. (LSF)	ABUNDANCES AND SOURCES OF LOW MOLECULAR WEIGHT HALOCARBONS MEASURED IN THE ARCTIC TROPOSPHERE	41
Frey S., Steine B., Woste L., Neuber R., Rairoux P. (LSF)	OZONE AND AEROSOL MONITORING IN THE ARCTIC TROPOSPHERE IN NY-ÅLESUND USING LIDAR	45
Gernandt H., Dethloff K., Neuber R., Notholt J., von der Gathen P.	CHEMICAL AND DYNAMICAL ASPECTS OF VARIABILITY AND LONG-TERM CHANGES IN THE ARCTIC STRATOSPHERE	47
Groß C., Tüg H., Hanken T.	UV-B RADIATION MEASUREMENTS AT KOLDEWEY-STATION	51
Hermansen O., Lunder C., Schmidbauer N.	METHANE MEASUREMENTS AT MT. ZEPPELIN	55
Kriews M., Schrems O. (LSF)	ANALYSIS OF CHEMICAL COMPOSITION IN TOTAL DEPOSITION SAMPLES FROM NY-ÅLESUND (SPITSBERGEN)	59
Kriews M., Schrems O. (LSF)	EVENT DEPENDENT AEROSOL SAMPLING IN NY-ÅLESUND	63

<i>Krognes T., Beine H.J.</i>	<i>IN-SITU MEASUREMENTS OF ALKYL NITRATES</i>	67
Moriconi M.L., Rafanelli C., Anav A., Di Menno I., Di Menno M.	UV SOLAR RADIATION AND CLOUDS: EXPERIMENTAL DATA AND MODELLING	71
Perner D.	THE EMISSION OF HALOGENS FROM THE ARCTIC PACK-ICE AND ITS ROLE IN THE TROPOSPHERE FROM MEASUREMENTS AT NY-ÅLESUND AND SÖNDRE STRÖMFJORD	77
<i>Rafanelli C., Ciattaglia L., Anav A., Valenti C., Di Menno M.</i>	<i>POLAR UMKEHR PROFILING DURING THE OZONE HOLE PERIOD</i>	81
<i>Shumilov O., Kasaktina E.A., Raspopov O.M.</i>	<i>SURFACE OZONE IN ARCTIC</i>	85
Shumilov O.I., Kasaktina E.A., Raspopov O.M.	SOLAR PROTONS CREATE OZONE MINIHOLE ABOVE SVALBARD	87
<i>Solberg S., Dye C., Schmidbauer N.</i>	<i>MEASUREMENTS OF VOLATILE ORGANIC COMPOUNDS AT ZEPPELIN MOUNTAIN</i>	89

### **Geophysics and Geodesy**

<i>Kerr A.</i>	<i>ARCICE: THE UK 'ARCTIC ICE AND ENVIRONMENTAL VARIABILITY' PROGRAMME</i>	93
Ørbæk J.B., Hisdal V., Svaasand L. E.	SURFACE RADIATION BUDGET IN NY-ÅLESUND DURING THE PAST TWO DECADES	97
Plag H.P.	GEODETTIC CONTRIBUTIONS TO GLOBAL CHANGE RESEARCH AT NY-ÅLESUND	101
Shumilov O.I., Raspopov O.M., Kasaktina E.A., Dergachev V.A.	GLOBAL TEMPERATURE CHANGES AND SOLAR CYCLES	105
Tomatore V. ( <i>LSF</i> )	THE ROLE OF EXTRAGALACTIC RADIO SOURCE STRUCTURE FOR IMPROVED REFERENCE FRAMES AND GLOBAL CHANGE	107
Winther J-G., Gerland S., Ørbæk J.B., Ivanov B., Blanco A., Boike J.	SPECTRAL REFLECTIVITY AND PHYSICAL PROPERTIES OF SNOW AND SEA ICE NEAR NY-ÅLESUND, SVALBARD	113

### **Biology and Biodiversity**

Alexander I., Madan N., Woodin S., Hogböm L.	THE FATE OF NITROGEN DEPOSITED ON POLAR HEATH AND POLAR DESERT NEAR NY ÅLESUND	119
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Brittain J.E., Lencioni V., Maiolini B.	ARCTIC AND ALPINE STREAM ECOSYSTEM RESEARCH (AASER)	123
Hessen D.O., Ørbæk J.B., Hansen G.D., Hobæk A., Dahlback A., Svenøe T., Stokke K.	EFFECTS OF UV-RADIATION ON ARCTIC FRESHWATER PLANKTON IN NY-ÅLESUND	127
Moyerson B., Alexander I.J., Shand I.	DIVERSITY OF ECTOMYCORRHIZAL MORPHOTYPES ASSOCIATED TO <i>Salix polaris</i> AND <i>Dryas octopetala</i> IN A TUNDRA HEATH NEAR NY-ÅLESUND, SVALBARD	131
Pelliccioni F.	TOWARDS THE NECESSITY OF A NEW "URGENT ANTHROPOLOGY": ARCTIC ANTHROPOLOGY AND THE "NEW" (BUT ANCIENT, BECAUSE TRADITIONAL) ECOLOGICAL INDICATORS	135
Solheim B., Myklebust R., Endal A., Vigstad H.	FACTORS AFFECTING BIOLOGICAL NITROGEN FIXATION BY EPIPHYTIC CYANOBACTERIA IN ARCTIC VEGETATION	143
Svenning M.A., Gullestand N.	THE EFFECTS OF ENVIRONMENTAL CHANGE ON THE LENGTH OF THE MIGRATORY WINDOW OF SPITSBERGEN ARCTIC CHARR.	145
Wängberg S.A., Gustavson K. (LSF)	EFFECTS OF THE AMBIENT UV-B RADIATION ON CARBON DIOXIDE FIXATION AND BACTERIAL ACTIVITY OF MARINE PLANKTON COMMUNITIES IN KUNGSFJORD	149
Widdicombe S., Kendall M.A., Weslawski J.M. (LSF)	BENTHIC BIODIVERSITY STUDIES IN THE KONGSFJORD	151
Woakes A.J., Butler P.J. (LSF)	THE AUTUMN MIGRATION OF BARNACLE GEESE	155
Wookey P.A. (LSF)	IMPACTS OF SVALBARD REINDEER ( <i>Rangifer tarandus platyrhynchus</i> ) ON THE REPRODUCTIVE DEVELOPMENT OF HIGH ARCTIC PLANTS	159
Zuppi C., Forni F., Callà C., Colacicco G., Lippa S., Gozzo M.L., Zappacosta B., Messina I., Giardina B.	DARK-LIGHT SEASONAL CHANGE AND HUMAN OXIDATIVE METABOLISM: PRELIMINARY OBSERVATION AT NY-ÅLESUND	163

## Marine Science

Alabiso G., Scotto V., Montini U., Mollica A., Milillo M.	STAINLESS STEEL CORROSION BEHAVIOUR IN POLAR SEA WATER: PRELIMINARY RESULTS OF SIX-MONTH FIELD TESTS	173
Karsten U., Hanelt D., Bischof K., Tüg H., Brouwer P.E.M., Wiencke C.	ENHANCED ULTRAVIOLET RADIATION OVER THE ARCTIC - WHAT ARE THE CONSEQUENCES FOR THE SEAWEED PHYSIOLOGY AND ECOLOGY ?	177

Lipizzer M., Luchetta A.	WATER MASS EXCHANGES BETWEEN ARCTIC AND ATLANTIC OCEANS: THE VEINS PROJECT	181
Papucci C., Delfanti R., Mordeglia B.	RADIONUCLIDES AS TRACERS OF PARTICLE DYNAMICS IN THE WESTERN SVALBARD MARINE ENVIRONMENT	185
Socal G., Luchetta A., Civitarese G., Owrid G., Nöthing E.M., Wiktor J., Andreassen I., Schauer U., Sörensson F., Strass V.	SPATIAL VARIABILITY OF PHYTOPLANKTON AND NEW PRODUCTION IN THE WATERS AROUND SVALBARD IN RELATION TO HYDROLOGICAL AND NUTRIENT CONDITIONS	193
Degetto S., Tubertini O., Schintu M., Cianchi A.	<i>DETERMINATION OF ATMOSPHERIC FLUXES OF RADIONUCLIDES, HEAVY METAL AND PERSISTENT ORGANIC POLLUTANTS IN WELL DEFINED WATERSHED, LAKES AND COASTAL MARINE SEDIMENTS OF SVALBARD ISLANDS FROM THE BEGINNING OF THE NUCLEAR AGE</i>	197

*Atmospheric Science*



# PHYSICO-CHEMICAL PROPERTIES OF AEROSOLS COLLECTED IN POLAR ATMOSPHERE

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**Abstract.** Measurements of several species in gas phase and in particulate matter were collected at Ny-Alesund, Svalbard Islands, in Spring 1997. Aerosol data were obtained for coarse particles, fine particles and nitrogen and sulphur containing species which are adsorbed on coarse and fine particles. In addition, size distribution of the major species were also determined by means of a low pressure impactor. Chemical properties of particulate matter are presented with a special emphasis to the components which are adsorbed and which can be released into the atmosphere. These species, such as nitrous acid, are able to alter the oxidising properties of the atmosphere

## Introduction

Aerosols in polar troposphere are becoming very important because of the role which they play in the definition of the physical and chemical properties of the troposphere. Radiative transfer and the presence of species relevant for the protection of environment are just trivial examples. Unfortunately, the characterisation of arctic aerosols is far to be satisfactory since it requires accurate, sensitive and reliable analytical methods which need to be employed in severe or extreme environments. In fact, the species present on particulate matter in remote sites have extremely low concentrations so that most of the analytical methods which have been developed and employed for their measurement are not very suitable for use in polar regions.

Recently, the use of annular denuders (Diffusion denuders), which allows the precise and accurate measurement of several species in aerosol phase with a sensitivity level approaching few tens of nanograms per cubic meter, was found to be a major step toward the measurement of arctic airborne particles, especially for inorganic components. In fact, the aerosols can be easily separated by the components in gas phase, avoiding the mutual interference which, in most cases, prevent the practical use of aerosol oriented analytical techniques. The use of this technique in Antarctica provided new and interesting information about the occurrence of nitrogen and sulphur containing species and about their size distribution. However, data obtained in Antarctica did not cover an extensive set of species and are far to be complete.

In this paper we are reporting the first extensive set of data related to measurements of particulate matter and gas phase components ever collected in polar sites and are demonstrating the great potential of the denuder technique toward the solution of important scientific issues relevant to studies of the aerosols in polar troposphere.

## Experimental

Sampling was carried out at Zeppelin Station near Ny-Alesund, Svalbard Islands (78°54'29" N, 11°52'53" E, 474 m. a.s.l.) for a duration of 24 and 12 hours from May 27th to June 12th, 1997.

The sampling train consists of a combination of annular denuders and filter pack. Air passes through two denuders coated with Sodium Fluoride where strong acids (HCl and HNO<sub>3</sub>) are collected, and through two Sodium carbonate coated denuders where weak acids, including HNO<sub>2</sub> and SO<sub>2</sub> are collected. After the alkaline denuders, air passes through a citric acid coated denuder which removes ammonia in gas phase. The sampling flow rate (12 L/min) ensure collection efficiencies for those gas-phase components very close to 98%. After the denuders, the air passes through a Cyclone having a cut off of 2.5 µm where coarse particles are removed and through another sodium carbonate denuders which collects weak acids desorbed from the material collected on the cyclone. Then air is filtered in a filter pack. This included a 47-mm Teflon filter for the collection of particles, a Nylon filter for the collection of nitric acid and hydrochloric acid evaporated from the front filter and two sodium carbonate-glycerol impregnated paper filter (Whatman 41) for the collection of nitrous acid and sulphur dioxide released from particles. Therefore, the sampling train gives the concentration of almost all the species responsible for acid deposition with a very high analytical sensitivity and free from mutual interferences.

Denuder lines were sampled by means of an electronic sampler which ensure high precision and accuracy while the lines were accommodated in a properly box at controlled temperature. After sampling all the denuders, cyclones and filters were extracted with appropriate aqueous solutions and their ionic content analysed by ion chromatography. Analysis was carried out as soon as possible after extraction. When this was not possible samples were stored at 4°C. The detection limit for most of the species of interest was within few tens of µg/m<sup>3</sup>. Quality assurance in the sampling line was carried out through a parallel line which was intended for the collection of nitrogen dioxide and Nitrogen (V) containing compounds (F. De Santis *et al.*, 1996). Since the second line also included the same cyclone-filter pack configuration, it was possible to compare the aerosol content of the two sampling lines.

Aerosols were also collected on a low pressure impactor operating at 12 L/min. The impactor is characterised by 12 impaction stages from 0.035 to 15 µm. After sampling, the impaction surfaces were analysed using the same procedures used for the filters.

Parallel measurements were carried out during the campaign. They were mainly concerned with automatic measurements with a chemiluminescence NO<sub>x</sub> analyser, ozone and meteorological parameters. During the campaign, it was possible to identify periods characterised by Southerly flows and periods with Northerly flows with different concentration of species. In addition, an event of tropospheric ozone depletion was also observed.

## Results and discussion

The Denuder/Filter pack and impactor data obtained during the campaign were very high, so that a comprehensive presentation will require time and space which may be provided only by splitting the data into several individual papers. However, a general presentation might be attempted taking into account for the information that the technique is able to provide in the scientific issues related to global change.

Size distribution: Size distribution of Sulphates and Nitrates is not very different from those observed in other polar sites. Two modes for sulphates are observed located at 0.3-0.4 µm and at 8-9 µm respectively. A third mode at 0.05 µm, observed in Mediterranean sites and assigned to photochemically produced sulphates was not evidenced. Nitrate yields a very distinct mode at 4 µm indicating a surface distribution on particles caused by the interaction of sea salt chloride with nitrogen containing reactive gases (NO<sub>2</sub> and HNO<sub>3</sub>). Very little nitrate was found in the low size region due to irreversible losses of nitrate in the impactor body (R. Hillamo *et al.*, 1995). This result is consistent with that found in Antarctica. Results from

Sodium and Chloride indicate that coarse sulphate particles are from marine spray. The comparison between fine and coarse particles measured in the impactor and in the denuder line was found very similar for sulphates. Nitrates show a much higher content in the denuder line. The agreement of the sulphate measurements in the impactor and in the denuder line is a further indication of the data quality assurance.

The size distribution of ammonium is consistent with that of sulphates indicating that the sulphate aerosol in the fine particle region is mainly composed of sulphuric acid or ammonium bisulphate (P. Masia *et al.*, 1997).

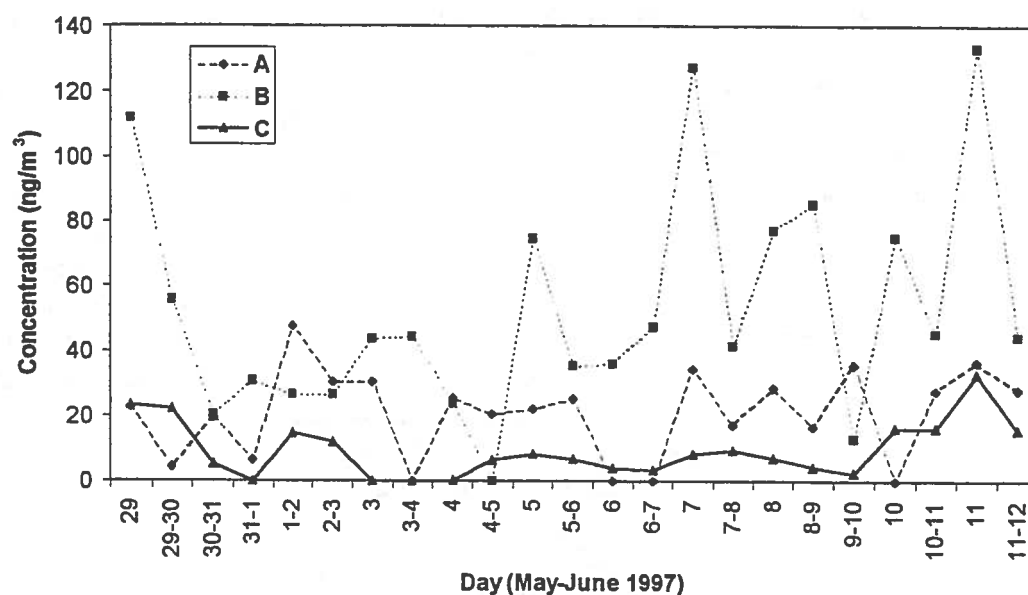


Figure 1. Nitrites measured at Ny-Alesund by means of Annular Denuders/Filter Pack. A: Gas-Phase nitrous acid, B: Nitrous Acid desorbed by fine particulate matter, C: Nitrous acid desorbed by coarse particles.

Adsorbed species: As said before, the sampling line allows the measurement of acidic gas adsorbed in the coarse particles fraction. Sulphates and Nitrites being the most abundant species found after the cyclone. The sources of this species is largely unknown. Since most of the coarse particles are from sea-spray, it is possible that its alkaline properties are responsible for the irreversible absorption of strong acids (as nitric acid) and for the reversible absorption of weak acids such as sulphur dioxide and nitrous acid. It is remarkable that the amount of sulphur found in adsorbed phase is of the same order of magnitude of that found in gas phase or in the fine particle region. This result may be important for the calculation of sulphur budget.

The presence of nitrites on coarse particulate matter is also extremely important. In fact, desorption of nitrites gives out nitrous acid which is rapidly photolysed to NO and OH radicals. This mechanism may be responsible for the long range transport of NO<sub>x</sub> into polar regions, thus contributing to changes into the oxidising capacity of the atmosphere. The amount of nitrites on coarse particles is relatively high and the source for its formation is possibly the heterogeneous reaction between nitrogen dioxide and water. This reaction,

evidenced in urban areas where the amount of nitrogen dioxide is very high, also yields nitric acid which may partly explain the occurrence of nitrate ions in the high particle size range.

Fine particles: Measurements of fine particles by means of the combination Denuders/Filter pack, are very accurate because reactive gases and coarse particles are removed before the filter. Fine particles are composed, as said before, of sulphates which are present as sulphuric acid or as ammonium bisulphate. Nitrates are also present although most of them are found in the back-up nylon filter. The source of evaporated particulate is not known. The hypothesis that it is from ammonium nitrate evaporated from the filter is not supported by any evidence. However, if the pH of particulate is very low, it is possible the formation of  $\text{NO}_2^+$  ions which are in equilibrium with gas phase nitric acid (Shao-Meng Li, 1994). The origin of nitrates in particulate matter is still matter of investigation and will be the subject of a specific campaign which needs to be carried out in the near future.

Nitrites also were found as released species from particulate matter and, in several instance, they were also evidenced in particulate collected in the first front filter. The observation that nitrites are in particulate phase is not new. The source for nitrites in particulate matter may be ascribed to the direct dissolution of nitrous acid into acidic particles giving nitrosonium ( $\text{NO}^+$ ) ions or to the heterogeneous reaction of nitrogen dioxide on acid particles. At increasing pH, the nitrosonium ion may retro dissociate to yield nitrous acid. This mechanism does not require the addition of any alkaline material, since the trivial addition of water, do to increased humidity conditions, may cause the desorption of Nitrous acid. It is remarkable the observation that the amount of nitrous acid associated to particulate matter is similar, and very often higher, of the nitrous acid available in gas phase, even though the radiation intensity was high. In conclusion, as a function of the physico-chemical evolution of particulate matter, it is possible to postulate the injection of nitrous acid in the polar environment, thereby affecting the oxidising properties of polar troposphere (I. Allegrini *et al.*, 1997). A more detailed study about the equilibrium between sulphuric acid, nitric acid and nitrous acid is strongly advised and additional experimental field tests may shed some light into this interesting field. Figure 1 shows some data relevant to nitrites collected on the annular denuder sampling train.

## Conclusions

The combination of a low pressure impactor and a denuder/filter pack sampling line offers great opportunities to study the physico-chemical properties of particulate matter with precision, accuracy and reliability. The information gathered from the Ny-Alesund 1997 campaign are extremely useful for the assessment of budgets for sulphur and nitrogen containing compounds, for the study of the physico-chemical properties of the atmosphere and, finally, to interpret changes into the oxidising capacity of the atmosphere. Future campaigns are planned in order to extend the range of compounds which have been measured and for test in the field hypothesis about the occurrence of species in gas phase and particulate matter relevant to polar atmospheric chemistry.

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# A comparison of NO<sub>2</sub> measurements in the Arctic

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**Abstract.** Measurements of NO<sub>2</sub> were carried out for 10 days during spring 1997 at the Zeppelin station near Ny-Aalesund using two independent methods; a chemiluminescence and a denuder system. The concentrations found during this period were between 20 and 100 ng/m<sup>3</sup> NO<sub>2</sub>. The means of all data from the two methods were identical at the 99% confidence level.

## Introduction

Measurements of NO<sub>2</sub> in the Arctic are rare. The only previous measurements during the Arctic winter-spring transition were made by *Beine et al.* [1996] during 1994 using high-sensitivity chemiluminescence. They reported a mean background NO<sub>2</sub> mixing ratio of 26 pmol/mol.

Recent advances with carbon denuders [*De Santis et al.*, 1996] have led to the development of a reliable time averaging technique for NO<sub>2</sub>. Results from these denuders are here compared to NO<sub>2</sub> measurements made with a commercial Cranox system. This system is based on chemiluminescence, however, detection limits appropriate for the low mixing ratios expected in the Arctic can only be achieved through time-averaging.

## Instrumental

Measurements of NO<sub>2</sub> were carried out at NILU's atmospheric research station on Zeppelin mountain, near Ny-Aalesund, Svalbard. In addition to NO<sub>2</sub>, NILU measures continuously ozone, meteorology, and other parameters at the Zeppelin station.

Measurements of NO<sub>2</sub> were made with two independent methods; a.) by NILU as NO following UV broadband photolysis with a Xe-arc lamp using a chemiluminescence NO-analyzer (Cranox), and b.) by CNR-IIA as NO<sub>2</sub> using an annular diffusion denuder system with an alkaline carbon surface.

The Cranox system is calibrated daily using a 5 ppmv standard, the average sensitivities for NO and NO<sub>2</sub> were 220 and 175 counts per second/nmol mol<sup>-1</sup>, respectively. The 3- $\sigma$  detection limits for a 12-hour sampling interval were 4 and 6 pmol mol<sup>-1</sup>. However, NO artifacts of the same order of magnitude were observed, so that the method detection limit (3- $\sigma$ ) is determined as about 15 pmol/mol for NO<sub>2</sub>. The Cranox reports results as mixing ratio, for the purpose of this comparison the data have been converted to ng/m<sup>3</sup>.

NO<sub>2</sub> on the denuder walls yields the nitrite ion, which is analyzed by ion chromatography. The method detection limit is better than 50 pmol/mol. The sampling lines were placed in a temperature controlled housing, which was operated by a microprocessor controlled automatic sampler. The accuracy and the precision of the method were assessed as 1-3%, and better than 0.5%, respectively.

## Results

Table 1a. Results from the Cranox

Table 1b. Results from the Denuder

sample	start DOY	end DOY	n [hours]	NO <sub>2</sub> [ng/m <sup>3</sup> ]	95% confidence interval [ng/m <sup>3</sup> ]	NO <sub>2</sub> [ng/m <sup>3</sup> ]
				Cranox		Denuder
1	147.9	148.2	5:30	20.13	20.2	29.85
2	148.5	149.4	18:18	22.41	13.2	27.54
3	149.4	149.9	12:00	19.26	17.5	73.91*
4	149.9	150.4	11:55	26.21	17.1	12.20
5	150.5	150.9	22:57	60.73	30.9	60.24
6	151.7	152.4	22:25	36.50	39.6	109.61
7	152.5	153.4	23:02	94.47	64.1	170.92
8	153.4	154.4	23:29	38.27	30.2	36.32
9	154.4	154.9	11:55	12.29	15.8	31.53
10	154.9	155.4	11:55	14.52	14.7	41.53
11	155.4	155.9	12:00	22.26	17.1	31.05
12	155.9	156.4	12:00	60.41	77.3	68.93
13	156.5	156.9	11:00	15.33	16.3	34.98
14	156.9	157.4	12:00	7.06	14.1	32.32

\* Sampling problems were encountered with the denuder due to snowstorms.

The relatively wide spread of the data, as expressed in the 95% confidence interval, is not generated by instrumental uncertainty, but by several short episodes of increased NO<sub>x</sub> mixing ratios. These episodes, where NO<sub>x</sub> spikes up to several 100 pptv's are likely to occur from local contamination from the small settlement of Ny-Aalesund. Similar events were observed and documented before [Beine *et al.*, 1996]. Since both methods measure the same air mass, also the denuders see concentrations that are increased above the true background of NO<sub>x</sub> in the Arctic. However, a time averaging method can not assess the spread of the data.

Based on meteorology, two main flow episodes were identified at Zeppelin during our measurement period; 1.) with southerly flow, starting on May 26, 1997 at 18:55 (DOY 146.79), ending June 1, 1997 at 23:00 (DOY 152.96), and 2.) northerly flow, starting June 1, at 23:10, ending June 6, 11:00 (DOY 152.97 - 157.46). Thus, samples 1 - 6 were obtained during southerly flow, the airflow changed during sample 7, and samples 8-14 were collected during northerly flow. Sample 6 was not included in the comparison, since the Cranox stopped working during this period.

Table 2. Results during the two flow periods

	mean NO <sub>2</sub> [ng/m <sup>3</sup> ] Cranox	s.d.	n	mean NO <sub>2</sub> [ng/m <sup>3</sup> ] Denuder	s.d.	pooled variance	99% uncertainty	observed difference
all data (except samples 6 & 7)	26.5	17.6	12	54.4	41.9	86.0	33.2	27.8
southerly flow (samples 1 - 5)	29.7	17.5	5	40.7	25.4	95.4	31.9	11.0
northerly flow (samples 8 - 14)	24.3	18.8	7	39.5	13.5	38.2	18.9	15.2

Using Theil's non-parametric regression, a linear relationship can be calculated as  $\text{NO}_2(\text{denuder}) = 25.13 + 0.52 \text{NO}_2(\text{Cranox})$ . However, table 2 shows the results of a paired t-test; the mean  $\text{NO}_2$  concentrations measured by the two methods were identical at the 99% level. This is true for the entire data set, as well as for the two flow periods that were identified.

### Conclusion

Results of both methods show  $\text{NO}_2$  concentrations close to the respective detection limits, well below the respective limits of quantification. Even though there is a systematic difference between the methods, as expressed in the linear relationship, the results agree on the 99% confidence level. Individual spikes were seen with the Cranox, and thus an assessment of the atmosphere's variability at Zeppelin is possible. We are confident that either method, the denuder and the Cranox, can be used to measure time averages of  $\text{NO}_2$  in the Arctic. Future campaigns will be carried out to refine the denuder system.

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## Italian participation in the ARTIST project

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In the frame of the EU Program on "Environment and Climate" the Project ARTIST (Arctic Radiation and Turbulence Interaction Study) has been proposed and supported by a three years financial grant.

The project, coordinated by A. Wegener Institute (Germany), includes the following partners: Institute FISBAT (CNR-Italy); Finnish Institute for Marine Research (Finland); Remote Sensing Consult (Denmark), Istituto di Fisica dell'Atmosfera (CNR-Italy); Institute of Atmospheric Physics (GKSS-Germany).

The main objective of the research is twofold: i) "to obtain an improved understanding of the radiation and thermodynamic interaction of Arctic clouds and sea ice" and ii) "to derive optimized physical parametrizations for improved models of the Arctic Climate System". In order to reach these goals the project is arranged on five Work packages :

- Arctic field studies;
- Analysis of field data;
- Analysis of satellite data;
- Derivation of parametrizations;
- Process modeling.

Italian research groups are inserted in all the items with exception of the modeling one. In particular the core of the Arctic field studies is represented by a experimental survey, that will be carried out during the next spring for a five week period aimed to collect radiative and meteorological data, both over sea and ground by means of aircraft and ground based equipment. The survey will give the possibility to realize the data base necessary i) to analyze the effect of clouds, haze and sea ice on the radiative fluxes both at ground and in atmosphere and ii) to study the dynamics of the PBL and the exchange of heat, momentum and water vapor in Arctic. To support the above activities observations from satellite will be effected both to monitorize the cloudiness and sea ice over the analyzed area and to evaluate the radiation budget at the air-ground interface. The aircraft, taking off from Longyearbyen (Svalbard) and Station Nord (Greenland), will fly over the Arctic ocean in the region, going from 290° long.W to 50° long E and between 72° and 85° lat N (fig.1).

While aircraft measurements will be effected by German researchers, the ground based measurements are entrusted all to Italian participants and will be carried out installing the instrumentation near the Italian Arctic base of Ny-Alesund.

The measurements by ground equipment foresee two different activities: the first one concerns the use of an equipped mast to collect data on the turbulent fluxes in the surface layer and the second one is instead devoted to make measurements by a Sodar in order to characterize the dynamical and thermal properties of the PBL.

The local flows and consequently the interaction between the different components of the environmental system are mainly driven by the energy partition at the surface. This is triggered by the cloud coverage, the synoptic features and the structure

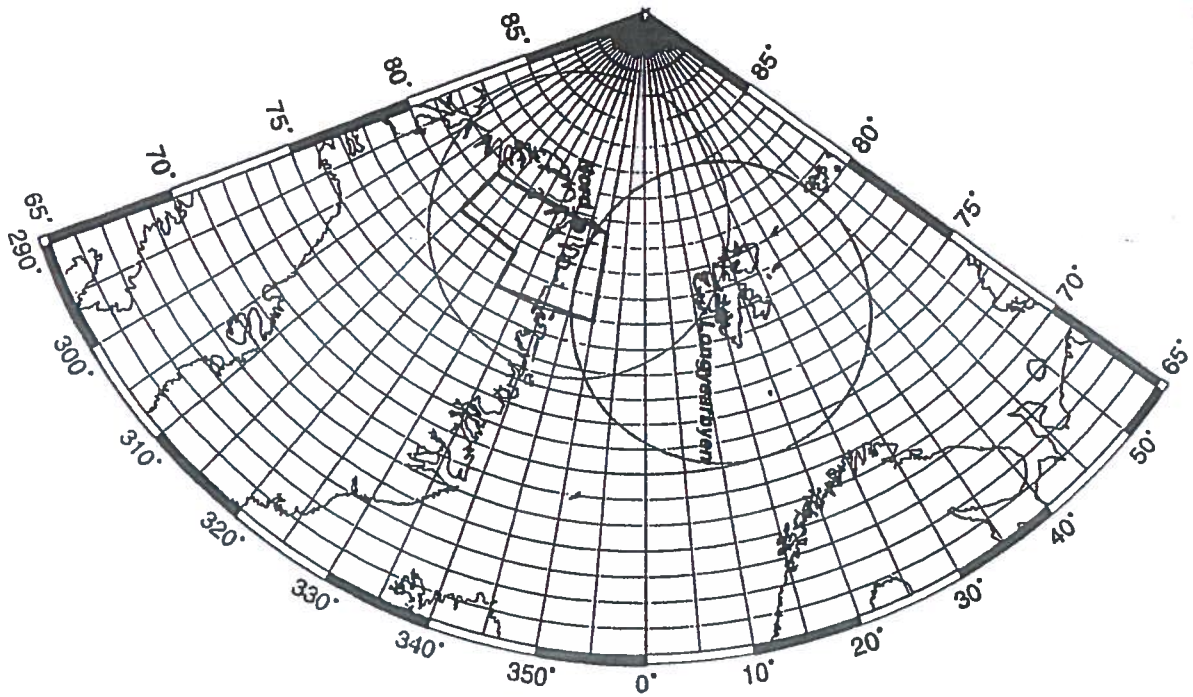


Figure : Operational regions of the aircraft from the airports at Longyearbyen and Station Nord. The aircraft can reach any point within the circle and perform additional flight patterns of at least 1-2 hours duration.

and evolution of planetary boundary layer. The parametrisation of surface turbulence assumes a relevant importance in the energy balance of polar regions, because the present day formulations obtained in presence of strong atmospheric stability are poorly accurate. The surface measurements provide important information on the lowest meters of the atmosphere, while the acoustic remote sensing gives the characteristics of the atmospheric layer up an height of about 800÷1000m.

In addition the determination of some local situations at the surface, by means of specific case studies, can be extended to a large part of territory utilizing the measurements obtained contemporary by satellites and aircraft. It could then possible to define the behavior of the whole system (atmosphere-ground-ocean) on a regional scale.

A radiometric station (Kipp and Zonen mod. CNR1), able to furnish the solar energy partition into long- and short-wave, and a station (S&T METEOFLUX) based on the eddy-covariance technique, for the determination of energy fluxes and of local characteristics of turbulence, will provide to the project:

- the parametrisation of energy fluxes and momentum in the atmospheric surface layer;
- the parametrisation of the surface radiative fluxes.

A specific software will furnish the main aerodynamic characteristics of the flow such as the three velocity components, the standard deviations, the friction velocity and the Monin-Obukhov length as well as the covariance of the parameters and their spectra

These stations, especially designed to work in extreme environment (already utilized in Antarctica at Dome Concordia station in the frame of PNRA campaigns), are suitable to be utilized as mobile stations and consequently moved during the experimen:

in different areas with varying surface characteristics in order to furnish the ground-truth to the airborne measurements and the link to the surface characteristics for the remote sensing PBL monitoring.

This one will be carried out by means a triaxial Sodar equipment.

The Sodar ( sound detection and ranging) has been used successfully in the past to study the Antarctic boundary layer structure and evolution (Argentini et al., 1996, Gera et al., 1997, Naithani and Dutta, 1995, Culf, 1989). Although the Sodar is used primarily to measure the wind speed profiles in the Planetary Boundary Layer (PBL), data reduction techniques of vertical velocities and variances derived by Sodar have been proposed and utilized in recent years to derive surface heat fluxes (Weill et al. 1980, Greenhut and Mastrantonio, 1989, Melas, 1990, Melas, 1993, Casadio et al., 1996 ). Further the flux parameters ( friction velocity, roughness, Monin-Obukhov length) may be evaluated by Sodar wind profiles (Giannini et al., 1997).

The site chosen for the ground based experiment within the ARTIST program is located close to the Italian Arctic station of NY-Alesund in the near proximity of the NE site of the Svalbard island coast. A Special Observation Period is planned for the period 15 March - 15 April, 1998. A Doppler Sodar and a tethered balloon will be run by the Italian team simultaneously to aircraft and turbulence instrumentation, which will be carried on by the other European groups. The Sodar used in this field experiment is similar to that used in the Antarctic campaigns ( Argentini et al., 1992, Argentini and Mastrantonio, 1994 ). It is a monostatic three-axis Doppler system with 1.2 m diameter antennas, emitting three acoustic tones, one for each antenna, at 1750, 2000, and 2250 Hz. The vertical resolution of the system is 27m whereas the 6s pulse repetition frequency allow the echo recording up to 1000 m. The unit provides the facsimile recording of the backscattering intensity due to the thermal inhomogeneities of the atmosphere. The profiles of the radial wind are derived from the Doppler shift of the acoustic echo. From the radial velocities, with simple trigonometric formulas, the zonal, the meridian and the vertical velocity are computed ( Mastrantonio et Argentini, 1997 ). For a short period during the field experiment the Sodar will be used with the three antennas converging at one point ( around 50 m) to estimate the momentum fluxes.

The air-balloon carrying the tethered sonde is shaped to facilitate the orientation upwind. The tethered sonde, suspended about 2 m below the balloon, provides measurements of pressure, temperature, humidity, wind speed and wind direction every 6s. The wind speed is obtained by a three cup anemometer within an accuracy of 0.5 m/s whereas the direction is measured with a magnetic compass, that relies on the orientation of the balloon within an accuracy of  $\pm 5$  degrees. An aneroid barometer gives the pressure to an accuracy of 10Pa; pressure and temperature profile then provide the altitude at the sensor package above the surface. During the flight the electronics of the sonde scanned the sensors sequentially and transmitted the raw data to the ground station. The data are then transferred to the computer and processed to give the profiles of the potential temperature, the relative humidity, the wind speed and direction. While the Sodar data will be available continuously, the tethered sonde profiles will be taken each hour and only when the wind speed will not overpass 4-6 m/s. Tethered sonde wind profiles will be used in conjunction with the Sodar data to describe the local circulation during the flights as well as to evaluate the thermal exchange coefficients for heat during the experiment.

All these ground based activities will be completed by the satellite observations, from which an estimate of the radiation budget at the sea surface will be obtained.

The radiation budget at the sea surface will be evaluated from NOAA/AVHRR-2 accordingly to previously developed methods for METOSAT, GOES and NOAA data.

Because the geostationary satellite provide data only up 75° N we plan to use measurements of planetary albedo, obtainable from channels 1 and 2 of AVHRR, to estimate short-wave radiation budget (Gautier et al. 1980, Marullo et al. 1987). Moreover, repeated AVHRR passes will be used to estimate the solar radiation over the ocean by using information provided by cloud detection algorithm and bulk formulas. Firstly the radiation budget will be estimate for clear sky conditions only using empirical formulae available on the market and compared with in situ measurements. Coefficients of bulk formulae will be eventually newly estimated making regressions against in situ direct measurements.

The data on the infrared channels of AVHRR will be used to estimate the long-wave radiation budget (Frouin et al. 1988, Morcrette and Deshamps, 1986) using simple empirical formulae (Bignami et al., 1995). The estimate can be obtained combining cloud detection methods, sea surface temperatures and total water content obtainable the differences in brightness temperature between channels 4 and 5 of AVHRR.

Cloud detection is of major concern for all components. Non cloudy sea pixels will be individuated applying standard algorithms then new clouds detection algorithms will be implemented and tested also considering the occurrence of sea ice within the satellite pixels.

During the Arctic campaign all the available NOAA-AVHRR satellite data, relative to period of the campaign, will be acquired and processed. The estimate of the short radiation budget relative to each in situ measurement (ship and aircraft) data will be made in order to have a sufficient large data set to validate the different satellite algorithms. This data set could be eventually used for a toning of the coefficients used in the satellite estimate for clear sky condition.

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# Photochemistry in the Arctic Troposphere

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**Abstract.** NILU measures since 1991 many tropospheric trace species that are relevant in the photochemical ozone budget, such as O<sub>3</sub>, PAN, or VOCs, together with meteorology and photolytic parameters such as J(NO<sub>2</sub>) at the Zeppelin mountain station.

The winter-spring transition is the most interesting period for Arctic photochemistry, as light intensities and temperatures increase and reservoir species such as PAN or alkyl nitrates decompose. While OH radicals react with VOCs, CO, and methane, *in-situ* ozone production is possible. At the same time local halogen chemistry in the Arctic boundary layer can destroy ozone and can have a profound influence on other trace species.

## Introduction

Tropospheric ozone is the main precursor for the OH radical, together these two species determine the oxidative capacity of the atmosphere. Ozone is furthermore a greenhouse gas and is in high concentrations toxic to humans. The concentrations of tropospheric ozone are increasing in high northern latitudes. One of the goals of NILU is to understand the budget of tropospheric ozone and its precursors at high northern latitudes.

$$dO_3/dt = \pm \text{horizontal advection} \pm \text{vertical advection} \pm \text{chemistry} - \text{deposition} \quad [1]$$

## Measurements

At NILU's atmospheric monitoring station near Ny-Ålesund, Svalbard (78°54'42"N, 11°53'30"E, 474 m a.s.l.) many trace species are measured continuously, including ozone, peroxyacetylnitrate (PAN), volatile organic compounds (VOC), and carbon monoxide. In addition many species are measured during specific campaigns, so for example various nitrogen oxides.

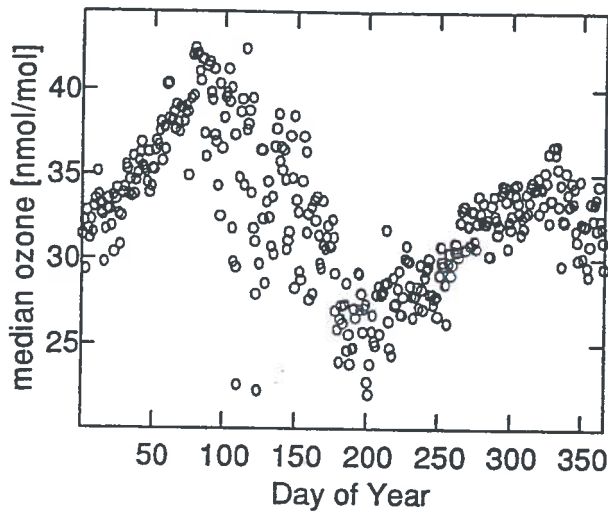


Figure 1. Median ozone mixing ratio at Zeppelin 1991 - 1997.

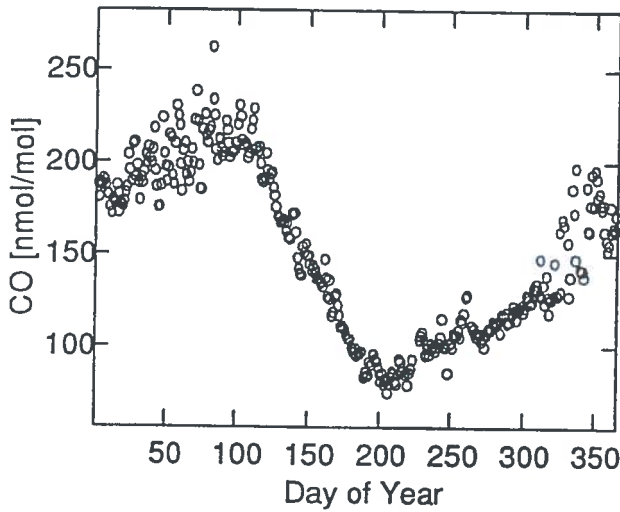


Figure 2. Median CO mixing ratio at Zeppelin 1992 - 1994

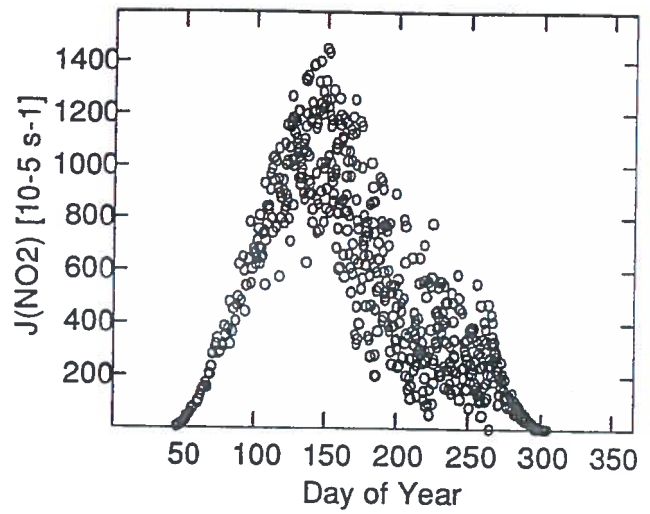


Figure 3. Median  $J(\text{NO}_2)$  rate at Zeppelin 1994 - 1996

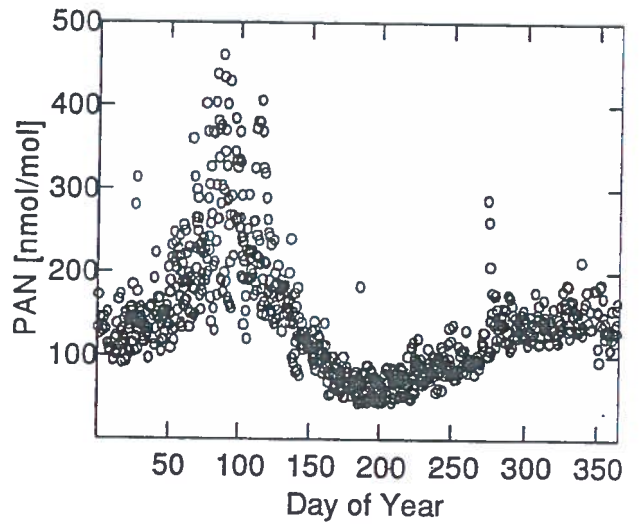
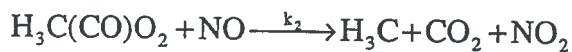
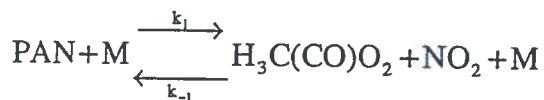


Figure 4. Median PAN mixing ratio at Zeppelin 1994 - 1996

## Discussion

### PAN as $\text{NO}_x$ source



$$k' = \frac{k_1 k_2 [\text{NO}]}{k_{-1} [\text{NO}_2] + k_2 [\text{NO}]}$$

$$[\text{PAN}]_t = [\text{PAN}]_0 \times e^{(-k't)}$$

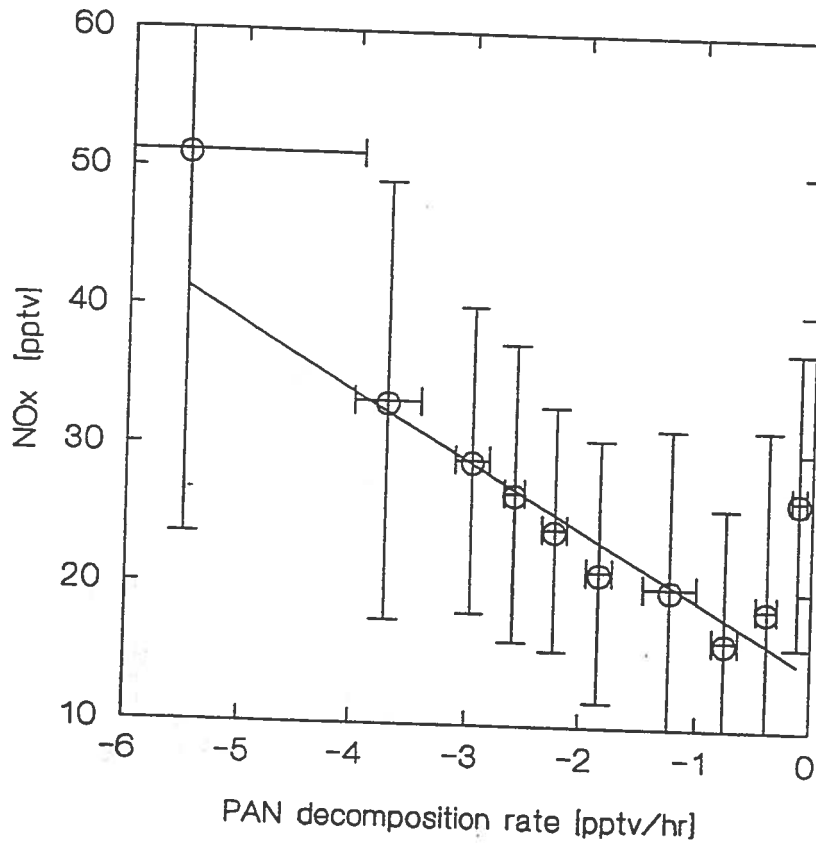


Figure 5. Thermal PAN decomposition rate [ $\text{pmol/mol h}^{-1}$ ].  $1 \text{ pmol/mol h}^{-1}$  decomposing PAN results in  $4.9 \text{ pmol/mol NO}_x$  addition. Median springtime  $\text{NO}_x$  is  $26.7 \text{ pmol/mol}$  [Beine et al., 1997].

$d\text{PAN}/dt \rightarrow d\text{O}_3/dt$

$$\frac{d\text{O}_3}{dt} = J(\text{NO}_2) [\text{NO}_2] - k_{\text{NO}+\text{O}_3} [\text{NO}][\text{O}_3]$$

*In-situ* ozone production is small at Zeppelin. During spring 1994 the daytime median value was  $62.4 \text{ [pmol/mol h}^{-1}\text{]}$ . An influence on the ozone budget is not visible at Zeppelin.

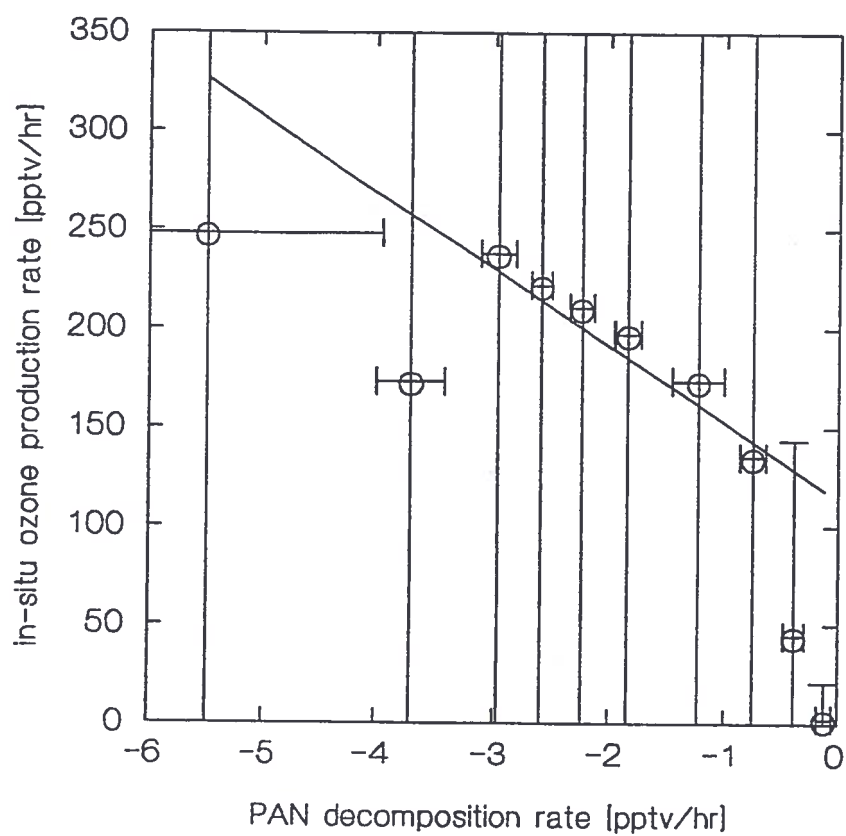


Figure 6. Thermal PAN decomposition resulting in in-situ ozone production. The slope of Theil's nonparametric regression shows that 44 [pmol/mol h<sup>-1</sup>] ozone are produced for each [pmol/mol h<sup>-1</sup>] PAN decomposing.

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# J(NO<sub>2</sub>) at Ny-Ålesund: Measurements and Model Calculations

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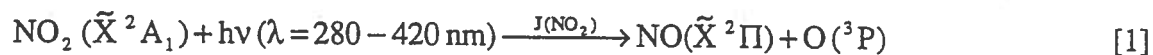
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**Abstract.** The photolytic rate constant of NO<sub>2</sub>, J(NO<sub>2</sub>), has been determined using two independent methods at the *Ny-Ålesund International Arctic Research and Monitoring Facility*. At the Zeppelin mountain station NILU has operated since 1994 a J(NO<sub>2</sub>) radiometer, and additionally during 1995/96 a filter UV filter instrument. The results of the latter, together with UV data measured by NP are used as input in a radiative transfer model using the discrete ordinate method to calculate J(NO<sub>2</sub>) rates. In this paper we present the measured quality controlled J(NO<sub>2</sub>) timeseries from the radiometer, and compare noon-time values with model results.

## Introduction

The photodissociation of NO<sub>2</sub> by near-ultraviolet radiation plays a key role in the atmosphere.



In the troposphere this reaction supplies odd oxygen, and thus precedes ozone production. This reaction is kinetically a first order process. The photochemical rate constant of this process, J(NO<sub>2</sub>), has units of s<sup>-1</sup>. Summer midlatitude noon-time values are on the order of 10<sup>-2</sup> s<sup>-1</sup>.

## Measurements

Accurate measurements of J(NO<sub>2</sub>) in the atmosphere can be carried out actinometrically, however, because of the complexity of such measurements errors can occur which might be difficult to explain [e.g. *Lantz et al.*, 1996]. Since 1994 J(NO<sub>2</sub>) is measured radiometrically at the Zeppelin station. The instrument (metcon, Germany) consists of two separate units, each of which

provides an isotropic response over a solid angle of  $2\pi$  steradian, facing up and downwards. The instrument was calibrated yearly against a set of master  $J(\text{NO}_2)$  radiometers [Schultz *et al.*, 1995]. Because solar zenith angles are small in the Arctic, correction factors for angular and spectral response and temperature were applied to the data. The overall uncertainty is better than 25%.

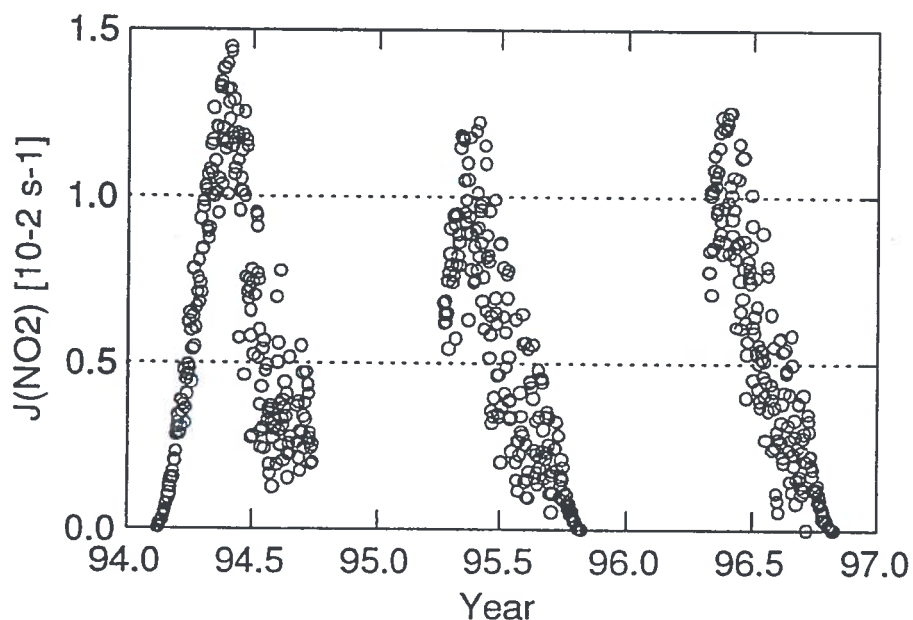


Figure 1. Daily noontime  $J(\text{NO}_2)$  rate at Zeppelin for the years 1994 to 1996

From the two independent measurements (up and down) a UV-albedo can be calculated. This albedo, however, shows a dependence on the zenith angle because the radiometers are not cosine weighted. It can therefore not be used for radiative transfer calculations. However, since an albedo value is generated with each  $J(\text{NO}_2)$  measurement, a complete timeseries is created that reflects ambient factors such as snow and cloud cover. It can be seen from Figure 2 that snowcover during 1994 lasted until the middle of June, which helps explain the higher  $J(\text{NO}_2)$  values during spring of that year.

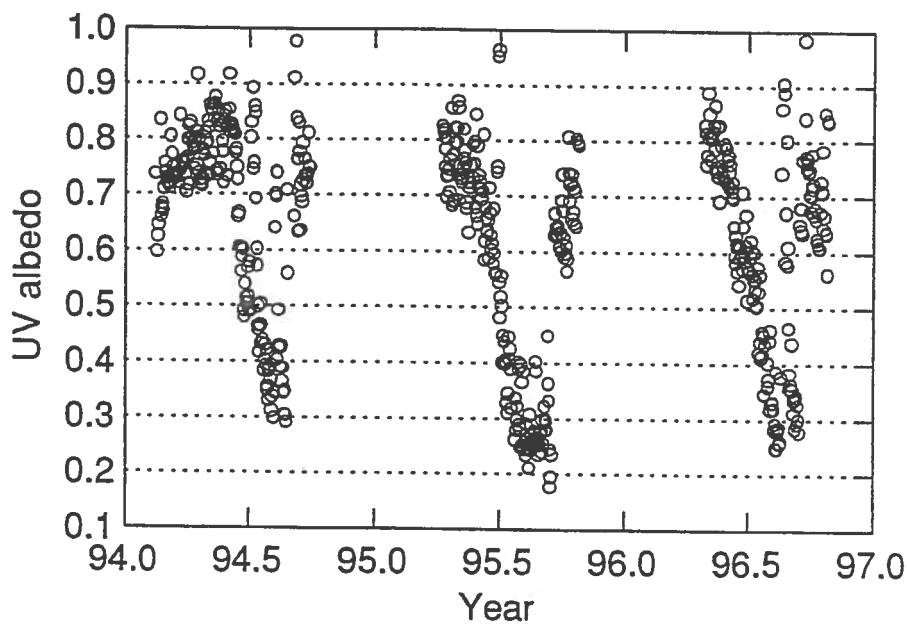


Figure 2. UV-albedo generated from the J(NO<sub>2</sub>) radiometer

Shortwave albedo is measured by NP using Eppley and Kipp&Zonen pyranometers at their research station in Ny-Ålesund. A comparison of 1996 data showed that the two albedos are linearly correlated.

$$\text{UV-albedo} = 0.242 + 0.653 \times \text{albedo}, p = 0.000, R^2 = 0.769. \quad [2]$$

As stated above, the UV-albedo underestimates the real albedo at high solar zenith angles.

### Model calculations

Since 1995 NILU measures UV radiation using a multi channel filter instrument (GUV-541, Biospherical instruments, U.S.A.). These data are used, together with the albedos determined by NP, as input to a radiative transfer model using the discrete ordinate solution [Stamnes *et al.*, 1988; Dahlback and Stamnes, 1991; Dahlback, 1996] to calculate J(NO<sub>2</sub>) values.

The comparison of the two data sets in Figure 3 shows a  $J(\text{NO}_2)_{\text{modeled}}/J(\text{NO}_2)_{\text{measured}}$  slope of 0.884 ( $p = 0.000, R^2 = 0.974$ ). This is a good agreement, considering the errors of the various measurements and the uncertainty in the model calculations.

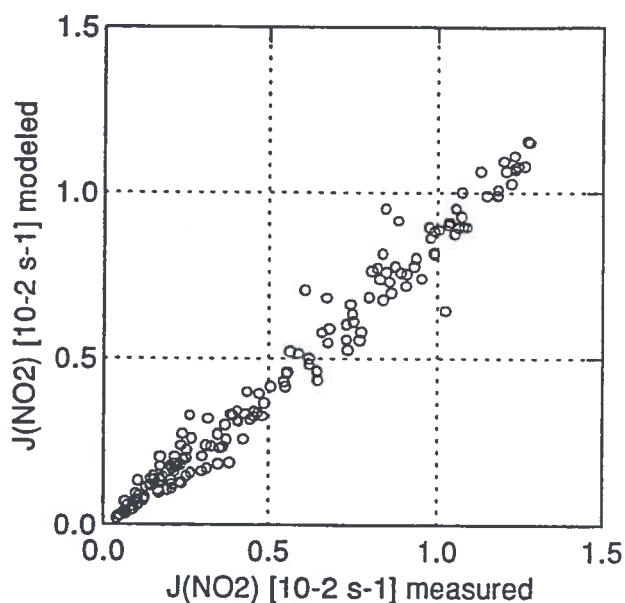


Figure 3. Comparison of measured and modeled  $J(\text{NO}_2)$  data for local noon at the Zeppelin station during the years 1995 and 96.

### Consequences for Arctic photochemistry

During the Arctic winter-spring transition very high  $J(\text{NO}_2)$  values are observed. The maximum values occur during April and May due to the local snowcover. *In-situ* ozone production in the Arctic is potentially high during that time, but  $\text{NO}_x$ -limited at Svalbard [Beine *et al.*, 1997].

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## **On the Comparison of Ozone Measurements in the Lower Troposphere**

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Hourly surface ozone measurements made since 1991 at the Zeppelin mountain (474 a.m.s.l.), Svalbard, using a UV-absorption ozone analyzer are compared to 530 coinciding homogenized balloon borne electrochemical cell ozonesonde observations from nearby Ny-Ålesund (11 a.m.s.l.). Through this study, we attempt to extend surface ozone measurements in the pristine environment of the Ny-Ålesund International Arctic Research and Monitoring Facility to the lower troposphere by using in-situ ozone measurements from sondes. The seasonal characteristics are established within the context to the prevailing meteorological conditions and the points of origin the airmasses at different altitudes.



# OCCURRENCE OF OXYGENATED VOLATILE ORGANIC COMPOUNDS (OVOC) IN THE ARCTIC AND ANTARCTIC REGIONS AND THEIR POSSIBLE RELEVANCE ON OZONE FORMATION

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## Introduction

Recently GC-MS methods capable of analysing and quantifying polar and non-polar volatile organic compounds (VOC) in air have been developed and tested (Ciccioli et al., 1992). Analysis performed in urban, suburban, rural, forest and remote areas showed that more than 300 different components from C<sub>4</sub> to C<sub>11</sub> can be present in the troposphere (Ciccioli et al., 1994). A large number of them is comprised of oxygenated components. Semi-volatile carbonyl compounds (aldehydes and ketones), free acids, alcohols, methoxy alcohols and furans were found to be widespread and abundant. These compounds account for a substantial portion (ca. 50%) of the volatile organic fraction not identified in previous studies carried out in forest areas of the US.. A critical analysis of tropospheric data shows that sources of oxygenated VOC might be present in the Arctic and Antarctic regions. Their contribution can be important for local ozone formation

## Experimental

VOC compositions and distributions used in this paper were derived from the data base of VOC created in our Institute. It is based on the analysis of more than 1000 samples collected during various campaigns carried in different areas. The data base is comprised of a list of more than 300 components grouped according to chemical classes (Ciccioli et al., 1994). Quantitative values are provided for the following components: linear and cyclic alkanes, alkenes, alkenes from C<sub>5</sub> to C<sub>11</sub>, all arenes, linear, cyclic and aromatic aldehydes and ketones from C<sub>4</sub> to C<sub>11</sub>, alcohols, methoxy-alcohols and diols from C<sub>4</sub> to C<sub>11</sub>, all free acids, all dienes starting from isoprene, all monoterpene and sesquiterpene compounds, CFC above CFC-11. In the data base are also included other classes such as furans, esters, ethers, phenols and nitrogen containing compounds. The list also includes some compounds that can be identified in air but not quantified. The experimental methodology used for the collection, separation and identification of listed compounds can be found in the technical literature (Ciccioli et al., 1992; Ciccioli et al., 1993a; Ciccioli et al., 1993b). Urban samples mainly refer to data collected in Milan, Rome and Taranto located in Northern, Central and Southern Italy, respectively. Data relative to suburban areas mainly refer to sites located near Rome (Montelibretti) and Madrid (Majadahonda). Forest values are derived from data collected in sites located in Italy, France, Spain and Germany. Data from coniferous forest were obtained in the Monti Cimini Park (Viterbo, Italy) and Storkow (Berlin, Germany). Data from Mediterranean ecosystems were collected in Castelporziano (Rome, Italy), Viols-en-Laval (Montpellier, France) and Burriana (Valencia, Spain). The ecosystems investigated were comprised of pine-oak forests, Mediterranean Pseudosteppe, French Maquis, sandy dunes vegetation and orange fields. Samples were collected during various field campaigns carried out in the time interval ranging between 1988 and 1997. Rural-forest samples were collected in a station placed in the middle of the Appennini mountains at the same latitude of the city of Urbino. Remote samples were collected at the Italian station set up by CNR at the foot of the Everest mountain in Nepal, the NILU station located in the Arctic Region (Svalbard Islands under the Norwegian administration) and the Antarctic base set up by the Italian government in the Ross Bay.

## Results and Discussion

To provide a clear idea of the important role that oxygenated volatile organic compounds (OVOC) can play in remote areas in general, and particularly in Polar regions, we have compared in Table 1 the percent composition of the main classes of organic compounds measured in different tropospheric sites. In the same Table and we have also reported the total amount of organic material that can be detected by GC-MS. Data reported in this Table show that

- 1) The percent composition of arenes rapidly declines from urban to suburban sites. For sites located far from the emission sources their levels account for a fraction varying from 2 to 10% of the whole organic content.
- 2) Alkanes follows a trend similar to that of arenes.
- 3) The percent of olefin compounds drops rapidly down to zero outside the urban areas. Semi-volatile components survive only in very cold ecosystems like the Antarctic region and the Himalayan plateau.
- 4) The decline of olefins is mirrored by an increase in the percent composition of oxygenated compounds in air. Particularly relevant is the increase of carbonyl compounds and free acids.
- 5) Isoprene is an ubiquitous component of the troposphere. Monoterpenes are detected only in areas located very close to the emission sources. The presence of monoterpenes in urban airsheds can be justified by the use of these components in house-cleaning products.

6) The absolute levels of the organic material in air decrease going from urban to forest-rural areas. However, levels recorded in remote areas often exceed those measured in vegetation covered areas.

The large differences between rural/forest sites and remote areas highlight the key role played by atmospheric reactions, heterogeneous removal processes and meteorological conditions in determining the aerometric levels of VOC in the troposphere.

However the high levels of OVOC measured in the Antarctic and Arctic regions relatively to those found in suburban, forest-rural and remote sites located in temperate regions cannot be simply explained by photochemical degradation of anthropogenic components transported over such remote areas. In these environments removal of organic compounds by chemical and physical processes is, indeed, much smaller than in other parts of the Earth. Such low reactivity is demonstrated by the persistence in air of large olefins (such as heptenes and octenes), isoprene and many unsaturated aldehydes and ketones (Ciccioli et al., 1996). It is more likely, therefore, that the air composition reflects the pattern of local sources of biogenic origin. In sites characterised by low atmospheric turbulence and reduced mixing height even tiny sources can, indeed, produce substantial concentrations of VOC in air. Very likely, marine sources are responsible most for the release of many OVOC in vegetation-free environments.

The occurrence of 6-methyl-5-hepten-2-one (MHO) (Ciccioli et al., 1993c, 1994) in the Ross Bay and Svalbard samples seems to strongly support this hypothesis as large amounts of this component have been reported in the remote station of Mauna Loa Observatory (Helmig et al., 1996) located in the middle of the Pacific Ocean.

Similar considerations apply to the aldehyde fraction as the largest portion of it was represented by semi-volatile components from hexanal to decanal (Ciccioli et al., 1993c, 1994) that were also detected in a remote sites of the Pacific Ocean (Yokouchi et al., 1990; Helmig et al., 1996).

Very little can be said about the alcohol and free acid fraction because compounds detected might either arise from photochemical degradation of large molecules or biogenic and anthropogenic emission.

The fact in the Arctic and Antarctic regions OVOC account for a substantial fraction of the semivolatile organic VOC present in air can be of great importance for local ozone formation because the main components of the carbonyl fractions (MHO and aldehydes from hexanal to nonanal) can strongly react with OH and NO<sub>3</sub> radicals or ozone and photolyse during the polar spring.

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TABLE I

## PERCENT COMPOSITION AND TOTAL AMOUNT OF VOCs DETECTED BY GC-MS IN DIFFERENT SITES

Site	Milan	Rome	Taranto	Montelibretti	Madrid
Country	Italy	Italy	Italy	Italy	Spain
Type of site	Urban	Urban	Urban	Suburban-rural	Suburban
Alkanes	29,7 %	34,9 %	47,0 %	9,2 %	33,6 %
Alkenes	4,5	6,4	11,9	0,5	8,4
Arenes	43,7	32,9	34,1	6,0	34,5
Alcohols	6,7	3,1	1,3	3,0	3,8
Aldehydes	4,0	9,0	3,0	38,6	13
Ketones	0,7	2,4	0,7	6,2	3,5
Free Acids	3,4	8,8	1,4	35,2	0,4
Monoterpenes	0,5	0,7	0,0	0,2	0,6
Isoprene	0,1	0,2	0,2	0,2	0,8
Others	6,7	1,5	0,3	1,0	0,1
Total Amount (ug/m3)	490,8	583,5	586	360,5	104,3
Site	Castelporziano	Castelporziano	Viols en Laval	Monti Cimini	Storkow
Country	Italy	Italy	France	Italy	Germany
Type of site	Forest	Forest	Forest	Forest	Forest
Ecosystem	Pseudosteppe	Pine-oak forest	Maquis	Pine forest	Pine forest
Alkanes	11,0 %	8,6 %	3,0 %	12,6 %	12,6 %
Alkenes	0,0	0,0	0,0	8,4	0,2
Arenes	2,6	3,9	6,0	8,7	25,8
Alcohols	4,9	14,2	13,0	1,1	0,0
Aldehydes	20,1	28,1	31,0	47,3	34,5
Ketones	7,7	15,0	21,0	10,2	7,3
Free Acids	48,8	4,5	14,0	0,2	0,0
Monoterpenes	1,3	8,9	4,0	10,0	18,5
Isoprene	2,3	0,6	8,0	1,4	0,6
Others	1,3	16,2	0,0	0,1	0,4
Total Amount (ug/m3)	88,7	95,5	36,0	96,2	91,2
Site	Burriana	Appennini Mountains	Svalbard Islands	Ross Bay	Himalaya
Country	Spain	Italy	Norway	Antarctica	Nepal
Type of site	Rural	Rural-Forest	Remote	Remote	Remote
Ecosystem	Orange field	Mixed	Arctic	Antarctic	High elevation
Alkanes	5,0 %	1,6 %	14,9 %	3,3 %	18,2 %
Alkenes	0,0	0,0	0,0	1,1	2,2
Arenes	5,0	1,6	5,2	0,5	9,9
Alcohols	3,3	6,4	7,0	9,6	10,5
Aldehydes	24,9	35,2	16,6	30,3	24,5
Ketones	15,8	38,0	6,0	43,1	15,7
Free Acids	26,6	12,8	45,3	9,6	14,0
Monoterpenes	18,3	0,0	0,0	0,0	1,2
Isoprene	0,0	0,2	0,3	0,2	0,2
Others	1,2	2,4	4,8	1,5	1,8
Total Amount (ug/m3)	25,5	34,0	48,3	93,4	126,1

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# ABUNDANCES AND SOURCES OF LOW MOLECULAR WEIGHT HALOCARBONS MEASURED IN THE ARCTIC TROPOSPHERE

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## Introduction

Production of halocarbons by the chemical industry is now restricted under terms laid out in the Montreal Protocol and subsequent revisions. Controlled substances include CFCs, halons, carbon tetrachloride, methyl chloroform, HCFCs, HBFCs and methyl bromide. Long term monitoring of all such species is therefore important to verify the expected decrease in the atmospheric halogen burden, and to assess the environmental impact of the new substitute compounds.

There are also a variety of halocarbons known to be produced biogenically, the most abundant being  $\text{CH}_3\text{Cl}$ . These species provide a significant contribution to the total atmospheric halogen load and are synthesised predominantly by oceanic biota, fungi, or released during biomass burning. Detailed information about the sources, sinks, and diurnal, seasonal and annual cycles for many of these naturally occurring halocarbons is sparse, and high frequency, high precision measurements are needed to quantify their global atmospheric budgets.

## Methodology

From 19<sup>th</sup> July to 14<sup>th</sup> September 1997 tropospheric concentrations of low molecular weight halocarbons were monitored at the Zeppelin Station, Ny-Ålesund. The fully automated instrumentation consisting of a novel twin ECD gas chromatograph with sample enriching Adsorption-Desorption System (ADS), enabled halocarbon concentrations at pptv levels to be determined at hourly intervals. The effluent from the first ECD detector passes into the second ECD which has enhanced sensitivity due to oxygen doping of the detector make-up gas. The procedure allows precise quantification of compounds such as  $\text{CH}_3\text{Cl}$ , which are poorly detected by both normal ECDs and mass spectrometry. Compounds determined include anthropogenic halocarbons, such as the chlorofluorocarbons and halons, (well known for catalysing the destruction of the ozone layer,) and compounds attributed to biogenic sources, such as  $\text{CH}_3\text{Cl}$ ,  $\text{CH}_3\text{Br}$ ,  $\text{CH}_2\text{Br}_2$  and  $\text{CHBr}_3$ . The data collected allows comparison with atmospheric data obtained on similar campaigns such as at Mace Head Atmospheric Research Station, Ireland. The data will help to determine the extent of global tropospheric mixing of the anthropogenic halocarbons and to compare global source strengths of the naturally produced compounds. Through local meteorological data and wind trajectory analysis the concentrations of halocarbons observed at Ny-Ålesund can be explained in terms of source strengths, for example comparing air of predominantly European origin with that originating from the Arctic Ocean. Anthropogenic pollutants can be identified using anthropogenic marker species such as tetrachloroethene (PCE) and trichloroethene (TCE) which rise significantly during pollution incidences of European air recorded at Ny-Ålesund. Other man-made compounds, such as  $\text{CH}_2\text{Cl}_2$  should be correlated with these marker species during pollution events. Species of predominantly biological origin can be identified by peaks in concentration during baseline periods - time periods when only clean background Arctic or oceanic air is recorded. These increases in concentration can often be correlated with wind masses passing over areas of high

marine biological productivity, such as phytoplankton blooms or coastal areas with large macroalgae populations.

#### **Observations:**

#### **Comparison of Ny-Ålesund Summer 1997 data with data recorded at Mace Head Atmospheric Research Station, Ireland during Summer 1996.**

Although the determination of exact concentrations for some compounds is awaiting further standardization, and linearity checks on the ECD detector response need to be carried out, the preliminary concentrations calculated can be used to compare concentrations monitored at Ny-Ålesund with those obtained during the summer of 1996 at Mace Head, Ireland. The halons monitored at Ny-Ålesund show a constant level, with 1301 (CF<sub>3</sub>Br) at an average concentration of approximately 2 pptv higher than Mace Head, but with maximums reaching 10.5 pptv at Mace Head compared to only 5 pptv at Ny-Ålesund. Methyl chloride shows an average concentration of 625 pptv at Ny-Ålesund, compared to 431 pptv at Mace Head, however while Mace Head concentration peaks reach 1.43 times the average level, Ny-Ålesund concentration peaks reach only 1.17 times. Methyl bromide average concentrations are approximately 3 pptv higher at Ny-Ålesund than Mace Head, but again with a smaller range at Ny-Ålesund, suggesting the station is located closer to a natural source of this compound or alternatively concentration of halocarbon pollutants is occurring in the Arctic troposphere. Very similar average, maximum and minimum values are obtained for the two data sets for methyl iodide, which supports a natural source for this compound. Dichloromethane shows an average concentration at Ny-Ålesund 84% of that recorded at Mace Head, with much less variation in concentration. Chloroform shows an average concentration of 14 pptv at both stations, but with a maximum value of only 21 pptv at Ny-Ålesund compared to 43 pptv at Mace Head. Methyl chloroform is a heavily controlled halocarbon, shown by the low % standard deviation in concentration recorded at Ny-Ålesund. CH<sub>3</sub>CCl<sub>3</sub> has an average concentration of  $82.6 \pm 1.61$  pptv at Ny-Ålesund compared to  $118.96 \pm 46.2$  pptv at Mace Head.

#### **European sources vs. Local Ny-Ålesund sources of ozone depleting substances.**

During the two month monitoring period only two major incidences of polluted air reaching Ny-Ålesund were recorded. The first occurred from the 30/8/97 to 2/9/97 and the second from 5/9/97 to 9/9/97. The first incident was due to wind trajectories originating over central Russia and Eastern Europe. The second event was due to air from Western Europe, particularly France, Denmark and Scotland. Polychloroethene (PCE) and trichloroethene (TCE) are excellent markers of anthropogenic pollution incidences and show marked increases in concentration during these time periods. Earlier in the monitoring time period smaller pollution incidences can also be identified in the traces of these compounds, showing polluted air from Eastern Canada and the USA. On 15<sup>th</sup> August 1997 the Zeppelin station cable car cable was reiled as part of the annual maintenance programme. This caused levels of PCE to rise from about 1.6 pptv to give a peak of 846 pptv. As a consequence of the introduction of this local PCE source, the baseline level of PCE rose by about 0.5 ppt, and low wind speeds were marked by sharp rises in the PCE concentration recorded for the remainder of the monitoring period.

A trendline placed through the CFC-11 (CFCl<sub>3</sub>) data shows a constant overall level, however the background level is superimposed with sharp rises in concentration from a background of

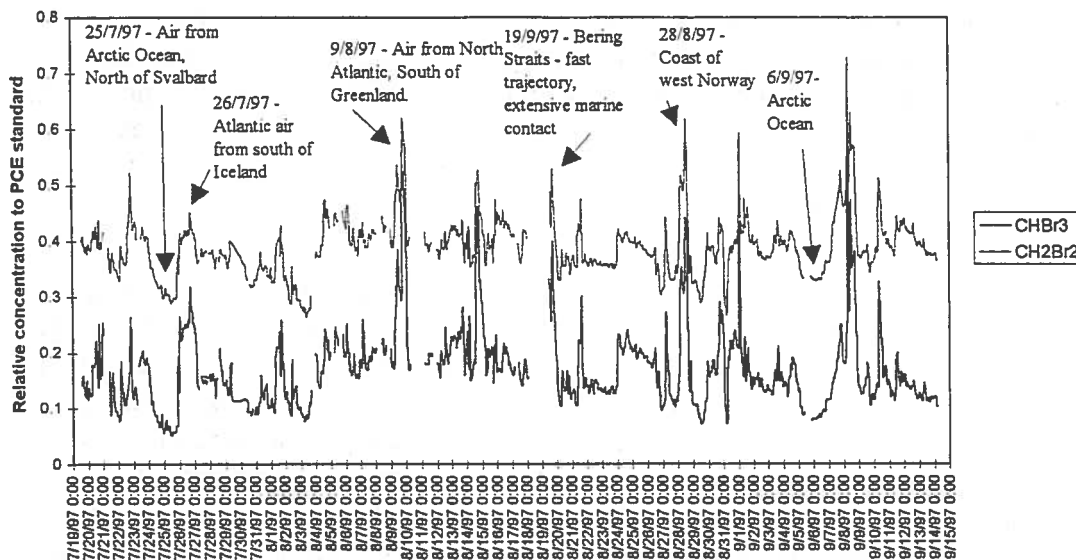
about 280 pptv to a maximum of 352 pptv, a 26% rise coincident with low wind speeds. This suggests a local source of CFC-11 in Ny-Ålesund, either as insulation foam blown with this chlorofluorocarbon or as a refrigerant. A wind rose showing the correlation of CFC-11 concentration with wind direction shows perfect correspondence of the CFC-11 concentration peak with the direction of the village.

## Biological Production of Halocarbons:

### 1. Bromoform and Dibromomethane production

Concentrations recorded at Ny-Ålesund during the summer of 1997 show a strong correlation between bromoform and dibromomethane suggesting a common source ( $R^2 = 0.771$ ). This corresponds with similar correlations observed at Mace Head, Ireland. Both plots show a range of peaks and troughs in concentration occurring outside the two major European pollution incidences. As Figure 1 shows these have been compared with the 5 day back trajectories obtained from the Deutscher Wetterdienst.

Fig. 1: Variation of Bromoform and Dibromomethane with time.



Extended troughs in concentration, such as observed on the 25/7/97 can often either be linked with air masses passing over the extreme northerly Arctic Ocean, north of Svalbard; short trajectories indicating low wind speed and therefore a low sea to air flux, or alternatively trajectories originating from low pressures corresponding to high altitudes. Trajectories producing peaks in concentration can normally be characterised by one or more of a number of identifying features:

- Fast moving trajectories with extended distances covered over the sea, e.g. 9/8/97.
- Trajectories originating south of the Arctic circle, e.g. 26/7/97
- Trajectories passing for extended periods over coastal areas e.g. 28/8/97

### 2. Methyl Iodide production

The methyl iodide concentration observed at the Zeppelin station, shows an overall trend of declining concentration from July to the end of August. It then show two peaks occurring approximately coincident with the European pollution incidences. This observation provokes several explanations:

- a) The European/Russian air transported methyl iodide from an urban/industrial source.
- b) The air mass from temperate latitudes carried naturally produced methyl iodide from more temperate oceans of higher bioproductivity.
- c) The stronger winds associated with the first pollution incident resulted in greater sea to air flux of methyl iodide.
- d) The warm air from southerly latitudes raised air and sea temperatures, which induced a late phytoplankton bloom in the Kongsfjord. This process is supported by the correlation between temperature and methyl iodide concentration recorded at the Zeppelin station. Peaks in methyl iodide concentration throughout the sampling period appear to occur between two and four days after peaks in temperature. The variation of methyl iodide and dichloromethane with time also shows that in the case of the second pollution incident the peak in methyl iodide concentration occurs approximately 2 days after the peak in dichloromethane - an anthropogenic pollutant. On 12/9/97 an extensive scum of dead phytoplankton was also observed in the fjord suggesting the death of a large bloom.

The methyl iodide concentration at Ny-Ålesund shows no correlation with bromoform, dibromomethane or dichlorobromomethane, suggesting a different source species and region. Although the methyl iodide concentration fluctuates extensively with varying wind speed, there is no marked increase in concentration with increasing wind speed as exhibited by bromoform nor a decline in concentration as shown for compounds such as CFC-11 which appear to have a local source in the village.

### **Conclusions and Future work**

The dual channel ECD instrument used for near-real time tropospheric monitoring at the Zeppelin station represents a departure from traditional methods and extends the range of environmentally important trace gases that can be routinely monitored at remote field stations such as Ny-Ålesund. Atmospheric measurements of the biosynthesized halogenated compounds are very sparse, and the deployment of this analytical system represents important progress in elucidating sources and fluxes. The system is capable of quantitatively measuring a wide range of atmospheric halocarbons in a 200ml air sample, at concentrations as low as 0.1 pptv. Continuous, near-real time measurements obtained are far superior to flask sampling methods, because although long term trends can be discerned by both techniques only continuous measurements provide information on short term variations. It is also suspected that certain halocarbons, such as methyl iodide, are prone to sample degradation and loss when air samples are stored in flasks.

During Spring and Summer 1999 we are planning for a further deployment of the instrumentation at Ny-Ålesund. We aim to monitor the production of naturally produced halocarbons during the intense spring bloom of macroalgae, ice microalgae, and phytoplankton. We aim to link concentration levels recorded to wind trajectories and satellite imagery showing bloom areas, particularly as NASA's new SeaWiFS satellite is now fully operational. We also aim to further investigate correlations between concentrations, light intensity, temperature and wind speed. We also plan to deploy flux chambers to monitor emissions from the ice free tundra and utilise purge and trap work to investigate sea saturation anomalies for the low molecular weight halocarbons.

# Ozone and Aerosol monitoring in the Arctic Troposphere in Ny-Ålesund using lidar

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At polar sunrise photolytic reactions and dynamical effects induce various changes in the composition of the lower Arctic atmosphere. In 1985 the phenomenon of complete depletion of boundary layer ozone was discovered in the Arctic. The sudden, episodic losses of ozone occur only after polar sunrise and have been observed at several Arctic sites (Barrie et al., 1988) (Solberg et al., 1994). Measurements showed a strong anticorrelation between ozone and levels of bromine compounds in the boundary layer (Hausmann and Platt, 1994). This led to the hypothesis, that halogen oxide catalyzed reaction cycles are responsible for the very efficient ozone depletion.

During ARCTOC<sup>1</sup> campaign in spring 1996 a lidar<sup>2</sup> system was integrated into the NDSC-Station in Ny-Ålesund to monitor vertical ozone distribution and aerosol loading in the lower troposphere. In spring 1997 we extended the detection system in order to simultaneously monitor the aerosol formation of the Arctic troposphere, with respect to ice clouds, "Diamond Dust" and Arctic Haze.

The lidar is based on a tunable, flashlamp pumped Titanium Sapphire Laser. The ozone concentration was measured with the frequency tripled light by DIAL<sup>3</sup> - technique in the ultraviolet Hartley absorption band of the ozone spectrum. Aerosol sounding was performed in the 400 nm range, which allow us an excellent detection sensitivity.

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<sup>1</sup> Arctic tropospheric ozone chemistry  
<sup>2</sup> Light detection and ranging  
<sup>3</sup> Differential Absorption LIDAR



# **Chemical and dynamical aspects of variability and long-term changes in the arctic stratosphere**

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## **1. Introduction**

Ozone, trace gases and polar stratospheric clouds (PSCs) are regularly observed by balloon-borne sondes as well as by active and passive remote sensing instruments at Ny-Ålesund International Arctic Research and Monitoring Facility (79°N; 12°E). The Koldewey-Station is part of the global network for detection of stratospheric change (NDSC). Regular balloon-borne ozone records are one of the most important measurements for detection of changes in the Arctic stratospheric ozone layer. Additionally correlative balloon soundings are performed at Neumayer station (70°S; 08°W) in the Antarctic.

## **2. Chemical ozone loss in the Arctic stratosphere**

Since the middle eighties PSC related chemical ozone loss has been recorded in the lower Antarctic stratosphere during spring season. Recently similar ozone loss rates were detected in the lower Arctic stratosphere by using the Match technique (von der Gathen et al., 1995).

It is well known that the formation of PSCs forces heterogeneous reactions converting the longer-lived chlorine reservoir species HCl and ClONO<sub>2</sub> into temporary reservoir species such as Cl<sub>2</sub> which are readily photolysed into species involved in ozone destruction cycles. Recently processes controlling the duration of chemical ozone loss were also studied.

Model studies as well as measurements of chlorine reservoir species revealed an underlying mechanism for "trapping" of reactive chlorine in ClONO<sub>2</sub> (Rex et al., 1997). For certain conditions this process can stop the ozone reduction despite the existence of PSCs.

The heterogeneous activation of chlorine also depends on the microphysical characteristics of PSC particles. During winter 1996/97 the stratospheric vortex has been very stable from February until early April. These exceptional dynamical conditions made it possible to observe directly the relations between the occurrence of PSC, their properties and subsequent ozone loss indicating a strong stratification of chemical processes (Neuber et al., 1997). In the layer where only spherical particles occurred, the ozone loss stopped two weeks earlier than above and below. Strongest ozone loss by mixing ratio (ppm) and strongest loss rates (ppm/sunlit hour) occur where low backscatter signals from aerosol particles are observed but coinciding with

strongest depolarization signals from aspherical particles. This may indicate a possible different chemical forcing by the different PSC types on ozone loss so far not studied in detail.

### 3. Annual variation and trends of ozone in the Arctic and Antarctic

The mean annual ozone variation can be shown for both polar regions. Both stations have a fairly similar position with respect to the stratospheric vortex pattern. So the records can be used to show the different behaviour of the ozone layer for corresponding seasons in the Arctic and Antarctic. Although chemical ozone losses were measured in the Arctic stratosphere from January until March, lowest ozone concentrations occur during summer season from July until September. In the Antarctic the ozone minimum appears during spring from September until November. Thus the balance between both polar regions has a significant annual asymmetry.

A preliminary analysis was made to retrieve trends in stratospheric ozone based on balloon soundings. The trends (ppm per decade) for both polar regions show local differences but also similarities. There are significant trends in the middle and lower stratosphere. Arctic ozone trends are shown in Fig. 1.

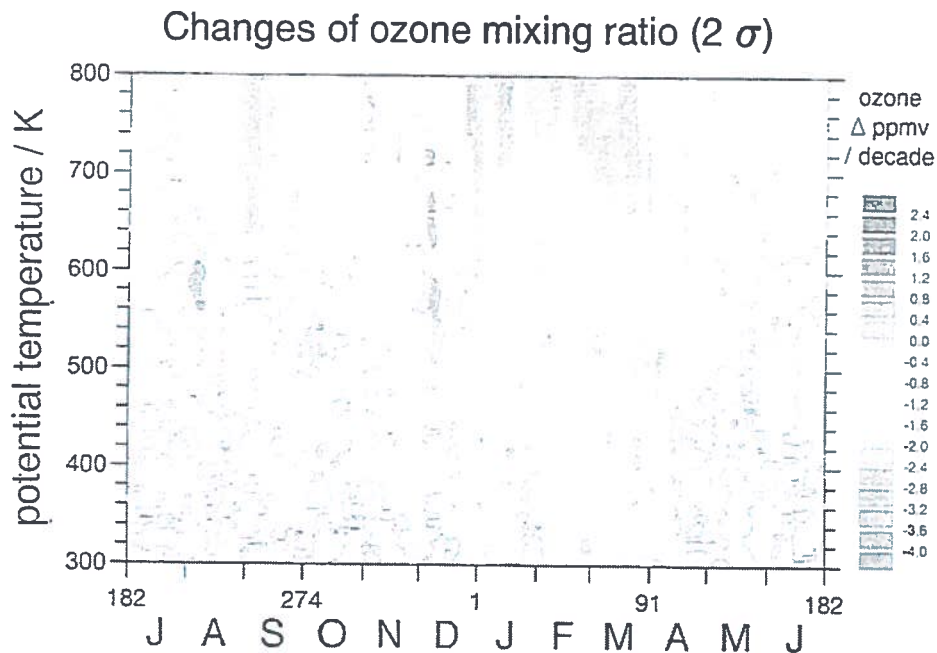


Fig. 1: Preliminary results of trends of ozone mixing ratios above Ny-Ålesund as derived from ozonesonde data within the last 9 years. Trends which are significant ( $2\sigma$  or better) are color coded. Altitude coordinate is potential temperature.

In the Arctic significant decreases of stratospheric ozone were found in the middle stratosphere above 600 K (25 km altitude) and between 500 and 600 K (18 - 24 km). Mixing ratios decreased substantially by more than 25% at the 800 K level. First signs of this decrease can already be seen in the middle stratosphere when the vortex begins to form in August and September. Such deficits are one order of magnitude larger than predicted by homogeneous chemically induced ozone destruction. Thus it suggested a dynamical reason which could reduce the transport of ozone rich air into the vortex at these altitudes.

The negative ozone trend in the lower stratosphere during late winter is consistent with the chemically induced ozone reductions. Such ozone losses occurred already in winter 1991/92 and even more in 1992/93. The winters 1994/95, 1995/96, and 1996/97 showed the largest ozone destruction in the Arctic vortex since observations started at Ny-Ålesund. Ozone had been depleted by 60% or more at about 500 K (18 km) at the end of the winters.

This trend in ozone depletion is consistent with the analysis by Pawson and Naujokat (1997) where the coldness of the lower stratosphere is measured by the area with  $T < 195$  K at 50 hPa. This temperature threshold is relevant for PSC formation. It increased considerably over the 31 years owing largely to the persistence of cold days.

#### **4. Trends and teleconnection patterns for polar stratospheric ozone**

The similarity of ozone changes for both polar regions suggests a global impact. That might be connected with changes caused by greenhouse gases or other natural long-term changes.

A study was made for Antarctic ozone records from Georg Forster station (71°S; 12°E) and Neumayer station (70°S; 08°W) (Gernandt et al. 1997). In October three altitude ranges with significant negative trends were found for the 10 year record. The trends above 500 K are similar in both separated levels and roughly three times stronger by mixing ratio as in the lower stratosphere. The trends are connected with the appearance of lower minimum temperatures during winter.

In October the interannual variability of ozone inside the vortex shows a dominating teleconnection pattern to the Southern Oscillation Index retrieved for the Pacific region from the monthly normalized surface pressure difference between Tahiti and Darwin (Australia).

In the North Atlantic region a similar feature is known as the North Atlantic Oscillation (NAO). The NAO index is based on the normalized difference between normalized sea-level pressure time series at Lisbon, Portugal and Stykkisholmur, Iceland. Over the past 130 years, the NAO has exhibited considerable variability at quasi biennial and quasi-decadal time scales, the latter have become especially pronounced the second half of this century (Hurrell, van Loon; 1997).

A significant correlation is found between geopotential heights in the Arctic stratosphere and NAO. Lowest geopotential heights and lowest temperatures appear inside the Arctic stratospheric vortex for winters with high (positive) NAO index. As NAO has a considerable variability in decadal time scales the colder stratospheric vortex and subsequent lower ozone values discussed above might be controlled by this teleconnection pattern. Whether the observed NAO changes are in response to greenhouse gas forcing, or whether the changes are part of a natural decadal time scale variation, is difficult to assess (Hurrell, van Loon; 1997). On the other hand natural fluctuations in the NAO may result from internal atmospheric dynamical processes (Wallace et al., 1995).

## 5. Natural variability and nonlinear dynamics

An approach to study the reasons of long-term natural variability is to analyse long-term integrations of appropriate simple models. A nonlinear atmosphere-like dynamical system with sparse horizontal resolution including orographic and thermal forcing in a long wave and its interaction with both a baroclinic wave and zonal flow is constructed and has been integrated over 10.000 years (Dethloff et al., 1998). It reproduces variability in a broad range of time scales from interseasonal to decadal and even centenary ones. These long-term variations are understood as a nonlinear response to fluctuations associated with the daily and weekly variability in the atmospheric circulation patterns. It is hypothesized that variations of atmospheric climate or variations of SOI and NAO might also be controlled by those processes exhibited in the nonlinear dynamical system.

## 6. Conclusion

Although chemical and dynamical causes for the interannual variability of stratospheric ozone may be understood in terms of chemical processes and increasing concentrations of greenhouse gases and aerosols, a reliable assessment of trends seems to be unlikely on the base of present knowledge. The unknown long-term natural climate variability may probably also have a significant impact causing trends over decadal or centenary time scales independent from greenhouse gas impacts.

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# UV-B Radiation Measurements at Koldewey-Station

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## Introduction and Instrumentation

One of the major objects of UV measurements is to detect long-term trends in UV irradiance. The most interesting areas corresponding to ozone depletion are Antarctica and of course the region around the northern pole. Long-term field measurements under these extreme climatical and logistical conditions could not be realized simply by using a commercial spectrophotometric laboratory system. It seemed to be necessary to develop a specialized instrument for this intended use. One of the most important features of the instrument should be a stable operation in field for a period of about one year without intensive manpower for service necessary.

For this purpose we built a non-scanning spectrometer based on a Bentham DM 150 double monochromator with a multichannel detector system. The detector is based on a low-resistance microchannel plate with 32 channels working in a photon counting mode. We run our double monochromator with a broad center slit to enable the detection of the whole UV-B range simultaneously. To handle the straylight problem in the detector chamber due to the broad center slit, we cut 3 magnitudes of dynamic in the UV-B range using a steep interference filter with transmission maximum at 289 nm. By this we enhanced the dynamic range of our system up to  $10^6$ .

In consequence of the fixed gratings, our spectrometer is less sensitive toward transport by ship and plane, and shows a better wavelength stability as scanning systems. The latter means that there is no further calibration necessary for up to one year.

Since March 1996 our System is installed in Ny-Ålesund and at Neumayer Station (Antarctica). This means the instrument is built up in early polar spring (this should be early March at Ny-Ålesund), and brought back to our laboratory for calibration after final sunset (late October). In 1998 the UV-B device will be upgraded by an equivalent instrument for the UV-A range (320 – 400 nm).

## UV-B measurements at Koldewey-Station 1996 / 1997

For the first time we are able to present comparable measurements of UV-B irradiation and ozone sonde launches at Koldewey-Station for two years. For this comparison we use the ratio of the wavelength pair 300 nm / 320 nm. This ratio is called ozone-index in the following. Due to the weak wavelength dependence of aerosol and cloud effects, this quantity is suitable to

describe the influence of ozone on the UV-B spectrum. Unfortunately in 1997 we were not able to start our spectrometer at Koldewey before 30<sup>th</sup> of April for technical and logistical reasons so that the values for march and april are missing.

Fig. 1: Ozone-Index 300 nm / 320 nm (Koldewey)

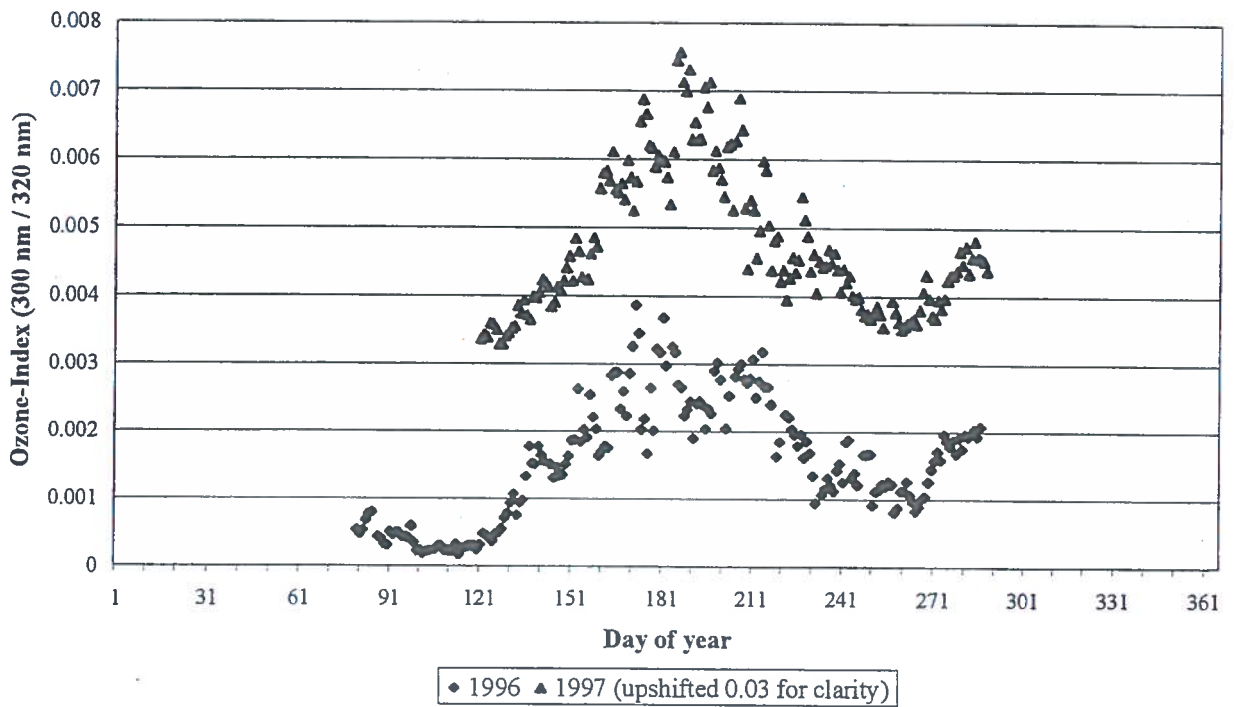
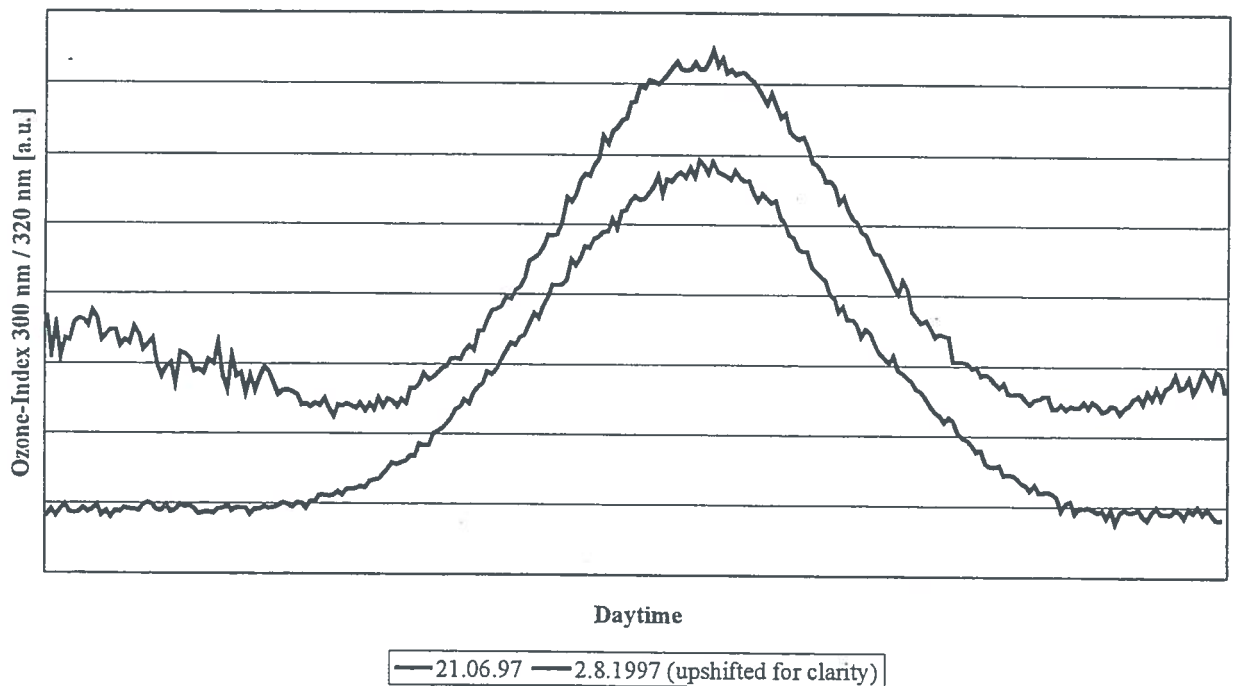


Fig. 2: Daily Variation of the Ozone-Index (Koldewey 1997)



In Fig. 1 the noon values of the ozone-index are shown for both years. The characteristic change over the year is an effect of the airmass due to season depending elevation of the sun. The increasing values of the ozone-index at very low sun elevation in the early spring in 1996 and the late autumn in 1996 and 1997 is due to the Umkehrreffekt. For the reason of this well-known effect the ozone-index is not suitable to describe the correlation between ozone and UV-B irradiation when the sun is very close to the horizon (elevation smaller  $\sim 12^\circ$ ).

For one day the behavior of the ozone-index looks similar. In Fig. 2 the daily variation of the index is plotted for two days: midsummer day in comparison with 2<sup>nd</sup> august. In June the sun's elevation is larger  $12.5^\circ$  the hole day, so no Umkehrreffekt occurs, whereas on 2<sup>nd</sup> august the sun goes down to  $7^\circ$  leading to an increase of the index around midnight.

Comparing Fig. 1 and Fig. 2 one notices the different statistics of the curves. The variation along arbitrary days describes a comparatively smooth curve whereas the variation over the year is very noisy. We assume, that this is an effect of the daily change in ozone. Until the present evaluation we use the ozone data of the weekly sonde launches at Koldewey, so we can't see fast changes in ozon. To proof the assumption that the statistics in Fig. 1 is due to fluctuations of the ozone layer, we have to compare with daily ozone measurements done at Koldewey by other groups.

The effect of changing sun elevation is overlaying the influence of seasonal differences in the stratospheric ozone layer. Therefore in Fig. 3 (1996) and Fig. 4 (1997) the airmass corrected ozone-indices are shown in comparison with the results of weekly ozone sonde launches at Koldewey. In both years the ozone layer shows the typical arctic behavior with an ozone maximum in the beginning of may (around day of year 120). This maximum leads to a minimum in the 300 nm / 320 nm ratio due to the stronger absorption at the lower wavelength.

**Fig. 3: Comparison of Ozone and Airmass Corrected Ozone-Index (Koldewey 1996)**

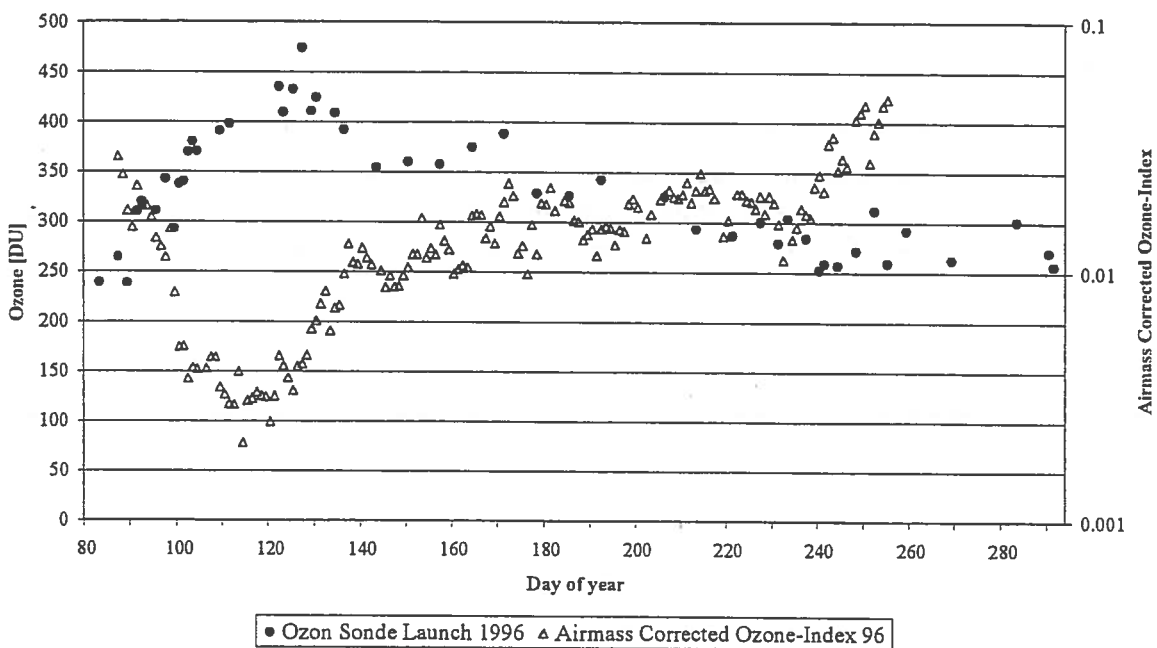
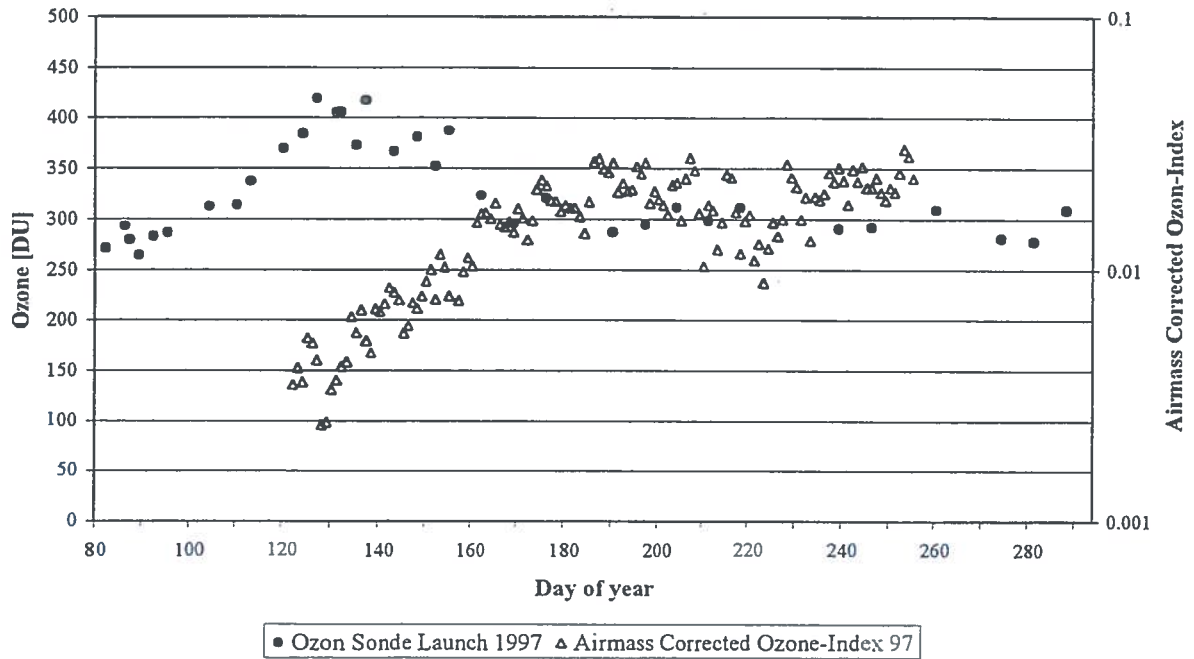


Fig. 4: Comparison of Ozone and Airmass Corrected Ozone-Index (Koldewey 1997)



### Acknowledgement

The development of the UV-B spectrometer was funded by the BMBF under reference number 03PL000A. Six identical instruments are available now and in operation for field measurements. One additional instrument is modified for UV-A measurements. Technical support and service during 1996 was due to Hauke Schütt (AWI). The ozone data for 1996 and 1997 for comparison reasons were provided by Thomas Seiler.

# Methane Measurements at Mt Zeppelin

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## Background

The abundance of methane in the atmosphere has shown a rapid growth since the beginning of the industrial revolution. The present concentration level is more than twice the preindustrial level. About 2/3 of methane released to the atmosphere is supposed to have antropogenic origin. Main antropogenic sources are the use of fossil fuel, waste management, enteric fermentation (cattle, sheep etc.), biomass burning and rice paddies.

Methane is an important greenhouse gas, it is one of the strongest contributors to radiative forcing. It is also a reactive gas that participates in establishing the oxidizing capacity of the troposphere, and therefore affects the lifetime of many other trace gases. In the stratosphere it is a source of hydrogen and water vapor, and a sink of atomic chlorine.

From 1990 to 1995, NILU has been collecting air samples at Mt Zeppelin three times a week for analysis of methane at NILU's laboratory. In 1997 an automatic instrument for semi continuous measurements in situ was completed and placed at the monitoring station at Mt Zeppelin, hence increasing the sampling interval to three times per hour.

## Method

Methane is analysed by a gas chromatograph with a flame ionisation detector (GC/FID). Sampling and calibration is controlled by a PC. Three samples and one standard (NIST, concentration level 2,28 ppm<sub>v</sub>) is analysed per hour. Chromatographic data are collected on the PC and sent to NILU each hour. A consecutive plot of preliminary data at NILU helps monitoring the status of the unmanned instrument. Final calculations, calibration and quality control of the data is carried out at NILU.

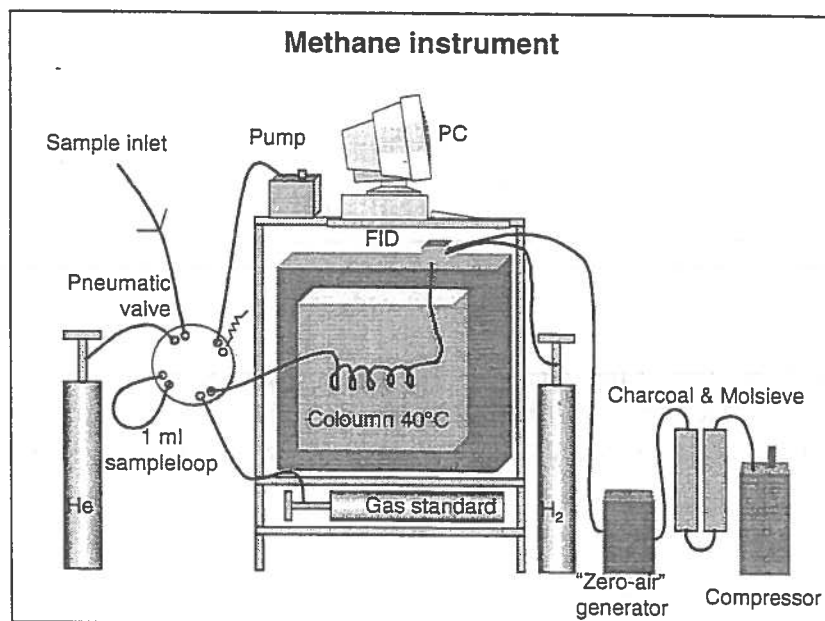


Figure 1: The automatic semi continuous methane instrument

The new instrument provides a much higher sampling rate than the old method (three times per hour versus three times per week). The old method was relatively labour intensive and included logistic problems of handling and transporting a large number of sample flasks. Samples were collected on specially treated steel canisters involving an extensive cleaning process.

The need of sample handling is eliminated with the automatic instrument. Air samples are injected directly on the chromatographic column without cryofocusing, hence eliminating the need for cooling agents (liquid N<sub>2</sub>). The higher sampling rate provides a more extensive basis of data and will also catch up with variations due to episodes and short term meteorological changes.

The high number of data necessitates automatic computer based handling of calculations and reporting of results, which again calls for extensive procedures for quality control of the data.

## Results

All data are preliminary. The standard used for the flask samples needs to be recalculated against a reference standard from the CMDL network. Present analysis indicates that the concentration levels are slightly too high. Yet, the data indicates seasonal variations as expected due to photochemical reactions (fig. 2).

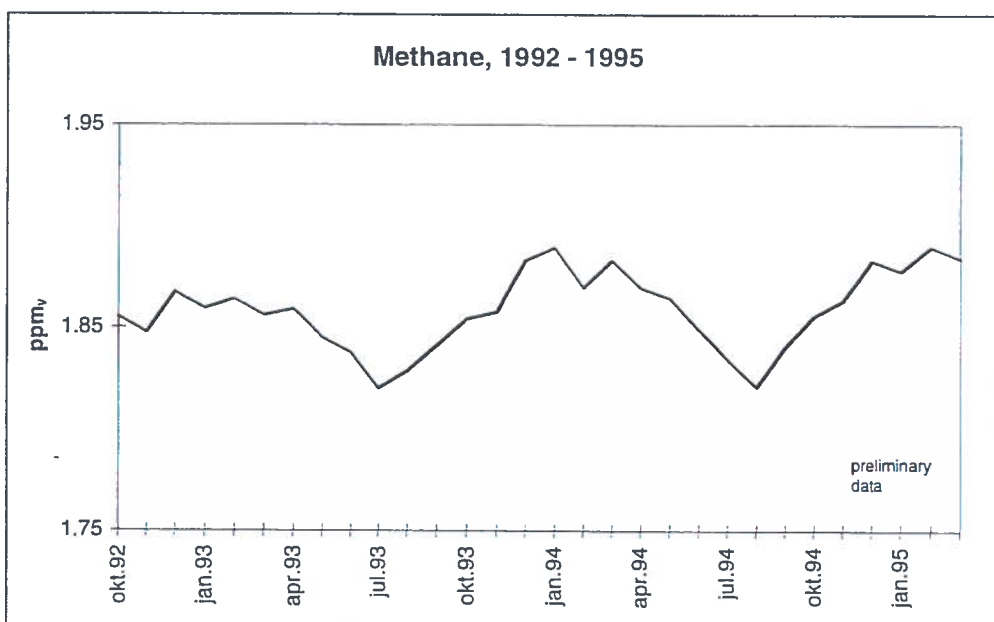


Figure 2: Methane data from flask sampling 1992-1995, monthly mean values.

Methods for validation and quality control of the data from the new instrument are still under development. This might influence the spread of the data. They should still give a good indication of the concentration level since the samples are directly calibrated against a NIST standard (fig. 3).

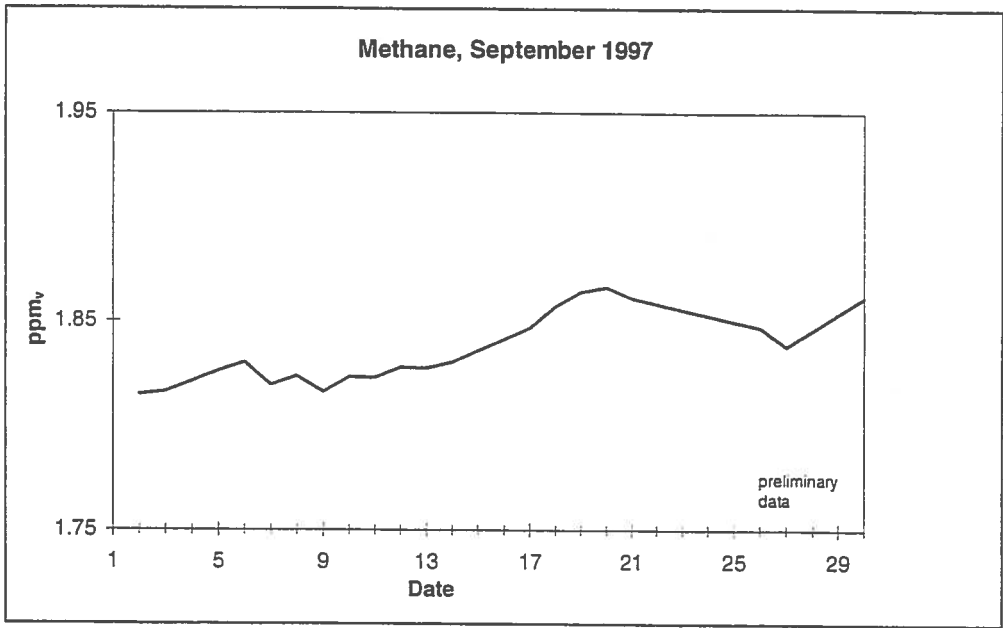


Figure 3: Methane data from automatic instrument, daily mean values September 1997



# Analysis of chemical composition in total deposition samples from Ny-Ålesund (Spitsbergen)

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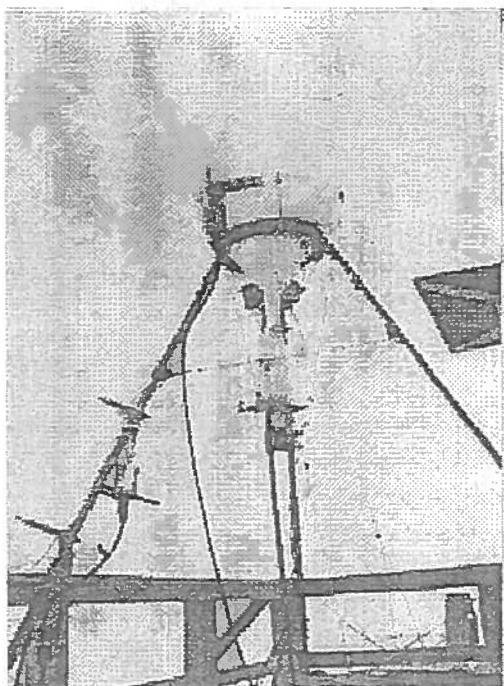
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## Introduction

Atmospheric transport from the highly industrialized areas at mid latitudes of the northern hemisphere to the high Arctic is the main pathway of trace metals and ionic species. Removal processes of gaseous and particulate air pollutants from the atmosphere to snow-covered land or sea surfaces take place either by wet or dry deposition. In this contribution we will present new results of our deposition measurements which are carried out since September 1993. The aim of our investigations is to characterise the chemical composition as well as to quantify the removal of trace metals and ionic species from the atmosphere by wet deposition via snow and rain as well as by dry deposition in Ny-Ålesund (Spitsbergen 79°N, 12°E).

## Materials and Methods

Total deposition measurements are carried out with a simple and reliable total deposition sampler, consisting of a well precleaned polyethylene funnel connected to an exchangeable bottle (Kriews et al. 1995, 1997, Kriews and Schrems 1995). With this permanent open funnel wet and dry fall-out is collected. One total deposition sampler was equipped with snow drift sensors (fig.1) to get information about precipitation intensity and variability.



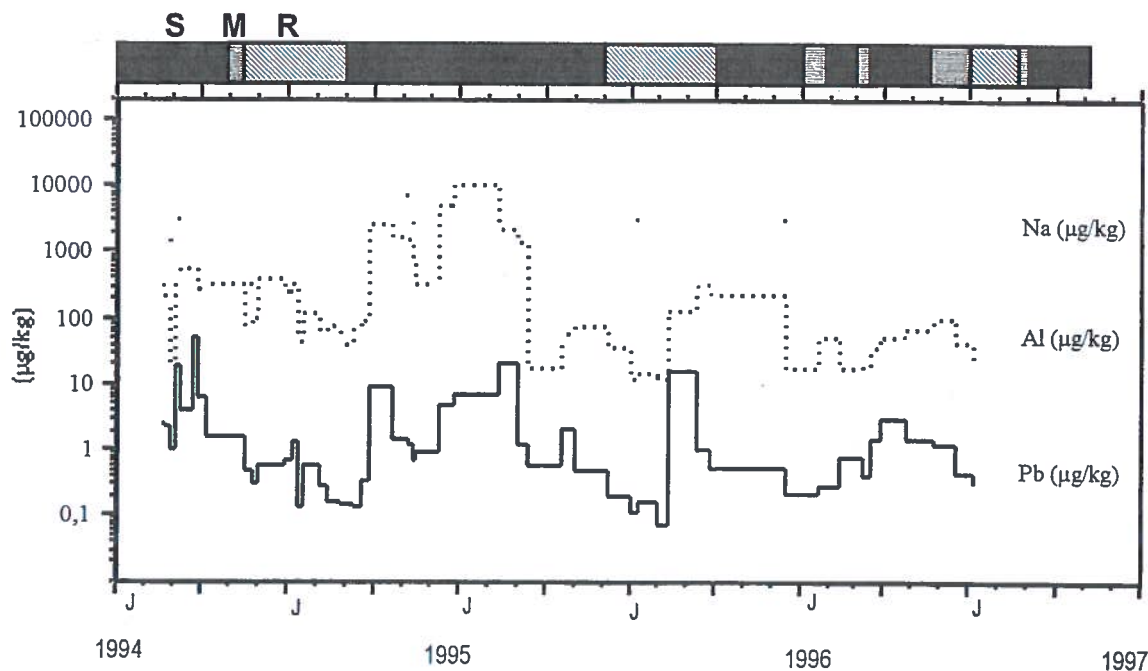
**Figure 1:** Total deposition sampler with snow drift sensors

For trace metal analyses the filtered and unfiltered molten snow samples were acidified immediately and stored in double polyethylene bags for transport to the home laboratory. There, further steps in sample preparation (Kriews and Schrems 1995) and element analyses for 35 elements were carried out by GF-AAS, F-AAS and ICP-MS. In addition, physical parameters (pH and conductivity) as well as anions and ammonia were determined.

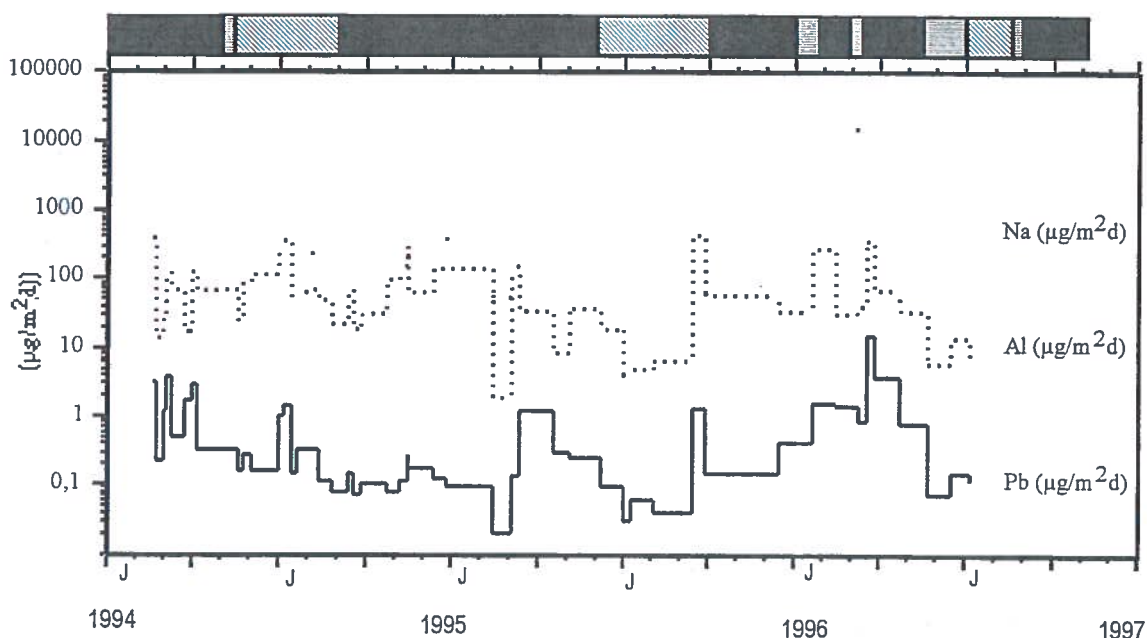
## Results and Discussion

Time series of element concentrations as well as deposition rates are exemplarily shown for the presumably anthropogenic element Pb in fig. 2 and 3 for the sampling period from February 94 until July 96. Al and Na as tracers for earth crust weathering and seaspray complete the time

series. Supplementary results for some anions and physical parameters (pH and conductivity) are shown in fig. 4 and 5. In winter and spring time element concentrations are about one order of magnitude higher than during summer. However in summer comparable deposition fluxes can be observed due to high precipitation rates.



**Figure 2:** Na, Al and Pb concentrations in total deposition samples from Ny-Ålesund (S=snow, M=mixed samples, R=rain)



**Figure 3:** Na, Al and Pb deposition rates in total deposition samples from Ny-Ålesund

The data presented in fig. 2 are derived from bulk samples. The average distribution of selected elements between the dissolved and particulate phase in melted snow samples is shown in fig. 6. The pH is within a range of 4.5-7. This value could also be obtained in eluates

from long range transported aerosols. It can also be seen that the quantities of insoluble components of long range transported aerosols (Kriews and Schrems 1995) are in the same range as in snow samples from Spitsbergen. As examples the Pb, Fe and Na acid soluble amounts are depicted in fig. 7. It is obvious that it is necessary to perform a wet oxidative digestion, to determine the real element concentrations for further evaluation like for the calculation of enrichment factors for source characterization.

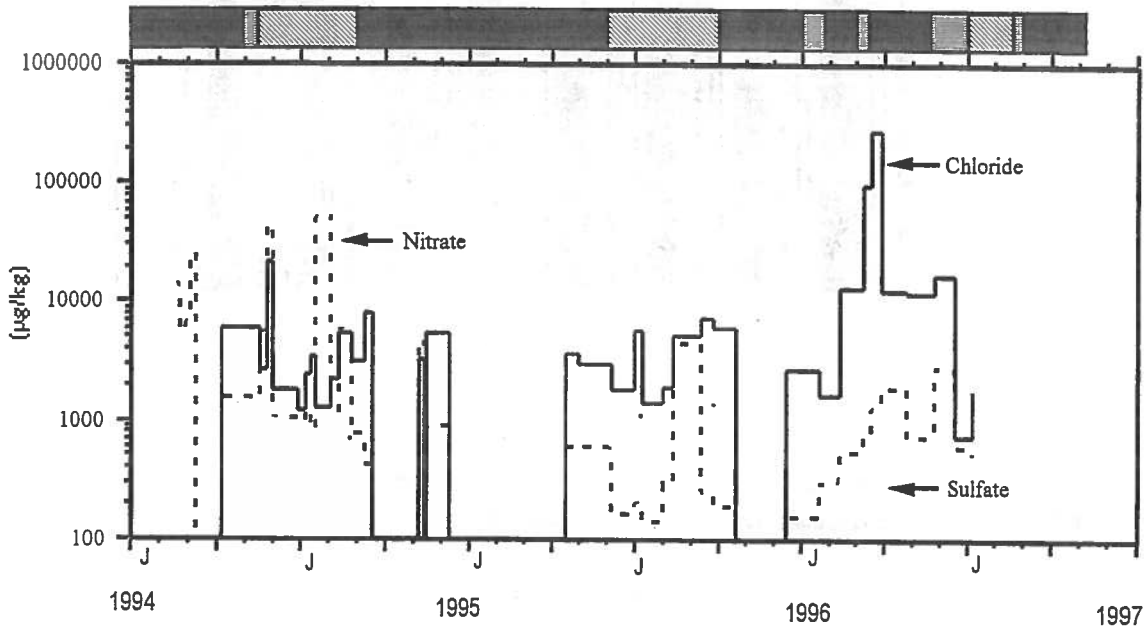


Figure 4: Nitrate, sulfate and chloride concentrations in total deposition samples from Ny-Ålesund

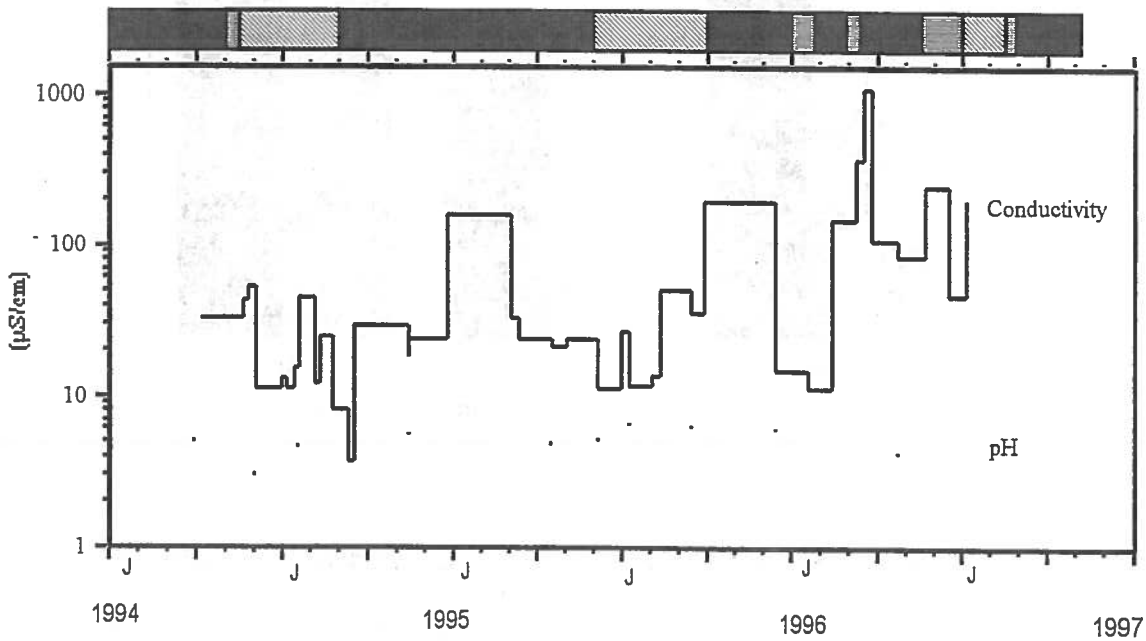
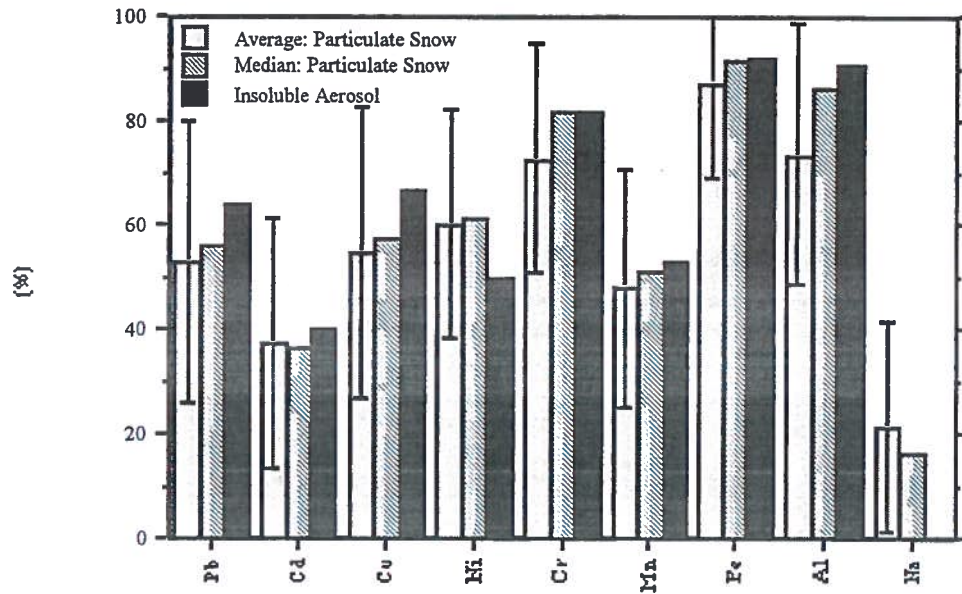
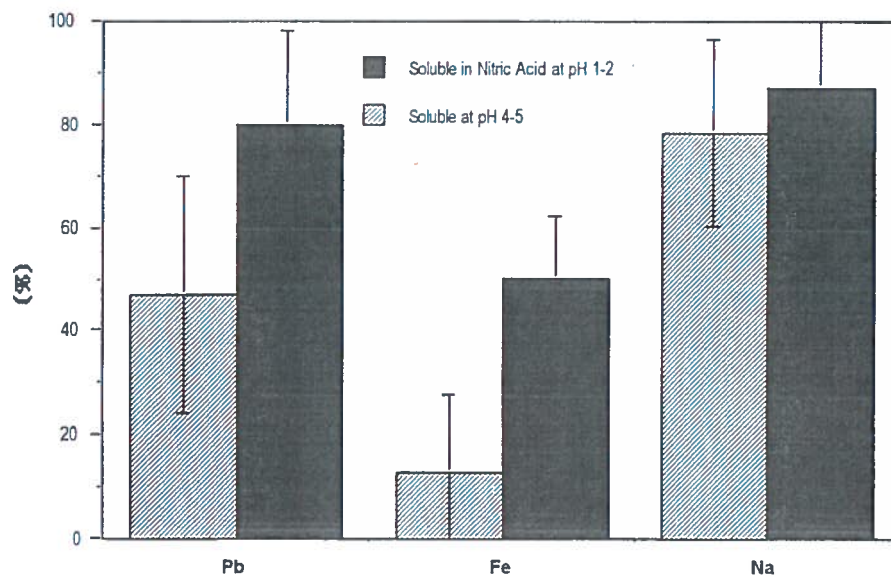


Figure 5: pH-value and conductivity in total deposition samples from Ny-Ålesund



**Figure 6:** Average percentage distribution of selected elements in melted snow samples (n=20) and in long range transported marine aerosols (n=25)



**Figure 7:** Dissolved and acid soluble amount in snow samples (n=10)

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## Event dependent aerosol sampling in Ny-Ålesund

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### Introduction

For a better understanding of the atmospheric transport of aerosol bound heavy metals to the Arctic and their deposition processes to the snow surface we perform wet and total deposition sampling as well as aerosol sampling at Ny-Ålesund since 1996. Multielement analyses of these samples are performed in the home laboratory. We will present new sampling strategies with an automatic aerosol sampler which is designed as a *stand-alone-system* for remote areas. This system can be operated and controlled by a modem from the home laboratory.

### Aerosol sampling device

A newly designed aerosol sampler (ISAP 2000, Fa. G. Schulze) which works completely automatic, was installed in late 1996 on top of the roof (8 m above ground level) of the Japanese Research station which is located 3 km northwest of the center of Ny-Ålesund. In order to obtain significant information regarding the sources of aerosols and transport mechanisms the device allows an event-induced changing of filters. This sampler (fig. 1), which was specially designed for low temperature applications, is equipped with a high-volume-pump and an automatic filter changer for 30 filters or with 15 single stage impactors for size separated aerosol sampling.

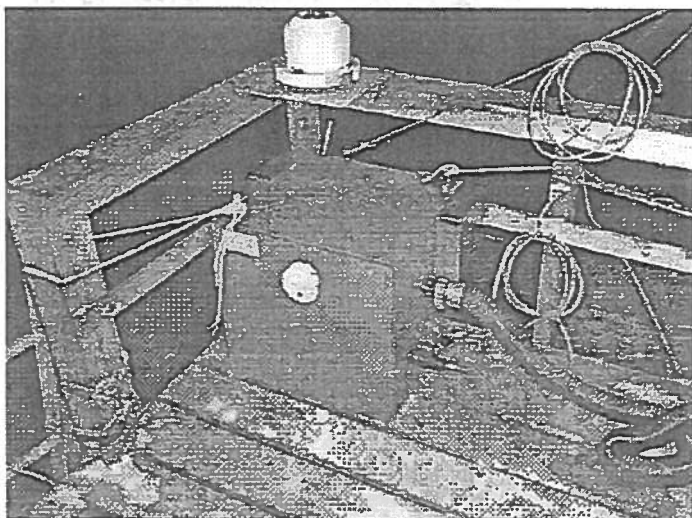
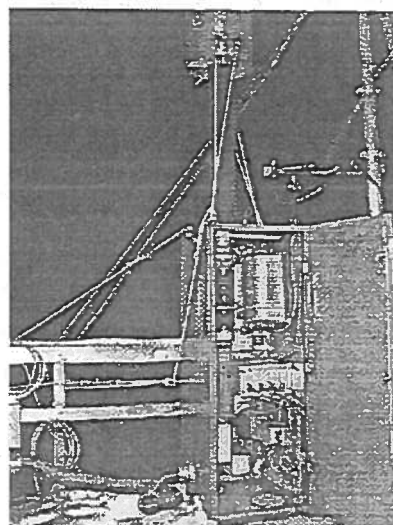


Fig 1: Left: Pump



Right: Automatic filter changer and suction tube

Aerosol sampling is controlled by a computer programme which permits repeatedly selection of each filter. The flow rate is kept to be constant although the filter resistance is increasing due to the aerosol load.

The aerosol sampler is connected to a Server PC (fig. 2, left) combined with a modem located in Ny-Ålesund. Via the host PC at the home laboratory (fig. 2, middle) it is possible to perform on-line control of the device and of meteorological parameters, such as flow rate, starting and sampling time of the individual filters and wind direction, wind speed, air temperature and air pressure as well as the combination of event parameters may be altered. In addition to on-line control all sampling relevant parameters can be stored on the Server PC and transferred by telecommunication to the host PC for further evaluation.

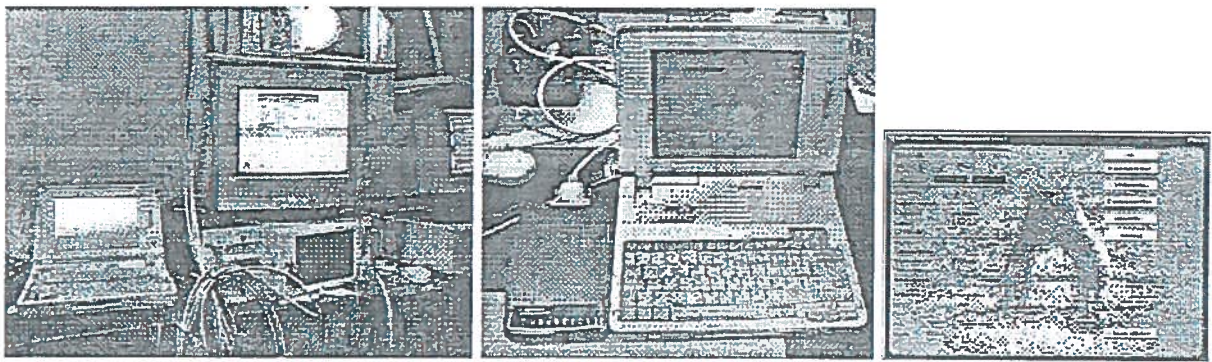


Fig. 2: Left: Server-PC, Middle: Modem and host PC at home laboratory, Right: User surface

For example meteorological conditions, pump and filter parameters are shown in fig. 3 and 4 for a sampling period from 19.12.97-12.01.98. This sampler can be used for two different sampling strategies as described below. The obtained samples are analysed in the home laboratory for anthropogenic elements as well as for terrigenous and marine tracers by GF-AAS, F-AAS and ICP-MS (Kriews and Schrems 1995, 1996). Water soluble anions and cations are determined by ion chromatography.

### **Aerosol sampling depending on wind direction**

The main purpose of the sampling procedure is to obtain specific information about the origin and spatial distribution patterns of trace elements polluting the atmosphere in the Arctic by using a sampling system which takes direction and speed of the local horizontal wind into account. Up to eight sectors can be chosen as sampling sectors on max. eight filters. The system assures that each filter is charged only with aerosol from a selected sampling sector. Situations with low wind speeds and variable wind directions are sampled on two separate filters. During strong wind situations the sampler will be shut off in order to protect the filters from snow drift (for example see fig. 3).

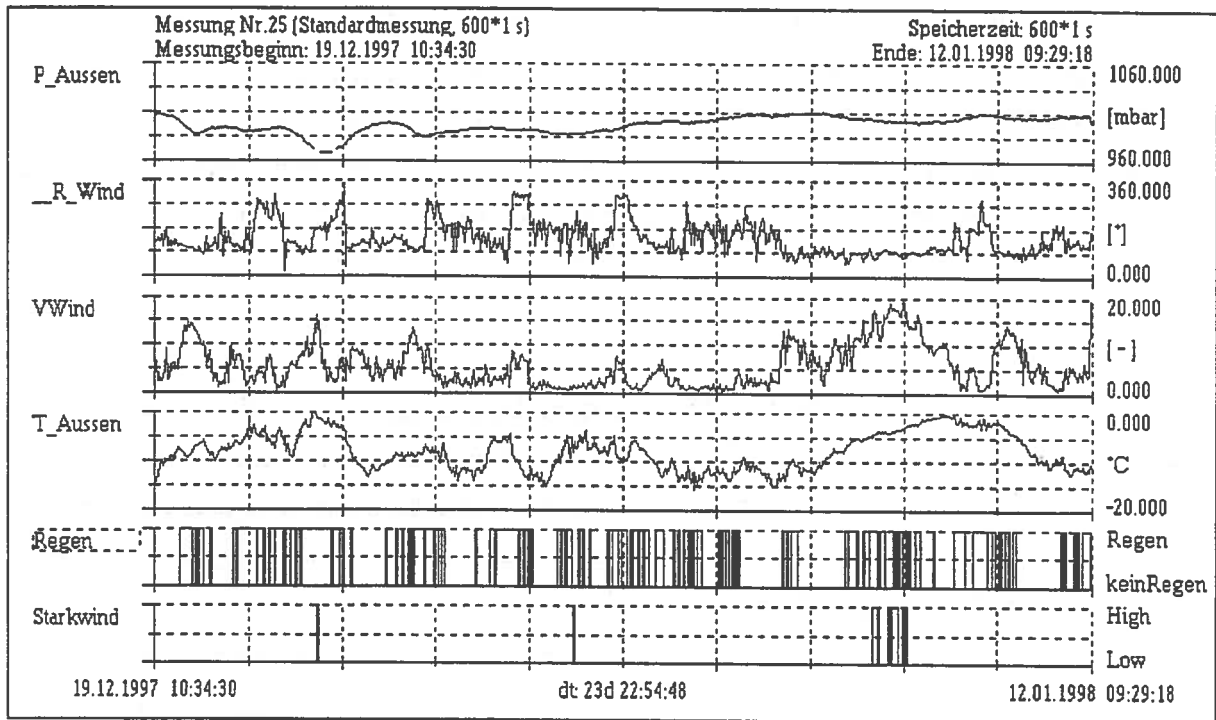


Fig. 3: Meteorological parameters 1. Air pressure, 2. Wind direction, 3. Wind speed, 4. Ambient air temperature, 5. Precipitation (yes/no), 6. High wind speed (>17.5 m/s)

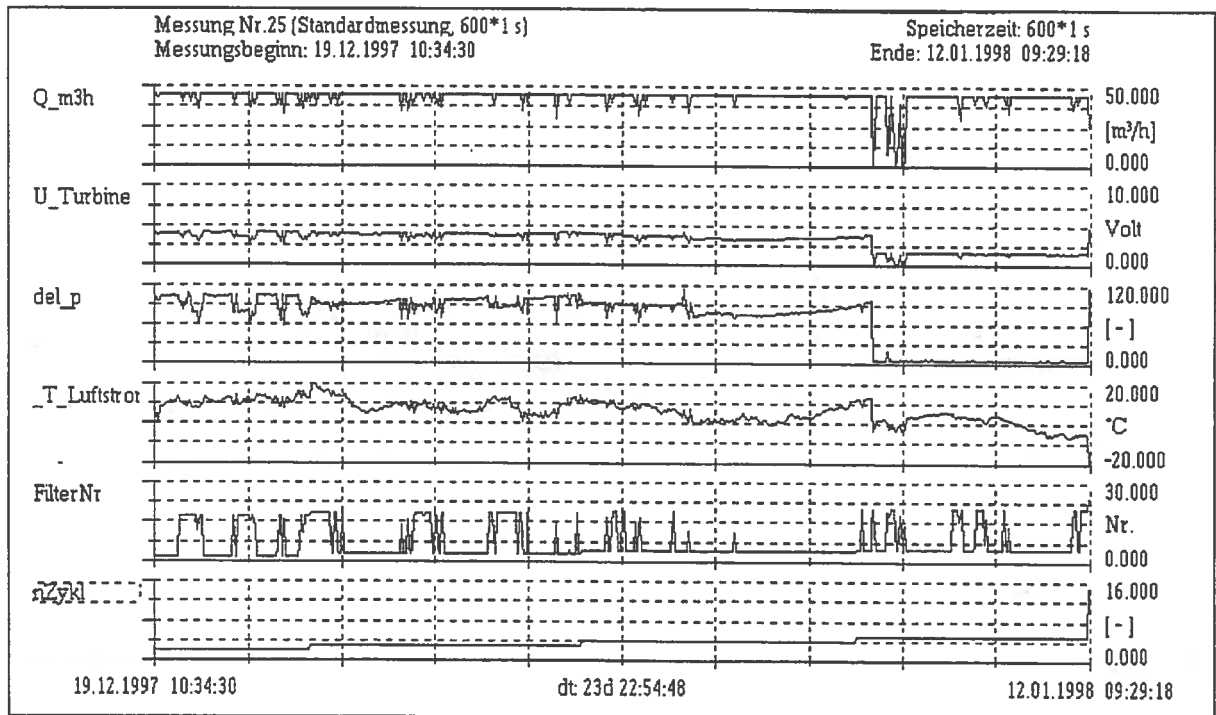


Fig. 4: Sampling system parameters 1. Flow rate, 2. Pump Voltage, 3. Air pressure difference behind the filter, 4. Air temperature behind the pump, 5. activated filters, 6. Monitoring cycle

### Aerosol sampling depending on precipitation

The main purpose of this sampling strategy is to study the aerosol wash out via rain and snow. The sampler is coupled with an optical precipitation sensor. One filter collects aerosol during

dry periods while another filter will be charged with aerosol during wet periods. The precipitation will be sampled by an automatic precipitation sampler, which is also connected to the precipitation sensor. With this strategy we will obtain two aerosol filters and one precipitation sample for each sampling period. This sampling is performed since late 1996. Fig. 3 and 4 shows recorded data for meteorological and aerosol sampler device parameters.

## Results

As first results for element analyses of the automatic aerosol sampling for the investigation of trace element wash out the size distribution of Pb in aerosol particles is shown in fig. 5. For this samples obtained during dry periods in November and December 1996 it is obvious that the main part of Pb is associated to particles smaller than 2  $\mu\text{m}$ . Element analyses for aerosols samples from wet periods are not yet completed.

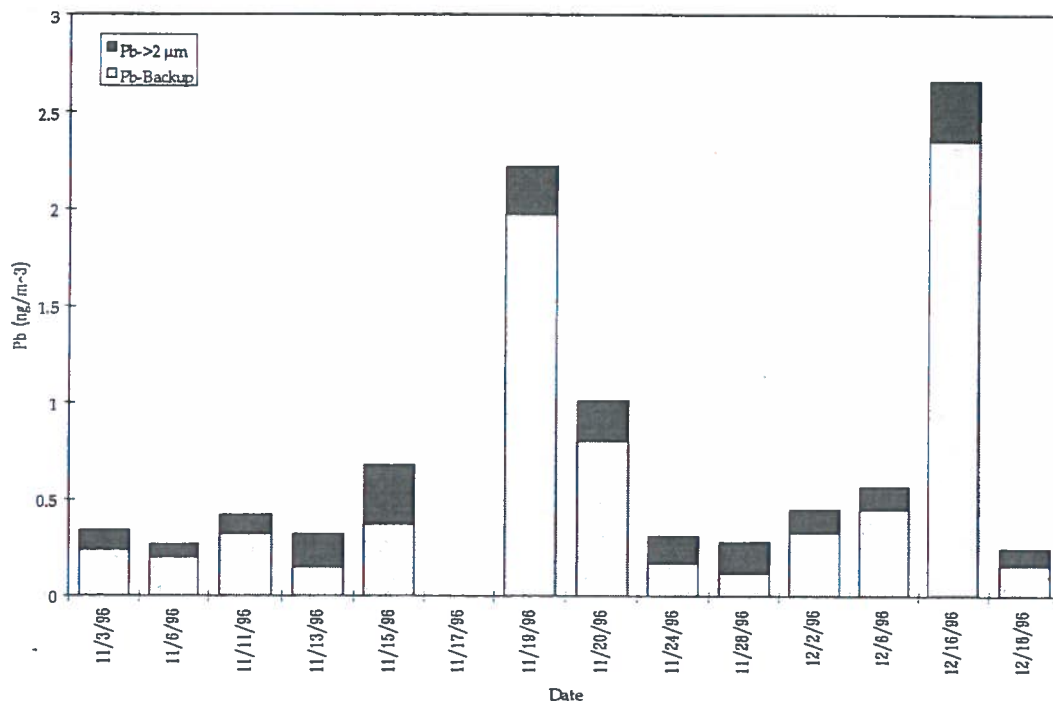


Fig. 5: Pb size distribution in aerosol particles from Ny-Ålesund during dry periods

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# In-Situ Measurements of Alkyl Nitrates

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## 1. Introduction

Alkyl nitrates and PAN are reservoir species for odd nitrogen. They are produced in mid-latitude anthropogenic pollution. During the winter, reduced insolation and/or temperature increases their atmospheric lifetime so that they may be transported over large distances into the Arctic. Subsequent warming and increased insolation at the onset of spring can lead to the decomposition of these reservoir species and a return of  $\text{NO}_x$  to the atmosphere [Beine *et al.*, 1997; 1996].

Because the Nitric acid reservoir is depleted during transport to the Arctic, organic nitrates are a major fraction of the  $\text{NO}_y$  ( $\text{NO}_y \equiv \text{NO}_x + \text{PAN} + \text{HNO}_3 + \text{RONO}_2 + \text{N}_2\text{O}_5 + \dots$ ) budget. While  $\text{NO}_x$  provides a minor addition to the budget [Beine *et al.*, 1997], PAN and alkyl nitrates have been reported to contribute 70 - 80% to  $\text{NO}_y$  during spring in the high Arctic. The sum of alkyl nitrates are about 50 - 60% of the PAN mixing ratio [Bottenheim *et al.*, 1993; Muthuramu *et al.*, 1994]. However, possible shortcomings in the experimental methods used to determine  $\text{NO}_y$  [e.g. Solberg *et al.*, 1997] are still preventing a full understanding of the  $\text{NO}_y$  budget, its contributions and their annual cycles.

The natural conclusion is to measure the main  $\text{NO}_y$  species separately, as was done in the Arctic on a campaign basis for example by Beine *et al.* [1996], or Muthuramu *et al.* [1994]. However, no continuous annual cycles from *in-situ* measurements of alkyl nitrates have been reported to date in the literature. The properties of both PAN and alkyl nitrates are extensively described by Roberts *et al.* [1990].

## 2. Experimental

NILU's PAN-instrument was cleaned and rebuilt in the autumn 1997 after three year continuous operation at Spitsbergen. A wide-bore capillary column (10 m \* 0.53 mm i.d., 2.65  $\mu\text{m}$  HP-1, a non-polar stationary phase) was installed in place of the original packed column, and a preliminary set of operating parameters was determined through a minimum amount of testing. The results were very good, as the detection limit was improved from 10-50 pptv of PAN in a 5 ml sample, to approximately 4 pptv of PAN in a 0.5 ml sample of ambient air. This corresponds to a total amount of 10 fg ( $10 \cdot 10^{-15}$  g) of PAN in one sample, close to the normally accepted physical limit of the ECD sensitivity.

The increased sensitivity also allowed detection of 8-10 compounds that were not seen at Spitsbergen with the original PAN-instrument. Comparison with a chromatogram from Roberts *et al.* [1989], made with a capillary column with stationary phase DB-1 (very similar to HP-1),

provides a close to positive identification of all these additional peaks. The retention indices measured by Roberts and by NILU are not expected to be equal, since column diameter, film thickness and flow are different in the two cases. The linear relationship between the two sets of retention indices, however, is a strong argument for our identification of peaks.

Table 1.: Component names, formulae, and retention indices in the experiments at Spitsbergen in October 1997, compared with results published by Roberts in 1989.

Name	Formula	Retention index (Roberts 1989)	Retention index (NILU, 1997)
R11	CFCl <sub>3</sub>	1	2.64
Methyl nitrate	CH <sub>3</sub> ONO <sub>2</sub>	1.19	2.91
Ethyl nitrate	CH <sub>3</sub> CH <sub>2</sub> ONO <sub>2</sub>	2.93	3.57
Carbon tetrachloride	CCl <sub>4</sub>	5	4.48
PAN	CH <sub>3</sub> C(O)OONO <sub>2</sub>	5.11	5.32
Isopropyl nitrate	(CH <sub>3</sub> ) <sub>2</sub> CHONO <sub>2</sub>	5.23	5.59
n-Propyl nitrate	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> ONO <sub>2</sub>	7.72	6.93
PPN	CH <sub>3</sub> CH <sub>2</sub> C(O)OONO <sub>2</sub>	12.91	8.82
sec-Butyl nitrate	CH <sub>3</sub> CH <sub>2</sub> CH(CH <sub>3</sub> )ONO <sub>2</sub>	13.63	10.00
	C <sub>2</sub> Cl <sub>4</sub>	18	12.61
n-Butyl nitrate	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>3</sub> ONO <sub>2</sub>	21.21	15.36

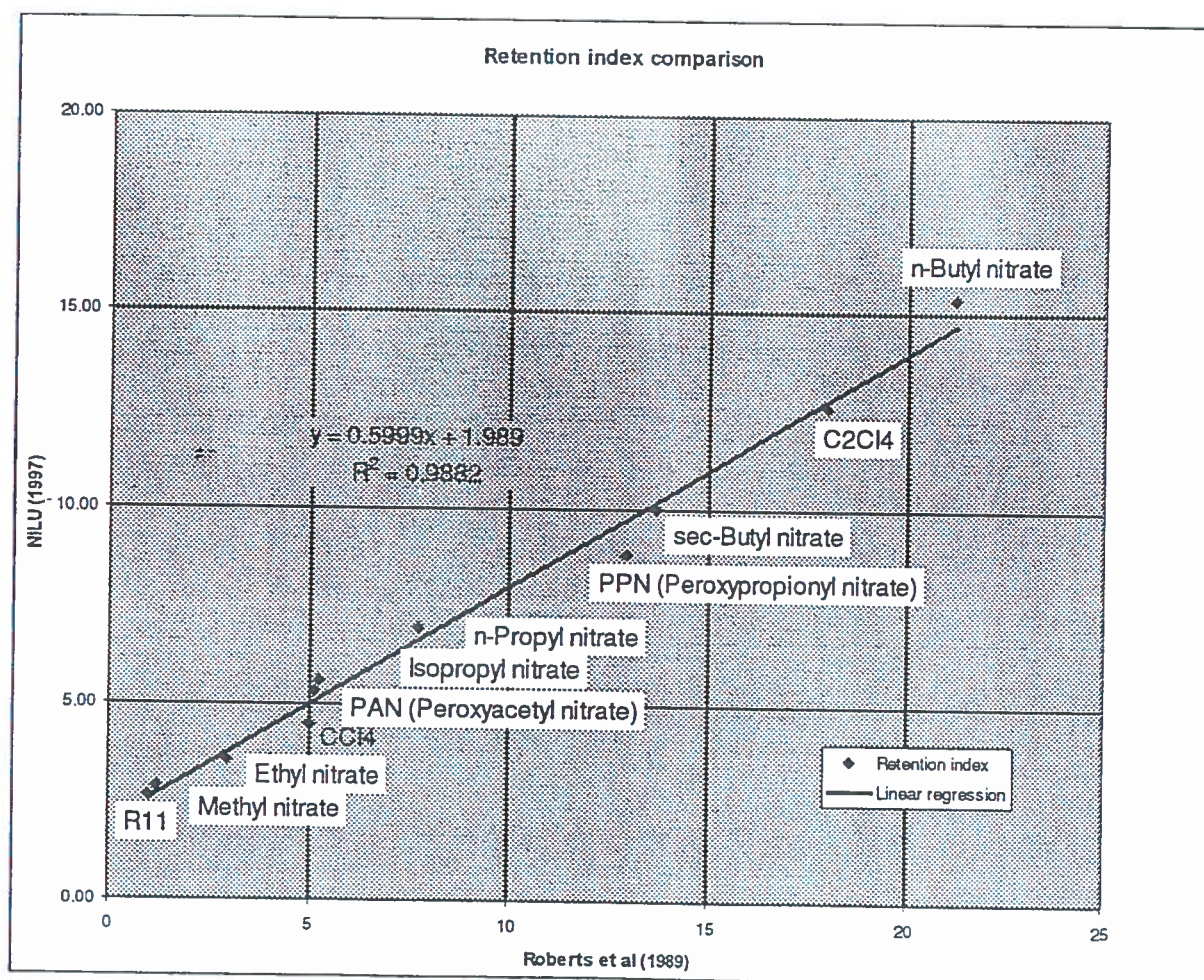


Figure 1.: Justification for our preliminary identification of peaks is found in the linear relationship between retention indices found by Roberts et al., and at NILU in October 1997.

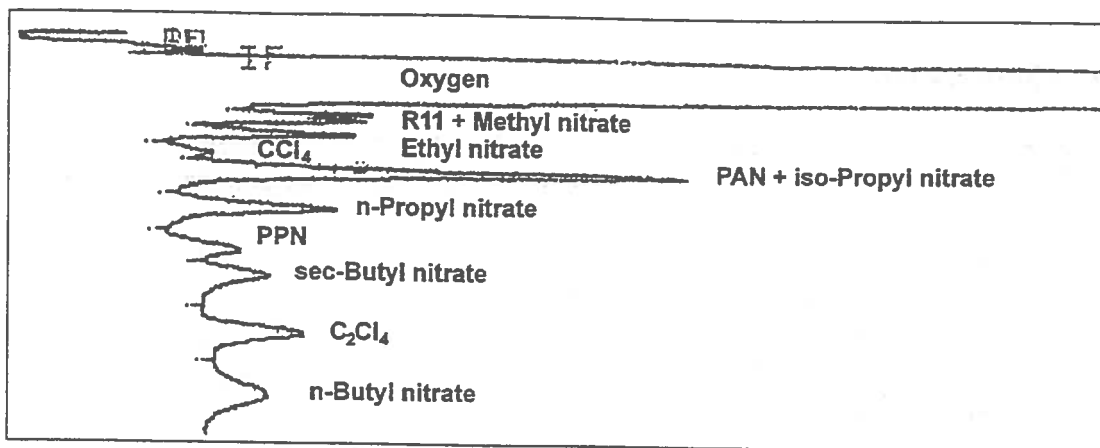


Figure 2.: A typical chromatogram from the PAN/alkyl nitrate GC with the 10 m \* 0.53 mm column (2.65 $\mu$  HP-1) and isothermal operation with nitrogen carrier gas.

One preliminary experiment has been performed with a 30 m column. This revealed that the preliminary identification of peaks above was based on several merged components. Even further increase in resolution is required. The nitrogen carrier gas should be replaced by helium, to increase the resolution and allow higher column flow without resolution degradation. The make-up gas should still be nitrogen to ensure proper operation of the ECD. The separation should also be improved by temperature programming in the range +5°C to +85°C. PPN should elute before the temperature exceeds 40°C, since higher temperatures would destroy PAN and PPN.

### 3. Preliminary measurement results

The modified instrument has been in operation at the Zeppelin Mountain since the end of August 1997. In figure 3 we see a clear trend of increasing PAN mixing ratio during September, consistent with results from the autumn period of the three previous years. In comparison, a stronger increase is indicated for n-Propyl nitrate.

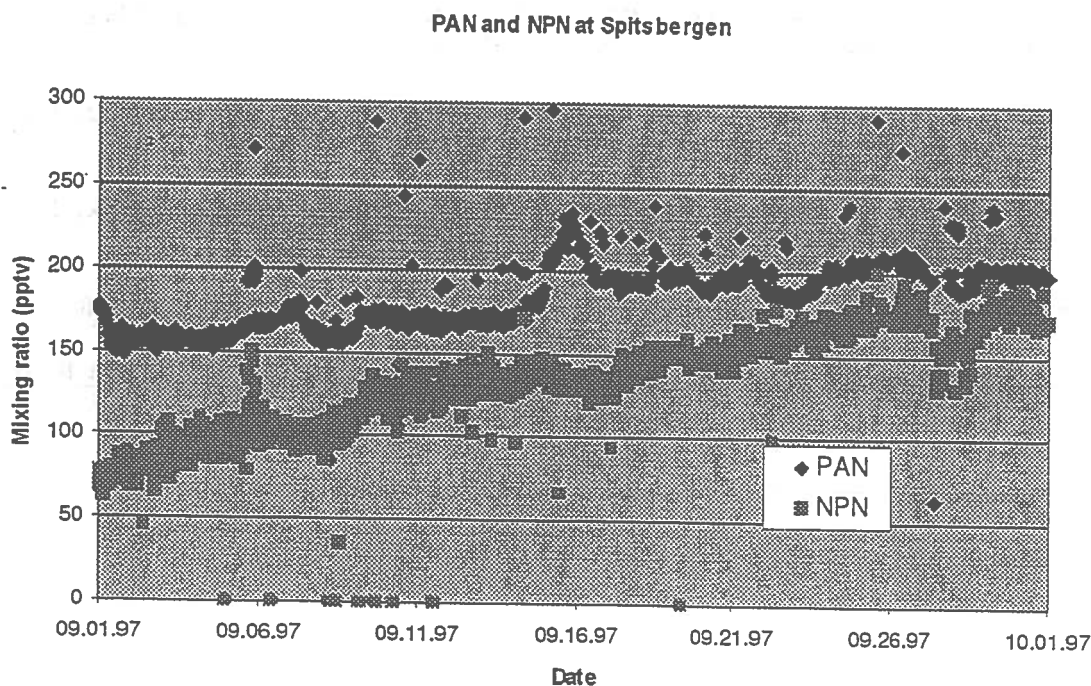


Figure 3.: Preliminary results for PAN and NPN at the Zeppelin Mountain during September 1997.

#### 4. Conclusions

- The first in-situ measurements of alkyl nitrates in the arctic are presently being performed by NILU. They are expected to provide an important data set for understanding of the NO<sub>y</sub> composition in the arctic atmosphere.
- The improved sensitivity obtained in the GC/ECD measurement method is in itself an important result. The method is however unfinished.
- An increase in alkyl nitrates is indicated during the autumn period, and these compounds will be important for understanding the atmospheric chemistry during the spring photochemical episodes.
- Previous measurements of alkyl nitrates in the atmosphere have been made with complex cryogenic pre-concentration techniques, or by extraction from charcoal traps, to achieve the required sensitivity. The method used by NILU allows alkyl nitrate with higher time resolution to be performed at a lower cost.
- For the first time, the ratio between PAN and alkyl nitrates in the arctic may now be investigated with an in-situ measurement technique. The annual cycle of this ratio gives important information about photo-chemistry in the arctic.
- Ratios of alkyl nitrates to their parent VOC's may yield information about transport times of air masses arriving at the Zeppelin Mountain Station.

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# UV solar radiation and clouds: experimental data and modeling

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## Abstract

In the perspective of determining cloud effects on ultraviolet (UV) radiation reaching the ground, a preliminary comparison in clear sky conditions between UV global radiation measured by a Brewer spectrophotometer and calculated by a semi-empirical radiative transfer model has been realized. Comparison has been made for global UV-B irradiances (290–325 nm) by integrating model and instrument data. Global UV-B irradiances measured and calculated are in good agreement ( $\approx 5\%$ ) in two different sites: Vigna di Valle (42.083 N, -12.2167 E) in Italy and Ushuaia (-54.822 S, 68.323 W) in Argentina. For spectral irradiances, differences between instrument and model are larger, due to smoothed results of calculations.

## Introduction

For an efficient utilization of broadband radiometers, cloud effects on UV radiation reaching the ground knowledge is very important. In fact this kind instrument calibrations are realized always in isotropic conditions, and a cloudiness situation can reflect in a distortion of measured irradiances. This handicap can be overcome by using a radiative model simulating UV irradiances together with measured irradiances. In this case cloud effects on UV radiation can be characterized by the ratio between the irradiance actually received at the ground and the irradiance that would have existed under clear skies. As a first stage of our working program, a comparison between model and measurement results in clear sky conditions has been realized. For our calculations we used the last version of Green model<sup>1</sup>, an evolution of that one furnished by Yankee Environment Inc. together with their instruments<sup>2</sup>.

Green model uses semi-empirical formulas for calculating the direct, diffuse and global ultraviolet spectral irradiance penetrating to the ground. Analytic spectral functions for the extraterrestrial solar spectral irradiance, the ozone absorption coefficient, Rayleigh scattering coefficients and aerosol scattering and absorption coefficients fitting four type of aerosol models<sup>3</sup> are used as basic inputs. The direct component is then calculated by the Beer's law and the diffuse component is derived by a ratio technique described in Green et al.<sup>4</sup>. The influence of ground reflectivity and of cloud effects can be also inserted in the calculations. We tested the agreement between instrument and model UV irradiances in two case studies: the 6/7/1994 day in Vigna di Valle (42.083 N, -12.2167 E) and the 10/26/1996 in Ushuaia (-54.822 S, 68.323 W).

### Model description

The Green model describes in a "engineering way" the global spectral irradiance  $G(\lambda, \theta)$  in the middle ultraviolet (290-360) reaching the ground, as a function of wavelength  $\lambda$ , angle of the sun  $\theta$  and various parameters which characterize the state of the atmosphere. The model calculates separately the downward direct spectral irradiance  $D(\lambda, \theta)$  and the downward diffuse spectral irradiance  $S(\lambda, \theta)$  at the ground. The direct component, derived from the Beer's law, may be placed in the form:

$$D(\lambda, \theta) = \cos\theta H(\lambda) \exp\left[-\sum_j (\tau_j(\lambda) / \mu_j(\theta))\right] \quad (1)$$

where  $H(\lambda)$  represents the extraterrestrial solar spectral irradiance,  $j=1,2,3$  denote the air, aerosol and ozone indices,  $\tau_j$  the relative optical depths and  $\mu_j$  denote generalized cosine functions which are appropriate to the three species in view of the roundness of the earth. In the last version of the Green model  $H(\lambda)$  allows for the Fraunhofer structure of the solar irradiance and aerosol optical depth allows for the different type of aerosol models (rural, urban, maritime and tropospheric) by Shettle and Fenn<sup>3</sup>. On the other hand the ozone optical depth is described by a spectral function fitting the Vigroux data<sup>5</sup> and then allows for the ozone absorption bands only in a mean way. For this reason the Green model is not suitable to calculate the spectral irradiances with a good resolution.

The diffuse component at the ground is presented in terms of two ratios and the direct spectral irradiance for an overhead sun ( $\theta=0$ ), that is:

$$S(\lambda, \theta) = S(\lambda, \theta) M(\lambda, \theta) H(\lambda) \exp\left[-\sum_j \tau_j\right] \quad (2)$$

where

$$S(\lambda, \theta) = S(\lambda, \theta^\circ) / S(\lambda, 0^\circ) \quad \text{and} \quad M(\lambda, \theta) = S(\lambda, 0^\circ) / D(\lambda, 0^\circ).$$

This combination of ratios permits a variation less than one order of magnitude for the  $M$  dynamic range and a reasonable variation for the  $S$  dynamic range consenting a representation at few percent level of accuracy except at solar zenith angle  $>80^\circ$  and for wavelength  $<290$  nm.

### Results

To verify the agreement between irradiance measurements and model results two case studies have been selected: a measurement campaign realized in the 1994 at Vigna di Valle<sup>6</sup> near Rome and a measurement campaign realized in the 1996 at Ushuaia near Tierra del Fuego. In both the cases clear sky days have been selected for the comparison between the experimental data obtained by a Brewer spectrophotometer (290-325 nm working range) and the Green model calculations.

Fig. 1 shows the comparison between global irradiances integrated on the 290-325 nm range (UV-B range) as measured by the Brewer (dots) and calculated by the model (solid curve) for the 7 June 1994 at Vigna di Valle. The good agreement between the experimental points and the model curve is quantified in Fig. 2 where the normalized differences, calculated at the scan time of the Brewer, are reported. As can be seen the difference between instrument and model results remains in the 5% limits for the central hours of the day, whereas at sunrise and sunset the values rise dramatically. This effect is probably due to the sum of two different ones: the cosine response of the instrument, that lead to underestimate the UV radiation at large solar zenith angles, and the level of accuracy of the skylight determination in the Green model, as reported in the previous section.

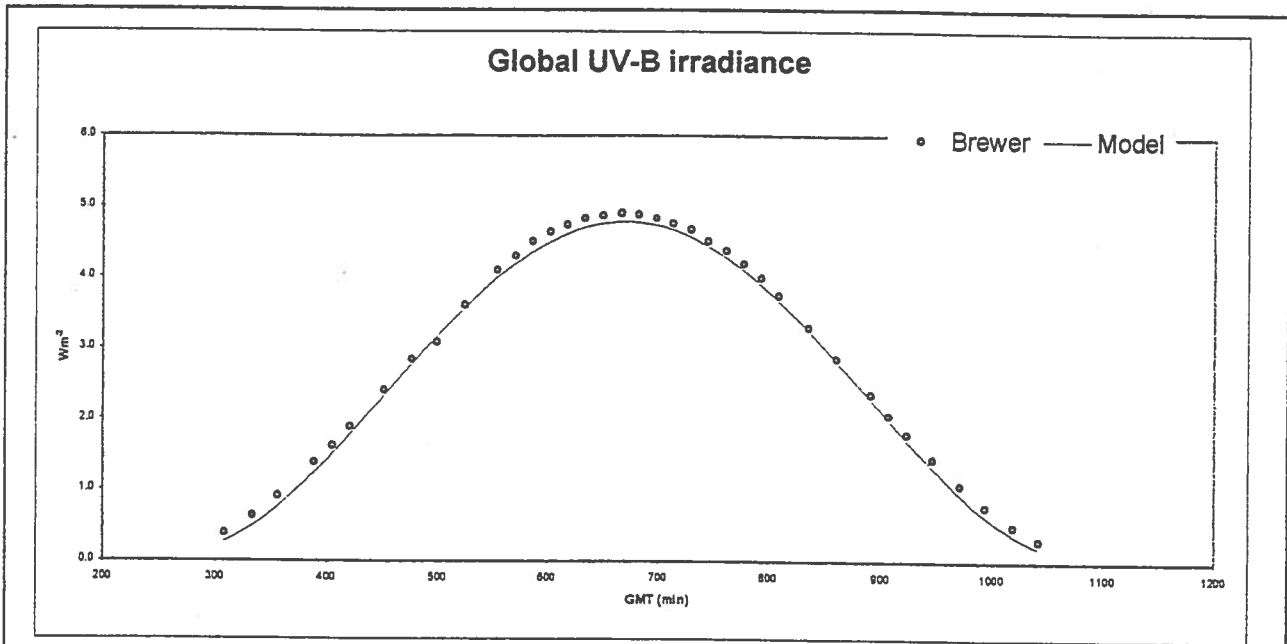


Fig. 1 - UV-B global irradiances of Brewer and model, at Vigna di Valle for 07 June 1994.

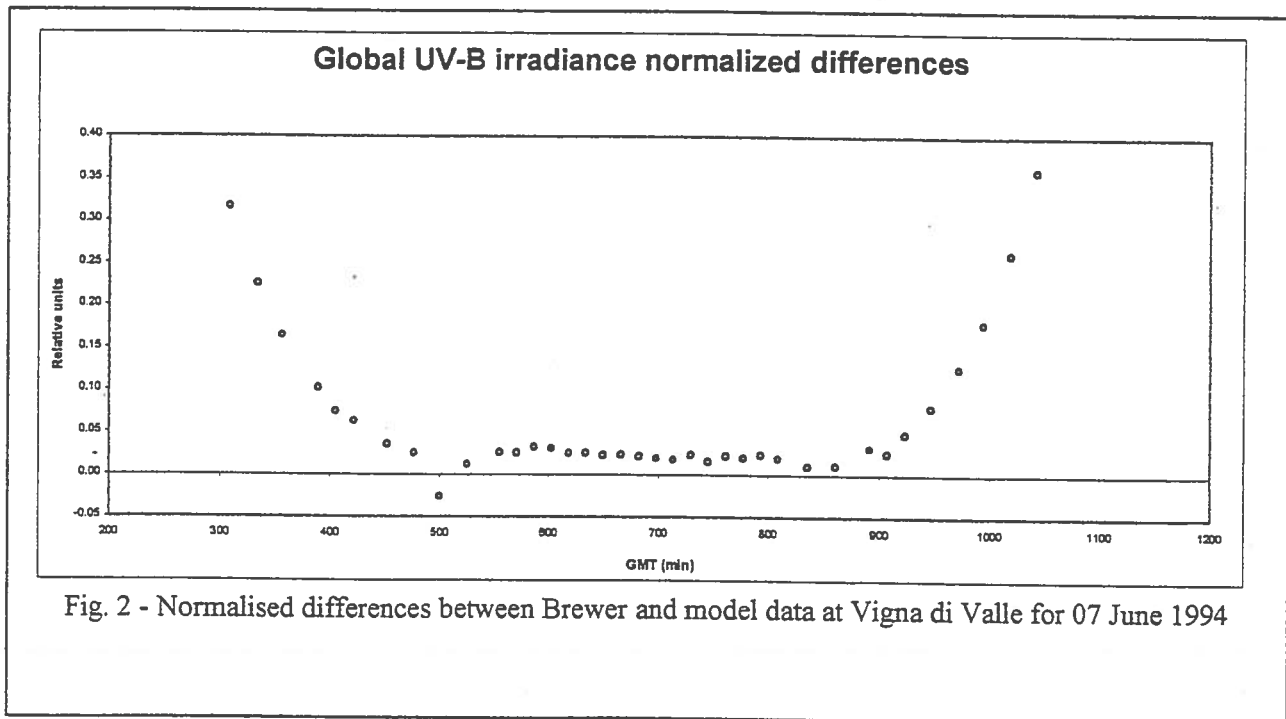


Fig. 2 - Normalised differences between Brewer and model data at Vigna di Valle for 07 June 1994

Fig. 3 shows the comparison between the spectral irradiances for the same day. The model curve shows a structure much smoother in comparison with the experimental points, as the previous section anticipates.

Fig. 4 shows the comparison between global UV-B irradiances as measured by the Brewer (dots) and calculated by the model (solid curve) for the 26 October 1996 at Ushuaia. Though in this case there was some cloudiness the agreement between model curve and experimental point is satisfactory.

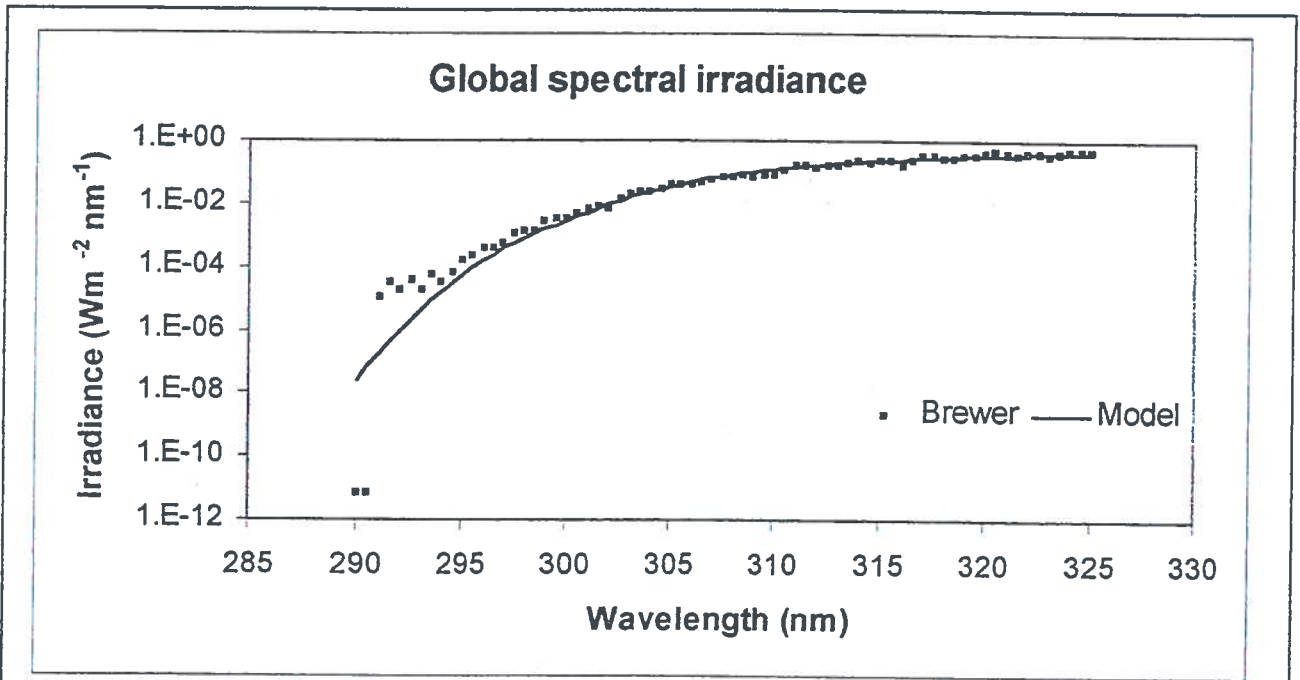


Fig. 3 - Comparison between Brewer and model global spectral irradiance

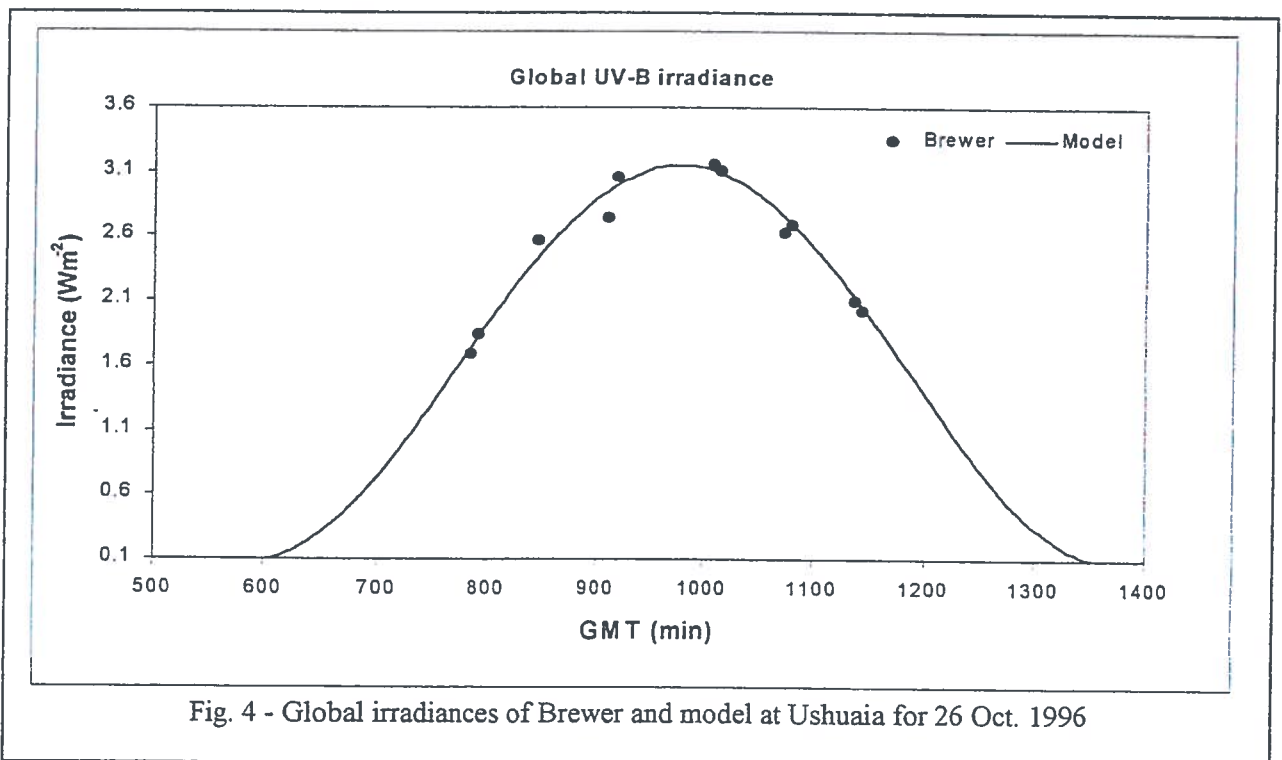


Fig. 4 - Global irradiances of Brewer and model at Ushuaia for 26 Oct. 1996

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## **THE EMISSION OF HALOGENS FROM THE ARCTIC PACK-ICE AND ITS ROLE IN THE TROPOSPHERE FROM MEASUREMENTS AT NY ALESUND AND SÖNDRE STRÖMFJORD.**

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The study of reactive nitrogen and halogen compounds in the troposphere is particularly important because of their role in catalytic destruction of ozone, O<sub>3</sub>. The potential for O<sub>3</sub> depletion is controlled by the balance between reactive species, X, XO (X=Cl, Br, I) and NO<sub>x</sub> (=NO + NO<sub>2</sub>), and reservoir compounds such as X<sub>2</sub>, XONO<sub>2</sub>, HX, HOX, HNO<sub>3</sub>. OH/HO<sub>2</sub> radicals that participate in most catalytic cycles that destroy O<sub>3</sub> and control, in part, the partitioning of the reactive halogen and nitrogen species within the reservoirs. The processes that control the relative abundances of species in these groups are essential to understanding the O<sub>3</sub> depletion processes and their potential large scale effects.

Several important species depend strongly on the solar flux on time scales of hours or less. This holds for example for BrCl whereby chlorine and bromine compounds are tightly linked.

Sea salt aerosol has been proposed by Vogt et al., 1996 as source for halogens in air above the oceans. Surface ozone mixing ratios suddenly drop from about 40 ppb to often below the detection limit when air passed over the north polar ice cap (Bottenheim et al., 1990). This suggests an involvement of bromine chemistry in the arctic ozone destruction (Barrie et al., 1988). Since those findings were confirmed at Barrow, Alaska, (Oltmans et al., 1989; Li et al., 1990; Sturges et al., 1993) it seemed to be an Arctic wide phenomenon (Barrie et al., 1994; EC-Report, 1996). Now the emission of large amounts of bromine from Antarctic pack ice regions were found during sunlit periods (Kreher et al., 1997) which shows the global significance of this process.

### **Experimental Observations**

In the boundary layer inorganic active halogen is scarce. The pattern of hydrocarbon depletion usually indicates only a minor participation of chlorine in comparison with that of the hydroxyl radical, OH (Jobson et al., 1994). Bromine and iodine monoxide also seem to be present only sporadically in the marine environment.

Convincing evidence for the participation of halogen in the low ozone events, LOE, of the boundary layer has been found so far during the arctic spring when Berg et al., 1983 observed large amounts of bromine in such air. The causality with ozone depletion was proposed by Barrie et al., 1989. The first spectroscopic evidence for BrO was later obtained by Hausmann and Platt, 1994 who observed around 15 ppt of BrO during a LOE.

Follow up experiments within the EC-sponsored Arctic campaigns at Ny Alesund, Spitsbergen, in April 1995 and 1996 (ARCTOC) showed BrO mixing ratios up to 30 ppt during LOEs (EC Report, 1996). Ozone dropped at low temperatures (-20°C) and extending to 1000m a.s.l. from 40 ppb to virtually zero. Both species were observed by differential optical absorption spectroscopy (DOAS) along a 2 km lightpath between 20 and 475m a.s.l. well separated from ground and along a 5 km path close to the ground sloping up to 400m a.s.l. (Martinez et al., 1998). The causes of the depleted ozone were assumed to have been chemical in nature involving up to 30 ppt BrO.

At the same time a chemical amplifier (ROx-box) was applied to measure the concentration of the peroxyradicals, HO<sub>2</sub> and RO<sub>2</sub>, coming from normal ozone chemistry and intended to gain information about the detailed chemistry (Arnold, 1998). However, the signals suggested a sensitivity of the chemical amplifier also towards Cl and ClO. First laboratory calibration experiments showed the chain length for Cl/ClO to be comparable to that of HO<sub>2</sub>. In general the BrO was accompanied by several ppt of chlorine. Apparently both bromine and chlorine are indeed involved in the chemical depletion of the boundary layer ozone. Furthermore, similar amounts of active chlorine were sometimes found in the absence of BrO or outside any significant O<sub>3</sub> depletion.

At Søndre Strømfjord, Greenland, in July/August 1995 during the Second European Stratospheric Arctic and Mid-latitude Experiment (SESAME) a transient episode of tropospheric BrO was detected by its absorption in zenith sky scattered sunlight spectra. The temporal behaviour of the vertical columns of BrO retrieved by differential optical absorption spectroscopy (DOAS) suggests the photolysis of a bromine reservoir, probably BrONO<sub>2</sub>, yielding BrO beginning at a solar zenith angle of 80°. The reformation of this or another reservoir is indicated by the decrease of the BrO signal towards sunset.

Backtrajectories point also to the Arctic as source of that atmospheric bromine. Similar observations had been made already several times before during spring at that location. Also at the Jungfrauoch, Switzerland, this phenomenon was found. However, under both those circumstances the additional BrO absorption appeared less intense.

Several chemical mechanisms have been proposed to account for the link of bromine chemistry with ozone (Barrie et al., 1988; Finlayson-Pitts et al., 1990; McConnell et al., 1992; Fan and Jacob, 1992; Mozurkewich, 1995; Sander and Crutzen, 1996; Wessel et al., 1996; Vogt et al., 1996; Tang and McConnell, 1996).

The origin of the bromine is the arctic ice float. The initiation of the bromine ablation is probably by chlorine atoms which may stem from oxidation of gaseous HCl by OH or are produced from the sea salt on the ice by other processes. The formation of HOCl and subsequent oxidation of Cl<sup>-</sup> leads to dissolved or adsorbed Cl<sub>2</sub>. Cl<sub>2</sub> attaches to Cl<sup>-</sup> and the Cl<sub>3</sub><sup>-</sup> will live long enough until it encounters one of the much less abundant Br<sup>-</sup> and exchanges the halogen to form BrCl<sub>2</sub><sup>-</sup>. This ion is in equilibrium with BrCl and Cl<sup>-</sup>. If the exchange process goes on, Br<sub>2</sub>Cl<sup>-</sup> is formed for which the equilibrium between halogen and halogen ion is even more on the side of the Br<sub>2</sub> and Cl<sup>-</sup>. The Br<sub>2</sub> may then escape to the atmosphere where it is photolysed.

In addition to those primary production mechanisms autocatalytic cycles provide the necessary strong release of bromine from sea-salt. Mozurkewich, 1995 proposed the oxidation of bromide by hypobromous acid, HOBr, on sea-salt to elemental bromine, Br<sub>2</sub>. He considered this mechanism not effective as source of photochemically active chlorine. In contrast Vogt et al., 1996 proposed the oxidation of bromide and chloride by HOBr and the release of BrCl and Br<sub>2</sub>. They provide a detailed picture of the chemical mechanism in this process. Tang and McConnell, 1996 proposed the autocatalytic release of Br<sub>2</sub> at polar sunrise from sea-salt bromide residing under the snow pack stimulated by a bromine seed. The discussion with the help of a chemical box model will concentrate on bromine and a possible participation of chlorine. The meteorological conditions and the back trajectories argue in favour of a primary halogen activation and its continuing recycling by heterogeneous reactions.

The chemistry was verified by a chemical box model including the initiation of the halogen release by photochemistry of chlorine. Following this primary process an autocatalytic activation of bromine from the pack ice must occur to obtain the large mixing ratios of bromine observed.

Later during transport of the air masses continuous recycling of the halogen species by probably heterogeneous reactions must take place. Part of this bromine finds its way into the free troposphere where it reacts with  $\text{NO}_2$  to form the highly photolysable  $\text{BrONO}_2$  which only for part of the day releases  $\text{BrO}$ . So in the free troposphere the ozone is partially protected from depletion.

The emission of inorganic bromine from the sunlit polar regions is estimated from the groundbased observations as performed at Ny Alesund to be about  $10^{12}$  molec  $\text{m}^{-2}$   $\text{sec}^{-1}$ .

During transport the chlorine may be deposited from the airmass in the form of  $\text{HCl}$ . Reprocessing of  $\text{HOBr}$  and  $\text{HBr}$  on ice surfaces keeps bromine going.

## Conclusions

It seems certain that the ultimate cause for ozone depletion during polar sunrise is the photochemical action of halogens. The main actor is bromine with occasional participation of chlorine and possibly iodine. Taken the global pack ice area the total source of inorganic bromine for the sunlit periods is estimated to be  $30 \text{ kt yr}^{-1}$  which may in part find its way into the free troposphere. The ozone depletion will be restricted to the noon hours if the bromine exists in the  $\text{BrONO}_2$  reservoir (Perner et al., 1998).

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# Polar Umkehr profiling during the Ozone hole period

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## Abstract

Continuing the study of ozone depletion in polar areas the Umkehr vertical profile trends are studied. The data of two bases, Marambio and Ushuaia, both Argentinean sites, are considered.

The variations of the shapes during the hole period linked to the polar vortex position are considered. Particular attention to the differences into each layer is too. Finally the results are compared with the ozonesounding data collected in Marambio, Antarctic peninsula station on the hole boundary site.

## Introduction

As known F.W.P. Goetz discovered the Umkehr effect in his expedition in the Spitzbergen Island in the 1931 (Dütsch & Staehelin). The discovery produced in 1934 (Goetz *et al.*) the "Umkehr model" for the vertical profile of ozone concentration by UV solar measurements. The inversion algorithm proposed by Mateer and Dütsch, 1964, was considered as standard procedure for studies of Umkehr effect. In the 1992 Mateer and DeLuisi (Mateer *et al.* 1992) developed a new algorithm that was implemented by the World Ozone Data Center for the Brewer spectrophotometric Umkehr measurements.

This algorithm utilized as starting values of stratospheric aerosols content, ozone absorption coefficients and their temperature dependence. A more important factor is the hypothesis about the sky conditions for the radiance transmitted in the zenith direction of solar UV measurements. The sky (the atmosphere) must be clear, dry, and spherically homogeneous for the molecular scattering and ozone absorption (Mateer *et al.* 1996). These are conditions that not always are founded and especially in a campaign of measurements in remote areas.

This paper shows some results about the Umkehr sampling with the spectrophotometer Brewer compared with the *a priori* vertical profile model and vertical profile model compared with ozonesounding sampling. The experimental data set was carried out in the campaign in Ushuaia (Tierra del Fuego, Argentina, 54.822° S - 68.323° W) and in the Argentinean Antarctic bases of Belgrano II (77.870° S - 34.620° W) and Marambio (64.223° S - 56.717° W).

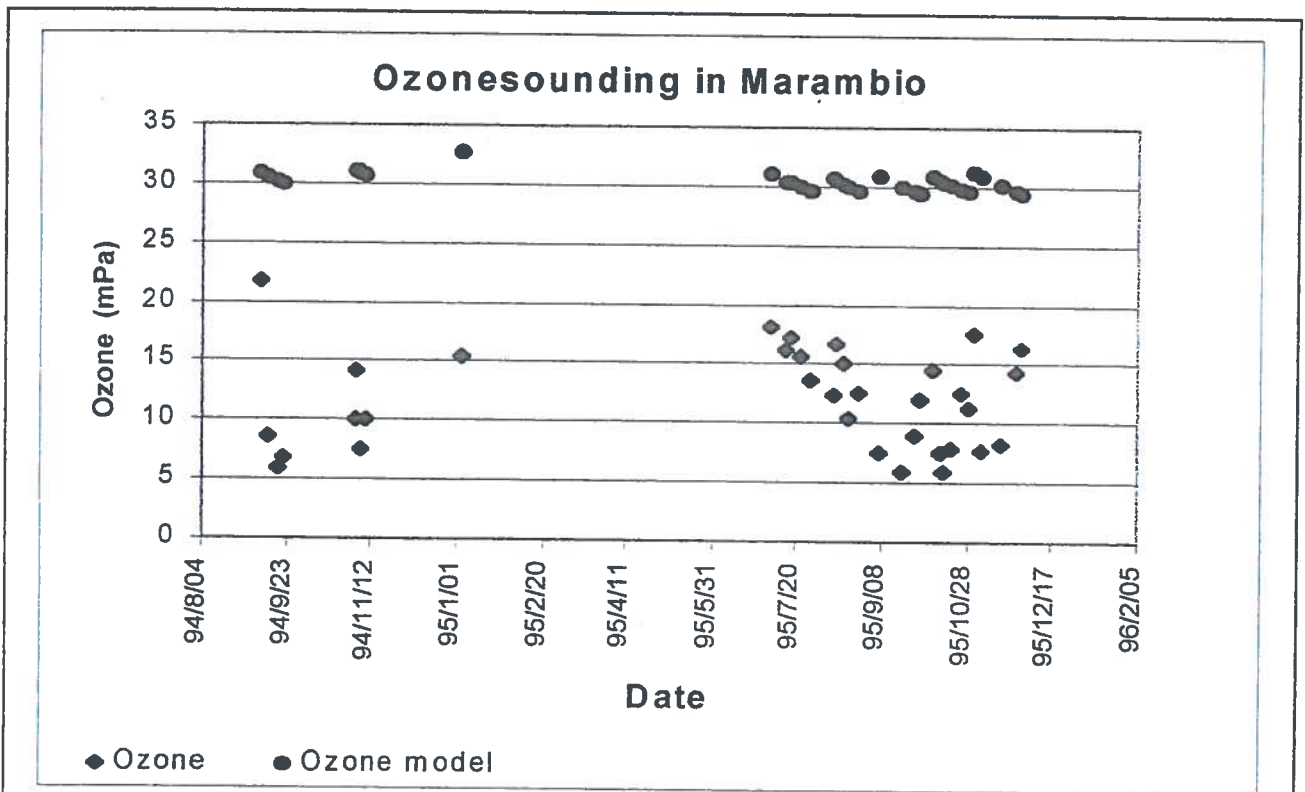


Fig. 1 - Ozonesounding in Marambio: Comparison of Ozone concentration sounding and *a priori* profile

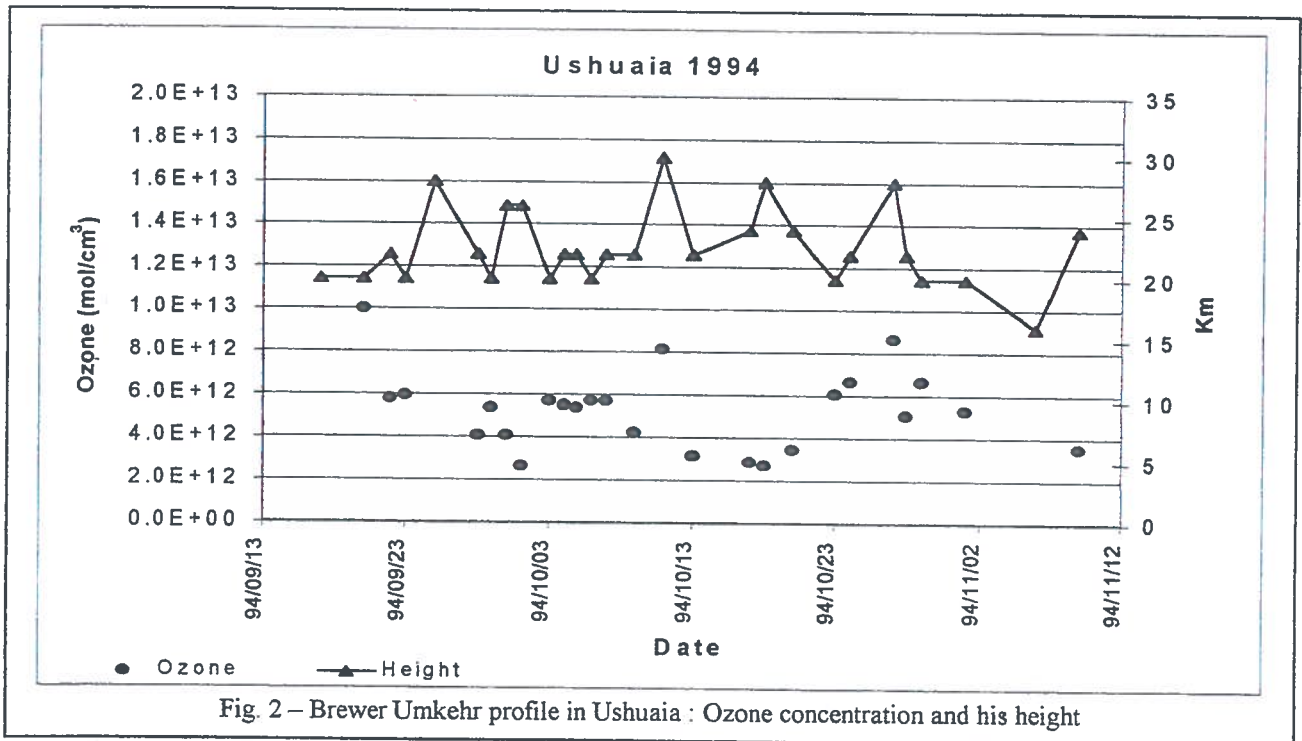


Fig. 2 – Brewer Umkehr profile in Ushuaia : Ozone concentration and his height

**Umkehr *a priori* model**

The amount of Ozone (x) in *a priori* profile was computed in each layer *k* by:

$$x^k = A_k + B_k \cos[(J - J_{0k}) * 2 \pi / 365] \quad (1)$$

for the layers from 6 to 12; and

$$x^k = A_k + B_k (x - 300) + C_k (x - 300)^2 \quad (2)$$

for the layers from 0 to 3.

The values of the coefficient  $A_k$ ,  $B_k$  and  $C_k$  that was utilized was founded in Mateer *et al.* 1992, the data are those of 75 °S of latitude, very close to Marambio.

The amount of the layers 4 and 5 was computed by a regression with the model:

$$\ln y = A + B x^2 + C x^3 \quad (3)$$

Where  $x$  is the height of the layer and  $y$  is the amount of Ozone, the correlation coefficients of the models are  $> 0.98$ .

### Preliminary results

In figure 1 there is a comparison between the values of ozonesounding carried out in Marambio and an *a priori* profile. The maximum values of Ozone concentration, diamonds in the

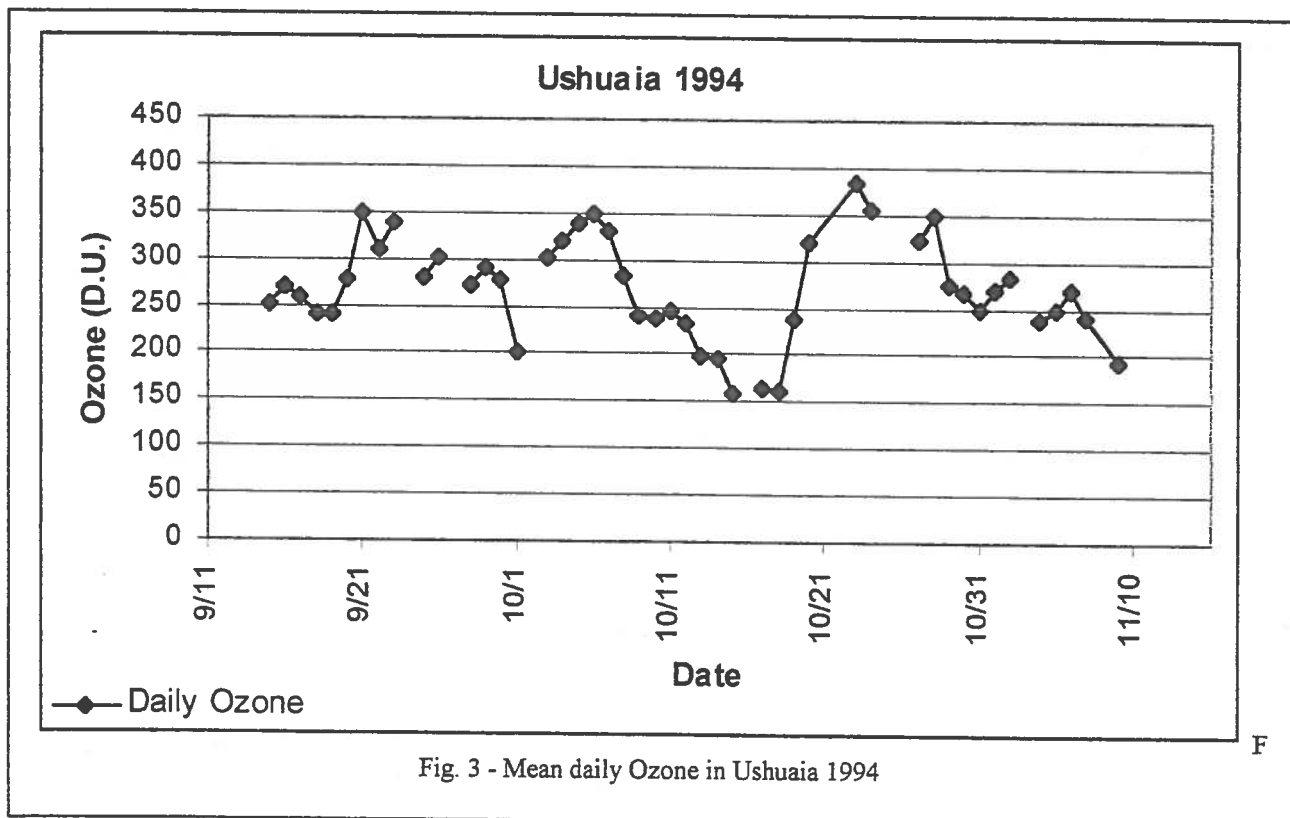


Fig. 3 - Mean daily Ozone in Ushuaia 1994

bottom of the plot, are compared with the maximum amount of *a priori* profile. The difference of the model data are due to the ozone hole season, September and October. The weak periodicity is shown by the model is in agreement with the trend of real data and also with the shape of fig 3.

In figure 2 the maximum value of Ozone, computed by the Brewer Umkehr model in Ushuaia, and the his maximum height are shown. Generally to the high values of Ozone correspond a more low height of the maximum, in this case not always happen, Rafanelli *et al.* .

In figure 3 the daily mean Ozone, expressed as ZS, carried out in Ushuaia in 1994 campaign is shown. As it is possible to note the deep hole of October 15/16 not pointed in evidence in the model, see fig 2.

## Conclusion

To contribute to understand the consequences that clouds, aerosols and mainly steep gradients of Ozone, as expected during the Ozone hole season, produce on the Umkehr algorithm implemented on the Brewer, it will be carried out campaign in Ny Ålesund (Is. Svalbard) in cooperation between Institute of Atmospheric Physics (IFA) and Alfred Wegener Institute (AWI).

The project, funded by L.S.F. of U.E., provides the comparison of simultaneous long period measurements by spectrophotometer Brewer (IFA), the ozonesounding (AWI), tropo- and stratospheric data by LIDAR (AWI). All those equipments are present in the site of Ny Ålesund.

In particular from February to October will be developed a campaign where at the early spring time and at the autumn, when the zenith angles of the sun and the daylight afford it, the vertical profiles of Ozone will be sampled with Brewer (Umkehr profile) and analyzed in the light of the data of tropo- and stratospheric aerosols and vertical profile by LIDAR, obviously until the light allows the sampling. The ozonesounding data will be the reference.

In the middle part of the campaign will be studied the Ozone level with the Brewer and the effect that the clouds produce on the columnar content data. The sampling will be compared also with the UV solar radiometers equipment (IFA), the ozone microwave radiometer (AWI) and with the Dobson spectrophotometer running in the NILU base.

## Acknowledgements

The authors are grateful to the Italian Antarctic Project, PNRA, which has founded the research. They are grateful also to the Argentinean staff of the CADIC in Ushuaia, and to the personnel of the DNA in the bases of Belgrano II and Marambio for their irreplaceable help.

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## SURFACE OZONE IN ARCTIC

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Surface ozone was measured at Svalbard (78 N) by Russian chemiluminescent ozone analyser AM-01 in August 1995. The surface ozone measurements were supported by ozone total content measurements with help of Russian M-124 ozonometer and were compared with some meteorological parameters. It was shown that the usual mean surface ozone concentration is equal to 30 ppb and does not demonstrate diurnal course. Rapid surface ozone depletions up to 80% and one intense enhancement of 120% value lasting about ten hours were discovered. Another interesting phenomenon observed during the whole interval of measurements is the periodical oscillations having period about 20 min. This oscillation phenomenon has been explained in frame of the physical model connecting these variations with atmospheric pressure changes and resonance processes that seem to appear in Adventdalen valley. A physical interpretation of all kinds surface ozone variations observed was considered in terms of local topographically induced wind system that brings high bromine concentrations from surface sea water.



## **SOLAR PROTONS CREATE OZONE MINIHOLE ABOVE SVALBARD**

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The influence of solar cosmic rays on ozone total content at high latitudes is investigated. It has been shown that solar protons could produce so-called ozone "miniholes" (decreases of ozone total content up to 25%) inside the polar caps. Such ozone "minihole" was detected above Svalbard during solar proton events of Ground Level Event (GLE) type in May 1990. It was shown that such ozone "miniholes" appeared in Arctic and Antarctic in local spring during several GLE-events (29 September 1989, 19 October 1989, 21-27 May 1990).

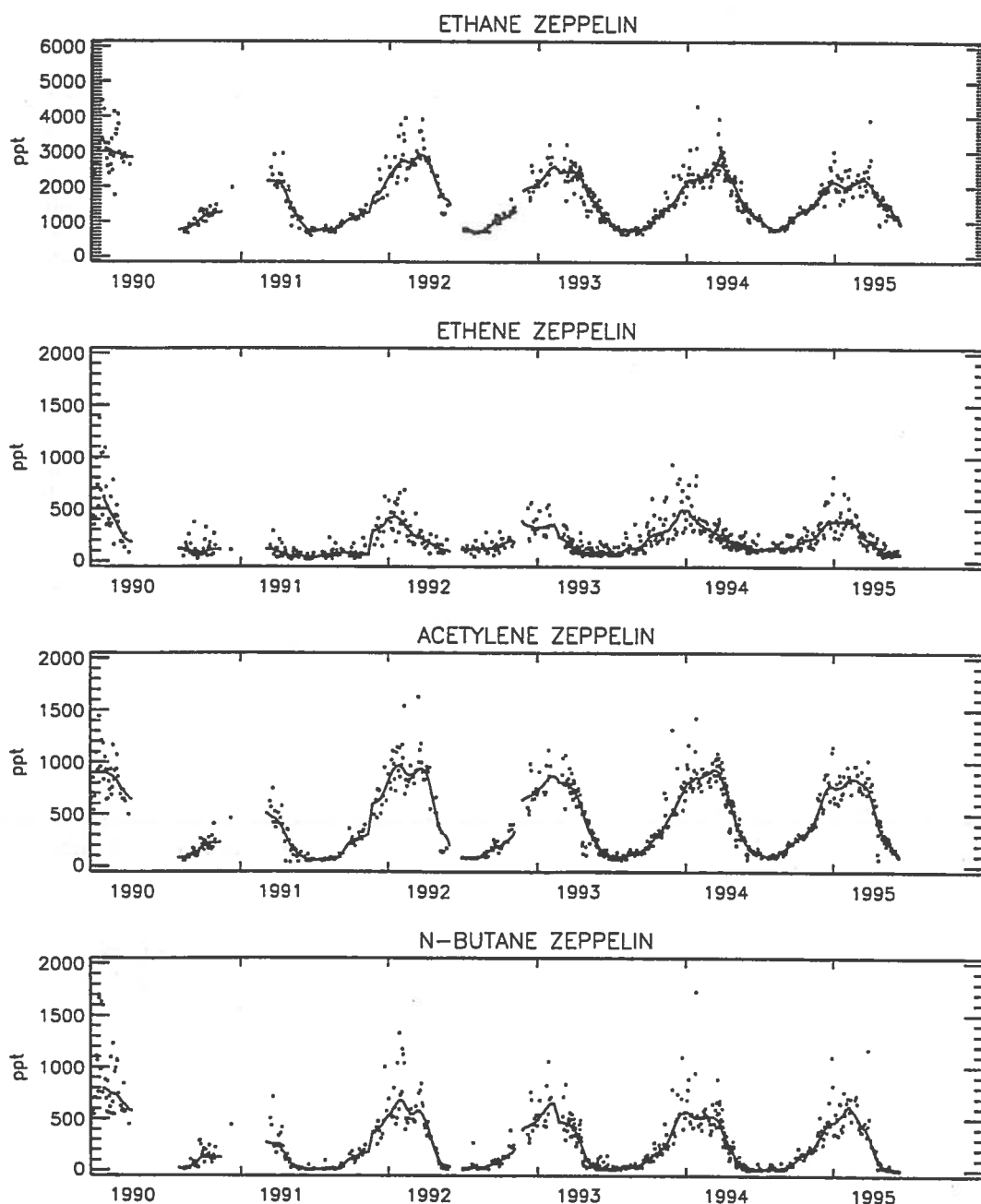
The results of model calculations have shown that ordinary gas phase photochemical theory can not explain the appearance of ozone total content depletions during GLE events. A possible trigger mechanism including ion nucleation and heterogeneous chemistry is discussed. Lidar measurements at Kola peninsula and model calculations of aerosol concentration enhancement after some GLE events seem to support the trigger influence of solar protons on stratospheric aerosols and ozone layer.

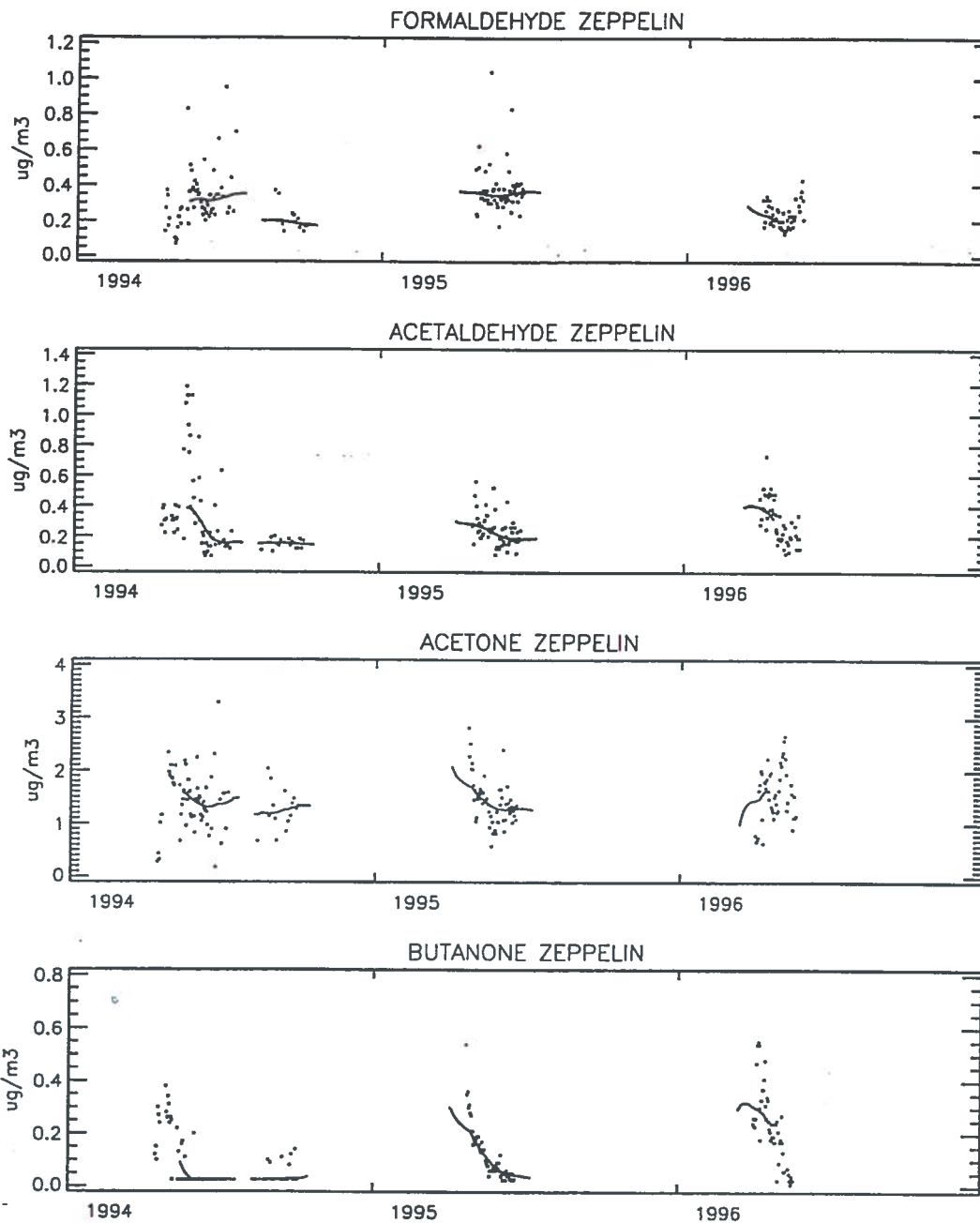


## Measurements of volatile organic compounds on the Zeppelin Mountain

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NILU has measured light non-methane hydrocarbons (NMHC) regularly on the Zeppelin Mountain in the period 1989 - 1995 by use of grab samples. Low-weight aldehydes and ketones were measured during spring-autumn campaign periods in the years 1994 - 1996. The long-term time series are shown for selected components, indicating pronounced winter maxima for the primary hydrocarbons, and a more constant, or even late-spring increase for the secondary carbonyls. Thus, the contribution of secondary species to the sum of organic carbon increases substantially from winter to summer, consistent with an increase in the background atmospheric oxidation processes.





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*Geophysics and Geodesy*



# **ARCICE: THE UK 'ARCTIC ICE AND ENVIRONMENTAL VARIABILITY' PROGRAMME**

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## **SUMMARY**

The ice cover of the Arctic, comprising sea ice, glaciers and ice sheets, and seasonal snow cover, is an important constituent of the linked ice-atmosphere-ocean system that determines the climate of northern latitudes. Understanding environmental variability in the Arctic system is essential for a number of reasons:

- Coupled atmosphere-ocean climate models indicate that the Arctic has a uniquely high sensitivity to changed climate forcing.
- The changing size of Arctic glaciers and ice sheets has a significant impact on global sea level.
- Deep-sea cores and ice cores from the North Atlantic region reveal evidence of abrupt changes in the climate over periods of less than one hundred to tens of thousands of years.

Improving our understanding of these topics and enhancing our ability to predict future changes requires a well-coordinated series of field and satellite measurements linked to numerical modelling studies. The Arctic Ice and Environmental Variability (ARCICE) Programme is a UK contribution to international cryospheric research.

## **OBJECTIVES**

- To enhance our understanding of, and capacity to predict, variations in the Arctic cryosphere relevant to climate and sea-level change in the UK and NW Europe. To achieve this by providing improved insights into:
- The dynamics driving the responses of three Arctic cryospheric provinces (sea ice, ice caps and small glaciers, and the Greenland Ice Sheet) to climate forcing, and
- The relationship between these dynamic responses and the abruptness of high latitude climate and cryospheric change revealed in North Atlantic marine geological and ice-core records.

## RESEARCH PROGRAMME

Our proposed programme of research on Arctic ice and its links with environmental variability is divided into a three part framework. Each component of ARCICE will contain a mix of numerical modelling and field and/or satellite measurements. The measurements are used to provide one or more of: (a) model boundary conditions, (b) the improved specification of fundamental cryospheric physical processes, and (c) the testing of predictions from numerical modelling experiments. **The Ny-Ålesund research facility and the UK ice-strengthened RRS *James Clark Ross* are critical to the field components of the investigations we propose below.**

### 4.1 Glacier Growth and Decay and the Evolution of Arctic Continental Margins

At timescales of millennia and longer, the marine geological record in Arctic seas provides evidence critical to our understanding of Arctic palaeoclimate, the waxing and waning of ice sheets and the possible rapid collapse of huge ice drainage basins over a few decades. This information provides a context for contemporary studies of high latitude cryospheric, atmospheric and oceanic processes through its implications for the magnitude and abruptness of past environmental change.

The following are key research questions:

- (a) What does the Arctic marine record tell us about the frequency and rate of change in Arctic glacier and sea-ice extent? Is there significant evidence of very rapid instabilities in the Arctic cryosphere?
- (b) What is the time-dependent flux of glacier-derived debris to continental margins and how is this linked to the climate-related waxing and waning of ice sheets, particularly those of the little investigated margins of the Arctic Basin? What enhancements of the basal boundary condition in existing numerical ice sheet-models are needed to make such predictions?
- (c) Where are the locations of areas of major slope instability around the Arctic continental margins of both the North Atlantic and the Arctic Basin and what are the magnitude and frequency of such large-scale events? The acquisition and dating of core material from key sites, identified from existing seismic datasets, is a crucial step in pinning down the timing and frequency of large-scale failures of the continental slope, and the links between such failures and ice sheet growth and decay over glacial cycles.

### 4.2 Mass Balance of Arctic Ice Masses and Global Sea-Level Change

Temperatures in the more climatically sensitive parts of the high Arctic have risen by several degrees since the beginning of the Twentieth Century, and glaciers and ice caps have undergone general retreat and thinning since this time. The IPCC has identified the polar ice sheets to be the largest source of uncertainty in explaining the present rise in eustatic sea level. Arctic ice, if completely melted, would contribute 8 m to global sea level rise. A change of only 1 or 2% is therefore of considerable significance to Humankind.

The Greenland Ice Sheet, as one of the World's two great ice masses, is an important control on global sea level, yet even the sign of its change is not presently known. The Arctic ice bodies of Greenland, Canada, Svalbard and Russia, are likely, according to GCM predictions, to be particularly sensitive to anthropogenic warming, and have a reservoir size capable of threatening significant sea level rises. Our limited ability to predict the future evolution of these

ice masses arises because: (a) systematic satellite surveying of the entire Greenland Ice Sheet was initiated only recently (1991); (b) high resolution atmospheric modelling of ice-sheet precipitation began only recently, and the coupled modelling of ice-sheet surface ablation and melt processes is in its infancy; and (c) a number of Arctic ice masses, of sea-level significant reservoir size, particularly in the Russian High Arctic, are not well characterised. Critical research questions for the next five years include:

(a) How accurately can the variability of the surface balance of Arctic ice bodies be modelled? Climate models, such as UKMO, provide timely predictions for determining the surface balance and meltwater outflow of the large and/or remote ice bodies of the Arctic. Very little has been done to determine how accurately this may be achieved. Work is required to develop coupled atmosphere-surface balance models, and to determine their accuracy.

(b) What is the likely contribution of the High Arctic ice masses (outside Greenland) to changing mean sea level? While the 20th Century contribution to sea level from small ice caps and glaciers has been estimated, these estimates are based largely on small glaciers whose reservoir size is insignificant in sea-level terms and whose mass balance may be unrepresentative of larger ice caps in the Eurasian Arctic. Work with satellite imagery, SAR interferometry and field campaigns, to calibrate numerical model predictions, are required to constrain the mass balance of these glaciers.

### 4.3 Atmosphere-Sea Ice-Ocean Interactions

The Arctic and its seas are a system of high climatic sensitivity, which are predicted to have a greatly amplified response to global warming relative to lower latitudes. The behaviour of the linked Arctic ice-ocean-atmosphere system exerts a considerable influence on the environment of NW Europe. For example, the links between sea-ice production and transfer, Arctic freshwater budgets and the thermohaline circulation in the Norwegian-Greenland Sea may also impact significantly on European climate through any variability in northward oceanic heat transfer.

A number of major scientific questions, associated with ice in the ocean-climate system, relate to the Arctic seas. These include:

(a) What is the interannual variability and climatology associated with Arctic sea ice and its thickness? Studies of the variability of ice thickness in, and flux between, the Arctic Basin and Greenland Sea are required to relate changes in ice extent to variability in key driving forces, such as surface radiation balance and winds.

(b) How accurately must the Arctic atmosphere-ocean fluxes of heat, momentum and mass be constrained to permit accurate modelling of the North Atlantic thermohaline circulation? This work includes improved representations of sea ice and of the circulation of water and ice in the Arctic Ocean, together with its variability on time-scales from seasonal to interannual in response to climate change.

## COLLABORATION AND LINKS WITH OTHER PROGRAMMES

ARCICE will have strong links with a number of international science programmes, providing an umbrella for coordinated UK contributions, which include the following:

- The WCRP Arctic Climate System Study (ACSYS) highlights the importance of linked Arctic atmosphere-ice-ocean processes and variability in modulating the northern hemisphere climate.
- The EU European Subpolar Ocean Programme (ESOP) highlights the study of ice-ocean processes affecting Greenland Sea convection.
- The International Arctic Science Committee (IASC) has a core science programme on the mass balance of Arctic glaciers.
- The European Space Agency PIPOR and PISP programmes focus on the links between satellite remote sensing and sea and land ice variability, respectively.
- The ESF Quaternary Environments of the Eurasian North (QUEEN) programme highlights the Arctic marine environment as a record of past changes in ice sheet extent and the rate of ice-sheet response to past climate change.

European Union policies at a number of levels have also demonstrated a recognition of the significance of the Arctic and its position at the northern frontier of the Community, for example:

- Strong commercial interest in a Northern Sea Route for shipping between Europe and the Far East and the research and development challenges that its realisation would require.
- The vast hydrocarbon reserves of the Russian Arctic as an exploitable resource

## DELIVERABLES

The deliverables and milestones for ARCICE will depend on the mix of projects supported under the programme. Expertise exists to complete the following tasks:

*Glacier Growth and Decay and the Evolution of Arctic Continental Margins:* Indicators of the timing and rapidity of past changes in glacier and sea-ice extent; model predictions for sediment delivery from ice sheets to continental margins through time; enhanced understanding of the magnitude and frequency of large-scale slope failure on Arctic margins.

*Mass Balance of Arctic Ice Masses:* Satellite-derived measurements of the mass balance of the Greenland Ice Sheet; Arctic-wide predictions of glacier-derived sea-level contributions in a warming world; linkage of GCMs and climate impacts on Arctic ice masses.

*Atmosphere-Sea Ice-Ocean Interactions:* Improved parameterisation of sea-ice processes in mesoscale ice-ocean models and coupled climate models; enhanced understanding of Arctic sea-ice thickness variability and flux from the Arctic Basin; improved model predictions of circulation in the Arctic Basin from large-scale models in a changed climate.

## Surface Radiation Budget in Ny-Ålesund during the past two decades

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### Motivation

As a result of the increasing concentrations of greenhouse gases in the atmosphere since the industrial revolution, the global mean temperature is slowly rising (IPCC, 1995). While the regional effects of this temperature increase are uncertain, the GCMs show with consensus a poleward amplification of the climate signals. A warming climate is expected to give early and large effects in the polar areas, followed by an increased climate variability with more extreme weather situations and stronger seasonal cycles as a result of the intensified temperature gradients in the atmosphere. However, being a matter of continuous controversy, these climate predictions are uncertain because the arctic climate and feedback processes are not fully understood and described.

The negative annual radiation budget of the Arctic is balanced by the poleward transport of mild and humid air. A number of climate studies shows that the low pressures entering the polar ocean are getting stronger and more frequent. The most important area for the transport of mild air to the polar ocean is the Norwegian and Barents Sea. The European Arctic is therefore potentially sensitive to climate perturbations. Since the radiation processes and feedback mechanisms are very important for the Arctic climate and energy balance, the radiation parameters may be used as a signal of possible climate changes in the Arctic.

### Introduction

The Norwegian Polar Institute has performed measurements of the surface radiation budget (SRB) on a permanent basis in Ny-Ålesund since 1974, with the main objective to investigate the long and short term variability in the Arctic radiation climate as related to other parameters such as seasonal snow cover, atmospheric variability and meteorological conditions. The program also support multidisciplinary studies of the interaction between the changing environmental conditions and Arctic ecosystems. Since 1994 the SRB measurements are performed within the framework of the global BSRN-network (Baseline Surface Radiation Network)

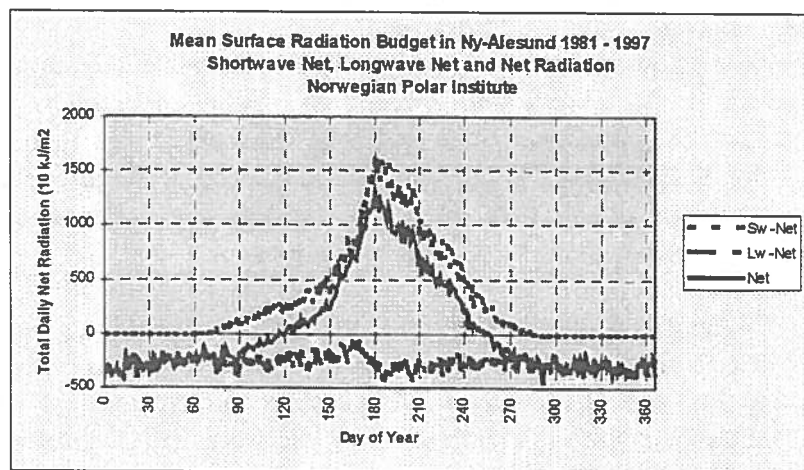


Figure 1

in co-operation with AWI. The program includes measurements of Global, Diffuse, Direct, Reflected, UV, UVB, Longwave Downward and Longwave Upward Radiation as well as derived quantities like Albedo, Shortwave Net, Longwave Net and Net Radiation. Figure 1 presents the mean Surface Radiation Budget averaged over the years 1981 - 1997. The plot shows the negative longwave balance during winter and summer. While the surface snow cover melts away the net shortwave radiation increase sharply producing the positive summer radiation budget due to the sharp decrease in surface albedo and the high global radiation.

A database of the components of the Surface Radiation Budget for Ny-Ålesund is now established at the Norwegian Polar Institute suitable for statistical studies of the radiation climate and its short and long term (1974 ->) variability. This paper discusses briefly the inter-annual variation of Global and Longwave Radiation as well as the Albedo variation in Ny-Ålesund during the period 1981 - 1997.

### Global and Longwave Downward Radiation

The polar night in Ny-Ålesund lasts from 23 October to 18 February. Figure 2 shows the annual variation of the global radiation in the period 1981 - 1997. The extra-terrestrial global radiation (radiation at top of the atmosphere) is also included in the figure as are the daily total mean, max and minimum radiation values for the 17 year series. It is interesting to note the asymmetry of the global radiation with respect to the extra-terr. global radiation, with maximum surface radiation shifted towards early June and increased mean radiation in spring as compared to the autumn values. This is due to the higher frequency of clear days in spring (April, May) than in the summer months from June.

Because of the high albedo of the snow covered ground in winter and spring, the successive reflections and multiple scattering of the shortwave radiation between the ground and the atmosphere and clouds will enhance the global radiation at the surface, hence apparently increasing the atmospheric transmittance. This effect also reduce the difference between clear and cloudy conditions. From late June to the end of August multiple reflection is not possible over the low albedo bare ground, increasing the variance of the global radiation due to changing clear and cloudy weather conditions.

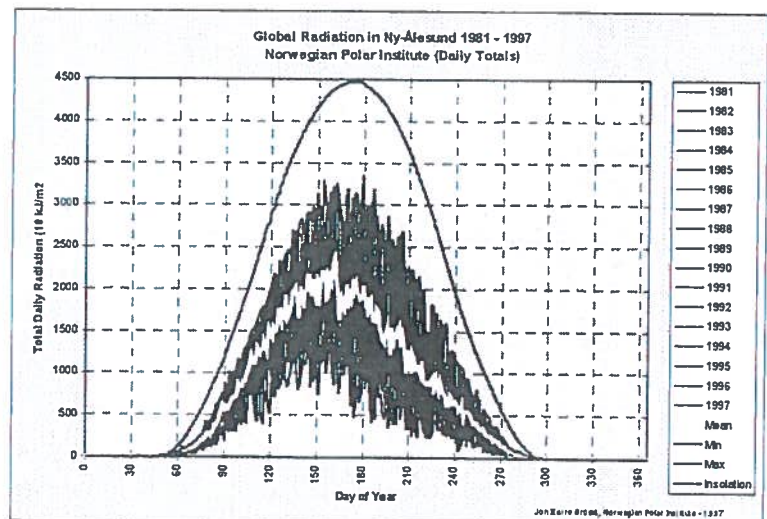


Figure 2

Another feature of interest is the peculiar sharp decrease in global radiation in mid June (evident in the mean and maximum radiation), which coincides with the period of intense melting of the snow cover. A possible explanation for this reduction of shortwave transmittance is the increase in atmospheric water vapor following the increase in atmospheric temperature. It seems that the onset of melt occurs within a very short time frame each year. As the whole snow pack is heated to 0 degrees and melts, the flux of latent heat from the

surface increase the atmospheric humidity. When the surface dries up after snowmelt, the atmosphere becomes less humid due to the reduced supply from below. However, more investigations are needed to give a final climatological explanation for this feature.

The longwave downward radiation also show an asymmetry with peak radiation conditions occurring during the warm summer months July and August. The variability of the downward longwave radiation is highest during the winter months and much smaller in the summer. The large variability during winter reflects the variable weather conditions with fluctuating clear and cloudy days between periods of stable cold arctic air and warmer, humid air transported to

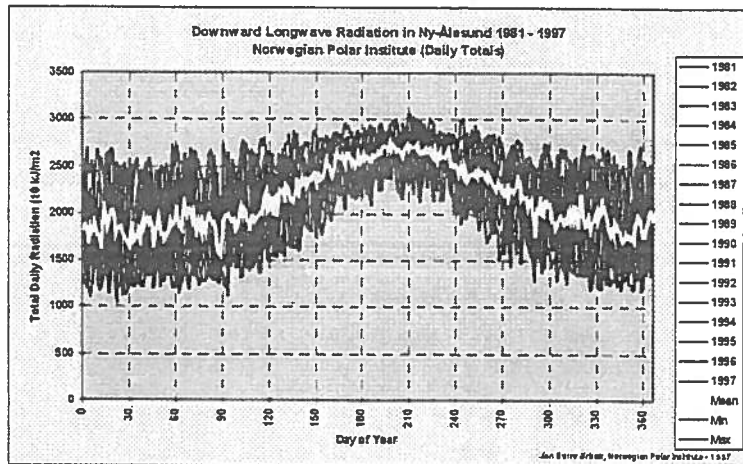


Figure 3

the arctic by low pressures from the south. During summer conditions, the warmer and more humid atmosphere increase the downward longwave radiation compared to the low winter values. The variance induced by clear and cloudy days is reduced in the summer due to the stable high atmospheric temperature and humidity during clear summer days.

### Albedo variation

Figure 4 shows the annual albedo variations from from the years 1981 to 1997. The maximum and minimum values are marked with separate curves. From the time the sun turns above the horizon in late February until the middle of May, the albedo remains high above approx. 80%. The slight reduction of the albedo in the period is due to the slow metamorphosis of the snow crystals as the snow cover ages. This change of reflecting properties of the snow speed up during the melting season starting in beginning of June. In this period, the albedo drops down to summer values below 20% within a very short time period of maximum 2-3 weeks. Then from the end of August the snow returns but may not stay permanent before the end of October. As can be seen from the figure, the spring melt period occurs within a very narrow time frame with little variation from year to year, whereas the broader transition period in the autumn when the first snows turns up shows a larger inter-annual variability.

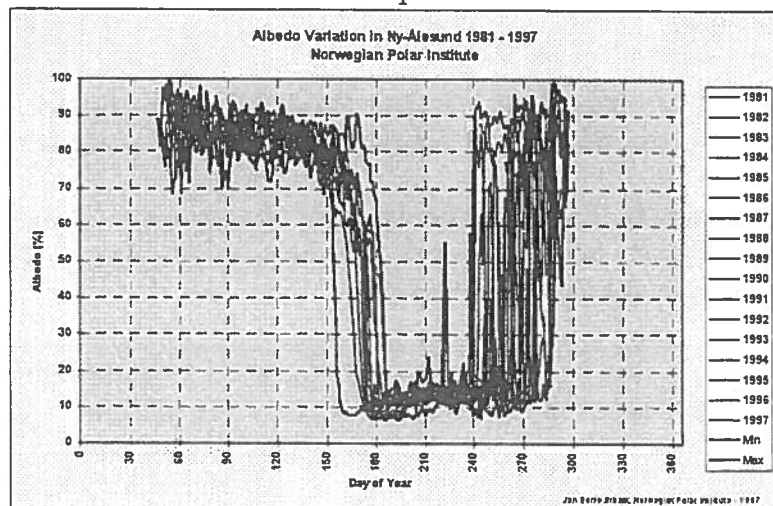


Figure 4

### Conclusions and further work

Figure 5 shows the 17 year averaged mean daily values of global radiation, downward longwave radiation, surface albedo and shortwave transmittance based on the 1981- 97 radiation data, plotted on the same graph. The plot shows the asymmetries with respect to midsummer (day 173), as well as the interdependence between the global radiation, the albedo and the shortwave transmittance as discussed above.

The SRB database of NP is useful for statistical analysis of the radiation climate variability and trends in the arctic. As an example, the number of snow free days in Ny-Ålesund (at the point of measurements) can be extracted from the albedo data, as can the

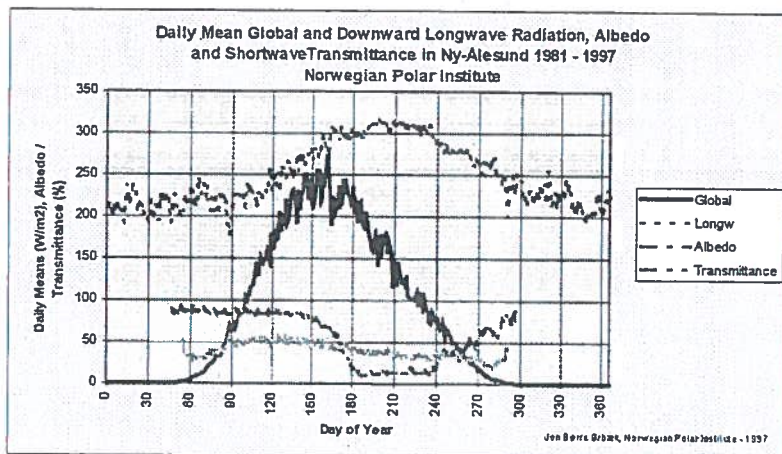


Figure 5

day-number when snow disappears, when it first returns in the autumn and the number of days with intermediate albedo values (for example wet snow). Detailed quality check and data validation are necessary before exact conclusions can be drawn, but preliminary calculations indicate very interesting trends in the parameters which will be a matter of future investigations.

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# Geodetic contributions to global-change research at Ny Ålesund

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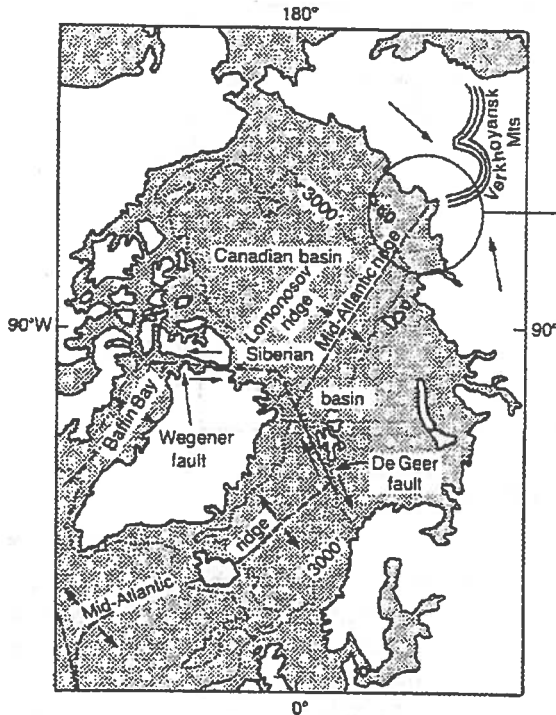


Figure 1: Tectonics of the Arctic Ocean. From [12].

**The multi-parameter geodetic observatory at Ny Ålesund is integrated into global geodetic networks. Due to its remote location in the Arctic, the station constitutes a unique cornerstone for these networks. The environmental parameters recorded at the station include sea level, surface deformations and gravity. The potential contribution of the site to global change research is demonstrated using four examples.**

Global change and particular climate change is expected to affect the Arctic at an early state and to a particular extent. Therefore, on the one hand, the Arctic is prone to experience severe impacts in the course of the expected global warming. On the other hand, the Arctic is a region highly indicative for both climate variability and change.

Ny Ålesund is situated at a location interesting from a climatological, meteorological, oceanographic and tectonical viewpoint. Tectonically, Svalbard is located on the north-eastern side of a long north-northwest striking transform fault (the De Geer fault, Fig. 1), which connects two parts of the mid-Atlantic ridge, namely the north-east striking ridge segment in the Norwegian Sea (north of Ice-

land) to the more north-northeast striking segment in the Siberian basin [12]. The active mid-Atlantic ridge passing through Iceland terminates SW of Svalbard at the De Geer Fault. This dextral ridge-ridge transform connects to the northernmost part of the mid-Atlantic ridge, which in turn transforms into the Verkhoyansk Mountains of Siberia by means of rotation about a fulcrum in the Siberian Islands. However, there are rather large uncertainties in the actual structure of the ridge segment southwest of Svalbard. For example, in [11], the large DeGeer transform fault is replaced by a north striking spreading center. Again another sketch can be found, for example, in [2]. Nevertheless, the distance of the ridge-related tectonically active region to Svalbard is small (of the order of 100 km) and the activity might well have some regional to local effects at the Kings Bay and Ny Ålesund. At large scales, the motion across the ridge segment in the Siberian basin and particular its change along the ridge leads to a rotation in the Arctic affecting the position of Svalbard in a global reference frame.

Climatologically, Svalbard is located within the northernmost part of the area with strong seasonal changes in sea-ice [see, e.g., 1]. This area is likely to be affected by climate change at an early state. The main ice drift in the Arctic Ocean is characterised by the Transpolar Drift, which carries ice from the Beaufort Sea and the eastern Arctic Ocean westward towards the Fram Strait west of Svalbard, through which most of the ice exits into the North Atlantic [see 8]. Moreover, the main current due to the Arctic Ocean Interbasin exchange passes along the Fram Strait, too [see, e.g., Fig.1-1 in 14].

The geodetic research facility at Ny Ålesund is a multi-parameter environmental monitoring site located in a sensitive area. At the site, surface deformations of the Earth's crust are monitored with mm precision utilizing the most advanced space-geodetic techniques. These geodetic activities at Ny Ålesund are strongly interwoven with international programs and organisations which provide the background for monitoring the state of the Earth system and for studies of the system's dynamics and climate. Thus, the Very Long Baseline Interferometry (VLBI) station is contributing to the global VLBI network (Fig. 2) and all observations are coordinated with international programs such as the one for Continuous Observations of the Rotation of the Earth (CORE). The site will also be part of the network contributing to the new international VLBI organisation currently under discussion. The Global Positioning System (GPS) receivers deliver data to the International GPS Service for Geodynamics (IGS),

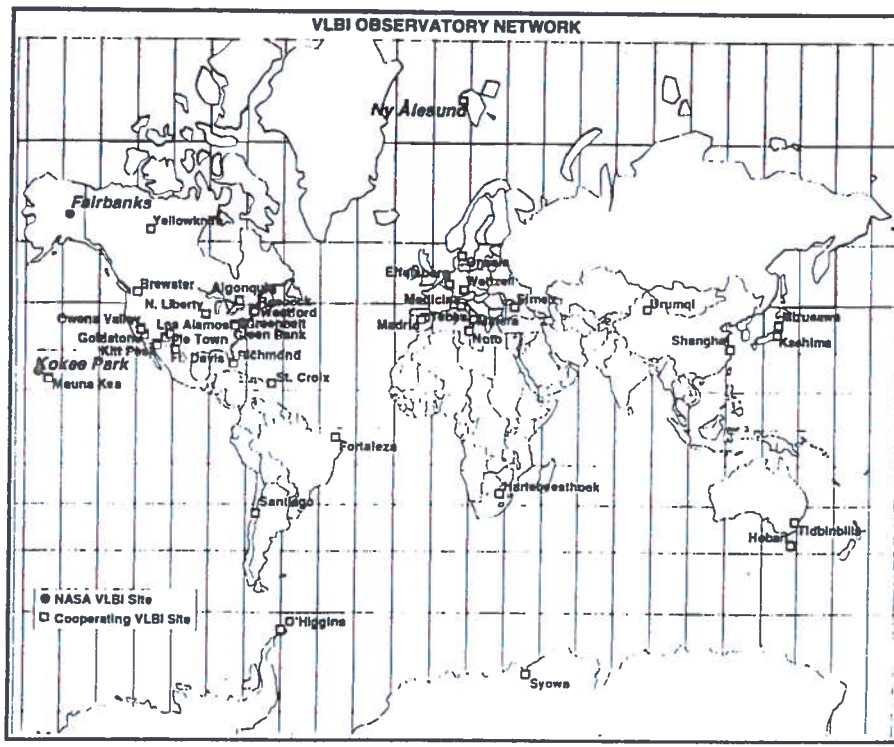


Figure 2: The global VLBI network.

which maintains a network of more than 100 stations globally distributed, though with large gaps in the Arctic. Both networks contribute to the definition and maintenance of the International Terrestrial Reference Frame (ITRF) and the monitoring of the Earth Orientation Parameters (EOP) as available from the International Earth Rotation Service (IERS). The Global Sea Level Observing System (GLOSS) includes the tide gauge operated at Ny Ålesund. GLOSS strongly recommends the collocation of tide gauges with permanent GPS receivers and gravity measurements, conditions which both are or will be met in the near future. The geographical distribution of the sites in all these nets is characterised by a low number of Arctic stations, and this clearly demonstrates the importance of Ny Ålesund for the networks. It should also be mentioned that the space-geodetic infrastructure at the observatory is being developed in close co-operation and contact with these organisations.

Geodetic measurements of gravity variations, surface deformations, and Earth's rotation perturbations increasingly are used to study global change phenomena and to constrain climate models [see, e.g., the Diagnostic Subproject 15 of the Atmospheric Model Intercomparison Programme, 7]. To illustrate the geodetic contributions in more detail, four examples are discussed below, namely sea level changes, ice load changes, plate tectonics, and ocean tidal models.

Sea level changes due to mass exchange between cryosphere and ocean are not globally uniform [6]. Due to the combined effect of the viscoelastic response of the Earth to ice deloading and ocean loading and the change in the gravitational potential, relative sea level will fall

stances there will be nearly no changes. A rise in sea level will only be observed in the far-field. Thus, melting/accreting Antarctic ice will have a sea-level signature distinctively different from melting/accreting Greenland ice. Therefore, the pattern of relative sea level changes, in principle, can be used as a constraint for the origin of the mass added to or extracted from the ocean due to melting or accreting ice sheets, respectively. Tide gauges should record the "footprint" in relative sea level due to present-day changes in the large ice sheets. Tide gauges in the near-field are particularly important for this detection. Therefore, the tide gauge data observed at Ny Ålesund combined with space-geodetically observed crustal motion at the location is an important contribution to the monitoring of the current pattern in relative sea level changes particularly in the Arctic ocean.

Changing ice loads induce significant viscoelastic deformations of the Earth's crust and mantle as is documented by a wealth of observations related to the postglacial rebound induced by the last ice age. The present-day deformations are the results of a convolution of the Green's function (i.e., the impuls response of the Earth to surface loading) with the complete time history of the combined ice and water load. Therefore, these deformations are also affected by recent changes in both the present-day ice sheets and the ocean waters. The effect of the present-day forcing potentially is large enough to use the induced deformations to constrain, for example, concurrent changes in the volume of the Antarctic and Greenland ice sheets [e.g. 3, 10, 17]. However, the post-glacial signal in these deformations is of the same order as the deformations induced by present-day ice changes. Any interpretation therefore requires the separation of the two

experiments carried out by [16], the ratio between gravity and height changes  $\dot{g}/\dot{u}$  associated with purely viscous deformations due to past mass movements (i.e. ice and water load) is approximately equal to  $-0.15 \mu\text{gal}/\text{mm}$ . This constant ratio provides the basis for the required separation. A comparison of observed gravity and height changes in the land-uplift area in Scandinavia indicates a ratio of  $\dot{g}/\dot{u} = -0.24 \mu\text{gal}/\text{mm}$  [5]. However, the  $\approx -0.09 \mu\text{gal}/\text{mm}$  in excess of the theoretically expected value may represent the elastic response to present-day mass changes, which partly are to be explained by the de-loading of the Baltic Sea as a consequence of the land uplift. Therefore, we can expect that high-precision space-geodetic observations of present-day deformations in the vicinity of ice sheets together with gravity measurements, in principle, provide valuable constraints on changes in the ice cover.

Secular changes in gravity result from two processes. Firstly, gravity changes whenever mass movements take place. Therefore, changes of the Svalbard ice sheet result in gravity changes due to the direct attraction. Secondly, changing the distance between mass and the measuring point also affects gravity. Therefore, the vertical displacement of the measuring point due to glacially induced viscoelastic deformations changes gravity, too. The present-day accuracy of gravity measurements is at the  $\mu\text{gal}$ -level, which is equivalent to vertical motions in the range of a few millimetres. Thus, the continuous space-geodetic observations of crustal motion combined with continuous relative and episodic absolute gravity measurements can provide an important observational constraint for geophysical models of changes in the ice cover on Svalbard.

Detailed knowledge of the present-day motion of the tectonic plates is fundamental for the validation of geophysical and geological models related to plate tectonics. The plate motion also constitutes a crucial contribution to the motion of any point on the Earth's surface. As the plate move, any fixed coordinates for observing sites become inconsistent. Relative motion between observing sites in the global geodetic networks are of the order of  $5 \text{ cm}/\text{yr}$  or larger. Therefore, accounting properly for these motion is a principle task in the definition and realisation of any terrestrial reference frame. The 1996 IERS conventions [13] recommend that the NNR-NUVEL1A model [4] is used to represent the velocities due to plate motion. The residual velocity vectors at all geodetic sites can then be used to validate and/or improve this model. Particularly the availability of observations from various space-geodetic techniques at Ny Ålesund renders the station a key site for the determination of the present-day kinematics of the tectonic plate and the subsequent validation of the model. However, due to the complicated tectonics discussed above, more detailed studies of the local to regional movements around Ny Ålesund are required.

The precision and accuracy of space-geodetic methods (both for point-positions and remote sensing) depend on our knowledge of the forces acting on the Earth's surface

the forces still known with insufficient accuracy are the gravitational and deformational effects due to ocean tidal loading. The most accurate ocean tidal models are derived from satellite altimetry [for references, see 13]. However, satellite altimeter coverage over the Arctic is poor and, consequently, there the accuracy of ocean tide models is low. Particularly in the Arctic region, Earth tide observations provide weighty constraints for the ocean tidal models. Earth tidal measurements in Ny Ålesund indicate a significant tidal loading effect particularly at semi-diurnal frequencies. The amplitudes and phases of harmonic tidal constituents in the astronomical tidal potential are known with high accuracy [see e.g. 9]. The transfer function between the astronomical excitation and solid Earth tides can be easily computed for visco-elastic, spherically symmetric Earth models [see, e.g. 18]. For each harmonic constituent, the transfer function can be given as  $\delta_s = A_a/A_s$  and  $\Delta\varphi_s = \varphi_s - \varphi_a$ , where the indices  $a$  and  $s$  denote astronomical potential and theoretical solid Earth tides, respectively, and  $A$  and  $\varphi$  are amplitude and phase of the harmonic constituent. For the main semi-diurnal constituent, which is usually denoted as  $M_2$ , the theoretical transfer function for a visco-elastic oceanless Earth is  $\delta_s = 1.155$  and  $\Delta_s\varphi \approx 0$ . However, at Ny Ålesund, the observed  $\delta_o = 0.533$  and  $\Delta\varphi_o = 60.7^\circ$  (Table 1), indicating a loading signal as large as  $M_2$  itself. At Tromsø, where Earth tide measurements were carried out by H.-J. Dittfeld (see <http://www.gfz-potsdam.de/pb1/pg3/grav/motive.html>), the loading effect is of the same order.

Summarising, we can state that the geodetic observations at Ny Ålesund are fundamental for the stability of the ITRF through their contribution to the global VLBI and GPS networks. The multi-parameter observations are of potential value for global change studies and the value of the data set is expected to increase greatly as the observation period is extended into the future. Nevertheless, a detailed exploitation of the available data is warranted already now.

#### Acknowledgments

The author would like to thank Knut Røthing, who is responsible for the Earth tidal measurement at Ny Ålesund and who kindly provided Table 1, as well as Oddgeir Kristianson for their support in the preparation of this note.

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Table 1: Results of tidal analysis of the Earth tidal record at Ny Ålesund.

From cpd	To cpd	const.	$A_o$ nm/s <sup>2</sup>	$\delta$	stdv.	$\delta_s$	$\varphi_o$ deg	stdv
.721500	.721500	Q1	23.721	1.05540	.00960	1.15028	-.3052	.5499
.921941	.940487	O1	132.947	1.13254	.00178	1.15008	1.0842	.1022
.958085	.974188	M1	11.084	1.20061	.01442	1.14948	-2.1519	.8257
.989049	1.011099	K1	187.010	1.13275	.00104	1.12907	-1.2494	.0598
1.013689	1.044800	J1	9.932	1.07589	.02373	1.15209	-.4012	1.3574
1.064841	1.216397	OO1	5.863	1.16063	.05812	1.15137	1.4942	3.3332
1.719381	1.872142	2N2	1.187	1.39652	.15048	1.15503	16.6076	8.6280
1.888387	1.906462	N2	1.088	.20435	.02933	1.15503	39.6611	1.6801
1.923766	1.942754	M2	14.835	.53346	.00536	1.15503	60.6810	.3069
1.958233	1.976926	L2	1.197	1.52325	.13318	1.15503	54.5831	7.6311
1.991787	1.182843	S2	14.560	1.12530	.01204	1.15503	36.7934	.6879
2.753244	3.081254	M3	.164	1.55264	.45233	1.06645	66.4025	25.9048

The table is provided by Knut Røthing, Norwegian Mapping Authority. Details of the analysis will be described elsewhere.  $\delta_s$  is given for a viscoelastic Earth model. In the analysis, air pressure was taken into account. A total of 306 days were used; degree of freedom is 6229; standard deviation is 4.600 nm/s<sup>2</sup> the tidal potential is from [15], viscoelastic Earth model is the Wahr/Dehant/Zschau model; a unity window is used for least squares adjustment; the data is numerically filter with the Pertzov-59 filter with 51 coefficients; estimation of noise is done by FOURIER-spectrum of residuals.

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## GLOBAL TEMPERATURE CHANGES AND SOLAR CYCLE

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The solar variability action on the climate is analyzed on the basis of the physical mechanism suggested by the authors.

The general idea of the mechanism supported by experimental, model and theoretical studies: the variations of stratospheric aerosol concentration under the influence of cosmic (galactic and solar) ray fluxes modulated by solar activity.

Taking into account the pronounced cyclic variation of galactic cosmic ray intensity it is demonstrated that the linear dependence between mean surface temperatures ( $dT$ ) and solar activity (sunspot number  $W$ ) takes place:  $dT=0.0051W-0.76$  (this dependence would "work" if one use only mean cycle values of  $W$  and  $dT$ ). On the basis of the physical mechanism suggested it is possible to interpret the well-known dependence of surface temperatures on solar cycle duration when during longer cycles lower temperatures were observed and during shorter cycles the higher ones.

On the much longer time-scale of hundreds of thousands of years, (i.e. periods of glaciation), the pattern of temperature variations inferred from oxygen isotope studies of Arctic and Antarctic ice cores seem to follow variations in cosmic ray flux which are inferred from measurements of the variations of concentration of the cosmogenic isotope  $^{10}\text{Be}$ . On the base of physical mechanism suggested the temperature decrease during the "Little Ice Age" and features of Antarctic "ozone hole" phenomenon are explained. On the dendrochronological data the sharp changes of climate in the 19th century in extreme North forests of Kola peninsula and Taymyr were investigated. This phenomena seem to be connected to variations of climate external forcing regime.



# The Role of Extragalactic Radio Source structure for Improved Reference Frames and Global Change

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## ABSTRACT

Geodetic VLBI observations of AGN (Active Galactic Nucleuses), designed to study earth rotation parameters and plate tectonics, to estimate the elastic parameters of the Earth, or to define a quasi-inertial extragalactic reference system, are frequently carried out in several monitoring programs. European campaigns, called EUROPE, are regularly carried out with a bimonthly duty cycle since 1990 to determine relative site motions, to study regional motions and to provide a stable reference network for the other geodetic techniques used in this area. The radio sources used for geodetic VLBI measurements, typically quasars and BL Lac objects, have a number of properties that make them ideally suited for use as celestial fiducial marks. However quasars and BL Lac are not always point-like as high dynamic range VLBI imaging revealed. Most of the celestial radio sources with flux densities higher than 0.5 Jansky exhibit complex and extended spatial structures at the milliarcsecond scale. For high-precision geodetic VLBI analysis, having the long-term goal of including all the phenomena that can cause effects at 10 ps level, source structure effects must be accounted for. The determination of the source-structure effects and their proper correction in the analysis is possible but brightness distributions of the radio sources must to be well-known.

A project with the purpose of obtaining detailed images of all the radio sources observed during EUROPE campaigns and correcting structure effects on geodetic data is presented. The contribution of the Ny Alesund VLBI Observatory to the project will be underlined.

## INTRODUCTION

The main geodynamical phenomena such as polar motion, UT1 variations, nutation and precession, Earth tides, ocean tidal response, and tectonic plate motions, require accurate and stable positions of the objects composing the reference frames. Enormous improvements in the insight of such phenomena have been made possible through the use of space geodetic techniques. Each of these methods relies upon extra-terrestrial reference sources, such as distant natural radio sources used for very long baseline interferometry (VLBI), Earth orbiters (e.g. LAGEOS) used for satellite laser ranging (SLR) and active satellites (NAVSTAR) employed by global positioning system (GPS). In the past 30 years the precision of measurements over large baselines (hundreds and thousands of kilometres) has reached the level of few parts in  $10^9$  and new phenomena such as global geodynamic changes are measurable for the first time. Space based geodetic measurements have contributed significantly to the establishment of the International Terrestrial Reference Frame (ITRF) (Boucher et al., 1996) that includes more than 100 fiducial points fairly uniformly distributed over the Earth surface whose coordinates and velocities are known at the centimetre level. The ITRF provides a global reference for national geodetic networks which have been traditionally established by conventional triangulation methods; these networks are being densified by GPS measurements. The existence of such a frame is opening the possibility to study a variety of important phenomena including sea-level variations and regional and global tectonic motions. The VLBI technique in comparison to the most advanced spatial techniques has the advantage of being free from orbital parameters errors, it's in fact referred to a reference system, defined

in terms of extragalactic compact radio sources. This reference system can be considered a truly inertial reference system (leaving out the motion of the Solar System due to the rotation of our Galaxy relative to the extragalactic radio sources). The International Astronomical Union has adopted since January the 1st 1998 a new fundamental celestial reference frame (the International Celestial Reference System, ICRS) that is based on the angular coordinates of 212 radio sources (Feissel & Mignard 1998). These sources are the most compact and most observed extragalactic radio sources with a median uncertainty of 0.4 mas on individual positions. It's the first time that the fundamental celestial coordinate system is no longer based on observations at visible wavelengths. The ICRS is approximately 100 times more accurate than the FK5 catalogue the previous realisation of the fundamental optical celestial frame. The adoption of such reference system is possible due to the stability of the positions of these sources. Thus far an upper limit of the order of 0.2 mas (milliarcseconds) per year has been set on the proper motion of these objects.

Limitations of reference frames based on extragalactic radio sources have been recognised in the intrinsic source structure. Monitoring these complex structures reveals variability on timescales of months. Several studies about the importance of these effects in Geodesy and Astrometry have been performed (Campbell et al 1988, Charlot 1990; and others). Rates of changes in the source positions caused by structural variability have been found to be much greater than 0.1 mas/year (Takahashi Y. et Kurihara N. 1993).

Maintaining the stability of the reference frame requires a careful definition of a fiducial point for each source and a constant monitoring of changes in the source structure. Specialised experiments to realize images of the radiosources are carried out to correct for source structure and its variation (Fey et al., 1996). Imaging is also feasible, via reanalysing data collected for geodetic purposes (Charlot, 1994 , Pohl et al 1995).

## **FUNDAMENTALS OF VLBI TECHNIQUE AND THE PROBLEM OF SOURCE STRUCTURE CORRECTION**

The VLBI technique has reached the capability of point positioning on the Earth's surface at the centimetre level and angular positioning for point-like extragalactic radio sources at the sub-milliarcsecond, (nanoradian) level, about 1 centimetre for a 10000 kilometre baseline. The basic idea that underlies geodetic VLBI observations is that of measuring the delay  $\tau$ , or difference in the arrival times, of a signal from an extragalactic radio source received at two, or more, observatories. Being extragalactic radio sources at a sufficiently great distance from the Earth the signals arrive as essentially plane-wave fronts. This delay is in a first approximation proportional to the component of the vector baseline  $\mathbf{b}$  between the VLBI stations in the direction of the radio source. More than two antennas (stations) commonly participate in an experiment and samples of 30-40 sources uniformly distributed in the sky of each station are observed at the same time and repeatedly during a 24 hours experiment. The fundamentals of the technique can be adequately illustrated by considering only a couple of stations and only one source (see figure 1). The signal of the radio source prior to its arrival at the first antenna has already been affected by electromagnetic and gravitational fields that it encountered along its journey through interstellar space, the Solar System, and the Earth's atmosphere. Between this time and the reception time at the second antenna, any motions of the Earth also make their influence felt. All these varied aspects need to be taken into account in the analyses. The signal received at each station is heterodyned, clipped, sampled and recorded digitally on magnetic tape. The digitisation is carefully done so as to preserve high precise information concerning the signal phases (arrival times) measured with hydrogen

maser atomic clocks. Observations are made in two bands centred at 2.3 GHz (S band) and 8.4 GHz (X band).

The signals recorded at all participating antennas are combined pairwise, thereby producing the interference pattern. The facilities for signal combination are called correlators. The correlation process is carried out in parallel for many (usually 14) frequency channels, with each channel

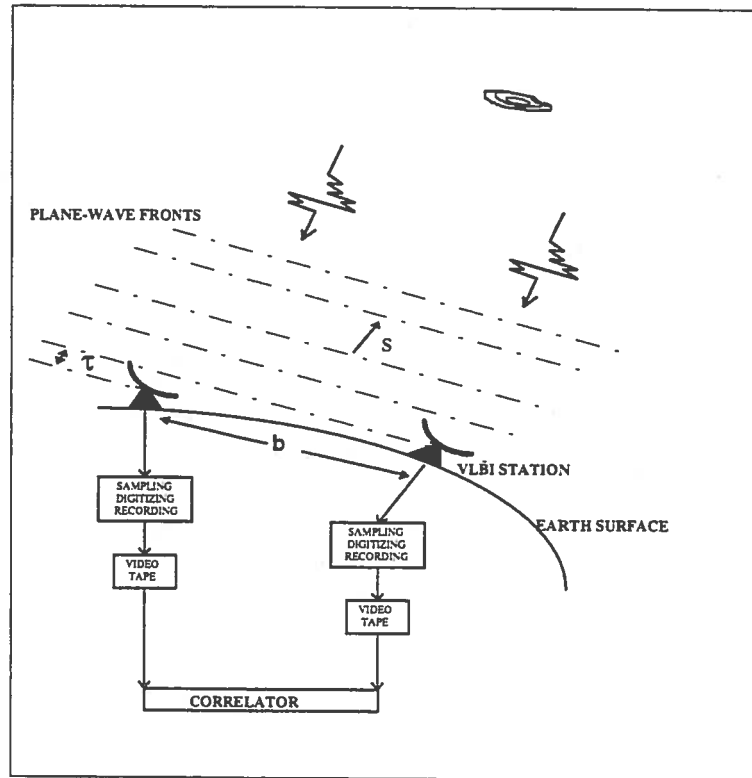


Figure 1

producing average amplitudes and phases every 1-2 seconds. During the post-correlation stage the set of phase samples  $\phi(\omega_i, t_j)$  from the various frequency channels  $\omega_i$  and times  $t_j$  are used to obtain the observables : the phase  $\phi_0$ , the group delays  $\tau_{gd}$  and the phase rate  $\dot{\tau}_{pd}$ , respectively defined as

$$\tau_{pd} = \frac{\phi_0}{\omega}, \quad \tau_{gd} = \frac{\partial \phi}{\partial \omega}, \quad \dot{\tau}_{pd} = \frac{\partial \phi}{\partial t}$$

The observable used in geodetic/astrometric VLBI experiments is the  $\tau_{gd}$ , problems with resolving  $2\pi$  ambiguities in the signal phase over large distances preclude the direct use of the  $\dot{\tau}_{pd}$  observable. For a varying extended source it occurs to consider time dependent corrections to the  $\tau_{gd}$  and  $\dot{\tau}_{pd}$  observables; the group delay can be written as

$$\tau_{gd} = \frac{\partial \phi}{\partial \omega} + \frac{\partial \phi_s}{\partial \omega} = -\frac{1}{c} b \cdot s_0 + \tau_s$$

where the first term is the delay correspondent to the reference direction  $s_0$  and the second term is an additional delay introduced by the source brightness distribution  $I(s, \omega, t)$ . The detailed expression of  $\tau_s$  and a more thorough discussion for the phase delay can be found on

Charlot, 1990. When the brightness distribution for an extended source is known and the reference direction is chosen, the structure correction can be calculated.

To this aim a subsample of 16 sources of the whole set of sources, used during the geodetic VLBI experiments EUROPE has been observed in November 1996 (these sources resulted, after a research in astronomical literature, with no images in the S and X bands). It was possible to obtain an observation epoch of the 16 sources immediately preceding the EUROPE5 experiment of 1996. The sources have been observed with six stations of the EVN (European VLBI Network) Effelsberg, Onsala, Noto, Shanghai, Urumqi, Simez, plus four stations mostly devoted to geodetic VLBI experiments : Madrid, Matera, Wettzell and Ny Alesund. The participation of Ny Alesund together with the Chinese antenna (Urumqi) improves the resolution of this network to a value which is even higher than that of the very long baseline array (VLBA). The correlation of the data has been completed. The next step will be to realise the images of these 16 sources with dedicated astronomical packages. Images of the remaining 22 sources are obtainable by data collected during the EUROPE5 geodetic experiment or older geodetic VLBI experiments.

In order to make a reliable VLBI image of radio sources it's important an accurate external calibration such as the knowledge of the change of aperture efficiency of the antenna with the elevation (the gain curve). A dedicated campaign of single dish measurements has been performed by the author at the Ny Alesund VLBI observatory to obtain gain curves of the antenna in the two bands S and X. Due to the high latitude of the telescope  $78^{\circ} 55'$ , it was necessary to follow different calibration sources to cover almost the full range of elevation. The figure 2 shows the plot of the gain data collected and of the best fit curve obtained (a second order polynomial) for the two bands S and X.

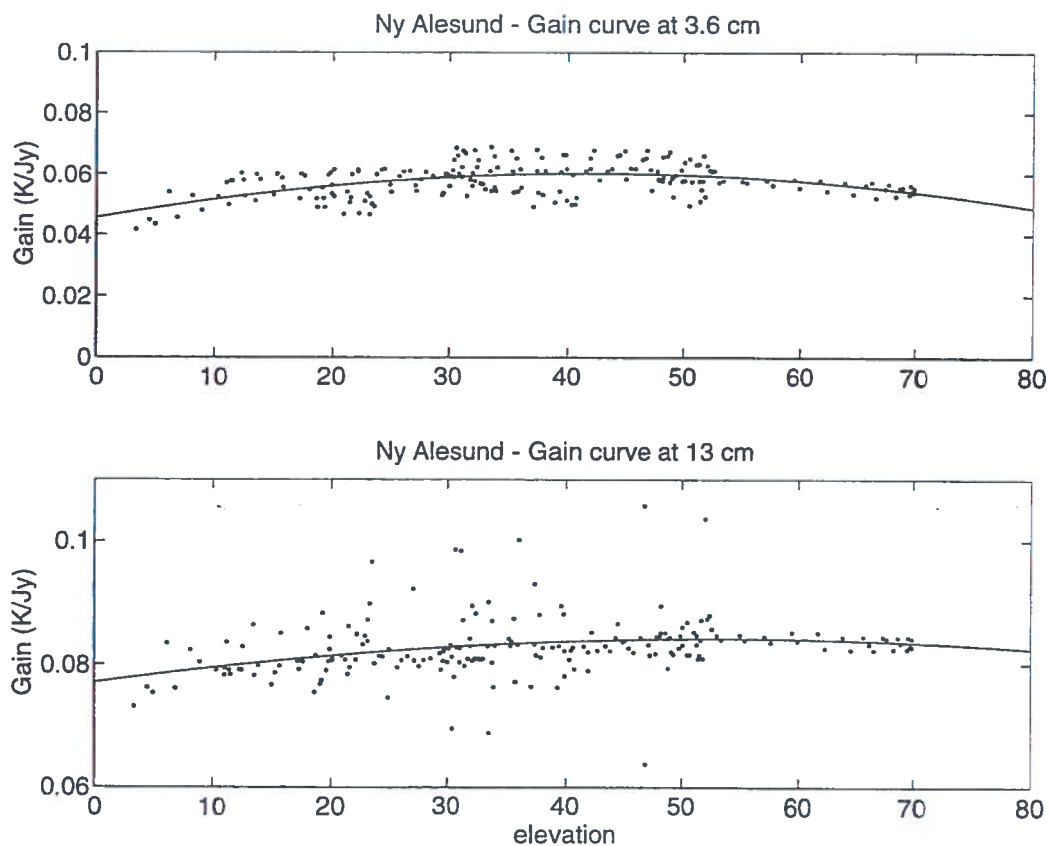


Figure 2

## CONCLUSIONS

The achievement of images of brightness distribution for the whole set of sources used in geodetic EUROPE experiments, expected in the near future, will contribute to improve the precision of the determination of the baseline lengths and site positions of the EUROPE programs and other geodynamical programs in which these sources are involved. The availability of data of the geodetic experiment EUROPE5 at a contemporary epoch gives a unique opportunity to exclude problems of variability of the source structures in time.

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# Spectral reflectivity and physical properties of snow and sea ice near Ny-Ålesund, Svalbard

by

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## Introduction and motivation

First, it is known that the surface albedo controls the amount of solar radiation that penetrates into the snow pack or sea ice in an Arctic environment. Usually, the albedo in polar regions is high. However, these surfaces show a significant natural variability spectrally as well as in time and space, especially in the melt season (Winther 1993a, 1993b). It is advantageous to obtain a clear understanding of the natural variability of surface energy balance before addressing the complexity concerning effects on energy balance due to climate change.

Second, it is known that pollution from industrialised regions propagates into the Arctic Basin, resulting in the deposit of highly absorbing particles (e.g., soot) on sea-ice floes (Warren & Clarke 1990; Grenfell et al. 1994). In this project we aim at describing the most important radiation processes connected to the Arctic atmosphere-snow/ice-ocean system. These studies are encouraged by the fact that the processes that couple the atmosphere and ocean such as the cloud-radiation and snow/ice-albedo feedbacks are too poorly parameterised in Global Circulation Models (GCMs). This leads to large uncertainties in the simulation of the Arctic climate as well as future greenhouse scenarios. As an example, a reduction of the surface albedo represents a positive feedback on the climate system, resulting in an increased absorption that again can accelerate melting with a followed decrease in albedo, and so on.

Third, the variability in time of the spectral reflective surface properties of snow and sea ice as well as the attenuation through snow and sea ice determine the spectral distribution of radiation that reaches the underlying vegetation and water masses below the sea ice during the melt season. This is of important for the productivity of some of the terrestrial and marine biota.

This project is funded by the Norwegian Research Council and the Norwegian Polar Institute (1996-2000).

## Objectives

The following main objectives are identified in the project:

- To determine the variation of spectral surface albedo at different types of snow and sea ice in the Arctic; at the tundra, at Arctic fjords and in the Arctic Ocean
- To determine the variation of spectral UV/NIR-radiation within snow/sea ice and within the upper layer of the water beneath the sea ice
- To determine of the physical factors responsible for the spectral attenuation of short-wave radiation in snow and sea ice and in Arctic water columns
- To investigate the natural variability of spectral reflective characteristics in space and time and the physical processes controlling these
- To investigate the effects from extreme meteorological events, e.g. on the conditions for biological production

### **Study area and some preliminary results**

In spring (May/June 1997), extensive field work was carried out on Svalbard in order to study spectral reflectance characteristics of snow and sea-ice surfaces before and during the melting phase. The investigation was performed in the Kongsfjorden area on Spitsbergen at about 79°N on both snow-covered tundra and sea ice (Fig. 1). Spectral reflectance or albedo as well as the attenuation of light in the snow pack and sea ice were measured with a spectroradiometer covering wavelengths from 350 to 2500 nm. Accompanied observations using a pyranometer were also performed above and in the snow pack. Snow and sea-ice thickness were monitored throughout the spring as well as physical properties (e.g. density, temperature) and snow stratigraphy (including crystal characterisation and grain-size determination). Thermistor chains with data logger units for monitoring of air, snow and soil temperatures throughout the year were installed on two tundra sites in August 1997.

The surface albedo that has its maximum in the visible range decreases by about 30% during the melting season over apparently clean snow surfaces. Most of the snow cover over the tundra disappears within less than 20 days, apparently almost regardless of the initial snow depth. Within our observation period on the sea ice (from early May to mid-June), the total sea-ice thickness within a very homogeneous fast ice cover decreased from about 95 cm to 75 cm. More than 70% of that makes the loss of the snow cover, and thus only a small portion is contributed by the thinning of the sea ice itself.

Figure 2 presents the spectral albedo for four different surfaces, i) clean snow in May, ii) clean, metamorphosed snow in June, iii) "dirty" snow where the surface has been blackened, mainly due to dust from surrounding snow-free areas and iv) tundra soil. The large drop in albedo due to the presence of liquid water and increasing grain sizes is illustrated by the two upper curves. Next, the albedo drops even further when transport of dust from surrounding areas take place later in the snow melt season.

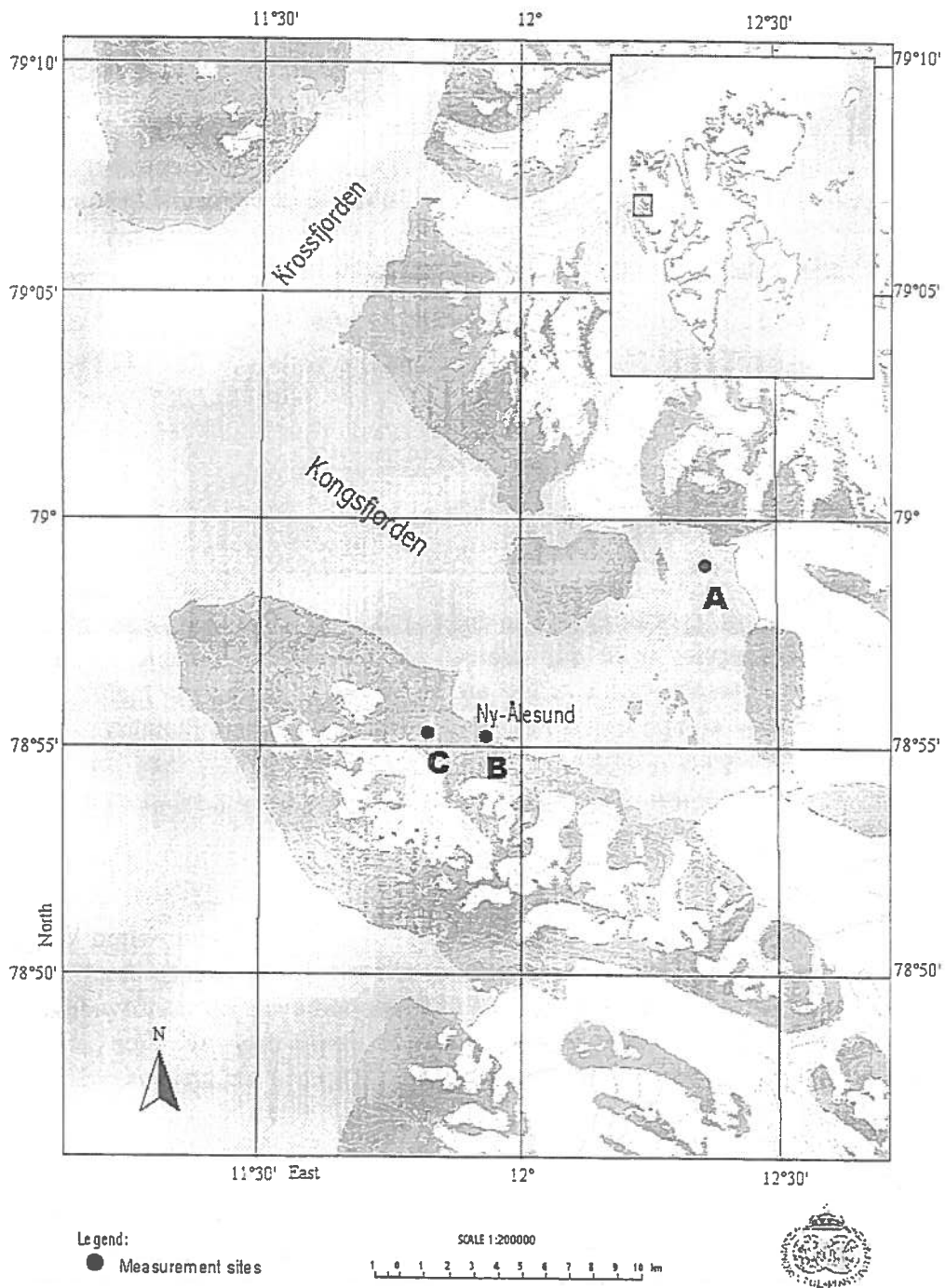


Figure 1. Locations of measurements sites; A) sea ice, B) and C) tundra.

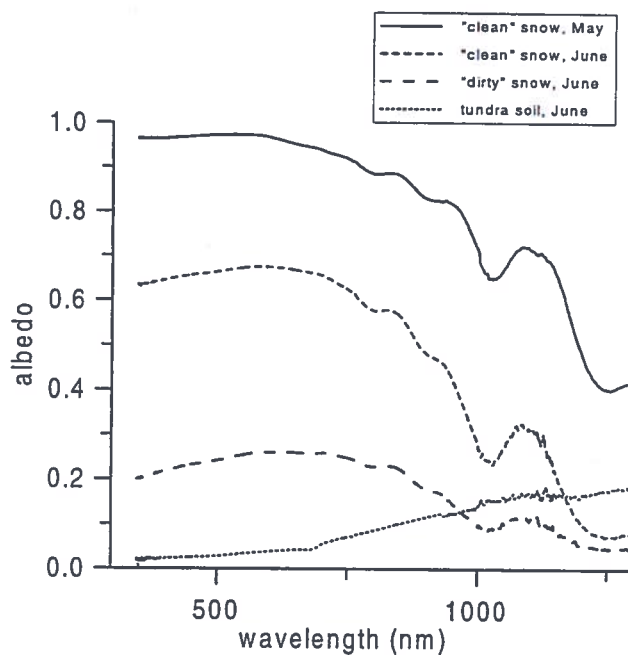


Figure 2. Spectral albedo for tundra soil and snow surfaces with different degrees of metamorphosis and surface blackening.

### Outlook

For the next two years, further extensive field studies will be performed in the Ny-Ålesund area. The results from this project are supposed to enable for a better understanding and characterisation of the processes active during the melting season and their effects on the energy balance and the Arctic environment including the onset and variation of biological production, both terrestrial and marine, and processes in the active layer. Furthermore, they would provide an extensive ground-truth data set for remote sensing and modelling studies.

### Acknowledgements

We would like to thank colleagues at the research stations of NP and Alfred Wegener Institute (AWI) in Ny-Ålesund for their support and prompt assistance in any matter. H. Miller, H. Eicken and C. Haas from AWI in Bremerhaven are acknowledged for kindly lending us the EM31 electromagnetic device for sea ice thickness measurements as well as letting us use their laboratory for sea ice analysis.

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*Biology and Biodiversity*



# The fate of nitrogen deposited on polar heath and polar desert near Ny Ålesund

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## Introduction

At most arctic study sites nitrogen (N) deposition from the atmosphere, from 1 to 5 kg N ha<sup>-1</sup> a<sup>-1</sup> (Woodin 1997), is low compared to deposition further south in Europe and North America. However, at a few polluted arctic sites deposition has reached 10 kg ha<sup>-1</sup> a<sup>-1</sup> (calculated from Nenonen 1991, Jaffe & Zukowski 1993, see Woodin, 1997) and the difficulties of controlling NO<sub>x</sub> and NH<sub>3</sub> emissions are such that it is possible that N deposition to arctic ecosystems will increase in the next decades. Pristine arctic vegetation is usually considered to be "nitrogen limited" and ecologists therefore consider that increased nitrogen inputs are likely to cause changes in productivity and/or species composition (Chapin et al 1997). In these circumstances it is important that we discover more about the effects of nitrogen deposition on arctic vegetation, particularly the deposition load at which harmful effects are first noted, and that we determine the fate of deposited N. The capacity of terrestrial ecosystems to retain N is of particular interest as any N not retained in plant/soil/microbial pools is likely either to be re-released to the atmosphere, with consequences for climate change, or to be lost to freshwater/marine systems, with consequences for eutrophication.

Since 1991 we have been applying NH<sub>4</sub>NO<sub>3</sub> in solution at rates equivalent to 10 and 50 kg N ha<sup>-1</sup> a<sup>-1</sup> to areas of tundra heath to the east of Ny Ålesund dominated by one or other of the dwarf shrubs *Salix polaris* and *Dryas octopetala*. These two species are major components of European arctic vegetation. We have shown harmful effects of long-term N-addition on the shrubs, even at the lower rate of addition, related at least in part to reduced winter hardiness (Woodin et al 1997 and unpublished data). In 1996 we spiked the NH<sub>4</sub>NO<sub>3</sub> with <sup>15</sup>N and then determined the fate of applied N in vegetation and soil pools. At the same time we applied <sup>15</sup>N to polar heath which had not previously been treated with N, to see whether the capacity of the soil/plant system to retain N had been reduced by six years of N application. Finally we compared <sup>15</sup>N-recovery from the polar heath vegetation with that from a polar desert site where vegetation cover was considerably less. In this paper we report briefly on the extent of N-recovery, the uptake of N by the shrubs and the location of the most important N-sinks in the soil/plant system.

## Methods

In 1991 two factorial experiments were established in closed polar heath vegetation at Zeppelinhamna where either *Salix polaris* or *Dryas octopetala* was the dominant dwarf shrub. The soil consisted of a layer of organic matter of varying depth overlying frost-shattered limestone and silt. Each shrub species received three rates of N-application (0, 10, 50 kg N ha<sup>-1</sup> a<sup>-1</sup>) and two rates of phosphorus application (0, 5 kg P ha<sup>-1</sup> a<sup>-1</sup>) on thirty 1.5m x 1.5m plots. Each year from 1991-1995 N & P were applied in a total of 10mm of solution in 4 or 5 doses evenly spaced between mid-June and mid-August.

In 1996 the first N & P applications were made as usual but at the second application the  $\text{NH}_4\text{NO}_3$  applied to three (*Salix*) or six (*Dryas*) 15 x 15 cm areas in each plot was 10% enriched with  $^{15}\text{N}$  (double labelled). The remainder of each plot received unlabelled  $\text{NH}_4\text{NO}_3$ . Ten days later the enriched  $^{15}\text{N}$  was chased with the third normal treatment application, and ten days after that harvesting began.  $^{15}\text{N}$  was also applied in a similar way at rates equivalent to 10 and 50  $\text{kg ha}^{-1} \text{a}^{-1}$  to new plots which had previously received no fertiliser at the heath site and also at a polar desert site close to Morebekken to the west of Bayelva.

In July 1996 three 50 $\text{cm}^2$  blocks of vegetation, surface organic matter, and mineral soil to a depth of 4cm were taken from each of the *Salix* plots. The *Dryas* plots were stratified into areas with and without *Dryas* cover and three blocks were taken from each. Each block was hand-sorted into *Dryas/Salix* green leaves, *Dryas/Salix* stem and rhizome, grasses and sedges, other angiosperms, moss and litter. The organic matter and mineral soil were separately passed through a 2mm sieve and roots were picked out and separated into coarse (woody) and fine fractions. All fractions were bulked within plots, dried at 80°C, weighed and expressed as  $\text{g m}^{-2}$ . Data from *Dryas* plots were adjusted for % live *Dryas* cover recorded at the time of harvest. Subsamples from each fraction were finely ground and  $^{15}\text{N}$  content determined by isotope ratio mass spectrometry.

## Results and Discussion

On the polar heath overall recovery of N was greatest on the *Salix* plots (50%-90%) and up to 8% was in stems and leaves of *Salix* at both application rates. This confirms that even at rates of N-deposition currently experienced in parts of the arctic, N from the atmosphere is directly taken up by the dominant dwarf shrub species and that major ecosystem processes are therefore likely to be affected. Moss and surface organic matter were important sinks for N and accounted for up to 50% of the recovery on these plots. N-recovery was lower on the *Dryas* plots (15%-40%) but again up to 11% was in the shrubs. In this more open and patterned vegetation recovery was higher on the N+P-treated plots than on those receiving N only, partly because P promoted moss growth but also because uptake rates into vegetation were higher. This indicates that the capacity of the system to act as a sink for N is to some extent limited by the availability of other elements. We believe that the N which was not recovered in the harvest had either moved below 4cm in the mineral soil, and thus potentially into ground water, or had been lost to the atmosphere in denitrification or  $\text{NH}_3$  volatilisation. At higher rates of N-deposition this represents a substantial amount of N.

At the higher rate of application, in both *Salix* and *Dryas*, overall recovery was greater from those plots to which N had not previously been applied, and specific uptake rates (uptake of N per g of tissue) into moss and *Salix* were significantly higher in these plots. This suggests that where N had been applied for six years the capacity of these important sinks within the system to trap and retain N was becoming saturated, and that if this rate of deposition were to continue losses to ground water or to the atmosphere would increase.

In the polar desert overall recovery of labelled N from *Dryas* clumps was similar to that from *Dryas* at the heathland site, but specific uptake rates into the shrubs were 50-75% lower. Moss was again the most important sink. However, recovery of N from the bare ground between the *Dryas* clumps was negligible. This frost-heaved soil, with low organic matter content, cannot retain N from the atmosphere.

This study demonstrates that the harmful effects of N-deposition on *Salix* and *Dryas* are consistent with the evidence that even at a deposition rate of  $10\text{kg ha}^{-1} \text{a}^{-1}$  N finds its way directly into the shrubs. The capacity of arctic ecosystems to act as a sink for N is related to the extent of vegetation cover and particularly to the amount of moss and soil organic matter. At deposition rates similar to those experienced over parts of northern Europe ( $50\text{kg ha}^{-1} \text{a}^{-1}$ ) some arctic ecosystems would become N-saturated over a relatively short period of time.

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# Arctic and Alpine Stream Ecosystem Research (AASER)

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## Introduction

Arctic and Alpine Stream Ecosystem Research (AASER), a multidisciplinary project financed within the Environment and Climate Programme of the European Commission, aims to study ecosystem processes within arctic and alpine running waters influenced by glacial runoff. Using a latitudinal and climatic transect of sites across Europe, a functional analysis of the sensitivity of cold stream ecosystems to variations in water balance, determined by the relative contributions of glacier-melt, snowmelt, rainfall runoff and groundwater, is being undertaken. Such a balance will be sensitive to climate change. The project seeks to isolate the main physical and chemical variables that determine aquatic macroinvertebrate distributions downstream of glacial margins.

The AASER project started in 1996 and will run until 1999. It is a cooperative effort between several different institutions: the University of Oslo (Freshwater Ecology and Inland Fisheries Laboratory), the University of Birmingham (Environmental Science, School of Geography), the University of Iceland (Institute of Biology), the University of Geneva (Laboratory of Ecology and Aquatic Biology), the Trento Museum of Natural Sciences in Italy and the Icelandic National Energy Authority. The project is coordinated by the University of Oslo.

The characteristics of stream ecosystems in arctic, alpine and mountain areas are determined primarily by their water balance, that is the relative contribution of glacier-melt, snowmelt, rainfall runoff and groundwater. Each of these sources generates a seasonal hydrological signature and runoff of different physical and chemical quality. Thus stream catchments comprise a complex spatial pattern reflecting the water balance from various sources. This pattern is highly sensitive to climatic change.

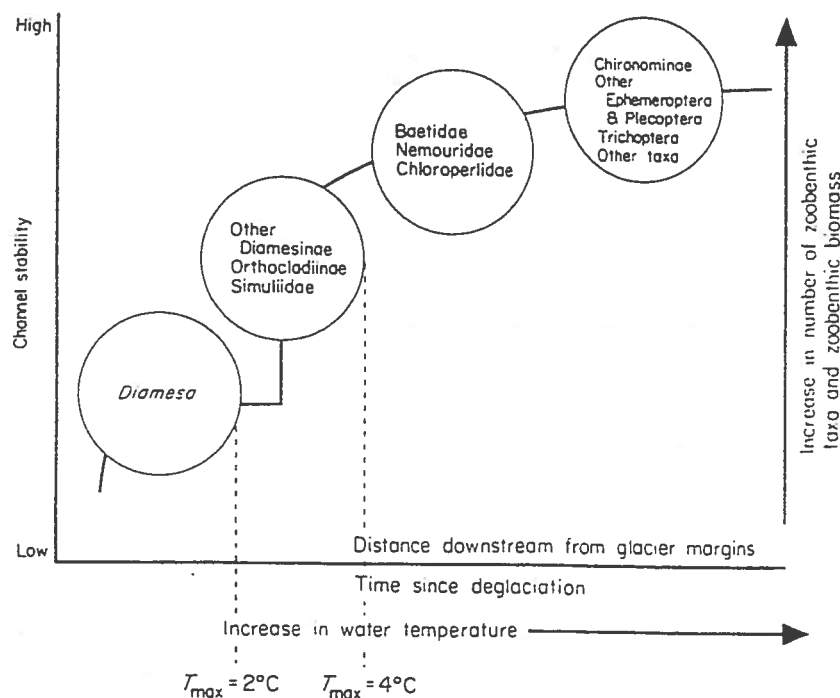


Figure 1 - The conceptual model of Milner and Petts for the zonation of stream macroinvertebrates downstream of glacial margins as a function of channel stability and water temperature.

From a synthesis of the European and Alaskan literature, Milner and Petts (1994, *Freshwater Biology* 32: 295-307) proposed a conceptual model to predict the gradient of macroinvertebrate benthic communities in streams downstream of glacial margins (Fig. 1). This model suggests that two principal variables, temperature and channel stability, determine the occurrence of certain key macroinvertebrate taxa. One of the objectives of the project is thus to validate the Milner and Petts conceptual model and to quantify the parameters of the model.

These objectives are only possible using a latitudinal and climatic transect of sites and the project encompasses sites across Europe, from the Alps and the Pyrenees in the south to Iceland and Svalbard in the north. Their climates range from strongly oceanic to continental. In some of these areas the glaciers are retreating, in some they are advancing, while in others they are more or less stable.

In the present presentation a brief account will be given of our studies in the Italian Alps and on Svalbard.

### Studies in the Italian Alps

The Italian study area is situated in the central-eastern Alps, within the Adamello-Brenta Natural Park in the Trentino region. The glacial system selected as the main study area comprises a southern exposed glacial stream with high daily temperature ranges and a snow and rain fed tributary. In all, eight stations (Fig. 2) were sampled during spring, summer and autumn 1996 and 1997. In 1997 two other glacial streams were investigated for comparison: one fed by the same glacier as the first but with a northern exposure and another chosen because of its higher sediment transport.

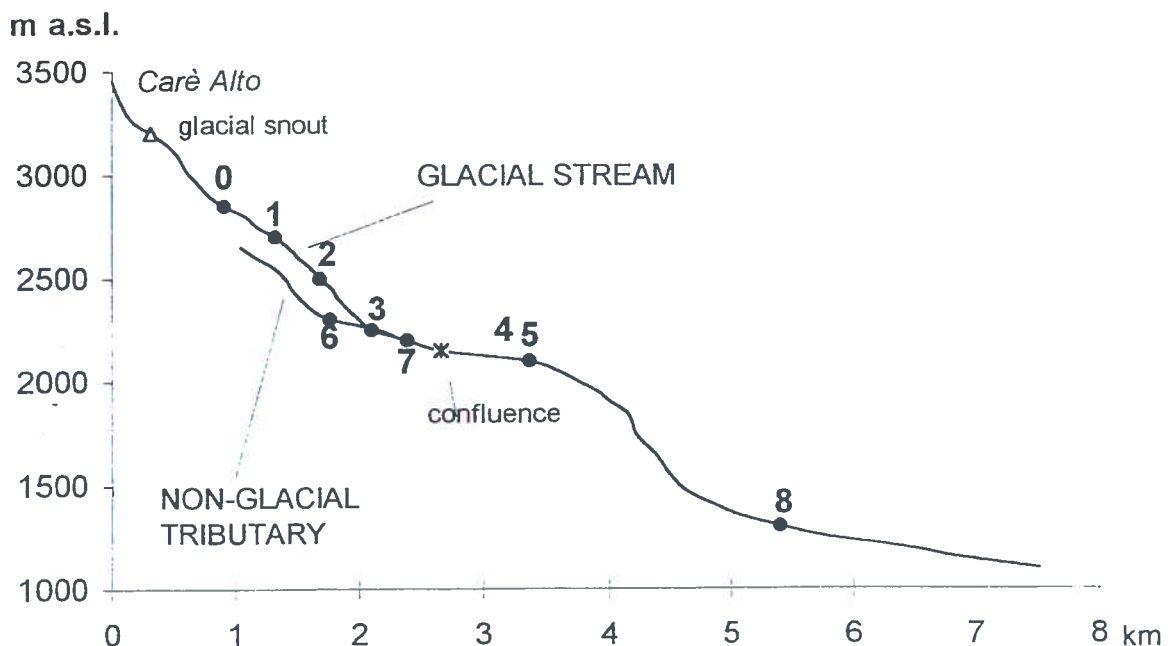


Figure 2, Profile and sampling stations of the main glacial system (Carè Alto)

On account of the siliceous nature of the catchments conductivity rarely exceeds 10  $\mu\text{S}/\text{cm}$  and pH ranges from slightly acid to neutral values. Temperature seasonal patterns proved to be strongly affected by exposure, with maxima up to 15 °C two kilometres below the glacial snout in the southern exposed stream. Discharge was measured using different methods and the longitudinal pattern is complicated by the presence of two paleomoraines through which water is dispersed. Values range from average 70 l/s at the glacier snout to 200

at the last station downstream (station 5).

Primary production was estimated by Chlorophyll *a* in the phytobenthos and it was generally low, with peaks of activity in spring and autumn in the lower stations. In the upper stations Chlorophyll *a* showed no summer decrease, but on the contrary exhibited highest values during summer.

A similar pattern was found in the total seasonal population density of the macroinvertebrates. In Figure 3 an example of the relative composition of the zoobenthic community is shown.

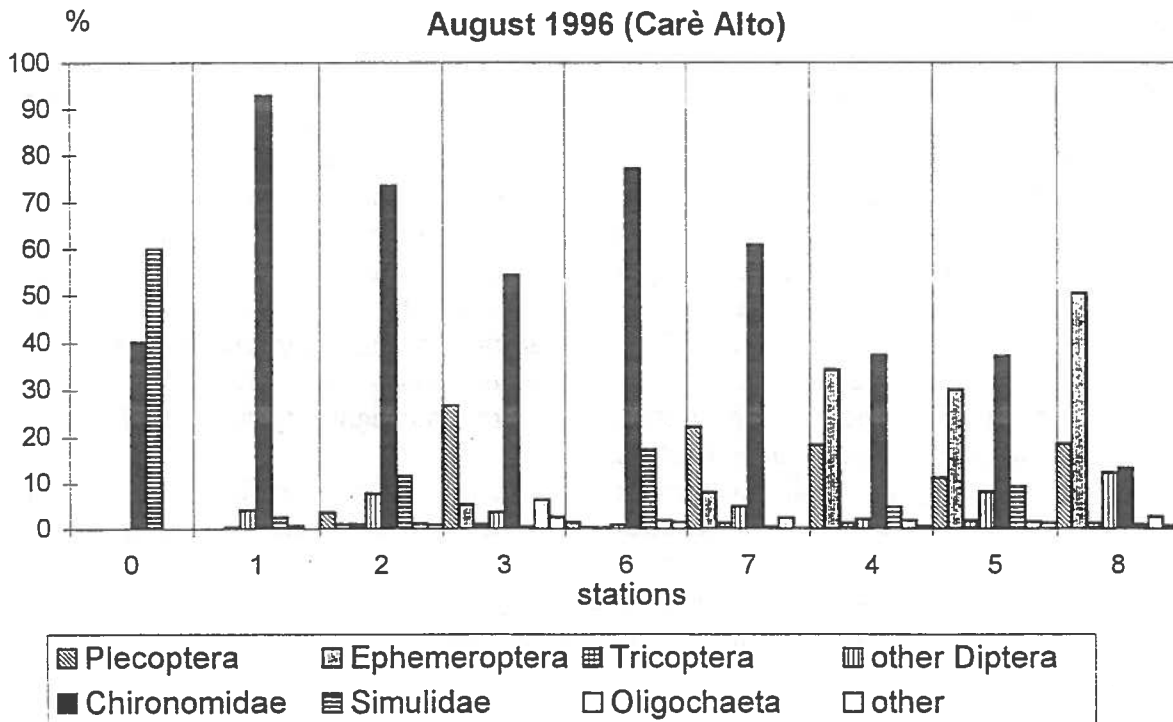


Fig. 3, Relative composition of the macroinvertebrate community in the Carè Alto system during August 1996

The higher stations, near the glacial snout, are clearly dominated by chironomids and their relative importance decreases downstream. The same occurs in the two stations on the non-glacial stream.

Other insect orders become more and more present downstream and a well structured community is already present in station 4, with several genera of Plecoptera, Ephemeroptera and Trichoptera, besides oligochaetes and triclads. Station 8 represents the lower valley with an Ephemeroptera dominated community. Further information will be gained by results of emergence traps and of drift samples.

The chironomid population appears to be of particular interest and identification of larvae, pupae and adults is well under way. Stations 0, 1 and 2 are almost exclusively occupied by the subfamily Diamesinae with the genus *Diamesa*. The main species to be found as colonisers of the first section of the stream belong to the *latitarsis* and *zernyi* groups. Here we also found specimens belonging to *Diamesa wulkeri*, a species new to the Italian fauna. Further downstream other Chironomids of the subfamily Orthocladinae with many genera appear, while Tanypodinae are rare everywhere and few genera of Chironominae are present in the lower section.

The presence of Simuliidae is lower than expected, probably on account of the oligotrophic state of the waters and low levels of suspended organic matter. The most representative species have been ascribed to the sub family Prosimulinae, genus *Prosimulium*.

## Studies on Svalbard

The fieldwork on Svalbard during the summer of 1997 focused on two catchments in the vicinity of Ny Ålesund (79°N), both of which drain into the Kongsfjorden. The systems comprise a glacial river system, Bayelva, which discharges from Brøggerbreen and a contrasting non-glacial system, Londonelva. The fieldwork, although coordinated by the University of Oslo, was a joint project effort involving all partners. The project was registered with the Norwegian Polar Institute, and British, Italian and Norwegian research facilities were used during the two field periods, 5-10 July and 12-17 August.

Among the parameters investigated were substrate composition, bedload transport, sediment transport, discharge, water temperature, algal communities, invertebrate drift and macroinvertebrate distribution and density.

The Norwegian Water Resources and Energy Administration (NVE), which is also involved in the Svalbard work, gauge the main study rivers, Bayelva and Londonelva and long-term discharge data are available. Water temperatures are also monitored in both rivers. The rivers differ in a number of aspects. In Bayelva, the bottom is unstable, sediment transport is high and temperatures low compared to Londonelva, especially during the summer period of glacial melt. However, almost all Svalbard stream and river systems represent the extreme in a European context in several aspects. The summer season when systems are ice and snow free is very short, only 2-3 months. The watercourses are also highly dynamic, with unstable channels and considerable variation in discharge.

The isolated nature of the Svalbard archipelago has also reduced faunal diversity and the freshwater invertebrate fauna is dominated by chironomids. There are for instance no Plecoptera or Ephemeroptera and the trichopteran fauna is limited to a single species. However, despite the impoverished fauna, preliminary results indicate clear difference both between the two study rivers and along downstream gradients.

## Conclusions

During 1998 the data from Svalbard will be analysed along with data from the other arctic and alpine streams across Europe to provide a more quantitative and widely valid conceptual framework for the distribution of aquatic macroinvertebrates downstream of glaciers. However, the present AASER project is really only a starting point for a new overall multidisciplinary approach to the study of arctic and alpine freshwaters in relation to global and arctic changes. It is therefore the aim of the AASER team to continue their studies of freshwaters on Svalbard in future years as one of the extremes on a European environmental gradient. The availability of data from other fields and the opportunity to carry out research at such high latitudes with a minimum of logistic problems is also a great advantage and will ensure our continued interest in the Ny Ålesund area.

## Effects of UV-radiation on Arctic freshwater plankton in Ny-Ålesund

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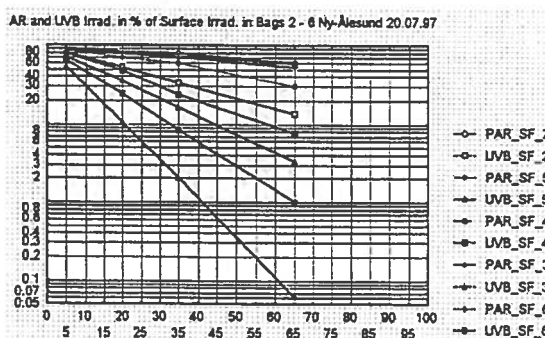
### Experimental outline

The biological damaging UV-radiation is expected to increase in the Arctic as a result of the continued chemical depletion of ozone in the polar stratosphere, despite the fact that the emissions of CFCs etc. are now reduced. Significant ozone depletion (small holes) have during the past few years been observed in the spring months over the Arctic, but the effects have a more patchy character compared to the massive ozone hole over the Antarctic. Also reduction of dissolved organic carbon (DOC), following global warming, could be a major cause of increased UV-penetration in aquatic ecosystems. Increased levels of UVB give genetic damage and reduced production in Arctic ecosystems. The highly fluctuating light and temperature regimes in the would add to this stress.

Whereas the amount of UV-radiation at the surface generally decrease with increasing latitudes, high UV-doses in the spring and summer may occur in the Arctic due to the reduced amounts of ozone as well as the generally high albedo surfaces. Arctic freshwaters are vulnerable to shortwave radiation due to their shallowness and the small amounts of DOC. UV-radiation is therefore a potentially important factor for Arctic freshwater organisms, influencing both geographical and vertical distribution, production and evolution.

The main objective of this four year, multidisciplinary project, is to study the effect of atmospheric UV-radiation on Arctic planktonic organisms in the vicinity of Ny-Ålesund. The studies also focus the important role of stochastic climate variability of other geophysical parameters. The experimental studies were performed in a gradient of dissolved organic carbon (DOC) (0.5 - 10 mg C/l) in six large (2 m<sup>3</sup>) enclosures made of UV-transparent plastic, fixed to a wooden frame in lake Brandallaguna close to Ny-Ålesund. Two of the bags received no humus, and one of these covered by a mylar film on top, to selectively remove UV-B radiation. The bags are exposed to natural light and environmental stress. The studies includes detailed measurements and modelling of the spectral UV-radiation at the surface and in the water column with simultaneous measurements of temperature. Planktonic production (bacteria, phyto- and zooplankton) as well as population dynamics, pigmentation and anti-oxidant expression (*Daphnia*) were followed over a three week period.

At the onset of the experiments at July 15. (shortly after ice-off), the bags were filled with surface water, and added zooplankton from a vertical net-haul (2-0m). The humus gradient was made by addition of freeze dried humus isolated by reverse osmose filtration from a humic lake at the Norwegian mainland. The humus gradient created a clear response in down-welling UV-radiation



(Fig. 1). The light penetration in bags as well as the daily irradiation regimes at the surface was assessed by a series of broad-band instruments as well as two different under-water spectrophotometers.

During the first week, primary production ( $^{14}\text{C}$ -bicarbonate incorporation in quartz bottles) was determined at two depths (0.2 and 1 m) on three different days in all bags to reveal eventually effects of humus additions. Bacterial production was studied by the  $^3\text{H}$ -thymidine incorporation method. Phytoplankton species composition and biomass was estimated every second to third day during three weeks from integrated samples over three depths of the bags by counting in Utermöhl chambers. Bacterial numbers and biomass was counted from the same samples by a fluorescent microscope after DAPI staining. Samples of chlorophyll a and DOC was analyzed from the same samples.

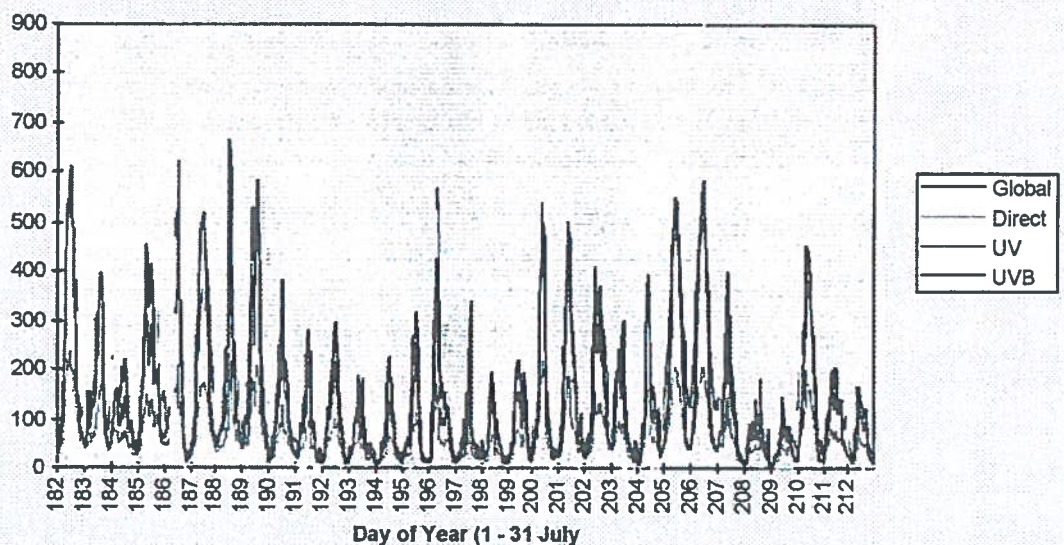
Main effort was devoted to the zooplankton dynamics and pigmentation. The metazoan zooplankton was composed almost entirely of *Daphnia pulex* (note: the taxonomy and final species affinity is under revision). Zooplankton was sampled from a mixed sample from three vertical samples by a 5 l Schindler trap. In addition, zooplankton for assays on anti-oxidants (catalase, glutation transferase) and clonal affinities (mtDNA sequencing) were preserved on liquid nitrogen for later analysis.

In addition, a set in short term assays in 1.5 l bottles with different UV-transparency (only PAR-light, PAR+UV-A or PAR + UV-A + UV-B) were performed on site. The bottles were attached to a frame in a buoy, allowing for exposure to natural irradiation for various periods of time near the surface. These experiments studied direct responses on natural phytoplankton, on selected cultured algae and on *Daphnia*-algae interactions (grazing).

### *Biological responses*

The weather was clody and rainy during most of the experiment, yet with a few days of bright sun that could have induced UV-effects on the biota.

Fig. 2. Global, Direct, UV (A+B) and Erythemal UVB Radiation Ny-Alesund July 1997 (Hourly Means)



The chlorophyll a levels were low in all bags (1.3-2.7  $\mu\text{g Chl a /l}$ ), with slightly lower concentrations in the lake relative to bags, but with no obvious relation to the DOC-levels (Table 1).

Table 1. Chlorophyll a concentrations ( $\mu\text{g/l}$ ) in the lake and bags. Nominal DOC concentrations given as mg/l)

Date	Lake	Mylar	Control	1.0	2.5	5.0	10
21. July	0.8	1.4	2.2	1.6	1.4	2.2	2.6
23. July	1.2	1.3	1.6	1.6	1.3	2.7	2
27. July	1.2	1.4	1.7	1.5	1.5	1.9	1.3
29. July	1.3	1.3	1.9	2.1	2.3	2	1.5
6. Aug.	1.4	1.4	1.9	2.4	2.3	2.7	1.8
<u>Average:</u>	<u>1.18</u>	<u>1.36</u>	<u>1.86</u>	<u>1.84</u>	<u>1.76</u>	<u>2.3</u>	<u>1.84</u>

Primary production was, for most measurements, clustered around 3  $\mu\text{g C/l/hour}$ . With the exception of 17. July, there was no clearcut linkage between primary production and DOC-levels. The surface incubation on this day gave clearly increased productivity with increased levels of DOC at 0.2 m depth, ranging from 3 mg C/l/h in the control to 6 mg C/l/h at 10 mg DOC/l. A similar, but less pronounced trend was seen at 1 m depth (range 3 - 4 mg C/l/h). Most likely, this was due to some direct stimulation by the humus rather than its UV-screening properties, since the control with Mylar cover (i.e. no direct UV-B) had even lower production (2.5 mg C/l/h). Moreover, this was a cloudy day, while no such productivity gradient was seen during bright sun on 19. July. Data on phytoplankton community structure is still under preparation.

Bacterial numbers as well as bacterial productivity both peaked initially in the bags with highest DOC-concentrations, as would be expected since humus may constitute a significant source of carbon for the heterotrophic bacteria. Bacterial numbers peaked at more than 4 mill. cells/ml. at the second date of sampling, and then gradually decreased and levelled off around 2 mill. cells/ml in all bags. Lowest bacterial numbers were recorded in the UV-B screened control. Bacterial production ranged 1000 - 2000 ng C/l/h, again with highest production at highest DOC and lowest production in the Mylar covered control.

The *Daphnia* community started as newly hatched juveniles (1st. generation hatched from ephippia) at the onset of the experiment, and matured towards adults within a two-week period. Egg-bearing females were recorded approximately three weeks after hatching. There was a total dominance of strongly melanized (black) individuals in all bags throughout the experimental period. Previous experiments has verified a higher UV-B tolerance in melanized relative to juvenile individuals, and it is believed that the pigmentation primarily is for photoprotective purposes (Hessen 1996). Pigmented and hyaline morphotypes normally belong to distinctly different clones of the same species (Hobæk et al. 1993). While most of adult and egg-bearing individuals possessed a conspicuous dark coloration, new-born and freshly molted individuals were more hyaline since the carapace melanin was lost with the exuvia. There was, however, always a few individuals of the purely hyaline morphotype in all bags, but the clonal affinities of these morphs have yet not been analyzed. During the past decade, there has apparently been

shifts is morphotype in the lake, that could be linked to UV-effects (unpubl. data). A previous predominance of the hyaline morphotype was replaced by the melanized morph after the unusually sunny Arctic summer in 1993.

The phenomenon with carapace melanization is only seen in Arctic and alpine *Daphnia*. The need for an extensive UV-protection under the Arctic regime with low doses of solar UV-B as well as long periods of cloud cover and foggy weather is puzzling. Further, many of the freshwater localities are ice-covered until mid July. However, the shallowness as well as the high transparency of these localities, offer no depth refugia from detrimental radiation. Moreover, they are exposed to 24 h light at very low temperatures, which could slow down or prevent dark repair mechanisms. The ephippia (resting eggs) are floating on the surface, and most commonly hatch during ice-off. At this time, the neonates are highly exposed at the very surface and have yet not developed a melanin protection. Most probably, these few days must be considered a bottleneck period. Once a population of migrating and strongly colored adults have been developed, shorter periods of bright weather is less detrimental.

Anti-oxidant assays are not yet finally analyzed, but preliminary data indicate lower levels of glutathione transferase and catalase in pigmented populations, whereas carotenoids were low (and equal) in both morphs. No sign of MAA's were seen in *Daphnia*.

The short term bottle experiments gave no effects under cloudy conditions. In periods of bright sky, particular responses was seen on the flagellated algae *Chlamydomonas reinhardtii*, that has previously been suggested as a bio-dosimeter for UV-effects (Hessen et al. 1995, Van Donk and Hessen 1996). There was a clear response with inactivation and loss of flagella under clear periods in the low-DOC bags, while almost no responses at the highest DOC

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## Diversity of ectomycorrhizal morphotypes associated with *Salix polaris* and *Dryas octopetala* in a tundra heath near Ny Ålesund, Svalbard.

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### Introduction

The functional and taxonomic diversity of soil fungi in the Arctic is poorly documented. This is certainly the case for ectomycorrhizal (EcM) fungi which are probably the most important component of the fungal biomass in many Arctic soils, where they are likely to play a central role in nutrient cycling (Read 1991). Evidence from other regions suggest that there may be strong selection for particular host/fungus combinations according to vegetation type, substrata (particularly organic matter content), microclimate and degree of disturbance (for example Molina *et al.* 1992). There is also increasing evidence that plants of the same or different species are linked below-ground by their mycorrhizal fungi (Trappe and Luoma 1992) and that this allows the transfer of carbon and mineral nutrients between individuals (Finlay and Read 1986). The consequences of this for the community processes are unknown but they could be profound, particularly in highly stressed environments. Up to date, no detailed studies have been published on the community of ectomycorrhizal fungi associated with roots in arctic ecosystems. The objective of this study was therefore to compare the diversity of ectomycorrhizal fungi associated with the roots of two common woody species of tundra heath: *Salix polaris* and *Dryas octopetala*.

### Methods

The diversity of ectomycorrhizal morphotypes associated with *S. polaris* and *D. octopetala* was evaluated in two tundra heath areas 1,5 km SE of Ny Ålesund where *S. polaris* grows either in isolation or in mixture with *D. octopetala*. Ten (1,5 X 1,5 m) plots were studied. Ectomycorrhizal types were scored in two 4 cm diam soil cores per plot and organic and mineral soil were studied separately. The depth of organic and mineral cores varied between approximately 1 and 7 cm. Ectomycorrhizal morphotypes were classified using morphological and anatomical features of the mantle (Agerer 1991). A survey of fruiting bodies was also carried out in August 1993 and 1994 in the general area of the plots.

### Results and discussion

A total of 28 clearly defined EcM morphotypes were observed. In addition, up to a further 10 rare morphotypes could not be clearly distinguished and require further investigation. Individual cores contained on average 4 different EcM morphotypes with a range of 0 to 9 morphotypes. 15 morphotypes occurred in more than 10% of the cores. The most frequent morphotypes were the Ascomycete *Cenococcum geophilum* (frequent in both *S. polaris* and *D. octopetala*) and an unknown variable coloured (white, grey, brown, dark brown or black), loosely woolly type with a distinctive thin plectenchymatous mantle (associated mainly with *S. polaris*). A third common type (observed in more than 20 % of the cores) was characterised by a smooth white mantle and a pseudoparenchyma of epidermoid cells characteristic of *Russulaceae* covering a plectenchyma with no recognisable pattern in the organisation and was associated only with *S. polaris*. Fruiting bodies of over 40 potentially ectomycorrhizal species

were recorded, the majority of these being species of *Hebeloma*, *Cortinarius*, *Inocybe* and *Russula*. Results of both fruiting bodies surveys and EcM morphotyping indicate that the EcM flora in arctic tundra heath is rich.

There were marked differences in EcM community composition associated with *S. polaris* in the two sites surveyed. Where *S. polaris* grew in pure stands there were 14 well defined EcM morphotypes and 8 of these occurred in more than 20 % of the cores. When growing with *D. octopetala*, although mean fractional colonisation was reduced ( $61.6 \pm 8$  % in mixed community and  $77 \pm 6.5$  % in pure stands), 20 well defined EcM morphotypes were associated with *S. polaris* and only 10 of these were also present in the pure stand. Similarly, amongst the commonest types (occurring in more than 20 % of cores) only 50 % of these occurred in both sites. 60 % of the total number of types associated with *S. polaris* were rare (occurring in less than 20 % of cores) in the *Salix/Dryas* community whereas only 40 % of the total number of types were rare in pure *S. polaris* stands. Several factors are mentioned in the literature which can influence host-fungus species associations (Molina et al. 1992) among which soil characteristics and influence of neighbouring plant community are likely to contribute in our study site.

Several EcM morphotypes were observed on both *S. polaris* and *D. octopetala* in mixed host communities. Approximately 60 % of common (occurring in more than 20 % of cores) EcM morphotypes associated with *S. polaris* were also observed on *D. octopetala* and approximately 40 % of the common types found on *D. octopetala* also occurred on *S. polaris*. The other common types appeared to be restricted to one or the other host species. Our results show that the pattern of colonisation of several fungus species varies depending on host species. This was clearly observed with a morphotype bearing cystidia characteristic of the genus *Russula* which formed clusters of tips on *D. octopetala* and was associated with this host in more than 50 % of cores and contributed  $61 \pm 13$  % of tips. In contrast, this cystidia-bearing type associated with *S. polaris* only in 20 % of cores and colonised only  $32 \pm 11$  % of tips. Apparent differences in host specificity and receptivity to EcM fungus species might therefore explain the increase in the total number of EcM morphotypes (25 well defined types) observed in mixed cores and our results suggest that the diversity of EcM fungi might increase as a consequence of the co-occurrence of host species.

Results of this study provided us with a significant reference database on EcM morphotypes and allowed us to better understand patterns of host specificity in *S. polaris* and *D. octopetala* in an arctic tundra heath area. Our investigations into the mycorrhizal ecology of *S. polaris* and *D. octopetala* have shown that the EcM community is rich, possibly more so than in other vegetation that has been similarly studied. There are examples both of host-specificity and host-preference and clear differences in community composition between two species and on a single species, *S. polaris*, in different environments. Our database is currently used in our laboratory to investigate the impact of atmospheric N-deposition on the EcM flora associated with *S. polaris* and *D. octopetala*.

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## TOWARDS THE NECESSITY OF A NEW "URGENT ANTHROPOLOGY": ARCTIC ANTHROPOLOGY AND THE "NEW" (BUT ANCIENT, BECAUSE TRADITIONAL) ECOLOGICAL INDICATORS

By Franco Pelliccioni, Italian Geographical Society

*"In thinking about what we are doing to our world's oceans, I contemplate the wisdom of the ancients. They us that nothing can be manifest outside us that is not first manifest within us." We cannot create something in the "outer world" without first creating it within each of us. We are trashing our physical world because we are trashing our "inner world." Long term change cannot take place until we deal with our trashing within and transform our inner world into one of peace, tranquility, and balance. The elders say that the only thing that transform darkness into light is love". Larry Merculieff, Aleut, Coordinator of Alaska's Bering Sea Coalition.*

### AN INTRODUCTION TO THE ARCTIC AND THE GLOBAL CHANGE

The *Guidelines for Environmental Impact Assessment (EIA)* in the Arctic (1996), identify the typical Arctic characteristics: 1) It is not a uniform region; 2) *Physical/Abiotic Systems*: extent of ice-cover on waters; prominence of cryosphere -permafrost, glaciers/ice sheets- stored greenhouse gases such as CO<sub>2</sub>, methane; 3) *Biotic Systems*: low productivity in general, but some areas are of very high productivity; short food chains; slow recovery; 4) *Sociocultural systems*: high subsistence dependence; extensive vs intensive patterns of land use; low population densities; 5) *Implications for: infrastructure*: roads/pipelines/sea routes; construction/buildings - onshore/offshore-; waste disposal.

Arctic ( but also sub-Arctic) ecosystems, due to their short growing, are, not only, very sensitive to chemical, biological, and physical changes of human origin, but now they are facing global climate change. Climate change is of immediate interest to the Arctic. So that the *International Geosphere-Biosphere Program* has identified it as the "bellwether of global change and the zone of early warning for global greenhouse warming". The Arctic plays a crucial role in global climate change, indeed. It is not only an indicator of change but its snow and ice features and ocean temperatures and sea ice are good integrators of change. It stores long-term climatic records in its ice sheets, such as the Greenland *ilandsis*. It affects the global climate directly through interactions between the atmosphere, ice cover, and ocean, and through feedback processes. All climate models predict an amplification of the global greenhouse effect at high northern latitudes, but models and observations have produced results not easily interpreted. Global effects on the Arctic are reflected in regional climate changes. All snow and ice of the Arctic will be affected. The extent and thickness of the seasonal snow cover, sea ice, permafrost, glaciers, and river and lake ice are going to decrease. These changes will affect also the ecosystems with their fauna and flora. Cultural and socio-economic consequences to the arctic populations and their lifestyles will be inevitable. Anyhow not all the changes will be necessarily negative. Less sea ice may allow, for instance, the opening of trans-Arctic shipping routes, like the mythical North-East Passage, the *Northern Sea Route*.

But in general there is considerable uncertainty in the predicted long-term climate changes, and thus the consequences of these, whether due to natural or anthropogenic influences, remain unknown, as I have already underlined (AMAP, 1997a). A recent AMAP report points out that "the ozone depletion, ultraviolet radiation, climate change and human-caused pollutants pose a more serious threat to the pristine environment of the Arctic than previously believed". There are "serious gaps in our present knowledge, which prevent us from making firm predictions on how the Arctic will respond to future changes (...) the climate of

the Arctic can influence the rest of the earth by increasing sea level through glacial melt, and by altering oceanic circulation which is responsible for transporting colder water from the Arctic to lower latitudes. Recent increases in surface UV in winter and spring are adversely affecting ecosystems, and human health in the Arctic (...) Eye damage and weakening of the immune system are of particular concern to people living in the Arctic because of the difficulties and cost associated with obtaining medical care" (AMAP, 1997b)

Two recent studies concerning changes in northern ecosystems are of some interest: 1) an analysis using a simplified climate/biosphere model predicts that all boreal forest vegetation will shrink and replaced by *taiga*. Temperate forest will move northward (Monserud et al. 1993); 2) using paleoecological data it is possible to imagine which could be the future change in the boreal forest/tundra vegetation. We know that during a warm period (4000-5000 years BC) vegetation changed from tundra to canopy black spruce within a 150 years period (MacDonald et al. 1993). The past historical warm period had more or less the same climate conditions then the ones are producing the temperature changes predicted now for the Arctic. But the final question mark, also in the case of the two researchers, concerns always the same impossibility to know which exactly the "change effects" will be.

The U.S. *Global Change Research Program* recently published a report entitled *Forum on Climatic Modeling* (1995) which provides the latest conclusions on future climate conditions, according three categories: *Very Probable*, *Probable* and *Uncertain*. For the North they are: VERY PROBABLE : 1) Global temperatures will increase by 2050 between 0.5 - 2.0°C; 2) Northern Hemisphere sea ice will decrease. However some areas will have expansion; 3) Arctic land areas will show increased warming and reduced snow cover; 4) Sea level will rise between 5 - 40 cm.

PROBABLE : 1) High latitude precipitation will increase; 2) The North Atlantic Ocean will warm at a slow rate than the average.

UNCERTAIN : 1) Changes in climatic variability will occur; 2) Regional scale (100-2000 km) climate change will be different than the global average; 3) Details of climate change over the next 25 years are uncertain; 4) Biosphere-climate feedbacks are expected but whether these feedbacks will amplify or moderate climate change is uncertain. (Lewis e Wool 1996).

#### **KNOWLEDGES: NATURAL VS. SOCIAL, SCIENTIFIC VS. TRADITIONAL**

There is a manifold knowledge confrontation in the Arctic. The first is between aboriginal Peoples Knowledge and the scientific eurocentric Knowledge. In a word, between them and us! The second is wholly eurocentripetal, because is played between natural and social scientists. I will start from this "second *vis-à-vis*".

The mistrust and the incomprehension, that especially in the past, and in some scientific *milieux* also today, have negatively marked the contribution to the understanding of problems of a more and global significance, among scholars belonging to natural and social sciences, should be overcome. Today's paper could exactly start from what climatologists Lewis and Wood said about "the urgency to bring the two together" (II ICASS, *International Congress of Arctic Social Sciences*, Rovaniemi, 1995). Kuhn and Phillips in the '70 already outlined the benefits coming from the *cooperation of natural and social scientists*. So to go "beyond the constraints of the paradigms of the individual disciplines". Researchers will have to be willing to accept the validity of multiple paradigms, which appears to go against the norms of science as we have defined it.

"Global change is occurring at an ever increasing rate, and this change is nowhere felt more than in the *delicate* environmental systems within both the oceanic and terrestrial regimes for the northern latitudes. These regions face a myriad of environmental problems that at times

appear to be overwhelming - depleting of fishing stocks and decline in marine mammal populations; decreased habitat for caribou/reindeer herds; continual pressures of mineral exploration and its social consequences on native groups; and the socio-economic impacts of climatic change". (Lewis and Wood, 1996)

"Generally, the modern scientific knowledge of Arctic ecology is not as advanced as the ecological understanding in temperate latitudes. There is lack of extensive modern research and a shortage of qualified Arctic scientists. The southern experience and intuition cannot readily be transferred to the Arctic. However, the practical knowledge of the indigenous peoples on the environment and its sustainable use is extensive. Many indigenous peoples in the Arctic are repositories of long term knowledge about local ecosystem characteristics and *variations over time, including recent trends. Often they can also identify reliable indicators of stress in valued ecosystem components* [my italic]. " (EIA, 1996).

"While there has been a great deal of ecological information collected by, or from indigenous peoples of the Arctic, a large amount of this information has remained unused or unaccessible as reference material, only in recent years have researchers seriously examined the potential of using this knowledge in conjunction with western science to study the impacts arising from development projects." (Sallenave, 1994)

#### **HOW THE LIFE-STYLE (AND ETHNOSCIENCE) OF THE NORDIC ABORIGINAL PEOPLES CAN HELP IN UNDERSTANDING AND MONITORING THE DRAMATIC GLOBAL CHANGE PHENOMENON: LAUNCHING AN ARCTIC URGENT ANTHROPOLOGY PROGRAM?**

It is possible to say that in the Northern regions do exist brand new (but, at the same time, with a very ancient origin) indicators that we may place together with the others-ones scientists already possess, as excellent theoretic and working tools, to find out the exact and up-to date picture of Arctic (and "Global") change. They are indicators, it has been said, new and old at the same time, because strongly connected to traditional life-styles of the aboriginal peoples that there live.

And they are deeply interrelated with the protection of the original *habitat* (pastures, hunting and fishing grounds, seasonal movements, ecc.) of the hunters and pastoral peoples of the Euro-Asiatic and American *Great North*.

Now, with the Third Millenium almost at the door, we have new motives and reasons to re-start a "new" Program of *Urgent Anthropology*, after those spoken (about) and carried out in the '60 and '70. But those, I should add, had the (not at all secondary, this is true!), task to take records, among tribes and peoples all over the world, of traditional cultures and customs: "before it was too late". As to add them in the Inventory of Humanity. But those Arctic peoples, those men and women, who since time immemorial live in the circumpolar areas, know, I should think, exactly, what is going on, since little, or long time, in their native countries. What is changed already since their father's time, or what is -perhaps still now-changing under their own eyes. And these findings, their discoveries and know-hows can help them and us. Can help the world, as a whole, to correct and change single and collective ecological behaviours. And, at the end, also they will help, at large, the same Nordic peoples and communities to restore, we hope, better ecological, economical and living conditions. Because indications and main lines (also of a compulsory nature, if it is the case) should be given to Governments and Administrators, below the Polar Circle, so to keep control and/or diminish the degree of pollution and of the green-house effect. As a matter of fact, the eight Nordic countries have developed, since 1991, the AEPS, that rightly has incorporated knowledges and traditional practices of the cultures of autochthonous peoples. And CAFF is the Program of AEPS for *the Conservation of Arctic Flora and Fauna* and practically is integrating indigenous peoples and their knowledge [Nordic Aboriginal Peoples have been

directly involved since its inaugural meeting (1992). The projects that have been ongoing are the following: "Beluga Whale Mapping Pilot Project" (Alaska e Chukotka, Russia); "Indigenous Knowledge Data Directory"; "Indigenous Peoples and Co-Management"; "Ethical Principles for Arctic Research"] "*since they represent the repository of traditional indigenous ecological knowledge and skills of the Arctic*".

But already the *Indigenous and Tribal Peoples Convention* - ILO - states that:

"The peoples concerned shall have the right to decide their own priorities for the process of development as it affects their lives, beliefs, institutions and spiritual well-being and the lands they occupy or otherwise use, and to exercise control, to the extent possible, over their own economic, social and cultural development. In addition, they shall participate in the formulation, implementation and evaluation of plans and programmes for national and regional development which may affect them directly" (art.7,1).

The traditional indicators of Arctic change must not be invented. It is not necessary to guess them. They are already there. Since the beginning of time. Since the "Golden Age" or the "Cultural Foundation Myth" of each Nordic community and they form an integrating part of tradition, of the orally transmission of know-hows, knowledges, and so on, connected also to the environment, the habitat, the fauna and vegetation, the climate...In the last few years all these last knowledges have been renamed as: "*Traditional Ecological Knowledge*" (TEK).

#### **A DIFFERENT LOOK TO GLOBAL CHANGE FROM THE ABORIGINAL CULTURES AND PEOPLES : TRADITIONAL ECOLOGICAL KNOWLEDGE (TEK)**

It has been defined as :

"a cumulative body of knowledge and beliefs, handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment. Further, TEK is an attribute of societies with historical continuity in resource use practices; by and large, these are non-industrial or less technologically advanced societies, many of them indigenous or tribal" (Berkes 1993: 3).

Traditional knowledge is what anthropologist, more formally, use to call *ethnoscience*. That is, according the definition of the late Cardona: "the theoretic total of the practical knowledge about the world, owned by a community; knowledges that have a "learning value", not a "credence value", coherent and verified by experience" (1995:36). TEK is day by day adjusted to habitat changes of each community, and it will be of vital importance, value and validity as far as peoples will turn themselves on the environment for their subsistence (and survival).

Aboriginal traditional ecological knowledge should be integrated formally into the process, and aboriginal peoples should be given greater decision-making powers concerning EIA research and policy. At present, most environmental assessments and monitoring systems neither involve significantly aboriginal communities or include northern aboriginal peoples' knowledge of the environment, so "...most EIAs are ineffective" (Sallenave, 1994).

It should be added, and this is not a "new thing" for Students of Man, that: "the aboriginal view of the world sees all aspects of the environment as equally important. In their "holistic" view, the components (of the biosphere or the human components—the social, cultural, spiritual, and economic aspects of the environment) cannot be separated each from the other."(Sallenave, 1994)

Already, almost twenty years ago, Freeman,1979 ( and, after him, Howes,1980, Johnson, 1989, Nakashima, 1990) have pointed out the advantages of involving aboriginal peoples as environmental researchers, also with greater speed and less cost compare to the traditional

scientific research methods. "As long as aboriginal communities in the study region are not involved in the research, it will be difficult—if not impossible—and more costly for researchers to identify and *understand* the ecological, social, cultural, economic, and spiritual value of the various components of the environment" (Sallenave, 1994).

"There are numerous knowledge gaps in the ecological information about northern regions that science alone cannot fill. TEK, which encompasses the biophysical, economic, social, cultural, and spiritual aspects of the environment, is in many instances better suited to answer scientists' many questions" (Freeman, 1992). Because, as a matter of fact, "TEK emphasizes the inter-relationships between components of the environment and avoids scientific reductionism. It views humans as part of the environment. (...) Integrating TEK into the EIA process entails more than a transfer of information from one culture to another: it will require a change in the mind of policy makers and of scientists." (Sallenave, 1994).

In 1996, a Seminary held by the ICC (*Inuit Circumpolar Conference*) in Inuvik, Canadian Western Arctic, saw all together elders, researcher, Inuit hunters (from Canada, Alaska, Greenland and Northern Russia), all of them with strong backgrounds in traditional ecology. The participants stressed that "TEK collecting" is urgently needed. In all the represented circumpolar regions, elders who grew up living on the land and sea are passing away, and with them their knowledge of the land and of the traditions of the community. It is essential that it is documented the elders' knowledge and promoted the transmission of that knowledge to the younger generation. This must include the protection of the land and the use of its resources, otherwise traditions and knowledge will be lost, and the people who remain will be left without the benefit of this heritage. In particular, there is a need to revive traditional methods of using natural resources for the continued survival of indigenous peoples of the circumpolar north (ICC, 1996). In the same paper the first recommendation addressed by the participants, entitled *Perpetuating the Use of TEK at the Community Level*, was: that should be encouraged the promotion of the use of indigenous knowledge in the community, and the documentation of the knowledge of community elders, making it locally available. "Work in this area is particularly urgent, since so much knowledge is being lost so rapidly". Afterwards, in the paragraph *Documenting TEK*, it is further pointed out that: "due to the urgency with which TEK documentation is needed, funding agencies and local organizations should make this work a high priority". Not only! A recommendation of a purely anthropological flavour, concerning the globality of the right direction to take, is that: "TEK interviews should be holistic in their approach. Topics should include land, animals, people, culture, language, and environment, as appropriate. All are connected, and the interview should discuss environmental and cultural processes and influences that relate to the subject being studied".

But there are some overall difficulties in accepting TEK. The first barrier to its integration is perceptual. Because, as we can imagine, there is a difference between what aboriginal peoples and foreigners see as "significant"... This poses an obstacle to the effective monitoring of impacts. The gap between the two perceptions is due to the fact that generally it is not possible to fully understand the attitude of a People to development and change, out of the context of its own cultural history. And we know very well that there is a continuous trend, almost in all the world, to exclude aboriginal peoples (and their knowledge, too!) from development processes. A second, not secondary, barrier towards the inclusion of traditional knowledge in the EIA process is the scepticism within the scientific community: the more or less reliability of indigenous information coming through interviews, and/or field participant observations. It could be anecdotal and no-scientific.

Urgent Anthropology looks for several causes, besides those concerned to the world's processes, more or less deep and extended, of cultural change in progress, and as to peoples threatened (for several causes), still more vital than ever. "Urgent Anthropology" University

Courses, Fellowships and Scholarships, concerning Programs and Projects in Urgent Anthropology, are yearly conferred by the most prestigious scientific organizations. Not only... The most important World's Meetings show evidence of the urgency of ethno-anthropological studies, which have characterized, almost from birth, modern Ethnology (and Cultural/Social Anthropology), with researches in all corners of the world. It is possible to say, as a matter of fact, that the adjectif "urgent", or the word "urgency" are tightly connected to these sciences. They have been a sort of *raison d'être* of our science, both belonging to the foundation act of the discipline.

Recently Osherenko (INSROP) underlined the "complexity of the human systems in the Arctic and the need for both detailed and geographically broad-ranged baseline studies" (1993:122). As a matter of fact gaps exist also in the basic knowledge of many Nordic Peoples, first of all Siberians. So, to conclude, I hope the topic of my paper has been of some utility to the general discussion of this Seminar. And here I suggest the possibility to launch a new *Program of Urgent Anthropology*, focalizing it in the circumpolar regions for the following main reasons:

- 1) to collect general background data on Arctic Peoples, when our knowledge of those cultures is insufficient (Northern Russia), or it is out of date;
- 2) to collect data on Arctic Peoples cultural change, in progress;
- 3) to collect data on ecological matters;
- 4) to collect data on ecological (and global) change.

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## FACTORS AFFECTING BIOLOGICAL NITROGEN FIXATION BY EPIPHYTIC CYANOBACTERIA IN ARCTIC VEGETATION

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Nitrogen availability in the Arctic is low in mineral soils, and only low concentrations of nitrate and ammonium are precipitated in rain and snow (Rempfler 1989). The main input of nitrogen is biologically fixed, and in a High Arctic ecosystem at Kongsfjorden, Spitsbergen (79°N, 12°E) biological nitrogen fixation was mainly found to be due to epiphytic cyanobacteria on different bryophytes (Solheim et al. 1996). When the ability to support an epiphytic flora was studied in bryophytes growing intermingled at Solvatnet, great variations between species was found. Especially *Calliergon richardsonii* and *Sanionia uncinata* seemed to be well adapted to harbor epiphytic cyanobacteria, but the extent of nitrogen fixation also varied with growing location.

The rate of nitrogen fixation was greatly influenced by grazing by geese and reindeer. Herbivore animals are removing nutrients, including nitrogen, from their grazing areas. This harvest together with other losses of nitrogen (leaching, denitrification, etc.) must be replenished by mineralisation, nitrogen fixation and nitrogen in precipitation. In a geese and reindeer grazing area around Solvatnet values of nitrogen fixation were found with a maximum of  $693.6 \pm 1.5 \text{ nmol ethylene h}^{-1} \text{g} [\text{dry weight}]^{-1}$  while maximum values for ungrazed areas was  $65.3 \pm 16.6 \text{ nmol ethylene h}^{-1} \text{g} [\text{dry weight}]^{-1}$ . In the grazed area cyanobacteria were also found fixing nitrogen epiphytically on grass. Under cliffs harboring colonies of birds feeding in the sea biological nitrogen fixation was inhibited by the high nitrogen content of bird droppings.

The nitrogen fixation along the moss plants was highest in the upper 2 cm, normally with a maximum 0,5-1.0 cm from the apex. Most of the cyanobacteria were located in a matrix, probably polysaccharides, in the space between the leaves and the stem of the moss. This location gives some protection against sudden fluctuations in humidity.

Cyanobacteria need light for photosynthesis, but they have to be protected from direct sun light. The effects of elevated levels of UV-B radiation on terrestrial vascular plants have been extensively documented. Only a few papers have studied the effect on mosses (Sonesson et al. 1996), plants playing a major role in Arctic ecosystems. Increase in UV-B radiation of moss vegetation in Adventdalen during two growing seasons markedly decreased nitrogen fixation. To determine if this is a result of changes in biodiversity of the cyanobacterial population or damage to the nitrogen fixing system will be the aim of future studies. Diminished availability of nitrogen might over time greatly influence the primary production and the support of herbivore animals in the Arctic.

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# The effects of environmental change on the length of the migratory window of Spitsbergen Arctic charr

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## Biological background

Freshwater lake systems on Svalbard are characterized by very low temperatures, long-term or even permanent ice cover and low levels of nutrients. Food is thus limited and may lead to growth stagnation and early maturity in Arctic charr (*Salvelinus alpinus*). The individual growth pattern may alternatively follow a sigmoid-shaped curve, i.e. the fish grow slowly for a number of years until a dramatic increase in growth takes place in some individuals as a result of a major change in diet (Hammar 1991). The cause of this dietary change is a shift to either anadromous (migration to sea) or cannibalistic behaviour (Svenning 1993, Svenning and Borgstrøm 1995).

Populations, including migratory charr, may consist of a mixture of parr, postsmolt and adult migratory individuals, small-sized residents and large-sized resident (cannibals). Additionally some individuals are even large formerly resident individuals which have transformed to an anadromous behaviour, and have spawned without having previously been sea-run fish (Radtke et al. 1996).

The high plasticity observed in Arctic charr attests to the adaptability of the species (Maar 1949, Frost 1963, Nyman 1972, Behnke 1980, Svenning et al. 1991). Two major types of phenotypic responses to the environment (plasticity) have been considered in the literature. The most common discussed is the reaction norm, i.e. an array of phenotypes produced by a single genotype across a range of environments. Central to the concept of the reaction norm is that the environments involved are repeatable and predictable aspects of the organisms habitat (see Real 1994), such as presence or absence of predators (cannibals) for landlocked charr that may exhibit induced behavioral defenses (Svenning and Borgstrøm 1995). This is in contrast to the largely unpredictable variability found in freshwater environments on Svalbard, inhabited by migrant charr (Svenning 1993).

The term partial migration (Berthold 1991) describes the phenomenon of populations split into migratory and resident individuals. It is known from several species of fish and occurs among freshwater, anadromous and marine species (Jonsson and Jonsson 1993). Partially migratory charr populations are often polymorphic and previously resident mature individuals may transform to anadromous behaviour (Nordeng 1983, Svenning et al. 1992). Migratory behaviour in charr, which is only one aspect of the complex life history of the species (Dempson and Kristoffersen 1987), is restricted to the northern areas. This is also in accordance with a number of salmonid species, in which anadromy is suggested to be more frequent in cold than in warmer, temperate latitudes (McDowall 1987, Baker 1978). One explanation is that the growth advantage to be gained by undertaking a seaward migration is maximized, when conditions for feeding and growth in freshwater are critical (Gross 1987).

Consequently, anadromy should be more advanced in charr inhabiting the cold and low-nutrient lake systems on Spitsbergen, than in those found in the southernmost parts of the distribution areas. However, this doesn't always seem to be true, and there is evidence that in several lake systems on Svalbard (not exploited by man), the fraction of seagoing individuals is unexpectedly low (Gullestad 1973, Svenning 1993).

#### **Climatic conditions**

Climatic statistics from Svalbard show a great year to year variability in air temperatures. During the last 60 years the mean winter temperatures (Dec. 1. to March 1.) in Longyearbyen varied between - 23.6 and - 7.8 centigrade. These variations are due to variations in large scale atmospheric circulation and in sea ice conditions.

The thickness of the ice on lakes depends on the air temperatures and the snow cover. In years with low temperatures in autumn combined with little or no snow, the ice thickness will increase rapidly. The thermal conductivity of ice is 10 to 20 times that of snow. Consequently, a thin snow layer on the ice will reduce the rate of increase in the thickness considerably. Dry snow reflects 80 - 90 % of the total solar radiation while an ice surface or wet snow will reflect about 20 % and 50 % respectively. The melting of ice on lakes is therefore sensitive to episodes of advection of warm air in spring which lead to snow melt and a reduction of surface albedo. The timing of ice break-up and when lakes become covered with ice, thus, vary greatly between years. Based on climatic and satellite data it is even possible to reconstruct the ice conditions and the duration of ice-free periods in a lake, and consequently the retrospective annually variations in ice-free periods can be established for Svalbard lakes.

Because the permafrost seals the subsoil on Svalbard, ice-melt or snow-melt provide a flush of water only in late spring or early summer. In most lake systems with migratory charr on Svalbard, glaciers contribute significantly to the catchment area. Since rainfall is limited (less than 350 mm/year), surface runoff accounts for most of the flow in the outlet streams. The annual flow patterns are thus mostly due to: 1) ice-melt during spring break-up (late June to mid-August); 2) relatively high and fluctuating flows in summer and late autumn (from late July to late August) due to the melting of glaciers caused by fluctuating air temperature; 3) strongly decreasing flow in late autumn due to decreasing temperature (late August to mid-September) and; 4) no flow during winter (from late September to early July) (Svenning and Gullestad unpublished). Thus, as seen from the view of an Arctic charr, the outlet streams in lake systems on Svalbard function as a transport system, providing "there-and-back" access to the high nutrient sea water for one to two months a year at the most. A critical period is the last week of August and the first two to three weeks of September, when only a slight decrease in air temperature (< than 1 °C) would prevent glacial melting, and thus «dry up» the outlet river.

#### **Migratory behaviour in the Arctic charr in the Dieset lake system**

In this study, we examined the length of the migratory window of Arctic charr in the Dieset river, northwestern Spitsbergen. A hoop trap was used to catch migrating charr in the river throughout the summer in 1971, 1975 and 1977. During these three years, the fish trap was operating from mid of July to the beginning of September. The abundance of migrating charr was correlated to daily variance in river flow (water depth), rainfall and air temperature.

The average length of sea residence in migrant charr from the Dieset river is approx. 40 days. Based upon our results, we suggest that the ability of the charr population to ascend their home river in late autumn is somewhat restricted and varies highly between years, due to annual climatic variation. In some years migrant charr would not be able to complete the sea

residence before the river has dried up. We suspect that in "worst case scenarios", diminished stream flow coupled with winter freezing, may prevent a significant part of the charr population from migrating upstream in late autumn (i.e. leaving them "sea-locked"), and thus result in disastrous mortality.

#### **Future research**

Determination of the effect of the environment upon phenotype and life history relies upon detailed information about environmental conditions, growth rates and mortality during each life history stage. New techniques have recently been developed to collect detailed life history information from the microstructure and trace-elemental composition of otoliths (i.e. Coutant 1990). Any movement of individual charr between fresh- and sea water will be reflected as a change in the Sr/Ca ratio of the otoliths (Radtke et al. 1996). This means that each individual can be studied retrospectively (followed backwards in life), like a flight recorder, and thus it is possible to detect to what extent each individual has followed a distinct behavioural pattern, or alternated between life-history tactics. Further, based on climatic and satellite data it is also possible to reconstruct the annual climatic conditions in the lake systems, and consequently the annually variations in the length of the migratory window can be established.

By using element analysis of the otoliths life-history data for individual fish will be provided. These data will allow us to compare in some detail the life histories of resident and (facultative) anadromous charr. Specifically, we will be able to: (1) determine whether charr classified as anadromous based upon characteristics such as growth, condition factor, colour of flesh and infection of freshwater versus marine parasites, demonstrate Sr/Ca profiles consistent with movement between fresh and sea water; (2) determine the age at which charr recruit to the anadromous population; (3) compare growth rates associated with resident and anadromous life histories; (4) determine if and when interruptions of the seasonal migrations among anadromous charr occur; (5) determine if resident behaviour occurs at the same calendar year irrespective the age of the fish and correlate these data to climatic conditions in the lake (based upon satellite images). Such information will ultimately lead to an understanding of which environmental factors are significant for recruitment into either resident or anadromous populations. The suitability of the otolith microchemistry method has already been confirmed for Arctic Svalbard charr (Radtke et al. 1996)



## Effects of ambient UV-B radiation on carbon dioxide fixation and bacterial activity of marine plankton communities in Kungsfjord.

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The short-wavelength ultraviolet radiation, UV-B (280-315 nm) have attracted substantial interest the last years. Reasons for this are increased knowledge of its biological and chemical effects together with the discovery of the reduction in the stratospheric ozone layer.

The effects of UV-B radiation is especially interesting in polar regions by two reasons.

- The breakdown of the stratospheric ozone layer is most dramatic in polar regions.
- The low water temperature will make the organism more vulnerable for injuries as the activity in repair systems decreases is highly temperature dependent while the damage production are not.

Most studies of effects of UV-B radiation on marine systems in polar regions are made in Antarctica with only a few studies in Arctic. The ecology, especially nutrient conditions, are very different in between the two polar regions making it hard to extrapolate from one to the other. This project is some first measurements on the acute effects of ambient UV-B radiation on phytoplankton and bacteria in the Kungsfjord close to Ny-Ålesund.

The technique used is *in situ* incubations at different depth with plankton communities either sheltered from the incoming UV-B radiation with mylar foils or not using radioactive isotopes ( $^{14}\text{C}$ -carbonate and  $^3\text{H}$ -Thymidine).

Measurements have been done in 1996 (late June) and 1997 (early July). In 1996 was only carbon dioxide fixation measured and the samplings and incubations was done close to the shore which was influenced by the water run-off from rivers. In 1997 the incubations were done west of Brandalspunten which avoided the effects of run-off from rivers but still the water had quite high and variable turbulence which was depending on the tide.

The results for carbon dioxide fixation varied between the two years. In 1996 the activity was clearly photoinhibited by the PAR and UV-A radiation in the surface samples and significant inhibition by the UV-B radiation found at larger depths (down to 3 meters). The inhibition was, however, variable. In 1997 the photoinhibition from PAR and UV-A was much lesser and the activity was not inhibited by the UV-B radiation. This was especially found at median depths (1-4 m) but not at 0.5 and 8 meters depths. When doing incubations at different times of the day it was found, however, that the UV-B inhibited the incorporation in early morning (between midnight and 6 a.m.) at 1 and 2 meters depth. In contrast to the carbon dioxide fixation was the bacterial significant inhibited (30-40%) down to 2.5 meters depth on days with clear sky. When doing incubations at different times of the day it was found that, for bacterial activity the largest inhibition was in the early morning.

In conclusions we found that the ambient UV-B radiation are inhibiting both the carbon dioxide fixation and bacterial activity in plankton communities in Kungsfjord but there needs more work to be done both on the actual under-water radiation levels as they are very much dependent on tide and surface run-off and one also should look further on the effects on different times of the day. It could also be expected that the effects are much stronger earlier in the season (April-May) as the water is clearer, weather better and it is a large reflection of radiation from land.



# Benthic Biodiversity Studies in the Kongsfjord

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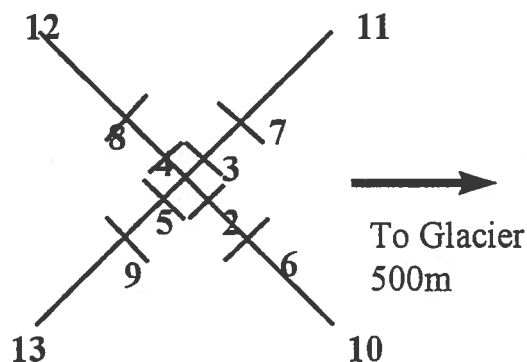
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<sup>2</sup>Polish Institute of Oceanology, Sopot, Poland

The research described in this paper had a number of objectives; these were

- 1) To undertake a fine grain survey of benthic macrofaunal biodiversity at sites in the inner and outer Kongsfjord. It was intended to use methodology similar to that of Kendall and Aschan (1993) and Kendall (1996). Those studies showed that the  $\alpha$ diversity of the benthos of Sassenfjord and that of a range of sites around the coast of Svalbard was similar to that around the coast of Britain.
- 2) To make estimates of species turnover ( $\beta$  diversity) in undisturbed high latitude situations
- 3) To examine the effects of glacial disturbance on the multivariate variance among samples collected from the same location. Accepted theory suggests that multivariate variance will increase with increasing disturbance

During August 1997 52 van Veen grab samples were taken from 13 stations in front of the Kongsbreen glacier (northerly corner 78°58.6'N 12°23.3'E) (Figure 1). The stations were set out along intersecting transects and were spaced out at geometrically increasing intervals. At these sites the mean depth was 30-40m metres and differed little from place to place. A further 36 grabs were taken using a similar design, but with only 3 replicates/station in deeper water (180-200m) in the outer fjord (northerly corner 79° 1.3'N 11° 54.6'E). At each station samples were collected from as closely as possible to the same point on the ships track. We estimate that the replicates taken at particular station came from within a circle of 60m diameter.



**Figure 1.** Station layout at Kongsbreen station. Inner square has 200m side. Middle square has 800m side; outer square has 2200m side

The samples were sieved over a 0.5mm mesh and fixed on board the RV Oceania before being returned to Ny Aalesund for preliminary sorting and preservation. All the animals extracted have been identified to species or putative species. To date 20 samples from the inner fjord and 2 from the outer fjord have been fully analysed and hence the results given in this paper must be treated as being of a preliminary nature.

$\alpha$  diversity. The fauna of the area in front of the Kongsbreen glacier is superficially similar to that found at a similar depth in the glacial outflow at Gipsvika in Sassenfjord (Kendall and Aschan 1993). It is dominated by small bodied animals particularly polychaetes (cirratulids, Paraonids and sabellids) tanaid crustaceans and bivalves ( notably protobanchs and Thaysirids) and has low biomass. In general, there are fewer species and individuals/sample; diversity values tend to be lower.

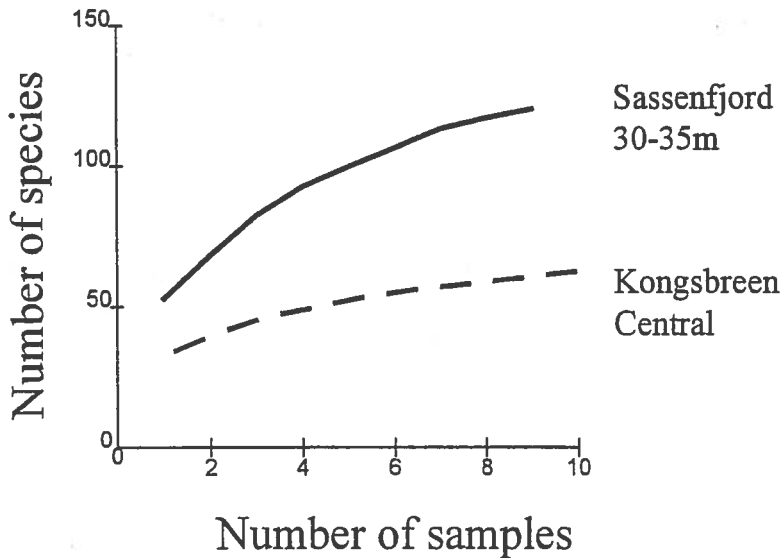
The outer fjord site has a fauna similar to that of the open sea, rather than to that of a similar depth in the Sassenfjord. However, it is not fully dominated by large polychaetes as big Sipunculids are common; biomass is high. Some smaller polychaetes, particularly lumbrinerids, ariciids, capitellids and cossurids are abundant. The basic  $\alpha$  diversity properties are summarised in Table 1 below and are compared with comparable Sassenfjord, Storfjord and Barents Sea stations

	observations	NI (range)	NS (range)	H' (log <sub>e</sub> ) (range)	NS(200) (range)
Kongsbreen	20	255-567	18-38	1.51-2.78	15.5-29.3
Outer fjord	2	576-647	40-47	2.81-3.06	29.2-34.5
Sassenfjord 30m	4	775-964	45-59	2.45-2.83	26.4-34.5
Sassenfjord 35m	4	765-1107	46-62	2.72-2.8	30.2-33.7
Storfjord 122m	4	348-405	42-49	2.87-3.16	34.0-41.2
Sassenfjord 123m	4	322-462	41-44	2.8-3.0	32.7-35.2
Barents Sea 197m	4	293-835	52-55	2.99-3.27	35.2-45.2

**Table 1.**  $\alpha$  Diversity measures of some comparable arctic sites.

### $\beta$ Diversity

There are no accepted protocols for estimating  $\beta$  diversity in the sea. At any but the shallowest depths, the need to employ remote sample collection dictates that the methods of terrestrial ecologists cannot be employed. To estimate  $\beta$  diversity we compare the species turnover among replicate samples taken randomly within an area of consistent dimensions. In this case, we have attempted to take all replicates at each station from within a 60 diameter circle. To date, we have not analysed all our material but for the sake of preliminary analysis, have grouped together samples from within the innermost square of the Kongsbreen and compared them with samples taken between 30 and 35m depth in Sassenfjord Figure 2. It is evident that the species pool in the former area is substantially smaller than of the latter. In part, this might be a result of a substantial quantity of hydroid debris which was incorporated into the surface sediment at the Sassenfjord site, forming a secondary substratum. However, as no more than 20 of the species from Gipsvika are normally considered epifaunal, other factors must be considered. The striking differences between the size of the species pool in two such outwardly similar areas warrants further investigation. In particular, the physical and chemical properties of the glaciers involved merit particular consideration.



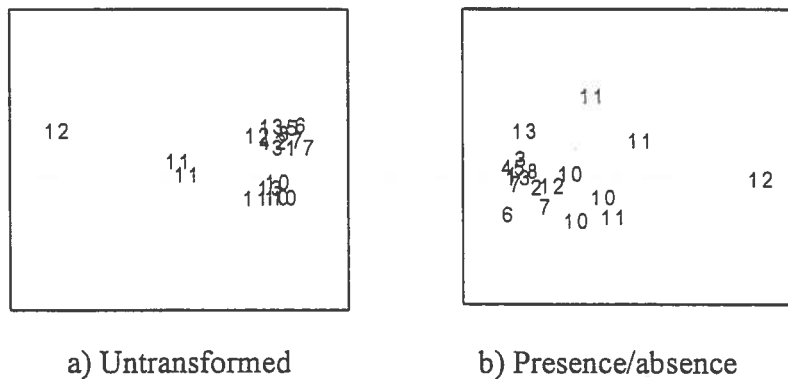
**Figure 2.** Species accumulation curves for samples from the central square of the Kongsbreen site and 30/35m sites from Sassenfjord.

For the purposes of latitudinal comparison, 5 samples collected using the same techniques from a similar sediment and depth in the North Sea contained 89 species and a similar sample set from the English Channel contained 94 species. As yet, there is no satisfactory method for making a statistical comparison of species accumulation curves.

**Fauna change in relation to the glacier.**

There is a clear and substantial difference between the fauna of the sites which we studied in the inner and the outer basin of the Kongsfjord. The causes are open to speculation but might be related to the differences in depth of the 2 sites, the differences in the hydrography of the 2 basins or the proximity of the inner sites to the Kongsbreen. Ideally, an extension of one of our inner transects would have helped resolve this. Further comparative studies are required.

The preliminary analysis of the faunal distribution at the Kongsbreen station has been carried out by non-metric MDS on untransformed and presence/absence transformed data. The former emphasises patterns relating to the distribution of the dominant species while the latter gives equal weighting to all species.



**Figure 3.** MDS plots of the similarity between samples based on untransformed and presence/absence transformed data

The plots in Fig 3 are remarkably similar, with stations within the innermost 2 squares (within 800m  $\pm$  c60m navigation error) clustering closely together. In the untransformed analysis, data from sites 12 and 13, the sites furthest from the ice, cluster with the main group of sites. There is one exceptional sample from site 12 which contained a considerable amount of mucus but few animals. In both plots, the replicates from sites 10 & 11 (the stations closest to the glacier) are clearly separated from the main cluster. It appears that there is a faunal gradient away from the glacier towards the centre of the sampling area but there is little evidence for further change thereafter. It might also be noted that the replicate samples from the innermost stations are widely separated on the MDS plots, unlike those further out from the ice, suggesting that there may indeed be increased faunal variability in areas of natural disturbance.

# The Autumn Migration of Barnacle Geese.

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## Introduction

The barnacle goose (*Branta leucopsis*) is a small, distinctive grey and white bird weighing less than 2kg which breeds in the high arctic and overwinters in coastal Europe. We have studied these geese for many years, initially looking at their physiology during flight (Butler & Woakes, 1980), but now trying to understand how these responses are used in the wild. One British population overwinters in the Solway estuary in southern Scotland and breeds in Svalbard, with one breeding site at Ny Ålesund.

The energy output of an animal is probably the major stressor in its life, and this project aims to estimate the energetic costs of barnacle geese during all aspects of their year. This includes the migratory phases of the yearly breeding cycle which are likely to place the highest demands on the birds internal transport systems and metabolic substrates. Indeed, if the autumn migration of the Svalbard population of barnacle geese consists of 30-40 h of non-stop flying from Bjørnøya (Bear Island) to Caerlaverock, southern Scotland, as suggested by Owen & Gullestad (1984), even the adults, let alone the juveniles, may be close to exhausting their fat stores, deposited before departing from Svalbard.

## Methods

Heart rate increases markedly during flight, and can therefore be used to indicate the times and durations of flying activity. It can also be used to measure the metabolic rate of animals, as long as the relationship between these two variables is known. Heart rate and body temperature were recorded by implanting data loggers developed by ourselves (Woakes *et al*, 1995 ). They were programmed to store 76 days of data with a resolution of one minute. The path of their autumn migration was also studied by using miniature satellite transmitters (PTTs) supplied by Microwave Telemetry Inc. which weighed 33g including the harness. We attached these to 6 geese per year (failed breeders only, to avoid disrupting family groups) in July 1994, 95 and 96 while they were flightless during moult. These PTTs could operate continuously for about 30 days, but a multiphase timer allowed optimum use of this restricted lifetime. We were able to use a low duty cycle initially (6 h on: 250 h off), switch to a higher on:off ratio when the birds start moving down Svalbard (4 on:12 off), then to continuous transmissions when we expected the migration. In 1995 and 96, the PTT's timer was modified to be triggered from the internal temperature sensor (during flights in 94 the PTT temperature was seen to drop considerably). In addition, their partners were implanted with data loggers, along with a further 6 successful breeders.

## Results

In our first year, we successfully tracked the geese on their movement down through Svalbard, a rest on the small island of Byørnøya, then along the coast of Norway to Scotland. Five definitely reached their wintering ground at Caerlaverock, while the remaining bird was still in S. Norway when the PTT stopped transmitting. Again, in both following years, the migration track was via Byørnøya and along the coast of Norway, with occasional stops on coastal islands.

A number of data loggers were recovered a year after implantation. The data from these confirmed that all the birds were stopping along the migration path. In 1995, the average total flight time for 4 birds was  $61.2 \pm 2.3$  h, with a mean longest stage of  $13.1 \pm 0.5$  h. The average number of flights longer than 1 h duration was  $11.5 \pm 0.6$ . The mean heart rate during migration was only  $253 \pm 9.5$  beats/min, approximately 50% of previously recorded values (Butler & Woakes, 1980). Fig. 1 shows both positional data from a male carrying a PTT with heart rate data from its partner which had a data logger implanted. The following comments are made on the assumption that this pair of geese flew together. For the fixes obtained on 7th and 9th October 1995, the straight line route between them is across the Norwegian Sea. From the heart rate data, there seem to have been three flights of a few hours duration, with periods of non-flying in between. This would tend to indicate that, if they did not go via the Shetland Islands, the birds landed on the sea. A clearer example can be seen on the night of the 2nd October, when several fixes were obtained when the birds were out at sea, yet not flying.

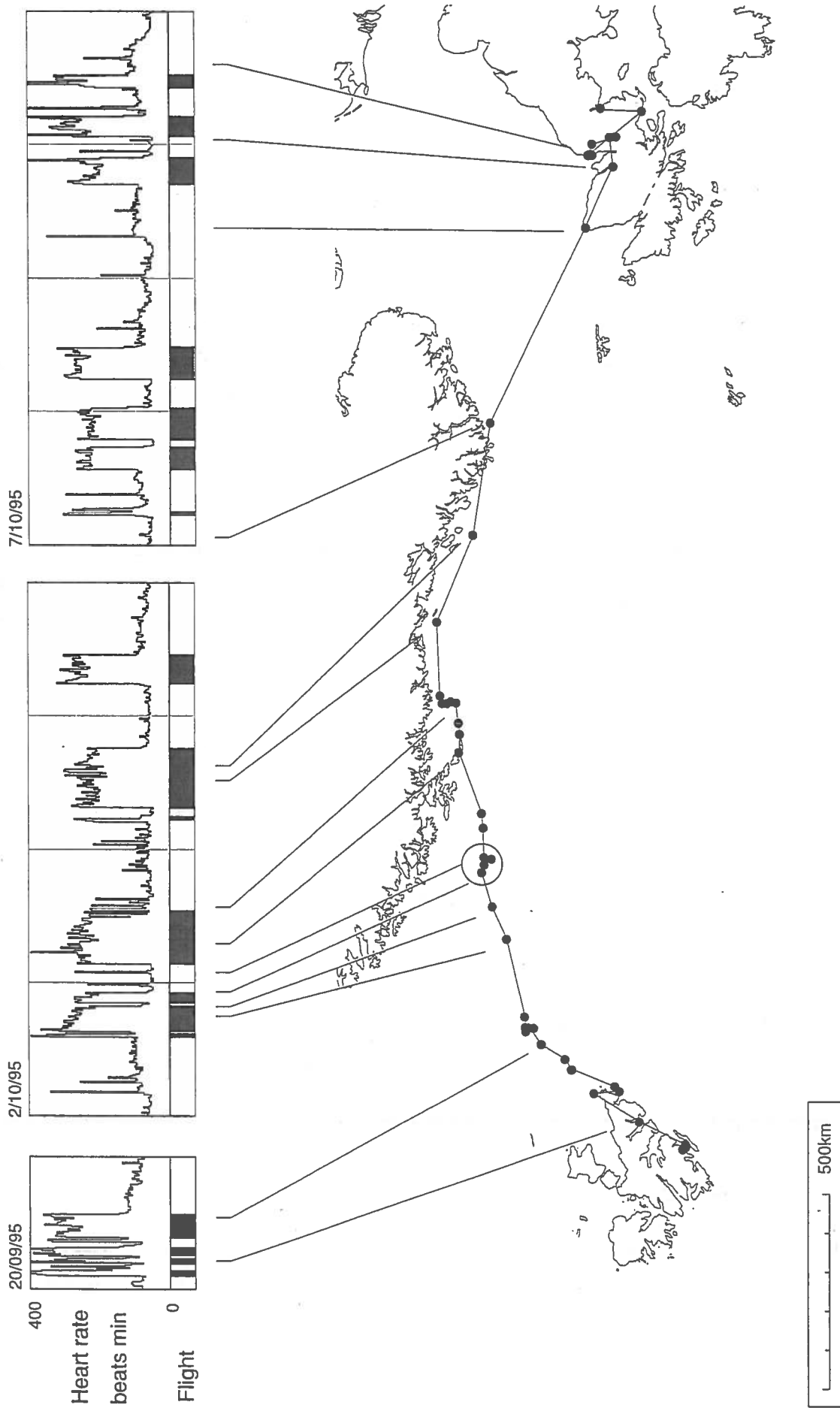
There was a clear diurnal rhythm in heart rate from approximately 10th August with the magnitude of the oscillation increasing as the migratory period approached. There was a decrease in the mean day time heart rate, from  $133.0 \pm 3.3$  in mid August to  $122.9 \pm 7.3$  one day before the start of migration, and a larger drop in the minimum hourly mean rate, from  $107.9 \pm 5.2$  to  $75.2 \pm 7.6$  beats/min at the same times.

## Discussion

The present study indicates that, for the Ny-Ålesund population at least, barnacle geese do not fly non-stop to Scotland, either from Spitsbergen or from Bjørnøya. Although not all of the birds seem to stop off at Bjørnøya, all of those with PTTs did fly along the Norwegian coast. In addition, all of those with data loggers, whether or not their partners wore a PTT, did not fly for longer than about 14 h without stopping. If their ground speed was around  $70 \text{ km h}^{-1}$ , they would have covered approximately 1000 km during such a flight. Whether they stopped because of loss of navigational cues, in order to feed, drink, wait for favourable winds or merely for a rest, is not known. These birds appear to perform flights that would not of themselves reduce their fuel stores close to exhaustion.

Possible explanations for the relatively low heart rates during migratory flight are: (a) Bishop et al. (1998) reported that heart mass of premigratory adult geese was some 17% greater than that in captive geese and 24% greater than that of wild postmoult geese. Thus, for a given oxygen uptake, heart rate could be lower in wild, premigratory geese than in captive geese, or even than in postmoult wild geese. (b) inter-species heart rate during flight is

Figure 1. Heart rate and position during the autumn migration of a pair of barnacle geese.



negatively related to body mass (Bishop & Butler 1995). Although it is not clear whether the same relationship exists for intra-species scaling, the premigratory birds are much larger than the other barnacle geese that have been studied, (c) the energy cost of flight during migration in these birds may be much lower than has been suggested from data obtained from birds flying in wind tunnels.

The data presented here have clarified many aspects of the behaviour of the Ny-Ålesund population of barnacle geese before and during their autumn migration, but have raised more questions than they have answered concerning the physiology and energetics of this behaviour. The physical condition of the birds (e.g. fat stores immediately before departure from Svalbard/Bjørnøya, oxygen carrying capacity of their blood, oxygen extraction factor during flight), their flight behaviour (e.g. altitude, formation flight) and prevailing weather conditions are some of the important features upon which we need more information before it will be possible to begin to give a full explanation of these data

### Acknowledgements.

The authors wish to thank M. Owen and F. Mehlum for their help and encouragement during the planning stages of this project. Expert assistance in the field was provided by M. Loonen and colleagues from the University of Groningen, G.W. Gabrielsen and colleagues from the Norsk Polarinstitt, and N. Cox of the Natural Environmental Research Council (NERC) base at Ny-Ålesund. The project was funded by NERC and the Ny-Ålesund LSF programme.

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# Impacts of Svalbard reindeer (*Rangifer tarandus platyrhynchus*) on the reproductive development of high arctic plants

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## Introduction

Recent research on polar semi-desert communities near Ny-Ålesund has demonstrated that the reproductive development of vascular plants (such as *Dryas octopetala*) is strongly responsive to experimental amelioration of growing season temperatures (Wookey et al. 1993; Wookey et al. 1995). On the basis of these measurements it has been suggested that climatic warming - in line with the predictions of GCMs (General Circulation Models) - could substantially increase seedling recruitment into such communities. In polar desert or semi-desert communities, where >50% of the surface is unvegetated, it is hypothesised that such recruitment would (i) result in the colonisation of bare patches in the vegetation mosaic by seedlings, and (ii) increase the intraspecific genetic diversity of the populations. Both of these changes in polar semi-desert and polar desert communities have important broader implications in terms of surface carbon and energy balances, forage quantity and quality for grazers, and the ability of vegetation to withstand rapid environmental changes.

These conclusions are based upon the assumption that increased seed viability under warmer conditions would translate directly into increased seedling recruitment into the population. There are compelling reasons, however, why this assumption is unsatisfactory (see Wookey et al. 1995): (i) seedling recruitment is dependent on the availability of suitable microsites for germination and establishment; such conditions may not be enhanced by summer warming (surface desiccation may be a particular constraint in the high Arctic), and (ii) other biotic factors, such as grazing pressure by ungulates, may exert a strong influence on seedling recruitment. The latter factor is one that has received little attention, although empirical observation indicates that herbivores (in this case Svalbard reindeer; *Rangifer tarandus platyrhynchus*) consume large numbers of reproductive shoots, particularly at the flowering stage, when they are easily visible and a clear search image can develop (Tyler, pers. comm.; Wookey, pers. obs.). The ecological implications of this feeding pattern are potentially of considerable interest: (i) because heavy mortality of reproductive shoots, as a result of grazing, could profoundly influence plant demography and community structure (with repercussions at the 'whole system' level, as indicated previously), and (ii) reproductive shoots may form a significant component of the reindeer diet.

In polar semi-desert communities of the Brøggerhalvøya it is possible that population turnover of vascular plants is currently being constrained by a combination of low summer temperatures (accumulated growing degree days; GDDs) - and hence the failed production of viable seeds during most growing seasons - and herbivory (principally by Svalbard reindeer). The specific objectives of the current project were therefore: (i) to test the hypothesis that reproductive output of vascular plants (in particular *Dryas octopetala*) could be significantly reduced due to intense selective grazing of flowering shoots by reindeer on the Brøgger Halvøya, (ii) to determine the proportion of reproductive shoots consumed by reindeer, and hence the reduction in potential reproductive fecundity, (iii) to compare results from the Brøggerhalvøya with data collected from the less heavily grazed Blomstrandhalvøya and Ossian Sarsfjellet areas of Kongsfjord, (iv) to evaluate the potential nutritional significance of this form of grazing for the reindeer, and (v) to quantify seedling recruitment of *D. octopetala* into polar semi-desert communities around Kongsfjord.

## Materials and Methods

(1) Experimental enclosures: polar semi-desert vegetation communities within the *Dryas octopetala* zone of Svalbard (Brattbakk 1986) were selected on 24 June 1997 in two locations ca. 3 km to the west of Ny-Ålesund in northwest Spitsbergen. Both sites were on gentle ridges, one on a low bluff above the Bayelva river (78°55.89'N, 11°49.92'E) and the other to the south of a small lake,

Trehyrningenvatnet (78°56.03'N, 11°48.92'E). The sites lie within 500 m of one another, and are both <50 m a.s.l.. The vegetation communities are similar to those described by Wookey et al. (1993). At each site six plots (each 2.5 m by 2.5 m) were set-up systematically in linear sequence, with 5 m between each plot: subsequently three of the plots were assigned randomly as either (i) 'control' plots, to which reindeer had open access, or (ii) reindeer exclosures, from which reindeer were barred access by the erection of temporary lightweight wooden exclosures (these were 2.45 m by 2.45 m, with two cross beams, one 0.35 m above the ground surface, and the second at 0.80 cm: the corner posts were constructed using 2×2' planks, while the cross beams were made from 2×1'). The exclosures were erected on 26 June 1997 and removed on 23 July.

Immediately after the exclosures were put in place, and then subsequently every second day until 7 July, and thereafter every third day until 22 July, the phenology of flowering ramets of *D. octopetala* and *Saxifraga oppositifolia* was determined for all shoots within a 1 m<sup>2</sup> central area within each plot, as described in Wookey et al. (1995). In addition, the central areas were repeatedly searched for signs of herbivory (e.g. severed pedicels of flowers, with or without additional signs of leaf herbivory).

(2) Monitoring plots on Brøggerhalvøya and on Blomstrandhalvøya: In addition to the experimental exclosures we also conducted a comparative survey of reindeer herbivory at five 10 m<sup>2</sup> plots on both the Brøggerhalvøya and on Blomstrandhalvøya (the latter is presumed to have a recent history of less severe reindeer grazing). These plots were established in the immediate environs of the experimental exclosures (within 1 km) on the Brøggerhalvøya (on 2 July), and on a raised beach sequence above Jakobskjelda on Blomstrandhalvøya (4 July). When the plots were established a complete survey was made of reproductive ramets of *D. octopetala*, and all signs of herbivory noted. The measurements were repeated on 14 and 15 July (for Brøggerhalvøya and Blomstrandhalvøya, respectively) and the extent of herbivory during the intervening period quantified.

(3) Seedling surveys: a detailed search for seedlings of *D. octopetala* was made over a total area of 10 m<sup>2</sup> (based on 4×10 m line transects) at each of three sites around Kongsfjord: (i) adjacent to the Trehyrningenvatnet reindeer exclosures on Brøggerhalvøya, (ii) adjacent to the monitoring plots on Blomstrandhalvøya, and (iii) at a polar semi-desert community on Ossian Sarsfjellet, in inner Kongsfjord. The purpose of this survey was to determine whether there was any evidence for seedling recruitment into the population.

## Results and discussion

At present the analysis of the data is still in progress, although the evaluation at this stage has prompted the following preliminary conclusions. In spite of the low to moderate reindeer densities on the Brøggerhalvøya in 1997 (actual data from the annual springtime survey are to be sought from Nils Are Øritsland - Norsk Polarinstitutt) they consumed 54.4% of the flowering shoots of *D. octopetala* in the 'control' plots (without exclosures) during the 25 day period of observation, and none in the exclosures (see Fig. 1). It was interesting to note that just 16.7% of the flowering shoots that had been grazed showed any sign of associated leaf herbivory, indicating careful selection for flowers and pedicels by the reindeer. Data from the experimental exclosures were further supported by the more extensive monitoring plots on the Brøggerhalvøya and on Blomstrand: 63.2% of flowering shoots were removed on the Brøggerhalvøya plots compared with only 7.3% on Blomstrand (which does not have a recent history of such intense herbivory). These results are also consistent with the observation that no evidence of seedling recruitment of *D. octopetala* could be found on either Brøggerhalvøya or Blomstrand (although seedlings were recorded, at low density - 1.6 m<sup>-2</sup> - on the climatically more favourable Ossian Sarsfjellet). On-going work with Svein Disch Mathiesen and Nicholas Tyler (Tromsø University) will examine the digestibility and nutritional content of vegetative and reproductive tissues of *D. octopetala* (samples collected 9 July 1997) in order to evaluate any physiological basis for selective herbivory. Co-operative links with Nils Are

Øritsland (Norsk Polarinstitut) will enable the data to be placed into clearer context with the 1997, and antecedent, reindeer densities.

The data from the project reinforce the view that significant components of polar semi-desert vegetation may be persisting largely clonally in areas grazed by reindeer and/or with unfavourable summer temperatures for seed development. This has profound implications for intraspecific genetic diversity of the populations (Crow 1992; Wookey & Robinson 1997), together with their responsiveness or resilience to future environmental change in this and other parts of the high Arctic (Wookey & Robinson 1997).

### Acknowledgements

I would like to thank the Ny-Ålesund LSF and the CEC TMR programme for the opportunity to work at Ny-Ålesund during 1997. I am grateful for the technical and logistic support provided by the staff of the Norwegian Polar Institute (in particular Monica Sund, Lars Edin Svaasand and Sverre Thon), the UK Base Manager Nick Cox (NERC Harland Huset) and the Kings Bay Kull Company AS. Special thanks, also, to my field assistant, Mats Fröberg, from Uppsala University.

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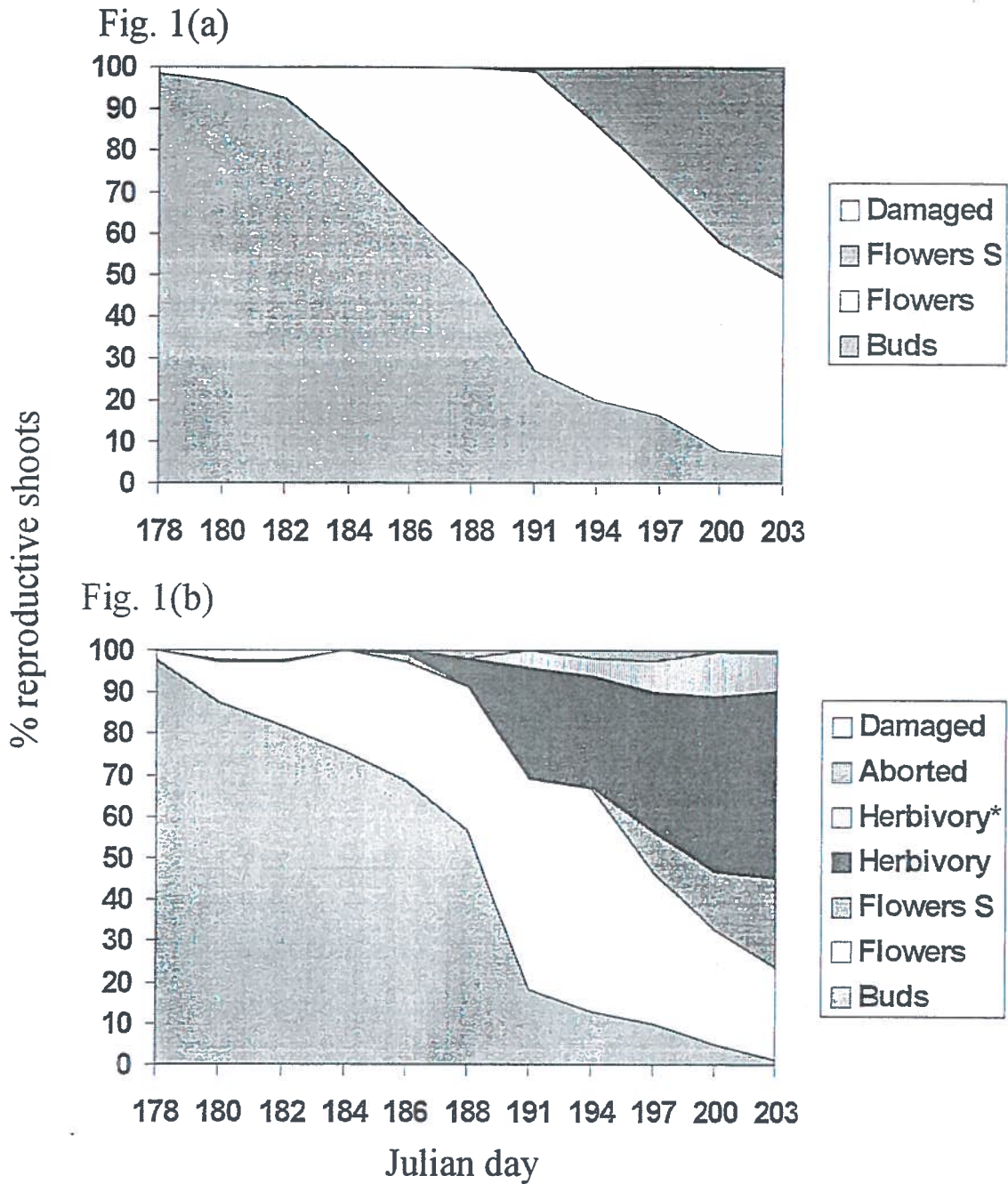


Fig. 1. Percentage of *Dryas octopetala* flowering ramets within three phenological phases (as buds, open flowers and flowers with senescent petals - denoted as 'Flowers S') and other categories (including flowers removed by reindeer grazing - denoted 'Herbivory', and those where flower removal was accompanied by signs of leaf herbivory of the same ramet - denoted 'Herbivory\*') plotted against Julian day. 1(a) shows data from within reindeer exclosures, and 1(b) gives the mean data ( $n=6$ ) for 'control' plots where reindeer access was not restricted. (Note the non-linear intervals on the x axis).

## **Dark-Light Seasonal Change And Human Oxidative Metabolism: Preliminary Observations At Ny-Alesund.**

**Cecilia Zuppi, Franca Forni, Cinzia Callà, Gino Colacicco, Silvio Lippa, Maria Luisa Gozzo, Bruno Zappacosta, Irene Messana, Bruno Giardina.**

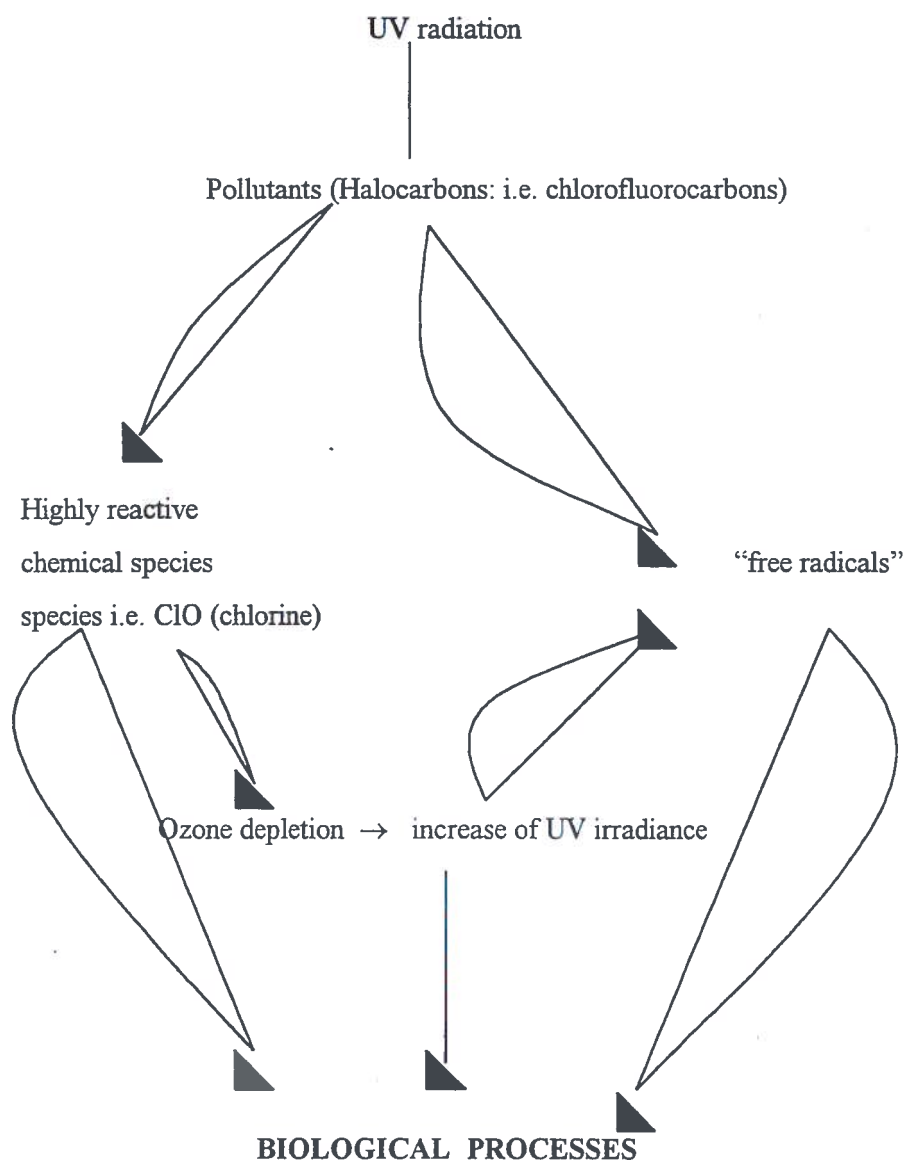
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The main goal of the project is the characterization of the effects that combination of UV radiation with chemical pollutants of various kinds may have on the onset of several pathologies, for example at the level of the skin and of the immunosystem (there are several evidences showing a high incidence of diseases related to the immunosystem at Arctic latitudes). Another particularly interesting aspect is linked to the role of marine aerosol as source of reactive species of halogens which may influence the atmosphere in a season-dependent way.

The complex "nature" of the problem under investigation comes out very clearly if one envisages that several biological processes are affected by all the below reported causes and their network of interactions. Hence, we may take into consideration:

- (a) UV radiation;
- (b) Exogenous compounds (i.e. pollutants);
- (c) Ozone (O<sub>3</sub>) concentration.

In the Arctic these three aspects are strongly linked and in some cases may give rise to a complex chain of synergic effects. Moreover, from the following scheme it appears clear that biological processes may be influenced in a seasonal dependent way according to the dark-light cycle.



In summary, the biological damage produced by the highly reactive radical species may derive from:

- (a) A direct reaction with functional groups of biomolecules (i.e. amino and sulphydryl groups) with a consequent loss of their biological activity.
- (b) An alteration of membrane permeability and functions.
- (c) The initiation of lipid peroxidation chain reactions.

It may be worthwhile to outline that reactive oxygen species (i.e. ROS) are normally produced in living organisms, under physiological conditions, by the partial reduction of molecular oxygen. For example, superoxide anion ( $O_2^-$ ) is formed in most cells and tissues either during mitochondrial respiration through the electron transport chain, or as a consequence of the

biological activity of some enzymes such as microsomal NADPH-cytochrome P<sub>450</sub> reductase and nuclear ribonucleotide reductase. Specialised cells, like polymorphonuclear leukocytes and macrophages, use ROS for their peculiar biological role, i.e. phagocytosis.

Due to the ROS capability of unspecifically reacting with any electron donor, all living organisms are provided of several enzymatic and non- enzymatic antioxidants with the specific purpose of protecting functional and structural integrity of biologically fundamental macromolecules (nucleic acids, proteins, phospholipids). Imbalance between ROS production and antioxidant cell defenses has been reported to occur in several physiopathological conditions, both in animals and human beings, such as inflammatory diseases, nervous trauma and aging. Moreover, lipid peroxidation, due to its possible linkage with cell death induced by loss of membrane integrity, is generally used for monitoring ROS-mediated cell damages.

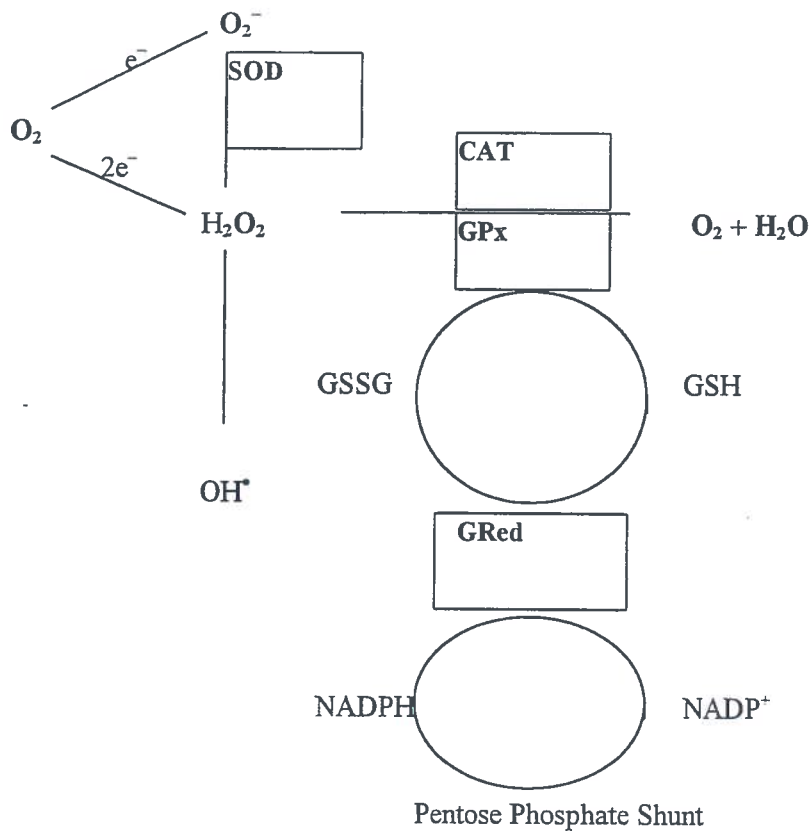
The metabolic antioxidant defenses of most organisms and in particular of mammals are based on a number of enzymes and metabolites that, under oxidative stresses, increase significantly. Among these substances a fundamental role is played by: glutathione (GSH), glutathione reductase (Gred) and peroxidase (GPx), catalase (CAT), superoxide dismutase (SOD), glucose-6-phosphate dehydrogenase (G6PD), NADPH,  $\alpha$ -tocopherol, ascorbic acid and uric acid.

Hence, in the light of the seasonal dependence of the phenomena described and outlined by the scheme reported above, the study is focussing on the monitoring of:

- scavenger enzymes such as superoxide dismutase and catalase;
- lymphocytes and granulocytes function;
- lipids and lipid peroxidation with particular concern to functional modulation of cellular membrane ;
- structural and functional properties of erythrocytes with special regard to their metabolic modulation mechanisms.

All these aspects may be summarised as follows:

Reactive oxygen Species	Targets	Mechanism	Injury
	Lipids	Peroxidation	Membrane Damage
Singlet oxygen Superoxide Enzyme	Proteins	Oxidation and SH Depletion	Inactivation
Hydrogen peroxide Hydroxyl radical	Nucleic Acids	Strand Breaks	Impaired Repair and Mutagenesis



The Pentose Phosphate Shunt of human erythrocytes acquires a particular significance in the light of recent observations showing the metabolic behaviour of these cells strongly influenced by their oxygenation-deoxygenation cycle through a specific interaction between Hemoglobin and Band 3 (the anion transport system). Thus, many evidences support the hypothesis of a modulation of the relative rates of pentose phosphate pathway and glycolysis achieved through competition between deoxy-hemoglobin and glycolytic enzymes for the cytoplasmic domain of Band 3. The consequence is that, in oxygenated erythrocytes, more glucose appears to be metabolized by the pentose phosphate pathway in order to ensure adequate levels of NADPH to protect the cell from the oxidative stress deriving from the high oxygen erythrocyte load. It would be of particular significance to investigate the possible presence of metabolic changes in people exposed to the dark-light transition and therefore to the oxidative stress elicited by the shining Arctic Summer. In this perspective all the biochemical parameters reported above have to be evaluated on biological samples from resident people to investigate the effect of a chronic exposure as well as from non-residents, such as tourists and researchers, to establish the effect of a rapid and short exposure. Of course, the effect of the diet and of particular substances such as vitamin E, Coenzyme Q and trace elements (Zn and Selenium) must not be disregarded.

At the beginning of the project, 5 subjects were recruited between the clerical staff of KBC and the researchers present continuously in Ny-Alesund for at least five months. The subjects (2 males, 3 females, mean age  $40 \pm 5$ , no history of hypertension, diabetes or other metabolic diseases, no drugs or vitamins) were submitted to venipuncture on february, at the end of the polar night.

10 ml of heparinized blood were drawn from each subject. Blood samples were immediately centrifuged, plasma and cells were separated and freezed at  $-10^{\circ}$ . Determination of selenium, SOD, GPX, Q10, Vit. E and beta-carotene were performed within one month.

The same subjects were again submitted to venipuncture on august, after three months of sunlight, and, at this time, they collected also a morning urine sample for  $^1\text{H}$ NMR analysis.

The results obtained on blood samples collected on the two different seasonal periods are compared in Table 1 where the mean and relative SEM value of selenium, Q10, Vitamin E, beta-carotene, glutathione peroxidase (GPX) and superoxide dismutase (SOD) activities are shown.

	Dark period			Light period			p
	N	Mean	SEM	N	Mean	SEM	
Selenium $\mu\text{g/L}$ (40-140)	5	76.4	9.0	12	98.2	16.0	ns
GPX U/L (4171-10871)	5	6921	951	12	24900	1763	0.0001
SOD U/ml (129-214)	5	104.0	2.1	12	302.8	18.6	0.0001
Q10 $\mu\text{g/ml}$ (0.6-1.0)	5	0.48	0.04	12	1.26	0.17	0.05
Vit.E $\mu\text{g/ml}$ (5-18)	5	8.01	0.9	12	8.01	0.96	ns
$\beta$ -carotene $\mu\text{g/dl}$ (20-200)	5	122.6	35.1	12	12.06	1.74	0.03

We can observe no significant variation of Selenium and Vit. E and small changes of Q10 and beta-carotene on going from the dark to the light period. However values of enzymatic activities (SOD and GPX) increase significantly in the light period.

<sup>1</sup>HNMR spectra of urine samples from people living at arctic latitudes were compared to those obtained on subjects of the same age living in Rome.

Table 2 shows the mean and relative SEM values of the metabolites measured in those two subject groups.

	Rome subjects		Svalbard subjects	
	Mean	SEM	Mean	SEM
Lactate	36.8	2.1	<b>13.7</b>	6.5
Alanine	36.4	1.5	<b>12.4</b>	1.8
Citrate	213.6	8.8	<b>101.1</b>	71.3
DMA	25.2	1.2	34.6	4.0
TMAO	56.2	4.2	<b>122.8</b>	71.3
Glycine	191.1	11.1	<b>69.7</b>	9.3
Hippurate	341.0	20.2	<b>679.9</b>	108.3

Data of urine NMR spectra indicate a reduced excretion of some metabolites, such as alanine

and lactate, involved in the intermediary metabolism, while other compounds, such as hippurate, are probably influenced by food.

Although preliminary these data show that the potential toxicity of Reactive Oxygen Species (ROS) is counteracted by the action of a number of cytoprotective enzymes and of antioxidant substances. These protective mechanisms operate probably in an interdependent way. Hence, the increase, in the light period, of enzymatic activities implicated in the metabolism and in the removal of reactive radicals may be correlated to the increased exposition to atmospheric influences. On the contrary, other antioxidants, such as beta-carotene, selenium etc., do not show variation in relation to seasonal period very likely because they are abundantly present in diet.

On the whole this preliminary analysis appears to be encouraging and could be taken as a first step towards a critical evaluation of the biological effect of the dark to light transition on human beings living in Arctic regions.

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*Marine Science*



# STAINLESS STEEL CORROSION BEHAVIOUR IN POLAR SEA WATER: PRELIMINARY RESULTS OF A SIX-MONTH FIELD TEST.

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## Introduction

In the European conditions the biofilms, adhering on stainless steel surfaces, increase the risk of localised corrosion onset and the propagation rate of corrosion attacks, when started (1-11). In Europe these bioeffects, shortly indicated as Microbial Induced Corrosion (MIC), are resulted almost independent of seasons, geographic location and light conditions in the temperature range from 8 to 30 °C. However, any shifting of the seawater temperature higher than 30 °C and lower than 8°C drastically reduces the MIC interference as shown in Fig. 1. The figure includes data coming from various European marine stations and from Antarctica and shows how the maximum potentials of fouled s.s. in passive state change with seawater temperature at which the biofilm settlement occurred.

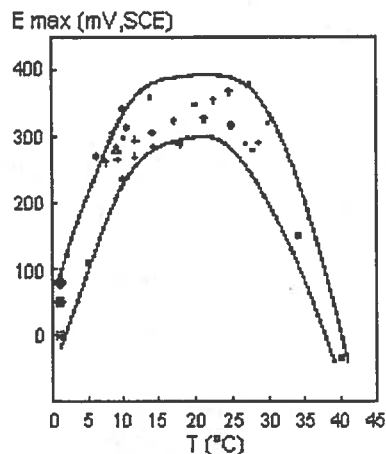


Fig. 1 - Maximum open circuit potentials of s. s. in passive state, when covered by marine biofilms, vs. seawater temperatures (from Alabiso et al, 1996).

Indeed, short-term corrosion tests carried out in Antarctica, during the summer Campaigns of the National Italian Research Programme, have demonstrated that two-month old biofilms, grown at -1 - +1°C, induced electrochemical effects less important than those in warmer conditions. Likewise, a comparison of the incubation times of localised corrosion attacks in Antarctica and in Mediterranean Sea has confirmed the lower corrosivity of the cold regions (12-14). The percentage of s.s. samples which were still uncorroded (the so called Survival %) is reported in function of the immersion time in Genoa and Antarctica conditions in Fig. 2.

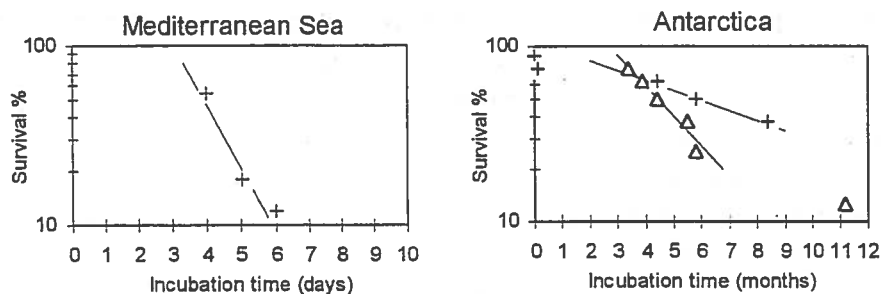


Fig. 2 - Comparison between the survival curves vs. time obtained in Antarctica and in Genoa working on s.s. AISI 316 (+) and 304 (Δ) under artificial crevice (from Alabiso et al., 1993).

The figure shows that s.s. samples, exposed in natural seawater under artificial crevice conditions, nucleate corrosion attacks more quickly in Mediterranean Sea than in Antarctica. The data referring to Antarctica have been deduced only from the weight losses data, by attributing arbitrarily to the most corroded sample an incubation time of zero months, whereas the incubation times of the Mediterranean data were exactly defined by the potential falls which signal the nucleation of crevice corrosion attacks on samples.

A long term confirmation of these data with, at least, one-year long exposure tests of stainless steel samples in natural polar conditions together with the identification of the actual incubation times and corrosion rates by means of a continuous monitoring of the main electrochemical data during the immersion period became, therefore, necessary.

A suitable data underwater acquisition system was set up in the framework of the Italian National Antarctic Research Programme (PNRA) and immersed in Antarctica for 1 year during the period 1994-95 but without success as the apparatus was lost for the adverse environmental conditions.

The opening of the Italian National Research Council (CNR) base at Ny-Ålesund, Svalbard, has recently offered a good opportunity to evaluate in safer field conditions the working capability of the system and to collect data on the corrosivity in the Arctic conditions for future comparisons with the results obtained in Antarctica.

### Results

A structure, loading 80 stainless steel samples, with and without crevice formers, electrically connected to the underwater acquisition system, has been immersed at Kongsfjorden near a pier of Ny-Ålesund base, at 4 m of depth, in May 1997 (Photo 1).

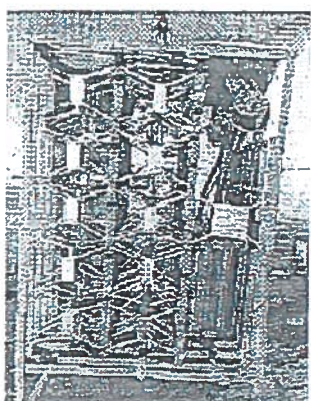


Photo 1 - Sample loading structure with the data underwater acquisition system.



Photo 2 - AISI 304 stainless steel after six months of exposure test at Svalbard

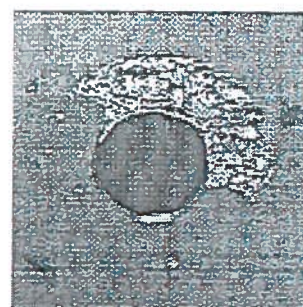


Photo 3 - Particular of the same sample of photo 2 after the removal of the crevice formers and after cleaning.

In November 1997, the structure has been recovered to control the functioning of the data acquisition system and to exam the corrosion behaviour of samples.

All samples of AISI 304 and 316 have shown severe corrosion attacks (Photo 2 and 3) which, in several cases, have caused the detachment of the electrical connections; unfortunately, once again, the purpose was missed as the Data Logger failed the acquisition of the electrochemical data after 7 days of immersion, due to problems coming from the battery management system. For all these reasons, the structure has been recovered and the s.s. samples sent to Italy for examination. The weight losses measured on AISI 304 and 316 are reported in Tab. 1; the translation of the weights in corrosion currents show corrosion rates around  $1 \mu\text{A}/\text{cm}^2$ , value which can be justified only by the catalytic effects of biofilms.

Tab. 1 - Weight losses measured on AISI 304 and 316 samples.

AISI 304		AISI 316	
Sample	Weight loss (mg/cm <sup>2</sup> )	Sample	Weight loss (mg/cm <sup>2</sup> )
D 1	2.425	B 1	3.411
D 2	4.342	B 2	1.732
D 3	2.694	B 3	2.783
D 4	2.155	B 4	2.232
D 5	2.213	B 5	2.374
D 6	1.903	B 6	3.478
D 7	3.001	B 7	2.306
D 8	2.835	B 8	1.983
D 9	3.295	B 9	3.888
D 10	4.460	B 10	2.971

Considering that the potentials measured in the first week of immersion were very low (around -230 mV, SCE), it becomes reasonable to attribute an incubation time of one month to the AISI 304 sample which has showed the highest weight loss. Therefore, its monthly weight loss was used for calculating the corrosion time and consequently the incubation times of the single samples. The percentage of samples AISI 304 and 316 which have survived to the attack in the Arctic conditions are reported in Fig. 3 as a function of the immersion time.

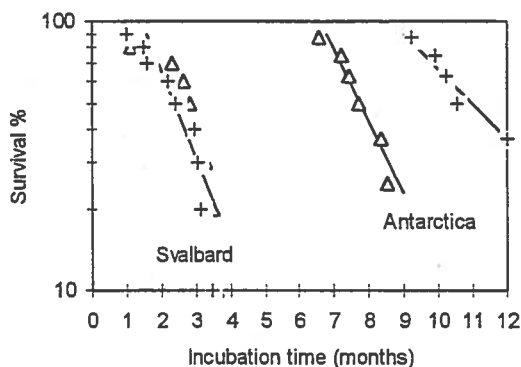


Fig. 3- Comparison between the survival curves vs. time obtained at Svalbard Islands and in Antarctica working on s.s. AISI 316 (+) and 304 (Δ) under artificial crevice.

In the same figure the Antarctic data re-worked out on the basis of monthly corrosion rate established in the Arctic condition are reported.

The figure shows that at Svalbard Islands the AISI 304 and 316 samples have suffered very similar corrosion attacks whereas the two s.s. grades showed a very different behaviour in Antarctica (Fig. 2 and 3), independently on the extrapolation method used.

### Conclusions

These preliminary results suggest that Arctic conditions might be more aggressive than the Antarctic ones and that the analogous corrosion behaviour of AISI 304 and 316, at Svalbard Islands, could only be justified by admitting that biofilms cause on passive s.s. higher potential ennoblement than in Antarctica.

In this respect, one observation should be done on the basis of the results of corrosion tests carried out some years ago in the Baltic Sea (15): if during the Arctic summer seawater temperatures rise sufficiently to let the settlement of biological layers causing important potential ennoblement on s.s. surfaces, the subsequent reduction of temperature could not be able to affect the potential values which would remain stationary on the previous ones in spite of the shifting of seawater temperature towards 0°C.

This could be a possible explanation of the Arctic results but, obviously, such a hypothesis needs some more direct confirmations, which could come only from the success of a next field exposure of the data underwater acquisition system.

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## Enhanced ultraviolet radiation over the Arctic - what are the consequences for seaweed physiology and ecology?

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Enhanced solar ultraviolet radiation (UVR) due to the depletion of the stratospheric ozone layer, has been proposed as a major stress factor for many phototrophic organisms in marine ecosystems, particularly in the polar regions where the relative increase in UV-B (280-320 nm) is most pronounced. Ocean vegetation along the coast lines in cold waters is dominated by benthic macroalgae which ecologically interact with their physicochemical environment and other marine organisms. Seaweeds are important primary producers, and their communities provide habitat and shelter for many marine organisms such as fish and crustaceans. These sessile plants represent good model-systems to study the adverse effects of increased UVR on algal physiology and ecosystem structure, as well as on potential mechanisms avoiding or counteracting UVR damage. Within the framework of the EU-funded Environment and Climate Programme, the influence of UVR on photosynthesis (photoinhibition and recovery), growth, metabolism of sunscreen substances and possible changes in communities of Arctic macroalgae are under investigation. In this contribution our first physiological data from a field study at Ny-Ålesund in summer 1997 are presented.

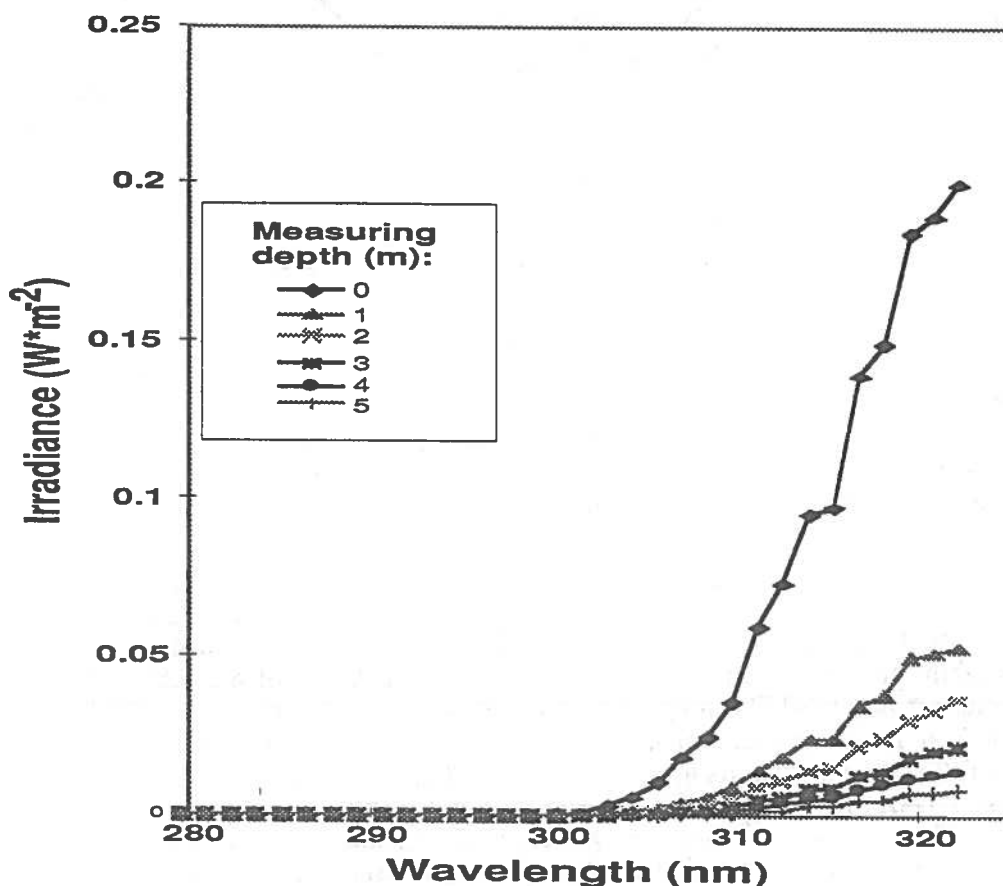


Figure 1.

UV-B radiation inside the water column. Measured on June 15th, 1997 at 12.00 UCT.

For the first time radiation measurements in the water column of the Kongsfjord near Ny-Ålesund were conducted with a newly designed underwater spectroradiometer (Physics

Department, Alfred-Wegener-Institute) to show penetration depth of UV-B (Fig. 1). During summer we recorded typical atmospheric UV-B values just above the water surface of between 0.8 and 1.2 W m<sup>-2</sup>. Penetration of UVR into the water column was strongly attenuated with depth, and was highly variable depending of inherent optical properties of the respective water body and in relation to seasonal aspects. In the Kongsfjord, highest transparency of the water was usually measured in spring after sea-ice break-up (1% water depths for UV-B of about 8.5 m). Later during the season melting glaciers brought a high influx of suspended particles into the water column resulting in a strong decrease of transmittance, i.e. the 1% water depth was at 2.5 m or sometimes even less.

As a model-system for UVR effects on physiological parameters we studied the red macroalga *Devaleraea ramentacea*, an abundant species of the upper sublittoral zone (1-7 m). This plant is characterized by relative low temperature demands and is one of the few endemic Arctic species (Bischoff & Wiencke 1993).

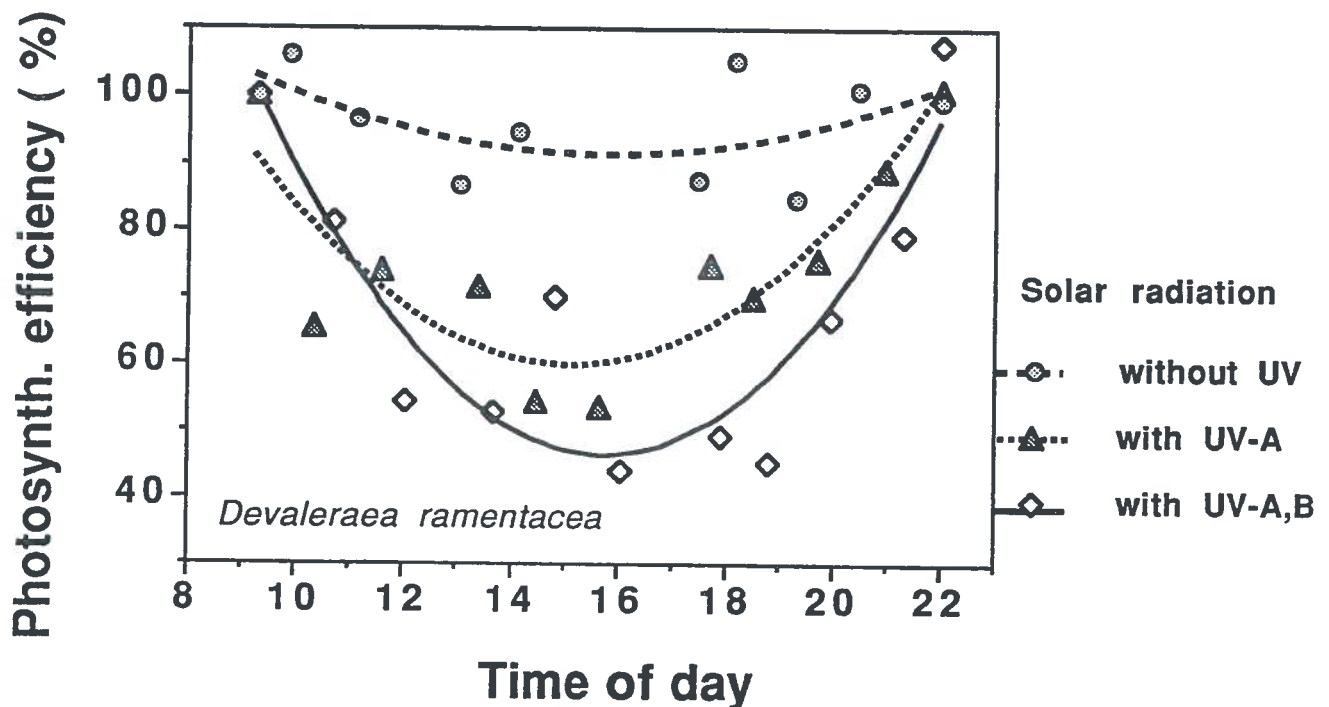
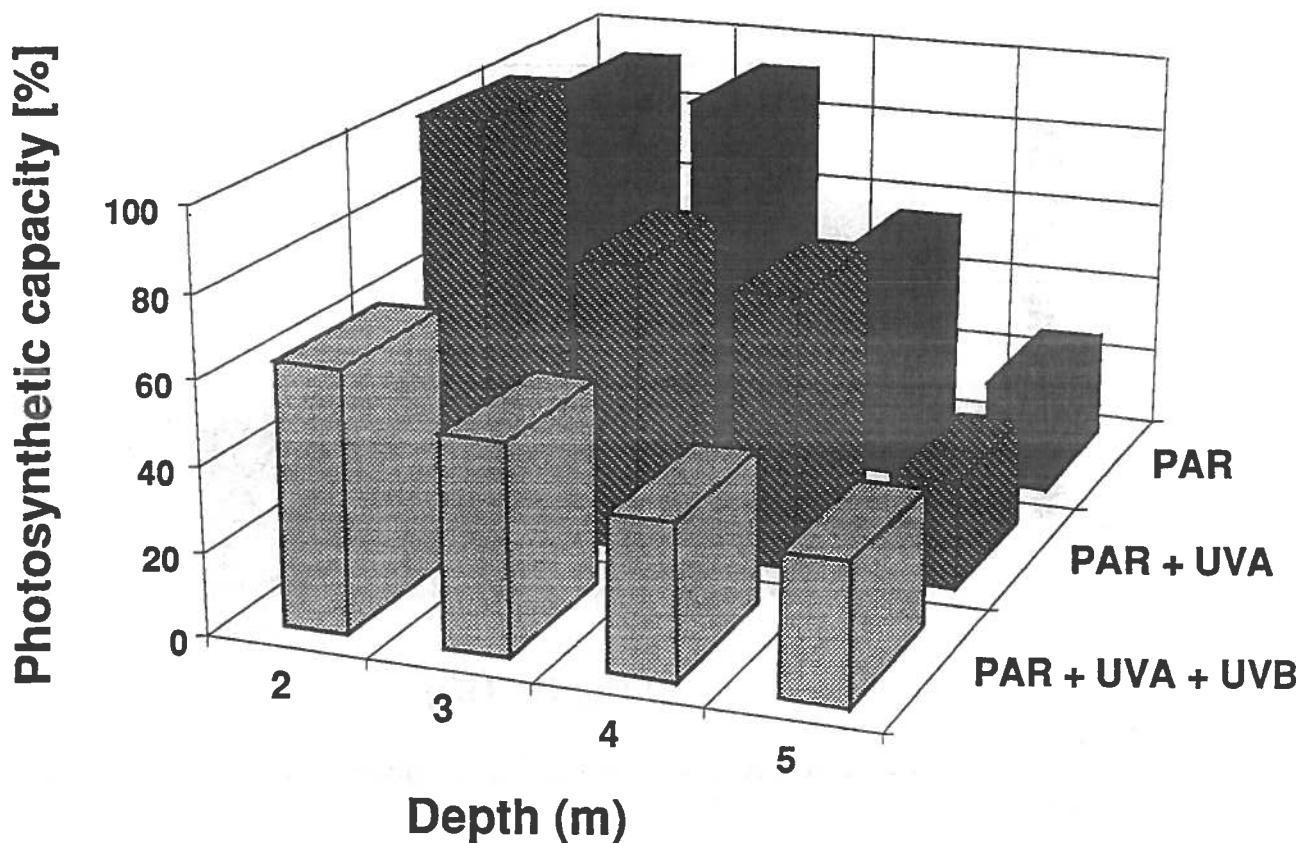


Figure 2.

Daily course of the photosynthetic efficiency in the red alga *Devaleraea ramentacea* growing close to the water surface. Thalli were exposed to full solar radiation and solar radiation depleted of different UV-wavelength ranges by using different cut-off filters (Schott, FRG).

This species was exposed to various natural solar radiation conditions using cut-off filters and the photosynthetic efficiency was recorded during the course of a day by measuring *in vivo* chlorophyll fluorescence of photosystem II (Fig. 2). Photosynthesis of *D. ramentacea* was only slightly photoinhibited at noon by strong solar radiation of the PAR (photosynthetic active radiation) region (400-700 nm) without UVR. In contrast, exposure to PAR plus UV-A (320-400 nm) at noon was accompanied by 40% photoinhibition compared to the control followed by full recovery towards the end of the day (Fig. 2). A treatment at noon with the full natural solar spectrum including UV-B led to an even stronger degree of photoinhibition resulting in 55% of the control value. However, plants incubated under these conditions also fully recovered at the end of the day so that photosynthesis was optimal again in the dawn (Hanelt et al. 1997). Therefore, at that time low fluence rates can be utilised with high efficiency for assimilation. These data clearly indicate that during the day the UVR component of the spectrum is mainly responsible for the depression of photosynthesis in *D. ramentacea*, and that this shallow-water species exhibits a high ability for physiological regeneration.

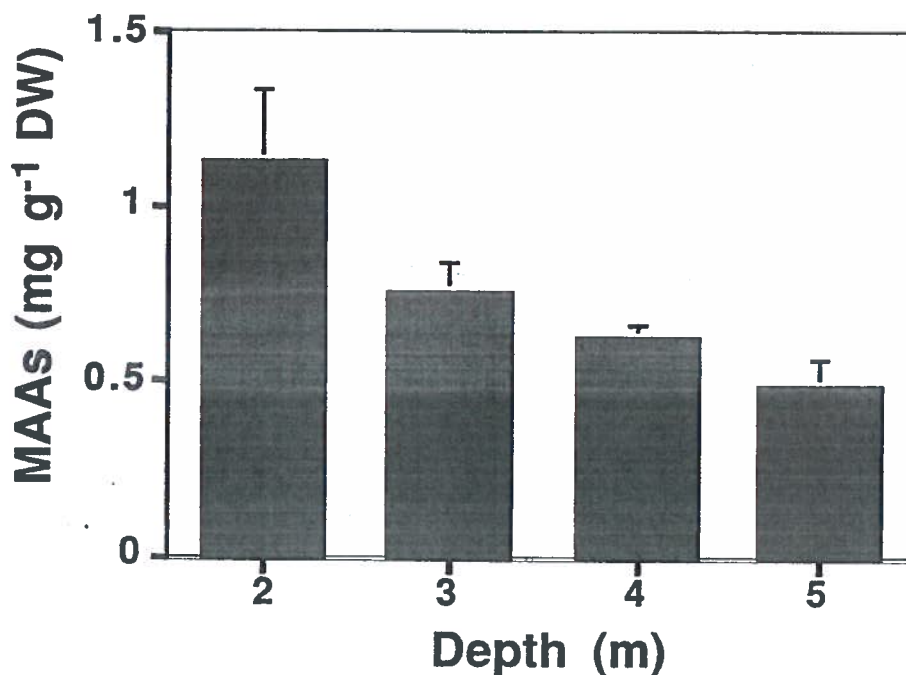


**Figure 3.**

Changes in photosynthetic capacity in *Devaleraea ramentacea*. Samples were exposed for 4 h to  $60 \mu\text{mol m}^{-2} \text{s}^{-1}$  artificial PAR;  $9 \text{ W m}^{-2}$  UV-A;  $0.9 \text{ W m}^{-2}$  UV-B under different cut-off filters.

The potential for acclimation of photosynthesis to changing radiation regimes was further studied in *D. ramentacea* growing over a range of water depths (2, 3, 4 and 5 m) (Fig.3). The plants were collected by SCUBA diving, and kept in black bags until a 24 h acclimation period in the lab at  $0^\circ\text{C}$  under low-light conditions of  $20 \mu\text{mol photons m}^{-2} \text{s}^{-1}$ . Afterwards the various isolates were exposed to well defined doses of artificial light sources and the various parts of the UVR spectrum were successively cut-off using specific filters. The photosynthetic capacity was determined by measuring *in vivo* chlorophyll fluorescence of photosystem II. Plants from shallow-water were generally more resistant to PAR, PAR + UVA, or PAR + UVA + UVB stress than plants from deeper water (Fig. 3) (Bischof et al. 1998). The sensitivity to radiation continuously increased with depth. Inhibition of photosynthetic capacity was most severe in specimens collected at the same depth under the full spectrum compared to irradiance treatments without UV-B (Fig.3). Our results indicate that ozone depletion and related further enhancement and deeper penetration of UV-B into the water column will influence macroalgal photosynthetic performance. Consequently primary production of these plants may adversely be affected.

An important strategy of many marine primary producers counteracting UVR damage is the biosynthesis and accumulation of UV-absorbing sunscreen compounds. The most common substances are the mycosporine-like amino acids (MAAs), which qualitative and quantitative occurrence in *D. ramentacea* was studied in samples collected from 2, 3, 4 and 5 m water depth by SCUBA diving (Fig.4). MAAs were extracted and samples were analysed using HPLC (Karsten & Garcia-Pichel 1996). Seven different MAAs were detected in this species, namely mycosporine-glycine, shinorine, porphyra-334, palythine, asterina, palythanol and palythene. The highest content of total MAAs was found in isolates from 2 m depth ( $1.134 \text{ mg g}^{-1}$  dry weight (DW)). This amount continuously decreased with increasing depth to  $0.488 \text{ mg g}^{-1}$  DW in plants collected at 5 m (Fig. 4). These data are in good agreement with the decreasing photosynthetic capacity after UVR treatment in isolates from greater depth (Fig. 3), i.e. the presence of higher MAA concentrations may be responsible for the higher resistance against



**Figure 4.**

The effect of increasing collecting depth on the total mycosporine-like amino acid contents (MAAs) in the marine red alga *Devaleraea ramentacea*.

enhanced UVR in shallow-water algae. Moreover, the higher total MAA contents in shallow-water *D. ramentacea* compared to plants collected from deeper locations indicate the physiological capability to quantitatively and qualitatively acclimate to changes in radiation (Karsten et al. 1998). However, the underlying mechanisms and degree of acclimation, as well as the required timescale for evolving is still unknown.

#### Acknowledgements

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# Water mass exchanges between Arctic and Atlantic Ocean: the VEINS Project.

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## Introduction:

Within the frame of research conducted on global change and climate variability, an increasing interest is being dedicated to the study of the possible effects of the Arctic Ocean on the Northern hemisphere and, in particular, on the exchanges of water, ice and heat between the Arctic and Atlantic Ocean through the Nordic seas (Greenland, Iceland and Norwegian seas). The key importance of northern seas to the climate system as expected site of enhanced global warming signal is, in fact, undisputed (Østerhus & Gammelsrød, 1997); furthermore, it has been proposed that Arctic regions may not only reveal but even control global climate change as several evidences show that much of the global response is controlled by conditions of insolation, of temperature and of ice cover at high northern latitudes (Alley, 1995).

The most probable mechanism wielding Arctic influence over global climate is oceanic circulation and, in particular, deep-water formation in the Nordic seas which drives a vigorous oceanic circulation pattern - the "conveyor belt" - that spans the world oceans (Broecker & Denton, 1989) affecting heat transport, hydrology cycle, nutrient and carbon inventory.

In relation to this topic, the European Research Project VEINS (MAST III), which started in February 1997, has as overall objective that of measuring and modelling the variability of fluxes between the Arctic and the Atlantic Ocean with a view of implementing a longer term system of critical measurements needed to understand the high-latitude oceans steering role in decadal climate variability.

For this purpose, the research activities focus on the main connections between the Arctic, the Nordic Seas and the Atlantic Ocean, as variations in the amount and sense of interchanges between these basins may have important consequences on global climate.

This contribution intends to present the activities conducted within this project by Istituto Sperimentale Talassografico of Trieste in the Fram Strait, which is the most important connection between Arctic and Atlantic Ocean and represents a key feature for the large-scale world ocean circulation.

Most of heat, salt and water exchange between Arctic Ocean and the rest of the world occurs through Fram (Smith et al., 1987) which has a sill depth of 2600 m, whereas the deepest connections elsewhere range from 45 m through Bering Strait to about 250 m through either the Barents Sea or Nares Strait, in the Canadian Archipelago (Swift et al., 1983). Variations of ice-fluxes, of water mass exchanges and of balance between inflowing and outflowing currents through Fram are considered important indicators of climate variability (Østerhus & Vinje, 1997; Dickson pers. comm., 1997; Lemke pers. comm., 1997; Mauritzen pers. comm., 1997).

### Field activity:

Within VEINS Project, the activity of Istituto Talassografico is aimed to obtain time-series of heat, salt and water fluxes between the Arctic and the Nordic Seas and to quantify the magnitude and the variability of these fluxes.

The experimental activity started with the first oceanographic campaign in August 1997 and investigated the area presented in figure 1. The same area will be monitored during two further oceanographic campaigns in order to determine interannual variability of transports through Fram.

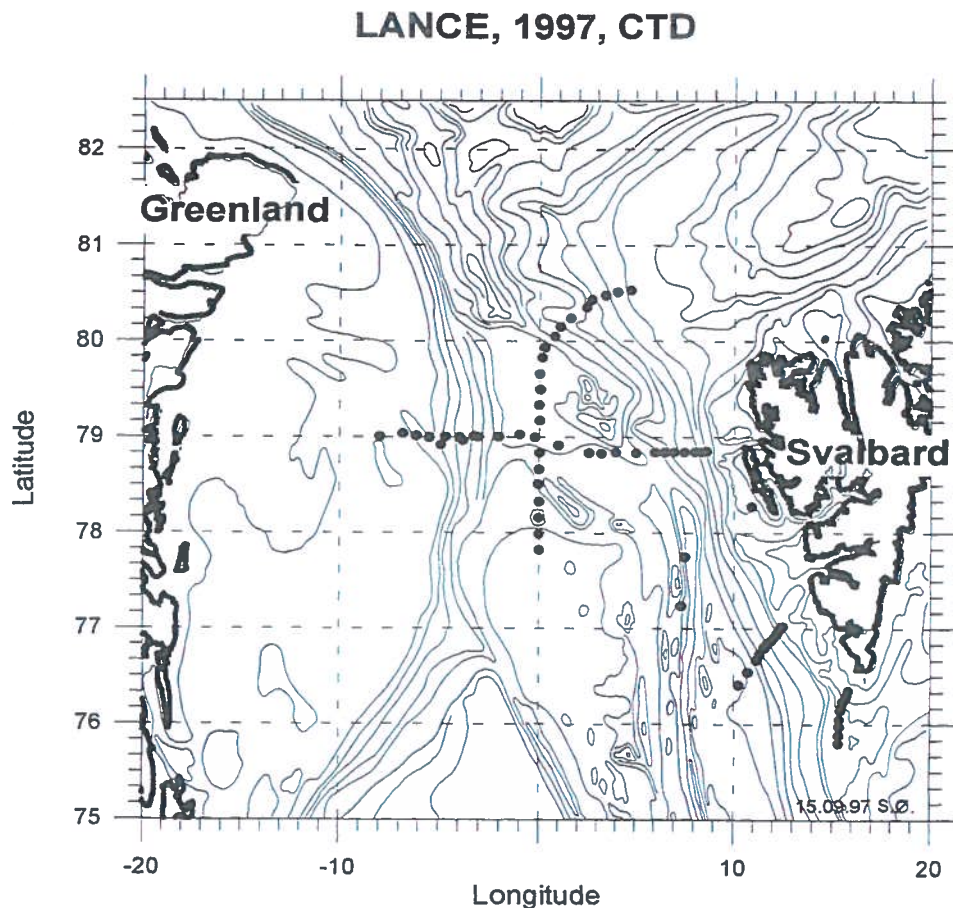


Fig. 1: General topography and location of the hydrological stations in the Fram Strait and in the southern slope of Svalbard archipelago.

Two hydrographic sections across Fram Strait and two sections across the southern slope of the Svalbard archipelago were carried out in order to obtain CTD-profiles and to measure dissolved oxygen,  $^{18}\text{O}$  Oxygen and dissolved inorganic nutrient concentration to identify water masses; furthermore, an Acoustic Doppler Current Profiler (ADCP) was lowered with the CTD to measure currents along the water column and 14 moorings were deployed in the West - East section by the Norsk Polar Institute of Tromsø (Norway) and by the Alfred Wegener Institute of Bremerhaven (Germany) in order to measure the current fields in the Strait during the whole project.

Istituto Talassografico (Trieste) collected and analysed on board samples for the determination of dissolved oxygen and nutrient concentration; these chemical data will be used to identify water masses, to estimate transports of salts through the Strait and, with the data of the next cruises, to verify variability of exchanges between Arctic and Nordic Seas.

The use of chemical constituents and especially of conservative tracers such as NO and PO (Broeker, 1974) has been widely used to identify and follow different water masses in the Arctic Ocean (Jones et al., 1991; Jones & Anderson, 1986) as, especially in the upper 200 m of the Arctic Ocean, chemical tracers provide a valuable addition to water mass characterisation based only on temperature and salinity data (Moore & Lowings, 1983).

**First results:**

The first available data present a quite clear distinction of different water masses occurring in the first 250 m of the water column. Figure 2 presents, as an example, silica concentration in the upper 250 m in the West-East section and reveals a subsurface core of a different water type, very rich in silica, which is not evident from the salinity data (Fig. 3).

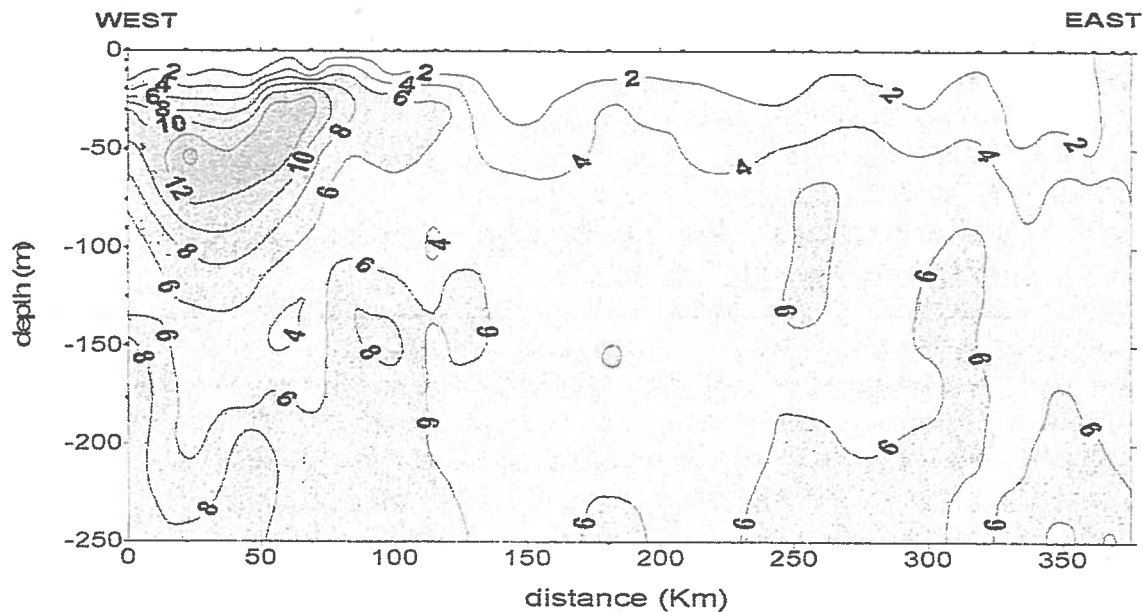


Fig. 2: Silica concentration ( $\mu\text{M}$ ) in the upper 250 m of the West-East section in the Fram Strait.

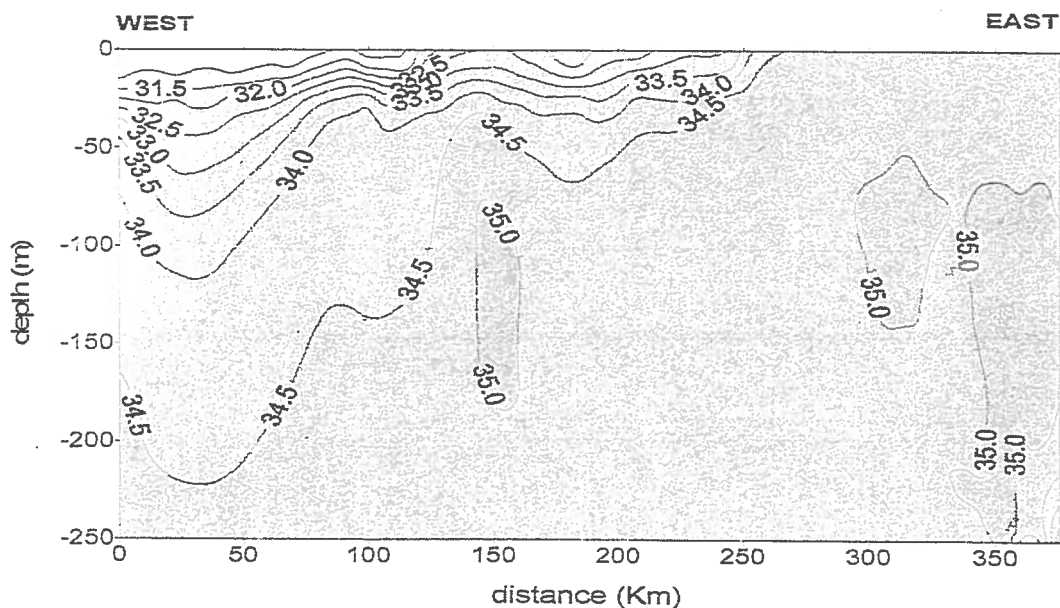


Fig. 3: Salinity distribution in the upper 250 m of the West-East section in the Fram Strait.

Water mass characterisation, together with data provided by current meters, by ship-borne and lowered ADCP will allow estimates of fluxes across the Strait and of balance between inflowing warm Atlantic waters and outflowing cold Arctic waters.

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# Radionuclides as tracers of particle dynamics in the Western Svalbard marine environment

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Due to their radioactive decay, radionuclides can be used as chronometers for dating many environmental processes, and as tracers for geochemical pathways and their time scales. In this paper, results are presented on a) scavenging rate and residence time of particles in the water column, using the disequilibrium  $^{234}\text{Th}$ - $^{238}\text{U}$  and b) sediment accumulation rate in surficial sediment, calculated from the  $^{210}\text{Pb}_{\text{ex}}$  vertical profile. Levels of the present radioactive contamination of sediments from  $^{137}\text{Cs}$  are also reported, as a by-product of the same set of results.

## 1. Scavenging rates and residence times of particles in the continental shelf of W-Svalbard.

Modelling the biogeochemical cycles and the long-term behaviour of contaminants released into the Arctic marine environment requires the assessment of some key parameters, among which fluxes and residence times of particulate matter within the water column. Till now, these parameters have been estimated at few sites in Arctic environments (Cochran et al., 1995a; Cochran et al., 1995b; Moran et al., 1997). Most of the studies are based on the use of the disequilibrium between  $^{234}\text{Th}$  and  $^{238}\text{U}$ .  $^{234}\text{Th}$  is a particle-reactive, naturally occurring radionuclide, produced in the water column by the decay of its soluble parent  $^{238}\text{U}$ . After production, Thorium can be scavenged onto particles and removed from the water column in association with them. The extent of the disequilibrium between  $^{234}\text{Th}$  and  $^{238}\text{U}$  is a useful tracer of scavenging processes and particle residence times in coastal waters and in the upper ocean. Due to its short half-life (24.1 days),  $^{234}\text{Th}$  can be used to trace scavenging processes on time scales varying from few to about 100 days.

Thorium fluxes and residence times were estimated at 3 sites on the continental shelf of the Western Spitsbergen, in summer 1996. The sampling area is influenced by northward flowing currents, the East Spitsbergen Current, close to the coast. The bathymetry of the study area is characterised by two troughs, corresponding to the exit of Isfjord and Kongsfjord. Samples were taken on the Isfjord Bank (St. B-05), in the Isfjord trough (St C-05) and on Sjubre Bank, on the limit of the Kongsfjord trough (St. C-08).

Particulate and dissolved  $^{234}\text{Th}$  were determined by filtration of about 1 m<sup>3</sup> of seawater using battery-powered *in-situ* pumps (C.O.S.S.,UK) through a prefilter (1µm, polypropylene) and two identical MnO<sub>2</sub> polypropylene impregnated cartridges, in series, to extract dissolved thorium.  $^{234}\text{Th}$  activity was measured using a gamma spectrometric system and HPGe detectors. The location of the sampling points and the vertical profiles of salinity, temperature,  $^{238}\text{U}$ , particulate, dissolved and total  $^{234}\text{Th}$ , measured at the three stations, are shown in Fig. 1. Three samples were collected at each station: two in the euphotic zone and one below.  $^{238}\text{U}$  concentration was estimated by its relationship to salinity.

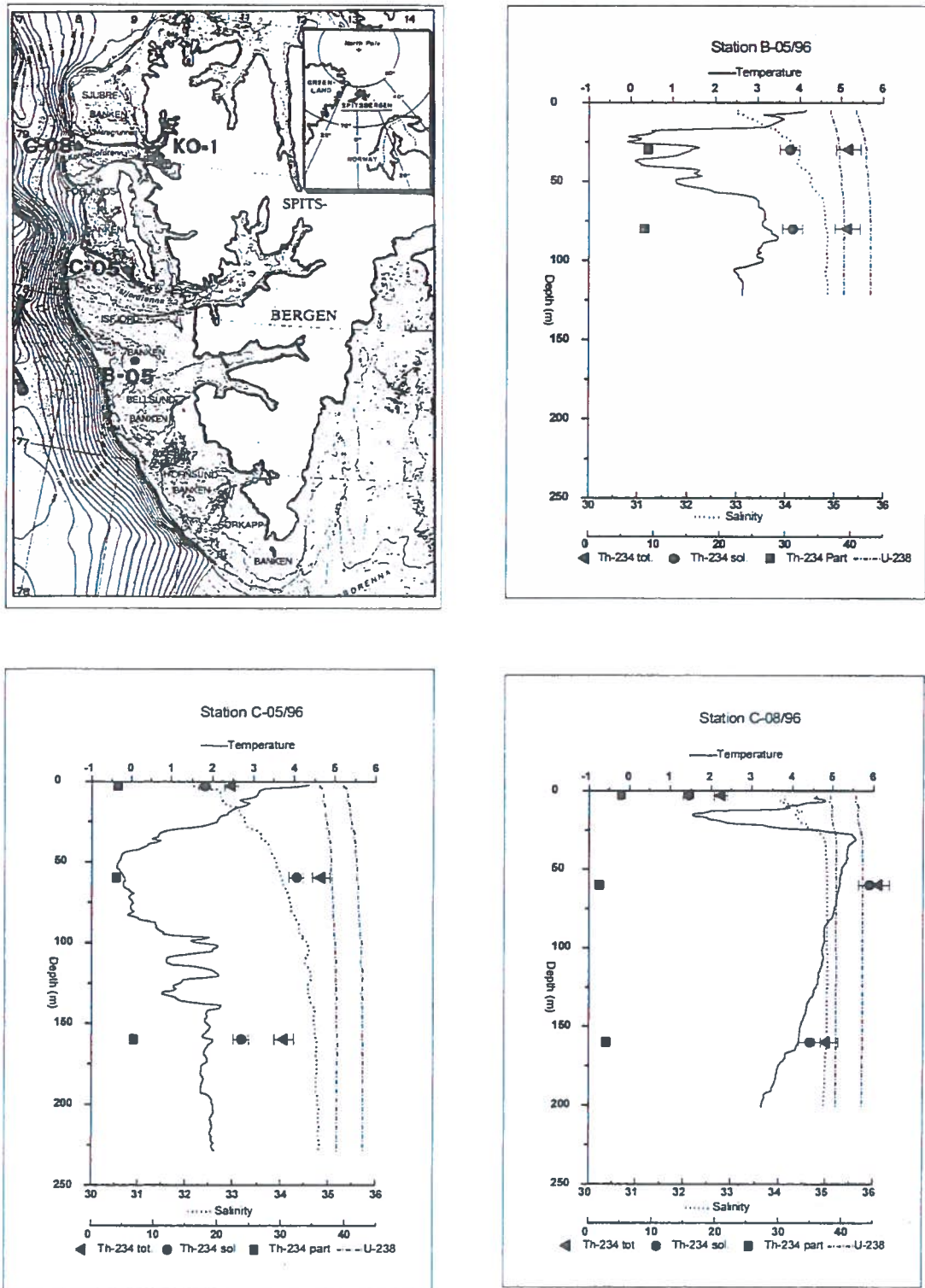


Fig. 1 - SVA 96: sampling points and vertical profiles of salinity, temperature ( $^{\circ}\text{C}$ ), U-238 and particulate, dissolved and total Th-234 ( $\text{Bq}\cdot\text{m}^{-3}$ ).

The fraction of  $^{234}\text{Th}$  associated to particles ranged from 7-30 % of the total and was highest at station B-05, the shallowest one, located on the shelf. At Station C-08, particulate thorium concentration decreases from surface to the bottom, while at Station C-05 the maximum concentration is found in the deepest sample. A marked disequilibrium between  $^{234}\text{Th}$  and  $^{238}\text{U}$  is present near the surface, whereas the radioactive equilibrium is usually achieved within the upper 60 m. In fact, other authors (Manley and Smith, 1994) report that the mean depth of the euphotic zones at these latitudes, in summer, is less than 70 m. This implies that thorium scavenging by biogenic particles mainly occurs within that upper layer. Only at Station C-05 total  $^{234}\text{Th}$  concentration is far from equilibrium with  $^{238}\text{U}$  at 160 m, probably not only in relation to vertical transport, but also to particle resuspension inside the Isfjord trough.

The model proposed by Buesseler et al., (1992) was used to estimate the rate of thorium scavenging and removal by sinking particles. Assuming that i) thorium profiles are in steady state, ii) advection and diffusion are negligible, the flux of dissolved thorium onto particles  $J_{\text{Th}}$  and the flux of particulate thorium  $P_{\text{Th}}$  can be written as:

$$J_{\text{Th}} = \lambda \cdot (A_U - A_{\text{Th}}^d)$$

$$P_{\text{Th}} = \lambda \cdot (A_U - A_{\text{Th}}^d - A_{\text{Th}}^p)$$

where  $A_U, A_{\text{Th}}^d, A_{\text{Th}}^p$  are the activities of  $^{238}\text{U}, ^{234}\text{Th}$  in the dissolved form and  $^{234}\text{Th}$  in the particulate form and  $\lambda$  is the decay constant of  $^{234}\text{Th}$  ( $0.0288 \text{ d}^{-1}$ ).

The residence time of dissolved ( $\tau_{\text{diss}}$ ) and particulate ( $\tau_{\text{part}}$ )  $^{234}\text{Th}$  with respect to scavenging onto particles and particle sinking are given by:

$$\tau_{\text{diss}} = \frac{A_{\text{Th}}^d}{J_{\text{Th}}} \quad \text{and} \quad \tau_{\text{part}} = \frac{A_{\text{Th}}^p}{P_{\text{Th}}}$$

Fluxes and residence times have been calculated at each station, in the depth layer 0 to 60 m, corresponding to the limit of the euphotic zone. Within this depth interval, equilibrium between  $^{238}\text{U}$  and  $^{234}\text{Th}$  is established at both stations. Errors on the estimated fluxes and residence times are given as propagated in  $1\sigma$  counting uncertainties in  $A_{\text{Th}}^d$  and  $A_{\text{Th}}^p$ .

$^{234}\text{Th}$  fluxes and residence times relative to the removal from solution onto particles are very similar. Dissolved thorium fluxes are  $23 \pm 5 \text{ Bq m}^{-2} \text{ d}^{-1}$  at station C-05 and  $18 \pm 4 \text{ Bq m}^{-2} \text{ d}^{-1}$  at station C-08, resulting in residence times in the dissolved form of  $63 \pm 13$  and  $95 \pm 19$  days, respectively. The same applies to particulate thorium: estimated fluxes out of the euphotic zone are  $16 \pm 3$  and  $12 \pm 2 \text{ Bq m}^{-2} \text{ d}^{-1}$ , corresponding to residence times of  $14 \pm 3$  and  $16 \pm 3$  days at stations C-05 and C-08, respectively. The results obtained are mainly related to thorium scavenging by biogenic particles and are in good agreement to those reported by Cochran et al. (1995) for the East Greenland shelf and by Moran et al. (1997) for the Central Arctic Ocean. However, thorium vertical profile at station C-05 shows that enhanced thorium scavenging can take place also below the euphotic zone, in relation to the particular geomorphology of the bottom, triggering particle resuspension.

## 2. Sedimentation rates (and present levels of anthropogenic radioactivity) in sediments of the W-Spitsbergen continental shelf.

The  $^{210}\text{Pb}$ , a member of the  $^{238}\text{U}$  natural radioactive series, having a half-life of 22 years, is a most useful time clock for sedimentological processes having time scales of the order of a century (Appleby and Oldfield, 1983). The flux of Lead-210 of atmospheric origin ( $^{210}\text{Pb}_{\text{ex}}$ ) that reaches the sea surface is rapidly adsorbed onto the settling particles which eventually are incorporated in the sediments (where, in turn, some "supported"  $^{210}\text{Pb}$ , coming from *in-situ* decay of its parents  $^{238}\text{U}$  and  $^{226}\text{Ra}$  is present). The determination of the sedimentation rate is based on the continuing decay of the  $^{210}\text{Pb}_{\text{ex}}$  deposited on the upper layers of sediment.  $^{137}\text{Cs}$  has been used both as tracer of sedimentation processes occurred after its injection into the atmosphere from nuclear weapon testing, and as indicator of anthropogenic radioactive contamination. All radionuclides were simultaneously determined on the same sample, using HPGe detectors and a gamma spectrometric system. Excess  $^{210}\text{Pb}$  levels were calculated by subtracting radium-supported  $^{210}\text{Pb}$  activity from the total  $^{210}\text{Pb}$  concentration in each section of the core ( $^{226}\text{Ra}$  activity being supposed to be in equilibrium with "supported"  $^{210}\text{Pb}$ ).

Sediment cores were collected by ENEA during the "SVA96" expedition (July-August 1996) in the continental shelf of the W-Spitsbergen, at the same locations where samples were taken for estimating scavenging rates and particle residence times, and inside Kongsfjord. The samples were collected by a gravity corer having a diameter of 10 cm, and were sectioned on land in layers 1 to 2 cm thick. Figure 2 shows the vertical profiles of  $^{137}\text{Cs}$  and  $^{210}\text{Pb}$  in 4 cores.

In the 3 stations on the shelf, unsupported  $^{210}\text{Pb}$  is only present in the upper 8-10 cm, while inside the fjord excess  $^{210}\text{Pb}$  is detectable down to 30 cm. Its concentration in the surface layers varies from 60 Bq/kg at stations B-05 and C-08 to 130 in Kongsfjorden and to maximum values of 250 Bq/kg at station C-05. The inventories of excess  $^{210}\text{Pb}$  in the shelf range from 1.3 kBq/m<sup>2</sup> at St. C-08 to 7.5 kBq/m<sup>2</sup> at St. C-05 and are highest in Kongsfjord (10.1 kBq/m<sup>2</sup>).

$^{137}\text{Cs}$  is only present in the upper 8-10 cm and its concentration usually decreases from surface values of 2-10 Bq/kg toward the bottom. The inventories range from 40 Bq/m<sup>2</sup> at Station C-08, the deepest one, to 400 Bq/m<sup>2</sup> at Stations C-05, located in a trough, and at Station KO-1, in the fjord.

Among the shelf stations, St. C-05 shows the highest inventory of both  $^{137}\text{Cs}$  and excess  $^{210}\text{Pb}$ . This is probably due to the fact that this station is located at the margin of a trough, where slumping processes can transport surface sediment from elsewhere, thus enhancing the total quantity of both radionuclides. Moreover, as discussed above, at this station a marked disequilibrium between  $^{234}\text{Th}$  and  $^{238}\text{U}$  indicates that scavenging processes are active in the deeper water layer, probably in relation to bottom morphology, that favours particle resuspension in the trough.  $^{210}\text{Pb}$ , being particle reactive, can also be effectively scavenged from the water column, thus leading to the observed high concentrations and inventory.

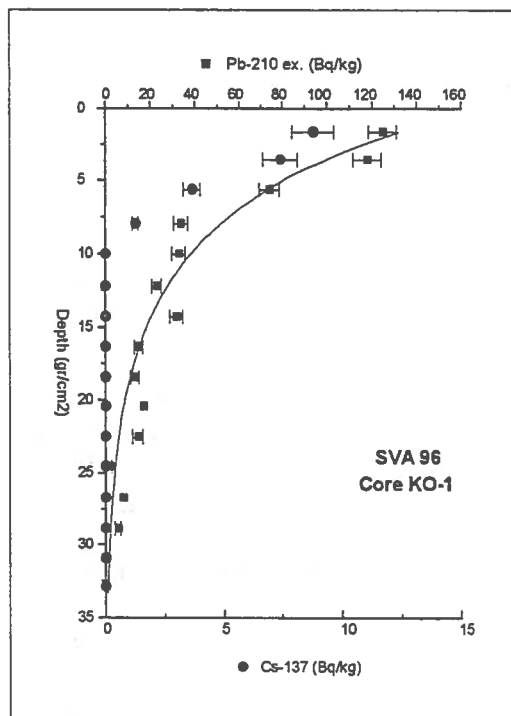
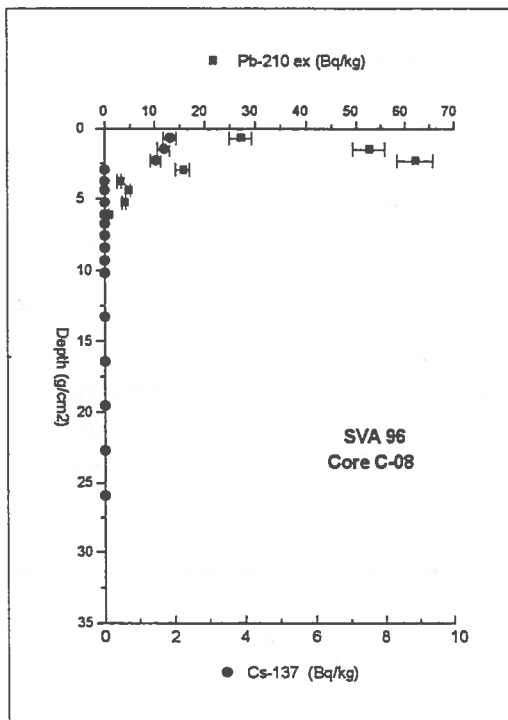
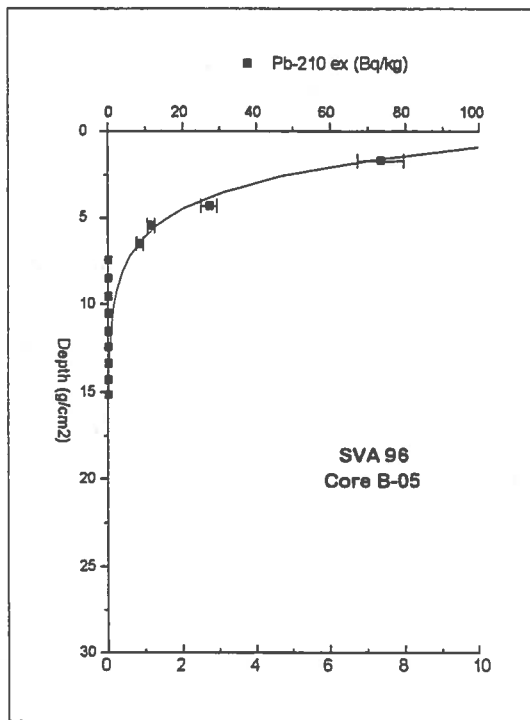
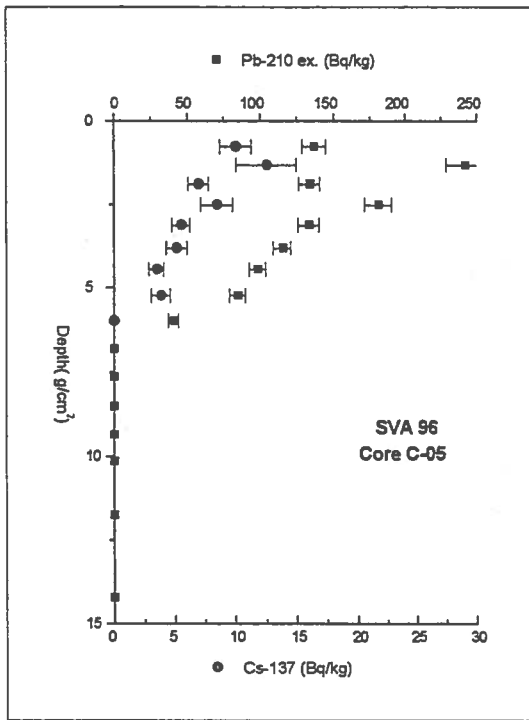


Fig. 2 - SVA 96: vertical profiles of Pb-210 and Cs-137 in sediment cores from the W-Spitsbergen continental shelf (B-05, C-05, C-08) and from Kongsfjorden (KO-1).

In general, the vertical radionuclide profiles on the W-Spitsbergen shelf seem to be mainly controlled by mixing processes:

- radionuclide penetration into the sediment is relatively low: it never exceeds 10 cm, which is a depth compatible with physical and/or biological mixing;
- the vertical profiles of  $^{137}\text{Cs}$  and unsupported  $^{210}\text{Pb}$  have usually the same shape, including subsurface maxima. As the two radionuclides have different input functions (constant input for  $^{210}\text{Pb}$  and maximum in 1963 for  $^{137}\text{Cs}$ ), this feature clearly points to low sedimentation rate and penetration into the sediment mainly controlled by mixing.

The situation is different inside Kongsfjord: relatively large amounts of terrigenous particles are transported to the fjord, due to ice melting, and the hydrodynamics of the area allows particle settling. This is clearly reflected in the vertical profile of the excess  $^{210}\text{Pb}$ , that shows an exponential decrease from the surface down to about 30 cm. Using the constant flux - constant sedimentation rate model, we can estimate the sedimentation rate at this station from the vertical profile of  $^{210}\text{Pb}$  by the following equation:

$$A(t) = \frac{P}{w} \cdot e^{-\lambda t} + A'$$

where  $A(t)$  is the expected activity of  $^{210}\text{Pb}$  (Bq/kg) in a sediment with age  $t$ ,  $P$  is the flux of excess  $^{210}\text{Pb}$  (Bq/cm<sup>2</sup> y),  $w$  is the sedimentation rate (g/cm<sup>2</sup> y) and  $A'$  is the activity of supported  $^{210}\text{Pb}$  (Bq/kg). In this way at St. KO-1 we obtain a sediment accumulation rate of 0.25 g cm<sup>-2</sup> y<sup>-1</sup>. This sedimentation rate is also in good agreement with the profile of  $^{137}\text{Cs}$ , whose penetration into the sediment is 8 cm.

**In conclusion**, we can say that:

- the vertical profiles of the natural radionuclides  $^{238}\text{U}$  and  $^{234}\text{Th}$  in the water column of the continental shelf show that in summer there is a remarkable particle flux from the photic zone toward the bottom and that particle residence times are quite homogeneous in the study area, ranging between 14 and 16 days. These results are in good agreement with those (18-29 days) obtained for Chlorophyll-*a*, using sediment traps deployed in the fjords.
- the vertical profiles of  $^{210}\text{Pb}$  and  $^{137}\text{Cs}$  in sediments of the continental shelf show that mixing processes are prevailing with respect to sedimentation, indicating that either particles, after leaving the euphotic zone, decompose before accumulating on the bottom or, once deposited on the bottom, are re-suspended and transported elsewhere. In contrast, inside Kongsfjord, where particle supply from land is significant, sedimentation rates are in the order 0.25 g cm<sup>-2</sup> a<sup>-1</sup>.
- the present radioactive contamination from anthropogenic radionuclides is confined, within the study area, in the upper 10 cm of sediment. Both the measured  $^{137}\text{Cs}$  concentrations (around 5 Bq/kg) and inventories (around 400 Bq/m<sup>2</sup>) are similar to those found in other Arctic areas, only influenced by global and Chernobyl fallout, suggesting that -at the moment- there is no significant contribution from the radioactive wastes dumped in the surrounding seas.

## Acknowledgements

We owe thanks to H. Svendsen, University of Bergen, for support and suggestions and to the crew of the Norwegian R/V "H. Mosby" for their co-operation. This work was partially carried out under the EU contract ARMARA F14P-CT95-0035.

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## **Spatial variability of phytoplankton and new production in the waters around Svalbard in relation to hydrological and nutrient conditions**

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### **ABSTRACT**

This paper deals with the second European "Polarstern" Study (EPOS II), patronized by the European Science Foundation as an ecological Study of the European Arctic Shelf (SEAS). In the frame of this project a cruise was performed onboard of the German RV "Polarstern", started and finished in Tromso, Norway, from June 20th to July 30th, 1991. Seven transects were carried out in the Central Barents Sea, in the Fram strait and north of Svalbard (Figure 1)

In relation to various pelagic regimes around Svalbard, the influence of sea ice on phytoplankton development was investigated. Estimates on new production were provided from nutrient data for the Central Barents Sea (east of Svalbard) across the Barents Sea Polar Front, and further to the north following the receding ice-edge. Spatial variability of phytoplankton abundance and species composition were observed along the seven transects (Figure 2). According to the plankton ecology in relation to ice cover, hydrological and nutrient conditions, three main pelagic regimes, were identified (table 1).

1. The region to the west of Svalbard was mainly influenced by warm Atlantic water and relatively free of sea ice. Some nutrients were consumed by phytoplankton at the shallower

locations where a minor bloom of diatoms was observed. At other stations flagellates dominated the communities. Biomass was generally low and there was evidence of grazing at some stations. Zooplankton grazing appeared to be one of the main controls of phytoplankton biomass.

2. The region to the north of Svalbard was influenced mainly by cold Arctic waters, but also here warm Atlantic water was present. Most of the area was covered by multi-year ice, their waters indicated low stability of the water column and low light conditions. At station with modest ice cover some nutrients were consumed by phytoplankton, but biomass was extremely low (chlorophyll-*a* around  $0.3 \mu\text{g l}^{-1}$ ). New production was also very low (around  $0.1\text{-}0.2 \text{ g C m}^{-2} \text{ day}^{-1}$ ) as were sedimentation rates. In contrast ice floes, which were broken and turned over by the ship, showed a brown colouration caused by high amounts of ice algae (mainly *Melosira arctica*). Zooplankton grazing was also evident.

3. In the northwestern Barents Sea, the hydrological regime was more complicated. Southern region of the transect was occupied by Modified Atlantic Water whilst Arctic Water was present to the north. During our study, the Marginal Ice Edge receded at a daily rate of about 11 km revealing waters rich in nutrients with a layer of melt water formed at the surface. The availability of nutrients together with the increase in water stability resulted in the development of phytoplankton blooms at the receding ice edge with maximum chlorophyll-*a* values obtained in surface waters ( $>4.0 \mu\text{g l}^{-1}$ ). Phytoplankton communities were typical for spring bloom characterised by phytoplankton species of the Marginal Ice Zone. In the surface layer to the south of the receding ice edge, nutrients decreased. The higher concentration of the chlorophyll (Deep Chlorophyll Maxima) were found at depths of between 30 and 50 m, deepening towards the south. Phytoplankton communities were here typical for a post-bloom situation. New production estimates revealed the net production of carbon to the north of the Barents Sea Polar Front and at the receding ice edge reaching values of  $2 \text{ g C m}^{-2} \text{ day}^{-1}$ , but carbon loss to the south of the Polar Front.

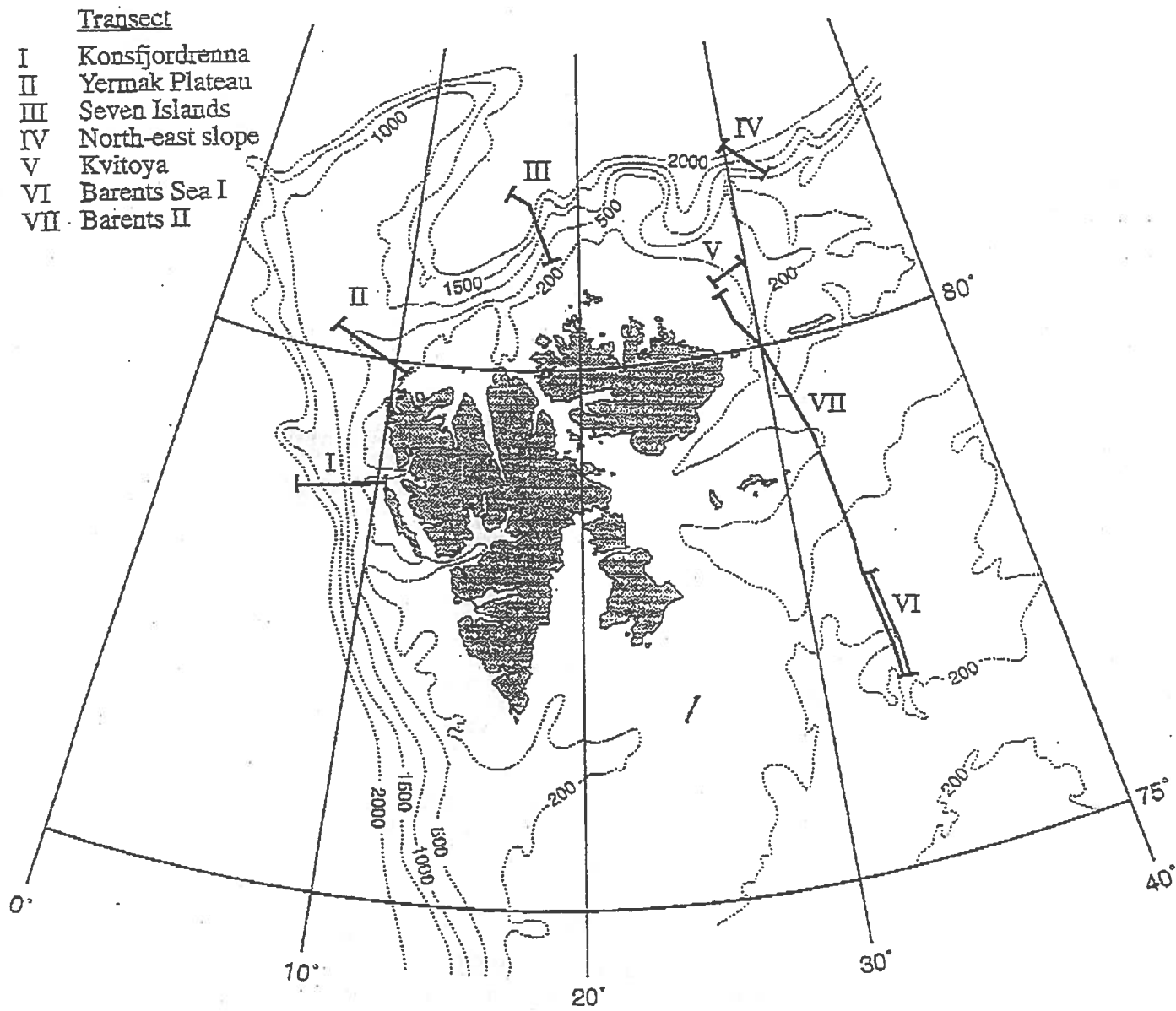


Figure 1. Location of the transects around Svalbard during EPOS II.

Table 1. Range, average, and confidence limits for the oceanographic parameters (salinity, temperature, relative oxygen %), nutrients, and phytoplankton biomass (as chlorophyll a and PhytoPlankton Carbon), in the different area around Svalbard.

	WEST OF SVALBARD			NORTH OF SVALBARD			CENTRAL BARENTS SEA		
	range	avg	conf lim	range	avg	conf lim	range	avg	conf lim
SAL (PSU)	33.0-35.1	34.9	0.1	33.0-35.0	34.3	0.1	31.3-35.0	34.2	0.1
t	0.5-5.8	4.3	0.2	-1.8-3.5	-0.4	0.2	-1.8-3.7	-0.6	0.2
OXY%	73-121	102	2	77-115	96	1	88-127	101	1
NH4 uM	0-2.2	0.7	0.1	0-1.8	0.4	0.1	0-2.2	0.3	0.04
NO3 uM	0.3-12.8	8.0	0.4	1.1-12.5	9.2	0.3	0-12.8	6.4	0.5
PO4 uM	0.10-1.13	0.45	0.02	0.16-0.77	0.56	0.02	0.04-0.83	0.44	0.05
SiO4 uM	0-5.3	3.2	0.2	0-5.2	3.7	0.1	0-6.3	2.2	0.2
PPC ug/l	0-91	11	4	0-13	3	1	0-144	26	6
CHLa ug/l	0-3.0	0.8	0.3	0-1.1	0.3	0.1	0-6.8	1.3	0.3

**SEAS (EPOS II)**  
Phytoplankton abundance (average)

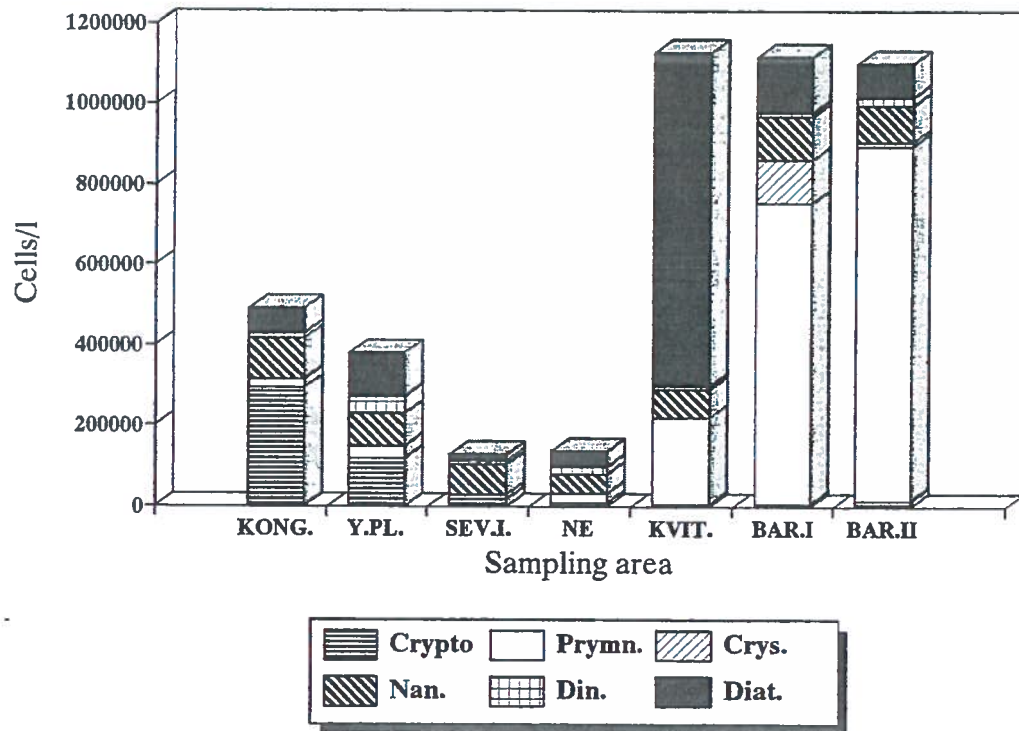


Figure. 2. Abundances of main phytoplankton classes in waters around Svalbard. Crypto = Cryptophyceans; Prymn. = Prymnesophyceans; Crys. = Crysophyceans; Nan. = other Nanoflagellates; Din. = Dinoflagellates; Diat. = Diatoms.

KONG. = Kongsfjordrenna transect; Y.P.L. = Yermak Plateau transect; SEV.I. = Seven Islands transect; NE = Northeast transect; KVIT. = Kvitøya transect

BARI. = Central Barents Sea transect VI; BAR.II = Central Barents Sea transect VII

**DETERMINATION OF ATMOSPHERIC FLUXES OF RADIONUCLIDES,  
HEAVY METALS AND PERSISTENT ORGANIC POLLUTANTS IN WELL  
DEFINED WATERSHED, LAKES AND COASTAL MARINE SEDIMENTS OF  
SVALBARD ISLANDS FROM THE BEGINNING OF NUCLEAR AGE.**

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*“ Ist.Chimico P.Levi Mirano(Venezia)*

The aim of the project include the characterisation of a specific site (around Ny-Alesund) as regards the history of total atmospheric deposition and its evolution in recent times. The inventories of main pollutants will be determined as well as their accumulation rates in the course of time. The project entails:

- the determination of the activity of natural and artificial radionuclides (Be7, Pb210, Ra226, Cs137, Cs134, Pu(238, 239+240), Am241, Bi207);
- the measurement of the concentration of organic contaminants (PAH's, PCB's, PCDD, PCDF) and of inorganic species (Hg, Cd, Pb, Zn, etc.). Data obtained will be of interest for the study of radionuclides diffusion mechanism, the long-range transport of pollutants, the environmental persistence of organic contaminants and the transfer of pollutants along the trophic chain.

In the present note preliminary data on radionuclides inventories regarding the sampling campaign of august 1997 will be reported.



**Appendix A**

**Programme**



# THE ARCTIC AND GLOBAL CHANGE

Multidisciplinary approach and international efforts  
at Ny-Ålesund, Svalbard

4th NySMAC Scientific Seminar  
Ravello, Italy, March 5-6, 1998

## Programme

(LSF) Papers supported by Large Scale Facility

### THURSDAY 5.3.1998

0830                      **Registration**

0900-1000              **Welcome**

#### Atmospheric Science 1

**Chair: Ivo Allegrini - Harald J. Beine**

1000-1020      **Allegrini I., Beine H.J., Ianniello A., Hillamo R., Masia P., Sparapani R. (LSF)**  
PHYSICO-CHEMICAL PROPERTIES OF AEROSOLS COLLECTED IN POLAR  
ATMOSPHERES

1020-1040      **Beine H.J.**  
PHOTOCHEMISTRY IN THE ARCTIC TROPOSPHERE

1040-1100      **Perner D.**  
THE EMISSION OF HALOGENS FROM THE ARCTIC PACK-ICE AND ITS ROLE IN THE  
TROPOSPHERE FROM MEASUREMENTS AT NY-ÅLESUND AND SÖNDRE  
STRÖMFJORD

1100-1130              *Coffee*

1130-1150      **Dimmer C., Simmonds P.G., Nickless G. (LSF)**  
ABUNDANCES AND SOURCES OF LOW MOLECULAR WEIGHT HALOCARBONS  
MEASURED IN THE ARCTIC TROPOSPHERE

1150-1210      **Gernandt H., Dethloff K., Neuber R., Notholt J., von der Gathen P.**  
CHEMICAL AND DYNAMICAL ASPECTS OF VARIABILITY AND LONG-TERM  
CHANGES IN THE ARCTIC STRATOSPHERE

1210-1230      **Kriews M., Schrems O. (LSF)**  
ANALYSIS OF CHEMICAL COMPOSITION IN TOTAL DEPOSITION SAMPLES FROM  
NY-ÅLESUND (SPITSBERGEN)

1230-1250      **Frey S., Steine B., Woste L., Neuber R., Rairoux P. (LSF)**  
OZONE AND AEROSOL MONITORING IN THE ARCTIC TROPOSPHERE IN NY-  
ÅLESUND USING LIDAR

1250-1430              *Lunch*

**Geophysics and Geodesy**  
**Chair: Bjørn Ragnvald Pettersen**

- 1430-1500 **Plag H.P.**  
GEODETIC CONTRIBUTIONS TO GLOBAL CHANGE RESEARCH AT NY-ÅLESUND
- 1500-1520 **Shumilov O.I., Raspopov O.M., Kasaktina E.A., Dergachev V.A.**  
GLOBAL TEMPERATURE CHANGES AND SOLAR CYCLES
- 1520-1540 **Tornatore V. (LSF)**  
THE ROLE OF EXTRAGALACTIC RADIO SOURCE STRUCTURE FOR IMPROVED  
REFERENCE FRAMES AND GLOBAL CHANGE
- 1540-1600 **Winther J-G., Gerland S., Ørbæk J.B., Ivanov B., Blanco A., Boike J.**  
SPECTRAL REFLECTIVITY AND PHYSICAL PROPERTIES OF SNOW AND SEA ICE  
NEAR NY-ÅLESUND, SVALBARD
- 1600-1620 **Ørbæk J.B., Hisdal V., Svaasand L. E.**  
SURFACE RADIATION BUDGET IN NY-ÅLESUND DURING THE PAST TWO  
DECADES
- 1620-1650 *Coffee*

**Poster session**  
**Chair: Dieter Perner**

1650-1735 **Atmospheric Science**

Allegrini I., Beine H.J., Ianniello A., Sparapani R. (LSF)  
A COMPARISON OF NO<sub>2</sub> MEASUREMENTS IN THE ARCTIC

Beine H.J., Dahlback A., Ørbæk J.B.  
J(NO<sub>2</sub>) AT NY-ÅLESUND: MEASUREMENTS AND MODEL CALCULATIONS

Bojkov B.R., Beine H.J.  
ON THE COMPARISON OF OZONE MEASUREMENTS IN THE LOWER TROPOSPHERE

Ciccioli P., Brancaleoni E., Frattoni M., Mabilia R.  
OCCURRENCE OF OXYGENATED VOLATILE ORGANIC COMPOUNDS (OVOC) IN THE ARCTIC AND  
ANTARCTIC REGIONS AND THEIR POSSIBLE RELEVANCE ON OZONE FORMATION

Krognes T., Beine H.J.  
IN-SITU MEASUREMENTS OF ALKYL NITRATES

Solberg S., Dye C., Schmidbauer N.  
MEASUREMENTS OF VOLATILE ORGANIC COMPOUNDS AT ZEPPELIN MOUNTAIN

Hermansen O., Lunder C., Schmidbauer N.  
METHANE MEASUREMENTS AT MT. ZEPPELIN

Kriews M., Schrems O. (LSF)  
EVENT DEPENDENT AEROSOL SAMPLING IN NY-ÅLESUND

Rafanelli C., Ciattaglia L., Anav A., Valenti C., Di Menno M.  
POLAR UMKEHR PROFILING DURING THE OZONE HOLE PERIOD

Shumilov O., Kasaktina E.A., Raspopov O.M.  
SURFACE OZONE IN ARCTIC

1735-1740      **Geophysics and Geodesy**

Kerr A.

ARCICE: THE UK 'ARCTIC ICE AND ENVIRONMENTAL VARIABILITY' PROGRAMME

1740-1750      **Biology and Biodiversity**

Zuppi C., Forni F., Callà C., Colacicco G., Lippa S., Gozzo M.L., Zappacosta B., Messina I., Giardina B.  
DARK-LIGHT SEASONAL CHANGE AND HUMAN OXIDATIVE METABOLISM: PRELIMINARY  
OBSERVATION AT NY-ÅLESUND

Wängberg S.Å., Gustavson K. (*LSP*)

EFFECTS OF THE AMBIENT UV-B RADIATION ON CARBON DIOXIDE FIXATION AND BACTERIAL  
ACTIVITY OF MARINE PLANKTON COMMUNITIES IN KUNGSFJORD

1750-1800      **Marine Science**

Alabiso G., Scotto V., Montini U., Mollica A., Milillo M.

STAINLESS STEEL CORROSION BEHAVIOUR IN POLAR SEA WATER: PRELIMINARY RESULTS OF SIX-  
MONTH FIELD TESTS

Degetto S., Tubertini O., Schintu M., Cianchi A.

DETERMINATION OF ATMOSPHERIC FLUXES OF RADIONUCLIDES, HEAVY METALS AND PERSISTENT  
ORGANIC POLLUTANTS IN WELL DEFINED WATERSHED, LAKES AND COASTAL MARINE SEDIMENTS  
OF SVALBARD ISLANDS FROM THE BEGINNING OF NUCLEAR AGE

1900-2000

*Cocktail*

**FRIDAY 6.3.1998**

**Atmospheric Science 2**

**Chair: Ivo Allegrini**

0900-0920      Argentini S., Santoleri R., Georgiadis T., Colacino M.  
ITALIAN PARTICIPATION IN THE ARTIST PROJECT

0920-0940      Shumilov O.I., Kasaktina E.A., Raspopov O.M.  
SOLAR PROTONS CREATE OZONE MINIHOLETS ABOVE SVALBARD

0940-1000      Groß C., Tüg H., Hanken T.  
UV-B RADIATION MEASUREMENTS AT KOLDEWEY-STATION

1000-1020      Moriconi M.L., Rafanelli C., Anav A., Di Menno I., Di Menno M., Valenti C.  
UV SOLAR RADIATION AND CLOUDS: POLAR EXPERIMENTAL DATA AND  
MODELLING

1020-1100

*Coffee*

**Biology and Biodiversity 1**

**Chair: Andrew Clarke**

1100-1120      Svenning M.A., Gullestand N.  
THE EFFECTS OF ENVIRONMENTAL CHANGE ON THE LENGTH OF THE  
MIGRATORY WINDOW OF SPITSBERGEN ARCTIC CHARR

1120-1140      Moyerson B., Alexander I.J., Shand I.  
DIVERSITY OF ECTOMYCORRHIZAL MORPHOTYPES ASSOCIATED TO *Salix polaris*  
AND *Dryas octopetala* IN A TUNDRA HEATH NEAR NY-ÅLESUND, SVALBARD

- 1140-1200 **Woakes A.J., Butler P.J. (LSF)**  
THE AUTUMN MIGRATION OF BARNACLE GEESE
- 1200-1220 **Wookey P.A. (LSF)**  
IMPACTS OF SVALBARD REINDEER (*Rangifer tarandus platyrhynchus*) ON THE REPRODUCTIVE DEVELOPMENT OF HIGH ARCTIC PLANTS
- 1220-1240 **Pelliccioni F.**  
TOWARDS THE NECESSITY OF A NEW "URGENT ANTHROPOLOGY": ARCTIC ANTHROPOLOGY AND THE "NEW" (BUT ANCIENT, BECAUSE TRADITIONAL) ECOLOGICAL INDICATORS
- 1240-1400 *Lunch*

## **Biology and Biodiversity 2**

**Chair: Guido di Prisco**

- 1400-1420 **Alexander I., Madan N., Woodin S., Högbohm L.**  
THE FATE OF ATMOSPHERIC NITROGEN DEPOSITED ON DWARF SHRUB HEATH AT NY ÅLESUND
- 1420-1440 **Hessen D.O., Ørbæk J.B., Hansen G.D., Hobæk A., Dahlback A., Svenøe T., Stokke K.**  
EFFECTS OF UV-RADIATION ON ARCTIC FRESHWATER PLANKTON IN NY-ÅLESUND
- 1440-1500 **Brittain J.E., Lencioni V., Maiolini B.**  
ARCTIC AND ALPINE STREAM ECOSYSTEM RESEARCH (AASER)
- 1500-1520 **Widdicombe S., Kendall M.A., Weslawski J.M. (LSF)**  
BENTHIC BIODIVERSITY STUDIES IN THE KONGSFJORD
- 1520-1600 *Coffee*

## **Marine Science**

**Chair: Bruno Battaglia**

- 1600-1620 **Papucci C., Delfanti R., Mordegli B.**  
RADIONUCLIDES AS TRACERS OF PARTICLE DYNAMICS IN THE WESTERN SVALBARD MARINE ENVIRONMENT
- 1620-1640 **Karsten U., Hanelt D., Bischof K., Tüg H., Brouwer P.E.M., Wiencke C.**  
ENHANCED ULTRAVIOLET RADIATION OVER THE ARCTIC - WHAT ARE THE CONSEQUENCES FOR THE SEAWEED PHYSIOLOGY AND ECOLOGY ?
- 1640-1700 **Lipizzer M., Luchetta A.**  
WATER MASS EXCHANGES BETWEEN ARCTIC AND ATLANTIC OCEANS: THE VEINS PROJECT
- 1700-1720 **Socal G., Luchetta A., Civitarese G., Owrid G., Nöthing E.M., Wiktor J., Andreassen I., Schauer U., Sörensson F., Strass V.**  
SPATIAL VARIABILITY OF PHYTOPLANKTON AND NEW PRODUCTION IN THE WATERS AROUND SVALBARD IN RELATION TO HYDROLOGICAL AND NUTRIENT CONDITIONS
- 1720-1800 *Final remarks*

**Appendix B**  
**List of Participants**



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