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SOURCES AND SIGNIFICANCE OF NATURAL AND MAN-MADE AEROSOLS IN THE ARCTIC

REPORT OF A WORKSHOP SUPPORTED
AND ORGANISED BY THE
U.S. OFFICE OF NAVAL RESEARCH
AND THE
NORWEGIAN INSTITUTE FOR AIR RESEARCH
LILLESTRØM, 27-28 APRIL 1977

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NORWEGIAN INSTITUTE FOR AIR RESEARCH

Lillestrøm 21st June, 1977

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1. INTRODUCTION

Already in 1883, Fridtjof Nansen, when wandering on the icepack from the sealer "Viking" observed dark patches which he thought might affect the melting. Part of this material, he reflected, could have been transported through the atmosphere. We are now in a better position, technically, to determine this amount. At the same time, we know that the Arctic icecap and the radiation in this region is very critical for the climatic pattern of the Northern hemisphere.

Measurements of arctic haze at Point Barrow in Alaska in 1975-1976 (and later) of anthropogenic aerosols, gave the first clear evidence of larger natural and pollutant aerosol inputs to the Arctic. These observations are supported by data from programmes conducted by several European countries, and chemical analysis of samples from the Greenland ice cap show that the content of sulphur and lead in precipitation has been increasing during this century.

The present meeting was convened by the Office of Naval Research and the Norwegian Institute for Air Research. The purpose was to bring together scientists who have been working separately with aerosol measurements in the Arctic, in order to establish a co-operation which could make it possible to determine the sources, transport mechanisms and effects of aerosols in the Arctic.

DISCUSSION OF FUTURE RESEARCH CO-OPERATION

The following is a brief summary of the conclusions from the discussion of future research co-operation.

PURPOSE AND OBJECTIVES

It was agreed that a study of the origin and nature of atmospheric trace compounds is highly desirable because of a general concern for the environment in this area. Recent studies indicate that the influx of natural and pollution aerosols to the Arctic region includes much larger quantities of materials than previously assumed. This raises a need for including the Arctic region in a general, scientific investigation of the atmospheric circulation of materials brought into the atmosphere.

The objectives of a co-operative research programme can be formulated in four steps:

1) Verify and broaden existing evidence regarding transport and nature of aerosols into the Arctic region, principal pathways, natural and anthropogenic sources, and seasonal variations.

2) Determine the climatic effects of this aerosol in the Arctic region. Aerosols affect the radiation balance either directly by absorption and scattering in the atmosphere, or indirectly by changing the albedo of the snow cover by deposited material. The albedo may also be affected by changes of the cloud cover and droplets size distribution, because the aerosols, by acting as condensation nuclei, influence cloud formation processes and precipitation patterns. The character of the cloud cover as revealed by shower activity is also of importance. This problem is under study (e.g. University of Arizona). Rain water is being analysed for chemical content in an effort to sort out the nuclei responsible for cloud formation and also what nuclei possibly have a role in charge separation in clouds.

3) Regular measurements of aerosols and other atmospheric components supported by an understanding of transport mechanisms and seasonal variations will provide 1977-1980 baseline air quality values for the Arctic, which may be of considerable interest in relation to the rapid expansion of human activities in this region.

4) Biological effects were not discussed specifically, although the possibility, and attendant concern, was noted.

PRESENT ACTIVITIES

Participants in the meeting were actively engaged in or planning for measurement programmes in the Arctic. Some of these activities are listed in Table 1. The positions of permanent and proposed sampling stations are given in Fig. 1.

As seen from the table, most of the present and planned stations will be used to measure aerosol composition. Several of the stations are oriented towards investigating the transport of aerosols into the Arctic, e.g. from North America or from the European Continent. In addition to the stations shown in Table 1, several stations and networks outside the Arctic area will act as support for studies of transport of airborne particles. Among these is the European Monitoring and Evaluation Programme which will come into operation in the second half of 1977, and which will be specifically devoted to a study of the transport of sulphur compounds in its first phase. The detailed measurements of the chemical and physical properties of aerosols at the IVL station near Gothenburg also belong to this category.

Mention was also made of the extensive measurements of Aitken nuclei on ships across the North Atlantic, which are co-ordinated by Dr. Mohnen of the State University of New York, Albany.

At each of the sampling sites shown in Fig. 1, there is also the possibility of performing more specialised measurements in co-operation with other interested scientists. This should, however, be arranged individually with the country and organisation operating the stations.

TABLE 1: MEASUREMENT PROGRAMMES

* meteorological observation-stations operated by the Danish Meteorological Institute

INSTITUTIONS	PARAMETERS MEASURED	LOCATIONS	OBSERVATIONS
University of Alaska (Dr. Ch. Deehr)	NO_2 (also O_3, ClO, SO_x)	Alaska Spitsbergen	continuous
Danish Air Pollution Laboratory (Dr. H. Flyger)	Aerosols, composition physical properties	Greenland, two locations *	dependent on financiation
Danish Meteorological Institute	Precipitation chemistry (WMO regional stations)		continuous (monthly samples)
AERE, Harwell (Dr. D. Peirson)	Aerosol composition precipitation, dry dep.	Shetland	continuous, weekly or monthly samples (financial support from DOE on a year-to-year basis)
University of Stockholm (Dr. L. Granat)	Physical and chemical properties of aerosols	possibly Spitsbergen North-East Passage	campaign, up to three weeks, "Vega" expedition, depends on financiation
Finnish Meteorological Institute (T. Ruoho)	Precipitation, aerosol composition, gases	Sodankylä	continuous
University of Lund (Dr. H. Lannefors)	Aerosol composition, size distribution	Spitsbergen (9 stations in Sweden)	summer 1977, dependent on funding
University of Alaska (Dr. G. Shaw)	Optical properties of aerosols, influence on radiation	Point Barrow SAS Polar flights	occasional
University of Rhode Island/ ONR (Dr. K. Rahn)	Aerosol composition, transport pathway	Point Barrow	continuous
Environment Canada (Dr. D. Whelpdale)	Aerosol composition precipitation chemistry (WMO Programme)	Alert 5 stations in N Canada	1978 onwards after governmental approval
Norwegian Institute for Air Research	Aerosol composition, aerosol composition, precip. chemistry, SO_2	Spitsbergen Bear Island Northern Norway	continuous from 1973 " " 1977 " " 1977
Iceland	precipitation chemistry	2 stations	extension of progr. dependent on financiation

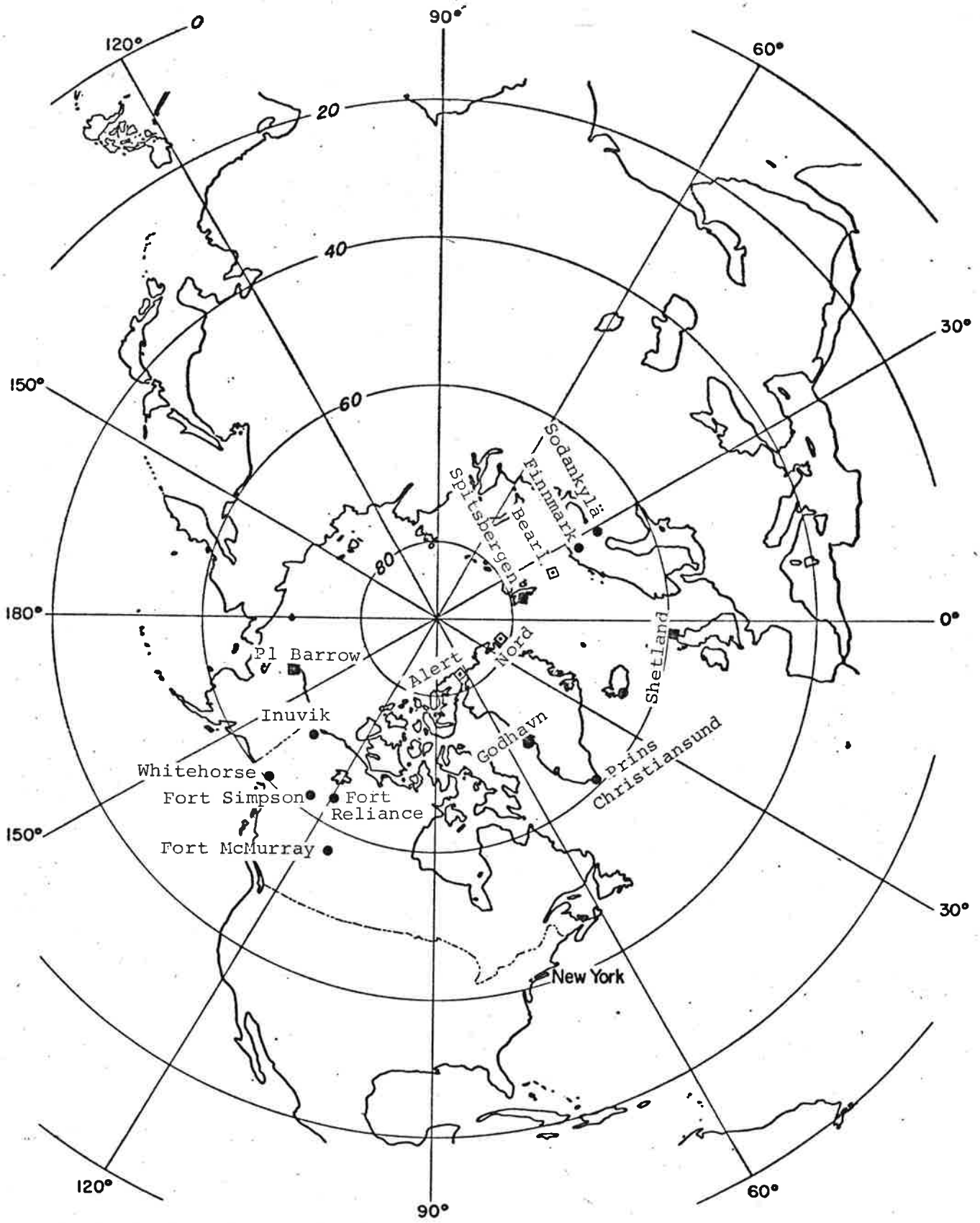


Fig. 1: Location of some relevant established and proposed stations

- Precipitation stations
- Aerosol composition
- Proposed station

MEASUREMENT PROGRAMME

The measurement programme can be considered as composed of a chemical, a physical and an optical part.

With respect to aerosol composition, most samples will be analysed (by INAA or PIXE) for a number of components, which gives an indication of the amount of insoluble material of crustal origin, as well as the concentration of certain minor constituents typical of man-made air pollutants (V and Pb).

A measure of the concentration of water-soluble particulate matter is also desirable. A major component of the water-soluble fraction is sulphate. The hygroscopic properties of the water-soluble part depend on the chemical composition. Thus, ammonium sulphate is different from acid ammonium hydrogen sulphate. Since sulphate aerosols are formed from gaseous sulphur dioxide, simultaneous measurements of sulphur dioxide are also desirable.

With respect to physical measurements, data for cloud condensation nuclei, ice nuclei and Aitken nuclei are all desirable. At present, however, it may not be possible to measure cloud condensation nuclei adequately.

Measurement of atmospheric extinction as a function of wavelength gives a measure of the vertically integrated aerosol mass loading and size distribution. Use of the newly designed 12-wavelength sun photometer should provide significantly improved sensitivity and precision relative to the simple two-wavelength instruments. In addition, it provides measurements of ozone and water vapor. Dr. Glenn Shaw (University of Alaska) is willing to supply a limited number of these instruments to the network on a non-profit cost basis.

The University of Alaska is also willing to assist in the analysis of the resulting data.

The use of a nephelometer was proposed as a continuously recording instrument in order to provide real time detection of events with high concentrations of pollution aerosols. The nephelometer reading depends on the relative humidity and the size distribution of the aerosols in a complex way which makes the quantitative interpretation difficult.

Atmospheric extinction may also be used to determine selected stratospheric and tropospheric trace gases, particularly NO_2. This requires special and sophisticated equipment.

SAMPLING AND ANALYTICAL TECHNIQUES

It was suggested that during the preliminary phase, emphasis should be placed on utilisation of established methods of sampling and chemical analysis.

In order to determine a large number of elements, high-volume filtering is generally desired. Size segregated sampling was mentioned, specifically as a means to avoid obscuration of samples by sea-spray. The choice of sampling technique also depends on the analytical technique, for instance X-ray techniques require thin samples collected on flat substrates.

Sampling frequency

For general characterisation of aerosol composition and measurements of concentration levels, relatively long sampling periods, i.e. from one week to a month, may be necessary. In order to be able to identify and describe events of aerosol transport, a higher degree of time resolution is required. Shorter sampling periods increase the analysis effort and reduce the number of elements which can be determined.

The best compromise would be a sampling period between one day and one week, but this probably also depends on the sampling sites. It is recommended that the variations in aerosol concentrations with time should be investigated specifically as a function of sampling time at sites with on-going programmes this year.

AIRCRAFT SAMPLING

The main use of aircraft would be to investigate the vertical structure of aerosol concentrations. Vertical stratification is very pronounced in the Arctic, and the so-called arctic haze occurs in layers up to several km above the surface. The main limitation of present aircraft sampling techniques is the time required to obtain a sufficiently large sample, which limits the number of data for individual flights. Direct recording instruments, such as nephelometers and optical counters, may to some extent be used to overcome this difficulty.

Several aircraft facilities are available to participants for measurements in the Arctic, but there are obvious economic and operational limitations with respect to the extent to which these can be utilized. Certain facilities required that research proposals and programmes are worked out well in advance of planned flights.

EXCHANGE OF INFORMATION AND CO-ORDINATION OF FUTURE ACTIVITIES

It was considered important for the future development of the co-operative research programme that data and other available information from this year could be made available at an early stage. Such information should be mailed to Dr. K. Rahn, University of Rhode Island, not later that December 1st, 1977.

A small technical meeting will be convened in January 1978, at the Danish Air Quality Laboratory at Risø, to consider plans for future activities. Invitations will be extended to representatives of countries which did not participate in the first meeting.

NEWSLETTER

It is proposed that research groups send a brief summary of their activities this summer to Dr. K.A. Rahn by September 1st. A short newsletter on the basis of this information will then be sent to all participants in September.

3. ABSTRACTS OF PRESENTATIONS

IDEAS FOR A MEASUREMENT PROGRAMME IN THE ARCTIC REGION

B. Ottar, Norwegian Institute for Air Research

BACKGROUND

During the past three years, a co-operation has gradually developed between Dr. K. Rahn, University of Rhode Island, and the Norwegian Institute for Air Research (NILU) on measurements of the aerosol composition in the Arctic region. Aerosol samples from Alaska, Norway and Spitsbergen have been analysed by neutron activation, and the results indicate that transport of industrial/urban aerosols from the North American and European Continent to the Arctic region takes place.

The present meeting was arranged partly to see if other countries carrying out measurements in the Arctic region would be interested in a co-ordinated approach. In the following, some ideas for possible studies are presented.

OBJECTIVES AND PROGRAMME CONSIDERED

The general purpose of a programme would be to provide a basis for evaluation of the impact of man-made air pollutants in the Arctic region. Information of major interest would be:

- the chemical composition of air and precipitation,
- the transfer of air pollutants to the Arctic region,
- the dry and wet deposition of air pollutants,
- the long term changes in the composition of air and precipitation in the Arctic region.

The means for providing this information would be measurements at ground stations and possibly from aircraft, and available meteorological data.

Several years would be required to meet all the objectives mentioned, and it will be necessary to specify programmes which fall within the resources available. Also limited practical experience is available with respect to measurements of air pollutants in the more remote parts of the Arctic region. The programme may therefore start with a preparatory phase lasting until summer 1978, during which a number of exploratory experiments could be performed. Based on this experience, larger co-ordinated measurement programmes may then be organised.

Chemical composition of air and precipitation

To obtain a first survey, it is suggested to collect samples at a number of ground stations, some of which may be temporarily operated during the summer of 1977.

There are three types of samples which can be collected: gaseous components, aerosols, and precipitation. The most comprehensive and directly applicable information will probably be obtained from chemical analysis of the fine aerosol particles (below 2-3 μm) which have the longest residence time in the atmosphere. The gaseous components have a much shorter residence time, particularly sulphur dioxide. Analysis of sulphur dioxide, nitrogen oxides (as NO_2) and ammonia is, however, of great interest in connection with chemical transformations and production of sulphate aerosol. Some data will therefore be of great interest. The content of air pollutants in precipitation will probably be closely related to the composition of the aerosol fraction. The aerosols may therefore be selected as the main object of study.

The number of aerosol particles as measured by a particle counter or a nephelometer, will probably be a good general indicator of polluted air masses. Samples for chemical analysis should preferably be collected in two or more fractions, with a main separation at about 3 μm.

To study the fate of major pollutants such as sulphur dioxide and nitrogen oxides, the water soluble part of the aerosol fraction should be analysed for hydrogen, sulphate, nitrate, ammonium ions and manganese (the main catalyst for SO_2 oxydation).

The elemental composition of the aerosol fractions, as determined by neutron activation or PIXE analysis would give valuable information on the origin of the materials, particularly if combined with trajectory analysis. This generally requires separate samples and larger sampling volumes. The same applies to analysis of organic components. To obtain a general idea of the chemical composition of the aerosols such samples probably will have to be collected over periods of several days. This may reduce the possibility of trajectory analysis.

Transfer of air pollutants to the Arctic region

This type of study requires detailed meteorological evaluations. Also for this purpose, measurement of the aerosol components are expected to provide data which can be readily interpreted. The aerosol fractions may be analysed on the same components as under the above paragraph, but daily measurements may be necessary.

Deposition of air pollutants

The amounts deposited by precipitation may be determined in monthly or weekly samples. Using monthly samples, the danger of contamination from dry deposition is rather large, and the sampler should be provided with an automatic lid. If this is technically impossible, daily sampling and cleaning of the sampling vessel may be used. The precipitation samples should be sufficiently large to permit analysis of a number of different components. Furthermore, the samplers should be designed to give reasonably accurate values for the amount of precipitation.

An other possibility of studying the deposition of air pollutants including dry deposition is by analysis of ombrogenic or epiphytic mosses or lichens. In regions where it is possible, samples may be collected for analysis in conjunction with other programmes in the countries.

Long term changes of the composition of air and precipitation in the Arctic region

For this, monthly samples of air and precipitation over a long period of time are necessary. An indication of long term changes could also possibly be obtained from annual analysis of soil and plant materials.

Aircraft measurements

The purpose of aircraft measurements will be to obtain information on vertical profiles and horizontal distributions of pollutants.

Measurements should preferably be made of components which will show the difference between polluted and clean air masses. Particle counters may be suitable for this purpose. Generally, automatically recording instruments are preferable. Aerosol samples for detailed chemical analysis may be collected and analysed by PIXE. However, such sampling should be limited to cases when a distinction can be made between polluted and clean air masses by other means.

A point of particular interest may be collection of cloud droplets for detailed chemical analysis.

IMPLEMENTATION

In the Arctic region, there are very few inhabited places. At Svalbard (Spitsbergen) the areas around the coal mines at Longyearbyen and Barentsburg are hardly suitable for air pollution measurements because of local contamination. In New Ålesund, a research station is operated by Norwegian authorities. There are, however, burning coal tips in the area. There are permanent meteorological stations at Hopen and at Isfjord.

On the Bear Island, there is a permanent Norwegian meteorological station. There is also a station on Jan Mayen, but the active volcano may limit the possibilities for air pollution studies.

On Greenland, there are some meteorological stations in addition to the permanent settlements. There are also stations along the Arctic coastline of Canada and Alaska, and the research station at Point Barrow will be of particular importance.

Along the northern coast line of U.S.S.R. areas of interest might be Novaya Zemlya and the Murmansk region.

In the summer, there are usually a number of scientific expeditions to the Arctic region. For Svalbard, these activities are co-ordinated by the Norwegian Polar Institute. In 1978, the 100-year anniversary of the discovery of the North-East passage will be celebrated. On this occasion, Sweden, together with other nations, intends to send a scientific expedition through this passage. Special, short-term measurement campaigns may be conducted in connection with these activities.

How the experiments outlined can be implemented, and how the tasks can be divided between the participating laboratories will be a subject for later discussions. Main points will be co-ordination of measurements and intercalibration of methods. With respect to equipment, possibilities for loan between the participating laboratories may exist.

AIR POLLUTION IN THE ARCTIC - SOME EMERGING IDEAS

Kenneth A. Rahn, Randolph D. Borys, Glenn E. Shaw
University of Rhode Island, Kingston, and
Geophysical Institute of Fairbanks

A series of measurement programmes on the Arctic aerosol since 1971 has demonstrated conclusively that the Arctic is exposed to air pollutants, especially during winter. In northern Norway (70^{o}N), a series of 5 pulses of high aerosol concentrations were found during 1971-1973. Two of these pulses, during February and March 1972, occured during periods of intense air flow from the south and were undoubtedly pollution aerosol from central Europe (50^{o}N), 2000 km distant. In 1976, it was discovered that Arctic haze, the name given to layers of aerosol found in the troposphere north of Barrow, Alaska, was composed of soil dust transported from the arid and semi-arid regions of eastern Asia, some 10 000 km distant. Amounts of this natural crustal dust brought into the Arctic via the atmosphere seem to be huge, on the order of millions of tonnes per year. During non-haze periods at Barrow, pollution aerosol aloft is clearly detectable by vanadium enrichment factors of 2 to 5. During the winter, the surface aerosol at Barrow is also polluted, surely from far distant sources. Vanadium enrichment factors range from 3 to 30. Excess (non-crustal) vanadium shows a sudden increase of nearly an order of magnitude about the first of November. It is hypothesized that this is due to large-scale changes of the hemispheric circulation patterns which occur about this time, namely rapid southward expansion of the polar air mass to include major pollution sources such as the northeastern United States and Europe. In contrast to the popular view of the Arctic atmosphere as being insulated from incursions of air from the south, it was demonstrated that frequent northward penetrations do occur, especially during winter. Thus the Arctic aerosol is not as

aged as is often thought. Rather, it contains relatively high concentrations of surprisingly fresh natural and pollution aerosol generated far to the south. It is now possible to speculate about the principal pathways of aerosol into the Arctic (Fig. 1). The major sources and routes seem to be Asian soil dust over Alaska, U.S. pollution over Iceland and Spitsbergen, and European pollution via northern Scandinavia and Siberia.

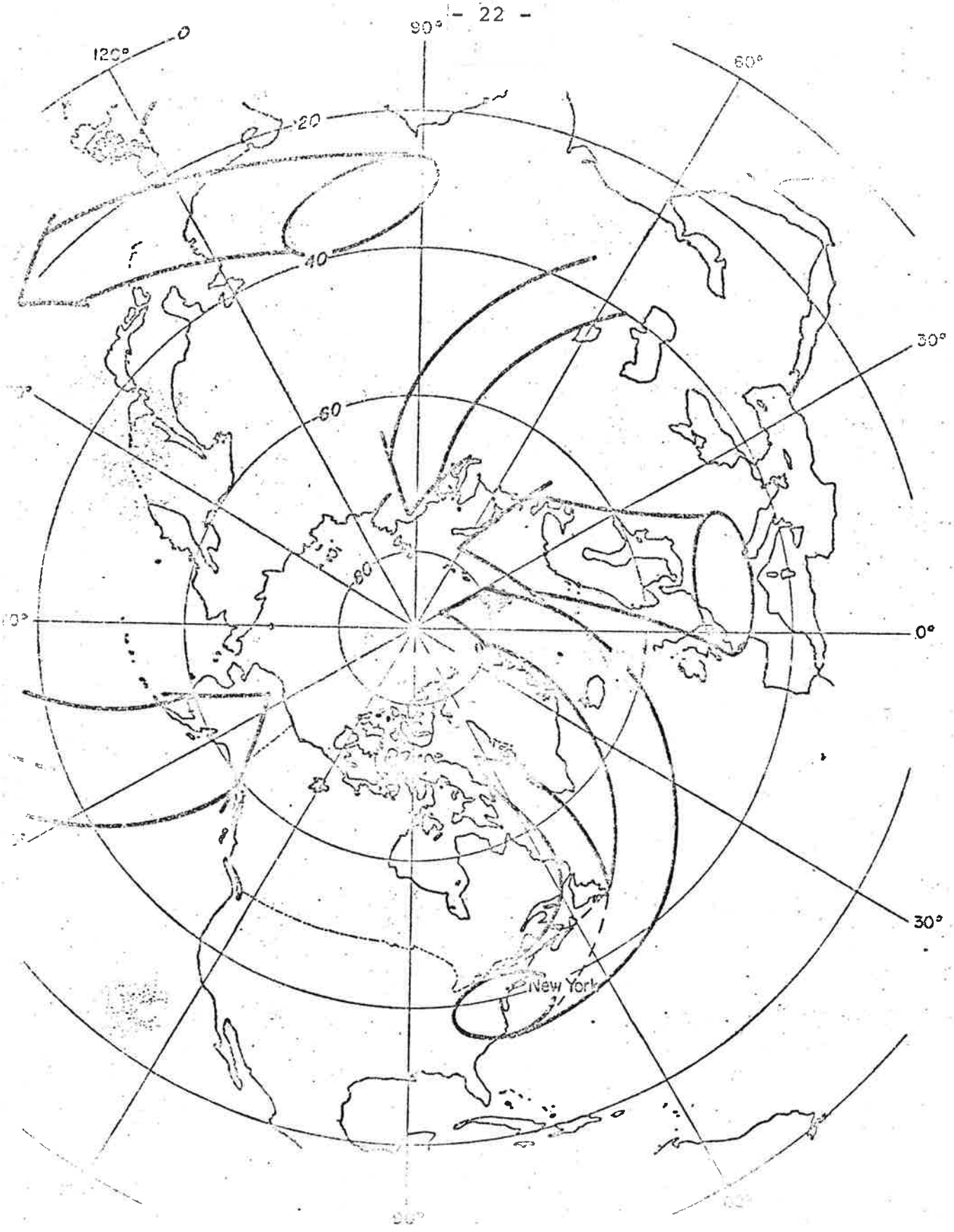


Figure 1

EFFECTS OF ANTHROPOGENIC AEROSOLS

W.J. Megaw, York University, Toronto.

Since 1971, the Aerosol Group of the Danish A.E.K., Risø (now the Danish Air Quality Laboratory) has mounted a series of expeditions to Greenland in an effort to detect changes in the background tropospheric aerosol. Greenland was chosen as an area where, although the atmospheric aerosol level did not vary rapidly in the short term, it was nevertheless typical in the long term of the general northern hemisphere aerosol. Dr. Heidam will be giving details of the results of these expeditions.

I would like to put forward the view that the most significant result of anthropogenic pollution is the injection of particles into the atmosphere and that the most important property of these particles is their ability to condense water at the super-saturation which may occur in the atmosphere. Squires (1966) estimated that, of the particles present in the atmosphere which were capable of condensing water, only about 14 % over North America were man-made, and only 5 % over the northern hemisphere as a whole. Weickmann and Pueschel have said that the man-made contribution is increasing so quickly that within about 25 years it may equal that of nature. It is scarcely conceivable that this can take place without considerable climatic effects.

The ability of particles to condense water depends not only on their size, but on their nature. Fig. 1 (from Juisto, 1967) shows curves in which supersaturation and relative humidity is plotted against particle radius, for insoluble wettable, and soluble particles. The space above each curve is an area of drop growth and that below an area of drop evaporation. This figure shows the marked difference in behaviour between soluble and insoluble particles. This is reinforced in Table 1 which shows the size

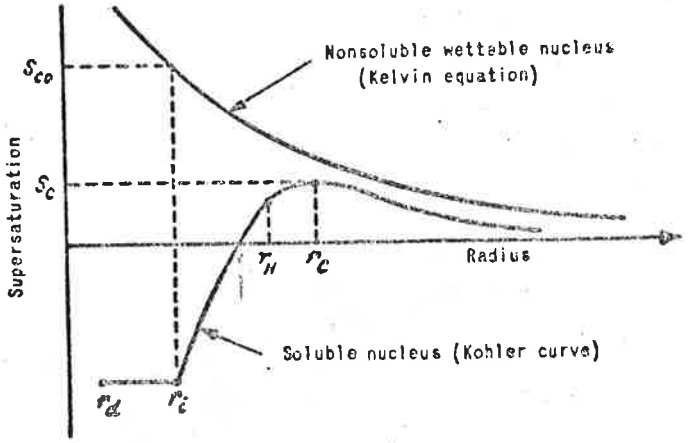


Figure 1 Critical supersaturation-nucleus size relations.
(from Jiusto, 1967)

MINIMUM SIZE " CLOUD " NUCLEUS
ACTIVATED VERSUS SUPERSATURATION

	HYGROSCOPIC	NONHYGROSCOPIC/WETTABLE
S	r_d	r_i
10%	.0025 μ	.011 μ
3	.005	.033
1	.011	.113
0.3	.025	.380
0.1	.054	1.13
0.03	.12	3.8
0.01	.25	11.3
	$S_c \propto \frac{1}{r_d^{3/2}}$	$S_{co} \propto \frac{1}{r_i}$

Table 1 (from Jiusto, 1967)

of particles which grow into droplets at various supersaturation. It is apparent that the behaviour of soluble and insoluble particles is quite different. For example, an hygroscopic particle of radius 0.12 micron will grow into a drop at a supersaturation of 0.03 %, but a similar non-hygroscopic wettable particle requires a 1 % supersaturation. Measurements of the size distribution of atmospheric aerosols not only do not take account of this, but are actually misleading, since they imply that all particles of the same size will behave in a similar manner.

There is considerable evidence that most of the atmospheric aerosol consists of particles which are either soluble or have some soluble component, and this may cause the formation of haze at relative humidities less than 100 %. This is illustrated in a thin layer of brown haze which appears occasionally over Toronto. It is thought (Megaw, 1977) that this is due to the growth into droplets of soluble particles at humidities above 75 %. It is of interest that the appearance of the intense brown colour is dependent on rather low levels of air pollution since a large concentration of intervening aerosol would mask the colour by scattering white light towards the observer.

REFERENCES: Squires, P., J Rech Atmospheriques 2, 297, 1966

Weickmann, H.K. and Pueschel, R.I. Beitrage für Physik der Atmosphäre 46, 1973

Jiusto J.E., Nucleation factors in the development of clouds Ph D thesis, University of Pennsylvania, 1967

Megaw W.J., Thin layer brown haze, J. Aerosol Sci. 8, 21, 1977

DANISH AEROSOL MEASUREMENTS IN GREELAND

Niels Heidam, Dansk Central-og Referencelaboratorium for luftforurening

Measurements of particles and various trace gases were carried out in Greenland from aircraft in 1971 (Cessna), 1973 (DC-4) see Fig.1, and 1976 (C-130 Hercules). On the ground, measurements were made in 1972 (South Greenland), 1973 (Ice cap), 1974 (North Greenland), and 1976 (various coastal locations). The purpose has been to examine concentrations and natural variations and, if possible, to discern trends in the pollution level.

The aircraft measurements revealed that although particle concentrations are generally very low, rather high concentrations were found in stratified layers, possibly connected with haze layers, see Fig. 2. The air sampled had not recently passed over any heavily populated area, but was considered to be representative of the Arctic region, see Fig.3. This casts doubt on the conventional concept of a background aerosol. On a statistical basis, particle concentrations were lower over the ice cap than over the sea.

On the other hand, surface measurements on the ice cap and in North Greenland show a constant, very low particle concentration, possibly due to a shallow boundary layer at the surface.

Element analyses of particulate samples taken in North Greenland indicate that the bulk of the particulate is of crustal origin, but there are traces of elements believed to be of anthropogenic or industrial origin.

REFERENCES: Flyger, Hansen, Megaw and Cox, 1973, J. Appl. Met. 12, 161

Flyger, Heidam, Hansen, Megaw, Walther and Hogan, 1976, J. Aerosol Sc. 7, 103.

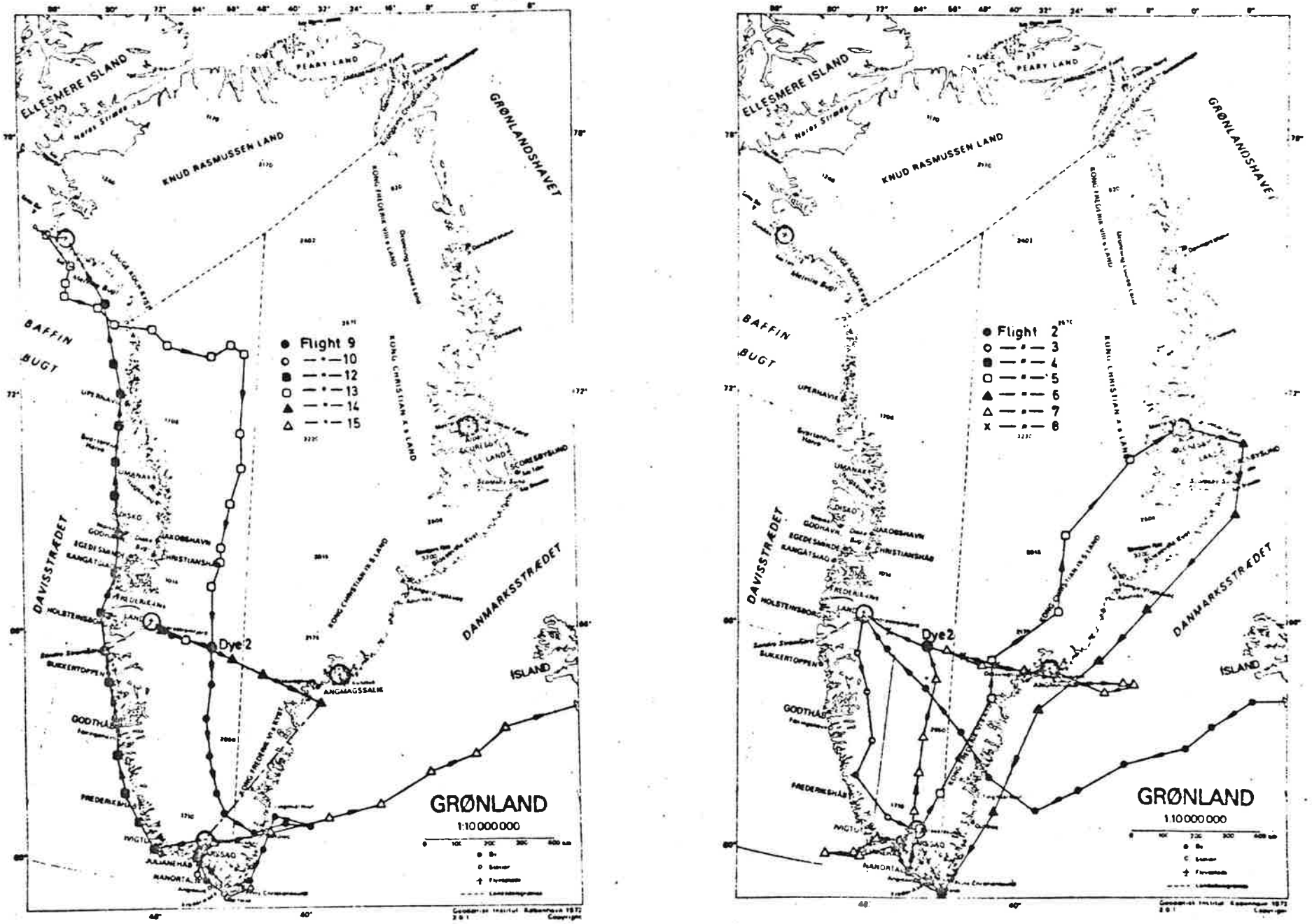


Fig. 1. Flights performed over Greenland in August 1973.

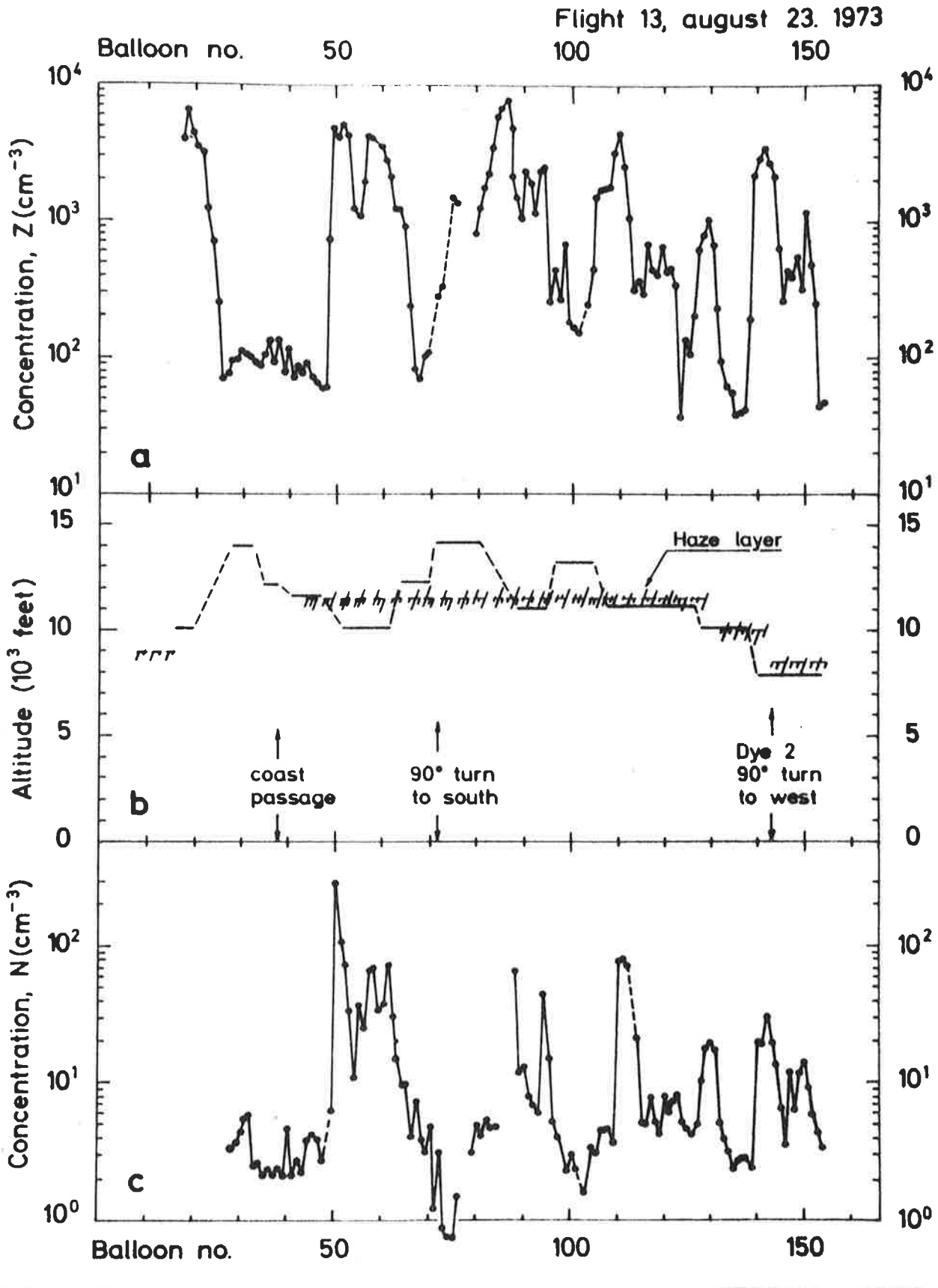


Fig. 2. Particle concentrations and flight altitudes as function of time (approx. 2 1/2 min between ballons). Note the simultaneous excursions with factors 10-100 of concentrations of Aitken nuclei (fig. a) and large nuclei (fig. c) with penetrations of haze layer (fig. b).

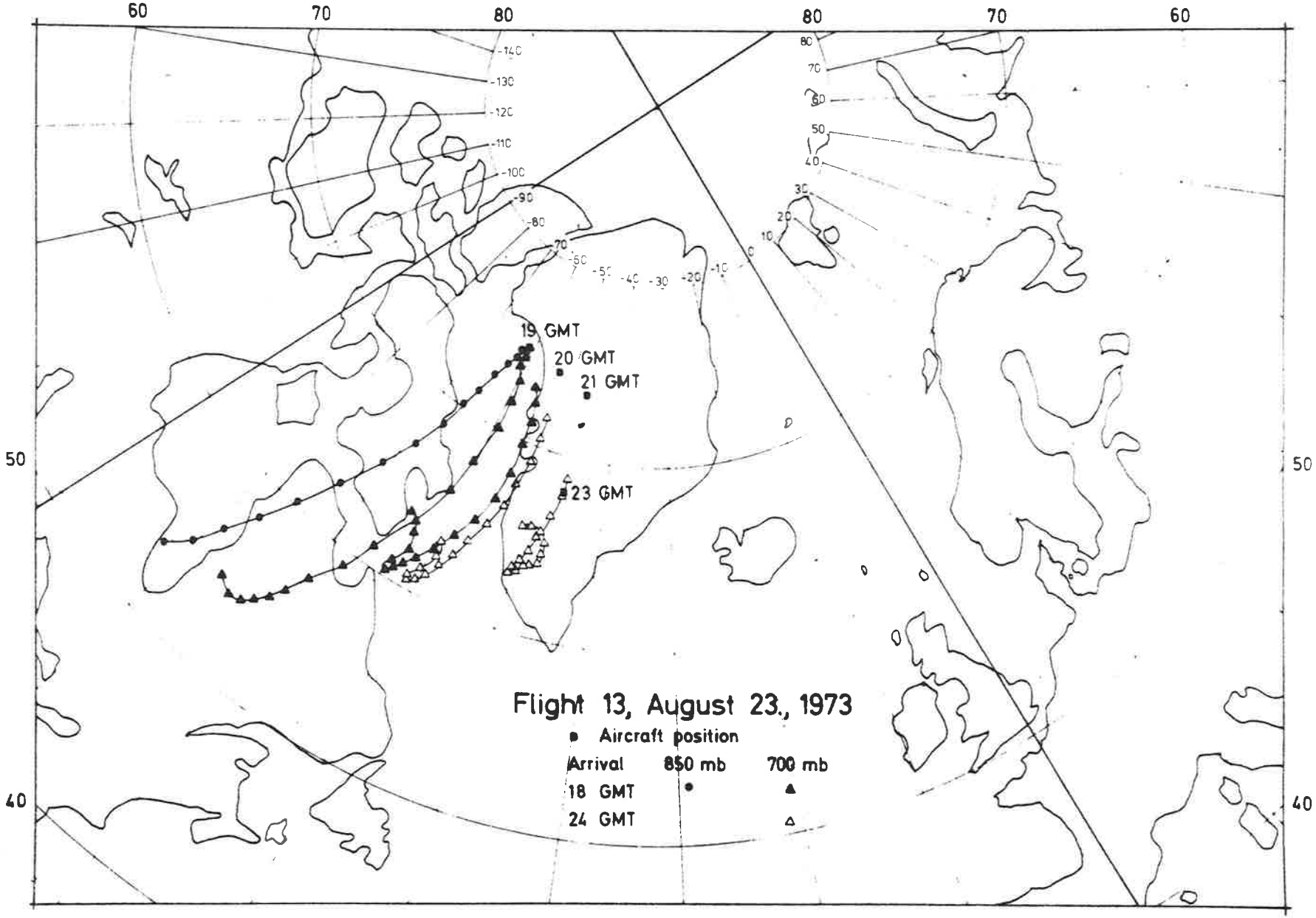


Fig. 3. Isobaric trajectories pertaining to fig. 2; note that the air has not passed polluted areas.

PIXE USED FOR ELEMENTAL ANALYSIS OF ARCTIC AEROSOL AND PRECIPITATION SAMPLES

Kåre Kemp, Dansk Central-og Referencelaboratorium for luftforurening

Proton induced X-ray emission analysis offers two advantages which are particularly usefull for analysis of samples collected in remote areas:

1) Small samples can be used (1 ng detection limit in 1 mg sample).
2) Elements with atomic number greater than 14 (Si) can be determined simultaneously.

The first makes it possible to use easily transportable equipment, while the second is usefull f.ex. when groups of elements are selected as indicators for the origin of the aerosols.

An automatic aerosol sampler designed for use with PIXE collecting two size fractions (division $\sim$ 5 µm) is under construction. Using a sampling time of one week, it will be possible to determine the concentrations of several elements (e.g. S, V, Cr, Fe, Ni, Br and Pb) down to 0.02 ng/m^3. When using one week sampling intervals, the sampler will in principle be able to run for up to one year without filter change and maintainance. The power consumption will be below 5 watt.

When used for precipitation analysis, PIXE is able to detect elements in concentrations down to $\sim$ 0.1 µg/l in a 10 cm^3 sample.

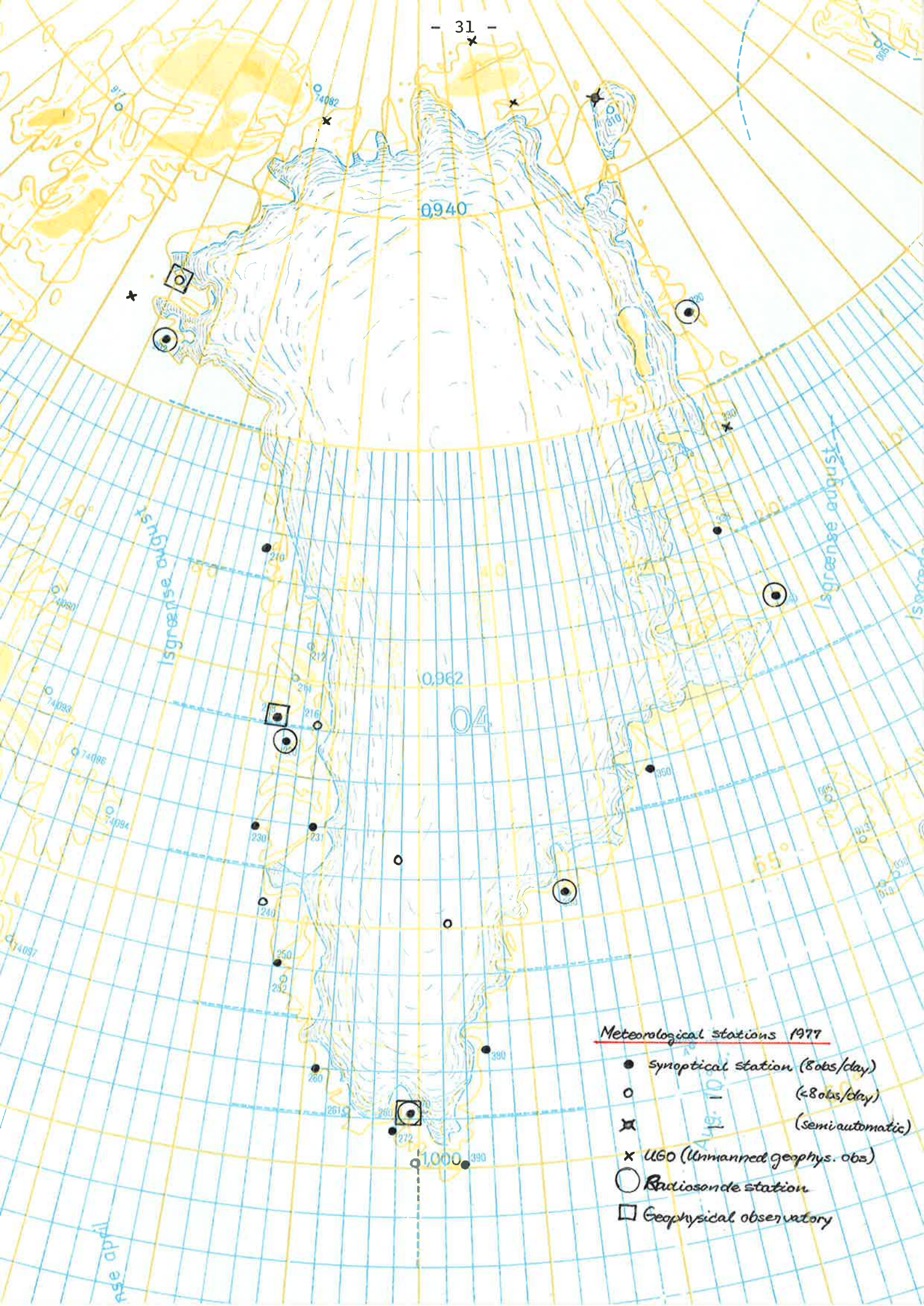
METEOROLOGICAL AND GEOPHYSICAL OBSERVATION STATIONS IN GREENLAND

Hans Buch and Leif Rasmussen, Dannish Meteorological Institute

The maps are showing meteorological and geophysical observation stations in Greenland. In the future, some changes are expected, in particular the number of radiosonde stations will be reduced from January 1st, 1979. The meteorological analyses over the region therefore will be less reliable in the future.

The stations named on the map may be suggested as air pollution stations. The stations in southwest Greenland (for instance Julianehaab) are relatively often exposed to polluted air from North America, while the stations on the eastcoast are more protected. Sometimes, northeast Greenland (station Nord) is under influence of air of European origin.

At present, there are high volume samplers at Prins Christianssund in southern Greenland and at Thule (Qanaq) in northern Greenland. Furthermore, precipitation samplers (WMO) for monthly sampling are operating at Prins Christianssund and at Godhavn in western Greenland.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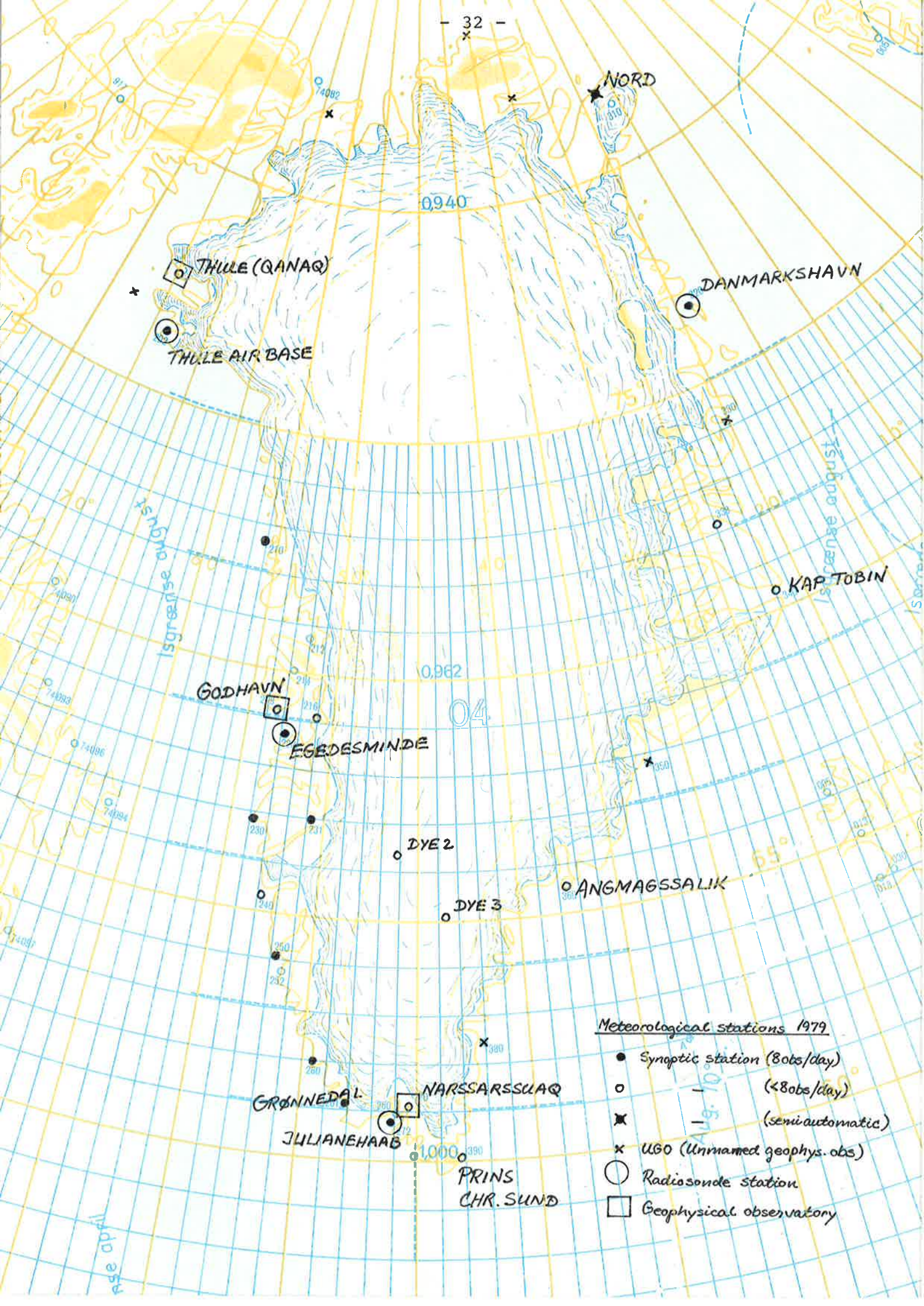
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ANGMAGSSALIK
NARSSARSSUAQ
GRØNNEDAL
JULIANEHAAB
1,000
PRINS
CHR. SUND
Meteorological stations 1979
Synoptic station (8obs/day)
(<8obs/day)
(semi-automatic)
UGO (Unnamed geophys. obs)
Radiosonde station
Geophysical observatory

OPTICAL STUDIES OF ARCTIC HAZE

Glenn Shaw, Geophysical Institute of the University of Alaska, Fairbanks

The phenomenon of substancial haze in the Arctic atmosphere was first deduced from results of a programme conducted off Point Barrow, Alaska in 1972, which had as its objective the precise measurement of optical transmission through the atmosphere at several narrow wavelengths regions placed within the visible optical spectrum. Since these early measurements, the technique of precision multi-wavelength sun photometry has been under continual study at the Geophysical Institute, University of Alaska, and has resulted in the development of a small ten-wavelength sun photometer that has now been operated for two years at remote regions in the Arctic, Antarctic, and Central Pacific to sense aerosol parameters. This instrument has provided a great deal of useful scientific information about the column mass loading and size distribution of the background aerosol, and it would be useful if such devices could be employed at aerosol study stations in an Arctic network. In actual use, one obtains from the data analysis the following parameters:

1) the haze extinction spectrum within the visible region referred to the vertical direction (wavelengths extending from 4000 Å to 10 000 Å) as illustrated in Fig. 1.
2) the total amount of atmospheric ozone,
3) the total water vapor content in a vertical column (from absorption in a water vapor band at 9500 Å wavelength).

Of the above parameters, the haze extinction spectrum is particularly useful since it provides an estimate of the column-integrated aerosol mass loading and the size distribution function for particles in the range of 0.1 to 1.0 micrometre radius. This determination of column-integrated aerosols nicely supplements chemical information about the aerosol which, for instance, might be derived from surface-based filter sampling.

In the event that several stations in the Arctic begin a systematic study of the atmospheric aerosol, it would be extremely interesting from both practical and scientific viewpoints to simultaneously aquire the haze extinction spectra, when the weather permits. In this way, a sort of column-integrated haze climatology for the Arctic region could be slowly built up over several years, and perhaps in some cases, even related to specific episodal events of haze injected into the Arctic Basin from both natural (desert dust) and man-made sources. Such a study would be a first important step to take, in order to make it possible for scientists to judge whether or not the turbid Arctic air imposes any real threat of a climatic change that might come about due to changes in the radiation balance caused from absorption or scattering of light by the Arctic haze.

In view of the simplicity of carrying through the multi-wavelength sun photometry measurements, as well as the known practical and scientific usefulness of the data, as verified by actual use of remote Arctic stations, the Geophysical Institute, University of Alaska, will construct and supply sun photometers and instructions at self-cost to interested scientists who participate in the Arctic sampling network.

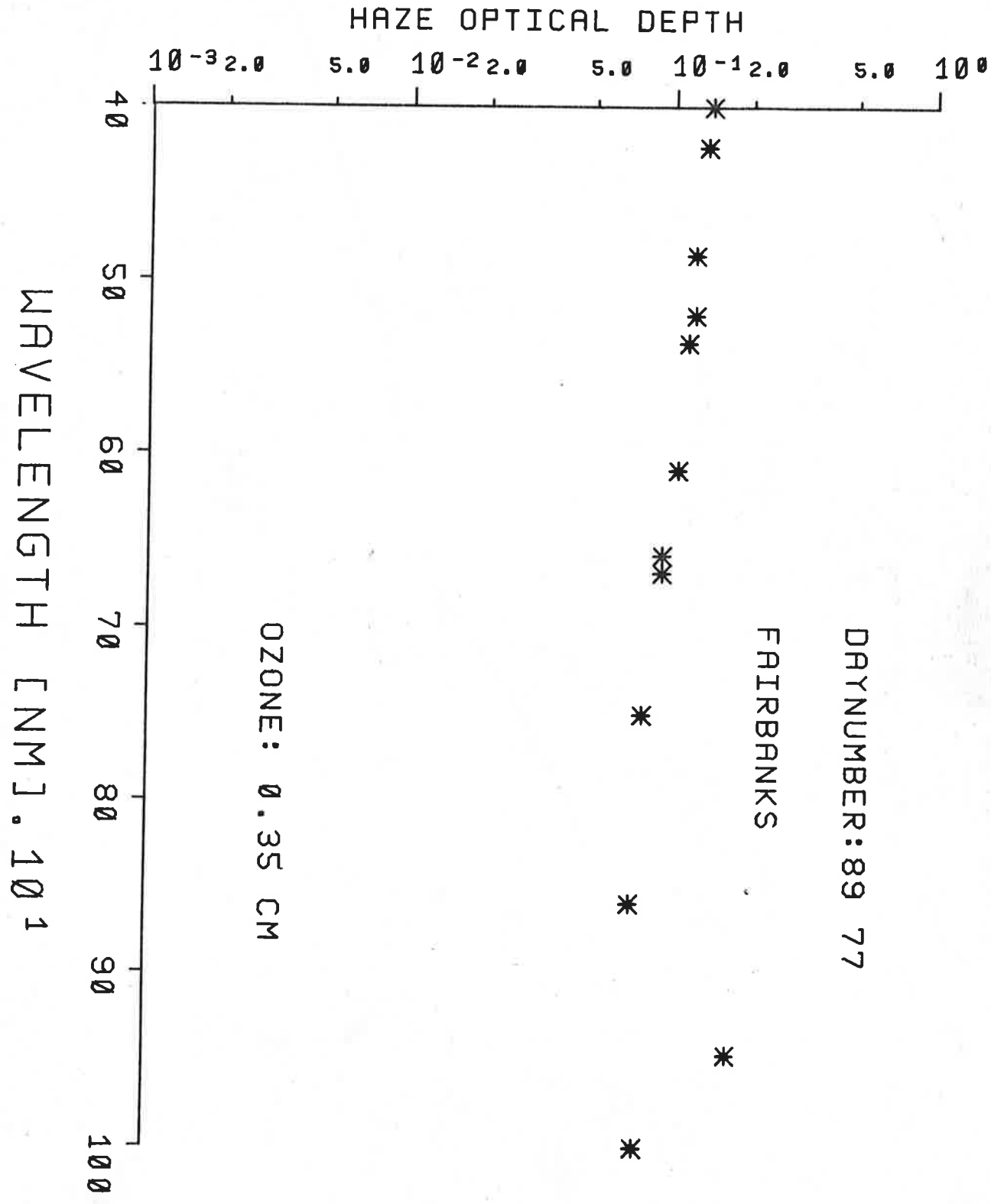

HAZE OPTICAL DEPTH
10-3 2.0 5.0 10-2 2.0 5.0 10-1 2.0 5.0 100
40
50
60
70
80
90
100
WAVELENGTH [NM].101
OZONE: 0.35 CM
FAIRBANKS
DAYNUMBER:89 77

Fig. 1:

IDENTIFICATION OF SOURCE AND ALTITUDE REGION OF ARCTIC AIR POLLUTION BY OBSERVATION OF GASEOUS COMPONENTS USING ABSORPTION SPECTROSCOPY

Charles Deehr, Geophysical Institute of the University of Alaska, Fairbanks

The measurement of gaseous components of arctic air pollution requires baseline measurements of very low concentrations of background constituents. One of the most sensitive methods makes use of the characteristic absorption of visible light by species such as O_3, NO_x, ClO_x, NH_2, OH and SO_x. At the Geophysical Institute, a wavelength scanning grating spectrometer with associated mini-computer designed for auroral studies, has been used to detect these species in the atmospheres of Earth, Jupiter, and Venus. Subtracting the wavelength scan made of the sun or moon high in the sky from that made low in the sky, leaves a measure of the height-integrated amount of the species of interest due to the different path length in the atmosphere.

Measurements in Alaska of atmospheric NO_2 using the 4500 Å wavelength region absorption bands are in agreement with the findings of Noxon (1975) who has observed a low stratospheric concentration poleward of 50° latitude in winter, increasing in the spring to levels found near the equator. Using the method in twilight allows the separation of the stratospheric from the tropospheric components. The latter concentration is found to be very small in the unpolluted Arctic.

Atmospheric NO_2 results from combustion processes, is self-regenerative to a certain extent (and therefore relatively long-lived), and can be observed in the stratosphere and the troposphere, separately. It is therefore proposed that NO_2

observations be included as a part of the Arctic air pollution network as a possible means of identifying the source of the pollution events and the altitude regime. Initial measurements could be made using existing equipment in Alaska and at a recently proposed station on Spitsbergen. The system is such that other species could be monitored if necessary to identify different sources of pollution, and a great advantage is that the measurements are almost independent of cloud cover.

REFERENCE

Noxon, J.F., Nitrogen Dioxide in the Stratosphere and Troposphere Measured by Ground-Based Absorption Spectroscopy. Science, 189, 547 (1975)

STUDY OF ELEMENTAL COMPOSITION ON DIFFERENT SIZE FACTORS IN AN ARCTIC AEROSOL

Hans Lannefors, Lund Institute of Technology

BACKGROUND

A number of sampling stations are operated both in urban and rural areas of Sweden. Cascade impactors of the Batelle Type are used to fractionate the aerosol into 5 logarithmtically equidistant intervals from 0.25-0.50 µm to 4-8 µm aero-dynamic particle diameter.

In analysing 24h samples from one of these sites during the first 5 months of 1976 and classifying the samples according to the length and direction of their air-mass trajectory, large differences were observed between classes. Comparing for example air masses coming in from the north with those from the west, the latter gives concentrations which are higher by a factor of 5-20 for most elements measured (sulphur and heavier). Comparison of the concentrations in the northern air-masses with values observed by K. Rahn in the north- west territories of Canada, shows roughly the same concentration level.

SAMPLING AND ANALYSES FACILITIES

Proton induced X-ray emission offers low detection limits and rapid analysis of about 20 elements from sulphur and up. Special samplers have been developed for this technique and a suitable 2-stage impactor with cut-off diameters of 2 µm and 0.5 µm has recently been developed. Unfortunately, there are still problems in finding a suitable back up filter which is clean, thin and has a flow rate which is high enough. Estimated detection limits for each stage of this sampler (24h sample) and a comparison with measured concentrations at the South Pole are given on next page.

ng/m^3	PIXE 2-stage sampler	SOUTH POLE Zoller et al.
S	0.3	-
Cl	0.1	-
K	0.06	0.14 - 0.5
Ca	0.03	0.15 - 1.1
Ti	0.02	-
V	0.008	0.0006 - 0.0025
Cr	0.008	0.0025 - 0.010
Mu	0.006	0.004 - 0.018
Fe	0.006	0.51 - 1.19
Ni	0.008	-
Cu	0.008	0.025 - 0.064
Zu	0.01	0.018 - 0.051
Pb	0.06	0.19 - 1.2

PROPOSED PROJECT

A preliminary study of the elemental composition on different size fractions of aerosols at Spitsbergen is planned. The project will include sampling with total filters, both 2 and 6-stage impactors to see which is the more suitable in this region. Samples of different duration will be collected.

Information from this study will serve as a basis for selection of suitable sampling devices in conjunction with PIXE in future extended measurements. It will also provide information on the elemental composition of the air at the sampling site during the study. From these data, together with meteorological data, some conclusions on transportation, local contamination etc... could possibly be made. Unfortunately, the financiation of this programme is still very uncertain.

CANADIAN INTEREST IN ARCTIC SAMPLING NETWORK

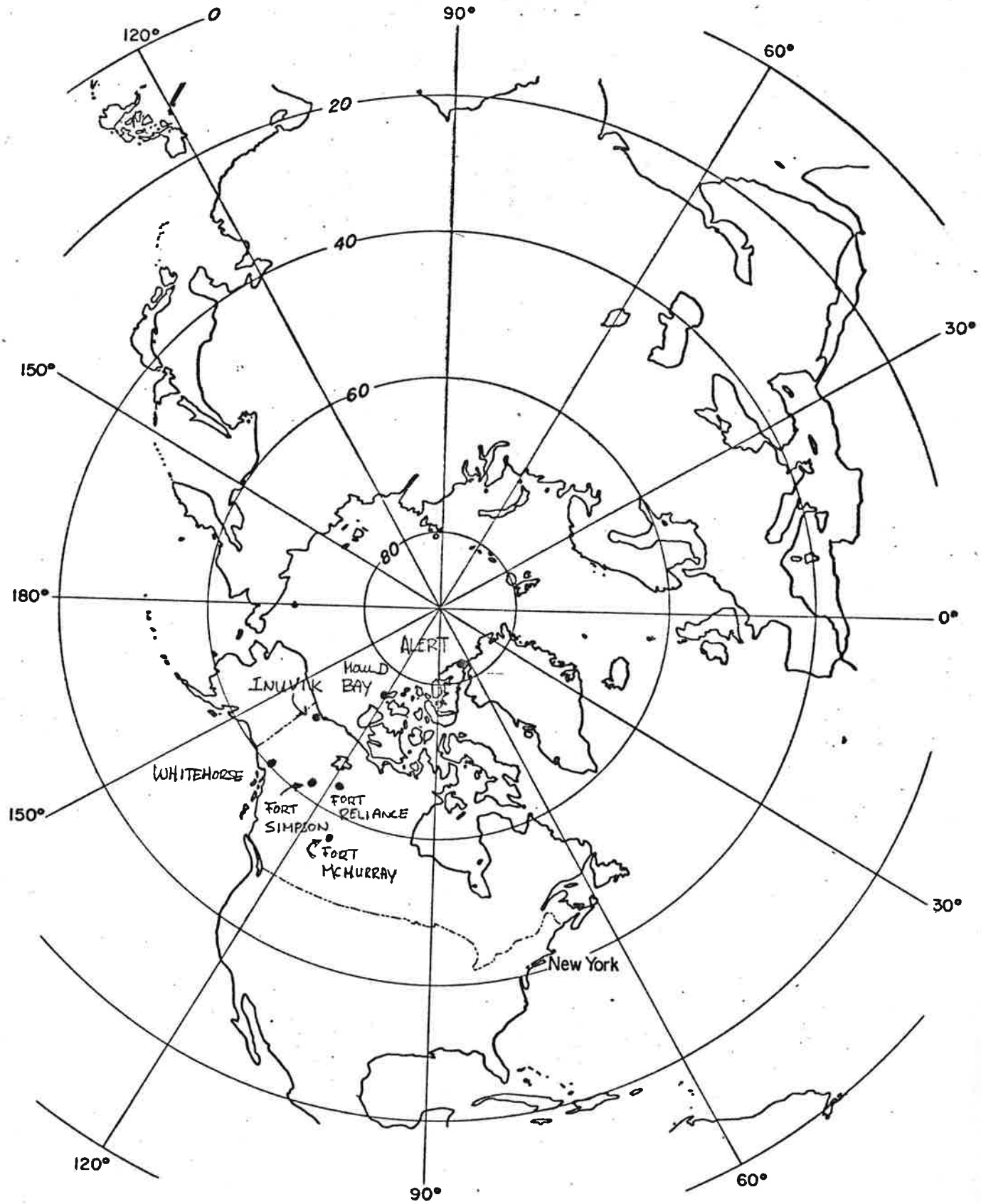
D.M. Whelpdale, Environment Canada, Downsview, Ontario

Most research and monitoring activity in the Canadian Arctic related to background air quality is in connection with the WMO Background Air Pollution Network. Monthly precipitation chemistry samples are collected at the Fort Simpson and Mould Bay regional stations. Turbidity is measured at Fort Simpson.

Three additional precipitation chemistry stations have recently begun operation north of 60°N, at Whitehorse, Inuvik and Fort Reliance. A sampling programme at Fort McMurray in northern Alberta for background aerosol composition has been started and will continue for three years.

Canada has an interest in participating in the proposed aerosol sampling programme in the Arctic. Aerosol composition measurements would contribute directly to the assessment of a site for a baseline station in the WMO Background Air Pollution Network, and to the eventual measurement programme at such a site. In addition, aerosol composition measurements would be useful supporting information for Arctic lichen studies and for background air chemistry measurements made in other parts of the country.

A 2-year assessment is currently underway (July 1975 - July 1977) to determine the suitability of Alert as a WMO baseline station site. Continuous CO_2 measurements and Aitken nuclei counting have been carried out during an initial investigation of the site, and CO_2 flask samples are collected there on a regular basis. If the suitability of Alert is confirmed at the end of summer 1977, an intensive field sampling programme will be undertaken during summer 1978 to identify the optimum sampling location of Alert. Pending the necessary approval and funding, we would propose to incorporate an aerosol composition sampling programme (as suggested by K. Rahn) into the Canadian programme at Alert.


90°
120°
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60°
20
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ALERT
INUVIK
BAY
WHITEHORSE
FORT
SIMPSON
FORT
RELIANCE
FORT
McMURRAY
150°
New York
30°
120°
90°
60°

AEROSOL CONCENTRATIONS IN THE UNITED KINGDOM AND RADIOACTIVE FALLOUT AS AN ATMOSPHERIC TRACER

D.H. Peirson, AERE, Harwell

Atmospheric trace elements in the United Kingdom

In Fig. 1 are shown the positions of a number of stations set up in 1972 to establish non-urban base-lines and to study interaction between air, rain and deposition. Concentrations in air, rain and dry deposition are sampled continuously.

Analysis is mainly by neutron activation, but also X-ray fluorescence, atomic absorption and chemical methods are used.

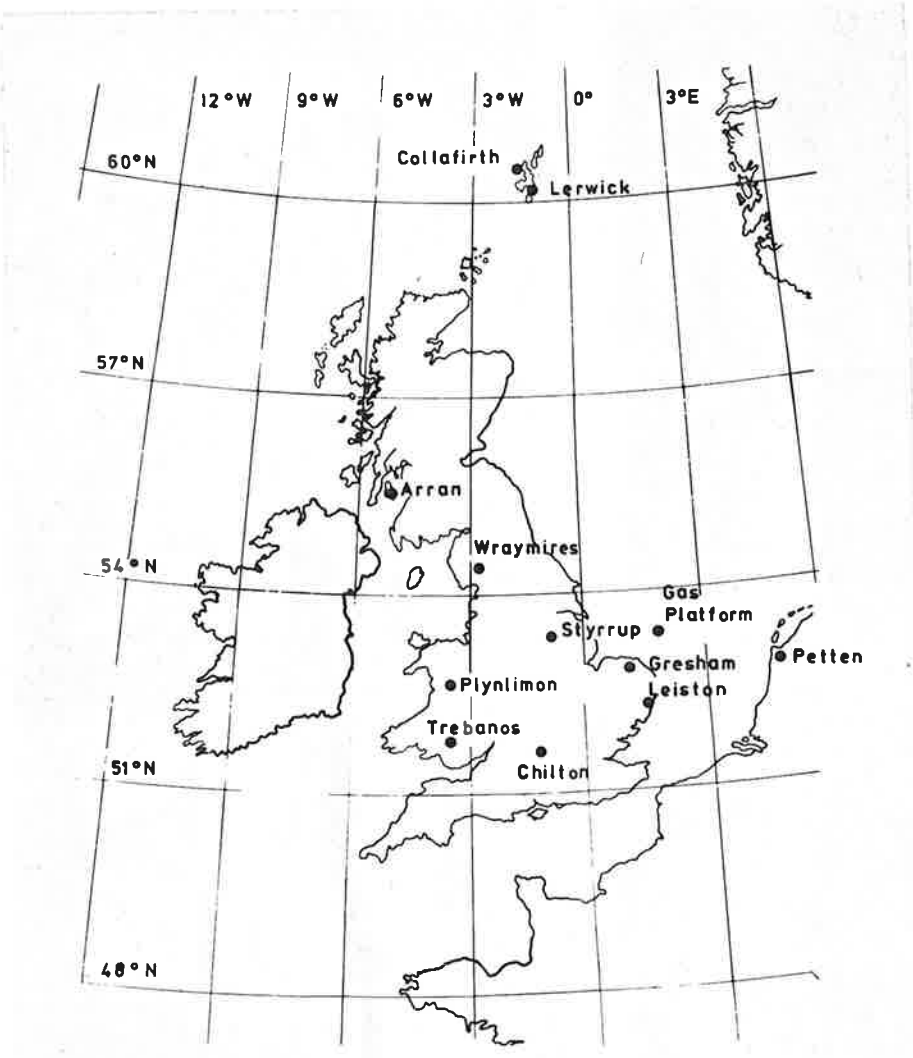


FIG. 1 LOCATION OF SAMPLING STATIONS

(note Collafirth and Lerwick)

Table 1 Elemental concentrations in air (ng per kg air) January–December 1972

Element	Chilton Berks.	*Leiston Suffolk	Lerwick Shetland Is	Plynlimon Montgoms.	Styrrup Notts.	Trebanos Glamorgs.	Wraymires Lancs.	Average soil (ref. 5) (p.p.m.)
Na	760	990	1,900	800	900	1,000	540	6,300
Al	270	230	58	115	640	280	96	71,000
Cl	2,100	2,000	3,100	1,350	4,100	2,300	1,050	100
Ca	<610	<410	<550	<570	<1,100	<550	<260	13,700
Sc	0.065	0.058	0.014	0.029	0.18	0.102	0.029	7
V	14	11	2.3	4.2	21	14	5.0	100
Cr	4.4	7.5	1.1	2.0	17	9.6	1.5	100
Mn	20	20	3.1	9.0	47	18	7.8	850
Fe	310	340	67	140	940	430	140	38,000
Co	0.35	0.37	0.066	0.20	0.76	8.5	0.11	8
Ni	4.5	4.1	2.0	3.1	8.8	66	2.8	40
Cu	13	<9	<3	11	34	29	<6	20
Zn	155	160	39	76	340	190	56	50
As	5.1	4.9	1.9	2.0	24	7.0	2.7	6
Se	1.2	1.3	0.41	0.44	3.2	1.8	0.52	0.2
Br	39	31	13	11	130	40	16	5
Rb	<4	<3	<0.6	<1	<12	<8	<1	100
Cd	<27	<11	<7	<7	<34	<22	<16	0.06
In	<0.4	<0.3	<0.1	<0.2	<0.9	<1	<0.1	—
Sb	2.1	2.8	0.51	0.72	5.9	2.1	1.2	~6
I	<2	<1	<0.7	<2	<4	<4	<2	5
Cs	0.23	0.31	0.05	0.09	0.59	0.31	0.10	6
La	<0.3	<0.1	<0.3	<0.2	<0.6	<0.7	<0.7	30
Ce	0.36	0.32	0.07	0.14	0.70	0.50	0.15	50
W	<0.6	<0.5	<0.6	<0.3	<2	<0.9	<0.9	1
Au	<0.02	<0.01	<0.01	<0.02	<0.08	<0.04	<0.01	—
Hg	<0.3	<0.2	<0.04	<0.06	<0.4	<0.4	<0.1	0.03
Pb	130	110	29	43	330	190	56	10
Th	0.068	0.046	0.026	<0.02	0.12	<0.1	0.017	5

* February–December 1972
No adjustments have been made for filter efficiency[2].

Table 1 shows average concentrations in 1972 at seven non-urban sites. The range of values for (non-maritime) elements span one order of magnitude or more. The variation is much less if elements are referred to a single element (say Sc). If then the ratio to Sc in air is normalised to the same ratio in average soil, this gives "enrichment factors" which separate elements into two classes "soil-derived" and industrial (or "anthropogenic"). Some anomalies are noted at Trebanos, see Fig. 2.

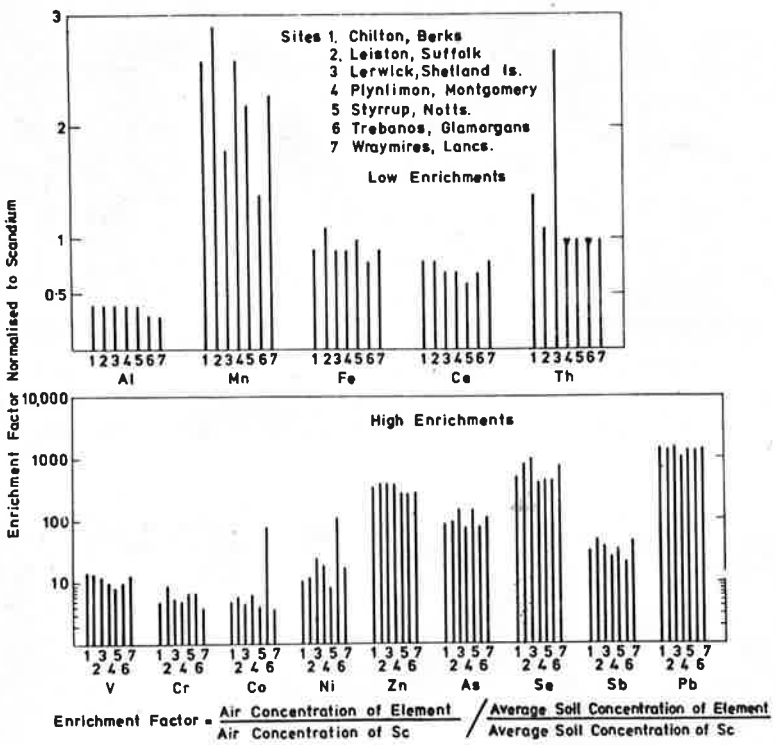


FIG. 2 AIR PARTICULATE ENRICHMENT FACTORS (1972)

Fig. 3 shows that the enrichment factor decreases with dry deposition velocity (rate of dry deposition/air concentration). The dry deposition velocity is related to the particle size (at Chilton, 0.5 cm/sec ≡ 1 μm MMD)

These findings are significant with regard to origin and behaviour of atmospheric trace elements in the northern temporate latitude band (cf. Pretoria).

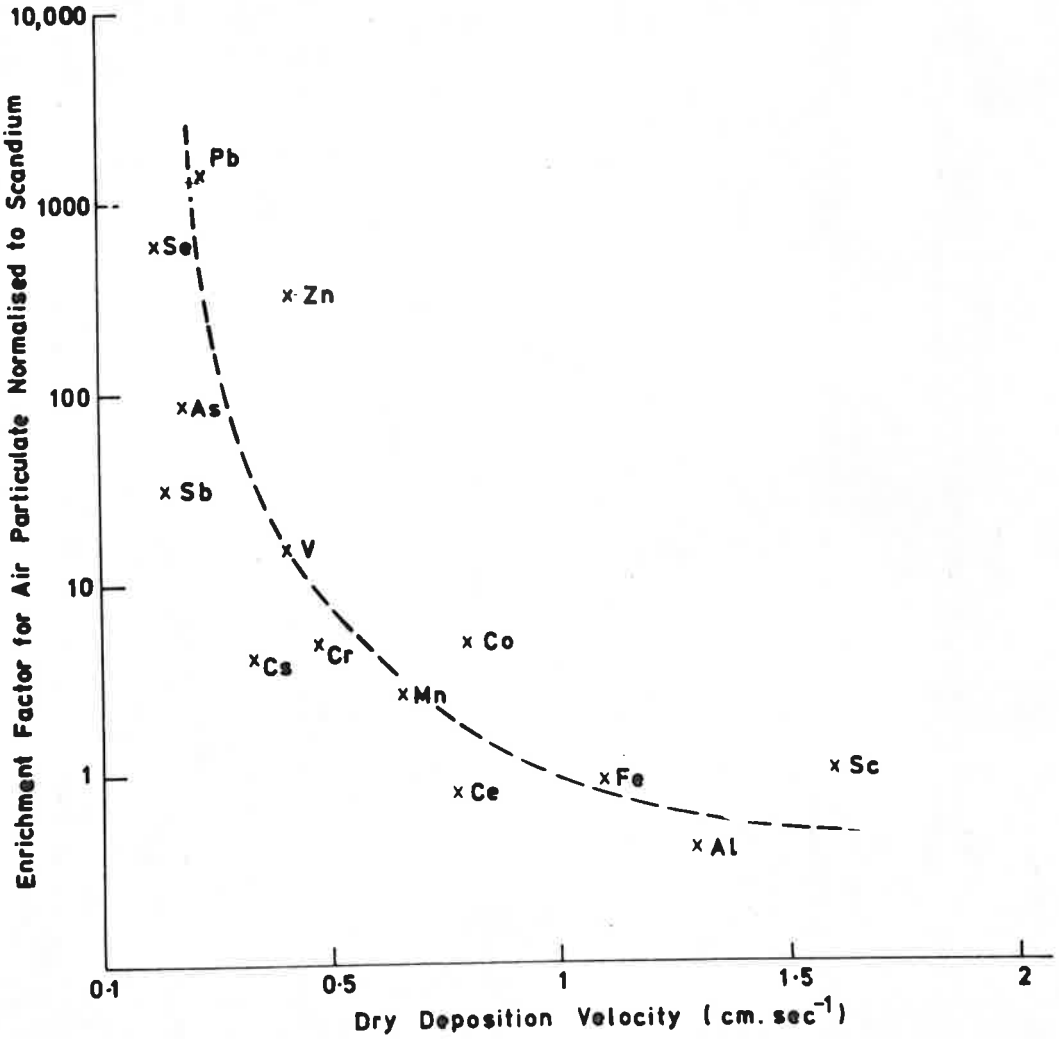


FIG. 3 ENRICHMENT FACTOR AND DRY DEPOSITION VELOCITY AT CHILTON (BERKS) 1972

REFERENCES: Nature 251, 675 (1974)
AERE-R 7669 (Cawse 1974).

Radioactive fallout: stratospheric transport

The seasonal variations of the air concentrations of Cs^{137} in Fig. 4 is evidence for stratospheric transport mechanisms;

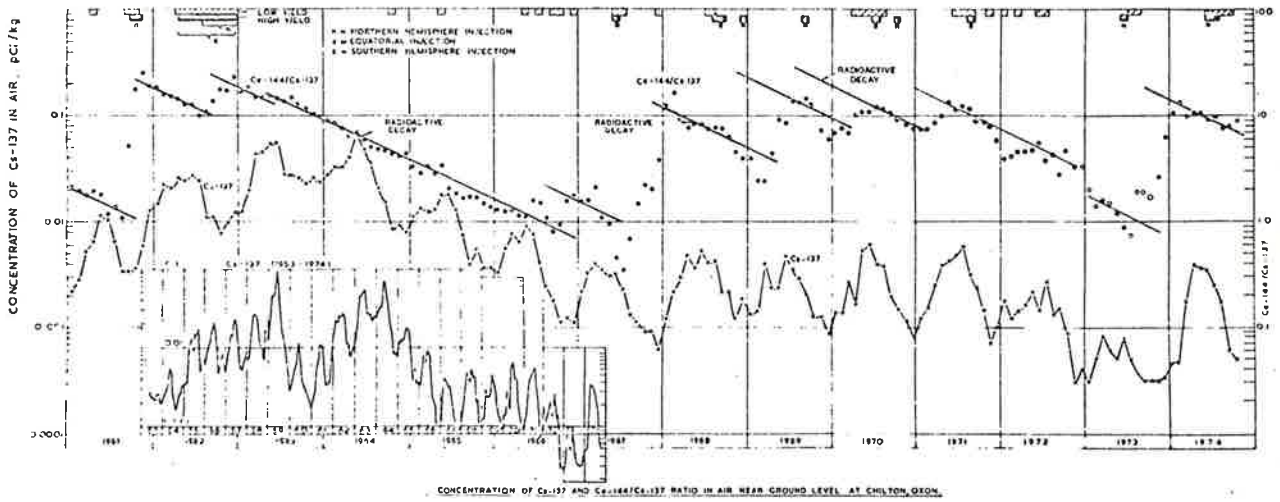
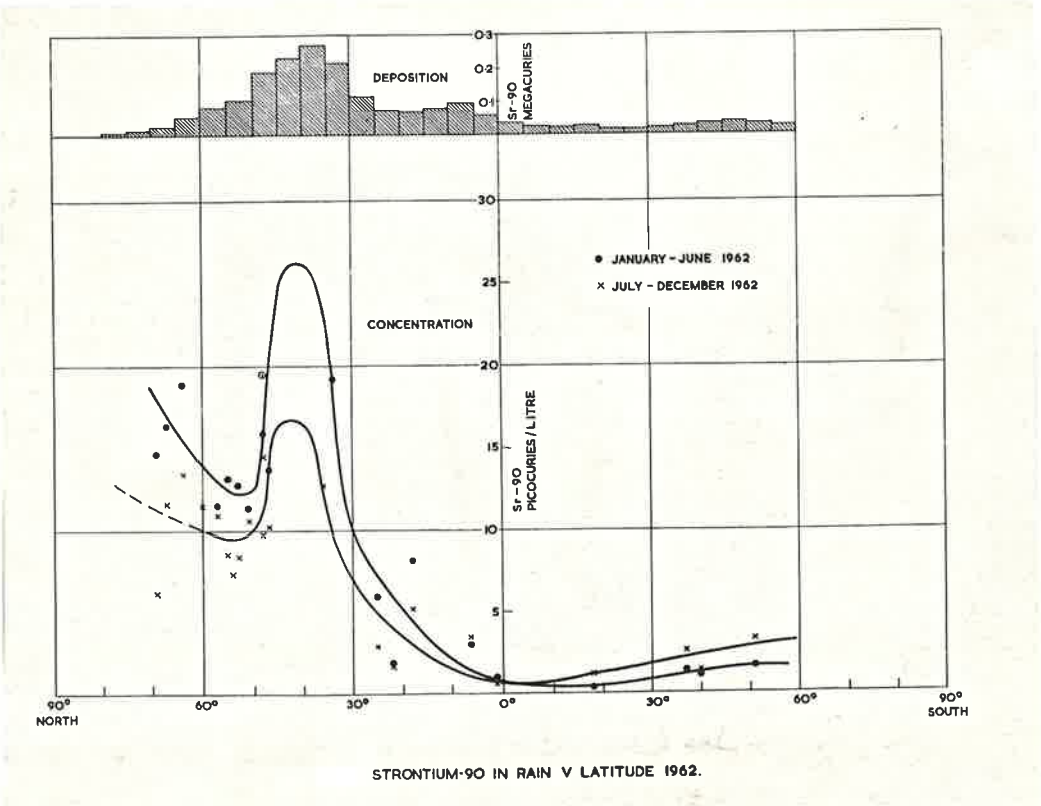


Fig. 4: There is a spring peak each year in the ground level air concentration, independent of the weapon testing calendar.



Further, Fig. 5 shows that the latitudinal concentration of Sr-90 in rain is retained in the hemisphere of origin, as evident from the peak at mid-latitudes.

The atmospheric model includes an injection through the tropopause, caused by a sudden subsidence into the lower stratosphere in mid-winter, subsequent transfer to troposphere through the tropopause, preferentially through the gap. The circulation (or diffusion) is presumably completed by a rise of tropospheric air through the equatorial tropopause.

Radioactive fallout: tropospheric trajectories

It is possible to trace the radioactivity inserted into or remaining in the troposphere by trajectories.

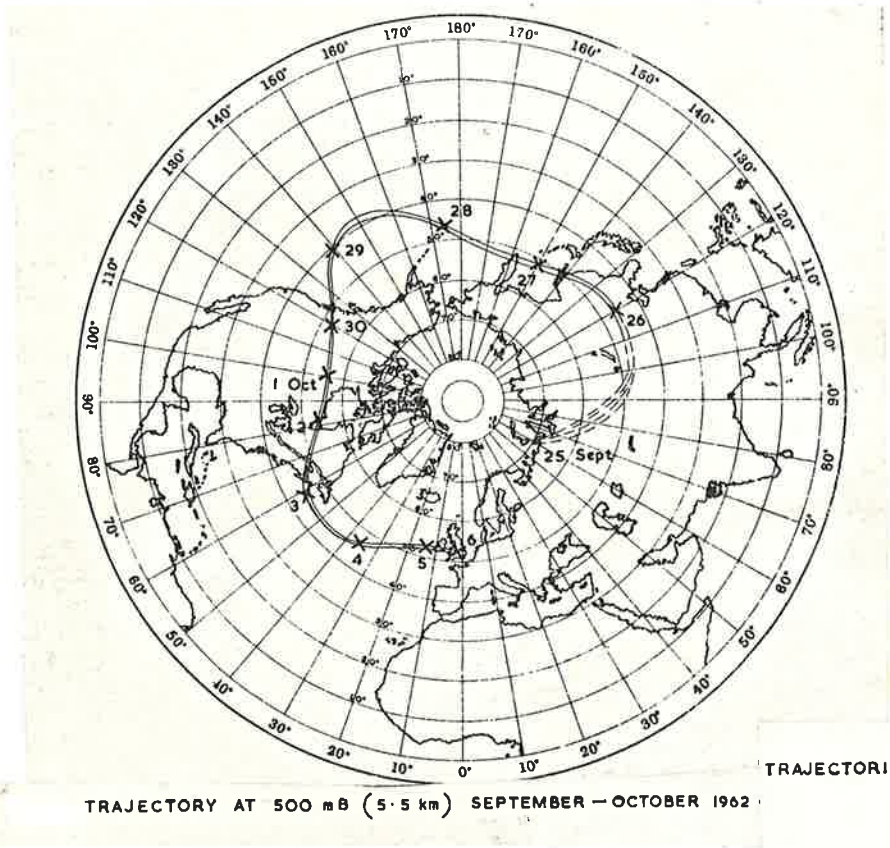


Fig. 6: Conventional trajectory in mid-troposphere

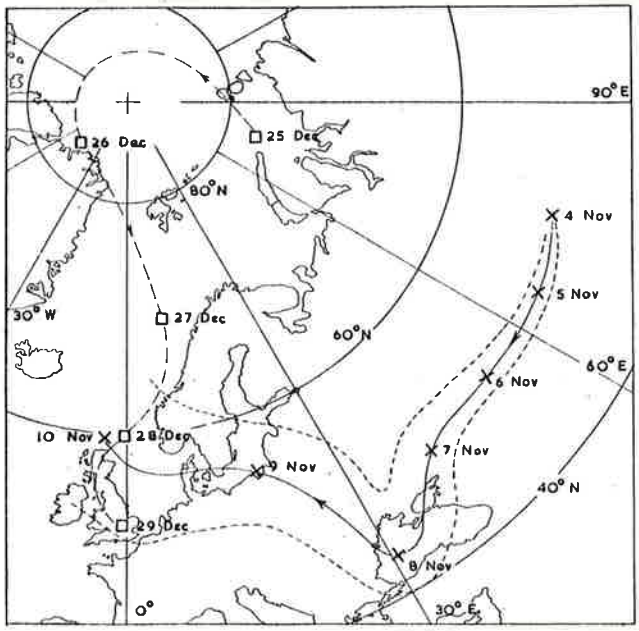


Fig. 7:
Shorter Trajectories

TRAJECTORIES □———□ 500 mB (5·5 Km) 25 - 29 DEC. 1962
×———× < 2·5 Km 4 — 10 NOV. 1962
--------- ROUGH INDICATION OF SPREAD

By examining the observations of radioactive fallout, it is possible to obtain a qualitative impression of the manner in which aerosol from populated areas can reach the Arctic. Possible mechanismes are the ascent to the stratosphere (convection, turbulent diffusion) and then redistribution on a global scale, or by more local deviations from the prevailing westerly circulation in the mid-troposphere.

REFERENCE: Nature 205, 433 (1965).

STEINAR LARSSEN

MEASUREMENTS OF ELEMENTAL CONCENTRATIONS IN AEROSOLS AT NY ÅLESUND, SPITSBERGEN

Total suspended particulates (TSP) has been sampled at Ny Ålesund at Spitsbergen $\sim 79^{\circ}$N since November 1973. The TSP has been collected on a cellulose fiber filter (Whatman 41) by means of a high-volume sampler with an air flow of approximately 350 l/min.The sample intake and the filter was positioned at approximately 10 metres above ground level. In the period November 1973-November 1974, weekly samples of the TSP was obtained.

The table shows some results from elemental analysis of 33 of the filters, from winter and summer periods. Determination of the ions was done after leaching filter segments in distilled water. Pb and Cd were determined by atomic absorption analysis. The other elements were determined by neutron activation analysis at the Institute of Atomic Energy at Kjeller, Norway.

It is apparent that the concentrations of all presented elements are significantly higher in the winter period than during summer, as is also most often the case in regions of lower latitudes more directly affected by anthropogenic pollution. Within each period, there is a considerable spread in weekly mean concentrations, the maximum concentration being typically an order of magnitude higher than the minimum.

Ny Ålesund is a research station operated the year round. There are local sources of pollution, the effect of which on the samples is not known. Presently, the sampling is sector controlled to minimize the possible effect of local sources.

A study of the topographic maps of the 850 mb pressure surface reveals that filters with maximum concentrations of several elements were exposed in periods when transport of polluted air from lower latitudes was probable. This occured at three instances

within the year in question, two with probable transport from Europe, one with probable transport from the U.S. A more accurate trajectory analysis will show the actual pathways of the air masses during these periods.

	Elemental concentrations					
	WINTER 4.11.73 - 1.4.74			SUMMER 6.5.74 - 12.8.74		
ng/m^3	Mean	Max	Min	Mean	Max	Min
Al	43	81	16	<17	42	<5
Na	758	2016	168	266	452	137
Cl	606	2622	1.7	100	403	3
Mn	.79	2.8	.07	<.50	1.2	<.2
V	.59	1.47	.15	<.15	.40	<.10
Pb	4.9	28.3	.86	.65	1.96	.15
Cd	.10	.24	.02	.019	.052	.007
SO_4	1836	3200	990	880	1880	380
NO_3	116	350	30	47	150	<4
NH_4	100	270	10	63	214	4

Weekly TSP samples, Ny Ålesund, Spitsbergen.

ANTON ELIASSEN

OBSERVED HIGH CONCENTRATIONS OF PARTICULATE SULPHATE IN ICELAND, RELATED TO AIR TRAJECTORIES

As a part of the measurement programme under the OECD project "Long Range Transport of Air Pollutants", a sampling station was located at Rjupnahæd, at about 8 km SE from Reykjavik, Iceland. The available data include daily mean values of particulate sulphate for a period of 33 months (1004 days) starting in August 1972. The mean value for the complete measurement period was 1.23 $\mu g/m^3$ as SO_4. There are 28 days with observed concentrations of 5.0 $\mu g/m^3$ or higher.

The 28 cases with high measured values may be related to air trajectories arriving at Rjupnahæd in the middle of the daily sampling period. The trajectories used for this purpose were calculated from observed winds in the 850 mb surface. In the Atlantic Ocean, where wind observations are scarce, they were completed with values of a quasi-geostropic balanced wind calculated by the Norwegian Meteorological Institute.

The 28 trajectories for the days with high measured values of particulate sulphate were subjectively allocated to 3 transport sectors. Fig. 1 shows the sectors, and the number of trajectories allocated to each sector. No trajectories were allocated to the sector facing North to East. Considering the prevailing westerly winds a high proportion (18/28) of the trajectories were allocated to the sector facing southeast. This suggests that in many cases the high observed values of particulate sulphate at Rjupnahæd can be explained by long-range transport of sulphur from the industrialised areas of Europe.

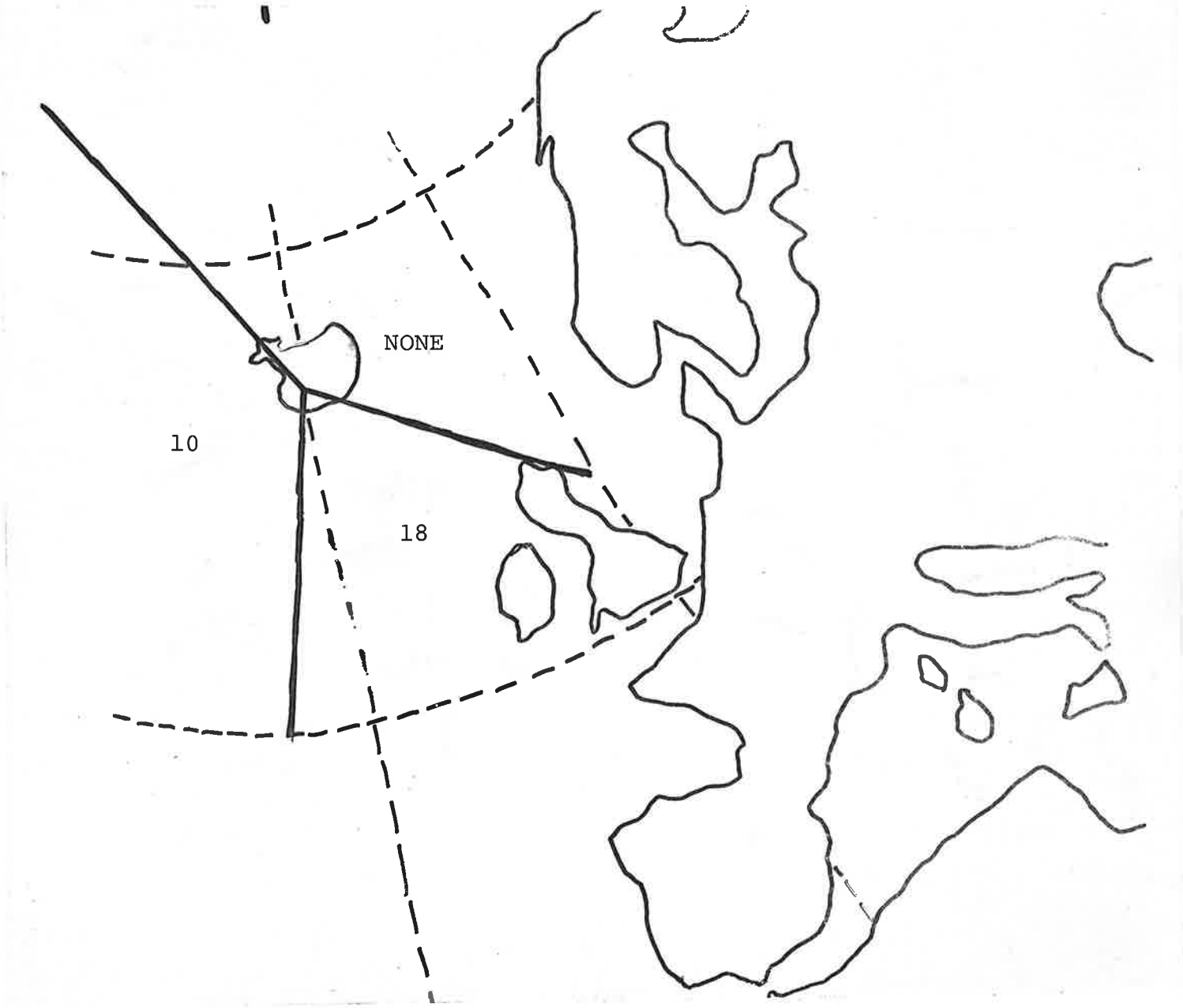


Fig.1: The three transport sectors, and the number of trajectories allocated to each sector, for days with high observed values of particulate sulphate at Rjupnahæd.

11.5.1977

APPENDIX

CONFERENCE FOR A STUDY OF ARCTIC AEROSOLS

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OPPDRAGSGIVER NILU/U.S. Office of Naval Research		
3 STIKKORD (á maks.20 anslag) Aerosoler | Arktis		

REFERAT (maks. 300 anslag, 5-10 linjer)
Rapport fra et arbeidsmøte om planlegging av forskningsprogram for å undersøke omfanget og betydningen av den atmosfæriske tilførsel av luftforurensninger, og støv fra naturlige kilder, til Arktis. Med sammendrag av faglige innlegg.

TITLE Sources and significance of natural and man-made aerosols in the Arctic

ABSTRACT (max. 300 characters, 5-10 lines)
Report of a workshop meeting concerned with planning of a research programme to investigate the extent and significance of ingressing natural and man-made aerosols to the Arctic. With summaries of presentations.

**Kategorier: Åpen - kan bestilles fra NILU A
Må bestilles gjennom oppdragsgiver B
Kan ikke utleveres C