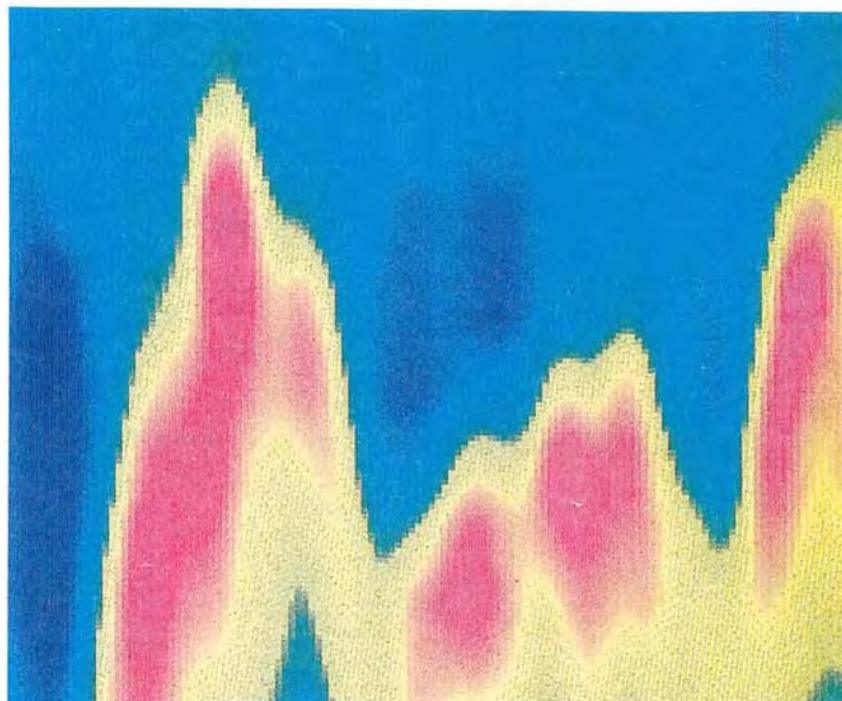


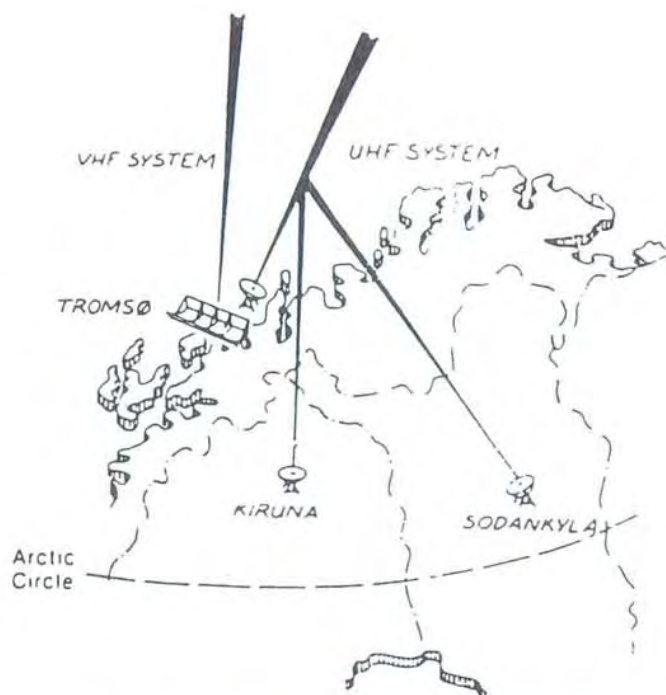


E I S C A T

EUROPEAN INCOHERENT SCATTER SCIENTIFIC
ASSOCIATION

ANNUAL REPORT 1992

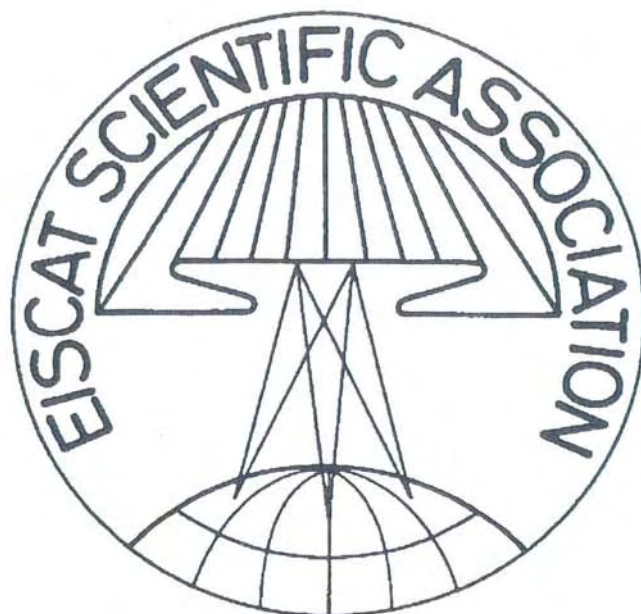
S-981 28 KIRUNA, SWEDEN



The EISCAT Radar Systems - Operating Parameters 1992

	UHF Radar	VHF Radar
Centre operating frequency:	931.5 MHz	224.0 MHz
Tuneable bandwidth:	8 MHz	3 MHz
Pulse peak power:	1.5 MW	2 x 1.5 MW
Average power:	280 kW	2 x 140 kW
Pulse duration:	1 μ s - 10 ms (phase/freq coded)	1 μ s - 1 ms (phase/freq coded)
Minimum pulse interval:	1 ms	1 ms
Antennas:	Parabolic dishes 32 m diameter	Parabolic cylinder 40 m x 120 m
Feed systems:	Cassegrain	128 crossed dipole line
Gain:	48.1 dB	43.1 dB
Polarization:	Circular (Tromsø) Any (Receiving sites)	Circular, Linear
System Temperature:	90-110 K (Tromsø) 30-35 K (Receiving sites)	250-300 K
Geographic coordinates:		
Tromsø:	69.59° N, 19.23° E	
Kiruna:	67.86° N, 20.44° E	
Sodankylä:	67.36° N, 26.63° E	
Invariant Latitude (Tromsø):	66.26° N	
Geomagnetic Inclination:	77.50° N	
L-shell (Tromsø):	6.17	

The cover illustration shows a colour-coded representation of F-region electron temperature for the period 22:00 to 22:30 UT (along the x-axis) over the latitude range 73°-76° N (along the y-axis) measured by the EISCAT VHF radar on 24 November, 1992. Red depicts regions of highest temperature ($T_e \sim 2000$ K) and indicates structures moving poleward within the cooler ambient plasma (blue, $T_e \sim 1000$ K). These results come from the first operation of experiment CP-4-B, which provides simultaneous observations in two beam directions over the latitude range 73°-80° N for the study of ionospheric convection in the region north of EISCAT. A wider overview of the results from this operation is shown on page 25 of this report.



ANNUAL REPORT 1992

EISCAT, the European Incoherent Scatter Scientific Association, is established to conduct research on the lower, middle and upper atmosphere and ionosphere using the incoherent scatter radar technique. This technique is the most powerful ground-based tool for these research applications. EISCAT is also being used as a coherent scatter radar, for studying instabilities in the ionosphere, as well as for investigating the structure and dynamics of the middle atmosphere and as a diagnostic instrument in ionospheric modification experiments with the Heating facility.

There are seven incoherent scatter radars in the world, and EISCAT operates two of the highest-standard facilities. The experimental sites of EISCAT are located in Scandinavia, north of the Arctic circle. They consist of two independent radar systems (see schematic and operating parameters on the inside of the front cover). A new radar has been decided to be constructed on Svalbard - the EISCAT Svalbard Radar.

The EISCAT UHF radar operates in the 931 MHz band with a peak transmitter power of 1.5 MW and 32 m, fully steerable parabolic dish antennas. The transmitter and one receiver are in Tromsø (Norway). Receiving sites are also located near Kiruna (Sweden) and Sodankylä (Finland), allowing continuous tristatic measurements to be made.

The monostatic VHF radar in Tromsø operates in the 224 MHz band with a peak transmitter power of 2 x 1.5 MW (to be raised to 4 MW) and a 120 m x 40 m parabolic cylinder antenna, which is subdivided into four sectors. It can be steered mechanically in the meridional plane from vertical to 60° north of the zenith; limited east-west steering is also possible using alternative phasing cables.

The basic data measured with the incoherent scatter radar technique are profiles of electron density, electron and ion temperature and ion velocity. Subsequent processing allows a wealth of further parameters, describing the ionosphere and neutral atmosphere, to be derived. A selection of well-designed radar pulse schemes are available to adapt the data-taking routines to many particular phenomena, occurring at altitudes between about 50 km and more than 2000 km. Depending on geophysical conditions, a best time resolution of less than one second and an altitude resolution of a few hundred meters can be achieved, whereas typical resolutions are of the order of minutes and kilometres. Tropospheric and stratospheric measurements are carried out with altitude resolution of some 100 m and 10-sec time resolution.

Operations of approximately 1500 hours each year are distributed equally between Common Programmes (CP) and Special Programmes (SP). At present, seven well-defined Common Programmes are run regularly, for between one and six days, about 20 times each year to provide a data base for long term synoptic studies. Three Unusual Programmes (UP) can be started ad hoc during particular geophysical conditions. A large number of Special Programmes, defined individually by Associate scientists, are run to support national and international studies of both specific and global geophysical phenomena.

The Annual Reports present a summary of EISCAT's operations, developments, scientific results, publications and budget for each year. Further details of the EISCAT system and operation can be found in various EISCAT reports, including an illustrated brochure, which can be obtained from EISCAT Headquarters in Kiruna, Sweden.

The investments and operational costs of EISCAT are shared between:

*Suomen Akatemia, Finland
Centre National de la Recherche Scientifique, France
Max-Planck-Gesellschaft, Federal Republic of Germany
Norges Almenvitenskapelige Forskningsråd, Norway
Naturvetenskapliga Forskningsrådet, Sweden
Science and Engineering Research Council, United Kingdom*

EISCAT ANNUAL REPORT 1992

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Annual Report 1992 of the EISCAT Scientific Association

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Council Chairman's Page

The year 1992 was very important in the history of EISCAT. In November, during its fall meeting in Uppsala, the Council took a major step forward and decided that the Svalbard Radar shall be constructed. According to my notes the exact time was 17:56 on the 12th of November, 1992. This was the culmination of the hard preparatory work that had preceded this meeting.

But that is not the whole story of 1992. We have completed the VHF radar so that we now have two fully operational klystrons. The UHF radar is in very good shape. We also have added the Heating facility to EISCAT instrumentation. The final signing of the take-over document took place during the same Uppsala meeting. And finally, the computer systems are being continuously modernized. All this means that EISCAT has today a very good set of high class equipment which is used for research by scientists from its Associate countries. The results of that research are briefly related in this Annual Report.

All this has been achieved through hard work and great determination by our staff. Even under the pressure to keep EISCAT running for the scientists they have been able to carry out all necessary preparations and design work for the new Svalbard radar. The members of our Long Term Planning group have done their share of the groundwork. During 1992 they met three times, working mainly on financial and administrative problems connected with the Svalbard Radar. Initial financial support by several Associates allowed us to add two new staff positions in the preparatory stage of this project, for which we are very grateful.

The economical situation in many countries is difficult. Severe cuts in research funding are common, big projects are in deep trouble, and some are even cancelled totally. Under these conditions it is very important that there exists an organization, EISCAT, that is able to launch a major new project that will extend our scientific capability into new areas. Our Associates have shown their willingness to invest in the future on a scale that is rare today. Now our staff has a great project to work on and in a few years time the scientists will have new challenging tasks in their hands. Our project has a great symbolic value: there still exist people who are willing to invest in the future of science.

My time as the Council Chairman is over. In retrospect I find it most interesting and in the end rewarding. I am happy that I was given the opportunity to serve EISCAT during such an important period. I would like to thank the whole EISCAT staff for all they have done, the Director for his enthusiasm and great patience, and my colleagues in the Council for excellent co-operation and continuous support. It is clear that a great effort by every participant is needed to complete the ESR and I wish all the best for Professor Asgeir Brekke who will chair the Council during the next two years.

Antti Siivola

Director's View on 1992

The view of the Director on a past year naturally constitutes a selective summary of the standard operation and some highlights, which were seen as important in the progress of the Association. I am very pleased to report on the EISCAT staff's enthusiasm and active involvement in the multiple tasks which were performed to assure reliable operation, together with efficient preparations of new developments, namely the final preparation of the take-over of the Heating facility and in particular the design of the EISCAT Svalbard Radar.

This Director's view will first summarize the operational part of the existing EISCAT systems. The historical development as well as more details of the additional new and major project of the EISCAT Svalbard Radar are laid down in the special part of the introduction following this Director's view on the year 1992.

Another major step forward in the evolution of the EISCAT Scientific Association took place in this year. Following a few years of ideas, thinking, studies, preparations and search for funds, the EISCAT Council decided in November 1992 to begin the construction of the EISCAT Svalbard Radar - the ESR. It is to be noted that the development of the ESR took place in addition to the continuing operation and improvements of the existing EISCAT facilities, consisting of the UHF and the VHF radars. Furthermore, work proceeded on the preparation of the take-over of the Heating facility in Tromsø from the Max-Planck-Institut für Aeronomie. The signing of the corresponding documents was done at the EISCAT Council meeting in November 1992 to transfer this facility on 1 January 1993.

In the year 1992 a total of 1599 hours of operating time were accounted, whereof 776 hours were Common Programmes and 823 hours were Special Programme operations. Several Common and Special Programmes were performed in the dual-radar mode, i.e. the UHF radar and the VHF radar were run simultaneously. This means that the real data records cover more than the accounted hours. A detailed break-up of the operations in 1992 is found on pages 21-23 of this report.

In particular, some of the following experiments were performed: coordinated observations with the UARS, Akebono, Freja and Galileo spacecraft, campaigns in coordination with optical and radar aurora experiments, convection, Joule heating, ionospheric blobs studies, plasma line observations using chirp techniques and tracking techniques to study field-aligned currents, coherent echoes on VHF, interferometry of polar mesosphere summer echoes, gyro-line observations, experiments to calibrate ionospheric tomography, and new troposphere-stratosphere observations. Further improved high altitude observations were performed, proving that the VHF system allows detection of signals up to altitudes above 2000 km. A first Heating test campaign was successfully carried out by EISCAT in November 1992.

A particularly long Common Programme operation took place at the end of July and the beginning of August 1992 to participate in the Mesosphere-Lower Thermosphere Coupling Study (MLTCS) of the international STEP program. An example of results from this six-day reliable operation, using alternating codes in the Common Programme, is shown in the colour graphs in Fig. 1, which were obtained with a new data visualization routine. The archiving of the acquired data is now on Exabyte and can also be provided on DAT medium if required. As usual, the analyzed data of Common Programmes were distributed to the Associates and the World Day data to the NCAR Data Center. A special summary of the Common Programme data analysis is given later in this Annual Report (page 24).

The operations computing system, which consisted so far of Norsk Data (ND) computers, was expanded by SUN Sparc-2 workstations. This expansion is firstly regarded as an initial step into a refurbishing of the whole EISCAT computer system, and it secondly constitutes a foundation for the design of the EISCAT Svalbard Radar computing hardware and software, which will be mostly designed in-house. A block diagram of the EISCAT operations computing system, as it was configured at the end of 1992, is shown on Figure 2. It is particularly noted that DMA applications are provided between the ND and the SUN computers, which allows fast experimental data transfer and further processing in the SUN workstations. In addition to this system, a series of partially networked PCs exist, and a further extension by adding more workstations and improved networking was planned for the next year in order to provide adequate tools for software development for the EISCAT Svalbard Radar.

The UHF system was in excellent condition and no problems were reported on the spare klystron, which replaced the klystron broken in October 1991 and shipped to Varian for tests. Since it was not recommended to repair this broken klystron, a new klystron was ordered from Varian in 1992 for delivery in 1993.

The UHF antennas are in proper shape, but need permanent attention by monitoring the status of the pintle bearings and the cracks which have been detected in the foundations in recent years. However, there are no signs of critical developments. In September 1992 the water level of the Kitinen river in Sodankylä was raised after completion of the Kurkiaska dam. No effect on the antenna has been observed.

After the body cooling system of the VHF transmitter had been split into two circuits, very successful and almost uninterrupted operation at power levels of 2×1.5 MW was carried out. Testing of 2 ms pulse length operation of the VHF klystrons, which is essential for high altitude observations, was accomplished successfully. Additional klystron body cooling will be necessary to apply full duty cycle. The rebuilt focusing magnet coil-modules of the VHF transmitter performed reliably. The two VHF klystrons can be run either separately (for instance in split-beam experiments) or combined in the phase-lock mode. Since there are limitations with the capacitor bank of the transmitter power supply, which cannot be paralleled in dual mode operation of UHF and VHF radar, the VHF transmitter power is then restricted to 0.9 MW and the UHF transmitter to 1.3 MW. Further dipoles and dummy loads of the VHF antenna feed had been repaired and replaced. The VHF antenna positioning is now under full computer control and position read-back. West-East VHF split beam operation, by manually changing phasing cables, was successfully carried out. Both the UHF transmitter and the VHF transmitter are now monitored and controlled by dedicated PCs, and further local oscillators with GPIB control via EROS are being installed. Investigations to replace the cesium time standards by GPS controlled oscillators were continued in order to meet our stringent requirements.

The shielding of one neighbour's house has effectively eliminated the interference at this place in Ramfjordmoen, Tromsø. Negotiations with another neighbour as well as discussions with some others were still continuing on the interference and radiation matter. However, it is ratified by measurements that EISCAT is well below the compulsory radiation limit in our neighbourhood. Limitation of the VHF antenna pointing to north of the zenith when transmitting has certainly to remain to minimize interference to other neighbours. NMT 900 interference to the EISCAT UHF systems was further improved by installing ultra-low-noise oscillators.



EISCAT Scientific Association

Property of the EISCAT Scientific Association - not for publication
Full data can be obtained through Associate Data Representatives

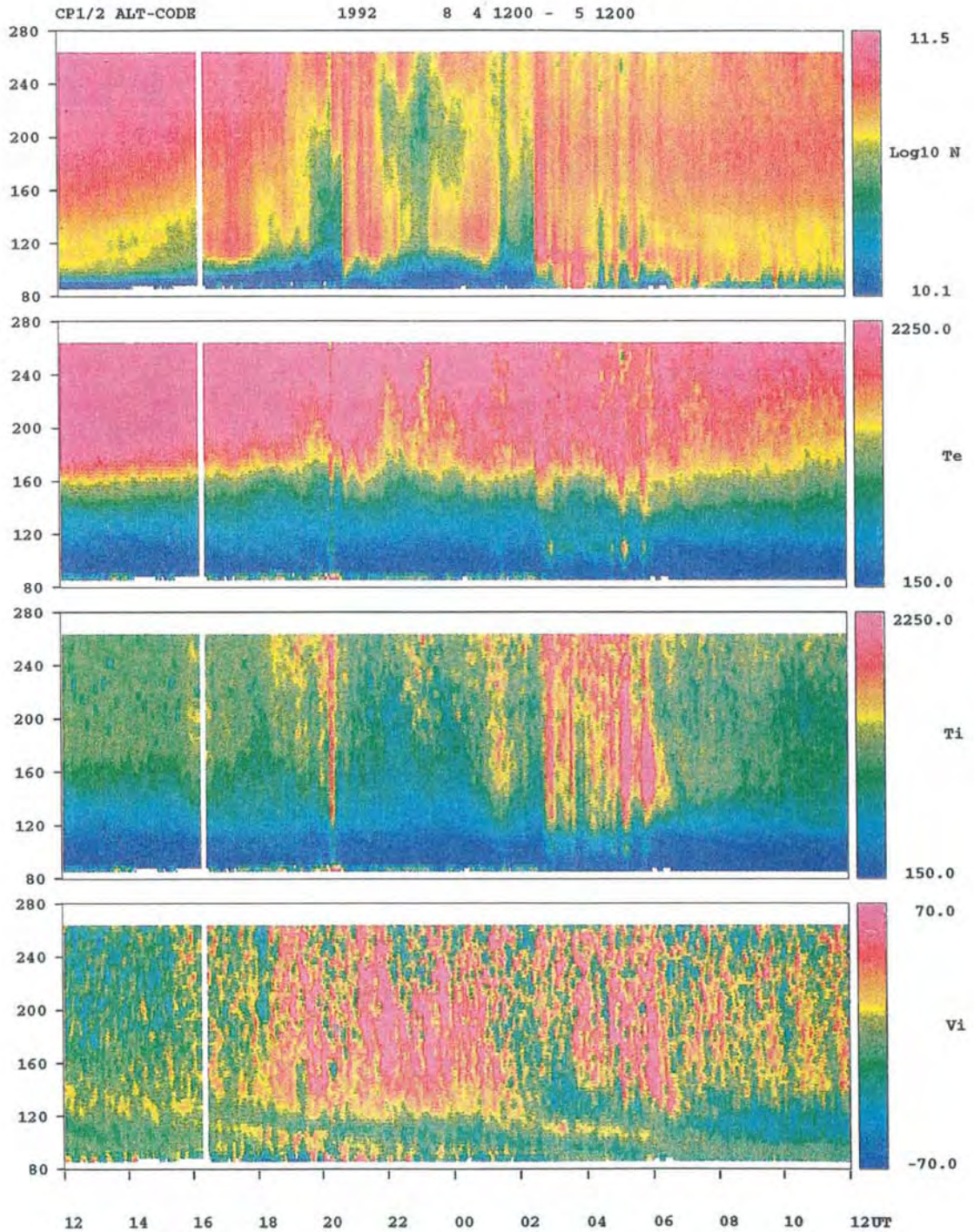


Fig. 1. Visualization of CP-1 alternating code data of electron density, electron temperature, ion temperature and magnetic-field parallel ion velocity measured with the UHF radar on 3-4 August, 1992, during the MLTCS campaign. These results illustrate a range of features of the auroral ionosphere; density enhancements due to particle precipitation, E-region electron heating and F-region ion heating due to electric fields, atmospheric waves and tides.

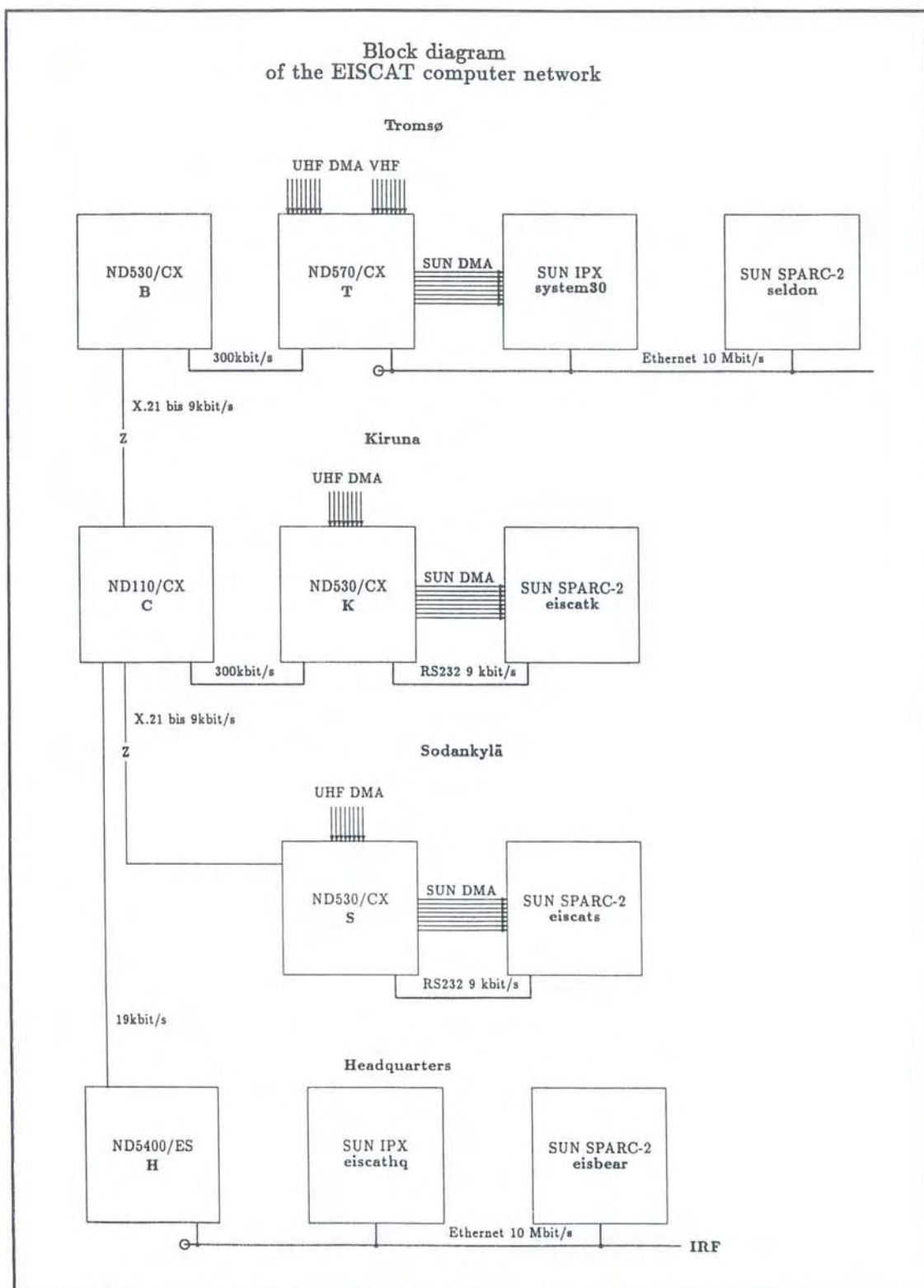


Fig. 2. Expansion of the EISCAT computer system by SUN workstations with DMA connection to the ND computers in 1992.

In general, it can be stated that the UHF system and the VHF system are in very satisfactory condition. The reported events are not regarded as unusual for a facility of this complexity. It was a great challenge for the staff to maintain the excellence of the systems and to work also on the EISCAT Svalbard Radar preparations.

In addition to the common operations and the EISCAT Svalbard Radar work, an enormous variety of meetings took place in this year. In January 1992 a full-week workshop dealing with preparations of specifications of receiver and digital-signal-processing for the EISCAT Svalbard Radar was held in Kiruna, to which representatives from all Associates were invited. Executive and budget meetings took place in February and October 1992. The considerations during these meetings frequently dealt with effects of the ESR preparations on the common EISCAT operation, staffing and budget. In August 1992 formal management meetings for the ESR project were introduced in order to streamline in a most regular way the coordination of the ESR project design and development. By the end of 1992 four ESR Management meetings (MM01 - MM04) were convened with participation of ESR work task persons. In addition to the regular semi-annual Council and Committee meetings also three meetings of the EISCAT Long-Term Planning Group took place, consisting of one Council member of each Associate and the Director. In the beginning of October 1992 the regular Annual Review Meeting (ARM) of the EISCAT staff was held. This year's meeting, which was later in the year than usual due to the ESR preparations, was dominated by the ESR Design Review Meeting, which took place over more than three days preceding the Annual Review Meeting. As a standard, during the ARM the status of operations, developments of the system and budgetary matters are analyzed. The photo in Fig. 3 shows most of the participants of the Annual Review Meeting 1992 in Ylläsjärvi, Finland. The Proceedings of this ARM as well as the ESR-DRM were published by EISCAT Headquarters.



Fig. 3. Annual Review meeting at Ylläsjärvi, Finland, 1-2 October 1992.

Persons from left to right: Roger Jacobsen, Jussi Markkanen, Markku Postila, David Tetenbaum, Stefan Heck, Gurli Hultqvist, Mike Rietveld, Arvid Øvergård, Patrick Guio, Jürgen Röttger, Ernst-Rolf Albrigtsen, Lena Ståhl, Ingemar Wolf, Halvard Boholm, Carmen Kroll, Stephan Buchert, Toivo Iinatti, Unni Pia Løvhaug, Peter Collis, Anna-Liisa Tiuraniemi, Kent-Ove Johansson, Tarmo Laakso, Tony van Eyken. (ARM participants not on the photo: Birger Benjaminsen, Stein Eliassen, Michael Halvorsen, Jim-Arne Hansen, Torill Johansen, Ralf Larsen, Arild Stenberg, Lars-Göran Vanhainen, Gudmund Wannberg. Photograph by Alan Farmer).

The personnel situation and the budget allocations of EISCAT were quite stable in 1992, although a few adjustments had to be regarded. During this year a significant effect of the EISCAT Svalbard Radar preparations became noticeable in the personnel and the budget.

The personnel was allocated to the following places as shown in the table. The total number of EISCAT personnel is 38, whereof three positions were vacant at the end of 1992. On the average about 30 % of the personnel was involved in the preparations for the EISCAT Svalbard Radar (ESR). Two of these positions shown were exclusively available for the EISCAT Svalbard Radar work.

Personnel:	Kiruna Headq.	Kiruna Site	Sodankylä Site	Tromsø Radar	Tromsø Heating	Tromsø ESR	Total
Directing:	2	-	-	1	-	-	3
Scientific:	1	-	1	2	1	-	5
Engineer.:	-	4	3	7	2	1	17
Computing:	1	1	1	1	-	-	4
Admin.etc.:	5	-	-	3	-	1	9
Total:	9	5	5	14	3	2	38

Budget expenses 1992:

Recurrent chapter in MSEK:	5.27	2.34	2.26	6.03	1.03	1.56	18.49
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Total spent in 1992:

Recurrent chapt. (total):	18.96 MSEK	(incl. Council and Committee meetings)
Capital investm. (EISCAT):	2.62 MSEK	(+ 4.94 MSEK total transfer for evolution)
Capital investm. (ESR):	2.05 MSEK	

The last lines in this table show the expenditures for the operations and investments at Headquarters and the sites in million Swedish Crowns (MSEK). Since the personnel was partially working for EISCAT Svalbard Radar preparations, the budget figures shown here include a partial contribution to this new project. About 10 % of the total regular recurrent budget (EISCAT sites and Headquarters without Tromsø ESR) was estimated to be used for this purpose. The first capital investment expenditures occurred in 1992 for the ESR. This ESR capital investment as well as the recurrent expenditures under Tromsø ESR are funded by new money provided by the Associates for the ESR construction. The balance sheet showing the assets, capital, reserves, liability and the break-up of the total recurrent expenditures in personnel, administration and operation of the EISCAT Scientific Association at the end of 1992 is shown at the end of this report.

We all appreciate this healthy personnel and budget development of the EISCAT Scientific Association, which is essential for the operation and evolution of the Association. My thanks are directed to the staff for their enthusiastic collaboration, and the Council and Committees for their continuous support to make this positive development possible. The result of these operations are mirrored in the scientific output from EISCAT, of which a summary follows later in this Annual Report. The support of the Associates' scientists in providing the scientific material and of Peter Collis in editing this report is much appreciated.

Jürgen Röttger

The EISCAT Svalbard Radar: an Evolutionary Step into EISCAT's Future

EISCAT has substantially contributed to studies of the auroral ionosphere and the coupling between the magnetosphere, the ionosphere, the thermosphere, the middle atmosphere and lower atmosphere. The altitude range covered is between about 2 km and more than 2000 km, and the latitude coverage is limited to about 65°N to 75°N. The maximum magnetic invariant latitude that can be reached is about 76°. The ionospheric measurements of EISCAT at these high latitudes are limited due to the low elevation angles of the antennas and the large ranges.

To obtain improved measurements in the high latitude ionosphere in the polar cap, in the magnetospheric cusp region and in the atmospheric region of the Arctic an additional radar station was decided to be set up north of the present EISCAT stations on Spitsbergen, in the archipelago of Svalbard (see Fig. 4 on the following page). This radar is also seen as an essential ground based tool for studies of the cusp/cleft region of the magnetosphere, which are planned to be carried out with the Cluster spacecraft mission of ESA and other ground-based instrumentation.

The EISCAT Svalbard Radar will undoubtedly allow new scientific research of the geo-space coupling to the ionosphere and related plasma-physical processes. Investigations of the Arctic stratosphere and troposphere, which are essential in view of global change and environmental research, will also be added.

In 1990 the EISCAT Council had accepted that the Svalbard Radar represents the next important evolutionary step for the development of the EISCAT facilities. In the report "The EISCAT Svalbard Radar", which was prepared on a decision of the EISCAT Council, details of the scientific rationale, the preliminary design specifications and initial cost estimates for the EISCAT Svalbard Radar were published in 1991.

During the EISCAT Council meeting on 12-13 November 1992 in Uppsala, Sweden, the Council approved the project planning and unanimously decided to begin the construction of the EISCAT Svalbard Radar, which is termed the **ESR**.

The primary specifications of the ESR system were presented and largely frozen at the ESR Design Review Meeting, which took place from 28 September to 1 October 1992 in Ylläsjärvi, Finland. The global system specifications, the management, the personnel and the financing plan were presented to the Council and were generally adopted. In the following one finds the history of major milestones of the ESR planning, a summary of the project management, the personnel and financing concepts and the abridged description of site and instrumentation of the EISCAT Svalbard Radar.

Together with the EISCAT mainland radars in Tromsø, Kiruna and Sodankylä, the EISCAT Svalbard Radar will allow an extensive view of the high latitude region of the Earth's atmospheric environment. It is awaited that this expansion of EISCAT by the EISCAT Svalbard Radar will also provide a focal point for ionospheric and atmospheric research in the auroral, polar and Arctic region.

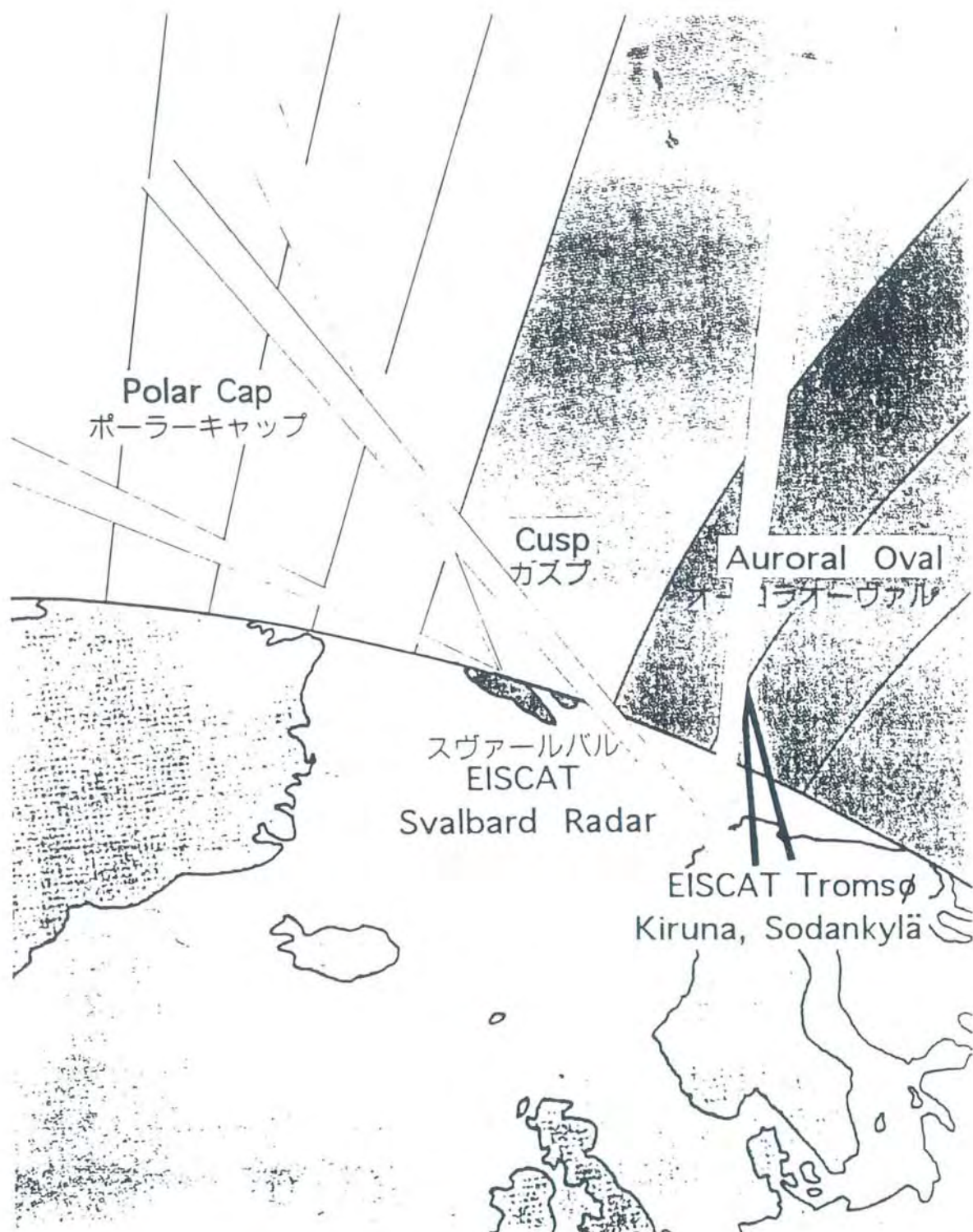


Fig. 4. This schematic shows the locations and selection of possible beam directions of the combination of the EISCAT radar systems in the future. This system is the most unique combination of research radars on the globe and will allow exceptional observations in the polar cap - cusp - auroral oval ionosphere, the coupling with the magnetosphere as well as environmental studies of the Arctic middle and lower atmosphere. The Japanese characters in the figure symbolise the plans in Japan to join the EISCAT Svalbard project.

Some Major Milestones in the Development of the EISCAT Svalbard Radar (ESR) Planning

1989

SERC Ground-Based Plan included a proposal for a major ionospheric and atmospheric radar in the polar cap

UK report on scientific and technical specifications
for a radar on Svalbard
Presentation of this plan to EISCAT

Endorsement of this proposal by EISCAT SAC and Council

1990

May: Installation of the Polar Cap Radar (PCR) Working Group during the EISCAT Council meeting on Svalbard: Aim for 3 MW, 3 antennas

Monthly meetings of this EISCAT PCR Working Group

Antenna Pre-feasibility Study

Oct.: Presentation of draft report to EISCAT Council on scientific goals and design specifications for an ionospheric and atmospheric radar facility on Svalbard

Nov.: EISCAT Council agreement to continue planning in order to meet the Cluster mission in 1995

1991

Continuation of organizational, administrative, management and technical preparations of an EISCAT radar system on Svalbard by EISCAT Executives

Aug.: Issue of the final version of the "Report on the design specifications for an ionospheric and atmospheric radar facility based on the archipelago of Svalbard" (the EISCAT Svalbard Radar Report)

Installation of first extra personnel for the planning of the new radar

Sep.: Technical design specification meeting, discussions on coordination with Japanese plans for a radar on Svalbard

Oct.: First meeting of the Long-Term Planning (LTP) Group of EISCAT Council

Nov.: Council agreement on principal project management plan for the EISCAT Svalbard Radar "ESR"
All EISCAT associates agree at the Council meeting on the continuation of the ESR planning, using existing EISCAT and some new resources

1992

- Jan.:** Meeting on the definition of data acquisition and digital signal processing
- Executive meeting to explore further utilization of EISCAT resources for ESR development
- Feb.:** Second meeting of the LTP Group
- Apr.:** AFC meeting agrees on transmitter amplifier tender action
- Transmitter tender action, antenna studies
Preparations for site, infra-structure, frequency clearance, etc.
- May:** EISCAT Council memorandum on the intention to construct the ESR and consensus to proceed with the preparations necessary to accomplish the phased development of the radar with the objective to reach an agreement to proceed with the construction of the initial phases of the radar at the Council meeting in November 1992 with the aim that the first two phases should be operational during the Cluster space mission.
- July:** Third meeting of LTP Group:
Evaluation of expected funds would allow a minimum initial version of the ESR to be constructed
Receipt of transmitter bids
- Aug.:** First formal ESR Management Meeting MM-01
Announcement of opportunity for antenna(s)
Evaluation of transmitter bids, arrangements for site groundwork
Directions for DSP, control and monitor standards
Recommendation of SCOSTEP
- Sep.:** SAC meeting investigates scientific merits of one-dish and two-dish systems and minimum power
- ESR Design Review Meeting (DRM), Second Management Meeting MM-02
- Oct.:** AFC meeting, Fourth LTP Group meeting
- Nov.:** Third ESR Management Meeting MM-03
EISCAT Council decides to begin the construction of the initial phases of the ESR
Order of transmitter prototype module from Harris Allied in UK
Request for Proposal of the antenna sent out
Announcement of Opportunity for project participation issued to Associates
- Dec.:** Fourth Management Meeting MM-04

The EISCAT Svalbard Radar Project

The EISCAT Svalbard Radar is being built up in several phases and should finally incorporate at least two antennas and a peak power greater than 1 MW. Phases 1 and 2, as determined at the Council meeting in May 1992, consist of one antenna, a 500 kW transmitter and the main infrastructure, such as building etc.

In order to allow proper planning, tracking of critical developments as well as providing a base-line for internal guidance of the project performance a Project Management Plan had been implemented. This initial Project Management Plan for the EISCAT Svalbard Radar consisted of 17 main Work Packages:

- 01 Management and Organization
- 02 System Specifications
- 03 RF Generation (Transmitter)
- 04 Antenna(s) and Receivers (analog)
- 05 Hardware Monitor and Control
- 06 Receiver (digit.), Data Acquisition
- 07 Computing, Software and Basic Data Processing
- 08 Exciter
- 09 Basic Infrastructure
- 10 Logistics
- 11 Communications
- 12 Quality and Reliability Control
- 13 Financial and Business Matters
- 14 On-site Installation
- 15 On-site Performance Analysis
- 16 Transition into Operation
- 17 Operational Maintenance

The work packages have been precisely developed and specified. They are described in more detail in the Baseline Description Document, which was prepared after the ESR Design Review meeting at the end of 1992. A Project Management Plan presents details of milestones, and is included in the Baseline Description Document (BDD). Management Meetings to coordinate the work between the different work packages are regularly held. The milestone schedule, published in the BDD, should allow to begin test operation of the EISCAT Svalbard Radar at the end of 1995.

As noticed from the historical development, the planning for the EISCAT Svalbard Radar has speeded up in the year 1992 as much as the personnel resources and some additional funds allowed. The effect on the present EISCAT became more noticeable, but it can be stated that the operation of the present EISCAT systems is generally secure and can continue. This is under the assumption that the existing staff and financial resources will remain available and major system failures will not happen. Certain effects cannot be excluded, such as the already effective reduction of accounted operating time to 1500 hours per year, the freezing of evolution of the present system and minimization of visitors' support.

At the end of 1992 EISCAT had 35 staff members at work, distributed over the sites in Sodankylä, Tromsø, and Kiruna, as well as at Headquarters. About one third of this regular staff was involved in the ESR preparations. One radar engineer and a project administrator were available as additional staff for the ESR in 1992. The Council agreed in November 1992 to increase the temporary ESR staff by an additional radar engineer and a programmer.

The total project costs were budgeted at 123 MSEK at the beginning of November 1992. This included investment and recurrent costs during construction. The funds available from new contributions from EISCAT Associates were budgeted at 98 MSEK (11.11.93). Further 9 MSEK are taken over a five years period from the regular capital investment and 16 MSEK from the regular recurrent operating chapter of the EISCAT budget.

Abridged Technical Description of the EISCAT Svalbard Radar

(Dec. 1992)

The EISCAT Svalbard Radar - the ESR - is a high power UHF radar to be operated near Longyearbyen, which is the main community on the island of Spitsbergen belonging to the archipelago of Svalbard.

The funding, planning, construction and operation is performed as an integral component of the EISCAT Scientific Association.

The radar system is designed to allow incoherent scatter observations of the ionosphere and extendable for coherent scatter observations of the middle and lower atmosphere.

Detailed full system specifications of the EISCAT Svalbard Radar was compiled for release in the Baseline Description Document. A summary follows here:

INFRASTRUCTURE:

Location:	12 km south-east of Longyearbyen at 78° 09'N, 16° 02'E, and 434 m above MSL, about 550 m south of the main entry to Mine 7 of the Store Norske Spitsbergen Kulkompani (SNSK)
Road Access:	Open road from Longyearbyen to Mine 7 and extension road to the radar
Electrical power:	22 kV line serving Mine 7, step-down transformers, emergency generator on site
Building:	Operations building close to the antenna, consisting of transmitter hall, instrument and control rooms as well as office, workshop, laboratory, storage and personnel facilities rooms. Fully shielded for minimum radio frequency interference and electromagnetic compatibility. Constructed for severe Arctic climate conditions.

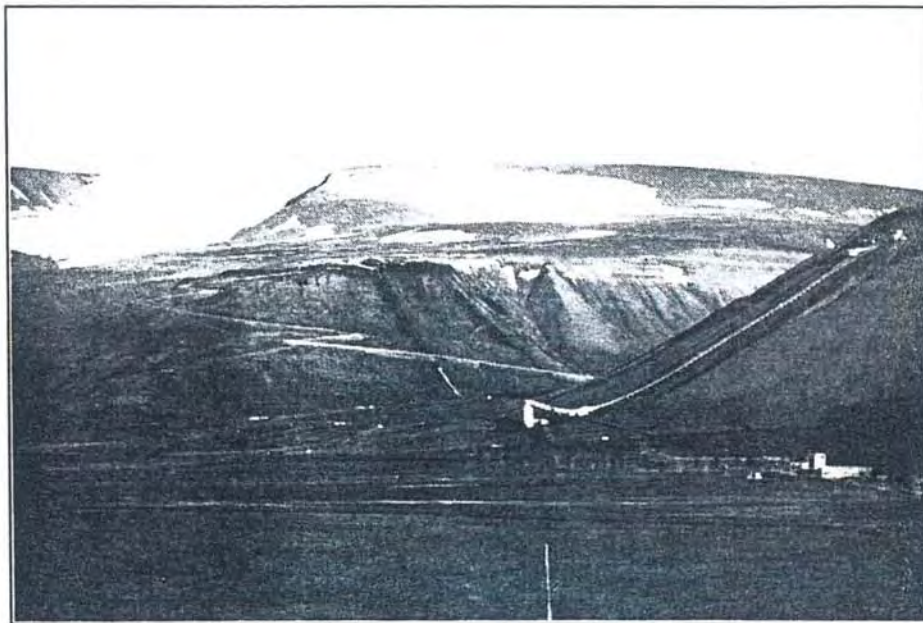


Fig. 5. View of the mountain near Longyearbyen, where the EISCAT Svalbard Radar will be built. The selected location is on the plateau approximately below the centre snow field above the facilities of the SNSK Mine 7 (Photo: Torfinn Kjernet).

INSTRUMENTATION:

The initial configuration will consist of one parabolic dish antenna and a 500 kW peak power transmitter with 125 kW average power. The operating frequency will be close to 500 MHz. The receiver, data acquisition and analysis will apply state-of-the art digital signal processing standards and devices. This configuration will result in a system sensitivity, which is about equal to the present monostatic EISCAT UHF radar in Tromsø.

Frequency:	Centre:	500 MHz
	Bandwidth:	± 2 MHz (transmit)
		± 10 MHz (receive)

Antenna(s) specifications:

Type: Circular parabolic dish of 32 m diameter design with solid surface.
Slewing ring (turning head) type, designed for severe Arctic climate conditions:

Temperature range:	$-55^{\circ} \div +25^{\circ}\text{C}$
Operational wind speed:	$< 27 \text{ ms}^{-1}$
Survival wind speed:	50 ms^{-1}
Ice warning system	
Slewing rate (elev. + azim.):	$1.5^{\circ} \text{ s}^{-1}$
Slewing acceleration:	1° s^{-2}
Slewing range:	elev.: $0^{\circ} - 180^{\circ}$ azim.: $\pm 270^{\circ}$
Pointing accuracy:	$< 0.05^{\circ}$
Feed system:	Secondary focus, waveguide, 2 rotary joints
Polarization:	Circular (right-hand transm. left-hand receive)
Gain:	42 dBi
Sidelobes:	-16 dB (1. sidelobe) -24 dB (2. sidelobe) -34 dB (3.-5. sidelobes) < -40 dB (others)
VSWR:	< 1.20
Ant. temperature:	45 K at 90° elevation
(excl. sky-, preamp. noise etc.)	60 K at 10° elevation
Max. power:	2 MW peak, 500 kW average

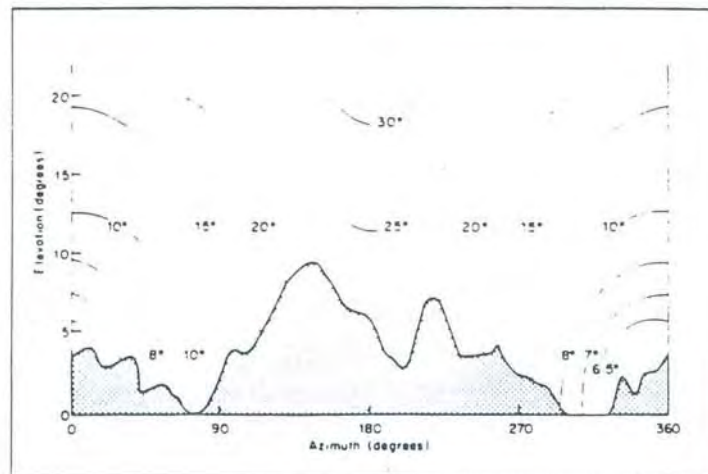


Fig. 6. The horizon profile at the location of the ESR site ($0^{\circ} = \text{N}$), allowing long-range view to the north. The aspect angle to the Earth's magnetic field lines is also shown in this figure. Low antenna sidelobe levels are essential to minimize potential coherent scatter from auroral field-aligned irregularities (from: *The EISCAT Svalbard Radar Report*, 1991).

Transmitter:

Type: Modular system consisting of combined single RF-amplifier modules, which allows high redundancy, use of standard amplifiers and easy system expansion to higher power levels.

The single modules base on standard television transmitters employing external cavity vapour cooled klystron tubes yielding 62.5 kW RF-power. A beam pulse modulator is added.

The transmitter is being constructed by Harris Allied Broadcast Division, Cambridge, UK (delivery for tests in Tromsø in summer 1993). The klystron tubes will be supplied by 2 independent vendors, Philips, Germany, and EEV, UK. These klystrons have typical lifetimes of about 25000 hours.

Module 1 (prototype):

Power:	250 kW peak obtained by combining 4x62.5 kW
Power bandwidth (-1dB):	4 MHz
Duty cycle:	25 % max.
Input power:	10 mW
Load VSWR:	< 1.2
Harmonic emission:	-60 dBc
Spurious emission:	-50 dBc
Interpulse noise:	< -155 dBm/Hz
Pulse length:	1 μ s $\div$ 2 ms
Rise/fall time:	< 0.5 μ s
Voltage droop (at 2ms):	3 %
Pulse rep. rate:	0.02-2 kHz
Interpulse period:	0.5 ms min.
Modulation:	amplitude and phase
Dynamic range:	20 dB
Mains voltage:	3-phase 400 V
HV for klystron:	23-27 kV
Power combiner (2x125 kW):	switchless
Harmonic filter	
Security:	Obey standards on RF leakage, magnetic and electric fields, x-ray and materials
Control and monitor:	allow mostly unattended operation under automatic or remote control
Cooling:	air and water vapour
Size (lxwxh):	5.2 x 4.2 x 3.1 m
Klystrons:	YK1265, EEV K3673BCD

Module 2:

Same as module 1. To be ordered in 1993 when module 1 has been tested. Modules 1 and 2 will subsequently be combined on Svalbard to yield the peak RF-power level of $2 \times 250 \text{ kW} = 500 \text{ kW}$. In later expansion phases further modules can be added.

Radar Controller:

The radar controller is a dual design. One controller is in control while the other is accessible from the crate CPU. The idea is to be able to reload the radar controller program during operation. If it is possible to fit two radar controllers on one VME card, this solution is to be preferred.

Inputs: A 10 MHz clock signal (sinus), a 100 Hz synchronization pulse and a start command from the real time clock.

Program memory: The address space is 20 bits. This means that it may contain up to 1 M Word memory. This gives the maximum program size that will be possible with this design. How much memory that actually will be installed, will depend on how much memory we can fit on a VME card in addition to the other circuits. The aim is to install at least 256 k word on the prototype.

The memory is organized so that each word contains a 32 bit control word section, a 24 bit dwell time section and 8 bits for internal control and program instructions.

Outputs: 32 bit control word with 100 nanoseconds time resolution, 1 bit end of scan.

Receiver:

The receiver chain is configured as a dual superheterodyne with a first IF at 70 MHz and a second IF at 7.5 MHz or higher. This is sampled at 10 MHz at 12 bits of resolution. All further frequency translation, filtering, rate decimation and/or resampling is performed in a digital back end before the data stream passes into the digital signal processing units. The receiver is fully phase coherent, i.e. all oscillators, including the sampling clocks, are phase locked to, or derived from, a common reference.

The three main subsystems of the receiver are:

(a) Front-end: low noise cooled GaAsFET preamplifier and high dynamic range first mixer. Physically located in the antenna cabin. Equipped with low noise local oscillators.

Flange noise temperature:	< 20 K
Bandwidth (- 3dB):	60 MHz
Overall gain:	40 dB
Local oscillator step size:	2 (1) MHz
Output band (each mixer):	70 $\pm$ 5 MHz

There can be up to three, first mixers connected to the common preamplifier, each with its own local oscillator and its own IF distribution and back end.

(b) IF distribution: first I.F. stages and the second mixer(s). Physically located at a central point in the RF equipment area (possibly the transmitter hall). One independent IF distribution subsystem for each first mixer output from the front end.

Input band:	70 $\pm$ 5 MHz
Number of outputs:	up to 4
Output bands:	7.5 $\pm$ 2 MHz or 5.0 $\pm$ 4 MHz
2nd LO frequency:	77.5 MHz, 75 MHz
(individually selectable for each mixer/output)	
Total gain:	>130 dB
Output level:	2 V pk-pk into 50 ohms

(c) Back-end: sampler, A/D converter, complex digital mixer and FIR filters. These will be realized in all digital technology. One independent back end for each IF distribution channel output. More than one mixer and FIR filter can be connected to the same ADC over a broadcast mode data bus.

Receiver back end specifications:	
Bus environment:	VME
Analog-Digital-Converter:	
Input power bandwidth (-3 dB):	25 MHz min.
Sample rate (sustained):	10 MHz min.
Resolution:	12 bits min.
Input voltage for 1 MSB:	1.024 V
Input impedance:	50 + j0 Ω

Digital multiplier:	
Input bandwidth:	10 Mhz min.
Frequency resolution:	< 0.01 Hz
HW FIR filter:	
Input data rate:	10 MHz min.
Number of taps:	512 min.
Coefficient accuracy:	16 bits min.
Decimation:	2,..., 512 min.

Digital Signal Processors (DSP):

These should be of two types, viz. devices optimized for narrowband modes and lag-profile computations, using industry-standard DSP-specific microprocessors, and devices optimized for wideband modes and/or fast decoding, using special-purpose FFT processor hardware. Initially, only the narrowband mode devices will be implemented. Commercially available VME-compatible boards are used to configure the system.

DSP specifications:

Bus environment:	VME
Host processor type:	SparcEngine 2 or 68040
Lag profile processor:	Chip family TMS 'C40
Input data rate/processor:	10 MHz max.
Input data format:	16+16 bit complex
Output data format:	32+32 bit complex or IEEE FP
Processing rate (complex mpy/add):	30 MOPS/channel

Computing, Software

The structure of the software systems will be as follows:

The software will be divided into two main areas which will communicate via a data base system.

The first area:

- (a) will contain all the time-critical elements, while the second,
- (b) will contain all the packages required to use the radar for scientific purposes.

The two areas will provide a logical separation between (a) the real-time tasks and (b) the user packages. A further series of interfaces to the database system will provide engineering information both for operational maintenance and long term monitoring.

The design philosophy behind the EISCAT Svalbard Radar system procurement exercise is to use high-technology industry-standard components and subsystems wherever possible. In-house design is tried to be kept at minimum, although the expertise of in-house staff, acquired over many years of the EISCAT operation, is indispensable in defining, supervising and developing certain system partitions of the hardware and software. This is mandatory to allow a system design and development, which is exceptionally specialized as an advanced incoherent and coherent scatter radar system. Associates' institutions support on certain work packages, such as software design is also envisaged.

The design of the industry-constructed system parts will be in close coordination with experienced EISCAT staff and selected consultants from other observatories and Associates' institutions. The testing of many parts will be performed at the mainland sites before these will be installed on the site near Longyearbyen in 1994 and thereafter. Test operation is planned to start at the end of 1995, experiments should commence as soon as possible after successful testing. Later remote monitoring and control from an operations centre in the Longyearbyen community or at the mainland is planned to be added, when corresponding facilities and funds will be available.

EISCAT OPERATIONS IN 1992

The target for the total of EISCAT operations in 1992 was about 1500 hours. This was a reduction from the previous year due to the transfer of resources to the planning and construction of the EISCAT Svalbard Radar. In addition to these 1500 hours, the EISCAT Council added 20 hours for the EISCAT-Heating campaign in November, where a charge factor of 1.5 was used for one radar system and Heating. There were 408 hours of dual radar operations and 20 hours of passive observations. The total number of operation hours for 1992 was 1599 hours (see Tables 1 and 2).

The total for Common Programme Operations was 776 hours. Highlights included the introduction of alternating codes in Common Programmes One and Two, a split-beam operation of Common Programme Six and a very successful, continuous 7-day combined run of Common Programmes One and Six. A two-klystron, split-beam, Common Programme Four experiment was also run on the VHF radar in November. In general, the two radars were run together during most of the year, usually as test operations, to prepare the systems and procedures for regular two radar operation.

Special Programme Operations amounted to a total of 823 hours. There were no Special Programme runs in April and September, and very few in the intervening months (see Fig. 1), perhaps in response to the SAC resolution calling for a quiet period in the summer to allow work on the ESR to proceed unhindered.

Special Programme objectives included studies of FTE (Flux Transfer Events) signatures, the storm-time ionosphere and non-Maxwellian plasmas. The distribution of Birkeland, Pedersen and Hall currents were studied, as were the evolution and dynamic coupling of parallel arcs, relative arc-plasma drift motions, electric fields in auroral arcs, pulsating aurora and arc-induced distortions in the received radar spectra.

Much effort was expended on investigations of coherent echoes, including dual radar searches for unusual echoes, and on the dynamics of induced ionisation patches in the D and E regions and the effects of the convection electric field, the spatial extent of the precipitation region, electron density blobs and irregularity instability processes and medium scale F region irregularities.

Other studies involved co-ordination with the UARS and Akebono satellites (the latter involving both radars) while the first EISCAT-Freja campaign took place in November. Further data on both gyro-lines and H^+ and O^+ ion outflow were collected.

Novel experiments included automatic tracking of the up- and down-shifted plasma lines, a direct test of competing theories using a determination of the aspect sensitivity of PMSE (Polar Mesospheric Summer Echoes) and tests of computerised ionospheric tomography using data from the NNSS satellites.

The study of echoes from the troposphere and stratosphere, and the related turbulence, set the new minimum altitude limit to about 3 km, while the first 2-klystron VHF high-altitude experiment, conducted in March, set a new high-altitude record close to 2600 km.

Besides the radar experiments there were also Heating-Radar campaigns involving plasma-line measurements and studies of accelerated electrons produced by plasma instabilities during ionospheric heating. The first official EISCAT-Heating campaign included the test of improved chirp experiments.

COMMON PROGRAMMES 1992													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot %
CP1			28	63			32	112					235 30
CP2	54			30			30			53			167 22
CP3		29				53			49			49	180 23
CP4										77			77 10
CP6						24	16	20					60 8
CP7		30			27								57 7
UPs													0 0
Total	54	59	28	93	27	77	78	132	49	53	77	49	776 100%
%	7	8	4	12	3	10	10	17	6	7	10	6	100 %
Achieved							Target						
CP1	CP2	CP3	CP4&CP5	CP6&CP7	UPs		CP1	CP2	CP3	CP4&CP5	CP6&CP7	UPs	%
30	22	23	10	15			25	20	25	15	15		

Table 1. EISCAT Common Programme operations in 1992, showing the distribution by month and programme type.

SPECIAL PROGRAMMES 1992													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot %
EI	2		1		9		7	3		14	12	5	53 6
FI		57											57 7
FR		62	24		60						12	40	198 24
GE		73	58			23	40	13					207 25
NO		7	2			8	7	2		20	3		49 6
SW											67		67 8
UK	10		98							41	15	28	192 23
Total	12	199	183		69	31	54	18		75	109	73	823 100 %
%	1	24	22		8	4	7	2		9	13	9	100 %
	EI	FI	FR	GE	NO	SW	UK						
	6	7	24	25	6	8	23	100 %		(of	823 hrs)		
	7	7	25	26	6	8	24	103 %		(of	800 hrs)		

Table 2. EISCAT Special Programme operations in 1992, showing the distribution by month and Associate. Also shown is the proportion of the total Special Programme time used by each Associate.

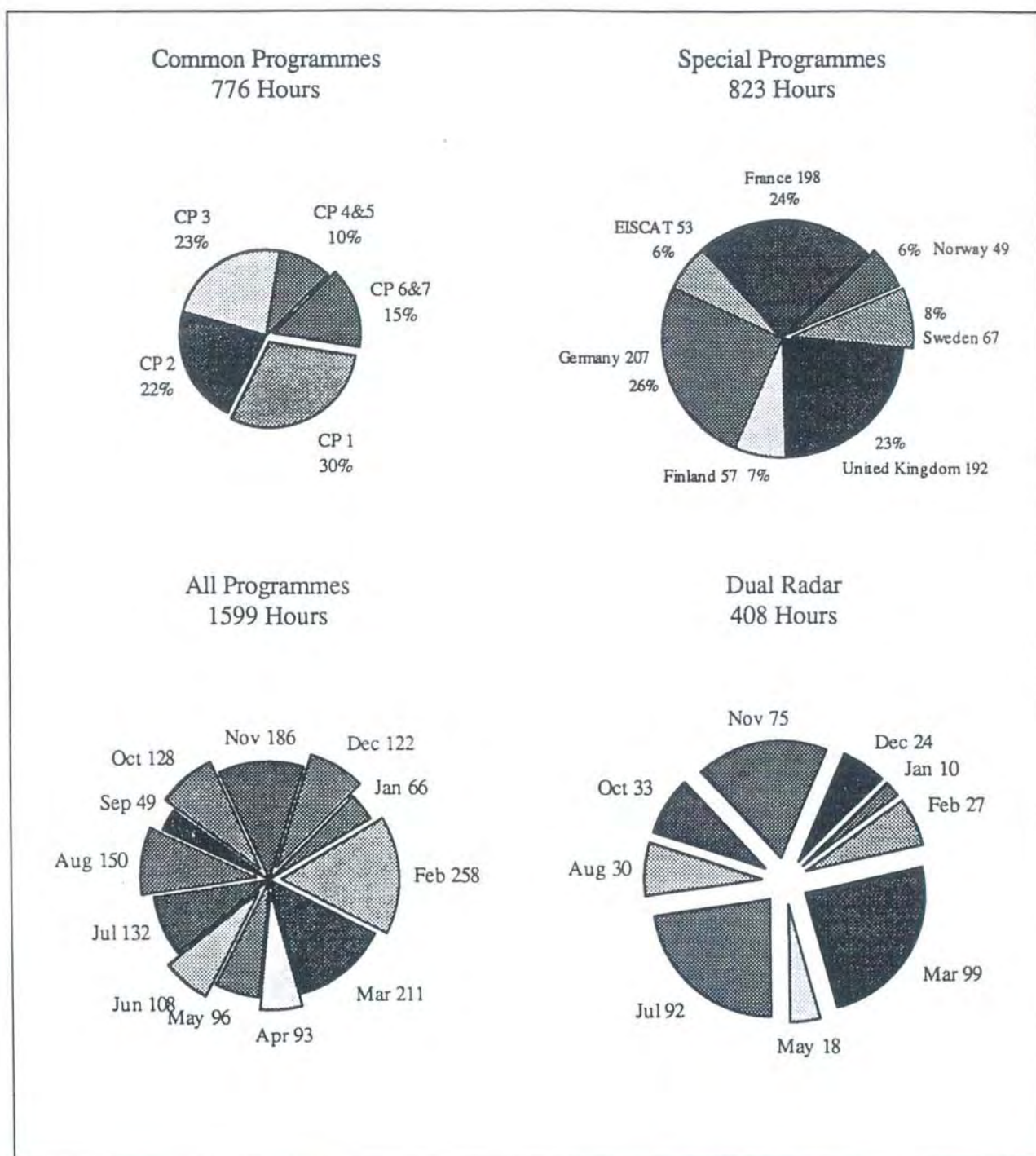


Fig. 7. Total EISCAT Common and Special Programme operations in 1992 distributed by programme (upper left) and Associate (upper right). The lower panels show the monthly distribution of total operating hours (left) and dual radar hours (right).

COMMON PROGRAMME OPERATIONS DURING 1992

UHF Common Programmes

START		END		expt
date	time	date	time	
92-01-27	10UT	01-29	16UT	CP-2-D WD
92-02-13	10UT	02-14	16UT	CP-3-F
92-03-30	16UT	04-03	16UT	CP-1-J WD
92-04-13	10UT	04-14	16UT	CP-2-D
92-06-22	11UT	06-24	16UT	CP-3-F WD
92-07-07	10UT	07-08	16UT	CP-2-E
92-07-30	16UT	08-05	16UT	CP-1-J WD
92-09-22	10UT	09-24	16UT	CP-3-F WD
92-10-27	10UT	10-29	16UT	CP-2-E WD
92-12-15	15UT	12-17	19UT	CP-3-F

VHF Common Programmes

START		END		expt
date	time	date	time	
92-02-11	10UT	02-12	16UT	CP-7-D
92-05-05	10UT	05-06	16UT	CP-7-E
92-06-10	15UT	06-11	16UT	CP-6-B
92-07-30	16UT	08-05	16UT	CP-6-B WD
92-09-22	10UT	09-24	10UT	CP-7-E WD
92-10-27	10UT	10-29	16UT	CP-6-B WD
92-11-23	10UT	11-26	16UT	CP-4-B WD
92-12-15	15UT	12-17	19UT	CP-7-E

Table 3. Overview of EISCAT Common Programme experiments during 1992. WD indicates a World Day operation, the results from which are also sent to the CEDAR data base at NCAR in Boulder, USA.

Operating Modes Employed in 1992

Common Programme One, CP-1, uses a fixed transmitting antenna, pointing along the geomagnetic field direction. The three-dimensional velocity and anisotropy in other parameters are measured by means of the receiving stations at Kiruna and Sodankylä (see map, inside front cover). CP-1 is capable of providing results with very good time resolution and is suitable for the study of substorm phenomena, particularly auroral processes where conditions might change rapidly. On longer time scales, CP-1 measurements support studies of diurnal changes, such as atmospheric tides, and seasonal variations. Solar cycle variability will also be studied when sufficient data have been collected.

Common Programme Two, CP-2, is designed to make measurements from a small, rapid transmitter antenna scan. One aim is to identify wave-like phenomena with length and time scales comparable with, or larger than, the scan (few tens of km and about ten minutes). The present version consists of a four position scan which is completed in six minutes. The first three positions form a triangle with vertical, south and south-east positions, while the fourth is aligned with the geomagnetic field. The remote site antennas provide three-dimensional velocity measurements in the F-region.

Common Programme Three, CP-3, covers a 10° latitudinal range (in the F-region) with a 17 position scan up to 74°N in a 30 minute cycle. The observations are made in a plane defined by the magnetic meridian through Tromsø and the Kiruna and Sodankylä antennas make continuous measurements in the F-region.

Common Programmes One to Three are run on the UHF radar. Three further programmes are designed for use with the VHF system. When applicable, it is increasingly common practice to have operations with one UHF and one VHF experiment running simultaneously.

Common Programme Four, CP-4, covers latitudes up to almost 80°N (77°N invariant latitude) using a low elevation, split-beam configuration. CP-4 is particularly suitable for studies of high latitude plasma convection.

Common Programme Six, CP-6, is designed for low altitude studies, providing spectral measurements at mesospheric heights. Vertical antenna pointing is used.

Common Programme Seven, CP-7, probes high altitudes, up to 1700 km, and is particularly aimed at polar wind studies. Vertical antenna pointing is used.

The suffix to CP names indicates the version of the experiment. These increase alphabetically as new versions are introduced.

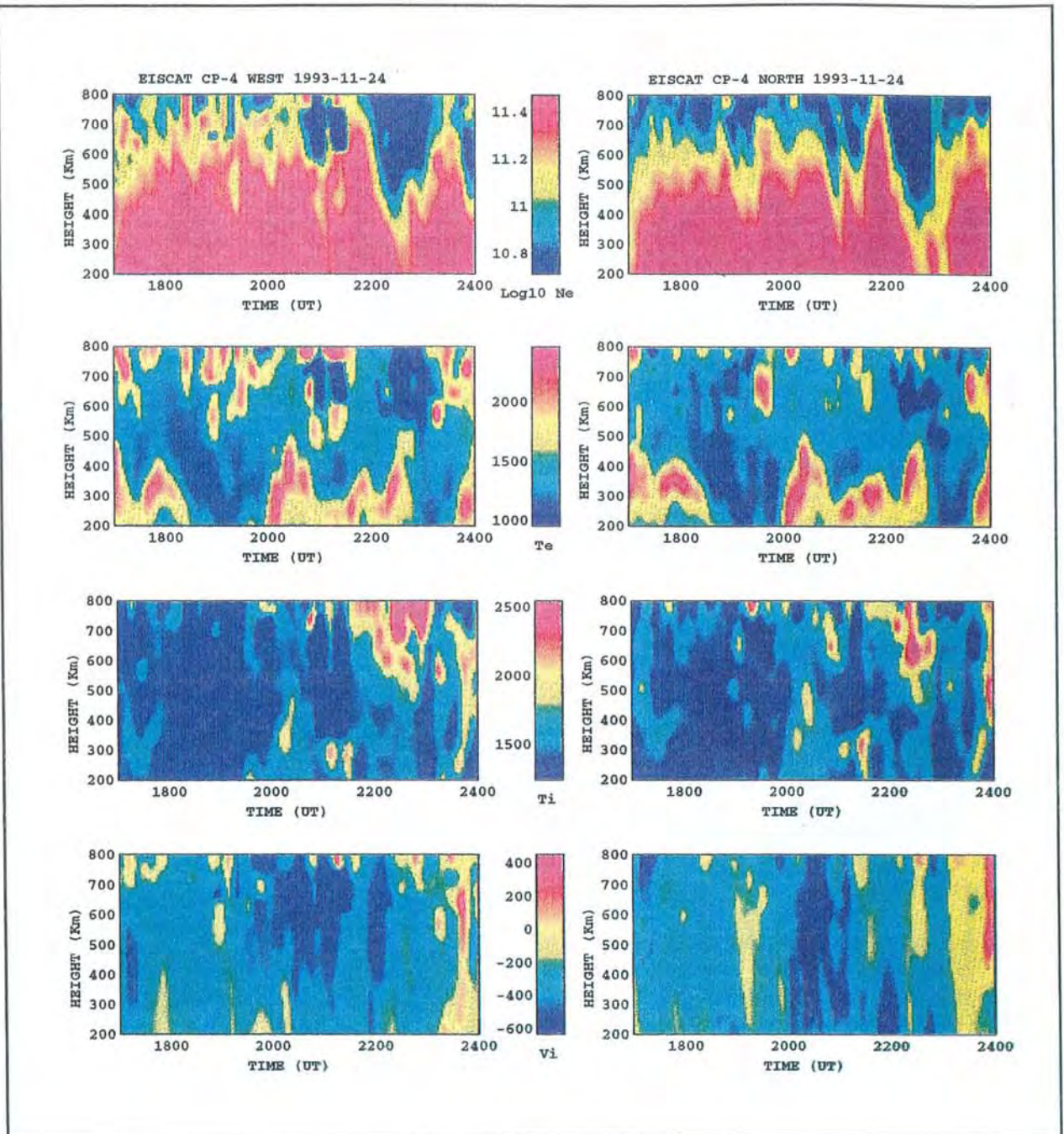


Fig. 8. A new introduction to EISCAT's Common Programmes during 1992 was version B of experiment CP-4. The design of this experiment takes advantage of the flexibility of the VHF system in allowing split-beam operation by phasing one half of the antenna away from the meridian plane. Thus simultaneous measurements can be obtained from two different azimuthal directions (both at elevation 30°), allowing derivation of horizontal velocities with fewer assumptions than the beam-swinging method used in the earlier (UHF) version of CP-4. This figure shows the standard ionospheric parameters derived from measurements obtained during the first operation of CP-4-B on 24 November, 1992. The right panels show results from the beam directed due north and the left panels from the beam steered 14.8° to the west of north.

SCIENTIFIC RESEARCH AND DEVELOPMENTS

TOPSIDE IONOSPHERE

The thermal escape of ionospheric ions towards the magnetosphere has been studied in a two-fold approach - experimentally with the EISCAT radar and numerically with modelling the topside ionosphere (Blelly et al., 1992)*. The numerical description of the topside ionosphere needs various degrees of approximations based on various possible velocity distribution functions. Four time-dependent models were developed and their steady-state and dynamic results cross-compared (Blelly and Schunk). One of the important conclusions was that for studying the mean behaviour of the ionosphere, it is necessary to solve the 8-moment approximation equations, i.e. equations of continuity, momentum, energy and heat flux (Robineau, 1992). When the possible development of anisotropies was considered, particularly for high altitude phenomena where collisions are infrequent, it was shown that the commonly used 13-moment approximation method can fail and it is necessary to specify a bi-Maxwellian distribution and solve the equations resulting from the 16-moment approximation, i.e. continuity, momentum, anisotropic pressure and heat flux (Blelly and Schunk)*.

Another interesting result from this cross-comparison of the models was that, whatever the approximation, the resulting electron heat flow distribution with altitude, above the collision-dominated region, follows a divergence free law. This property was used to infer from the radar data the electron heat flow coming from the magnetosphere, together with the F2-region heat flow resulting from the classical Fourier law which holds in the collision-dominated region. Some of the characteristics of these two quantities are the diurnal variations with peaks in the downward F2-region heat flow at the terminators, but also large increases of the topside heat flow associated with events of O^+ and H^+ vertical acceleration, Fig. 9 (Blelly and Alcaydé).

* References given without dates indicate work in progress or in press. Those including the year can be found in the reference lists starting on page 50.

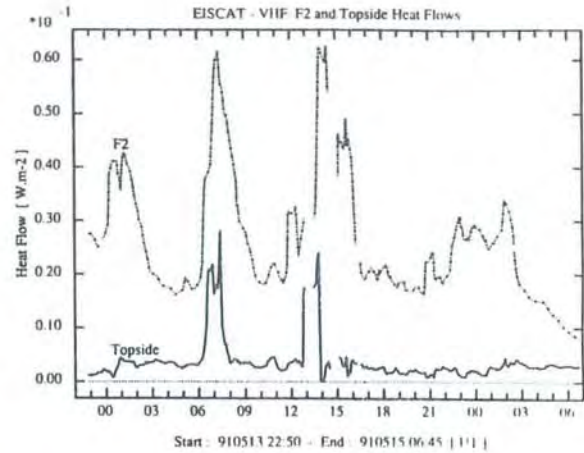


Fig. 9. Electron heat flow inferred from the May 1991 Common Programme VHF experiment (see Fig. 12 of the 1991 EISCAT Annual Report). The electron heat flow is computed from the electron temperature profile at two levels - in the F2 collision dominated region, and in the upper part of the ionosphere where it is assumed to be divergence free. The two events at 07 UT and 13 UT correspond to vertical acceleration of the O^+ ions.

One of the possible mechanisms by which heat is transported downwards is the presence of a field aligned current. It has been shown that by applying an upward current, compatible with the topside electron heat flow derived from the data, the resulting ionospheric response is very similar to the observed one: electrons are heated up to temperatures of 6000 K, O^+ field-aligned acceleration produces upward velocities reaching 600 ms^{-1} at 1600 km altitude and the ionosphere is emptied by this process with electron densities decreasing by a factor of 2 (Fig. 10). In this simulation, the O^+ temperature increase was obtained by applying a perpendicular E-field which causes frictional heating of the ions (Blelly, Robineau and Fontanari).

The O^+ field-aligned acceleration is induced by both the strengthening of thermal diffusion (which results from the energy input associated to the increased downward electron heat flux) and the increase of the

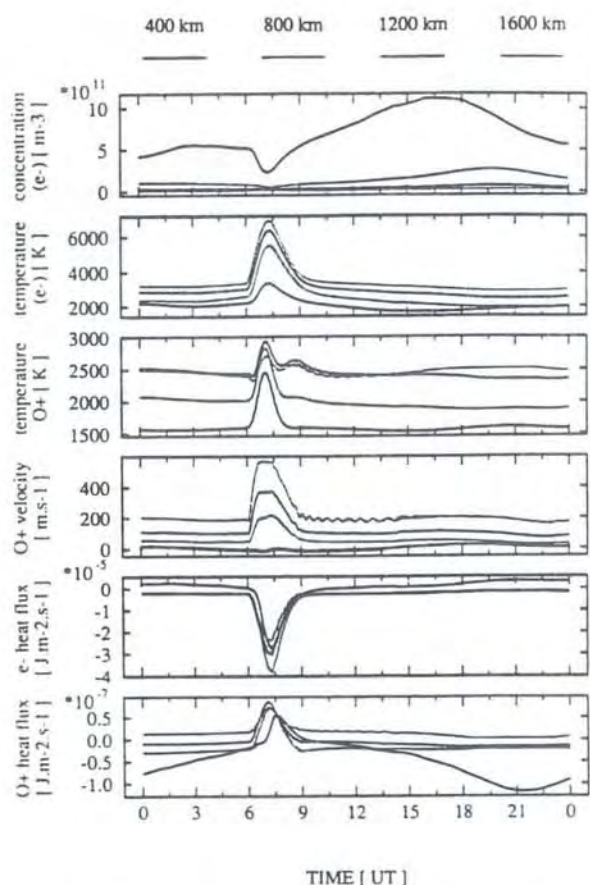


Fig. 10. Numerical modelling of the ionosphere corresponding to the 14 May 1991, Common Programme VHF EISCAT observations (see Fig. 12 of the 1991 EISCAT annual report). The panels from top to bottom show the time variation of electron density, electron and O^+ ion temperature, O^+ upward velocity, and electron and O^+ heat flux, respectively, at four selected altitudes. The event starting at 06 UT was generated by applying simultaneously an upward current of $10 \mu\text{Am}^{-2}$ and a perpendicular convection E -field of 50 mVm^{-1} .

acceleration terms resulting from the increase of the pressure gradients (in particular the electron pressure gradient).

Transport equations were also approached analytically. Analytical solutions were derived for the 13-moment approximation of the transport equations in a steady-state multi-species gas. Combined with EISCAT VHF data, these solutions give access to the O^+ and H^+ heat flux in the high latitude ionosphere. The comparison with Fourier's law shows large discrepancies that should

be taken into account for future studies (Wu and Taieb).

The conditions under which both the velocity and the ion temperature of the minor ion H^+ can be directly measured by the radar have been investigated. The main conclusion was that, except during time periods where the proportion of H^+ ions is sufficiently large, and for very good signal-to-noise ratios, it is barely possible to determine either the H^+ temperature or the velocity (Diloy, 1992).

The structure of the high altitude thermospheric composition $n(H)/n(O)$ has been investigated using EISCAT VHF observations. The transport in the high-latitude ionosphere is shown to influence the height profile of the neutral atomic hydrogen concentration. By taking into account this effect in the treatment of EISCAT VHF data, the usual models (CIRA or MSIS) are found to underestimate the H concentration below 600 km, and to overestimate it above (Wu and Taieb).

LARGE SCALE ELECTRODYNAMICS AND CONVECTION

The large scale convection of ionospheric and magnetospheric plasma, driven by the solar wind - magnetosphere dynamo, is controlled by coupling processes along magnetic field lines such as field aligned currents and precipitation. The role of these processes on the convection pattern has been evaluated using a numerical model simulating self-consistently the MHD transport of the magnetospheric plasma injected from the tail earthward, the current circulation in the ionosphere, and their couplings. As a first step, the results were compared to statistical distributions of electric fields and currents inferred from EISCAT data (Fontaine, Peymirat and Senior). EISCAT statistics were then interpreted by means of this new numerical tool (Peymirat and Fontaine).

Recent theories of how reconnection at the dayside magnetopause causes the transfer of mass, energy and momentum from the solar wind flow into the Earth's magnetosphere and upper atmosphere have been tested and extended using high latitude EISCAT

measurements. Fig. 11 shows data from a close conjunction of the DMSP (Defense Meteorological Satellite Program) F10 satellite over the EISCAT field of view on 28 March, 1992. The combined observations provide the first direct evidence for the pulsating cusp model. The top panel of Fig. 11 shows the magnetosheath-like particle precipitation seen by the satellite, the large arrows marking step-like features in the ion dispersion signature at the edges of the precipitation usually termed cusp (poleward and equatorward of which are classified as cleft and mantle, respectively). Such features have been predicted to result from pulsed magnetopause reconnection. Theory predicts that these steps should move poleward with any features produced by the associated electron precipitation. That this is the case is shown directly by the radar data which revealed a series of poleward-moving electron temperature enhancements (Fig. 11b), each event forming equatorward of its predecessor before drifting poleward at the observed convection speed, also plotted in Fig. 11c. Each event also shows an electron temperature enhancement by a factor of about 1.5, typical of the effect of cusp particle precipitation. The EISCAT data show that the electron temperature enhancements drift through the cleft, cusp and mantle regions, which are therefore a single class of event seen at different phases of their evolution, and are not static spatial structures. This is direct evidence for an extreme limit of the pulsating cusp model which allows the cusp to be the ionospheric signature of a series of flux transfer events (FTEs). The combined radar and satellite data can be used with the equation for the ions' time of flight to show that reconnection took place close to the subsolar magnetopause, consistent with various magnetopause observations. The step-like feature in the cusp ion spectrogram shows that very little reconnection took place between the pulses, i.e. the FTEs were the only mechanism for driving convection at this time (Lockwood, Denig, Farmer, Davda, Cowley and Luhr).

Other observations of the cusp region have been made in association with optical observations at Svalbard near winter solstice. Flows observed by EISCAT in association with transient 630 nm emissions are in excellent agreement with the

theoretical model of Cowley and Lockwood (1992). Three features known to follow a southward turning of the IMF are observed. The cusp/cleft aurora migrates southward, closely followed by the onset of quasi-regular, transient 630 nm emissions which drift poleward. The third feature is the rise in the voltage associated with sunward convection in the afternoon auroral oval, as seen by EISCAT. This voltage rises from ~7 kV to ~40 kV in just 100 s. However, this flow onset does not take place until after most of the equatorward motion of the cusp/cleft region and at the same time as the onset of the transient 630 nm events. The flow enhancement propagated eastward (away from noon) at about 6 km s^{-1} from the resulting ion temperature enhancement, as was observed following southward IMF turnings in earlier EISCAT-AMPTE observations. The transient 630 nm forms are associated with transient increases in the poleward flow component and move poleward at the local plasma convection speed (Lockwood, Moen, Cowley, Farmer, Løvhaug, Lühr and Davda).

These observations provide excellent tests of the Cowley-Lockwood (1992) flow model, which has implications for how polar-cap density patches can be formed by variation in the magnetopause reconnection rate. Examples of such patches seen by EISCAT are shown in Fig. 12. Patches move anti-sunward with the convective flow over the polar cap. Examples moving equatorward on the nightside, and poleward on the dayside, have been found. It has been shown how such patches could be produced by pulsed magnetopause reconnection, using theories of how such reconnection pulses excite ionospheric flow developed from earlier EISCAT data (Lockwood and Carlson, 1992).

Ps6 pulsations as a manifestation of Ω -bands have been studied using CP-2 data and geomagnetic measurements from the EISCAT magnetometer cross (EMC). One of the CP-2 positions is very close to the EMC station at Kilpisjärvi, yielding a very good correlation of the EISCAT derived currents and conductivities and the EMC signatures on the ground. Fig. 13 shows the current system of the Ω -band which emerged from this comparison. The whole structure moves to the east with a velocity of about 1 km s^{-1} (Schlegel and Lühr).

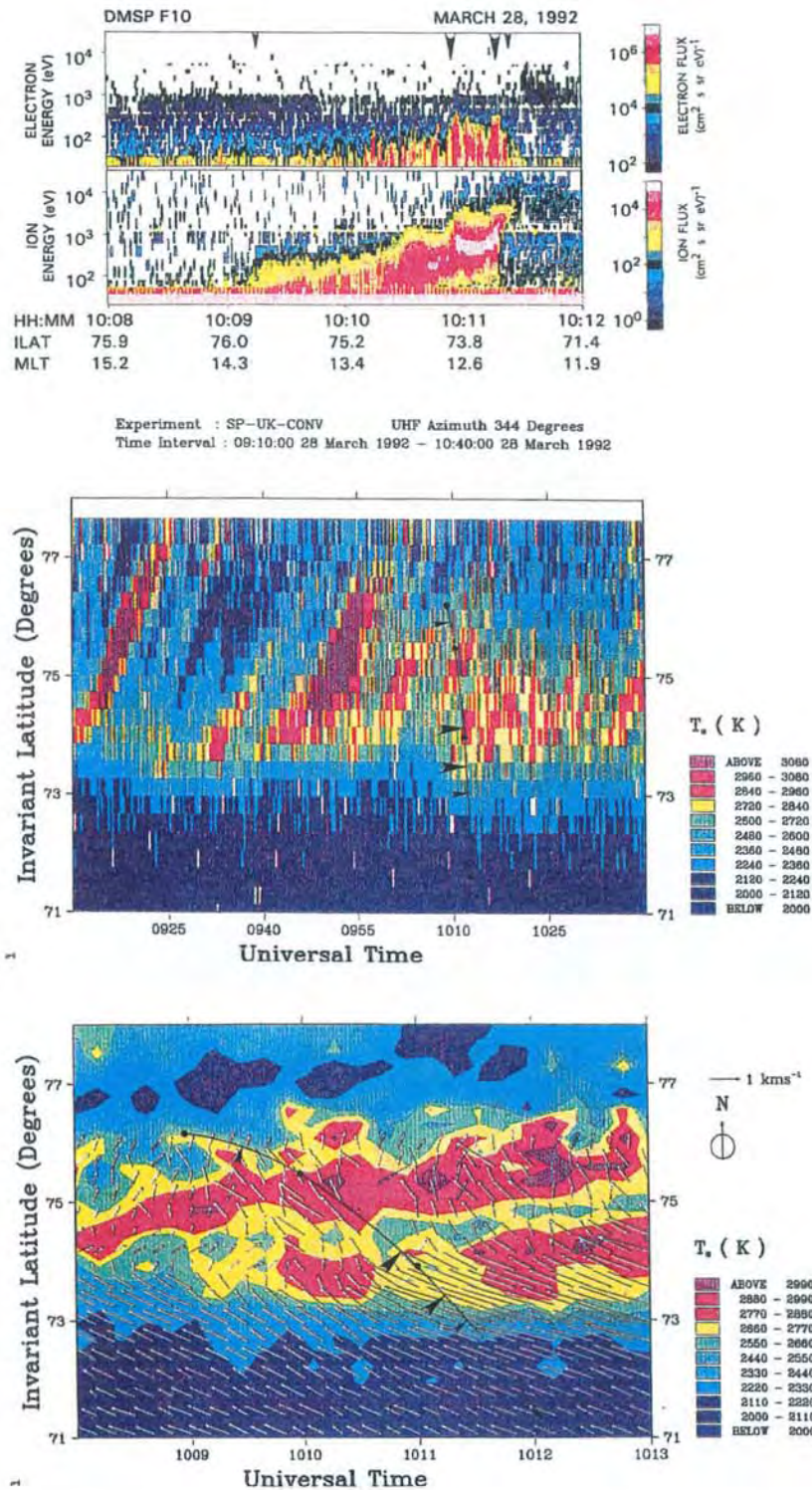


Fig. 11. (a) The magnetosheath-like particle precipitation seen by the DMSP-F10 satellite on 28 March 1992 shown as differential number fluxes as a function of time and energy (top panel electrons, lower panel ions). The small arrows bound the edges of the magnetosheath-like precipitation and the larger arrows the two step-like features in the ion dispersion signature around the region classified as the "cusp". (b) The electron temperatures seen by the EISCAT UHF radar as a function of invariant latitude and time - the black line gives the DMSP-F10 satellite footprint and the arrows mark the features seen by the satellite, as marked in (a). (c) Higher resolution view of the EISCAT data around the satellite pass, with 10-second flow vectors derived by combining the UHF and VHF data.

EISCAT CP-4 -A (Polar)
Electron Density, $N_e(10^9 \text{m}^{-3})$

Azimuth: 332°
Elevation: 21.5°

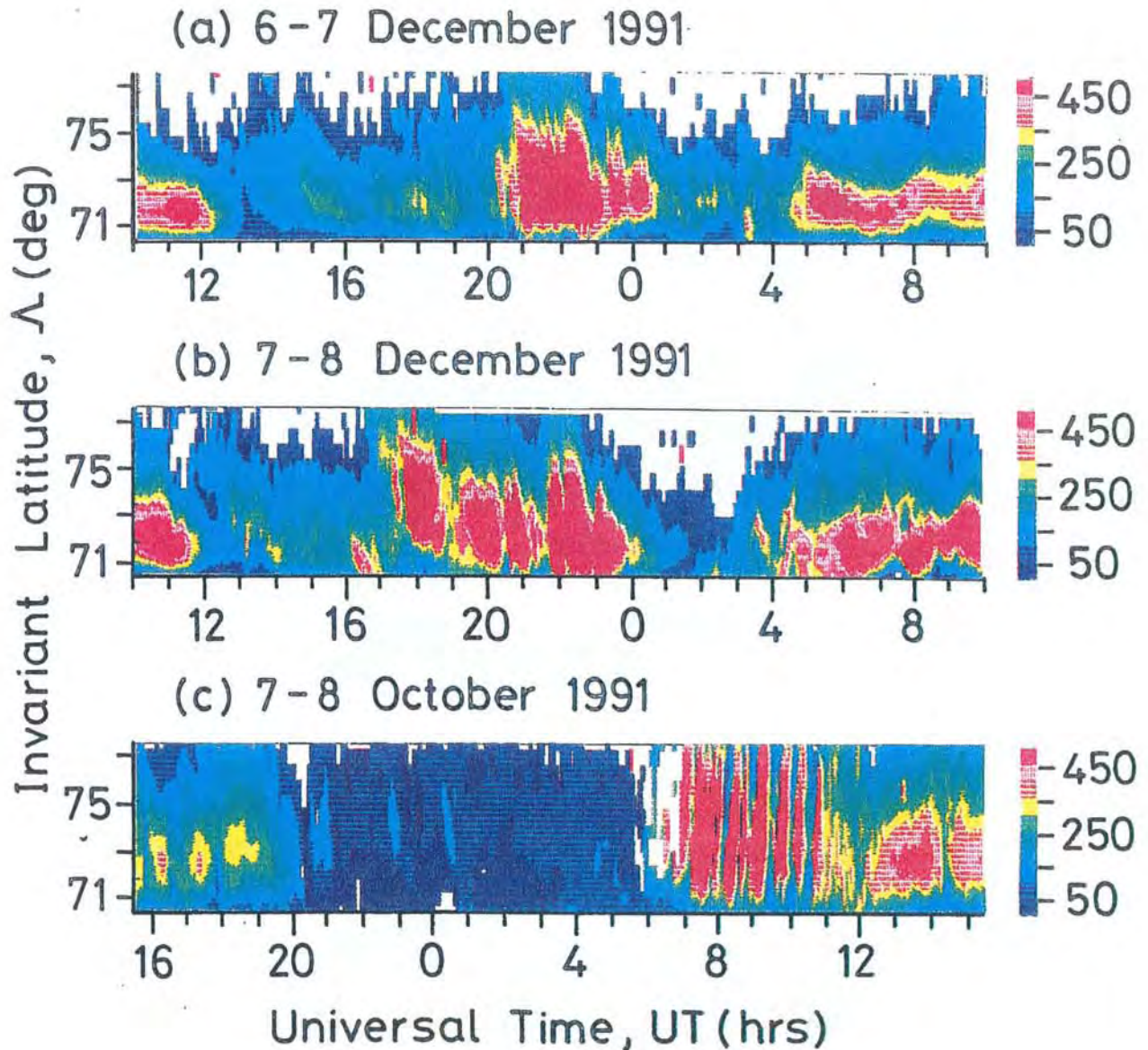


Fig. 12. Plasma density as a function of latitude and time on three days. (a). On 6-7 December, 1991, an almost continuous "tongue" of ionisation is seen in the polar cap (although some patch-like structure can be seen). (b). On the following night, the high plasma density is clearly broken up into a series of equatorward-moving patches. (c). On the night of 7-8 October, 1991, two relatively weak patches are seen and 8 hours later a string of poleward-moving patches moved into the polar cap near noon.

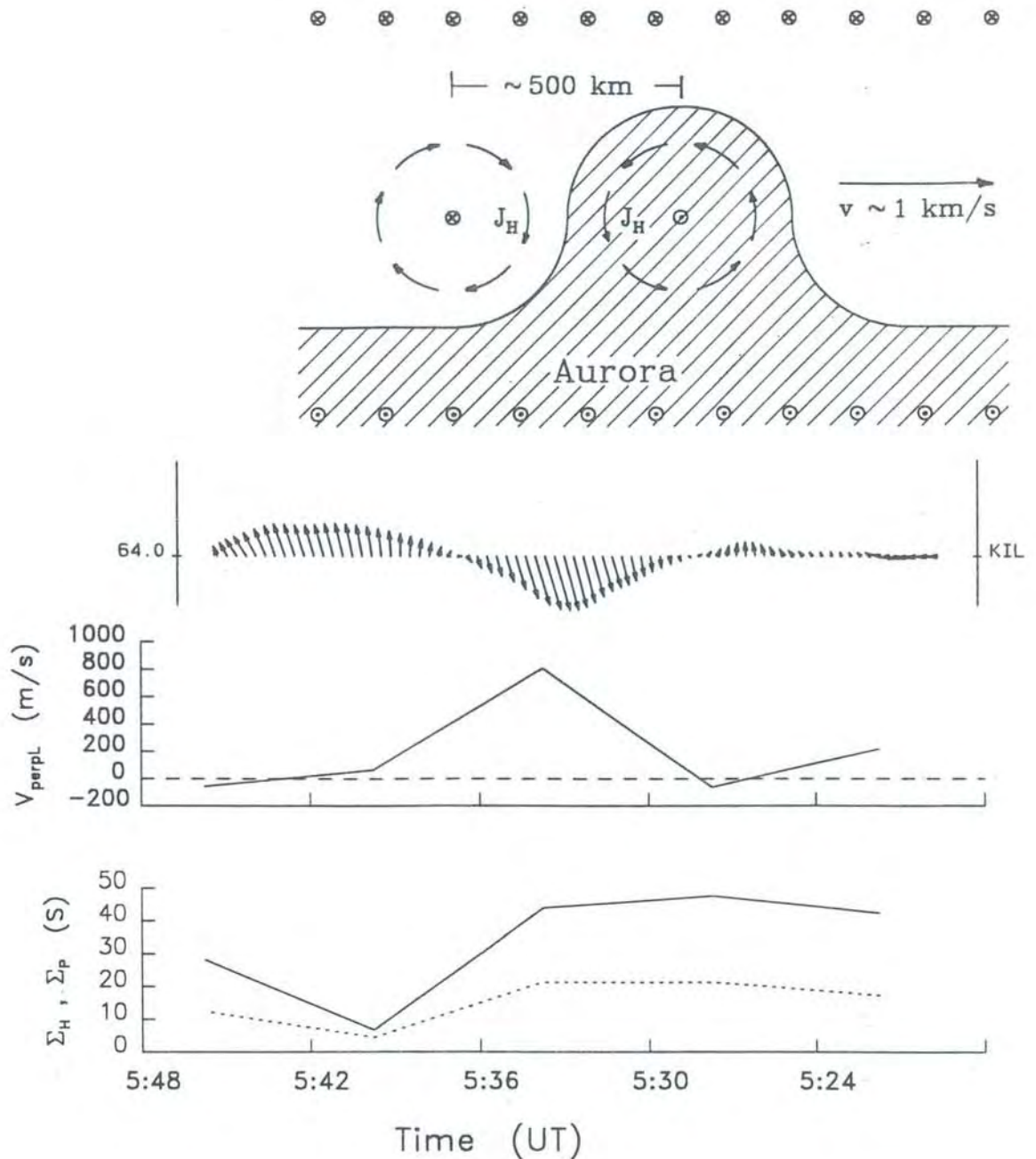


Fig. 13. Current structure within an Ω -band, consisting of two Hall current vortices. In the luminous part of the Ω -band (shaded area) the vortex rotates counter-clockwise and is driven by an upward field-aligned current (FAC); in the dark area the vortex rotates clockwise and is driven by a downward FAC (uppermost panel). This current structure is confirmed by the equivalent currents inferred from the magnetometer cross data (second panel): at the boundary between the dark and the luminous part the current contributions from both vortices add together yielding maximal values, at the centre of the vortices the currents are minimal and change their signs. The EISCAT derived ion-drift perpendicular to the corresponding L-shell (third panel) also confirms this current structure. The lowest panel shows the EISCAT derived conductances, indicating high energy particle precipitation within the luminous part of the Ω -band which supports the upward FAC. Within the dark part the conductances are small, there is no particle precipitation. The time axis is drawn in a reverse sense, since the whole structure moves to the east and therefore the right hand part of the structure passes an observer at an earlier time than the left hand part.

F-REGION STUDIES

The EISCAT radar has been used in an experiment to verify the application of tomographic techniques to ionospheric imaging (Pryse and Kersley, 1992). Radio transmissions from NNSS satellites were used to measure electron content along multiple intersecting satellite-to-receiver paths at a linear chain of stations in Scandinavia. Inversion of the resulting data sets provided tomographic images of ionospheric electron density. During a preliminary campaign, simultaneous tomographic and CP-3 measurements from a common volume revealed good correspondence between large-scale ionisation density features. In March, 1992, a special programme designed specifically for comparison with tomographic measurements was used to give further verification of ionospheric tomography images. The dependence of the image on the initial conditions of the reconstruction algorithm has been of particular interest. Geometric constraints on the satellite-to-receiver paths result in an incomplete data set for the inversion process, and a background ionosphere is required as the starting condition for the reconstruction. A recent development has been the incorporation of ionosonde data into this background, resulting in an improved vertical ionisation distribution in the image (Raymund, Pryse, Heaton and Kersley).

The structuring of auroral zone electron density on a horizontal scale of tens of kilometres has been studied. A real-time display of the returned signal strength in a vertical slice through the ionosphere enables the experimenter to identify regions of structuring. Interactive input then allows the extent of subsequent scans to be restricted to the region of interest so that it can be studied at higher time resolution. Results from the first run of the experiment show field-aligned structures of different types. Some are long-lived features which have convected into the field-of-view, while others appear to be formed in-situ; local enhancements in density are related to particle precipitation while depletions are associated with ion heating (Kersley, Pryse and Sheen).

The statistics of electron content and properties of electron density irregularities

(i.e. the size, occurrence, magnitude and drifts) have been studied in relation to solar and geomagnetic activity. Electron content, derived from the electron density profiles measured over EISCAT, is seen to increase with an increase in sunspot number. Irregularities occur at a greater height at the highest sunspot numbers. Together these suggest that the irregularities might be long-lived plasma enhancements that have been produced on the dayside and then convected over the pole. At low sunspot numbers ($R_z < 50$) fewer F-region irregularities are seen, and those that do occur have a maximum enhancement at a lower height (200 km or less). These are more likely to be short-lived structures caused by particle precipitation so a dependence on geomagnetic activity is expected. This is not unambiguously seen in the data, however. An increase of electron content with K_p index is seen in the daytime but it is difficult to assess the night-time data because of the masking effect of the high-altitude irregularities. A detailed study of the most active periods reveals quasi-periodic structures and drifts both in the scan plane and across it. The apparent inclination of irregularities to the field line can be used in estimating their drift. By correcting for this, one can then reproduce the vertical structure. Drifts of several hundred ms^{-1} are found, with irregularities of median width (taken at half the maximum) of 35km in the meridional plane and 25km in the zonal (Burns and Hargreaves).

A total of 32 EISCAT experiments from October 1981 to August 1986 have been analysed in terms of ion composition in the altitude region ranging from 150 to 300 km for statistical analysis purposes. The diurnal variation of the transition altitude between molecular and oxygen ions was found to be 26 km. This is much larger than the seasonal variation, which is 8 km between summer and winter, and also larger than the magnetic activity variation, which is 10 km for K_p ranging from 0 to 4. In addition, it was found that the extension of the transition region increases with the transition altitude. From these results a simple analytical model of ion composition, including only diurnal variation, has been proposed for use in EISCAT incoherent scatter data analysis (Lathuillere and Pibaret, 1992).

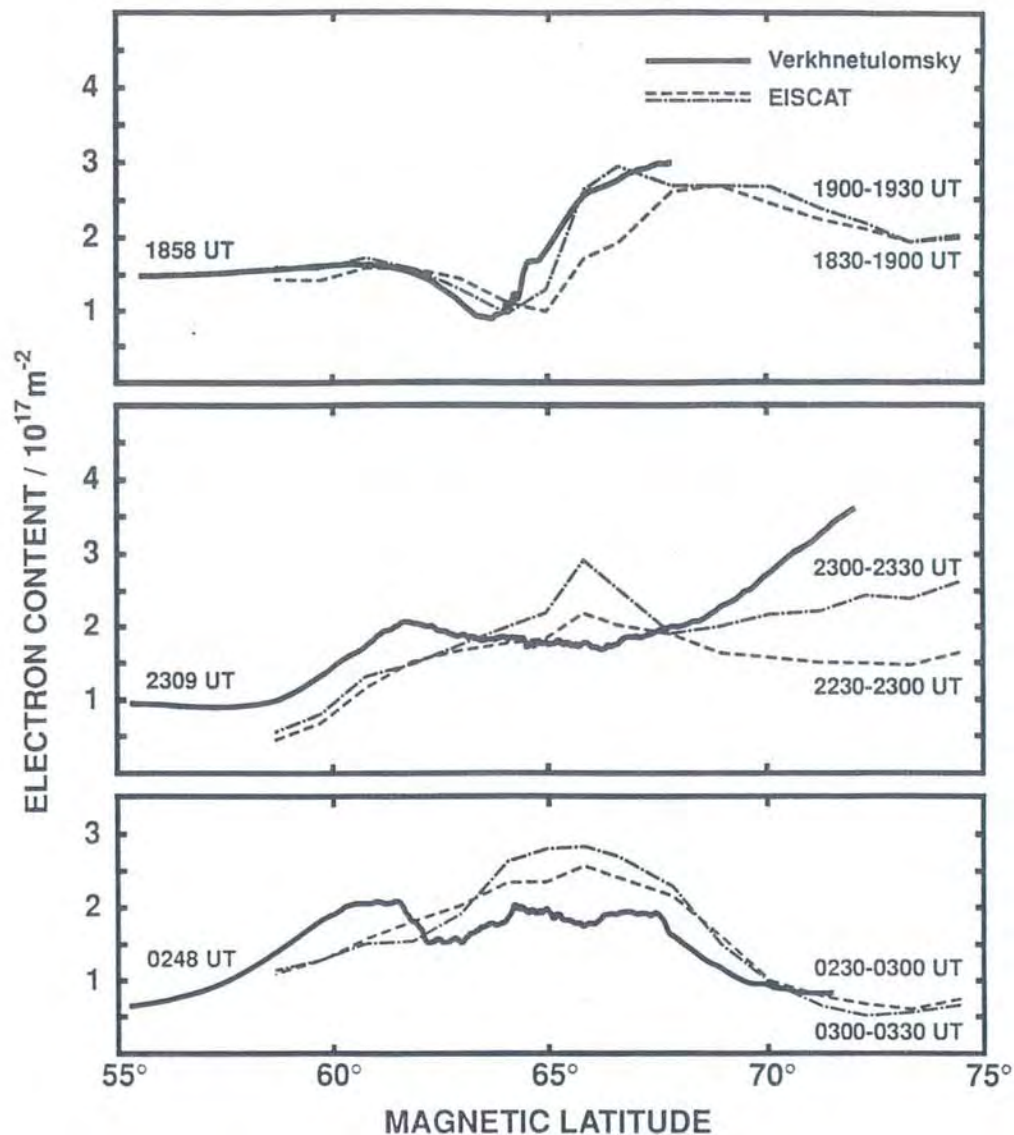


Fig. 14. Selected latitudinal profiles of total electron content from Verkhnetulomsky obtained using the difference Doppler measurements and the two-station method (heavy line), together with electron content calculated from EISCAT CP-3 observations (dashed and dash-dotted lines).

The measurement of non-Maxwellian auroral plasma parameters using the EISCAT facility has received much attention. The usual assumption of an equality of the O^+ ion temperature and NO^+ ion temperature in the lower F region has been shown to be questionable (Hubert and Kinzelin, 1992). New properties of the O^+ and NO^+ non-Maxwellian distribution functions have been predicted. A new scenario for the measurement of the non-equilibrium auroral plasma parameters has been established (Hubert, Bonnard, Lathuillere and Kofman).

Difference Doppler measurements have been carried out using satellites and a receiver chain extending from Verkhnetulomsky (near Murmansk) to Moscow. These observations have been analysed to determine the latitudinal profile of ionospheric total electron content using the two-station method (Fig. 14). The results have been compared with the total electron content calculated from EISCAT CP-3 data, and a reasonable agreement has been observed. This is the first time the two-station method has been tried at high latitudes in the presence of strong horizontal gradients (Chernyakov, Tereshchenko, Brunelli and Nygrén).

IONOSPHERE-THERMOSPHERE COUPLING

Analysis of CP-1 data from 3 April, 1992, has shown an interval of prolonged and intense dayside ion frictional heating. The measured parameters (N_e , T_e and T_i) for this heating interval were compared with those predicted by the Sheffield ionosphere and plasmasphere model assuming an F-region ion velocity signature based on EISCAT observations. The modelled field-parallel ion temperatures were found to exceed the observed values when the effect of the neutral wind was ignored in the model. However, the inclusion of a calculated neutral wind term, caused by ion drag, reduced the modelled ion temperature and predicted values which are more consistent with those observed by EISCAT (Davies, Lester, Jenkins and Moffett).

Substantial effort has been devoted to the analysis of data from ion temperature enhancements observed using a novel radar geometry which enables the anisotropy of the ion temperature in the lower F-region to be probed at an unusually large range of aspect angles within a small scattering volume. Interest has centred on two events occurring on 6 June, 1990, when the ion velocity exceeded 1.6 km s^{-1} , and the field-aligned ion temperature rose to 2000 K. At the same time, the electron temperatures fitted by the standard analysis program were reduced, an effect probably caused by changes in ion composition. The reduction in electron temperature has enabled the variation in composition to be modelled, and the derived compositions to be used in a re-analysis of the data, producing new ion temperatures from which an improved estimate of the temperature anisotropy can be calculated (McCrea, Jones and Lester).

Ways have been suggested in which EISCAT data can be used, via ion energy and momentum equations, to provide valuable information on ion-neutral dynamics. For example, under some conditions the ion drag dominates in such a way that the zonal ion and neutral flows are highly correlated (Fig. 15). At these times an alternative way of deriving the ion-neutral collision parameter, from the more traditional approach via the ambipolar diffusion coefficient, becomes possible (Davis). Other work has shown that, as long

as the electron density stays high enough to get usable plasma velocities, assumptions that the ion temperatures should rise in line with Joule heating, but that the ISR analysis is distorted by changes in mean ion mass, give one way of estimating changes in mean ion mass during heating events. The complication introduced into this equation by possible non-Maxwellian ion velocity distributions can be offset partly by the design of experiment.

Work continues on explaining the equinoctial asymmetry in Kiruna Fabry-Perot interferometer observations and average EISCAT plasma flow data. Although both sources show an asymmetry, probably linked to the Russell-McPherson effect, the fact that they show different asymmetries is hard to understand. More statistical analysis is needed on both data sets to evaluate the significance of the results, and runs of the Sheffield-UCL coupled model have been carried out to try to simulate the effect, usually although usually such models assume equinoctial symmetry in the way they are set up.

A theoretical model of the relationship between the electron concentration, the electron temperature and the ratio of the concentrations of molecular nitrogen to atomic oxygen in the F-region, gave very good agreement with EISCAT CP-1 measurements made under quiet conditions, but suggested concentrations of molecular nitrogen considerably greater than the predictions of the MSIS-86 theoretical model. The model has now been extended to include the effects of metastable excited ions and neutrals on the heating and cooling rates of the electron gas. This revised model also takes account of a revised relationship between the solar EUV flux and the Covington index ($S_{10.7}$) and includes electron cascading in its treatment of electron heating. It now predicts the relationship between electron temperature and concentration with increased accuracy, consistent with MSIS. The temperatures predicted by the new model under quiet daytime conditions have been compared with the predictions of the International Reference Ionosphere. It was found that while the new model temperatures agreed very well with EISCAT measurements they were significantly higher than the values predicted by IRI (Breen and Williams).

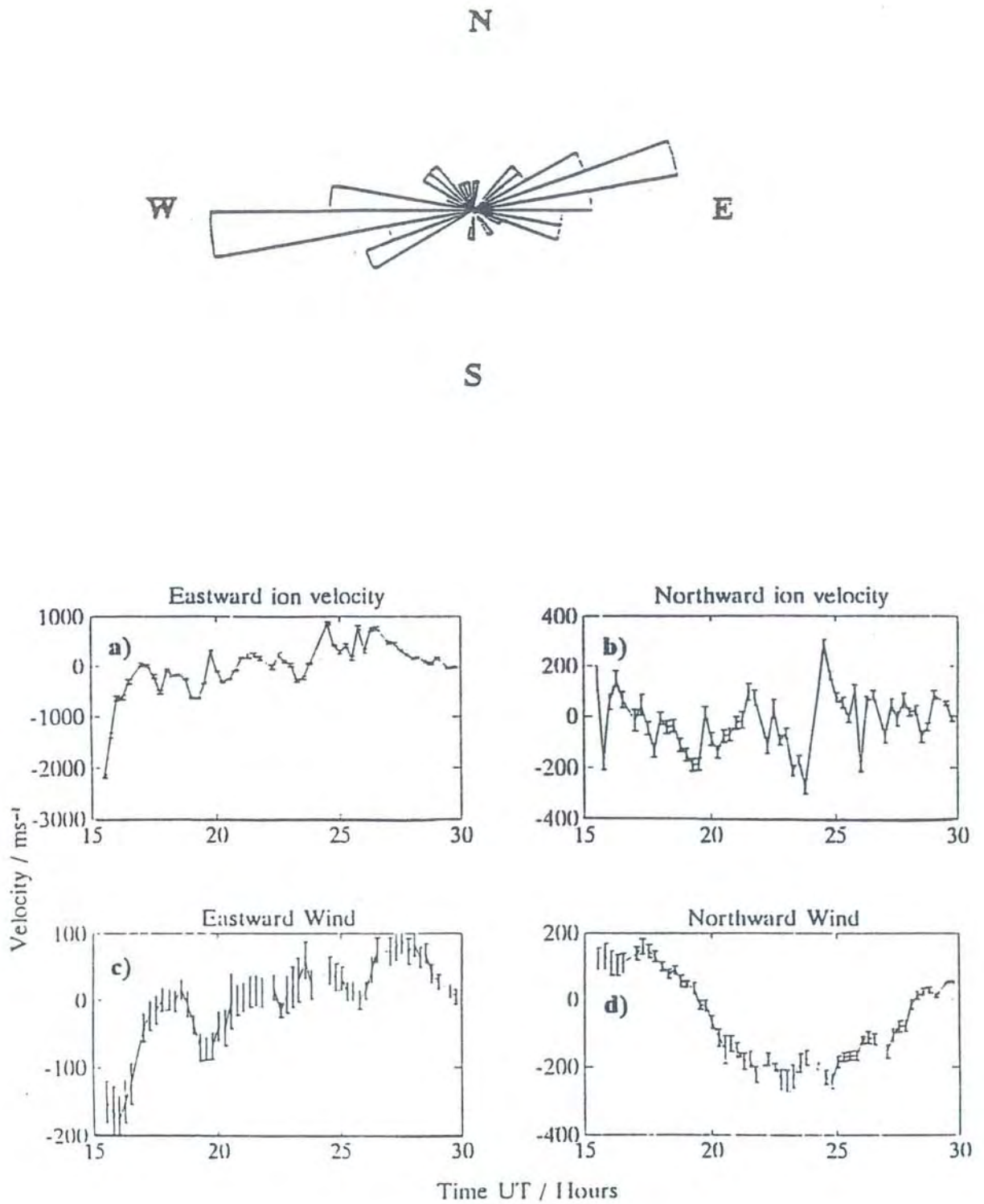


Fig. 15. Eastward and northward components of the F-region neutral wind measured by the Fabry-Perot interferometer at Kiruna, compared to EISCAT measurements of the plasma velocity, for 15 UT, 21 January, 1990, to 06 UT, 22 January, 1990. The diagram at the top shows the distribution of ion drift direction over that period.

ION-ACOUSTIC TURBULENCE

The effects of low-frequency turbulence, due to current-driven instabilities, on the ion and electron temperatures in the topside ionosphere, have been investigated. It has been found that these instabilities should occur at altitudes much higher than the coherent echoes observed by EISCAT. This model also shows that low-frequency turbulence is a major contributor in the energy balance of the topside ionospheric thermal plasma (Forme, Wahlund, Opgenoorth, Persson and Mishin). Observational work on the subject of ion-acoustic turbulence within the topside ionosphere has continued. Two different types of ion-acoustic turbulence have been detected, one occurring within a large altitude range of several hundred km, associated with enhanced precipitation of low energy particles (~few hundred eV) and large field-aligned ion outflows, and a second type limited to a small altitude range (100-200 km) near the F-region peak, associated with high energy particle precipitation (Wahlund, Opgenoorth, Fontaine, Forme and Lilensten). Both observed types of enhanced ion-acoustic lines are associated with enhancements of the electron temperature by a few thousand degrees and these enhancements have been shown to have a local maximum within the turbulent ion-acoustic region. It is concluded that the turbulence is the source of the electron heating, thereby suggesting that field-aligned currents and associated enhanced electric fields due to anomalous resistivity are present. The question whether the two observed types of ion-acoustic turbulence may only be different stages in the temporal evolution of the turbulence cannot be resolved from the available data set. While the origin of the first type can be explained by an ion-ion two-stream instability (if a non-ambipolar ion acceleration mechanism is assumed), the other case is more problematic since no associated ion-outflows are detected.

Development of a general theory for weakly turbulent plasma density fluctuations is under way, and efforts are now being directed towards a comparison of this theory with actual EISCAT observations of enhanced ion lines in the topside ionosphere. The use of a more exact theory should allow a better determination of bulk

plasma parameters such as electron temperature and density inside the ion-acoustic turbulent regions (Wahlund, Opgenoorth, Persson, Mishin and Volokitin).

ATMOSPHERIC WAVES AND TIDES

Gravity wave activity in the F-region over Tromsø has been studied in detail using measurements from EISCAT and the NOAA digital ionospheric sounder (Dynasonde). It has been shown that the field-aligned EISCAT measurement of electron density contains variations which indicate the presence of upward propagating gravity waves with downward progressing wavefronts (Fig. 16). The spectral components of these waves have a harmonic relationship, which strongly suggests a non-linear generation mechanism. The different frequency components have been separated using digital filtering, and the observed frequencies and field-aligned wavelengths, together with the background neutral wind (which has been determined from the average field-aligned ion velocity using an appropriate diffusion correction), have been incorporated into the Hines dispersion equation to obtain the horizontal and vertical wavelengths. The periods and horizontal wavelengths have been compared with those measured by the Dynasonde and found to be in excellent agreement (Lanchester, Nygrén, Jarvis and Edwards).

Monitoring of tidal modes in the lower thermosphere has been carried out using more of the EISCAT database. Earlier studies were based on CP-1 data, but more recently the use of CP-2 has been found to be better suited for the purpose. Three methods of determining the E-region neutral wind using EISCAT have been compared, namely (i) from the full vector of E-region ion velocity determined at four separate heights from CP-1 tristatic data, (ii) from complete profiles of E-region ion velocity determined from CP-2 monostatic data, and (iii) from the complete profile of the field-aligned component of the meridional ion velocity determined from CP-1 and CP-2 field-aligned measurements. Methods (ii) and (iii) enjoy better signal to noise ratios than method (i) and they have the further advantage that they can use simultaneous F-region measurements of the electric field

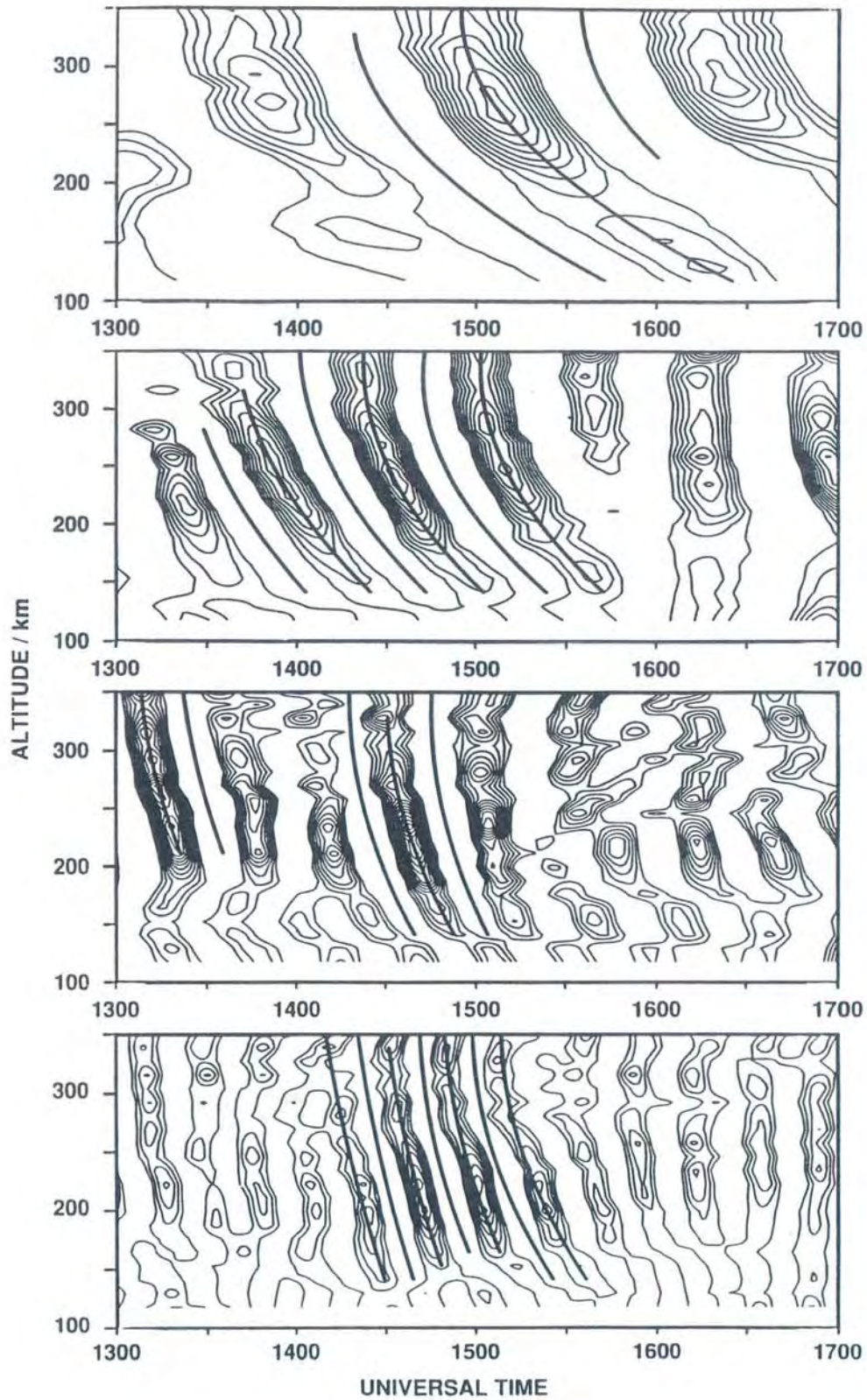


Fig. 16. Filtered electron density, 13-17 UT on 3 August 1988. Starting from the top panel, the pass bands are 0.15-0.25 mHz, 0.35-0.5 mHz, 0.55-0.65 mHz and 0.75-0.95 mHz. Only non-negative contours are shown. The contour intervals in the respective panels are 10^9 m^{-3} , $5 \cdot 10^8 \text{ m}^{-3}$, $2 \cdot 10^8 \text{ m}^{-3}$ and 10^8 m^{-3} . The heavy lines are results of polynomial fits to selected maxima and minima.

along the same magnetic field line. Method (iii) has the additional advantage that it is independent of the ion-neutral collision frequency, but it suffers the two disadvantages that it only provides the meridional component of the tidal mode and the results are strongly affected by vertical velocities. A comparison between the field-aligned and beam-swinging determinations of the average profiles of the meridional component of the tidal modes shows very good agreement for the mean, semi-diurnal and ter-diurnal modes, but a systematic difference in the amplitude of the diurnal mode. This is due to a small diurnal variation in the vertical velocity (Williams, Viridi, Jones and Huuskonen).

There has also been work going on considering tidal influence in studies of polar mesospheric summer echoes (PMSE). Early studies of PMSE at EISCAT were concentrated near midday or midnight because there was some evidence that the rate of occurrence was highest at these times. Only with the introduction of Common Programme 6 were measurements made over the full 24 hours. The results confirm that the occurrence of PMSEs is a minimum at 0700 and 1900 UT. As PMSEs are only observed in summer this variation is not directly related to solar illumination, so the semi-diurnal variation in occurrence rate points to the influence of a semi-diurnal tide. Further evidence of a tidal influence is provided by the many examples of PMSE layers which are seen to descend in height. In some cases a single layer can be followed unambiguously for up to an hour. The average rate of descent is usually about 2 km h^{-1} but on a shorter time scale this is almost always modulated by the effects of atmospheric gravity waves. In other cases, there are significant gaps in the time record of a single layer, and interpolation can be difficult and even ambiguous when more than one layer is present. If, however, only unambiguous examples are taken, the average rate of descent is about 2.3 km h^{-1} , which for a semi-diurnal mode suggests a vertical wavelength of about 28 km, which is close to the predicted vertical wavelength of 34 km of the (2,4) tidal mode. A tentative interpretation is that the combination of a strong, steady zonal wind with a semi-diurnal tidal mode leads to a maximum in the horizontal wind speed twice a day.

Related wind shears can result in turbulence, which can affect PMSE (Williams, Palmer, Rishbeth and Jones). Further results relating to PMSE are discussed in the section on mesospheric science.

Gravity waves produce wave-like perturbations in the electron density, N_e , electron temperature, T_e , ion temperature, T_i , and ion velocity along the geomagnetic field line, V_i . The phase relationships between these parameters have been derived for 45 TID events with periods in the range 30-150 min selected from CP-1 and CP-2 data with low geomagnetic activity and low horizontal ion drift. In the data analysis, the power spectra of the relative fluctuations were calculated with the maximum entropy method (MEM). After bandpass filtering the fluctuations at the dominant periods with a Butterworth filter, the phase relationships between the TID parameters N_e , V_i , T_i and T_e were determined by cross correlation. The selected TIDs have characteristic phase relationships which do not depend on the wave period. In the height range 301-345 km the averaged phase differences with respect to V_i are $\phi(V_i)-\phi(N_e)=210^\circ\pm35^\circ$, $\phi(V_i)-\phi(T_i)=70^\circ\pm50^\circ$, $\phi(V_i)-\phi(T_e)=20^\circ\pm35^\circ$, (a positive V_i denotes an upward motion of the ions). The height dependence of the averaged phases of N_e , V_i , T_i , T_e and their phase differences are illustrated in Fig. 17. The phase profiles of N_e , V_i and T_i have similar inclinations in the height range 250-450 km, so that the phase differences between these parameters are nearly constant. The variation of T_e due to the TID shows an interesting phase behaviour: at heights below 250 km the phases of T_e and T_i are close together. With increasing height the phase of T_e approaches the phase of V_i , and at heights above 350 km the T_e -TID is nearly in phase with the V_i -TID. Therefore the T_e -TID, which is well measured by the EISCAT radar, can supply the V_i -TID as an indicator for a gravity wave induced fluctuation in the field-aligned neutral gas velocity at heights above 350 km (Hocke and Schlegel).

In CP-1 data, quasi-periodic electron density enhancements in the E-region are found which last for several hours (Fig. 18). Are these electron density variations due to a corresponding modulation of production and loss of ionization by an AGW or due to

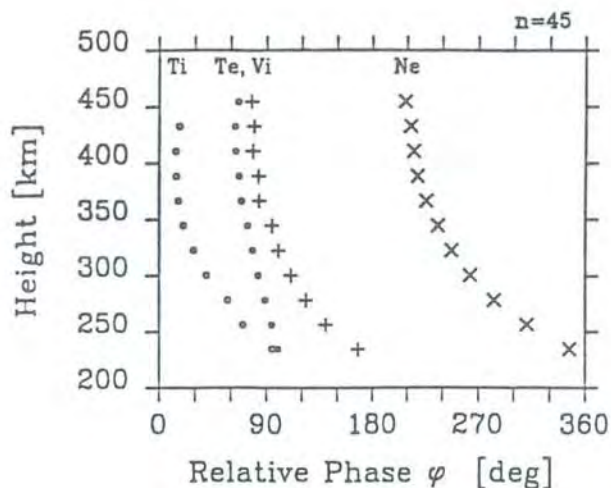


Fig. 17. Phase profiles $\phi(T_i)$, $\phi(T_e)$, $\phi(V_i)$ and $\phi(N_e)$ averaged for 45 gravity wave induced TIDs.

modulated precipitation? In a statistical study, two ranges of periods have been distinguished, one around 30-min and another from 60 to 90 min. The intensity seems to increase with magnetic activity. The overall occurrence frequency is larger at night, especially for periods in the 30-min range. The longer periods (60 to 90 min) are dominant around noon. These statistical dependencies are probably related to the distance of the measurement (Tromsø field-line) from the auroral oval. It was concluded that there is a possible relation of these characteristics with magnetospheric-ionosphere dynamics (Rinnert).

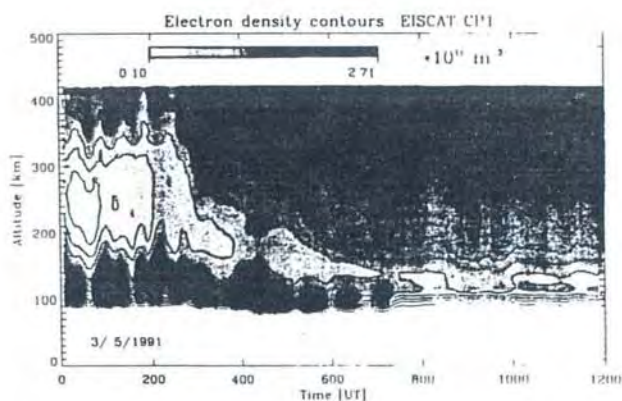


Fig. 18. Electron density contours for the E- and F-region from experiment CP-1 for the interval 00-12 UT on 3 May, 1991.

SUBSTORM PHENOMENA

The substorm recovery phase has been identified as a much more interesting period than previously assumed. A number of interesting auroral features occur in the morning sector of the auroral oval during this phase. Often the diffuse morning sector aurora brightens, in association with an enhancement of the morning sector westward electrojet, while the evening and midnight sector aurora is seen to recover. Using combined EISCAT scan and Viking imager data it was shown that this optical feature is associated with relatively energetic electron precipitation, enhancing mainly the morning sector Hall conductivity. Converting the EISCAT electron density profiles into electron flux-energy spectra (Fig. 19) it was concluded that the morning sector precipitation could be caused by adiabatic particle acceleration in a finally contracting magnetosphere during the late substorm development. These observations can be interpreted in support of a magnetospheric substorm model which involves the formation and release of a magnetospheric plasmoid (Opgenoorth, Persson, Pulkkinen and Pellinen).

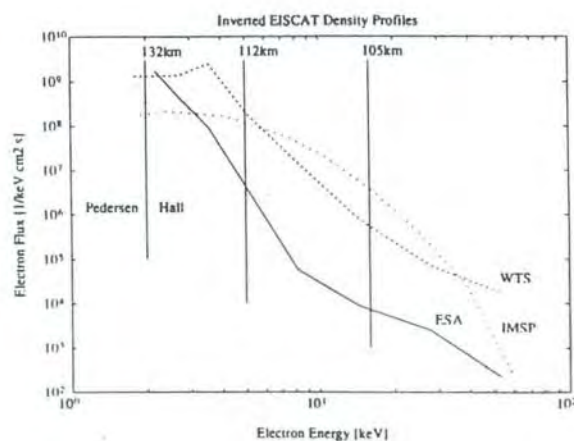


Fig. 19. Flux-energy spectra of precipitating electrons for three situations: evening sector arc (ESA), westward travelling surge (WTS) and intense morning sector precipitation event (IMSP). The vertical lines mark penetration altitudes for particles of the corresponding energies. Most of the Pedersen conductivity is produced by particles with energies below the line marking penetration to 132 km.

Comparing conductivities derived from EISCAT data with Viking images in two UV frequency bands (123.5-160.0 nm and 134.0-180.0 nm), it was found that such dual band UV images contain some information on the ionospheric conductivity characteristics. The resulting calibration was coarse, but it could nevertheless be concluded that in evening sector aurora the emissions seen by both cameras are correlated to changes in the ionospheric conductivity, but emissions in the longer wavelength band correspond more to increases in the Hall conductivity. In the morning sector the IMSP results in emissions in the shorter wavelength band, which are correlated with extreme ionospheric Hall-to-Pedersen conductivity ratios (Persson et al., 1992).

In November, 1992, the first EISCAT campaign in coordination with the Freja satellite was carried out. With a combination of high altitude experiments on both the VHF and UHF facility the nature of topside ionospheric turbulence and the associated ion outflows will be investigated. The experiments also contain a special part for the detection of naturally enhanced plasma lines, which hopefully will allow the direct determination of field-aligned currents. The data will also be useful for other studies of auroral phenomena, such as arcs and substorms.

Large, short-lived, bursts of plasma velocity in the night-time auroral zone are typically observed by EISCAT during periods of southward-pointing IMF. These bursts are associated with maximum Joule heating and so represent large energy transfers from the magnetosphere into the ionosphere. Such bursts are probably associated with reconnection in the magnetotail and a subsequent release of stored energy into the auroral atmosphere, as expected during the expansion phase of a magnetospheric substorm. Simultaneous observations by EISCAT and coherent radars such as PACE, SABRE and STARE show that flow bursts are often observed simultaneously by different radars, which confirms that the bursts detected in the EISCAT data are genuine phenomena and not artifacts of the technique. However, the relationship is not always simple due to the different threshold conditions and selection effects that apply for the different techniques (Freeman,

Cowley, Lester, Lewis, Pinnock, Rodger, Williams and Yeoman).

The relationship between the flow bursts and the different phases of the substorm is a topic of considerable importance. Multi-instrument studies using EISCAT data with other radars, magnetometers, all-sky cameras and spacecraft are therefore crucial in a full interpretation of the bursts. Data from one such study are displayed in Fig. 20. The top panel shows the energy transferred from the solar wind into the magnetosphere and subsequent panels show the response of the night-side magnetosphere and ionosphere to this energy input. The EISCAT flow bursts in general coincide with impulsive behaviour in magnetometer records at a similar location and with Pi2 pulsations observed at mid-latitude. However, the relationship is not straightforward: the magnetometer measurements suggest that some of the flow bursts occur during the growth phase of the substorm and several of the flow bursts cannot be associated with Pi2s. Comparison with particle measurements from geostationary orbit confirms that some of the flow bursts are linked with thinning of the plasma sheet, as expected in the growth phase, while others are clearly associated with multiple injections during the expansion phase. This complex relationship between the flow bursts and associated transfer of energy from the magnetosphere on the one hand and the different stages of the substorm on the other, poses a challenge to the conventional paradigm of substorm dynamics (Lewis, Yeoman, Cowley, Freeman, Lester, Lockwood, Lühr, Orr, Reeves, Rodger and Williams).

EISCAT data have been employed in two studies involving the CRRES spacecraft. An interval of substorm activity has been investigated in a number of CRRES instruments, along with ground-based data from the EISCAT radar, the PACE radar, all sky camera and magnetometer data. One substorm onset was observed to be centred at low geomagnetic substorm expansions. In addition the EISCAT radar, ground-based magnetometers and CRRES particle and field instruments have been used in a study of an interval of magnetic pulsation activity, which was stimulated by increased particle fluxes injected during earlier substorm activity.

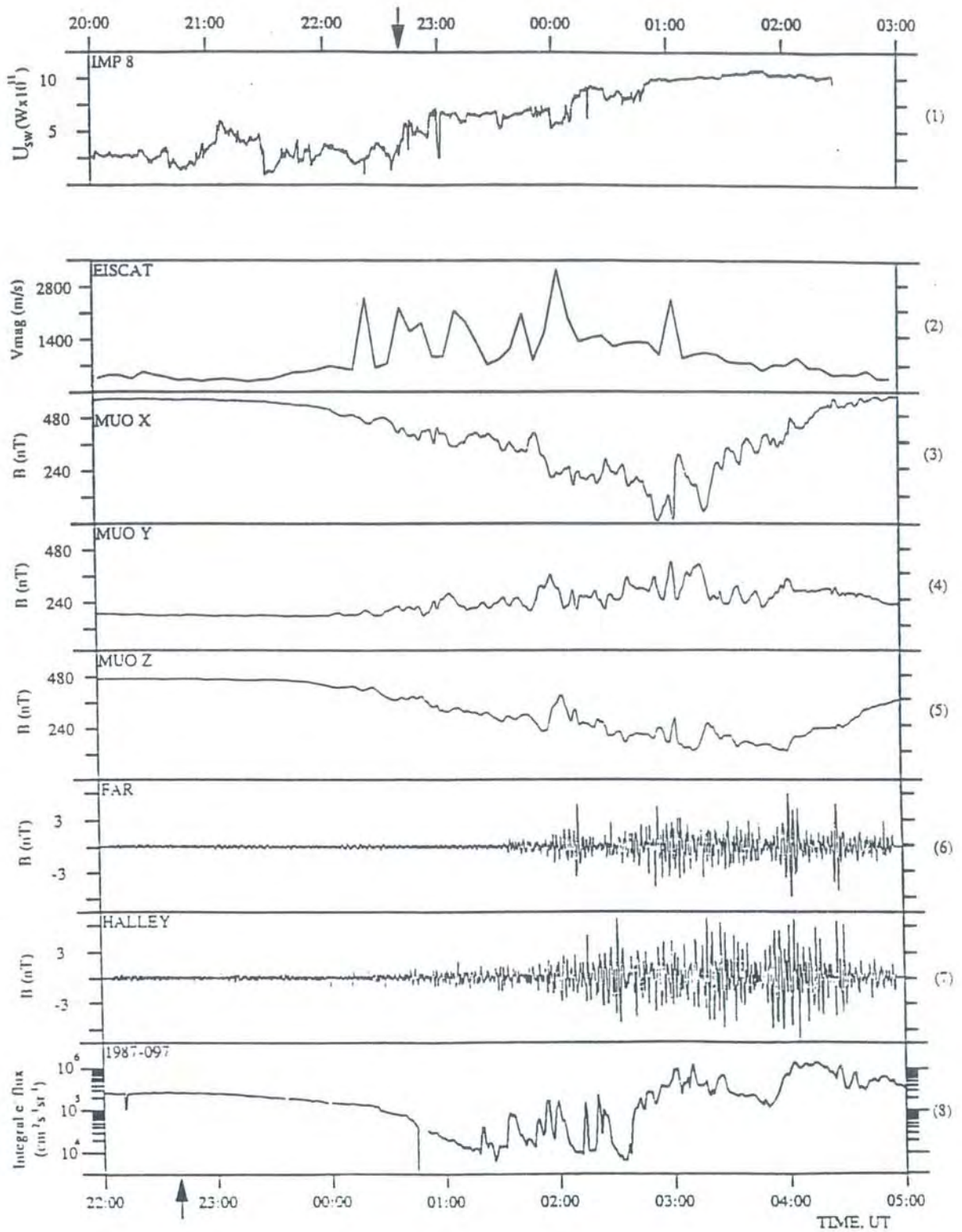


Fig. 20. A series of flow bursts observed during the night of 13-14 June, 1988. The top panel indicates the entry of energy from the solar wind. The second panel shows the flow burst measured by EISCAT. Panels 3-5 are from the EISCAT cross magnetometer at Muonio, panels 6-7 show Pi2s at Faraday and Halley stations (Antarctica), and panel 8 shows the integral electron flux from the geostationary satellite 1987-097. Notice the 2-hour delay between the top panel and the subsequent panels.

E-REGION STUDIES

The characteristics of an auroral pulsating patch were measured by photometer, TV-camera and EISCAT on 1 February, 1987, at 0132-0136 UT. Photometric data were used to deduce the intensity of the 427.8 nm emission from TV measurements and the characteristic energy of the electrons from the 557.7/427.8 nm emission ratio. Electron density profiles from EISCAT measurements were used to obtain the energy parameter α of a Maxwellian distribution of auroral particles during the 'on' phase of the pulsation. It appears that photometric data give a reliable energy parameter only for diffuse background aurora. Using calibrated TV-intensities, electron densities were calculated for altitudes of 92-110 km along the radar beam. The results agreed well with the radar measurements. It is thus possible to model ionospheric electron densities in a large area covered by the TV camera. In addition, the TV-data were used to investigate the form and behaviour of the drifting patch, e.g. the decrease in the diffuse background auroral intensity inside and in front of the patch (Kaila, Rasinkangas and Kangas).

Sudden increases, on a time scale of a few seconds, have been observed in E-region electron density, followed by slower decays of the order of 1-2 min. The 427.8 nm optical emission showed abrupt peaks coincident with the density enhancements. The results were interpreted as bursts of short-lived electron precipitation. The decaying electron density was used for the determination of the effective recombination coefficient profiles in the E-region (Figs. 21 and 22). The accuracy achieved was better than in any previous observations. The results were used in interpreting the changes in E-region chemistry caused by the electron precipitation. They seem to indicate an increase in the O_2^+ abundance caused by the precipitation bursts (Nygrén et al., 1992).

In December 1990 and 1991, EISCAT measurements were performed before, during and after the Geminid meteor shower. The aim was to establish whether there exists a true cause-and-effect relationship between variations in meteor

activity on the one hand, and the density and composition of layers of heavy ions (sporadic E layers) in the ionosphere on the other, and to study what detailed relationship there exists between meteor activity and the frequency of occurrence of the sporadic E layers. Within the very small volume of the EISCAT radar beam, a large number (461) of such echoes were seen during an observation time of 50 hours. Of these, 352 were very short-lived Doppler shifted "head echoes" indicative of a rapid meteor, while the rest of the echoes were ordinary trail echoes coming from the ionization left behind a meteor. While the trail echoes were quite uniformly distributed over the whole measurement interval from 65 to 160 km, the head echoes were concentrated in the interval from about 75 to 105 km (Fig. 23). The upper edge of the distribution is very sharp. This might be associated with the sharply increasing atmospheric density. An air cap giving the head echo might be formed around the meteor. Another reason can be the 32 cm wavelength of the EISCAT UHF system, which might cause an upper limit for detectable signals at the altitudes where the radar wavelength is comparable with the atmospheric mean free path. Measurements with the VHF system can give more information for the reason for the sharp upper cut-off for the head echoes (Pellinen-Wannberg).

The nocturnal high latitude E layer has been studied during extremely quiet conditions. When the E layer electron density was of the order of $5 \cdot 10^9 \text{ m}^{-3}$, a complex structure of thin, weak layers of enhanced electron density was visible (Fig. 24). The main features of the pattern were observed to prevail on three consecutive nights. The layers were interpreted in terms of gravity waves and tides. Although some of the layers were necessarily composed of metal ions, some may have had a considerable molecular ion content. This is possible, because the lifetimes of the molecular ions in such low density plasma is very long, of the order of 10 min (T. Turunen, Nygrén and Huuskonen).

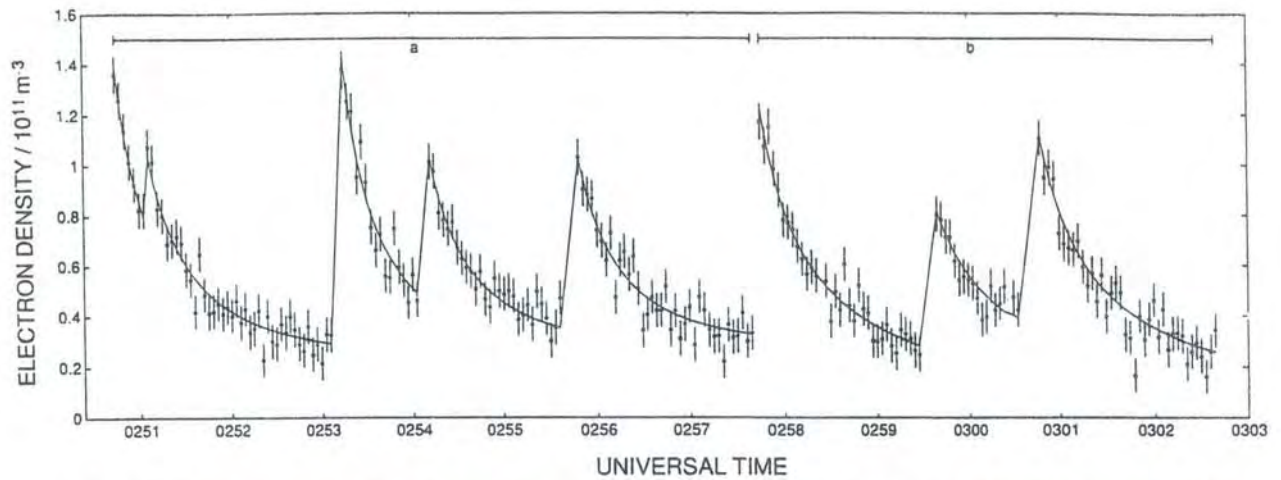


Fig. 21. Least squares fits of theoretical decays to measured electron densities at 98.9 km.

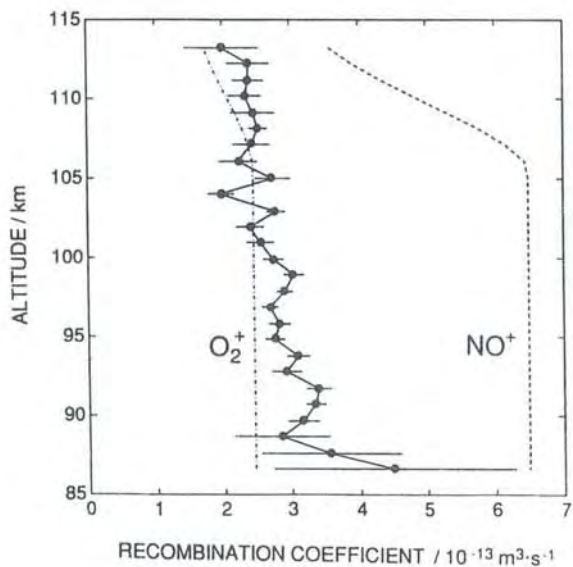


Fig. 22. Continuous line: measured effective recombination coefficient profile. The error bars are standard deviations. Dashed and dash-dotted curves: model recombination coefficient profiles for NO^+ and O_2^+ ions, respectively.

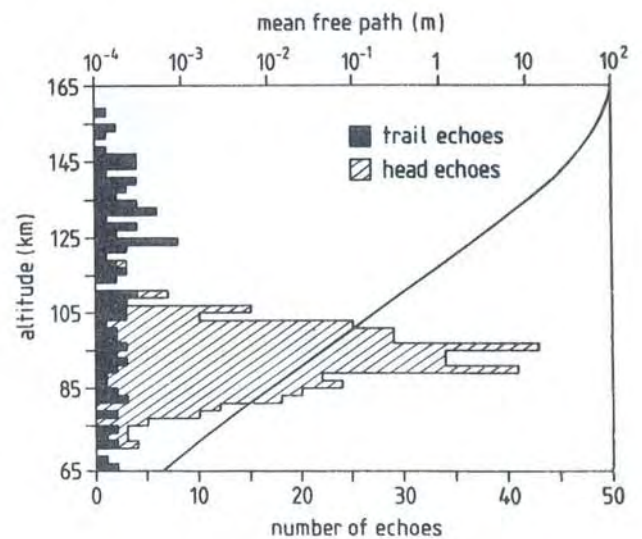


Fig. 23. The altitude distributions of the observed meteor trail and head echoes. The line shows the atmospheric mean free path.

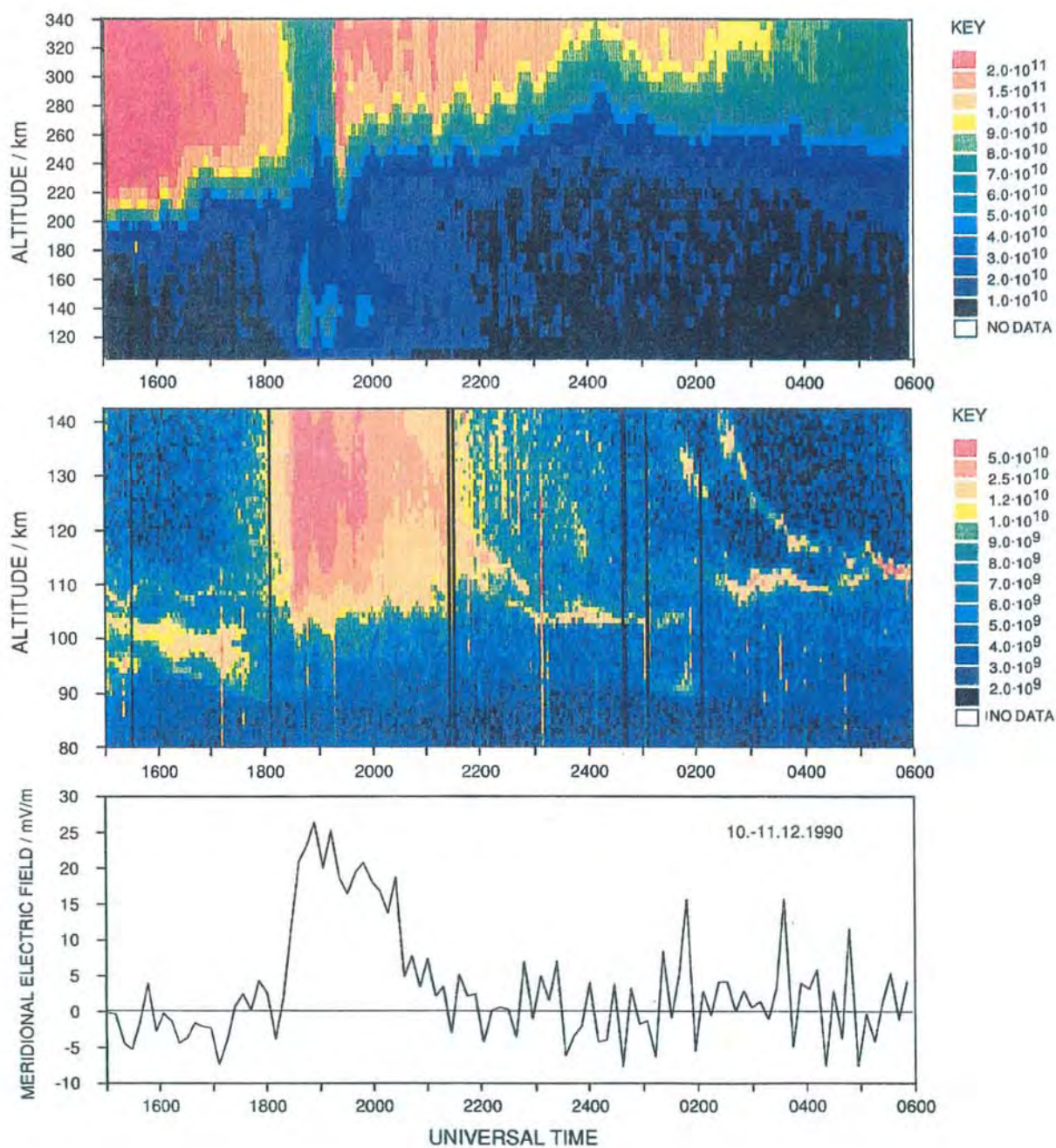


Fig. 24. F- and E-layer electron density (in m^{-3}) and meridional component of electric field (positive northwards) above Tromsø during the night of 10-11 December, 1990.

MESOSPHERE

Analysis of the observations made during the NLC-91 campaign (a joint radar, optical and sounding-rocket campaign from Esrange in the summer of 1991) has shown that the presence or absence of polar mesosphere summer echoes was not directly related to the presence or absence of noctilucent clouds, and that these two phenomena did not occur at exactly the same height. During the events studied, PMSE were not related to the level of geomagnetic activity, nor was the presence of energetic particle precipitation generally required for PMSE to be visible. There was a minimum in PMSE occurrence in the evening (17-22 LST). From the sounding rockets it was clear that the PMSEs were associated with layers containing extremely sharp gradients and/or intense turbulence in plasma density and/or neutral density.

While PMSE layers have been detected simultaneously at widely separated locations (eg. Esrange and EISCAT, at about 200 km distance), observations using the EISCAT VHF radar in split-beam mode, with a horizontal separation between the two beams of about 18 km at PMSE height (80-90 km), showed cases of both similar and uncorrelated echo characteristics in the two beams (Fig. 25). This result has obvious implications for the comparison of rocket and radar observations of PMSE layers. Signatures of PMSE are seen only rarely by the EISCAT UHF radar. Results from a study using both the EISCAT UHF and VHF radars indicated that the appearance of PMSE on UHF coincided with the only time that strongly divergent vertical velocities were seen by the VHF radar at the height of the layer (Collis, Rietveld and van Eyken).

A common, though not omnipresent, phenomenon detected in connection with PMSE is a bite-out in the electron density profile in the vicinity of the layer. This may result from the action of tides (see earlier) or long-period gravity waves modulating the temperature of the mesospheric gas, and thereby the local recombination rate. In regions of low temperature this effect could be amplified by the production of heavy positive ions which increase the recombination rate even further. Electron density gradients at the top and bottom of

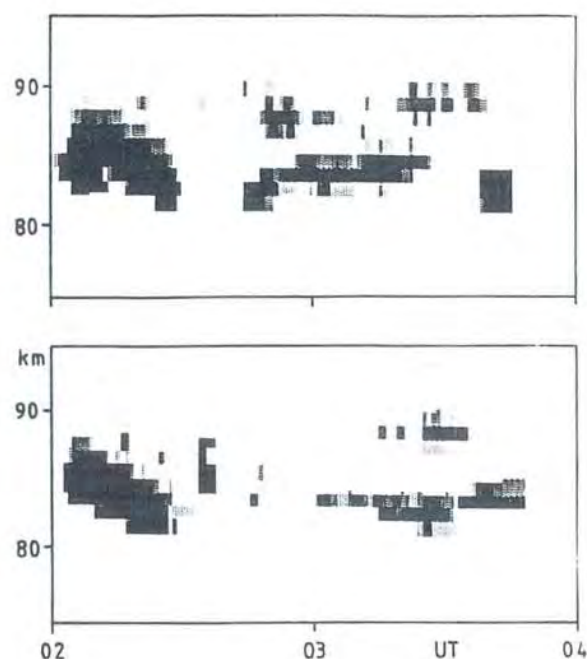


Fig. 25. Simultaneous backscattered power observations of PMSE by the EISCAT VHF radar using a vertical beam (upper panel) and a beam at 75.2° elevation to the west (lower panel).

these depletions, mixed by weak, remnant turbulence, would enhance the scatter cross-section and produce PMSE (Röttger).

STRATOSPHERE AND TROPOSPHERE

The ability to make measurements at tropospheric and stratospheric heights with EISCAT was demonstrated almost a decade ago, but, mainly due to hardware limitations, few similar results have been obtained, until now. After hardware improvements these methods were again employed for the study of the structure and dynamics of this region of the atmosphere. Ground clutter is unavoidable in such measurements, but in most cases can be effectively removed by subtracting out the corresponding persistent component of the ACF (Fig. 26). The cleaned spectra then indicate the prevailing wind as a function of altitude, and by moving the UHF antenna between the zonal and meridional directions the horizontal wind vector can be deduced (Fig. 27). This scheme, which takes only a few minutes to determine such vector profiles, is now operated regularly before each UHF common programme (Röttger).

PLASMA LINES

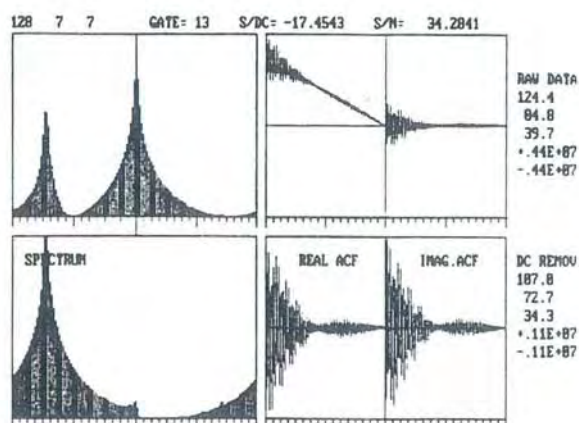


Fig. 26. EISCAT tropospheric measurements showing the real and imaginary parts of the ACF and the spectrum, before and after application of the algorithm to remove the ground clutter echo at zero frequency.

Recent high frequency-resolution studies of the electron plasma line have shown that the difference between the upshifted and the downshifted frequency does not depend only on the electron drift in the plasma and the electron temperature through the classical dispersion relation using the Maxwellian electron distribution. The difference also contains an additional strong nonlinear dependence on the electron temperature. It was shown that the origin of this shift in the centre frequency between the upshifted and downshifted lines can easily be due to heat flows in the electron gas. A new expression for the dispersion relation that includes the heat flow contribution is established and a recently acquired data set was used to demonstrate that the heat flow correction gives quantitatively correct results. For radar frequencies at 931 MHz and plasma frequencies of the order of 7 MHz, this means that an electron temperature gradient of $\sim 1 \text{ K km}^{-1}$ can produce a shift close to

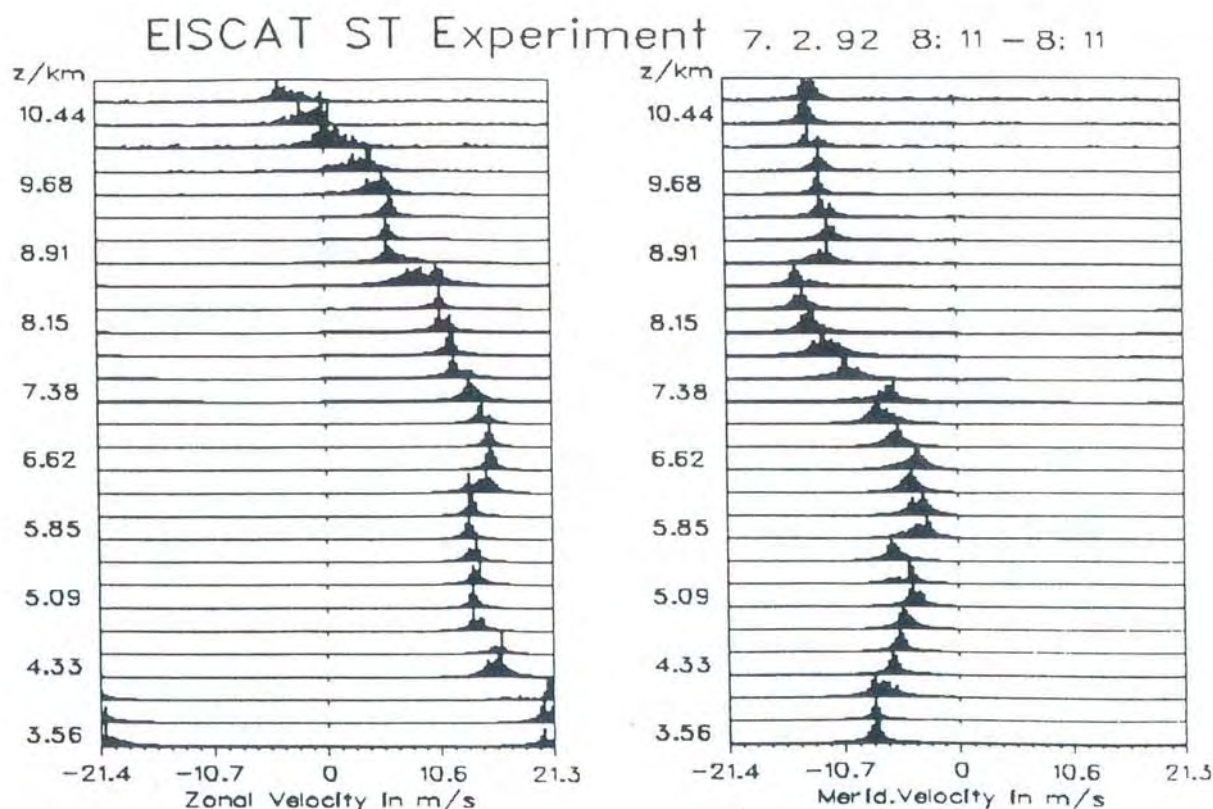


Fig. 27. Examples of zonal (left) and meridional (right) wind profiles through the troposphere and stratosphere obtained on 7 Feb. 1992 during the EASOE (European Arctic Stratospheric Ozone Experiment) campaign. Single profiles can be obtained within a 10-sec interval.

1 kHz between the up- and down-shifted frequencies. This frequency shift is important as it is comparable to the shift caused by parallel currents of a few μAm^{-2} (Kofman, Saint-Maurice and van Eyken).

The first estimates of electron temperatures derived from plasma lines observed in Kiruna and Sodankylä have been reported, demonstrating that this technique can indeed be used in practice. The more difficult problem of estimating field-aligned currents using plasma lines is still not completely solved. During 1992, both measurement and analysis techniques for natural plasma lines were further developed. Real-time software has been developed which analyses both ion line and plasma line signals on-line and steers the remote antennas and the frequency tuning of both Tromsø and remote receivers automatically. This software has been successfully tested. During operations in coordination with the Freja satellite, the first observations of the cutoff frequencies for both up- and down-shifted plasma lines at night were performed in a region of diffuse auroral precipitation. In addition, software has been developed for calculating the expected difference between the offsets of the up- and down-shifted plasma lines, and taking into account the heat-flow correction term. An accurate estimate of this expected difference is essential if the remaining discrepancy is to be interpreted in terms of field-aligned currents (Alcaydé, van Eyken, Guio, Løvhaug and Saint-Maurice; Kirkwood and Bjørnå, 1992).

THE CHIRPED RADAR TECHNIQUE

Considerable effort has been invested into obtaining successful observations of natural plasma lines using the chirped incoherent scatter radar technique. This work was rewarded on 25 October, 1992, by the first successful natural plasma line observations using the EISCAT digital chirp generator (Fig. 28). This observation was followed by the trial use of the EISCAT chirp during the first EISCAT-run heating campaign at the Heating facility. Fig. 29 clearly shows the natural, photo-electron-enhanced plasma line (PEPL) and the HF-induced plasma line (HFPL) separated by approximately 300 kHz. Given a chirp rate of 52 kHz km^{-1} , this indicates that the range

where the ambient Langmuir frequency as seen by the radar equals the heater frequency lies about 6 km below the source of the induced line. This is a significant result since, while it is in agreement with similar observations made at Arecibo, it appears to contradict previous studies performed at EISCAT. Current plans for the use of this new plasma line observing technique include further observations of the natural and induced plasma lines during heating experiments and the observation of natural plasma lines enhanced by energetic electrons during auroral precipitation events (Isham, La Hoz, Rietveld and Leyser).

EISCAT-HEATING EXPERIMENTS

Observations of Langmuir turbulence with high range and time resolution were already reported in the EISCAT Annual Report for 1991. These experiments were continued in two campaigns in 1992 using both radars simultaneously and applying new correlator programs. Fig. 30 shows such spectra measured between 204 km and 207 km altitude with a gate separation of 225 m. The VHF radar echoes lie about 1.5 km higher than the UHF echoes. This is in agreement with the parametric decay theory (weak turbulence), which predicts that this altitude difference should be proportional to $k_U^2 - k_V^2$, the altitude of the VHF excitation region being higher (k_V and k_U are the two radar wave numbers). Also, the structure of the spectra in Fig. 30 is in agreement with the parametric decay theory. This is true in particular for the UHF observations, where we see a clear purely growing line, a first decay line and one additional cascade line.

It is remarkable that both UHF- and VHF-spectra appear over a rather broad altitude range of $\sim 1 \text{ km}$; from theoretical arguments one would expect a width of several hundred meters for UHF and less than 100 m for VHF. A possible explanation is that the ionosphere over Tromsø is usually slightly inhomogeneous so that the matching altitude is not exactly defined. This also means that it is of no use to increase the altitude resolution of the experiments any further.

Fig. 30 represents observations done with 1-second integration after heater switch on.

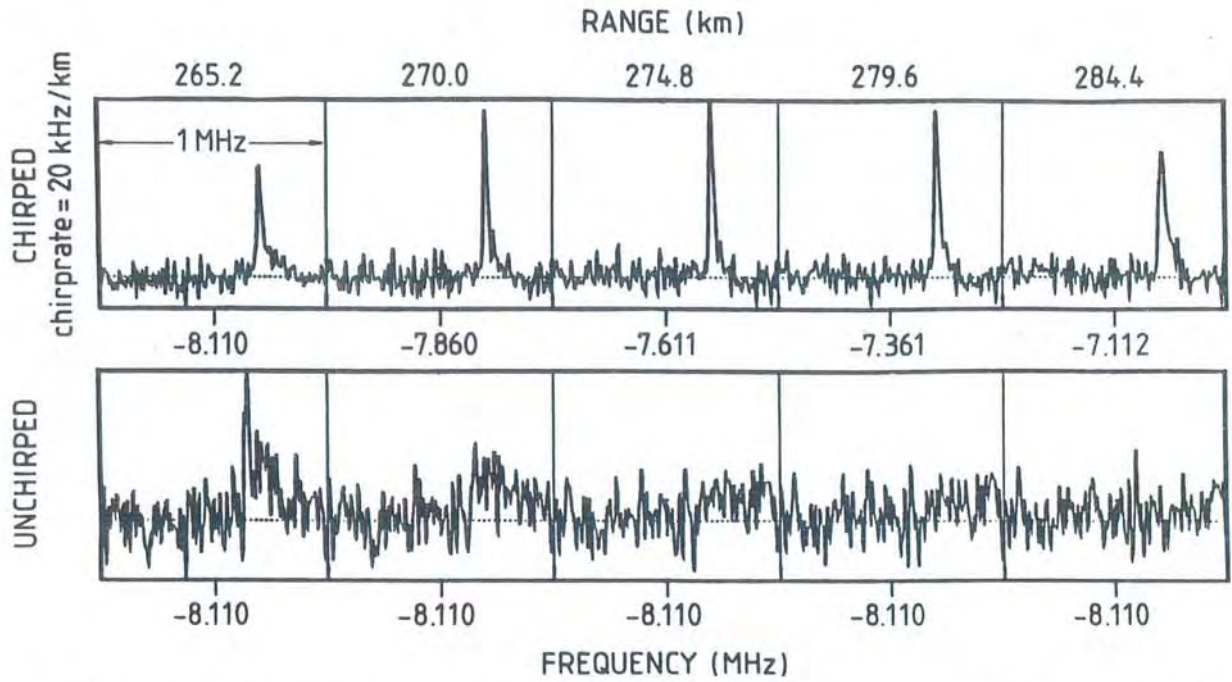


Fig. 28. Spectra of downshifted natural plasma lines measured from the EISCAT Tromsø site on 25 October, 1992, at 1329 UT. The chirped measurements allow the observation of the natural line with high signal to noise ratios away from the F-region peak. The sharp spectrum appearing in the lowest gate of the unchirped data is due to the proximity of the F region peak, which during this observation lay at a range of about 250 km.

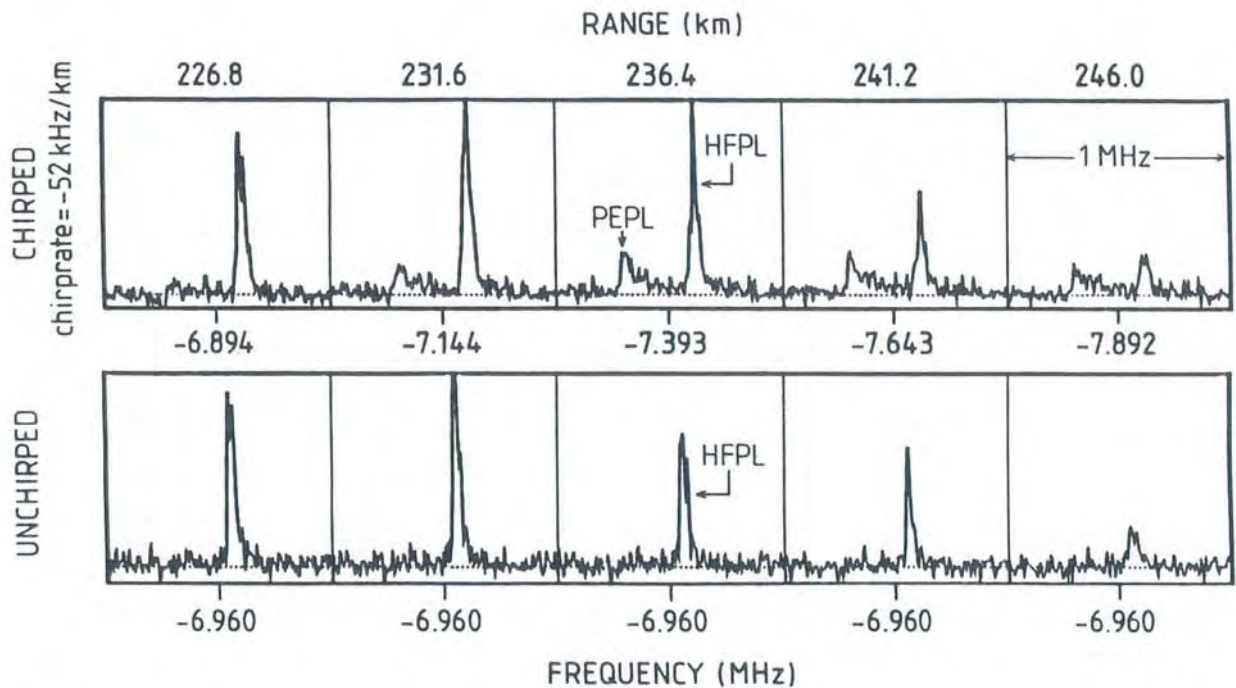


Fig. 29. Spectra of downshifted photo-electron-enhanced and heater-induced plasma lines (PEPL and HFPL, respectively) measured from the EISCAT Tromsø site on 18 November, 1992, at 1139 UT. The approximately 300 kHz separation between the two lines in the chirped spectra indicate that the HFPL source region lies about 6 km above the height where the heating frequency equals the ambient Langmuir frequency as seen by the radar. The heating frequency was 6.960 MHz and the cycle was 2 s on, 58 s off at approximately 1 GW effective radiated power.

The same kind of observations have also been performed with a resolution of some 10 ms, but there was basically no difference in the spectra.

The VHF spectra in Fig. 30 show a line structure on top of a broad background. Weak, broad spectra have also occasionally been seen in the uppermost gates of the VHF experiment. This may indicate that besides parametric decay some strong turbulence is present. The typical features of weak turbulence, however, as a clear line structure of the spectra, are present in almost every case. It seems that in heating experiments at Tromsø, strong turbulence is less important than at Arecibo.

The chirp results mentioned earlier indicate that the natural plasma line appears at a lower altitude than the artificially excited plasma line, as previously reported from Arecibo observations. This leads to the interpretation that the excitation seen by the UHF radar happens at the reflection level of the heater wave, which is in contrast to the present results, where excitation is seen with the VHF radar still above the corresponding UHF excitation. A joint campaign is envisaged in 1993 to clarify this discrepancy (Kohl, Rietveld and Stubbe).

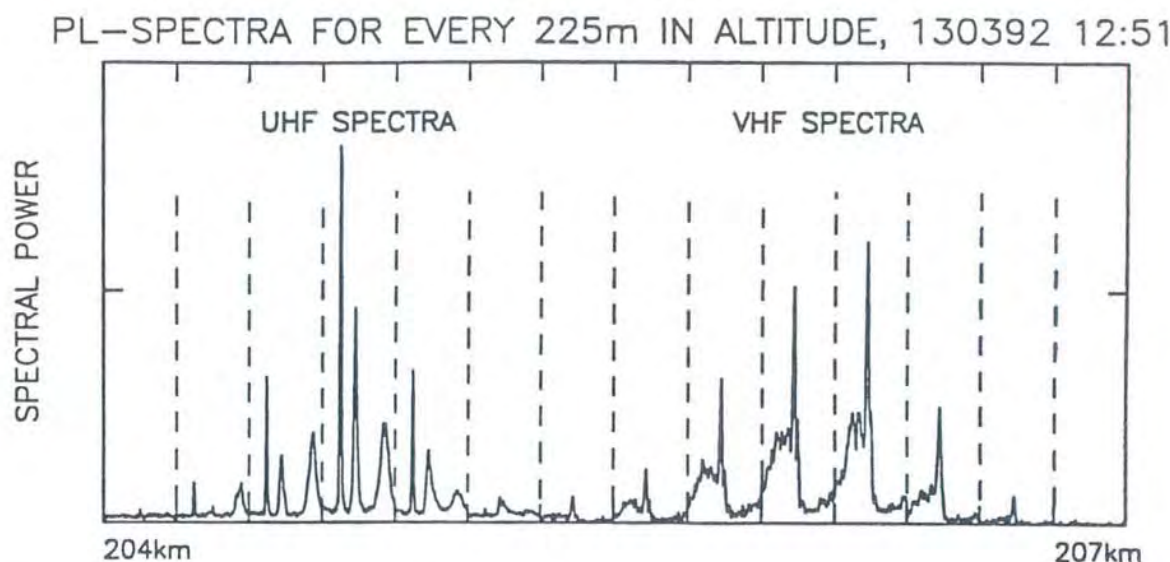


Fig. 30. UHF- and VHF-spectra of heater-induced plasma lines observed simultaneously during a Heating experiment at Tromsø. The dashed lines denote the limits of the gates, the lowest gate being at 204 km the highest at 207 km. The heater frequency (6.77 MHz) corresponds to the middle of the gate for the VHF spectra, while for the UHF spectra it is shifted to the left. In the UHF spectra three lines are clearly seen (from left to right): the purely growing mode (at heater frequency), the first decay line and one cascade line.

Obituary

Peter Christiansen died suddenly on 30 July 1992, aged fifty. At the time of his death he was Chairman of the United Kingdom's EISCAT Project Committee and he played a crucial role in guiding UK participation in the EISCAT Svalbard Radar project. He was head of the Space and Plasma Physics Group at the University of Sussex, and was actively involved in major satellite missions such as GEOS I and II, AMPTE, CRRES, and Cluster, as well as novel research programmes using the EISCAT radars. Peter was an outstanding space physicist and his scientific talents, wise counsel and warm personality will be greatly missed.

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Hocking, W.K. and J. Röttger, Amplitude statistics, absolute scatter cross sections and persistency of scatterers of polar mesosphere summer echoes deduced with the EISCAT 224 MHz radar, Proceedings of the Fifth Workshop on Technical and Scientific Aspects of MST Radar, ed. B. Edwards, Scostep Secretariat, Univ. Illinois, Urbana, USA, 318-323, 1992.

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EISCAT REPORTS AND MEETINGS

Reports 1992:

EISCAT Annual Report 1991

Proceedings of the ESR Design Review Meeting 1992

Meetings 1992:

COUNCIL	38th meeting, 20/21 May 39th meeting, 12/13 Nov	Copenhagen, Denmark Uppsala, Sweden
SAC	42nd meeting, 10 April 43rd meeting, 25/26 Sept	Edinburgh, United Kingdom Sodankylä, Finland
AFC	38th meeting, 7 April 39th meeting, 7/8 Oct	Abingdon, United Kingdom Kiruna, Sweden
Long-Term Planning Group	7 February 16 July 16 October	Stockholm, Sweden Copenhagen, Denmark Copenhagen, Denmark
ESR Design Review Meeting	28 September - 1 October	Ylläsrinne, Finland
Annual Review Meeting	1 - 2 October	Ylläsrinne, Finland

BALANCE SHEET AT 31 DECEMBER 1992

Assets	At 31 Dec 1991	Pool	Additions Cap Op Other	Depre- ciations	MSEK At 31 Dec 1992	Liabilities	At 31 Dec 1991	MSEK At 31 Dec 1992
FIXED ASSETS						CAPITAL		
Buildings	7.4		2.2	0.2	9.4	Contributions	95.0	94.3
Transmitters	25.6	0.2	-0.9	1.9	23.0	Pool		0.7
UHF antennas	9.4			1.3	8.1	UHF Spare Klystron		23.6
VHF antenna	12.9			1.5	11.4	Capital operating	21.9	25.1
Computers, etc	3.5		1.1	1.2	3.4	In kind	25.1	25.1
Other	4.5		0.8	0.5	4.6	Other	0.4	0.4
UHF Spare Klystron			0.7		0.7	Heating Building		2.3
ESR Transmitter			2.0		2.0	ESR Transmitter		2.0
Total	63.3	0.2	4.6	6.6	62.6		142.4	148.4
						Depreciations	79.1	85.8
						Total Capital	63.3	62.6
CURRENT ASSETS						RESERVES		
Debtors	0.9				4.9	Pool	0.4	1.2
Prepayments and accrued income	0.3					Capital Operating	3.0	4.9
Cash and Ordinary						Other	3.1	2.8
Bank Accounts	9.1				12.1	Total Reserves	6.5	8.9
Special Accounts						ESR Allocation	0.4	
Total	10.3				17.0			
						LIABILITIES		
						Provisions	0.8	0.2
						Other Liabilities	2.6	7.9
						Total Liabilities	3.4	8.1
GRAND TOTAL	73.6				79.6	GRAND TOTAL	73.6	79.6
Total budget outcome in 1992 (MSEK):					Recurrent chapter:	Personnel:		9.96
						Administration:		4.36
						Operations:		3.09
						EISCAT Svalbard Radar:		1.56
						Total:		18.97

(Totals may not match because of rounding; MSEK = Million Swedish Crowns)

EISCAT SCIENTIFIC ASSOCIATION

31 December 1992

	Finland	France	Germany	Norway	Sweden	United Kingdom
COUNCIL	J. Kangas A. Siivola*	A. Berroir G. Caudal W. Kofman	G. Haerndel T. Hagfors M. Meinecke	A. Brekke B. Benterud	B. Hultqvist J. Gustavsson	S.W.H. Cowley T.B. Jones R.L.T. Street
SAC	M. Lehtinen	D. Fontaine D. Alcaydé	W. Baumjohann K. Rinnert	C. La Hoz	H. Opgenoorth*	M. Lockwood P.J.S. Williams
AFC	E. Ikonen	D. Alloin	G. Hoch	A. Andersen	J. Gustavsson*	P. Fletcher

SAC = Scientific Advisory Committee; AFC = Administrative and Finance Committee; * = Chairman

EISCAT Senior Staff

Director: J. Röttger (on secondment from MPG) Deputy Director (Science): A.P. van Eyken Site Leaders: Kiruna: I. Wolf
 Deputy Director (Technical): G. Wannberg Head of Computer Operations: S. Buchert Sodankylä: M. Postila
 Tromsø: R. Jacobsen

D.M. Schildt (UK), O. Havnes (Norway) and W.I. Axford (Germany) also held appointment on Council, and N. Bjørnå on SAC. Non-Associate members of SAC were N. Matuura (Japan), M. Uspensky (Russia) and P. Hoeg (Denmark).



THE EISCAT ASSOCIATES

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SA

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MPG

Max-Planck-Gesellschaft
Germany

NAVF

Norges Almenvitenskapelige Forskningsråd
Norway

NFR

Naturvetenskapliga Forskningsrådet
Sweden

SERC

Science and Engineering Research Council
United Kingdom

December, 1992

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EISCAT Scientific Association
November 1993