

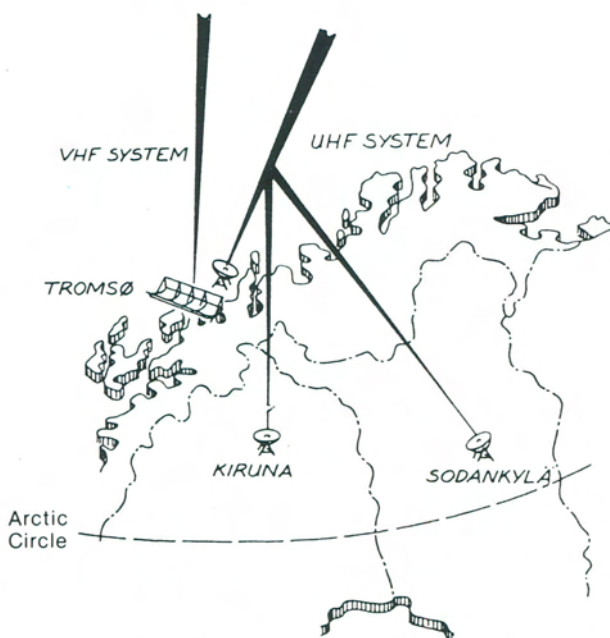


E I S C A T

EUROPEAN INCOHERENT SCATTER SCIENTIFIC
ASSOCIATION

ANNUAL REPORT 1985

S-98127 KIRUNA, SWEDEN, PHONE (0980) 18740



EISCAT, the European Incoherent Scatter Scientific Association, is established to conduct research on the upper atmosphere, ionosphere and aurora using the incoherent scatter radar technique. The experimental facilities are located in Scandinavia, north of the arctic circle. They consist of two independent radar systems (UHF at 933 MHz and VHF at 224 MHz) with transmitters and receivers in Tromsø. The UHF system also has receivers in Kiruna and Sodankylä.

Investments and operational costs are shared between:

Suomen Akatemia, Finland

Centre National de la Recherche Scientifique, France

Max-Planck-Gesellschaft, W. Germany

Norges Almenvitenskapelige Forskningsråd, Norway

Naturvetenskapliga Forskningsrådet, Sweden

Science and Engineering Research Council, United Kingdom.

*The cover photo shows the EISCAT site at Ramfjordmoen near Tromsø with the UHF antenna, the main buildings and the VHF antenna as well as antennas and buildings of the MPAE Heating Facility.
(Photo by courtesy of University of Tromsø)*



ANNUAL REPORT 1985

COUNCIL CHAIRMAN'S PAGE

The responsibility for the day to day management of our Association lies with the Executive Staff and specially with the Director and the Business Manager.

During the year 1985 our Council was faced with a major problem: replacing almost simultaneously the Business Manager and the Director. I am quite confident that P. Hagström and J. Röttger whom we have selected to respectively fill these two positions will be fully successful in their job. I am sure, they will even surpass themselves when remembering the merits of their predecessors who deserve special words of thanks from the Council. B. Thorwid had for four years the responsibility of keeping track of the various contracts passed by our Association and to present justifications in a form compatible with the administrative rules of six different countries. The Council on every occasion appreciated his dedication to his job and his competence.

When leaving us, Murray Baron is entitled to be proud of his accomplishments since 1982 when he joined EISCAT as Director of the Association. The UHF radar has been checked and all defects have been corrected. We now enjoy a reliable system which provides our scientists with excellent data on a regular basis. We have unfortunately not yet reached the same level of operation for the VHF radar. However, the progress has been very impressive: after termination of our contract with the builder of the VHF transmitter, efficient ways of putting this equipment into operation have been implemented so successfully that the Council members could see some of the first ionospheric echoes during their 1985 Spring Meeting in Tromsø and no major problem seems to remain in our way to an operational system. Murray was also an excellent group leader sharing with his entire staff his will to overcome any difficulty. We wish him full success in his new achievements.

I would also like to address special words of thanks to Tor Hagfors for the excellent design of our radar system which he made when he was EISCAT Director and as well for the help he subsequently provided us with on every occasion.

The Council has now full confidence in the future of our Association under the leadership of the new officers and looks forward to the successful exploitation by the member countries' scientists of the excellent data which will be obtained during the coming years.

Michel Petit



Tor Hagfors



Murray Baron



Jürgen Röttger

OUTGOING DIRECTOR's PAGE

The year 1985 has been quite a successful one for EISCAT. The UHF facility is now internationally recognized as the most up-to-date incoherent scatter facility in the world. There is no doubt that scientific productivity has also increased to a level which places EISCAT at the forefront of high-latitude upper-atmospheric research. The Second EISCAT Workshop held in Aberystwyth in September was well-attended and revealed a great deal of interesting work in progress.

EISCAT users have grown used to and have come to expect reliable operation of the system. It is easy to lose sight of the fact that continuing hard work on the part of the site staffs is essential in order to maintain the planned level of operations. Without a competent and experienced staff, a facility such as EISCAT cannot function effectively, and their contributions should be individually and collectively recognized by the Associates.

In 1985, the routine processing at EISCAT of Common Programme data became a reality. Associates are now receiving magnetic tapes of analyzed Common Programme data within some weeks of the time an experiment was performed. This saves the Associates time, effort and expense and ensures equal access to experimental results in a timely manner. By the end of the year, computer programs for visualization of the results in terms of overview color graphs were being prepared. It is expected that these overview graphics capabilities will be in place and distribution of the visual summaries will begin in 1986.

The portion of the existing facility that has given the most troubles during the past year or two has been the site computers. Their age has resulted in ever-increasing maintenance problems and their limited capacity has been a roadblock toward providing better on-line monitoring capability, more flexible experiments, and (most importantly) real time data analysis. I am very pleased that a plan has been developed and a funding mechanism put in place for initiating the replacement of the site computers in 1986.

With respect to the VHF system, I must admit to some disappointment that the system did not become operational in 1985. However, a great

deal of progress was made and prospects are good that the transmitter will be completed in 1986. The mile-stones achieved in 1985 were:

- * A negotiated severance of the VHF transmitter contract with AYDIN
- * Achievement of full power operation of the transmitter with the one remaining original Varian klystron
- * Completion of the in-plant acceptance tests of the first of two new klystrons from Valvo.

The severance of the AYDIN contract was important financially because it eliminated any possibility of litigation over the transmitter system, a possibility that in the light of subsequent delivery delays by VALVO would have become increasingly real. It also was important technically and administratively since it enabled us to have direct control over the completion of the transmitter installation and testing.

The achievement of full power, one-klystron operation of the VHF transmitter demonstrated the intrinsic capability of the transmitter to meet its design specifications once reliable tubes become available. And the successful completion of in-plant testing of the new klystron brings us an important step closer to the provision of the tubes.

In closing this, my last annual report, I want to express my appreciation to the Council and in particular to the past and present Chairmen for giving me the opportunity to be associated with EISCAT and for providing support and encouragement through some difficult times. My best wishes to the incoming Director, Dr. Jürgen Röttger, and the entire EISCAT staff and user community for a productive and successful future.

Murray Baron

INCOMING DIRECTOR's PAGE

The compilation of this Annual Report 1985 gave me a suitable opportunity to refresh my knowledge upon returning to EISCAT. Compared to late 1984 when I had left EISCAT, it is most obvious to me that the system as well as the scientific output has further progressed and has gained an advanced worldwide recognition. The improved reliability of the instruments has led to extended routine operations with the ionospheric parameters now becoming analysed in real time. The competence and enthusiasm of the staff and the visiting scientists have further grown, and the technological limits of the system have been approached fairly closely. These achievements and the unique tristatic UHF-radar capability as well as the envisaged experimental applicability of the VHF-radar, form the basis for the statement that the EISCAT facility is becoming the most outstanding incoherent scatter radar of the world.

In an Annual Report only a short review on the progress and status of the EISCAT system can be given and a few selected high-lights can be demonstrated. The most impressive advances appeared to be the implementation of the sophisticated GEN-System data taking algorithm and the detection of the first echoes with the VHF-radar.

There are many internal notes and reports discussing the technical developments as well as numerous papers which were presented at meetings and conferences, particularly at the very successful Second International EISCAT Workshop at Aberystwyth, and published in reports or scientific journals. The most striking ones are those utilizing the high temporal and spatial resolution of the EISCAT system, those utilizing the unique tristatic velocity measurements and those verifying the relation of the ionosphere with other phenomena in the neutral atmosphere, the magnetosphere and the solar wind.

Another remarkable accomplishment is the fact that the UHF-radar facility has become so reliable that continuous operations over many days are possible and again almost 2000 hours of data were collected during the last year. This means that the radar system was operated during one quarter of all time in 1985, which has to be regarded as an outstanding efficiency for an incoherent scatter radar facility.

It is unquestionable that one encounters in the system everywhere the original and substantial ideas and remarkable achievements of the first Director of EISCAT, Professor Tor Hagfors, and his co-workers. It is very much due to Dr. Murray Baron, the second Director of EISCAT, that the system reached its present high standard and reliable state and is now widely recognized and accepted in the scientific community.

It will be a demanding duty for me to complete the remaining tasks and to keep EISCAT in a condition which will enable it to remain a facility in the forefront of ionospheric and atmospheric research. To achieve this goal will obviously require a continuous and reliable operation. Even more essential —, it also demands continual refinement, progress and growth to improve the technology of the system, to keep a competent administrative, technical and scientific staff team, and to implement new kinds of techniques and methods, which will continuously attract attention, allow testing of novel ideas and unveil new phenomena.

I believe that the developing EISCAT system and the cooperation with the remarkably experienced and competent Assistant Directors and staff as well as the liaison with the distinguished community of the EISCAT users, combined with the support of Council and Committees, will allow many more years of high-standard EISCAT operation, research and science.

Jürgen Röttger



EISCAT holds regular Annual Review Meetings of the staff in order to review earlier and ongoing work, to discuss and agree upon recent and future developments as well as to strengthen the personal contacts between staff members from the locally separated sites and Headquarters. The Annual Review Meeting 1985 was held 25—27 March in Abisko/Sweden.

REVIEW OF THE EISCAT RADAR SYSTEM

The UHF system reached a status allowing the routine operation with negligible interruptions. The transmitter has been reliably working at power levels of 1.2 to 1.5 megawatts. The maximum power appears to be primarily limited by the switch tubes which are used to modulate the klystron beam.

After an elaborate bolt-tightening and reconditioning operation the UHF antennas are in a good condition, but we continuously have to maintain their electrical and mechanical performances. The receiving system in Tromsø has been considerably improved by reducing the recovery time of the preamplifiers, making possible more reliable measurements at shorter ranges. Local oscillators have been replaced and a full complement of receiver post detection filters at full 8-channel capability is now available at all three sites. With the installation of the fast analogue-digital converter in connection with the CCD spectrum analyser, a means is available to observe a wide bandwidth allowing simultaneous observations of the ion line and plasma line spectra.

All four correlators have been completely rebuilt and they consequently work much more reliably. The doubling of the result memory size will soon provide an increased capability for optimum adaption to the high demands of the improved data taking programs. The Barker decoders will permit decoding of all code sequences up to 13 bit and enable coded and non-coded pulses to be used in the same transmission sequence.

A new and sophisticated data acquisition system, the GEN-System, has been developed. It permits a combination of long pulses, multipulses and power profiles to be processed in a most flexible way and allows the EISCAT system to be used to its full capabilities. Experiments using all eight receiver channels, the full transmitter duty cycle and near-optimum spatial weighting and resolution become possible with the new GEN-System.

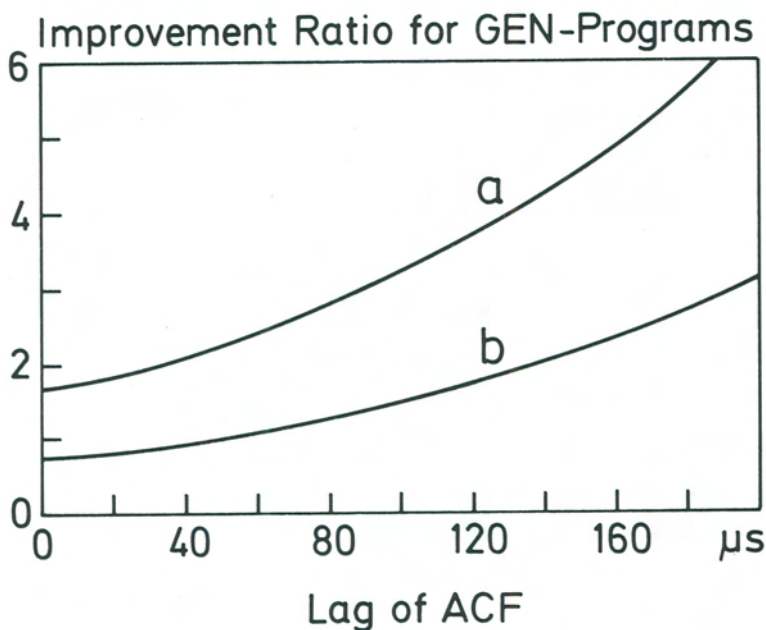
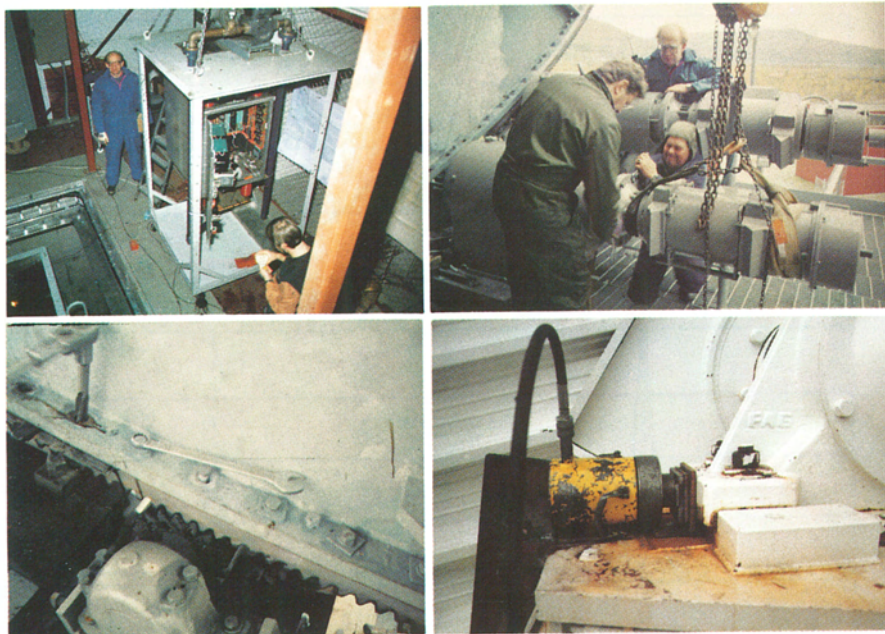


Figure 1: The ratio of integration time necessary to obtain the same statistical significance of results when applying the standard common programmes (curve a for CP3C and curve b for CP1F) and the newly developed GEN programs (T. Turunen: The GEN-System for the EISCAT incoherent scatter radars).

In Figure 1 some examples of improvements are displayed which can be achieved with this new algorithm. This diagram shows the ratio of integration times which is needed to obtain the same statistical accuracy when using standard programmes, such as the Common Programmes, CP1F and CP3C, compared to GEN programmes. In practice this means that the time resolution can be improved by a factor given by the ratio number in Figure 1. It can be shown that time resolutions as short as 1 second can be achieved. Furthermore, the statistical accuracy of the longer lags of the autocorrelation function (ACF) is drastically raised. This improves the significance of the incoherent scatter spectra and consequently that of the derived ionospheric parameters. It is expected that the GEN-System will replace most of the presently applied data acquisition routines.

The flexibility of the radar control system was further enhanced by options to change the correlator program during the experiment and by a new radio-star tracking program for passive experiments. The VHF-antenna control part was finalized offering calculation possibilities for the geographical position of any range gate and 2 antenna sweeping modes. An independent control system with own console terminal was implemented to simplify tests and experiments of the UHF- and the VHF-system. Several automatic test and recovery features were built into the system to alert the operator in time or correct detected problems when the station was operated under remote control without a local operator.

The old Norsk-Data computers, which had served the EISCAT facilities since the beginning, were no longer reliable and constituted bottlenecks for further system development. Consequently the Council had authorized replacing these old computers and a call for tender was sent out at the end of the year. It is foreseen that all the site computers will be replaced in the year 1986.



Work on the modulator deck of the VHF transmitter, the elevation motors (upper photos) and gear of the UHF antenna and the main central bearing of the VHF antenna (lower photos).

Following the severance of the Aydin company from completing the VHF transmitter, the project was continued by engineers of SRI-International and EISCAT staff. The work concentrated on one side of the transmitter since only one Varian klystron was left and the Valvo klystron had not been delivered. It became possible to operate one side of the transmitter with half of the antenna. Aside from the transmitter, other portions of the VHF system were prepared. In May 1985 the first VHF echoes with the one-tube transmitter operating at less than half of its rating were detected. The first echoes, presented to the Council at its meeting in Tromsø, are displayed in Figure 2. A long pulse of 500 microseconds was transmitted and the transmitter power was about 1 Megawatt. Half of the antenna (gain of 42 dB) was used with circular polarization and the beam pointed approximately along the magnetic field line at 13° off the zenith. The figure shows the real part of the autocorrelation functions (upper diagrams) and the corresponding spectra (lower diagrams) obtained with 10 seconds integration time for the two range gates at 163.5 km and 253.5 km. A substantial improve-

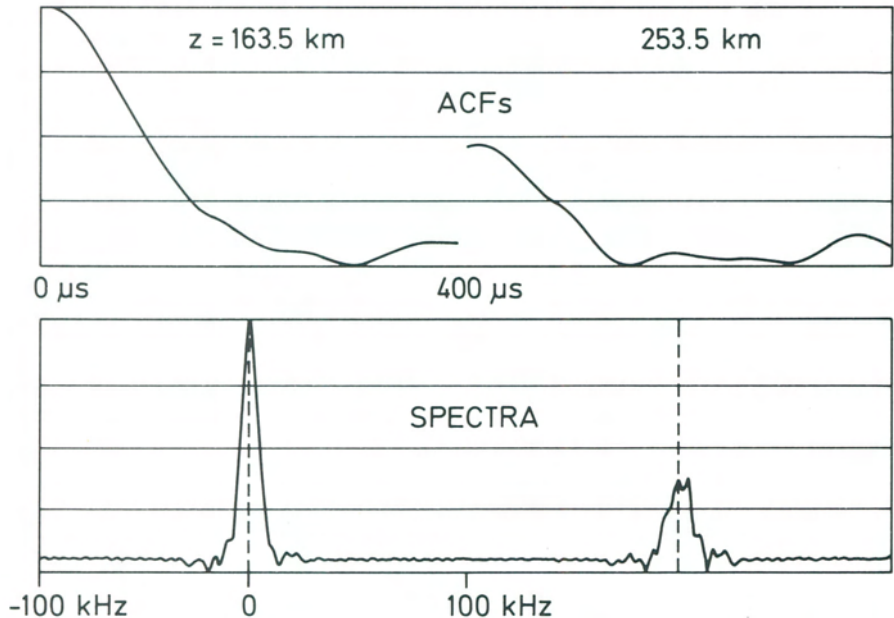
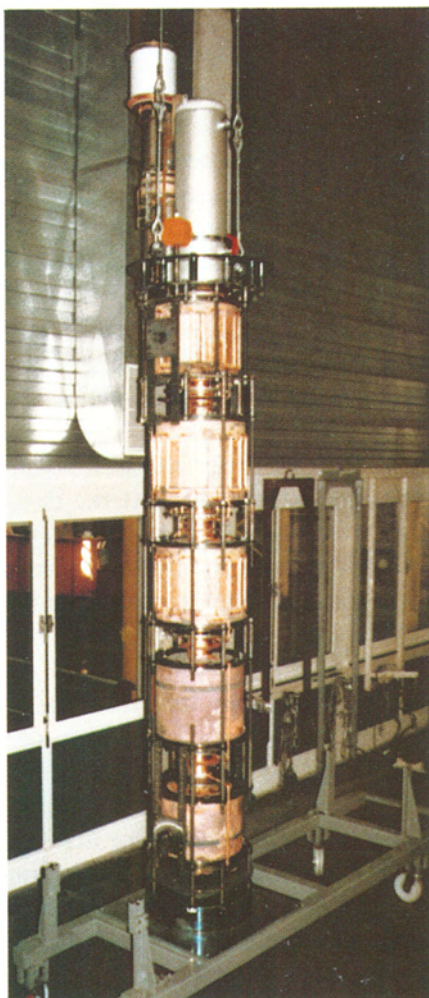
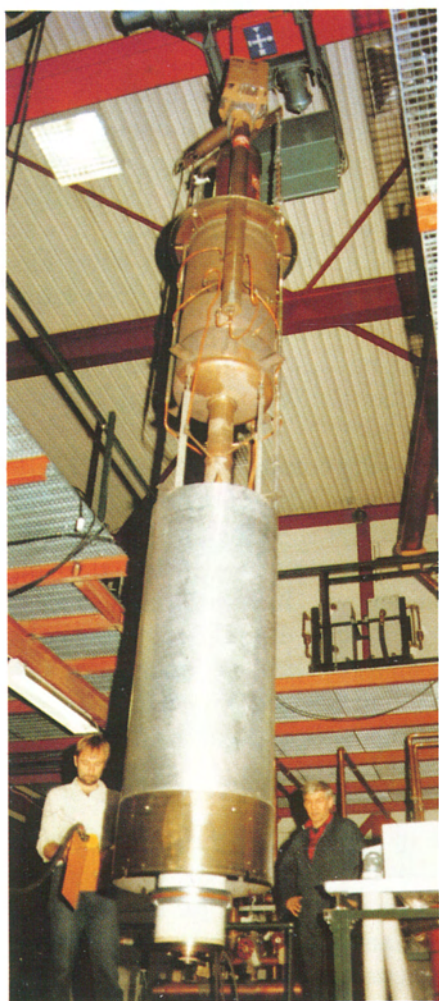


Figure 2: Autocorrelation functions (ACFs) and spectra of the first echoes detected with the EISCAT VHF system on 8 May 1985 at 1148 UT.



The VHF klystrons of Varian (left) and Valvo (right).

ment in the data quality was achieved later in August when the power was increased to 2.3 Megawatt and a longer pulse length and longer integration time was applied.

After three unexpected failures and subsequent rebuilds during the development of the new VHF-klystrons at the Valvo plant in Hamburg, a partial in-plant acceptance of the first Valvo klystron was possible at the end of the year. To avoid further complications due to the restricted short-pulse modulation capabilities at the Valvo facility, it was agreed to continue the testing and conditioning of the Valvo klystrons at the EISCAT site in Tromsø. The first klystron was shipped from Hamburg around the turn of the year. It then was installed into the EISCAT system. Following a careful aging, testing and tuning procedure the klystron operation is planned for the second part of 1986.

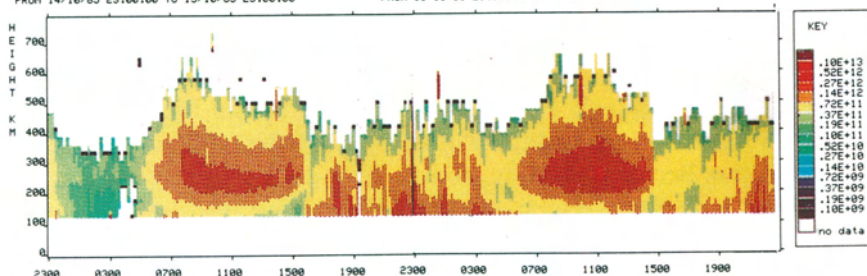
Considerable progress was made in analysing common programme data from the UHF radar. At the end of the year all useful raw data from the three EISCAT sites had been analysed back to the middle of 1984. The result data, comprising the parameters electron density, electron temperature, ion temperature and ion velocity, have been made available to scientists in the associate countries through the distributing contractor CNES in Toulouse. The result data of world day operations will also be sent to the International Incoherent Scatter Data Base which is set up at the National Centre for Atmospheric Research in Boulder, Colorado, USA.

Important advances were also made in performing the data analysis on-line, although this will remain somewhat troublesome until the old processing computers are replaced by new ones. The on-line analysis should reduce the workload on the staff and has the eminent advantage of monitoring the ionospheric parameters in real-time.

By cooperation between EISCAT and the Auroral Observatory in Tromsø a colour display routine is being developed to provide a means for the assessment of the data quality and for searching for geophysically interesting events. In Figure 3 an example is shown in which the profiles of four result parameters are displayed for an extended common programme operation period in October 1985. The display also demonstrates the continuous performance of the UHF radar operation over periods of days without any substantial interruption.

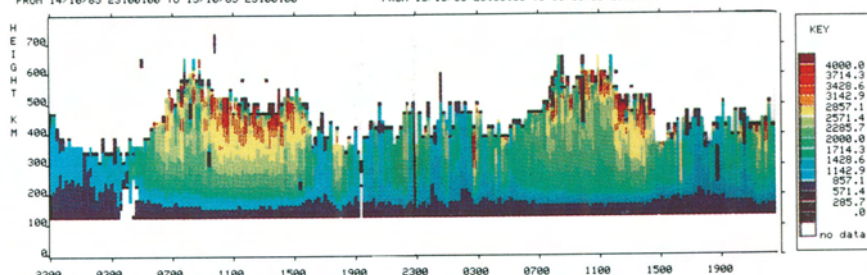
EISCAT Tromsø (CP-2 - ACF DATA)
Electron density (electrons per cubic meter)
FROM 14/10/85 23:00:00 TO 15/10/85 23:00:00

EISCAT Tromsø (CP-2 - ACF DATA)
Electron density (electrons per cubic meter)
FROM 15/10/85 23:00:00 TO 16/10/85 23:00:00



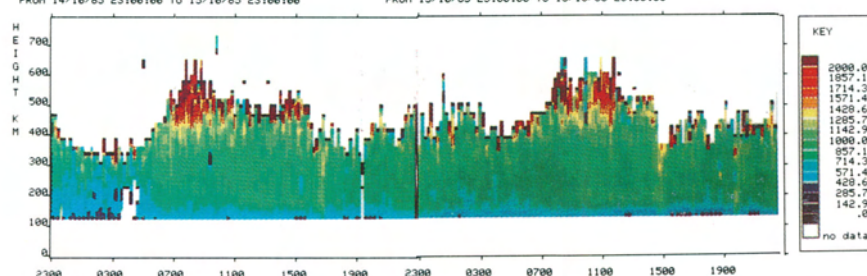
EISCAT Tromsø (CP-2 - ACF DATA)
Electron temperature (Kelvin)
FROM 14/10/85 23:00:00 TO 15/10/85 23:00:00

EISCAT Tromsø (CP-2 - ACF DATA)
Electron temperature (Kelvin)
FROM 15/10/85 23:00:00 TO 16/10/85 23:00:00



EISCAT Tromsø (CP-2 - ACF DATA)
Ion temperature (Kelvin)
FROM 14/10/85 23:00:00 TO 15/10/85 23:00:00

EISCAT Tromsø (CP-2 - ACF DATA)
Ion temperature (Kelvin)
FROM 15/10/85 23:00:00 TO 16/10/85 23:00:00



EISCAT Tromsø (CP-2 - ACF DATA)
Line-of-sight ion velocity (meters per second - positive)
FROM 14/10/85 23:00:00 TO 15/10/85 23:00:00

EISCAT Tromsø (CP-2 - ACF DATA)
Line-of-sight ion velocity (meters per second - positive)
FROM 15/10/85 23:00:00 TO 16/10/85 23:00:00

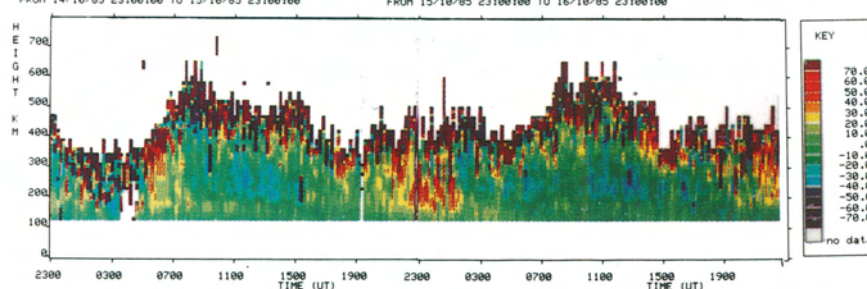


Figure 3: Colour plots of electron density, electron temperature, ion temperature and ion velocity, using common programme data of 15–16 Oct 1985.

OPERATIONS

The operation of the UHF radar has performed very reliably during the year 1985, although the sequence of operations had to be interrupted at times for the installation and test of the VHF radar system. The total number of operating hours, during which experiments were carried out and data were taken, was a little lower (by about 5%) than in the previous year, but again reached almost 2000 hours. This fact is explained by the concurrent work on the VHF transmitter installation, for which about 92 days were used in 1985. In accordance with the EISCAT Agreement, the operation time was again almost equally shared between common programme and special programme experiments, although in this year the common programme time was for the first time slightly higher (by about 10%) than the special programme time. The annual distribution of the common programme (CP) and the special programme (SP) operations is shown in Figure 4.

The diurnal variation, shown in Figure 5, is quite similar to that of the previous year. Common programme operations are fairly equally distributed over day and night, as planned. Again, the individually allocated special programme operations clearly peak before midnight. This shows the tendency of many observers to carry out experiments during the geophysically most interesting evening times.

The evening and night hour operations impose an additional load of shift work and on-call time on the EISCAT staff, which is particularly pronounced at the Tromsø site. It is therefore agreed that the operation should not exceed a total of about 2000 hours per year, which matches the experienced operation hours of the last two years.

The magnetic tapes handled during these operations added up to the number of 1980 in the year 1985. This now results in a total of almost 7500 data tapes which were accumulated during the first four years of the EISCAT operation.

During these years more than 5000 hours of data were collected, almost all of these simultaneously at all three sites. This means that the EISCAT UHF radar, despite all the time expended for installation, test, maintenance, calibration and break-downs, has been taking data

during more than one tenth of all its total lifetime to date. During the last two years EISCAT was even operated at one quarter of the time. This can be regarded as a substantial accomplishment for an incoherent scatter radar facility.

The accumulated special programme time per associate country was agreed to be subdivided by a prescribed ratio. During the year 1985, the accounted time among the EISCAT associate countries approached fairly acceptably the prescribed percentage special programme time (25% for France, Germany and United Kingdom, 10% for Norway and Sweden, and 5% for Finland). The development of the accumulated hours per associate and for EISCAT staff is demonstrated by Figure 6.

During the year 1985 more than 120 visits were paid to EISCAT by scientists to perform experiments, about two third of these visits were to the Tromsø site.

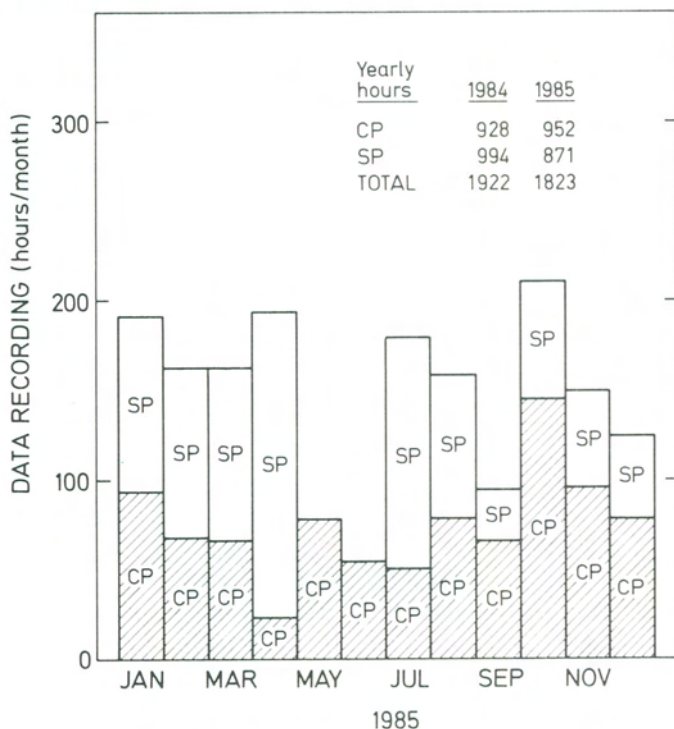


Figure 4: EISCAT data recording by month with Common Programme (CP) and Special Programme (SP) shown separately.

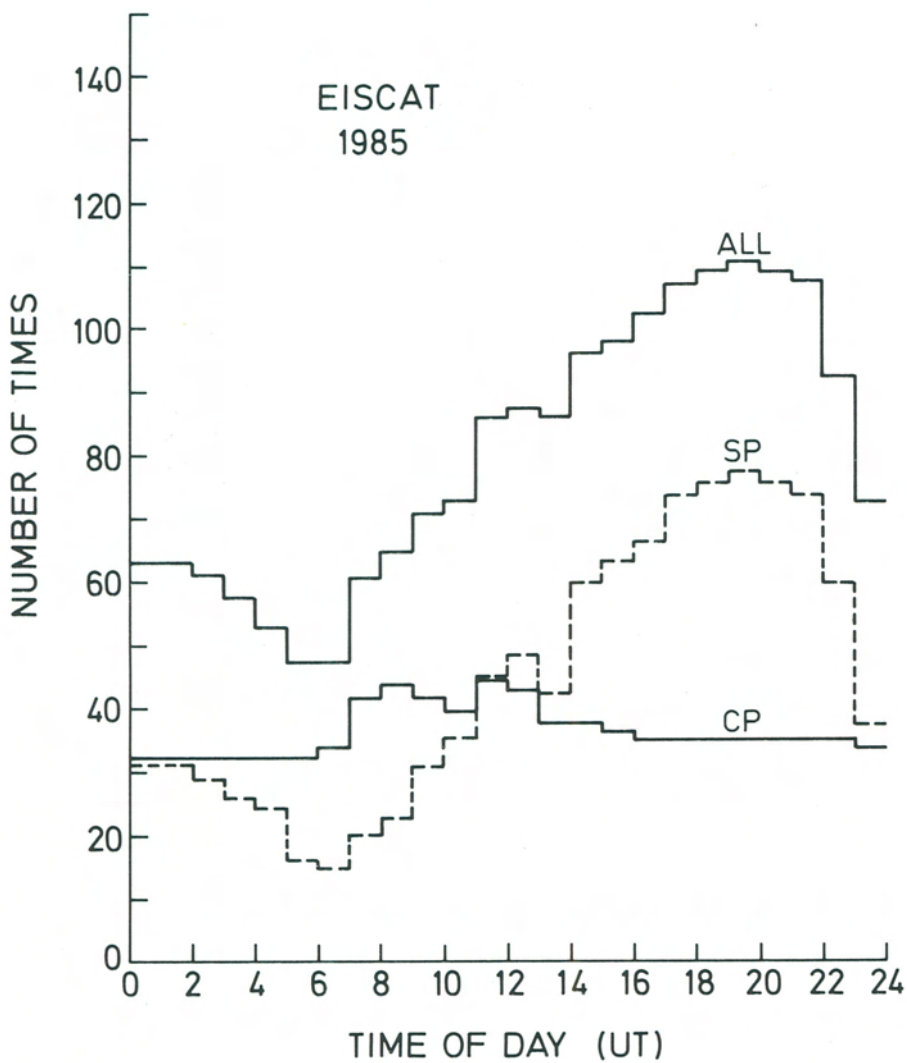


Figure 5: Distribution of operations as function of the time of the day.

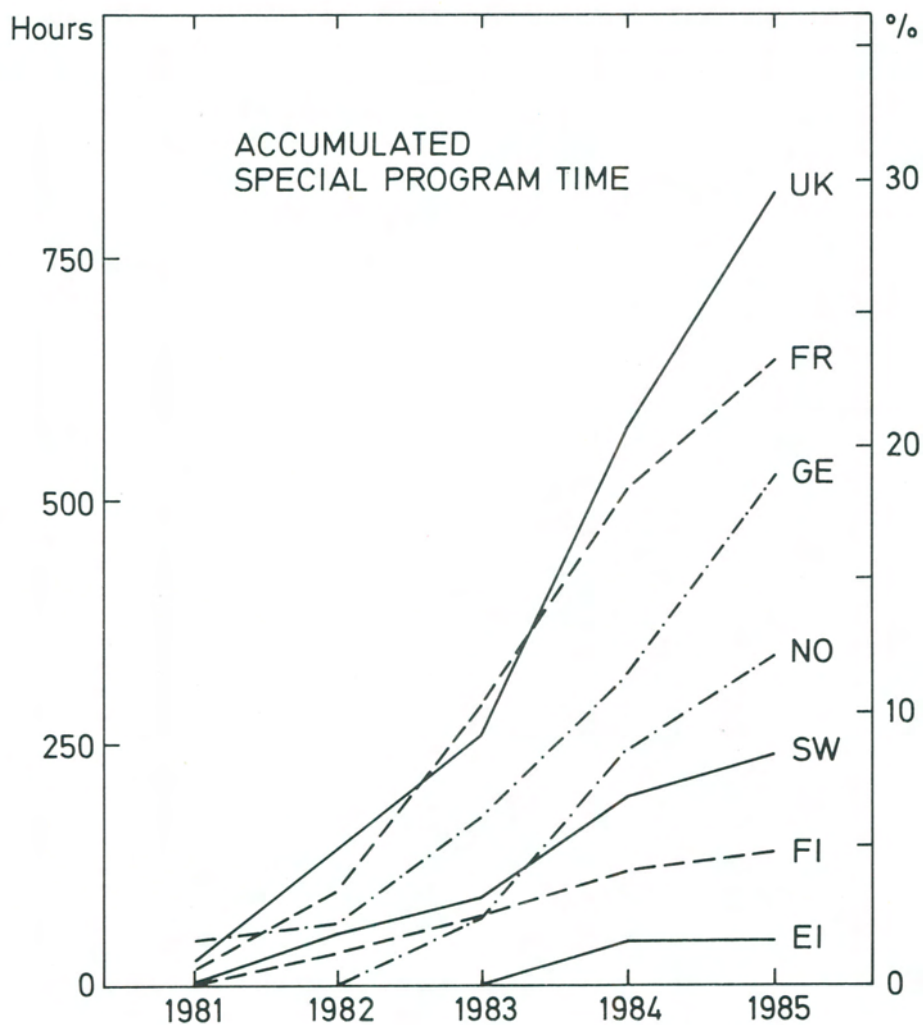


Figure 6: Cumulative distribution of accounted time among the EISCAT associates (United Kingdom, France, Germany, Norway, Sweden and Finland) and EISCAT staff.

SCIENTIFIC RESULTS

The scientific output from EISCAT has steadily increased during the past years. Whereas in the beginning the scientists in the associate countries mostly used common programme data, there is now a stronger tendency to make use of data from particular experiments which are specially designed to serve particular research topics. This development can also be taken as a good sign that the scientists visiting and using EISCAT have become more interested and familiar with the system as well as more experienced designing their own programs. Common programme data are most regularly collected, particularly during world days and special international campaigns. They form a basis for long term routine observations covering different times and seasons during varied geomagnetic conditions and different phases of the solar cycle.

The availability of the now quite extended geophysical data set, the improved quality of the results, the high technology of the EISCAT system, the uniqueness of the tristatic EISCAT UHF radar facility, as well as the contributions from the enthusiastic scientists and EISCAT staff have made EISCAT well known in the international scientific community.

It is becoming more and more difficult to keep track and to summarize the wide field of scientific results which has evolved from EISCAT so far. One means is to follow the papers presented at seminars, meetings, symposia and conferences as well as papers published in scientific journals. The most convenient opportunity, to follow the development of the EISCAT facility and its scientific output is to observe the participation and the interest in special EISCAT workshops.

The Second International EISCAT Workshop was held in September 1985 at the University College of Wales in Aberystwyth. About 65 papers were presented and a substantial number of posters displayed. The sessions dealt with all the research topics of EISCAT: The technical status and planned improvements, the analysis, use and presentation of EISCAT data, comparisons with other experiments (other groundbased, rockets and satellites), topics including high latitude morphology and convection, auroral activity and ionospheric irregularities, currents and conductivities, heating (natural and man-made) and

non-linear effects, as well as interactions between the neutral and ionized components of the atmosphere. Many of the papers presented, in total 25, will be published in a special EISCAT issue of the Journal of Atmospheric and Terrestrial Physics.

The publication of the papers from the First EISCAT Workshop in Aussois/France had strongly raised the number of publications in 1984, as can be seen in Figure 7. It is expected that another peak will occur in 1986 due to the publication of the Aberystwyth Workshop papers. This will compensate the decline of publications in 1985. The total number of publications in 1985 (incl. proceedings, reports etc.) was 30, and 93 different authors contributed to all these publications. The papers published in refereed journals are listed on pages 42—43 of this annual report.

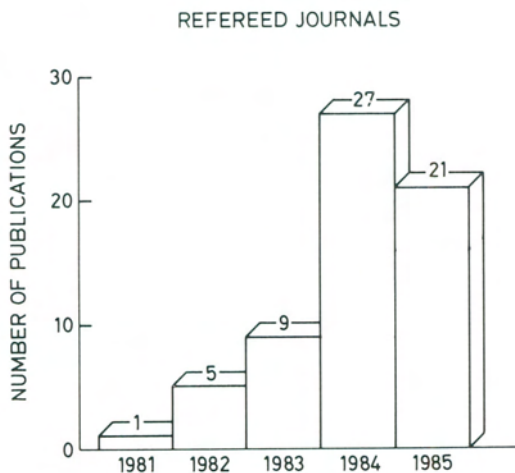


Figure 7: Number of publications in refereed journals.

The following examples of a few selected scientific highlights were compiled from oral and published papers of 1985. They briefly demonstrate contributions from all EISCAT associate countries and from EISCAT staff. Other contributions as well as the references, where some of these results are described in more detail, can be found in the publications list given later in this annual report.

EISCAT's participation in the Worldwide Atmospheric Gravity Wave Survey (WAGS)

During October 1985, EISCAT operated for five days as part of the international WAGS project, aimed at investigating the source and characteristics of large scale motions in the upper atmosphere, so-called atmospheric gravity waves. These waves have periods between several minutes and a few hours, and the experimental mode used by EISCAT was Common Programme 2 (CP-2) which includes four antenna positions in a six minute cycle, allowing the study of the passage of such waves with good temporal and spatial resolution. The figure 3 on page 15 shows ionospheric parameters derived from the EISCAT data. From top to bottom the parameters are electron density, electron temperature, ion temperature and ion velocity. The velocities occasionally show marked periodical variations with altitude and time (e.g. during the post-midnight hours on 15 Oct 1985) and when combined with simultaneous measurements from the remote sites at Kiruna and Sodankylä, a detailed study will reveal more on the nature of the atmospheric waves generating these travelling ionospheric disturbances. The inclusion of the EISCAT data in other worldwide data sets is expected to contribute much further to our understanding of the global morphology of atmospheric gravity waves.

EISCAT also participates in other worldwide coordinated programs, such as MITHRAS (Magnetospheric—Ionospheric—Thermospheric Radar Studies), GISMOS (Global Incoherent Scatter Measurements and Observations of Substorms) and GTMS (Global Thermospheric Mapping Study).

Power spectra of atmospheric gravity waves

Full day data sets of the ion velocity parallel to the magnetic field measured by CP-0 and CP-1 during 1982—1984 have been used to study tides and atmospheric gravity waves in the thermosphere. The maximum amplitude of the tides have been studied as a function of altitude, time of the day and season. For gravity waves, it was possible to calculate several parameters of the waves as well as average power spectra in the period range of 15 minutes to 6 hours. It was found that the behavi-

our of the waves varies with season, they are more rapidly attenuated at the shorter wavelengths in the summer than in the winter time, as can be seen in the figure 8. Further studies should reveal if source or propagation effects are the cause for these seasonal differences. (From Schegel: The study of tides and gravity waves with the help of field-aligned velocities measured by EISCAT).

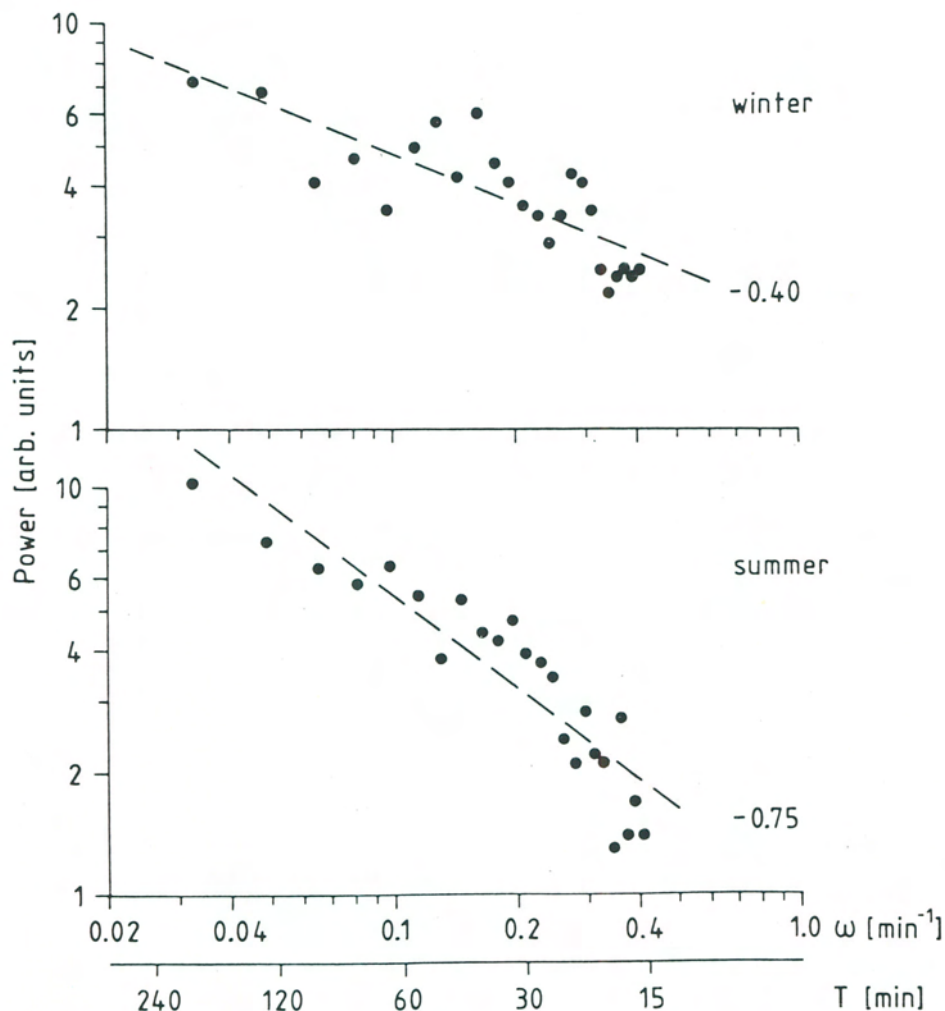


Figure 8: Power density of wavelike oscillations of velocities due to atmospheric gravity waves as function of their angular frequency ω , respectively period T .

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ELECTRON DENSITY

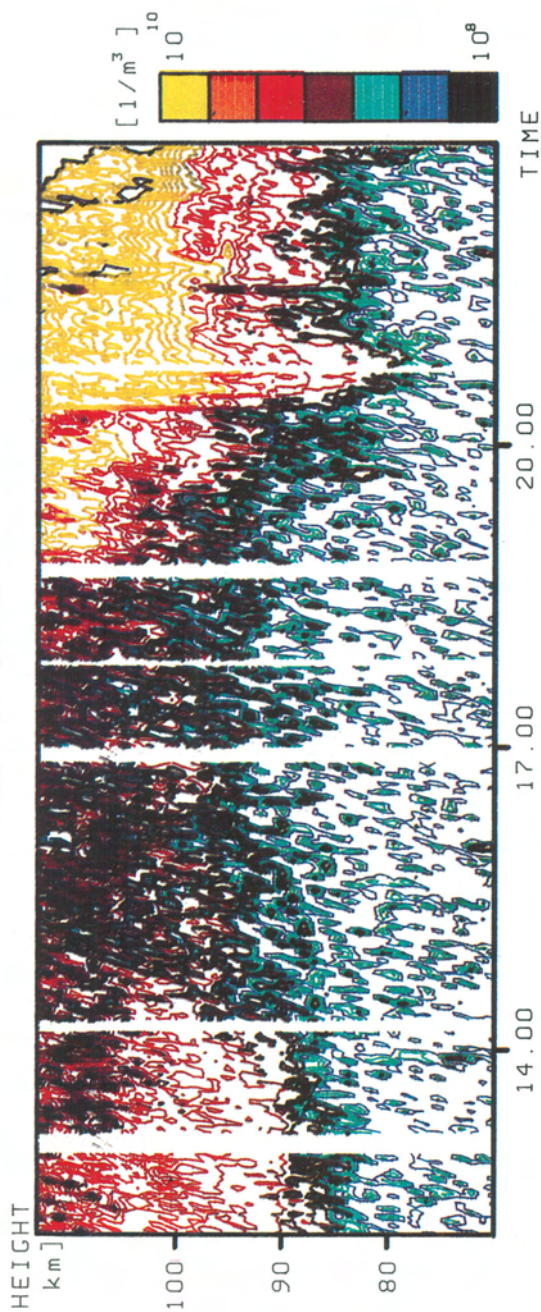


Figure 9: Electron densities in the D- and E-region.

High resolution measurements of the electron density in the D-region

By applying the newly designed GEN algorithm it became possible to verify the remarkable capabilities of the EISCAT UHF system. Measurements of the ionospheric D-region constitute one of those limits where the system has to be pushed to its utmost sensitivity. The figure 9 shows colour contours of the electron density between 70 km and 110 km altitude during the afternoon and evening of a magnetically quiet day. The integration time is 2.5 minutes and the altitude resolution 1.05 kilometers. The sunset leads to a reduction of the electron densities in the D- and E-region around 1500 UT. An onset of particle precipitation is seen around 1900 UT. Electron densities as low as 500 per cubic centimeter are clearly detectable at altitudes of 80—90 km. Conceivably, with longer integration times it could be possible to detect electron densities as low as 200 per cubic centimeter. (From T. Turunen et al., High resolution measurements in the D-region).

Comparison of electron densities derived from incoherent scatter and differential absorption techniques

The MAP-WINE campaign (Middle Atmosphere Program — Winter in Northern Europe) provided the first opportunity to run the EISCAT and Partial Reflection Experiment (PRE) radars simultaneously. With the Ramfjordmoen ionosonde in support, it proved possible to generate composite profiles of electron density from 70 km, with good agreement at the overlap around 90 km. Subsequent to MAP-WINE, comparisons between PRE using the differential absorption technique and EISCAT Common Programme CP1 have yielded results very similar to those shown in Figure 10. The outcome has been an increase in confidence in the ground-based methods for determining mesospheric electron densities. (From Brekke et al.)

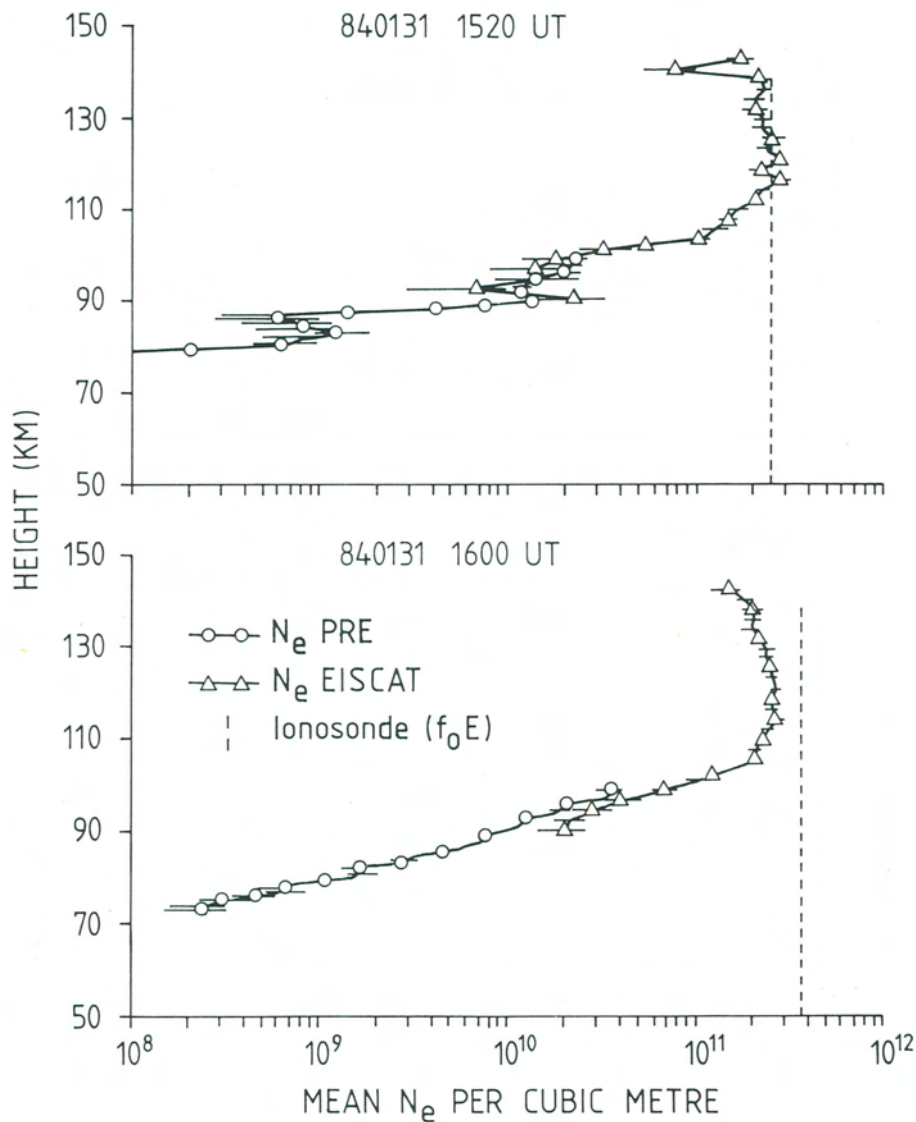


Figure 10: Electron densities, N_e , measured with Eiscat, PRE and ionosonde.

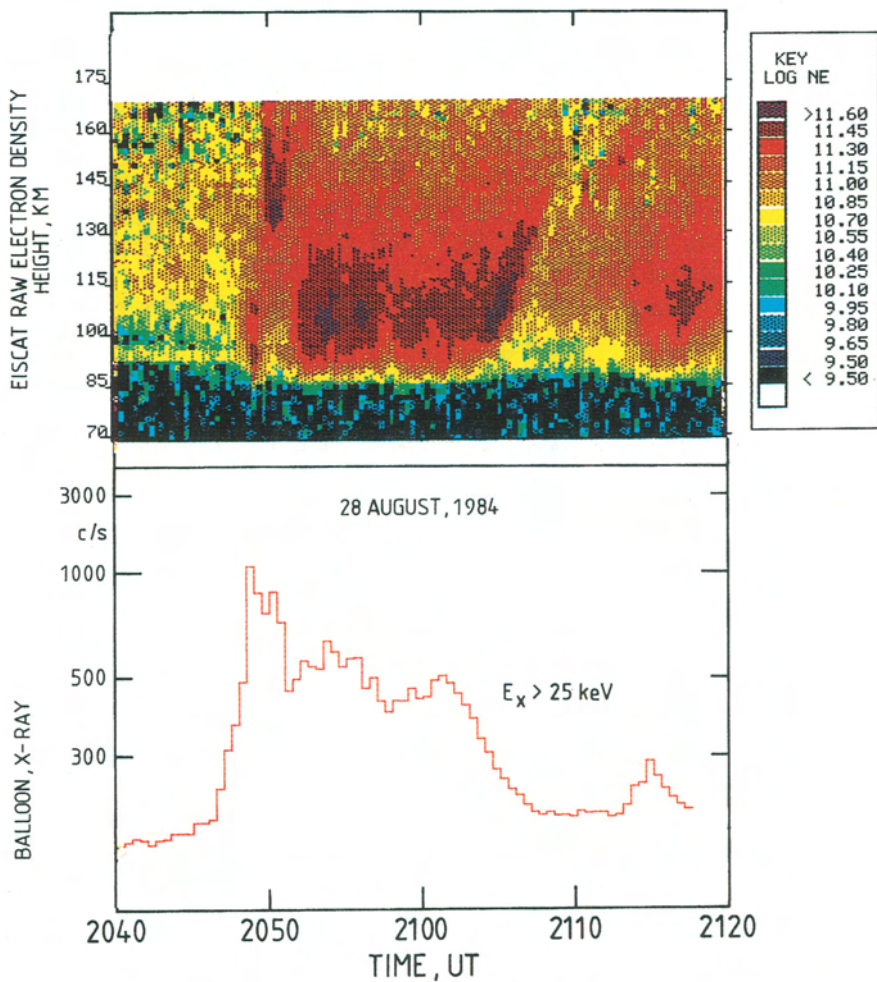


Figure 11: EISCAT electron density, N_e , as function of height and time from 2040—2120 UT on 28 August 1984, and electron precipitation in the auroral zone, inferred from X-ray measurements in balloons.

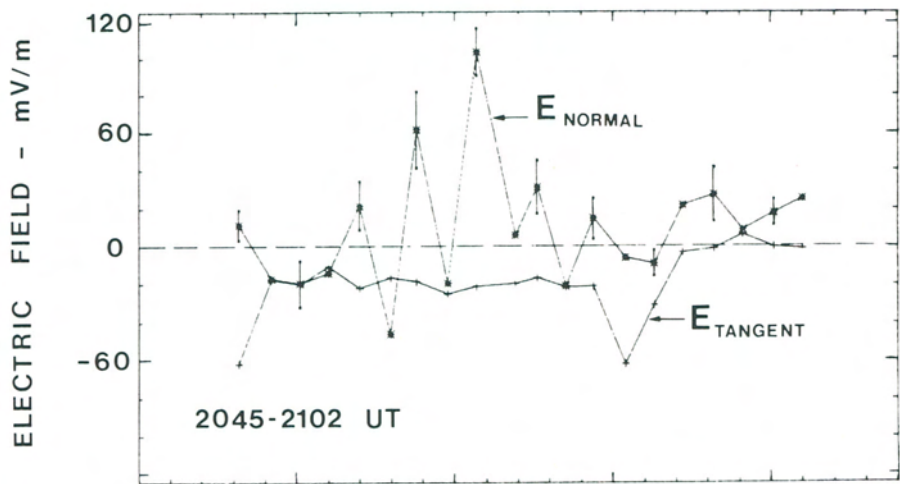
Coordinated EISCAT-Balloon Observations (CEBO) of auroral particle precipitation

In the CEBO campaign X-ray fluxes and electric fields were measured with balloons, and electron density, temperatures and electric fields above the balloon were measured with EISCAT. In Figure 11 the electron density measured with EISCAT (upper panel) is compared with electron precipitation inferred from X-ray measurements in the balloon (lower panel). The build-up and decay of the X-ray event corresponds very well with the electron density variations. The height variation of the electron density profile is consistent with changes of the energy of the precipitating electrons. The shift in height may also represent the energy-dependent arrival of drifting electrons from a distant injection area. (From Ullaland et al.: The coordinated EISCAT and balloon observations).

Measurements of electric fields and currents in auroral arcs

Elevation scan measurements took place when a two arc system had developed in a region close to magnetic midnight in the evening sector and remained stationary over about 1 hour. The 3-dimensional velocity measurements from EISCAT were used to deduce the proper arc reference frame by calculating the normal velocity vector. It was found that the arc orientation was rotated by about 42° away from the L-shell in the southwest—northeast direction. The tangential electric field was constant almost everywhere, whereas the normal component displayed large amplitude variations (up to $100 \mu\text{V/m}$ in the southern arc) which corresponded to tangential velocity shears at the arc boundaries.

Another electrodynamic parameter measured by EISCAT was the field aligned current shown also in the lower diagram of Figure 12 as a function of distance from the center of the two arc structure. Pairs of adjacent current sheets were observed whose densities reached $100 \mu\text{A/m}^2$ above conductivity gradients in the ionosphere. Both upward and return current regions appeared to be confined over limited regions of scales of 15—20 km at around 120 km altitude. (From Girard and Senior: Electrodynamic structure of auroral arcs from EISCAT measurements: A case study).



11 March 1984 : 2045 - 2102 UT

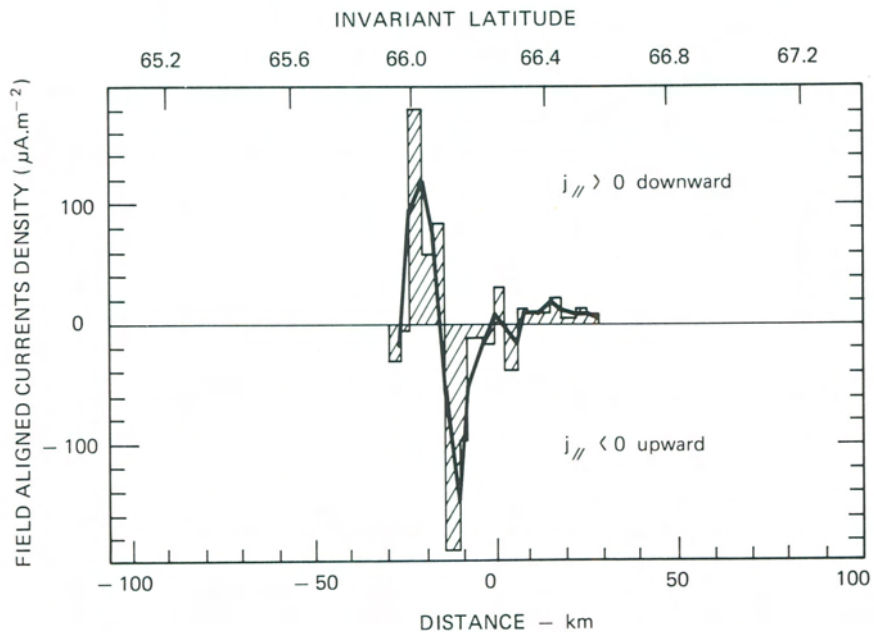


Figure 12: Electric field and the current density in direction of the magnetic field in auroral arcs.

Observations of anomalously enhanced electron temperatures in the E-region of the ionosphere

A high space and time resolution experiment carried out at EISCAT with the UHF radar has shown the existence of anomalously enhanced electron temperatures at altitudes of around 110 km. The enhancements can be up to 10 times over the typical background values, have a short duration of a few seconds, and be confined to altitude ranges of 2 km or less.

A typical example of one of these events is shown in Figure 13. These measurements were carried out on 29 January 1985 around 2106 UT with 20 sec integration time. The numbers on the left side of each panel are the fitted values of electron density, electron temperature, ion temperature, and ion drift velocity. It can be seen that for the central panel the electron temperature was 1891 K and the ion temperature 286 K. Typically, the electron and ion temperatures at these altitudes are equal with values around 200–300 K.

The current hypothesis is that these high electron temperatures are the result of wave heating by unstable plasma waves associated with auroral precipitation and electrojet currents. There is evidence of the existence of unstable ion acoustic waves traveling at anomalously high acoustic speeds associated with these heating events. The high acoustic speeds are the result of the high electron temperatures which in turn are produced by the unstable waves themselves. (From Häggström et al.)

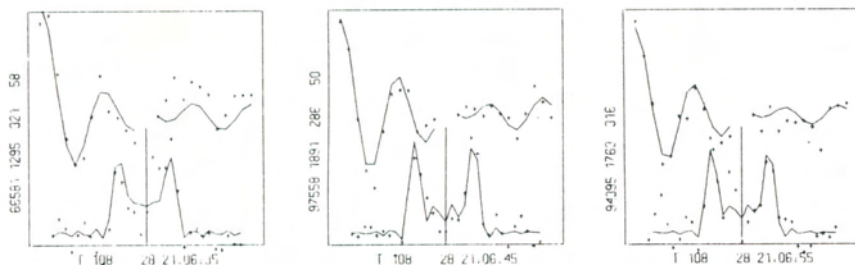


Figure 13: Sequence of measured (dots) and fitted (lines) autocorrelation functions in real and imaginary parts as well as the corresponding spectra during an event of anomalous electron temperatures.

Damping of pulsations by Joule heating

By means of EISCAT data it has been possible to measure ion temperature and velocity perturbations with a time resolution of 30 sec during PC5 pulsations determined from groundbased magnetometer observations. The precise correlation between the magnetic observations and the large velocity and temperature perturbations is consistent with theoretical predictions that Joule heating is the main damping mechanism of the pulsations. Detailed quantitative analysis has shown that Joule heating is sufficient to account for all of the observed pulsation damping. This was done by comparing a theoretical estimate of the damping rate based on the assumption of Joule heating as the lone damping mechanism and the actual damping rate measured from the magnetic records. Further, it has been possible to estimate the energy dissipated by the pulsation. The conservative estimate represents about 1% of the energy which would be deposited in the atmosphere of the Northern hemisphere during a typical magnetospheric substorm, and thus emphasizes the importance of hydromagnetic waves in transferring energy from the outer regions of the magnetosphere to the high latitude ionosphere. In the figure 14 we show a record of the measured ion temperature perturbations over 1100 K at 312 km altitude (upper panel) and the predicted perturbation derived from ion velocity measurements (From Crowley and Jones: Joule heating during a PC5 pulsation observed by the EISCAT radar).

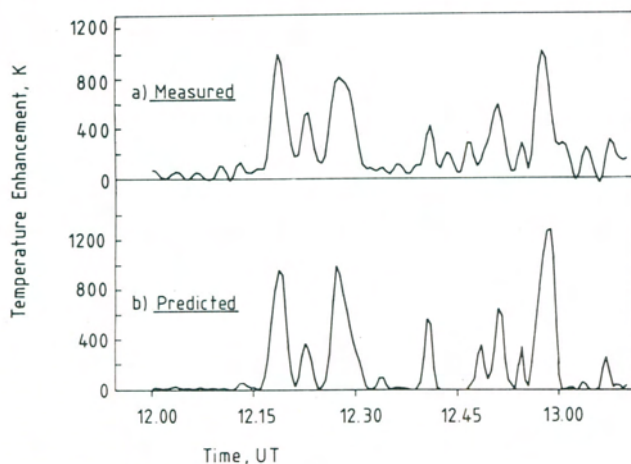


Figure 14: Temperature enhancement during pulsations, measured with EISCAT and predicted from magnetometer observations.

4 November 1983

DYNAMIC SPECTRUM

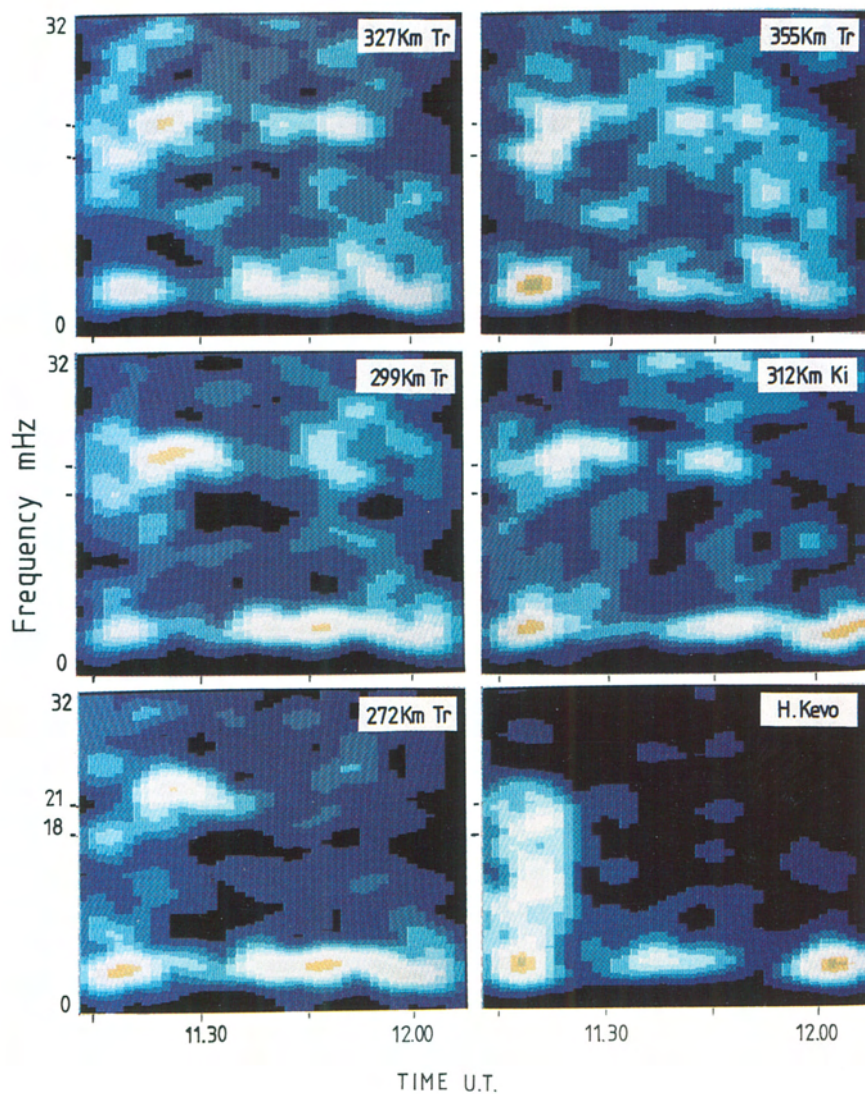


Figure 15: Dynamic spectra of ion velocity measured with EISCAT (TR and KI) and of the H-component of the magnetic field at Kevo/Finland.

Comparison of ion velocity measurements with EISCAT and magnetometer measurements

Specially designed ion velocity measurements have resulted in the detection of PC3-4 pulsations in the range of periods 10—150 sec at a resolution of 10 sec. It was found that the H-component on the earth's surface and the E-W ionospheric component of the ion velocity are in phase. But the D-component was much less coherent with the ionospheric velocity measurements. Time and frequency variability and spatial (longitudinal) distribution were studied. When polarization studies were possible it was found that it was mainly east—west and in a horizontal plane, but with a significant vertical component. The figure 15 shows the dynamic spectra of Tromsø ion velocity at different altitudes (different longitudes) and of the H-component measured at Kevo/Finland. It demonstrates the close correlation between the ground magnetic measurement and the ionospheric ion velocity measurements. The PC 3-4 burst occurs at around 1120 UT and has a frequency of 21 mHz (48 sec) in the ionosphere and 18 mHz (56 sec) on the ground. (From Glangeaud et al.: PC3-4 ULF magnetic variations measured in the ionosphere by EISCAT)

F-region irregularities and velocities

Simultaneous data were obtained between SAFARI (Scandinavian and French Auroral Radar Investigation) HF coherent radars in Lycksele and Oulu, and the EISCAT UHF radar. The SAFARI radars were used to detect F-region irregularities at scales of 10 m and to measure the phase velocity of the waves causing them. EISCAT operated in the latitudinal scan mode of CP-3 and provided electron density contours and ion vector velocities. The electron density contours were used to calculate the localization of the HF echoing regions by means of ray tracing. The figure 16 shows Doppler spectra of the HF signals. The dotted lines correspond to the velocities measured by EISCAT when projected in the radial direction of the HF radar. The similarity of the HF radar mean Doppler velocity and the projected EISCAT velocity for most of the cases represents evidence that F-region plasma and irregularity drift velocities are equal. (From Villain et al.: A SAFARI—EISCAT comparison between the velocity of F-region small-scale irregularities and the ion drift).

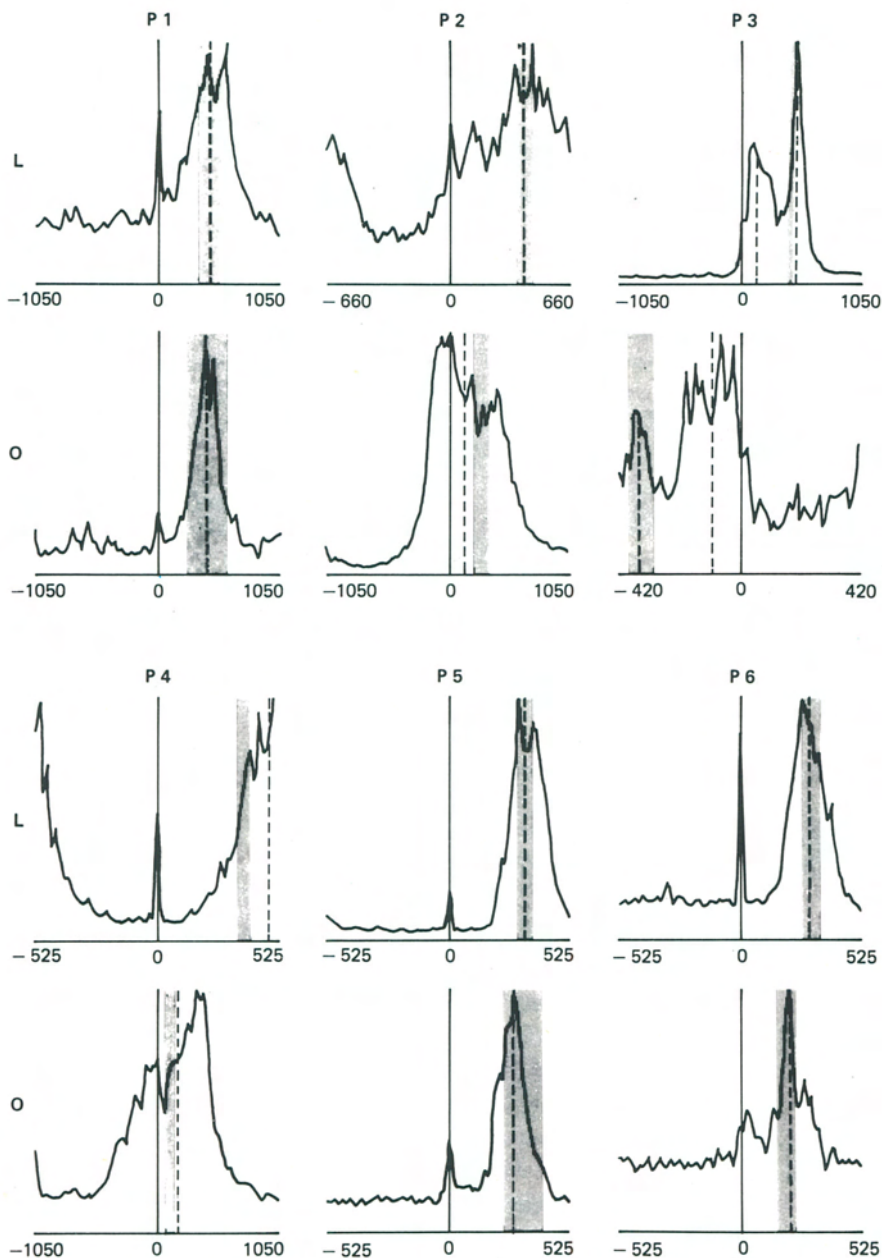


Figure 16: Doppler spectra from the SAFARI radar and the corresponding ion drift velocities in m/sec measured with EISCAT (shaded).

Magnetospheric convection and electric field potential from EISCAT and GEOS 2

Using latitudinal ion drift measurements in the F-region from CP-3 it has been possible to calculate the convection potential pattern between $\lambda = 62^\circ$ to 72° . When the corotation field is included in these potential patterns, it is possible to predict the location of the plasmapause as the place of the outermost closed equipotential line. This indirect prediction has been tested for a number of 24 hour sets of data under various geomagnetic conditions by comparison with actual plasmapause measurements by the geostationary GEOS2 satellite located near the apex of the EISCAT magnetic field. The agreement between these two experimental results validates the method inferred from the EISCAT F-region ion drift measurements. In addition, it demonstrates the capability of the EISCAT system to reproduce correctly the large-scale structure of the magnetospheric convection over a wide equatorial region from about 4 to 10 earth radii. This is illustrated in the figure 17 which shows (a) the convection velocities including the contribution of the corotation field, (b) the deduced potential pattern and (c) the projection of the latter to the equatorial plane covering up to 10 earth radii. The figure 17 in the center has also the projection of the trajectory of the GEOS2 satellite. The thick continuous line represents the part of the trajectory that traverses the plasmapause. It can be seen that it coincides very well with the region dominated by the corotation field (dashed lines) which is a signature of the plasmapause. (From Fontaine et al.: Large-scale structures of the convection inferred from coordinated measurements by EISCAT and GEOS2).

The ionospheric response to interplanetary magnetic field changes

Simultaneous measurements of ionospheric plasma parameters between the magnetic invariant latitudes 70° — 75° and the UKS magnetometer on the AMPTE satellite in the solar wind has resulted in the verification that a southward turning of the B_z -component produces an enhancement of the ionospheric plasma flow in accordance with current theories on solar wind-magnetosphere-ionosphere interactions. Further, the data have shown that the onset of convection lags the change in the B_z -component by 13 min and that the convection en-

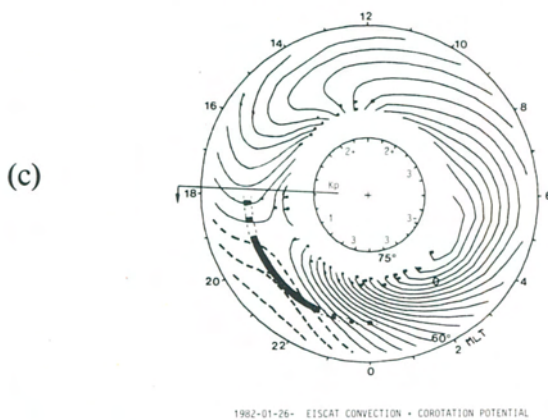
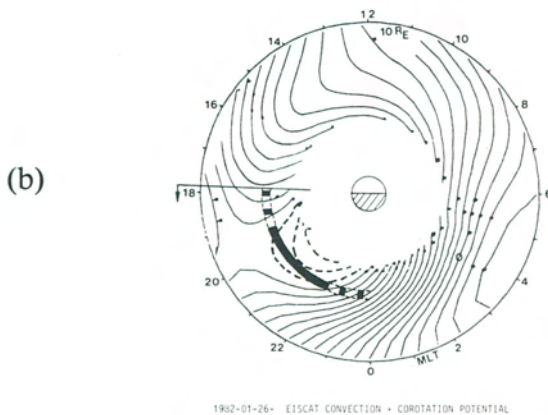
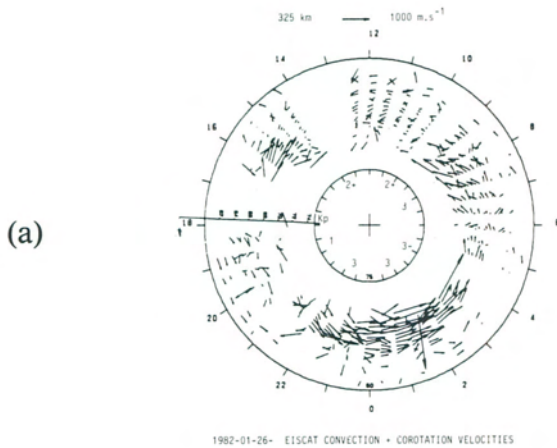


Figure 17: Convection velocities measured with EISCAT (a), the electric field potential (b) and its projection to the equatorial plane at 10 earth radii (c).

hancement propagates eastward around the afternoon magnetic local time sector at a velocity of about 1 km/sec. Assuming that the southward turning of B_z and the accelerated convection are related through processes that involve fieldline reconnection, only half of the 13 min delay can be accounted for at present.

An ion heating event was observed in association with the enhanced convection and it has been shown that this event can be explained by ion-neutral frictional heating.

In the figure 18, the plasma parameters measured by EISCAT, N_e , T_e , T_i and the plasma drift perpendicular to B are shown. The sudden enhancement of the ionospheric flow is seen to occur at around 13:45 MLT. See the 1984 Annual Report for a figure showing the satellite data. (From Willis et al.: A survey of simultaneous observations of the high latitude ionosphere and interplanetary magnetic field with EISCAT and AMPTE-UKS).

The ionospheric response to magnetic field changes and proton events in the earth's magnetotail

In March/April 1985 the apogees of the AMPTE satellites precessed through the earth's magnetotail. The EISCAT UHF radar was used in a British-German campaign for coordinated measurements with one of the AMPTE satellites, namely the German IRM (Ion Release Module). The aim was to investigate the origin of auroral phenomena by simultaneous measurements at IRM's location in the magnetotail and its conjugate point in the ionosphere.

As an example, Figure 19 shows one "conjugate" event on 28 March 1985 during the recovery phase of a substorm. The IRM instruments recorded a short-lived structure in the ambient magnetic field and fast streaming protons. At the same time the ground magnetometer shows a sudden deflection due to more easterly disturbance fields and the EISCAT power profiles indicate a change in the distribution of precipitating particles towards both higher intensity and energy. (From Haerendel et al.)

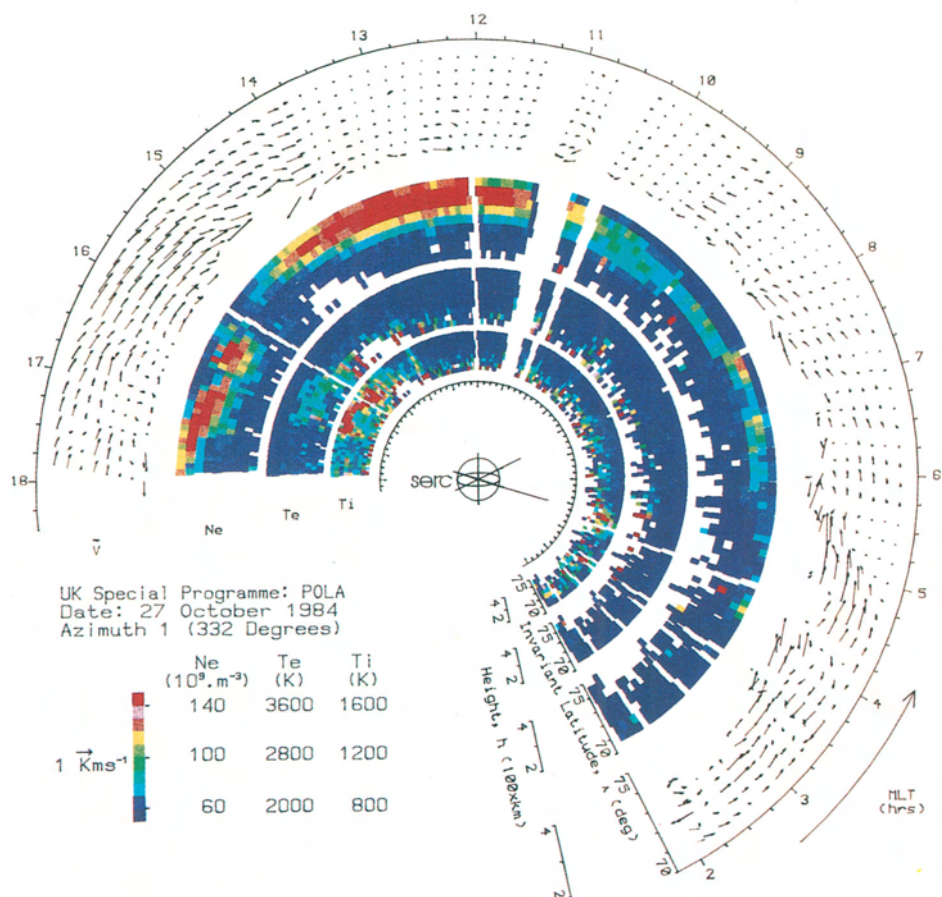
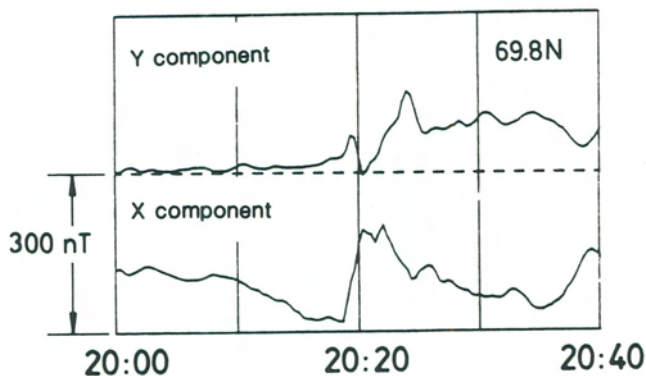
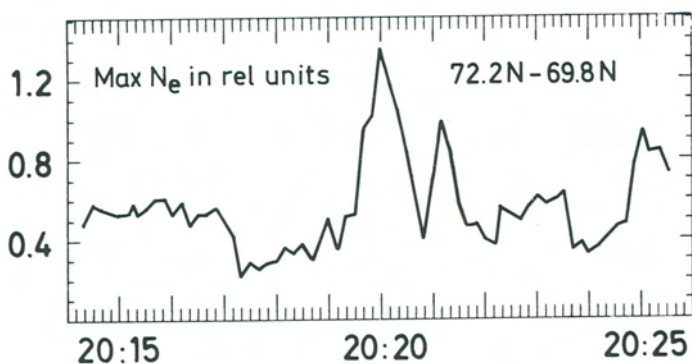


Figure 18: Electron density, N_e , electron temperature, T_e , ion temperature, T_i , and plasmadrift perpendicular to the earth's magnetic field during interplanetary magnetic field changes (between 13 and 14 MLT).

Magnetometer Kevo



EISCAT



AMPTE/IRM

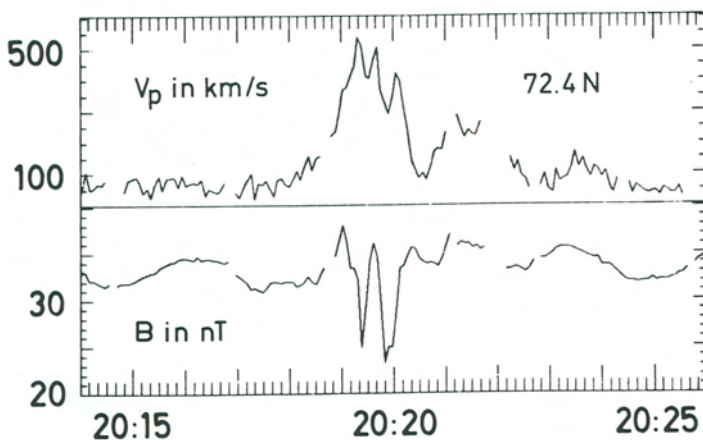


Figure 19: Groundbased magnetometer, maximum electron densities in the ionosphere and the releasing phenomena of fast streaming protons and magnetic field changes in the magnetotail (AMPTE/IRM).

Plasma processes studied by EISCAT-Heating cooperation

To investigate heater excited plasma lines and ion lines two joint campaigns were carried out in 1985. Low absorption and relatively high critical frequencies made one of the campaigns a great success and very clean results were obtained. These are summarized as follows and are elucidated in the example of Figure 20:

Upshifted plasma lines were usually stronger than downshifted ones. Upshifted plasma lines could also be excited with lower heater power. Maximal excitation of plasma lines was observed when the radar looked 10° – 20° off vertical. A possible explanation is that the polarization of the heater wave is optimum for obliquely reflected heater waves. In contrast to previous experiments plasma lines were observed during continuous (non-pulsed) operation of the heater.

The "purely growing mode" is generally considered as a standing wave and should, therefore, result in equal power in the upshifted and downshifted receiver channels. However, strong asymmetries have been observed, as seen in Figure 20.

Usually plasma lines are observed from an altitude region <1 km. Sometimes plasma lines appeared over a range of 10 km and exhibited a distinct fine structure. (From Kohl et al.)

In another experiment a successful heating of the lower ionosphere was performed (see Fig. 21).

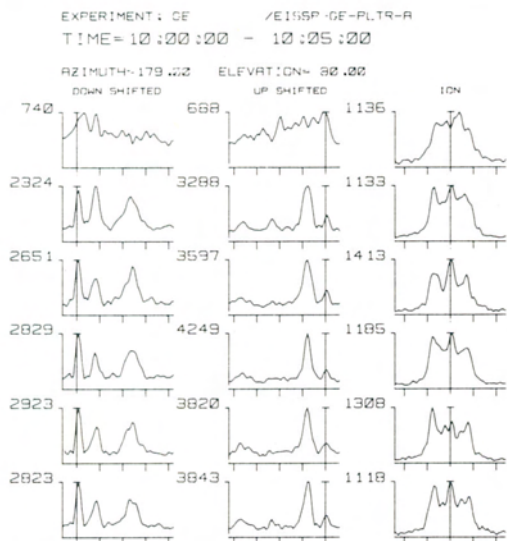


Figure 20:
Downshifted and upshifted
plasma line and ion line spectra
observed with the EISCAT
UHF-radar during ionospheric
heating.

SP-FI-GEN-11 27.10.1985
ELECTRON DENSITY

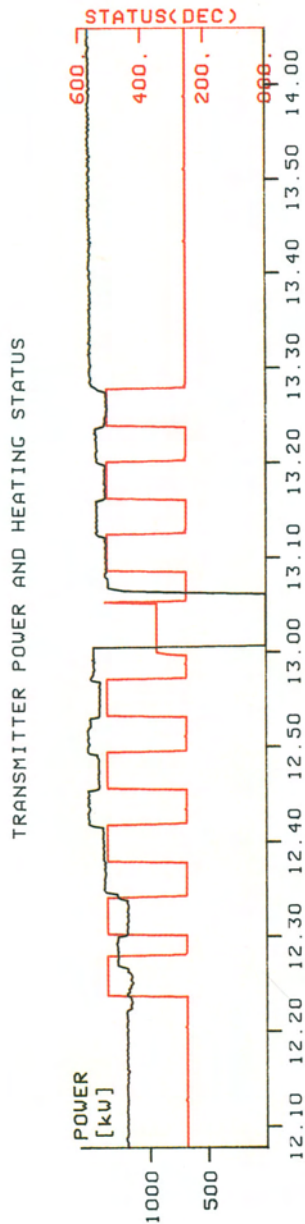
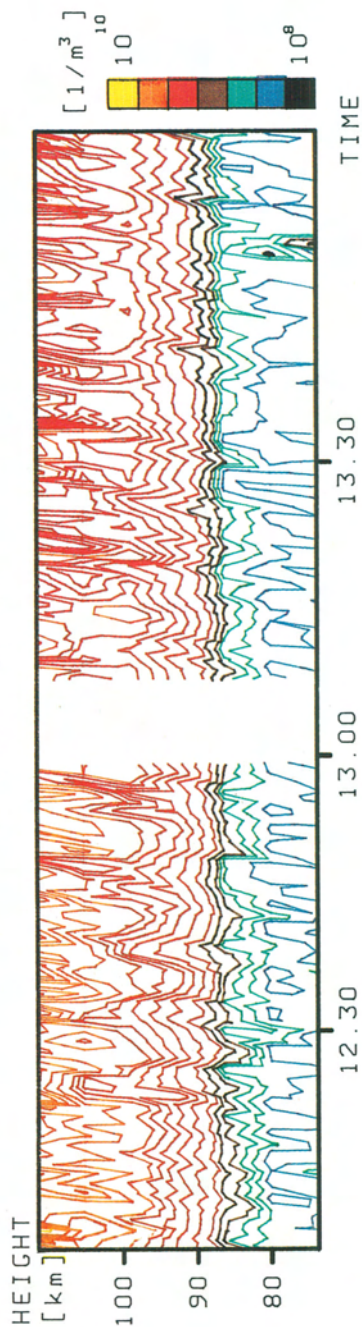


Figure 21 shows a first example of the modification of the lower ionosphere by underdense heating. This causes an increase of electron temperature due to enhanced absorption of the heater wave and consequently a reduction of electron density due to the temperature enhanced recombination (from E. Turunen et al.).

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(includes also supplements of earlier years)

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EISCAT Meetings

Council: 25th meeting, Tromsø, 9—10 May, 1985
26th meeting, Munich, 7—8 Nov., 1985

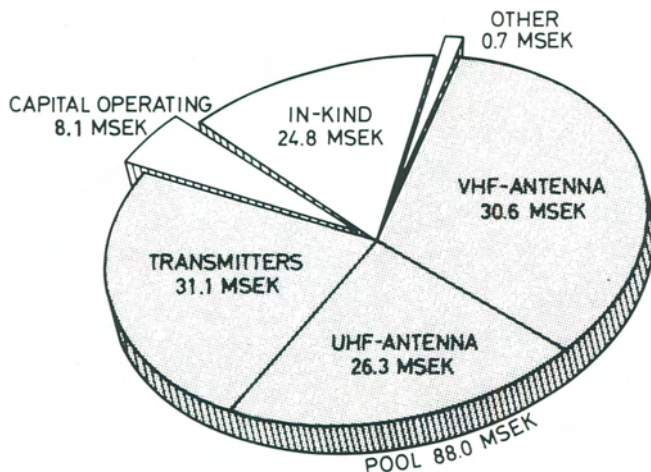
SAC: 28th meeting, Brussels, 19—20 March, 1985
29th meeting, Aberystwyth, 13 Sept., 1985

AFC: 24th meeting, Stockholm, 28 March, 1985
25th meeting, Hamburg, 20 Sept., 1985

Annual Review Meeting: 10th meeting, Abisko, 25—27 March, 1985

CAPITAL INVESTMENTS

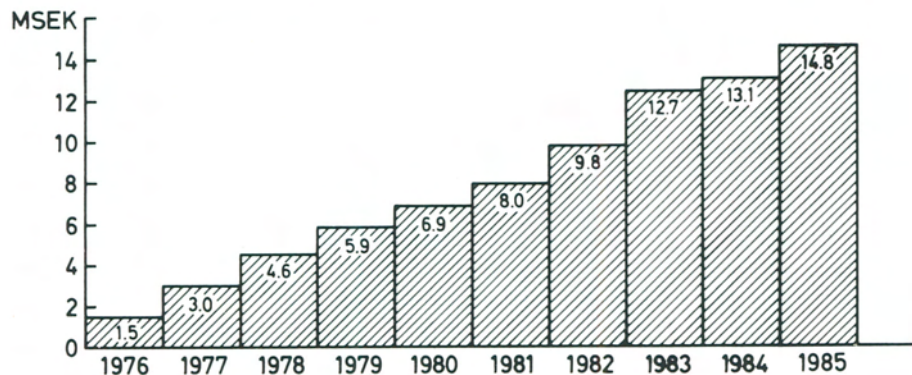
The cumulative capital investments (sum of costs at time of expenditure) to the end of 1985 are shown below:



TOTAL = 121,6 MSEK (1984 = 116,4 MSEK)

OPERATING COSTS

The operating costs increased to 14,8 MSEK in 1985.
The annual cost history follows:



BALANCE SHEET

MSEK

Assets	At Dec. 31, 1984	Pool	Additions		Depre- ciation	At Dec. 31, 1985
			Cap.Op.	Other		
FIXED ASSETS						
Buildings	8.8	3.9		0.1	0.2	8.6
Transmitters	26.6				1.4	29.1
UHF-antenna	18.7				1.3	17.4
VHF-antenna	23.2				1.5	21.7
Receivers	3.0				0.7	2.3
Computers etc.	2.9		0.6		1.4	2.1
Other	2.2		0.8		0.5	2.4
Total	85.4	3.9	1.4	0.1	7.0	83.6
CURRENT ASSETS						
Debtors	1.7					1.1
Prepayments and accrued income	0.1					0.2
Cash and Ordinary Bank Accounts	12.9					9.3
Special Accounts	0.1					0.3
Total	14.8					10.9
GRAND TOTAL	100.2					94.5

Totals may not match because of rounding.

AT 31 DECEMBER 1985

	MSEK	
	At Dec. 31, 1984	At Dec. 31, 1985
Liabilities		
CAPITAL		
Contributions		
Pool	84.1	88.0
Capital Operating	6.8	8.1
In Kind	24.8	24.8
Other	0.7	0.7
	116.4	121.6
Depreciations	31.0	38.0
Total Capital	85.4	83.6
RESERVES		
Pool	8.0	4.6
Capital Operating	0.2	0.7
Other	2.3	2.4
Total Reserves	10.5	7.7
Special Accounts	0.1	0.3
LIABILITIES		
Provisions	1.6	0.4
Other Liabilities	2.6	2.5
Total Liabilities	4.2	2.9
GRAND TOTAL	100.2	94.5

MEMBERSHIP OF COUNCIL AND COMMITTEES

	France	Finland	Federal Republic of Germany	Norway	Sweden	United Kingdom
COUNCIL	M. Petit* P. Bauer A. Berroir	O. Ranta A. Siivola	G. Haerndel H. Kohl G. Preiss	A. Brekke L. Westgaard	B. Hultqvist M.-O. Ottosson	W.J.G. Beynon B.R. Martin H. Rishbeth
SAC	G. Caudal W. Kofman	J. Kangas	W. Baunjohnann K. Schlegel	N. Bjørnå	H. Opgenoorth	T.B. Jones* P.J.S. Williams
AFC	A. Jubier	O. Ranta	M. Meinecke	L. Westgaard	J. Gustavsson	G. Rowe*

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

HEADQUARTERS SENIOR STAFF in 1985:

Director	—	M. Baron
Associate Director	—	C. La Hoz
Associate Director	—	T. Turunen
Business Manager	—	B. Thorwid (from Aug. P. Hagström)

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