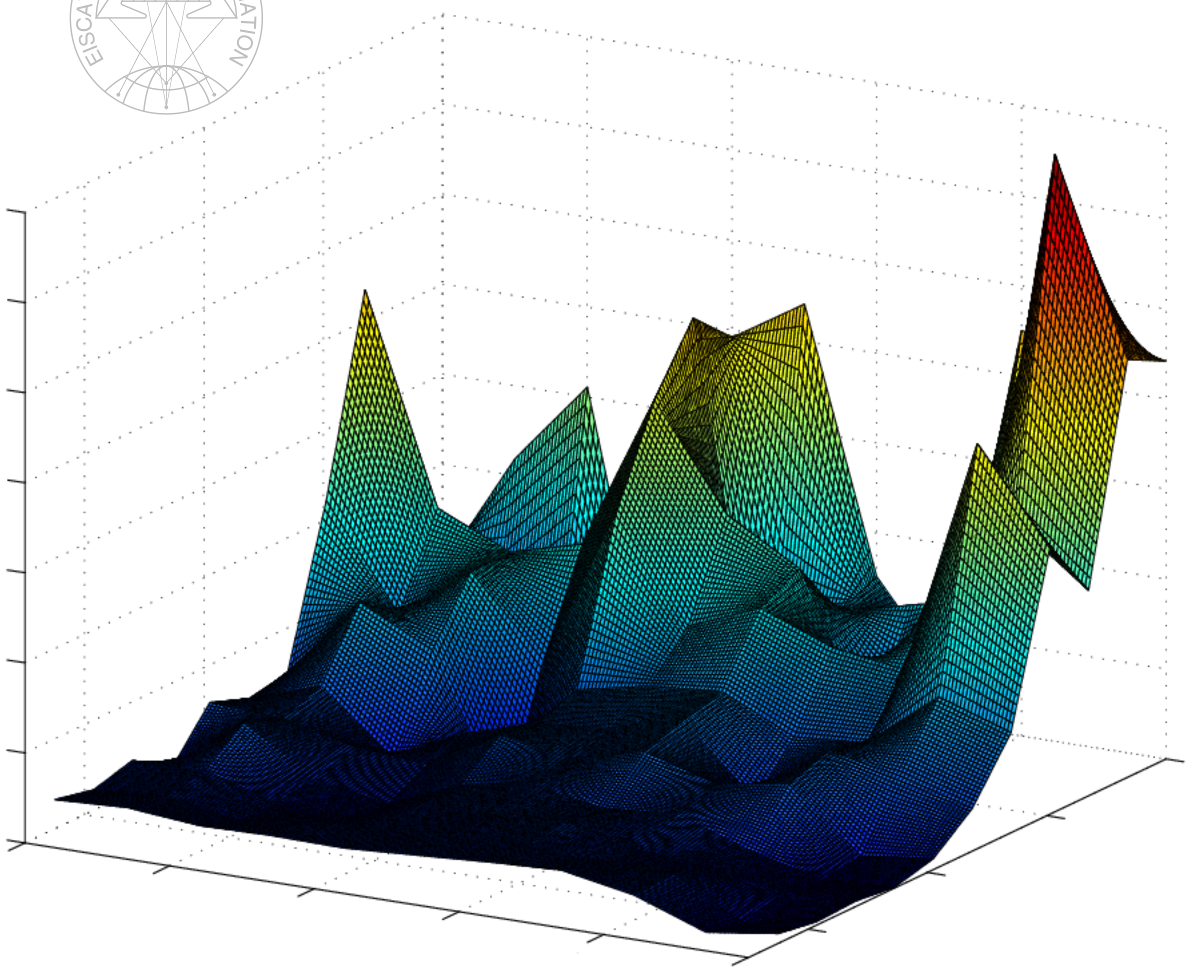
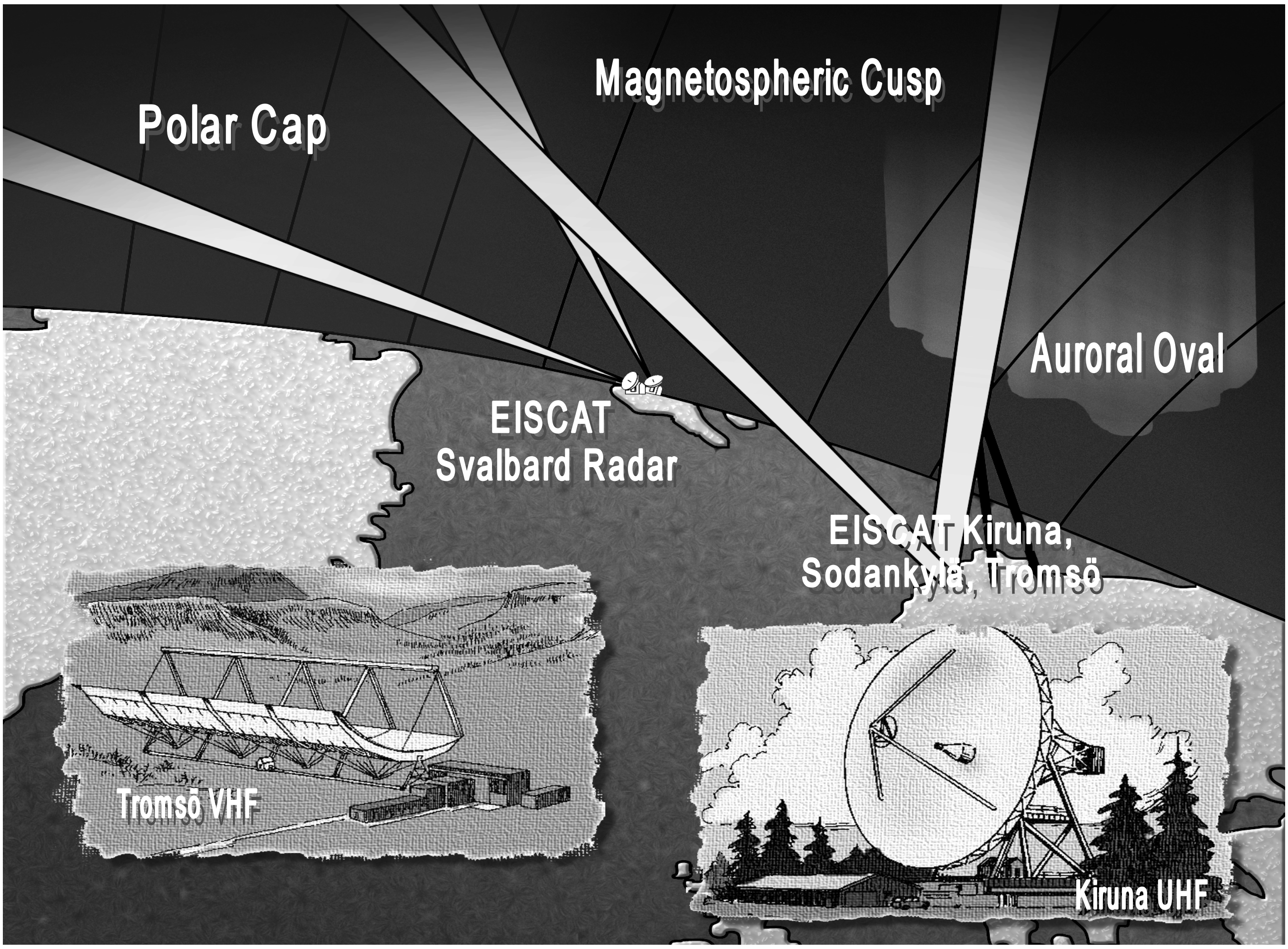


EISCAT

EUROPEAN INCOHERENT SCATTER
SCIENTIFIC ASSOCIATION

REPORT 1998 - 2001



EISCAT Radar Systems

Location	Tromsø		Kiruna	Sodankylä	Longyearbyen	
Geographic Coordinates	69°35´N 19°14´E		67°52´N 20°26´E	67°22´N 26°38´E	78°09´N 16°02´E	
Geomagnetic Inclination	77°30´N		76°48´N	76°43´N	82°06´N	
Invariant Latitude	66°12´N		64°27´N	63°34´N	75°18´N	
Band	VHF	UHF	UHF	UHF	UHF	
Frequency (MHz)	224	931	931	931	500	
Maximum bandwidth (MHz)	3	8	8	8	10	
Transmitter	2 klystrons	2 klystrons	-	-	16 klystrons	
Channels	8	8	8	8	6	
Peak power (MW)	2x1.5	2x1.3	-	-	1.0	
Average power (MW)	2x0.19	2x0.16	-	-	0.25	
Pulse duration (ms)	0.001-2.0	0.001-2.0	-	-	<.001-2.0	
Phase coding	binary	binary	binary	binary	binary	
Minimum interpulse (ms)	1.0	1.0	-	-	0.1	
Receiver	analog	analog	analog	analog	anal.-digital	
System temperature (K)	250-350	90-110	30-35	30-35	55-65	
Digital processing	14 bit ADC, 32 bit complex, autocorrelation functions, parallel channels				12 bit ADC, lag profiles 32 bit complex	
					Antenna 1	**Antenna 2**
Antenna	parabolic cylinder 120m x 40m Steerable	parabolic dish 32m Steerable	parabolic dish 32m Steerable	parabolic dish 32m Steerable	parabolic dish 32m Steerable	parabolic dish 42m Fixed
Feed system	line feed 128 crossed dipoles	Cassegrain	Cassegrain	Cassegrain	Cassegrain	Cassegrain
Gain (dBi)	46	48	48	48	42.5	45
Polarization	circular	circular	any	any	circular	circular

EISCAT Heating Facility in Tromsø

Frequency range: 4-8 MHz, Maximum transmitter power: 12 x 0.1 MW, Antennas: two arrays (4-8 MHz): 24 dBi, one array (5.4-8 MHz): 30 dBi. Additionally, a Dynasonde is operated at the Heating facility.

EISCAT Scientific Association
1998-2001

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 ten incoherent scatter radars in the world, and EISCAT operates three of the highest-standard facilities. The experimental sites of EISCAT are located in the Scandinavian sector, north of the Arctic Circle. They consist of two independent radar systems on the mainland, together with a new radar constructed on the island of Spitzbergen in the Svalbard archipelago - the EISCAT Svalbard Radar - Scandinavia (see schematic and operating parameters on the inside of the front cover).

The EISCAT UHF radar operates in the 931 MHz band with a peak transmitter power of more than 2.0 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 tri-static 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 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^o north of the zenith; limited east-west steering is also possible using alternative phasing cables.

The EISCAT Svalbard radar (ESR), located near Longyearbyen, operates in the 500 MHz band with a peak transmitter power of 1.0 MW, a fully steerable parabolic dish antenna of 32 m diameter, and a fixed field aligned antenna of 42 m diameter. The high latitude location of this facility is particularly aimed at studies of the cusp and polar cap region.

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.

Operations of approximately 2500 hours each year are distributed equally between Common Programmes (CP) and Special Programmes (SP). At present, six well-defined Common Programmes are run regularly, for between one and three days, typically about once per month, to provide a data base for long term synoptic studies. 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, budget, and Council and committee structure for each year. Further details of the EISCAT system and operation can be found in various EISCAT reports, including illustrated brochures, 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
National Institute of Polar Research, Japan
Norges forskningsråd, Norway
Vetenskapsrådet, Sweden
Particle Physics and Astronomy Research Council, United Kingdom

EISCAT Scientific Association 1998-2001

Contents

Introduction

This Report covers the four year period between 1998 and 2001. Neither the fact that it covers twice the period of recent Reports, nor that its publication has been delayed into 2003, indicate lack of progress in the Association, but rather the tremendous workload carried by the staff in simultaneously conducting both extensive upgrades and greatly extended operations, as reported elsewhere in this document.

Similarly, the vast range of scientific work published by the EISCAT community over these years, as evidenced by the extensive reference lists included here, is much too large to be adequately summarised in a document of any reasonable size. A small sample of the work is included for illustration, but the bulk of the material has been made available on EISCAT's World Wide Web site (www.eiscat.com), where it is more easily and widely visible, together with this report itself.

Following changes in Swedish legal requirements, the style of EISCAT´s Annual Accounts changed; the new version is included for the year ending December 31, 2001. Future Annual Reports will follow a similar format. This report was prepared by EISCAT staff members Tony van Eyken, Anette Snällfot, Tauno Turunen, Gudmund Wannberg, Henrik Andersson, and Brett Isham, with invaluable assistance from Ian McCrea and Liz Williams of the Rutherford Appleton Laboratory in the United Kingdom.

Cover

One of several measurements considered feasible when EISCAT was first conceived was the regular observation of the polar wind. Whereas most of the other measurements promised with EISCAT have been successful, the polar wind observations have proven to be elusive until now. The cover illustration represents a two-dimensional plot of hydrogen outflow velocity as a function of time and height on April 11, 1997. The time (x) axis runs from 12 to 22 UT, the altitude (y) axis from 350 to 1000 km, and the velocity (z) axis 0 to 1400 ms^{-1}; individual profiles represent 15 minute integrations. The light ion velocity was determined using specially optimized observing and analysis schemes [Løvhaug, Hagfors, and van Eyken, 2001] and shows an overall increase with altitude consistent with H+ outflows predicted by thermal polar wind models.

Council Chairs' Page

While Chairing the EISCAT Council over the period covered by this report, we witnessed first-hand both the technological development of the EISCAT systems and the wide variety of scientific research that they make possible. Several major events occurred which dramatically changed the future development of EISCAT science and opened new opportunities for the future of EISCAT and its user community. The quality and excitement of this work has meant that the EISCAT facilities maintained their pre-eminence in the field and allowed the Association to triumph over the financial difficulties it has faced.

The EISCAT radars have produced world-leading data for research into space plasmas for more than 20 years. The majority of the observations are of the ionosphere; however, because the behaviour of the ionospheric plasma is strongly linked through collisions to the upper neutral atmosphere and, through electromagnetic coupling and auroral particle precipitation, to the magnetosphere, EISCAT is able to study both these regions of geospace as well.

The major development in the first twenty years was the definition and subsequent construction of the EISCAT Svalbard Radar (ESR) and the first data with the full power system were recorded in 1998. The ESR dramatically extends the scope of the EISCAT facilities. Located directly beneath the cusp, it allows studies of how Earth's magnetosphere-ionosphere system interacts with the solar wind. In addition, the combination of the ESR and the mainland systems is ideal for studying the internal dynamics of the magnetospheric tail. Much of the extraordinary research highlighted in this report depends on the unique power and potential of this combination of EISCAT radars.

The procurement of a second, 42 m diameter, antenna for the Svalbard radar was approved by the Council in 1998 and the completed antenna was already in use in 1999, allowing field-aligned profiles of the cusp ionosphere to be monitored continuously while the 32-metre antenna can be deployed in a variety of modes to define the surrounding conditions. This opened a completely new world for the high latitude incoherent scatter measurements. With two simultaneous look directions, it is finally possible to study both the details of cusp processes, with the field aligned beam, and at the same time monitor their latitudinal dynamics, using a second oblique beam. It also transformed EISCAT into a "network" of radars and beams, linking the ESR measurements to the processes occurring over the mainland radar systems, in contrast to the earlier situation in which the systems made individual point measurements. Further novel studies of cusp precipitation, ion outflow, and the mysterious and intriguing anomalous coherent echoes could also now be conducted much more effectively.

The mainland radars have enjoyed a series of major, and very beneficial, upgrades. The availability of enhanced signal processing power allows yet better range and time resolutions, the systems now support a range of new alternating code experiments, and further advanced new coding schemes have been introduced to support, for example, studies of auroral arcs and D-region physics. Ultimately the upgrades will allow higher transmitter powers to be used for the UHF with consequent further increases in range and time resolutions.

EISCAT is unique in having a high-power HF modification ("heater") facility co-located with the mainland incoherent scatter radars. In addition to both the UHF and VHF incoherent scatter radar diagnostics, the heater field-of-view is also monitored by a digital ionosonde, the CUTLASS HF radar system, various sophisticated optical instrumentation, and an imaging riometer. This combination really does turn the ionosphere over Tromsø into a natural laboratory for studying the mechanisms and behaviour of large-scale plasma; for example: studies of "artificial aurora", induced by the heater, have given new insights into plasma-wave interactions.

In addition to the broad diversity of science supported by the active radars, the passive observation of interplanetary scintillation has been exploited with great success at EISCAT, particularly using the receiving antennas in Kiruna and Sodankylä, to observe the interplanetary medium closer to the Sun than any other instrument and, consequently, to study the acceleration of the solar wind. Developments to transfer this work to the protected 1.4 GHz band, together with enhanced use of the received signal polarisation, promise remote sensing of the magnetic field, which should prove to be a crucial advance for space-weather applications.

Further diversification is planned into areas such as the study of both space debris and interplanetary particles.

Solar-terrestrial physics is now a multi-point, multi-instrument, multi-technique discipline. The EISCAT radars are extremely powerful diagnostics of fundamental space plasma processes and their value becomes particularly apparent when they are used in conjunction with other instrumentation. Such new opportunities inspired the user community to design of a whole catalogue of new Common Programs and coordinated observations with other instruments, such as ground based networks and satellites, give EISCAT a strong position in the community of space science far beyond purely ionospheric applications. The struggle to design, construct, and bring the ESR into full operation culminated in the highly successful coordinated observations with the European Space Agency's Cluster II quartet of spacecraft, which started operations in late 2000. Eleven years of preparations for ground-based involvement of this mission finally came to fruition, and, by then, EISCAT had developed to become easily the most important single instrument supporting that prestigious mission.

Similar co-ordinated experiments with Geotail, FAST and TIMED are underway. Furthermore, the location of the ESR on Svalbard means that there are many, and frequent, conjunctions with various low-altitude satellites; the combination of these data is very effective. Supporting ground-based diagnostics continue to be put in place. New spectrographs at Tromsø and Svalbard will allow important new studies of proton-induced aurora in combination with the radars while the SPEAR HF radar/heater on Svalbard will soon be ready, making possible a completely new portfolio of experiments.

Reading this report it is clear that scientific production of EISCAT is both substantial and of the highest quality. EISCAT is used by a wide scientific community and should have a long future. EISCAT is a major facility in the Solar Terrestrial research and an essential part of existing observatories. In spite of this, the EISCAT financial situation is difficult. In the 1996-1997 Report, we wrote 'The role of the Council will be to solve the difficult budgetary problems by a number of measures such as by increasing the membership in the Association and by encouraging new uses of EISCAT'; that statement is still true and even more urgent. We hope that we will be able to attract the new members, continue the process of opening the facilities to a wider range of users, and organize EISCAT such that its viability after 2006 will be secure.

These matters have developed during our tenures of the Council chair and we are hopeful that the hard work of many individuals will be successful so that EISCAT can carry its proud reputation as the World's most powerful facility into a new era with a new agreement and a larger user community

Wlodek Kofman	Hermann Opgenoorth	Mike Lockwood
Chair 1997-1998	Chair 1999-2000	Chair 2001-2002

Director's Pages
Years 1998-2001

1997 ended with a major change at EISCAT Headquarters as Dr Jürgen Röttger completed his term as EISCAT director. Dr Tauno Turunen took over the position on January 1, 1998, the date coinciding with the beginning of the interval covered by this report.

It is a great pleasure to start by thanking Jürgen Röttger once again for the tremendous work he did for EISCAT during the eleven years he was the director of EISCAT. It is a long time in human life; it is also a long time in geophysics - a sunspot cycle.

The EISCAT host institution in Finland had already changed by the beginning of 1998. The Geophysical Observatory of the Finnish Academy of Science and Letters had been the host of the EISCAT Sodankylä site since 1975 but it became part of the University of Oulu on August 1, 1997 and changed its name to the Sodankylä Geophysical Observatory. A new contract between the EISCAT Scientific Association and the University of Oulu was signed in June 1998 and the EISCAT staff in Finland became employees of the University.

The EISCAT Scientific Association and the University of Tromsø signed a new host agreement covering the EISCAT Svalbard Radar in December 2000.

EISCAT Headquarters had occupied rented offices in the Swedish Institute of Space Research, Kiruna, since the beginning but was forced to move when building extensions at the Institute required the demolition of the area where EISCAT was accommodated. EISCAT Headquarters moved to a new location in the centre of Kiruna, where it has since remained.

Two large scale EISCAT Svalbard Radar (ESR) projects were carried over from 1997 to 1998.

The ESR had begun operations in 1996 with only half of the planned transmitter installation. The second phase of the transmitter installations was planned to be ready at the end of 1997. Some minor difficulties caused delays, and the final transmitter was brought into use in February 1998 and immediately delivered the full planned output power of 1 MW. The completed ESR transmitter is the first transmitter in EISCAT which can truly deliver the planned nominal power in routine operations. Electrically the first and second halves of the transmitter are essentially identical but mechanical improvements, particularly in the cooling system, proved much better than the originals and the first part of the transmitter was updated to the same standard. This work was ready in summer 2000 and it turned out to be very successful.

The other major project was the second antenna to the ESR radar. The contract for the provision of the second ESR antenna was awarded to Alcatel Telspace (France) in January 1998, with planned delivery in autumn 1999.

Everything went smoothly; the final design was accepted in June 1998 and work on preparing the foundations for the dish began in August. Some rearrangements in the details of the delivery compared with the original plans took place, but from EISCAT point of view these changes were quite transparent; negotiations and contacts between the contractors were carried out in a good business atmosphere and no surprises or difficulties were experienced. EISCAT staff both from Svalbard and Kiruna sites assisted EISCAT Headquarters in the negotiations. The planned schedule was followed as closely as one might hope for a project of this size and the new antenna was erected in the summer of 1999, accepted by EISCAT on December 12, 1999, and it has been in routine use ever since. The first common mode experiment was actually completed successfully during an extended test on testing on October 8 and 9, 1999. Formal inauguration of the second ESR antenna took place during the Council meeting held on Svalbard in May 2000.

The new antenna is a 42m rotationally symmetric, low side-lobe Cassegrain design, with 45.3 dBi gain. It is fixed in the field-aligned direction, although pointing corrections of about 1° can be achieved by offsetting the feed.

The system is designed to support fast switching between the first and second antennas and the switching between integration periods quickly became the norm. Pulse-to-pulse switching of the transmitter power between the two antennas should ultimately be possible, but has not yet been attempted.

A semi-automatic lubrication system was fitted to the drive system of the steerable 32-m ESR antenna.

A new receiver line for the second antenna was also delivered in 1999. These receiver modules were identical to those delivered earlier to the Svalbard radar and were also constructed at the EISCAT sites in Kiruna and Sodankylä.

When ESR started operations in 1996 it was clear that the radar would suffer from severe ground clutter difficulties. Although the experiments used supported much of the planned research and were scientifically productive, the ground clutter was a severe nuisance and it was impossible to carry out effective general purpose and low altitude experiments. A method to handle the problem was developed which relies on the fact that the ground clutter signal maintains its phase coherence over much longer time scales than the typical inter pulse period used in incoherent scatter experiments. Every modulation group is transmitted twice and the return signals from the two instances sampled. The time separation between the two transmissions is chosen to be longer than the correlation time of the plasma waves being studied, but shorter than the correlation time of the contaminating clutter. Subtracting the two sample sets sample-for-sample strongly suppresses the clutter while leaving the target and noise contributions unaffected. There is an overhead in that the measurement variance is doubled, requiring longer integration time for a given accuracy, but the benefits of the clutter reduction far outweigh this disadvantage. The technique was first tested in March 1998, and has been in regular use since August 1998 allowing routine observations down to 90 km.

Together with the development of algorithms needed in ground clutter cancellation, some new experimental modes were developed and tested by EISCAT. The new codes in which all transmissions are modulated using alternating codes, the same modulation covers the whole range, true power is not measured from target signal, and background subtraction is not needed, have become increasingly popular amongst users of ESR and the majority of ESR experiments used this approach by the end of 2001, including very extensive data sets collected in conjunction with operations of the ESA CLUSTER satellites.

However, developing new experiments on the existing hardware turned out to be very difficult; only a few different experimental modes existing and most experiments being based on different modifications of a single, well understood, general purpose alternating code experiment. It became clear that it was impossible to develop a more extensive experiment library without updating certain critical parts of the radar. This work was planned before the end of 2001 and scheduled for 2002.

In the beginning, the ESR site had a resident Site Manager, but otherwise the site and development work was based on commuting staff from other EISCAT sites together with some project workers, who were assigned to ESR tasks. The EISCAT Svalbard site started to get its own staff in 1998 and at the end of the year three persons were working at the site. The Science Director of EISCAT also moved from Tromsø to Svalbard in 1998 to boost radar operations and the complement was later further increased to five, but reduced again to four near the end of 2001.

The experimental policy at the ESR changed in 1998 and users were allowed to be present at the radar site and carry out their own experiments as on the mainland. Although having non-staff at the site involves some risks due to the sometimes very dangerous artic conditions, the possibility to attend the site has been enthusiastically adopted by the user community. EISCAT has developed proper procedures to ensure the safety of both staff and visitors and also improved its own snow clearing capabilities. No real safety problems have been experienced so far.

EISCAT Svalbard radar has been extensively used in scientific experiments in 1998-2001 and has been very reliable especially after the cooling system modifications.

The original EISCAT radars on the mainland (often referred to as the KST system) operated normally during the period 1998-1999, essentially conducting the planned operations according to schedule. However, the computer and signal processing systems were more than ten years old, in most places the receiver lines were almost twenty years old, and practically everywhere the designs were 20-25 years old and these had become limiting factors and had essentially stopped new experimental development several years ago. Further, the UHF transmitter could not reach high power levels and the VHF transmitter was temporarily causing problems. Because the sites had been heavily involved in ESR construction and operations the possibility for extended maintenance had been limited. The UHF-antennas were apparently in good shape, but some aging problems were evident in the VHF antenna.

The KST system had simply become too old and required extensive renovation. Plans existed to replace the receiver, signal processing and computer systems, but the renovation program finally became much more extensive than originally planned. The resulting renovation and refurbishment programme was the most ambitious maintenance exercise undertaken in the twenty-year history of EISCAT.

Serious transmitter problems were experienced October 13, 1998, when the last fully working Varian-built UHF klystron failed. The klystron, which was in use in the UHF-radar in 1998 had already been run for about 11000 hours. The spare klystron, which had already been rebuilt once, proved to be incapable of transmitting all of the modulation schemes used at the time, although it did improve slowly with use.

Even before the failure it had been known for a long time that the klystrons must have been approaching the limits of their expected lifetime. Council had asked EISCAT Headquarters to be prepared to this situation and Headquarters had analysed different alternatives for obtaining one or two new tubes. Some of the available options were financially practical and consequently EISCAT Council were able to accept a Headquarters proposal only a little more than one month after the klystron failure and, after detailed negotiations, two new klystrons were ordered from Thomson CSF, France, at the beginning of February 1999 for delivery about one year later. This decision was certainly one of the fastest in the history of EISCAT, and particularly amazing when considered in the light of the financial and other consequences of the decision.

The decision to purchase new klystrons meant that the UHF-transmitter could also be upgraded, allowing practically the whole UHF-system except the antenna, to be renovated. It was quickly decided to change the transmitter configuration. As originally installed, the transmitter used a single tube, but the design could support two parallel tubes and the newly ordered tubes would be capable of delivering over two megawatts peak output power at lower voltage levels than previously required. Even if the configuration change looked quite dramatic, many of the old parts in the old transmitter could be used effectively in the new configuration.

Figure 1: One of the new EISCAT UHF klystrons

From the end of 1999, the UHF and VHF systems were unavailable for all but passive experiments. The old UHF klystron was removed, the transmitter oil tank was modified to accept two tubes, and the new pair of highly efficient Thomson-CSF klystrons installed. Each of the new tubes (Figure 1) is capable of delivering 1.3 MW power at 12.5% duty cycle with pulse-lengths from 1 µs to 2 ms. The new transmitter tubes need freshwater cooling requiring substantial modifications in the transmitter hall.

The remaining renovation work on the KST systems had already started in spring 1998. The development work and construction of the new receiver lines was mainly done at the EISCAT sites in Kiruna and Sodankylä. The Kiruna site did the cryogenic amplifier systems, front ends, and analogue parts of the receivers, both for the KST renovation and the second ESR antenna while the Sodankylä site designed and constructed new digital parts of the receivers for the KST renovation. The radar controllers needed were built at the Tromsø site using essentially the same design as that used for the ESR, but with larger memories.

Originally it was planned to upgrade the mainland EISCAT sites using the technology developed for ESR. However, when KST renovation started the ESR design was already 6-8 years old and some of the ESR solutions were no longer supported commercially.

The main difference between the ESR design and the KST renovation design is that the renovated KST system includes no dedicated signal processors. All the real time computations necessary after signal filtering and detection are done by standard computers using well-known programming languages.

At the end of 1999, EISCAT was ready to start the final installation work needed for the KST renovation. The schedule was slightly delayed because of some last minute changes needed in the design and the expected delivery dates for the new UHF-klystrons were now in 2000. It was then only practical to do the receiver renovation and transmitter renovation at the same time.

Acceptance tests of the new UHF-klystron were done in first half of the year 2000. The first klystron was delivered in April; the second tube arrived in Tromsø in October.

The modifications needed in Tromsø site for the new transmitter configuration started in the beginning of February 2000. The new fresh water cooling system for both the VHF and UHF radars in Tromsø was ready at the end of August.

The UHF waveguide system was also renovated. A power combiner, required for the paralleling of both klystrons, was constructed at essentially no cost using leftovers from the unadopted “duplexer” project attempted in the very earliest days of EISCAT. Several tuning sections were also added to the waveguide to improve its power handling capabilities. The old Varian klystron was used in testing the renovated waveguides and an output power level of 1.9 MW was reached at the beginning of September 2000. After that, the old klystron was removed from the system and stored securely. The new tubes were then installed and the increase in UHF transmitter power is expected to improve the measurement accuracy at the receiver sites by a factor of at least two.

In Tromsø, the old UHF receiver front end was replaced by a cryogenically cooled amplifier, lowering the system noise temperature from about 110 K to below 90 K. Together with the power increase, this offers a potential improvement in the time resolution of the UHF radar by a factor of four or more.

The first phase of VHF-system renovation started in May 2000 and the new configuration was tested in June. This also verified that the newly designed receiver parts worked and that the real time computing system did not cause surprises during real experiments. Unhappily the VHF antenna developed some mechanical problems and several bearings had to be replaced.

At all three mainland sites, the old all-analogue down-converters, and the old signal processing hardware (analogue-to-digital converters, matched filters, and digital correlators) were replaced with state-of-the-art back-end units. In these, the received signals are digitised at the last intermediate frequency of 11.5 MHz and all subsequent processing (channel separation, down-conversion to base band and low-pass filtering) is performed in the digital domain, achieving superior flexibility, noise immunity and long-term stability. An EISCAT-developed signal processing software package, running on embedded UNIX computer systems, replaced the old digital correlators. In Tromsø, where dual radar operation occasionally imposes a heavy real-time processing load, the signal processing software was moved onto a new high-performance 14-processor Sun server acquired specifically for this purpose. The computing power increased by more than one order of magnitude, particularly for real-time applications.

The old Norsk Data computers used for controlling the radar and running all background software were replaced by powerful UNIX workstations. The old EROS control software was replaced by a new Tcl-based monitoring and control software package, EROS IV, offering a familiar user interface and providing most of the same functionality as the earlier EROS versions. Examples of the new monitoring and control systems are shown in Figures 2 and 3.

The antenna pointing and tracking software for the new UNIX/VME environment was tested in the beginning of January 1999. This work was mainly done at Sodankylä site, along with other projects such as the construction of the first new-philosophy, measuring algorithms needed for the ESR.

It turned out that the computer used in the renovated signal processing creates small level of RF interference at the EISCAT band. The interference was disturbing at Sodankylä site and RF shielding was needed. The other sites were shielded already when they were built.

The renovated EISCAT UHF and VHF systems were again operational at the end of year 2000 and many new experiments were run immediately. Generally the renovated part of the system has worked very well. Some minor faults were found and corrected but this can be considered quite normal, when considering the volume of work needed in the renovation process. EISCAT had to take extensive risks during the renovation, it would have been very difficult if the new transmitter had not been operational after renovation, but, although many system parts were completely redesigned, the project succeeded at the first trial.

After the renovation the radars have been used extensively and have worked well.

The experiments for the renovated KST radars can be divided into two groups. The most important old experiments have been ported to the new system and have been used successfully by several groups. A new experiment group resembling the ESR experiments and based totally on alternating codes was also developed together with a new D-layer experiment. These experiments make full use of the new possibilities supported by the renovation.

The first experiment campaign on the renovated EISCAT mainland systems was carried out in November 2000, well in time for the start of the Cluster science phase in January 2001. Initially only a small subset of experiments was available, these being copies of experiments on the old system which had been “retro-fitted” to run on the new hardware. Although these experiments did not exploit the improved signal processing possibilities of the new system, they enabled a limited operational capability in the winter season 2000/2001.

During 2001, the number of available experiments increased rapidly such that the range of possibilities available to the user is now as large as was the case before the renovation. The table on page 20 summarises the modulation schemes currently available, their pre-integration times and range coverage, and the use for which they are intended.

The data analysis facilities also needed corresponding development and EISCAT took over the support and development of the GUISDAP package. The Madrigal database system was installed and extended for EISCAT purposes and processed data, starting with the ESR, began to be routinely made available through this web-based facility. Extensive raw data archiving tools developed at the ESR were also installed at the mainland sites again making data handling consistent across the Association.

The KST renovation to large extent controlled the whole period 1998-2001. Although experimental activity had to be suspended only during the most active period in the year 2000, the design and preparation phases covered the years 1998-1999 and even in 2001 there were some fine-tuning issues to be addressed. Some technical points require further work, especially concerning the wave-guide in Tromsø and the UHF antenna control systems (still the original 1970s implementation), and a report listing the remaining old parts in the system, and risks related to them, has been prepared by Headquarters.

There were developments in KST system, which did not belong to renovation process. The use of un-cooled amplifiers in the receiver front end became possible but, for experiments requiring a wide, interference-free bandwidth, such as interplanetary scintillation (IPS) studies, the 930 MHz range is already unusable due to the high number of in-band emissions. EISCAT is therefore developing wide-band waveguide feeds and receiver front ends for the 1400-1427 MHz radio astronomy band for the UHF antennas. Once the 1.4 GHz system is operational, future IPS activity at EISCAT will use this frequency band.

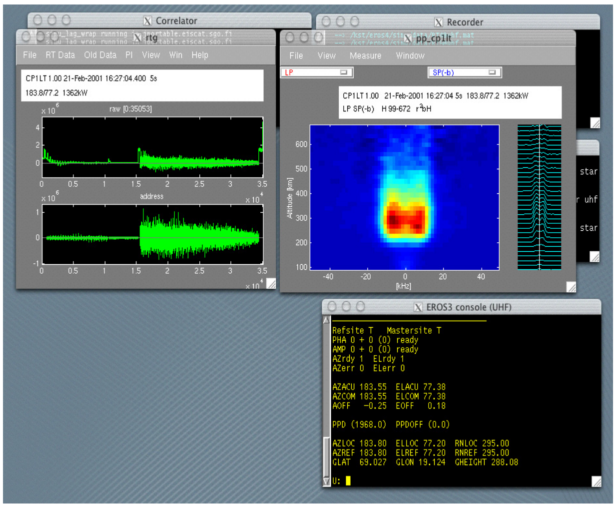


Figure 2: The new data monitoring software from the Tromsø site.

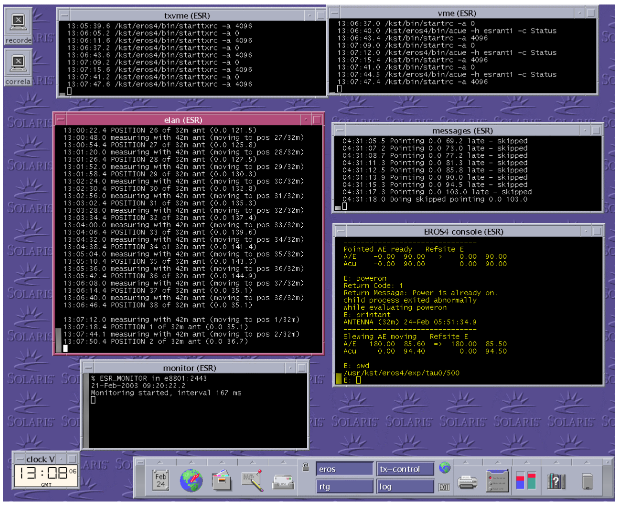


Figure 3: An example of the operator interface for the new control system at the Tromsø radars.

The EISCAT Svalbard Radar continued to operate very reliably during 2000 and 2001 and attracted a high level of usage, particularly during the period where the mainland radars were unavailable. An improved interface with the airport at Longyearbyen greatly reduced the length of interruptions due to air traffic around the site, as well as offering the possibility to control the transmitters of several instruments (e.g. ESR, SOUSY and in the future, SPEAR) via a common system. Improved computing and data storage facilities were also added at the ESR.

The tau0 modulation scheme continued to be used as the basis for all ESR operations, with the default pre-integration time being changed from 12.8 to 6.4 seconds, once it had been established that the larger data sets could be handled reliably. A specialised “Cluster mode”, in which 6.4 second data dumps are alternated between the field-aligned 42 meter dish and the 32 meter steerable dish pointed at 30^{o} elevation to the magnetic north, has become the basis for much of the ESR operation.

Everything appeared to be progressing well by the summer of 2001, but then an unexpected nightmare appeared. A professional company checked the EISCAT UHF antennas and “tightened” the bolts in summer 2001. This work has been done at intervals of some years during the last 20 years, but not by the same company used now. It was found that our bolts were over tightened, so the bolt tightening became mostly loosening the bolts. When the mechanical structures of the antennas were checked it turned out, that in all UHF antennas we have cracks in certain supporting structures which take the load caused by counterweights. As material fatigue could not be excluded, expert advice was sought from antenna manufacturing companies and a certified inspection company was called in to do an ultrasound inspection. Happily, it was determined that the cracks were the result of frost damage caused by water collected inside badly drained backing sections an no signs of metal fatigue were found. However, the antennas had to be repaired practically immediately and the work was done in autumn 2001. After welding the cracks and draining the structures, the antennas are now expected to provide good service for the foreseeable future.

The EISCAT Heating facility achieved one of its highest-ever peaks of activity (233 hours) in 2001. Technically, the heating facility has operated reliably with only the usual level of maintenance problems associated with damage to the arrays during the Scandinavian winter. Some expected problems have occurred with the ageing components but nothing critical has happened. A new operating agreement has extended the number of available frequencies and the computer control of the heater has been upgraded. The Dynasonde has also been upgraded and a new control computer installed. A number of new sounding schemes have been added to the range of measurements that the instrument can perform.

EISCAT shares its UHF frequency band around 930 MHz with a number of communications systems, notably the GSM cell-phone base stations. The increasing public demand for mobile telephony in the last years of the 1990s led to an unfortunate situation in Sodankylä, where the Finnish telecom authority found itself treaty bound to assign a major portion of the EISCAT band to a new cell-phone network. However, the telecom authority also successfully mediated a discretionary agreement between the network operator and EISCAT, reserving the 929.0-930.5 MHz range for EISCAT use, thereby safeguarding the continued EISCAT UHF operation. The situation in Norway and Sweden is more favourable, as the telecom authorities in these countries have been in a position to establish co-ordination zones around the EISCAT sites, where all active use of frequencies in the 925-935 MHz band is subject to EISCAT approval.

So far EISCAT Headquarters has managed every time to negotiate enough frequency space for EISCAT purposes, but a lot of work has been needed. This is mentioned here as a separate item, because for the tri-static EISCAT UHF radar system the loss of a clear operating band common to all three sites could stop the operations totally. EISCAT Headquarters has to follow this carefully all the time and take appropriate actions when needed.

One of the most important tasks addressed by the incoming Director was to improve the financial situation of the EISCAT Scientific Association. In fact, just before the period handled in this report, there was even serious consideration given to closing some parts of the EISCAT to save money. Some Associates had also warned that their economic situations were very tight and some savings would be necessary.

When looking back, it is quite clear that the economic situation was not as difficult as then estimated. The Associates were able to follow the Agreement and EISCAT could also save money. The recurrent costs were only 25.2 MSEK in 1998 and 25.7 MSEK in 1999. Capital operating expenses were about 1 MSEK in 1998 and 1.7 MSEK in 1999. The use of evolution funds amounted to 14.6 MSEK in 1998 and 30.8 MSEK in 1999. Savings were made in recurrent expenses, mainly due to vacant positions and some rearrangements in working routines. The total savings and additional income in recurrent costs amounted to 4.9 MSEK in 1998 and 2.4 MSEK in 1999. The year 2000 resulted in an under spend, relative to the agreed budget, of about 1.9 MSEK.

The savings were transferred to surplus funds for later use. The Associates have decided no longer to increase their contributions to compensate for inflation and this decision, if followed, unavoidably leads to overspending of the surplus funds. The use of surplus funds started in 2001 and they were forecasted to be exhausted by 2003. New economic strategies are needed and discussions in EISCAT Council already started in 2001.

Mainland experimental activity was at about the nominal level when averaged over the years 1998-01 although below target in some years due to the renovation activity. The EISCAT Svalbard radar operated extensively, including one continuous operation lasting more than 18 days, and use of the Heating facility was close to the planned level. The measured hours and the national use of EISCAT are shown in detail elsewhere in this report.

During the period 1998-2001 more than 310 papers on EISCAT related matters were published in scientific literature, together with more than 30 masters and doctoral theses and more than 50 other articles in conference proceedings and the popular press.

The EISCAT Scientific community held its 9th International Workshop at Wernigerode, Germany, in September 1999. Nearly 100 scientists from the Associate countries and elsewhere participated in the workshop showing that scientific interest on research based on EISCAT is at high level. Even more attended the 10th Workshop, held at the National Institute of Polar Research in Tokyo, Japan in July 2001. Participants of twelve different nationalities used the opportunity to discuss science, exchange scientific achievements, and agree on the future scope in the development of EISCAT radar study of our Earth environment.

EISCAT staff members have had 3-4 day review meetings in every year but one since the Association began. With staff distributed across five different sites and employed by almost as many different host organisations, such meetings play an essential team-building role, as well as providing a very effective forum for the discussion and resolution of all sorts of design, maintenance, and operational issues. The accompanying photographs provide a striking record of the EISCAT staff over this four year period.

Of particular note at the 1998 Review Meeting was an award ceremony for six EISCAT staff members who had each achieved a working life with EISCAT spanning more than twenty years. The contribution made by (from left in the photograph below) Gunnar Isberg from Headquarters, Tarmo Laakso and Anna-Liisa Piippo from the Sodankylä site, and Ingemar Wolf, Lars-Göran Vanhainen and Kent-Ove Johansson (unfortunately not in the picture) from the Kiruna site have been invaluable over the years and it is a pleasure to acknowledge them again here.

The years 1998-2001 have seen enormous changes in EISCAT. These changes have been accomplished solely by the efforts of the EISCAT staff who have worked with diligence, skill, and unfailing good humour throughout this very difficult and often disheartening period. Without them, the EISCAT radars are nothing. I thank all of them who have been so generous over these years; the EISCAT community owes them a great debt.

Tauno Turunen
Director

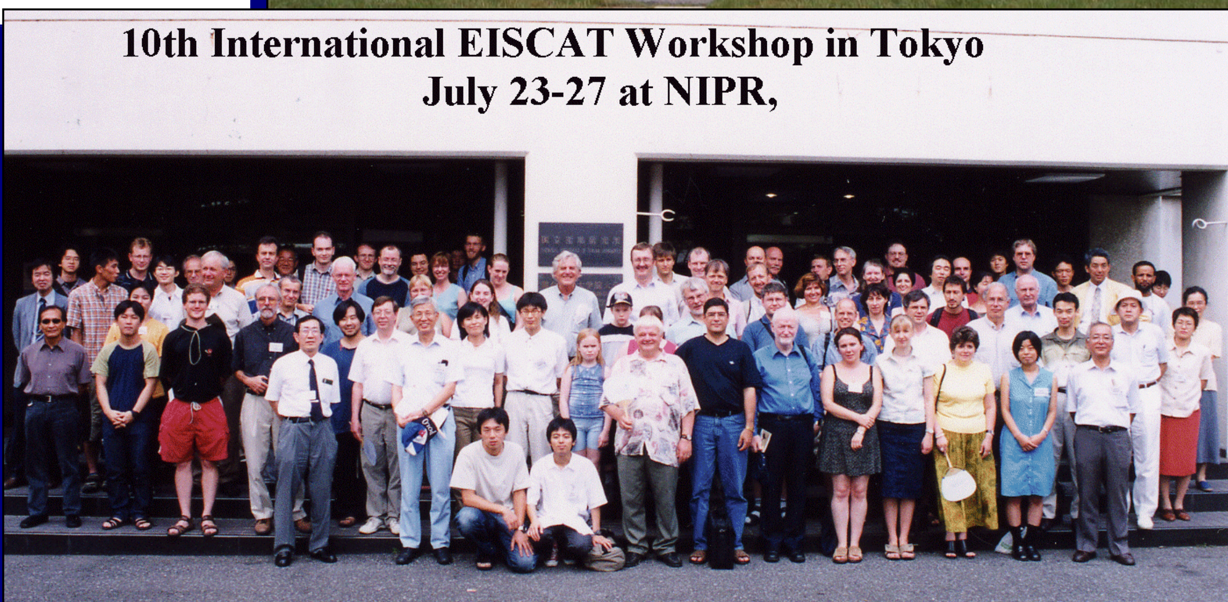
EISCAT staff gathered at Gällivare, Sweden, in 1998…

100 years of combined EISCAT service…

…at Levi, Finland, in 1999….

…on the Norwegian coastal express in 2000…

…and in Karesuando, Sweden, in 2001



While more than 100 scientists participated in the 10th EISCAT International Workshop, Tokyo, July 2001

Obituaries

Several scientists and engineers closely connected with EISCAT passed away in the reported years. Two were EISCAT staff members at the time of their deaths.

Dr. Klaus Rinnert (1938-1998)

Klaus Rinnert passed away on April 29, 1998 from the effects of cancer, at the age of sixty.

Klaus Rinnert worked intensively and successfully in the EISCAT group at the Max-Planck-Institut für Aeronomie since the late seventies. He had obtained his 'Diploma' at the institute in 1966, followed by a doctoral thesis in 1972 on the propagation of very low frequency radio waves in the Earth-ionosphere waveguide. After working briefly on a partial reflection radar, Klaus started investigating Jupiter's atmosphere in a long-lasting US-collaboration with L. Lanzerotti. This culminated in the descent of the Galileo probe into the Jovian atmosphere in 1995, when his lightning detector showed a much lower flash rate than expected.

In addition to working with incoherent scatter radars in Alaska and Peru (Jicamarca), Klaus also worked together with Prof. J. Fejer und Dr. R. Woodman on Brillouin-scattering. His diverse talents were shown through the electric field sensors he developed for the successful CAESAR and ROSE rocket campaigns, which also involved EISCAT measurements. He was the German member of EISCAT's Scientific Advisory Committee from 1989 to 1995. He made over sixty publications, of which his last EISCAT work was on periodic precipitation following magnetic storms.

Klaus was always friendly and helpful, and is missed by his colleagues.

Dr. David Tetenbaum (1955-1998)

David Tetenbaum passed away, aged only forty-three, on June 29, 1998 after a long illness.

David was born in Washington DC but grew up in Chicago, later studying at MIT and the University of Illinois and obtaining his PhD in 1986. He started working in Incoherent Scatter at the Millstone Hill Radar, from where he was persuaded to join EISCAT in 1993 to work on the software required for the new EISCAT Svalbard Radar. He contributed to the development of meteor scatter techniques for the study of atmospheric tides and winds and subsequently worked in the newly developing field of coherent echoes observed by incoherent scatter radars. He played a full role in the scientific life of EISCAT and provided invaluable support to innumerable vesting experimenters, and EISCAT staff, at the Tromsø site.

Outside work, David had a wide range of interests built around his young family. He was also a skilled craftsman and an accomplished musician with a great interest in Renaissance and pre- Baroque music, frequently played on suburb instruments, including several beautiful harpsichords, which he built himself.

David bore his illness with stoicism and unfailing good humour, even formally changing his name to David Hope towards the end. He is survived by his wife and two children and his loss leaves a large hole in all our lives.

Stein Johnny Eliassen (1949-2000)

On May 26, 2000, Stein passed away after a two-year battle with cancer. He was fifty-one years of age.

Stein joined EISCAT in 1992 as the engineer responsible for the technical side of the Heating facility, just as it was being transferred to EISCAT from the Max-Planck-Institute für Aeronomie. With his extensive background in both analogue and digital electronics, he proved to be a most capable engineer both maintaining the facility and improving it as required by the users. For example Stein implemented a PC-based replacement of the control computer with expanded diagnostic capabilities. He contributed to the building of the EISCAT Svalbard Radar, and was a valuable member of the EISCAT staff.

Stein will also be remembered for his attempts, before he joined EISCAT, to produce a beacon transmitter for seamen in distress. He formed a company, Exotech, but ended up in legal battles with the telecommunication authorities to get licensing approval. He was very dedicated and persevering in everything he did. We will always remember him, especially for his enthusiasm and helpfulness.

EISCAT Operations 1998-2001

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. The basic time resolution is 5 sec. Continuous electric field measurements are derived from the tri-static F-region data. On longer time scales, CP-1 measurements support studies of diurnal changes, such as atmospheric tides, as well as seasonal and solar-cycle variations. The observation scheme uses alternating codes and long pulses for ACF measurements, as well as short pulses for power profiles.

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 (a 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. The pulse scheme is identical with that of CP-1.

Common Programme Three, CP-3, covers a 10^{o} latitudinal range in the F-region with a 17-position scan up to 74^{o}N in a 30 minute cycle. The observations are made in a plane defined by the magnetic meridian through Tromsø, with the remote site antennas making continuous measurements at 275 km altitude. A power profile and long pulse ACFs are measured. The principle aim of CP-3 is the mapping of ionospheric and electrodynamic parameters over a broad latitude range.

Common Programmes One, Two, and Three are run on the UHF radar. Three further programmes are designed for use with the VHF system. The UHF and VHF radars were often operated simultaneously during the CP experiments in 1994 and 1995. Such observations offer comprehensive data sets for atmospheric, ionospheric, and magnetospheric studies.

Common Programme Four, CP-4, covers geographic latitudes up to almost 80^{o}N (77^{o}N invariant latitude) using a low elevation, split-beam configuration. CP-4 is particularly suitable for studies of high latitude plasma convection and polar cap phenomena.

Common Programme Six, CP-6, is designed for low altitude studies, providing spectral measurements at mesospheric heights. Velocity and electron density are derived from the measurements and the spectra contain information on the aeronomy of the mesosphere. Vertical antenna pointing is normally used.

Common Programme Seven, CP-7, probes high altitudes and is particularly aimed at polar wind studies. The present version uses both of the VHF klystrons and is designed to cover altitudes up to 2500 km vertically above Ramfjordmoen.

Equivalent Common Programme modes are available for the EISCAT Svalbard Radar. CP-1L is directed along the geomagnetic field (81.6^{o} inclination). CP-2L uses a four position scan with spacing matching CP-2. CP-3L is a 30 position elevation scan with southerly beam swinging positions overlapping those of CP-3. CP4-L combines observations in the F-region viewing area of the two beams of CP-4 with field-aligned and vertical measurements. CP-1L, CP-2L, CP-3L, CP-4 L, and CP-7L (same as CP-1L) have been operated in conjunction with the corresponding modes on the mainland. Two different pulse schemes have been used extensively for each mode, one using four long pulses to cover approximately 80 to 900km in range. Data below 150km range are contaminated by ground clutter. The second covers approximately 80 to 1200km using two alternating codes with integral clutter removal below 150 km.

The table on the next page summarises the presently available modulation schemes on the three incoherent scatter radars.

The subsequent table provides an overview of EISCAT Common Programme experiments in 1998-2001. WD indicates a co-ordinated 'World Day' incoherent scatter experiment, * indicates multiple radar operation for some or all of the interval.

The remaining tables show the accounted hours on the various facilities for each month and for each Common Programme mode (CP) or Associate (SP)

UHF Common Programmes during 1998

98-01-20 10UT	01-21 16UT	CP-1	WD	
98-03-23 10UT	03-27 24UT	CP-2	WD	*
98-04-27 10UT	04-30 24UT	CP-3	WD	*
98-08-17 10UT	08-19 16UT	CP-1	WD	*
98-09-21 10UT	09-25 16UT	CP-2	WD	*
98-10-19 10UT	10-21 16UT	CP-3	WD	*

VHF Common Programmes during 1998

98-03-23 10UT	01-27 24UT	CP-6	WD	*
98-05-26 10UT	05-28 16UT	CP-7	WD	*
98-06-23 10UT	06-24 16UT	CP-4	WD	*
98-09-21 10UT	09-25 16UT	CP-6	WD	*
98-10-22 10UT	10-25 16UT	CP-7	WD	*
98-12-08 10UT	12-09 16UT	CP-4	WD	*

Experiment Name	Radar	Pulse Schemes Used	Time Resolution	Range Coverage	Comment
tau0	ESR	Alt. Code	3.2, 6.4, 12.8 s	90-1200 km	General purpose ESR experiment
tau1	VHF	Alt. Code	5 s	300-1900 km	Low elevation (replaces cp4)
tau2	UHF	Alt. Code Power Profile	5 s	90-750 km	General purpose (replaces cp1)
tau3	UHF	Alt. Code Power Profile	5 s	90-1400 km	Modified tau2 with more range coverage, used for scanning
tau7	VHF	Alt. Code	5 s	150-2000 km	High altitude (replaces cp7)
tau8	VHF	Alt. Code	5 s	150-1400 km	General purpose dual beam VHF experiment
arc 1	UHF	Alt. Code	0.4 s	95-350 km	High time resolution for auroral studies
d layer	VHF	Coded pulse-to-pulse	5 s	60-120 km	High spatial resolution for D-layer and PMSE
cp1l	UHF	Alt. Code Long Pulse Power Profile	5 s	90-700 km	Cp1k converted for new system
cp4b	VHF	Long Pulse Power Profile	10 s	400-1800 km	Cp4b converted for new system
cp7h	VHF	Long Pulse Power Profile	10 s	280-2000 km	Cp7g converted for new system
gup3	ESR	Alt. Code Long Pulse	10 s	90-875 km	ESR general purpose experiment

ESR Common Programmes during 1998
98-03-23 12UT 03-27 24UT CP-2L WD *
98-04-27 16UT 04-30 24UT CP-3L WD *
98-05-26 12UT 05-28 16UT CP-1L WD *
98-06-23 13UT 06-24 16UT CP-4L WD *
98-08-17 13UT 08-19 16UT CP-1L WD *
98-09-21 10UT 09-25 22UT CP-2L WD *
98-10-19 10UT 10-21 16UT CP-1L WD *
98-11-22 10UT 11-22 18UT CP-7L WD *
98-12-08 22UT 12-09 16UT CP-4L WD *

UHF Common Programmes during 1999
99-02-09 10UT 02-12 16UT CP-1 WD *
99-03-08 10UT 03-12 16UT CP-2 WD *
99-04-20 10UT 04-22 16UT CP-3 WD *
99-07-05 10UT 07-08 16UT CP-2
99-08-11 06UT 08-11 22UT CP-1
99-09-15 10UT 09-17 16UT CP-1 WD
99-10-12 10UT 10-15 16UT CP-1 WD
99-12-02 10UT 12-03 16UT CP-1 *

VHF Common Programmes during 1999
99-01-12 10UT 01-13 16UT CP-4 WD *
99-03-15 18UT 03-15 22UT CP-4
99-03-16 18UT 03-16 22UT CP-4
99-06-15 08UT 06-17 14UT CP-4
99-06-22 08UT 06-23 14UT CP-6
99-09-28 10UT 09-30 16UT CP-6
99-10-08 10UT 10-09 16UT CP-7 WD *
99-11-22 10UT 11-24 16UT CP-4
99-11-25 10UT 11-27 16UT CP-6
99-12-09 10UT 12-10 16UT CP-7 WD *

ESR Common Programmes during 1999
99-01-12-10UT 01-13 16UT CP-4L WD *
99-02-09 08UT 02-12 16UT CP-1L WD *
99-03-08 10UT 03-12 16UT CP-2L WD *
99-04-20 10UT 04-22 16UT CP-3L WD *
99-07-01 10UT 07-09 16UT CP-2L WD
99-10-08 10UT 10-09 15UT CP-7L WD *
99-12-02 11UT 12-03 16UT CP-1L *
99-12-07 10UT 12-08 16UT CP-1L
99-12-09 10UT 12-10 16UT CP-7L *

UHF Common Programmes during 2000
None

VHF Common Programmes during 2000
00-05-20 11UT 05-20 15UT CP-7
00-05-22 07UT 05-22 13UT CP-7
00-05-23 10UT 05-23 13UT CP-7
00-05-29 08UT 05-29 13UT CP-7
00-05-30 07UT 05-30 13UT CP-7

ESR Common Programmes during 2000
00-01-06 10UT 01-07 14UT CP-7L WD
00-03-14 12UT 03-20 16UT CP-4L WD
00-04-11 10UT 04-13 16UT CP-3L WD
00-07-05 10UT 07-07 16UT CP-1L WD
00-07-14 04UT 07-14 12UT CP-4L
00-07-15 04UT 07-15 12UT CP-4L
00-07-16 04UT 07-16 12UT CP-4L
00-07-17 04UT 07-17 10UT CP-4L
00-07-18 04UT 07-18 12UT CP-4L
00-07-19 04UT 07-19 12UT CP-4L

00-07-20 04UT 07-20 12UT CP-4L
00-07-21 04UT 07-21 12UT CP-4L
00-07-23 04UT 07-23 11UT CP-4L
00-08-28 04UT 08-28 12UT CP-4L
00-08-30 06UT 08-31 12UT CP-4L
00-09-01 04UT 09-01 12UT CP-4L
00-09-25 21UT 09-27 16UT CP-2L WD
00-10-13 15UT 10-14 15UT CP-1L
00-10-24 10UT 10-27 16UT CP-1L WD
00-12-07 02UT 12-07 13UT CP-4L

UHF Common Programmes during 2001

01-02-06 14UT 02-07 12UT CP-1
01-02-13 09UT 02-15 16UT CP-1 WD *
01-04-16 22UT 04-17 07UT CP-1 *
01-04-21 16UT 04-21 24UT Cluster *
01-04-28 18UT 04-29 12UT Cluster *
01-09-17 11UT 09-23 22UT CP-1 WD *
01-09-25 15UT 09-27 01UT CP-2 *
01-10-01 14UT 10-01 22UT Cluster *
01-10-05 09UT 10-05 11UT Cluster *
01-10-08 14UT 10-08 22UT Cluster *
01-10-13 14UT 10-13 22UT Cluster *
01-10-15 13UT 10-13 22UT Cluster *
01-10-16 16UT 10-17 02UT CP-1 WD *
01-10-17 16UT 10-18 03UT CP-1 WD *
01-10-27 13UT 10-27 22UT Cluster *
01-10-29 14UT 10-29 22UT Cluster *
01-11-13 10UT 11-15 18UT CP-3 WD *
01-12-11 14UT 12-14 07UT CP-2 WD *

VHF Common Programmes during 2001

01-02-13 09UT 02-15 16UT CP-4 WD *
01-03-09 18UT 03-10 12UT Cluster *
01-03-17 00UT 03-17 12UT Cluster *
01-03-21 18UT 03-21 23UT Cluster *
01-04-04 06UT 04-04 10UT Cluster *
01-04-16 22UT 04-17 11UT CP4 *
01-04-21 16UT 04-21 24UT Cluster *
01-04-28 18UT 04-29 12UT Cluster *
01-06-20 10UT 06-22 16UT CP-6
01-07-02 11UT 07-05 16UT CP-4 *
01-07-11 10UT 07-15 16UT CP-4 WD *
01-07-19 00UT 07-19 08UT Cluster *
01-07-19 22UT 07-20 04UT Cluster *
01-08-14 20UT 08-14 24UT Cluster *
01-08-26 18UT 08-27 04UT Cluster *
01-09-07 18UT 09-07 23UT Cluster *
01-09-11 13UT 09-11 17UT Cluster *
01-09-13 19UT 09-13 22UT Cluster
01-09-17 11UT 09-23 22UT CP-4 WD *
01-09-25 17UT 09-27 01UT CP-4 *
01-10-01 14UT 10-01 22UT Cluster *
01-10-08 14UT 10-01 22UT Cluster *
01-10-09 12UT 10-11 16UT CP-4 WD *
01-10-13 14UT 10-13 22UT Cluster *
01-10-15 13UT 10-13 22UT Cluster *
01-10-16 10UT 10-18 13UT CP-7 WD *
01-10-27 14UT 10-27 22UT Cluster *
01-10-29 14UT 10-29 22UT Cluster *
01-11-03 14UT 11-02 20UT Cluster *
01-11-05 06UT 11-07 18UT Cluster *
01-11-11 09UT 11-11 15UT Cluster *
01-11-13 10UT 11-15 18UT CP-4 WD *
01-11-20 09UT 11-20 15UT Cluster *
01-12-11 09UT 12-11 14UT Cluster *
01-12-11 14UT 12-14 16UT CP-4 WD *

ESR Common Programmes during 2001

01-01-07 07UT 01-07 15UT Cluster
01-01-14 07UT 01-14 15UT Cluster
01-01-21 04UT 01-21 18UT Cluster
01-01-26 06UT 01-26 17UT Cluster
01-02-02 07UT 02-02 15UT Cluster
01-02-05 11UT 02-23 14UT CP2-L
01-02-26 07UT 02-26 15UT Cluster
01-03-03 06UT 03-03 10UT Cluster
01-03-09 18UT 03-10 12UT Cluster *
01-03-14 06UT 03-14 12UT Cluster
01-03-17 00UT 03-17 12UT Cluster *
01-03-21 18UT 03-21 23UT Cluster *
01-03-28 05UT 03-29 10UT Cluster
01-04-02 06UT 04-02 12UT Cluster
01-04-04 06UT 04-04 14UT Cluster *
01-04-14 06UT 04-14 12UT Cluster
01-04-16 22UT 04-17 12UT CP-4L *
01-04-21 16UT 04-21 24UT Cluster *
01-05-17 05UT 05-17 12UT Cluster
01-06-27 14UT 06-28 22UT Cluster
01-07-02 10UT 07-05 16UT CP-4L *
01-07-11 10UT 07-15 16UT CP-2L WD *
01-07-19 00UT 07-19 08UT Cluster *
01-07-19 22UT 07-20 04UT Cluster *
01-08-14 20UT 08-15 08UT Cluster *
01-08-16 06UT 08-17 06UT Cluster
01-08-26 19UT 08-27 13UT Cluster *
01-09-07 18UT 09-07 23UT Cluster *
01-09-11 13UT 09-11 17UT Cluster *
01-09-17 10UT 09-23 22UT CP-2L WD *
01-09-25 10UT 09-27 09UT CP-2L *
01-10-08 14UT 10-01 22UT Cluster *
01-10-09 10UT 10-10 02UT CP-3L WD *
01-10-16 10UT 10-18 15UT CP-7L WD *
01-10-20 00UT 10-20 12UT Cluster
01-10-27 14UT 10-27 22UT Cluster *
01-10-29 14UT 10-29 22UT Cluster *
01-10-30 13UT 10-30 20UT Cluster
01-11-03 14UT 11-02 20UT Cluster *
01-11-05 06UT 11-07 18UT Cluster *
01-11-11 09UT 11-11 15UT Cluster *
01-11-13 10UT 11-15 18UT CP-4L WD *
01-11-20 09UT 11-20 15UT Cluster *
01-11-27 06UT 11-26 18UT Cluster
01-12 04 09UT 12-04 16UT Cluster
01-12 05 08UT 12-05 13UT Cluster
01-12-11 09UT 12-11 14UT Cluster *
01-12-11 14UT 12-14 16UT CP-2L WD *

1998 CP UHF & VHF

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
CP1	30	10	6					55					101	15
CP2			55						106				161	24
CP3				86									86	13
CP4						30						30	60	9
CP6			110						53				163	24
CP7			3		44						56		103	15
Total	30	10	174	86	44	30	0	55	159	0	56	30	**674**	100 %

1998 SP UHF & VHF

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
3rdP											6		6	1
EI			7							12	25		44	5
FI											33		33	4
FR		82				12						22	116	14
GE	25	34	6	2	3	65	23	10	18	30	33	4	253	32
NI		13											13	2
NO	4		11			25	11	10					61	8
SW	15			35	15						7		72	9
UK			12	7	11	9	14	54	14	58	1	24	204	25
Total	44	129	36	44	29	111	48	74	32	100	105	50	**802**	100 %

1998 CP ESR

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
CP1L	34				68			134			8	5	249	38
CP2L			110						114				224	34
CP3L				86						54			140	21
CP4L						28						18	46	7
Total	34	0	110	86	68	28	0	134	114	54	8	23	**659**	100 %

1998 SP ESR

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
EI			12										12	3
FI	6										4	5	15	4
FR		9										28	37	10
GE				6		79					3		88	24
NI	12	15					4			2		6	39	10
NO	18		32							9		6	65	17
SW	18			5								13	36	10
UK	8							44				28	80	22
Total	62	24	44	11	0	79	4	44	0	11	7	86	**372**	100 %

1999 CP UHF & VHF

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
CP1		78						16	55	78		30	257	34
CP2			98				76						174	23
CP3				54									54	7
CP4			9			54					54		117	15
CP6						30			51		54		135	18
CP7										22			22	3
Total	0	78	107	54	0	84	76	16	106	100	108	30	**759**	100 %

1999 SP UHF & VHF

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
3rdP											25		25	3
EI							5				53		58	6
FI							5				57		62	7
FR							23					79	102	11
GE	2	37	3	6	2		56	4	17	12	38		177	19
NI	8	19	2				11	1	1	15	5		62	7
NO	11						32			10	8		61	7
SW	5	8	5	18			30			12	54		132	14
UK	14	26			66		28	9	3	102	5		253	27
Total	40	90	10	24	68	0	190	14	21	151	245	79	**932**	100 %

1999 CP ESR

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
CP1L		76		8				6	12			30	132	29
CP2L			102				78						180	40
CP3L				54									54	12
CP4L	30												30	7
CP7L										29		30	59	13
Total	30	76	102	62	0	0	78	6	12	29	0	60	**455**	100 %

1999 SP ESR

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
FI							5				12		17	4
FR	30						24						54	13
GE							83						83	20
NI	12	4	22				12						50	12
NO	18		12		6		15	26				17	94	23
SW	8		12				8						28	7
UK	28						31					23	82	20
Total	96	4	46	0	6	0	178	26	0	0	12	40	**408**	100 %

2000 CP UHF & VHF

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
CP7					25								25	100
Total	0	0	0	0	25	0	0	0	0	0	0	0	**25**	100 %

2000 SP UHF & VHF

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
FI			2	2							1	1	6	2
FR											4	4	8	3
GE	3	3	5						10	5	9	3	38	15
NI		3	5						5		6	6	25	10
NO											25	21	46	18
SW		3	5							7	2	2	19	8
UK		3	5		12				5	5	51	26	107	43
Total	3	12	22	2	12	0	0	0	20	17	98	63	**249**	100 %

2000 CP ESR

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
CP1L							58			60			118	25
CP2L									44				44	9
CP3L				30						36			66	14
CP4L			73				76						149	32
CP7L	28												28	6
UP1								38		18		11	67	14
Total	28	0	73	30	0	0	134	38	44	114	0	11	**472**	100 %

2000 SP ESR

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
FI											1	1	2	0
FR		48			22			24			3	3	100	22
GE			72				10	8			3	3	96	21
NI		4					16				10	8	38	8
NO							3	16		8	36	23	86	19
SW		20									2	2	24	5
UK				17	12			12		6	41	27	115	25
Total	0	72	72	17	34	0	29	60	0	14	96	67	**461**	100 %

2001 CP UHF & VHF

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
CP1	3			33			43						79	7
CP2									78			63	141	12
CP3											56		56	5
CP4		48		21			184		39	53	60	37	442	38
CP6						56					10		66	6
CP7										53			53	5
UP1		87	36	22							32	6	183	16
UP2			16	12						44			72	6
UP3						20				44			64	6
Total	3	135	52	88	0	76	227	0	117	194	158	106	**1156**	100 %

2001 SP UHF & VHF

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
3rdP	1												1	0
EI						11							11	1
FI		38				6		19			51		114	10
FR			76					67					143	12
GE		29		50		75		64			87		305	26
NI					10		20	26		38			94	8
NO						44	7	35				34	120	10
SW						21		35		12			68	6
UK		29	42	29	82	50		73	11	1	15		332	28
Total	1	96	118	79	92	207	27	319	11	51	153	34	**1188**	100 %

2001 CP ESR

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
CP2L		437							78			74	589	41
CP3L										16			16	1
CP4L											50		50	4
CP7L										53			53	4
UP1	27	16	50	48	7	30	200	33	87	60	95	16	669	47
UP2									48				48	3
Total	27	453	50	48	7	30	200	33	213	129	145	90	**1425**	100 %

2001 SP ESR

2001	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
FI		12									20		32	8
FR													0	0
GE						13	2	9					24	6
NI							20						20	5
NO	69						7					69	145	38
SW													0	0
UK	49		30	25							12	40	156	41
Total	118	12	30	25	0	13	29	9	0	0	32	109	**377**	100 %

Scientific Research and Developments

First D-region ESR echoes

Figure 4 shows the spectrum of an ESR incoherent scatter echo from the D-region. The total integration time is 280 seconds and the frequency resolution is 0.7 Hz. The ground clutter power at zero frequency extends over less than one frequency bin and peaks at $2.8 \cdot 10^7$ units, whereas the signal peak is at $4.5 \cdot 10^4$, this means that there is a signal-to-clutter ratio of about -30 dB. The signal-to-noise ratio is about -3 dB, when considering only the noise within the signal bandwidth. These D-region observations with the ESR made us confident of the capability of this radar for performing D-region studies.

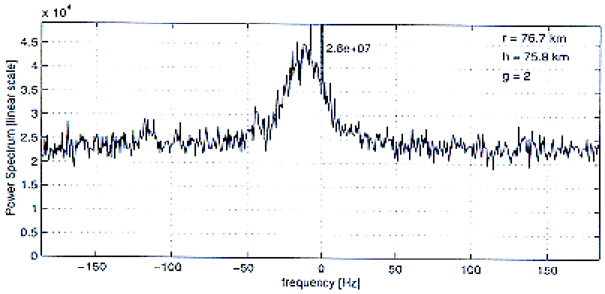


Figure 4: First D-region spectra observed with the EISCAT Svalbard Radar, April 23,1998.

Stimulated optical emissions

HF-enhanced airglow is one of the few means of detecting energetic electrons produced from plasma turbulence generated by powerful HF waves in the ionosphere. The energisation threshold for the $O(^1D)$ 630 nm emission is 1.96 eV. Enhanced airglow has been attributed to energetic electrons accelerated by Langmuir turbulence as well as energetic electrons coming from the tail of a Maxwellian velocity distribution of HF-enhanced electron temperature.

The first unambiguous detection of stimulated optical emissions at auroral latitudes was obtained on February 16, 1999, with EISCAT-Heating transmitting in ordinary mode at 4.04 MHz at an effective radiated power of 125 MW [Brändström et al., 1999]. The emissions were observed simultaneously at 630 nm by up to three stations of the Auroral Large Imaging System (ALIS) in the Kiruna area. The optical emissions occurred along with large increases in the electron temperature up to approximately 3500 K, which corresponds to an enhancement of 250% of the unperturbed temperature of about 1000 K, as determined with the EISCAT-UHF radar [Leyser et al., 2000]. The temperature enhancement extended several tens of kilometres below and up to 600 km altitude above, which was several hundred kilometres above the pump reflection height of approximately 250 km. Figure 5 shows a volume rendering of the temporal evolution of the stimulated optical emission region above EISCAT during a single HF pump pulse of 4-min duration. The bottom plane of the figure shows a map of the Tromsø/Kiruna region [Gustavsson et al., 2001].

Figure 5: Volume rendering of the stimulated optical emission region above EISCAT Tromsø.

HF-induced airglow at 630 nm was also observed by the Digital All-sky Imager (DASI) to come from F-region altitudes above the EISCAT HF facility near Tromsø on February 21, 1999. Geomagnetic conditions were very quiet with $K_p = 1$, preceded by 9 hours of $K_p = 0^+$. DASI is an auroral TV imager which was located at Skibotn (69.35° N, 20.36° E), Norway, about 50 km from Heating. A patch of airglow started to appear ~10 s after HF turn-on, developing to a maximum peak intensity of about 100 Rayleighs above background within ~60 s. When the HF was switched off the airglow decayed within ~30 s. The artificial airglow was observed to come from a region equatorward of the HF beam's projection on the F-region reflection altitude, which was obtained from Dynasonde ionograms. From 16:48 to

18:16 UT the interaction height in the F region varied from about 210 to 290 km as the ionospheric electron density declined after sunset. During the entire recording interval there was no detectable auroral precipitation. Generally, the optical intensity maximum occurred near the Spitze or magnetic dip angles. The equatorward displacement is a unique feature of these observations and is unexpected for both mechanisms.

Figure 6 shows artificial 630-nm airglow data from February 21, 1999. Each panel shows the last 10 sec integration image of an HF on cycle. The field of view is in the zenith above Skibotn with north and east to the top and right, respectively. The images are background subtracted and calibrated into absolute Rayleighs at 630 nm. The start time of each integration is overlaid in the images. The circle is the real-height mapping of the modelled HF beam at the -3 dB level. Assuming no refraction, the effective beam diameter corresponds to ~15°. The crosses inside and outside the circle corresponds to the Spitze angle (6°) and the magnetic field line through the HF facility (12.8°), respectively. There is one notable example of a double patch at 18:03:50 UT.

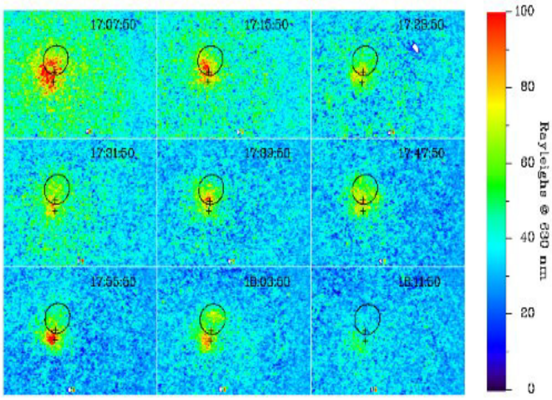


Figure 6: Artificial 630-nm airglow from February 21, 1999.

Interplanetary scintillations

Co-ordinated observations from coronal imagers, interplanetary scintillation (IPS) measurements from EISCAT and in-situ data have been used to study the evolution of the solar wind with increasing distance from the sun [Breen et al., 2000b; Bromage et al., 2000; Breen et al., 2000d; Breen et al., 2002a]. Intensive programmes of measurements were carried out using the SOHO LASCO instrument, EISCAT, WIND, and Ulysses during the second Ulysses orbit. These have revealed significant changes in the longitudinal structure of the solar wind between 25-60 solar radii (IPS measurements) and 1.0-4.5 AU (215-960 solar radii) (the orbits of the spacecraft). Velocities measured by IPS were generally consistent with those seen in-situ, except in cases when large longitudinal gradients in solar wind speed were seen in the in-situ data. In these cases the IPS results suggested that solar wind velocities varied much more near the Sun than they did at the spacecraft [Breen et al., 2002c]. The degree of "self-smoothing" in solar wind velocity increased with distance from the Sun. Velocities seen at 4.5 AU (960 solar radii) by Ulysses were much more uniform than those seen by WIND at 1 AU (215 solar radii). These were in turn less variable than those seen at 25-65 solar radii by EISCAT. The underlying mechanism is proposed to be stream-stream interaction between narrow regions of solar wind with different velocities. It is suggested that this is an important process in converting the highly non-uniform slow wind observed in the corona into the less variable flow seen at 1 AU and beyond.

Figure 7 shows Ulysses in-situ speed measurements (circles) and EISCAT IPS speeds (triangles) from within ±10° of the latitude of Ulysses during its fast equatorial scan in Carrington rotation 1976 (May 2001), mapped to a uniform heliocentric distance of 30 R using either a ballistic projection for EISCAT results and a MHD mapping for Ulysses and plotted as speed vs. Carrington longitude. The large vertical bars in the EISCAT data points represent an upper bound on the variation in solar wind speed across the width of the stream observed and are not estimates of statistical error [Breen et al., 2002c].

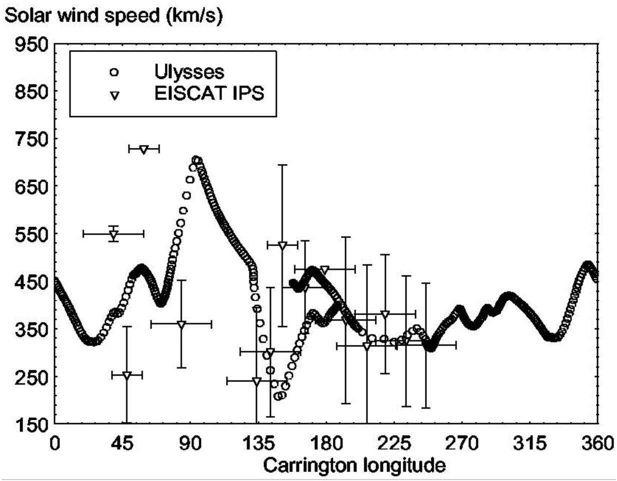


Figure 7: Ulysses (circles) and EISCAT (triangles) measurements of solar wind speed.

EISCAT studies of flux transfer events

Observations by the EISCAT VHF radar, taken on November 23, 1999, have offered a new insight into the signatures of flux transfer event (FTE) activity observed by HF coherent scatter radars. Davies et al. [2002] present EISCAT CP-4 observations of a series of poleward-propagating F–region plasma density enhancements, which, the authors concluded, were fossil signatures of transient reconnection, having been formed by structuring of the ionosphere in the cusp region in response to processes associated with FTEs. Poleward-moving radar auroral forms (PMRAFs) were observed at the same time by the CUTLASS HF coherent scatter radar at Hankasalmi in Finland.

Figure 8 demonstrates pictorially the simultaneous occurrence of transients in electron density and HF backscatter power, using data from azimuthally-aligned beams from the two radar systems. Interpreting the HF observations with reference to the plasma parameters diagnosed by the incoherent scatter radar led the authors to suggest that the field-aligned irregularities within the PMRAFs are generated by the gradient-drift mechanism due to the presence of structure in the electron density. The figure is a composite plot showing backscattered power from beam 7 of the CUTLASS radar at Hankasalmi and electron density from beam 1 of the EISCAT VHF radar, as a function of magnetic latitude between 0645 and 0945 UT on November 23, 1999. Data below 77º are from the VHF radar and those above 77º from the HF radar.

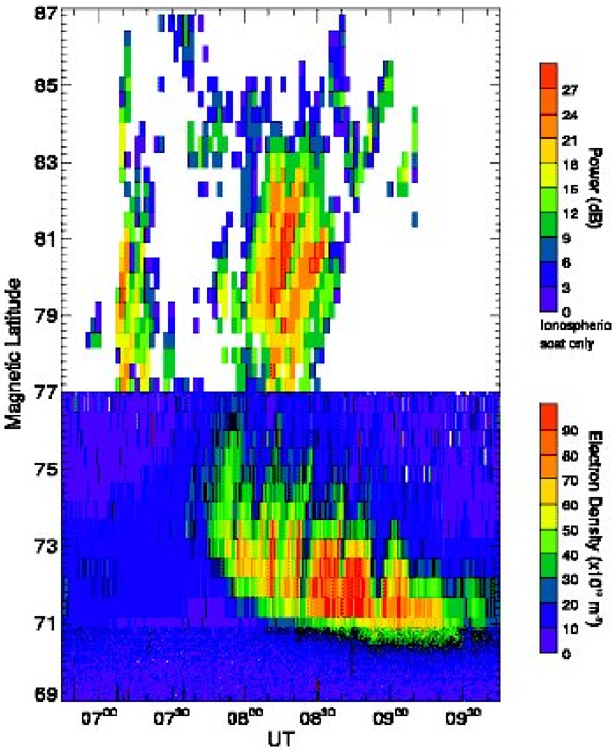


Figure 8: Composite latitudinal plot of poleward-moving radar auroral forms (PMRAFs) observed simultaneously by the EISCAT VHF incoherent scatter radar in Tromsø, Norway (69-77º) and the CUTLASS HF coherent scatter radar at Hankasalmi, Finland (77-87º).

ESR mapping of polar-cap patches

In January 2001, December 2001, and February 2002 campaigns were carried out with the EISCAT Svalbard Radar (ESR) to study patches in the polar-cap ionosphere. Patches are 100-1000 km wide islands of high density F-region plasma surrounded by significantly lower density plasma. They dominate the character of the polar cap ionosphere about half of the time, whenever the interplanetary magnetic field has a southward component. Patches move anti-sunward across the polar cap at velocities ~1 km/s from near noon toward the midnight sector and are highly structured over scale sizes of 0.1 to tens of km, giving severe scintillation effects on satellite communication and GPS navigation signals. The goal of the observations was to record the full thermal plasma properties of an ionospheric patch in full darkness in the noon region where patches are believed to form. In order to provide unambiguous information on patch location and motion, and to discriminate between competing theories, measurements of plasma density, ion velocity, and electron and ion temperatures were all required on a time scale of about 8 to10 minutes. To accomplish this, a new fast azimuth and elevation scanning modes were implemented on the ESR antenna.

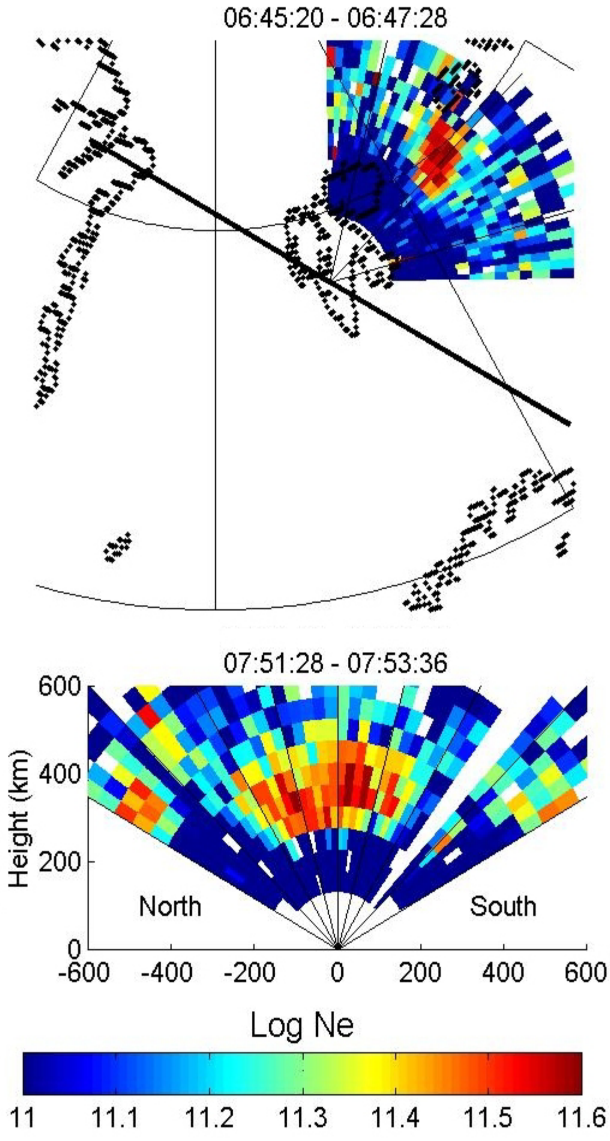


Figure 9: EISCAT Svalbard Radar observations on January 20, 2001 of an ionospheric plasma density patch east of Svalbard (top) and another patch directly above the radar site (bottom)...

An example of an azimuth scan is shown in the upper part of Figure 9, where a distinct plasma density patch is observed east of Svalbard. An example of an elevation scan with a plasma density patch above the radar site is shown in the lower part of Figure 9.

In the elevation scan mode the antenna moves along the magnetic meridian at a fixed azimuth angle of -45°. For

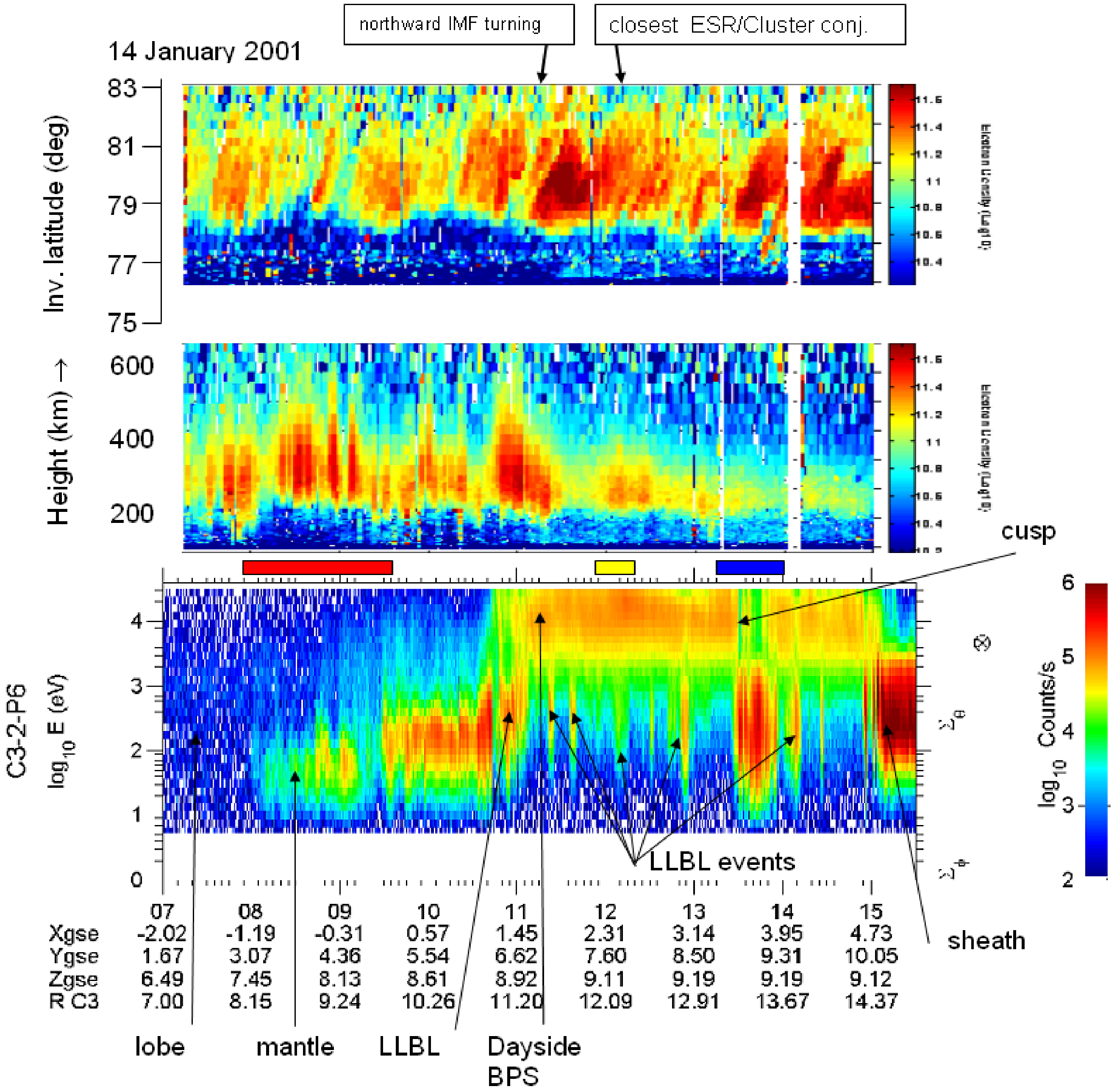


Figure 10: Simultaneous observations of electron density by the EISCAT Svalbard Radar steerable antenna (top) and fixed antenna (middle panel) taken on January 14, 2001. The lower panel shows ion measurements made at the same time by one of the Cluster spacecraft as it moved from the lobe into the magnetosheath.

both scan modes the windshield-wiper motion is repeated every 128 seconds, and data is sampled every 3.2 seconds at a range resolution of 50 km. These modes give accurate identification of boundaries between neighbouring plasma populations and provide plasma properties with sufficient accuracy to discriminate between plasma processes.

The new measurement mode passes the threshold of 2- to 3-minute image frame-rate, specifying thermal plasma properties across mesoscale areas and opens the door to testing for ionospheric transient events on time scales of the order of one to ten minutes and studying their significance for global ionospheric convection

Coordinated EISCAT and Cluster studies

The start of the science phase of the Cluster mission marked a very important point in the development of EISCAT since, as well as being the spur for the mainland renovation, this mission was one of the original drivers for the development of the EISCAT Svalbard Radar. Data from the ESR have played a key role in the first tranche of Cluster ground-based papers, which have recently appeared in a special issue of Annales Geophysicae. Figure 10 shows ESR and Cluster measurements made on January 14, 2001. Between 0800 and 0930 UT the four Cluster spacecraft were moving from the central magnetospheric lobe, through the dusk sector mantle, on their way towards intersecting the magnetopause near 1500 MLT and 1500 UT.

Throughout the interval, the EISCAT Svalbard Radar observed a series of poleward-moving transient events of enhanced F-region plasma concentration ("polar cap patches"), with a repetition period of the order of 10 minutes.

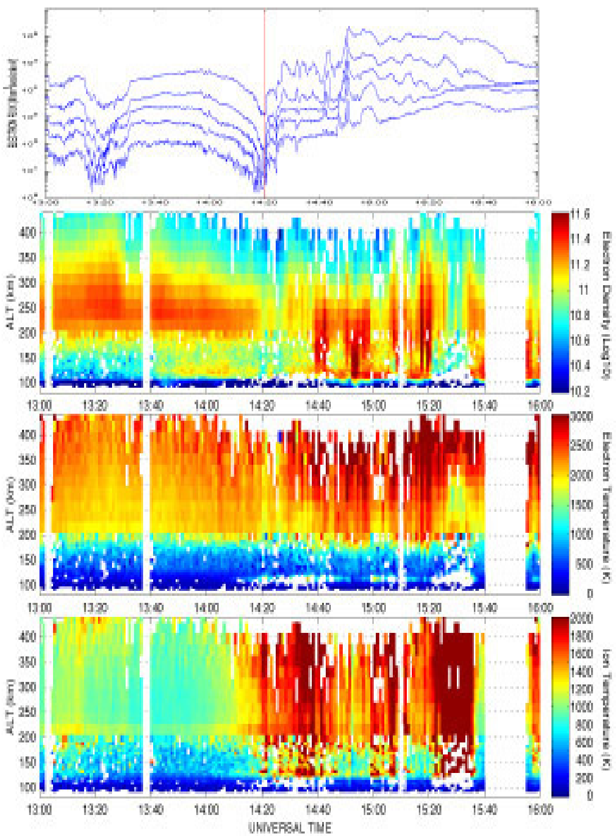


Figure 11: Data from September 27, 1995. The top panel shows electron flux measured by LANL 1994-084, with the vertical line indicating substorm onset. The following panels show electron density and electron and ion temperatures measured by the EISCAT UHF radar (field-aligned, cp1k mode).

Allowing for the estimated solar wind propagation delay of 75 (±5) minutes, the interplanetary magnetic field (IMF) had a southward component during most of the interval. The magnetic footprint of the Cluster spacecraft, mapped to the ionosphere using the Tsyganenko T96 model (with input conditions prevailing during this event), was located to the east of the ESR beams [Lockwood et al. [2001a].

On the same day, the four Cluster spacecraft passed through the northern magnetospheric mantle in close conjunction to the ESR and approached the post-noon dayside magnetopause over Greenland between 1300 and 1400 UT. During that interval, a sudden reorganisation of the high-latitude dayside convection pattern occurred after 1320 UT, most likely caused by a direction change of the solar wind magnetic field [Opgenoorth et al., 2001].. The global ground-based data proved to be an invaluable tool to monitor the dynamics and width of the affected magnetospheric regions.

Storms and substorms

Figure 11 shows the onset of a substorm over Russia, with EISCAT in the dusk sector (about 16 MLT), on September 27, 1995. This study pursued a global ionospheric measurement of electrojet reactions to substorm onset, with the dawn and dusk electrojets monitored by magnetometers and ionospheric radars. Enhancements of both electrojets were visible at magnetometer stations over a longitudinally and latitudinally extended area, indicating a large-scale magnetospheric response to substorm onset. Onset was determined by a geostationary satellite, LANL 1994-084, located over Russia at 105 degrees east longitude. The energetic particle injection at substorm onset is marked in the top panel. Substorm onset is here defined by the appearance of the night-side-located substorm electrojet and energetic particle injections at geostationary orbit. The three lower panels show electron density and electron and ion temperatures up to 450 km altitude, measured by EISCAT UHF radar. At the time of onset (14:20 UT) the ion temperature increases, indicating an enhanced electric field. Particle precipitation, resulting in enhanced conductivity, is evident in the data at 14:39 UT, i.e., roughly 20 minutes after substorm onset. Also, the electron temperature gives an indication that particle precipitation is delayed and not involved at onset, since there is no clear increased electron temperature at E-region onset.

Onset reactions in the electrojet at longitudes far separated from magnetic midnight can thus be responses to an imposed electric field, rather than to conductivity increases which are delayed up to 20 minutes. The results indicate a very short time delay, on the scale of a few minutes, between onset at local midnight and reactions at dawn and dusk [Borälv et al., 2000].

Tides and planetary waves

One of the most unexpected results to arise from the EISCAT Svalbard Radar has been the discovery that strong tidal or quasi-tidal modes are present in the ionosphere above Svalbard with periods of 24, 12, and 8 hours. Classical theory, based on Hough modes, suggests that tides so close to the North Pole should be extremely weak, so that the results reported by van Eyken et al. [2000] appear extremely puzzling. These authors showed that semi-diurnal oscillations with amplitudes as large as 50 ms-1 could be observed. Weaker diurnal and ter-diurnal modes were also seen. Both the semi-diurnal and ter-diurnal modes displayed the consistent phase progression with height expected from tidal modes. At the lowest heights, around 93 km, there was evidence of a 2.5 day planetary wave, together with other oscillations which could have arisen from non-linear interactions between tides and planetary waves. In order to confirm these conclusions, a number of long ESR observations have been undertaken in the last two years – the longest was a 15-day continuous Common Programme in February 2001, the results of which are presently under investigation. Figure 12 shows Lomb-Scargle periodograms of the field-aligned velocity observed with the ESR on August 12-14, 1998 at 110 km altitude (upper panel) and at 92 km (lower panel).

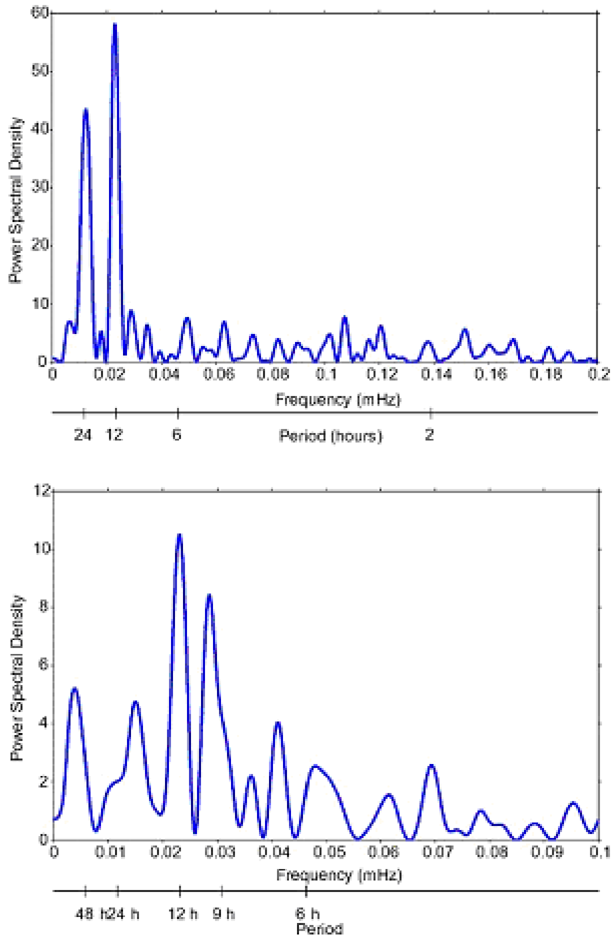


Figure 12: Lomb-Scargle periodograms of the field-aligned velocity observed with the ESR.

Substorm-related changes in precipitation

A case study of varying precipitation in the morning sector, and across noon, during an active period on February 11, 1997 was made using the EISCAT UHF radar and the imaging riometer (IRIS) at Kilpisjärvi. Data from a chain of wide beam riometers and two pulsation magnetometers were also used, in conjunction with satellite and HF radar measurements. Night side observations were provided by the CANOPUS array of instruments (including a meridian scanning photometer, magnetometers and riometers). These observations were compared to lagged solar wind pressure and IMF B_y observations by GEOTAIL.

Figure 13 shows EISCAT, IRIS, and pulsation magnetometer data compared to lagged solar wind pressure and IMF B_y observations by GEOTAIL. The precipitation appears to be controlled by changes in scattering and diffusion caused by variations in solar wind pressure and direction. Precipitating electrons at EISCAT were linked to substorm injection and subsequent gradient-curvature drift. A controlling influence from the solar wind has been identified in the

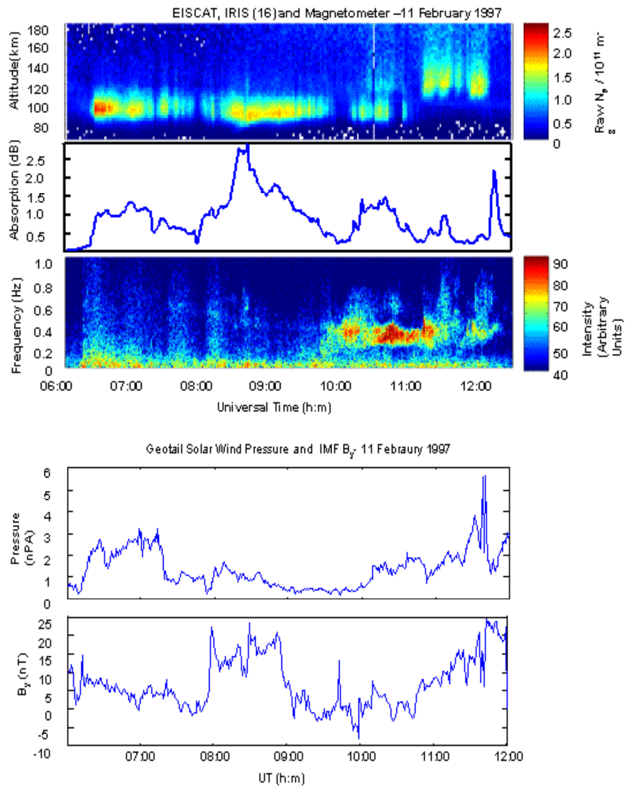


Figure 13: EISCAT, IRIS, and pulsation magnetometer data from February 11, 1997 compared to lagged solar wind pressure and IMF B_y observations by GEOTAIL.

form of small-scale pressure changes at the magnetopause, leading to increases in pitch angle scattering in an already unstable energetic population of electrons. The time separation of absorption increases across the IRIS field of view has provided an estimate of the characteristic energy of precipitation. This is due to a lag in the drift time of particles on lower L shells. Observations of electron density from EISCAT verified that the estimate is reasonable in supporting the gradient-curvature drift theory.

Numerical studies of small-scale auroral arcs

The optical detection of auroral sub-arcs a few tens of meters in width as well as the direct observation of shears several m/s per m over km to sub km scales by rocket instrumentation both indicate that violent and highly localised electrodynamics can occur at times in the auroral ionosphere over scales 100 m or less in width. These observations as well as the detection of unstable ion-acoustic waves observed by incoherent radars along the geomagnetic field lines has motivated the development of a detailed two-dimensional model of short-scale auroral electrodynamics that uses current continuity, Ohm's law, and 8-moment transport equations for the ions and electrons in the presence of large ambient electric fields and of auroral arcs with sharp edges.

Figure 14 illustrates the essential elements of this new model, showing the results of a sample run in which the ambient electric field is 100 mV/m away from the arc and electron precipitation cuts off over a region 100 m wide. The run demonstrates that parallel current densities of the order of several hundred μA m^{-2} can be triggered in these circumstances, together with shears several ms^{-1} per m in magnitude and parallel electric fields of the order of 0.1 mVm^{-1} around 130 km altitude. It also illustrates that local ionospheric properties such as densities, temperatures, and composition can be strongly affected by the violent localised electrodynamics.

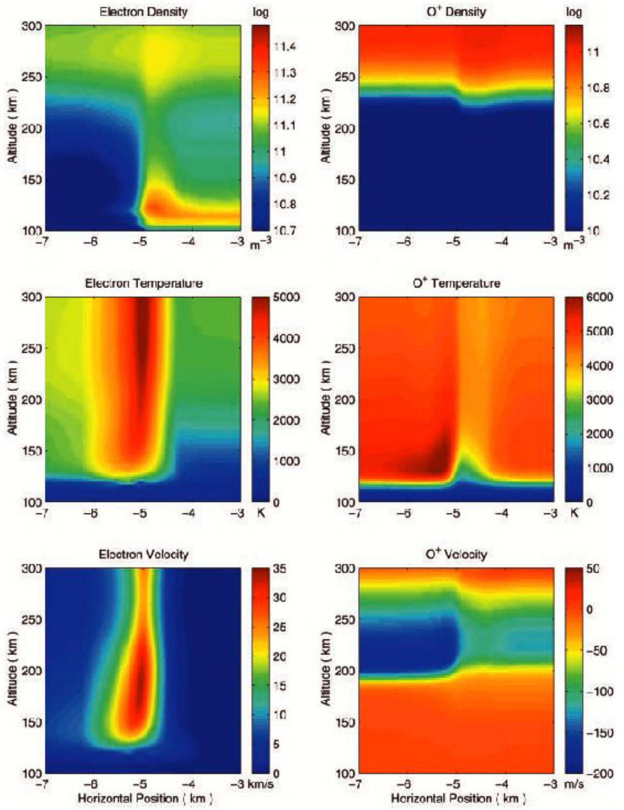


Figure 14: Results of the self-consistent coupling of the TRANSCAR ionosphere fluid model with the ELECTRO electrodynamic model. From top to bottom, n_e and n_{O+}, T_e and T_{O+}, $v_{e||}$ and $v_{O+||}$.

Combined optical and radar measurements

During an optical/radar campaign in December 1994, there were several nights when the dominant auroral signatures were the result of both pulsating arcs and the passage of dark patches and lanes within diffuse aurora, often known as “black aurora”. Figure 15 shows an example with data obtained with a very narrow angle camera from the Max Planck Institute which images 9 km x 13 km at auroral heights in the field-aligned direction. Changes in electron density during the passage of these dark lanes are also shown. Without the benefit of optical data, the signatures could be interpreted as pulsating aurora; the camera showed, however, that spatial features moving through the radar beam caused the variations. The arrow links the time of the image to the radar measurement.

The relationship between electron density and the optical signature is dependent on the recombination rate and is not instantaneous. Modelling of the density profiles has shown that the energy flux varied between 5 and 15 mW m^{-2} with a sinusoidal time variation. The energy spectra of the particles causing these features were a combination of Maxwellians throughout, with a distinct mono-energetic component superimposed. The peak energy of this component varied between 5 and 10 keV, slightly out of phase with the flux variations. The profiles at heights around 120 to 130 km appeared to be affected by horizontal electric fields during the times of low energy flux. Work is ongoing to identify whether field-aligned currents can be detected in the dark regions through changes in the temperatures.

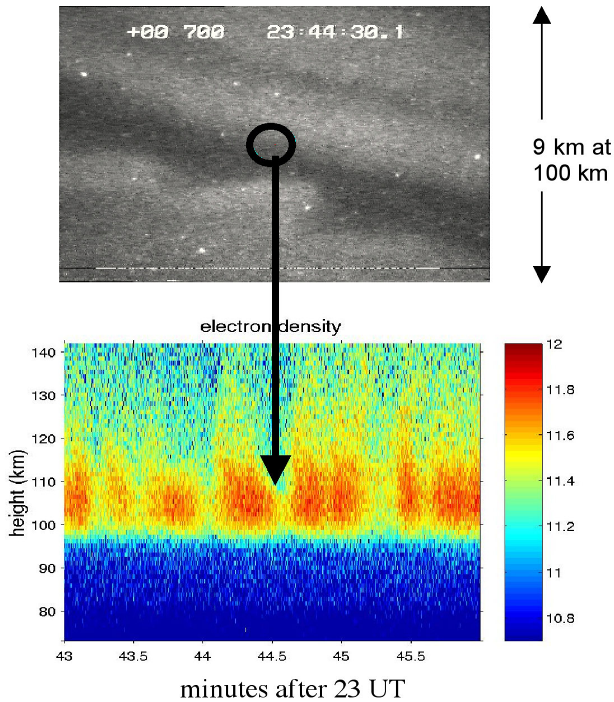


Figure 15: Optical and radar data from an interval in December 1994 showing that the apparent temporal variations in the electron precipitation in fact arise from a series of spatial features moving through the observing volume

Naturally-enhanced ion-acoustic spectra

Figure 16 shows naturally-enhanced ion-acoustic spectra from the EISCAT Svalbard Radar and a simultaneous narrow-angle auroral image with a 16 x 12-degree field of view and a resolution better than 100 m.

Enhanced ion-acoustic spectra are most likely due to either streaming plasma instabilities, due to field-aligned currents of order 1 mA m^{-2} or to Langmuir turbulence. Such spectra occur typically as transient events and are correlated with discrete and dynamic auroral structures. The dashed circle in the auroral image represents the position and size of the radar beam.

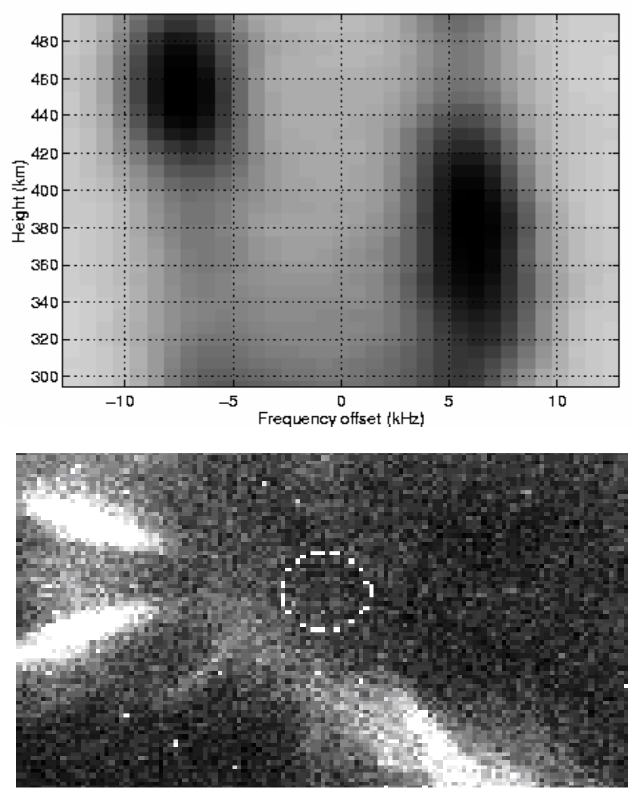


Figure 16: Naturally-enhanced ion-acoustic spectra observed by the EISCAT Svalbard Radar (top panel), and a simultaneous narrow-angle auroral image (bottom panel).

Coherent radar echoes within an auroral arc

In November 1999 the EISCAT 224 MHz radar was used to obtain measurements of incoherent scatter ion and plasma lines. During these observations unusual F-region echoes were seen in both the ion and plasma line channels. The echoes coincide with the passage of an auroral arc through the radar beam. These echoes are the first plasma line signals seen from natural coherent echoes, which have been the subject of much study.

Figure 17 shows VHF backscatter power profiles of auroral-arc-related coherent echoes as a function of height and time seen on November 11, 1999. The upper panel shows the up-shifted plasma line (UPL), the middle panel shows the downshifted plasma line (DPL), and the bottom panel shows the ion line. The plasma lines are offset by ±5.03 MHz from the radar frequency, respectively. All three channels have a linear ±25-kHz bandwidth. The echoes from near 300 km between 18:18 and 18:24 UT are those associated with the auroral arc.

Also seen in Figure 17 are artificially-enhanced echoes from the E and F regions showing 1 minute on-off HF-induced modulation. Artificially-enhanced spectra of E-region plasma waves were measured for the first time at auroral latitudes during this period with both the VHF and the UHF radars. During periods with suitable peak E-region electron density, Z-mode propagation of the HF pump wave to the topside E-region occurred, and topside instability-enhanced plasma waves were observed.

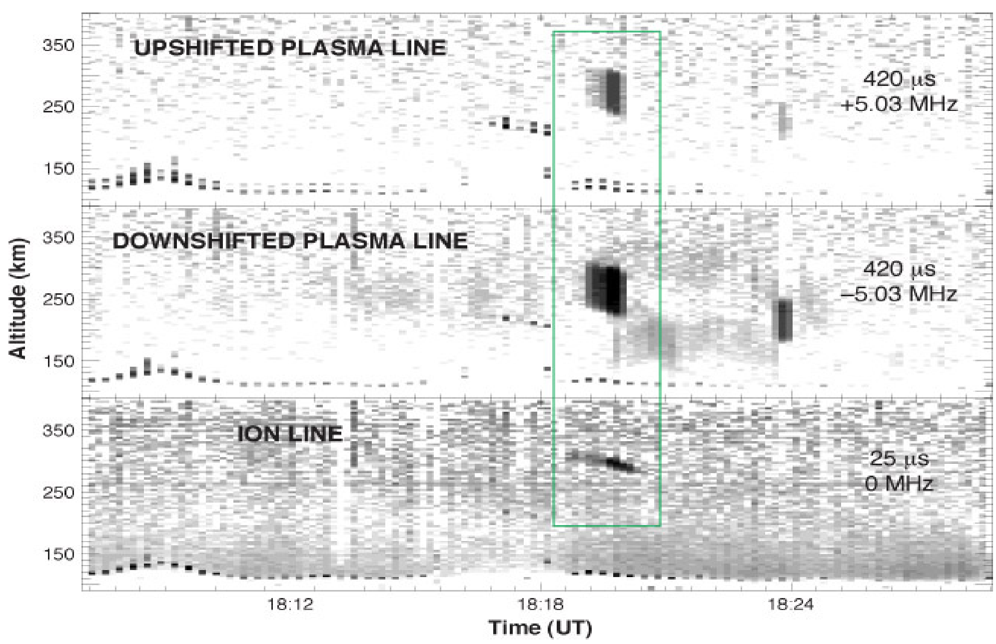


Figure 17: Backscatter intensity in three VHF power profile channels on November 11, 1999. The top, middle, and bottom panels show up- and down-shifted plasma lines and the ion line, respectively. Auroral enhancements are seen at about 18:20 UT (green rectangle) and at 18:24 UT. HF E-region enhancements are seen below 150 km. HF F-region enhancements are seen near 18:17 UT

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EISCAT Reports and Meetings

Reports 1998 - 2001:

EISCAT Annual Report 1996/1997
Brochure

Meetings 1998:

COUNCIL	50th meeting, 11/12 May	Burnham, U.K.
	51st meeting, 16/17 Nov.	Paris, France
SAC	54th meeting, 16/17 April	Copenhagen,
Denmark		
	55th meeting, 15/16 October	Lund, Sweden
AFC	50th meeting, 23/24April	Copenhagen,
Denmark		
	51st meeting, 8/9 October	Paris, France

Meetings 1999:

COUNCIL	52nd meeting, 10/11 May	Sigtuna, Sweden
	53rd meeting, 15/16 Nov.	Tokyo, Japan
SAC	56th meeting, 22/23 March	Berlin, Germany
	57th meeting, 10/11 Sept.	Lindau, Germany
AFC	52nd meeting, 9 April	Tromsø, Norway
	53rd meeting, 7/8 October	Copenhagen,
Denmark		

Meetings 2000:

COUNCIL	54th meeting, 15/16 May	Longyearbyen, Norway
	55th meeting, 30/31 October	Munich, Germany
SAC	58th meeting, 30/31 March	Longyearbyen, Norway
	59th meeting, 20/21 Sept.	Abingdon, U.K.
AFC	54th meeting, 10 April	Uppsala, Sweden
	55th meeting, 11 October	London, U.K.

Meetings 2001:

COUNCIL	56th meeting, 15/16 May	Helsinki, Finland
	57th meeting, 8/9 November	Knivsta, Sweden
SAC	60th meeting, 23/24 March	Grenoble, France
	61st meeting, 13/14 Sept.	Tromsø, Norway
AFC	56th meeting, 19 April	Copenhagen, Denmark
	57th meeting, 11 October	Longyearbyen, Norway

EISCAT Scientific Association

Balance Sheet 1998

As at 31.12.98

Values in SEK

Assets

	Book Value 31.12.97	Additions	Disposal	Depreciation	Book Value 31.12.98
Fixed Assets					
Computers	3 792 561	698 216	-1 038 190	37 687	3 490 275
Vehicles	1 141 547	265 242	-220 560	-168 403	1 017 826
Office & Workshop	1 019 951	97 318	-147 064	-244 819	725 386
Instrumentation	1 060 236	246 880	-23 353	-417 454	866 309
ESR Transmitter	29 031 863	1 170 582		-3 086 405	27 116 040
ESR Antenna	38 372 249	11 024 412		-4 354 890	45 041 770
ESR Site Building	23 561 673	68 315		-2 611 626	21 018 362
ESR Testhall	125 774			-17 968	107 806
ESR Receiver	715 023	332 092		-82 215	964 899
ESR Data Acquisition	3 902 597			-1 026 649	2 875 948
ESR Controller	338 118			-37 194	300 924
ESR Peripheral	173 858			-19 317	154 541
ESR Housing	1 593 553			-207 288	1 386 265
KST Buildings	7 406 586			-351 418	7 055 168
KST Tenancy	137 304		-5 927	-2 663	128 714
KST VSQ	150 636			-28 302	122 334
KST Transmitter	16 322 029			-2 005 647	14 316 382
KST UHF Antenna	1 538 675			-1 318 871	219 804
KST VHF Antenna	3 596 521			-1 541 362	2 055 159
KST Receivers	53 225	1 055 897		-14 123	1 094 999
KST Time & Frequency	127 606			-14 178	113 428
	134 161 586	14 958 952	-1 435 094	-17 513 105	130 172 339

	Book Value 31.12.97	Book Value 31.12.98
Current Assets		
Prepayments and accrued inc.	528 971	164 010
Petty Cash	2 464	4 146
Debtors:		
Value added tax	348 214	277 833
Others	67 134	400
Associate contribution	2 061 464	
Banks:		
Ordinary Accounts	60 934 475	57 799 460
	63 942 721	58 245 848
Total Assets	198 104 307	188 418 187

Capital and Liabilities

Capital		1997	1998
Funds invested			
Pool		94 298 256	94 298 256
UHF Spare Klystron		3 019 411	3 019 411
Capital Operating		29 342 771	30 271 229
In Kind		25 123 200	25 123 200
Other		421 160	421 160
Heating		2 289 000	2 289 000
ESR		110 689 416	123 284 816
	(gross)	265 183 215	278 707 073
Depreciation		-131 021 629	-148 534 734
	(net)	134 161 586	130 172 339
Funds held on reserve			
Evolutionary Development func		50 349 953	39 067 339
Spare parts reserve		755 556	559 609
Capital Operating reserve		3 635 385	4 436 769
Surplus Fund		3 588 496	8 452 721
		58 329 390	52 516 438
Total Capital		192 490 976	182 688 777

Liabilities	1997	1998
Creditors	5 395 332	5 527 410
Provisions	218 000	202 000
	5 613 332	5 729 410
Total Capital and Liabilities	198 104 307	188 418 187

Recurrent Operation 1998

	Outcome	*Budget*
Income		
Associate contributions	28 877 170	*28 877 500*
Other income	995 725	*350 500*
	29 872 895	*29 228 000*
Expenditure		
Personnel	-13 615 456	*-15 503 000*
Administration	-5 893 646	*-7 528 000*
Operation	-5 695 515	*-6 197 000*
Total	-25 204 618	*-29 228 000*
Year-end transactions	-4 668 278	*0*
Result	0	*0*

EISCAT Scientific Association

Balance Sheet 1999

As at 31.12.99

Values in SEK

Assets

	Book Value 31.12.98	Additions	Disposal	Depreciation	Book Value 31.12.99
Fixed Assets					
Computers	3 490 275	2 604 244	-6 928 481	5 616 429	4 782 467
Vehicles	1 017 826	638 767	-166 924	-196 954	1 292 715
Office & Workshop	725 386	222 908	-74 779	-255 407	618 108
Instrumentation	866 309	389 902	-54 282	-301 588	900 341
ESR Transmitter	27 116 040			-3 193 710	23 922 332
ESR Antenna	45 041 770	25 800 228		-6 805 313	64 036 685
ESR Site Building	21 018 362			-2 617 887	18 400 476
ESR Testhall	107 806			-17 967	89 839
ESR Receiver	964 899	69 362		-117 996	916 265
ESR Data Acquisition	2 875 948			-966 504	1 909 444
ESR Controller	300 924			-37 192	263 732
ESR Peripheral	154 541			-19 318	135 222
ESR Housing	1 386 265			-207 316	1 178 950
KST Buildings	7 055 168			-351 421	6 703 747
KST Tenancy	128 714			-2 781	125 933
KST VSQ	122 334			-28 302	94 032
KST Transmitter	14 316 382	254 935		-2 005 639	12 565 678
KST UHF Antenna	219 804			-219 803	
KST VHF Antenna	2 055 159			-1 541 361	513 798
KST Receivers	1 094 999	1 990 548		-207 644	2 877 903
KST Time & Frequency	113 428	54 726		-17 372	150 782
	130 172 339	32 025 623	-7 224 466	-13 495 046	141 478 449

	Book Value 31.12.98	Book Value 31.12.99
Current Assets		
Prepayments and accrued inc.	164 010	487 223
Petty Cash	4 146	2 000
Debtors:		
Value added tax	277 833	446 854
Others	400	
Banks:		
Ordinary Accounts	57 799 460	38 176 402
	58 245 848	39 112 479
Total Assets	188 418 187	180 590 928

Capital and Liabilities

Capital

	1998	1999
Funds invested		
Pool	94 298 256	94 298 256
UHF Spare Klystron	3 019 411	3 019 411
Capital Operating	30 271 229	29 202 804
In Kind	25 123 200	25 123 200
Other	421 160	421 160
Heating	2 289 000	2 289 000
ESR	123 284 816	149 154 399
(gross)	278 707 073	303 508 229
Depreciation	-148 534 734	-162 029 780
(net)	130 172 339	141 478 449
Funds held on reserve		
Evolutionary Development fund	39 067 339	13 577 434
Spare parts reserve	559 609	674 472
Capital Operating reserve	4 436 769	974 365
Surplus Fund	8 452 721	10 044 398
	52 516 438	25 270 669
Total Capital	182 688 777	166 749 119

Liabilities

	1998	1999
Creditors	5 527 410	13 458 174
Provisions	202 000	383 635
	5 729 410	13 841 809
Total Capital and Liabilities	188 418 187	180 590 928

Recurrent Operation 1999

	Outcome	*Budget*
Income a)		
Associate contributions	27 209 945	*27 210 000*
Other income	231 322	*350 000*
Surplus Fund transfer	811 532	*812 000*
	28 252 799	*28 372 000*
Expenditure		
Operation	-5 204 240	*-6 100 500*
Administration	-5 320 318	*-5 786 500*
Personnel	-15 210 156	*-16 485 000*
Total	-25 734 713	*-28 372 000*
Year-end transactions	-2 518 086	*0*
Result	0	*0*

a) The presentation of the Recurrent Chapter in the Accounts was partially changed in 1999.

EISCAT Scientific Association

Balance Sheet 2000

As at 31.12.2000

Values in SEK

Assets

	Book Value 31.12.1999	Additions	Disposal	Depreciation	Book Value 31.12.2000
Fixed Assets					
Computers	4 782 467	789 483		-1 165 525	4 406 425
Vehicles	1 292 715	441 379	-143 200	-327 696	1 263 198
Office & Workshop	618 108	296 550		-285 922	628 736
Instrumentation	900 341	758 489		-379 505	1 279 325
ESR Transmitter	23 922 332	1 384 751		-3 251 088	22 055 995
ESR Antenna	64 036 685			-7 943 516	56 093 169
ESR Site Building	18 400 476			-2 617 889	15 782 587
ESR Testhall	89 839			-17 968	71 871
ESR Receiver	916 265	46 719		-123 594	839 390
ESR Data Acquisition	1 909 444			-363 558	1 545 886
ESR Controller	263 732			-37 193	226 539
ESR Peripheral	135 222			-19 317	115 905
ESR Housing	1 178 950			-207 287	971 663
KST Buildings	6 703 747			-550 241	6 153 506
KST Tenancy	125 933			-2 782	123 151
KST VSQ	94 032			-28 301	65 731
KST Transmitter	12 565 678	5 803 101		-2 176 990	16 191 789
KST UHF Antenna					
KST VHF Antenna	513 798			-513 798	
KST Receivers	2 877 903	263 662		-328 835	2 812 730
KST Time & Frequency	150 782			-19 650	131 132
	141 478 449	9 784 133	-143 200	-20 360 655	130 758 728

	Book Value 31.12.1999	Book Value 31.12.2000
Current Assets		
Prepayments and accrued inc.	487 223	589 688
Petty Cash	2 000	2 000
Debtors:		
Value added tax	446 854	405 110
Others		2 558 555
Banks:		
Ordinary Accounts	38 176 402	24 673 883
	39 112 479	28 229 235
Total Assets	180 590 928	158 987 963

Capital and Liabilities

Capital

	1999	2000
Funds invested		
Pool	94 298 256	94 298 255
UHF Spare Klystron	3 019 411	3 019 411
Capital Operating	29 202 804	37 412 267
In Kind	25 123 200	25 123 200
Other	421 160	421 160
Heating	2 289 000	2 289 000
ESR	149 154 399	150 585 868
(gross)	303 508 229	313 149 162
Depreciation	-162 029 780	-182 390 435
(net)	141 478 449	130 758 728
Funds held on reserve		
Evolutionary Development func	13 577 434	5 679 061
Spare parts reserve	674 472	622 157
Capital Operating reserve	974 365	1 920 612
Equipment Repair fund	0	1 978 845
Surplus Fund	10 044 398	8 761 191
	25 270 669	18 961 865
Total Capital	166 749 119	149 720 593

Liabilities

Creditors	13 458 174	8 885 129
Provisions	383 635	382 241
	13 841 809	9 267 370
Total (Capital + Liabilities)	180 590 928	158 987 963

Recurrent Operation 2000

	Outcome	*Budget*
Income		
Associate contributions	26 974 689	*26 975 000*
Other income	1 984 240	*350 000*
Surplus Fund transfer	1 283 220	*1 283 000*
	30 242 149	*28 608 000*
Expenditure		
Operation	-6 734 205	*-5 378 000*
Administration	-5 266 516	*-5 567 000*
Personnel	-16 314 899	*-17 663 000*
Total	-28 315 620	*-28 608 000*
Year-end transactions	-1 926 529	*0*
Result	0	*0*

EISCAT Scientific Association
Registered as a Swedish non-profit organisation
Organisation number: 897300-2549

Annual report for the financial year 2001-01-01 – 2001-12-31

The EISCAT Council and the Director for the Association herewith submits the annual report for 2001.

ADMINISTRATION REPORT

Ownership, organisation and objective

The EISCAT Scientific Association was established in 1975 via an agreement between the Centre National de la Recherche Scientifique (France), Max-Planck-Gesellschaft (Germany), Vetenskapsrådet (Sweden), Norges forskningsråd (Norway), Particle Physics and Astronomy Research Council (United Kingdom) and Suomen Akatemia (Finland). In 1996, the National Institute of Polar Research (Japan) joined the Association. These organisations are called EISCAT Associates. The Association is seated in Kiruna, Sweden and is registered as a non-profit organisation.

The aim of the Association is to make significant progress in the understanding of physical processes in the high latitude atmosphere by means of experimental programmes, which may be carried out as part of wider international project. For this purpose, the Association have developed, constructed and is now operating radar facilities in high latitudes, comprising so far a system of stations at Tromsö (Norway), Kiruna (Sweden), Sodankylä (Finland), and Longyearbyen (Svalbard).

The Association is fully funded by the Associates. Depending on the available funding, scientific priorities and operational requirements are adjusted on an annual basis.

The Association is governed by the EISCAT Agreement, Statutes, Financial Rules and the Rules for the Management of Scientific Programmes.

The EISCAT Council is charged with the overall administration and supervision of the Association's activities. The Council consists of a Delegation of each Associate with a maximum of three members from each Associate. The Council have appointed a Director, who is responsible for the daily management of the facilities of the Association and their operation, sign negotiable instruments, cheques and contracts entered into in the Association's name, and execute the Council's decisions, subject to such rules as may be laid down by the Council. Both the Council and the Director are organs of the Association. To support the EISCAT Council, two regular committees exist, one to handle scientific aspects and one to handle administrative and finance matters. In addition, a Future Committee was established during the year. The Future Committee consists of a total of about 25 members (of these about 10 is part of the core Future Committee group) and the committee is charged with the task to advice the Council on the interest in, and the scientific merits of, the facilities the Association might provide after 2006.

The current Director is Dr. Tauno Turunen. His employment contract with the Council runs until December 31, 2002.

Operation and scientific development

The facilities were operating at normal or higher than normal measuring rate during the year 2001. In general, the users of the facilities started to make full use of the finalised technical renovation of the radar systems and several new experimental developments, which were introduced in 2001. The radars and the Tromsö heating system measured all together 4 433 hours in 2001. From these hours, 2 025 were measured using UHF – or the VHF-radar (from which 532 hours were overlapping) and 1 802 were measured using the Svalbard radar. The heating system measured 223 hours. All together 192 hours were used in passive experiments (interplanetary scintillation studies). This is an exceptionally high number of annual measuring hours. There are several reasons for this. For the first, there is a Council decision, which allows high number of hours if they are technically possible. Secondly, the technical renovation caused that the number of measuring hours was quite low in the year 2000 and to certain extent, this was reflected in the 2001 operations, but even more important is that the radar support for the CLUSTER satellite mission essentially increased the number of operating hours. This last point can be seen also in the way that from the radar measuring hours, 2 581 were so called "common mode program (CP) hours", which includes also the satellite operations, and only 1 246 hours were so called "special mode program (SP) hours" giving a CP/SP ratio of about 2:1 although normally this should be about 1:1. However, this high amount of operations is financially heavy and these high numbers of operating hours cannot be expected in the future operations.

Future operation and scientific development

In the year 2002, the technical situation of Kiruna-Sodankylä-Tromsø radar system (KST) is essentially ready. Some major improvements in the computing capabilities took place in the beginning of 2002. The remaining recognised weaknesses will be removed to the extent the solutions are found and the Association can afford them. The available experiments developed for the UHF- and VHF-radars during the past two years are already in the beginning of 2002 at a level, which certainly fully satisfies the great majority of users and no problems in routine data analysis exist. For improving the scientific capabilities of the Svalbard radar (ESR) some parts in the real time signal processing will be changed following essentially the solutions developed recently for the KST system. The original ESR-solution basing on available technology before mid 90´s has formed a bottleneck in the experimental development. Further development work is in these matters needed when new experiments become possible in ESR after the signal processing improvements.

Due to the long-term effects of inflation and the current poor exchange rate, the financial situation in 2003 may become challenging. Options are being developed to manage this situation and will be implemented if required. The Associates highest priority remains the running of the full facility at normal operational levels or higher. The outcome of the Future Committee will be used to target further investments in developing the facility.

The work of the Council and its committees

The Council held two meetings during 2001. The Administrative and Finance Committee had two meetings and the Scientific Advisory Committee had two meetings. The Future Committee had also two meetings.

The Council decided to take over the Sousy Svalbard Radar from January 1, 2002. A new Council Chairperson was elected at the spring meeting, Prof. Mike Lockwood. Also the Chairpersons of the Scientific Advisory Committee and the Administrative and Finance Committee changed during the year. The Future Committee chairperson is Prof. Hermann Opgenoorth.

Budget development during the year
The negative result this year was mainly caused by the weakening of the Swedish crown (SEK). The Association has facilities in Norway and Finland in addition to Sweden. Expenses in Norway are paid in the Norwegian currency and for Finland, Finnish mark / EURO is used. The Associates contributes to the Association in SEK. In addition to unfavourable exchange rates, some unexpected technical issues, mainly relating to the transmitter installation on Svalbard and the mainland UHF antennas caused unbudgeted costs.

The drop of the value of SEK resulted in a 7% cost increase. Temporary cost reduction measures were implemented but the technical issues removed most of the achieved cost reduction. Except for these issues, the year developed as planned.

The currency development was not expected at the time the budget was prepared and finally approved by Council in October 2000. The predicted improvement of the exchange rate situation towards the end of the year did not happen.

The financial five years plan
The financial situation during the coming years is partially dependent on the currency development. The decreased value of SEK during 2001 has caused a much higher spending rate than earlier anticipated. For 2002, own reserves are still available to finance the difference between expenses and available funding from the Associates.

The Associates find it difficult to increase the contributions to the Association and therefore, from 2003 and onwards, the five years plan is currently not balanced. A strengthened SEK will improve the situation but the main difficulty is the lack of sufficient funding from the Associates.

To handle the unbalanced five years plan, a cost reduction strategy has been prepared and will be incrementally implemented as required.

The result for 2001 and the deficit handling
The Association had a negative result for year 2001. The deficit amounts to 2 055 kSEK. The deficit is covered using own reserves.

PROFIT AND LOSS ACCOUNTS

in thousands of Swedish Crowns

	Note 1	***2001***	***2000***
Associate contributions	Note 2	29 489	29 489
Other operating income		203	32
		29 692	29 520
Operation costs		-7 475	-7 019
Administration costs		-6 084	-5 272
Personnel costs	Note 3	-19 142	-16 325
Depreciation of fixed assets		-22 458	-20 361
		-55 159	-48 977
Operating profit/loss		*-25 467*	*-19 457*
Interest income		722	712
Other financial income and cost		-6	1 241
Own reserves and funds	Note 4	238	-877
		954	1 075
Profit/loss after financial items		*-24 514*	*-18 382*
Appropriations	Note 5	2 055	-1 979
Transfer from funds invested	Note 6	22 458	20 361
		24 514	18 382
Net profit/loss for the year		*0*	*0*

BALANCE SHEET

in thousands of Swedish Crowns

		2001	2000
ASSETS			
Fixed assets			
Tangible fixed assets	Note 7		
Buildings		19 943	23 169
Radar systems		84 047	100 013
Equipment and tools		8 905	7 578
		112 895	130 759
Current assets			
Receivables		1 397	2 964
Prepayments and accrued income	Note 8	715	590
Cash at bank and in hand	Note 9	19 278	24 676
		21 390	28 229
Total assets		*134 285*	*158 988*
CAPITAL AND LIABILITIES			
Capital			
Funds invested	Note 10	112 895	130 759
Funds held on reserve	Note 11	12 121	18 962
		125 016	149 721
Liabilities			
Liabilities, trade		7 836	8 329
Provisions	Note 12	1 017	382
Other liabilities		416	556
		9 270	9 267
Total capital and liabilities		*134 285*	*158 988*
Pledged assets		*none*	*none*
Contingent liabilities		*none*	*none*

STATEMENT OF CASH FLOWS

in thousands of Swedish Crowns

	2001	***2000***
Operating activities		
Operating result before financial items	-25 467	-19 457
Transfer from funds invested	22 458	20 361
Interest received	945	1 331
Currency exchange rate changes	-55	101
Extra ordinary income and cost	49	1 140
Increase/decrease of receivables	1 566	-2 517
Increase/decrease of prepayments and accrued income	-125	-102
Increase/decrease of creditors and liabilities	2	-4 574
Cash flow from operations	*-627*	*-3 718*
Investment activities		
Investments in tangible assets	-4 771	-9 784
Cash flow from investment activities	*-4 771*	*-9 784*
Cash flow for the year	*-5 398*	*-13 503*
Liquid assets at the beginning of the year	*24 676*	*38 178*
Liquid assets at the end of the year	*19 278*	*24 676*

Note 1 *Accounting principles*
The accounting and valuation principles applied are consistent with the provisions of the Swedish Annual Accounts Act and generally accepted accounting principles (bokföringsnämnden allmänna råd och vägledningar).

All amounts are in thousands of Swedish kronor (SEK) unless otherwise stated.

Receivables
Receivables are stated at the amounts estimated to be received, based on individual assessment.

Receivables and payables in foreign currencies
Receivables and payables in foreign currencies are valued at the closing day rate. Where hedging measures have been used, such as forwarding contracts, the agreed exchange rate is applied. Gains and losses relating to operations are accounted for under other financial income and cost.

Bank accounts in foreign currencies
Bank balances in foreign currencies are valued at the closing day rate.

Fixed assets
Tangible and intangible fixed assets are stated at their original acquisition values after deduction of depreciation according to plan. Assets are depreciated systematically over the their estimated useful lives. The following periods of depreciation are applied.

The following depreciation rates are used: Buildings 10 - 50 years, Radar systems 3 - 20 years, Equipment and tools 3 - 5 years.

Note 2 *Associate contributions*
The Associates contributed to the operation during the year according to a fixed percentage.

		2001
CNRS (France)	23.25%	6 856
MPG (Germany	23.25%	6 856
NIPR (Japan)	7.00%	2 064
PPARC (United Kingdom)	23.25%	6 856
RCN (Norway)	9.30%	2 742
SA (Finland)	4.65%	1 371
SRC (Sweden)	9.30%	2 742
	100.00%	29 489

Accumulated contributions status as of 31.12.2001

	1976 - 2001
CNRS (France)	155 793
MPG (Germany	149 124
NIPR (Japan), 1996 -	52 242
PPARC (United Kingdom)	167 072
RCN (Norway)	102 613
SA (Finland)	41 295
SRC (Sweden)	77 715
	745 854

Note 3 *Personnel costs and average number of employees*
The Association employs directly the Headquarters staff, which includes the Director and deputies. The Headquarters is located in Kiruna, Sweden. The personnel working at the Kiruna (Sweden), Sodankylä (Finland), Svalbard and Tromsö (Norway) sites are not employed by the Association. Instead the personnel are provided via site contracts by the Swedish Institute of Space Physics (Kiruna site staff), Oulu University (Sodankylä staff) and Tromsö University (Tromsö and Svalbard staff). The Association refunds all expenses related to the provided staff, as well as an additional overhead.

	2001	*2000*
Personnel costs in total		
Salaries and emoluments paid to the Deputy Directors and the Director	2 346	2 097
Other personnel, employed and provided via site contracts	12 098	9 207
Social security contributions amounted to	3 700	4 193
of which for pension costs	1 319	2 315

Of the pension costs, 620 kSEK (1 280 kSEK) relates to the Deputy Directors and the Director. The Deputy Directors, the Director and all other directly employed staff are included in ITP based occupational pension plans. For the personnel provided via site contracts, the pension plans are handled by their respective employer.

The members of the board (EISCAT Council) and members of committees do not receive remunerations from the Association. Travel expenses in connection with Council and committee meetings are paid by the different Associates and then reimbursed from the Association, excluding the Japanese Associate who pay the travel cost for their own members.

Salaries and emoluments and average number of staff per country

Finland		
Salaries and emoluments	1 682	1 608
Average number of staff - men and women	4 + 1	4 + 1
Norway (including Svalbard)		
Salaries and emoluments	8 319	6 016
Average number of staff - men and women	17 + 2	15 + 2
Sweden		
Salaries and emoluments	4 442	3 680
Average number of staff - men and women	8 + 2	7 + 2

Note 4 *Own reserves and funds*

The following is the financing using of our own reserves and funds. The deficit for this year is also covered by using our own reserves (see note 5).

Capital Operating reserve		
Budgeted transfer to the reserve for capital operating use	-1 441	-2 514
Evolutionary Development fund		
Transfer from the fund to cover recurrent expenses relating to the evolutionary projects	323	301
Spare parts reserve		
Budgeted transfer to the reserve	-126	-136
Spare parts purchased	282	188
Surplus Fund		
Budgeted transfer	1 199	1 283
Sum own reserves and funds	*238*	*-877*

	2001	2000

Note 5 *Appropriations*
The outcome for this year became a deficit amounting to 2 055 kSEK. It is covered by funds from the surplus fund. The 2000 outcome was positive (1 979 kSEK) and the surplus was transferred to the equipment repair fund.

Note 6 *Transfer from funds invested*
The depreciation cost is covered by funds from Capital - funds invested.

Note 7 *Tangible fixed assets*
Changes in tangible fixed assets during 2001

	2001	***2000***
Buildings		
Opening acquisition value	41 367	41 367
Acquisitions during the year	0	0
Disposals during the the year	0	0
Closing acquisition value	41 367	41 367
Opening accumulated depreciation	-18 198	-14 774
Depreciations during the year	-3 226	-3 424
Closing accumulated depreciation	-21 424	-18 198
Closing residual value	19 943	23 169
Radar Systems		
Opening acquisition value	242 084	234 586
Acquisitions during the year	538	7 498
Disposals during the the year	0	0
Closing acquisition value	242 622	242 084
Opening accumulated depreciation	-142 071	-127 294
Depreciations during the year	-16 503	-14 778
Closing accumulated depreciation	-158 574	-142 071
Closing residual value	84 047	100 013
Equipment and tools		
Opening acquisition value	24 303	22 160
Acquisitions during the year	4 233	2 286
Disposals during the the year	-176	-143
Closing acquisition value	28 360	24 303
Opening accumulated depreciation	-16 725	-14 567
Depreciations during the year	-2 730	-2 159
Closing accumulated depreciation	-19 455	-16 725
Closing residual value	8 905	7 578
Sum tangible fixed assets	*112 895*	*130 759*

Note 8 *Prepayments and accrued income*

Prepaid rents	68	0
Other items	647	590
	715	590

	2001	2000
Note 9 *Bank balances status*		
Nordbanken (Sweden)	18 892	24 321
Sparebanken NOR (Norway)	384	353
Cash in hand	2	2
	19 278	24 676

Note 10 *Funds invested status*

	2001	2000
Pool	6 337	8 191
UHF Spare Klystron	125	1 942
Capital Operating	17 702	16 986
In Kind	4 189	4 375
Other	131	148
Heating	717	869
ESR	83 694	98 247
	112 895	130 759

Note 11 *Funds held on reserve*
The Evolutionary development fund interest for the year was 223 kSEK.

	2001	2000
Spare parts reserve	466	622
Capital operating reserve	2 085	1 921
Surplus fund	5 507	8 761
Equipment repair fund	1 979	1 979
Evolutionary development fund	2 084	5 679
	12 121	18 962

Note 12 *Provisions*

	2001	2000
Associate travel	360	221
Evolution contracts and services	657	0
Pension payments	0	161
	1 017	382

Grenoble, 2002-06- 04

Dr. Denis Alcaydé

Prof. Takehiko Aso

Prof. Asgeir Brekke

Mr. C. Graham Brooks

Mrs. Fabienne Casoli

Prof. Ryoichi Fujii

Prof. Shoichiro Fukao

Dr. Finn Karlsson

Mr. Wieland Keinath

Dr. Wlodek Kofman

Prof. Hannu Koskinen

Prof. Mike Lockwood

Prof. Tuomo Nygrén

Dr. Jürgen Röttger

Dr. Tone Vislie

Dr. Tauno Turunen
Director

Our audit report was issued on 2002- 06-27

Mrs. Annika Wedin
Authorised Public Accountant

Mr. Robert Barnden
Authorised Public Accountant

Öhrlings

PRICEWATERHOUSECOOPERS

Audit report

To the council of EISCAT Scientific Association

Corporate identity number 897300-2549

We have audited the annual accounts, the accounting records and the administration of the council and the director of EISCAT Scientific Association for the year 2001. These accounts and the administration of the association are the responsibility of the council and the director. Our responsibility is to express an opinion on the annual accounts and the administration based on our audit.

We conducted our audit in accordance with generally accepted auditing standards in Sweden. Those standards require that we plan and perform the audit to obtain reasonable assurance that the annual accounts are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the accounts. An audit also includes assessing the accounting principles used and their application by the council and the director, as well as evaluating the overall presentation of information in the annual accounts. We examined significant decisions, actions taken and circumstances of the association in order to be able to determine whether any council member or the director has acted in contravention of the statutes.

The annual accounts have been prepared in accordance with the Annual Accounts Act and, thereby, give a true and fair view of the association´s financial position and results of operations in accordance with generally accepted accounting principles in Sweden.

The council and the director have not acted in contravention of the statutes.

Stockholm 2002-06-27

Annika Wedin
Authorized Public Accountant

Robert Barndén
Authorized Public Accountant

EISCAT SCIENTIFIC ASSOCIATION
Dec. 1998

	Finland	France	Germany	Japan	Norway	Sweden	United Kingdom
COUNCIL	J. Kangas M. Lehtinen	D. Alcaydé W. Kofman * J. F. Minster	T. Hagfors M. Meinecke	R. Fujii S. Fukao T. Hirasawa	B. Benterud A. Brekke K. Kveseth	J. Gustavsson H. Opgenoorth	G. Brooks T. B. Jones M. Lockwood
SAC	A. Huuskonen	C. Lathuillere	M. Kosch	T. Ogawa	C. La Hoz *	S. Kirkwood	P.J.S. Williams
AFC	M. Vihma-Kaurinkoski	G. Debouzy	A. Röhr	Y. Koike	A. Andersen	F. Karlsson	G. Brooks *

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

EISCAT Senior Staff:

Director: T. Turunen
Deputy Director Science: A.P. van Eyken
Deputy Director Technical: U. G. Wannberg
Head of Administration: H. Andersson

Site Leaders:
EISCAT Svalbard Radar: H. Boholm
Kiruna: I Wolf
Sodankylä: M. Postila
Tromsö Radar: R. Jacobsen
Tromsö Heating: M. Rietveld

Non-Associate member of SAC was P. Stauning (Denmark)

EISCAT SCIENTIFIC ASSOCIATION
Dec. 1999

	Finland	France	Germany	Japan	Norway	Sweden	United Kingdom
COUNCIL	J. Kangas M. Lehtinen	D. Alcaydé W. Kofman J. F. Minster	T. Hagfors M. Meinecke	R. Fujii S. Fukao T. Hirasawa	B. Benterud A. Brekke K. Kveseth	J. Gustavsson H. Opgenoorth*	G. Brooks T. B. Jones M. Lockwood
SAC	A. Huuskonen	C. Lathuillere	M. Kosch	T. Ogawa *	C. La Hoz	M. André	I. McCrea
AFC	P. Pulkkinen	G. Debouzy	A. Röhr	Y. Koike	T. Vislie *	F. Karlsson	G. Brooks

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

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EISCAT SCIENTIFIC ASSOCIATION
Dec. 2000

	Finland	France	Germany	Japan	Norway	Sweden	United Kingdom
COUNCIL	J. Kangas M. Lehtinen	D. Alcaydé G. Debouzy W. Kofman	T. Hagfors W. Keinath	S. Fukao	B. Benterud A. Brekke T. Vislie	J. Gustavsson H. Opgenoorth *	G. Brooks M. Lockwood
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SAC = Scientific Advisory Committee; AFC = Administrative and Finance Committee; * = Chairperson

EISCAT Senior Staff:

Director: T. Turunen
Deputy Director Technical: U. G. Wannberg
Deputy Director Science: A.P. van Eyken
Head of Administration: H. Andersson

Site Leaders:
EISCAT Svalbard Radar: H. Boholm
Kiruna: I Wolf
Sodankylä: M. Postila
Tromsö Radar: R. Jacobsen
Tromsö Heating: M. Rietveld

EISCAT SCIENTIFIC ASSOCIATION
Dec. 2001

	Finland	France	Germany	Japan	Norway	Sweden	United Kingdom
COUNCIL	H. Koskinen T. Nygrén	D. Alcaydé G. Debouzy W. Kofman	T. Hagfors W. Keinath	T. Aso R. Fujii S. Fukao	B. Benterud A. Brekke T. Vislie	F. Karlsson H. Opgenoorth	G. Brooks M. Lockwood *
SAC	A. Aikio	C. Lathuillere	M. Förster	T. Ogawa *	C. La Hoz	M. André	I. McCrea
AFC	P. Pulkkinen	P. Louarn	A. Röhr *	M. Abe	T. Vislie	F. Karlsson	S. Horne

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Tromsö Heating: M. Rietveld

Non-Associate members of SAC were J. Forbes (USA) and M. Ruohoniemi (USA)

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EISCAT Headquarters
Box 164, SE-981 23 Kiruna, Sweden

Scientific contributions: EISCAT Associates and staff

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THE EISCAT ASSOCIATES

December 2001

SA
Suomen Akatemia
Finland

CNRS
Centre National de la Recherche Scientifique
France

MPG
Max-Planck-Gesellschaft
Germany

NIPR
National Institute of Polar Research
Japan

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Research Council of Norway
(Norges forskningsråd)
Norway

VR
Vetenskapsrådet
Sweden

PPARC
Particle Physics and Astronomy Research Council
United Kingdom

EISCAT Scientific Association

HEADQUARTERS

EISCAT Scientific Association
Box 164
SE-981 23 KIRUNA, Sweden
Phone +46-980-78700
Fax +46-980-78709
Email: eiscat@eiscat.com

SITES

Kiruna

EISCAT
Swedish Institute of Space Physics
Box 812
SE-981 28 KIRUNA, Sweden
Phone +46-980-79136
Fax +46-980-79161
Email: eiscat@eiscat.irf.se

Sodankylä

EISCAT
Geophysical Observatory
FIN-99600 SODANKYLÄ, Finland
Phone +358-16-619880
Fax +358-16-610375
Email: eiscat@eiscat.sgo.fi

Tromsø

EISCAT
Ramfjordmoen
N-9027 Ramfjordbotn, Norway
Phone +47-776-00550
Fax +47-776-00551
Email: eiscat@eiscat.uit.no

Longyearbyen

EISCAT Svalbard Radar
P.O. Box 432
N-9171 Longyearbyen, Norway
Phone +47-7902 1236
Fax +47-7902 1751
Email: eiscat@esr.eiscat.no