1 Introduction

Described in this document is the progress that has been achieved on Work Package 10 “New Techniques” within the first year of the EISCAT_3D project (01 May 2005 – 30 April 2006).

A search for recent scientific papers dealing with non-traditional uses of geospace research radars has been performed to obtain an overview of the state-of-the-art in the field. Based on the results of the search, an outline of possible new uses of incoherent scatter radars is given, with special focus on global climatic change.

A retrospective analysis of observations made by the currently operating EISCAT radar systems has been done aimed at assessing the computational resources that will be necessary to carry out another task of Work Package 10, namely the development of tools for the utilization of long term data series, whose principle application will be the study of climatic change signatures in geospace accessible to the eventual EISCAT_3D radar system.

Brief conclusions and plans for continuing the work on WP10 are summarized.

2 Search for papers and other references

To obtain a better understanding of knowledge and expertise accumulated in the area of climatic studies and non-dedicated applications of existing incoherent scatter radars, an overview of scientific papers and other relevant material has been carried out. In total over 200 documents were processed, including:

- Climatic change studies: over 150 documents. A set of parameters of the ionosphere and the middle atmosphere indicative of global climatic changes as well as some assumptions and conclusions concerning their long-term behaviour has been determined.
- New (or rather non-traditional) uses of incoherent scatter radars (ISR): over 50 documents. It has been found rather difficult to find *genuine new* applications of ISR. Many of the non-traditional experiments with the use of radar facilities (including other than incoherent scatter radars) that are feasible have already been conducted.

The literature search and evaluation will continue at subsequent stages of WP10.

3 Climatic change studies

Climatic monitoring. is an essential part of WP10.

The objective of the literature search is to evaluate the extent to which incoherent scattering radars, or similar, have been employed for climatic studies.

According to the American Meteorological Society the definition of “climate change” (also called “climatic change”) is “*Any systematic change in the long-term statistics of climate elements (such as temperature, pressure, or winds) sustained over* *several decades or longer. Climate change may be due to natural external forcings, such as changes in solar emission or slow changes in the earth's orbital elements; natural internal processes of the climate system; or anthropogenic forcing.*" Thus the Earth's upper atmosphere and ionosphere, being subject to the same kind or similar external forcings, can show phenomena indicative of long-term global changes in those environments.

Among a wide variety of scientific publications, we focused on those relevant to climate change. The goal was to determine what atmospheric parameters can be of particular use for climatic studies.

A long series (1911-1981) of *surface potential gradient* (of the global atmospheric electric circuit) measurements were analyzed by Harrison, 2004. A long-term decline in the monthly mean values in all months was detected. Global variations of total electron content (TEC) based on satellite measurements are studied by the International GPS Service (IGS) Ionosphere Working Group (Feltens, 2003). Lastovicka and Bremer, 2004 present an overview of the effects of increasing concentration of greenhouse gases in the atmosphere and their impact upon radio wave absorption, low frequency (160 kHz) radio waves reflection height, electron density and ion composition in the lower ionosphere. Long time series of maximum height and critical frequency of F2 and E ionospheric layers as well as the ratio [NO+]/[O2+] and greenhouse effect are subjects for investigations in Gulyaeva and Gulyaev, 1993; Upadhyay and Mahajan, 1998; Danilov, 2001; Danilov, 2005; Bencze, 2005. More than 30 years data series of F2 critical frequency and maximum height obtained with ionosondes have been studied by Bremer et al., 2004. Long-term changes in the characteristics of gravity waves (GW) have been analyzed by Manson et al., 2004. The main features of planetary waves and the variability of the semidiurnal tide with planetary wave periods observed by meteor radar over Esrange (68ºN, 21ºE) have been investigated by Pancheva and Mitchell, 2004.

Ionospheric parameters obtained with the use of incoherent scatter radars were also analyzed in terms of climatic-related investigations. For instance, the EISCAT data base providing data on electron density, electron and ion temperatures, and ion composition was used in the context of the International Reference Ionosphere (IRI) model (Collis, 1995). A 9-year long data set from Sondrestrom ISR was used for interpreting trends of electron densities in the lower ionosphere (Doe et al., 2005). Diurnal and seasonal variations of F2 layer parameters (maximum density and height) were analyzed in Lei et al., 2004 using data from the Millstone Hill ISR. These papers do not directly relate to climatic studies.

Among the works specially devoted to the analysis of long-term variations of ionospheric parameters and their relation to climatic changes we can mention Hall and Cannon, 2002 who have utilized regular ionosonde observations from Tromso dating back since 1935. Their analysis and trends of the critical frequency of the F2 layer are found to be negative. Ulich and Turunen, 1997 discovered a decrease in the altitude of the F2 layer peak during almost 4 solar cycles which they attribute to increasing concentrations of greenhouse gases.

Brief conclusion: feasible, warrants further investigations.

4 Outline of possible new (non-traditional) uses of the new radar

The objective of this item is to evaluate the feasibility of different “unusual” applications of the new radar based on the results of the literature search. The applications and brief preliminary conclusions are as follows:

- Artificial ionospheric targets. Possibly new applications of ionospheric releases of small particles fabricated using modern nanotechnology methods that may induce very large radar cross-sections to ISR in the ionospheric environment.

Experiments involving artificial ionospheric injections of different materials were conducted in the 1980’s. For example, Millstone Hill 440-MHz ISR was used to observe the spatial and temporal development of heavy negative ion plasma clouds created during four active chemical release experiments: the Ionospheric Modification Study (IMS) in 1983, the Space-Plasma Negative Ion Experiments (SPINEX 1 and 2) in 1984 and 1986, and NICARE 1 in 1989 (Sultan et al., 1992). The METAL campaign (Kirkwood and Vonzahn, 1993) was a multi-instrument campaign conducted in 1991 that was designed to investigate the relationship between neutral and ionized metallic layers in the high-latitude lower ionosphere. Measurements included electron density profiles and electric fields from the EISCAT UHF radar, ionosonde measurements of E(s) layers, neutral Fe profiles from lidar, rocket observations of winds (by chaff releases), and measurements of plasma density and ion composition (by mass spectrometer). The Arecibo incoherent scatter radar was used to observe enhanced ion acoustic and Langmuir wave turbulence after the release of 30 kg of CF3Br into the F region at 285 km (Bernhardt et al., 1995). In July 1992, as part of the NASA Combined Release and Radiation Effects Satellite (CRRES) El Coqui rocket campaign, the AA 2 experiment was performed. Its purpose was to study the interaction between a powerful radio wave and a high ion mass (Ba+) "collisionless" plasma. Approximately 35 kg of Ba were explosively released near the center of the Arecibo high-frequency heater beam at 253 km altitude (Djuth et al., 1995). Barium cloud releases were studied by Sridharan et al., 1997. Among other materials used for active experiments the following can be mentioned: metallic needles (Goldstein et al., 1998), CO2 (released near Millstone Hill ISR, Semeter et al., 1996), trimethyl aluminum (Roper, 1996).

Recent advances in nanotechnology open new horizons for active experiments in space. In particular, the so-called “nanoparticles” (0.015 to 2.5 µm in diameter, Postnova Analytics, 2005) can be charged to very high (up to a few hundreds, depending on the environment) charge numbers. If injected at ionospheric heights, they can create strong and sustainable artificial inhomogeneities of ionization (electron density enhancement or depletion) comparable or stronger than that of the background ionosphere. One possible application could be the excitation of artificial polar mesosphere summer echoes (PMSE).

Brief conclusion: feasible, warrants further investigations.

- Space debris. This kind of application has been conducted at different radars, including the EISCAT radar system.

A European space surveillance system is discussed by Flohrer et al., 2005. A satellite capture, repair and removal system is considered in Ishige et al., 2004. Mehrholz et al., 2004 analyze results obtained with the L-band (1.333 GHz) radar of TIRA (Tracking and Imaging Radar) System. Space debris observations in interferometric mode were conducted at Evpatoria RT-70 (5.01 GHz) radar complex (Molotov et al., 2004). The extreme sensitivity of incoherent scatter radars provide additional potential for the observations (Stansbery et al., 1995; Landgraf et al., 2004; Markkanen et al., 2005).

Brief conclusion: feasible.

- Planetary radar. Observations have been conducted before, for example, at the Arecibo observatory.

Radar mapping of Solar system planets began in 1946 (first observations of the Moon) and has been in progress ever since (for example, Kotelnikov et al., 1980). Well known results obtained with the use of incoherent scatter radars belong to Arecibo observatory when the radar system was used for a wide range of solar system studies. Radar images revealed a wealth of information about the shapes and surface properties of solid bodies in the solar system. In particular, the radar was used to make images of Mercury's north polar region (Harmon et al., 2001), map surfaces of Mars (Harmon et al., 1999), Venus (Carter et al., 2004), the Moon (Nozette et al., 2001), and asteroids (Benner et al., 2002).

Brief conclusion: feasible.

- Magnetospheric radar. Experiments are known to be conducted mainly in the HF band (due to lower electron densities).

The first observations of ion acoustic waves at altitudes of about 4000 km in the auroral zone were carried out using the powerful Russian SURA HF radar in 1991 (Gurevich et al., 1992). Additional observations were made with the SURA radar and the Ukrainian UTR 2 receiving system in December 1992 (Hysell et al., 1997). ISR measurements are also used in studies of the upper ionosphere (up to 700-800 km) Wild et al., 2001; Grydeland et al., 2004, often in combination with satellite observations, Pitout et al., 2004. A common limitation for magnetospheric investigations using incoherent scatter radars is insufficient sensitivity. According to the satellite measurements described in Denton et al., 2004 and Laakso et al., 2002, electron density at altitudes up to 1 R_E can reach 10^8 m^{-3}. Assuming enhanced operating capabilities of the new radar (higher transmitted power and antenna gain) it seems feasible to probe the lower magnetosphere.

Brief conclusion: apparently feasible in combination of high sensitivity of the new radar and longer integration intervals. Requires further investigations.

- General relativity theory applications.

A few classical examples of the general theory of relativity are:

- Gravitational red-shift of light. The frequency of light or radio waves will decrease as it moves to higher gravitational potentials. Confirmed by the Pound-Rebka experiment (Pound and Rebka, 1959). This effect is too small to be detected by a typical ISR. For example, the red-shift at an altitude of 500 km of a wave with frequency 224 MHz is approximately 10^{-2} Hz.
- Gravitational time dilation. Clocks will run slower at stronger gravitational potentials. Confirmed by the Haefele-Keating experiment (Hafele and Keating, 1972) and GPS satellite measurements (Wolf and Petit, 1997).
- Shapiro effect (a.k.a. gravitational time delay). Signals will take longer to move through a gravitational field. Confirmed through observations of signals from spacecraft and pulsars passing behind the Sun as seen from the Earth. Also tested at MIT Haystack radar (200 ms delay of signals bounced from Venus surface).

Parenthetical note: All the experiments mentioned above and the effects they measure are a consequence of a single relativistic property, namely time dilation in stronger gravitational potentials.

So, the effects in the near-Earth environment are rather weak and often unobservable. Nevertheless, sometimes the effects have to be taken into account. For example, in (Gudimetla and Kavaya, 1999) the theory of special relativity is used to analyze some of the physical phenomena associated with space-based coherent Doppler lidars aimed at the Earth and the atmosphere. They have examined the error in estimates of winds due to the Doppler shift caused by special relativity effects.

Brief conclusion: such applications require extra-accurate measuring equipment and techniques, thus *apparently* infeasible. Requires further consideration.

- Radiation belts monitoring.

The radiation belts were discovered in the 1950's. The inner and outer belts (approximately 1.5 R_E and 2.5-8 R_E in the equatorial plane, respectively) consist of highly energetic (up to 100 MeV) populations of trapped by geomagnetic field ions and electrons. The belts are a hazard for artificial satellites and especially for manned spacecraft and difficult to shield against. This determines the importance of monitoring and studying the radiation belts.

The dynamics of relativistic electrons in the inner magnetosphere around the time of geomagnetic disturbances have received considerable attention in recent years. In addition to the environmental impact these electrons have on space-hardware and their obvious impact on space weather, the scientific issues surrounding the transport, acceleration and loss of these particles in the inner magnetosphere were analyzed in many papers such as Baker et al., 1994, Friedel et al., 2002, Vassiliadis et al., 2003, Taylor et al., 2004, Green and Kivelson, 2004, and Elkington et al., 2004. Measurements of proton fluxes, caused by precipitation from the belts, in the energy range 0.07 - 9.1 GeV have been performed with the Alpha

Magnetic Spectrometer (AMS) at altitudes of 370 – 390 km in the geographic latitude interval +/- 51.7° (Fiandrini et al., 2004).

There is a number of papers on studies of the effects due to the radiation belts with the use of IS radars. Strong precipitation of energetic particles from the outer radiation belt was observed by Millstone Hill ISR (Foster et al., 1998). Kirkwood and Osepian, 2001 used EISCAT UHF radar data for conjugate observations of electron density disturbances produced in the ionosphere. The data were used to determine the fluxes of precipitating electrons with energies greater than or equal to 30 keV.

Brief conclusion: needs further investigations.

- Meteor radar. Experiments have been conducted with different radars including the EISCAT radar system (Kunitake and Schlegel, 1991; Pellinen-Wannberg and Wannberg, 1994; Gonzalez et al., 1994; Janches et al., 2002; Westman et al., 2004). Among other instruments used for meteor detection are MLT-MST radars (Clemesha, 2004; Singer et al., 2004; Janches et al., 2004), interferometric meteor radar systems (Holdsworth et al. 2004), and optical and UV band instruments (Scarsi, 2004).

  Brief conclusion: feasible.

- SETI (search of extra-terrestrial intelligence).

The search has been conducted since the 1980's with a wide variety of instruments, first of all by attempting to receive "intelligent" (narrow band) radio transmissions (Horowitz et al., 1986, Kardashev et al., 1998, Shirai et al. 2004) and optical emissions (Blair and Zadnik, 2002; Howard et al., 2004). Some authors consider methodological questions (Ellery et al., 2003) and sophisticated techniques aimed at improving the chances of detection: selection of targets for use by the microwave search for technological signals (Turnbull and Tarter, 2003a; Turnbull and Tarter, 2003b), optimal detection of fast radio transients (Cordes and McLaughlin, 2003), possible types of transmitter/receiver synchronization schemes (Corbet, 2003). In Tarter, 1985, the approach of "parasitic search" is considered. A similar approach can be used with ISR data bases. A considerable portion of ISR data considered as noise or interference might be subject to re-processing aimed at detection of extra-terrestrial signals.

Brief conclusion: feasible, requires specialized software and processing techniques.

A brief outline of these items can be found in Table 1 in this document. The work is to be continued at later stages of WP10.

5 Assessment of the desirable technical specifications of the new radar

The objective is to work out the technical specifications desirable from the point of view of the most demanding new applications (item 4 above) and to compare them to the specifications suggested in the EISCAT_3D Design Specification Document. The desired operational capabilities (Table 2 in this document) do not deviate considerably from the latter.

6 Evaluation of total observational time

The motivation is to assess the amount of ISR data currently available for analysis aimed at the discovery of long-term trends of ionospheric parameters possibly connected to global climatic changes. The evaluation of monthly observational time accumulated by the existing EISCAT radars for the period 1981 through 2005 has been performed in two ways:

- as indicated in the EISCAT auto-generated schedule
- available at the Madrigal inventory web-page

The results of the evaluations are shown in figs. 1 and 2 of this document, respectively.

Figure 1 presents the number of scheduled observation hours per month for each of the EISCAT radars in the time span 1981-2005. A constant growth of the observation hours at the tristatic UHF radar system (from approximately 70 in the 1980s to more than 200 in the 2000s) is clearly visible indicating both increasing demand for and improving capability of EISCAT personnel and equipment to provide observation time. A similar growth for VHF and Svalbard radars can be seen beginning in the years when the instruments were brought into operation (1988 for VHF and 1996 for ESR). Distinct peaks in the observation time correspond to long runs, for example, one month long continuous measurements in September 2005.

Shown in figure 2 are the number of hours per month of observational data available at the Madrigal inventory web site. The data represent altitude vs. time series of ionospheric parameters (electron density, electron and ion temperatures, etc.) pre-computed from the raw EISCAT radar data. Not surprisingly, the amount of Madrigal data is considerably less than the number of hours scheduled for experiments. The reasons could be:

- Overbooking of observational time. Radar users are allowed to reserve up to 10% more time than they actually need in order to conduct experiments during most suitable time periods.
- Cancellations of observational time. The users are allowed to cancel up to 10% of the reserved time in the case of unacceptable ionospheric or weather conditions.
- Data absent at intervals of repositioning of antenna(s) during scanning experiments. Tristatic UHF measurements are particularly vulnerable to the effect. This emphesizes the advantages of the 3D solution for the new radar.
- Data gaps due to technical problems.
- Considerable portion of the data collected during special program (SP) experiments which might not be configured for processing with standard EISCAT software.

Almost complete absence of Madrigal data in 1995 and 1996 can be explained by the works on construction and putting into operation of the EISCAT Svalbard radar.

Figure 3 shows the distribution histograms of scheduled 0.5-hour observation intervals of time of day hours at each of the EISCAT radars. The histograms reveal that the observations, being rather evenly distributed, nevertheless have an increasing tendency toward afternoon and evening hours (10-22 UT). This can be explained by increased interest in conducting observations around local magnetic midnight and by the fact that the EISCAT users are encouraged not to run expensive night observations without a special necessity. The capability of the new radar system to run continuously unattended will result in a more uniform distribution of the observations providing better coverage of night-time measurements which may be important for climatic studies.

This work will continue at later stages of the project with a focus on the EISCAT data archive containing all raw data accumulated since 1981.

7 Summary

The review of scientific publications (2) and subsequent analysis of possible non-traditional uses of the new radar (4) prove very difficult to find *entirely* new ones. Most of imaginable new applications of IS radars have been tested in one or another form.

The potential for climatic studies (3) provided by the already existing EISCAT data appears very high and promises new important scientific results, in particular after the new radar is put into operation.

The technical specifications (5), desirable from the point of view of the most demanding new applications, prove to be in an agreement with those suggested for the new radar.

Retrospective analysis of scheduled observations and the geophysical data computed from EISCAT data (6) show ever growing potential of the radar system. This work is to be continued with a focus on the EISCAT raw data archive.

On the next stage of works on WP10, we plan to continue the survey of possible new applications and to develop a prototype software package to acquire long time series data from large data bases to be used for climatic studies.

Acknowledgement. The authors thank Tony van Eyken for useful comments and discussions concerning the analysis of observation time data.

Table 1. New ways of exploiting ISR

Task	*Reason*	*Consequent requirements*
Climatic monitoring of the ionosphere and middle atmosphere	The studies of climate changes involve analysis of a vast variety of ionospheric phenomena with characteristic time scales from minutes to years. Along with regular monitoring of the ionosphere, the capability of measuring the parameters of the lower atmosphere (temperature, water content, etc.) will lead to a better understanding of important phenomena indicative of climate changes such as polar mesospheric summer echoes (PMSE) and noctilucent clouds (NLC).	Continuous operation.
Artificial ionospheric targets	Neutral atmospheric mass motions can be studied by tracing the radar returns from artificially injected materials (barium releases, nanospheres, rocket exhausts). Different kinds of artificial targets can be created in the atmosphere by ground-based facilities, for example, periodic structures due to HF pumping or powerful acoustic wave transmission.	High spatial resolution; special software for tracking point-like [discrete?] targets.
Space debris	Ground-based remote monitoring is one of the most effective means of detecting space debris which endanger space activities of orbiting satellites and, especially, manned spacecraft.	Continuous operation; dedicated software for debris detection and determination of their trajectory parameters.
Planetary radar	Radar probing of solar system planets. Mapping Venus surface by optical instruments is impossible due to constant heavy clouds in its atmosphere. Investigations of planets' ionospheres (Venus, Jupiter) and solar magnetospheres. Monitoring of coronal mass ejections at the Sun. Probing of the Moon surface.	To be investigated.
Magneto-spheric radar	Magnetospheric plasma studies are actively conducted by means of HF radars (using coherent scatter technique). Investigations of the magnetosphere using ISR may yield new valuable scientific data. ISR observations combined with powerful HF "illumination" of the magnetosphere can be scientifically fruitful.	To be investigated.
General relativity theory applications	Super accurate measurements of probe pulse flight time to massive objects, for example, Sun or Jupiter, to calculate the time and trajectory deviations due to relativistic effects.	To be investigated.
Radiation belts monitoring	Studies and monitoring of the Earth radiation belts can become an important application of the radar since the high energy particles trapped in the belts readily penetrate spacecrafts and can damage instruments and be a hazard to crew.	To be investigated.
Meteor radar	For observing meteors and man-made re-entrant objects as they enter the Earth's atmosphere. A wide range of atmospheric and astronomical parameters may be measured from these observations.	To be investigated.
SETI	Search of Extra-Terrestrial Intelligence. A considerable portion of ISR data considered as noise or interference might be subject to re-processing aimed at detection of extra-terrestrial signals.	To be investigated.

Table 2.a

Transmitter/Receiver specifications			
Parameter	*Value*	*Reason*	*Consequent requirements*
Duty cycle	Up to 100%	CW transmission can be useful for multistatic and interferometric high-resolution Doppler frequency observations of point-like targets such as: (1-D) space debris, satellites, artificial releases; (2-D) particle beams, meteor traces, rocket exhaust traces, striations; (3-D) PMSE, regions of HF-enhanced plasma waves.	High accuracy time/phase synchronization between receiving sites.
Time/space resolution	<= 50 m (300 ns)	To study detailed vertical structure of HF induced plasma waves, PMSE and small-scale discrete auroral phenomena.	Enhanced transmitter power and/or receiver sensitivity.
Transmitter band width	>=3 MHz	To provide short pulse transmissions (<=300 ns).	
Transmitter peak power	5 MW	To provide required SNR for high range resolution experiments as well as probing of remote and small effective cross-section targets (space debris, magnetosphere, planets, etc.).	
Observation schedule	Continuous (24/7)	Atmospheric gravity waves (AGW) and tidal waves (TW) play significant role in energy coupling and thus are important for climate studies. Their time periods range from a few minutes to a few hours (AGW) and days (TW) implying sampling rate <=1 min and observation times >=4 hours. On the other hand, to study daily variations of average ionosphere parameters the observations should be conducted at least every 4 hours.	High reliability of the entire system.
Minimum range	1.5 km (10 µs)	Weather is formed by processes in lower atmosphere (0-20 km). Wind and temperature measurements at low altitudes (10-90 km) for monitoring local weather conditions (in particular water content) as well as global climate changes (PMSE). Sophisticated ground clutter suppression techniques should be developed.	Enhanced receiver protection reliability design.
Receiver band width	±8-10 MHz	To cover all possible plasma wave frequencies. Maximum F-layer plasma frequency at peak solar activity can reach 10 MHz.	Low-noise reception scheme.

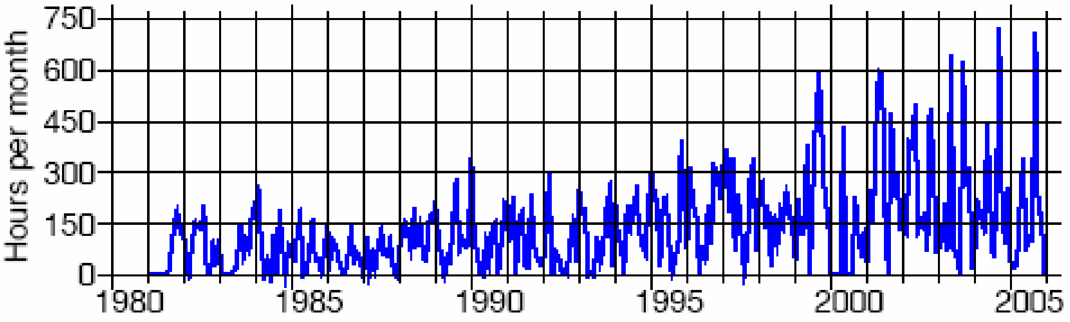
Table 2.b

Antenna specifications			
Parameter	*Value*	*Reason*	*Consequent requirements*
Beam width	<=0.5 deg.	To provide reasonable horizontal space resolution (a few km without interferometry).	Antenna field dimensions >=200 by 200 m.
Number of beams	>=5	To provide (quasi-) simultaneous multidirectional observations. Simultaneous plasma density data at horizontally spaced locations allow measurements of horizontal density gradients important for AGW and TW monitoring.	Transmit antenna consisting of several independently controllable sections.
Number of reception sections	>=10 (to be specified in WP5)	To enable radio imaging. Ideally, signals (voltages) from every elementary antenna (dipole) should be recorded (radio holographic approach).	Low-noise antenna amplifiers.
Number of transmit sites	2	Two-site transmission could allow forming of complex quasi-periodic illumination pattern due to interference.	

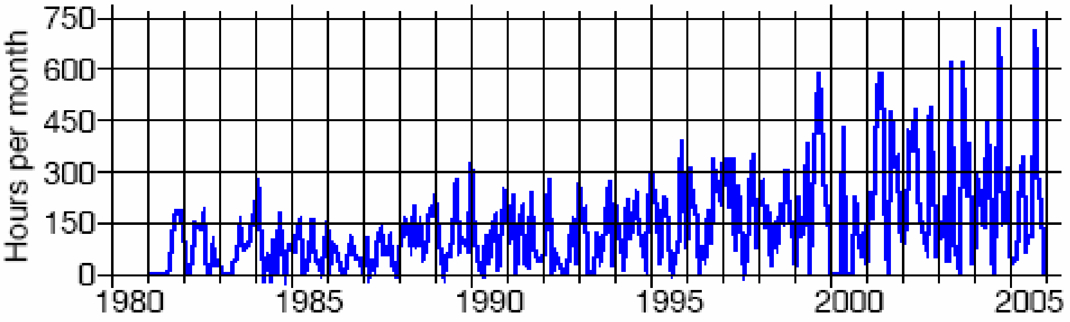
Table 2.c

Software specifications		
Function	*Requirements*	*Consequent requirements*
Data archiving and access	Data archive should provide easy access to any portion of recorded data. The archive should be equipped with a powerful search engine allowing seeking required data (data mining) by a variety of parameters (date/time, experiment name/description, integration time, range coverage, geophysical parameters, etc.). Sparse data analysis algorithms can be useful for processing long irregular data series.	Internet-compatible, modular, object-oriented, user-upgradeable, open source- and open standards- based, platform-independent, non-proprietary software implementing metadata format(s).
Data processing	Software should furnish basic modules for computing frequently used output values (power profiles, spectra, plasma parameters, etc.). The modules should allow user modifications for special mode processing. The software should be executable from/at remote computers.	
Experiment development	The environment for experiment development and debugging should be user-friendly. The programming language and operating system providing complete radar control should be as simple as possible, furnishing various procedures and/or templates for selecting required transmit/receive options “on-the-fly” (in the course of an experiment). The steps for debugging and testing of newly developed experiments should not require user’s presence at or direct connection to radar control computers.	
Data visualization	Data collection software should provide real-time “raw data” visualization and quick analysis results easily accessible from remote computers.	
Inter-connection between different instruments	The radar control software should provide easy real-time exchange of basic data with other diagnostic (ionosonde, riometer, etc.) and experiment-control (HF pump transmitter etc.) equipment and allow real-time automated modification of the current experiment.	

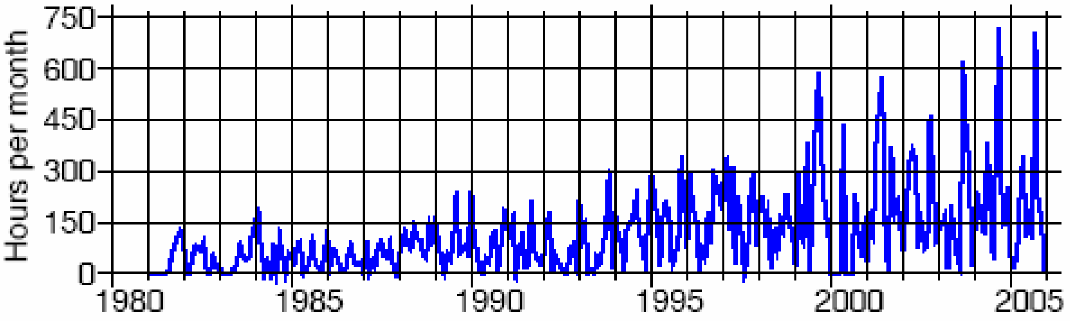
Figure 1. Number of observational hours per month at EISCAT ISR instruments as indicated in the EISCAT auto-generated schedule.



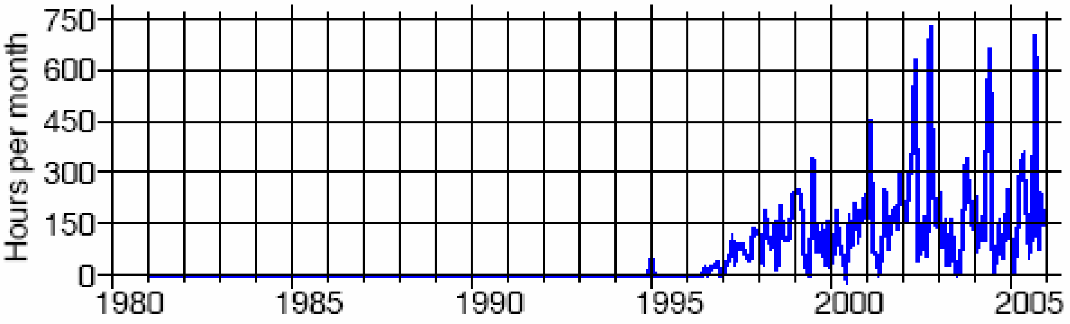
Kiruna UHF



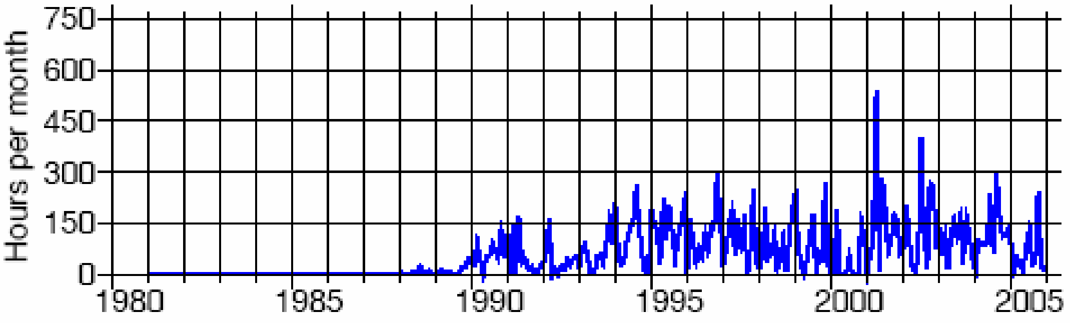
Sodankyla UHF



Tromso UHF

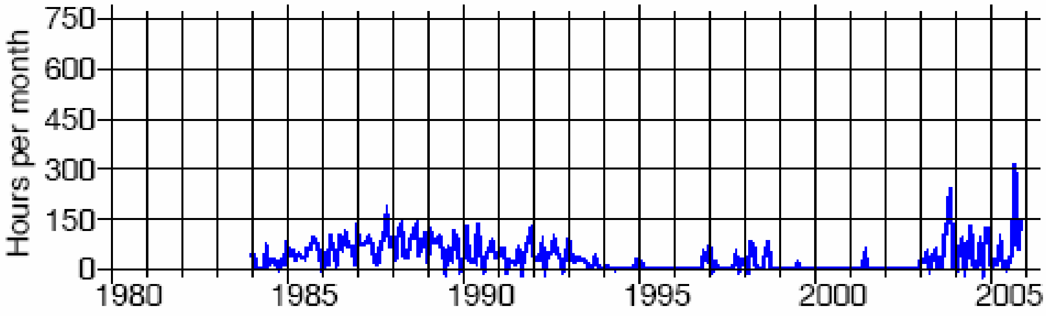


ESR

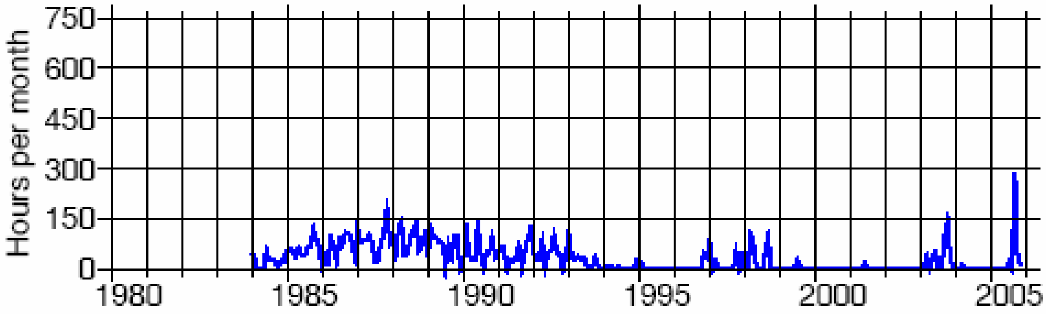


Tromso VHF

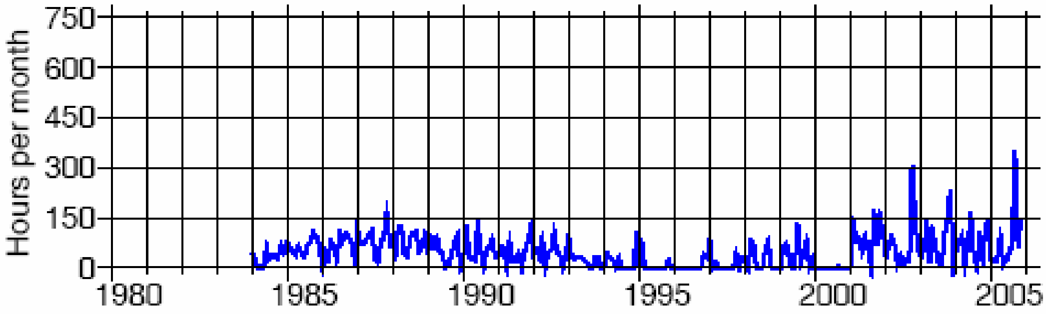
Figure 2. Number of observational hours per month at EISCAT ISR instruments available at the Madrigal inventory web-page.



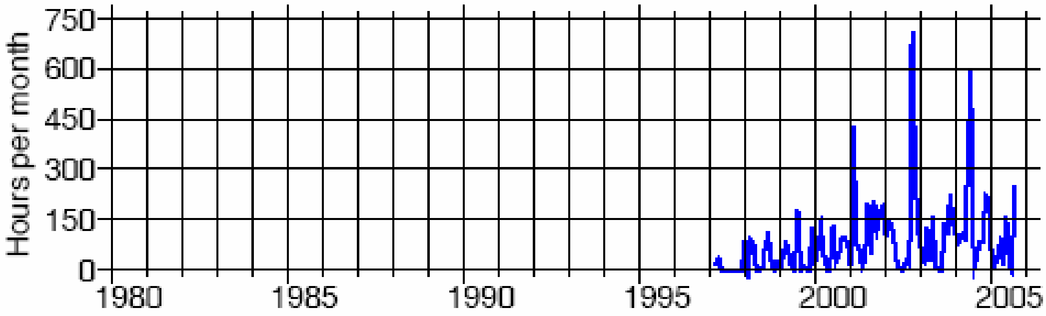
Kiruna UHF



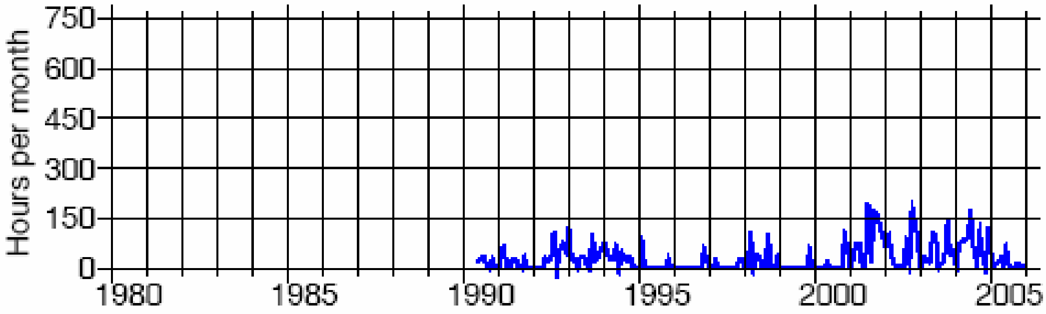
Sodankyla UHF



Tromso UHF

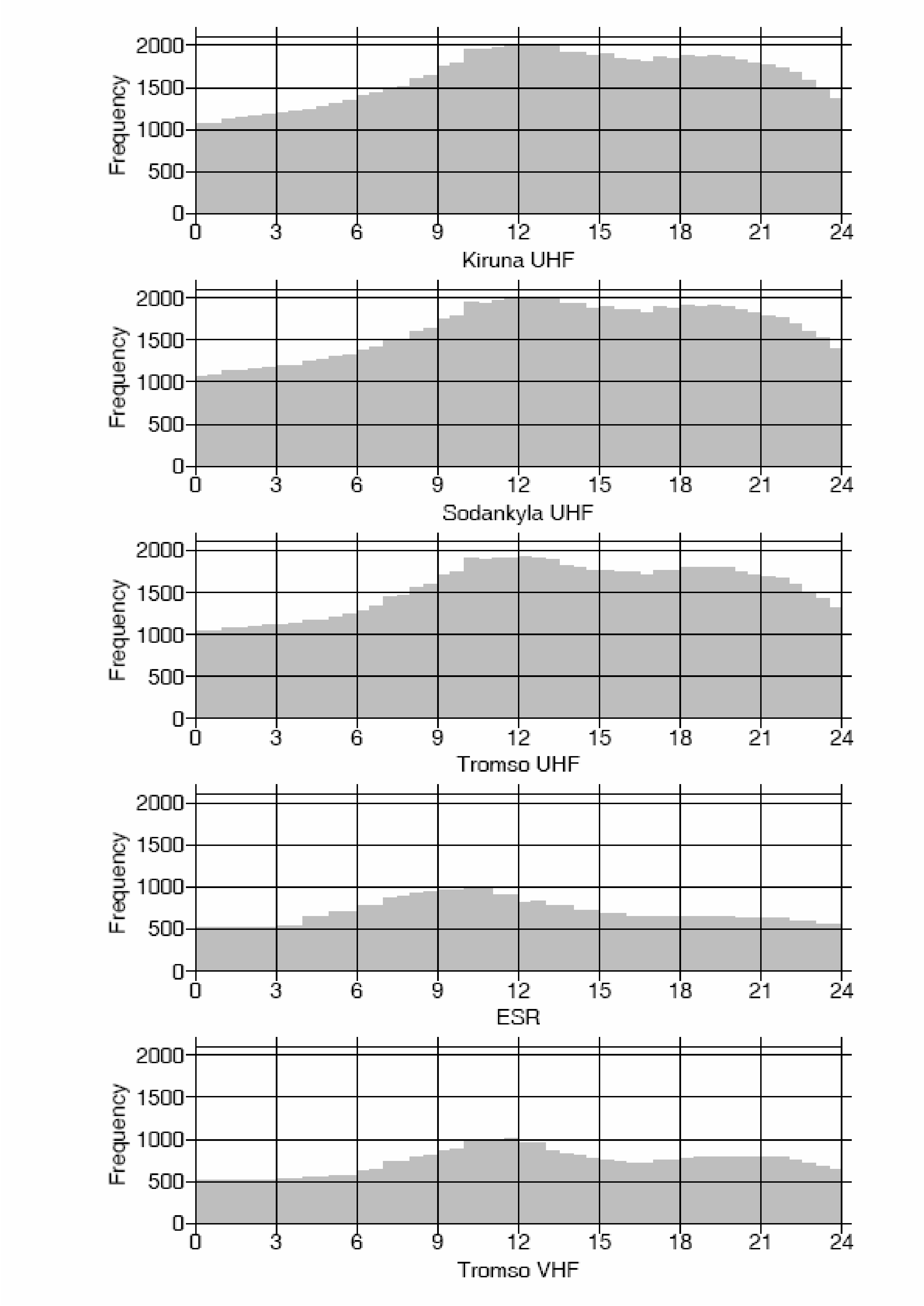


ESR



Tromso VHF

Figure 3. Distribution (occurrence frequency) of 0.5-hour observation intervals between day hours at EISCAT ISR instruments as indicated in the EISCAT auto-generated schedule.



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