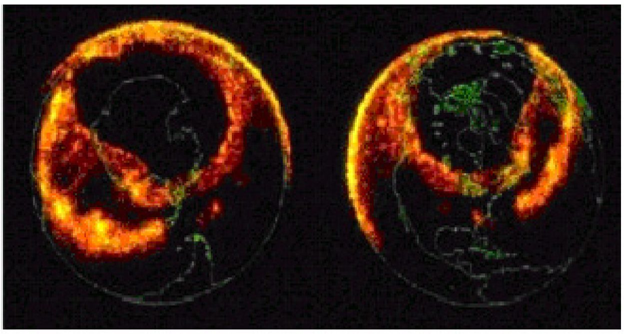

IPY-ICESTAR
Interhemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research

A proposal to the Norwegian Research Council IPY Programme

Assoc. Prof. N. Østgaard, University of Bergen
Proposal coordinator

in support to ICESTAR, endorsed by the ICSU/WMO Joint Committee for IPY
http://www.siena.edu/physics/ICESTAR/

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This is a joint cluster proposal from the Norwegian participants in the program: "ICESTAR/IHY – Interhemispherical Conjugacy in Geospce Phenomena and their Heliospheric Drivers" that has been endorsed by the ICSU/WMO Joint Committee of IPY [1]. The proposal comprises 5 different initiatives and these are in the following outlined as project elements with its own project leader, team, collaboration and budget. The project leader of this cluster proposal is Ass. Prof. Østgaard, who is a member of the Steering Committee of the ICESTAR Scientific Research Programme [2], co-leader of the ICESTAR program [3] and the national coordinator for IHY.

1 INTRODUCTION

The study of the geospace phenomena of the ICESTAR/IHY program is inherently interdisciplinary because it brings together solar, heliospheric, space, and atmospheric sciences in order to understand the chain of processes from the solar interior to the Earth. This interaction will be facilitated by the SCAR information portal which will provide access to a wealth of geospace data. The IPY provides an excellent framework in which such an interdisciplinary endeavour can be accomplished. The IPY Committee endorsed the ICESTAR initiative as a core initiative.

The Norwegian ICESTAR/IHY Program is an integrated part of the international ICESTAR program [3, 4] and will both take advantage of and contribute to that program. It will take full ***advantage*** of the shared data base, i.e., the ICESTAR Virtual Data Port, which will make data available from a large ground based network covering both the northern and southern Hemisphere. This data base comprises global optical networks and riometers, magnetometers and radars. It will ***contribute*** by making continuous measurements by the EISCAT radar on Svalbard during the entire 2007 and offering on-demand observations from the EISCAT radar at Ramfjordmoen. It will take ***advantage*** of the Norwegian ground based facilities in North of Norway and at Svalbard It will also ***develop*** the Norwegian ground based facilities by building a state-of-the-art calibration laboratory for optical instruments at Svalbard and developing high resolution multi-camera systems for studying fine structures in the Aurora using tomography techniques.

The scientific goals of the Norwegian ICESTAR/IHY Program are closely linked to the international ICESTAR Program [3, 4] and will focus on Inter-hemispherical Studies of magnetosphere-ionosphere coupling, the heliospheric drivers, and the effects of geomagnetic disturbances in the mesosphere and stratosphere. The overall objective of the program is to assess the relative role of the various constituents of the magnetosphere-ionosphere system for the formation of geomagnetic disturbances under different heliospheric conditions, and how these disturbances interact with the polar upper and middle atmosphere.

We will determine the timing and location of substorm onsets in the two hemispheres, and the observation of the scaling characteristics of the aurora will allow us to improve existing theoretical models of this fundamental magnetospheric process. In particular, we will test the hypothesis of scale invariant size distribution of auroral structures in the range from 100 m to hundreds of km, which at present is based on satellite UV-imaging and ground based all-sky TV cameras. The method includes deployment new optical systems in Svalbard, in combination with other calibrated optical systems in the region. We will also attempt to determine the relative importance of dynamics of the ionosphere, the auroral acceleration region and the magnetotail plasma sheet in establishing this distribution of structures on various scales.

We will study the conjugacy or non-conjugacy of theta aurora to obtain information about structure and dynamics of the closed magnetosphere during positive z - component of the interplanetary magnetic field. Knowledge of the magnetic reconnection rates (dayside and nightside) is needed to clarify the energy/mass exchange with the solar wind.

We will obtain new knowledge about interaction between magnetosphere and ionosphere by radar observation of ion outflow and related fine scale ionospheric structures and plasma physics, and also from observations of conductance, convection patterns, polar cap potentials and field aligned currents in the two hemispheres.

Interaction with the middle atmosphere will be assessed by use of satellite and ground-based observations of minor constituents in the middle atmosphere, and measures of energetic particle precipitation (EPP) during IPY, to further develop models of the EPP-induced chemical changes, in particular with regard to nitrogen species.

The Norwegian ICESTAR/IHY Program also has an ambitious public outreach element, i.e., a conference for journalists in public media (newspapers, magazines and television) which aims at creating a stronger relation between the scientific and communication community. This will make science more visible, catch public attention and boost the scientific interest among people in Norway and encourage young people to become scientists.

2 PROJECT ELEMENTS

2.1 CONJUGATE AURORA FROM SPACE AND GROUND – INTERNAL AND EXTERNAL DRIVERS

Assoc. Prof. Nikolai Østgaard, University of Bergen
Dr. Arve Aksnes, now at Florida Space Institute, Kennedy Space Center, USA

This element of the proposal is for a three-year Post Doc fellowship (Dr. Arve Aksnes) and focuses on the main questions of the international ICESTAR Program utilizing the data set that are made available through the ICESTAR Virtual Data Port (both hemispheres), including the Global Auroal Imaging Access (GAIA), as well as from the Norwegian ground based facilities; the European Incoherent Scatter (EISCAT) facility consisting of three incoherent scatter radar systems, and a large collection of optical instruments at the Auroral Station in Adventdalen, Svalbard, operated by the University Centre in Svalbard (UNIS). It will benefit from the results from the ongoing IMAGE project, funded by the Research Council for 2006 and 2007 (Østgaard et al., 2003; 2004; 2005a; 2005b; 2005c) as well as studies of ionospheric conductances (Aksnes et al., 2002; 2004; 2006). This element also outlines an ambitious public outreach element, i.e., a conference for journalists in public media (newspapers, magazines and television) which aims at creating a stronger relation between the scientific and communication community.

2.1.1 Asymmetries of conjugate magnetic field footpoints controlled by the IMF

If the magnetic field lines connecting the two hemispheres are symmetric, any disturbance/instability in the magnetosphere that causes particles to precipitate in the ionosphere will result in auroral features that can be observed at exactly the same geomagnetic locations in the southern and northern hemispheres. On the other hand, if the magnetotail is twisted (i.e., rotated around the Sun-Earth line), the pair of footpoints of the nightside field lines will have different geomagnetic coordinates. Simultaneous images from the conjugate hemispheres of substorm onset locations (Østgaard et al., 2004; 2005b) have revealed significantly larger asymmetries than provided by model predictions (Tsyganenko, 1995; 2002). Considering the importance of magnetic field models to model our geomagnetic environment, as well as interpreting in situ measurements correctly, a more thorough analysis of this asymmetry is required. Utilizing ground-based data within ICESTAR, we will investigate the asymmetry of conjugate magnetic field points.

2.1.2 The non-conjugate theta aurora

A manifestation of the differences between the two hemispheres is clearly revealed by the observation of non-conjugate theta aurora using IMAGE and Polar data (Østgaard et al., 2003). While Østgaard et al. (2003) focused on solar wind conditions, we suggest to perform a different approach, using the extensive ICESTAR ground-based data network to study the ionospheric conditions for periods with non- conjugate occurrences of theta aurora.

2.1.3 Reconnection and cusp precipitation

Recently, Østgaard et al (2005c) presented the first simultaneous optical observations of the cusp aurora in both hemispheres, utilizing conjugate images from IMAGE and Polar. According to Phan et al. (2003), the cusp precipitation is the ionospheric signature of lobe reconnection during northward IMF. We want to proceed with this cusp analysis by combining satellite imaging (when available) with ground-based signatures of reconnection to retrieve temporal and spatial aspects of the cusp (e.g., Farrugia et al., 2004) as well as estimating the reconnection rate on dayside and in the magnetotail. Our approach to determine the open-closed boundary will be similar to what was developed by Østgaard et al. (2005a), where IMAGE measurements were used as guidance to confine a more exact location based on electron temperature measured by the two EISCAT radars at Tromsø (VHF) and Svalbard (ESR) (Østgaard et al., 2005a). In addition to satellite data we will utilize the ground-based optical network in the two hemispheres.

2.1.4 Differences in conductivity between the two hemispheres

In two papers we have documented that global Hall and Pedersen conductances can be inferred from global UV and X-ray emissions (Aksnes et al., 2002; 2004). In a ground-truth experiment performed by Aksnes et al. (2006), comparing height profiles of the electron density from Polar measurements with EISCAT radar data we showed that the two measurements were in reasonable agreement, supporting the space-based technique. A natural continuation of these studies is to combine satellite-derived conductances with local ground-based measurements provided by the ICESTAR data base to resolve seasonal and hemispherical similarities and differences.

2.1.5 Public Outreach: Conference for journalists

Norway has long traditions in the field of space physics, well illustrated by portraying Kristian Birkeland on the Norwegian 200 kroner bank note. The country's unique location within the auroral zone should suggest a boost for the scientific interest among people in Norway. Unfortunately, this is not reflected very well in the public domain. To improve the current situation, we suggest to arrange a three-day-seminar for journalists in public media (newspapers, magazines and television). Lectures will be given in an understandable way for non-physicist focusing on different aspects of Sun-Earth interaction (i.e., the ICESTAR/IHY program) and printed and electronic material will be handed out. This material is either provided by us or us in collaboration with the IPY, IHY and ICESTAR programs. The conference will aim at creating a stronger relation between the scientific and communication community and initiate discussions about possible future arrangements to improve this relation. We will consider opening parts of the conference for the general public.

2.2 EISCAT

Prof. A.P. van Eyken (on behalf of the EISCAT Scientific Association)
Prof. A. Brekke. University of Tromsø

Incoherent scatter radars provide some of the highest quality ionospheric data available for monitoring purposes. We plan to dramatically extend the availability of incoherent scatter data during the IPY period, achieving essentially continuous availability of data in the northern high-latitude region. The expected output will be the most extensive, and most detailed, dataset describing the polar atmosphere ever collected and it will be invaluable for the purposes of monitoring, modelling, and basic scientific research in a variety of areas. The impact of this initiative will be greatly enhanced through close cooperation with other programmes in the ICESTAR/IHY portfolio.

The basic dataset will comprise measurements of the density, velocity, and temperatures of the ionosphere, typically as profiles between altitudes of about 80 and 1000km, with altitude resolutions matching the ionospheric scale heights and time resolutions of the order of a few minutes, or less. An extensive range of parameters describing both the ionised and neutral components of the atmosphere, as well as remote sensing of the terrestrial magnetosphere, can be further derived. Analysed and validated data will be freely available through an existing, distributed, web-based, data system (Madrigal), currently used by a number of the radars and connected to other existing databases including NCAR - USA - and the Centre de Données de la Physique des Plasmas - France. Integration into the ICESTAR data portal for data assimilation and distribution would be valuable and straightforward. EISCAT Incoherent scatter radar data will form a foundation data set describing the Arctic ionosphere and atmosphere. It is of crucial importance to many Norwegian plans for approved activities within the IPY, as well as to those of scientists from China, Germany, Italy, Japan, Poland, South Africa, Sweden, the UK, and the USA. The activities of the radar strongly enhance the potential return on investments in other instrumentation to be deployed by Norwegian scientists during the IPY. Incoherent scatter radar data makes important contributions to essentially every element in the ICESTAR/IHY framework; and to all four areas covered by ICESTAR working groups. The value of these contributions is greatly enhanced if the data are available over most of, or all, the IPY interval.

Norwegian scientists will play a key role in several ICESTAR/IHY projects including studies of the fundamental plasma physical processes which mediate energy flow in the solar-terrestrial system, and the ways in which these processes couple together. Many of these are not well understood, because the underlying physics is complex, involving non-linearity, turbulence and multiple feedback mechanisms. Examples of such processes include magnetic reconnection, anomalous transport, wave-particle acceleration and irregularity generation. For the quantitative understanding of energy flow, leading to true predictability, it is necessary to secure detailed and reliable measurements. In addition, studies of naturally occurring processes such as the structure and dynamics of auroral arcs, proton aurora, ionosphere-thermosphere interactions, ion outflow and non-Maxwellian plasmas are of critical importance to understanding the complex coupling and feedback mechanisms which exist in the solar-terrestrial system. The EISCAT data set will be uniquely applicable to these studies.

The polar middle and upper atmosphere is a key region to study global change in that it is closely coupled to both the magnetosphere, which is subject to solar wind and short-wave radiation, from above, and to the lower atmosphere, where various climatic changes are taking place excited by major insolation and meteorological processes. Coordinated Arctic and Antarctic radar studies are crucial in understanding the distribution of these effects over the globe. The effects of global climate change are expected to be enhanced in the polar region, particularly in the arctic region. The energy input to thermosphere/ionosphere originated from the solar wind and the energy transfer processes within the atmosphere will be studied using coherent radars (SuperDARN), which already operate continuously, and EISCAT. The mesosphere-thermosphere is an important transitional zone where processes act to filter and shape the field of waves and tides ascending from below. It is perhaps the least understood part of the Earth's atmosphere and fundamental processes are poorly understood. Approved IPY projects will emphasise polar regions because many vertical coupling phenomena are best observed there. For example: polar mesospheric clouds occur above the summer pole, due to cooling caused by ascent forced globally by waves; their increase is speculated to have resulted from globally increased greenhouse gases, an interpretation now challenged by new data. Long-term, continuous monitoring, coupled with intensive campaigns, will allow selected mechanisms to be investigated in great detail.

This activity leverages the very substantial capital and operating investments in the EISCAT facilities (already made both by Norway and others) to provide dramatically expanded data availability during the IPY for modest additional costs compared to the basic investment. The proposal is coordinated with the World's other incoherent scatter radars, particularly the high latitude instruments in Greenland, New England, and northern Canada (under construction) through the International Union of Radio Scientists (URSI) to ensure that these facilities operate during as much of the IPY as possible. The EISCAT Svalbard Radar can provide essentially continuous incoherent scatter radar data throughout the entire interval IPY interval. Additional operations of the mainland radars, and the ionospheric modification facility, at Ramfjordmoen, near Tromsø, can be provided to cover on-demand observations in response to events identified by the Svalbard radar and/or other instrumentation such as optical sensors

NFR currently funds 10-12% of EISCAT annual costs through the EISCAT Agreement; the remainder is provided by Finland, France, Germany, Japan, Norway, Sweden, and the United Kingdom. This proposal request:

1) Additional funding to raise the EISCAT Svalbard Radar operation from 1500 hours per year to full-time operation during the period of the IPY (March 2007-March 2009).

2) Additional funding to add 650 hours per year of operations at the Ramfjord site to cover on-demand operation during the period of the IPY (March 2007-March 2009).

2.3 EQUIPMENT FOR CALIBRATION LABORATORY AT UNIS, SVALBARD (UNISCAL)

P.I.: Dr. Dag A. Lorentzen, Assoc. Prof. UNIS
Co-I.: Dr. Fred Sigernes, Assoc. Prof. UNIS

2.3.1 Introduction

Absolute calibration is essential for all measuring devices used in science. This type of calibration allows for comparison of data from similar and different types of instruments, making it possible to combine information from separate sources. In order to understand the physical phenomena studied and to apply these measurements in e.g., a model, data provided in absolute units are vital. It is also important to have easy access to calibration labs and equipment in order to absolute calibrate instruments on a routine basis.

2.3.2 The Auroral Observatory

A new optical auroral observatory close to Longyearbyen, Svalbard will be ready for operation during the IPY. The Kjell Henriksen Observatory (KHO) will provide an outstanding platform for optical measurements of auroral and ionospheric related physical processes. The observatory will be located close to the existing radar and heating installations (EISCAT, SPEAR) on the mountain of *Breinosa*, some 12 km from Longyearbyen. The observatory will contain about 20 optical instruments. In order to provide the best possible measurements during the IPY it is crucial that an easy access calibration facility exits.

2.3.3 UNIS calibration lab

The new science park at the University Centre in Svalbard (UNIS) has recently been opened. Within the science park is a calibration facility for optical instruments. The calibration lab features a mounting room, lamp room and screen room, with an ideal distance from lamp to screen of 10 meters. The calibration lab is currently outfitted with equipment from the old calibration lab at UNIS. In order to make this a state-of-the-art calibration laboratory we therefore propose to install an *integrating sphere* with necessary equipment.

2.3.4 The integrating sphere

An integrating sphere is a calibration tool providing uniform radiance *or* irradiance. It basically consists of a sphere coated on the inside by a diffuse reflecting material, with a coating reflectance of typically 98 %. Several entrance apertures introduce light with known intensity into the system, and the exit aperture provides a completely stable and uniform light source for absolute calibration. We propose to buy a system from Labsphere - a company that specializes in the design and manufacture of integrating spheres and systems. The Labsphere Large Uniform Source System USS 4000C, is an integrating sphere system capable of achieving a uniformity better than 98 % at the exit aperture.

The system features a 102 cm diameter integrating sphere designed to provide exceptionally uniform illuminance over a full 36 cm diameter sphere exit port. It also includes multiple lamps and associated lamp power supplies, as well as a monitor detector, photometer, and system calibration, which permit real-time monitoring of the system's luminance output. Calibration is traceable at the National Institute of Standards and Technology (NIST).

2.3.5 Conclusion

In order to meet the increasing interest of doing optical measurements of ionospheric related processes at Svalbard, the new calibration lab at UNIS will prove an important facility for measurement integrity, not only during the IPY, but for years to come. With the inclusion of an integrating sphere the calibration lab will have all the equipment needed for doing absolute calibration of optical instruments. The calibration facility is meant to be used by national and international scientists doing optical observations from Svalbard, and is as such an integral tool for assuring robust and reliable measurements.

2.4 MULTIPOINT OPTICAL OBSERVATIONS OF AURORAL SCALE INVARIANCE

PI: Prof. K. Rypdal, University of Tromsø, Norway.
Co-I: Dr. B. Kozelov, Polar Geophysical Institute, Apatity, Russia.
Co-I: Dr. E.M. Blixt, University of Tromsø, Norway.
Co-I: Dr. B. Gustavsson, University of Tromsø, Norway.
Co-I: Dr. A. Milovanov, University of Tromsø

The global magnetosphere – ionosphere system is a highly complex system which resides in a quasi-stationary state far from thermodynamic equilibrium. Such a system exhibits correlations across a wide range of scales in space and time. Despite the underlying complexity, observed signatures of the dynamics indicate a strong degree of self-organization manifested in fractal structure of high-latitude auroral disturbances. In particular, it has been found that spatiotemporal evolution of auroral emission regions, as depicted by the ultraviolet imager (UVI) onboard the Polar spacecraft and by ground-based television (TV) observations [Kozelov et al., 2004], follows broad-band power-law statistical relations. This includes power-law occurrence probabilities of the duration, area and energy output of the auroral emissions. These scaling relations strongly suggest the existence of a universal dynamical principle, such as self-organized criticality (SOC), which arranges the diverse plasma phenomena in a uniform scale-free fashion across quite different spatial and temporal scales [Freeman and Watkins, 2002].

Large-scale auroral activity is associated with activity in the magnetospheric tail, and it is possible to understand the UVI auroral image results in terms of SOC-dynamics in the tail.

At smaller scales, the observed scale-free statistics may represent the behavior of the coupled magnetosphere-ionosphere system and may be produced by plasma sheet instabilities and/or turbulence in the auroral acceleration region. If the auroral acceleration region plays a significant role, then the nearly identical power-law exponents for large and small scales might be explained by assuming that the tail and the auroral acceleration region both are in critical states described by so-called unified mean-field theory. Unfortunately, the relative contribution of the auroral acceleration region and the plasma sheet to the distribution of auroral structures remains unknown and can only be established through more sophisticated observations than is available at present. Observation of the scaling characteristics of the magnetosphere-ionosphere system via the optical aurora is very difficult because of the short scaling range of a single imager. The short range is caused by two factors; the resolution of the imager and the geometry of the aurora. Limited resolution means that one needs several imagers to cover a larger spatial range. The geometrical effect is more difficult to handle. Aurora is usually covering a large altitude region, from about 250 down to 100 km, and if the aurora is not within, say, about 10 degrees of magnetic zenith, the altitude spread can easily be misinterpreted as a wide horizontal feature.

To properly correct for the latter effect we will use three identical, spatially separated, optical systems with overlapping fields of view. The horizontal scales can then be correctly estimated through tomographic inversion techniques. The position and resolution of the imagers are optimized to study auroral features on scales ranging from 100 m to a few 10's of km. To cover larger scales than this, we need to integrate other optical imaging systems designed for larger scales. If the various optical systems are not properly inter-calibrated it is impossible to make proper analysis of the distribution of structures across the scales covered by the individual systems. Thanks to the IPY, this part of the problem can be solved. Many international research institutes perform optical observations in Svalbard, and these will intensify their work during the IPY. There also exist IPY programs that will coordinate these efforts, and specifically aim for inter-calibrating as many of the optical instruments as possible. See Expression of Intent, ID no: 118 within IPY, the Auroral Optical Network (co-PI Dr. Blixt is a member of that project), and also subproject UNISCAL of this project.

The optical auroral spectrum is mainly formed from line or band emissions from neutral or ionized N_2, O, O_2, H, and N. Emissions from metastable, "forbidden", states often dominate the spectrum and cause problems for interpretations as their long life time will smear out the optical signature of the aurora when it moves. The only way to capture the proper scale size of the aurora is by filtering out the metastable emission lines combined with high time resolution, a combination not easily satisfied. As scale invariance also should be observed in time, we also need high time resolution to span the largest possible range in time.

Our proposed solution is to deploy a three camera setup on Svalbard, where the individual cameras are filtered and extremely light sensitive in order to capture the true motion and scale of the prompt emission in the aurora. Each camera will have a 50 deg field of view to focus on the small to medium sized auroral events, and by locating them within the existing infrastructure in Longyearbyen (the new Kjell Henriksen Observatory), Barentsburg (Polar Geophysical Institute), and Svea, we will obtain perfect overlapping fields of view. One mobile imager will be borrowed from the Swedish ALIS system, and located in Svea, the second imager will be financed from UiTø and the money for the third imager is applied for in this project. The science part of this sub project has already begun in the NFR granted project: "Scale invariance in plasma and geospace systems - A cross-disciplinary approach to self organized critical behavior". In our aid we will hire MSc Josef Höök, Royal Institute of Technology, as a PhD student. His excellent background in both the technical side of operating advanced optical instruments and image processing will lend strong support to this project element.

Even though the present multipoint study will specifically focus on auroral scale invariance, it should be emphasized that detailed observation of small and medium scale auroral features constitutes an essential element of any coordinated optical, radar and satellite investigation of space weather related processes during IPY. The multipoint observations could also be very important during artificial aurora campaigns produced by the SPEAR facility near Longyearbyen.

2.5 MIDDLE ATMOSPHERE CHEMISTRY CHANGES INDUCED BY ENERGETIC PARTICLE PRECIPITATION.

Dr. Yvan J. Orsolini, Senior Scientist, Norwegian Institute for Air Research

Polar ozone and the chemistry of a variety of minor constituents in the middle atmosphere are influenced by energetic particle precipitation, primarily during solar proton events (SPE) in the polar regions, and by precipitating electrons in the auroral zone and lower latitudes. These solar-driven events produce ionisation, dissociation and excitation of various constituents. While the impact of such SPEs on the high-altitude nitrogen-dominated ozone chemistry has been known for decades [Crutzen et al, 1975], recent observations by several atmospheric chemistry space-borne instruments (e.g. MIPAS, HALOE, POAM, SAGE, OSIRIS,…) has allowed unprecedented coverage of many species, some for the first time. The effects of the exceptional "Halloween" solar storms of autumn 2003 have hence been studied in great detail [Natarajan et al., 2004; Randall et al., 2005; Jackman et al., 2005; López-Puertas et al., 2005].

The spring 2004 witnessed the largest decline in upper stratospheric ozone ever recorded in the northern hemisphere, with reductions up to 60%, associated to extraordinary high levels of nitrogen oxides (NOx). This unanticipated decline followed months of intense solar activity, in the aftermath of the autumn solar storms. Days following the "Halloween" SPEs, the stratospheric chemistry was very perturbed with short-lived anomalies in many species implicated in ozone chemistry (e.g. N_2O_5, HNO_3, $ClONO_2$, etc..). Longer-term effects mediated by nitrogen species (NOy) are important for ozone chemistry. MIPAS detected a distinct, anomalous high-altitude polar maximum in HNO_3 that appeared in late November 2003 near 40-45 km, giving rise to a remarkable double-peaked layer [Orsolini et al, 2005]. The HNO_3-enhanced layer in the polar vortex descended slowly into the mid stratosphere over a nearly two-month period. The slow formation and build-up of upper stratospheric HNO_3 is consistent with the heterogeneous chemistry on hydrated ion clusters in NO_2-rich conditions (de Zafra and Smyshlaev, 2001). These chemical processes are not commonly included in stratospheric chemistry transport models.

While nitrogen gases formed in the upper atmosphere (above 50km, in the mesosphere) as a result of the solar energetic particles, it is the unusual stratospheric weather in the winter and spring 2004 that allowed these anomalies to descend readily in the stratosphere. In February and March 2004, the polar stratospheric vortex sped up to record levels, thereby confining the NO_X-rich air to the dark high latitudes. This highlights that the coupling processes between the upper and lower atmosphere involved the interplay of chemistry and dynamics.

While weak HNO_3 enhancements are normally observed in both polar regions in winter [de Zafra and Smyshlaev, 2001], they are at times considerably magnified. Large enhancements have been also observed over Antarctica in winter 2003, a period void of SPEs [Stiller et al., 2005]. A recent analysis by Renard et al. [2006] based on satellite observations of electron fluxes by the SAMPEX instrument suggests that a second pulse of mesospheric NO_X originated in January 2004 from an intense precipitation of energetic electrons from the high-altitude magnetosphere, and that the second pulse could be implicated in the spring ozone decline. The impact of the precipitating electrons is harder to measure, but recent model studies [Rozanov et al., 2005] suggest that it is an important process for polar ozone chemistry in the stratosphere. It hence appears that several classes of geospace phenomena (SPEs, precipitating electrons from magnetospher) are involved in the observed perturbations of the stratospheric chemistry, and that these are coupled with dynamics, through downward but also meridional transport (e.g. during a stratospheric sudden warming, when the vortex is pushed off the pole into daylight).

2.5.1 Objectives

Use satellite and ground-based observations, as well as model studies to understand stratosphere and mesosphere chemistry changes induced by energetic particle precipitation. Study coupling processes between the different atmospheric layers and their connection with the solar activity.

2.5.2 Methodology and implementation

- **Comprehensive study of HNO_3 and NO_X high-altitude polar enhancements in both hemispheres, during the IPY years (2007-2008).**

A series of satellite observations will be mapped and analyzed in various ways, incl. flow-following coordinates. The concomitant meteorological conditions in the middle atmosphere will also be examined. We will use trace gases measurements (e.g. NO) from Antarctic Troll station microwave radiometer (British Antarctic Survey).

- **Correlation with particle precipitation and space weather events**

Space-borne and ground-based measurements of electron and proton fluxes will be examined, using satellite data (e.g. SAMPEX, DMSP, others), and the riometer network GLORIA in northern Norway (Tromsø, Andøya). The latter will be a collaboration with GLORIA coordinator Prof. Honary (U. of Lancaster), while in the former we will rely on the expertise of the Dept. of Phys. And Techn. at the Univ. of Bergen (N. Østgaard, A. Aksnes, [Sætre et al., 2004]). In addition, we will analyse a new, reprocessed MLS UARS data, where HNO_3 retrieval is extended higher, allowing for a correlative study with SPEs throughout the UARS years (1991-).

Table 2-1 Satellite Data (Primary data in bold)

Instrument	Species	Comments
EOS-MLS	**HNO_3,O_3,ClO**	
GOMOS	**NO_2**	
MIPAS	NOy, O_3	Pending reprocessing by ESA
IASI	HNO_3	Exploratory use of column values; launch on Met-Op in 2006
SAGE	NO_2, O_3	
ODIN-MR	HNO_3, O_3	

- **Modelling of NO_X and HNO_3 enhancements during selected periods in IPY, with atmospheric chemistry and transport models.**

The NILU lagrangian stratospheric chemistry box model will be used along a large number of trajectories, aiming at re-constructing chemical portrait of the upper stratosphere during the events. A lagrangian ensemble data assimilation experiment will be carried out for a selected, interesting period, based on observed constraints of, e.g. the NO_X abundances.

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