WP 16

Agenda Item: 6.4

Person Responsible: Dr. Maurizio Candidi

XXXI SCAR Delegates Meeting

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ICESTAR

Interhemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research

2010 Report to the Delegates

Executive Summary

Title: ICESTAR: Interhemispheric **C**onjugacy **E**ffects in **S**olar-**T**errestrial and **A**eronomy **R**esearch

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- We gratefully acknowledge contribution from the entire ICESTAR team.

Relevant URLs or references to other reports: http://scar-icestar.org and http://www.ipy-id63.org/

Introduction/ Background:
Near-Earth space (geospace) is an integral part of the Earth system, providing the material link between the Sun and Earth, primarily through the polar-regions. A primary goal of the ICESTAR Programme is to create an integrated, quantitative description of the upper atmosphere over Antarctica, and its coupling to the geospace environment.

Important Issues or Factors: ICESTAR will not propose for a second term as a Scientific Research Programme.

Recommendations/Actions and Justification:
At the completion on the programme in July 2010, ICESTAR will create an expert group to further develop the subject, building on the successes as a Scientific Research Programme.

Expected Benefits/Outcomes:
ICESTAR scientists have published more than 200 papers in journals that include Nature, Geophysical Research Letters, and the Journal of Geophysics Research. Since the start of the program, ICESTAR further enhanced the SCAR profile by hosting and convening numerous scientific sessions at international conferences (e.g., American and European Geophysical Union Conferences, CEDAR, GEM).

ICESTAR has, or is in the process of, delivering a wide variety of products ranging from a better scientific understanding of the polar atmosphere to a data portal that will enable scientists to create a systems-view of the polar region. Specific current/future plans include the following:

- update and maintain ICESTAR website;
- publish in journals and conference proceedings;
- provide input to databases;
- develop and grow data portals;
- develop and quantify the role of seasonal differences in polar ionospheric conductance and the effects on magnetospheric, ionospheric, and thermospheric dynamics;
- constrain models based on conjugate remote sensing of inner magnetospheric dynamics; and
- characterize the basic state of the polar middle atmosphere.

Budget Implications:
The Scientific Research Programme ICESTAR will not be requesting funds during the next SCAR cycle. A small amount of funding will be requested to maintain the ICESTAR expert group.

1. Rationale

The ICESTAR Programme is defining and implementing an integrated, quantitative description of the upper atmosphere over Antarctica, and its coupling to the global atmosphere and the geospace environment. The primary reasons to embark on the endeavour are outlined below.

A. **The Emergence of New Datasets and Grid Technology:** The volume of experimental data has been increasing significantly in recent years. In addition, many new datasets are expected to come on-line in the near future. At this time, there are new magnetometer chains, new polar orbiting satellites which allow the simultaneous view of the Southern and Northern polar regions, new ionospheric (SuperDARN, AMISR, and EISCAT) radars, new mesospheric/thermospheric wind measurements (meteor radars, FPIs), new digisonde and TEC data. ICESTAR is helping create the tools needed to examine the entire system as a whole. The creation of visualization tools that can utilize globally distributed data sets will push the limits of the current technologies and will spark the creation of new Grid functions. In addition, enabling the convergence of data and models is another strong goal of the Grid technology, which is synergistic with the programme goals.

B. **Focused Science:** ICESTAR fosters focused upper atmosphere scientific research from Antarctica. One goal is to determine how this region of space fits within the global system. No other programme exists which is focused specifically on the quantitative understanding of the upper atmosphere above the Antarctic.

C. **International Cooperation:** Studies of the polar upper atmosphere fundamentally require international collaboration. Consider first the deployment of instruments across Antarctica. These instruments are either located at manned bases or are remotely deployed and serviced from such bases. From a logistical and financial standpoint, it is not feasible to deploy a network of instrumentation in Antarctica without international collaboration. The problem is even more complex in the Arctic as individual countries there have control over portions of the region. With instruments being deployed and operated by different countries, international collaboration is essential so that data can be exchanged and integrated.

D. **Uniqueness of Antarctica.** The Antarctic continent offers a unique vantage point for examining the near-Earth space environment, spanning from the top of the troposphere, through the stratosphere, mesosphere, thermosphere, and ionosphere, and into the magnetosphere. Here we underscore some of the similarities and differences between the Arctic and Antarctic:
   - different underlying neutral atmosphere, e.g., planetary waves and gravity waves morphology is very different, and more intense jet stream exists in the Antarctic;
   - Much larger displacement of the magnetic dip pole in the South than in the North, which means it is much easier to separate effects that are controlled by solar radiation;
   - The geomagnetic field is weakest in the South Atlantic sector and thus, the flux of energetic particles is higher than anywhere else on Earth.

2. Overview of Progress

Selected Scientific Highlight 1: ICESTAR scientists present in Nature images of the aurora taken simultaneously in the Northern and the Southern hemispheres. These images reveal indisputable evidence that the auroras in the two hemispheres can be totally asymmetric. These findings contradict the commonly made assumption of aurora being mirror images of each other. See Nature 460, 491-493 (2009).

Selected Scientific Highlight 2: An international scientific consortium that includes ICESTAR team members has successfully developed a series of autonomous observatories in Antarctica that for the first time provide critical year-round "space weather" data from the Earth's harshest environment. Recently, data from these observatories were used in conjunction with the array of THEMIS satellites to reveal new information about magnetospheric substorms, the sudden release of energy that causes auroral displays. See J. Geophys. Res., doi: 10.1029 /2008JA013507 (2008) and Rev. Sci. Instrum., doi: 10.1063/1.3262506 (2009).

AGU Special Session: Interhemispheric Similarities and Asymmetries in Geospace Phenomena: The ICESTAR team convened a scientific session at the 2009 Fall American Geophysical meeting in San Francisco. More than 20 papers reported on measurements of high-latitude electromagnetic fields, currents, and auroras in the conjugate hemispheres have revealed latitudinal, longitudinal and hemispheric asymmetries. Such global-scale MI coupling effects should be predicted by global models, yet many fundamental questions remain. For example, can asymmetries in auroral intensity and morphology be accounted for by tilt angle and IMF influence on the magnetosphere? Or is the energy input from the solar wind to the magnetosphere different in the two hemispheres? What is the role of seasonal conductivity differences and inter-hemispherical currents? Conjugate imaging from space, measurements from ground-based facilities and statistical studies are used to address these questions. These and other outstanding questions were discussed, together with suggestions on how they could be solved with the massive data sets which we now have in our hands. ICESTAR plays an important role in these activities by organizing and helping to develop data portals, such as GAIA (see below).

GAIA Data Portal: The ICESTAR team continues to develop and refine the Global Auroral Imaging Access (GAIA) data portal; see http://gaia-vxo.org. GAIA is a virtual observatory for dealing with data from geospace optical and riometer systems. While these two instruments differ in observational technique, they both remotely sense auroral precipitation. GAIA is a network-based set of tools for browsing summary data from All-Sky Imagers (ASIs), Meridian Scanning Photometers (MSPs), and riometers worldwide. It provides indexes for direct access to data. Over 10,000,000 summary images are registered in the GAIA database. They and the associated metadata provide a link to hundreds of “imager years” of data from observational programs in at least seven countries. This program is the virtual observatory component of the IPY Auroral Optical Network (AON) and GLORIA projects, and falls under the ICESTAR IPY umbrella. Prof. Eric Donovan, the lead on GAIA, joined the ICESTAR team as a Thematic Action Group (TAG) leader in 2008. Dr. Eric Donovan is an Associate Professor in the Department of Physics and Astronomy at the University of Calgary.

International Polar Year Project #63: ICESTAR co-chair Dr. Kirsti Kauristie of the Finnish Meteorological Institute provides leadership in IPY Project # 63, *Heliosphere Impact on Geospace*, which includes 29 international research groups and is jointly managed by the International Heliophysical Year (IHY) group.

International Heliophysical Year (IHY, http://ihy2007.org) was established as a "sister program" for IPY. IHY coordinates multinational research advancing the understanding of the fundamental heliophysical processes that govern the Sun, Earth and Heliosphere. During the IPY years IHY established with the support of United Nations space science activities in several developing countries. The activities were organized as Coordinated Investigation Programmes which were categorized under seven themes as schematically illustrated in the figure below.

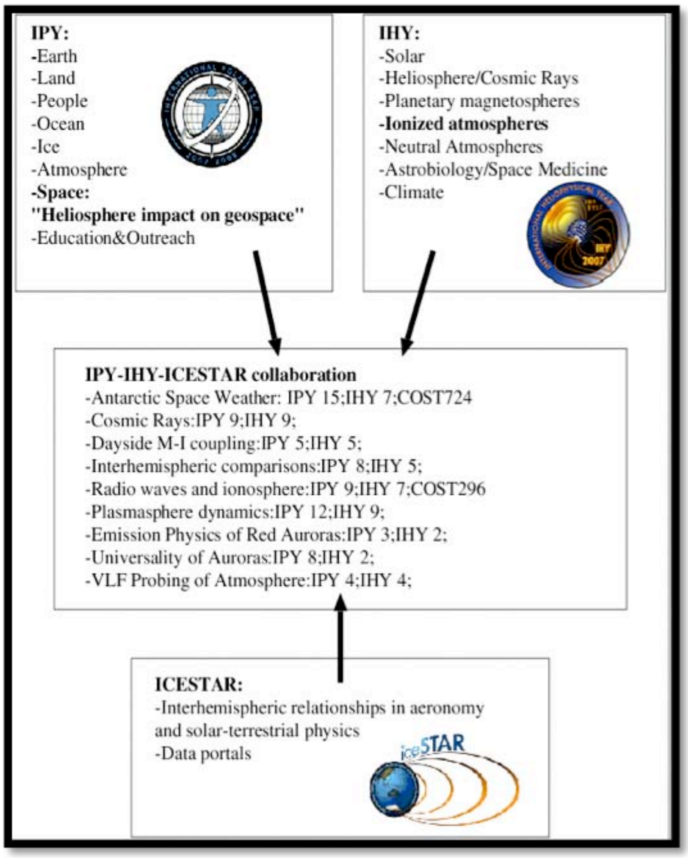

Figure 1: *Networking between IPY, IHY and ICESTAR. The contents of IHY-IPY-ICESTAR box highlight collaboration between some projects that participated in all three initiatives (Figure adapted from Kauristie et al., 2008).*

Already at the beginning of the IPY campaign more than 50 research groups had submitted their proposals for CIPs. The outcome of these activities is summarized in the book "Putting the "I" in IHY" (Editors: Thompson, Gopalswamy, Davila, and Haubold). IHY officially ended in March 2009 but multinational research still continues through the International Space Weather Initiative and as Whole Heliosphere Interval activities.

ICESTAR and IHY, together with 27 other initiatives, conducted the IPY core project #63 with the title "Heliosphere impact on geospace". A kick-off meeting of the program was arranged in Helsinki in February 2007. Nine of the sub-projects within the IPY-cluster 63 registered themselves also as IHY CIPs. Figure 1 lists these projects and describes the networking between IPY, IHY and ICESTAR in space science coordination. ICESTAR and IHY have had complementary roles in the Cluster 63 activities: IHY has arranged overarching synoptic observation campaigns and provided systems and assessment processes in order to facilitate the harvesting of interdisciplinary observations. ICESTAR has led the efforts in establishing Virtual Observatories (VOs) for various geospace observations.

Selected ICESTAR Publications in Peer Reviewed Literature

ICESTAR scientists have published more than 200 papers since 2006.

- Ebihara, Y., R. Kataoka, A. T. Weatherwax, and M. Yamauchi (2010), Dayside proton aurora associated with magnetic impulse events: South Pole observations, *J. Geophys. Res.*, 115, A04301, doi:10.1029/2009JA014760.
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- Østgaard, N., K. Snekvik, A. L. Borg, A. Åsnes, A. Pedersen, M. Øieroset, T. Phan, and S. E. Haaland (2009), Can magnetotail reconnection produce the auroral intensities observed in the conjugate ionosphere?, *J. Geophys. Res.*, 114, A06204, doi:10.1029/2009JA014185.

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- Engebretson, M. J., et al. (2008), Pc1–Pc2 waves and energetic particle precipitation during and after magnetic storms: Superposed epoch analysis and case studies, *J. Geophys. Res.*, 113, A01211, doi:10.1029/2007JA012362.
- Bhardwaj, Anil; Randall Gladstone, G.; Elsner, Ronald F.; Østgaard, Nikolai; Hunter Waite, J.; Cravens, Thomas E.; Chang, Shen-Wu; Majeed, Tariq; Metzger, Albert E.: First terrestrial soft X-ray auroral observation by the Chandra X-ray Observatory, Journal of Atmospheric and Solar-Terrestrial Physics, Volume 69, Issue 1-2, p. 179-187, 10.1016/j.jastp.2006.07.011, 2007.
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- Kozlovsky, Alexander; Aikio, Anita; Turunen, Tauno; Nilsson, Hans; Sergienko, Tima; Safargaleev, Vladimir; Kauristie, Kirsti: Dynamics and electric currents of morningside Sun-aligned auroral arcs, Journal of Geophysical Research, Volume 112, Issue A6, CiteID A06306, 10.1029/2006JA012244, 2007.
- Kuznetsov, E. A.; Savin, S. P.; Amata, E.; Dunlop, M.; Khotyaintsev, Y.; Zelenyi, L. M.; Panov, E. V.; Büchner, J.; Romanov, S. A.; Blecki, J.; Rauch, J. L.; Nikutowski, B.: Strong space plasma magnetic barriers and Alfvénic collapse, JETP Letters, Volume 85, Issue 5, pp.236-241, 10.1134/S0021364007050049, 2007
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Selected ICESTAR presentations and invited talks

- **Heliosphere Impact on Geospace:** ICESTAR and IHY initiatives together with 27 other multinational research projects will form one of the core projects of the forthcoming International Polar Year (IPY, March 2007 - March 2009): IPY ID 63 "Heliosphere Impact on Geospace". The project has three main themes in its scientific work: (i) Coupling processes between the different atmospheric layers and their connection with solar activity, (ii) Energy and mass exchange between the ionosphere, the magnetosphere, and the heliosphere, and (iii) Inter-hemispheric similarities and asymmetries in geospace phenomena. Examples of topics to be addressed are remote sensing of ionospheric and radiation belt dynamics and of global geoelectric circuit, effects of solar energetic particles in mid-atmospheric chemistry, and planetary waves in the coupled mesosphere-thermosphere- ionosphere system. The final goal is to achieve better understanding on the geospace response to solar activity as a unified system and consequently to improve our capabilities to predict space weather phenomena. In addition to high-quality science IPY anticipates its core projects to conduct comprehensive education and public outreach activities and to develop efficient data sharing methods. *See A. T. Weatherwax, K. Kauristie et al,, Heliosphere Impact on Geospace - Solar-Terrestrial and Aeronomy Research During the IPY Years, Eos Trans. AGU, 87*(52), *Fall Meet. Suppl., Abstract U14C-01 for further details.*

- **IHY/IPY study of Interhemispheric Relationships:** ICESTAR (Interhemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research) is a programme coordinating multinational research on Sun-Earth connections. ICESTAR concentrates on magnetospheric and upper atmospheric responses to solar inputs, with a particular focus on inter-hemispheric relationships. Key aspects of our approach include the networking of ground-based instruments, the closely related issue of fostering international collaboration, and open web-based access to the relevant data. To accomplish the latter, we are involved in the development of virtual observatories and are adhering to the overarching philosophies of the IHY and eGY. IHY and ICESTAR have submitted a proposal for a core project status to the Joint Committee of the International Polar Year (IPY). This initiative, "ICESTAR/IHY - Interhemispheric Conjugacy in Geospace Phenomena and their Heliospheric Drivers", includes 24 research groups from more than twenty countries. Harvesting the unique opportunities of IPY in a timely fashion will be challenging. In addition to far- reaching interdisciplinary scientific work IPY is looking forward to exciting new education and outreach activities and efficient utilization of the latest advancements in computer and communications technology. Preparatory work to meet these ambitious objectives has already started within the ICESTAR/IHY community. In the presentation we outline our scientific goals and implementation plan, our progress to date, and describe activities to facilitate cooperative research. *See Donovan et al., Eos Trans. AGU, 87(36), Jt. Assem. Suppl., Abstract U34A-05.*

Selected details of the SRP web site

- **ICESTAR Website**: Established to facilitate international communication.
    - http://www.scar-icestar.org

- **ICESTAR-IHY-IPY Website***:* A distinct website established to facilitate international communication on IPY Project #63, *Heliosphere Impact on Geospace.*
    - http://www.ipy-id63.org/

Information on SRP database(s), and amount of use of database(s)

At the ICESTAR workshop in July 2005 Toulouse, data sharing issues were discussed for the first time among a wider community including representatives of some of the most widely used existing geospace data servers (e.g. SPIDR and CDAWeb, for more details see the notes of this meeting in http://scar-icestar.org. It was decided in the workshop that special attention in the first phase will be paid to three data servers: VGMO (magnetometer data), GAIA (auroral precipitation data), and Madrigal (Incoherent scatter radar data). The aim is to build or upgrade these systems so that they have easily adoptable interfaces both to the direction of the users and the data providers. A more ambitious goal will be to make the systems to communicate electronically.

GAIA Virtual Observatory

- GAIA is presently operational and managed by research groups at the University of Calgary, Lancaster University, and the Finnish Meteorological Institute.
- See http://gaia-vxo.org.
- Prof. Eric Donovan recently joined the ICESTAR team as a Thematic Action Group (TAG) leader focused on VO development.

SuperMAG

- ICESTAR scientists are key contributors to SuperMAG, an initiative which will use data from all available ground magnetometer stations.

Education and Training

For direct communication with the general public ICESTAR-IHY-IPY has established an outreach programme which aims to coordinate parallel semi-annual media events in all participant countries during the IPY years. These events will be realized as press releases and popular lectures summarizing the recent scientific findings of the project. For the audience keen on observing the environment several research groups will put up web-interfaces to show real-time data from their instrumentation. The public understanding of geospace science will be expanded also in collaboration with national research councils. The IPY 2007 Space Science Symposium and the “Life on Icy Worlds” conference, respectively, planned to be arranged in Greenland and in Alaska will be important forums for educating national science administrators and teachers about historical and forth coming research activities with the perspectives from Arctic natives, Antarctic scientists, and solar system explorers.

To educate next generation of geospace scientists ICESTAR-IHY-IPY will together with space science centres provide plenty of material for interesting and challenging exercises and thesis works. Students will participate in the measurement campaigns and in the development of the modern data-sharing systems. The easily accessible data-archives will provide important reference material for observational and theoretical investigations.

ICESTAR Coordinated Workshops and Scientific Meetings

- **AGU Special Session: Interhemispheric Similarities and Asymmetries in Geospace Phenomena:** The ICESTAR team convened a scientific session at the 2009 Fall American Geophysical meeting in San Francisco, as detailed above.
- **International Riometer Workshop III (June 22, 2008):** Riometers are emerging as an important tool in both space science and space weather. Global networks of imaging and single beam riometers support studies of high energy CPS and radiation belt electron precipitation, dynamic magnetosopheric processes such as dispersionless injections, the effect of geospace processes on high latitude atmospheric composition and dynamics, and the effects of polar cap high energy proton precipitation on communications Agreements between data providers, under the auspices of the IPY ICESTAR and Gloria initiatives, and facilitated by the GAIA Virtual Observatory, are on the verge of enabling ready access to these data. The Third International Workshop on Riometry is being held from 9:00 AM to 5:00 PM on Sunday, June 22, 2008 at the Zermatt Resort in Utah.
- **Polar Gateways Arctic Circle Sunrise (Jan. 23-29, 2008):** ICESTAR co-sponsors the Polar Gateways Arctic Circle Sunrise 2008, Barrow, AK, Jan. 23-29, 2008
- **Greenland Space Science Symposium (May 2007):** The Greenland Space Science Symposium was arranged in May 2007 to celebrate Greenland’s rich history in using arrays of scientific instruments for monitoring geospace phenomena. The program of the symposium included both historical reviews and presentations describing the latest advancements in observations and modeling of solar-terrestrial and aeronomy phenomena in polar areas. The ICESTAR project had a dedicated

session in the symposium with the title "Solar Influence on Geospace as Determined by Hemispherically Conjugate Observations".

3. Major Tasks and Timeframe

ICESTAR will transition from a Scientific Research Programmes to an Expert Group in 2010

4. Final Deliverables

The aim is to deliver a wide variety of products ranging from a better scientific understanding of the polar atmosphere to a data portal that will enable scientists to create a systems-view of the polar region. Specifics include the following.

A. update and maintain ICESTAR website;
B. publish in journals and conference proceedings;
C. provide input to databases;
D. develop and grow the GAIA data portal;
E. develop and quantify the role of seasonal differences in polar ionospheric conductance and the effects on magnetospheric, ionospheric, and thermospheric dynamics;
F. constrain models based on conjugate remote sensing of inner magnetospheric dynamics;
G. characterize the basic state of the polar middle atmosphere.

5. Budget

The ICESTAR budget has been spent down and has a zero balance.

END OF ICESTAR REPORT