# THE CEDAR POST

COUPLING, ENERGETICS AND DYNAMICS OF ATMOSPHERIC REGIONS

## From the CSSC Chair

New Research Opportunities
for Aeronomy Scientists Abound:

- AMISR Poker Flat operations have begun.
- AMISR - NASA rocket campaigns at Poker Flat underway.
- AIM launched successfully.
- THEMIS launched and THEMIS Ground-Based Observatory running.
- A thermospheric MURI approved.
- Arecibo Observatory to get a heater facility.
- IPY ISR campaign has begun.

Planning for Future NSF Aeronomy Concepts is also in the Works:

- NSF organizes a Small Satellite Workshop.
- An Aeronomy DASI Workshop day at CEDAR 2007.

The CEDAR Community welcomes Dr. Cassandra Fesen as the new Aeronomy Program Director, while Bob Kerr takes over at Arecibo. Additional updates and information are found inside.

See you all at the CEDAR 2007 Workshop in Santa Fe!

Jan J. Sojka
Utah State University

## From the CEDAR Science Steering Committee Chair

*Jan J. Sojka*

The CEDAR 2007 Workshop will be giving the entire day on June 29 to the topic of Distributed Arrays of Small Instruments (DASI).

This topic applies to almost every aspect of CEDAR science and aeronomy. Specifically our cutting edges in research have matured to the point that simultaneous, multi-point, observations of many parameters are needed in order to understand the complex inhomogeneous system we call the upper atmosphere-ionosphere.

Originally, the concept was highlighted in the recent space science Decadel Survey that suggested one DASI that was possibly global in extent. As our community discusses and debates its needs, it is evident that even within CEDAR science there are many cutting-edge problems that need DASI approaches. These differ not only in instrumentation, but also in regional distributions. However, they do all have the same infrastructure and networking needs. One way to move forward is through mini-DASIs for specific science questions with the long-term plan of having them coalesce into one DASI.

There are prototype DASIs in place. Cesar Valladares has his LISN distributions of ionosondes, GPS receivers, and magnetometers being deployed on either side of the magneticequator in South America to study the dynamics of the low-equatorial latitude ionosphere. Eric Donavan has deployed similar instruments in the Canadian auroral region, including an overlapping mosaic of all-sky cameras. This THEMIS Ground-Based Observatory (GBO) will observe the auroral substorms while the NASA THEMIS satellites lie in the magnetosphere on the same auroral field lines. See real time auroral imagery at the GBO website, *http://aurora.phys.ucalgary.ca/cgi-bin/themis_gbo_realtime.pl*

Both of these DASIs have had unique challenges in terms of infrastructure and networking. They provide excellent first-hand experiences to us all as we consider DASI approaches to solving other CEDAR science questions. In 2006 the CEDAR Workshop held a CEDAR Science Frontiers Workshop which generated almost 40 Frontier questions. Almost half of these are DASI in nature, hence, we have a core of questions. The DASI 2007 Workshop will be an open forum workshop covering the diverse range of CEDAR and aeronomy science questions. It will consider aspects of infrastructure, networking, and how science is generated from vast amounts of multi-point and multi-instrument observations.

I encourage you all to attend and help drive CEDAR to a new science frontier.

## CEDAR 2007 Workshop at a Glance

**Sunday 24 June:** Student Workshop
"*Winds in the Upper Atmosphere*"

**Monday 25 June:** *4 Workshops*
Plenary presentations
CEDAR Prize Lecture by John Plane
Poster Session #1 (non-MLT)

**Tuesday 26 June:** *9 Workshops*
Tutorial 1: "*Meteor Science*" by Diego Janches
Poster Session #2 (MLT)

**Wednesday 27 June:** *6 Workshops*
Tutorial 2: "*Modeling the Mesosphere*"
by David Siskind

**Thursday 28 June:** *6 Workshops*
Tutorial 3: "*Observations of the Mesosphere*"
by John Meriwether

**Friday 29 June:**
Distributed Arrays of Small Instrument (DASI) Workshop

**For Details See: http://cedarweb.hao.ucar.edu**

## Update from NSF

*Bob Robinson*

Bob Kerr left his position as the Aeronomy Program Director on February 16, 2007. Bob is now the Site Director at the Arecibo Observatory. All his colleagues at NSF thank him for his years of outstanding work here, and we wish him well with his new position.

The new Aeronomy Program Director is Cassandra Fesen serving as an IPA from Clemson University. We are extremely happy to welcome Cassandra to NSF. Her excellent scientific record in atmospheric sciences and her active participation in the CEDAR Program assure us that the community will be well-served and well-represented at NSF. During the time between Bob Kerr's departure and Cassandra's arrival, Dr. Therese Moretto was Acting Aeronomy Program Director. Therese has been helping out with the Aeronomy Program for a long time, and she will continue to assist as Cassandra learns the NSF ropes. We greatly appreciate Therese's diligence in ensuring continuing attention to Aeronomy proposals.

In January 2007, the Assistant Director for Geosciences, Dr. Margaret Leinen, left NSF, and the Division Director of Atmospheric Sciences, Jarvis Moyers, became Acting Assistant Director. In turn, Rich Behnke was appointed Acting Division Director and Bob Robinson moved up to become Acting Section Head for the Upper Atmospheric Research Section. These reassignments will be in place until a new AD for Geosciences is selected.

This is a particularly challenging time for the Aeronomy Program. The past year has seen a record number of proposals submitted to the program. Although NSF's 2007 budget finally came through with a substantial increase over FY2006, budget uncertainties up till then made it difficult to make final decisions on many pending proposals. Even now, we are not sure what the final operating plan will be for the Upper Atmospheric Research Section, so processing of proposals will still be somewhat delayed.

An important new endeavor being undertaken by the Upper Atmospheric Research Section is an investigation of the feasibility of launching small satellites to fill unmet observational needs, particularly in space weather. This is in response to a specific recommendation from a recent review of the National Space Weather Program conducted by a high level committee led by Louis Lanzerotti. The report of that committee can be found at *http://www.nswp.gov/nswp_acreport0706.pdf* . As a major step in this effort, NSF is organizing a Small Satellite Workshop to be held in Arlington, Virginia, May 17-19, 2007.

We are all excited about the initiation of operations of the Advanced Modular Incoherent Scatter Radar (AMISR) at Poker Flat, Alaska, in January 2007. Referred to as the Poker Flat Incoherent Scatter Radar or PFISR, the new radar is already making high quality measurements of the auroral ionosphere, and successfully made coordinated observations with ten NASA sounding rocket launches from Poker Flat. The NSF press release for AMISR is included in this CEDAR Post.

Another recent development is the official announcement that the Air Force Office of Scientific Research and the Office of Naval Research are jointly funding a Defense University Research Instrumentation Project (DURIP) from Cornell University to construct an ionospheric heating facility at the Arecibo Observatory. The balance of the funding for this facility will be from NSF. The new heater will reestablish an important capability that was lost from Arecibo many years ago as a result of hurricane damage. The unsurpassed sensitivity of the Arecibo Radar will enable unique studies of the heated regions of the ionosphere, opening up new frontiers in radio science, plasma physics, and aeronomy.

All in all, the outlook for Aeronomy and CEDAR remains extremely positive. Our community will continue to benefit from the excellent progress in scientific understanding

and broader impacts that has been the hallmark of CEDAR for many years.

## SRI International Begins Alaska Operation of its New Upper Atmospheric Radar System

***Unique system provides unprecedented view into the complex physical processes that couple the sun, magnetosphere, and ionosphere***

NSF press release for the AMISR project.

MENLO PARK, Calif. – April 2007 – SRI International, an independent nonprofit research and development organization, announced today that it has completed construction and begun operation of the Advanced Modular Incoherent Scatter Radar (AMISR), a modular, mobile radar facility. The development and construction of the facility was funded by the National Science Foundation (NSF), and is designed to study the high-latitude atmosphere and ionosphere and to observe space weather events, which can potentially damage and interrupt power grids and satellite and electronic communication.

Although the NSF operates other large incoherent scatter radars, including ones located in Greenland, Peru, Puerto Rico and Massachusetts, SRI's AMISR facility in Poker Flat, Alaska is the first NSF-funded radar that was designed and built specifically for scientific research. AMISR also supports the International Polar Year (IPY), an international research program focusing on the polar regions of the world.

The term "incoherent scatter" refers to the way in which transmitted radio waves are reflected by ambient electrons in the atmosphere. Using high-powered transmitters and sensitive receivers, scientists can analyze the backscattered signals to determine the density, temperature, and velocity of electrons in the ionosphere over several hundreds of kilometers of altitude. Whereas other incoherent scatter radars use a single high-powered transmitter, AMISR uses an array of antennas, each of which is driven by a specially designed, solid-state, 500-watt transmitter. AMISR measures 40 meters on a side and is made up of about 3,000 antennas, giving a combined power of 1.5 megawatts. By phasing the signal coming from the individual antennas, the radar beam can be steered almost instantaneously from one position in the sky to another. This unique feature of AMISR is especially important for studying rapidly moving features of the atmosphere.

In Poker Flat, the radar system will be used to study the aurora borealis and other dynamic features of the high-latitude ionosphere. By measuring the electric fields and particles at high latitudes, scientists can study how the magnetosphere, an immense comet-shaped structure around the Earth that extends tens of thousands of kilometers into space, changes in response to solar storms. This is important for predicting space weather, which can disrupt technical systems such as electric power distribution, navigation, communication, and aviation.

AMISR began operations in January 2007. Many of the observations in its first two months of operation were coordinated with NASA rockets launched from the nearby Poker Flat Research Range. AMISR observations were critical in determining the correct launch conditions, and its measurements will be used extensively in the analysis and interpretation of data sent by the rockets. Utah State University researcher, Jan Sojka, is one of many scientists who have requested experiment time on the new radar. His objective is to study how the ionosphere changes in response to energy input from above and below. He has scheduled AMISR observations every 10 minutes for the entire year. Sojka explains, "The year-long AMISR data set will contain the information we need to resolve long-standing questions about how the ionosphere responds to energy input associated with such phenomena as the aurora borealis and atmospheric waves and tides. Only AMISR has the necessary temporal and spatial resolution to study this very dynamic region of Earth's atmosphere."

The AMISR system at Poker Flat is the first of three radars to be constructed by SRI. The next two radars will be constructed in 2008 in

ArcticCanada, at Resolute Bay in the territory of Nunavut. These will be the highest-latitude incoherent scatter radars in the world and will provide unprecedented views of the complex physical processes that couple the sun, magnetosphere, and ionosphere.

"Because the AMISR system is configured in modules, the facility can be relocated for studying upper atmospheric activity around the globe," said John Kelly, Ph.D. program director at SRI's Center for GeoSpace Studies. "In addition, each of the three antennae faces of the AMISR system can operate together or be independently deployed in up to three separate locations. This facilitates comprehensive data gathering to increase our scientific understanding of upper atmospheric phenomena, which ultimately will help prevent the potentially large economic losses that can result from severe space weather events."

Several companies are supporting the SRI-led project. These include subcontractor Sanmina-SCI, which manufactures the Antenna Element Units, the basic building blocks of the radar panels. VECO Alaska Inc. oversees design and structural engineering of the radar, including the panels and support scaffolding. The Massachusetts Institute of Technology (MIT) is a co-investigator on the project.

More information about AMISR can be found at *http://isr.sri.com/iono/amisr*.

## Congratulations to AIM!


On April 25, 2007 this NASA Small Explorer spacecraft was launched successfully by an Orbital Science Corporation Pegasus rocket into a high inclination, near circular 600 km orbit. AIM (Aeronomy of Ice in the Mesosphere) is a 2-year mission designed specifically to investigate why Polar Mesospheric Clouds (PMCs) form and to discover what is causing them to vary. Recent measurements have shown significant increases in cloud brightness and occurrence frequency possibly in association with global warming trends. The spacecraft commissioning is nearing completion and first measurements of the northern summer polar region are expected to start later in May. AIM carries 3 instruments: the Solar Occultation for Ice Experiment (SOFIE) which measures mesospheric ice mass, temperature, water vapor, dust, ozone, methane, nitric oxide and carbon dioxide; the Cloud Imaging and Particle Size (CIPS) instrument which will obtain large field UV images to study PMC occurrence frequency and extent, cloud particle microphysics, and gravity waves; and the Cosmic Dust Experiment (CDE) which measures the daily input of 100 $\mu$m radius cosmic dust particles into the Earth's upper atmosphere, which following ablation and re-condensation, are thought to produce nanometer size nucleation sites on which the PMC ice particles grow. The AIM mission is led by Dr. James M. Russell III (Hampton University) and includes a team of scientists from Virginia Tech, GATS Inc., University of Colorado, Naval Research Laboratory, Utah State University, George Mason University, and British Antarctic Survey.

Dr. David Byers of the Air Force Office of Scientific Research (AFOSR) office announced that a new Multi-University Research Initiative (MURI) is to be awarded to a team led by Dr. Jeff Forbes and Dr. Tim Fuller-Rowell in the area of thermospheric research with an emphasis on satellite drag issues.

## PFISR is open for business!

*Craig Heinselman*

The Poker Flat Incoherent Scatter Radar (PFISR), which is the first deployment of a fully capable AMISR system, commenced operations in January and February of this year to support the launches of ten NASA sounding rockets. The ISR measurements were used for launch decisions (via near real-time displays of basic and derived ionospheric parameters) and will provide important input to the analysis of the rocket measurements on several of the missions. Of particular interest were the on-line displays of ion velocity vectors as functions of invariant latitude and time, in conjunction with electron

density measurements in the same regions. These measurements helped locate regions with, e.g., sustained large Joule heating rates for two of the campaigns. In all, approximately 200 hours of observations were completed during these two months and these measurements will be available via the Madrigal Database as soon as final analysis and calibration are completed.

The PFISR system became available for all users (beyond the rocket campaign) on 1 March and has been operating a full schedule since that time. The initial user requests emerged, primarily, from the AMISR Science Planning Workshop in October 2006, though other observation campaigns have also been performed. The procedures for requesting time on PFISR can be found at *http://amisr.com*. Several on-line displays of currently operating experiments (when available) can also be found at *http://amisr.sri.com/pokerflat/monitor*.

## Summary of the CEDAR 2006 Workshop Eldorado Hotel, Santa Fe, NM June 19 - 23

*Barbara Emery, HAO/NCAR*

The CEDAR (Coupling, Energetics and Dynamics of Atmospheric Regions) Workshop for 2006 was held at the Eldorado Hotel in Santa Fe, New Mexico. A total of 312 participants, 91 coming to CEDAR for the first time, came from 67 institutions, 9 outside the United States and Puerto Rico. There were 42 universities, 18 laboratories, and 7 small businesses. Of the 124 CEDAR students and post-docs, 18 were undergraduate students, and 11 came from universities or labs in Taiwan (4), Japan (3), Peru (2) and Brazil (2). There were fewer foreign universities this year compared to previous years.

The Student Workshop was held on Monday instead of on Sunday, so three times the normal number of non-students came or about 40% of the audience. The coordinator of the Student Workshop was the first year CEDAR student representative Michael Nicolls of Cornell University, who just graduated last May, but who still has a second year on the CEDAR Science Steering Committee (CSSC). The theme of the Student Workshop was 'Introduction to Incoherent Scatter Theory, Techniques, and Coordinated Science' because the panels from the Advanced Modular Incoherent Scatter Radar (AMISR) are close to being ready for general use at Jicamarca in Peru, and at Poker Flat and Gakona in Alaska. The keynote tutorial was given by John Sahr of the University of Washington on 'Introduction to Ionospheric Radar Remote Sensing'. This talk and others are available in .pdf form at *http://cedarweb.hao.ucar.edu/workshop/archive/2006/agenda_2006.html*. Everyone enjoyed a quick sandwich for lunch before talks were resumed in the afternoon. After 4 PM, the students had free time for soccer in the park, or swimming and volleyball at the Fort Marcy Recreation Center under the direction of Carlos Martinis of Boston University, who was the second year student on the CSSC. Carlos also organized a salsa dance party Tuesday night, where Ilgin Seker of the Pennsylvania University gave dancing lessons to students and non-students alike. The new student representative joining Michael is Romina Nikoukar of the University of Illinois.

Ilgin Seker of PSU leads the class in salsa dancing in the Sunset room on Tuesday night.

The plenary sessions started on Tuesday, with introductions and the CEDAR Prize Lecture by Erhan Kudeki of the University of Illinois on 'Incoherent Scatter Radar Perpendicular to B'. Three tutorials were presented on the following days by Michael Mendillo of Boston University

('Comparative Aeronomy: Thermospheres and Ionospheres in the Solar System'), Larry Paxton of the Applied Physics Laboratory at the John Hopkins University on 'UV Remote Sensing', and Robert Schunk of Utah State University on the 'Ionosphere: Past, Present and Future Problems'. All these talks are available in .pdf form at *http://cedarweb.hao.ucar.edu /workshop/videolist.html*. Also on-line at *http://cedarweb.hao.ucar.edu/workshop/archive/ 2006/agenda_2006.html* is the science report on the Low-latitude Ionospheric Sensor Network (LISN) by Ceasar Valladares of Boston College and 5 of the 6 CEDAR Post-Doc reports by Josef Drexler of Cornell, Lars Dyrud of Center for Remote Sensing, Mitsum Eijiri of Utah State, Lara Waldrop of the University of Illinois, Paul Withers of Boston University, and Tao (Titus) Yuan of the Colorado State University. Peter Fox of HAO/NCAR also updated the community on 'The CEDAR Database and Virtual Observatory Efforts'. All the tutorials, student keynote and CEDAR Prize lecture are on video tape. Please contact Barbara Emery (emery@ucar.edu, HAO/NCAR, PO Box 3000, Boulder CO 80307) if interested in obtaining hard copies and/or videos.

A special plenary workshop coordinated by Richard Collins of the University of Alaska and Eric Donovan of the University of Calgary was on 'Frontiers in CEDAR Science: A workshop to develop campaigns that advance the frontiers in CEDAR Science'. Copies of the summaries by four panelists and the summary of community inputs given on Tuesday are located at *http://www.gi.alaska.edu/splidar/ CEDAR.html* along with 42 submissions from the community, 36 of which were submitted early enough to be part of the summaries. A follow-up session during a pizza lunch on Friday opened the floor to comments from the audience. Including the Student and Frontiers Workshops, there were 28 workshops total, the same number as last year. Final reports for most of the specific workshops are at: *http://cedarweb.hao.ucar.edu/workshop/archive/ 2006/wklist_2006.html*.

There were 136 posters at the Wednesday and Thursday poster sessions, including 88 student posters (4 more than the record from last year), of which 63 took part in the student poster competition. Prizes were a certificate and a selection of new and classic books collected by the poster chairman, Rick Doe of SRI. (Thanks to the community for the selection of books!) The judges picked first place winners from each session, Michael Nicolls of Cornell University who chose a book by Gurevich, and Kim Nielsen of Utah State University who chose a book by Hines. The second place ties were Alessandro Cerruti of Cornell (Schunk and Nagy book), Romina Nikoukar of the University of Illinois (Rishbeth and Garriott book), Luke Moore of Boston University (Chamberlain book), and Jeremy Riousset of the Pennsylvania State University (Landau and Liftshitz book). A special undergraduate award was also given to Tanya Rae Phillips of the University of Texas at Dallas (Schunk and Nagy book).

Part of the pleasures of CEDAR are dining/working outside the conference. At the Plaza Cafe from left to right: Pamela Loughmiller of Embry-Riddle, Ron Woodman from Jicamarca, Don Farley of Cornell, Barbara Emery of NCAR, Doug (Emery-)Geiger, and Wes Swartz of Cornell.

Santa Fe Destinations arranged most of the extra-curricular activities for the 2006 CEDAR Workshop. We took a 52-passenger bus from

Boulder, Colorado to Santa Fe and back with 9 students and 2 non-students. This bus was then used for trips and to take students back and forth between Fort Marcy Suites and the Eldorado Hotel. Santa Fe Destinations offered extra fee cooking classes and tours of Tsankawi Indian ruins, Tent Rocks, and the Pecos National Monument. We also took the bus for a shopping expedition at Tin-Nee-Ann's Trading Company.

The 2007 CEDAR Workshop will return to the Eldorado Hotel in Santa Fe, New Mexico June 24-29.

## Data Assimilation Article

The prior two issues of the CEDAR Post carried a series of articles on *data assimilation*. Specifically, the authors were asked to provide an overview on their implementation and concept of *data assimilation,* the objective of this approach being to provide the reader with a breadth appreciation of what *data assimilation* means to different researchers, all of whom are involved in assimilating data. This theme continues in this issue with the last article.

### A Comparative Perspective on Data Assimilation: How Can We Learn From Atmospheric/Oceanic Data Assimilation?

*Tomoko Matsuo*
*National Center for Atmospheric Research*

Since objective analysis of meteorological data was first attempted about 50 years ago, data assimilation methods have been successfully applied to various Earth systems. Data assimilation has benefited from the recent increase of (real-time) global observing systems and computing resources, and promises to increase our understanding and eventual prediction of those systems. This outlook makes data assimilation an appealing next-generation scientific tool for the CEDAR/GEM community. However, it is not straightforward to adapt the data assimilation methods traditionally developed in the atmospheric/oceanic context to the near-Earth space regimes. The near-Earth space is more strongly forced by the highly variable external sources and is significantly more dissipative in comparison with the meteorological and oceanic systems. The time scale of ``space weather'' (hours) is significantly shorter than that of ``meteorological weather'' (days) or ``oceanic weather'' (months). Furthermore, the characteristics of spatial coherence in the system becomes highly anisotropic because of the nature of electromagnetic forces. Owing to still relatively sparse observational data, the problem presents significant challenges. In this article I want to discuss how our community can take advantage of data assimilation developments in other fields, and shed light on commonalities and differences that emerge when applying the same statistical principles on very different physical systems.

**Lack of chaotic behavior**

The notion of a chaotic dynamical system which has traditionally underpinned meteorological and oceanic data assimilation developments becomes almost irrelevant, as the systems we are interested in do not exhibit a sensitive dependence on initial conditions (chaotic behavior). Instead, the systems are highly sensitive to their forcings, which often appear as time-dependent boundary conditions. Atmospheric/oceanic data assimilation (e.g., 4-dimensional variational methods) has often been formulated as a minimization problem being solved for initial conditions. Initial conditions obtained from data assimilation analysis are in turn used for forecasting, and hence data assimilation becomes a synonym for a forecasting technique. For the systems we are interested in, an analog would be to use such advanced dynamical data assimilation methods to obtain the (time dependent) forcing/boundary conditions in agreement with all the available observations. Although useful, this approach does not necessarily lead to a forecast of the systems. In ensemble filtering problems, the lack of chaotic behavior manifests in the way of populating ensemble members: By taking advantage of systems' sensitivity to their forcing, suitable ensemble members can be obtained by perturbing the forcing rather than by perturbing the initial conditions. This perturbation needs to be selectively applied with physical

understanding of the systems' sensitivity to a particular mode of the forcing variation. Furthermore, the damping nature of the system will contribute to the problem of filter divergence unless the variability of the system due to uncertainty in the forcing/boundary condition specification is properly accounted for. It is important that the numerical model of the physical system displays realistic sensitivity to variations in the forcing.

**Balance issues**

For multivariate analysis, it is important to fully recognize the assets of constraints (e.g., Ohm's law) posed by electromagnetic forces in the ionosphere and the magnetosphere. In analogy to dynamical (e.g., geostrophic and hydrostatic) balances in atmospheric data assimilation, electromagnetic balances serve as statistical properties that link the different variables. Such balance properties effectively reduce degrees of freedom, and should be incorporated into modeling of the prior (background error) covariance. For example, the electric field can be constrained from the observations of electric currents when the electric filed is unobservable. On the other hand the electric field observations should be consistent with observations of currents when both observations are available. These balance properties could be regarded as troublesome constraints to be imposed on the analysis, especially when the balance is not explicitly built into the prior covariance.

**Space/Time correlation**

Temporal and spatial coherence of the variables needs to be well incorporated into modeling of the prior (background error) covariance so that data void regions can be constrained from observations. For data sparse regions, it is critical to take advantage of long-range correlations, e.g., due to electromagnetic forces in the ionosphere and the magnetosphere or due to tidal features in the mesosphere and lower thermosphere. It is important to retain the long-range correlation even in ensemble filtering problems where the sample covariance is usually tapered in order to reduce the impacts of spurious correlations on large scales in the atmospheric/oceanic data assimilation applications.

**Representativeness error**

A simple probabilistic formula, the Bayes' theorem, under the assumption of a Gaussian process, which serves as a unifying framework for many of commonly used data assimilation methods, explains how the prior (background/forecast) and the observation are combined to produce the data assimilation analysis. This formula accounts not only for the mean state of the geophysical system (the first moment statistics) but also for the information of the geophysical variability summarized as covariance (the second moment statistics). There are two error covariances that come into play: the background/forecast error covariance and the observational error covariance. The observational error is actually composed of instrumental error and more importantly, of the representativeness error. The representativeness error stems from representing the state variables in a finite-dimensional computational model space, often at a resolution less than the required resolution to resolve observations. Additionally, inadequately approximated physics employed in the observation (forward) operator, which plays a role to convert the state variables to the observed quantity, contributes to the representativeness error. In AMIE e.g., the operator for ground magnetometer data assumes perfect knowledge of the conductance, negligible wind dynamo effects, and simplified current geometry when applying Biot-Savart's law (assumption of radial field-aligned currents and thin current layers for the ionospheric and induced terrestrial current systems). Difficulty to properly account for the representativeness error is one of the outstanding problems faced in applications of data assimilation to all geophysical systems.

# NOTEWORTHY

## Sodium Lidar Pioneer Turns 70

*Contributed by David A. Krueger*

Professor Chiao-Yao (Joe) She was greeted by a rousing cheer from the 90 students, family members, close friends, and collaborators gathered in August at the Fort Collins Senior Center to celebrate his 70th birthday. He was honored as a physicist who has provided ideas, motivation, inspiration, and guidance for research in nonlinear optics and lidar measurements in the atmosphere for over 38 years at the Physics Department at Colorado State University.

Some of the students and collaborators at the Fort Collins party: David Krueger, Shoou-yu Tang, Lucia She, Max Caldwell, Joe She, Sebastian Knitter, Raul Alvarez, Zhao-Ai Yan, Phil Acott, Sean Harrell, Angela Zhong, Titus Yuan, Joe Vance, Hans Moosmuller.

As many shared their personal experiences, common threads emerged. It seems like Professor She never sleeps. Until the day-time filter was developed, all the Lidar measurements were done at night. No matter when an exciting discovery occurred, Joe always wanted to be called at his home. He is always accessible to students and pushes their thought processes by simple, fundamental questions which are hard to answer without careful thought. The photos show many faces familiar to the CEDAR community as, over the years, they have all attended CEDAR annual meetings.

Earlier this summer, former students and collaborators celebrated with Professor She in Japan while attending the 23rd International Laser Radar Conference in Nara, Japan.

Joe She, Josef Höffner, Jonathan Friedman, John Hair, Jia Yue, Jay Yu in Japan

## A Week-Long Mini-Workshop on Sodium Resonance Lidar

*By C. Y. She, D. A. Krueger and S. C. Reising*

At the request and leadership of Michael Gaussa, Director of the Arctic Lidar Observatory for Middle Atmosphere Research (ALOMAR, 69°N, 16°E), Andenes, Norway, a five-day workshop on sodium resonance lidar was held at Fort Collins, Colorado during the week of August 21, 2006. The ALOMAR facility hosts a sodium resonance lidar developed by a partnership between CSU and Colorado Research Associates, with contributions from Institute of Atmospheric Physics, Germany, Andoya Rocket Range, Norway, and Norwegian Defence Research Institute. Although this workshop was not planned to coincide with the formal initiation of the Consortium of Resonance and Rayleigh Lidars (CRRL) on August 15, 2006, by the NSF Upper Atmosphere Research Section, it was none-the-less very timely. The original aim of this informal workshop was to provide to Michael Gaussa and Sandra Blindheim of ALOMAR an opportunity to gain further understanding of and hands-on experience with the physics, technology and operation of a sodium resonance lidar.

The workshop focused on five topics:

Monday: Doppler-free spectroscopy and laser locking – Joe She

Tuesday: Frequency shift using dual pass acousto-optic modulators – Titus Yuan

Wednesday: YAG laser and Pulsed Dye Amplifier (PDA) – Titus Yuan

Thursday: Faraday filter function and operation – Biff Williams

Friday: Monolithic Yag lasers and scanning of Sum-Frequency Generator – Phil Acott

The format for each daily topic except for Wednesday was the same, starting with 1-2 hours of classroom lecture and discussion led by the present and past Colorado State University (CSU) Physics Department personnel listed above, followed by demonstrations in the lidar facility at CSU's Christman Field. Since clear skies enabled lidar operation, no classroom lecture was conducted on Wednesday. The students learned about the YAG laser and PDA by observing CSU personnel start the lidar system in the early evening. Many students stayed until midnight and the data acquisition continued until Thursday afternoon when typical summer clouds arrived.

In addition to Michael Gaussa and Sandra Blindheim, five scientists from the University of Colorado (Xinzhao Chu, Johannes Wiig, Chihoko Yamashita, Paloma Farias, and Wentao Huang), eight from Colorado State University (Joe She, Titus Yuan, Zhaoai Yan, David Krueger, Sebastian Knitter, Sean Harrell, Phil Acott, and Steve Reising), and Biff Williams from Colorado Research Associates took advantage of this opportunity. Most were included in the group photo.

Group photo in front of Physics Department: in photo (from left to right) are Zhaoai Yan, Xinzhao Chu, Titus Yuan, Sandra Blindheim, Michael Gaussa, Phil Acott, Joe She, Sean Harrell, Wento Huang, Johannes Wiig, Paloma Farias, Dave Krueger, and Chihoko Yamashita.

## Select 2006 CEDAR Workshop Final Reports

**The CEDAR community has emphasized its annual workshops as the high point of community research activities. Each year the community comes together to hear from each other, to present, and to discuss scientific progress in workshops sponsored by the leaders of ongoing CEDAR working groups. These working groups and the creation of new ones, is a CEDAR grassroots enterprise and one our students are encouraged to actively take ownership in. This year's meeting in Santa Fe had 22 CEDAR workshops that presented ongoing CEDAR working group efforts. A selection of workshop reports are presented to provide a measure of the breath and depth of the CEDAR science, as well as student creativity and development.**

### CEDAR Frontiers - A session to present new initiatives that will advance our understanding of the Coupling, Energetics and Dynamics of Atmospheric Regions

*Conveners - Richard Collins, Eric Donovan*
*Panelists – Anthea Coster, Eric Donovan, Cassandra Fesen, Michael Kelley*

The CEDAR Science Steering Committee (CSSC) recognize the fact that much of the progress in CEDAR science has been associated with organized campaign studies. Recent community reviews and assessments have shown that campaign studies are associated with increases in the number of published studies and enhanced collaboration between investigators.

Acting on behalf of the CSSC the conveners invited members of the CEDAR community to identify new frontiers in CEDAR science that could spur new campaign initiatives. Community members were invited to submit their concepts to the convener before the

CEDAR meeting and these were posted to a public website that remains accessible at *http://www.gi.alaska.edu/splidar/CEDAR.html*.

The conveners organized the submissions into four broad areas and four summary talks. The summary talks and presenter were;

1. "Ionosphere, Magnetosphere and Thermosphere", Anthea Coster,
2. "Middle and Lower Atmosphere", Michael Kelley
3. "Validation and Assimilation", Cassandra Fesen,
4. "The Global View", Eric Donovan

These talks were presented on Tuesday morning in the plenary session. The conveners and panelists hosted a follow-up lunch town-hall meeting on Friday.

The community submissions and discussion highlighted the following questions;

1. How will the CEDAR community better coordinate the use of increasingly accurate and high-resolution models (e.g. WACCM) in planning key observational studies?
2. How will the CEDAR community respond to societal needs to predict and forecast the state of the middle and upper atmosphere?
3. How can the CEDAR community foster better collaboration between US and international investigators to comprehensively address global challenges.
4. How can the CSSC better structure the annual workshop to facilitate the development of new CEDAR community-driven campaigns?
5. Should the CSSC chair and NSF staff host a town-hall meeting to discuss current issues at the end of each annual workshop?

## Continuing on Towards an Integrated Data Environment with the Virtual Observatories

*Conveners: Michele Weiss, John Holt, Peter Fox, Daniel Morrison, Stuart Nylund*

The goal of this workshop was to bring together user-scientists, existing data center representatives, and representatives of the new domain specific Virtual Observatories to engage in a discussion of how the new Virtual Observatories can best serve the user community and integrate with existing data centers and model providers. Approximately 18 – 20 people attended this session.

The session started out with the introduction and first talk by Peter Fox (NCAR) on the Virtual Solar Terrestrial Observatory (VSTO). He provided an introduction to the upcoming EGY in 2007-2008 (*www.egy.org*). The EGY has a working group on Virtual Observatories (VOs) that the community should support. His talk provided a definition and an introduction to Virtual Observatories. The VSTO is nearing operational stage and will integrate the CEDAR database, CISM, and resources from Mauna Loa Solar Observatory. Further information is available from *http://vsto.hao.ucar.edu/*.

Daniel Morrison (APL/JHU) provided the next talk on the Virtual Ionosphere Thermosphere Mesosphere Observatory (VITMO) one of the newly announce NASA domain specific VxOs. This system will tie together ground based data sets such as SuperDARN and satellite data from TIMED, AIM, SNOE, C/NOFS, UARS, and DMSP. It will also integrate with data sets and facilities from CDAWeb, SSCWeb, and ModelWeb at the Space Physics Data Facility at NASA Goddard. In addition, the VITMO like all of the other VxOs plan on cross connecting to each other.

Bill Rideout (MIT Haystack Observatory) provided an introduction to Madrigal that is used extensively at many radar installations. Madrigal is an open source system and represents perhaps the first Virtual Observatory for the Space Physics community. This system ties together Millstone Hill, Arecibo, EISCAT, Jicamarca, SRI International, Cornell University, and others. The basic data format is the same as the format used in the CEDAR database. A good discussion followed about the use of the format and the Madrigal software as a standard for other ground based sites including those with optical imagers.

Tony van Eyken (EISCAT) gave a presentation on AstroGrid: an Astronomy and Solar System

VO for Silvia Dalla (Univ. of Manchester). This VO is part of the International Virtual Observatory Alliance (*www.ivoa.net*) and is focused very much on the concept of "workflows" that may be used over and over to insure that data is analyzed in a consistent fashion. Presented as part of this was a movie on a data discovery tool called HelioScope. HelioScope allowed solar data from the Virtual Solar Observatory (VSO) and space physics data from NASA CDAWeb to be retrieved based on proposed Simple Time-range Access Protocol (STAP).

Eric Donovan (Univ. of Calgary) presented GAIA (Global Auroral Imaging Access) for accessing auroral imagery from ground and space. GAIA is being developed by an international consortium for integrating data from the world-wide networks of optical instruments and riometers (*www.gaia-vxo.org*).

Masha Kuznetsova (CCMC/GSFC) tied things up with a talk on the Community Coordinated Modeling Center (CCMC) (*http://ccmc.gsfc.nasa.gov*) support of science needs for the integrated data environment. The CCMC supports ionospheric models such as CTIP, SAMI-2, and GAIM as well as many others. Because the output of many of the models are extremely large the system operates in a batch mode, with submission through a user-friendly interface. A discussion followed on how to integrate knowledge of the output from the models into the search capabilities of Virtual Observatories. Discussions were also held on the possibility of "flying a satellite trajectory" through large 3-dimensional model output to simulate instrument observations.

The talks demonstrated that a lot of progress has been made in improving the Integrated Data Environment for users but that a lot of work still needs to be done. A listserv newsgroup for coordinating the VxO activity has been set up at vxo@listserv.gsfc.nasa.gov.

## Midlatitude Nighttime Ionospheric Structures: Theory, Modeling and Physical Explanations

*Convenors: Jon Makela, John Mathews, John Meriwether*

A small evening workshop was held to discuss the current status of our understanding of mid-latitude nighttime ionospheric structures. Despite observations spanning over a decade, the physical mechanism responsible for the development of these structures remains elusive. In this workshop, several presentations were made on the current status of our understanding from optical, radio, and theoretical standpoints. Presenters included Jonathan Makela (U of Illinois), Dave Hysell (Cornell U), Carlos Martinis (Boston U), and Russell Cosgrove (SRI). Many of the observations to date have been made in the Caribbean sector where there is increasing evidence for correlation between the coherent scatter in the E region and banded structure in optical imagery. This matches recent theoretical advances suggesting a coupling between sporadic E instabilities and F-region instabilities.

The participants of the workshop concluded that more coordinated observations are required to solidify our understanding of this connection. Few truly coordinated/collocated observations of both the E and F regions during events of this type have been made to date. Observations from magnetically conjugate locations would also be useful in unraveling the physical processes at play, as the structures may have an effect (or source) in the conjugate hemisphere. Furthermore, we concluded that future experiments should be carried out with instrumentation spread across a wider area to expand the region of the ionosphere simultaneously studied, increasing the likelihood of capturing these events. Experiments combining optical and radio techniques show the greatest promise in measuring the necessary parameters needed to come to a better physical understanding of these nighttime mid-latitude structures.

## Summary of the Applications of the Consortium of Resonance and Rayleigh Lidars (CRRL) to CEDAR Science Workshop

*Conveners: Jeff Thayer, Xinzhao Chu, Chiao-Yao She, Dave Fritts, and Gary Swenson*

The workshop was held to introduce the concept of a lidar consortium and to discuss how this organization of lidar systems, people, and technology can benefit the CEDAR science community. Jeff Thayer gave the first talk describing the impetus for the lidar consortium. Bob Robinson from NSF provided perspective on how this effort relates to upper atmospheric facilities and the expectations involved. Discussion of the concept was open and clarification was requested on why only the Na wind/temperature systems made up the consortium. This important question was addressed by illustrating these systems' measurements are in greatest demand by the science community and, therefore, must be maintained and technology must be developed to keep them producing robust, high fidelity data. It was also demonstrated that these lidars are located at high, middle and low latitudes, thus contributing to the broad range of science topics. Furthermore, two of the other four existing US lidar programs are supported by Upper Atmospheric Facilities, the Arecibo broadband and narrowband resonance systems and the broadband and Rayleigh systems in Sondrestrom Greenland, and have a built-in support infrastructure. It is planned as the consortium evolves that these and the other lidar systems (the broadband Rayleigh system at Utah State University and the broadband resonance and Rayleigh system at the University of Alaska) will join or participate in consortium activities. The guest investigator program was also discussed and was called out as a program that should not be cut from the lidar consortium budget. Talks from the three Na wind/temperature lidar groups (Colorado State University representing the CSU lidar system, Colorado Research Associates representing the WEBER lidar at ALOMAR, Norway, and the University of Illinois representing the Maui lidar) were then given by Chiao-Yao She, Dave Fritts, and Gary Swenson respectively to discuss status and how they will function collaboratively under the consortium to serve CEDAR community better.

**Don Farley at the 2006 CEDAR Meeting**

Following the descriptions of the three existing lidars, Xinzhao Chu (University of Colorado) introduced a new concept, i.e., the Consortium Technology Center (CTC). The CTC will be built for the CEDAR community. The primary responsibilities of the CTC are to advance, consolidate and lead lidar technology development; to provide technical support and ensure robust and high-quality measurements of CRRL lidars; to share lidar and optical technologies within and outside CRRL; and to establish a lidar school for the community to educate and train next-generation lidar researchers. The ultimate goal of the CTC is to establish a community center of excellence of lidar technology for advancing CEDAR science. A question was raised, concerning how the CTC will improve lidar development over individual PI lidar development. A few examples were presented by Xinzhao Chu to answer this question. First, the development of a mobile Doppler lidar for global wind and temperature measurements needs contributions from the whole community. As a team consisting of the CTC and CRRL, we are much stronger in lidar technology advancement. Second, the CTC will

retain and continue wind and temperature lidar technology expertise, which will ensure the continuity of lidar technology in each individual lidar group in case of key personnel change. The CTC will also work to improve technology transfer to various lidar groups, enable other research groups to develop lidar capabilities without specific in-house expertise, and more rapidly advance the development.

Science campaign talks were introduced by Murry Salby and Richard Collins. Murry Salby described a lidar campaign that combined the US lidar assets with those of the European lidar community to study Kelvin waves at middle latitudes. Richard Collins introduced the thermospheric lidar concept and the need to develop a campaign centered on lidar resonance measurements from aurorally excited nitrogen ions.

## CEDAR Workshop on Thermospheric Density and Composition

*Convener: Art Richmond*

The density and composition of the thermosphere are strongly dependent on variations in solar XUV radiation, on high-latitude Joule heating, on thermospheric dynamics, and on dynamical, chemical, and radiative coupling with the lower atmosphere. This workshop presented to the CEDAR community the NASA Living With a Star (LWS) coordinated research project on thermospheric density and composition, which has an objective of improving the modeling of satellite drag and of ionospheric effects. Active research projects presented not only by the LWS team members, but also by other scientists and students, are evaluating our ability to quantify thermospheric responses to variable solar and magnetospheric energy inputs. Although first-principles models with recently improved parameterizations are able to reproduce climatological thermospheric variations reasonably well, the simulated response to magnetospheric inputs for particular events depends significantly on uncertainties in the magnitude of the inputs. Progress in the coordinated LWS research project and in related CEDAR research are expected to improve our ability to model the thermosphere more accurately under a broader range of conditions.

## Meteors and the Upper Atmosphere

*Conveners: Lars Dyrud and Diego Janches*

The workshop was held in a short presentation style followed by discussions. We had 11 presentations in the 3 hour session, 5 of which where student presentations. The agenda left room for discussion which was interspersed among the presentations and was attended by approximately 50 participants. The speakers were, Lars Dyrud of CRS, Sigrid Close from LANL, Jorge Chau from Jicamarca Radio Observatory, Meers Oppenheim from Boston University; Jonathan Fentzke, Chunmei Kang, Elias Lau, Santiago de la Peña from University of Colorado, Diego Janches from CoRA/NWRA; and Stan Briscinski and John Mathews from Penn State University. The speakers and the topics discussed reflected the multi-disciplinary nature of this field. Topics included the meteor deposition of metal layers, modeling of meteor trail and head echoes, modeling of the global meteoric mass flux, observation using ISR radars and satellites and a novel meteor radar calibration methods. All these subjects showed, once again, the growing interest by the community in the effects and understanding of meteors and the mesopause. The talks specifically demonstrated a growing consensus, at least among CEDAR researchers, that the sources of small, dust size meteors are unaccounted for in earlier studies and existing characterizations of the meteor flux. These dust size meteors are the dominant ISR meteor observation. Finally, the conveners, Diego Janches and Lars Dyrud would like to thank everyone that took part and attended this year's workshop.

## Summary of the Plasma Structures and Turbulence Workshop

*Conveners: Evgeny Mishin and Anatoly Streltsov*

The workshop was held to address CEDAR science interests in the effects of plasma

instabilities and nonlinear wave processes/structures in the ionosphere. Presentations included recent results of theoretical, numerical, and experimental studies of various wave phenomena occurring in the ionospheric plasma. R. Cosgrove and R. Doe discussed how AMISR's multi-beam capability can be used to identify the ionospheric Alfven resonator (IAR) signature. A. Streltsov presented the results from a numerical study of the generation of small-scale density structures in the topside ionosphere by intense, nonlinear Alfven waves caused by the feedback instability inside the IAR in the downward current region. G. Milikh showed that the enhanced electron density, observed by the Sondrestrom ISR in the stormtime auroral electrojet region void of electron precipitation, is in good agreement with the anomalous heating due to the Farley-Buneman instability. E. Mishin presented electromagnetic and plasma disturbances in stormtime subauroral ionosphere from the CRRES and DMSP satellites, indicating the dominant role of various unstable processes in the ring current-plasmasphere overlap. R. Greenwald's presentation aimed at showing that the source for decameter-scale irregularities, routinely observed by the SuperDARN radars, is the temperature gradient instability on plasmapause field lines. P. Guzdar & N. Gondarenko showed numerically how a combination of the gradient drift and Kelvin Helmholtz instabilities forms structuring of high-latitude plasma patches via the sequence of developing secondary instabilities. D. Hysell presented the latest radar images of equatorial spread F at Jicamarca, as well as the results of numerical simulation of the fully-developed turbulence, where secondary instabilities form all over the place, partly resembling that in the polar patches. Yue Deng concluded the program showing the GITM results demonstrating the effect of a vertical circulation on the electron density altitude distribution, which has been proposed to help understand the source of the tongue of ionization. Overall, the presentations show the importance of plasma instabilities and nonlinear processes for ionosphere–magnetosphere coupling.

## Radar Meteor Studies: Where next?

*Conveners: Sigrid Close, Lars Dyrud, John Mathews*

Large-aperture radar study of meteors has matured greatly in the approximate decade since the first observational results were being reported. However, many questions remain including the radio science and plasma instability issues implicit to the head-echo and range-spread trail echo scattering mechanisms and the possible influence of meteor-trails on E-region electrodynamics. The purpose of this workshop is to discuss how to approach these issues observationally and the likely need for new radar capabilities.

Approximately twenty attended this session that was dedicated to discussion of new approaches to meteor observations given the maturity of the current generation of observations. An immediate consensus emerged that multi-frequency, multi-look angle, common-volume radar observations are needed to solve the numerous radio science and plasma physics questions. More observations at ALTAIR are considered necessary as it allows two-frequency observations of head/trail-echoes. David Hysell will be installing a 30 MHz radar on Saint Croix that will look over Arecibo Observatory and that plus a modernization of the on-dish VHF radar would provide a major new capability. Additional ideas included ultra bandwidth pulsed radars creating meteor "ionosondes" and utilization of passive radar techniques—especially in combination with existing radars—to achieve the desired frequency/look-angle diversity. The latter would surmount the difficulties of FCC limitations on transmit frequencies at current observatories. Other discussion centered on the minor biases that have emerged in the current large-aperture V/UHF radar studies.

## Optical Calibration and Issues

*Convener: Susan Nossal*

Calibration is important for comparing observations taken by different instruments, for model-data comparisons, and for acquiring long-

term data records. The Optical Calibration workshop at this year's CEDAR conference addressed both absolute intensity and line center calibration methods. In addition, there was discussion concerning the need for publication and/or other documentation of calibration techniques to enable students and other researchers to calibrate their instruments and to understand the techniques used by other observers with whom they might compare data. Another idea proposed to share knowledge about calibration is to have hands-on, interactive calibration demonstrations at a future CEDAR meeting.

D. Pallamraju described the absolute intensity calibration of observations made with the ground-based Boston University spectrograph. Determination of the absolute brightness requires accounting for factors including the filter transmission, the solid angle field of view, vignetting (cutting off of light rays within the instrument), cosmic ray hits on the CCD detector, as well as characteristics of the absolute brightness calibration reference. Similar considerations are required for the calibration of other passive optical spectrometers and imagers using CCD detection. The Boston University Imager is calibrated using a Keo incandescent lamp source that has been cross-calibrated with a similar Stanford source.

John Meriwether followed with a discussion of a Cerium hallow cathode Secondary Standard source developed by Fred Biondi for thermospheric zero wind determination. The Cerium line (630.02 nm) is very close spectrally to the OI sky emission (630.03 nm). The secondary source method provides an alternative to the use of zenith observations for zero wind determination, thus reducing the uncertainty in the measurements. The uncertainty associated with determination of the wavelength difference between the OI 630.03 nm line and the Cerium 630.02 nm line corresponds to an equivalent velocity uncertainty of about 34 m/s.

Rick Niciejewski then turned to the line center calibration of satellite wind observations taken with the TIDI instrument, a Fabry-Perot Interferometer on-board the TIMED satellite. Accurate line center determinations are required for accurate wind measurements made by comparing Doppler shifts in the spectral emission to the line center reference. Initially, the average of the zonal mean of the meridonal wind component during equinox was taken as the zero wind reference. However, long term statistics indicated systematic variations in the wind trend. Corrections for these variations required high precision knowledge of the satellite altitude and monitoring of thermal gradients on the instrument. After such corrections, the TIDI measurements are now able to reach an accuracy and precision of a few m/s in the horizontal wind vector.

Pamela Loughmiller ended the session with a discussion of the intensity calibration of the Cornell All-sky Imager. The Cornell CCD-based Imager is calibrated for brightness using the same white incandescent KEO lamp source used to calibrate the Boston University spectrograph. To determine the intensity of the imager data, multiple factors must be considered including the filter transmission, variations in pixel sensitivity, vignetting within the instrument, the spatial mapping of the sky onto the detector, as well as the characterization of the absolute intensity KEO reference source. Pam also spoke about the need for calibration publication/documentation to assist students and researchers with calibration of their own instruments and with understanding of methods used for other instruments. One purpose of such documentation would be to clarify terms such as "flat field" that are used with different meanings by different observers when discussing calibration methods. Pam outlined such documentation that she has drafted regarding calibration of the Cornell imager.

In addition, Tom Slanger from SRI and John French from the Australian Antarctic Division submitted contributions to the workshop, but were not able to attend. Their presentations are also on the CEDAR website. Tom Slanger's addresses corroboration of intensity calibration using knowledge of atomic and molecular line spectral intensity ratios. John French describes calibration of their Czerny-Turner grating spectrometer and Bomem Fourier-transform

spectrometer, both used to measure OH rotational temperatures in the mesosphere over Davis, Antarctica. The presentations by each of the speakers are posted on the CEDAR website.

## Storm Effects on the Global Electrodynamics and the Middle and Low Latitude Ionosphere

*Convener: Tim Fuller-Rowell*

The workshop provided the first opportunity for the PIs selected by NASA's Living With a Star Focused Science Topic (LWS-FST) on "Storm effects on the global electrodynamics and the middle and low latitude ionosphere" to present their proposals to the rest of the team. Recent observations have revealed that the response of the mid and low latitude ionosphere and thermosphere to geomagnetic storms is much more dynamic and dramatic than previous envisaged. In particular, understanding the role of global electrodynamics in plasma redistribution is a topic of intense interest. This LWS-FST targets this science question. The workshop was a natural follow-on to the morning workshop on penetration electric fields; the morning session focused on some aspects of our current understanding and the afternoon session addressed future research plans.

The team consists of the following PIs and research titles:

John Foster - Multi-instrument investigation of inner-magnetosphere/ionosphere disturbances

Tony Mannucci - Ionospheric behavior during the first few hours of intense geomagnetic storms

Bela Fejer - Storm-time ionospheric electric fields

Pontus Brandt - Storm-time sub-auroral electric fields: Ionosphere and magnetospheric control

Ray Greenwald - Understanding the evolution and impacts of storm-enhanced electric fields in the mid-latitude ionosphere

Elsayed Talaat - Sub-auroral polarization streams effects on the ionosphere and thermosphere

Stan Sazykin and Tim Fuller-Rowell - Modeling the impact of storm-time electrodynamics on the mid and low latitude ionosphere

The workshop provided an ideal opportunity to begin the communication, for each PI to state what they think are the important science questions within this LWS FST, and to describe their approach to tackling the problem. The workshop spanned both the traditional CEDAR and GEM disciplines, so was held on the last day to give GEM scientists the opportunity to include it in their travel plans. This was a chance for the team to hear about each others plans and start to think about how we can interact and collaborate. The workshop was followed by the first formal meeting of the science team in Boulder to define the integrated three-year research plan.

## Ground-Based Coordination with AIM Satellite Mission

*Conveners: M. J. Taylor (Utah State University), J. M. Russell III (Hampton University), and S. Bailey (Virginia Tech).*

The Aeronomy of Ice in the Mesosphere (AIM) mission is a new NASA Small Explorer satellite designed specifically to investigate "*why* polar mesospheric clouds form and why they vary". Polar mesospheric clouds (PMC) are of considerable importance to the CEDAR program as they form and grow under exceptionally cold conditions (temperatures below ~150 K) that are present only in the summer months at high-latitudes when the mesopause region is driven far from thermodynamic equilibrium by strong upwelling. The Aim mission is currently scheduled for launch in April 2007 and will make measurements in both the northern and southern hemisphere summer seasons over the following two years. Ground-based observations in coordination with AIM measurements will enhance significantly the scientific potential allowing new objectives to be addressed as well as cross validation. Our goal for this first workshop was to introduce the AIM program and science team to interest researchers in the CEDAR ground-based community to develop new collaborations and to begin planning for

coordinated observations during the AIM mission. These measurements are especially timely with the upcoming International Polar Year (2007-08) and the much heightened scientific and public interest in these clouds as possible harbingers of climate change.

AIM will make the first simultaneous measurements of mesospheric temperature, $H_2O$, PMC content (and other trace gasses and aerosols) at high-latitudes essential for quantifying PMC formation. The data will be obtained by three instruments: SOFIE (Solar Occultation For Ice Experiment), an IR solar occultation differential absorption radiometer; CIPS (Cloud Imaging and Particle Size experiment), a panoramic UV imager comprising four cameras; and CDE (Cosmic Dust Experiment) that will detect and measure in-situ dust particles. The workshop was divided into two parts with presentations by the AIM PI (Dr. Jim Russell) who described the basic mission and overarching science goals, and several of the AIM Science team members (Drs. Dave Rusch, Mark Hervig and Scott Bailey) who presented details on the flight instrumentation and their measurement capabilities. This was followed by a very interesting and lively "open forum" discussion that concentrated on gaining more details about AIM science and the planned operations in both hemispheres. Several short presentations by interested researchers were also made broadening the fundamental capabilities of the AIM mission. The workshop concluded with a discussion on the initial planning for ground-based coordinated measurements and a list was circulated to interested researchers to sign on for more information as the mission moves towards launch. Overall a well attended and very informative new workshop.

## Data Assimilation In Space Science (Panel Discussion)

*Convener: Mihail Codrescu*
*Panel Participants: Art Richmond, Bob McCoy. Bob Schunk, Cliff Minter, Gary Bust, Stan Solomon and Tomoko Matsuo*

The panel members gave 5-minute presentations of their personal view of Data Assimilation.
Art Richmond viewed Data Assimilation as "Representing a system through a synthesis of observations with a model". "Data assimilation requires a thorough understanding of the observations and the model".

Bob McCoy noted that meteorologists use DA to drive the physics by constantly adjusting the initial conditions. In the ionosphere we have large variability on multiple time-scales and various forcing mechanisms.

Bob Schunk noted that "DA models need multiple data types with error bars, physics-based time dependent models and a rigorous technique". In this case DA models can give you reliable specifications with error estimates.
Cliff Minter talked about DA models from an engineering standpoint and pointed out that "data assimilation" is being heavily used for orbit determination and for example for the determinations of the Earth gravitational field.

Gary Bust asked the question weather "Data assimilation can and should be used to answer science questions". He noted that "when theory does not agree with the observations the science is not well understood".

Stan Solomon stressed the need for "a broad definition for data assimilation". "Different regions need different definitions". He added that "for example driving a model with ACE data could be considered as Data Assimilation".

Tomoko Matsuo noted that "Data assimilation" uses the prior knowledge of the state of the system (empirical or physical model) together with observations". She stressed out that "Data assimilation" systems can help in the design of observing systems".

As a result of the panel discussion no definition of the term data assimilation could be agreed upon, although it was noted that it might be useful to have a definition for fair proposal and paper evaluations.

After the workshop, the following working definition of "Data Assimilation" was agreed upon by the panel: *Data assimilation is a method in which observations of the current (and possibly, past) state of a system are combined with the results from a mathematical simulation model to produce an analysis, which is considered as 'the best' estimate of the current state of the system.*

## Opportunities of Research in Aeronomy in Latin America

*Conveners: Diego Janches, Carlos Martinis*

This workshop was organized with the goal of describing existing, planned and foster research opportunities in Aeronomy in Latin America. Approximately 35 people attended the session. The first part of the workshop was focused on topics of relevance in the region: the comparison of radar measurements from Jicamarca and Sao Luis (D.Hysell); the significance of gravity-wave energy deposition in Southern Patagonia (D.Fritts); the description of Brazilian campaigns related to sprites( F. Sao Sabbas) and gravity wave interactions with the ionosphere (D. Pautet).

The focus of the second part was the importance of conjugate studies in the region. It started with a summary of a recent workshop on the installation of an Upper Atmospheric Facility at the magnetic conjugate point of Arecibo, in Argentina (D. Janches). Then, results obtained from almost conjugate all-sky imagers located at Arecibo and El Leoncito showed the occurrence of simultaneous thermospheric and ionospheric processes in both hemispheres (C. Martinis). The importance of measuring the conjugate ionosphere of Arecibo was also discussed as well as the potential installation of an ionospheric facility near the conjugate point that would help to understand the electrodynamics of Arecibo (J. Meriwether). This presentation was followed by the description of an experiment consisting in the installation of all-sky imagers and GPS receivers at conjugate locations in the western part of South America (J. Makela). Finally, the status of the installation of several dynasondes located at conjugate sites that will allow the simultaneous sampling of E and F region ionospheric parameters was also presented (C.Valladares).

A brief summary of each presentation is given below.
Dave Fritts (CORA) described the need for studies of the neutral atmosphere in Patagonia Southern Argentina. This geographic region seems to be one of the most Gravity Wave-driven active regions in the planet

Dave Hysell (Cornell University) spoke about research opportunities combining the imaging radars at Jicamarca, Peru and at Sao Luis, Brazil. The new Brazilian imaging data should help in establishing irregularity drifts at the altitudes most responsible for scintillations and for identifying morphological characteristics (dominant wavelengths) for comparison with imager data.

Dominique Pautet (Utah State University) focused on results of gravity wave interactions with the ionosphere, topic of a 2005 campaign, a collaboration between D. Fritts LWS NASA proposal and the Brazilian FAPESP DEELUMINOS proposal.

Fernanda Sao Sabbas (INPE) presented a summary of Aeronomy facilities of the Brazilian National Institute for Space Research, INPE. She described the four year Sprite and Transient Luminous Events project DEELUMINOS and gave preliminary results of the first sprite campaign performed in Brazil and stressed how international collaboration can contribute to develop new science in South America.

Diego Janches (CORA) gave a summary of the recent workshop held at Arecibo focused on developing an Upper atmospheric facility at the Arecibo Magnetic Conjugate point located near the coast of Argentina

Jonathan Makela (University of Illinois) described a new experiment that will begin in Fall '06 with dual imagers and GPS scintillation equipment at conjugate locations in Chile and Colombia, observing the same set of magnetic flux tubes that pass over Jicamarca. From the two sites it will be possible to study the role that the local ionosphere plays in the development and characteristics of scintillations.

Carlos Martinis (Boston University) presented results of conjugate observations of ionospheric and thermospheric processes using all-sky imagers at Arecibo and El Leoncito, Argentina, with supporting information from GPS phase fluctuations measurements. He stressed the need to continue these types of observations and the need to model how mid-latitude processes reach into low-latitudes and vice versa.

John Meriwether (Clemson University) talked about the importance of the conjugate point on the local electrodynamics of Arecibo. Several questions were posted: how can the current be conserved given that there is a divergence in the zonal current?, are the F-region heights at both hemispheres anticorrelated?. Thus, to understand the driving forces that underlie plasma height variations of the Arecibo ionosphere is necessary to measure the neutral and plasma properties of both the local and conjugate hemispheres.

Cesar Valladares (Boston College) gave an update of the installation of five dynasondes in South America. He indicated that all five sites have been visited and local scientists and engineers are very enthusiastic about this project. He also explained the importance of measuring the E region at Leticia (~8 N mag lat) and Carmen Alto (~8 S mag lat) for the forecasting of the onset of ESF.

## Summary of the Climatology/Long-Term Trends

*Conveners: Jan Sojka and Jeffrey Thayer*

The workshop was held to address CEDAR science interests in long-term trends in aeronomy as well as to discuss the status of CEDAR's long-term data sets. Five formal talks were given on these topics, a further three impromptu presentations were given and extended discussion from the audience occurred. One of the major points raised was that CAWSES and other international long-term efforts primarily study the mean climatology, perhaps it would be important for this working group to consider the trends in variability, i.e., weather. A discussion on data quality and data "validation" before being archived in the CEDAR database raised the need for a "BEST PRACTICES" white paper to be circulated to all interested in submitting data sets. The issue of how the data archive includes new information on data set biases and calibration was also raised. Several long-term data sets were discussed: (i) satellite mass spectrometers, (ii) FPI winds and temperatures, (iii) ISR temperatures in the F-region, (iv) hydrogen geocorona, (v) lidar mesospheric temperatures, (vi) ISR densities, and (vii) Michelson Interferometer temperatures. Several scientists also provided analysis on long-term trends. These results provided further basis for discussion on best practices in terms of statistical analysis.

## MLT Structure and Dynamics in Tropical/sub-tropical Regions

*Conveners: Xinzhao Chu, Jonathan Friedman, and Gary Swenson*

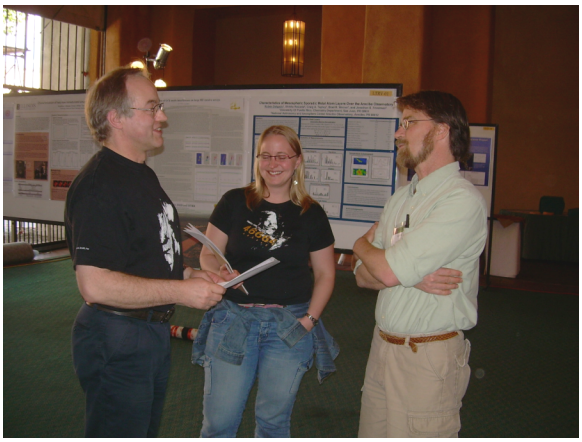
Recent analyses of lidar-measured MLT (mesosphere and lower thermosphere) temperatures at Maui (20.7°N, 156.3°W) and Arecibo (18.35°N, 66.75°W) have shown significant differences between these two tropical/sub-tropical sites. The MLT over Maui experiences the low summer mesopause altitude (~86.5 km) that is observed at mid and high latitudes, while at Arecibo the summer transition does not occur. Maui and Arecibo are separated in longitude by 90°, so these observations point to possible longitudinal effects. Such effects, if global, would be most noticeable at the transition region from mid to low latitude, such as represented by these sites. In an attempt to understand these differences, a workshop was called for at the 2006 CEDAR Workshop. This

workshop brought together a wide spectrum of views of this atmospheric region that has been little studied and is poorly understood. Presentations were given on observational results still under study, and how tidal studies may contribute to understanding the low latitude MLT thermal structure and dynamics.

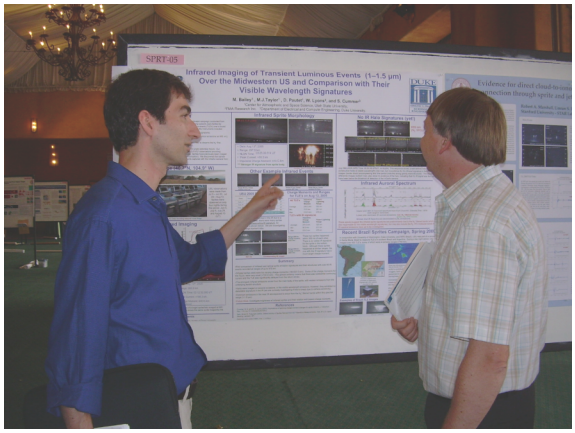
To open the workshop, Xinzhao Chu (CU) introduced the motivations described above. Jonathan Friedman (Arecibo) presented the observational results from Arecibo and Maui that prompted convening this workshop. Jeffrey Forbes (CU) followed with a tutorial presentation that cleared misconceptions on how modelers describe solar tides, and with a thorough description of the basics of tidal and wave modeling and their nomenclature. His talk also gave a basis for beginning to understand how tidal modulation may influence the differences observed in the MLT at disparate sites such as Maui and Arecibo. Many of the roughly 100 participants in the workshop praised Jeff's tutorial as providing the means to understand papers on tides and waves.
Elsayed Talaat (APL) presented SABER low-latitude temperature measurements and how he has developed a technique for extracting the diurnal tide from SABER-measured temperatures. This technique will be very useful in further analysis of the differences between Arecibo and Maui, as the lidar temperature observations are still made exclusively at night. There was agreement, though, on the necessity for full diurnal cycle measurements at the ground-based sites. Qian Wu (NCAR) presented multi-year TIDI neutral wind observations and compared them to TIME-GCM. A CEDAR student, Rubén Delgado (UPR), gave a presentation on metal layer chemistry and the status of its understanding at Arecibo.

Mike Taylor (USU) also presented a comparison, in this case between an all-sky temperature mapper at Maui and the Arecibo K Doppler lidar and discussed the influences of phenomena such as the Quasi-Biennial Oscillation (QBO) and Semi-Annual Oscillation (SAO). At the end Xinzhao Chu (CU) compared the semidiurnal tides between Maui and Arecibo, and pointed out the opposite phases in January between these two sites. Apparently, these interesting results call for further investigation of tropical MLT thermal structure and dynamics through the combination of lidar and satellite observations with atmospheric model simulations.

**Even the task of judging CEDAR's excellent student posters is an enjoyable undertaking!**



Poster Judges Rick Doe of SRI, the poster chair (on the right), discusses strategy with two of his judges, Tony van Eyken and Anja Stromme of EISCAT.




Farzad Kamalabadi of U IL is asking Mike Taylor of USU about his student's poster

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