THE CEDAR POST

COUPLING, ENERGETICS AND DYNAMICS OF ATMOSPHERIC REGIONS

From the CSSC Chair

The successful 16th Annual CEDAR Workshop was held jointly with our GEM colleagues in Santa Fe in July with 542 participants. Our joint student ranks were 214. Historic presentations of CEDAR by Tim Killeen (NCAR) and GEM by Chris Russell (UCLA) outlined the respective paths the two vibrant research communities have followed in arriving at our next set of frontiers. Our CEDAR community eagerly awaits the coming on-line of AMISR, the challenges of multi-instrument deployments as advertised by DASI, the science yields from assimilation, and a successful C/NOFS launch to spur on equatorial science.

I encourage all of you to respond to the electronic questionnaire seeking feedback on the first ten years of the National Space Weather Program (*www.nswp_comminput.php*). The program has complemented our CEDAR science for the past decade as well as having brought us closer to colleagues at NASA, DoD, and NOAA.

On behalf of us all, I wish to thank Sixto González for his exemplary leadership of the CEDAR science steering committee over the past two years. It was a pleasure working with him.

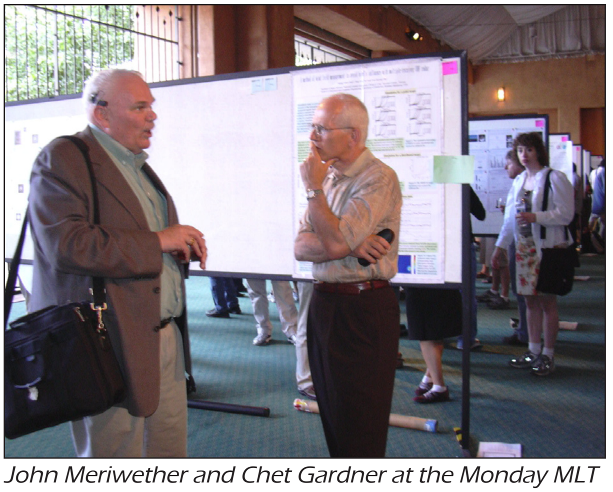
Jan J. Sojka

Jan J. Sojka
Utah State University

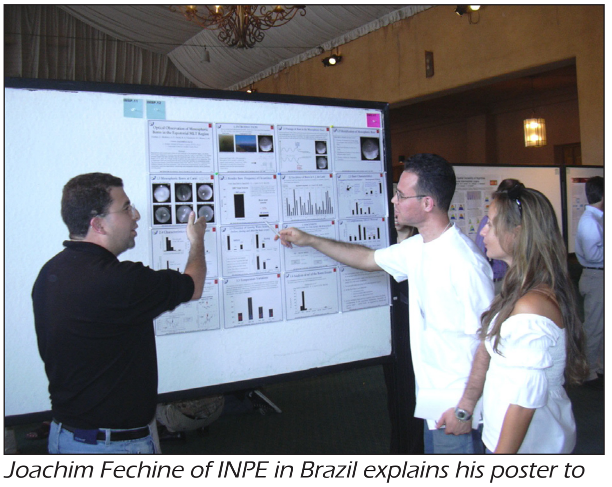
Incoming CSSC chair Jan Sojka of USU gives outgoing CSSC chair Sixto González of Arecibo a book about Santa Fe.

INSIDE ▶

At the INPE table during the joint reception Sunday at the Eldorado Hotel.



John Meriwether and Chet Gardner at the Monday MLT poster session in the Pavilion.



Joachim Fechine of INPE in Brazil explains his poster to Delano Gobbi and Pedrina Morais Terra dos Santos of INPE.

Summary of the Joint CEDAR-GEM 2005 Workshop

Eldorado Hotel and La Fonda Hotel, Santa Fe, NM
June 26 - July 1
Barbara Emery, HAO/NCAR

The CEDAR (Coupling, Energetics and Dynamics of Atmospheric Regions) Workshop for 2005 was held at the Eldorado Hotel in Santa Fe, New Mexico in cooperation with the GEM (Geospace Environment Modeling) Workshop at the La Fonda Hotel. We celebrated the combined meeting with joint scientific sessions, social events, and a commemorative T-shirt. The higher level of energy was very beneficial, so we would like to have joint meetings about once every 5 years in the future.

A total of 313 CEDAR registrants joined 229 GEM registrants for a grand total of 542 participants from 94 institutions, 24 outside the United States and Puerto Rico. There were 62 universities, 25 labs, and 7 small businesses, with 17 universities and 13 laboratories shared between the two communities. The 130 CEDAR students and post-docs combined with 61 GEM students for scientific and social events. There were also 23 undergraduate students, all of them in the CEDAR community. GEM hosted one student from France, while CEDAR hosted 17 students from outside the United States, including Canada (3), Japan (3), Taiwan (3), Brazil (3), Peru (2), the United Kingdom (2) and Norway (1). The number of CEDAR participants was about the same as last year, with a few more students.

The Student Workshop on Sunday at La Fonda was organized by the new CEDAR student representative Carlos Martinis (Boston U.) in cooperation with Jichun Zhang (U. Michigan), the GEM student representative. There was a joint session on Magnetosphere-Ionosphere Coupling in the morning with a tutorial by Robert McPherron of UCLA looking from the magnetosphere perspective, and another tutorial by Rod Heelis (UT at Dallas) from the ionospheric side. After the student lunch, the theme was continued for the CEDAR students with four more speakers, while the GEM students went into a closed session to prepare their students for the other GEM campaigns of Inner

Magnetosphere/Storms and Global Interactions. The talks are available in .pdf form at: *http://cedarweb.hao.ucar.edu* (Click 'Workshop', then 'Tutorials'.)

The students also enjoyed a Bar-B-Q with our NSF representatives on Monday night at Fort Marcy Suites where most of the CEDAR students were lodged. Carlos will continue next year in his second year as student representative, joined by Michael Nicolls (Cornell).

Aside from the Student Workshop on Sunday, we had four joint plenary sessions, and six joint workshop sessions between Monday and Friday, although all sessions were open to any from both communities. We also shared a joint poster session on Wednesday. During the joint plenary sessions, we had historical talks about CEDAR and GEM from Tim Killeen (NCAR) and Chris Russell (UCLA), respectively. There were three longer tutorials by Bob Spiro (Rice U.) on sub-auroral electric fields, Janet Kozyra (U. Michigan) talked about mass and energy flows in superstorms, and auroral boundaries was the topic of Gang Lu (HAO/NCAR). There were shorter talks by John Foster (MIT Haystack), Vladimir Papitashvili (U. Michigan), Mike Wiltberger (HAO/NCAR), and Tomoko Matsuo (IMAGE/NCAR) on distributed instruments, e-science, modeling and data assimilation, respectively. The CEDAR Prize Lecture was given by James Hecht of The Aerospace Corporation on 'The Turbulent Oxygen Mixing Experiment (TOMEX) and Instabilities in the Mesopause Region'. The sole CEDAR tutorial was given by Edward Llewellyn (U. Saskatchewan) on 'Atmospheric Tomography: The Odin/OSIRIS Experience'. The talks are available in .pdf form at: *http://cedarweb.hao.ucar.edu* (Click 'Workshop', then 'Tutorials'.)

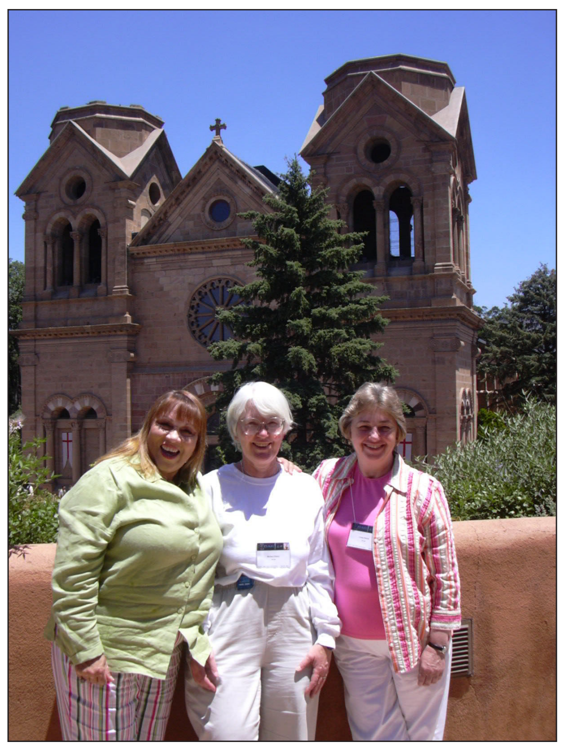
The joint talks are also in .pdf form at: *http://www-ssc.igpp.ucla.edu/gem/tutorial/index.html*
Please contact Barbara Emery (*emery@ucar.edu*, HAO/NCAR, PO Box 3000, Boulder CO 80307) if interested in obtaining hard copies and/or videos.

Including the joint workshops, there were 28 workshops, which was 3 more than last year. Some of the specific workshops are described elsewhere in this issue or at: *http://cedarweb.hao.ucar.edu/workshop/previous_meetings.html*

The 2005 joint meeting continued the trend started in 2004 to use less plenary time for programmatic talks. We had about six programmatic talks during the joint plenary sessions for introductions, a report on the student workshop, and topics about NSF, IHY/IPY/eGY and AMISR. CEDAR had additional talks to announce the student poster prize winners, present the Passive Optics Report, update the CEDAR Database, discuss the NASA Roadmap, and give a couple of announcements. The total was about two and a half hours of programmatic talks, or about half of the time spent for programmatic talks in 2004.

Additional plenary talks were six CEDAR and related post-doc reports given by Rebecca Bishop (Clemson), Weilin Pan (SRI), Lars Dyrud (Boston U.), Lara Waldrop (U. Illinois), Tao Yuan (Colorado State), and Josef Drexler (Cornell).

We enjoyed three poster sessions, one on Monday late afternoon for CEDAR mesosphere-lower-thermosphere (MLT) topics with 52 posters in the Eldorado Pavilion, a joint session from 4–9 PM on Tuesday with 74 'CEDAR' and 64 'GEM' posters, and a GEM session on Thursday evening with 48 posters at La Fonda. Abstract handouts were available for each session. There were 238 posters total, 126 'CEDAR' and 112 'GEM', with 134 student posters. 83% of the GEM students had a poster and 37%



The organizers on the La Fonda Terrace overlooking the Cathedral: Umbe Cantu of Rice for GEM, and Barbara Emery and Louise Beierle of NCAR for CEDAR.

of the non-students, while 44% of the undergrad CEDAR students, 69% of the non-undergrad, and 23% of the non-student population of CEDAR participated. There was a record number of 84 CEDAR student posters, which broke the previous record of 78 student posters last year. 61 of these posters were judged in the student competition.

There were four student winners and two honorable mentions in the poster competition. The two winners from the MLT poster session were Jonathan Snively (Penn State) and Ruben Delgado (U. Puerto Rico), with an honorable mention for Erin Lay (U. Washington). The two winners from the joint poster session with GEM were Fabiano Rodrigues (Cornell) and Marco Milla (U. Illinois). Another honorable mention went to Pedrina Morais Terra dos Santos who recently graduated from the Instituto Nacional de Pesquisas Espaciais (INPE) in Brazil. The winners received autographed copies of the paperback book 'Ionospheres' by Robert Schunk (USU) and Andrew Nagy (U. Michigan) and achievement certificates, which will also go to the honorable mentions. The GEM students were not involved in the poster competition.

Santa Fe Destinations arranged most of the extra-curricular activities for the 2005 joint CEDAR-GEM Workshop. We took a 48-passenger bus from Fort Collins, Colorado to Santa Fe with 7 CEDAR and 6 GEM students coming down from Colorado. This bus was then used to take students to the student bowling social at Silva Lanes on Sunday evening and to go back and forth between Fort Marcy Suites and the Eldorado and La Fonda hotels. Santa Fe Destinations offered extra fee cooking classes and tours of Tsankawi Indian ruins, Museum Hill, Tent Rocks, Bandelier/Bradbury and Chimayo Village. We also took the bus for a shopping expedition at Tin-Nee-Ann's Trading Company.

The **2006 CEDAR Workshop** will take place at the Eldorado Hotel in Santa Fe, New Mexico June 19-23. Due to scheduling conflicts at the Eldorado, this is an unusual 4-day workshop from Tuesday through Friday, with the Student Workshop on Monday.

Data Assimilation Articles

The prior issue of the CEDAR Post carried the first of 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 three more articles. In the following selection of articles, several have a broader than "ionosphere" relevance. Interested readers are encouraged to contact the editor for follow on articles or comments on the topic of data assimilation.

➢ Assimilative Ionospheric Modeling

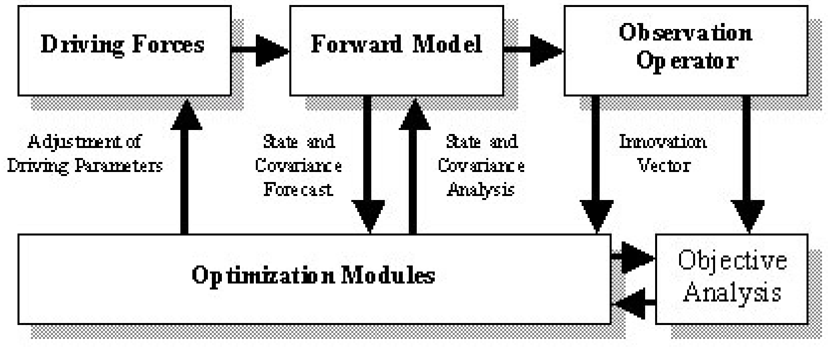
Xiaoqing Pi[1,2], Chunming Wang[2], George A. Hajj[1,2], I. Gary Rosen[2], Brian D. Wilson[1], Anthony J. Mannucci[1], Lukas Mandrake[1], and Vardan Akopian[1,2]
[1]Jet Propulsion Laboratory, California Institute of Technology
[2]University of Southern California

Data assimilation is a methodology for estimating the state of a physical system by combining observational data with the underlying physics principles governing the system. In the case of modeling the Earth's ionosphere, the state is electron and ion densities. Their spatial and temporal variations are governed by the conservation laws of collisional plasma hydrodynamics. Unlike the lower atmosphere and oceans, the ionosphere is created by solar EUV radiation and charged particle precipitation that partially ionize the upper atmosphere. The system is electrodynamically coupled to the magnetosphere, and collisionally coupled to the thermosphere, both driving ionospheric convection. The complex nature of these couplings dictates that the ionosphere is a strongly driven system. Therefore, prediction of ionospheric weather using first-principles modeling and data assimilation must include forecasts of the driving parameters that determine the processes of ionospheric production, chemical loss, and dynamics.

Data assimilation for ionospheric weather prediction becomes appealing due to several factors: (1) the promise of characterizing and predicting the space weather driving parameters with adequate spatial resolution and continuity in time; (2) globally distributed ionospheric measurements, largely total electron content (TEC) obtained using the GPS observation system, have become readily available; (3) although large in amount, measurement samples are unevenly distributed in space (poorly sampled above oceans), and continuously available observations are mostly integrated quantities, so that observations alone are inadequate for ionospheric weather specifications; (4) the need of ionospheric weather forecast.

A desired ionospheric data assimilation system performs three tasks in an assimilation cycle: (1) initialization of the ionospheric state and its error covariance as the *a priori* guess for the initial condition; (2) objective analysis to deduce a minimum-error estimate of the state consistent with observations, and to estimate the model drivers that are consistent with the state error minimization and physics principles; (3) forecast by propagating the estimated state, covariance, and driving parameters to the next time step following the governing physics principles and the optimal estimation algorithms. In practice, task (3) in the present cycle naturally becomes task (1) in the next cycle, and the data assimilation process can be conducted sequentially with new data assimilated in subsequent cycles ordered in time.

To accomplish the goal, a forward model, an observation operator, a data processor, and optimal estimation modules are the key elements to be included in an assimilative ionospheric modeling system. The forward model based on the first principles governing the system carries out the initialization and forecast, by propagating the state in time consistently with the required driver parameters. The observation operator (also known as observation matrix) maps the modeled state to the observation geometries, which is required for quantifying the differences between the modeled state and data. For example, one function of the observation operator is to identify the volume elements of 3-D model grid along receiver-to-satellite radio links for electron density integration to compute TEC. The data processor controls data quality and also provides estimation of measurement error. The optimal estimation modules perform the objective analysis and propagate the state covariance, to minimize the state estimation error and to estimate the model drivers in consistence with the data assimilated.
A fundamental difficulty in assimilative ionospheric modeling arises from the attempt to estimate both state and model drivers. The drivers can vary significantly in space and time under space weather conditions. Estimating multiple types of them with limited types of data is extremely challenging. Yet, the need of ionospheric weather forecast must address the drivers, so that the state can be forecast as far as it gets with consistent drivers. To overcome the difficulty, the development of assimilative ionospheric models so far has taken an approach to separate the tasks of estimating the state and driving parameters. Taking the Global Assimilative Ionospheric Model (GAIM) developed by the University of Southern California and Jet Propulsion Laboratory as an example, two primary optimization modules have been implemented: (1) Kalman filter to estimate the state only [*Hajj et al.*, 2004; *Wang et al.*, 2004]; (2) four-dimensional variational (4DVAR) approach to estimate the drivers [e.g., *Rosen et al.*, 2001; *Pi et al.*, 2003; *Wang et al.*, 2004]. A diagram is provided to describe GAIM schematically.



A schematic diagram showing the main components of Global Assimilative Ionospheric Model.

The Kalman filter implemented in GAIM conducts fundamentally tasks (2) and partially task (3) afore-mentioned recursively without estimating the driving parameters of the ionospheric model. Implementation and operation of the Kalman filter in a data assimilation system often involve dealing with two major difficulties: (1) reducing very costly computational burden in covariance matrix operations for global and three dimensional modeling; (2) specifying proper covariance for the state error, model transition error, and measurement error. To overcome the first major difficulty, several approximations of the Kalman filter have been tested and a band-limited Kalman filter is currently implemented in GAIM. The 4DVAR approach adjusts selected model drivers to satisfy the minimum state error as possible, by conducting non-linear least square minimization of a cost function through assimilation cycles. The cost function is a sum of three covariance-weighted squared differences between the following: (1) true observations and model-predicted observations; (2) *a priori* and estimated parameters of selected model drivers; (3) *a priori* and estimated initial state. In an assimilation cycle, the minimization can be conducted using a gradient-based iterative searching technique such as the quasi-Newton method. An adjoint method is implemented in the GAIM 4DVAR process to compute the gradient of the cost function. This method elegantly reduces the number of required integrations of the model equations such that the computational burden remains fixed and independent of the number of interested parameters. Parameterization of the model drivers also helps to reduce the number of parameters so that the optimal estimation is manageable.

Validation of the band-limited Kalman filter approach assimilating ground and space GPS data, UV radiance made from sensors on board DMSP satellites, and ionosonde measurements, has been conducted intensively against independent measurements by the JPL-USC team. With the adjoint method, 4DVAR simulations have been also conducted with synthesized GPS data for a low-latitude region enclosing global longitudes, to estimate equatorial vertical plasma drift and magnetic meridional wind simultaneously at all longitudes. It is desired to incorporate the two techniques so that they can compensate each other and estimation of the state and drivers can be performed consistently. Assimilative ionospheric modeling is still at a primitive stage. A major topic along with many others is to forecast ionospheric weather many hours ahead. It will certainly benefit from increasingly available and various types of space environment measurements, and from improvement of other space weather predictions in the Sun-Earth system.

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➢ Data Assimilation in the Ionosphere and Magnetosphere

A. Ridley and D. Bernstein (U. Michigan)

Data assimilation is the altering of model result to make it more consistent with data. Data assimilation can be done in either a very simple way, or can involve the use of sophisticated methodologies. In this article, we describe the differences between the simple techniques and the more sophisticated and how these techniques apply in different regions of space.

The simplest data assimilation technique is called *nudging*. Nudging involves just pushing the model result towards the measurement results in a single location (per data point) over some amount of time. If the time is infinitesimally small, then the model result is being overwritten by the data. If the time is infinitely large, then data assimilation is basically not taking place. In many ways, this technique is like a point source (or sink) on the system. For example, if the model says the density is 10, but the measurement says it should be 100, then the data assimilation adds density in a single cell until the model agrees with the data.

Nudging is an easy technique to use and implement, involving only a few lines of additional code, but the lack of sophistication in this technique could lead to instabilities in the code or non-physical results. In the example described above, if the density were pushed from 10 to 100 in a single cell, in a single iteration, huge flows could build up due to the gradient of pressure, or maybe an island could form in the magnetic field. A better methodology would be to increase the density over a longer time period, to allow the unphysical properties to be minimized and possibly washed away by the dynamics of the code.

A similar technique would be nudging a quantity over a given area or volume, instead of nudging in a single cell (let's call this technique volume nudging).

This technique would minimize the non-physical results from the simplistic data assimilation, but would require significant a-priori knowledge of the system and the data to be ingested. In the previous example, if the density was in the thermosphere and we were measuring at some altitude, latitude, and longitude, then we could probably spread the density around in latitude and longitude, but we would have to do something much more sophisticated in the vertical direction. We could calculate a scale height and decrease the density for grids points above and increase the density for those grid points below. The data can then be distributed over a much larger volume. We could also nudge with a longer time scale the further we get away from the data point. This way we "trust" the data less and less the further we get away from the source. Volume nudging is an ad hoc method, and needs to be tuned for each data type and modeling region.

In reality, what each of the above techniques is doing is taking the difference between the data and the model and multiplying it with a *filter gain*. In the nudging case, the filter gain is a single value that is just the inverse of the nudging time period. In the second case, the filter gain is a matrix that applies the difference in the data over number of grid points in some way.

A *Kalman filter* provides a methodology for constructing the filter gain in a much more rigorous way. Operationally, the Kalman Filter does exactly the same thing as nudging and the volume nudging, but the filter gain has (or can have) a lot more elements in it. In fact, a Kalman filter takes into account not only the spreading out of the data over grid, but the influence of the particular measurement on all primitive variables (or states) in the model.

The Kalman filter performs optimal nudging through a *covariance matrix*. This matrix basically describes the influence of one state at one point on another state at a different point. For example, if we modulate the density at point X, how does the velocity at point Y modulate? Another way to think about the covariance matrix is that it plays the role of a correlation matrix between all of the points and states in the model.

Thinking about the covariance as a correlation matrix allows us to understand how it works. Let us first consider tropospheric weather modeling. We can ask questions such as, "If I know the weather in Ann Arbor now, do I know the weather in Los Angeles? No. Do I know the weather in Denver? No. Chicago? Maybe. Detroit? Most likely, yes. Boston? No." This means that in order for data assimilation to have a significant impact on the modeling results, we need to have measurements very close together, since the length-scales in tropospheric weather are very small. Mathematically, this means that the covariance matrix is mostly a diagonal matrix, with off-diagonal elements being close to zero.

The thermosphere and ionosphere are very similar to the troposphere in this respect—a single data point will influence only a small region of the system, because the length scales are so small. The magnetosphere also has small length scales, but they can be quite anisotropic. The length scale across the magnetic field may be very, very small, but the length scale along the magnetic field line make be quite large. This would make the covariance matrix non-diagonal, but possibly still sparse (i.e. lots and lots of near zero values).

Does this mean that it is not worth considering data assimilation in a model where there is little data and the covariance matrix is sparse? This is up for debate. In models that are non-diffusive and are strongly driven by advection, the data assimilation can still make a huge impact. This is because the change in the model results (i.e. the alterations made by the data assimilation) will be swept downstream, causing the downstream values to be much better. Upstream, there will be very little to no influence.

Next let us consider the ionospheric potential, like in the assimilative mapping of ionospheric electrodynamics. We know that the electric field is transmitted by magnetosonic waves that travel at almost the speed of light in the upper ionosphere. This means that when we change the electric field at one location, all other locations know about this change quite quickly (much faster than our time-step), indicating that the covariance matrix may not be diagonal at all, but may be quite full, with numbers whose magnitudes are larger than zero at almost all matrix locations. This means that having a single measurement could dramatically influence the model results. Having 150 magnetometer stations allows us to examine the high-latitude large-scale electric potential pretty easily. Having 150 temperature sensors across the United States would not allow researchers to create a very good tropospheric data assimilation model.

In summary, most techniques of data assimilation are identical in their underlying methodologies, but the implementations vary from being simplistic (like nudging), to ad hoc (like volume nudging), to quite sophisticated (like a Kalman filter). They all involve taking the difference between the model results and data and using this knowledge to alter the model over some region. The Kalman filter uses a covariance matrix to do this. The covariance matrix can be thought of as a measurement correlation between different regions of the system, and is very dependent on the length scales of that system. The ionospheric electrodynamics has very large length scales, so minimal amounts of data could be used to correct the model, while the thermosphere, ionosphere, and magnetosphere have very small scale lengths, so much more data may be needed to correct the model.

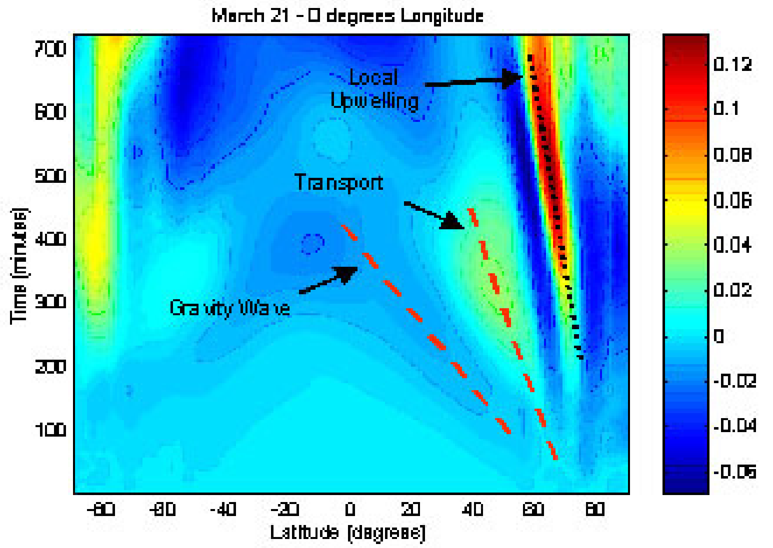
➢ Data Assimilation and the Thermosphere

Cliff Minter (NOAA/SEC), Tim Fuller-Rowell (NOAA), and Mihail Codrescu (CIRES/NOAA)

The neutral component of the thermosphere comprises more than 99% of its mass. Characterizing and predicting total neutral density is important in its own right for the drag it imposes on satellites, which affects orbit prediction, collision avoidance, and re-entry calculations (*Alfonso et al.*, 1985; *Rubicam*, 1990; *Marcos*, 1990; *Storz et al.*, 2002; *Doornbos et al.*, 2002). The importance of the neutral upper atmosphere on the ionosphere has also been recognized for many years, particularly to its impact of ion recombination rates (*Rishbeth and Garriott*, 1969; *Prölss*, 1991) and its subsequent impact on radio communication and navigation signals.

The significance of the neutral atmosphere becomes most apparent during geomagnetic storms when material is ejected from the Sun during a coronal mass ejection. If this ejected material hits the Earth with a southward magnetic field, a strong coupling of the solar wind with the Earth's magnetosphere occurs, allowing an intense transfer of energy into the upper atmosphere. Initially, plasma convection increases, and particle precipitation patterns expand, which introduce heat into the upper atmosphere through collisions. This energy input in the high latitude thermosphere in the form of Joule and particle heating, first produces a thermal expansion of the thermosphere causing large increases in neutral density. These density increases launch gravity waves from high to low latitudes. Strong equatorward winds follow, creating an overall change in the global circulation. The divergent nature of the circulation forces upwelling at high latitudes, transporting molecular rich air from low to higher altitudes. This transport decreases the neutral O/N_2 ratio in the F-region. The increase in the number of heavier molecular species, primarily molecular oxygen and nitrogen, speeds up the capture free electrons in the ionosphere first through charge exchange and subsequently through dissociative recombination. These heavier neutral species can also be transported to mid and low latitudes by both the background and storm winds, altering the recombination rate in the ionosphere over a large area.

The figure illustrates the storm evolution of the quiet-minus-storm height-integrated O/N_2 ratio difference as a function of latitude and time in a particular longitude sector in response to an increase in magnetospheric forcing, particularly Joule heating. Thermospheric data assimilation techniques will need to capture all of these physical processes: the response to localized upwelling, the launch and propagation of gravity waves, and composition transport by the global circulation.



The storm evolution of the neutral composition.

The need for specification and forecast of neutral atmosphere density and composition has led to the development of data assimilation techniques in the thermosphere. Compared with meteorology, neutral thermosphere data assimilation is unusual in that its variability originates more from external sources than internal stochastic processes. As already described, magnetosphere sources imposed at high latitudes can dump thousands of terajoules of energy into the upper atmosphere during a geomagnetic storm. This energy is injected into the neutral atmosphere at a highly variable rate, and can create significant changes on the timescale of minutes. Since the neutral atmosphere is so strongly driven, incorrectly estimated drivers can also push the physical model description away from reality, creating biases in the solution. Usually, models of rapidly changing systems can be corrected with observations, but for the neutral upper atmosphere, only a handful of satellites currently exist. The satellite revisit rate at a given longitude may take hours, a much longer timescale than the minute-to-minute storm variability. A physical model can help account for these rapidly-changing, unobserved regions by 'transferring' information from the observed to the unobserved regions through the physical equations. However, this remedy is easier said than done. One must recall that one is dealing with a highly coupled and nonlinear system. Such a system, where small changes in the initial conditions lead to substantially different solutions, is one of the most studied and perhaps most thorny problems in mathematics (*Bryson and Ho*, 1975).

Several avenues exist that can improve neutral atmosphere data assimilation. Perhaps the most straightforward would come from increasing the number of available observations by expanding the number of satellites. Adding to the number of scanning or broad-viewing instruments, such as the GUVI instrument on the TIMED satellite or an imager viewing the Earth from geostationary orbit, allows observations of larger areas of the neutral atmosphere, while decreasing the size of the problematic unobserved regions. Since the neutral atmosphere drivers are so influential, observations of the storm-induced heating from constellations like Iridium for example could help forecast storm changes before they even occur in the thermosphere.

Information about the neutral atmosphere can also come from ionosphere data assimilation by exploiting the strong coupling between the neutral atmosphere and ionosphere. The ionosphere typically has greater coverage through ground-based, dual-frequency GPS and ionosonde networks, or from space using occultation from new satellite constellations, like COSMIC. Ionosphere data can improve neutral atmosphere data assimilation, and the improved neutral density estimates can, in turn, provide information for the ionosphere in the form of a feedback loop.

Improved numerical techniques can help avoid the essentially infinite number of incorrect solutions that make solving coupled and nonlinear systems so difficult. Ensemble Kalman filters are also likely to provide a valuable resource, as seen in meteorology.

Even though neutral atmosphere data assimilation systems already provide optimal specifications for the available data sources and numerical techniques, this field, like meteorology, will always have room to grow. For ionosphere data assimilation to advance, neutral atmosphere data assimilation must remain in step as the two systems are indeed so strongly tied together.

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2005 CEDAR Workshop 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 and a further 7 joint CEDAR-GEM 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.

➢ Joint CEDAR-GEM Student Workshop on Magnetosphere-Ionosphere Coupling (Final Report)

Conveners: **Carlos Martinis** (martinis@bu.edu) CEDAR student co-representative and **Jichun Zhang** (jichunz@umich.edu) GEM student representative

2005 Sunday 26 June 1000 AM - 0415 PM

This year the theme of the student workshop was Magnetosphere-Ionosphere (MI) coupling. During the morning we held a joint session with the GEM community where two speakers were invited to give tutorial talks. The plan was to look at this coupling from 'above' (magnetospheric point of view) and from 'below' (ionospheric point of view). The first speaker, Bob McPherron (UCLA), talked about MI coupling from the magnetospheric point of view. Basic concepts were introduced as well as the processes that create magnetospheric electric fields and how these create field-aligned currents that couple the magnetosphere to the ionosphere. The second speaker, Rod Heelis (UT Dallas), gave a tutorial on MI coupling from the ionospheric point of view. He discussed the current systems connecting the ionosphere and magnetosphere and the electromagnetic and particle energy inputs. It was interesting to see how similar topics were presented with different perspectives. The active role of the ionosphere regulating the energy transfer from the magnetosphere to the ionosphere was clearly shown.

After lunch we held separate workshops, with the CEDAR workshop continuing with the MI coupling theme. The first speaker was John Foster, (MIT Haystack), who stressed the importance of the use of distributed array of small instruments to study MI coupling and gave some example of space weather effects at mid-latitudes. His talk was followed by Cheryl Huang (AFRL), who showed the presence of low-energy electrons from DMSP, during superstorms. Ionospheric conductances calculations usually underestimate the observations during these events, with important consequences for modeling.

The second part of the afternoon session started with a talk by Stan Sazykin, from Rice University. His focus was on ionospheric electric fields of magnetospheric origin and how they cause re-distribution of electron density at low- and mid-latitudes during geomagnetic storms. Shielding effects and Sub-Auroral Polarization Streams (SAPS) were also discussed. Finally, Dirk Lummerzehin (U. of Alaska), talked about MI coupling using the aurora as a typical example. The ionosphere is modified in the aurora, leading to upflowing heavy ions that move into the magnetosphere and provide a source of plasma. A comparative study with the aurora in Jupiter was also presented.

Evaluation forms were handed out to the attendees and the feedback from the students showed that in general they were pleased with the level and selection of topics presented. All the talks are available online at *http://cedarweb.hao.ucar.edu/workshop/videolist.html#2005*.

➢ Student Workshop on Introduction to Proposal Writing

Conveners: **Stan Briczinski** (sjb144@psu.edu) and **Carlos Martinis** (martinis@bu.edu)

2005 Wednesday 29 June 0400 - 0600 PM

The introduction to proposal writing workshop was a panel type workshop composed of Bob Kerr (NSF Aeronomy), Phil Richards (NASA) Pamela Loughmiller (CEDAR post doc Embry- Riddle) and Jonathan Makela (U. Illinois). The workshop began with a brief talk by Dr. Richards on how NASA reviews and grades proposals, which is available at *http://cedarweb.hao.ucar.edu/workshop/archive/*

richards05a.pdf. He also included as an example proposal one of his own proposals from 1999 at *http://cedarweb.hao.ucar.edu/workshop/archive/richards05b.pdf.* After his presentation, the floor was opened up to allow questions from the audience. The questions ranged from collaborating with foreign institutions to fulfilling all of the requirements on the NSF's proposal guide. Dr. Loughmiller shared her recent experience of what it was like to apply for and receive the CEDAR post doc, and Professor Makela was able to present the perspective of an academic just entering a university faculty position. About 75 people attended the workshop and the large number of questions asked made it a very productive session.

➢ Meteors and the Upper Atmosphere (Final Report)

Conveners: **Lars Dyrud** (ldyrud@bu.edu) and **Diego Janches** (diego@cora.nwra.com)

2005 Monday 27 June 0130 - 0330 PM

The workshop was held in a short presentation style followed by discussions. We had 11 presentations in the 2-hour long session, 5 of which where student presentations. The speakers were Lars Dyrud from Center for Remote Sensing; Meers Openheim and Yacob Dimant (Boston .); Elias Lau and Santiago de la Peña (U. Colorado); Anne Smith (NCAR), David Fritts and Diego Janches (CoRA/NWRA); and Stan Briscinski, Akshay Malhotra and Arnab Roy (Penn State). 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 for momentum flux measurements. All these subjects showed once again the growing interest by the community in the effects and understanding of meteors and the mesopause. Finally, the convenors, Diego Janches and Lars Dyrud would like to thank everyone that took part and attended this year's workshop.

➢ Magnetosphere-Ionosphere Coupling and Ionospheric Storms Workshop (Final Report)

Conveners: **Chaosong Huang** (cshuang@haystack.mit.edu) and **Bela Fejer** (bfejer@cc.usu.edu)

2005 Thursday 30 June 0130 - 0330 PM

The M-I Coupling and Ionospheric Storms Workshop was held on Thursday, 30 June 2005 in the Anasazi North Room. About 80 participants attended the workshop. This workshop focused on ionospheric electric fields and global ionospheric disturbances during magnetic storms. Prompt penetration electric fields generally last for less than one hour because of the shielding effects of the ring current. However, a recent study suggests that they can last for several hours. Disturbance winds and neutral composition also play a crucial role in the generation of ionospheric storms. The outstanding problems include what causes the long-duration enhancement of the ionospheric electric field, how significantly the penetration electric field causes ionospheric disturbances, how the penetration electric field effect can be separated from wind dynamo effect, and how the ionospheric electron density disturbances are related to neutral winds and composition changes. The speakers of the workshop presented the latest observational and simulation results related to these problems.

Bela Fejer (USU) began the workshop with a presentation of how prompt penetration electric fields vary with latitude. Temporal variations of penetration electric field patterns at two storm times at different latitudes were derived from simulations using the Rice Convection Model (RCM), and the simulation results were compared with observations. It is concluded that ionospheric conductivity changes strongly affect the local time, latitudinal, and longitudinal variations of the prompt penetration electric fields.

Ray Greenwald (JHU/APL) reported new observations of storm-time ionospheric convective flows obtained with the SuperDARN Wallops radar. The Wallops radar was constructed to provide improved geophysical monitoring instrumentation at GSFC/WFF and to study plasma flows and ionospheric electric fields at mid-latitudes under disturbed geomagnetic conditions. The radar detected very strong plasma convection flows at mid-latitudes in two instances of disturbed/storm-time activity within one month. In both cases, the storm-time expansion of the convection cells lasted a number of hours. The observations indicate that there was no temporary undershielding, but rather a long-term reconfiguration of electric fields and plasma convection in the inner magnetosphere.

Chaosong Huang (MIT) presented the observations of penetration electric fields obtained with the Millstone Hill and Jicamarca incoherent scatter radars during magnetic storms. It is shown that the interplanetary electric field can penetrate to the low-latitude ionosphere without obvious attenuation for several hours during the main phase of storms as long as the IMF remains southward. The observations imply that the polarization electric field cannot be built in the ring current when the magnetic activity is strengthening, so the magnetospheric convection electric field can continuously penetrate to the low-latitude ionosphere without shielding.

Joe Huba (NRL) presented the simulation results of storm-time penetration electric fields and ionospheric disturbances with a self-consistent coupling of the RCM and SAMI3 codes. Different variations of the polar cap potential were used in the simulations. It is found that temporal changes in the polar cap potential produce electric fields that modify the F region equatorial drift velocities; the velocities increase in the daytime and decrease in the nighttime by up to a factor of 2. Total electron content (TEC) in the mid-latitude ionosphere is increased by up to 35%, and the equatorial fountain effect is enhanced in the post-sunset period.

Naomi Maruyama (HAO/NCAR) also presented simulation results of storm-time ionospheric electric field using the RCM. It is shown that the magnitude of the penetration electric field from simulation depends on the plasma sheet conditions and conductivity as input to the RCM boundary conditions. The simulations reproduced the ionospheric electric fields and density disturbances during the magnetic storms on 31 March 2001 and 17 April 2002 and were in reasonable agreement with observations.

Marlene Colerico (MIT) showed storm-enhanced density (SED) events detected with global GPS network during magnetic storms. Ionospheric SED is characterized by high TEC values (>50 TEC units) and correlated with plasmaspheric drainage plume. SED plumes over Northern Europe and American sectors are compared. This may be the first time that the occurrence of strong SED plumes over European sector was derived. Magnetic conjugacy effects of SED formation were analyzed from GPS and multiple satellite data.

Mariangel Fedrizzi (NOAA/SEC) reported the simulation studies of different mechanisms that are responsible for F-region height changes during geomagnetic storms. Ionosonde observations during the 31 March 2001 storm are compared with the CTIPe model. CTIPe results are in good agreement with the observations. The contributions of mechanisms at middle latitudes include thermospheric wind that is dominant during the night and thermal expansion that is larger in the nightside sector during the first hours after the storm commencement.

Yongliang Zhang (JHU/APL) presented GUVI observa-tions of composition changes and ionospheric behavior during magnetic storms. It is found that energy input (particle and Joule heating) from the magnetosphere causes significant O/N_2 depletion down to and beyond the magnetic equator. Time delay between the energy input and O/N2 depletion supports the idea of co-rotation. There is a fairly good positive correlation between O/N_2 and TEC. This provides a way to use GUVI O/N_2 to estimate TEC over oceans where no land GPS observations are made.

John Emmert (GMU) presented observations of average storm-induced thermospheric disturbance winds. It is shown that the average disturbance winds at equatorial to upper-mid-latitudes are mostly westward and equatorward. Daytime disturbance winds extend down to at least 110 km and are generally constant with height above 130 km. Low- and mid-latitude nighttime zonal disturbance winds are westward, with average peak magnitudes of 15 m/s for moderately disturbed conditions to 50 m/s for strongly disturbed conditions.

Hien Vo (NAIC/Arecibo) reported the observations of the low-latitude ionospheric response to the November 2004 magnetic storm obtained with Arecibo all-sky imager and global GPS network. Two sequences of ionospheric density depletion were observed to move northward and westward over Arecibo in response to the large Dst drop. The incoherent scatter radar data from Millstone Hill and Arecibo can be used to address the low-latitude formation of SED.

➢ Electrodynamic Magnetosphere-Ionosphere Coupling at Sub-auroral Latitudes

Conveners: **Stanislav Sazykin** (sazykin@rice.edu) ,
Phil Erickson (pje@haystack.mit) , and
Bob Lysak (bob@aurora.space.umn.edu)

2005 Tuesday 28 June 1000 AM -1200 PM

The workshop was an opportunity for both CEDAR and GEM scientists to compare notes and exchange data and ideas on the subject of electrodynamic coupling between the sub-auroral/mid-latitude ionopshere and the inner magnetosphere.

Although the “focus” topic was Sub-Auroral Polarization Stream (SAPS) electric field phenomena, the 14 speakers addressed a broader range of issues in this very active research topic from the theoretical, modeling and observational points of view. The workshop was oversubscribed, and although there was no time left for a separate open discussion, many talks were followed by multiple questions and brief discussions.

Opening the workshop, John Foster (MIT Haystack) presented an ionospheric perspective of the SAPS phenomena, based on Millstone Hill incoherent radar measurements of subauroral electron densities and convection velocities combined with GPS Total Electron Contect (TEC) maps. It was emphasized that the magnetosphere drives SAPS but the ionosphere controls SAPS characteristics. John also suggested that inside the (latitudinally) wider SAPS region, narrower and structured regions of highly dynamic large-amplitude electric fields have been observed in DMPS ion-drift data that may be caused by an ionospheric feedback-instability mechanism. Anatoly Streltsov (Icarus Research Inc.) presented his theoretical/modeling work that gives one possible explanation of this effect in terms of Alfven waves resonator effect. Mike Liemohn (U. Michigan) showed structured inner-magnetospheric electric fields calculated with the self-consistent version of the RAM ring current model. Some of those structures appear to be similar to SAPS. Mike pointed out that such structures are not found in IMAGE HENA particle flux maps of the ring current region, and challenged experimentalists to reconcile model results with HENA observations. Two other presentations by modelers addressed more general aspects of global magnetosphere-ionosphere coupling at subauroral and mid-latitudes. Austrid Maute (NCAR/HAO) gave a short update on her work in developing an electrostatic potential solver to be used with the Lyon-Fedder-Mobary (LFM) global MHD code as part of the Center for Integrated Space Modeling (CISM) project. One purpose is to allow for hemispheric asymmetry in the code. The code is still under development. Bob Lysak (U. Minnesota) described his current work in first-principles magnetosphere-ionosphere modeling extending his model to mid-latitude regions of low conductivity. All of these modeling talks indicated that we are still quite far from being able to explain the observations.

The need for modeling was evident as there was an abundance of observations presented at the session. Jerry Goldstein (SRI), in his talk, used IMAGE EUV and HENA observations to point out the close relation of the (cold) plasmaspheric and (hot) ring current particle populations. According to him, among the still-unanswered questions are: How do magnetospheric electric fields very spatially, and what is the role of SAPS electric fields on sharpening storm-time plasmaspheric plumes? An emerging role of meter scale (HF and VHF) coherent radar measurements in deducing convection electric fields at subauroral latitudes was evident from three talks by Ray Greenwald (APL/Johns Hopkins) (initial observations of SAPS with the newest SuperDARN Wallops Island HF radar), Murray Parkinson (La Trobe U.) (Australian TIGER HF radar observations of SAPS during substorms, talk given by Stan Sazykin (Rice U.), and Melissa Meyer (U. Washington MRO passive radar VHF coherent scatter SAPS and SAID observations). In the next few years, these new techniques will give us a new way to look at the dynamics of sub-auroral convection. In-situ electric field measurements by CLUSTER spacecarft presented by Pamela Puhl-Quinn (U. New Hampshire) indicate the presence of SAPS in the dusk-side inner magnetosphere. While SAPS were shown in case studies, there is also an empirical parameterized model of the convection electric field constructed from CLUSTER observations. Pamela pointed out that when the location of the plasmapause is estimated from spacecraft potential and electron density measurements, it roughly coincides with the SAPS region.

On the subject of observations of broader M-I coupling at mid-latitudes, Attila Komjathy (NASA/JPL) gave an overview of ionospheric electron density global changes during the initial phases of “superstorms” based on TEC maps derived at JPL from GPS receivers on board the CHAMP satellite. Enormous changes in mid-latitude TEC are necessarily related to magnetospheric electric fields, although a quantitative explanation has not been given yet. Ian Mann (U. Alberta) talked about another global aspect of M-I coupling during superstorms — observations of intense ULF (Pc5-band) waves at mid-latitudes, and challenged those working in the field to come up with an explanation. Chin Lin (Boston College) described his recently-published work on modeling ionospheric low-latitude effects of storm-time magnetospheric electric fields.

The workshop generated plenty of interest evident in the number of presenters (14) and also in terms of participation. In summary, there is a clear need for continuation of the very productive discussion started at this workshop.

➢ Auroral Boundaries: Finding Them in Observations and Model Output Files (Final Report)

Conveners: **Bill Peterson** (Bill.Peterson@lasp.colorado.edu) Co-Chair of GEM WG-1 on Plasma Outflow in the Magnetosphere-Ionosphere Coupling (MIC) Campaign and **Josh Semeter** (jls@bu.edu) Chair GEM MIC WG-2 and CEDAR Representative

2005 Wednesday 29 June 0130-0330 PM

Dr. Gang Lu (HAO/NCAR) set the tone for a joint GEM/CEDAR workshop that followed. She discussed the physics associated with boundary formation and reviewed the work that has been done to use in-situ plasma observations, high frequency and incoherent scatter radar observations to elicit boundary locations. She also discussed techniques used to identify boundaries in MHD code outputs and gave a brief introduction to the enhanced boundary finding abilities of the new AMISR radar.

The lively joint GEM/CEDAR session had 11 speakers and quite a bit of discussion. Mervin Freeman (British Antarctic Survey) discussed the spectral width features in the SuperDarn radar that can be used boundary identifications. He showed that, except between 02 and 06 LT the agreement between boundaries identified by SuperDarn and DMSP plasma agree well. Josh Semeter (BU) discussed various representations of the polar cap boundary over Sondrestrom, Greenland, using IMAGE, FAST, ISR, and spectral imagery. In particular, comparisons between sheared plasma flow in the ionosphere and optical auroral boundaries agree very well.

Dan Weimer (Mission Research Corp) showed pathological examples of open and closed boundaries with structure to illustrate that automatic boundary identification is a very challenging task indeed. Bob Strangeway (UCLA) made the same point using data from the FAST satellite.

Michelle Thomsen (LANL) noted that the success that Kp has in organizing magnetospheric phenomena follows from the locations of the magnetometer stations used to construct Kp being at latitudes near the auroral boundary where they are very sensitive to changes in the convection electric field which drives magnetopsheric processes. Karen Remick (USGS) made the same point but with the very extensive set of magnetometer data she has accumulated.

Joe Borovsky (LANL) made two major points, one unintended. First: he showed comparisons of all sky camera images at/near the magnetic foot points of geosynchronous satellites. Comparisons of plasma observed at geosynchronous altitude and auroral arcs showed that the diffuse aurora is associated with the displacement of the ion and electron plasma sheets. He unintended point was that the chairperson was so used to electronic projection, that old-fashioned view graphs were difficult to accommodate!

Erika Harnett (U. Washington) presented multi-stream MHD results demonstrating change in auroral boundary, field aligned currents, and outflow with increasing southward IMF - currents enhance and move to nightside. H+ outflow increases in area while O+ outflow increases particularly more on the dayside. Lutz Rastaetter (CCMS/GSFC) presented a polar cap metric study for Feb. 18, 1999 event using the BATSRUS, Weimer-2K and OpenGGCM. The results showed substantial deviation of all models from data. He noted that field line tracing produced better results than using field-aligned currents.

Thomas Sotirelis (JHU/APL) showed examples of nightside boundary identifications using automated procedures on DMSP plasma data. He noted that the interval selected by the conveners did not have believable boundaries until instrumental degradation was accounted for. He noted that there are limits to correlations involving Dst and the stretching index because of relatively long magnetopsheric response times

Bill Peterson (LASP/U. Colorado) argued that dynamic coordinates derived from plasma data provide better ordering that geomagnetic coordinates of invariant latitude and magnetic local time, but that their definition is instrument and platform dependant.

➢ Nighttime Midlatitude F-Region Structures: What Are They and How Should We Study Them? (Final Report)

Conveners: **Jonathan Makela** (jmakela@uiuc.edu) , **John Mathews** (jdmathews@psu.edu) and

John Meriwether (john.meriwether@ces.clemson.edu)

2005 Monday 27 June 0130 - 0330 PM

A workshop entitled "Nighttime midlatitude F-region structures: What are they and how should we study them?" was held at the 2005 joint CEDAR/GEM workshop in Santa Fe, NM. The purpose of this workshop was to examine the current status of our understanding of the various forms of F-region structure that have been observed over the years at mid-latitudes. Approximately 70 people attended the session. Although the focus of the session was on the Caribbean region, mainly due to coordinated studies centered on the Arecibo incoherent scatter radar in Puerto Rico, significant work has been performed at other longitude sectors. As was pointed out by the introductory talk given by Jonathan Makela (U. Illinois at Urbana-Champaign), many observations of different types of structure (F-layer height bands, brightness waves, MSTIDs, to name a few) have been carried out using a variety of instruments over the past thirty years. These structures can pose a hazard to space-based communication and navigation systems that rely on trans-ionospheric propagation as they tend to be characterized by sharp gradients and small-scale structure in electron density. The observations have been carried out in the past by a variety of instruments, including both incoherent and coherent scatter radars, imaging systems, Fabry-Perot interferometers, and GPS. In a few specific cases, campaigns have been carried out bringing many of these instruments together to perform coordinated observations. However, a large portion of results to date has been gathered by one or two instruments operating independently. One of the clear results from this workshop was the recognition of the need to perform more coordinated, long-term campaigns operating multiple instruments from a variety of closely spaced locations to study these structures in more detail.

Wes Swartz (Cornell) discussed how new technologies have evolved that give us new capabilities in studying these structures that were not available during the last set of campaigns held in the Caribbean. New radar modes have been developed for the Arecibo radar that give us higher resolution data in the E region, which may play an important role in the development of these structures. In addition, new methods are being used to image these irregularities using small portable coherent scatter radars. This will prove useful in comparing the radar data to other two-dimensional data sources, such as those provided by all-sky imaging systems, and will provide new insights into the physics of mid-latitude F-region structures. Many other instruments have been upgraded and new technologies have been developed, all of which present new capabilities for studying mid-latitude F-region structure. Bailes Brown (Harvard University), an undergraduate student, presented information on the MiniME Fabry-Perot interferometer (FPI) that is being developed at Clemson University. The miniaturization of the FPI will allow for collecting information on the thermospheric winds from locations that were previously unaccessible due to the infrastructure required by previous FPIs. MiniME will also have a higher sensitivity than previous systems, allowing for the study of the winds and temperatures during structuring events in greater detail than before.

The importance of the E region in the development of F-region structure discussed by Dr. Swartz was also echoed by Rebecca Bishop (Aerospace Corp.) and Russell Cosgrove (SRI). Dr. Bishop presented results from a study investigating E- and F-region coupling during the passage of tropical storms. Her results suggested that pressure variations caused by the passage of these storms could result in the launching of gravity waves that could be the seed for some of the structures seen in the mid-latitude F region. Dr. Cosgrove presented modeling results from recent simulations. His model results showed how wave breaking in sporadic-E layers could translate into dramatic changes in the F-region electron density. More accurate measurements of, among other quantities, the Poynting flux are needed to verify these results. It was suggested that simultaneous measurements of the magnetically connected E and F regions are needed, something that could be accomplished during future campaigns. During the discussion, it was noted by several people that the modeling of mid-latitude F-region structure is still in its infancy. Several researchers have studied two-dimensional linear models, but more realistic three-dimensional non-linear models are still needed to fully understand the complex physics at play. Thus, in addition to more experimental campaigns, it was suggested that more theoretical studies are needed.

Another new development is the use of micro-baragraphs to search for the origin of the waves responsible for the generation of the F-region structure. John Mathews (Penn State) presented data from three collocated instruments: the Arecibo

ISR, an all-sky imager, and a microbaragraph. The data from the imager show a clear wave structure that can also be seen in the electron density profiles obtained from the radar, but only after a high-pass filter has been applied to the data. The coincident microbaragraph data shows evidence for an oscillation in the pressure corresponding to the oscillations in the other data sets. It was suggested that an array of microbaragraphs should be deployed in the Caribbean to study the spatial characteristics of these oscillations.

Finally, the importance of geographical coupling in the development of mid-latitude stricture was discussed by two graduate students. Carlos Martinis (Boston U.) showed results from an imager at the Arecibo Observatory and one in El Leoncito, Argentina. Although the two imagers are not exactly magnetically conjugate, similar features are often seen by the two. Interestingly, these two sites are subject to structures due to both equatorial physics (such as equatorial plasma bubbles) and the mid-latitude physics discussed above. The importance of conjugate observations was discussed and it was noted that sites with better conjugacy need to be instrumented to study these phenomena. Michael Nicolls (Cornell) presented results from a case study showing how a large-scale traveling ionospheric disturbance launched from the auroral region generated plasma instabilities over Arecibo. The traveling ionospheric disturbance was observed in GPS total electron content data over North America and in all-sky images at both Arecibo and Hawaii. The instabilities were observed by both the Arecibo ISR and the radar at Jicamarca, Peru at the magnetic equator, and were initiated in the morning hours after the F region had been raised to an abnormally high altitude. To study these conjugate and global events, more instrumentation and future collaborative campaigns are needed.

Overall, this session demonstrated the many out-standing questions relating to nighttime midlatitude F-region structure. There seems to be enthusiasm from many of our colleagues, suggesting that the time may be ripe for putting together a multi-technique, multi-site campaign following in the tradition of many other successful CEDAR campaigns. We would suggest that the appropriate time to carry out a prototype campaign would be in the summer of 2006. We encourage anyone with interest to contact the session organizers. By combining the strengths of many different instruments and the expertise of members of the CEDAR community, we believe we can begin to come to a better understanding of the physics causing these many different types of structures.

➢ Improving Neutral Wind Specifications in the E and F Regions

Conveners: **John Emmert** (jemmert@gmu.edu) and **Douglas Drob** (douglas.drob@nrl.navy.mil)

2005 Thursday 30 June 0400 - 0600 PM

Neutral winds are an important component of the coupled ionosphere-thermosphere system, and affect the distribution of ionospheric plasma via numerous processes. Experimental and theoretical studies often require accurate estimates of neutral dynamics, but concurrent wind data are generally sparse or not available. In these cases, empirical assimilations of past winds measurement can be used to predict large-scale wind patterns for given geophysical conditions.

Currently, the only global empirical model of thermospheric neutral winds is the Horizontal Wind Model (HWM), which was last updated in 1993. Development of an upgraded empirical model is underway, and the current focus is on improving the performance of HWM in the E and F regions, particularly during geomagnetically disturbed conditions. In this workshop, we discussed large-scale thermospheric wind behavior, the impact of winds on ionospheric properties, and ways to improve empirical wind specification.

Our goal was to get CEDAR community involved in contributing and developing timely strategies for the HWM upgrade. We solicited contributions related to climatological wind results in the E and F regions as they relate to important aspects of winds in ionospheric studies. We were particularly interested in supporting numerical simulations (especially multi-year studies and investigations of systematic storm effects), which can benefit from and contribute to empirical studies. Thirty-three scientists attended the workshop including the speakers and conveners. Of those thirty-three, about half were students. The two-hour workshop consisted of eight short presentations followed by about 45 minutes of open discussion and debate.

Douglas Drob (US Naval Research Laboratory) began the workshop session with a review of the HWM statistical data analysis and assimilation codes, overview of new upper atmospheric wind data sets, and model upgrade strategy.

Geoff Crowley (Southwest Research Inst.) discussed the need for a rigorous data based validations of winds in current TIEGCMs, as well as the utility of updating the current HWM empirical wind model for the purposes of specifying neutral atmospheric inputs in first-principles ionospheric models which lack a theoretical neutral atmosphere. In both instances there is a need to understand the geophysical drivers of the neutral thermospheric and ionospheric climatology. In addition, just as statistical and empirical data analysis can provide valuable insight into current theoretical thermospheric and ionospheric modeling efforts, TIEGCM modeling efforts can provide valuable information for the development of improved mathematical representations for empirical models, especially synthetic data sets for the development of empirical data assimilation procedures. A series of multi-year TIEGCM runs will be generated to develop and test a new HWM model formulation.

Larisa Goncharenko (Haystack Observatory) presented new data and climatology of lower thermospheric winds over Millstone Hill. In general, current empirical and tabular climatologies under-estimate the magnitude of the winds over Millstone Hill, but there is relatively consistent agreement with seasonal and tidal phases. In addition, good agreement is seen between the Millstone Hill wind observations and observations made by the NASA-UARS WINDII instrument. The new ISR data set shows differences from earlier Millstone Hill climatologies, including larger wind magnitudes, greater differences between equinoxes, and the occurrence of a distinct westward wind in summer morning. Planning for a continuous 30-day data collection campaign, to be conducted in September 2005, was discussed.

Michael Faivre (Clemson) presented results from the Arequipa, Peru FPI. This instrument was recently outfitted with a new CCD camera that improved instrument sensitivity. Data processing techniques for estimating the line-of-site wind velocities and temperatures from the circular fringe pattern on the new CCD were presented. This was followed by a presentation of line-of-site wind measurements. The relationship between measured temperatures and wind, as well as divergence and convergence quantities were in the context of the midnight temperature maximum phenomena, other low latitude temperature enhancements, and the terdiurnal tidal oscillation.

Next, Geonhwa Jee (USU) presented results of a theoretical study of the sensitivity of total electron content (TEC) to neutral winds. It was demonstrated that the neutral wind has a significant effect on the mid-latitude ionospheric plasma density both during the day and night. Without meridional neutral winds there would be a factor of 2 increase of TEC during the daytime, and a factor of 4 decrease of TEC during the nighttime, thus highlighting the importance on meridional neutral winds on the maintenance of the mid-latitude nighttime ionosphere. The effect of the zonal wind showed a strong dependence on the magnetic declination angle, and consequently on geographic longitude.

Joe Huba (US Naval Research Laboratory) similarly discussed the influence of wind specifications on modeled ionospheric plasma density profiles. The impact of different neutral wind specifications on calculations of the low- to mid-latitude ionosphere calculated by the SAMI2 model was shown. Changes in the neutral wind specification can significantly modify the calculated width and symmetry of the ionization crests. A neutral wind/ionosphere coupling mechanism was offered to explain observed 'brightness waves' associated with the midnight temperature maximum. Model calculations with SAMI2 and TIEGCM using HWM specified winds were unable to reproduce or explain the observed phenomena, whereas calculations using the SLIM model (Anderson) in conjunction with SAMI2 showed consistency with the observations.

Bela Fejer (USU) discussed low-latitude winds and electric fields. The coupling of quiet-time thermospheric wind to the electric field varies significantly with latitude, season, and solar flux. Geomagnetic storm generated perturbation winds are more closely coupled to plasma drifts than is the case during quiet conditions. Comparison of thermospheric winds and plasma drift provides important information on ionospheric conductivities, which are otherwise difficult to measure directly.

John Emmert (George Mason U.) highlighted quiet and disturbed wind features seen in recent ground-based and satellite wind measurements that are potentially worth including in the new HWM. These included reformulation and specification of the global disturbance wind patterns, including clear seasonal and solar activity dependence. In addition, the new data indicates greater solar cycle dependence, including coupled seasonal effects during geomagnetically quiet conditions. Additional equinoctial asymmetries in the high-latitude wind patterns were also shown to be of significance. Finally, the known organization of high-latitude winds in geomagnetic coordinates was highlighted and supported using recent high-quality experimental data wind data sets.

In addition to discussion resulting from the items presented above, several main issues relating to the development of the next-generation model were clearly recognized as important to the CEDAR-GEM community in the open discussion that followed. The first was the need to continue collecting high-quality wind data in the lower thermosphere, particularly over the complete range of possible geophysical conditions, latitudes, longitudes, and local time. Data in the nighttime E region is desperately needed as the number of techniques to do so is currently very limited. The second important issue was related to a proper formulation and representation of low-latitude terdiurnal tidal component, believed to be related to the MTM and other significant ionospheric phenomena. Finally, of great importance to thermospheric modelers, and also to the eventual evolution of HWM into a full-fledged operational data assimilation system that can be utilized in combination with current first principles models, is the proper specification and provision of the statistical uncertainty. Such a specification would estimate the natural geophysical variability beyond the slowly varying seasonal and tidal fluctuations of the upper atmospheric winds, and would be determined from the residual noise of the comprehensive data sets after proper estimation and removal of the seasonal, tidal and other low-order variability represented by the HWM.

➢ Synergistic Mesosphere and Lower Thermosphere (MLT) Science Study with Ground-based and Satellite (TIMED and others) Observations

Conveners: **Chiao-Yao (Joe) She** (joeshe@lamar.colostate.edu) and **Qian Wu** (qwu@ucar.edu)

2005 Wednesday 29 June 0130 - 0330 PM

Approximately 50 people attended the workshop. Speakers were asked to describe collaborative research using satellite and ground-based observations in MLT region. Some speakers and audiences discussed the benefit of the combining the space-based and ground-based observations. Particularly, the satellite observations of the two-day wave are of interest to many ground based investigators.
Prof. Chiao-Yao (Joe) She (Colorado State) started the workshop by providing an overview pointing out the importance of synergistic studies with both ground-based (GB) and satellite observations, to help fine-tune the algorithm and to provide complementary (high spatial resolution vs. global) information. Joe then turned to the recent observations by the ODIN Odin/OSIRIS satellite on global sodium layers. The work was jointly done by Dr. John Plane and his student, Zeyu Fan, and Chiao-Yao She with Joe supplying the GB lidar data. While overpass comparisons between the satellite and ground-based lidar measurements at Ft. Collins initially helped to establish the retrieval algorithm, and to reveal or confirm the ~2 km altitude offset in the limb observation, the resultant retrieval showed very good agreement, although an offset of the 2 km in height was noted. The ground-based measurements not only helped correct the altitude offset, they also provide necessary information for the development of the retrieval algorithm. In the end, the satellite observations were able to provide a global view of the sodium layer distribution, confirming ice particle-sodium anti-correlation in the polar region summer and dramatizing diurnal perturbations in the equatorial region. Since OSIRIS is a Canadian instrument, an alternative title for the talk could be "Swedish God Odin uses Canadian instrument to observe Na day-glow, and British chemistry Guru retrieves global Na layers".

Dr. Tao Li (Colorado State) presented analysis results for a 9-day continuous lidar MLT temperature and wind observations in 2003 of low-pass filtered contour plots of temperature, zonal and meridional winds in August 2002, 2003 and 2004, revealing a quasi two day wave (QTD) signal. The variations in the diurnal and semidiurnal tides were examined. Planetary waves were also observed in the lidar data set. Comparisons with TIMED SABER temperatures in all 3 years and TIDI wind measurements in 2004 were made. Consistent results on S=3 and S=4 quasi-two-day waves were noted. It is interesting to note that both lidar and SABER showed stronger QTD activities in 2002 and 2004 than in 2003, implicating quasi-biennial oscillation.

Dr. Yucheng Zhao (USU) gave a brief description on her recent work with Mike Taylor (USU) on comparisons between ground-based temperature mapper data and comparisons with SABER. She talked about her effort to extract the annual and semiannual oscillations and the difficulty due to limited local time coverage of both the satellite and ground based optical measurements.

Dr. Jeremy Winick (Air Force Research Lab) presented recent results from SABER observations of temperature-inversion layers in conjunction with ground-based measurements. He noted that TILs are associated with tidal phase at low latitudes. SABER revealed their spatial extent to be larger than anticipated, 1000-5000 km or more along the TIMED orbital track. Large inversions provide a duct for bores. Extended collaboration with ground-based data can be very useful for the bore study.

Dr. Irfan Azeem (Embry Riddle Aeronautic U.) described his recent work on the 4-day wave over the South Pole in the mesospheric temperature before and during a stratosphere warming event obtained from a Michelson interferometer. More study with satellite observations will help to determine the extent of the 4-day wave and its zonal wave number.

Dr. Qian Wu (NCAR) gave an overview of the TIDI observational results from migrating diurnal and semidiurnal tides. Comparisons between TIDI observations and ground-based meteor radar data were made and showed promising consistency. In addition, a non-migrating diurnal tide analysis was also discussed. Moreover, the two-day wave and comparisons with observations from AURA satellite MLS data were also shown during the talk.

Dr. Han-Li Liu (NCAR/HAO) showed his model simulation (with TIME-GCM) of tidal and planetary wave interactions. The focus was on the 9-day continuous observations by the CSU lidar observation. Overall, he was able to reproduce many of the features in the lidar and TIMED SABER and TIDI data. The results imply the possibility of planetary wave effects on the tidal waves in mid-latitudes.

➢ Collaborative Research Using the Low and Mid-latitude Facilities (Final Report)

Conveners: **Dave Hysell** (dlh37@cornell.edu) and **Mike Sulzer** (msulzer@naic.edu)

2005 Friday 01 July 1030 AM - 1230 PM

This session was convened to bring the community of users surrounding the low-latitude upper atmospheric facilities (Arecibo and Jicamarca) into contact with the investigators developing the modes and experiments performed there. Our objective was to familiarize both groups with the activities of the other to assure that the most crucial parameters are being measured and that the resulting data are being fully utilized. The session began with the theme of the data needs of modelers, shifted to presentations on new experimental capabilities, and concluded with an introduction to emerging optical capabilities at the two sites.

Mihail Codrescu (CIRES/NOAA) stressed the necessity of exospheric temperature, composition, wind, and plasma number density measurements at low latitudes for validating general circulation models (GCMs). Mark Swisdak (NRL) pointed out that electric field transients are expected to produce large TEC modifications during storms and that electric field measurements therefore need to be made with fine temporal resolution, something at which both facilities excel. Dave Anderson (NOAA/SEC) discussed the latitude dependence of prompt penetration electric fields, highlighting the importance of chain studies to space weather research, a theme returned to by Vince Eccles (SEC). Meers Oppenheim (Boston U.) presented new numerical simulations of Farley Buneman waves and instabilities, which could be validated using the AMISR-7 system at Jicamarca.

A number of new experimental capabilities have arisen at Jicamarca and Arecibo since the last CEDAR workshop. Jorge Chau (Jicamarca) presented results of the first D and E region incoherent scatter experiments performed at Jicamarca. Marco Milla (U. Illinois) showed how plasma number densities and drifts can now be rapidly extracted from Jicamarca differential phase measurements using a Kalman filter approach. Mike Sulzer (NAIC/Arecibo) reviewed a number of new capabilities at Arecibo designed to promote collaborative studies there, including an optimized version of the MRACF World Day mode. Among these are dual beam velocity measurements that were analyzed by Nestor Aponte (NAIC/Arecibo). Esayas Shume (Cornell) likewise reviewed a new technique for inferring zonal MLT wind profiles in the electrojet region at Jicamarca. New gyroline observations at Arecibo (Asti Bhatt, Cornell) and mesospheric turbulence measurements at Jicamarca (Li Guo, Clemson) were also described.

A number of optical instruments are being deployed or upgraded at the low-latitude facilities. John Meriwether (Clemson) summarized efforts by his team to install a miniaturized Fabry Perot interferometer at Arecibo. He also presented results from the upgraded FPI at Arequipa, Peru, which showed nighttime neutral temperatures in substantial agreement with plasma temperatures measured simultaneously at Jicamarca. This instrument will be complemented by the SOFDI instrument to be deployed at Huancayo for daytime and nighttime thermospheric wind measurements.

Finally, prospects for new joint campaigns and studies utilizing the low-latitude facilities were outlined by Sixto González (NAIC/Arecibo). A workshop geared toward planning and coordinating the campaigns is being scheduled.

➢ Optical Calibration Techniques and Issues

Conveners: **Susan Nossal** (nossal@wisp.physics.wisc.edu), **Mike Taylor** (mtaylor@cc.usu.edu) and **Tom Slanger** (tom.slanger@sri.com)

2005 Thursday 30 June 0130 - 0330 PM

Accurate calibration is important for comparing observations taken by different instruments, for model-data comparisons, and for acquiring long-term data records. Consistent calibration techniques are critically important when multiple observers contribute to a long-term data set and when there are upgrades to the instrument(s) acquiring the data set. This year's optical calibration workshop continued discussion of these topics addressed at the 2004 CEDAR optical calibration workshop.

The workshop began with an historical perspective by Fred Roesler (U. Wisconsin). He described the development of a nebular calibration method used by Wisconsin observers for absolute and relative calibration of diffuse terrestrial, planetary, and astronomical observations. Roesler followed with a description of additional challenges associated with cross-calibration between instruments.

The Wisconsin observations are compared with the intensity of nebular sources, all of which are tied to the North American Nebula. The observations are then corrected for differences in atmospheric extinction due to the slant path of the sky observation compared with that of the nebular calibration. The primary nebular calibration sources used for Wisconsin H-alpha observations were calibrated using standard stars and corroborated using a blackbody source. More recently, observations of the interstellar medium taken as part of the Southern H-alpha Sky Survey Atlas by *Gaustad et al.* [2001] were compared with those taken by the Wisconsin H-alpha Mapper Fabry-Perot [*Haffner et al.*, 2003], further corroborating the calibration.

Nebular calibration offers long-term stability and like the geocorona and interstellar medium, nebulae are spatially extended line emission sources. The nebular calibration method has produced internally consistent results for Wisconsin-based geocoronal, planetary, and interstellar medium observations.

Inter-calibration of instruments participating in the NSF-CHARM geocoronal observation campaign of the early 1990s led to unforeseen challenges. Roesler made a hydrogen hollow cathode lamp placed in a diffusing box that was flown to different sites for inter-calibration using a line emission rather than a continuum emission source. A study of calibration differences that persisted after the instruments viewed the lamp indicated that careful consideration was required of both the source characteristics and the respective instruments viewing the source. Issues that arose included that the instruments saw different portions of the lamp emission spectrum depending upon whether they were single- or double-etalon FPI instruments, and the parasitic light (light from outside the filter bandpass) differed between instruments. The CHARM campaign indicated some of the subtle challenges associated with inter-calibration between optical instruments.

Brian Sharpee (SRI) spoke about standard star calibration, a method that is the basis for several other types of calibration. For example, the nebular calibration method discussed by Roesler and the calibration of the Keck echelle spectrographs discussed by Tom Slanger (SRI) are methods both tied to standard star calibration. Standard stars are stars with smooth spectral output and sufficient intensity to make their use as reference stars practical. Primary calibration stars have been calibrated against blackbody sources. Sharpee has been using standard stars to calibrate the Keck spectrographs. When performing this calibration it is essential that the star be fully enclosed within the field of view of the instrument.

Tom Slanger spoke about relative calibration of the Keck spectrographs using emission properties of molecular bands. The Keck instruments, located at Mauna Kea, Hawaii, are high-resolution echelle spectrographs used primarily for astronomical studies. The terrestrial emissions in the Keck astronomical spectra also provide a rich resource for aeronomical studies. Slanger spoke about relative calibration of emission lines within O_2 and OH bands. The intensity ratios between emission lines within these bands are known by atomic and molecular spectroscopy. Once one of the lines within each band has been calibrated using standard stars, the calibration can be transferred to other lines within the band by using information about relative line intensity within each band.

J. Baumgardner (Boston U.) spoke at the 2004 CEDAR Optical Calibration workshop about calibration of the Boston University spectrograph using Carbon-14 and laboratory lamp sources, and at this year's workshop focused on techniques used to characterize and calibrate Boston University's all-sky imagers. Processing of the CCD observational images to correct for instrumental effects involves subtracting the CCD bias and the dark thermal noise (differs with exposure time). Flat field exposures are used to normalize the observational images in order to correct for vignetting, i.e. cutting off of light rays, within the instrument. It is a challenge to obtain a spatially and spectrally uniform flat field that fills the field of view of the instrument. At Boston University, researchers use a diffusing light box and a diffuser at the location of the filter wheel in order to create a flat field used to correct the imager data.

Researchers use a tungsten lamp source for intensity calibration of the Boston all-sky camera observations. Knowledge of the brightness versus wavelength of the tungsten lamp as well as the transmission of the interference filter are both required to accurately calibrate the all-sky images using the tungsten lamp source. It is especially important to accurately characterize the transmission properties of the interference filter as the information about filter transmission properties supplied by the manufacturer may not be sufficiently accurate to reduce calibration errors to below 10%. In addition to the filter transmission, uncertainties about tropospheric scattering and atmospheric transmission probably are the major sources of error in the calibration of the airglow's absolute intensity.

Sam Yee (APL/Johns Hopkins) discussed mutual consistency of calculated dissociation and ionization rates using measurements from the Solar EUV Experiment (SEE) on board the Thermosphere Ionosphere Mesosphere Energetics and Dynamics Satellite (TIMED) with rates calculated using overlapping observations from other instruments. The SEE instrument observations are compared with long-term solar irradiance ultraviolet and extreme ultraviolet data from the SOLSTICE instrument on the UARS satellite and from the SORCE satellite. The TIMED/SEE derived O_2 photo-dissociation rates and their response to solar activity are found to compare favorably with those derived from UARS/SOLSTICE, while those calculated from SORCE observations are 10-20% less. Atomic oxygen and N_2 photo-ionization rates derived from TIMED/SEE X-ray and EUV measurements are generally higher than those calculated using EUV models. Measurement discrepancies provide an assessment of the uncertainties associated with parameters derived from SEE and other satellite observations and used in upper atmospheric modeling. The new information from TIMED/SEE suggests that ionospheric and airglow photochemistry might need to be reexamined.

Mike Taylor (USU) reported on the portable Lindau Calibration Photometer used by European scientists for inter-calibration of optical instruments. The calibration photometer uses a Fritz Peak standard source and makes calibration measurements at seven wavelengths. The photometer is easily portable and is used at annual European Optical meetings for cross-calibration of instruments.

Participants acknowledged the challenges associated with calibration and the need to optimize methods for intensity and spectral calibration and inter-calibration between instruments. We plan to continue these discussions at next year's CEDAR workshop. Please contact us with suggestions regarding the format of the CEDAR Optical Calibration Techniques and Issues workshop and if you would like to give a presentation next year. In addition, we are considering the idea of organizing a more extended optics workshop, perhaps in conjunction with the annual CEDAR workshop, where instrument characterization and calibration along with other optical aeronomy issues can be discussed at greater depth.

Most of the presentations given at the CEDAR 2005 Optical Calibration Techniques and Issues Workshop can be found on the CEDAR website.

➢ Report of the IPY/IHY/eGY Meeting at CEDAR

Convener: **Roger Smith** (roger.smith@gi.alaska.edu)

2005 Tuesday 28 June 0130-0330 PM

The workshop took place on Tuesday, June 28 from 1330 to 1530 and was attended by an estimated 40 participants. The meeting was intended to provide a place for discussion on involvement in the

International Polar and International Heliophysical Years, and also the Electronic Geophysical Year. The agenda provided for a mix of short presentations on programs and funding together with time for workshop discussion. The outcome of the meeting was a better appreciation for the opportunities presented by the target years of 2007 and 2008 and the parts to be played by IPY, IHY, eGY and their relationship to major longer-term programs such as CAWSES and virtual observatories.

Participants learned that IPY (*www.ipy.org*) expressions of intent had been processed and gathered into clusters for more formal proposals to the international secretariat. One leading cluster is the Interhemispheric Conjugacy Effects in Solar Terrestrial and Aeronomy Research (ICESTAR) project was presented by Aaron Ridley. This international program is an excellent example of a coordinated effort including many countries. It arises through the Scientific Committee on Antarctic Research (SCAR) and the International Arctic Science Committee (IASC) working groups and focuses on the opportunity to coordinate measurements and studies of conjugacy during the IPY years. The outcome will be a better understanding of concerted responses of both polar regions to electromagnetic variations and plasma dynamics in interplanetary space that specify near-earth space climate and weather.

Bill Petersen (LASP/U. Colorado) explained the Electronic Geophysical Year (*www.egy.org*) and how it will benefit entire communities through improved interoperability and exchange of data. In the geosciences, as elsewhere, providing ready and open access to the vast and growing collections of cross-disciplinary digital information is the key to understanding and responding to complex Earth system phenomena that influence human survival. EGY will support improvements in data access, data release, data description, data persistence, data rescue, common standards and cooperation, capability building, education and public outreach. The eGY recognizes that scientific information comprises content, context and structure held together like Borromean Rings such that the removal of one element causes the remainder to fall apart.

Nikki Fox (APL/Johns Hopkins) presented the primary goals of IHY (*www.ihy2007.org*) as advancing our understanding of the heliophysical processes that govern the Sun, Earth and heliosphere , continuing the tradition of international research and advancing the legacy on the 50th anniversary of the International Geophysical Year , and demonstrating the beauty, relevance and significance of space and earth science to the world. Internationally, IHY has made progress at the United Nations with their Basic Space Science Initiative. A program establishing TEC instrumentation in Africa is under way.

A National Science Foundation view was provided by Bob Kerr, emphasizing that the Upper Atmosphere Section would encourage the use of key facilities such as SuperDARN, AMISR and the ISR network as tools. It was emphasized that Solar Terrestrial Physics links both poles in a natural way and that international cooperation has been the historical hallmark of previous major STP programs. NSF can act as a catalyst for interagency, international and community development. It will also support and spotlight basic polar research underpinnings such as magnetosphere-ionosphere coupling, noctilucent clouds and convection.

CAWSES (*www.bu.edu/cawses/*) is a major longer-term program running successfully in the international arena and sponsored by COSPAR. Duggirala Pallamraju (Boston U.) described the current campaign activities and recent successes. It is clear that both IHY and IPY anticipate activities that could and should be coordinated with CAWSES. Both the US and international IHY and IPY coordinating committees should be consulting with the organizers of CAWSES to find ways in which these programs could draw strength from each other.

Virtual Observatories are on the horizon for many of our activities in GEM and CEDAR. Some are closer to operation than others, indeed some are working today in the sense that observations are being reported in near real time. Eric Kihn (NOAA/NGDC) reported on VO possibilities, mentioning that some prototypes are coming online despite shortage of funding. It is clear that there is a need for defined standards of metadata. He further discussed pertinent considerations of basic navigation, data catalog and search, visualizations, data ingestion, and data mirroring. His recommendations for the I*Y is to avoid reinventing the wheel, consider open archival information systems, use structured storage, have a portal site and get greater buy-in through use of commonly adopted standards.
Ensuing discussion reviewed the prospect for special funding for IHY and IPY. It was recognized that there would be more opportunity for funding of projects in such programs through leveraging

resources at federal agencies rather than waiting for special announcements of opportunity. Despite the anticipated lack designated funds, IPY and IHY can succeed through PI enthusiasm to leverage where possible and thereby benefit from participation in coordinated research that integrates a broader range of investigations.

➢ CEDAR 2005 Workshop Report: Middle Atmospheric Data Assimilation and Forecast Techniques

Conveners: **A. J. Gerrard** (agerrar@clemson.edu) and **Ruth Lieberman** (ruth@cora.nwra.com)
2005 Friday 1 July 1030 AM -1230 PM

Like last year's workshop devoted to the same topic(s), this workshop allowed for both invited and contributing presenters to informally discuss atmospheric data assimilation techniques and their use in subsequent forecasting endeavors. Unlike last year's workshop, we primarily focused on issues/phenomena associated with the middle atmosphere, leaving upper atmospheric data assimilation and forecasting issues to be addressed in other workshop sessions at the joint GEM-CEDAR 2005 meeting. The overall goals of this workshop were to 1) continue to raise awareness of the importance and application of such data assimilation and forecasting research in the stratospheric and mesospheric regions, 2) allow for an informal setting for both students and new researchers to participate, and 3) allow for a unique forum that such topics could be discussed within the CEDAR community, much like similar workshops held by the SPARC and IUGG communities.

The 10:30 AM Friday morning workshop was well attended and three core presentations were given by:

- Tomoko Matsuo (NCAR)
  Ensemble Filtering using a Middle Atmosphere Model

- Han-Li Liu (NCAR/HAO)
  Sensitivity of WACCM and Implications for Predictability

- Andrew Gerrard (Clemson)
  Gravity Wave Propagation from the Ground to the Thermosphere: Initial Results from the FOREGRATS Model

The workshop ran over its allotted time slot due to the active and lively discussions of both the presenters and the attendees. Specifically, numerous participants raised interesting issues and/or made informal, short presentations on related subjects (e.g., Rich Collins (U. Alaska) discussed the upcoming IPY and role of forecasting, Jan Sojka (USU) discussed the timescales involved in middle atmospheric predictability). Furthermore, small group discussions ran well into Friday afternoon.

Each core presentation had its own specific scientific conclusions, which can be identified from the presenter's slides available online. Larger issues facing the community, which were also actively discussed during the workshop, included such topics as:

1) The role of the CEDAR community in progressing the state-of-the-art in middle atmospheric data assimilation and forecasting. Specifically, given that CEDAR members are largely experimentalists or theoreticians, is there enough internal support for such research? Might it be better to address these issues from within other organizations [such as those mentioned above]?

2) What is the source of funding for such middle atmospheric work? NSF is largely divided between upper and lower atmospheres, with neither specifically claiming the middle atmosphere as a realm. Given that an understanding of the "weather" of the middle atmosphere is believed to be crucial in many upper and lower processes, how/to whom should proposals be submitted to or funded by?

3) There is a lengthy and ongoing argument of whether "forecasting" should be considered a "science" or an "art form." This topic has a large number of implications and repercussions. For example, some scientific journals do not accept forecasting papers. So how do the members of the middle atmospheric forecasting community advance the field?

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