Proposal to the American Geophysical Union

Chapman Conference
"Scientific Challenges Pertaining to Forecasting Space Weather Including Extremes"

Co-Convenors:
A. J. Mannucci[1], Delores J. Knipp[2], Huixin Liu[3], A. Surjalal Sharma[4],
Bruce T. Tsurutani[1] and Olga P. Verkholyadova[1]

[1]*Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA USA*
[2]*University of Colorado, Boulder, CO, USA*
[3]*Kyushu University, Fukuoka, Japan*
[4]*University of Maryland, College Park, MD USA*

ABSTRACT:

We propose to bring together the solar and geospace communities to review and advance our scientific understanding of solar-terrestrial relationships as they relate to forecasting space weather, from moderate to extreme conditions. Recent years have brought significant new developments in modeling, observations, and scientific understanding to research that pertains to space weather, as well as renewed interest in space weather extremes. Despite its being a long sought goal of the Space Physics and Aeronomy (SPA) community, forecasting space weather remains a challenge. This Chapman Conference is being proposed to create new community perspectives that will accelerate space weather forecasting as a scientific discipline, and address the barriers that currently exist in its development. There is an urgent need to develop new approaches for predicting space weather extremes. The outcome of this meeting will be guidance for the community on new research directions to pursue that will yield significant scientific benefits and the potential for societal benefits as well.

Table of Contents

1. General Description and Objectives

Successfully predicting or forecasting the future remains one of the most remarkable achievements of modern science, which also has practical applications. Examples are found in the disciplines of weather and climate, and long-term seismic forecasting being is of active interest. Successful forecasting is often among the most stringent tests of scientific understanding. Forecasting space weather has been a high-priority national goal since the advent of the National Space Weather Program, initiated by the Office of the Federal Coordinator for Meteorology in 1994 (Bonadonna et al., 2017). Space weather has recently received renewed attention and priority as part of the National Space Weather Strategy, summarized in the "Space Weather Action Plan" (SWAP) issued by the Office of Science and Technology Policy (OSTP) in October 2015, and further reinforced in the recent Executive Order from the White House: "Coordinating Efforts to Prepare the Nation for Space Weather Events". Emphasis on forecasting space weather extremes is a priority.

While weather forecasting has its operational side, there is also a scientific aspect of forecasting that is the primary focus for this Chapman Conference. Our objective is to bring together an international and multi-disciplinary group of scientists to discuss forecasting space weather as a scientific problem. In considering how terrestrial weather forecasting evolved, it is clear that it could not have been contemplated without significant scientific knowledge on the general circulation of the atmosphere having been developed in the 1920s to 1930s. The scientific giants of the day, including von Neumann, were heavily involved in the topic. The science of chaos as a sub-field of non-linear dynamics, which now permeates geophysics and many other fields, finds its origins with studies of the weather forecasting problem. It is clear that the forecasting challenge had an impact on scientific understanding of the atmosphere, from global to mesoscale to microphysical processes. We believe similarly that a focus on forecasting space weather will spur positive directions for solar-terrestrial science but that could also benefit a broader range of geophysical sciences.

Space Weather

"Space weather" as a discipline requires scientific understanding of how the Sun affects the space environment of Earth and how Earth's lower atmosphere influences the space-atmosphere interaction region. These connections are central scientific questions of our field, and dominate high priority science questions offered in the latest Heliophysics Decadal Survey of the National Research Council ("Solar and Space Physics: A Science for a Technological Society"). "Space weather" as a discipline emphasizes predictability of solar and geospace phenomena. We believe scientific understanding is closely tied to questions of predictability and success in forecasting.

Space weather as a scientific discipline inherently cuts across traditional AGU group boundaries (solar/heliosphere – SH, magnetosphere – SM, upper atmosphere and aeronomy – SA). The origin of space weather is often the explosive release of magnetic energy within the solar corona, which manifests itself as solar flares and the initiation of coronal mass ejections (CME). Another solar driver of space weather is the emergence of open-flux regions known as coronal holes from which high-speed solar wind streams emanate. These solar disturbances travel across interplanetary space to Earth, where they profoundly alter the magnetosphere, ionosphere and upper atmosphere. CME shocks also accelerate particles up to near-relativistic energies. These energetic particles have practical consequences for satellites and human safety. Another driver of space weather is "from below": over the past decade, scientists have increasingly recognized the significant role of the lower atmosphere in creating space weather (perhaps of a less extreme variety), particularly nearer to solar minimum periods.

The Challenge of Forecasting Space Weather

Several methods could be used to produce a space weather forecast. It is useful to consider tropospheric weather forecasting by analogy (also known as "numerical weather prediction" or NWP). An essential need for all forecasts is observations available at a certain epoch, generally obtained as globally as possible. How these observations are used to produce a forecast varies widely. Methods that have been used include: graphical methods with humans in the loop, time series forecasting methods, machine learning methods, empirical methods, methods based strongly on "first principles" (FP) or physics-based models, and combinations of the above. A major success of the tropospheric numerical weather prediction community is the use of FP models that produce forecasts superior to strictly climatological approaches or approaches that rely on human intuition. This has ushered a golden age of synergy and interaction between the scientific community trying to understand the atmosphere, and the operational community improving their forecasts based on advances in scientific understanding. There has also developed a valuable "operations to research" benefit: the NWP community generates long-term "reanalyses" which are consistently-produced three-dimensional multi-parameter maps of the global atmosphere, now used routinely as an essential research tool. These reanalyses are based on FP models combined with actual observations, and are widely used in atmosphere and climate studies.

Experience with tropospheric forecasting holds valuable lessons for space weather, but also some cautionary lessons. For example, it is now understood that state-of-the-art models are inherently limited in their ability to predict the weather more than 6-10 days ahead, even with near-perfect initialization of the forecast and with very complete physics. This limitation is due to sensitive dependence of the models on initial conditions, leading to the phenomenon known as *chaos*.

Tropospheric forecasting established the value of FP models, but also that timely observations must be incorporated into the forecasting procedure. The need for observations is due to the mathematical structure of our FP models: there are an infinite number of solutions to the primitive equations that underlie FP-based forecasts. Yet, observations are not extensive enough to fully constrain the possible solution space. Incorporating observations into forward-in-time simulations of nature, which is essentially what weather forecasts are, is in many respects an "art form". There is no single approach that works best in all circumstances.

Given the inherent challenge of space weather forecasting, it remains to be defined what FP models are best suited, and how observations are to be used. Tropospheric forecasting has revealed significant challenges when using a technique known as "data assimilation" – that is incorporating observations to better initialize FP-based simulations. The algorithms and data quality decisions made for NWP are in many respects an "art form". A deeper understanding of how to connect models and observations is needed for space weather also.

In space weather forecasting, we also face the possibility that significant gaps in our ability to forecast will stubbornly persist. For example, it is widely known that the north-south component of the interplanetary magnetic field (B_z) is of primary importance to predicting the intensity of the storm-time response. For less intense storms, the state of the lower atmosphere plays a role as well. What if we simply lack the means to forecast B_z at the needed accuracy? What would a space weather forecast then become? We may need to acknowledge that, in space weather, the forecast itself needs clearer definition. In addition, new approaches to combining FP models and observations must be developed.

A foundational aspect of our proposed conference is that a focus on forecasting space weather will bring profound scientific benefits, and that forecasting is a very useful way to test our scientific understanding. Over the past decade, the space physics and aeronomy (SPA) community has developed FP models sufficiently comprehensive that a chain of such models from Sun to Earth can be instantiated for predicting space weather impacts at Earth starting at the Sun. This model chain can form the basis for FP-based forecasts by analogy to tropospheric weather. Such a model suite represents in some form our current scientific understanding of the connected Sun-Earth system. Forecasting space weather using these models represents an excellent test of that understanding. However, there are unique challenges in assimilating observations into such a modeling chain that spans such a broad range of physical scales, from 10s to hundreds of millions of kilometers.

Producing a usefully constrained set of predictions from the theory often requires information that is not readily available. This leads to the prediction being only partially based on the theory, creating an ambiguity in how we interpret comparisons between the forecast and actual events. One of the difficulties is in the large variety of systems and processes that need to be modeled to produce "Sun-to-mud" forecasts. These processes are understood to varying degrees. Another difficulty is in providing sufficient observations to constrain the FP-based forecasts.

A primary goal of the conference will be to review and summarize the *most critical problems in scientific understanding* that limit our ability to forecast space weather. We must also address *unique and innovative ways that observations are incorporated into forecasts*, to constrain the very broad solution space that FP-based simulations can produce. We will need to develop approaches that differ from those employed by our colleagues in tropospheric weather in view of the much broader space and time scales involved and lack of adequate data. A credible and new research plan is needed by the community.

Extreme Space Weather

Space weather extremes continue to garner major attention because of their potential impacts on society. Impacts are well documented in a National Research Council report (2008). Extreme events are also a major area where our scientific understanding needs to increase. Often, extreme events occur outside the bounds of where models can be tested adequately. Thus, extreme events present tests to our fundamental understanding of space weather processes. In the context of this Chapman Conference, we will address extreme events along the spectrum of phenomena to be studied, and pathways to improving forecasting capability. This will entail an improved understanding of the limitations of the current set of FP models in representing extreme events, and finding alternative approaches to global modeling, driven by observations or theory, to produce predictions of how extreme events may unfold.

Forecasting extremes in space weather is particularly challenging due to the rarity of these events. This differs from tropospheric forecasting where extreme weather (e.g. hurricanes) happens every year. We know that an extreme space weather event such as the Carrington event (1859) will occur again, and likely almost occurred in July of 2012. The lack of sufficient observations of these extremes challenges our ability to develop robust

FP models for such events, and renders our statistical approaches weak because there is insufficient sample size. What is the appropriate way forward for forecasting extreme events?

Scientific study of extremes will be integrated across the Conference program. We will solicit invited speakers who have specialized knowledge of the statistics of extreme events, and speakers who have studied extreme events from theoretical perspectives or historical observations. We will devote a portion of the conference to the discussion of how extreme events fit within a spectrum of space weather phenomena, and how further scientific progress on understanding extremes can be developed.

Summary

A Chapman conference that is focused on scientific problems as they pertain to forecasting space weather, including extremes, must address the following trinity of perspectives:

1. Gaps in our fundamental physical understanding and how these gaps can be overcome
2. First-principles and data-driven modeling, i.e. taking the physical understanding we have acquired to develop methods and models with improved predictability
3. Observational capabilities: how can observations be used to improve forecasts and which observations are crucial?

We believe a focus on these topics will significantly advance solar-terrestrial science.

2. Meeting Approach, Emphasis on Discussion and a Forward Path

An overarching goal of the meeting is to develop a path forward for research into space weather forecasting. The meeting will be organized to be intellectually stimulating for the participants and significantly advance scientific understanding in new ways. We will encourage contributions across a spectrum of career levels and not overly prioritize the contributions of senior scientists at the expense of new ideas that may arise from early-career perspectives. The scientific challenges associated with space weather forecasting dictate that innovative approaches and new paradigms are needed.

The four-day conference will be organized around daily themes that frame the activities for that day. The first day will center on the idea that *space weather is simply too challenging to forecast in any meaningful way*. We will solicit speakers who can express this view, based on their understanding of FP models of space weather domains, or based on observations that could be very challenging to forecast.

The theme of the second day will be space weather extremes, and scientific issues related to forecasting such conditions. This is a somewhat specialized topic that may require different approaches than for less extreme situations, but there is certainly overlap. At the end of this day, preliminary suggestions for future research will be crafted.

The third day will center on the opposing idea that *useful space weather forecasts can be developed*. We will solicit speakers with ideas for generating such forecasts, including reasonable accuracy targets of forecasts that might be developed. The discussions on the second day must address the problems raised in the first day. On the fourth day, the conference attendees will jointly develop a way forward: the elements of a research program that will advance space weather forecasting.

A set of strawman requirements will be established prior to the meeting to define what is meant by a "meaningful" forecast. Speakers will be asked to refer to these requirements to the extent possible when addressing the feasibility of space weather forecasting. As part of the research plan developed at the conference, the community will define forecasting targets that could be achieved, which can serve as benchmarks for assessing community progress.

We will solicit perspectives by more junior colleagues to balance the contributions of more senior scientists. We will allow ample time for discussion of how to achieve the objectives of the conference. An over-arching question that we will emphasize is: in those areas where a strong scientific consensus appears, why do space weather predictions remain so challenging? Are there limits to predictability and if so, why?

Poster sessions are an excellent opportunity for in-depth discussion, but too often very few meeting participants benefit from such discussion. Towards the end of the poster session, we will solicit impromptu discussion from 2-3 volunteers who felt that excellent discussion occurred at their poster that they would like to share with the full meeting. This will permit junior colleagues to express their views. We will repeat this as often as necessary. Attendees will be notified in advance of the nature of these interruptions, so that reasonable quiet is maintained during the discussions.

Finally, to maintain an emphasis on forecasting, and its scientific utility, we will seek participants who have examples to share from the meteorological discipline. These examples may include 1) how scientific research improved forecasts, and 2) how forecast-oriented products stimulated research.

3. Meeting Format and Schedule

3.1. Overall Format

The meeting will span four days, with a target date in October of 2018. The block schedule is shown in Figure 1.

Daily theme:	Space weather forecasting will not succeed	Forecasting Space Weather Extremes	Space weather forecasting can succeed	Synthesis and Way Forward
	Day 1	**Day 2**	**Day 3**	**Day 4**
8:00 AM	Light breakfast	Light breakfast	Light breakfast	Light breakfast
8:30 AM	Setting the stage for the day's activities	Setting the stage for the day's activities	Setting the stage for the day's activities	Setting the stage for the day's activities
8:45 AM	3 talks	3 talks	3 talks	Sub-groups present
10:00 AM	Break	Break	Break	Break
10:15 AM	4 talks	4 talks	4 talks	Plenary synthesis
11:30 AM	Discussion	Discussion	Discussion	
Noon	Lunch	Lunch	Lunch	Lunch
1:30 PM	4 talks	4 talks	4 talks	Remaining business, programmatics, etc.
3:00 PM	Discussion	Discussion	Discussion	
3:30 PM	Break	Break	Break	
3:45 PM	4 talks	4 talks	4 talks	
5:15 PM	Poster intros	Discussion of way forward on Extremes	Sub-group discussion	Adjourn
5:45 PM	Poster session w/ refreshements			
6:30 PM				
7:00 PM			Meeting dinner	

Figure 1. Meeting schedule and format.

Following a light breakfast every morning, the conference organizers will define goals for the day's activities. Blocks of talks are followed by discussion periods of 30 minutes. Discussion leads will be selected for all these periods. Discussion is a main focus of the conference.

The poster session will be preceded by a 1-minute "lightening round" of poster introductions by the poster presenters. The poster session will have a meeting-wide interactive component, as described in the previous section. We will alert poster attendees in advance that their attention is requested during the discussion periods towards the end.

For the third day, we will encourage the formation of sub-groups within the different SPA disciplines: solar/heliosphere, magnetosphere, ionosphere/thermosphere (aeronomy), and a cross-cutting group emphasizing numerical methods and data science. The sub-groups will discuss the previous two days from the perspective of their discipline. The following should be addressed: is it convincing to suggest that space weather can be forecast within the requirements set prior to the meeting? How convincing were the speakers that suggested space weather forecasts can succeed? What are reasonable near-term targets for forecast accuracy in each domain? What approaches appear most promising? What fundamental research is most needed? What are the crucial observations?

On the fourth day, each sub-group will present their thoughts and opinions on these questions. The material will be synthesized in the discussion period before lunch. The remaining afternoon of the conference will treat concrete actions such as dates for the report, engagement of the various funding agencies, etc. Publication plans will be finalized during this discussion. A purpose of the wrap-up is to discuss how the Conference can have a lasting influence on the field.

3.2. Social Events

Social events will center around the poster session on the first day, when refreshments will be served, and the dinner on the third day.

3.3. Social Media

Social media will be used to engage meeting participants, in particular the junior ones. A Facebook page and a Twitter account will be created for the conference, for updating via mobile phone. News and changes will be broadcast this way. The web site for the conference will be updated regularly throughout the conference, in the manner of a blog.

3.4. Conference Topics

To remain focused on the unique challenges we face, and to keep the meeting compact and targeted, conference topics cannot cover the full range of solar and geospace phenomena. Rather, topics will be covered that are most relevant to predictability. We expect the following to be covered, in addition to the themes listed in the summary of Section 1:

1. Near-Sun environment:
    a) Challenges in determining solar inputs for physics-based modeling
    b) Extreme solar eruptions
2. Processes in transit:
    a) Physical processes contributing to uncertainty in modeling CME propagation (e.g. CME-CME interactions and deflection)
    b) Observational needs
3. Solar energetic particles: modeling and predictability

4. Geospace (Magnetosphere-Ionosphere-Thermosphere system):
    a) Predictability of geospace
    b) Predictability of the magnetosphere's interaction with the ionosphere and thermosphere
    c) Coupling from below and its impact on near-Earth space weather
    d) Superstorms, supersubstorms, and extreme events
5. Forecasting science
    a) First-principles models used in space weather forecasting: strengths and limitations
    b) Data-driven methods (machine learning), empirical models, diagnostic methods, data assimilation, uncertainty quantification
    c) Analogies to weather forecasting
    d) Forecasting extremes
6. Current challenges in space weather forecasting
    a) Specific accounts from users
    b) Characterizing and understanding extreme events
    c) Impacts of storms and substorms on technological infrastructure

4. Meeting Organizers

Conveners:
Anthony Mannucci, USA
Delores Knipp, USA
Huixin Liu, Japan
Surja Sharma, USA
Bruce Tsurutani, USA
Olga Verkhoglyadova, USA

Program Committee (agreed to participate):
Yue Deng, University of Texas at Arlington
Cheryl Huang, Air Force Research Laboratory
Mamoru Ishii, National Institute of Information and Communications Technology (NICT), Japan
Kanya Kusano, Nagoya University, Japan
Hermann Lühr, GFZ Potsdam, Germany
Tomoko Matsuo, University of Colorado, Boulder
Larry Paxton, Applied Physics Laboratory, Johns Hopkins University
Tuija Pulkkinen, Aalto University, Finland
Nathan Schwadron, University of New Hampshire
Harlan Spence, University of New Hampshire

5. Location of Conference

Location can play a role in who attends the conference. Attendance by key individuals is our main criterion for selection. Our preference for location is a reasonably-priced venue with a sufficiently large conference room. A few side-rooms would be valuable also, but this is not critical. Accommodation for the break-out groups will need to be made. Reasonably-priced (<$200/night, preferably below $150/night if possible) local hotel accommodations is a plus.

The ideal location would permit attendees to walk on their own to lunch and dinner locations. This would permit small-group discussions that we believe would be a positive for the outcome of the meeting.

Our preference is for locations in the US, for a variety of reasons. The US is a "compromise" distance for Asian and European participation. Candidate locations we have discussed are (in no particular order):

San Diego, CA. There are likely several venues here. The question is whether they offer "walking distance" dining options.

Coronado Island, CA. There is a walk-able town area, but this may be too expensive with limited hotel options.

La Jolla, CA. The La Jolla Beach And Tennis Club may have reasonable rates and is near to a town, and has hosted relatively small meetings in the past. However, the conference facilities may not be large enough.

Oahu, HI. Hawaii may attract attendees, but cost is a factor. The difficulty for Europeans to attend is partially compensated by location interest. Other islands are possible (e.g. Hawaii, also known as the "big island").

Carlsbad, CA. This may be a nice setting if the appropriate facilities can be found.

San Juan Capistrano, CA. Similar to Carlsbad, a potentially nice setting with some historical interest.

Monterrey, CA. Monterrey hosts the Asilomar conference center. There is also nearby Carmel, CA. This is not the easiest venue to reach.

Santa Barbara, CA. This venue requires a ~2 hour ride from Los Angeles International airport, but there are probably several transportation options.

Colorado. The state of Colorado has several options (Boulder, Estes Park, Keystone, etc.), although weather in October can be challenging.

Logistical note: three of the conveners are from JPL. Venues within 50 miles of JPL will require these conveners to commute to the meeting each day from their homes. Therefore venues that are not close to JPL, but less than 50 miles away, are undesirable.

6. International Participation and Conference Cosponsorship

The meeting will be primarily supported via the conference registration fee. Logistics will be handled by AGU. Strong international participation of the conference is essential for the success of the conference and we foresee a need for travel funds to accommodate selected attendees, including invited speakers. Also support for young scientists and graduate students is envisaged. We will apply to international and national agencies for funds to support international invitees. In the USA such agencies include National Oceanic and Atmospheric Administration, National Aeronautical and Space Administration, National Science Foundation and the Air Force Office of Scientific Research.

7. Anticipated Attendance

~75

A compilation of all of the potential invited speakers submitted by the Conveners and the Program Committee included ~65 individuals. This list did not come close to exhausting the entire community. While we do not expect 100% attendance from the community, we think that the potential invited speaker list is a guide to attendance.

8. Invited Speakers

A preliminary list of potential speakers spanned US, Japan, Europe, Korea, and China. This can be provided on request. Additional speakers will be being pursued with the program committee.

9. Relationships to Previous Chapman Conferences

The following Chapman Conferences significantly contributed to scientific understanding of various aspects of SPA physics, or to the development of first-principles models. None were focused on scientific aspects of forecasting. Conferences older than 2007 are not considered.

- Chapman Conference on Modeling the Ionosphere/Thermosphere System, 2011
- Chapman Conference on Currents in Geospace and Beyond, 2016
- Chapman conference on Complexity and Extreme Events in Geosciences, 2010
- Chapman Conference on Longitude and Hemispheric Dependence of Space Weather, 2012

10. Anticipated Conference Reports and/or Publications

The Conveners, in collaboration with the Program Committee, will prepare a summary report on the conference for publication in Space Weather as a feature. In addition, the Conveners will solicit papers for a Conference Proceedings in two forms: an AGU monograph and an AGU journal special issue. All publications will go through a similar editorial process including peer review. Papers will be placed in the monograph or journal, by decision of the conveners and program committee, to achieve balance in each publication. We anticipate that the Monograph may include more papers from invited speakers, with the special issue having a mix of invited and contributed papers and posters. The conveners will write a preface to the Monograph. A combination of conveners and program committee members will contribute an introduction to the special issue.

11. Biographies of Conveners

Anthony J. Mannucci

Professional Preparation: Ph.D. in Physics, University of California, Berkeley, 1989.
B.A. in Physics, with honors, Oberlin College, 1979.

Relevant Experience: Dr. Mannucci has been at the Jet Propulsion Laboratory since 1989. He has been supervisor of the Ionospheric and Atmospheric Remote Sensing group, which specializes in applications of GPS to remote sensing of the atmosphere and ionosphere, since 1999. He is presently a Senior Research Scientist and Principal. Dr. Mannucci helped develop the widely used Global Ionospheric Mapping technique and is co-inventor of the rate-of-TEC-index (ROTI) to monitor ionospheric small-scale irregularities. Dr. Mannucci also manages Global Assimiliative Ionosphere Model development at JPL. Dr. Mannucci's scientific focus areas include ionospheric behavior during large geomagnetic storms and during high-speed solar wind streams. He has served on the CEDAR science steering committee and the Living With a Star Targeted Research and Technology steering committee. He has organized several workshops, and convened numerous special sessions at Fall AGU and for other meetings. He organized the Technical Interchange Meeting on Scientific Challenges in Thermosphere-Ionosphere Forecasting held at JPL in October 2014. Dr. Mannucci is currently Principal Investigator of an effort sponsored by the NASA/NSF Partnership for Collaborative Space Weather Modeling titled "Medium-Range Thermosphere-Ionosphere Storm Forecasts."

Selected Refereed Publications

Meng, X., **A. J. Mannucci**, O. P. Verkhoglyadova, and B. T. Tsurutani (2016), On forecasting ionospheric total electron content responses to high-speed solar wind streams, J. Space Weather Space Clim., 6, A19–11, doi:10.1051/swsc/2016014.

Mannucci, A. J., B. T. Tsurutani, O. P. Verkhoglyadova, and X. Meng (2015), On scientific inference in geophysics and the use of numerical simulations for scientific investigations, Earth and Space Science, 2, 359–367, doi:10.1002/2015EA000108.

Mannucci, **A. J.**, B. T. Tsurutani, O. Verkhoglyadova, A. Komjathy, and X. Pi (2015) Use of radio occultation to probe the high-latitude ionosphere, Atmospheric Measurement Techniques, 8, 2789–2800, doi:10.5194/amt-8-2789-2015.

Mannucci, A. J., Verkhoglyadova, O. P., Tsurutani, B. T., Meng, X., Pi, X., Wang, C., Rosen, G., Lynch, E., Sharma, S., Ridley, A., Manchester, W., Van Der Holst, B., Echer, E., Hajra, R. (2015), Medium-Range Thermosphere-Ionosphere Storm Forecasts, Space Weather, 13(3), 125-129, 10.1002/2014sw001125.

McDonald, S. E., F. Sassi, and **A. J. Mannucci** (2015), SAMI3/SD‐WACCM‐X simulations of ionospheric variability during northern winter 2009, *Space Weather*, *13*(9), 568–584, doi:10.1002/2015sw001223.

Liu, G., S. L. England, T. J. Immel, H. U. Frey, **A. J. Mannucci**, and N. J. Mitchell (2015), A comprehensive survey of atmospheric quasi 3 day planetary-scale waves and their impacts on the day-to-day variations of the equatorial ionosphere, *J. Geophys. Res. Space Physics*, *120*(4), 2979–2992, doi:10.1002/2014ja020805.

Meng, X., A. Komjathy, O. P. Verkhoglyadova, Y. M. Yang, Y. Deng, and **A. J. Mannucci** (2015), A new physics-based modeling approach for tsunami-ionosphere coupling, *Geophysical Research Letters*, *42*(1), 4736–4744, doi:10.1002/2015GL064610.

Mannucci, A.J., G. Crowley, B. T. Tsurutani, O. P. Verkhoglyadova, A. Komjathy, P. Stephens (2014), Interplanetary magnetic field B_y control of prompt total electron content increases during superstorms, *Journal of Atmos. Sol. Terr. Phys*., 115-116, pp. 7–16, doi:10.1016/j.jastp.2014.01.001.

Immel, T. J., and **A. J. Mannucci** (2013), Ionospheric redistribution during geomagnetic storms, J. Geophys. Res-Space Phys., 118(12), 7928-7939, 10.1002/2013ja018919.

Shume, E. B., and **A. J. Mannucci** (2013), First calculation of phase and coherence of longitudinally separated L-band equatorial ionospheric scintillation, Geophysical Research Letters, 40(14), 3496-3501, 10.1002/grl.50702.

Mannucci, A. J., B. D. Wilson, D. N. Yuan, C. H. Ho, U. J. Lindqwister, and T. F. Runge (1998), A global mapping technique for GPS-derived ionospheric total electron content measurements, Radio Science, 33(3), doi:10.1029/97rs02707.

Bruce T. Tsurutani

Bruce T. Tsurutani received his B.A. and PhD degrees in physics at the University of California at Berkeley (1972). He has been at the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, since receiving his PhD degree and is presently a Principal Scientist and a Senior Research Scientist at that Institution. Tsurutani has held Visiting Professor/Visiting Associate positions at Kyoto University (1988, 1989, 2005, 2006-7), Univ. Alaska (1992), NOAA, Boulder, CO (1993), Univ. Cologne, Germany (1993-4, 2013), Tech. Univ. Braunschweig, Germany (1993-1994, 2010), CalTech (1996-

2001, 2012-2013), Univ. So. Calif. (2003-2007) and INPE, Brazil (2010). He has been the main organizer of four previous Chapman Conferences: “Collisionless Shocks in the Heliosphere” (1984-Napa, CA), “Plasma Waves and Instabilities in Magnetospheres and at Comets” (1987- Sendai, Japan), “Magnetic Storms” (1996- Pasadena, CA), and “Corotating Solar Wind Streams and Recurrent Geomagnetic Activity” (2005-Manaus, Brazil). Tsurutani was the lead Editor/Guest Editor for AGU monographs and JGR special issues following all four of the Chapman Conferences. He has organized many (~40) AGU Space Physics and Aeronomy (SPA) Solar and Heliospheric special sessions while AGU Secretary (1982-1986), and has been the Organizer or Co-Organizer of 10 Nonlinear Wave and Chaos Workshops (1994, 1997, 1999, 2001, 2003, 2006, 2008, 2010, 2013, 2017). He is a past President-Elect/President of the AGU SPA Section (1988-1992) and an AGU Fleming Medalist and Fellow (2009). Tsurutani has interest in all facets of space weather, from the Sun to the atmosphere and is particularly interested in extreme/nonlinear processes therein. He is an Editor of the EGU/AGU joint journal Nonlinear Processes in Geophysics and has established an AGU SPA/NG prize for “Nonlinear Waves and Processes”.

Selected Relevant Refereed Publications

Tsurutani, B. T., and C.-I. Meng, Interplanetary Magnetic Field Variations and Substorm Activity, *J. Geophys. Res., 77*, 2964, l972.

Tsurutani, B.T., W.D. Gonzalez, F. Tang, S.-I. Akasofu, and E.J. Smith, Origin of Interplanetary Southward Magnetic Fields Responsible for Major Magnetic Storms Near Solar Maximum (l978-l979), *J. Geophys. Res., 93,* 8519, 1988.

Tsurutani, B.T. and W.D. Gonzalez, F. Tang, and Y.T. Lee, Great Magnetic Storms, *Geophys. Res. Lett., 19,* 73, 1992.

Gonzalez, W.D., J.A. Joselyn, Y. Kamide, H.W. Kroehl, G. Rostoker, **B.T. Tsurutani** and V. M. Vasyliunas, What is a geomagnetic storm?, *J. Geophys. Res*., 5771, 1994.

Tsurutani, B.T., W.D. Gonzalez, G.S. Lakhina and S. Alex, The extreme magnetic storm of September 1-2, 1859, *J. Geophys. Res., 108*, SSH 1-1, doi:10.1029/2002JA009504, 2003.

Tsurutani, B.T., A. Mannucci, B. Iijima, M.A. Abdu, J.H.A. Sobral, W.D. Gonzalez, F. Guarnieri, T. Tsuda, A. Saito, K. Yumoto, B. Fejer, T.J. Fuller-Rowell, J. Kozyra, J.C. Foster, A. Coster and V.M. Vasyliunas, Global dayside ionospheric uplift and enhancement associated with interplanetary electric fields, *J. Geophys. Res., 109,* A08302, doi:10.1029/2003JA010342, 2004.

Mannucci, A.J., **B.T. Tsurutani**, B.A. Iijima, A. Komjathy, A. Saito, W.D. Gonzalez, F.L. Guarnieri, J.U. Kozyra and R. Skoug, Dayside global ionospheric response to the major interplanetary events of October 29-30 2003 “Halloween storms”, *Geophys. Res. Lett*., 32, L12S02, doi:10.1029/2004GL021467, 2005.

Tsurutani, B.T., F.L. Guarnieri, T. Fuller-Rowell, A.J. Mannucci, B. Iijima, W.D. Gonzalez, D.L. Judge, P. Gangopadhyay, A. Saito, T. Tsuda, O.P. Verkhoglyadova and G.A. Zambon, Extreme solar EUV flares and ICMEs and Resultant extreme ionospheric effects: Comparison of the Halloween 2003 and the Bastille Day events, *Radio Sci.*, *41*, RS5S07, doi:10.1029/2005RS003331, 2006.

Echer, E., W.D. Gonzalez, **B.T. Tsurutani** and A.L.C. Gonzalez, Interplanetary conditions causing intense geomagnetic storms (Dst < -100 nT) during solar cycle 23 (1996-2006), *J. Geophys. Res.*, *113*, A05221, doi:10.1029/2007JA012744, 2008.

Echer, E., W.D. Gonzalez and **B.T. Tsurutani**, Interplanetary conditions leading to superintense geomagnetic storms (Dst < -250 nT) during solar cycle 23, *Geophys. Res. Lett., 35*, L06S03, doi:20.1029/2007GL031755, 2008.

Tsurutani, B.T., O.P. Verkhoglyadova, A.J. Mannucci, A. Saito, T. Araki, K. Yumoto, T. Tsuda, M.A. Abdu, J.H.A. Sobral, W.D. Gonzalez, H. McCreadie, G.S. Lakhina, and V.M. Vasyliunas, Prompt penetration electric fields (PPEFs) and their ionospheric effects during the great magnetic storm of October 30-31, 2003, *J. Geophys. Res*., *113,* A5, A05311, doi:10.1029/2007HA012879, 2008.

Tsurutani, B.T., O.P. Verkhoglyadova, A.J. Mannucci, G.S. Lakhina and J.D. Huba, Extreme changes in dayside ionosphere during a Carrington-type magnetic storm, *Space Weather and Space Climate, 2,* A05, doi:10.1015/swsc/2012004, 2012.

Tsurutani, B.T. and G.S. Lakhina, An extreme coronal mass ejection and consequences for the magnetosphere and Earth, *Geophys. Res. Lett., 41,* doi:10.1002/2013GL058825, 2014.

Tsurutani, B.T., E. Echer, K. Shibata, O.P. Verkhoglyadova, A.J. Mannucci, W.D. Gonzalez, J.U. Kozyra, and M. Paetzold, The interplanetary causes of geomagnetic activity during the 7-17 March 2012 interval: a CAWSES II overview, *J. Spa. Weath. Spa. Clim., 4,* A02, doi:10.1051/swsc/2013056, 2014.

Gopalswamy, N**., B.T. Tsurutani** and Y. Yan, Short-term variability of the Sun-Earth system: An overview of progress made during the CAWSES-II period, *Prog. Earth Planet. Sci., 2:13*, doi:10.1186/s40645-015-0043-8, 2015.

Tsurutani, B.T., R. Hajra, T. Tanimori, A. Takada, R. Bhanu, A.J. Mannucci, G.S. Lakhina, J.U. Kozyra, K. Shiokawa, L.C. Lee, E. Echer, R.V. Reddy and W.D. Gonzalez, Heliosppheric plasmasheet (HPS) impingement onto the magnetosphere as a cause of relativistic electron dropouts (REDs) via coherent EMIC wave scattering with possible consequences for climate change mechanisms*, J. Geophys. Res. Spa. Phys., 121,* doi:10.1002/2016JA022499*,* 2016.

Lakhina, G.S. and **B.T. Tsurutani**, Geomagnetic storms: historical perspective to modern view, *Geos. Lett., 3:5*, doi:10.1186/s40562-016-0037-4, 2016.

Lakhina, G.S. and **B.T. Tsurutani** (2017) Super geomagnetic storms: Past, Present and Future, to appear in *Extreme Events in Geospace: Origins, Predictability and Consequences*, edited by N. Buzulukova, Elsevier Publ. Co.

A. Surjalal Sharma

Attended University of Delhi and received B. Sc. (Honors) (1970) and M. Sc. (1972) degrees, both in physics. His graduate research in nonlinear plasma physics was carried out at Physical Research Laboratory, Ahmedabad and received his Ph. D. degree in 1976. He held a post-doctoral position at Cornell University (1977-1981) and joined the faculty of Institute for Plasma Research, Gandhinagar in 1983. He has been at the University of Maryland, College Park since 1987, and currently director of the Goddard Planetary Heliophysics Institute. He was a visiting professor at Solar Terrestrial Environment Laboratory, Nagoya University in 1999 and 2002, and has held visiting positions at Institute for Plasma Research, Gandhinagar, International Center for Theoretical Physics, Trieste, Royal Institute of Technology, Stockholm, Max Planck Institute for Plasma Physics, Garching, Ruhr University, Bochum and UKAEA Culham Laboratory, Abingdon. He has been active in the community, including the chair of AGU Focus Group on Nonlinear Geophysics (2004-2008), AGU Chapman Conference Program (2009 – 2012 Currently he is a member of the AGU Committee for International Participation, and an editor of EGU/AGU Nonlinear Processes in Geophysics. He was the AGU Lorenz

Lecturer (2009) and was awarded the University of Maryland Distinguished Research Scientist Prize in 2011 (Inaugural). With publications in plasma theory, numerical simulations, complex systems and data science, his research has addressed a wide range of topics including space weather prediction, plasma processes in current sheets, nonequilibrium systems, planetary atmospheres, extreme events, and data-driven modeling.

Selected recent publications

Transient and localized processes in the magnetotail: A review, **A. S. Sharma**, R. Nakamura, A. Runov, E. E. Grigorenko, H. Hasegawa, M. Hoshino, P. Louarn, C. J. Owen, A. Petrukovich, J. -A. Sauvaud, V. Semenev, V. Sergeev, J. A. Slavin, B. U. O. Sonnerup, L. Zelenyi, G. Fruit, S. Haaland, H. Malova and K. Snekvik, *Ann. Geophys.*, *26,* 955–1006, 2008.

Electron-scale processes in collisionless magnetic reconnection, N. Jain, and **A. S. Sharma**, *Phys. Plasmas., 16*, 055905, 2009.

Efficient spectral and pseudo-spectral algorithms for 3D simulations of whistler wave in plasmas, N. A. Gumerov, A. V. Karavaev, **A. S. Sharma**, X. Shao, K. Papadopoulos, *J. Comput. Phys*., *230(7),* doi: 10.1016/j.jcp.2010.12.038, 2605-2619, 2011.

Generation of ELF waves during HF heating of the ionosphere at midlatitudes, **A. S. Sharma**, B. Eliasson, X. Shao and K. Papadopoulos, *Radio Sci., 51,* doi:10.1002/2016RS005953, 2016.

25 Years of Self-Organized Criticality: Space and Laboratory Plasmas, **A. S. Sharma**, M. J. Aschwanden, N. B. Crosby, A. J. Klimas, A. V. Milovanov, L. Morales, R. Sanchez, V. Uritsky, *Space Sci. Rev.,* (2016) 198:167–216 DOI 10.1007/s11214-015-0225-0

Brief Communication: Breeding Vectors in the Phase Space Reconstructed from Time Series Data, Lynch, E., Kaufman, D., **Sharma, A. S.**, Kalnay, E., and Ide, K., *Nonlin. Proc. Geophys., 23,* 137-141, doi:10.5194/npg-23-137-2016, 2016.

Predictive Capability for Extreme Space Weather Events, **A. S. Sharma**, E. E. Kalnay, and M. Bonadonna, *Eos, Trans. Amer. Geophys. Union, 98,* https://doi.org/10.1029/2017EO071721. Published on 26 April 2017.

Data-Driven Modeling of Extreme Space Weather, **A. Surjalal Sharma**, in *Extreme Events in Geospce,* ed. N. Buzulukova, Elsevier, 2017.

Predictability at intraseasonal time scale, V. Krishnamurthy and **A. S. Sharma**, *Geophys. Res. Lett.,* submitted, 2017.

Delores J. Knipp

Delores J. Knipp received a B.S. and M.S. in Atmospheric Sciene from the University of Missouri, Columbia and a Ph. D. in Atmospheric Science from UCLA. She is an Emeritus Professor in the Physics Department at the US Air Force Academy and is a Research Professor at the University of Colorado's Smead Aerospace Engineering Sciences Department. Dr. Knipp is also a Senior Research Associate at the High Altitude Observatory at the National Center for Atmospheric Research, Boulder, CO and an Adjunct Professor of Atmospheric Science at the University of Missouri. She was a National Research Council Fellow at the Space Weather Prediction Center during 2009-2010. Dr. Knipp was awarded the 2017 Coupling Energetics and Dynamics of Atmospheric Regions Lecture Prize for her work on thermospheric forcing associated with complex solar ejecta and ejecta-solar wind ambient interactions. Her research interests include Her research focuses on 1) solar wind forcing of the geospace environment and 2) data assimilation for describing high latitude electrodynamics. She is pursuing aspects of thermospheric forcing related to satellite drag

Dr. Knipp is the Editor in Chief of AGU's Space Weather Journal. As such, she is responsible for the strategic direction of the Journal including the vision of what constitutes "space weather." She is also the co-Chair of the American Meteorological Society's ad hoc panel investigating possibilities for an AMS Space Weather Certification.

Selected Relevant Publications (Italics indicates students advised by Prof. Knipp)

Kilcommons, L. M., R. J. Redmon, and **D. J. Knipp** (2017), A New DMSP Magnetometer & Auroral Boundary Dataset and Estimates of Field Aligned Currents in Dynamic Auroral Boundary Coordinates, J. Geophys. Res. Space Physics, 122, doi:10.1002/2016JA023342.

Redmon, R. J., W. F. Denig, L. M. Kilcommons, and **D. J. Knipp** (2017), New DMSP Database of Precipitating Auroral Electrons and Ions, J. Geophys. Res. Space Physics, 122, doi:10.1002/2016JA023339.

Knipp, D. J., D. V. Pette, L. M. Kilcommons, T. L. Isaacs, A. A. Cruz, M. G. Mlynczak, L. A. Hunt, and C. Y. Lin(2017), Thermospheric nitric oxide response to shock-led storms, Space Weather, 15, 325–342, doi:10.1002/2016SW001567.

Knipp D.J., Ramsay A.C., Beard E.D., Boright A.L., Cade W.B., Hewins I.M., McFadden R.H., Denig W.F., Kilcommons L.M., Shea M.A. "The May 1967 great storm and radio disruption event: Extreme space weather and extraordinary responses." SPACE WEATHER. 14 (9) (September 01, 2016): 614-633.

McGranaghan R., **Knipp D. J.,** Matsuo T. "High-latitude ionospheric conductivity variability in three dimensions." Geophysical Research Letters. 43 (15) (August 16, 2016): 7867- 7877.

Zhang B., Wang W., Wu Q., **Knipp D.**, Kilcommons L., Brambles O.J., Liu J., Wiltberger M., Lyon J.G., Haggstrom I. "Effects of magnetospheric lobe cell convection on dayside upper thermospheric winds at high latitudes." Geophysical Research Letters. 43 (16)(August 28, 2016): 8348-8355.

McGranaghan R., **Knipp D. J.**, Matsuo T., Cousins E. "Optimal interpolation analysis of high latitude ionospheric Hall and Pedersen conductivities: Application to assimilative ionospheric electrodynamics reconstruction." J. Geophys. Res. Space Physics. 121 (5) (May 01, 2016): 4898-4923.

Rastaetter L, Shim JS, Kuznetsova MM, Kilcommons LM, **Knipp DJ**, Codrescu M, Fuller-Rowell T, Emery B, Weimer DR, Cosgrove R. "GEM-CEDAR challenge: Poynting flux at DMSP and modeled Joule heat." SPACE WEATHER. 14 (2) (February 01, 2016): 113-135.

Matsuo, T., **D. J. Knipp**, A. D. Richmond, L. Kilcommons, and B. J. Anderson (2015), Inverse procedure for high-latitude ionospheric electrodynamics: Analysis of satellite-borne magnetometer data, J. Geophys. Res. Space Physics, 120, 5241–5251, doi:10.1002/2014JA020565.2.

McGranaghan, R., **D. J. Knipp**, S. C. Solomon, and X. Fang (2015), A fast, parameterized model of upper atmospheric ionization rates, chemistry, and conductivity. J. Geophys. Res. Space Physics, 120, 4936–4949. doi: 10.1002/2015JA021146.

Knipp, D. J., L. M. Kilcommons, J. Gjerloev, R. J. Redmon, J. Slavin, and G. Le, A Large-Scale View of Space Technology 5 Magnetometer Response to Solar Wind Drivers, Earth and Space Science, DOI: 10.1002/2014EA000057

McGranaghan, R., **D. J. Knipp**, R. L. McPherron, and L. A. Hunt (2014), Impact of equinoctial high-speed stream structures on thermospheric responses, Space Weather,

12, 277–297, doi:10.1002/2014SW001045.
Knipp, D. J., T. Matsuo, L. Kilcommons, A. Richmond, B. Anderson, H. Korth, R. Redmon, B. Mero, and N. Parrish (2014), Comparison of magnetic perturbation data from LEO satellite constellations: Statistics of DMSP and AMPERE, Space Weather, 12, doi:10.1002/2013SW000987.
Tobiska, W. K., **D. Knipp**, W. J. Burke, D. Bouwer, J. Bailey, D. Odstrcil, M. P. Hagan, J. Gannon, *and* B. R. Bowman (2013), The ANEMOMILOS prediction methodology for Dst, Space Weather, 11, 490–508, *doi:*10.1002/swe.20094
Deng, Y., T. J. Fuller-Rowell, A. J. Ridley, **D. Knipp**, and R. E. Lopez (2013), Theoretical study: Influence of different energy sources on the cusp neutral density enhancement, J. Geophys. Res. Space Physics, 118, 2340–2349, doi:10.1002/jgra.50197.
Knipp, D., L. Kilcommons, L. Hunt, M. Mlynczak, V. Pilipenko, B. Bowman, Y. Deng, and K. Drake (2013), Thermospheric damping response to sheath-enhanced geospace storms, Geophys. Res. Lett., 40, doi:10.1002/grl.50197.
Deng, Y., Y. Huang, S. Solomon, L. Qian, **D. Knipp**, D. R. Weimer, and J.-S. Wang (2012), Anomalously low geomagnetic energy inputs during 2008 solar minimum, J. Geophys. Res., 117, A09307, doi:10.1029/2012JA018039
Knipp, D., S. Eriksson, L. Kilcommons, G. Crowley, J. Lei, M. Hairston, and K. Drake, Extreme Poynting flux in the dayside thermosphere: Examples and statistics, *Geophys. Res. Lett*., 38, L16102, doi:10.1029/2011GL048302. 2011
Li, W., **D. Knipp**, J. Lei, and J. Raeder, The relation between dayside local Poynting flux enhancement and cusp reconnection, *J. Geophys. Res*., 116, A08301, doi:10.1029/2011JA016566. 2011
Crowley, G., **D. J. Knipp,** K. A. Drake, J. Lei, E. Sutton, and H. Lühr, Thermospheric density enhancements in the dayside cusp region during strong B_Y conditions, *Geophys. Res. Lett., 37*, L07110, doi:10.1029/2009GL042143, 2010

Huixin Liu

Huixin Liu is an associate Professor in Kyushu University, Japan. Dr. Liu received a B.Sc. in Electronic Engineering from Wuhan University in China and did Ph.D. in space physics in Max-Plank-Institute for Aeronomy, Germany. Before becoming a professor in Kyushu university, she worked in the National Center for Atmospheric Research (NCAR), German Helmholtz geophysics research center in Potsdam (GFZ), Hokkaido University and Kyoto University in Japan. Dr. Liu received several distinguished young researcher awards from the Japanese Society of Geomagnetism and Earth, Planetary and Space Science (SGEPSS), also from Japan Ministry of Education, Culture, Science and Technology (MEXT). She also received distinguished women researcher award from Shisedo science foundation in Japan. Dr. Liu's research interests include Ionosphere/Thermosphere response to solar flares and storms, their coupling to the magnetosphere via ion outflows, vertical coupling between the ionosphere/thermosphere system and the lower atmosphere in the meteorological regime. She works with both model simulation and satellite observations.

Dr. Liu has organized many sessions and workshops at international conferences, as convener or program chair/co-chair. She was the science program co-chair of the 2017 joint AGU-JpGU meeting, representing the Japan Geophysical Union (JpGU). She has served on many scientific program committees, including review panels at NASA, at National Research Council Canada, and JSPS in Japan.

Selected Relevant Publications

Huixin Liu, Y. Sun, Y. Miyoshi, H. Jin, ENSO effects on MLT diurnal tides: A 21 year reanalysis data-driven GAIA model simulation, *J. Geophys. Res., 122*, doi: 10.1002/2017JA024011, 2017.

Huixin Liu, E. Doornbos, J. Nakashima, Thermospheric wind observed by GOCE: wind jets and seasonal variations, *J. Geophys. Res.,* 121, 1-13, doi:10.1002/2016JA022938, 2016.

Huixin Liu, Y. Miyoshi, S. Miyahara, H. Jin, H. Fujiwara, H. Shinagawa, Thermal and dynamical changes of the zonal mean state of the thermosphere during SSW: GAIA model simulations, *J. Geophys. Res.,* 119, doi:10.1002/2014JA020222, 6784-6791, 2014.

Huixin Liu, H. Jin, Miyoshi, Y., H. Fujiwara, H, Shinagawa, Upper atmosphere response to stratosphere sudden warming: Local time and height dependence simulated by GAIA model, *Geophys. Res. Lett.,* 40, 635-640, doi:10.1002/grl.50146, 2013a.

Huixin Liu, T. Hirano, S. Watanabe, Empirical model of the thermospheric mass density based on CHAMP satellite observations, *J. Geophys. Res.,* 118, 843-848, doi:10.1002/jgra.50144, 2013b.

Huixin Liu, M. Yamamoto, S. Tulasi Ram, T. Tsugawa, Y. Otsuka, C. Stolle, E. Doornbos, K. Yumoto, Equatorial electrodynamics and neutral background in the Asian sector during the 2009 stratospheric sudden warming, *J. Geophys. Res.,* 116, A08308, doi:10.1029/2011JA016607, 2011.

Huixin Liu, E. Doornbos, M. Yamamoto, S. T. Ram, Strong thermosphere cooling during the 2009 major statratosphere warming, *Geophys. Res. Lett.,* 38, L12102, doi:10.1029/2011GL047898, 2011.

Huixin Liu, S. V. Thampi, M. Yamamoto, Phase reversal of the diurnal cycle in the mid-latitude ionosphere, *J. Geophys. Res.,* 115, A01305, doi:10.1029/2009JA014689, 2010.

Huixin Liu, M. Yamamoto, H. Lühr, Wave-4 pattern of the equatorial mass density anomaly- A thermospheric signature of tropical deep convection, *Geophys. Res. Lett.,* 36, L18104, doi:10.1029/2009GL039865, 2009.

Huixin Liu, H. Lühr, S. Watanabe, A solar terminator wave in thermospheric wind and density simultaneously observed by CHAMP, *Geophys. Res. Lett.,* 36, L10109, doi:10.1029/2009GL038165, 2009.

Huixin Liu, S. Watanabe, T. Kondo, Fast thermospheric wind jet at the Earth's dip equator, *Geophys. Res. Lett.,* 36, L08103, doi:10.1029/2009GL037377, 2009.

Olga P. Verkhoglyadova

O.P. Verkhoglyadova received a B.Sc. in Physics, M.Sc. (Summa Cum Laude) in Space Physics and Ph. D. in Theoretical Physics and Astrophysics from Kiev National University, Kiev, Ukraine. She has been working at the Jet Propulsion Laboratory, California Institute of Technology since 2008. She is also an Adjunct Professor at the Department of Space Science, University of Alabama, Huntsville. Earlier Dr. Verkhoglyadova worked at the Institute of Geophysics and Planetary Physics, University of California in Riverside. She has held positions of Research Scientist, Acting Head of the Space Physics Research Laboratory, Assistant Professor and then Associate Professor at Astronomy and Space Physics Department, Kiev National University. Dr. Verkhoglyadova was a visiting researcher at RISH, Kyoto University, Japan. Dr. Verkhoglyadova is a recipient of several NASA and JPL awards for scientific or technical innovations. Her research interests include GPS data processing and analysis, ionosphere modeling, space weather, and magnetospheric-ionospheric-atmospheric coupling under various solar wind conditions.

She is involved in radio-occultation data processing and atmospheric studies. Dr. Verkhoglyadova also works on simulation of particle acceleration at interplanetary shocks.

Dr. Verkhoglyadova co-organized international conferences, workshops, AGU and CEDAR sessions and served on several scientific program committees. Among these conferences are the Lorentz Center International Workshop "Shock acceleration: from the Solar system to cosmology" in Leiden, the Netherlands, (2015); "Technical Interchange Meeting on Scientific Challenges in Thermosphere-Ionosphere Forecasting" in Pasadena, CA (2014); 9th International Nonlinear Wave Workshop (NWW9) in La Jolla, CA (2013); 11th Annual International Astrophysics Conference "Space weather; the space radiation environment" in Palm Springs, CA (2012); High Speed stream and Solar Minimum Workshop, Boulder, CO (2010).

Selected Relevant Publication

Verkhoglyadova, O. P., B. T. Tsurutani*,* A. J. Mannucci*,* M. G. Mlynczak*,* L. A. Hunt*,* L. J. Paxton*, and* A. Komjathy *(*2016*),* Solar Wind Driving of Ionosphere-Thermosphere Responses in Three Storms Near St. Patrick's Day in 2012, 2013 and 2015*.* J. Geophys. Res. Space Physics*,* 120*, doi:* 10.1002/2016JA022883.

Mannucci, A.J., M. Hagan, A. Vourlidas, C. Huang, **O. Verkhoglyadova** and Y. Deng (2016), Scientific Challenges in Thermosphere-Ionosphere Forecasting, J. Space Weather Space Clim., J. Space Weather Space Clim., 6, E01, 10.1051/swsc/2016030.

Verkhoglyadova, O. P., J. M. Wissing, S. Wang, M.-B. Kallenrode, and G. P. Zank (2016), Nighttime mesospheric hydroxyl enhancements during SEP events and accompanying geomagnetic storms: Ionization rate modeling and Aura satellite observations, J. Geophys. Res. Space Physics, 121, doi:10.1002/2015JA022217.

Verkhoglyadova, O.P., X. Meng, A. J. Mannucci, B.T. Tsurutani, L.A. Hunt, M.G. Mlynczak, R. Hajra, and B.A. Emery, Estimation of energy budget of ionosphere-thermosphere system during two CIR-HSS events: observations and modeling, *J. Space Weather Space Clim.,* 6, A20, 2016, DOI: 10.1051/swsc/2016013.

Verkhoglyadova, O. P., B. T. Tsurutani, A. J. Mannucci, M. G. Mlynczak, L. A. Hunt, A. Komjathy, and T. Runge (2011), Ionospheric VTEC and thermospheric infrared emission dynamics during corotating interaction region and high-speed stream intervals at solar minimum: 25 March to 26 April 2008, J. Geophys. Res., 116, A09325, doi:10.1029/2011JA016604.

12. References

Bonadonna, M., L. Lanzerotti, and J. Stailey (2017), The National Space Weather Program: Two decades of interagency partnership and accomplishments, *Space Weather*, *15*(1), 14–25, doi:10.1002/2016SW001523.

National Research Council (2008) " Severe Space Weather Events--Understanding Societal and Economic Impacts Workshop Report", ISBN: 0-309-12770-X, http://www.nap.edu/catalog/12507.html.

National Research Council, Solar and Space Physics: A Science for a Technological Society. Washington, DC: The National Academies Press, 2013. doi:10.17226/13060. (hap://www.nap.edu/catalog.php?record_id=13060)

Presidential Executive Order – 13 October 2016, https://www.whitehouse.gov/the-press-office/2016/10/13/executive-order-coordinating-efforts-preparenation-space-weather-events