2016 Space Weather Workshop Agenda with Abstracts
Omni Interlocken Hotel

Monday, April 25

9:00 - 12:00 **Update on the Implementation of the National Space Weather Action Plan (Fir Boardroom)**
1:00 - 5:00 **Economic and Operational Impacts (Pine Boardroom)**
1:00 - 5:00 **Working Meeting on the Harmonization of Solar Energetic Particle (SEP) Data Calibrations (Interlocken AB)**
3:00 - 5:00 **Ionospheric Scales Discussion Group (Spruce Boardroom)**

5:00 - 7:00 **Welcome Networking Session (Lobby Court)**

Tuesday, April 26

8:30 **Conference Welcome**
Brent Gordon, NOAA/SWPC

8:35 **State of the Space Weather Prediction Center**
Thomas Berger, NOAA/SWPC

8:45 **What Happened to Those Sunspots and What Can We Expect?**
Doug Biesecker, NOAA/SWPC

Now that we're well past solar maximum, what's in store for the rest of solar cycle 24? We will review the current status of the solar cycle and what we can reasonably say about the rest of the cycle. We will also look at some early hints of what we can expect for solar cycle 25. About that sunspot number, it turns out SWPC was right all along, it's everyone else who was wrong. What are the implications of the new international sunspot number? What is SWPC doing about it? We will let you know what we are planning.

9:05 **Space Weather Activity – A Year in Review**
Robert Rutledge, NOAA/SWPC

Although solar cycle 24 hasn't produced overall activity levels reaching what was observed in recent decades, the Sun has still been active. This past year saw events that affected the grid and disrupted air travel. This talk will review the activity since last year's meeting, covering the events and exploring a few specifics of the impacts that were observed.

9:25 - 9:40 **Break**

9:40 - 11:00 **White House Space Weather Activities**
Chair: William Murtagh, OSTP (Office of Science and Technology Policy)

9:40 **Update on the National Space Weather Strategy and Action Plan**
Tamara Dickinson, OSTP

10:00 **Air Force One and Other Elements of the White House Military Office**
Tom Geyer, WHMO

10:20 **Update on the U.S. Government Satellite Space Weather Data Public Release**
Matthew Heavner, OSTP

10:40 **Live! From the White House Situation Room**
Jason Novick, The White House

11:00 - 12:00 **DSCOVR**
Chair: Alysha Reinard, NOAA/SWPC

11:00 **NOAA Goes to L1 with DSCOVR**
Doug Biesecker, NOAA/SWPC

The DSCOVR satellite is NOAA's first operational space weather satellite positioned at the distance of the L1 Lagrange point. It represents a significant milestone for space weather, as for the first time, NOAA has a satellite devoted entirely to space weather. We will provide an overview of the current status of the DSCOVR mission and what SWPC's plans are for the ACE mission. We will show what improvements can be expected with DSCOVR, as well as how access to data and plots has changed. We think you'll like the new web displays. We will also show the work we have done on new products driven by DSCOVR data.

11:20 **DSCOVR Magnetometer Observations**
Adam Szabo, NASA/GSFC

The Deep Space Climate Observatory (DSCOVR) fluxgate magnetometer completed its in-flight commissioning procedures by the time the spacecraft reached its final orbit at the Sun-Earth first Lagrange point in early June, 2015. Since that time, in-flight calibrations have been performed on a regular interval to track changes in the spacecraft produced magnetic fields, and hence in the instrument zero levels. Both spacecraft rotations and an independent Alfvenicity technique has been employed to demonstrate that the magnetic field measurements absolute accuracy is within +/- 0.2 nT, significantly better than the mission level 1 requirements. These calibration results and some early science validations will be presented.

11:40 **Design and Early observations from the DSCOVR solar wind Faraday Cup**
Justin Kasper, University of Michigan

The Deep Space Climate Observatory (DSCOVR) Faraday Cup is a sun-pointed plasma instrument that uses segmented collector plates and a wide field of view to make high time resolution, stable, and radiation tolerant measurements of solar wind velocity, density, and temperature. Key aspects of the Faraday Cup design, including low calibration drift and robustness to ionizing radiation will be covered. Running 20-30 times faster than prior plasma instruments at the L1 Lagrange point, the Faraday Cup is able to detect and track rapid jumps in speed from shocks, and to resolve small scale structures such as magnetic reconnection exhausts and waves. Calibration results, including in flight agreement with instruments on the Wind spacecraft will be presented, along with some initial observations of the solar wind.

12:00 - 2:30 **Lunch and 12:30 SWPC Tour**

1:00 - 2:30 **Poster Session: Solar and Heliosphere Applications and Research**

2:30 - 3:00 **Afternoon Keynote: The Role of Academia in the Nation's Space Weather Program**
Dan Baker, LASP (Laboratory of Atmospheric and Space Physics)

The Federal government has long relied on the science community to identify and prioritize leading-edge scientific questions, make the observations, conduct data analysis, and draw conclusions necessary to gain a better understanding of the space environment. One National Space Weather Strategy and Action Plan objective is to leverage such capabilities and apply the knowledge gained to mitigate the effects of space weather phenomena. Many academic labs are leaders in scientific space research and exploration, specifically in the fields of solar influences, atmospheric, and space physics.

As such, these academic institutions should step up and assume appropriate roles in furthering our understanding of space weather. To achieve a comprehensive knowledge of the space environment, to identify actionable objectives, and to strike a responsive posture from within the science and technology sector, forefront Labs must focus on the goals and opportunities related to space weather. As a specific instance, the CU-Boulder Laboratory for Atmospheric and Space Physics (LASP) experience and resident expertise in space research can support both the aspirations of the CU Grand Challenge and the objectives of the National Space Weather Strategy. LASP's intent is to play an active role in the realization of the national strategic goals. To that end LASP has devised a Space Weather mission plan to work with federal agencies and with academic and commercial partners that will be described in this talk.

3:00 - 5:00 **Space and Ground Based Observations / Advances**
Chair: Rodney Viereck, NOAA/SWPC

3:00 **Neutron Monitors – Perhaps the Original Space Weather Instrument**
Jim Ryan, University of New Hampshire

Before it was called such, neutron monitors were used for space weather measurements. They were introduced in a standard configuration over sixty years ago and have been used, individually and in a world-wide network, to monitor and measure several key space weather phenomena over the span of five solar cycles. Long before interplanetary missions, we were able to glean knowledge about the structure and dynamics of coronal mass ejections, the large scale heliospheric magnetic field and the violence and potency of energetic solar particle storms. More recently, neutron monitor measurements can be joined to complementary measurements made in space to gain in-depth knowledge of the heliospheric energetic particle environment. In my talk, I will briefly cover what neutron monitors are and what they sense, but I will spend most of my time on the associated heliospheric phenomena to which neutron monitors respond. I will conclude with a status report on the neutron monitor global system and its future.

3:20 **GOES-VW Free-Flyer Concept for Space Weather Instruments**
Frank Eparvier, LASP

Historically, many of NOAA's space environment monitors have flown on the GOES series of satellites. The primary weather instruments on the GOES platform are earth-viewing, which makes accommodating non-earth-viewing space weather instruments a technical and budgetary challenge. The continuity of space weather observations are also put at risk as they are lower priority than the terrestrial weather instruments on GOES. We present a concept for independent, or "free-flying", satellites and mission operations for the GOES-VW space weather instruments. The free-flyer concept can inexpensively accommodate the solar extreme ultraviolet (EUV) and X-Ray irradiance sensors (equivalent to GOES-R EXIS), EUV and Soft X-Ray solar imagers (equivalent to GOES-R SUVI and GOES-N SXI), a magnetometer, and electron and ion flux sensors (equivalent to GOES-R SEISS) on a smaller spacecraft than currently utilized for the GOES series. This approach also has the advantage of being more flexible in serving the operational needs of the NOAA space weather program independent of the GOES-VW weather satellite needs and priorities and with the potential for fewer satellites in operation at a time for space weather monitoring.

3:40 **QuakeFinder Induction Magnetometer Network: Hi Res Observations During Solar Storms**
Tom Bleier, QuakeFinder

The QuakeFinder project currently has a network of 165 three-axis induction magnetometers located in California and 5 other countries. The data from this network shows high definition solar storm magnetic disturbances and waveforms at 50 sps. collected over a large geographic area. This presentation discusses the potential use of this data for solar storm modelling and geomagnetic induced currents (GIC) as well as thoughts for potential remedial actions.

4:00 GOES - 40 Years of Satellite Space Environmental Monitoring
William Denig, NOAA/NCEI

For more than 40 years the Geostationary Operational Environmental Satellite (GOES) system has been the backbone of NOAA's space weather program by providing the data required by forecasters to issue alerts and warnings of potentially disruptive space weather. Prior to GOES space weather forecasters were forced to relied on a variety of ground-based assets and limited satellite data to provide assured radio communications and, as time evolved, numerous other dependent users. While the capabilities of the GOES spacecraft and sensors have steadily evolved over time, the program has remained the stalwart provider of solar and space environmental information that currently drives two of the three NOAA Space Weather Scales. The GOES-R series of spacecraft is the next phase of geostationary weather satellites for NOAA. The first in the series satellite, GOES-R, will launch in late 2016 and the projected lifetime of the series will continue out through 2036. The GOES-R space weather sensors will provide unprecedented capabilities for operations and research. In this talk I will trace the history of the GOES program starting from its humble beginnings to the premier space weather monitoring program that serves the needs of NOAA and, in many respects, the world-wide community of space weather forecasters and others.

4:20 Carrington – an Operational Mission to L5
Mark Gibbs, UK Met Office

The STEREO mission demonstrated the value of an off Sun-Earth line view, increasing both our understanding of CMEs and also our forecast accuracy of CME arrival at Earth. This talk sets out the UK's efforts to date on developing a conceptual operational mission to the Lagrange 5 location, commonly known as the Carrington mission. It will also provide an update on the progress made over the past 18 months, both politically and also further defining the mission requirements. Finally I will look ahead to how the mission may become a reality and what can be done to increase the chances of successfully getting the mission to the launch pad.

4:40 An Update on the COSMIC-2 Mission
Lidia Cucurull, NOAA Global Systems Division (GSD)

With the launch of FORMOSAT-3/COSMIC satellites in April 2006, the availability of Global Navigation Satellite Systems (GNSS) Radio Occultation (RO) observations for operational Numerical Weather Prediction (NWP) applications began. GNSS RO profiles started being assimilated operationally in the major worldwide weather centers soon after. The incorporation of COSMIC into the operational assimilation systems was shown to produce a significant improvement in global model forecast skill. After COSMIC, other missions carrying GNSS RO receivers became available for operational uses. Since its launch in 2006, the COSMIC constellation has been the mainstay of the global RO system. However, COSMIC is already past the end of its formal lifetime, and only two satellites are still operating. The COSMIC-2 mission, a 12-satellite constellation, will replace COSMIC. In addition, the first six COSMIC-2 satellites will carry ionospheric payloads. During the talk, an update on COSMIC and COSMIC-2 will be discussed.

5:00 End of Session

5:30 - 7:30 10th Annual SWPC - Commercial Space Weather Interest Group (CSWIG) / American Commercial Space Weather Association (ACSWA) Summit Meeting - by invitation

Wednesday, April 27

8:30 - 8:40 **Space Weather Morning Forecast Brief**
Dave Marshall, SWPC Space Weather Forecasting Office

8:40 - 10:10 **Commercial Space Weather Interest Group (CSWIG)/**
American Commercial Space Weather Association (ACSWA)
Roundtable Session: "Growing the Space Weather Enterprise"

Keynote Speaker:
Admiral Thad Allen, U.S. Coast Guard (ret); and Executive Vice President, Booz Allen Hamilton.

"The Benefits of Collaboration Between Commercial Industry and the Government in Confronting the Complexities of Co-producing Successful Outcomes in Achieving National Goals Associated with the Preparation and Mitigation of Natural and Human-made Disasters."

Featured Speaker:
Dr. Conrad C. Lautenbacher, Jr., Chief Executive Officer, GeoOptics, Inc.; and Member, ACSWA Executive Committee.

"Growing the Space Weather Enterprise: Progress in Partnership."

Dr. Geoff Crowley, Chief Executive Officer, ASTRA LLC; and Member, ACSWA Executive Committee.

"The Role of the Commercial Sector in the Nation's Space Weather Program."

Panel: Keynote & Featured Speakers
Q & A

Moderator and Organizer:
Dr. Devrie S. Intriligator, Director, Space Plasma Laboratory, Carmel Research Center, Inc.; and Member, ACSWA Executive Committee.

10:10 - 10:30 **Break**

10:30 - 12:00 **Agency Activities**
Chair: Thomas Berger, NOAA/SWPC

10:30 **NASA Heliophysics Division - The Science of Space Weather**
Steven Clarke, NASA/Heliophysics

10:45 **Space Weather Research at the National Science Foundation**
Therese Moretto Jorgensen, NSF

11:00 **Department of Defense Space Weather**
Lt Col Mark Allen, AFW (Air Force Weather Agency)

The Air Force (AF) uses operational space weather models and ground- and space-based sensors to provide timely operational space weather forecasts and products to support warfighters, coalition partners and the classified national-level users. We partner with other federal agencies, the private sector, and international partners to achieve space weather mitigation and preparedness.

11:15 **National Weather Service**
Bill Lapenta, NOAA/NWS

11:30 **NESDIS**
Karen St. Germain, NOAA/NESDIS

11:45 **The USGS Geomagnetism Program**
Jill McCarthy, USGS

The mission of the Geomagnetism Program of the U.S. Geological Survey (USGS) is to monitor the Earth's magnetic field at ground-based magnetic observatories, to reliably report magnetometer data having high accuracy and resolution, to provide the ground truth measurements that calibrate space weather hazard models, and to perform scientific research of societal importance. This mission is consistent with USGS priorities for pursuing natural hazard science of societal importance. Data and products from the USGS Geomagnetism Program support related priority projects of the National Oceanic and Atmospheric Administration, the U.S. Air Force, NASA, and other allied agencies in government, academia, and private industry, both domestically and internationally. The USGS Geomagnetism Program is committed to continuing its support of these existing responsibilities, which are critical to meeting many of the goals and objectives detailed in the new Space Weather Action Plan developed by the National Science and Technology Council. In response to this plan, USGS will also be expanding its research and operational focus to support the monitoring and assessment of magnetic-storm induction hazards that are a concern for the electric-power grid industry. Over the next few years, and, as always, subject to Federal funding initiatives, the Geomagnetism Program is planning to: (1) improve and expand geomagnetic observatory operations, (2) initiate geoelectric monitoring at some observatories, (3) augment national-scale magnetotelluric surveys presently supported by the National Science Foundation's EarthScope Program, (4) support three-dimensional modeling of the Earth's electrical conductivity structure, (5) facilitate scenario and real-time geoelectric mapping, (6) assess induction hazards, and (7) support global geomagnetic monitoring and data exchange. These projects are important for the national economy and national security, and they will also promote fundamental understanding of space-weather hazards.

12:00 - 12:10 **Benchmarking Progress in Space Weather: Reprise of the 2001 AGU Monograph on Space Weather - Space Weather Journal Special Collection Announcement**
Delores Knipp, Space Weather Journal

12:10 - 1:30 **Lunch**

1:30 - 3:10 **<u>Space Weather Impacts: Electric Power Grid</u>**
Chair: Bill Murtagh, OSTP

1:30 **An Ensemble Approach to Communicating Extreme Space Weather Event Probability**
Seth Jonas, STPI (Science and Technology Policy Institute)

1:50 **Adventures in Geoelectric Field Calculations and Validation**
Chris Balch, NOAA/SWPC

Near-real time calculation of the induced Geoelectric field has been identified as a key need for users affected by geomagnetically induced currents, such as the electrical power grid. The practical aspects of carrying out such estimates has required an interdisciplinary, collaborative effort between space science, real-time space weather operations, and solid earth geophysics. We highlight in this talk an ongoing collaboration between NOAA, USGS, and NASA to develop real-time tools to provide this kind of service, and show case studies that compare calculated, estimated geoelectric fields with actual measurements from a magnetotelluric (MT) survey. Initial results show good agreement between calculations and observations when realistic impedance tensors, consistent with three-dimensional Earth structure, are used. We identify cases where the full impedance tensors and measurements show

significant differences from what would be predicted from estimates using available one-dimensional, depth-dependent conductance models. Results demonstrate the necessity for more complete MT surveys of the continental United States.

2:10 **Space Weather Power System Impacts and PJM Response**
Frank Koza, PJM (Pennsylvania-New Jersey-Maryland Interconnection)

Brief explanation of the impacts to the electric transmission system due to space weather and how PJM responds to space weather situations in operations. Also, the forthcoming NERC GMD planning standard will be explained.

2:30 **GIC modeling: From the Solar Wind to Power System Impacts**
Jennifer Gannon, Computational Physics, Inc.

A quantitative understanding of how GMDs can have severe consequences on the power grid is critical to helping the utility industry better plan for and greatly reduce risk while meeting operational requirements. However, integrating the critical parts of the relevant geophysical modeling and analysis techniques is a challenge. We present an update from an NSF-funded project that takes a comprehensive, streamlined approach, beginning with space weather and ending with impacts to grid operation. The study team includes academic, government, commercial and industry partners. The goal is to develop algorithms that both advance the science of induced electric fields and develop system impact models in the real-time and planning time frames. This work will provide a better understanding of the effects of GIC in the bulk power system and help inform utility operators on how to respond to a geomagnetic storm.

2:50 **Create a 21st Century US Electricity System**
Sandy MacDonald, Spire

The US faces two great threats right now and for the remainder of the 21st century: global change driven by greenhouse gases and the danger of a large solar or manmade electromagnetic event that destroys the electrical and digital infrastructure that its people are utterly dependent on. Both of these problems could be largely mitigated in the next decade by creation of a national High Voltage Direct Current electricity network.

I will discuss the results of a NOAA study that shows a national HVDC network solves the intermittency problem of wind and solar energy. The network would reduce the US greenhouse gas emissions due to electric power generation by up to 80% without increasing the cost of electricity. It would the necessary first step to de-carbonizing other energy sectors such as autos and space heating. A preliminary study shows this concept would work in other major economies such as China and Europe, which means that there is an economically viable mitigation path globally in time to stop before carbon dioxide reaches a doubling.

It is proposed that an underground, protected HVDC network, built using the latest in cable technology, could designed and built to be impervious to natural and EMP attacks from rogue states. Such a network would provide a robust backbone for the US electric system and indeed its entire national economy. The HVDC network could be built right now with existing technology by the private sector, funded through electric bills that would not increase. It requires national leadership similar to that provided by President Eisenhower in the creation of the Interstate highway system.

3:10 - 5:00 **Poster Session - General Space Weather Services & Magnetosphere Applications and Research (2 Groupings)**

5:00 **End of Session**

6:00 - 9:00 **Banquet Dinner at Omni Interlocken Ballroom**

Special Guest Speaker:

Dr. Tony Phillips, Spaceweather.com

“Mutant Fungi in the Stratosphere...and other Space Weather Surprises”

Thursday, April 28

8:30 - 8:40 **Space Weather Morning Forecast Brief**
Shawn Dahl, SWPC Space Weather Forecasting Office

8:40 - 10:00 **Space Weather and the Arctic: Challenges and Opportunities in the New Frontier**
Chair: Rodney Viereck, NOAA/SWPC

8:40 **Ionospheric Mapping Using a Ground-Based GPS Receiver Network in Alaska**
Geoff Crowley, ASTRA (Atmospheric and Space Technology Research Associates)

The question is often asked "how can we provide more regional assessments of the state of the ionosphere that would be more useful and relevant for our users?" In this paper, we present recent results from a latitudinally extended array of GPS receivers that create local maps of ionospheric scintillation in Alaska. The receivers were deployed at 6 sites in Kaktovik (70.1° N, 143.6° W), Toolik (68.6° N, 149.6° W), Fort Yukon (66.6° N, 145.2° W), Poker Flat (65.1° N, 147.4° W), Eagle (64.8° N, 141.2° W), and Gakona (62.4° N, 145.2° W). The phase scintillation database analyzed covers November 9, 2012 to present. We use the latitudinal GPS array to demonstrate our ability to map scintillation in real-time, and to provide space weather services to GPS users. Results from the statistical analysis of multi-year phase scintillation data from the GPS chain show that the severity of phase scintillation decreases with decreasing latitude and that the largest phase scintillations occur near magnetic midnight. We also present the scintillation frequency distribution statistics from the GPS chain in Alaska to highlight the differences in temporal variations of low, moderate, and severe scintillation events. The results show that weak scintillation events show a diurnal variation with a well-defined minimum near 0000 MLT while moderate and strong scintillations both have Gaussian distributions with peaks near the midnight sector. As a validation of our mapping results, we compare phase scintillation measurements from the GPS array and auroral emissions from an All-Sky Imager (ASI) and a Meridian Spectrograph at Poker Flat to characterize the correspondence between scintillation and auroral features. Phase scintillation results show a strong correlation with 630.0 nm auroral emissions indicating F-region irregularities may be a source of the scintillations.

9:00 **Space Weather Impacts in Alaska**
Carven Scott, NOAA/NWS

Extreme space weather events are responsible for a variety of global impacts such as power grid issues, high frequency radio communications degradation and/or outages, and GPS errors. In Alaska the issues are magnified due to a higher likelihood of cascading impacts where weather and lack of sunlight in the winter often play a complicating factor.

For example a cargo ship traversing the North Pacific approaches Unimak Pass (Central Aleutian Islands) and loses steerage ahead of a storm moving through the area, and drifts into the rocks in a protected wildlife area. The ship begins to lose fuel and oil in the sensitive waters. Exacerbating this mishap is an ongoing space weather event that is causing an HF radio outage and loss of GPS lock. Flying conditions, for search and rescue, are 100-foot cloud ceilings and a half-mile visibility in snow and fog.

This mishap could very quickly turn into a major environmental disaster as space weather impact hamper efforts to direct USCG and other assets (NOAA Office of Restoration and Recovery, etc.) to the scene. The combination of many factors (e.g., remote location, limited in situ mitigation resources, large distances for response, poor weather conditions AND a space weather event) can turn a bad situation into a potential catastrophe.

The NWS in Alaska, the primary agency providing weather, water, and ice forecasts for safety of flight and navigation, is at the forefront of efforts to integrate space and terrestrial weather information to provide superior Impact Decision Support Services to Alaskan customers and stakeholders.

9:20 **Space Weather Effects with the Flip of a Switch**
Robert McCoy, University of Fairbanks

The usual way to study space weather effects involves the use of ground-based optical or radio frequency instruments and observations are made of whatever phenomena passes overhead. Alternatively, satellites can be launched and used to amass a large amount of data from orbit or a sounding rocket can be prepared and launched when the desired phenomena, or something reasonably close, appears in the sky. An alternative way to study space weather involves the use of high power, high frequency, radio waves and if the power is sufficient, as is the case with the High frequency Active Aurora Research Program (HAARP), space weather effects can be created at will overhead and then studied with ground-based or orbiting observations. The HAARP facility located in Gakona Alaska is the most powerful and versatile laboratory in the world for active experimentation in the ionosphere and upper atmosphere. Many systems are affected by propagation through or into the ionosphere including communication, navigation, radar and others. HAARP consists of an HF phased array with 180 antennas spread across 33 acres with a transmit power of 3.6 MW. The array is powered by five 2500 kW generators, each driven by a 3600 hp diesel engine (4 + 1 spare). Transmit frequency can be chosen anywhere in the range 2.8 to 10 MHz and complex configurations of rapidly slewed single or multiple beams are possible. The HAARP facility was recently transferred from the Space Vehicles Directorate of the Air Force Research Laboratory (AFRL/RV) in Albuquerque, NM to the Geophysical Institute of the University of Alaska Fairbanks (UAF/GI). The transfer is being implemented in stages including a Cooperative Research and Development Agreement (CRADA) and an Educational Partnership Agreement (EPA) which provide access to the facility and ownership of the equipment. The UAF/GI plans to operate HAARP for continued ionospheric and upper atmospheric experimentation. In their 2013 "Decadal Survey in Solar and Space Physics" the National Research Council (NRC) made the recommendation to "Fully realize the potential of ionospheric modification…" and in their 2013 Workshop Report: "Opportunities for High-Power, High-Frequency Transmitters to Advance Ionospheric/Thermospheric Research" the NRC outlined the broad range of future ionospheric, thermospheric and magnetospheric experiments that could be performed with HAARP. The HAARP facility contains a variety of RF and optical ionospheric diagnostic instruments to measure the effects of the heater in real time. The UAF/GI encourages the scientific community to plan experiments at HAARP and bring their remote sensing instruments to HAARP for extended or permanent operation. The power and flexibility of HAARP and its ideal location in the subarctic will help secure the future of this facility as the foremost laboratory for active experimentation in the ionosphere and upper atmosphere.

9:40 **The Arctic: NORAD and USNORTHCOM Perspective**
Lt Col Jason Julian / Charlotte Browning, USNORTHCOM

10:00 - 10:20 **Break**

10:20 - 12:00 **<u>Improving SWx Forecasting I: Modeling and Data Assimilation</u>**
Chair: Doug Biescker, NOAA/SWPC

The DSCOVR satellite is NOAA's first operational space weather satellite positioned at the distance of the L1 Lagrange point. It represents a significant milestone for space weather, as for the first time, NOAA has a satellite devoted entirely to space weather. We will provide an overview of the current status of the DSCOVR mission and what SWPC's plans are for the ACE mission. We will show what improvements can be expected with DSCOVR, as well as how access to data and plots has changed. We think you'll like the new web displays. We will also show the work we have done on new products driven by DSCOVR data.

10:20 **Living with a Star**
Elsayed Talaat, NASA/Heliophysics

NASA Heliophysics' Living With a Star (LWS) program emphasizes the science necessary to understand those aspects of the Sun and the Earth's space environment that affect life and society. The ultimate goal is to provide a predictive understanding of the system, and specifically of the space weather conditions at Earth and in the interplanetary medium. LWS missions have been formulated to answer specific science questions needed to understand the linkages among the interconnected systems that impact us. LWS products impact technology associated with space systems, communications and navigation, and ground systems such as power grids. The coordinated LWS program includes strategic missions, targeted research and technology development, a space environment test bed flight opportunity, and partnerships with other agencies and nations.

10:40 **Atmosphere and Surface Impacts by Auroral Energetic Electron Precipitation (EEP)**
Ethan Peck, Columbia University

The effects of auroral (< 30 keV) energetic electron precipitation (EEP) on tropospheric and surface climate remain poorly understood. This is largely due to the short observational record, and missing parameterizations of EEP forcing in most state-of-the-art climate models. Here we examine the long-term atmospheric and surface impacts of EEP forcing, by comparing a set of simulations from the Whole Atmosphere Community Climate Model. This study improves upon past work by only changing auroral EEP between simulations, coupling with an interactive ocean model, and using long (300 year) model integrations. Results show 6% decreases in southern hemisphere upper stratospheric (~40 km) ozone caused by EEP-induced NOx. No significant changes are seen in northern hemisphere stratospheric ozone. As a consequence, temperature and wind changes in the stratosphere are small and/or not significant. Surface temperature changes over selected periods of the simulations are consistent with previous modeling studies. However, it is shown that these results are not robust over a 300 year period. Lack of an EEP caused signal at the surface is attributed to internal model variability. This work suggests that there are no robust impacts on surface climate caused by auroral EEP. In contrast, there is a significant response found in the stratosphere and above. Effects on surface climate from other sources of energetic particle precipitation outside auroral EEP are not examined in this study. Given large internal variability, any surface signals from EPP will be difficult to attribute until mechanisms tying together polar stratosphere-troposphere coupling by upper stratospheric ozone loss are identified.

11:00 **Space Weather Modeling Framework (SWMF) University of Michigan Perspectives**
Dan Welling, University of Michigan

Predicting ground-based magnetic perturbations is a critical step towards specifying and predicting geomagnetically induced currents (GICs) in high voltage transmission lines. Currently, the Space Weather Modeling Framework (SWMF), a flexible modeling framework for simulating the multi-scale space environment, is being transitioned from research to operational use (R2O) by NOAA's Space Weather Prediction Center. Upon completion of this transition, the SWMF will provide localized time-varying magnetic field (dB/dt) predictions using real-time solar wind observations from L1 and the F10.7 proxy for EUV as model input.

This presentation describes the operational SWMF setup and summarizes the changes made to the code to enable R2O progress. The framework's algorithm for calculating ground-based magnetometer observations will be reviewed. Metrics from data-model comparisons will be reviewed to illustrate predictive capabilities. Early data products, such as regional-K index and grids of virtual magnetometer stations, will be presented. Finally, early successes will be shared, including the code's ability to reproduce the March 2015 St. Patrick's Day Storm.

11:20 **Forecasting Solar Indices with ADAPT**

Carl Henney, AFRL (Air Force Research Laboratory)

Recent progress to forecast key space weather parameters with the ADAPT (Air Force Data Assimilative Photospheric flux Transport) model is highlighted in this presentation. Using a magnetic flux transport model, ADAPT, we evolve global solar magnetic maps forward 1 to 7 days in the future to provide realistic estimates of the solar near-side field distribution used to predict the solar 10.7 cm radio flux (abbreviated F10.7), the Mg II core-to-wing ratio, and selected bands of solar far ultraviolet (FUV) and extreme ultraviolet (EUV) irradiance, ranging from 0.1 to 175 nm. Input to the ADAPT model includes the inferred photospheric magnetic field from the NISP ground-based instruments, GONG & VSM. Besides a status update of the ADAPT model, we will summarize the recent findings solar indices modeling: 1) the observed F10.7 signal is found to correlate strongly with strong magnetic field regions (Henney et al. 2012); 2) the observed integrated full-disk solar UV signals were found to be strongly correlated with weak field (Henney et al. 2015). This work utilizes data produced collaboratively between Air Force Research Laboratory (AFRL) and the National Solar Observatory (NSO). The ADAPT model development is supported by AFRL. The input data utilized by ADAPT is obtained by NSO/NISP (NSO Integrated Synoptic Program). NSO is operated by the Association of Universities for Research in Astronomy (AURA), Inc., under a cooperative agreement with the National Science Foundation (NSF). The 10.7 cm solar radio flux data service, utilized by the ADAPT/SIFT F10.7 forecasting model, is operated by the National Research Council of Canada and National Resources Canada, with the support of the Canadian Space Agency.

11:40 **Between Earth and Space: Ensemble Modeling and Data Assimilation of the Space-Atmosphere Interaction Region**
Tomoko Matsuo, NOAA/SWPC

The Space-Atmosphere Interaction Region (SAIR), encompassing the mesosphere, thermosphere and ionosphere, is an intersection between geospace and the Earth's atmosphere, and is exposed to vacillating conditions of both space and terrestrial weather. Recent observational and modeling studies have revealed clear reaches of terrestrial weather far beyond the Mesosphere Lower Thermosphere (MLT) region into the topside ionosphere. At the same time, the region lends itself to forcing originating from the Sun and solar-wind magnetosphere interactions. To fully address the predictability of the SAIR, it is important to embrace a paradigm shift from a deterministic to a probabilistic modeling framework and a systematic integration of observations into a numerical predictive modeling system through data assimilation. With funding from NASA's Heliophysics Grand Challenges Research program, we are constructing an ensemble forecasting and data assimilation system that will ultimately be capable of assimilating observations from the ground to SAIR by building on the National Weather Service's operational ensemble forecasting and data assimilation systems.

This talk will report on the project's progress and potential of comprehensive ensemble forecasting data assimilation systems for SAIR.

12:00 - 2:30 **Lunch and 12:30 SWPC Tour**

1:00 - 2:30 **Poster Session – Ionosphere / Thermosphere Research and Applications**

2:30 - 3:00 **Afternoon Keynote: How Space Weather got to Boulder in the Post-WWII Years**
Joe Bassi, Embry Riddle University

This talk will cover the efforts of Walt Roberts, Donald Menzel, Alan Shapely, and many others in bringing sun-earth connection science (including space weather) to Boulder in the decade following WWII.

3:00 - 3:20 **A Report from the Recent Workshops on Economic and Operational Impacts**
Nicola Fox, Johns Hopkins University/Applied Physics Laboratory

There are a number of regularly scheduled space weather workshops but historically these have focused on scientific understanding, current forecasting capabilities, or impacts to specific technologies. To date there has not been an open, coordinated, community approach to studying space weather effects on economic vitality and national security, and how the awareness of natural conditions could improve the ability to lessen disruption to operations. At the present time, there has been little comprehensive analysis of these impacts and their role in defining research and development of forecasting capability. Nor has there been significant comprehensive analysis of the impacts of space environment effects on military operations or studies of how space weather awareness can be smoothly integrated into existing NSS systems. In many cases, competition-, national security-, or certain business constraints have prevented access to this information, further complicating an encompassing assessment of space weather impacts on macro-economic scales, on military operations, and on the basic functionality of our technical society. Such an assessment is critical to understanding the necessity and benefits to investing in forecast and warning capabilities, as well as into mitigating strategies, enhancing preparedness and resilience. Moreover, it is essential to assess the economic and national security impacts of events of various magnitudes, not just the extreme events. The aggregate impact of such events is likely to be large, and thus provide a key input to vulnerability assessments, simply due to the large numbers of events and effects. Such comprehensive assessments are necessary in order to develop an optimized architecture for future forecast and warning capabilities, and mitigating strategies, but additionally to determine and outline methods for addressing of the gaps in our scientific knowledge, modeling capability, and, most importantly, measurement ability.

Over the past six months, we have begun a comprehensive analysis of economic, infrastructural, and military impacts of space weather, ranging from typical space weather conditions, to the best estimate of possible extreme cases. With sponsorship from NASA, NSF, NOAA and Air Force Weather, two workshops have been convened to date to focus on the Economic and National Security aspects of the space environment, conducted at the appropriate classification level. These workshops have included impacts as a function of economic loss and degradation of infrastructure (e.g., satellite navigation), and reduced or eliminated military operational capabilities. We have also examined the transition of readily available space weather assets into operational, robust decision aids. In particular, what scientists can concentrate on in order to make the transition easier, and how the military can incorporate new technologies into their arsenal. Follow-on workshops will be convened throughout the remainder of the year (including one just prior to the SWW). A concise, written, summary of findings for dissemination to stakeholders is being produced that will assist with the response for the National Security community to the recently released National Space Weather Strategy and Action Plan that calls for better understanding of the impacts of space weather. In this presentation we will give a brief version of the workshops and their preliminary findings.

3:20 - 5:00 **<u>International Coordination of Space Weather Activities</u>**
Chair: Terry Onsager, NOAA/SWPC

3:20 **Project for Solar-Terrestrial Environment Prediction (PSTEP)** in Japan
Kanya Kusano, Institute for Space-Earth Environmental Research (Nagoya University)

Project for Solar-Terrestrial Environment Prediction (PSTEP) is a Japanese nation-wide research collaboration, which was recently launched with the support of a Grant-in-Aid for Scientific Research on Innovative Areas from MEXT/Japan. PSTEP aims to develop a synergistic interaction between predictive and scientific studies of the solar-terrestrial environment and to establish the basis for next-generation space weather forecasting using the state-of-the-art observation systems and the advanced physics-based models. For this project, we coordinate the four research groups and the proposal-based research units. The research groups and research units are organized by multiple institutes for the following subjects: 1) The development of a next-generation space weather forecast system, 2) The prediction of solar storms, 3) The prediction of magnetosphere and ionosphere dynamics, 4) The prediction and understanding of solar cycle activity and its impact on climate, and 5) Mathematical

sciences for solar-terrestrial environment prediction. By this project, we seek to answer some of the fundamental questions concerning the solar-terrestrial environmental system such as the mechanisms for the onset of solar flares, the mechanism for radiation belt dynamics in the Earth's magnetosphere, and the physical process by which solar activity affects the climate. In this lecture, I will explain the basic strategy of PSTEP as well as discuss the role of PSTEP for the international cooperation in space weather prediction study.

3:40 **ESA SSA Federated Approach for Space Weather Services**
Juha-Pekka Luntama, ESA (European Space Agency)

ESA Space Situational Awareness (SSA) Period 2 started at the beginning of 2013 and will last until the end of 2016. For the Space Weather Segment, transition to Period 2 introduced an increasing amount of development of new space weather service capability in addition to networking existing European assets. This transition was started already towards the end of SSA Period 1 with the initiation of the SSA Space Weather Segment architecture definition studies and activities enhancing existing space weather assets. The objective of Period 2 has been to initiate SWE space segment developments in the form of hosted payload missions and further expand the federated service network. A strong focus has been placed on demonstration and testing of European capabilities in the range of SWE service domains with a view to establishing core products which can form the basis of SWE service provision during SSA Period 3, which will start in 2017.

The approach chosen by the ESA SSA Programme for space weather service provision is based on federation of European expertise and assets through a network of Expert Service Centres (ESCs). The ESC concept has been prototyped already since 2010 with an initial network. New industrial contracts to set up the expanded ESC network and to define the ESC concept for the coming years of the ESA SSA Programme were started in September 2015. The current network includes 36 European centres of space weather expertise and is capable of providing a substantial portfolio of services to the end users.

This presentation will cover the current status of the ESA SSA space weather ESC network, the service capabilities and ESA's near and long term plans regarding the expansion of the network. The presentation will also address ESA's plans for the SSA space weather system for the next Programme period in 2017-2020.

4:00 **Space Weather Services in Korea**
Dong-Hun Lee, Korean Space Weather Center

4:20 **Mexican Space Weather Service (SCIESMEX)**
Juan Americo Gonzalez Esparza, Mexican Space Weather Service

Modifications of the Civil Protection Law in Mexico in 2014 include now specific mentions to space hazards and space weather phenomena. The Mexican Space Agency (AEM) was founded in 2013 and during the last few years, the UN has promoted international cooperation on Space Weather awareness, studies and monitoring. These internal and external conditions motivated the creation of a Space Weather Service in Mexico. The Mexican Space Weather Service (SCIESMEX / www.sciesmex.unam.mx) is operated by the Geophysics Institute at the National Autonomous University of Mexico (UNAM). The UNAM had the experience of operating several critical national services, including the National Seismological Service (SSN); besides that a well established scientific group with expertise in space physics and solar-terrestrial phenomena. SCIESMEX became a Regional Warning Center of the International Space Environment Services (ISES) in 2015, and also participates in the Inter-progamme Coordination Team on Space Weather (ICTSW) of the Word Meteorological Organization (WMO), and in the Space Weather expert group of UNCOPUOS. The service combines a network of different ground instruments covering solar, interplanetary, geomagnetic, and ionospheric observations. The service operates an early warning system replaying, translating and adapting to the region the SWPC-NOOA alert messages in real time to different users. In October 2015 the National

Center of Disasters Prevention (CENAPRED) created a Space Weather working group, which includes different governmental sectors and military agencies, to develop a space weather strategy in Mexico. We report the advances of the working group and the current space weather products of the service.

4:40 **The Australian Bureau of Meteorology: Space Weather Services**
Phillip Maher, Bureau of Meteorology

The Australian Bureau of Meteorology's Space Weather Services (SWS) provides support for the Australian region and beyond on a wide range of systems and technologies affected by space weather. Since its beginnings as the Ionospheric Prediction Service (IPS) in 1947 (and recently changed to SWS in 2014) we have maintained and developed an extensive sensor network to provide daily forecasts and nowcasts of space weather impacts on the local region. In this presentation I will discuss recent modelling efforts in support of the National Positioning Infrastructure (NPI) project, advancements in ionospheric modelling and forecast capabilities, improvements in solar analysis and flare prediction, and our engagement with aviation and representatives of critical infrastructure to mitigate the effects of severe space weather events.

5:00 **End of Session**

Friday, April 29

8:30 - 8:40 **Space Weather Morning Forecast Brief**
Rob Steenburgh, SWPC Space Weather Forecasting Office

8:40 - 10:00 **Improving SWx Forecasting II: Modeling and Data Assimilation**
Chair: Howard Singer, NOAA/SWPC

8:40 **Community Coordinated Assessment and Rapid Implementation of Space Weather Analysis and Forecasting Capabilities**
Masha Kuznetsova, NASA/CCMC

The Community Coordinated Modeling Center (CCMC, http://ccmc.gsfc.nasa.gov) is hosting a rapidly expanding collection of space environment models and is collaborating with model developers on on-boarding of newly developed state-of-the-art capabilities. Over the years the CCMC acquired a unique experience and built a modular infrastructure for ingestion, assessment and flexible dissemination of models and data products. The CCMC provides highly utilized web-based tools and simulation services that facilitate community research to improve understanding of space weather phenomena and to enable model testing by the international space weather community. The CCMC is addressing the need for rapid evaluation and experimental implementation of latest advances in research and newly emerging ideas in the fast growing field of space weather. The CCMC is effectively serving as a hub in the interconnected Research-Data-Model-Assessment-Dissemination-Prototyping-Operations system for coordinated and collaborative development of operational space weather forecasting capabilities. Partnership with operational agencies and user of space weather applications is a key for developing actionable displays and tools ready-to-be-used by forecasters and decision makers. The presentation will focus on latest deliverables and developments, advances in CCMC-led community-wide ensemble predictions and uncertainties assessments projects, and perspectives on further expanding of CCMC-SWPC partnership.

9:00 **An Operational Geospace Model at the National Weather Service: Latest Update**
George Millward, NOAA/SWPC

The SWPC project to transition the Geospace component of the Space Weather Modeling Framework (SWMF) to full operations at the National Weather Service (NWS) is progressing, with full operational status set for October 1st 2016. The operational system utilizes real-time measurements of the Solar wind, made at L1 and then propagated to the location of Earth, with the model then able to provide a forecast of the Geospace environment 20 to 60 minutes into the future, dependent upon the prevailing Solar wind speed. Initial output products will focus on predictions of relevance to the electric power industry, a regional ground magnetic perturbation (dB) and regional K, the aim being to improve upon current predictions such as Kp which are global in nature. Issues related to running a large-scale Geospace model in real-time will be reviewed and the latest updates on the project presented.

9:20 **Overview of NASA MSFC and UAH Space Weather Modeling and Data Efforts**
Linda Neergaard Parker, Jacobs/MSFC

Marshall Space Flight Center, along with its industry and academia neighbors, has a long history of space environment model development and testing. Space weather efforts include research, testing, model development, environment definition, anomaly investigation, and operational support. This presentation will highlight a few of the current space weather activities being performed at Marshall and through collaborative efforts with University of Alabama in Huntsville scientists.

9:40 **Van Allen Probes and Space Weather**
Mona Kessel, NASA HQ

Space weather data is being generated and broadcast from the Van Allen Probes spacecraft 24/7 when not sending science data. There are four locations around the world that download the space weather data and make it available to the project and hence the public. The JHU/APL Science Gateway provides access to the space weather data, as well as to models, software and tools in support of the Van Allen Probes mission for researchers, students and the general public. The Van Allen Probes mission targets one part of the space weather chain: the very high---energy electrons and ions magnetically trapped within Earth's radiation belts. The understanding gained by the Van Allen probes will enable us to better predict the response of the radiation belts to solar storms in the future, and thereby protect space assets in the near---Earth environment.

10:00 - 10:20 Break

10:20 - 12:00 <u>Space Weather Impacts: Radiation Modeling and Observations</u>
Chair: Terry Onsager, NOAA/SWPC

10:20 45th Weather Squadron Space Weather Support to Launch
Kathy Winters, USAF

The 45th Weather Squadron (45WS) provides weather support for all launch operations at Cape Canaveral Air Force Station and Kennedy Space Center. Space weather constraints are a concern for most launch vehicles. As launch day approaches and during the launch countdown, the 45 WS informs the launch customer on solar activity and potential for violating space weather constraints. To do so, the 45 WS coordinates with the 557th Weather Wing and monitors space weather products from the Space Weather Prediction Center. This presentation describes this process and includes a case from 2001 in which launch weather delayed an Athena 1 launch at the Kodiak Launch Complex in Alaska.

10:40 Predicting Solar Energetic Particle (SEP) Events Using SEPMOD with ENLIL
Janet Luhman, UC Berkeley

The SEPMOD approach to SEP event modeling (described in JASR 2006 and 2010) provides the potential for forward modeling with predictive heliospheric models. The timely combination of the STEREO mission and the further development and availability of ENLIL simulations of the global heliospheric responses to coronal mass ejections (also enabled by SOHO LASCO) has allowed further testing. In particular, we have now used ENLIL runs for a number of several-week periods starting with August 2010 when multiple CMEs were observed. This required modified SEPMOD procedures to calculate SEP consequences of the presence of multiple shock sources but required no other alterations to the existing scheme. The primary hurdle for making SEPMOD results routinely available is the ongoing pipeline of accurate heliospheric model results. The impact of reduced multiperspective coronal imaging availability is still being evaluated, as is the ability to include coronal and CME ejecta detail. Nevertheless, the potential for ongoing production of SEPMOD results based on ENLIL runs exists today if the needed attention is dedicated to its installation.

11:00 The Radiation Dosimetry Experiment (RaD-X) Flight Mission: Observations for Improving the Prediction of Cosmic Radiation Health Risk at Aviation Altitudes
Christopher Mertens, NASA

The NASA Radiation Dosimetry Experiment (RaD-X) stratospheric balloon flight mission address the need to reduce the health risk of human exposure to cosmic radiation in the aircraft environment by taking high-altitude measurements that characterize the dosimetric properties of cosmic ray primaries, the ultimate source of aviation radiation exposure. In addition, radiation detectors were flown to assess their potential application to long-term,

continuous monitoring of the aircraft radiation environment. RaD-X was successfully launched from Fort Sumner, New Mexico (34.5N, 104.2W) on 25 September, 2015. Over 20 hours of science data were obtained from four different type dosimeters at altitudes above 20 km. The RaD-X flight mission was also supported by coordinated aircraft radiation measurements. Flight data from the RaD-X campaign are presented and discussed.

11:20 **Comparison of Cosmic Radiation Detectors in the Radiation Field at Aviation Altitudes**
Matthias Meier, DLR

An assessment of the exposure of aircrew and passengers to the complex radiation field at aviation altitudes has been a challenging task and a legal obligation in the European Union for many years. The response of several radiation measuring instruments to this radiation field was investigated by different European research groups within the framework of the CONCORD campaign (COmparisoN of COsmic Radiation Detectors) in the Radiation Field at Aviation Altitudes. We measured dose rates at four positions in the atmosphere in European airspace, two altitudes at two locations respectively, under quiet space weather conditions during joint measuring flights with the twin-jet research aircraft Dassault Falcon 20E operated by the DLR flight facility Oberpfaffenhofen. The results show a very good agreement between the readings of the instruments of the different research groups as well as for the comparison of the corresponding average values with PANDOCA model calculations.

11:40 **Space Weather at Mars: Energetic Particle Measurements on the Surface of Mars with MSL RAD**
Don Hassler, SwRI (Southwest Research Institute)

The Radiation Assessment Detector (RAD) is a compact, lightweight energetic particle analyzer currently operating on the surface of Mars as part of the Mars Science Laboratory (MSL) Mission. RAD is providing the first measurements of the energetic particle radiation environment on the surface of another planet due to solar flares, coronal mass ejections (CMEs), and galactic cosmic rays (GCRs).

RAD is providing synoptic measurements of the energetic particle environment at a 2nd location in heliosphere (other than near-Earth or L1), and will aid heliospheric modeling over solar cycle. These observations of SEP fluxes are contributing to a solar energetic particle (SEP) event database at Mars and the Martian surface to aid prediction of Solar Particle Events (SPEs), including onset, temporal & size predictions. This presentation will provide an overview of the RAD investigation and present measurements of the solar flare, GCR and radiation environment on the surface of Mars, and discuss the importance of providing broad heliospheric coverage for situational awareness of space weather as we plan to send humans out into deep space and to Mars.

RAD is supported by NASA (HEOMD) under JPL subcontract #1273039 to SwRI, and by DLR in Germany under contract with Christian-Albrechts-Universitat (CAU).

12:00 **Closing Remarks**
Thomas Berger, NOAA/SWPC

12:10 **End of Conference**