2015 Space Weather Workshop Agenda with Abstracts
Millennium Hotel Ballroom

Monday, April 13

9:00 - 4:50 GOES-VW (NEXT) Requirements Session

5:00 - 7:00 Welcome Networking Session (NCAR Mesa Lab – 1850 Table Mesa Drive)
Buses depart the Millennium Hotel at 4:45 p.m. & 5:00 p.m.

Tuesday, April 14

8:30 Conference Welcome
Brent Gordon, NOAA/SWPC

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

8:45 Space Weather in Boulder: A Brief History
Ernest Hilder, Former Director, Space Environment Center

Space weather in Boulder comprises two intermingled streams, research and services. The research stream began when Harvard graduate student Walter Orr Roberts established an observatory containing a coronagraph at Climax, Colorado in 1940. This grew into the High Altitude Observatory, whose headquarters moved to Boulder, becoming part of the University of Colorado in the late 1940s, and, later, a Division of the National Center for Atmospheric Research when NCAR was formed in 1960. Space weather research continued and continues at NCAR, the University, and at many institutions in Boulder. We can date the service stream's beginning in Boulder to President Eisenhower's dedication of the National Bureau of Standards' (NBS') Radio Building in 1954; NBS-Boulder included the Central Radio Propagation Laboratory, "Central" because it was formed from consolidating the space weather (and radar) research and service units each of the armed forces had set up after World War II. With name changes along the way, this unit segued through the Environmental Science and Services Administration (1965) into the National Oceanic and Atmospheric Administration (NOAA, formed in 1970). Today, the Space Weather Prediction Center (SWPC), part of NOAA's National Weather Service (NWS) in the Department of Commerce, provides space weather data and forecasts on-line and to more than 3500 subscribers to its services.

The intermingling of the research and services streams began very early, during World War II, when Walt Roberts would get on the phone to Washington – at their request – to advise the military on the current and expected activity of the Sun which might affect communications and radar performance. As another example of intermingling, NOAA's creators put space weather monitoring and forecast into its research component, the Office of Oceanic and Atmospheric Research, because space weather services were so heavily dependent upon research. Though SWPC's predecessor began to issue daily space weather forecasts to the public 50 years ago, SWPC left the research side to join the operations side of NOAA, the National Weather Service, only 10 years ago.

9:10 Solar Maximum...We Hardly Knew Ye
Doug Biesecker, NOAA/SWPC

At the 2014 Space Weather Workshop, we said that solar maximum was finally here. How right we were, because we can now say with considerable certainty that solar maximum was in April, 2014. Solar cycle 24 peaked at Ri=81.9 (TBC). This is within the error bar of the prediction Ri=90±10 issued in May, 2009. However, that prediction was for solar maximum to occur in May, 2013, a full 11 months earlier and well outside the error bar of ±6 months. This contrasts with the Cycle 23

prediction, which got the time of maximum nearly perfect, but missed the amplitude by a significant margin. We will review the previous solar cycle panel predictions and place cycle 24 in context. In addition, we will discuss why we can confidently state that it's all downhill from here and what we can expect in the next few years.

9:25 - 9:45 **Break**

9:45 - 11:15 **Space Weather National Strategy**
Chair: William Murtagh, Office of Science and Technology Policy

9:45 **Task Force Overview**
Co-leads: Tammy Dickinson, OSTP/Louis Uccellini, NWS

In November 2014, as Chair of the National Science and Technology Council (NSTC), and on behalf of the President of the United States, Dr. John Holdren chartered the interagency Space Weather Operations, Research, and Mitigation (SWORM) Task Force. The Task Force is developing a National Space Weather Strategy that will articulate high-level strategic goals for enhancing our Nation's preparedness for a severe space weather event. In addition, a Space Weather Action Plan will be developed that will establish a process to implement the National Strategy. Strengthening America's resilience to space weather is a challenge that will require insight, expertise, and dedication from many; consequently, this is a coordinated approach across numerous Federal Departments and Agencies. SWORM Task Force members will share details of the National Strategy and provide an opportunity for input from workshop attendees during the panel discussion.

10:00 - 11:15 **Panel: Goal Team Leads**
Seth Jonas, STPI; Sarah Ellis Peed, DHS; Tom Berger, SWPC; Chris Cannizzaro, DOS

11:15 - 12:15 **DSCOVR**
Chair: Alysha Reinard, CIRES

11:15 **DSCOVR – Halfway to L1**
Doug Biesecker, NOAA/SWPC

The first operational satellite in deep space, NOAA's DSCOVR satellite was launched on February 11, 2015 and is half-way to final orbit insertion. DSCOVR is the operational replacement of the Real-Time Solar Wind aspect of the NASA/ACE satellite. When operational, it will provide high time resolution interplanetary magnetic field and solar wind measurements from a Lissajous orbit around L1. Here we will update you on the project status since launch and the plans going forward. We will present the plans for transition from ACE to DSCOVR, as well as the SWPC data display, data access, archive and product plans.

11:35 **Instrumentation - Capabilities and Calibration Test Plans**
Adam Szabo, NASA/GSFC

The Deep Space Climate Observatory (DSCOVR) was successfully launched on February 11, 2015 and it is on its way to its L1 vantage point. While in cruise, the space weather instrumentation has been activated and in-flight calibrations have begun. The capabilities of the fluxgate magnetometer and Faraday Cup thermal plasma analyzer will be discussed. First observations and detailed calibration plans will be presented.

11:55 **Space Weather Follow-on (Presentation Not Available)**
Pat Mulligan, NOAA/NESDIS

NOAA's National Environmental Data, Satellite, and Information Service (NESDIS) is engaged in on-going studies for the next generation of operational space weather observations. We will be

conducting architecture studies for our observational requirements as a whole - primarily focusing on, but not confined to, continuation of solar wind data after DSCOVR and the acquisition of Coronal Mass Ejection (CME) imagery. We will give a summary of options studied to this point and will discuss how we are aligning our planning process with SWORM Strategic Plan objectives. Continuation of NOAA support for NASA advanced technology development, in particular solar sail propulsion, and coordination with foreign partners' complementary potential missions will also be covered.

12:15 - 3:00 **Lunch**

1:00 - 3:00 **Poster Session - General Space Weather Activities and Operational Services & Solar and Interplanetary Research and Applications (Two Groupings)**

3:00 - 4:40 **<u>Space and Ground Based Observations and Advances</u>**
Chair: Rodney Viereck, NOAA/SWPC

3:00 **GOES-VW Workshop Summary**
Howard Singer, NOAA/SWPC

On Monday, 13 April, there will be a workshop to discuss space weather observational requirements associated with the NOAA Geosynchronous Operational Environmental Satellite or GOES. Discussions are about to begin on the next generation of GOES, which will be ready for launch sometime around 2025. We would like to be sure that the needs and requirements of space weather customers and forecasters are well documented and captured in the NOAA Consolidated Operational Requirements List (CORL) as the planning for the GOES-Next begins. In this presentation we will provide a very short overview of the Monday workshop and the outcome of the discussions.

3:20 **Solar Data for Space Weather Forecasts from GONG**
Frank Hill, National Solar Observatory

GONG, the Global Oscillation Network Group, is a ground-based system of six solar observing stations distributed geographically around the world. The sites are located in California, Hawaii, Australia, India, Spain, and Chile, and have provided continual observations of the sun with a median daily duty cycle of 0.91 since 2001. GONG, deployed by the National Solar Observatory in 1995, was designed as and continues to be a primary source of helioseismology data, but has also been producing full-disk high-cadence line-of-sight magnetograms since 2006 and H-α intensity images since 2010. The 1k X 1k quick-look magnetograms are returned in near-real time with a 10-min cadence, and drive the background solar wind model of the SWPC WSA/Enlil system to forecast geomagnetic storms. They are also being used in the AFRL ADAPT system, and fully-calibrated science-grade magnetograms are available with a 1-min cadence. The 2k X 2k H-α images are returned every minute in near-real time from each sites, with a data acquisition time chosen so that the network produces one image every 20 sec. GONG also produces helioseismic maps of the magnetic field on the farside of the Sun. These farside maps are being further developed into a space weather forecast tool, and will be used to improve predictions of the FUV flux.

3:40 **The Ionospheric Connection Explorer: ICON**
Elsayed Talaat, NASA/Heliophysics

The Ionospheric Connection Explorer (ICON) is a NASA Heliophysics Explorer Mission designed to study the ionosphere, the boundary between Earth and space. This region, where ionized plasma and neutral gas collide and react, exhibits dramatic variability that affects space-based technological systems like GPS. The ionosphere has long been known to respond to space weather drivers from the sun, but recent NASA missions have shown this variability often occurs in concert with weather on our planet. This paper addresses the overall mission design and architecture of ICON, system design trades that have occurred through phase B of development, and challenges unique to the ICON mission. Set

to launch in June 2017, ICON will perform a two-year mission to observe conditions in both the thermosphere and ionosphere. ICON's science objectives are to: 1) understand the source of strong ionospheric variability, 2) the transfer of energy and momentum from our atmosphere into space, and 3) how solar wind and magnetospheric effects modify the internally-driven atmosphere-space system. ICON will accomplish these 3 science objectives using a suite of 4 instruments mounted to a composite deck aboard an Orbital Sciences Corporation LEOstar-2 spacecraft bus. Dual Michelson Interferometers for Global High Resolution Thermospheric Imaging (MIGHTI) will measure neutral winds in the thermosphere, and temperatures at the boundary of space. Two Ion Velocity Meters (IVM) will measure in situ ion drifts in the ionosphere. Two ultraviolet spectrographic imagers, a Far Ultraviolet (FUV) and an Extreme Ultraviolet (EUV), will observe the airglow layers in the upper atmosphere in order to determine both the ionospheric and thermospheric density and composition. Finally, the current state of the program will be summarized and the project's plans for the future will be discussed.

4:00 Imaging the Boundary Between Earth and Space - A Preview of Space Weather Data from the Global-scale Observations of the Limb and Disk (GOLD) Mission
Richard Eastes, University of Central Florida

The GOLD mission will provide unprecedented imaging of the Earth's space environment and its response to forcing from the Sun and the lower atmosphere. The mission will fly a far ultraviolet imaging spectrograph and is scheduled for launch into geostationary (GEO) orbit in October 2017 as a hosted payload on a commercial communications satellite flying over eastern South America. From this vantage point GOLD will repeatedly image the American hemisphere at a thirty-minute cadence. Fundamental parameters that will be derived from these measurements include composition (O/N2 ratio) and temperature of the neutral atmosphere on the dayside disk. Imaging of atmospheric composition has already proved to be a key parameter for understanding the behavior of the Thermosphere-Ionosphere (T-I) system. Combining composition with simultaneous temperature images will provide revolutionary insights into the behavior of the T-I system and its response to external forcing. Since GOLD will repeatedly observe the same geographic locations, it can distinguish between spatial and temporal variations in the TI system caused by geomagnetic storms, variations in solar EUV, and forcing from the lower atmosphere. In addition, due to near real-time availability of GOLD data, it may be useful for space weather specification and forecasting. Consequently, GOLD's measurements and observing approach provide an opportunity for both scientific and operational advances in understanding the T-I system.

4:20 Impact of FORMOSAT-7/COSMIC-2 on Ionospheric Space Weather Monitoring
I-Te Lee, Central Weather Bureau - Taiwan

The FORMOSAT-3/COSMIC (F3/C) constellation has provided ionospheric electron density profiles with high vertical resolution through radio occultation measurements to reconstruct the three-dimensional structures of global ionospheric electron density which almost impossible be made in the past decade. Based on the success of F3/C mission in providing reliable observations for atmospheric and ionospheric researches, the National Space Organization in Taiwan has proposed a follow-on mission named Formosa Satellite-7/Constellation Observing System for Meteorology, Ionosphere and Climate-2 (FORMOSAT-7/COSMIC-2, hereafter shortened to F7/C2), which deploys an operational constellation system of twelve satellites to receive US GPS, Russian GLONASS and European Galileo system signals to perform occultation observations. Slated for deployment starting in 2016, F7/C2 constellation will further provide more than four times the number of the F3/C occultation soundings for weather forecasting and space weather monitoring. More detail system information, launch schedule, possible data products, and preliminary observing system simulation experiment results will be presented in this paper.

4:40 Space Weather Ballooning
Tony Phillips, SpaceWeather.com

Spaceweather.com and the students of Earth to Sky Calculus have developed a "Space Weather Buoy" for suborbital research helium balloons. The payload, which is relatively inexpensive and easy to assemble, can be quickly deployed by a small launch crew to measure the effect of solar and geomagnetic storms on Earth's atmosphere. Sensors include multiple radiation sensors, a GPS altimeter, and a cryogenic thermometer. The Buoy has flown more than 30 times since October 2013, and we are ready to share the result of our monitoring, which includes detection of three Forbush Decreases.

5:00 **End of Session**

5:30 - 7:30 **9th Annual SWPC - Commercial Space Weather Interest Group (CSWIG) / American Commercial Space Weather Association (ACSWA) Summit Meeting - by invitation**

Wednesday, April 15

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"

Featured Speakers:

Major General Steve Denker, Director, Integrated Air, Space, Cyberspace and ISR Operations, Air Force Space Command
Space Weather - Key Element to Space Domain Awareness

Dr. David Chenette, President and CEO, Celdex Space, LLC
Success and Challenges in Government-Industry Partnering

Dr. Conrad C. Lautenbacher, Jr., Chief Executive Officer, GeoOptics, Inc.
Growing the Space Weather Enterprise: Building a Committed Partnership

Panel: Featured Speakers

Moderator and Organizer:
Dr. Devrie Intriligator, Director, Space Plasma Laboratory, Carmel Research Center, Inc.

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

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

10:30 **NASA Heliophysics Division**
Lika Guhathakurta, NASA/Heliophysics

10:45 **Space Weather Research at the National Science Foundation**
Vladimir Papitashvili, NSF

11:00 **Department of Defense Space Weather**
Ralph Stoffler, AFW

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

11:30 **NESDIS**
Greg Mandt, NOAA/NESDIS

11:45 **Question and Answer Session**

12:00 - 3:00 **Lunch**

1:00 - 3:00 **Poster Session - Ionosphere Research and Applications**

3:00 - 3:20 **Superflares on Solar Type Stars and Their Implications on the Possibility of Superflares on the Sun**

Kazunari Shibata, Kyoto University

Using Kepler data, Maehara et al. (2012) have discovered 365 superflares (1034-1036 erg) on 148 solar type stars (G type dwarfs). They revealed that the occurrence frequency of superflares of 1034 erg is once in 800 years, and that of 1035 erg is once in 5000 years on Sun-like stars whose surface temperature and rotation are similar to those of the Sun. It was also found that these superflare stars show quasi-periodic brightness variation, which can be interpreted as a result of rotation of stars with large star spots (Notsu Y. et al. 2013). This interpretation is consistent with standard theory of solar flares and dynamo (Shibata et al. 2013), and has partly been confirmed by spectroscopic observations of some of these stars using Subaru telescope (Notsu S. et al., 2013; Nogami et al. 2014). Furthermore, there were no evidence of hot Jupiters around these superflare stars, suggesting the possibility that superflares may occur on the Sun (Nogami et al. 2014). Shibayama et al. (2013) extended Maehara et al.'s work to find 1547 superflares on 279 solar type stars from 500 days Kepler data. They basically confirmed the results of Maehara et al., but found that in some Sun-like stars the occurrence rate of superflares was very high, 5 superflares in 500 days (i.e., once in 100 days). We shall discuss what would happen on the civilization and environment of the Earth if such superflares would occur on the Sun.

3:20 - 5:00 **Space Weather Impacts: Emerging Issues in Aviation**

Chair: Robert Rutledge, NOAA/SWPC

3:20 **NIOSH Aircrew Studies**

CAPT Barbara Grajewski, U.S. Public Health Service

The commercial aircraft cabin environment is the workplace of approximately 168,000 air crewmembers in the United States. Workplace exposures of concern for health effects include cosmic ionizing radiation, circadian disruption, and physical factors. The International Agency for Research on Cancer estimates 250,000 aircrew worldwide are monitored for radiation exposure; US airline crewmembers are not currently monitored. The National Institute for Occupational Safety and Health (NIOSH) has conducted exposure and health effects studies of aircrew. Exposure estimates for several of these studies have been strengthened, and misclassification has been decreased, by assessing records of individual flight segments flown by each crewmember, rather than estimating metrics based on hours worked or duration of employment. For flight segment radiation estimates in these reproductive and biomarker studies, galactic cosmic radiation doses were estimated with the Federal Aviation Administration's CARI program; solar particle event exposures were estimated in collaboration with NOAA and NASA researchers. Exposure assessment for a biomarker study of US pilots and a study of miscarriage in flight attendants are examples of how these estimates can be created and deployed in health effects studies. Results from these studies indicate that several aircrew exposures have potential health consequences. With adequate study design, including route selection and sufficient sample size, the effects of individual aircrew exposures can be separated in analyses of health outcomes. This improves our ability to better inform air crewmembers about specific hazards in their work environment.

3:40 **Rockwell Collins GLOBALink Voice Services / Impact of Solar Event on HF Comms**

Hugh Pat Guido and Anthony Abate, Aeronautical Radio, Incorporated (ARINC)

High Frequency (HF) Communications are routinely effected by Solar and Space weather. Rockwell Collins' ARINC Air/Ground International Voice Service provides HF single side band aeronautical operational control (AOC) voice communications for aircraft flying over the Atlantic, Caribbean, and Pacific oceans; Canadian and Arctic regions; and the Gulf of Mexico and Central and South America. We connect far-reaching corners of the world to one of two Rockwell Collins long-distance operational control facilities located in New York and San Francisco. The radio operators at these facilities also control remote, high-powered HF radio sites.

The following presentation will illustrate how the solar activity that occurred on March 11, 2015, effected long range HF communications at the NYC Communications center.

4:00 **EURADOS Activities on Space Weather Effects: Comparison of Codes Assessing Radiation Exposure of Aircraft Crew During Solar Energetic Particle Events**
Peter Beck, Seibersdorf Laboratories

The European Community Council Directive 96/29/EURATOM defines the basic safety standards for the protection of aircrew against the dangers arising from cosmic radiation. According to European Union legislation, this directive is binding to every country of the European Union and implemented by national law. Annual effective dose for aircrew members due to galactic cosmic radiation (GCR) range from about 0.2 to 5mSv, depending on flight routes and number of hours per year [1]. Investigations from literature show we cannot exclude that a single extreme solar cosmic radiation (SCR) event can cause an effective dose on a subsonic flight of up to several mSv in a worst-case scenario [2]. While we understand dose assessment procedures for GCR exposure of aircrew members well and assessed doses agree within 30% for the different models [3], the radiation exposure due to SCR events is still a matter of scientific research. In the presentation, we describe the status of investigation by the EURADOS Working Group WG11. We compare existing models and corresponding results for dose estimation at flight altitudes during SCR events. The results show that further research and verification of the codes, in particular by on-board measurements are necessary.

AVIDOS 2.0 – Aviation Dosimetry Service at ESA's Space Weather Portal

AVIDOS (aviation dosimetry) is a web-based service of the Seibersdorf Laboratories federated with ESA's Space Weather portal, accessible under: http://swe.ssa.esa.int/web/guest/avidos-federated. It is an informational and educational online software for the assessment of the radiation exposure at flight altitudes caused by galactic cosmic radiation. It estimates route doses for flights between any two locations. It also provides a comparison of assessed exposure with natural background radiation on Earth. Since the current version of AVIDOS does not take into account ionizing radiation impact of the occasionally energetic solar cosmic ray events, we are extending AVIDOS for the provision of dosimetry at aircraft altitudes due to solar radiation exposure. We will present the status of the developments.

The development of AVIDOS was supported by the European Space Agency (ESA Contract: No. 44000105734/12/D/MRP), the Austrian Federal Ministry of Transport and Innovation, and the Austrian Agency for Aviation and Space (ALR) as part of the Austrian Promotion Agency, FFG.

4:20 **Establishment of Requirements for Space Weather Information Service by the International Civil Aviation Organization (ICAO)**
Terry Onsager, NOAA/SWPC

Following the endorsement by the Air Navigation Commission of a conclusion emanating from the 5th Meeting of the International Airways Volcano Watch Operations Group (IAVWOPSG) held in Lima, Peru, from 15 to 19 March 2010, ICAO has been working on the establishment of requirements for the production and dissemination of space weather information to support international air navigation. The work also included the development of a concept of operations concerning space weather, intended to aid the understanding of how service provision is expected to evolve over the coming years to support the emerging global air traffic management system.

The ICAO/World Meteorological Organization (WMO) Meteorology Divisional Meeting (Montreal, Canada 7-18 July 2014) noted the ongoing work carried out by ICAO with the assistance of the WMO Inter-Programme Coordination Team on Space Weather (ICTSW) in the field of space weather. The Divisional Meeting agreed that space weather information services which will serve international air navigation should be organized through the establishment of an optimal number of global centres (for solar radiation storms and solar flares, as well as for geomagnetic storms and ionospheric disturbances

at the predictive stage) augmented by an optimal number of regional centres (for geomagnetic storms and ionospheric disturbances at the observation stage). The Divisional Meeting agreed to the need for the further development of service requirements and capabilities and any additional related guidance material in view of enabling the inclusion in 2018 of provisions, related to space weather information services for international air navigation, in Annex 3- Meteorological Service for International Air Navigation to the Convention on Civil Aviation.

The intention of this paper is therefore to provide information on ongoing and future work by ICAO in the area of space weather.

4:40 **Economic Impact and Effectiveness of Radiation Exposure Mitigation Measures during a Ground Level Enhancement**
Daniel Matthiä, German Aerospace Center (DLR)

In addition to the omnipresent radiation exposure from galactic cosmic rays and their secondary particles at aviation altitudes, aircrew and passengers may receive an increased dose from solar cosmic rays during ground level enhancements. In many cases, reducing the altitude or changing the route to lower latitudes are measures generally applicable to immediately reduce the dose rate and the corresponding total dose on a flight. In practice, however, taking such action necessarily leads to deviations from the operational flight plan and the consequential, additional fuel consumption constrains the mitigating action and also increases operating costs.
Using an aircraft performance tool and the Monte-Carlo based PANDOCA model for the calculation of the radiation exposure we investigate in a case study how mitigation procedures might have affected the dose rates and the total radiation exposure on a transatlantic flight during the ground level event of December 13th 2006. The reduction in radiation exposure achievable for a realistic flight scenario is examined in the context of the related additional fuel consumption and possible flight delay.

5:00 **End of Session**

6:00 - 8:30 **Banquet Dinner (UCAR Center Green Auditorium - 3080 Center Green Drive)**
Bus transportation available

Thursday, April 16

8:30 - 8:40 **Space Weather Morning Forecast Brief**
Meghan Stockman, SWPC Space Weather Forecasting Office

8:40 - 10:20 **Space Weather Impacts: Power Grid**
Chair: Chris Balch, NOAA/SWPC

8:40 **Solar Shield: Update and Path Forward**
Antti Pulkkinen, NASA/GSFC

A NASA Goddard Space Flight Center (GSFC) Heliophysics Science Division-lead team that includes NOAA Space Weather Prediction Center, Electric Power Research Institute (EPRI) and Electric Research and Management, Inc. (ERM) participants has recently partnered with the Department of Homeland Security (DHS) to better understand the impact of Geomagnetically Induced Current (GIC) on the electric power industry. NASA GSFC, initially working with EPRI and ERM, developed a Solar Shield system to predict the GICs. The present focus is to extend the Solar Shield system project to enhance the forecast capability (for a description of the "old" system, see http://ccmc.gsfc.nasa.gov/Solar_Shield). We call the new activity as "Solar Storm GIC Forecasting: Solar Shield Extension."

One of the general goals of Solar Shield Extension is to extend the prediction system coverage across CONUS. The team also uses the latest enhancements in space weather modeling capacity to increase the technological readiness level of the system. As a part of the process to enhance system reliability, the team worked to improve understanding of the power industry user requirements with emphasis on improving the forecasting system to better support operational decisions about proactive GIC mitigation actions. The GIC forecasting system requirements were developed and measured against this end goal. In this report, we will discuss the latest Solar Shield activities including end-user requirements development.

9:00 **NERC Reliability Standards for Geomagnetic Disturbances**
Frank Koza, Pennsylvania-New Jersey-Maryland Interconnection (PJM)

NERC has developed two mandatory reliability standards related to GMD that will become mandatory on power grid entities operators and planners in North America. The first establishes requirements for system operators and became effective on April 1, 2015. The second, which applies to system planning, is in the approval process. Highlights of both standards will be reviewed as well as what the standards are expected to achieve.

9:20 **Electric Power Grid Impacts of GMDs**
Tom Overbye, University of Illinois

Geomagnetic disturbances (GMDs) have the potential to impact the operation of the high voltage power grid by causing geomagnetically induced currents (GICs) to flow in the transmission lines and transformers. These GICs can cause half-cycle saturation in the transformers, resulting in increased transformer reactive power losses. In their 2012 report NERC noted that there are two major risk caused by GICs. The first is the potential for damage to transmission system assets, primarily the high voltage transformers. The second is the loss of reactive power support leading to the potential for a voltage collapse. This presentation focuses on the second risk, considering the power system modeling needed to consider the impacts of GMDs on the grid.

9:40 **Assessing the Impact of Space Weather on the Electric Power Grid Based on Insurance Claims for Industrial Electrical Equipment**
Karel Schrijver, Lockheed Martin

Geomagnetically induced currents are known to induce disturbances in the electric power grid. Here, we perform a statistical analysis of 11,242 insurance claims from 2000 through 2010 for equipment losses and related business interruptions in North-American commercial organizations that are associated with damage to, or malfunction of, electrical and electronic equipment. We find that claims rates are elevated on days with elevated geomagnetic activity by approximately 20% for the top 5%, and by about 10% for the top third of most active days ranked by daily maximum variability of the geo- magnetic field. When focusing on the claims explicitly attributed to electrical surges (amounting to more than half the total sample), we find that the dependence of claims rates on geomagnetic activity mirrors that of major disturbances in the U.S. high-voltage electric power grid. The claims statistics thus reveal that large-scale geomagnetic variability couples into the low-voltage power distribution network and that related power-quality variations can cause malfunctions and failures in electrical and electronic devices that, in turn, lead to an estimated 500 claims per average year within North America. We discuss the possible magnitude of the full economic impact associated with quality variations in electrical power associated with space weather.

10:00 **Information Needed from GMD Forecasters**
Trevor Gaunt, University of Cape Town

Geomagnetically induced currents (GICs) potentially threaten power systems by their effect on transformers. The quasi-dc GICs cause transformers to generate harmonics, absorb non-active power, and heat up. In turn, these cause power system disturbances and possibly initiate damage in transformers, depending on the GIC characteristics and the transformer design. The nature of disruption is the starting point for determining what information power systems engineers need from forecasters of geomagnetic disturbances (GMDs).

10:20 - 10:40 **Break**

10:40 - 12:00 **<u>Research to Operations (R2O) and Modeling</u>**
Chair: Michele Cash, CIRES

10:40 **Space Weather Prediction Testbed: Status and Update**
Rodney Viereck, NOAA/SWPC

The Space Weather Prediction Testbed (SWPT) encompasses the applied research and development activities within the NOAA Space Weather Prediction Center. The mission of this testbed is to improve the specification and forecasting of space weather by developing new models and products, and to facilitate the transition of models and products into operations. The SWPT is at the heart of Space Weather Research-to-Operations (R2O) activities. The SWPT development and R2O activities cover the entire range of physics and physical space from the sun to Earth. In this presentation, I will review the current development and R2O activities of the SWPT.

11:00 **Developmental Testbed Center: Facilitating R2O for Numerical Weather Prediction**
Louisa Nance, Developmental Testbed Center - NCAR

The primary mission of the Developmental Testbed Center (DTC) is to facilitate the transition of research related to Numerical Weather Prediction (NWP) into operations. To fulfill this mission, the DTC (i) provides user support for community NWP systems in close collaboration with the system developers, (ii) performs testing and evaluation of promising new NWP techniques, as well as the operational systems, to inform the operational implementation process, and (iii) brings together the research and operational NWP communities through workshops, tutorials and the DTC Visitor Program. Currently, the DTC focuses its activities in five task areas: mesoscale modeling, data assimilation, hurricanes, ensembles and verification. In this presentation, we will highlight results from recent testing and evaluation activities and how these tests have the potential to impact future operational implementations. We will also present examples of how the DTC has engaged the

research community in its testing and evaluation activities such that they have the potential to make valuable contributions towards advancing the skill of the U.S. operational NWP systems.

11:20 **Advancements in Empirical Geomagnetic Field Modeling During the THEMIS and Van Allen Probes Era**
Grant Stephens, Johns Hopkins University Applied Physics Laboratory

The advent of numerous spacecraft magnetometer missions has allowed for the development of empirical magnetic field models with unprecedented spatial and temporal evolution during geomagnetic storms. Empirical models have long been used to reconstruct the response of the magnetosphere as a function of the solar wind driving and serve as a ground truth complement to first-principles approaches, for example, by adjusting the equation of state in MHD models with the empirical plasma pressure. Until recently, empirical models had a rigid predefined structure for all current systems both spatially and temporally. Beginning with TS07D, ad-hoc equatorial current systems were replaced with basis-function expansions allowing the morphology of the equatorial currents to be inferred directly from data. Additionally, TS07D employs pattern-recognition techniques to dynamically bin magnetometer data determined by solar wind conditions which are used to fit the model, allowing for the reconstruction of the temporal evolution of storm-scale features also inferred directly from data. New spacecraft missions (THEMIS and the Van Allen Probes) make it possible to enhance the TS07D model in the inner-magnetosphere. The enhanced model findings include a highly asymmetric ring current during the main phase of storms that returns to a symmetric ring current during the recovery phase. Other findings include a closed banana current in the inner-magnetosphere closing through asymmetries in the westward and eastward ring current system. Additionally, an enhanced Birkeland current module that more accurately reconstructs the morphology as determined by the TRIAD and AMPERE data, including the Harang discontinuity, is also discussed. The dynamical nature of these new models makes them useful tools for the investigation of space weather and its geo-effectiveness on the global and inner-magnetosphere.

11:40 **Ensemble Assimilation Using First-Principles Models as a Tool for Three-Day Space Weather Forecasts**
Geoff Crowley, Atmospheric and Space Technology Research Associates (ASTRA)

Much as aircraft are affected by the prevailing winds and weather conditions in which they fly, satellites are affected by the variability in density and motion of the near earth space environment. Drastic changes in the neutral density of the thermosphere, caused by geomagnetic storms or other phenomena, result in perturbations of satellite motions through drag on the satellite surfaces. This can lead to difficulties in locating important satellites, temporarily losing track of satellites, and errors when predicting collisions in space. As the population of satellites in Earth orbit grows, higher space-weather prediction accuracy is required for critical missions, such as accurate catalog maintenance, collision avoidance for manned and unmanned space flight, reentry prediction, satellite lifetime prediction, defining on-board fuel requirements, and satellite attitude dynamics. We describe our ongoing work in building a comprehensive nowcast and forecast system for neutral density, winds, temperature, composition, and satellite drag. This modeling tool is called the Atmospheric Density Assimilation Model (ADAM). It is based on three state-of-the-art coupled models of the thermosphere-ionosphere (TIMEGCM, TIEGCM and CTIPe) running in real-time, using assimilative techniques to produce a thermospheric nowcast. It will also produce 72 hour predictions of the global thermosphere-ionosphere system using the nowcast as the initial condition, near real time and predicted space weather data and indices as the inputs. We will review the requirements for this system, a feasibility study showing the performance of the first-principles models as it pertains to satellite-drag operational needs, provide a status update of the ADAM project, and review challenges in developing an assimilative space-weather prediction model.

12:00 - 3:00 **Lunch**

1:00 - 3:00 **Poster Session - Magnetosphere Research and Applications**

3:00 - 3:20 **Space Weather Journal Overview and Prospectus**
Delores Knipp, Space Weather Journal

Space Weather: The International Journal of Research and Applications is the American Geophysical Union's journal devoted to the science of understanding and forecasting of space weather. The Journal is a research resource that also provides news and information for space weather professionals and reaches out to, and informs policy makers, members of the Executive and Legislative branches, and industrial leaders. Nearly 400 space-weather related articles have published since the Journal's inception in late 2003. New peer-reviewed research articles now appear at the rate of about one per week. Additionally, the journal publishes shorter features about new ideas and the history of space weather, as well as articles on policy, news, and meeting reports. Manuscripts emphasize impacts on technical systems including telecommunications, transportation, electric power, satellite navigation, avionics/spacecraft design and operations, human spaceflight, and other systems. After a solar cycle of growth and development, the Journal's new editorial team has revisited the statement of aims and scope of the journal. The editorial staff are actively soliciting articles that describe applications of observations, models and climatology related to: origins, propagation and interactions of solar-produced processes within geospace; interactions in Earth's space-atmosphere interface region produced by disturbances from above and below; influences of cosmic rays on humans, hardware and signals; and comparisons of the these types of interactions and influences with the atmospheres of neighboring planets and Earth's moon. In this presentation I will discuss several new initiatives aimed at making the Journal even more valuable to the space weather community.

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

3:20 **Predicting Space Weather: Impact on Fugro Offshore Precise Positioning Services**
Yahya Memarzadeh, Fugro Worldwide

Fugro provides global GNSS augmentation services for the offshore industry using a dedicated and highly redundant infrastructure. Several space weather phenomena create disturbances in the Earth's magnetic field and ionosphere in the polar latitudes and equatorial areas (where significant offshore oil exploration activities are).

After a brief introduction of these services, we will give an overview of the effects of the current solar maximum on precise GNSS positioning results in areas such as Brazil, Africa, India, Scandinavia and Alaska. We will in particular focus on the effects of the recent 17 March 2015 St Patrick solar storm.

The effects can be summarized as follows:

1) Ionospheric disturbances for GNSS single-frequency services.
2) Satellite L-band communication outages for the 9 geostationary satellites Fugro operates.
3) Ionospheric scintillations on GNSS signals in the equatorial and auroral regions.

Possible solutions to mitigate these effects will also be discussed, such as:

1) Removal of gross errors using statistical techniques.
2) Use of multiple GNSS constellations adding Glonass, BeiDou and Galileo

Fugro recently launched a worldwide ionospheric scintillation prediction service, which can forecast scintillation for the next 24 hours. It will help Fugro's clients with the planning of large offshore operations such as rig moves. Results of this new service for recent St Patrick solar storm will be shown. A new scintillation index for GNSS users will be proposed.

3:40 **International Committee on Global Navigation Satellite Systems (ICG)**
Shafa Gadimova, Office for Outers Space Affairs (UN)

The combination of multiple global navigation satellite systems (GNSS) can significantly improve many applications, as the increased number of satellites strengthens the orbit geometry, resulting in increased precision, accuracy, and overall availability and coverage of GNSS signals. These improvements are particularly important for applications in difficult environments where the visibility of the sky is restricted, such as in urban areas or in the vicinity of geographic formations such as mountains and canyons. Furthermore, scientific applications benefit from the additional available signals and their frequencies and the different orbital characteristics of each GNSS satellite.

The Office for Outer Space Affairs, in its capacity as the executive secretariat of the International Committee on GNSS (ICG) and its Providers' Forum, is organizing regional workshops, training courses and international meetings focusing on capacity-building in the use of GNSS-related technologies in various rapidly growing fields of science and industry . Those activities bring together a large number of experts every year, including experts from developing countries, to discuss and act on issues that are also of great relevance to ICG. ICG was established under the umbrella of the United Nations in 2005 as an informal, voluntary forum to discuss all matters regarding GNSS and its applications on a worldwide basis.

4:00 **State of GNSS in Africa: Applications, Observational Infrastructures, Research Implications and Prospects**
Babatunde Rabiu, Nigerian National Space Research and Development Agency

This paper highlighted the applications of GNSS–based technologies in agriculture, defence, public security, economy, environment, disaster management, civil aviation, land administration (surveying and mapping), space weather, and telecommunication and other vital sectors of development in Africa. The present state of Ground based GNSS Infrastructure in Africa is also presented. Various research and mapping initiatives that are contributing to the densification of ground infrastructures for GNSS are listed. These include: the UN International Heliophysical Year/International Space Weather Initiative IHY/ISWI, African Geodetic Reference Frame AFREF, some national mapping agencies activities and African Array. Data from these GNSS monitors are being used to improve existing global models of the ionosphere with relevance to earth satellite communication and GNSS positioning. Scientific results, depicting space environment, obtained from GPS data analysis are also presented. Some results of temporal variabilities of ionospheric total electron content TEC and its spatial variation are presented. Equatorial ionospheric anomaly and its associated phenomena were also investigated with TEC obtained from GPS. TEC is a proxy for space weather monitoring and ionospheric variability. Potentials of GNSS technology in solving present security and socio-economic challenges facing Africa are presented.

4:20 **ESA SSA Space Weather Service System**
Juha-Pekka Luntama, European Space Agency (ESA)

ESA SSA Programme is half way through Period 2, the second phase of the programme. This phase is aimed at advancing the system from the initial utilisation of existing European assets to development of new assets corresponding to the required architecture elements. Networking of existing and emerging European assets will be continued in parallel to the new developments. The Space Weather Segment of the ESA SSA system will be based on a federated architecture where the service provision will be carried out by Expert Service Centres in the Programme Member States. These collaborative centres bring together European expertise and assets and were initially demonstrated during SSA Programme Period 1. The established precursor services have been kept available to the end users after the first demonstration at best effort basis. Building on this experience, five Expert Service Centres (ESCs) focusing on Solar Weather, Heliospheric Weather, Space Radiation Environment, Ionospheric Weather and Geomagnetic Conditions are being established and the space weather end user services from the ESA SSA system are being made available to the users on the basis of a framework addressing service level agreements, leading to both a substantial extension of products available and improved reliability of provision. In parallel to provision of the current services, the ESCs are challenged to introduce new, innovative services based on assets that have been prototyped under

various European activities. Consequently, the SWE network of services is expected to grow substantially in the coming 2 years.

In order to ensure the long term availability of the observation data for the services, SSA Programme is carrying out space weather instrument developments together with ESA technology programmes. Implementations of the first space weather hosted payload missions are already in progress. In parallel, SSA Programme has started mission concept studies for dedicated space weather missions that are required for example for solar imaging, solar wind monitoring and heliospheric imaging. Analysis of dedicated missions was started in two SSA space weather system architecture definition studies that were completed in 2014. Mission concept analysis will be continued in 2015 in two studies focusing on space weather missions to L1 and L5.

This presentation will provide an overview of the recent advances in the ESA SSA Space Weather Segment including the key results from the architecture definition studies. The presentation will show the layout of the federated Expert Service Centre network, highlighting ongoing and upcoming service developments. This presentation will also give an overview of the space weather related technology developments ongoing within ESA programmes and provide a perspective on the plans for the next phase of the programme after 2016.

4:40 **UK Met Office Update**
Mark Gibbs, UK Met Office

The UK government continues to have space weather on the UK's National Risk Register as a medium-high risk. The past year has seen the official opening of the Met Office Space Weather Operations Centre (MOSWOC), by the UK Science Minister Greg Clark MP, along with the continued development of forecast capability and services.

I will outline the developments of the past year within the Met Office and parallel activities being undertaken within the UK. I will also address some short-term and longer-term research & development projects underway and also identify some wider goals and initiatives that the Met Office space weather team is involved with.

5:00 **End of Session**

Friday, April 17

8:30 - 8:40 **Space Weather Morning Forecast Brief**
Meghan Stockman, SWPC Space Weather Forecasting Office

8:40 - 10:00 **Research to Operations (R2O) and Modeling (Continued)**
Chair: Howard Singer, NOAA/SWPC

8:40 **Community Coordinated Modeling Center: Pioneering the Path from Research to Operations**
Masha Kuznetsova, NASA/CCMC

The Community Coordinated Modeling Center (CCMC, http://ccmc.gsfc.nasa.gov) was established at the end of past millennium as a long term and flexible solution to the problem of transitioning advances in space science research to space weather operations. Over the years the CCMC acquired the unique experience in on-boarding and preparing complex models and model chains for operational environment and in developing real-time space weather applications. The presentation will overview challenges and key elements of a successful research to operations (R2O) transition and discuss opportunities for further expansion of CCMC-SWPC partnership in accelerated implementation of advanced space weather prediction capabilities.

9:00 **Transitioning the SWMF Geospace Model into Operations at the National Weather Service**
George Millward, CIRES

The National Center for Environmental Protection (NCEP), a part of the National Weather Service, utilizes large-scale operational supercomputing to provide a production suite of computational weather forecasts. These forecasts include the regularly-updated regional and global terrestrial weather forecast, hurricane prediction, tornado prediction and other severe weather, as the need arises. Since 2011, this production suite has included a Space Weather component, with models derived from the Space Physics academic community, and transitioned to operational status at the Space Weather Prediction Center (SWPC) in Boulder.

The first model transitioned, the WSA-Enlil model of the Heliosphere, has been fully operational since December 2011. The model provides a 2-hourly updating forecast of the solar wind at Earth, with each forecast extending 5 days into the future. WSA-Enlil predicts “ambient” background solar wind conditions but most importantly it allows for the input of Coronal Mass Ejections (CMEs) at the model’s inner boundary, with CME parameters calculated by analysis of Coronagraph images from the SOHO and STEREO spacecraft.

In addition to forecasting the solar wind, we are now in the process of transitioning a global model of the Earth's magnetosphere, with the aim of providing a short time scale prediction of regional geomagnetic activity. The model, the Geospace component of the Space Weather Modeling Framework (SWMF), will be driven by real-time measurements of the solar wind, taken at the L1 point by NOAA's new DSCOVR satellite, and propagated forward in time to the position of Earth. I will review our progress on the Geospace model transition which is anticipated to be in full operations early in 2016.

9:20 **Integrated Dynamics in Earth's Atmosphere - IDEA**
Rodney Viereck, NOAA/SWPC

Variability in the ionosphere is the cause of space weather impacts on many technologies and for many customers. Ionospheric variability is driven primarily by three forcing agents: variations in solar x-ray and EUV irradiance, geomagnetic storms, and dynamics from the lower atmosphere. To fully specify and forecast the ionosphere requires accurate specification and forecasts of all three forcing agents. At the NOAA Space Weather Prediction Testbed, we are coupling the Whole-Atmosphere-Model (WAM) with the Ionosphere-Plasmasphere-Electrodynamics (IPE) model to create a fully coupled

modeling system that captures all of the forcing, dynamics, and interactions of the ionosphere-thermosphere system. In this presentation, we will provide an overview of the IDEA concept and an update on the model development activities.

9:40 WSA/ADAPT (Air Force Data Assimilative Photospheric Flux Transport)
Nick Arge, Air Force Research Laboratory

Estimation of the global solar photospheric magnetic field distribution is currently difficult, since only approximately half of the solar surface is magnetically observed at any given time. With the solar rotational period relative to Earth at approximately 27 days, these global maps include observed data that are more than 13 days old. Data assimilation between old and new observations can result in spatial polarity discontinuities that result in significant monopole signals. To help minimize these large discontinuities and to specify the global state of the photospheric magnetic flux distribution as accurately as possible, we have developed the ADAPT (Air Force Data Assimilative Photospheric flux Transport) model, which is comprised of a photospheric magnetic flux transport model that makes use of data assimilation methods. The ADAPT transport model evolves the solar magnetic flux for an ensemble of realizations using different model parameter values, e.g., for rotational, meridional, and super-granular diffusive transport processes. In this presentation, the ADAPT model and the data assimilative methods used within it will be reviewed. Coronal, solar wind, F10.7, and EUV model predictions based on ADAPT global photospheric magnetic field maps as input will be discussed.

10:00 - 10:20 Break

10:20 - 11:40 <u>Space Weather: The Future</u>
Chair: Rodney Viereck, NOAA/SWPC

10:20 Carrington L5 Mission
Markos Trichas, Airbus Defense and Space

Airbus Defence and Space (UK) has carried out a study to investigate the possibilities for an operational space weather mission, in collaboration with the Met Office, RAL, MSSL and Imperial College London. The study looked at the user requirements for an operational mission, a model instrument payload, and a mission/spacecraft concept. A particular focus is cost effectiveness and timelineness of the data, suitable for 24/7 operational forecasting needs. We have focused on a mission at L5 assuming that a US mission to L1 will already occur, on the basis that L5 (earth trailing) offers the greatest benefit for the earliest possible warning on hazardous SWE events and the most accurate SWE predictions. The baseline payload has been selected to cover all UK Met Office/NOAA's users priorities using instruments with extensive UK/US heritage, consisting of: a heliospheric imager, coronograph, magnetograph/EUV imager, magnetometer, solar wind analyser and radiation monitor. The platform and subsystems are based on extensive re-use from past Airbus missions to minimize the cost and a Falcon-9 launcher has been selected on the same basis. A schedule analysis shows that the earliest launch could occur in 2020, assuming Phase A KO in 2015-2016. The study team has selected the name “Carrington” for the mission, reflecting the UK’s proud history in this domain. The design could easily fit to a potential UK/US bilateral mission with UK providing the S/C and some of the payloads and US providing the launcher, ground segment and the rest of the payloads.

10:40 Opportunities in the First Solar Maximum with Social Media
Elizabeth MacDonald, NASA

This is the first solar maximum on record with new social media technologies. Aurorasaurus.org is a new mobile citizen science platform for crowd-sourcing volunteered observations of the Northern Lights. The resulting data are relevant to the space science community that lacks for such real-time observations. In turn the platform aims to improve nowcasting of the local visibility of the aurora for the public through location-based notifications and an updating real-time map. This talk will highlight observations from the recent March 17, 2015 storm and their future applications to space science.

Bringing together the public with a broad scientist network allows for the exchange of ideas about auroral observations, possible satellite-ground conjunctions, and further study of rare events. The frequency of aurora-related tweets also shows characteristic behavior that correlates strongly with real-time geomagnetic activity. Altogether the platform aims to provide state-of-the-art software utilizing human-computer interactions for interdisciplinary advances in scientific research.

11:00 USGS Induction Hazard Science
Jeff Love, USGS

In support of the US Geological Survey mission for pursuing science of societal importance, and as part of a priority to pursue natural hazard science, the USGS Geomagnetism Program has recently been concentrating its operational and research efforts to support a National priority project for monitoring and assessing induction hazards for electric-power grids. In addition to on-going responsibilities for maintaining the National network of magnetic observatories, recent USGS Geomagnetism Program accomplishments include: (1) Installing and operating a test geoelectric monitoring system at the Boulder observatory; (2) Constructing a simplified 1D conductivity model for the lithosphere beneath Florida; (3) Performing a magnetotelluric survey of the Florida Peninsula to constrain a 3D conductivity model of the region; (4) Developing (in collaboration with NASA and NOAA) a method for interpolated mapping magnetic disturbance across North America; (5) Pursuing research (in collaboration with the Colorado School of Mines) on time-domain methods for estimating geoelectric induction; (6) Pursuing research on the statistical occurrence frequency of extreme-event geomagnetic storms.

The present budget of the USGS Geomagnetism Program is $1.9 million/year, which the US Air Force augments by several hundred thousand dollars per year. The President's budget for 2016 proposes that this funding be increased to $3.6 million/year. Should this be enacted, the USGS will be positioned to: (1) Relieve the USAF of its financial support of observatory operations; (2) Augment magnetotelluric surveys undertaken by the EarthScope Program of the National Science Foundation to more completely cover the continental US; (3) Support 3D modeling of US continental conductivity; (4) Expand geomagnetic monitoring across the US, in the Pacific, and at South Pole; (5) Support geoelectric monitoring at several magnetic observatory sites; (6) Perform targeted assessments of induction hazards across the US; (7) Provide real-time maps of induced geoelectric fields across the US; (8) Facilitate the international acquisition and exchange of ground magnetometer data; (9) Undertake additional induction-hazard scientific research of importance for the Nation. These projects will be coordinated with USGS partners in government, academia, and private industry, and, in particular, new data acquisition projects will include external contractor work.

11:20 Four-Year Plan for World Meteorological Organization Space Weather Activities
Terry Onsager, NOAA/SWPC

Terry Onsager (NOAA Space Weather Prediction Center) and Jerome Lafeuille (WMO, Space Programme Office)

The World Meteorological Organization (WMO) is a specialized agency of the United Nations with a membership of 191 countries and territories. Along with its mission to foster collaboration in the areas of weather, climate, and hydrology, the WMO has included space weather as one of its areas of involvement. The WMO has been actively involved in space weather since May, 2010, including the documentation of space weather observing requirements, an assessment of gaps in observing systems, the establishment of a space weather product portal, and coordination with the International Civil Aviation Organization on space weather information for global aviation. In recognition of the increasing societal demand for space weather services, of the need for global coordination, and that WMO was in a position to facilitate a useful synergy between meteorological and space weather services, a four-year plan for WMO space weather activities has been developed. This plan describes the high-level goals for effort among WMO Members, actions to be accomplished, and a proposed

organizational structure. The four-year plan will be presented to the 17th WMO Congress for consideration in May, 2015.

11:40 **Closing Remarks**
Tom Berger, NOAA/SWPC

12:00 **End of Conference**