GLOBAL CHANGE
AND THE SOLAR-TERRESTRIAL ENVIRONMENT

JUNE 12-17, 2010

<u>TWO-POINT SUMMARIES</u>

<u>Sunday, June 13</u>

Session A: **Heliophysics and Space Climate**
Discussion Leader: Ernie Hildner

Jim Spann, Heliophysics 2009 Roadmap and Global Change: Possibilities for improved understanding of the connection

1. Heliophysics relates to global change through its study of solar variability and how this modulated energy flows through the near Earth space environment (called geospace or also called magnetosphere-ionosphere system), eventually affecting the terrestrial atmosphere; heliophysics is also relevant to global change as reflected by space weather's changing impacts to society's technical systems.

2. This workshop has the unique opportunity to articulate the state of knowledge of the relevance of the Solar-Terrestrial environment to global change, through a peer reviewed publication and popular publication, and to suggest to future research directions

Howard Singer, Space Weather to Space Climate: Societal Impacts

1. Understanding how society deals with the societal and economic impacts of space weather provides us with lessons learned that may influence our approach to dealing with climate and global change.

2. Solar cycle variations in magnetospheric mass density in the outer

magnetosphere have been determined through the analysis of magnetic oscillations observed by the GOES geosynchronous satellites (Takahashi, Denton, and Singer). Greater solar UV/EUV (based on the F10.7 proxy) increases the ionosphere density and/or scale height, which in turn decreases the magnetic wave frequency of oscillations on geomagnetic field lines threading the outer magnetosphere. Increasing the mass density by a factor of 4 or 5 during solar maximum is important for radiation belt climatology and radiation belt impacts on satellite operations. These results also demonstrate the important contribution of long-term space weather observations for understanding space climate.

Session B: **Climate Impacts and Response**
Discussion Leader: Lesley Gray

Don Wuebbles, Solar Influences on Climate Change and Resulting Impacts: Past and Near Future

1. Climate change is largely being driven by human activities, with solar playing almost no role in the substantial changes over the last 40 years except to affect the variability.
2. Solar inputs can only explain a small part (<15%) of the overall changes in climate since the beginning of the industrial revolution.

Session C: **Lower Atmosphere and Solar Response – 2**
Discussion Leader: Charles Jackman

Jerry Meehl, Amplifying the Pacific climate system response to a small 11 year solar cycle forcing.

1. Peaks of the 11 year solar cycle forcing produce SST and precipitation anomalies with a La Niña-like pattern in the Pacific
2. Bottom-up coupled air-sea mechanism and top-down stratospheric ozone mechanism add to strengthen tropical convection more than either one alone, and leads to amplifying cloud feedbacks
3. Due to timing of cool SST response to peak solar years early in solar max in composites, correlations and regressions miss this signal in favor of the lagged warm SST response that's more aligned with the broad decadal solar peak

Lesley Gray, Modeling and Mechanisms in the Stratosphere and Troposphere

1. The stratosphere (10-50 km) can play a role in transmitting the signal of solar variability to the Earth's surface. Increased temperatures are seen at solar maximum due to (a) direct heating effects of irradiance increases and (b) indirect heating effects due to the associated ozone increases. The

temperature changes lead to background wind changes which affect wave propagation. Through these wave propagation changes the solar signal can penetrate deep into the atmosphere and influence circulation and weather patterns at the Earth's surface. This is often referred to as the 'top-down' mechanism.

2. The top-down mechanism for solar influence has been tested in chemistry-climate models that extend high enough to include the full stratosphere. The models capture the broad signatures of solar response seen in the observations but there are details that require more attention and the exact mechanism for the extension of influence to the Earth's surface is still not well understood. This top-down mechanism may not be the only mechanism at work and more model studies that include a coupled ocean are required, so that the relative influences of the top-down and bottom-up mechanisms, and the feedbacks between them, can be better understood.

Monday, June 14

Session E: **Climate Impacts of Aerosols/Clouds**
Discussion Leader: Charles Jackman

Ralph Kahn, Aerosols and Climate: What We Can Say, and What We Can't

1. Assessing the significance of climate forcing mechanisms, be they due to aerosols, clouds, surface albedo, or solar input, is a *quantitative* matter.

2. Adequately constraining direct aerosol radiative forcing (DARF) to significantly improve the IPCC assessment, and more generally, our knowledge of climate sensitivity, will require the *combination* of satellite and suborbital measurements with models.

Session F: **Charged Particles and Geomagnetic Effects - 1**
Discussion Leader: Howard Singer

Richard Mewaldt, Galactic Cosmic Ray Intensities during the Space Age and the Holocene

1. In late 2009 the cosmic-ray intensity was at its highest level of the space age just as the interplanetary magnetic field (IMF) reached record-low levels: indeed, for the past ~60 years cosmic rays and the IMF have been inversely correlated.

2. Correlated variations of cosmic rays with the IMF, and the IMF with total solar irradiance (TSI), enable 10Be measured in ice cores to trace solar activity (the IMF and TSI), back over ~10,000 years.

David Gubbins, Internal Geomagnetic Fields on the Millennium Time Scale: Are we Going Into Another Excursion?

1. The Earth's dipole moment has decreased at a rate of 5% /century; this is likely to continue on the climate-change time scale.

2. This decrease will influence our geomagnetic weather and possibly the atmosphere.

Session G: **Charged Particles and Geomagnetic Effects - 2**
Discussion Leader: H. Singer

Robert McPherron, Effects of Geomagnetic Reversals on Solar Wind-Magnetosphere Coupling

1. The earth's magnetic field is decreasing in strength at a rate that would bring it to zero in the next 1000 years, if it were to continue at the current rate. This decrease makes the magnetosphere smaller, increases the size of the polar caps, alters the access of energetic particles, and changes the way solar wind energy is dissipated in the atmosphere.

2. If it is shown that this energy plays a role in climate change then the effects should be included in future models of this phenomenon. More important, these changes will alter the environment experienced by human assets in space and on the ground.

***Cora Randall and Charles Jackman,** Atmospheric Coupling via Energetic Particle Precipitation. An Overview of the Impact of Energetic Particle Precipitation on the Stratosphere and Mesosphere

1. Energetic Particle Precipitation (EPP) can have significant impacts on polar mesospheric and stratospheric chemistry and, possibly, circulation, providing a feasible pathway for sun-climate coupling. Such impacts occur after solar eruptions or particular geomagnetic storms and can also be connected with unusual wintertime polar meteorology, which occurs even during times of low geomagnetic activity.

2. Even though some EPP impacts occur impulsively over short periods of time (~few days) after solar eruptions or particular geomagnetic storms, the most important impacts are caused by long-lived EPP-produced polar NOy on time

scales of months to years. This EPP-produced NOy can then impact polar ozone, leading to significant decreases and increases.

3. The response of the atmosphere to EPP is controlled to a significant extent by middle atmosphere meteorology, which itself is affected by tropospheric dynamics, so human-induced impacts on the troposphere will likely cause unanticipated changes in the response of the middle atmosphere to EPP.

Tuesday, June 15

Session H**: Education and Public Outreach**
Discussion Leader: E. Hildner

John Katzenberger, Questions about the Sun – Earth System: A Teacher's Perspective

1. Interdisciplinary technical dialog and education/public outreach based upon the AGCI workshops over the last 20 years have not included significant participation from the middle/upper atmosphere and heliophysics communities with important implications for expanding the AGCI mission from "furthering the understanding earth system science and global environmental change" to "furthering the understanding of the earth-sun system and global environmental change."

2. For over 50 years there has been a sporadic national effort to improve science education in the U.S. Much has been learned about how people learn and pedagogical approaches that work, however this hasn't translated into better results -- the U.S. performs below average compared to other OECD countries while spending more per student. These students become the citizens that perform poorly in surveys of basic science literacy and lack the necessary critical thinking tools to assess important environmental issues such as climate change. By a greater level of engagement, the science community can play a critical role in improving education and public outreach.

Cherilynn Morrow, Learning Theory and Practical Lessons from Experiences in Science Education Reform

1. There are many sources of misconceptions and misunderstandings related to Sun-Earth climate science. These include:
    a. Phenomenological Primitives – part of your intuitive formation as a human being experiencing everyday life that goes insufficiently challenged by science instruction;
    b. Well meaning Science Instruction & Science Communication – unwitting introduction of misconceptions based on use of

metaphors, models with insufficient vigilance

c. Mis-information campaigns – deliberate strategies intended to plant scientifically inaccurate ideas in the public mind.

ALL of these call for a more scholarly approach to science communication on the part of scientists, science educators, and other science communicators based in research about How People Learn.

1. Attributes of Scholarly Science Instruction and Science Communication include:

   - Misconception awareness and anticipation and effective techniques for challenging them
   - Using interactive engagement techniques, ideally within a learning cycle structure (e.g. OPERA), that challenges common misconceptions and invites learners/listeners to think & reason for themselves;
   - Being vigilant about jargon, metaphors, and models that can introduce misunderstanding (e.g. the "weather" and " wind "analogies; animations that convey more than intended);
   - Relating stories about scientific investigations that make the nature of scientific inquiry explicit;
   - Using effective communication techniques and strategies from fellow communicators (with attribution when appropriate).

Rick Chappell, Communicating Global Change Science to the Public

1. Science is tremendously important to the world and the media does a very poor job communicating it to the public. Scientists must be proactive in explaining their science understandably to their "stockholders."

2. Stories of science are part of the narrative that forms our culture. These stories are not just about the results, but they are about amazing people doing amazing things. We must all share our stories of exploration!

Session I**: Solar Variability and Influences - 1**
Discussion Leader: Peter Pilewskie

Jerry Harder, What the SORCE SIM observations tell about solar spectral irradiance.

1. The variability in the solar spectrum is not easily parameterized.

a) SIM indicates irradiance trends that are larger than the solar modulation that compensate to produce the TSI trend
b) Active region evolution by itself is not sufficient to account for the observation - suggestive of changes in the internetwork/network radiance

2. Spectral observations from SIM suggest a very different response in the Earth's atmosphere. Further modeling studies and analysis of existing atmospheric observations are needed at this time.

Jeffrey Hall, Spectral and Brightness Variations of Cycling and Flat Activity Sun-Like Stars.

1. There is no dynamo model yet that can tell us *ab initio* how active a star will be, how it will vary in time, what the statistics of emerging bipolar regions or eruptive/explosive processes will be. Need: stellar observations for guidance and validation of advanced modeling.

2. Whereas the Sun is in a characteristic dynamo state of the solar/stellar ensemble, stellar observations show a range of patterns that the Sun has not shown in the instrumental era. Cycle-property characterization and cycle forecasting need stellar guidance. Need: continuation and (pan-chromatic) expansion of observational base.

Wednesday, June 16

Session J*:* **Solar Variability and Influences - 2**
Discussion Leader: P. Pilewskie

Gregg Kopp, How Well Do We Know Solar Irradiances on Climate Time Scales and How Can We Improve These?

1. The climate research community needs composite climate data records with associated uncertainties for four primary climate forcing agents (GHGs + aerosols, TSI, ENSO, volcanic)

2. TSI measurements are the most stable solar irradiance measurements, achieving stabilities necessary to detect solar variability of the entire radiative input to Earth's climate system on climate-relevant time scales, and are striving for sufficient absolute accuracy

Karel Schrijver, The stellar complement: what we cannot readily learn from the Sun alone about its activity.

1. Sun and stars exhibit many scale-invariant (power-law) properties that appear insensitive to stellar fundamental properties (mass, age, composition, ...). Need: learn to exploit these relationships (and their - as yet - hidden

correlation) in order to extrapolate to historical and future Sun, and to characterize variability (and extreme events) of solar and space climate.

2. Many solar/heliospheric records remain hidden in Earth's deposits of ice and sediments with information that is needed by solar/heliospheric physicists and climate physicists for long-term trend characterization. Need: trans-disciplinary studies to exploit that information in iterative analyses with, at least, biologists/chemists, geomagnetic physicists, heliospheric physicists, solar physicists.

Session K**: Solar Cycle / Atmosphere Effects**
Discussion Leader: Jim Spann

Dick White, Terrestrial Climate History Discussion

- Cycle 23-24 minims is a new benchmak in solar variability because of a change in sunspot production in laste cycle 23
- The last 40 years is a crucial epoch in the development of global changes as the world's population increases to 11 billion persons

Hauke Schmidt, The solar cycle effect in the MLT region - Simulations with HAMMONIA

1. The mesopause region reacts to solar cycle forcing by an increase of temperature. The amount of this increase simulated by the HAMMONIA is of about 3-5 K from solar minimum to maximum. Available observations give numbers varying from about 0-10 K. The mesopause region also reacts to other types of forcing and internal variability (from volcanoes, ENSO, QBO and GHGs), so that an attribution of signals from short time series is difficult. However, a fairly accurate estimation of the solar cycle effect in low latitudes (where interannual variability is weaker than at high latitudes) should be possible from observation of one solar cycle only.
2. Models and observations suggest that summer mesopause region and winter stratosphere are strongly coupled dynamically. Therefore, the high latitude mesopause shows a response not only to local forcing but also to forcing affecting the stratosphere. Accordingly, signals in the high latitude mesopause are obscured by stratospheric variability.

Session L**: Middle and Upper Atmosphere Effects - 1**
Discussion Leader: Jim Spann

Jeffrey Forbes, Inter-annual Variability Due to the El Niño - Southern Oscillation (ENSO).

1. Earth's atmosphere 0-500 km is a single connected system.

2. Latent heating and other processes (e.g., heating by H2O absorption) excite a spectrum of waves (tides, planetary waves, gravity waves, Kelvin waves, etc.) that carry amplified tropospheric signals throughout the atmosphere. Analysis of these signals can inform us about tropospheric processes and changes.

Maura Hagan, Anthropogenic and natural variability in the Earth's upper atmosphere: unraveling solar cycle variations and decadal trends

- Variations in solar irradiance have profound effects on T-I system temperatures and densities
- We need know better the altitudinal structure and variability of thermospheric winds on multiple horizontal and temporal scales

Session M**: Middle and Upper Atmosphere Effects - 2**
Discussion Leader: Rick Chappell

Victor Pasko, Lightning-related transient luminous events at high altitude in the Earth's atmosphere

1. Phenomenology and physical mechanisms of lighting related transient luminous events in the middle atmosphere termed sprites, jets and elves were discussed. Possible effects and relationships of these energetic events to atmospheric infrasonic emissions, global electric circuit and terrestrial gamma ray flashes were reviewed.

2. The history of observations of these events is relatively short. Although there are some data already available indicating that very large quantities of charge (>140 C, Cummer et al., Nature Geoscience, 2, 1-4, doi:10.1038/NGEO607, 2009) can be moved to the lower ionosphere in association with these events, their effects on the global electric circuit remain to be quantified.

Thursday, June 17

Session N: **Solar Variability and Influences - 3**
Discussion Leader: Peter Pilewskie

Phil Chamberlin, Reconstructing the Solar VUV Spectral Irradiance Over the Past 60 years.

1. The solar VUV irradiance (0.1-190 nm) is modeled as accurately as possible from 1947 to date (and is available)

2. Recent studies should be done with the most accurate data to define dynamics and processes, then extrapolations back can be more valuable

Tom Woods, How Low is Low? Putting Our Current Solar Cycle Minimum in Context with Secular Variations.

1. This recent solar cycle minimum in 2007-2009 is more extended and has lower activity (irradiance, solar wind, magnetic field) than the 1996 cycle minimum. Furthermore, this 2007-2009 minimum appears to be similar to those in the early 1900s (named the Gleissberg Minimum).
2. Most studies have not been completed or even started to relate how the Earth system has responded to this low minimum. One study on the thermosphere (Emmert et al., GRL, 2010) reports 28% less density at 400 km.