

# Solar Variability, Earth's Climate, and the Space Environment

Bozeman, Montana  
June 1-6, 2008



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*“One of the major challenges facing humanity is global climate change. In order to gauge the response of the terrestrial climate system to natural and anthropogenic forcings, the TR&T needs to deliver the understanding of how and to what degree variations in the solar radiative and particulate output contribute to changes in global and regional climate over a wide range of time scales”*

**– NASA Living With a Star Program’s TR&T Steering Committee Report  
(2006-2007)**

## Notes from the Organizers

Dear Participants,

Welcome to the International Workshop on "Solar Variability, Earth's Climate and the Space Environment". We are glad that you have decided to participate in this Workshop and we look forward to hosting you in Bozeman, Montana. We would like to bring to your attention a few important points concerning this workshop.

This abstract book and the conference materials package will serve as a comprehensive guide to both the scientific program on offer as well as to the community of Bozeman and surrounding areas.

Please go through the workshop program carefully. If you are scheduled to give a talk ("Invited" talks are marked as such), please contact your session chairman and the organizer in charge of audio-video set-up to make sure that the electronic file of your talk is uploaded (prior to the start of your session) in the conference computer (MS Windows-XP operating system) and works as intended. Speakers in the morning session should do this the previous day evening. Session Chairs are responsible for ensuring this. Attendees scheduled to make a poster presentation will have a poster space of 5x6 feet (if you are not in the main schedule you have been assigned to the poster session). Please ensure that your poster fits within these dimensions.

In the section on "Local Area Information" you will find maps, parking information and a guide to restaurants. You may also want to consult the "Visitors Guide" and handouts included in your conference materials for such information. In the section "Useful Phone Numbers" you will find information on whom to contact during any emergencies; we hope that you will not have to use these phone numbers!

Have you ever wondered how much plastic and paper is typically wasted in conferences – either in the form of cups or in the form of conference materials and their impact on the environment? We have tried to minimize the usage of these materials and have provided you with the option of having this book in a CD form. We are also placing an electronic file of this book in the workshop webpage hoping that you can download this electronic file and will therefore not even need a CD. We are also providing you with a small (metal) water bottle; it is our hope that you will carry this every day to the workshop and will abstain from using paper or plastic cups. We will also provide a bin where you can drop-off your plastic name-tag holders (at the end of the workshop) so that they can be recycled. Small steps towards a "green" workshop...

Finally, enjoy the workshop, have a good time while you are in Bozeman, and support the local community in any way you can. And oh yes, there are (driving) speed limits in Montana; there are also Wolves, Grizzlies, Cowboys and at least one Astronaut that we know of. Hopefully, you will get to meet some of them!

Cheers,

Dibyendu Nandi

On behalf of the Organizing Committees

# **1 Workshop Program**

# Solar Variability, Earth's Climate and the Space Environment

June 1–6, 2008, Montana State University, Bozeman, USA

*Note: Registration desk will be open and posters will be on display throughout the meeting*

## Sunday, June 1, 2008

### Evening [Strand Union Building (SUB) Ballroom A]

05:30–08:30 PM Opening Reception and Registration  
Sponsored by MSU and UMBC

## Monday, June 2, 2008

### Morning Session [Engineering and Physical Sciences (EPS) Building Room 103]

#### Opening Plenary Session (Chair: Dibyendu Nandi)

09:00–09:15 AM MSU Welcome  
University President Geoff Gamble  
09:15–09:30 AM Opening Remarks and Information  
Dibyendu Nandi (LOC) and W. Dean Pesnell (SOC)  
09:30–10:00 AM Solar Dynamics Observatory  
W. Dean Pesnell (Invited)  
10:00–10:25 AM COFFEE BREAK

#### Scientific Session 1.1: The Sun as a Star (Chair: Edward Guinan)

10:30–11:00 AM The Various Variations of Solar-like Stars  
Steven Saar (Invited)  
11:00–11:30 PM What does Helioseismology tell us about the Sun  
Jørgen Christensen-Dalsgaard (Invited)  
11:30–12:00 PM What Helioseismology can tell us about Changes in  
the Solar Interior, Rachel Howe (Invited)  
12:00–12:30 PM Solar Dynamo Models  
Matthias Rempel (Invited)  
12:30–12:45 PM Update to the Babcock–Leighton Solar Dynamo  
and Use for Activity Predictions  
Kenneth H. Schatten  
12:45–02:00 PM LUNCH BREAK

**Afternoon Session [SUB Ballrooms A and B]**

**Scientific Session 1.2: Solar Atmosphere and Magnetic Fields (Chair: Loren Acton)**

- 02:00–02:30 PM Dynamics of the Solar Atmosphere Revealed by Hinode  
Saku Tsuneta (Invited)
- 02:30–03:00 PM Magnetic Field Measurements  
Yang Liu (Invited)
- 03:00–03:30 PM Observations of the Sun's Corona  
Kathy Reeves (Invited)
- 03:30–04:00 PM The Sun's Magnetic Atmosphere  
Dana Longcope (Invited)
- 04:00–06:00 PM POSTER SESSION BEGINS AND COFFEE BREAK  
REGISTRATION CONTINUES

**Tuesday, June 3, 2008**

**Morning Session [SUB Ballrooms A and B]**

**Scientific Session 1.3: Solar Radiative Output Variations and Modeling (Chair: Gary Chapman)**

- 09:00–09:30 AM Solar Irradiance Variability Observed During  
Solar Cycle 23, Tom Woods (Invited)
- 09:30–10:00 AM Solar Surface Magnetic Field-based Irradiance  
Models, Sami Solanki (Invited)
- 10:00–10:30 AM Long-Term Variations in UV and EUV Solar Spectral  
Irradiance, Linton Floyd (Invited)
- 10:30–10:55 AM COFFEE BREAK AND POSTER SESSION
- 11:00–11:15 AM The Flare Irradiance Spectral Model and its  
Contributions to the Studies of the Ionosphere  
and Thermosphere, Phillip Chamberlin
- 11:15–11:30 AM Reconstruction of TSI from Broad Band Facular  
Contrast Measurements by the Solar Bolometric  
Imager, Pietro Bernasconi

**Scientific Session 2.0: The Earth's Atmosphere and Space Environment (Chair: Doug Rabin)**

- 11:30–12:00 PM Major Solar Energetic Particle Events of Solar  
Cycle 22 and 23: Intensities Above the Streaming  
Limit, David Lario (Invited)
- 12:00–02:00 PM LUNCH BREAK

**Afternoon Session [SUB Ballrooms A and B]**

- 02:00–02:15 PM Particle Precipitation Effects on the Southern Hemisphere Tropical/Subtropical Lower Stratosphere, Luis Eduardo Vieira
- 02:15–02:30 PM Solar Wind Control of Field–Aligned Current Dynamics, Yongli Wang

**Working Group I Meeting: Irradiance Variability, Modeling and Internal Processes  
(Convenor: Werner Schmutz)**

- 02:30–02:35 PM Overview of WG–I and Topics of Discussion  
Werner Schmutz
- 02:35–03:05 PM Physical Interpretation of Irradiance Variations  
Sabatino Sofia (Invited)
- 03:05–03:20 PM Can the Total Solar Irradiance be Reconstructed from Solar Proxies, Thierry Dudok de Wit
- 03:20–03:35 PM Can Flares Contribute to Total Solar Irradiance Variations, Matthieu Kretzschmar
- 03:35–03:50 PM Invisible Sunspots and Implications for Space Weather Monitoring of Solar Active Regions  
Silvia Dalla
- 03:50–04:05 PM TSI Correlated with Sunspot Area, Sunspot Number, and Group Sunspot Number at Different Temporal Scales using Wavelet Analysis, Peter Wintoft
- 04:05–04:30 PM Open Discussion (Including Poster Highlights)
- 04:30–06:00 PM POSTER SESSION AND COFFEE BREAK

**Evening [SUB Ballroom A]**

- 06:30–07:30 PM Public Lecture  
Global Climate Change: Is the Sun to blame?  
Sami K. Solanki
- 07:30–08:30 PM Public Reception  
Public events sponsored by the  
MSU Office of the Provost

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## **Wednesday, June 4, 2008**

### **Morning Session [SUB Ballrooms A and B]**

#### **Scientific Session 2.0: The Earth's Atmosphere and Space Environment (Continued...)**

- 09:00–09:30 AM An Overview of the Impact of Energetic Particle  
Precipitation on the Mesosphere and Stratosphere  
W. Dean Pesnell (for C. Jackman, Invited)
- 09:30–10:00 AM Influences of the 11-year Solar Cycle on the  
Stratosphere and the Importance of the QBO  
Karin Labitzke (Invited)
- 10:00–10:15 AM The Effect of Galactic Cosmic Rays on the Middle  
Atmosphere: A Study using the CMAM, Stella Melo
- 10:15–10:55 AM COFFEE BREAK AND POSTER SESSION

#### **Scientific Session 3.0: The Earth's Climate (Chair: Dean Pesnell)**

- 11:00–11:30 AM The Sun's Potential Role in Past Climate  
Variability and Change, Caspar Ammann (Invited)
- 11:30–12:00 PM Solar Influence on Climate in Observation and  
IPCC Models, Ka-Kit Tung (Invited)
- 12:00–12:30 PM Solar Variability and Climate Change  
Ulrich Cubasch (Invited)
- 12:30–12:45 PM Variability of Solar Irradiance from UV to NIR  
from GOME and SCHIAMACHY for use in GCMs  
Joseph Ambrose Pagarán
- 12:45–02:00 PM LUNCH BREAK

### **Afternoon Session [SUB Ballrooms A and B]**

#### **Working Group IV Meeting: Solar Influence on Climate (Convenors: Ulrich Cubasch and Caspar Ammann)**

- 02:00–04:00 PM Overview of WG-IV  
Poster Highlight and Discussions  
Ulrich Cubasch/Caspar Ammann
- 04:00–06:00 PM POSTER SESSION AND COFFEE BREAK

## Thursday, June 5, 2008

### **Morning Session [SUB Ballrooms A and B]**

#### **Working Group II Meeting: Progress in Space Weather Modeling and Forecasting (Convenors: Dana Longcope and David Webb)**

- 09:00–09:05 AM Overview of WG–II and Topics of Discussion  
Dana Longcope
- 09:05–09:30 AM Toward Data Assimilation Models of Active  
Regions, David J. Bercik (Invited)
- 09:30–09:55 AM Modeling and Forecasting the Solar Wind  
Dusan Odstrcil (Invited)
- 09:55–10:20 AM Data Assimilation Models for Space Weather  
R.W. Schunk (Invited)
- 10:20–10:50 AM Open Discussions  
D.W. Longcope (Moderator)
- 10:50–11:05 AM COFFEE BREAK

#### **Working Group III Meeting: Long–Term Solar Variability, Solar–Stellar Connection and Space Climate (Convenor: Dibyendu Nandi)**

- 11:10–11:15 AM Overview of WG–III and Topics of Discussion  
Dibyendu Nandi
- 11:15–11:35 AM The Faint Young Sun Paradox  
Piet Martens (Invited)
- 11:35–11:55 AM Effects of the Young Sun’s Strong XUV Radiation  
and Plasma Fluxes on the Young Earth  
Edward Guinan (Invited)
- 11:55–12:15 PM Long–Term Solar Activity Reconstruction:  
Grand Minima and Maxima  
Sami Solanki (Invited)
- 12:15–12:35 PM Solar Activity During Grand Minima: Open Flux  
Variation and State of the Heliosphere  
Duncan H. Mackay (Invited)
- 12:35–12:50 PM Transition of the Schwabe/Hale Solar Cycles  
Associated with Long–Term Variation of Solar  
Activity, Hiroko Miyahara
- 12:50–01:00 PM Open Discussions  
Dibyendu Nandi (Moderator)
- 01:00–01:45 PM LUNCH BREAK

**Free Afternoon [SUB Ballrooms A and B]**

01:45–05:00 PM Recreational Events  
Transport for events start and end at  
SUB Ballrooms

**Evening [Deer Park Chalet, Bridger Mountains]**

07:00–11:00 PM Workshop Banquet  
Sponsored by the MSU Offices of the President  
and the Vice-President for Research

Transport will be arranged from SUB Ballrooms, hotels, and dormitories to the banquet venue and back (pick-ups start at 05:30 PM). Note that attendees who have made their own hotel reservations will be picked up from the SUB.

**Friday, June 6, 2008**

**Morning Session [SUB Ballrooms A and B]**

**Ending Plenary Session (Chair: Loren Acton)**

09:00–09:30 AM NASA Earth Science Plans  
Jack Kaye (Invited)  
09:30–10:00 AM The SOLAR–C Mission  
Saku Tsuneta (Invited)  
10:00–10:30 AM The PICARD Mission  
Gerard Thuillier (Invited)  
10:30–10:55 AM COFFEE BREAK AND POSTER SESSION  
  
11:00–11:30 AM PREMOS/PICARD  
Werner Schmutz (Invited)  
11:30–12:00 PM Solar Orbiter  
Daniel Mueller (Invited)  
12:00–12:30 PM Workshop Summary  
Douglas Rabin (Invited)  
12:30–02:00 PM LUNCH BREAK

**Afternoon Session [SUB Ballrooms A and B]**

02:00–03:00 PM POSTER SESSION  
03:00–04:00 PM COFFEE BREAK, POSTER REMOVAL,  
LWS MEETING REPORT AND EDITORIAL DISCUSSIONS  
04:00 PM END OF WORKSHOP

## 2 Organizing Committees

### **Scientific Organizing Committee**

Judit Pap (Chair), Raimund Muscheler (Co-chair), Werner Schmutz (Co-chair), Susan Avery, Tom Bogdan, Joe Davila, Piet Martens, Kalevi Mursula, Dibyendi Nandi, Dean Pesnell, Doug Rabin, Jan Rybak, Kazunari Shibata, Drew Shindell and Gerard Thuillier

### **Local Organizing Committee**

Dibyendu Nandi (Chair), Ravindra Belur, Wendy Chou, Lewis Fox, Bill Hiscock, Maria Kazachenko, Toni Lee, Dana Longcope, Piet Martens, David McKenzie (EPO Lead), Andres Munoz, Jiong Qiu, Lucas Tarr, and Keiji Yoshimura

### **3 Scientific Abstracts**

# The Sun's Potential Role in Past Climate Variability and Change

Caspar M. Ammann<sup>1</sup>, Hee-Seok Oh<sup>2</sup>, Bo Li<sup>1</sup> and Douglas Nychka<sup>1</sup>

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We review how solar influence on the Earth's climate has been perceived over time and how this branch of climate research has made progress over the past decades. We show how important mile stones in the science have opened new questions and discussions and how the recent estimates of solar variations fit into the climate variability and climate change context. Improvements in the observational and proxy data have provided us with the necessary foundation in which we can look for temporal as well as spatial fingerprint candidates of solar influence on climate. The combination of better geophysical understanding of how external forcing affects the earth atmosphere with new tools that are better tailored to the signal detection problem in noisy climate data has led to the possibility to better disentangle the contributions of different forcing factors on climate. The goal is to establish a seamless framework where solar and other forcings are recognized with their corresponding climate impacts across different time scales and periods. Such a framework would allow for a more complete understanding of past climatic changes at regional scales and form a strong basis to develop future climate change predictions.

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## **Satellite Measurements of Ring Current During Three Solar Cycles**

Timo Asikainen, Kalevi Mursula and Ville Maliniemi

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Nearly all long-term studies of ring current have relied on the Dst index as a proxy of ring current energy content. The use of Dst or any ground based index, for that matter, inherently contains contributions from all other magnetospheric and ionospheric current systems and thus does not truly represent only the ring current intensity. We have compiled an extensive database of energetic particle measurements by the MEPED instrument onboard the low-altitude polar orbiting NOAA/POES satellites since 1978. These satellites yield nearly continuous measurements of energetic particle fluxes in the magnetosphere for three complete solar cycles. Here we present an initial analysis of this long-term particle dataset.

# Longitudinal distribution of Coronal Mass Ejections

Timo Asikainen, and Kalevi Mursula

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Up to now a considerable amount of evidence has accumulated to support the existence of persistent active or preferred longitudes in the Sun. These features have been observed, e.g., in sunspots, solar wind speed and HMF sector structure. In this work we analyze the longitudinal distribution of coronal mass ejections (CMEs) observed by the SOHO LASCO instrument during the solar cycle 23. We find evidence for active longitudes also in the CME data. We also reject the recent claim that the CME distribution depicts an annual variation, suggesting an uneven longitudinal distribution in a fixed (non-rotating) reference frame.

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## **Rotation of an Auxiliary Sunspot in AR 10486 and the October 28, 2003 Flare**

Ravindra Belur and Dana W. Longcope

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Active Region 10486 is one of the largest sunspot groups to have appeared in the declining phase of the solar cycle 23. Active region 10486 produced several large flares, the largest of which, X28 occurred on November 04, 2003 when the active region was at the limb. The second largest, X17 occurred when the active region was close to the disk center (October 28, 2003) and was accompanied by a halo coronal mass ejection. To understand the driver for this unusual activity, we use line-of-sight magnetograms from the Michelson Doppler Imager (MDI) instrument. The horizontal flow field in the active region is computed using the local correlation tracking technique. The result shows a rotation of the auxiliary sunspot. In this paper, we present the rotation rate of the auxiliary sunspot, the total spin helicity injection due to this rotation into the corona. The estimation of the total helicity due to the braiding and spinning motions of the regions will also be presented.

## **Toward Data Assimilation Models of Active Regions**

David J. Bercik, George H. Fisher, Brian T. Welsch and William P. Abbett

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The solar magnetic field is the principal driver of space weather. Coupled physics and empirically-based Sun-to-Earth models necessarily depend on measurements of the solar magnetic field, and an understanding of the physics of eruptive events. The sources of space weather events are understood to be magnetically driven events initiated in the solar corona, yet the only routinely available measurements of the magnetic field on the Sun are obtained at the photosphere. Therefore, to better predict the magnetic evolution of the solar atmosphere we must understand how best to include photospheric measurements into numerical models of the solar atmosphere. We briefly describe how magnetic field measurements are currently incorporated into magnetostatic models, then describe recent progress and remaining challenges associated with directly incorporating solar measurements into dynamic, physics-based numerical models. We also speculate on how data-assimilation techniques can be applied to solar problems.

## **Reconstruction of TSI from Broad Band Facular Contrast Measurements by the Solar Bolometric Imager**

Pietro, N. Bernasconi<sup>1</sup> and Peter, Foukal<sup>2</sup>

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The Solar Bolometric Imager (SBI) represents a totally new approach in finding the sources of the solar irradiance variation. The SBI detector is an array of 320x240 thermal IR elements whose spectral absorptance has been extended and flattened by a deposited layer of gold-black. The telescope is a 30-cm Dall-Kirkham with uncoated primary and secondary Pyrex mirrors. The combination of telescope and bolometric array provide an image of the Sun with a constant spectral response between 280 and 2600 nm, over a field of view of 960x720 arcsec with a pixel size of 3 arcsec. On September 1, 2003 SBI flew for the first time suspended from a balloon flying at 110,000 feet altitude. SBI produced the first broad band measurements of the center-to-limb variation of bolometric facular contrast. Variations in total solar irradiance (TSI) correlate well with changes in projected area of photospheric magnetic flux tubes associated with dark sunspots and bright faculae in active regions and network. This correlation does not, however, rule out possible TSI contributions from photospheric brightness inhomogeneities located outside flux tubes, and spatially correlated with them. Previous reconstructions of TSI report agreement with radiometry that seems to rule out significant “extra-flux tube” contributions. We show that these reconstructions are more sensitive to the facular contrasts used than has been generally recognized. The 2003 Measurements with the Solar Bolometric Imager provide the first reliable support for the relatively high, wide-band, disc-center contrasts required to produce 10% rms agreement. Longer-term bolometric imaging will be required to determine whether the small but systematic TSI residuals we see here are caused by remaining errors in spot and facular areas and contrasts, or by extra-flux tube brightness structures such as bright rings around sunspots, or “convective stirring” around active regions. We also present early results of the analysis of the bolometric images taken by SBI on the September 13, 2007 during its second balloon flight, when the Sun was at the minimum of its activity cycle.

## Some Key Issues in Modeling the Solar Surface Magnetic Field

Luca Bertello, Roger K. Ulrich, John E. Boyden, and L. Webster

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Photospheric magnetic field maps are the primary drivers of coronal and heliospheric models, and their calibration will ultimately test the diagnostic capabilities of these models. The determination of the topology and strength of the solar surface magnetic field is one of the most difficult tasks in the construction of these maps, but nonetheless a fundamental step to properly model the heliosphere. The solar physics group at UCLA has dedicated over the years an extensive effort to this task, in particular through the analysis of magnetograms obtained using the 24-channel system at the 150-foot solar tower telescope on Mount Wilson and MDI magnetic field observations. In an effort to improve our knowledge for the calibration of the future magnetic observations made by the HMI instrument aboard SDO, we have carried out a new series of observations aimed at establishing a more complete understanding of the scale factors relating different observing methodologies for determining the photospheric field strength. A set of five special magnetograms were obtained in 2007 using the system installed at the 150-foot solar tower telescope. The special spectrograph configuration used for these observations allowed us to compute the magnetic field from five different spectral sampling pairs of FeI 5233, in addition to the standard sampling of FeI 5250 used as a part of the Mount Wilson synoptic program of magnetic observations. The analysis of these measurements and the main results will be described in this report. In combination with the analysis of the magnetic field strength we have also investigated a technique to recover the radial component of the field from the observed line-of-sight magnetic field. A severe limitation for coronal and heliospheric models is the quality of polar data. Because the photospheric field is assumed to be nearly radial, the observed line-of-sight component of the magnetic field diminishes from equator to pole by a factor of about  $\cos(\text{center-to-limb-angle})$ , and the background noise level rises by the same factor. In order to mitigate this effect we have introduced in the Shrauner and Scherrer method, used to produce 360-degree magnetic charts of the solar surface, an additional parameter that takes into account for a tilt angle between the actual direction of the magnetic field and the radial direction. Some preliminary results will be discussed here.

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## **The Flare Irradiance Spectral Model (FISM) and its Contributions to Studies of the Ionosphere and Thermosphere**

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The Flare Irradiance Spectral Model (FISM) is an empirical model of the solar irradiance spectrum from 0.1 to 190 nm at 1 nm spectral resolution and on a 1-minute time cadence. The goal of FISM is to provide accurate solar spectral irradiances over the vacuum ultraviolet (VUV: 0-200 nm) range as input for ionospheric and thermospheric models. A brief summary of FISM is presented, followed by initial results from various models that use FISM as a driver to study the atmospheric response to solar flares.

## **On the Sources of TSI Variation**

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It has been claimed recently, that 50 percent or more of the variation in the TSI is caused by changes in the quiet sun. We will discuss the known sources of TSI variation with a view to putting limits on how much the quiet sun might contribute.

## **Investigation of the Halo (I)CME from August 25, 2001**

Lulia Chifu<sup>1</sup>, Adrian Oncica<sup>1</sup>, Marilena Mierla<sup>1,2</sup>, Oana Chiricuta<sup>1</sup>,  
Cristiana Dumitrache<sup>1</sup> and Guadalupe Munoz<sup>3</sup>

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<sup>3</sup>IGEOF-UNAM/ESFM-IPN, Mexico City, Mexico

In this work we analyze one of the events produced by the active region (AR) 9591. We focused on the source, dynamics and evolution of the halo CME from August 25, 2001. We also studied the consequences of this event in the interplanetary space. The halo CME left the Sun with a speed in excess of 1600 km/s which dropped to 1000 km/s at 30 R<sub>sun</sub>. Some 50 hours later it crossed at 1AU at a speed just below 600 km/s. We also tried to find traces of the event up to 1.7AU using Ulysses data around August 31. For the solar event we have used the data from Solar and Heliospheric Observatory (SOHO) - LASCO C2, C3, EIT, from Big Bear Solar Observatory (BBSO), Mauna Loa Observatory and Meudon Observatory. For the dynamics of the propagation up to 1AU data from near-Earth missions such as ACE, WIND, and SOHO were used. We used also corroborated data from CDAWeb and OMNI databases such as interplanetary magnetic fields, basic interplanetary plasma parameters (density, speed, and temperature), waves and selected ions charge states. Farther away to 1.7 AU, we used Ulysses data.

## What Does Helioseismology Tell us About the Sun

Jørgen Christensen-Dalsgaard

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Observed frequencies of solar oscillation provide accurate information about the properties of the solar interior. Observations over more than a decade from ground-based networks and from space have yielded extensive sets of frequencies, and other properties of the oscillations, and analyses of these data have led to detailed and reliable inferences about the structure and rotation as functions of position within the Sun. Here I briefly review the data and the techniques used to analyze them and discuss some aspects of the inferences on the average properties of the present Sun. Important issues concern the origin of the present solar internal rotation, and an apparently serious discrepancy between the sound speed and other properties in up-to-date solar models and in the helioseismic results.

## **Solar Variability and Climate Change**

Ulrich Cubasch, Thomas Spanghel, Semjon Schimanke, Anne Kubin, and  
Ulrike Langematz

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The role of solar variability in climate change is investigated using two global climate models with an explicitly resolved stratosphere. The first model (EGMAM) consists of a combination of the atmosphere model ECHAM4 with an extension to the middle atmosphere (T30/L39) and the ocean model HOPE-G. This model is used for long simulations, where the ocean plays an important role. For more elaborate, but shorter experiments, the new ECHAM5/MESSy model system (T42/L39) with prescribed climatological SSTs is employed. The extended FUBRad radiation code is included enabling the model to better represent solar cycle associated UV changes. Solar cycle induced changes in ozone are prescribed. To simulate the pre-industrial climate with the EGMAM model, the solar forcing, the forcing by volcanic aerosols and the greenhouse gas concentration are prescribed. For the future climate, ensemble simulations using the SRES scenario A2 have been carried out with the same model. Additionally, to investigate the solar effect in more detail, two equilibrium experiments are performed with the ECHAM5/MESSy model representing 11-year solar cycle maximum and minimum conditions, respectively. During the Maunder Minimum (1645-1715) and during the Dalton Minimum (1790-1830) the model simulates a significant global cooling. The cooling is particularly strong north of Iceland, and in the North-Atlantic between Newfoundland and the southern tip of Greenland. In these regions this temperature change is connected to an increase of sea ice. The NAO, however, is hardly changing during the pre-industrial period. The present day climate, however, shows a more positive NAO-index and stronger tropospheric westerlies in mid-latitudes when compared to the Maunder Minimum. In a future climate an increase in the frequency of stratospheric winter warmings can be seen. This perturbs the stratospheric polar vortex which in turn affects tropospheric variability, which is confirmed by a comparison with the simulations without explicit representation of the stratosphere. The inclusion of the stratosphere leads to a weaker increase of the tropospheric westerlies in mid-latitudes and a less pronounced shift of the NAO towards more positive values. The detailed analysis reveals that the 11-year solar signal is transferred downward from the upper to the lower stratosphere via dynamical processes involving a modulation of the polar night jet and the mean meridional circulation. This confirms the transfer mechanism proposed by Kodera and Kuroda (2002). An AO-like response pattern in January occurs which extends from the stratosphere to the troposphere leading to changes in temperature and circulation in the troposphere during northern winter.

# **Invisible Sunspots and Implications for Space Weather Monitoring of Solar Active Regions**

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The identification and cataloguing of solar active regions is of major importance to scientific investigations of transient solar activity, as well as to predicting Space Weather. Currently, the presence of a sunspot is key to a solar region being assigned an Active Region number by the Space Weather Prediction Centre. In this paper we present new results demonstrating that the visibility of small sunspots has a strong center-to-limb variation, far larger than would be expected from geometrical (projection) effects (Dalla et al, *Astron. Astrophys. Lett.*, in press (2008)). This results in a large number of young spots being invisible: 44% of new regions emerging in the West of the Sun go undetected. For sunspot regions that are detected, large differences exist between actual locations and times of flux emergence, and the apparent ones derived from sunspot data. The implications on the monitoring and tracking of solar active regions are discussed.

## **Creation of a Composite Solar Ultraviolet Spectral Irradiance Data Set from Satellite Measurements**

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Solar ultraviolet (UV) irradiance is deposited in the atmosphere at altitudes ranging from the lower stratosphere to the lower thermosphere. Understanding the spectral and temporal dependence of solar UV variations is thus critical to characterizing the long-term terrestrial energy input over a wide vertical region of the atmosphere. Regular spectral solar UV measurements from space began in late 1978 with the Nimbus-7 SBUV instrument, and have continued to the present using overlapping data sets from multiple instruments (SME, SBUV/2 on NOAA satellites, SUSIM and SOLSTICE on UARS, SIM and SOLSTICE on SORCE). However, wavelength-dependent absolute biases and drifts are observed when any two overlapping data sets are compared, making it difficult to assess multi-decadal irradiance variations. We have recently created a composite spectral irradiance data set covering the wavelength range 120-400 nm at 1 nm sampling for the period November 1978 - July 2005 as part of the NASA Living With a Star program. We will briefly describe the methods used to produce this data set, and present comparisons with the proxy model irradiance data set of Lean et al. (2005). The composite UV irradiance data set is available at the LASP Interactive Solar Irradiance Datacenter (LISIRD) web site, along with the individual data sets used in this work. We hope to extend our data set in the future using SORCE SOLSTICE and SIM irradiance data.

## Can the Total Solar Irradiance be Reconstructed from Solar Proxies?

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One of the key issues in the reconstruction of past values of the Total Solar Irradiance (TSI) is the determination of the empirical models by which the TSI can be inferred from proxies for solar activity. Before actually designing such a model, however, it is essential to know which proxies should be used. Surprisingly, this problem is rarely addressed in the literature. We address it by comparing the TSI to a dozen proxies for solar activity, using daily values since 1978. Our statistical analysis is based on information theoretic criteria, which, strictly speaking, quantify the amount of information on the TSI we can obtain from each proxy. Using a graphical representation, we show why the TSI cannot be properly reconstructed from any linear or nonlinear combination of proxies (whereas several proxies can be reconstructed from others). By comparing these quantities on different time-scales, we also reveal which physical processes contribute the most to the variability of the TSI. A major asset of this approach is its non-parametric nature, in the sense that conclusions can be drawn without actually knowing which model relates the TSI to other quantities.

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## Long-Term Variations in UV and EUV Solar Spectral Irradiance

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The solar ultraviolet (UV) and extreme UV (EUV) irradiance and their variation influence the structure and dynamics of Earth's atmosphere through various atomic and molecular processes. Variations in the EUV and Far UV irradiance directly affect the Earth's upper atmosphere observed as space weather. Variations in the solar UV also may affect terrestrial climate disproportionate to their relative intensity. Originating in the solar corona, transition region, chromosphere, and upper photosphere, the solar EUV and UV irradiance is a consequence of and thus informs us about various solar mechanisms. Since solar UV and EUV light is absorbed by the atmosphere, accurate intensity records exist only during the spaceflight era. Experimental observations of the solar UV and EUV are difficult, often requiring sophisticated measurement strategies. The resulting EUV and UV spectral irradiance time series exhibit persistent periodic variations associated with the solar rotation and activity cycle as well as other variations that are associated with the growth and decay of active regions. Models having empirical, proxy, or physics-based subcomponents can extend estimates of the solar UV to past or future periods when measurements are unavailable. Ongoing and planned experimental programs are reviewed in the context of operational and scientific requirements.

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## Exploring Sources of the High Speed Solar Wind with Slitless Spectroscopy

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Source points of the high speed solar wind are believed to be associated with outflows discovered in the Ne VIII 770Å line in SUMER data by Hassler and others. The 2nd flight of the Multi-Order Solar EUV Spectrograph (*MOSES*) rocket mission will apply a novel imaging spectroscopy technique to examining these potential source points and their dynamics using a very similar EUV spectral line, Ne VII 465Å. This technique will allow us to obtain cotemporal image data over a wide field of view (10'x20') in the Ne VII line with the doppler shift of the line at every pixel. With *TRACE*-like spatial resolution and cadence (45 sec), and line-shift to a resolution of 7 km s<sup>-1</sup> we will be able to observe the time-varying morphology of the sources, constrain models of energy release, and observe potential reconnection sites, explosive events, and possible signatures of Alfvén waves in the upper transition region.

## **Effects of the Young Sun's Strong XUV Radiation and Plasma Fluxes on the Young Earth**

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Multi-wavelength studies of solar analogs (G0-G5 V stars) with ages from 40 Myr to 9 Gyr are being carried out as part of the "Sun in Time" program for over 15 yrs. These studies infer that the young Sun was rotating over ten times faster than today and as a consequence, these young solar-type stars, and the young Sun, had vigorous magnetic dynamos and correspondingly strong coronal X-ray and chromospheric far-UV and UV emissions up to several hundred times stronger than seen for the present Sun. The chief science goals are (1) to study the solar magnetic dynamo (with rotation as the only variable) and (2) to determine the radiative and magnetic properties of the young Sun with the purpose of constructing spectral X-UV irradiances and plasma densities that are being used to study paleo-planetary atmospheres. This study indicates that the young Sun (age < 1 Gyr) was extremely active with large flares, strong winds, and high energy X-ray emissions up to 10,000 times stronger than the present Sun. The strong radiation and particle fluxes inferred for the young Sun have major implications and impacts on the photochemistry and photo-ionization of paleo-planetary atmospheres (in particular for the terrestrial planets) and also play important roles in the possible atmospheric erosion as well as the study of the suitability of the planets for life. Recent results of the effects of the young, active Sun's enhanced XUV emissions and wind fluxes on the early Earth (as well as on Venus and Mars) will be discussed. The importance of planetary magnetic fields in protecting young planets' atmospheres from the erosive effects of young Sun's strong XUV and plasma fluxes is also discussed. This research is supported by grants from NASA (XMM, Chandra, HST, and FUSE programs) as well as from the NSF/RUI program. We are very thankful for this support.

## **What Helioseismology Can Tell us About Changes in the Solar Interior**

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Helioseismology – particularly the continuous observations from the Michelson Doppler Imager aboard the SOHO spacecraft, and from the GONG network, since 1995 – enables us to probe the structure and dynamics of the solar interior and see the deep-seated changes during a solar cycle. In this review, I will discuss the variations in the dynamics of the convection zone, in particular the deep-penetrating pattern of migrating flows known as the torsional oscillation, and how they may relate to the solar dynamo. I will also discuss the possible, but less well-established, changes in the interior structure that have been reported in recent years, and the inherent difficulties in this type of measurement.

## **An Overview of the Impact of Energetic Particle Precipitation on the Mesosphere and Stratosphere**

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Energetic precipitating particles (EPPs) can cause significant constituent changes in the polar mesosphere and stratosphere (middle atmosphere) during certain periods. Both protons and electrons can influence the polar middle atmosphere through ionization and dissociation processes. EPPs can enhance HO<sub>x</sub> (H, OH, HO<sub>2</sub>) through the formation of positive ions followed by complex ion chemistry and NO<sub>x</sub> (N, NO, NO<sub>2</sub>) through the dissociation of molecular nitrogen.

The HO<sub>x</sub> increases can lead to ozone destruction in the mesosphere and upper stratosphere via several catalytic loss cycles. Such middle atmospheric HO<sub>x</sub>-caused ozone loss is rather short-lived due to the relatively short lifetime (hours) of the HO<sub>x</sub> constituents. The HO<sub>x</sub>-caused ozone depletion has been observed during several solar proton events (SPEs) in the past 40 years. HO<sub>x</sub> enhancements due to SPEs were confirmed by observations in the past solar cycle. A number of modeling studies have been undertaken over this time period that show predictions of enhanced HO<sub>x</sub> accompanied by decreased ozone due to energetic particles.

The NO<sub>x</sub> family has a longer lifetime than the HO<sub>x</sub> family and can also lead to catalytic ozone destruction. EPP-caused enhancements of the NO<sub>x</sub> family can affect ozone promptly, if produced in the stratosphere, or subsequently, if produced in the lower thermosphere or mesosphere and transported to the stratosphere. NO<sub>x</sub> enhancements due to auroral electrons, medium and high energy electrons, relativistic electron precipitation (REP) events, and SPEs have been measured and/or modeled for decades

This talk will attempt to provide an overview of several of the EPP-related important processes and their impact on the mesosphere and stratosphere. Much progress has been made in this field in the past several years.

## Periodicities Inferred from SOXS Mission in Soft and Hard X-ray Emission from the Solar Corona

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We have detected 1.24-year and 131-day periodicities in the time series of daily X-ray index (DXI) in 10-20, 20-30 and 30-56 keV energy band observed by “Solar X-ray Spectrometer (SOXS)” mission, which was launched onboard GSAT-2 Indian spacecraft on 08 May 2003. The SOXS employs Si and CZT semiconductor detectors to observe the full disk integrated Sun in 4-25 and 4-56 keV energy bands respectively. The time series of X-ray emission data obtained by both Si and CZT detectors for the period from 13 November 2003 to 29 February 2008, declining phase of solar cycle 23, was subjected to Fourier analysis to obtain the noise free power spectra. The prominent periods of 27 and 13.5 days related to 1800 oppositely directed active longitudes were visible in soft X-ray i.e. 4-10 keV as well as in hard X-ray i.e., 10-56 keV energy bands. We also detected 31-day periodicity as another prominent period in our time series whose amplitude increases with energy. The well known periods of solar flares and hot spots have been observed but clearly found that they are sensitive to soft and hard X-ray energy bands. The 1.24-year periodicity in high energy band suggests corona is connected with base of the convection envelope, which represents changes in the rotation of the Sun of 1.3-year. The 131-day periodicity reveals hard X-ray flare activity recurrence rate during decaying phase of solar cycle 23. We discuss our findings in context to surface manifestations of varying solar rotation and flare activity.

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## **Is Western U.S. Precipitation Regulated by the Solar Dynamo?**

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Quasi-biennial (QB) oscillations in the range of 2-3 years are well-documented but poorly understood features of solar magnetic and terrestrial surface climate variability. In particular, Western U.S. winter precipitation and North Pacific tropospheric pressure exhibit a strongly periodic QB signal, with effects evident from the late 19th century to the present winter of 2007-08. This signal is traced to the coherent oscillation of planetary waves in both polar regions at the same QB frequency. Similar patterns of QB activity are illustrated for the solar magnetic field, the interplanetary magnetic field (IMF), and tropospheric pressure near earth's magnetic poles. Evidence of a common QB signal suggests that the solar wind and IMF may regulate terrestrial planetary waves, though a physical linkage is not likely to operate through known mechanisms of solar wind-IMF influence on surface pressure. It is further shown that QB oscillations of the atmosphere and sun can be described as a series of Hale cycle harmonics.

## Loop-Top X-ray Source and Magnetic Reconnection in 2003 October 24 Flare Event

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We present a detailed analysis on the evolution of an M7.6 flare occurred near the south-east limb on October 24, 2003 utilizing a multi-wavelength data set. The GOES and RHESSI light curves reveal two phases of flare evolution. The emission during the first phase is seen in RHESSI measurements only at energies below 25 keV, while the second phase is evident in all the X-ray energy bands between 6-300 keV. The first phase is characterized by emission from a loop system and intense loop-top (LT) brightening is observed in RHESSI images below 25 keV as well as TRACE 195 Å images right at the flare onset. The LT source then shows an altitude decrease with X-ray emission at higher energies comes from the upper part of the loop-top. The LT source exhibits a very long duration of altitude decrease (about 15 minute) followed by a stationary position (about 6 minutes) which is rather unusual. A comparison of LT source motion in RHESSI and TRACE images during the altitude decrease is presented. Many observational features during the second phase of flare evolution are consistent with the typical two ribbon flare. TRACE 1600 Å and H-alpha images reveal two parallel flare ribbons with single hard X-ray source on each of them. As the flare evolves the X-ray loop system moves upward. The two ribbons are connected by very bright and high density loop systems visible in H-alpha which always lie below X-ray loops. The first phase seems to be mostly dominated by hot thermal emission from flaring loops with temperatures  $T \geq 25$  MK. The second phase is found to be dominantly non-thermal in nature, with distinct emission from hard X-ray foot points and the spectrum at high energies follows hard power laws. We note that the thermal emission does not increase any further in the second phase but temperature as well as emission measure reached their peaks already during the first phase. The results are interpreted in terms of reconnection models of solar flares.

## Statistical Comparison of Intense, Major and Minor Geomagnetic Storms During the Solar Cycle 23

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One hundred and sixty nine geomagnetic storms of Intense if ( $Dst < -100\text{nT}$ ), Major if ( $-50\text{nT} \geq Dst \geq -100\text{nT}$ ) and Minor if ( $-20\text{nT} \geq Dst \geq -50\text{nT}$ ) were statistically studied during the 9-year period of the solar cycle 23 from July 1996 to Jan 2005 and their possible interplanetary and solar causes were looked upon. A significant decline in the number of Intense and Minor GMSs was observed from 1998 to 1999; whereas, there was an increase in Major GMSs. However, during 1997-1998, the number of Intense and Minor GMSs decreased. It is observed that the accumulated effect of  $H\alpha$  and X-ray solar flares are better associated with GMSs than CMEs.  $H\alpha$  and X-ray solar flares occurring over the western limb of the solar disk cause larger disturbances in magnetosphere leading to occurrence of Intense GMSs; whereas, those solar flares which occur on the eastern limb of the solar disk lead to occurrence of Major and Minor GMSs.

## Modeling and Measuring the Flux and Helicity Ejected by the Two-Ribbon Flare on 2005-05-13

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In this work we study an eruptive flare event in order to quantitatively understand flux and helicity transfer through reconnection in the associated coronal flux rope formation. Quantitative observational studies of solar flare reconnection have been made by a number of research groups (Poletto and Kopp, 1986, Fletcher and Hudson 2001, Qiu and Yurchyshyn, 2005). However, their work does not allow one to predict, from observations, both the flux and twist that coronal reconnection contributes to interplanetary flux ropes. Our hypothesis is that the flux and helicity associated with eruptive solar flares is created through a sequence of magnetic reconnections. Longcope et al. (2007) introduced a topological method of studying flux rope formation in 3D. In our study we use MDI, SOHO and TRACE data. We apply two methods to derive the reconnection sequence:

1. The flaring sequence from the TRACE observations of ribbon brightening (Qiu et al, 2007)
2. The reconnection sequence from the topological model of the coronal field based on the Minimum Current Corona model (Longcope, 2001).

From the topological model we calculate the toroidal flux and total helicity of the flux rope. We study in detail the M8.0 flare in active region NOAA 10759, 05-13-2005, 16:13UT. The total magnetic flux of the active region is  $1.7 \cdot 10^{22}$  Mx. From the photospheric magnetogram evolution we determine that  $1.9 \cdot 10^{42}$   $Mx^2$  of magnetic helicity has been injected into the active region during the 40-hour build-up prior to the flare. From the domain flux evolution we show that reconnection in the model (2) must occur in a specific sequence which would produce a twisted flux rope containing significantly less flux and helicity than the whole active region. The reconnection sequence from the model (2) compares favorably with the one inferred from the observation sequence (1). However, the topological analysis might be sensitive to the beginning of the buildup time, so its choice will be discussed.

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## **Topics for a Space Climate Chapter in an Undergraduate Text Book on Space Weather**

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The Air Force Research laboratory has commissioned an undergraduate textbook on space weather to be used at the US Air Force (USAF) Academy and other educational forums. The Academy currently offers a junior/senior level course in Upper Atmosphere and Geospace Physics course to students with the following majors: astronautical engineers, space operations, meteorology, physics and basic science. The draft text is currently developed with chapters in four blocks dealing with the quiescent and active space environment, impacts and effects and observing and modeling space weather. The third block on impacts and effects is a natural place for a chapter on space climate. Potential topics include: Solar Dynamo and Polarity Cycles; The 27-day Rotation Cycle and its Harmonics; Cycles in the Coupled Interplanetary Medium and Geomagnetic Field; Cycles Attuned to Earth's Motion, Geomagnetic Field and Internal Modes; The differences between solar cycles and space weather cycles; Radiative Forcing Related to Space Weather and Space Environment; and Cosmic Ray Forcing Related to Space Weather and Space Environment. This poster will be an open discussion on additional or alternative topics.

## **Can Flares Contribute to the Total Solar Irradiance Variations?**

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We will first report on the discovery of (quasi) systematic flare signatures in the total solar irradiance (TSI) time series. We have analyzed 11 years of high temporal resolution TSI measurements made by the PMO and DIARAD sensors of the VIRGO instrument onboard SoHO, and we show that a solar flare results in a small but very probably systematic increase of the TSI. We estimate the spectral distribution of the radiated energy and we find evidence for an important contribution of the visible domain. Then we will discuss the new possibility that flares contribute significantly to the TSI variation over the solar cycle.

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## **Influences of the 11-year Sunspot Cycle on the Stratosphere- and the Importance of the QBO**

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Large effects of solar variability related to the 11-year sunspot cycle are seen in the stratosphere, but only if the data are grouped according to the phase of the QBO. New results based on an extended, 66-year long data set fully confirm earlier findings and suggest a significant effect of the SSC on the occurrence of the Major Midwinter Warmings (MMWs) over the Arctic as well as on the strength of the stratospheric polar vortex and on the mean meridional circulation. The stratosphere is least disturbed during the northern summer when the interannual variability is small. And if the different phases of the QBO are introduced, a large solar signal is found. It is shown that the QBO not only modulates the solar signal on the decadal scale, but that the QBO is itself modulated by the solar variability.

## Major Solar Energetic Particle Events of Solar Cycles 22 and 23: Intensities Above the Streaming Limit

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Large solar energetic particle (SEP) events constitute a serious radiation hazard to astronauts and spacecraft systems. It is essential to determine the highest particle intensities reached in SEP events, especially at the energies that pose serious risks to human health and spacecraft performance. It has been argued that the highest particle intensities measured during large SEP events occur in association with the passage of shocks driven by coronal mass ejections known as the Energetic Storm Particle (ESP) component. Furthermore, it has been argued that the intensities measured early in the SEP events (known as the prompt component) are bounded by a maximum-intensity plateau that results from wave-particle interactions that restrict the free streaming of particles (also called the “streaming limit”). We analyze proton intensities measured by the GOES spacecraft at the energy channels P5 (~39-82 MeV) and P7 (~110-500 MeV) during solar cycles 22 and 23 and examine whether the highest intensities were measured during the prompt or the ESP components of the SEP events. We find three (one) SEP events in which the highest proton intensities measured during the prompt component at the energy channels P5 (P7) exceeded by a factor of four or more the previously determined “streaming limit”. Arguments to explain intensities during the prompt components exceeding this limit invoke either interplanetary conditions that inhibit the amplification of waves resonating with the streaming particles, or the presence of interplanetary structures able to confine and/or mirror energetic particles. We analyze these possibilities for each one of these events.

## **Magnetic Field Measurements**

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In this talk, we will present magnetic field measurements made by instruments on the ground and onboard satellites, and discuss short and long term variation of magnetic field.

# The Sun's Magnetic Atmosphere

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The outer atmosphere of the Sun consists of the chromosphere and corona. The structure and dynamics of these layers are strongly influenced, even dominated, by magnetic field. Magnetic energy seems to be stored rather slowly and then released suddenly. This gives rise to the bursty activity and rapid variations such as flares and corona mass ejections. I will review the current state of current theoretical models of coronal magnetic field.

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## **Solar Activity During Grand Minima: Open Flux Variation and State of the Heliosphere**

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From studying the varying abundances of cosmogenic isotopes it can be clearly seen that during the Maunder Minimum and other Grand Minima that magnetic activity cycles, continued although at a much lower rate. The talk will first consider our present day understanding of the variation in time of the Sun's Open Flux throughout the solar cycle from observations. Following this theoretical models of open flux will be discussed. Finally our present day knowledge will be used to describe possible scenarios for the variation of the Sun's large scale field and open flux during the Maunder Minima.

## **Modelling the Large Scale Corona: Formation of Sheared Magnetic Fields Leading to CMEs**

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A new technique for modelling the long term evolution of the global coronal field based directly on observed magnetic field configurations will be presented. The modelling will describe the long term build up of helicity and non-potential magnetic structures within the solar corona. Once constructed the model will be applied to a continuous six month period where it is compared to the formation of sheared magnetic field in filaments and the location of CMEs. The model presented will be used as a prediction method for CMEs.

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## Feature Classification of NSO/Kitt Peak Magnetograms

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We present new segmentations of daily NASA/NSO Spectromagnetograph (SPM) multidimensional magnetograms obtained at the NSO/Kitt Peak Vacuum Telescope from 1992-2003. Full-disk images are divided into areas of quiet Sun, network, active regions, and sunspots using a three-dimensional adaptation of a statistical image classification method developed by Turmon, Pap, and Mukhtar (ApJ 568:396-407, 2002). Probability distributions for each feature class are derived from a training set of images independently segmented using thresholds in magnetic flux and continuum intensity. We summarize our analysis procedures and compare segmentations derived from class-conditional probabilities computed with Gaussian mixture models and histogram interpolation. We also compare our segmentations with features identified by other methods and with solar irradiance variation.

## The Faint Young Sun Paradox

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While much (necessary) attention is going to the possible influence of the Sun on global climate variation in the last millennium, there is an even more astounding problem in the mismatch between solar luminosity and terrestrial climate in the first several billions of years of the Earth's existence, an issue known as the "Faint Young Sun Paradox". In brief the paradox is this. The geological and biological record support that the Earth's biosphere was considerably warmer than currently during the origin of life on Earth and for several billions of years thereafter. Yet, stellar evolution calculations support the Sun reaching the Zero Age Main Sequence at about 75% of its present luminosity, and linearly increasing in time up to its current level. Climate models predict a "Snowball Earth" for such a low solar constant, unless the greenhouse effect is much stronger than what it is now. However, there is no geological evidence for a hugely increased presence of greenhouse gasses in the early atmosphere. For possible solutions scientists have typically pointed fingers at other disciplines: Earth scientists suspect the Sun was much more luminous in the past than astronomers calculate. Solar scientists point to stronger geological activity on the early Earth, etc. As of now there is no theory, or even a credible scenario, to resolve this paradox. Solving this paradox will require a sustained truly interdisciplinary collaboration.

## **High Latitude Methane Sulphonic Acid Variability Associated with Solar Activity**

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The direct impact of solar activity on climate has been widely studied through the Total Solar Irradiance (TSI). Biological processes also impact climate and are deeply affected by the TSI. Some marine phytoplankton emissions to the atmosphere have been proposed to change the cloud albedo through cloud formation. In this work we use wavelet analysis to investigate the decadal relation between high latitude concentrations of Methane Sulphonic Acid (MSA), a product of seawater algae, and the TSI. Here we found that some of the MSA main periodicities coincide with the solar activity periods. The NH-MSA presents the most consistent coherence with TSI at 21.5yrs. For the SH-MSA it is at 10.7yrs, strongly present after 1930. At the time scales coincident with the 22yrs magnetic solar cycle, the NH-MSA and TSI follow each other, favouring a negative feedback on local climate. At the time scales of the 11yr solar cycle, the DMS-TSI anti-correlation has increased since the 1940s favouring a positive feedback on local climate. Therefore although the TSI could influence climate through the production of DMS that is reflected in the MSA abundance studied here, our results do not point to a consistent time and phase local relationship between MSA (DMS) and TSI, and therefore on climate along decadal time scales.

# SC and QBO Effects on Planetary Wave Amplitude from Chemistry-Climate Model Simulations and ERA-40

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The 11-year solar variability modulates the extratropical NH winter stratosphere through the interaction of solar heating, zonal winds, and upward propagating planetary waves. The enhanced incoming solar radiation during maximum conditions induces stronger stratospheric westerly winds during NH winter and hence a modification of the propagation conditions for planetary waves with consequences for the polar vortex and the Brewer-Dobson circulation. Previous observational and modeling studies have shown that the quasi-biennial oscillation (QBO) of equatorial zonal winds modulates the solar cycle effect on the stratosphere. Besides this influence of internal atmospheric variability, observational analyses of the stratospheric response to solar cycle forcing may also be contaminated by volcanic eruptions close to the maxima of the solar cycles 21 and 22. This is why the combination of observational analyses with more or less idealized numerical experiments seem pertinent to study this issue. Here, we examine the 11-year solar cycle influence on the planetary wavenumber 1 and 2 amplitudes and the possible modulation by the stratospheric equatorial winds. We present results from simulations with the HAMMONIA chemistry climate model that is particularly suited for studying the stratospheric solar cycle response as it internally produces a realistic QBO. Two multi-year time-slice runs for solar maximum and solar minimum conditions are analyzed with focus on the Northern Hemisphere during winter. The results are compared with those from ERA-40 reanalysis geopotential height data that are used as a substitute for observations. The modulation of the solar cycle effect by the QBO phase can be very clearly identified in the amplitude of wavenumber one throughout the winter from mid to high northern latitudes in ERA40 data. The change of amplitude between solar maximum and minimum reaches 200 gpm at about 1 hPa-65N. In the case of wavenumber one, the signal is less clear in the model than in the reanalysis data. In the case of wavenumber two it is insignificant in large regions in both model and reanalysis data. Besides the seasonal mean effects also differences between early and late winter are discussed.

## **Transition of the Schwabe/Hale Solar Cycles Associated with Long-term Variation of Solar Activity**

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We report on the transition of the Schwabe/Hale solar cycles during the last 1200 years, including the periods of the Maunder Minimum, the Spoerer Minimum and the Medieval Maximum, revealed by the measurements of radiocarbon content in tree-rings. We also report on the solar cycles during the Maunder-type grand solar minima occurred around the 4th century B.C. The previous studies using radiocarbon as solar index (e.g. Stuiver et al., 1980, 1998) had revealed that there are three types of grand solar minima, whose durations are 50, 70, 100-120 years respectively. Based on our newly obtained annual resolution radiocarbon record, we investigated the difference in the variations of solar activity during the Maunder-type ( $\sim 70$  year duration) and the Spoerer-type ( $\sim 100$ -120 year duration) grand minima in order to clarify the determining factors of the duration of grand solar minima. We find that the solar cycles are stretched by a few years during either type of grand solar minima, but the recovering process is different by the types of the grand minima. In this paper, we also report on the influence of such stretching of solar cycles on climate change.

## **20th Century EUV Solar Spectral Irradiance Modeling Based on Solar Cycle 23 Measurements**

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Our long term solar spectral irradiance model under development will include EUV spectral irradiance estimates. This model is based, in part, on Ca II K images collected from various observatories. For example, images from the Mt. Wilson Observatory supplemented with Greenwich Sunspot data are used in the model to produce irradiance estimates for the time period before space-based spectral irradiance observations. The Mt. Wilson Ca II K film archive extending back to 1915 has been recently digitized. We expect to generate estimated UV/EUV spectra back to the start of this data set. We discuss the development details of the EUV spectral component derived from various spectra and proxies measured during Solar Cycle 23. Measured and estimated spectra will be compared in time series of various spectral bands as well as in spectra for days with specific solar surface configurations. This work is supported by the NASA LWS program.

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## Solar Orbiter

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The Solar Orbiter Mission will study the Sun in greater detail than ever before due to the close proximity of the spacecraft as it orbits the Sun. At its closest point, Solar Orbiter will be about 0.22 AU from the Sun, closer than any other satellite to date. In addition to providing high-resolution images of the solar surface, perihelion passes at these distances occur in near co-rotation with the Sun, allowing the instruments to track features on the surface for several days. The mission profile also includes a high-latitude phase that will allow observations from up to 35 degrees above the solar equator. Multiple Venus gravity assist manoeuvres will be employed to increase the inclination of the orbital plane. The combination of near-Sun, quasi-heliosynchronous and high-latitude observations by remote-sensing and in-situ instruments makes Solar Orbiter a unique platform for the study of the links between the Sun and the inner heliosphere. In this paper, we will review the mission goals and the corresponding mission requirements, together with the technical challenges, and give an update on recent activities.

## **Recent Results from Solar Dynamo Modeling in the Context of the Stars as Suns Project**

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Solar variability controls our space environment and is also believed to play a role in shaping the global climate. The variability of the Sun can be traced back to the presence and evolution of magnetic fields - which has its origin in a dynamo mechanism working in the solar interior. The “Stars as Suns” project aims to determine the long-term variability of Sun, through a combination of stellar magnetic activity observations of Sun-like stars and theoretical dynamo modeling. Here we present recent results from simulations using our recently developed 2.5D stellar kinematic dynamo code within the framework of this project.

## **Geomagnetic Activity and Magnetic Storms During the Last Hundred Years**

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Changes in the properties of the solar wind and the heliospheric magnetic field (HMF) lead to disturbances of the Earth's space environment that are collectively called geomagnetic activity. The largest disturbances are global magnetic storms. Continuous measures of geomagnetic activity exist since the mid-19th century, covering more than 160 years. The standard measure of magnetic storms, the Dst index now covers the last 75 years, with proxies extending for about 110 years. Several studies have recently noted of problems in the standard measures of geomagnetic activity and storminess. E.g., it is now known that the longest and most used long-term geomagnetic index, the aa index, is inhomogeneous and depicts an excessively large centennial increase. Errors in archival magnetic data have been found that lead to seriously flawed estimates of the centennial trend in some indices of geomagnetic activity. Moreover, the Dst index was found to include an excessive, seasonally varying non-storm component. These problems have led to the development of new indices of geomagnetic activity and magnetic storms. These indices are based on digitally available hourly values of the geomagnetic field, which allows for a detailed examination of their properties. Thus they are more straightforward and reliable than earlier indices. One group of new indices of geomagnetic activity, the Ah indices, follows the traditional definition of the 3-hourly K index method, yielding an interesting and reliable substitute for the aa index. Against some recent claims, all estimates prove that geomagnetic activity, and thereby solar activity has significantly increased during the last century. However, this increase is considerably slower than given by the aa index, although the exact amount of increase is still under some debate. Accordingly, the long-term change of the solar wind and HMF parameters and all related solar parameters must be re-evaluated. Here I will review the traditional and new indices of geomagnetic activity and magnetic storminess, and discuss their recent developments and their implications for the long-term change of the Sun.

# **A Comparative Study of Net Solar Forcing and Global Temperature Changes Since 1600 AD**

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The Total Solar Irradiance (TSI) is the primary external energy input into the Earth system. It is also hypothesized by some that Cosmic Ray flux on Earth – modulated by solar activity, may alter Earth’s available energy budget by seeding clouds (the latter reflects incident radiation). In this study, we reconstruct Total Solar Irradiance (TSI) and Cosmic Ray Flux variations using empirically determined fits to observed sunspot number, TSI and Cosmic Ray Flux relationships. Subsequently, based on some assumptions, we estimate the net solar radiative forcing (cumulatively calculated using both TSI and Cosmic Ray Flux variations) and compare it to global temperature reconstructions over the last four centuries. We discuss the possible influence of solar variability on global climate change over this period.

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## **Modeling and Forecasting the Solar Wind**

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Knowledge of the prevailing background solar wind structure is essential for predictions of recurrent geomagnetic storms as well as for an understanding of the context of CME propagation. We have developed an experimental web page predicting solar wind parameters at the inner heliosphere. We will describe displays showing the predicted solar wind parameters: (1) on the ecliptic, meridional, and radial slices passing through Earth; (2) as temporal profiles at planets and spacecraft; and (3) as synthetic white-light images as might be observed by STEREO Heliospheric imagers.

## **On the Nigerian Environmental and Climatic Observing Program (NECOP)**

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We discuss details of our new experiment similar to those set up in Delaware by the University of Delaware. NECOP is a network of many stations equipped with Campbell Automatic Weather Stations and connected by telephone modern and recently by wireless. The network is designed to measure simultaneously real time climatic variables. The information gathered enables us predict environmental hazards especially in costal and desert areas that are vulnerable to extreme climatic conditions. The working of the network will be presented. Other uses of this system other than prediction of hazards will be discussed. The analysis carried out so far with the data obtained from the network will also be presented, plans for future improvement of the network will be mentioned.

## **Solar Flares of Different Types and their Influence on Formation of Interplanetary Medium Disturbance**

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Reasons for statistical relation observed between duration of nonstationary processes on the Sun and power of disturbances relevant in the interplanetary medium are studied. Homogeneous data on soft X-ray radiation of more than 50000 flares make it possible to study their number distribution with duration for four ranges of event powers. Three event types are separated, namely, impulse flares of the total duration less than 30 minutes, typical (two-ribbon) flares of less than 1-2 hours in duration, and very long-term events including in phenomena in activity complexes and dynamical flares. These results are in good agreement with expected phenomena durations determined from the energy balance in the flare source of the soft X-ray radiation. In particular, free leaking of hot plasma generated takes place in impulse flares, while heating near a coronal - loop top is significant in two-ribbon flares and determines a whole process in prolonged flares. Comparison between data on soft and hard X-rays demonstrated rather powerful impulses are followed as a rule by formation of a coronal loop system. In an impulse phase of these typical flares, upward plasma flows appear near each footpoint with the increase of the total event duration resulting in CMEs and subsequent disturbance of the interplanetary medium. In the most prolonged flares, CMEs often give rise new flares formation, the ejection of substance from coronal levels continuing and increasing the CMEs and disturbances in the interplanetary space for a long time.

## Using Atmospheric $^7\text{Be}$ as a Tracer of the Solar/Geospace-Earth Relationship

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Beryllium-7 is a radionuclide ( $t_{1/2} = 53.3$  d) produced by spallation of the atmospheric nitrogen and oxygen by solar or galactic cosmic ray particles with energy above 10 MeV. Cosmic rays are charged particles that interact with magnetic fields, like Interplanetary Magnetic Field (IMF) and Geomagnetic Field (GM). Consequently,  $^7\text{Be}$  atmospheric concentration varies with the cosmic ray local flux, which depends on the GM variations and characteristics of the IMF, modulated mainly by the solar activity cycles. The higher atmospheric concentration of this cosmogenic radionuclide is found between 20 km above the surface, and decrease with the altitude. After its production in the lower stratosphere, the  $^7\text{Be}$  attaches predominantly to small aerosols (diameter 0.3  $\mu\text{m}$ ) and follows its transport and deposition process. Therefore, temporal variations of the atmospheric  $^7\text{Be}$  inform on the atmospheric transport process, stratosphere-troposphere coupling and cosmic ray spectral/flux variations, making it a useful tracer of the Geospace-Earth interactions, geomagnetic field conditions and atmosphere dynamics. Through continuous near-surface air sampling in the last 30 years (with trimestral resolution), around the Angra Nuclear Power Stations (Rio de Janeiro / Brazil), it was made an interesting  $^7\text{Be}$  database, mainly because the sampling area is into the South Atlantic Magnetic Anomaly (SAMA). We present an interpretation of this extensive  $^7\text{Be}$  database, which was kindly made available for this work, and its correlation with another available isotopic databases (Finland and Australia), showing the solar activity variation influence on the  $^7\text{Be}$  modulation and the role of the SAMA on these interaction.

## **Variability of Solar Irradiance from the UV to NIR from GOME and SCIAMACHY for use in GCMs**

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The Sun is the primary energy source that drives the Earth's climate system. Its radiative output is known to vary in time, for instance, with the 11-year solar cycle and 27-day solar rotation period. Variations in the solar spectral irradiance (SSI) affect the thermal structure and chemical composition of the Earth's atmosphere. Although the largest solar variations are observed in the UV spectral region, a large fraction of the total solar irradiance (TSI, solar constant) variation over a solar cycle comes from the visible and near IR spectral range. In order to understand how SSI variations cause a detectable change in climate, we need to quantify UV, visible, and near IR variation in the solar spectral irradiance to a high level of certainty both over the short-term solar rotation 27-day period and 11-year solar cycle. Using daily solar irradiance observations from SUSIM (1992-2005), GOME (1995-present), and SCIAMACHY (2002-present), we study solar variations over 27-day solar rotations from 120 nm to 1600 nm. The variability is modelled by parameterizing SSI in terms of faculae brightening (using the Mg II core-to-wing ratio proxy) and sunspot darkening (using the photospheric sunspot index). Since the variations in the visible and NIR are well below 1% and the instrument stability over an extended period is only on the order of a few percent, the 11-year solar cycle variations have to be estimated using the SSI model adjusted to the 27-day period observations. We compare our results with the semi-empirical model SATIRE. In terms of radiation bands that are relevant for applications in GCMs, we present 11-year solar cycle amplitudes in the Herzberg, Hartley, Huggins, and Chappuis ozone bands.

## Long-Term Irradiance Variations Based on the 30-year Long Observational Record

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Total solar and UV irradiances have been measured from space since late 1978, now covering three consecutive solar cycles. These measurements have demonstrated that both total and UV irradiances vary on time scales of months to years. The most prominent variation is related to the 11-year solar activity cycle, irradiance being higher at solar maximum. It has been assumed that the observed irradiance changes are directly related to solar magnetic activity. However, during the maximum of the weak cycle 23, when less and smaller active regions appeared on the Sun, both total and UV irradiances were as high as at the maxima of the two previous cycles. Furthermore, the magnetic activity was strong during the declining phase of cycle 23, and observations show that the current minimum of total irradiance may be lower than the previous ones. In this paper we compare the long term variations in total and UV irradiances as well as various activity indices like the Ca II K index, 10.7 cm radio flux, magnetic field strength and the sunspot number.

## **Modeling TSI Variations Using Automated Pattern Recognition Software on Mount Wilson Data**

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This poster presents the results of using the AutoClass software, a Bayesian finite mixture model based pattern recognition program developed by Cheeseman and Stutz (1996), on Mount Wilson Solar Observatory (MWO) intensity and magnetogram images to identify spatially resolved areas on the solar surface associated with TSI emissions. Using indices based on the resolved patterns identified by AutoClass from MWO images, and a linear regression fit of those indices to satellite observations of TSI from the Virgo instrument, we were able to model the Virgo observations from the MWO data with a correlation of better than 0.96 for the period 1996 to 2007. The association of the spatial surface regional patterns identified by AutoClass with the indices developed from them also allows construction of spatially resolved images of the Sun as it would be “seen” by TSI measuring instruments like Virgo if they were able to capture resolved images. This approach holds out the possibility of creating an on-going, accurate, independent estimate of TSI variations from ground based observations which could be used to compare, and identify the sources of disagreement among, TSI observations from the various satellite instruments and to fill in gaps in the satellite record. Further, the spatial resolution of these “images” should assist in identifying with greater accuracy the particular solar surface regions associated with TSI variations. Also, since the particular set of MWO data on which this analysis is based is available on a daily basis back to at least 1985, and on an intermittent basis before then, it may be possible to construct an independent estimate of TSI emission at several solar minima to ascertain if there has been any significant increase or decrease, a topic of significance to determining what part, if any, solar TSI variations play in global warming. (Dewitte, et al, 2004; Ulrich, et al, 2002) Cheeseman, P. & Stutz, J., 1996, in *Advances in Knowledge Discovery and Data Mining*, U.M. Fayyad, G. Piatetsky-Shapiro, P. Smyth, and R. Uthurusamny (Eds.). (AAAI Press), p.61. Dewitte, S, Crommelynck, D., Mekaoui, S & Joukoff, A., 2004, *Sol. Phys.*, 224, 209 Ulrich, R.K., Evans, S., Boyden, J.E., & Webster, W, 2002, *Ap. J. Supp.*, 139, 259.

## **Meridional Circulation Variations for the Last 250 years Inferred from a Low Order Dynamo Model**

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We present a possible reconstruction of the variations that the meridional circulation of the Sun might have undergone during the last 250 years. In order to do this, we reduce an alpha - omega dynamo to a low order system that describes the time evolution of one of the solar magnetic field components. Afterwards we used a method based in the analysis of phase space of the surface toroidal magnetic field to infer changes in the superficial meridional circulation. We use sunspot numbers to build a time series that approximately represents the magnetic field behavior. After reconstructing the time series' phase space we assume equilibrium solutions for each solar cycle and we fit them to our model. The resulting fit parameters are shown to depend on background quantities of the theoretical model, such as magnetic diffusivity, differential rotation, meridional circulation, etc. The methodology presented here allows to extract information about the meridional circulation average behavior, and possibly other parameters, from more than 250 years of sunspot number observations.

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## The Solar Dynamics Observatory

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The Solar Dynamics Observatory (SDO) is the first Space Weather Mission in NASA's Living With a Star Program. SDO's main goal is to understand, driving towards a predictive capability, those solar variations that influence life on Earth and humanity's technological systems. The past decade has seen an increasing emphasis on understanding the entire Sun, from the nuclear reactions at the core to the development and loss of magnetic loops in the corona. SDO's three science investigations (HMI, AIA, and EVE) will determine how the Sun's magnetic field is generated and structured, how this stored magnetic energy is released into the heliosphere and geospace as the solar wind, energetic particles, and variations in the solar irradiance. SDO will return full-disk Dopplergrams, full-disk vector magnetograms, full-disk images at nine E/UV wavelengths, and EUV spectral irradiances, all taken at a rapid cadence. This means you can "observe the database" to study events, but we can also move forward in producing quantitative models of what the Sun is doing today. SDO is scheduled to launch in 2008 on an Atlas V rocket from the Kennedy Space Center, Cape Canaveral, Florida. The satellite will fly in a 28 degree inclined geosynchronous orbit about the longitude of New Mexico, where a dedicated Ka-band ground station will receive the 150 Mbps data flow. How SDO data will transform the study of the Sun and its affect on Space Weather studies will be discussed.

## **How do Active Region Magnetic Fields Affect Solar Irradiance?**

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We explore the connection between active region evolution and changes in the solar radiation spectrum. We compare  $|B|$ , the full-disk average magnetic field strength from Kitt Peak, with the disk-integrated spectral irradiance at different wavelengths. An underlying relationship clearly exists, and we employ numerical methods to analyze the temporal nature of the relationship. Establishing an empirical relationship between changes in  $|B|$  and changes in the solar spectrum may provide useful constraints for physics-based models of solar variability.

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## **Analysis of Magnetic Reconnection Sequence**

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We present quantitative analysis to observationally determine the sequence of magnetic reconnection between magnetic cells defined by partitioning the observed photospheric magnetic field. The method is applied to an X2.0 two-ribbon flare, revealing that magnetic reconnection proceeds between individual magnetic cells in a sequential manner. We find two distinctive stages of magnetic reconnection (as also reported in previous studies, e.g. Moore et al. 2001), the first stage characterized by formation of skeletons of flare ribbons with reconnection primarily along the ribbons and parallel to the polarity inversion line (PIL), and the second stage characterized by large-scale expansion of flare ribbons perpendicular to the PIL. In both stages, the apparent expansion speed of the ribbon fronts is a fraction of the local Alfvén speed. The observationally determined reconnection sequence provides constraints to topological models of magnetic reconnection.

## Observations of the Sun's Corona

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The corona, the outer atmosphere of the Sun, is tenuous, hot and dynamic. In this talk, we will review observations of the corona, particularly results from the X-Ray Telescope on Hinode. This new telescope shows the hot plasma of the corona in spectacular detail, and it is revolutionizing our view of coronal activity. We examine observations pertinent to the coronal heating problem, the morphology and structure of active regions, and the dynamic energy release that occurs in solar flares and coronal mass ejections.

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## Solar Dynamo Models

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In this talk I give a general overview of solar dynamo models. Special emphasis will be put on the flux-transport dynamo, which has gained significant interest over the past decade, mainly due to the fact that this class of models can explain the majority of the observed cycle features with a minimum amount of tuning. After a brief summary of the main properties of flux transport dynamos I will review the basic assumptions underlying these models and discuss their validity in view of results from 3D local and global MHD simulations as well as non-kinematic mean field models that consider the feedback of the Lorentz force on meridional flow and differential rotation. Using a non-kinematic mean field model I will discuss the energetics of a solar flux-transport dynamo and possible implications for dynamos in faster rotating solar-like stars.

## **The Solar Activity Effect on the Earth Troposphere and Scenario for Climate Changes in the 20th Century**

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The main points of the model of the solar activity effect on the Earth climatic system are presented. The key concept of the model is heliogeophysical disturbance effect on the Earth climatic system parameters, which control energy flux, going from the Earth to the space, in high-latitude areas. The model is based on the physical mechanism of heliogeophysical factors? influence on climatic characteristics and atmospheric circulation in the high-latitude troposphere through the atmospheric electricity. In accordance with this mechanism, the atmospheric electricity parameters in the high latitudes depend on the solar activity; at the same time, they influence the altitude distribution of charged condensation nuclei in the troposphere, as well as the cloudiness formation and radiation balance. The mechanism is proved to operate more efficiently in the high latitudes resulting in additional cloudiness formation in areas with adequate vapour concentration. We present complex analysis results of response of temperature and tropospheric pressure fields to different heliogeophysical disturbances. Particularities and regularities are considered of long-term variation in temperature regime of the troposphere and ocean in 1950-2007. It is showed that a continuous increase of the Earth climatic system heat content has been observed from 1910 till now. The so-called “cooling” of 1945-1975 presents inherent natural fluctuations in the Earth climatic system. The “cooling” can be explained by changes of circulation in the atmosphere and ocean as well as heat exchange between the atmosphere and ocean. Under the model, we made analysis of regularities, which underlie variations of geomagnetic activity and troposphere thermobaric characteristics. These results and changes of the global circulation in the atmosphere and ocean allow the conclusion that the warming observed in the 20th century can be mostly explained by variations of the solar activity level. The surface temperature anomalies in 1940-1975 and 1976-1979 and the World Ocean heat content changes result from a response peculiarity of thermal and dynamic regimes of the World Ocean and atmosphere to changes of processes in the atmosphere, ocean and cryosphere. These changes are associated with the warming in polar areas in the early 20th century. The main determining factors of the process are changes in the Arctic Ocean’s frost mass and north rivers’ outflows, which regulate the North Atlantic salinity, thermohaline circulation characteristics and atmosphere-ocean energy exchange. Scenario for changes of physical processes in the Earth atmosphere, cryosphere and ocean is presented on the basis of the model of the solar activity effect on the troposphere circulation and thermobaric characteristics. Climatic changes in the 20th century depend on these changes. Necessity was shown to consider changes in

the atmosphere and ocean circulation (including El Nio-La Nia), cryosphere, thermohaline circulation and volcanic effects to determine quantitative contribution of the solar activity and anthropogenic factors to fluctuations of the global surface temperature, heat content of the atmosphere and ocean.

## The Various Variations of Solar-like Stars

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I review the variability of sun-like stars, and how the measured variability changes as a function of stellar properties (e.g., mass, rotation, age), of what is being observed (e.g., photosphere, chromosphere, corona), and of the timescale involved. I revisit the question of Maunder-like magnetic minima among stars, exploring how common or rare the phenomenon might be, and what it might look like. I give a sketch of solar variability properties at various points in its evolution.

## **A New Research and Forecast Tool for the Solar Magnetic Cycle**

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Previous work by Saba, Slater, and Strong (2005, 2008) showed that Solar Cycle 23 erupted with a sudden, global outburst of magnetic and coronal activity in August 1997. This rapid cycle “onset” is defined - not by the appearance of the first high-latitude, reverse-polarity sunspot region - but, rather, by a rapid blossoming of the new cycle (as seen in active region size, longevity, distribution, and flare productivity) accompanying a sudden and sustained increase in soft X-ray emission and strong-field magnetic flux. Quick-look analysis suggests that a rapid onset may be a common feature of solar cycles and that a series of such activity bursts throughout a cycle may help define the size and timing of the cycle. Further, there seem to be reproducible spatial/temporal patterns in the surface magnetic flux that show promise for predicting episodes of increased solar activity levels a year or more in advance. For example, comparing the strong-field magnetic flux in mid-latitudes and in the equatorial region yields an activity index (the “B-ratio”) with a dynamic range of over 1000; this sensitive index defines the rapid cycle onset precisely and promptly, apparently with a year’s warning. The B-ratio showed a very similar evolution throughout Cycles 21 and 22 and the rise phase of Cycle 23, increasing steadily for about a year before the rapid onset. However, the B-ratio has fallen far more slowly during the decay of Cycle 23, offering the intriguing possibility that we could have predicted the delayed onset of Cycle 24 as long as 3 years ago. The current B-ratio trend [through Carrington Rotation 2066 (Feb 2008)] suggests that the rapid onset of Cycle 24 will occur no earlier than January 2009. In addition to having apparent forecast potential, such patterns in the magnetic flux evolution over the solar cycle may offer new insights into the underlying source dynamo.

## Update to the Babcock-Leighton Solar Dynamo and Use for Activity Predictions

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We discuss a modern update to the Babcock-Leighton (BL) Solar Dynamo as well as its usage for making solar activity predictions. Two papers have been written concerning the update of the BL solar dynamo (see, paper I *Astrophys. J., Supp.*, 161, 1, 137-153, 2007, and paper II, submitted). This update considers a new origin for sunspots, namely that magnetic field from photospheric ephemeral regions (EPRs) cluster together into like-sign elements forming sunspots. This unusual behavior is physics-based, and results from an offshoot of one of Parker's theories. We describe the process and refer to it as superadiabatic percolation. We focus on improved cellular automata (CA) models that allow EPR fields to grow into sunspots, aligned along Babcock's subsurface toroidal field geometry, and then allow these fields to migrate into a large-scale solar dynamo. We discuss how field growth and migration are controlled by a Babcock-like sub-photospheric field and the superadiabatic gradient. Locations of high superadiabaticity allow ephemeral regions to coalesce into like-sign sunspots, whereas low superadiabaticity manifests itself by a reduced energy flux with the concomitant result that concentrated fields undergo normal percolation. In our model, normal percolation acts in a dispersive manner, so that spot fields weaken into large-scale field regions. As a further consequence, old active regions release any previous energy that had been blocked, when the fields were in their more active sunspot phase; these weakened fields thus resemble faculae and plage. Field birth, death and magnetic transport all play roles in the development of our large scale CA solar dynamo model. Our dynamo model suggests that fields from decaying bipolar magnetic regions (BMRs) move not solely through diffusion, but rather through subsurface magnetic forces, a novel change from the Babcock-Leighton diffusive models. We also mention how these views are consistent with our Solar Polar Field Precursor Prediction of a weak solar cycle 24.

## **PREMOS/PICARD**

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The radiometers on PREMOS/PICARD are calibrated in vacuum against a cryogenic radiometer at NPL. This should result in best possible transfer of the radiometric reference to space.

## Reconstructing the EUV Spectrum

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The variable solar irradiance is an important forcing of climate model as it is known that the climate reacts to a changing solar irradiance. As Rozanove et al.(2002) has shown, the  $\text{Ly}_\alpha$  irradiance is of particular importance to the chemical reaction of the upper atmosphere. We present a method to reconstruct the EUV based on a four component approach with filling factors quantifying the contributions from sunspots, plage and the network, and the remaining radiation from the quiet Sun. The synthetic spectra are computed with COSI, a non-LTE line formation code. This approach reproduces well the variabilities in the visible, and thus reproduces the variability of the Total Solar Irradiance, but it is not successful to reproduce the variability in the EUV. E.g. the variability of Lyman-Alpha is underestimated by a factor of two. One reason for the failure can be identified when inspecting Lyman-epsilon images of the Sun. There is an obvious increase of area of active regions from the photosphere up to the formation height of the Lyman lines. We evaluate the increase of the area by comparing Lyman-epsilon images from the SUMER instrument to the active area on MDI magnetogramms. Based on a representative value of the enlargement we modify the original approach by intruducing an enlargement factor of active areas as a function of formation height. Thus, the filling factors for the active regions become height dependent, and thus wavelength dependent. We present the new spectral reconstruction and evaluate it against of observed spectral evolution of the Sun.

## **Data Assimilation Models for Space Weather**

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Space weather can have detrimental effects on a variety of civilian and military systems and operations. It can affect over-the-horizon (OTH) radars, HF communications, surveying and navigation systems, surveillance, spacecraft charging, power grids, pipelines, and the FAA's Wide-Area Augmentation System (WAAS). In an effort to mitigate and/or forecast the adverse effects of space weather on these systems, we developed two physics-based data assimilation models of the ionosphere under a program called Global Assimilation of Ionospheric Measurements (GAIM). One of the data assimilation models is now in operational use at the Air Force Weather Agency (AFWA) in Omaha, Nebraska. This model is a Gauss-Markov Kalman Filter (GMKF) model, and it uses a physics-based model of the ionosphere and a Kalman filter as a basis for assimilating a diverse set of real-time (or near real-time) measurements. The physics-based model is the Ionosphere Forecast Model (IFM), which is global and covers the E-region, F-region, and topside ionosphere from 90 to 1400 km. It takes account of five ion species (NO<sup>+</sup>, O<sub>2</sub><sup>+</sup>, N<sub>2</sub><sup>+</sup>, O<sup>+</sup>, H<sup>+</sup>), but the main output of the model is a 3-dimensional electron density distribution at user specified times. The GMKF model is also running at the Naval Research Laboratory, Air Force Research Laboratory, Community Coordinated Modeling Center, and Battlefield Environments Institute. The second data assimilation model uses a physics-based ionosphere-plasmasphere-polar wind model and a Kalman filter as a basis for assimilating a diverse set of real-time (or near real-time) measurements. This Full Physics model, which is global and covers the altitude range of from 90 to 30,000 km, is more sophisticated than the Gauss-Markov model, and hence, should provide more reliable specifications in data poor regions and during severe weather disturbances. The Full Physics model is scheduled for operational use in 2010. Both of these GAIM models assimilate bottomside Ne profiles from a variable number of ionosondes, slant TEC from a variable number of ground GPS/TEC stations, in situ Ne from four DMSP satellites, line-of-sight UV emissions measured by satellites, and occultation data. Quality control algorithms for all of the data types are provided as an integral part of the GAIM models and these models take account of latent data (up to 3 hours). Recently, we have devoted a significant effort on developing forecasting schemes, and the difficulties encountered and our progress will be reviewed.

## The Effect of Galactic Cosmic Rays on the Middle Atmosphere: a Study Using the CMAM

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It is recognized that climate is affected by the presence of humans. The challenge is to understand and be able to model exactly how. One of the most critical aspects of the climate system, and also one of the least understood, is that it varies naturally on a large range of time scales. As a consequence, perturbations to climate caused by anthropogenic processes may be masked within the climate system, making their detection difficult. A variety of mechanisms have been proposed to explain the solar signal detected in datasets. Among them there is the forcing by penetration of galactic cosmic rays. While there are suggestions that ionization by the penetration of galactic cosmic rays at the lower atmosphere can affect the global climate, existing evidences have been so far based on empirical correlations with the nature of this connection remaining unclear. In fact, energetic cosmic rays initiate a nucleonic electromagnetic cascade in the atmosphere, affecting its physical-chemical properties, in particular the ion balance, being the dominant source of ionization of the troposphere. In this work we use the 3D cosmic ray induced ionization of the atmosphere calculated by Usoskin and Kovalstov (2006) covering the time from 1979 to 2006 as additional source of NO<sub>x</sub> and HO<sub>x</sub> in the chemistry-climate 3D model, the Canadian Middle Atmosphere Model, to investigate the influence of galactic cosmic rays on the composition and dynamics of the middle atmosphere. Our results show a relatively weak response in ozone and even weaker in the temperature field. However, when compared to other particle precipitation forcings, due to their persistence, galactic cosmic rays may have a larger long-term temperature effect than solar proton events.

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## Physical Interpretation of Irradiance Variations

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Structural changes of the solar interior produced by a variable (dynamo-type) magnetic field produce time-dependent variations of all global solar parameters, including the luminosity. Of course, a variation of the solar luminosity will produce variations of the total solar irradiance (TSI), which are superposed to those due to the surface magnetic features. We have developed a code that can model these processes, whose properties will be discussed. We will also discuss forthcoming observations that will uniquely identify the properties of the variability engine of the solar interior.

## **Solar Surface Magnetic Field-Based Irradiance Models**

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The magnetic field at the solar surface influences the Sun's total and spectral irradiance. This is in particular true for the fraction of the magnetic flux concentrated into strong, kG fields. Depending on the size of a flux concentration, i.e. on the amount of magnetic flux that it contains, it has a significantly different effect on the irradiance. The current state of our knowledge of the brightness contrast of magnetic flux concentrations and of our understanding of the underlying causes is briefly reviewed. Reconstructions of the Sun's total and spectral irradiance observations based on the surface magnetic flux are then discussed. Finally, future improvements in the data and modelling needed from a solar irradiance point of view are mentioned.

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## Reconstruction of Solar Magnetic Activity During the Holocene Based on Cosmogenic Radionuclides

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In the framework of the ETH Zurich poly-project “Variability of the Sun and Global Climate - Phase II” and the NCCR climate project a composite record of the force-field solar modulation function at 1AU during the Holocene has been reconstructed. The record is a compilation of different modulation reconstructions that are based on cosmogenic radionuclide data from ice cores and data from neutron monitors. It is used to reconstruct the past interplanetary magnetic field and the solar open magnetic flux. We show that the open flux has not vanished during the Maunder minimum, which implies that magnetic activity occurred on the Sun although no sunspots were observed. This has important implications for reconstructions of solar irradiance, which assume that irradiance variations are described by magnetic phenomena on the solar surface only.

## Solar Irradiance Derived from the Soft X-ray Images in Yohkoh Legacy Data Archive

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Yohkoh is a Japan/US/UK mission, which had provided X-ray images and spectra of the sun for more than ten years, since September, 1991 through December, 2001. The Yohkoh Legacy data Archive (YLA) is a project, intended to make available all usable scientific data and information materials from Yohkoh, in forms convenient for use by non-experts. Starting from 2002, significant effort has been made for improving the quality of the soft X-ray images, part of which need complicated procedures to correct the effect of problems with straylight and X-ray analysis filters and that of the aging of the satellite's attitude control system. The calibration database has now reached a mature state and is the best that can be achieved. We computed the solar X-ray irradiance from the soft X-ray images calibrated with most recent database in the YLA. Following the same method as described in Acton et al.(1999), the solar irradiance in 4 wavelength bands (0.2-0.8, 0.8-2, 2-3, and 0.2-3nm) were calculated in the unit of  $W/m^2$ . Comparison of our irradiance in the 0.2-0.8nm band with GOES/XRS soft X-ray flux (0.1-0.8nm) shows generally good correlation, but our values are systematically lower by 5-10% in logarithmic scale. However, the residuals significantly increases around solar minimum (late 1995 - early 1997), when the solar X-ray flux drops below the detective limit of the GOES/XRS sensor. This indicates that our result provides unique X-ray irradiance for this period, and can be used to obtain the corrected GOES time-averaged flux.

## The PICARD Mission

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The PICARD mission will measure the total and spectral solar irradiance, solar diameter, limb shape, solar asphericity, and helioseismic waves. These measurements are key inputs to validate solar models and to understand the origin of the solar activity. They will be carried out by two absolute radiometers, three sunphotometers, and an imaging telescope onboard a microsatellite built by the French Space Agency CNES, with launch foreseen for June 2009. The radiometers are similar to the ones onboard SOHO. The imaging telescope contains an angular reference allowing a permanent control of the instrument geometric scale, which is referred to angular stars distances by rotating the spacecraft. Optical distorsion and flat-field of the imaging telescope are regularly measured. The measurements carried out by the sunphotometers and the imaging telescope use the same wavelengths. Past and present solar diameter measurements on the ground revealing discrepancies among results with solar activity, to understand the role of the atmosphere, ground-based instruments will be also run during the mission allowing PICARD to extent its domain of interest to atmospheric physics by comparing ground and space simultaneously measured as well as the atmospheric turbulence by a dedicated instrument. The state of development of the instruments will be presented as well as the PICARD mission center, which will process data to generate preliminary results for scientific analysis. PICARD and the NASA Solar Dynamics Observatory will be in space at the same period for complementary and simultaneous measurements. Given the specific observations of each mission, a strong synergy exists between these two programs. PICARD is scheduled for launch in June 2009.

## **High and Low Latitude Activity of the Sun According Observation in Ca II-K Line in Last Century**

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We present analysis of synoptic full disk daily spectroheliograms taken in Ca II-K spectral line at Kodaikanal Observatory (1907-1999), Mount Wilson Observatory (1915-1985), and the National Solar Observatory at Sacramento Peak (1963-2002). All Photographic images were digitized and reduced in a systematic way. The data reduction included circularization of solar disk images and correction for scattered light and response function of photographic film. Using localized intensity threshold, we identified three types of chromospheric features: plage, network element, and ephemeral bright point; and we study coordinates, total area, and irradiance of these features. In this talk, we discuss relationship between sunspot activity, total area of chromospheric plages and their irradiance over a period of several solar cycles. We also have found the polar Ca II-K bright point cycles have priority development to the sunspot cycles on an average 5.5 years. The number of the Ca II-K bright points reaches the maximum in the minimum sunspot activity.

## **The formation of the permanent poloidal magnetic field in the radiative zone of the Sun**

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The number of indirect signs of the observation data of the solar activity analysis is the evidence of the presence of the Sun's quasi-constant poloidal magnetic field. This paper touches upon the hypothesis of the slowly varying poloidal magnetic field's formation. Relying on the data of the surface large-scale magnetic fields, we discovered that there is a difference between the amplitudes of the odd and even cycles both in the global magnetic field's solar cycles and in the sunspots' activity cycles as well. During the poloidal magnetic field's transfer from the upper layers of the solar atmosphere towards the bottom of the convective zone with meridional circulation there can be a diffused penetration of the magnetic field into the radiant zone and so the formation of the permanent solar poloidal magnetic field. Permanent solar magnetic field can be responsible for the difference in even-odd cycles within the 22nd Hale Cycle modulation and long-period modulation of the solar activity in constrained convection of the permanent magnetic field. Modeling of transport dynamo model's approximation of the formation of the permanent poloidal magnetic field was carried out, and its effect on activity cycles was established.

## The SOLAR-C Mission

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Solar physics community in Japan has so far developed 3 solar missions over past 25 years with strong NASA and UK participation. With the success of the Hinode (SOLAR-B) mission, SOLAR-C working group was officially approved by ISAS/JAXA to develop a mission plan in December 2007. Two plans are being considered: The Plan A mission performs out-of-ecliptic magnetic and helio-seismic observations to investigate the internal structure and dynamo mechanism of the Sun. The spacecraft maintains approximately 1AU distance from the Sun with orbit inclination upto 60 degree, so that the spacecraft observes two polar regions as well as equatorial regions in one year. The Plan B mission pursues high resolution observations that the Hinode initiated by enhancing spectroscopic and spectro-polarimetric capability and by extending wavelength coverage to UV. The plan B mission covers the entire solar atmosphere from photosphere to corona including chromosphere and transition layer with suite of telescopes with high spatial, temporal and spectral resolutions. We request the launch in mid 2010s. The working group is expected to propose a single mission plan in one year by ISAS/JAXA. Solar physics community and related-disciplines in Japan strongly desire and endorse the SOLAR-C mission to be realized in mid 2010s. The JAXA SOLAR-C working group invites US and European participation to the SOLAR-C program, following our remarkable history of collaboration.

## Dynamics of the solar atmosphere revealed with Hinode

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The Sun has strong magnetic fields, and emits intense X-rays from its outer atmosphere. Though observations with the Yohkoh satellite point to magnetic reconnection as a necessary ingredient for sporadic coronal heating on various scales from major flares to ubiquitous tiny bursts, the specific mechanisms of coronal and chromospheric heating remain essentially unknown. Recent rapid progress of the groundbased observations show that the solar magnetic fields consist of an ensemble of fine ( $\approx 0''.1 - 0''.2$ ) scale magnetic fields in addition to sunspots and pores. Detailed properties of solar magnetic fields are, however, still unknown due to limitations of spatial resolution and accuracy of magnetic field measurements.

The main objective of the Hinode is to use a systems approach to understand the generation, transport, and ultimate dissipation of solar magnetic fields with a complex of three high-resolution imaging telescopes. Hinode carries the X-ray Telescope (XRT: Golub et al., 2007; Kano et al., 2008), the EUV Imaging Spectrometer (EIS: Culhane et al., 2007), and the Solar Optical Telescope (SOT; Tsuneta et al 2008). The energy release and dissipation phase of the magnetic fields are observed with the XRT and EIS, while the SOT performs high-resolution photometric and magnetic observations of the magnetic flux emergence and their subsequent evolution in the photosphere and chromosphere.

Since its launch in September 2006, the Hinode, has continued its observation of the sun, sending back solar images of unprecedented clarity every day. Discoveries so far made include (1) ubiquitous transient horizontal magnetic fields, (2) detection of Alfvén waves, (3) large apparent turbulence near footpoint of coronal loops, (4) extremely high chromospheric activity with ubiquitous chromospheric jets and penumbral micro-jets, (5) magnetic amplification with supersonic downflow (convective collapse), (6) kG magnetic patches in polar regions, (7) identification of footpoint for slow solar wind etc. Overview on the initial results from Hinode is presented. Dynamic video pictures captured by the Hinode can be viewed on the website of the National Astronomical Observatory of Japan (NAOJ), [http://hinode.nao.ac.jp/index\\_e.shtml](http://hinode.nao.ac.jp/index_e.shtml).

## **Solar Influence on Climate in Observation and IPCC Models**

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We discuss the statistical robustness of the Earth's climate response to the 11-year solar cycle in five datasets. Since the periodic solar forcing has been measured by satellites, the recently obtained response then gives us a calibration of our climate's sensitivity to solar radiative forcing. Once calibrated, we can then estimate the long term climate change caused by the secular trend of the solar radiation since the Maunder Minimum. One remaining question is whether such a response was included in the IPCC AR4 GCMs. The answer is rather surprising.

## **Long-term solar activity reconstruction: grand minima and maxima**

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Using a reconstruction of sunspot numbers stretching over multiple millennia derived from <sup>14</sup>C data, we analyze the statistics of the occurrence of grand minima and maxima. The occurrence of grand minima/maxima is driven not by long-term cyclic variability, but by a stochastic/chaotic process. The waiting time distribution of the occurrence of grand minima/maxima deviates from an exponential distribution, implying that these events tend to cluster together with long event-free periods between the clusters. Two different types of grand minima are observed: short (30-90 years) minima of Maunder type and long (>110 years) minima of Spörer type, implying that a deterministic behaviour of the dynamo during a grand minimum defines its length. The duration of grand maxima follows an exponential distribution, suggesting that the duration of a grand maximum is determined by a random process.

## Variability of Solar Coronal Rotation Derived from Radio Observations of the Sun

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The rotation of Sun is very complex and that of solar corona is more so. The coronal rotation has been investigated using optical, X-ray and radio emissions. The radio measurements show a differential rotation of the corona as a function of altitude and long term temporal variation give evidence of 11 and 22 years periodicities. The first one could be related to solar activity and the later may be related to magnetic reversals of the Sun as in Hale effect. In this presentation some of these issues of solar radio astronomy will be addressed and compared with the measurements from other methods. The radio measurements of coronal rotation are quite close by optical measurements (special at lower latitude of 90 and 240) of the same during 1986 1991. Thereafter the two starts diverging, the radio values reach a minimum during 1998 and differ in excess of 2 days from the optical measurements even at low latitude. It may be noted the radio measurements are based on the disk integrated flux of the Sun, so these will be more dominated by equatorial rotation. Thus it is reasonable that optical measurements of low latitude are closer to radio measurements. The simultaneous radio flux investigations indicate that the sidereal rotation period at the highest frequency (2800 MHz), which originates from the lower corona around 6 10 <4> km is 24.1 days. The sidereal rotation period decreases with height to 23.7 days at the lower frequency (405 MHz), which originates at 13 10 <4> km. A 2% variation of the sidereal coronal rotation in this height range presents an interesting new complexity for the solar coronal rotation. The coronal rotation rate obtained by radio method is faster than those by optical method in the equatorial region.

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## **On the North-South Asymmetry of Solar Active Region Phenomena**

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We report here a study of various solar activity phenomena occurring in both north and south hemispheres of the Sun during solar cycles 8-23. In the study we have used sunspot data, flare index data, H-alpha flares data and solar active prominences data. Earlier Verma(1992) reported long-term cyclic period in N-S asymmetry and also predicted that the N-S asymmetry of solar activity phenomena during solar cycles 21, 22, 23 and 24 will be south dominated and the N-S asymmetry will shift to north hemisphere in solar cycle 25. The present study shows that the N-S asymmetry during solar cycles 22 and 23 are southern dominated as predicted by Verma 1992).

## Particle Precipitation Effects on the Southern Hemisphere Tropical/Subtropical Lower Stratosphere

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The effects of changes in the solar radiative emission on ozone levels in the stratosphere have been considered as a candidate to explain the link between solar activity and its effects on the climate. As ozone absorbs electromagnetic radiation, changes in ozone concentrations alter Earth's radiative balance by modifying both incoming solar radiation and outgoing radiation. In this way, ozone controls solar energy deposition in the stratosphere and its variations alter thermal structure of the stratosphere. These changes are assumed to propagate downward through a chain of feedbacks involving thermal and dynamical processes. The effects of high energy particle precipitation on mesospheric and stratospheric ozone have also been investigated. However, while the effects of high energy particle precipitation on ozone distribution in the auroral region has been investigated during the last decades, little is known about the role of the high energy particle precipitation on the stratospheric composition and thermal structure in the tropical/subtropical region. Here we show that the spatial distribution of the lower stratosphere temperature is affected by the presence of the southern hemisphere magnetic anomaly. We found that during the austral winter and spring, in the subtropical region (below 30° S), the reduction of the lower stratosphere temperature occurs systematically in the magnetic anomaly area. This result is consistent with the observations that in the southern hemisphere subtropical region the energy of precipitating particles is deposited lower in altitude in regions with weaker magnetic field intensity. A global coupled ocean-atmosphere (GISS ModelE) is used to investigate the effects of the asymmetry of the zonal ozone distribution in the southern hemisphere atmospheric circulation. Our preliminary results indicate that the structure of the tropical Pacific sea-surface temperature in response to the asymmetry of zonal ozone distribution resemble a La Nina-like pattern. Furthermore, these results indicate that the westward drift and expansion of the magnetic anomaly may be related to the observed changes in the southern hemisphere tropical Pacific coupled atmosphere/ocean circulation.

## **Solar Wind Control of Field-Aligned Current Dynamics**

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Field-aligned currents (FACs) are the currents flowing into and out of the ionosphere which connect to the magnetosphere. They provide an essential linkage between the solar wind - magnetosphere system and the ionosphere, and the understanding of these currents is important for global magnetosphere dynamics and space weather prediction. The three spacecraft ST-5 constellation provides an unprecedented opportunity to study in situ FAC dynamics in time scales (10 sec to 10 min) that can not be achieved previously with single spacecraft studies or large-spaced conjugate spacecraft studies. In this study, we use the magnetic field observations during the whole ST-5 mission to study the dependence of FAC current sheet motion and intensity on solar wind conditions. FAC peak current densities show very good correlations with some solar wind parameters, including IMF Bz, dynamic pressure, E<sub>y</sub>, and some IMF angles, but not with other parameters. Instant FAC speeds show generally much weaker dependence on solar wind conditions comparing to FAC peak current densities. This obvious uncorrelation between FAC peak current densities and speeds implies that FAC peak current densities are more consistently controlled by solar wind conditions and geomagnetic activities, while FAC speeds are more oscillatory, sometimes with higher speeds during quieter times and lower speeds during more turbulent times. Detailed examination of FAC current sheet speed during two major storms in the ST-5 mission will also be given to illustrate the temporal evolution of the FAC dynamics with geomagnetic storm.

## **Total Solar Irradiance Correlated with Sunspot Area, Sunspot Number, and Group Sunspot Number at Different Temporal Scales Using Wavelet Analysis**

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The total solar irradiance (TSI) time series is correlated against time series of sunspot number (Rz), group sunspot number (Rg), and sunspot area (As). Before the time series are correlated a wavelet transform is applied so that variability on different time scales can be studied. It is found that all time series are highly correlated with TSI on time scales around 11 years. Rg and TSI are uncorrelated at scales shorter than 3 years, while Rz-TSI and As-TSI are anticorrelated. The strongest anticorrelation (-0.83) is found between As and TSI. The physical interpretation is that Rg is a proxy for the TSI brightening component from faculae associated with active regions that evolves more slowly than sunspots. Rz, and more strongly As, contain both dimming and brightening components that dominate on different temporal scales. By dividing As into low frequency and high frequency components, with a cut-off at 1.3 years, we can model the dimming and brightening components separately. This model has a correlation of 0.88 between observed and reconstructed TSI using monthly data. The cut-off may be placed somewhere in the range 1.3 to 2.7 years because As has no contribution to TSI in this band. Rz may also be used instead of As, but as the dimming effect is weaker in Rz the result will be slightly poorer reaching a correlation of 0.84 on monthly data.

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## **Short Term (Months to Years) Prediction of Solar Activity Based on the Sunspot Number**

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We apply state space models and recurrent neural networks to analyse the predictability of the sunspot number times series. The time series has a monthly resolution but have been filtered using a wavelet transform to capture variability with time scales above 2.7 years. It is found that these models, given no other information than the sunspot number, are only capable of making predictions with a lead time of about 2 years. As we are close to solar minimum we also study the possibility of predicting the time of minimum. Again, it is shown that it is extremely difficult to accurately predict the time of minimum. We discuss these result in relation to the different rules for predicting sunspot maximum using sunspot cycle length and sunspot minimum, and their relation to overlapping cycles.

## **Solar Weather and Terrestrial Climate: Works in Progress**

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We report on two undergraduate research projects at Middlebury College, one involving energetics of coronal mass ejections and the other geographical patterns of decadal climate variability in U.S. climate. In the CME work, we explore energy buildup in a quadrupolar magnetic field, extending work on dipolar and bipolar fields done previously at Middlebury. There are two distinct classes of solutions, depending on whether magnetic footpoint shear occurs in both hemispheres or only one. Maximum magnetic energy is an impressive 2.47 times the potential-field energy. However, it proves far more difficult to compute the open-field energy in the quadrupole case, so we have not yet been able to determine how much of this energy is available to lift and accelerate a CME. In the climate work, we analyze U.S. Historical Climatology Network data on a state-by-state basis for periodicities. We find substantial variation at an 11-year periodicity. This is greatest in the upper Midwest, where the 11-year peak stands out at about 3 standard deviations. However, multiple regression against atmospheric carbon dioxide concentration, volcanic dust veil index, and sunspot numbers shows ambiguous indication of correlation with the solar cycle, so we cannot conclude that we are seeing solar-cycle effects on climate. The CME work reported here was supported in part by NASA grant NNG04GB91G to Middlebury College, and both were supported by the College's Benjamin F. Wissler Endowed Chair Fund.

## **Solar Irradiance Variability Observed During Solar Cycle 23**

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The total solar irradiance (TSI) and solar spectral irradiance (SSI) from 0.1 nm to 2400 nm have been measured daily by NASA's Solar Radiation and Climate Experiment (SORCE) and Solar Extreme ultraviolet Experiment (SEE) aboard the TIMED satellite. These irradiance observations over solar cycle 23 range from solar cycle maximum levels in early 2002 to minimum levels in late 2007. Additional observations of the TSI and the ultraviolet range between 119 nm to 420 nm provide a more complete understanding of the variations during this solar cycle. The dominant temporal variations are due to flares (minutes-hours), active region evolution and solar rotation (days-weeks), and solar cycle magnetic evolution (months-years). The variations in wavelength are dependent on where in the solar atmosphere the emissions arise. The photospheric emissions, which dominate in the near infrared, visible, and near ultraviolet ranges, vary by about 0.1% over the 11-year solar cycle and are characterized by dark sunspots and bright faculae. The emissions from the solar chromosphere and transition region are easily identified in the extreme ultraviolet and far ultraviolet ranges, and their solar cycle variations of 20% to 300% are associated with the evolution of bright plage and active network features on the Sun. Finally, coronal emissions, which dominate in the X-ray and the lower part of the extreme ultraviolet range, vary by factors of 5 to 1000 over the solar cycle. LASP's Interactive Solar Irradiance Datacenter: <http://lasp.colorado.edu/lisird/>

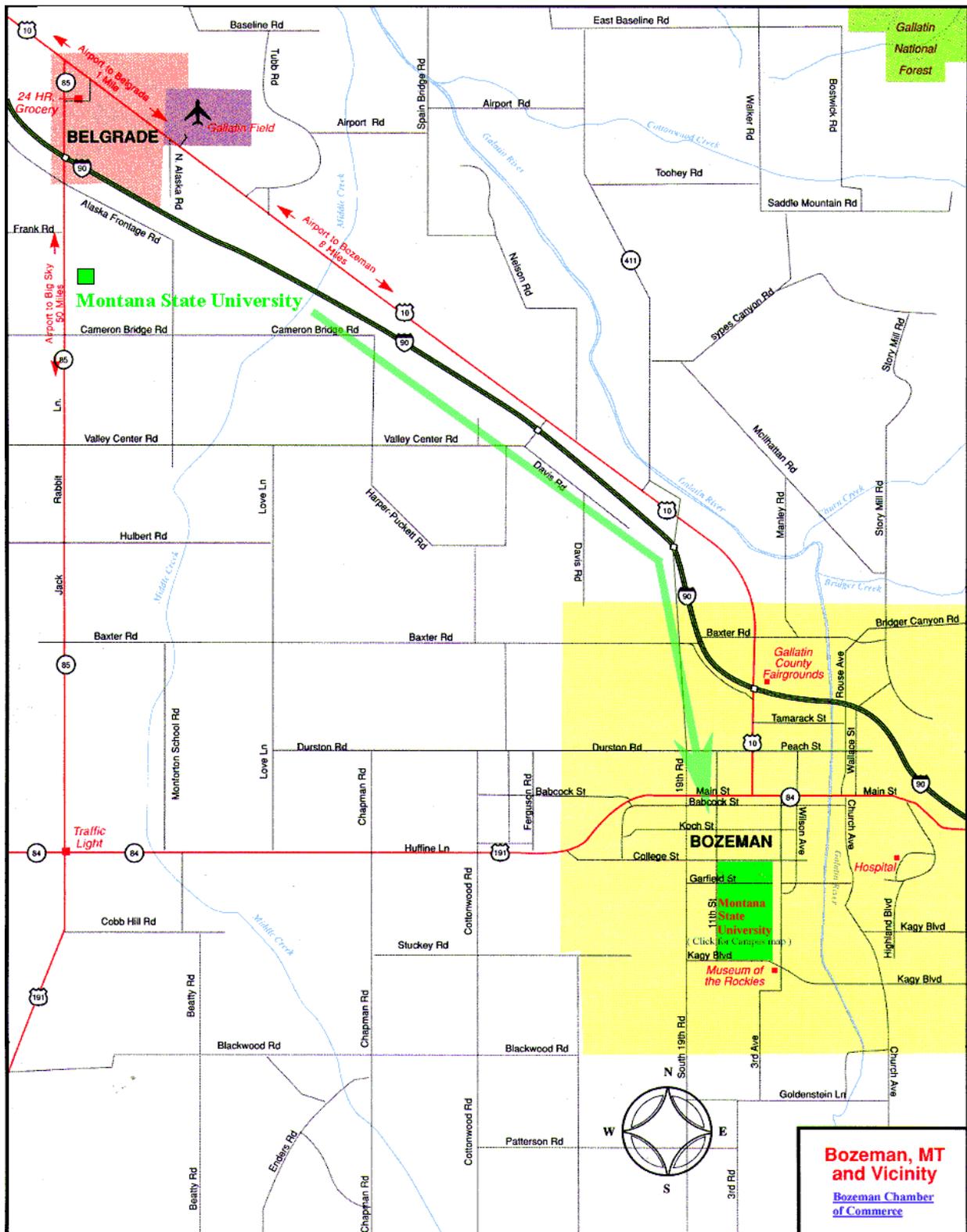
## **Coronal Bright Features Appearing Around Emerging Flux Regions**

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We study the characteristics of emerging flux regions (EFRs), where magnetic flux tubes appear to the upper solar atmosphere from interior photosphere. Since EFRs can cause various large activities on the Sun, it is important to study their characteristics not only from the point of view of Solar Physics, but also from that of Sun-Earth connection. One of the main themes of our study is to understand how the cool flux tubes are heated up to the coronal loops ( $> 1\text{MK}$ ) which can be seen in Soft X-ray (SXR) images. For this purpose, we first identified EFRs in sequential magnetic field maps taken by MDI/SoHO. After coalignment between the magnetograph and the SXR images from XRT/HINODE, we checked when, where and how the SXR features appeared (or did not appear) around the identified EFRs. We could categorize the EFRS into three groups based on the SXR structures around them: (1) no apparent structures, (2) loop brightening connecting between two opposite polarity in the EFR, and (3) brightening around the edge of the EFR. For the group (2), we found the delay time between the first appearance in magnetograph data and that in SXR is longer than 1 hour. The other characteristics will be also presented.

# 4 Local Area Information



# Visitor Parking Information

## Welcome to Montana State University-Bozeman!

We hope you enjoy your visit to the campus. We do ask that visitors park in our 134-space designated lot. It is marked on the reverse-side map with diagonal lines and located next to the Information Kiosk at the corner of Seventh and Grant Streets. The Kiosk attendant can answer many of your questions and direct you to your designation.

**Free for first half-hour**

**\$ 2.00 for 1/2 – 1 hour**

**\$ 0.50 for each additional hour**

**\$ 5.00 maximum per entry**

**\$1.00 – 6 p.m. to 11 p.m.**

## Other Options:

You may purchase a **\$2.50 daily hangtag** which allows you to seek parking in any of the lots designated with a dot pattern on the reverse-side campus map. Buy your hangtag at the Information Kiosk or from the University Police.

Handicapped parking spaces are designated in black and located in convenient spots throughout the campus.

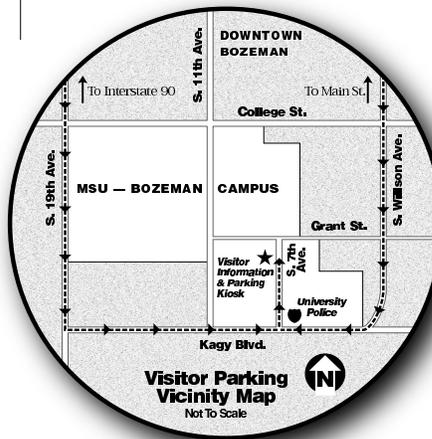
## Conference Participants/Vendors:

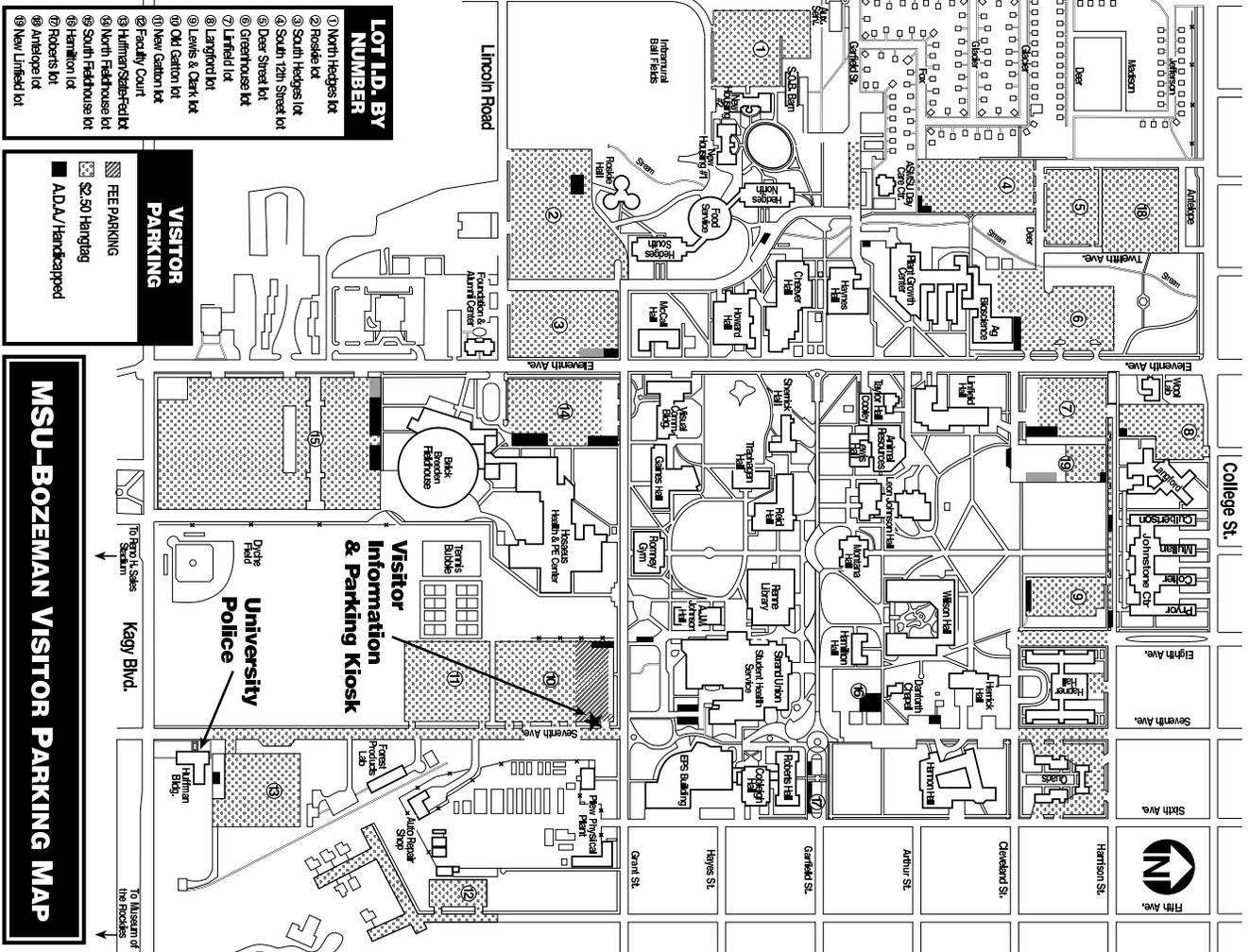
If you are attending a conference on campus, you probably received parking information in advance. If not, check in at the Information Kiosk for initial assistance. Vendors should abide by visitor parking regulations or request permission to use campus loading docks and delivery areas from University Police.

## Parking Hours

The Visitor (fee) Lot and Information Kiosk is open from **6 a.m. to 11 p.m.** for your convenience. If you wish to park elsewhere on campus, **visitor parking regulations apply from 6 a.m. to 6 p.m.**, Monday through Friday. You may park anywhere you wish during the evenings and on weekends, except in service drives, handicapped zones, 24-hour reserved areas, 30 minute zones, and posted no parking. Parking Rules and Regulations are enforced 24 hours a day, 7 days a week. We remind you that visitors who do not acquire a permit during parking hours will risk receiving a citation. Anyone receiving three citations or more will be towed. **If you have questions about visitor parking or special needs, please call 994-2121.**

**University Police is open 24 hours a day, 7 days a week.**





<b>Breakfast</b>	<b>find it</b>	<b>notes</b>
Nova Café	east Main Street	One of the best. Go early to avoid lines. Don't overlook the specials!
Cateye Café	Tracy, north of Main	
Main Street Overeasy	central Main Street	
Looie's Down Under	Main Street	The buffet is great
Cafe Zydeco		Café au lait & beignets on weekends
<b>Coffee &amp; Danish</b>		
Wheat Montana	North 19th & Oak	Fresh pastries
Leaf and Bean	central Main Street (also on N. 19th)	Best cappucino, good baked goods; wireless
Rocky Mountain Roasting Co.	central Mendenhall St; also 7th & Main; also east Main	Excellent coffee; best espresso milkshakes
Homepage Cafe	Main Street	Also sweetbreads, sandwiches; wireless
On the Rise	Main & 9th	Very fresh bakery, great scones (closed Sunday)
Bagelworks	Main & 7th	Bozeman's source for bagels
Rockford Coffee	Main & 7th	
<b>Lunch</b>		
Frank's	East Babcock @ Rouse	Best sandwiches, and soups
La Parilla	Babcock & 16th	Wraps; local favorite
Nova Café	east Main Street	Best breakfast, but good lunches too (closes at 2pm)
Emerson Grill	Grand & Olive, near downtown	Italian dishes; excellent if you're not in a hurry
Plonk	central Main Street	Wine bar with good food menu
Wheat Montana	North 19th & Oak	Soups & sandwiches
Dave's Sushi	Bozeman Ave, north of Main	Good sushi if you need a fix--tends to get crowded
Cafe Zydeco	Main & 15th	Cajun, casual
La Tinga	central Main Street	Delightful simple Mexican--exceptionally fresh
MacKenzie River Pizza Co.	Main Street	Outstanding sandwiches, salads; pizzas are a local favorite
Pickle Barrel	Main Street; location at College & 8th might be better	Great sub sandwiches

**Dinner**

			<b>phone</b>
Montana Ale Works	east Main Street	Microbrew pub with good food (often crowded)	587-7700
Gallatin River Lodge	next to Gallatin River, west edge of Bozeman	Excellent, if pricey (reservations advised)	
The Mint	Belgrade Main Street (just west of airport)	Good but a little pricey. The bar is recommended. (reservations advised)	388-1100
Sir Scott's Oasis	Manhattan—20-25 minute drive	Where half the locals go for steak (reservations advised)	284-6443
Land of Magic	Logan—25-30 minute drive	Where the other half of the locals go for steak (reservations advised)	284-3794
Emerson Grill	Grand & Olive, near downtown	Italian dishes; excellent if you're not in a hurry (reservations advised)	586-5245
Plonk	central Main Street	Wine bar with great food menu	
Boodles	central Main Street	Excellent, if a little pricey (reservations advised)	587-2901
Looie's Down Under	Main Street		522-8814
MacKenzie River Pizza Co.	Main Street	Their pizzas are a local favorite	
Cafe Zydeco	Main & 15th	Cajun, casual	
Cateye Cafe	Tracy, north of Main	May have dinner on weekends only?	

**Ice Cream** (Enjoy it year 'round!)

Moo Casa	central Main Street, shares space with La Tinga	local favorite
Bridger Ridge	Huffine (a.k.a. west Main)	eclectic variety, best gelato
Pickle Barrel	College & 8th, near MSU	local favorite
Rocky Mountain Roasting Co.	central Mendenhall St; also 7th & Main; also east Main	best espresso milkshakes

## 5 Useful Phone Numbers

MSU Police:		(406) 994-2121
Bozeman Police:	Non-Emergency	(406) 582-2000
Bozeman Police:	Emergency	911
Ask Us:	MSU Help Desk	(406) 994-4636
Dibyendu Nandi:	LOC Chair	(406) 556-8312

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