Science for Space Weather

24-29 January 2016, Goa, India

PROGRAM AND ABSTRACT BOOKLET

Sunday, January 24, 2016

9.30	12.30	**School and Workshop Registration**	

CCMC Space Weather School (Sponsors: CAU/CESSI/COSPAR/ILWS/SCOSTEP-VarSITI/PRL/ISRO)
Introduction to Space Weather: Concepts and Tools
Chair: Maria Kuznetsova (CCMC/NASA)

10:00	10:30	Setting the scene: overview of space weather phenomena, spatial domains and models	M. Kuznetsova
10.30	11.00	Solar magnetism and space weather: A theoretical primer	D. Nandi
11:00	11:30	Flares and CMEs and space weather consequences	A. Taktakishvili
11.30	12.00	Coffee/Tea Break	
12.00	12.30	Q&A, discussion	
12.30	1:00	Coronal holes and space weather consequences	M. Temmer
1.00	1.30	Solar Energetic Particles (SEPs) and impacts	Y. Zheng
1.45	15:00	Lunch Break	
15:00	15:30	Q&A, discussion	
15:30	16:00	Near-Earth particle environment relevant to space weather	I. Daglis
16:00	16:30	Space weather impact on ionosphere/thermosphere	S. Bruinsma
16:30	17:00	Q&A, discussion	
17:00	17:30	Coffee/Tea Break	
17:30	18:00	Space weather impacts on space assets	J. Minow
18:00	18:15	Q&A, discussion	
18:15	19:00	Overview of web-based resources for space weather research, analysis, and forecasting	Y. Zheng, M. Maddox, M.Kuznetsova
19:00	21:00	Opening Reception / Conference Registration / Interaction of Students and Scientists	

Monday, January 25, 2016

8:30	8:45	**Opening**	**Chair: Dibyendu Nandi and Bob Wimmer**
8:45	10:00	**Panel Discussion**	**Chair: Bob Wimmer**
		Nat Gopalswamy, President, SCOSTEP	
		Alexi Glover, Chairperson, COSPAR Space Weather Panel	
		S. Seetha, Space Science Program Officer, ISRO	
		Madhulika Guhathakurta, NASA Heliophysics Division	
10:00	10:30	Coffee/Tea Break	
10:30	12:45	**From Sun to Earth and Beyond: CME propagation in interplanetary space**	**Chair: Manuela Temmer**
10:30	10:55	Propagation of Coronal Mass Ejections in the Inner Heliosphere	P. K. Manoharan
10:55	11:10	Pruning of Ensemble CME modeling using Interplanetary Scintillation and Heliospheric Imager Observations	A. Taktakishvili
11:10	11:25	The Hvar Observatory CME-Effectiveness Forecast Tools	Mateja Dumbovic
11:25	11:40	Study of interacting CMEs using STEREO/HI observations	N. Srivastava
11:40	12:05	ICME properties at 1AU: from a generic shape to magnetic field budgets	Miho Janvier
12:05	12:20	Cause and consequences of a prolonged southward IMF-Bz and solar wind density pulses observed at 1 AU	Janardhan Padmanabhan
12:20	12:45	CME initiation and evolution of magnetized CMEs in the heliosphere	Stefaan Poedts
12:45	14:15	Lunch Break	
14:15	15:15	**Plenary Session on Aditya (see also posters on Aditya Mission)**	**Chair: Dibyendu Nandi**
14:15	15:15	The Indian Solar Mission Aditya-L1	S. Seetha
15:15	16:05	**Effects of CMEs on Earth and Other Planetary Bodies I**	**Chair: Hermann Opgenoorth**
15:15	15:40	Extreme CMEs in Time: Effects on Earth and Mars	Vladimir Airapetian
15:40	16:05	Influence of Space Weather on Planetary Environments	Anil Bhardwaj
16:05	16:30	Coffee/Tea Break	

16:30	17:55	**Effects of CMEs on Earth and Other Planetary Bodies II**	**Chair: Manuel Grande**
16:30	16:45	Forbush decrease precursors observed using GRAPES-3	Arun Babu K. P.
16:45	17:00	On the cause of electron acceleration and loss in the outer Van Allen belt	Ioannis Daglis
17:00	17:25	Space weather at Mars: MAVEN observations and models	S. Curry/H. Opgenoorth
17:25	17:40	Space Weather Measurements from the Surface of Mars with the RAD Instrument on the Mars Science Laboratory	Don Hassler
17:40	17:55	Impacts of solar events on the surface radiation on Mars	Jingnan Guo

Tuesday, January 26, 2016

8:30	18:45	**Down to Earth: Coupling Space Weather and Atmospheric Response**	**Chair: David Jackson**
8:30	8:55	The Drivers of Space Weather in the Thermosphere Ionosphere System	Tim Fuller-Rowell
8:55	9:20	Energetic particle impact on the atmosphere and the link to regional climate: Observational constraints and current understanding	Bernd Funke
9:20	9:45	Upper atmospheric dynamics: influence of solar radiation versus forcing from below	D. Pallamraju
9:45	10:00	Uncertainty Quantification of Ionosphere-Thermosphere Predictions	Ja Soon Shim

10:00	10:30	Coffee/Tea Break

10:30	12:15	**From Cradle to Grave: Particle Energization and Space Environmental Effects**	**Chair: Arnaud Masson**
10:30	10:55	New Results Concerning Particle Energization in Earth's Van Allen Radiation Belts	Daniel N. Baker
10:55	11:10	Dynamics of the radiation belt during the two largest geomagnetic storm of solar cycle 24	Yihua Zheng
11:10	11:35	Space weather effects on ionospheric radio propagation and mitigation methods.	N. Jackson-Booth
11:35	11:50	Turbulence and particle acceleration by inertial Alfvén waves in auroral ionosphere	Nitin Yadav
11:50	12:15	Geospace Exploration Project: ERG	Yoshizumi Miyoshi

12:15	13:30	Lunch Break

14:00	17:30	CCMC Integrated Space Weather Analysis (iSWA) system: a Web-based tool for space weather monitoring, analysis, event studies, and system science: demo and hands-on	M. Maddox, Y. Zheng

Wednesday, January 27, 2016

8:00	15:00	Excursion	
16:00	17:55	**Towards improved specification and nowcasting/forecasting of the particle radiation environment I**	**Chair: Yannis Daglis**
16:00	16:25	The use of event-specific models in DREAM3D	Gregory Cunningham
16:25	16:50	Operational Control of Radiation Conditions Provided by Space Monitoring Centre of Moscow State University	Vladimir Kalegaev
16:50	17:05	New Probabilistic Forecast Models of Solar Flares and CMEs	Kangjin Lee
17:05	17:30	Multivariate autoregressive (AR) prediction of MeV electron flux variation in Geostationary and Medium Earth orbits	Tsutomu Nagatsuma
17:30	17:55	Radiation Environment Specification Models: Engineering needs, Uses, Uncertainties and Reliability	Hugh Evans

17:55	18:30	Coffee/Tea Break

18:30	18:45	**Towards improved specification and nowcasting/forecasting of the particle radiation environment II**	**Chair: Tsutomu Nagatsuma**
18:30	18:45	SPRING network for realtime space weather prediction	Sanjay Gusain
18:45	20:15	**From Convective Zone to Heliosphere: CME precursors, initiation, and onsets I**	**Chair: Jörg Büchner**
18:45	19:10	Keynote Lecture: Evolution of solar magnetic flux tubes from the interior to the lower atmosphere of the Sun	Sami Solanki
19:10	19:25	Predicting solar magnetic activity and its implications for global dynamo models	Nishant Singh
19:25	19:50	Simulation of active region flux emergence, formation of delta-sunspots and the convective dynamo	Fang Fang
19:50	20:15	Eruptions driven by magnetic flux emergence	Klaus Galsgaard

20:30	23:00	Dinner

Thursday, January 28, 2016

8:30	9:00	**From Convective Zone to Heliosphere: CME precursors, initiation, and onsets II**	**Chair: Jörg Büchneri**
8:30	8:45	Observational diagnostics of the energy release in the confined X-class flares of October 2014	Astrid Veronig
8:45	9:00	CME propagation - where does aerodynamic drag take over	Prasad Subramanian
9:00	10:05	**Predicting Energetic Solar Phenomena and the Geospace response**	**Chair: Nat Gopalswamy**
9:00	9:15	Climatological response of Low latitude ionosphere to Space Weather events	N. Dashora
9:15	9:40	Forecasting the magnetic field configurations of CMEs	Volker Bothmer
9:40	10:05	MAG4: A Near-Real-Time Method of Forecasting Flares and CMEs from HMI Vector Magnetograms of Active Regions	David Falconer

10:05	10:30	Coffee/Tea Break	

10:30	11:35	**Predicting Energetic Solar Phenomena and the Geospace response**	**Chair: Lika Guhathakurta**
10:30	10:45	Solar wind Magnetosphere Ionosphere Link	Escoubet C. P.
10:45	11:10	MHD simulation of interplanetary propagation of multiple coronal mass ejections with internal magnetic flux rope (SUSANOO-CME)	Daikou Shiota
11:10	11:35	Observations of solar induced variability in the mesosphere and thermosphere over the past 14 years – and longer!	Martin Mlynczak
11:35	12:50	**Space Weather and the Solar Cycle**	**Chair: Dibyendu Nandi, Manuela Temmer**
11:35	12:00	Explorations of Solar Activity and the Heliophysical Environment	Lika Guhathakurta
12:00	12:25	Simulation and Prediction of Solar Cycles	Mausumi Dikpati
12:25	12:50	Models and Data Combined to Progress Towards a Better Understanding of the Magnetism of Solar-type Stars	Laurene Jouve
12:50	13:05	Solar Surface Convection and the Solar Cycle	Arnold Hanslmeier
13:05	13:15	Kinematics of Slow and Fast CMEs in Solar Cycle 23 and 24	Dipankar Banerjee

13:15	14:00	Lunch Break	

14:00	17:30	CCMC Runs-on-request system: demo & hands-on	A. Glocer, M. Kuznetsova, J-S.Shim

18:00	20:00	Poster Session (see separate sheet “posters”)	

20:00	22:30	Conference Dinner	

Friday, January 29, 2016

10:00	10:50	**Metrics to Assess Space Weather Predictions I**	**Chair: Masha Kuznetsova**
10:00	10:25	Adapting meteorological verification techniques for space weather at the UK Met Office	Suzy Bingham
10:25	10:50	Performance Verification of Solar-Flare Prediction Models: from Climatology to Skill and from Forecast Probabilities to Certainty	Manolis Georgoulis
10:50	11:15	Coffee/Tea Break	
11:15	12:00	**Metrics to Assess Space Weather Predictions II**	**Chair: David Jackson**
11:15	11:40	Community-wide validation of geospace model local K-index predictions to support model transition to operations	Alex Glocer
11:40	11:55	How would the thermosphere and ionosphere respond to an extreme space weather event and how would we validate a modeled response?	Tim Fuller-Rowell
11:55	12:15	Metrics for space weather: needs, challenges, initiatives, coordination, path forward (discussion)	Maria Kuznetsova
12:15	14:00	Lunch Break	
14:00	15:30	**Space Weather Effects on Technological and Biological Systems**	**Chair: Alexi Glover**
14:00	14:25	The semi-empirical thermosphere model DTM201	Sean Bruinsma
14:25	14:50	Spacecraft Charging and Auroral Boundary Predictions in Low Earth Orbit	Joseph I Minow
14:50	15:15	Radiation Exposure Analysis for Crewed Missions	Guenther Reitz
15:15	15:30	Modeling the Impact of Geomagnetic Disturbances on New York State Power Transmission System	Ouedraogo Djibrina
15:30	16:00	Coffee/Tea Break	
16:00	17:00	**Closing Session**	**Chair: Bob Wimmer**

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6	Cho, KyungSuk	Minor and Major geomanetic storms driven by similar CMEs	2
7	Daglis, Ioannis	Pre-processing methods for energetic particle measurements	3
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13	Gopalswamy, Nat	Sun-to-Earth Propagation and Geoeffectiveness of CMEs	8
14	Goyal, Ravinder	Temporal evolution of linear kinetic Alfvén waves in inhomogeneous plasmas and turbulence generation	8
15	Grande,Manuel	The Europlanet Horizon 2020 Planetary Space Weather Service	1
16	Ibrahim, M.Syed	Interplanetary parameters of ICME/IP shock associated with solar eruptive events	1
17	Johri Abhishek	Interplanetary propagation of CME in the inner Heliosphere	1
18	K. Suresh	Investigation of Coronal and Interplanetary Shocks and their associated Solar activities	1
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Session 1: From Sun to Earth and Beyond: CME propagation in interplanetary space
Chair: Manuela Temmer

Coronal mass ejections are the most dynamic phenomena in our solar system. They abruptly disrupt the continuous outflow of solar wind by expelling huge clouds of magnetized plasma into interplanetary space with velocities enabling to cross the Sun-Earth distance within a few days. Earth-directed CMEs may cause severe geomagnetic storms when their embedded magnetic fields and the shocks ahead compress and reconnect with the Earths magnetic field. The transit times and impacts in detail depend on the initial CME velocity, size, and mass, as well as on the conditions and coupling processes with the ambient solar wind flow in interplanetary space. This session is dedicated to derive more insight into the physical processes that CMEs encounter when propagating from Sun to Earth and beyond. Due to the wealth of observational data from multiple viewpoints, over a wide range of wavelengths, and over large distance ranges, as well as recent progress in simulations, we may adequately address this issue. We focus on studies covering observations as well as simulations from which parameters might be gained, essential to better understand the propagation behavior of CMEs in interplanetary space.

25 Jan
10:30

Propagation of Coronal Mass Ejections in the Inner Heliosphere

Periasamy K Manoharan

National Centre for Radio Astrophysics, Tata Institute of Fundamental Research

Energetic coronal mass ejections (CMEs) drive solar wind disturbances, accelerate particles to high energies, and contribute to space weather phenomena affecting the near-Earth environment, e.g., severe geomagnetic storms. In understanding the range of space weather effects of a CME, the knowledge of the radial evolution of the CME is important for the determining of its arrival at the near-Earth space and for inferring of its interaction with the disturbed/ambient solar wind in the course of its travel to 1 AU and further. The interplanetary scintillation (IPS) technique provides an essential tool to track CMEs and their associated disturbances in the Sun-Earth distance, and it has demonstrated the ability to make correct association between CMEs and their effects at the Earth's environment. The IPS measurements at 327 MHz obtained from the Ooty Radio Telescope (operated by the National Centre for Radio Astrophysics, Tata Institute of Fundamental Research, India) are capable of providing estimates of solar wind speed and density turbulence along directions of a large number of radio sources (1000 sources per day) in the heliospheric distance range of 20 250 solar radii. This talk will review results on the radial evolution of CMEs based on the large IPS database collected from the Ooty Radio Telescope. Additionally, the solar wind estimates along different cuts of the heliosphere allow the reconstruction of three-dimensional structures of propagating transients in the inner heliosphere. The results on three-dimensional evolution of size and speed of solar wind transients (e.g., propagating CMEs as well as co-rotating interaction regions (CIRs)), are reviewed and discussed on the possibility of forming a basic model to forecast the arrival/impact of solar and solar wind generated space weather effects at the Earth or else where.

Pruning of Ensemble CME modeling using Interplanetary Scintillation and Heliospheric Imager Observations

25 Jan
10:55

A. Taktakishvili

A. Taktakishvili (2), M. L. Mays (2), L. Rastaetter (3),
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(1) Rad. Astr. Ctr., Tata Inst. Fund. Res, India,
(2) NASA/GSFC-CAU, USA, (3) NASA/GSFC, USA

We use interplanetary scintillation (IPS) observations from the Ooty Radio Telescope facility in India and heliospheric imager data from STEREO to track coronal mass ejections (CME) in real-time and use the observations to improve ensemble forecasting of CME arrival times performed at the NASA/GSFC Space Weather Research Center (SWRC) team of the Community Coordinated Modeling Center (CCMC). At the CCMC/SWRC we have been using real-time modeling of CMEs with the WSA-ENLIL heliosphere model for a number of years. The input parameters for the model are obtained from coronagraph images of SOHO, STEREO-A and STEREO-B spacecraft. Uncertainty in CME initial parameters create uncertainties in specification of CME propagation through the heliosphere and of predicted impacts. Recently, ensemble modeling of CME propagation in the heliosphere has been developed at the CCMC: 48 copies of the WSA-ENLIL CME simulations with varied input parameters are run to obtain a range of possible CME propagation scenarios and arrival times. The ensemble modeling transforms uncertainties in the initial conditions to an estimate of errors in the forecast, a crucial metric of reliability that is lacking in forecasts based on single model runs. However, without meaningful constraints, ensemble modeling allows only modest gains in predictive accuracy. On the other hand IPS observations allow the observer to derive line-of-sight integrated solar wind densities in the inner heliosphere. With the availability of year-round IPS observations from over 1000 distant sources obtained by the Ooty Radio Telescope in India, it is possible to obtain images of heliospheric density at sufficient spatial and temporal resolution to track the propagation of CMEs in the heliosphere starting at AU. CME shock fronts can be compared to virtual images calculated from the model runs, thus enabling an unprecedented way of verifying model forecasts using current observations of the state of the heliosphere.

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25 Jan
11:10

The Hvar Observatory CME-Effectiveness Forecast Tools

Mateja Dumbovic

Vrsnak B., Calogovic J.
Hvar Observatory, Uni. Zagreb

We present two simple online forecast tools that estimate a possible geo-effective and GCR-effective impact of the observed CME based on the remote solar observations. The CME Geo-effectiveness Forecast Tool (CGeFT) estimates the expected disturbance storm time (Dst) index amplitude range, whereas the Forbush decrease Forecast Tool (FDFT) estimates the expected Forbush decrease (FD) amplitude range. Both tools are based on the empirical probabilistic models, developed using the statistically derived relations between remote solar observations and Dst amplitude (CGeFT), i.e. Forbush decrease amplitude (FDFT). The input parameters for both tools are CME speed and apparent width, the source position and soft X-ray class of the associated flare and estimated CME-CME interaction parameter (likeliness of interaction with another CME). The output is a probability distribution for a Dst/FD level, based on which the expected Dst/FD range is given. The evaluation of both tools is given and discussed, as well as the feasibility of the FDFT to improve the forecast of CGeFT. We acknowledge the support of Croatian Science Foundation under the project 6212 Solar and Stellar Variability and of European social fond under the project PoKRet.

Study of interacting CMEs using STEREO/HI observations

25 Jan
11:25

Nandita Srivastava

Udaipur Solar Observatory, PRL

We report on kinematics and consequences of several Coronal Mass Ejections (CMEs) observed during the period 2009-2013 that occurred in quick succession and interacted as they propagated in the inner heliosphere. The interaction of these CMes occurred in the heliosphere as recorded by STEREO/HI instruments. The stereoscopic observations were used to obtain the 3D kinematics of the interacting CMEs. Using the estimated kinematics and true masses of the CMEs, the nature of collision was also defined by estimating the coefficient of restitution for these interacting CMEs. We found that the nature of CME-CME collision can range between elastic to perfectly inelastic. A study of interaction signatures in particular by examining the in situ data close to 1 AU has also been carried out. We examined the role of the post-collision kinematics of interacting CMEs in deciding their arrival time and their impact on the Earth's magnetosphere.

25 Jan
11:40

ICME properties at 1AU: from a generic shape to magnetic field budgets

Miho Janvier

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(2) LESIA - Observatoire de Paris, Meudon, France
(3) Universidad de Buenos Aires, Buenos Aires, Argentina

Interplanetary Coronal Mass Ejections (ICMEs) are detected in situ by instruments measuring the magnetic field and plasma properties of the ambient solar wind. In particular, a subset of ICMEs, referred to as Magnetic Clouds (MCs), are well defined by the presence of a rotating magnetic field, indicative of a twisted magnetic structure. Shocks, on the other hand, are also well defined in the interplanetary medium as sharp discontinuities in the plasma and magnetic properties. Taking several catalogues of MCs and shocks from different authors, and covering wide time periods (up to 15 years), we have conducted an analysis of ICME properties, so as to assess the existence, and define the shape, of a generic ICME. To do so, we have proposed a new approach using statistical methods to investigate a data-constrained shape both for the flux rope axis in magnetic clouds and for the ICME shocks. These new statistical methods rely on the computation from the data of a parameter that defines the location of the interplanetary spacecraft along the detected structures. From the distribution of this parameter, we were able to 1) constrain an analytical shape that describes best these observed distributions, and 2) analyse the properties of ICMEs along the structures (e.g. along the magnetic cloud axis). These studies, tested on different catalogues, enable us to obtain budgets of magnetic field flux and helicity inside magnetic clouds over a solar cycle, as well as to obtain the generic shape of ICMEs at 1AU.

Cause and consequences of a prolonged southward IMF-Bz and solar wind density pulses observed at 1 AU. 25 Jan 12:05

Janardhan Padmanabhan

Susanta Kumar Bisoi, D. Chakrabarty
Physical Research Laboratory, India.

We report investigations of a prolonged (44 hours), weakly southward IMF-Bz condition during May 02–04, 1998, prior to the typical main phase of a geomagnetic storm. The magnetic field structures during the period of interest were found to be radial between 2.5 Rsun and 1 AU while the solar wind velocity was steady and showed no variations. In addition, multiple solar wind density enhancements were observed during this prolonged southward IMF-Bz phase. The density pulses showed a distinct one-to-one correspondence with ground magnetic responses during 0700–1700 UT on May 03, 1998 demonstrating that solar wind density enhancements can cause detectable global geomagnetic disturbances in the absence of significant variations in polarity of the IMF-Bz and the solar wind velocity. These observations, thus, provide a deeper insight into the possible causes and geomagnetic consequences of a prolonged period of weak southward IMF-Bz, under steady solar wind flow conditions. The magnetic configuration of the source region of the solar wind flows were also studied using potential field computations of the source surface magnetic fields and a solar wind trace-back technique.

25 Jan
12:20

CME initiation and evolution of magnetized CMEs in the heliosphere

Stefaan Poedts

Stefaan Poedts (1), Jens Pomoell (2), Christine Verbeke (3)
(1) KU Leuven, (2) CmPA (Belgium), (3) University of Helsinki (Finland)

We present the first results of the new physics-based forecasting-targeted inner heliosphere model Euhforia (European heliospheric forecasting information asset) that we are developing. Euhforia consists of a coronal model and a magnetohydrodynamic (MHD) heliosphere model with CMEs. The aim of the baseline coronal model is to produce realistic plasma conditions at the interface radius r = 0.1 AU between the two models thus providing the necessary input to the time-dependent, three-dimensional MHD heliosphere model. It uses GONG synoptic line-of-sight magnetograms as input for a potential (PFSS) field extrapolation of the low-coronal magnetic field coupled to a current sheet (CS) model of the extended coronal magnetic field. The plasma variables at the interface radius are determined by employing semi-empirical considerations based on the properties of the PFSS+CS field such as the flux tube expansion factor and distance to nearest coronal hole. The heliosphere model computes the time-dependent evolution of the MHD variables from the interface radius typically up to 2 AU. Coronal mass ejections (CMEs) are injected at the interface radius using a hydrodynamic cone-like model using parameters constrained from fits to coronal imaging observations. In order to account for the modification of the heliosphere due to the presence of earlier CMEs, the standard run scenario includes CMEs launched five days prior to the start of the forecast, while the duration of the forecast extends up to seven days. In addition to presenting results of the modeling, we will highlight our on-going efforts to advance beyond the baseline in the forecasting pipeline. In particular we discuss our path towards using magnetized CMEs, application of a time-dependent coronal model as well as modeling the transport of solar energetic particles (SEPs) in the heliosphere.

Session 2: Effects of CMEs on Earth and Other Planetary Bodies Chair: Hermann Opgenoorth and Manuel Grande

The arrival of CME's at Earth and other planets leads to a number of different processes of solar wind magnetosphere / exosphere coupling which may vary, depending on the velocity of the CME and the density and steepness of the associated shock-fronts. Also the polarity of the magnetic field structure enclosing the solar ejecta is of crucial importance at magnetised planets. A sudden compression of the magnetopause (and magnetosphere) leads to associated magnetic effects (like sudden storm commencements) and reconnection at either subsolar or polar magnetic boundaries (depending of the polarity of the CME magnetic field leads to fundamental changes in the efficiency of energy coupling, transport and conversion within the magnetosphere itself. This in turn results in dramatic changes in the magnetospheric current systems and acceleration of increased fluxes of magnetospheric particles to very high energies, which on Earth can be potentially harmful to man and man-made equipment both on ground and in space. At Earth and other magnetised planets with atmospheres also the loss-rate of atmospheric constituents is affected during such events. During extreme CME events some satellites of the outer planets can even find themselves in the unshielded solar wind or magneto-sheath (as e.g. Cassini has observed for Titan). Unmagnetised planets will experience extreme draping of magnetic fields around the exosphere with deep intrusions of solar wind magnetic fields into the upper atmosphere, with consequent drastic increases of atmospheric loss processes. Even comets have been seen to loose their entire plasma tail during CME encounters. SEP from the original solar flares and from

CME shockfronts can penetrate to the surface of the planets and, in particular on Mars, pose potential threats to future astronauts and settlers. The envelope of variability of planetary objects in our solar system (magnetized and unmagnetised with either thick, thin or no atmosphere, and even magnetospheres in other magnetospheres) allows us to draw conclusions on possible conditions in other similar solar systems where alien planetary environments might be exposed to more or less active stars For this session we invite papers on subjects illuminating any of the described processes of CME planetary interaction, in particular those of relevance for space weather effects on Earth and future human exploration of the solar system.

Extreme CMEs in Time: Effects on Earth and Mars

25 Jan
15:15

Vladimir Airapetian

Airapetian V., Glocer A., Dong C., Gronoff G., Kuznetsova M.
NASA/GSFC, UCAR/Princeton, SSAI/LaRC

Our Sun, G2V star, exhibits magnetically driven solar explosive events (SEE) in the form of flares, coronal mass ejections and energetic particle events. Extreme SEEs can significantly perturb Earth's magnetosphere, cause strong geomagnetic storms and initiate atmospheric loss. We use Kepler data from young solar-like stars to recover the frequency of extreme events in the Sun's past. We present three-dimensional magnetohydrodynamic models of interactions of extreme events with magnetospheres and atmospheres of early Earth and Mars. We also discuss the implications on the impact of these effects on evolving climate and habitability conditions of Earth and Mars.

Influence of Space Weather on Planetary Environments

25 Jan
15:40

Anil Bhardwaj

Space Physics Laboratory, Vikram Sarabhai Space Centre, Trivandrum 695022, INDIA

It is known that the solar electromagnetic radiation and solar wind interact with the planetary environment. The solar flare and coronal mass ejection events are now known to directly affect planetary bodies in several ways. In this talk I will discuss few examples of the direct correlation of the energetic events happening on the Sun and how they are traced or linked to processes happening on the planets. These would include impact of solar flares and CMEs on phenomena occurring in planetary upper atmospheres and ionospheres. I would then link it to interaction of solar wind with atmosphere-less bodies, focusing on the Moon and provide an overview of our current understanding on solar wind-Moon interaction.

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25 Jan
16:30

Forbush decrease precursors observed in GRAPES-3

Arun Babu K. P.

Tata Institute of Fundamental Research, Mumbai, India

Earth-directed Coronal mass ejections (CMEs) emanating from the Sun and the shock associated with it are the primary drivers of space weather disturbances. Forbush decrease precursors are advance warning of these upcoming magnetic field disturbances. GRAPES-3 tracking muon telescope which is a part of GRAPES-3 experiment located in Ooty, India, provides high statistics measurement of the muon flux with good temporal resolution. In this study we are using data from GRAPES-3 muon telescope and making use of its multidirectional observations to study the Forbush decrease precursors in greater detail. We have identified few Forbush decrease precursor signatures in muon flux well before the arrival of the actual shock. We use these Forbush decrease precursors to study the characteristics of magnetic field compression associated with the upcoming CME shock-sheath system.

On the cause of electron acceleration and loss in the outer Van Allen belt

25 Jan
16:45

Ioannis Daglis

Ioannis A. Daglis (1,2), Christos Katsavrias (1), W. Li (3), Stavros Dimitrakoudis (4), Constantinos Papadimitriou (1,2), Marina Georgiou (1) and Drew L. Turner (5)
(1)National and Kapodistrian University of Athens, Athens, Greece, (2)National Observatory of Athens, Athens, Greece, (3)University of California Los Angeles, Los Angeles, CA, United States (4)University of Alberta, Canada (5)The Aerospace Corporation, El Segundo, CA, United States
NASA/GSFC, UCAR/Princeton, SSAI/LaRC

We have investigated the response of the outer Van Allen belt electrons to various types of solar wind and internal magnetospheric forcing in particular to Interplanetary Coronal Mass Ejections (ICMEs) and High Speed Streams (HSS), to geospace magnetic storms of different intensities and to intense magnetospheric substorms. We have employed multi-point particle and field observations in the inner magnetosphere (both in-situ and through ground-based remote sensing), including the Cluster, THEMIS, Van Allen Probes and GOES constellations, the XMM and INTEGRAL spacecraft, and the CARISMA and IMAGE ground magnetometer arrays. The data provide a broad range of particle energies and a wide radial and azimuthal spatial coverage. Observations show that the equatorial mirroring electron losses are primarily caused by magnetopause shadowing, which due to outward diffusion driven by Pc5 ULF waves - even during non-storm periods. In addition, there is a 300 MeV/G threshold in energy that separates the source of relativistic electrons inside the outer belt even after the arrival of a prominent pressure pulse.

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25 Jan 17:00

Space weather at Mars: MAVEN observations and models

Shannon Curry

UC Berkeley, SSL

The MAVEN spacecraft has observed the Mars upper atmosphere, ionosphere, magnetic topology and interactions with the Sun and solar wind during numerous Interplanetary Coronal Mass Ejection (ICME) impacts spanning from March 2015 to October 2015. Observations include dramatic changes in the bow shock and magnetosheath boundaries, open and closed magnetic field lines, formation of diffuse aurora, and enhancement of pick-up ions. We will compare three MAVEN observations of ICMEs at Mars and discuss the results with respect to previous measurements made by MEX and MGS. Additionally, we will present global models using the MAVEN ICME observations as initial conditions, which show a significant enhancement in the precipitation and escape rates of planetary ions during these events. Accordingly, atmospheric escape during extreme solar events in Mars early history may have been a significant contributor to the evolution of the Martian atmosphere and may also have implications for exoplanets interacting with younger, more active stars.

Space Weather Measurements from the Surface of Mars with the RAD Instrument on the Mars Science Laboratory

25 Jan
17:25

Don Hassler

Don Hassler (1,2), Robert F. Wimmer-Schweingruber (3), Bent Ehresmann (2), Jingnan Guo (3), Cary Zeitlin (4)
(1) Institut dAstrophysique Spatiale, Orsay, France
(2) Southwest Research Institute, Boulder, Colorado, USA
(3) Christian Albrechts University, Kiel, Germany (4) NASA JSC, Houston, Texas, USA

The Radiation Assessment Detector (RAD) is a compact, lightweight energetic particle analyzer currently operating on the surface of Mars (CAU).as part of the Mars Science Laboratory (MSL) Mission. RAD is providing the first measurements of the energetic particle radiation environment on the surface of another planet due to solar flares, coronal mass ejections (CMEs), and galactic cosmic rays (GCRs).RAD is providing synoptic measurements of the energetic particle environment at a 2nd location in heliosphere (other than near-Earth or L1), and will aid heliospheric modeling over solar cycle. These observations of SEP fluxes are contributing to a solar energetic particle (SEP) event database at Mars and the Martian surface to aid prediction of Solar Particle Events (SPEs), including onset, temporal and size predictions. This presentation will provide an overview of the RAD investigation and present measurements of the solar flare, GCR and radiation environment on the surface of Mars, and discuss the importance of providing broad heliospheric coverage for situational awareness of space weather as we plan to send humans out into deep space and to Mars. RAD is supported by NASA (HEOMD) under JPL subcontract number 1273039 to SwRI, and by DLR in Germany under contract with Christian-Albrechts-Universitat(CAU).

25 Jan
17:40

Impacts of solar events on the surface radiation on Mars

Jingnan Guo

University of Kiel

The Radiation Assessment Detector (RAD), on board Mars Science Laboratory's (MSL) rover Curiosity, measures the particle fluxes of both energetic charged and neutral particles along with the radiation dose rate at the surface of Mars. With these first-ever measurements on the Martian surface, RAD has observed, during the first 1000 sols of mission, four solar particle events (SPEs) and many Forbush decreases (FDs) in the GCR-induced fluxes. We study the dose rates, linear energy transfer (LET) as well as the resulting equivalent dose rates during these solar impacts. These statistical results give us insights into the biological effects caused by solar impacts on the surface of Mars and are important for future manned missions to the planet.

Session 3: From Cradle to Grave: Particle Energization and Space Environmental Effects
Chair: Arnaud Masson

Particle energization in the Earth's magnetosphere and in the vicinity of the Earth's bow shock reflects multiple processes over various spatial and temporal scales. These processes are key to understand in order to predict the dynamical behaviour of the Earth's ring current and radiation belt energetic electron and ion populations, both local and global, and their space environmental effects. This session welcomes papers related to particle energization and its technological impacts. It is especially timely with the unprecedented opportunity of in-situ magnetospheric observations from the Van Allen Probes, GOES, Cluster, Themis, MMS, ePoP missions, the large ground based arrays of instrumentation (e.g. CARISMA, SuperMAG), the balloon-based observatories and CubeSat measurements. We also invite simulations and theoretical studies to advance our understanding of particle energization and space environmental effects.

26 Jan
10:30

New Results Concerning Particle Energization in Earth's Van Allen Radiation Belts

Daniel N. Baker

CU Boulder LASP

The first great scientific discovery of the Space Age was that the Earth is enshrouded in toroids, or belts, of very high-energy magnetically trapped charged particles. Early observations of the radiation environment clearly indicated that the Van Allen belts could be delineated into an inner zone dominated by high-energy protons and an outer zone dominated by high-energy electrons. The energy distribution, spatial extent and particle species makeup of the Van Allen belts has been subsequently explored by several space missions. However, recent observations by the NASA dual-spacecraft Van Allen Probes mission have revealed wholly unexpected properties of the radiation belts, especially for electrons at highly relativistic (E greater than 2 MeV) and ultra-relativistic (E greater than 5 MeV) kinetic energies. In this presentation we show using high spatial and temporal resolution data from the Relativistic Electron-Proton Telescope (REPT) experiment on board the Van Allen Probes that multiple belts can exist concurrently and that an exceedingly sharp inner boundary exists for ultra-relativistic electrons. Using additionally available Van Allen Probes data, we demonstrate that these remarkable features of energetic electrons are driven by strong solar and solar wind forcings. The comprehensive Van Allen Probes data show more broadly and in many ways how extremely high energy particles are accelerated, transported, and lost in the magnetosphere due to interplanetary shock wave interactions, coronal mass ejection impacts, and high-speed solar wind streams. The new data have in many ways rewritten the textbooks about the radiation belts as a key space weather threat to human technological systems.

Dynamics of the radiation belt during the two largest geomagnetic storm of solar cycle 24

26 Jan
10:55

Yihua Zheng
Lutz Rastaetter, Maria M. Kuznetsova
NASA Goddard Space Flight Center

In this paper, radiation belt response to the two largest geomagnetic storms (the 17 March 2015 one and the 22 June 2015 one) of solar cycle 24 is investigated. What is emphasized here is how different solar origins/drivers affect radiation belt dynamics. Both storms are primarily CME driven, but each has its own complexities [Liu et al., 2015, Kataoka et al., 2015]. Regardless whether the 17 March storm is a result of two CMEs [Liu et al., 2015] or just one CME from 15 March [Kataoka et al. 2015], the solar drivers of both storms are associated with an active region (AR) on the sun (AR 12297 - S22W25 for the former, and AR 12371 - N12E13 for the latter).

Liu et al. 2015s analysis points out that there are some peculiarities associated with the 17 March 2015 storm as it does not possess a southward flux-rope orientation. The fact the intense storm ensued despite the relatively weak solar flares/CMEs and a likely flank encounter is largely due to the interaction between two successive CMEs plus compression by a high-speed stream from behind.

The June storm, meanwhile, exhibits a multistep development that is caused by the southward fields due to amplification by a series of preceding shocks and those within the CME ejecta. The multiple preceding shocks and sheaths from CMEs on June 18 and 19 may have helped preconditioning of the magnetosphere and led to the growth of an intense storm.

Our study utilizes the modeling capability at the Community Coordinated Modeling Center to examine how the differences in solar source control the complexities of the radiation belt behavior. Ensemble results from different models (the coupled SWMF+RCM+RBE, SWMF+CRCM+RBE and CIMI) will be shown. Modeling results will be compared with observations from GOES, Van Allen Probes and other data sources.

Liu, Ying D.; Hu, Huidong; Wang, Rui; Yang, Zhongwei; Zhu, Bei; Liu, Yi A.;Luhmann, Janet G.; Richardson, John D. (2015), Plasma and Magnetic Field Characteristics of Solar Coronal Mass Ejections in Relation to Geomagnetic Storm Intensity and Variability, The Astrophysical Journal Letters, Volume 809, Issue 2, article id. L34, 6 pp. arXiv:1508.01267v1.

Kataoka, R., D. Shiota, E. Kilpua, and K. Keika (2015), Pileup accident hypothesis of magnetic storm on 17 March 2015, Geophys. Res. Lett., 42, 51555161, doi:10.1002/2015GL064816.

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26 Jan
11:10

Space weather effects on ionospheric radio propagation and mitigation methods

Natasha Jackson-Booth
QinetiQ

The ionosphere is a region of the Earths atmosphere which is ionised by extreme UV solar radiation and varies in response to events such as solar flares, geomagnetic storms, and lightening. All of these can have a huge, and often adverse, impact on the performance of radio equipment, which interacts with the ionosphere. Space weather events can affect radio propagation in and through the ionosphere as a result of sudden (and then persistent) increases in the bulk density and magnitude of wave-like structures throughout the ionosphere. The former can cause propagation delays whilst the latter increases the prevalence of small-scale structures, which cause scintillation (i.e. rapid changes in amplitude and phase) of radio signals. Both of these can adversely affect systems relying on propagation in or through the ionosphere, including Global Navigation Satellite Systems (GNSS) and HF communications. This talk describes some of the biggest problems faced by systems reliant on ionospheric propagation and the mitigations that can be used including; early warning systems (through specification and modelling), waveform selection and artificial ionospheric modification.

Turbulence and particle acceleration by inertial Alfvn waves in auroral ionosphere

26 Jan
11:35

Nitin Yadav

R. P. Sharma
Centre for Energy Studies, Indian Institute of Technology Delhi

Using pseudospectral method based simulation and fluid model of plasma; we investigate the nonlinear interaction of three dimensionally propagating inertial Alfvn wave and parallel propagating ion acoustic wave. The nonlinear evolution of inertial Alfvn wave in the presence of ion acoustic wave undergoes filamentation instability and results in the field intensity localization. These localized intense filaments are supposed to play a very crucial role in charged particle acceleration. The presented model is also intended to explore about the observed turbulence in auroral ionosphere. Turbulence provides unstable conditions and the amplitude of low frequency inertial Alfvn waves keeps growing and eventually cascades to smaller wavenumber modes resulting in turbulent spectrum. Thus the presented coupling also suggests a mechanism of energy transfer from larger length-scales to smaller length-scales. To get the physical insight of this proposed interaction, a simplified semi-analytical model based on paraxial approximation is also developed. The relevance of present investigation with recent spacecraft observations is also pointed out.

26 Jan
11:50

Geospace Exploration Project: ERG

Yoshizumi Miyoshi

Y. Miyoshi(1), I. Shinohara(2), T. Takashima(2), K. Asamura(2), N. Higashio(2), H. Matsumoto(2), T. Mitani(2), S. Yokota(2), S. Kasahara(2), Y. Kazama(3), M. Hirahara(1), Y. Kasahara(4), Y. Kasaba(5), S. Yagitani(4), A. Matsuoka(2), H. Kojima(5), K. Shiokawa(1), K. Seki(1), T. Ono(5), and ERG Science Team

(1) ISEE, Nagoya University, Japan (2) JAXA, Japan (3) ASIAA, Taiwan (4) Kanazawa University, Japan (5) Tohoku University, Japan (6) RISH, Kyoto University, Japan

The ERG (Exploration of energization and Radiation in Geospace) is Japanese geospace exploration project. The project focuses on the geospace dynamics in the context of the cross-energy coupling via wave-particle interactions. The project consists of the satellite observation team, the ground-based network observation team, and integrated-data analysis/simulation team. The ERG satellite will be launched in 2016. Comprehensive instruments for plasma/particles, and field/waves are installed in the ERG satellite to understand the cross-energy coupling system. In the ERG project, several ground-network teams join; magnetometer networks, radar networks, optical imager networks, etc. Moreover, the modeling/simulations play an important role for the quantitative understanding. In this presentation, we will talk about an overview of the ERG project and its contribution to Space Weather study.

Session 4: Towards improved specification and nowcasting/forecasting of the particle radiation environment Chair: Ioannis A. Daglis and Tsutomu Nagatsuma

Accurate specification of the particle radiation environment is of crucial importance for mission and spacecraft design with respect to the quantification of radiation effects and the choice of alternative mission architectures. Reliable nowcasting and forecasting of the particle radiation environment is indispensable for our efforts to diagnose the anomalies of space assets and to plan and implement effective mitigation actions. This session solicits papers on recent advances in our understanding of the processes that control the dynamics of the particle radiation environment in geospace and beyond and contribute to its improved specification and forecasting.

27 Jan
16.00

The use of event-specific models in DREAM3D

Gregory Cunningham
Los Alamos National Laboratory

DREAM3D is a 3D Fokker-Planck diffusion code that has been used to model the dynamic evolution of MeV electrons in the radiation belts. The effects of drift-resonant ultra-low frequency (ULF) waves and gyro-resonant very-low frequency (VLF) waves, are modelled with quasilinear theory, which yields a 1D diffusion equation in dipole L at fixed values of the first and second invariants, and a 2D diffusion equation in pitch-angle and momentum at fixed L. The 1D and 2D diffusion equations are decoupled in DREAM3D because the background field is assumed to be a dipole and the cross-terms are ignored. The diffusion coefficients are determined by the wave intensity in the ULF and VLF frequency ranges, and historically have been determined by statistical models for the wave intensity that depend on geomagnetic activity. Recently we have shown that the statistical models do not always perform well for a specific event, but event-specific models that combine in-situ observations with the statistical models can be used to improve the model. For example, we have used measurements of the low-energy (100 keV) population generated by the Van Allen Probes MagEIS instrument to define a low-energy boundary condition for DREAM3D as a function of time and L, and showed that modeling this seed population correctly is critical for the model to predict the observed acceleration during the October 2012 storm. Similarly, we combined observations of the equatorial chorus wave intensity from the Van Allen Probes EMFISIS instrument, with precipitation observed by the NOAA POES instrument, to define an event-specific low-band chorus wave intensity. We showed that an event-specific model for the low-band chorus wave intensity is also critical for the model to predict the observed acceleration during the same storm. Our current efforts are aimed at extending our recent work on using event-specific models by incorporating non-dipole field models into DREAM3D for calculating more realistic radial and pitch-angle/momentum diffusion coefficients. In this talk, I will review our earlier results for the October 2012 storm using the dipole field model, present our approach to computing radial diffusion coefficients using the background field models developed by Tsyganenko and co-authors, and new results from

DREAM3D using the new radial diffusion coefficients.

Operational Control of Radiation Conditions Provided by Space Monitoring Centre of Moscow State University

27 Jan
16:25

Vladimir Kalegaev

Vladimir Kalegaev
Skobeltsyn Institute of Nuclear Physics, Moscow State University, Moscow, Russia

Space Monitoring Data Centre (SMDC) of Moscow State University provides mission support for Russian satellites and give operational analysis of radiation conditions in space. SMDC Web-sites (http://smdc.sinp.msu.ru/ and http://swx.sinp.msu.ru/) give access to current data on the level of solar activity, geomagnetic and radiation state of Earths magnetosphere and heliosphere in near-real time. For data analysis the models of space environment factors working online have been implemented. Interactive services allow one to retrieve and analyze data at a given time moment. Forecasting applications including solar wind parameters, geomagnetic and radiation condition forecasts have been developed. Radiation dose and SEE rate control are of particular importance in practical satellite operation. Satellites are always under the influence of high-energy particle fluxes during their orbital flight. The three main sources of particle fluxes: the Earths radiation belts, the galactic cosmic rays, and the solar energetic particles (SEP), are taken into account by SMDC operational services to estimate the radiation dose caused by high-energy particles to a satellite at LEO orbits. ISO 15039 and AP8/AE8 physical models are used to estimate effects of galactic cosmic rays and radiation belt particle fluxes. Data of geosynchronous satellites (GOES or Electro-L1) allow to reconstruct the SEP fluxes spectra at a given low Earth orbit taking into account the geomagnetic cut-off depending on geomagnetic activity level.

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27 Jan
16:50

New Probabilistic Forecast Models of Solar Flares and CMEs

Kangjin Lee

Kangjin Lee (1), Yong-Jae Moon (1), Jin-Yi Lee (2),
Hyeonock Na (1), Jongyeob Park (3)
(1) Space of Space Research, Kyung Hee University, Rep. of Korea
(2)Astronomy and Space Science, Kyung Hee University, Rep. of Korea
(3) Korea Astronomy and Science Institute, Rep. of Korea

We describe new probabilistic flare/CME forecasting models based on morphological scheme of active regions (ARs). The new model is designed for probabilities of C-, M-, X- class flares, and front-side halo CMEs (FHCMEs) from each AR and on solar disk. The McIntosh sunspot group classification, which presents the morphological and magnetic characteristics of ARs, is used for classifying ARs using Solar Region Summary (SRS) data provided by NOAA Space Weather Prediction Center (SWPC). Each McIntosh sunspot class is classified into three groups by its area change: Decrease, Steady, Increase. The area change of ARs can be a proxy of magnetic flux emergence or cancellation, which is one of the main triggering mechanism for solar flares and CMEs. Historical flare/CME occurrence rates are calculated by the number of flares/CMEs divided by the number of ARs for a given McIntosh class using the GOES and SOHO/LASCO data from 1996 to 2013. The input parameters of these models are type of the McIntosh classes, AR number, area change of each AR and its historical occurrence rate. The output parameters, probabilities of flares and CMEs for a given AR and on the disk, are issued once a day. Further improvements of the models will be discussed.

Multivariate autoregressive (AR) prediction of MeV electron flux variation in Geostationary and Medium Earth orbits

27 Jan
17:05

Tsutomu Nagatsuma

Kaori Sakaguchi , Tsutomu Nagatsuma
National institute of Information and Communications Technology (NICT), Japan

The deep dielectric charging produced by penetrating relativistic electrons inside a satellite body is known as one of significant risks for causing satellite anomaly. The flux of relativistic electrons in the radiation belts impacting satellites depends on their position from the Earth, and also depends on the conditions of the solar wind and on magnetosphereic activities. For the prediction of future flux variations, we have developed multivariate autoregressive (AR) models as a function of McIlwains L value. The model estimates a delayed response of radiation belt electron variations at each L from solar wind parameters and geomagnetic indices. In this talk, we present details of the multivariate AR prediction method developed for the prediction of ¿2 MeV electron flux variation at Geostationary orbit based on GOES and Himawari satellite data [Sakaguchi et al., 2013]. Also, we show prediction models for each L value created by the Van Allen Probes observation data and discuss about the differences of optimized parameters among the models of each L value.

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27 Jan
17:30

Radiation Environment Specification Models: Engineering needs, Uses, Uncertainties and Reliability

Hugh Evans

H. D. R. Evans
ESA, Rhea System SA

Radiation Belt Specification models are an integral component for specifying the radiation environment of a spacecraft in the preliminary design phases. Knowledge of the uncertainties and errors inherent in these models is essential for establishing reasonable radiation design margins to mitigate risk and avoid expensive over engineering.

The various specification models from the ECSS-E-ST-10-04C standard and the latest AE-9 and AP-9 models will be compared to in-situ data to demonstrate the uncertainties and reliability of these models.

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27 Jan
18:30

SPRING network for realtime space weather prediction

Sanjay Gusain

Markus Roth, (2) F. Hill (3), M. Thompson(4)
(1) NSO, Tucson, (2) KIS Freiburg, (3) NSO Boulder, (4) HAO Boulder

We will present the design of a next generation solar observing network SPRING that will address many areas of solar physics including space weather. The distributed network of identical instruments across the globe will provide realtime information of solar magnetic fields and chromospheric thermodynamic changes to enable realtime space weather predictions. Observing from ground with distributed identical instruments provides a very reliable source of information that cannot be achieved from space platforms due to their vulnerability to space weather itself.

Session 5: From Convective Zone to Heliosphere: CME precursors, initiation and onsets
Chair: Jorg Buchner and Cristina Mandrini

Solar activity is the ultimate driver of Space Weather. From its various manifestations, coronal mass ejections (CMEs) have the most severe impacts on ground- and space-based technological systems. CMEs are massive eruptions of magnetically confined plasma within structures that can stay stable for up to several solar rotations and be suddenly ejected into the heliosphere. There is a long chain of processes leading to these highly dynamical phenomena, from the generation of the solar magnetic field at the bottom of the convective zone, the emergence of magnetic flux tubes through this inner solar layer, the interaction of the emerged flux with the surrounding coronal magnetic field, and, finally, the destabilization of the coronal structure and CME initiation. Understanding the physics behind these processes is fundamental to improve our capability to mitigate space weather impacts. Session 5 is devoted to review our current understanding, from observational, theoretical, and modeling points of view, of some key aspects in the chain of processes leading to CMEs.

27 Jan
18:45

Keynote Lecture: Evolution of solar magnetic flux tubes from the interior to the lower atmosphere of the Sun

Sami Solanki

Max-Planck-Institute for Solar System Research

The Sun's large-scale magnetic field is produced by a dynamo process acting deep inside the Sun. It concentrates magnetic fields in the form of flux tubes whose buoyancy takes them towards the solar surface where they appear as opposite polarity magnetic features forming active regions in the case of the largest of these. The emergence at the solar surface itself is quite complex and it is only after some time that the an unambiguous bipolar pattern emerges. In the chromosphere and later in the corona the rising fields become visible as loop-like structures. The appearance of new field in the corona, often leads to flaring, while the destabilization of the field, usually later in the lives of active regions, can produce coronal mass ejections.

Predicting solar magnetic activity and its implications for solar dynamo models

27 Jan
19:10

Nishant K. Singh

Harsha Raichur, Axel Brandenburg
NORDITA, Stockholm

Using the solar surface mode, i.e. the f-mode, we attempt to predict the emergence of active regions (ARs) in the days before they can be seen in magnetograms. Our study is motivated by earlier numerical findings of Singh et al (2014) who showed that, in the presence of a nonuniform magnetic field which is concentrated a few scale heights below the surface, the f-mode fans out in the diagnostic k-omega diagram at high wavenumbers. Here we exploit this property using data from the Helioseismic and Magnetic Imager aboard the Solar Dynamics Observatory, and show for three ARs 11768, 11158 and 12051, that at large latitudinal wavenumbers (corresponding to horizontal scales of around 3000 km), the f-mode displays strengthening about two days prior to AR formation and thus provides a new precursor for AR formation. The idea that the f-mode is perturbed days before any visible magnetic activity occurs on the surface can be important in constraining dynamo models aiming at understanding the global magnetic activity of the Sun.

27Jan
19:25

Simulation of active region flux emergence, formation of delta-sunspots and the convective dynamo

Fang Fang

Fang Fang (1), Benjamin Brown (1), Yuhong Fan (2)
(1) Laboratory for Atmospheric and Space Physics, University of Colorado
(2) High Altitude Observatory, National Center for Atmospheric Research

Among various active regions, delta-sunspots of aggregated spots of opposite polarities, are of particular interest due to their high productivity in energetic and recurrent eruptive events, such as X-class flares and homologous eruptions. We here study the formation of such complex magnetic structures by numerical simulations of magnetic flux emergence from the convection zone into the corona in an active-region scale domain. In our simulation, two pairs of bipolar sunspots form on the surface, originating from two buoyant segments of a single subsurface twisted flux rope. Expansion and rotation of the emerging fields in the two bipoles drive the two opposite polarities into each other with apparent rotating motion, producing a compact delta-sunspot with a sharp polarity inversion line (PIL). The formation of the delta-sunspot in such a realistic-scale domain produces emerging patterns similar to those formed in observations, e.g. the inverted polarity against Hales law, the curvilinear motion of the spot, strong transverse field with highly sheared magnetic and velocity fields at the PIL. Strong current builds up at the PIL, giving rise to reconnection, which produces a complex coronal magnetic connectivity with non-potential fields in the delta-spot overlaid by more relaxed fields connecting the two polarities at the two ends.

Eruptions driven by magnetic flux emergence in a coronal hole environment

27 Jan
19:50

Klaus Galsgaard

Niels Bohr Institute University of Copenhagen, Denmark

Magnetic flux emergence in to an existing coronal magnetic configuration represents one of the simplest ways to generate fast magnetic energy release processes. When the coronal magnetic field contains the favorable configurations different eruptions may take place forming simple jet like features or ejections of flux robes in the from a CMEs.

This talk discusses the evolution of a magnetic flux emergence into a simple unipolar magnetic field using 3D non-ideal MHD modelling. The simple model gives rise to a much more complicated temporal evolution than expected. After a longer steady state jet phase the system reaches a phase where five eruptions take place. These are discussed in terms of the stressing of the system as it approaches the instability and the eruptions impact on the ambient magnetic field.

28 Jan
8:30

Observational diagnostics of the energy release in the confined X-class flares of October 2014

Astrid M. Veronig

Julia K. Thalmann, Yang Su, Manuela Temmer
Institute of Physics/Kanzelhohe Observatory, University of Graz, Austria

NOAA 12192 was the largest active region (AR) on the Sun since NOAA 6368 in November 1990, and it developed to the most flare prolific AR in the present solar cycle no. 24, being the source of 6 X-class flares, 29 M-class flares and numerous smaller events. However, all the major flares it produced (i.e. all X-class flares and all M-class flares except one) were confined events, i.e. they were not associated with a coronal mass ejection (CME). As a consequence, the space weather effects of this period of major flaring activity in October 2014 were small. This raises the question what makes NOAA 12192 and its flaring activity so distinct, and whether we can understand its non-eruptive nature. To this aim, we performed a study on the magnetic environment and the flare energy release process of selected major flares produced by NOAA 12192 using SDO AIA, HMI, RHESSI and Kanzelhohe Halpha. Key findings include the following: The confined flares all occurred in the core of the AR and the strong overlying arcade fields and its small decay index served for the confinement, whereas the one eruptive M-class flare occurred on the border of the AR close to neighboring open field regions. A detailed analysis of the confined X1.6 flare on 2014 October 22 reveals a steep power-law hard X-ray spectrum (delta ¡ 5). The total energy in non-thermal electrons derived is almost an order of magnitude than in eruptive flares of class X1, and corresponds to about 10 percent of the excess magnetic energy present in the active-region corona. The magnetic reconnection flux derived for the event lies well within the distribution of eruptive X1 flares. A large initial separation of the flare ribbons and no separation motion during the flare is observed, suggesting a confined reconnection site high up in the corona. In addition, enhanced emission at flare ribbon structures and hot loops connecting these structures is already present before the event starts. These findings are suggestive of flare initiation by magnetic reconnection of localized newly emerging flux tubes with pre-existing large and sheared coronal loops.

CME Propagation-Where Does Aerodynamic Drag Take Over

28 Jan
8:45

Prasad Subramanian
IISER Pune

We investigate the Sun-Earth dynamics of a set of eight well observed solar coronal mass ejections (CMEs) using data from the STEREO spacecraft. We seek to quantify the extent to which momentum coupling between these CMEs and the ambient solar wind (i.e., the aerodynamic drag) influences their dynamics. To this end, we use results from a 3D flux rope model fit to the CME data. We find that solar wind aerodynamic drag adequately accounts for the dynamics of the fastest CME in our sample. For the relatively slower CMEs, we find that drag-based models initiated below heliocentric distances ranging from 15 to 50 solar radius cannot account for the observed CME trajectories. This is at variance with the general perception that the dynamics of slow CMEs are influenced primarily by solar wind drag from a few solar radius onwards. Several slow CMEs propagate at roughly constant speeds above 15–50 solar radius. Drag-based models initiated above these heights therefore require negligible aerodynamic drag to explain their observed trajectories.

Session 6: Predicting Energetic Solar Phenomena and the Geospace response
Chair: Nat Gopalswamy and Lika Guhathakurta

Energetic phenomena on the Sun that evoke significant geospace response over a timescale of minutes to days are mass emissions (CMEs and high speed streams) and electromagnetic transients (solar flares). CMEs and flares originate from closed magnetic field regions, while high speed streams originate from open field regions on the Sun. CMEs are responsible for large solar energetic particle events and major geomagnetic storms. High speed streams form CIRs, which can also lead to moderate geomagnetic storms. Flares can modify the conductivity of the ionosphere. The conditions created by the energetic phenomena are collectively termed space weather, which has emerged as an important natural hazard to life and society in various ways. Predicting the occurrence of these energetic phenomena and how the geospace responds to them has become an important task for the solar terrestrial science community. Once a closed field region appears on the Sun, when will it erupt? When it will not erupt? Will it produce only confined flares or it will involve mass ejections? How do CMEs develop shocks that accelerate SEPs? When and with what magnetic structure do CMEs arrive at Earth? How do CMEs propagate to Earth and what substructures cause geomagnetic disturbances? After a coronal hole appears on the solar disk, when will the associated CIR and high speed stream arrive at Earth and with what speeds? These are some of the questions that are being addressed in developing prediction schemes using various techniques. This session invited papers that discuss any of these issues that will contribute to the improvement in predicting the energetic phenomena and their geospace response.

Climatological response of Low latitude ionosphere to Space Weather events

28 Jan
09:00

Dr. Nirvikar Dashora
N. Dashora, S. Suresh
National Atmospheric Research Laboratory, Gadanki, India

A systematic statistical study of storm-time departures of low latitude ionospheric variations is presented that can be used to forecast the extent to which a typical kind of storm could perturb the low latitudes at a given time of day. During last decade or so, the ionospheric TEC (total electron content) has emerged as a crucial parameter for satellite based navigation and its various applications that demand high precision. It is not surprising that the anomalous departures and sharp gradients in daytime low latitude ionospheric TEC severely impede the quality of precise applications [Musa et al., 2012, Astafyeva, 2014]. Hence, the ionospheric forecast has become a prime topic of research on regional and global scales [Bust and Mitchell, 2008, Kutiev et al., 2013]. The climatology of responses of low latitude TEC during geomagnetic storms can serve as a basis for short and medium range forecast. A forecast skill based on the climatology can be developed according to the category of a geomagnetic storm. Since the severity of a geomagnetic storm can be predicted based on the intensity and occurrence of CME or ICME [Srivastava and Venkatakrishnan, 2004, Gonzalez and Echer, 2005] a final ionospheric forecast could be achieved for desired applications. In this work, statistical analysis is performed to specifically bring out the responses of the equatorial and low latitude ionosphere to the geomagnetic storms that occurred during solar cycles 23 and 24 from 1998 to 2015. Results are demonstrated only for daytime ionospheric deviations that are further divided into forenoon and afternoon durations. In contrast to many previous studies, a new generic storm identifier is used in present work based upon monthly standard deviation of VTEC. Thus, this study for the first time reveals the mean behaviour of the severity of TEC deviations during main phase of different types of storms at various levels of solar activity. Also the seasonal dependence of low latitude ionospheric response to geomagnetic storms over Indian zone is presented for the first time.

28 Jan
09:15

Forecasting the magnetic field configurations of CMEs

Volker Bothmer

Georg-August-Universitt Gttingen Institut fr Astrophysik
Friedrich-Hund-Pl-1
37077 Gttingen, Germany

Fast coronal mass ejections driving interplanetary shock waves are the causes of extreme geomagnetic storms. The storms are triggered by intense values of the CME speeds and magnetic field strengths in case the magnetic field is directed antiparallel to the Earths magnetic field. Thus it is of key importance for space weather forecasts to predict the arrival times, speeds and magnetic field intensities and directions of CMEs. This can be achieved by identifying the source regions of CMEs at the Sun from the locations of commonly associated flares and low coronal activity signatures, such as post-eruptive arcades and EUV waves, and by analyzing the photospheric magnetic fields in solar magnetograms. From determination of the orientation of the 'neutral line' separating opposite photospheric magnetic fields and by applying the hemispheric helicity dominance the magnetic configuration of CMEs can be inferred and extrapolated to 1 AU. Additionally to this so-called Bothmer and Schwenn flux rope scheme for CMEs, new modeling methods that have been recently developed are also briefly reviewed. The CME speed at 1 AU can be determined from coronagraph observations by taking into account the position of the Earth with respect to the CME apex and its interplanetary evolution. Simultaneous observations of CMEs propagating along the Sun-Earth line made by the STEREO/SECCHI telescope suites from two perspectives have provided unprecedented knowledge about the 3D structure of CMEs and their interplanetary evolution. The observations are analyzed in detail in the EU FP7 project HELCATS (Heliospheric Cataloguing, Analysis and Techniques Service). The HELCATS project will also provide results facilitating the development of operational CME imagers that can be flown in dedicated orbits such as L1 and L5. This presentation provides a brief summary of the state-of-the-art modeling of CME magnetic field configurations enabling the quantitative forecast of geomagnetic storms.

MAG4: A Near-Real-Time Method of Forecasting Flares and CMEs from HMI Vector Magnetograms of Active Regions

28 Jan
09:40

David Falconer

University of Alabama Huntsville

We will describe our operational method (MAG4) of forecasting of major flares and CMEs, from measurements of vector magnetograms of active regions. We will present the performance of this method, compared to similar forecasting methods that are based on active region magnetograms, and sunspot configuration. We will also describe our plans on improving MAG4 by using a data base of AR having HMI vector magnetograms. This work is based on the following three papers: Falconer, D.A., Barghouty, A. F., Khazanov, I., and Moore, R.L., 2011, "A Tool for Empirical Forecasting of Major Flares, Coronal Mass Ejections, and Solar Particle Events from a Proxy of Active-Region Free Magnetic Energy", Space Weather 9, S04003. Falconer, D.A., Moore, R.L., Barghouty, A. F., and Khazanov, I., 2012, "Prior Flaring as a Complement to Free Magnetic Energy for Forecasting Solar Eruptions", Astrophys. J. 757, 32. Falconer, D.A., Moore, R.L., Barghouty, A. F., and Khazanov, I., 2014, "MAG4 versus alternative techniques for forecasting active region flare productivity", Space Weather 12, 306..

28 Jan
10:30

Solar wind Magnetosphere Ionosphere Link

Escoubet C. P.

Escoubet C. P. (1), G. Branduardi-Raymont (2), C. Wang (3)
(1) ESA/ESTEC (NL) (2) MSSL - UCL (UK) (3) NSSC/CAS (China)

The interaction between the solar wind and the Earths magnetosphere, and the geospace dynamics that result, comprise a fundamental driver of space weather. Understanding how this vast system works requires knowledge of energy and mass transport, and coupling between regions and between plasma and neutral populations. In situ instruments on a fleet of solar and solar wind observatories now provide unprecedented observations of the external Sun-Earth connection drivers. However, we are still unable to quantify the global effects of those drivers, including the conditions that prevail throughout geospace. This information is the key missing link for developing a complete understanding of how the Sun gives rise to and controls Earths plasma environment and space weather. Solar wind Magnetosphere Ionosphere Link Explorer (SMILE) is a novel self-standing mission to observe the solar wind-magnetosphere coupling via simultaneous in situ solar wind/magnetosheath plasma and magnetic field measurements, X-Ray images of the magnetosheath and polar cusps, and UV images of global auroral distributions. Remote sensing of the cusps with X-ray imaging is now possible thanks to the relatively recent discovery of solar wind charge exchange (SWCX) X-ray emission, first observed at comets, and subsequently found to occur in the vicinity of the Earths magnetosphere. SMILE is a collaborative mission between ESA and the Chinese Academy of Sciences (CAS). The SMILE science as well as the results of the on-going study undertaken jointly by ESA and CAS will be presented.

MHD simulation of interplanetary propagation of multiple coronal mass ejections with internal magnetic flux rope (SUSANOO-CME)

28 Jan
10:45

Daikou Shiota

Daikou Shiota(1), Ryuho Kataoka (2)
(1) ISEE, Nagoya University, Japan (2) NIPR, Japan/Sokendai, Japan

Coronal mass ejections (CMEs) are the most important drivers of various types of space weather disturbance. Here, we report a newly developed magnetohydrodynamic (MHD) simulation of the solar wind, including a series of multiple CMEs with internal spheromak-type magnetic fields. Firstly, the polarity of the spheromak magnetic field is set as determined automatically according to the Hale-Nicholson law and the chirality law of Bothmer and Schwenn. The MHD simulation is therefore capable of predicting the time profile of the interplanetary magnetic field at the Earth, in relation to the passage of a magnetic cloud within a CME, which is the most important parameter for space weather forecasts of magnetic storms. In order to evaluate the current ability of our simulation, we demonstrate a test case: the propagation and interaction process of multiple CMEs associated with the highly complex active region NOAA 10486 in October to November 2003, and present the result of a simulation of the solar wind parameters at the Earth during the 2003 Halloween storms. We succeeded in reproducing the arrival at the Earth's position of a large amount of southward magnetic flux, which is capable of causing an intense magnetic storm. It was found that the observed complex time profile of the solar wind parameters at the Earth could be reasonably well understood by the interaction of a few CMEs.

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28 Jan
11:10

Observations of solar induced variability in the mesosphere and thermosphere over the past 14 years and longer!

Martin Mlynczak

Linda A. Hunt
NASA Langley Research Center and SSAI

Coronal mass ejections (CMEs) are the most important drivers of various types of space weather disturbance. Here, we report a newly developed magnetohydrodynamic (MHD) simulation of the solar wind, including a series of multiple CMEs with internal spheromak-type magnetic fields. Firstly, the polarity of the spheromak magnetic field is set as determined automatically according to the Hale-Nicholson law and the chirality law of Bothmer and Schwenn. The MHD simulation is therefore capable of predicting the time profile of the interplanetary magnetic field at the Earth, in relation to the passage of a magnetic cloud within a CME, which is the most important parameter for space weather forecasts of magnetic storms. In order to evaluate the current ability of our simulation, we demonstrate a test case: the propagation and interaction process of multiple CMEs associated with the highly complex active region NOAA 10486 in October to November 2003, and present the result of a simulation of the solar wind parameters at the Earth during the 2003 Halloween storms. We succeeded in reproducing the arrival at the Earth's position of a large amount of southward magnetic flux, which is capable of causing an intense magnetic storm. It was found that the observed complex time profile of the solar wind parameters at the Earth could be reasonably well understood by the interaction of a few CMEs.

Session 7: Metrics to Assess Space Weather Predictions
Chair: Masha Kuznetsova and David Jackson

Appropriate validation methods to evaluate the performance of space environment models, forecasting techniques and procedures are critical to the development and further improvements of operational space weather prediction capabilities. Confidence assessment is an essential component of space weather forecasting. The approach to the validation, uncertainty assessment and to the format of the metrics is strongly dependent on specific applications and end user needs.There is a need to understand which aspects of spatial and temporal characteristics of space environment parameters are the most important for specific impacts on technological and biological systems. There is a need to agree on a set of standard metrics that can be used to assess the current state of space environment predictive capabilities and trace improvements over time. It is also necessary to address challenges of model-data comparisons, such as observational data quality and availability, sensitivity of model outputs to external drivers (input parameters), boundary conditions, modeling assumptions, adjustable parameters. etc.There are a number of on-going community model validation activities (e.g., GEM-CEDAR-SHINE community-wide Modeling Challenges) that have demonstrated the value of systematic and coordinated model validation projects. In addition the experience of Numerical Weather Prediction in developing standardized, well understood verification tools could be invaluable in developing similar tools for space weather predictions. The goal of the session is to bring together modelers, observational data providers, application developers and space weather service providers in an international framework to review the state of model and service validation activities, to build upon successes, to identify challenges, and to develop a strategy for continuous assessment of space weather predictive capabilities and tracing the improvement over time, building on the direction of travel.

Adapting meteorological verification techniques for space weather at the UK Met Office

29 Jan
09:55

Suzy Bingham
David Jackson, Edward Pope, Michael Sharpe, Sophie Murray
Met Office, UK

The UK Met Office has been providing 24/7 operational space weather forecasts, alerts and warnings since 2014. In order to provide this service, the Met Office has drawn on its extensive experience in Numerical Weather Prediction (NWP). We have been continuing this adaptation of NWP methods by developing terrestrial verification techniques for space weather. For forecasters, modellers, customers and stake-holders, its of vital importance to monitor, improve and compare forecast quality. Verification techniques for meteorology are well-documented, with libraries and tools freely available. Although terrestrial and space weather forecasts are inherently different, there are many similarities which allow successful adaptation of terrestrial verification methods. Met Office forecasters provide twice daily guidance. Included in this guidance are predictions for CME arrival times at Earth, and 4-day probabilistic forecasts of geomagnetic storms, X-ray flares, high energy protons and high energy electron events. Progress has been made in analysing CME arrival time predictions compared to observations using 2x2 contingency tables and assessing forecast skill. Progress has also been made in verification of probabilistic forecasts of geomagnetic storms. These forecasts are categorical and so a probability is given for exceeding minor/moderate, strong, severe and extreme levels, each day for the next 4 days. As a consequence, different verification methods have been employed to those for CME forecasts. For example, the Ranked Probability Skill Score (RPSS) has been used to quantify forecast skill compared with a climatology benchmark. Progress has been made in adapting a terrestrial weather verification visualisation system used for shipping-forecasts, for verification of geomagnetic storms. This will enable forecasters to view verification of forecasts in near real-time. The Met Office is also collaborating on the EUs Horizon 2020 Project, Flare Likelihood And region Eruption foreCASTing (FLARECAST). FLARECAST will develop an automatic solar flare prediction system based on state-of-the-art flare prediction methods and will be validated using appropriate forecast prediction

measures. This presentation will discuss the challenges encountered and the techniques employed during this initial verification work.

Performance Verification of Solar-Flare Prediction Models: from Climatology to Skill and from Forecast Probabilities to Certainty

29 Jan
10:20

Manolis Georgoulis
RCAAM of the Academy of Athens

Solar flare occurrence is known to obey a time-dependent Poisson distribution, stemming from solar active-region sources that emerge, evolve, and disappear continuously on a roughly 11-year pulse-shaped number pattern. In addition, flare size parameters obey extensive power-law distributions, pointing towards an intrinsically nonlinear dynamical triggering mechanism. As such, the solar flare phenomenon involves significant stochasticity of a practically unknown degree. Thus, flare prediction seems to be a purely probabilistic task. In assessing the quality of this task, the study of terrestrial weather patterns has contributed the "reliability diagram" tool, that has only recently been used for the validation of existing flare prediction models. In addition, dichotomous (i.e., categorical [YES/NO]) validation practices have been attempted, albeit necessarily (and restrictively) as functions of varying forecast probability thresholds. We investigate possible avenues that could lead to a standardized performance verification practice for existing and future flare prediction methods. We further probe potential paths to upgrade probabilistic flare prediction into a dichotomous task, with a set of excellent bench-marking metrics already available in our toolbox. These paths cut through grounds that likely involve multi-parameter forecasting and subsequent parameter classification, discriminant analysis and, possibly, ensemble flare forecasting. As these practices are yet to be sufficiently tested in flare prediction, significant progress is possibly ahead of us, also in view of the continuous accumulation of flaring records and observational databases.

This work has received partial support by the FLARECAST project. FLARECAST received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No. 640216.

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29 Jan
11:15

Community-wide validation of geospace model local K-index predictions to support model transition to operations

Alex Glocer

L. Rastatter, M. Kuznetsova, A. Pulkkinen
NASA/GSFC

We present the latest result of a community-wide space weather model validation effort coordinated among the Community Coordinated Modeling Center (CCMC), NOAA Space Weather Prediction Center (SWPC), model developers, and the broader science community. Validation of geospace models is a critical activity for both building confidence in the science results produced by the models and in assessing the suitability of the models for transition to operations. Indeed, a primary motivation of this work is supporting NOAA SWPCs effort to select a model or models to be transitioned into operations. Our validation efforts focus on the ability of the models to re- produce a location specific index of geomagnetic disturbance, the local k-index. Six geomagnetic events representing a range of events and six geomagnetic observatories representing mid- and high-latitude locations is considered in our analysis. Model performance is evaluated quantitatively by the use of contingency tables, skill scores, and distribution metrics. We consider model performance on an event-by-event basis, aggregated over events, at specific station locations, and separated into high- and mid-latitude domains. The summary of results are presented in this report, and an online interface built at CCMC is available for detailed time series analysis.

How would the thermosphere and ionosphere respond to an extreme space weather event and how would we validate a modeled response?

29 Jan
11:40

Tim Fuller-Rowell

Mariangel Fedrizzi, Naomi Maruyama, Mihail Codrescu, Jimmy Raeder
University of Colorado

If a Carrington-type CME event of 1859 hit Earth how might the thermosphere, ionosphere, and plasmasphere respond, and how would we validate a modeled response. To start with, we have to rely on estimates of what the magnetospheric forcing might be, and how the magnetosphere channels the energy into the upper atmosphere. For now we can assume the magnetospheric convection and auroral precipitation inputs would look similar to a 2003 Halloween storm but stronger and more expanded to mid-latitude, much like what the Weimer empirical model predicts if the solar wind Bz and velocity were -60nT and 1500km/s respectively. For a Halloween-level geomagnetic storm event, the sequence of physical process in the thermosphere and ionosphere are thought to be well understood. The physics-based coupled models, however, have been designed and somewhat tuned to simulate the response to this level of event that have been observed in the last two solar cycles. For an extreme solar storm, it is unclear if the response would be a natural linear extrapolation of the response or if non-linear processes would begin to dominate. Numerical simulation has been performed with a coupled thermosphere ionosphere model to quantify the likely response to an extreme space weather event. The simulation predict the neutral atmosphere would experience horizontal winds of 1500m/s, vertical winds exceeding 150m/s, and the top of the thermosphere well above 1000km. Predicting the ionosphere response is somewhat more challenging because there is significant uncertainty in quantifying some of the other driver-response relationships such as the magnitude and shielding time-scale of the penetration electric field, the possible feedback to the magnetosphere, and the amount of nitric oxide production. Within the limits of uncertainty of the drivers, the magnitude of the response can be quantified and both linear and non-linear responses are predicted.

29 Jan 11:55

Metrics for space weather: needs, challenges, initiatives, coordination, path forward (discussion)

Maria Kuznetsova

M. Maddox, S. Bakshi, J. Boblitt, A. Chulaki, P. Macneice, M.L. Mays, M. Mendoza, R. Mullinix, J-S. Shim, A. Pulkkinen, L. Rastaetter, Y. Zheng, C. Wiegand
Community Coordinated Modeling Center, NASA/GSFC

The Community Coordinated Modeling Center (CCMC) at NASA Goddard Space Flight Center was established in 2000 as an essential element of the National Space Weather Program and was designed to be a long-term and flexible solution to the Research-to-Operations (R2O) transition problem. Over its 15-year existence, the CCMC has changed how state-of-the-art space weather models are utilized in research, and has also facilitated the transition of many research models into operational environments. The CCMC currently hosts a large and expanding collection of physics-based space weather models that have been developed by the international research community, and has amassed a peta-byte of model simulation output that represents advances in space weather modeling and space science research for the past 15 years.

The ability of the CCMC to engage the international research community and support community challenges, campaigns, studies, and general research is vital to its success - so a flexible cyberinfrastructure that facilitates data discovery and interoperability with external systems is a necessity. There are many challenges associated with supporting a large number of disparate, physics-based models and the computational infrastructure to support them. This paper will highlight the CCMCs past, present, and future computational infrastructure, and showcase several examples of how the CCMC continues to support many self-organized efforts in the space science community.

http://ccmc.gsfc.nasa.gov

Session 8: Space Weather and the Solar Cycle
Chair: Dibyendu Nandi and Manuela Temmer

The 11 year cycle of sunspots modulates the frequency of solar storms, the radiative output of the Sun and the solar wind thereby forcing the heliospheric environment and planetary atmospheres. Advance knowledge of solar cycle induced changes in the space environment is essential for planning for and protecting technological assets in space. A first principle based approach to gaining this knowledge requires an understanding of the solar magnetic cycle to extent that accurate predictions are possible. This session will focus on the physics of solar cycle forecasting and development of prediction models, impacts of decadal scale forcing of space and planetary environments and will critically assess future needs for transitioning from research to operational solar cycle forecasting.

28 Jan
11:35

Explorations of Solar Activity and the Heliophysical Environment

Madhulika Guhathakurta
Heliophysics Division, NASA Headquarters Washington DC 20546

As human activity expands into the solar system, the need for accurate space weather and space climate forecasting is expanding, too. Space probes are now orbiting or en route for flybys of Mercury, Venus, Earth and the Moon, Mars, Vesta, Ceres, Saturn, and Pluto. Agencies around the world are preparing to send robotic spacecraft into interplanetary space. Each of these missions (plus others on the drawing board) has a unique need to know when a solar storm will pass through its corner of space or how the subsequent solar cycle will behave. Ultimately, astronauts will follow, traveling beyond Earth orbit, and their need for interplanetary space weather and climate forecasting will be even more compelling.
Until recently, forecasters could scarcely predict space weather in the limited vicinity of Earth. Interplanetary forecasting was even more challenging. This began to change in 2006 with the launch of the twin STEREO probes followed almost four years later by the Solar Dynamics Observatory. These three spacecraft along with SOHO now surround the sun, monitoring active regions, flares, and coronal mass ejections around the full circumference of the star. No matter which way a solar storm travels, the STEREO-SOHO-SDO fleet can track it. Missions like SDO and Kepler are giving us a better view of sun-like stars and their inner workings to understand their cyclic behavior, while missions like MAVEN and JUNO are investigating interaction of solar radiation and solar wind with Mars upper atmosphere and Jupiters intense auroras, a branch of heliophysics called comparative heliophysics.
To capitalize on the science that will naturally emerge from the growth and modernization of the observational assets, researchers from many different fields will have to work together. Interplanetary space weather and climate forecasting is essentially interdisciplinary. Progress requires expertise in plasma physics, solar physics, weather forecasting, planetary atmospheres, and more. In the past, NASA has assembled such teams under the umbrella of virtual institutes, where widely dispersed researchers confer from a distance using the Internet and other

forms of tele-collaboration. Interplanetary space weather might call for a similar approach. One thing is sure: The Sun is not waiting and the stakes are as big as the solar system itself.

The solar-stellar connection can inform us about the long-term variation of the Sun, relevant for Space Climate.

28 Jan 12:00

Petrus C Martens
Georgia State University

The solar-stellar connection can inform us about the long-term variation of the Sun, relevant for Space Climate. Specifically we'd like to be able to construct a time-line for solar irradiance over the life of the Sun, using information derived from solar-type stars throughout their evolution. This is relevant for Earth's climate history, in particular with regard to the "Faint Young Sun Paradox", and consequently also for the evolution of life on our and other planets.

One consequence of stellar evolution theory, rarely mentioned, is that the habitable zone around stars moves outward as the star matures, due to the gradual but significant increase of stellar luminosity over the star's lifetime. Hence, ceteris paribus, planets that start out with conditions favorable for life, liquid water in particular, heat up astheir mother star grows older, and end up like Mercury or Venus. Meanwhile, planets further out will spend the first couple of billion years of their life in deep-freeze, not advantageous for the development of life, and once they melt may not have enough time for the development of multi-cellular organisms – that took four billion years on Earth.

I will discuss several possible scenarios that can resolve what is now "The Faint Young Stars Paradox". The most important one has to do with the fact that solar-type stars in general have their rotation slow down more rapidly than can be explained with standard theory, which is probably due to a combination of a different dynamo mode with a much higher rate of mass loss. I will explore that scenario in depth during my lecture and also refer to observations of Sun-like stars that can help solve this problem.

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28 Jan
12:25

Simulation and prediction of solar cycles

Mausumi Dikpati
NCAR/HAO

Solar activity cycle manifests in various forms, including waxing and waning in the number of sunspots with an average 11 year periodicity, reversal of the Sun's polar fields approximately every 11 years, and variations in the global structure of the corona. These have profound influence on the terrestrial system, producing beautiful aurorae as well as dreadful blackouts and causing damages in our technological society. The solar activity cycle is most likely caused by dynamo processes inside the Sun.However it is a formidable task to accurately predict the features of an upcoming cycle. Starting in the 1960s, following Ohl, solar cycle predictions have been made using empirical methods. After the failure of cycle 23 predictions, NASA and NOAA called for physics-based solar cycle predictions. To respond to that call, dynamo-based prediction schemes started to be developed, and certain properties of cycle 24 were predicted in 2006-2008. However, predictions for cycle 24 from physical models as well as empirical techniques covered a wide range, from a very weak cycle to a very strong one. Now we know that cycle 24 has not been strong. After reviewing various predictions of cycle 24, we will describe how to refine the model-based prediction scheme by incorporating the sophisticated modern data assimilation techniques like those being used in oceanic and atmospheric predictions over the past 40 years. After demonstrating how cycle 24 would have been predicted if modern data assimilation techniques would have been implemented, I will present results for how the minimum at the end of cycle 24 is going to look.

Models and data combined to progress towards a better understanding of the magnetism of solar-type stars

29 Jan
09:00

Laurene Jouve

IRAP Toulouse

We will review recent progress made in modeling solar-type stars in 2D and 3D in the recent years. In particular, we will focus on advances in our understanding of the dynamo processes in such astrophysical objects and the necessary ingredients to reproduce what is found in the observations. We will also present recent attempts to introduce such observational data into multi-D MHD models. The idea is to implement data assimilation techniques to solar physics in order to have some tools to give tentative predictions of future solar activity.

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29 Jan
09:25

Solar surface convection and the Solar Cycle

Arnold Hanslmeie

A. Hanslmeie (1), R. Muller (2), B. Lemmer (1)
(1) Institut fr Physik, Univ. Graz, Austria
(2) Observatoire Midi Pyrenees, Tarbes, France

We present results from Hinode data concerning the variation of solar surface convection over the ongoing activity cycle. Observations in the blue continuum were selected and the data segmented in order to calculate the number of convective cells, their surface area and their perimeter. These parameters then have been analyzed in order to find out whether there is a variation with solar activity cycle.
The variation found was small in amplitude, there seems to be a tendency toward smaller convective elements when solar activity increases. The results do not confirm suggestions from analyses made earlier by other authors.
Thus convection seems to be only marginally influenced by solar activity. The observed variations are compared with theoretical predictions that give a relation between the variation of the solar constant that is relevant for climate input and the convective parameters.

Kinematics of slow and fast CMEs in soar cycle 23 and 24

29 Jan
09:40

Dipankar Banerjee
Vaibhav Pant, Ankur Chauhan
Indian Institute Of Astrophysics

CMEs are episodic expulsion of plasma and magnetic fields from Sun into heliosphere. CMEs cn be classified, based on their speeds, as slow CMEs and fast CMEs. We find that slow CMEs and fast CMEs behave differently in two cycles. While fast CMEs seems to follow the sunspot variations, slow CMEs have much flatter distribution. Thus the distribution of total CMEs is affected by slow CME populations. We find double peak behaviour in fast CMEs, since they follow the sunspot distribution, in both the cycles without any significant delay from sunspot variation. It suggests that most of the fast CMEs originates from active regions associated with sunspots. We also find double peak behaviour in slow CMEs in cycle 24 but not in cycle 23. In addition to this the number of slow CMEs are far more than in cycle 23. These findings point towards the fact that in cycle 24 slow CMEs to some extent are associated with sunspots and due to weak heliospheric field they could somehow escape easily thus giving double peak behaviour and larger distribution in cycle 24. Apart from this we also find that slow and fast CMEs follow different power laws.

Session 9: Down to Earth: Coupling Space Weather and Atmospheric Response Chair: David Jackson

We are now approaching the point where we can start investigating Solar-Terrestrial relations from a systems point of view. The terrestrial system remains in a quasi-stationary state with respect to the solar energy inputs with the lower neutral atmosphere being especially stable. Of interest, in the study of the terrestrial response, is identifying which Solar influences are of most importance and how the terrestrial system (troposphere, stratosphere, mesosphere, thermosphere and ionosphere) accommodates the associated variability. Most of the solar variability is associated with the Solar wind and radiation in the ultra-violet and x-ray spectral regions. The magnitude of the resulting terrestrial response is roughly inversely proportional to the atmospheric density with very little direct response in the stratosphere and troposphere. Nevertheless, there is an indirect lower atmosphere response which is larger than expected. In addition, in recent years it has become clear that the lower atmosphere has considerable influence on the upper atmosphere through wave coupling. This session is directed toward identifying, the solar inputs of most importance to the terrestrial system, understanding how these inputs are accommodated, understanding wave coupling processes and investigating the causes of the terrestrial lower atmosphere response to solar variability. Contributions involving observational studies and models (including whole atmosphere models) which provide insights into which aspects of solar variability are of most importance and the nature of the terrestrial response are welcomed.

26 Jan
08:30

The Drivers of Space Weather in the Thermosphere Ionosphere System

Fuller-Rowell

Atmospheric Chemistry Observations and Modeling National Center for Atmospheric Research, Boulder, Colorado

The NCAR Whole Atmosphere Community Climate Model (WACCM) and its thermosphere/ionosphere extension (WACCM-X) provide powerful numerical tools for the study of Solar-Terrestrial connections on climate and weather timescales. This talk will provide an overview of the WACCM and WACCM-X models and their use in studies that seek to identify the coupling processes that link geospace and the terrestrial lower atmosphere. These studies include the response of the ionosphere to variability that originates in the troposphere and the response of the ozone layer to energetic particle precipitation, both of which depend on wave coupling. The talk will conclude with identifying key gaps in our quantifying the forcing of the terrestrial system and characterizing its response.

Energetic particle impact on the atmosphere and the link to regional climate: Observational constraints and current understanding

26 Jan
08:55

Bernd Funke

Instituto de Astrofsica de Andaluca (CSIC), Granada, Spain

Precipitating energetic particles from the sun and the magnetosphere affect the ionization levels in the polar middle and upper atmosphere, leading to significant changes of the chemical composition. In particular, the production of NOx and HOx imposes changes of ozone via catalytic cycles, potentially affecting temperature and winds. Vertical coupling of this signal to the lower atmosphere could provide a link between space weather in the form of energetic particle precipitation (EPP) and surface climate: model studies and the analysis of meteorological data have indeed provided evidence for EPP-induced climate variations on the regional scale. This talk summarizes recent progress in constraining the impact of EPP on the atmosphere with a special focus on observational results. Additionally, current capabilities and limitations in the representation of EPP impacts in climate studies will be discussed.

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26 Jan
09:20

Upper atmospheric dynamics: influence of solar radiation versus forcing from below

D Pallam Raju

Duggirala Pallamraju (1), Deepak K. Karan (1) and Fazlul I. Laskar (2)
(1) Physical Research Laboratory, Navrangpura, Ahmedabad, 380009
(2) Leibniz Institute of Atmospheric Physics, Kuehlungsborn, Germany, 18225

Earths upper atmosphere has conventionally been treated as being influenced by solar radiation. Until about a decade ago this notion had generally been considered to be valid. Owing to primarily the very low solar activity of cycle 24 and the preceding prolonged deep solar minima, several new insights have emerged in the recent past on the upper atmospheric influence with respect to both solar and lower atmospheric forcings. Coordinated investigations using multiple optical emissions originating at different latitudes/longitudes and radio measurements revealed several interesting aspects of vertical and horizontal coupling in the low-latitude thermosphere-ionosphere during daytime. The daytime optical measurements were enabled by multi-wavelength high spectral resolution imaging echelle grating spectrograph (MISE). MISE is capable of obtaining daytime optical emissions over a large field-of-view (140o) simultaneously at a high-data cadence (5 min.) at oxygen emissions wavelengths at 557.7 nm, 630.0 nm, and 777.4 nm that originate at around 130 km, 230 km, and peak height of the F-region, respectively. Continuous and systematic daytime optical emission intensity measurements carried out during 2000 2006 and from 2010 2015 from low- and mid-latitudes have revealed a systemic variation of thermospheric effects to varying solar activity. It is seen that during high solar activity period the daytime air glow emission intensities vary with the variation in solar flux indicating an unambiguous signature of solar forcing on the upper atmosphere. With reduction in the solar activity, large scale (planetary-size) waves from the lower atmosphere show their influence in the upper atmospheric parameters such as the optical emission intensities and GPS-TEC. Whereas, in the smaller scale (e.g., gravity wave) regime number of waves in the upper atmosphere increase with the increase in solar activity. With regard to the diurnal behavior of the optical emissions, they seem reasonably symmetric during low solar activity period whereas their behaviour seems asymmetric during high solar activity

period, which is attributed to be due to the greater electrodynamical influence of the equatorial processes in the low-latitude ionosphere thermosphere system. Further, based on the daytime optical emission measurements it has been revealed that during events such as, the Stratospheric Sudden Warmings, global scale wind circulation in the mesosphere lower thermosphere region is set up. Furthermore, due to large field of view measurements of the optical emission intensities, meridional / zonal scale sizes of neutral waves have been obtained in the daytime at the three altitudes of oxygen emissions. In addition to the diurnal variability, these show variability with regard to solar activity. These new results obtained recently reveal greater insights into the fundamental nature of coupling between the thermospheric regions in the daytime and their solar activity dependence. Some of the findings of these investigations will be presented and discussed.

26 Jan
09:45

Uncertainity Quantification of Ionosphere- Thermosphere Predictions

Ja Soon Shim

M. Mays, A. Taktakishvili, L. Rasttter, M. Kuznetsova, M. Codrescu, T. FullerRowell, M. Fedrizzi
CUA/NASA GSFC

The Community Coordinated Modeling Center (CCMC), which is an interagency partnership to enable, support and perform the research and development for next-generation space science and space weather models, has been leading community-wide model validation efforts for Ionosphere/Thermosphere (IT) models along with other models that cover different domains of the Sun-Earth system such as heliosphere and magnetosphere. Uncertainty quantification plays a critical role in model validation. As a preliminary study on uncertainty analysis, we investigate how uncertainty in external forcing such as geophysical parameter F10.7 and the interplanetary magnetic field (IMF) impacts on the IT model results during geomagnetic storm times (e.g., 2006 Dec. and 2013 Mar. events). For this study, CTIPe (Coupled Thermosphere Ionosphere Plasmasphere Electrodynamics) model is used. In addition to uncertainty in the external forcing, we also examine effects of the uncertainty in the O+- O momentum collision frequency, which is one of the most important uncertain parameters for IT modeling and represented by the Burnside factor. In this paper, we focus on the impact of the uncertainty of the parameters (F10.7, IMF and Burnside factor) on regional TEC (North American sector) and neutral and electron densities at the CHAMP orbit. Model output and observational data used for the validation study will be permanently posted at the CCMC website (http://ccmc.gsfc.nasa.gov) as a resource for the space science communities to use.

Session 10: Space Weather Effects on Technological and Biological Systems
Chair: Alexi Glover

The prediction of space environmental conditions and the mitigation of their impacts on life, society and its infrastructure are primary objectives of the discipline of space weather. Different types of space environments can affect different technologies. Examples of space weather impacts include: effects of geomagnetically induced fields and currents on power grids, satellite drag, satellite surface and internal charging, single event upsets, total dose effect, astronaut and aircrew exposure to space radiation, ionospheric scintillations, interference with GPS signals and HF communications, etc.. There is a need to quantify space weather effects on technological and biological systems and to understand which aspects of spatial and temporal characteristics of space environmental parameters are the most important for specific impacts. Linking modern space environment models with engineering models, which estimate impacts, is not only an essential component of the end-to-end Sun-to-Impact prediction system, but also a key to defining appropriate validation methods and metrics tailored for specific applications. As space weather services become more advanced and service user awareness grows, increasing opportunities are developing for partnership between service users and the scientific community towards further understanding the effects of the space environment on operators systems, and using this information to support the development of tailored applications. If made available, accessible space environment impacts databases could provide another important element that will facilitate assessment of space weather forecasting. The goal of this session is to facilitate bridging between space environment specification forecasting and applied aspects of space weather. As such, this session encourages presentations highlighting case studies of space weather effects on space and ground based systems. It will also focus on applications developed in collaboration with service users in order to monitor and predict these effects. Presenters are encouraged to highlight underpinning model development including validation work and space environment data used in each case, identifying the key parameters considered essential for their application, current availability, upcoming challenges and opportunities.

The semi-empirical thermosphere model DTM2013

29 Jan
14:00

Sean Bruinsma

CNES, dept. of Terrestrial and Planetary Geodesy, Toulouse, France

Atmospheric density models are used in satellite orbit determination and prediction programs to compute the atmospheric drag force, as well as in upper atmosphere studies. They represent temperature and (partial) density as a function of altitude, latitude, local solar time, day-of-year, and parameters related to the state of atmospheric heating due to solar EUV emissions and solar wind. One of the objectives of the Advanced Thermosphere Modelling for Orbit Prediction (ATMOP; www.atmop.eu) project was to develop a new semi-empirical thermosphere model, which is more accurate than the CIRA models (COSPAR International Reference Atmosphere) thanks to the assimilation of new data. DTM2013 is the final model of this project. DTM2013 was fitted to the complete CHAMP high-resolution density data set from 2000-2010, to GRACE density data for 2003-2010, and low-altitude (270 km) GOCE data from November 2009 through May 2012 in particular. High altitude density data as well as the Dynamics Explorer-2 and Atmosphere Explorer A/C/E mass spectrometer data have also been used. Daily-mean densities in the 200-500 km altitude range from the US Air Force were made available for validation. DTM2013 has the best overall fit to the density data when taking both assimilated and independent data into account. This presentation will describe DTM2013, its performance compared to the pre-ATMOP DTM2009 and the CIRA reference models JB2008 and NRLMSISE-00, as well as the errors and uncertainty in the data (due to simplified satellite models, mass spectrometer scale factors, etc), and the use of proxies for solar and geomagnetic activity.

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29 Jan
14:25

Spacecraft Charging and Auroral Boundary Predictions in Low Earth Orbit

Joseph I Minow

NASA

Spacecraft charging in space plasma environments is one example of an important impact of space weather on technological systems. Space weather models used to specify charging must be designed to provide the appropriate characteristics of the plasma environment responsible for charging and improvements in operational space weather prediction capabilities relevant to charging must be tested against charging observations. In addition, there is a need to predict auroral boundaries for space situational awareness applications when spacecraft operators need to know if their spacecraft are exposed to auroral environments regardless of charging behavior. This presentation will describe two applications in this area relevant to low Earth orbit spacecraft. We will first show examples of low Earth orbit charging from the International Space Station (ISS) and the Defense Meteorological Satellite Program (DMSP) to demonstrate the differences between charging driven by solar array interactions with the space plasma environment and auroral charging. Next, specific characteristics of charged particle environments that space weather models must provide in order to specify charging environments and auroral boundaries at high latitudes will be described. Finally, we will show examples of ISS and DMSP charging events and auroral boundaries from a Space Environment Impacts database and discuss how they can be used as a resource for assessing results from space weather predictions with an emphasis on the specification and prediction of auroral boundary locations.

Radiation Exposure Analysis for Crewed Missions

29 Jan
14:50

Dr. Guenther Reitz

Guenther Reitz Department of Radiation Biology, Institute of Aerospace Medicine, German Aerospace Center (DLR), 51477 Kln, Germany,

The radiation exposure during human missions can be reduced through constructive measures of the spacecraft and careful mission planning, but it cannot be prevented. There are two sources which determine the exposure; these are galactic cosmic rays (GCR) and solar cosmic rays (SCR).

GCR consist mainly of protons and heavier ions with very high energies up to 1011 GeV resulting in a high penetration depth in matter. Highest fluxes are observed at minimum solar activity and vice-verse With increasing depth in matter the production of secondary radiation increases. After a first decrease in exposure due to absorption of primary particles in spacecraft structures, secondary particle cause an increase in exposure until about 200 g cm-2, before it declines again. Hydrogen rich materials as structural materials instead of aluminum help to reduce the exposure, but only by a factor less than two. Recent measurements with the Radiation Assessment Detector (RAD) on the Mars Science Laboratory provided particle flux, absorbed dose and dose equivalent during the cruise and on the surface of Mars. The high level of detail of the data allow for bench marking of space radiation transport models and thereby supports predictive models for health risks of astronauts during space missions.

The solar component is released in coronal mass ejections and solar flares and consists mainly of protons, with a small amount of heavier particles. Energy spectra are different for each solar event, same holds for particle flux. Long term forecast of the events is not possible so far and probably also not in the future. Particle energies are mostly below 1 GeV, but in some very rare events up to several GeV can be reached. Large events occur regularly at increasing or decreasing solar activity, whereas in the maximum phase events are absent, but solar events could be observed sometimes during solar minimum, too. Provision of shielding shelters prevent a heightened exposure of astronauts in most cases and limit excessive exposure in case of extreme events to exposure values which are not life threatening. Precursor measurements for a now cast of events requires instrumentation onboard the spacecraft to allow astronauts to reach the shelter. On the moon excursions in the space suite requires special attention, whereas on Mars the situation is more relaxed due to at least 20 g cm-2 atmospheric shielding. Exploration spacecraft shielding should therefore focus on SCR instead on GCR. Since risks due to exposures by GCR cannot not be significantly reduced and whereas SCR exposures are manageable by shielding measures, a human trip to Mars during solar maximum seems the most probable one. A major risk reduction lies in the reduction of travel time, but requires new propulsion systems. The presentation will discuss the current knowledge on exposure levels and risks involved in interplanetary missions and the potential measures to mitigate these risks.

Session 11: Plenary Session on Aditya Chair: Dibyendu Nandi

The Indian solar mission Aditya-L1

25 Jan 14:15

S. Seetha
Space Science Programme Office ISRO

The Indian Space Research Organisation (ISRO) has recently launched a few satellites dedicated for planetary exploration and space science. The next goal in this roadmap is to launch a satellite to study the Sun with a suite of experiments. This will be another mission which will have participation from several institutions of India. This mission will carry onboard a solar coronagraph which will study the dynamics and origin of Coronal Mass Ejections in visible and IR channels; a NUV imaging telescope to study the solar Photosphere and Chromosphere and measure solar irradiance variations; two payloads to study the solar disc in low and high energy X-rays; two payloads to study the insitu charge particles, and a magnetometer to study magnetic field variations during energetic events. This talk will cover some of the salient features of the experiments and the overall mission.

List of Posters

Geo-effectiveness of magnetic clouds and their associated features 1

Muhammed Aslam OP

Badruddin
Department of Physics, AMU, Aligarh-202 002

Magnetic clouds observed in the near-earth space have different magnetic orientations, they move with different speed, and different features (e.g., shocks) are associates with them. The field orientation, their speed, and associated features are likely to influence the geo-effectiveness of individual magnetic cloud. We have isolated magnetic clouds with distinct properties and studied their relative geo-effectiveness. We have also searched for solar wind plasma and field parameters that play important role in influencing the geo-effectiveness of magnetic clouds. We find large differences in the geo-effectiveness of magnetic clouds with different field orientation and associated features. The implication of this study on the solar wind-magnetosphere coupling during the passage of magnetic clouds is also discussed.

2 **Sunspot cycle 24: Validation of our prediction model**

Nipa J Bhatt

Nipa J Bhatt (1) and Rajmal Jain (2)
(1) Physics Dept, C. U. Shah Science College, Ashram Road, Ahmedabad 380014, India.
(2) Research Cell, Kadi Sarva Vishwavidyalaya, Gandhinagar, India

Solar eruptions occur on a wide variety of scales depending upon the available magnetic energy, which, however, is drawn from sunspot magnetic fields. They influence space weather and sometimes create adverse impact on technological systems on which our society is progressively more dependent. In view of this Sun-Earth connection, the predictions of sunspot and geomagnetic activity are important. In order to predict the amplitude of sunspot cycle 24, we considered the long term data of international sunspot numbers and geomagnetic activity aa indices from year 1868 to 2008. Employing the precursor technique, we predicted the annual maximum amplitude for cycle 24 to be about 92.8 19.6 (1-sigma accuracy), indicating a somewhat weaker cycle 24 as compared to cycles 21-23 (Bhatt et al. 2009a). We have currently witnessed the solar maximum of cycle 24 with an annual mean of 79. This observed amplitude is within the range of our prediction. Further, we estimated the annual mean geomagnetic activity aa index for the solar maximum year in cycle 24 to be 20.6 4.7 (Bhatt et al. 2009b). The observed annual mean is 15.8. Owing to the extended minimum of cycle 23 upto 2009, we re-examine our prediction model in the light of observed international sunspot numbers as well as geomagnetic activity index which may help in improving the precision of prediction. The level of geomagnetic activity near the time of solar activity minimum seems to be a reliable indicator for the forecast of sunspot amplitude of the following solar activity maximum.

Models and data driven simulation of Solar eruptions [3]

Buechner, Joerg

Max Planck Institute for Solar System Research, Goettingen, Germany

We compare the main theoretical models of Solar eruptions causing flare eruptions and coronal mass ejections (CMEs) as they actually are considered with the results of numerical simulations of the Solar atmosphere based on data obtained by photospheric observations. We also compare our findings with current laboratory experiments carried out at the Princeton Plasma Physics Laboratory (MRX).

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4 Minor and Major geomanetic storms driven by similar CMEs

KyungSuk Cho
Korea Astronomy and Space Science Institute

Solar cycle 24 is very modest compared to previous solar cycles. During this period, it has been reported that only a few events produced strong X-class flares, fast Halo CMEs, solar proton events, and geomagnetic storms. In this study we have investigated the moderate geomagnetic storm ($Dst_{min} \sim$ -75 nT) occurred on September 12 2014 and the strong storm ($Dst_{min} \sim$ -223 nT) occurred on March 17 2015. The moderate storm is associated with X1.6 flare and the strong storms is associated with C9.1 flare. The storms with different strength are generated by the Coronal Mass Ejections (CMEs) with similar physical properties. Because the strength of the storms mainly come from the difference in the solar wind magnetic fields, we have investigated the magnetic field structures near the Earth by using the flux rope models and compared with detailed features of the CMEs to answer how the difference in the magnetic fields can be connected to the features of the active regions that produced the CMEs. It is found that the moderate storms is generated by the sheath region of ICME that erupted in the west part of the AR 12518 with left-hand (LH) helicity during the X1.6 flare. The ICME (flux rope) itself brought about the northward magnetic fields and caused the recovery of the magnetic storm. The magnetic geometry of the polarity inversion line (PIL) in the west part is well consistent with that of the IFR identified by adopting the Torus model based on LH helicity. An interesting point is that the Earth was located in the northward field throughout the passage of the interplanetary flux rope (IFR) although the IFR axis is directed southward. In case of the March 17 2015 event, the strong geomagnetic storm is generated by the fast halo CME associated with a filament eruption driven by the weak flare occurred at AR12297. Our IFR analysis reveals that the Earth passed the very position with southward fields near the surface of the IFR. The long passage of the Earth in the southward fields is the main cause of the strong storm. We conclude that the magnetic field structure of IFR controls the strength of geomagnetic storm, but the control changes depending on where the Earth was located in the IFR.

Magnetopause standoff position changes and its time-dependent response to solar wind conditions: Models and Observations 5

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NASA GSFC Space Weather Laboratory (674)

The Earth's magnetopause is the boundary that separates the solar wind with the Earth's magnetosphere. It's location has been studied and estimated via simulation models, observational data and empirical models. Accurately predicting the magnetopause location and dynamics is critical for space weather forecasting. This research aims to study the changes of the magnetopause standoff location due to different solar wind conditions using a combination of all the different methods. We will use the Run-On-Request capabilities within the MHD models available from the Community Coordinated Modeling Center (CCMC) at NASA Goddard Space Flight Center, specifically BATS-R-US, OpenGGCM, LFM and GUMICS models. The magnetopause standoff position prediction and response time to the solar wind changes will then be compared to results from available empirical models (e.g. Shue et al. 1998), and to THEMIS, Cluster and the Geotail missions magnetopause crossing observations. We will also use times of extreme solar wind conditions where magnetopause crossing have been observed by the GOES satellites. Rigorous analysis/comparison of observations and empirical models is critical in determining magnetosphere dynamics for model validation. We will identify which solar wind conditions affect the model predictions significantly and lead to differences between the models. Preliminary results show that there are some discrepancies between the MHD models standoff positions of the dayside magnetopause for the same solar wind conditions that include an increase in solar wind dynamic pressure and a step function in the IMF Bz component. In cases of nominal solar wind conditions, it has been observed that the models do agree with the observational data from the different satellite missions.

6 Pre-processing methods for energetic particle measurements

Ioannis Daglis

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One of the most important aspects in the development and evaluation of radiation environment models is the quality of the measurements. Such models usually incorporate data from different instruments on board satellites from various missions that may present caveats, such as spikes, discontinuities, saturation issues or increased background levels. Thus, before such an endeavor can be undertaken, the data must be carefully pre-processed and evaluated.

In this work, we launch a comparative study using several data cleaning methods on energetic flux data. We demonstrate our results, using a large number of different measurements from ESA radiation monitors and RBSP twin mission. The ultimate goal of this effort is to create a semi-automated method to flag datasets.

Acknowledgements: This work is performed in the framework of the Hellenic Evolution of Radiation data processing and Modeling of the Environment in Space (HERMES) project, implemented by IASA under ESA contract no. 4000112863/14/NL/HB.

Data Unfolding using Neural Networks

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Ioannis Daglis

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In this work we demonstrate a new approach for the inverse problem of unfolding energetic particle measurement based on the application of Artificial Neural Networks (ANN). We have used data from ESA Standard Radiation Environment Monitor (SREM). SREM detects high-energy electrons and protons and bins the measurements in fifteen counters of overlapping energy bands that are characterized by strong contamination.

AAN are information processing systems, inspired by biological neural networks, that are used to estimate functions that can depend on a large number of inputs and are generally unknown. ANNs have been employed in various and seemingly disparate fields and in the course of the last decades they have repeatedly proven their usefulness.

In this study, we use radial basis function ANNs to unfold proton and electron flux measurements of SREM units on-board INTEGRAL and GIOVEB satellites. The obtained results are evaluated successfully through extensive comparisons with SREM fluxes derived with the Singular Value Decomposition method as well as against NOAA GOES/EPS proton fluxes.

Acknowledgements: This work is performed in the framework of the Hellenic Evolution of Radiation data processing and Modeling of the Environment in Space (HERMES) project, implemented by IASA under ESA contract no. 4000112863/14/NL/HB.

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Calibration of Radiation Monitors

Ioannis Daglis

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Spacecrafts are exposed to several distinct radiation sources over their lifetime. The European Space Agency (ESA) systematically measures geo-space particle radiation with a number of radiation monitors on-board ESA missions. These measurements are valuable for the characterization of the particle radiation levels in the geo-space environment, resulting from solar eruptive events, radiation belt particles and galactic cosmic rays. In order to evaluate the measurements and derive reliable proton and electron fluxes, the determination of reliable response functions through experimental and numerical calibrations is needed. In this work, we present recent efforts for the determination of the response functions of the Radiation Environment Monitor (REM) on-board the STRV1c spacecraft, and the Radiation Monitor on-board the X-ray Multi Mirror (XMM) mission. Moreover, preliminary work on the Environmental Monitor Unit (EMU) unit on-board Galileo/GIOVE-B is also performed. The numerical calibrations are based on detailed Monte Carlo simulations by means of the GRAS/Geant4 software package. Our results are compared to available experimental data and previous simulations.

Acknowledgements: This work is performed in the framework of the Hellenic Evolution of Radiation data processing and Modeling of the Environment in Space (HERMES) project, implemented by IASA under ESA contract no. 4000112863/14/NL/HB.

THOR Turbulence Heating ObserveR

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Escoubet C. P.

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Turbulent fluctuations in astrophysical plasmas reach up to scales as large as stars, bubbles or clouds blown out by stellar winds, or even entire galaxies. However, most of the irreversible dissipation of energy within turbulent fluctuations occurs at the very small scales kinetic scales, where the plasma no longer behaves as a fluid and the properties of individual plasma species (electrons, protons, and other ions) become important. The energy transferred to different particle species, the acceleration of particles to high energiesall are strongly governed by kinetic processes that determine how the turbulent electromagnetic fluctuations dissipate. Thus, plasma processes at kinetic scales will directly affect the large-scale properties of plasma.

Turbulence Heating ObserveR (THOR) is the first mission ever flown in space dedicated to plasma turbulence. It will explore the kinetic plasma processes that determine the fundamental behavior of the majority of baryonic matter in the universe. THOR will lead to an understanding of the basic plasma heating and particle energization processes, of their effect on different plasma species and of their relative importance in different turbulent regimes. THOR will provide closure of these fundamental questions by making detailed in situ measurements of the closest available dilute and turbulent magnetized plasmas at unprecedented temporal and spatial resolution. THOR focuses on particular regions: pristine solar wind, Earths bow shock and interplanetary shocks, and compressed solar wind regions downstream of shocks. These regions are selected because of their differing turbulent fluctuation characteristics, and reflect similar astrophysical environments. THOR is a candidate for selection as the next ESA M4 mission and the science as well as the results of the on-going study, currently undertaken at ESA, will be presented.

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10 Sun-to-Earth Propagation and Geoeffectiveness of CMEs

Nat Gopalswamy

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We report on a study that compares the properties of corona mass ejections (CMEs) associated with magnetic clouds (MCs) during the first 73 months of solar cycles 23 and 24 in order to understand the low geoeffectiveness in cycle 24. Although the average sunspot number declined by about 40 percent compared to cycle 23, the number of MCs did not decline in cycle 24. The reduction in the CME rate seems to be energy dependent, showing a slight reduction in the fast and wide CMEs in cycle 24. The reduction in the strength of geomagnetic storms in cycle 24 as measured by the Dst index is a direct consequence of the reduction in the factor VBz (the product of the MC speed and the out-of-the-ecliptic component of the MC magnetic field). The reduction in MC-to-ambient total pressure in cycle 24 is compensated for by the reduction in the mean MC speed, resulting in the constancy of the dimensionless expansion rate at 1 AU. However, the MC size in cycle 24 was significantly smaller, which can be traced to the anomalous expansion of coronal mass ejections near the Sun reported by Gopalswamy et al. (2014a). One of the consequences of the anomalous expansion seems to be the larger heliocentric distance where the pressure balance between the CME flux ropes and the ambient medium occurs in cycle 24.

The Europlanet Horizon 2020 Planetary Space Weather Service 11

Manuel Grande

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PSWS is a European Union initiative to set in place a Planetary Space weather service for use by a community of Space Agencies, Scientists, Amateur observers and commerce to provide a space weather service covering the solar system planets and interplanetary space. PWSW will make five entirely new toolkits accessible to the research community and to industrial partners planning for space missions:

1. General planetary space weather toolkit

2. Novel event-diary toolkit aiming at predicting and detecting planetary events like meteor showers and impacts as well as three toolkits dedicated to the following key planetary environments:

3. Mars (in support of ESA ExoMars missions to be launched in 2016 and 2018)

4. Comets (building on the success of the ESA Rosetta mission)

5. Outer planets (in preparation for ESA JUICE mission to be launched in 2022)

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Successes and Challenges in Assessment of Space Science Models for Space Weather Applications

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Science for space weather is increasingly relying on numerical simulations. The community has recognized that due to the maturity and increasing complexity of state-of-the-art space weather models, there is a great need for a systematic and quantitative assessment of different modeling approaches. There is a need for performance tracking tools as well as the detailed feedback necessary to improve models. There is a challenge to identify and quantify physical phenomena in data and in models and to define an approach to measure model-data and model-model agreements. There is an even bigger challenge to find the way to quantify knowledge and understanding. Systematic evaluation of space environment models and tools and confidence assessment of space weather forecasting techniques and procedures are critical for development and further improvements of operational space weather prediction capabilities. Quantifying the confidence and predictive accuracy of model calculations is a key information needed for making high-consequence decisions. The approach to the validation, uncertainty assessment and to the format of the metrics is strongly dependent on specific applications and end user needs. There is a need to understand which aspects of spatial and temporal characteristics of space environment parameters are the most important for specific impacts on technological and biological systems. The presentation will review progress in on-going coordinated model validation activities and metrics studies, focus on tasks associated with model-data comparisons, such as appropriate metrics selection for specific applications, preparation of observational data, sensitivity analysis of model outputs to input parameters, boundary conditions, modeling assumptions, adjustable parameters. We will discuss ideas for community-wide initiatives to build upon successes and to address challenges of metrics and validation activities, to develop guidelines and procedures to trace improvements over time and to pave a path forward.

CIRs Observed by MSL/RAD on the Martian Surface 13

Henning Lohf

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Co-rotating Interaction Regions (CIRs) are recurrent Stream Interaction Regions in the solar wind which are stable transient plasma structures lasting several solar rotations. They can modulate Galactic Cosmic Rays (GCRs) and to some extent result in a modulation of GCR induced secondary energetic particles on the Martian surface. The Mars Science Laboratory/ Radiation Assessment Detector (MSL/RAD) has been measuring the Martian Surface Radiation Environment for more than three years and observes this modulation effect. We will show that the effect of CIRs can be measured on the Martian surface with MSL/RAD and this can be used to derive the arrival times of CIRs at Mars. These can provide (limited) solar wind plasma properties in the vicinity of Mars and thus serve as important constraints for modeling atmospheric response to variations in the solar wind. We use multi spacecraft observations of the solar wind and compare them with the heliospheric MHD Model ENLIL to verify that a certain class of dose rate variations we see on the Martian surface is due to CIRs. We use ballistic back-mapping as well as a time-shift algorithm to map the plasma properties measured at individual spacecraft locations and times to Mars. We compare these predictions with those of the CCMC ENLIL heliospheric MHD simulations.

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14 **Modelling and mitigation of GICs in the Australian power network**

Richard Marshall
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Geomagnetically Induced Currents (GICs) have been long been considered a hazard for power networks in high latitude regions due to the relatively intense overhead currents systems present during geomagnetic activity. More recently, studies have shown that power networks located in low-middle latitude regions such as South Africa (Gaunt and Coetzee, 2007), Spain (Torta et al., 2012), Brazil (Trivedi et al., 2007), Japan (Watari et al., 2009), China (Liu et al., 2009), New Zealand (Marshall et al., 2011) and Australia (Marshall et al., 2013) may also be at risk of GICs. The Australian power network spans large distances which provides an increased susceptibility to GICs. This paper discusses recent activities being conducted within Australia to better understand and mitigate the impacts of GICs in that region.

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15 **Magnetic reconnection vs. Kelvin-Helmholtz instability: is the debate really over?**

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Magnetic reconnection is widely considered as the main mechanism for plasma entry into the Earths magnetosphere. Another plasma entry mechanism called Kelvin-Helmholtz instability (KHI) is also known for decades to occur, when the Interplanetary Magnetic Field is oriented Northward. Over the past 10 years, the Cluster mission has brought a wealth of new results and shed a total new light on the KHI mechanism. Very recent statistics based on the Themis mission tend to confirm the importance of the KHI. Hence: is there a need to quantify plasma entry in the magnetosphere for these two mechanisms at the same time? Which observations would be then needed? A summary of these new results will be presented and an attempt of the new observations needed will be proposed.

Lessons from empirical space weather forecast models based on solar data

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Yong-Jae Moon
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For the last decade, we have developed several empirical space weather (solar flare, coronal mass ejections, solar proton event, and geomagnetic storm) forecast models based on solar data. In this talk we will review our main results and discuss scientific implications. First, we have examined solar flare (R) and CME occurrence probabilities depending on sunspot McIntosh classification, its area, and its area change. We find that sunspot area and its increase (a proxy of flux emergence) greatly enhance solar flare and CME occurrence rates for several sunspot classes. Second, a solar proton event (S) forecast model depending on flare parameters (flare strength, duration, and longitude) as well as CME parameters (speed and angular width) has been developed. We find that solar proton event probability strongly depends on these parameters and CME speed is well correlated with solar proton flux for disk events. We also developed a model to forecast the proton flux profiles for well-connected events. Third, we have developed an empirical storm (G) forecast model to predict the probability and strength of a storm using halo CME Dst storm data. For this we use storm probability maps depending on CME parameters such as speed, location, and earthward direction. We are also looking for geoeffective CME parameters such as cone model parameters and magnetic field orientation. Fourth, we have developed a full ice-cream cone model for CME 3-D parameters using single coronagraph data and found that the derived 3-D parameters are similar to those from stereoscopic methods using multi-spacecraft. Scientific lessons earned from the models will be discussed in view of future development.

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17 # Kinematics of CMEs seen through the Heliospheric Imager-1

Sudharshan Saranathan

Vaibhav Pant
Indian Institute of Astrophysics

Computer Aided CME Tracking (CACTus) is an automated software for tracking CMEs in coronagraphic data (C2/C3 on board SOHO and COR-2 on board STEREO) routinely. We developed an automated method of detecting, estimating the speed and planar width of CMEs in the heliosphere using the CACTus software in HI-1 field of view. We compared the speeds of CMEs in heliosphere with that of speeds derived from the coronagraphs on board STEREO COR-1 and COR-2 using manual and automated catalogs respectively. We segregated CMEs as slow and fast based on their speeds and found that on an average, slow CMEs accelerated while fast CMEs decelerated until they eventually achieved terminal speeds. Using this data we tested the drag model by Vrsnak et al and estimated the constraints on the drag coefficient.

Science of Turbulence and Reconnection interplay and its Effect on Particle Acceleration in the Magnetosphere [18]

R. P. Sharma

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Whistler waves are known to play a very crucial role in magnetic reconnection and have been a topic of interest from decades in the context of turbulence. In the present work we study the role that whistler wave plays in the formation of coherent structures while propagating in the pre-existing fully developed chain of magnetic islands. The governing dynamical equation of whistler wave in the presence of chain of magnetic islands has been derived and the investigation is carried out using numerical simulations and analytical tools. The scale size of the coherent structures obtained is found to be of the order of electron inertial length. Therefore, the present work may be the first step to understand how magnetic reconnection generated islands may lead to the localization of whistler waves. The presence of these localized structures indicates the generation of turbulence in the site of chain of magnetic islands which can eventually contribute to magnetic turbulence and hence particle acceleration. The obtained results become even more important in view of recent MMS mission which sharply focus on the electron scale size structures observed during reconnection process and on the role played by electron inertial effects, turbulent dissipation and particle acceleration. Relevance of the obtained results to spacecraft observations from THEMIS, Cluster and other space environment effects will also be discussed. * This work is partially supported by ISRO, India and DST, India.

19 **Validation of the CME Arrival Time and Geomagnetic forecast alerts under COMESEP**

Nandita Srivastava

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Under the EU FP7 project COMESEP (COronal Mass Ejections and Solar Energetic Particles), an automated space weather alert system has been developed for the estimated occurrence of SEP radiation and CME geomagnetic storms. It provides an estimation of the CME arrival probability and itslikely geo-effectiveness, based on CME parameters, as well as an estimate of the geomagnetic-storm duration. In this paper, we present an evaluation of the COMESEP Alert System based on a study of several geo-effective CMEs observed during 2014-2015. Based on the alerts released by the COMESEP tool, the validation of the forecast tool is done for a set of recent CME events in the following two ways. First the performance of the forecast tools is evaluated by comparing the actual arrival time of the CMEs estimated from measurements by in-situ spacecraft with that predicted by the COMESEP Alert System. Second, a comparison of the geomagnetic activity forecast with the actual geomagnetic storm occurrence has also been made in an attempt to test the tools for predicting geomagnetic activity. In addition, the COMESEP alerts have also been compared with the alerts of other existing space weather forecasting tools operated by NOAA's Space Weather Prediction Center (SWPC) and Community Coordinated Modeling Center (CCMC) of the GSFC. The results are important and will be used to improve the algorithms and tools implemented for automatically predicting the arrival time of CMEs and their geomagnetic impact.

Thermospheric and geomagnetic responses to interplanetary coronal mass ejections observed by ACE and GRACE: Statistical results

20

Manuela Temmer

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For the period July 2003 to August 2010, the interplanetary coronal mass ejection (ICME) catalogue maintained by Richardson and Cane lists 106 Earth-directed events, which have been measured in situ by plasma and field instruments on board the ACE satellite. We present a statistical investigation of the Earths thermospheric neutral density response by means of accelerometer measurements collected by the Gravity Recovery And Climate Experiment (GRACE) satellites, which are available for 104 ICMEs in the data set, and its relation to various geomagnetic indices and characteristic ICME parameters such as the impact speed (vmax), southward magnetic field strength (Bz). The majority of ICMEs causes a distinct density enhancement in the thermosphere, with up to a factor of 8 compared to the pre-event level. We find high correlations between ICME Bz and thermospheric density enhancements (approx. 0.9), while the correlation with the ICME impact speed is somewhat smaller (approx. 0.7). The geomagnetic indices revealing the highest correlations are Dst and SYM-H (approx. 0.9); the lowest correlations are obtained for Kp and AE (approx. 0.7), which show a nonlinear relation with the thermospheric density enhancements. Separating the response for the shock-sheath region and the magnetic structure of the ICME, we find that the Dst and SYM-H reveal a tighter relation to the Bz minimum in the magnetic structure of the ICME, whereas the polar cap indices show higher correlations with the Bz minimum in the shock-sheath region. Since the strength of the Bz componenteither in the sheath or in the magnetic structure of the ICMEis highly correlated (approx. 0.9) with the neutral density enhancement, we discuss the possibility of satellite orbital decay estimates based on magnetic field measurements at L1, i.e., before the ICME hits the Earth magnetosphere. These results are expected to further stimulate progress in space weather understanding and applications regarding satellite operations.

21 **The drag-based model application**

Tomislav Zic

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The drag-based model (DBM) is an analytical model appropriate for calculating kinematics of coronal mass ejections (CMEs) in the interplanetary space and allows the prediction of their arrival times and impact speeds at any point in the heliosphere (target). The model is based on the assumption that beyond a distance of about 20 solar radii from the Sun, the dominant force acting on CMEs is the aerodynamic drag force. In the previously used form of DBM, the input parameters of the model are chosen on statistical basis, considering average and unperturbed conditions in the interplanetary space and common CME properties which are not necessarily appropriate for a particular CME under study. Therefore, we advanced the model, providing a DBM usage in a perturbed and time dependent environment without constraint on the distances above 20 solar radii. A modified and extended version of DBM is suitable for various applications, starting from automatic least-square fitting on initially detected CME kinematic data suitable for a real-time space-weather forecasting system, and ending with an embedding of the DBM into various numerical simulations of the interplanetary ambient conditions (solar wind speed, density, CMECME interactions, etc.). For example, the DBM could be embedded into numerical codes of ENLIL, EUHFORIA, and similar advanced numerical models. A demonstration and evaluation of already available versions of the tool are discussed, and their feasibility of synergy with different numerical models is presented. Various DBM versions are available at web-site: http://www.geof.unizg.hr/ tzic/dbm.html. We acknowledge the support of European Social Fund under the PoKRet project.

Sun-Earth Connection of an Earth Directed CME Magnetic Flux-Rope 22

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Coronal mass ejections (CMEs) are magnetically driven events whose disturbance in the outer corona influences the space-whether to a wide-range. On the sun, most of the observed features of these eruptions are described by magnetic flux rope (MFR) based models. On this perspective, we investigated an eruption event of a CME MFR from the source active region (AR) NOAA 11719 on 2013 April 11 utilizing observations from the Solar Dynamic Observatory, the Solar Terrestrial Relations Observatory, the Solar and Heliospheric Observatory, and the WIND spacecraft. The source AR consists of a pre-existing sigmoidal structure stacked over a filament channel which is regarded as an MFR system. EUV observations of low corona suggest further development of this MFR system by added axial flux through tether-cutting reconnection of loops at the middle of the sigmoid under the influence of continuous slow flux motions for two days. Our study implies that the MFR system in the AR is initiated to upward motion by kink instability and further driven by torus instability. The CME morphology, captured in simultaneous three-point coronagraph observations, is fitted with a Graduated Cylindrical Shell (GCS) model and discerns an MFR topology with its orientation aligning with a magnetic neutral line in the source AR. This MFR expands self-similarly and is found to have source AR twist signatures in the associated near-Earth magnetic cloud (MC). We further derived the kinematics of this CME propagation by employing a plethora of stereoscopic as well as single-spacecraft reconstruction techniques. While stereoscopic methods perform relatively poorly compared to other methods, fitting methods worked best in estimating the arrival time of the CME compared to in situ measurements. Supplied with the values of constrained solar wind velocity, drag parameter, and three-dimensional kinematics from the GCS fit, we construct CME kinematics from the drag-based model consistent with in situ MC arrival.

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Zenith-Angle Dependence of the Martian Radiation Environment at Gale Crater Altitudes

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We report the zenith-angle dependence of the radiation environment at Gale Crater on Mars. This is the first determination of this dependence on another planet than Earth and is important for future human exploration of Mars and understanding radiation effects in the Martian regolith. Within the narrow range of tilt angles experienced by Curiosity on Mars, we find a dependence $J \propto \cos^{\gamma'}(\theta)$ with $\gamma' = 1.18 \pm 0.07$, which is not too different from an isotropic radiation field and quite different from that at sea level on Earth where $\gamma' \approx 2.0$.

Tracing Heliospheric Structures to Their Solar Origin 24

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The solar wind creates a plasma bubble in our immediate, very local interstellar medium (VLISM), the heliosphere. Its structure is determined by dynamic processes and by the boundary conditions at the Sun and in the VLISM. Because of the supersonic expansion of the solar wind the structure of the inner (several AU) heliosphere is (nearly) exclusively determined by the Sun. As simple as this may all appear, the problem of linking heliospheric structure to solar features is remarkably complex and has so far eluded satisfactory solutions. ESA and NASA have implemented the Solar Orbiter and Solar Probe Plus missions to tackle and solve the mystery of how the Sun creates and controls the heliosphere. Previous missions, especially the twin Helios mission, lacked two crucial elements, remote-sensing of solar features and their dynamics, and composition measurements of the solar plasma, wind, and energetic particles. Solar Orbiter has both elements in its highly sophisticated payload and will allow us to link solar features to the solar wind sampled in situ by using composition and energetic particles as tracers. The composition of the solar wind is altered from its photospheric origin by two processes very probably acting at different altitudes in the solar atmosphere. Elemental composition of the solar wind appears to be fractionated by its First Ionization Potential (FIP) or time (FIT), indicating that some mechanism separates neutral atoms from ions. This requires temperatures low enough to allow a substantial neutral fraction of the solar plasma and therefore the FIP-effect is believed to act primarily in the chromosphere. Charge states on the other hand are determined by the expansion and acceleration of the solar wind and the electron temperature high in the corona. In the case of energetic particles, charge state composition affects measured elemental abundances by m/q-dependent acceleration/fractionation processes. Solar Orbiter will allow remote-sensing measurements of the elemental composition and, to a limited degree source temperatures of solar features such as coronal holes, active regions, or even flares. Comparison with in situ measurements of solar wind and energetic particle composition and their timing will provide key information about the linkage between Sun and heliosphere.

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Developing a Magnetofrictional model to study the solar corona

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The solar corona spews out vast amounts of magnetized plasma into the heliosphere which has a direct impact on the Earth's magnetosphere. Thus it is important that we develop an understanding of the dynamics of the solar corona. With our present technology it has not been possible to generate 3D magnetic maps of the solar corona, this warrants the use of numerical simulations to study the coronal magnetic field. A very popular method of doing this, is to extrapolate the photospheric magnetic field using NLFF or PFSS codes. However the extrapolations at different time intervals are completely independent of each other and do not capture the temporal evolution of magnetic fields. On the other hand full MHD simulations of the global coronal field, apart from being computationally very expensive would be physically less transparent, owing to the large number of free parameters that are typically used in such codes. This brings us to the Magnetofrictional model which is relatively simpler and computationally more economic.

Temperature of a Hot Flux Rope

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Identifying structures corresponding to hot and cool temperatures separately is a challenging task using images of wide passbands such as that of SDO/AIA, wherein higher temperature channels like 94 (FeXVIII) and 131A (FeXXI) are contaminated with cooler FeX and FeVIII emissions. In order to identify high temperature structures in an erupting filament event that occurred on Oct 31, 2010, a method contrived by Warren et al. (2012) is applied to separate the cooler emission from the 94A channel. The kinematics of the filament eruption is also studied along with the identification of an associated flux rope. The flux rope is only seen in the 94 and 131 A channels. The applied algorithm confirms the temperature of the flux rope corresponding to FeXVIII emissions. DEM analysis is also conducted on the flux rope to compare the temperatures obtained using the two methods. An alternate method to remove the cool components provided by Del Zanna (2013) is also applied to the eruption of Oct 31 to compare the results with that of Warren et al (2013). Most of the results related to the structure of the flux rope and filament are similar except the emission from the rising filament, which is lesser in Del Zanna (2013).

27 Interplanetary propagation of CME in the inner Heliosphere

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RAC, NCRA-TIFR

In this paper, we present the study of an intense X-ray flare event (X2.7) occurred on 05 May 2015 at 22:08 UT, close to the east limb of the Sun. This event is one of the bright few events of the current solar cycle, which seems to be low in activity in comparison with recent previous cycles. We present the multi-wavelength analysis of the above flare and the associated coronal mass ejection (CME) using measurements from ground- and space-based observatories. When the X-ray flux was in the increasing phase, the extreme ultra violet images obtained from the SDO space mission recorded a fast moving ejection from the flare site at heights less than about 0.4 Rsun above the surface of the Sun. The shock associated with this ejection propagated with a speed of 1100 km/s as indicated by the type-II radio burst in the frequency range of 30-80 MHz. However, the CME marginally decelerated in the LASCO field of view and again got accelerated in the Sun to 1 AU distance range as revealed by the interplanetary scintillation images obtained from the Ooty Radio Telescope. Results on the speed profile of the CME and its rate of expansion are discussed on possible space weather consequences.

Investigation of Major Solar Eruptions of Solar Cycle 23 and 24 and their geoeffectiveness 28

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The fiery Sun goes through some markedly different cycles and causes change in the geospace environment. The Coronal Mass Ejections (CME) is the major cause of geomagnetic storms, when its direction is towards the Earth. These CMEs erupt from the outer atmosphere of the sun (corona) in the form of closed loops having magnetised plasma inside. The intensity of the geomagnetic storm depends on the product of the solarwind speed and the value of Bz, which intensify the ring current when the time duration Bz remains negative. Owing to the weak polar magnetic field, the solar cycle 23 went into a prolonged minimum characterized by unusually large number of days without sunspots. This was marked by the reduced number of geomagnetic intense events during solar cycle 24 compared to solar cycle 23, even though the number of CMEs is same. To investigate this, the average values of CME speed and Dst index for the moderate and intense events of solar cycle 23 and 24 is compared. An interplanetary magnetic flux rope is the major cause of large geomagnetic storms. To examine the effect of the type of ICME (i.e. Magnetic cloud, Ejecta or Sheath) giving moderate or intense geomagnetic storm, the ascending phase of the solar cycle 23 and 24 will be investigated. However, the excess CME expansion contributes to the diminished effectiveness of CMEs in producing magnetic storms during cycle 24, due to the fact that the magnetic content of the CMEs is diluted and ambient fields has weakened (Gopalswamy 2014). Some of the results regarding the intense and moderate events for solar cycle 23 and 24 and the geoeffctiveness will be discussed in the meeting.

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29 Modeling The Impact of Geomagnetic Disturbance on New York State Power Transmission System

Ouedraogo Djibrina

QCC Solar and Atmospheric Physics Research Program

The New York City (NYC) power grid is a complex electrical apparatus that has well known sensitivities to space weather disturbances. Events produced by space weather includes solar storms or geomagnetic disturbances [GMD]. The propagation of such events in the direction of Earth perturbs the electric currents in the magnetosphere and the ionosphere, causing a unique effect known as a Geomagnetically Induced Current [GIC]. GICs are known to saturate and overheat transformers in the power grid, threatening the safe operation of the power system. A GMD induces a geoelectric field in high-voltage and extra high-voltage transmission circuits. This geoelectric field represents electromotive force, and causes GICs to circulate through transmission circuits and transformers. Power models were developed using MATLAB/Simulink software to simulate the propagation of GIC flows in a power system, while using New York State (NYS) power transmission network as an example. In phase I, we presented results of the models used to assess the impacts of possible GMD strikes on the various parts of the power network in upstate New York. In Phase II, we are currently looking at GMD strikes on the New York City power network. The results could have consequences for other large cities.

Nonlinearity and turbulence in plasmas 30

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Waves and instabilities play a very crucial role in astrophysical plasmas e.g. solar wind, Geospace etc. The investigation of the importance of nonlinear processes has been done to understand the physical mechanism behind the magnetopause turbulence. In space plasmas the modes of energy transfer are primarily the magnetohyrodynamic waves, e.g., kinetic Alfvn wave (KAW) and fast magnetosonic waves. A set of dimensionless equations has been derived taking ponderomotive nonlinearity into account due to KAW in the fast magnetosonic wave dynamics. Numerical simulation of the coupled equations has been performed for intermediate beta plasma applicable to the magnetopause. The numerical prediction of power law scaling is just consistent with the observation of THEMIS spacecraft in the magnetopause. The results also show the appearance of localized structures of KAW, which may be accountable for the heating and acceleration of plasma.

Polar Predictions with a Surface Flux Transport Model 31

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Surface Flux Transport Models study the spatio-temporal evolution of the magnetic field on the solar photosphere. Observational data driven SFT models can give a good estimate of the strength of polar fields. Since the polar field at the end of a cycle is known to be strongly correlated with the amplitude of the subsequent sunspot cycle, data driven SFT modelling of the polar field can extend the prediction window by a full cycle. Our aim is to develop a SFT model for prediction of polar flux and finally couple this with a dynamo model for extended solar cycle forecasts.

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32 Equatorial and low latitude Ionospheric Response to Some of the Space Weather Events over Indian region

Ram Singh

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Geomagnetic storms are the most important Space Weather phenomena from the point of view of the impact on the global magnetosphere-thermosphere ionosphere system. The storm is supplied by solar wind energy, captured by the magnetosphere, and transformed and dissipated in the high latitude upper atmosphere. It affects the complex morphology of the electric currents, winds, temperature and neutral composition, and it causes changes in the state of ionospheric ionization. Studies of the ionospheric reaction to geomagnetic storms are of great importance because they can impact ground and space based technological systems such as Global Navigation Satellite Systems (GNSS) etc. In the current solar cycle-24 solar activity during the 17 March 2015 produced a very strong Geomagnetic storm which reached intense geomagnetic activity level. During this strong geomagnetic storm event the significant effects observed on the equatorial and low latitude ionosphere over Indian sector. Data obtained from the ground based CADI Ionosonde at Tirunelveli (8.730 N, 77.700 E) and Allahabad (25.450 N, 81.850 E), GPS receivers, magnetometer (Alibag and Tirunelveli) over Indian region and space based ACE satellite Data for magnetospheric conditions etc.

Investigating the cause of fewer geomagnetic storms during the higher peak of the double-peaked sunspot cycle 24 33

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The Solar Cycle 24 showed two distinct sunspot number peaks in 2012 and 2014. Although the peak in 2014 was higher, the number of major geomagnetic disturbances during the 2014 peak was lower than that compared to 2012. It is thought that major geomagnetic disturbances are usually associated with CMEs having high velocities. It has also been shown in some studies that fast CMEs are associated with solar active regions having high values of certain magnetic parameters such as flux and non-potentiality. We show in our statistical analysis that the subset of active regions which could be associated with CMEs and contributed to the 2012 peak had higher values of these magnetic parameters compared to active regions which contributed to the 2014 peak. This provides a possible explanation for the higher number of geomagnetic disturbances during the first, weaker peak of solar cycle 24 in 2012.

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Temporal evolution of linear kinetic Alfvn waves in inhomogeneous plasmas and turbulence generation

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The coronal ion heating in the Sun is primarily considered due to Alfvn wave dissipation. The Hinode data which has provided strong evidence for the presence of Alfvn waves in the corona and in coronal loops, has lead laboratory investigations and numerical simulations of Alfvn wave propagation and damping. The inhomogeneous plasmas with steep density gradients can be employed to study such phenomenon in relatively shorter systems. This article presents a model for the propagation of Kinetic Alfvn waves (KAWs) in inhomogeneous plasma when the inhomogeneity is in transverse and parallel directions relative to the background magnetic field. The semi-analytical technique and numerical simulations have been performed to study the KAW dynamics when plasma inhomogeneity is incorporated in the dynamics. The model equations are solved in order to study the localization of KAW and their magnetic power spectrum which indicates the direct transfer of energy from lower to higher wave numbers as well as frequencies. The inhomogeneity scale lengths in both directions may control the nature of fluctuations and localization of the waves and play a very important role in the turbulence generation and its level. We present a theoretical study of the localization of KAWs, variations in magnetic field amplitude in time, and variation in the frequency spectra arising from inhomogeneities. The relevance of the model to space and laboratory observations is discussed.

Investigation of Coronal and Interplanetary Shocks and their associated Solar activities

35

Suresh K

Madurai Kamaraj University

The type II bursts are assumed to be driven by CME in coronal and interplanetary space. Sometimes, multiple type II bursts are encountered in the dynamic spectrum. From these studies, the sources for these bursts might be CMEs front and flank or CMEs nose and the interaction region between CME and streamer. In this paper, we derive the relationship between the CMEs and its associated multiple bursts. For this, we have chose the event on December 31, 2007. Two bursts were reported for the time span of 10 minutes. Of which, firsts one was started at 00:54 UT and other was at 01:05 UT. We have carried out this work to support the result that either one of the type II bursts is driven by nose of the CME while other is not. Our main aim of this work is to point out which one of the type II burst were occurred at nose of the CME, that is, to determine the type II burst which associated with the shock ahead of CME continuously from close to the sun to the outer corona. Also, we derived the relationship between multiple type II bursts with coronal and interplanetary shocks. If the one of the type II bursts were generated at the interaction region, then it should not have continued up to the outer corona since the interaction between CME and streamer is very weak at the larger distances since it deflect one another. Based on our studies, we may concluded that the probability of association between first type II burst and shock ahead of CME is high and we obtained this relationship up to outer corona.

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Localization of Circularly Polarized Dispersive Alfvn Wave in Solar wind plasmas

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Solar wind turbulence at large inertial scales is well known for decades and believed to consist of Alfvn cascade. The inertial range of Solar wind turbulence can be described by a magnetohydrodynamic model. But at small scales the MHD description is not valid. At scales of the order of proton inertial length, Alfvn cascade excites kinetic Alfvn wave or fast wave or whistler wave that carries wave energy to smaller scales. On the other hand, parallel propagating right(R) and left(L) circularly polarized Alfvn/ ion cyclotron wave in the framework of Hall MHD are also thought to be essential ingredients of the solar wind turbulence. Recently, He et.al[1] have used the magnetic field data from the STEREO spacecraft to calculate the magnetic helicities in the solar wind turbulence and reported the possible existence of Alfvn - cyclotron waves and their coexistence with the right handed polarized fluctuations. In the present article we intend to study the right circularly polarized dispersive Alfvn wave (DAW) and their role in the solar wind turbulence. The inclusion of the Hall term causes the dispersion of the AW which, in the present study, is considered on account of the finite frequency (frequency comparable to ion gyro frequency) of the pump wave. Filamentation instability has been reported to occur for the case of circularly polarized dispersive Alfvn wave (DAW) propagating parallel to ambient magnetic field. In the present study, the instability arises on account of the transverse density perturbations of the acoustic wave that may couple nonlinearly with the Alfvn wave and the driven ponderomotive force sequentially leads to growth of density perturbations. Numerical simulation involves finite difference method for the time domain and pseudo spectral method for the spatial domain. The power spectrum is investigated which shows a steepening for scales larger than the proton inertial length. These findings have been reported by Alexandrova et al. [2], using the data obtained from the CLUSTER spacecraft.

Automated Detection of CMEs in heliosphere

Vaibhav Pant

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Computer Aided CME Tracking (CACTus) is a automated software developed in Royal Observatory Of Belgium to detect CMEs automatically in coronagraphic data. Until today CACTus is compatible with LASCO and SECCHI(COR-2) coronagraphic images.I tried to expand the current limitations of CACTus and used it to automatically track CMEs in heliosphere using HI-1 on board STEREO. Method of detection is based on the principle of Hough transform, a technique of detecting ridges in noisy data. The CME signal in HI images is comparable to background corona and Hough transform is very sensitive to noise. Therefore, in order to extract the CME signal from background corona, we performed pre-processing of HI images to reduce the influence of stars and planets. We compared our detection with the manually created catalogs and find satisfactory results. The catalog will be available online soon and detection procedures will be added to NASA pipeline.

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38 Interplanetary parameters of ICME/IP shock associated with solar eruptive events

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In the present work, we considered a set of 101 Interplanetary Coronal Mass Ejection (ICME) associated with solar eruptive events observed during the period 1997 2005 [listed by Manoharan et al. (2004) and Mujiber Rahman et al. (2013)]. The interplanetary parameters like solar wind speed, density, magnetic field, shock strength are obtained from ACE (Advanced Composition Explorer)/Wind spacecraft observations reported in OMNI (Operating Missions as a Node on the Internet) data base. Comparing these events with the list available in Cane and Richardson catalog, the duration of ICME is identified for 52 events and the radial width of ICME is determined. The range of radial width lies between 6 100 Ro for majority of the events consistent with the reported results. Also, the dependence of ICME parameters with respect to source longitude is analysed.

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39 Study of Low Latitude Pc3 Magnetic Pulsations in South-East Australia and Their Dependence on Solar Wind Velocity

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Magnetic pulsations recorded on the ground are the signatures of the integrated signals from the magnetosphere. Pc3 Geomagnetic pulsations are quasi-sinusoidal variations in the earths magnetic field in the period range 10-45 seconds. The magnitude of these pulsations ranges from fraction of a nT (nano Tesla) to several nT. These pulsations can be observed in a number of ways. However the application of ground based magnetometer arrays has proved to be one of the most successful methods of studying the spatial structure of hydromagnetic waves in the earths magnetosphere. The solar wind provides the energy for the earths magnetospheric processes. Pc3-5 geomagnetic pulsations can be generated either externally or internally with respect to the magnetosphere.

The Pc3 studies undertaken in the past have been confined to middle and high latitudes. The spatial and temporal variations observed in Pc3 occurrence are of vital importance because they provide evidence which can be directly related to wave generation mechanisms both inside and external to the magnetosphere. At low latitudes (L less than 3) wave energy predominates in the Pc3 band and the spatial characteristics of these pulsations have received little attention in the past. An array of four low latitude induction coil magnetometers was established in south-east Australia over a longitudinal range of 17 degrees at L=1.8 to 2.7 for carrying out the study of the effect of the solar wind velocity on these pulsations. Digital dynamic spectra showing Pc3 pulsation activity over a period of about six months have been used to evaluate Pc3 pulsation occurrence.

Pc3 occurrence probability at low latitudes has been found to be dominant for the solar wind velocity in the range 320-700 Km/sec. The results suggest that solar wind controls Pc3 occurrence through a mechanism in which Pc3 wave energy is convected through the magnetosheath and coupled to the standing oscillations of magnetospheric field lines. Evanescent surface waves on the magnetopause (one possible source of Pc3 waves) may find it difficult to penetrate to these low L-values. Waves generated at the bow shock, swept into the magnetosheath and subsequently coupling into the field line resonance are better candidates. The Match number dependence of the bow shock characteristics provides a natural link between Pc3 occurrence and solar wind velocity.

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CME Propagation-Where Does Aerodynamic Drag Take Over

Manolis Georgoulis

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We outline a method to infer the magnetic-field magnitude of coronal mass ejections (CMEs) by monitoring the relative magnetic helicity of the source solar active regions and tracking differences between helicity budgets in the pre- and post-eruption phases. Due to the conservative property of the relative magnetic helicity in plasmas of high magnetic Reynolds number, appreciable helicity differences attributed to solar eruptions may be assigned to the resulting CMEs. The CME magnetic field is estimated by this principle, also taking into account near-Sun geometrical constraints (i.e., flux-rope length and radius), inferred by forward modeling of STEREO and/or SOHO coronagraphic observations. We then extrapolate parametrically the inferred near-Sun CME magnetic field to 1 AU and compare with ICME magnetic-field measurements at L1. Using plausible CME helicity budgets, we obtain a significant qualitative agreement between model prediction and observations that may pave the way for the application of the method to observed CME - ICME sequences. Combined with assessments of the ICME arrival time and axis orientation, this information could conceivably lead to a viable geoeffectiveness assessment of an observed CME tens of hours in advance of its encounter with geospace. Challenges and potential obstacles toward an automated geoeffectiveness prediction of CMEs are discussed.

This research has been partly co-financed by the European Union and Greek National funds through an Operational Program of the National Strategic Reference Framework (NSRF) Research Funding Program: "Thales: investing in knowledge society through the European Social Fund".

Space Weather Research, Education and Development Initiative (SW REDI) at CCMC

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Yihua Zheng

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Space Weather Research, Education and Development Initiative (SW REDI) at the Community Coordinated Modeling Center was established in 2012 with the goal of promoting space environment awareness as an important component of next generations core education, facilitating establishment of space weather programs at universities worldwide, and providing internship opportunities at CCMC to develop skills beneficial for any future career pursuit. Since its establishment, a core signature of SW REDI is the 2-week long annual space weather bootcamp held in the first two weeks of June. Interspersed in between are also the shorter duration (1-3 days), tailored space weather training opportunities. Past bootcamps have attracted and benefited participants from several countries and with diverse backgrounds, from high school students, undergraduates, graduates, scientists, engineers and other professionals. We welcome collaboration opportunities with professors/space weather professionals worldwide for further improvement of the training materials and for other educational efforts.

42 Solar Low Energy X-ray Spectrometer (SoLEXS) on-board Aditya-L1

Sankarasubramanian
ISRO Satellite Centre

A soft X-ray spectrometer is being developed to study the solar flare spectra in the energy range of 1 - 30keV. The objective of this instrument is to obtain the sun-as-as-star flare spectra for all classes of flare using a single instrument with a moderate spectral resolution (less than 4 percent at 6keV) allowing us to model the coronal physical parameters including abundances with better accuracy compared to RHESSI. The instrument will utilize the high count rate capability of Silicon Drift Detector (SDD) to look at the Sun. This instrument is also designed to provide flare trigger to other instruments on-board Aditya-L1 to optimize their observing mode. The status of this instrument and its first result will be discussed in this paper.

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43 HEL1OS (High Energy L1 Orbiting X-ray Spectrometer) on Aditya-L1

Vivek Kumar Agrawal
Manju Shudhakar
ISRO Satellite Center

HEL1OS is being designed with the aim to study particle acceleration during the impulsive phase of solar flares in the energy range 10 keV to 150 keV. HEL1OS is one among a suite of instruments to be flown on ISROs upcoming Aditya-L1 mission. HEL1OS consists of two pairs of detectors, each suited for a different energy range: two CdTe (Cadmium Telluride) detectors with a combined area of 0.5 cm2, for the 10 keV to 40 keV energy range, and two CdZnTe (Cadmium Zinc Telluride) detectors, with a combined area of 32 cm2, for the 20 keV to 150 keV energy range. The instrumental FOV (field of view) of 60x60 is maintained using a stainless steel collimator. We are currently developing the Engineering Model of HEL1OS. In this poster, we present some of the experimental results of the characterization of the Engineering Model.

Visible Emission Line Coronagraph on Board Aditya-L1 44

Dipankar Banerjee

Indian Institute of Astrophysics

Aditya is India's first dedicated scientific mission to study the sun. Visible Emission line Coronagraph (VELC) will image the solar corona and perform the spectroscopic observations. Spectroscopy and Spectro-polarimetric capabilities are key features of this payload. The Coronagraph will have a FOV up to 3 Ro and will image the solar corona from 1.05Ro to 3Ro at 500nm with an image scale of 2.51 arc sec / pixel. The multi-slit spectrograph is designed to study the solar corona in the three emission lines at 530.3nm, 789.2nm and 1074.7nm. A combination of imaging and spectroscopy in Multi-wavelength will enhance our understanding of the solar atmosphere. Modeling of the three-dimensional structure of the solar corona requires an accurate empirical description of the coronal plasma parameters (densities, temperatures, and velocities) for the coronal plasma. The spectroscopic instruments on board Aditya will enable us to measure these plasma parameters for a diagnostics of the corona and the solar wind.

45 ## The Solar Ultraviolet Imaging Telescope on board Aditya-L1 Mission

Durgesh Tripathi
IUCAA

The Solar Ultraviolet Imaging Telescope (SUIT) is an instrument onboard the Aditya-L1 spacecraft, the first dedicated solar mission of the Indian Space Research Organization (ISRO), which will be put in a halo orbit at the Sun-Earth Langrage point (L1). SUIT uses an off-axis RitcheyChrtien configuration telescope with a combination of 11 narrow and broad bandpass filters that will take images of the full solar disk in the UV wavelength range 200-400 nm. It will provide near simultaneous observations of lower and middle layers of he solar atmosphere, namely the Photosphere, Chromosphere and lower transition region. These observations will help to improve our understanding of coupling and dynamics of various layers of the solar atmosphere, mechanisms responsible for stability, dynamics and eruption of solar prominences and CMEs, and possible causes of solar irradiance variability in the NUV region, which is of central interest for the Suns influence on climate.

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46 ## Solar wind exploration using Plasma Analyser Package for Aditya (PAPA) payload onboard Aditya-L1 Mission

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Solar wind is a magnetized plasma consisting of charged particles (protons, alpha particles, electrons, and heavier ionized atoms, with magnetic field embedded in it) flowing out of the Sun in all directions at very high speeds -an average of about 400 km/sec. Plasma Analyser Package for Aditya (PAPA) is one of the seven payloads onboard Aditya-L1 Mission for exploring the solar wind and its energy and velocity distribution. PAPA consists of two sensors: Solar Wind Electron

Energy Probe (SWEEP) and Solar Wind Ion Composition AnalyseR (SWICAR). SWEEP measures the solar wind electron energy spectra in the energy range from 10 eV to 3 keV from which electron velocity distribution function moments such as the electron number density, particle flux, bulk velocity, dynamic pressure, temperature and the energy flux can be derived. SWICAR does the mass (m/q) determination of the positively charged ions using time of flight measurement technique and yields the solar wind ion fluxes as a function of direction and energy. SWICAR also provides: (1) the elemental composition of solar wind low energy ions, and (2) the differential energy spectra, abundances of dominant ion species in the mass range 1-30 amu with energies between 0.01 and 25 keV/q. Other than the sensors, the major subsystems of the PAPA payload are the Front End Electronics (FEE), Papa Processing Unit (PPU) and the programmable High Voltage Power Supply (HVPS). The FEE translates the incident charged particles into impulses. These impulses are processed by the subsequent electronics. PPU is the central control for the payload, and acts as the interface between sensors and the spacecraft. It also provides the Tele-command interface, decoding and execution, interface to spacecraft telemetry for science data and HK data transfer, generate Sensor ON/OFF commands , ramp HVPS based on ground commands, and Time stamp all data with respect to Universal time. The HVPS caters to all the biasing requirements of different plates of both sensors-SWEEP and SWICAR. Salient features of PAPA payload, which is under development at VSSC are presented and discussed in detail in this paper.

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Magnetometer Payload in ADITYA L1 Mission

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ADITYA L1 is the first Indian solar mission, to be placed in a halo orbit around the first Lagrangian point in the Sun Earth system. The in situ vector Magnetic field data at L1 is essential for the better understanding of the data provided by the particle and plasma analysis experiments on board Aditya. Also the dynamics of Coronal Mass Ejections (CME) can be better understood. It is proposed to fly a Triaxial fluxgate Magnetometer on board Aditya-L1 mission; the science objective is the "Study of the variable conditions and extreme events at L1". The primary objective is to study the variability in the in-situ magnetic field at the Sun-Earth L1 region. There exists an Interplanetary Magnetic field (IMF) at L1, caused by the emanating magnetic field out of the Sun and provides an estimate of the quiet Sun/background magnetic field at L1. The IMF is expected to increase by a factor of 5-6 times during a CME which are energetic events leading to huge expulsion of charged particles and energy from the Sun. Magnetic field measurements are difficult due to the residual magnetic field of the spacecraft elements. In Aditya, two triaxial fluxgate magnetometers will be placed on a 6m boom, one at the tip and the other midway. The instrument will be operated in 2 modes, a) the quiet mode where data from both the sensors are saved b) the burst mode wherein the data from the tip sensor will be stored.

II. Challenges Involved

Magnetic Cleanliness, Magnetic Property Control, Testing, Perming, Boom design, Mechanical Stability of deployed boom, Thermal control

III. Design Details

A Fluxgate type vector Magnetometer with high permeability ring core as the sensing element works as a Magnetic modulator. The sensor consists of a magnetic core, an excitation coil and a sensing coil. Sensor ring core is of supermalloy (80 per Ni, 3-5 per Mo,15 per Fe) magnet, OD (23.7mm),ID (19.7 mm). The electronics works on all - harmonic detection principle. The high resolution is achieved using sigma delta and multirate filter in digital domain.

Specifications

Range (nT) : 60,000 and 256

Resolution (nT) : 2 and 0.1

Accuracy (nT) : 8 and 0.5

Sampling rate (Vectors/s) : 5 and 8

Output interface : MIL-STD-1553B

Operating temperature (C) : -50 to 70

Weight (kg): Triaxial sensor : 0.3 (dual sensor)

Electronics : 3

Power (W) : 6

Non linearity (ppm) : 10

Size: Triaxial Sensor (mm3) : 71 x 42 x 36 [3 orthogonal coils]

Connector : 15 pin pigtail

In this differential measurement system, changes in the spacecraft generated fields can be determined without any ambiguity. The sensors have to be maintained within 10C.The gradients across the sensor is to be maintained within 2C.Thermal control system is passive with auto-controlled heaters. The Design details, sensor construction, signal processing, boom design, testing will be described in this paper.

48 **Developmental status of Supra Thermal and Energetic Particle Spectrometer (STEPS), a subsystem of ASPEX payload**

Shiv Kumar Goyal

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Aditya Solar wind Particle EXperiment (ASPEX) has been selected as one of the payloads onboard the Aditya - L1 mission to be placed in a halo orbit around the L1 Lagrangian point, lying between the Sun and the Earth at a distance of 1.5 million km from the Earth. ASPEX will make in-situ, multi-directional measurements of alpha particles and protons in the energy range of 100 eV/n to 5 MeV/n. This will be first time when such a large energy range measurements will be carried out from multiple directions using a 3 axis stabilized spacecraft. The ASPEX payload has two independent science experiments: 1) Solar Wind Ion Spectrometer (SWIS), 2) Supra Thermal and Energetic Particle Spectrometer (STEPS). SWIS will measure the angular and energy distributions of Solar wind ions in the energy range of 100 eV to 20 keV, while STEPS will measure the spectrum of protons and other heavier particles in the energy range of 20 keV/n to 5 MeV/n. The STEPS instrument has been configured into 3 packages: viz. the STEPS - 1 detector package, the STEPS - 2 detector package and the processing electronics package. The STEPS - 1 detector package has 4 detector units, pointing in 4 different directions with each having different field of view. In this package, 2 detector units (1: between Sun and Parker spiral direction, 2: North pointing) will measure the integrated energy spectrum of incoming particles, while other 2 detector units (3: Sun pointing, 4: Parker Spiral pointing) will provide the information of particle type and its energy. Similarly STEPS - 2 detector package has 2 detector units, pointing in 2 different directions viz. South pointing for measurements of the integrated energy spectrum, and Earth pointing for measurements of the energy spectrum along with particle identification. For the identification of particle type and its energy, custom made Si detectors along with plastic Scintillators are planned to be used. Si detectors are fabricated in a single package with two different thicknesses of dead layers (0.1 m and 1.0 m) of high Z material. The Plastic Scintillator is placed below the Si detector package, which provides a possibility of measuring particles up to a very high energy (50 MeV/n) along with particle identification using E-E mode. Si detectors with single dead layer are planned to be used for the measurement of integrated energy spectrum without particle type identification. In this paper, we will present the development of bread - board model, preliminary results and salient features of STEPS

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49 Solar Wind Ion Spectrometer (SWIS) onboard ADITYA-L1 Mission

K P Subramanian

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A payload to study the solar wind particles has been proposed for the upcoming Aditya-L1 mission. The objective of this payload is to carry out systematic and continuous in-situ measurement of particle fluxes over an energy range from 100 eV to 5 MeV from the L1 point of the Sun-Earth system. The information on flux ratios of He2+/H+ from the above measurement will be used to differentiate ions of quiet solar wind origin to CME, CIR or SEP related events. The mounting orientation of the payload is such that it covers both the radial as well as the direction of Parker spiral. SWIS is a sub-system of this payload and is primarily meant to measure ions in the energy range of 100eV20keV. Considering the overall scientific requirements, top hat energy analyser was chosen as an ideal candidate for the ion spectrometer. It has the capability to measure both the angular and energy distributions simultaneously in the required energy range. The instrument covers full 360 in azimuth and 26 in elevation. Post energy analysis, a magnetic mass separator, consisting of 16 thin permanent magnets, is used to differentiate masses of ions arriving on the detector. The detector consists of chevron MCP pair followed by a position sensitive detector. The overall dimension of the instrument is 120120150 mm.

The design parameters for electrostatic part (ESA) was optimised based on ion trajectory simulations performed in SIMION. The design limits the spread in ion beam to less than 1.4mm at all energies and also minimizes the electric field leakages. The designed ESA has an energy resolution of 10 percent. The design parameters for the magnetic mass analyser (MMA) was decided based on the field analysis using an in-house developed MATLAB code. Magnet specification was finalized by considering the deflection values and size of the anode. Theoretical deflection values for ions of different mass were obtained using these field calculations.

Experiments on a similar instrument were conducted in lab using a Nier type ion source and position sensitive anode made from PCB with metallic tracks. The energy spread and the deflection values obtained for different masses are in agreement with the simulated values. The instrument was successful in differentiating ions of H2+, He+, Ar+ and Ne+ at 2keV energy.

We expect the measurements from this payload will help to discern some of the fundamental issues related to the solar wind and particle acceleration processes in the inner heliosphere.

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