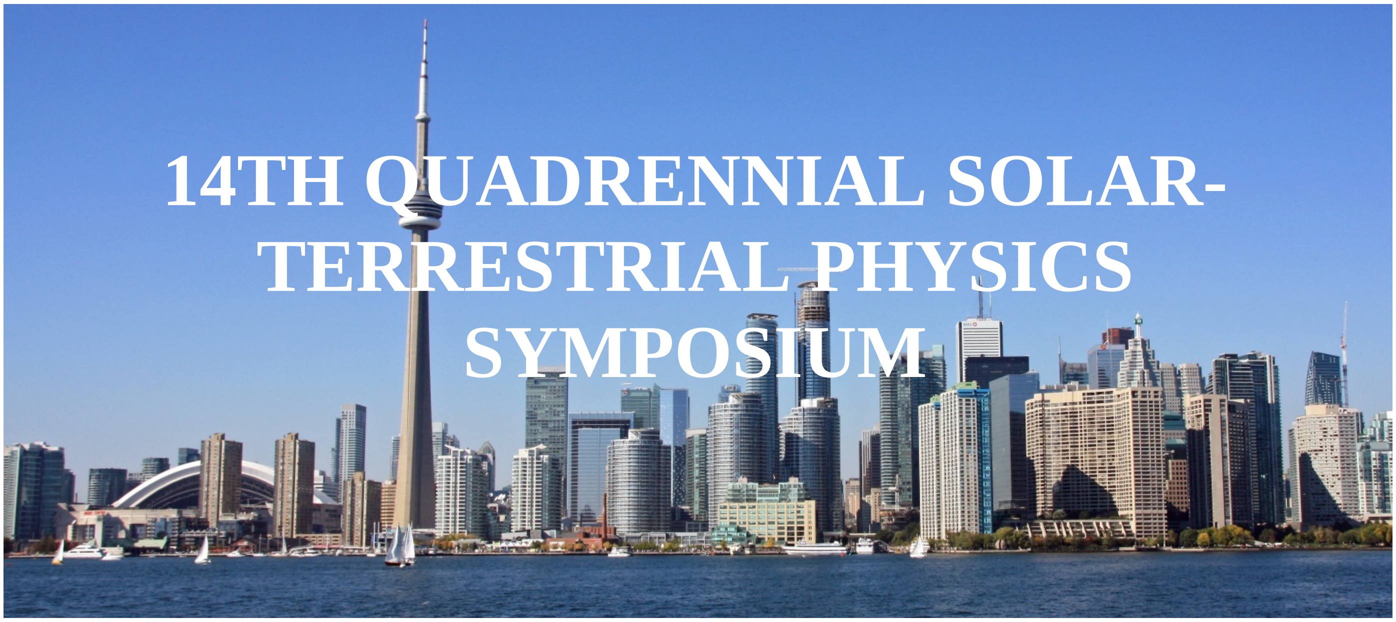

14TH QUADRENNIAL SOLAR-TERRESTRIAL PHYSICS SYMPOSIUM

July 9 - 13, 2018
York University
Toronto, Canada

Scientific Committee on Solar Terrestrial Physics

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A Special Recognition

Thank you for all your support to STP14, the 14th Quadrennial Solar-Terrestrial Physics Symposium held from July 9-13, 2018 in Toronto, ON, Canada.

York University Brief History

The Symposium will take place at York University's primary campus. York University is the largest post-secondary campus in Canada. York University is a public research university and Canada's third-largest university having approximately 53,000 students, 7,000 faculty and staff, and 295,000 alumni worldwide.

It is located in the north of the City of Toronto and 30 min from the downtown. A newly opened subway line connects the campus directly with the downtown and the rest of the city.

York has eleven faculties, including Faculty of Science, Lassonde School of Engineering, Faculty of Graduate Studies and 28 research centres including the Centre for Research in Earth and Space Science (CRESS), host of the SCOSTEP Secretariat and the sponsor of the STP14 symposium.

CRESS serves as an agent to enhance and facilitate collaborative, interdisciplinary research within the areas of astronomy and astrophysics, atmospheric science, earth science, planetary science, geomatics engineering, and space engineering.

York University participates in the Canadian Space Program and is home to Canada's only space engineering program. The Faculty of Science and Lassonde School of Engineering are Canada's primary research facilities into Martian exploration, and have designed several space research instruments and applications currently used by NASA.

Message from the President

Dr. Nat GOPALSWAMY
President SCOSTEP

On behalf of the Scientific Committee for Solar-Terrestrial Physics (SCOSTEP) I am pleased to welcome the participants and guests to the Fourteenth Solar-Terrestrial Physics Symposium (STP 14). These quadrennial symposia have been organized for the past 45 years, showcasing new results obtained from its signature long-term international scientific programs such as VarSITI. The symposia also feature all major aspects of a science that affects life and society on Earth.

SCOSTEP is an interdisciplinary body of the International Science Council (ISC). The SCOSTEP Bureau is constituted by the representatives from five international scientific unions, viz., IAGA, IAMAS, IAU, IUPAP, and URSI and three ISC interdisciplinary bodies, viz., COSPAR, SCAR and WDS. All these organizations have significant interest in solar-terrestrial relationship and its impact on humans.

STP14 has been organized focusing on the three traditional chains of physical processes operating in the solar-terrestrial domain that are discerned by: (i) the mass chain in the form of plasma and particles emitted from the Sun, (ii) the electromagnetic radiation chain in the form of irradiance and flare emissions, and (iii) the chain of intra-atmospheric activity and Earth-to-space energy flow. STP14 also features special sessions on space weather, the level of next solar cycle (25), long-term behavior of the Sun, and new STP missions from ground and space. SCOSTEP is at the verge of completing the VarSITI program launched in 2014. Therefore, the results from the VarSITI program constitute a large portion of the symposium content. A session has also been devoted to discuss the future directions that SCOSTEP should take in organizing its next scientific program as a follow-on to the successful VarSITI program.

The symposium will feature keynote talks, invited talks, contributed talks, and poster presentations. The keynote talks will provide a broad overview of STP science from the point of view of the speakers. The invited talks set the stage for each scientific session. The scientific program includes presentations by 2018 SCOSTEP Distinguished Young Scientist, Dr. Kok Leng Yeo and Distinguished Scientist Professor Jeffrey M. Forbes. Each session was organized by an expert committee headed by one or two conveners and approved by the entire Scientific

Organizing Committee. I thank the SOC for putting together an excellent program. The Local Organizing Committee, under the leadership of Professor Marianna Shepherd, has planned everything meticulously, so we all can focus on science and benefit from the deliberations. With limited resources, she has done an exceptional job. On behalf of SCOSTEP, I would like to express my deepest gratitude to all the individuals in these committees for their tireless efforts. Finally, I would like to thank all the sponsors of STP14, whose contributions have made STP14 a great success: York University and its Lassonde School of Engineering, the United States National Science Foundation, the Japan Society for Promotion of Science, Nagoya University's Prediction of Solar-terrestrial Environment program, SCOSTEP's member organization, IAGA.

Members of the Scientific Organizing Committee

Nat Gopalswamy (Chair), Heliophysics Division, NASA/GSFC, USA
Franz–Josef Lübken (Vice-Chair), Leibniz-Institute of Atmospheric Physics, Kühlungsborn, Germany
Kyung-Suk Cho, KASI, South Korea
Vladimir Kuznetsov, IZMIRAN, Russia
Mark Lester, University of Leicester, UK
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Takuji Nakamura, National Institute of Polar Research, Japan
Craig Rodger, University of Otago, New Zealand
Annika Seppälä, University of Otago, New Zealand
Katya Georgieva, Space Research and Technologies Institute (SRTI), Bulgaria
Kazuo Shiokawa, Institute for Space-Earth Environmental Research (ISEE), Japan
Jacob Bortnik, Dept. of Atmospheric and Oceanic Sciences, UCLA, USA
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Manuela Temmer, University of Graz, Austria
William Ward, University of New Brunswick, Canada
Yihua Yan, National Astronomical Observatories, CAS, China
Andrew Yau, University of Calgary, Canada
Jie Zhang, George Mason University, USA

Inaugural Speakers

David Boteler,
NRCan, Canada

Dr. David Boteler has extensive experience in engineering and geophysics, including work on multidisciplinary projects in the Arctic and Antarctic. He has specialised in research on the effects of space weather on technological systems and is the author of over 130 papers and reports. In 1990, Dr. Boteler joined Natural Resources Canada and has organised studies of space weather effects on technological systems involving many international partners.

Dr. Boteler was Director of the International Space Environment Service (ISES) from 2002 to 2012. He is an Associate of the Infrastructure Resilience Research Group, Carleton University, and has also been active in industry groups concerned with space weather such as the North American Electric Reliability Corporation (NERC) Geomagnetic Disturbance Task Force and International Standards Organisation (ISO) pipeline working group.

Inaugural Speakers

Kazuo Shiokawa
ISEE, Nagoya University
Japan

Dr. Kazuo Shiokawa is currently a professor and a vice-director of the Institute for Space-Earth Environmental Research (ISEE), Nagoya University. He is also the director of the Center for International Collaborative Research (CICR) of ISEE. He acts as a co-chair of the SCOSTEP's 5-year program VarSITI (Variability of the Sun and Its Terrestrial Impact) for 2014 - 2018. In 1990 after the graduate Master course of Tohoku University, he joined the University, as a research associate. He obtained PhD in 1994. He was a visiting scientist of the Max-Planck-Institut fuer extra-terrestrische Physik, Germany, from July 1996 to June 1997.

He became an associate professor on January 1999 and full professor on September 2008. His topic of research is space science and aeronomy in general, particularly for dynamical coupling of the solar wind, magnetosphere, ionosphere, thermosphere, and mesosphere. He has been making many ground-based optical and electromagnetic measurements related to aurora and airglow as well as ULF/ELF/VLF waves.

Keynote Speakers

Irina MIRONOVA,
St. Petersburg State University

Irina Mironova received the joint PhD degree from St. Petersburg State University and Potsdam University, in 2005, with specialty Solar Physics (Russia) and Atmospheric Physics (Germany). Since 2010, she has been a Senior Researcher of Earth's Physics Department of Physical Faculty of St. Petersburg State University. Basic education was obtained at Physical Faculty of St. Petersburg State University, St. Petersburg, Russia. During 2000-2003, she has been a Researcher of Department of Numerical Mathematics, Institute of Mathematics, University of Potsdam, Potsdam, Germany. During 2010-2015, Dr. Mironova has been a Team Leader of Projects of International Space Science Institute, Bern, Switzerland. Projects were dedicated to specification of Ionization Sources affecting Atmospheric Processes. During the period of programs CAWSES II and VarSITI, she has been an active participant of working groups where considered questions about role of solar activity in climate changes. Dr. Irina Mironova is an expert in solar-terrestrial physics with a keen interest in solar and outer space energetic particles propagation and their effects into polar atmosphere.

Keynote Speakers

Larry J. PAXTON,
Johns Hopkins University Applied Physics Laboratory, USA

Larry J. Paxton is a member of the Principal Professional Staff at the Johns Hopkins University Applied Physics Laboratory (JHU/APL) and the Head of the Geospace and Earth Science group. He is the President of the American Geophysical Union Space Physics and Aeronomy Section; this is the world's largest association of scientists studying space weather and space physics. Dr. Paxton is the Principal Investigator or PI on 7 instruments that have flown in space. His research interests include space science, space technology, satellite- and ground-based mission design, the implications of global climate change for the stability of nations; and innovation. He earned his Ph.D in Astrophysical, Planetary, and Atmospheric Sciences from the University of Colorado in Boulder. He is an Academician member of the International Academy of Astronautics and the President-elect of the American Geophysical Union's Space Physics and Aeronomy section. He is also a member of the National Academies Space Studies Board. Awards include JHU/APL publication of the Year Awards in 2014, 2004, and 1992; JHU/APL Government Purpose Invention of the Year Nominee 2015, 2011, and 2010; Best Paper – 7th IAA Symposium on Small Satellites for Earth Observation 2009 NRC. Other recent relevant experience includes JHU's Global Water Institute Board and the Executive Board of JHU's Earth Environment Sustainability and Health Institute (2013-) as well as the NASA Heliophysics Roadmap Committee (2012-2015); NSF Aeronomy Review Panel (2013) and NSF Aeronomy Committee of Visitors; Chair of IAA Commission 4 and Small Satellite Program Committee. Member of the National Academies Space Studies Board (2016-2018).

Keynote Speakers

David KENDALL,
UN COPUOS, Canada

Dr. David Kendall was the Chair of the United Nations Committee on the Peaceful Uses of Outer Space for 2016-2017. During his career he has held senior positions with the Canadian Space Agency including as the Director General of Space Science and Space Science and Technology. He is also an adjunct faculty member of the International Space University based in Strasbourg, France. Dr. Kendall is an academician of the International Academy of Astronautics (IAA) and, during his career, has acted in various capacities on a number of national and international bodies, including the International Space University, the International Astronautical Federation, the Committee on Space Research (COSPAR), UN COPUOS, the European Space Agency, the Inter-Agency Space Debris Coordination Committee, the Group on Earth Observations and the Natural Sciences and Engineering Research Council of Canada. He is a member of the Board of Advisors of SEDS Canada and recipient of the CASI 2017 C.D. Howe Award. In 2002, Dr. Kendall was awarded the Queen Elizabeth II Golden Jubilee Medal in recognition of his significant contributions and achievement to Canada.

Keynote Speakers

Spiro ANTIOCHOS
NASA Sciences and Exploration Directorate, Space Weather, USA

Dr. Spiro Kosta Antiochos is an internationally recognized authority on solar physics and plasma physics. His research is distinguished by the development of innovative models to explain major observational problems. His work relies heavily on magneto-hydrodynamic (MHD) theory and state-of-the-art numerical simulation. Dr. Antiochos has made many fundamental advances to our understanding of the Sun and Heliosphere. Among his best-known contributions are the following: He performed the original analytic and numerical calculations of chromospheric evaporation - the response of the Sun's lower atmosphere to heating in the solar corona. He proposed the cool loop model for the transition region that links the upper and lower levels of the solar atmosphere. He is one of the founders of coronal loop theory, and his ideas on coronal plasma structure and dynamics are in widespread use today. Dr. Antiochos developed the thermal nonequilibrium model for the formation of coronal condensations. It is widely believed to be the definitive explanation for how cool filaments/prominences form in the hot corona, and is the basis for most of the current studies on coronal condensation formation. Dr. Antiochos proposed the 3D sheared arcade model for prominence magnetic fields, and verified with some of the first 3D MHD simulations of solar plasma that it produces a magnetic topology capable of supporting prominence material. The model is the basis for much of the present research on prominence structure and eruption. In another seminal contribution, Dr. Antiochos demonstrated how magnetic reconnection in a multi-polar topology can produce the explosive energy release required to explain coronal mass ejections and eruptive flares. His "breakout" model has spawned great theoretical and observational interest, and is being used throughout the world for the interpretation of coronal eruption observations. It also has major potential for application to space weather predictions. In recent work Dr. Antiochos has derived several far-reaching theorems on the topology of the Sun's open magnetic field regions, and has shown how magnetic reconnection determines the dynamical interaction of open and closed field. This work is critical for understanding how the Sun's atmosphere and magnetic couples to the heliosphere.

Distinguished Science Award

Prof. Jeffrey M. Forbes
Professor Emeritus and Research Professor, Ann and H.J. Smead Department of Present Aerospace Engineering Sciences, University of Colorado, Boulder

Professor Jeffrey M. Forbes' work has provided the foundation for understanding the role of atmospheric tides in the electrodynamics of the ionosphere; wave driven variability in the mesosphere-thermosphere-ionosphere system, and thermospheric wind and neutral density variations due to solar flares and geomagnetic storms. He has played a leading role in both satellite missions and model development. Prof. Forbes' work has had a profound influence in this area of Solar-Terrestrial Physics not only through his publications, which have been cited over 10,000 times, but also through his guidance of a large number of Ph.D. students. Prof. Forbes has also played a leadership role in several international programs, such as the Middle Atmosphere Program, World Ionosphere Thermosphere Study program and Solar-Terrestrial Energy Program of SCOSTEP.

Professor Forbes has been scientifically active for more than 45 years and in that time has published over 280 articles in refereed publications, an h index of 53 and over 10,000 citations. His graduate work was undertaken with Richard Lindzen, a colleague of Sidney Chapman, and the resulting papers (Forbes and Lindzen, JASTP, 1976a, b, 1977) and his 1981 review paper on the equatorial electrojet (Rev. Geophys. Space Phys.) laid the foundations for tidal/ionospheric coupling.

During his career he has made important contributions to our understanding of the dynamics, electrodynamics and chemistry involved in the coupling of solar activity and its variability to the terrestrial atmosphere and geospace environment. His work involves the analysis of satellite data, the validation and development of numerical models which describe these coupling processes, and support of satellite missions involved in observing the geospace environment. He has been instrumental in identifying the role waves play (in particular atmospheric tides) in coupling the lower atmosphere to the upper atmosphere. He has contributed significantly to the development of this field through his participation in numerous national and international review panels which defined the key scientific questions of the field.

Professor Forbes has plead a leadership role in many of the SCOSTEP programs in the 1980's and 1990's.

Professor Forbes has made (and is continuing to make) outstanding contributions to the field of solar-terrestrial relations. He has enriched the field scientifically, strategically given direction to international activities and provided service and support to SCOSTEP and his students and colleagues throughout his career.

Distinguished Young Scientist Award

Dr. Kok Leng Yeo,
Max Planck Institute for Solar System Research
Göttingen, Germany

Dr. Yeo is clearly poised to become a future leader in the important field of solar irradiance modeling and Sun-climate connections. He has already made substantial contributions to improving the leading-edge SATIRE model at MPS, including the assimilation of observed solar magnetograms and, even more significantly, synthesizing magnetograms from 3-D MHD simulations of solar surface convection. He received his PhD only four years ago and he already has 7 first-author papers, 5 papers with more than 10 citations, 7 invited talks, and two review papers. His work has appeared in Physical Review Letters and Nature Astronomy as well as ApJ and A&A. His reconstruction of solar irradiance from 1974-2013 (Yeo et al 2014) has already garnered 63 citations and his new work on SATIRE-3D may prove to be even more innovative and influential.

The work of Kok Leng focuses on understanding and modelling solar irradiance variations on time scales of days to decades, a topic of great interest and importance for models of global change of Earth's climate.

Kok Leng has reconstructed the total (TSI) and spectral (SSI) solar irradiance since 1974. Kok Leng has proposed and developed two independent empirical test models, which have helped to identify the source of the disagreement between the empirical and semi-empirical models. One of them is the EMPIRE model (Yeo et al. 2017a JGR 122), the first ever empirical model that takes the errors-in-variables (i.e. errors in the solar activity proxies) into account. These results have convincingly proved that the larger solar cycle variability in the UV range, critical for Earth's atmospheric models, returned by the semi-empirical models is more accurate, which has significant implications for Earth's atmospheric and climate-chemistry models.

In the last years, Kok Leng has been working on the development of the first irradiance model of a new generation, SATIRE-3D. He has create the first ever model entirely independent of irradiance measurements (Yeo et al. 2017b, Physical Review Letters 119).

A remarkable aspect of Kok Leng's work is that he did it rather independently and that many of the ideas were his own. He is very independent, very inventive, deep thinking and original young researcher. For his PhD thesis, he received the very prestigious Fred L. Scarf Award “for outstanding PhD thesis” of the American Geophysical Union, an indication of Kok Leng’s great standing in the field and is a tribute to the quality of his work and to his intellect.

Used in conjunction with climate simulations, his new reconstruction of solar total and spectral irradiance will definitely lead to a great leap in our understanding of solar influence on global climate change.

Distinguished Lecturer Abstracts

PERIODIC SOLAR FORCING OF THE ATMOSPHERE-IONOSPHERE SYSTEM

Jeffrey M. Forbes (University of Colorado at Boulder, USA) forbes[at]colorado.edu

Abstract

This talk provides a broad perspective on solar-driven periodic variations in the atmosphere-ionosphere (A-I) system, which extends from Earth's surface to roughly 500 km altitude. Earth's gravity, spherical shape, and its rotation with respect to the Sun and Moon admit the existence of many oscillations within its vertically-stratified atmosphere, e.g., small-scale gravity waves (GW), solar thermal tides, lunar gravitational tides, and planetary waves (PW) with periods ~2-20 days. A prominent subset of the PW are the "resonant" or "normal mode (NM)" oscillations with periods near 2, 6, 10 and 16 days. Solar thermal tides are forced at periods of 24/n hours (n = 1,2, ...) by visible, IR, UV, and EUV solar radiation absorption at various levels in the atmosphere. Zonal asymmetries in the A-I system (e.g., surface topography and land-sea differences, Earth's magnetic field) additionally translate to longitudinal periodicities. Nonlinear interactions between all of the above wave types introduce additional complexities into how the A-I system responds to solar forcing.

Emphasis here will be placed on temporal and longitudinal oscillations in the A-I system due to solar thermal tides, PW, and PW-tide interactions; and how these interactions ultimately lead to zonally-symmetric oscillations at PW periods. These results will be discussed in the context of PW-period (13.5d, 9d, 6.75d, 5.4d) (mostly zonally-symmetric) oscillations in the A-I system driven by the recurrent magnetic activity that arises from high-speed streams from coronal holes distributed around the Sun.

MEASUREMENTS AND MODELS OF TOTAL AND SPECTRAL SOLAR IRRADIANCE VARIABILITY IN THE SATELLITE-ERA

Kok Leng Yeo (Max Planck Institute for Solar System Research, Göttingen, Germany) yeo[at]mps.mpg.de

Abstract

Total and spectral solar irradiance, at least in the ultraviolet, have been tracked from space since 1978 through a succession of space missions. The body of satellite observations reveal correlations between solar irradiance variability and the passage of bright/dark magnetic structures across the solar disc and the 11-year solar magnetic cycle. This led to the development of models aimed at reconstructing solar irradiance by relating the variability at timescales greater than a day to solar magnetic activity. Such models have been successful in replicating most of the observed variability, particularly

in total solar irradiance. However, there remains controversy over the secular trend and the spectral-dependence of the variability, with clear implications on our understanding of the influence of solar irradiance variability on the Earth's climate. In this talk, we provide an overview of the measurement and modelling of total and spectral solar irradiance variability over the period of space-based observation, with a focus on these outstanding issues.

ORIGIN ENERGETIC PARTICLES AND THEIR IMPACT ON EARTH

Irina Mironova (St. Petersburg State University, Russia) i.a.mironova[at]spbu.ru

Abstract

Significant improvements have been made recently in observations and modelling of Energetic Particles, so that many links of the chain coupling Energetic Particle Precipitation to atmospheric processes are now better understood. However large uncontrolled uncertainties in some Energetic Particles data sets still lead to uncertainties in our knowledge of their Impact on the Earth's atmosphere, which can be up to an order of magnitude and still leave some responses inconclusive. The many different aspects of atmospheric physics and chemistry are concerned and the new level of understanding emerging gives a better perspective on the problem of Energetic Particles contribution to natural atmospheric variability. The present level of knowledge of various sources and energies of Energetic Particles such as galactic cosmic rays, solar energetic particles and energetic electron precipitation, as well as the level of scientific understanding of various Energetic Particle Precipitation processes and assess the importance of Energetic Particle Precipitation in terms of their potential climate impacts is presented here with an outline of open questions and summary.

EXPLORATION OF EARTH'S ATMOSPHERE FROM SPACE

Larry Paxton (JHU/APL, USA) larry.paxton[at]jhuapl.edu

Abstract

The world's space science community stands at the threshold of an exciting new era in the study of the Earth and its connection to our Sun. We have an opportunity to connect our science to the greater human needs to understand where we have come from, where we are going and what these questions tell us about our place in the cosmos. One of the many exciting developments that enables us to explore these questions is that there are now far more opportunities to both observe our atmosphere from the ground (including endo-atmospheric platforms) and from space. The context of what is known as "Heliophysics" has become broader as the number and variety of exoplanets has increased enormously; this lends particular relevance to our understanding of how the Earth interacts with the space environment. In this talk I will describe why we need to study the Earth's atmosphere by considering two kinds of questions: "I wonder …" and "I need to know..". These two questions capture the essence of why we explore, how we reach the public and how we build capacity. Specific examples will be discussed as well as how new approaches are empowered by technology. I'll provide an overview of the techniques, technology and challenges and indicate some new opportunities that have the potential to revolutionize the way we explore our planet's connection to the space environment. The focus will be on understanding the ionosphere and thermosphere and how the upper atmosphere is connected to the Sun and magnetosphere.

SPACE WEATHER IN THE UN COPUOS CONTEXT

David Kendall (UN COPUOS, Canada) david.kendall[at]canada.ca

Abstract

Space weather has been a topic of discussion at the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) for many years. Recently, these discussions have sharpened and focused on the development of guidelines relating to space weather under the Working Group on the Long-Term Sustainability of Outer Space Activities and a proposed mechanism to develop expanded international collaboration at the governmental policy level for improved resilience against space weather effects.

THE ORIGINS OF MAJOR SOLAR ERUPTIONS

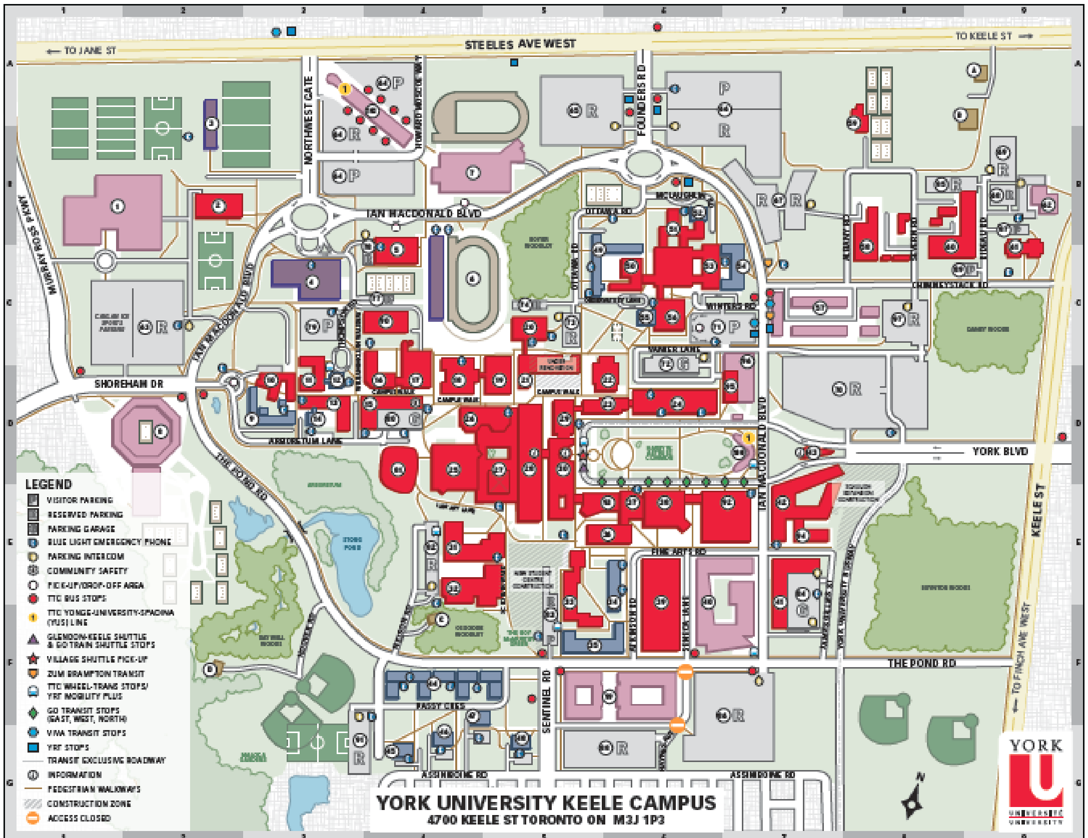
Spiro Antiochos (NASA/GSFC, USA) spiro.antiochos[at]nasa.gov

Abstract

The primary drivers of the two major chains connecting the Sun to the Earth, mass and electromagnetic energy, are the fast coronal mass ejections (CME) and the accompanying X-class solar flares, often referred to as Solar Eruptive Events (SEE). These events are responsible for the most destructive space weather at Earth and throughout interplanetary space; consequently, predicting their onset and impact is a primary goal for solar-terrestrial physics. It is now well accepted that SEEs are due to the explosive release of magnetic free energy stored in the corona; specifically, in the highly stressed magnetic field that supports filaments and prominences. Predicating SEEs, therefore, requires understanding how these magnetic structures form and why they disrupt catastrophically. I will review the present state-of-art in SEE theory and modeling. An important observational finding in recent years is that the mechanisms underlying solar eruptions may be invariant over many decades in energy release. I will discuss our latest 3D MHD numerical simulations of the self-consistent energy buildup and eventual explosive energy release that are the defining features of a CME/flare event. Our results demonstrate that the Sun's corona is an amazing example of self-organization on cosmic scales.

Layout Guide

YORK UNIVERSITY KEELE CAMPUS COLOUR



CAMPUS DIRECTORY

ACADEMIC, ADMINISTRATIVE & COMMERCIAL BUILDINGS

59	190 Albany Road	ALB	A8
92	Accolade East	ACE	E7
93	Accolade West	ACW	E6
33	Atkinson	ATK	E5
29	Behavioural Science	BSB	D5
41	Bennett Centre for Student Services, Admissions	BCS	E7
81	Bergeron Centre for Engineering Excellence	BRG	E4
24	Bookstore, York Lanes	YL	D6
10	Calumet College	CC	D3
27	Central Square	CSQ	D5
58	Central Utilities Building	CUB	B6
38	Centre for Film & Theatre	CFT	E6
16	Chemistry	CB	D4
26	Curtis Lecture Halls	CLH	D5
94	Executive Learning Centre	ELC	E7
21	Farquharson Life Sciences	FRQ	D5
50	Founders College	FC	C6
31	Health, Nursing & Environmental Studies	HNE	E4
32	Ignat Kaneff Building, Osgoode Hall Law School	OSG	E4
36	Joan & Martin Goldfarb Centre for Fine Arts	CFA	E5
95	Kaneff Tower	KT	D7
61	Kinsmen	K	C9
19	Lassonde Building	LAS	D5
90	Life Sciences Building	LSB	C4
43	Lorna R. Marsden Honour Court & Welcome Centre	HC	D7
20	Lumbers	LUM	C5
51	McLaughlin College	MC	B6
11	Norman Bethune College	BC	D3
17	Observatory Petrie	PSE	D4
17	Petrie Science & Engineering	PSE	D4
60	Physical Resources Building	PRB	B9
28	Ross Building	R	D5
25	Scott Library	SCL	D4
27	Scott Religious Centre, CSQ	SRC	D5
42	Seymour Schulich Building	SSB	E7
2	Sherman Health Science Research Centre	SHR	B2
18	Steacie Science & Engineering Library	STL	D4
22	Stedman Lecture Halls	SLH	D6
13	Stong College	SC	D3
23	Student Centre	STC	D6
4	Tait McKenzie Centre	TM	C3
56	Vanier College	VC	C6
30	Vari Hall	VH	D5
39	Victor Phillip Dahdaleh Building (Formerly Technology Enhanced Learning - TEL)	DB	E6
5	West Office Building	WOB	C4
15	William Small Centre	WSC	D4
53	Winters College	WC	C6
24	York Lanes	YL	D6

RESIDENCES & APARTMENTS

48	320 Assiniboine Road	AS2	G5
47	340 Assiniboine Road	AS4	F4
46	360 Assiniboine Road	AS6	G4
45	380 Assiniboine Road	AS8	G4
34	Atkinson Residence	AR	E5
12	Bethune Residence	BR	D3
9	Calumet Residence	CR	D3
49	Founders Residence	FR	C5
44	Passy Gardens, 2–18 Passy Cres	PASSY	F4
35	The Pond Road Residence	PON	F5
14	Stong Residence	SR	D3
52	Tatham Hall	TH	B6
55	Vanier Residence	VR	C6
54	Winters Residence	WR	C7

PARKING GARAGES – VISITORS

80	Arboretum Lane Parking Garage	ARB	D4
84	Student Services Parking Garage	SSP	E7
72	York Lanes Parking Garage	YLP	D6

PARKING LOTS – VISITORS

83	Atkinson Lot	E5
66	Founders Road East Lot	A6
87	Kinsmen Lot	B9
64	Northwest Gate Lot	B4
89	Physical Resources Building South Visitor Lot	C9
77	Tait McKenzie Lot	C3
79	Thompson Road Lot	C4
71	Vanier Lot	C7

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67	Albany Road Lot	B7
83	Atkinson Lot	E5
97	Chimneystack Lot	C8
66	Founders Road East Lot	A6
65	Founders Road West Lot	A5
73	Lumbers Lot	C5
74	Lumbers North Lot	C5
82	Nelson Road Lot	B4
64	Northwest Gate Lot	B4
91	Passy Crescent Lot	G3
85	Physical Resources Building North Lot	B7
68	Physical Resources Lot	B9
69	Rideau Road Lot	B9
88	Sentinel Road Lot	F6
63	Shoreham Drive Lot	C2
86	The Pond Road Lot	F7
71	Vanier Lot	C7
78	West Office Building West Lot	C4
70	York Boulevard Lot	B8

VISUAL PERFORMANCE ARTS FACILITIES

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37	Burton Auditorium°	BU	E6
93	Gales Gallery	ACW	E6
38	Joseph G. Green Studio Theatre	CFT	E6
92	McLean Performance Studio	ACE	E7
92	Price Family Cinema	ACE	E7
92	Sandra Faire & Ivan Fecan Theatre	ACE	E7
92	Tribute Communities Recital Hall	ACE	E7

SPORT & RECREATION FACILITIES

4	Tait McKenzie Centre	TM	C3
3	York Stadium	STA	A2
6	York Lions Stadium	YLS	C4

HISTORICAL HOUSES

C	Skennen'kówa Gamig "............"	SKG	F4
D	Hoover House	HOH	F2
B	Stong Barn	SB	A9
A	Stong House	SH	A9

NON-YORK U BUILDINGS

96	Archives of Ontario *	AO	D7
1	Canlan Ice Sports *	ICE	B1
62	Computer Methods Building	CMB	B9
57	Harry Sherman Crowe Housing Co-op	HOC	C7
40	Seneca @ York, Stephen E. Quinlan Building	SAY	E7
8	Tennis Canada - Aviva Centre *	TC	D2
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JANUARY 2018

SCOSTEP
Scientific Committee on Solar-Terrestrial Physics

Credits

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Session 1: Mass Chain (MC)

MC1.1 Origin, Evolution, and Earth Impact of Coronal Mass Ejections

Lead Conveners
J. Zhang
S. Kanekal
V. Kuznetsov

Plenary Speaker
Noe Lugaz

Invited Speakers
Satoko Nakamura
Qui Gang Zong

Session Description

A coronal mass ejection (CME) is a large-scale energetic eruptive phenomena originating in the Sun's lower atmosphere. Carrying a large amount of kinetic and magnetic energy often in an organized flux rope structure, it bursts into the interplanetary space and interacts with the ambient solar wind. The CME may drive ahead a large-scale interplanetary shock, which in turn accelerates energetic particles permeating the heliosphere. Upon arriving at the Earth, the CME usually generates a cascade of physical effects in the geospace, collectively called space weather, i.e., geomagnetic storms including storm sudden commencement (SSC) and geomagnetically induced current (GIC) on the ground, development of ring current and energetic particles in the radiation belts. In this Session, we invite contributions that study the origin, evolution and Earth-impact effects of CMEs. These studies include, but not limited to, the following topics. What is the initiation mechanism of CMEs that concerns the pre-eruption magnetic structure, the role of magnetic flux rope and magnetic reconnection? How does a CME accelerate and expand in developing the flux-rope-shock complex? How does a CME propagate and evolve in the interplanetary space? How does the CME-driven interplanetary shock accelerate and inject energetic particles? What are the space weather effects of CME interaction with the magnetosphere? How does the SSC associated with CME arrival cause GIC on the ground? How does the ring current energy and composition changes during geomagnetic storms? How do the radiation belt particles dropout and re-appear at various energy levels during the main and recovery phase of storms? Developing the capacity of predicting the time of arrival of CMEs and modeling CME's internal magnetic structure are also sought in this Session.

THE WIDTH DIFFERENCES OF HALO CORONAL MASS EJECTIONS BETWEEN SOLAR CYCLES 23 AND 24

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Abstract

Coronal mass ejections (CMEs) propagating toward (away from) the observer that appear to surround the coronagraph's occulting disk and are known as halo CMEs. Halo CMEs are regular CMEs, but they appear as halos due to projection effects. Inherently wide CMEs are more likely to be observed as halos, therefore even limb CMEs could be halos if they are sufficiently wide. Usually limb halo CMEs are seen as normal CMEs in the LASCO/C2 field of view (FOV) and as halos in the C3 FOV. On the other hand, symmetric halos that usually originate near the disk center are seen as halos already in the C2 FOV. We investigated whether CMEs could be classified as halo CMEs in the LASCO/C2 or C3 FOV, which is related to the CME expansion. Out of the 212 front-side (longitude ≤ E/W80˚) halos in solar cycle 23, 109 (51%) became halos within C2 FOV (C2 halos) while 95 (45%) became halos within C3 FOV (C3 halos). We could not determine the remaining 8 events (4%) because of the low data quality. Whereas in cycle 24, the 145 front-side halos consisted of 55 (38%) C2 halos and 86 (59%) C3 halos with a data gap for 4 (3%) events. The fraction of the C3 halos was higher in solar cycle 24. We also found that a significant number of the C3 halos in cycle 24 originated near the limb (E/W80°≤longitude<E/W60°), whereas in cycle 23 this occurred less frequently. We suggest that the limb CMEs in cycle 24 became halos more frequently due to anomalous CME expansion during cycle 24.

RE-EXAMINATION OF THE SOLAR ACTIVITY OF MARCH 1989 AND ITS IMPACT ON EARTH

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Abstract

From March 5 to 19, 1989, sunspot region 5395 crossed the Sun's disk and was the source of numerous X-class and M-class flares. Coronal mass ejections associated with these flares hit the Earth on March 13 resulting in the now-famous impacts in technology on Earth. Solar and solar wind observations at the time were limited which has made it difficult to assess exactly what happened during this event. This presentation reviews the available evidence for this period, some of which has only come to light since that time. This provides a reconstruction of the chain of events from coronal mass ejections to their interaction with the Earth's magnetic field, and the resulting disturbances to power systems in different parts of the world. Lessons learned from this contribute to understanding the space weather hazards to power systems and other critical infrastructure.

EFFECTS OF GEOMETRIES AND SUBSTRUCTURES OF ICMES ON GEOMAGNETIC STORMS

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Abstract

For better understanding of storm generation by an ICME, we consider the geometries (impact location of flux rope at the Earth) and substructures (sheath and magnetic cloud

(MC)). We apply the toroidal magnetic flux rope fitting model to 59 CDAW ICME-storm pairs to identify their substructures and geometries, and select 25 MC-associated and 5 sheath-associated storm events. We investigate the relationship between the storm strength indicated by Dst index and the solar wind conditions. As the results, we found that all solar wind parameters have relatively high correlation coefficients (CC) with the storm strength (CC ~ 0.8). The sheath-storm events show better correlations than MC-storm events for all solar wind parameters. Moreover, the slope of a linear regression line for sheath-storm events is about two times steeper than that of the MC-storm events in the relationship between Dst index and integrated convectional electric field; this implies that the sheaths can produce stronger storms than MCs at a given solar wind condition. Regarding the geometric encounter of ICME, we found that 73 % (11/15) of storms and 100 % (4/4) of intense storms (Dstmin ≤ -100 nT) occur in the regions at negative PY (relative position of the Earth trajectory from the ICME axis in the Y component in GSE coordinate) when the eastern flanks of ICMEs encounter the Earth, while 60 % (6/10) of storms and 83 % (5/6) of intense storms occur in positive PY regions when the western flanks hit the Earth. Our results demonstrate that the strength of a geomagnetic storm is strongly affected by not only the solar wind conditions but also substructures (sheaths and MCs) and ICME-Earth impact geometries (PY on ICME-Earth trajectory).

STUDYING THE EARLY EVOLUTION OF EARTH-DIRECTED CMES BY ANALYZING CORONAL DIMMINGS

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Abstract

Earth-directed coronal mass ejections (CMEs) are the main drivers for severe space weather events affecting the near-Earth environment. However, they allow the least accurate measurements of their properties due to strong projection effects and seeing as their early evolution is not well observed with traditional coronagraphs. The most distinct phenomena associated with CMEs is coronal dimming, localized regions of reduced emission in the EUV and soft X-rays low in the corona. They are interpreted as density depletions due to mass loss or rapid expansion of the overlying corona during the CME lift-off. We extract characteristic parameters describing the dynamics, morphology, magnetic properties and the brightness evolution of coronal dimming regions to obtain additional information on the initiation and early evolution of Earth-directed CMEs. To this aim, we developed an automatic dimming detection algorithm (based on logarithmic base-ratio images) that allows us also to distinguish between core and secondary dimming regions. Using this method, we extract the physical properties of 76 coronal dimming events in optimized multi-point observations and compare them with characteristic parameters describing their corresponding CMEs. The on-disk dimming evolution is studied using high cadence, multi-wavelength data of SDO/AIA and line-of-sight magnetograms of SDO/HMI, while STEREO/EUVI, COR1 and COR2 data is used to measure the associated CME close to the limb with low projection effects. For the majority of events, the total unsigned magnetic flux of the dimming regions is balanced and for selected events up to 30% of this flux results from localized core dimming regions covering only ~10% of the total dimming area. The dimming area, the total unsigned magnetic flux, and its intensity decrease are strongly correlated with the CME mass. Events where high-cadence observations from STEREO that are available show a moderate correlation between the growth rate of the dimming and the maximum speed of the CME.

SMALL SOLAR WIND FLUX ROPES DURING SOLAR MAXIMUM: DISTINGUISHING BETWEEN FORCE-FREE MODELS THROUGH THEIR TWIST

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Abstract

During solar maximum, small solar wind flux ropes (FRs) may be modeled with force free methods. Using a set of 16 such FRs (radius: ~0.003–0.043 AU) observed by STEREO or Wind, we inquire into which analytical model fits them best. Considerations of magnetic twist is used to augment this modeling. The observational fact that these FRs do not expand radially into the ambient medium makes static models ideal for this study. We first chose by eye those cases whose FR duration are unambiguous. We then consider three models: (i) linear force free field with fixed alpha (Lundquist solution); (ii) linear force free field with changing alpha (Lundquist-alpha solution); and (iii) Uniform twist field (Gold-Hoyle). We retained only those cases where the impact parameter is below half of the FR radius, so the results should be robust. Comparing the results, we found that in most cases the Lundquist-alpha and Uniform Twist solutions yielded comparable and small normalized chi-squared values. We then used Grad-Shafranov (GS) reconstruction to analyze these events further in a model-independent way. The FR orientations derived from GS are close to the results obtained from the Uniform Twist field model. We then considered the twist per unit length (tau), both its profile through the FR and its absolute value, applying a graphical approach to the GS solution for each example. The results are in better agreement with the Uniform Twist model. We find tau to lie in the range [3, 34], i.e., much higher than typical of magnetic clouds. It also shows a clear tendency to increase with decreasing FR radius. We report a functional relation between tau and this inferred radius. This work thus extends recent efforts on large flux FRs (magnetic clouds) to a smaller spatial regimes and larger twist values.

ROLE OF THE TERRESTRIAL BOW SHOCK ON THE GEOEFFECTIVITY OF MAGNETIC CLOUDS

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Abstract

Magnetic clouds are known as very geoeffective solar events capable to trigger strong magnetic storms in the terrestrial magnetosphere. However, the strength of these storms cannot be simply predicted from the clouds' properties measured just upstream of Earth at the Lagrange point L1 (magnetic field, plasma). It is argued in the literature that the presence of a turbulent sheath ahead of a cloud or the presence of other events (i.e. jets, shocks, other clouds) in its immediate surroundings may affect its geo-effectivity. We here consider an additional effect related to the interaction of magnetic clouds with the terrestrial boundaries: bow shock and magnetopause. From observations and simulations, we show that the quasi-perpendicular or quasi-parallel configuration of magnetic clouds at the bow shock preserves or changes the cloud's magnetic structure downstream of the bow shock. In order to estimate further the consequences of these effects for the clouds' interaction with the magnetosphere, we run 3D hybrid simulations of the interaction of a

magnetic cloud with the Earth's bow shock. We investigate the plasma and field distributions downstream of the bow shock and next to the magnetopause. We compare and discuss the effects of clouds both in quasi-perpendicular and quasi-parallel configurations at the bow shock.

GEOMAGNETIC ACTIVITY DRIVEN BY CORONAL MASS EJECTIONS: LATITUDINAL DIFFERENCES AND SOLAR CYCLE VARIATION

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Abstract

Coronal mass ejections (CMEs) are important drivers of geomagnetic activity and various other space weather effects. Here we study the spatial and temporal evolution of geomagnetic activity driven by CMEs during solar cycles (SC) 23 and 24 using a wide network of magnetic observatories. We show that CMEs are most geoefficient during the declining phase of both solar cycles. The geoefficiency of CMEs maximizes during the declining phase at all latitudes, but most clearly at high latitudes. This indicates that CMEs drive substorms most efficiently during the declining phase. We also show that the latitudinal distribution of CME-driven geomagnetic activity is different between SC23 and SC24. In SC23 the peak in the latitudinal distribution is at a lower latitude than during SC24, indicating that CME driven substorms are weaker in SC24 than in SC23.

INTER-COMPARISON OF INTERPLANETARY MAGNETIC FLUX ROPES AND THEIR SOLAR SOURCES: IMPLICATION FOR FLUX ROPE MODELS

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Abstract

Interplanetary magnetic flux ropes, especially the large-scale ones (i.e., magnetic clouds) embedded in interplanetary coronal mass ejections (ICMEs), are often approximated by cylindrical or toroidal configurations based on in-situ spacecraft measurements. Such modeling based on quantitative but limited spatial measurements across the flux rope structure provides extended characterization of the structure. The Grad-Shafranov (GS) reconstruction method, representative of these common approaches, can yield quantitative characterizations of the flux rope, such as the magnetic flux content, relative magnetic helicity, the current density and field-line twist distributions. Studies have been carried out to relate these physical quantities to the corresponding solar source region properties. We continue such effort by performing a few case studies with identified flare/CME/ICME associations. The magnetic topology of the source region will be obtained by a well-established state-of-the-art coronal magnetic field extrapolation code, and the corresponding ICME flux rope will be reconstructed by the GS method in toroidal geometry. Various physical quantities will be inter-compared quantitatively, and we will discuss the implications of our results for alternative models of magnetic flux ropes.

INTERPLANETARY CMES OBSERVED BY TWIN STEREO SPACECRAFT ON THE FAR SIDE OF THE SUN

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Abstract

About 20 interplanetary coronal mass ejections (ICMEs) were encountered by both STEREO A and B spacecraft within ±1 day apart in August 2013 – September 2014, before STEREO B went lost in contact. Kilpua et al. (2011) reviewed the multipoint ICME encounters in April 2007 – March 2008, which was near solar minimum, and concluded that the ICMEs might span at least up to 40 degrees in longitude. During August 2013 – September 2014, the twin spacecraft were separated by 80 – 30 degrees in heliographic longitude, expanding the multipoint observations of ICMEs to solar maximum. With stronger CMEs near solar maximum, we see a wider longitudinal span of them as well. The SECCHI suite onboard STEREO enabled the dual remote-sensing observations of the source CMEs, providing opportunities to study the CME-ICME connection and to validate the CME models. Using the selected events, we conduct the coupled Wang-Sheeley-Arge (WSA)-ENLIL+Cone model to study the CME evolution and explore the influence of different CME parameters on the model performance.

RAPID ENERGIZATION OF RADIATION BELT ELECTRONS TO INTERPLANETARY SHOCKS

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Abstract

Electron energization is generally thought to proceed by two classes of processes, namely radial transport and in-situ wave-particle interactions, or even a combination of these two processes. These processes result in increased electron fluxes and at times spectral hardening over time scales of a few days. However, electrons can also be very rapidly energized on time scales of a few minutes by interplanetary shocks (IP), which compress the magnetosphere and result in a magnetosonic wave propagating through the outer zone with associated azimuthal electric fields. Electrons of the right energy can 'surf' the waves and get energized sometimes to very high energies. We present data on two shock events observed by the Relativistic Electron and Proton Telescope and the Magnetic Electron and Ion Sensors on board NASA's Van Allen Probes. These events occurred during March 2015 and September 2017 and resulted in shock-induced energization, drift echoes in the L range of 4 to 5, and increased electron fluxes to energies up to >5 MeV. We also present the results of a statistical study that investigates the relationship between IP shock parameters and energized electrons.

THE EFFECTS OF UNCERTAINTY ON DEFLECTION, ROTATION, AND BZ PREDICTIONS

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Abstract

Understanding the effects of coronal mass ejections (CMEs) requires knowing not only if and when they will impact, but also their properties upon impact. In particular, the severity of the effects depends on the strength of a CME's southward magnetic field component (Bz). The simplified analytic model ForeCAT can be used to reproduce the deflection and rotation of CMEs. A new model introduced, FIDO, which uses the

position and orientation from ForeCAT to simulate magnetic field profiles. FIDO reproduces the in situ observations on roughly hourly time scales, suggesting that the combination of ForeCAT and FIDO could be extremely useful for predictions of Bz. However, as with all models, both ForeCAT and FIDO are sensitive to their input parameters, which may not be precisely known for actual predictions. We explore the sensitivity of both models to small changes in the initial latitude, longitude, and orientation of the erupting CME. Additionally, thus far ForeCAT has only been run using a Potential Field Source Surface (PFSS) magnetic background, driven by a synoptic map. We explore the effects of different magnetic backgrounds - the Schatten Current Sheet model and synchronic maps. We find that the changes resulting from the uncertainty in the initial parameters tend to exceed the changes from different magnetic backgrounds, and discuss how these ensembles could be used for future predictions.

TIME DOMAIN SIMULATION OF GIC FLOWING IN POWER GRID IN JAPAN

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Abstract

We performed time domain simulation of geomagnetically induced currents (GICs) flowing in the Japanese 500 kV power grid. The three-dimensional distribution of the geomagnetically induced electric field (GIE) was calculated by using the finite-difference time-domain (FDTD) method with a three-dimensional electrical conductivity model constructed from a global relief model and a global map of sediment thickness. First, we imposed a uniform sheet current at 100 km altitude with a sinusoidal perturbation to illuminate the influence of the structured ground conductivity. The simulation result shows that GIE exhibits localized, uneven distribution that can be attributed to charge accumulation, due to the inhomogeneity below the Earth's surface. The charge accumulation becomes large when the conductivity gradient vector is parallel, or anti-parallel, to the incident electric field. For given GIE, we calculated the GICs flowing in a simplified 500 kV power grid network in Japan. The influence of the structured ground conductance on GIC appears to depend on a combination of the location of substations and the direction of the source current. Uneven distribution of the power grid system gives rise to intensification of the GICs flowing in remote areas where substations/power plants are distributed sparsely. Secondly, we imposed the equivalent sheet current inferred from the ground magnetic disturbance for the magnetic storm of May 27, 2017 as a source current of the FDTD simulation. The calculated GIC agrees well with the observations at substations around Tokyo when the uneven distribution of GIE is incorporated with the simulation.

INTERPLANETARY SHOCKS, THEIR SOURCE AND SOME SPACE WEATHER EFFECTS

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Abstract

Magnetic ejecta associated with coronal mass ejections (CMEs) are often preceded by dense sheaths and, when their speed is significantly faster than that of the solar wind, by fast-mode shocks. The propagation of CMEs in the inner heliosphere can now be routinely imaged by heliospheric imagers onboard STEREO and measured in situ by the fleet of spacecraft in the inner heliosphere. This has helped advance our understanding of the deceleration and interaction of CMEs on their way to Earth. Long-duration periods of strong southward magnetic fields are known to be the primary cause of geomagnetic storms. The majority of such events are caused by the passage over Earth of a magnetic ejecta, although sheath fields, corotating interaction regions and compressed ejecta are also common drivers of geomagnetic storms. I focus here on the causes and consequences of geo-effective shocks, and highlight cases where the combination of remote observations and in-situ measurements can shed light on unusual properties and characteristics. I specifically discuss instances of: 1) slow CMEs driving shocks and their effects on Earth's magnetosphere, and 2) shocks measured at 1 AU as propagating inside a previous CME, their geo-effects and their ability to accelerate particles.

CME ACCELERATION AND EUV WAVE KINEMATICS FOR SEPTEMBER 10TH 2017 EVENT

Tatiana Podladchikova (Skolkovo Institute of Science and Technology, Moscow, Russia) t.podladchikova[at]skoltech.ru, A. M. Veronig, K. Dissauer, M. Temmer, and D. B. Seaton

Abstract

On September 10, 2017, a large solar eruption accompanied by an X8.2 solar flare, from NOAA active region 12673 was observed on the Sun's western limb by the new Solar Ultraviolet Imager (SUVI) on the GOES-16 spacecraft. We present a method to identify the CME bubble shape and to determine its radial and lateral acceleration. The large field of view of SUVI allows us to study the early impulsive CME acceleration up to 2 solar radii. The CME bubble reveals a fast evolution and strong overexpansion. The radial propagation of the CME revealed a peak value of the acceleration of about 5 km/s2, whereas the lateral expansion reached a peak value of 9.5 +/- 0.5 km/s2. The EUV wave associated with this eruption was observed by SUVI and STEREO-A, which had a separation angle with Earth of 128°, and the common field of view of both spacecraft was 52°. SUVI images above the solar limb reveal the initiation of the EUV wave by the accelerating flanks of the CME bubble, followed by detachment and propagation of the wave with a speed of 1100 km/s. Above the limb, the wave front can be observed as high as 0.7 Rsun. The EUV wave shows a global propagation over the full SUVI disk as well as into the STEREO-A field-of-view, and can be followed up to distances of about 2200 Mm from the source region. We study the propagation and kinematics of the direct as well as the various reflected and refracted EUV wave components on the solar sphere, finding speeds in the range from 370 to 1010 km/s. Finally, we note that this EUV wave is also distinct as it reveals propagation and transmission through a polar coronal hole.

SOLAR-MAGNETOSPHERE COUPLING INVESTIGATION FOR INTENSE GEOMAGNETIC STORMS OF SOLAR CYCLE 24

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Abstract

Coronal mass ejections (CMEs) are large eruptions of plasma that introduce a significant out-of-the-ecliptic component, which when southward pointed, can cause intense geomagnetic storms via the magnetic reconnection process. Geomagnetic storms and solar energetic particle (SEP) events are the two most serious space weather hazards resulting from CME. During storms, waves, and particle processes and their interactions

significantly alter the energetic particle distribution and ring current in the magnetosphere with further consequences to the ionosphere, atmosphere, and even to the ground. Therefore, understanding the propagation and the magnetic content of CMEs starting from the Sun to inner magnetosphere is crucial for predicting space weather effects at Earth and other destinations of interest to humans. In the present work, we have taken some intense geomagnetic storms that have occurred during solar cycle 24. This work starts with the identification of solar source which resulted in geomagnetic storms. After the identification of CME, the reconnection flux is computed and the corresponding magnetic structure is determined. As the ICME reaches 1au, the energy flux parameter (Ɛ) is determined for the selected intense storms during main phase which gives the magnetosphere-solar wind coupling energy. The dynamics of inner magnetosphere during magnetic storms will be established by the contribution and understanding of the current systems such is the ring current, partial ring current, and magnetotail current. We will use different ground and satellite data for this work like SOHO, STEREO, Geotail, ACE, WIND, RBSP (Van Allen Probes). Observations from the ground will play a role to compliment to satellite observations. This work will track the start of CME, inner magnetosphere, and the ground observations, which completes the understanding.

NEW TECHNIQUE TO DETERMINE ARRIVAL TIME BASED ON MAXIMUM VELOCITY

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Abstract

Here we present the statistical analysis of 46 CMEs using STEREO and SOHO/LASCO observations to predict the arrival time of CMEs. The prediction of the arrival time of a CME has been one of the main problems for forecasting space weather as the previously studied models have significant differences between their accuracies, with an estimated error of 10 hours. These considerations were mostly based on CME velocities included in the SOHO/LASCO catalogue. In the present study, we have applied different techniques for determining the speed of CMEs and we have extended these techniques to the twin STEREO satellites that observe CMEs from two points up to the Earth's orbit. These observations were used to develop empirical or analytical models that significantly improved the accuracy in determination of CME arrival times. For this purpose, we performed our own height-time measurements of 46 CMEs in the STEREO field of view. Next, using the maximum velocity technique, we obtained profiles of CME velocities and accelerations versus distance from the Sun (up to the distance 1au). This allowed us to determine cessation distance of acceleration. Analysis of these profiles helped us to build analytical models to predict the 1AU arrival time of CMEs with greatly improved accuracy in contrast with those from models based on old observations.

PROPERTIES OF SOLAR WIND STREAMS IN RELATION TO THEIR SOLAR ORIGINS

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Abstract

Regular solar observations in EUV range provides detailed and timely data about the structures and active processes, which can form the potentially geoeffective solar wind streams, such as HSS (high-speed stream) and ICME (interplanetary coronal mass ejection). We consider solar origins and formation of solar wind streams, their ion composition, streams interaction in the corona and interplanetary space, and its influence on the solar wind parameters in-situ. For the period January 2010 – August 2011, we identified solar sources of the ICMEs as the Earth-directed coronal mass ejections (CMEs) from coronagraph observations (STEREO-A, -B and LASCO). It was found, that in 11 cases out of 23 the observed ICME might be associated with two or more CME sources. As a reliable marker for identification of interacting streams and their sources, we used the plasma ion composition, as it becomes frozen in the low corona and remains unchanged in the heliosphere. We described in-situ temporal profiles of the ion composition for the single-source and multi-source solar wind structures and compared them with the ICME signatures determined from the kinematic and magnetic field parameters of the solar wind. In the cases of multiple-source events, the resulting solar wind disturbances look as complex structures occurred due to the stream interactions with properties depending on the type of participating streams. The obtained results can be used for improving the model for prediction of solar wind streams based on observations of their solar origins.

EARTH-AFFECTING CME EVENT: COMBINING REMOTE-SENSING IMAGE DATA WITH IN-SITU MEASUREMENTS SUPPORTED BY MODELING

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Abstract

We analyze the well observed flare-CME event from October 1, 2011 and cover the complete chain of action – from the Sun to Earth. We study in detail the solar surface and atmosphere (SDO and ground-based instruments) associated to the flare/CME and also track the off-limb CME signatures in interplanetary space (STEREO-SoHO). This is complemented by surface magnetic field information and 3D coronal magnetic field modeling. From in-sit measurements (Wind), we extract the corresponding ICME characteristics. Results show that the flare reconnection flux is most probably a lower limit for estimating the magnetic flux within the flux rope as 1) magnetic reconnection processes were already ongoing before the start of the impulsive flare phase and 2) the dimming flux increased by more than 25% after the end of the flare, indicating that magnetic flux was still added to the flux rope after eruption. When comparing this to the in-situ axial magnetic flux of the magnetic cloud, we find that it is reduced by at least 75%, referring to substantial erosion in interplanetary space. Careful inspection of on-disk features associated with CMEs are essential for interpreting such scenarios.

CHARACTERIZATION OF CMES FROM ASSOCIATED HIGH FREQUENCY SOLAR RADIO BURSTS DETECTED WITH CALLISTO SPECTROMETERS

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Abstract

Solar radio bursts (SRBs) are electromagnetic radiations originating from solar active regions by plasma emissions. Type II SRBs present particular interest for space weather studies as they often occur in association with geo-effective CMEs. This paper outlines methods and major results from a study conducted to characterize solar CMEs using physical parameters of associated SRBs emitted at relatively higher frequency (150 MHz). In this study, type II SRBs events that occurred between January 2010 and December 2016 were considered. Bursts data considered are dynamic spectra corresponding of 25 such bursts events that were detectable CALLISTO instruments. Firstly, statistical trends of high frequency SRBs is presented during the period under investigation. Next, the drift rate (df/dt) of observed SRBs were derived and were further used in a model to estimate the speed of associated CMEs. Other physical parameters associated with high frequency SRBs were also computed and used to establish various spacio-temporal evolution of accompanying CMEs. The results obtained indicate the importance of considering the high frequency SRBs events in all steps and models for space weather prediction.

WHICH FACTORS OF AN AR DETERMINE WHETHER A STRONG FLARE WILL BE CME ASSOCIATED OR NOT?

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Abstract

We study how the magnetic field determines whether a strong flare launched from an active region (AR) will be eruptive or confined, i.e. associated with a coronal mass ejection (CME) or not. 44 flares of GOES class >M5.0 during 2011 to 2015 were analyzed in SDO data. We used 3D potential magnetic field models to study their location within the host AR (using the flare distance from the flux-weighted AR center, d_FC) and the strength of the overlying coronal field (via decay index n). We also present a first systematic study of the orientation of the coronal magnetic field changing with height, using the orientation phi of the flare-relevant polarity inversion line as a measure. We analyzed all quantities with respect to the size of the underlying active-region dipole field, defined by the distance between the flux-weighted opposite-polarity centers, d_PC. We find that flares originating from the periphery of an AR dipole field (d_FC / d_PC > 0.5) are predominantly eruptive. Flares originating from underneath the AR dipole field (d_FC / d_PC < 0.5) tend to be eruptive when they are launched from a compact AR and confined when launched from an extended AR (d_PC > 60 Mm). In confined events, the flare-relevant field adjusts its orientation quickly to that of the underlying dipole field with height (delta phi > 40° between the surface and the apex of the active-region dipole field), in contrast to eruptive events where it changes more slowly. The critical height for torus instability discriminates best between confined (h_crit > 40 Mm) and eruptive flares (h_crit < 40 Mm). It discriminates better than delta phi, implying that the decay of the confining field plays a stronger role in the eruptive/confined character of a flare than its orientation at different heights.

THE ELECTRON ACCELERATION BY ICME-DRIVEN SHOCKS AT 1 AU

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Abstract

We present two case studies of the in situ electron acceleration at the 11 February 2000 shock and the 22 July 2004 shock with the strongest electron flux enhancement at 40 keV across the shock, respectively, among all the quasi-perpendicular and quasi-parallel ICME-driven shocks observed by the WIND 3DP instrument from 1995 through 2014 at 1 AU. We find that for this quasi-perpendicular (quasi-parallel) shock on 11 February 2000 (22 July 2004), the shocked electron differential fluxes at ~0.4-50 keV in the downstream generally fit well to a double-power-law spectrum, J ~ E^(-beta), with an index of beta ~ 3.15 (4.0) at energies below a break at ~3 keV (~1 keV) and of beta ~ 2.65 (2.6) at energies above. For both shock events, the downstream electron spectral indexes remain similar in all the traveling directions, significantly larger than the DSA theoretic prediction. In addition, the downstream electron fluxes show the strongest intensity in the anti-sunward direction, while the ratio of the downstream over ambient fluxes appears to peak in the traveling directions perpendicular to the interplanetary magnetic field, at all energies of ~0.4-50 keV. These results suggest that in both the two shocks, the SDA likely plays an important role in accelerating electrons in situ at 1 AU. Such ICME-driven shocks could contribute to the formation of solar wind halo electrons at energies <~2 keV, as well as the production of solar wind superhalo electrons at energies >~2 keV, in the interplanetary space.

THE CME INITIATION ASSOCIATED WITH DECIMETRIC RADIO BURST OBSERVATIONS WITH MUSER

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Abstract

The burst event on Dec 17, 2014 for a M8.7 flare/CME was recorded by MUSER in 400MHz-2GHz. Mingantu Spectral Radioheliograph (MUSER) is a solar-dedicated interferometric array with a frequency range from 400MHz to 15 GHz, established recently in Mingantu Town, Inner Mongolia of China. The flare was with circular ribbons over multiple-scale loop structures as revealed by AIA/SDO. There were groups of small-scale low-lying arcades or loops, intermediate dome-like structure, and the large-scale loops as shown in EUV images involved in this flare/CME process. The multi-frequency images in decimeter wave ranges of the burst processed by MUSER demonstrate the large-scale sweeping motion which is agreeable with the CME development which may be associated with the initiation of the CME process.

MAGNETIC ENVIRONMENT ON THE SHOCK DRIVEN BY THE 2012 JANUARY 27 CORONAL MASS EJECTION

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Abstract

We report on the properties of the coronal mass ejection (CME) on 2012 January 27 and the magnetic environment into which the CME driven shocks propagate. The CME erupted from near the northwest limb (N27°W71°) and was associated with the X1.7 flare at 17:37 UT. The CME-driven shock was observed by the Large Angle and Spectrometric

Coronagraph (LASCO) on Solar and Heliospheric Observatory (SOHO) and the COR1 and COR2 coronagraphs on Solar Terrestrial Relations Observatory (STEREO). Using the shock standoff distance technique , we obtained the Alfven Mach number at various heights from the standoff distance and the curvature of the CME flux rope. From the shock speed measured by the coronagraph observations, the local solar wind speed derived from the empirical relation, and the obtained Alfven Mach number, we were able to derive the local Alfven speed (Va in km/s). The plasma density profile (n in cm^{-3}) was measured from the polarized brightness of the corona observed by SOHO and STEREO. Finally, the magnetic field strength (B in Gauss) upstream of the shock is derived by the relation, $B=4.6 \times 10^{-7} n^{0.5} Va$. By combining all observations, we obtained the magnetic field strength profile as $B=0.669 r^{-1.59}$, where r is in solar radius. The obtained profile is steeper than what was found for 2008 ($r^{-1.23}$. The magnetic environment information is important for understanding the particle acceleration.

EARTH AFFECTING CORONAL MASS EJECTIONS: TEXTBOOK EVENTS VERSUS STEALTH EVENTS

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Abstract

Geomagnetic storms and other adverse space weather phenomena are known to be mostly caused by energetic eruptions from the Sun, resulting in coronal mass ejections (CMEs) as observed near the Sun, and upon arriving at the Earth, appearing as Interplanetary ICMEs (ICMEs) from in-situ solar wind plasma, magnetic field, and particle observations. We will be presenting two types of extreme events across a broad spectrum of events that connect the Sun and the Earth. First, the textbook type of events, which are characterized by excellent observations continuously tracking the complete cause-effect chain, including photospheric source regions, various pre-eruption and post-eruption phenomena in the corona, near-Sun CME observations, CME propagation and expansion in the inner heliosphere, near-Earth in-situ solar wind observations, and finally the occurrence of geomagnetic storms. These types of events can be well constrained by data and reasonably understood in theory, thus can be used as excellent test bed for various numerical MHD models. Secondly, on the other hand, there exists one set of ICMEs that have unambiguous signatures in in-situ observations, but lack of apparent progenitor CMEs. A progenitor CME is often shown as a full halo (angular width of 360º) or partial halo (angular width larger than 120º) CME in the coronagraphs situated along the Sun-Earth line, such as LASOC onboard SOHO at the L1 point. We coin this type of events as Stealth ICMEs, following the term of Stealth CMEs. The lack of successful observations of progenitor CMEs poses a serious challenge to the effectiveness of current space weather prediction. This study emphasizes the importance of having off-Sun-Earth-line missions in the future i.e., L5 and L3 missions.

FAST ACCELERATION OF "KILLER" ELECTRONS AND ENERGETIC IONS BY INTERPLANETARY SHOCK STIMULATED ULF WAVES IN THE INNER MAGNETOSPHERE

Quiang Zong (Institute of Space Phyics and Applied Technology, Peking University, China) qgzong[at]pku.edu.cn, X. Zhou, and Y. Wang

Abstract

Energetic electrons and ions in the Van Allen radiation belt are the number one space weather threat. How the energetic particles are accelerated in the Van Allen radiation belts is one of major problems in the space physics. Recently, by using four Cluster spacecraft observations, we have found that after interplanetary shocks impact on the Earth's magnetosphere, the acceleration of the energetic electrons in the radiation belt started nearly immediately and lasted for a few hours. The time scale (a few days) for traditional acceleration mechanism of VLF wave-particle interaction, to accelerate electrons to relativistic energies is too long to explain the observations. It is further found that interplanetary shocks or solar wind pressure pulses with even small dynamic pressure change can play a non-negligible role in the radiation belt dynamics. Interplanetary shocks interact with and the Earth's magnetosphere manifests many fundamental important space physics phenomena including energetic particle acceleration. The mechanism of fast acceleration of energetic electrons in the radiation belt response to interplanetary shock impact contains three contributing parts: (1) the initial adiabatic acceleration due to the strong shock-related magnetic field compression; (2) then followed by the drift-resonant acceleration with poloidal ULF waves excited at different L-shells; and (3) particle acceleration due to fast damping electric fields associated with ULF waves. Particles will have a net acceleration since particles in the second half circle will not lose all of the energy gained in the first half cycle. The results reported in this paper cast new lights on understanding the acceleration of energetic particles in the Earth's Van Allen radiation belt. The results of this study can be widely used in interplanetary shock interacting with other planets such as Mercury, Jupiter, Saturn, Uranus and Neptune, and other astrophysical objects with magnetic fields.

Session 1: Mass Chain (MC)

MC1.2 Origin, evolution, and Earth impact of high speed streams

Lead Conveners
M. Temmer
V. N. Obridko

Plenary Speaker
Dan Baker

Invited Speakers
Lan Jian
Rui Pinto

Session Description

Coronal holes are regions of reduced density and low temperature in the solar corona produced by quasi-open magnetic field lines enabling plasma to freely escape into IP space. They generate so-called high speed solar wind streams (HSS) with higher-than-average speeds up to ~800 km/s. The slow solar wind, formed above active regions, interacts with the fast wind and form stream interaction regions (SIRs) or, when persistent over several solar rotations, corotating interaction regions (CIRs). Together with sporadic fast flows of transient ejecta, such as CMEs, SIRs/CIRs shape the distribution of solar wind flow in the inner heliosphere. With this they permanently change the environmental conditions of near-Earth space and determine our space weather. We invite contributions about studies on CH evolution and related HSS/CIR/SIR signatures using in-situ measurements at multiple viewpoints as well remote sensing data from space-borne and ground-based instruments in multi-wavelength range (like He I 1083 nm, radio, white-light) and magnetic field information; interaction of solar wind structure with transient events (CMEs); geomagnetic disturbances and inner magnetosphere impact.

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THE SUN-EARTH CONNECTION: SOLAR FORCING OF THE EARTH'S MAGNETOSPHERE AND ATMOSPHERE SYSTEM

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Abstract

Observational and numerical modeling evidence demonstrates that geomagnetic storms are a coherent set of processes within the coupled near-Earth system. The magnetosphere progresses through a specific sequence of energy-loading and stress-developing states until the entire system suddenly reconfigures. Related long-term studies of relativistic electron fluxes in the Earth's magnetosphere have revealed many of their temporal occurrence characteristics and their relationships to solar wind drivers. Early work showed the obvious and powerful role played by solar wind speed in producing subsequent high-energy electron enhancements. More recent work has also pointed out the key role that the north-south component of the IMF plays: In order to observe major relativistic electron enhancements, there must typically be a significant interval of southward IMF along with a period of high (VSW≥500 km/s) solar wind speed. This has led to the view that enhancements in geomagnetic activity (i.e., magnetospheric substorms) are normally a key first step in the acceleration of radiation belt electrons to high energies. A second step is suggested to be a period of powerful low-frequency waves that is closely related to high values of VSW or higher frequency ("chorus") waves that rapidly heat and accelerate electrons. Hence, substorms provide a "seed" population, while high-speed solar wind drives the acceleration to relativistic energies in this two-step geomagnetic activity scenario. This picture seems to apply to most storms examined whether associated with high-speed streams or with CME-related events, but not all. In this talk, we address broad Sun-Earth relationships starting with major solar forcing events and culminating with effects in Earth's magnetosphere-ionosphere-atmosphere region. Observational and numerical modeling evidence demonstrates that geomagnetic storms are a coherent set of processes within the coupled near-Earth system. The magnetosphere progresses through a specific sequence of energy-loading and stress-developing states until the entire system suddenly reconfigures. Related long-term studies of relativistic electron fluxes in the Earth's magnetosphere have revealed many of their temporal occurrence characteristics and their relationships to solar wind drivers. Early work showed the obvious and powerful role played by solar wind speed in producing subsequent high-energy electron enhancements. More recent work has also pointed out the key role that the north-south component of the IMF plays: In order to observe major relativistic electron enhancements, there must typically be a significant interval of southward IMF along with a period of high (VSW≥500km/s) solar wind speed. This has led to the view that enhancements in geomagnetic activity (i.e., magnetospheric substorms) which is normally a key first step in the acceleration of radiation belt electrons to high energies. A second step is suggested to be a period of powerful low-frequency waves that is closely related to high values of VSW or higher frequency ("chorus") waves that rapidly heat and accelerate electrons. Hence, substorms provide a "seed" population, while high-speed solar wind drives the acceleration to relativistic energies in this two-step geomagnetic activity scenario. This picture seems to apply to most storms examined whether associated with high-speed streams or with CME-related events, but not all. In this talk, we address broad Sun-Earth relationships starting with

major solar forcing events and culminating with effects in Earth's magnetosphere-ionosphere-atmosphere region.

GROWING CORONAL MEGA-HOLES TOWARDS THE SOLAR MINIMUM

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Abstract

The coronal holes (CH) are observed in the EUV and soft X-ray wavelengths on the solar disc as the colder and less bright regions compared to the background brightness. The magnetic field lines of CH stay open and generate high speed solar wind (HSS). Coronal Mega-Hole (CMH) has been observed during twenty-four Carrington Rotations from CR2165 (June 2015) to CR2188 (March 2017). When a coronal hole is positioned near the center of the Earth-facing solar disk, the plasma flows towards Earth at a higher speed than the regular solar wind and cause geomagnetic disturbances on Earth with enhanced auroral activity. We present here the results of analysis of the CH Power index, Pch, for a period from March 2011 to December 2017, built up with SOHO EIT 284 Å observations by Luo B. et al. [Solar Phys. 250, 159-170, 2008]. The Pch index is evaluated daily from the SDO/AIA images (Fe XII 193Å) by the Space Environment Prediction Centre, Beijing, China, for forecasting the solar wind velocity three days in advance (Vsw) from the intensity of brightness of the CH near the center of solar disc at [10°E,10°W], [30°N, 30°S]. It is found that the Pch variation near the center of solar disc is consistent with the total area of the CMH which is located near the North pole and passes to 30°S at its maximum development. The long-term variation of the Pch index shows a trend of growing Pch towards the minimum of the solar cycle SC24 while the HSS does not reveal a similar phenomenon. The impact of the central CH and HSS on the geomagnetic and ionospheric disturbances is discussed in the paper.

THE 3-PHASE EVOLUTION OF A LONG-LIVED LOW-LATITUDE CORONAL HOLE AND ITS ASSOCIATED HSS

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Abstract

We investigate the evolution of a well-observed, long-lived, low-latitude coronal hole (CH) that occurred in the year 2012, combining STEREO-A/B (EUVI, PLASTIC, IMPACT), SDO (AIA, HMI), WIND (SWE, SMS, MFI), and ACE (MAG, SWEPAM) data. This enables continuous 360° observations of the surface properties of the CH and their relation to the in-situ signatures of the associated HSS. By investigating the different evolutionary states of the CH in the solar atmosphere and its effects at 1au, a three-phase evolution is revealed covering a growing, maximum, and decaying phase. The three-phases manifest themselves in multiple parameters of the CH, extracted from the photosphere (magnetic field strength, magnetic flux) and corona (EUV area and intensity) as well in interplanetary space (solar wind proton bulk velocity). During the growing phase, the CH area increases from $1x10^{10}$ km^2 to > $6x10^{10}$ km^2, followed by a plateau of rather constant area (maximum phase, 8 to $10x10^{10}$ km^2) and finally the CH area decreases (decaying phase, <1x10^10 km^2) again until the CH is cannot be identified anymore. We also find a strong linear correlation between the magnetic properties (i.e., signed/unsigned magnetic field strength) and area of the CH. From the in-situ measurements of the associated high-speed solar wind stream, we derive a clear correlation between the CH area and solar wind proton bulk speed, which is in good agreement with previous studies.

THE DEPENDENCE OF THE PEAK VELOCITIES OF HSS ON THE CO-LATITUDES OF THEIR SOURCE CHS

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Abstract

The peak velocities of high-speed streams are linearly dependent on the areas of their solar source coronal holes. We revise this relationship in a comprehensive study of 115 events in the time-range from August 2010 to March 2017, whereby we analyse the properties of the solar source coronal holes, the corresponding high-speed solar wind streams at 1au, and for a subset their geomagnetic consequences using data from the satellites SDO, ACE, STEREO-A, STEREO-B, and the geomagnetic Kp index. Thereby, we find a further distinct dependence of the high-speed stream peak velocities measured and of the geomagnetic Kp indices on the co-latitudes of the solar source coronal holes. High-speed streams arising from coronal holes located near the ecliptic result in the highest peak velocities per coronal hole area, and they linearly decrease with increasing latitudes of the source coronal holes. For coronal holes located at latitudes >60°, the corresponding high-speed stream peak velocities per coronal hole area statistically even turn to zero. Analogously, the highest Kp indices per coronal hole areas are found for coronal holes located near the solar equator, and turn statistically to zero for coronal holes located at latitudes >60°. By adding the coronal hole latitudes as a further parameter to the high-speed stream peak velocity – coronal hole area relationship, the Spearman's correlation coefficient between predicted and measured high-speed stream peak velocities increases from cc=0.50 to cc=0.72. We interpret this as an effect of the three-dimensional propagation of high-speed streams in the heliosphere: high-speed streams arising from coronal holes directly looking towards the Earth directly hit the Earth leading to the largest signals at the satellites and stronger geomagnetic effects, whereas high-speed streams arising from coronal holes located at higher solar latitudes propagate into the direction of higher heliospheric latitudes usually only grazing the Earth.

UNDERSTANDING THE STRUCTURE AND EVOLUTION OF STREAM INTERACTION REGIONS FROM AN OBSERVATIONAL ASPECT

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Abstract

In the interplanetary space, as fast wind overtakes the preceding slow wind and outruns the following slow wind, it forms a compressed stream interaction region (SIR) in the front part and a rarefaction region in the trailing part. If the solar source regions are steady, the SIRs would reoccur in one or more solar rotations, forming co-rotating interaction regions (CIRs). The SIRs can cause geomagnetic storms and affect the evolution of radiation belt. In contrast to interplanetary CMEs, there are many SIRs throughout a solar cycle, typically more than 30 events per year, thus they are a persistent factor impacting the space weather. The SIRs occur more often and are generally stronger at the declining phase of a solar cycle, providing an important clue to the solar cycle evolution. According to historical long-term observations including Helios, Ulysses, Pioneer, etc., the SIRs become stronger relative to the background solar wind, widen as the compression between slow and fast wind increases with heliocentric distance, and eventually they form merged interaction regions in middle heliosphere. Although SIRs are quasi-steady solar wind structures, the multi-point observations of them especially in the STEREO era have revealed the dynamics of SIRs, such as the changes of the stream interface between the slow and fast wind, as well as the variations of associated shocks. We will also examine the differences between the SIRs with and without heliospheric current sheet crossings, to explore the stream boundaries coming from the main streamer belt versus the ones from pseudostreamers.

SPACE WEATHER FORECAST USING BACKGROUND INFORMATION GENERATED BY SUPERPOSED OBSERVATIONS OVER PREVIOUS CARRINGTON CYCLES

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Abstract

It is well known that there are good relations of coronal hole (CH) parameters such as the size, location, and magnetic field strength to the solar wind conditions and the geomagnetic storms. Especially in the minimum phase of solar cycle, CHs in mid- or low-latitude are on of major drivers for geomagnetic storms, since they form co-rotating interaction regions (CIRs). We have done daily forecasts of geomagnetic storms from 2011. Through years of experience, we realize that the geomagnetic storms caused by CHs have different characteristics from those by CMEs. Therefore, we analyze the characteristics and causality of the geomagnetic storms by the CHs and solar activities statistically. Results show the different trends of the solar wind parameters and geomagnetic indices depending on the degree of solar activities. This can suggest space weather forecast using background information generated by superposed observations over previous Carrington cycles to improve forecasting capability.

NEW STRATEGIES FOR MODELING AND FORECASTING THE SOLAR WIND

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Abstract

The solar wind is an uninterrupted flow of highly ionized plasma that is accelerated in the low solar corona and expands into the interplanetary space. Fast and slow wind streams develop at different places in the solar atmosphere, reflecting the global distribution of the coronal magnetic field during solar cycle. The background solar wind flow is a key component of space weather, being the source of co-rotating density structures that perturb planetary atmospheres and affecting the propagation of impulsive perturbations (such as CME). Commonly used semi-empirical predictive laws for the solar wind speed use simple parameters describing the global geometry of the coronal magnetic field and require, in practice, ad-hoc corrections. Numerical models of the solar wind, on the other hand, provide a fuller physical description of the wind, albeit requiring higher computational resources. I will also present a new real-time solar wind forecasting

pipeline (SWiFT-FORECAST) based on a multiple flux-tube approach (model MULTI-VP) allowing for very significant gains in computation time in respect to the full 3D MHD problem. The pipeline takes a coronal magnetic field map as input (past data or forecast), and computes a collection of solar wind profiles spanning a region of interest of the solar atmosphere (up to a full synoptic map) at any instant desired in quasi-real time, while keeping a good description the plasma heating and cooling mechanisms. SWiFT can be setup to provide continuously (nearly real time) a full set of bulk physical parameters of the solar wind (surface to ~1au) based solely on physical principles (wind speed, density, temperature, magnetic field, phase speeds) up to a few days in advance. The model benefits from multi-point observations and in-situ measurements and used several intermediate control points for calibration.

DEVELOPMENT OF ADAPTIVE KALMAN FILTER FOR SOLAR WIND FORECAST

Tatiana Podladchikova (Skolkovo Institute of Science and Technology, Russia)
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Abstract

Accurate solar wind modeling is important for predicting the arrival and geomagnetic response of high-speed solar wind streams as well as for modeling the transit of coronal mass ejections in interplanetary space and their impact at Earth. Data assimilation techniques combining the strength of models and observations provide a very useful tool for accurate solar wind forecasts. We develop a method to predict the solar wind speed at Earth one-day ahead by using coronal hole areas derived from SDO AIA images in combination with in situ solar wind plasma and field data (speed, density, and magnetic field magnitude) from ACE and Wind spacecraft. To forecast the solar wind speed, we form a multi-dimensional linear regression model relating the solar wind speed one day ahead with the fractional coronal hole area observed three days before the current moment, as well as proton density, magnetic field magnitude, and solar wind speed at the current moment. One of the major concerns with such data assimilation scheme is that the regression coefficients do not remain constant and are time-varying. To avoid the fitting of regression coefficients to a particular situation, that can be changed in future, we develop an adaptive Kalman filter to create a dynamic linear regression for the 1-day ahead prediction of the solar wind speed. By testing the developed forecasting technique for the period 2010-2017, we obtained a correlation coefficient between the predicted and observed solar wind speed of 0.93, with an RMS error of prediction of 33 km/s. These results demonstrate that the proposed adaptive Kalman filter method significantly improves the quality of the solar wind forecasts and can be applied for reliable real-time warnings of the space weather conditions in the near-Earth environment.

GLOBAL PC1 PULSATIONS AND PURPLE AURORAL RAYS AT THE CIR ARRIVAL ON MARCH 21, 2017

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Abstract

This paper reports two unique features, i.e., postmidnight purple auroral rays and global Pc1 geomagnetic pulsations, observed at the beginning of the storm of March 21, 2017 associated with the arrival of a Corotating Interaction Region (CIR). This is during the first campaign observation of our new PWING longitudinal ground network with the Arase satellite. The auroral rays with blue/purple colours were observed at ~0315-0430 UT (~03-04 magnetic local time) in the northeastern sky at Husafell, Iceland (magnetic latitude: 64.9°N). The entry of high-density solar-wind plasma into the magnetotail may cause these auroral rays in the sunlit ionosphere. The Pc1 geomagnetic pulsations at frequencies of 0-0.5 Hz were observed after ~00 UT over a wide longitudinal range of 13 hour local times from midnight to afternoon sectors at subauroral latitudes. Based on the estimation of the scattering rate of radiation belt particles from these widely distributed Pc1 waves, we conclude that these global Pc1 waves did not contribute to the loss of the radiation belt particles, because of their small amplitudes.

STATISTICAL STUDY ON CORONAL HOLE EVOLUTION AND APPLICATION FOR SOLAR WIND SPEED FORECASTING

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Abstract

The evolution of coronal holes (CHs), which are the sources of high speed solar wind streams, play an important role in the persistence of the solar wind structure in interplanetary space. Forecasting tools that are based on persistence models, i.e., for the in-situ solar wind speed, might be less reliable during times when CHs undergo strong changes. To assess the speed uncertainty in persistence models, we perform a statistical study on the CH area evolution from combined EUV observations (STEREO versus SoHO/SDO) and the response of that evolution in the in-situ measured solar wind speed (STEREO versus ACE). By comparing the extracted fractional CH area in each spacecraft, we derive a relation between expanding CH areas and increase in the solar wind speed. In comparison, there is no consistent trend found for decaying CHs to be related to solar wind streams of decreasing speed. These results can be applied to modify solar wind speed forecasting models when monitoring EUV data and CH evolution from different vantage points. For expanding CHs we give an uncertainty estimate in the forecasted speed which leads to an improvement of the hit/miss rate in the prediction of solar wind high speed streams. The obtained results support a future L5 mission and show the importance and valuable contribution using multi-viewpoint data.

MAGNETOSPHERE RESPONSE TO IMPULSE SPACE WEATHER EVENTS: RELATIONSHIPS BETWEEN PC, AE AND SYMH INDICES

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Abstract

Index of the polar cap magnetic activity (PC index) is regarded [Resolution of the XII IAGA Assembly, 2013] as a proxy of the solar wind energy that entered into the magnetosphere. Relationships between the 30 min smoothed PC and SymH indices examined for 430 magnetic storms [Troshichev and Sormakov, 2017] showed that magnetic storms can be classified, by features of the PC evolution, as classic, pulsed and composite magnetic storms. The classic and pulsed storms are related, correspondingly, to such solar drivers as Coronal Mass Ejections (CME) and Stream Interaction Regions (SIR), whereas the composite storms are produced by joint action of these drivers. The results of the statistical analysis demonstrate that depression of the geomagnetic field generally follows the time evolution of the PC index with typical delay time of $\Delta T \sim 1\pm0.5$ hours, the storm intensity (SymHMIN) being linearly related to maximal value of the foregoing PC index (PCMAX). Relationships between PC, AE and SymH indices in course of classic, pulsed and composite magnetic storms were examined for conditions of the impulse solar wind impact on the magnetosphere. Analysis of magnetic disturbances related to the solar wind dynamic pressure pulses showed that delay times ΔT between the PC index leap and the corresponding response in SymH is reduced in these cases. Reason of the evident ΔT reduction is sharp enhancement of the DCF currents flowing along the magnetopause, their close through the field-aligned current (FAC) system across the polar cap ionosphere and the appropriate sharp increase of the polar cap magnetic activity PC index. The PC and SymH response to different types of the impulse SW events is examined.

Session 1: Mass Chain (MC)

MC1.3 Origin, Evolution, and Earth Impact of Energetic Particles from Solar, Magnetospheric and Galactic Sources

Lead Conveners
B. Heber
S. Kanekal

Plenary Speaker
Monica Laurenza

Invited Speakers
Allison N Jaynes,
Miriam Sinnhuber

Session Description

The radiation effects of energetic particles have not only severe implications for interplanetary manned space missions but can also cause fatal damage of satellites due to charging or radiation damage of electronic components. Although the intensity of galactic cosmic rays that have their origin outside the heliosphere varies by less than an order of magnitude over the solar cycle flux GCRs form the most energetic radiation component. Less energetic are solar energetic particles. Energetic electrons in the outer radiation belts have been known to increase by several order of magnitude for sustained periods of time and cause spacecraft damage via deep dielectric discharge. Together with energetic particles of magnetospheric origin like those in the dynamic radiation belts these particles have their impact on the Earth' environment. We invite contributions that present modeling as well as observational results on the origin, evolution and impact of these radiation components.

STOCHASTIC MAGNETIC RECONNECTION AND PARTICLE ACCELERATION NEAR STRONG CURRENT SHEETS IN THE SOLAR WIND

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Abstract

Several theoretical, numerical, and observational analyses have been concentrated on studying the acceleration of charged particles via magnetic islands. Particles propagating through a sea of magnetic islands experience islands contraction, islands merging, and the induced electric field generated by the islands merging. We studied the particle acceleration in the vicinity of the reconnecting current sheet via magnetic islands and the observations made by the ACE spacecraft. We found a corelation between the theoretical and observed particle acceleration. We found that the Alfven Mach number, the diffusion time scale, the contraction time scale, and the particle speed are important in the particle acceleration.

ELECTRON PRECIPITATION FROM THE OUTER RADIATION BELT DURING THE ST PATRICK'S DAY STORM

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Abstract

Recently, a model for 30–1000 keV radiation belt driven energetic electron precipitation (EEP) has been put forward for use in climate models. That EEP model is based on precipitation data spanning 2002-2012 from the constellation of low Earth orbiting POES satellites. In this presentation we will test the EEP model's ability to represent the EPP during a large geomagnetic storm which occurred outside the original data span. In a study of narrow band sub-ionospheric VLF transmitter data collected during March 2015, continuous phase observations have been analysed throughout an entire geomagnetic storm period for the first time. Using phase data from the UK transmitter, GVT (22.1 kHz), received at an AARDDVARK site in Reykjavik, Iceland, electron precipitation fluxes from L=2.78-5.44 are calculated for magnetic local noon time (12 MLT), and magnetic midnight (00 MLT). Good agreement is seen between VLF phase modelling and POES zonal mean fluxes (within a factor of 2) during the eight days of storm-induced precipitation. A new model of electron precipitation, which includes MLT variability[1], compares well with POES/VLF fluxes, but appears to be a factor of ~5 too low during the recovery phase of the storm, mainly due to overly low model fluxes in the MLT afternoon sector. The similarities and differences between electron precipitation characteristics determined from observations and models will be discussed.

COMPARISON OF SAMPEX OBSERVED RELATIVISTIC MICROBURST ACTIVITY AND GROUND BASED WAVE MEASUREMENTS AT HALLEY, ANTARCTICA

Emma Douma (University of Otago, New Zealand) emmadouma[at]gmail.com, C.J. Rodger, M.A. Clilverd, A.T. Hendry, M.J. Engebretson, and M.R. Lessard

Abstract

Relativistic electron microbursts are a known radiation belt electron precipitation phenomenon; however, experimental evidence of their drivers have just begun to be observed. Recent modelling efforts have shown both whistler mode chorus waves and

EMIC waves are capable of causing relativistic microbursts. We create a database of relativistic electron microbursts using an automated detection algorithm applied to the SAMPEX HILT >1MeV electron flux observations. We use the VELOX and SCM at Halley, Antarctica, to investigate the ground based wave activity at the time of SAMPEX observed relativistic microbursts. We present three case studies of relativistic microburst events, where one or both of the wave modes are present in the Halley ground based observations. Based on the inconsistency in the case studies, we conduct superposed epoch analyses of the wave activity present at the time of the larger database of relativistic microburst events. Increased VLF wave amplitude is present at the time of the relativistic microburst events, identified as whistler mode chorus wave activity. While there is also an increase in Pc1–Pc2 wave power at the time of the relativistic microburst events, it is identified as broadband noise and not structured EMIC emissions. We conclude that whistler mode chorus waves are, most likely, the primary drivers of relativistic microbursts. However, our case studies confirm the potential of EMIC waves as a possible occasional driver of relativistic microbursts.

CHARACTERISTICS OF SUBIONOSPHERIC VLF SIGNAL PROPAGATION DURING ENERGETIC ELECTRON INJECTIONS

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Abstract

Charged particles can be lost from the Earth's radiation belts, and geomagnetic events can be considered as drivers. Distribution of these electrons into the atmosphere or "precipitation" is one of the major routes for loss. Precipitated electrons deposit energy into the atmosphere and alters the ionization rate over a wide altitude range. Changes in D-Region ionization caused by energetic particle precipitation are monitored by the Array for Broadband Observations of VLF/ELF Emissions (ABOVE) - a network of VLF receivers deployed across Western Canada. The observed amplitudes and phases of subionospheric VLF signals from distant artificial transmitters depend sensitively on the free electron population created by precipitation of energetically charged particles. So precipitation affects subionospheric VLF signal propagation, influencing the amplitude and phase of the received signal in ground based instruments. We characterized energetic electron injections from substorms based on Van Allen Probes data ("RBSP"-Radiation Belt Storm Probes). We analyzed data from the ground based instrument, ABOVE, to constrain when, where, and how much precipitation happens. We used phase/amplitude data for six different transmitter-station paths which cover western Canada. Finally, by comparing Van Allen Probe data and ground based data we investigated the correlation of phase of VLF signals with losses from Van Allen Probes and ended up with clear phase signatures in northern station, FSMI(L=6.68). Then we use a full-scale model to predict the received VLF signals to compare previous observation based results with modeling expectations.

THE FASCINATING DYNAMICS OF THE HIGH-ENERGY VAN ALLEN RADIATION BELTS

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Abstract

High-energy particles contained within the Van Allen belts can be dangerous to sensitive electronics in space, and can affect human activity on the Earth's surface. Precipitating radiation leaving the radiation belts of the Earth's atmosphere can play a role in terrestrial weather and climate systems. Over nearly six years of high-energy particle measurements obtained by the Relativistic Electron Proton Telescope (REPT) instrument of NASA's Van Allen Probes mission, a fascinating array of variation and dynamics can be observed in the outer belts. Here we present several key results showing how the belts can be accelerated up to these very high energies. We also show that it is difficult to generalize from one event to the next, since the resulting dynamics are a complex interplay between various acceleration and loss mechanisms. No two storm events or non-storm events are quite alike, and as such we point out the need for event-specific simulation efforts to enhance our understanding of the full system.

A COMBINATION OF DIFFERENT MECHANISMS OF PARTICLE ACCELERATION IN THE HELIOSPHERE: OBSERVATIONAL AND THEORETICAL ASPECTS

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Abstract

Both case and theoretical studies of particle acceleration and transport throughout of the heliosphere show that the co-existence of several simultaneously acting sources of energetic particles may lead to observations of poorly predicable and puzzling energetic particle flux enhancements at 1au and beyond. Particles of keV-MeV energies are known to be observed at the Earth's orbit owing to diffusive shock acceleration or acceleration by flares. At the same time, recent results show that the occurrence of coherent structures such as current sheets and magnetic islands impacts time-intensity profiles of energetic particle flux of the keV-MeV energy ranges considerably both in terms of their modulation and additional acceleration of energetic particles. Since the latter occurs directly in the solar wind, particle energization processes associated with coherent structures represent an underestimated risk of space weather. Energetic particles can be accelerated locally during merging and reconnection of magnetic islands. Magnetic reconnection at strong current sheets in the solar wind is associated with particle energization too. We show observations from different spacecraft at various heliocentric distances and present a summary of the evidence that supports the idea of combination of different particle acceleration mechanisms in the solar wind.

CONTRIBUTION OF GALACTIC AND SOLAR COSMIC RAYS TO THE INTERPLANETARY AND NEAR- EARTH PARTICLE RADIATION ENVIRONMENT

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Abstract

The particle radiation environment in the interplanetary and near-Earth space is composed by several populations of different origin and characteristics (composition, energy spectrum, timing), among galactic cosmic rays (GCRs) and solar energetic

particles (SEPs, also called solar cosmic rays). The estimation of these radiation components is essential for space missions, as they produce a background that can interact with spacecraft and instruments. Moreover, they cause biological effects and ionization in the Earth's atmosphere with consequences on radio communications, ozone content and climate. This talk gives an overview of the physical processes affecting the evolution of the aforementioned sources of radiation and their impact in the near-Earth space. Recent results are presented on the variability of GCRs and SEPs and their access in the terrestrial environment. In particular, the role and contribution of solar activity and drifts in the GCR modulation are investigated by a novel approach based on the Empirical Mode Decomposition. Finally, the dynamics and spectral features of large SEP events are discussed.

SMALL SEP EVENTS WITH METRIC TYPE II RADIO BURSTS

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Abstract

Recent studies have shown that the fluence spectrum of large solar energetic particle (SEP) events harden with increasing initial speed of coronal mass ejections (CMEs) and that the average type-II starting frequency of ground level enhancements (GLEs), regular SEP events, and filament-eruption-associated SEP events decreases consecutively. These hierarchical relationships provide further evidence on the importance of CME-driven shocks in accelerating SEPs. However, the previous studies have concentrated on large SEP events. Here we report on our study of less-intense SEP events. These small SEP events are identified using low-background proton measurements by the Energetic and Relativistic Nuclei and Electron (ERNE) instrument on the Solar and Heliospheric Observatory (SOHO) spacecraft. We compare our results with those of the earlier studies on hierarchical relationships. Comparisons suggest that while the CME-driven shock probably is weaker and laterally narrower, the CME-driven shock still is able to accelerate SEPs.

A NOVEL APPROACH TO QUANTIFYING EPP INFLUENCES ON THE BUDGETS OF STRATOSPHERIC NOY AND OZONE

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Abstract

Energetic particle precipitation (EPP) is thought to be one of the ways the geospace environment can affect the middle and lower atmosphere. EPP leads to ionization of the major molecular species and through a series of neutral and ion reactions, leads to the production of odd-hydrogen (HO_x = {H, OH, HO_2}) and odd-nitrogen (NO_x = {N, NO, NO_2}). NO_x is of particular interest because it can catalytically destroy ozone, effecting the energy budget of the stratosphere. Energetic particles that precipitate in the stratosphere, mesosphere include medium energy electrons (MEE), energetic solar protons, and galactic cosmic rays (GCR). These EPP NO_x sources are now part of the recommended forces used to drive upcoming simulations for Coupled Model Intercomparison Project Phase 6 (CMIP6). To date, it has been difficult to quantify the influence of EPP on the budgets of stratospheric total inorganic nitrogen (NO_y) and ozone. In this work, we employed the approach developed for tropospheric chemistry studies [Emmons et al., Geosci. Model Dev., 2012] to 'tag' NO_y from specific sources and the associated ozone production and loss. This ‘tagging’ allowed us to quantify the relative impacts on NO_y and ozone loss rates from each EPP source. Furthermore, we are able to calculate the residence time of EPP NO_y in the stratosphere following a large EPP event; a necessary step in understanding solar cycle induced variability on stratospheric ozone.

INFLUENCE OF SOLAR PROTON EVENT ON THE INFRARED RADIATIVE COOLING BY NITRIC OXIDE

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Abstract

The solar proton events bring highly energetic protons into the Earth’s atmosphere. They originate either from intense solar flares or CME associated shock waves. The solar protons normally have insufficient energy to penetrate the Earth’s magnetic field. However, during unusually strong flare and coronal mass ejection events, protons can be produced with sufficient energy to reach the earth’s magnetosphere, ionize, and heat the polar thermosphere. The nitric oxide is mainly responsible for maintaining the overall heat budget of the thermosphere. The SABER instrument onboard the TIMED satellite provides continuous observation of energy radiated from the vibrational excited states of NO at 5.3 μm. The most intense solar proton events during 2002-2017 have been identified using GOES satellite observations. During these events, the fluctuation in overall heat loss from the thermosphere is studied using SABER measurements. It has been found that the NO emission shows a large enhancement during proton events. There is hemispheric asymmetry in the magnitude of fluctuations induced in thermosphere during proton events. The physical mechanism responsible for the fluctuations in NO radiative energy and the hemispheric asymmetry will be discussed in this paper.

THE RELATION OF SOLAR ELECTRON EVENTS WITH EUV WAVES REVISITED FOR SOLAR CYCLE 24 EVENTS

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Abstract

Thanks to data from the Atmospheric Imaging Assembly (AIA) on the Solar Dynamics Observatory (SDO), we can characterize EUV waves more thoroughly than before. They are correlated with SEP events including electrons, especially with those that show wide longitudinal distributions. We study the onset phase of electron events during solar cycle 24 in comparison with EUV waves observed by AIA and STEREO EUVI. Our interest is whether the EUV wave reaches the footpoint of the field line that connects to the observer (connection point) around the time at which electrons are injected. The connection point is derived by the Parker spiral plus either the PFSS model or Predictive Science's MHD model. In several cases, the wave may never arrive at the connection point, or it may arrive either too early or too late. The distance between the connection point and the wave front is measured along a great circle at the particle injection. We investigate how the 3D structure of the EUV wave (as rendered using STEREO observations) changes the timing relations. We check the consistency of the polarity at the connection point and at 1au. Solar wind data are examined to detect disturbances and

discontinuities that may alter the Parker spiral. We also discuss how adequate the input synoptic maps are for global magnetic field extrapolations.

IMPROVED EMPIRICAL MODEL TO PROVIDE LONG-TERM DATASETS OF RADIATION BELT MEDIUM ENERGY ELECTRON PRECIPITATION

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Abstract

The influence of solar variability on the polar atmosphere and climate due to energetic electron precipitation (EEP) has remained an open question largely due to lack of a long-term EEP forcing data set that could be used in chemistry climate models. Motivated by this, we have developed a model for 30–1000 keV radiation belt driven EEP. [Van de Kamp et al., JGR, 10.1002/2015JD024212, 2016] The EEP model is based on precipitation data from the constellation of low Earth orbiting POES satellites which is organized with respect to an empirically described plasma sphere structure, where both are scaled using a geomagnetic index. Using this EEP representation avoids the challenges posed by storm time solar proton event contamination in the POES data, and also allows the precipitation to be included over extremely long time scales suitable for climate modelling sensitivity studies. This model was endorsed for CMIP-6[Matthes et al., Geosci. Mod. Dev., doi:10.5194/gmd-10-2247-2017]. We will describe the original EEP model, and recent improvements to the original EEP model. These improvements allow a better characterisation of the fluxes during periods impacted by the low sensitivity "noise floor" of the POES electron observations. This should provide more realistic descriptions of low fluxes during geomagnetically quiet times. This is our new recommended EEP representation for climate modelling. In addition, we developed a second EEP model, which includes the improved quiet time low EEP flux approach described above, and also describes flux and energy spectral variations that are organized by magnetic local time (MLT). The later is an important factor when looking at diurnal variations in EEP impact on atmospheric chemistry because the majority of EEP occurs on the nightside. Previously, this effect was under-represented because of the use of zonal averaging. We are investigating the importance and implementation of the MLT-dependent forcing.

RECENT RESULTS OF EMIC/ELF/VLF WAVE MEASUREMENTS AT ATHABASCA (L=4.2), CANADA

Kazuo Shiokawa (Institute for Space-Earth Environmental Research, Nagoya Univeristy, Japan) and M. Connors

Abstract

We review our recent results on the observation of the electromagnetic ion cyclotron (EMIC) waves and magnetospheric ELF/VLF (electron cyclotron) waves observed at Athabasca, Canada at L=4.2 at subauroral latitudes. These waves are strongly related to the acceleration and loss of Earth’s radiation belt particles. One-to-one correspondence between the EMIC waves and isolated proton auroras has been reported by Sakaguchi et al. [JGR, doi:10.1029/2006JA012135, 2007; JGR, doi:10.1029/2007JA012888, 2008]. Miyoshi et al. [GRL, doi:10.1029/2008GL035727, 2008] showed that this isolated proton aurora is also accompanied by the high-energy (~MeV) electron precipitation. Nomura et al. [JGR, doi:10.1002/2015JA021681, 2016] and Ozaki et al. [GRL, doi:10.1002/

2016GL070008,2016] showed that the EMIC sub-packet structures with a time scale of tens of seconds coincide with the intensity pulsation of the isolated proton auroras in the same time scale. Ozaki et al. [GRL, doi:10.0002/2017GL076486, 2018] found ~1-Hz modulation of proton auroral intensity which corresponds to the frequency of the EMIC wave power, suggesting also the modulation of high-energy electron precipitation by the EMIC waves. For the magnetospheric ELF/VLF waves, Martinez-Calderon et al. [JGR, doi: 10.1029/ 2015JA021347, 2015] showed occurrence characteristics of the waves observed at Athabasca statistically using one-year data. Martinez-Calderon et al. [JGR, doi: 10.1002/ 2015JA022264, 2016] reported the first simultaneous observations of the quasi-periodic emissions on the ground and the RBSP-A satellite, and estimated their propagation paths from the magnetosphere to the ground using the observed 2-3 sec time difference and a ray-tracing model. Yonezu et al. [JGR, doi: 10.0002/ 2017JA024211, 2017] reported simultaneous observation of the magnetospheric ELF/VLF waves at three stations including Athabasca to show longitudinal extent of the waves. Shiokawa et al. [EPS, doi: 10.1186/s40623-017-0745-9, 2017] also reported that the waves tend to be localized in longitudes based on the simultaneous observations at Athabasca and Kapuskasing, Canada.

ENERGETIC ELECTRON PRECIPITATION IMPACT ON THE COMPOSITION AND DYNAMICS OF THE UPPER AND MIDDLE ATMOSPHERE

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Abstract

Energetic electrons from the magnetosphere accelerated in geomagnetic storms and substorms can precipitate into the high-latitude upper mesosphere and lower thermosphere. They impact atmospheric composition in these regions due to excitation, ionization, and dissociation of the most abundant species, and by subsequent ion chemistry and neutral reaction chains. Most important for the neutral composition is the formation of NO and OH. Thermospheric temperatures and dynamics are affected directly by Joule heating, indirectly by the strong radiative cooling by NO. As NO is rather long lived in the absence of sunlight, it is carried down in large-scale downward motions over the polar winter poles. In years of high geomagnetic activity, significant amounts of NO can reach down to ~30 km, and contribute to catalytic ozone loss in the middle and upper stratosphere. As ozone is one of the key species of radiative heating and cooling of the stratosphere, this is expected to have an impact on stratospheric winter and spring temperatures and dynamics. In this talk, an overview of the state-of-the-art is given, focusing on observational evidence of the impact of energetic electron precipitation on atmospheric composition. In a second part, recent results from a global chemistry-climate-model reaching from the surface to the thermosphere (~320 km) will be analyzed to investigate the impact of Joule heating, NO cooling, and ozone loss on temperatures and dynamics of the whole atmosphere.

OBSERVATIONS OF ENERGETIC PROTONS BY VAN ALLEN PROBES AT RADIATION BELTS DURING SOLAR PROTON EVENTS

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Abstract

Solar proton events have been recorded based on the criteria when the proton fluxes at energies larger than 10MeV measured by GOES spacecraft at geosynchronous orbit exceeds or equals 10 pfu (particle flux unit) for a continuous time. These events have been observed to affect the atmosphere and ionosphere through the Earth's poles in the form of enhanced ionization causing radio signal absorption. Some events with intensified fluxes at higher energies (i.e. >100MeV) may possibly cause damages to spacecraft in the magnetosphere. Since the Relativistic Proton Spectrometer (RPS) carried by Van Allen Probes, launched on August of 2012, are able to measure protons with energies above ~ 60 MeV up to ~ 2 GeV. In this study, we analyzed available observations from RPS during periods of solar proton events for the Solar Cycle 24. Comparisons in the observed fluxes at different energy levels with the intensities of solar proton events will be made through temporal and spatial analyses. This will enhance our understanding on changes in proton fluxes with energies higher than the order of 100 MeV, as well as effects on the radiation belts from solar proton events with different intensities.

A MODEL OF THE SEP INTENSITY AS A FUNCTION OF CME SPEED, WIDTH, CONNECTION ANGLE

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Abstract

We study large solar energetic particle (SEP) events with intensity > 10 pfu in > 10 MeV proton channel observed by STEREO A, B and near-Earth spacecraft (SOHO, ACE) during solar cycle 24. We first compute connection angles (CAs), the longitudinal distances between solar events and magnetic foot-points connecting to each observing spacecraft. We then determine Gausssian distribution of the SEP intensity using the maximum intensity (in 48 hrs) from the time profile of multi-spacecraft observations. By determining the SEP peak intensity I0 at the center of the Gausssian distribution we study the relationship between SEP intensity and CME shock properties, and the time delay of maximum intensity observed in each spacecraft. We found that the correlations between SEP peak intensity I0 and CME shock speed can be improved by taking into account CME width effect and its solar source location. We developed a model to predict the SEP intensity and determine the prediction warning time for each spacecraft as a function of shock speed, CME width and connection angle, which may be used in the future SEP forecast.

TRANSIENT GALACTIC COSMIC RAY MODULATION DURING SOLAR CYCLE 24

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Abstract

Forbush decrease (FD) events are of great interest for transient galactic cosmic-ray (GCR) modulation study. In this study, we statistically analysis the energy spectra evolution and the recovery time of Forbush events during solar cycle 24, utilizing the measurements from the worldwide neutron monitor (NM) network. Despite their

comparable magnitudes, these Forbush events are distinctly different in terms of evolving GCR energy spectrum and energy dependence of the recovery time. These difference are essentially related to their associated solar wind disturbances. Some events are associated with a complicated shock-associated interplanetary coronal mass ejection (ICME) disturbance with large radial extent, most probably formed by the merging of multiple shocks and transient flows, and which delivered a glancing blow to Earth. Conversely, some events are accompanied by a relatively simple halo ICME with small radial extent that hit Earth more head-on. This comparison provides similarities and differences in the GCR intensity related to different solar wind structures. It helps to clarify the occurrence mechanisms of different kinds of Forbush events. The observed different characteristics of Forbush events could be used to distinguish the structures and mechanisms responsible for transient cosmic-ray modulation. Such comparisons will lead to the further understanding of the underlying physics of energetic particle transport through solar-terrestrial space and provide valuable insight into the transient cosmic ray energetic particles modulation.

Session 2: Electromagnetic Chain (EC)

EC2.1 Long-term Solar Variability (magnetism, total irradiance, and spectral irradiance) and its Impact on Geospace and Earth

Lead Conveners
K. Georgieva
P. Charbonneau

Plenary Speaker
Jie Jiang

Session Description

The solar dynamo is the engine and dynamical driver of solar magnetic variability, including the prominent 11-yr activity cycle as well as its modulation on longer timescales. Proper physical understanding of the mechanisms driving this long timescale variability is thus needed in order to quantify the response of the geospace environment and Earth's upper atmosphere, and assess the relative impacts of natural versus anthropogenic factors in climate change. This session will focus on the long-term (from cycle-to-cycle to millennial and beyond) variability of solar magnetism, including grand minima and maxima of solar activity, total and spectral solar irradiance, solar wind modulation, the frequency and intensity of solar extreme events, and their impact on geomagnetic activity and long-term changes in the lower, middle and upper atmosphere, and in the ionosphere. Reports on theoretical, modeling and observational approaches on this topic are welcome.

VARIABILITY OF ULTRAVIOLET SOLAR SPECTRAL IRRADIANCE OVER CYCLE 24 WITH SOLAR/SOLSPEC 9 YEARS OF DATA

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Abstract

Accurate measurements of solar spectral irradiance (SSI) and its temporal variation are of primary interest to better understand solar mechanisms and the links between solar variability and Earth's atmosphere and climate. We present recent Ultra Violet (UV) SSI observations performed by the SOLAR/SOLSPEC spectrometer on board the International Space Station. SOLAR/SOLSPEC observations cover the essentials of the solar cycle 24, from April 5, 2008 to February 15, 2017.We provide an evolution of the solar spectral irradiance during Cycle 24 using the SOLAR/SOLSPEC data thanks to revised engineering corrections, improved calibrations, and advanced procedures to account for thermal and aging corrections of the instrument. The SOLAR/SOLSPEC observations are compared with other measurements (SORCE/SOLSTICE, SORCE/SIM, SCIAMACHY) and models (SATIRE-S, NRLSSI).

THE RECALIBRATION OF THE SUNSPOT RECORDS: JUSTIFICATION AND CONSEQUENCES

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Abstract

The sunspots are the most visible manifestation of solar activity, and have been recorded on a regular basis for more than 400 years. For this reason, though the sunspots are themselves not geoeffective, their records are widely used to study both the solar variability and its impacts on the terrestrial system. The two indices based on the number of sunspots used to quantify the solar variability are the International sunspot number calculated from the observed number of sunspots and the number of sunspot groups, and the Group sunspot number determined by only the number of sunspot groups. Recently both indices have been recalibrated, and the in 2015 WDC-SILSO stopped the production of the International sunspot number and replaced it by the recalibrated "Version 2" series. This transition is still not unambiguously accepted by the community, and as a result, a number of alternative series are constantly being proposed. In this paper we will comment on the motivation for the recalibration of the sunspot series, and the consequences for the solar-terrestrial physics.

HEMISPHERIC ASYMMETRY OF THE PHOTOSPHERIC MAGNETIC FIELD

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Abstract

The solar magnetic activity is often asymmetric between the northern and the southern hemispheres. Such hemispheric asymmetry has been found to have systematic features over the course of the solar cycle. During most recent solar cycles, the northern hemisphere is more active than the southern hemisphere in the ascending phase of the solar cycle, while the south is more active than the north during roughly three years of the declining phase. In this paper, we investigate the hemispheric differences of the photospheric magnetic field during solar cycles 21-24 using Wilcox Solar Observatory

(WSO) and Mount Wilson Observatory (MWO) photospheric magnetic field data sets. We study the asymmetry of the signed and unsigned fluxes, field intensities, and areas between the two hemispheres. We also study the latitudinal distribution of these parameters and compare that between the two hemispheres.

SOLAR SPECTRAL IRRADIANCE FROM THE SATELLITE INSTRUMENT SCIAMACHY

Tina Hilbig (Institute of Environmental Physics- University of Bremen, Germany), M. Weber, K. Bramstedt, J.P. Burrows, hilbig[at]iup.physik.uni-bremen.de

Abstract

SCIAMACHY (Scanning Imaging Absorption spectroMeter for Atmospheric CHartographY) on-board Envisat performed daily sun observations for nearly a decade from 2002-2012 covering the UV-vis-NIR spectral range (212-1760 nm and two narrow bands from 1930-2040 nm and 2260-2380 nm). Recent developments in the SCIAMACHY calibration (e.g. a physical model of the scanner unit including degradation effects and an on-ground to in-flight correction using the on-board white light source) are used to provide a new SCIAMACHY solar reference spectrum. The SCIAMACHY solar reference spectrum from February 27, 2003 was compared with several other established solar reference spectra and is in good agreement to within 3 % for most parts of the visible spectral range from about 400 to 1200 nm. In the NIR the various SSI reference data do not agree within their confidence interval and this led to a controversial debate (e.g. Bolsee et al., Sol. Phys., doi:10.1007/s11207-014-0474-1, 2014; Thuillier et al., Sol. Phys., doi:10.1007/s11207-015-0704-1, 2015; Weber, 2015; Bolsee et al., doi: 10.1007/s11207-016-0914-1, 2016; Elsey et al., GRL, doi: 10.1002/2017GL0739022017). Special emphasis was placed on the spectral region above 1500 nm. The re-calibration shows a deficit of 4-8 % of SCIAMACHY with respect to the ATLAS-3 composite (Thuillier et al., Sol. Phys., DOI:10.1007/s11207-013-0461-y, 2014) and WHI (SORCE/SIM) reference spectrum (Woods et al., JGR, doi:10.1029/2008GL03637, 2009). In contrast, SCIAMACHY matches very well (above 400 nm) the SOLAR-ISS (Meftah et al., Astron. Astrophys., doi: 10.1051/0004-6361/201731316, 2018) and new ground-based measurements from Mauna Loa (Pereira, A new Accurate Ground-based Exo-atmospheric Absolute Solar Spectrum in the Near Infrared: The PYR-ILIOS Campaign, 2018) as well as revised ground-based data from Elsey et al., (GRL, doi: 10.1002/2017GL073902, 2017). There is now increasing evidence that the ATLAS-3 composite seems to be high biased in the NIR. In this talk we will also report on trends and variability on different time scales derived from the 10 year time series of re-calibrated SCIAMACHY SSI with a focus on the visible spectral range.

SOLAR MAGNETISM AND ITS LONG-TERM BEHAVIOR FROM THE POINT OF VIEW OF DYNAMO THEORY

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Abstract

Solar activity rises and falls with an 11-year cycle varying in amplitude and duration. The Sun's large-scale magnetic field is at the root of all solar activities. The observations of the large-scale field show overall ordered features, which is much simpler than the small-scale field. Recently, the Babcock-Leighton (BL) type dynamo received strong supports for the large-scale field generation. This implies that the magnetic flux connected to the polar fields is the relevant poloidal field for the generation of the toroidal field by the differential rotation in the convective zone. The BL process over the surface has the stochastic nature due to the scatter in the properties of sunspot groups brought about by the flux emergence process. Including the inherent randomness leads to a series of models from surface flux transport models to 3D flux transport dynamo models to understand the solar cycle variability during the past few years. The statistical properties of the variability of the solar cycle amplitudes from decadal to millennial time scales are well reproduced. This indicate that the inherent randomness of BL process is an efficient mechanism to modulate the solar cycle amplitudes. As a key part of the solar dynamo loop, the surface observable part of the BL mechanism makes the physics-based solar cycle prediction feasible. Including the effects of scatter in the properties of sunspot groups on the polar field generation, the possible amplitudes of the subsequent cycle can be predicted when a cycle starts for a few years.

SPYING ON THE HEART OF THE SOLAR DYNAMO

Sushant Mahajan (Georgia State University, USA) mahajan[at]astro.gsu.edu

Abstract

Sunspots have been observed and recorded for over four centuries but their origin still remains a mystery. In this work, we propose that torsional oscillations are simply a consequence of magnetic field amplification coupled with the conservation of energy deep inside the solar convection zone. Applying our hypothesis to helioseismic measurements of torsional oscillations gives us an elegant way to map the toroidal magnetic field amplification inside the Sun. We find that the active latitudes on the Sun's surface follow a region of decreasing rotational kinetic energy and latitudinal shear deeper inside the solar convection zone (around 0.8Ro). We can also see the signatures of magnetic field of the next solar cycle about four years before the cycle actually begins.

HELIOSPHERIC IMPACTS OF THE LONG-TERM SOLAR ACTIVITY (SPACE CLIMATE)

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Abstract

The main drivers of solar effects in the heliosphere are the coronal mass ejections (CME) and the high-speed solar wind streams. The occurrence frequency and heliolatitudinal distribution of these drivers vary systematically over solar cycle, determined by the changes in the global structure of the solar magnetic field. CMEs closely follow sunspot activity (the toroidal phase of solar dynamo), while high speed streams arise from large coronal holes, which maximize in the declining phase of the solar cycle. Polar coronal holes are related to the poloidal phase of the solar dynamo. CMEs and HSS/CIRs are also the two main drivers of geomagnetic activity. CMEs cause the largest storms, but HSSs produce most of geomagnetic activity in most years. New methods have recently been developed to extract detailed information about the relative contribution and long-term occurrence of these two drivers. Since systematic geomagnetic observations have been made from 1840s onwards, geomagnetic activity is able to give information about the evolution of the two phases of the solar dynamo long before the start of solar magnetic field observations. The 20th century marks a period of exceptional solar activity, now termed the Grand Modern Maximum (GMM). Sunspot activity increased from a low level at the beginning of the 20th century to a maximum during the solar cycle 19, and reduced back to a low level during cycle 24. This also caused a dramatic variation in geomagnetic activity which can be used to obtain interesting information on the evolution of the solar magnetic field and coronal holes over the GMM. We review these developments on the effect of centennial solar activity to the structure of solar magnetic fields, solar wind, magnetospheric particles and geomagnetic activity. Moreover, we discuss the long-term effect of solar wind on winter climate at high latitudes.

HOW 'ROGUE' ACTIVE REGION EMERGENCES AFFECT THE VARIATION OF THE SOLAR CYCLE?

Melinda Nagy (Department of Astronomy, Eötvös Loránd University, Hungary)
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Abstract

The building up process of the polar magnetic field is still debated; however, the peak value of that is the most promising solar cycle predictor. According to earlier results, the tilt angles of active regions (AR) emerging close to or across the equator have a crucial role in this question. Besides this, it is pointed out that the flux of an individual AR can be commensurable to the polar cap flux. In the case of strong, cross-equatorial emergences, the contribution to the solar dipole moment is huge. In order to investigate in detail the effect of such peculiar AR emergences on the amplitudes of following cycles, test regions were inserted into sunspot cycles simulated by a coupled 2×2D Babcock-Leighton kinematic solar dynamo model. Several series of simulation runs were done while we changed the emergence epoch, the latitude of the emergence, the flux and the tilt angle of the AR and the angular separation between the leading and trailing polarities. It was found that ARs emerging close to the equator during the rising phase of a cycle affects the amplitude of the ongoing cycle itself. The peak value of the following cycle is affected the most when the AR appears near cycle maximum. If the flux tilt angle or the separation was changed, the amplitude of the next cycle changed accordingly. By changing the emergence latitude, we found that an AR emerging >20° far from the equator still can have significant effect. Interestingly, the duration of the ongoing cycle is affected as well, despite the constant meridional circulation speed used within the dynamo model used for the analysis.

LONG-TERM VARIABILITY AND DISTINCT MODES IN A HYBRID BABCOCK-LEIGHTON SOLAR DYNAMO MODEL

Deniz Ölçek (University of Montréal, Canada) deniz[at]astro.umontreal.ca

Abstract

Understanding the long-term solar variability and its effects on space/Earth's climate and the nature of grand minimum/maximum occurrences have been an important and intriguing issue in solar-terrestrial physics. The emphasis of my work is to pinpoint the physical causes behind long-term solar variability and whether grand minimum and grand maximum events are special states of the solar dynamo corresponding to distinct modes or results of random variability, using a hybrid, kinematic 2x2D Babcock-Leighton dynamo model with a secondary source term based on a small-scale turbulent

mechanism. In this talk, I will present my simulation results and statistical analysis regarding grand minimum/maximum as well as comparing my findings with the reconstructed data concerning past solar activity with indirect solar proxies such as cosmogenic isotopes.

SUNSPOT CYCLES AND IMPACT ON EARTH

Kumud Pandey (Lovely Professional Univeristy, India) kumudpandey56[at]yahoo.com

Abstract

Different solar indices are studied about flares, coronal holes, and electromagnetic radiation in various bands such as 10.7 cm radio flux, sunspots, the total solar irradiance, coronal mass ejections, geo-magnetic activity. Among them sunspot number is considered as a best index of solar activity because of its reliability and reliability. The sunspot number series has been studied for more than a century, but unique feature is being discovered even recently. To analyze the sunspot number, we used the data of the monthly and yearly mean sunspot number. From our analysis, we have found that the maxima of yearly mean sunspot number, monthly mean sunspot number and daily mean sunspot number during different solar cycles. We have also displayed the behavior of standard deviation of sunspot number as time series graph and reported their maxima and minima values. Therefore, this work aims to make us enable to understand physics of sunspot number, solar activity and their relations with our climate.

ON DIFFERENT RESPONSE OF MESOPAUSE REGION CHARACTERISTICS TO LONG-TERM AND SHORT-TERM SOLAR VARIABILITY

P. Dalin, V. Perminov, Nikolay Pertsev (A.M. Obukhov Institute of Atmospheric Physics RAS, Russia) n.pertsev[at]bk.ru

Abstract

It is well known that some parameters of the terrestrial mesopause region are sensitive to solar activity variations on the scale both of the 11-year and 27-day cycles, as well as to intense solar flares on day-to-day scale. Physical processes explaining the solar influence on the mesopause region, are still poorly understood. Statistical analysis helps to understand these processes through the examination of amplitudes and time lags of atmospheric data response to solar activity. Such an analysis has been carried out for ground-based estimations of noctilucent cloud brightness, intensity, and temperature of the OH* airglow layer, and for some other characteristics of the mesopause region, separately for year-to-year and day-to-day variations. The solar Lyman alpha flux has been used as a proxy of the solar activity and has been considered on monthly and day-to-day scales. It has been found that these different scales of the solar activity produce significantly different effects on the mesopause region, both in the magnitude and sign of regression coefficients. In this presentation we present preliminary statistical results for mid-latitude mesopause data and discuss physical processes lying behind the obtained statistics.

LONG-TERM VARIATIONS OF SOLAR IRRADIANCE

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Abstract

Solar brightness varies on all timescales that have ever been resolved or covered by space-born instruments. Driven by the climate community's interest in links between solar variability and climate change, our understanding of solar brightness variations has dramatically improved over the last decade. We review the recent progress in the field and discuss new state-of-the art radiative transfer techniques which allow taking models of solar irradiance to a new level of realism.

WHICH INTERPLANETARY MAGNETIC FIELD ORIENTATION IS FOR THE TRUE GROUND STATE OF THE MAGNETOSPHERE?

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Abstract

Northward interplanetary magnetic field (IMF) has been well known to be a quiet IMF orientation for geomagnetic activity of the magnetosphere in contrast to a disturbed southward IMF orientation. Radial IMF and zero IMF are other quiet IMF orientations, which are usually less studied in the field of magnetospheric physics. A comparison among the geomagnetic activity for the three quiet IMF orientations has not been performed in the past. Here we use two solar cycles of OMNI solar wind data and the six geomagnetic indices (AE, PCN, PCS, Kp, ASYH, and SYMH) to study which IMF orientation has the quietest geomagnetic activity. We find that the northward or zero IMF orientation is for the quietest, depending upon the type of the geomagnetic indices. The geomagnetic activity for northward IMF is the lowest in the high-latitude AE, PCN, and PCS indices while those for zero IMF is the lowest in the mid-latitude Kp, ASYH, and SYMH indices. The geomagnetic activity for radial IMF is not the lowest because of an extra dayside reconnection that occurs during the period of radial IMF. Geomagnetic activity can be contributed by the direct-driven and loading-unloading processes of the solar wind-magnetosphere interaction. Since the latter process for the quiet IMF orientations is minimum, this study allows us to focus on the former process.

PHASE ANALYSIS OF SOLAR CYCLES AND IMPLICATIONS FOR THE FORTHCOMING SOLAR ACTIVITIES

Baolin Tan (National Astronomical Observatories of Chinese Academy of Sciences, China)
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Abstract

Is the present solar cycle 24 a unique and anomaly cycle? What factors do dominate the forthcoming solar cycle? In order to answer these questions, we analyze the data of monthly mean sunspot number since 1749 to present. We partition solar cycle into for phase: valley, ascend, peak, and descend phases by an unified criterion, and then measure all lengths of each phase of the last 24 solar cycles. We find that minimum sunspot number is positively correlated to the maximum sunspot number of the forthcoming solar cycle, and the length of valley phase in strong anti-dependent to the minimum sunspot number. These facts imply that the characteristics of solar cycle valley phase may

dominate the main behavior of the forthcoming solar cycles. The existing observations of solar cycle 24 indicates that it is very weak, but not so weak to show its anomaly or unique. In the history of recorded solar activity, there are still some cycles which should be weaker and longer than the present solar cycle 24.

HOW DOES THE SUN TAKE IMPACT ON THE AIR POLLUTION ON THE EARTH?

Chengming Tan (National Astronomical Observatories of Chinese Academy of Sciences, China) tanchm[at]nao.cas.cn

Abstract

The former work investigated the relationship between the air pollution of Chinese main cities and solar activity by using the geophysical and environmental data during the period of 2000–2016. It is quite certain that the solar activity may have an impact on air pollution, but the relationship is very weak and indirect. The work analyzed the air pollution index (API), air quality index (AQI), sunspot number (SSN), radio flux at wavelength of 10.7 cm (F10.7), and total solar irradiance (TSI). The analysis implies that the correlation coefficient between API and SSN is weak ($0.17 < r < 0.32$) with complex variation. The main results are: (1) For cities with higher air pollution, the probability of high API will be increased along with SSN or TSI, then reach to a maximum, and then decrease; (2) For cities with lower air pollution, the API has lower correlation with SSN or TSI; (3) The relationship between API and F10.7,or API and TSI are also similar as API and SSN. The solar activities take direct effect on TSI and the energetic particle flux, and indirect and long-term effect on lower atmosphere and weather near the Earth. All of these factors contribute to the air pollution on the Earth. We want to know if there is any indicator from the Sun to take a stronger impact on the API on the earth. Thus, we go on to study the relationship between API on the earth and solar irradiance of different wavebands (i.e., white light, UV, EUV, and X-ray). Comparing the relationship between API and TSI, the results are a little different.

IMPACT OF THE SOLAR AND GEOMAGNETIC ACTIVITY ON ATMOSPHERIC VARIABLES: A STUDY WITH WACCM

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Abstract

The impact of geomagnetic and solar activity is evaluated by means of 40 year simulations obtained by running the model WACCM under different solar and geomagnetic activity conditions. We analyzed the results of the difference fields of a few climatic variables in a comparison between each couple of experiments. Statistical and dynamical diagnostics were performed in order to distinguish the impact of the solar and geomagnetic activity on the climate variables both in stratosphere and troposphere. We faced the problem of the effects of multiple hypothesis testing using a permutation test. We will show how the solar activity plays a primary role on modulating the impact of geomagnetic activity on climate variables. Extension, timing, and significance of such impact on the atmospheric variables like temperature and wind are dependent on the joint effects of both the activities.

ANALYSIS OF POWER SPECTRAL DENSITY SLOPES OF NEUTRON MONITOR MEASUREMENTS IN 1953-2016

Pauli Väisänen (University of Oulu, Finland) pauli.vaisanen[at]oulu.fi

Abstract

Neutron monitors (NM) measure the variation of the fluxes galactic cosmic rays (GCR) at Earth, modulated by the Sun and heliosphere. Network of NMs have been in operation for over 60 years, which offers a comprehensive database for heliospheric studies. Heliospheric modulation of cosmic rays, caused by the scattering of particles from inhomogeneities of the heliospheric magnetic field (HMF), is largely affected by solar activity. Using one-hour resolution NM measurements from the global NM network, we have computed a total of 16 667 power spectral density (PSD) estimations. The PSDs were calculated for two-year data intervals at steps of 27 days, using the multitaper PSD method. The PSDs include a power-law behaviour between the 27-day and diurnal peaks. We have tested the frequencies between 5.56×10^{-6} and 2.14×10^{-6} Hz, corresponding to time scales of 50 and 130 hours to calculate the slope. The mean power-law spectral index was -1.81 ± 0.02. Statistical analysis of the slope values from different solar cycle phases reveals that the average slope value is steeper for ascending and maximum phase than for declining and minimum phase. This implies that the scaling of HMF turbulence varies in the course of the solar cycle, reflecting different physical processes affecting GCR modulation.

Session 2: Electromagnetic Chain (EC)

EC2.2 Origin of Solar Flares and their Impact on Earth's Ionosphere/ Atmosphere

Lead Conveners
K. Cho
K. Shiokawa
D. Marsh
F.-J. Lübken
V. N. Obridko

Plenary Speaker
Aaron Ridley

Invited Speakers
Jean-Pierre Raulin

Session Description

Solar flare is a sudden increase in solar X-ray and extreme ultraviolet (EUV) irradiance. Enhanced X-ray and extreme EUV irradiance during a solar flare causes the extra ionization at Earth's ionosphere and results in deleterious effect on radio wave communication and navigation. Since solar flares are a key topic to understand influence of the Sun on Earth's ionosphere and atmosphere, Interest in the effects of flares on the ionosphere has gradually increased over the last few decades and extensive studies have been carried out. However, the fundamental process and origin of solar flares are still not well understood. This Session will focus on the origin of solar flares and their impacts on the changes in Earth's ionosphere and atmosphere. Reports on both modeling and observational approach on this topic is very welcome.

THE EFFECT OF SPACE WEATHER ON SODIUM AIRGLOW EMISSION

Gaurav Bharti (Indian Institute of Technology Roorkee, India) bharti09081990[at]gmail.com

Abstract

The influence of solar proton events and geomagnetic storms has been studied over the mid latitude Utah (41.8º N, 112º W). During the intense space weather events, the Na airglow intensities are modeled using ground based measurements of Na abundance by a Na lidar at Utah State University and SABER retrieved ozone density profiles. It has been observed that the effect of proton events on the mesospheric ozone influences the modeled volume emission rate of sodium. It has also been found that in the vicinity of peak sodium concentration, the volume emission rate of Na airglow, abundance of sodium and ozone show a strong positive correlation with the progression of the storm. The altitudinal profile of nightly averaged sodium density shows a downward shift in the peak density during intense proton events. During the periods of combined solar proton events and geomagnetic storms, the shift is found in the upward direction. The physical phenomenon responsible for the findings will be discussed in this paper.

EFFECT OF SOLAR FLARE X-RAYS ON DIGISONDE FMIN VALUES

S. C. Tripathi (Department of Physics, School of Advanced Sciences, VIT Bhopal University, India), Haris Haralambous (Frederick University, Cyprus) eng.hh[at]frederick.ac.cy

Abstract

Solar flares are high energetic solar transients which radiate over a wide waveband of electromagnetic radiation and releases the energetic particles viz. electrons, protons, as well. Flares affect the Earth's atmosphere in general and ionosphere-thermosphere (IT) system; in particular, almost immediately and hence, the systems dependent on IT system. In order to investigate such impacts, we have taken X-Class Solar flares and investigated their response on the fmin, observed at the station of DIDBASE Network. We have observed almost immediate, one-to-one in time, response over ionospheric characteristics. The intensity of perturbation depends on the location of the active regions releasing flares and maximum effects occurs due to those flares which have occurred near the central meridian of solar disc.

SOLAR X-CLASS FLARES EFFECT ON THE D-REGION IONOSPHERE AT LOW LATITUDE DURING 24 SOLAR CYCLE

Ajeet Kumar Maurya (Department of Physics Banaras Hindu University, India) ajeet.iig[at]gmail.com

Abstact

Solar flares are the important component of space weather phenomenon. The flares perturbed entire daytime of ionosphere but their effect is more pronounced in the D-region of ionosphere. The X class solar flares are relatively less in number, and causes most significant effect on the D-region. The Very low frequency waves (3-30 kHz) are found to be a cost-effective tool for continuous monitoring of D-region ionosphere perturbed by the solar flares. Although, there have been several work on the correlation between solar flares and VLF signal anomaly, but effect of X class flares not and well understood. Further, as the solar activity have diurnal, seasonal and solar cycle variations, hence is the X-class flares. Therefore, in this work, we have analyzed X class solar flares occurred during 24th solar cycle (2008-2016). For this work, we have chosen NWC

signal recorded at Allahabad during the above period. The X class flares, that happened on the day time of Allahabad-NWC TRGCP are selected and classified based on diurnal, seasonal and solar cycle. The detailed analysis results will be discussed during the conference.

TRANSIENT AND LONG-TERM SOLAR ACTIVITY: ORIGIN AND IMPACT ON THE EARTH'S ATMOSPHERE

Jean-Pierre Raulin (CRAAM/EE/UPM, Brazil) raulin[at]craam.mackenzie.br

Abstract

Solar flares are fast releases of energy in the form of radiation covering the whole electromagnetic spectrum, produced by the heating of the atmospheric plasma and by particles accelerated to ultra-relativistic energies. Significant release of plasma and magnetic field know as Coronal Mass Ejection can also occur, although not necessarily related to solar flares. All these phenomena, radiation, energetic particles, and CMEs are not completely understood and can affect the Earth's atmosphere. In this report we give attention to the GigaHertz-to-Infrared diagnostic of solar flares. This extended range at high frequencies, allowing us to describe the dynamics of the lower solar atmosphere as well as the radiation produced by fast particles. After few minutes up to a few hours, enhanced radiation fluxes and energetic particles produced by the rapid energy dissipation in solar active regions reach the environment of the Earth. We show how the sub-ionospheric monitoring technique can detect the transient disturbances produced by solar flares, as well as subtler long-term changes due to the solar activity cycle. In general, these perturbations traduce the change of the local electrical conductivity produce by extra ionization. We also describe the use of a novel diagnostic to investigate possible effects of transient and long-term solar disturbances in the global atmospheric electric circuit (GAEC). If any, such studies could inform if GAEC is a reliable coupling agent between space weather phenomena and the behavior of the lower Earth's atmosphere.

THE THERMOSPHERIC AND IONOSPHERIC REACTION TO SOLAR FLARES

Aaron Ridley (University of Michigan, USA) ridley[at]umich.edu

Abstract

Solar flares are rapid intensifications of the solar irradiance. These intensifications can add significant amounts of energy to the upper atmosphere on the dayside, creating both a temperature increase and an increase in the ionization rate. We have simulated a variety of events showing the thermospheric and ionospheric reaction to solar flares in a global non-hydrostatic model. In the neutral part of the atmosphere, the temperature increase causes a large-scale gravity wave to propagate towards the nightside, converging on midnight, and then reflecting back towards the dayside. Additionally, there are acoustic waves generated on the dayside that propagate in the vertical direction. These acoustic waves force ions to move vertically also. The energy in the thermosphere is dissipated primarily through the nitric oxide radiative cooling, which takes several hours to operate. In the ionosphere, the effects are much more complicated, and are strongly dependent on the background conditions in the atmosphere. When the magnetic field topology is changed, there is little effect. When a flare is moved in time from one season to another, the ionospheric reaction is very different, implying that the thermospheric state is one of

the most important determinants of how the ionosphere reacts to a flare. In addition, the neutral atmospheric reaction to the flare drives significant activity in the ionosphere, with the winds forcing ions up and down field lines. We will present results that illustrate all of these effects.

RADIO DIAGNOSTICS OF SOLAR FLARES AND OF THEIR IMPACT ON EARTH

Nicole Vilmer (LESIA, Paris Observatory, France) nicole.vilmer[at]obspm.fr

Abstract

Radio and X/ EUV electromagnetic emissions from solar flares are among the first signatures of space-weather relevant disturbances originating from the solar atmosphere. Electromagnetic radiation from the Sun as well as energetic particles associated with flares or CMEs can affect the terrestrial environment (i.e., radio black outs, radiation damage) on short timescales (i.e., eight minutes to a few hours). In this talk, I will present results from recent studies of radio observations of flares at decametric/metric wavelengths on the relation between escaping electrons that generate type III emissions in the corona and in the interplanetary medium and electrons confined to the lower atmosphere of the Sun that produce HXRs. I will also present the results of a recent study based on the observations of an unusually large source of gyro-synchrotron radiation associated with a CME on September 1, 2014 and show how these observations allow the diagnosis of the magnetic field in the core of a coronal mass ejection, a crucial quantity for the understanding of the driving of coronal mass ejections from the low corona to the interplanetary medium. I shall finally present a few examples of moderate solar flares associated with intense radio fluxes in the GHz and discuss possible origins of these intense emissions.

Session 3: Intra-Atmospheric Chain (IAC)

IAC3.1 Geospace Response to Variability of the Lower Atmosphere

Lead Conveners
K. Shiokawa
W. Ward

Plenary Speaker
Sharon Vadas

Invited Speakers
Jaeheung Park
Fabrizio Sassi

Session Description

Variations of plasma, electromagnetic field, and neutrals in geospace regions, particularly those in the ionosphere and thermosphere, are significantly affected by various inputs from the lower atmosphere. This session focuses on the geospace response to the variability of the lower atmosphere, including topics on the penetration of sound waves, gravity waves, tides, and planetary waves from the lower atmosphere to the thermosphere and ionosphere, and their connection to the inner and outer magnetosphere. The impact of longer term variability such as ENSO and the quasi-biennial oscillation which affect the upward propagating wave fluxes are also encouraged. Reports on both the modeling and observational approaches on this topic are very welcome.

COMPOSITE ANALYSIS OF OROGRAPHIC GW HOTSPOTS' BEHAVIOR AND THE POSSIBLE LINK WITH SSW

Aleš Kuchař (Department of Atmospheric Physics Faculty of Mathematics and Physics, Charles University, Czech Republic) ales.kuchar[at]mff.cuni.cz

Abstract

Several studies reported an importance of East Asia regions as a "vertical communicator" from the troposphere into the stratosphere. Orographic hotspot constituted by Eastern Asian orography can generate zonally asymmetric GW breaking in the lower stratosphere and can play an important role in PV stability and therefore, influence frequency of sudden stratospheric warnings. In the presented analysis, we assessed orographic GW hotspots' behaviour in the lower stratosphere and their possible link with displaced and split stratospheric polar vortex events. The study is based on composite analysis that has been applied to the nudged chemistry climate model CMAM30 allowing the study of the implications of the OGWD variations in the lower stratosphere before split events for the upper stratosphere and mesosphere. It has been shown from reanalysis that the OGWD strengthens in the lower stratosphere and weakens higher in the stratosphere before the displacement events. However, a role of specific GW hotspots has not been described yet. That has to be done carefully with knowledge of the OGWD climatological distribution on selected pressure levels. Our results are also supplemented with 3-D wave activity analysis allowing investigation of the synoptic nature of compensation between the resolved drag and OGWD, which shows to be a distinct feature of the zonal mean composites.

CHARACTERIZING AIRGLOW EMISSIONS AS A FUNCTION OF SOLAR ZENITH ANGLE WITH PASI

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Abstract

The dynamics of the middle atmosphere can be inferred from measurements in the airglow layer using the PEARL All-Sky Imager (PASI, located in Eureka, Nunavut) by identifying periodic intensity patterns in airglow emissions. Some of this variability is associated with scattering of moonlight and sunlight. One significant instance of this is the increase in intensity near twilight which can mask smaller scale variations and introduce diurnal variability into the data. As the Sun nears the horizon, the observed irradiance is modified due to the scattering of sunlight by the Earth's atmosphere into the imager line of sight. This increase in intensity overshadows the geophysical variability and makes identification and characterization of atmospheric events difficult. In this paper we describe the solar zenith angle dependence of the background irradiance measured by PASI and present a model which allows the optical airglow measurements to be detrended.

ION FRICTION AND GEOMAGNETIC INFLUENCE ON GRAVITY WAVE PROPAGATION IN THE THERMOSPHERE-IONOSPHERE

Alexander Medvedev (Max Planck Institute for Solar System Research, Germany) medvedev[at]mps.mpg.de

Abstract

Motions of neutrals and ions in the thermosphere-ionosphere do not generally coincide due to the presence of the geomagnetic field and associated electromagnetic forces affecting plasma. Collisions of ions with gravity wave (GW)-induced motions of neutrals impose damping on the latter. We present a practical parameterization for the vertical damping rate of GW harmonics that accounts for the geometry of the geomagnetic field and the direction of GW propagation. It can be incorporated into parameterizations of GW effects developed for general circulation models extending from the lower atmosphere into the mesosphere and thermosphere. Vertical damping of GW harmonics by ion-neutral interactions in the thermosphere-ionosphere depends only on the geometry of the geomagnetic field, but not the strength of the latter. The ion damping of harmonics propagating in the meridional direction (in the geomagnetic coordinates) maximizes over the poles and reduces to zero over the equator. Waves propagating in the zonal direction are uniformly affected by ions at all latitudes. We shall discuss consequences of the geomagnetic control of GWs in the F region, and on the vertical coupling between the lower and upper atmosphere produced by GWs.

IRREGULARITIES IN QUIET-TIME LOW-/MID-LATITUDE UPPER THERMO-SPHERE: BOTH PROPAGATING UPWARD FROM BELOW AND THOSE DRIVEN IN-SITU

Jaeheung Park (Korea Astronomy and Space Science Institute (KASI), South Korea) and Hermann Lühr pj[at]kasi.re.kr

Abstract

It is by now well known that the quiet-time low-/mid-latitude upper thermosphere is strongly influenced by atmospheric gravity waves (GWs). These are responsible for a significant amount of energy transport. In the first part of our presentation we review recent advances in upper-thermospheric GW observations, especially focusing on in-situ observations by low-Earth orbiting satellites at altitudes between 250 km and 450 km. We discuss various generation mechanisms, such as tropospheric convection and orographic waves. We also address possible filtering effects of background wind existing between the near-surface GW source regions and the satellite altitude. In the second part of this presentation we report about upper-thermospheric irregularities that are driven in-situ, for example by equatorial plasma bubbles. Dependences of their strength are discussed, e.g. on solar activity, season, local time, and latitude.

THE IMPACT OF UPPER ATMOSPHERIC OBSERVATIONS ON SIMULATIONS OF SHORT-TERM VARIABILITY IN THE THERMOSPHERE-IONOSPHERE SYSTEM

Fabrizio Sassi (Naval Research Laboratory, USA) fabrizio.sassi[at]nrl.navy.mil

Abstract

Until recently, short-term (days to weeks) variability in the neutral upper atmosphere was considered to be largely controlled by atmospheric drivers (tides and planetary waves) originating from the lower atmosphere. Whole atmosphere models that fully capture the propagation of these drivers from lower to upper atmosphere were believed to be sufficient enough to reproduce the type of short-term variability in the neutral upper atmosphere that produces observed variations in ionospheric parameters related to lower atmospheric phenomena such as stratospheric sudden warmings. However, recent studies suggest that upper atmospheric observations are needed to accurately represent short-term variability in both planetary-scale mass transport and tidal behavior crucial to representing the structure of the thermosphere and the wind-dynamo coupling in the ionosphere. To address this, we use atmospheric specifications from the prototype High-Altitude Navy Global Environmental Model (HA-NAVGEM) from the ground to 92 km to nudge the Whole Atmosphere Community Climate Model extended version (WACCM-X) coupled to the Navy Highly Integrated Thermosphere Ionosphere Demonstration System (Navy-HITIDES) ionospheric model. The HA-NAVGEM data assimilation/forecast system is run in two configurations: a reference experiment for the time period December 2012-March 2013, where satellite-based middle atmospheric observations (SABER temperature retrievals; Aura MLS temperature, ozone, and water vapor retrievals; and SSMIS microwave radiances) are included between 20-90 km; and a perturbed experiment, during the same time period, in which the middle atmospheric observations are removed. The resulting nudged simulations using WACCM-X coupled to Navy-HITIDES are used to study the impact of upper atmospheric observations in reproducing the observed short-term variability in the thermosphere-ionosphere system, both in terms of the thermospheric structure and the ionospheric response via wind-dynamo coupling. A statistical comparison between the two experiments and a verification of the ionospheric simulations against NASA/JPL observations of total electron content highlight where and how the upper atmospheric observations are important.

SOLAR/INTERPLANETARY EFFECTS AND POSSIBLE CONSEQUENCES FOR ATMOSPHERIC VORTICITY

Bruce Tsurutani (Jet Propulsion Laboratory, California Institute of Technology, USA) bruce.tsurutani[at]jpl.nasa.gov, R. Hajra, T. Tanimori, A.Takada, B. Remya, A.J. Mannucci, G.S. Lakhina, J.U. Kozyra, K. Shiokawa, L.C. Lee, E. Echer, R.V. Reddy, and W.D. Gonzalez

Abstract

We present a new scenario of magnetospheric relativistic electron precipitation and potential effects in the atmosphere and on weather. High density solar wind heliospheric plasmasheet (HPS) and interplanetary shock events impinging upon the magnetosphere lead to the possible rapid loss of these particles to a small region of the atmosphere. A peak total energy deposition of 3 x 1020 ergs is derived for the precipitating electrons. Maximum energy deposition and creation of electron-ion pairs at 30-50 km and at < 30 km altitude are quantified. We focus attention on the relevant correlation between solar wind heliospheric current sheet (HCS) crossings and high atmospheric vorticity centers at ~300 mb altitude. Other possible scenarios potentially affecting weather are discussed.

GRAVITY WAVE PENETRATION INTO THE THERMOSPHERE AND IONOSPHERE

Sharon Vadas (NorthWest Research Associates, USA) vasha[at]cora.nwra.com

Abstract

In this paper, we investigate the propagation and dissipation of primary and secondary gravity waves (GWs) in the thermosphere from various sources in the lower, middle, and upper atmosphere. These sources include deep convection, wind flow over mountains,

tsunamis, secondary GWs from body forces created by wave breaking in the middle atmosphere, and secondary GWs from body forces created by the viscous dissipation of GWs in the thermosphere. We show that the dissipation of GWs in the thermosphere can lead to large accelerations which dramatically change the structure of the neutral wind in the thermosphere. We also examine the effect that secondary GWs have on the ionosphere via TEC and other data. We show that secondary GWs from deep convection create travelling ionospheric disturbances (TIDs) that have concentric ring-like structure in the F-region. These model results and data point to the importance of GWs for understanding the variability and dynamics of the thermosphere and ionosphere.

THE JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY

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Abstract

TIMED/GUVI has been operating in spectrograph mode since 2008. Global scale wave signatures were detected in the TIMED/GUVI spectrograph data, specifically in the N2 Lyman-Birge-Hopfield (LBH) bands. Model calculations indicate that the intensity ratios between two N2 LBH bands (144.5–145.5 and 141.0–142.0 nm) quasi-linearly depend on N2 vibrational/rotational temperature. The ratios and temperature calculated from GUVI spectra under a sunlit condition frequently show wave 3 and wave 4 features over a given day or period. Wave decomposition analysis of the temperature in the equatorial region (0-5° latitude) confirms the existence of wave 3 and wave 4 features that are likely due to non-migrating tides such as SE2, DE3 and DW4 in the thermosphere around 160 km where the 141-145 nm emissions peaked.

EXTERNAL AND INTERNAL DRIVING SOURCES OF THE IONOSPHERE: ANALYSIS BASED ON THE WAVELET DECOMPOSITION

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Abstract

The ionosphere is influenced by solar, interplanetary, geomagnetic, neutral atmospheric, and some other variations. Here, the wavelet decomposition method is applied to obtain the variance distributions of these parameters in 2002 and 2007, and the ionospheric variability in the period intervals of 2-64 days is analyzed. For the ionosphere, nearly half of the variances are concentrated on the two to four days period interval, and the variance proportion goes down with the increase of the period. In both 2002 and 2007, the pronounced two to four day period variances show some latitudinal trend and local time dependence. The solar parameters show the maximum variance in the 16-32 days period interval. For solar wind speed and geomagnetic activities, most of the variance is about averagely distributed on periods shorter than 32 days. The variance distributions of IMF Bz and lower thermospheric temperature are similar to those of the ionosphere. Their variances of periodic oscillations show the maximum in the two to four days period interval and decline with the increase of the period. And the variances of the O/N_2 ratio are mainly in the two to four days and 32-64 days period intervals. The characteristics of the variance distributions of these space environmental parameters are analyzed. And by comparing with those of the ionosphere, the possible qualitative contributions of various sources are discussed.

Session 3: Intra-Atmospheric Chain (IAC)

IAC3.2 Long Term Variability of the Whole Atmosphere

Lead Conveners
D. Marsh
K. Georgieva

Plenary Speaker
Rolando Garcia

Invited Speakers
William Ball
Gunter Stober

Session Description

This session focuses on numerical and observational studies of changes in the entire atmosphere (troposphere to exosphere) that occur on timescales from a decade to centuries. Of interest are studies that focus on the detection and attribution of atmospheric variability that is of solar and anthropogenic origin, i.e., solar cycle changes in irradiance and energetic particles and increases in greenhouse gases and ozone depleting substances. Submissions are particularly encouraged that examine how the response to these drivers of long-term variability in one atmospheric layer propagates upwards or downwards to other layers.

ASSESSING LONG-TERM CHANGES IN STRATOSPHERIC OZONE

William Ball (IAC/ETH Zürich & PMOD/WRC, Switzerland) william.ball[at]pmodwrc.ch

Abstract

Detection and attribution of changes in stratospheric ozone is essential to diagnose the influence of external forcing on the surface climate, such as solar variability, and anthropogenic emissions of, i.e., ozone depleting substances, which impact radiative forcing and surface ultra-violet levels. However, due to short time-series, large unaccounted for variance, and caveats in the standard approach to time series analysis, namely multiple linear regression, the detection task is not simple, and separating drivers can be difficult. Nevertheless, progress is being made. Here, we focus on changes in stratospheric ozone on decadal and longer timescales, and discuss new approaches and solutions being applied to resolve differences in solar signals detected in multiple observational datasets, and the remaining problems that still need to be addressed to make robust estimates. We will present up-to-date estimates of decadal-scale solar cycle changes in the upper stratosphere. Additionally, despite the enactment and success of the Montreal Protocol in protecting the ozone layer, recent work applying new, improved regression methods have resulted in clear evidence that lower stratospheric ozone. In addition, mid- and tropical latitudes continues to decline, preventing total ozone recovery. This result contradicts expectations and may impact future estimates of ozone layer recovery and, among other things, future surface levels of solar ultraviolet radiation. I will discuss our current understanding of these surprising trends and where focus should be made to determine what is going on with stratospheric ozone.

LONG-TERM CLIMATE CHANGE IN THE D-REGION

Mark Clilverd (British Antarctic Survey, United Kingdom) macl[at]bas.ac.uk, R. Duthie, C. J. Rodger, R. L. Hardman, and K. H. Yearby

Abstract

Controversy exists over the potential effects of long-term increases in greenhouse gas concentrations on the ionospheric D-region at 60-90 km altitudes. Techniques involving in-situ rocket measurements, remote optical observations, and radio wave reflection experiments have produced conflicting results. This study reports a novel technique that analyses long-distance subionospheric very low frequency radiowave observations of the NAA 24.0 kHz transmitter, Cutler, Maine, made from Halley Station, Antarctica, over the period 1971-2016. The analysis is insensitive to any changes in the output power of the transmitter, compensates for the use of different data logging equipment, and can confirm the accuracy of the timing systems operated over the 45-year long record. A ~10% reduction in the scale size of the transmitter nighttime interference fringe pattern has been determined, taking into account the quasi-11-year solar cycle. Subionospheric radiowave propagation modeling suggests that the contraction of the interference fringe pattern about the mid-latitude NAA transmitter is due to a 3 km reduction in the effective height of the night-time ionospheric D-region over the last 45 years. This is consistent with the effect of enhanced infra-red cooling by increasing greenhouse gases.

LONG-TERM AND TIDAL VARIATIONS OF NOCTILUCENT CLOUDS AT ALOMAR

Jens Fiedler (Leibniz Institute of Atmospheric Physics, Germany) fiedler[at]iap-kborn.de, G. Baumgarten, F.J. Lübken

The highest clouds in the Earth atmosphere are located around 83 km altitude. They were first documented in 1885 and are called noctilucent clouds (NLC) because of the impressive bluish-white displays they form against the dark night sky. NLC are the visible manifestation of ice particles, persistently present in the polar summer mesopause region, which are subject to the variability of the ambient atmosphere as well as solar radiation. Ice formation and growth at these high altitudes is very sensitive to temperature and water vapor content which are both hard to measure directly with high accuracy. Thus, NLC are used as tracers for variations on different time scales, including tides and long-term changes. We will present results obtained by the ALOMAR RMR-lidar, a ground-based remote sensing instrument at 69°N, which is in regular operation since 1997. The NLC database covers more than 6 400 measurement hours during the summer months, a subset of 3 100 hours contains NLC. On multi-year time scales, trend investigations of NLC parameters show only small changes within the last two decades. NLC above ALOMAR are strongly influenced by solar tides, i.e. in the mean the clouds occur per hour twice as often during the morning compared to the rest of the day. The cloud altitude shows mean variations of about 1 km in the course of the day. We will show the variability of tidal parameters over two decades for NLC occurrence, altitude, and brightness. Furthermore, the lunar influence on NLC is addressed. In particular, we will quantify the amplitude of the lunar in relation to the solar semidiurnal tide in NLC parameters.

NATURAL AND ANTHROPOGENIC LOW-FREQUENCY AND SECULAR VARIABILITY IN THE MIDDLE ATMOSPHERE

Rolando Garcia (National Center for Atmospheric Research, USA) rgarcia[at]ucar.edu

Abstract

The middle atmosphere (MA; ~10-100 km) is expected to undergo changes in the near to middle-term future driven by anthropogenic forcing associated with the development and recovery of the ozone hole and with increasing concentrations of greenhouse gases (GHG). Here we review observational and modeling evidence for anthropogenic change, and how to distinguish such change from natural, long-period variability, in particular, variability induced by the 11-year solar cycle in solar irradiance and energetic particle precipitation. This becomes increasingly more important at higher altitudes in the MA. We focus on a few salient examples: changes in transport and composition in the southern hemisphere driven by the evolution of the Antarctic ozone hole and changes in the temperature and chemical composition of the entire MA driven by GHG cooling. We emphasize the need for long observational records in order to be able to distinguish between such changes and the variability induced by natural, low-frequency forcing.

LONG-TERM SPREAD F MORPHOLOGY OVER EUROPE

Krishnendu Sekhar Paul, Haris Haralambous (Frederick Research Center, Frederick University, Cyprus), Christina Oikonomou, Ashik Paul, Anna Belehaki, Tsagouri Ioanna, Daniel Kouba and Dalia Buresova, eng.hh[at]frederick.ac.cy

Abstract

After seven decades of extensive research works, the plasma dynamics of mid-latitude ionosphere is not fully understood. One of the most dominant effects is spread F which is observed during nighttime mid-latitude ionosphere as a sudden distribution of plasma structures at F region due to generation of field aligned irregularities with different scale sizes or the tilted ionospheric surface produced by the travelling ionospheric disturbances (TIDs). Several studies have investigated the origin and the triggering mechanisms of mid-latitude spread F underlying the role of plasma instability and neutral drivers of night time mid-latitude ionosphere and other candidate factors such as sporadic E (Es) layers, travelling ionospheric disturbances, and plasma density irregularities associated with Parkins instability. This paper presents the fundamental morphological aspects of nighttime spread F considering different spread F types, spread F dependence on solar activity, diurnal and seasonal variations over three European stations Nicosia, Athens and Pruhonice during 2009, 2015, and 2016 accordingly. To observe the distinct effect of latitudinal and longitudinal variation, common spread F events were selected between Nicosia-Athens and Athens-Pruhonice stations along with different mechanism signatures and precursors, which appear prior to the triggering of instabilities in the bottom of F layer observed over both station pairs simultaneously prior to the onset of common spread F events, and thereby statistics have been compiled for analysis. To study the effect of travelling ionospheric disturbances GPS total electron content was monitored from IGS stations. Efforts has been made to detect the precursors and mechanisms that triggers the spread F occurrence at the three stations. Thus, those common mechanisms and precursors are selected for the study that affects more than one station simultaneously for a certain case of spread F to understand the nature of the nighttime mid-latitude ionosphere more prominently.

SPORADIC E TIDAL VARIABILITY AND CHARACTERISTICS OVER THREE MID-LATITUDE DIGISONDE STATIONS

Christina Oikonomou, Haris Haralambous (Frederick Research Center, Frederick University, Cyprus), I. Tsagouri, A. Belehaki, D. Buresova, and Z. Mošna, eng.hh[at]frederick.ac.cy

Abstract

Long sequences of ionograms obtained from three European mid-latitude ionospheric stations (Athens, Nicosia, and Pruhonice) are examined for the first time simultaneously by utilizing the innovative ionosonde ‘height–time–intensity’ (HTI) analysis. The purpose is to investigate at different latitudes the seasonal variations of sporadic E (Es) and intermediate descending layers (IDL), which are generated by vertical wind shears in the horizontal thermospheric winds. The HTI traces of Es and IDL layers observed in all three locations are characterized mostly by a 12-hour periodicity in layer occurrence and descent, albeit some differences that exist in layer occurrence and intensity. For the first time, additional shorter-scale periodicities in IDL and Es occurrence are detected. Specifically, a 6-hour periodicity is observed during winter in all stations and around equinoxes only in Pruhonice. An 8-hour periodicity is also found mainly in the lower

mid-latitude stations during summer. These periodicities can be attributed to the semi, quarter, and terdiurnal thermospheric tides respectively. Our results confirmed that: (a) the semidiurnal tides are dominant at mid-latitudes during the whole year and (b) the terdiurnal tides become active during summertime at lower and occasionally at higher mid-latitudes. The quarter-diurnal tides, though weaker than semidiurnal ones, are consistent through all years and can also affect the formation of ionization layers primarily in higher and less in lower mid-latitude regions. For the first time evidence of a 4-hour periodicity only in January in Pruhonice is provided, possibly due to the interaction between tides and atmospheric gravity waves.

DISENTANGLING TOP-DOWN- AND BOTTOM-UP-DIRECTED CONTRIBUTIONS OF 11-YEAR SOLAR CYCLE INDUCED CLIMATE SIGNALS

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Abstract

Several mechanisms of solar influence on climate are currently known. The top-down mechanism involves variations in solar UV radiation over the solar cycle which have significant impacts on the radiative heating and ozone budget of the middle atmosphere, affecting atmospheric dynamics that communicate the solar signal to the lower atmosphere and surface. Enhanced energetic particle precipitation leads to ionization of NO_x and HO_x species in the middle atmosphere which contribute to catalytic ozone loss. Through radiative and dynamical interactions this provides another source of downward coupling from the middle atmosphere to the surface. Finally, the bottom-up mechanism involves changes in the visible and near-infrared part of the solar spectrum which directly penetrate to the ocean surface. This small near-surface signal is dynamically enhanced through atmosphere-ocean coupling. Although, most existing studies focus on one or the other pathway. We present a first systematic comparison of both effects and their interaction based on sensitivity experiments with state-of-the-art chemistry-climate-models. All experiments cover the period of 1850-2099, conducted as coupled atmosphere-ocean simulations driven by transient external forcing according to observations throughout the historical period and following the RCP8.5-scenario thereafter. One experiment is subject to full solar variability in spectral solar irradiance and auroral electron precipitation from the CMIP6 solar forcing, and therefore includes both, top-down and bottom-up solar induced climate signals. The other two experiments are set up to either represent top-down (variations in the UV part of the solar spectrum and auroral electron precipitation only) or bottom-up (variations in the VIS and NIR part of the solar spectrum only) solar induced signals separately. Small ensembles of each experiment enlarge our statistical basis, for the first time permitting a robust assessment of the relevance of the different pathways for different regions and altitude ranges of the coupled climate system.

LONG TERM TRENDS IN STRATOSPHERIC DYNAMICS AND TEMPERATURE DERIVED FROM FOUR REANALYSES

Jan Lastovička (Institute of Atmospheric Physics CAS, Czech Republic) jla[at]ufa.cas.cz, M. Kozubek, and P. Krizan

Abstract

Stratospheric zonal and meridional winds and temperature over the whole globe are analyzed at pressure levels of 100, 50, 10 and 1 hPa for long-term trends for the period 1979-2016 based on MERRA, ERA-Interim, JRA-55 and NCEP-DOE re-analyses. Trends are presented for each individual month of winter separately for two periods, 1979-1997 and 1998-2016 (periods of different trend in ozone). The main focus of the paper is to search for differences in trends among different reanalyses. Every grid point is analysed, not zonal averages to study longitudinal distribution of trend. The comparison of trends in meridional or zonal wind and temperature brings a new insight on the trends analysis in the middle atmosphere. The trends generally reveal a good mutual agreement for all four reanalyses in main features, i.e. in areas of statistically significant trends in the stratosphere (1-100 hPa), even though there are some differences in their magnitudes. Temperature trends agree among reanalyses better than wind trends. Wind trends are longitudinally dependent and that is why the zonal averages can sometimes provide results which miss some phenomena. As for the ozone trend changes in the mid-1990s, we observe mainly changes in temperature trends (but not regularly in every month), zonal and meridional wind trends are less sensitive to the ozone trend change.

SCIENTIFIC HIGHLIGHTS FROM ROMIC

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Abstract

The German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung, BMBF) has launched a research initiative in 2013-2014 called ROMIC (Role of the Middle Atmosphere in Climate). The aim of ROMIC is to improve our understanding of long term variations in the stratosphere, mesosphere, and lower thermosphere and to investigate their potential role for climate changes in the troposphere. This includes to study coupling mechanisms between various layers and the relative importance of anthropogenic and natural forcing, i.e. by the Sun. Scientists at a total of 15 research institutes in Germany are involved and cover a large range of experimental and theoretical topics relevant for ROMIC. Some scientific highlights from the research projects within ROMIC will be presented. The first phase of ROMIC terminated in 2017, but a second phase was announced by BMBF in October 2017 and will presumably be running from 2018 until 2021.

N_2O PRODUCED IN THE MLT AND ITS EFFECT ON O3 IN THE MIDDLE ATMOSPHERE

Patrick Sheese (University of Toronto, Canada) psheese[at]atmosp.physics.utoronto.ca

Abstract

The satellite limb sounder ACE-FTS (Atmospheric Chemistry Experiment – Fourier Transform Spectrometer) is a solar occultation instrument that has been measuring trace gases and temperatures in the atmosphere since February 2004 and is still in operation.

Throughout the mission, ACE-FTS has been measuring N_2O concentrations in the mesosphere – lower thermosphere (MLT), which increases with altitude in the mesosphere. N_2O has been hypothesized to be produced at high latitudes through energetic particle precipitation, and this study will compare the ACE-FTS N2O time series to simulations with the Whole Atmosphere Community Climate Model (WACCM) in different configurations to test possible N_2O production mechanisms. WACCM-D (version with detailed ion chemistry in the lower D region of the ionosphere) will be used in a specified dynamics mode where temperature and wind values below ~60 km are nudged towards reanalysis fields. The SD-WACCM-D runs will be modified to include the ion chemistry that can lead to N_2O production in the MLT. In separate experiments, an updated version of WACCM but with simplified ion chemistry will be used to look at the potential additional role of photoelectrons in producing the MLT N_2O, particularly at extra-polar latitudes. For both model versions, runs spanning the ACE-FTS time series with and without the relevant N_2O production chemistry will be compared to ACE-FTS profile measurements in order to better understand how N_2O is created in the MLT and its effects on O_3 and NO_x budgets throughout the middle atmosphere.

TRENDS IN THE MIDDLE ATMOSPHERE FROM GROUND BASED SENSORS AT MID AND HIGH LATITUDES

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Abstract

Long term changes in the middle atmosphere are important indicators of a changing climate in lower atmospheric layers, but also provide valuable insights into the solar driven and solar induced variability of the mesosphere. The Leibniz-Institute of atmospheric physics sustains several long atmospheric measurement time series of noctilucent clouds, polar mesospheric summer echoes and mean winds. These observations cover more than a solar cycle and are sensitive indicators of changes in the mesosphere with regard to the temperature, water vapor or dynamics. The collection of long measurement time series and data sets is usually a rather big challenge as most systems undergo life-cycles that are much shorter than a solar cycle leading to break points in the resulting observations. Meteor radars are continuously operating and several long data sets of neutral air density variations and winds became available covering more than a decade. Based on these long MR observations we are able to identify a long term change in the neutral air density, which shows a decrease with 5-7% per decade at 90 km altitude. Further, the wind data is analyzed with respect to such long term changes at different altitudes and seasons. These changes show an anti-correlation between the zonal and meridional wind component and modulations which are likely related to the solar cycle and other longer period atmospheric modes.

Session 3: Intra-Atmospheric Chain (IAC)

IAC3.3 Regional, Hemispheric and Inter-hemispheric Couplings and Transport in the Atmosphere

Lead Conveners
F.-J. Lübken
T. Nakamura

Plenary Speaker
Eric Becker

Invited Speakers
Bernd Funke
Erdal Yigit

Session Description

Variations of plasma, electromagnetic field, and neutrals in geospace regions, particularly those in the ionosphere and thermosphere, are significantly affected by various inputs from the lower atmosphere. This session focuses on the geospace response to the variability of the lower atmosphere, including topics on the penetration of sound waves, gravity waves, tides, and planetary waves from the lower atmosphere to the thermosphere and ionosphere, and their connection to the inner and outer magnetosphere. Inter-hemispheric variations associated with seasons, the response associated with major dynamical events such as sudden stratospheric warmings and the impact of longer term variability such as ENSO and the quasi-biennial oscillation which affect the upward propagating wave fluxes are also encouraged. Reports on both the modeling and observational approaches on this topic are very welcome.

MECHANISMS OF DYNAMICAL COUPLING FROM THE TROPOSPHERE TO THE LOWER THERMOSPHERE

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Abstract

We present new modeling results on inter-hemispheric coupling from the winter mesosphere to the summer polar mesopause, and on vertical coupling from the troposphere to the lower thermosphere. Inter-hemispheric coupling has been known as global mode of variability. It has also a permanent effect which can explain the observed hemispheric differences in the MLT during July/January. Intra-hemispheric coupling describes how the onset of the cold summer mesopause in the SH depends on the breakdown of the polar vortex. The same mechanism explains the hemispheric asymmetry that is foundduring several weeks prior to summer solstice. A new aspect of vertical coupling within the winter hemisphere is due to the generation of secondary gravity waves (GWs) in the stratosphere and lower mesosphere. This process is simulated with a new GW-resolving version of the Kuehlungsborn Mechanistic general Circulation Model (KMCM). In the SH, secondary GWs are generated from the intermittent momentum deposition (body force) of mountain waves over the Southern Andes/Antarctic Peninsula. Eastward secondary GWs propagate to high altitudes because of the negative zonal wind shear in the winter mesosphere. These waves have amplitudes, periods, and vertical wavelengths in the MLT as observed by lidar in the Antarctic. Regarding the general circulation, the secondary GWs exert an eastward drag in the upper winter mesosphere, thereby contributing to the low temperatures and inducing an additional zonal wind maximum around 100 km. The model also simulates sources of secondary and tertiary GWs in the lower thermosphere. For example, we find events of concentric rings at ~130 km above the Southern Andes/Antartic Peninsula hotspot which correspond to large-scale tertiary GWs generated in the mesopause region. Our general conclusion is that important GW effects in the MLT are left out by models that use a configuration with parameterized GWs.

MESOSPHERE-STRATOSPHERE COUPLING BY POLAR WINTER DESCENT OF ODD NITROGEN

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Abstract

Polar winter descent of odd nitrogen produced by energetic particle precipitation (EPP) represents an important vertical coupling mechanism transferring the solar signal from the mesosphere and lower thermosphere down to the polar stratosphere and possibly below. While the production mechanisms of odd nitrogen and the dynamical processes affecting its downward transport are qualitatively well understood, uncertainties remain; however, with respect to their quantitative assessment. This talk summarizes recent progress in constraining these processes by observational data. Particular emphasis will be given to the analysis of the 10-years record of global NO_y obtained from MIPAS-Envisat during 2002-2012; as well as to the results of the HEPPA-II model–measurement inter-comparison project conducted within SPARC/SOLARIS-HEPPA that focused on the polar winter descent during the dynamically perturbed Arctic winter 2008/2009.

GRAVITY WAVE OBSERVATIONS AND CHARACTERIZATION WITH THE ERWIN-II

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Abstract

The E-Region Wind Interferometer (ERWIN-II) is a Michelson interferometer, located at the Polar Environment Atmospheric Research Laboratory (PEARL) in Eureka, Nu. It detects the airglow irradiance and determines winds via Doppler shift in the airglow emissions – green line (557.7 nm) at a height of ~97 km, O2 (860 nm) at ~94 km, and OH (843 nm) at ~87 km. These measurements are of a high precision (~1 m/s for green line and OH, and~4 m/s for O_2) and cadence (~5 minutes). This high cadence allows for measurements of frequencies close to that of the Brunt- Väisälä, allowing for accurate measurements and characterization of gravity wave phenomena. In addition, measurements of the vertical winds and irradiance show a correlation between the irradiance and the vertical motion of the airglow layer. The degree to which these observations conform to linear gravity wave theory will be discussed.

EFFECT OF SEVERE GEOMAGNETIC STORMS IN THE LOW AND MIDDLE LATITUDE MESOSPHERE

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Abstract

The effect of geomagnetic storms on the mesospheric region is not studied in detail. In particular, it is not clear how the low and middle latitude mesosphere is affected due to severe geomagnetic storms. In this work, we analyzed six severe geomagnetic storms that have occurred between 2003 and 2015 with Dst indices dropping below -200 nT. We utilized measurements made by SABER payload on TIMED mission for this purpose. Nitric oxide volume emission rates showed noticeable enhancements coincident with the storm onset in the low and middle latitude mesosphere. Other chemical constituents like ozone, hydroxyl and carbon dioxide did not reveal considerable and consistent variations to the extent of nitric oxide. The enhancement in the nitric oxide concentration associated with geomagnetic storms in the thermosphere is well known. Recently, the variations in the mesospheric nitric oxide concentrations during storm time are observed in polar mesosphere as well. Here we find that similar enhancements, with comparably lesser magnitudes, occur in nitric oxide concentrations of the low and middle latitude mesosphere as well. Noticeably, there is no time lag between commencement of the storms and the nitric oxide enhancements indicating that this increase is not due to any meridional transport from high latitudes. It is also found that storms occurring near December solstice cause significant effects while only marginal effects are identified for the storms occurring during June solstice periods. These are preliminary results and further analysis is being carried out.

EXCURSIONS OF INTERHEMISPHERIC FIELD-ALIGNED CURRENTS IN AFRICA

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Abstract

We have examined digital magnetic records from September 2008 to August 2009 at eleven Magnetic Data Acquisition System (MAGDAS) stations in order to uniquely determine the variability of the Interhemispheric Field – Aligned Currents (IHFACs) in the African sector. Different from theoretical prediction, we found prominent positive IHFACs around dusk in February and March equinox. A novel IHFACs feature of this study is the semidiurnal variation control of the coupling between the northern and southern hemispheres. In addition, we found terdiurnal variation in September with their associated strong diurnal variations from the months of October through December. Quite unexpectedly, in the month of January, a significant latitudinal depletion in the intensities of IHFACs was observed from dawn to dusk, compared to any other months under investigation, accompanied with a marked reduction of the prominent diurnal variations at the magnetic equator (Addis Ababa, AAB). Our results showed that much of the IHFACs variability in the month of January arises mainly from sudden stratospheric warming (SSW) through the activities of planetary waves, rather than ionospheric wind and conductivities or the imbalance of the ionospheric horizontal Sq current.

LIDAR BACKSCATTERING SIGNALS OF UPPER ATMOSPHER DURING CHARGED PARTICLES PRECIPITATION

Andrey Perezhogin (Institute of Cosmophysical Research and Radio Wave Propagation FEB RAS, Russia)

Abstract

Lidar method is used in low and middle atmosphere. Some investigations of upper atmosphere by lidar methods gave ability to research a changed particles precipitation due to solar-terrestrial interconnection. Two-frequency lidar sounding of the ionosphere is considered. Resonance frequencies of oxygen and nitrogen are represented. Backscattering lidar signals are recorded above 100 km. Correlation of lidar signal and foF2 are shown. We consider physical mechanisms of resonance scattering during a changed particles precipitation. Database of lidar signals at heights above 100 km is represented at the period of 2015-2018 under VARSITI support.

MODELLING THE CHEMICAL IMPACT OF PARTICLE PRECIPITATION IN THE MIDDLE ATMOSPHERE AND COMPARISON WITH OBSERVATIONS

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Abstract

Energetic particles from the Sun or originating in the magnetosphere of the Earth cause partial ionization in the atmosphere leading to considerable amounts of NO_x and HO_x in the lower thermosphere and mesosphere. Depending on the energy of the particles, these radicals affect the ozone chemistry on shorter and longer time-scales directly or via vertical transport in the stratosphere and impact dynamics by radiative coupling. Here we present simulations of the direct and indirect effects of energetic particle precipitation with the Karlsruhe Simulation Model of the Middle Atmosphere KASIMA. The primary

production of the radicals HO_x and NO_x is calculated using ionization rates from the AIMOS model and an Ap-index based parameterization for comparison. The model is run with specified dynamics in the stratosphere using ERA-Interim analyses. The gravity wave drag scheme has been modified in this version of the model to yield a more realistic representation of downward transport from the lower thermosphere during elevated stratosphere events in the northern polar winter middle atmosphere. The model simulations are compared with observations of the MIPAS-Instrument on the ENVISAT satellite with special foci on the MLT temperature and on the NO_y partitioning inside the NO-intrusions including HNO_3 buildup via protonized water clusters. The impact of the particle precipitation on the chemistry is derived by comparison with a reference run without ionization.

WINDII OBSERVATIONS OF A STATIONARY THERMOSPHERIC HIGH-LATITUDE "WALL" OF EXTREME WINDS

Gordon G. Shepherd (York University, Canada) gordon[at]yorku.ca, M. G. Shepherd, and Y. Cho

Abstract

Recently it was discovered that at southern hemisphere geographic latitudes between 60° and 70° S, there was a consistent sharp reversal in the thermospheric zonal winds from eastward to westward. The winds were observed by the Wind Imaging Interferometer (WINDII) on NASA's Upper Atmosphere Research Satellite (UARS), launched in September 1991, with WINDII providing data until 2003; the wind wall is observed from Doppler shifts in the O(1S) atomic oxygen green line at 557.7 nm. These westward winds were confined to a narrow stationary region between 100° and 200° in longitude with zonal values regularly of -400 m s^{-1}, sometime reaching -600 m s^{-1}, so sharply defined that the authors describe it as a "wind wall". The same feature was observed in the northern hemisphere, except that it appeared at a longitude different by 180°. The peak velocity varies from day to day and can persist in sequences of several days. In the days so far examined it was present about one half of the time, and for the southern hemisphere appears to be occur primarily in austral summer and fall. The wind reversals at the wall boundaries creates a convergence on the west side of the wall and a divergence on the east side that is expected to generate vertical flows. Observations of the $O(^1S)$ emission rates show a bifurcated pattern near 100 km, with an enhanced emission rate on the west side of the wall and an increased altitude of the emission on the east side, suggesting that the influence of the convergences and divergences in the thermosphere at 250 km can reach as low as 100 km.

DYNAMICAL PERTURBATIONS IN O(1D) NIGHTGLOW, WINDS AND TEC SATELLITE OBSERVATIONS AT SOUTHERN HIGH LATITUDES

Marianna Shepherd (Centre for Research in Earth and Space Science, York University, Canada) mshepher[at]yorku.ca

Abstract

The focus of the current study is an investigation of the effect of the high latitude (50ºS – 70ºS) thermosphere and ionosphere dynamics on the global seasonal, local time, altitude and longitudinal variability of $O(^1D)$ nightglow at southern mid-latitudes (20ºS – 40ºS). The study employed multi-year observations of $O(^1D)$ airglow volume emission rates

(VER) and neutral winds over the altitude range of 190 – 300 km by the Wind Imaging Interferometer (WINDII) experiment on board the Upper Atmosphere Research Satellite. A persistent signature observed during daytime and nighttime was an enhancement at 100ºE –200ºE, which corresponds to a wave 1 or is a part of a wave 2 signature. The peak $O(^1D)$ emission rates at the 50ºS – 70ºS latitude band vary from day-to-day, but its location remains almost constant within the region of 50ºE – 150ºE. It is accompanied by strong westward zonal winds with velocities reaching up to 450 m s^{-1}. The peak of the $O(^1D)$ emission rates and zonal wind extends equator ward and appears related to the wave signatures observed at mid-latitudes. WINDII thermospheric atomic oxygen concentrations from O^+ emission observations, as well as correlative in time TOPEX TEC (Total Electron Content) data are also employed to investigate the mechanisms underlying the observed enhancement in $O(^1D)$ VER, including the effect of vertical winds on the $[O]/[N_2]$ ratio and of plasma transport associated with the Weddell Sea Anomaly.

RECENT RESULTS ON ATMOSPHERIC AND IONOSPHERIC DISTURBANCES USING THE OPTICAL MESOSPHERE THERMOSPHERE IMAGERS (OMTIS)

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Abstract

We review our recent progresses on the observation of the mesosphere, thermosphere, and ionosphere using the Optical Mesosphere Thermosphere Imagers (OMTIs) which consist of 21 airglow imagers, five Fabry-Perot interferometers (FPIs), three airglow temperature photometers and three tilting photometers. They are in automatic operation at Canada, Russia, Finland, Iceland, Norway, Japan, Alaska, Indonesia, Thailand, Australia, and Nigeria. Three-dimensional Fourier analysis of airglow images makes it possible to analyze long-term airglow imaging data to see the short-period gravity wave activities. Using this method, Takeo et al. (JGR, 2017) studied 16-year variation of horizontal phase velocity and propagation direction of mesospheric and thermospheric waves in airglow images observed by an airglow imager at Shigaraki (34.8ºN), Japan. We show yearly and seasonal variation of gravity wave propagation characteristics. Statistical characteristics of plasma bubbles at Abuja, Nigeria were studied by Okoh et al. (JGR, 2017) with their relation to the GNSS scintillation statistics. Coordinated observations of post-midnight irregularities and thermospheric neutral winds and temperatures at low latitudes were reported to show the relation of the post-midnight irregularities with the midnight temperature maximum and associated thermospheric winds. Average thermospheric temperatures observed by four FPIs at Norway, Thailand, Indonesia, and Australia for 2-3 years are compared with those estimated by the GAIA model to investigate the validity of the model. We also show geomagnetic conjugacy and non-conjugacy of ionospheric and thermospheric variations accompanied by a midnight brightness wave at low latitudes using airglow imagers, ionosondes and an Fabry-Perot interferometer at Thailand and Indonesia.

DYNAMICAL VARIABILITY IN THE WINTER POLAR MESOPAUSE REGION

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Abstract

During Polar winter, the dynamics of the mesopause region are not directly influenced by solar irradiance. As a result, the dynamical variability in this region is the result of influences from other regions of the atmosphere. In this paper, observations from the Polar Environment Atmospheric Research Laboratory (PEARL) at (80ºN, 85ºW) along with results from the CMAM30 assimilative run are used to examine the nature of this variability. The instruments involved include the PEARL All Sky Imager (PASI, airglow images) and the ERegion Wind Interferometer II (ERWIN2, wind, airglow irradiance). The PEARL instruments are used to characterize the small timescale variability and in combination with the CMAM30 results are used to characterize the larger scale variability. It is found that much of the variability in the winds occur in the ~7 to 14-hour range in the ground based observations. The airglow variability, although more difficult to characterize because of the influence of twilight, appears to exhibit a different range of variability. At low frequencies, although the variability in the CMAM30 results is of comparable amplitude to the observations, the two data sets are not well correlated.

PHYSICAL COUPLING PROCESSES WITHIN THE ATMOSPHERE-IONOSPHERE SYSTEM INDUCED BY PROPAGATING WAVES

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Abstract

Primarily through upward internal wave propagation, the lower atmospheric weather continuously perturbs the middle atmosphere and upper atmosphere at ionospheric heights. These internal waves cover a broad spectrum of harmonics, extending, i.e., from small-scale gravity (buoyancy) waves (GWs) to large-scale (or planetary-scale) tides and Rossby waves, with varying spatiotemporal properties. These waves can produce a significant amount of regional, interhemispheric, and/or vertical coupling within the atmosphere due to their capabilities of mixing, energy and momentum transport. Here, we will report on recent research results, focusing specifically on the effects of atmospheric GWs and solar tides of lower atmospheric origin on the middle and upper atmosphere. Additionally, we will present some scientific and community activities of "ROSMIC - Coupling by Dynamics Working Group". In this context we will primarily focus on atmospheric gravity waves, whose time-dependent three-dimensional effects are conveniently studied by general circulation models; including whole atmosphere subgrid-scale GW parameterizations. Overall, GWs can propagate from the lower atmosphere to the thermosphere, influencing the dynamical and thermal structure of the large-scale circulation and significantly modulating solar tides.

TRAVELLING PLANETARY WAVE COUPLING OF THE MIDDLE ATMOSPHERE AND IONOSPHERE-THERMOSPHERE

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Abstract

The coupling mechanisms of the middle atmosphere and ionosphere-thermosphere via the quasi-two-day planetary waves (QTDW) and five day waves will be reviewed. Results

from TIME-GCM numerical simulations and satellite observations will be presented. First of all, the QTDW winds in the lower thermosphere modulate the dynamo electric fields in the E-region ionosphere. The modulated electric field is transmitted into the F-region along the magnetic field and leads to quasi-two-day oscillations in the ion drift and electron densities. The second mechanism is via the dissipation of the QTDW in the lower thermosphere and acceleration of the mean wind. The driven poleward meridional circulation enhances the mixing of constituents in the lower thermosphere. Through molecular diffusion, the decrease of the O mixing ratio and the increase of the N_2 and O_2 mixing ratios propagate from the lower thermosphere into the upper thermosphere. As a result, the mean O/N_2 ratio and electron density near the ionospheric F_2 peak is reduced by about 16-20% at low and mid latitudes. The third mechanism is through the interaction between the QTDW and migrating tides in the mesosphere and lower thermosphere. This interaction reduces the amplitude of the migrating diurnal tide in the lower thermosphere in neutral winds and also generates sum and difference secondary waves in the lower thermosphere and E-region ionosphere. As a result of the changed migrating diurnal tide and sum/difference secondary wave, vertical ion drift and electron density vary with local time at different longitudes. The sum and difference secondary waves can cause additional oscillations in vertical ion drift and ionospheric electron densities. In addition, we will shed some light on the possibility of planetary wave like oscillations in the thermosphere driven by geomagnetic activities.

Session 3: Intra-Atmospheric Chain (IAC)

IAC3.4 Magnetosphere – Ionosphere – Thermosphere Coupling in SC 24

Lead Conveners
A.W. Yau
I.R. Mann

Plenary Speaker
Gang Lu
David Miles

Session Description

The transfer of mass and energy from the solar wind and magnetosphere to the ionosphere and thermosphere occurs primarily but not exclusively at high and mid latitudes. This transfer affects the entire geospace in one way or another, through a variety of physical processes coupling the magnetosphere, ionosphere and thermosphere (MIT) system which often exhibit strong variability in occurrence and behavior with the 11-year Solar Cycle (SC). At high latitudes, the impact of such processes is often seen in the form of disturbed electric fields, currents, electron densities, ion and electron temperatures, brightening aurora displays, ionospheric ion outflows, increase in small-scale plasma-density irregularities, and energetic particle precipitation, particularly during geomagnetic storm and substorm times. At mid and low latitudes, the impact is seen in the form of ring current intensification, stable auroral red arcs, storm-enhanced electron densities, sub-auroral polarization streams, sub-auroral electric fields and their penetration to equatorial latitudes, F3 layer strengthening, disturbance neutral winds and dynamo electric fields, plasma bubbles, and change in total electron contents during magnetic storms. The extensive satellite and ground-based observations in the current SC (SC24), which is the weakest SC in a century, provide an excellent opportunity for probing the behavior of MIT coupling under the quietest solar conditions. We invite contributions of observation and modeling studies on the various aspects of MIT coupling in the context of SC24.

COUPLING OF GEOMAGNETIC DISTURBANCES AND GCRS FLUX WITH CLOUD COVERING AND TOC AT ABASTUMANI

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Abstract

We studied possible coupling of long-term trends and inter-annual changes of geomagnetic disturbances and galactic cosmic rays (GCRs) flux with the total ozone content (TOC) observed at Abastumani Astrophysical Observatory during 1957-1993. These observations were carried out during cloudless conditions which allows us to investigate possible coupling of TOC and cloud covering with cosmic factors. According to these data the annual and seasonal mean TOC and GCRs flux have negative trends. The tendency of decrease of the TOC is greater for geomagnetically disturbed days, which is evident for planetary geomagnetic indices Ap≥8 and Ap≥12. The TOC and corresponding number of cloudless days, observed on geomagnetically disturbed days, show their seasonal peculiarities. The TOC and GCRs flux decreases mainly during strong geomagnetically disturbed days (Ap≥50), except summer, when in June, in spite of GCRs flux decreases, there is a tendency of its increase and decrease in the number of cloudless days. The observed sensitivity of TOC inter-annual distribution on cosmic factor are important for the troposphere-stratosphere coupling processes which may influence inter-annual variations day- and night-time cloud covering processes. The different behavior of TOC at spring equinox and summer time on magnetically disturbed days could be coupled with different inter-annual distributions of number of cloudless days and nights and the presence of semi-annual variations in them. It is also noted that observed cloud covering and ozone content sensitivity on cosmic factors is important for climate change and human life.

LOWER THERMOSPHERE FACTOR IN FORMATION OF SPORADIC E UNDER INFLUENCE OF HORIZONTAL WIND AND AGWS

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Abstract

The specific conditions, convenient for formation sporadic E in the mid-latitude lower thermosphere under influence of horizontal background wind and atmospheric gravity waves (AGWs) are considered. It is shown, that northward horizontal wind influences downward motion of the long-lived heavy metallic ions and due to decrease their vertical diffusive displacement, causes their density increase at heights, below about 120 km. In the similar way, the combined effects of collision of ions with zonal neutral wind particles and Lorentz Forcing also influences the ions vertical drift, which can provide an additional convergence or divergence of their density. The values of northward wind velocity providing the ions vertical convergence into a horizontal layer and the height of region of additional convergence under influence of zonal wind are estimated. It is shown that AGWs along with background horizontal wind can cause additional convergence of ions and formation multilayered sporadic E. The numerical results describing formation of sporadic E in the lower thermosphere under influence of horizontal wind and its multilayered structure caused by the declined propagation of AGWs are demonstrated.

SUBSTORMS DEVELOPMENT BY SIMULTANEOUS GROUND BASED AND THEMIS SATELLITE MEASUREMENTS

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Abstract

In this work we studied the development of sub-storms during the geomagnetic storm on December 23, 2014 by simultaneous data of THEMIS D (THD) satellite, ground based magnetic field measurements and auroras observations by the Multiscale Aurora Imaging Network (MAIN) in Apatity, Russia. Solar wind and interplanetary magnetic field parameters were taken from the OMNI data base. THEMIS D was located at ~ 7Re and the projection of its orbit crossed Kola peninsula from 18:30 to 19:30 UT in the time interval December 23-26, 2-14. Two substorms were observed from Apatity during the passages of THD above the station: the substorm at 19:19:50 UT on December 24, 2014 and the substorm at 19:32 UT on December 26, 2014. A comparative analysis between ground based and satellite data was carried out. High energy electrons (1-10 keV) injections and reduction of the less energetic electrons flux (~100 eV) were observed during the substorm auroras. Particles density reduction was found at the time about the auroral intensifications. Plasma fast flows were identified during the consecutive auroras intensifications. The time delay between the beginning of the different parameters disturbances registered by THD and the ground based observed ones is about 1.0 ¸ 1.5 min.

PERFORMANCE OF NEQ-2 & IRI-PLAS 2017 MODEL DURING SOLAR MAX OVER GLOBAL EQUATORIAL LOW LATITUDE

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Abstract

This paper inspects the prediction Capability of Nequick-2 model and the latest version of International Reference ionosphere IRI Extended to the Plasmasphere (IRI-Plas 2017) model in predicting the Total electron content (TEC) over eight different equatorial and low latitude regions across the globe during solar maximum year 2013-2014. In all, the diurnal and the seasonal variations agree fairly well with GPS-TEC in all the stations, although with some upward and downward offsets. The observed GPS-TEC shows the presence of winter anomaly which is high in December (DecSol) and Low in June solstices (June sol). The monthly and seasonal variations of the NeQuick-2 model TEC with IRI-Plas 2017 model has been compared with the GPS-TEC. From the prediction errors, it shows that the monthly and seasonal variation of the IRI-Plas 2017 overestimate GPS-TEC in all the regions when compared with NeQuick -2 models except in Addis Ababa station where there is a good agreement with the GPS-TEC. The NeQuick -2 model, in general performed better when compared with IRI-Plas 2017 in months and in season. These models exhibit latitudinal variation and showed a seasonal trend. The main problem of the NeQuick-2 model TEC representation is not situated in the Plasmaspheric part, its absence in NeQuick-2 model or its presence in IRI Plas 2017 model, the main source of the resulted discrepancies is still in the IRI topside ionosphere representation.

ELECTRON ENERGIZATION BY SUBSTORM DIPOLARIZATIONS

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Abstract

Substorms are one of the processes transferring energy and particles throughout the magnetosphere-ionosphere coupled system. Observations of increased fluxes of energetic electrons and ions in the inner magnetosphere are often associated with substorm dipolarizations. We discuss a new conceptual model of the electric and magnetic fields in the tail which has only a few easily controlled adjustable parameters, such as the thickness and the earthward extent of the cross-tail current sheet. We consider a substorm dipolarization to be a tail-ward retreat of the current sheet during which the size of the area threaded by the dipole-like magnetic field around the Earth increases. The calculated fields are used to describe the motion of electrons and changes in their energies. The resulting distribution functions are characterized by very anisotropic temperatures leading to high rates of pitch-angle diffusion; therefore, precipitation into the ionosphere. In some cases, energies of the particles increase by a factor of 25, which is, sufficient to explain observations of energetic particle injections at the geostationary orbit as well as some ionospheric observations, for example, those carried out by riometers. Therefore, we consider our scenario of the dipolarization process to be feasible. We also study the effects of a dipolarizing electromagnetic pulse propagating towards the Earth. The transient pulse fields are also three-dimensional, thus allowing us to study energization of electrons and ions with different pitch angles. The energized particles are transported towards the Earth where they can be observed by satellites as substorm injections.

GLOBAL IONOSPHERE AND THERMOSPHERE RESPONSE TO THE MARCH 2015 ST. PATRICK'S DAY STORM

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Abstract

This paper presents a comprehensive investigation of the March 2015 St. Patrick's Day storm. The storm was triggered by a fast-moving coronal mass ejection, and it was a major storm with a minimum Dst near -250 nT and a maximum AE value of ~2800 nT. The Thermosphere-Ionosphere Electrodynamics General Circulation Model (TIEGCM) is used to simulate the thermospheric response to the storms, and the model is driven by time-dependent global patterns of ionospheric convection and auroral precipitation based on various ground and satellite observations. The simulations reveal complex electron and neutral density variations throughout the ionosphere and thermosphere, including large-scale traveling ionospheric and atmospheric disturbances (i.e. TIDs and TADs). The model results are compared with the TEC observations from GPS receivers as well as the neutral density measurements from Swarm in order to validate the model's performance. An overarching goal of the paper is to elucidate the main physical processes responsible for the storm-time dynamical, electro-dynamical, and compositional changes in the ionosphere and thermosphere.

ALFVÉNIC DYNAMICS AND FINE STRUCTURING OF DISCRETE AURORAL ARCS: SWARM AND E-POP OBSERVATIONS

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Abstract

The electrodynamics associated with dual discrete arc aurora with anti-parallel flow along the arcs were observed nearly simultaneously by the enhanced Polar Outflow Probe (e-POP) and the Swarm A and C spacecraft. Auroral imaging from e-POP reveals 1-10 km structuring of the arcs, which move and evolve on second timescales and confound the traditional single-spacecraft field-aligned current algorithms. High-cadence magnetic data from e-POP shows 1-10 Hz, inferred Alfvénic, perturbations co-incident with and at the same scale size as the observed dynamic auroral fine structures. High-cadence electric and magnetic field data from Swarm A reveals non-stationary electrodynamics involving reflected and interfering Alfvén waves and modulation consistent with trapping in the Ionospheric Alfvén Resonator (IAR). These observations suggest a role for Alfvén waves, perhaps also the IAR, in discrete arc dynamics on 0.2 - 10s timescales and ~1-10 km spatial scales and reinforce the importance of considering Alfvén waves in magnetosphere-ionosphere coupling.

PLASMA DENSITY IRREGULARITIES AND THEIR EFFECTS ON TRANS-IONOSPHERIC RADIO SIGNALS STUDIED WITH THE SWARM SATELLITES

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Abstract

Geomagnetic storms can lead to plasma density irregularities at various scales. Small and medium-scale irregularities can influence the propagation of trans-ionospheric radio signals, such as of the Global Navigation Satellite Systems (GNSS) including GPS, Galileo or GLONASS. Measurable effects are radio wave scintillations in the phase and amplitude, which are significant issues at low geomagnetic latitudes and in the polar regions. Satellite in-situ data of plasma density variations combined with the ground based observations can provide better understanding of the phenomena associated with the largest disturbances of the GNSS signals in the polar regions. The phenomena of interest, where plasma irregularities can be substantial, include polar cap patches, auroral particle precipitation, and auroral blobs. To identify, monitor, and quantify regions with the strongest variations in the electron density in the ionosphere, we employ in-situ data from the European Space Agency's Swarm mission; for which we developed the polar cap patch index, and are now working towards the Ionospheric Plasma Irregularities (IPIR) product for a global characterisation of ionospheric irregularities. In this work, we present results from both products and analyze them together with the measurements from the ground based scintillation receivers located in the Scandinavian Arctic and in Antarctica as well as optical instruments. We quantify the effects of varying geomagnetic activity on ionospheric irregularities at different geomagnetic latitudes, and give indications of the severity of their impact on the trans-ionospheric radio signals.

COMPARISON OF IONOSPHERIC RESPONSE OVER BRAZILIAN SECTOR DURING GEOMAGNETIC STORMS OF MARCH 2013 AND 2015

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Abstract

Understanding and mitigating the effects of geomagnetic storms on the ionosphere continues to be an active research problem. Not all the geomagnetic storms produce similar effects. In the current solar cycle, two geomagnetic storms occurred on March 17, 2013 and 2015, respectively. Both the storms occurred in the morning UT sector while the storm on 2015 was more severe compared to that of 2013. This offers a unique opportunity to understand the ionospheric response by comparing the storm effects during 2013 and 2015. In this study, we investigate the response of low latitude ionosphere over the Brazilian region during these two storms utilizing multi-station ionosonde and TEC measurements. While the NmF2 show enhancements following both the storms, the duration of enhancement was longer for the stronger storm of 2015. However, the TEC measurements show different behavior in the pattern of their variation while comparing the storms. Following March 2013 storm, TEC was enhanced for two days while there was a reduction in TEC on the second day during 2015 case. Further, we also notice that the responses seen in NmF2 and TEC are different during 2015 case in that NmF2 remained high for a few more days, though TEC returned to quiet time values. During both the storms, the onset of equatorial spread F was suppressed on the evening of March 17. Regarding the storm time TIDs, more oscillations are seen in both NmF2 and TEC during 2015 storm compared to 2013 storm. The results and implications are discussed in detail in this work.

MAGNETOSPHERIC DYNAMICS DURING MAIN PHASE OF ST. PATRICK'S DAY GEOMAGNETIC STORM: GLOBAL MHD SIMULATIONS

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Abstract

Magneto-hydro-dynamic simulation models have been extensively used for the last few decades to describe dynamical nature of Magnetosphere – Ionosphere (MI) system. In the present study, two simulation MHD models such as AMIE and OpenGGCM-CTIM models are used for better understanding of the MI system; specifically, for studying spatial and temporal variations of electric field and currents in high latitude ionosphere, during magnetically disturbed periods. For the study, the plasma and electrodynamics field variables, such as the cross polar cap potential, magnetopause standoff distance and ionospheric joule heating are critically analysed during the main phase of the St.Patrick's Day geomagnetic storm on March 17 2015. The cross polar cap potential (ΦPC) inferred from AMIE vary from 19 kV to 229 kV over the selected period. Magnetopause standoff position and response time changes due to solar wind conditions are estimated from the Open GGCM-CTIM model. Both the mapping techniques yield better high latitude convection patterns too. Moreover, ionospheric energy dissipation through ionospheric joule heating, in northern, as well as southern hemispheres, during the aforesaid period are estimated and compared with global indices related empirical formulations. The study reveals that a proper “mapping procedure” provides knowledge of ionosphere dissipations rather than that obtained from empirical formulations.

ASSESSMENT OF MULTI-FREQUENCY GNSS SIGNAL OUTAGES OBSERVED FROM NORTHERN EQUATORIAL IONIZATION ANOMALY (EIA) CREST LOCATIONS

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Abstract

Multi-frequency GNSS signals will provide advanced three-frequency correction schemes for which knowledge of correlation of different frequency pairs under scintillation conditions is desirable. A significant factor in de-correlating the signals arises from the different phase de-correlation effects due to diffraction of signals from local random in-homogeneities of the medium of propagation frequently found to develop in the equatorial region during post-sunset hours. Understanding the correlation of signal fades across multiple frequencies is important to assess their collective mitigation effectiveness. A GNSS receiver capable of tracking GPS, GLONASS and GALILEO at multiple frequencies (L1, L2, L5) is operated at Calcutta (22.58ºN, 88.38ºE geographic; magnetic dip: 32dºeN) since April 2013, situated in the anomaly crest region in the Indian longitude sector. In the present analyses, the equinoctial periods of February-April and August- October 2014 have been selected. To observe the effects of signal decorrelations at L1, L2 and L5 during periods of scintillations, correlations were measured between C/N0 deviations recorded at the three frequencies separately for samples of three minute intervals for $S4 \geq 0.2$. In order to understand the impact of different nature of scattering at the three frequencies, three scattering coefficients were introduced in the analyses defined in terms of the ratio of difference and sum of C/N0 deviations for a pair of frequencies. Receiver position deviations were calculated at 50Hz sampling and expressed in terms of latitude and longitude in meters. It is found that during February through April 2014, low correlation coefficients between C/N0 deviations at L1, L2 and L5 were associated with high S4, high scattering coefficient and resulting large receiver position deviations for 39% of a scintillation patch at L1, L2, 37% for L2, L5 and 41% for L1, L5 respectively. The corresponding figures for August through October 2014 were 32%, 29% and 33% respectively.

A CASE STUDY ON THE RESPONSE OF THERMOSPHERIC NIGHTGLOW EMISSIONS TO PENETRATING ELECTRIC FIELD

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Abstract

The present paper discusses the role of Prompt Penetration Electric Field (PPEF) on the nighttime Thermosphere- Ionosphere-System (TIS) system over a dip equatorial station, Trivandrum (8.5º N, 77º E, 0.5º dip lat.). The event occurred on January 5, 2016. The atomic oxygen line emission intensities having different altitudes of emission (OI 777.4 nm, OI 630.0 nm and OI 557.7 nm) are measured using a Multi-wavelength Nighttime Photometer. It is revealed that the upper thermospheric airglow emissions, especially OI 777.4 nm and 630.0 nm, respond rapidly to the PPEF event during nighttime. It has been

observed that these nightglow emissions show a drastic enhancement after a time delay of ~15 minutes. On the other hand, OI 557.7 nm emissions (emission from lower thermosphere) did not exhibit any prompt change during the event. During the PPEF event, the base height of the ionosphere showed a sudden downward movement. It is conjectured that the sudden intrusion of the electric field to equatorial upper atmosphere has compressed topside ionosphere (>300 km) to lower altitudes. This has significant ramifications as far as the nocturnal F region dynamo is concerned. Such a sudden downward layer movement brings more ionization to the centroid of these airglow emissions, which in turn, enhances the emission rates. The study unequivocally demonstrates the coupling between interplanetary medium and TIS during the nighttime PPEF events.

STATISTICAL ANALYSIS OF SAR ARCS DETACHED FROM AURORAL OVAL BASED ON ALL-SKY IMAGING OBSERVATIONS

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Abstract

Stable Auroral Red (SAR) arcs observed at subauroral latitudes are the 630-nm optical emissions caused by low-energy electron precipitation into the ionospheric F layer from the interaction region between the ring current and the plasmasphere. Thus, SAR arcs are mainly observed at subauroral latitudes during geomagnetic storms. Recently, an event of SAR arc detached from the main oval after substorms, based on observation at Athabasca, Canada (54.7ºN, 246.7ºE, magnetic latitude = 61.7ºN). However, statistical analysis of such SAR arcs detached from the main oval has not been done yet. In this study, we perform a statistical analysis of SAR arc detachment observed at Athabasca. We analyzed 11 years of all-sky images at wavelengths of 630.0 nm obtained at Athabasca from 2006 to 2016. The SAR arcs move equatorward after the detachment from the oval. We investigate MLT distribution, yearly variation, dependence on AU/AL index and SYM-H index. The occurrence rate is high before midnight and has a correlation with the Ap index. The SAR arc detachment tends to occur during substorm recovery phase. We also estimate the equatorward velocity of the SAR arc motion and investigate dependence of these SAR arc velocities on AU/AL indices, SYM-H, solar wind pressure, and IMF-Bz. The equatorward velocities of SAR arcs are higher in the dusk and dawn local times compared with those around midnight. In the presentation, we will discuss these results in the context of possible cause of the SAR arc detachment.

Session 4: Special Topics (ST)

ST4.1 Long-term Sun-Earth-Climate Chain

Lead Conveners
P. Martens
D. Nandi

Invited Speakers
Jose Dias do Nascimento

Session Description

Life has existed on planet Earth for over four billion years, so it must have originated fairly soon after Earth formed. Until a billion and a half years ago life consisted only of single cell organisms in bodies of water and shorelines. However, the radiation coming from the Sun was not very conducive to the development of life on Earth.

First of all, the initial luminosity of the Sun was only 70% of what it is now, linearly increasing in time to its current value. Climate models show that the Earth's oceans must have been completely frozen over for most of the four billion period: "Snowball Earth". Yet geological evidence points to a warmer climate on Earth in a distant past. This is known as the "Faint Young Sun Paradox", and researchers from various fields have come up with very different hypotheses for solving it.

Secondly, the young Sun was far more magnetically active than the current Sun, and hence X-rays, gamma rays, EUV, and UV radiation was probably orders of magnitude more intense than currently, and that without a protective Ozone layer for much of Earth's history. Hence, the DNA of all living organisms was under constant assault, certainly not a benign environment for the evolution of life. Still, life not only developed, it flourished and colonized the entire planet. Many hypotheses have been developed in very distinct fields (biology, geology, atmospheric science, astronomy) to resolve this double conundrum, but no completely satisfactory and complete theory has been developed yet.

In this session we aim to bring together experts in various fields to address the double paradox – not enough visible photons, too many high energy photons – with the goal of building a comprehensive multi-disciplinary understanding of the problem.

EVOLUTION SIGNATURES OF A SUSTAINED MASSIVE SOLAR WIND

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Abstract

It has been demonstrated that the torque required to slow down the young sun from a rotation period of the order of five days to its current rotation rate requires a sustained (~ 3 Gyr) massive solar wind, or an unrealistically large lever arm for the Alfven surface, well beyond the orbit of Venus. A sustained massive solar wind would resolve the well-known "Faint Young Sun Paradox", in that a young sun more massive by several percent than the current sun would be sufficiently more luminous to prevent the young earth from turning into a permanent "Snowball Earth" - for which there is no geological and paleo-climatological evidence. The question we address here is whether there is any observational evidence for such a sustained massive solar wind. We are performing standard solar evolution calculations for two scenarios. The first is the standard one in which an initial massive mass loss of the order of 1%/Gyr rapidly declines to the current rate. The second scenario is one in which the same mass loss is sustained for about three billion years, which as mentioned above, can explain both the observed spin-down rate and resolve the Faint Young Sun paradox. We are searching for observable differences in the current Sun with regard to composition, luminosity, rotation rate, etc. between the two scenarios. These results will be presented at the meeting.

KAPPA 1 CETI AS A PROXY OF THE YOUNG SUN AND ITS EVOLUTION AND ACTIVITY

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Abstract

A better understanding of young solar analogs evolution and its magnetic behavior is essential for studies of young planetary atmospheres. For the young sSun, the magnetic activity has steadily declined throughout its early evolution lifetime. The stellar dynamo is affected by the star spins down caused by angular momentum losing through its magnetized wind. The magnetic activity of the young solar analogs expresses itself in a variety of features, like spots, faculae, flares and plages producing optical and ultraviolet excess radiation, and a magnetically confined coronae containing million degree plasma that emits X ray emission and extreme ultraviolet. Solar activity variability may happen on timescales of a few decades to thousands of years, and are thought to disturb planet atmospheres and space weather. In this context, Kappa 1 Ceti, it is a proxy of the young Sun with same age of the Sun when life arose on Earth. In this study, we show how solar analogs like Kappa 1 Ceti can constraint the young Sun activity and its evolution.

RECONSTRUCTION OF HORIZONTAL VELOCITY FIELDS AT THE PHOTOSPHERE FROM INTENSITYGRAMS AND MACHINE LEARNING

Benoit Tremblay (Université de Montréal, Canada) benoit[at]astro.umontreal.ca

Abstract

Recent numerical models are capable of evolving over short time scales granulation patterns and active region emergences that are consistent with observations. The next step for such realistic simulations would be the prediction of the short term evolution of the

Sun’s photosphere for space weather modelling by the means of data assimilation. Only the line-of-sight component of the plasma motions is directly measured at the surface. Multiple algorithms were consequently developed to infer the transverse components from observed continuum images or magnetograms. We compare horizontal velocity fields reconstructed at the photosphere from pairs of consecutive continuum images by the LCT, FLCT and CST methods and the DeepVel neural network. The objective is to identify the method that is best suited for generating synthetic observations to be used for data assimilation.

A NEW ADF (ACTIVE-DAY FRACTION) METHOD OF SUNSPOT NUMBER CALIBRATION

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Abstract

There are different reconstructions of the sunspot-number series which diverge before mid-19th century. The largest uncertainty is related to the “calibration” of individual observers to a "reference" level. A traditional approach based on a daisy-chain regression method may lead to a significant bias and error accumulation. A new independent method of calibration has been recently proposed based on an assessment of the visual acuity of individual observers to the reference data set of Royal Greenwich Observatory sunspot groups for the period 1900 – 1976, using the statistics of the active-day fraction. The quality of an observer is quantified via the observer's acuity thresholds. As a result, a new calibrated series of sunspot group numbers is obtained, since the 1740s without any daisy-chain regression. The new series is fully consistent with proxy data of the cosmogenic isotopes in terrestrial archives or in meteorites. Related uncertainties are discussed.

Session 4: Special Topics (ST)

IAC4.2
Space Weather

Lead Conveners
N. Nitta
K. Shiokawa

Plenary Speaker
Gang Lu
David Miles

Invited Speakers
Mamoru Ishii
Meng Jin

Session Description

Space weather represents short-term variations of conditions in the heliosphere that affect planets such as our own Earth. Interest in space weather has grown significantly in recent years as we get better informed of its possible impact on our highly technology-dependent society. Space weather is ultimately attributable to the Sun, whether the central role is played by transient phenomena such as solar flares and coronal mass ejections or by high-speed solar wind streams from coronal holes. These then drive processes in interplanetary space and the planet's atmosphere. We tend to expect big space weather events while solar activity is high. Interestingly, during the weak solar cycle 24, we witnessed a few extreme events, which may have been comparable to the so-called Carrington event. They could have caused disastrous effects on terrestrial assets if they had occurred days earlier and been directed to Earth. The primary purpose of this session is to discuss recent progress in our understanding and prediction capabilities of space weather, made possible by the availability of advanced coordinated data and the development of innovative theory and modeling. We particularly welcome studies of recent major space weather events such as those in September 2017.

GEOMAGNETICALLY INDUCED CURRENTS AND HARMONIC DISTORTION OBSERVED DURING THE 07-08 SEPTEMBER 2017 DISTURBED PERIOD

Mark Clilverd (British Antarctic Survey, United Kingdom) macl[at]bas.ac.uk, C. J. Rodger, J. B. Brundell, D. H. M. Manus, N. R. Thomson, M. Dalzell, I. Martin

Abstract

Several periods of Geomagnetically Induced Currents (GIC) were detected in the Halfway Bush substation in Dunedin, South Island, New Zealand, as a result of intense geomagnetic storm activity during September 6, 2017 to September 9, 2017. Unprecedented data coverage from a unique combination of instrumentation is analyzed, i.e., measurements of GIC on the single phase bank transformer T4 located within the substation, nearby magnetic field perturbation measurements, very low frequency (VLF) wideband measurements detecting the presence of power system harmonics, and high-voltage harmonic distortion measurements. Two solar wind shocks occurred within 25 hours, generating four distinct periods of GIC. Two of the GIC events were associated with the arrival of the shocks themselves. These generated large, but short-lived GIC effects that resulted in no observable harmonic generation. Nearby and more distant magnetometers showed good agreement in measuring these global-scale magnetic field perturbations. However, two subsequent longer-lasting GIC periods, up to 30 minutes in duration, generated harmonics detected by the VLF receiver systems, when GIC levels continuously exceeded 15 A in T4. Nearby and more distant magnetometers showed differences in their measurements of the magnetic field perturbations at these times, suggesting the influence of small-scale ionospheric current structures close to Dunedin. VLF receive systems picked up harmonics from the substation, up to the 30th harmonic, consistent with observed high-voltage increases in even harmonic distortion, along with small decreases in odd harmonic distortion.

LARGE IMPULSIVE MAGNETIC EVENTS (LIME)

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Abstract

Examination of times of voltage distortion events (a GIC proxy) in the Hydro-Québec power grid in northeastern North America suggests that most are associated with auroral currents on the night-side of earth. Some fraction, during the daytime, is instead associated with changes in the solar wind, including but not restricted to compressional sources of sudden impulses (SI). In both cases, GIC activity seems to mainly be associated with spikes, mainly in the vertical component, of magnetic fields detected in the nearby AUTUMNX, MACCS, and CANMOS magnetic networks. These spikes can be very large, exceeding 1000 nT, and last of order only minutes, giving rise to large rates of change of the magnetic field. Consideration of Faraday's Law suggests that the vertical component is the most geoeffective field component. Night-side magnetic spike signals associated with voltage distortion triggers in the Hydro-Québec grid tend to be large, leading us to refer to them as Large Impulsive Magnetic Events (LIME) in distinction to other magnetic impulse events (MIE). With emphasis on two large events, an SI and a LIME, we will discuss physical processes giving rise to such spikes, with reference to pre-existing models developed by Araki and Lanzerotti, respectively. In the case of SI, shock aurora is already well known. We present a case of LIME showing a clear association with an unusual and dynamic streamer aurora, combining THEMIS ASI

images with magnetic perturbations/equivalent currents. The amplitude, spatial localization, and short duration of LIME events suggest that they are distinct from substorms, although they occur during magnetically active periods.

EXTREME KINEMATICS OF THE 2017 SEPTEMBER 10 CME AND ITS HELIOSPHERIC CONSEQUENCES

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Abstract

NOAA active region 12673 produced a series of major eruptions from September 4, 2017 during its disk passage before producing an extreme coronal mass ejection event on September 10 just before rotating behind the west limb. The initial acceleration and speed of the CME were among the highest observed in the SOHO era. The CME was driving a shock that accelerated particles from close to the Sun to large distances in the heliosphere as inferred from the large solar energetic particle (SEP) event and type II radio burst from metric to kilometric wavelengths. The SEP event had a ground level enhancement (GLE), which is only the third such event in solar cycle 23. We compare the September 10, 2017 CME and the associated phenomena with the known extreme events from the past.

ON THE CHARACTERIZATION OF IONOSPHERIC SCINTILLATION AT HIGH LATITUDES

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Abstract

Ionospheric scintillation of radio waves is an important phenomenon that results from the propagation of electromagnetic waves through a conducting ionosphere. Quantifying the scintillating signals has conventionally relied on indices like S_4 and Sigma_Phi, which would be adequate for signals that satisfy Boltzmann-Gibbs statistics, which is not the case in general. The time series associated with both the amplitude and the phase of the GPS signals have unveiled the non-Gaussian nature of the scintillating signals. This in turn has suggested the use of statistics that allow for distribution functions with non-Gaussian tails, and the need to characterize the signals observed by more than just the variance, including at least the third and forth moments, the Skewness and Kurtosis, respectively. We show that it is possible to develop new indices that can capture some genuine features that can help differentiate between amplitude and phase scintillations and at the same time allow a differentiation between refracted and diffracted signals.

IMF BY-DEPENDENT ENHANCEMENT IN HIGH-LATITUDE GEOMAGNETIC ACTIVITY IN LOCAL WINTER

Lauri Holappa (University of Oulu and NASA GSFC, Finland) lauri.holappa[at]oulu.fi

Abstract

The interaction of the solar wind and the interplanetary magnetic field (IMF) with the Earth's magnetic field produces geomagnetic activity, which is critically dependent on the orientation of the north-south (Bz) IMF component. Most solar wind coupling functions quantifying the relation between solar wind and IMF parameters and geomagnetic activity include the dependence on the sign (polarity) of Bz, within the so-called IMF clock angle. Coupling functions depend on the clock angle in a way, which is symmetric with respect to the sign of the By component. However, recent studies indicate that the sign of By is an additional independent driver of high-latitude geomagnetic activity, leading (for the same clock angle) to higher (weaker) geomagnetic activity in Northern Hemisphere winter for By > 0 (By < 0). In this paper we quantify this explicit By-effect both for Northern and Southern high-latitude geomagnetic activity. We show that the By-effect maximizes when the Earth's dipole axis points towards the night sector, i.e., when the auroral region is maximally in darkness. The By-effect affects the westward electrojet strongly, but hardly at all the eastward electrojet. We find that there is a similar By-effect in the occurrence frequency and strength of substorms, largely explaining the By-effect in the westward electrojet. These results are important for predicting space weather effects at high latitudes and for understanding how the solar wind and IMF parameters produce geomagnetic activity.

SPACE WEATHER RESEARCH AND OPERATION IN NICT

Mamoru Ishii (Space Environment Laboratory, NICT, Japan) mishii[at]nict.go.jp

Abstract

NICT provides Space Weather information service every day including holidays and weekend since 1988 as an original member of ISES (International Space Environment Service). In addition, we have research activities to strengthen the monitoring ability of space weather and to improve the precision of the forecast. We have ground-based observation, solar radio telescope, ionosondes, magnetometers and GPS receivers. Development of simulation code and models is important to improve the ability of space weather forecast. In our project we are developing empirical and theoretical code in sun, solar wind, magnetosphere, and ionosphere. We are developing not only forecast models but also softwares for users to use the space weather information easily, for example, radio propagation simulator, satellite anomaly estimator, and exposure estimator on aviation. NICT has been contributing the activities of international organization, for example, ITU, WMO, UN/COPUOS, ICAO and ISES. Now ICAO discuss to use space weather information for operation of civil aviation. NICT contributes to prepare the document and submit the selection of ICAO space weather forecast center. The selection process is now going and finalize by mid-2018. NICT organizes AOSWA, Asia-Oceania Space Weather Alliance which was established on 2010 for discussing research cooperation and sharing data and information related to space weather. Presently, the number of attending organizations is 29 from 13 countries. We had four face-to-face meetings biannual, and next meeting is planed on September 2018 hosted by LAPAN, Indonesia.

SUN-TO-EARTH MODELING OF CMES WITH A GLOBAL MHD MODEL: FACILITATING PHYSICAL UNDERSTANDING AND SPACEWEATHER FORECASTING

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Abstract

Coronal Mass Ejections (CMEs) are one of the major sources of destructive space weather. However, our understanding of CMEs and their propagation in the heliosphere is limited by the insufficient observations. First-principles-based numerical models play a vital role in interpreting observations, testing theories, and providing forecasts. By modeling realistic CME events using the newly developed Alfven Wave Solar Model (AWSoM) together with the data-driven Eruptive Event Generator by Gibson-Low (EEGGL), we demonstrate that many of the observed features can be reproduced near the Sun, in the heliosphere, and at the Earth, which illustrates the new capability to predict the long-term evolution of CMEs in interplanetary space. Furthermore, through several case studies (i.e., March 7, 2011, September 1, 2014, September 10, 2017 etc.), we emphasize how the unique information provided by the model (i.e., time-varying shock parameters, dynamical field line connectivities, plasma evolutions) could facilitate our understanding of fundamental processes of solar and heliophysics.

SPACE WEATHER EFFECTS ASSOCIATED WITH SMALL-SCALE MAGNETIC ISLANDS IN THE SOLAR WIND

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Abstract

The constant improvement of geomagnetic storm prediction techniques represents the key task of the solar-terrestrial physics. Meanwhile, the pre-history of geomagnetic storms is generally ignored in most space weather prognoses. We fill this gap with the analysis of the solar wind plasma and interplanetary magnetic field (IMF) parameters that usually are not treated as major storm-makers. The role of density/IMF variations (DIVs) in the ULF range is found to be very important. ULF solar wind pressure variations are known for their “instantaneous” geoeffectiveness, but we show that pre-storm ULF DIVs can be used as predictors of geomagnetic storms. DIVs are mostly related to the occurrence of small-scale magnetic islands (SMIs) in large-scale magnetic cavities formed by strong current sheets of various origins. Magnetic cavities can be created by the heliospheric current sheet from one side and an ICME or a CIR from the other. For an observer at the Earth’s position characteristic ULF DIVs occur before the onset of a geomagnetic storm produced by a geoeffective ICME or CIR. Furthermore, SMI contraction or merging can produce energetic particle flux enhancements up to 1 MeV. Such Atypical Energetic Particle Events often precede geomagnetic storms and may be as dangerous as well-known SEP events. We find that DIVs represent the most appropriate input parameter for the mid-term forecast of geomagnetic storms. We build a mid-term prognosis of geomagnetic storm, showing that if the rates of a smooth density growth as well as the power of density and IMF variations exceed certain thresholds, a geomagnetic storm is highly probable to occur in the next few days.

EXTREME SPACE WEATHER EFFECTS OF THE GREAT SOLAR AND GEOMAGNETIC STORM OF MAY 1967

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Abstract

The great solar and geomagnetic storm of May 1967 was an event in which space weather nearly changed the world as we know it. Solar flares rocked the ionosphere. Extreme solar radio bursts and solar energetic protons challenged radio communication and military surveillance systems. The ensuing geomagnetic storm allowed the first views of how severe the satellite drag environment might be under extreme storm conditions.

Half of the space catalog had to be recovered. I will explain how nascent efforts at space weather forecasting prevented an all-out geopolitical disaster.

FORECASTING SOUTHWARD BZ PERIODS FOLLOWING SHOCKS

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Abstract

Long-duration periods of strong southward magnetic fields are known to be the primary cause of geomagnetic storms. The majority of such events are caused by the passage over Earth of a magnetic ejecta, although sheath fields, co-rotating interaction regions and compressed ejecta are also common drivers of geomagnetic storms. Independently of the interplanetary cause, fast forward shocks often precede such strong southward Bz periods. Here, we first look at all long-duration periods of strong southward magnetic fields measured by the Wind spacecraft as well as fast-forward shocks measured by the Wind spacecraft. We find that about 20% of shocks are followed within 48 hours by a strong Bz south period, but 75-80% of strong Bz period are preceded within 48 hours by a shock. Then, we devise a probabilistic forecasting method based on the shock properties and the pre-schock solar wind plasma and interplanetary magnetic field characteristics. Preliminary results show that a combination of the magnetic field strength (B), the southward magnetic field (Bz) and the solar wind proton density (N) can forecast with improved accuracy the occurrence of a long-duration southward period after a shock.

COMPONENTS OF THE LUNAR GRAVITATIONAL TIDE IN THE TERRESTRIAL ATMOSPHERE AND GEOMAGNETIC FIELD

Nikolay Pertsev (Obukhov Institute of Atmospheric Physics RAS, Russia) n.pertsev[at]bk.ru, P. Dalin, V. Perminov

Abstract

A wide term “space weather” is mainly associated with solar variability. This presentation aims to draw attention to the significant lunar influence on the terrestrial atmosphere, namely, tropospheric cloudiness, characteristics of the mesosphere and lower thermosphere as well as on geomagnetic activity. The results of our investigations are based on multiple regression analysis of long-term atmospheric and geomagnetic data series.

In this study we show that the lunar influence on the terrestrial atmosphere and magnetic field is implemented through several statistically significant oscillation modes, extracted from a number of measured data series. The list of these active lunar-terrestrial oscillation modes includes not only the well-known lunar semidiurnal tide, but also the semimonthly zonal tide (mean period is 13.67 days; present in summer mid-latitude relative tropospheric cloud amount, winter and summer temperature of the mesopause hydroxyl layer, noctilucent clouds ground-based occurrence frequency, noctilucent clouds ground-based brightness, PMSE volume reflectivity, PMSE meridional velocity, AE geomagnetic index), the anomalistic monthly and semimonthly tides (mean periods are 27.55 and 13.78 days), the lunar semimonthly synodic oscillation (~14.77 days) and some others. The physical mechanisms generating the oscillations are clear for some of these components only.

AN INTEGRATED SOLAR WIND-MHD MODEL FOR SPACE WEATHER FORECASTING

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Abstract

Growing interest in adverse space weather effects has stimulated research and development of operational space weather forecast models. To enhance Canadian space weather forecast capabilities, a numerical framework for propagation of solar wind disturbances has been developed. Here, the development of a three-dimensional (3-D) integrated Sun-to-Earth solar wind-MHD model is reported. This numerical model encompasses two components: a semi-empirical model of the solar corona, and a MHD code which is used to propagate the solar wind through interplanetary space. The coronal component of the framework uses the Potential Field Source Surface (PFSS) and Schatten Current Sheet (SCS) model to derive the global coronal magnetic field from photospheric magnetic field observations. Furthermore, this numerical component uses empirical relations, such as the Wang-Sheeley-Arge (WSA) relation, to associate solar wind properties with the properties of the coronal magnetic field and to provide boundary conditions to the MHD code. The 3-D MHD model uses a finite-volume discretization procedure with limited piecewise linear reconstruction for solving the governing partial differential equations on body-fitted hexahedral multi-block meshes. Implicit as well as explicit techniques are available within the framework for time-marching. An anisotropic block-based refinement technique provides significant reductions in the size of the computational mesh by locally refining the grid in selected directions as dictated by the flow physics. The capabilities of the framework in accurately capturing background solar wind structure and forecasting solar wind properties at the Earth are demonstrated using Global Oscillation Network Group (GONG) synoptic maps of the photospheric field as the input to the model.

CHARACTERISTICS OF STORM-TIME SUBSTORMS IN HIGH LATITUDE MIDNIGHT SECTOR AND THEIR LOW LATITUDE SIGNATURES

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Abstract

Magnetospheric substorms are fundamental instabilities in Earth's magnetotail that causes sudden bursting of solar wind energy into the Magnetosphere-Ionosphere (MI) system. The sudden discharge of solar wind energy during substorms triggers unique manifestations in the MI system such as auroral substorms, geomagnetic pulsations in Alfven modes, and magnetic dipolarization in midtail of Earth's magnetosphere. In addition, these produce some latitudinal perturbations such as negative (positive) bays in magnetic disturbances in high (mid) latitudes and irregular geomagnetic pulsations in low latitudes. In the present study, high and low latitude signatures of substorms which are occurring mainly in main phase of intense storms are analysed. 65 intense substorms, with its minimum values of local electrojet index (IL) $\geq$ -200 nT, during the main phase of intense geomagnetic storms, over the present solar cycle (SC 24) have been selected. The selected substorms are all in high latitude midnight sector showing negative bay in Hcomponent of geomagnetic disturbances, observed in IMAGE magnetometer longitudinal chain. The associated Pi2s, during the selected periods, in between 600 and 700 latitudes, covering auroral oval region in midnight sector, have been extensively studied. For investigating low latitude signatures, simultaneous variations in AL and WP indices have further been looked into. It is also found that ~ 38% of the selected substorm events, over high latitude midnight sector, show significant low latitude signatures.

NETWORK-BASED TIME SERIES ANALYSIS OF SUBSTORM DYNAMICS

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Abstract

Nonlinear methods have been proven effective for the study of dynamical phase transitions associated with self-organization and spontaneous emergence of long-range correlations in magnetosphere during substorms. Network-based time series analysis has been a prominent method for the investigation of the evolutionary properties associated with complex dynamical systems like magnetospheric system. By mapping geomagnetic time series into hierarchically structured networks, it is possible to study both microscopic as well as macroscopic behaviours of magnetospheric dynamics during substorm periods. In the present study, we propose a novel method based on visibility graphs, in which geomagnetic series segments are mapped to visibility graphs as being descriptors of the corresponding states in such a way that the successively occurring states are also having a connection with the present states. The main idea is to convert a geomagnetic time series into a scale-free time-domain network. This approach has the convenience of capturing relevant dynamical relationships of both local and global magnetospheric dynamics during calm and disturbance periods while providing a link between time series analysis and network theory which could also help in machine-learning based forecasting. Hence, the evolutionary features of magnetospheric dynamics associated with substorm phenomena obtained through network-based analysis will provide vital statistical information which will benefit both short and long-term predictions. Our study also shows that the relationships between the scaling exponents of degree distributions show variations in dynamical characteristics during calm and storm times. Hence, we propose that network-based method can be used to obtain reliable values of Hurst exponents that quantify the persistence/anti-persistence of magnetosphere.

STUDY OF TEC VARIABILITY IN EQUATORIAL IONOSPHERE USING BDS-GEO SIGNALS

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Abstract

With the development of GNSS systems, the coherent multi-frequency L band transmissions are now available from a number of geostationary satellites. These signals can be used for ionospheric TEC estimations in the same way as widely used GPS/GLONASS signals, taking the advantage of almost motionless ionospheric pierce points. Among these geostationary satellites, Chinese BDS-GEO are of the peculiar interest, providing the best noise pattern in TEC estimations, which corresponds to those of GPS/GLONASS systems. In this work, we discuss the capabilities of BDS-GEO data for studying ionospheric variability driven by space weather and meteorological sources at different time scales. Analyzing data from a number of IGS receivers, we present seasonal variations of geostationary TEC in near equatorial ionosphere and its relation to Solar activity, as well as day-to-day TEC variability driven by Solar flares, geomagnetic storms, SSWs and typhoon activity. We also discuss seasonal and diurnal variations of ROTI index constructed from geostationary TEC estimations and its relation to the EPB occurrence. Our results show large potential of geostationary TEC estimations with BDS-GEO signals for continuous monitoring of low-latitude and equatorial ionosphere.

NEW ZEALAND LONG TERM GEOMAGNETICALLY INDUCED CURRENT OBSERVATIONS: PEAK CURRENT ESTIMATES FOR EXTREME GEOMAGNETIC STORMS

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Abstract

Transpower New Zealand Limited has measured DC currents in transformers in the New Zealand electrical network at multiple South Island locations. The measurements provide an unusually long and spatially detailed set of Geomagnetically Induced Current (GIC) measurements. GIC are a clear hazard to the New Zealand electrical network, with the loss of $2 million transformer in November 2001 during a severe magnetic storm. Near continuous archived DC current data exist since 2001, starting with 12 different substations, and expanding from 2009 to include 17 substations. From 2001-2015 a total of 61 individual transformers were monitored. We have recently started a research project to analyse the New Zealand GIC dataset in order to better understand the occurrence and impact of GIC to the New Zealand electrical network. Of particular focus is the peak GIC values expected during extreme geomagnetic storms. We are working with Transpower New Zealand Limited to examine existing, and recommend options to, their GIC mitigation plans. Initial results from that effort will be discussed. In addition, we have worked on looking at the detailed GIC observations from the multiple measuring locations. As expected, we find that in most locations and for most times the observed GIC is best correlated with the rate of change of the horizontal component of the geomagnetic field. Using the ~14-year dataset and results from previous extreme storm studies, we have estimated the likely extreme GIC magnitude expected at the transformer which was written off in November 2001. This is ~460-2720 A, depending on the storm case used, which should be compared with our estimate of roughly 100 A during the failure event.

SANDPILE MODEL AND DEEP NEURAL NETWORK FOR THE PREDICTION OF SOLAR FLARES

Benoit Tremblay (Université de Montréal, Laval, Canada) benoit[at]astro.umontreal.ca

Abstract

X-class (and above) solar flares are amongst the largest (and rarest) eruptive phenomena of the sun. They are often accompanied by the acceleration of energetic particles which can have significant impacts on Earth's environment. The statistical features of large eruptive events can be reproduced by self-organized criticality models such as sandpile models. We previously developed a minimalistic sandpile model which, coupled with a modern data assimilation technique (i.e. 4D-Var), holds promising predictive capabilities. Our recent efforts focused on training a neural network using time sequences of synthetic

X-ray flux emissions generated by the sandpile model to infer a set of initial conditions of the sandpile model compatible with this sequence of emissions (given as input). The training process is only carried out once and replaces the computationally expensive minimization step of the data assimilation procedure. Past sequences of GOES X-ray flux measurements are then fed to the neural network to obtain a sandpile model representative of a given epoch of the Sun. The inferred initial conditions are then used in an assimilated sandpile model for the prediction of upcoming/later flaring events.

PC INDEX AS A STANDARD OF MAGNETO-IONOSPHERIC DISTURBANCES IN THE AURORAL ZONE

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Abstract

Index of the polar cap magnetic activity (PC index) is regarded as a proxy of the solar wind energy input into the magnetosphere (Resolution of XII IAGA Assembly, 2013). This assertion is based on examination of relationships between PC-index and the solar wind parameters, on the one hand, and relationships between the PC evolution and development of magnetospheric disturbances (AL and Dst-indices), on the other hand. The spatial-temporal distribution of the substorms manifestations, such as: magnitude of magnetic disturbances in the auroral zone, intensity of the auroral precipitations and auroral absorptions, the radio-wave critical frequencies (f0) in the E, Es and F layers of auroral ionosphere was analyzed in form of maps calibrated with PC value. The results of the analysis clearly demonstrated that PC index can be regarded as a reliable standard of the space weather influence. Generally, the PC index perfectly correlates with EKL field, which is derived from the solar wind data, measured in the point of libration L1 (at distance of ~ 1.5 million km upstream of the Earth) and reduced to the magnetopause. However, sometimes the correlation turned out to be negative (in ~1.5% of the examined substorm events) or zero (in about of 10% events). Analysis of this kind substorm events indicates on incorrect estimation of the solar plasma travel time from the L1 point to magnetopause (in the first case), or suggests that the solar wind observed on board ACE spacecraft did not encounter the Earth’s magnetosphere at all (in the second case). Thus, the PC index might be useful not only for calibrating of different phenomena and processes in the disturbed magnetosphere and fitting the solar wind-magnetosphere coupling function, but also for checking whether or not the solar wind fixed in Lagrange point L1 actually impacts on the magnetosphere.

Session 4: Special Topics (ST)

IAC4.3
Will Cycle 25 Be Special?

Lead Conveners
V. N. Obridko

Plenary Speaker
Gang Lu
David Miles

Session Description

Our symposium occurs in a very special period for the analysis of the solar activity. After a year or two, solar activity should fall to a minimum. This minimum between 24 and 25 cycles will allow a more accurate prediction of the height of the next maximum. It will be possible to use the most reliable forecast methods. The height of cycle 25 is of particular importance for the physics of the sun. If it is at least slightly above the 24 cycle, then we can say that there have been no violations of statistical regularities, and we more or less correctly describe the 11-year cycle over a time interval of the last 200 years. If it turns out to be at least a little lower than 24 cycles, this will mean the second consecutive violation of the Gnevyshev-Ohl rule, which may mean breaking the basic (previously found) regularities, possibly changing the sign of this rule. And, finally, if the 25th cycle is very low, this may mean the beginning of a new grand minimum, which we generally do not know the nature of and we do not know how to predict them. In recent years, the method of combining experimental data with dynamo theory has been intensively developing (the method of data assimilation). This method gives quite good results at relatively short time intervals (3-5 years). It is hoped that the period 2018-2010 will make it possible to use this method for a more accurate forecast of the 25th cycle.

PHYSICAL BASIS FOR SOLAR CYCLE PREDICTIONS AND CYCLE 25

Robert Cameron (Max Planck Institute for Solar System Research, Germany)
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Abstract

The physical basis for making predictions of the solar cycle, and the observations on which the theory is based will be briefly outlined. The observations include 40 years of synoptic observations which give both the radial and toroidal fields at the surface of the Sun. These observations support the Babcock Leighton Flux-Transport dynamo model. The prediction of solar cycle 24 from the model then reveals (within reasonably large error bars which are decreasing as cycle 24 progresses) that solar cycle 25 will have a similar strength to cycle 24, with some authors predicting levels either slightly above or below that of cycle 24.

A PREDICTION OF SOLAR CYCLE 25

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Abstract

The predictions of solar cycle is of interest because of its practical significance for space weather and of its roles to test theoretical understanding of the solar cycle. Here we present a semi-empirical model to predict the possible profiles of cycle 25. A set of random realizations which obey the statistical relations were used to predict the possible sunspot emergence during the rest of the ongoing cycle 24. Then we use the surface flux transport model with the latest observed synoptic magnetograms, CR2189, as the initial condition, to investigate the lager-scale field evolution over the solar surface. Based on the features of sunspot emergence and the correlation between the axial dipole moment at cycle minimum and strength of the subsequent cycle, the shape of the cycle 25 can be predicted. Our results show that 1) the southern polar field will keep flat until the end of the cycle, and the northern polar filed will keep increasing. 2) the predicted amplitude of cycle 25 will be 124 , which is about 10% higher than cycle 24. Most probably cycle 25 is a normal cycle.

SHANNON ENTROPY-BASED PREDICTION OF SOLAR CYCLE 25

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Abstract

A new model is proposed to forecast the peak sunspot activity of the upcoming solar cycle (SC) using Shannon entropy estimates related to the declining phase of the preceding SC. Daily and monthly smoothed international sunspot numbers are used in the present study. The Shannon entropy is the measure of inherent randomness in the SC and is found to vary with the phase of an SC as it progresses. In this model each SC with length Tcy is divided into five equal parts of duration Tcy/5. Each part is considered as one phase, and they are sequentially termed P1, P2, P3, P4, and P5. The Shannon entropy estimates for each of these five phases are obtained for the nth SC starting from n = 10 – 23. We find that the Shannon entropy during the ending phase (P5) of the nth SC can be efficiently used to predict the peak smoothed sunspot number of the (n + 1)th SC. The prediction equation derived in this study has a good correlation coefficient of 0.94. A noticeable decrease in entropy from 4.66 to 3.89 is encountered during P5 of SCs 22 to 23. The entropy value for P5 of the present SC 24 is not available as it has not yet ceased. However, if we assume that the fall in entropy continues for SC 24 at the same rate as that for SC 23, then we predict the peak smoothed sunspot number of 63±11.3 for SC 25. It is suggested that the upcoming SC 25 will be significantly weaker.

WHAT IS THE TIME SERIES OF SUNSPOT NUMBERS TELLING US ABOUT MAGNETIC FLUX TRANSPORT?

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Abstract

Around 1765, the sunspot cycle began sooner, and then early in the 19th century regained its earlier phase as the Sun entered the Dalton minimum. Recently, the Sun has repeated this behaviour. Cycle 24 has been weak and the phase returned to that of the expected 11-year cycle. If the Dalton minimum can be any guide, then cycle 25 will also be weak and it will arrive with the 11-year clock. The sunspot cycle can also be analyzed by examining the varying rise times and decay times of the sunspot cycles. The relationship between the varying rise times/rates and peak sunspot numbers has been termed the Waldmeier effect. We interpret this behaviour in terms of variations in the rate of transport of magnetic flux from the dynamo region/tachocline to the surface of the Sun where sunspots are formed. Most probably, the dynamo near the tachocline works at a constant rate, but the transport of magnetic flux to the surface can be variable, shortening and lengthening the time for the solar cycle rise. This interpretation of variable transport rates gives us insight that helps understand the relationship of high sunspot numbers to greater field strength on the solar surface and in the solar wind and hence stronger geomagnetic activity. The occurrence of periods of weak polar cap fields suggests that at times, the flux is removed in the polar caps more rapidly. Monitoring the magnetic flux in the polar caps is thus a good way to judge the efficacy of the transport to and from the tachocline. We need continuous monitoring over both poles and urge that plans be developed to initiate such a program.

THE SUN'S NEAR FUTURE: PREDICTIONS OR DIVINATIONS?

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Abstract

As the Grand maximum of solar activity of the second half of the twentieth century has come to its end, prognoses of solar activity for the next solar cycle and beyond become in focus for the solar-terrestrial community. The main intrigue is whether the next cycle will be lower than the current cycle 24, indicating a start of the Grand minimum, or remain at a low but stable level. A bunch of predictions have been already made, based on various approaches from data-driven models to ungrounded divinations, and lead to a diversity of the results. We will compare different results and discuss their consequences for the Space weather and solar-terrestrial implications.

SUNSPOT NUMBER PROGNOSIS FOR THE 25TH SOLAR CYCLE USING AR-MODELS SEPARATELY FOR THE BOTH HEMISPHERES

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Abstract

The solar activity changes have important impacts on space weather and on the Earth atmospheric processes. It is therefore not surprising that in the past decades a multitude of methods were developed to predict the solar activity. Here the sunspot number, a proxy of the solar activity, was considered as a times series and its statistical characteristics were studied. As it is well known the dynamic processes in both Sun hemispheres are not strong coupled. Hence using semi-annual data the progress of the solar cycles was described by auto-regression models worked out separately for northern and southern hemispheres and by summation, the total sunspot numbers were calculated. For control ex-ante prognosis of the last solar cycle is carried out, giving a sunspot number of 130 in 2014. For the new 25th Solar cycle a similar progress as during the 24 cycle is predicted. The sunspot maximum in the northern hemisphere should be achieved before the maximum in the southern hemisphere, when a higher activity in the southern hemisphere would be expected. A total sunspot number of about 110 is predicted for 2023.

Session 4: Special Topics (ST)

IAC4.4
New Missions (Space, Ground) for STP

Lead Conveners
N. Gopalswamy
F. J. Lübken

Plenary Speaker
Alexei Pevtsov

Invited Speakers
Chi Wang
Martin Mlynczak

Session Description

This session involves new efforts around the world in building ground-based and space-based observing systems that provide data for solving problems in solar terrestrial physics. There are several new efforts to make use of cube-sats and small-sats to explore the solar-terrestrial to provide crucial data that fill current data gaps. There are efforts to deploy instruments at different viewpoints located off the Sun-Earth line (L5 and L4 Lagrange points) and above the ecliptics. There are new ground-based efforts to enhance the long-term and short-term data sets to make substantial progress in solar terrestrial physics. Papers are invited to deal with all aspects of new missions: concepts, missions, instruments, and data systems.

PASSBAND RATIO IMAGING OF THE SOLAR CORONA USING A BALLOON CORONAGRAPH: THE BITSE MISSION

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Abstract

Traditional coronagraphy from ground and space provides electron density in the corona. The passband ratio imaging (PRI) originally proposed by L. Cram in 1976 can be extended to provide information on the electron temperature and flow speed in the corona, especially in the solar wind acceleration region (2 - 10 solar radii). Current spectroscopic observations from SOHO provides electron temperature only around the inner edge of this window. We expect electron temperature and flow speed information from the Parker Solar Probe at the outer edge of this window. We show that the PRI technique can provide temperature, flow speed, and density information in the solar wind acceleration region using a balloon coronagraph. The BITSE (Balloon-borne Investigation of Temperature and Speed of Electrons in the corona) mission will utilize the arc-second pointing capability available at NASA's Wallops Flight Facility to pint a single-stage coronagraph at the Sun and a polarization camera for PRI. The BITSE mission will use four passband filters between 380 and 460 nm for PRI and a broadband filter in the same wavelength range for traditional coronagraphy so that all the three physical quantities can be obtained in the solar wind acceleration region.

A SMALLSAT MISSION TO INVESTIGATE THE MESOSCALES IN INTERPLANETARY SPACE

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Abstract

In situ measurements provide our best way to investigate the magnetic structure of coronal mass ejections (CMEs), as well as the physics of shocks and solar energetic particle (SEP) acceleration. Multi-spacecraft and conjunction studies in the 1960s to 1980s led to the much of the current knowledge about the extent and evolution of CMEs, shocks, corotating interaction regions, and SEPs. The STEREO mission has revealed the large longitudinal spread of SEPs but, due to its launch during the depth of solar minimum, there has only been a handful of multi-spacecraft CME, shock and SEP measurements at low angular separation. In addition, most of what is known about the evolution of SEPs, CMEs and CIRs with radial distance has been based on statistical studies. This makes it impossible to investigate the evolution of the properties over "mesoscales", i.e. scales comparable to the studied physical scales (0.02 - 0.2 AU), where the event-to-event variability makes a statistical approach unfeasible. Here, I identify a clear gap in our understanding of the dynamic inner heliosphere, present recent analyses that highlight how CME and shock properties may change over scale as small as 0.01 AU, and propose a concept for a small mission to fill this gap in our knowledge.

FRONTIERS IN SATELLITE OBSERVATION OF THE MESOSPHERE AND THERMOSPHERE

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Abstract

Satellite observations of the terrestrial mesosphere and thermosphere have experienced a “golden age” over the past 25 years. Beginning with the Upper Atmosphere Research

Satellite in the early 1990's and continuing today with the long-running TIMED satellite and the newly-launched GOLD instrument, complemented in-between by numerous international instruments and missions, the mesosphere and thermosphere are the "ignorosphere" no longer. Looking forward to the next 25 years, there are still several frontiers in this region to be explored and discovered, and two frontiers in particular stand out. The first is to close the "thermosphere gap" in terms of a comprehensive, focused global measurement of kinetic temperatures, vector winds, energy input, and energy output of the atmosphere from 110 km to 200 km altitude. New technology in detection of terahertz frequency radiation offers the potential for exploring this frontier with relatively small, lower power instrumentation. A second, related frontier, is the detection and attribution of trends in temperature and density in the mesosphere and thermosphere. These trends are being driven by the continued buildup on carbon dioxide throughout the entire atmosphere. Ultimately, trends in carbon will drive a substantial cooling of the thermosphere, substantially lowering density at satellite altitude, and increasing lifetime of all orbiting objects including orbital debris. These effects will have a substantial impact on international space policy for the balance of the 21st century regarding the very habitability of some regions of low earth orbit. In this talk we will discuss the new technology for observing the mesosphere and thermosphere, as well as the factors that must be considered in accurately detecting long-term trends from satellite observations. A further challenge facing the community is to balance the needs for long-term measurements for trend detection with the many process-oriented missions typically recommended in Decadal Surveys and similar community-developed roadmaps.

POSSIBLE SCENARIO TO EFFECTIVELY IMPROVE SPACE WEATHER PREDICTIONS FROM SPACEBASED OBSERVATIONS

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Abstract

We discuss how distributed remote-sensing and in situ observations from space will alleviate the two factors below that pose severe limitations on today's space weather forecasting capability. First, we only have incomplete knowledge of the photospheric magnetic field that has been used for computing the coronal magnetic field. This impacts the capability of accurately modeling solar wind, which then makes it hard to know how and when interplanetary coronal mass ejections (ICMEs) affect the geo-space. A number of efforts have been made to correct the polar field measurements, but we may not know its properties unless we directly and routinely measure it clear of foreshortening. Presently, we still need to wait for the technology to mature that facilitates high-inclination heliocentric orbits, but we eventually should place several small satellites with a compact magnetograph in such orbits to constantly observe both poles. Second, we have only limited understanding of the solar wind structures at 1au that directly cause geomagnetic disturbances. After the arrival of the shock wave from a CME that occurred typically two to three days earlier, we cannot predict how the solar wind will evolve during the next day or two. This is because we characterize the solar wind structures on the basis of single measurements, i.e., at L1. Multiple cubesats or small satellites in sub-L1 orbits (covering ranges of distance from the Sun and angle from the Sun-Earth line) will not only improve our now-casting capability but also advance our understanding of the structure of the ICME and its interaction with solar wind, as shown in examples of state-of-the-arts numerical simulations such as the University of Michigan Alfven Wave Solar Model (AWSoM). This sub- L1 concept may be easily executed even now, and it should represent an important first step toward larger constellations that include a polar mission.

NEW GROUND BASED INSTRUMENT INITIATIVES FOR SOLAR AND SOLAR TERRESTRIAL PHYSICS

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Abstract

Heliophysics research community is pushing hard to explore the Sun with new instruments in new wavelength bands, with the highest possible spatial resolution and the fastest time cadence. We also have the societal “mandate” to develop a reliable space weather forecast. The developments in high resolution solar physics are fueled by the recent progress in adaptive optics, radiative transfer, full Stokes polarimetry, and realistic numerical modeling allowing the true fusion of state-of-the-art numerical modeling and equally sophisticated observations. Ground-based initiatives in high spatial resolution solar physics are now under development in USA (DKIST and GST), Europe and China (CLST). Future large-aperture solar telescopes have been also discussed in Europe (EST), India (NLST) and China (CGST). Measuring magnetic fields in the chromosphere and corona has been long considered as one of critical issues for proper understanding of magnetic field topology and in improving the space weather forecast. The instruments for observing coronal magnetic fields include direct measurements at the limb (CoMP, COSMO), full Stokes polarimetry in infrared and He I 10830A in prominences, and multifrequency observations in radio frequencies (OVRO, CSRH). Solar phenomena often occur on large spatial scales (e.g., large-scale connectivity and flare/CME-related restructuring of solar corona) and long temporal scales of several decades or longer (solar cycles, Maunder minima). The long-term monitoring is critical for understanding of these solar phenomena, which calls for development of synoptic programs. Relevant projects include SPRING initiative (EU and USA), CHAIN project (Japan), synoptic “Solar Service” and STOP-2 network of magnetographs (Russia). In addition, there are smaller in scale projects aimed at creating facilities for specific research goals (flare prediction, sun-as-star, Brazilian magnetograph). This talk will review the present instrument initiatives in ground-based solar and solar-terrestrial physics, and emphasize the importance of close international collaboration in this area of research.

GLOBAL SPACE WEATHER OBSERVATIONAL NETWORK: CHALLENGES AND CHINA’S CONTRIBUTION

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Abstract

To understand space weather physical processes and predict space weather accurately, global space-borne and ground-based space weather observational network, making simultaneous observations from the Sun to geo-space (magnetosphere, ionosphere and atmosphere), plays an essential role. In this talk, we will present the advances of the Chinese space weather science/solar-terrestrial physics missions, including the ASO-S

(Advanced Space-borne Solar Observatory), MIT (Magnetosphere – Ionosphere-Thermosphere Coupling Exploration), and the ESA-China joint space weather science mission SMILE (Solar wind – Magnetosphere – Ionosphere Link Explore), a new mission to image the magnetosphere. Compared to satellites, ground-based monitors are cheap, convenient, and provide continuous real-time data. We will also introduce the Chinese Meridian Project (CMP), a ground-based program fully utilizing the geographic location of the Chinese landmass to monitor the geo-space environment. CMP is just one arm of a larger program that Chinese scientists are proposing to the international community. The International Meridian Circle Program (IMCP) for space weather hopes to connect chains of ground-based monitors at the longitudinal meridians 12°E and 60°W. IMCP takes advantage of the fact that these meridians already have the most monitors of any on Earth, with monitors in Russia, Australia, Brazil, the United States, Canada, and other countries. This data will greatly enhance the ability of scientists to monitor and predict the space weather worldwide.

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