Observatory Days 2022

10.-14. January 2022

Sodankylä Geophysical Observatory

Abstracts

EISCAT_3D and its current status

Anita Aikio

Space Physics and Astronomy Research Unit, University of Oulu

In this talk, I will give a short overview of the scientific aims of the EISCAT_3D incoherent scatter radar, its basic configuration, and the current status of the construction project.

Current status of the LappiSat-1: The first satellite of SGO's LappiSat Space Programme

A Binios(1), J Envall(1), E I Tanskanen(1), J Biström(1), S Keskinen(1), M Keskinen(1), M Meskanen(1), H Vanhamäki(2), L Holappa(2), and the LappiSat team

(1) Sodankylä Geophysical Observatory, University of Oulu;
(2) Space Physics and Astronomy Research Unit, University of Oulu

The LappiSat Space Programme shall expand SGO's current geophysical observations and instrument know-how to orbits – starting with the first mission named LappiSat-1. The LappiSat-1 is a six-unit CubeSat-class satellite in the small satellite domain. The mission aims to perform in-orbit measurements from various geophysical phenomena, namely of the aurorae and the local magnetic fields. These mission objectives shall be carried out with in-house designed and developed space-grade instruments which include two cameras, magnetometers, and a photometer. The scientific & technical requirements and objectives were formulated for the LappiSat-1 mission during this autumn. Furthermore, the preliminary technical details & requirements for the payloads were constructed. We will present the current status of the project at the Observatory Days.

Upper and lower thermospheric winds during substorms

L Cai(1), A Aikio(1), N Ivchenko(2), S Oyama(1,3,5), S Buchert(4), I Virtanen(1), and H Vanhamäki(1)

(1) Space Physics and Astronomy, University of Oulu, Finland;
(2) Space and Plasma Physics, EECS, KTH, Sweden;
(3) ISEE, Nagoya University, Japan;
(4) Uppsala University, Sweden; (5) NIPR, Japan

Substorms cause sudden momentum and energy transfer from the magnetosphere to the high-latitude ionosphere-thermosphere system. The responses of the thermospheric neutral winds are not well known. In this study, both upper and lower thermospheric winds are investigated during isolated substorms based on the measurements of the Fabry-Perot interferometer (FPI) at Tromsø, Norway, and colocated EISCAT incoherent scatter radar. We will show the different responses of the neutral winds regarding substorm phases, onset location, and auroral electrojets in the E and F regions. The driving forces are also analysed.

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Sudden depletion of Alfvénic turbulence in the rarefaction region of corotating solar wind HSS at 1 AU: possible solar origin?

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(4) University of Michigan, Ann Arbor [MI], United States

A canonical description of a corotating solar wind high speed stream, in terms of velocity profile, would indicate three main regions: a stream interface or corotating interaction region characterised by a rapid flow speed increase and by compressive phenomena due to dynamical interaction between the fast wind flow and the slower ambient plasma; a fast wind plateau characterised by weak compressive phenomena and large amplitude fluctuations with a dominant Alfvénic character; a rarefaction region characterised by a decreasing trend of the flow speed and wind fluctuations dramatically reduced in amplitude and Alfvénic character, followed by the slow ambient wind. Interesting enough, in some cases the region where the severe reduction of these fluctuations takes place is remarkably short in time, of the order of minutes, and located at the flow velocity knee separating the fast wind plateau from the rarefaction region. The aim of this work is to investigate which are the physical mechanisms that might be at the origin of this phenomenon. We firstly looked for the presence of any tangential discontinuity which might inhibit the propagation of Alfvénic fluctuations from fast wind region to rarefaction region. The absence of a clear evidence for the presence of this discontinuity between these two regions led us to proceed with ion composition analysis for the corresponding solar wind, looking for any abrupt variation in minor ions parameters (as tracers of the source region) which might be linked to the phenomenon observed in the wind fluctuations. In the lack of a positive feedback from this analysis, we finally propose a mechanism based on interchange reconnection experienced by the field lines at the base of the corona, within the region separating the open field lines of the coronal hole, source of the fast wind, from the surrounding regions mainly characterised by closed field lines.

EISCAT 3D user access

C-F Enell(1), EGI Checkin team(2,3), EGI Perun team(2,4)

(1) EISCAT Scientific Association, Sweden;
(2) EGI, Netherlands;
(3) GRNET, Greece;
(4) Cesnet, Czech Republic

We will continue to test the use of EGI Checkin as Authentication and Authorisation Infrastructure (AAI) for EISCAT. This session will be practical, expecting more EISCAT users to sign up for EGI user accounts and become members of the EISCAT Virtual Organisation (VO) groups required to access EISCAT_3D data and services.

Abstracts

Auroral electron precipitating fluxes generated with eVlasiator as an input to WACCM-D runs: Method and preliminary results

M Grandin(1), M Battarbee(1), M Alho(1), T Häkkilä(2), T Manglayev(1), M E Szelag(2), N Kalakoski(2), P T Verronen(2,3), M Bussov(1), M Dubart(1), U Ganse(1), H George(1), K Horaites(1), A Johlander(4,1), K Papadakis(1), Y Pfau-Kempf(1), J Suni(1), V Tarvus(1), L Turc(1), H Zhou(1), M Palmroth(1,2)

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(3) Sodankylä Geophysical Observatory, University of Oulu, Sodankylä, Finland;
(4) Swedish Institute of Space Physics, Uppsala, Sweden

Recently, the Vlasiator global hybrid-Vlasov model of near-Earth space underwent new developments to simulate the dynamics of electrons in a setup dubbed eVlasiator. In this setup, the time evolution of electrons described as velocity distributions is considered at a chosen step in the global proton simulation, thus giving a snapshot of electron distribution functions in near-Earth space when quasi-steady state is reached, after tens of electron gyroperiods. As a result, we can evaluate the differential number fluxes of precipitating electrons at auroral energies (≈0.5–20 keV), using a method analogous to that already employed to calculate precipitating proton fluxes in Vlasiator simulations. We present the methodology enabling the evaluation of auroral electron precipitating fluxes in a 2D eVlasiator simulation with southward interplanetary magnetic field driving and the obtained preliminary results. The produced dataset can be used to generate input data for ionospheric and atmospheric models, such as the Whole Atmosphere Community Climate Model with D-region ion chemistry (WACCM-D), improving the accuracy of their driving conditions. We show preliminary results of a WACCM-D simulation driven by eVlasiator electron fluxes, and we discuss the current challenges and upcoming developments.

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Software-Defined Radio implementation for Metsähovi Compact Array 1

E Hirvonen, J Kallunki, P Kirves

Aalto University Metsähovi Radio Observatory, Kylmälä

The Metsähovi Compact Array 1 (MCA-1) is first of the four telescopes which were donated to the Aalto University's Metsähovi Radio Observatory (MRO) in 2014. Prior to this work a terminal operable pointing and tracking system has been built for the MCA-1 and a receiver with a frequency range of 4 - 8 GHz has been ordered and installed. The telescope is thus already working but without a back-end implementation. This work focuses on finishing the MCA-1 by creating a Software Defined Radio (SDR) implementation as a back-end. The newest commercially available SDR Ettus X410 is selected since it is fast and efficient. Generally, SDRs are easily modified for different purposes and thus the software can be easily changed later if the desired usage shifts. The software is designed to operate autonomously, thus it can be easily used in teaching with inexperienced users for instance.

The new software back-end implementation is then used primarily to make observations of methanol (CH3OH) masers. During the work, the strongest masers are observed and their spectral shapes are analysed. The measurements are done by integrating the received signal for multiple minutes. The signal is Fast Fourier Transformed (FFT) for acquiring the spectrum. The strongest spectral lines can be detected already in a few minutes and the weakest observed maser requires over 30 minutes of integration. The effect of the atmosphere is taken into account at the averaging calculations to increase the sensitivity. The catalogued mean doppler velocities are used to predict the approximate frequency for the maser. After the detection, the precise peak frequency can then be used to calculate the current doppler speed. The G111.542 is the weakest detected CH3OH maser and has a catalogued power of 346 Jy. Other detected masers so far are G109.871, G49.488, G81.877 and G37.427.

The sign and magnitude of IMF By-component modulate substorm dynamics

Lauri Holappa

Space Physics and Astronomy, University of Oulu, Finland

The most important driver of space weather is the southward (Bz) component of the interplanetary magnetic field (IMF). However, recent studies have shown also the dawn-dusk (By) component of IMF can also significantly modulate space weather, especially the dynamics of substorms and auroral electrojets. The recent progress in understanding these IMF By-effects are reviewed.

Abstracts

Ground-response of geomagnetic ULF waves to solar wind speed

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(2) Aalto University of Technology, Espoo, Finland

We look at the diurnal and seasonal behaviour of ultra-low frequency (ULF) waves in the geomagnetic field, as detected from the data of IMAGE magnetometers. Sampling the observations with solar wind quantities like solar wind speed, we can examine some of the characteristics of their relationship.

We show that the largest contributor to Pc5 type ULF waves on the ground is the solar wind speed, and its effect in the northern Finland is the strongest in the morning and midnight hours, with a weak tertiary peak in the afternoon. Effect is altogether diminished in summer. In winter, the midnight peak is both enhanced and de-centralised in time, and shifted morning-ward.

A connection between solar photosphere magnetic field strength and millimeter solar radio emission

J. Kallunki, M. Tornikoski

Metsähovi Radio Observatory, Aalto University, Finland

Solar activity has a tight connection to the magnetic properties of the Sun. Sunspots, for instance, are highly magnetic regions, where the magnetic field strength can be several thousand Gauss. Radio brightenings are features in high solar atmospheric layers, from the chromosphere to the corona. They are formed either in processes where the magnetic field is present, or due to mainly thermal processes. In this work, we study a connection between the photospheric magnetic field strength and 8 mm radio brightenings, which are located in the upper chromosphere. We used radio data from Aalto University Metsähovi Radio Observatory (MRO) and magnetogram data from SDO (Solar Dynamic Observatory) HMI (Helioseismic and Magnetic Imager). The analysed data set starts on 26 May 2010 and it ends on 30 October 2021. We had in total 2623 days when we had observations from both instruments, which means that 63% of days were covered from the whole period. The data set covers almost the whole Solar Cycle 24 and also the beginning of Solar Cycle 25. Our results show that approximately 70% of solar radio brightenings are in locations where the photospheric magnetic field is strong. A major difference can be noticed at high latitudes, where strong radio brightenings are seen especially at the beginning of the new solar cycle.

In our presentation we will discuss the connections between the radio brightenings and the magnetic field data.

Abstracts

Energetic particle precipitation flux spectrum as a standard high-level data product for the upcoming EISCAT_3D?

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We have developed inversion methods for deriving characteristics of the energetic particle precipitation (precipitation spectrum, chemical consequences) from any electron density height-profiles, but in particular for the incoherent scatter radar measurements. Applicability of these methods for a routine based EISCAT_3D analysis will be investigated in the new three years lasting Academy funded project called HPC-approach to Ionospheric Situational Awareness (HISSA), starting in January 2022!

Where does Space begin?

S Kirchner

Arctic Centre, University of Lapland, Rovaniemi, Finland

One of the classical unanswered questions in international space law is the question of where outer space begins and where the jurisdiction of nation-states over their airspace begins. A number of different theories have been offered over time - and for a long time, the matter was of no practical relevance as spacecraft operated at altitudes that were generally accepted as outer space. More recently, however, the matter has gained practical importance as private space flight companies have begun to offer commercial sub-orbital flights at altitudes for which there is no consensus as to whether it is already outer space or still air space. In this presentation different historical approaches to this question will be introduced and placed in the context of the ongoing work at the United Nations, in particular the United Nations Committee on the Peaceful Uses of Outer Space.

Abstracts

Reborn 30 GHz experimental radiometer for atmospheric tau evaluation

P Kirves, J Kallunki, M Tornikoski, K Holmberg

Aalto University Metsähovi Radio Observatory

The opacity of atmosphere, tau always affects sky observations. The bigger tau of the medium the less we get observable radiation thru. The thicker atmosphere attenuates the signal and emits more background thermal radiation. If we knew tau accurately we could better calibrate the measured results to actual flux density and our single dish observations would gain accuracy.

There are several ways to estimate atmosphere tau. We present an experimental tau radiometer operating at 30 GHz. First results of the radiometer are compared with other atmospherical data, acquired during November and December 2021. The outcome looks reasonable this far. The measured result seem to have dependency on both the relative humidity and the sky temperature. Work is under way for installation as a permanent instrument in the collection of Metsähovi backyard instruments. For now the instrument will be azimuth stationary and capable of elevation scan.

New reconstruction of event-integrated spectra (spectral fluences) for major solar energetic particle events

S Koldobskiy(1,2), O Raukunen(3), R Vainio(3), G A Kovaltsov(4), and I Usoskin(1)

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Here we report a new reconstruction of the event-integrated spectra of solar energetic particles (SEP) detected by neutron monitor (NM) network and space-borne detectors (mainly GOES data) during ground-level enhancement (GLE) events. The reconstruction of SEP fluences is based on the “bow-tie” method employing the latest advances in the NM data analysis (a time-dependent GCR background and the use of the NM yield function directly verified with the AMS-02 experiment data), usage of different space-borne detectors data, and a detailed study of various uncertainties. As a result of this work, we obtained integral fluences of SEPs in the energy range from 30 MeV to a few GeV for 58 moderate and strong GLE events since 1956. The results were fitted with the modified Band-function (a double power-law function with two exponential cutoffs). An easy-to-use presentation of SEP fluences in the form of an analytical expression forms a solid basis for new studies in different fields, such as the influence of SEPs on the atmosphere and a statistical study of extreme solar activity.

Abstracts

Development of a new magnetospheric computation tool

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The study of how cosmic rays (CRs) interact with the Earth's magnetic environment is heavily reliant on simulations of the CRs trajectory within said environment. These simulations are computationally taxing and require sophisticated computation tools to conduct, with MAGNETOCOSMICS being the most used tool currently. MAGNETOCOSMICS, while functional and reliable, is dated and requires an older version of Geant4, which is no longer supported, to run. There is also the challenge that MAGNETOCOSMICS is precompiled, making editing the tool beyond the original code to fit research needs . As such, the development of an alternative open access magnetospheric tool would benefit the CR research community greatly.

Using freely available pre-made code and models of the magnetosphere a more user-friendly tool for magnetospheric computations was created. To achieve fast processing speeds with user-friendly inputs both the FORTRAN and Python computing languages are used as the basis of the tool. The tool can conduct large scale computations of particle trajectories, cutoff rigidities, and asymptotic cones of acceptance. Despite not knowing the exact models used within the MAGNETOCOSMICS program the calculations conducted by the new tool have a good agreement with previous results.

The close agreement between prior tools and this modern code shows clear promise in the new program. The future open access nature of the tool will also allow further improvements to the computational accuracy as more researchers add to the existing code. Ideally the tool will provide the groundwork for a community driven magnetospheric tool that will be used throughout the community.

Abstracts

Radar methods and equipment development 1980-2021

M S Lehtinen(1,2)

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(2) Inverpolis Oy, Sodankylä

I summarise my life long career in radar methods. Radar coding and rigorous statistical data analysis by mathematical inversion theory have resulted in a combined improvement factor (processing gain) of up to 10^5 in analysed data accuracy and resolutions. Much of my older innovations are now worldwide recognised and in routine use in applications like IS, space debris and other. Unfortunately many more recent developments still remain unknown to wide public.

Along with theoretical work, development of instruments facilitating real time processing by state-of-the-art digital technology like FPGAs and SoCs has proceeded to high quality commercial products. They have the computational power necessary for practical implementation of the most recent methods developments.

Unfortunately some of today's most challenging enterprises like EISCAT_3D and plans for major space debris radars still base on legacy technologies 1 to 4 decades old. I will point out some of their most dangerous pitfalls in the hope that something could still be done to correct the course in these undertakings. They might still be corrected to be orders of magnitude more cost-efficient than what they seem to be developed towards at the moment.

The fall-effect in ionospheric and mesospheric parameters

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(6) Sodankylä Geophysical Observatory, University of Oulu, Finland

A spring-fall asymmetry is observed in daytime amplitude values of very low frequency (VLF) radio wave signals propagating over the North Atlantic. The signal variability shows a slower rate of change from summer to mid fall than from spring to summer. The climatological (2008–2021) measurements before summer and during winter follow the seasonal variation of the solar zenith angle. Then, after removing the background level, a large deviation is observed during fall, which we call the fall-effect. We explore the processes behind this effect by comparing against mean temperature, nitric oxide, and gravity wave seasonal variabilities. The gravity wave data is derived from mesospheric horizontal winds. We found that after removing their respective background level, the three mesospheric parameters display also a spring-fall asymmetry. We also perform a latitudinal dependence analysis of the fall-effect employing VLF receivers located in Peru (low-latitude), USA (middle-latitude), UK (middle-latitude), Finland (high-latitude), and Ny Ålesund (high-latitude). We found that the fall-effect is mostly observed from middle- to high-latitudes in both ionospheric and mesospheric parameters.

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Real-time simulation of the geoelectric field due to space weather events

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(3) Institute of Geophysics, ETH Zurich, Switzerland

We present a methodology that allows real-time simulation of the geoelectric field (GEF) spatiotemporal evolution in a given 3-D conductivity model of the Earth based on continuously augmented inducing source data.

The presented concept is validated using Fennoscandia as a test region. The choice of Fennoscandia is motivated by several reasons. First, it is a high-latitude region, where the GEF is expected to be particularly large. Second, there exists a 3-D ground electrical conductivity model of the region. Third, the regional magnetometer network, IMAGE, allows us to build a realistic model of the source for a given geomagnetic disturbance.

Taking the 7-8 September 2017 geomagnetic storm as a space weather event, we show that real-time high-resolution 3-D modelling of the GEF is feasible and requires only a few tens of seconds.

The first Ground Level Enhancement of solar cycle 25: study using neutron monitor data

A Mishev(1,2), N Larsen(1), I Usoskin(1,2)

(1) Sodankylä Geophysical Observatory, University of Oulu;
(2) Space Physics and Astronomy Research Unit, University of Oulu

The first solar proton event of solar cycle 25 (SC25) was detected on 28 October 2021 by several neutron monitors (NMs), specifically located in polar region. The strongest signal was registered by high-altitude polar NMs at Concordia French-Italian research station, namely DOMC and DOMB, standard and bare NM, respectively. The event was observed also by the particle detectors on the Geostationary Operational Environmental Satellite (GOES) in the near-Earth space. The solar of the observed particles was revealed on the basis of different measurements, that is proton observations from $E>10$ MeV to $E\geq500$ MeV were combined with the detection of a solar flare in soft X-rays (SXRs), a coronal mass ejection (CME), Type III and II radio bursts and extreme ultraviolet (EUV) observations as well by NMs.

Here, we report the observations by the global NM network, specifically by DOMC/DOMB, and present the derived angular and spectral features of the solar protons with their dynamical evolution throughout the event.

Abstracts

SDI-3D and collaborations with ground-based instruments in Fennoscandia

Shin-ichiro Oyama(1,2,3), SDI-3D project team and JSPS Kokusai-B team

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The dynamics of terrestrial Thermosphere-Ionosphere system is governed by particle collisions between neutrals and plasmas. At high latitudes, external forces originated in the Magnetosphere accelerate ionospheric plasmas, and plasma kinetic energies are exchanged to kinetic and thermal energies of neutral particles. Since these energy transfer processes can be expressed by partial differential equations that incorporates numerous vector fields, it is essentially important to measure vector fields of the Ionosphere and Thermosphere in the common volume at the same time. European Incoherent Scatter (EISCAT) Scientific Association is now building a new international research infrastructure, EISCAT_3D, which adopts the phased-array system capable of conducting volumetric measurements of the ion velocity vector with the separated three radar systems in Norway, Sweden and Finland. The EISCAT_3D is the most powerful diagnostic to measure the ionosphere, but not suitable for measuring the Thermosphere or neutral particles. Then in 2018, a new scientific-oriented project of SDI-3D was established. SDI (Scanning Doppler Imager) is a passive optical instrument, which can measure 2D pattern of the thermospheric wind from the optical Doppler shift. The SDI-3D project has aimed for deploying three SDIs in the common volume of the EISCAT_3D in order to achieve spatiotemporally simultaneous observations of the Ionosphere and Thermosphere. A proposal including three SDIs was awarded in 2020, and we are now working for starting observation in 2023. This presentation will update status of the SDI-3D project and future collaborations with other ground-based instruments in Fennoscandia.

Abstracts

MLT dependence of auroral peak emission heights

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(3) University of Southampton, UK;
(4) Finnish Meteorological Institute, Helsinki

We present the bulk behaviour of the auroral peak emission height as a function of magnetic local time (MLT). These data are collected from the Fennoscandian Lapland and Svalbard latitudes from a total of seven identical auroral all-sky cameras over about one solar cycle. The analysis focusses on green auroral emission, which is where the morphology is clearest visible and the number of images is highest. The typical peak emission height of the green and blue aurora varies from the 110 km on the nightside to about 118 km in the morning MLT over the Lapland region, but stays systematically higher (at 118–120 km) at high latitudes (Svalbard) at nighttime reaching 140 km at around magnetic noon. During high solar wind speed (above 500 km/s) nightside emission heights appear about 5 km lower than during slow solar wind speed (below 400 km/s). The sign of the Interplanetary Magnetic Field (IMF) had nearly no effect on the emission heights in the night sector, but northward IMF caused lower emission heights in the dawn over Lapland and during the noon hours over Svalbard. While the former is interpreted as a change in the particle population within the field-of-view, the latter is rather due to the movement of the cusp location due to the IMF orientation. The morning sector difference is equally pronounced when earlier detected pulsating aurora events have been excluded/included in the dataset, suggesting that this type aurora is a dominant phenomenon in the morning and an important dissipation mechanism.

Abstracts

Field-Aligned and Ionospheric Equivalent Currents from AMPERE and SuperMAG During ICME Driven Geomagnetic Storms

M N Pedersen(1), H Vanhamäki(1), A T Aikio(1), S Käki(1), A Workayehu(1), C L Waters(3), J W Gjerloev(4,5)

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(5) Faculty for Physics and Technology, University of Bergen, Bergen, Norway

The most intense ionospheric equivalent and field-aligned currents (FACs) occur during geomagnetic storms. However, the statistical storm-time characteristics and evolution of the currents over time-scales of storms remain unclear. In a previous study (Pedersen et al. 2021, https://doi.org/10.1029/2021JA029437), we studied the response of currents to storms driven by solar wind high speed streams (HSS) and their associated stream interaction regions (SIR). This study addresses that question for interplanetary coronal mass ejection (ICME) driven storms by considering 45 events with a minimum Dst ≤-50 nT. The FACs and ionospheric equivalent currents have been studied using a superposed epoch analysis using data from AMPERE and SuperMAG, respectively. The zero epoch (t0) is centred at the onset of the storm main phase, when the 10-min averaged SYM-H index drops below -15 nT. The currents and number of substorm onsets gradually increase 3 h before t0 and reach maximum around t0+1.5 h. The currents and number of substorm onsets remain high throughout the entire storm main phase, until at t0+14 h they start to slowly relax back to quiet time conditions. By separating the storms into two groups based on the solar wind dynamic pressure pdyn around t0, very different solar wind driving and behaviour in the currents emerge. High p storms are mostly triggered by the forward shock and sheath region ahead of the magnetic cloud (MC)/ejecta. These storms have shorter main phase durations and larger currents early in the main phase which maximise at t0+50 min. On the other hand, the low p group contains storms triggered by the MC structure and have gradually increasing currents that maximise at t0+11 h, close to the end of the storm main phase. Additionally, the Russell-McPherron effect is much less dominant for ICME driven storms than for HSS/SIR driven storms.

Abstracts

Cosmic ray measurements by SGO: status report

Stepan Poluianov (1,2), Ilya Usoskin (1,2), Alexander Mishev (1,2)

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The contribution covers the status of cosmic ray measurements conduced by Sodankylä Geophysical Observatory in 2021. The observatory has three neutron monitors registering secondary species of the cosmic ray cascade and observing the cosmic ray variability in real time. The most important instrument is the full-size neutron monitor 6NM64 working in Oulu, Finland. There are also two other mini-neutron monitors so-called DOMC (standard design) and DOMB (lead-free), which are located at the high-altitude polar station Concordia on the Antarctic plateau. The status of those instruments and the galactic cosmic-ray variability observed by them are reported. Particular attention is given to the registered major Ground-Level Enhancement event GLE#73 on 28 October 2021, which was caused by solar energetic particles accelerated by the Sun after a strong X-class flare.

Variability of D region ionization during the solar minimum of cycles 24/25

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(1) Leibniz Institute of Atmospheric Physics at the University of Rostock (IAP), Germany;
(2) Hochschule Wismar, University of Applied Sciences, Germany;

The Saura radar was built in 2002 on Andøya island to predominantly measure wind velocities in the mesosphere.

Furthermore, it allows the measurement of electron densities applying differential absorption and phase techniques. Given the polar location and operating frequency of 3.17 MHz, it is also very sensitive to the ionospheric conditions. The solar and geomagnetic activity prescribes the altitudinal coverage of the radar.

The extreme solar minimum between the cycles 24 and 25 was characterised by very low ionisation conditions, but with abrupt ionisation enhancements caused by particle precipitation events.

In this study, we'll demonstrate examples for both extreme situations and relate them to earlier years.

Abstracts

Substorm injections as major driver of Energetic Electron Precipitation events

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(2) Arctic and Antarctic Research Institute, St. Petersburg, Russia

Intense energetic electron precipitation (EEP) is one of important Space Weather hazards for which important scientific and practical questions, like “What controls the EEP intensity and distribution?” and “Which measures are suitable to parametrise the injection/precipitation models” are still open. Noticing that substorm dipolarisation and injection are closely coupled by their flow burst origin, we studied and confirmed a close relationship between magnitudes of EEP (as given by the peak magnitude of cosmic noise absorption (CNA) bays) and substorm current wedge parameters (total SCW current and its azimuthal size). Motivated by injected drifted electron cloud scenario, we used linear prediction filter (LPF) technique which allowed to reconstruct the distributed time-delayed EEP response to individual injection and present the EEP variation as a superposition of such ‘individual injections’ effects. In this way we built the statistical empirical dynamical model of EEP in the auroral zone, driven by the midlatitude positive bay (MPB) index time series as a proxy of nightside dipolarisations. Good agreement is found between response functions reconstructed separately for CNA data and D-region EISCAT ionisation data sets as well as between their reconstructions made for isolated substorms or for complicated activity consisting of substorm clusters. Therefore, the azimuthal EEP dynamics is robustly captured and this method can be used in further investigations of EEP physics or practical implementations, particularly in the frame of Arctic Space Hub network activity. This work is supported by RSF grant 22-27-00169.

Investigation of midlatitude MSTIDs by ionosonde and dense GNSS-receivers' network

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The paper deals with the property of the mid-latitude MSTIDs with small amplitude, ΔN/N≈10-20%, using the GNSS trans-ionospheric sounding method. A dense network of GNSS receivers located in the territory of the Russian Federation (more than 150 receivers) has been used to collect data. For each signal source or satellite, two-dimensional maps of TEC perturbations were generated, which revealed a different contrast of the band structures (MSTID signature on two-dimensional TEC perturbations map) depending on the line-of-sight (LOS) viewing angle. Three satellites, R03, R18 (GLONASS satellites) and G18 (GPS satellite) were simultaneously observed on 21 September 2016. The signatures of MSTID were observed for two satellites, R03 and G18, that had similar viewing geometry, but for another satellite R18, that had different viewing geometry from the previous two, the signatures wasn't observed. For this spatial layout of the MSTIDs, the maximum amplitude of the TEC perturbations was observed when the elevation angle of the satellite-receiver LOS was approximately 50 degrees. Based on the data of the GNSS receivers' network and the spatial form of the MSTID, a schematic diagram that explains the reason for the appearance of preferred viewing angles in the trans-ionospheric sounding technique was constructed. This proposed model made it possible to create a method for determining the vertical slope of MSTIDs according to GNSS data. For the first time, we performed a study for the European territory of Russia, which allows us to determine the occurrence rate of the vertical slopes of the MSTID phase front depending on the local time and MSTID propagation azimuth. It was found that summer nighttime MSTIDs over the region near Samara (≈55° N, 50° E) have the traditional southwest directions of propagation and sloping forward phase fronts, while near Sevastopol (≈45° N, 35° E) they have northwest directions with sloping backward phase fronts. We do not propose the exact mechanism of their formation in this paper, however, we note that sloping backward phase fronts of MSTIDs couldn't be formed by the GWs with sources in the troposphere. We suppose that this plasma fluctuations may be caused by MEF/MMF with amplifying by NMPBE in ≈45° N latitudes, which moves poleward because of ambipolar diffusion. Also Perkins instability may be a possible cause of MSTIDs growth with phase fronts aligned in NE-SW due to the presence of westward neutral winds at predawn hours.

Abstracts

The unique role of observatories and infrastructures in safe space exploration

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Observatories play an important role in the arctic and space situational awareness. Observatories are the places to make observations, store the critical information and create understanding of the consequences of the changing Arctic. Observatories provide a long-term memory to the society on geohazards and space safety.

Sodankylä Geophysical Observatory (SGO) has a long tradition of designing forefront instruments and measurement techniques and use them for top-tier science and services to the society. SGO has a national and international task to continuously provide long-term observations of space and geoenvironment around the clock non-stop, and to detect and warn about the related natural hazards. The national task includes the monitoring of the magnetic environment, auroral measurements, determination of the atmospheric structure and its properties, monitoring seismic activity, galactic cosmic rays, and solar disturbances, as well as changes in the radio environment.

The Observatory coordinates the national FIRI infrastructure Earth-Space Research Ecosystem (E2S), and operates as the home institute for the EISCAT and EISCAT_3D, and participates in the ESFRI/EPOS and FIRI/FIN-EPOS infrastructures. SGO maintains national measurement networks such as riometers and pulsation magnetometers as well as seismic network in the Northern Finland, and has dedicated instruments from the Antarctica to the deep Arctic.

University of Oulu have its own special role in the research of the biosphere-atmosphere-space connections. The Space Campus's location under the auroral oval, in the green zone around the magnetic poles, gives a unique view to the near-Earth and deep space, and improves the safety of the space exploration.

Abstracts

Precipitating electron energy spectra and auroral power estimation by incoherent scatter radar with high temporal resolution

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Electron precipitation is a key physical process in the magnetosphere-ionosphere coupling. The precipitating particles carry field-aligned currents and transport energy from the magnetosphere to the ionosphere. This study presents an improved method to observe differential energy flux of rapidly varying electron precipitation using incoherent scatter radars. The improved method uses Bayesian filtering technique to fit the electron density, electron temperature and ion temperature to the incoherent scatter autocorrelation function data with few seconds time resolution. Energy spectra of precipitating electrons are then inverted from the electron density profiles with high time resolution (4 s). Previous such high-time resolution studies have been based on the raw electron density, which is calculated from the radar backscatter power profiles assuming that electron and ion temperatures are equal. We find that using the fitted electron density may lead to wider energy spectra and larger auroral power estimates (by 50%) than using the raw electron density, when the electron gas is heated in the upper E region. In our study, this occurs when differential energy flux of the precipitating electrons peak at energies 3 – 5 keV.

The total energy flux (auroral power) is proportional to the intensity of blue photons (427.8 nm) emitted by the relaxation of excited molecular Nitrogen ions. We validate the radar auroral power estimates using a 427.8 emission intensity data from an auroral event that contains a wide range of different auroral structures. We find a good correlation (0.96) between the radar and optical auroral power estimates. In addition, the high-resolution optical data shows that differences in between the two data sets are caused by auroral structures narrower than the radar beam, and variations in time scales shorter than temporal resolution of the radar data.

Abstracts

EISCAT_3D Finland – Peculiarities and Status Update

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EISCAT_3D-Finland is a FIRI project contributing to the construction of the new EISCAT_3D Incoherent Scatter Radar Facility. Here we give an overview of the status and peculiarities of the project.

SGO Status

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Here we present a brief update on recent developments of the SGO observations portfolio. We will also report on the recent activities of the Nordic Observatory Collaboration.

Study of cosmic-ray modulation by AMS-02 spectrometer onboard ISS

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Alpha Magnetic Spectrometer v.2 (AMS-02) is the largest ever cosmic-ray detector in space. It was launched in 2011 and is still fully operational onboard the International Space Station (ISS). The primary goal of AMS-02 is to search for signatures of dark matter and anti-matter, but it has collected a unique dataset of cosmic-ray variability near Earth. SGO actively participates in the scientific analysis of AMS-02 data. Here we present the results related to unusual solar modulation of low-energy cosmic rays based on the AMS-02 high-precision data.

Abstracts

Ozone response to high-energy electron precipitation related to pulsating aurorae

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Recent simulation studies have provided evidence that a pulsating aurora (PsA) associated with high-energy electron precipitation is having a clear local impact on ozone chemistry in the polar middle mesosphere. However, it is not clear if the PsA is frequent enough to cause longer-term effects of measurable magnitude. There is also an open question of the relative contribution of PsA-related energetic electron precipitation (PsA EEP) to the total atmospheric forcing by solar energetic particle precipitation (EPP). Here we investigate the PsA-EEP impact on stratospheric and mesospheric odd hydrogen, odd nitrogen, and ozone concentrations. We make use of the Whole Atmosphere Community Climate Model and recent understanding on PsA frequency, latitudinal and magnetic local time extent, and energy-flux spectra. Analysing an 18-month time period covering all seasons, we particularly look at PsA-EEP impacts at two polar observation stations located at opposite hemispheres: Tromsø in the Northern Hemisphere (NH) and Halley Research Station in the Southern Hemisphere (SH). We find that PsA EEP can have a measurable impact on ozone concentration above 30 km altitude, with ozone depletion by up to 8% seen in winter periods due to PsA-EEP-driven NOx enhancement. We conclude that PsA-EEP has the potential to make an important contribution to the total EPP forcing; thus, it should be considered in atmospheric and climate simulations.

Abstracts

Joule heating and its influence on thermospheric density during geomagnetic storms

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During geomagnetic storms, the energy deposition from the magnetosphere to the thermosphere in the form of Joule heating leads to variations in the total mass density of the thermosphere. We investigate the thermosphere response to Joule heating from 265 geomagnetic storms during the period of 2002 to 2008. The total mass density enhancements at 400 km are derived from Challenging Minisatellite Payload (CHAMP) and the Gravity Recovery and Climate Experiment (GRACE) satellites. We examine Joule heating and its influence on the thermospheric density using data from the Defense Meteorological Satellite Program (DMSP) spacecraft and the Weimer electric potential model for storms. The results show that between thermospheric density and Joule heating during weak and moderate geomagnetic storms, the time lag is only about 0-2 hours, while the time lag for intense storms is 3-5 hours. This indicates that the time lag increases as the storms intensify. In addition, Joule heating can cause the thermospheric density to enhance at higher latitudes. During weak and moderate geomagnetic storms, the difference in the latitude corresponding to strong Joule heating with the latitude where high-latitude thermospheric density enhances is only 0°-10° latitudes, while increases to 10°-15° for the intense storms. Besides, it is found that the peak duration of Joule heating increases for more intense geomagnetic storms.

Two-step determination of auroral breakup seen in all-sky jpeg images

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We developed realtime alert system of auroral breakup seen in Kiruna All-Sky Camera using the jpeg images. The identification of auroral breakup is made in two steps:

(1) Using R, G, B, and H values of each pixel in RGB and HLS colour code, each pixel of a jpeg image (255x255x255 colours) into simple set of numbers into “diffuse (visible strength)”, “green arc”, “strong (=saturated or mixed with N2+ line)”, cloud, artificial light, and moon. We then obtain pixel coverage (%) of each category and also average intensity of “strong” aurora: this set is the “All-Sky Camera auroral index”. The obtained ASC-auroral Index is posted in ascii format similar to IAGA2002 in real-time at www.irf.se/alis/allsky/nowcast/latest.csv.

(2) Using this ASC-auroral Index, we define the level of aurora as Level 6, Level 4 etc. Level 6 corresponds to auroral breakup. When Level 6 is detected, automatic alert e-mail is sent out immediately.

The alert system started 5 November, 2021, and so far nearly one-to-one corresponding with actual breakup when mpeg of the ASC images are examined after 40 days of operation.

Observatory Days 2022

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Sodankylä Geophysical Observatory

Abstracts