Observatory Days 2021

11.-15. January 2021

Sodankylä Geophysical Observatory

Abstracts

LappiSat Satellite Centre & Program – LappiSat-1

A. Binios, J. Envall, J. Biström, E. Tanskanen, T. Teppo

Sodankylä Geophysical Observatory

The LappiSat Satellite Centre & Program will be the Sodankylä Geophysical Observatory's (SGO's) new centre of knowledge in the rapidly growing field of space technology, and the program features the first Laplandic satellite – the LappiSat-1. The LappiSat-1's main scientific payloads will be designed and built by the SGO, and these instruments shall observe the near-Earth space environment – especially focusing on aurorae and magnetic disturbances. The long-term goal of the LappiSat Satellite Centre & Program is to have a variety of different in-house built and operated satellites and space instruments on different orbits and trajectories – from Earth-centred orbits to lunar, asteroid and deep space missions.

CubeMAG – A miniaturised magnetometer payload for small satellites

J. Biström, J. Envall, A. Binios, E. Tanskanen

Sodankylä Geophysical Observatory

We are developing a miniaturised magnetometer payload for small satellites. The first missions will be on-board Aalto-3, ESTCube-2, and the LappiSat satellites. We are aiming at a resolution of 1 nT, and it will be compact in size. The first tests are being conducted with the latest scientific prototype.

Abstracts

ALOMAR 2020 – remotely operated and controlled LiDAR measurements from summer 2020

Kolbjørn Blix (1), Gerd Baumgarten (2)

(1) Science & Technology div., Andøya Space, Andenes, Norway;
(2) Leibniz Institute of Atmospheric Physics (IAP), Kühlungsborn, Germany

Since 1994 the LiDAR operations at ALOMAR has been completely dependent on available personnel for practical and safety reasons, although for example the RMR-lidar has largely been capable of remotely controlled operation, but due to overall safety and lack of total systematic (both LiDAR system and observatory infrastructure) overview it has not been utilized so far. This greatly limits measurement frequency and efficiency, since finances and workloads limit measurement numbers and hours. Increased automation/enabling remote operation of LiDARs at ALOMAR can provide great benefits in the future, in the form of increased efficiency and increased numbers of measurements.

In late 2017 Andøya Space initiated a process called ALOMAR-2020, were the goal was to enable and offer remotely controlled LiDAR operations for capable systems from the start of the NLC-season 2020. These investigations had to deal with both LIDAR systems operations, fire- and personnel safety, weather observations and warnings, infrastructure control and feedback, ALOMAR duty system and cost (last defense in case of failures).

Little did we know back in 2017 about the upcoming 2020 COVID-19 pandemic, but it surely justified and intensified the investigations and prepretory work from both Andøya Space and Leibniz Institute of Atmospheric Physics (IAP), Kühlungsborn, Germany, who owns and operate the ALOMAR RMR-lidar. Currently the only LiDAR system capable og such operations. Thanks largely to the ALOHA (ALOMAR LiDAR Operation Health Administration) system (IAP) and modernizations/modifications made by Andøya Space to the observatory infrastructure the RMR LiDAR and necessary infrastructure could be operated and controlled from Germany within our defined time limit – May 25th 2020.

The results and experiences have been assessed and found to be a success, hence we are currently working on an extended test during winter conditions early 2021.

Abstracts

SGO Drone Program – New Opportunities for Science and Industry

Jouni Envall, Eija Tanskanen

Sodankylä Geophysical Observatory

Sodankylä Geophysical Observatory (SGO) is building a fleet of uncrewed aerial vehicles (UAV's, drones) in order to broaden its capabilities to conduct measurements and offer related services. Such aerial platforms are ideal to carry out measurement campaigns over relatively large areas to serve the needs of several fields of research (e.g. geophysics, environmental studies, forestry) and industry (e.g. mining, forest products). Currently the fleet consists of three drones, two of which are built in-house, and one commercially acquired. In the early part of 2021, two more drones, with enhanced payload capacities and extended flight times, will be acquired as part of the new Earth-Space Research Ecosystem (E2S). The drones may be equipped with either commercial devices, or instruments that are custom designed at SGO for any number of dedicated campaigns. In parallel with the acquisition and commissioning of the aircraft, a dedicated instrument platform, called DroneBed, is being developed. DroneBed shall act as the interface between the drone and the instrument, offering suitable means of mechanical fastening and supply voltages in its most basic configuration. In addition, DroneBed may be customized to provide housekeeping data (information about location, altitude, temperature, to name a few) and data storage.

Explicit IMF By-effect in geomagnetic activity

Lauri Holappa, Kalevi Mursula and Timo Asikainen

University of Oulu

The interaction of the solar wind with the Earth's magnetic field produces geomagnetic activity, which is critically dependent on the orientation of the interplanetary magnetic field (IMF). Most solar wind coupling functions quantify this dependence on the IMF orientation with the so-called IMF clock angle in a way, which is symmetric with respect to the sign of the By component. However, recent studies have shown that IMF By is an additional, independent driver of high-latitude geomagnetic activity, leading to higher (weaker) geomagnetic activity in Northern Hemisphere (NH) winter for $By > 0$ ($By < 0$). For NH summer the dependence on the By sign is reversed. We quantify the size of this explicit By-effect with respect to the solar wind coupling function, both for northern and southern high-latitude geomagnetic activity. We show that for a given value of solar wind coupling function, geomagnetic activity is about 40% stronger for $By > 0$ than for $By < 0$ in NH winter. We also discuss recent advances in the physical understanding of the By-effect. Our results highlight the importance of the IMF By-component for space weather and must be taken into account in future space weather modeling.

Abstracts

Inversion Method for Finding the Signal-to-Noise Ratio of Spectriometer

Miikka Hyötylä

Sodankylä Geophysical Observatory

Spectriometer is used for measuring the radio wave absorption happening in the ionosphere. The frequency band for the measurement can for example be around 20-50MHz. As a final result the measurement produces an absorption spectrum. Usually we are interested in the shape of the spectrum curve.

The shape depends on the height of the absorption event. But if the measurement has weak signal-to-noise ratio the SNR can significantly affect the shape of the spectrum. The effect of SNR can make it seem that the event is happening lower in the Ionosphere than it actually is. With high absorption levels the effect gets more significant. In conclusion with weak SNR the stronger absorption events seems to be happening lower in the ionosphere. That is why it's important to know the SNR.

In this study we investigate the theory of propagation of the radio waves in the ionosphere and based on that knowledge we produce method for finding the SNR of spectriometer measurement. We also demonstrate the effects of the SNR. The search algorithm in this study is based on Markov chain Monte Carlo method.

Telluric currents play a larger role in geomagnetic variations than previously thought

Liisa Juusola (1), Ari Viljanen (1), Heikki Vanhamäki (2), Maxim Smirnov (3)

(1) Finnish Meteorological Institute, Finland; (2) University of Oulu, Finland;
(3) Luleå University of Technology, Sweden

Fast geomagnetic variations are primarily produced by currents in the ionosphere and magnetosphere. There is always an associated secondary (internal, telluric) current system induced in the conducting ground and contributing to the total variation field measured by ground magnetometers. Mathematically, it is possible to fully explain the variation field by two equivalent current systems, one at the ionospheric altitude and another just below the ground. In practice, this separation is feasible using dense magnetometer networks such as IMAGE. It has been a common practice in space physics to implicitly neglect the internal part and interpret ground field variations only in terms of ionospheric currents. This is often a reasonable assumption, since a typical internal contribution is about 30%. However, the time derivative of the magnetic field (dB/dt) behaves differently. For IMAGE, the internal part of dB/dt exceeds the external one nearly at all stations. This is most prominent at coastal sites close to highly-conducting ocean water and at inland locations close to highly-conducting near-surface anomalies.

Observatory Days 2021

11.-15. January 2021

Sodankylä Geophysical Observatory

Abstracts

Multimethod IMS measurements

O. Kärhä & E. Tanskanen

Sodankylä Geophysical Observatory

The International Magnetospheric Study (IMS) took place from 1977 to 1979. A considerable amount of data was recorded to study geomagnetic changes in the proximity of the auroral zone. In Northern Europe, important data were recorded by IMS magnetometers (42 stations), riometers (23) and all-sky cameras (14). For this period, the most important near-Earth IMF data sources are recordings from IMP-7, IMP-8, ISEE-1 and ISEE-3 spacecrafts. Disturbances in the magnetosphere can be better understood when the observations from the different altitudes are combined. The process of digitizing the data recorded by IMS magnetometers has begun. DigiMAG is a custom-built device specifically for this purpose. After photographing the magnetograms, data needs to be collected and this has been done for a great storm which occurred in October 1977.

Spatio-temporal development of large scale auroral electrojet currents relative to substorm onsets

Sebastian Käki, Ari Viljanen, Liisa Juusola, Kirsti Kauristie

Finnish Meteorological Institute (all authors); University of Helsinki (Sebastian Käki)

During auroral substorms the electric currents flowing in the ionosphere change rapidly and a large amount of energy is dissipated in the auroral ionosphere. An important part of the auroral current system are the auroral electrojets whose profiles can be estimated from magnetic field measurements from low Earth orbit satellites. We have combined electrojet data derived from the Swarm satellite mission of ESA with the substorm database derived from the SuperMAG ground network data. We organize the electrojet data in relation to the location of the onset and obtain statistics for the development of the integrated current and latitudinal location for the auroral electrojets relative to the onset. Especially we show that just after the onset the latitudinal location of the maximum of the westward electrojet determined from Swarm satellite data is mostly located close to the onset latitude in the local time sector of the onset regardless of where the onset happens.

Abstracts

Dynamics of ionospheric and telluric currents during large events of geomagnetically induced currents

Mirjam Kellinsalmi, Ari Viljanen, Liisa Juusola, Sebastian Käki

Finnish Meteorological Institute (FMI)

Geomagnetic variations are mainly produced by external currents in the ionosphere and magnetosphere, and secondarily by induced (internal/telluric) currents in the conducting Earth. Large geomagnetically induced currents (GIC) are associated with large time derivatives of the horizontal magnetic field. Recent results show that the time derivative is typically dominated by the contribution from the telluric currents. Our study aims to find measures to quantify the behaviour of external and internal currents and their time derivatives during large GIC events. Results of this study show that strong external currents have quite narrow directional distributions. Angular variation is larger for internal currents, and especially for their time derivatives. For external currents, angular variation is larger at higher latitudes. Similar behaviour is not seen with internal currents.

Harvesting Icebergs and Space Rocks

Stefan Kirchner (1), Krittika Singh(2), Ilona Mettiäinen(1) & Pamela Lesser(1)

(1) Arctic Centre, University of Lapland, Rovaniemi, Finland;
(2) O. P. Jindal Global Law School, Sonipat, India

The extraction of resources from actual or perceived global commons or areas beyond national jurisdiction is often seen as potentially highly profitable. It is therefore not surprising that the demand of natural resources has led to both technical and legal developments. While Part XI of the United Nations Convention on the Law of the Sea (UNCLOS) regulates the extraction of natural resources from the Deep Sea Bed, other forms of resource extraction in extreme spaces are less well regulated. Looking at the practical examples of iceberg harvesting in the North Atlantic and sample return missions from celestial objects such as the Moon, Ryugu, Bennu and Mars, the interdisciplinary research presented here aims at identifying key regulatory aspects. Building on the researchers' prior expertise in areas as diverse as space law, mining, climate change and the law of the sea, and based on an investigation of the available literature, it will be shown in how far existing regulatory systems still fall short of the needs of different state and non-state actors when technically challenging forms of resource extraction are concerned. The text shows the need for - and possibility of - improved international governance in light of current and emerging technical developments.

Abstracts

Polar mesosphere summer echoes and possible signatures of pulsating aurora detected by the meteor radar

A. Kozlovsky(1), S. Shalimov(2), and M. Lester(3)

(1)Sodankylä Geophysical Observatory of the University of Oulu, Sodankylä, Finland; (2)Institute of Physics of the Earth, Moscow, Russia; (3)Department of Physics and Astronomy, University of Leicester, Leicester, UK.

Using data of the all-sky interferometric meteor radar (SKiYMET, 36.9 MHz) operating in the Sodankylä Geophysical Observatory we found a specific type of polar mesosphere summer echo (PMSE), which power exhibits irregular variations at a frequency of the order of a few Hz. We classified such radar echoes as pulsating PMSE. This phenomenon relates to the two different high-latitude phenomena, aerosol ice particles near the mesopause and pulsating aurora. Because of the global atmospheric circulation the lowest temperature down to about –160°C occurs in the polar mesosphere at altitudes 80-90 km during summer time. Due to the low temperature, ice aerosol particles of the size up to 200-nm exist there, which can be observed as noctilucent clouds (NLC). On the other hand, this is the region where aurora occurs. In the summer time aurora can't be seen visually, nevertheless precipitating auroral electrons produce ionization (free electrons) at the height of NLC. The ice particles can accumulate free electrons from surrounding space, so that spatial irregularities of the density of ice particles give rise to irregularities of electron density, which can be detected by radars. In the case of pulsating aurora, power of the radar return is varying in accordance with the auroral pulsations. This makes possible radar monitoring of the auroral pulsations even when although visual auroral observations are impossible.

Consistent retrievals of atomic oxygen based on multiple emissions, reduction to the O2(0-0) A band emission and outlook to ion chemistry

Olexandr Lednyts'kyy

University of Greifswald, Germany

Combining diagnostic models and extending the corresponding reactions, the Multiple Airglow Chemistry (MAC) model was developed and validated using in situ measurements in the mesopause region.

Consistent in situ data resulted in consistent profiles of retrieved atomic oxygen.

Importance of electrons in the retrievals motivates the investigator to extend the MAC model for reactions of ion chemistry.

Abstracts

Comparison of three approaches for the simulation of the geoelectric field induced by space weather events in Fennoscandia

Elena Marshalko (1,2,3), Mikhail Kruglyakov (1, 4), Alexey Kuvshinov (1), Liisa Juusola (5)

(1) Institute of Geophysics, ETH Zürich, Switzerland; (2) Institute of Physics of the Earth, Moscow, Russia; (3) Geophysical Center, Moscow, Russia; (4) Geoelectromagnetic Research Center, Institute of Physics of the Earth, Moscow, Russia; (5) Finnish Meteorological Institute, Finland

Large eruptions from the solar corona release massive amounts of plasma, which flow into interplanetary space at a high speed. The interaction of the plasma flow with the Earth's magnetosphere leads to the intensification of the geomagnetic field. According to the principle of electromagnetic induction, this field induces the so-called geomagnetically induced currents in the earth and ground-based technological systems (power grids, pipelines, railway systems, etc.).

To estimate the potential hazard to these systems from the space weather events, it is necessary to understand the spatiotemporal evolution of the geoelectric field. Once the geoelectric field is quantitively estimated, the geomagnetically induced currents can be calculated from the geometry of transmission lines and system design parameters.

In this work we present the first-ever comparison of three approaches to the geoelectric field simulation in Fennoscandia. In the first two approaches the source is represented by a laterally varying sheet current flowing above the Earth. Specifically, within the first approach the the source is computed on the basis of a 3-D magnetohydrodynamic simulation of the geospace; the source in the second approach is constructed by applying the SECS method to magnetic field data from the IMAGE observatories. The third approach is the impedance-based one, in which the local plane wave concept is used. We perform these simulations for the Fennoscandian region by using a realistic 3-D conductivity model (SMAP). The geoelectric field induced by these three sources is computed using a 3-D EM forward modelling code PGIEM2G which is based on a contracting integral equation method. We compare modelling results to EM field observations and discuss advantages and disadvantages of the considered approaches.

Abstracts

A century of geomagnetic storms

K. Mursula, T. Qvick, and L. Holappa

University of Oulu

Geomagnetic storms are traditionally quantified by the Dst index that measures the intensity of the ring current and is available since 1957. We have corrected some early errors in the Dst index and extended its time interval from 1932 onwards using the same stations as the Dst index (CTO preceding HER). This extended storm index is called the Dxt index, which is available at http://dcx.oulu.fi. We have also constructed Dxt3 and Dxt2 indices from three/two of the longest-operating Dst stations to extend the storm index back to 1903, covering more than a century of storms.

We divide the storms into four intensity categories (weak, moderate, intense and major), and use the classification of solar wind by Richardson et al. into CME, HSS/CIR and slow wind -related flows in order to study the drivers of storms of each category since 1964. We also use the list of sudden storm commencements (SSC) collected by Father P. Mayaud, and divide all storms into SSC-related storms and non-SSC storms.

Here we present the annual occurrence of storms of each category and use these results to discuss the long-term evolution of the different drivers and to derive new information on the centennial evolution of the structure of solar magnetic fields.

Magnetic Evolution and Lifetime of Solar Active Regions

Shabnam Nikbakhsh, Eija Tanskanen

Sodankylä Geophysical Observatory

The magnetic structure of solar active regions (ARs) has been broadly studied since G. Hale in 1908 first discovered the presence of magnetic field within ARs. It is well known that the majority of solar flares and coronal mass ejections (CMEs) are emerged from ARs and these two are among the major drivers of space weather. Hence, investigating the magnetic structure (or complexity) of ARs can effectively contribute to space weather prediction. We studied the magnetic evolution and lifetime of 4801 individual ARs available in the Solar Region Summary (SRS) list, provided by National Oceanic and Atmospheric Administration (NOAA). The SRs list includes ARs data such as the Mount Wilson Classification, lifetime and area from January 1996 to December 2019, which covers both solar cycle 23 and 24. We used our new classification approach in order to divide ARs into two groups according to their magnetic complexities: magnetically simple ARs (SARs) and complex ARs (CARs). We show that the magnetic complexity of SARs and CARs varies with solar cycle, as previously reported by Jaeggli & Norton (2016) and Nikbakhsh et al. (2019). We also demonstrate that how magnetic evolution is different in CARs than SARs. In addition, we present the results from the analysis of ARs lifetime which shows CARs have greatly longer lifetime than SARs.

Abstracts

The effect of HSS/SIR geomagnetic storms on the ionospheric and field-aligned current systems

Marcus N. Pedersen(1), Heikki Vanhamäki(1), Anita Aikio(1), Sebastian Käki(2), Ari Viljanen(2), Abiyot Workayehu(1), Colin L. Waters(3), Jesper W. Gjerloev(4,5)

(1) Space Physics and Astronomy Research Unit, University of Oulu, Oulu, Finland; (2) Finnish Meteorological Institute, Helsinki, Finland; (3) School of Mathematical and Physical Sciences, University of Newcastle, Callaghan, New South Wales, Australia; (4) The Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA; (5) Faculty for physics and technology, University of Bergen, Bergen, Norway

High speed streams (HSS) and associated stream interaction regions (SIR) in the solar wind are one of the major drivers of geomagnetic activity, especially during the declining phase of the solar cycle and near solar minimum. We have identified 33 HSS/SIR driven geomagnetic storms that have a Dst drop to less than -50 nT during the period 2010-2017 and have investigated their impact on the field-aligned currents (FAC) and ionospheric horizontal currents using data from AMPERE and SuperMAG, respectively. The events are studied using a superposed epoch analysis with zero epoch at the onset of the storm main phase to see the evolution of the current systems with respect to the development of the geomagnetic storm. The events have been analyzed together and in two groups based on the maximum solar wind dynamic pressure in the SIR around the time of zero epoch. Storms with high pressure have currents with more abrupt developments at the beginning of the storm and reach maximum integrated FAC on average 40 min after the zero epoch. Meanwhile storms associated with low dynamic pressure have more elongated current development that reaches maximum activity 5 h and 20 min after zero epoch. A high degree of the variability observed in the currents are predicted by the solar wind-magnetosphere coupling, but with a non-linear relationship. The maximum integrated FAC, westward electrojet and coupling in the high pressure storms are 1.35, 1.56 and 1.84 times larger than in the low pressure storms, respectively.

Abstracts

Dome C neutron monitors after the upgrade

Poluianov S.1,2, Usoskin I.1,2 , Similä M.1,2 , Mishev A.1,2 , Kovaltsov G.3, Strauss D.T.4

(1) Sodankylä Geophysical Observatory, University of Oulu; (2) Space Physics and Astronomy Research Unit, University of Oulu, (3) Ioffe Physical-Technical Institude, St. Petersburg, Russia, (4) Centre for Space Research, North-West University, Potchefstroom, South Africa

SGO operates two neutron monitors DOMC and DOMB located at the French-Italian station Concordia (Dome C, Antarctic plateau, 3233 m a.s.l.). Both instruments have been upgraded with new electronics in 2019. After that, they can register individual detector pulses and digitize their shape with 2 MHz sampling. Unfortunately, from November 2019 to December 2020, DOMB was out of operation. Its parts have been sent to Oulu for tests and possible repair. Now the neutron monitor is recovered. DOMC is working well after the upgrade in November 2019.

A careful study of new, more detailed data of DOMC (pulse shapes, magnitudes and lengths) shows that pulses can be classified as neutron-induced, muon-induced, multi-particle events and noise. This result is important because now we are able to distinguish neutron- and muon-induced signals routinely. Additionally, accurate studies of the cosmic-ray multiplicity are possible. These achievements may lead to a potential use of the DOMC/DOMB pair as a stand-alone particle spectrometer, which would be very useful in the analysis of solar energetic particle events.

Abstracts

Solving the long-standing problem of the biasing effect in meteor radar temperature

Emranul Sarkar(1), Alexander Kozlovsky(1), Thomas Ulich(1), Ilkka Virtanen(2), Mark Lester(3) and Bernd Kaifler(4)

(1) Sodankylä Geophysical Observatory, U Oulu; (2) Space Physics and Astronomy Research Unit, University of Oulu; (3) University of Leicester, (4) Deutsches Zentrum für Luft- und Raumfahrt

For two decades meteor radars have been routinely used to monitor atmospheric temperatures around the 90 km altitude. A common method, based on a temperature-gradient model, is to use the height dependence of meteor decay time to obtain a height-averaged temperature in the peak meteor region. Traditionally this is done by fitting a linear regression model in the scattered plot of log10(1/tau) and height, where 'tau' is the half-amplitude decay time of the received signal. However, this method was found to be consistently biasing the slope estimate. The consequence of such bias is that it produces a systematic offset in the estimated temperature, and thus requiring calibration with other colocated measurements. The main reason for such a biasing effect is thought to be due to the failure of the classical regression model to take into account the measurement error in decay time or the observed height. This is further complicated by the presence of various geophysical effects in the data, which are not taken into account in the physical model. We demonstrate an alternative regression method that incorporates various error terms in the statistical model. An initial estimate of the slope parameter is obtained by assuming symmetric error variances in height and log10(1/tau). This solution is found to be a good prior estimate for the core of this bivariate distribution. A first-order correction is then carried out to address the effect of asymmetric error component in this data. This allows to construct an analytic solution for the bias-corrected slope coefficient for this data. With this solution, meteor radar temperatures can be obtained independently without using any external calibration procedure. When compared with colocated lidar measurements, the temperature estimated using this method is found to be accurate within 7% or better and without any systematic offset.

Abstracts

New infrastructures enable top-tier science and upgrading of monitoring capability

E.I. Tanskanen, FLEX-EPOS and E2S teams

Sodankylä Geophysical Observatory

Recently several new infrastructures have been started or granted funding which will enable extending and expanding the current monitoring capability of Sodankylä Geophysical Observatory. FLEX-EPOS of the FIN-EPOS infrastructure will create a national pool of instruments including geophysical instruments targeted for solving topical questions of solid Earth physics. Scientific fields represented by FLEX-EPOS are essential in order to identify and reduce the impact of seismic, magnetic and geodetic hazards and understand the underlying processes and their short- and long-term evolution. Observatory's FLEX-EPOS team concentrates on monitoring Arctic seismic activity, long-term modulation of the Earth's magnetic field and geomagnetic disturbances. New national infrastructure Earth-Space Research Ecosystem (E2S) will combine measurements from atmosphere to distant space. The combined infrastructure will enable resolving how the Arctic environment change over the seasons, years, decades and centuries. We target our joint efforts to improve the situational awareness in the near-Earth and space environments, and in the Arctic for enhancing safety on ground and in space.

Abstracts

ISR Electron precipitation Observation with High Time Resolution

Habtamu Tesfaw, Ilkka Virtanen and Anita Aikio

Space Physics and Astronomy Research Unit, University of Oulu

Electron precipitation is a magnetosphere-ionosphere coupling mechanism that causes night-time electron density enhancements and displays of auroral borealis in the high-latitude E region ionosphere. Indirect estimation of precipitating electrons' energy distribution from electron density altitude profile measurements is a well-known remote sensing method of electron precipitation. The electron density data is customarily obtained from incoherent scatter radar (ISR) observations of the E region ionosphere. The so-called raw electron density estimates have been used to observe electron precipitation events with rapidly varying differential energy fluxes. The raw electron density is obtained from the back-scattered power profile measurements of ISR under the assumption of equal ion and electron temperatures. However, it is apparent that during enhanced precipitation events there would be electron heating (Te > Ti) because of the large energy flux deposited by precipitating electrons. During such periods, the incorrect assumption Te=Ti will introduce biases to the raw electron density and electron differential energy flux estimates. Previous precipitation investigations have relied on the raw electron density estimates, because high time resolution fits of electron density, electron and ion temperatures, and ion velocity to the measured autocorrelation function (ACF) of incoherent scatter signal were not possible using existing ISR data analysis packages.

In this study, we used a new ISR data analysis package, BAFIM [1], to retrieve electron density, electron and ion temperatures, and ion velocity from ACF data with 4s and 1.8 km resolutions in time and range, respectively. BAFIM implements Bayesian filtering and full-profile analysis techniques inside GUISDAP to control gradients of plasma parameters in time and space. The ACF data is obtained from EISCAT's UHF radar electron precipitation event observation in the evening of March 09, 2016.

We used the ELSPEC [2] software to fit the differential energy flux of precipitating electrons to the raw and BAFIM-fitted electron densities. Integrated parameters such as auroral power (proportional to the total energy flux) and field-aligned current (proportional to the total number flux of precipitating electrons) are then calculated from the energy spectra fit results. We found that wider electron energy distribution is observed in the differential energy flux obtained from BAFIM electron density than in the differential energy flux obtained from the raw electron density. Specifically, the lower energy ends of the differential energy fluxes obtained from BAFIM electron density contain larger fluxes than the differential energy flux obtained from the raw electron density. In this specific event, the auroral power and FAC obtained from BAFIM electron density exceed the ones obtained from raw electron density by, on average 40% and 45%, respectively.

Abstracts

Major revision of GLE (Ground-Level Enhancement) database and solar energetic particle spectra reconstructions

I. Usoskin(1), S. Koldobskiy(2), G. Kovaltsov(3), I. Usoskina(1)

(1) University of Oulu, Finland; (2) MEPhI Moscow, Russia; (3) Ioffe Physical-Technical Institute, St. Petersburg, Russia

High-energy and high-intensity events of solar energetic particles, called ground-level enhancements (GLEs), form a special class of solar eruptive events with the highly efficient acceleration of charged particles. These events are studied using continuous measurements performed by the global network of ground-based neutron monitors (NMs). All available NM data related to GLE events since 1956 are collected in the International GLE Database (IGLED, http://gle.oulu.fi) hosted and maintained by SGO. The data are presented in the form of relative NM count-rate increases with respect to the constant pre-increase background count-rate level due to galactic cosmic rays (GCR). However, the implicit assumption of the constancy of the GCR background level throughout GLE events is often not valid, since the GCR background may vary essentially even during relatively short GLE events. Here we revisited all the GLE NM records and de-trended GLE count-rate increases considering the actual variable GCR background. The detrended count-rates have been added to the IGLED database for all GLE events since 1956. Based on this revised dataset, event-integrated spectra (fluences) of solar energetic particles for major events were re-assessed. This forms a basis for more precise studies of parameters of SEP events and, thus, for solar and space physics.

Report and plans of the cosmic-ray group

Ilya Usoskin

Sodankylä Geophysical Observatory, University of Oulu

A traditional annual review of the results, achievements and problems of the SGO cosmic-ray group in 2020 will be presented along with plans and prospectives for the future.

Abstracts

Fast multisheet solver for geomagnetic induction in time-domain

H. Vanhamäki(1), E. Marshalko(2,3,4), M. Kruglyakov(2,3), A. Viljanen(5)

(1) University of Oulu, Finland; (2) Institute of Geophysics, ETH Zürich, Zürich, Switzerland; (3) Institute of Physics of the Earth, Moscow, Russia; (4) Geophysical Center, Moscow, Russia; (5) Finnish Meteorological Institute, Finland

Changing ionospheric currents create induced electric fields and drive currents in the conductive ground, which in turn modify the electric field. Estimating the induced geoelectric field (GEF) at the ground surface from a given time series of the ionospheric currents and a regional 3D ground conductivity model is an important goal in geomagnetic field modeling, and is a prerequisite for predicting and modeling geomagnetically induced currents (GIC) in power grids and other technological systems.

We present a new type of solver for modeling the geomagnetic induction process and for estimating the GEF. The conducting ground is represented with several horizontal thin sheets placed at different depths, with each sheet having a non-uniform conductance distribution taken from the SMAP model for the Fennoscandian region by Korja et al. (2002). Within each sheet the induced electric field and current are represented in terms of Spherical Elementary Current Systems (SECS), which describe the curl and divergence of the vector fields. The ionospheric driver is represented as an equivalent current estimated from the IMAGE magnetometer data. This results in a systems of linear algebraic equations, which can be solved for the amplitudes of the SECS describing the induced fields. The solver works in time-domain, making it ideal for real-time applications, and is fast enough for analyzing several years of IMAGE data. We present first results of the GEF modeling for selected events and compare the results against a more accurate 3D induction modeling carried out by Marshalko et al. (2020).

Observations of the 2020 Pajala Fireball

J. Vierinen

U Tromsø

Meteoroids entering the Earth's atmosphere are associated with a number of phenomena including ablation, ambipolar diffusion, chemical reactions, and plasma turbulence. A bright daylight fireball observed on 2020-12-04 with two meteor cameras located in Skibotn and Sørreisa allowed the precise entry trajectory of the fireball to be determined. The path of the entering object is approximately between Angeli Finland and Pajala Sweden. Based on the brightness and entry trajectory, it is possible to estimate the approximate mass of the object, and associate it with a meteor shower (Northern Taurids). The effects of the fireball on the atmosphere were detected with a number of radar and radio instruments within the region, including ionosondes, meteor radars, and an all-sky VHF imaging system. These observations allow a detailed study of the atmospheric interaction of a large meteoric body with the Earth's atmosphere to be made. In this talk, we will describe the observations of this fireball and discuss preliminary findings.

Abstracts

Automatic ionogram scaling using convolutional neural networks

J. Vierinen

U Tromsø

Automated scaling of classical ionogram parameters such as the F-region maximum O-mode frequency or the virtual height of the F-region is a challenging task at high latitudes. Ionograms can be complicated by E-region and F-region ionospheric irregularities, as well as radio interference. The Sodankylä ionosonde is currently conducting soundings of the ionosphere once a minute, but ionograms are only scaled every half hour, as scaling more ionograms manually by an expert would not be feasible in terms of available resources. There are future plans to build oblique sounding links to study mesoscale ionospheric structure, which would increase the number of ionograms by up to a factor of ten or more. These measurements are likely to hold useful information on mesoscale ionospheric structure, such as travelling ionospheric disturbances. In order to access this information, automated scaling of ionograms is needed. It has been proposed that it may be possible to automate scaling using deep learning based techniques. In this study, we present preliminary results from using a convolutional neural network to identify and scale F- and E-region traces in vertical and oblique sounding ionograms, using the Sodankylä Geophysical Observatory ionosonde transmitter. Oblique ionograms have been received in Skibotn with a software defined ionosonde receiver.

BAFIM - a Bayesian Filtering Module for GUISDAP

Ilkka Virtanen(1), Habtamu Tesfaw(1), Lassi Roininen(2), Sari Lasanen(3), and Anita Aikio(1)

(1) Space Physics and Astronomy research Unit, University of Oulu, Oulu, Finland; (2) School of Engineering Science, Lappeenranta-Lahti University of Technology, Lappeenranta, Finland; (3) Sodankylä Geophysical Observatory, University of Oulu, Sodankylä, Finland

Full-profile incoherent scatter analysis allows one to control spatial gradients in fitted plasma parameter range profiles. In small time scales, one may reasonably assume similar smoothness in time, but this option has not been previously utilized in IS radar plasma parameter fits. We have developed a Bayesian Filter Module (BAFIM), which allows one to incorporate prior assumptions of smoothness in both range and time in GUISDAP plasma parameter fits. Effectively, the module allows one to use different resolutions in time and range for each plasma parameter, as well as to incorporate prior information about absolute values of the plasma parameters. We demonstrate how BAFIM can be used in high time resolution (4s) electron precipitation observations, and how it can be used to fit F1 region ion compositions. One could design an analysis tool similar to BAFIM for EISCAT3D, with the prior model in range replaced with a 3D volumetric model.