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Abstracts

Recent Results of D-Region Heating Experiments at HAARP

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We present an initial analysis of HF cross-modulation experiments, ELF/VLF wave generation experiments, and VLF scattering experiments conducted at the High Frequency Active Auroral Research Program (HAARP) Observatory in Gakona, Alaska in 2023.

Seasonal behaviour of MSTIDs at high latitudes using a Rapid-run Sodankylä Ionosonde

S T Moges (1), R O Sherstyukov (1), A Kozlovsky (1), T Ulich (1,2) and M Lester (3)

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We statistically investigated the seasonal behaviour of medium scale traveling ionospheric disturbances using the rapid-run Sodankylä ionosonde during the recent low solar activity period (2018-2020). A 1 minute resolution foF2 corresponding to the measured ionograms, obtained via applying deep learning was used to carry out this study. In our results, the daytime, nighttime and dusk MSTIDs are predominantly identified during winter, summer, and equinoctial months, respectively. The winter day-time higher (lower) occurrence rate is well correlated with the lower (higher) altitude of the height of the F2-layer peak (hmF2), and the low occurrence rate of the summer day-time is well correlated with the mesosphere-lower-thermosphere wind shear and higher gradient of temperature. Relatively high occurrence rate (> 0.4) of summer nighttime MSTIDs has a general – but not one-to-one agreement – with post-noon to evening IU (eastward auroral current index) inferred ionospheric conductivity. Rather, we see a one-to-one relationship between the summer nighttime MSTIDs and zonal wind shear suggesting that the wind shear-induced electrodynamic processes could play significant roles for higher occurrence rate of MSTIDs. Furthermore, significant MSTIDs with ~0.4 occurrence rate are so far revealed during spring and autumn transition periods. The enhanced nighttime MSTID amplitudes during the equinox are observed to be well correlated with IL index (westward auroral current indicator) suggesting that the particle precipitation during substorms could be the primary cause.

Status Report of the Oulu Cosmic Ray station for 2023

Ilya Usoskin

University of Oulu

The status report of cosmic-ray research performed at SGO during the year 2023 is presented.

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Ground truth validation of energetic particle precipitation forcing used in of the CMIP climate models

Antti Kero (1), Neethal Thomas (1), Ilkka Virtanen (2), Pekka Verronen (1,3), Max van de Kamp (3), and Hilde Nesse (4)

(1) SGO/University of Oulu, Finland; (2) University of Oulu, Finland; (3) Finnish Meteorological Institute, Finland, (4) University of Bergen, Norway

The energetic particle precipitation (EPP) forcing is recently added into the IPCC's official Coupled Model Intercomparison Project (CMIP) climate modelling. In this presentation, we evaluate various EPP forcing models proposed for the future CMIP climate models against the EISCAT VHF data. This can be regarded as a ground-truth approach for the mesospheric ionisation essential for the atmospheric consequences of the EPP.

Testing the updated CRAC and CRAC:DOMO model on GLE #60 (15-Apr-2001)

A. Mishev (1,2), N Larsen (1,2), S. Koldobskiy (1), I. Usoskin (1,2)

(1) SGO, University of Oulu, Finland; (2) Space Physics and Astronomy Research unit, University of Oulu, Finland

Study and quantification of the cosmic-ray-induced space weather effects such as exposure to radiation at flight altitudes, specifically important during ground-level enhancements (GLEs) are currently in the focus in the space physics community. It is known that following solar eruptions solar energetic particles (SEPs) can be accelerated to high energy and when entering the atmosphere, accordingly producing particle shower, enhance the radiation environment in the earth's atmosphere. A specific class of events when the secondary particles are detected at the ground, are events called GLEs. In this work, we present the analysis of one such GLE, the so-called Easter event observed on April 15, 2001, GLE 60. We show the spectral and angular characteristics of the SEPs during GLE 60 derived using neutron monitor records and employing the updated CRAC:DOMO model to compute the radiation dose at aviation altitudes during this event. The computed doses are compared with direct measurements obtained with the Liulun device. Applications and verification of the CRC radiation models are discussed.

Skywarden: 12 years of citizen science in Finland

E. Bruus (1,2), M. Takala (3,2)

(1) Sodankylä Geophysical Observatory, Finland; (2) Ursa Astronomical Association, Finland; (3) Finnish Meteorological Institute

Citizen science has been a discussed topic in the scientific world during the recent decade. Many projects have already involved volunteers into observation gathering and result analysis activities. In Finland, the local Astronomical Association Ursa has developed and maintained an observation system called Skywarden (Taivaanvahti) since 2011. The gathered dataset consists of more than 100 000 observations contributed by over 20 000 individual users. The presentation describes the available datasets, how to access them and the process of data gathering.

Abstracts

Investigating the relationship between radiation doses at aviation altitudes and real-time neutron monitor data during ground-level enhancements

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

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

Solar energetic particles accelerated during strong solar eruptions can penetrate the Earth's magnetosphere and enter the atmosphere after which they can be detected by ground-based instruments, such as neutron monitors (NMs). When multiple NMs detect an increase in count rates it is known as a ground-level enhancement (GLE). The increase in the flux of high-energy particles entering the atmosphere during GLEs leads to an enhancement of the complex radiation environment which can pose a serious risk to airplane crew and passengers. In this work, 21 of the, as of writing, 73 recorded GLEs have been analysed using the same verified method. A newly developed atmospheric radiation model is then used to determine the radiation dose experienced at aviation altitudes during the GLEs. A very strong relationship was established between the modelled dose and real-time empirical NM data taken during the analysed GLEs. This result provides scientific support for using real-time NM data as a potential proxy in future nowcasting models aimed at estimating and mitigating the hazardous impacts of GLEs on humans and the aviation industry.

Preparing for EISCAT_3D

Th Ulich (1,2), A Steuwer (1), and the EISCAT Staff (1)

(1) EISCAT Scientific Association, Kiruna, Sweden; (2) Sodankylä Geophysical Observatory, Sodankylä, Finland

We present an overview of the current status of the new EISCAT_3D Incoherent Scatter Radar and discuss the road ahead towards full operations.

Sodankylä Geomagnetic Observatory 110 years

T Raita (1)

(1) Sodankylä Geophysical Observatory, University of Oulu

The geomagnetic observatory at Sodankylä started official operation 1 Jan 1914. Its one of the oldest continuously operated geomagnetic observatory in the world having only minor data gaps during the 110 years of operation. This presentation will give an overlook of the geomagnetic observatory and data products. Also information about the present status of the geomagnetic observatory and possibilities for future developments will be presented.

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Improvement of ASC auroral index by correcting the exposure time and its correlation with the geomagnetic variation

Yuna Katsuyama (1), M. Yamauchi (2), U. Brändström (2), K, Noguchi (1)

(1) Nara Women's University, Nara, Japan; (2) Swedish Institute of Space Physics

Index representing the auroral activity in the all sky camera image (ASC auroral index) is improved by normalizing exposure time that changes automatically. Red, Green, Blue (RGB) values in the RGB color code and L value in the hue-lightness-saturation (HLS) color code are corrected using the logarithmic values of the exposure time, using two methods. Out of these two methods, we employed the method in which the correctedASC image becomes more close to naked eye, for further analyses using the geomagnetic data. We next compared the corrected ASC auroral index with geomagnetic variation dB/dt. For dB/dt, three methods are compared using 1-sec resolution Bx data: 1-min average of ldBx/dtl that is calculated every second, standard deviation of Bx over 1 minute (std(Bx)_60), and maximum value of 10-sec standard deviation over 1 minute (std(Bx)_10). It turned out that the last method is optimum for the present purpose. While the correlation coefficient between aurora activity levels and geomagnetic variation is not yet good even after correcting the dynamic exposure (the correlation was indeed improved), I still see some good positive relation between them during the period when they quickly increase toward the "Local Arc Breaking" that is the special explosive auroral activity. In other words, real-time monitoring might be used for the last-minute prediction of large aurora, which is a future task. Finally, using the corrected ASC auroral index, the activity level is compared with a different aurora identification scheme using machine learning (deep-learning) method such as the probability of certain type of aurora (arc, discrete, and diffuse). The morphology using machine learning method and intensity using ASC aurora index turned out to be independent, i.e., these two methods give independent information. This independence indicates that it is promising to combine them in order to improve real-time aurora monitoring system, as a future task.

Auroral events in 2023 observed by Kiruna all sky camera

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(1) Swedish Institute of Space Physics, Kiruna; (2) University of Electro-Communications, Japan

The monitoring all sky camera (ASC) using a consumer camera can still find auroral phenomena that was not (or rarely) reported previously. We found two phenomena during 2023. One is the nightside auroral forms and their propagations of the shock aurora on 2023-2-26. Thanks to quiet geomagnetic condition (plasma sheet activities), the ASC and other camera at 21 MLT identified three forms of the aurora directly related to the shock propagation in the magnetosphere. The other is related to the omega band on 2023-10-21 when the geomagnetic substorm prolonged more than half a day with nearly constant values of AU (about 300 nT) and AL (about 400 nT). The relevant omega band appeared a prolonged period for more than 5 hours. However, the empty part between the torch started to get filled with ray structure with both 558 nm and 630 nm. The filling starts from the westside (backside) of the torch.

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A Combined effect of the Earth's magnetic dipole tilt and IMF By in controlling auroral electron precipitation

Jussi Ananias Laitinen (1), L Holappa (1), H Vanhamäki (1)

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Precipitation of auroral electrons is usually assumed to be symmetric with respect to the sign of the dawn-dusk (By) component of the interplanetary magnetic field (IMF). This is also the case in most currently used precipitation models, which parameterize solar wind driving by empirical coupling functions. However, recent studies have showed that geomagnetic activity is significantly modulated by the signs and amplitudes of IMF By and the Earth's dipole tilt angle Ψ. This so called explicit By dependence is not yet included in any current precipitation models. In this paper, we quantify this By dependence for auroral electron precipitation for the first time. We use precipitation measurements of the Defense Meteorological Satellite Program (DMSP) Special Sensor J instruments from years 1995-2022. We show that the dawnside electron precipitation at energies 13.9-30 keV is greater at auroral latitudes for opposite signs of By and Ψ in both hemispheres, while the dusk sector is mostly unaffected by By and Ψ. For energies below 6.5 keV the By dependence is strong poleward of the auroral oval in the summer hemisphere, also exhibiting a strong dawn-dusk asymmetry. We also show that By dependence of precipitation modulates ionospheric conductance, which has important implications for solar wind response of ionospheric currents.

Results from VLF measurements SGO has made with the British Antarctic Survey over past 20 years

Mark Clilverd (1), Craig Rodger (2)

(1) British Antarctic Survey (UKRI-NERC), Cambridge, UK; (2) Physics Department, University of Otago, Dunedin, New Zealand

The British Antarctic Survey has been actively collaborating with the Sodankylä Geophysical Observatory since September 2001. Very Low Frequency (VLF) instruments were first installed in a remote farm near Rovaniemi, but were moved to Sodankylä a few years later. Eventually the observations were extended to another site, in Kilpisjarvi. The VLF instruments are low cost, passive, radio receivers primarily listening to man made radio transmissions at 20-30 kHz originating from up to 10,000 km away. The propagation of the VLF radio waves is influenced by energetic particle precipitation impacting the ionosphere at altitudes of about 60-90 km. As such, the VLF receivers are a good way of remotely monitoring the effects of space weather processes, like the aurora. Here we give a brief overview of the results gained from the SGO-BAS VLF instruments, highlighting the benefits of long term, high quality measurements.

Abstracts

About EPP-Driven Variability of Upper Atmospheric Nitric Oxide Over the Syowa Station in Antarctica

P. T. Verronen (1,2), Y. Miyoshi (3), A. Mizuno (3), T. Nakajima (3), S. Oyama (3), T. Nagahama (3), S. Nozawa (3), M. E. Szelag (2), A. Kero (1), and E. Turunen (1)

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Nitric Oxide (NO) is a minor atmospheric constituent. In the polar upper atmosphere, it is produced in relatively large amounts by both solar EUV and X-ray radiation and energetic particle precipitation (EPP). Due to its chemical loss also being solar-driven, upper atmospheric NO has a clear seasonal variability and a solar cycle dependency which have been measured by satellite-based instruments. On shorter time scales, NO response to magnetospheric electron precipitation has been shown to take place on a day-to-day basis. Despite recent studies using observations and simulations, it remains challenging to understand NO daily distribution in the mesosphere-lower thermosphere during geomagnetic storms, and how it is driven by EPP forcing and atmospheric chemistry and dynamics. This is due to the uncertainties existing in the available EPP flux observations, differences in representation of NO chemistry in models, and differences between NO observations from satellite instruments. Ground-based radiometers provide a regional view on NO, and can be used to understand sources of variability when compared to atmospheric simulations. Nagoya University has operated a millimeter-wave spectroscopic radiometer at the Syowa station in Antarctica since 2012. In this paper, we use NO data from the Syowa radiometer measured in the period 2012-2017 to study both its long-term and short-term variability. Comparisons are made with results from the Whole Atmosphere Community Climate Model (WACCM) to understand the shortcomings of current EPP forcing in models and how geomagnetic storms are driving day-to-day variability of NO.

Observation activities with passive optical and radio wave instruments in Fennoscandia by Japanese team

Shin-ichiro Oyama (1,2), Keisuke Hosokawa (3), Yasunobu Ogawa (2), Yoshizumi Miyoshi (1), and Claudia Martinez (1)

(1) ISEE, Nagoya University, Japan; (2) The University of Electro-Communications, Japan; (3) National Institute of Polar Research, Japan

Japanese researchers have been operating instruments, particularly passive optical cameras, in collaboration with local observatories in Finland, Sweden, and Norway for many years. Additionally, radio-wave receivers have been recently installed. The scientific objectives of these observations are varied, including the study of aurora, the relationship between the magnetosphere and ionosphere, and the interaction between the ionosphere and thermosphere. This presentation will provide an overview of the current observation equipment primarily operated by the Japanese team in Fennoscandia.

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Statistical characteristics of auroral electron precipitation at geomagnetic latitude 67° over Tromsø

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(1) University of Oulu, Finland

We studied statistical characteristics of 1–100 keV electron precipitation at 66.7° MLAT over Tromsø using the EISCAT Tromsø UHF incoherent scatter radar data measured in years 2001–2021. Peak energies, auroral powers and number fluxes of precipitating electrons are derived from electron density altitude profiles measured along the local geomagnetic field line during periods of no photoionization. The method allows us to include energetic 30–100 keV electrons, which are poorly covered in earlier satellite-based studies. We use the Feldstein-Starkov auroral oval model to determine locations of the radar within the auroral oval using the 1-hr Hpo geomagnetic index as input. The average peak energy of precipitating electrons increases almost monotonically from evening (18 MLT) to morning hours (09 MLT). The energetic (30–100 keV) electron precipitation is dominated by 30–50 keV electrons before 06 MLT, and by 50–100 keV electrons after 06 MLT. Large auroral powers (>60 mWm^–2) are observed in the 18–02 MLT sector in the main auroral oval. We obtain occurrence rate of electron precipitation in Tromsø by calculating the fraction of data points with auroral power larger than 2 mWm^–2. The occurrence rate peaks during the declining phases of solar cycles (sc), in 2002–2004 for sc23 and in 2015–2017 for sc24, caused by variations in geomagnetic activity. In addition, the occurrence rate has maxima during March and September, minimum in December to January, and it increases monotonically from evening to morning hours, reaching maximum at 05–06 MLT.

Incoherent scatter radar measurements of ion-to-neutral collision frequencies and neutral temperatures in the D region ionosphere

Neethal Thomas (1), Antti Kero (1), Ilkka Virtanen (2), Satonori Nozawa (3)

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Within the HPC-approach to Ionospheric Situational Awareness (HISSA) project, we have analyzed the existing European incoherent scatter (EISCAT) radar VHF measurements carried out together with the neutral temperature measurements from LIDAR collocated at Tromsø, Norway. Incoherent scatter radar (ISR) spectral parameters are estimated from the backscattered signal autocorrelation function by fitting the D region lag profiles (pulse-to-pulse fitting). This study focuses on the ISR spectral width which is a function of the ion-to-neutral collision frequency, neutral temperature, and ion mass. Using the neutral temperatures obtained from LIDAR, we have measured for the first time the ion-to-neutral collision frequency in the D region altitudes (80-100 km) by fitting the ISR spectral width. The study indicates that the ISR spectral width is largely influenced by the neutral density fluctuations. In the light of these observations, the inherent limitations of inferring the neutral temperatures from ISR spectral width are studied.

Abstracts

Time-varying trends from Arctic ozonesonde time series in the years 1994 to 2022

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Although evidence of recovery in Antarctic stratospheric ozone has been found, evidence of recovery in Arctic ozone is still elusive, even though 25 years have passed since the peak in ozone depleting substances. Here we have used a Dynamic Linear Model to derive time-varying 20-year trends in the Arctic ozone time series, measured in-situ by ozonesondes from 6 stations, from 1994 to 2022. The model accounts for seasonality, external forcing and 1st-order correlation in the residuals. As proxies for the external forcing, we have used tropopause pressure (replaced with Arctic Oscillation in the troposphere), eddy heat flux, the volume of polar stratospheric clouds multiplied by effective equivalent stratospheric chlorine, and solar radio flux at 10.7cm for the 11-year solar cycle. After accounting for these forcings, we find statistically significant negative 20-year trends in the Arctic stratosphere, varying between -0.30±0.25 and -1.00±0.85\% per decade, in the years after 2019. For the Arctic troposphere, we generally find statistically significant negative 20-year trends, varying between -0.31±0.27 and -1.76±0.41\% per decade, in the years after 2018. The recent negative 20-year ozone trends in the lower Arctic stratosphere suggest long-term changes in the polar vortex that are not explained by the known forcings. Our results highlight the importance of monitoring the Arctic ozone.

SGO-Luilin flight in 2021: data analysis and comparison with model results

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Cosmic rays (both galactic cosmic rays and solar energetic particles) are the main source of ionization in the Earth's atmosphere for altitudes above 1 – 3 km. In September 2021, Sodankylä Geophysical Observatory launched the Luilin ionization detector, which flew from Kiruna to Sodankylä reaching the maximal altitude of 33 km, with the purpose of ionization measurements for different altitudes in polar regions. In this study, we analyze the data from the Liulin detector and compare it with the results of the cosmic-ray-induced ionization (CRII) model created by our group. We test different models of the primary cosmic-ray radiation and compare the obtained results with some previous measurements.

Abstracts

Multiplicity measured with DOMC during GLE #73 and a Forbush decrease

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The multiplicity is the property of the time distribution of neutron monitor pulses, when some of the pulses are clustered in groups within very narrow time windows. It happens due to the multiple neutron production in the lead layer of a neutron monitor. More specifically, the multiplicity is the average number of registered neutron pulses per one incoming atmospheric neutron from a cosmic-ray cascade. Theoretically, this property is sensitive to the average energy of the atmospheric neutrons, and in turn, is related to the average energy of primary cosmic rays. We can potentially measure the hardness of the cosmic ray spectrum with the multiplicity from a single neutron monitor, which is a very desirable ability for solar energetic particle studies. We present the neutron-monitor (count) multiplicity observed during the most recent Ground-Level Enhancement (GLE) #73 caused by a solar energetic particle event and the following Forbush decrease, both happened in October-November 2021. The measurements were done by the high-altitude polar neutron monitor DOMC located at the Antarctic plateau and operated by Sodankylä Geophysical Observatory. The instrument was upgrated in late 2019 with new electronics that allows the neutron monitor to precisely time every recorded pulse. We calculated the multiplicity time series with hourly resolution covering September-November 2021. Unfortunately, there is no statistically significant signs of the GLE and Forbush decrease in the data. We explain it by the weaknesses of the events, which is confirmed by preliminary theoretical estimates.

Auroral Joule heating and its effects on thermosphere

H. Vanhamäki (1), H. Tesfaw (1), S. Hatch (2)

(1) University of Oulu, Oulu, Finland; (2) University of Bergen, Bergen, Norway

In this talk we present on-going work and future plans to estimate aurora Joule heating in global and regional scales, and to study its effects on the thermospheric density variations and neutral winds. This work is part of the "Auroral Joule" Academy project that started in September 2023.

In regional scales the Joule heating and thermospheric neutral winds will be estimates with the EISCAT_3D and Scanning Doppler Imager network (SDI-3D), respectively, both of which should start operations in 2024. We discuss how this could be done in practice and which kind of tools need to be developed.

Abstracts

Multi-proxy estimate of the long-term flux of solar energetic particles

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Fluxes of solar energetic particles (SEPs) are measured in situ by space-borne detectors providing a comprehensive statistic for the last several solar cycles. However, it is unclear if this is representative of the very long-term SEP flux. Cosmogenic isotopes in terrestrial archives can resolve extreme SEP events over the Holocene that are rare but extremely energetic. In addition, isotopic analysis of lunar rocks can reveal the mean SEP fluxes on the very long timescale of megayears. We present the results of a comparison of different approaches in the energy range of SEPs between 60 and 100 MeV. We show that the SEP fluxes directly measured in space during the recent decades are not well representative of the long-term averaged SEP flux, while rare extremely strong SEP events form a major part of it. The joint analysis of all these different datasets and timescales appears fully consistent, implying that our knowledge of the whole range of the SEP fluxes on different timescales, from frequent weak events to rare extreme ones, is likely complete now.

Observations of the atmospheric electric field at Sodankyla

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An electric field mill was installed at Sodankyla in 2018 to measure the atmospheric electric field at a height of 3m above the surface. This electric field is a consequence of Earth's global atmospheric electric circuit, which is maintained by global thunderstorm activity, but also influenced by space weather events. This talk will summarise the findings from the recent Sodankyla electric field measurements, including analysis of the electric field in fair weather, where a clear signal from the global electric circuit is observed. Analysis of electric field changes during space weather events will also be discussed, demonstrating the importance of the Sodankyla site for understanding space weather influences on the global electric circuit.

Abstracts

Transition to a weaker Sun: A dramatic change in solar parameters at the decay of the Modern Maximum

K. Mursula (1,2), A.A. Pevtsov (2), T. Asikainen (1), I. Tähtinen (1), A.R. Yeates (3)

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The Sun experienced a period of unprecedented activity during solar cycle 19 in 1950s and 1960s, now called the Modern Maximum (MM). The decay of the MM during the space age has changed the Sun, the heliosphere and the planetary environments in many ways. However, this decay may not have proceeded synchronously in all solar parameters. One of the related key issues is if the relation between the two long parameters of solar activity, sunspot number and the solar 10.7cm radio flux, has remained the same during this decay. While a number of studies agree that this relation has indeed changed, no consensus on its validity (whether real or artificial) exists. A recent study argues that there is an inhomogeneity in the 10.7cm radio flux in 1980, which led to a step-like jump ("1980 jump") in this relation. If true, this would imply that the 10.7cm radio flux is ineligible for long-term studies, which would seriously impede versatile studies of the Sun during the MM.

Here we use the 10.7cm radio flux and four other, independent radio flux measurements, the sunspot number, the MgII index and the number of solar active regions in order to study their mutual relations during the decay of MM. We find that all the five radio fluxes depict an increasing trend with respect to the sunspot number from 1970s to 2010s. This excludes the interpretation of the "1980 jump" as an inhomogeneity in the 10.7cm flux, and re-establishes the 10.7cm flux as a reliable and homogeneous long-term measure of solar activity.

We find that the fluxes of longer radio waves increased with respect to the shorter waves, which implies a long-term change in the solar spectrum at radio frequencies. We also find that both the MgII index (solar UV irradiance) and the number of active regions increased with respect to the sunspot number, indicating a difference in the long-term evolution in chromospheric and photospheric parameters. Our results give evidence for important structural changes in solar magnetic fields and solar atmosphere during the decay of the MM when solar activity weakened considerably. These changes have not been reliably documented so far. We also emphasise that the changing relation between the different (e.g. photospheric and chromospheric) parameters should be taken into account when using sunspot number or any single parameter in long-term studies of solar activity.

Abstracts

NOIRE-Net – A convolutional neural network for automatic classification and scaling of high-latitude ionograms

Andreas Kvammen (1), Juha Vierinen (1,2), Devin Huyghebaert (1), Theresa Rexer (1), Andres Spicher (1), Björn Gustavsson (1) and Jens Floberg (1)

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Every year, millions of ionograms are acquired to monitor the ionosphere. The accumulated data contain untapped information from a range of locations, multiple solar cycles, and various geomagnetic conditions. Statistical studies of the ionospheric behaviour under a wide range of conditions require however processing of ionograms with high reliability. Simple rule-based programs often fail to consistently analyze ionograms, especially at high latitudes where auroral precipitation and traveling ionospheric disturbances frequently occur. In this study, we propose the application of deep convolutional neural networks to automatically classify and scale high- latitude ionograms. A supervised approach is implemented and the networks are trained and tested using manually analyzed oblique ionograms acquired at a receiver station located in Skibotn, Norway. The classification routine categorizes the observations based on the presence or absence of E- and F-region traces, while the scaling procedure automatically defines the E- and F-region virtual distances and maximum plasma frequencies. Overall, we conclude that deep convolutional neural networks are suitable for automatic processing of ionograms, even under auroral conditions. The networks achieve an average classification accuracy of 93 % ± 4 % for the E-region and 86 % ± 7 % for the F-region. In addition, the networks obtain scientifically useful scaling parameters with median absolute deviation values of 136 kHz ± 13 kHz for the E-region maximum frequency and 88 kHz ± 10 kHz for the F-region maximum O-mode frequency. Predictions of the virtual distance for the E- and F-region yield median distance deviation values of 6.5 km ± 2.6 km and 8.7 km ± 1.5 km, respectively. Analysis of misclassified observations suggests that disagreement with human interpretation mainly arises for ambiguous ionograms, often with low signal-to-noise ratios. The developed networks and the proposed framework may support both case and statistical studies of ionograms, such as examining the temporal and spatial variability of traveling ionospheric disturbances at high latitudes. Additionally, there is a great demand for reliable monitoring of the ionosphere in relation to the forthcoming EISCAT3D incoherent scatter radar in Skibotn, Norway. The developed network may therefore facilitate EISCAT3D and other instruments in Fennoscandia by automatic cataloging and scaling of salient ionospheric features.

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Investigating the effect of time scale on the relationship between solar wind and ground-based ultra-low frequency power at auroral latitude

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Ultra-low frequency (ULF) waves are fluctuations of magnetic field at frequencies lower than the characteristic frequencies of plasmas, typically less than 1 Hz. They occur both in space plasmas and within magnetosphere. Within the magnetosphere they have various source mechanisms and regions, one significant being the external influence by solar wind. It has been well-established that on the ground their power spectrum is influenced by solar wind speed in daily time scales.

We investigate how the ULF power measured by SOD magnetometer is influenced at different solar wind speeds and longer time scales. We also show how the ULF power is influenced at longer time scales of days, months, and years.

Highlights of Solstice, FLEX-EPOS and E2S-industry projects

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This presentation describes what are space threats, how they affect satellite-based services, and how they can be best studied. The highlights will be given e.g. on Solstice, FLEX-EPOS and E2S-industry projects. Solstice project examines space storms and the magnetic disturbances caused by them. One of the goals is to find out how the Sun has varied in different time-scales and how the variability has affected to the near-Earth magnetic climate in different latitudes. E2S-industry project is part of E2S infrastructure, and it solves how does the northern Arctic environment change over seasons, years, decades and centuries. FLEX-EPOS project solves fundamental scientific questions in seismology, geomagnetism and geodesy. The FLEX-EPOS project is part of FIN-EPOS infrastructure, which is on the national FIRI roadmap, and EPOS, which is on the ESFRI roadmap.

Early years of Sodankylä Geophysical Observatory

Eija Tanskanen, Laura Lakso, Emma Bruus & SGO staff

Sodankylä Geophysical Observatory, Univ. of Oulu

The summary of the early years of Sodankylä Geophysical Observatory will be given including pictures from Tähtelä area. The material from the observatory's own library and from the National Archives of Finland will be shown. The previously unpresented magnetic data from Sodankylä and Petsamo from 1930's will shows as well as pictures on northern lights from 1920's.

Observatory Days 2024

10.-12. January 2024

Sodankylä Geophysical Observatory

Abstracts

Why two are better than one: combined results from VLF receivers at Oulujarvi and Kannuslehto

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Natural Extremely Low and Very Low Frequency (ELF/VLF, f= 0.3 – 30 kHz) waves of magnetospheric origin play a major role in radiation belt dynamics. These waves can resonantly interact with energetic electrons in the keV range, accelerating electrons to higher energies or resulting in their loss in the atmosphere. Understanding how these waves propagate gives you an insight into the ever-changing particle population of the radiation belts.

In October 2022, we installed a VLF receiver in Oulujarvi, Finland (OUJ, MLAT=61.3°N, L=4.4). Using simultaneous and conjugated observations with Kannuslehto (KAN, MLAT=64.4°N, L=5.5), we investigated the properties of VLF waves. We will introduce our most recent results, from wave occurrence at OUJ, occurrence and characteristics of VLF bursty-patches, to overall latitudinal VLF propagation and properties of the ionospheric exit point of ELF/VLF waves.

Long-term monitoring by FPIs of the thermosphere coupling with the ionosphere in preparation for EISCAT_3D

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The UCL Fabry-Perot Interferometer was installed at Pittioväara in November 2002. We have run it remotely every winter for 21 years with the SGO technical team's strong support. The SGO website displays daily results of our all-sky camera and cloud sensor. We measure neutral winds and temperatures using the 630 nm emission. We made the first ever tristatic, common volume measurements of thermosphere-ionosphere coupling by including an FPI at Skibotn, plus the EISCAT UHF tristatic radar mode, to combine 3 lines-of-sight wind and plasma speeds to determine true vectors, and to estimate the true altitude of the 630nm emission layer. These measurements allowed us to investigate ion-neutral coupling on meso-scales of 10s-100s kilometres and seconds to hours. The variability at such scale sizes was unexpected. We have added satellite drag and ML studies. UCL joins UK collaborators to provide instrument and modelling support for EISCAT_3D to revolutionise 3D imaging of the upper atmosphere.