Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

Continuum emission -- the weird aurora

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This presentation will show some recent observations of STEVE-like broad band continuum emissions, which are reported for the first time in the dayside aurora. They appear pale pink, white or mauve in full-colour auroral images and seem to relate to heating and upwelling of both plasma and neutrals. Our findings suggest that continuum emission is not a rare phenomenon in the aurora, and may occur in all latitudes and local time sectors. What exactly causes it to happen is a topic for future studies.

Introduction to UArctic thematic network Arctic Space Hub

Laura Lakso

UArctic, University of Oulu, SGO

The Thematic Network consists of research, observations, infrastructure building, public outreach and joint education activities aiming to improve Arctic and space situational awareness and space safety. SGO is the leading organisation of this network.

Activities

Examine long-term variability of geo-environment in the Arctic and its coupling to the extraterrestrial weather and climate. Share the data and knowledge on the Arctic and space hazards.

Increase Arctic and space situational awareness and provide input to the national risk assessment and Arctic policy.

Share educational material, good practices, on-line tools and remote educational infrastructures.

Enable exchange of researchers at all career stages for collaboration in science and education, and enable double degrees and multi-disciplinary MSc and PhD degrees.

A virtual meeting on discussing space related natural hazards and Arctic effects

Exchange observations and data homogenization routines for improved long-term Arctic monitoring capability and organize joint measurement campaigns

Share education material on space and geophysics related topics

Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

ARCTICS: Advances in auroral and subauroral research leveraging citizen science

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With the tremendous technological improvement of commercial cameras and smartphones, a growing number of (professional and amateur) auroral photographers capture high-quality images of the nightsky. This novel type of data has enabled the discoveries of previously unknown optical emission displays which reveal the presence of complex and unexplored processes at work in the near-Earth plasma. Those discoveries are the result of what is referred to as “citizen science”, i.e. scientific research involving contributors outside the academic world who provide data, contribute to the scientific discussion, and are co-authors of the resulting publications.

The ARCTICS (Auroral Research Coordination: Towards Internationalised Citizen Science) Working Group sponsored by the International Space Science Institute in Bern brings together academics and citizen scientists from Europe, North America, and Oceania to investigate auroral and subauroral physics. We combine citizen scientist observations with satellite and ground-based measurements to shed light on elusive optical phenomena such as STEVE, the dunes, fragmented aurora-like emissions, and continuum emission. We also collected nearly 700 auroral observation reports by citizen scientists from over 30 countries during the Gannon Storm which started on 10 May 2024 and published a paper discussing the findings yielded by those reports. Finally, ARCTICS recently released an open-access aurora Handbook and Field Guide to provide guidance and recommendations to make collaborations between academics and citizen scientists as smooth and fruitful as possible.

Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

Assessing GIC Risks in Fennoscandia: Insights from the September 2017 Geomagnetic Storm Using 1D and 3D Ground Conductivity Models

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(1) Finnish Meteorological Institute, Helsinki, Finland; (2) University of Helsinki, Helsinki, Finland

Geomagnetically induced currents (GIC) are one of the most studied and potentially hazardous form of space weather impacts. Our latest research focuses on GIC estimation during the severe September 2017 geomagnetic storm.

We use IMAGE magnetometer data and 1-dimensional (1D) and 3-dimensional (3D) ground conductivity models for modeling the geoelectric field during the September 2017 storm. Then, we calculate GIC in a simplified model of the Finnish 400 kV power grid, contrasting the results obtained with the 1D and 3D methods. This analysis is important for assessing localized GIC risks across the Fennoscandia region, highlighting regions where the two methods produce the largest differences. We present preliminary findings of this study. This comparative analysis improves our understanding of regional vulnerabilities and the importance of conductivity model accuracy, ultimately contributing to better risk assessment and mitigation strategies for future space weather events.

EISCAT – The Road Ahead

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

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

At the end of 2024, the EISCAT Scientific Association transferred all their assets into a limited liability company EISCAT AB, which was registered on 25th November 2024. The Scientific Association will formally be closed later this year after the books for 2024 are closed. It is foreseen that EISCAT AB will continue the work of the Association, for the EISCAT users, in much the same way as before. However, due to legal requirements, the governance of EISCAT AB will differ from the Association, and we will outline the most relevant differences.

Furthermore, we will give an update on the status of the legacy systems UHF, VHF, ESR, and Heating. We will discuss the current status of the deployment of EISCAT_3D and speculate on what users may expect in 2025.

Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

Estimating fireball geographic positions using citizen observations

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The Taivaanvahti (“Skywarden”) observation service collects citizen fireball observations in Finland. The service started in 2011 and a comprehensive set of fireball observations over Finland or neighbouring areas have been collected since. The web form used to collect data already existed before the actual observation service was established. The observations are quality checked by a group of volunteering specialists. The system can group observations belonging to the same event together automatically. Thus, the data is easily accessible using APIs. The authors have developed algorithms to automatically analyse the collected data. An interactive method with web visualisation using compass point information is fast but less accurate and can give only the end point of the luminous trajectory. The least squares method is more accurate and can use all the data provided by the observer. It can also estimate the flight direction of the fireball. It is possible to automatically run the algorithms in the same fashion as the event grouping. The least squares method could be used also to augment video camera observations when video data availability is scarce.

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), Claudia Martinez(1), and Akira Mizuno(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, impacts of the magnetospheric forcing to the ionosphere and the atmosphere, 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.

Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

Summary of the of Academy of Finland QUASARE project

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

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The main task of the project was to perform an analysis and quantification of solar energetic particles (SEPs) events, specifically ground level enhancements (GLEs) using neutron (NM) and space-borne data. Flux of high-energy particles viz. CRs, penetrates the Earth's atmosphere, interact with the atmospheric molecules and produce complicated cascade. In the cascade, only a fraction of the initial primary particle energy reaches the ground. Most of the primary particle's energy is released in the atmosphere by ionization. The majority of CRs originate from the Galaxy - galactic cosmic rays (GCRs). The Earth is also hit sporadically by high intensity, but with low occurrence rate solar energetic particles (SEPs), accelerated following explosive energy releases on the Sun, which may produce an atmospheric cascade in a similar way, leading to a GLE. GCRs and SEPs significantly affect the radiation environment at commercial flight altitudes. Both GCRs and SEPs are the most significant contributors to exposure and ionization, specifically over the polar region, where the magnetospheric shielding is not as strong compared to the middle and equatorial latitudes. In order to assess those effects it is necessary to possess information about SEPs spectra and anisotropy. Here we report the results derived in the frame of the project, the established networking, scientific visits, and publications.

Modeling regional electric field based on the EISCAT3D plasma velocity observation

Habtamu W. Tesfaw(1) , Heikki Vanhamäki(1) , Ilkka Virtanen(1) , Spencer Hatch(2) , Matt Zettergren(3) , Karl Laundal(2)

EISCAT3D, which is under its final stage of construction, will be the first incoherent scatter radar (ISR) system to provide the three-dimensional ion velocity across hundreds of kms in vertical and horizontal directions. This presents a tremendous opportunity to study the three-dimensional nature of ionospheric electrodynamics. Here we present a data-driven regional model of the electric field based on the EISCAT3D observations, where the measured F-region ion velocity data are fitted to a regional electric potential produced by a grid of spherical elementary systems. Performance of the model is demonstrated using simulated ionospheric parameters obtained from the three-dimensional GEMINI model. To simulate realistic radar measurement of the ion velocity, error estimates obtained from the e3doubt package are added to the ground truth GEMINI data. Our model can be used either with multistatic or monostatic measurements of the ion velocity, and it can also integrate ion velocity data from other platforms, such as satellite sensors, into existing ISR measurements. The model captures the ground truth electric field including its complex spatial structure with average percentile differences of about 1.5%. Most accurate results are achieved with the multistatic data, but the general spatial structure of the electric field can be captured also with monostatic data, if optimal beam patterns and regularization are used. The modeling method is also applied using real monostatic line-of-sight ion velocity data measured by the Poker Flat ISR. The modeled electric field shows reasonably well-behaved variations in latitude and longitude within the radar's field of view.

Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

On D region observations with EISCAT3D

Ilkka Virtanen(1), Antti Kero(2), Neethal Thomas(2)

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The multibeam remote receivers of EISCAT3D are known to enable groundbreaking observations of the plasma velocity field and to provide high-quality plasma parameter data in the E region and above, thanks to reduced incoherent scatter self-noise and fewer space debris echoes from the small beam intersection regions. One benefit that has received less attention until now is the ability to make accurate D region observations using pulse codes designed for E and F region observations with monostatic radars. This option allows for continuous monitoring of the D region without compromising the E and F region data. We demonstrate the benefits of remote reception using synthetic radar signals as well as real measurements with the EISCAT VHF radar in Tromsø and the KAIRA radio receiver in Kilpisjärvi. Additionally, we show that EISCAT3D could benefit from a "D region receiver" near its core site, and that it would be technically feasible to conduct such measurements using KAIRA.

Assessing the radiation impacts of the Halloween ground-level enhancement events using an updated CRAC:DOMO dosimetry model

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A period of heightened solar activity from late October to early November 2003 resulted in several strong solar eruptions directed at Earth. These eruptions produced disturbed heliospheric conditions, a deep Forbush decrease (FD), 3 ground-level enhancement (GLE) events, known as the Halloween events, and one of the strongest geomagnetic storms ever recorded. GLEs signal the arrival of solar energetic particles (SEP) at Earth. SEPs enhance the health risk posed by radiation at aviation altitudes. In this work, the complex geomagnetic conditions and FD were reconstructed and used as inputs, alongside previously derived GLE SEP spectra, for an updated CRAC:DOMO dosimetry model. Using an isotropic assumption for the incoming SEP flux, radiation dose values were computed, and the radiation impact of the GLEs was found to be minor. Comparison between in-situ dosimetry measurements made by flights during 2 of the GLEs and CRAC:DOMO using an anisotropic assumption showed a good agreement, validating the full chain modelling for GLE radiation impact analysis, i.e. the OTSO tool, SEP spectra unfolding procedure, and application of the CRAC:DOMO dosimetry model.

Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

High-cadence modulation potential for study of cosmic ray variation, solar activity and data quality

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The flux of galactic cosmic rays (GCRs) arriving at Earth varies according to solar activity. This solar modulation is often quantified by the modulation potential ϕ, which describes rigidity loss of GCR during transport in the heliosphere.

Recently, a daily version of ϕ was created based on neutron monitor (NM) data and was used to estimate GCR fluxes and compared to AMS-02 measurements, which showed a very good match. This can be utilized for inter/extrapolations and real-time datasets of GCR variation.

The daily ϕ offers utility for analyzing solar activity, but higher cadence at 1-hour and 1-minute are possible, if diurnal anisotropies can be addressed. We will present initial work on this.

It is also useful for assessing the quality of data and models. We will showcase calibrating recently discovered handwritten Oulu NM measurements from Jan-Mar 1964 and using snow-depth observations to account for the effect of snow on the Oulu NM roof during 1964-1973 when it was at Kontinkangas.

A Deep Learning Approach for Automatic Ionogram Parameters Recognition

Ruslan Sherstyukov, Samson Moges, Alexander Kozlovsky, Thomas Ulich

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Typical ionosondes operate with >5 minutes time intervals, which is enough to obtain regular parameters of the ionosphere, but insufficient to observe short-term processes in the Earth's ionosphere. The key point for this study is to increase the ionosondes data time resolution by automatization of ionogram scaling routine. In this study we show the results of implementation of deep learning approach for ionogram parameters scaling. We trained the model on 13 years ionogram dataset of Sodankyla ionosonde at high latitude region (67°N). We tested our autoscaling program tool on 2021 year dataset and evaluate errors between operator and automatic parameters scaling. The root mean square errors for critical frequencies foF2, foF1, foE, foEs, fmin, fbEs and virtual heights h′F, h′E, h′Es are estimated as 0.12 MHz (2 pixels), 0.07 MHz (1.16 pixels), 0.15 MHz (2.5 pixels), 0.33 MHz (5.5 pixels), 0.15 MHz (2.5 pixels), 0.17 MHz (2.83 pixels), 7.7 km (1.34 pixels), 7.0 km (1.22 pixels), 7.1 km (1.24 pixels), respectively.

Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

Scientist as a target person - Human Intelligence operator at work

Samuli Järvinen referring to a discussion with Eija Tanskanen

NUUH Intel

The presentation describes briefly the process how a vicious Humint operator targets, profiles, plans and builds trust with persons of interest and how they could defend oneselves from it.

The geopolitical situation at the moment is intense and hostile. The one who gains the information and tools for the future, walks a winning path. As part of their intelligence operations several governmental and nongovernmental actors are actively seeking new innovative information, ways to influence cognitively, ways to conduct sabotage and networks for future operations. The networks of scientists working with high technology themes provide a fruitful way for intelligence actors to achieve their objectives. Luckily there are ways to identify and protect oneself from this kind of actions.

Kiruna Atmospheric and Geophysical Observatory at IRF - status report

U. Brändström, J. Kero, T. Leyser, D. Mikhaylova, P. Nilsson, U. Raffalski, M. Rönnfalk, T. Sergienko, L-H. Snow, M. Yamauchi

Swedish Institute of Space Physics (IRF), Kiruna, Sweden

The Kiruna Atmospheric and Geophysical Observatory (KAGO) operates about 40 instruments at 12 different sites in Sweden, from Abisko in the north to Tormestorp in the south. We give a status report of these observatory activities (long-term monitoring) within the IRF, which to some extent concerns the Nordic observatory collaboration and the interfacing of observatory instruments as complementary instruments for EISCAT_3D.

NOrdic Space Tracking RAdar (NOSTRA)

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The European Space Agency (ESA) has tasked the Swedish Institute of Space Physics (IRF), the Norwegian Research Centre (NORCE) and the University of Oulu / Sodankylä Geophysical Observatory in Finland, to explore the possibilities of developing a NOrdic Space Tracking RAdar which we call NOSTRA.

During 2024–2025 we will map out the needs and requirements of Nordic stakeholders and compile a technical description of how a Nordic radar system that meets these demands could be realized. Stakeholders include space agencies, commercial entities, defense forces, and academic institutions. Enabling the system for academic research will be vital the success of the project.

We present an overview of the current problems within space surveillance and tracking, describe what NOSTRA could be and how it could solve some of these issues, as well as open up for discussing possible research conducted using such an instrument.

Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

Radioactivity soundings at Sodankylä, Finland – past and present activities

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Radiation detectors have been lifted to the upper atmosphere with hydrogen or helium balloons for over a century. The FMI acquired radioactivity sounding systems to its three sounding stations in the 1990s. The still operational system consists of a radioactivity sonde, a radiosonde (PTU sonde) and the ground equipment. With the system it is therefore possible to measure the vertical distribution of atmospheric radiation dose rate together with meteorological parameters from ground-level up to a pressure level of a few hPa. At Sodankylä over 30 radioactivity soundings have been performed since 1995.

The development of a new radioactivity sounding system became necessary recently. The measurement module of the system is a commercially available dose rate meter. It communicates to the radiosonde through a compact microcontroller board, that acts as an interface module. The radiosonde reads the messages and transmits them to the ground station along with the meteorological and technical (e.g. GPS performance) data using its 400 MHz telemetry link. The lifespan of the system is expected to last to the early 2040s.

Solar activity dependence of TID amplitudes using a rapid-run Sodankylä ionosonde

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We investigated the amplitude of medium scale traveling ionospheric disturbances (MSTIDs, with periods 25–100 min) and their dependence on the solar activity using 16 years data of the rapid run- ionosonde operating at high latitudes (67°N, Sodankylä, Finland). A deep learning neural network was applied to ionograms to extract critical frequency of the F2 region (foF2) with a 1 min time resolution. Then, we analyzed the relative amplitude of MSTIDs (i.e., 2δfoF2/foF2), which corresponds to the amplitude of atmospheric gravity waves (AGWs) causing MSTIDs. The amplitude of AGWs propagating upward increases with height due to the decreasing density of the air, and hmF2 varies depending on local time, seasonal and solar activity conditions. To account for this effect, we calculated a corrected MSTID amplitude by normalizing the relative amplitude for the air density at the hmF2. The corrected amplitudes show no clear dependence on F10.7 during winter (0–12 UT), equinox (20-01 UT) and summer (19-01 UT), while a positive dependence of corrected amplitudes on F10.7 was observed during winter and equinox, in 14–22 UT and 15–19 UT, respectively. Corresponding to the dependence behaviors of corrected and relative amplitudes, two likely mechanisms of MSTIDs, AGWs from the lower atmosphere and auroral sources, are inferred. Their subsequent roles in the solar activity dependence of MSTID amplitudes were separately discussed, although in reality, the observed dependence is complex and often involves several mechanisms together.

Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

Sodankylä Geophysical Observatory SKY-i Network

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In project Revot we extended the Sodankylä geophysical observatory (SGO) ground based one-shot-color (OSC) all-sky-camera (ASC) network (SKY-i Network) to the North-East part of Lapland in Finland. Presently the SGO SKY-i Network monitors optical events between [65, 70] latitude and [24, 29] longitude degrees with a mean minimum distance of <D> ~ 98 km between adjacent SKY-i units and images sky for one and half seconds in two second interval during Solar elevation is 8 degrees bellow horizon. Relatively dense network of SKY-i reduces local observation interference (e.g. due to overcast or electric outages) which increase the probability and coverage to observe variety of optical events over the network. With unprecedented level of ground-based visual now-casting and occurrence Aurora and intuitively approachable data format (color images), the SKY-i Network has an outstanding outreach and educational potential. The SKY-i Network produces roughly 5 million images (possible events) per SKY-i unit annually which solely benefit from AI driven methods to mitigate resources spend in the event parsing process and provides instrument-uniform, coherent training-set over different spatial locations to improve now- and forecast models and automating a tracing of variety of optical events.

Electrodynamics of an isolated substorm: Currents and spectra of precipitating electrons

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We investigate an isolated substorm that took place on 7.11.2018. Our aim is to study the development of ionospheric currents during this event, with focus in the field-aligned currents (FACs). The main data sources are EISCAT UHF incoherent scatter radar and IMAGE magnetometer network measurements. In general, FACs are hard to estimate from ground-based observations, but in this study, we determine them using two advanced methods: electron precipitation obtained from EISCAT electron density data with the ELSPEC method and SECS-based method to estimate the curl of the equivalent currents for IMAGE measurements. We also use NASA's OMNIWeb solar wind data and auroral all-sky cameras to support our findings. The two methods for estimating FACs give relatively similar results with enhancement in the upward FAC during increased electron precipitation. The most intense currents and auroras occur at the end of the expansion phase, along with a unique vortex structure seen in both.

Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

Asynchronous evolution of solar UV irradiance and sunspots during the Gleissberg cycle disclosed by dayside ionospheric currents

K. Mursula

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Solar cycle heights vary at a centennial period called the Gleissberg cycle (GC). The latest GC maximum was during solar cycle 19. Now we are in the GC minimum or in the early growth phase of the next GC. We have recently found that sunspots and solar UV irradiance did not change synchronously during the GC decay since 1960s (Mursula et al., 2024). Rather, UV irradiance was more intense than expected from sunspot activity.

We study here the relation between solar UV irradiance and sunspots during 130 years using the Earth's dayside ionospheric currents. Due to these currents, the daily range of declination can be used as a proxy of UV irradiance. We find that the solar UV irradiance increases relatively less than sunspots during the GC growth phase (when solar activity is increasing) but decreases relatively less than sunspots during the GC decay phase (when solar activity is decreasing). We also discuss the interesting implications of these changes to the stellar evolution of the Sun.

Calibrated aurora data and the R-index

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Finnish Meteorological Institute

Calibrated aurora pictures from the All-Sky Camera in Kilpisjärvi are represented by three single numbers per picture, which represent the average intensity of the aurora within the picture, at the three wavelengths. These data are used to analyse statistics of the aurora in Kilpisjärvi over the period 2013-2024. Similar results can be achieved for other cameras if the pictures are calibrated properly.

The R-index is an index developed at FMI, which can be used as a local proxy for aurora. It is based on the variability of the magnetic field measurements from a magnetometer. Data of the R-index from the magnetometer in Kilpisjärvi show a good correlation with the quantified aurora intensity in Kilpisjärvi.

Statistics of the R-index from different locations over the period 2013-2024 are presented. Comparison of these with the results at Kilpisjärvi give an indication of the statistics of visible aurora at the different locations.

Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

Three GLE events of 2024. Rich year after a drought

Stepan Poluianov (1,2), Ilya Usoskin (1,2), Alexander Mishev (1,2), Nicholas Larsen (1,2), Sergey Koldobskiy (1,2), Olga Kryakunova (3), Botakoz Seifullina (3)

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The Sun produces solar energetic particles (SEPs) as sporadic events associated with flare eruptions and coronal mass ejections. Although the majority of SEP events are relatively weak, some of them can have protons with rigidities exceeding 1 GV, sufficient to make the events observable on the ground by neutron monitors. Every registration of SEP by those instruments looks like an enhancement of the count rate over the background and is called a Ground-Level Enhancement (GLE). Such measurements are important for several reasons, for example, the possibility of studying high-energy SEP fluxes with good time resolution. Since the beginning of systematic cosmic ray measurements in the early 1940s and before 2024, there were 73 GLEs registered, and their list is particularly sparse in the last 20 years of weak solar cycles: 2 events in 2005, 1 event/year in 2006, 2012, 2017 and 2021. However, the year 2024 brought us 3 GLE events, and two of them are associated with a very long-living and highly productive active region AR3664, which also caused the widely discussed geomagnetic storms of May 2024. Here, we overview those three GLEs and present the results of preliminary analyses of their properties assessed with the global network of neutron monitors including the SGO instruments OULU, DOMC and DOMB.

Statistical Modeling and Prediction of Ionospheric Equivalent Currents Based on SuperMAG Data

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We present a statistical model of ionospheric equivalent currents as a function of solar wind electric field E, interplanetary magnetic field (IMF) clock angle, and Earth's dipole tilt. We used 12 years (1997–2008) of ground-based magnetometer data analyzed by the SuperMAG.

The equivalent currents predicted by our model show well-known characteristics, such as strong dependence on IMF Bz component and E. Also the IMF By component and dipole tilt have a combined effect on the currents, which will be investigated in future studies.

The model was tested in two case studies of geomagnetic storms, driven by a high-speed stream and a coronal mass ejection. We also carried out a statistical study using 227 storms during the solar cycle 24. In comparison with SuperMAG measurements the model succeeds in reproducing the main features of the storms. The model is most accurate during the storm main phase and most inaccurate during the initial phase.

Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

Some Results from VLF-CHAMP

C. Martinez-Calderon(1), J. Manninen(2), D. Pisa(3), O. Santolik(3,4), M. Hanzelka(5), F. Nemec(4), Y. Miyoshi(1), and K. Shiokawa(1)

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In recent years, the PWING project has allowed us to investigate the longitudinal characteristics of natural VLF emissions. Some interesting results from these previous studies have motivated us to focus on the latitudinal propagation and possible ionospheric propagation of certain types of VLF waves, particularly unusual high-frequency VLF bursty-patches.

In this study we will use three VLF receivers installed in Finland at approximately the same longitude but at three different latitudes (separated by 150-400 km). These are Kannuslehto (KAN, MLAT=65.0°N, L=5.5) active since 2006, Oulujarvi (OUJ, MLAT=61.3°N, L=4.4) since 2022, and Angeli (ANG, MLAT~66.1°N, L~6.2) from August 2024.

Here we will present the first results from this latitudinal chain comprising:

- Results from conjugated events from multi-point observations, incorporating when possible.
- Preliminary results of the PHLR/sferics filter to be installed at all PWING stations.

The contemporary geopolitical environment for critical infrastructure operators

P A Aalto

Politics Unit & Tampere Centre for Security Risk and Resilience (TASERR), Faculty of Management and Business, Tampere University

This presentation discusses the contemporary geopolitical environment from the point of view of critical infrastructure development, operation and maintenance. For this end, contemporary geopolitical rivalry is reconceptualised as comprising both territorial and digital domains; and both state and company actors, along with hybrid actors and alliances between them. The actors are seeking to affect and benefit from flows of trade, technologies, IPR, capital and regulation that crisscross the territorial and digital domains. The resulting vulnerabilities for critical infrastructure developers and operators are assessed along with directions for improving the resilience of such infrastructures.

Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

Cosmic radio noise absorption spectrum during the solar proton event in October 2024

A Kero, M Hyötylä, N Thomas, M Orispää

Sodankylä Geophsyical Observatory/University of Oulu

In this talk, we present a summary of riometer absorption spectrum observed by SGO riometers during the major SPE in Oct. 2024. The observations of the spectral shape are comaperd with what is expected by the SIC model results. It turns out that the negative ion chemistry plays a role in the CNA spectrum shape.

A Tristatic Array of Aeronomy Instruments to Support EISCAT-3D

Donald Hampton (1), Kylee Branning (1), Aaron Ridley (2)

(1) Geophysical Institute, University of Alaska Fairbanks,2156 Koyukuk Drive, University of Alaska Fairbanks, Fairbanks, USA, (2) College of Engineering, University of Michigan, Ann Arbor, Michigan

We have recently established an NSF-funded tristatic array of ground-based aeronomy laboratories in Finland and Sweden. These three labs each house an initial complement of five instruments for remote sensing of the high latitude ionosphere and thermosphere. These instruments are an all-sky imaging Fabry-Perot spectrometer (FPS), a narrow-field zenith-pointing FPS, a multi-filter monochromatic all-sky imager, a 3-component vector fluxgate magnetometer, and a GNSS satellite receiver. These instruments and their deployment sites are designed to complement the new EISCAT-3D incoherent scatter radar facility that is currently under construction in the same area. All observational data will be freely distributed on the internet for use by any interested parties. As of December 2024, all three labs are in place and operating. All instruments are installed and operating in the labs at Abisko in Sweden and at Aakenus in Finland. The third site is at Kevo in Finland, where we currently have two of the five instruments running, with the remainder scheduled for installation in late January 2025. This presentation will provide an update on the status of the labs and instruments, as well as presenting some "first light" data from instruments that are running now. Collaborative use of this new facility and its resulting data will be warmly welcomed.

Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

Fifth International Polar Year 2032-33

On behalf of IPY planning committee, Kirsi Latola (member of international IPY planning committee)

University of Oulu, Finland, University of Arctic

Fifth International Polar Year in 2032-33 aims to address urgent global challenges by advancing polar research, focusing on the impacts of climate change in the Arctic and Antarctic. This coordinated effort will bring together scientists, Indigenous knowledge holders, and global stakeholders to produce actionable insights for mitigating and adapting to environmental changes, while promoting international collaboration and inclusivity. The need for organising IPY 25 years from previous one rises from the urgent need to understand the consequences of rapid changes in the polar regions for global climate, biodiversity, and human societies which have never been greater.

Cybersecurity in the SafeEarth programme

Kimmo Halunen

(1) University of Oulu; (2) National Defence University of Finland

The SafeEarth programme tackles natural and manmade risk to our digital society. One key part of these risks is cybersecurity. This talk will focus on both existing and emerging technologies and their effect on cybersecurity in our digital society.

Cosmic-ray studies at SGO in 2024

I. Usoskin, A. Mishev, S. Poluianov

Sodankylä Geophysical Observatory, University of Oulu, Finland

Research in cosmic rays at SGO in 2024 is reviewed. SGO operates two ground-based neutron monitors (NMs), in Oulu and at Concordia station on the Antarctic Plateau, and participates in the AMS02 experiment onboard the ISS. The Oulu NM is a world-reference cosmic-ray station. Three ground-level enhancements (GLEs), GLE # 74--76, have been registered in 2024 in May, June and November. Several important research results obtained in 2024 are briefly presented.

Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

Improving neutral atmosphere models using NOSTRA observations of space debris

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(1) NORCE Norwegian Research Centre, Tromsø, Norway, (2) UiT Arctic University of Norway, Tromsø, Norway; (3) Institutet för Rymdfysik, Kiruna, Sweden; (4) University of Oulu, Oulu, Finland

Low Earth Orbits are significantly perturbed by drag with the neutral atmosphere, which can also be very hard to model. Turning this statement around, a measurement of orbit perturbation is a data point for an assimilating neutral atmosphere model. It is admittedly a very imprecise measurement, since it will typically be an integral along the trajectory of the object over a period comprising at least a sizable arc and up to several complete orbits. On the other hand, the huge number of objects currently in such orbits means that a consistent programme aimed at continuous maintenance of an object catalogue becomes a reliable and continuous data source for such an atmospheric model. The model itself is well suited for a stepwise and staged development, where initial effort can be concentrated on estimating a very small number of low-order coefficients (e.g. spherical harmonics), but in a way where these are continuously updated as new drag observations become available. This approach also lends itself well to gradual ramp-up of assimilative power. Initial demonstration has been made where a global scaling coefficient was estimated by means of a single observation [Gustavsson & Myhre]. The NOSTRA instrument currently under development in Norway, Sweden and Finland [talk by J. Kero et al, this meeting] will potentially provide several hundred thousand orbit updates per day. An atmospheric model which incorporates all this information is potentially more accurate than anything else available for this purpose. Our competence is mainly in the processing of radar data and orbit modelling, but we hope to get in touch with atmosphere modeling people who think this sounds interesting.

Induced Ionization by Solar Energetic Particles for the CMIP7 Solar Forcing Dataset

Sergey Koldobskiy, Ilya Usoskin

SGO, University of Oulu

Previous studies have demonstrated that solar energetic particles (SEPs) can impact the climate, notably through ozone depletion. Growing interest in this area has led to the inclusion of SEP-induced ionization data in the solar forcing dataset of the WCRP Coupled Model Intercomparison Project (CMIP).

We have developed an updated SEP-induced ionization dataset for the forthcoming CMIP7 release. This new dataset incorporates substantial improvements, including a revision of original satellite measurements, the integration of high-energy SEPs detected by ground-based instruments, and the implementation of a flexible yet robust flux approximation scheme. Additionally, the dataset leverages the latest version of the ionization yield function, which combines an analytical approach with Monte Carlo modeling.

Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

EISCAT-VHF observations of energetic particle precipitation during 10 -11 October 2024 geomagnetic storm

Neethal Thomas(1), Antti Kero(1), Ilkka Virtanen(2)

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

EISCAT-VHF radar was running a vertical mode manda experiment during the recent geomagnetic storm on 10-11 October (DST -330 nT). Energetic electron precipitation (EEP) events, with ionization down to 60 km are observed during the onset of the geomagnetic storm in the EISCAT measurements. An ongoing solar proton event causing enhanced background ionization down to 55 km, enabled us to visualize this EEP event in the EISCAT data, which otherwise would have been in the noise floor of the measurements. EISCAT-VHF incoherent scatter (IS) spectral measurements are studied in terms of 1) backscattered power to investigate the EEP events, and 2) the IS spectral width to study the negative ions in the mesosphere lower thermosphere altitudes. Preliminary results of the data analysis, along with the SIC model results, will be presented.

Global presentation of ground Pc5 power according to SuperMAG magnetometer network

R Hynönen (1,2), E I Tanskanen (1)

(1) Sodankylä Geophysical Observatory, University of Oulu; (2) Department of Electrical Engineering and Automation, Aalto University

Pc5 pulsations are shear Alfven waves that can be detected by ground-based magnetometers, particularly when used with a network of magnetometers. One such network is the SuperMAG that provides data globally at 1-min and 1-sec temporal resolutions.

In this preliminary study, we study the statistical properties of Pc5 power extracted from SuperMAG network's measurements at a global level. We show the horizontal component's dependence on latitude as well as how the ground-based Pc5 power depends inherently on properties of solar wind, particularly its speed.

Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

EISCAT_3D or Sanya Radar: which one will take the world leader title ?

M S Lehtinen

(1) RF Shamans Ltd., Finland (2) Inverpolis Oy; Finland

I will introduce the recent Chinese radar and its first results. It is a phased array of 4096 T/X antennas with also two similar size receiver stations. The paper written by 17 chinese scientists from 5 different chinese research institutes reports a fully operating new IS radar. The authors of the 2022 paper report that the radar was designed to take benefit of our Finnish developments including GUISDAP, lag profile inversion, multipurpose experiments and perfect radar codes -- all applications of our world-leading inverse problems mathematics and all originally motivated to benefit EISCAT. Our Chinese colleagues show actual high quality experimental results of all of these methods with their new radar. They also show results of Moon ISAR mapping we initiated with Finnish/American DSP hardware connected to EISCAT.

The Sanya radar is less digital than EISCAT_3D was intended to be. EISCAT_3D was planned to use True Time Delay (TTD) signal processing to be able to synthesize receiver beams pointing to several different directions at the same time. With this advantage connected to 3-dimensional mathematical inversion analysis of our 3D target EISCAT_3D has all necessary potential to become more powerful than the Sanya radar.

However, EISCAT_3D seems to be in serious problems not being able to demonstrate a working digital beam forming system for multiple simultaneous beams designed in the Handbook I wrote between 2010 and 2014 in the preparatory phase EU FP7 project. In 2018 RF-shamaanit ltd. gave a tender to answer a RFQ by EISCAT for electronics towards this purpose, but this tender resulted in total silence from EISCAT. Meanwhile we have developed a fully Finnish design and manufacturing chain of digital hardware capable of digital real-time TTD beam forming scalable to arbitrarily large antennas with processing perform in the antenna field itself.

Between 2018 and today, we have applied our HW in a series of commercial instruments for ionospheric tomograpy and riometers. Quite recently also for ionospheric sounding and radar detection of other targets with several transmitters and receivers.

I believe our company could solve EISCAT's obviously quite embarrassing situation delaying planned starts of operations of EISCAT_3D for a decade now. For this EISCAT as a soon-to-be company should open up their problems instead of trying to solve them by hiding them from the scientific community.

Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

Expansion to versatile multi-satellite Cal/Val activities by FMI at the Arctic Space Centre

A Kontu (1), J Lemmetyinen (2), T Karppinen (1), R Kivi (1), M Honkanen (1), J Tamminen (2), J Pulliainen (2)

(1) Space and Earth Observation Centre, Finnish Meteorological Institute, Sodankylä, Finland; (2) Space and Earth Observation Centre, Finnish Meteorological Institute, Helsinki, Finland

Finnish Meteorological Institute's facilities at the Arctic Space Centre (FMI-ARC) in Sodankylä, Finland has undergone systematic development and expansion for the past 15 years. Two goals have guided the development of measurement infrastructure thus far: (1) research of the local carbon and water cycles and (2) ground-based Cal/Val support for relevant satellite missions. From a satellite mission Cal/Val perspective, four key instrument sectors are microwave observations, multispectral/hyperspectral observations, greenhouse gas observations and ozone/UV observations. Currently, the number of instruments maintained comprises 139 measurement entities and includes 768 sensors, which include the key biophysical parameters targeted by satellite sensors. Additionally, the site hosts and expands ground segment services for satellite data reception, processing, and storage.

In this presentation, we will introduce the current suite of FMI-ARC ground-based instruments that enable versatile Cal/Val activities both regarding quasi-continuous monitoring and ad hoc campaigns targeting, e.g., specific ecosystems (wetlands, boreal forest). During the past 15 years, different instruments have been designed, purchased, and deployed over periods spanning up to several years of observations to serve needs of diverse scientific projects (e.g. ESA NoSREx, ESA SMOS ESL, ESA FRM4GHG, ESA SNOWITE, ESA WIFVOS). We will review the challenges and development needs for ground-based Cal/Val measurements to best support upcoming European Earth Observation missions, e.g. Sentinel-5, CO2M, FLEX, CHIME, CIMR, CryoRad, and HydroTerra+. Furthermore, we will highlight the specific advantages of our measurement setup where the cryospheric and atmospheric monitoring is intertwined.

Beyond routine satellite Cal/Val activities, the ground-based measurements have high scientific value for identifying algorithm improvements to space mission data products, developing new data products, advance process understanding through multisource data analysis or model evaluation, and testing preliminary instrument or operation concepts of future missions. The measurements at the site have also potential to support the testing of innovative mission operation concepts. Finally, the FMI-ARC vision is to become a central satellite Cal/Val supersite as well as an innovation testbed for the European Space Industry.

Observatory Days 2025

08.-10. January 2025

Sodankylä Geophysical Observatory

Abstracts

UMLT trace gas variations by geomagnetic storm and SSW

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This study focuses on the neutral trace gases in upper mesosphere and lower thermosphere (UMLT). The effects of energetic particle precipitation (EPP) from geomagnetic processes and from sudden stratosphere warming (SSW) on this UMLT neutral trace gases remain largely unexplored. In this research we investigated how ozone, atomic oxygen [O], atomic hydrogen [H], and temperature responds to these two types of events using SABER satellite observations. In addition, the residual Mean Meridional Circulation (MMC) derived from WACCM model simulations were used to characterise the residual circulation changes during EPP events. We report surprising responses across a wide latitude range or over a longer time span than expected.

SafeEarth Research Programme

Eija Tanskanen

Sodankylä Geophysical Observatory

This presentation will describe the new profiling theme SafeEarth, which starts in January 2025. The research programme study natural and human-made risks and societies' responses and will engage research and impact activities in space safety, cybersecurity and human security. SafeEarth is an interdisciplinary research programme led by the Sodankylä Geophysical Observatory (SGO), Faculty on Information Technology and Electrical Engineering (ITEE) and Faculty of Humanities, and it will hire tenure-track professors, post-doctoral researchers and PhD students. The programme will carry out different actions on safety and security themes to strengthen collaboration between existing teams of University of Oulu and with stakeholders within academia, industry and society in large.