Observatory Days 2026
Sodankylä Geophysical Observatory

Abstracts

Magnetic storms caused by coronal mass ejections and high-speed solar wind streams occur differently over the Modern Maximum

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Magnetic storms are mainly driven by two solar wind structures: coronal mass ejections (CME) and high-speed solar wind streams with related stream interaction regions (HSS/SIR). CME occurrence closely follows sunspots, the emergence of new strong magnetic flux on the solar surface. HSS/SIR occurrence depends on the global structure of solar corona, in particular the occurrence of coronal holes, which is determined by the evolution of decaying solar active regions (plages) with magnetic field weaker than sunspots.
We study here the occurrence of magnetic storms during the last 92 years (1933-2024), when a homogeneous storm index, the Dxt index based on observations of four standard magnetic stations, is available. This time interval covers almost the whole Modern Maximum (MM), the latest Gleissberg cycle of centennial solar activity variation. Studying storms of different strength and type can give interesting information on the evolution of the Sun during this exceptional period of solar activity.
We find that CME storms were relatively more frequent than HSS/SIR storms in the growth and maximum phase of the Modern Maximum. On the other hand, the relative occurrence of HSS/SIR storms increased with respect to CME storms in the MM decay phase. This curious change in the relative occurrence of storms of different type is in good agreement with the recent finding of a changing long-term relation between sunspots and plages [1, 2]. Sunspots are found to be relatively more frequent than plages in the MM growth and maximum phases, while the opposite relation is valid in the MM decay phase.
These results give interesting new information on the change of the structure and distribution of solar magnetic fields and the solar atmosphere with long-term solar activity. We also note on the implications of these findings on the stellar evolution of the Sun and Sun-like stars and make a long-term forecast on the future occurrence of CME and HSS/SIR storms at the Earth..

[1] K. Mursula, A. A. Pevtsov, T. Asikainen, I. Tähtinen and A. Yeates, Transition to a weaker Sun: Changes in the solar atmosphere during the decay of the Modern maximum, *Astron. Astrophys.*, 685, A170, https://doi.org/10.1051/0004-6361/202449231, 2024

[2] K. Mursula, Centennial solar EUV irradiance from ionospheric currents: Varying sunspot-EUV irradiance relation and modified spot-facula ratio, *J. Atm. Solar-Terr. Phys.*, https://doi.org/10.1016/j.jastp.2025.1066532025, 2025

Magnetic phases and evolution of complex solar active regions

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Understanding the magnetic evolution of solar active regions (ARs) is essential for identifying the conditions that lead to enhanced solar eruptive activity. In this study, we investigate the full magnetic evolution of both simple and complex solar active regions over the period January 1996–December 2020 using daily observations from the NOAA Solar Region Summary database.

We introduce a novel Magnetic Evolution Method (MEM) that tracks individual ARs throughout their entire visible lifetime and segments the evolution of complex active regions (CARs) into three distinct phases: growth, main, and recovery. Applying MEM to 4,841 ARs, we find that approximately 19% are complex, while the majority exhibit simple magnetic structures. Complex regions are shown to have significantly longer lifetimes than simple ones, with a mean lifetime of about 24 days, independent of solar cycle phase.

Our results demonstrate that 94% of complex regions initially emerge with simple magnetic configurations and transition into complex structures after an average of only three days. This growth phase is followed by a main phase lasting about five days, during which magnetic complexity peaks, before regions return to simpler configurations during a recovery phase. Notably, complex regions remain magnetically complex for roughly one-fifth of their total lifetime.

These findings provide new statistical insight into the timing and duration of magnetic complexity in solar active regions. The identified growth and main phases represent critical windows for increased eruptive potential and offer valuable constraints for improving space weather forecasting models and flare prediction strategies.

Abstracts

Multi-instrument reconstructions of solar energetic particle events properties

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SGO

Abstract

We present a multi-instrument reconstruction of solar energetic particle (SEP) event properties using a combination of ground-based neutron monitor (NM) data and space-borne measurements from GOES, PAMELA, and, potentially, AMS-02 and SOHO/EPHIN. Using these observations, we achieve continuous and overlapping coverage over a wide energy range, from tens of MeV to several GeVs, enabling a consistent characterization of SEP spectra, intensities, and its temporal evolution.

Low- and intermediate-energy SEP fluxes are primarily constrained by GOES proton observations, while PAMELA and AMS-02 provide high-precision measurements at higher energies. SOHO/EPHIN data could serve as an independent reference in the overlapping energy range, improving cross-calibration between instruments and reducing systematic uncertainties. NM observations are used to quantify the relativistic component of SEP events, ground level enhancements (GLEs), and to extend the reconstructions to periods lacking direct in situ measurements.

Within a analysis framework, we reconstruct event-integrated spectra, energy-dependent onset times, allowing us to investigate particle acceleration and transport processes in the heliosphere.

The first solar cycle of operation of the neutron monitors DOMC and DOMB in Antarctica

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In January 2026, we celebrate the first 11 years (the length of one solar cycle) of operation of neutron monitors DOMC and DOMB in Antarctica. Those instruments are a pair of mini neutron monitors in the standard and so-called “bare” (lead-free) configurations operated by Sodankylä Geophysical Observatory and located at the Concordia research station (3233 m asl) on the Antarctic plateau. The site is characterised by an exceptional suitability for cosmic-ray measurements because of the reduced atmospheric and absent geomagnetic shielding, allowing the neutron monitors to be very sensitive to the incoming flux of cosmic rays, especially to its lower energy part. This makes them perfect instruments for ground-based observation of solar energetic particle events. In this talk, we report how the instruments performed from January 2015, when they were deployed in Antarctica, up to January 2026. We cover the evolution of their electronics and the corresponding enhancement of capabilities. We talk about space-related phenomena observed by the neutron monitors, including the change of galactic cosmic rays over the solar activity cycle, six GLEs (ground-level enhancements caused by solar energetic particle events), and a number of Forbush decreases. The international neutron monitor community recognizes DOMC/B as a very valuable station in the global network of such instruments.

Near-Earth modulation parameter for study of the space climate

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The modulation to cosmic rays (CR) caused by the solar magnetic field and its variation is often quantified with the modulation parameter (or potential) ϕ. It enables us to describe the average modulation with a single parameter, calculated by employing the force-field approximation. Since individual CR's perform a random walk from the heliospheric boundary and can take months to travel to inner heliosphere and Earth, the parameter is usually considered only on monthly or longer timescales in order to focus on the wider heliospheric modulation.

However, recent results [1,2] show that the parameter is highly useful also for describing shorter term daily variations of the CR fluxes observed at Earth with ground- and space-based detectors. Taking this approach further, we have generated a hourly modulation parameter, describing short-term variations that happen in near-Earth space. The new process utilizes hourly data from 38 neutron monitors (NMs), as opposed to only 10 NMs in the previous version of the modulation parameter. The data also begins from the year 1951 instead of 1964.

In order to account for the variation of the geomagnetic field and the magnetosphere, rigidity cutoffs of particles are computed hourly for each 38 NM stations, which is an important database in itself for studying the CR variation. Work is underway to generate the modulation parameter automatically, creating a live, open-access dataset to the modulation parameter, which enables nowcasting of the near-Earth radiation environment

Initial results show that the hourly modulation potential can correctly describe the short-term modulation of the CR flux. Specific times exhibiting deviations in the result across the NM stations indicate, that during the onset phase of Forbush decreases caused by coronal mass ejections, we can observe the passing of the flux rope across near-Earth space. Also times of enhanced diurnal variation can be examined from the results. These promising results open new possibilities of utilizing NM data for the study of solar activity and the near-Earth radiation environment.

[1] Väisänen P., Usoskin I., Kähkönen R., Koldobskiy S. & Mursula K. (2023), Revised Reconstruction of the Heliospheric Modulation Potential for 1964–2022, Journal of Geophysical Research: Space Physics. https://doi.org/10.1029/2023JA031352
[2] Väisänen, P., Bertucci, B., Tomassetti, N., Orcinha, M., Usoskin, I., & Koldobskiy, S. (2025). Simulation of galactic cosmic ray proton fluxes with the daily modulation parameter: Validation with AMS-02 data for 2011–2019. Journal of Geophysical Research: Space Physics, 130, e2025JA033805. https://doi.org/10.1029/2025JA033805

Abstracts

Observation and analysis of recent transients in the heliosphere by space and ground-based instruments

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An omnipresent flux of high-energy subatomic particles, namely protons, alpha particles, and smaller amounts of heavier nuclei constantly bombard the Earth's atmosphere. These particles are of extra-terrestrial and extra-solar, mostly Galactic, origin and are collectively called galactic cosmic rays (GCRs). Variability of the energy-integrated GCR intensity is continuously measured by the worldwide network of neutron monitors (NMs) located around the globe. NMs are ground-based detectors measuring the nucleonic component of the cosmic-ray-induced atmospheric cascade and provide accurate monitoring of the GCR flux in the energy range of deka-GeV most affected by solar modulation. The flux of GCRs is nearly isotropic and varies at different timescales due to heliospheric modulation by the solar wind and embedded interplanetary magnetic field. In addition to the pronounced 11/22-year solar activity/magnetic cycle modulation, the GCR flux also exhibits notable transient suppressions due to coronal mass ejections (CMEs) and co-rotating interaction regions (CIRs) in the solar wind, called Forbush decreases (FDs). FDs strongly affect GCRs in the GeV – deka-GeV energy range, occurring on the timescale of hours to days and are caused by interplanetary shocks and/or magnetic flux ropes passing near the Earth. They are observed as relatively fast (within a few hours), sometimes two-step, decreases in the count rate of NMs, which can reach 25 –30. The decrease is usually followed by a slow gradual recovery taking up to several days or even a week, with a pronounced diurnal variability due to cosmic ray anisotropy. Strong FDs are often accompanied by major magnetospheric storms.

Moreover, Sun accelerates ions up to relativistic energies accelerated during solar eruptive events such as flares and CMEs. Such SEP events occur quite often when the Sun is active and are typically detected in open space, since Earth is protected by both its geomagnetic field and thick atmosphere. However, rarely, SEP events can be very energetic and intense, and initiate nucleonic-muon-electromagnetic cascades in the atmosphere, whose products can be detected on the ground, mostly by NMs. These types of SEP events are conventionally called Ground-Level Enhancements (GLE).

Herein, we report observations and analysis of recent transients, that is, FDs and GLEs, focusing on notable events: on September 2025 (FD) and the last GLE 77, occurred on 11 November 2025.

Leakage points in the Earth's magnetic shield: C-SpaRC and SafeEarth perspectives

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Polar regions are changing faster than other areas globally. The energy from the Sun emitted in a large variety of frequencies is powering the polar areas, but the energy is not distributed evenly over the latitudes.

We found out that over 40% of the available energy dissipates to the 2° wide band around 67° CGM when the area between 56-76° CGM is considered. During winter months the largest amount of energy dissipates to a narrower latitudinal range than in summer. Magnetic fluctuations are the most frequent about 5° more north, compared to the most energetic substorm impact area. These substorm-like magnetic features at Bear Island do not appear to distribute significant amounts of energy. Substorms in the southern Finland are relatively infrequent and furthermore bring as well quite small amounts of solar wind originated energy. However, the substorms reaching these latitudes are intense and long, resulting in relatively energetic substorm intervals.

SafeEarth Research Programme studies different aspects of comprehensive security e.g. space hazards and their impact to the technology and humans, cybersecurity and human security. SafeEarth together with C-SpaRC, a COSPAR Centre of Excellence, provide new knowledge on natural and human-made effects to the space-dependent societies.

Abstracts

Hemispheric and dawn-dusk asymmetries of Kelvin-Helmholtz waves

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Along with magnetic reconnection, Kelvin-Helmholtz (KH) waves are the main mechanisms controlling the solar wind-magnetosphere interaction. Kelvin-Helmholtz waves have been shown to be important for plasma transport into the magnetosphere, enabled by secondary processes such as reconnection, diffusion and wave-particle interactions. In this paper we use magnetohydrodynamical (MHD) simulations for studying how the Kelvin-Helmholtz instability (KHI) is modulated by the dipole tilt angle and IMF By. We find that KH wave activity on the magnetopause maximizes in the winter hemisphere and at dawn sector for positive IMF By. These asymmetries of KHI are caused by asymmetric draping of interplanetary magnetic field (IMF) in the magnetosheath and dawn-dusk asymmetry in magnetic reconnection, creating a broader boundary layer slowing the growth of KHI at dusk for positive By. These results are important, e.g., for understanding field-aligned currents generated by the KH vortices and their ionospheric effects during different seasons and IMF conditions.

Abstracts

Predicting geomagnetic activity in the ascending and declining phases of the solar cycle

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Most predictions of space climate, i.e., the long-term behavior of the solar-terrestrial environment, have focused on forecasting the 11-year sunspot cycle. Geomagnetic activity, on the other hand, has mainly been predicted in shorter, space weather time scales of up to a few days to weeks. Using a 180-year composite aa index, we aim to predict here the temporal behavior of geomagnetic activity over each solar cycle. By identifying separate peaks of activity in the ascending and declining phases of the cycle and a reduction of activity around the cycle maximum, we construct a simple double triangle wave model for each aa cycle. The large-scale features of the aa cycle depicted by the model are mainly related to changes in the occurrence of coronal mass ejections and high-speed solar wind streams. Using past aa and sunspot observations, we find interesting relationships for the predictability of the aa peak amplitudes and timings, suggesting intrinsic differences between even and odd cycles, possibly related to the magnetic (Hale) cycle of solar activity. Finally, we attempt to hindcast each past aa cycle as well as predict the ongoing Cycle 25, while also estimating the prediction uncertainty using a leave-one-out cross-validation methodology. Prediction of each cycle is made at the time of aa minimum at the start of the respective cycle, occurring typically a few months after the sunspot minimum.

Space Resilience CoE and effects of space weather storms on the Earth’s ionosphere-thermosphere

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The Research Council of Finland has selected SpaceResilience as one of the 11 Centres of Excellence for the 2026–2033 programme period. Prof Anita Aikio is the PI at University of Oulu, and she leads research related to the effects of space weather storms on the ionosphere-thermosphere system of the Earth. The whole consortium is led by Prof Minna Palmroth from the University of Helsinki, and other partners include the University of Turku, Aalto University and the Finnish Meteorological Institute. The Space Resilience CoE combines expertise in Space physics and technology to provide new information about the near-Earth space and upper atmosphere during normal and extreme space weather. The research will improve society's resilience to ever-changing space conditions and to the utilisation of space.

Long-distance propagation of VHF radio waves

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Radio waves at frequencies of tens MHz (HF-VHF band) may propagate in the Earth-ionosphere waveguide for such long distances as few thousand kilometres, if the ionospheric electron density is high enough. For example, in late October 2023 the Sodankylä meteor radar (36.9 MHz) detected powerful signal from a transmitter at presumable distance 1500 km. On the other hand, in November 2024 transmission of the Sodankylä meteor radar was received in the South UK, at 2500 km. These events occurred during high solar activity when ionospheric electron density was high. This feature is manifested in the power of radio noise at the SGO network of spectral riometers (20-55 MHz). We present and discuss dependences of the radio noise power on the solar activity and ionospheric F2-layer density during 2020-2023. Further, we suggest that the data of SGO spectral riometers may be used for passive ionospheric tomography to get 3D structure of the ionosphere.

Statistical insights to ionospheric disturbances detected by Swarm mission between 2014 - 2025

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Radio waves can be disrupted as they pass-through ionospheric irregularities. This directly impacts on performance and reliability of systems that use radio-wave-communication through ionosphere such as automated vehicles using satellite-based navigation systems. We investigate Swarm mission datasets for statistical properties of ionospheric irregularities sized from 50 km to 300 km, with amplitudes above one percent relative to the background electron density, measured in 2 Hz (~ 4 km) resolution by the Langmuir probe onboard Swarm satellites (A, B and C) that orbit Earth in near-polar orbits at 462 km (A and C) and 511 km (B) altitudes. Our observations indicate that the highest occurrence rate of these medium scaled ionospheric irregularities, globally, is observed during nighttime with preference towards the dawn side. The irregularities extend from high to low latitudes during night and show a deficiency for low latitudes during daytime. The disturbances are most often seen in solstice and solar minimum, and present higher relative amplitudes in winter.

Reconstruction of the full neutral wind velocity vector from measurements of scanning Doppler imagers

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Recently, a network of three scanning Doppler imagers (SDI) has been installed in the Fennoscandian region, at Abisko, Aakenus and Kevo [1]. The combined field-of-view of these instruments covers the EISCAT_3D observation volume. In parallel, a Fabry-Pérot interferometer (FPI) [2] has been relocated from Tromsø to Skibotn to complement the upcoming EISCAT3D observation of the thermosphere.

Both the FPI and SDI instruments provide measurements of line-of-sight (LoS) neutral wind velocity and temperature from green-line (E-region) and red-line (F-region) auroral emissions. Each SDI instrument observes the sky with about 140 degree field-of-view (FoV), and measurements are obtained from 115 looking directions. The FPI, in contrast, observes the thermosphere in the vertical and along the four cardinal directions (East, West, North and South), each with two zenith angles.

Together, the three SDIs form a tristatic configuration with an observation region extending more than 1000 km in both the east–west and north–south directions. However, only a small portion of this region contains overlapping viewing zones from all instruments, which limits the ability to directly retrieve the full three-dimensional neutral wind vector throughout the entire volume.

To address this limitation, here we present a new modeling technique that reconstructs the full neutral wind velocity vector from LoS measurements across observation volume of available SDIs. The method is based on the technique of spherical elementary systems and can incorporate measurements from both wide-FoV SDIs and narrow-FoV FPIs. We validate our approach using synthetic LoS data generated from WACCM-X thermospheric simulation. We also apply the technique to real LoS measurements from two SDIs and compare the reconstructed winds at FPI viewing locations with the corresponding FPI measurements. When combined with EISCAT_3D data, this approach will enable more detailed investigations of ionosphere–thermosphere coupling processes.

[1] https://baas.aas.org/pub/2023n3i076/release/1
[1] K.Shiokawa, et al., Earth, Planets and Space(2012). doi: 10.5047/eps.2012.05.004

A Deep Learning Approach for Modeling Ionospheric Equivalent Currents During Geomagnetic Storms

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The large-scale features of the equivalent currents are well known and captured by conventional models, but the storm-time dynamics and smaller-scale features are more difficult to predict. Here we present a new deep learning model for the ionospheric equivalent currents, based on a Residual Network (ResNet) architecture capable of handling large data sets and learning complex patterns in visual data. The model is trained on geomagnetic storms in solar cycle 23 (1997-2008) and it uses a 120 min time history of solar wind and magnetic indices as input parameters to predict the equivalent current vectors. Equivalent current vectors used in training are derived from SuperMAG ground magnetometer data covering the Northern Hemisphere [2,3]. Storms from solar cycle 24 (2009-2019) are used for evaluation, except those in 2015 which were used for validation during the training process. Case studies of geomagnetic storms show the potential of this ResNet model to represent the small-scale features of the equivalent currents during storm conditions. We will compare the model performance with a more conventional Solar Wind driven SuperMAG statistical Equivalent Current model (SW-SMEC) [1] and additionally test the performance of an alternative ResNet model trained solar wind data only (i.e. without ground-based magnetic indices).

[1] Manninen, J. T., Vanhamäki, H., Aikio, A. T., & Gjerloev, J. (2025). Statistical modeling and prediction of ionospheric equivalent currents based on SuperMAG data. *Journal of Geophysical Research: Space Physics, 130*, e2025JA034125. https://doi.org/10.1029/2025JA034125

[2] Waters, C. L., J. W. Gjerloev, M. Dupont, and R. J. Barnes (2015). Global maps of ground magnetometer data, *Journal of Geophysical Research: Space Physics, 120*, 9651–9660, https://doi.org/10.1002/2015JA021596

[3] SuperMAG (2025). About SuperMAG. https://supermag.jhuapl.edu/info/ (accessed December 11, 2025)

EISCAT_3D – New Capabilities in the European Arctic

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EISCAT is currently building EISCAT_3D, the World's most advanced 3-dimensional imaging radar for atmospheric, ionospheric and near-Earth space investigations. EISCAT_3D will be capable of tracking satellites as well as observe meteors and asteroids.

The fully steerable, tri-static, phased-array incoherent scatter radar is located in Skibotn (Norway), Karesuvanto (Finland), and Kaiseniemi (Sweden). It is foreseen that EISCAT_3D will be able to make first science observation with a subsystem of the Skibotn radar (NO-7) with 637 kW. Thereafter, EISCAT_3D will gradually expand to fully tri-static operations.

EISCAT_3D is a European Strategy Forum for Research Infrastructures (ESFRI) Landmark in the Environment domain.

Here we will give an overview of the current status of EISCAT and EISCAT_3D and it's future use for ionospheric as well as space object/space debris work.

Multipurpose modulations and optimal plasma parameter fit techniques for EISCAT3D

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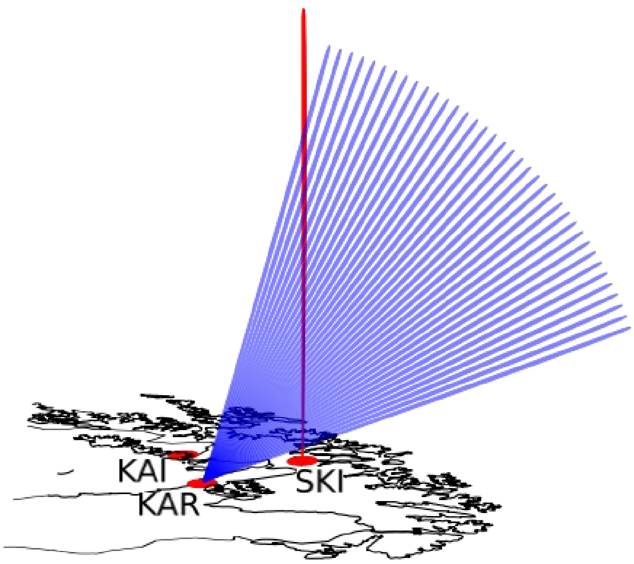
The EISCAT3D incoherent scatter radar will make volumetric measurements of the ionosphere by means of rapidly scanning a core-site transceiver beam that is followed by fans receive-only beams of two remote receivers. While the beam scanning provides coverage in horizontal direction, measuring the whole ionosphere from D region to topside requires transmission modulation and signal processing techniques that enable one to sufficiently sample the incoherent scatter spectra from the whole range of altitudes. Such techniques are not in routine use in any incoherent scatter radar system in the world. The numerous remote receive beams also provide large amounts of high-quality incoherent spectrum measurements, which should be optimally exploited to gain the best possible statistical accuracy of the plasma parameters fitted to the observed incoherent scatter spectra.

Using synthetic EISCAT3D radar signals, we show that the concept of multipurpose incoherent scatter modulations that enable one to sufficiently sample the spectra from D region to topside can be generalized to the EISCAT3D system, and the data processing is possible with modest computing power [1]. Furthermore, accuracy of the plasma parameter fits can be greatly improved if data from all receive sites and beams are optimally combined by means of "multistatic" incoherent scatter analysis [1,2]. The results suggest that the advanced transmission modulation techniques and the multistatic plasma parameter fits may provide an order of magnitude improvement to time resolution of EISCAT3D measurements, as compared to analysis of core transceiver site data with traditional modulation techniques. Accuracy of the E region measurements may be good enough for ion-neutral collision frequency fits.

[1] Ilkka I. Virtanen, Ayanew Nigusie, Antti Kero, Neethal Thomas, and Juhana Lankinen, Multipurpose incoherent scatter measurement and data analysis techniques for EISCAT3D, Atmos. Meas. Tech., 18, 5895-5917, 2025. https://doi.org/10.5194/amt-18-5895-2025

[2] I.I. Virtanen, D. McKay-Bukowski, J. Vierinen, A. Aikio, R. Fallows, and L. Roininen, Plasma parameter estimation from multistatic, multibeam incoherent scatter data, Journal of Geophysical Research: Space Physics, 119 (12), 10528-10543, 2014. https://doi.org/10.1002/2014JA020540



Characteristics of Medium Scale Traveling Ionospheric Disturbances using EISCAT VHF measurements

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The vertical profiles of medium scale traveling ionospheric disturbances (MSTID) characteristics in the ionospheric E and bottomside F regions using multiple daytime runs of EISCAT VHF measurements are revealed with manda experiment mode. Spectral analysis is applied to identify the dominant wave amplitudes and periods, while a cross-correlation method is used to determine the vertical wavelength, λ_z. It is observed that the dominant relative amplitude ($\delta Ne/Ne$) reveal both seasonal and height variations. The amplitudes of MSTIDs observed during winter are approximately 5 - 10 times larger compared to other seasons. Additionally, $\delta Ne/Ne$ exhibit a general increase with height during winter, whereas during other seasons, they show mixed trends. The seasonal dependence of MSTID amplitudes may depend on the pattern of meridional wind direction and the prevailing conditions such as absence or presence of strong mesospheric wind shear for upward propagating gravity waves. The vertical wavelength show a gradual/faster increase during winter/summer, corresponding to colder/hotter ionosphere. This suggests that although AGW-MSTIDs can reach higher altitudes in summer due to faster growth of λ_z, they can be less detectable due to lower amplitudes. Furthermore, waves with shorter λ_z that would reach the F2-region during winter are more likely to decay at lower altitudes in summer because of increased viscosity.

Recent observation of Joule heating in the D-region ionosphere utilising EISCAT, KAIRA and SGO spectral riometers

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EISCAT VHF experiment carried out during a recent geomagnetic storm plus a solar proton event on 12 November 2025, revealed an interesting and unique observation of plasma heating signatures in the D-region ionosphere down to 70 km altitude. The ongoing solar proton event causing enhanced ionization down to 50 km, enabled us to observe this heating event for the first time in the D-region altitudes. We have analysed the incoherent scatter (IS) spectral width and backscattered power in the D-region altitudes (50-95 km) by fitting these parameters to the measured autocorrelation function (ACF). The measurements show instances of enhanced spectral width which are short lived (approx. 10 min) in altitudes between 70-95 km. These spectral width enhancements observed in the D-region are found to be consistent with the GUISDAP estimates of ion and/or electron temperature enhancements in the E region. One of the interesting observations is that during these heating peaks, the backscattered power is found to be decreased in the D-region, which might have resulted by an enhancement in the electron temperature and not decrease in the ionization. In addition, the simultaneous cosmic noise absorption (CNA) measurements from KAIRA imaging riometer in Kilpisjärvi shows one to one correlation with the EISCAT heating peaks and anti correlation with the backscattered power. These observations from KAIRA also supports the idea of enhanced electron temperatures in the D-region altitudes causing these heating events. These heating signatures were found to be present in all KAIRA beams plus the SGO spectral riometers (Sodankylä, Ivalo, Kilpisjärvi, Abisko and Kevo) suggesting a large spatial extent of the event over the Northern Scandinavia. Our analysis utilizing simultaneous measurements from EISCAT, KAIRA and spectral riometers suggest Joule heating in the D-region altitudes down to 70 km caused by the frictional heating of electrons and the neutrals driven by enhanced conductivity and electric fields. Preliminary results from this study will be presented.

Status report from Kiruna Atmospheric and Geophysical Observatory

Urban Brändström (1) and many others
(1) Swedish Institute of Space Physics

Kiruna Atmospheric and Atmospheric Observatory (KAGO) is responsible for observatory (long-term monitoring) activities within Swedish Institute of Space Physics (IRF). About 55 instruments are operated at 12 locations within Sweden and includes many observatory instruments as: allsky cameras, atmospheric trace-gas measurements, magnetometers, infrasound measurements, ionosondes and riometers as well as many guest instruments and a national research infrastructure for imaging absolute measurements of atmospheric emissions (ALIS_4D). Many instruments are also complementary to EISCAT_3D. This presentation provides a brief status report of activities during 2025.

Atmospheric electrical variability due to ionisation rate changes at Sodankylä

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Ionisation is responsible for the existence of charge in the atmosphere, and key to driving atmospheric electrical processes such as thunderstorm electrification and the Global atmospheric Electric Circuit (GEC). In the lower atmosphere the main contributions to the ionization rate are from surface radioactivity (radon (Rn-222) and its progeny; as well as terrestrial gamma ray emission), but also galactic cosmic rays. Rn-222 is highly dependent on local geological factors, soil moisture conditions, and meteorological conditions – particularly the turbulent state of the lower atmosphere. Variations in Rn-222 cause fluctuations in the ionization rate, which is known to vary the local conductivity and atmospheric electric field (referred to here as potential gradient (PG)), but detecting such fluctuations in PG can be difficult due to the number of processes affecting PG locally, and few long term studies at clean air sites are available in the literature.

This work presents measurements of PG made in Sodankylä since 2017 using a Campbell Scientific CS110 Electric Field Mill, and analyses the diurnal and seasonal variability in PG alongside the variability in co-located ionisation measurements (Rn-222, as well as gamma radiation from natural radioactivity and galactic cosmic rays). Rn-222 typically maximises overnight and during early morning before sunrise, supporting previous research on the role of atmospheric turbulence in dissipating ion layers close to the surface. Rn-222 concentrations are highest during the winter months, which is when the boundary layer stability tends to be highest thus preventing upwards dilution of Rn-222. On a statistical basis, examining all fair weather data, there is little evidence that variations in ionization rate play a significant role in dominating PG behaviour at Sodankylä, however, this is not the case on an individual daily basis.

A week long case study during a prolonged fair weather period demonstrates strong inverse correlations between ionization rate and PG changes during overnight periods with strong boundary layer stability. The magnitude of these changes is comparable with that expected by theory, using the ion balance equations. Further analysis using radiosonde vertical profiles of temperature demonstrate a strong link between the stability of the boundary layer, and the overnight PG minima /ionization rate maximum, which is supported by statistical analysis from 51 daily case studies. Overall this work contributes to understanding around how conductivity variations resulting from changes in local ionisation rate contribute to PG variability over a range of diurnal and seasonal timescales.

A brief history of aurora-related citizen science in Northern Europe

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(4) Swedish Institute of Space Physics

The mechanism behind the formation of the Northern Lights remained a mystery for most of the 19th century. There were few instruments available to observe their formation and occurrence. Multiple observers across the country could gather information of aurora displays reliably by-passing local cloud covers.

In the 19th century, in a society largely based on agriculture, the people’s ability to write was still limited. Thus, personnel from parsonages and sea captains were regarded as capable observers. Through letter campaigns, more accurate statistics on the occurrence of the Northern Lights could be obtained. Interpreting the non-homogeneous observation data was considered time-consuming. (1, 2)

In the 20th century, technological advancements brought new communication methods within reach of more people. Mail was delivered faster by car, and having a radio receiver in the corner of the home was no longer uncommon. Radio also gave households the opportunity to set the time precisely.

During the International Geophysical Year (1957–1959), numerous research organizations in different countries launched observation campaigns targeting especially members of astronomical societies, radio amateurs, and pilots. (3)

Gradually, from the 1950s onward, film cameras became more common in homes, and even hobbyists well-versed in photography could capture auroras. It wasn’t until the spread of digital cameras in the 2000s that a true golden age of photographing natural phenomena began.
The rise of the internet in the late 1990s accelerated the sharing of observation data, and today, several digital observation databases are already in use. (4) In Finland, Taivaanvahti/Skywarden -site modernized the collection of aurora observations.

[1] H. Nevanlinna, *Magneettisia ja meteorologisia havaintoja Suomessa 1800-luvulla* https://doi.org/10.35614/isbn.9789523362079 (2025)
[2] K. Moss and P. Stauning, *Sophus Peter Tromholt: an outstanding pioneer in auroral research, Hist. Geo Space Sci., 3, 53–72 (2012)*
[3] W. Schröder, *Amateur observations of atmospheric phenomena during the IGY (2007).* EOS Trans Am Geophys Union 88(12):141–143. https://doi.org/10.1029/ 2007E O1200 02
[4] M. Grandin,V. E. Ledvina, S. Musset, S. et al.*, Citizen Science in Space and Atmospheric Sciences: Opportunities and Challenges*. Surv Geophys (2025)

Abstracts

Citizen science data for dune aurora study

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We are studying the mechanism associated with the phenomenon referred to as 'dune auroras', consisting of parallel stripes of brighter emission in the green diffuse aurora. For this purpose, we are collecting Citizen Science Data in the form of photographs of auroras taken by the general public.

There is a thriving community of aurora enthusiasts who share their photos on community websites like SkyWarden (www.taivaanvahti.fi). These photos provide a valuable and rich source of data for studying any aspect of auroras. The photos can be downloaded and collected, and used for further research. Also available are metadata of the time and location of the photos.

The precise direction in which the photos were taken, is obtained using software from the website https://astrometry.net/, which detects the stars visible in the photos and compares their formations to catalogues of star formations. This gives the right ascension and declination of the view direction of the photos. Together with the time and location information, these can be converted to azimuth and elevation of the view direction of the camera. With this information, and assuming a thin ionosphere at a certain altitude, the photos can be projected onto the ionosphere.

The development of the procedures for this (including error-catching, removal of unwanted objects from photos etc.) is still ongoing. Preliminary results however look promising. An example is shown in Figure 1.

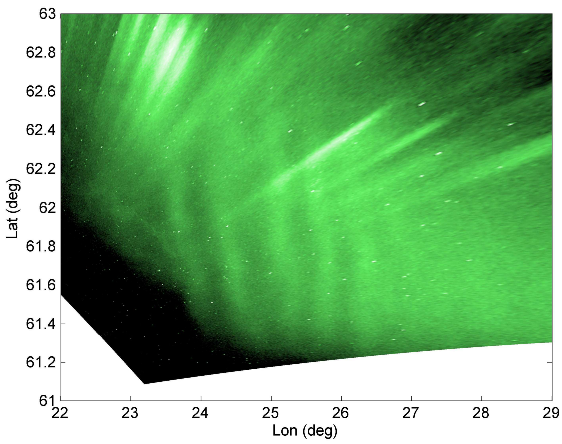

Figure 1: Left: Citizen-science photo of aurora taken on 17 December 2023 by Tapio Nylund at Eurajoki. The rightmost part of this photo contains dune auroras.
Right: The green colour of the photo projected on the ionosphere at 100 km altitude, as function of latitude and longitude. The dunes are seen here as north-south oriented lines.

Dune aurora: Statistical survey from a citizen science database

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(2) The University Centre in Svalbard, Longyearbyen, Norway,
(3) Sodankylä Geophysical Observatory, University of Oulu, Sodankylä, Finland
(4) Skywarden observation system, Ursa Astronomical Association, Helsinki, Finland
(5) Aurorasaurus, New Mexico Consortium, Los Alamos, NM, USA

Auroral forms can provide information not only on the state of near-Earth space but also on conditions in the lower-thermosphere–ionosphere. The so-called dune aurora, consisting of brighter stripes forming a wave-like pattern in the dim, diffuse green aurora, has been hypothesised as being an optical signature revealing the presence of large-scale atmospheric waves above or near the mesopause. However, only a few dune aurora events have been studied to date, leaving many open questions regarding the nature of this phenomenon. We carry out the first statistical analysis of dune aurora events by collecting citizen science observations of the dunes since 2000 using the Skywarden (https://taivaanvahti.fi) database of observations. From a total of 289 dune aurora observations made during 56 different events by citizen scientists from Northern Europe, North America, Australia, and New Zealand, we investigate the distribution of dune events as a function of location, month, local time, solar wind and interplanetary magnetic field (IMF) conditions, and geomagnetic activity. We compare those distributions to that of all the aurora observations reported in Skywarden since 2000. We also estimate the duration of dune events based on the available observations, and we investigate a possible relationship between dune aurora and equivalent current patterns derived from ground-based magnetometer measurements. We find that the vast majority of dune observations take place near the equatorward boundary of the auroral oval, in the dusk sector earlier than the peak in all auroral report distribution, and in association with strong (in most cases eastward but occasionally westward) auroral electrojet signatures. The dune observations are often associated with elevated solar wind density and IMF magnitude, and the IMF B_y component may play a role in their formation. Finally, their monthly distribution peaks in March and October, which could be the result of a combination of geomagnetic, atmospheric, darkness, and cloudiness conditions needed for them to form.

Abstracts

Textiles, Planetary Data, and Cultural Memory: Material Approaches to Geophysical Observation

A. Michèle Boulogne(1),
(1) Artist in Residence 2026, *Adaptation – Time is not on our side, towards possible futures*. Project Oulu 2026 PhotoNorth and SGO

This presentation introduces the artistic research practice of textile designer and researcher Michèle Boulogne [1][2], whose work investigates how scientific observation enters cultural memory through material translation.

Her practice examines how distant or abstract planetary phenomena become part of human narratives and collective imagination.
By combining handmade and industrial techniques with geospatial and astronomical data, textiles occupy a central role in this investigation: they hold technical, symbolic, and communal significance, and operate as material receptacles for data and carriers of meaning across history.

Recent projects, including knitted interpretations of Venusian SAR data from the Magellan mission developed in collaboration with planetary scientists, demonstrate how craft-based methodologies can render remote-sensing information tangible, while making visible the cultural frameworks that shape scientific data itself.
In this sense, planetary sensing, its naming, imaging, storage, and communication, appears not only as a technical process but as part of a broader cosmological construction.

During her residency at SGO in early 2026, Boulogne will focus on the material nature of planetary sensing generated at the Observatory, from VLF emissions to solar storm monitoring, as well as the human and historical infrastructures that have shaped their production since the Observatory's founding in 1913.

Her research aims to understand these signals as expressions of adaptation, rhythm, and vulnerability, captured in a local environment yet reflecting a planetary scale.

[1] *micheleboulogne.com*
[2]*https://www.makery.info/en/*

Enhancing the Kalman filter approach to ionospheric imaging with measurement-based background model

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Imaging of ionospheric electron density from GNSS measurements is an ill-posed inverse problem that cannot be uniquely solved from the measurements alone. The satellite-to-Earth measurement geometry inherently limits the available information, especially with regard to vertical structures. This fundamental issue is typically addressed by imposing additional constraints that ensure a unique and stable solution. These constraints may be introduced at various stages of the analysis, through the measurement model, the solution algorithm, or as additional statistical or physical assumptions, or combinations thereof.
The Kalman filter framework [1] introduces physically motivated statistical constraints by representing the ionospheric state and its associated uncertainty as a probability distribution. This explicit probabilistic formulation also exposes the substantial restrictiveness of the required constraints. In practice, the Kalman filter is typically configured to constrain the solution to remain close to a predefined climatological ionospheric background model. Consequently, if the background model is poorly aligned with the true ionospheric state, the measurements typically struggle to correct for the systematic errors, particularly in the peak height, where the measurement geometry poses the fundamental challenge.
To overcome this limitation, we extend the Kalman filter based TomoScand program [2] to incorporate measurement-based background models using generalised additive models (GAM). Existing key parameters, such as hmF2 and NmF2, are interpolated over the region of interest using GAM with local observations from ionosondes, incoherent scatter radars, and radio occultation profiles. The resulting 2D parameter fields are then used to construct a 3D electron density background using standard ionospheric profile models. By imposing smoothness assumptions that compensate for the spatiotemporal sparsity of the measurements, a realistic background representation is constructed, while remaining consistent with the available local observations. The method allows for near real time computation and is directly compatible with a Kalman filter based framework.
In this presentation, we describe the implementation of the method and demonstrate the performance for various geographic regions and geomagnetic conditions.

[1] Bust, G. S., Garner, T. W., & Gaussiran II, T. L. (2004). Ionospheric Data Assimilation Three-Dimensional (IDA3D): A global, multisensor, electron density specification algorithm. J. Geophys. Res., 109. https://doi.org/10.1029/2003JA010234
[2] Norberg, J., Käki, S., Roininen, L., Mielich, J., & Virtanen, I. I. (2023). Model-Free Approach for Regional Ionospheric Multi-Instrument Imaging. Journal of Geophysical Research: Space Physics, 128(1). https://doi.org/10.1029/2022JA030794

ESTIMATION OF COSMIC RADIO NOISE ABSORPTION SPECTRUM BY SPECTRAL RIOMETRY

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(2) Tampere University

In this talk in presented method to estimate the signal-to-noise ratio of a spectral riometer measurement. Often considering SNR effect is neglected from the analysis of spectral riometer measurements. Relatively poor SNR will introduce bias to the spectral shape of absorption spectrum and the overall absorption measurement. Measurement can be calibrated by finding the SNR. Calibrated measurement produces more reliable spectral shape and allows varied further studies from spectral riometer measurements.

"MIAMI Project: Overview, Planning and Coordination"

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Sodankylä geophysical observatory, University of Oulu

Project Concept: Develop a novel methodology and methods for continuously monitoring and short-term prediction the 3D electron density of the ionosphere, using scalable instruments for global coverage and ensuring effective implementation in disturbed high-latitude ionospheric conditions.

Project objectives:

1) Develop deep-learning-based models for precise and near-real-time ionosonde and all-sky camera data interpretation.

2) Investigate the characteristics, generation mechanisms, and sources of medium-scale ionospheric disturbances in the high- latitude.

3) Develop deep-learning-based short-term predictive models of ionospheric parameters.

Additional objective:

4) Develop deep-learning-based models for near-real-time reconstruction of 3D Ne(h) of the ionosphere.

Preliminary results:

The programming tool for determination of standard ionospheric parameters based on a deep-learning approach was developed [1]. This is currently the first and only deep-learning-based system used for routine interpretation of data from ionosondes without the need for verification by a qualified operator (https://www.sgo.fi/Data/Ionosonde/latestIonosonde.php). Currently, the development of an approach and deep-learning models to recognize the entire ionospheric layer—without ground truth data and compatible with any type of ionosonde—is ongoing and shows promising preliminary results (see Figure 1).

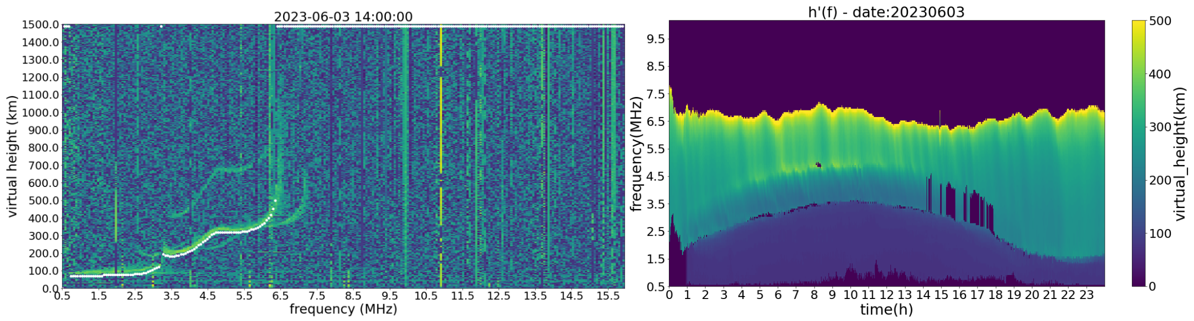

Figure 1. Typical ionosonde data (left) with white dots indicating the result of the automatic interpretation of ionospheric layers h'(f). The right image shows the daily representation of interpreted ionospheric layers.

[1] Sherstyukov, R., Moges, S., Kozlovsky, A., & Ulich, T. (2024). A deep learning approach for automatic ionogram parameter recognition using convolutional neural networks. Earth and Space Science, 11, e2023EA003446. https://doi.org/10.1029/2023EA003446

Volumetric Ion Composition Fitting Technique for EISCAT3D

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Ion composition is a crucial parameter for many aspects, such as determining ion–neutral energy exchange rates, studying ion upflow within the ionosphere and outflow from the ionosphere to the magnetosphere, and studying ion–neutral chemistry and electron recombination rates [2]. Incorrectly modelled ion compositions also bias electron and ion temperature fits to incoherent scatter spectra. However, making ion composition measurements in the lower F-region ionosphere is very challenging, because rocket measurements are rare and localized, and fitting ion composition to incoherent scatter spectra is very difficult.

EISCAT3D will be an invaluable instrument to provide volumetric observations of the ionosphere. Yet, optimal data-analysis tools need to be developed to fully exploit this unprecedented capability. ISfit [1] is a data analysis tool that enables optimal plasma parameter fits to data from multiple multibeam receivers of an EISCAT3D-like radar system. O^+ ion fraction fits to field-aligned incoherent scatter radar measurements are enabled by the Bayesian Filtering Module (BAFIM) [2], which applies Bayesian filtering in time and smoothness priors in range, coupled with the Ion Density Calculator (IDC) chemistry model. By combining the BAFIM–IDC technique with ISfit and binning the data in magnetic latitude and longitude, one can make volumetric fits of the O^+ ion fraction and several other plasma parameters. We apply this technique to estimate 2D plasma parameters, including the O+ ion fraction, using measurements from meridional scans of the EISCAT Svalbard Radar (ESR) 32-m antenna.

[1] Virtanen, I. I., D. McKay-Bukowski,J. Vierinen, A. Aikio, R. Fallows, andL. Roininen (2014), Plasma parameter estimation from multistatic, multibeam incoherent scatter data, JGR: Space Physics, https://doi.org/10.1002/2014JA020540.
[2] Virtanen, I. I., Tesfaw, H. W., Aikio, A. T., Varney, R., Kero, A., & Thomas, N. (2024). F1 region ion composition in Svalbard during the international polar year 2007–2008. JGR: Space Physics, https://doi.org/10.1029/2023JA032202.

Induced and Natural Space Environments and Effects on Spacecraft Science Payloads

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Spacecraft science payloads are integrated on a spacecraft, and can range from a space station to a dedicated probe or spacecraft. These science payloads will experience the combined effects induced by the spacecraft and the natural environment. This presentation will discuss spacecraft induced environments (i.e., molecular and particulate contamination) and the combined effects through the interaction with the local natural environment (i.e., plasma effects, ionizing radiation, ultraviolet radiation, atomic oxygen). Understanding the combined effects of the induced and natural environment is critical to protecting the mission science objectives, and ensuring our science payloads are successfully integrated with the spacecraft and other science instruments that may be co-located on the space system. Examples of science payloads that either failed to operate or had to be deactivated due to incompatibility with induced and natural environments will be presented to illustrate issues associated with science payload design and mission planning.

Can auroral activity have an effect on the upper-mesospheric temperature?

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(2) Aalto University, Finland,
(3) University of Southampton, UK,
(4) University Centre in Svalbard, Norway

Auroral electrons are not energetic enough to penetrate down into the mesosphere, therefore the influence of auroral activity on the upper mesospheric temperature (~87km altitude) has not been studied extensively. Only a handful of studies have investigated the response of upper-mesospheric temperature to auroral activity, and possible temperature enhancements have been revealed in individual events.

We utilize 13 seasons (October-March) of All-Sky Airglow Imager data from the Kjell Henriksen Observatory in Longyearbyen (75.24°N, geomagn. latitude) between 2011 and 2024. The rotational OH* airglow temperature is derived from the ratio of the P1(2) and P1(4) molecular rotation lines. In addition, data from the Svalbard All-Sky Imager in Longyearbyen is used to identify regions of active aurora. The 557nm (auroral green line) emission brightness is used as a proxy for auroral activity. Auroral emissions contaminate the airglow spectrum and thus airglow derived temperature estimates are only reliable during times of no aurora. From the airglow images, we extract regions of interest near zenith and compare the derived temperatures before and after auroral activity for each region. We present preliminary results of increased OH* rotational temperature after times of active aurora.

Ozone responses to the geomagnetic storms in 2024 and 2025

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(1) Finnish Meteorological Institute, Finland
(2) Norwegian Institute for Air Research-NILU, Norway
(3) Utah State University, USA
(4) Norwegian University of Science and Technology

Solar Cycle 25 has approached its maximum phase, bringing an elevated frequency of solar eruptive events and associated geomagnetic disturbances. During 2024 and 2025, several intense geomagnetic storms have provided rare opportunities to examine the short-term coupling between space-weather forcing and the middle atmosphere. Previous studies have shown that energetic particle precipitation (EPP) during geomagnetic storms can substantially modify the chemical composition of the mesosphere and lower thermosphere (MLT), particularly through the production of odd nitrogen (NOx) and odd hydrogen (HOx), which catalytically destroy ozone. In this presentation, we investigate the MLT ozone responses to several large geomagnetic storms occurring in 2024–2025 using satellite observations. We will also assess how these responses compare to those observed in previous solar cycles.

Ground based validation of the EPP models used in climate models by the EISCAT datasets

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The energetic particle precipitation (EPP) forcing is included into the recent CMIP climate modelling recommendations. According to these simulations, the impact of inclusion of the medium energy electrons to the ozone variability was estimated to be 12-24% in the mesosphere and 5-7% in the stratosphere. However, to obtain a continuous particle forcing required for these multi-decadal simulations, the precipitating particle flux spectrum was parameterised by the magnetic Ap index to match statistically to the POES satellite's MEPED particle detector data. This rather simple approach has several uncertainties, but the most critical one is that the existing satellite-borne particle detectors, including the MEPED instrument, struggle to separate the loss cone populations from trapped particles, leading to biases in EPP forcing especially in the relativistic energies. In this presentation, we evaluate the modelled electron densities against the EISCAT VHF datasets. This approach provides a direct ground-truth evaluation of the ionisation taking place in the mesosphere-lower thermosphere.

Propagation Efficiency of Lightning-Generated Whistlers into the Inner Magnetosphere using Arase and WWLLN data

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(2) Institute of Atmospheric Physics CAS, Czechia,
(3) Charles University, Czechia,
(4) Kanazawa University, Japan
(5) UCLA, USA,
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Lightning discharges in the Earth's atmosphere emit electromagnetic waves over a broad frequency spectrum. In the Very Low Frequency (VLF) range, a portion of this energy penetrates upwards into the ionosphere, propagating into the inner magnetosphere as whistler-mode waves. These lightning-generated whistlers (LGWs) are known to cause pitch-angle scattering of radiation belt electrons, leading to their precipitation into the atmosphere. Numerous studies have suggested that lightning significantly impacts radiation belt electrons. However, based on a year-long comparison between global lightning activity measured by the World Wide Lightning Location Network (WWLLN) and trapped electron fluxes observed by both Van Allen Probes (RBSP), Martínez-Calderón et al. (2020) reported an attenuated effect that did not align with theoretical expectations [1]. A more recent analysis incorporating WWLLN, RBSP, and Arase data for 2018 yielded similar results.

To account for these results, we suggest that LGWs, especially the ducted whistlers that drive pitch-angle scattering, propagate to the radiation belts with low efficiency. This study aims to verify this hypothesis using observational data, focusing on periods of high lightning activity in 2018. First, we extracted whistlers from the Arase satellite data to determine the proportion of ducted whistlers using a semi-automated whistler detection system based on the Oike et al. (2014) method [2]. We then applied a polarization analysis and selected ducted waves with wave normal vector angles below 32 degrees [3]. We finally compared these results with WWLLN data to investigate the ratio of ducted whistlers relative to the number of lightning strokes, thus estimating the propagation efficiency.

[1] C. Martinez-Calderon et al., *JGR: Space Physics* (2020) doi.org/10.1029/2019JA027763
[2] Y. Oike et al., *JGR: Space Physics* (2014) doi.org/10.1002/2014RS005523
[3] Alexandra M. Wold et al., *JGR: Space Physics* (2024) doi.org/10.1029/2024JA032781

Airborne lead-210 and lead-212 at Sodankylä, northern Finland

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Various components of airborne radioactivity have been monitored at Sodankylä, northern Finland since 1961. The activity concentration levels of lead isotopes 210 and 212 have been measured among other parameters. Lead-210 (^{210}Pb) in the atmosphere is a decay product of the radioactive noble gas radon-222 exhaled from the soil to the atmosphere. Radon-222 has an average lifetime of five days. Thus, it can quite efficiently penetrate into the atmosphere through the snow cover. Airborne lead-210 is attached mainly to the accumulation mode aerosol particles with an aerodynamic diameter of a few hundred nanometers. These aerosol particles are mainly removed from the atmosphere by wet deposition [1]. The removal rate of ^{210}Pb is governed by the aerosol particle residence time as the average lifetime of ^{210}Pb is almost 37 years.

Radon-220, in turn, has an average lifetime of only 1½ minutes and it cannot break through a snow cover within its lifetime. In the atmosphere radon-220 decays to lead-212 which has a mean lifetime of about 17 hours. Thus, airborne lead-212 can be transported over relatively large distances within its lifetime [2].

Owing to the different production and removal rates the activity concentration levels of the lead isotopes show opposite seasonal variation. Lead-210 has a seasonal minimum in summer and a maximum in winter while lead-212 has a seasonal minimum in winter and a maximum in summer.

[1]. J. Paatero et al. Aerosol particle size distribution of atmospheric lead-210 in northern Finland. Journal of Environmental Radioactivity 172: 10-14 (2017)

[2] R. Mattsson et al. Automatic Alpha/Beta Analyser for Air Filter Samples - Absolute Determination of Radon Progeny by Pseudo-coincidence Techniques. Radiation Protection Dosimetry 63: 133-139 (1996)