'MIST Open Session (OpenMIST)' Abstracts

Talks

Do Solar Energetic Particle events impact lower-atmospheric temperatures on Mars?

Authors

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Abstract

The martian atmosphere is sensitive to disturbances in interplanetary space due to the absence of a strong planetary magnetic field. Solar energetic particle (SEP) events comprise high-energy, electrically-charged sub-atomic particles and are produced during solar flares and coronal mass ejections. Previous work has shown that SEPs result in diffuse aurorae, disruption of radio propagation, the dispersion of atmospheric compounds, and the ionisation of atmospheric layers. In this study, we explore the relationship between SEP events and lower-atmospheric heating at Mars. Five SEP events with durations of four days or longer were identified in the years 2020-2021. Measurements from the Mars Atmosphere And Volatile EvolutioN (MAVEN) mission and the Trace Gas Orbiter (TGO) spacecraft are compared to atmospheric temperature profiles derived from the Mars Climate Database. Specifically, Mars' lower-atmospheric temperature profiles before, during and after the SEP events are analysed. No strong evidence is found that indicates SEP events lead to the heating of Mars' atmosphere. However, in the one case, a SEP event occurred concurrently with an expanding global dust storm. In this case, a clear heating effect is observed, but further research is required to attribute atmospheric temperature variations as a result of the global dust storms and SEP events where the two occur simultaneously.

Adapted empirical modelling of near-Sun solar-wind speeds for use in ensemble forecasts

Authors

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Abstract

Empirical relations are used to link modelled coronal magnetic-field structure --particularly flux-tube expansion and distance to coronal hole boundary-- to solar-wind speed. There is a lot of uncertainty embedded within these relations, particularly when used as an interface for heliospheric models. Hence, augmenting these relations could provide a powerful way to sample model uncertainty using ensemble techniques. We present a simplified empirical solar-wind speed equation that can be readily optimised for different configurations of a Potential Field Source Surface and Schatten Current Sheet (PFSS+SCS) coronal model, in-lieu of the full Wang–Sheeley–Arge (WSA) equation. Optimisation is performed using an 11-year reanalysis dataset of in-situ solar-wind speed observations, reconstructed at 21.5 rS across longitudes at the sub-Earth point via a combined corotation and backmapping technique. We trial several functional forms for the simplified equation and explore three linear-regression techniques, highlighting the challenges of fitting empirical relations to noisy data. To minimise overfitting, we select a regression approach that fits directly to the distribution of reconstructed observations. Using a k-fold cross validation method we find an equation candidate that successfully reproduces the distribution of observed solar-wind speeds and performs comparably to WSA when coupled with the Heliospheric Upwind eXtrapolation with Time-dependence (HUXt) model to generate hindcasts at 1 AU. The new equation is not intended to replace WSA; the internal complexity remains a key element for WSA. Due to its simplicity, our equation produces less variability than WSA on average. The trade-off in complexity is balanced by usability within ensemble/multi-model frameworks. The equation can be easily perturbed to quantify uncertainty in windspeed magnitude and easily re-optimised for PFSS+SCS models with different source-surface and outer-boundary heights.

Diffusion Coefficients for Resonant Relativistic Wave-Particle Interactions Using the PIRAN Code

Authors

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Abstract

Quasilinear diffusion coefficients can be used to model the response of charged particles to resonant wave-particle interactions. The calculation of these coefficients is sufficiently complicated and arduous to render it prohibitive to many potential users, because of the expense in time spent developing the code. The PIRAN software package (”Particles In ResonANce”) is written using Python, and allows the user to calculate local and bounce-averaged relativistic diffusion coefficients in energy and pitch-angle space via the two main current proposed methods in the literature. The code is predominantly based upon the formalisms and methods presented in Glauert and Horne (2005, https://doi.org/10.1029/2004JA010851) and Cunningham (2023, https://doi.org/10.1029/10.1029/2023JA031703). We solve for diffusion coefficients using exact relativistic formulae. We use Gaussian spectra in wave frequency and in tangent of the wave normal angle and solve the full cold-plasma dispersion relation. At present the code supports fully tested calculations for electron diffusion coefficients based on whistler-mode waves in a fully ionized proton-electron cold plasma. However the codebase architecture is built such that future developments to include other wave modes and other plasma compositions should involve incremental additions. The initial release of PIRAN may not have the same number of features as some other numerical codes, but is has the advantages of being a fully open-source diffusion coefficient code that: (a) supports calculation of both local and bounce-averaged diffusion coefficients via both of the two proposed methods; (b) is written fully in Python; (c) has detailed user pages, commit history and changelog on GitHub.

Kinetic energy variations within drift orbits: a study in UBK space

Authors

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Abstract

Three dimensional radiation belt models like the BAS Radiation Belt Model and the VERB code assume that trapped electrons within the model space remain at a fixed kinetic energy in the absence of wave-particle interactions. However, it is also accepted that at lower energies convection due to the electric field can significantly alter the trajectories and kinetic energy of trapped electrons. Using coordinates of electric potential, magnetic field strength, and the modified second invariant (UBK), we present a mathematically simple approach to describing the full phase space of possible particle trajectories within given magnetic and electric field models. We further demonstrate that it can be used to determine the change in kinetic energy around any particle orbit, and that changing trajectories and kinetic energies can have a significant effect on satellite measurements of energy spectra.

Towards predicting the variability (weather) of the mesosphere and lower thermosphere

Authors

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Abstract

Our knowledge of the dynamics and chemistry of the mesosphere and lower thermosphere (MLT) has increased greatly over the last several decades, aided by the satellite and ground-based observations and advances in numerical models. Together they provide estimates of the climatology of the MLT and how it varies with season and over decadal timescales. However, we have limited capability in predicting MLT day-to-day variations, i.e., its weather. Empirical models that take as input day of year, solar flux geomagnetic activity indices remain the standard tool for predicting such things as the drag on space debris in low earth orbit. Such models can disagree on the state of the atmosphere by a factor of two. Using the specified dynamics version of the Whole Atmosphere Community Climate Model (SD-WACCM) we explore MLT weather variations in a simulation that covers the period 2005 to 2015. Here we focus on variations near the mesopause at a representative equatorial and high-latitude site. After removing the seasonal variations, we find that the majority of short-timescale weather arises from changes in the amplitude and phase variations of atmospheric tides. Moreover, it is typical that at most 5 tidal modes are sufficient to capture most of the variability. Using wavelet analysis, we show that tidal variations can be linked to both external forcing (e.g., solar forcing) and variability from below. We confirm prior studies that have shown links to sudden stratospheric warmings, but also see variations linked to the North Atlantic Oscillation, El Nino-Southern Oscillation, the Quasi-Biennial Oscillation, solar storms (as reflected in F10.7 emission and sunspot numbers spikes), and solar cycle. Additionally, we explore if persistence of tidal variability can be used to improve prediction of near term MLT dynamics and demonstrate improvements over climatological approaches. Taken together these finding provide a gateway to improved MLT and space weather prediction.

The Effects of Statistical Uncertainty in Propagating Solar Wind measurements from L1 to the Earth's Bow Shock

Authors

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Abstract

Measurements of the solar wind (SW) plasma and interplanetary magnetic field near the L1 Sun-Earth Lagrange point are often used as input to 'coupling functions' that predict magnetospheric and ionospheric response metrics (e.g., the cross-polar cap potential (CPCP) derived from SuperDARN radar measurements). It is therefore important to quantify the uncertainties introduced in propagating these measurements from L1 to the near-Earth environment. To do this, we constructed a database (Rogers et al., 2026) of over 5000 hours of SW measurements from two ESA Cluster satellites that orbited close to Earth in years 2001 to 2023. These data were then compared with NASA's OMNI database of measurements by spacecraft near L1, projected in time to the bow shock nose. (Filters were applied to exclude Cluster measurements within a few Earth radii of the bow shock that may be affected by backstreaming ions and magnetic waves in the foreshock.) After scaling and calibrating relative error biases, we quantified probability distributions of differences between OMNI and Cluster measurements and quantified their correlations. We will demonstrate the extent to which these uncertainties in the SW parameters, when combined into coupling functions, contribute to regression dilution bias and saturation in the CPCP response.

REFERENCE

Rogers, N. C., J. A. Wild & A. Grocott (2026) Quantifying Uncertainty in OMNI Solar Wind Measurements Projected from L1 to the Earth's Bow Shock. Submitted to Journal of Geophysical Research: Space Physics.
https://doi.org/10.22541/essoar.177315062.26596008/v1

Modelling October 2024 extreme solar storm and radiation belt flux drop-out events

Authors

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Abstract

The radiation-belt electron flux exhibits dramatic variations across a range of spatial and temporal scales, including global-scale radial transport, mesoscale injections, and micro-scale wave-particle interactions. Long-term variability has been successfully captured by solving the Fokker Planck diffusion equation (e.g., BAS-RBM), incorporating energy, pitch-angle and radial diffusion imposed upon semi-empirical Tsyganenko magnetic field models. However, during geomagnetic storms, non-diffusive processes become significant which can lead to significantly degraded forecasts. Dropouts in the electron flux, across several orders of magnitude, are often observed in the outer radiation belt during the early phases of geomagnetic storms, hampering accurate modelling of the subsequent few days where forecasts are needed the most. These losses can occur either by direct escape through magnetopause, enhanced radial diffusion associated magnetopause losses, or precipitating into atmosphere. In this study, we employ global magnetohydrodynamic and test-particle (MHD-TP) simulations to investigate the dropout mechanisms. We first examine the extreme storms of May and October 2024 where aurora was observed over the UK and show how global MHD simulations can realistically capture the dynamic magnetospheric response. We evaluate key global MHD metrics for these events, including magnetopause location, cross-polar cap potential (CPCP), and geomagnetic Kp indices derived from modelled ground magnetic field disturbances. We then focus on a geomagnetic storm 2014, where the radiation belt flux was remarkably lost down to 4 Earth radii. We show how the pitch angle dependent last-closed drift shell (LCDS) can be significantly inward of the magnetopause, and dynamically varies as the magnetopause contracts and expands.

The role of the plasmapause in the dynamics of the outer radiation belt

Authors

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Abstract

During large geomagnetic storms, the flux of radiation belt electrons can decrease by orders of magnitude due to losses at the magnetopause. Global radiation belt models such as the BAS-RBM often exhibit large inward transport of electron flux that is not observed during storms. This occurs because the radial diffusion coefficients are assumed to increase at all L* when the geomagnetic activity increases. In reality, radial diffusion is driven by ultra-low frequency (ULF) waves generated at the edge of the magnetosphere by the solar wind and it has been suggested that the plasmapause might form an inner boundary that controls the spatial distribution of ULF waves. Here we assume that not all ULF waves are able to penetrate the plasmapause. Using observations of the plasmapause we present BAS-RBM simulations of several geomagnetic storms with radial diffusion reduced inside the plasmapause. The results suggest that the gradual erosion of the plasmasphere during the storm is crucial to reproducing the observed flux and prevent erroneous inward diffusion. This approach could be used to improve radiation belt forecasts and safeguard satellite infrastructure.

Distribution of Electromagnetic Ion Cyclotron (EMIC) waves in Jupiter's magnetosphere

Authors

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Abstract

Gyro-resonant interactions with electromagnetic ion cyclotron (EMIC) waves scatter electrons and ions into planetary atmospheres, making these waves central to understanding aurorae such as Jupiter's X-ray aurora. Using six years (2016–2022) of magnetic field data from the fluxgate magnetometer aboard NASA's Juno spacecraft, we present a statistical characterization of EMIC wave distributions throughout Jupiter's magnetosphere. We identify EMIC wave activity across five distinct ion bands — H^+, He^+, O^{2+}, O^+/S^{2+}, and S^+, and find that wave occurrence is preferentially enhanced toward the magnetospheric flanks, with activity largely confined to the range −40 to 20 Jovian radii (RJ) in the equatorial plane. The spatial extent of each band varies with ion species: S^+ band waves are restricted to the near-planet environment (within ±60 RJ), H^+ and He^+ band waves are predominantly found at larger radial distances, and the remaining two bands are distributed more broadly across the Jovian magnetosphere. Overall, the observed spatial distribution of EMIC waves aligns closely with the known distribution of their source ion populations.

Modelling ULF Waves in Plasmaspheric Plumes

Authors

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Abstract

Ultra-low frequency (ULF) waves (1 mHz – 1 Hz) are a long-studied feature of Earths magnetosphere. They communicate information about the space environment via solar wind–magnetosphere–ionosphere coupling. They carry field aligned current to the ionosphere via localised resonating regions in a process known as field line resonance (FLR). This study considers the measurable properties of an FLR existing within a plasmaspheric drainage plume acting as an azimuthal density inhomogeneity. It has previously been shown that such a density structure causes the resonant oscillation to develop a significant radial component at the sharp plume boundaries. The aims are to find out how this resonant structure varies when changing the density gradient, and to simulate how well a spacecraft moving relative to the magnetosphere can be expected to capture the properties of an FLR (amplitudes, phase relationship of the oscillation components, etc). This study should have implications for in situ observations of FLRs and to wave-particle interactions via radial diffusion.

Plasma temperature variability during the 2025 and 2026 DRIIVE/FINESSE Campaigns

Authors

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Abstract

Two UK EISCAT campaigns in support of the DRIIVE and FINESSE NERC consortium grants took place from December 14-20 2025 and March 16-22 2026. The campaigns, which used both the EISCAT UHF and VHF radars, covered a wide range of geophysical conditions from Kp 0 to 7. As well as very interesting variations in the morphology of the plasma density (described elsewhere in this session), highly dynamic behaviour was observed in both the electron and ion temperatures, displaying both correlation and anti-correlation with auroral precipitation. Of particular interest are some of the apparently strong but comparatively short-lived electron temperature enhancements seen in the topside ionosphere. While these appear to be related to the E-region density variability observed at the same time, we will examine whether these events could have a plasma physical explanation, which might affect their standard interpretation as bulk temperature increases.

ULF wave - cold plasma coupling and the impacts on radiation belt dynamics

Authors

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Abstract

ULF waves play a critical role in a host of magnetospheric phenomenon, including resonant energisation, substorm processes, particle precipitation, and radiation belt dynamics. But what regulates when and where ULF waves exist in the inner magnetosphere? The generation and propagation of Ultra Low Frequency (ULF) waves are intrinsically coupled to the cold plasma population. During geomagnetic storms, extreme reconfigurations of the cold plasma create a complex and dynamic system that drastically modifies this coupling. Using remote observations of global cold plasma imaging combined with ground magnetometer array measurements of ULF waves, we identify how cold plasma structures can alter the polarisation of the waves. As well as being associated with storm-time plasmaspheric plumes in the afternoon sector, dawn side features such as plasmaspheric shoulders also prove to be important. The discussion is placed in the context of radiation belt dynamics, where we will explore implications for electron energisation. Overall, we demonstrate that cold plasma dynamics are an important source of uncertainty in ULF wave processes and radiation belt dynamics, and understanding cold plasma-ULF wave coupling is a critical area of future investigations.

Variability of ionospheric electron density: a comparison between EISCAT and WACCM-D

Authors
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Abstract
We present a comparison of electron density measurements between 50-120 km from mainland European Incoherent Scatter (EISCAT) radars with the Whole Atmosphere Community Climate Model with D-region chemistry (WACCM-D) spanning 2005-2014. We investigate how the distributions of electron density vary depending on magnetic local time, season and geomagnetic and solar driving conditions. During summer and when geomagnetic driving is low, we find good agreement between WACCM and EISCAT. We also find EISCAT to be much more variable than WACCM, as expected, but that WACCM is missing a lower electron density population during higher geomagnetic activity; this is potentially a source of electron precipitation that is not yet included in WACCM. The aim of this work is to create pathways to improve how ionospheric variability is captured in WACCM, particularly at lower altitudes overlapping with the mesosphere where the variability is driven both by space weather and atmospheric effects.

How Broad Are the Polar Cusps? Insights from Cluster–EISCAT Svalbard Radar Conjugate Observations

Authors

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Abstract

Magnetic reconnection at the dayside magnetopause allows solar wind plasma to enter Earth's magnetosphere and ionosphere through the polar cusps. The width of the cusps and the recently-opened dayside field lines where they map to the ionosphere/upper atmosphere are therefore important indicators of solar wind–magnetosphere coupling. However, most previous estimates of cusp width have been statistical in nature, relying on single-point measurements or long-duration sampling of a region that is highly dynamic and sensitive to upstream solar wind conditions. We present a multi-instrument study of the northern polar cusp using conjugate ground- and space-based observations from the Cluster spacecraft and the EISCAT Svalbard Radar (ESR), enabling instantaneous measurements of cusp extent in magnetic local time (MLT). A case study on 16th December 2017 revealed a cusp spanning 5.4 h MLT, while the total extent of recently opened dayside field lines mapped to the ionosphere measured 7.2 h MLT, broader than the 1–4 h MLT typically reported in earlier statistical studies, despite relatively weak but predominantly southward IMF conditions ($|B| \approx 3–4$ nT). We extend this analysis to other event studies using a unified footprint-tracing method that "pinches" the cusp between ESR and Cluster on its dawn and dusk flanks. This broader event set will test whether the unusually wide cusp observed on 16th December 2017 is characteristic of instantaneous measurements, or whether additional factors influenced that event. These results highlight the value of short-timescale, conjugate observations for resolving cusp structure and dynamics.

Extending single-spacecraft techniques to investigate shock nonstationarity

Authors

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Abstract

Supercritical, collisionless shockwaves are known to exhibit nonstationarity, i.e. time-dependent structures even under steady upstream conditions, which can contribute to heating and particle acceleration. Here we examine the evolution of shock surface ripples (an example of nonstationary) by analysing Magnetospheric Multiscale (MMS) spacecraft observations of Earth's Bow Shock. To allow temporal analysis the spacecraft separation is large, and the time-separation between successive crossings is many ion gyroperiods. Given this separation standard multi-spacecraft methods cannot be used to resolve ripple wavelength and phase speed. A new method is presented that uses a model of ion reflection at the shock front to probe its spatial gradient. Incident (solar wind) and reflected beams are located in resampled ion distributions using HDBSCAN clustering. Gradients are then estimated from the velocity of clusters under the assumption of specular reflection of ions at the shock ramp. Using priors inferred from the gradient distribution and amplitude crossing times we then use a Monte Carlo Markov Chain method with Maxima A Priori estimator to infer ripple wavelength and speed for each spacecraft. This approach is demonstrated for both for a shock crossing previously analysed by multi-spacecraft methods and for an extended crossing from early 2019 when MMS was in string-of-pearls formation. If reflection is specular due to sufficient electric potential at the lag edge of the ripple our results suggest these structures are standing waves aligned nearly perpendicular to the magnetic field.

Preserving the Slough ionospheric data archive

Authors

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Abstract

The sequence of ionospheric measurements started in 1933 at the Radio Research Station at Ditton Park in Slough continues today at the Rutherford Appleton Laboratory in Oxfordshire. It is the longest continuous sequence of ionospheric data in the world. What makes this sequence particularly valuable is that all the original data records still exist, enabling a far greater insight into ionospheric conditions than is possible from the key data tabulated at the time. We present samples of these data, discuss the challenges in digitising them and preview a new citizen science project in which volunteers can help capture this information and thus enable novel research.

Characterising the Difference Between Empirical and Dipole Magnetic Field Approximations Under Varying Geomagnetic Conditions

Authors

Brad Ramsey (1), Sarah Glauert (1), Thomas Daggitt (1), Kaine Bunting (1)

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Abstract

Accurate magnetic field representations are fundamental to modelling radiation belt dynamics, underpinning wave-particle interaction diffusion coefficients and particle transport in codes such as PADIE and the BAS Radiation Belt Model. While the dipole approximation remains widely used for its simplicity, empirical models such as Tsyganenko TS04 offer a more physically realistic description of the geomagnetic field, incorporating responses to solar wind driving and geomagnetic activity. We present a comparison of the two models across a broad spatial domain and a range of geomagnetic conditions, including quiet-time, disturbed, and storm-time intervals, alongside seasonal variations. By examining magnetic field strength distributions along field lines, we identify the spatial and temporal regimes in which the dipole approximation breaks down most significantly, with particular focus on radiation belt L-shells and geomagnetically active periods. These findings provide valuable insight for developing improved magnetic field representations within radiation belt modelling frameworks, better capturing inner magnetospheric dynamics without the computational cost of full empirical field evaluations.

Neutral Temperature Changes in Fine Scale Aurora

Authors

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Abstract

The aurora is a significant source of heat in the high latitude upper atmosphere. Tens of gigawatts of energy from the solar wind is deposited as heat in the thermosphere and ionopshere (Østgaard et al 2002). Strong electric fields and currents associated with the aurora cause heating through friction between ions and neutrals (Joule heating) and resistive heating by magnetic field-aligned currents (Lanchester et al 2002). This energy input must be included in whole-climate models and models used to predict additional drag on spacecraft and space debris in Low Earth Orbit during geomagnetic storms. We present results from a new technique to measure neutral temperatures in fine-scale aurora at high spatial and temporal resolution (tens of milliseconds) using simultaneous images of emissions in two different parts of the auroral molecular nitrogen spectrum from the University of Southampton's Auroral Structure and Kinetics (ASK) multi-spectral imager. The technique measures the neutral temperature at the altitude of the auroral emissions, so the observations require careful interpretation to separate local neutral temperature changes from spatial variation in auroral altitude across each image. Height profiles of the neutral temperature are therefore obtained using a third image in an atomic oxygen emission to determine the energy of the auroral electron precipitation and hence estimate the altitude of the aurora and temperature measurement. The resulting profiles show rapid neutral temperature changes on the order of several hundred Kelvin across E-region altitudes (between 95 km and 130 km). The coolest temperatures are found within the brightest regions of the aurora, whereas higher temperatures are often associated with the edges of arcs where the electric field is expected to be strongest. The neutral temperature profiles are compared to ion temperature profiles from the European Incoherant Scatter (EISCAT) Svalbard radar (co-located with ASK) to better understand Joule heating and ion-neutral coupling in the extreme electrodynamic environment surrounding the aurora.

Posters

Energetic Particle Observations with SIXS During BepiColombo's Sixth Mercury Flyby

Authors

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Abstract

Mercury hosts a small global magnetic field, approximately 1% of Earth's magnetic field strength, capable of standing off the solar wind, resulting in a magnetosphere that is qualitatively similar in structure to Earth's. However, due to its closer proximity to the Sun, Mercury's magnetosphere experiences much stronger solar wind pressure than that at Earth, resulting in dynamic magnetospheric processes that occur on much shorter timescales. These extreme conditions can result in processes such as particle energization, transport and precipitation onto the planetary surface, which are strongly influenced by the external solar wind conditions. Here, we present observations of energetic protons ($> \sim 1$ MeV) and electrons ($> \sim 70$ keV) from the Solar Intensity X-Ray and particle Spectrometer (SIXS) onboard the BepiColombo spacecraft during its sixth and final Mercury flyby on 8 January 2025. Similar to the spacecraft's fourth Mercury flyby in 2024, a solar energetic particle event occurred a few days before closest approach, resulting in elevated fluxes of energetic particles both outside and within the Hermean magnetosphere. Furthermore, the KTH22 Mercury magnetic field model was used to help interpret these energetic particle observations and to evaluate whether features in the data were consistent with various magnetospheric processes.

Influence of Energetic Particle Precipitation on Antarctic Sea Ice During Spring: Based on WACCM-D Simulations

Authors

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Abstract

Antarctic spring (September–November) represents the period of most pronounced chemical ozone depletion in the Antarctic stratosphere. Polar climate variability is governed by complex feedback processes involving the atmosphere, ocean, and sea ice, among which sea ice plays an important role in regulating the surface energy budget and the coupled climate system. Variability in Antarctic stratospheric ozone is not only influenced by large-scale dynamical processes but is also closely linked to changes in upper atmospheric composition induced by energetic particle precipitation (EPP), particularly medium-energy electrons (MEE), and is associated with variations in sea ice. In this study, the Whole Atmosphere Community Climate Model with D-region chemistry (WACCM-D) is used to investigate the interannual variability of Antarctic spring stratospheric ozone and its impact on sea ice. Control and sensitivity experiments are conducted to isolate the contribution of MEE forcing. The results show thatthe model reproduces the observed variability of Antarctic total column ozone and NOx reasonably well. MEE-produced NOx is transported downward within the polar vortex into the lower stratosphere, leading to an increase of approximately 5% in NOx concentrations, and resulting in local ozone depletion of up to ~25% through catalytic reactions. Sea ice variability is mainly concentrated in the seasonal ice edge zone between 60°S and 70°S, with the most pronounced signals occurring in the Amundsen–Bellingshausen Seas (ABS) and the Weddell Sea. When springtime stratospheric ozone is anomalously high, sea ice concentration decreases in the ABS region but increases in the Weddell Sea. Thermodynamic and dynamical processes are both associated with this response. From a thermodynamic perspective, ozone anomalies correspond to changes in shortwave radiation absorption, accompanied by adjustments in surface net radiation and sea surface temperature near the ice edge, which are reflected in changes in sea ice formation and melt. From a dynamical perspective, ozone anomalies are associated with a weakening of the polar stratospheric westerlies and the polar vortex, together with changes in the high-latitude circulation. These changes extend downward into the troposphere through stratosphere–troposphere coupling, leading to adjustments in near-surface wind patterns. The wind-driven ocean response, including Ekman transport,redistributes ocean heat and sea ice mass, ultimately producing reduced sea ice in the ABS region and increased sea ice in the Weddell Sea.

Strong correlation between polar cap auroras and nonlobe reconnection under northward IMF

Authors

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Abstract

High-latitude reconnection between the northward IMF and the Earth's magnetosphere typically involves open lobe magnetic field lines in the polar cap. However, a study of plasma near the magnetopause has reported unusual high-latitude reconnection events featuring closed "nonlobe" magnetic field lines (Fuselier et al., 2018). Why closed field lines were present at the magnetopause was not determined, but partial/complete closure of the polar cap has been linked to reconnection mechanisms with telltale transpolar auroral arc (TPA) and horse-collar aurora (HCA) signatures (Milan et al., 2020b; Kaweeyanun et al., 2025). Can these mechanisms explain nonlobe reconnection? Nine events concluded to be nonlobe reconnection by Fuselier et al., (2018) have been analysed for the presence of TPAs/HCAs, with support from Defense Meteorological Satellite Program (DMSP) plasma measurements. Of these, eight cases exhibit visual evidence for TPA or HCA, and the other has plasma data suggestive of a potential TPA, indicating a strong correlation between nonlobe reconnection and polar cap auroras. We also report TPAs/HCAs in three further events suspected, but not confirmed, by Fuselier et al., (2018) to be nonlobe reconnection. Streamlined analysis of auroral images, with added flexibility from DMSP data, allows reconnection events linked to TPAs/HCAs to be obtained at increasing ease and frequency, laying groundwork for future investigations into northward IMF reconnection linked to polar cap auroras.

AMPERE observations of the asymmetry towards stronger Birkeland currents in the Northern Hemisphere

Authors

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Abstract

We quantify the asymmetry between the Birkeland currents (also known as field-aligned currents) in the Northern and Southern Hemispheres. We use data from the Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE) in 2010–2024 inclusive for both hemispheres, compute the observed asymmetry, and then subtract the modeled asymmetry. We use Block 1 data (based on the original Iridium constellation) and NEXT data (based on Iridium-NEXT spacecraft), and compare the effect of changing the data processing pipeline on the latter (yielding NEXT v1 and NEXT v2 subdatasets).
We find that the asymmetry is significantly smaller in NEXT v2 data (4±2%) than in Block 1 (21±2%) or NEXT v1 data (19±3%). The previously reported asymmetry seen in Swarm is ~12%, indicating that the new data processing pipeline goes from approximately twice the Swarm asymmetry to approximately half. This may indicate that the new AMPERE processing pipeline overestimates the amount of current flowing in the Southern Hemisphere, whereas the old one underestimated this quantity.
We use frequency analysis to find that the asymmetry varies with frequencies corresponding to seasonal effects, CME occurrence, Iridium constellation orbit precession, and geomagnetic storms. We find a correlation with IMF B_Y, indicating that more current flows in the Northern Hemisphere during positive B_Y and vice versa. We find that Block 1 data in 2010–2017 shows correlations with AL, AU, Kp, PCN, and PCS index which indicate that the asymmetry is less pronounced when Dungey Cycle convection is stronger, but NEXT data in 2019–2024 do not show this.

Vertical Coupling in the High-latitude Ionosphere-thermosphere during Geomagnetic Disturbances: Insights from Scandinavian Multi-Instrument Observations

Authors

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Abstract

The neutral dynamics defining the baseline conditions of the coupled ionosphere-thermosphere (I-T) region are well understood on global scales. However, localised meso-scale behaviours, which significantly influence thermospheric composition and drive subsequent ionospheric changes remain difficult to characterise due to observational gaps and model limitations. Identification and characterisation of such changes is crucial, especially at high latitudes where, alongside lower atmospheric forcings, short-lived space weather events can lead to meso-scale spatial structures. We characterise the changes induced by such events using a comprehensive multi-instrument dataset spanning over three decades from the Scandinavian region. By combining ionospheric measurements from EISCAT and Dynasonde with neutral winds and temperatures from Fabry-Pérot Interferometers (FPIs), we quantify the perturbations in the I-T system during geomagnetically disturbed periods. We will present key findings from these analyses, detailing the causal mechanisms of high-latitude ion-neutral coupling.

Meso-scale variability in the high latitude ionosphere - observations from the DRIIVE winter campaign

Authors

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Abstract

The high latitude ionosphere displays highly variable behaviour that can be attributed to a multitude of processes. These originate from sources that range from internal coupling with the neutral atmosphere to electrodynamics driven by external space weather. DRIIVE (DRivers and Impacts of Ionospheric Variability with EISCAT-3D) is a project aimed at identifying this variability across a range of scales and comparing the relative contributions of different drivers. In December 2025 the DRIIVE team ran a 5-day campaign using the mainland EISCAT incoherent scatter radars in conjunction with a suite of additional ground-based instruments to monitor the night side ionosphere. Both the UHF and VHF radars were operated to provide simultaneous measurements in different look directions. The UHF radar ran a scanning mode to provide an estimate of the local ionospheric electric field. Here we present the first observations and analysis of the radar data collected during this campaign; we examine the changes in ionospheric parameters through different substorm phases and quieter periods, identifying both spatial and temporal variability at selected altitudes.

Simulating extreme events in the radiation belts: Part 2

Authors

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Abstract

Society is becoming increasingly dependent on satellites that orbit through the Earth's radiation belts, so it is important to understand the effect of extreme space weather on the radiation environment. The aim of this work is to determine the effect of a severe interplanetary shock on the radiation belts. Part 1 of the study modelled the immediate response of the belts to a severe interplanetary shock of similar magnitude to the 1859 Carrington Storm and the 2012 event that missed the Earth. That showed that the outer radiation belt would be rapidly removed and that electrons with energies above 5 MeV would be found in the slot region. In this part of the study, we focus the evolution of the radiation belts in the days following the initial shock.

The British Antarctic Survey Radiation Belt Model normally uses data to provide model inputs such as solar wind parameters and the electron flux on the boundaries, so first we will describe how these drivers were determined without data for a specific event. We will then show that immediately after the shock the multi-MeV electrons from the slot region are transported into the inner belt by radial diffusion and that the enhanced inner belt will then persist for months, posing a risk to satellites orbiting in this region. The outer radiation belt rebuilds during the days following the storm and we demonstrate that the main mechanism for this is the acceleration of low energy electrons by chorus waves, rather than inward radial diffusion.

ESA Swarm products, tools, and services supporting open science

Authors

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Abstract

The ESA Swarm mission has been operating in low Earth orbit since 2013, providing critical data for monitoring Earth's magnetic fields. With research areas spanning from Solid Earth to Space Weather, an important aspect of the mission is the Swarm Data, Innovation, and Science Cluster (Swarm DISC). Swarm DISC is a consortium of around 30 institutions and companies involved in the creation of higher level data products, as well as tools and services to support usage of both data and models. See https://swarmdisc.org for more.
A core Swarm service is VirES (see https://vires.services). VirES comprises for main components: server, web client, Python client, and JupyterHub, providing a range of routes to access, visualise, and process the Swarm product portfolio and more.
Notable additional features include:

- LEO magnetometry from other missions: CHAMP, CryoSat-2, GRACE, GRACE-FO, GOCE
- INTERMAGNET ground observatories
- Notebook-based cookbook: https://notebooks.vires.services
- Heliophysics API (HAPI): https://vires.services/hapi

Building upon robust data access via VirES and HAPI, we also developing the SwarmPAL Python package to facilitate higher-level analysis. Overall, we aim to produce a sustainable ecosystem of tools and services, which together support accessibility, interoperability, open science, and cloud-based processing. All services are available freely to all, and the software is developed openly on GitHub.
The work presented is the result of many partners across Swarm DISC.

Simulating extreme events in the radiation belts: Part I

Authors

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Abstract

The Van Allen radiation belts exhibit flux variations spanning multiple orders of magnitude due to a complex balance of production and loss processes. Extreme space-weather events can push the radiation belt into extreme regimes that provide a unique opportunity to distinguish individual mechanisms responsible for generating hazardous relativistic electron populations. Based upon the major storm of March 1991 and "near-miss" of July 2012, we show that large interplanetary shock-driven magnetospheric compression at the the sudden commencement phase of geomagnetic storms can rapidly remove the entire outer radiation belt while simultaneously accelerating a distinct third belt deep within the slot region. For the strongest shocks, with speeds exceeding 2,000 km/s, electron energies in the slot region surpass 50 MeV, consistent with the unprecedented observations from March 1991 and representing the first physics-based simulation of such extreme belt formation. The resulting state, devoid of high-energy electrons in the outer belt, provides an optimal laboratory for diagnosing the dominant mechanisms that rebuild the belts, which is the focus of Part 2.

Simulating Exoplanet Magnetospheres

Authors

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Abstract

Magnetospheres are commonly depicted as unconditionally protective. However, there is a weak spot in the form of an additional energy source in the upper atmosphere: joule heating. Along with directly heating the thermosphere, this energy input may increase ionospheric outflow and lead to mass loss, affecting observable atmospheric properties. With the PLATO and Roman space observatories expected to launch within the next year, there is a new opportunity to consider this facet of habitability for exoplanets spanning Earth-to-Neptune masses and orbital separations. We develop a methodology for using 3D magnetohydrodynamic simulations to quantify joule heating rates for exoplanets covered by these new observatories, and discuss preliminary results.

TOMIRIS: A Real-Time Data Assimilation IRI

Authors

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Abstract

The IRI is very successful as a model for representing the climatological behaviour of the global ionosphere. It is designed to be able to capture the monthly median behaviour of the ionosphere, and includes a storm model to capture typical variability associated with geomagnetic storm conditions. There has long been interest in augmenting the IRI using data assimilation to produce a real-time ionospheric model. The first such model was the IRTAM model, which assimilated data from ionosondes. Other techniques have been explored, with particular interest given to techniques using effective driving indices }.
A new real-time data assimilation model based on the IRI, called TOMIRIS, has been operating at the University of Birmingham since April 4th, 2025. TOMIRIS uses the same bottomside and near-topside formulation as the IRI, but is capable of representing finer spatial and temporal scales. It assimilates data from the GIRO ionosondes , and slant Total Electron Content (sTEC) from over 2100 Global Navigation Satellite System (GNSS) receivers worldwide. This allows it to produce an updated ionospheric specification with less than 5 minutes latency. It uses a particle filter, a nonlinear data assimilation technique which has been successfully used for other ionospheric models such as A-CHAIM and AIDA. The results from the first year of TOMIRIS operation will be presented.