Fysikermøtet 2023

Abstracts for Space, plasma and climate physics

Onsdag (Room: CD)

13:30 Karl Magnus Laundal: How the ionosphere perturbs Earth's magnetic field

Ground magnetic field variations have been used to investigate ionospheric dynamics for more than a century. They are usually explained in terms of an electric circuit in the ionosphere driven by an electric field, but this is insufficient to explain how magnetic field disturbances are dynamically established. We present an explanation and simulations of how plasma fluid dynamics leads to magnetic field deformation via Faraday's law.

14:00 Margot Decotte: MAGLEGO - a LEGO model of the magnetosphere

The solar wind influence on the magnetosphere can be described as the sum of a directly driven component -dayside reconnection- and an unloading component that is associated with the release of magnetic energy via nightside reconnection (Laundal et al. 2020). To illustrate this concept, Akasofu (1989) identified the magnetosphere as a combination of a pitcher-type (directly driven component) and a tippy-bucket-type (unloading component) system. We have built a Lego model of Akasofu's illustration to emulate the magnetosphere-ionosphere system's mechanical behaviour. The model includes two water-driven wheels that simulate magnetospheric dayside and nightside reconnection and a central rotating platform illustrating the ionospheric convection pattern. Our model is interactive, with the ability to adjust the water input (≈ reconnection rates) to show how the ionospheric convection changes in response (in terms of rotation speed). We will exhibit our Lego model and show how it serves as a creative and fun pedagogical tool for visualizing the complex and dynamic nature of the solar wind-magnetosphere-ionosphere coupling.

14:20 Ville Maliniemi: Effect of energetic particle precipitation on Antarctic stratospheric ozone from the CFC era into the future

Chlorofluorocarbon (CFC) emissions in the latter part of the 20th century reduced the stratospheric ozone abundance substantially, especially in the Antarctic region. Following the Montreal Protocol, CFC emissions have been reduced since 1990s and Antarctic ozone amount is slowly beginning to recover. Current projections show that the CFC amount will diminish to pre-CFC era levels after 2050. Furthermore, because the stratosphere is cooling due to the climate change, ozone amount is expected to increase leading to so called super recovery of ozone by the end of the 21st century. Antarctic ozone is also influenced by reactive nitrogen oxides (NOx) descending from the mesosphere and thermosphere during winter. This NOx is produced by energetic particle precipitation (EPP) linked to solar activity and space weather. In this presentation, we will show interesting interplay between EPP, CFC originated active chlorine and ozone during the CFC era. Chemistry-climate model simulations show that EPP has been a significant modulator of ozone chemistry responsible for ozone hole formation. Furthermore, the mean meridional circulation is increasing due to the climate change in the future leading to enhanced EPP-NOx descent into the Antarctic stratosphere. Model simulations reveal that future levels of EPP-NOx in the Antarctic stratosphere will be substantially higher, which can potentially prevent the ozone super recovery in the Antarctic stratosphere.

14:40 Årsmøte i Rom-, Plasma og Klimafysikk - Hybrid - Ledet av Audun Theodorsen

Yearly meeting in Space, Plasma and Climate Physics – Lead by Audun Theodorsen

Torsdag (Room: AB)

10:20 Hilde Nesse: Energetic electron precipitation during slot region filling events

The slot region marks the equatorward boundary of the energetic electron precipitation (EEP). There are, however, numerous reports where energetic electrons cross these boundaries and fill the slot region. The ensuing EEP will occur long after the geomagnetic activity subsides. This is a missing energy input in current EEP estimates scaled by geomagnetic indices. This study explores the occurrence rate, duration, and local time dependence of slot region filling events using observations from the NOAA/POES over a full solar cycle from 2004 to 2014. The EEP flux estimates are based on the MEPED 0° and 90° detectors and the theory of pitch angle diffusion by wave-particle interaction. The occurrence rates of >43, >114 keV, and >292 keV events are found to be strongly energy and solar cycle dependent. Higher energy events are more likely to be associated with CMEs and stronger geomagnetic deflections compared to lower energy events. Solar wind speed, IMF Bz, and Ey reveal a calm period before the events, potentially important for preconditioning the ensuing magnetospheric mass convection. The slot region reforms more efficiently closer to the plasmapause, which creates a double EEP band throughout the recovery period. The slot region EEP maximizes around noon throughout the afternoon/evening sector, consistent with pitch angle scattering from plasmaspheric hiss and lightning induced whistler mode waves. Concurrent with slot region filling events, the MIPAS/Envisat NO density show an increase at <55° CGMlatitudes. This demonstrates the importance of including slot region EEP when assessing the EEP impact on the atmosphere.

10:40 Josephine Salice: When are energetic electrons producing NO directly in the upper stratosphere?

Compositional NOx changes caused by energetic electron precipitation (EEP) at a specific altitude are called the EEP direct effect. Changes co-dependent on vertical transport are referred to as the EEP indirect effect. The relative importance of EEP's direct and indirect effect on NO and its subsequent impact on ozone and dynamic changes remain unresolved. The challenges are partly due to inadequate particle measurement and the relative scarcity of NO observations. Moreover, lower production rates in the mesosphere make it challenging to determine EEP's direct impact on NO. In this study, the uncertainty of EEP observations is bypassed by exclusively identifying events applying

NO-observations from the SOFIE instrument on board the AIM satellite. SOFIE daily averaged data from 2007 to 2014 is used to create a climatology based on the median of the data. A direct EEP-produced NO-event at 90 km is identified when the NO density surpasses the climatology by 100%. If the NO density exceeds 25% above the climatology at 80, 70, 60, and 50 km, the event qualifies as a "50km-event". By contrasting the 90km and 50km events, the characteristics of the solar wind, geomagnetic indices, and observed electron fluxes from POES are studied. The goal is to unravel when EEP can produce NO directly in the upper stratosphere. The results will contribute to developing a parameterization of EEP from the radiation belt that includes both the direct and indirect impact of EEP and, thus, deciphering the total EEP effect on ozone and atmospheric dynamics.

11:00 Jone Edvartsen: Investigating the impact of space weather on the polar atmosphere using rigorous statistical methods

Recent years have seen a surge in observational, re-analysis, and model studies providing evidence of statistical correlations between both day-to-day and longer term-solar activity and climate and weather patterns. Two pathways, in particular, have received considerable attention, the Mansurov effect (day-to-day) and the Chemical-Dynamical coupling (longer-term). The Mansurov effect is related to the interplanetary magnetic field (IMF) ability to modulate the global electric circuit (GEC), further hypothesised to affect surface pressure through changes in atmospheric electric conditions affecting cloud formation processes. The Chemical-Dynamical coupling is related to energetic particle precipitation (EPP) ability to ionize the upper atmosphere, creating ozone destructive chemical species, further hypothesised to affect atmospheric temperature, pressure and winds due to ozones radiative properties. By usage of atmospheric re-analysis and model data, both mechanisms are thoroughly investigated according to up-to-date hypotheses of how they operate optimally. During the investigations, substantial focus is also placed on methodological considerations and significance testing methods. Our results show that earlier findings regarding the mentioned day-to-day solar activity and climatological impact are questionable, as they do not attain statistical significance according to rigorous standards. In addition, the methodology used in earlier studies produces statistical artefacts giving the impression of a response. In comparison, for the longer-term solar activity and climatological impact, robust significant results are found. These latter investigations use modelled data; however, the results closely resemble earlier findings using re-analysis data, which are based on actual observations. In general, the results highlight the importance of statistical rigor when handling complex and noisy systems such as the atmosphere, as well as how the choice of methodology affects the outcome. Specifically, the results suggest that longer term solar activity and particle precipitation significantly affect the climate.

11:30 Ingrid Bjørge-Engeland: High peak current lightning and the production of Elves

Elves are produced when electromagnetic pulses from lightning interact with the molecules in the lower parts of the ionosphere. They are observed as laterally expanding rings of light in the UV and visible optical bands, expanding to diameters of several hundred kilometers. Previous research has found Elves to be associated with high peak current lightning discharges, and different peak current thresholds for Elve production have been suggested. Using data from the Modular Multi-spectral Imaging Array (MMIA) of the Atmosphere-Space Interactions Monitor (ASIM) onboard the International Space Station, in combination with data from the global ground-based lightning location network GLD360, we have investigated whether Elves are always produced when a high peak current lighting discharge is detected by GLD360. We have searched for observations of Elves by the MMIA when peak currents above |40| kA were detected by GLD360, and identified two types of events; high peak current detections associated with Elves, and high peak current detections with no associated Elve. To understand why some current pulses associated with high peak currents do not generate observable Elves, we investigated the lightning activity occurring within 5, 20 and 40 minutes preceding the two types of events. Our results indicate that for current pulses above 120 kA, an Elve is nearly always produced, regardless of the preceding lightning activity. For current pulses with peak currents between 70 kA and 120 kA, the number of observed Elves depends on the preceding lightning activity within the minutes and tens of minutes before.

Torsdag (Room: D)

13:00 Audun Theodorsen: Algebraic pulses and exponential spectra in fluids and plasmas

Exponentially decaying power spectra have been observed in space- and fusion plasmas [1, 2], as well as in turbulent convection in neutral fluids [3]. Such spectra have been taken as a sign of deterministic chaos, and the fluctuations and coherent structures associated with these spectra in the time domain have been modeled using Lorentzian pulses [2, 3].

We discuss the connection between exponentially decaying spectra and algebraic pulses, demonstrating that such spectra admit a wide variety of pulse shapes when modelling coherent fluctuations in fluids and plasmas. For periodic rather than chaotic phenomena, the spectrum is a Dirac comb modulated by the spectrum of the pulse, but we show that the Dirac comb is quickly destroyed by alternating positive and negative pulses as well as by slight deviations from periodicity. The findings are applied to time series measurements of plumes in the periodic parts of Rayleigh-Bénard turbulence.

References:
[1] Thomas B. Leyser. "Deterministic Chaos in Ionospheric Plasma Pumped by Radio Waves", Geophysical Research Letters 48.12 (June 28, 2021).
[2] Z. Zhu et al. "Chaotic Edge Density Fluctuations in the Alcator C-Mod Tokamak". In: Physics of Plasmas 24.4 (Apr. 2017), p. 042301.
[3] G. Decristoforo, A. Theodorsen, and O. E. Garcia. "Intermittent Fluctuations Due to Lorentzian Pulses in Turbulent Thermal Convection". Phys. Fluids 32.8 (Aug. 1, 2020), p. 085102.

13:20 Sivert Eilertsen: Effects of Sampling Time on Complexity-Entropy Analysis

Complexity-Entropy analysis is a tool for distinguishing chaotic and stochastic origins of time series measurements[1,2], providing information on possible models for the underlying dynamics. Estimates of complexity and entropy are obtained from permutations in the time series, and are used to represent the system in the Complexity-Entropy (CH) plane. The location of the time series provides information on the system origin. Complexity-Entropy analysis has been applied to a wide variety of systems including fusion reactors[3,4], the medical field[5,6], economics[7], and linguistics[8].

In this contribution, we show that continuous-time models should be associated with curves in the CH-plane rather than individual points. The sampling time parameterizes these curves. One consequence of this is that the same system may show both stochastic and chaotic behavior depending on the sampling time. The true nature of the dynamics of the system may be obscured by the sampling time. A variety of models are used to illustrate this point and a stochastic model based on a superposition of pulses, filtered Poisson process[9,10], is used in detail as a test bed. With this in mind, the CH analysis may be used as a filter when choosing candidate models when modelling real-life time series as different models occupy different regions of the CH plane. Measurement time series of atmospheric aerosols, provided by the NOAA, is used as an example to illustrate this.

[1]Bandt, Pompe Phys. Rev. Lett., 88:174102, Apr 2002

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[3]Zhu Physics of Plasmas 24, 042301 (2017)
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[8]Rosso. Physica A, 388 (6) (2009), pp. 916-926
[9]Garcia. Phys. Rev. Lett., 108:265001, Jun 2012
[10]Theodorsen. Physics of Plasmas, 23(4):040702, 2016

13:50 Eirik Enger: Insensitivity of global temperature response to the magnitude of volcanic eruptions

We investigate how the global mean temperature responds to single volcanic events of different magnitudes and to multiple events occurring close in time. We are using the Community Earth System Model version 2 (CESM2) to simulate the Earth system forced only with stratospheric aerosols from explosive volcanoes, with the rest of the climate system fixed at 1850 conditions.

Previous efforts of estimating a response function assume a linear relationship between the forcing and the deterministic temperature response to the forcing [1], defined as T^{det(t)}=L[F(t)]. Studies also show that the forcing is similar across forcing agents [2] (although this is not a settled debate [3]), in which case volcanoes could provide a valuable means of estimating global temperature response to radiative forcing due to their short-lived and large temperature responses.

We present simulations of single volcano events with ejected sulphate aerosol loadings differing in orders of magnitude and simulations where two volcanic eruptions are close enough in time that the second eruption occurs as the temperature is still recovering from the first event.

We show that the functional form of the temperature response is similar for volcanic events of different magnitudes and that non-linearities are not important as a second eruption occurs when the temperature is well below equilibrium in a perturbed state. The results further suggest the global mean temperature time series may be reduced to a simple superposition of individual pulses, and thus that it may be described by a convolution between a linear response function and some forcing, analogous to the model used by [1].

[1] K. Rypdal and M. Rypdal, doi: 10.5194/esd-7-597-2016
[2] T. B. Richardson et al., doi: 10.1029/2019JD030581
[3] P. Salvi, P. Ceppi, and J. M. Gregory, doi: 10.1029/2022GL097766

14:10 Samuel Kočiščák: Complex electrical signatures of dust impacts within 1AU recorded by Solar Orbiter

The interplanetary space is a dusty environment, with several populations of dust contributing to the solar system’s dust cloud. Dust near the Sun displays interactions with the solar wind and the solar corona, while interstellar dust provides a unique access to the matter coming from outside of our solar system. Interplanetary dust was directly observed with dedicated instruments since the rocket age and more recently, with electrical antenna instruments present on many spacecraft, owing to the effect of hypervelocity impact ionization. However, interpretation of the antenna measurements, and even dust impact identification with antennas, is not straightforward, and only partially understood.

We present a set of impacts recorded in-situ with Solar Orbiter/ Radio and Plasma Waves electrical suite between 0.3AU and 1AU. An important portion of the impacts show a double peak structure, which is not understood in its fullness, since it is the first time such structure was observed. Peculiarly, every electrical antenna dust experiment is unique in not only the solar system region it covers, but also in the mechanical and electrical design, which leads to every data set being unique and complicates comparison between different experiments. We believe that the Solar Orbiter's data might be especially useful for understanding hypervelocity dust impact impact electrical signals, since the instrument was designed with dust data collection in mind and shows unprecedented data. In our effort to understand the process on Solar Orbiter we were able to distinguish the process happening close to the impact site from the effect on the antennas. We present our partial success with the signals' interpretation and the contribution to the current knowledge about dust impact impact electrical signals, as well as open questions.