

AUTUMN MIST 2009 Abstracts

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Oral Presentations

Mitigation and Exploitation of the Ionosphere

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The ionosphere is a critical element in the design and operation of many RF systems. Whilst judicious engineering choices, such as transmission frequency, can mitigate many ionospheric effects, the research scientist and engineer is being asked to meet ever more demanding operational requirements. These, in turn, require ever more sophisticated situational awareness, mitigation and exploitation techniques, which are being variously realized against a backdrop of evolving ground and space based instrumentation. The latter, in combination with improved modelling and assimilative techniques, promise a new generation of more capable real-time ionospheric models. Through examples, this paper describes the benefits and problems associated with the ionospheric medium. HF communications and space radar systems are discussed as exemplars and an emphasis is placed on the need to understand the engineering details of those systems if ionospheric R&D is to provide full benefit.

Statistical study of thermospheric temperature from the UCL Svalbard Fabry-Perot Interferometer over the recent solar cycle

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The UCL Svalbard (78N 16E) Fabry-Perot interferometer (FPI) has been observing the neutral thermosphere at ~250km altitude for nearly 25 years. It produces a database of thermospheric winds and temperatures, which are deduced from the Doppler shift and broadening of the 630nm atomic oxygen redline emission. Ten years of neutral temperatures are analysed in detail to study diurnal and solar-related trends over the recent solar cycle. The results are compared against MSIS-modelled temperatures and EISCAT ionospheric temperatures. A 27-days cycle can be seen in the temperature data corresponding to the solar rotation period and the corresponding geomagnetic activity levels. The effect of this particular deep solar minimum on the neutral thermosphere is also investigated.

Simultaneous calibration of Reimei particle and optical measurements using an ionospheric model

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University of Southampton

A method has been developed which allows inter-calibration of Reimei electron spectrum analyser measurements and optical measurements using an ionospheric model. Reimei is a Japanese micro-

satellite equipped with three cameras (“MAC”) observing auroral emission at 427.8nm, 557.7nm, and 670.0nm, together with an electron energy spectrum analyser (“ESA”). The ESA instrument measures electrons up to a maximum energy of 12keV only. This presents a problem when attempting to estimate the total precipitating energy flux during high-energy events. It is possible to estimate the total energy flux from the 427.8nm optical measurements, as the brightness of this emission is not dependent on the electron energy. However, this requires the MAC camera to be accurately calibrated. This is not straight-forward due to contamination from several sources such as the moon and snow reflection. By using unsaturated ESA measurements of the complete electron spectrum as input for a detailed ionospheric model we are able to calibrate the coincident camera observations. This then allows us to estimate accurately the total electron energy flux at other times during the same event when the maximum electron energy is well above that measured by ESA.

The Rise and Fall of Electron Temperatures: Experimental test of electron cooling and heating

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ABSTRACT: Cooling and heating of electrons control much of the energy flow in the ionosphere. So to properly understand the energetics of the upper atmosphere and ionosphere we have to be able to accurately model the heating and cooling processes of the electrons. Theoretical rates are typically calculated with the assumption that the electron distribution is Maxwellian. In practice this is often not a very good assumption. Here we will present an experimental test of how good the cooling rates and heating efficiency found in the literature is. The experiment was performed with the EISCAT Heating facility, and observations were made with the EISCAT UHF radar. During HF radio wave transmission at frequencies above the peak ionospheric critical frequency the electron temperature was increased up to 3000~K. The observed temperature variation is compared with numerical solutions to the electron energy equation with Ohmic heating modeling the effect of pump wave plasma heating.

Seasonal variation of polar cap patches in the high-latitude nightside ionosphere around solar minimum and solar maximum

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The influence of the season and solar cycle on the occurrence of polar cap patches in the nightside ionosphere was observed and simulated above northern Scandinavia close to solar maximum (1999 – 2001) and solar minimum (2007 – 2008). The observations were conducted under conditions which were predicted to be favourable for observing patches using the EISCAT Svalbard Radar (ESR) with the requirements based upon the convection pattern, the IMF and an absence of in situ precipitation. In each set of observations the patch-to-background ratio was calculated. This ratio showed a clear seasonal difference, with values of up to 9.4 ± 2.9 in winter and 1.9 ± 0.2 in summer. There was also a significant difference between solar maximum and solar minimum, with higher patch-to-background ratios in the lower part of the solar cycle.

The PLASLIFE computer simulation was used to model the observed trends in the patch-to-

background ratio and establish reasons for the variation. This difference was primarily attributed to changes in the chemical composition of the atmosphere which altered both the plasma densities drawn into the polar cap and the rate of plasma loss by recombination. A secondary factor in the seasonal trend was the maintenance of the background ionosphere by photoionisation in summer throughout the polar cap.

Observations and Modelling of a 3mhz ULF wave illustrating Alfvénic to Compressional behaviour

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Employing the Doppler Pulsation Experiment (DOPE), an HF Doppler sounder, in conjunction with the International Monitor for Auroral Geomagnetic Effects (IMAGE) network of ground magnetometers, the Advanced Composition Explorer and IMP-8 spacecraft and a numerical model, for the first time, it has been possible to examine the evolution of a Ultra Low Frequency (ULF) wave from fast compressional to Alfvénic behavior, caused by a magnetospheric impulse. The relative phases and amplitudes of the signatures in the Doppler and ground magnetometer data are compared with a numerical model for the generation of Doppler signatures from incident ULF waves. A one-dimensional model of wave propagation from the magnetosphere, through the ionosphere to the ground with an oblique magnetic field is employed. HF signals that propagate via the ionosphere exhibit Doppler shifts due to a number of processes that give rise to a time dependent phase path. Here, the effect of the modelled incident wave field on such an HF radio path is calculated, and compared to observations. The event that occurred on 16th April 1998 was the result of a low-m (-6) field line resonance with a large characteristic scale size. Ground magnetic field and Doppler observations were used to find model inputs at various points throughout the event. An impulsive disturbance was seen in the ACE and IMP-8 spacecraft data and the IMF dynamic pressure increased at approximately the right time. We show the first direct measurement of an Alfvénic wave mix during this impulse driven ULF wave event.

Case study of a single Coronal Hole and the geospace implications

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Lancaster University

This is a study of a single recurring Coronal Hole (CH) over 4 solar rotations identified using solar wind properties. The effects of the High-speed Solar-wind Stream (HSS) are examined using geomagnetic indices, particle data from geosynchronous orbit and ground based magnetometers and riometers. We find evidence of enhanced particle precipitation ($E > 30\text{keV}$) around the time of arrival at the magnetopause. We also find evidence of an increase in Pi2 pulsations, also at this time (an indicator of enhanced substorm activity during these events). Examination of high energy particle data from geosynchronous orbit indicates a dropout and recovery in the outer radiation belt, consistent with current understanding of HSS effects on the magnetosphere. The medium energy particle data indicate enhanced substorm activity, particularly for the 3rd and 4th rotation of this particular CH. We conclude that that these typical examples of HSS magnetosphere interactions, show differences over the lifetime of a CH.

A Statistical Analysis of predicted time-of-arrival of solar wind transients observed by STEREO HI: CMEs or CIRs

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The STEREO spacecraft provide a unique vantage point of the Sun-Earth line and each carries two Heliospheric Imagers (HI) to view this. The HIs provide the opportunity to study transient events during their passage through the inner heliosphere to the Earth and beyond. Using the images from HI we have created time-elongation plots (J-plots) of the intensity of scattered sunlight – a measure of the solar wind density - along the ecliptic, in order to study solar transient events. There exists a standard technique for estimating the velocity and direction relative to the spacecraft from the elongation variation of transient events. This technique assumes the event is point-like and has no change in speed through the field of view of the HI instrument. Using this technique we have created and analysed a list of 148 events covering a period from April 2007 to February 2009. We will show a statistical analysis of the distribution of velocity and direction estimates obtained using this technique and discuss these in the context of different types of solar wind transient, that is, coronal mass ejections and corotating interaction regions. We show that distinguishing between CMEs and CIRs is critical for accurate prediction of the time-of-arrival of these transients at Earth.

Anisotropy of Solar Wind Turbulence in the Dissipation Range

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Although turbulence is readily observed in the solar wind, some aspects are poorly understood with unexplained observations and conflicting theoretical descriptions. In particular the dissipation range (fluctuations smaller than the ion gyroscale) is only just beginning to be thoroughly investigated. Here we present methods and results from a multi-spacecraft analysis of the solar wind dissipation range between the ion and electron gyroscals using the four Cluster satellites. We find that the fluctuations are anisotropic, having a higher power in the direction perpendicular to the local mean magnetic field than parallel to it. We also compare the observed anisotropic scaling to predictions for a kinetic Alfvén wave cascade. The implications of anisotropic fluctuations for the interpretation of dissipation range measurements in general are also discussed.

Global scale-invariance of small-scale magnetic fluctuations in solar wind turbulence as seen by CLUSTER

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Spacecraft measurements of magnetic fluctuations of collisionless plasma turbulence in the solar

wind typically show an ‘inertial range’ of MHD turbulence with a power-law power spectra. At higher frequencies a spectral break is seen around the ion-gyroscale with a subsequent steeper power-law, indicating a cross-over to spatial-temporal scales where kinetic effects become important. Theories for this second scaling range, also known as the “dissipation/dispersion” range focus on the spectral slope and the associated scaling exponents.

We will present some results from very high-frequency magnetic field data from the four Cluster II spacecraft in intervals where the spacecraft were in quasi-stationary ambient solar wind and where the instruments were operating in burst mode. The magnetic field data are from the fluxgate and search-coil magnetometers from the Cluster FGM experiment (~67Hz), and the STAFF experiment (~450 Hz). These data sets provide observations of this dissipation/dispersion range over approximately two decades in frequency. This high cadence allows a better determination of the statistics at these small scales; especially the estimation of scaling exponents.

We present a robust multiscale statistical analysis focusing on power spectra, PDFs of field fluctuations and higher-order statistics to quantify the scaling of fluctuations; as well as describing the degree of anisotropy in the fluctuations parallel and perpendicular to the average magnetic field. Both neutral fluid and MHD turbulence share a “classic” statistical signature – namely an intermittent multifractal scaling seen in the higher-order statistics. We test the statistical properties of the dissipation range and find in contrast monoscaling behavior, i.e., a global scale invariance. This provides a strong discriminator for the physics and phenomenology of the dissipation range in collisionless plasmas.

Reference article: K. H. Kiyani, S. C. Chapman, Yu. V. Khotyaintsev, M. W. Dunlop, and F. Sahraoui, *Phys. Rev. Lett.* 103, 075006 (2009)

Bi-directional electrons in the low-latitude boundary layer: signatures of open or closed field lines?

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We study a low-latitude boundary layer (LLBL) crossing, lasting 2.5 hours while the THEMIS five spacecraft were located near the dawnside low-latitude magnetopause, between 05:30-09:00 UT on 26 August 2007. During this pass, the observed number density and temperature of the electrons show clear anti-correlation features suggestive of a well developed boundary layer. The plasma data is well ordered using a transition parameter (TP), based on the electron density and temperature, and we find there are clear sublayers in the LLBL, corresponding to: a bi-directional electron region; a newly open field line region, and an older open field line region. In the region containing bi-directional electrons, the populations are well balanced in both high and low energies. In the newly opened field line region, the electrons are dominated by outgoing (parallel) magnetospheric electrons and ingoing (antiparallel) magnetosheath populations, while in the older open field line region, the electrons are still dominated by outgoing magnetospheric electrons but have outgoing magnetosheath populations which may be mirrored from some point in the polar ionosphere. This study suggests that the bi-directional low-energy electrons are not consistent with an ionospheric source but are consistent with a magnetosheath source, indicating that this bi-directional region is located on open field lines, or recently closed field lines. The structures ordered by the TP are explicable in terms of mirror effects in the newly open field line region and older open field line region. Ion distributions show relatively simple, gradual evolution from magnetosphere-like to magnetosheath-like indicating that time of flight effects dominated.

Locating Auroral Oval Boundaries from IMAGE FUV Images

Nicola Longden, Gareth Chisham, Mervyn Freeman, and Gary Abel

British Antarctic Survey

Auroral oval boundaries can be estimated from the characteristics of latitudinal profiles of far ultraviolet (FUV) intensity derived from satellite images. When the oval has the form of a continuous, single oval, the auroral emission in these latitudinal profiles can often be described by a Gaussian. However, at times, such as during substorm activity, the oval may bifurcate. The bifurcated oval is more suggestive of a double Gaussian form. We present the results of applying an automated technique for oval boundary detection to auroral images recorded by the IMAGE satellite between May 2000 and July 2002. For each profile, it was determined whether the intensities were better represented as a single or double Gaussian. The oval boundaries were then determined from the more appropriate fit, enabling boundary estimates to be made during a range of geomagnetic activity levels. The poleward boundaries estimated using this technique provide a proxy for the open-closed magnetic field line boundary (OCB), which can be calibrated with estimates from other sources, such as particle precipitation boundaries detected by the low-altitude DMSP satellites. The resulting new dataset of millions of calibrated OCB estimates, in combination with data from the Super Dual Auroral Radar Network (SuperDARN), will open up the opportunity to measure the rate of magnetic reconnection across an unprecedented range of time and space scales and thereby systematically and quantitatively investigate the turbulent or otherwise complex properties of this fundamental energy transfer process..

Auroral Energy Deposition at Saturn

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Like all giant planets in the Solar System, Saturn is known to have an upper neutral atmosphere far hotter than what is expected from solar EUV heating alone. While the measured low to mid-latitude exospheric temperatures on Saturn range from 300 to 500 K, solar heating alone induces an exospheric temperature below 180 K. A major, additional source of energy originates in the high latitude regions, where magnetospheric currents can deposit globally several tens of TW, more than 50 times the absorbed solar EUV value, as thermal energy, primarily via Joule heating.

Using a General Circulation Model (GCM) of Saturn upper atmosphere and a kinetic, transport model applied to suprathermal electrons, we have assessed the response of Saturn's ionosphere to auroral electron precipitation in a self-consistent manner and evaluated the importance of Saturn's auroral ionosphere as a heating source of the neutral atmosphere. We find that including the effects of ion drag is also crucial for redistributing energy from the polar to equatorial regions. Ion drag reduces polar temperatures, bringing them closer to values observed through H₃⁺ emissions, while at the same time increasing the low latitude temperatures. Our calculations suggest that magnetosphere-ionosphere-thermosphere coupling may play a key role for solving the energy crisis at Saturn and other gas giants.

Saturn's equinoctial auroras

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We present the first images of Saturn's conjugate equinoctial auroras, obtained in early 2009 using the Hubble Space Telescope. We show that the radius of the northern auroral oval is $\sim 1.5^\circ$ smaller than the southern, indicating that Saturn's polar ionospheric magnetic field, measured for the first time in the ionosphere, is $\sim 17\%$ larger in the north than the south. Despite this, the total emitted UV power is on average $\sim 17\%$ larger in the north than the south, suggesting that field-aligned currents (FACs) are responsible for the emission. Finally, we show that individual auroral features can exhibit distinct hemispheric asymmetries. These observations will provide important context for Cassini observations as Saturn moves from southern to northern summer.

Negative ions at Titan – density trends

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The Electron Spectrometer of the Cassini Plasma Spectrometer (CAPS-ELS) has revealed the existence of negative ions in Titan's ionosphere (Coates et al, 2007, Waite et al, 2007). These are observed when the instrument points in the ram direction at altitudes between 950 and 1400 km. The ions have masses up to 13 800 amu/q. This indicates that complex hydrocarbon and nitrile chemical processes take place in Titan's upper atmosphere. With data from over 20 encounters and using spacecraft attitude changes and an increased number of measurements from recent CAPS actuator fixed flybys we have accumulated a large negative ion data base. Coates et al. (2009) discussed trends of the highest masses with solar zenith angle (SZA), altitude and latitude. We now extend this study to density trends of different masses. Groups of masses can be identified because similar peaks are observed in the mass spectra of different encounters. We investigate the effects of different controlling parameters such as altitude, solar zenith angle, latitude and Titan local time. The aim of this study is to help constrain the chemical formation and destruction processes of negative ions in Titan's ionosphere. We present the results and discuss their implications. For instance, for higher masses of 110-200 amu at an altitude range of 950 –1050 km the highest densities can be found on the nightside, whereas the highest densities of low masses (10 – 30 amu) can be found on the dayside at low SZAs in the same altitude range. Therefore, nightside reactions seem to yield the highest densities for higher masses and photochemical reactions yield the highest densities for the lower mass negative ions.

Posters

The dependence of Martian ionospheric conductivities on the interplanetary and crustal magnetic fields

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The Martian ionosphere is permeated by an extremely variable magnetic field that results from both the interplanetary magnetic field and the palaeomagnetic fields that emanate from magnetized portions of the planet's crust. This spatially and temporally varying magnetic field directly affects the ion and electron gyrofrequencies. In turn, the magnetic field and gyrofrequencies, together with the collision frequencies and the electron concentration, determine the parallel, Pedersen and Hall conductivities that characterize current flow in the ionosphere. We present initial findings of an investigation of these conductivities undertaken using magnetic field data obtained by the Mars Global Surveyor (MGS) spacecraft during the aerobraking phase of the mission. Results are shown from regions with strong crustal fields and also from areas where the magnetic pileup region may be identified clearly. A particular point of note is the dependence on the magnetic field of altitude regions of higher conductivity.

Sprites events captured using a broadband globally distributed four station sensor network.

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The Sprite project at the University of Bath first calibrated and tested state of the art magnetotelluric data loggers for the purpose of taking high resolution remote sensor measurements of electromagnetic Sprites signatures. Having tested these in the lab and suitable test sites in Scotland and Exmoor four stations were installed around the world.

The units were deployed at the geophysical observatory at Eskdalemuir in Scotland supported by the British Geological Survey, the geophysical observatory at Pinon Flat in California supported by the University of California and San Diego, the Astronomical Observatory at Sutherland supported by the South African Astronomical Observatory national research foundation and the geophysical observatory outside Canberra Australia supported by Geoscience Australia.

With optical observations taken over Europe an initial set of results captured using the network are presented along with details of the Network itself.

Observations of high latitude ion outflows with the EISCAT incoherent scatter radars and the FAST spacecraft.

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The loss of heavy ions from the upper atmosphere is an important process through which planetary atmospheres are lost, and plays an important role in determining the mass density of the overlying magnetosphere and thus, for example, the transport of magnetospheric energy by MHD waves. Detailed observations of such outflow events are required in order to establish the physical processes, such as energy input from precipitating electrons, the convection electric field and wave-particle interactions which can accelerate the heavy ions so they can overcome the effects of gravity. An important question to be addressed is whether ion-frictional heating or ambipolar electric fields set up by electron precipitation into the ionosphere is the main cause of the initial ion upwelling, which is then subsequently accelerated by some type of wave-particle interaction. Incoherent scatter radars offer a unique diagnostic of ionospheric composition and vertical motion, and a significant database of conjunctions between the EISCAT Svalbard and mainland radars in the Scandinavian sector and overpasses of the FAST spacecraft has been examined to address this problem. This presentation will present the results of these studies.

16 Years of the Super Dual Auroral Radar Network (SuperDARN)

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SuperDARN is a multi-national global network of HF radars currently consisting of 12 operational facilities in the northern hemisphere (plus 2 currently undergoing maintenance) and 6 in the southern hemisphere (plus 1 en route to the Falklands). The SuperDARN radars measure winds, waves, and tides in the upper atmosphere, and as such they are collectively one of the most important tools for understanding such Sun-Earth connections. In particular they have been demonstrated to work very effectively with space missions such as the ESA Cluster mission. In recent years the network has expanded both poleward (PolarDARN) and equatorward (StormDARN) with a further expansion due to see it grow by up to 15 radars over the next 4 years.

In this talk we review the current status of the network, demonstrate its data products and review its recent scientific achievements. Finally, we describe the latest addition to the network, the Falklands radar, a Natural Environment Research Council (NERC) funded project soon to be deployed at Goose Green.

Probing the large-scale topology of the heliospheric magnetic field using Jovian electrons

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Jupiter's magnetosphere acts as a point source of near-relativistic electrons within the heliosphere. In this study, three solar cycles of Jovian electron data in near-Earth space are examined. Jovian electron intensity is found to peak for an ideal Parker spiral connection, but with considerable spread about this point. Assuming the peak in Jovian electron counts indicates the best magnetic connection to Jupiter, we find a clear trend for fast and slow solar wind to be over- and under-wound with respect to the ideal Parker spiral, respectively. This is shown to be well explained in terms of solar wind stream interactions. Thus modulation of Jovian electrons by corotating interaction regions (CIRs) may primarily be the result of changing magnetic connection, rather than CIRs acting as barriers to cross-field diffusion. By using Jovian electrons to remote sensing magnetic connectivity with Jupiter's magnetosphere, we suggest that they provide a means to validate solar wind models between 1 and 5 AU, even when suitable in situ solar wind observations are not available. Furthermore, using Jovian electron observations as probes of heliospheric magnetic topology could provide insight into heliospheric magnetic field braiding and turbulence, as well as any systematic under-winding of the heliospheric magnetic field relative to the Parker spiral from foot-point motion of the magnetic field.

A statistical study of field-aligned currents in bursty bulk flows observed by Cluster

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Field-aligned currents associated with bursty bulk flows (BBFS) observed by Cluster during the 2001-2004 tail seasons are studied using the curlometer technique. The events are restricted to those for which all the spacecraft were on one side of the current sheet throughout. The currents are compared with spacecraft position, magnetic field components and ion moments of the BBFs and auroral electrojet indices at the times of the events. The results show positive correlations between field-aligned current magnitudes, magnetic field magnitude and ion density. These results are compared with the MHD model of Earthward moving depleted flux tubes by Birn et al. (2004).

Space- and ground-based substorm onset observations; a possible difference between near-earth and mid-tail substorm activity?

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We present observations at and around a substorm onset on 1st October 2005 from Cluster, Double Star, IMAGE & geosynchronous satellites, and ground-based magnetometers & riometers from the CARISMA and NORSTAR arrays. The observations reveal a complex substorm incorporating several auroral activations at different latitudes and local times, the locations of which are constrained through the analysis of both ground- and space-based data. Geomagnetic bays were detected in the auroral zone at the time of expansion phase onset, followed ~20 minutes later by larger bays at higher latitudes. These high-latitude bays were accompanied by an intensification of the poleward edge of the expanded substorm aurora. The tail plasma sheet as observed by Cluster, located ~15RE downtail, thinned before expansion phase onset and remained thin after expansion phase onset, only expanding over the Cluster spacecraft at the same time as the higher latitude geomagnetic and auroral activity, suggesting a possible decoupling between expansion phase onset and subsequent mid-tail/high latitude activity.

Energetic electron precipitation from the outer radiation belt during geomagnetic storms

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Relativistic electron precipitation changes the chemistry of the upper atmosphere and depletes ozone, but the spatial and temporal distributions are poorly known. Here we survey more than 9 years of data from low altitude satellites for different phases of geomagnetic storms. We find that for the outer radiation belt, electron precipitation > 300 keV peaks during the main phase of storms whereas that >1 MeV peaks during the recovery phase. Precipitation >300 keV can occur at all geographic longitudes in both hemispheres whereas that >1 MeV occurs mainly poleward of the South Atlantic anomaly (SAA) region. The data suggest that wave-particle interactions are strong enough to precipitate >300 keV electrons into the bounce loss cone, but precipitate >1 MeV electrons into the drift loss cone. We find that whistler mode chorus waves alone cannot account for the higher MeV precipitation flux during the recovery phase. We suggest that whistler mode chorus waves accelerate electrons up to MeV energies during the recovery phase which are then precipitated by EMIC waves. The effects on atmospheric chemistry due to MeV electron precipitation are more likely to occur in the southern hemisphere poleward of the SAA region with a delay of 1-2 days or more from the peak of the storm.

Cassini observations of a Kelvin-Helmholtz vortex in Saturn's outer magnetosphere

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We present the first observations of a plasma vortex in Saturn's dayside outer magnetosphere. The identification of the structure provides compelling evidence of the operation of the Kelvin-Helmholtz (K-H) instability at Saturn's morning magnetospheric boundaries. Cassini observations taken during the inbound pass of the spacecraft's Revolution B orbit in December 2004 are analysed. Magnetic field conditions during the magnetopause crossings that occurred on this orbital pass suggest that the boundary was likely to have been K-H unstable. Following multiple magnetopause crossings the spacecraft encountered the low-latitude boundary layer. Magnetic field and plasma observations made by Cassini during the spacecraft transition between the boundary layer and magnetosphere proper are consistent with an encounter with a K-H vortex on the inner edge of the boundary layer – this interface is also likely to have been K-H unstable. High-energy (>20 keV) directional electron fluxes observed while the spacecraft was within the vortex suggest that the structure produced an auroral signature. A simple model of the coupling between the vortex and Saturn's ionosphere via field-aligned currents is proposed, which is consistent with the magnetic field observations. Estimates resulting from the application of Knight's theory suggest that the vortex-induced current system could have generated large enough field-aligned potentials to produce an auroral signature. In the absence of coincident auroral imaging, we conclude that it is plausible that the K-H vortex generated bright spots of ultraviolet auroral emission. This discovery has implications for our understanding of the interaction between the solar wind and Saturn's magnetosphere.

Dual periodicities of planetary period magnetic field oscillations at Saturn

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Provan et al (2009) and Andrews et al (2009) reported on the observation of near-planetary period magnetic field oscillations by the Cassini spacecraft. Provan et al. (2009) found that the period of oscillations from the equatorial and southern hemisphere polar region was the same as the slowly varying period of ~10.8 hrs used to define the SLS3 longitude system (Kurth et al., 2008). However, Provan et al. (2009) found that the period of oscillations from the northern hemisphere polar region was much more scattered.

Kurth et al (2008) reported that the SKR radio emissions could exhibit a second period of ~10.6 hrs. Further investigation by Gurnett et al. (2009) revealed that ~10.6 hrs oscillations were observed when Cassini was at northern latitudes above 10°, while the 10.8 hour signal was observed when Cassini was at southern latitudes. Lamy (private correspondence)

demonstrated that SKR emissions from Saturn's northern hemisphere also revealed dual periodicities. Analysing data from 2004 to 2009 showed that ~ 10.6 hrs oscillations were present throughout the interval, while oscillations with ~ 10.8 h periodicities appeared to occur more intermittently.

We here present an analysis of near-planetary period magnetic field oscillations from the northern hemisphere polar region and demonstrate that the periodicity of the oscillations agrees closely with the ~ 10.6 hrs SKR periodicity. Our work agrees with several other observations, for example those of Carbary et al., 2009, who recently reported dual periodicities within the energetic electrons at Saturn.

Investigating the relationship between the open magnetic flux at the time of substorm onset and substorm particle injection signatures.

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The mechanism which leads to substorm onset is an outstanding question in magnetospheric physics. Previous studies have shown that substorm onset can be associated with external triggers in the solar wind whilst others occur independently of these changes. In this study we investigate the idea of a critical threshold in the open magnetic flux content of the magnetosphere as a necessary and/or sufficient condition for substorm onset. Using auroral images from the Wideband Imaging Camera (WIC) onboard the IMAGE spacecraft, an automated method of quantifying the open magnetic flux content of the magnetosphere has been developed. By applying this method to over 12000 auroral images from December and January 2000-2002, encompassing some 173 substorms, we determine the probability of substorm onset as a function of open flux. Splitting the substorm distribution into three categories based on their particle injection signatures at geosynchronous orbit as seen by the LANL spacecraft, we show that substorms associated with a classical substorm injection signature occur, on average, at higher values of open magnetic flux than those showing varied or no particle injection signatures. We investigate the apparent relationship between open flux at substorm onset with particle injection signatures by carrying out a superposed epoch analysis of the open magnetic flux, solar wind and magnetic activity around the time of substorm onset.

First E-region observations of meso-scale neutral wind interaction with auroral arcs

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We report the first observations of E-region neutral wind fields and their interaction with auroral arcs at meso-scale spatial resolution during geomagnetically quiet conditions at Mawson, Antarctica. This was achieved by using a scanning Doppler imager, which can observe thermospheric neutral line-of-sight winds and temperatures simultaneously over a wide field of view. In two cases, the background E-region wind field was perpendicular to an auroral arc, which when it appeared caused the wind direction within ~ 50 km of the arc to rotate parallel along the arc, reverting to the background flow direction when the arc disappeared. This was observed under both westward and eastward ion convection. The wind rotations occurred within 7-16 min. In another case, as an auroral arc propagated from the horizon toward the local zenith, the background E-

region wind field became significantly weaker but remained unaffected where the arc had not passed through. We demonstrate through modelling that these effects cannot be explained by height changes in the emission layer. The most likely explanation seems to be greatly enhanced ion drag associated with the increased plasma density and localised ionospheric electric field associated with auroral arcs. In all cases, the F-region neutral wind appeared only slightly affected by the auroral arc, although its presence is clear in the data.

The formation of a nightside ionosphere on Titan

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Titan, the largest moon of Saturn, is the only satellite in the solar system to sustain a permanent and dense atmosphere. Its ionosphere was first discovered by the Voyager 1 radio occultation experiment and has been regularly probed by Cassini for the past four years. While the formation of the dayside ionosphere on Titan has been confirmed to be mostly driven by solar EUV (X-ray) radiation, the source for the nightside ions is still under debate. The traditional picture is that the atmospheric ions on the nightside of Titan are mostly produced by electron impact ionization through precipitating electrons/ions from Saturn's magnetosphere. In this work, we propose a new scenario in which a significant amount of the ions created by solar radiation at the dayside may survive well to the nightside. Such a day-to-night transport scenario is supported by several observational evidences revealed by Cassini: (1) the strong correlation between the night-to-day ion density ratio and the associated ion lifetime; (2) the apparent asymmetry between the dawn and dusk ion distribution; and (3) the deviation of ion distribution from diffusive equilibrium on both the dayside and nightside.

Possible signatures of Kelvin-Helmholtz waves in the dusk flank of the kronian magnetopause

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A comprehensive survey of crossings of both Saturn's magnetopause and bow shock on the dusk side between January 2007 and December 2007 was compiled, using data from the Cassini fluxgate magnetometer and the Cassini electron spectrometer. Bow shock and magnetopause crossings were determined by the criteria discussed in Masters et al., 2008 and Masters et al., 2009 [1] respectively. 396 magnetopause crossings and 165 bow shock crossings were identified with large spatial variation; the high temporal frequency of crossings combined with the large radial variation was indicative of highly dynamic boundaries. A set of magnetopause crossings occurring near the nose of the magnetopause on the 30th June and 1st July 2007 were then analysed using minimum variance analysis (MVA) of the magnetic field vectors over the crossing interval to determine the direction of the boundary normal at each crossing. Using MVA analysis again to calculate the maximum variance direction of the magnetopause normals, I found a clear preferred direction of variance of the normals. The normals were found to deviate by an average of 30° about the average normal direction in the plane of maximum variance, but only by 12° in the perpendicular plane. The observed oscillation of dawn side crossing normals (Masters et al., 2009) was not present throughout the whole dusk set, but was present for subsets, which is suggestive of wave activity. Considering the orientation between the magnetospheric magnetic field and the direction of maximum variance of the normals, the Kelvin-Helmholtz (K-H) instability is the likely driving

force of these boundary perturbations. Current work involves analyzing two further magnetopause crossing sets, one further dusk-ward and one closer to noon (SLT), to identify whether K-H waves are also present at these locations.

[1] Masters, A.; McAndrews, H. J.; Steinberg, J. T.; Thomsen, M. F.; Arridge, C. S.; Dougherty, M. K.; Billingham, L.; Schwartz, S. J.; Sergis, N.; Hospodarsky, G. B.; Coates, A. J. Hot flow anomalies at Saturn's bow shock, *J. of Geophys. Res.*, Vol. 114, 2009

Return Flows in the Kronian Outer Magnetosphere: Cassini Observations

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In this study we use magnetometer data from the outer magnetospheres of Jupiter and Saturn to compare the sizes of dipolarized field regions believed to be associated with return flows from the Dungey and Vasyliunas cycles. These cycles, driven by the solar wind and planetary angular momentum respectively, are believed to play an essential role in the conservation of both mass and magnetic flux in giant planet magnetospheres. We find that the associated dipolarized field regions are significantly larger at Jupiter than at Saturn with the latter showing little or no evidence of the quasi-dipolar Cushion region often observed in Jupiter's post-dawn magnetosphere between the outer edge of the magnetodisk and magnetopause. These differences are discussed from a theoretical perspective, taking into account the different degrees of mass loading present at these planets as well as the differing size and overall flux content of their magnetospheric cavities.

Magnetic Nulls in the Kronian Magnetosphere: Cassini Observations

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Magnetic nulls are characterised by brief (~15 min), sharp depressions in field magnitude to values several tens of percent below that of the ambient background. Such phenomena have been observed in planetary magnetospheres throughout the solar system, and indeed also the solar wind, and have been attributed to a number of different causes (depending on the exact field and plasma characteristics of the event) including current sheet crossings and detached plasma islands which must remain in approximate pressure equilibrium with their surroundings. Here we analyse data from the Cassini fluxgate magnetometer (FGM) and survey the occurrence of such events in the Kronian magnetosphere. We discuss the origin and dynamics of these events within the framework provided by Saturn's known magnetospheric configuration and dynamics and compare our findings with magnetic nulls in the magnetospheres of Jupiter and the Earth.

Power and Spectral Index Anisotropy of the Whole Inertial Range of Turbulence in Fast Solar Wind.

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We show that in fast polar solar wind the power at the outer scale of turbulence is approximately isotropic with respect to the mean magnetic field direction. As the turbulent cascade develops the spectral index changes from isotropic and ~ -1 to anisotropic with values close to those corresponding to Goldreich-Sridhar critically balanced turbulence. By using data at different radial distances from the Sun we show that as the $1/f$ breakpoint moves to lower frequencies so does the anisotropy of power and spectral index, both at a similar rate to the increasing in size of the ion gyroscale. This allows us to use data taken at larger heliocentric distance to investigate smaller scales relative to the ion gyro radius and thus measure the power and spectral index anisotropy of the whole inertial range of solar wind turbulence for the first time. We find that this is consistent with evolving in-situ critically balanced turbulence and gives a precise and complete constraint for anisotropic magnetic field turbulence simulations and theory.

Thermospheric Flows at Jupiter for Differing Solar Wind Conditions

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The magnetosphere-ionosphere coupling at Jupiter is known to play a central role in generating auroral emissions at this planet. The strength of these emissions is partly determined by the relative rotational flows in the upper atmosphere (thermosphere) and in the magnetodisc. We present simulations of the atmospheric flow which employ an azimuthally symmetric global circulation model. In order to make preliminary estimates of the effects of upstream solar wind conditions on these flows, we calculate models which assume different profiles of magnetic field and plasma angular velocity in the magnetodisc, corresponding to compressed and expanded states of the planet's magnetosphere. We use these simulations to comment on the relationship between global magnetospheric configuration and the global pattern of winds and energy inputs into the thermosphere.

Observational evidence of a CME distortion directly attributable to a structured solar wind

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We present the first observational evidence of the near-Sun distortion of a coronal mass ejection (CME) by the ambient solar wind into a concave-outward structure. On November 14 2007, a CME was observed by coronagraphs onboard the STEREO-B spacecraft, possessing a circular cross-section. Subsequently the CME passed through the field of view of the STEREO-B Heliospheric Imagers where it was observed to distort into an increasingly concave-outward structure. The CME observations are compared to an analytical flux rope model constrained by a MHD solar wind solution. The resultant bimodal speed profile is used to kinematically distort a circular structure that

replicates the initial topology of the CME. The CME topology is found to change rapidly over a relatively short distance. This indicates an approximate radial distance in the heliosphere where the solar wind forces begin to dominate over the magnetic forces of the CME influencing the topology of the CME.