Autumn MIST, 29th November, 2013

Oral Presentations (in talk order)

The Met Office Unified Model and its extension to the thermosphere (INVITED)

David Jackson, Met Office, Exeter, UK

The Met Office Unified Model (UM) is a troposphere / stratosphere / mesosphere model which is used widely for both weather forecasting and climate studies. It includes a comprehensive representation of atmospheric dynamics, physics and chemistry, and currently has an upper boundary near 85 km.

In order to develop an improved capability for space weather forecasts, it is desirable to develop a coupled system of models representing the domain from the Sun to the Earth's surface. Much space weather forecast research is focused on the thermosphere and ionosphere, since that is where many space weather impacts are seen. While the thermosphere and ionosphere are largely driven from above, recent research has shown that the coupling between this region and the lower atmosphere is also important. For example, non-migrating tides forced in the tropical troposphere have been linked to variations in the ionospheric F region.

Therefore, representation of such coupling is important. An attractive way of doing this is by building a "whole atmosphere" model, which spans the neutral atmosphere from the Earth's surface to the exobase (around 600 km) and represents the coupling between different atmospheric levels in a self-consistent manner. Such a task is challenging, so an intermediate step may be to develop an extended model with an upper boundary in the lower thermosphere. This approach is more tractable while remaining scientifically useful. The UM is suitable for such developments since its dynamical core is non-hydrostatic and uses a deep atmosphere approximation. In this presentation, the dynamical, physical and chemical developments required to make this extended model a reality are discussed.

Physical models, empirical models and data in the ATMOP project

Timothy Spain, Alan Aylward and the ATMOP Consortium

The ATMOP project aims to improve the Drag Temperature Model (DTM) for better modelling of drag in satellite trajectory propagation. Through a combination of precise, but limited, accelerometer measurements and the global, but imperfect, UCL CMAT2 global circulation model, the global representation of thermospheric density in DTM is improved. The contributions to and strengths of CMAT2 in this effort will be highlighted.

From optical emissions to auroral acceleration – using three models

Sam Tuttle, John Spry, Betty Lanchester (presenting), Björn Gustavsson, Hanna Dahlgren

Starting with selected optical emissions from a small region surrounding the magnetic zenith, three models are used to obtain a theoretical understanding of the acceleration processes that create these emissions. The first model is a combined ion chemistry and electron transport model, which provides a powerful method for obtaining the energy and flux of the precipitation in the magnetic zenith, using selected emissions from atomic oxygen and one molecular source as input. The second model uses the combined optical emissions at these two distinct wavelengths to validate the energy spectra in a region surrounding the magnetic zenith, by comparing the measured fast and variable optical emissions at a frame rate of 20 fps and spatial resolution down to 20 m with modelled values. The resulting three dimensional emission profiles in the field of view of the cameras are then used to extract optical flows from a third wavelength emission, in the metastable emission at 732 nm from O^+ ions. Finally these flows are interpreted as small scale electric fields in the region of the auroral structures, and are used as input to a plasma-neutral MHD model to create acceleration by parallel electric fields generated by current striation in the lower magnetosphere.

A global model of meteoric metals

John Plane, Wuhu Feng, Daniel Marsh, Diego Janches, Erin Dawkins, Martyn Chipperfield, Josef Hoffner, Fan Yi and Chester Gardner

A unique feature of the mesosphere/lower thermosphere (MLT) region is the layers of metal atoms produced by meteoric ablation. These layers provide an important way to understand the coupling of atmospheric chemistry and dynamical processes, as well as testing the accuracy of climate models in the MLT. We have developed the first global atmospheric model of meteoric metals by combining three components: the Whole Atmosphere Climate Community Model (WACCM) from the US National Center for Atmospheric Research; a description of the neutral and ion-molecule chemistry of five metals (Na, Fe, K, Mg and Ca) based on the rate coefficients of more than 120 reactions measured by the Leeds group; and a meteor input function which combines the Leeds Chemical Ablation Model with an astronomical model of cosmic dust in the inner solar system. The model has been evaluated against a number of available ground-based lidar measurements covering a wide range of latitudes in both hemispheres, as well as with global observations of the Na and K layers using the Optical Spectrograph and Infra-Red Imager System (OSIRIS) on-board the Odin satellite. In general, the model performs well in simulating the mesospheric atomic metal layers (i.e., the layer peak densities and heights, total column abundances, and seasonal variability), although there are some significant discrepancies: in particular, the model overestimates metal ions above 95 km compared with rocket-borne mass spectrometric measurements. The model has also been run for the period 1955-2006 to investigate how changing climate and the solar cycle impact the different metal layers.

Three-dimensional simulation of complex plasma environment and its application

F. Honary, A. Anuar, S. Marple

Dust particles are ubiquitous in space and earth's environment and have been a subject of intensive research for decades. Dust interaction with local plasma population increases the complexity of the plasma system which is why it is referred to as complex plasma. In this presentation a new 3-D particle in cell code with Monte Carlo collision (PIC-MCC) will be reported which is capable of simulating the behaviour of dust particles in space plasma. The code considers the dust charging process by ambient plasma. Results for both single dust and dust cloud charging and the associated plasma response will be presented. Simulation of spacecraft charging in the presence of a dust cloud reveals that a cloud of dust particle close to spacecraft surface affects plasma densities around the spacecraft as well as the spacecraft's surface potential. The simulation suggests that dust cloud causes the surface to charge to higher negative potential and the combination of surface potential and dust cloud potential produces a region of trapped low-energy electrons.

The Swarm Mission: overview

Y.V. Bogdanova, M. W. Dunlop, A. W. P. Thomson, S. Macmillan, H. Luhr, R. Floberghagen, R. Haagmans, G. Ottavianelli, G. Plank and the Swarm team.

The ESA Swarm mission is a three-spacecraft 'constellation' designed to explore both external and internal parts of the Earth's magnetic field in unprecedented detail. Launch is scheduled for 14 November 2013 and will place the spacecraft into low, polar Earth orbits. The Swarm mission was developed primarily as a magnetic field missions, however additional plasma and electric field instruments on board expands the scientific goals of this mission, providing measurements of near-Earth plasma density, temperature and velocity as well as of electric field. The mission has four primary science objectives: (1) Studies of core dynamics, geodynamo processes, and core-mantle interaction, for example to produce high-resolution internal magnetic field models; (2) Mapping of the lithospheric magnetisation and its geological interpretation; (3) Determination of the 3-D electrical conductivity of the mantle; (4) Investigation of electric currents flowing in the magnetosphere and ionosphere. As both an Earth Explorer mission and an important resource for space weather science, the mission has attracted interest from both the geomagnetic and MIST communities. A number of proposed UK studies are intended on topics relating to: data verification, modelling and exploitation. These activities will support the wider ESA Swarm level 2 data facilities and science data verification and exploration. The Swarm activities highlight the crucial role of science in supporting Swarm operations, including the possible coordination with data from other spacecraft and with ground-based observations. This presentation will provide an ESA overview of the mission status, instruments, available data, and planned UK studies.

UK contributors to the Swarm team include: Rutherford Appleton Laboratory, British Geological Survey, Liverpool University (R. Holme), Edinburgh University (K. Whaler, N. Olsen), British Antarctic Survey (M. Freeman), University College London (A. Aruliah), Imperial College London (J. Eastwood), Leeds University (P. Livermore).

Assessing the effect of spacecraft motion on single-spacecraft solar wind tracking techniques

T. M. Conlon, S. E. Milan and J. A. Davies

Recent advances in wide-angle imaging by the Solar Mass Ejection Imager (SMEI) on board the Coriolis spacecraft and more recently by the Heliospheric Imagers (HI) aboard NASA's Solar TErrestrial RElations Observatory (STEREO), have enabled solar wind transients to be imaged and tracked from the Sun to 1 AU and beyond. In this presentation we consider two of the techniques that have been used to determine the propagation characteristics of solar wind transients based on single-spacecraft observations, in particular propagation direction and radial speed. These techniques usually assume that the observing spacecraft remains stationary for the entire time during which it observes the solar wind transient. We determine the inaccuracy introduced by this assumption for the two STEREO spacecraft and find that it can be significant, and can lead to an overestimation of the transient velocity as seen from STEREO A and an underestimation as seen by STEREO B. This has implications for the prediction or solar wind transients at 1 AU and hence is important for the study of space weather.

The radial evolution of an ICME

Simon W. Good, Robert J. Forsyth PRESENTING AUTHOR: Simon W. Good

Coronal mass ejections (CMEs) are large eruptions of magnetic field and plasma from the solar atmosphere whose interplanetary manifestations (ICMEs) can be detected in situ by spacecraft in the solar wind. The fleet of spacecraft currently exploring the inner solar system offers unprecedented opportunities for the multi-point, in situ observation of ICMEs - such observations are leading to a better understanding of ICME kinematics and dynamics, and of how ICME morphology and magnetic field structure evolve during propagation. A number of statistical studies have considered the properties of ICMEs observed at different radial distances from the Sun, but few have tracked the radial evolution of individual events in situ. In situ observations made by Venus Express and Wind of the same ICME whilst the two spacecraft were at near perfect radial alignment in October 2010 will be presented. We show that, between 0.72 and 0.99 AU, the magnetic flux rope embedded in this event (i) travels at an approximately constant speed, (ii) displays self-similar radial expansion, and (iii) expands in radial width by a factor of 1.28: this in situ expansion factor is in good agreement with an empirical relation for radial width that others have derived from the remote tracking of (I)CMEs using STEREO's Heliospheric Imagers.

Studying Solar Wind Magnetic Reconnection Events using the Cluster Spacecraft's 4-point Measurement Capability.

A. C. Foster, C. J. Owen, A.N. Fazakerly, I. J. Rae, C. Forsyth, A. Balogh, E. Lucek, H. Reme

We use detailed observations by the 4 Cluster spacecraft to study transient events in the solar wind which are apparently consistent with previous reports of magnetic reconnection events. The use of data from the 4 Cluster spacecraft allows the three dimensional structure of events to be studied at sub-second resolution.

Previous studies have concluded that active solar wind reconnection current sheets are predominately stable over scales of 100s R_E and timescales of a few hours. They conform to the classic model of a configuration of a pair of oppositely directed exhaust jets within magnetic field reversal region, as first identified by Gosling (JGR, 2005).

We present a case study of an event that occurred on the 2nd March 2006, in which we test the consistency of the temporal and spatial structure of magnetic reconnection from large scales to small scales. We show that the reconnection structures are not similar over relatively small (~10,000km) scales, suggesting either that the reconnection may not be structured as in Gosling (JGR, 2005), or that these structures are not necessarily large in the solar wind. We conclude that the analysis demonstrates that our current understanding, that magnetic reconnection is a large scale process in the solar wind, may not hold for all cases.

On the generation of magnetosheath high speed jets by bow shock ripples

H. Hietala and F. Plaschke

The terrestrial magnetosheath is embedded with coherent high speed jets of about 1 Re in scale, predominantly during quasi-radial interplanetary magnetic field (IMF). When these high dynamic pressure (Pdyn) jets hit the magnetopause, they cause large indentations and further magnetospheric effects. The source of these jets has remained controversial. One of the proposed mechanisms is based on ripples of the quasi-parallel bow shock.

In this study, we combine for the first time four years of subsolar magnetosheath observations from the THEMIS mission and corresponding NASA/OMNI solar wind conditions with model calculations of a rippled bow shock. Concentrating on the magnetosheath close to the shock during intervals when the angle between the IMF and the Sun-Earth line was small, we find that
(1) 97% of the observed jets can be produced by local ripples of the shock under the observed upstream conditions;
(2) the coherent jets form a significant fraction of the high Pdyn tail of the magnetosheath flow distribution;
(3) the magnetosheath Pdyn distribution matches the flow from a bow shock with ripples that have a dominant amplitude to wavelength ratio of about 9% (~0.1 Re/1 Re) and are present ~12% of the time at any given location.

Small scale particle dynamics in Kelvin Helmholtz waves at the Magnetopause: High time resolution Cluster observations

Ali Varsani, Christopher J. Owen, Andrew N. Fazakerley, I. Jonathan Rae, Colin Forsyth, Andrew P. Walsh

Interactions between the solar wind and the Earth's magnetosphere at the magnetopause are the key to understanding the mixing of these two plasma regimes. During periods of northward IMF, when there is expected to be an absence of low latitude reconnection at the magnetopause, there are questions as to how the low latitude boundary layer may be populated with magnetosheath-like plasma. Cluster multi-spacecraft observations have shown the existence of non-linear waves at the magnetopause that are thought to be results of Kelvin-Helmholtz instability; these waves can grow and form rolled-up vortices which may transfer the solar wind plasma into the magnetosphere. However, the particle behaviour at small scales is yet to be fully understood. In December 2007, Cluster encountered on-going waves as the four spacecraft crossed the Earth's dusk flank magnetopause through its low latitude boundary layer. During this event, the particle instruments returned a full 3D plasma distribution once every 4 s and the magnetic field was closely aligned with the spacecraft spin axis. In this study, we are thus able to use the 3D particle data to reconstruct near-full pitch angle distribution of electrons and ions at sub-spin resolution. These high-time resolution observations (up to 32 times faster than normal mode data) provide new insights into particle dynamics during the inbound-outbound movements of Cluster into the magnetosheath. Our aim is to understand the plasma behaviour during the development of non-linear wave growth, which may subsequently develop into rolled-up vortices further along the magnetopause towards the nightside. We present the initial results from this study which highlight multiple regions of field aligned particles observed at the magnetopause crossings within these waves; and investigate these signatures as possible reconnection bursts within the growing KH waves which facilitate transfer of magnetosheath plasma into the magnetosphere.

Magnetospheric 'magic' frequencies as standing magnetopause surface waves

M. O. Archer, M. D. Hartinger, T. S. Horbury

Statistical and event studies have shown that magnetospheric ULF waves are often observed at persistent discrete Pc5 frequencies known as 'magic' frequencies [see Menk 2011 for a recent review]. These are thought to be either directly driven by monochromatic solar wind pressure fluctuations or resonantly excited global (cavity/waveguide) modes or standing magnetopause surface waves, perhaps excited by localised pressure enhancements in the magnetosheath. To distinguish between these hypotheses, we identify transient jets in the magnetosheath (which occur about 2% of the time, predominantly downstream of the quasi-parallel shock) and statistically investigate the spectral response of the magnetospheric magnetic field at geostationary orbit. The broadband jets do not exhibit discrete frequencies but do drive waves at the discrete magic frequencies, with both direct and resonant driving. We show that the expected fundamental frequencies of magnetopause surface eigenmodes have two preferential values over a wide range of upstream conditions, corresponding to fast and slow solar wind, and that their harmonics are in good agreement with the 'magic' frequencies. We also show that the waves are largely inconsistent with global (cavity/waveguide) modes outside the plasmasphere. Thus we conclude that these 'magic' frequencies are most likely due to magnetopause surface eigenmodes.

Menk, F. W., Magnetospheric ULF waves: A review, in The dynamic magnetosphere, edited by W. Lui and M. Fujimoto, IAGA Special Sopron Book Series, pp. 223–256, Springer-Verlag Berlin, doi:10.1007/978-94-007-0501-2_13, 2011.

A statistical study of magnetospheric plasma mass loading using the Cluster spacecraft

J. K. Sandhu, T. K. Yeoman and R. C. Fear

Using Cluster data, from the WHISPER and CIS instruments, for the interval spanning 2000-2012, an empirical model describing plasma mass density distribution along closed geomagnetic field lines in the plasmatrough ($4.5 \leq L < 9.5$) is determined, with dependences with L shell and MLT (Magnetic Local Time) included. The method involves independently modelling field-aligned variations in the electron density and average ion mass, and combining these to infer the corresponding model for mass density. A key result obtained is the inclusion of a localised peak in electron density close to the magnetic equator in the electron density model, neglected by previous models. A possible application of the empirical mass density model, to predict ULF (Ultra Low Frequency) pulsation frequencies using a time-of-flight technique, is also introduced. Further improvements to the mass density model, involving quantifying dependences with solar wind and geomagnetic activity, are discussed.

Losses in the radiation belts caused by EMIC waves

Tobias Kersten, Richard B. Horne, Nigel P. Meredith, Sarah A. Glauert

Electromagnetic Ion Cyclotron (EMIC) waves are electromagnetic waves at frequencies below the local hydrogen cyclotron frequency. EMIC waves can cause electron loss in the radiation belts, if their frequency is Doppler shifted to the electron cyclotron frequency by the relative motion of the waves and electrons along the field line. This enables the EMIC waves to resonate with high energy electrons at energies greater than about 500keV and thereby causing losses due to pitch angle scattering into the loss cone.

To determine how effective EMIC waves are, we calculated bounce averaged pitch angle diffusion rates for a nominal model based on our analysis of data from the fluxgate magnetometer on the CRRES satellite, which sampled EMIC waves in the equatorial region from about L=4.0 up to about L=7 for latitudes up to 30°. The diffusion rates were calculated for 5 levels of kp between 12-18MLT. We found that these waves could diffuse electrons into the loss cone very effectively at energies greater than about 2MeV for pitch angles up to about 60°.

The diffusion rates were included in the BAS radiation belt model together with lower and upper band chorus waves. Using the model we were able to show that EMIC waves cause a significant reduction in the electron flux for high energies for a range of L-shells from L=4.0 – 9.0 but only for pitch angles lower than 60°.

An analysis of the effect of solar wind drivers on the Birkeland current ovals observed by AMPERE

J.C. Coxon, S.E. Milan, L.B.N. Clausen, B.A. Anderson and H. Korth

The Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE) technique utilises magnetic field measurements from the Iridium satellite constellation to determine the location and strength of the Birkeland currents. We characterise the locations of the region 1 and 2 Field-Aligned Current (FAC) ovals, giving us a proxy for the size of the polar cap and providing a measure of the open magnetic flux content of the magnetosphere. Using this measurement, we investigate the relationship between interplanetary conditions and dynamics in the solar wind-magnetosphere-ionosphere coupled system. Specifically, we focus on a large-scale statistical analysis of changes in the current magnitudes during expansions and contractions of the magnetospheric polar cap. The relationship between the solar wind driving and the observed currents is explored in the context of the expanding/contracting polar cap paradigm.

Evidence for the ionospheric outflow in Saturn's magnetotail

M. Felici, C.S. Arridge , A.J. Coates, M.K. Dougherty

The Cassini mission has orbited Saturn since 2004, but in 2006 it explored the deep magnetotail, reaching distances of about 68 RS. Various studies were centered on plasma parameters [Thomsen et al., 2010], sub-corotational plasma [Arridge et al., 2009; McAndrews et al., 2009], magnetic field in the tail [Jackman and Arridge, 2011], reconnection and plasmoids [Jackman at al., 2007; Hill at al., 2008; Jackman et al., 2008], Solar Wind effects on Saturn's magnetosphere [Arridge at al., 2008], and its effects on Saturn's magnetotail [Jackman et al., 2010].

In this presentation we focus on data from Cassini when the spacecraft was situated at ~2200 hours Saturn local time at 30 RS in Saturn's magnetotail. During several entries into the magnetotail lobe, cold ions and electrons were observed directly adjacent to the plasma sheet and apparently extending into the lobe. The electrons and ions appear to be dispersed, dropping to lower energies with time. The magnetic field has a swept-forward configuration which is atypical for this region. In the presentation we explore the hypothesis that these observations are evidence of polar ionospheric outflow from Saturn [e.g., Glocer et al., 2007].

Poster Presentations (in alphabetical order)

Large, sustained vertical winds in the magnetic cusp

A.L.Aruliah, A.Ronksley, T.C.Spain, H.Carlson, K.Oksavik UCL, Utah and Bergen

This paper will present observations from three FPI-EISCAT campaigns on Svalbard which support a mechanism to explain the unexpected density enhancements seen over the magnetic cusp by the CHAMP satellite. The proposed mechanism requires that soft particle precipitation increases the conductivity at 150-200km altitude and simultaneously there should be bursts of fast plasma convection to provide strong frictional heating.

Heating at this high altitude means that it requires little energy to lift the rarefied gas above, and thereby bring denser air into the region passed through by CHAMP (~400km).

Saturn's auroral dynamics during the 2013 observing campaign: in situ and remote observations

S.V. Badman, E.J. Bunce, H. Melin, T. Stallard, J.D. Nichols, D.G. Mitchell, W.S. Kurth, F.J. Crary, Marcia Burton, K.H. Baines, R.H. Brown and M.K. Dougherty

During the recent Saturn auroral observing campaign in April-May 2013 the Hubble Space Telescope (HST) and ground-based infrared telescopes observed Saturn's northern aurora while Cassini instruments observed either the northern or southern aurorae. This provided opportunity for unprecedented simultaneous observations of the auroral morphology and intensity in both hemispheres, as well as complementary sampling of the emissions at different spatial, spectral, and temporal scales.

We focus on observations of the infrared auroral emissions made by the Cassini Visual and Infrared Mapping Spectrometer (VIMS). We present examples of rotating and poleward-moving auroral blobs, as well as very narrow, wavy, and bifurcated arcs. We show the correspondence of the different features with detections of upward and downward field-aligned currents in the magnetic field, plasma wave, and energetic particle data, and their differences from images of the UV aurora.

A Finite-Difference Time-Domain Model of Electromagnetic Wave Interaction with an Ionospheric Plasma

Patrick Cannon, Farideh Honary

Experiments in artificial modification of the Earth's ionosphere by radio-frequency (RF) heating have observed significant enhancement of the electron temperature around the upper-hybrid resonance region. The magnitude of this temperature enhancement has been found to be strongly dependent on the initial angle of propagation of the RF pump wave relative to the geomagnetic field direction and the vertical electron density gradient, and is thought to be linked to the formation and growth of density-depleted irregularities. This poster describes a multi-GPU Finite-Difference Time-Domain code which has been developed to simulate the interaction between an RF wave and ionospheric plasma. The code couples the electromagnetic equations with the plasma-fluid equations describing temperature and density and allows the evolution of temperature and density perturbations to be simulated. Results of the simulation of a simple ionospheric heating experiment, in which an O-mode polarized EM wave was launched at varying angles into a vertically-inhomogeneous ionospheric plasma with small (<5%) density irregularities seeded around the O-mode reflection height, are presented. The results demonstrate an angular dependence in the growth rate of irregularities, with the most significant growth occurring when the incident pump wave is directed close to the magnetic zenith.

Spherical Harmonic Analysis and Climatological Averaging of SuperMAG Data

G. Dorrian, J.A. Wild, M.P. Freeman, J.W. Gjerloev

We present early results both for a spherical harmonic analysis (SHA) of instantaneous geomagnetic conditions and a longer term climatological analysis of the Earth's magnetosphere using data from the SUPERMAG network. A methodology is presented for comparing model outputs from the SHA with SuperMAG data to investigate which order of spherical harmonic expansion best represents the geomagnetic field under given solar-terrestrial conditions. We also present a climatological analysis by using time-averaging of SUPERMAG station data over extended periods of the most recent solar cycle.

The interaction between transpolar arcs and cusp spots

R. C. Fear, S. E. Milan & R. Maggiolo

Transpolar arcs and cusp spots are both auroral phenomena that occur within the polar cap (i.e. poleward of the main auroral oval) during periods when the interplanetary magnetic field is northward. Transpolar arcs are large-scale auroral features which extend from the night side oval towards the dayside, often connecting to the dayside oval; they are formed by the closure of lobe flux by magnetotail reconnection, and hence indicate the 'trapping' of closed magnetic flux which is embedded within the lobe. When a transpolar arc does connect to the day side oval, this indicates that all of the magnetic flux in a narrow local time sector in the magnetotail is closed. Cusp spots are emissions at the footprint of a lobe reconnection site; hence they indicate the occurrence of single lobe reconnection, which redistributes open magnetic flux in the lobe, causing flows in the lobe and polar cap. A key feature of single lobe reconnection is that it does not change the net topology of the magnetic flux in the magnetosphere (i.e. there is no net opening or closure of flux). However, the two phenomena are linked, as the circulation of lobe magnetic flux instigated by lobe reconnection causes the motion of transpolar arcs. We present further observations from the IMAGE satellite on 15th September 2005, during which time a transpolar arc is observed to intersect with a cusp spot. We argue that since cusp spots and motion of transpolar arcs are both manifestations of lobe reconnection, this should be a relatively common occurrence. We demonstrate that when this interaction occurs, the topologies associated with single lobe reconnection change, and hence it has the net effect of opening closed magnetic flux in the magnetotail. Finally, we show that the reconnection mechanism postulated to explain the formation of transpolar arcs is also capable of explaining the existence of such arcs at multiple locations within the polar cap.

In-situ spatio-temporal measurements of the detailed substructure of the substorm current wedge and its evolution

C. Forsyth, A.N. Fazakerley, I .J. Rae, C.E.J. Watt, K. Murphy, J.A.Wild, T. Karlsson, R. Mutel, C.J. Owen, R. Ergun, A. Masson, M. Berthomier, E. Donovan, H.U. Frey, J. Matzka, C. Stolle, Y. Zhang

The substorm current wedge (SCW) is a fundamental component of geomagnetic substorms. Models tend to describe the SCW as a simple line current flowing into the ionosphere towards dawn and out of the ionosphere towards dusk, linked by a westward electrojet. We use multi-spacecraft observations from perigee passes of the Cluster 1 and 4 spacecraft during a substorm on 15 Jan 2010, in conjunction with ground-based observations, to examine the spatial structuring and temporal variability of the SCW. At this time, the spacecraft travelled east-west azimuthally above the auroral region. We show that the SCW has significant azimuthal sub-structure on scales of 100~km at altitudes of 4,000-7,000 km. We identify 26 individual current sheets in the Cluster 4 data and 34 individual current sheets in the Cluster 1 data, with Cluster 1 passing through the SCW 120-240~s after Cluster 4 at 1,300-2,000 km higher altitude. Both spacecraft observed large-scale regions of net upward and downward field-aligned current, consistent with the large-scale characteristics of the SCW, although sheets of oppositely directed currents were observed within both regions. We show that the majority of these current sheets were closely aligned to a north-south direction, in contrast to the expected east-west orientation of the pre-onset aurora. Comparing our results with observations of the field-aligned current associated with bursty bulk flows (BBFs) we conclude that the structuring of the SCW cannot solely be due to BBF driven "wedgelets". Our results therefore represent constraints on future modelling and theoretical frameworks on the generation of the SCW.

Foreshock Dynamics Controlled by Hot Flow Anomaly: Relation between Dawn and Dusk Sector Events

C. Foullon, I. Dandouras, H. Kucharek, B. Lavraud, C. Mazelle, S. Rochel Grimald, C. Carr and A.N. Fazakerley

On 21 January 2005, the passage in the magnetospheric dawn sector of a tilted solar wind current sheet at the periphery of an Interplanetary Coronal Mass Ejection is not observed by Cluster in the dusk sector, where the Interplanetary Magnetic Field points in such a way to form a foreshock. It coincides however with the momentary transition of Cluster from a field-aligned beam region into a Ultra-Low-Frequency (ULF) wave field, with first ever reported 6s-periods in the spacecraft frame. The 4-spacecraft Cluster analysis shows that the ULF waves are intrinsically left-handed and propagating downstream in the proton plasma frame, and thus cannot be produced by the local upstream-directed field-aligned proton beam. Moreover, on each side of the magnetosphere, Double Star TC-1 and Geotail experience large variations in magnetosheath plasma parameters consistent with the tailward effects of a Hot Flow Anomaly (HFA) expected as a result of the interaction with the current sheet. Modelling of the bowshock and foreshock dynamics shows that the entry into the foreshock ULF wave field requires an expansion of the bow shock shape, consistent with the expected formation of a HFA bulge. We propose that the generation of the identified ULF waves on the dusk side is controlled by the production of beams of energetic particles, sufficiently hot for the ion/ion left hand resonant instability to emerge, consistent with those particles backstreaming downstream towards Cluster from a presumed HFA expansion in the solar wind.

Modelling the high-energy electron flux throughout the radiation belts using the BAS Radiation Belt model

S. A. Glauert, R. B. Horne, N. P. Meredith, T. Kersten

The flux of relativistic electrons in the Earth's radiation belts is highly variable and can change by orders of magnitude on timescales of a few hours. Understanding the drivers for these changes is important as energetic electrons can damage satellites. The BAS Radiation Belt model is a physics-based model that has been developed to simulate the energetic electron flux throughout the radiation belts, incorporating the effects of radial transport, wave-particle interactions and collisions. It is now used to forecast the energetic electron flux as part of the EU-FP7 SPACECAST project.

Here we apply a new version of the BAS Radiation Belt model to different types of space weather events. We show that a new model for plasmaspheric hiss and lightning-generated whistlers can reproduce the quiet time decay of the electron flux in the slot region, where the new O3B satellites will operate. We also demonstrate that the large increases in flux that can be observed during both CME and CIR driven storms in the heart of the radiation belts, where GNSS satellites operate, are well reproduced using a recently published model for upper and lower band chorus waves. Finally, using solar wind data, we model changes in the outer boundary of the Earth’s magnetic field and show how these changes can cause rapid radiation belt losses much closer to the Earth that can affect satellites in both MEO and GEO orbits.

The influence of IMF clock angle timescales in controlling the nature of high-latitude ionospheric convection

Adrian Grocott and Steve Milan

Reconnection between the terrestrial and interplanetary magnetic fields (IMF), and subsequent reconnection in the magnetotail, drives large-scale circulation of the magnetosphere, and leads to related patterns of convection of the high-latitude ionospheric plasma. Dayside and nightside reconnection each drive a component of the flow which combine to produce the instantaneous convection pattern (Cowley and Lockwood, 1992). Lockwood et al. (1986), Khan and Cowley (1999) and others showed that the ionospheric response to a change in dayside coupling propagates around the polar cap in 10 - 15 mins to establish a new steady state convection pattern. Average convection patterns, using 36 minutes as the timescale for steady IMF (Ruohoniemi and Greenwald, 2005), fail to adequately resolve certain known features of the convection, such as high-latitude reverse convection cells, and nightside flows resulting from tail reconnection during IMF-northward, non-substorm intervals (TRINNIs). Using observations of the ionospheric convection made by the Super Dual Auroral Radar Network (SuperDARN) we discuss longer timescale changes that occur if the IMF remains steady for many hours in a given orientation. Our analysis shows that a number of convection phenomena are better described when taking variable IMF timescales into account and helps to elucidate the mechanisms that drive them.

Saturn's magnetospheric dynamics: A study of tail reconnection signatures

C.M. Jackman, J. A Slavin, M.G. Kivelson, D. J. Southwood, N. Achilleos, M.F. Thomsen, G. A. DiBraccio, J.P. Eastwood, M.P. Freeman, M.K. Dougherty

The Pioneer 11 (1979), Voyager 1 (1980) and Voyager 2 (1981) spacecraft glimpsed Saturn's magnetotail on their flybys and provided the first clues as to its character and extent. Subsequently the Cassini spacecraft at Saturn (2004-2017 as currently planned) has shed huge light on this fascinating and complex environment. In particular the deep tail orbits of 2006 provided an opportunity to study dynamics such as magnetic reconnection in the tail, and to sample changing plasma flows and field topology in situ. I will provide an overview of my work on Saturn's magnetotail, with a strong focus on magnetotail reconnection, including observations of plasmoids, travelling compression regions and dipolarizations. I will describe the statistical properties of reconnection signatures in situ, and explain the effects of reconnection on global magnetospheric dynamics at Saturn.

Multiple-Spacecraft Density Measurements of Turbulence in the Fast Solar Wind: Preliminary Findings

Lauren Jeska, Xing Li, Owen Roberts

Investigations into solar wind turbulence suggest that a large proportion of the energy is Alfvénic (incompressible) at inertial scales. At smaller ion and electron scales, the properties of turbulence are still under debate, although many believe that Kinetic Alfvén waves are dominant. The properties of the remaining compressible turbulence are also contended. Using data from the four Cluster spacecraft, the power at different frequencies, and its distribution in k-space, can be measured without assuming the validity of Taylor's hypothesis. This is important to identify or rule out weak turbulence components, which cannot readily be determined by single-spacecraft measurements. For the first time, k-filtering is applied to evaluate the power from WHISPER electron density measurements, and this is compared to the power in |B(t)| at ion scales. As the WHISPER measurements have a cadency of only 2.2s, data derived from a proxy measurement, the spacecraft potential measured by the EFW instrument, are also investigated. These data have a higher cadency of 0.2s.

Wavenumber anisotropy in spectra, statistics and scaling in the turbulent solar wind using a locally defined background magnetic field

Khurom H. Kiyani, Kareem T. Osman and Sandra C. Chapman

One of the key characteristics of small-scale plasma turbulence within the solar wind that distinguishes it from hydrodynamic neutral fluids, is that the majority of the power is situated in spatial fluctuations (wavenumbers) that are perpendicular to the background magnetic field. As these fluctuations represent spatial gradients, this has been interpreted as the turbulent cascade proceeding primarily or exclusively perpendicular to the background magnetic field. However, definitions of what constitutes a background magnetic field for the turbulent magnetic fluctuations lack consensus and this topic is a subject of debate amongst researchers who study turbulence – a well-known multiscale phenomenon where there is no clear separation of scales. An appropriate and self-consistent definition of such a background field is essential if one desires to compare observational results with theoretical analysis and predictions –necessary for a deeper understanding of plasma turbulence.

We employ the use of the Undecimated Discrete Wavelet Transform (UDWT) to separate out the signal into a scale dependent local background magnetic field, and scale-dependent local fluctuations. The UDWT not only decomposes the signals into components fluctuating at different scales, but crucially also preserves the timing of events within signals. This allows one to project the fluctuations accurately onto a locally varying background magnetic field. We use solar wind measurements from the ULYSSES and STEREO spacecraft missions to illustrate the key concepts.

Mechanisms by which the interplanetary magnetic field influences polar and mid-latitude surface atmospheric pressure

Mai Mai Lam, Gareth Chisham and Mervyn P Freeman

The existence of a meteorological response in the polar regions to fluctuations in the interplanetary magnetic field (IMF) component By is well established. More controversially, there is evidence to suggest that this Sun-weather coupling occurs via the global atmospheric electric circuit. Consequently it has been assumed that the effect maximizes at high latitudes and is negligible at low and mid latitudes, because the perturbation by the IMF is concentrated in the polar regions. We demonstrate a previously unrecognized influence of IMF By on mid-latitude surface pressure. The difference between the mean surface pressure during times of high positive and high negative IMF By possesses a statistically-significant mid-latitude wave structure similar to atmospheric Rossby waves. Our results show that a mechanism that is known to produce atmospheric responses to the IMF in the polar regions is also able to modulate pre-existing weather patterns at mid latitudes. We suggest the mechanism for this from conventional meteorology (this mechanism is viable in principle for communicating any influence of solar variability on polar atmospheric pressure to the mid latitudes). The amplitude of the effect is comparable to typical initial analysis uncertainties in ensemble numerical weather prediction. Thus a relatively localized small-amplitude solar influence on the upper atmosphere could have an important effect, via the nonlinear evolution of atmospheric dynamics, on critical atmospheric processes.

Saturn's dayside UV auroras: Evidence for morphological dependence on the direction of the upstream interplanetary magnetic field

C.J. Meredith, I.I Alexeev, S.V. Badman, E.S. Belenkaya, S.W.H. Cowley, M.K. Dougherty, V.V. Kalegaev, G.R. Lewis, and J.D. Nichols.

We examine a unique set of seven Hubble Space Telescope (HST) imaging intervals of Saturn's northern dayside UV auroras exhibiting usual 'oval' morphologies, during which Cassini simultaneously measured the IMF upstream of Saturn's bow shock over intervals of several hours. These auroras generally consist of a dawn arc extending towards noon centred near ~15° co-latitude, together with intermittent patchy forms at ~10° co-latitude and poleward thereof, located between noon and dusk. The dawn arc is a persistent feature, but exhibits variations in position, width, and intensity, which have no clear relationship with the concurrent IMF. However, the patchy post-noon auroras are found to relate to the (suitably lagged and averaged) concurrent IMF Bz, being present in all four intervals of positive Bz and absent in all three intervals of negative Bz. The most continuous such forms occur in the case of strongest positive Bz. These results suggest that the post-noon forms are associated with reconnection and open flux production at Saturn's magnetopause, related to the similarly-interpreted small-scale structures observed previously in this LT sector in Cassini UVIS data, whose details remain unresolved in these HST images. One of the intervals with negative IMF Bz, however, exhibits a pre-noon patch of high-latitude emission extending poleward of the dawn arc towards the magnetic/spin pole, suggestive of the occurrence of lobe reconnection. Overall, these data provide evidence of significant IMF-dependence in Saturn's dayside auroras, a result that should be followed up if more such simultaneous data become available.

Observations of mesospheric gravity waves from a ship-borne imager

T. Moffat-Griffin, N.C. Cobbett, M. Rose, P. Breen, T. Stroud, R.E. Hibbins

Perturbations in airglow are a common way to observe mesospheric gravity waves from the ground. This presentation details the development of a novel ship-borne airglow imager system that will allow the first measurements of mesospheric gravity waves above the oceans to be performed from a ship.

Numerical Modelling of non linear wave particle interactions in oblique whistlers

D Nunn and Y Omura

Non linear wave particle interactions in parallel propagating whistlers has been investigated extensively in theory and by numerical modelling. Here we investigate in detail by non self consistent computation non linear wpi in oblique whistlers for a wavefield that is narrow band but may be completely arbitrary as far as space time dependence of propagation angle, frequency and wave amplitude go. The wavefield suite includes a detailed model of a chorus element. Unlike previous works we progress from trajectory computations to computation of resonant particle distribution function, resonant particle current and non linear growth rates, and this for ANY resonance order 'n'.

Landau damping and cyclotron growth are examined for chorus elements and for CW wavefields and important results secured. The code is written in Fortran90 and using MPI runs in about 2 hours on Southampton University IRIDIS supercomputer system.

Proton Kinetic Effects and Turbulent Energy Cascade Rate in the Solar Wind

K. T. Osman, W. H. Matthaeus, K. H. Kiyani, B. Hnat, and S. C. Chapman

The kinetic processes arising from non-thermal velocity distribution functions can affect the macroscopic evolution of space plasmas. We present the first observed connection between kinetic instabilities driven by proton temperature anisotropy and estimated energy cascade rates in the turbulent solar wind using measurements from the Wind spacecraft at 1 AU. We find enhanced cascade rates are concentrated in regions of high temperature anisotropy, which includes those theoretically unstable to the mirror and firehose instabilities. A strong correlation is observed between the estimated cascade rate and kinetic effects such as temperature anisotropy and plasma heating, resulting in protons 5-6 times hotter and 70-90% more anisotropic than under typical isotropic plasma conditions. These results offer new insights into kinetic processes in a turbulent regime.

Anisotropic Intermittency of Magnetohydrodynamic Turbulence

K. T. Osman, K. H. Kiyani, B. Hnat, and S. C. Chapman

A higher-order multiscale analysis of spatial anisotropy in inertial range magnetohydrodynamic turbulence is presented using measurements from the STEREO spacecraft in fast ambient solar wind. We show for the first time that, when measuring parallel to the local magnetic field direction, the full statistical signature of the magnetic and Elsasser field fluctuations is that of a non-Gaussian globally scale-invariant process. This is distinct from the classic multi-exponent statistics observed when the local magnetic field is perpendicular to the flow direction. These observations are interpreted as evidence for the weakness, or absence, of a parallel turbulent energy cascade, as is consistent with several theoretical models. As such, these observations present strong observational constraints on the statistical nature of intermittency in turbulent plasmas.

Planetary Period Oscillations in Saturn's magnetosphere: Comparison of magnetic oscillations and SKR modulations in the post-equinox interval

G. Provan, L. Lamy and S. W. H. Cowley

We present a comparison of Saturn's planetary period oscillations from two Cassini data sets; the magnetic field and Saturn kilometric radiation (SKR). Throughout the Cassini mission there is good overall agreement between the periods determined from the two data sets, though with some unexplained discrepancies occurring, especially around equinox. Both data sets show two distinct oscillations at close to the planetary period. To date, in October 2013, the northern period has remained shorter than the southern although the two periods closely converged (but did not cross) post-equinox. Starting in February 2011 the magnetic oscillations displayed a new behavioural regime, with abrupt changes in the amplitudes of the oscillations and smaller changes in their periods occurring approximately every 6-8 months. The first abrupt change resulted in the unexpected resumption of southern oscillation dominance within the core region. In August 2011 there was another abrupt change to northern dominance. During Cassini's equatorial orbits we report corresponding near-simultaneous sharp changes in the peaks of the SKR spectrogram, with the ratio of the northern to the southern magnetic amplitudes being similar to the ratio of the northern to the southern SKR peaks. Simultaneous changes in the behaviour of the SKR and magnetic oscillations were less discernible when Cassini commenced high-latitude orbits, presumably due to strong variations in the visibility of the SKR emissions along Cassini's orbit. During these post-equinoctial intervals there was close agreement between the periods of the SKR and magnetic oscillations when the SKR spectrogram peaks were high.

Observation of an Alfvén vortex in the solar wind at ion kinetic scales

Owen Roberts, Xing Li, Bo Li

The solar wind magnetic field power spectra usually consists of several power-laws, indicating the existence of non-linear plasma turbulent cascade. In this paper, magnetic field data from the Cluster mission during an undisturbed interval of slow solar wind is analyzed at 0.3Hz, near the spectral break point between the ion inertial and dissipation ranges where the nature of turbulence has fundamental importance to our understanding of plasma turbulence. Assuming Taylor's frozen in condition, the frequency corresponds to a proton kinetic scale $kvA=\Omega p \sim 0:38$, where the vA and Ωp are the Alfvén speed and proton angular gyrofrequency, respectively. Data shows that the Cluster spacecraft passed through a series of wavepackets. We present the first clear evidence of Alfvén vortex at the ion kinetic scale in the solar wind: an observed strong and relatively isolated wavepacket is due to the four Cluster satellites crossing an Alfvén vortex, a nonlinear solution to the incompressible MHD equations.

Modelling Total Electron Content (TEC) in equatorial Plasmasphere utilising electron density data from Double Star (TC1) mission

Aliyuthuman Sadhique, Dr Andrew Buckley

The TC1 spacecraft of the Double Star mission provides a unique opportunity to analyse the Total Electron Content profile in the altitude range between 35000 – 22000 km which corresponds to geosynchronous orbital altitude and GPS satellites' altitude. TEC contribution of this altitude region in trans-plasmaspheric radio transmissions has been hard to determine due to absence of empirical data.

The TC1 spacecraft of the Double Star mission (Joint Chinese- ESA program to study the Sun – Earth interaction/ magnetosphere) operated from 2003 till 2007. It had an orbit of 570 x 78 970 km with 28.5° inclination to the equator. It had 8 instruments from the ESA/NASA Cluster mission.

A new methodology is proposed to make use of the electron density data available from the TC1 mission to derive TEC profiles along the orbital trace of the spacecraft. The low perigee of the orbit and the smaller incident angle the orbital trace makes while in the 35000-22000 km altitude range resulting from it provide the ideal opportunity to utilise the in-situ measurements for TEC calculations.

The methodology is devised as below:

1 The orbital trace through the altitude 22000km to 35000km is considered.
2 The spacecraft passes this region in 1 hour and 7 minutes (4020 seconds - we consider 4000 seconds)
3 Mean electron densities are calculated every 40 seconds, equalling 10 spins.

4 If the variation in electron density within that 40 seconds period is greater than 10%, the period is divided by two repetitively till the variation is 10%.
5 The distance covered in every 40 second is called a TEC Bar
6 If the variation turns out to be more than 10% within that bar, halved sub bars are considered. (As in 4 above)
7 The orbital distance covered by the TEC bar is calculated.
8 The mean point along that path is calculated. This point is called the TEC bar tangent point.
9 The angle the tangent line to the orbit at this point makes with the imaginary incident plane on earth is called the incident angle.
10 Numerical integration is performed on electron density along the TEC bar orbital distance.
11 The resulting value is taken as the slant TEC at the tangent point, the incident angle being calculated in point 9 above
12. A small correction needs to be carried out to trim the orbital distance to equal the hypotenuse of the imaginary right angled triangle of a incident angle and opposite side distance equal to the altitude climbed or descended by the spacecraft in 40 seconds (or relevant TEC sub bar). The TEC is calculated proportional to the ratio of orbital distance and hypotenuse
13 The TEC values are calculated from corrected slant TECs and the incident angles.

The presentation includes explanatory diagrams to illustrate the methodology, the associated physics and the proofs for approximations.

The Magnetic Structure of Saturn's Magnetosheath

A.H. Sulaiman, A. Masters, M.K. Dougherty

The magnetosheath is the region between a planetary bow shock and magnetopause separating the highly supersonic solar wind from the planetary magnetosphere. Within this region, the flow is being deflected and field lines draped and it is an important site for plasma turbulence, instabilities, reconnection and plasma depletion layers. A relatively high plasma beta, high Mach number regime and polar flattening make the magnetosheath of Saturn both physically and geometrically different from the Earth's. Here we use Cassini magnetic field data to compare Saturn's magnetosheath structure with both analytical and MHD-simulated treatments. Using potential theory, the draped magnetic field across a bow shock can be characterised at steady state by solving analytically and this gives an overestimate of the field. A statistical study of most sheath traversals between 2004 and 2010 show good correspondence of the analytically reconstructed meridional angle distribution with the IMF, peaking at 0°. The reconstructed spiral angle however shows a double peak at $\sim 20^{\circ}$ and 210° at the dawn flank and $\sim 150^{\circ}$ and $\sim 330^{\circ}$ from the dusk flank – significantly deviated from the parker spiral. We anticipate our study to be a starting point for more sophisticated analyses on polar flattening as well as shedding light on physical activities in the magnetosheath driven by its magnetic structure such as plasma depletion layers.

Density profiles of different negative ions mass groups at Titan observed by Cassini's CAPS electron spectrometer

Anne Wellbrock, Andrew Coates, Geraint Jones, Gethyn Lewis, Hunter Waite

The discovery of heavy negative ions by Cassini's CAPS electron spectrometer (ELS) in Titan's ionosphere (Coates et al, 2007, Waite et al, 2007) suggests that complex hydrocarbon and nitrile processes occur in Titan's upper atmosphere which are also linked to haze formation. Negative ions are observed during Titan encounters at altitudes < 1400 km and reach masses up to 13,800 amu/q (Coates et al., 2009). Recurring peaks in the mass spectra can be used to identify different mass groups as reported by Coates et al. (2007). These have been updated by Wellbrock et al. (2013) who performed a study investigating trends of mass groups with altitude using data from 34 negative ion encounters. We continue this work here by studying individual flybys in more detail. We investigate density profiles for different mass groups and total densities.

Jovian thermospheric response to multiple solar wind shocks

Japheth Yates, Nicholas Achilleos, Licia Ray, Steve Miller and Patrick Guio

Recent work presented in Yates et al 2013 emphasised the importance of incorporating time-dependence in magnetosphere-ionosphere-thermosphere coupling when simulating this aspect of the Jovian system. We extend their model by simulating the response of thermospheric heating to multiple shocks in the solar wind, by employing a configurable magnetosphere model coupled to an azimuthally symmetric general circulation model. We compare the ensuing response of thermospheric temperatures to these transient compressions and expansions of the Jovian magnetosphere over a period of 100 Jovian rotations. We find that mean temperature generally increases throughout the simulation, with a maximum increase of ~ 15 K. We also show regions with above local average temperatures, propagating from the auroral region to the equator.