Autumn MIST 2014 – 28th November, 2014

Oral Presentations (in talk order)

Space Climate Change (INVITED)

Mike Lockwood

Historic data on geomagnetic activity has enabled us to reconstruct solar and solar wind properties since 1844 with low uncertainties. The results provide a context against which we can evaluate the significance of the recent decline in solar activity which began around 1985 and has given the long and low minimum between solar cycles 23 and 24 and a relatively weak cycle 24. The implications for the future will be discussed.

Causes of long-term change in the upper atmosphere

Ingrid Cnossen

The Earth's upper atmosphere has shown signs of cooling and contraction over the past decades. This is generally attributed to the increasing level of atmospheric CO_2, a coolant in the upper atmosphere. However, especially the charged part of the upper atmosphere, the ionosphere, shows more complicated patterns of change, which cannot fully be attributed to CO_2. Indeed, the ionosphere also responds to the Earth's magnetic field, which has been weakening considerably over the past century, as well as changing in structure. The relative importance of the changing geomagnetic field compared to enhanced CO_2 levels for long-term change in the upper atmosphere is still a matter of debate. I will present a quantitative comparison of the effects of the increase in CO_2 concentration and changes in the magnetic field from 1908 to 2008, based on simulations with the Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM). This demonstrates that magnetic field changes contribute at least as much as the increase in CO_2 concentration to changes in the height of the maximum electron density in the ionosphere, and much more to changes in the maximum electron density itself and to low-/mid-latitude ionospheric currents. Changes in the magnetic field even contribute to cooling of the thermosphere at ~300 km altitude, although the increase in CO_2 concentration is still the dominant factor here. Both processes are roughly equally important for long-term changes in ion temperature. Still, both processes combined do not fully explain observed trends. Further work is needed to estimate effects of other potential causes, such as long-term changes in solar activity and climate change in the lower and middle atmosphere.

Solar Cycle Variations in the Polar Ionosphere

Angeline Burrell, Tim Yeoman, Steve Milan, Mark Lester

The polar ionosphere is a dynamic region that readily responds to changes in solar irradiance, solar wind, the magnetosphere, and the neutral atmosphere. The most recent solar minimum brought to light gaps in the current understanding of the relationship between ionospheric structure and solar irradiance. The Super Dual Auroral Radar Network (SuperDARN) offers an invaluable dataset for studying long-term ionospheric variability, as it has been continuously providing extensive coverage of the northern and southern polar ionosphere since 1995 (the solar minimum preceding the 23rd solar cycle). An under-utilised portion of the SuperDARN dataset is the ground-backscatter: the backscatter that returns from a reflection point on the ground along an open (or irregularity-free) propagation path. The ground-backscatter provides a measure the ionospheric density at the peak of the radar signal's path. Northern hemisphere measurements are used to examine the changes in the bottomside, polar ionosphere over the 23rd and 24th solar cycles.

The dependence of high-latitude geomagnetic pulsations on magnetospheric plasma mass loading

Jasmine Sandhu, T. K. Yeoman, R. C. Fear, I. Dandouras

Field-aligned variations in the electron density and average ion mass were modelled based on Cluster data, from the WHISPER and CIS instruments, for the interval spanning 2000-2012. The combination of these models were used to infer an empirical model for the plasma mass density along closed geomagnetic field lines in the outer plasmasphere and plasmatrough ($5.9 \leq L < 9.5$), including dependences with L shell and MLT (Magnetic Local Time). Further analysis involved quantitatively examining the dependences of the magnetospheric mass density on geomagnetic activity and solar wind conditions.
In this study, the mass density model is utilised to investigate variations in the properties of magnetospheric ULF (Ultra Low Frequency) pulsations. This is a continuation of work by Wild et al. [Wild, J. A., T. K. Yeoman, and C. L. Waters (2005), Revised time-of-flight calculations for high-latitude geomagnetic pulsations using a realistic magnetospheric magnetic field model, *J. Geophys. Res., 110*, A11206, doi: 10.1029/2004JA010964], where a time-of-flight technique was used to calculate the frequency of standing Alfven waves on closed geomagnetic field lines. Whereas Wild et al. (2005) employed the T96 magnetospheric magnetic field model with a relatively simplistic plasma mass density model, the analysis is extended by combining both the T96 magnetic field model and the empirical mass density model.
The results illustrate the influence of including a more representative distribution of mass density along a field line on the calculated characteristic pulsation frequency. In addition, the variations in the field line frequency with geomagnetic activity and solar wind conditions are examined, indicating the dependence of FLRs on the mass loading processes in the region.

Scale Height variations with solar cycle in the ionosphere of Mars

Beatriz Sanchez-Cano, M. Lester, S.E. Milan, B.E.S. Hall, O. Witasse, M. Cartacci, S.M. Radicella

The Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) on board the Mars Express spacecraft has been probing the topside of the ionosphere of Mars since June 2005, covering almost one solar cycle. A good knowledge of the behaviour of the ionospheric variability for a whole solar period is essential because the ionosphere is strongly dependent on solar activity. Using part of this dataset covering the years 2005 – 2012 differences in the shape of the topside electron density profiles have been observed, and seem to be linked to changes in the ionospheric temperature due to the solar cycle variation. Plasma parameters such as the scale height as a function of altitude, the peak characteristics, the total electron content (TEC), the temperatures and the ionospheric pressures are seen to have characteristic signatures during specific periods of the solar cycle. The largest characteristic variation in the topside ionosphere is seen during the period of very low solar minimum, where a reduction in ionization occurs, resulting in a topside scale height decrease not predicted by modelling.

Assessment of Electron Flux Irregularities, or 'Holes', in the Upper Atmosphere of Mars

Ben Hall, M. Lester, J. Nichols, B. Sanchez - Cano, D. Andrews, H. Opgenoorth, M. Fraenz

We report the observation of low energy (20 - 200 eV) electron flux irregularities in the Martian upper atmosphere. In particular, extreme and sudden depressions, or ‘holes’, were found in measurements taken by the Analyser of Space Plasma and Energetic Atoms (ASPERA-3) electron spectrometer instrument on-board the ESA Mars Express spacecraft. The period of study includes early 2012 in which we show that the holes are preferentially observed over regions of remnant crustal magnetic field, as given by the Cain model [Cain et al., 2003], with increased clustering of events over denser field regions. The electron hole events are mostly observed between the altitudes of 350 – 1000 km, which are in correspondence with the location of the Martian upper atmosphere. With the absence of a magnetometer on-board Mars Express, we further demonstrate that with careful analysis of the variation in the low energy electron flux, it is possible to identify boundaries in plasma populations within the solar wind - Mars atmosphere system.

The Solar Stormwatch CME catalogue

Luke Barnard, Chris Scott , Mathew Owens , Michael Lockwood , Kimberley Tucker-Hood , Simon Thomas , Stephen Crothers , Jackie Davies , Richard Harrison , Chris Lintott , Robert Simpson , Jim O'Donnell , Arfon Smith , Natasha Waterson , Steven Bamford , Fiona Romeo , Marek Kukula , Brendan Owens , Neel Savani , Jules Wilkinson , E Baeten , Lionel Poeffel , B Harder

Since the launch of the twin STEREO satellites in late 2006, the Heliospheric Imagers have been used, with good results, in tracking transients of solar origin, such as Coronal Mass Ejections (CMEs), out through the inner heliosphere. A frequently used approach is to build a “J-Map”, in which multiple elongation profiles along a constant position angle are stacked in time, building an image in which radially propagating transients form curved tracks in the J-Map. From this the time-elongation profile of a solar transient can be manually identified. This is a time consuming and laborious process, and the results are subjective, depending on the skill and expertise of the investigator. With the Heliospheric Imager data it is possible to follow CMEs from the outer limits of the solar corona all the way to 1AU.

Solar Stormwatch is a citizen science project that employs the power of thousands of volunteers to both identify and track CMEs in the Heliospheric Imager data. The CMEs identified by Solar Stormwatch are tracked many times by multiple users and this allows the calculation of consensus time-elongation profiles for each event and also provides an estimate of the error in the consensus profile. Therefore this system does not suffer from the potential subjectivity of individual researchers identifying and tracking CMEs. In this sense, the Solar Stormwatch system can be thought of as providing a middle ground between manually identified CME catalogues, such as the CDAW list, and CME catalogues generated through fully automated algorithms, such as CACtus and ARTEMIS etc.

We provide a summary of the reduction of the Solar Stormwatch data into a catalogue of CMEs observed by STEREO-A and STEREO-B through the deep minimum of solar cycle 23 and review some key statistical properties of these CMEs. The reliability of the Solar Stormwatch identified CMEs is assessed by comparison of these results with a set of manually identified CMEs, extracted and analysed by an individual researcher.

Through some case studies of the propagation of CMEs out into the inner heliosphere we argue that the Solar Stormwatch CME catalogue, which publishes the time-elongation profiles of CMEs observed at multiple position angles, is a new and valuable dataset for space weather community.

Validation of a priori CME Arrival Predictions Made Using Real-Time Heliospheric Imager Observations

Kimberley Tucker-Hood, Christopher Scott, Mathew Owens, David Jackson, Luke Barnard, Jackie Davies, Steve Crothers, Robert Simpson, Neel Savani, J Wilkinson, B Harder, G Eriksson, E Baeten, Lily Wan Wah

Between December 2010 and March 2013, volunteers for the Solar Stormwatch (SSW) Citizen Science project have identified and analysed Coronal Mass Ejections (CMEs) in the near real-time STEREO HI observations, in order to make Fearless Forecasts of CME arrival times and speeds at Earth. Of the 60 predictions of Earth-directed CMEs, 20 resulted in an identifiable ICME at Earth within 1.5-6 days, with an average error in predicted transit time of 22h, and average transit time of 82.3h. The average error in predicting arrival speed is 151kms^{-1}, with an average arrival speed of 425kms^{-1}. In the same time period, there were 44 CMEs for which there are no corresponding SSW predictions, and there were 600 days on which there was neither a CME predicted nor observed. A number of metrics show that the SSW predictions do have useful forecast skill, however there is still much room for improvement. We investigate potential improvements by using SSW inputs in three models of ICME propagation: two of constant acceleration and one of aerodynamic drag. We find that taking account of interplanetary acceleration can improve the average errors of transit time to 19h and arrival speed to 77kms^{-1}.

Parametric study of preferential ion heating due to intermittent magnetic fields in the solar wind

Leopoldo Carbajal Gomez, Sandra C Chapman, Richard O Dendy and Nicholas Wynn Watkins

In situ observations and remote measurements of the solar wind show strong preferential heating of ions along the ambient magnetic field. Understanding the mechanism for this heating process is an open problem. The observed broad-band spectrum of Alfven waves permeating the fast solar wind provide a candidate mechanism for this preferential heating through wave-particle interactions on ion kinetic scales. Previous analytical and numerical studies have considered a single pump wave [1, 2] or a turbulent, broad-band spectra of Alfven waves [3, 4, 5] to drive the ion heating. The latter studies investigated the effects on ion heating due to different initial 1/f^\gamma power spectral exponents and number of modes and the signals were random phase. However, the observed solar wind fluctuations are intermittent so that the phases of the modes comprising the power spectrum are not random. Non-Gaussian fluctuations are seen both on scales identified with the inertial range of Alfvenic turbulence [6], and on longer scales typified by '1/f' spectra [7].
We present results of the first parametric numerical simulations on the effects of different levels of intermittency of the broad-band spectra of Alfven waves on the preferential heating of ions in the solar wind. We performed hybrid simulations for the

local heating of the solar wind, which resolves the full kinetic physics of the ions and treats the electrons as a charge-neutralizing fluid. Our simulations evolve the full vector velocities and electromagnetic fields in one configuration space coordinate and in time. We compare the efficiency of different levels of intermittency of the initial turbulent fields and their effect on the efficiency of the wave-particle interactions which are a mechanism for driving preferential ion heating in the solar wind.

[1] J. A. Araneda, E. Marsh, A. F. Viñas, J. Geophys. Res. **112**, A04104 (2007).
[2] J. A. Araneda, E. Marsh, A. F. Viñas, Phys. Rev. Lett. **100**, 125003 (2008)
[3] Y. G. Maneva, A. F. Viñas, L. Ofman, J. Geophys. Res. **118**, 2842 (2013).
[4] L. Ofman, J. Geophys. Res. **115**, 1461 (2010).
[5] L. Ofman, S. P. Gary, A. Viñas, J. Geophys. Res. **107**, 1461 (2002).
[6] R. Bruno, V. Carbone, Living Rev. Solar Phys. **10**, 2 (2013).
[7] R. M. Nicol, S. C. Chapman, R. O. Dendy, The Astrophysical Journal **703**, 2138 (2009).

Magnetic reconnection exhausts in the solar wind

Rishi Mistry, Jonathan Eastwood, Heli Hietala

Magnetic reconnection is a fundamental plasma process which converts magnetic energy into particle energies, and which is of great importance to many astrophysical and laboratory plasmas. Reconnection exhausts in the solar wind have been shown to frequently form large-scale and planar structures where they are unbound, unlike reconnection exhausts at the magnetopause or magnetotail. This makes the solar wind an excellent environment in which to study basic reconnection physics.

Observations of reconnection exhausts in the solar wind have typically used multiple widely-separated spacecraft using plasma instruments with varying time cadences, or single spacecraft measurements. High cadence plasma measurements enable the reconnection exhaust to be probed in greater depth, whilst multi-point measurements allow the structure of the exhausts to be far more accurately determined than has been possible with previous studies. Here we present the preliminary results from a survey of solar wind reconnection exhausts using high cadence and multi-point measurements from the four spacecraft Cluster mission.

Depleting effects of ICME-driven sheath regions on the outer electron radiation belt

Heli Hietala , E. K. J. Kilpua, D. L. Turner, and V. Angelopoulos

We study the effect of interplanetary coronal mass ejection (ICME)-driven sheath regions on relativistic outer radiation belt electron fluxes. We employ superposed epoch analysis, and, unlike previous studies, we segregate the sheath from the ejecta. We find that sheaths typically result in more than an order of magnitude decrease in the relativistic electron fluxes and that the fluxes stay below the pre-event level for more than 2 days after the sheath passage. The electron depletions are stronger for sheaths that exhibit higher power in magnetic and dynamic pressure fluctuations in the ultralow frequency range and cause larger magnetospheric compressions. Depletions are even stronger for sheaths that encompass the entire storm main phase. Our findings suggest that sheaths are effective at depleting the electron fluxes because they increase radial diffusion under magnetospheric compression conditions, thereby enhancing magnetopause shadowing losses, particularly when the Dst effect can act in concert.

The radial and azimuthal expansion of a magnetic cloud

Simon Good and R. J. Forsyth

Magnetic clouds are a magnetically well ordered subset of coronal mass ejections observed in interplanetary space. We present observations of the same magnetic cloud made by the MESSENGER spacecraft at Mercury (then at 0.44 AU from the Sun) and later by STEREO-B at 1.09 AU, while the two spacecraft were radially aligned in November 2011. Observation with two radially aligned spacecraft allows sampling of the same region of a magnetic cloud, and so allows any evolution that may have occurred within that region during propagation between the two spacecraft to be determined. The flux rope within the November 2011 cloud has been analysed using force-free fitting; it has been found that the diameter of the flux rope increased from ~ 0.22 to 0.50 AU (corresponding to a dependence of $r_H^{0.91}$ on heliocentric distance, r_H) and that the axial magnetic field strength dropped from ~ 46.0 to 8.7 nT (a dependence of $r_H^{-1.84}$) between the two spacecraft, both being clear indications of expansion in the radial direction. The axial length of the flux rope cannot be determined with the in situ observations presented. However, we are able to present an estimate of the magnetic cloud's angular width at 1.09 AU relative to its angular width at 0.44 AU, based on the assumption that the helicity of the flux rope is conserved; this estimate broadly agrees with the cone model of CME expansion.

AXIOM: Advanced X-ray Imaging Of the Magnetosphere

Graziella Branduardi-Raymont, S. F. Sembay, J. P. Eastwood, D. G. Sibeck, C. Wang, J. A. Carter, M. R. Collier, H. J. Hietala, D. O. Kataria, S. Milan, M. Palmroth, J. Rae, A. Read, T. Sun, B. Walsh

X-rays are generated when highly charged solar wind (SW) ions interact with the exospheres of planets. Imaging and spectroscopy of this emission provide the global view necessary to understand the plasma structures enveloping the planets and their response to changes in the SW. In particular, SW charge-exchange X-rays are produced in the Earth's magnetosphere and peak in the sub-solar magnetosheath and the magnetospheric cusps. Thus X-ray imaging of the Earth's magnetosphere offers global diagnostics which will add a new dimension to studies of space weather where remote

sensing is essential in order to close the gap between in situ measurements and modelling.

Our AXIOM (Advanced X-ray Imaging Of the Magnetosphere) team has proposed a new and elegant approach to study the Earth's day-side magnetosphere and cusps by using remote X-ray imaging. In this presentation we describe how this can be achieved with an appropriately designed X-ray telescope, supported by simultaneous in situ measurements of the magnetic field and particles precipitating down field lines. AXIOM imaging will have a temporal and spatial resolution sufficient to address several key outstanding questions concerning how the Earth's magnetosphere and the cusps work, and thus how the solar wind interacts with planetary magnetospheres on a global level.

The global magnetospheric impacts of Foreshock Bubbles

Martin Archer, D. L. Turner, J. P. Eastwood, S. J. Schwartz, T. S. Horbury

Foreshock Bubbles (FBs) are recently discovered transient kinetic phenomena caused by the interaction of suprathermal backstreaming ions with a rotational discontinuity. We discuss their understood formation mechanism and their signatures in spacecraft observations. A FB case study is presented, where the total pressure upstream of Earth's bow shock was observed to be reduced within the transient's core and sheath regions compared to the ambient solar wind. Multipoint observations reveal that magnetosheath plasma was accelerated towards the intersection of the FB's current sheet with the bow shock, resulting in fast sunward flows and the large-scale outward motion of the magnetopause. Ground-based magnetometers also show signatures of this magnetopause motion simultaneously across at least 7 hours of magnetic local time, corresponding to a distance of 21.5 RE transverse to the Sun-Earth line along the magnetopause. These observed global impacts of the FB are in agreement with previous simulations and in stark contrast to the known localised, smaller scale effects of other foreshock transients such as Hot Flow Anomalies.

Solar Wind Dynamics Controlling Wave Power in the Magnetosphere

Dimitry Pokhotelov, I. J. Rae, K. Snekvik, K. R. Murphy, I. R. Mann

First principle 3D radiation belt models require the parameterisation of plasma wave poweras an input for the assessment and forecast of the Earth's radiation environment as a function of external or internal driving. These statistical parameterisations are required in order to model wave-particle interactions across the entire spectrum from mHz to kHz including: ELF-VLF frequency plasma modes such as chorus and hiss, radial diffusion due to storm-enhanced ULF Pc 4-5 waves, and coherent interactions with ULF Pc 4-5 standing waves. The statistical distributions of magnetospheric wave power are known to be strongly dependant on solar wind parameters such as solar wind speed and IMF direction, particularly in the ULF frequency range. Traditionally, average solar wind conditions are used to characterise an interval of wave-driven activity. To determine whether the dynamic properties of the solar wind are critical drivers of ULF-VLF wave power, we characterise both the statistical wave power observed at geostationary orbit as a function of the average, and dynamic characteristics of solar wind defined by the cross-correlations between various solar wind parameters. We discuss these results in terms of future input into the first principle radiation belt models.

Dayside reconnection under IMF-By dominated conditions: the formation and movement of bending arcs

Jennifer Carter, S. E. Milan, R. C. Fear, A. Kullen & M. R. Hairston

Based upon a survey of global auroral images collected by the Polar UVI instrument, Kullen et al. 2002 subdivided polar cap auroral arcs into a number of categories, including that of `bending' arcs. We are concerned with those bending arcs that appear as a bifurcation of the dayside auroral oval, and which subsequently form a spur intruding into the polar cap. Once formed the spur moves polewards and antisunwards over the lifetime of the arc. We propose that dayside bending arcs are ionospheric signatures of pulsed dayside reconnection, and are therefore part of a group of transient phenomena associated with flux transfer events. We observe the formation and subsequent motion of a bending arc across the polar cap during a 30 minute interval on 8 January 1999, and we show that this example is consistent with the proposed model. We quantify the motion of the arc, and find it to be commensurate with the convection flows observed by both ground-based radar observations and space-based particle flow measurements. In addition, precipitating particles coincident with the arc appear to occur along open field lines, lending further support to the model.

Are Steady Magnetospheric Convection Events Prolonged Substorms?

Maria-Theresia Walach and Steve Milan

Steady magnetospheric convection events (SMCs), substorms, and sawtooth events are different modes of behaviour by which the magnetosphere responds to the opening of terrestrial magnetic flux via dayside reconnection with the interplanetary magnetic field. Substorms and sawtooth events are explosive episodes of magnetic flux closure in the magnetotail, releasing open flux that has previously accumulated, whereas SMCs are thought to be periods when the magnetotail reconnection rate grows to equal the dayside rate such that flux is transported steadily through the system. It is still a matter of controversy why the magnetosphere responds differently in each case, though it is certain that sawtooth events occur during periods of extreme solar wind-magnetosphere coupling. Classic substorms occur after the magnetospheric driving has enlarged the polar cap and loaded energy into the tail of the magnetosphere in the form of increasing polar cap flux. Some SMCs take place after a substorm has occurred but the magnetosphere does not recover until after the SMC has concluded.
This study focuses on the different magnetospheric behaviours exhibited during substorms and SMCs. We distinguish between SMCs that are disguised within the substorm-cycle and SMCs that are stand-alone events and compare their associated behaviour of magnetospheric and solar-wind parameters to that of substorm signatures. We show the average behaviour of solar wind and magnetospheric parameters before

and during these events. We demonstrate that for SMCs occurring independently of substorms, the event-preceding solar wind-magnetospheric coupling is considerably stronger and prolonged than for SMCs that occur as part of the substorm-cycle.

Magnetic Reconnection Outflows and their Critical Role in Driving the Coupled Magnetotail

Zhonghua Yao, C. J. Owen, J. Liu, C. Forsyth and I. J. Rae

Based on recent multi-probe observations from Cluster and THEMIS spacecraft, we studied the current systems associated with the magnetic reconnection outflows, and the interaction between reconnection outflows and the ambient plasma in the near-Earth flow braking region. Our main results can be summarised as: (1) Two kinetic scale current structures exist on the leading edge of reconnection outflow, which is well known as dipolarization front (DF). (2) The interaction between DF and the ambient plasma can generate a dawnward diamagnetic current, which reduce the north-south component of magnetic field ahead of the DF, and thus form a kinetic scale magnetic dip. (3) The interaction between DF and the near-Earth ambient can lead to local current disruption for pseudo-breakup or small substorm. (4) Flow braking in the near-Earth magnetotail can form magnetohydrodynamics (MHD) scale flow vortexes and diverging pressure gradient, which are two most important field-aligned current (FAC) sources in the magnetosphere. In our case study, we also found that the FAC associated with pressure gradient is the dominant source during substorm expansions.

The substorm onset arc: Diagnosing the magnetotail plasma instability from the ground

Nadine Kalmoni, I. Jonathan Rae, Clare E.J. Watt, Kyle R. Murphy, Colin Forsyth

The substorm expansion phase marks the explosive release of energy stored in the nightside magnetosphere accumulated through dayside magnetic reconnection under times of southward interplanetary magnetic field. The release of energy can be observed by a sequence of magnetic and auroral disturbances in the polar regions, however what detonates this sequence of events leading to substorm onset remains unknown. A repeatable signature of the auroral manifestation of the substorm is periodic azimuthal wave-like fluctuations along the onset arc, thought to represent the optical manifestation of a magnetospheric instability acting in the near-Earth plasma sheet projected into the ionosphere.
We use the Time History of Events and Macroscale Interactions During Substorms (THEMIS) All-Sky Imagers to statistically analyse the azimuthal auroral fluctuations and their evolution during the first tens of seconds of substorm onset. We show that the growth and spatial scales of these fluctuations are similar across multiple events, indicating the azimuthal structuring along the substorm onset arc is caused by a plasma instability operating in the near-Earth magnetotail.

Estimating ionospheric electric fields using optical observations of the aurora

Sam Tuttle, Bjorn Gustavsson and Betty Lanchester

Electric fields are a ubiquitous feature of the ionosphere. These fields are modified by the energetic particle precipitation which causes the aurora. Understanding the structuring and dynamics of these modifications is important, particularly at sub-kilometre scales where the processes which accelerate and structure the precipitating electrons are not fully understood.

We have developed a new method for estimating the plasma flow, under active auroral conditions, using observations of the aurora obtained by the Auroral Structure and Kinetics (ASK) instrument. Specifically, observations of emission from the metastable O+ (2P) ion at 732 nm, which has an altitude dependent lifetime of up to 5 seconds, are used. Once produced, the motion of the ions is governed by the E cross B drift. Modelled images of the 732 nm emission are produced from three dimensional distributions of O+ (2P) ions; these distributions are obtained by solving the continuity equation using a parameterised velocity field. The flow velocity is extracted by finding the parameters of the velocity field which minimize the difference between the observed and modelled images. Finally, the electric fields are inferred from the flow velocities, again via the E cross B drift.

We present some initial results in applying this method to a 12 second interval during an auroral event which occurred at 21:25 UT on 09/11/2006. In this interval the auroral brightness intensifies, resulting in a burst of production of O+ ions. These ions subsequently drift over the next five seconds. Here, the simplest parameterisation of the velocity field is used: a uniform flow perpendicular to the magnetic field. Flow velocities that vary between 500 and 2500 m/s to the east are obtained. The extracted velocities are in agreement with the direction of velocities measured by the SuperDARN network, which highlight the ability of the new model to track plasma flows at high spatial and temporal resolution.

Ionospheric Tomography using GNSS data in Africa: the challenges towards imaging small scale structures in Africa

Nigussie Giday, Z.T. Katamzi, L-A McKinnell

Ionospheric tomography can be a good tool to image the ionosphere from which ionospheric parameters of interest, such as the electron density and total electron content (TEC) can be explicitly monitored. MIDAS (Multi-Instrument Data Analysis System) is a tomographic imaging system that uses multi-instruments, such as GPS, LEO and ionosondes, to image the time-varying ionosphere in 3D. MIDAS has been used to study interesting structures such as the tongue of ionization linked to scintillation and DDMs (diurnal double maxima) in the African middle latitudes. Hence this motivated us to study the small scale ionospheric irregularities over the equatorial anomaly of the

African sector. However, the lack of adequate ground based GPS receivers over Africa, specifically over the equatorial region has been a challenge. Nevertheless, an attempt is done to supplement the data sparse region from radio occultation. Moreover, IRI is used to improve the imaging in data sparse regions.

Poster Presentations (in alphabetical order)

The role of the Sun in long-term change in the F2 peak ionosphere: new insights from Ensemble Empirical Mode Decomposition (EEMD) and numerical modelling

Ingrid Cnossen and Christian Franzke

We applied Ensemble Empirical Mode Decomposition (EEMD) for the first time to ionosonde data to study trends in the critical frequency of the F2 peak, foF2, and its height, hmF2, from 1959 to 2005. EEMD decomposes a time series into several quasi-cyclical components, called Intrinsic Mode Functions (IMFs), and a residual, which can be interpreted as a long-term trend. In contrast to the more commonly used linear regression-based trend analysis, EEMD makes no assumptions on the functional form of the trend and no separate correction for the influence of solar activity variations is needed. We also adopted a more rigorous significance testing procedure with less restrictive underlying assumptions than the F-test, which is normally used as part of a linear regression-based trend analysis. EEMD analysis shows that trends in hmF2 and foF2 between 1959 and 2005 are mostly highly linear, but the F-test tends to overestimate the significance of trends in hmF2 and foF2 in 45% and 25% of cases, respectively. EEMD-based trends are consistently more negative than linear regression-based trends, by 30-35% for hmF2 and about 50% for foF2. This may be due to the different treatment of the influence of a long-term decrease in solar activity from 1959 to 2005. We estimate the effect of this decrease in solar activity with two different data-based methods as well as using numerical model simulations. While these estimates vary, all three methods demonstrate a larger relative influence of the Sun on trends in foF2 than on trends in hmF2.

Cluster dual-spacecraft observations of Kinetic Alfven Waves in the Plasma Sheet Boundary Layer

Louise Cooper, Andrew Fazakerley, Jonathan Rae, Colin Forsyth, Clare Watt, Yuri Khotyaintsev, Chris Carr

Lysak and Lotko (1996) published a theoretical study of the kinetic dispersion relation of shear Alfvén waves. The results focused on the role of Landau damping in the dispersion process, and they showed that any Kinetic Alfvén Wave (KAW) with a perpendicular wavelength of ~10 km or more would have negligible damping, while waves with shorter perpendicular wavelengths are more strongly damped. Unlike shear Alfvén waves, KAWs may support parallel electric fields. KAWs carrying Poynting fluxes strong enough to power the brightest of aurora have been observed in the plasma sheet boundary layer (PSBL). Wygant et al. (2002) used single spacecraft Polar data in combination with theoretical results to make the case that they had observed small scale KAWs capable of electron acceleration. This study aims to provide the first direct observational evidence of the perpendicular wavelength of KAWs in the PSBL, using data from two closely spaced

Cluster spacecraft, to test the interpretation of Wygant et al (2002), thereby providing insights into the mechanisms that generate the aurora.

Birkeland current measurements compared with estimates derived from a Dungey Cycle-based model

John Coxon, S. E. Milan, L. B. N. Clausen, B. J. Anderson, H. Korth

Measurements made by the Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE) between 2010 and 2012 are processed to yield the total Birkeland (field-aligned) current flowing in both hemispheres. The contribution to the Birkeland currents due to dayside reconnection is removed from the data, such that the diurnal and seasonal variations in the data may be described. Clear variations due to the solar zenith angle are observed and discussed.

A model has been developed which gives the Birkeland current flow as a result of reconnection-driven ionospheric convection using assumed Hall/Pedersen conductances (Milan, 2013). To test this model, a well-established model of the ionospheric conductance due to solar contributions (Robinson and Vondrak, 1984) is employed to estimate the conductance across the daylit ionosphere. Using these conductance estimations as an input, a more realistic result can be obtained from the Milan (2013) model; the correspondence between the modelled and observed values is discussed.

Quantifying the spatio-temporal correlation during a substorm using dynamical networks formed from the SuperMAG database of ground based magnetometer stations

Joe Dods, Sandra Chapman, Jesper W. Gjerloev and Robin Barnes

The overall morphology and dynamics of magnetospheric substorms is well established in terms of observed qualitative auroral features and signatures seen in ground based magnetometers. The detailed evolution of a given substorm is captured by typically ~100 ground based magnetometer observations and this work seeks to synthesise all these observations in a quantitative manner.
We present the first analysis of the full available set of ground based magnetometer observations of substorms using dynamical networks. SuperMAG offers a database containing ground station magnetometer data at a cadence of 1min from 100s stations situated across the globe. We use this data to form dynamic networks which capture spatial dynamics on timescales from the fast reconfiguration seen in the aurora, to that of the substorm cycle. Windowed linear cross-correlation between pairs of magnetometer time series along with a threshold is used to determine which stations are correlated and hence connected in the network. Variations in ground conductivity and differences in the response functions of magnetometers at individual stations are overcome by normalizing to long term averages of the cross-correlation. These results are tested against surrogate data in which phases have been randomised. The network is then a collection of connected points (ground stations); the structure of the network and its variation as a

function of time quantify the detailed dynamical processes of the substorm. The network properties can be captured quantitatively in time dependent dimensionless network parameters and we will discuss their behaviour for examples of 'typical' substorms and storms. The network parameter provide a detailed benchmark to compare data with models of substorm dynamics, and can provide new insights on the similarities and differences between substorms and how they correlate with external driving and the internal state of the magnetosphere.

Ion dynamics near magnetotail dipolarization fronts associated with magnetic reconnection

Jonathan Eastwood, M. V. Goldman, H. Hietala, D. L. Newman, R. Mistry and G. Lapenta

Dipolarization fronts (DFs) are often associated with the leading edge of Earthward bursty bulk flows in the magnetotail plasma sheet. Here multi-spacecraft THEMIS observations are used to show that a spatially limited region of counter-propagating ion beams, whose existence is not evident in either the plasma moments or the electric field, is observed on the low density side of DFs. The THEMIS magnetic field data are used to establish appropriate comparison cuts through a particle-in-cell (PIC) simulation of reconnection, and very good agreement is found between the observed and simulated ion distributions on both sides of the DF. Self-consistent back-tracing shows that the ion beams originate from the thermal component of the pre-existing high density plasma into which the DF is propagating; they do not originate from the inflow region in the traditional sense. Forward tracing shows that some of these ions can subsequently overtake the DF and pass back into the high density pre-existing plasma sheet with an order-of-magnitude increase in energy, offering new insight into the mechanisms by which DFs may reflect ions. The interaction of the reconnection jet with the pre-existing plasma sheet therefore occurs over a macroscopic region, rather than simply being limited to the thin DF interface. A more general consequence of this study is the conclusion that reconnection jets are not simply fed by plasma inflow across the separatrices, but are also fed by plasma from the region into which the jet is propagating; the implications of this finding are discussed.

Increases in plasma sheet temperature with solar wind driving during substorm growth phases

Colin Forsyth, C.E.J. Watt, I.J. Rae, A.N. Fazakerley, N.M.E. Kalmoni, M. P. Freeman, P.D. Boakes, R. Nakamura, I. Dandouras, L.M. Kistler, C.M. Jackman, J.C. Coxon, C. Carr

During the substorm growth phase, magnetic reconnection extracts $\sim 10^{15}$ J from the solar wind through magnetic reconnection at the magnetopause, which is then stored in the magnetotail lobes. Plasma sheet pressure then increases to balance magnetic flux density increases in the lobes. We examine plasma sheet pressure, density and temperature during substorm growth phases using nine years of Cluster data (>316,000 data points). We show that plasma sheet pressure and temperature are higher during growth phases with higher solar wind driving whereas the density is approximately constant. We also show a weak correlation between plasma sheet temperature before onset and the minimum SuperMAG SML auroral index in the subsequent substorm. We discuss how energization of the plasma sheet before onset may result from thermodynamically adiabatic processes; how hotter plasma sheets may result in magnetotail instabilities and how this relates to the onset and size of the subsequent substorm expansion phase.

Magnetic Reconnection Structures in the Solar Wind

Alice Foster, Christopher J Owen, Colin Forsyth, Jonathan Rae, Andrew Fazakerley

Magnetic reconnection is a plasma process that occurs throughout the heliosphere and is invoked as the underlying driver for a wealth of phenomena. Descriptions of reconnection based on the Petschek-like framework contain common observable features including a reconnection exhaust bounded by two current sheets and Alfvén waves travelling along the boundary. Also commonly seen are decreases in magnetic field strength and a corresponding increase in ion density. However, through detailed analysis of a number of events we find this is not always the case. Here we show an event that occurred on the 7th February 2006 which exhibits many of these features, including a double magnetic field rotation co-incident with an ion velocity enhancement, density enhancement and magnetic field strength decrease. The changes in V and B are correlated on one side of the exhaust and anti-correlated on the other. However the exhaust appears to continue for a short time after the two main current sheets have passed as does the magnetic field depression and the ion density enhancement. The Walen test is satisfied when the changes in the Alfvén and the plasma velocity over a discontinuity are equal; a successful Walen test indicates the presence of Alfvén waves. However the Walen test over the discontinuities is not sufficiently satisfied to suggest the presence of Alfvén waves running along the boundaries of the reconnection exhaust. This suggests that the structure of the reconnection event could be more complicated than previously thought and may, for example be bounded by more than two current sheets and or other discontinuities.

Saturn's Field-Aligned Currents: Sub-corotation and Planetary Period Oscillation Components

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We investigate azimuthal magnetic field data showing the presence of field-aligned magnetosphere-ionosphere coupling currents on 31 Cassini passes during 2008 across Saturn's southern post-midnight auroral region. The currents are shown to be strongly modulated in magnitude, form, and position by the phase of the southern planetary period oscillations (PPO). PPO-independent currents are separated from PPO-related

currents by exploiting the anti-symmetry of the latter with respect to PPO phase. The PPO-independent system, associated principally with plasma sub-corotation, comprises distributed downward currents ~5-15 nA m 2 flowing over the whole polar region, a sheet of enhanced downward current on closed field lines mapping to the outer magnetosphere, and an adjacent sheet of upward current that closes these downward currents at ~17°-20° southern co-latitude, ~1.3 MA per radian of azimuth in averaged current profiles, mapping to the main middle magnetosphere hot plasma region. The upward sheet is co-located with the statistical ultraviolet auroral oval. No steady currents of comparable magnitude are found at larger co-latitudes, mapping to the inner magnetosphere at ~4-8 Saturn radii (RS) dominated by cool Enceladus plasma. The rotating PPO-related field-aligned currents are of comparable magnitude, and are essentially co-located with the main upward current layer of the PPO-independent system, though centered slightly equatorward to the inner part of the hot plasma region. Thus at phases where the PPO current is directed upward the overall upward current flowing in the auroral layer is approximately doubled, while at phases where it is directed downward the two currents approximately cancel.

Observation of field dipolarization, planetward ion beams and streaming energetic particles: A case study of long-duration reconnection in Saturn's tail

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We present a case study of an event from August 20th (day 232) of 2006, when the Cassini spacecraft was sampling the region near 32 R_S and 22 hours LT in Saturn's tail. Cassini observed a strong northward-to-southward turning of the magnetic field, which is interpreted as the signature of dipolarization of the field as seen by the spacecraft planetward of the x-line. This event was accompanied by very rapid (up to ~1500 km s^{-1}) plasma flow toward the planet, while hydrogen and oxygen at energies above 28 keV were also observed to stream planetward. Saturn Kilometric Radio emissions were stimulated shortly after the observation of the dipolarization. We discuss the field, plasma, energetic particle and radio observations in the context of the impact this reconnection event had on global magnetospheric dynamics.

Sub-ion scale intermittency and the development of filamentary current structures from the Hall effect

Khurom Kiyani, Romain Meyrand, F. Sahraoui, Kareem T. Osman and Sandra C. Chapman

The distinct quantitative nature of the intermittency seen on fluid and kinetic scales in solar wind plasma turbulence is now well documented from an observational point of view. The classic high-order statistical signature rapidly transitions to a monoscaling signature as one crosses to sub-ion scales. How this scaling depends upon plasma

conditions, and the underlying physical implications have yet to be fully explored. We present a study focusing on 28 intervals of solar wind magnetic field data from the Cluster spacecraft sampling a broad range of plasma parameters. We show how the scaling properties vary between these intervals and more importantly, if there are any correlations between the scaling exponents and the plasma parameter variations. We supplement this observational study with a computational investigation where we study spatial samples from an 1024^3 EMHD simulation -- a model for sub-ion scale magnetic field dynamics consisting solely of the Hall effect. From this, we show that the Hall-term can generate a topological change from current sheets at fluid scales to current filaments at sub-ion scales. We conjecture that this fundamental change in the coherent structures comprising the turbulence is also responsible for the change in the intermittency that we see from our observations; and which could also be responsible for dissipation at these scales.

Solar-wind-driven geopotential height anomalies originate in the Antarctic lower troposphere

Mai Lam, Gareth Chisham, and Mervyn P. Freeman

There are a large number of responses, on the day-to-day timescale, of the dynamics of the troposphere to regional changes in the downward current of the global atmospheric electric circuit (GEC). They provide compelling evidence that the GEC plays a role in influencing surface weather and climate. Here, we use reanalysis data to estimate the altitude and time lag dependence of one such response which until now has been observed as a correlation between the interplanetary magnetic field component, By, and the surface pressure in Antarctica. The correlation is most statistically significant within the troposphere, and not significant in the stratosphere. The peak in the correlation occurs at greater time lags at the tropopause (~ 6-8 days) and in the mid troposphere (~ 4 days) than in the lower troposphere (~ 1 day). This supports a mechanism involving the action of the global atmospheric electric circuit, modified by variations in the solar wind (through modulations of the spatial variation in ionospheric potential), on lower tropospheric clouds. The increase in time lag with increasing altitude is consistent with the upward propagation by conventional atmospheric processes of the solar wind-induced variability in the lower troposphere. This is in contrast to the downward propagation of atmospheric effects to the lower troposphere from the stratosphere due to solar variability-driven mechanisms involving ultraviolet radiation or energetic particle precipitation.

First results of simulations of 'multi-band' structures in spacecraft observations of inner magnetosphere plasma electrons and ions

Kirthika Mohan, A.N.Fazakerley, L.H.Kistler, C.J.Owen and I.Dandouras

Several authors have reported inner magnetosphere observations of proton distributions confined to narrow energy bands in the range 1 - 25 keV (Smith and Hoffman (1974), etc). These structures have been described as "nose structures", with reference to their appearance in energy-time spectrograms and are also known as "bands" if they occur for extended periods of time. Multi-nose structures have been observed if 2 or more noses appear at the same time (Vallat et al., 2007). Gaps between "noses" (or "bands") have been explained in terms of the competing corotation, convection and magnetic gradient drifts. Charge exchange losses in slow drift paths for steady state scenarios and the role of substorm injections has also been considered (Li et al., 2000; Ebihara et al., 2004). We analyse observations of electron and ion "multi-band structures" seen in Double-Star TC1 PEACE and HIA data mainly recorded in the equatorial plane of the inner magnetosphere (L < 15). The electron populations are not expected to exhibit multiple bands as the drifts are not in opposition. We use a simple particle drift model to try and illustrate whether drifts alone could cause these multi-bands structures in the cases of both ions and electrons (charge exchange or substorms are not yet considered). We present the first results of the simulation and compare them to the results of statistical surveys previously conducted on the DoubleStar TC1 PEACE and HIA data, where ion and electron multi-bands were observed during low kp. (Mohan et al., in prep). We use the simulation to explore possible explanations.

Modelling auroral currents at hot Jupiters: implications for auroral radio emissions

Jonathan Nichols and Steve Milan

Recently, the radio emissions of exoplanets have come under focus due to the commencement of observations using new radio telescopes such as LOFAR. A class of planet which has attracted significant attention in this respect is the close-orbiting `hot Jupiter', several of which, according to previous estimates, may produce detectable radio emissions driven by stellar wind-magnetosphere interactions. However, this expectation rests on the accuracy over many orders of magnitude of the `Radiometric Bode's Law' (RBL), an empirical relation between the solar wind energy input and radio power output of a variety of bodies in the solar system, some of which (e.g. Jupiter) are known to be dominated instead by internal processes such as planetary rotation. In this presentation we calculate the expected radio luminosity generated by a Dungey Cycle-like stellar wind interaction with a hot Jupiter's magnetosphere. Specifically, we adapt the Milan (2013) model of the terrestrial twin-vortical ionospheric plasma flow and resulting field-aligned currents to the case of hot Jupiters, and we compute the total auroral and radio luminosities for various parameters and compare with values given by the RBL. We show that many configurations of exoplanets are able to produce detectable emissions and, although the variation of the emitted radio power with orbital distance computed by our model is similar to that given by the RBL, the absolute values differ significantly, in some cases by several orders of magnitude.

Non linear wave particle interactions in oblique whistlers- computation of growth rates and resonant particle distribution functions

David Nunn and Yoshiharu Omura

Nonlinear wave particle interaction between oblique narrow band whistler waves and keV/MeV electrons has been studied in pioneering papers by Bell at Stanford and recently at UCLA. These works are however surprisingly confined to test particle studies. Here we employ the classic technique of backward trajectory integration followed by application of Liouville's theorem to compute for the first time resonant particle distribution currents, resonant particle currents and thus local nonlinear growth rates. We find all resonance orders n obey the same relativistic trapping equation, and that given enough wave amplitude and obliquity we may have trapping for cyclotron and Landau resonances as well as resonances of order n=-1 and n=2. With trapping, 'holes' or 'peaks' occur in the distribution function, depending on trapping history, resonance order and zero order distribution function. For n=1 resonance rising tones will produce a hole, falling tones a hill. For n=0 resonance a hill is normal. DF holes may be understood through Liouville's theorem and are not due to regions of phase space being inaccessible. For the n=1 cyclotron resonance growth rates roll off quickly with obliquity and due to the adiabatic effect maximise at a short distance from the equator ~2000kms. For a CW wave growth shows decisive saturation with amplitude at ~20pT here, again due to the adiabatic effect. The n=0 Landau resonance behaves differently as trapped resonant particles are moving away from the equator and adiabatic effects do not apply. Nonlinear damping does not saturate with amplitude and maximises at 6-8000km from the equator and at high obliquity ~55 degrees.
Finally we employ a complex model of a chorus element due to Omura and compute nonlinear growth rate throughout the z,t plane for the entire event. Growth rates maximise just below the half gyrofrequency and an extensive region of Landau damping is seen at 6000-10000km from the equator. Landau damping rates appear to be rather less than cyclotron growth rates but the ratio of the two depends critically on DF anisotropy factor.

Multi-Spacecraft Measurement of Turbulence within a Magnetic Reconnection Jet

Kareem Osman, K. H. Kiyani, W. H. Matthaeus, B. Hnat, S. C. Chapman, and Yu. V. Khotyaintsev

The relationship between magnetic reconnection and plasma turbulence is investigated using multi-point measurements from the Cluster spacecraft within a high-speed reconnection jet in the terrestrial magnetotail. We find that work done by electromagnetic fields on the particles, J.E, exhibits a non-Gaussian distribution and is concentrated in regions of high electric current density. Hence, energy in fields is converted into plasma kinetic energy in a manner that is intermittent. This suggests that J.E within the reconnection jet shares similarities with fluid-like turbulence phenomenology in that it could proceed via coherent structures generated by an intermittent cascade. Furthermore, we find that magnetic field fluctuations generated by reconnection exhibit a crossover from multi-fractal intermittent turbulence at larger scales to non-Gaussian mono-scaling at kinetic scales. These results could have far reaching implications for space and astrophysical plasmas where turbulence and magnetic reconnection are ubiquitous.

Thermospheric vertical winds and temperature enhancements associated with auroral energy deposition

Amy Ronksley

Auroral energy deposition, i.e., from Joule and particle heating, is capable of driving large vertical winds (upwellings) by local heating creating thermospheric temperature enhancements. Large F region upwellings have been observed with the Svalbard FPI 630nm red atomic oxygen emission within the polar cap and their relationship with auroral energy inputs is investigated. EISCAT radar data is used to put the thermosphere in context with the energetic ionosphere and to provide electric field estimates. Models such as MSIS and HWM are used to model thermospheric parameter height profiles, e.g., neutral density and horizontal wind. Joule heating profiles are estimated and contributions from the neutral wind dynamo are considered.