The annual UK MIST (magnetosphere, ionosphere, solar–terrestrial) meeting has evolved over 30 years to provide scientists with a range of experience with a platform to present their results to a wide and mixed audience of PhD students, post-docs and senior scientists. The MIST community investigates plasma processes in the solar system to include solar–terrestrial connections, gas-giant magnetospheres and solar wind–comet interactions, to name but a few. The autumn meeting took place on 26 November 2010 at the Royal Astronomical Society in Burlington House, London.

This year the themes were multi-perspective views of interacting plasma environments and hot topics in MIST science. The themes send a strong signal that, while the scientific community is in the depths of a funding crisis, MIST science is highly important, extremely collaborative and is inextricably coupled, requiring a systems-level diagram to explain it, as shown in figure 1 and discussed by Steve Milan (Leicester).

Hot flow anomalies

The solar wind and the magnetosphere interact strongly with one another. The supersonic solar wind is shocked as it approaches a magnetosphere; the size of the magnetosphere is then dependent on the pressure balance between the shocked solar wind and the magnetic field inside the magnetosphere. However, discontinuities in the solar wind magnetic field can disrupt this pressure balance, resulting in the significant motion of the magnetoopause resulting in what are called hot flow anomalies (HFAs).

Jonathan Eastwood (Imperial College) presented data from the Cluster and Rosetta spacecraft and ground-based magnetometers SAMNET and THEMIS GMAG, confirming the prediction that HFAs are responsible for the transient generation of Pc3 waves, which are normally associated with magnetic impulse events or travelling current vortices. Using the multiple spacecraft and ground-based data, an HFA was observed followed by a 10 minute interval of Pc3 waves. Analysis shows that HFAs can be a source of Pc3 waves and the underlying discontinuities interact with the bow shock, demonstrating that the bow shock itself can influence magnetospheric dynamics.

The gas giants have been shown to interact with the solar wind, in particular showing increased dynamic auroral activity in association with sharp changes in solar wind velocity and pressure. Unlike at Earth, where there is a constant upstream monitor of the solar wind conditions, the prevailing solar wind conditions have to be propagated out to the outer planets. Daniel Went (Imperial) presented a new empirical model of Saturn’s bow shock using propagated solar wind velocities instead of velocity estimates. Observations of the bow shock using Pioneer, Voyager and Cassini data...
provide many bow shock crossings covering all local times and latitudes up to 45°. Using multiple instruments on board Cassini, such as Langmuir wave observations from the Radio and Plasma Wave Science (RPWS) team, Went et al. used propagated solar wind velocities from the mSWiM model in order to estimate the solar wind dynamic pressure associated with each bow shock crossing, creating a model of Saturn’s bow shock. This new model is the most accurate empirical representation of shape and location of the bow shock because it relies on data from multiple instruments together with the propagated solar wind velocities.

The plasma populations in the magnetosphere are highly dynamic, with plasma injected, lost and energized by several different mechanisms. These mechanisms can be altered by the occurrence of high-speed solar wind streams (HSSs): regular, repeatable drivers of the magnetosphere which can drive geomagnetic storms. Using a superposed epoch study of data from the LANL satellites in geosynchronous orbit, Michael Denton (Lancaster) has been studying the evolution of the cold plasmasphere and hot radiation belts during the passage of HSSs orbit; many observations were made in these regions. Similarly, Nigel Meredith (British Antarctic Survey) presented results from a superposed epoch analysis of energetic electrons observed by the NOAA POES polar orbiting spacecraft during 42 HSS-driven geomagnetic storms, to determine the temporal evolution and global distribution of the precipitating flux. Denton et al. showed that the flux of high-energy electrons drops considerably when the HSS arrives Earth and persists for a few days before the flux levels become elevated. Meredith et al. found that flux drop-outs of relativistic electrons during the main phase of HSS-driven storms are not due to pitch angle scattering and loss to the atmosphere, although lower energy particles are scattered by wave–particle interactions.

Geomagnetic storms are periods of intense solar wind–magnetosphere coupling often associated with extreme solar wind conditions which result in long periods of mass and energy transport in the magnetosphere. In order to understand their effect it is necessary to study them in a global context. James Hutchinson (Leicester) described the initial results from a study of geomagnetic storms over a solar cycle, using geomagnetic and solar wind data, radar backscatter and auroral imagery. The results indicate that storms causing a SYM-H deflection greater than −150 nT had a decreasing main phase duration with increasing storm strength, in contrast to previous results. Initial statistical analyses show seasonal and solar cycle variation of storm occurrences and storm sizes as a function of solar wind properties and reconnection rates. The precipitation of electrons into the ionosphere excites auroral emissions, with the various different auroral forms indicative of different scattering and acceleration processes in the magnetosphere. Emma Woodfield (Lancaster) presented colour observations of aurora from the Rainbow all-sky imagers in Iceland showing pulsating aurora: patches of aurora that brighten and fade on a timescale of tens of seconds. They recorded several patches of pulsating aurora that pulse at different periods in the morning sector during the recovery phase of substorms, in conjunction with observations of electron cyclotron harmonic waves by Cluster in the magnetosphere. By cross-correlating these observations, Woodfield et al. hope to improve magnetic field models above the ionosphere.

Electron precipitation

Electron precipitation from the Earth’s inner magnetosphere transmits solar variability to the Earth’s upper atmosphere and may affect climate at the surface. The UCL Fabry–Perot interferometers (FPI) have been measuring the red line 630 nm emissions in the high-latitude polar regions for nearly 25 years. Iris Yiu (UCL) presented a study of the solar cycle effects on 10 years worth of ionospheric neutral temperatures and a comparison with temperature models. The FPI-measured temperature follows the local K indices variation where both activity and temperature peaked between two and three years after the solar maximum. The solar maximum neutral temperature is unexpectedly lower than modelled neutral temperature. The changes in red line emission profile can cause a 10% difference in average FPI measured temperatures – which needs to be considered in long-term neutral temperature studies. The F and E layer temperature and wind results suggest that E-region joule heating could play a part in sustaining density enhancement at the higher altitude cusp region, but this does not rule out soft precipitation.

The structure of the interplanetary magnetic field (IMF) determines the propagation of flare and solar energetic particles (SEPs) accelerated by coronal mass ejections to interplanetary locations where they can cause space-weather effects. Past investigations have used an IMF model including large-scale fluctuations arising from supergranular motion at the solar surface to study SEP arrival times. James Kelly (Central Lancashire) presented an analysis of the effects of such events on the spatial distribution of SEPs in order to estimate their velocity distributions and their role in transporting particles across the magnetic field. Large-scale fluctuations distort the structure of the IMF and can lead to a wide range of particle onset times. Simulations show a spatial spread in SEP distribution much larger in longitude and latitude than seen in a Parker spiral model.

Khuram Kiyani (Imperial) presented results on magnetic compressibility and isotropic scale invariant dissipation of solar wind turbulence, answering the questions “How does the behaviour fluctuations in the dissipation range compare to the turbulent fluctuations seen in the inertial range?” and “What are the natures of the structures in the dissipation range?” Fluctuation statistics in the dissipation range, at greater than the ion gyro scale, are of a different nature in scaling and anisotropy than the classic MHD turbulence inertial range. The scaling is a different nature, the power in transverse and parallel fluctuations tends to converge and fluctuations are as intermittent in the inertial range as in the dissipation range. These imply a magnetic compressibility signature consistent with kinetic Alfvén waves rather than Whistler waves, assuming linear theory in the dissipation range.

In order to predict the influence of the IMF and solar wind on the planets of the solar system, it is necessary to understand from where the variations in the IMF and solar wind arise. Fluctuations in the solar wind plasma and magnetic field are well described by the sum of two power-law distributions. It has been postulated that these distributions are the result of two independent processes: turbulence, which...
contributes mainly to the smaller fluctuations; and crossing boundaries of flux tubes of coronal origin, which dominate larger variations. Matthew Owens (Reading) explored the correspondence between changes in the magnetic field with changes in other solar wind properties which may indicate whether the variations originated on the Sun or in the solar wind. Their findings suggest that 25% of large B discontinuities had a solar origin, 40% originated in the solar wind and the remainder were indeterminate. However, a lack of detectable alpha-to-proton signatures is not sufficient to discount a structure as having a solar origin. More will become apparent with future data from Solar Orbiter.

In situ observations allow us to build models of the solar wind propagation through the solar system, but remote observations of the solar wind transients and their effect on other bodies can provide a wealth of new inputs into these models. Two such observational techniques were detailed at the meeting. Anthony Williams (Leicester) reported radial velocity observations of solar wind transients in the solar atmosphere from STEREO’s Heliospheric Imagers and outer coronograph COR-2, looking at solar wind transients ranging from mesoscale plasma parcels to CMEs of various speeds. These observations will allow Williams et al. to quantify and study the acceleration of these transients as they pass through the solar system.

Yudish Ramanjooloo (UCL-MSSL) showed that by using amateur images of Comet Machholz it is possible to probe the solar wind. Comparing images of comet plasma tails with near-Earth solar wind data and other heliospheric observations, it is possible to calculate solar wind speeds and search for comet tail disconnections that are often linked to heliospheric current sheet crossings. By observing comets further away from Earth, it may be possible to examine the solar wind conditions throughout the solar system.

Travelling compression regions (TCRs) are observed in the magnetotail lobes and are a consequence of magnetic reconnection. They are caused by the passage of localized expansion of the plasma sheet, which in turn may be caused by a flux rope or by a plasma bulge, resulting from time-dependent reconnection at a single X line as another possibility. Segheen Beyene (MSSL) has been modelling these flux bulges based on acceleration of particles during their interaction with the cross tail current sheet. This model considers a single particle regime and a simplified increase in the plasma pressure in the outflow region, while maintaining pressure balance across the tail such that the expansion of the accelerated plasma acts to compress the lobe, leading to a TCR.

Volcanism on Io

Orbit-to-orbit changes in the magnetodisc current system in Jupiter’s magnetosphere were inferred from Galileo magnetometer data and indicated modulations of about 5 nT, lasting less than one Galileo orbit. These observations show both positive and negative magnetic field perturbations associated with compression of the magnetosphere by the solar wind, and an increase in the mechanical stresses due to the force balance with the JXB force. Christopher Arridge (MSSL) examines the role that impulsive volcanism on Io can play in the mechanical stress portion of the ring-current modulations. By combining recent optical observations of the Io plasma torus with a model of Jupiter’s magnetodisc to investigate changes in the ring current associated with Io, Arridge et al. find negative magnetic field perturbations consistent with the magnetic field observations from Galileo, but these imply rapid transport of fresh plasma out of the Io plasma torus region. There is a need for a more time-dependent description of the interactions between variations in the mass loading and the model. These types of impulsive events could also occur on Enceladus, driving Saturn’s ring-current perturbations.

Jonathan Nichols (Leicester) provided the first consideration of magnetosphere–ionosphere coupling at Jupiter-like exoplanets with internal plasma sources such as volcanic moons. He considered the radio power emitted, assuming a system of near-rigid co-rotation throughout the closed magnetosphere in order to examine the behaviour of the best candidates for detection with next-generation radio telescopes. Nichols et al. estimate for different stellar EUV luminosities, and then consider the magnitudes of the large-scale magnetosphere–ionosphere currents flowing within the systems. The effects of planetary angular velocity and plasma mass outflow rate are examined. In all EUV luminosity cases a significant number of parameter combinations within an order of magnitude of the values at Jupiter are capable of producing emissions beyond 1 pc, requiring exoplanets orbiting at distances between 2 and 50 AU. For higher EUV luminosities these distances can be larger than 50 AU. These results imply that the best candidates for detection of internally generated radio emissions are rapidly rotating Jupiter-like exoplanets orbiting stars with high EUV luminosities beyond 2 AU. Searching for such emissions may provide a new method of detecting distant exoplanets.

Mike Hapgood (RAL) commented on space weather as there has been lots of UK political interest in this topic recently. This could provide opportunities for societal and economic impact of solar–terrestrial and space-plasma physics. A Space Environment Impact Expert group is being formed and there is a need to engage with the Met Office as well as the traditional space-weather community. One thing to explore is the threat from extreme events, which falls favourably in the media eye, but peer review is critical. On a day-to-day basis the media tends to ignore space weather, but the case needs to be built for a profound impact on business performance. In the long term the MIST community needs to consider more and wider research strategies.