MIST Take 2: A report on the rescheduled Autumn MIST Meeting 2019 (2020)

Maria-Theresia Walach[1], Gregory Hunt[2], Alexandra Fogg[3] and Alexander Bader[1] report.

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Traditionally, the UK's Magnetosphere, Ionosphere and Solar-Terrestrial (MIST) community comes together for a one-day meeting at Burlington House to present and discuss the community's work. This year, the arrangements were unusual: due to the UCU strike and its potential impact on attendance, the meeting was cancelled at short notice and later rescheduled to be held on 24th January 2020. To accommodate the high volume of abstracts received, the venue was also changed to the Geological Society. Despite the short notice rescheduling and the coinciding funeral of **Alan Rogers** (British Antarctic Survey) on the day of the meeting, attendance was very high with 90 researchers present. As part of this years' council update, **Mark Lester** (University of Leicester) said a few words in memoriam of Alan,

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a long-standing member of the MIST community. Alan is remembered by the community as an advocate for the young members of the community and rigorous questioning. It was a reminder to us all that the MIST community we have today would not exist without its members and their hard work, as well as the collaborative spirit.

This year's invited speaker was **Mathew Owens** (University of Reading) who covered space weather forecasting challenges in his talk titled "From Sun to Mud". He illustrated the need to start modelling from as close to the Sun as possible in order to achieve significant prediction lead times – typical forecasts which are run with measurements from the Lagrangian L1 point only provide roughly 35 minutes of warning at Earth. The complex chain of models needed to predict conditions at Earth requires a thorough estimation of the arising uncertainties, which may be done using ensemble models. Reduced physics models provide a simpler modelling approach, but one can achieve many runs of the model compared with higher resolution models, which is often preferable for forecasting. He concluded that an optimum estimate can be achieved using data assimilation from different upstream monitors.

Continuing the Solar theme, **Stuart Bale** (UC Berkeley/Imperial College/Queen Mary) shared the first results from the Parker Solar Probe. High resolution measurements of electric and magnetic fields revealed jets and so called "switchbacks", seemingly random reversals of the Sun's radial magnetic field. It was found that the radial jets are not formed from reconnection, which can be shown through correlations in the Alfvénic fluctuations. Data from the Solar Probes' Perihelia 1 and 2 are now available online and the 3rd is to follow on 10th Feb 2020.

Diego de Pablos (Mullard Space Science Laboratory, University College London) shared progress on the development of methodology which will be used to analyse data from the Solar Orbiter mission. The mission has just launched and will provide the capability to combine remote sensing of the Sun's surface with in-situ measurements of the related solar wind dynamics in order to investigate the origin of the solar wind. This type of data analysis methodology will be further tested on close approaches to the Sun.

Moving further out into the heliosphere, **Sofija Durward** (Lancaster University) focused on the solar wind variability at Mars. Data taken from the Mars Global Surveyor and the MAVEN spacecraft show that the Interplanetary Magnetic Field (IMF) strength is more variable in the rising phase of the solar cycle and steadier when it lies in the ecliptic plane. The study also showed that the IMF clock angle is highly variable, and independent of solar cycle, whereas the cone angle is less variable, especially in the declining phase of the solar cycle. We learn that the solar wind at Mars cannot be assumed to be steady several hours after a measurement has been taken.

Moving on to the outer planets, **Alexander Bader** (Lancaster University) showed data on Saturn's auroral acceleration region from Cassini's Grand finale. The data shows that ions are trapped in downward current regions until they are sufficiently energized to escape. The energization may occur through wave-particle interaction and the mechanisms appear to be similar to Earth but much more energetic.

Continuing the Saturn theme, **Gabrielle Provan**, on behalf of **Thomas Bradley** (both University of Leicester), showed that dynamics in Saturn's magnetosphere are modulated externally by the solar wind, and internally by the planetary period oscillations (PPOs). By combining a multitude of measurements from the Cassini spacecraft with solar wind propagation models, it is seen that large-scale magnetotail reconnection events occur when the two drivers work in concert to thin the current sheet, that is, when the two PPO systems are in anti-phase and the magnetosphere is confined by solar wind compressions .

Affelia Wibisono (Mullard Space Science Laboratory, University College London) presented XMM observations of strong pulsations in Jupiter's X-ray aurora. They appear to have been triggered by a solar wind compression and showed 23-33 min recurrence time in the Northern and Southern hemisphere. It was found that both poles pulse at the same time and at the same periods, which indicates that the X-ray pulses may be caused by Ultra Low Frequency (ULF) waves. Spectral analysis suggests that the precipitating ions driving the soft X-ray emissions originate from Io.

Switching planet once more, **James Waters** (University of Southampton) presented how Auroral Kilometric Radiation (AKR) measured by the Wind spacecraft can be utilised as a probe for Magnetosphere-Ionosphere coupling due to previous observations of its correlation with the AE index and substorm activity. While three-axis stabilised spacecraft have had analyses applied that account for partial polarisation this is not true for Wind, a spinning spacecraft. To return the full polarisation state of AKR, a new analysis technique is necessary. In the near future, a multi-decadal dataset of AKR will be available to explore.

The afternoon started with **Sean Elvidge's** (SERENE, University of Birmingham) presentation of AENeAs, a 4D physics based ionosphere-thermosphere ensemble data assimilation model used to generate probabilistic forecasts to predict ExB drift in the ionosphere. This talk illustrated the usefulness of ensemble forecasting, which can be used to improve forecasting errors, but which are unable to provide a priori probabilistic forecast on their own. .

Continuing the theme of ionospheric modelling, **Ingrid Cnossen** (British Antarctic Survey) showed simulations from the TIEGCM 2.0 model to investigate the effect of the predicted changes of the geomagnetic field on the ionosphere from 2015 to 2065. Predictions show that the magnetic equator moves and the South Atlantic anomaly intensifies, widens and moves westward. Changes in the thermosphere were overall observed to be small but significant changes were seen in the ionosphere (up to ±10 TECU), which are mainly due to changes in the ExB drift.

Another modelling method was presented by **Richard Boynton** (University of Sheffield), showing results from various models of the inner magnetosphere. Using a machine learning algorithm based on NARMAX models, which are physically interpretable, the spatiotemporal evolution of the GOES electron flux is modelled, along with lower band chorus, hiss and magnetosonic waves.

Focusing on wave-particle interactions, **Oliver Allanson** (University of Reading) tested to see how well standard theory can describe effects of wave-particle interactions for different kinds of plasma waves. The standard theory is designed for low amplitude and incoherent waves, but the applicability of standard theory for the other wave modes is not clear. Using a particle in cell (PIC) simulation, the interaction between incoherent waves of different amplitudes with particles was modelled. It was shown that the diffusion rate for low amplitude waves starts off non-linear but soon becomes linear and as such agrees with standard theory.

Lightning talks (1 slide and a strict 2 minute time limit) were given by **Joshua Wiggs** (Lancaster University) on behalf of **Chris Arridge** (Lancaster University), and by **Clare Watt** (University of Reading) on behalf of **Jonathan Rae** (Mullard Space Science Laboratory, University College London): The first talk advertised Ikuchi, an open-source 3D visualization tool of solar system magnetospheres (Arrige and Wiggs, 2019) and the second talk advertised a white paper submitted to the ESA Voyage 2050 program on the fundamental modes of energy transfer and partitioning in the coupled Magnetosphere-Ionosphere system and solicitated community interaction on the topic.

The last session of the day was focused on modelling, as well as interactions between the solar wind and the terrestrial magnetosphere. It was opened by **Matthew Brown** (University of Southampton) who presented his work on studying climate change in space by looking at neutral density changes in the thermosphere and their implications for space debris. In the worst-case scenario of CO2 emissions were estimated to lead to a 75% decrease in thermospheric density by 2100 in comparison to 2000 at 400 km altitude. Increasing CO2 levels in the atmosphere cause the thermospheric particle densities to decrease, leading to a significant increase of space debris lifetimes. This would have a highly adverse impact on the safety of satellites in orbit around Earth.

The modelling theme continued with **Heli Hietala** (Imperial College London), who modelled magnetosheath jets using global 3D hybrid simulations and found that their characteristics agree with observations, whereas 2D simulations were unable to represent observed magnetic field and plasma signatures. It was found that the jets have many different complex shapes, and most are attached to the bow shock.

Caoimhe Doherty (Mullard Space Science Laboratory, University College London) presented a case study of reconnection signatures observed in Earth's magnetospheric cusps. A magnetic flux transfer event was observed at the high latitude cusp and the estimation of flux yielded similar results using the ground-based SuperDARN radar network and the Cluster spacecraft.

Studying auroral forecasting, **Michaela Mooney** (Mullard Space Science Laboratory, University College London) used the OVATION-Prime 2013 (OP-2013) model to evaluate the forecast location and probability of aurora occurring against auroral boundaries determined by Longden et al. (2010) from Far-Ultraviolet (FUV) observations of the auroral oval from the IMAGE satellite. The OP-2013 model performs well at forecasting the location of the auroral oval however, the model tends to under-predict the probability of aurora occurring for lower probability values and slightly over-predict the probability of aurora occurring for the highest probability values.

Returning to the first topic of the day with space weather modelling, **Ravi Desai** (Imperial College London) on behalf of **Han Zhang** (University of Durham) presented 3D simulations of the most extreme space weather event on record (23 July 2012 Interplanetary Coronal Mass Ejection). A model called PLUTO was used solve hydrodynamic and MHD equations, which produces a realistic Parker spiral. The model output was compared with data from STEREO-A and showed that the magnitude of the ICME was reproduced well.

References:

Arridge, C., and Wiggs, J., *Ikuchi - Simple Magnetosphere Viewer*, https://github.com/chrisarridge/Ikuchi, DOI: 10.5281/zenodo.3451443.

Bader, A., Badman, S. V., Ray, L. C., Paranicas, C., Lorch, C. T. S., Clark, G., et al. (2020). Energetic particle signatures above Saturn's aurorae. *Journal of Geophysical Research: Space Physics*, 125, e2019JA027403. https://doi.org/10.1029/2019JA027403

Cnossen, I., & Maute, A.(2020). Simulated trends in ionosphere-thermosphere climate due to predicted main magnetic field changes from 2015 to 2065. *Journal of Geophysical Research: Space Physics*, 125, e2019JA027738. https://doi.org/10.1029/2019JA027738

Forsyth et. al. 2015, *A new technique for determining Substorm Onsets and Phases from Indices of the Electrojet (SOPHIE)*, DOI: 10.1002/2015JA021343.

Mooney, M. K., Forsyth, C., Marsh, M., Sharpe, M., Hughes, T., Bingham, S., & Jackson, D. (2019). *How well do we forecast the aurora?.* Astronomy & Geophysics, 60 (5), 5.22-5.25. DOI:10.1093/astrogeo/atz177.

Owens, M. J., Horbury, T. S., Wicks, R. T., McGregor, S. L., Savani, N. P., and Xiong, M. (2014), *Ensemble downscaling in coupled solar wind-magnetosphere modeling for space weather forecasting*, *Space Weather*, 12, 395– 405, DOI:10.1002/2014SW001064.

Plaschke, F., Hietala, H., Archer, M. *et al. Jets Downstream of Collisionless Shocks*. Space Sci Rev **214,** 81 (2018). https://doi.org/10.1007/s11214-018-0516-3.