Simulations of the ionosphere by the IPIM Model during extreme solar wind conditions

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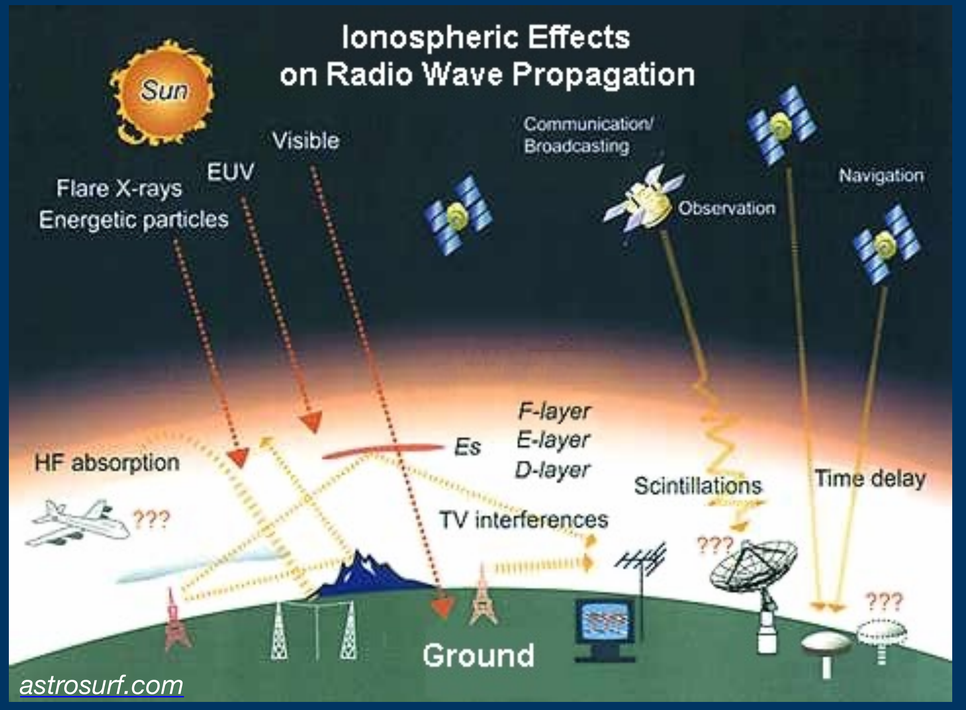
Key Points

- The IRAP Plasmasphere Ionosphere Model (IPIM) describes the transport equations of ionospheric plasma species along closed magnetic field lines.
- Recent developments have improved data inputs, given a new conductivity module to model geomagnetically induced currents and streamlined the model to run on operational time-scales.
- New version of IPIM in the testing phase for both ambient solar wind conditions and extreme events.

Motivation

- IPIM developments part of EUHFORIA project to model space weather events from the Sun to their impact at Earth.
- Provides input to models which will forecast ground-induced currents. These provide significant risks for the electrical grid.



If interested in running the model, please contact us on the email provided. The new version will be ready for scientific investigations in the coming weeks.

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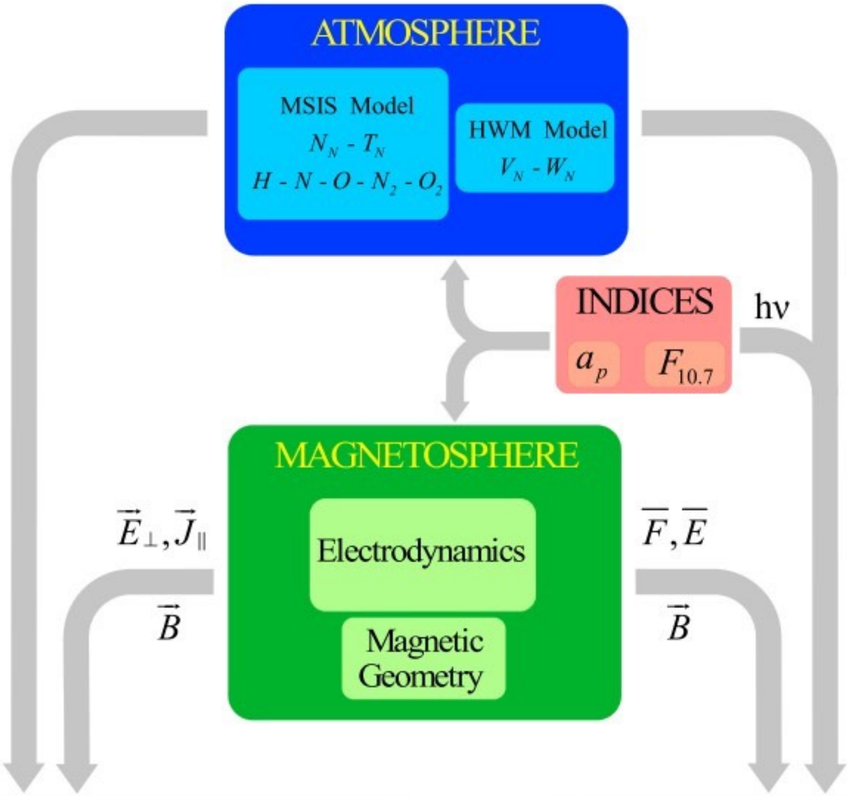
How Does IPIM Work?

The IRAP Plasmasphere Ionosphere Model (IPIM) is a 1-D ionospheric model which describes the transport equations of ionospheric plasma species along closed magnetic field lines.

More information on IPIM model can be found here: Marchaudon and Blelly, 2015; Blelly et al., 2019.



Inputs to the model come from models of the magnetosphere, neutral atmosphere and external indices such as the ap magnetic index and the F10.7 solar flux. Most inputs can be switched between different models but some are independent of observations.

The fluid module computes the thermal electron density and temperature which is then passed to the kinetic part to return the ion production and thermal electron heating rates.

The fluid module is coupled to a kinetic module which solves the Boltzmann transport equation of suprathermal electrons along the field lines.

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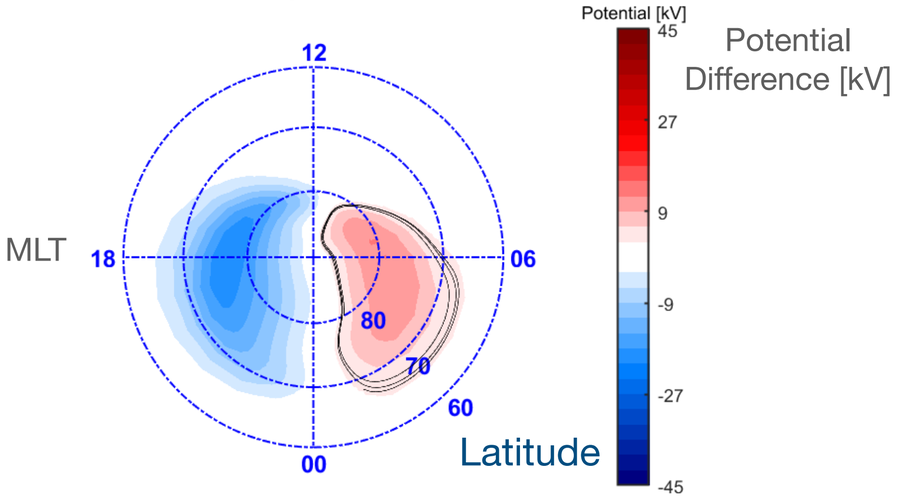
New IPIM Developments

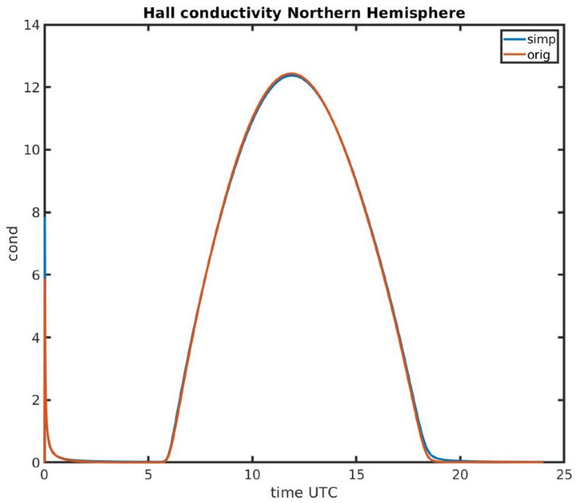
Solar Wind Drivers

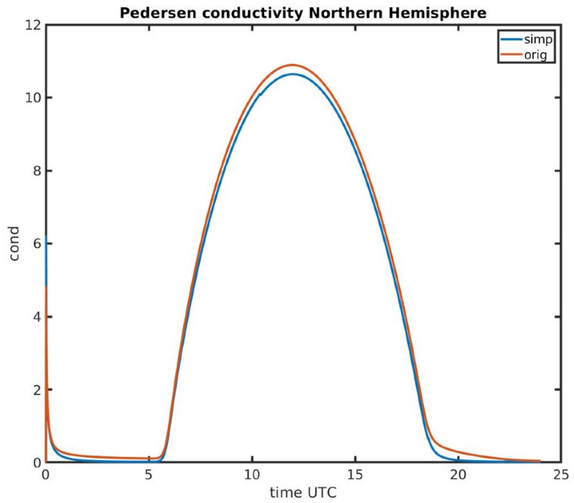
- We've developed IPIM to include observations & more complex models of ionospheric processes as inputs to improve the representation of the solar wind & to allow for coupling with solar wind and magnetospheric models. This upgrades the magnetosphere & atmosphere sections of the model.
- We now use OMNI solar wind data from L1, different convection map models of SuperDARN data and Ovation auroral precipitation models are now used as inputs. The NRLMSISE-00 empirical thermospheric model is also being added.
- Below: SuperDARN convection map of potential difference (colour bar) generated from Cousins & Shepherd (2010) model. The IPIM flux tube trajectory from the model (black line) on top.



Conductivity Module

- A simplified numerical model for conductivities has been developed for low/mid-latitudes for use in operational simulations of the ionosphere.
- Uses a kinetic model with photo-ionisation & an eccentric dipole magnetic field.
- Latest combined version of IPIM changes gives varying currents and conductivities based on the SuperDARN convection map used.
- Below: successful comparison with full IPIM simulations of Hall & Pedersen conductivities (here with units s^3·A^2/kg.m^3).





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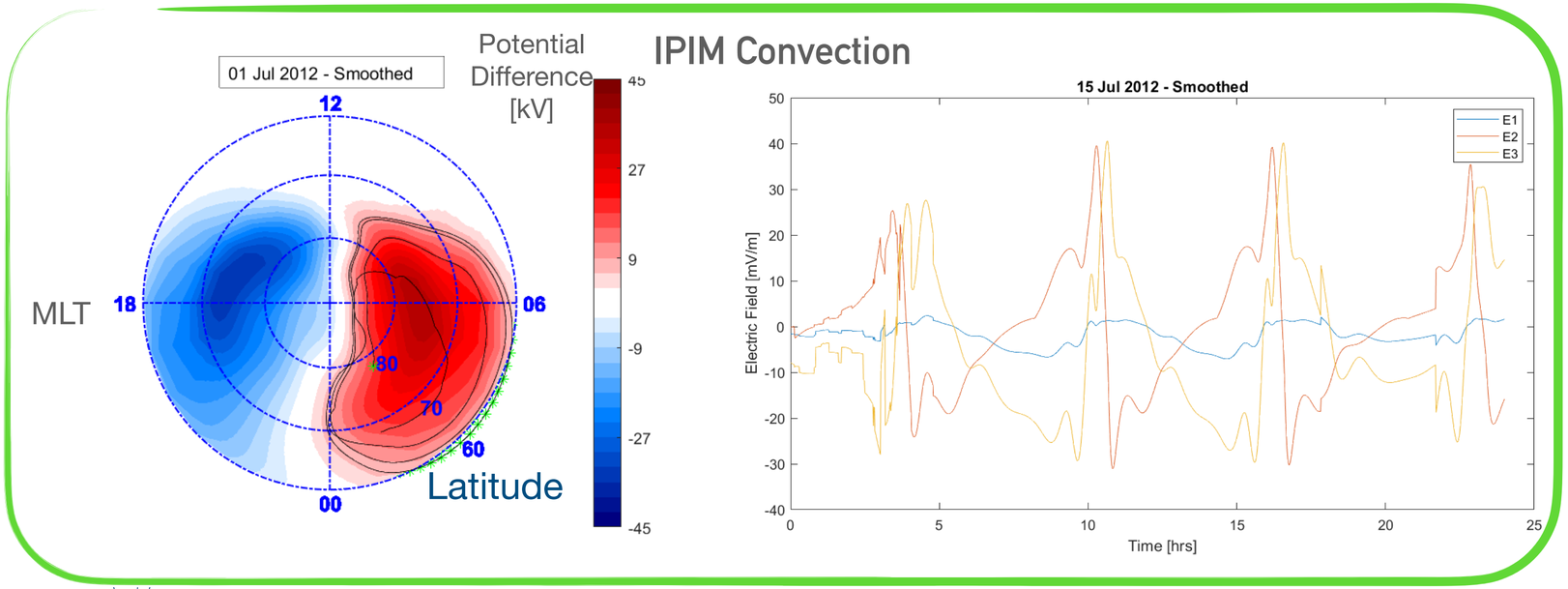
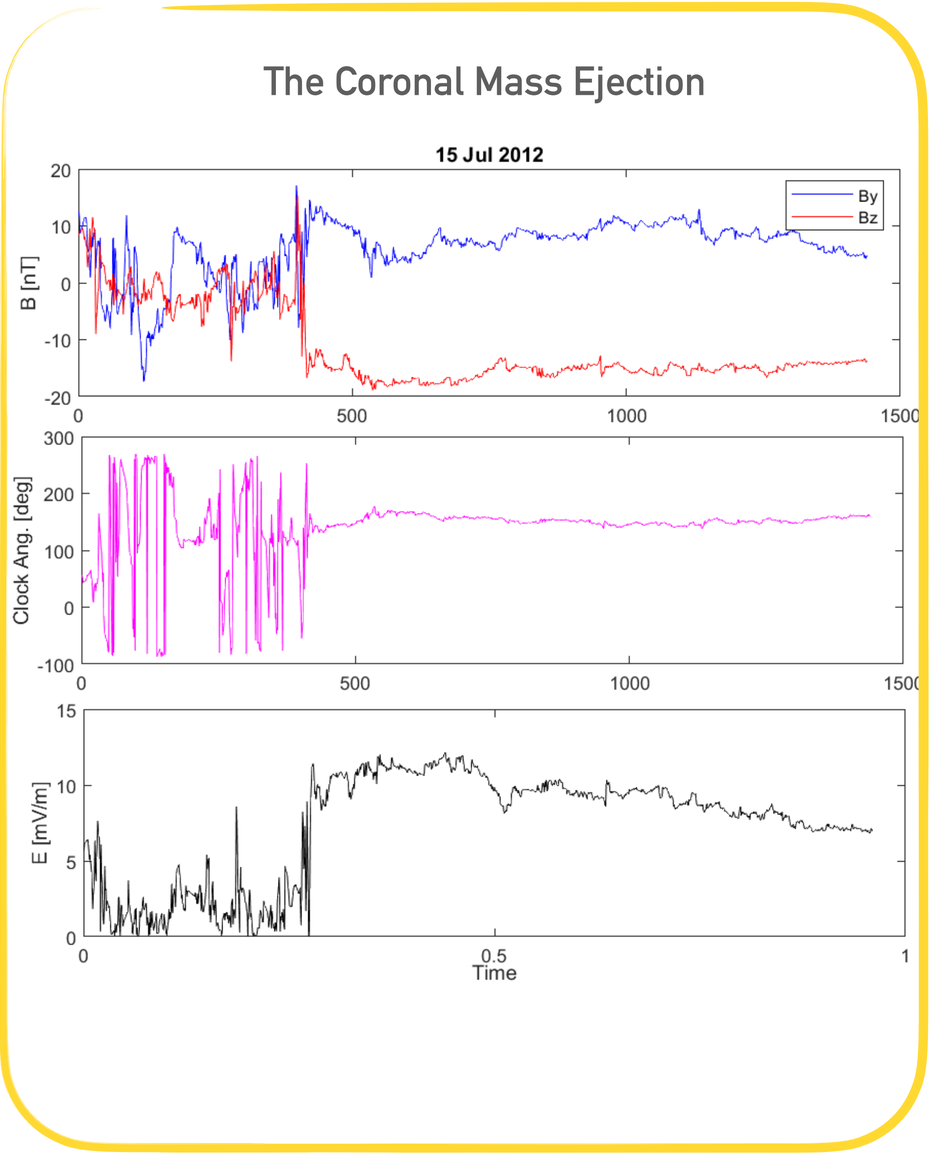
Testing & Initial Results

- We are currently in the testing phase of the new model version with solar wind inputs & new conductivity module.
- This is being tested on both “typical” and “extreme” solar wind conditions against the previous version & observations.
- EUHFORIA catalogue of coronal mass ejections used to find examples of storm-time events to assess how well IPIM deals with extreme space weather.
- Right: OMNI data of CME on 15th July 2012. Below: simulated impact of this CME on convection in the ionosphere (left) and electric fields components (right) using the developed version of IPIM including SuperDARN and Ovation inputs.





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