PNST Workshop
Sète, 19-21 November 2018

IPIM modeling of the ionospheric F2-layer depletion at high-latitudes during a High-Speed Stream (HSS) event

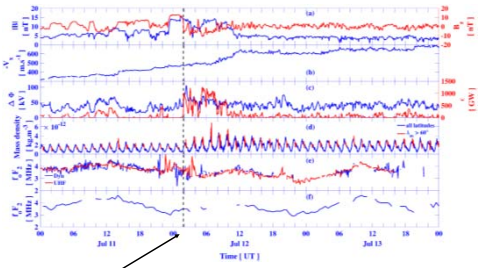
A. Marchaudon [(1)], P.-L. Blelly [(1)], M. Grandin [(2)], A. Aikio [(3)], A. Kozlovsky [(4)], I. Virtanen [(3)]

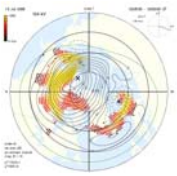
(1) IRAP; CNRS, CNES and UPS-OMP, Toulouse, France, (2) Departments of Phsyics; University of Helsinki, Finland,
(3) Ionospheric Physics Research Unit, University of Oulu, Finland, (4) Sodankylä Geophysical Observatory, University of Oulu, Finland.

Synopsis

- A summertime HSS event is successfully modeled with IPIM using comparison with SuperDARN and EISCAT radars, ionosondes and CHAMP satellite data
  - The ionosphere F2-layer is depleted as atomic oxygen density is reduced due to enhanced polar cap convection and neutral atmosphere heating
    - Electrodynamics can explain the short-term behavior of the ionosphere, while long term effects are due to neutral atmosphere perturbation

IMF and M-I coupling





Context:

- CIR/HSS impact on the magnetosphere
- Smooth, long lasting V_{SW} enhancement
- Strong B_{IMF} and P_{tot} increase
- IMF B_z turning: M-I coupling enhancement

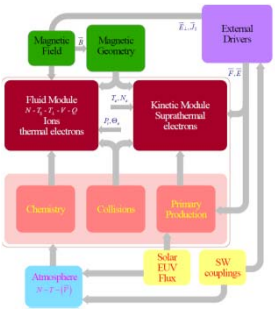
  → increase of Akasofu parameter and PCP

  → decrease of foF2 at SOD and TRO

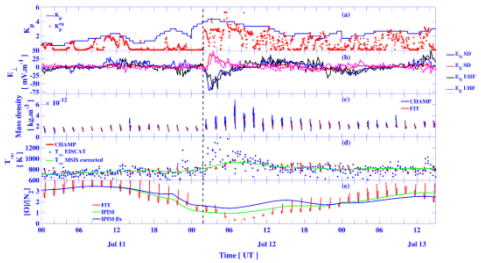
IPIM model

- ***Ionosphere model (legacy TRANSCAR)***
  Marchaudon and Blelly (2015)
- ***Fluid module:*** solve 13-moment transport equations for main ions and thermal electrons along **B**
- ***Kinetic module:*** solve Boltzmann transport equation for suprathermal electrons along **B**

fluid part provides the thermal electron density and temperature to the kinetic part which in return, provides the ion production and thermal electron heating rates



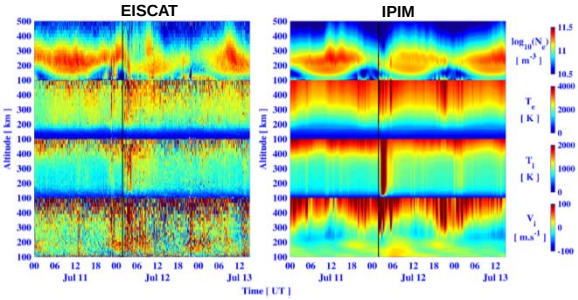
Inputs optimization



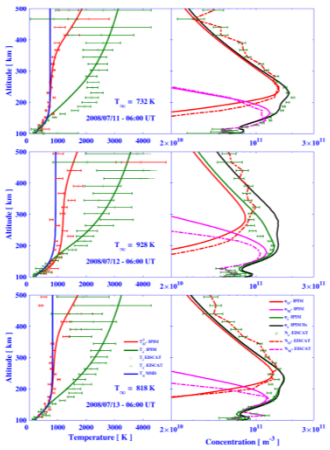
- ***Precipitation:*** use of OVATION-Prime model to construct a K_p^{eq} parameter used in the historical Hardy's model
- ***Convection:*** SuperDARN convection maps with a strong convection spot on the dawnside just after the IMF-B_z turning (to match EISCAT)
- ***Atmosphere:*** use of CHAMP mass density measurements above 60° MLAT to optimize exospheric temperature and O/N_2 ratio in NRLMSISE-00 model

Comparison observation-simulation at Tromsø and Sodankylä

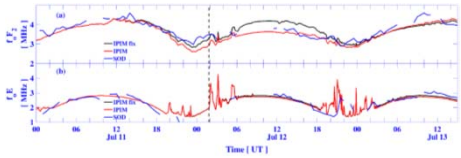
EISCAT **IPIM**



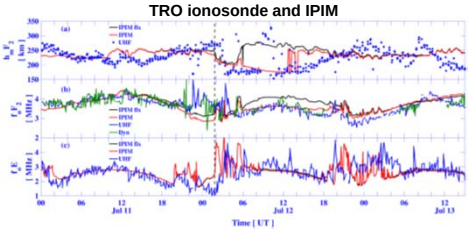
EISCAT and IPIM profiles



SOD ionosonde and IPIM



TRO ionosonde and IPIM



- ***Very good overall agreement between EISCAT-Tromsø and IPIM***
- ***Main features:***

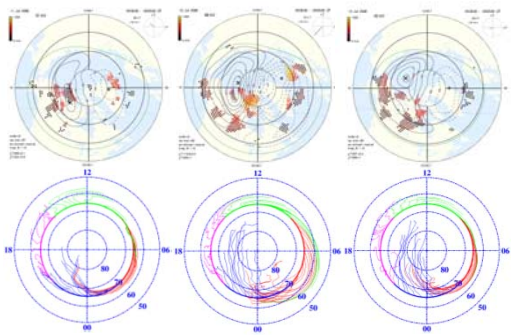
  → strong density decrease of F-layer during the day with M-I coupling enhancement

  → strong ion heating

  → strong ion upwelling (E- and F1-layers)

- ***Very good overall agreement between ionosondes and IPIM for E- and F-layers***
- ***Main feature:*** transition from F2- to F1-layer with density peak broadening

Tromsø simulated flux tubes trajectories



Discussion & Perspectives

- ***Observation:*** decrease of foF_2 associated with a transition from F2- to F1-layer resulting from a decrease of neutral atomic oxygen concentration.
- ***Simulation:*** two-steps mechanism

  → **1st step:** enhancement of plasma convection responsible for a sharp increase of ion temperature by Joule heating, leading through chemistry to an immediate reduction of the F2-layer on the scale of a few hours

  → .**2nd step:** ion drag on the neutral atmosphere responsible for a rapid heating and expansion of the thermosphere Expansion affects O through non-thermal upward flow resulting in decrease of O concentration and amplified decrease of $[O]/[N_2]$ ratio, this thermospheric change explains the long term extinction of the F2-layer.

- ***Eveningside simulation of the same event:*** PFSIR observations during the World Day campaign
- ***Southern Hemisphere (winter) simulations of the same event***
- ***Systematization of the simulated events*** (for different seasons, solar fluxes, latitudes)
- ***Combination with a study of flux tubes history***

References:
Marchaudon, A., P.-L. Blelly, M. Grandin et al., IPIM modeling of the ionospheric F2-layer depletion at high-latitudes during a high-speed stream event, J. Geophys. Res. Space Physics, https://doi.org/10.1002/2018JA025744, 2018.
Marchaudon, A., and P.-L. Blelly, A new interhemispheric 16-moment model of the plasmasphere-ionosphere system: IPIM, J. Geophys. Res. Space Physics, 120, 5728–5745, doi:10.1002/2015JA021193, 2015.