The unknown “Ionosphere” in positioning equation: how to solve it

Pierre-Louis BLELLY

IRAP

OUTLINE

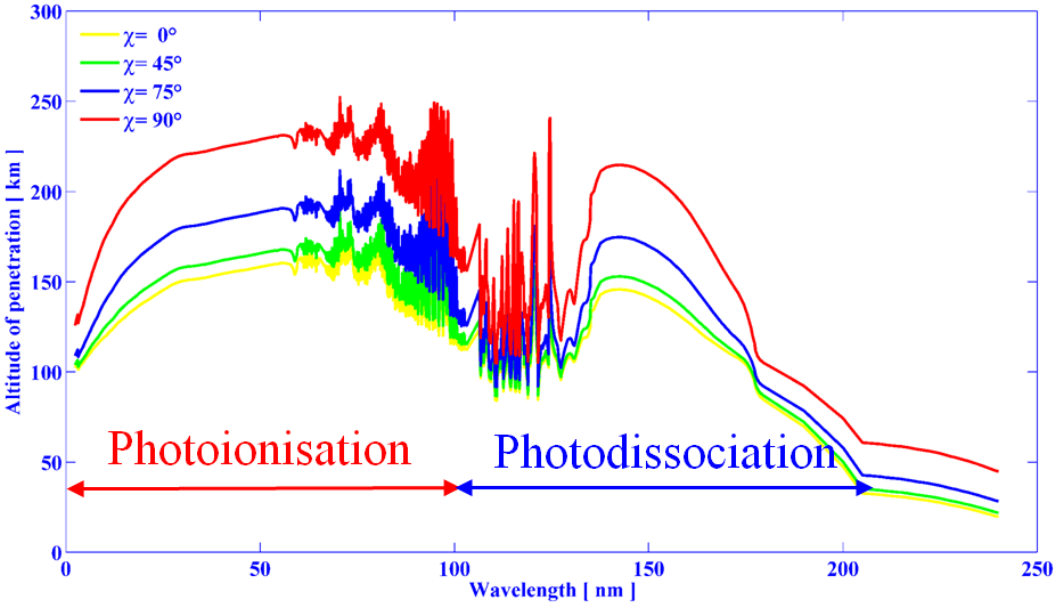
- Structure of the ionosphere
- Dynamics
- Couplings in the MIT system
- Connection with scintillations
- Conclusion

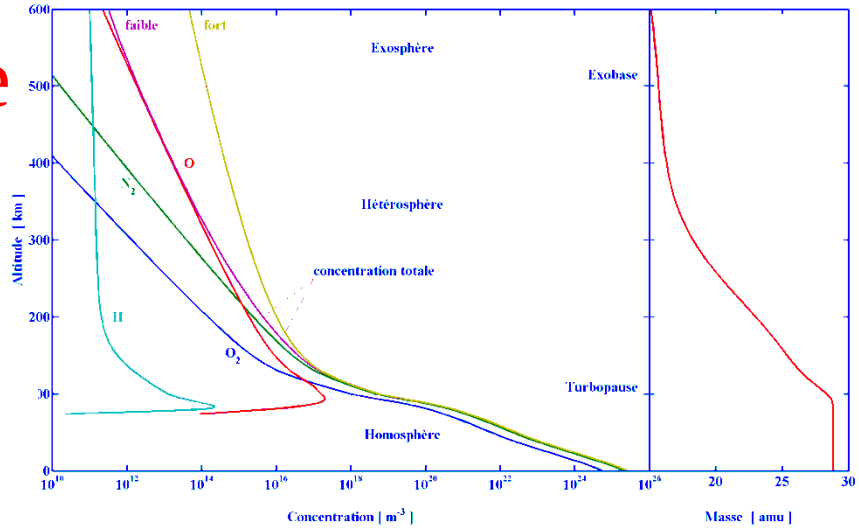
Structure

- Production
- Chemistry
- Vertical structure

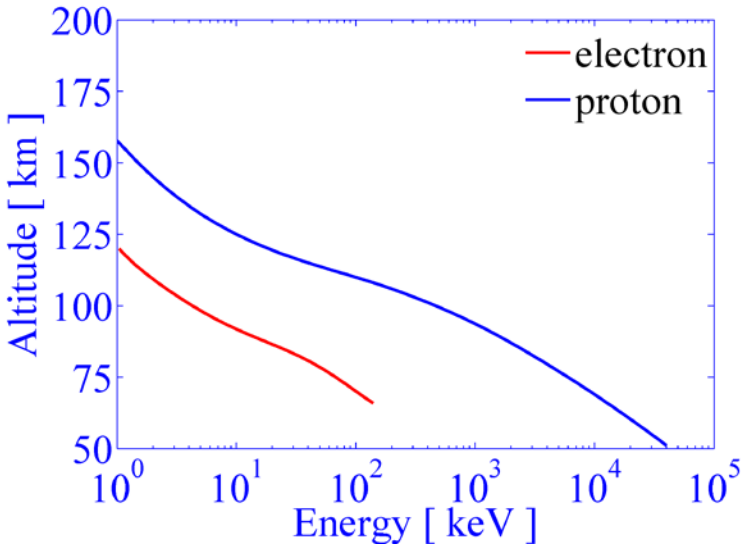
Production

- Ionization of the atmosphere
  - Photoionization
  - Precipitation





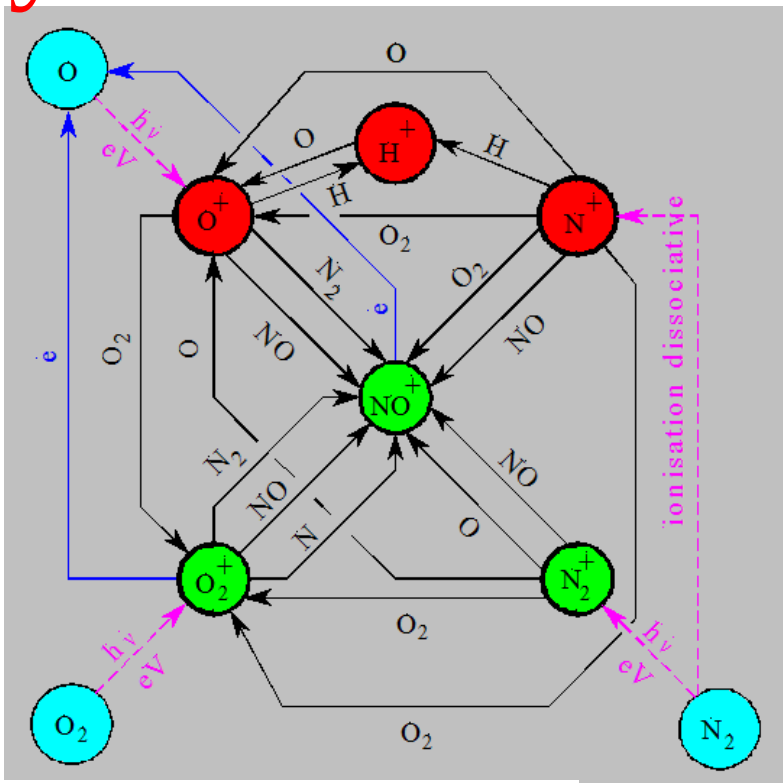
Penetration depth

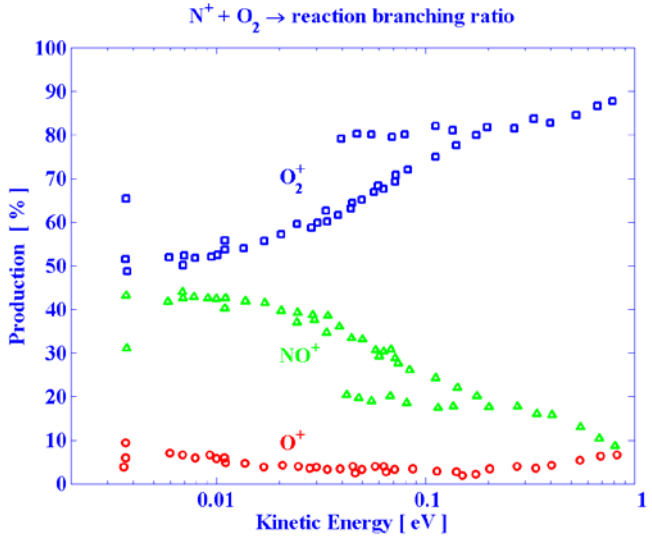


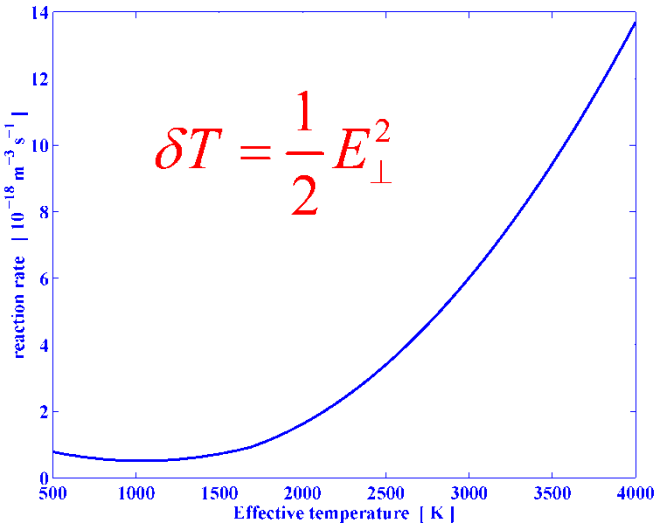
- Primary species: O_2^+,N_2^+,O^+,H^+

Chemistry

- Complex chemistry
- Highly variable with energy
  - Reaction rates
  - Products
- Alteration of initial structure
- Secondary species : NO^+

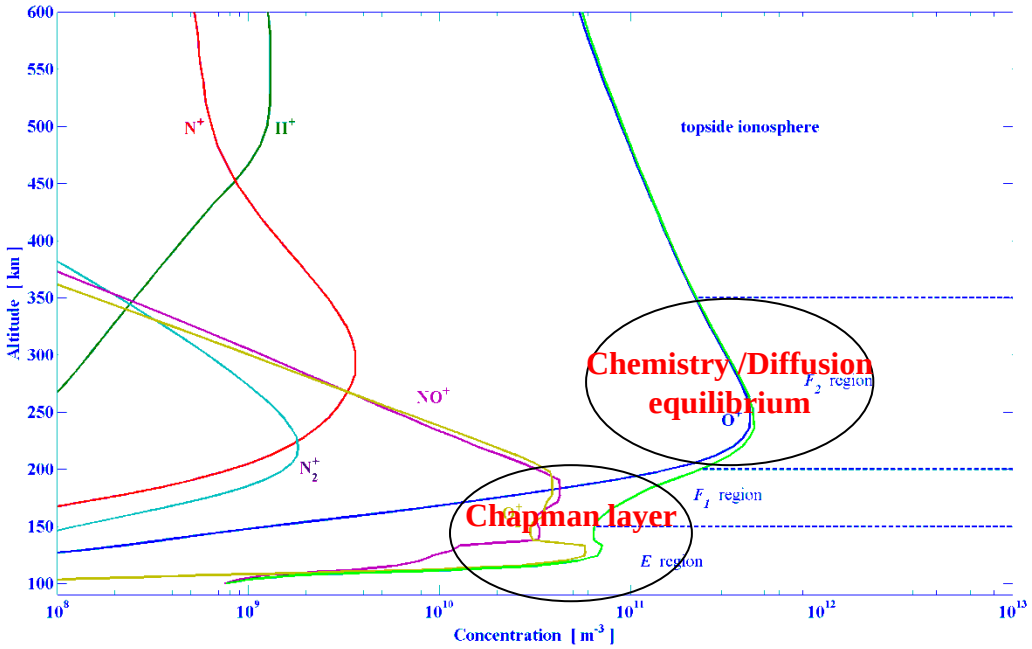


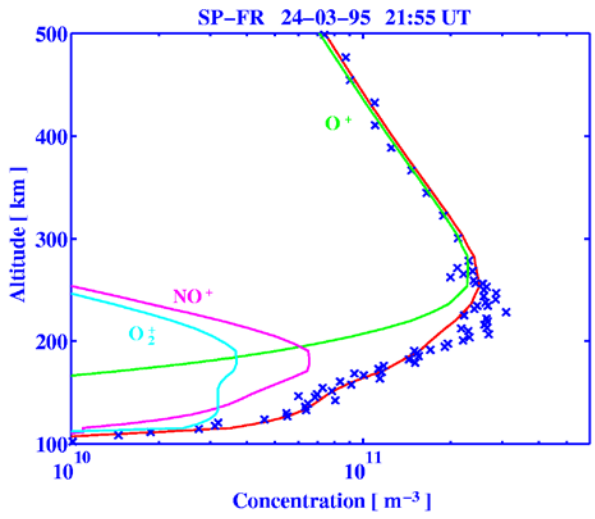


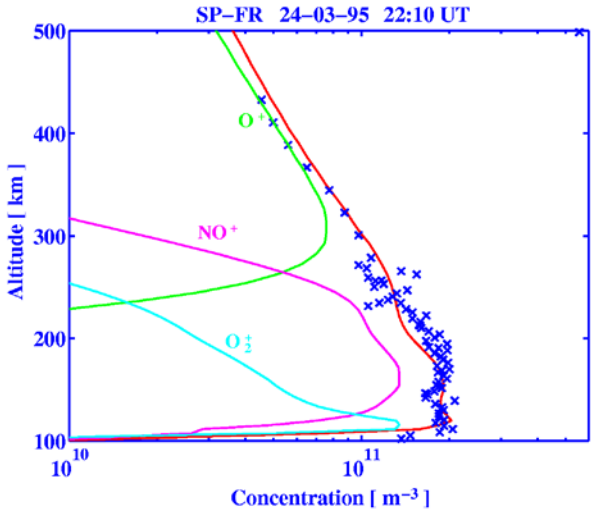


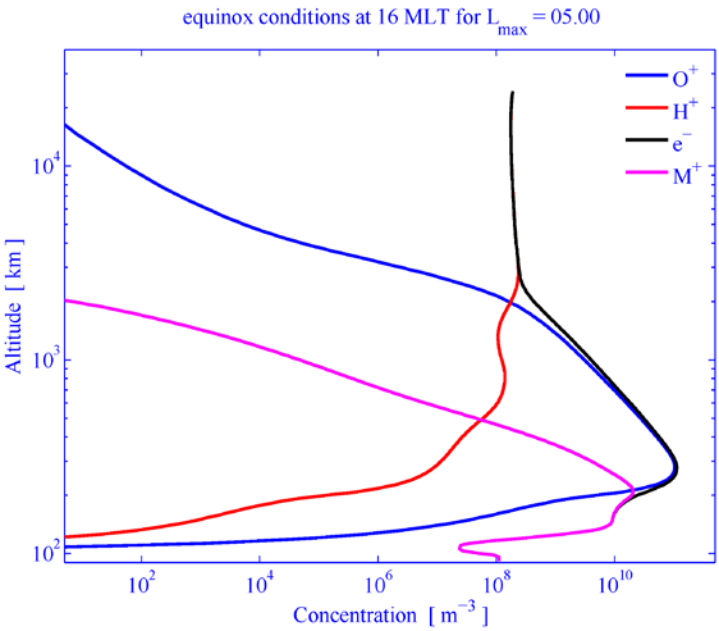
Vertical structure

- Strong dependency
  - altitude
  - latitude
- Strong variability
  - Local time
  - Source







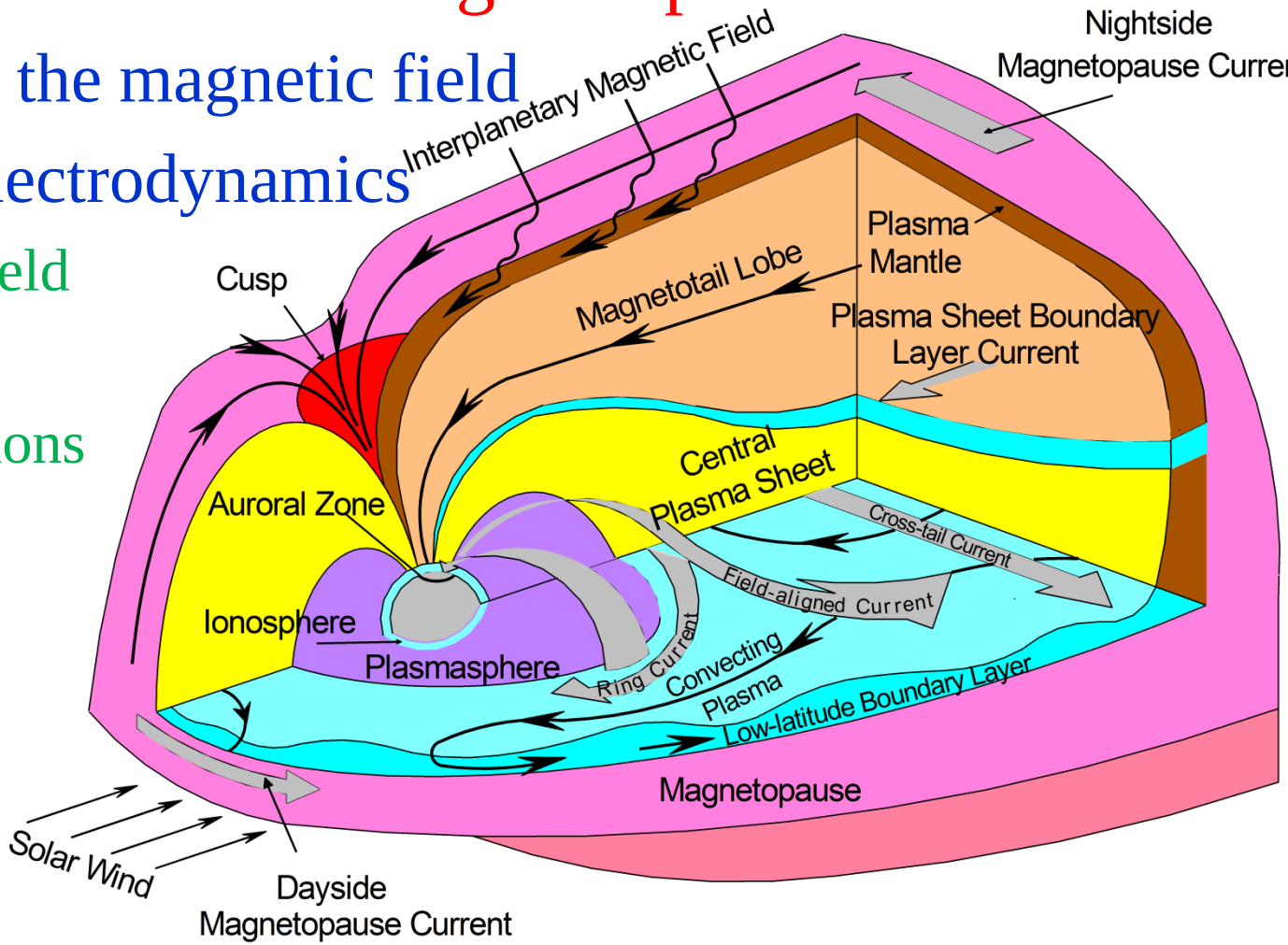


Dynamics

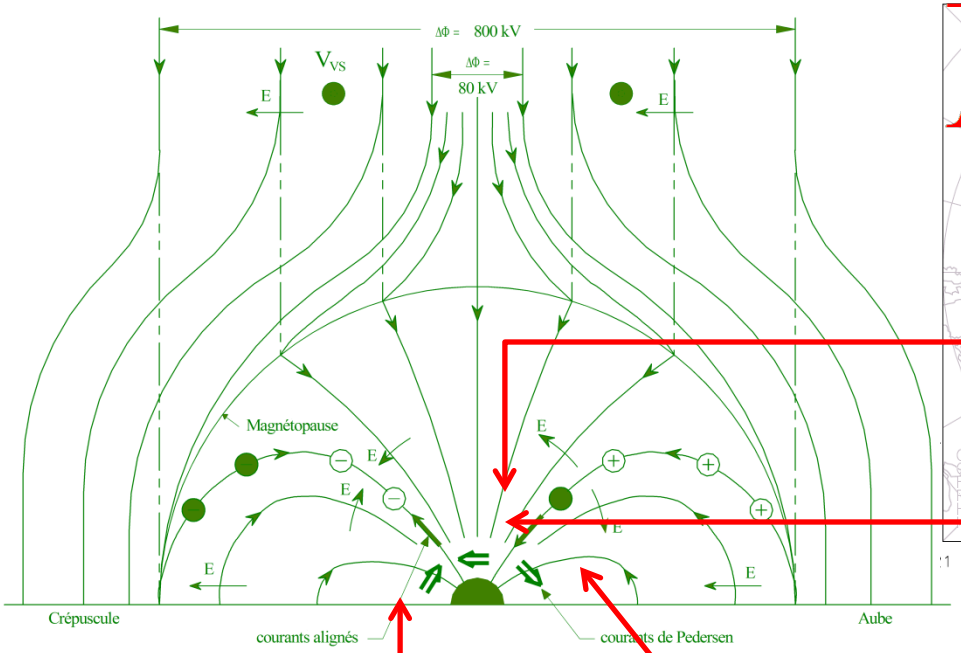
- Magnetospheric system
- Electrodynamics system
- Impact on the ionosphere

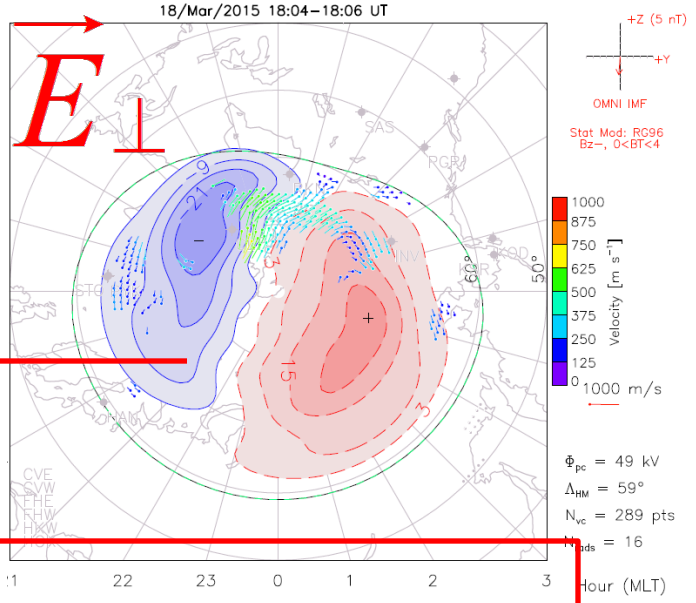
Dynamics

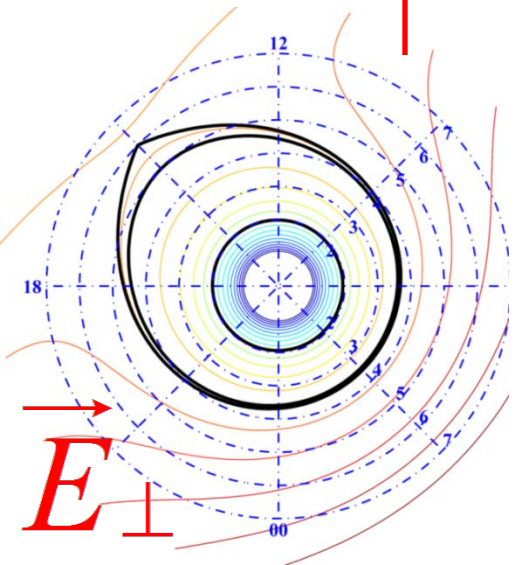
- Control by the solar wind
- Strong interaction with magnetosphere
  - Key role of the magnetic field
  - Complex electrodynamics
    - Electric field
    - Current
    - precipitations

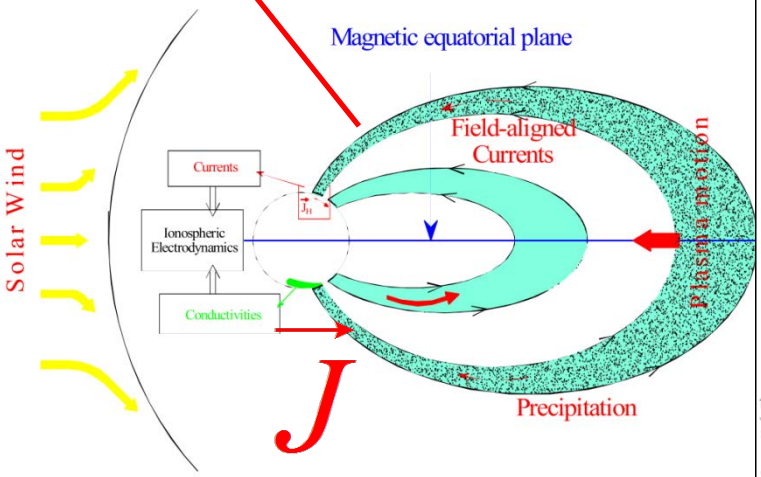


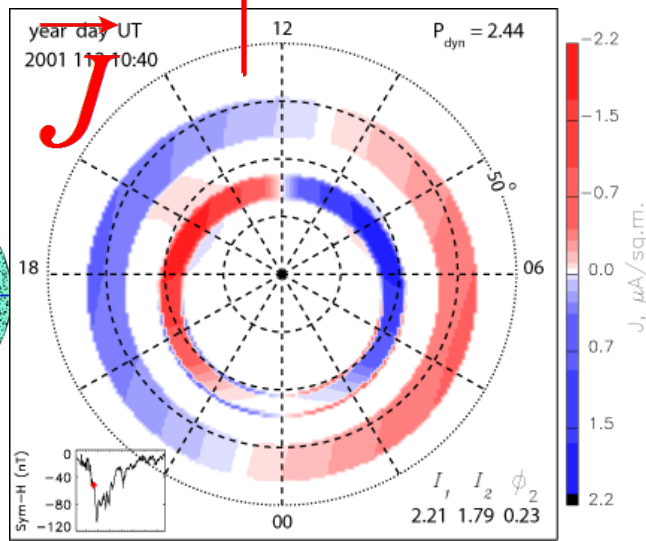
Electrodynamics system





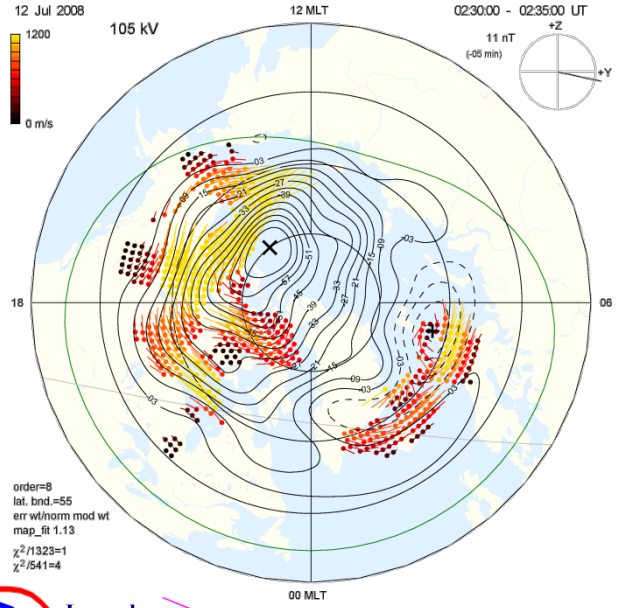


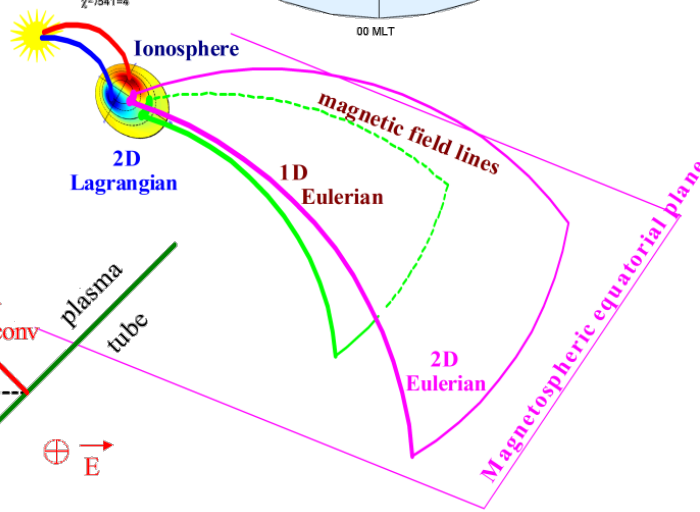


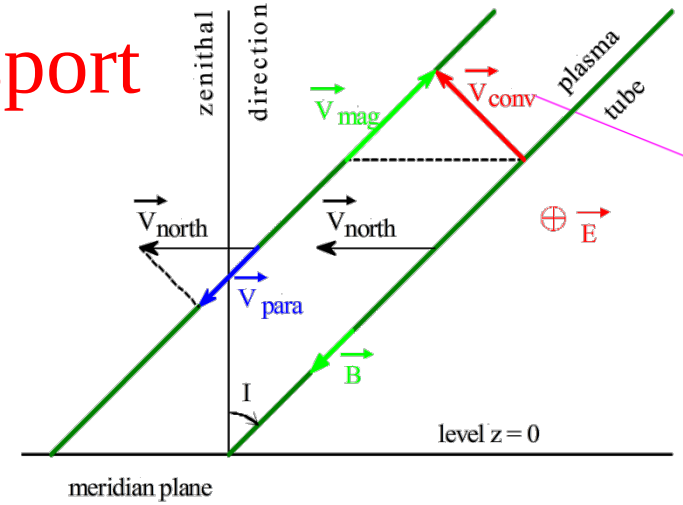


Impact at ionospheric level

- Ionospheric plasma convection
  - Drag on atmosphere
  - Frictional heating
    - Enhancement of the chemistry
- Splitted motion
  - 1D along magnetic field B
  - 2D perpendicularly to B
- Field aligned transport

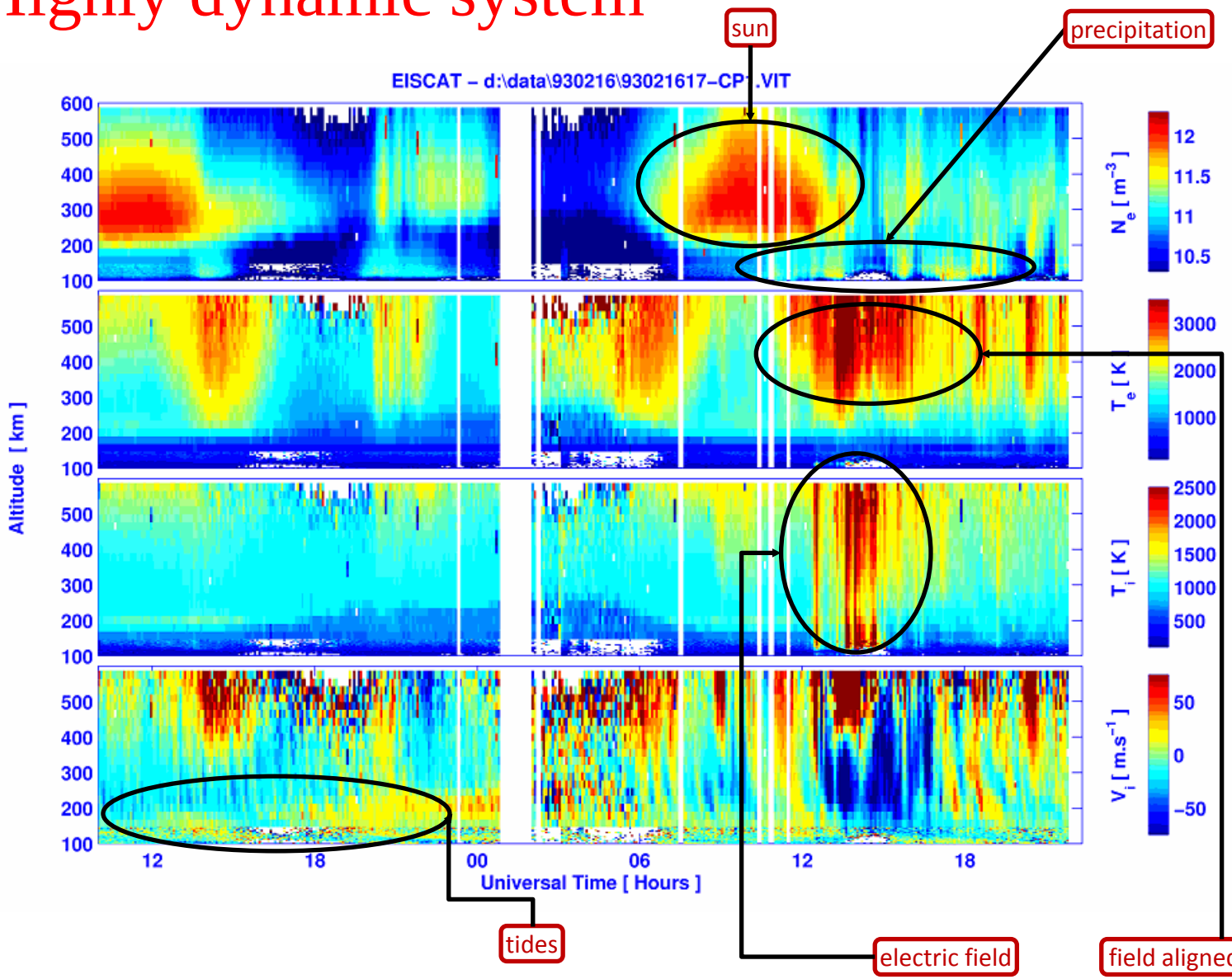






Full combination

- Highly dynamic system

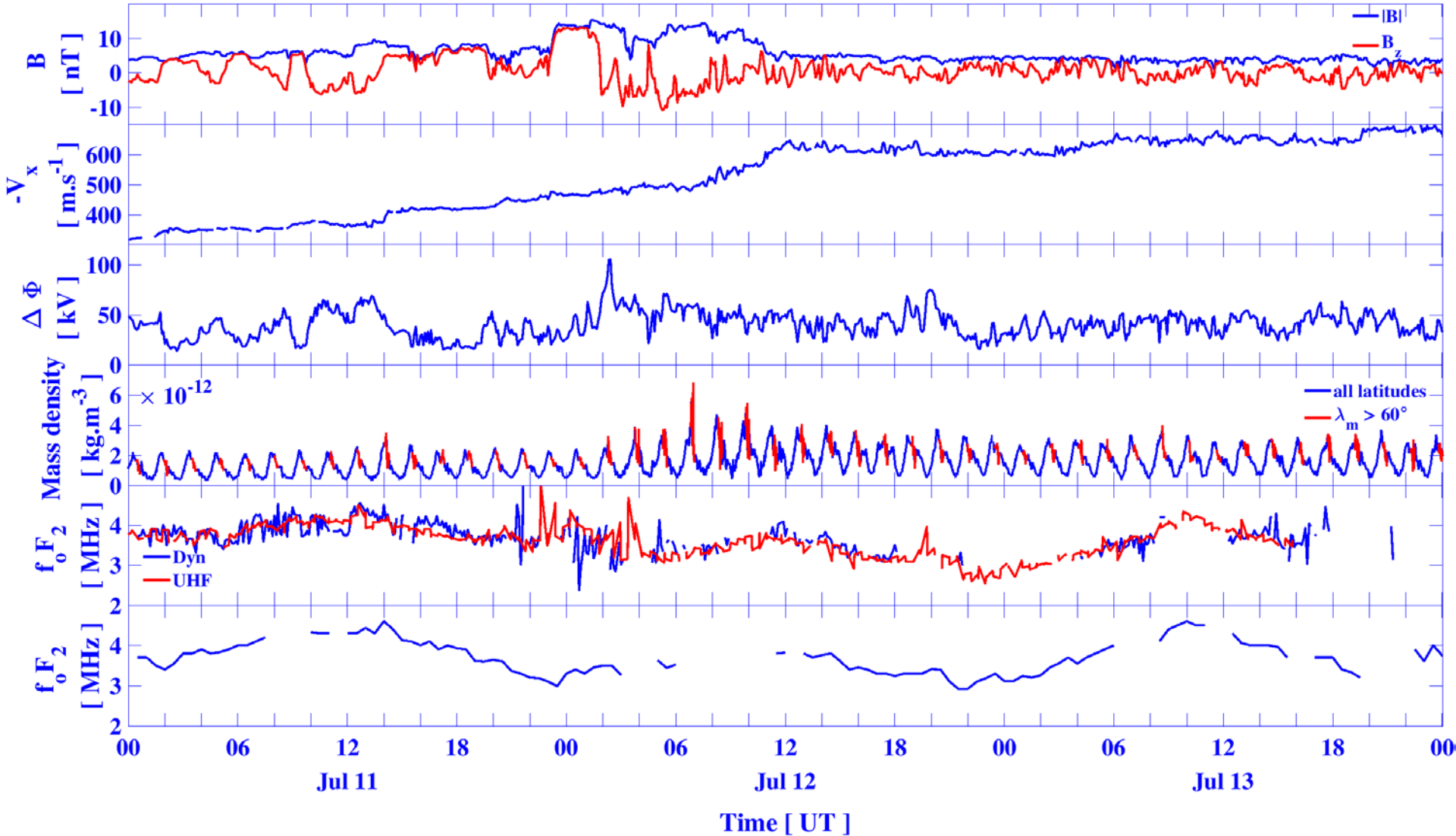


Couplings in MIT

- High speed stream
- Chemistry
- Vertical structure

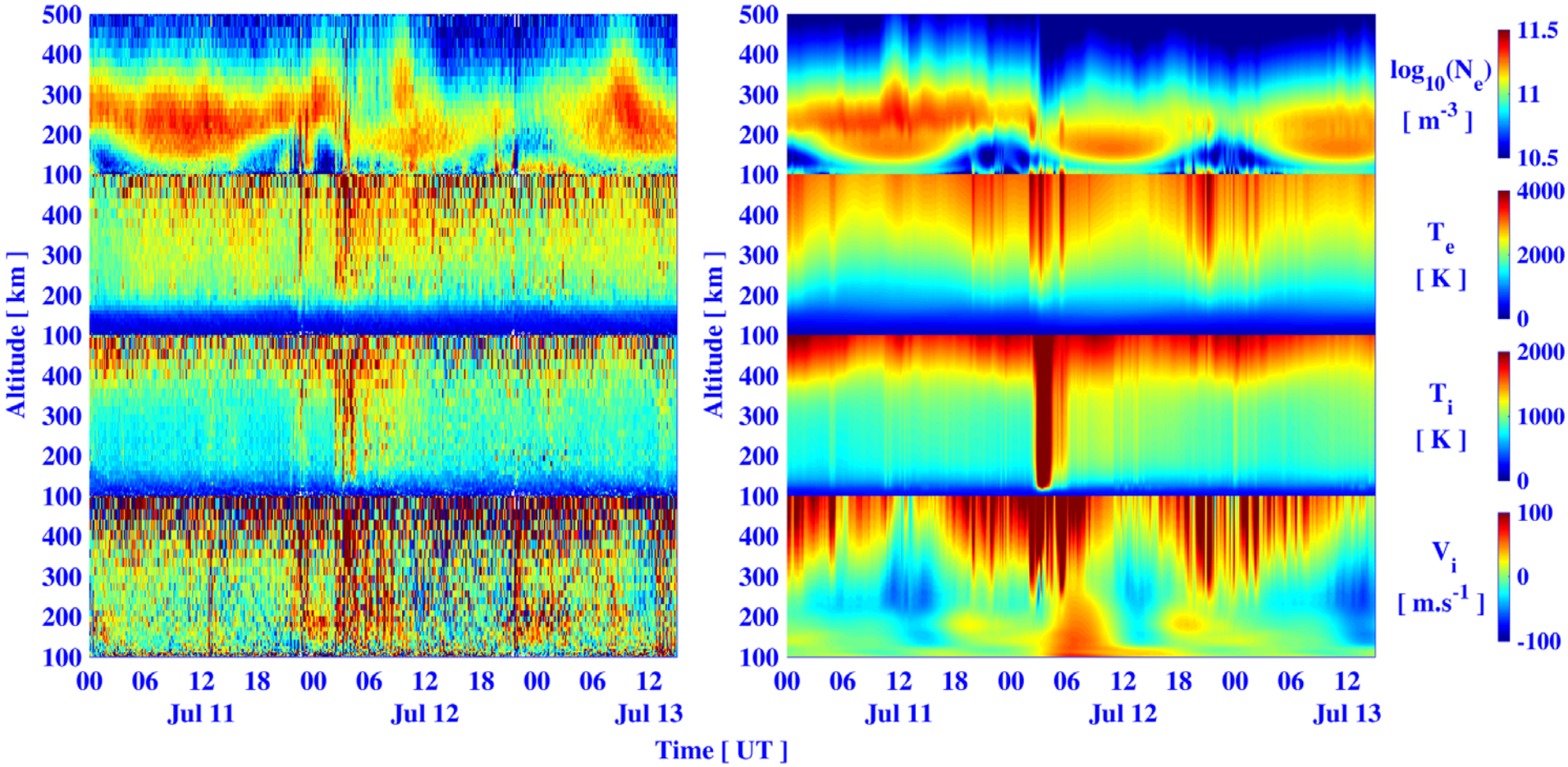
High speed stream

- Solar wind control



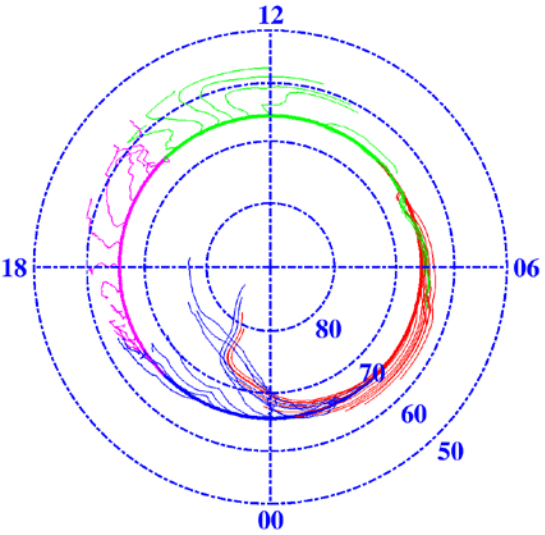
Response of the ionosphere

- Low solar activity: $F_{10.7} = 68$
- Disappearance of the F_2 layer

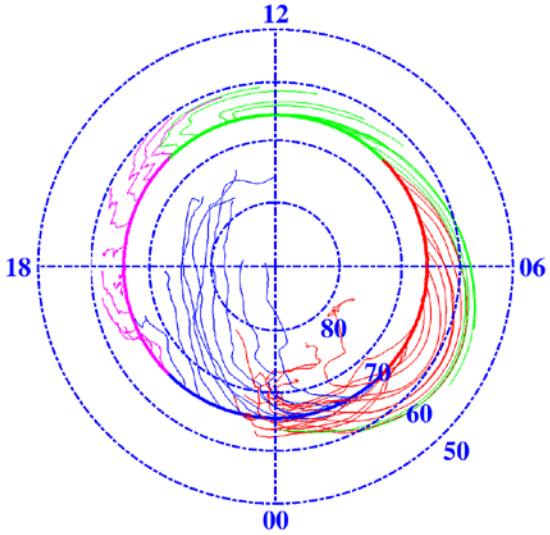


Importance of the convection

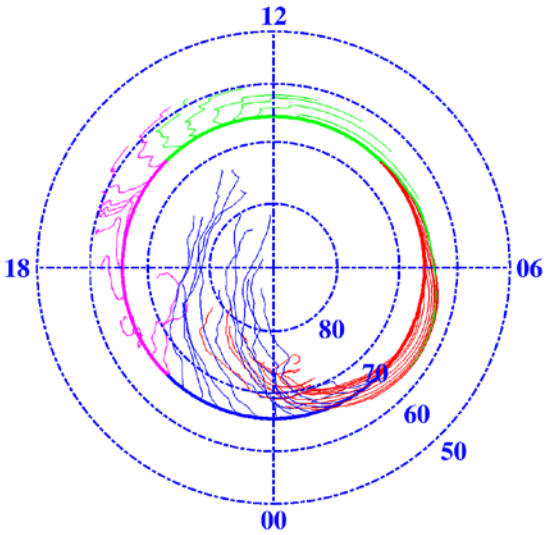
- History of the plasma tube



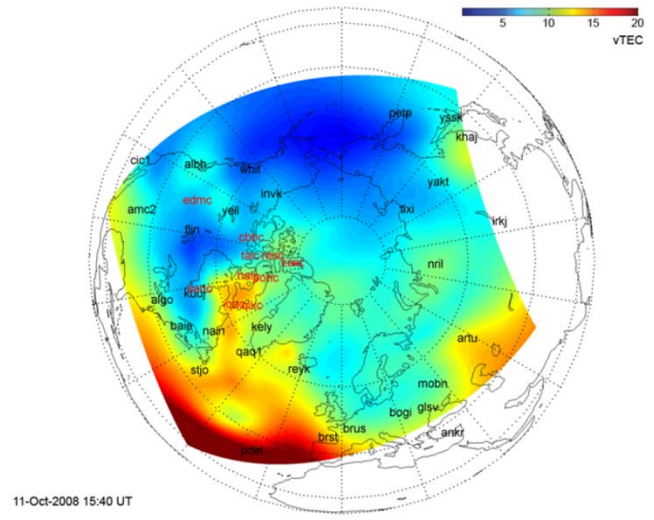
Jul 11



Jul 12



Jul 13

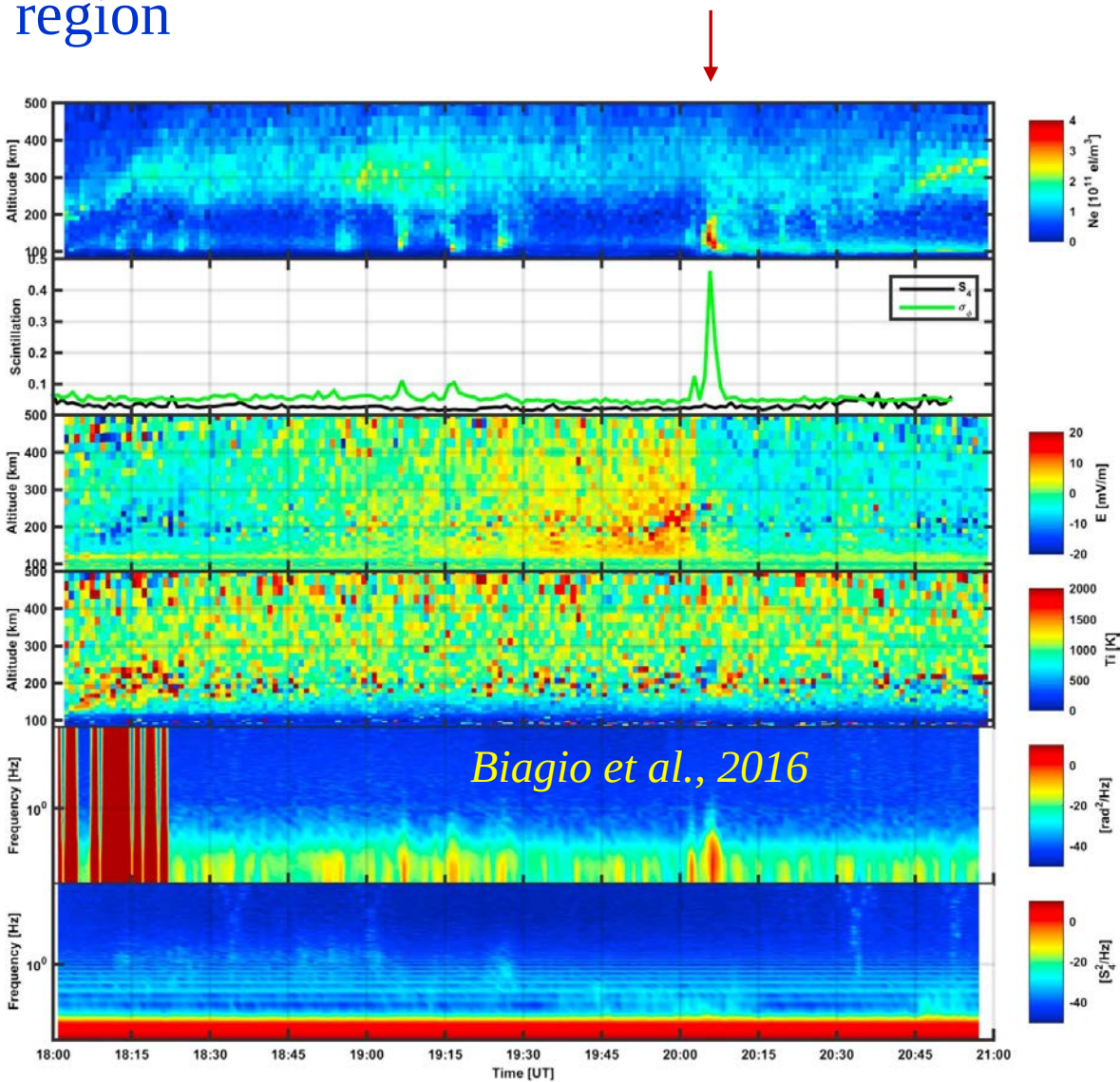


Connection with scintillations

- Ionospheric structure
- Large scale irregularities
- Magnetospheric activity

Ionospheric structure

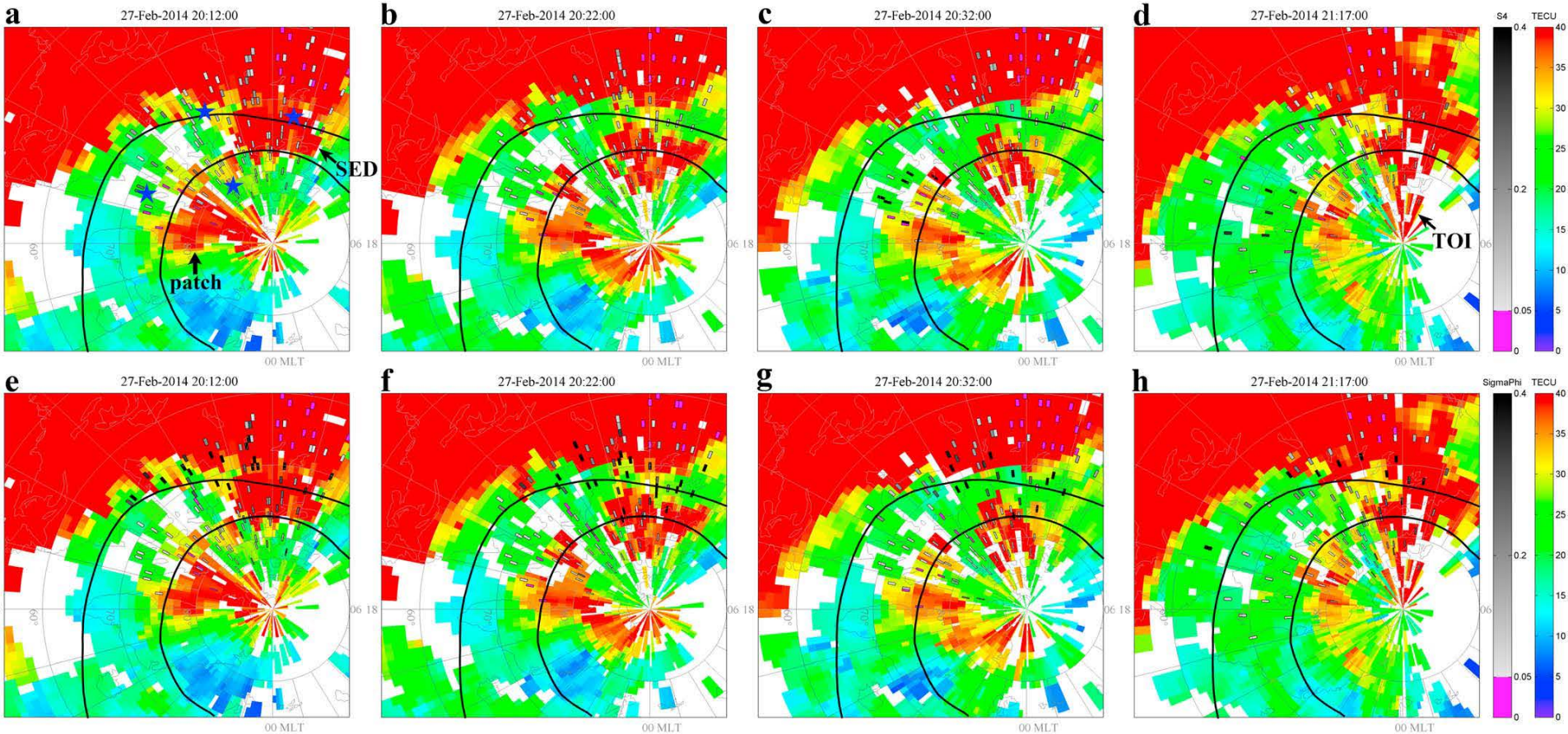
- Large scale ionization structures
  - Enhancement of the E region
  - Substorm onset
  - Vertical extension
  - No cascade to smaller
  - Phase without amplitude
  - Recombination rate
  - Plasma instability



Large scale irregularities

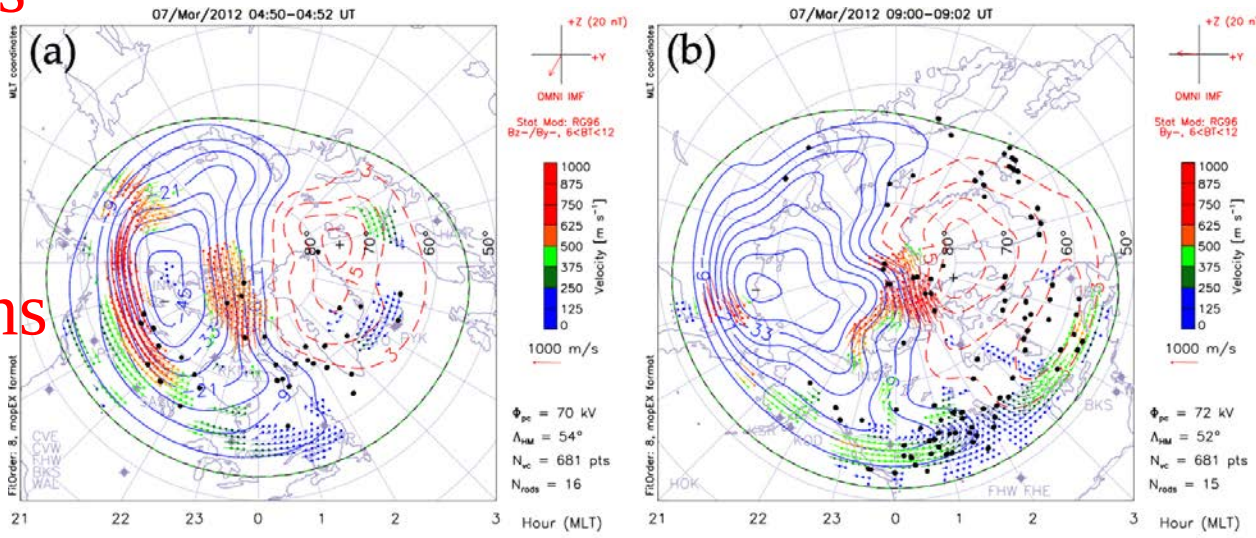
- Effect of the convection
  - Plasma patches over the polar cap

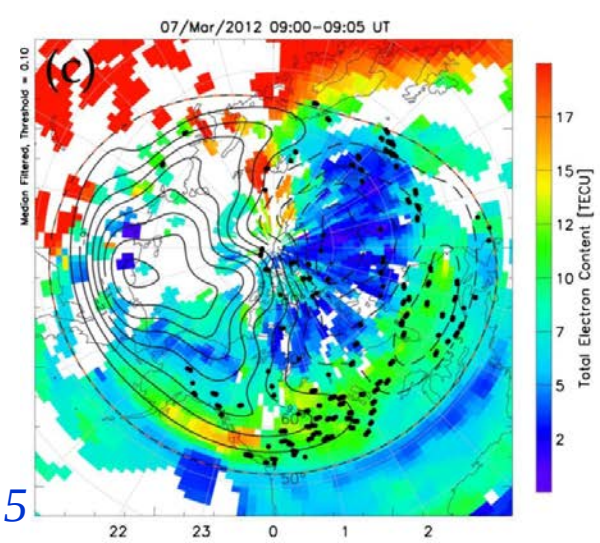
Wang et al., 2016

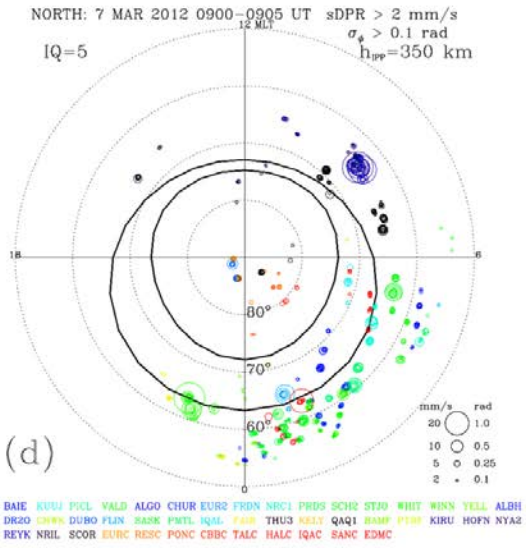


Magnetospheric activity

- Geomagnetic storm
- Strong scintillations
  - Nightside oval
- Collocated
  - auroral emissions
  - Expanded cells





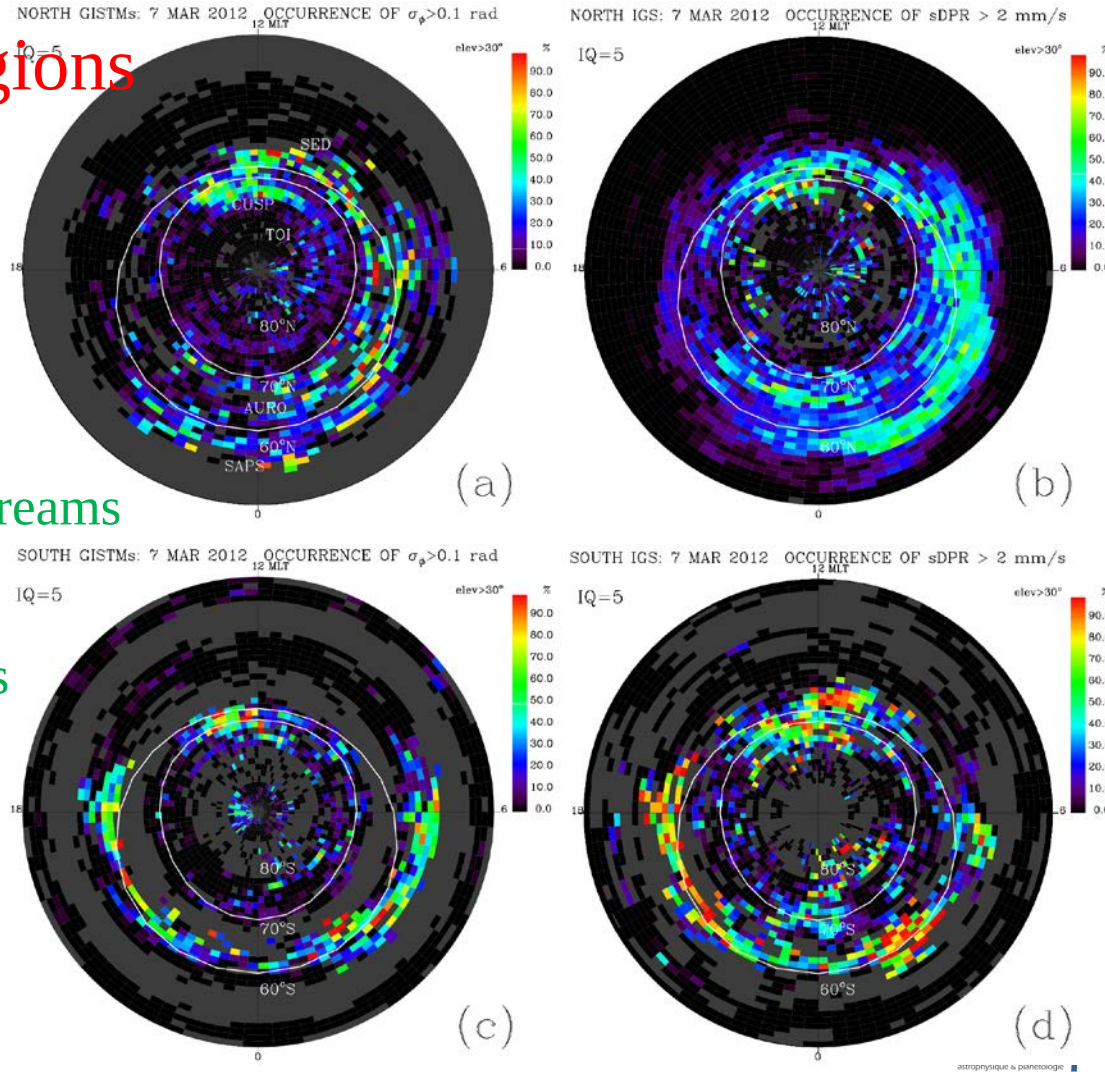


black dots : σ_ϕ > 0.1rad

Prikryl et al., 2015

Magnetospheric activity

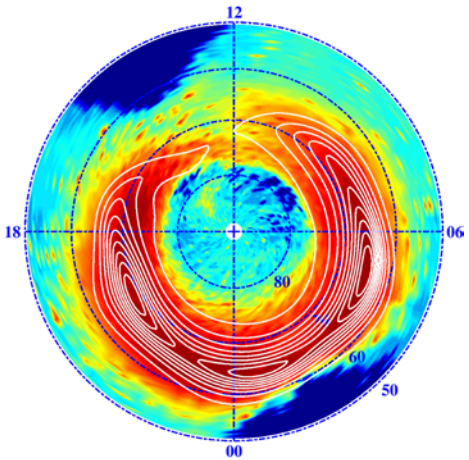
- Impact in both hemisphere
- Collocated with auroral oval
- Enhanced in specific regions
  - Cusp
  - TOI
    - Tongue of ionization
  - SAPs
    - Subauroral polarization streams
  - SEDs
    - Stroms enhanced densities
  - AURO
    - Auroral oval

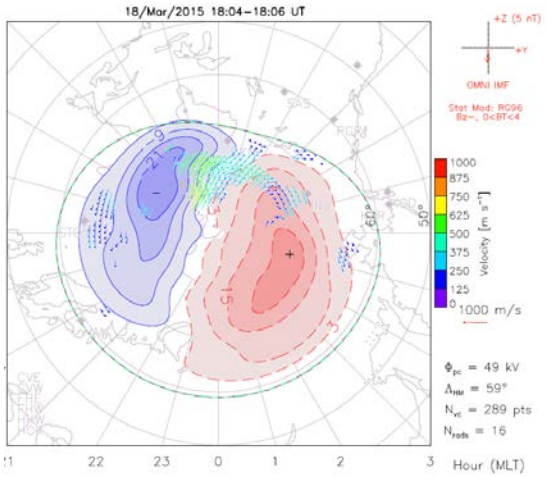


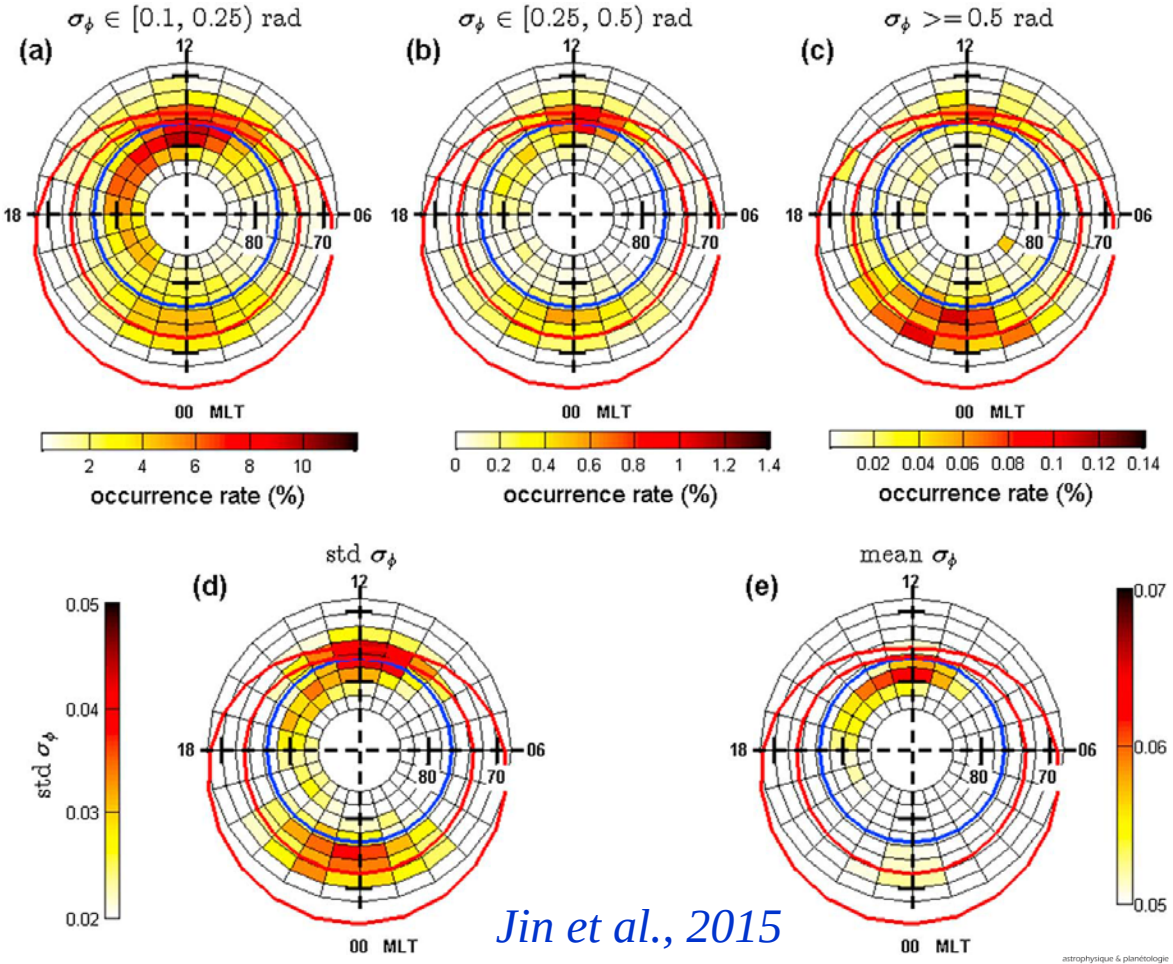
Prikryl et al., 2015

Auroral oval

- Scintillation occurrence level
  - Mainly noon and midnight sectors







Jin et al., 2015

Conclusion

- Highly dynamical system
  - Strong couplings
    - Electrodynamics
    - Chemistry
    - Precipitation
- Scintillations
  - Plasma instabilities
    - Magnetic field
    - electrodynamics
  - Ionospheric irregularities
    - Convection
    - plasma transport over large distances
  - Precipitation
    - Cusp
    - Density enhancement
- Strong modelling effort
  - Better understanding of couplings intrication
  - Provides global conditions for scintillations
  - Ability to simulate some irregularities
- Efforts to combine scintillation measurement and magnetospheric activity
- Extension towards equatorial region
  - Same medium
  - Different magnetic and electrodynamics configuration
  - Other instabilites