IONO-HF: High frequencies wave propagation in Earth ionosphere

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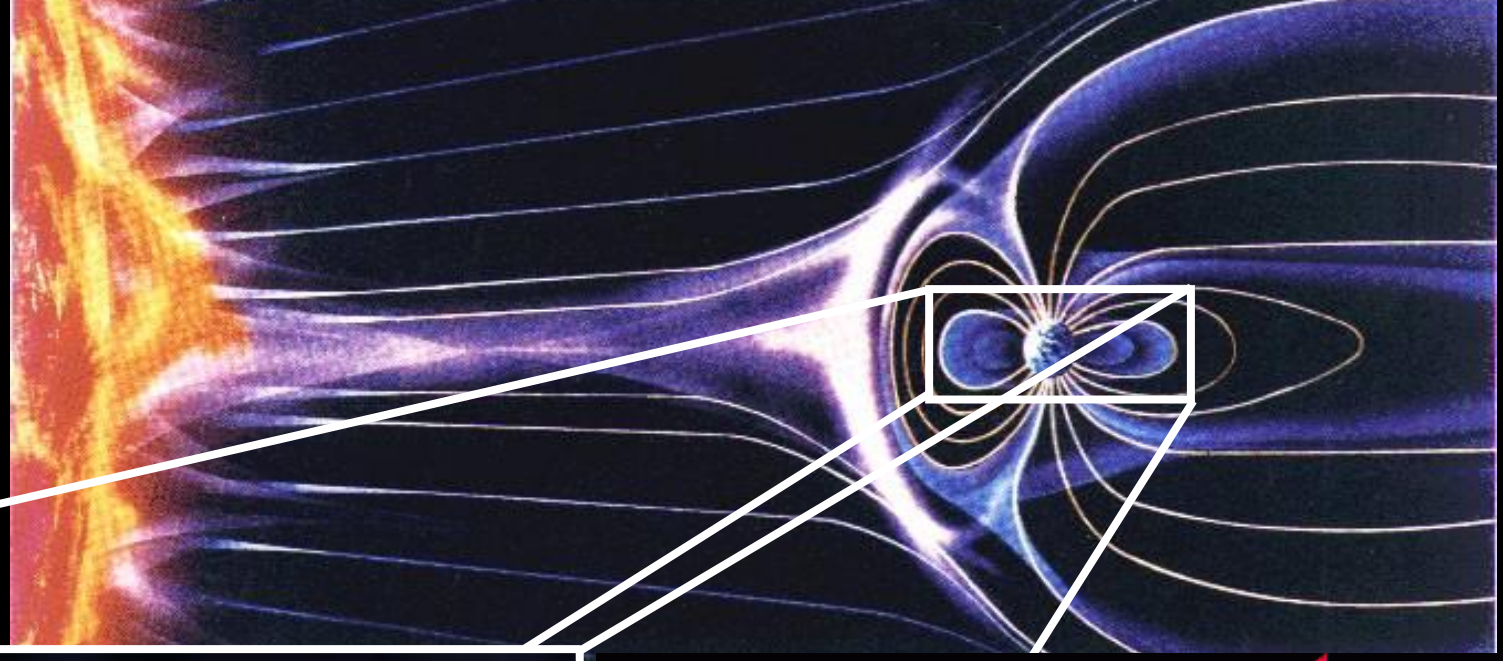
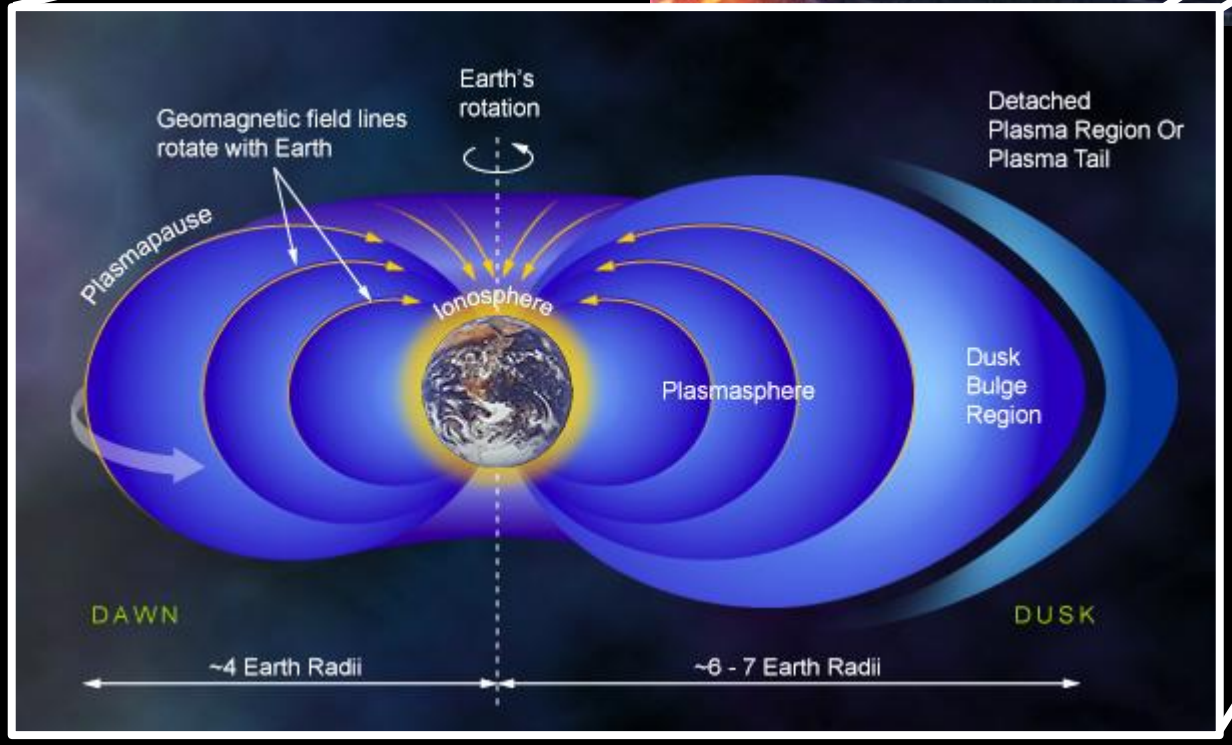
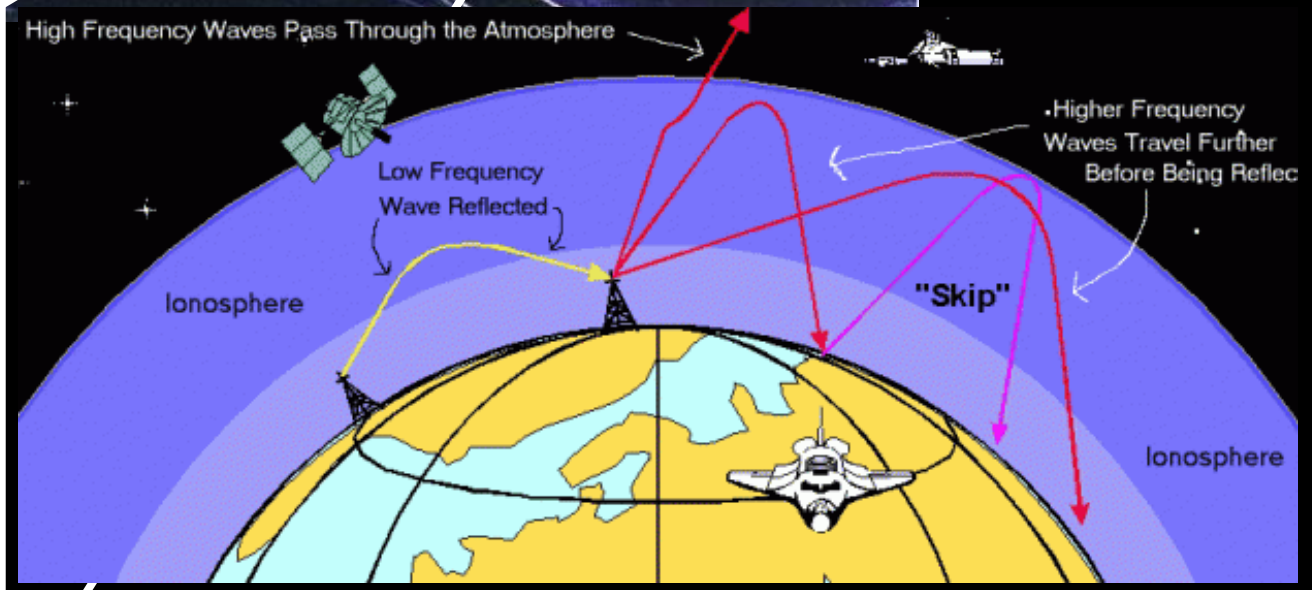
Outline

1. Motivation
2. Instrumentation and Ray Tracing tool
3. Application
4. Summary

Introduction:







Medium characterization, using HF wave propagation

Motivation

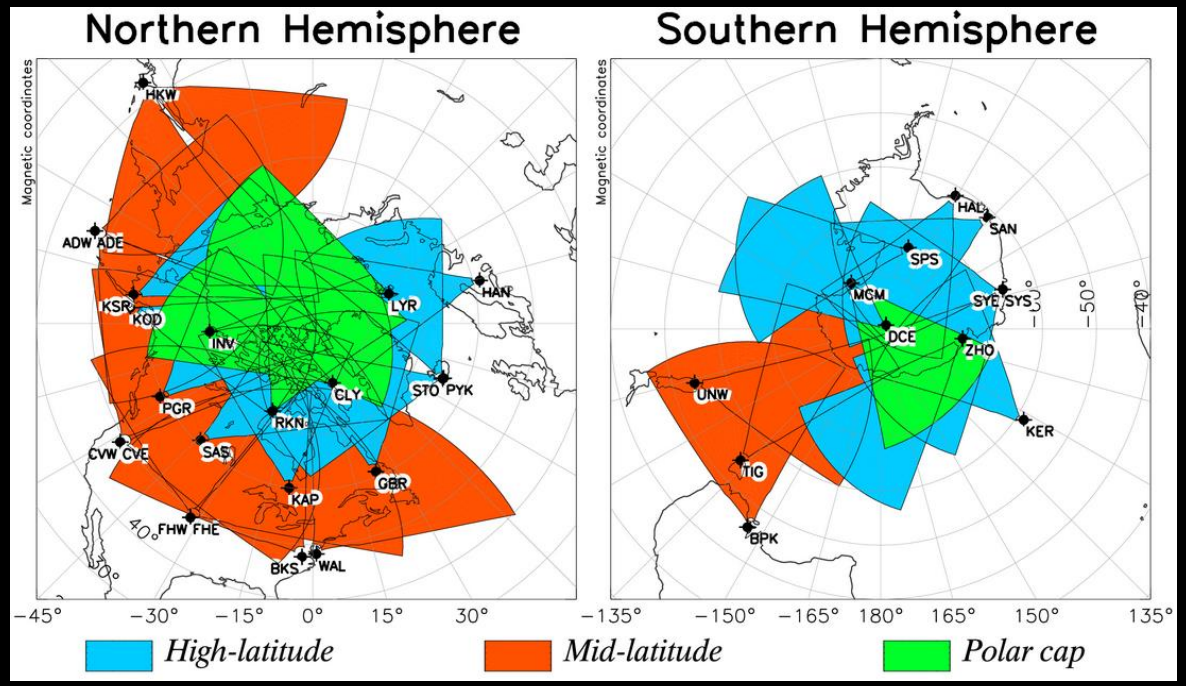
Objectives :

- Ray tracing tool Development
  - HF (~MHz) and VHF (~GHz) propagation
  - Ray bending estimation – Ionosphere Interaction
  - Propagation delay estimation
- Observed Data Assimilation (SuperDARN / GNSS)
  - Constraint the numerical model
- Fast plasmasphere-ionosphere numerical model
  - Based on physical processes
  - Calculating electron density profile
  - Operational Model

Instrumentation

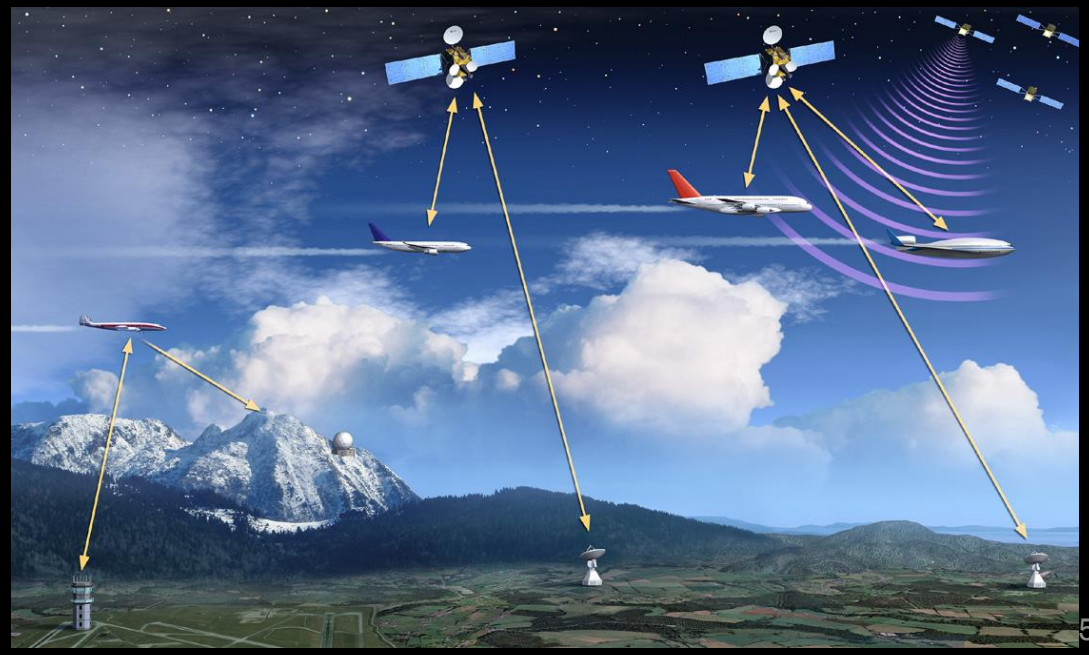
HF (~MHz)

- SuperDARN (Dual Auroral Radar Network)
- 30 HF radars
- Monitors the ionosphere
  - Magnetic convection speed
  - Perspective : 3D e^- density map



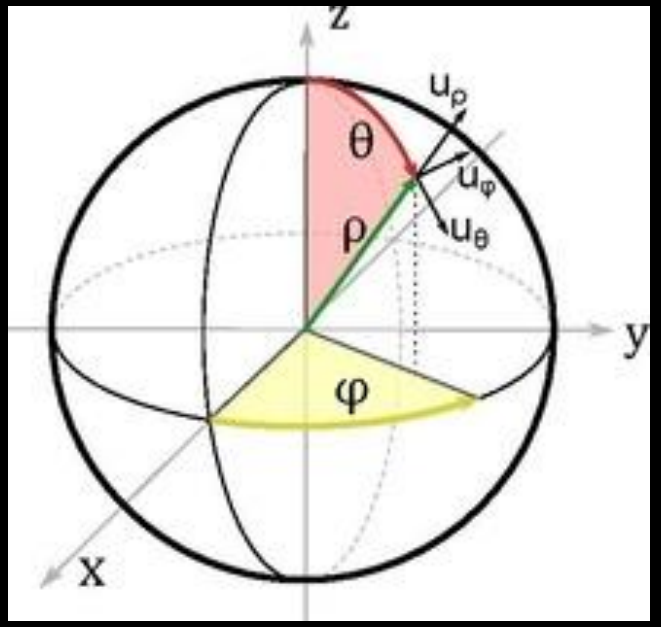
VHF (~GHz)

- GNSS (Global Navigation Satellite System)
  - GPS (United States)
  - Galileo (European Union)
- Space-Ground propagation
- Monitoring the Total Electron Content (TEC)



Ray tracing Tool

- **Aim:**
  - Calculating HF wave propagation path in a refractive medium
  - Ray bending estimation
- **Algorithm:**
  - Geocentric problem



Entries:
$(r, \varphi, \theta, \alpha, \beta)_i$

→ Runge-Kutta

Fermat principle →

Outputs:
$(r, \varphi, \theta, \alpha, \beta, t, S)_{i+1}$

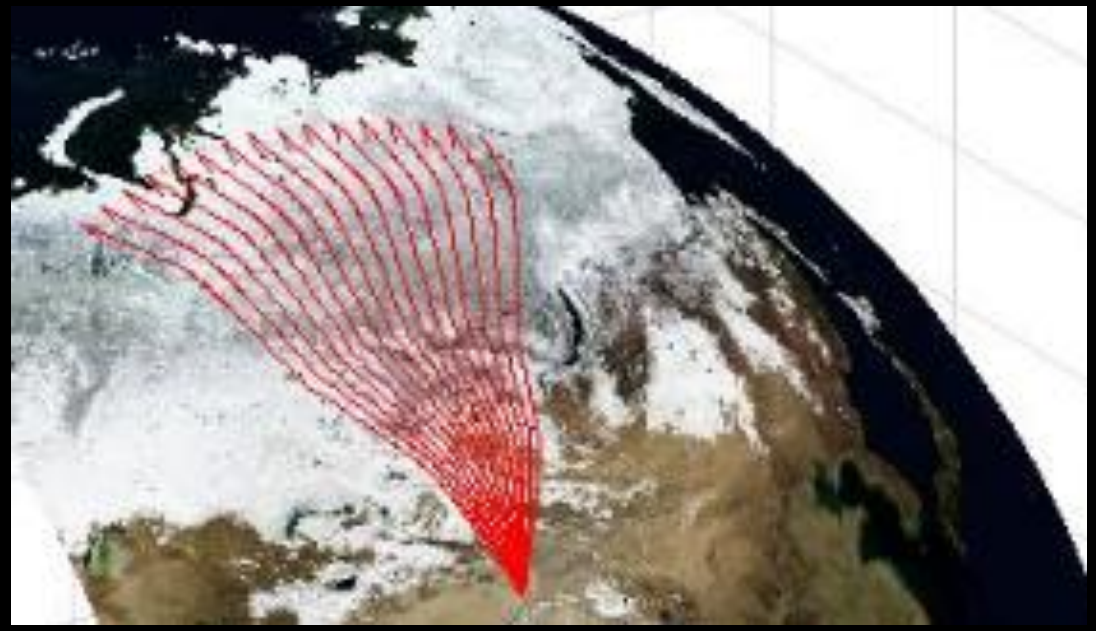
$$\frac{di}{ds} = \frac{\|\vec{\nabla} n\|_{\vec{v}}}{n} \cdot \vec{e}_s^{\perp} = -\frac{\|\vec{\nabla} n\|_{\vec{\tau}}}{n} \cdot \vec{e}_s$$

Where $n = \sqrt{1 - \frac{\omega_p^2}{\omega_f^2}}$, with w_p and ω_f respectively the plasma and radio wave pulsations.

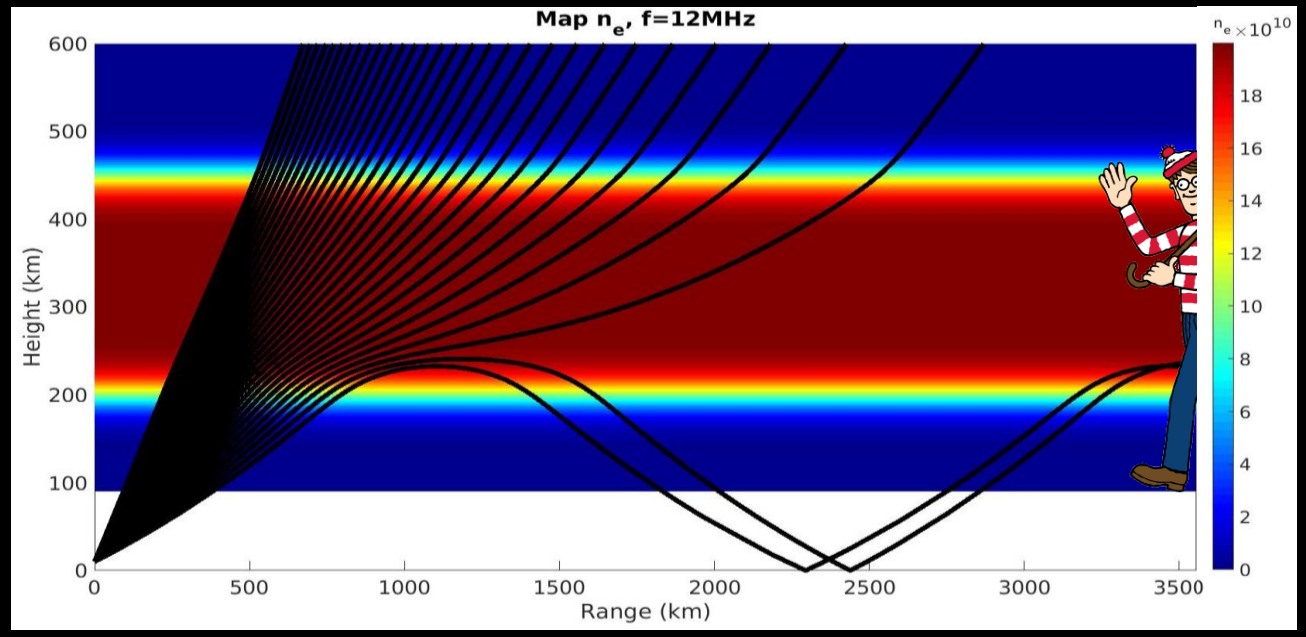
Ray tracing Tool

First Results:

SuperDARN-like Field of View
Lat=50°, Long=50°, f=9MHz, ne=$2e11$ m^{-3}, $\alpha = 0°, \beta = 10°$

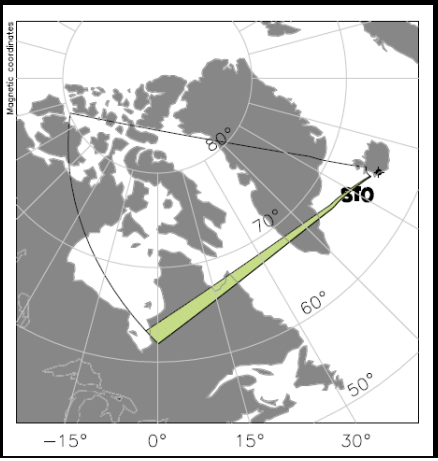


Ray paths in a numerical ionosphere
f=12 MHz, ne=$2e11$ m^{-3}, $\alpha = 0°, \beta \in [10; 40]°$



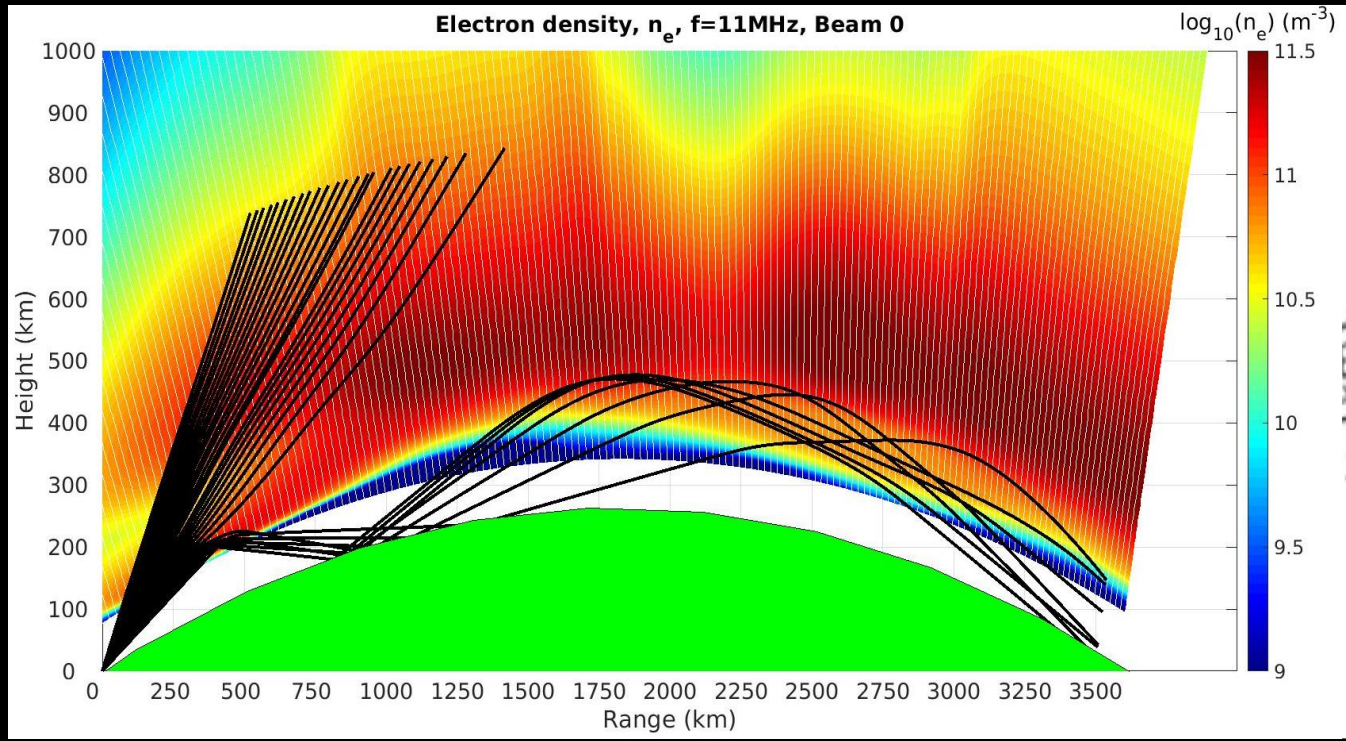
Application

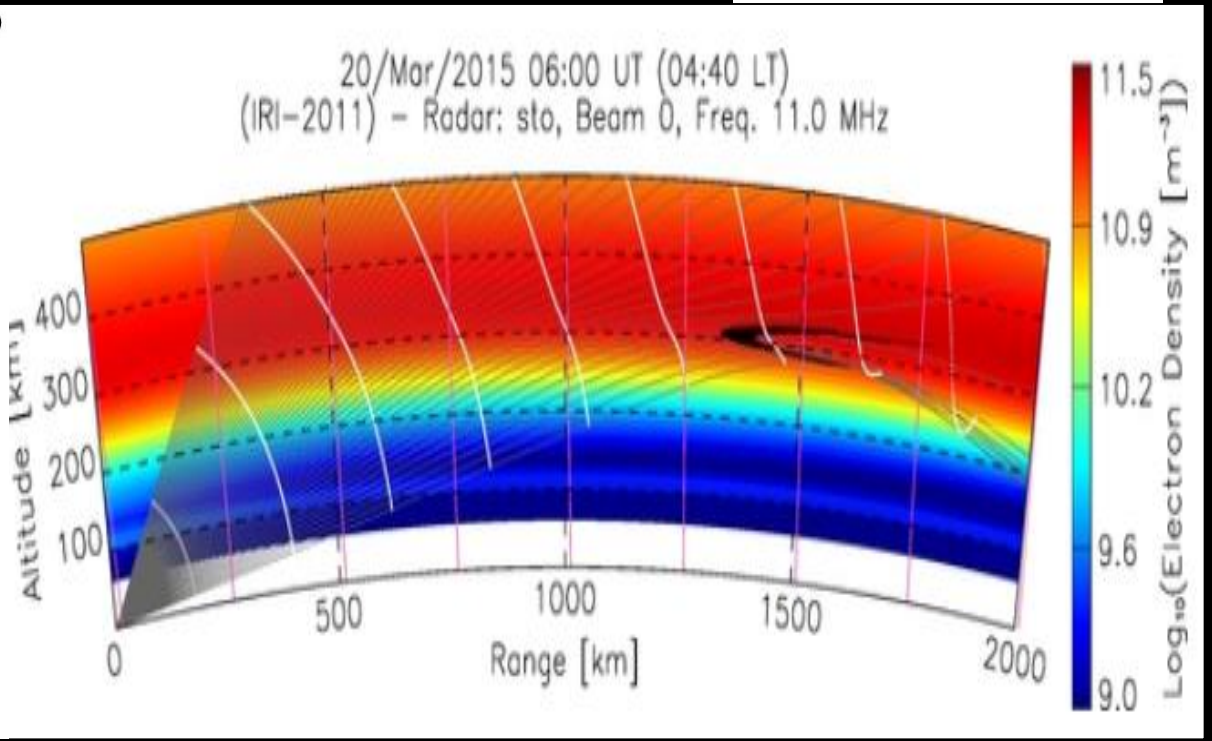
Ray path: Beam 0



Simulated ionosphere

Empirical ionosphere model





Stokkseyri, Island, Beam 0, f=11 MHz, elevation $\beta \in [10°; 40°]$

Summary

Acquired:

- HF wave propagation in a refractive medium
- Backscatter localization
- **Ray tracing tool validation (for HF propagation)**

Later work:

- Error estimation
  - Ionospheric backscatter localization (Range, Height)
  - Convection speed measurement
  - Propagation time
- VHF propagation integration (scintillation)
- Development of a new simple ionosphere model (based on IPIM model)
  - Keeping all the most important features of the original model (chemistry, transport, electrodynamics)
  - Operational model with faster numerical resolution
  - Constrained by observational data (SuperDARN) through ray tracing tool

Thank you !

Any questions ???