Ground-based Magnetoseismology Observations for the Next Decade

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The Future of Ground-Based Research for Magnetospheric and ITM Physics

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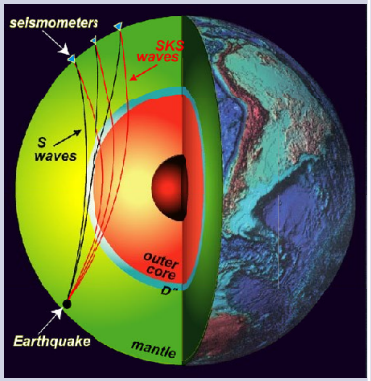
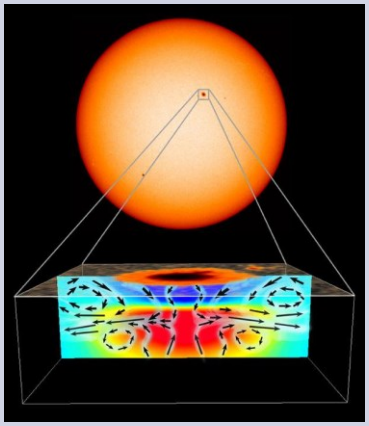
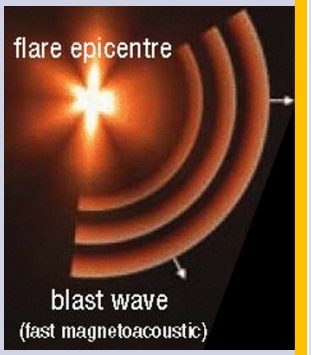
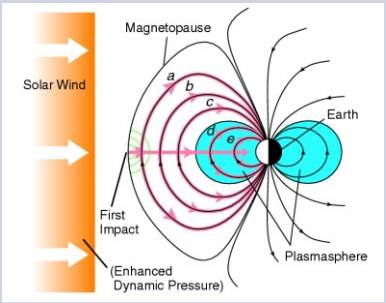
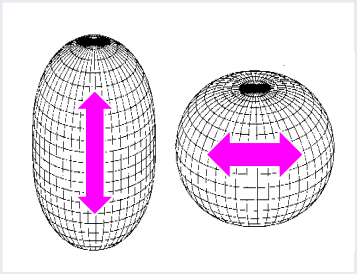
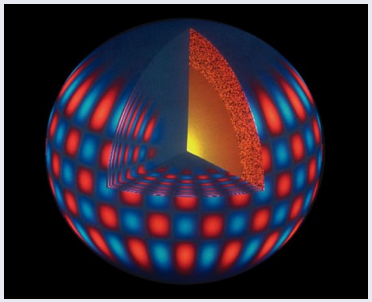
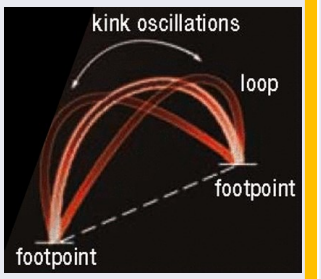
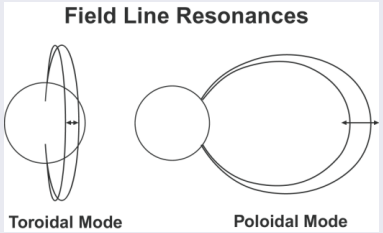
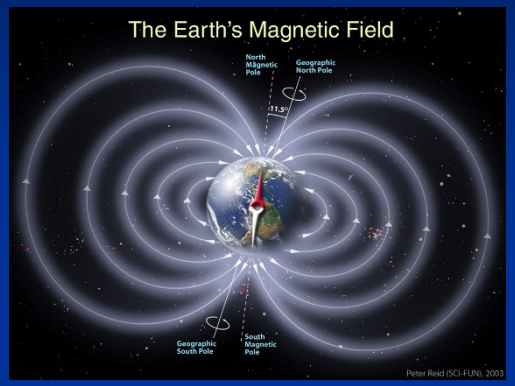
ISSI Magnetoseismology Team 2017-2018

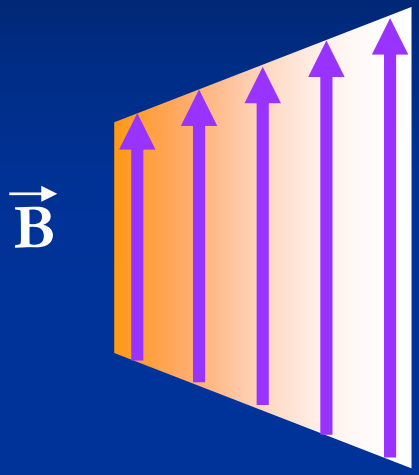
Two Seismic Methods in Four Disciplines

	Seismology	*Helio-/Astero-Seismology*	*Coronal Seismology*	*Magneto-seismology*
Travel-time Method				
Normal-mode Method				

Normal-mode Magneto-seismology

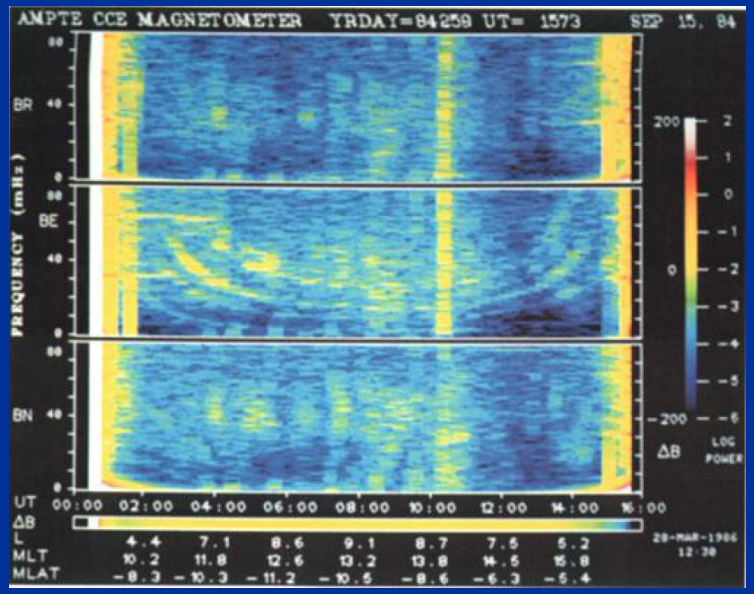


Satellite observations of resonant frequencies



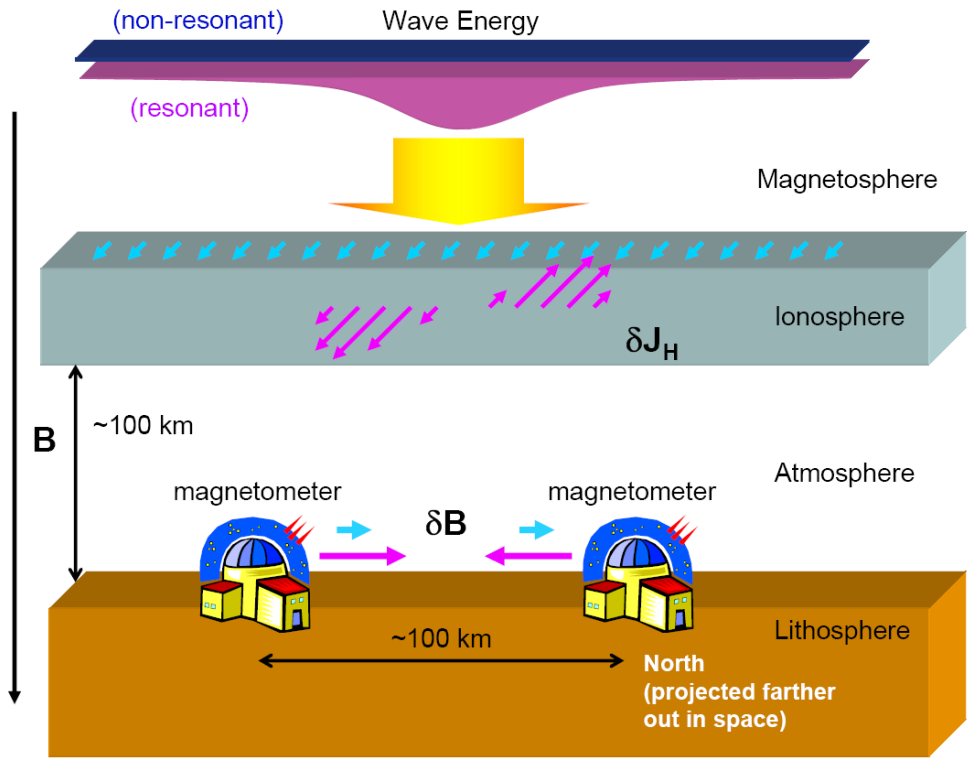
Resonant frequency:

$$f = \frac{V_A}{L} \propto \frac{B}{L\sqrt{\rho_m}}$$



- ***B*: magnetic field (well modeled)**
- ***L*: length of field line (well modeled)**
- **ρ_m: plasma mass density (less known)**

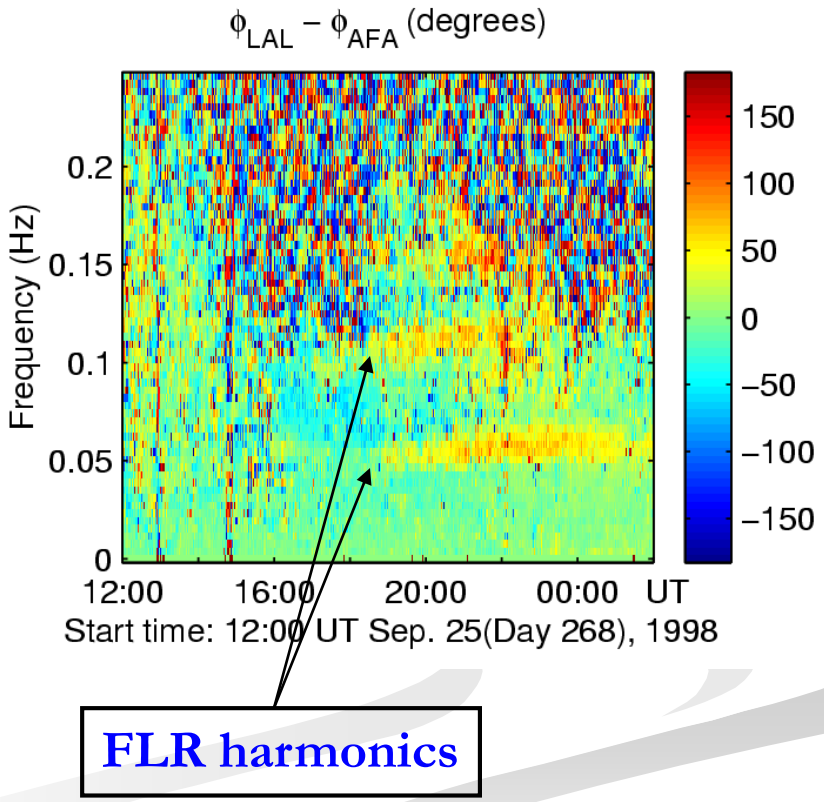
Detecting FLR frequencies from the Ground



distance bet'n stations ~ ionospheric height

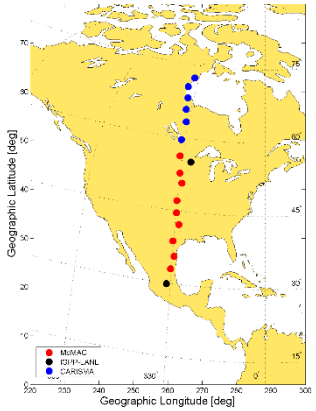
"The gradient technique"
(including "Cross-phase")

Phase-Difference Spectrogram
(Between two stations in N-S direction)



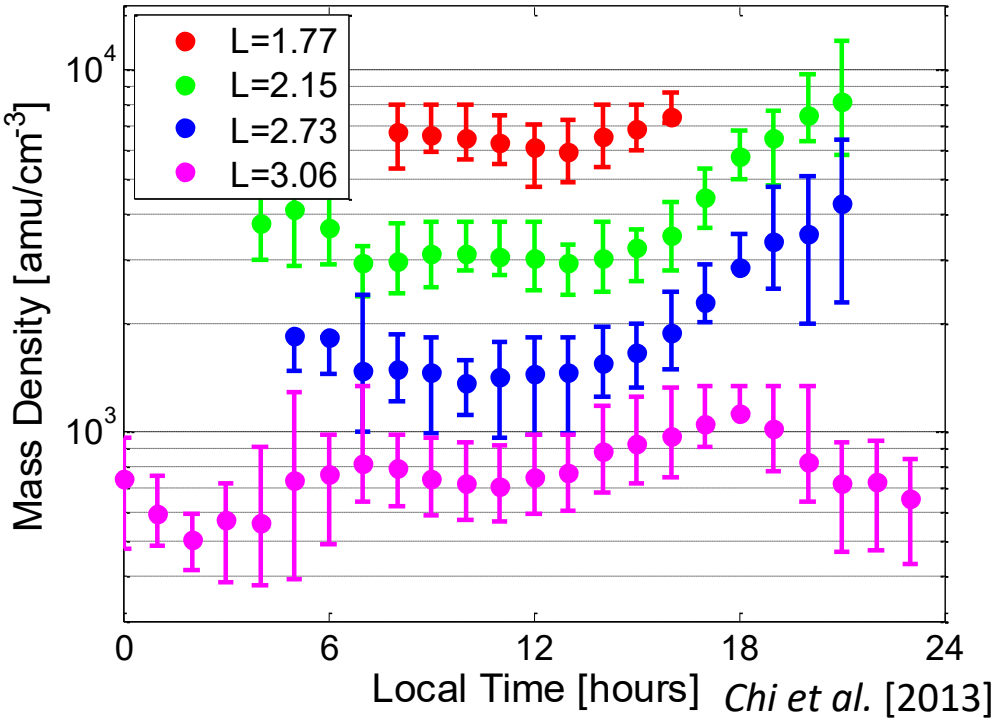
FLR harmonics

- The gradient technique can detect FLR frequencies for > 80% daytime hours



Thermospheric Effect on Plasmaspheric Density

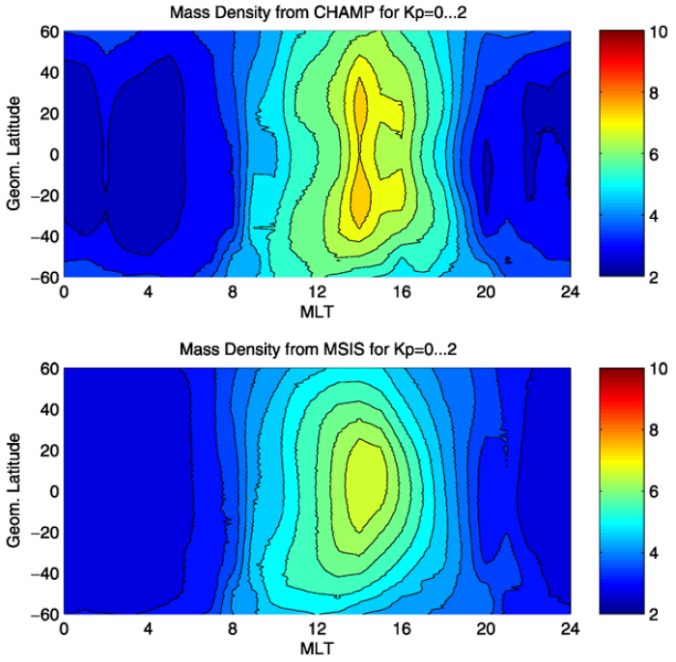
Plasmaspheric density estimated by normal-mode method

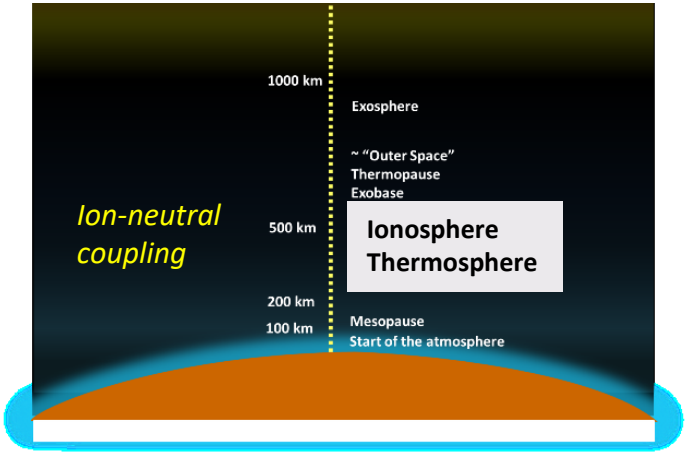


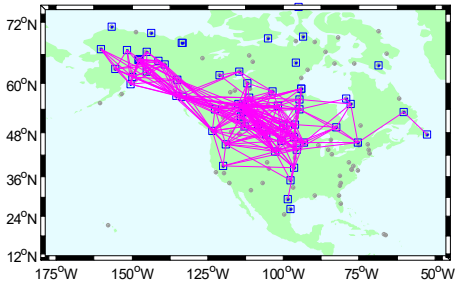
Chi et al. [2013]

- Plasmasphere: Density increases in afternoon/evening hours are not predicted by models.

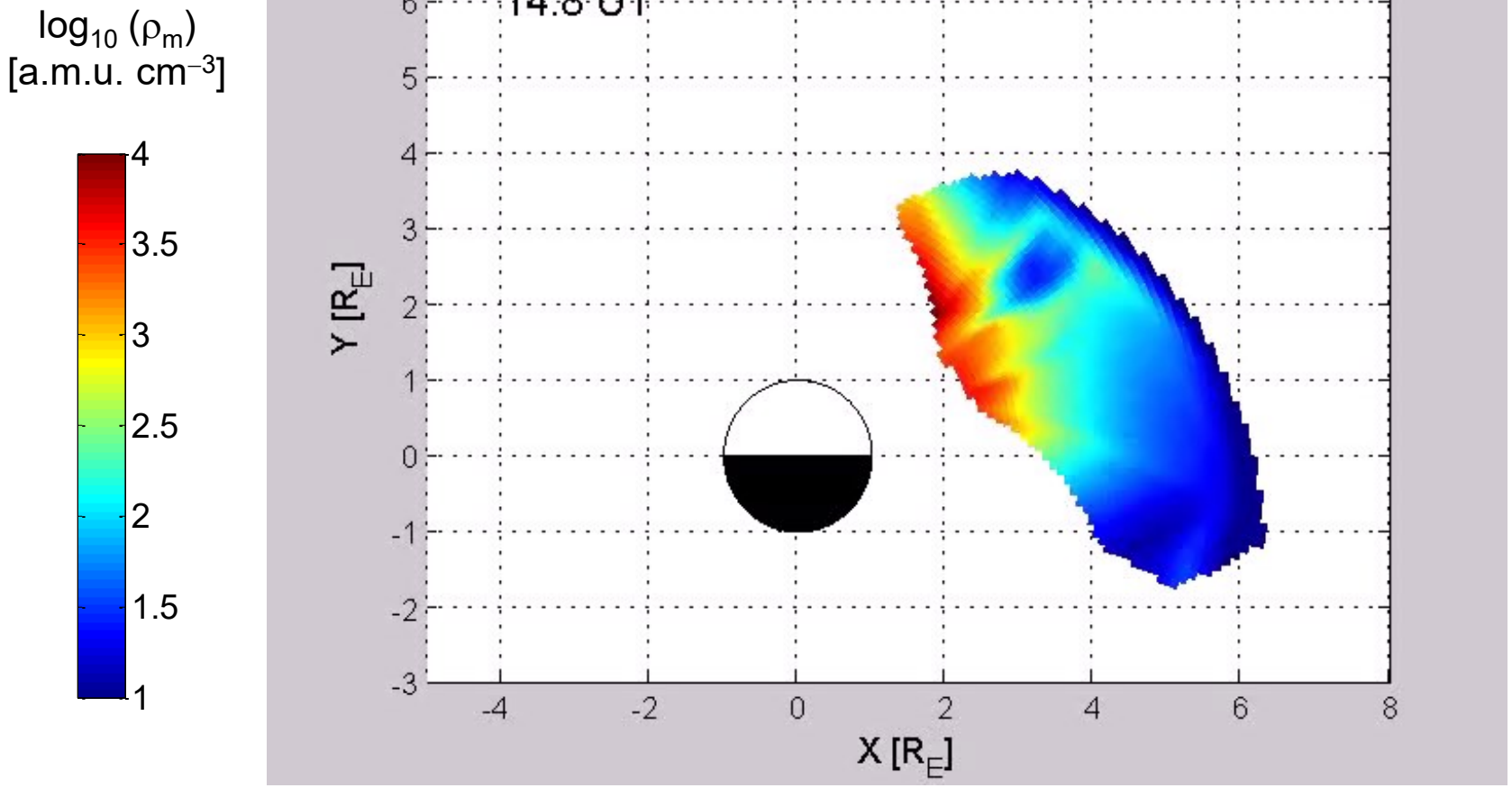
Thermosphere (neutral density)





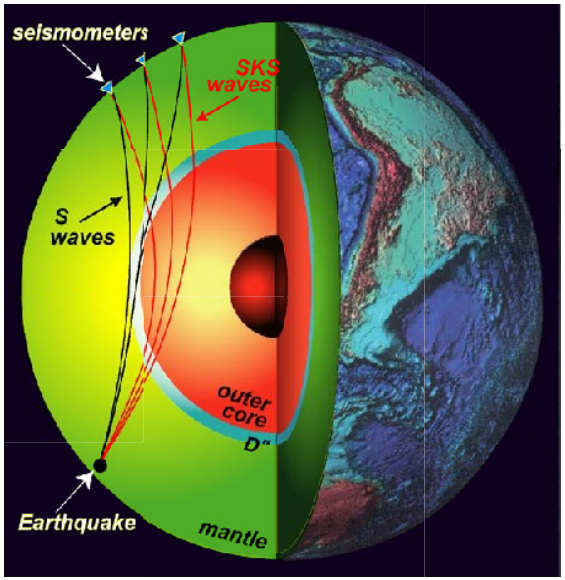


Monitoring Plasmaspheric Density by Ground-based Magnetometers (An example of



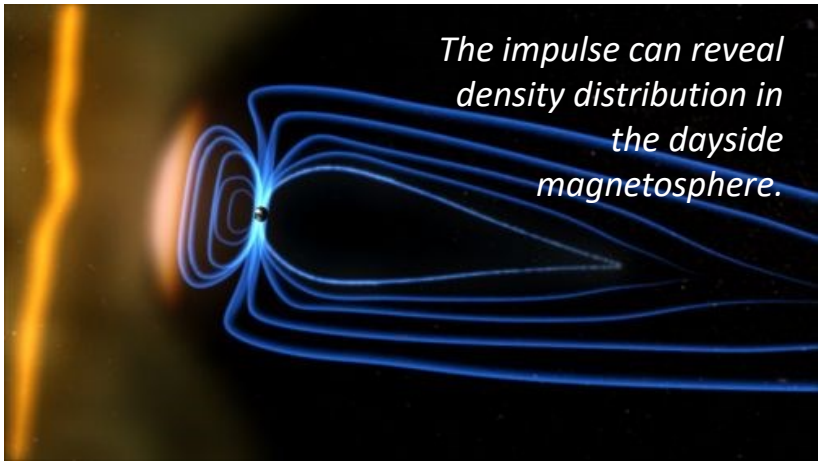
Travel-time Magneto-seismology

Earthquakes and seismic waves

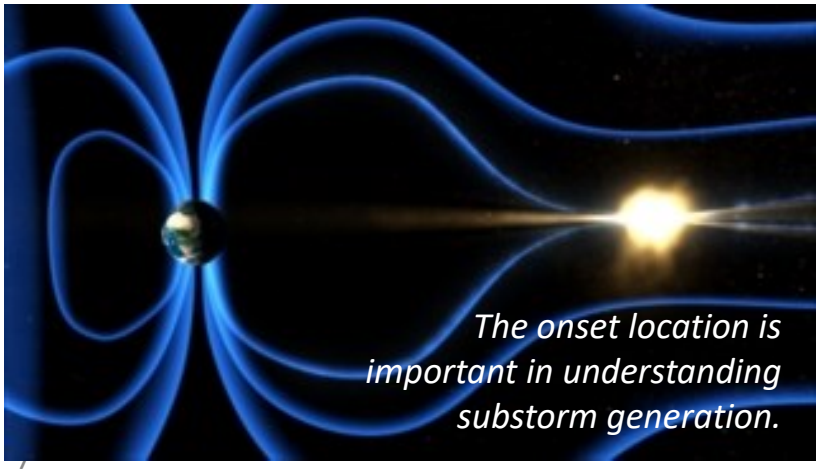


1. *Interior structure of Earth*
2. *Center of Earthquake*

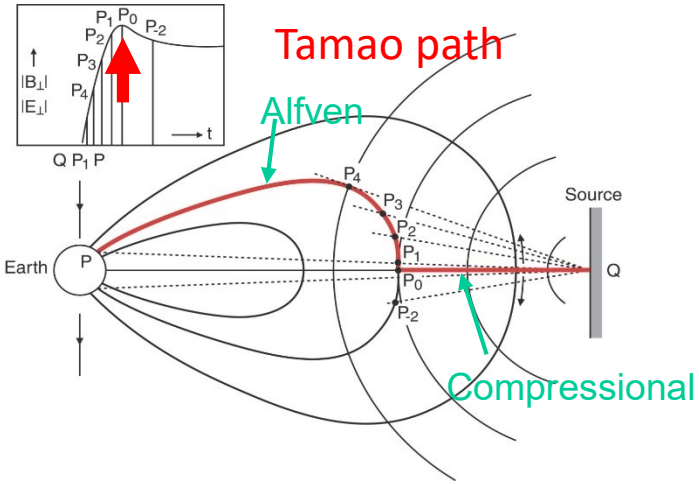
Sudden impulses



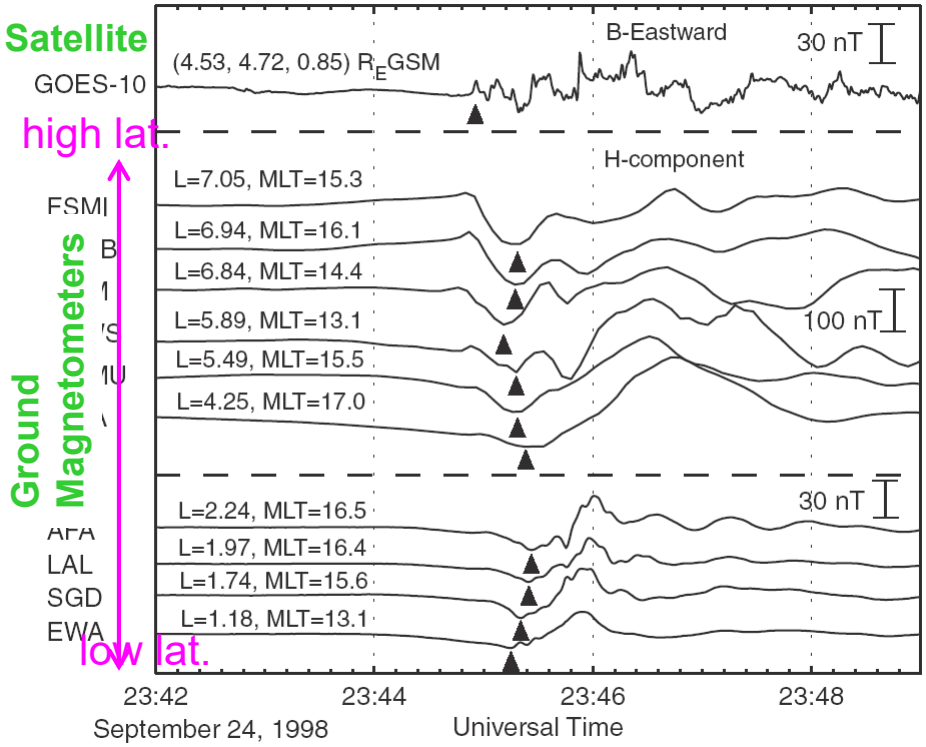
Substorm onsets



Travel-time Analysis for Sudden Impulses (Dayside)

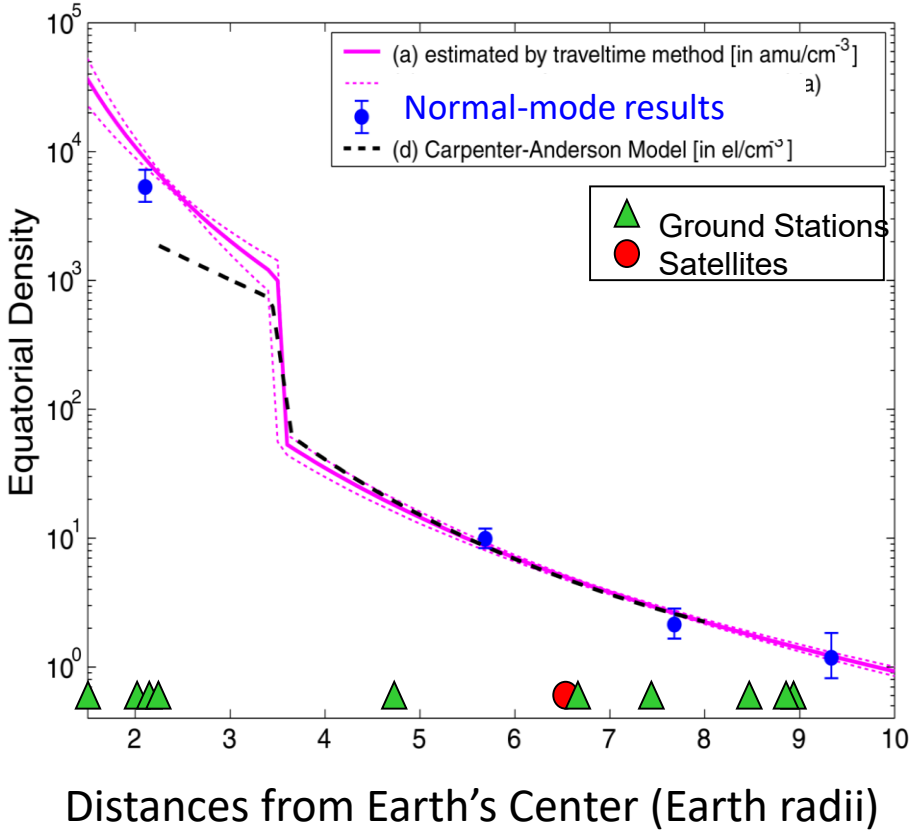


Observations



▲ Arrival Time

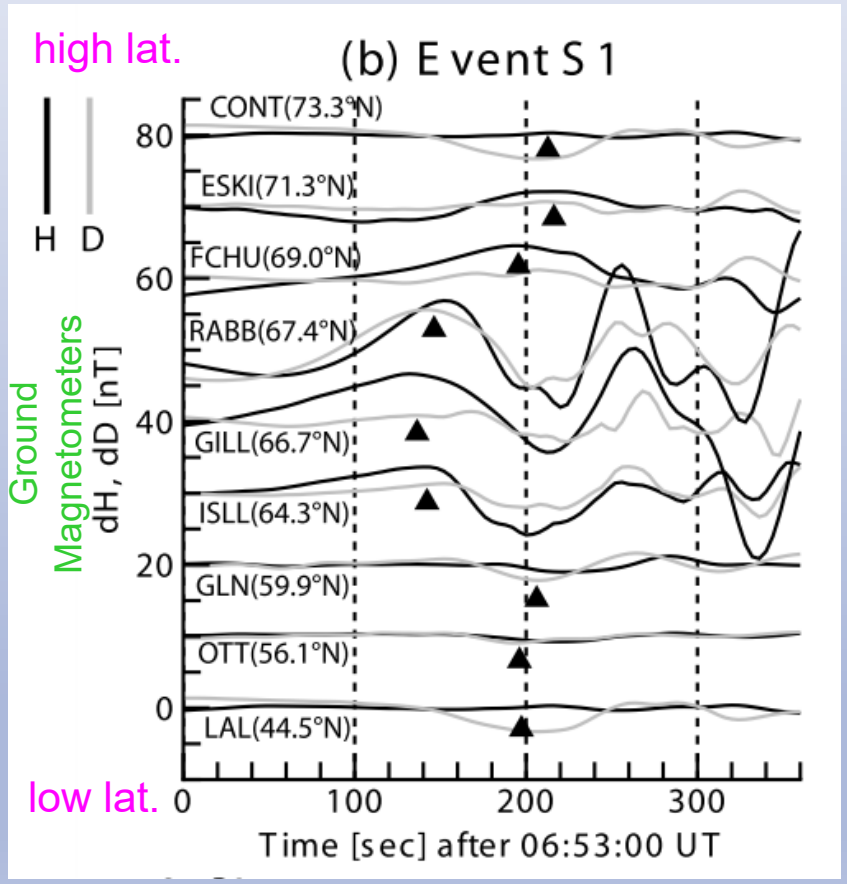
Inversion Results



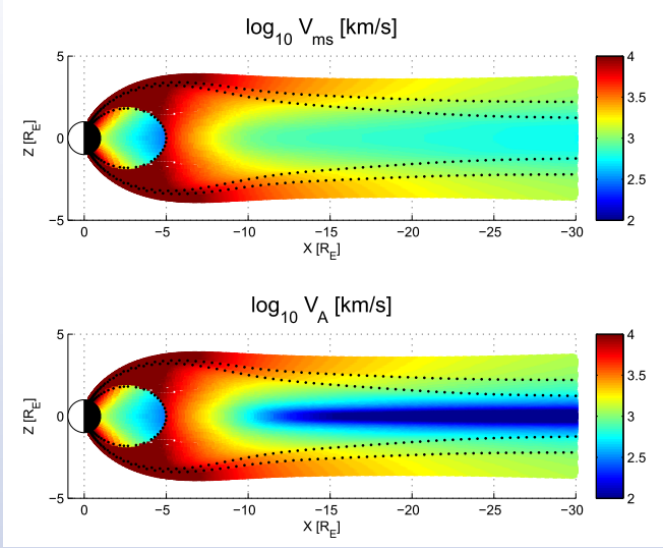
Distances from Earth's Center (Earth radii)

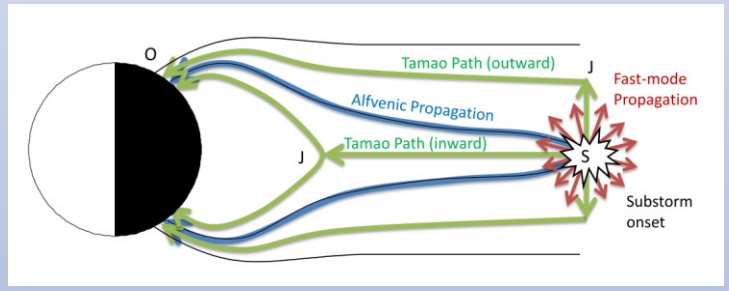
Travel-time Analysis for Substorm Onsets (Nightside)

Observations



▲ **Arrival Time**



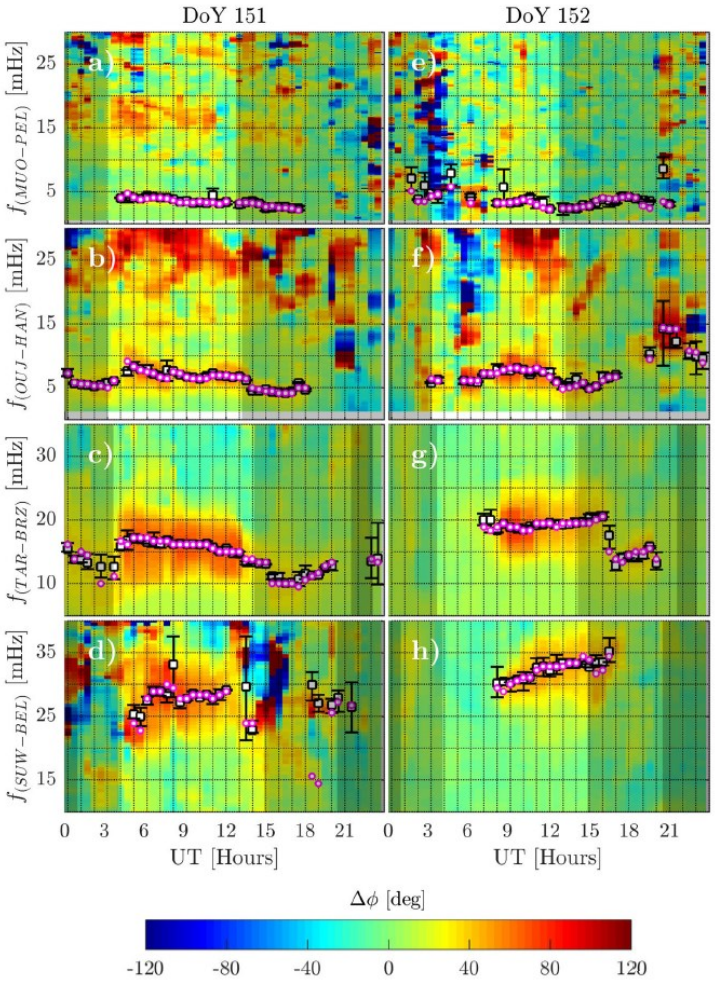


Inversion Results

- Locations of substorm onsets: 18-20 Earth radii in the tail direction
- Substorm onset starts in the magnetotail ~ 100 --200 sec before the first auroral brightening.

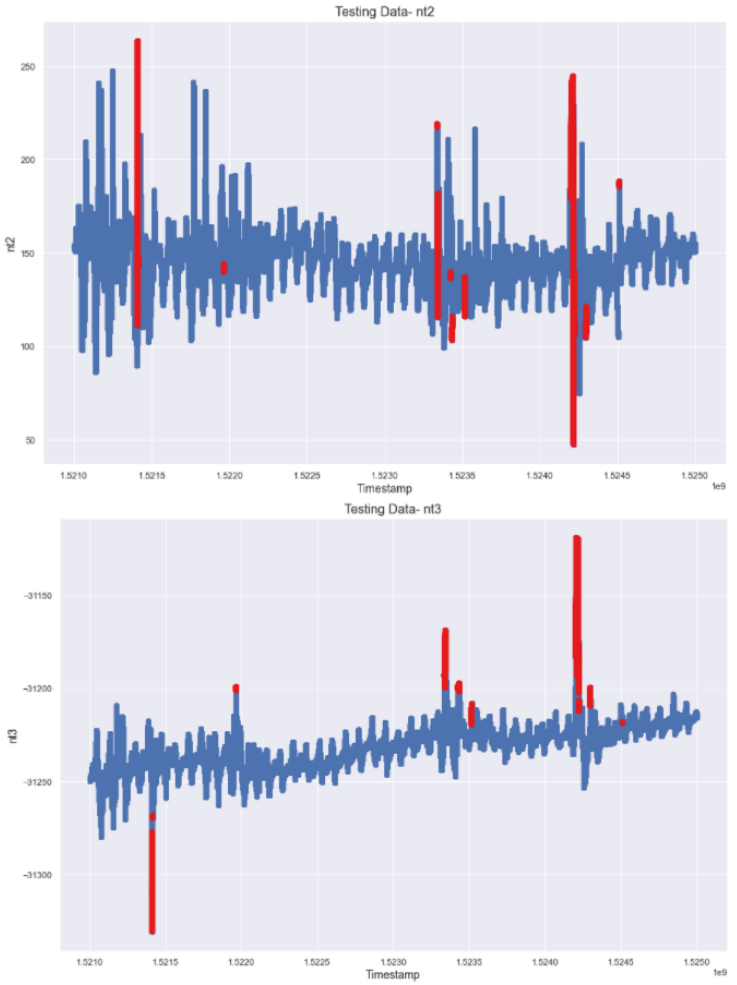
Machine Learning to Faciliate Big Data Analysis

Normal-mode magnetoseismology (FLR)



Foldes et al., JGR, 2021

Travel-time magnetoseismology



Zhao and Chi, AGU presentation, 2021

Summary

- Magnetoseismology has become a well-developed discipline for new ways to investigate the plasma structures and dynamics of the magnetosphere.
- The normal-mode (FLR) method requires a dense 2-D magnetometer network in the region where magnetospheric field lines are closed.
- The travel-time method needs data from the continuous operation of global magnetometer networks.
- The success in using machine learning methods is enabling many future opportunities.