



# Numerical Simulation of Ionospheric Response to Daytime MSTID

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LATMOS, St-Maur-des-Fossés, France

**DEMETER Workshop 2011**  
10-12 October 2011, Paris



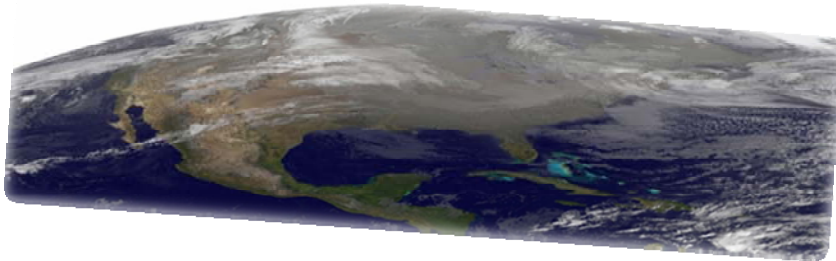


# Agenda

- Observation : DEMETER/GPS-TEC
- Simulation : SAMI2
- Comparison
- Conclusions

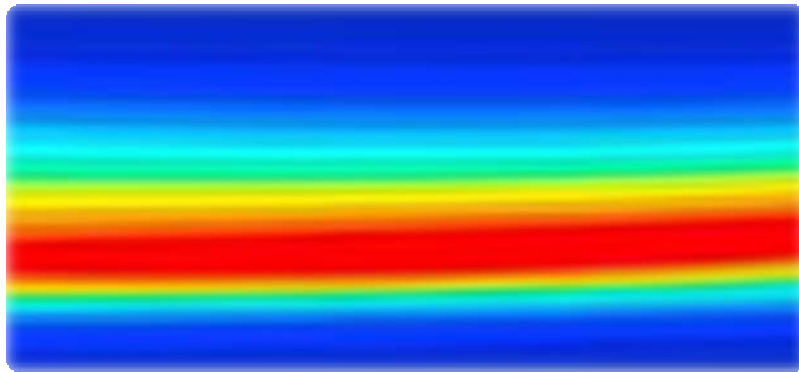


# Observation (DEMETER/GPS-TEC)

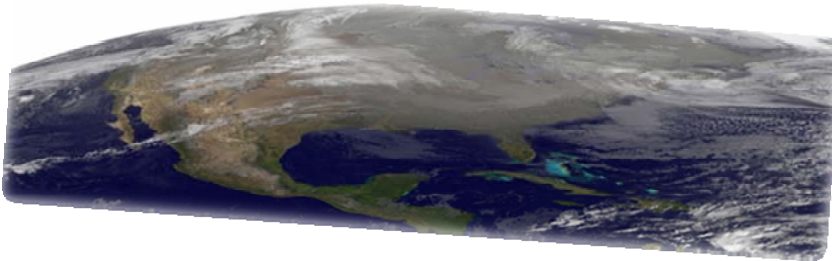




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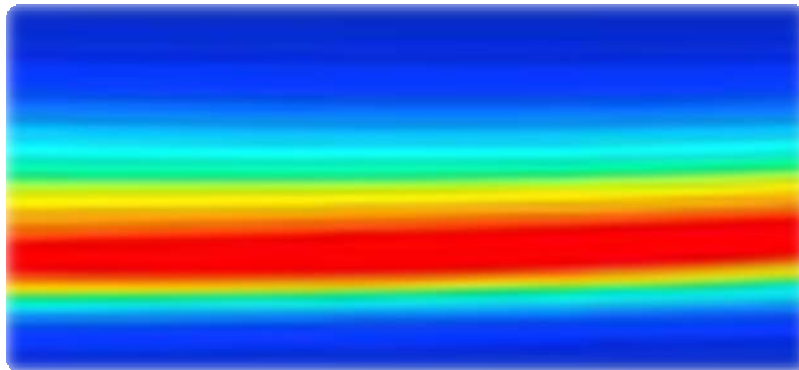


Ionospheric Plasma



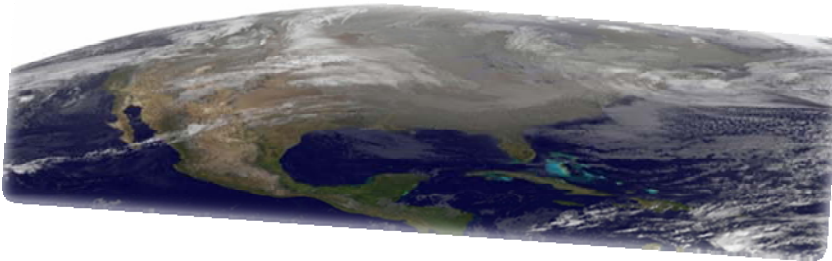


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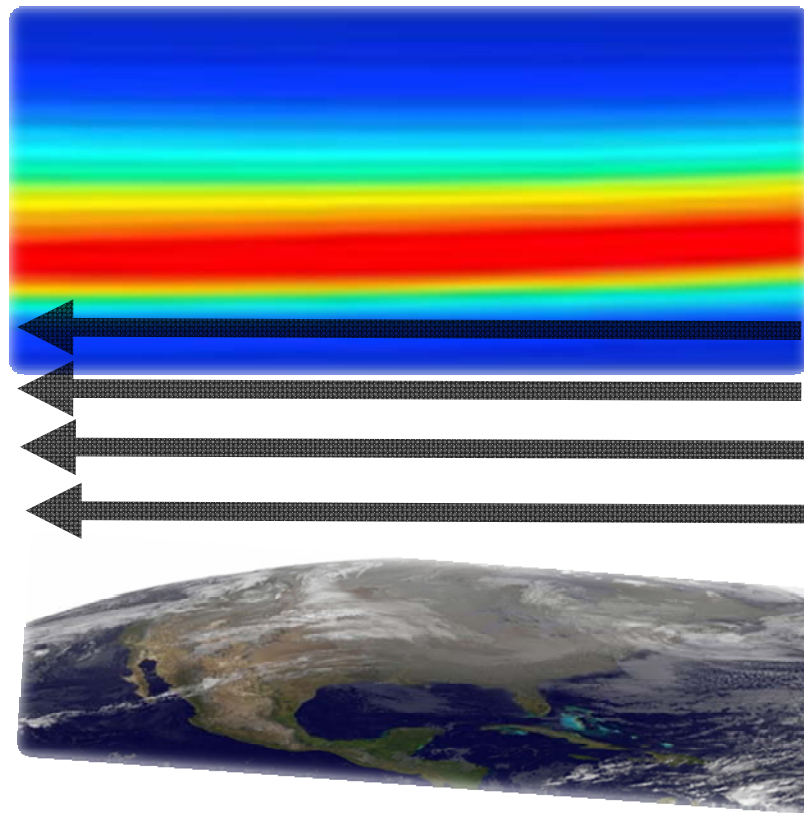
Ionospheric Plasma

F-peak at ~300km





# Observation (DEMETER/GPS-TEC)



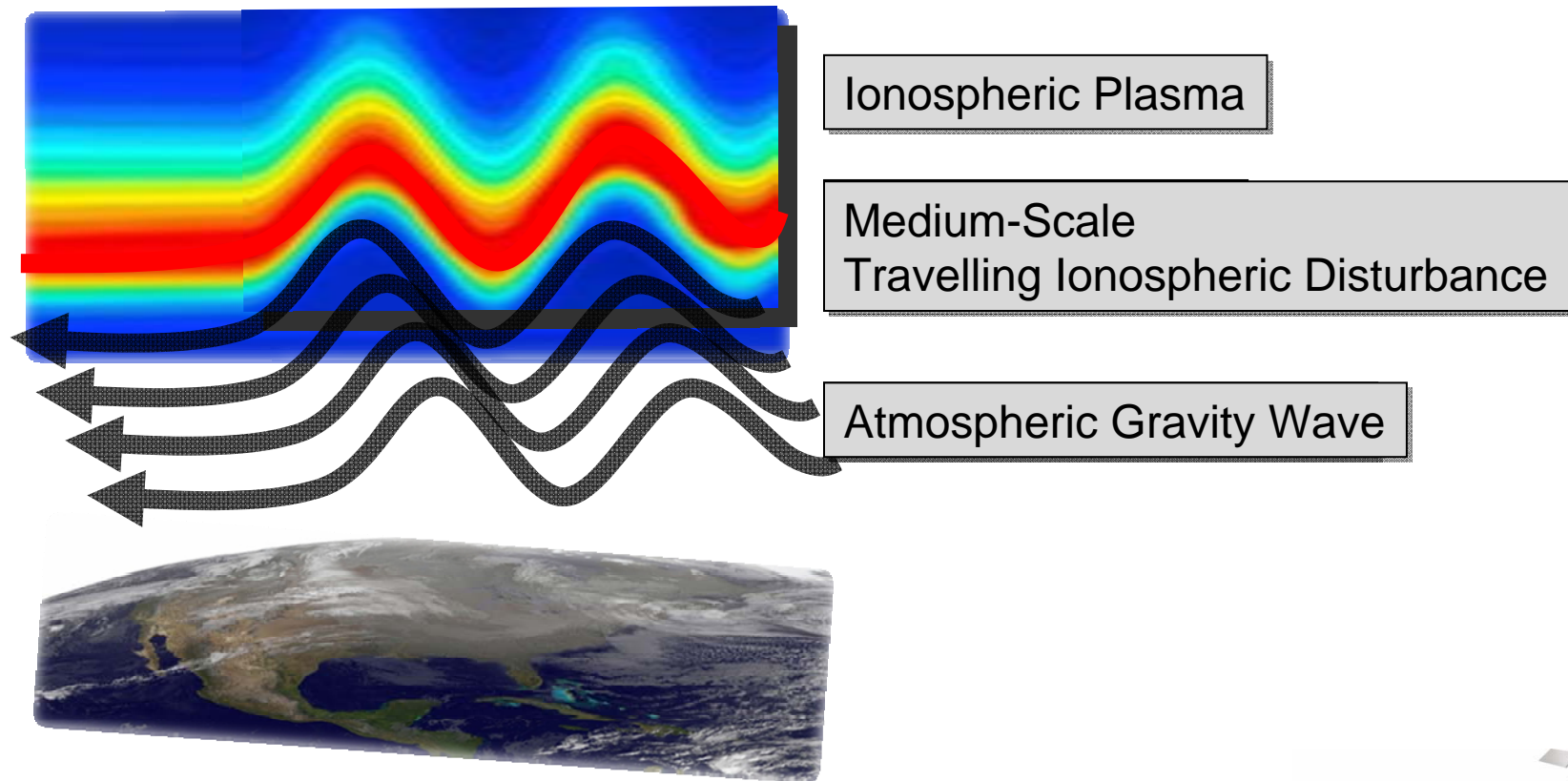
Ionospheric Plasma

F-peak at ~300km

Atmospheric Neutral Gas

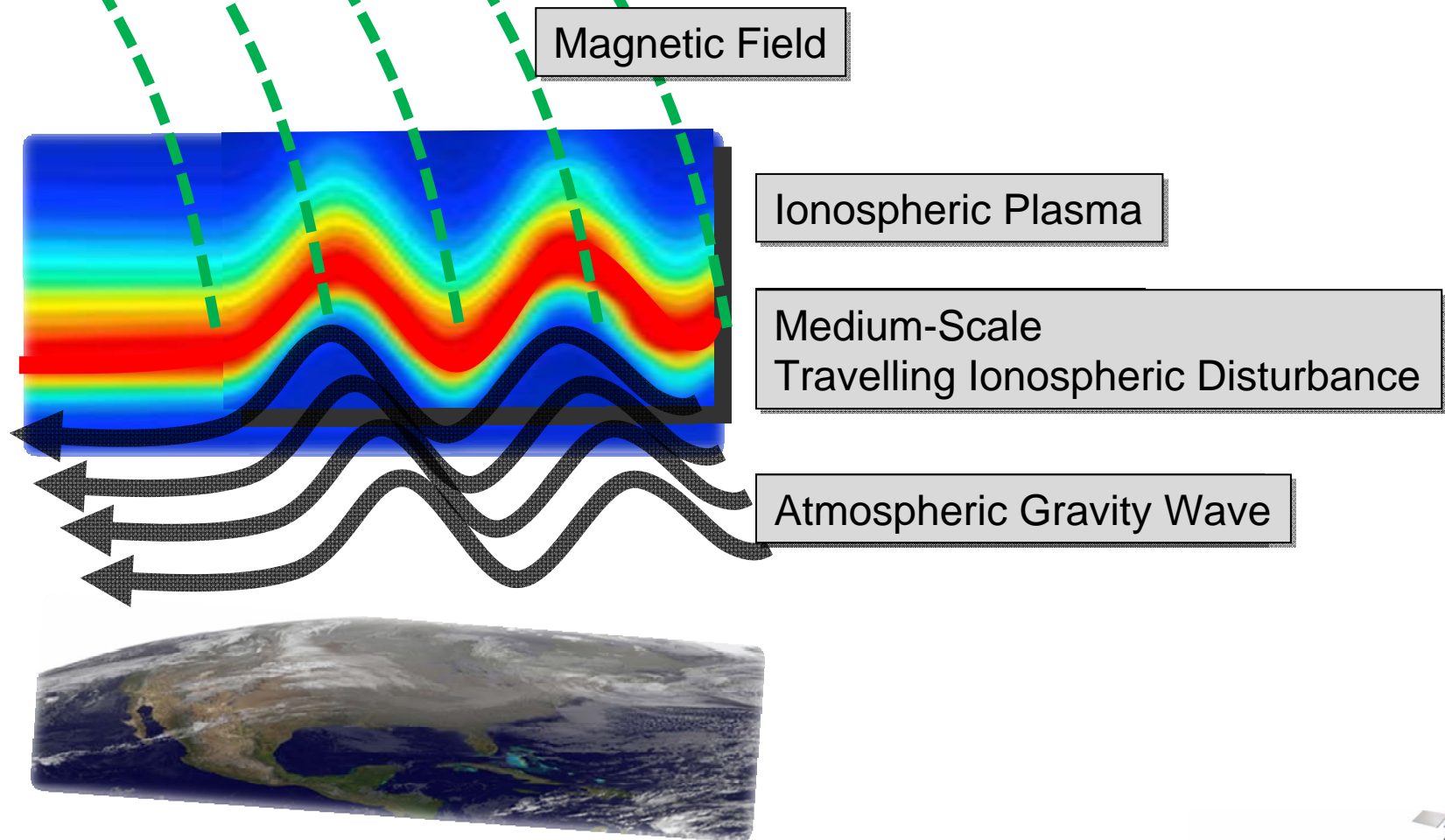


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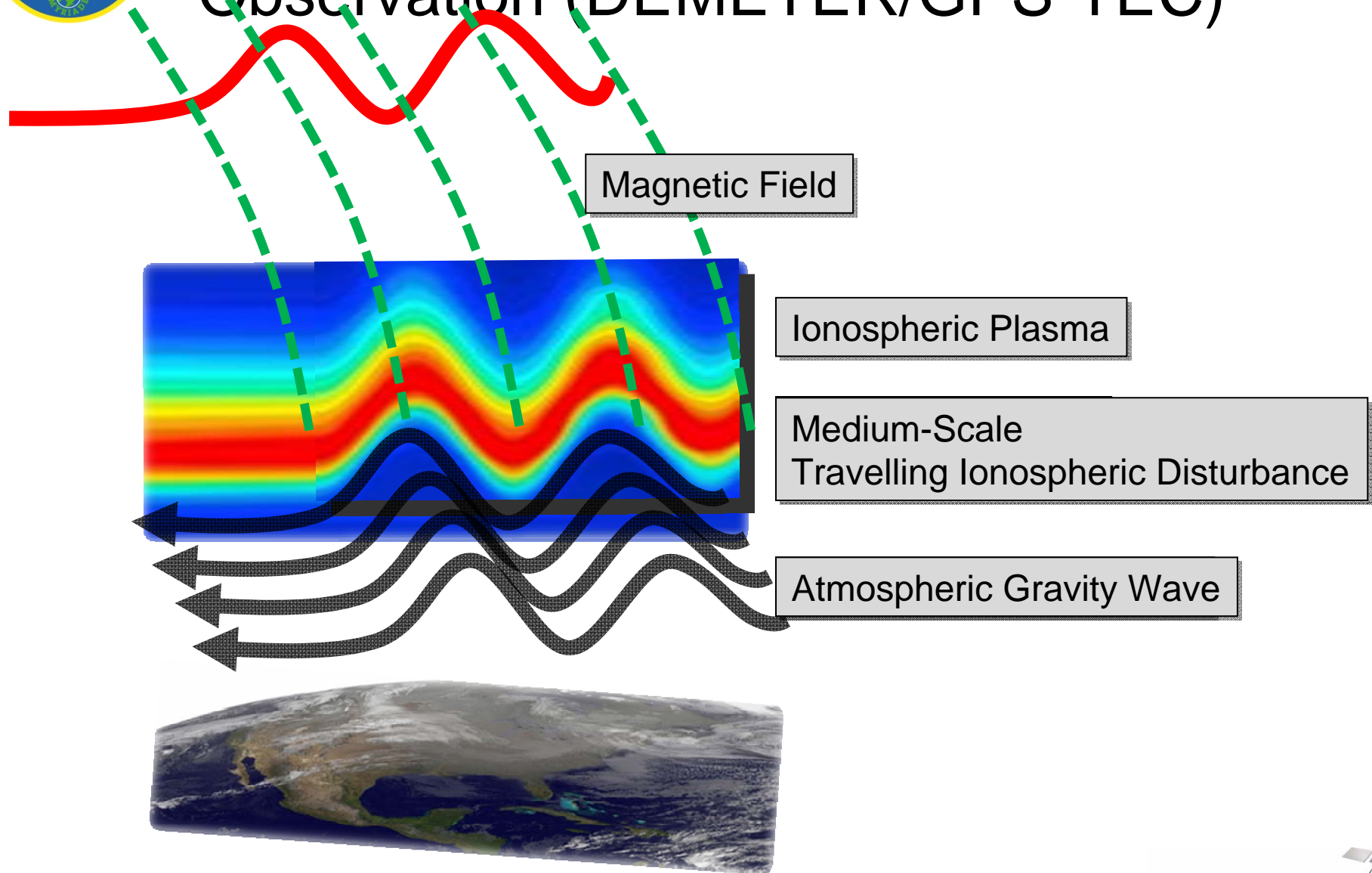


# Observation (DEMETER/GPS-TEC)



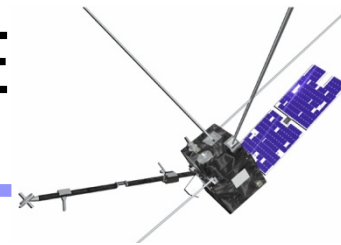


# Observation (DEMETER/GPS-TEC)





Observation (DEME



3-TEC)

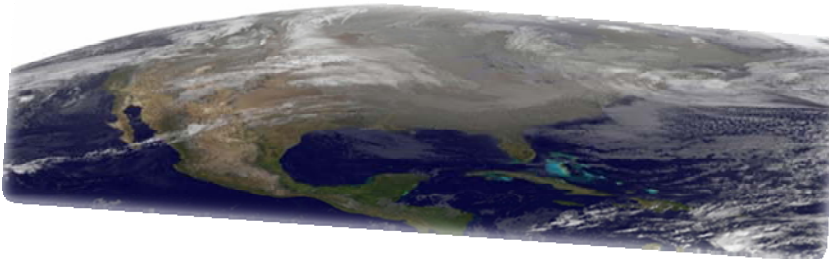
DEMETER

Magnetic Field

Ionospheric Plasma

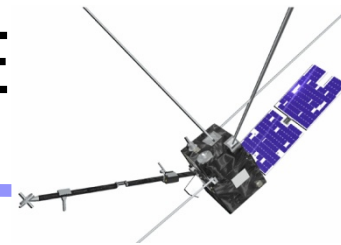
Medium-Scale  
Travelling Ionospheric Disturbance

Atmospheric Gravity Wave



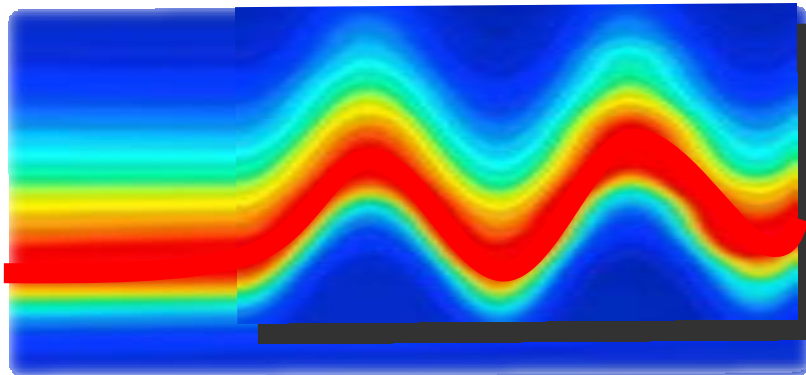


Observation (DEME



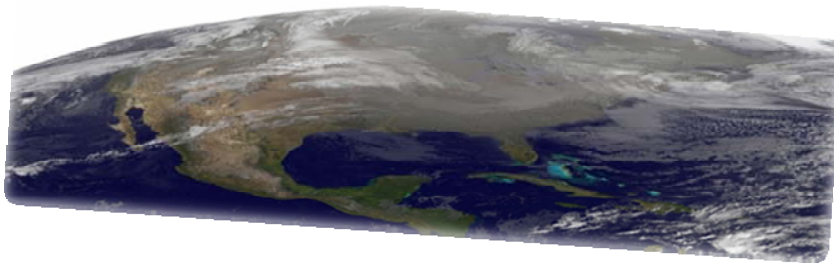
S-TEC)

DEMETER



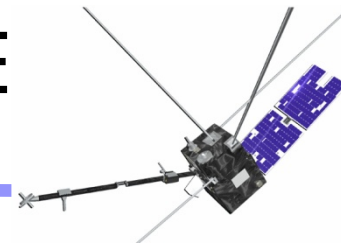
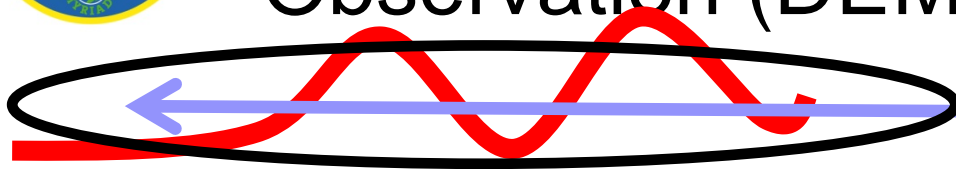
Ionospheric Plasma

Medium-Scale  
Travelling Ionospheric Disturbance



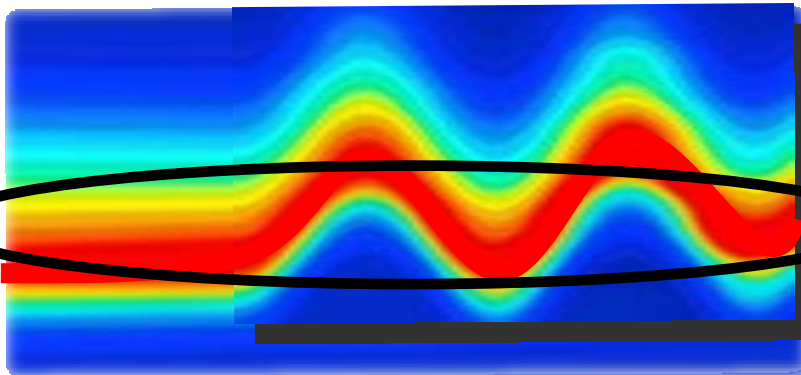


Observation (DEME



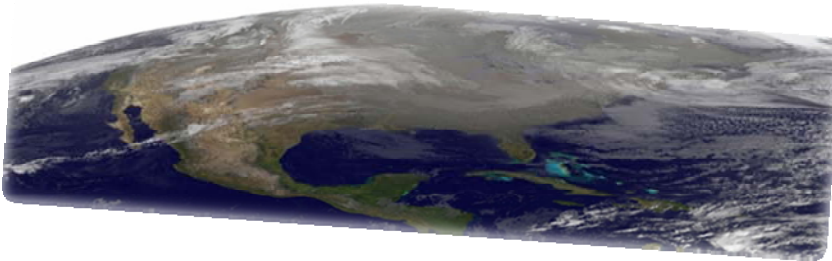
S-TEC)

DEMETER



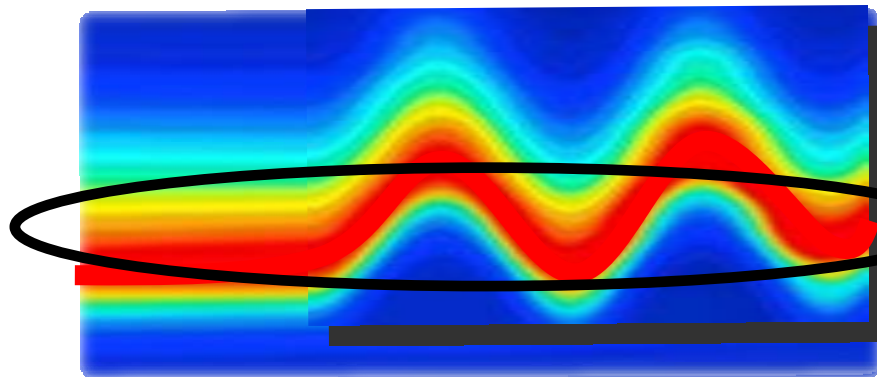
Ionospheric Plasma

Medium-Scale  
Travelling Ionospheric Disturbance



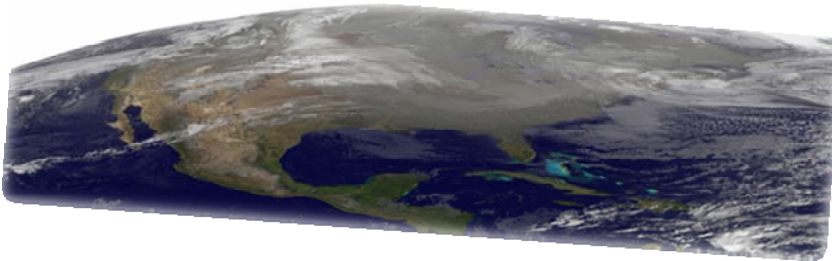


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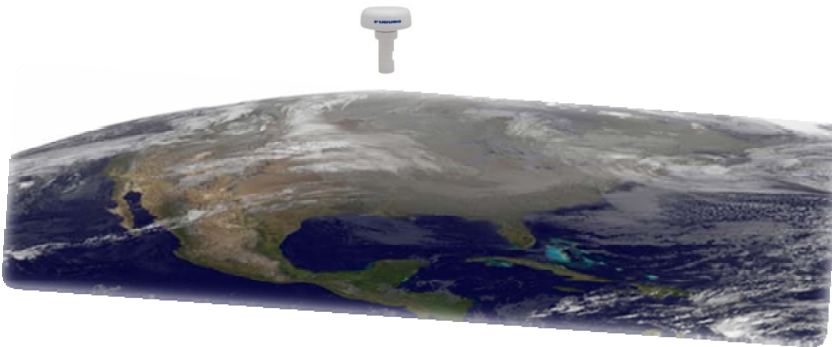
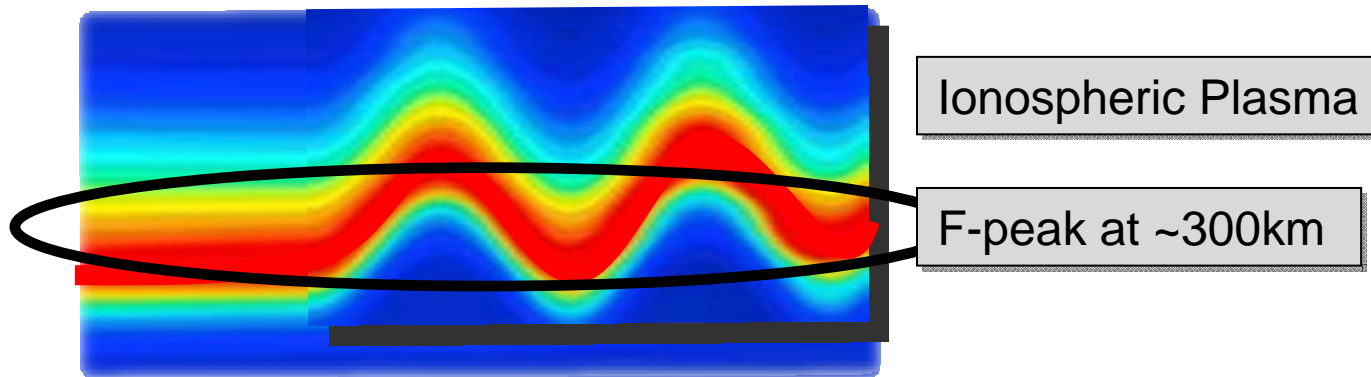
Ionospheric Plasma

Medium-Scale  
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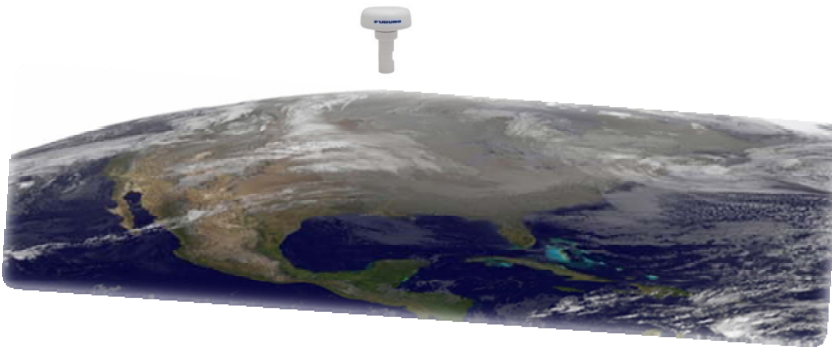
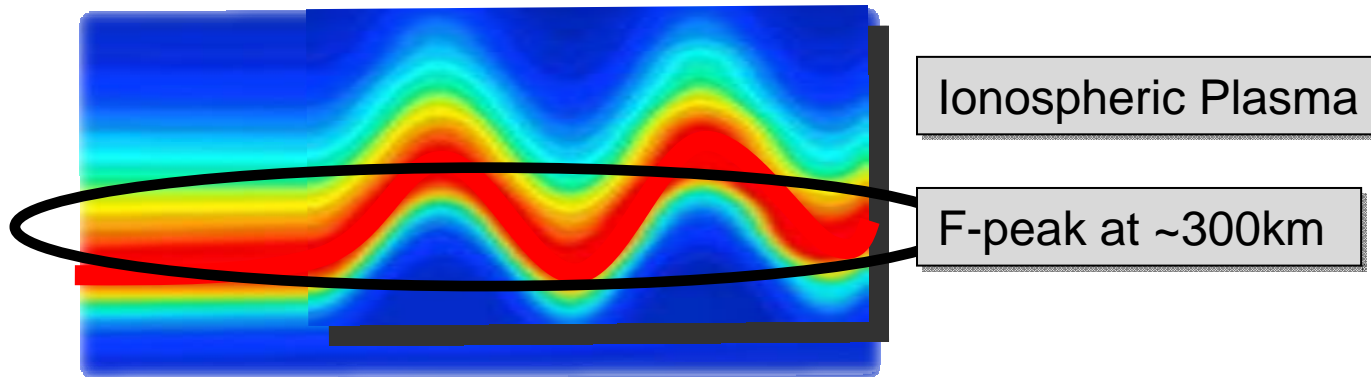
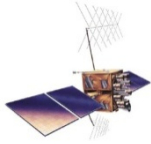


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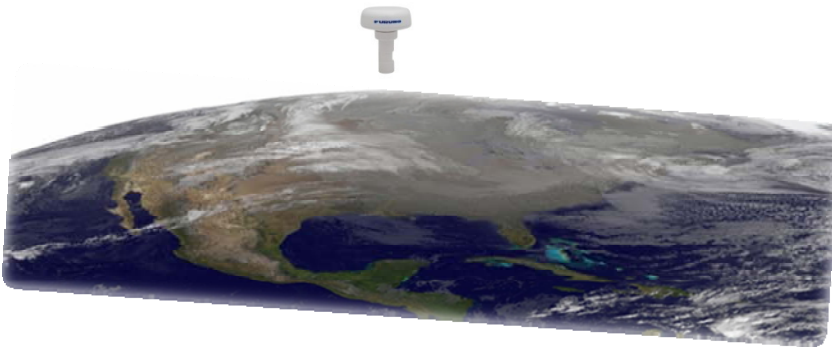
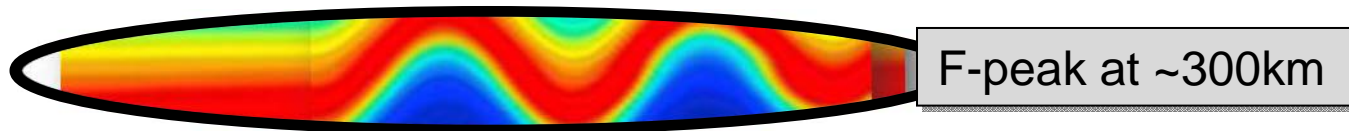
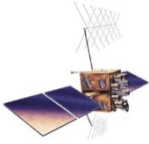


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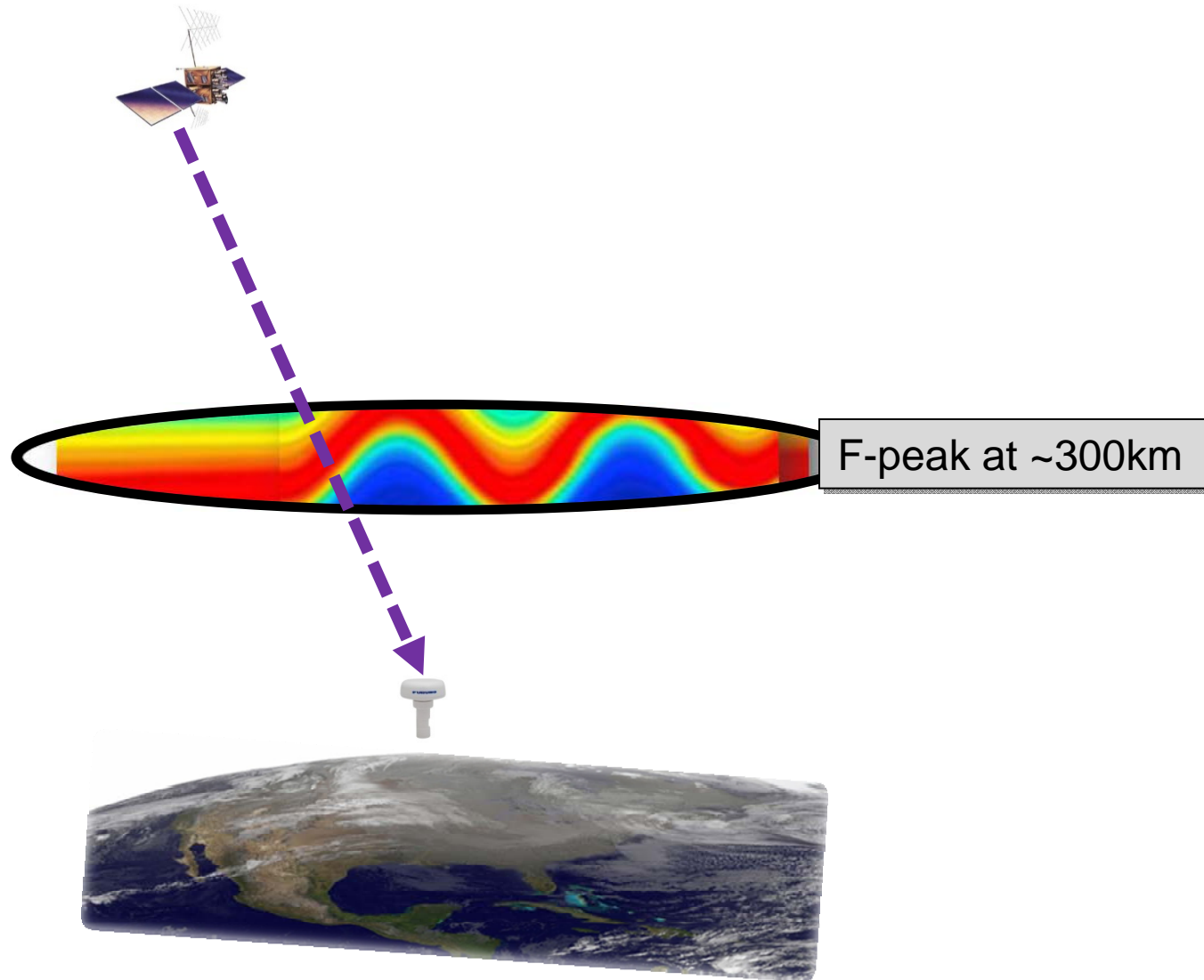


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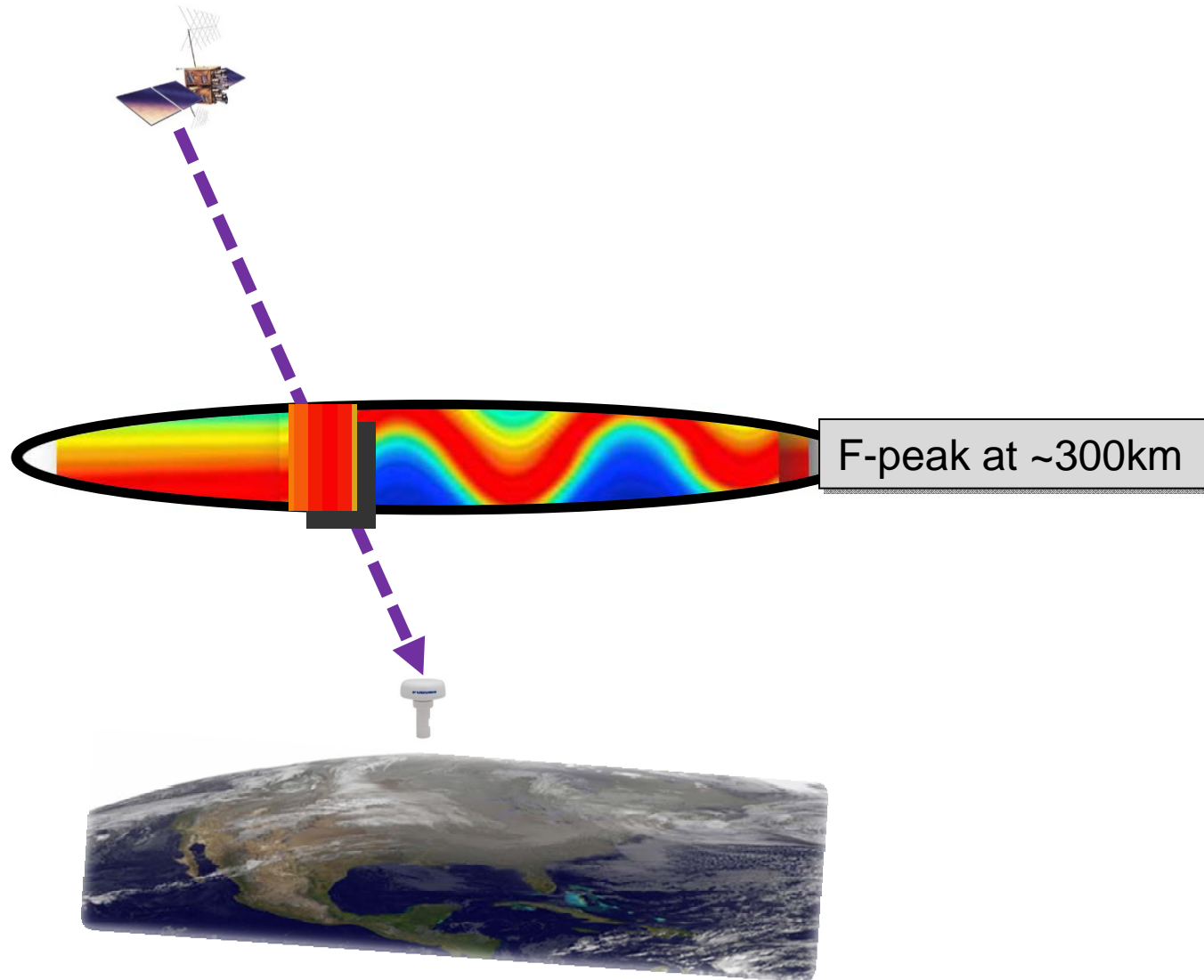


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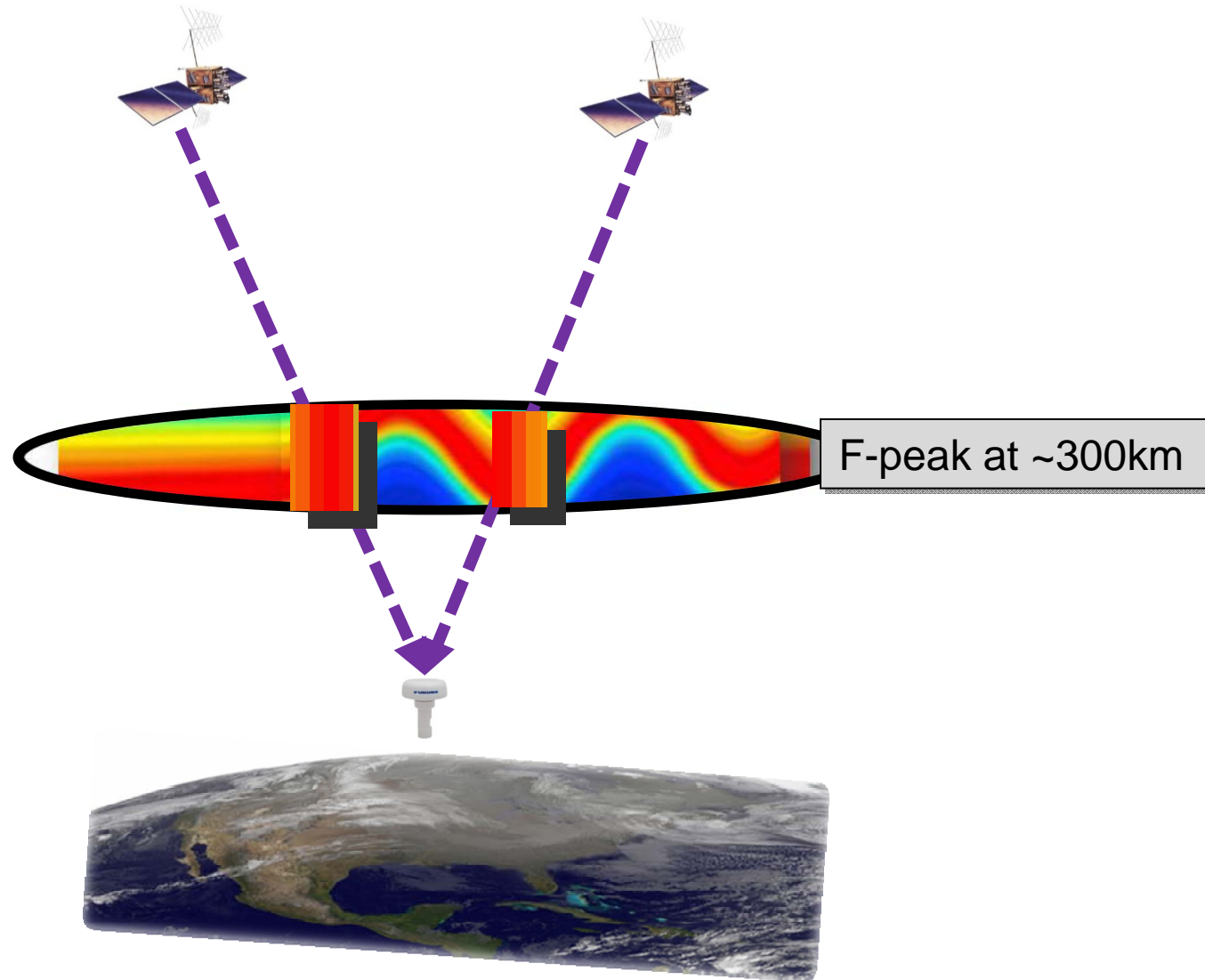


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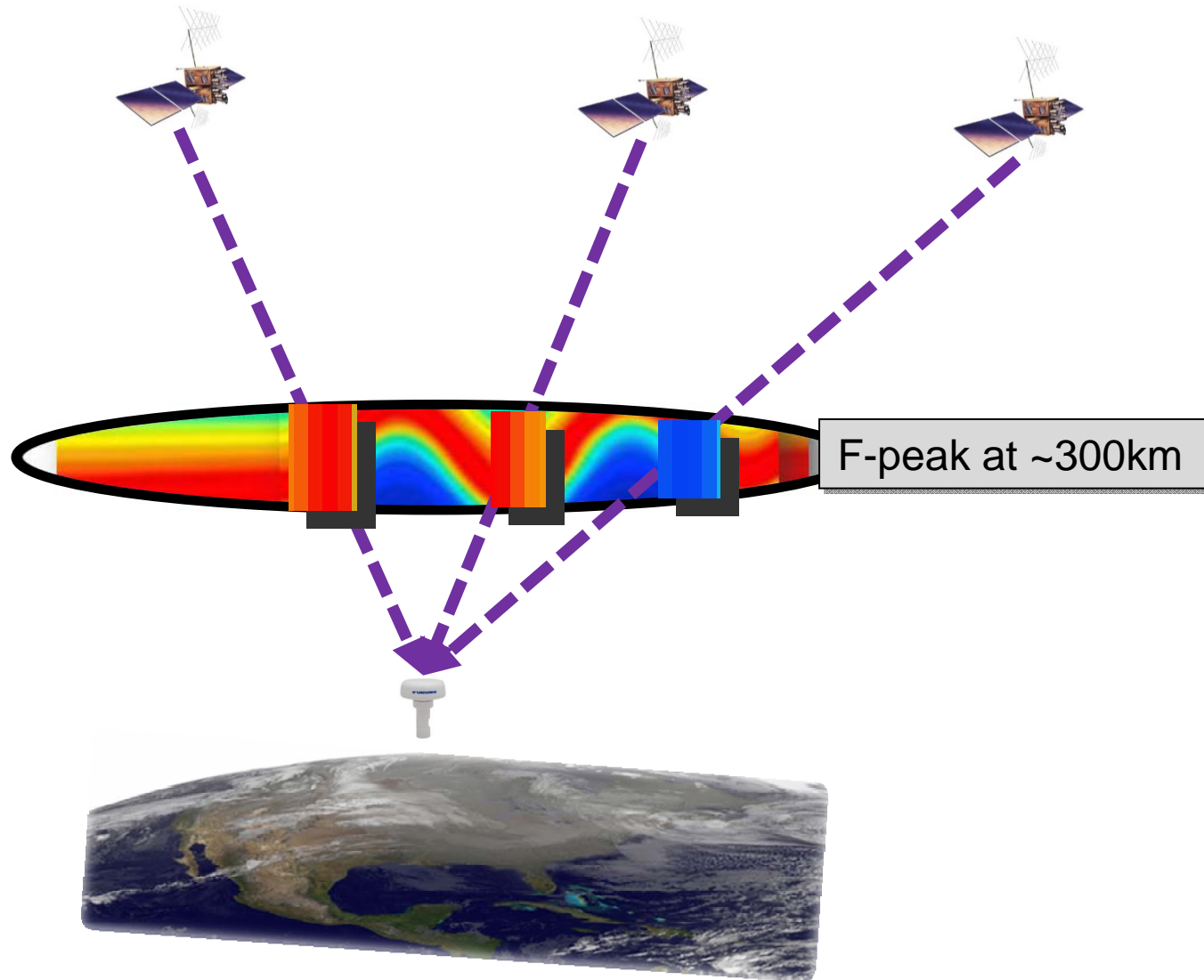


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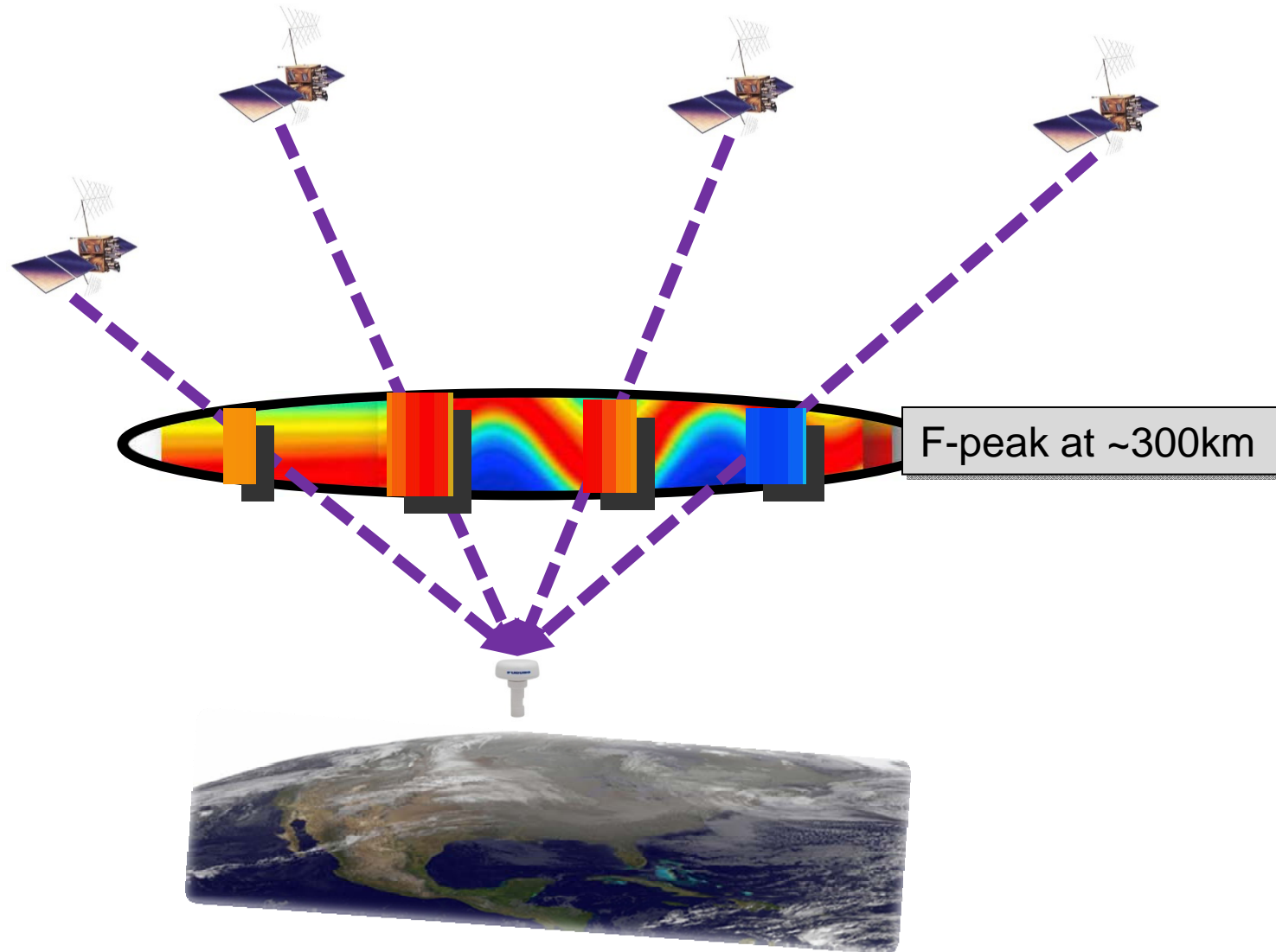


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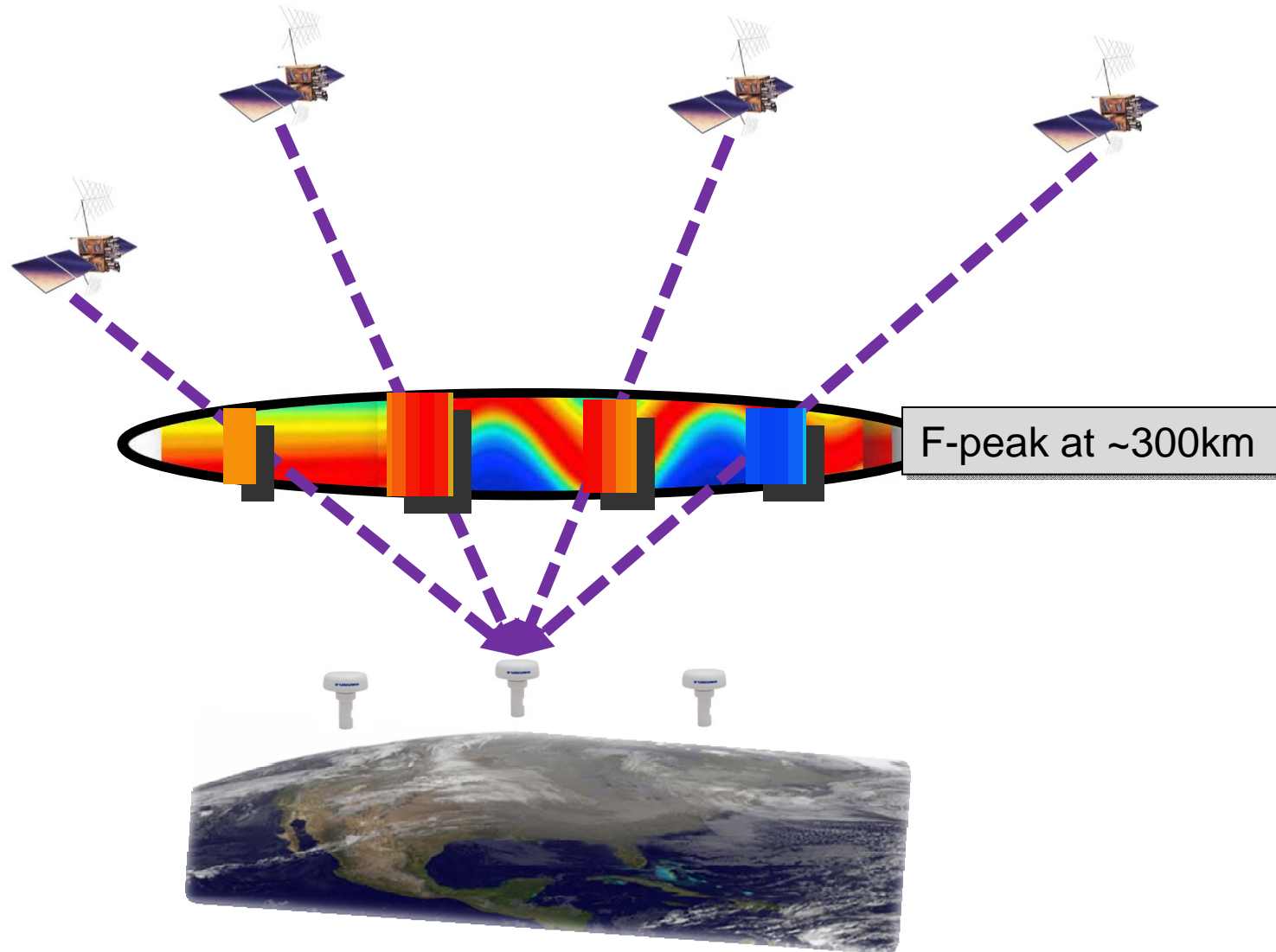


# Observation (DEMETER/GPS-TEC)



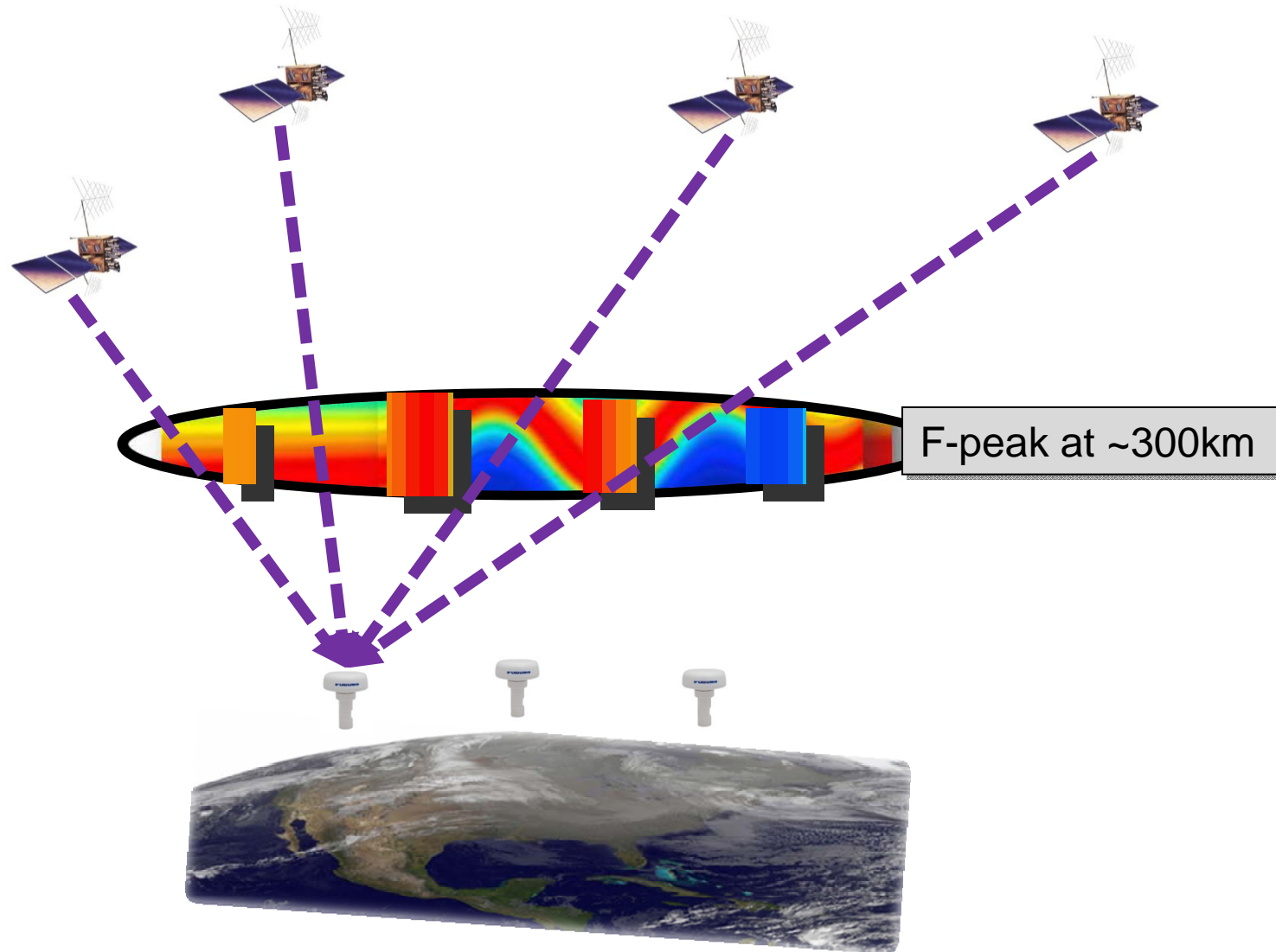


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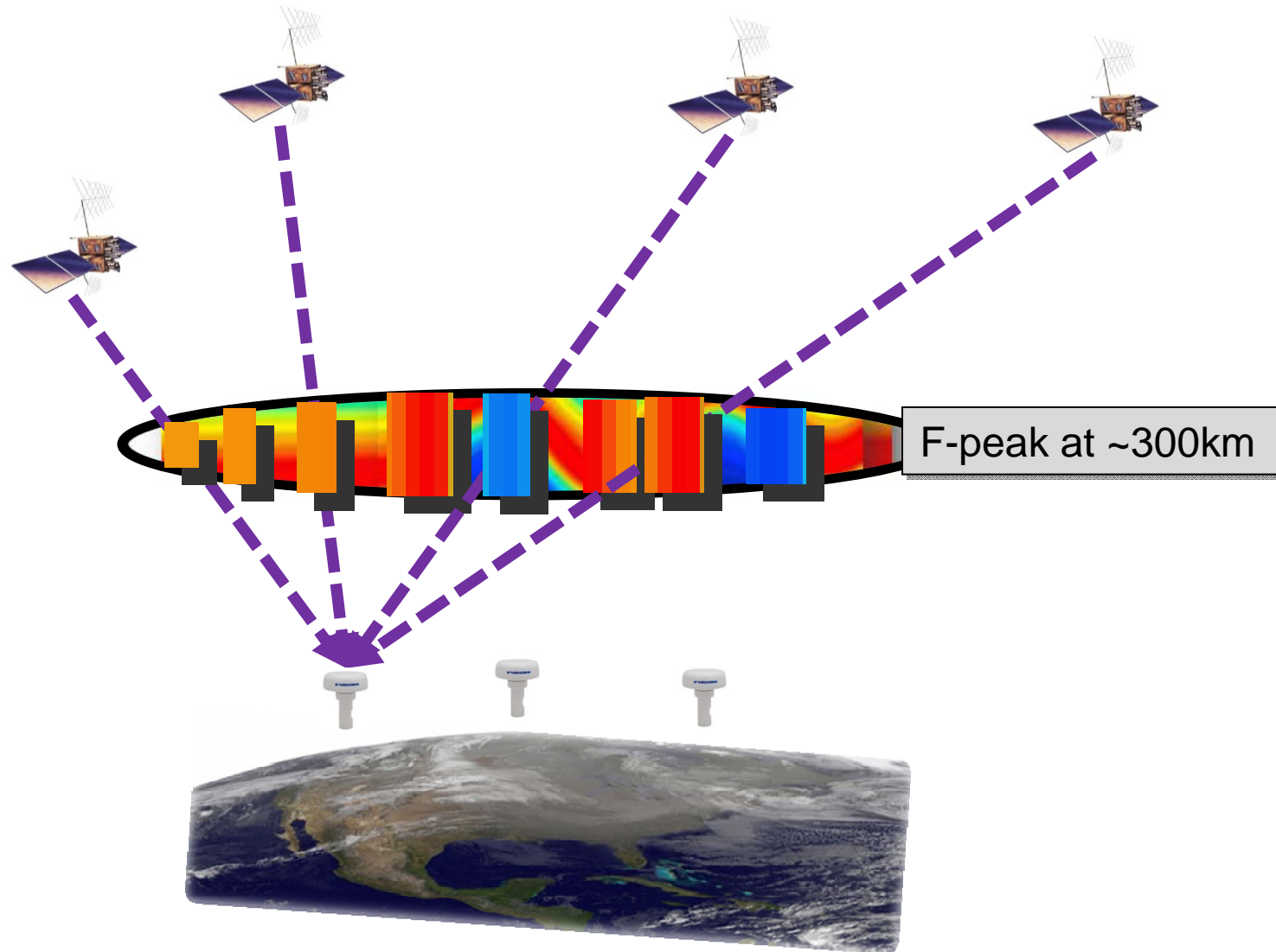


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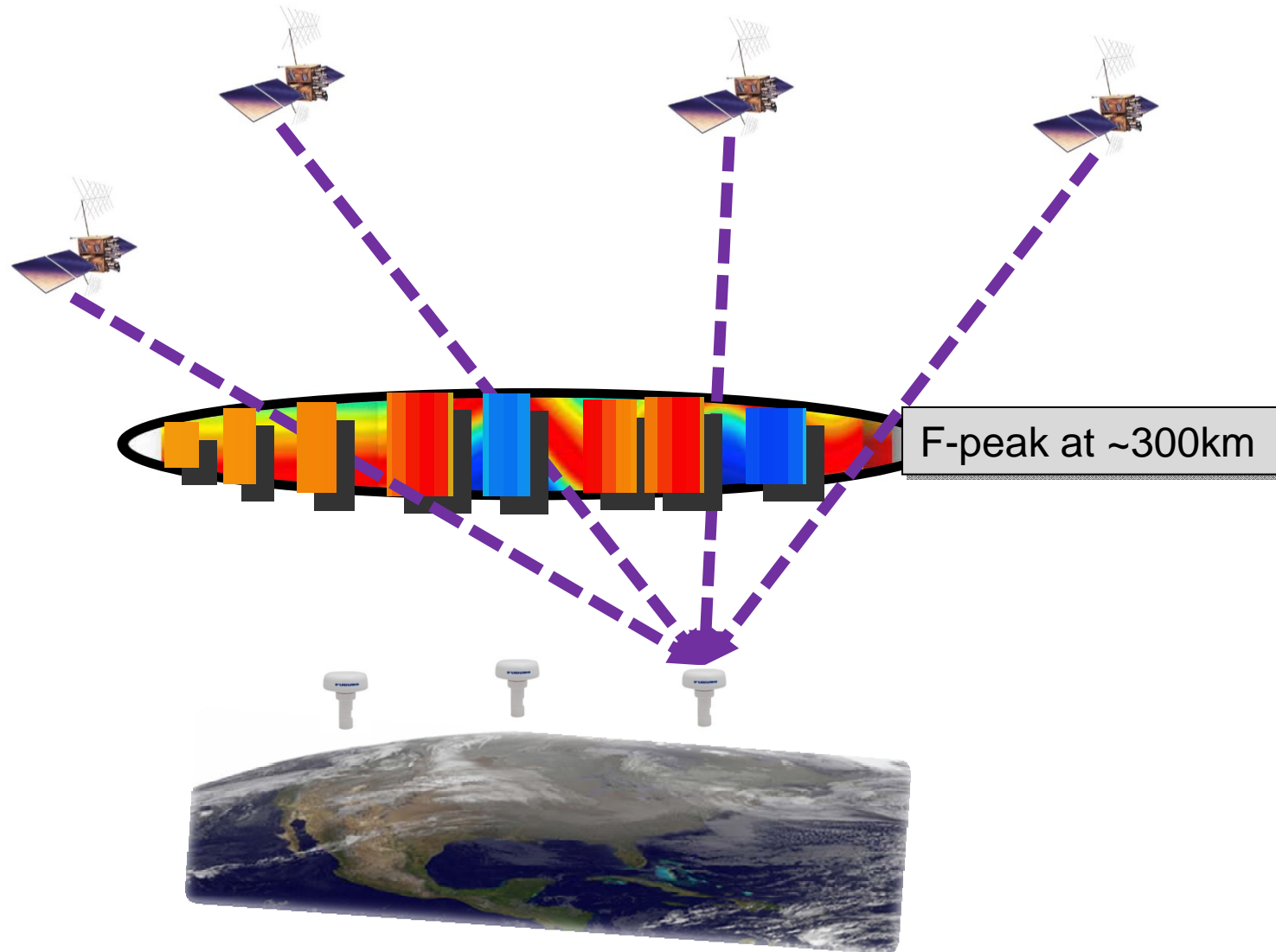


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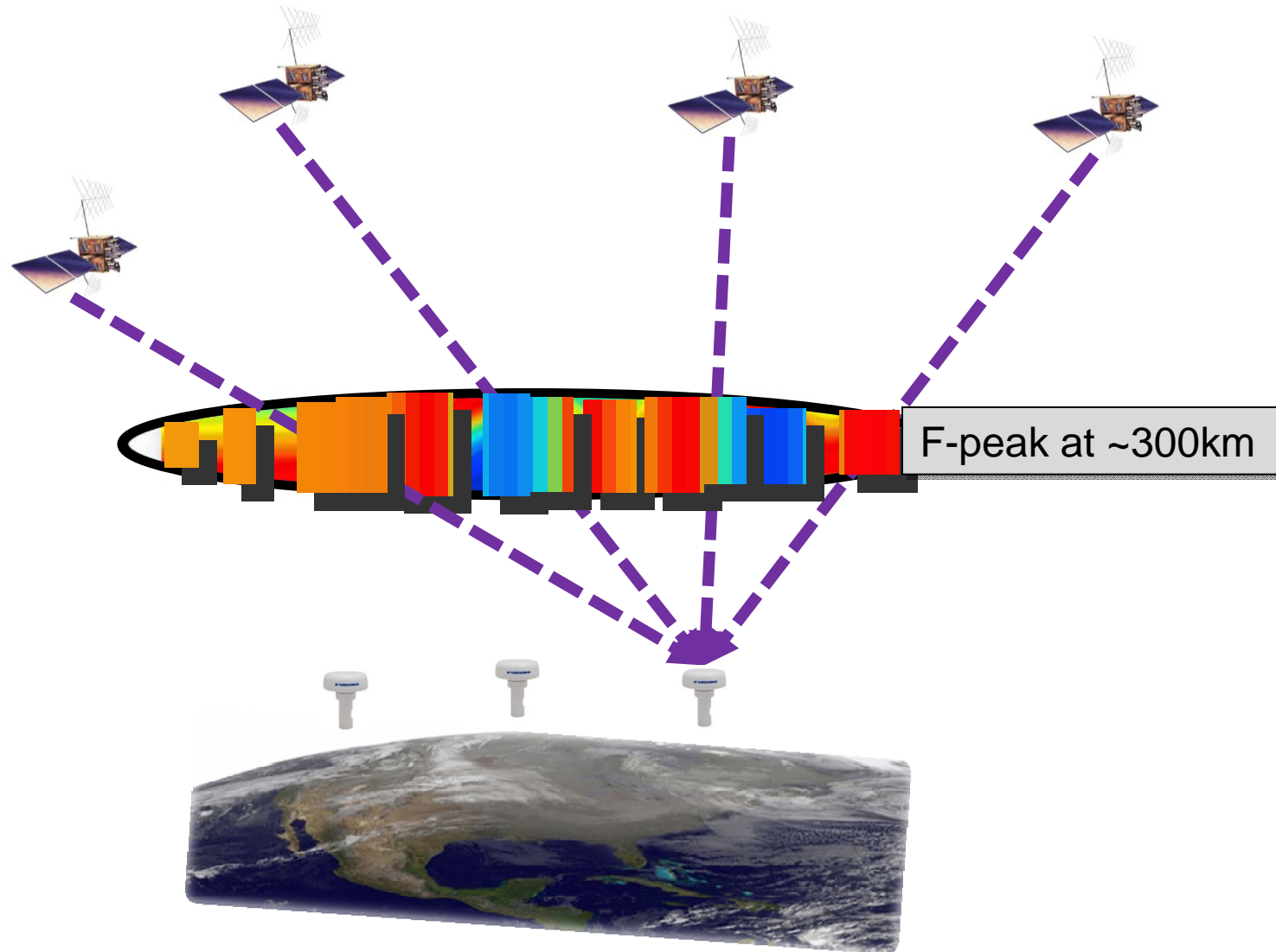


# Observation (DEMETER/GPS-TEC)



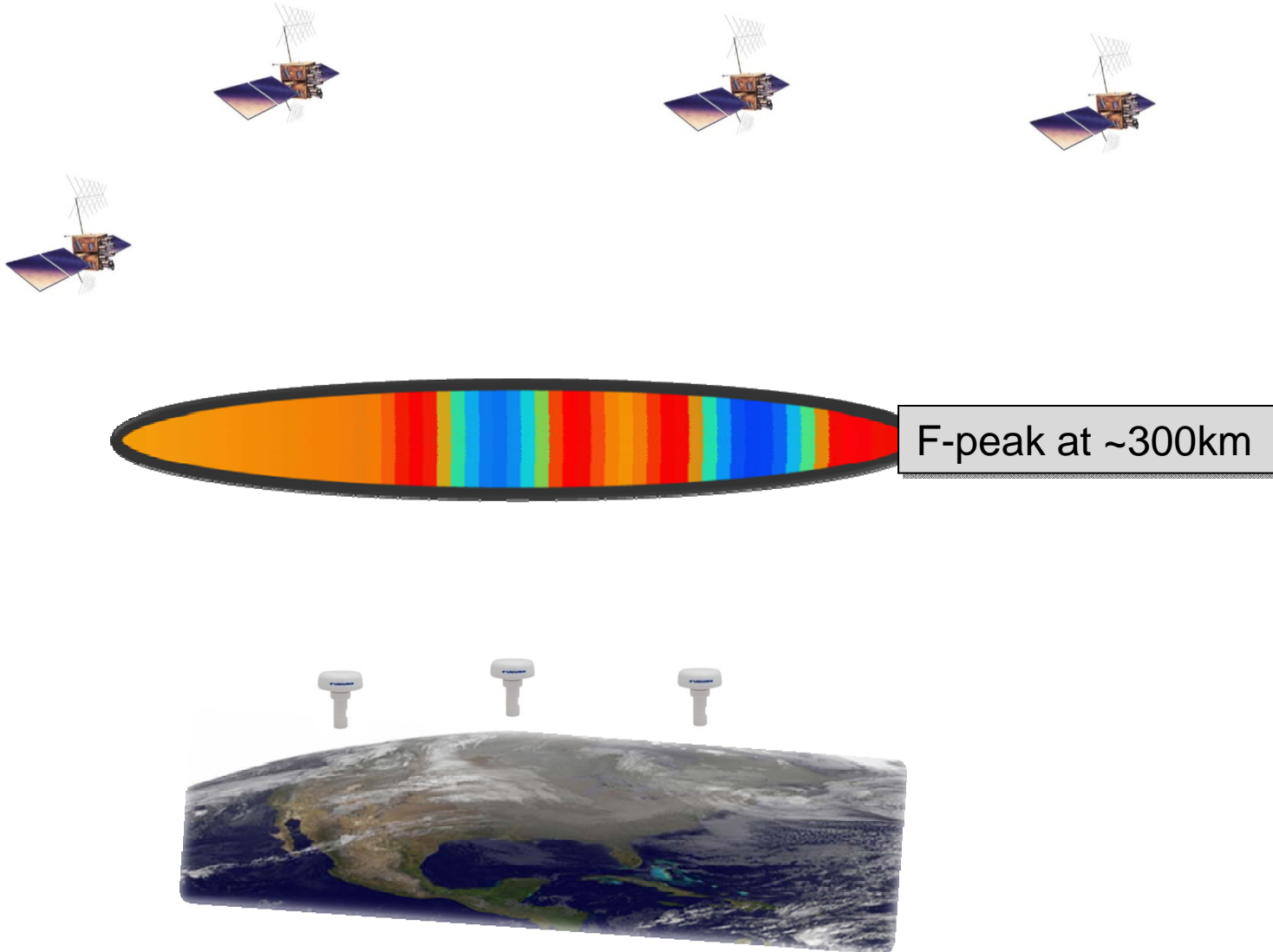


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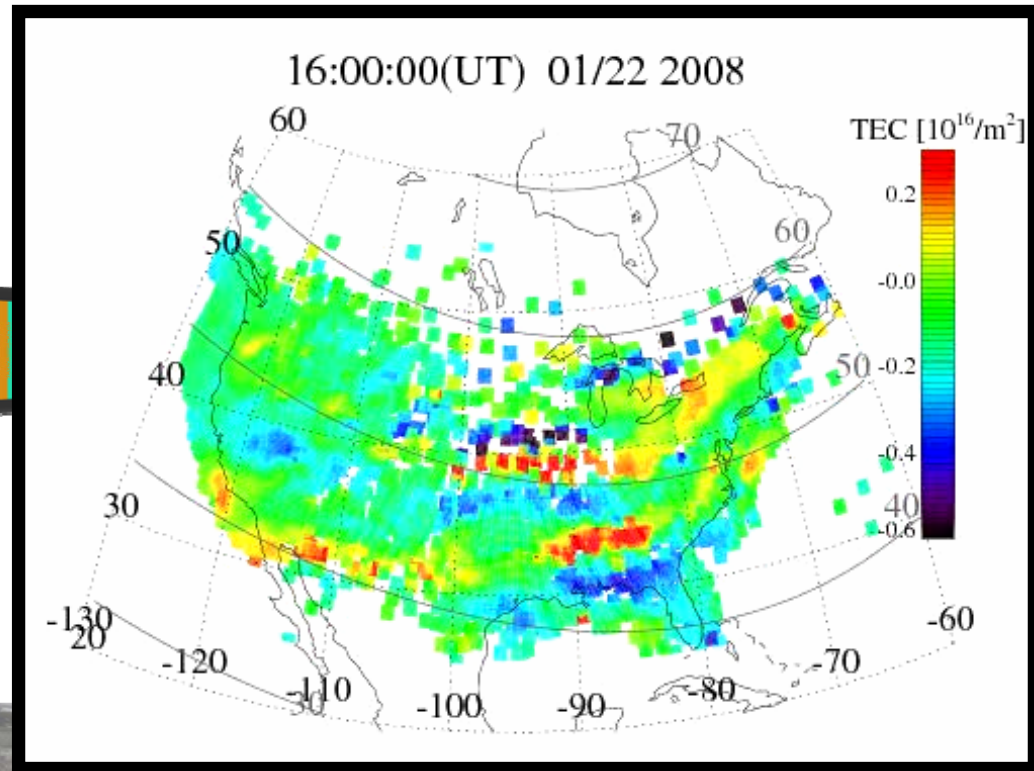
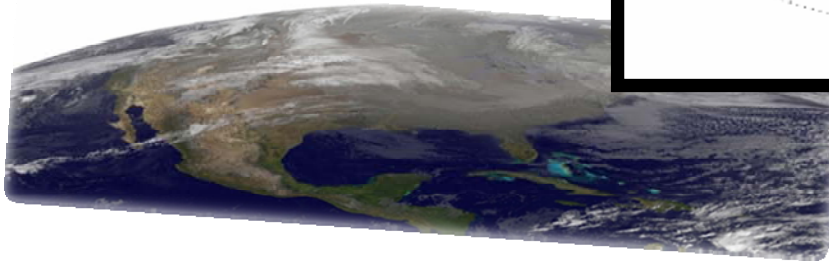
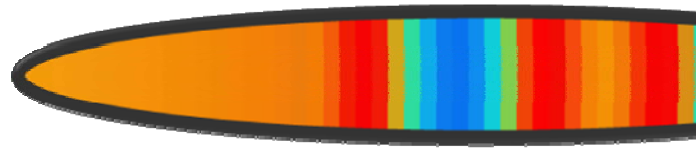


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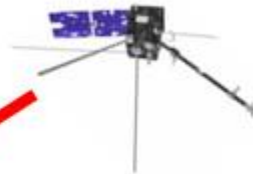


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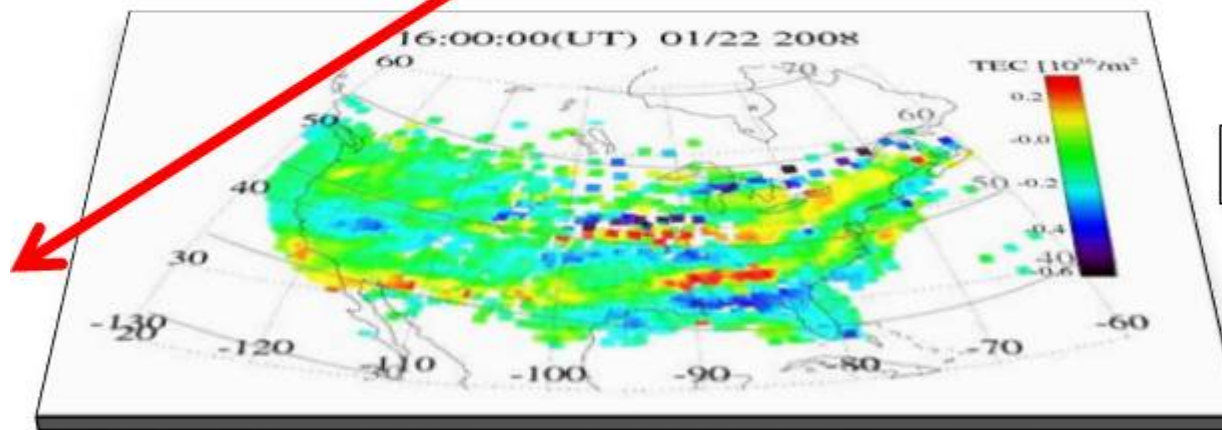




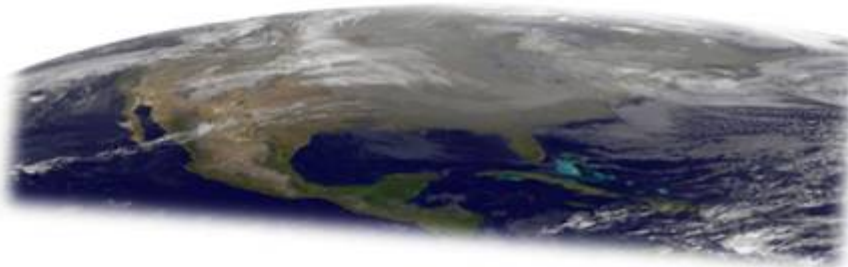
## Observation (DEMETER/GPS-TEC)



DEMETER at ~ 660km

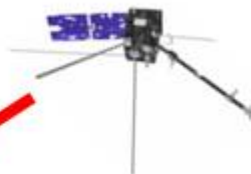


F-peak at ~300km

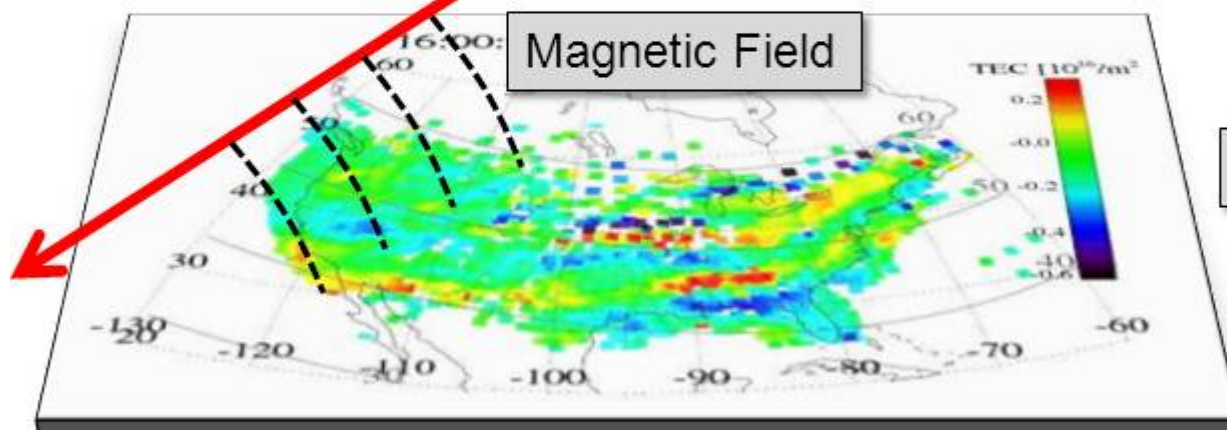




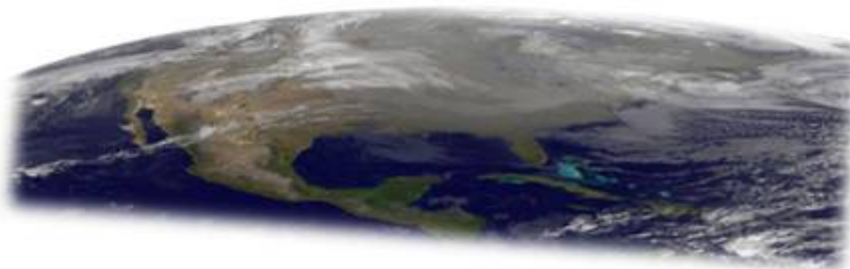
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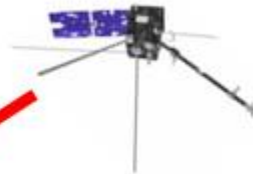


F-peak at ~300km

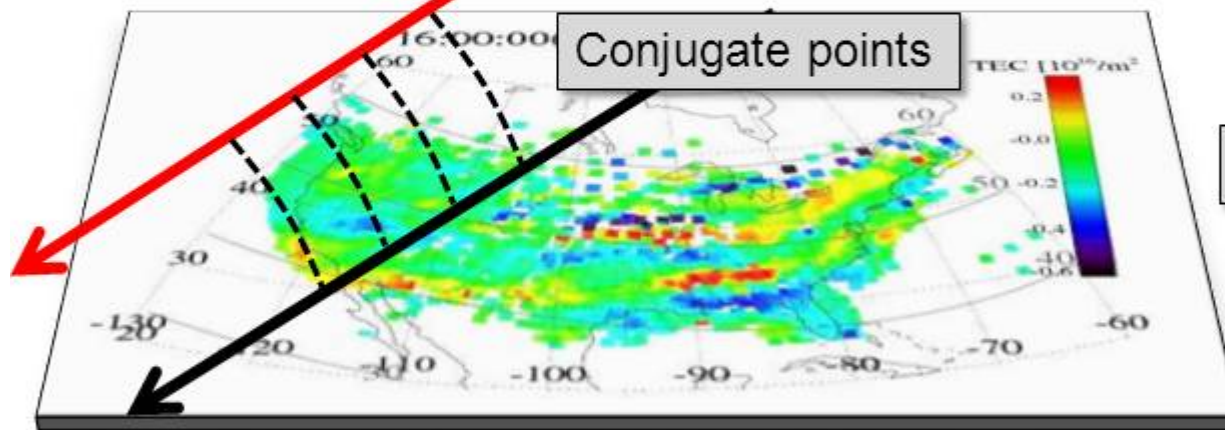




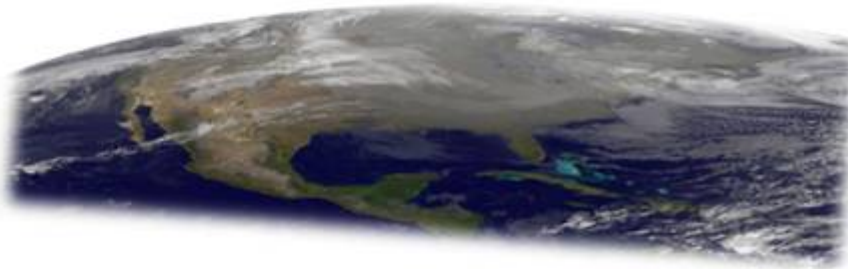
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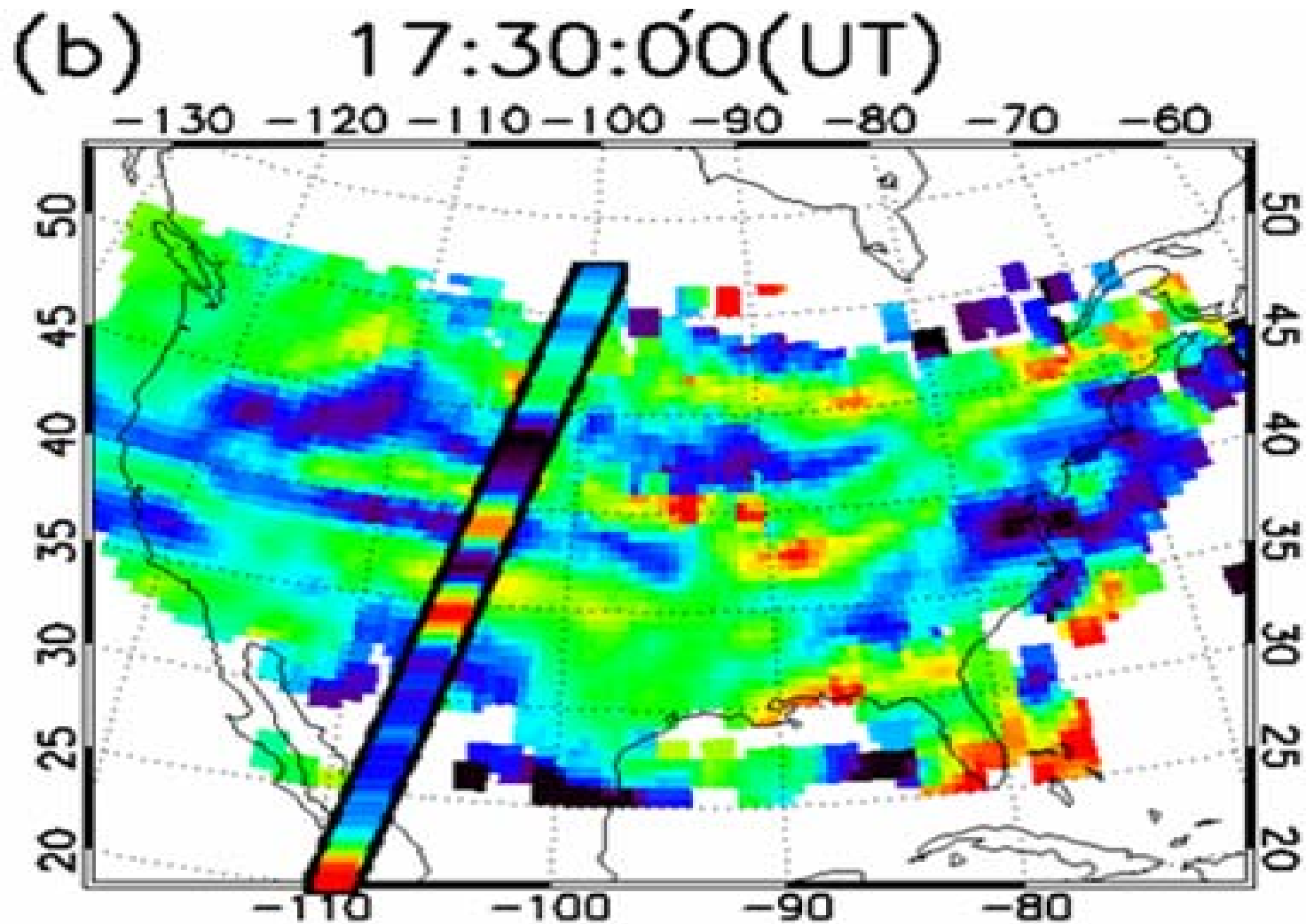


F-peak at ~300km



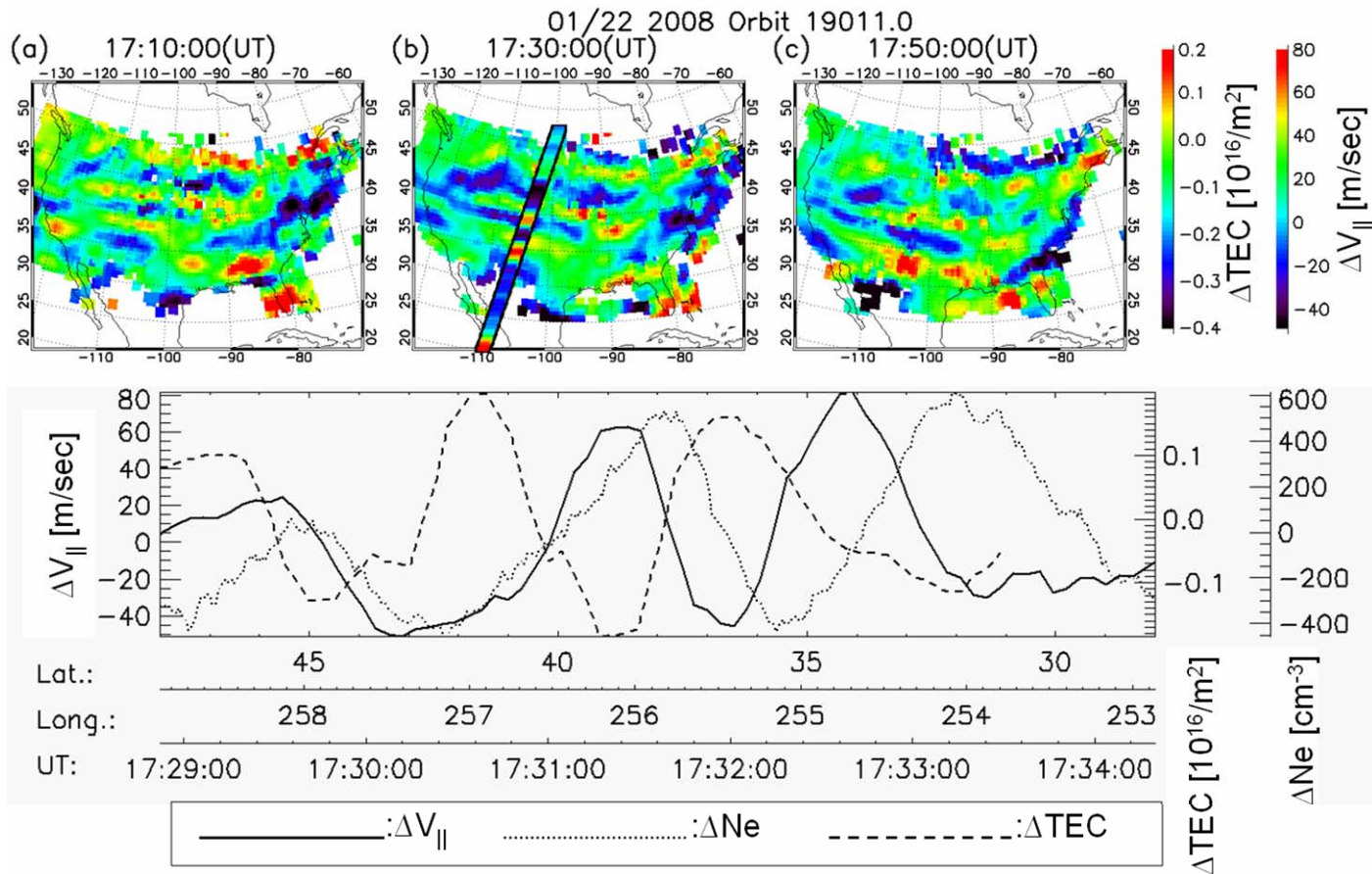


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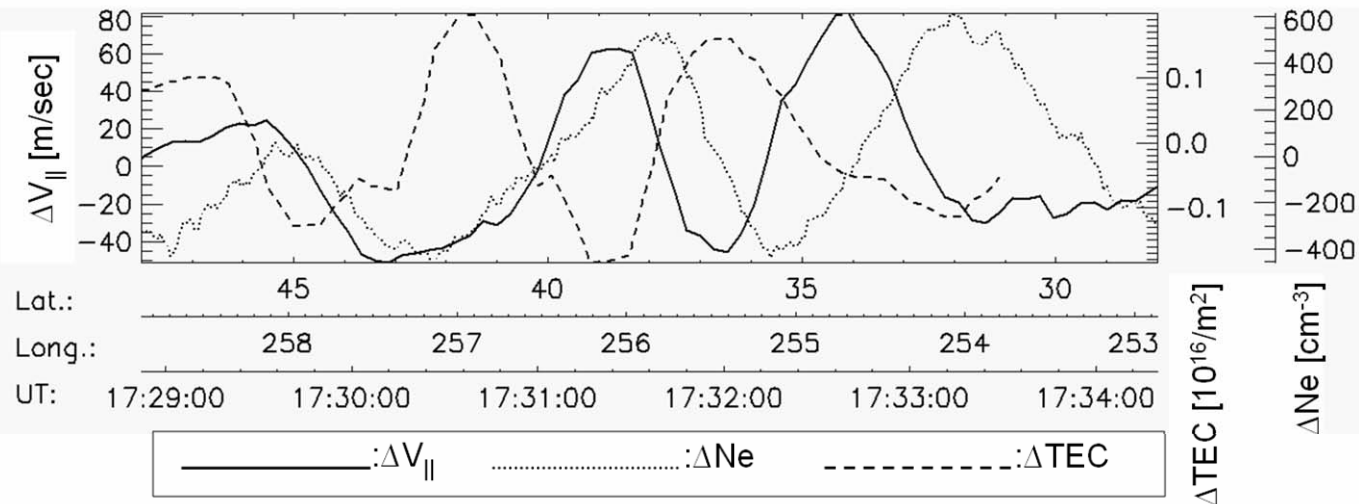
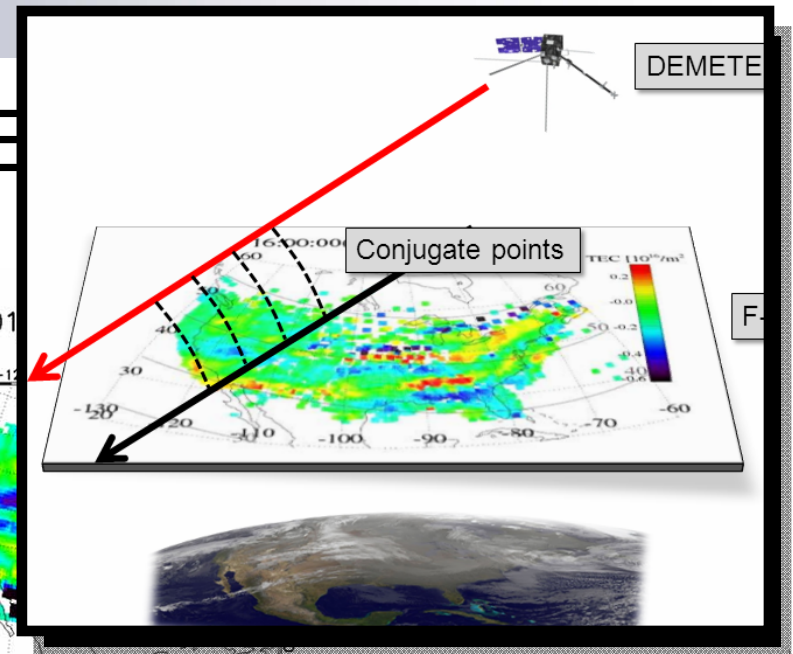
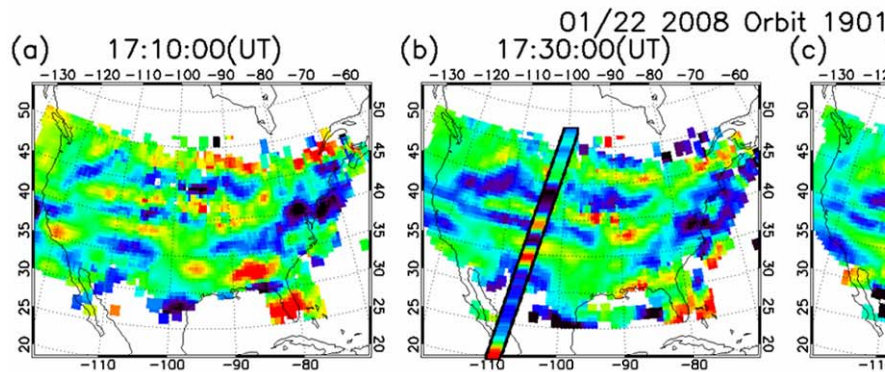


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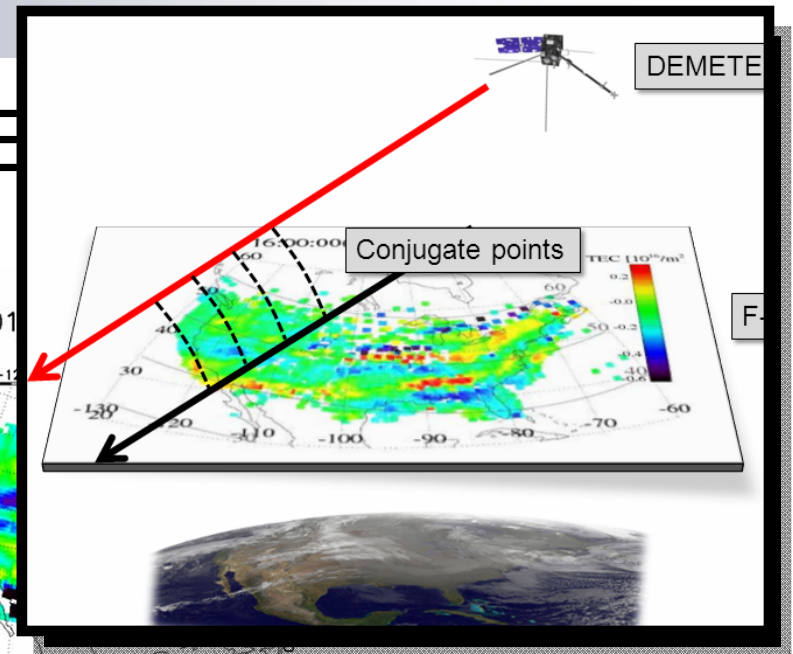
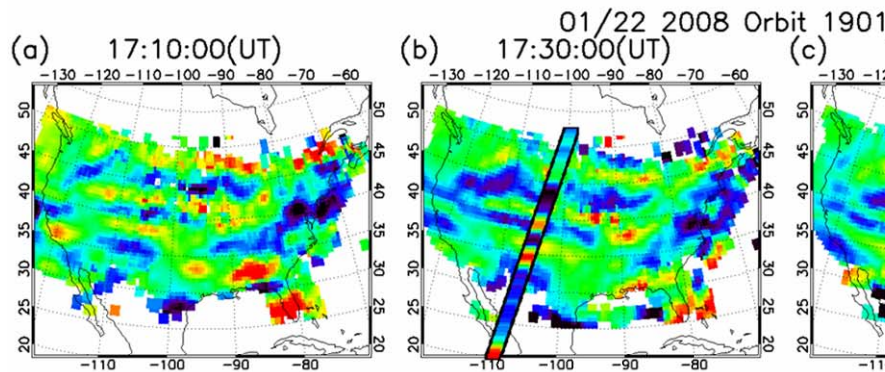


# Observation (DEMETER)



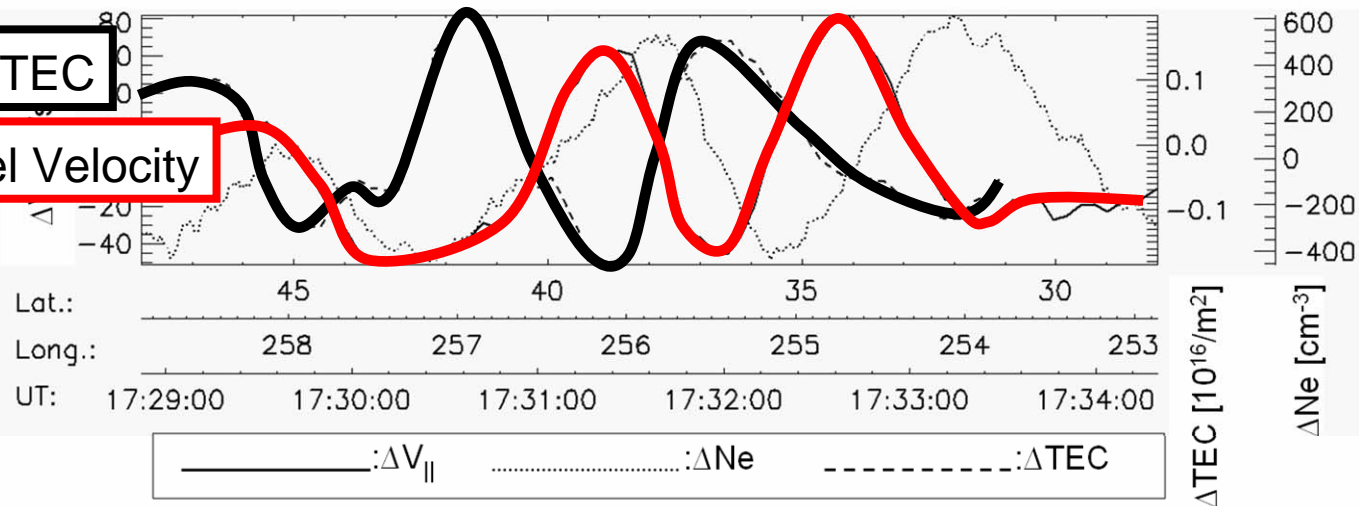


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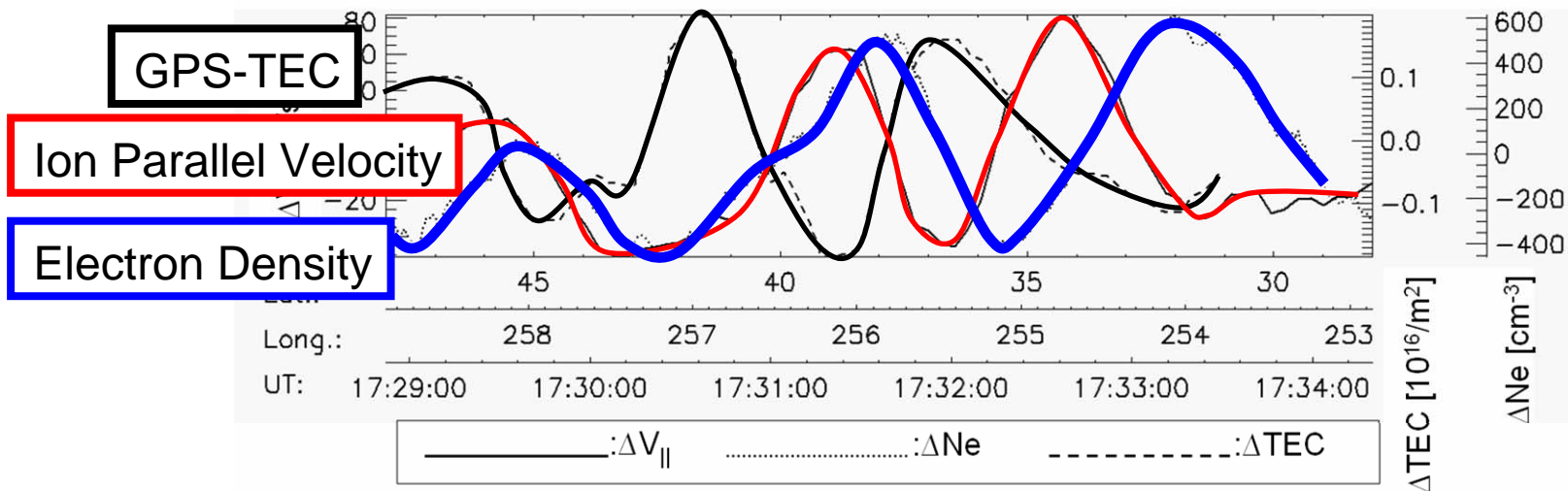
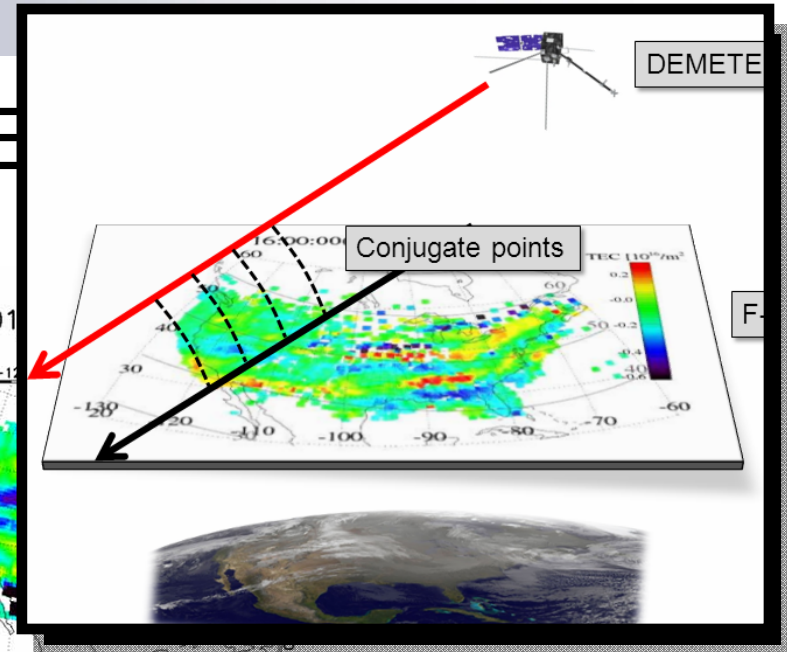
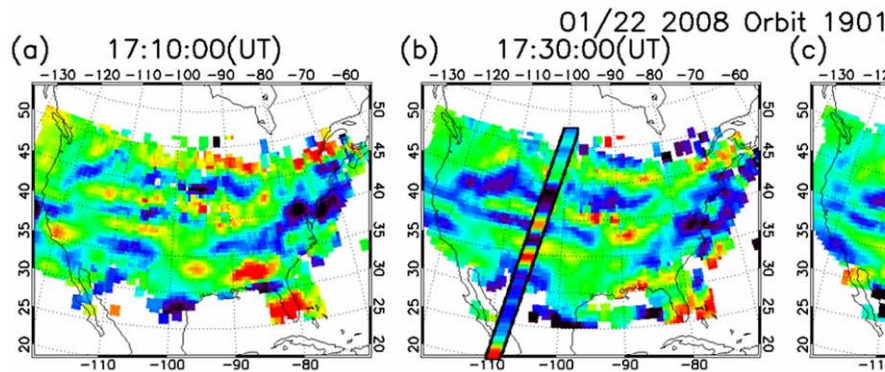
GPS-TEC

Ion Parallel Velocity



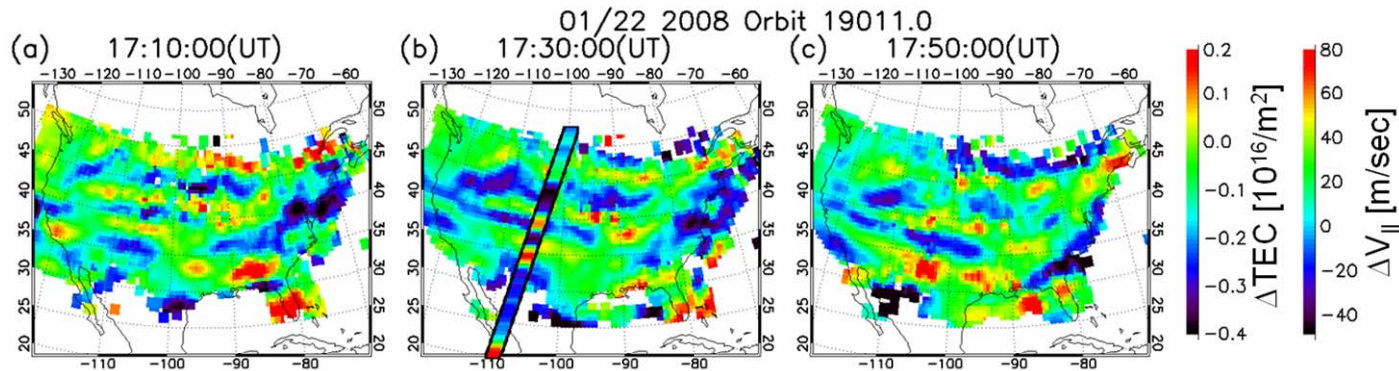
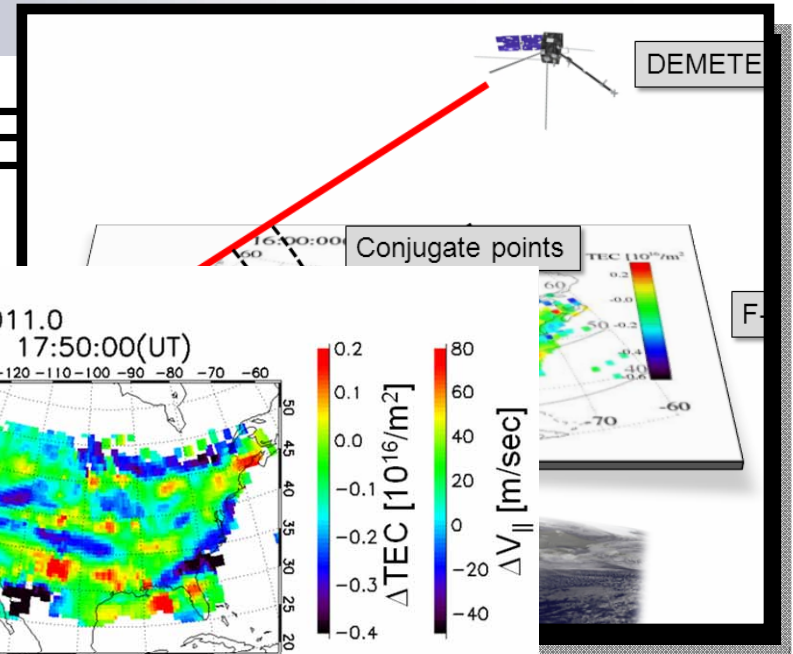


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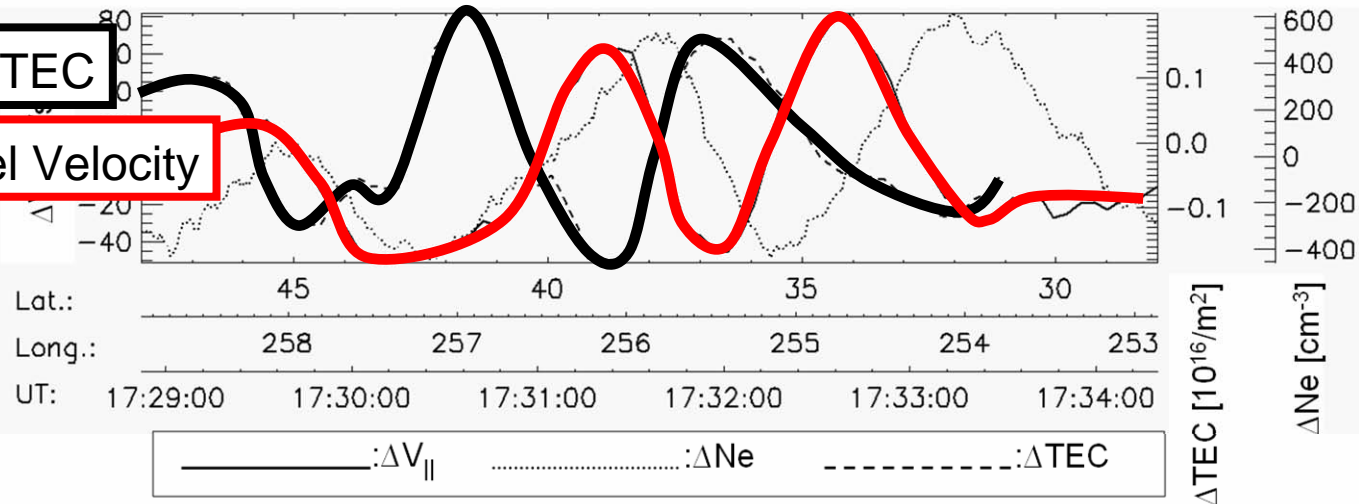


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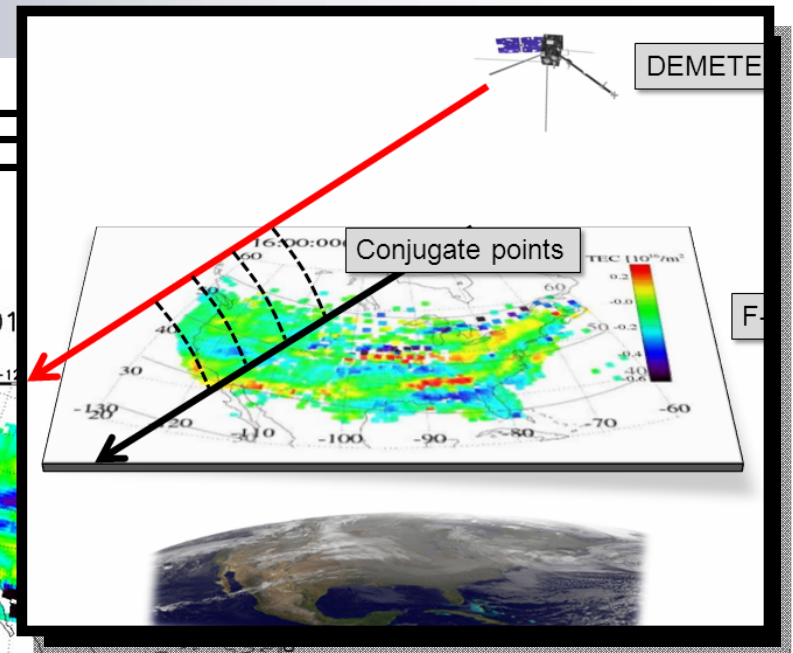
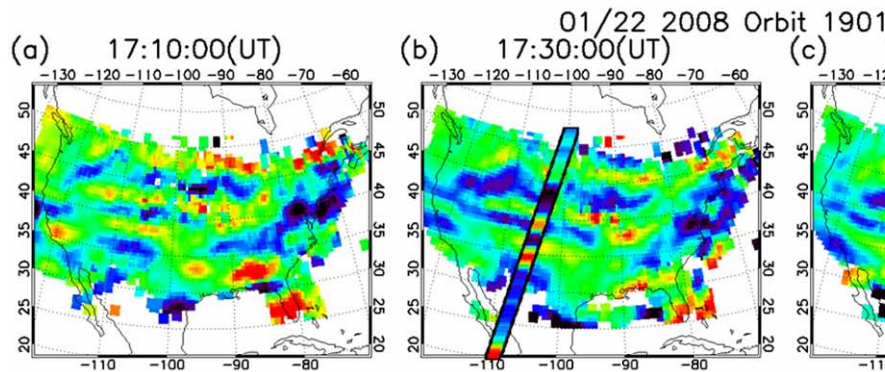
GPS-TEC

Ion Parallel Velocity



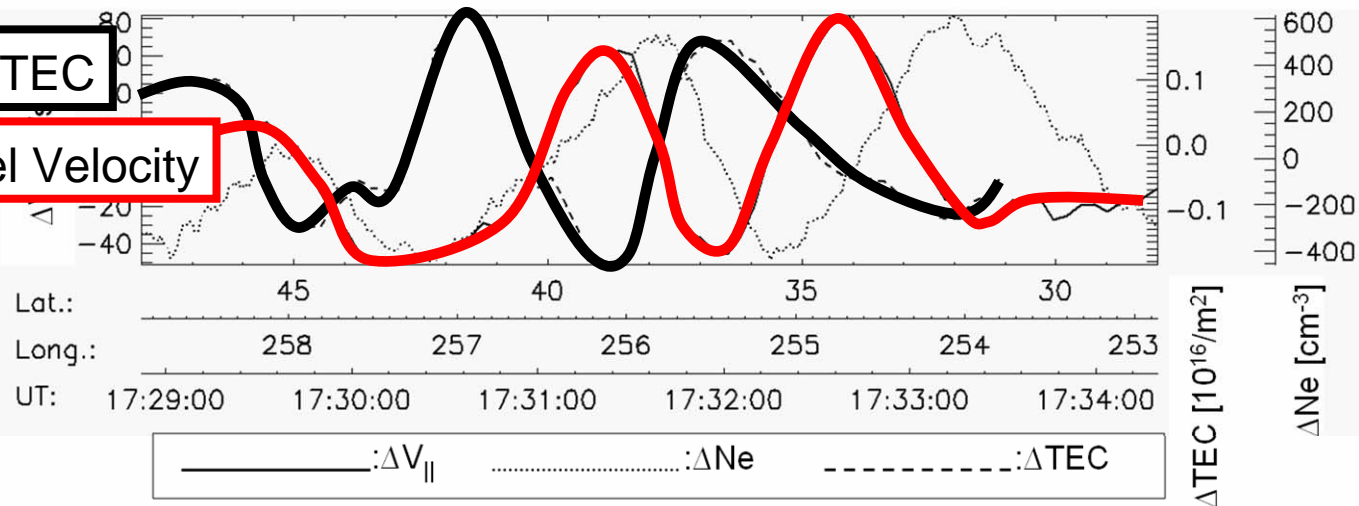


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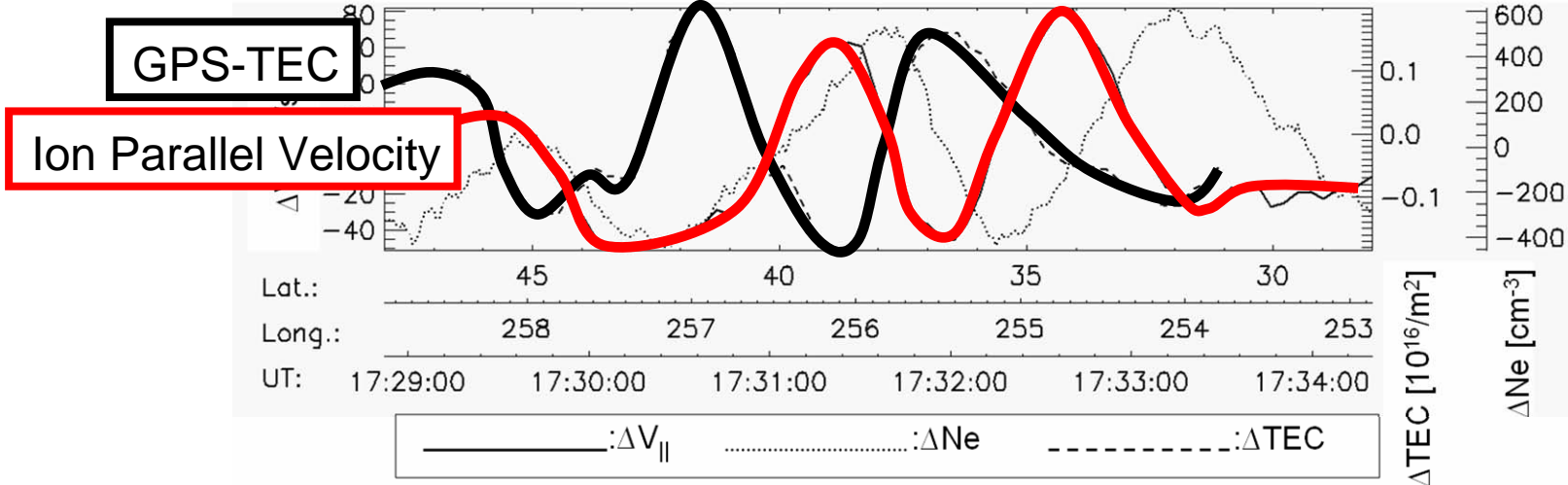
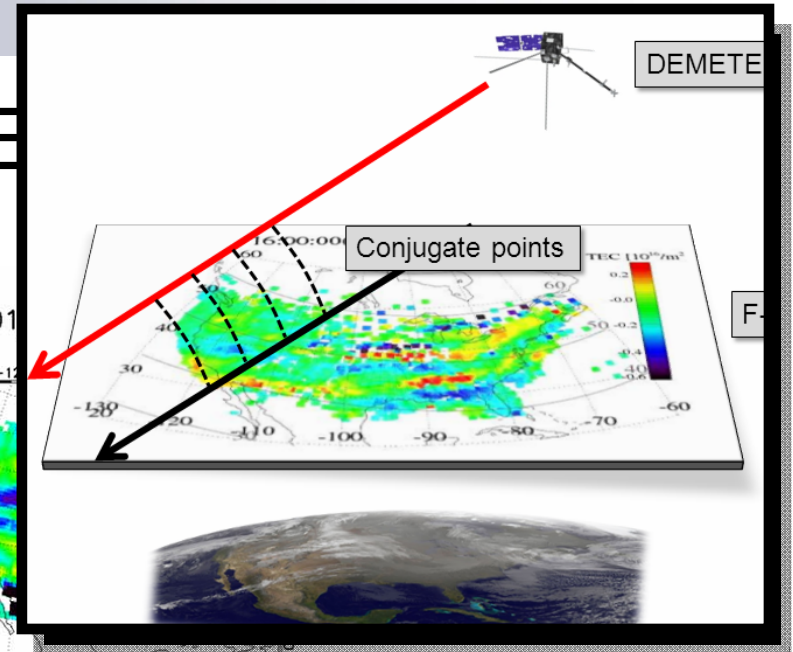
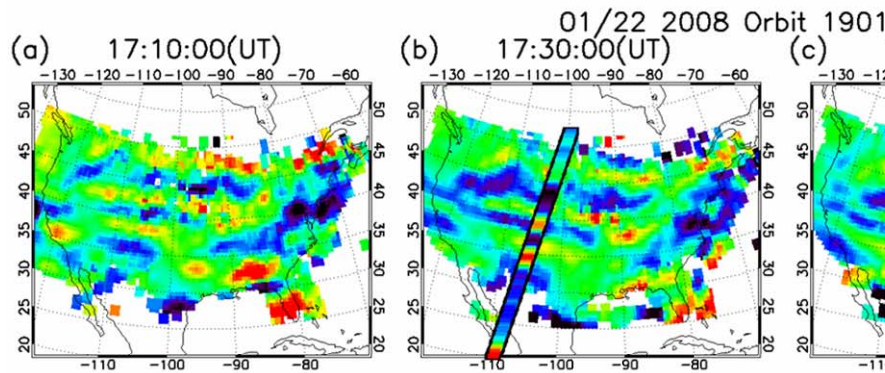
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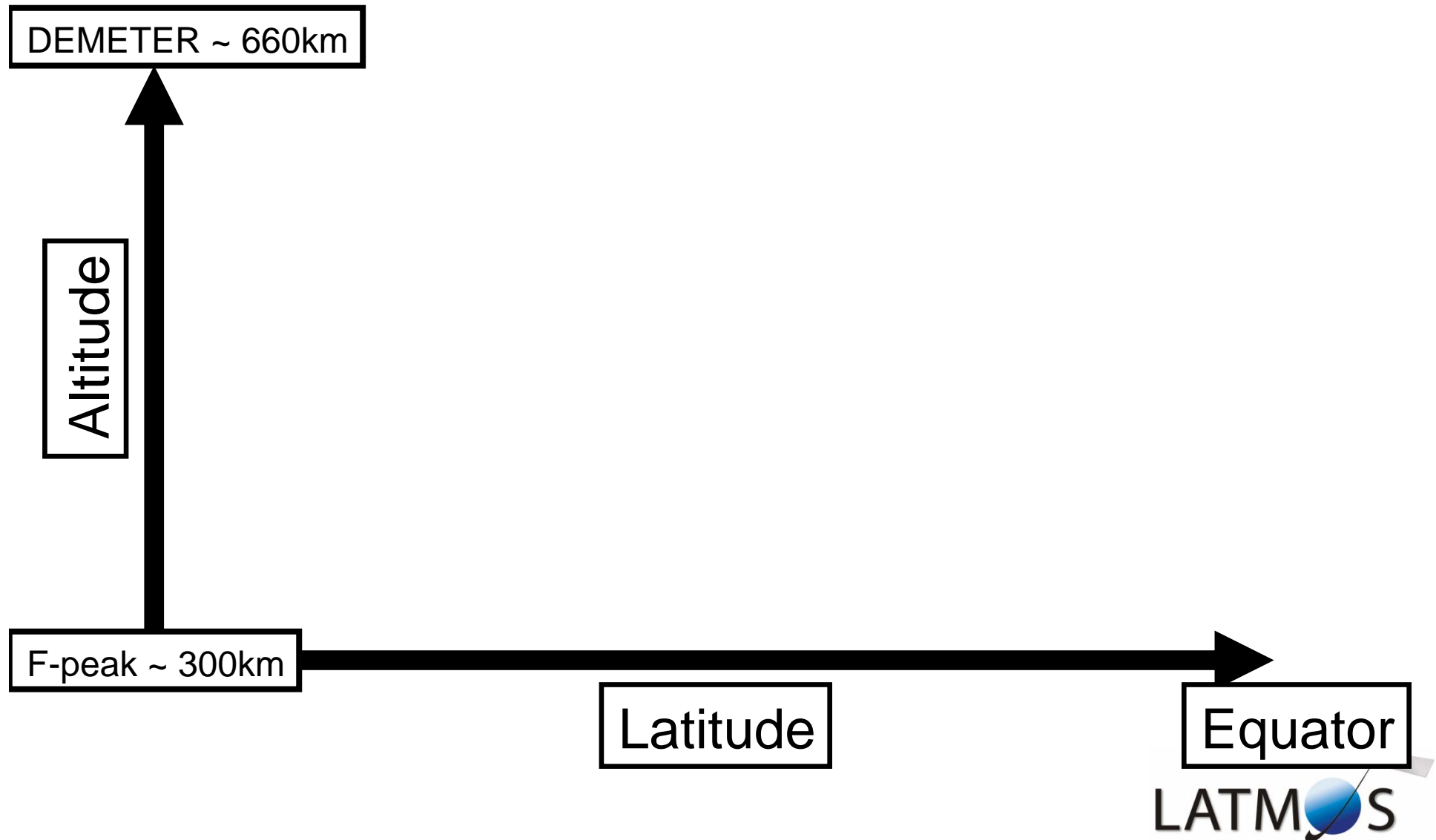


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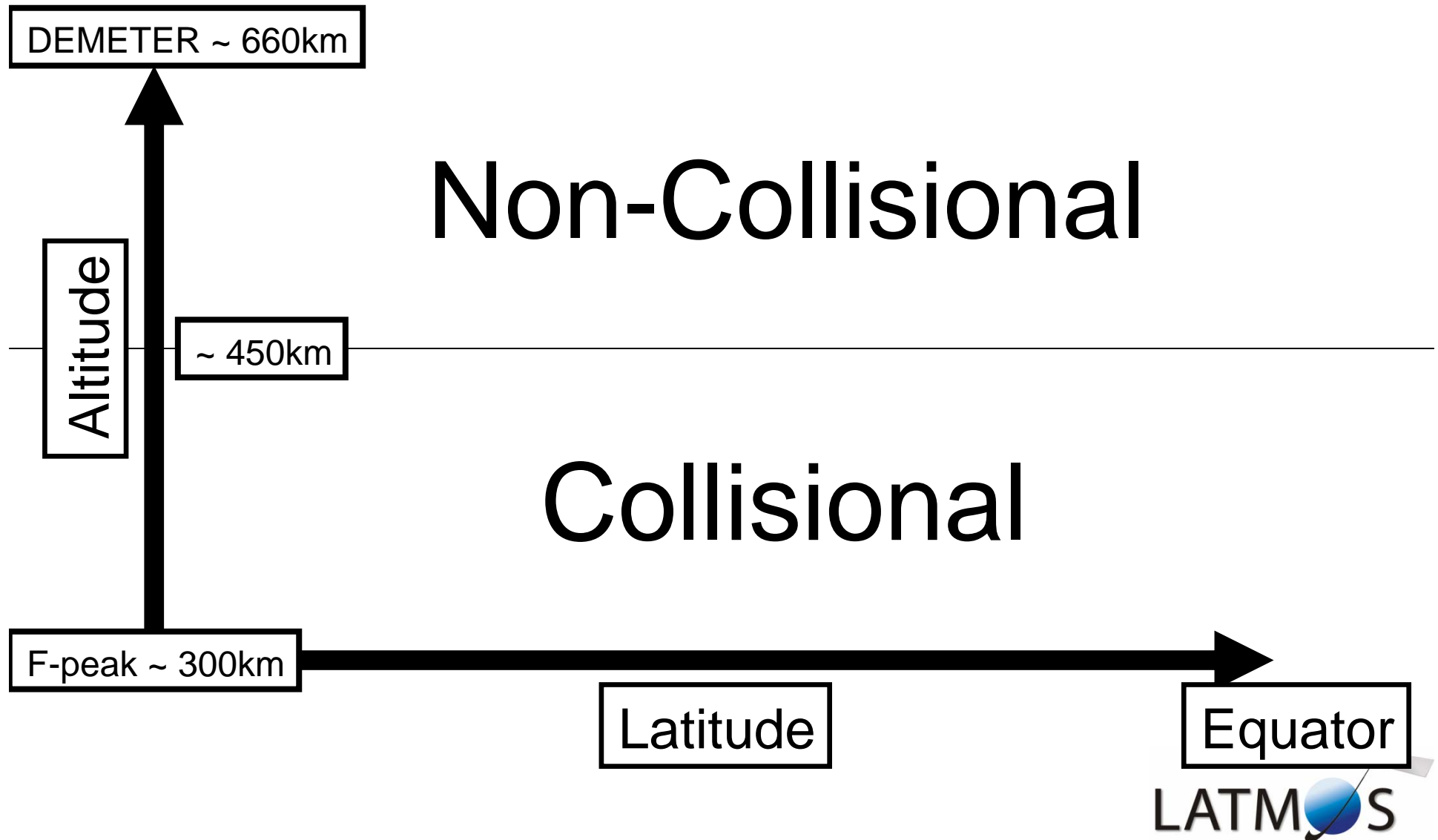


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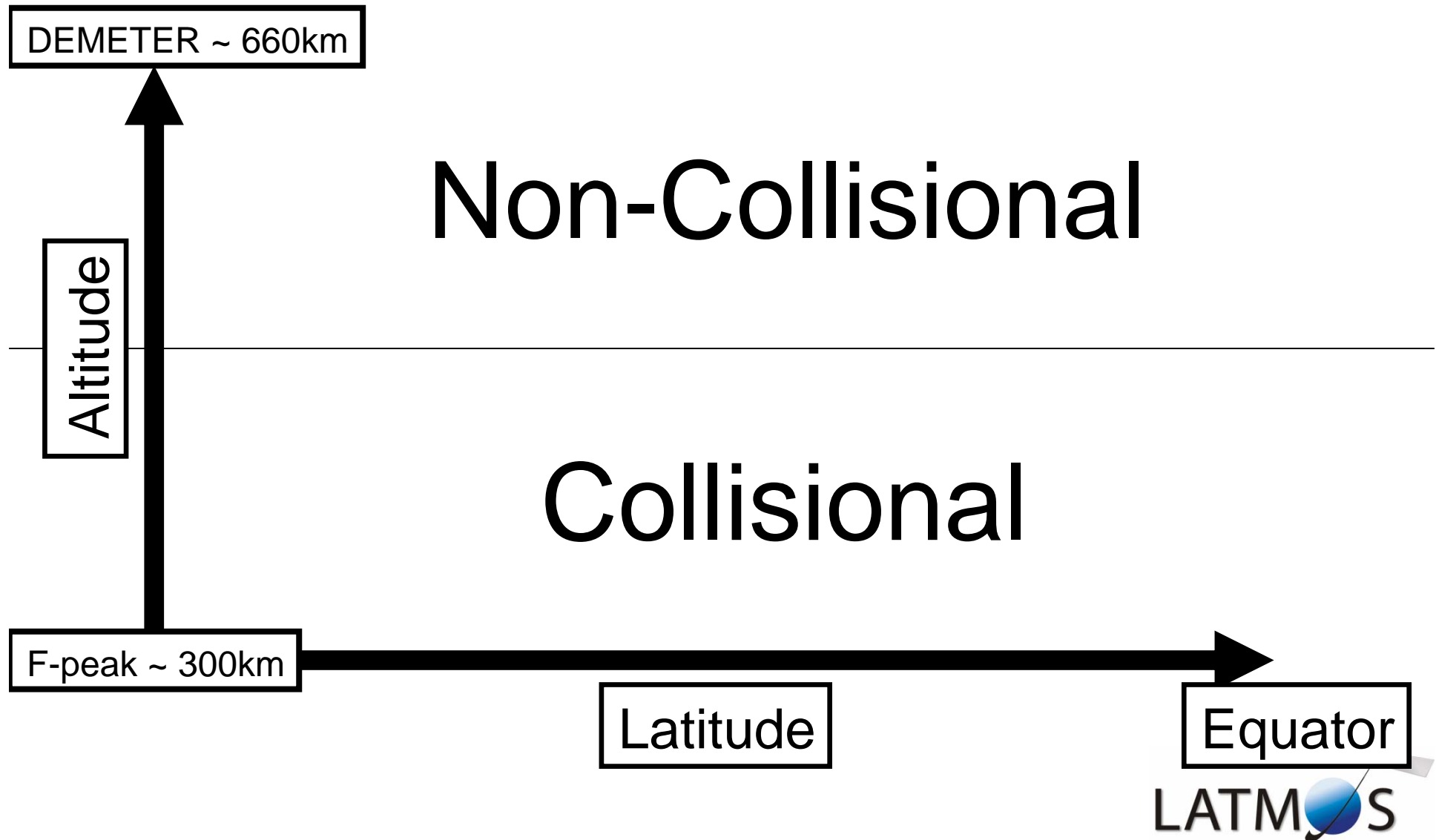


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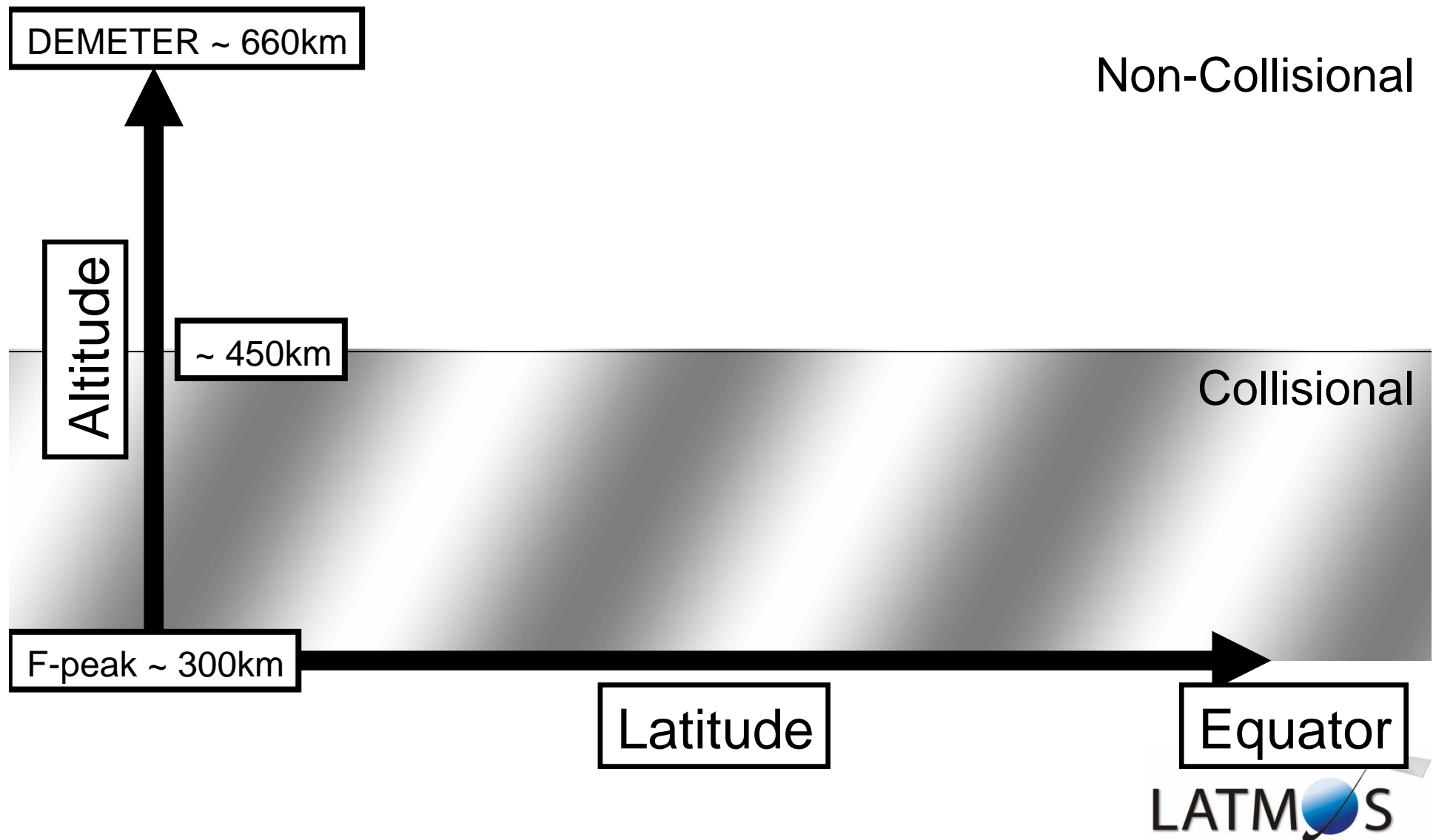


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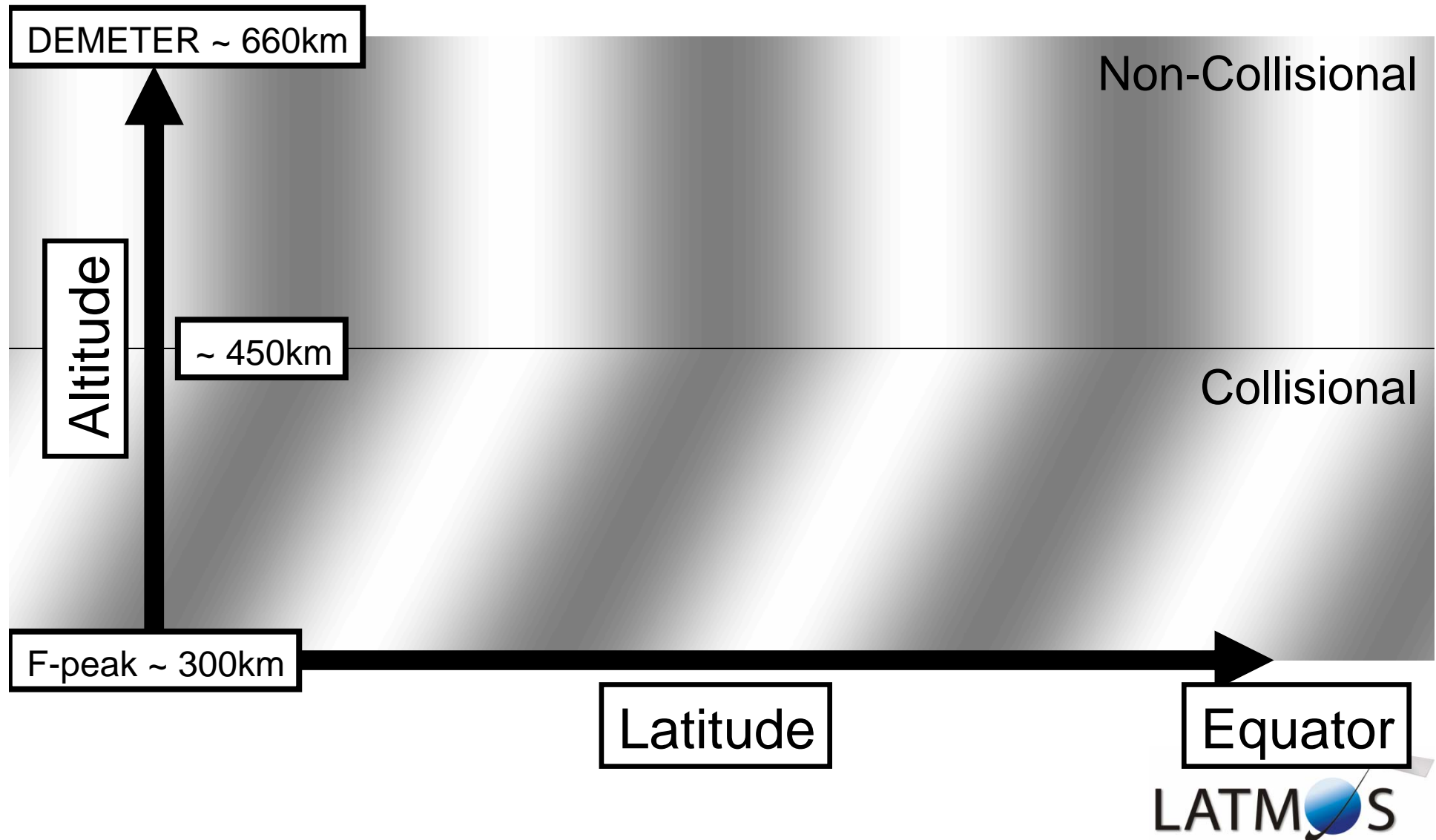


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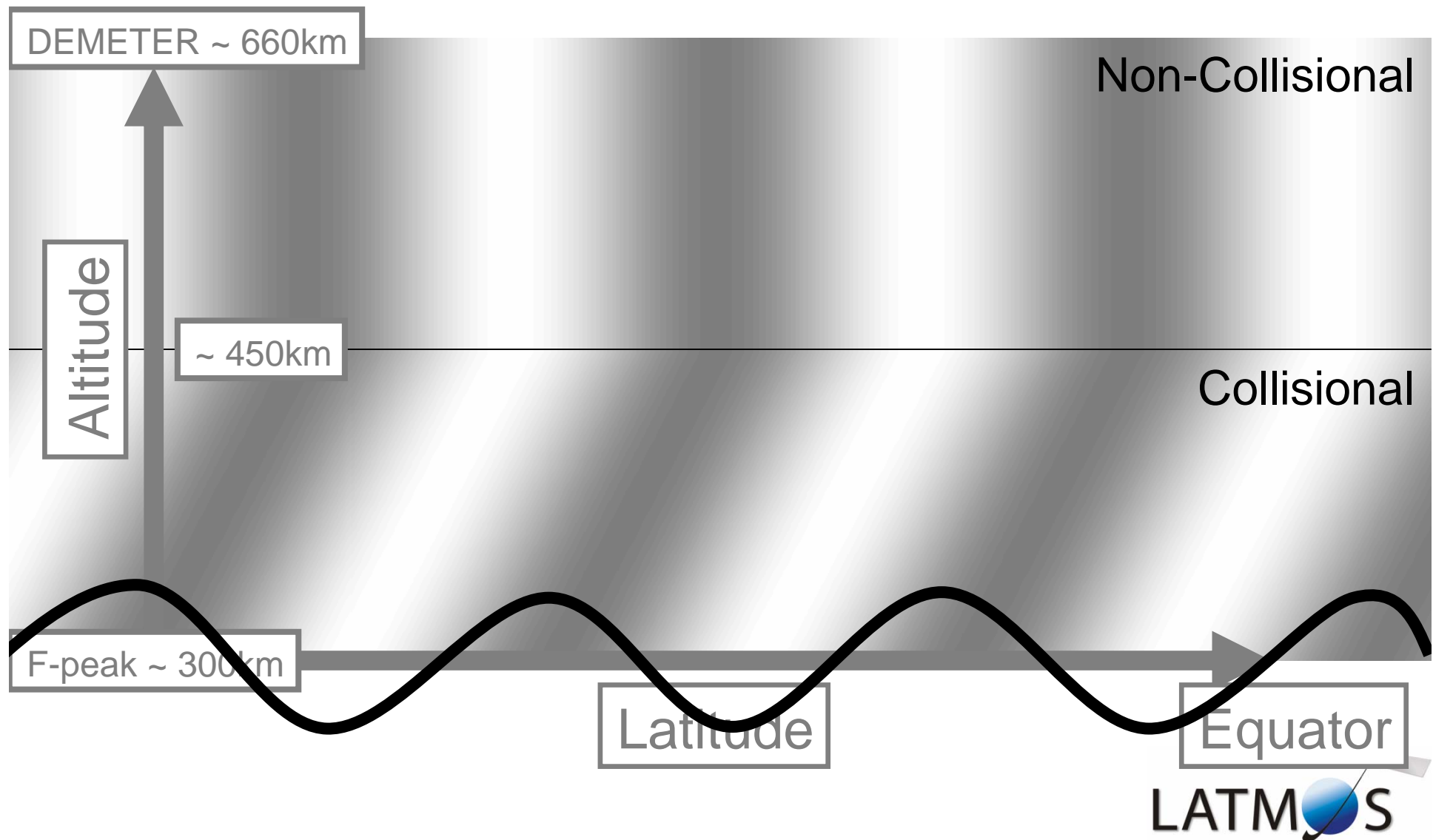


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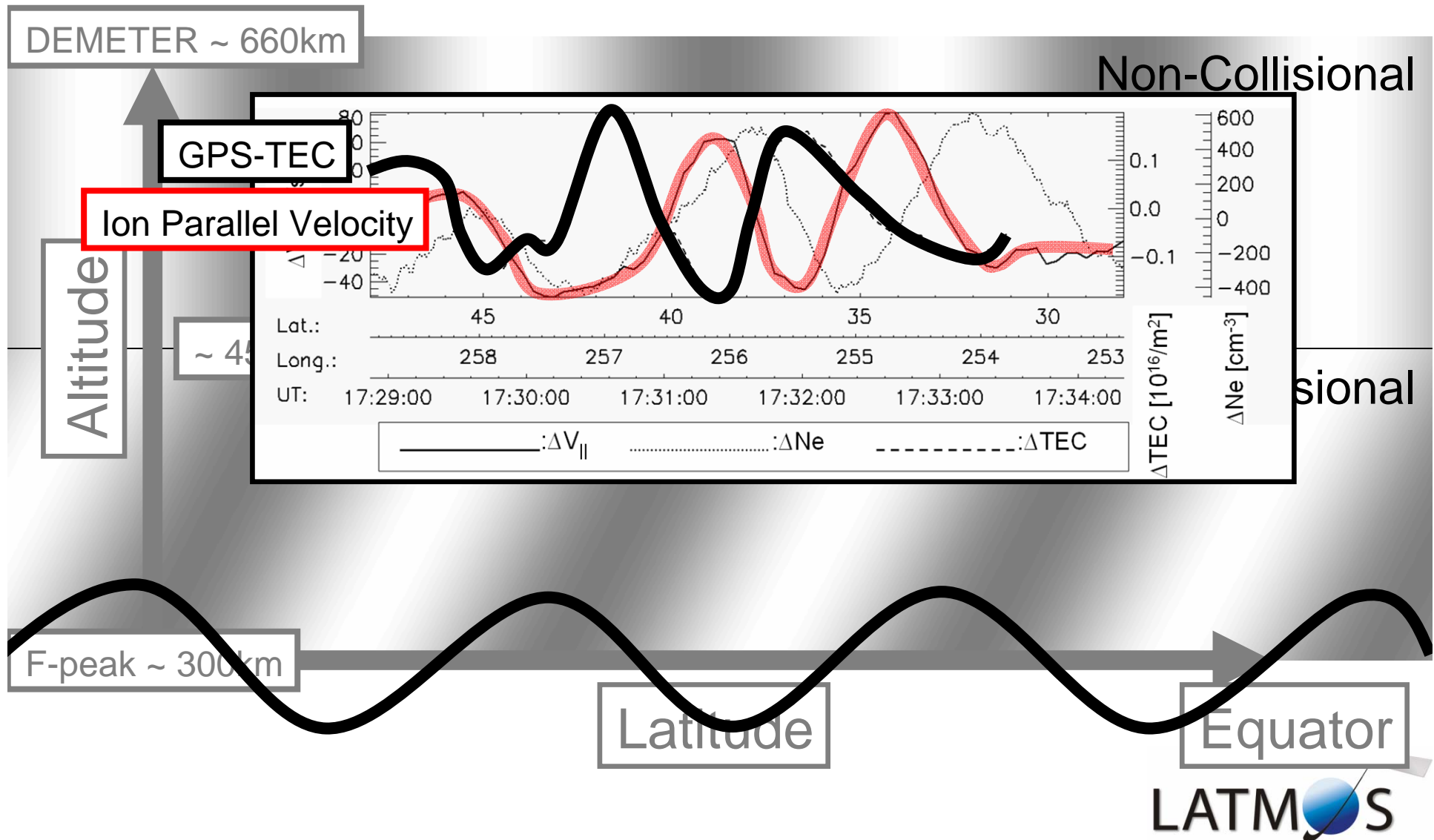


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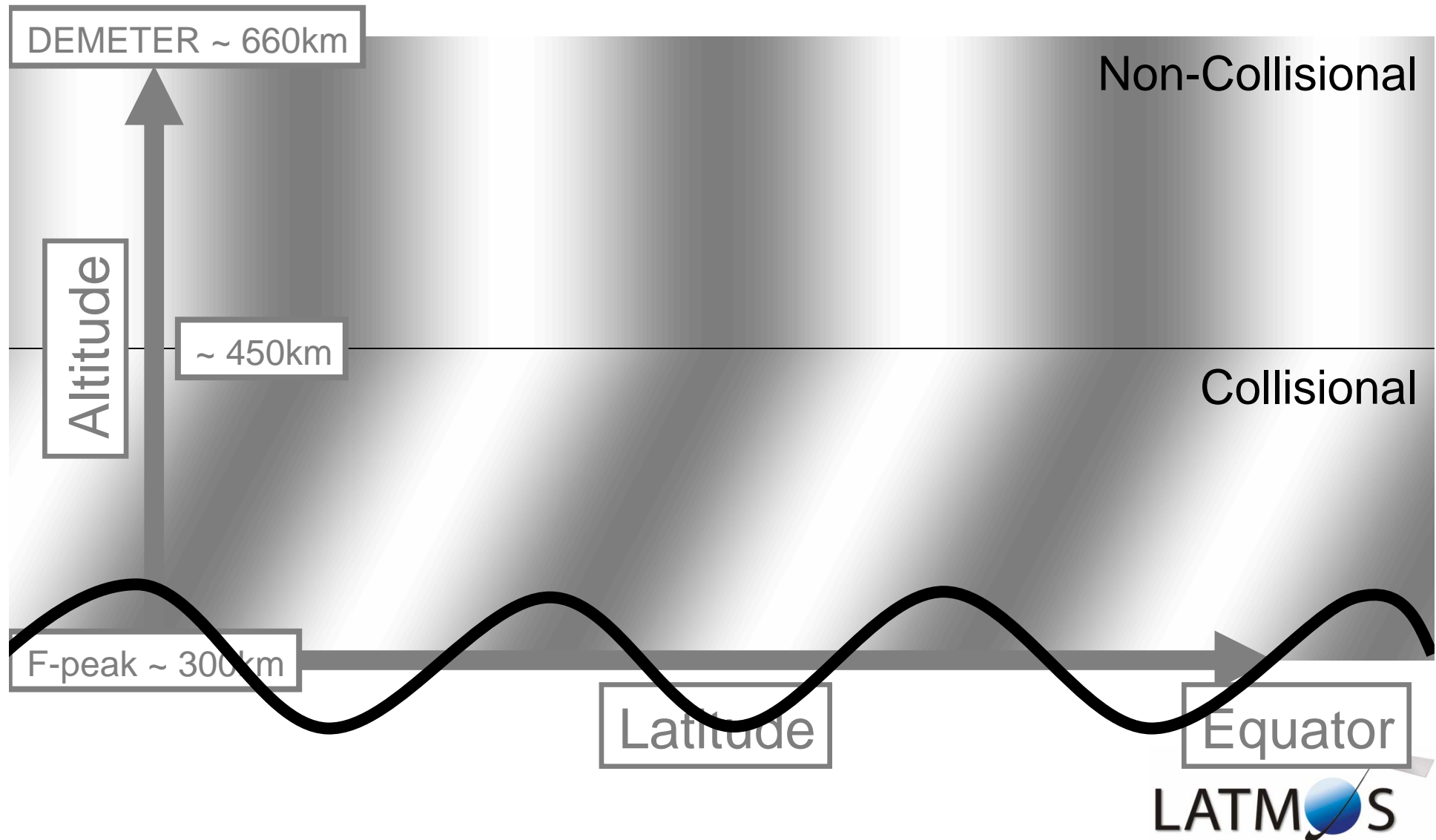


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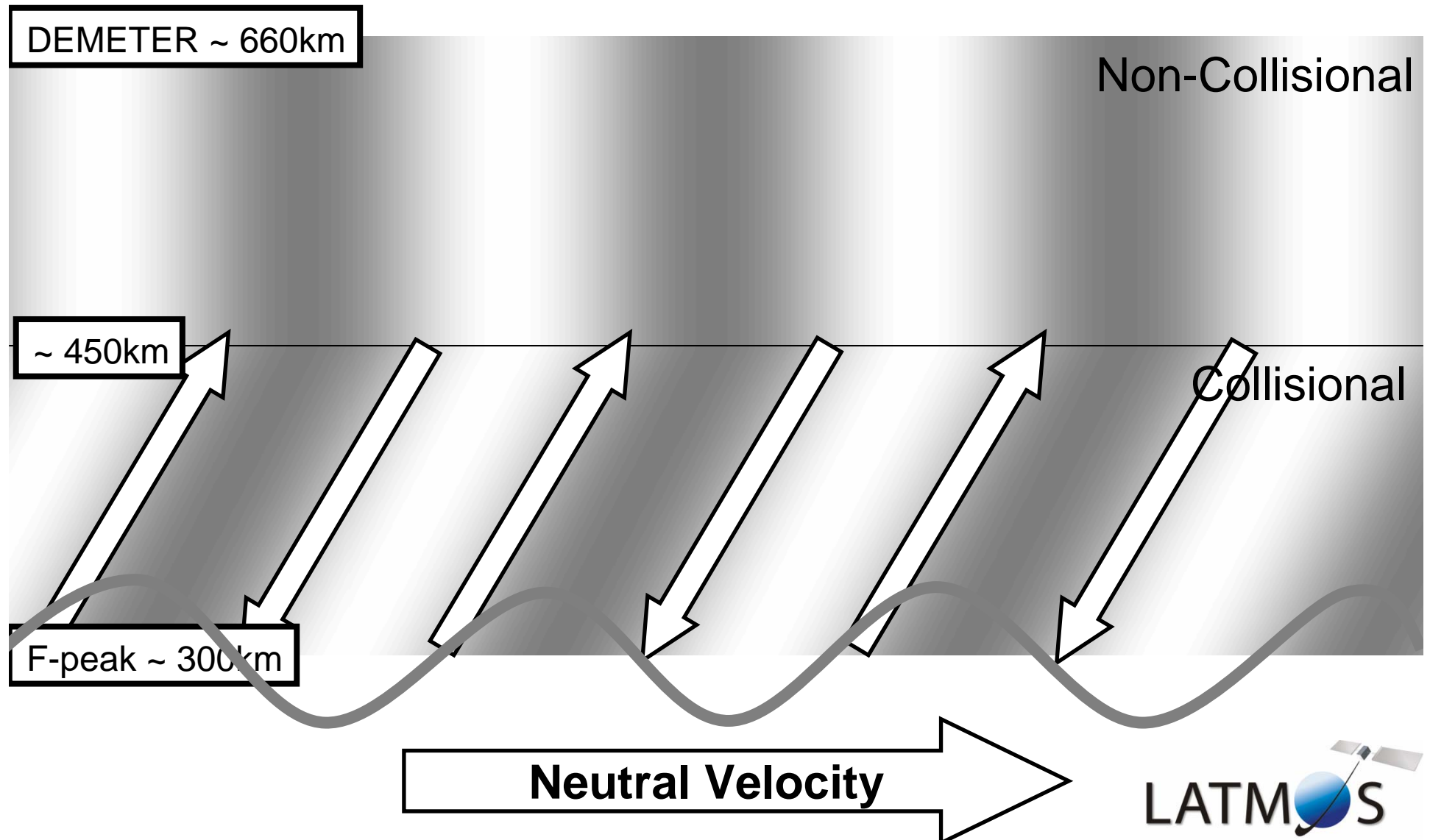


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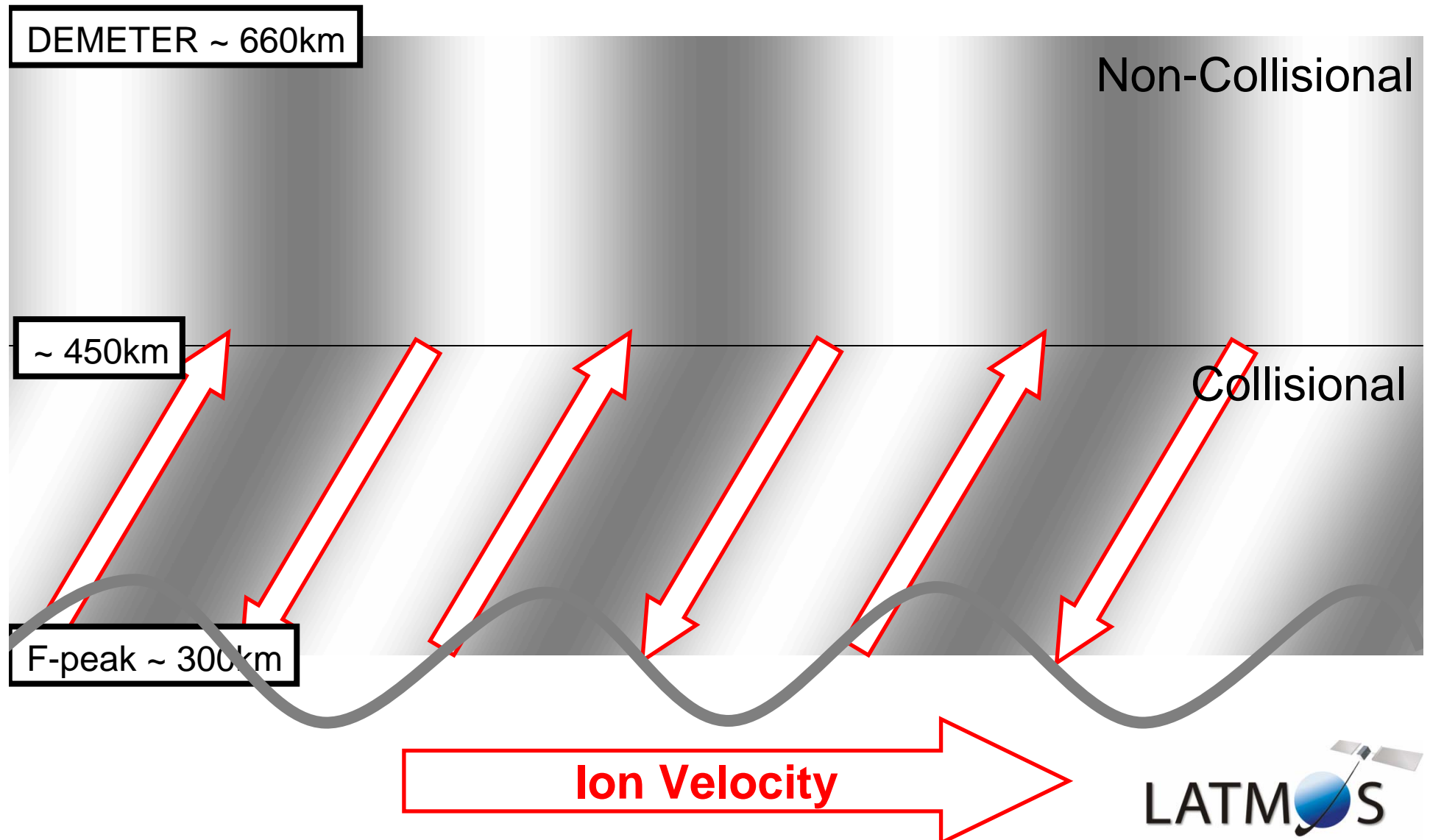


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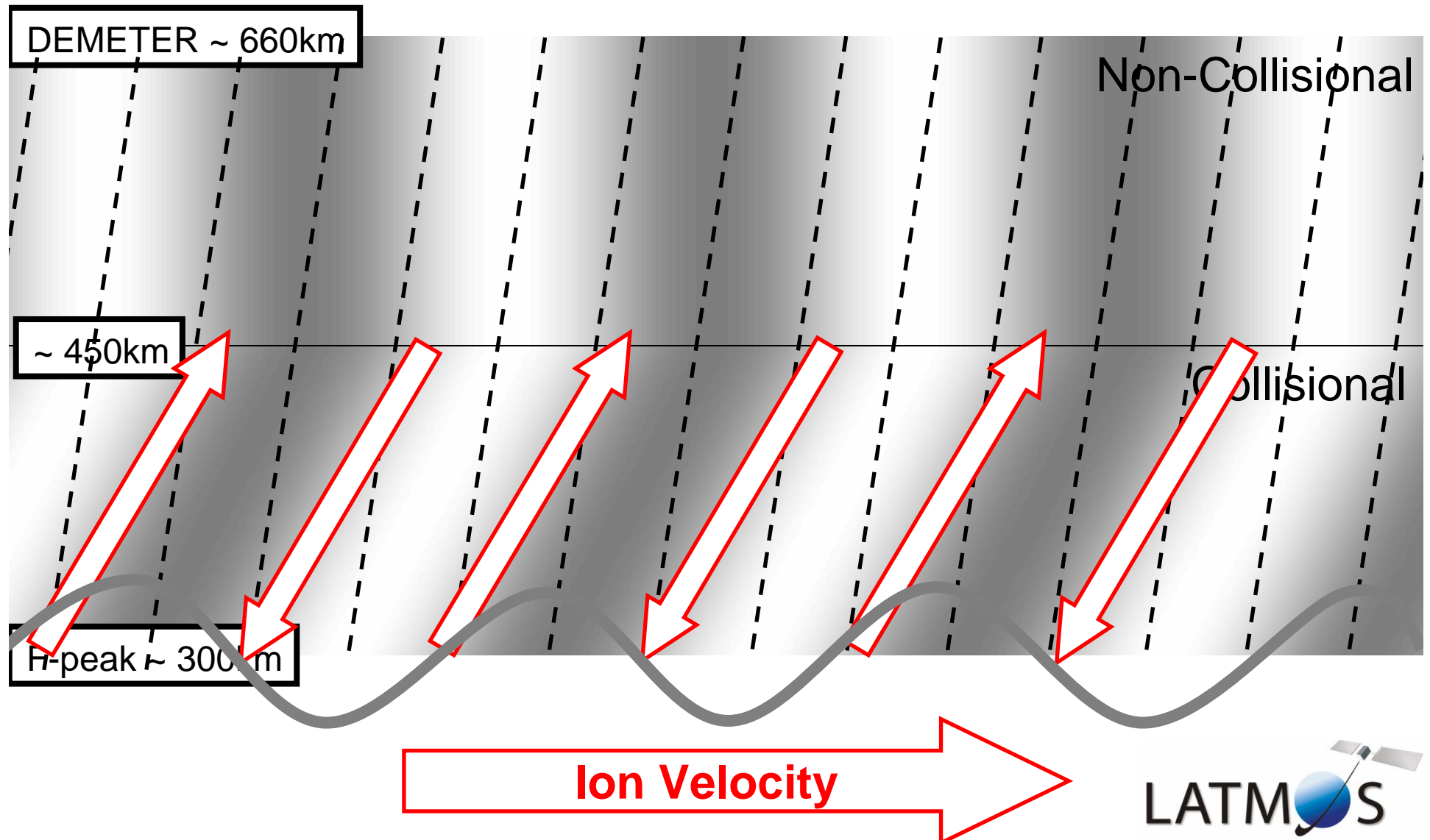


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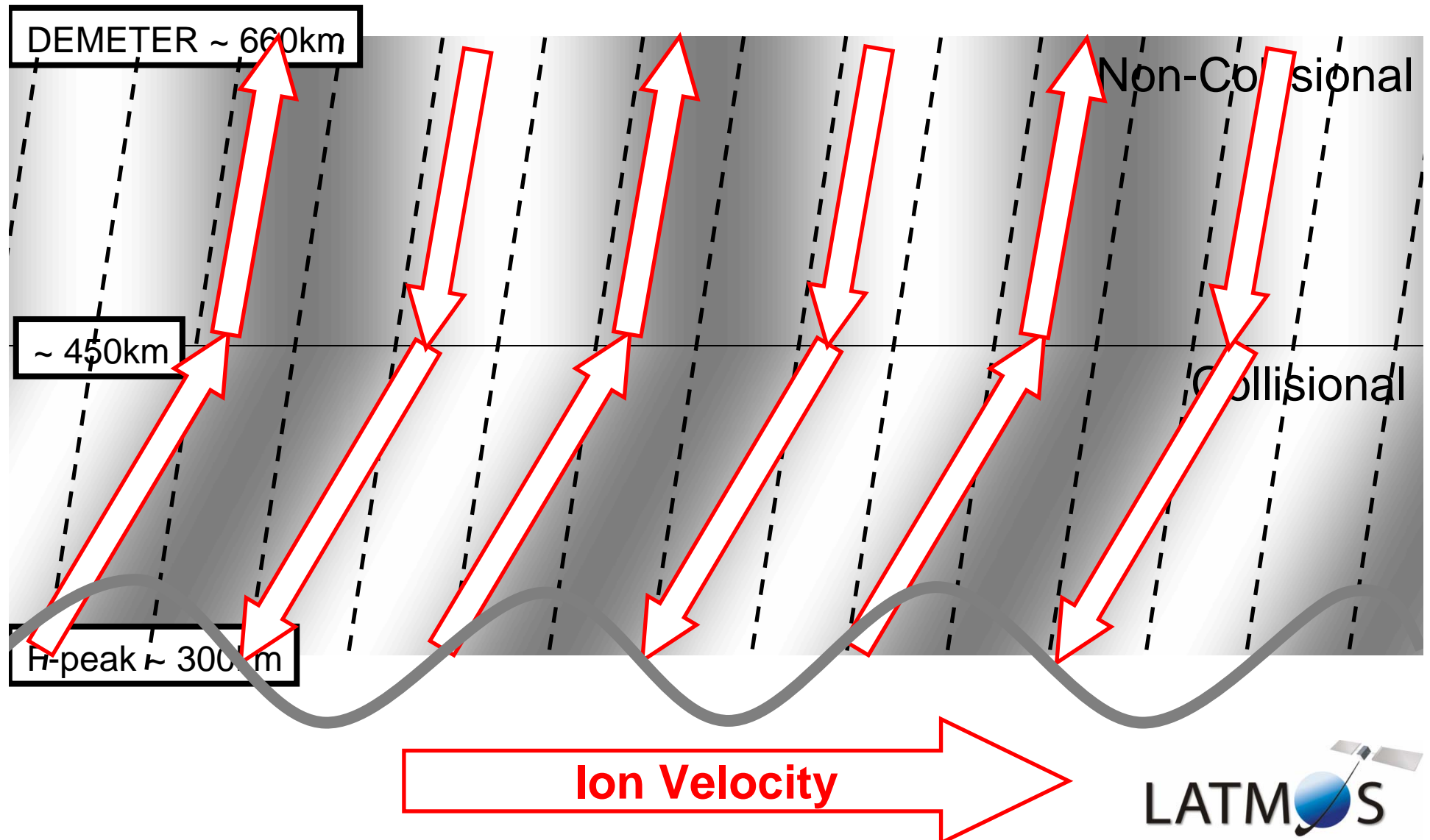


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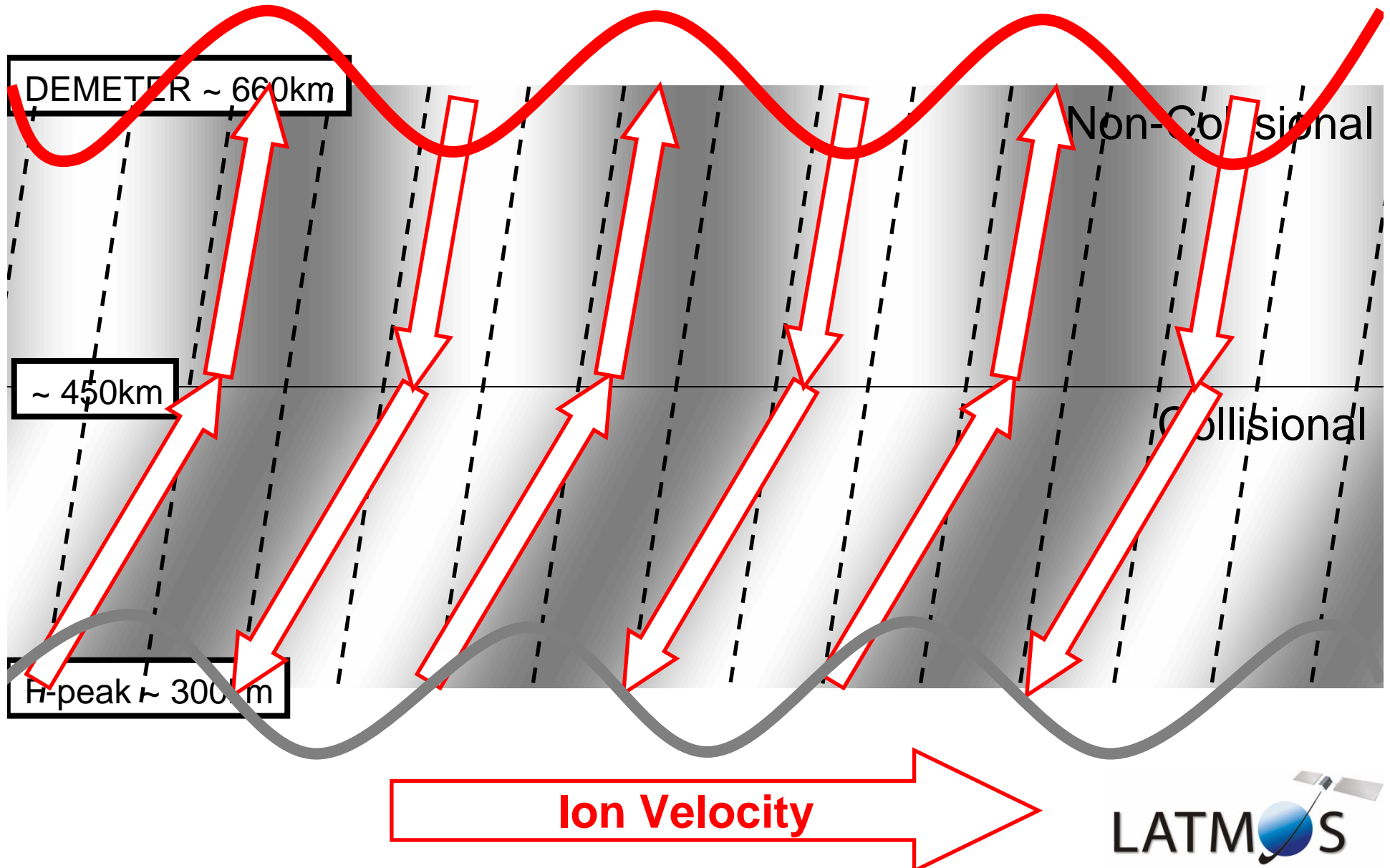


## Observation (DEMETER/GPS-TEC)



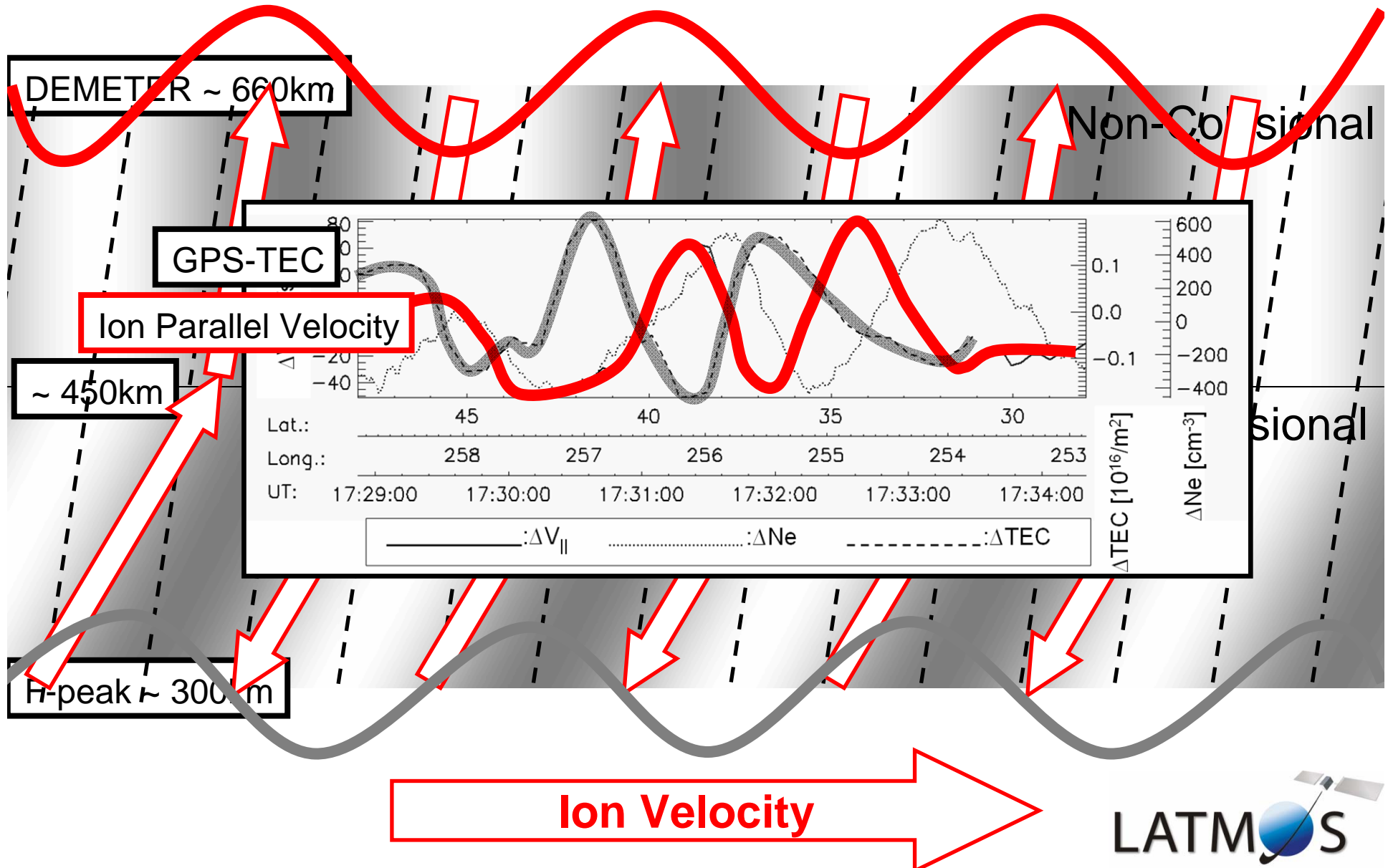


## Observation (DEMETER/GPS-TEC)



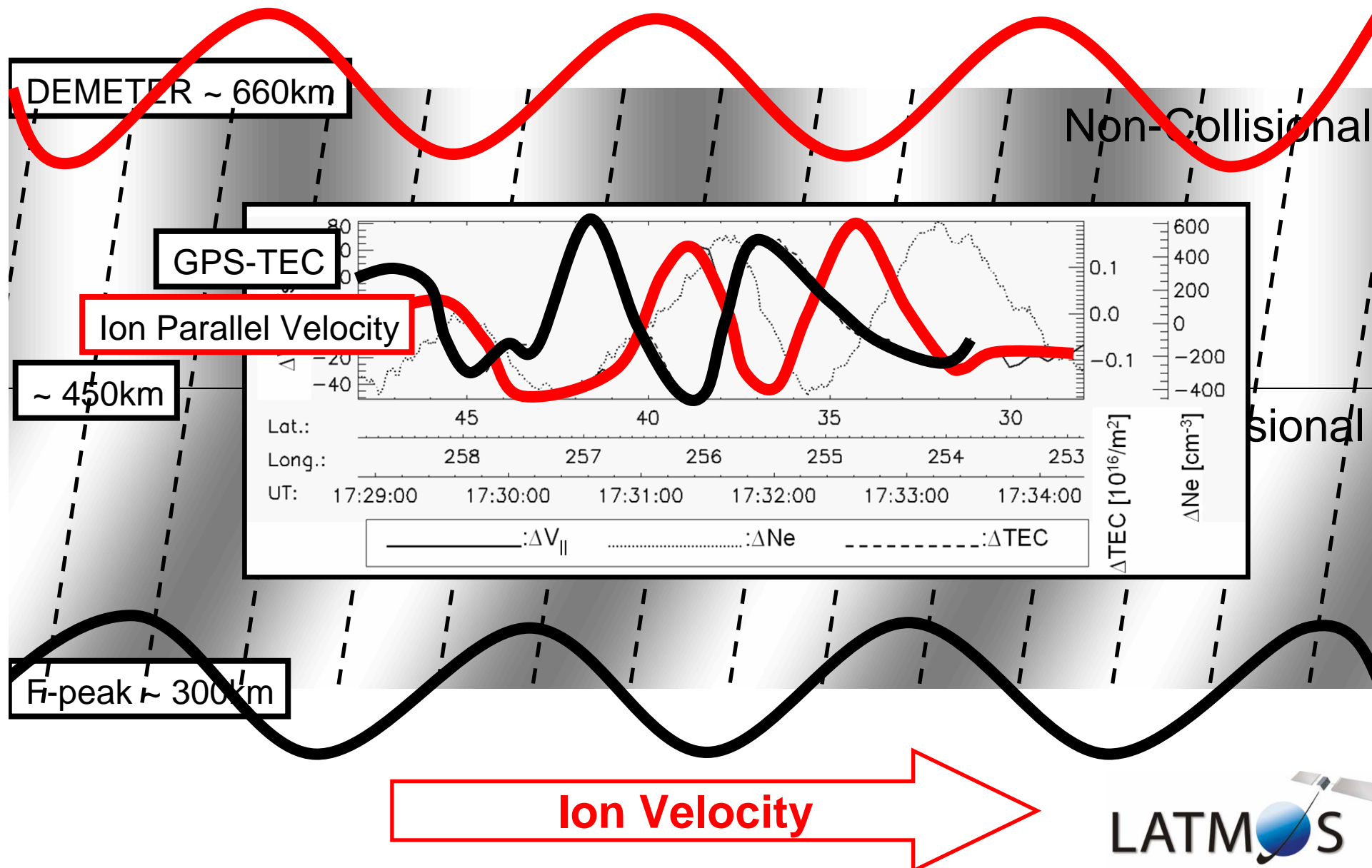


# Observation (DEMETER/GPS-TEC)



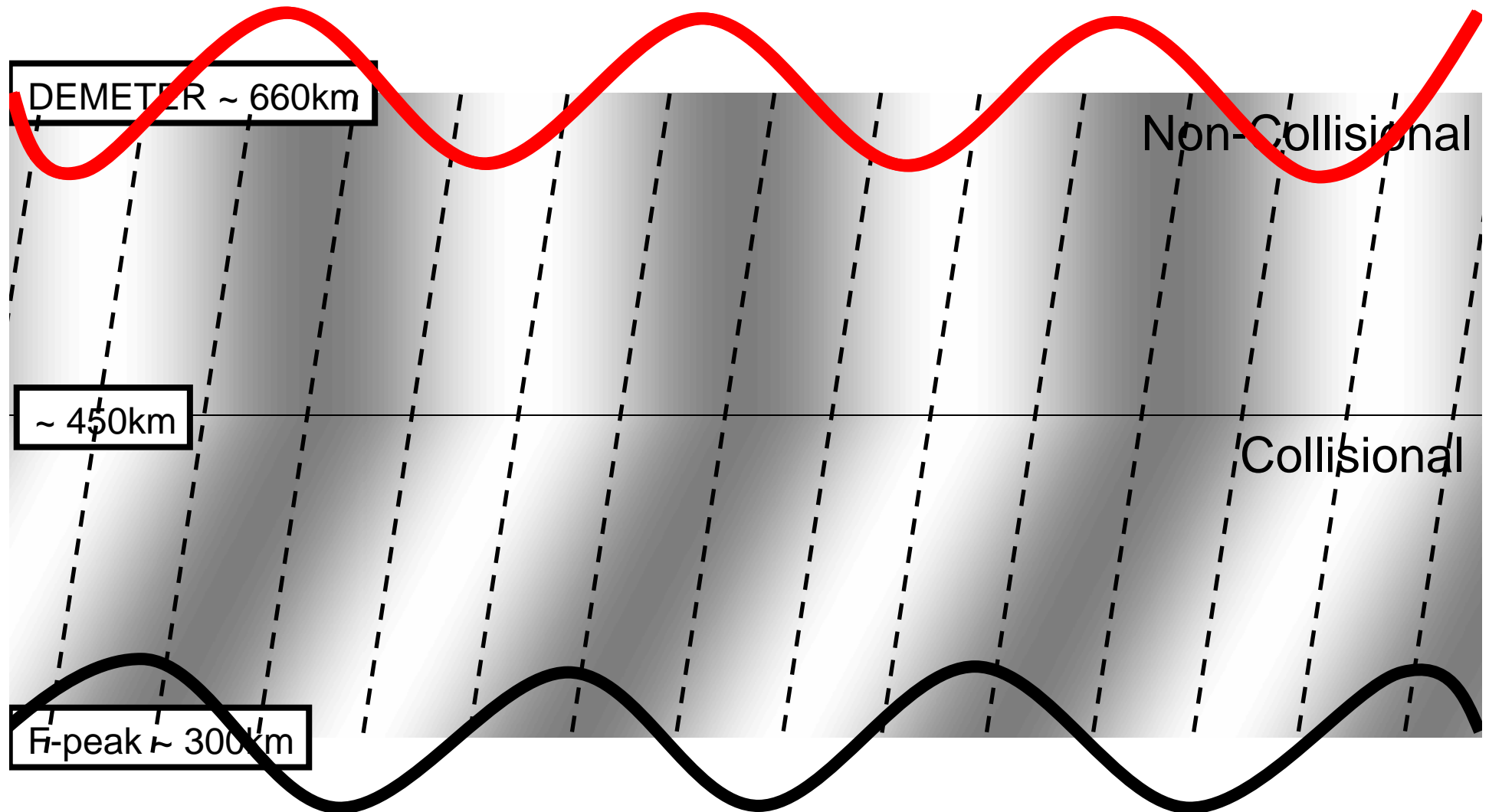


# Observation (DEMETER/GPS-TEC)



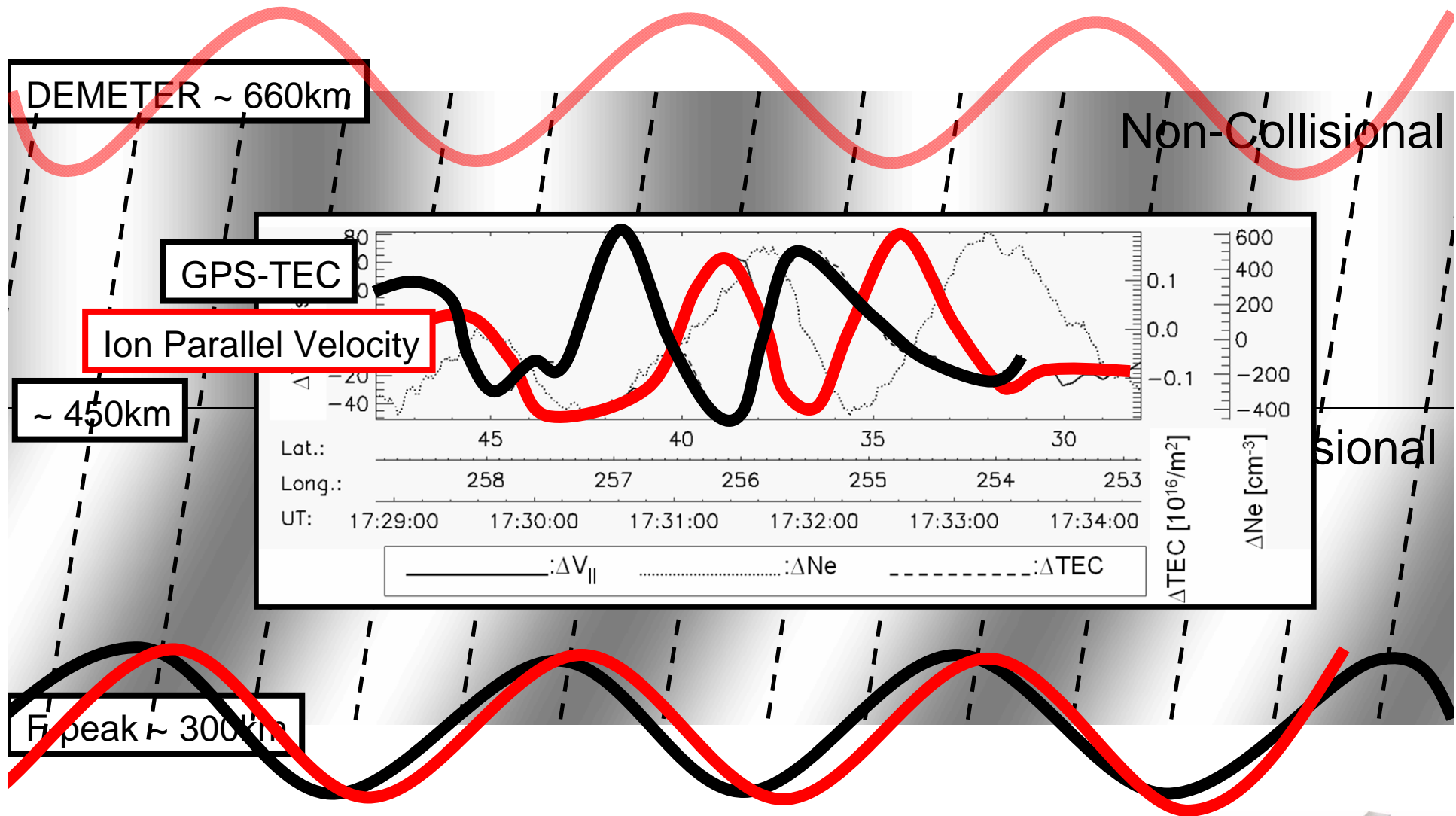


## Observation (DEMETER/GPS-TEC)



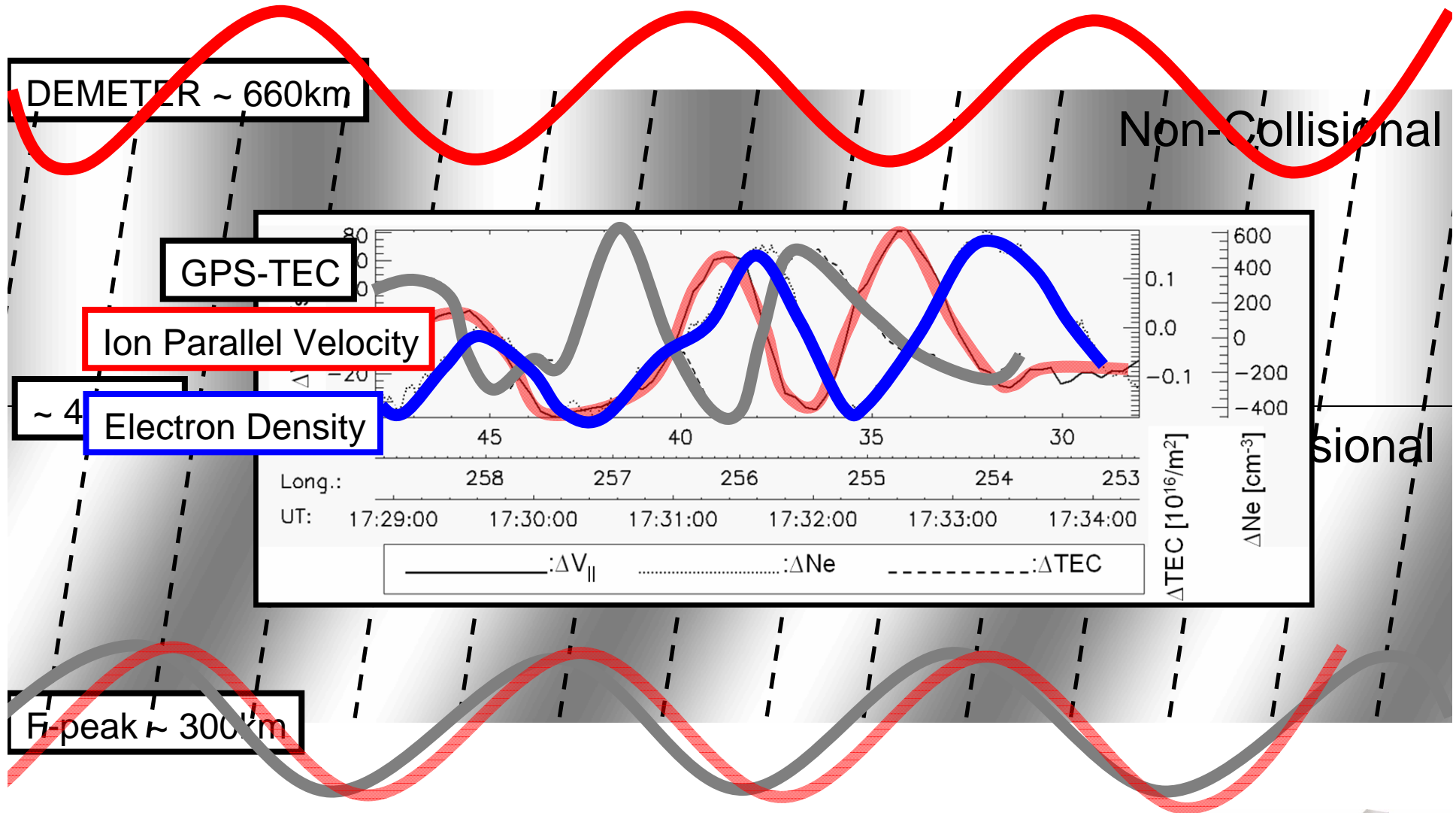


# Observation (DEMETER/GPS-TEC)



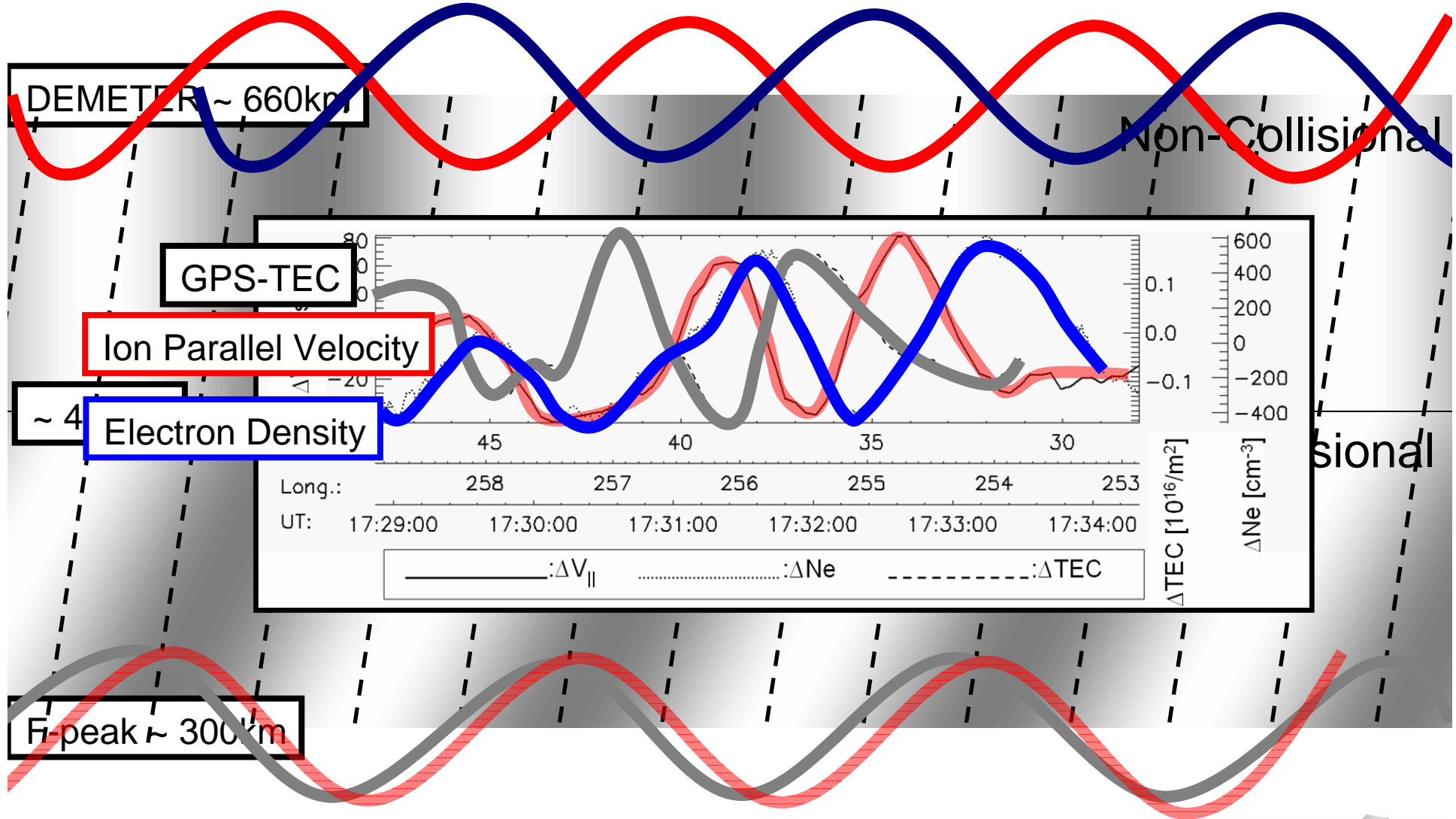


# Observation (DEMETER/GPS-TEC)



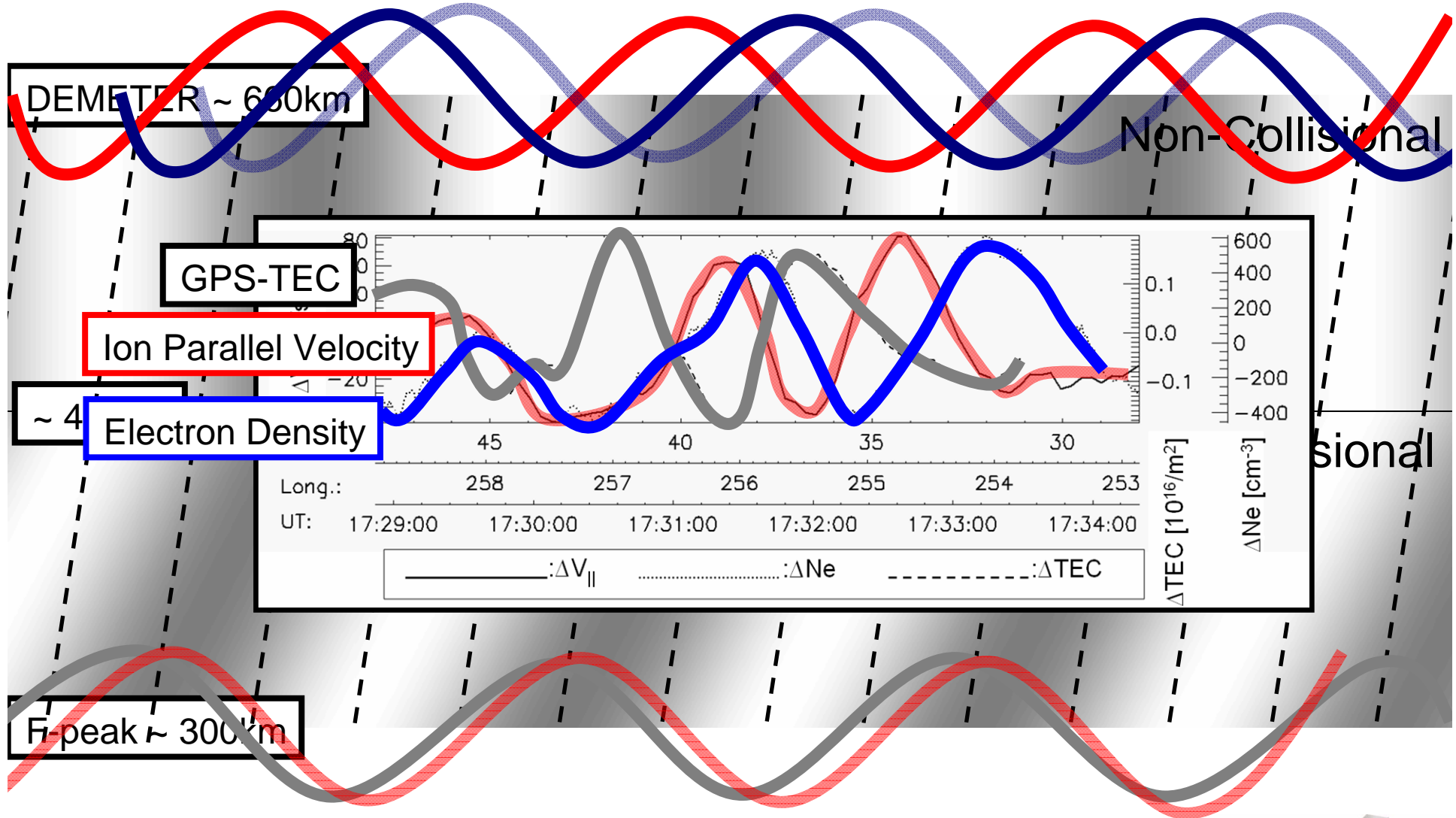


# Observation (DEMETER/GPS-TEC)





# Observation (DEMETER/GPS-TEC)

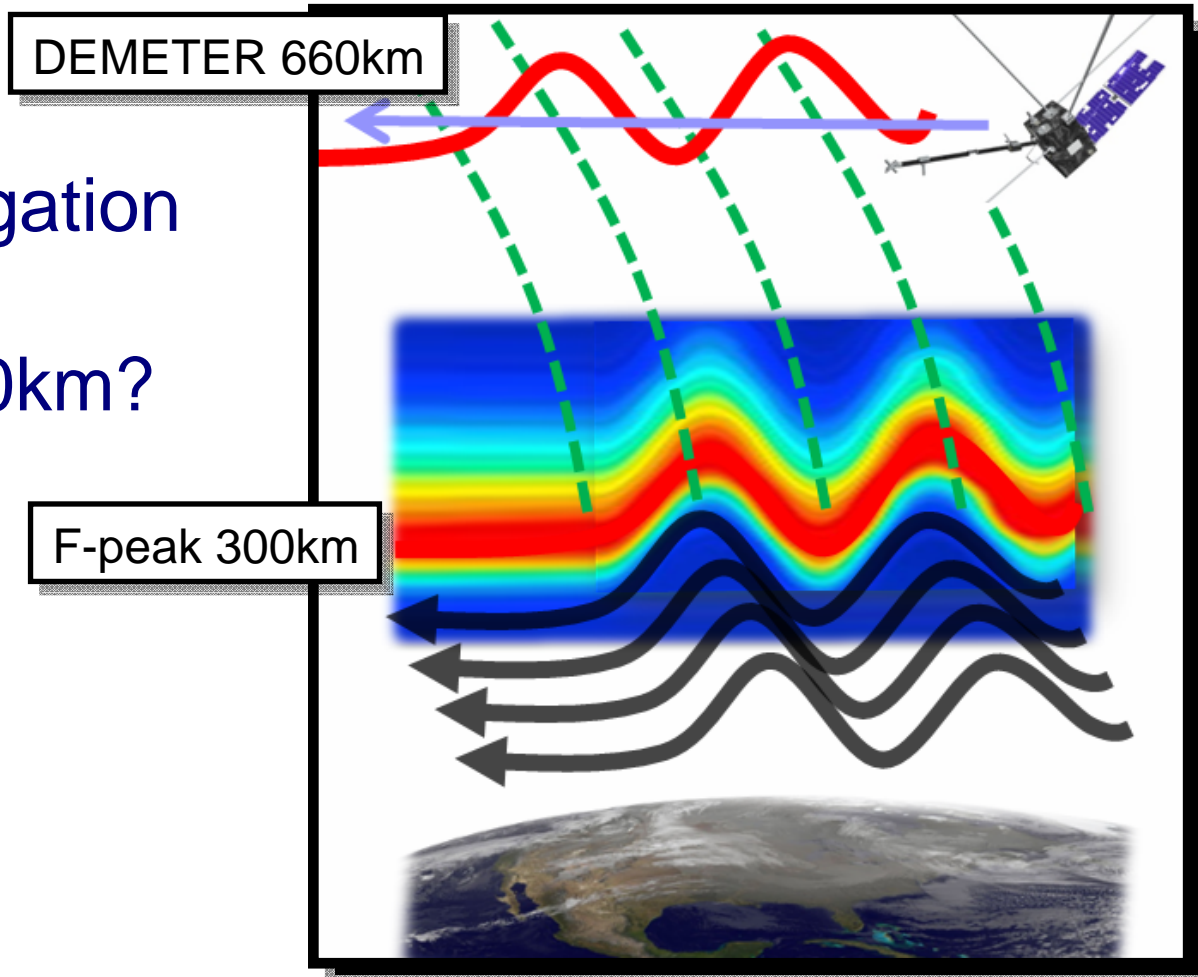




# Propagation in the Ionosphere

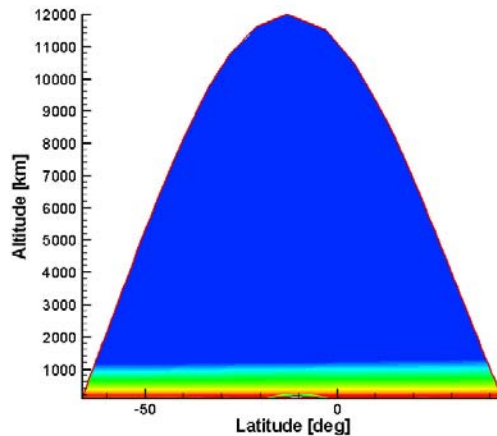
What is the propagation mechanism from 300km to 660km?

Ion Acoustic ?





# SAMI2



Normal SAMI2 Simulation

## OVERVIEW OF THE MODEL

*Low- to Mid-Latitude Ionosphere Models SAMI2/3*

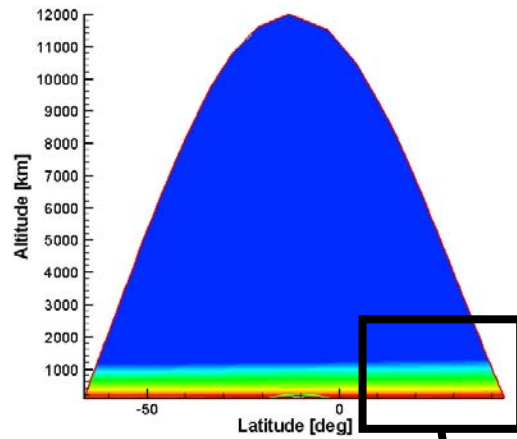
- ▷ Magnetic field: Offset, tilted dipole model
- ▷ Interhemispheric model
- ▷ **Nonorthogonal, nonuniform fixed grid**
- ▷ Seven (7) ion species (**all ions are equal**):
  - $H^+$ ,  $He^+$ ,  $N^+$ ,  $O^+$ ,  $N_2^+$ ,  $NO^+$ , and  $O_2^+$
  - Solve continuity and momentum for all 7 species
  - Solve temperature for  $H^+$ ,  $He^+$ ,  $O^+$ , and  $e^-$
- ▷ Plasma motion
  - $E \times B$  drift perpendicular to  $B$   
(both vertical and **longitudinal** in SAMI3)
  - **ion inertia included parallel to  $B$**
- ▷ Neutral species: NRLMSISE00 and HWM93
- ▷ Chemistry: 21 reactions + recombination
- ▷ Photoionization: Daytime and nighttime

<http://wwwppd.nrl.navy.mil/sami2-OSP/ionospheric-physics/index.html>

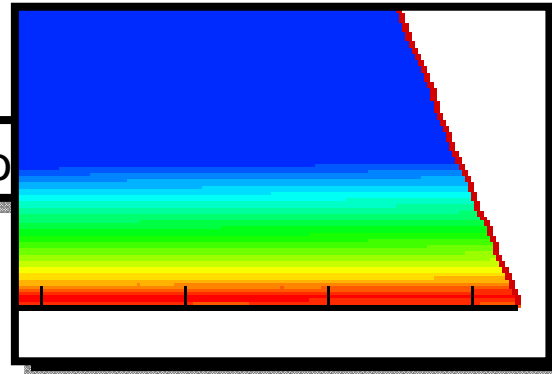




# SAMI2



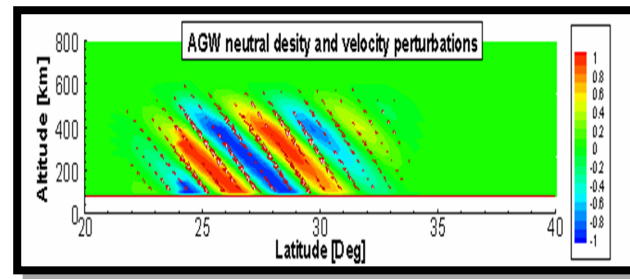
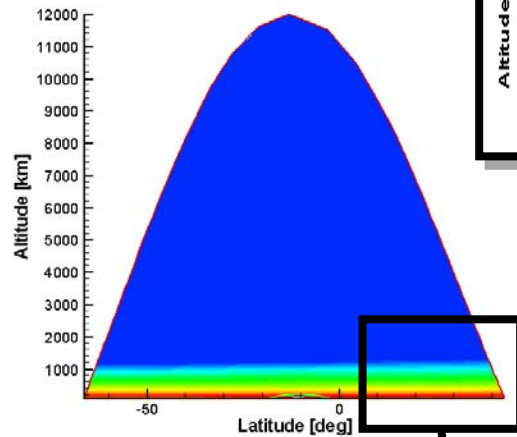
Normal SAMI2 Simulation



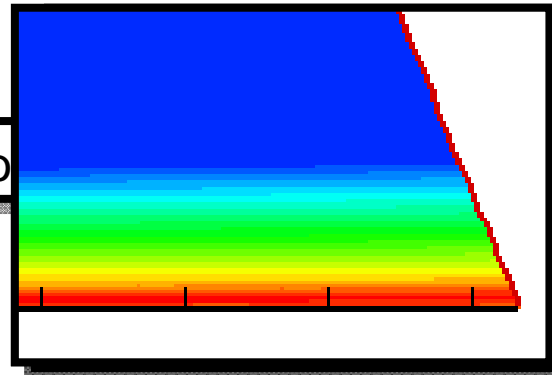


# SAMI2

## Neutral gas AGW perturbation



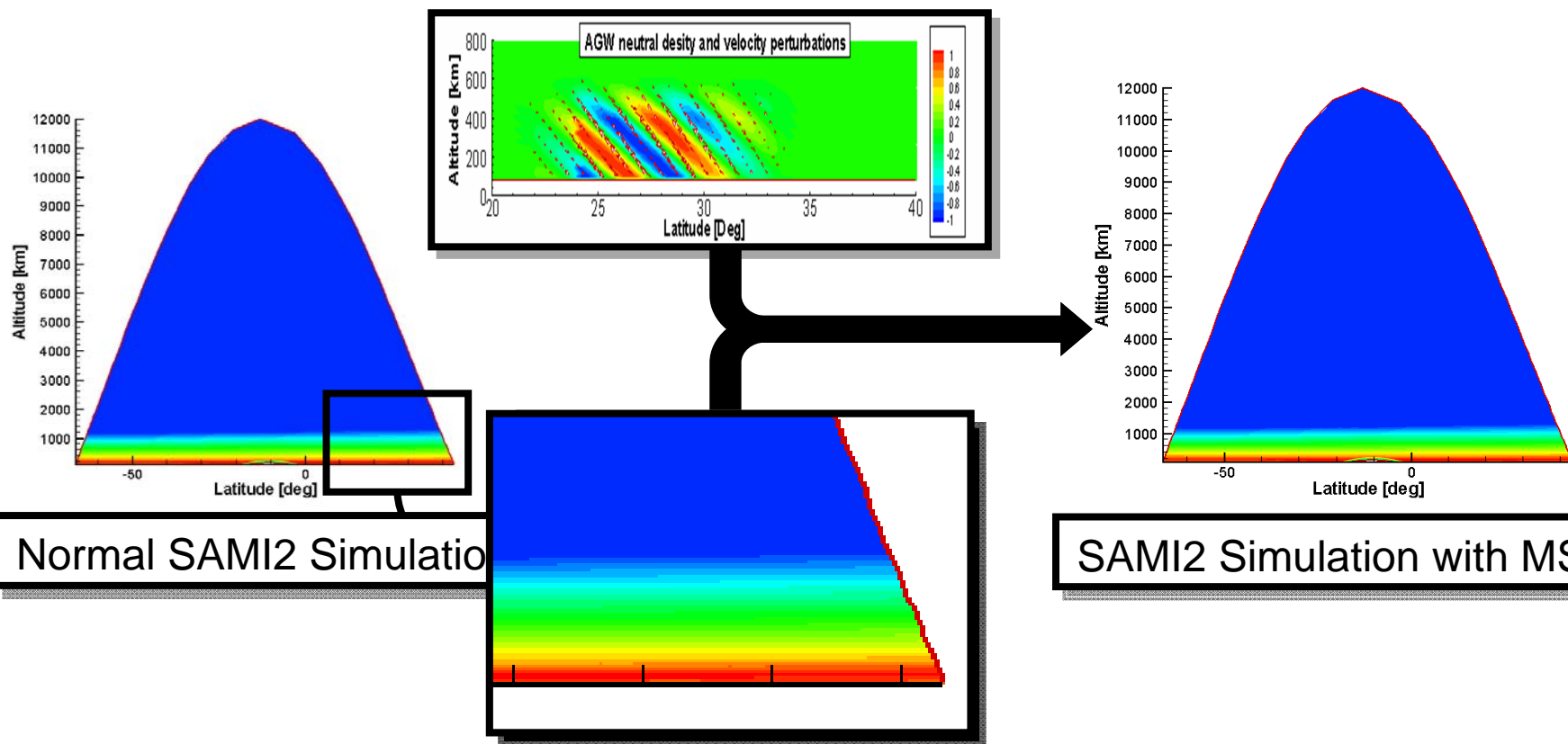
## Normal SAMI2 Simulation





# SAMI2

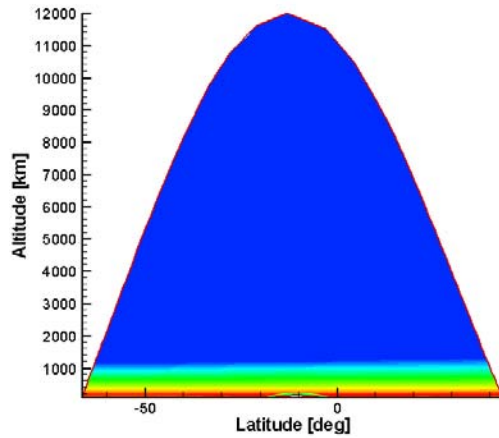
## Neutral gas AGW perturbation



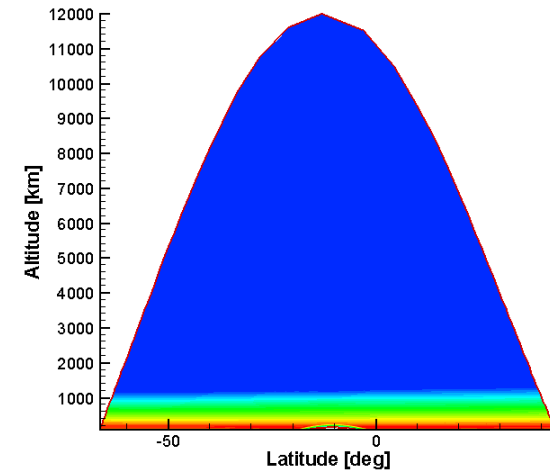


# SAMI2

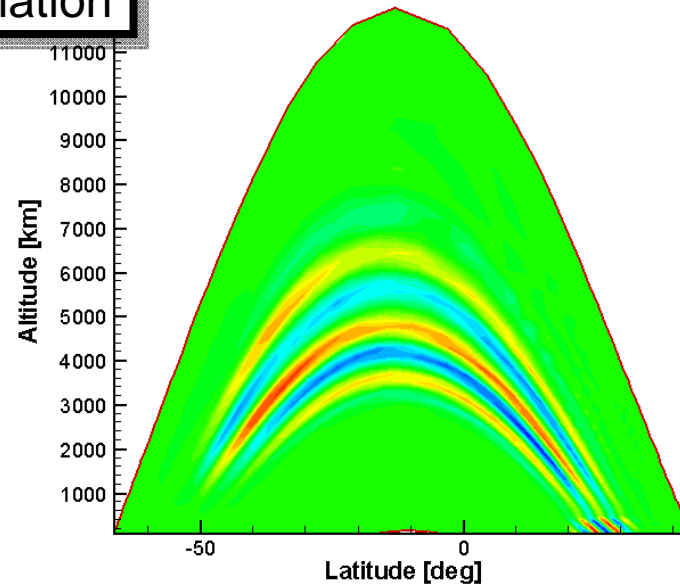
## Difference



Normal SAMI2 Simulation

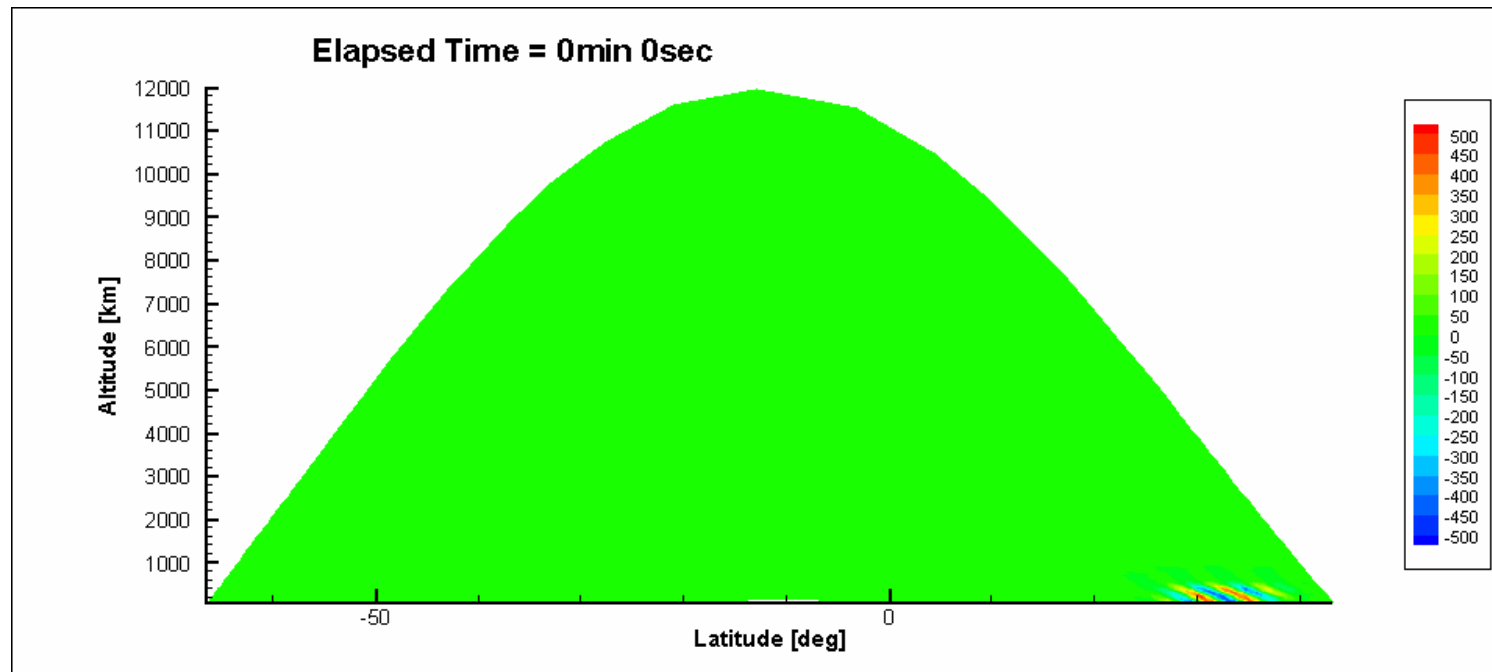


SAMI2 Simulation with MSTID





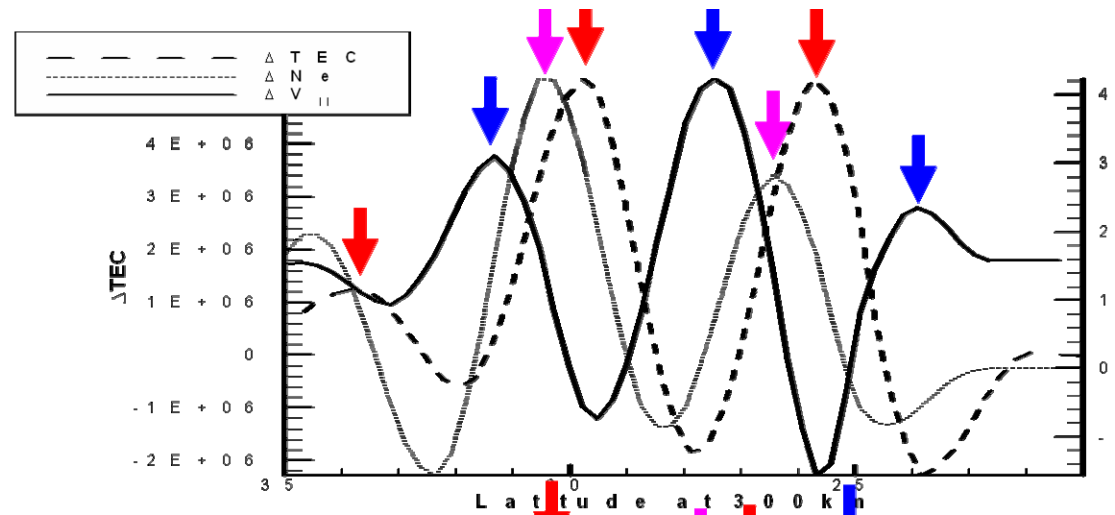
# SAMI2



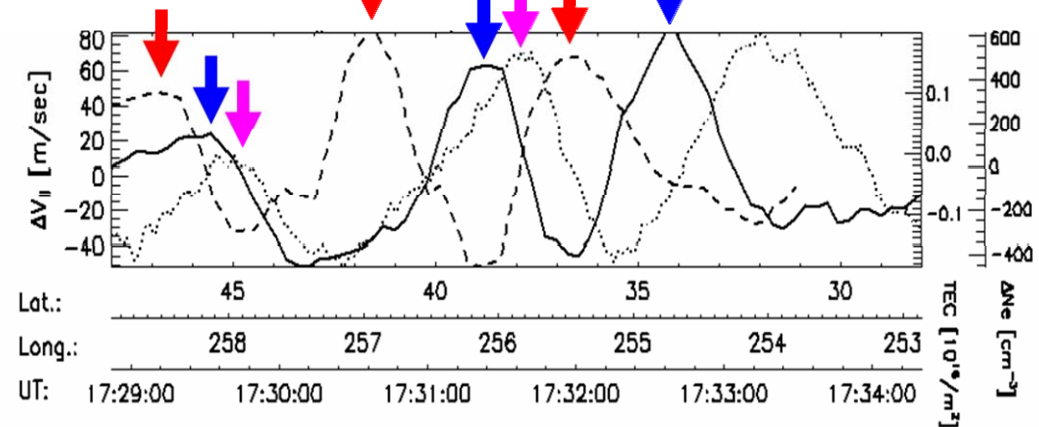


# Observation vs SAMI2

SAMI2  
(Simulation)



DEMETER/GPS-TEC  
(Observation)





# Observation vs SAMI2

Ion Acoustic wave in SAMI2  
for each ion species

$$v_s = \sqrt{\frac{\gamma_e K_e T_e + \gamma_i Z K_i T_i}{M}}$$

where

$K_B$  : Boltzmann's constant

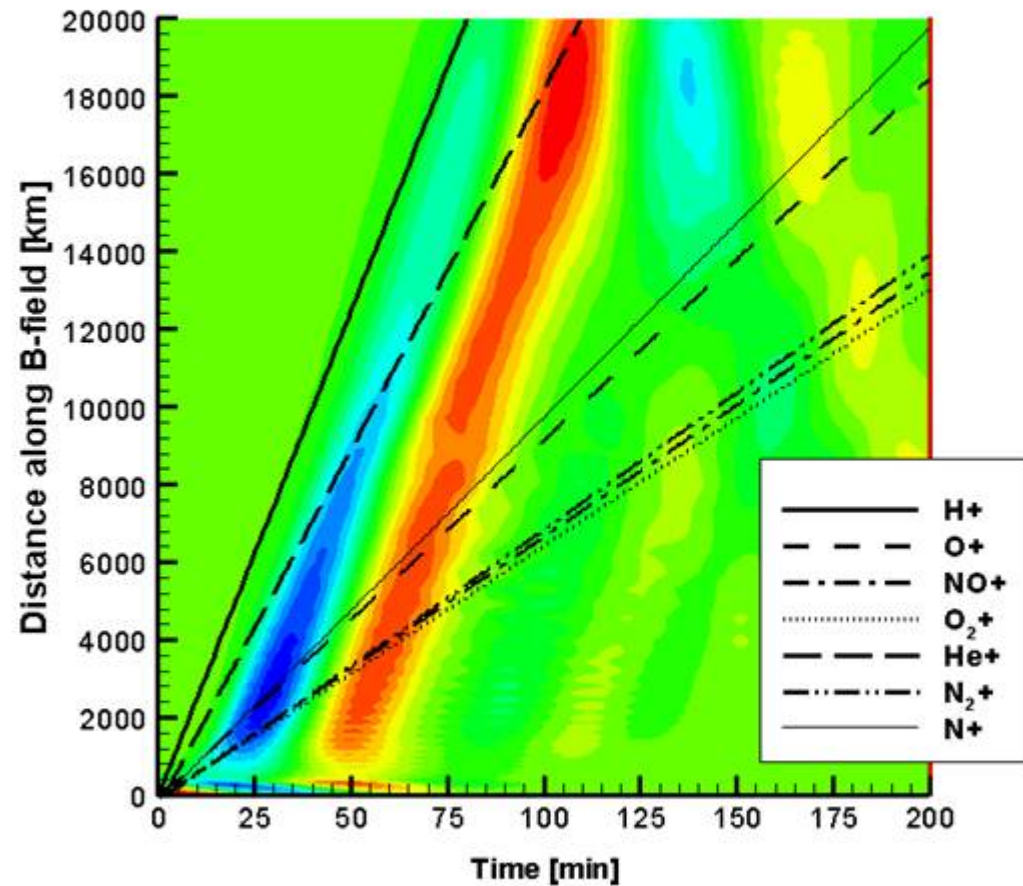
$M$  : Mass of the ion

$Z$  : Charge,

$T_e$  : Temperature of the electrons

$T_i$  : Temperature of the ions

$\gamma_e \sim 1$  and  $\gamma_i \sim 3$





# Conclusions

- First Simultaneous Observation of Day-time MSTIDs
- Simulation of plasma propagation in the ionosphere (SAMI2)
- Ion Acoustic Wave is identified as a propagation mechanism.



END OF PRESENTATION





# Observation vs SAMI2

Ion Acoustic wave in SAMI2  
for each ion species

$$v_s = \sqrt{\frac{\gamma_e K_e T_e + \gamma_i Z K_i T_i}{M}}$$

where

$K_B$  : Boltzmann's constant

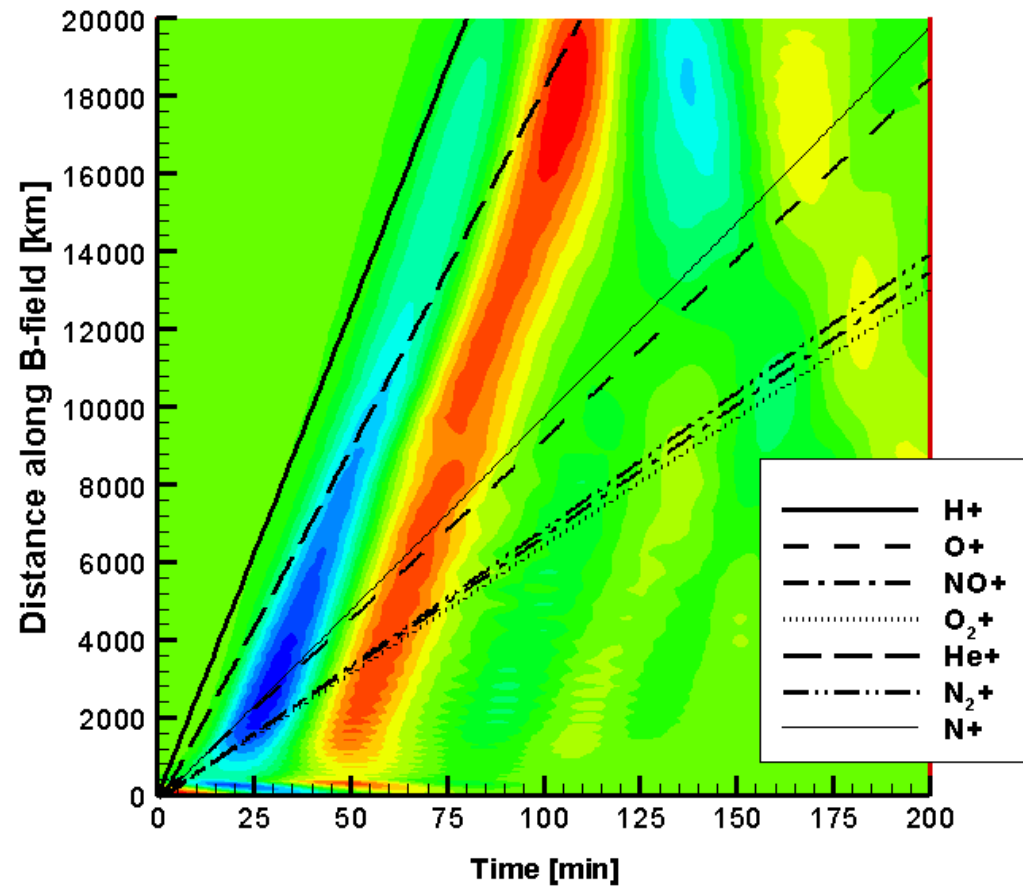
$M$  : Mass of the ion

$Z$  : Charge,

$T_e$  : Temperature of the electrons

$T_i$  : Temperature of the ions

$\gamma_e \sim 1$  and  $\gamma_i \sim 3$

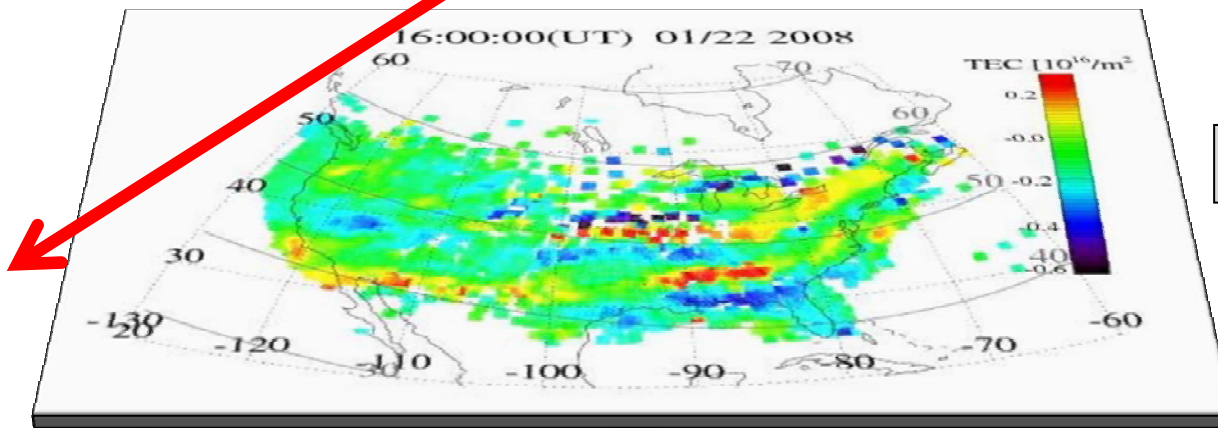




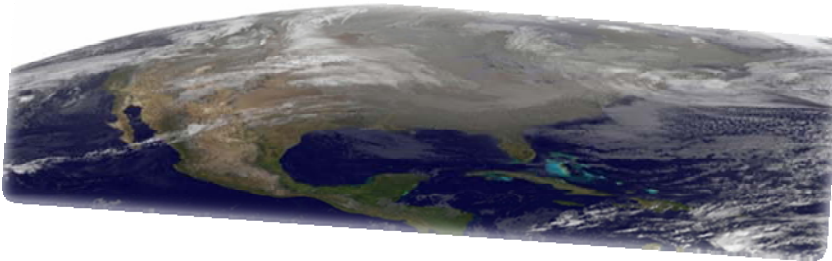
# Observation (DEMETER/GPS-TEC)



DEMETER at ~ 660km



F-peak at ~300km

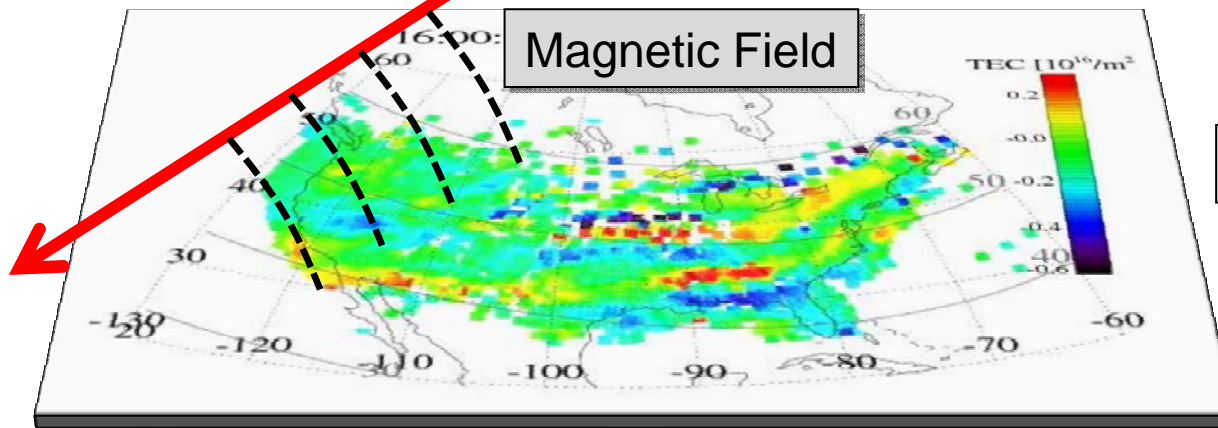




# Observation (DEMETER/GPS-TEC)

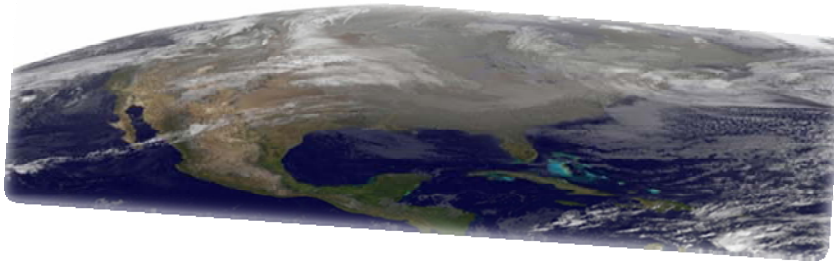


DEMETER at ~ 660km



Magnetic Field

F-peak at ~300km

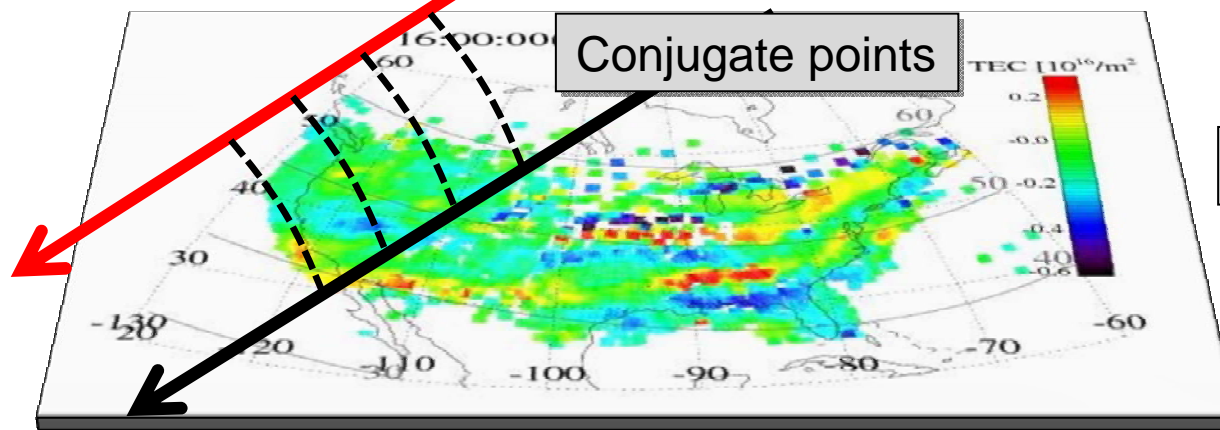




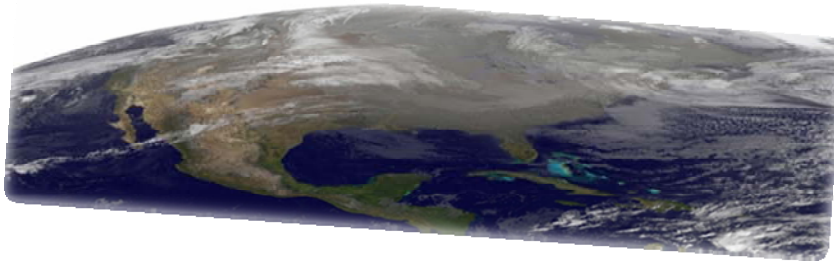
# Observation (DEMETER/GPS-TEC)



DEMETER at ~ 660km

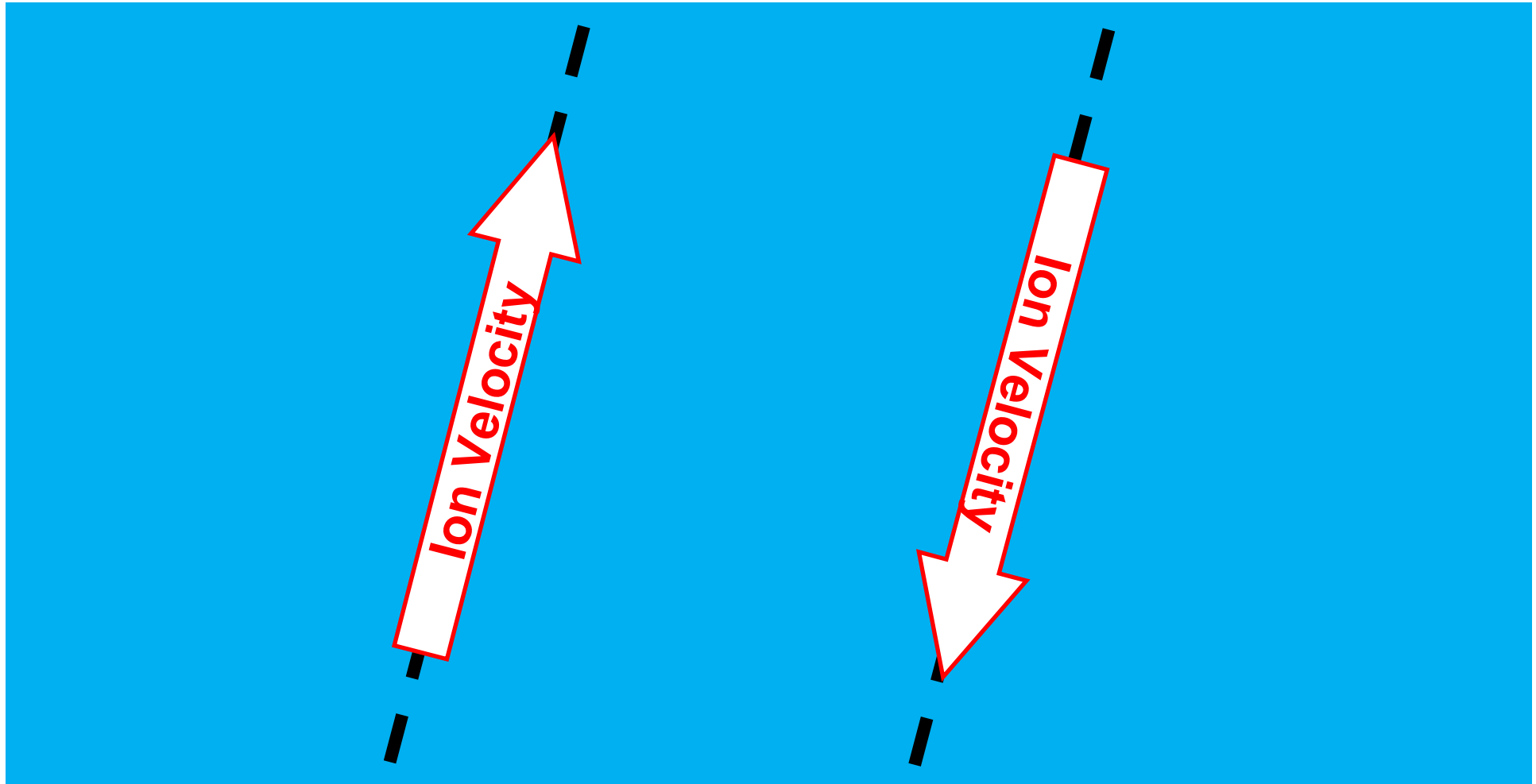


F-peak at ~300km



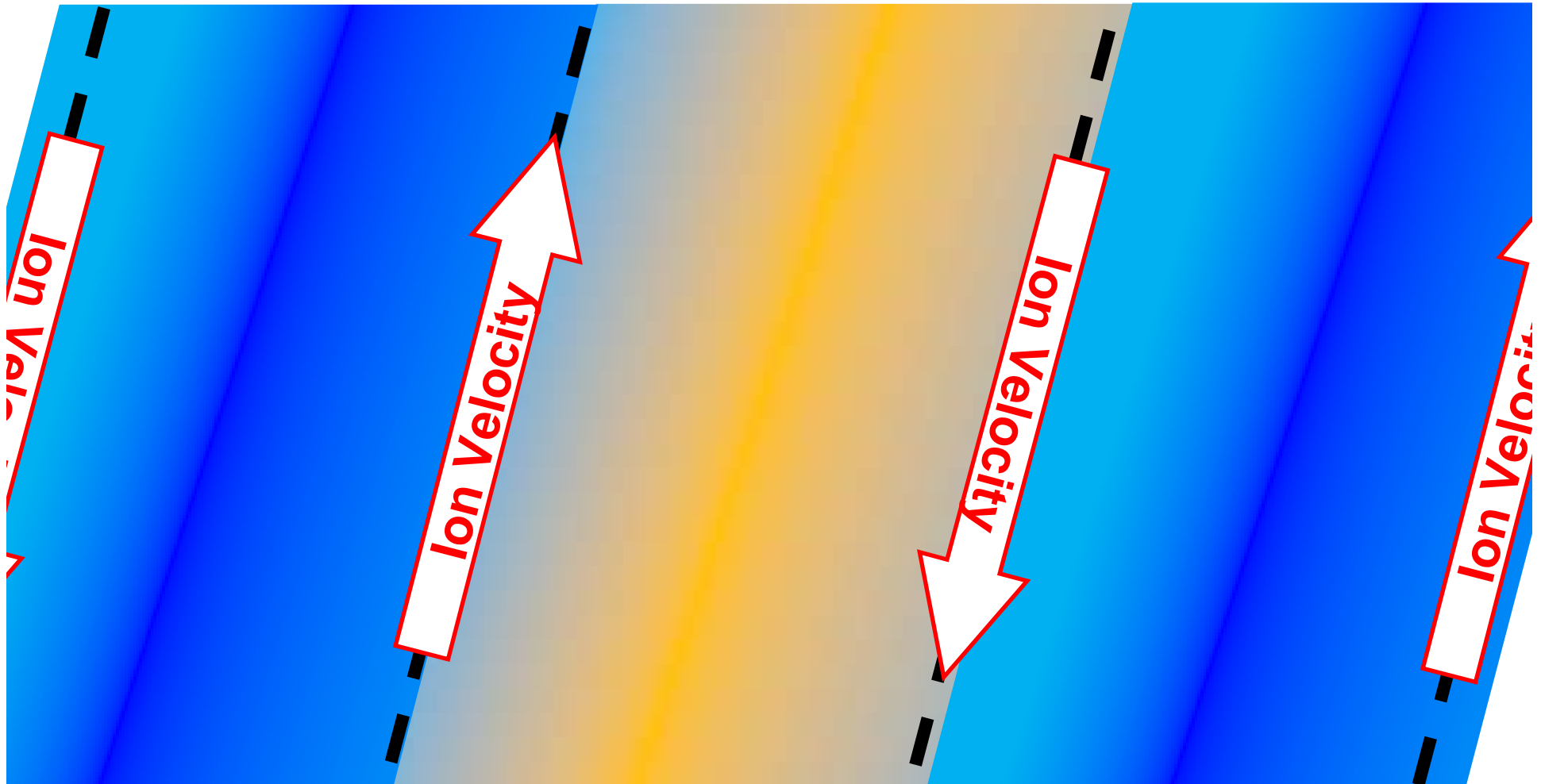


## Observation (DEMETER/GPS-TEC)



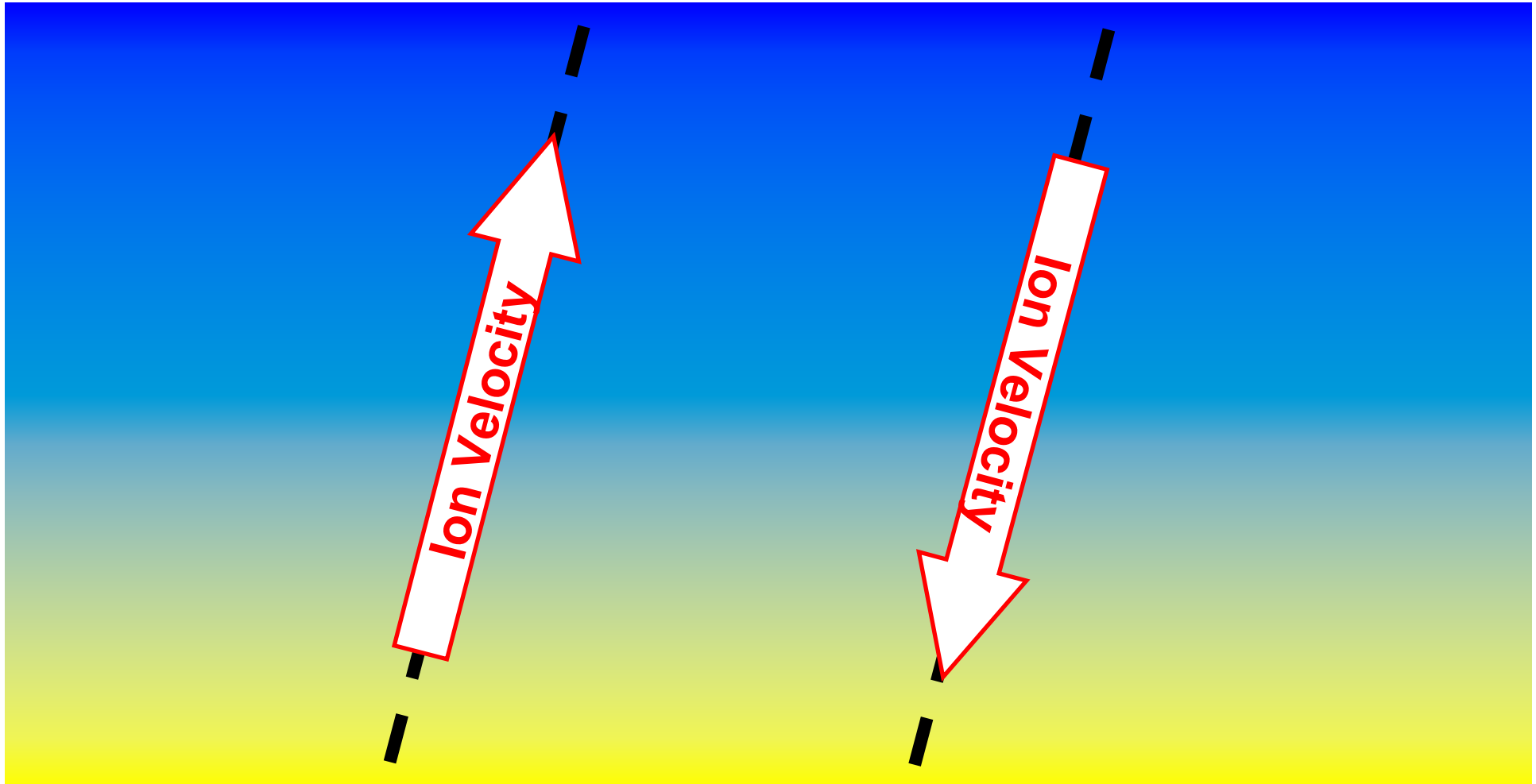


## Observation (DEMETER/GPS-TEC)



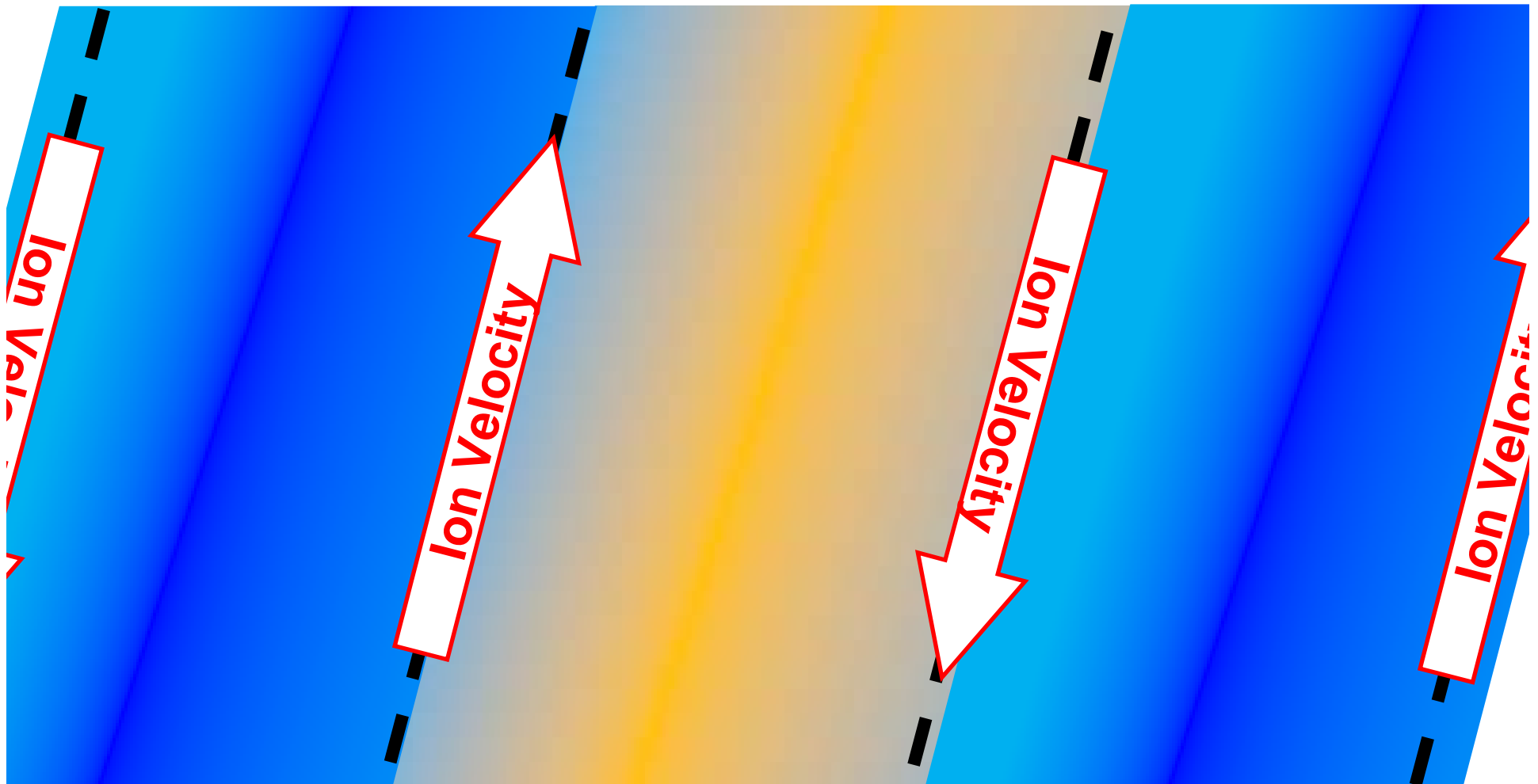


## Observation (DEMETER/GPS-TEC)





## Observation (DEMETER/GPS-TEC)





## Observation (DEMETER/GPS-TEC)

