Field aligned density perturbations and ion outflows at HAARP

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HF heating

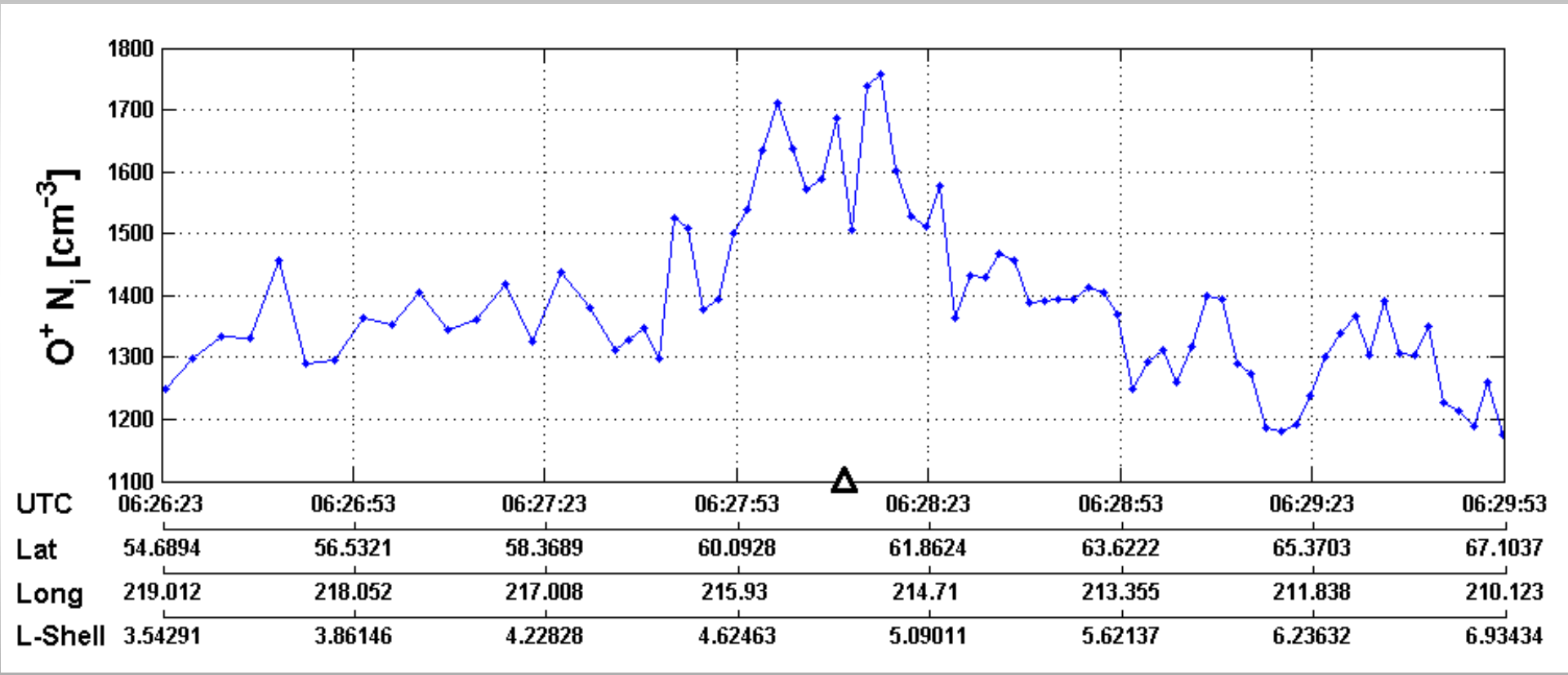
- Experiments are conducted by injecting HF radio-waves into the ionosphere's F-region plasma using the HAARP facility.
- Heating causes plasma density perturbations that travel along field lines, called ionospheric ducts.
- Effects of heating on quantities such as plasma density and temperature can be measured with the DEMETER and DMSP satellites during close flybys of HAARP's magnetic zenith.
- Satellite measurements were complimented by ground based diagnostics, such as the HAARP digisonde and Kodiak radar.

HAARP/DEMETER – 10/21/2009

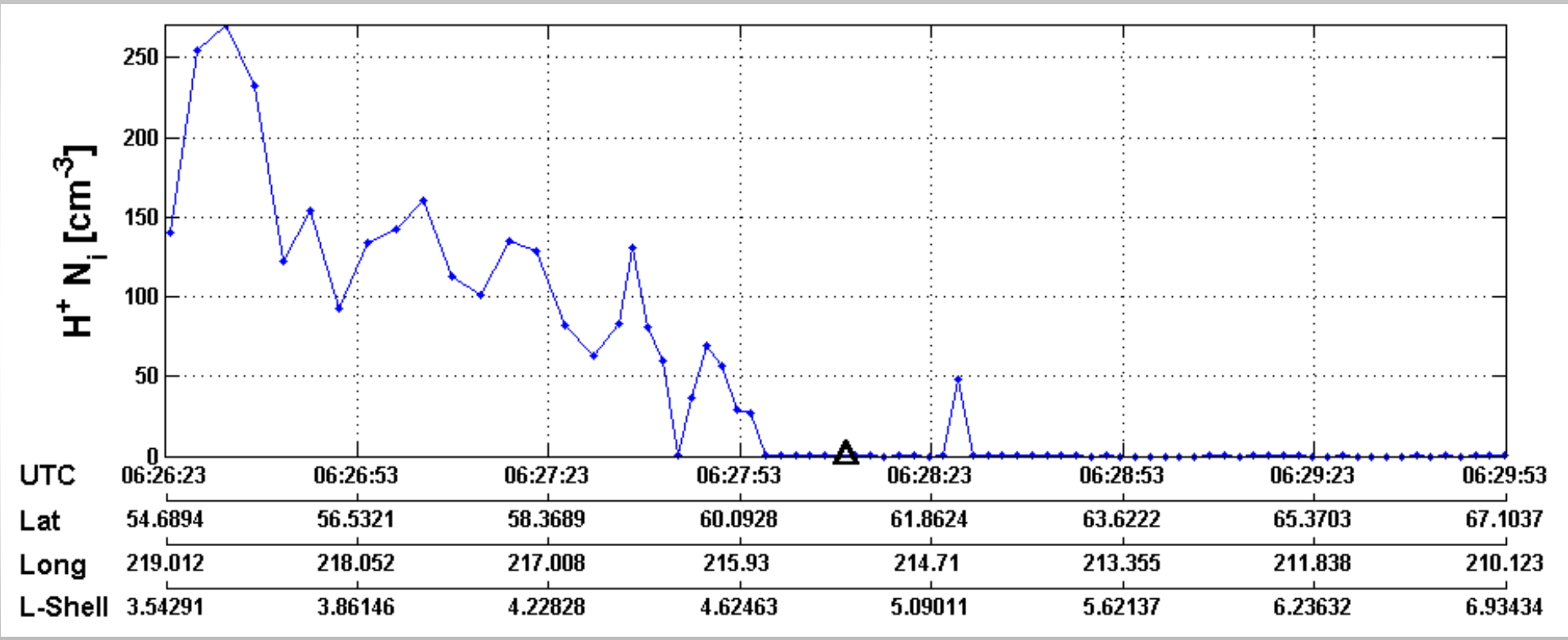
- Nighttime experiment
- Pump wave was 2.8 MHz (CW)
- f_0F_2 = 2.0 MHz

- Closest approach: 27 km

Oxygen ion density



Hydrogen ion density

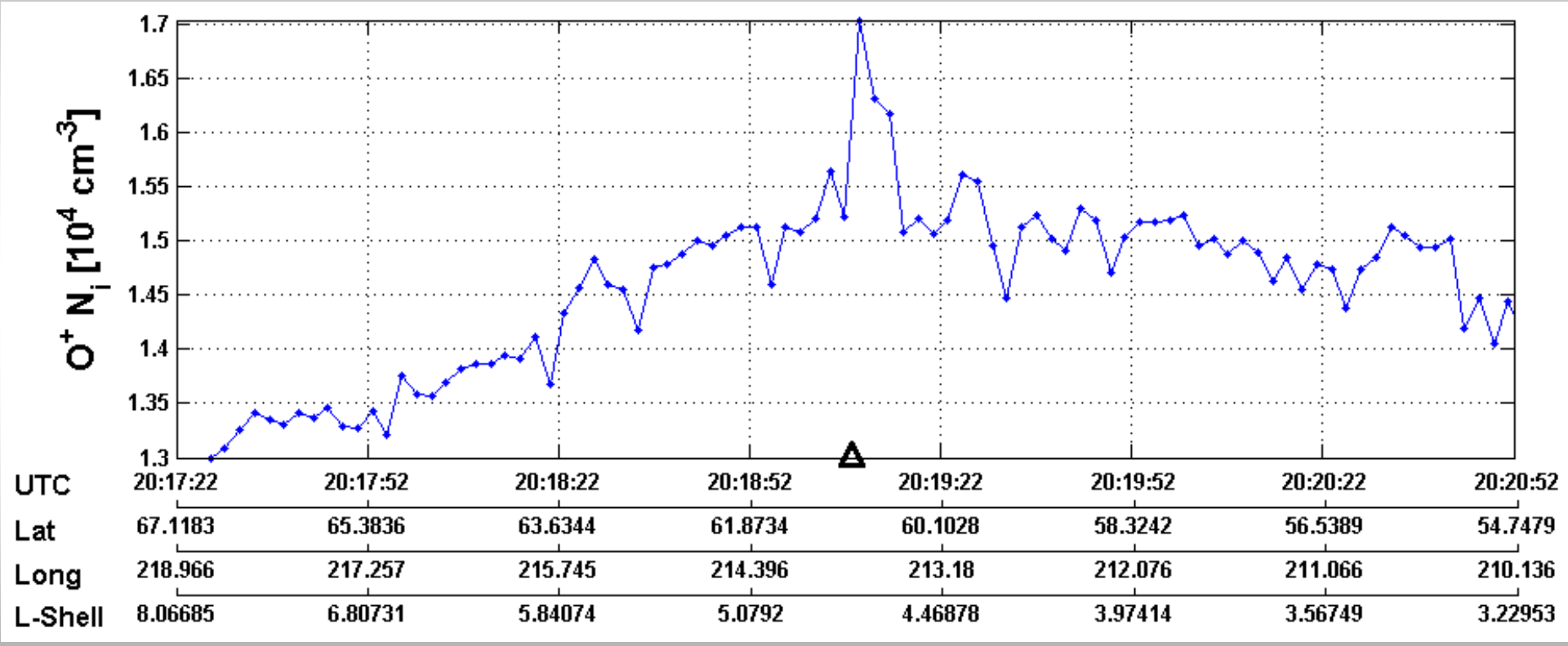


HAARP/DEMETER – 11/07/2010

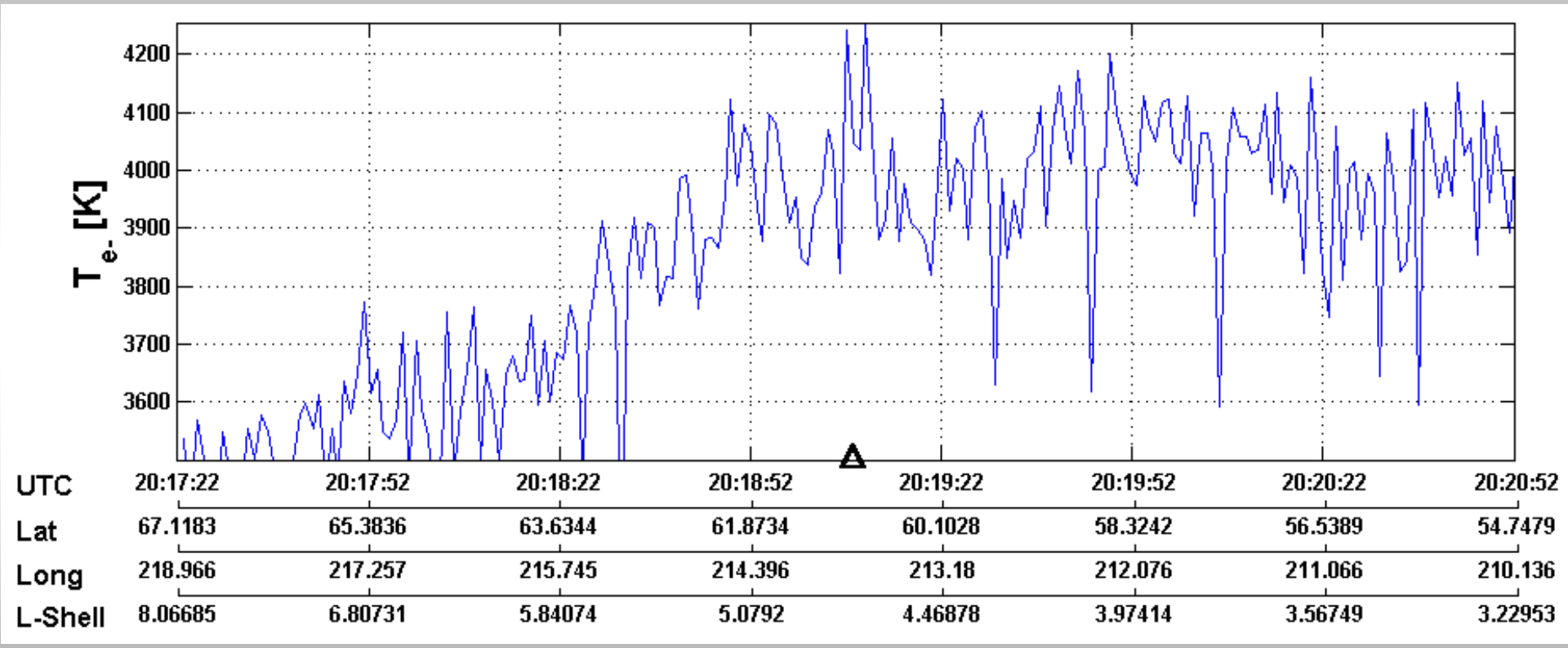
- Daytime experiment
- Pump wave was 6.5 MHz (CW)
- f_0F_2 = 6.5 – 7.0 MHz

- Closest approach: 56 km

Oxygen ion density



Electron temperature

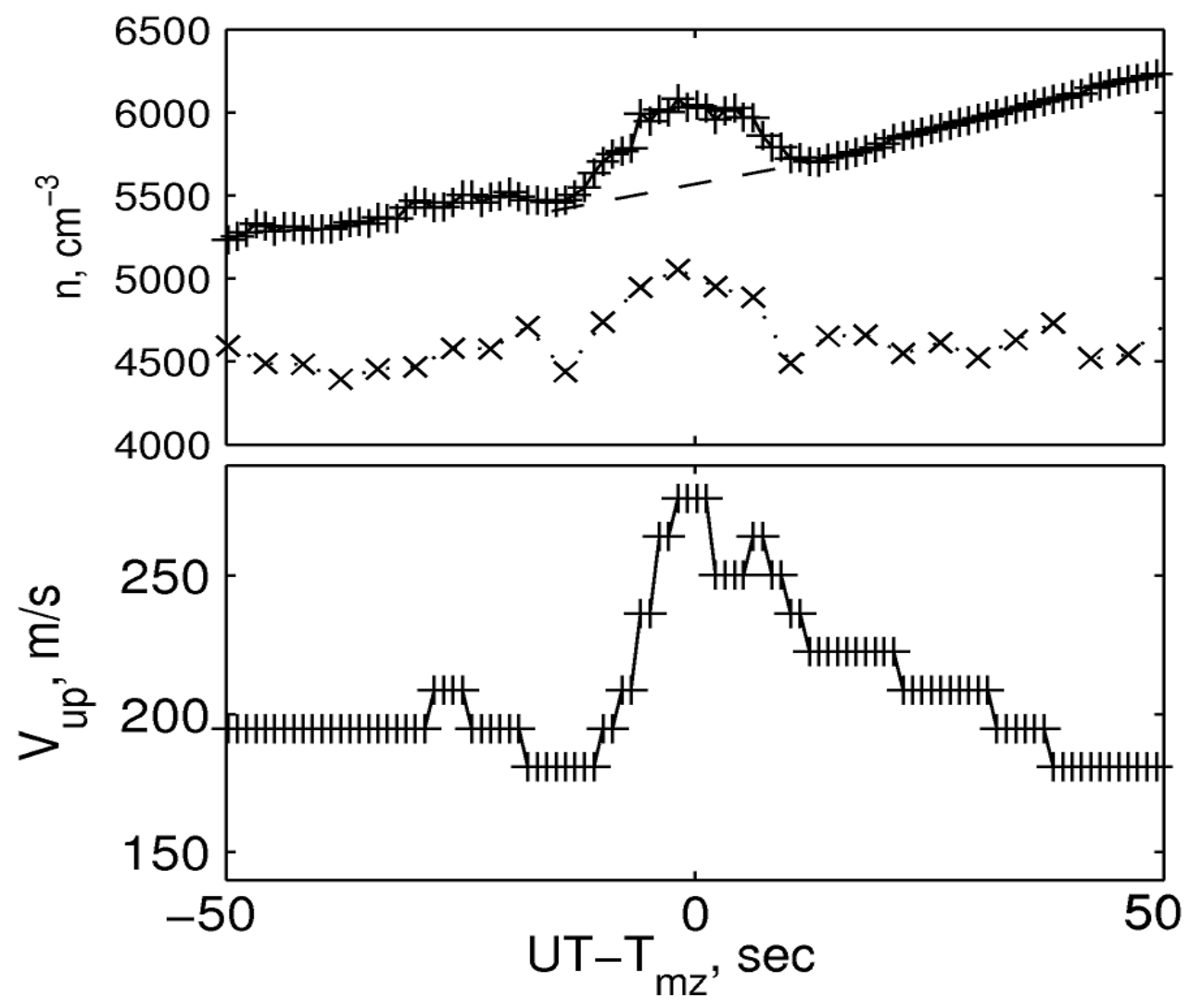


HAARP/DMSP F16 - 02/09/2010

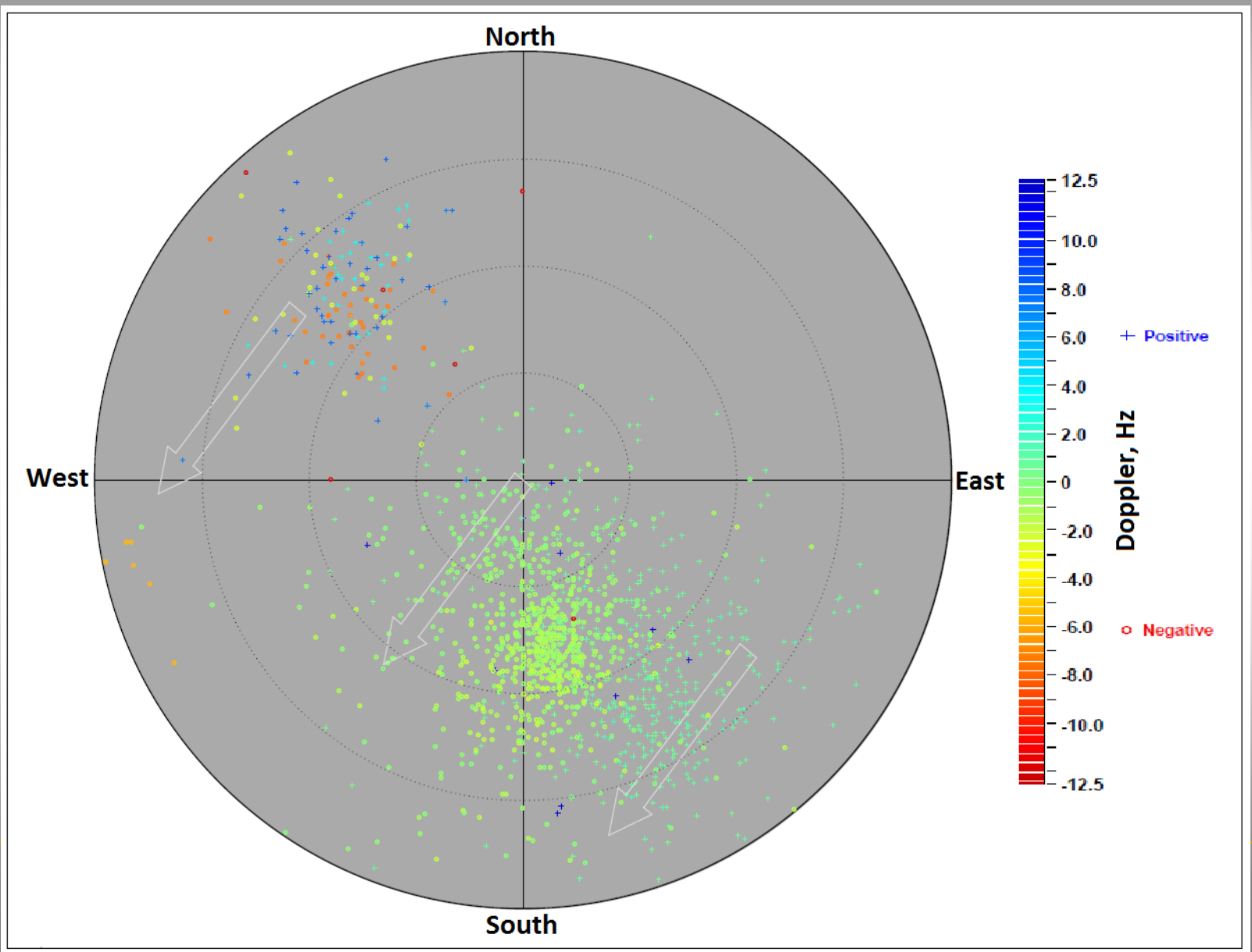
- Daytime experiment
- Pump wave was 2.8 MHz
- f_0F_2 was 3.4 MHz

- Closest approach: 65 km

Total ion density and O+ ion density (top) and upward field aligned ion velocity (bottom)



Skymap observation

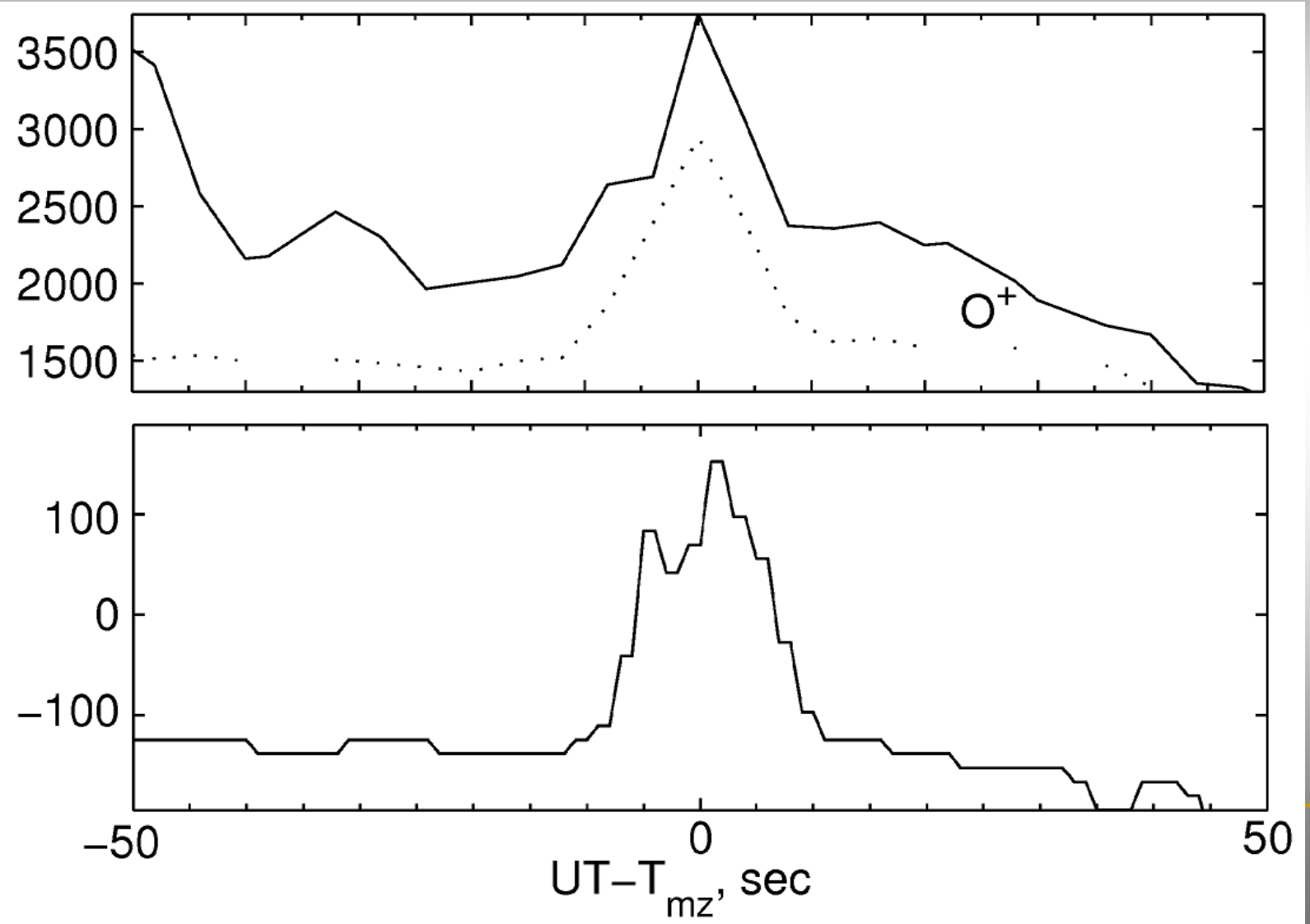


HAARP/DMSP F16 - 11/10/2010

- Nighttime experiment
- Pump wave was 2.85 MHz (CW)
- f_0F_2 was 3.0 MHz

- Closest approach: 96 km

Total ion density and O+ ion density (top) and upward field aligned ion velocity (bottom)

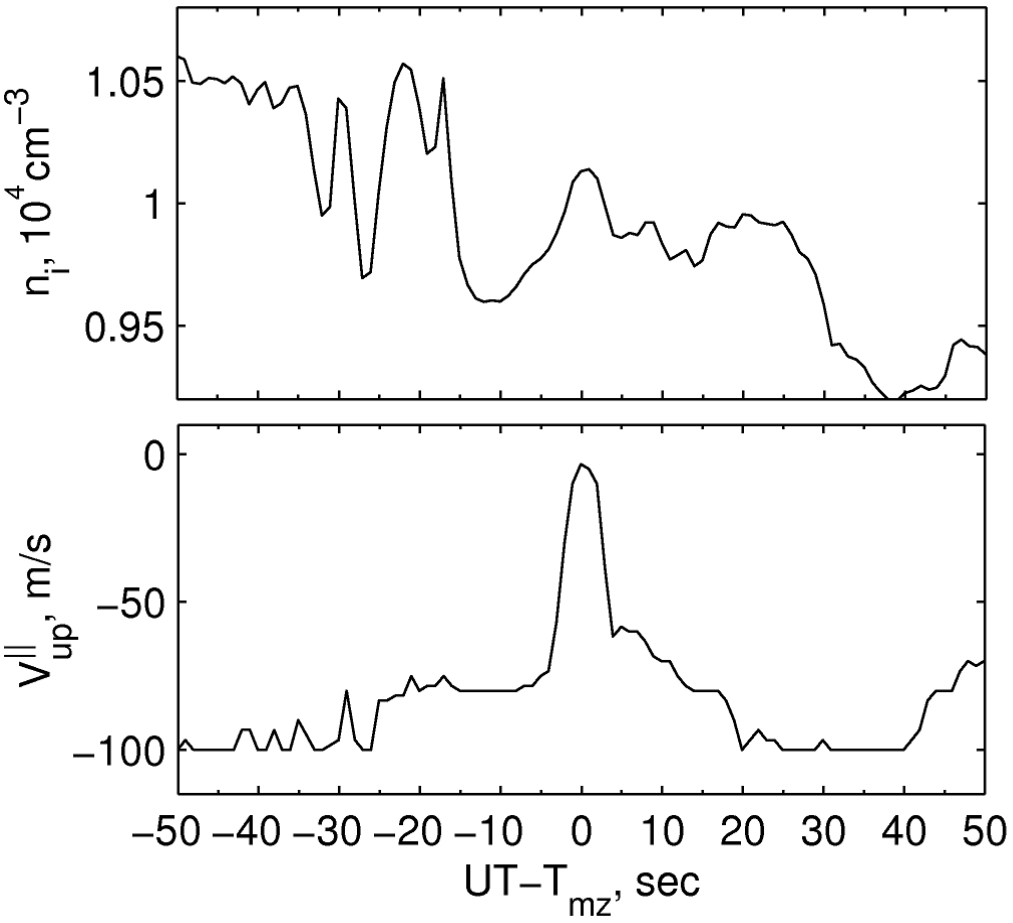


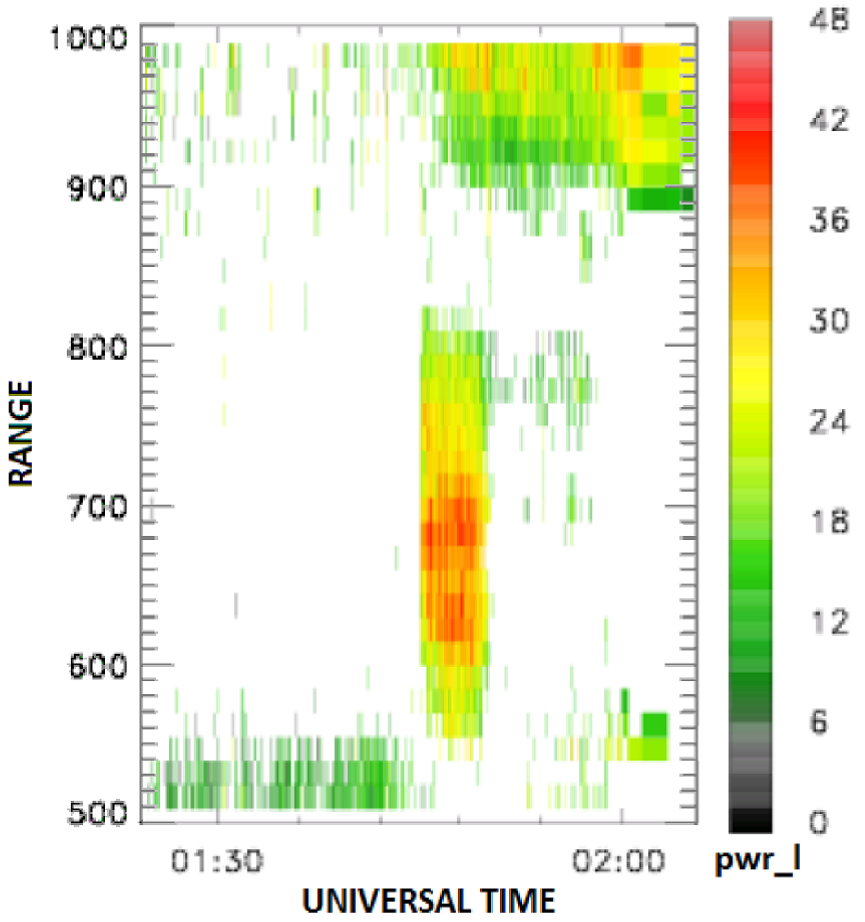
HAARP/DMSP F15 - 10/31/2010

- Dusk experiment
- Pump wave was 5.6 MHz (CW)
- f_0F_2 was 5.3 MHz

- Closest approach: 66 km

Ion density/velocity (left) and Kodiak radar observations (right)





SAMI2 Model

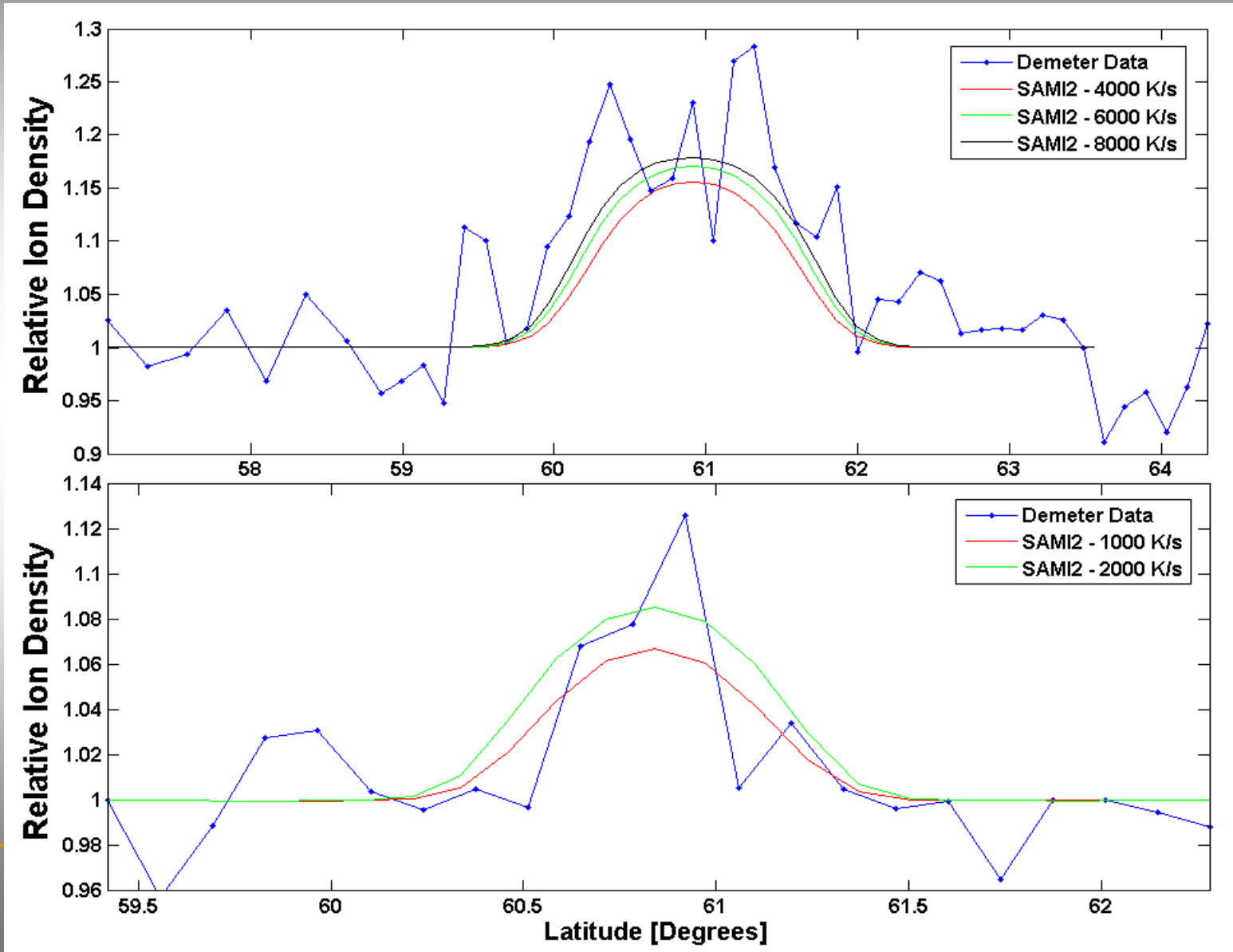
- Developed at the Naval Research Laboratory [*Huba et al.*, 2000].

- The SAMI2 model is an inter-hemispheric model and can simulate the plasma along the entire dipole magnetic field line [*Perrine et al.*, 2006]

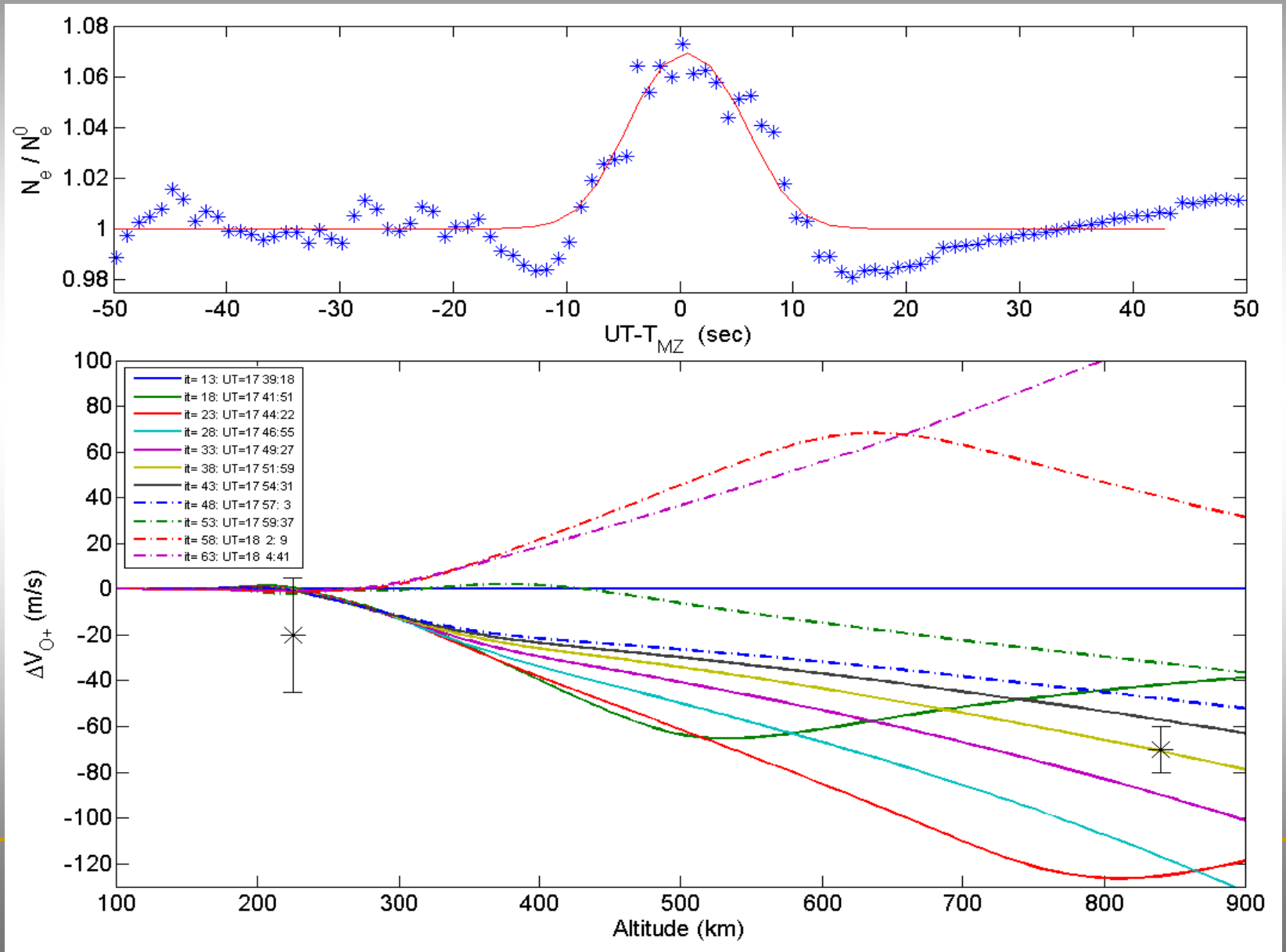
SAMI2 comparison with DEMETER data

10/21/2009

11/07/2010



SAMI2 comparison with DMSP data – 02/09/2010



Conclusions

- Examples of successful ionospheric duct detection were presented.
- Comparison of density and velocity data were checked against the SAMI2 model and show reasonable agreement.