Science with a Classic ISR: Examples from UAF Chain

Anthea Coster

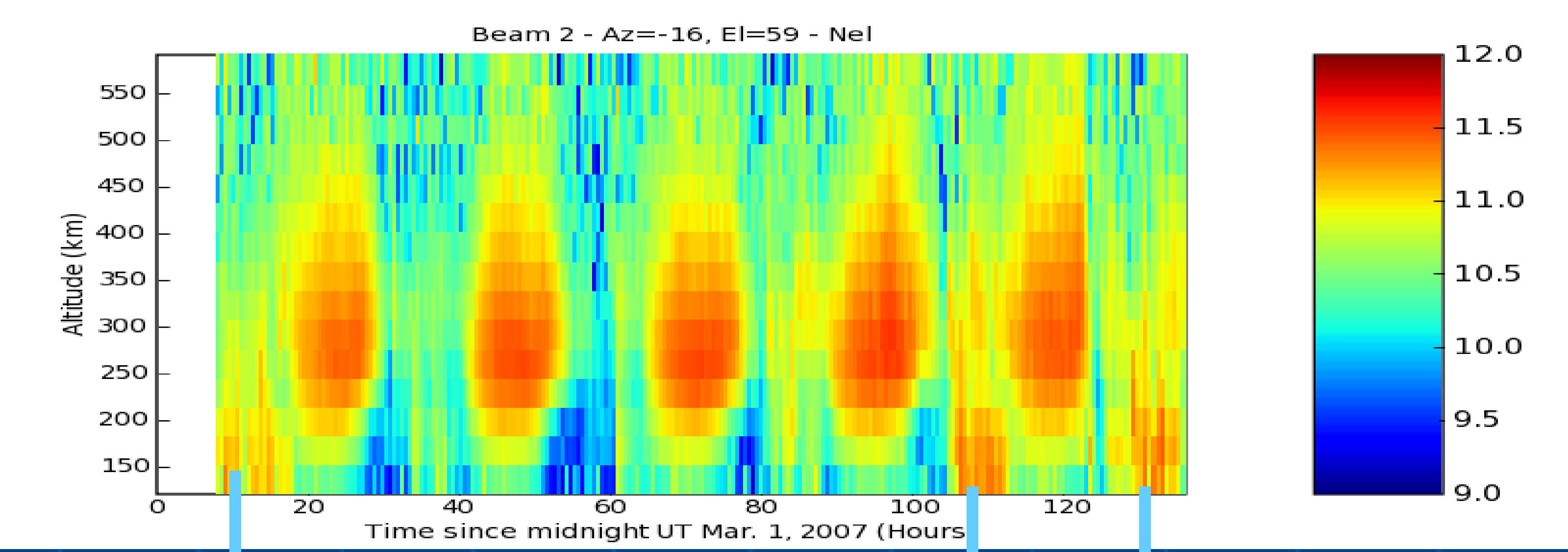
Two Examples of Chain Studies

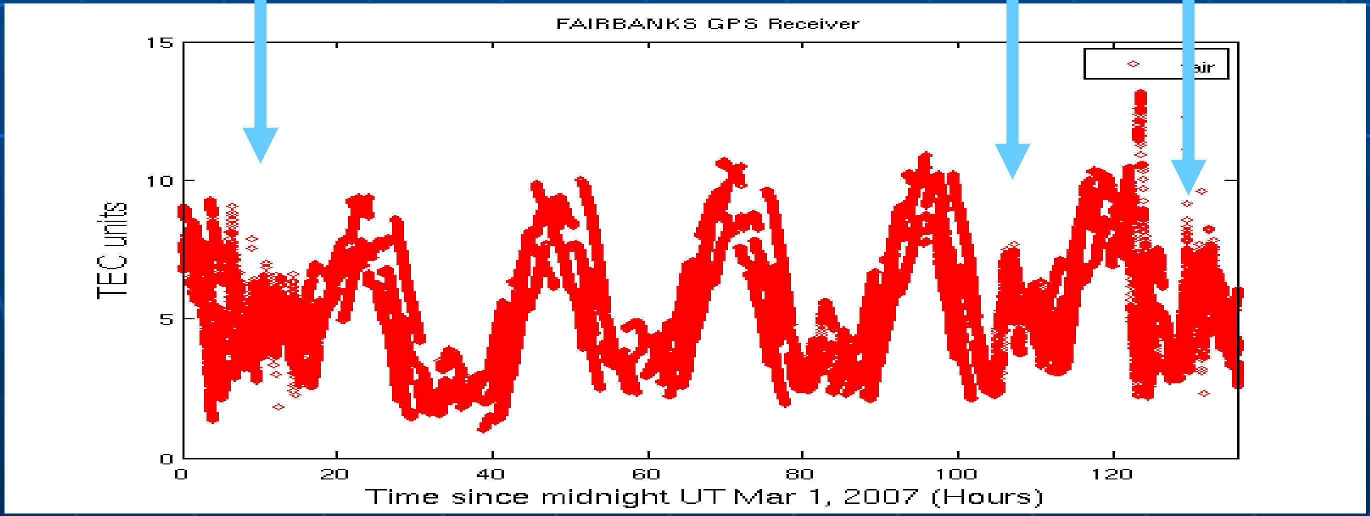
- Storm Studies
- The Ionospheric Response to Stratospheric Warming

Kintner, P. M., et al., 2008. *Midlatitude Ionospheric Dynamics And Disturbances. Volume 181*. Series – AGU Geophysical Monograph.

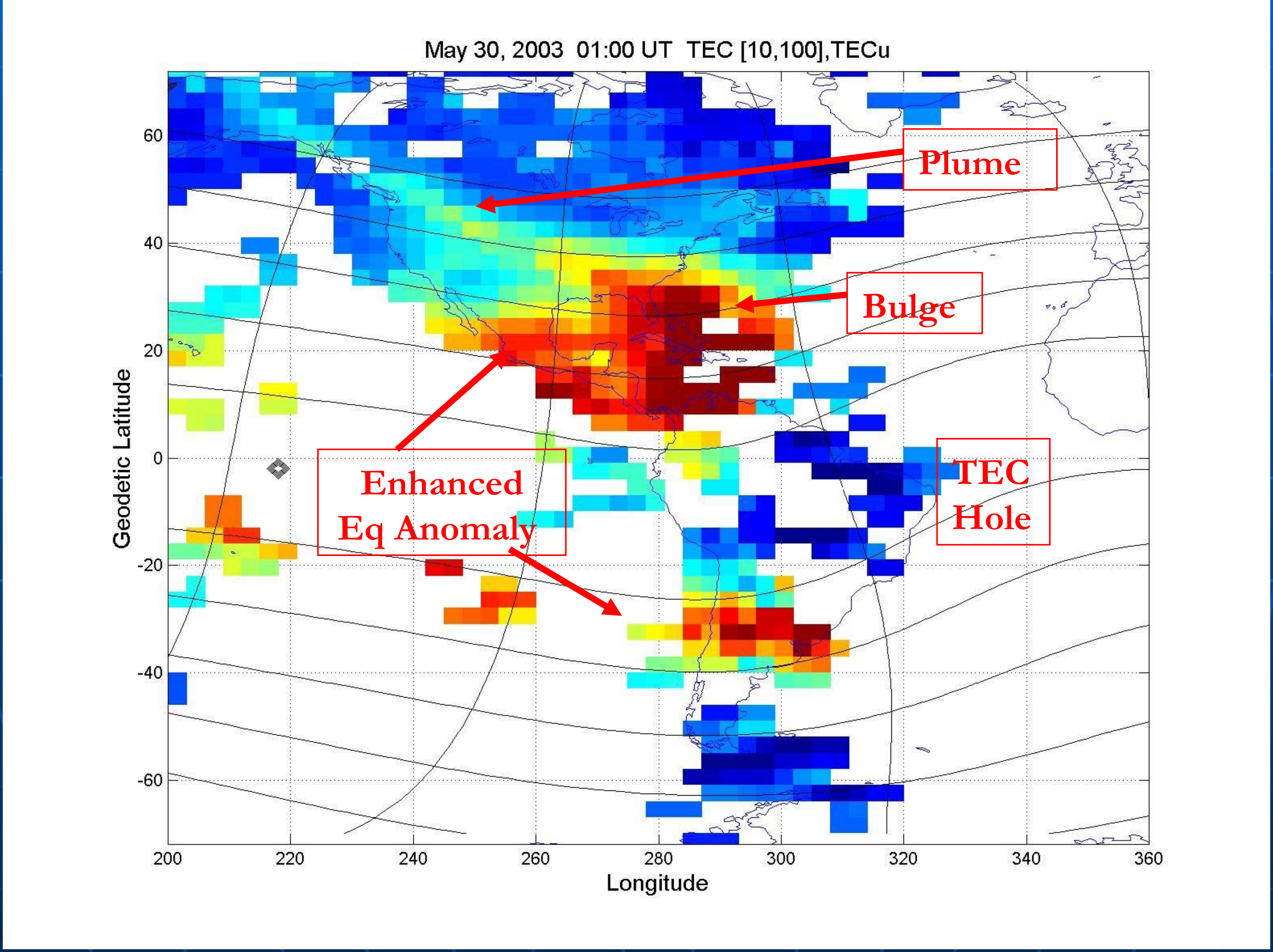
Foster J. C., A. J. Coster, P. J. Erickson, F. J. Rich, B. R. Sandel (2004), Stormtime observations of the flux of plasmaspheric ions to the dayside cusp/magnetopause, Geophys. Res. Lett., 31, L08809, doi:10.1029/2004GL020082.

PFISR ISR Electron Density Profiles and GPS TEC





Enhanced TEC Region observed in the Mid-Latitudes

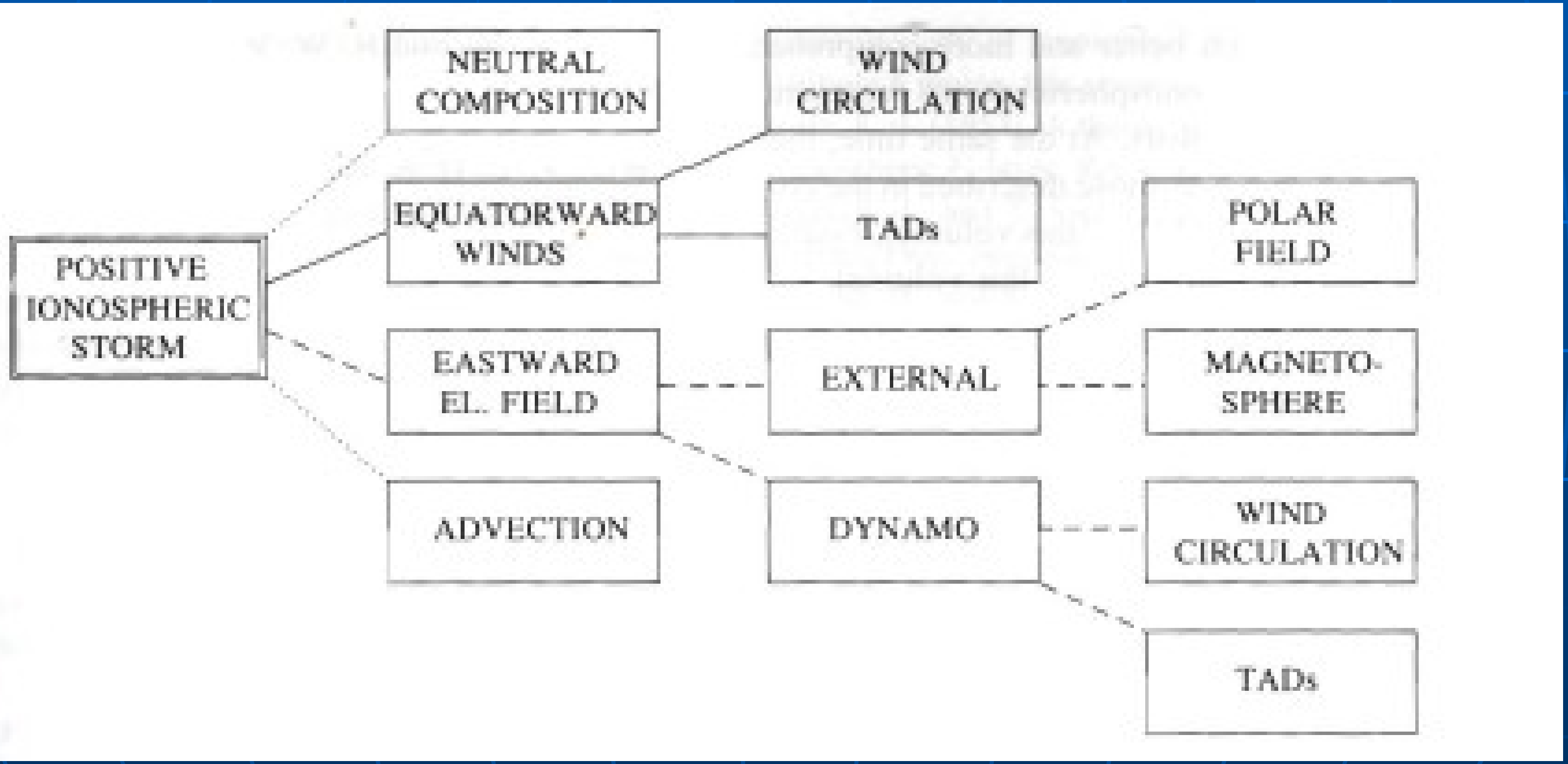


Mid-latitude F2 Layer is Uplifted

The crucial point is that the increase in the ionization density is preceded by a significant increase in the height of the F2 layer ……… This prior uplifting of the ionosphere is typical and is almost always observed. Therefore, any explanation of positive ionospheric storms must be consistent with this observation.

Prolss, Ionospheric Storms at Mid-Latitudes: A Short Review <u>MIDD</u>

Mechanisms contributing to positive storms at mid-latitudes



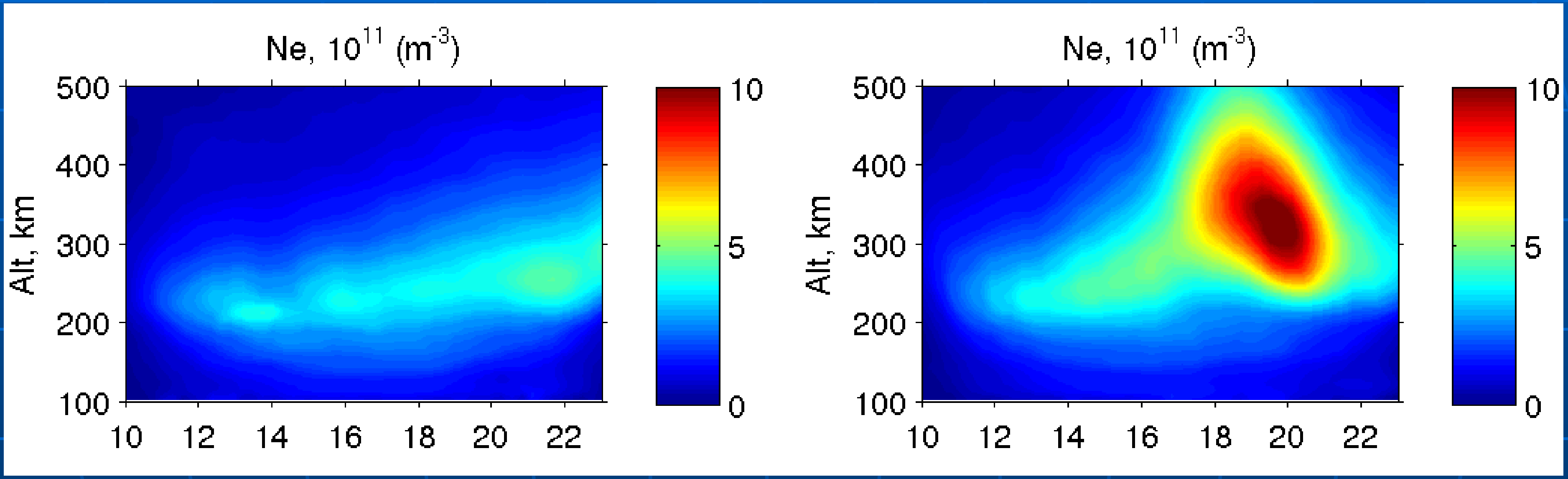
Prolss, Ionospheric Storms at Mid-Latitudes: A Short Review MIDD

Positive phase mechanisms

- Increase in oxygen density (*Burns et al, 1991, 1995*)
- Equatorward meridional wind (*Jones and Rishbeth, 1971*)
- Electric field (*Lanzerotti et al., 1975, Huang et al., 2005, Swisdak et al., 2006*)
- Downward protonospheric plasma fluxes

Positive Phase Storm Studies
Millstone Hill ISR, Ne

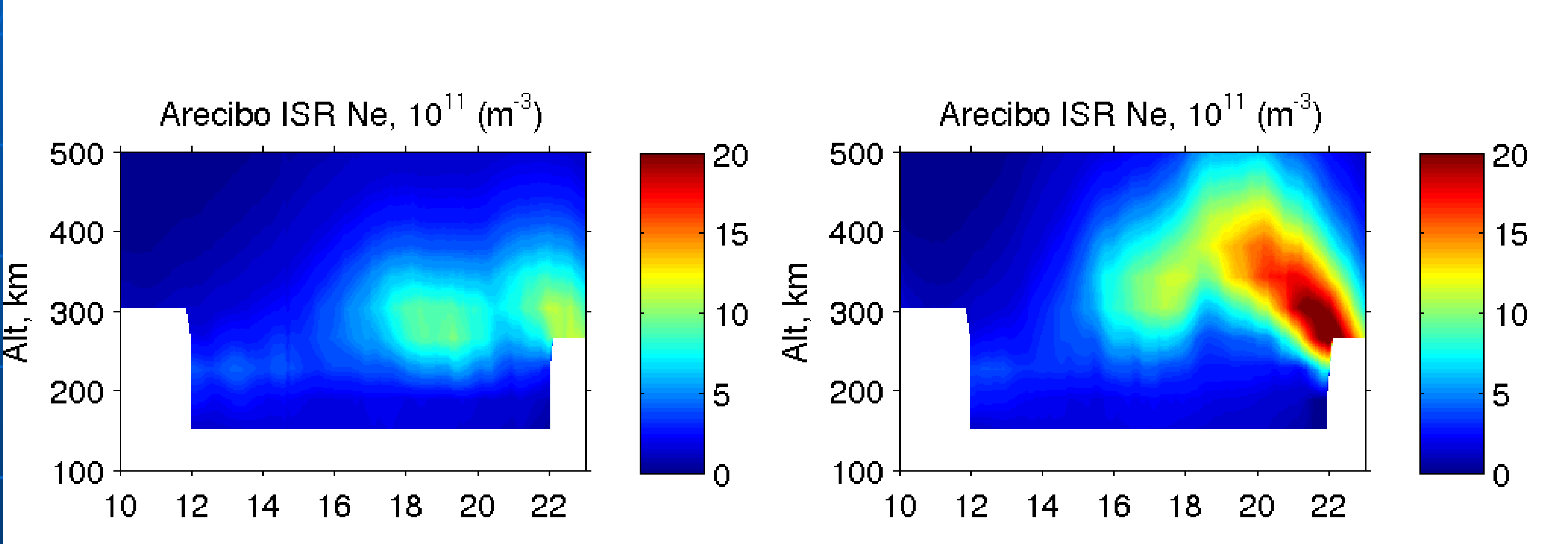
Sep 8, 2005 Kp = 2   Sep 10, 2005 Kp = 5



- Daytime positive phase lasting for ~13 hours
- Background increase after the sunrise; main increase after 17 UT
- Maximum Ne at 19-20 UT
- Increase in $h_m F2$ by ~100 km
- Decrease in Te by up to ~1000K, enhancement in Ti by 50-200K

Arecibo Ne

Sep 8, 2005 Kp = 2 Sep 10, 2005 Kp = 5



Positive storm phase after ~15 UT

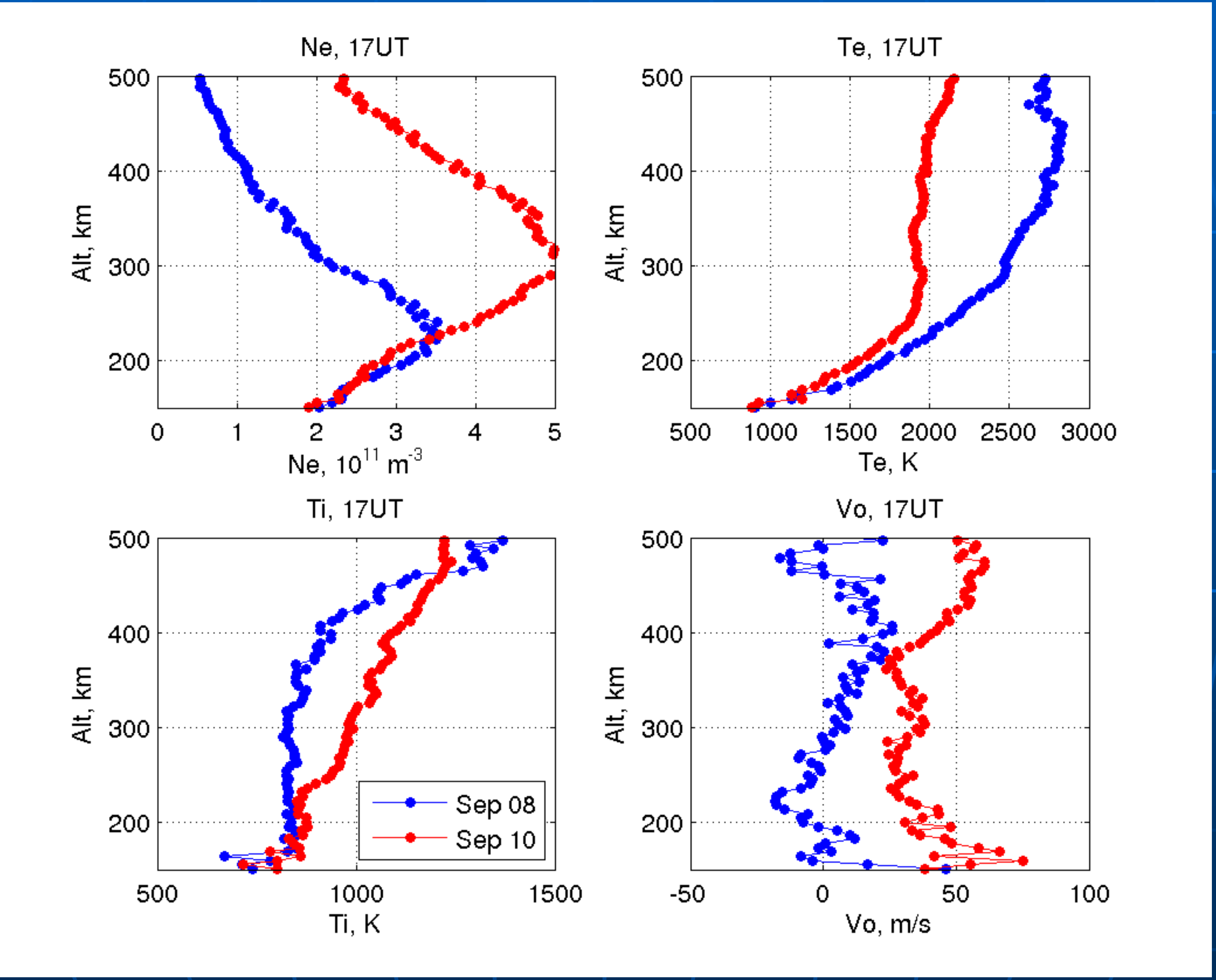
Maximum Ne at 21-22 UT, i.e. 1.5-2 hours later than at Millstone Hill

Uplift of the F-layer

Millstone Hill ISR: Ne, Te, Ti, Vi at 17 UT

Ne

Te



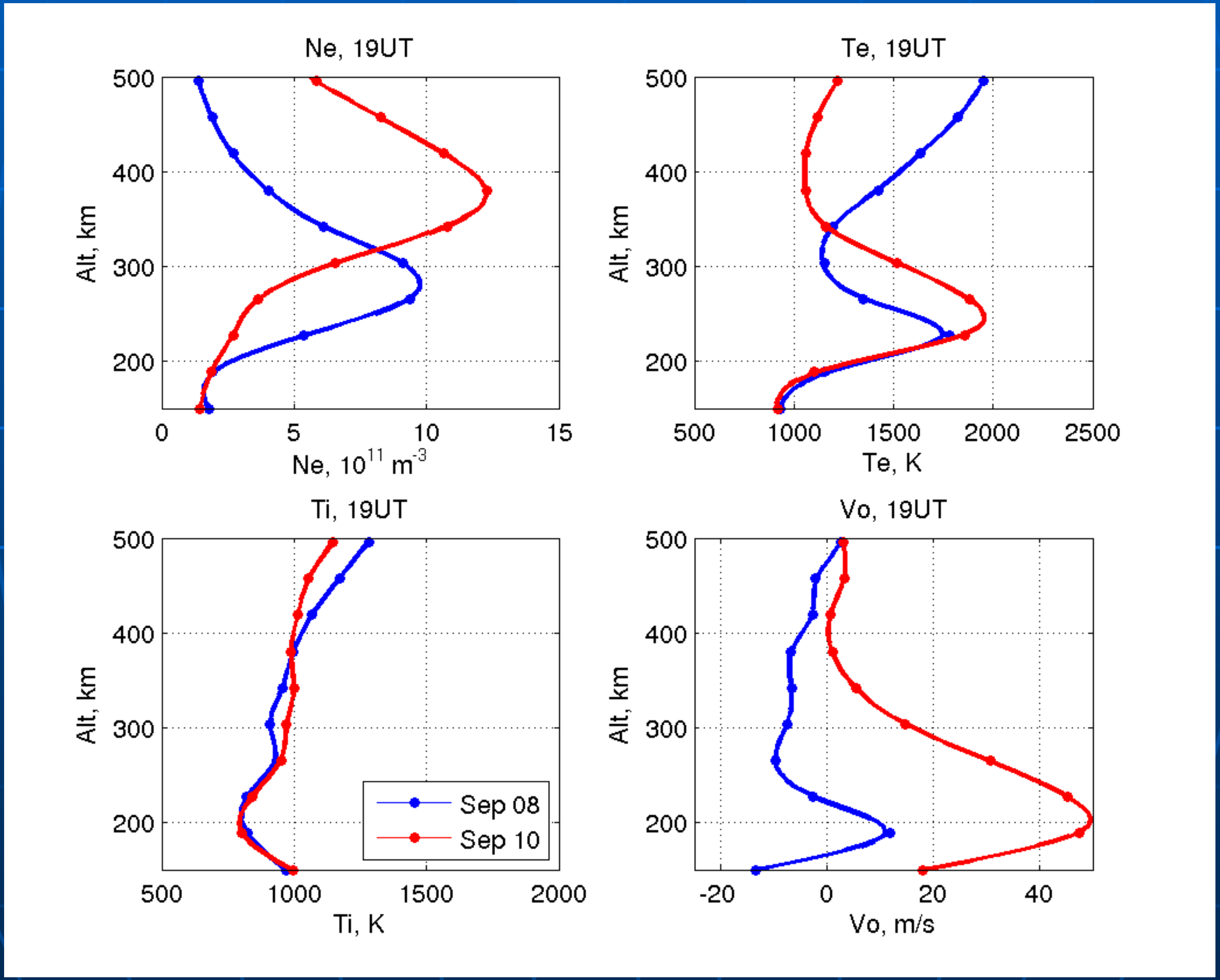
Ti

Vi

Arecibo ISR Ne, Te, Ti, Vi at 19 UT

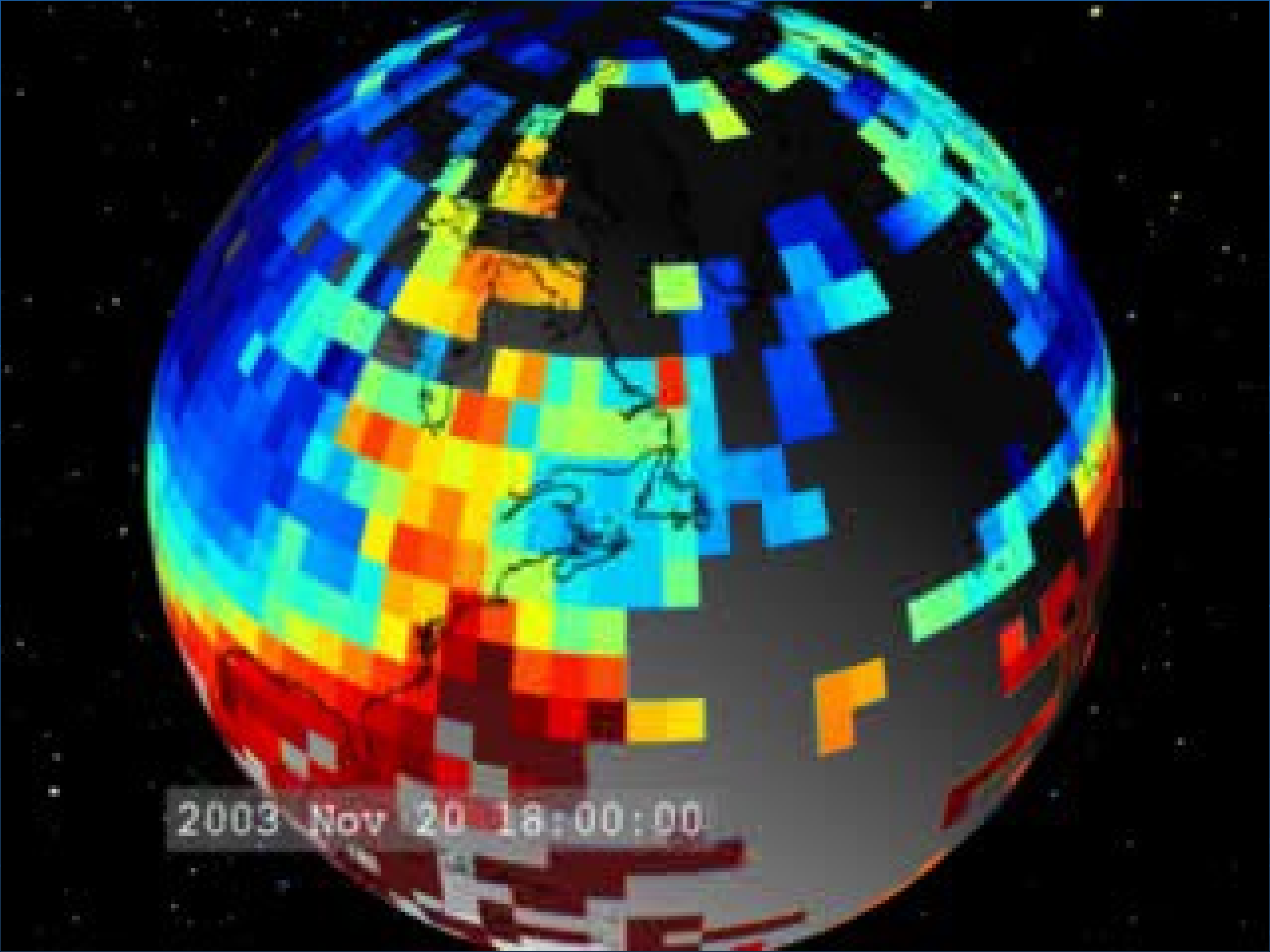
Ne

Te

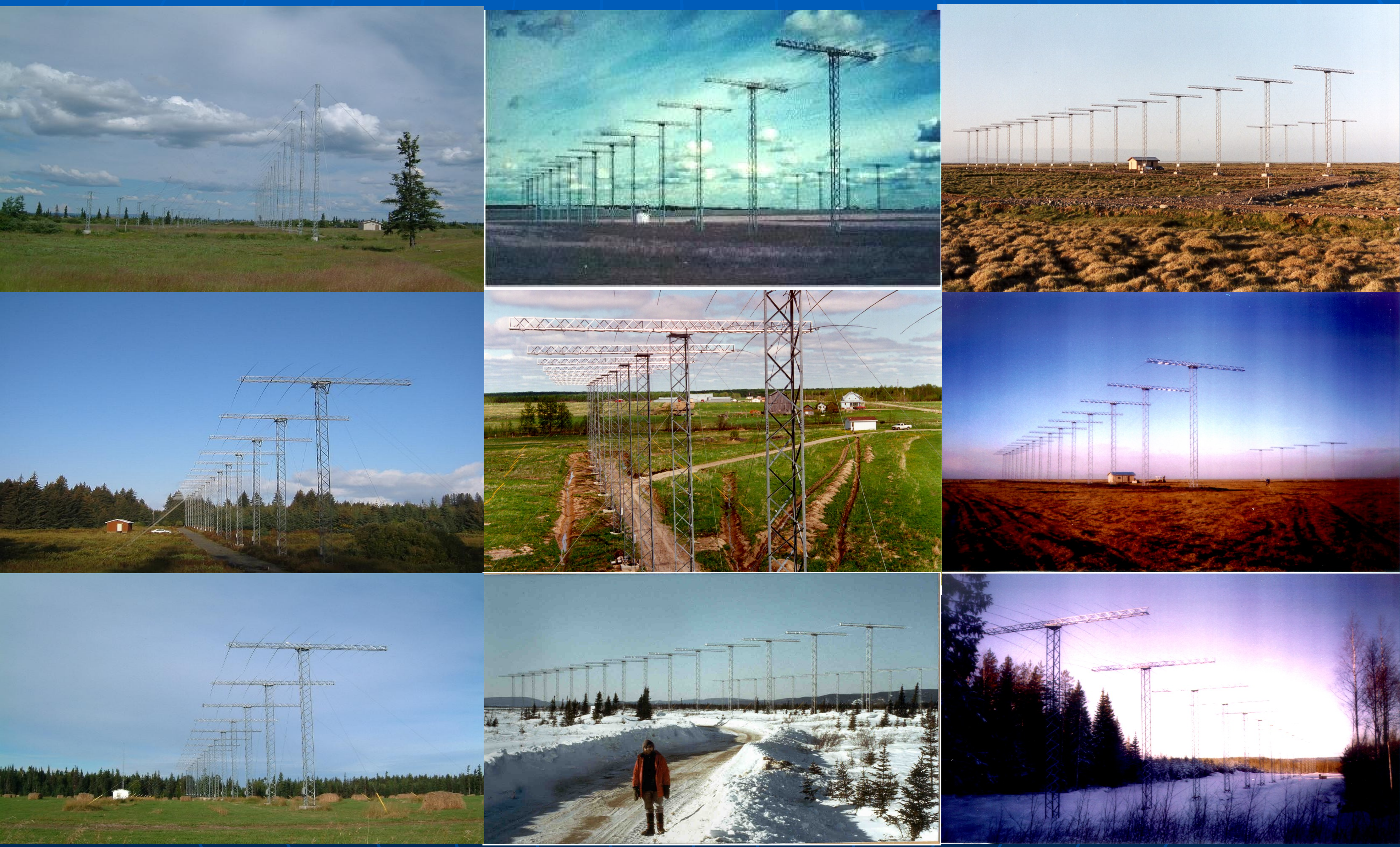


Ti

Vi

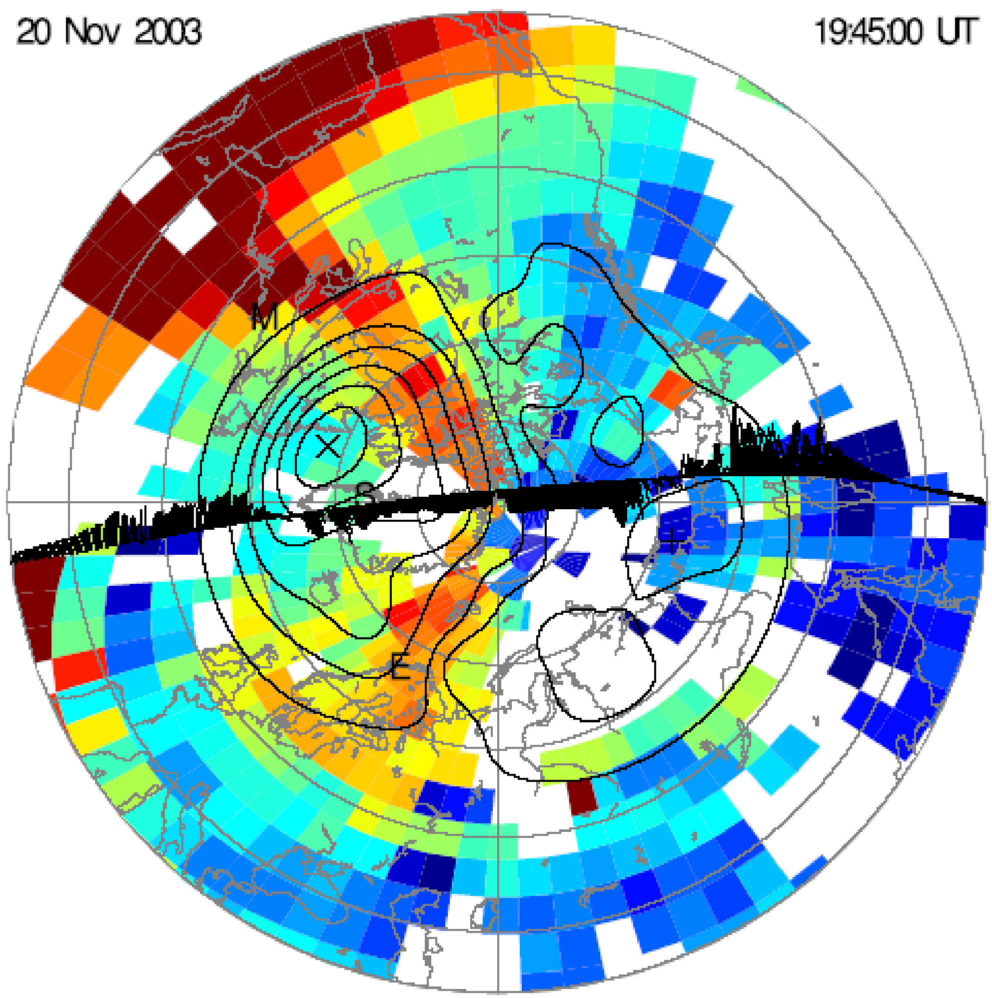

2003 Nov 20 18:00:00

SuperDARN HF Radars



20 Nov 2003 - GPS TEC, DMSP, SuperDarn Convection Patterns, and ISR Radar Measurements

[Foster et al., JGR 2005]



Two Examples of Chain Studies

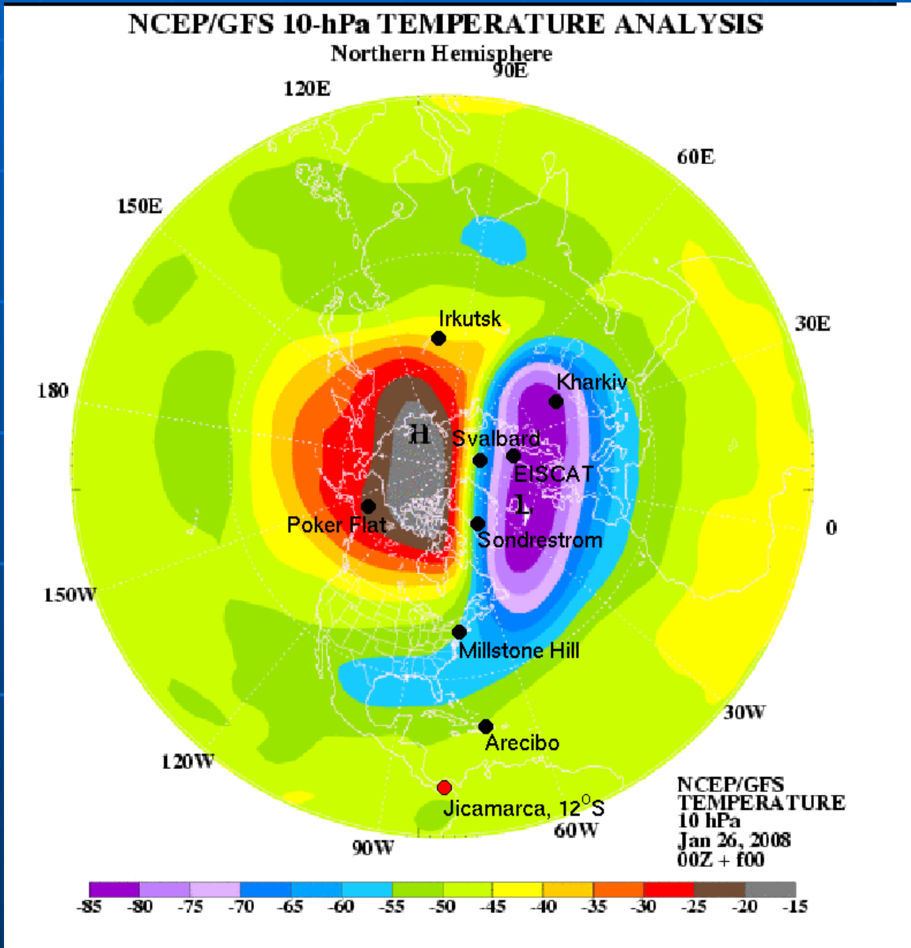
- Storm Studies
- The Ionospheric Response to Stratospheric Warming (L. Goncharenko)

Goncharenko, L., and S.-R. Zhang (2008), Ionospheric signatures of sudden stratospheric warming: Ion temperature at middle latitude, *Geophys. Res. Lett.*, 35, L21103, doi:10.1029/2008GL035684.

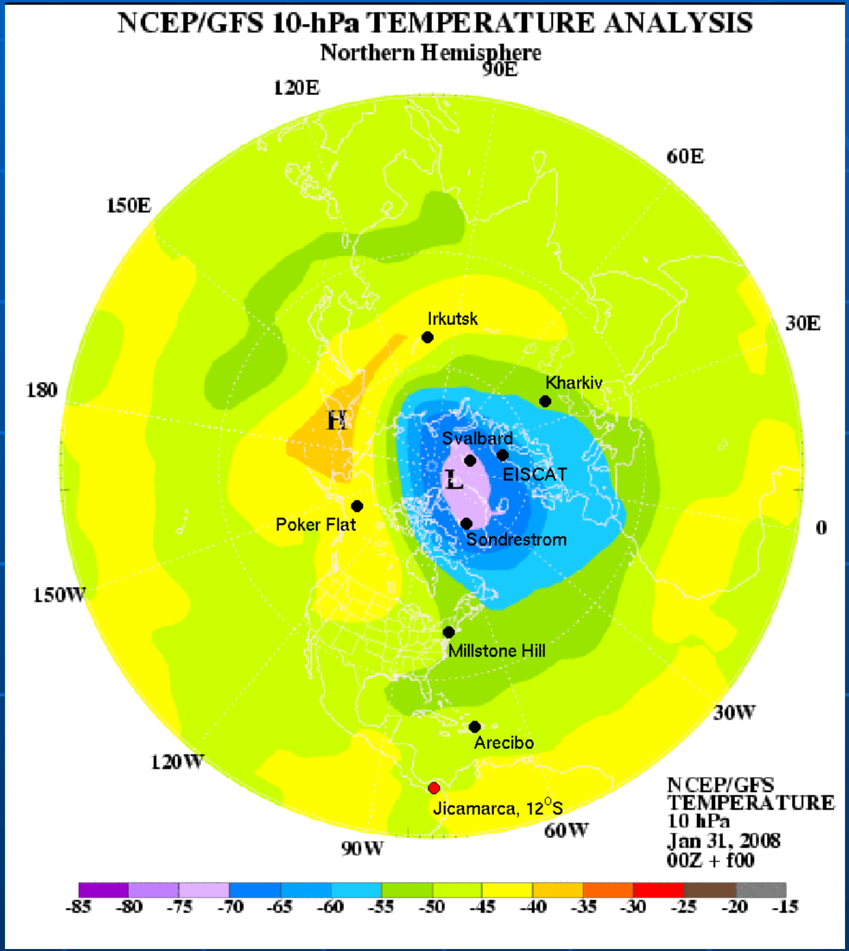
Chau, J. L., B. G. Fejer, and L. P. Goncharenko (2009), Quiet variability of equatorial **E** × **B** drifts during a sudden stratospheric warming event, *Geophys. Res. Lett.*, 36, L05101, doi:10.1029/2008GL036785.

Stratospheric temperatures at ~32 km

During stratwarming



After stratwarming



Sudden stratospheric warming is a dynamical event in high-latitude stratosphere

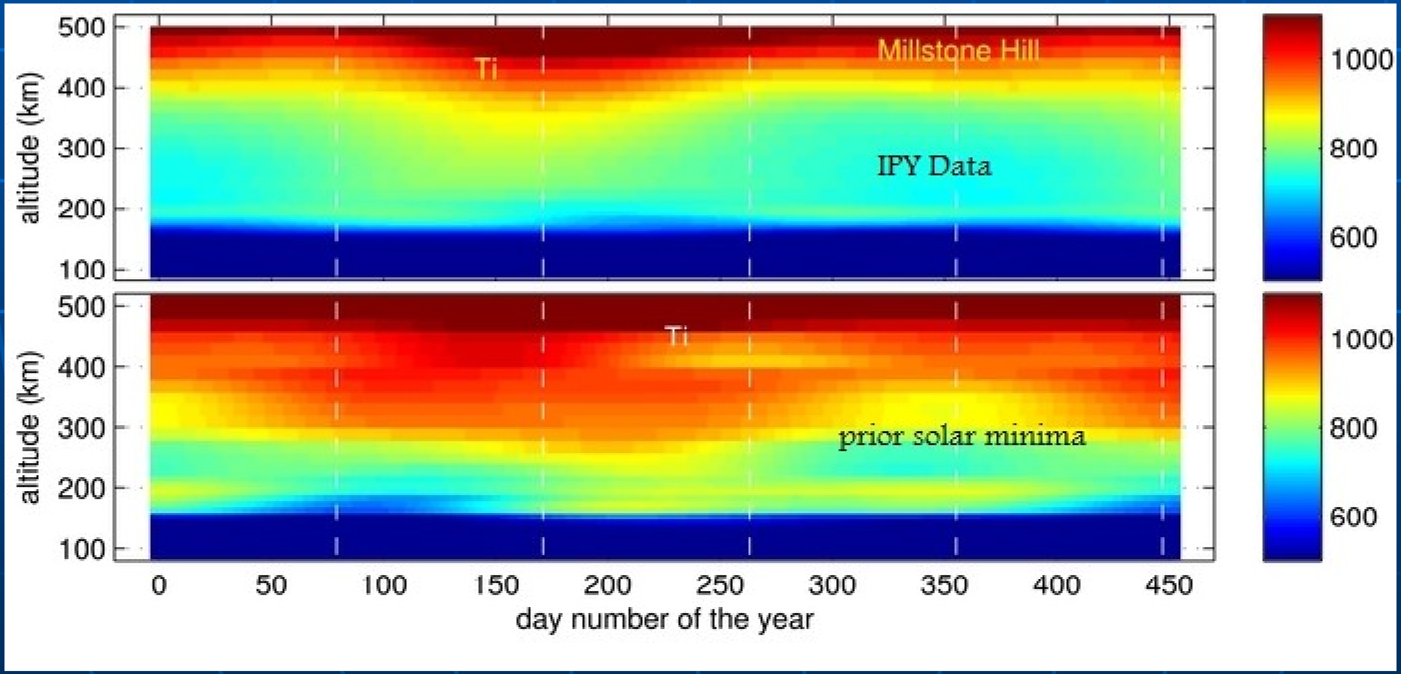
ISR Stratospheric Warming Campaign: Jan 17 – Feb 1, 2008

Goal: to extend studies of stratwarming effects above 100km

Current Solar Minimum - Cycle 24 – Pronounced Cooling

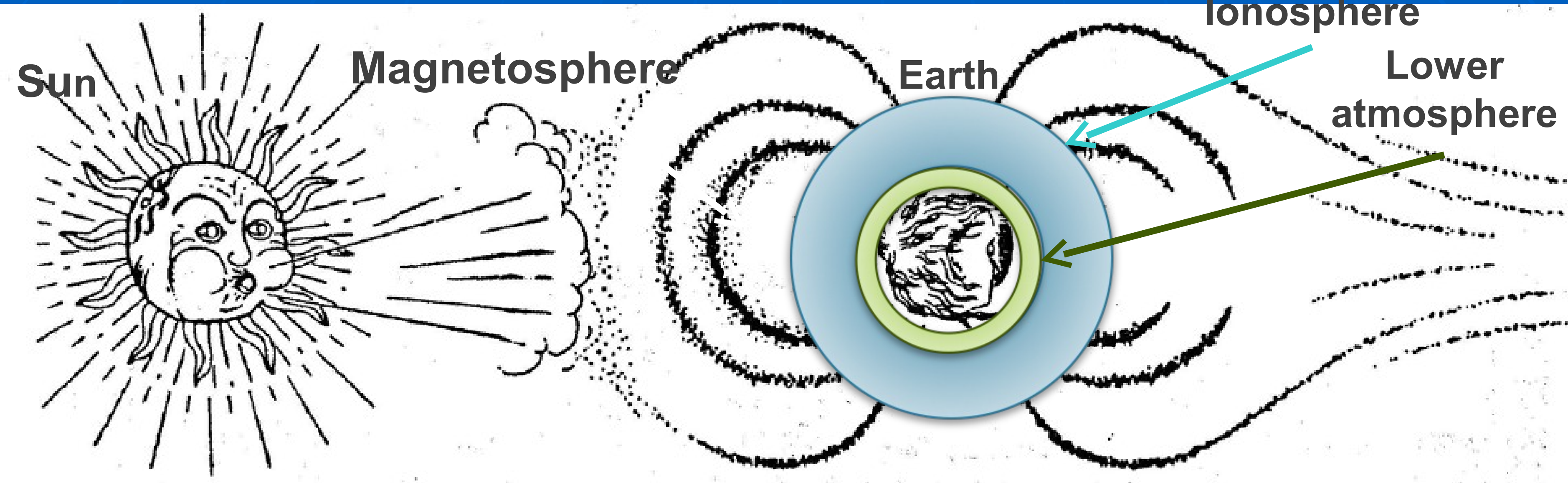
Millstone Hill ionospheric ion temperatures as a function of altitude

(top plot) for the IPY period (1 Jan 2007- 1 March 2008-above) and (bottom plot) for a similar time frame from the prior solar minima.



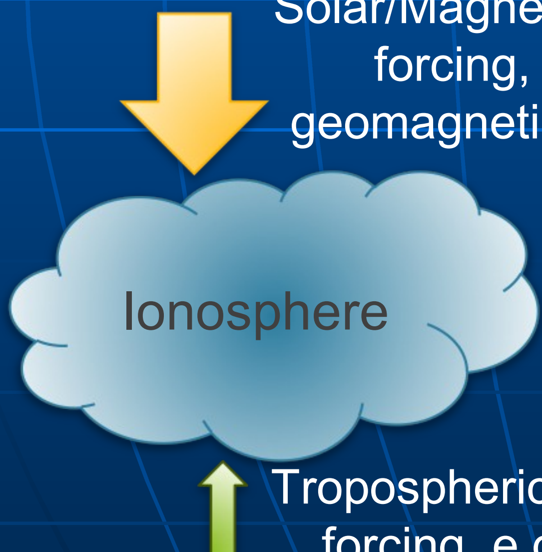
Zhang, 2009

Forces that act on the Ionosphere



[adapted from *Marchavilas*, 2007]

Solar/Magnetospheric forcing, e.g., geomagnetic storms

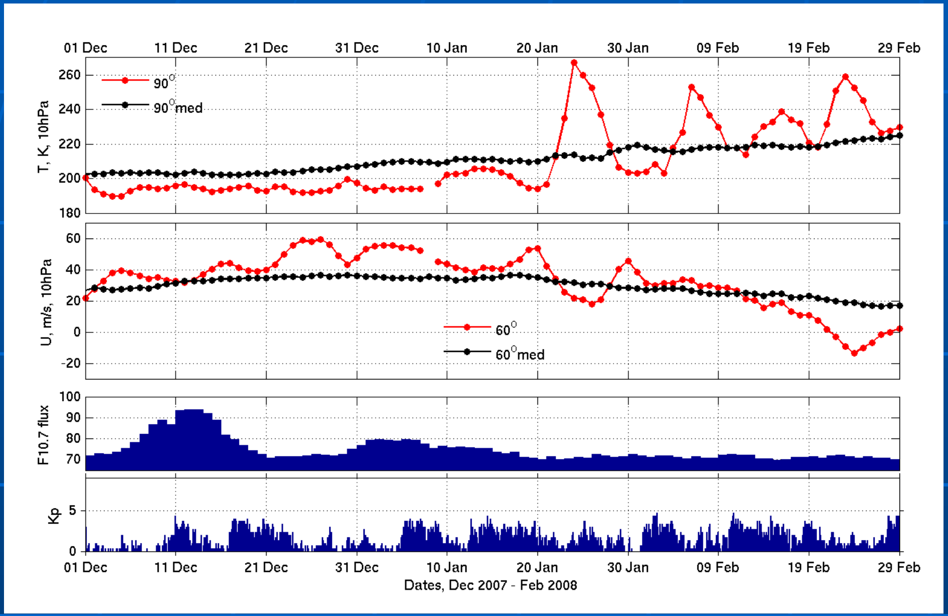


Tropospheric/Stratospheric forcing, e.g., planetary waves

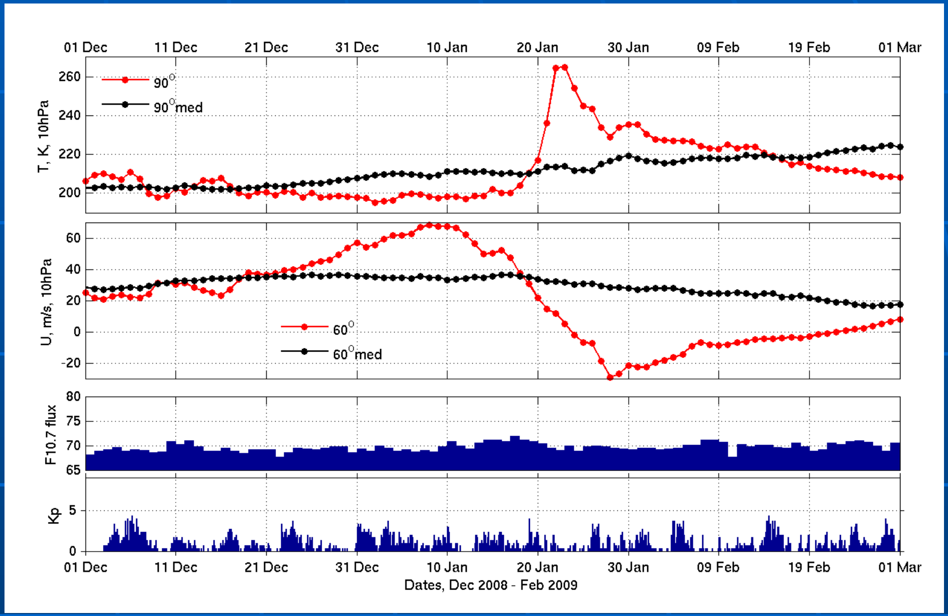
- These forces produce ionospheric changes: electric fields, electron density, temperature, composition,.

Stratospheric and geomagnetic conditions

Winter of 2007-2008



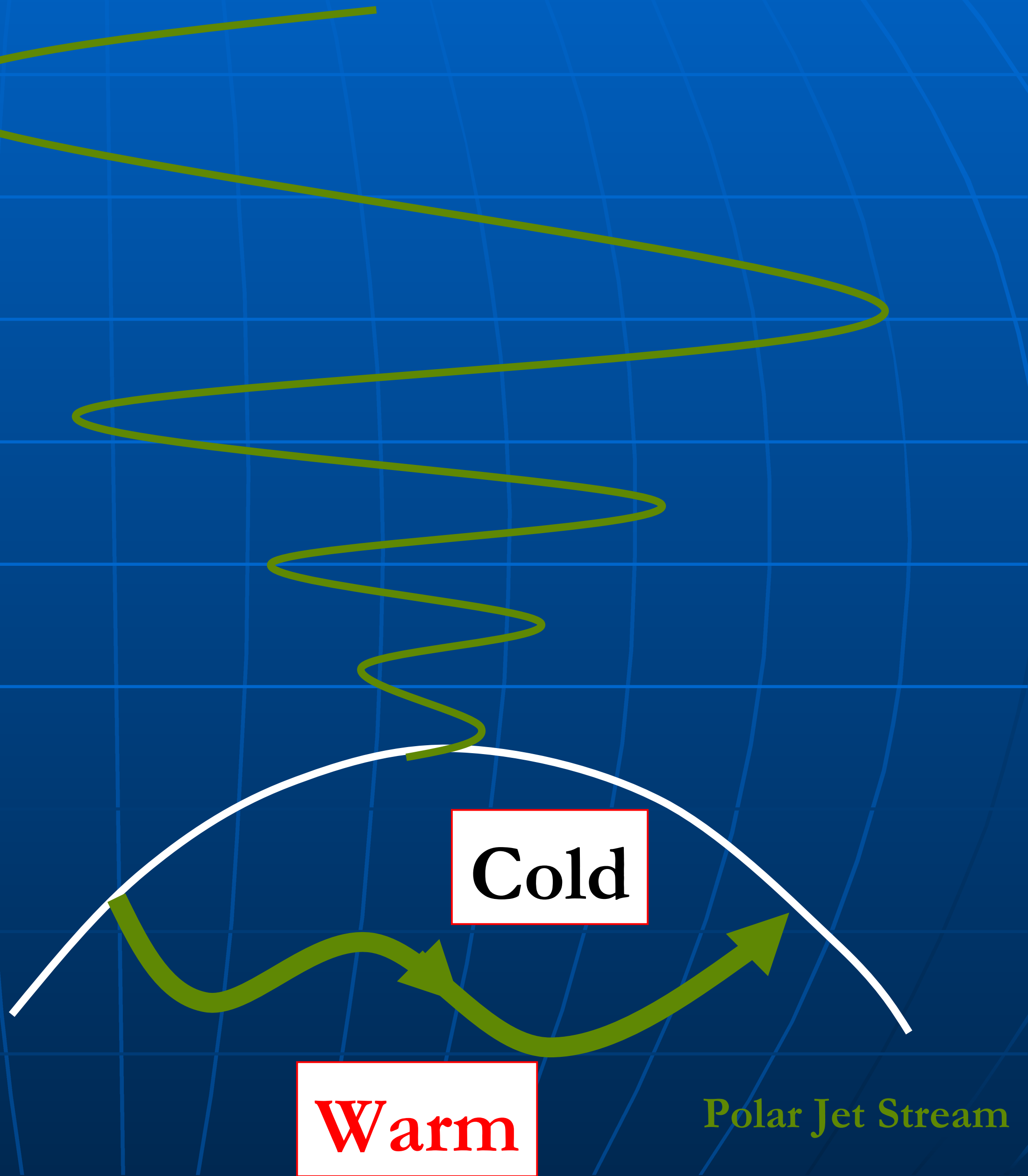
Winter of 2008-2009



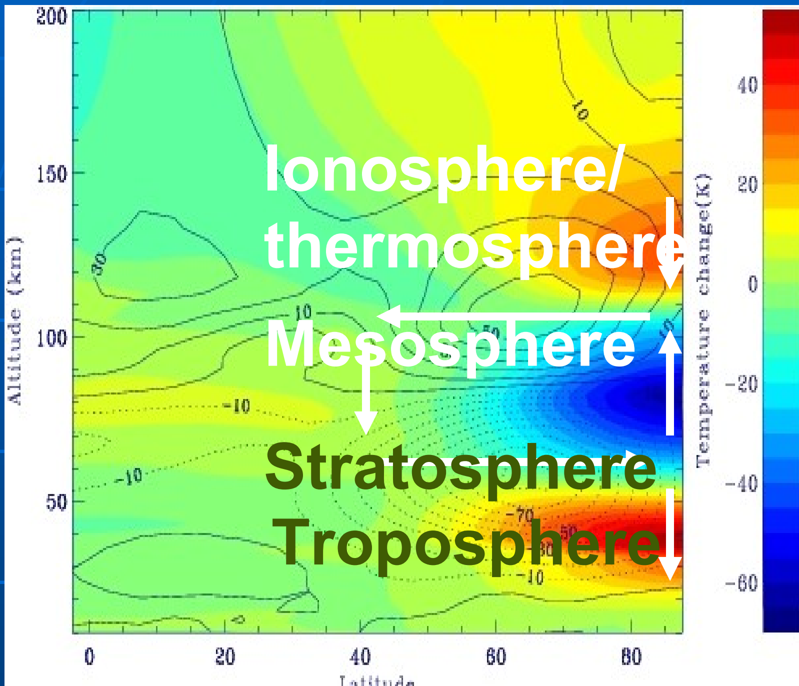
- 4 stratospheric sudden warmings in January-February 2008; record-breaking stratospheric temperature in January 2008 event
- 1 stratospheric sudden warming peaking in end of January 2009; major warming, the strongest and most prolonged on record
- Solar minimum, geomagnetically quiet periods

Physical interpretation

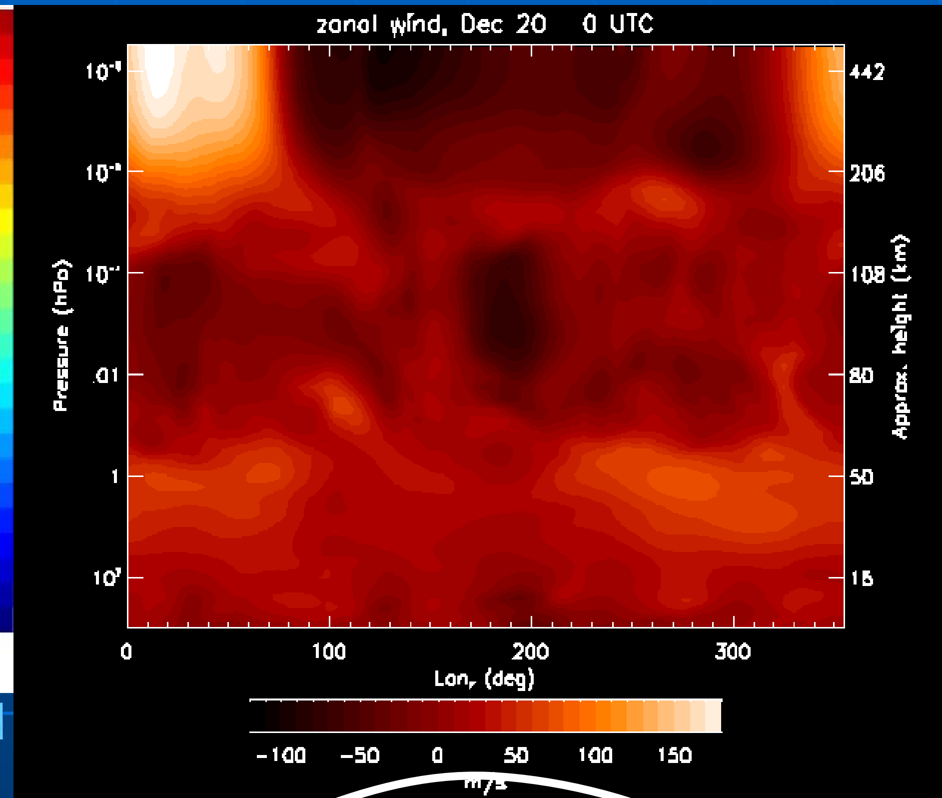
Atmospheric thermal tides from solar heating (e.g. ozone absorption of solar UV)



Development of stratospheric warming



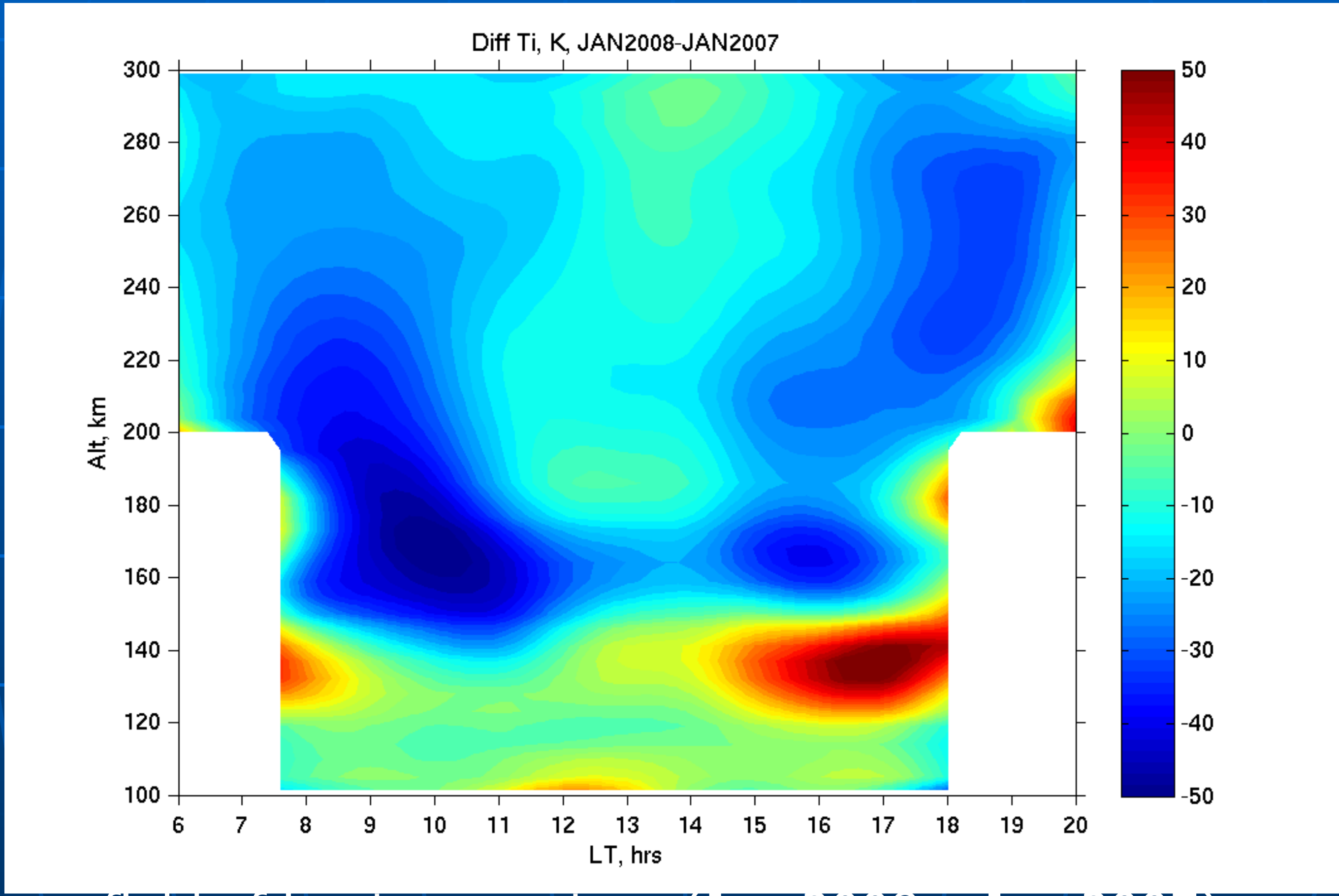
[*Liu and Roble*, 2002]



Normal

Stratospheric Warming

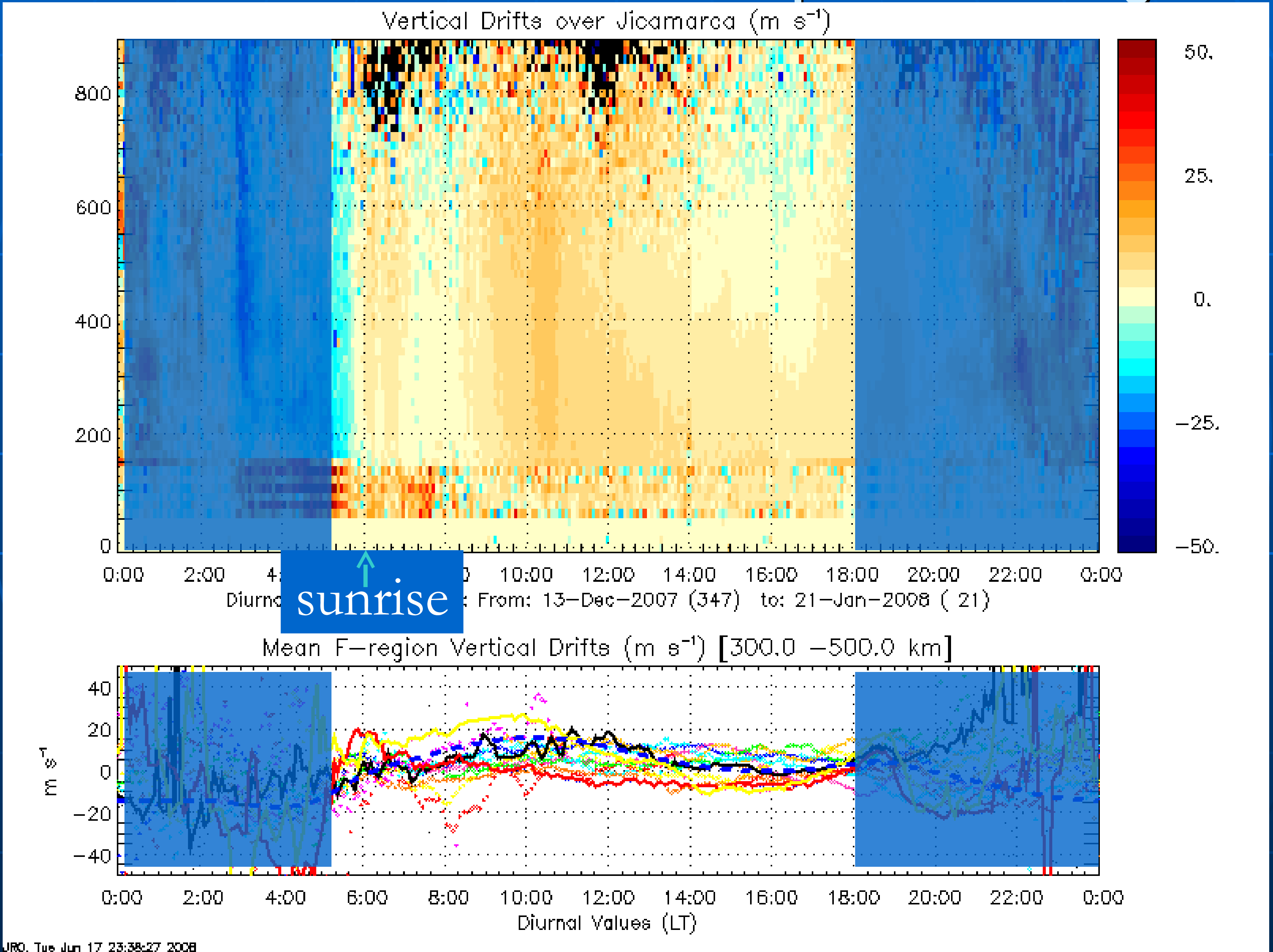
Middle latitude ionosphere: Millstone Hill ISR Ti data



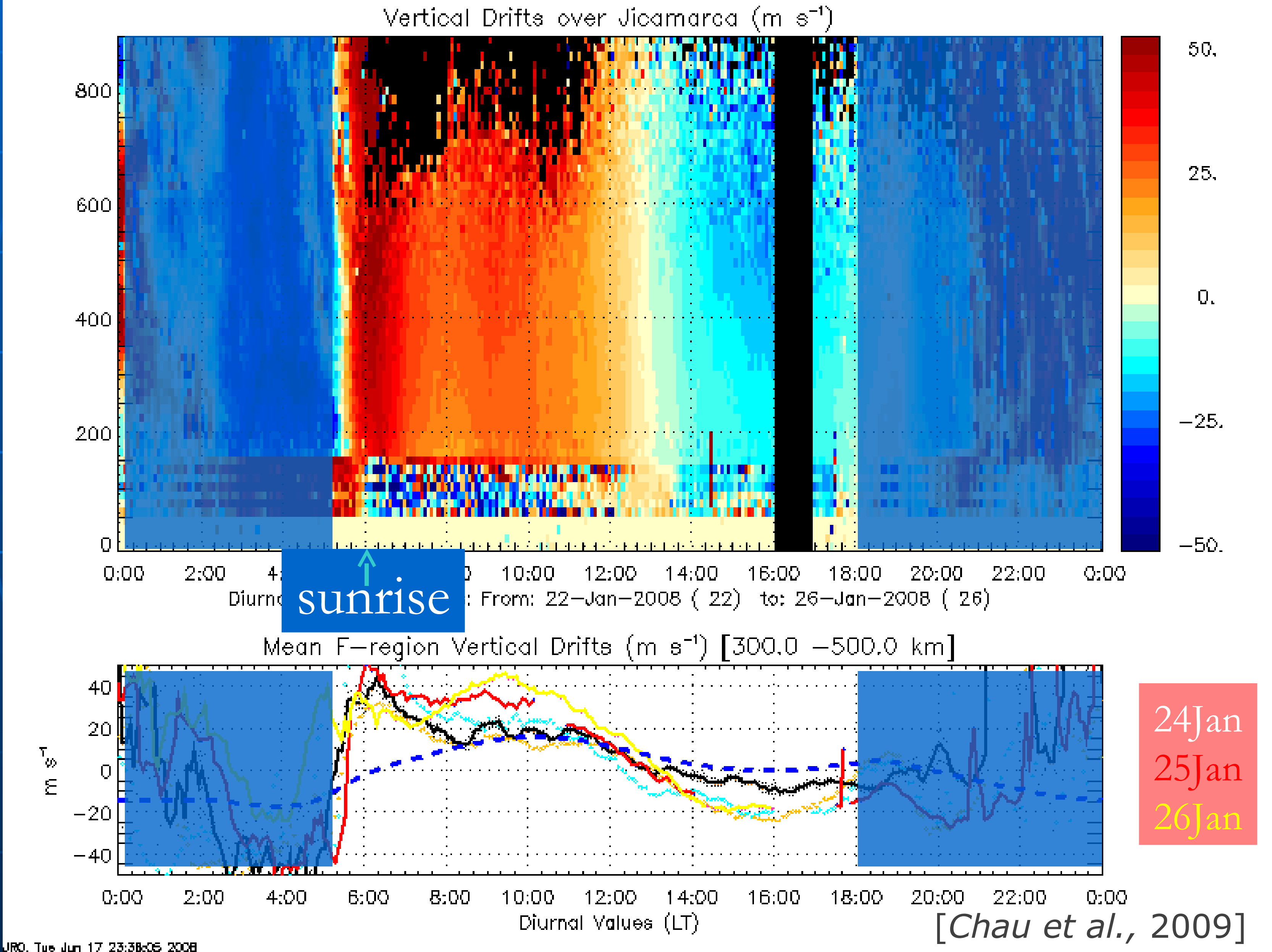
- Difference field of ion temperature (Jan 2008 – Jan 2007)
- Warming at 120-140km; cooling above ~150 km
- First experimental evidence of SSW effects in the ionosphere

Goncharenko and Zhang, GRL, 2008

Equatorial Ionospheric Drifts:
Diurnal values before stratospheric warming

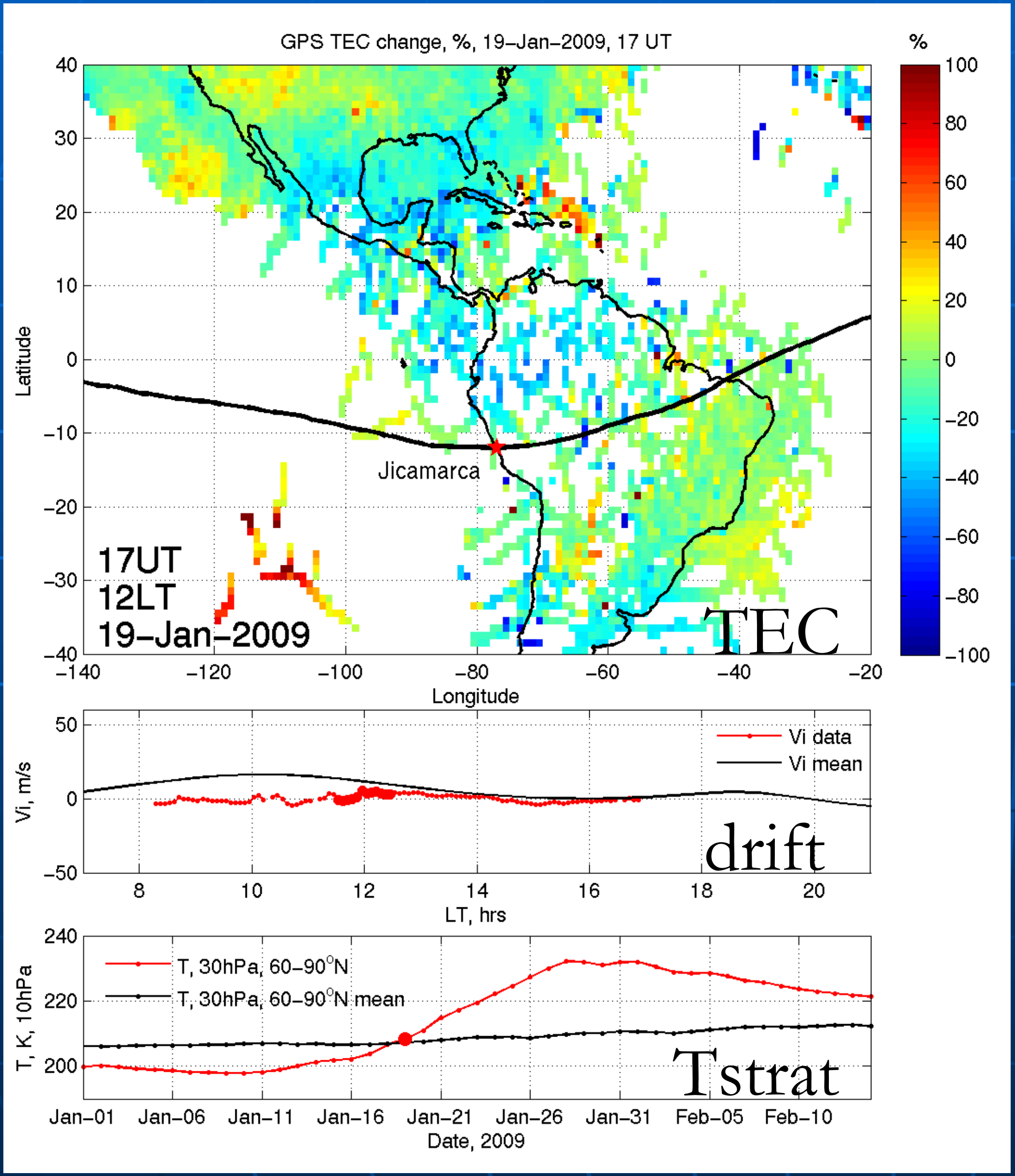


Equatorial Ionospheric Drifts: Diurnal values during stratospheric warming



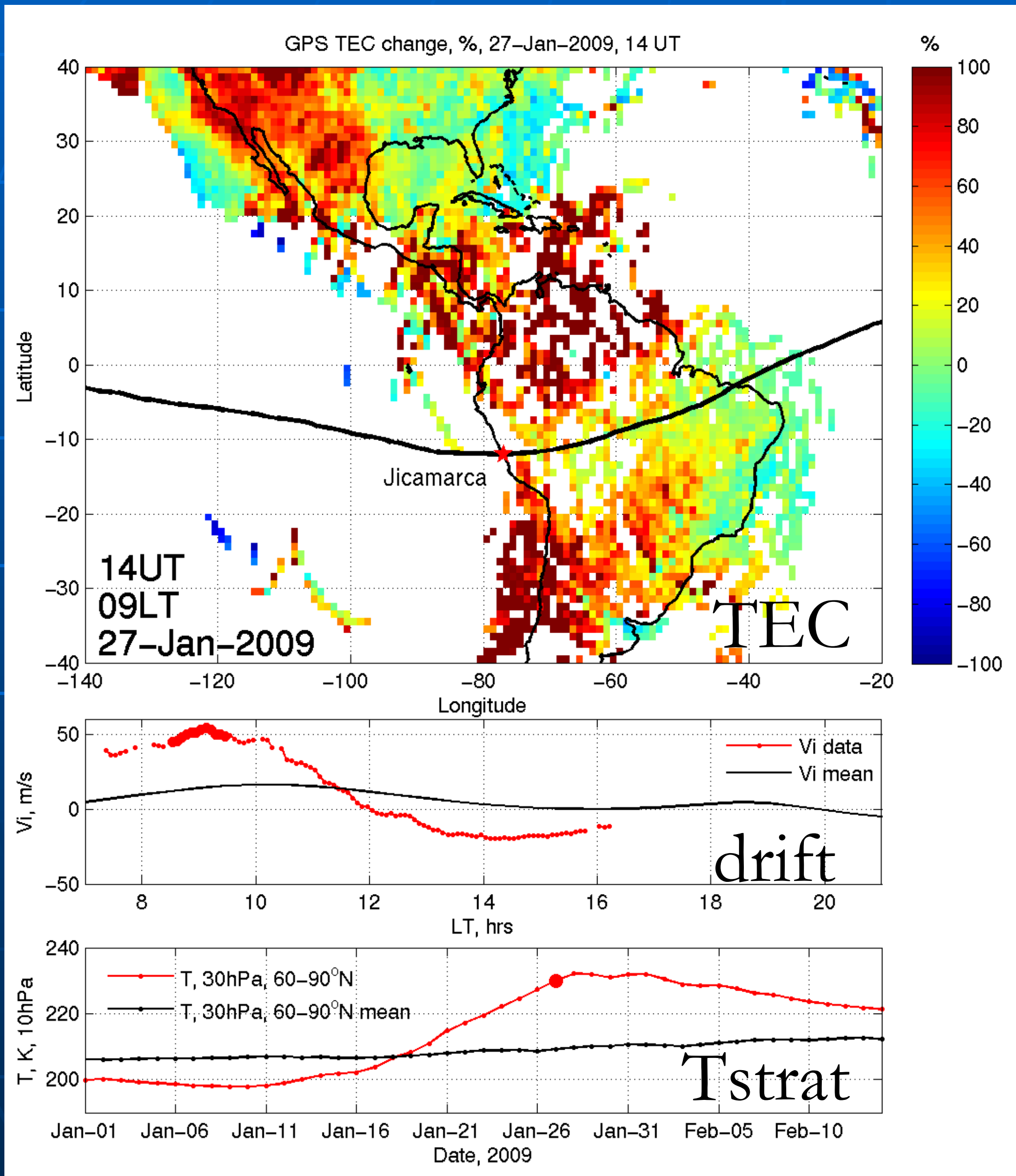
[*Chau et al.*, 2009]

GPS TEC change – no warming



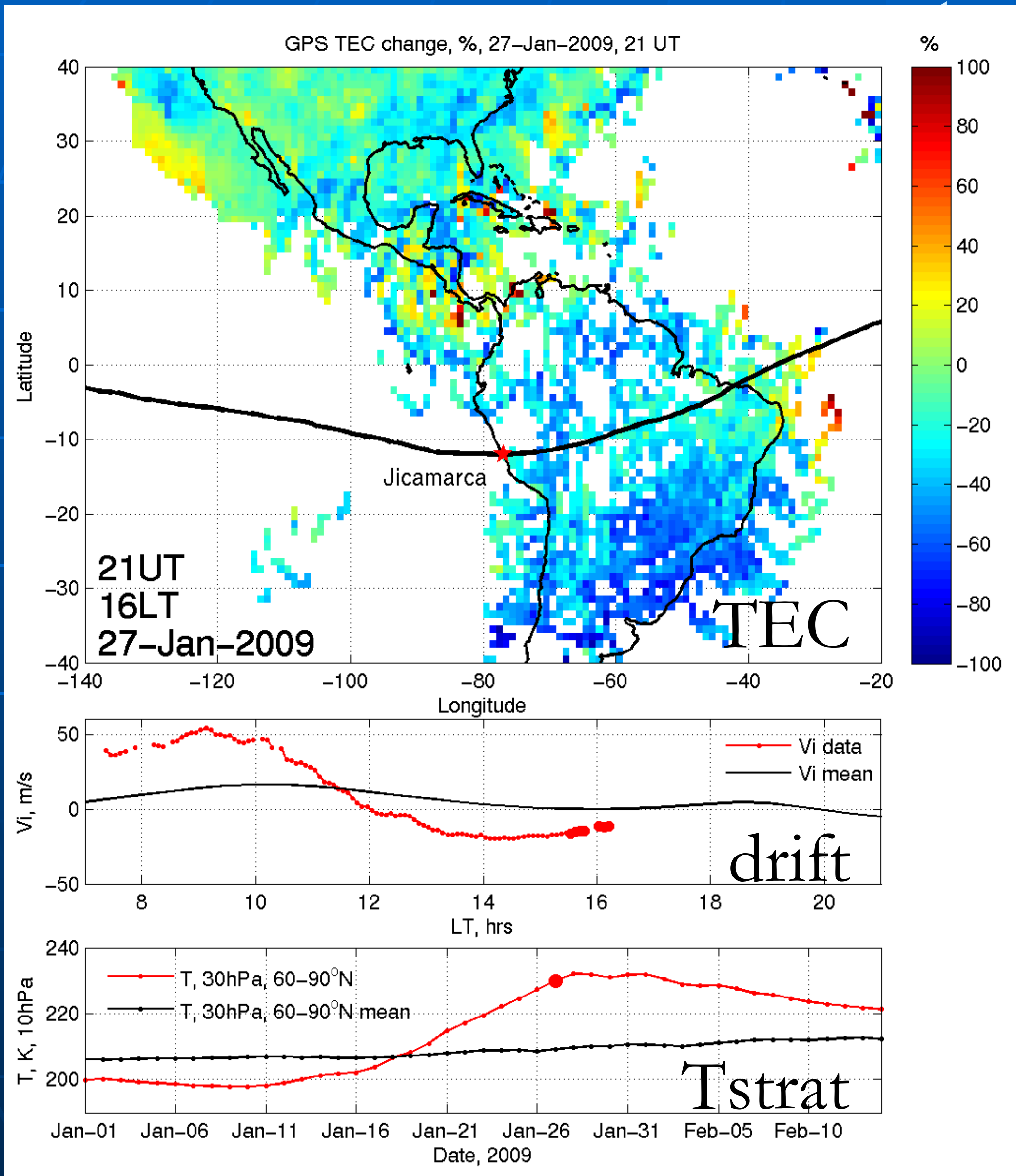
- GPS TEC (Total Electron Content) data show large-scale picture of ionospheric behavior
- Before the warming, TEC change is 10-20% from mean and vertical drift is small
- The mean is Jan 1-14, 2009

GPS TEC during warming: morning sector



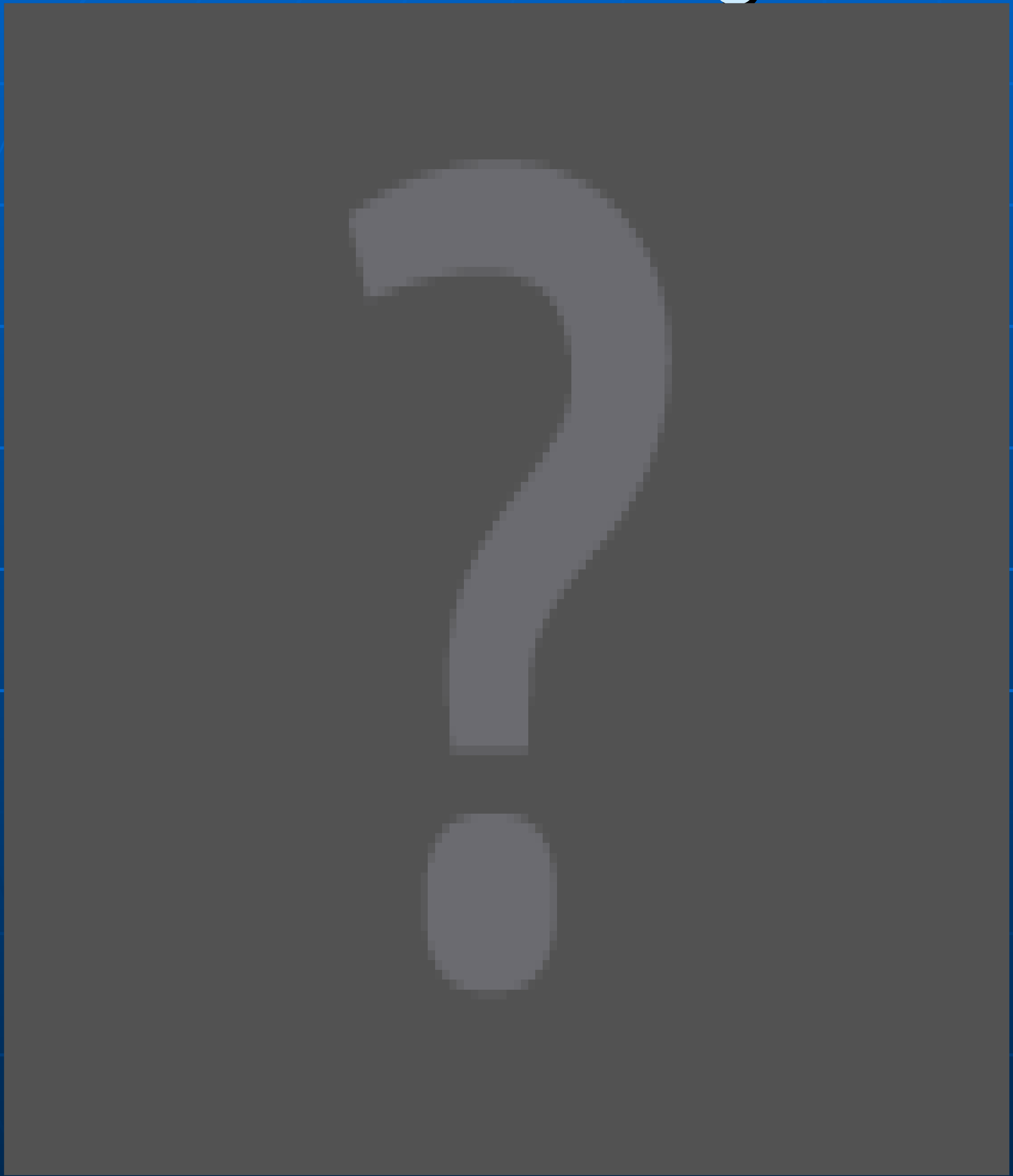
- During stratwarming, TEC increases in excess of 50-100% in the morning
- Large upward drift at Jicamarca
- The magnitude of increase is similar to effects of severe geomagnetic storms

GPS TEC during warming: afternoon



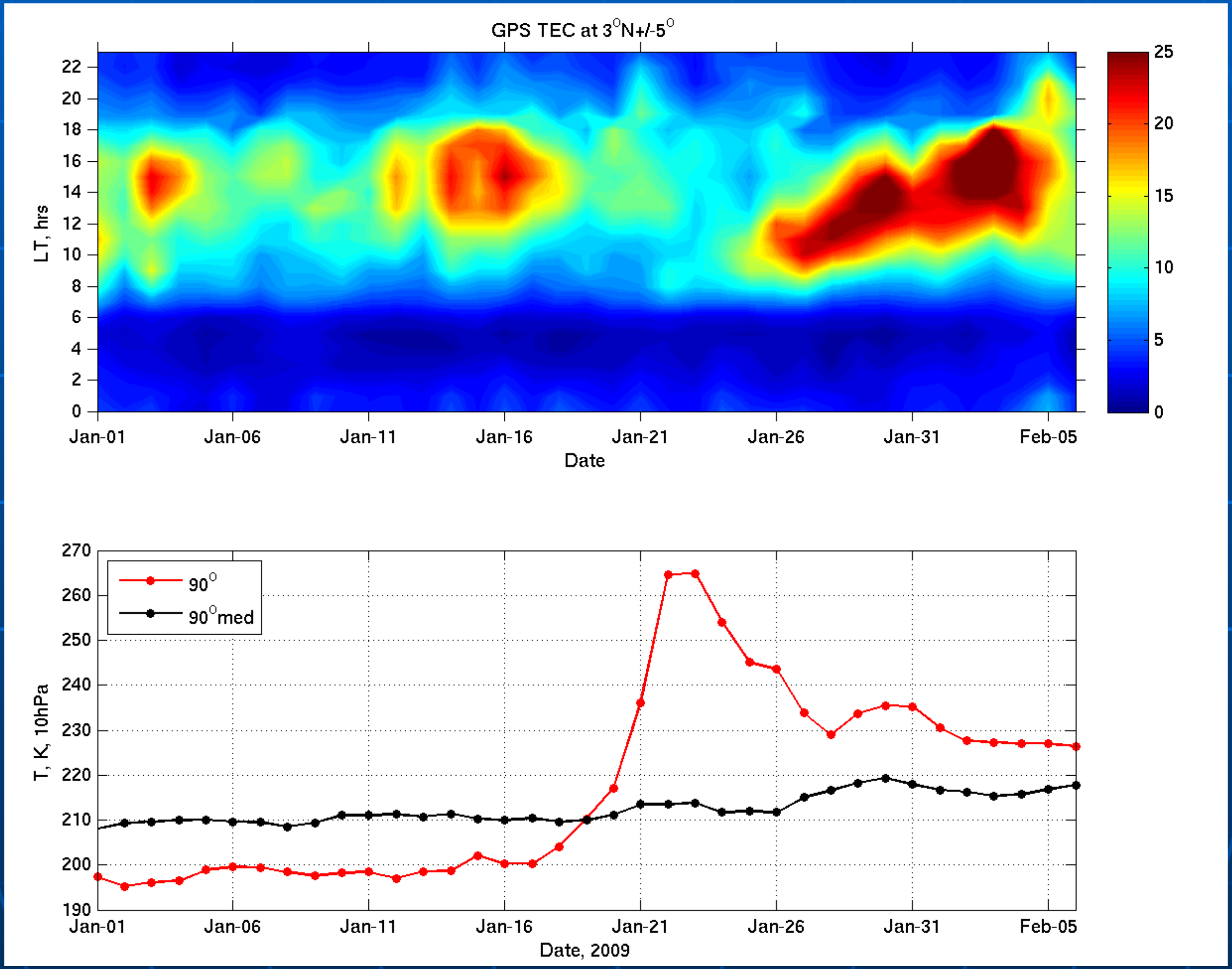
- During stratwarming, TEC decreases by ~50% in the afternoon
- Large downward drift at Jicamarca

GPS TEC change during the warming



- The entire daytime ionosphere is affected
- Persistent behavior for several days around stratospheric warming

Jan-Feb 2009: TEC variation with local time at 3°N, 75°W



Complex pattern of increase during SSW, shifting to later local times

Summary

- Evidence of dramatic changes in electron density during stratospheric sudden warmings
- Consistent with increase in Jicamarca electric field data and E-region dynamo mechanism
- Strong 12-h signature
- Increase in TEC in the morning sector by 50-150%; suppression in the afternoon by ~50%
- Disturbances extend to middle latitudes
- Shift to later local times