Connections between the stratosphere and ionosphere

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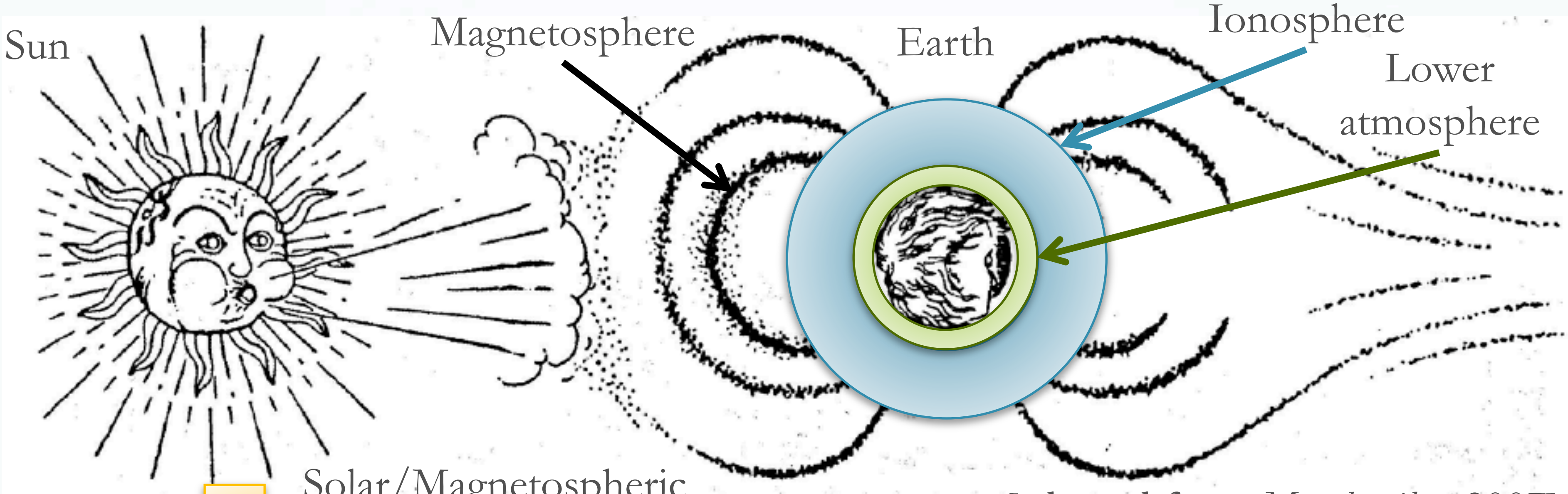
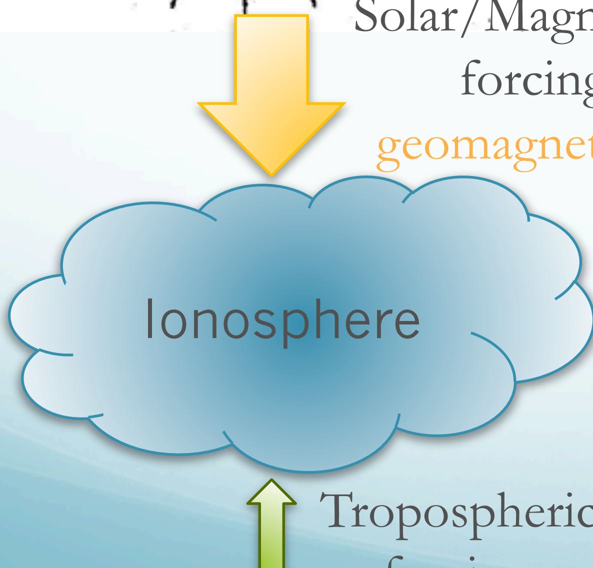
Ionosphere Forcing



[adapted from *Marchavilas*, 2007]

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

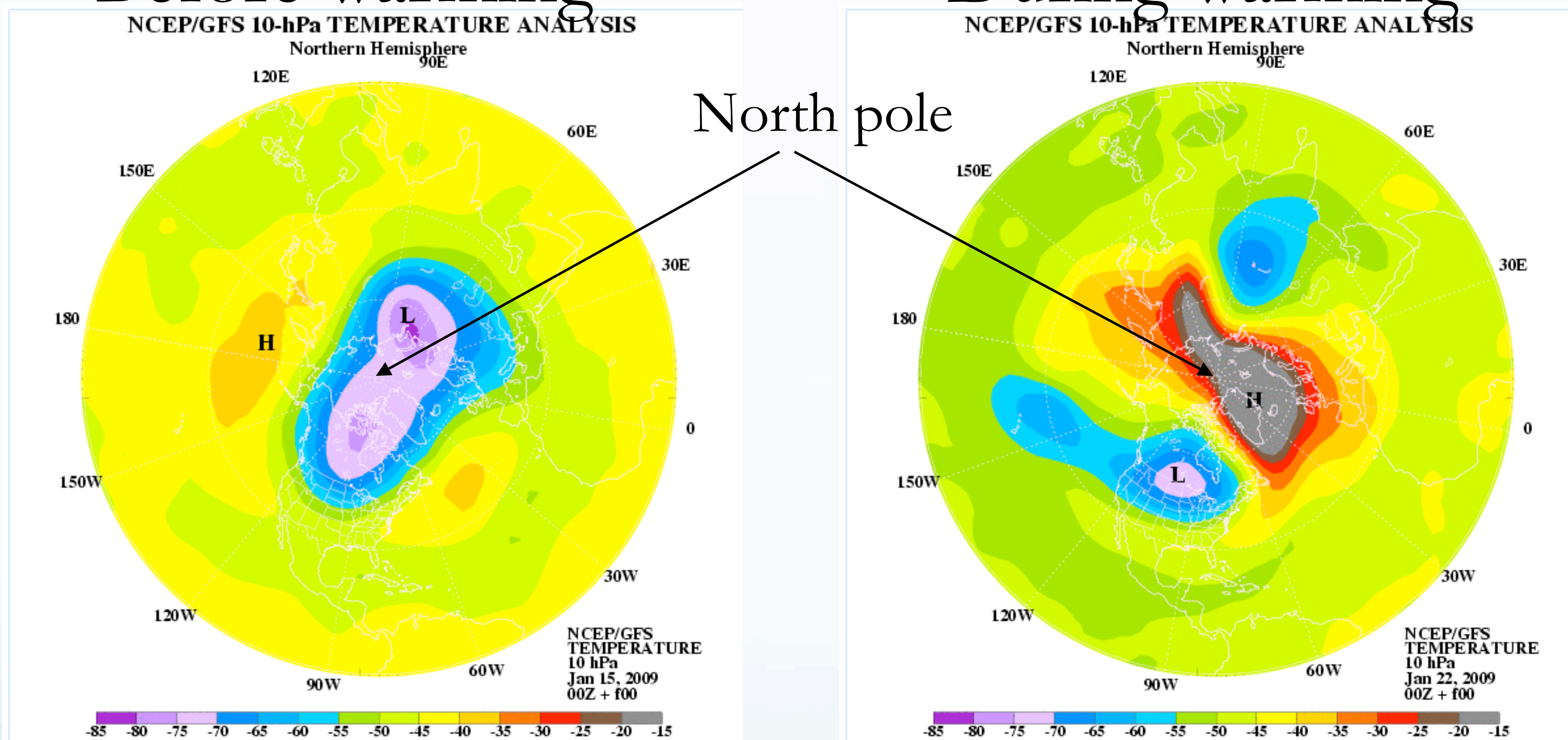


Tropospheric/Stratospheric forcing, e.g., planetary waves, tides, GW

- These forces produce ionospheric changes: electric fields, electron density, temperature, composition, …
- During solar minimum, Solar/Mag forcing is small, allowing the separation of lower atmosphere impact from the solar impact.

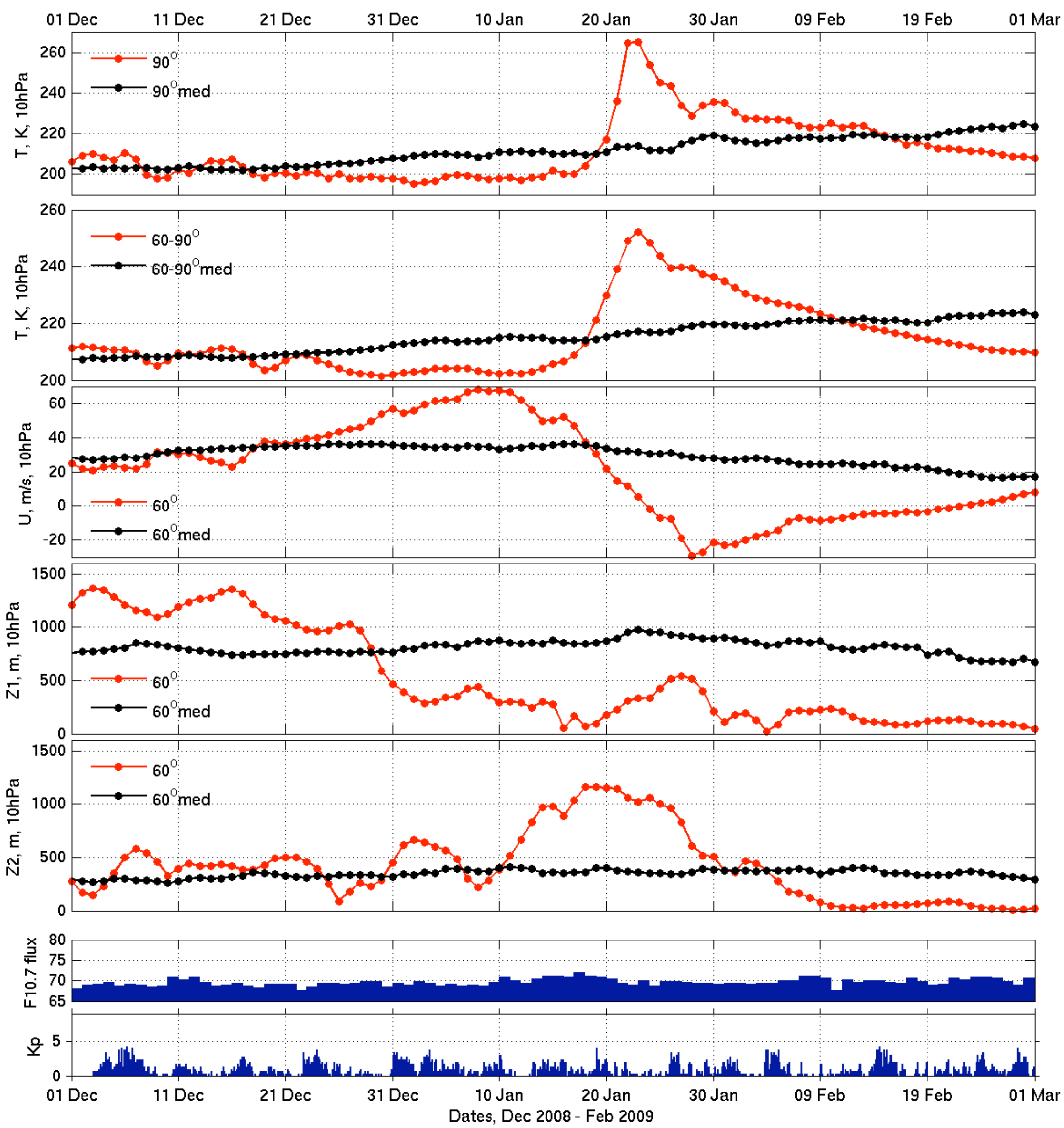
Stratospheric temperature at ~32km

Before warming | During warming



- Stratospheric sudden warming is a large-scale dramatic coupling event in the winter polar atmosphere
- Results from interaction of planetary waves with zonal mean flow

Stratospheric and geomagnetic conditions: winter 2008-2009



Red – 2009 data

Black – 30-year mean

Stratospheric Temperature over the Arctic and 60-90°N: increase by 40-70K

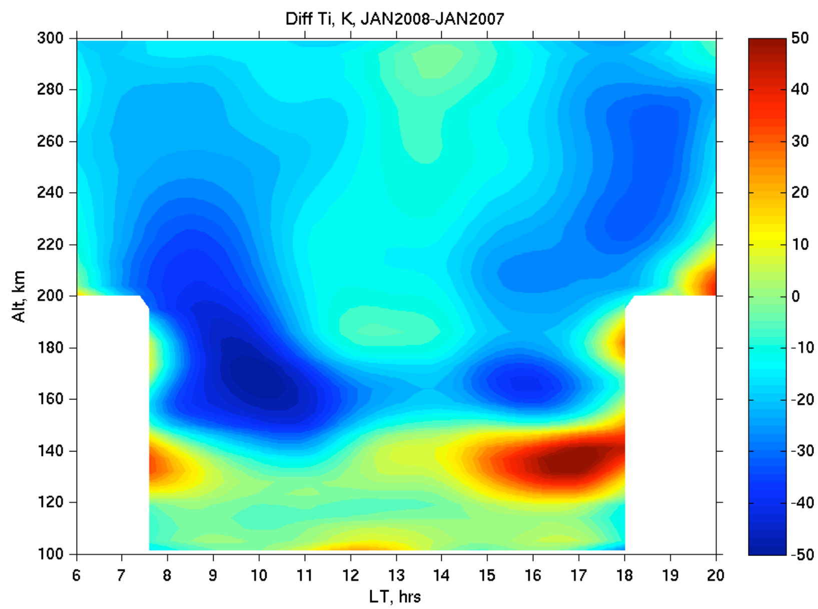
Stratospheric Zonal wind at 60°N: abatement and direction change

Planetary waves 1 and 2:
Factor of 3 increase in PW2 activity

Solar activity minimum: F10.7~70
Magnetic activity: quiet, Kp < 3

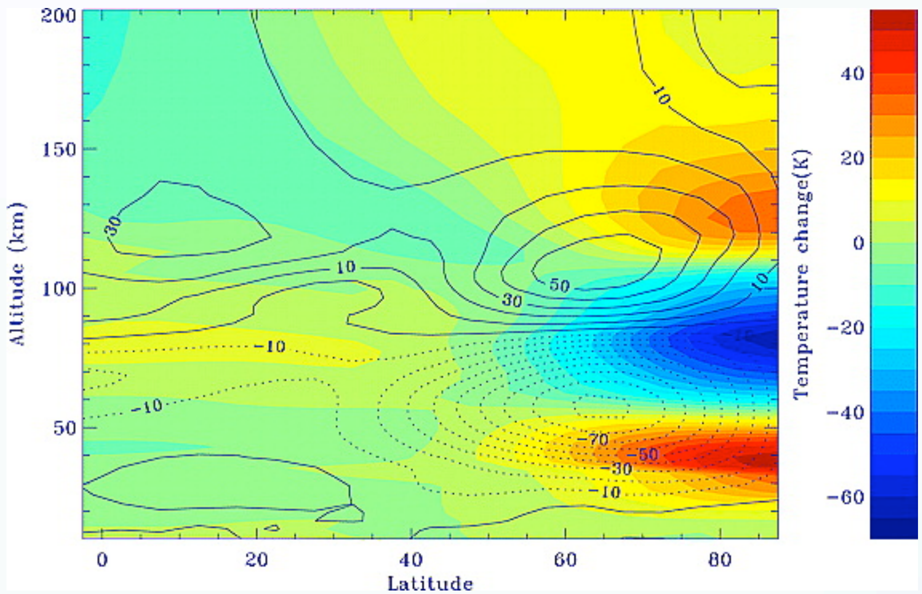
Temperature variations during SSW

Data: Millstone Hill ISR, 42°N



Goncharenko and Zhang, 2008

Model: TIMEGCM

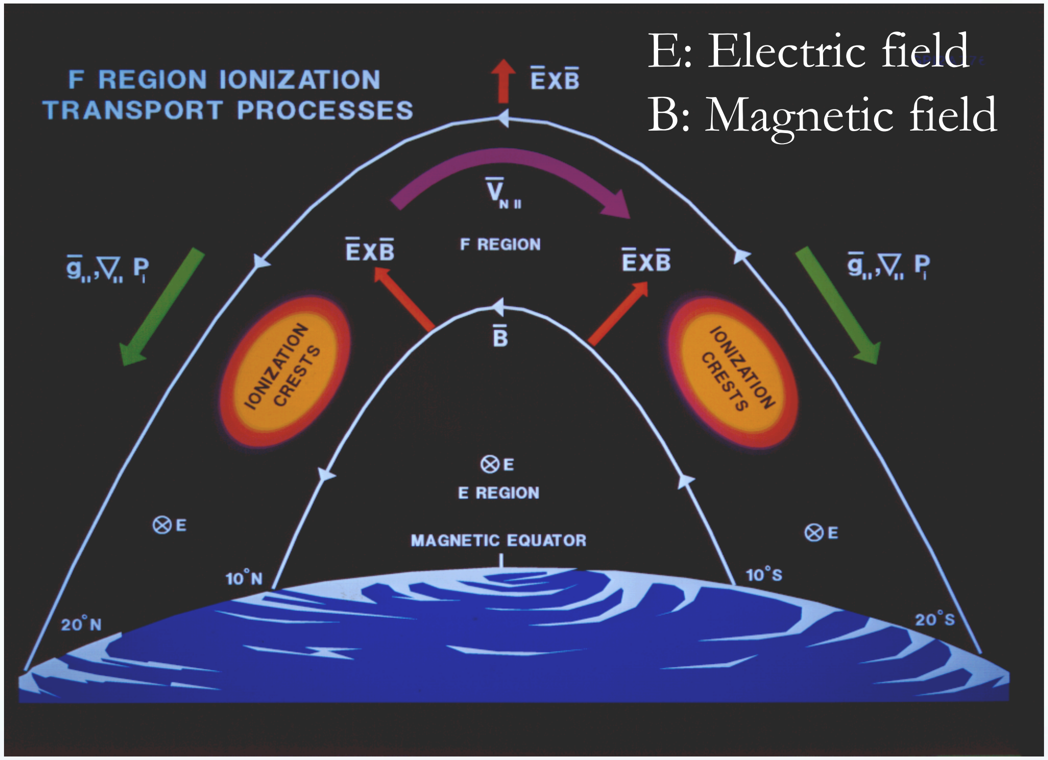


Liu and Roble, 2002

•Data: warming at 120-140km; cooling above ~150 km; 12-hour wave

•Model: mesospheric cooling and secondary lower thermospheric warming

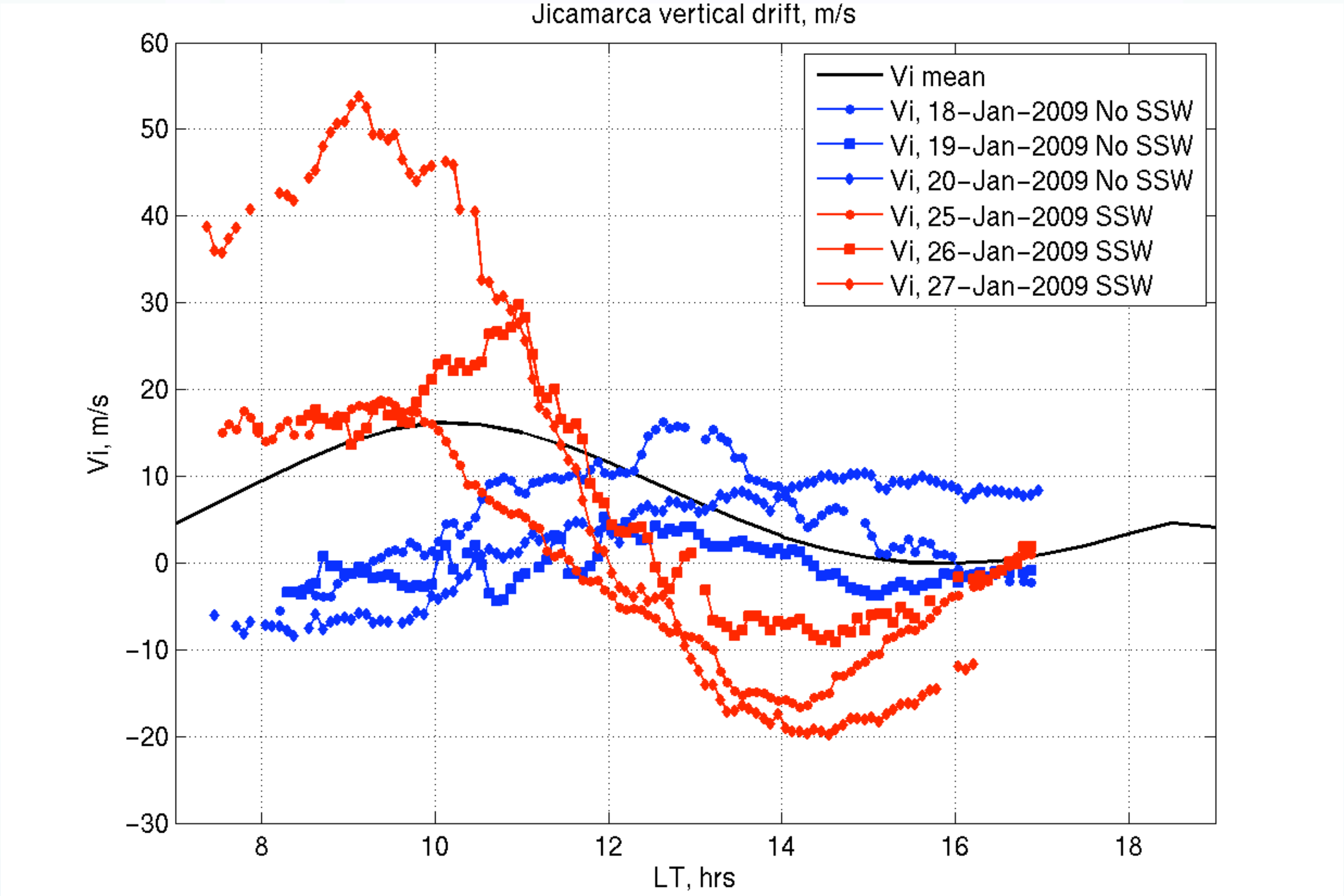
Low Latitude Ionosphere



•Highly sensitive to vertical transport

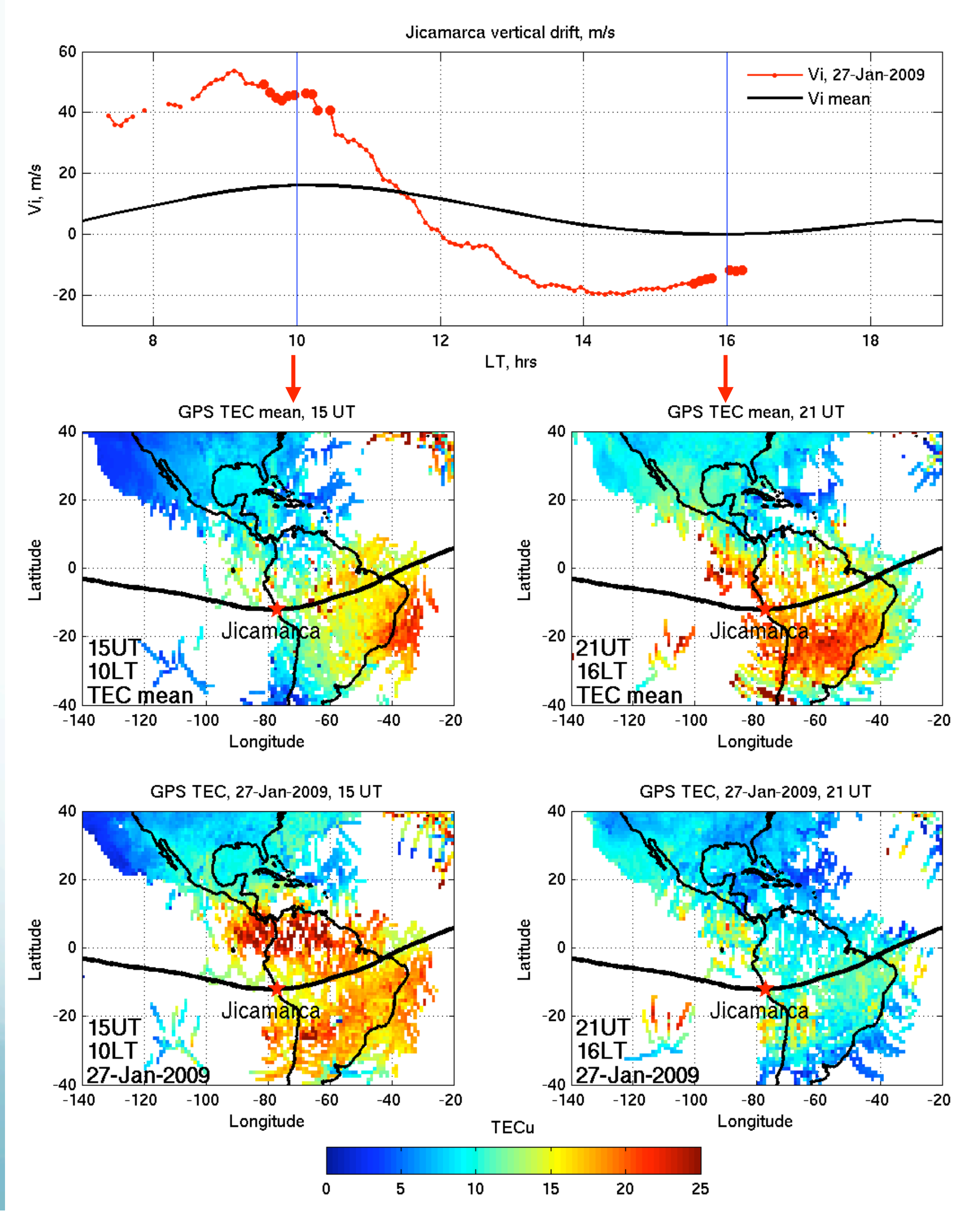
•The driver of vertical motion remains an unresolved problem

January 2009: Jicamarca vertical drift



- Strong 12-h perturbation in vertical drift
- Persistent for several days
- Similar to the drift during stratwarming of Jan 2008 (Chau et al., 2009)

Jicamarca drift and GPS TEC

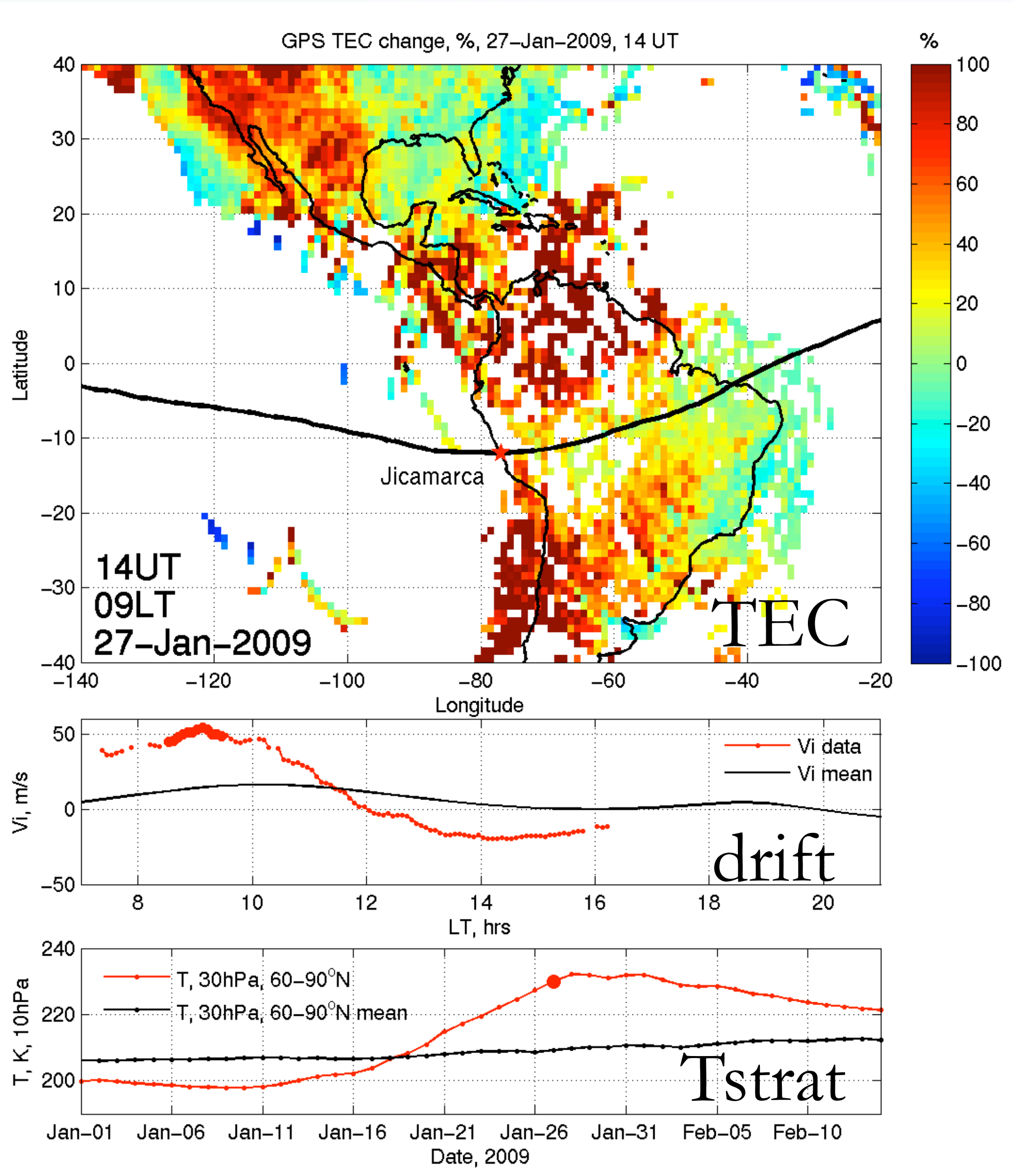


Jicamarca vertical drift

GPS TEC at 15UT and 21UT before stratwarming – 10 day mean

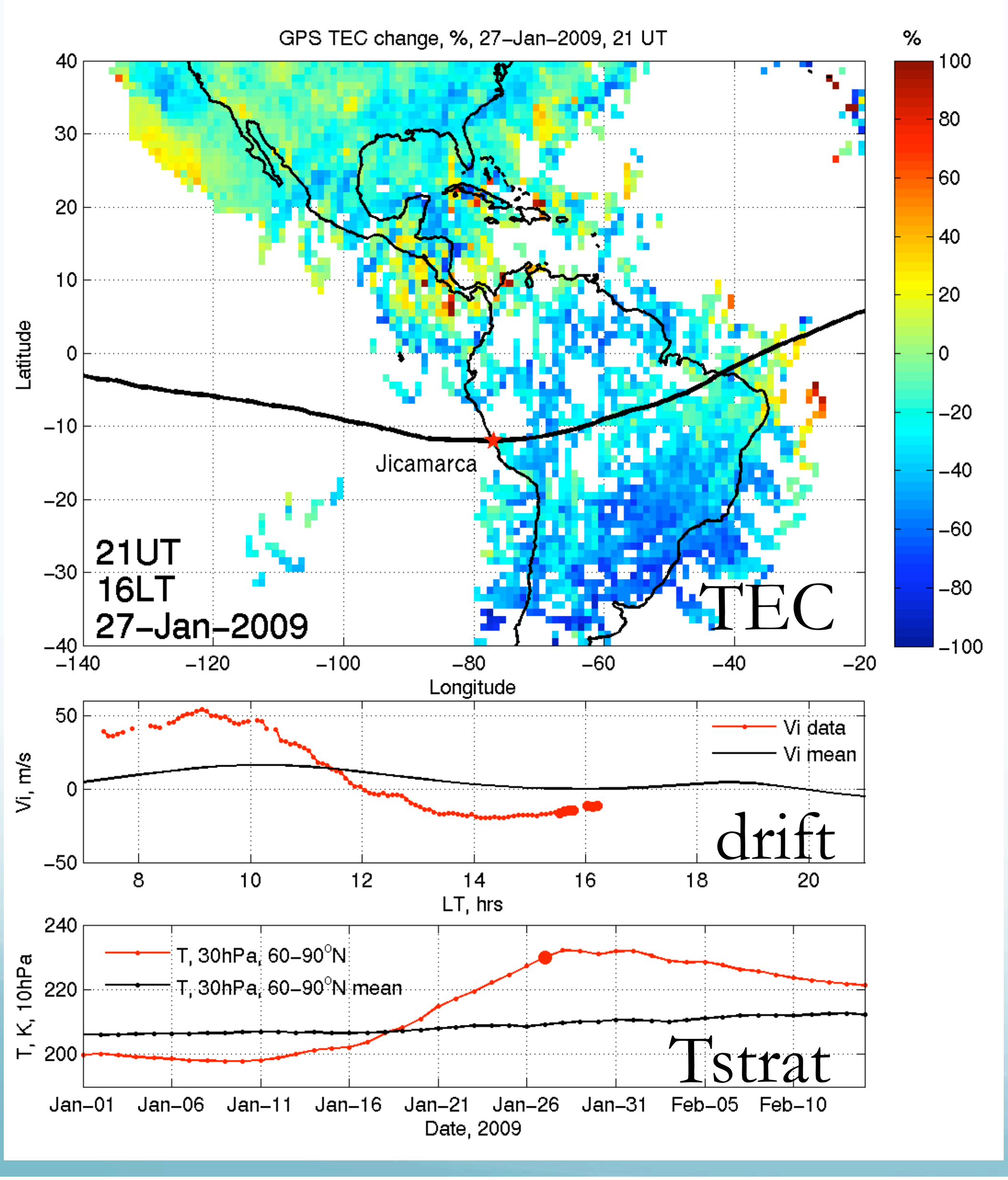
GPS TEC at 15UT and 21UT during stratwarming

GPS TEC during warming: morning sector



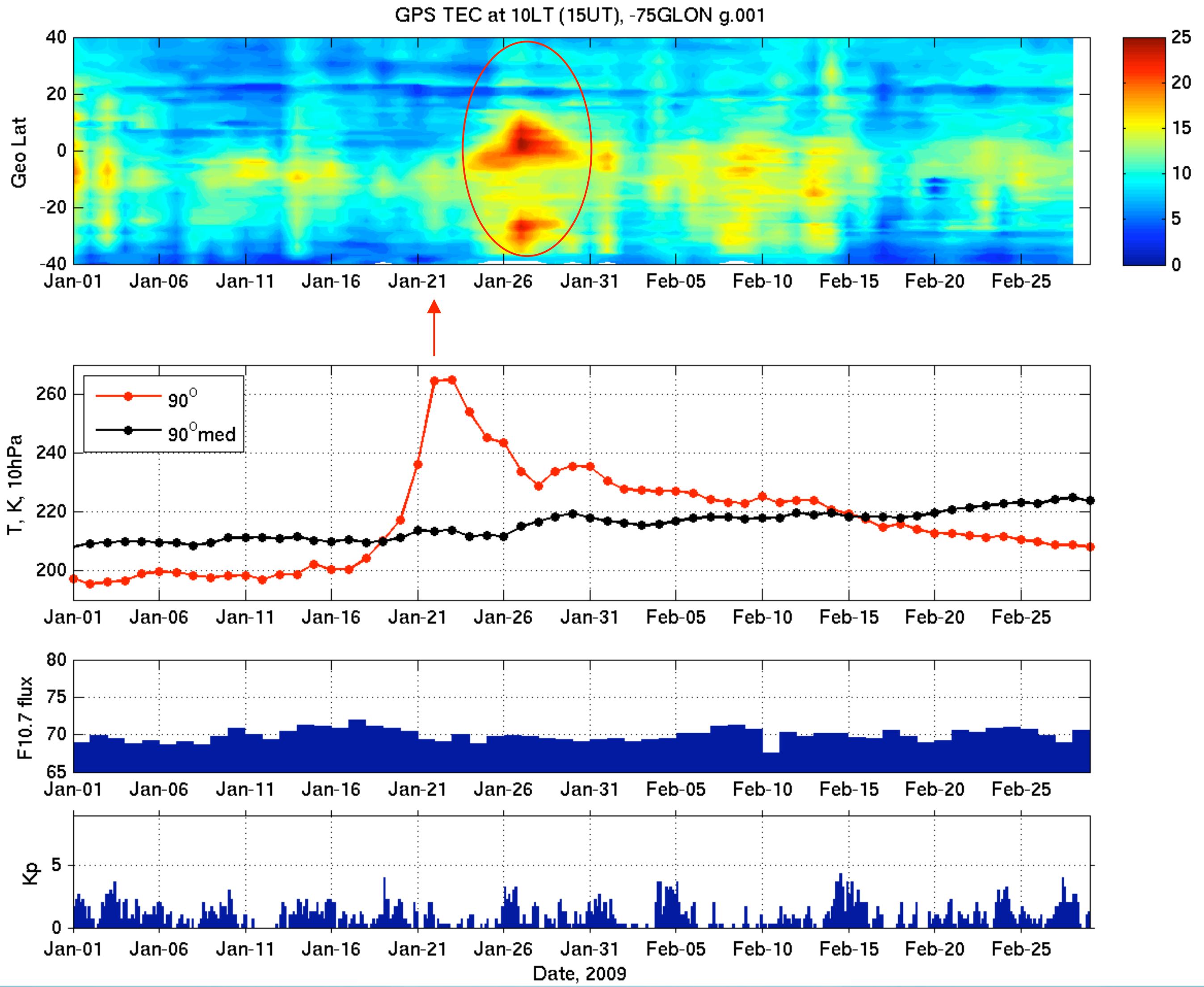
- During stratwarming, TEC increases in excess of 50-100% in the morning
- Large upward drift at Jicamarca
- The magnitude of increase is similar to effects of severe geomagnetic storms

GPS TEC during warming: afternoon sector



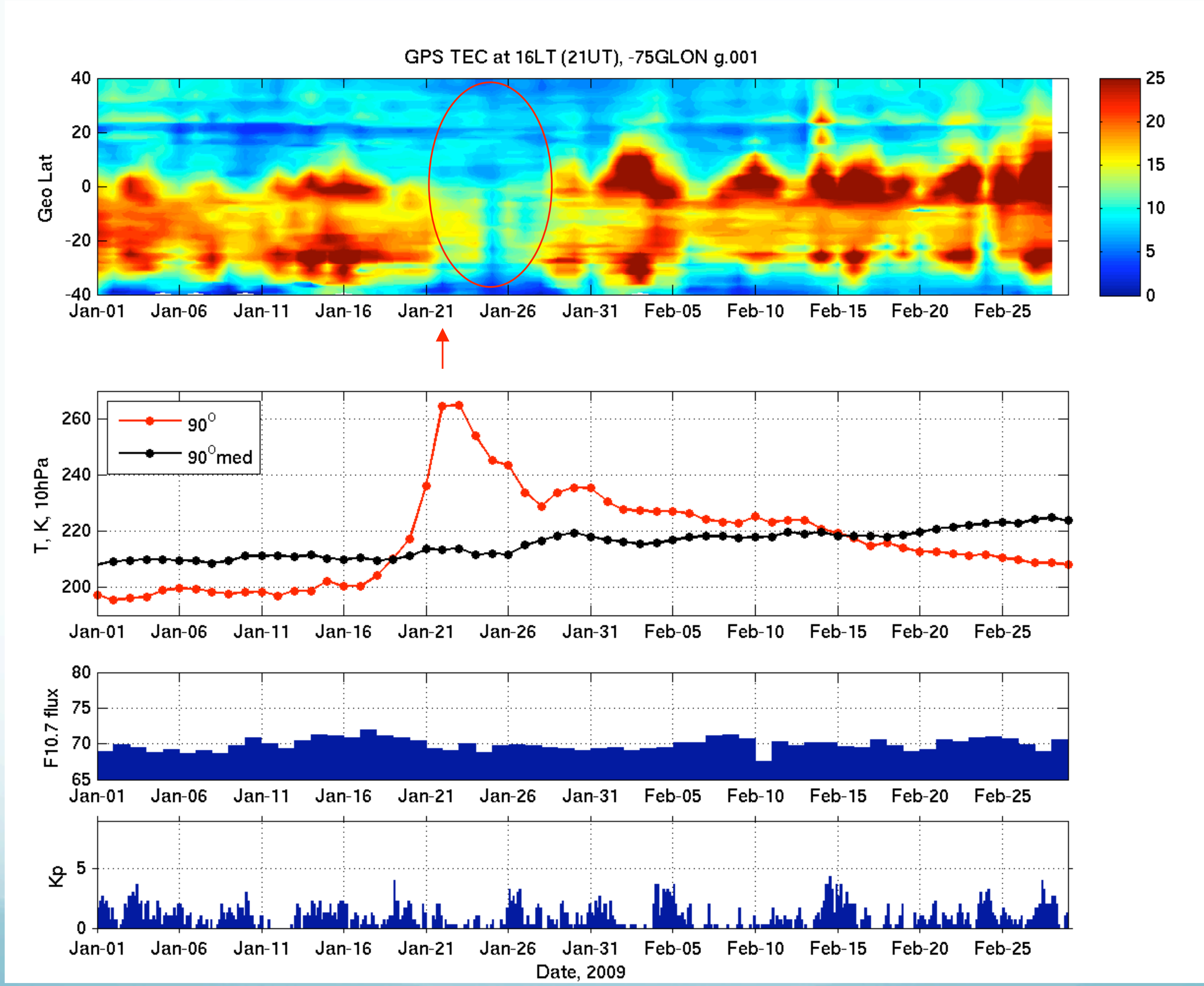
- During stratwarming, TEC decreases by ~50% in the afternoon
- Large downward drift at Jicamarca

GPS TEC Jan-Feb 2009, morning sector



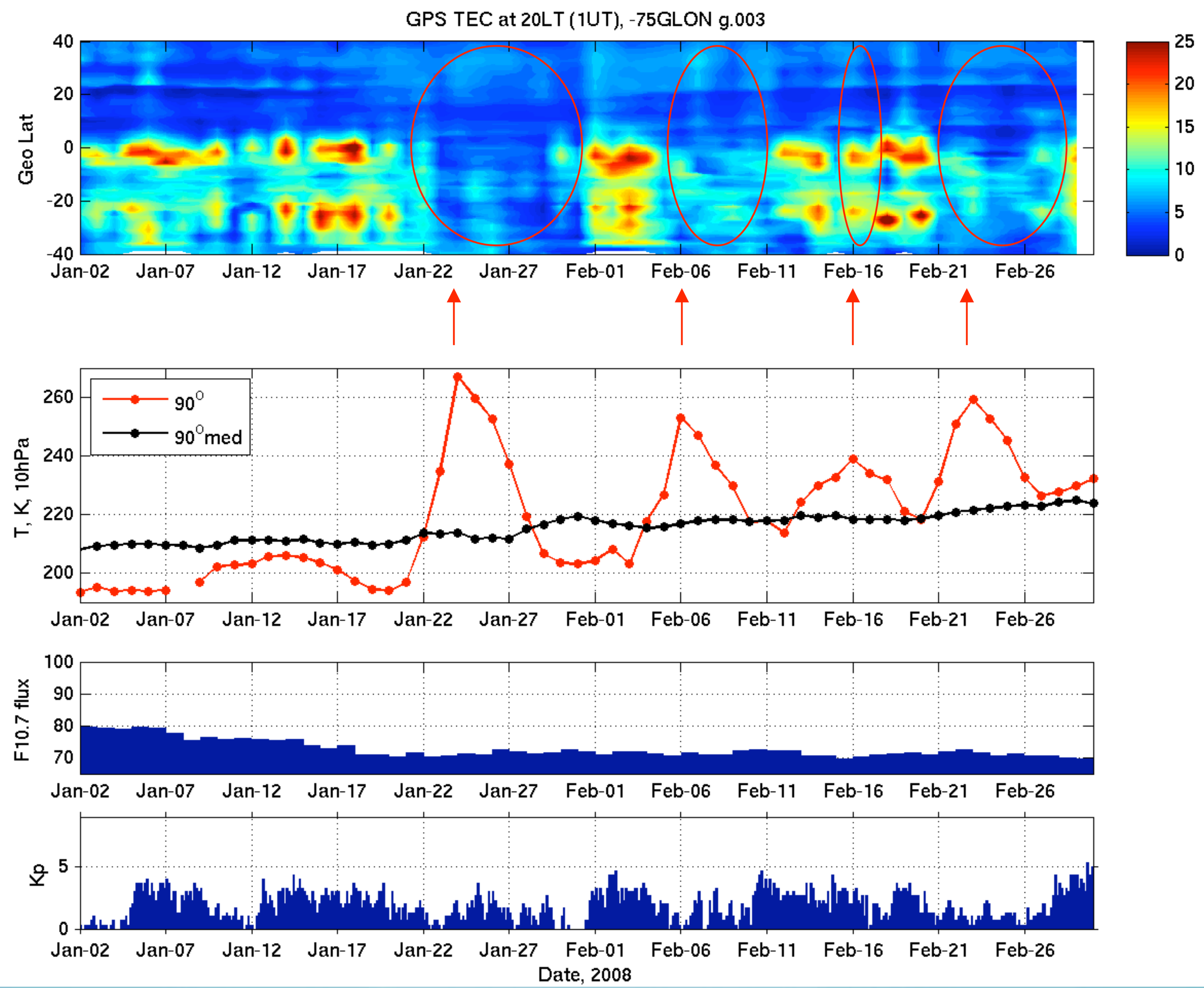
10LT

GPS TEC Jan-Feb 2009, afternoon sector

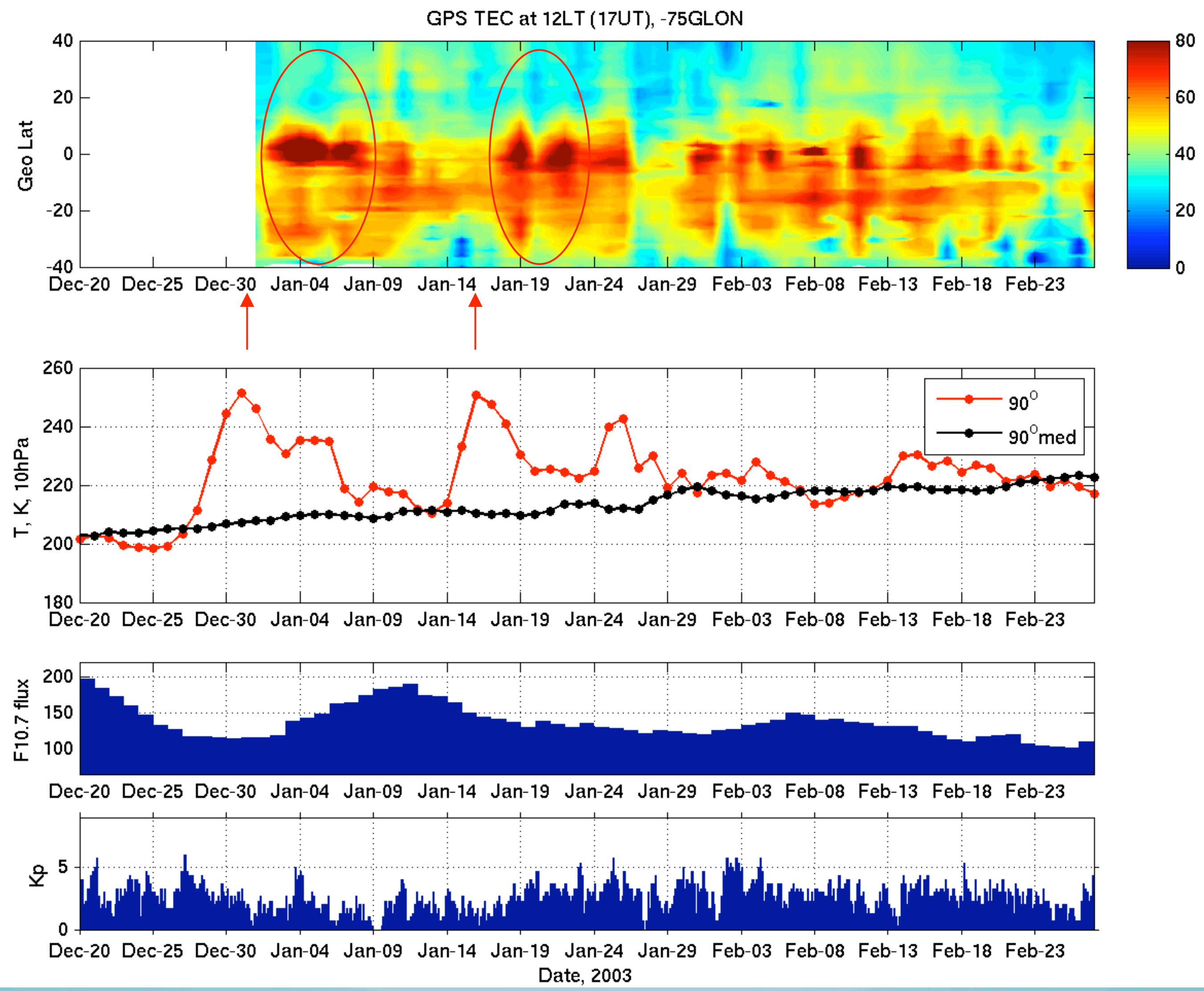


16LT

GPS TEC Jan-Feb 2008, dusk sector



High solar flux: winter of 2003, 12LT

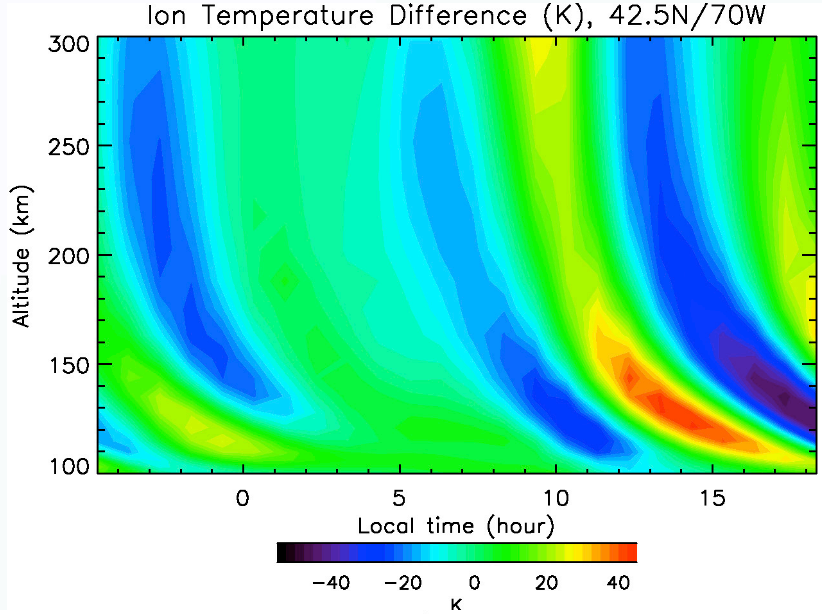


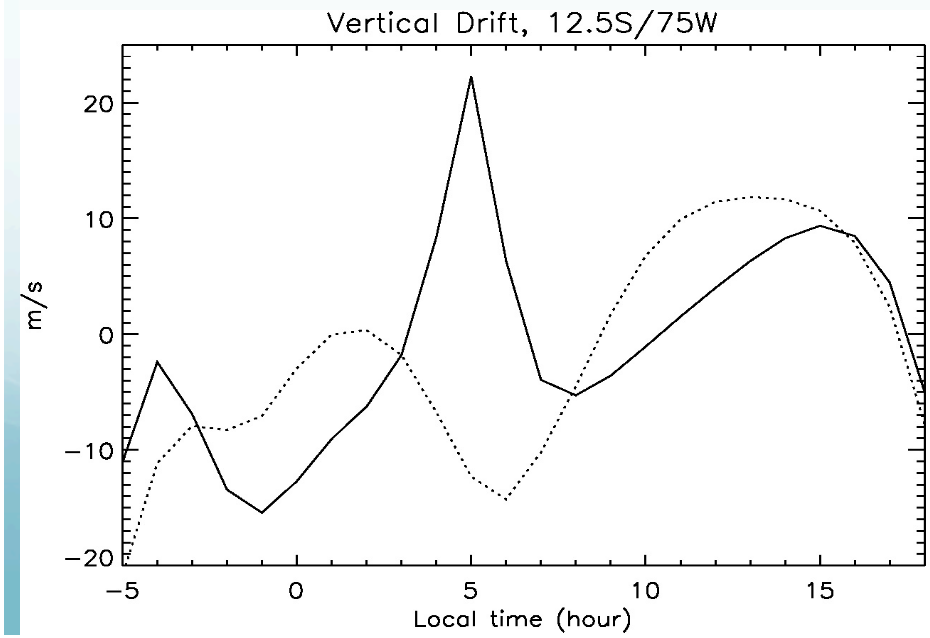
A plausible cause

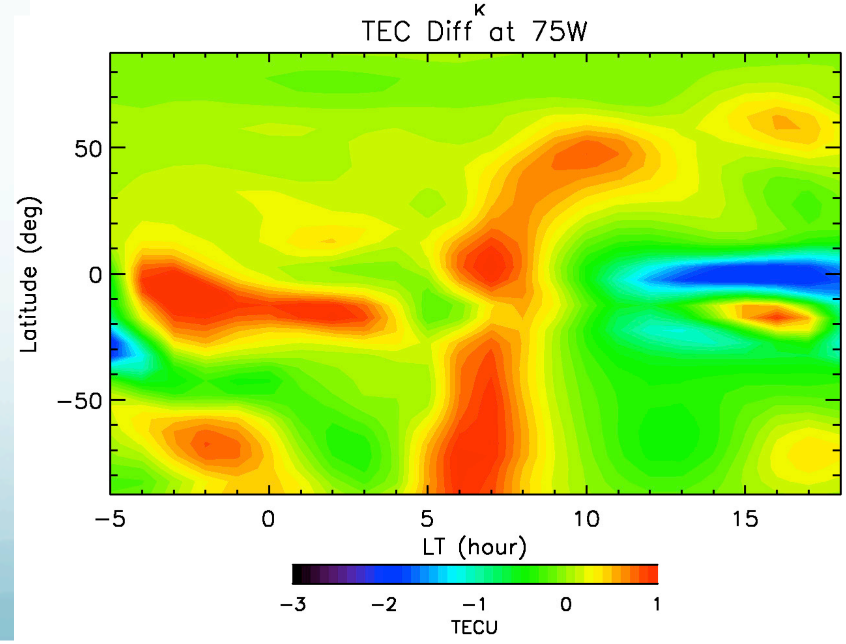
- **Major factors: planetary waves + tides**
- Stratospheric warming results from interaction of planetary wave with zonal mean flow
- Planetary waves propagate upward and to lower latitudes and are present at the lower thermosphere level (Pancheva et al., 2008,2009, Fuller-Rowell et al., 2008)
- Interaction of planetary wave with semidiurnal tide modulates the 12-h wave amplitude and E-region dynamo
  - Seasonal and longitudinal variation expected (Oberheide et al., 2008, Forbes et al., 2008, Pedatella et al., 2008)
  - Generation of non-migrating 12-h tide
- Changed mean wind affects tidal amplitudes?
- Gravity wave break-up generates secondary planetary wave in the MLT region?

Effects of Planetary Waves in the Ionosphere

- Wave structure in ion temperature differences (Millstone Hill results)
- Large electric fields around sunrise (Jicamarca observations)
- Total electron content (GPS results)







What do we know now…

- Clear observational evidence of lower atmosphere connection with the upper atmosphere, i.e., changes in electric field, electron densities, temperatures, associated with stratospheric warming events
- Changes observed by independent instruments, different observational techniques, for multiple cases of stratwarmings
- Major features: persistence, strength, 12-h tide
- The most surprising aspects are geographical location and magnitude of ionospheric variations
- New modeling results point to the propagation of lower atmospheric waves as one of the major causes of ionospheric variability

The big picture…

- The probability of SSW occurrence increases with solar flux
- SSW can be predicted 8-10 days in advance
- Stratwarmings are just one example of lower atmospheric forcing on ionosphere
- Space weather is the single largest contributor to GPS errors
- GPS handsets alone expected to rise to $100 billion by 2012

How the changing lower atmosphere affects ionosphere? What will it take to put lower atmospheric drivers in space weather models?