Atmosphere Coupling through Electrodynamics

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Sources of Ionosphere Variability

Table 1
Possible causes of ionospheric F-layer variability

(Rishbeth and Mendillo, 2001)

1. *Solar ionizing radiation*

Solar   ares
Solar rotation (27 day) variations
Formation and decay of active regions
Seasonal variation of Sun's declination
Annual variation of Sun–Earth distance
Solar cycle variations (11 and 22 years)
Longer period solar epochs

2. *Solar wind, geomagnetic activity*

Day-to-day 'low level' variability
Substorms
Magnetic storms
IMF/solar wind sector structure
Energetic particle precipitation
and Joule heating

3. *Neutral atmosphere*

Solar and lunar tides: generated within thermosphere
or coupled through mesosphere
Acoustic and gravity waves
Planetary waves and 2-day oscillations
Quasi-biennial oscillation
Lower atmosphere weather coupled through mesopause
Surface phenomena: earthquakes, volcanoes

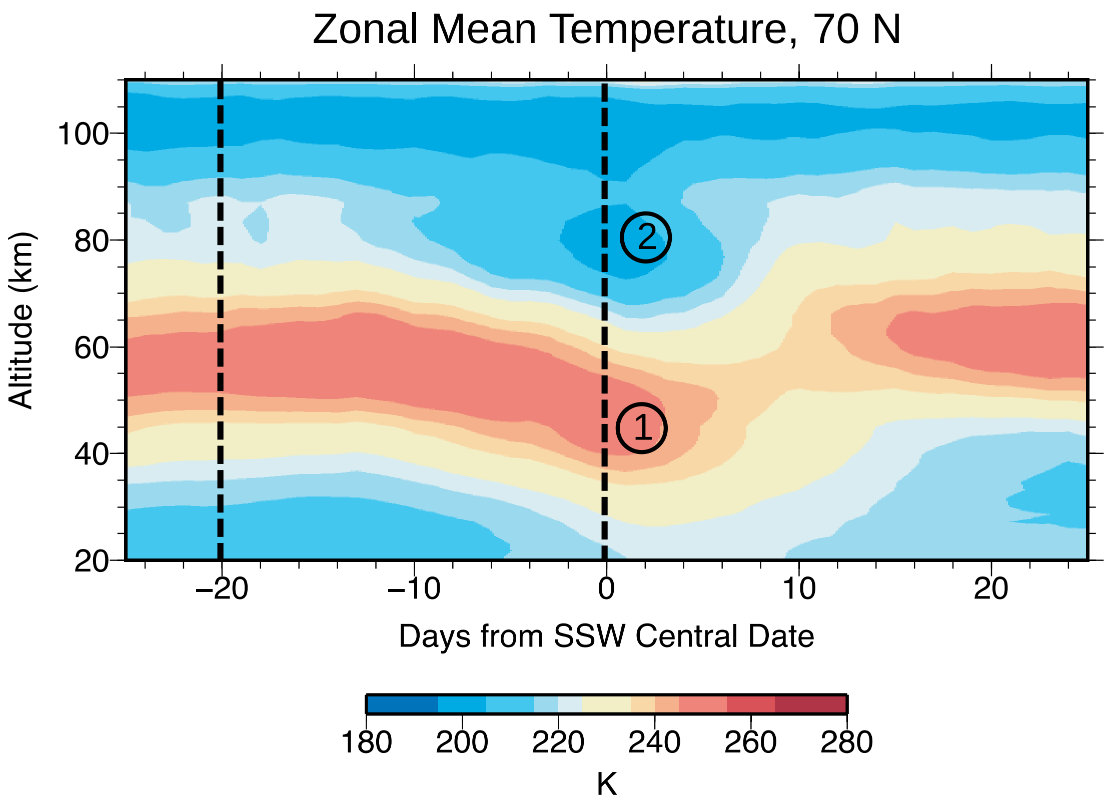
4. *Electrodynamics*

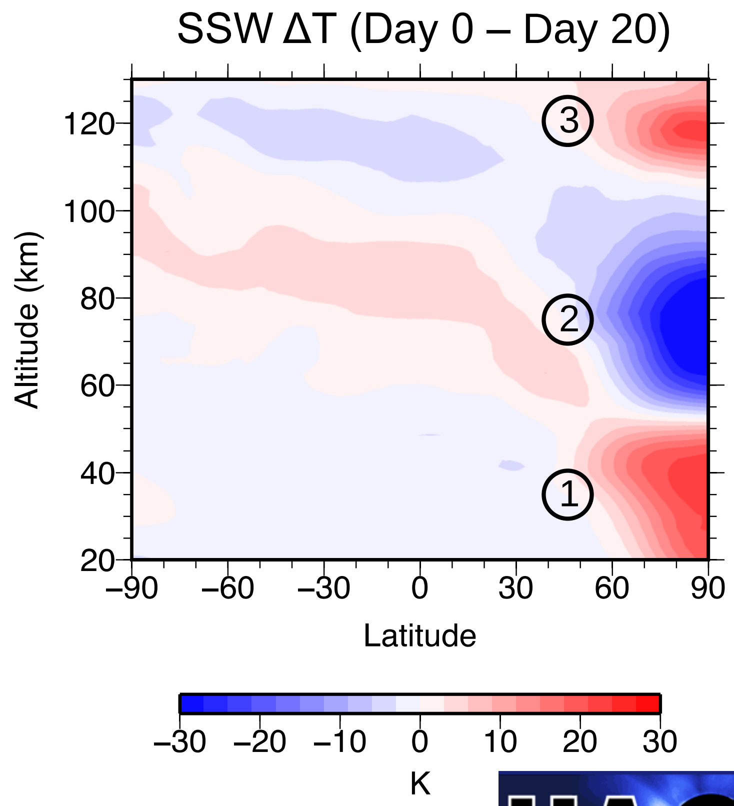
Dynamo 'fountain e ect' at low latitudes
Penetration of magnetospheric electric   elds
Plasma convection at high latitudes
Field-aligned plasma   ows to and from plasmasphere and
protonosphere
Electric   elds from lightening and sprites

Sudden stratosphere warmings are dynamical disturbances in the high latitude wintertime stratosphere, mesosphere, and lower thermosphere.

Characteristic features of SSWs:

1. Warming of the high latitude stratosphere
2. Cooling of the mesosphere
3. Warming of the lower thermosphere
4. Deceleration and/or reversal of stratospheric winds





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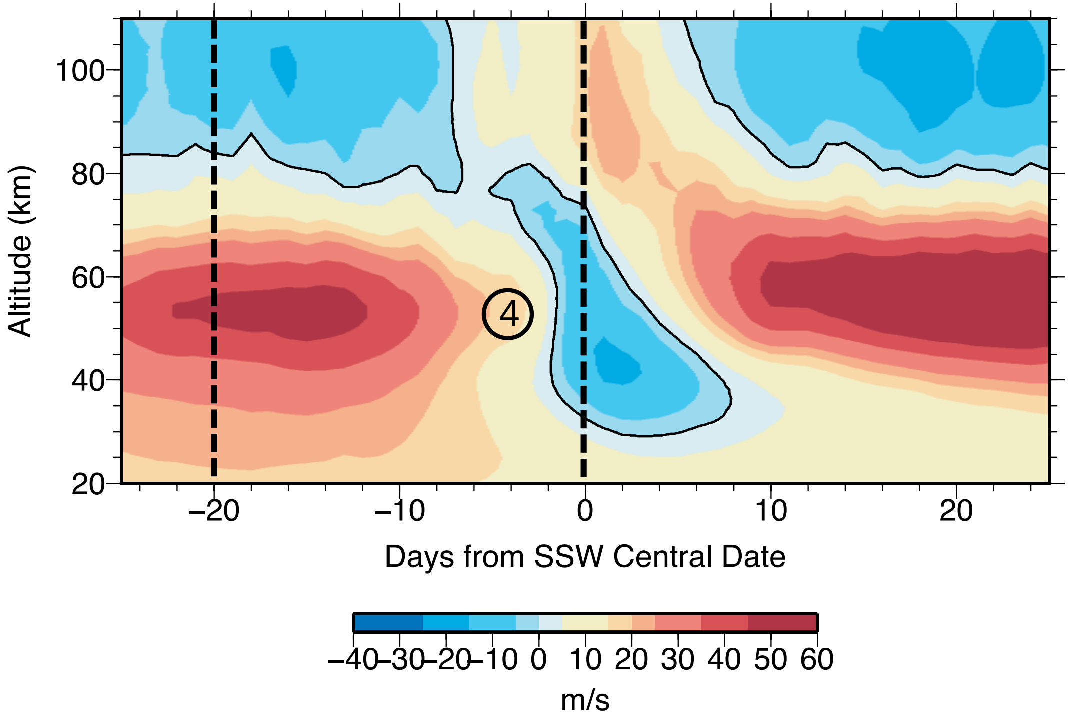
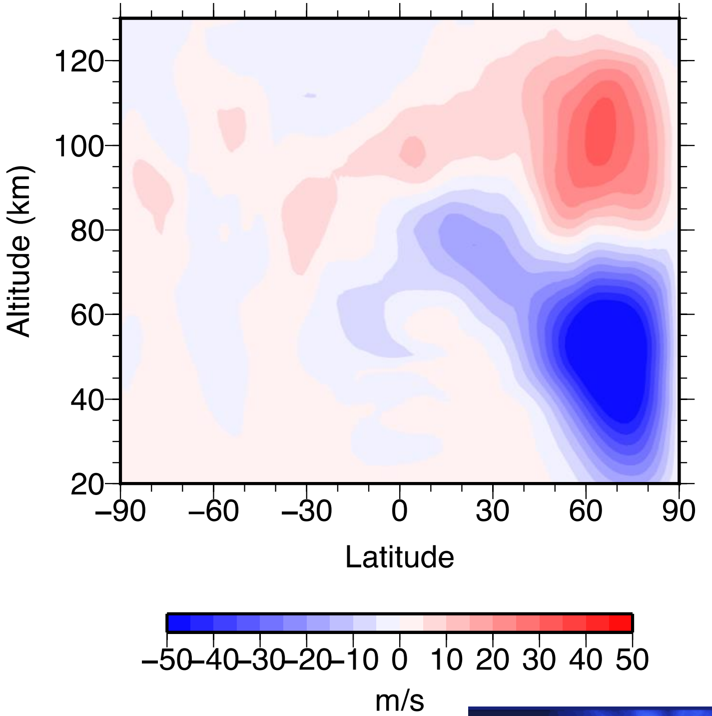
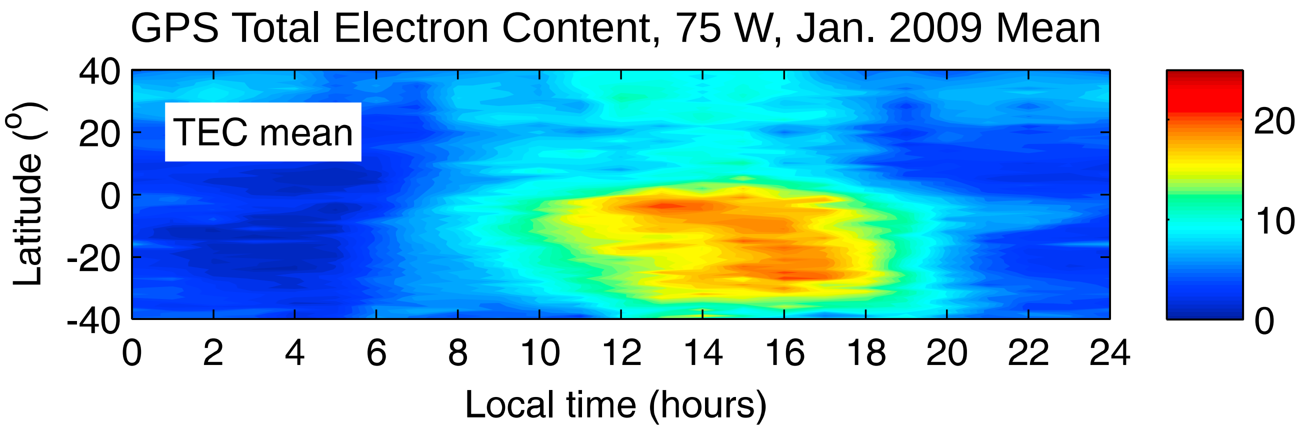
Zonal Mean Zonal Wind, 60 N

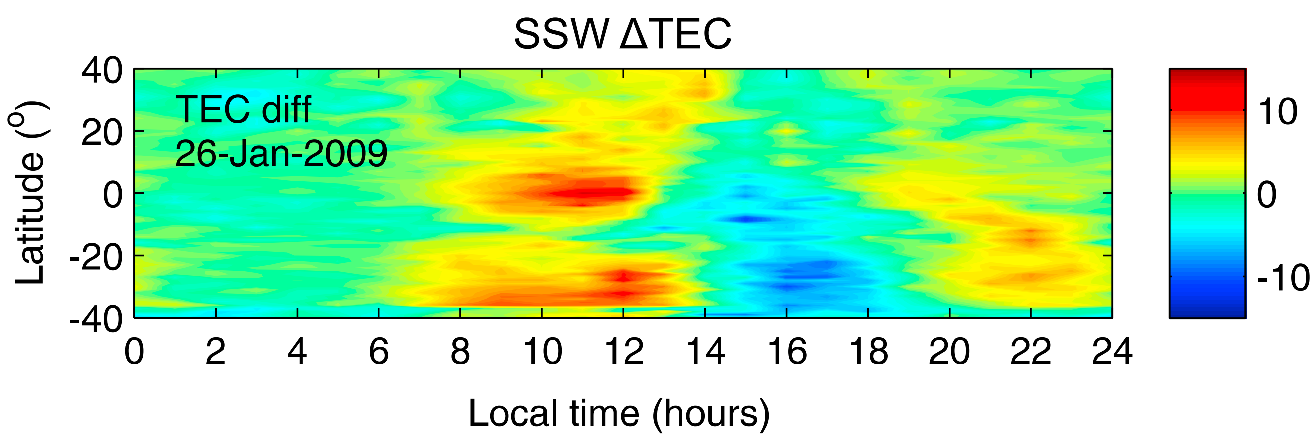


SSW ΔU (Day 0 – Day 20)



Although the dynamical changes associated with SSW occur in the high latitude stratosphere and mesosphere, observations reveal large changes in the equatorial ionosphere occur during SSWs.

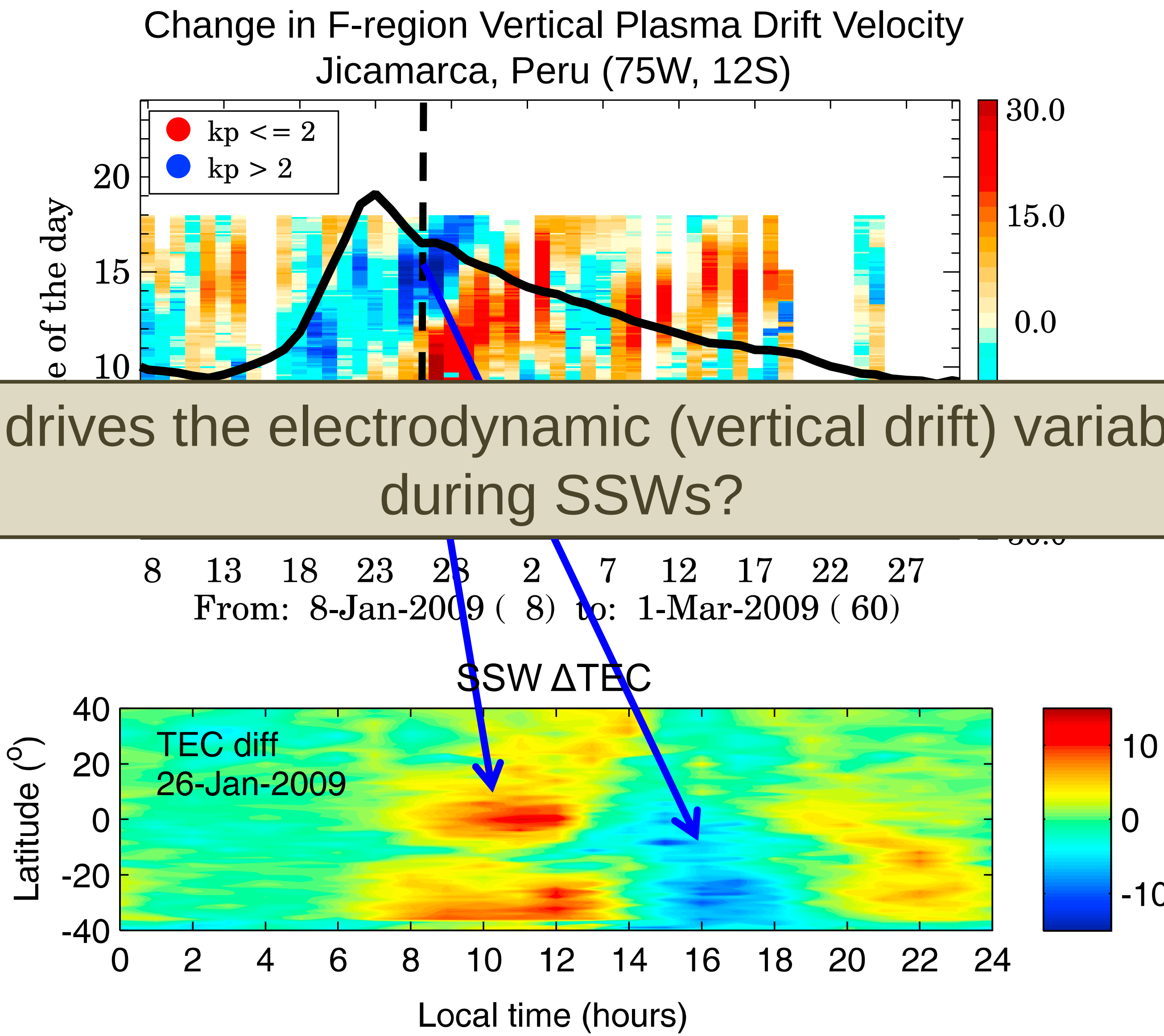




50-100% changes in TEC occur during SSWs

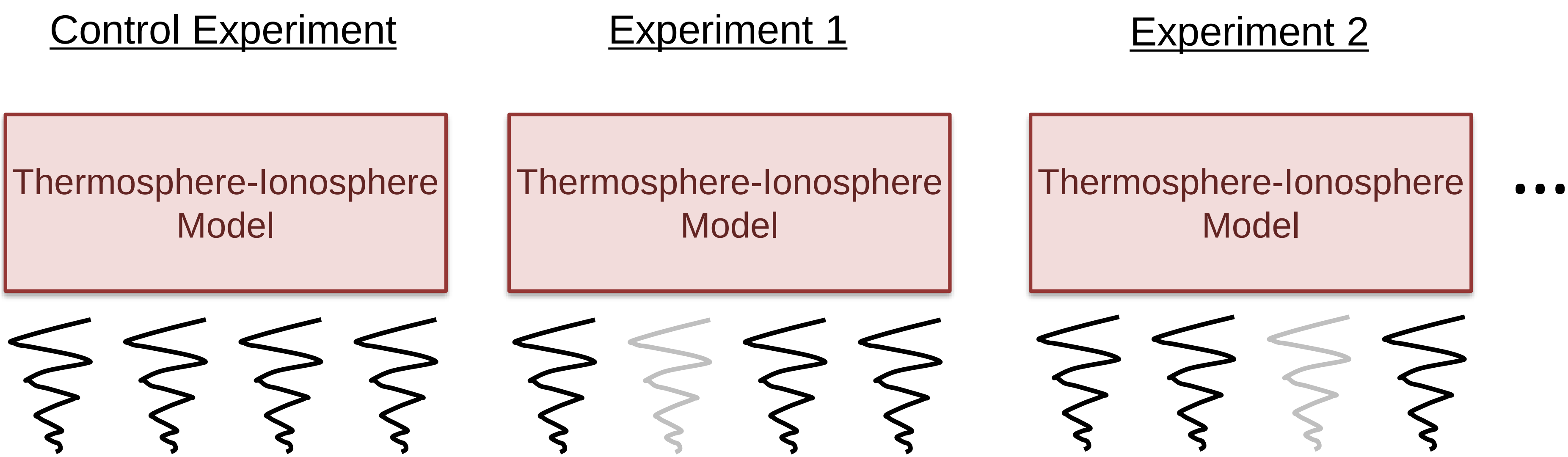
(Goncharenko et al., 2010)

Consistent changes occur in equatorial vertical drifts and low-latitude electron densities



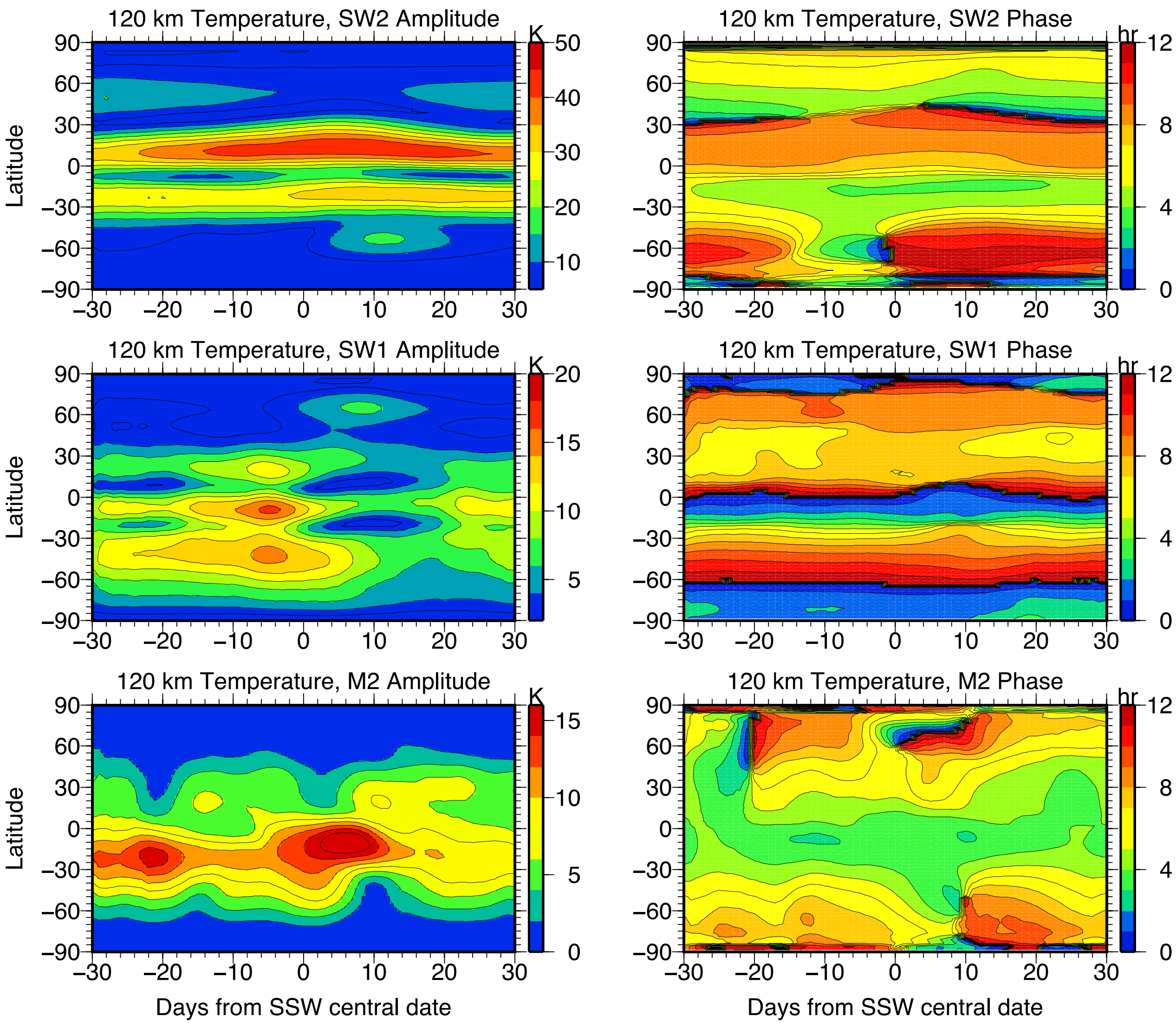
What drives the electrodynamic (vertical drift) variability during SSWs?

To identify the main mechanisms that generate the electrodynamic variability, numerical experiments are performed with different lower boundary forcing conditions, but an identical zonal mean SSW



By performing *controlled* experiments the source(s) of the electrodynamic variability can be determined

Tidal variability during sudden stratosphere warmings



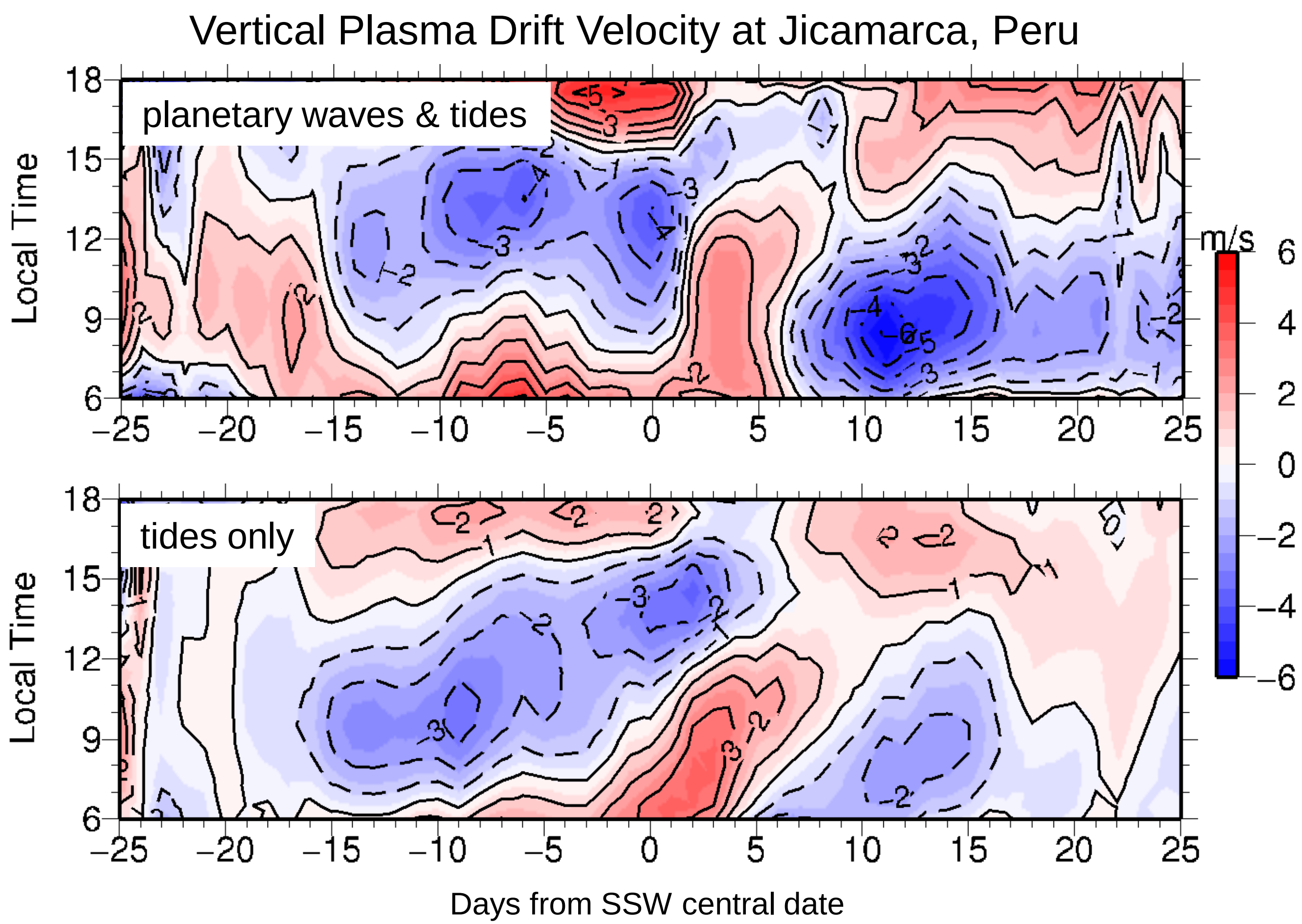
SW2: Migrating Semidiurnal Tide
SW1: Nonmigrating Westward Propagating Semidiurnal Tide w/ zonal wavenumber-1
M2: Migrating Semidiurnal Lunar Tide

(Pedatella and Liu, 2013)

Change in SW2 amplitude and phase can generate temporal plasma drift variability similar to what is seen in the observations

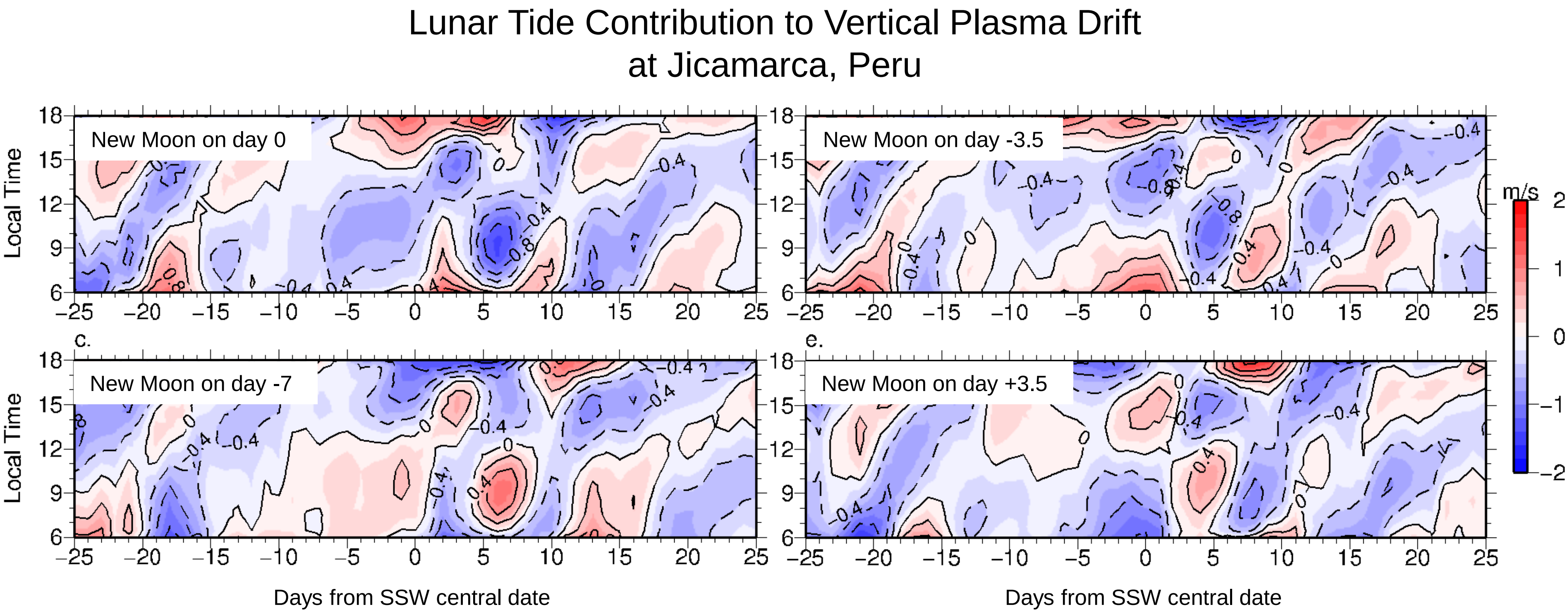
variability due to SW1+SW2

variability due to SW2



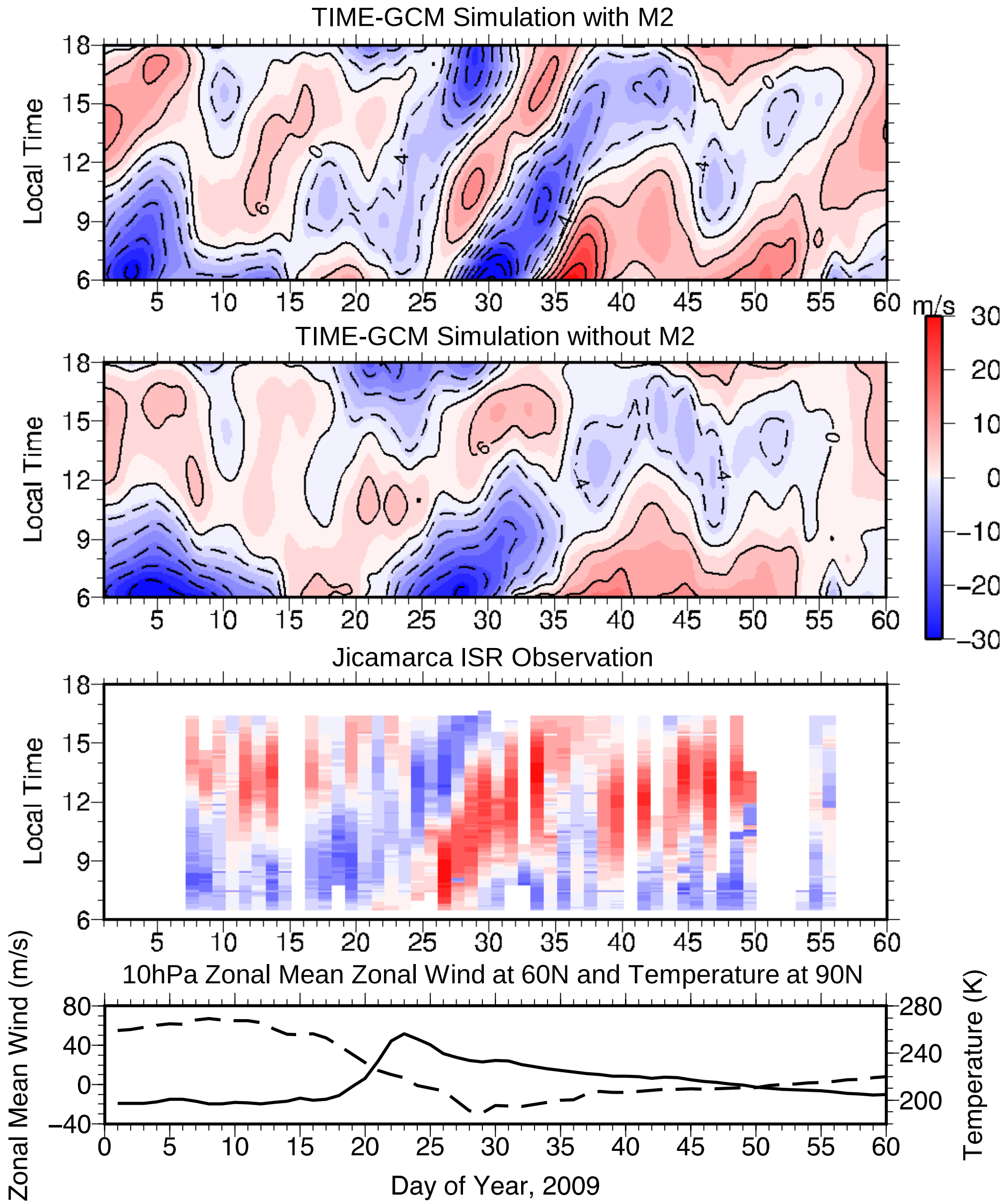
Results for simulation without lunar tide

The lunar tide contributes to ~30% of the ionosphere variability during SSWs



Impact of lunar tide depends on the phase of the moon relative to the SSW

The lunar tide is not only important in the idealized simulations, but also is critical for simulating the variability during realistic SSW events.



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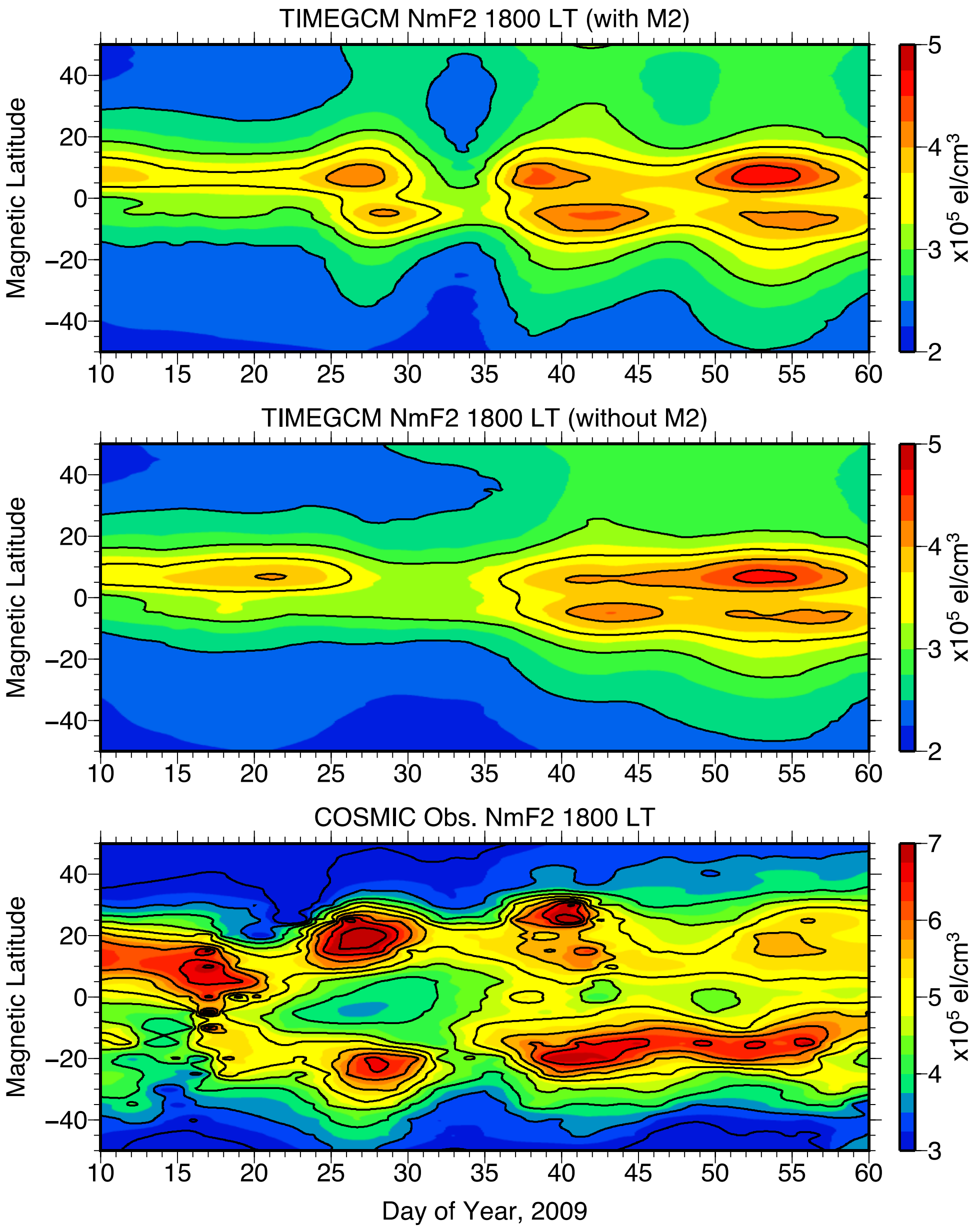
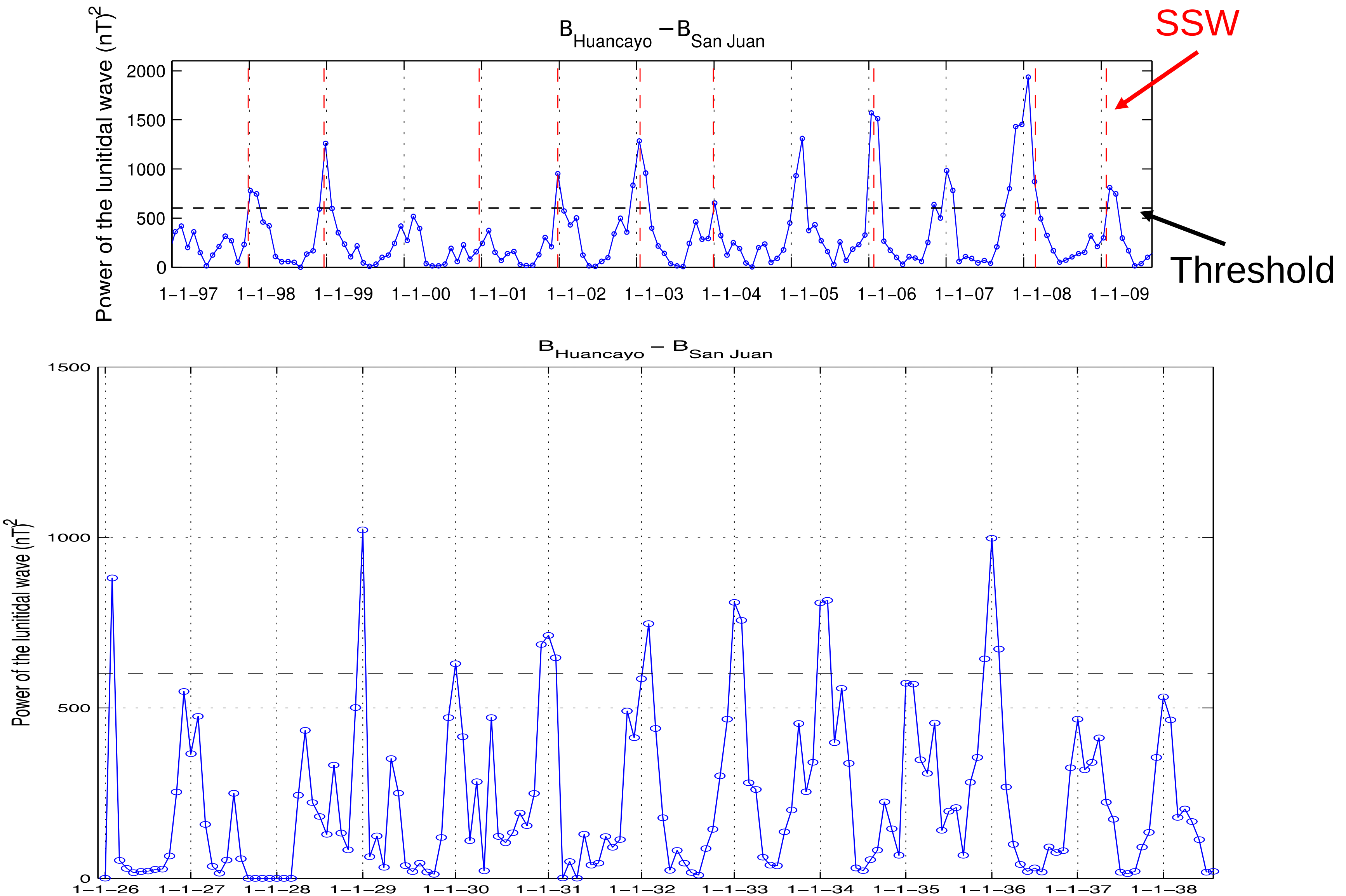


Historical record of magnetometer observations may provide insight into SSW frequency



(Siddiqui et al, 2015)

Summary

Electrodynamics are an important mechanism for transmitting lower atmosphere variability into the low-latitude ionosphere

Coupling occurs through modulating the ionosphere E-region dynamo

Variability in the electrodynamics can provide important insight into the spectrum of waves propagating upwards from the lower atmosphere

Sudden stratosphere warmings are only one example of atmosphere coupling through electrodynamics.

Questions for the future:

- How do lower atmosphere processes impact the nighttime electrodynamics?
- What is the variability on both short and long time scales?
- What can be learned about electrodynamics using global data assimilation models?