On the variability of the semidiurnal solar and lunar tides of the equatorial electrojet during sudden stratospheric warmings

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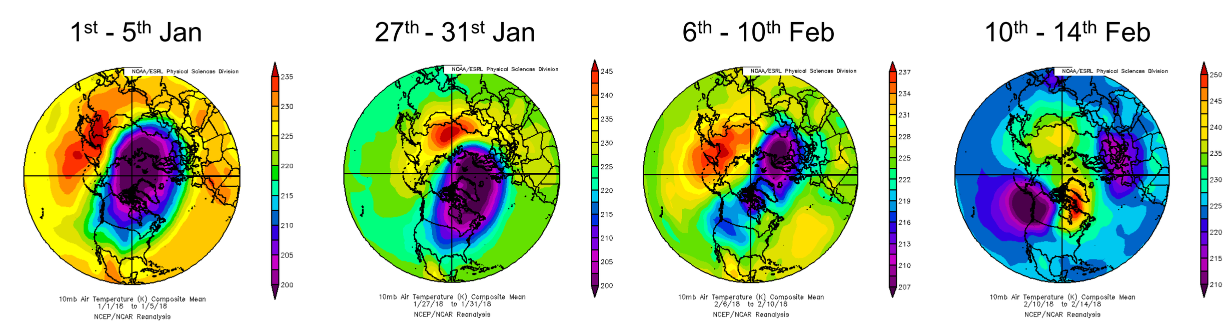
Introduction

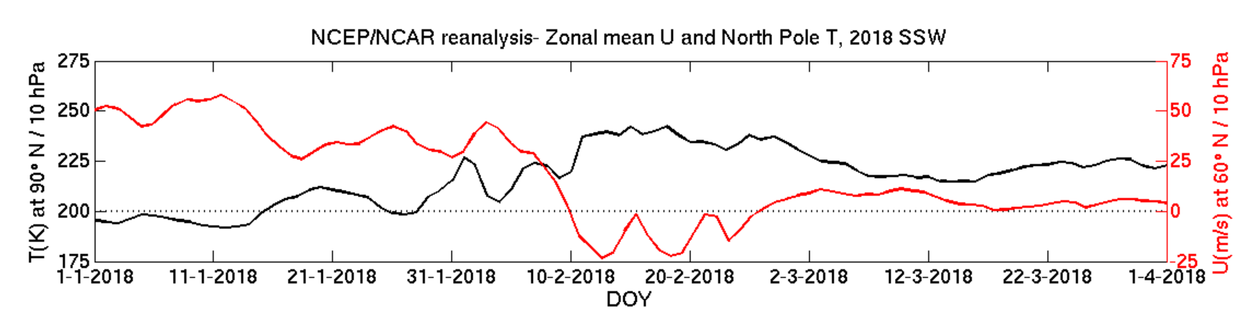
Sudden Stratospheric Warmings (SSWs)

- SSWs are large-scale meteorological events usually occurring during the northern hemisphere winters. SSW was first observed by Richard Scherhag at the Free University of Berlin in 1952.
- SSWs are characterized by a weakening or sometimes even a reversal of the westerly winds in the northern stratosphere that leads to a sudden rise in polar stratospheric temperature by several tens of degrees.
- The underlying mechanism behind SSWs is understood to be the nonlinear interaction of the vertically propagating planetary waves with the zonal mean flow (Matsuno, 1971).

The 2018 SSW event

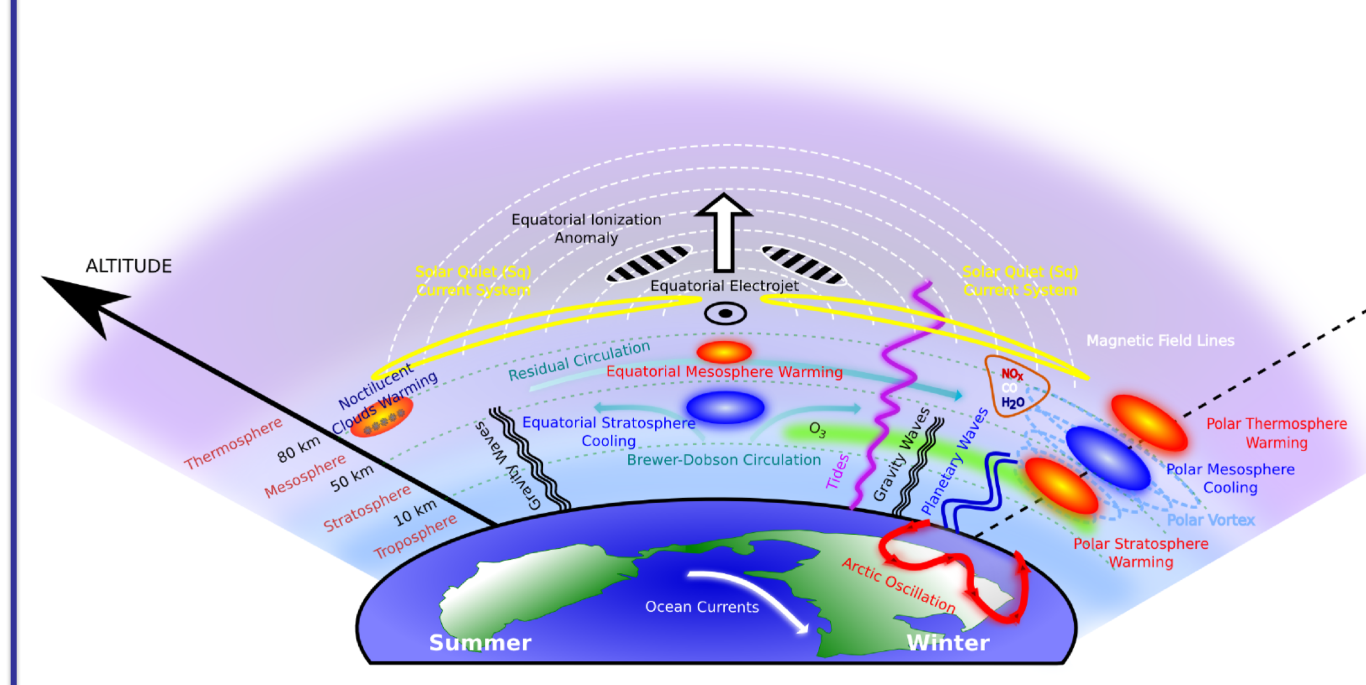


Composite means of the 10mb Air Temperature in the Northern Hemisphere (NCEP/NCAR reanalysis)



Zonal mean zonal wind at 60°N and 10 hPa (red line) & the North Pole temperature at 10 hPa (black line)

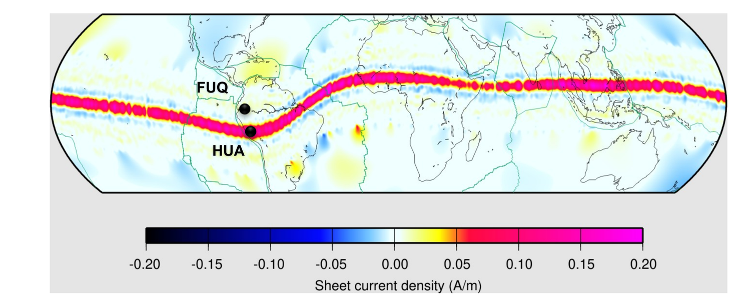
SSW related impacts in the atmosphere



Schematic illustrating the known effects of SSW in the atmosphere (Pedatella et al., 2018a)

The Equatorial Electrojet (EEJ)

- EEJ is a narrow band of an intense electric current flowing during daytime above the dip equator in the ionospheric E-region.



Electrojet current densities inferred from the CHAMP satellite over the magnetic equator. (Figure is taken from http://geomag.org/). The locations of Huancayo and Fuquene observatories are marked with dots.

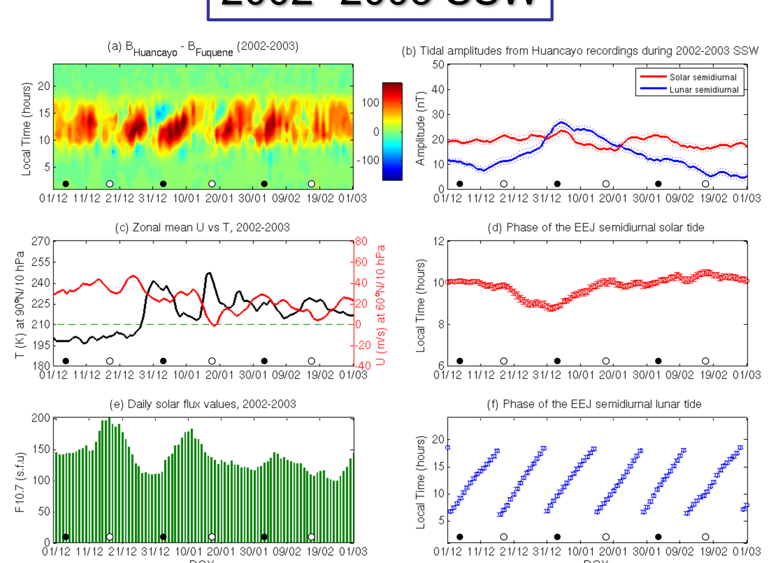
Motivation and goals of this study

- The EEJ variability due to SSWs is believed to be due to the SSW-induced modulation of the atmospheric tides. In particular, the changes in the semidiurnal solar and lunar tides have been found to be the major source of ionospheric variabilities during SSWs. The main purpose of this work is to investigate the variability of EEJ semidiurnal solar and lunar tidal enhancements with respect to the occurrence of SSWs and also to study the relative enhancements of the EEJ semidiurnal solar and lunar tides during SSWs.

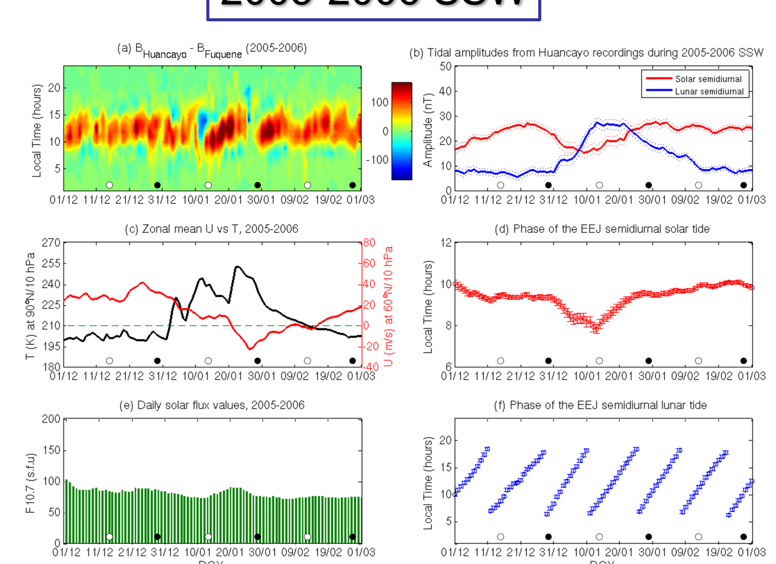
Results

Semidiurnal solar and lunar tides of the EEJ from ground-magnetometer recordings

2002 -2003 SSW



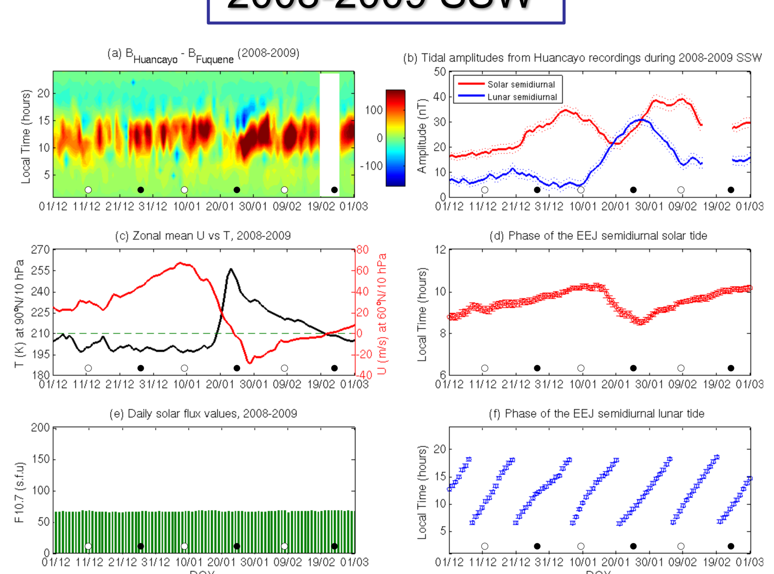
2005-2006 SSW



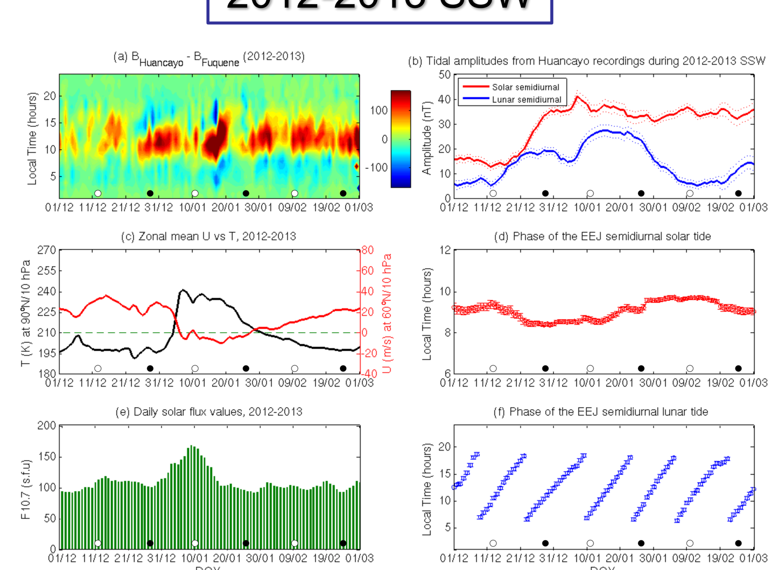
- The EEJ amplitudes presented in these figures are normalized to a solar flux level of 150 s.f.u.
- The semidiurnal perturbation pattern in the EEJ that increasingly shifts in local time on succeeding days can be seen near the new moon or full moon days during all the four SSW events

Case studies of four major SSWs have been performed and the semidiurnal solar and lunar tides of the EEJ have been determined. The subplots in the figures denote the following:
a) Day-to-day variations of the EEJ (in nT) obtained from Huancayo and Fuquene observations
b) The amplitude of the semidiurnal solar (red line) and lunar (blue line) tide of the EEJ
c) Zonal mean zonal wind at 60°N and 10 hPa (red line) and the North Pole temperature at 10 hPa (black line)
d) Phase of the semidiurnal solar tide e) Daily solar flux values f) Phase of the semidiurnal lunar tide
The open and filled circles at the bottom of the subplots denote the full moon and new moon, respectively.

2008-2009 SSW



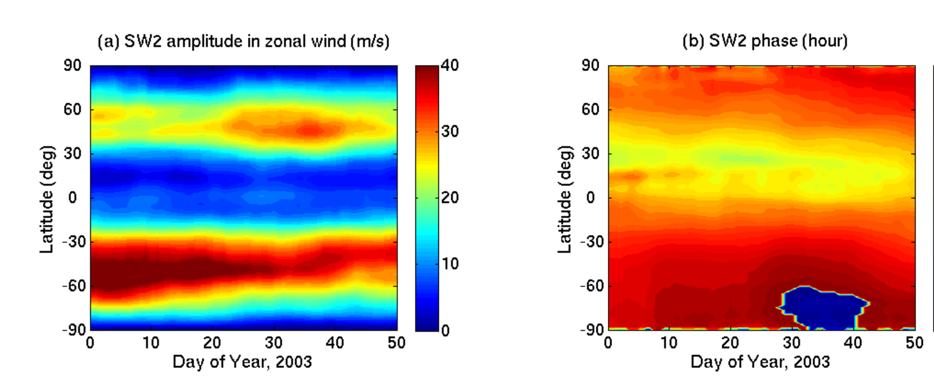
2012-2013 SSW



- The EEJ semidiurnal lunar tide shows major amplification during all the four SSWs and its amplitude becomes comparable or even greater than the EEJ semidiurnal solar tide.
- The EEJ semidiurnal solar tide shows amplification prior to the onset of SSWs, followed by a reduction and then another enhancement after the peak reversal of the zonal mean zonal wind at 60°N and 10 hPa.

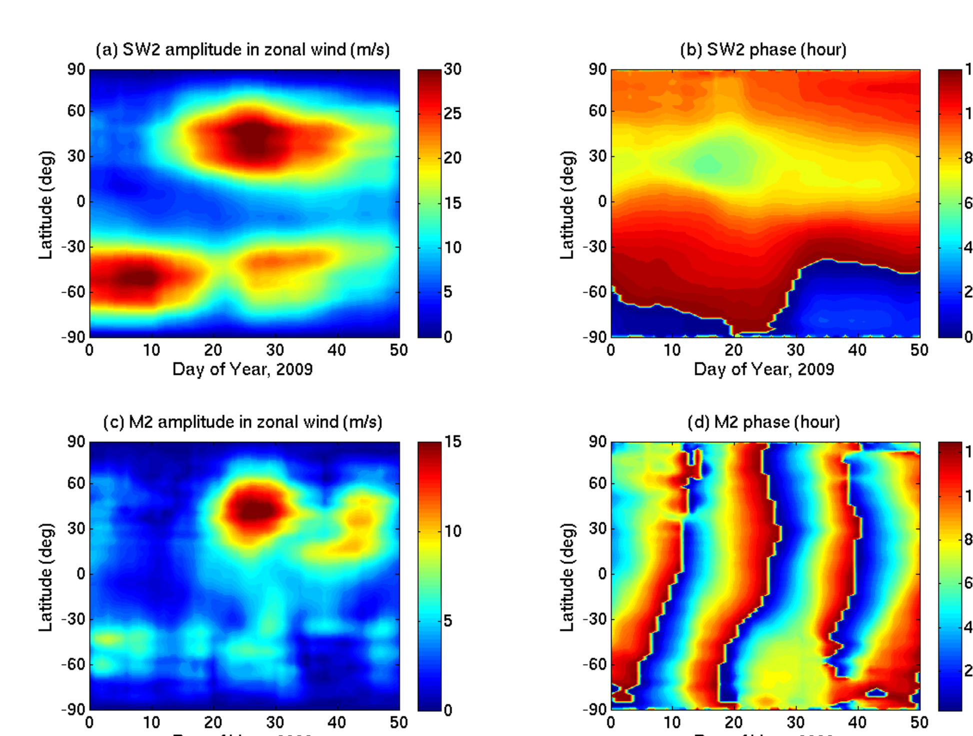
Comparison with numerical simulation results

2002-2003 SSW: WACCMX-SD



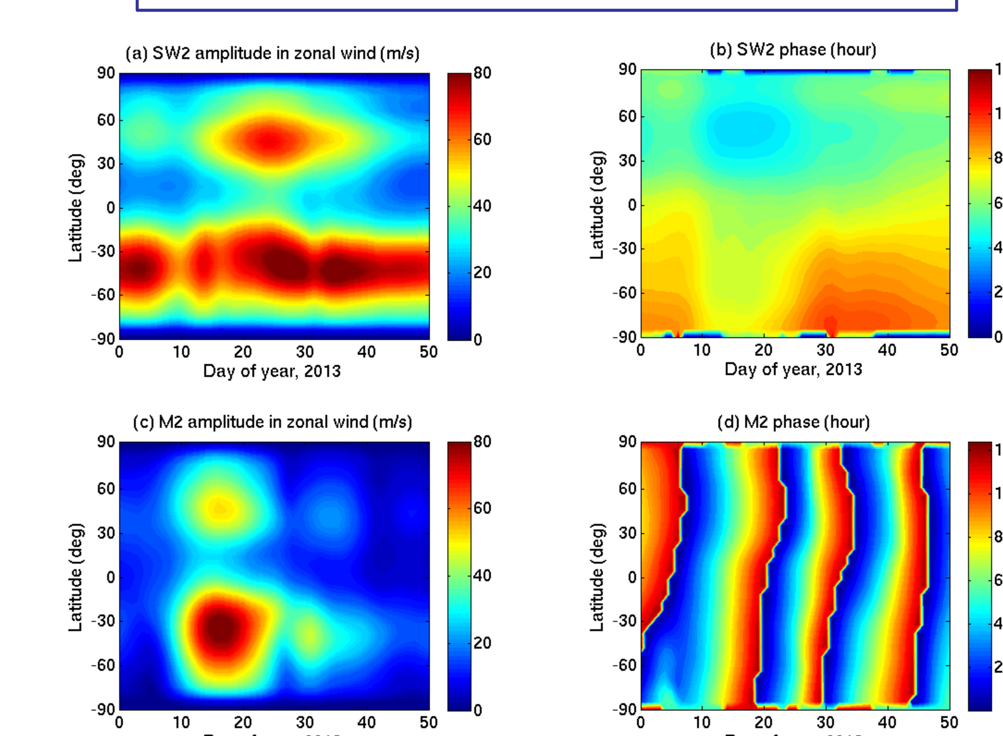
The zonal wind at ~120 km altitude from numerical simulations are used to estimate the amplitudes and phases of the semidiurnal tides. The subplots in the figures represent the following:
a) SW2 amplitude b) SW2 phase c) M2 amplitude d) M2 phase

2008-2009 SSW: WACCMX+DART



Simulation details are described in Pedatella et al., (2018b)

2012-2013 SSW: TIME-GCM nudged with WACCMX-L116/GEOS-5



Simulation details are described in Maute et al., (2015)

Summary

- The EEJ semidiurnal lunar and solar tides both show enhancements during the SSW events but the variability of the EEJ semidiurnal solar tide during the SSWs is more complex with enhancements occurring prior to the onset of SSWs followed by a reduction and another enhancement following the peak reversal of the zonal mean zonal wind at 60°N and 10 hPa.
- The relative amplification of the EEJ semidiurnal lunar tide is seen to be larger than the EEJ semidiurnal solar tide during all the four analyzed SSWs.
- The timing of global M2 enhancements in zonal wind at ~120 km altitude and the EEJ semidiurnal lunar tidal enhancements show a good agreement with each other. In case of a similar comparison between the SW2 and the EEJ semidiurnal solar tidal enhancements, the degree of agreement varies for each of the SSW events.

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