Relation between stratospheric sudden warming and the lunar effect onthe equatorial electrojet based on Huancayo recordings

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Abstract

It has been known for many decades that the lunar tidal influence in the equatorial electrojet (EEJ) is noticeably enhanced during northern hemisphere winters. Recent literature has discussed the role of stratospheric sudden warming (SSW) events behind the enhancement of lunar tides and their findings suggest a positive correlation between the lunar tidal amplitude and lower stratospheric parameters (zonal mean air temperature and zonal mean zonal wind) during SSW events. The positive correlation raises the question whether an inverse approach could also be developed which makes it possible to deduce the occurrence of SSW events before their direct observations(before 1952) from the amplitude of the lunar tides. This study presents an analysis technique based on the phase of the semi-monthly lunar tide to determine the lunar tidal modulation of the equatorial electrojet (EEJ). A statistical approach using the superposed epoch analysis is also carried out to formulate a relation between the EEJ tidal amplitude and lower stratospheric parameters. Using these results, we have estimated a threshold value for the tidal wave power that could be used to identify years with SSW events from magnetic field observations.

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Introduction

Stratospheric Sudden Warming (SSW) events have been responsible for extremely cold northern winters in recent years. An SSW is a large-scale meteorological event characterized by the weakening of the westerly winds in the northern stratosphere and a breakdown of the polar vortex which leads to a sudden rise in the polar stratospheric temperature by several tens of degrees. The phenomenon of SSW was first discovered in 1952 by Richard Scherhag at the Freie Universität Berlin and was initially known as the "**Berlin phenomenon**". The effects of SSW are not only restricted to the stratosphere but also extend into the ionosphere.

Motivation

SSW is a major meteorological phenomenon. However, their detection only dates back to 1952. Recent findings demonstrate a relation between the occurrences of SSW events and lunar tidal enhancements in ionospheric parameters. In this study we have tried to develop an approach to detect historical SSW events by estimating the enhancement of the lunar tidal amplitude in the Equatorial Electrojet during northern hemisphere winters.

Polar vortex strength and cold weather outbreaks

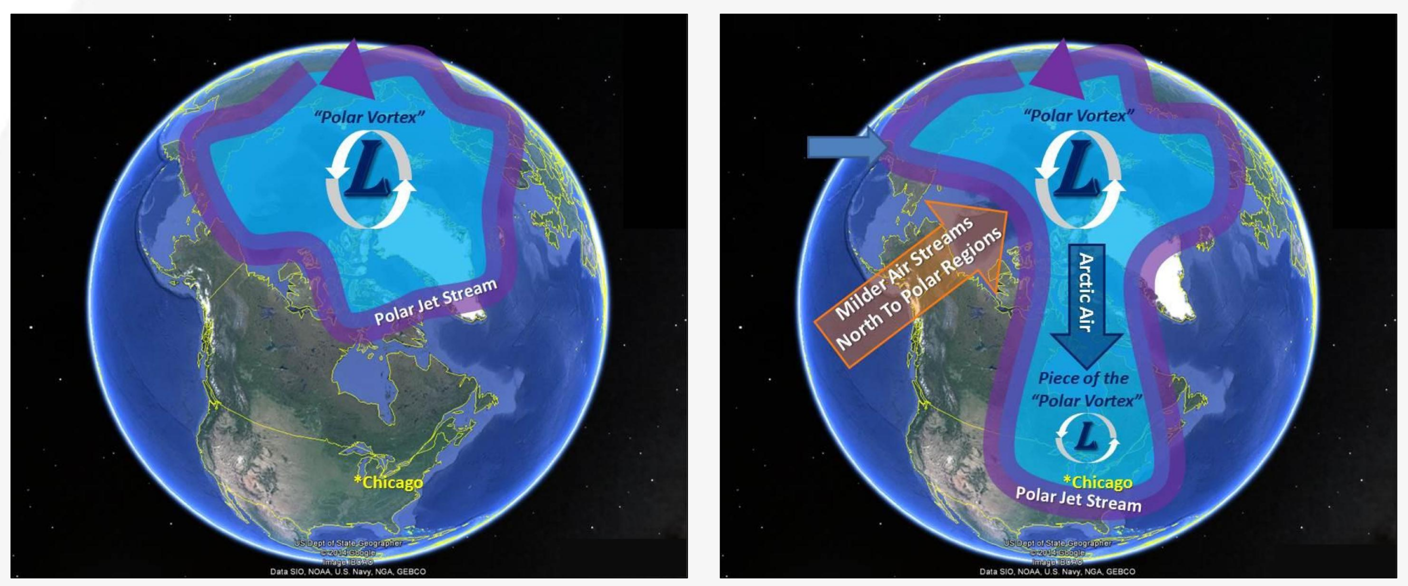
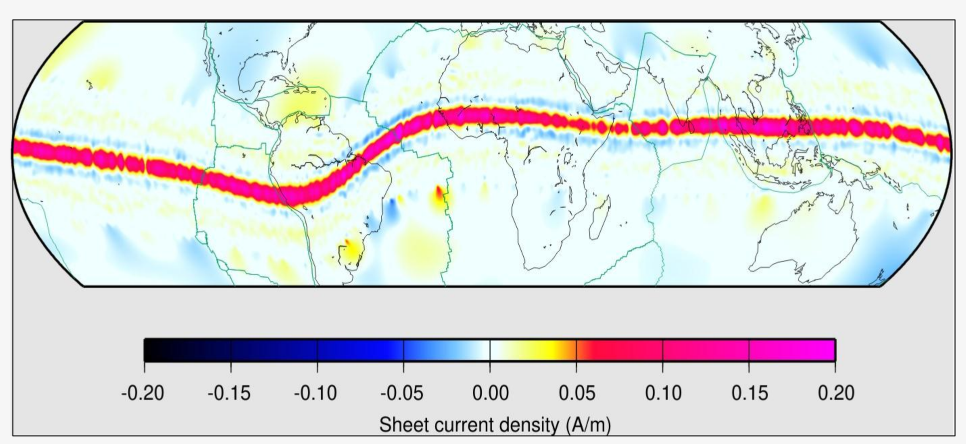


Figure 1: The left side of the figure shows a strong polar vortex keeping the cold arctic air bottled up north of the polar jet. The figure on the right shows a weak polar vortex resulting in the southward displacement of arctic air. (Picture credits : US Dept of State Geographer)

Lunar tidal signal in the Equatorial Electrojet



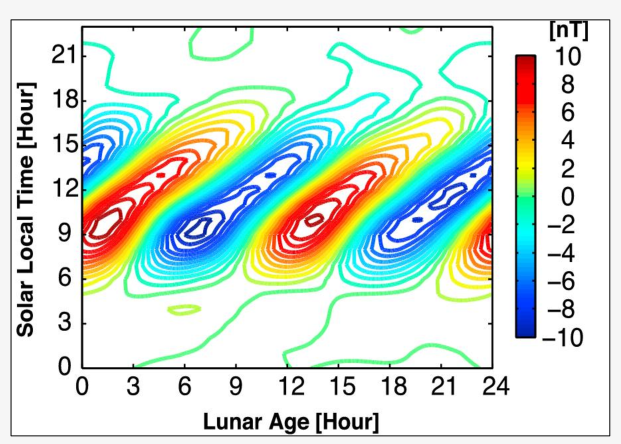


Figure 2: Equatorial Electrojet current densities inferred from the CHAMP satellite passes over the magnetic equator between 11:00 and 13:00 local time. Equatorial Electrojet (EEJ) is a narrow ribbon of intense electric current flowing eastward along the dip-equator in the E-region of the ionosphere. The EEJ represents a large enhancement of the diurnal variation in the horizontal component of the geomagnetic field at and in the vicinity of dip equator.

Figure 3: Geomagnetic lunar tides as a function of lunar age and local time at Addis Ababa averaged over the years 1958-2007. (Figure 2, Yamazaki et al., 2012a). The lunar tide manifests itself as a semi-diurnal wave that precesses through all local times within one lunar month.

Lunar tidal modulation of the EEJ during SSW events

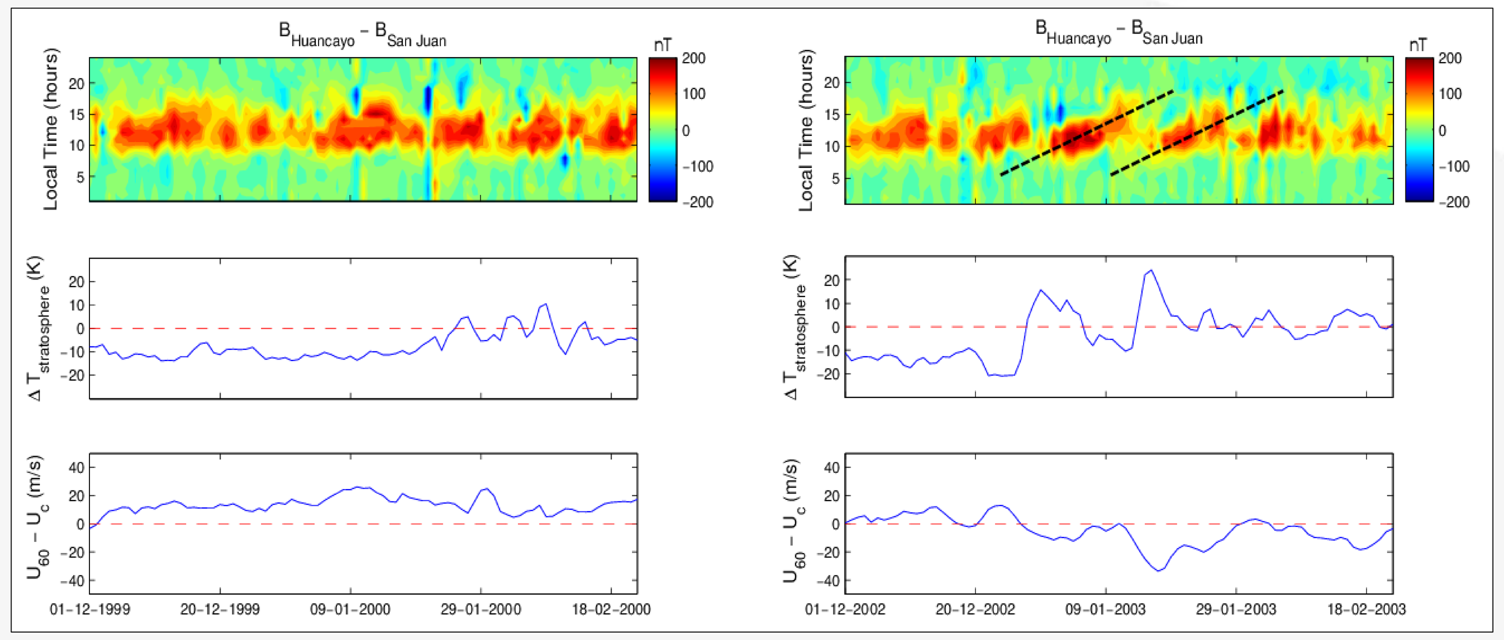
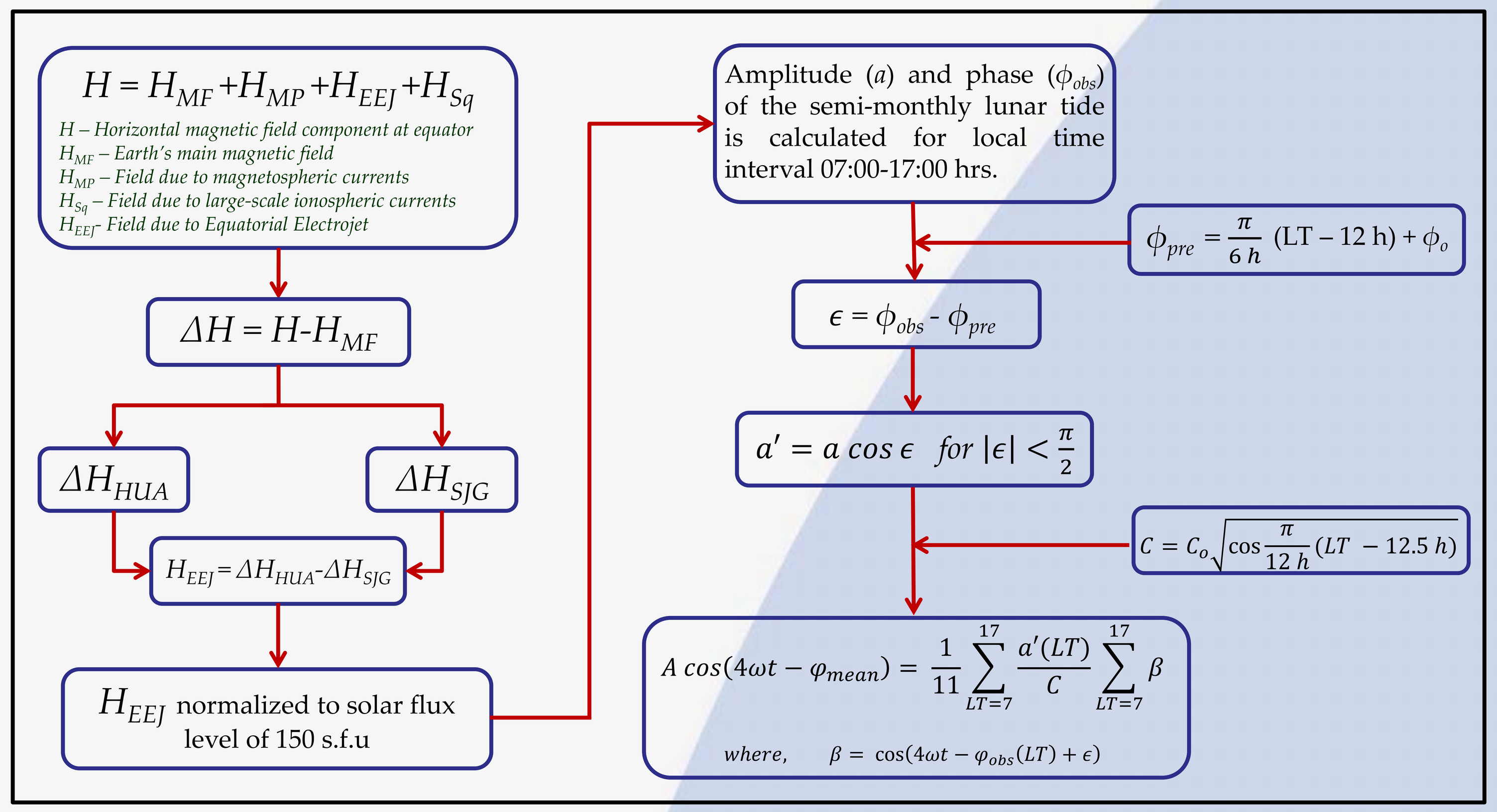


Figure 4: The top panels show the diurnal variation of the EEJ intensity (nT) as observed at Huancayo. The middle panels show the temperature difference in the stratosphere between the polar region and the 60°N latitude at 10 hPa. The bottom panels show the deviation of the zonal mean zonal wind at 60°N and at 10 hPa from the climatological mean. The left figure (top) shows the EEJ variation on normal days with weak lunitidal effect while the figure on the right (top) corresponds to the EEJ variation during an SSW event. The lines in the top right panel mark the expected lunar tidal wave propagation in local time.

Method of analysis



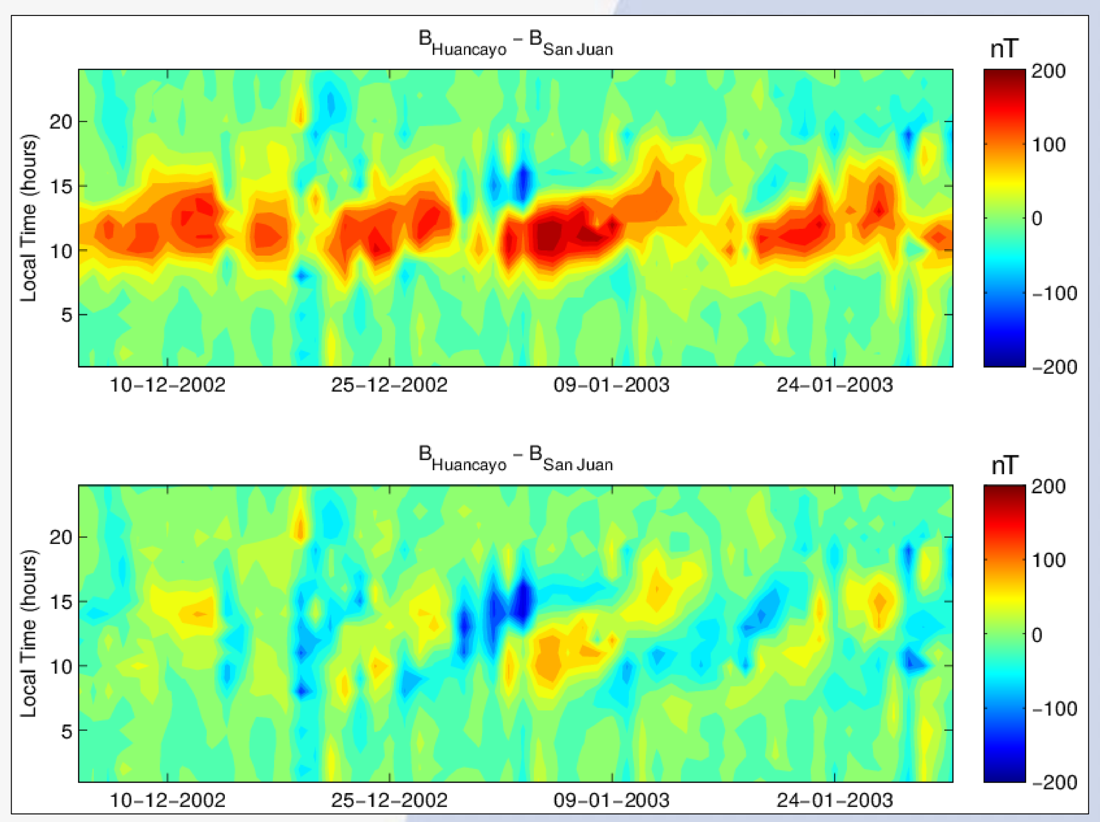


Figure 5: The upper panel shows the H_{EEJ} obtained from the Huancayo - San Juan pair during the December 2002 – January 2003 period before removing the solar tidal effects. The lower panel shows the same plot after the effects of solar tides have been removed by using the 59 day mean calculated for each local time hour.

Results

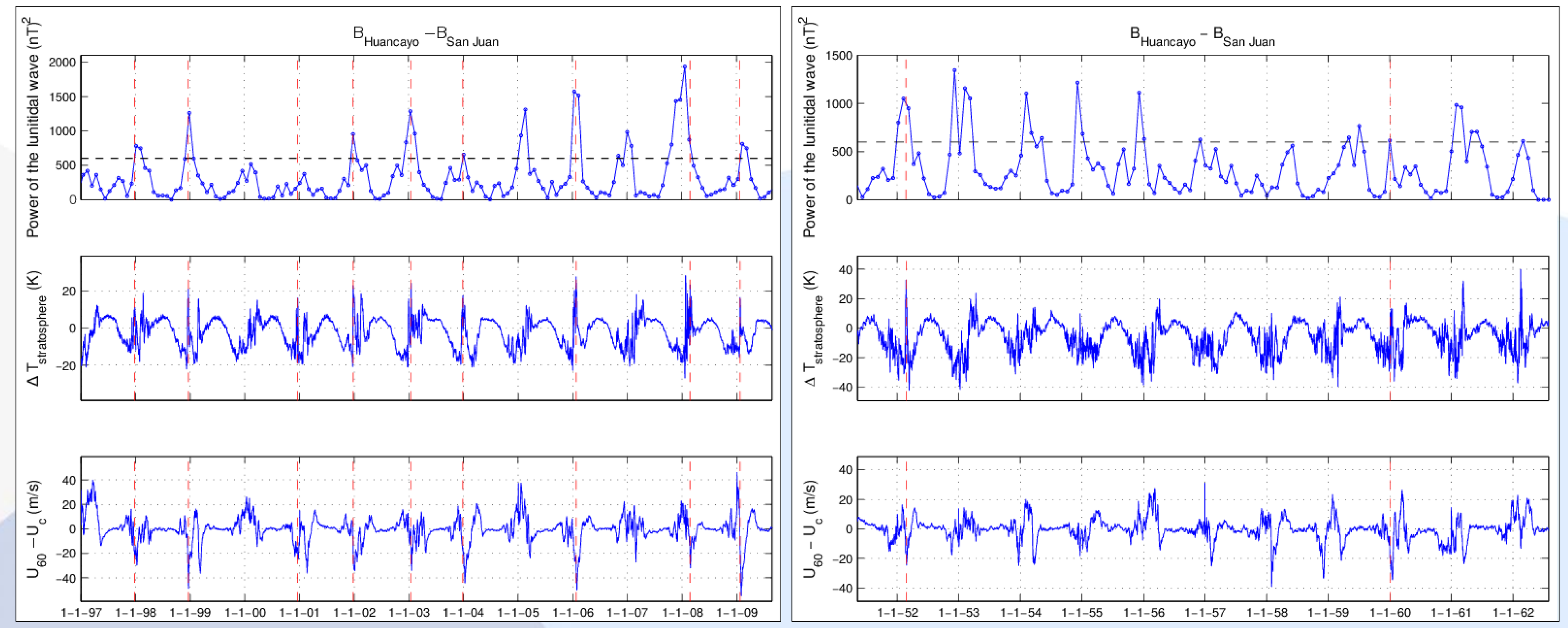


Figure 6: The top frames present the wave power of the lunar tide derived from Huancayo – San Juan pair for the years 1997-2009 (left) and 1952-1962 (right). The middle frames show the temperature gradient and the bottom frames show the deviation of zonal mean zonal wind at 60°N and 10 hPa from the climatological mean. The red lines mark the days of SSW (peak warming) and the black dashed line denotes the threshold level for classifying SSW and non-SSW years.

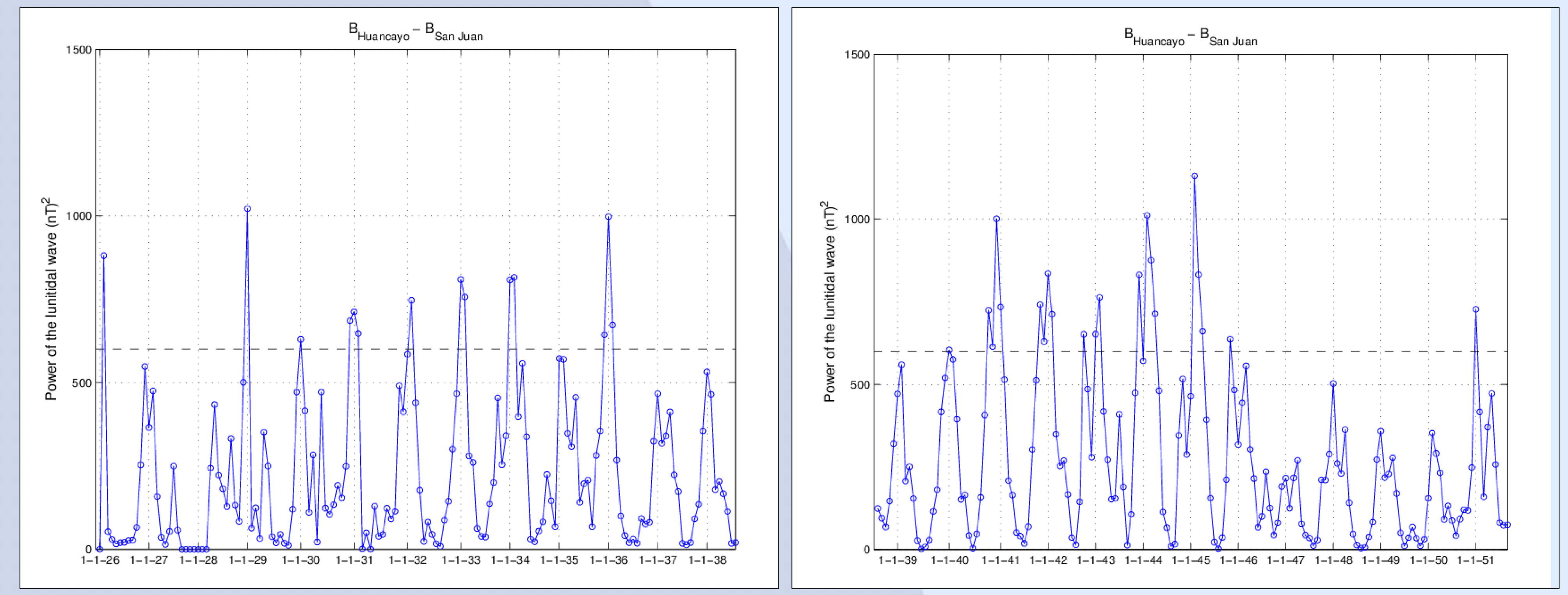


Figure 7: The figure presents the wave power of the lunar tide derived from Huancayo – San Juan pair for the years 1926-1951. The black dashed lines shows the threshold level for classifying SSW and non-SSW years.

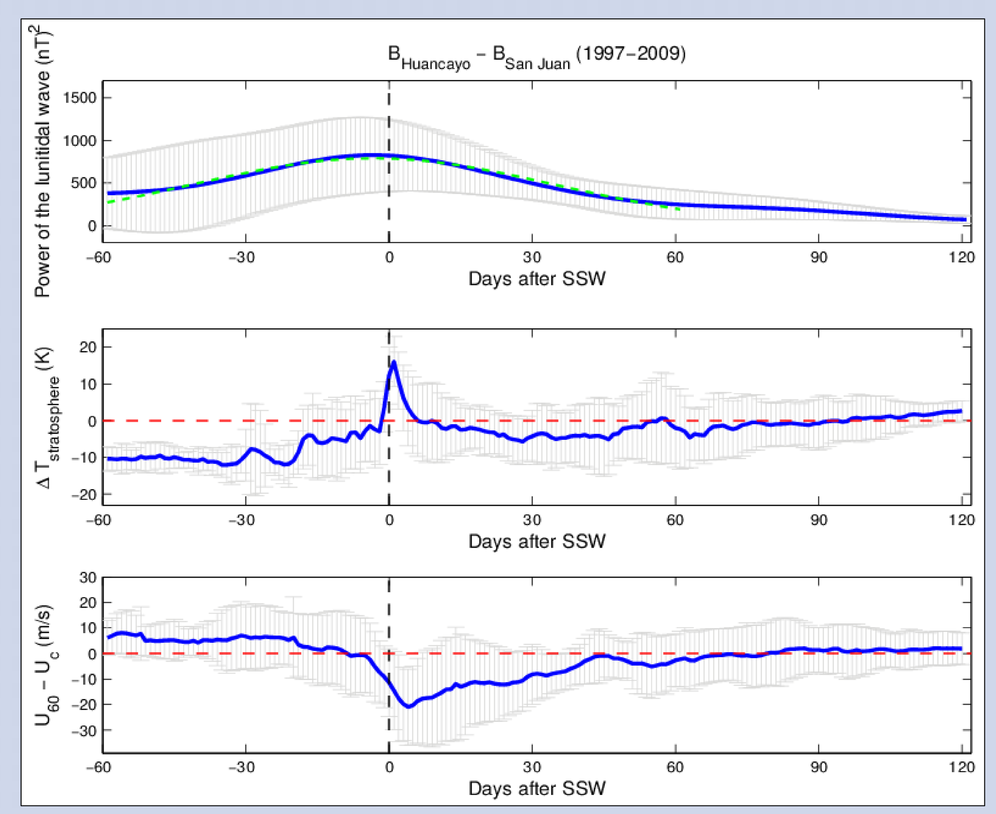


Figure 8: Composite of the semi-monthly lunar wave power (top), zonal mean temperature gradient (middle) and $U_{60} - U_c$ (bottom) for the years 1997-2009. The vertical dashed lines indicate the starting day of SSW events. The error bar represents the standard deviation in all the three panels. The dotted green curve in the top frame shows the Gaussian curve fitted for 60 days on the either side of starting date of SSW events.

Conclusions

- A new analysis technique focusing on the phase of the expected tidal wave is used. This helps efficiently to suppress the influence of solar activity dependent EEJ fluctuations and day-to-day variabilities.
- We have estimated a threshold value for the tidal wave power that may help to identify years with SSW events from magnetic field observations. Our results propose an approximately six SSW events per decade also before 1952.

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