Characterization of the Sq and Cross-Wavelet analysis of the geomagnetic activity at three stations in the Brazilian Sector

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Abstract

Magnetic data from the Brazilian ground stations Tatuoca (TTB), Vassouras (VSS) and São Martinho da Serra (SMS)) were examined. These stations cover a big latitudinal range in the Brazilian sector. The analyzed data was collected in the period of January-May 2010. The solar quiet daily variation for the horizontal component (H) of the geomagnetic field (Sq) and its daily range (ΔSR) were investigated with respect to the longitudinal and seasonal variations. The effect of the equatorial eletroject (EEJ) on the ΔSR was shown for the Tatuoca station. Wavelet spectral analysis for H in the VSS station shows peaks for 2 day (2d) and 4d periods, while for TTB only for the semidiurnal period. Using cross wavelet transform (XWT) were shown correlation peaks for the H component between VSS and SMS for 2d and 4d periods. However for TTB and VSS this correlation survives only for the 4d peak and disappears completely for TTB and SMS. These results are presented and discussed.

Introduction

It is well known that the normal solar activity alters the currents system in the ionosphere. It produces two magnetic effects that are prominent in the equatorial and mid-latitude regions and stronger at local noontime [1]. One of them is called solar quiet daily variation (*Sq)* and the other equatorial electrojet (EEJ). The Sq current has its centres near 30° magnetic (dip) latitude in both hemispheres, flowing counterclockwise in the northern and clockwise in the southern hemisphere. Its magnetic effects range up to about 40 nT near the Earth's surface. The EEJ, on the other hand, takes place in a narrow belt of ±3° centred over the dip magnetic equator and about 105 km high, which , flows eastward during the daytime. Its effects at the Earth's surface range up to about 100 nT.

Since the discovery of these effects and to date many investigations were made based on measurements at ground level of the geomagnetic field components in low and dip latitudes [2].

Data

The geographic coordinates of the magnetic observatories, from which the data was obtained, are listed in Table 1. We use a limited data collected in the first five months of 2011. The data consists in a record of the components X, Y and Z of the geomagnetic field with a resolution of one second. Date files were processed and smoothed using a moving average filter reducing the resolution to one hour which is appropriated for the study of the daily variation.

Table 1.- Geographic coordinates of the three magnetic observatories.

Observatory	Latitude (degrees)	Longitude (degrees)
Place	WGS84	WGS84
S. Martinho da Serra	-29,5382481629448	-53,8551909944555
Vassouras	-22,4043717284378	-43,662875122759
Tatuoca	-1,20072998594801	-48,5058099588494

We calculated the monthly means of the daily variation taking into account the international quietest days of the month, which are deduced from the planetary three-hour index Kp. The quietest days of the first ten months of the year 2010 are listed were obtained from the International Service of Geomagnetic indices of the International Association of Geomagnetism and Aeronomy.

The Daily Variation

Figure 1 shows the calculated monthly means of the quietest day variation for the components Hx, Hy and Hz of the geomagnetic field measured in TTB, SMS and VSS for the period of Jan-May 2010. In Figure standardized values were plotted in order to remove seasonal influences and to compare better with the daily variation. It can be observed that the shape of the Sq for the three stations matches better for the Hx component than for Hy and Hz components, but for May the correspondence of the daily variation is better for all components. It could be related with the seasonal behaviour of the EEJ [3]. Figure 2 shows two scatter plots where it can be seen that the correlation degree of the daily variation between the stations falls with the latitudinal distance.

The daily range (ΔS**R**) of the horizontal component for the period Jan-May 2010 is shown in Figure 3. It can be observed that the value ΔS**R** is greater in Tatuoca for all months, and also it is observed a tendency to diminish as we approach May. This is an expected result due to the influence of the EEJ [4]. On the other hand the ΔS**R** for the other two stations doesn't follow a defined trend except for the last two months.

Wavelet Spectral Analysis

Wavelet spectral analysis allows us a quantitative monitoring of the signal evolution by decomposing a time-series into time-frequency space. Thus one is able to determine both the dominant modes of variability and how those modes vary in time. Wavelets are useful especially for signals that are non-stationary, have short-lived transient components, have features at different scales or have singularities [5].
In our case we will analyse the time series of the horizontal component of the geomagnetic field limited to the month of January 2010 measured in each of the three stations. Figure 4 shows the times series for each of the three stations.

This data must be first processed (moving- average filtered, detrained, etc) to carry out the wavelet analysis. Figures 5 and 6 show the wavelet power spectrum (WPS) for the horizontal component measured in January 2010 at Vassouras and Tatuoca, respectively. These figures show, for both stations, a well defined period in the daily variation as is expected. However the WPS for the Tatuoca data scarcely shows other period for 8d, but just on the influence cone, while Vassouras shows three distinctive peaks for the 2d, 4d and 8d periods. It is well know that these characteristic periods are related with planetary waves due to dynamical processes occurring in the middle atmosphere-ionosphere-thermosphere system [6]. Especially the equatorial region is more subjected to the effect of planetary waves, specially to Kelvin waves, and in particular, to the slow Kelvin waves (6d-10d) and the ultra fast Kelvin waves (3d-4d)) [7]. The intriguing fact in our results is that the WPS of the Tatuoca doesn't show these characteristic periods, 2d and 4d, but only the semidiurnal and 8d scales

Cross-Wavelet Correlations

To investigate the correlations between the three stations was used the cross wavelet transform (XWT). The cross-wavelet analysis is a well know tool that permit detection, extraction, and reconstruction of relationships between two non stationary signals simultaneously in frequency and time [8]. Figure 7 shows the XWT for the three combinations of stations. It can be seen that, in addition to the diurnal correlation that is present for the three pairs, the case of VSS/SMS exhibits correlation for the scales semidiurnal, 2d, 4d and 8d that takes place in a temporal stripe centred in the middle of the month. For the pair of stations TTB/VSS, where the latitudinal distance increases, it can be observed that the correlations at the semidiurnal scale and 8d survive and scarcely for the 4d. For the case of the pair SMS/TTB, where the latitudinal distance is still bigger, only survive the correlation at the scale 8d.
From these results we suggest that the underlying phenomena that produce correlation at these scales could be the slow Kelvin planetary waves, and the semidiurnal tides.

Conclusions

We have studied the daily behavior of the geomagnetic field in three Brazilian stations: Tatuoca, Vassouras and São Martinho da Serra. Our analysis of the daily variation for these stations has confirmed early results on the influence of the EEJ and its seasonal character on the daily range. This fact is also confirmed through the comparison of the daily variation of the geomagnetic field components. The latitudinal dependence on the Sq has been confirmed.
The wavelet analysis of the daily variation of the horizontal component allowed us to show the complexity of this phenomenon, to confirm previous results with respect to the influence of planetary waves and to find newer signatures of the influences of other processes as the semidiurnal tides and ocean inductions.
The cross-wavelet analysis showed how the correlation between these stations separated by different latitudinal distances takes place for specifics scales, allowing us to suggest which could be the common phenomena involved.
An investigation with more extended data is in progress and will be published elsewhere.

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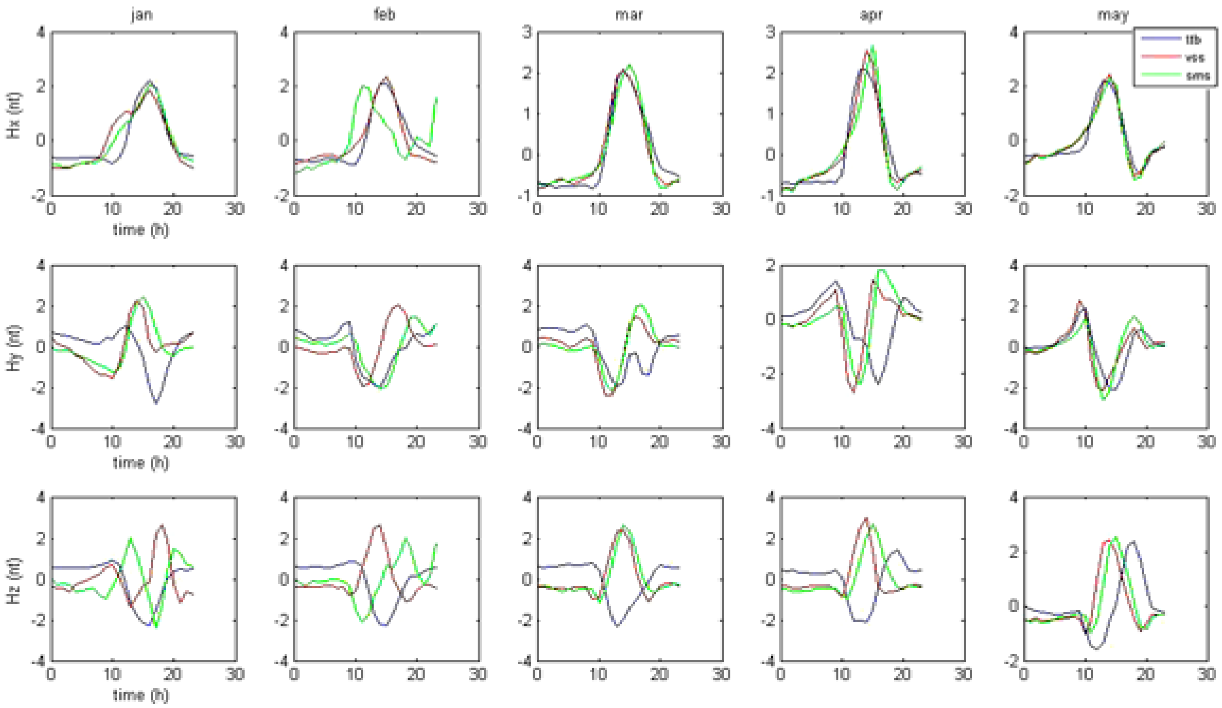

Fig 1 . Monthly mean for the components Hx, Hy and Hz of the quietest daily variation for Jan-may 2010 from Tatuoca, Vassouras and São Martinho da Serra.

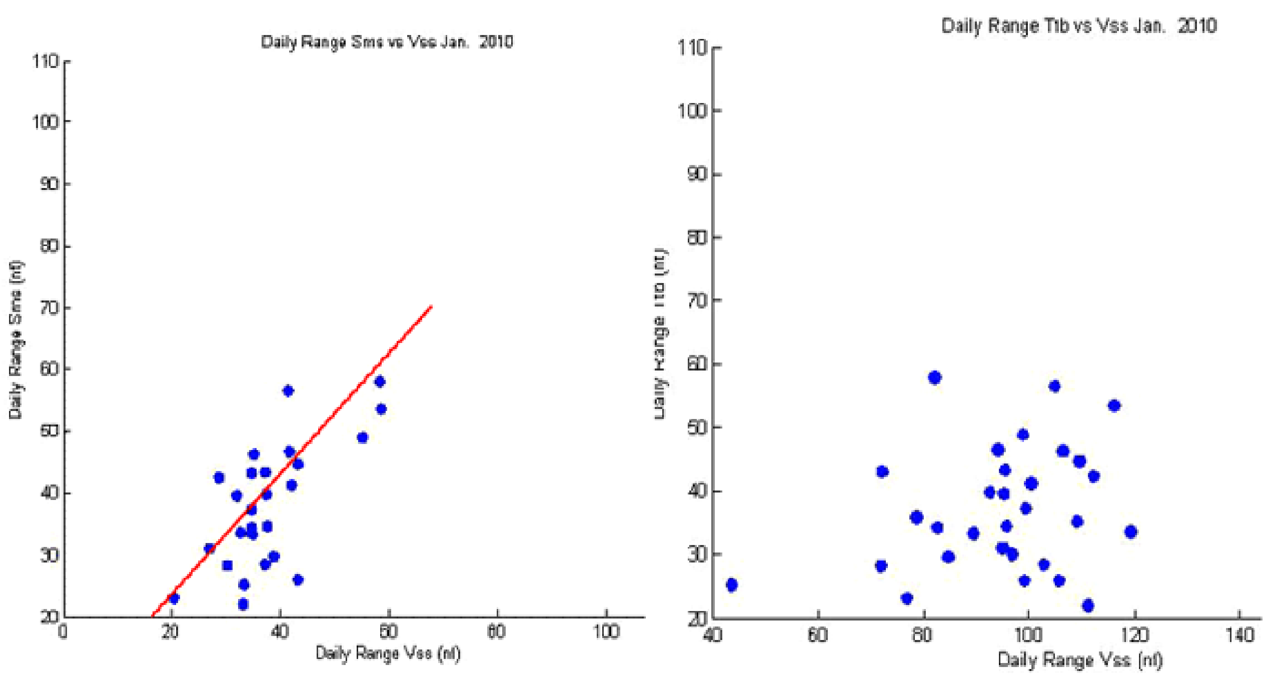

Figure 2. Mass plot of monthly daily means of H taken for SMS versus VSS and TTB vs VSS

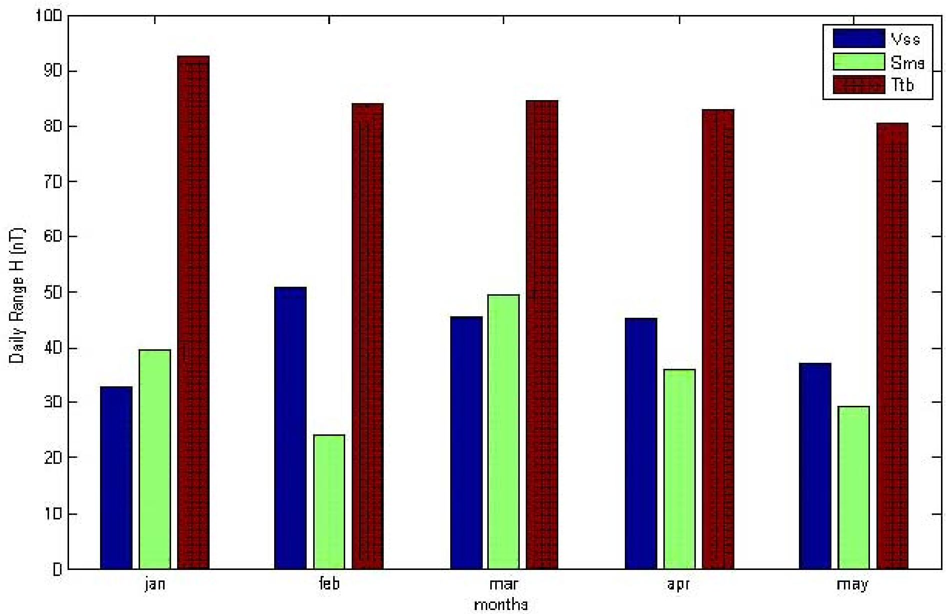

Figure 3.- Comparison of the daily range of the horizontal component in the three stations from Jan-May 2010

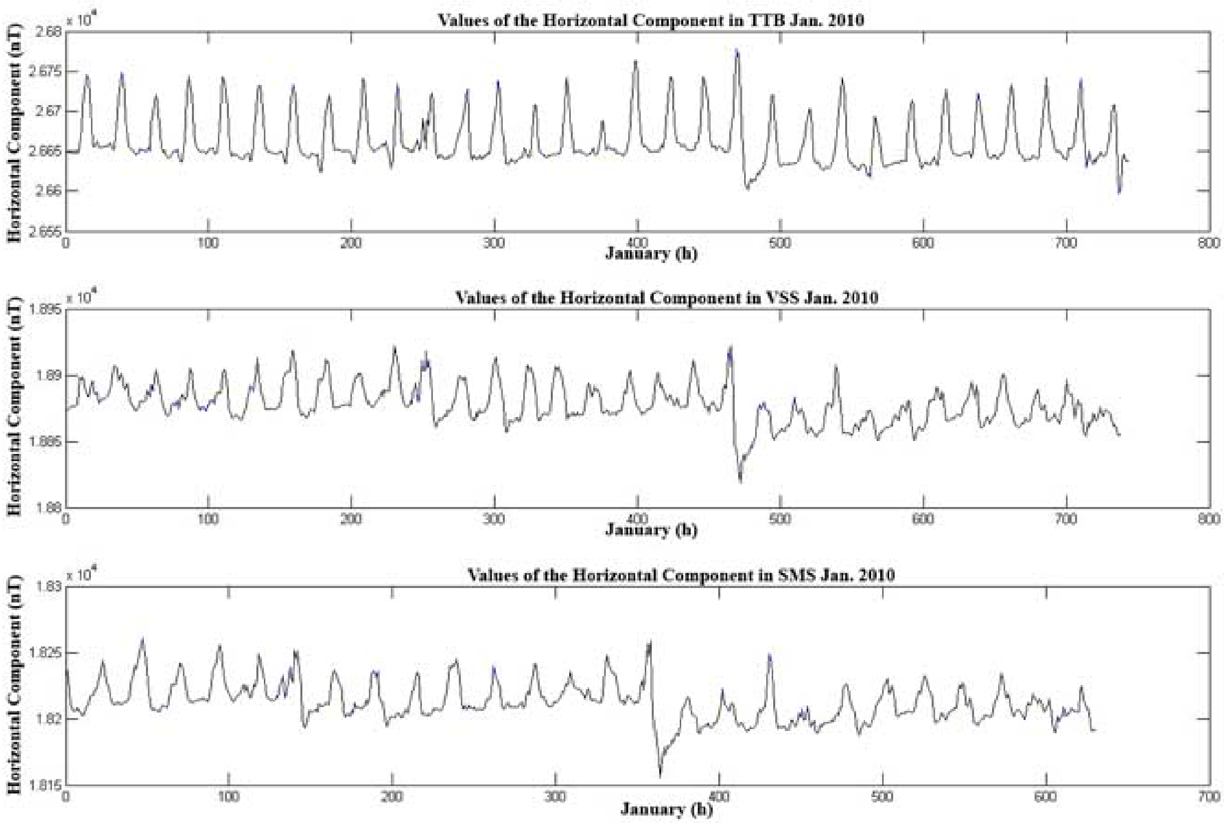

Figure 4. Time series of the horizontal component for each of the three stations measured in January 2010. The ordinates represent the standardized values, ie the z score.

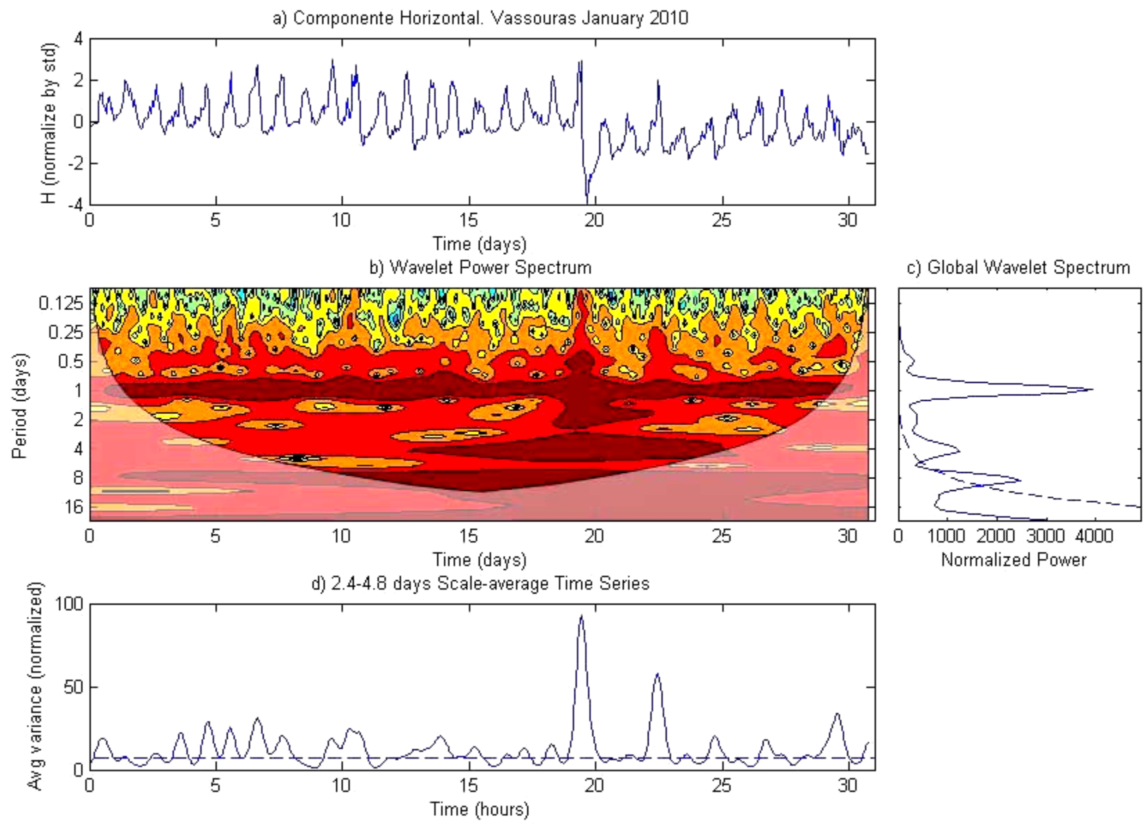

Figure 5. Wavelet power spectrum for H in Vassouras jan. 2010.

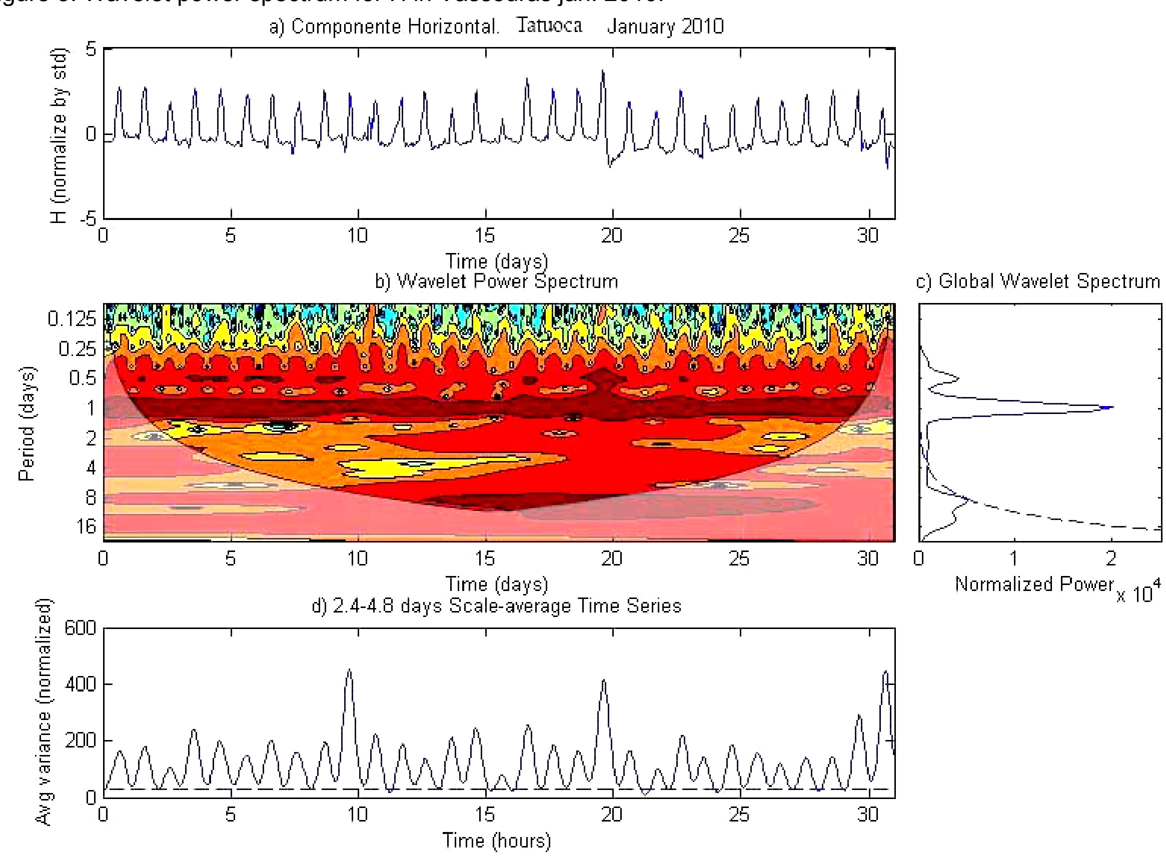

Figure 6. Wavelet power spectrum for H in Tatuoca jan. 2010.

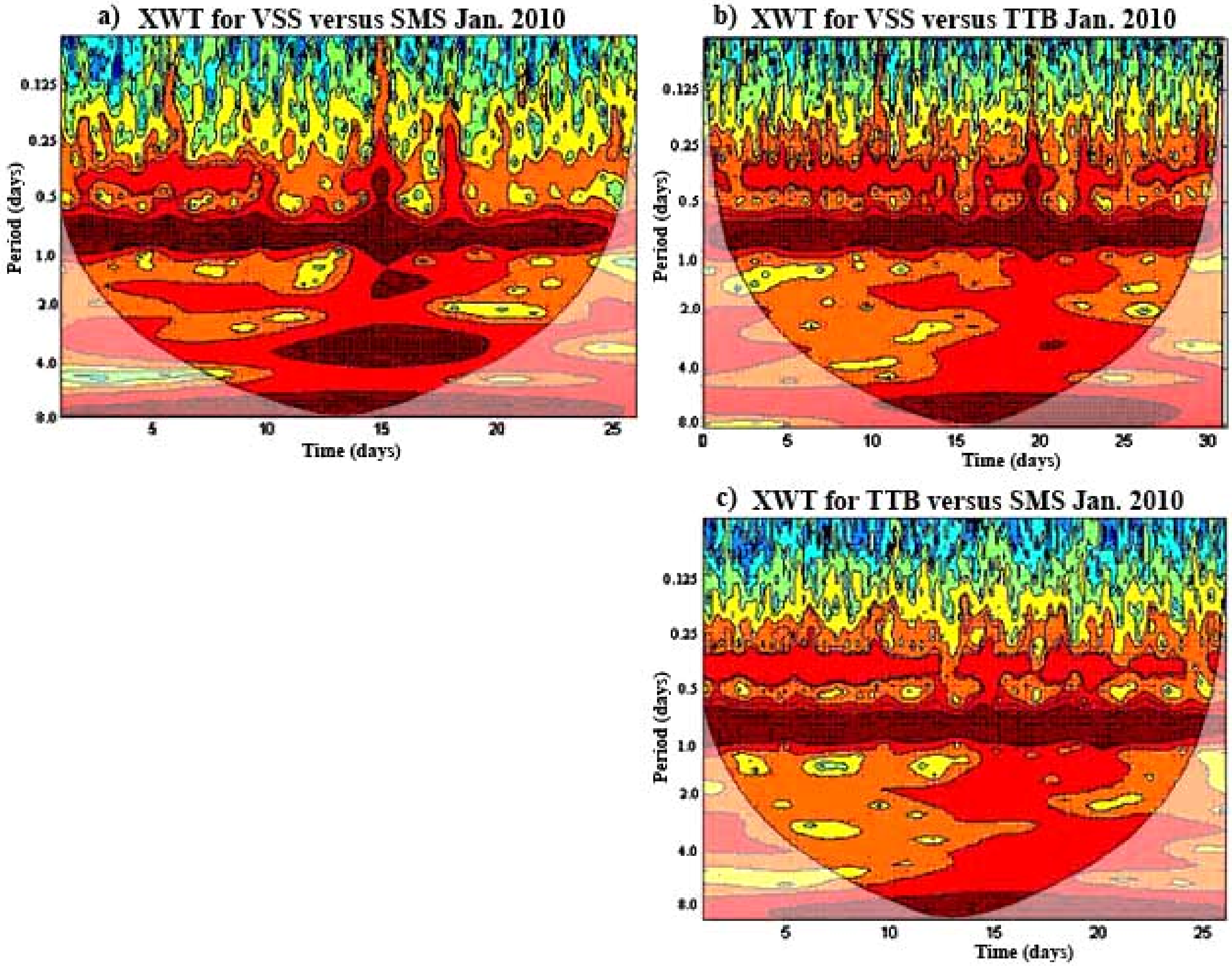

Figure 7.- XWT for the three combinations of stations. All combinations show correlation for the diurnal scale. For VSS/SMS occurs at the semidiurnal scale, 2d, 4d and 8d. In VSS/TTB survive the semidiurnal, 8d and scarcely the 4d. For TTB/SMS only survives the 8d.