Solar Quiet Current Response in the African sector due to a 2009 Sudden Stratospheric Warming Event

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ABSTRACT

We investigated $S_q H$ variability prior to and during SSW of 2009, which is a major one. In contrast to Yamazaki et al. (2012c), the northern hemisphere $S_q H$ is higher compared to the southern hemisphere during the SSW peak phase. This is a clearer evidence that the ionosphere is modified due to SSW. Interestingly, the SSW phase characterized by significant damping across the hemispheres is associated with reduced equatorial electrojet (EEJ) and counter electrojet (CEJ) at the dip equator compared to other phases. Also, we found intense westward currents visible immediately after ILR in the southern hemisphere around 1300 LT (daytime hours) and were more intense at Maputo (MPT) and Durban (DRB).

Aim and Scope of the Study

Vineeth et al. (2009), Yamazaki et al. (2012c) studies have disclosed direct connections between solar quiet (S_q) of the horizontal (H) magnetic field intensity ($S_q H$) and changes in the lower atmosphere over the low latitudes during the SSW events. In contrast to Vineeth et al. (2009), Yamazaki et al. (2012c) works, we will analyze results, not only for when the zonal mean wind flow in the polar stratosphere reverses, but also, when it gradually weakens and gets to zero value. Also, to the best of our knowledge, few observational studies on $S_q H$ currents in year 2009 that included January have been made over the African sector (El Hawary et al., 2012, Bolaji et al., 2013). However, they make no attempt to consider any link between the $S_q(H)$ current and 2009 SSW event. Hence, this work will investigate response of $S_q H$ current variability to the 2009 SSW event over the African sector and compare our results with previous studies from other regions.

Methods

We have used 9 Magnetic Data Acquisition System (MAGDAS) station covering African chain between geographic latitudes ~ ±30^0. The local magnetic perturbations at the ground (B **)** and the global magnetic perturbations associated with ring currents ($\boldsymbol{S_H}$) imposed on observed one-minute resolution of the horizontal (H) component of the geomagnetic field data (H_t) binned into hourly values are removed using the method of Le Huy and Amory-Mazaudier (2005). To quantify the solar quiet of the horizontal component ($S_q H$), the averaged nocturnal values between 2400 LT and 0100 LT for a day is subtracted from the hourly values of ΔH_g for that particular day (Bolaji et al., 2013). The stratospheric data are available at the National Centre for Environmental Prediction (NCEP). The January 2009 daily $S_q H$ values are grouped into six phases: As a result of this, we have categorized the zonal mean air temperature of the stratosphere into six phases: (1) SSW Pre-condition, when the temperature of the stratosphere is normal without any noticeable surge (January 01-17); (2) SSW Ascending Phase, when there is a surge in the temperature of the stratosphere (January 18-21); (3) SSW Peak Phase, when the surge in the temperature of the stratosphere is strongest (January 22-24); (4) SSW Descending Phase, when the surge in temperature of the stratosphere, which is strongest begins subsiding (January 25-31); (5) After the SSW, when the stratosphere recovered from the surge of the strongest temperature (February 01-22) and (6) No-SSW, when the stratospheric temperature variability is similar to SSW pre-condition (February 23-March 31). There are no March data available, hence, we restricted our No-SSW phase to February 28. For a phase, all the days were averaged and the 9 stations were plotted in two-dimension from the Northern hemisphere (Tetouan, TETN) to the Southern hemisphere (Sutherland, SUTH) through the equator (Nazret, NAZR).

Results

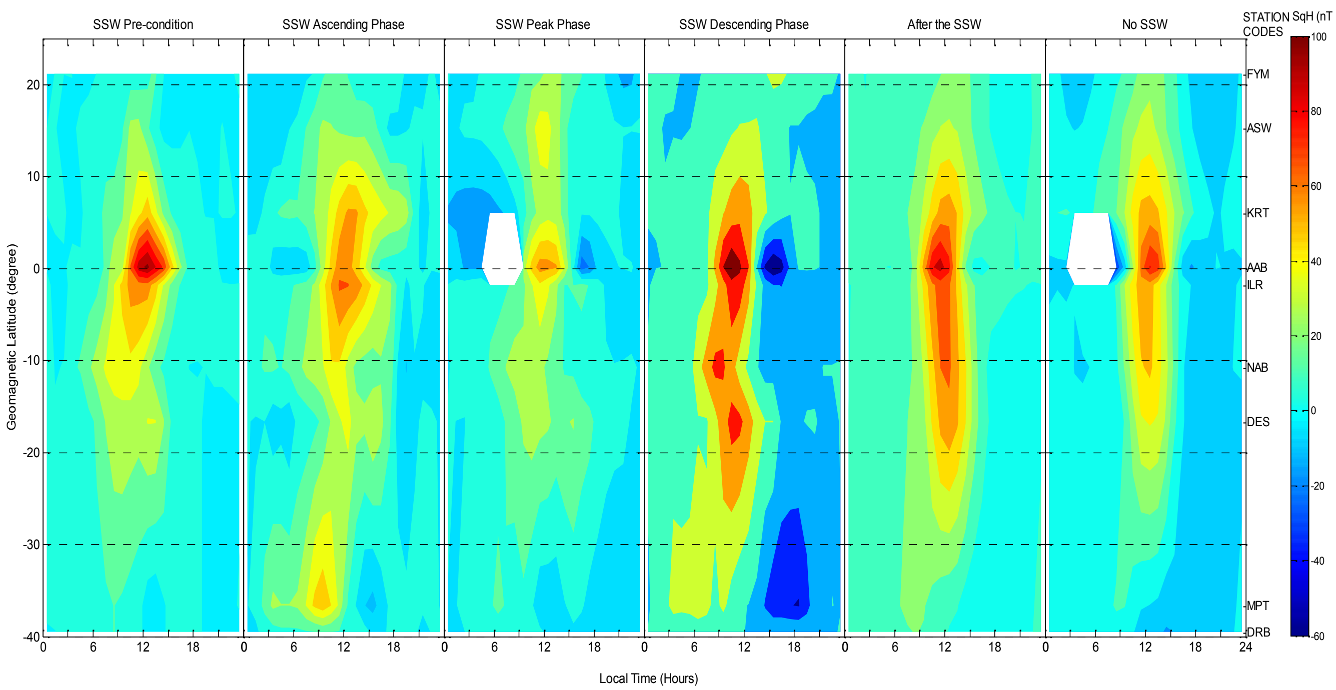

Fig. 1: Latitudinal profile of S_qH before, during and after the SSW event of 2009.

The SSW descending phase has been given a lot of attention by Vineeth et al. (2009), Yamazaki et al. (2012a, b, c) because the stratospheric mean zonal wind reverses easterly at that phase and signifies that a major SSW event is in-place. They observed decrease and increase in the northern and southern S_qH current intensities, respectively (Yamazaki et al., 2012c), enhanced EEJ and CEJ currents (Yamazaki et al., 2012c; Vineeth et al., 2009), which is similar to our results (Fig.1). However, it is interesting that in the SSW peak phase, ~ 40 nT of S_qH magnitude straddled Aswan (ASW) in the northern hemisphere. Between Nairobi (NAB) and Dares-Salaam (DES), where ASW could be found in the southern hemisphere, S_qH magnitude is ~ 28 nT. This is indicative of adjusted (2,3) semidiurnal mode suggested by Yamazaki et. al. (2012c). Whereas, in the case, it is reversed in the middle atmosphere and simultaneously reversed the ionospheric wind dynamo that initiated unusual hemispheric asymmetry in S_qH over the African sector.

The highest S_qH magnitude of ~ 61 nT was observed at ILR during the SSW ascending phase. This indicate that the S_qH peak, which is significant near noon hours at AAB (0.18^0S of geomagnetic latitude) in all the SSW phases considered was absent during the SSW ascending phase. During this SSW ascending phase when S_qH is maximum at ILR (1.82^0S of the geomagnetic latitude), the stratosphere is characterized by weaken zonal mean wind and a surge in the temperature more than 25 Kelvin within a week. It is worthy to note that this is a clearer evidence of modified $S_q H$ at the dip equator due to SSW, which contrast the quiet period morphology of $S_q H$ current intensity at the dip equator revealed by Matsushita and Campbell (1967) and the study of longitudinal difference in the EEJ current over the African sector by Rabiu et al. (2011). Irrespective of higher $S_q H$ magnitude found at AAB during the SSW peak phase, further reduction in $S_q H$ value (~ 39 nT) is significant at ILR. This indicates that the $S_q H$ magnitudes over AAB, ILR and across the hemispheres were further depleted during the SSW peak phase compared to all the SSW phases under investigation. The effort of Liu and Roble (2002) using a self-generated SSW model of coupled Thermosphere Ionosphere Mesosphere Electrodynamics-General Circulation Model/Community Climate Model-3 (TIME-GCM/CCM3) showed that the intensity of the upward westward propagating gravity and planetary waves increase when the stratospheric zonal mean wind gets to zero level, which coincides with the SSW peak phase when the stratospheric air temperature is highest. The upward propagation of these waves would modulate the tidal components (diurnal and semidiurnal) by damping (Meyer, 1999). Hence, a reduction in the magnitudes of $S_q H$ across all the latitudes during the SSW peak phase is possible.

Conclusions

Our results reveal significant changes in the $S_q H$ currents response in the African chain due to the 2009 SSW event. We found a different morphology in $S_q H$ current during the SSW peak phase, where the $S_q H$ in the northern hemisphere is significantly stronger than that in the southern hemisphere.

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