Institute for Scientific Research,
Boston College
Presentation

Solar quiet current response in the African sector due to a 2009 sudden stratospheric warming event

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10th August, 2016

Outlines

- Forcing on the Ionosphere
- Waves motion in the atmosphere
- Long-term forcing of atmospheric wave: Sudden Stratospheric Warming (SSW)
- Planetary wave forcing and residual circulation
- Current hypotheses and possible mechanisms of coupling between the polar stratosphere and low latitude ionosphere
- Experimental evidences over Africa

Forcing on the ionosphere

- 1. Photochemical processes
- 2. Transportation processes

- Forcing from Above

  -Magnetospheric coupling

  1. Substorms- Transient/Localized

  2. Geomagnetic storm- Persist for longer period/Global

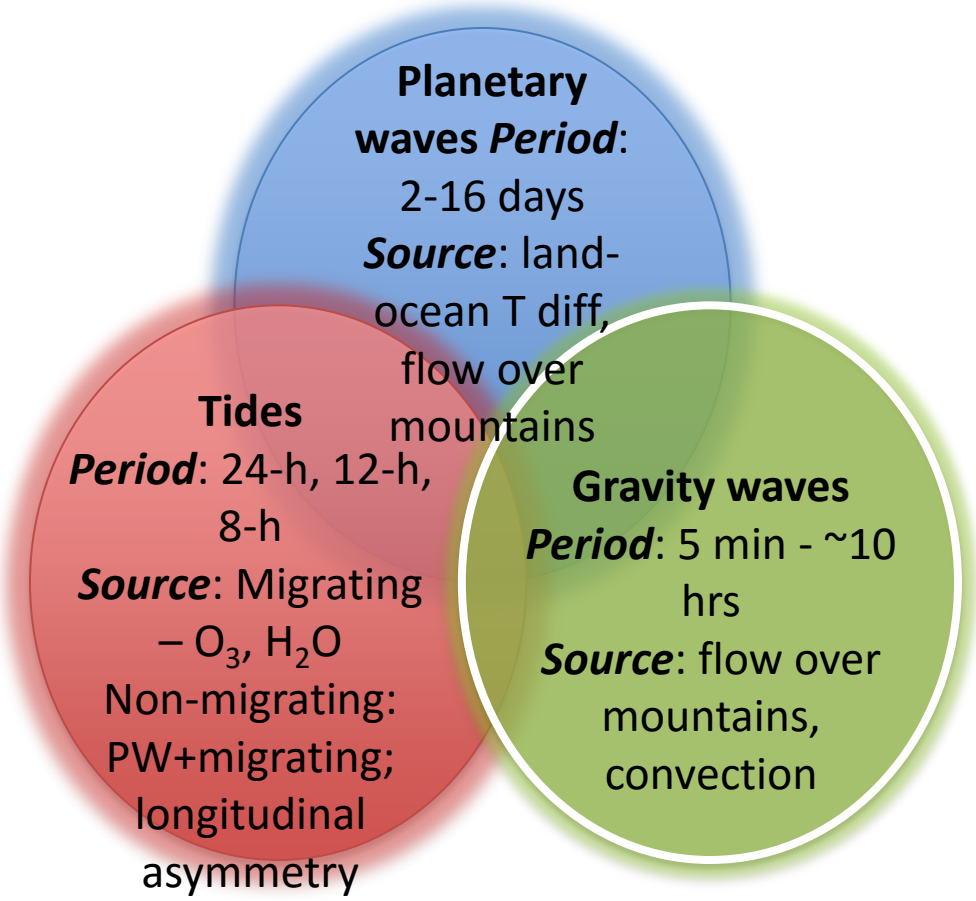
- Forcing from Below

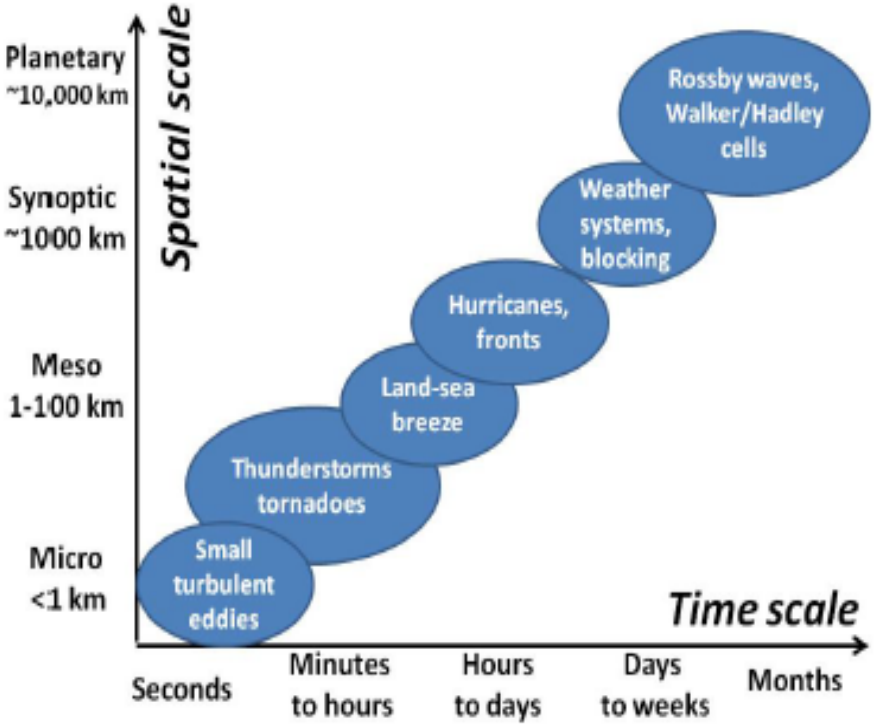
  -Lower atmospheric coupling

  1. Transient forcing of atmospheric waves- Small amplitudes/Local events

  2. Long-term forcing of atmospheric waves- Large amplitudes/Global events

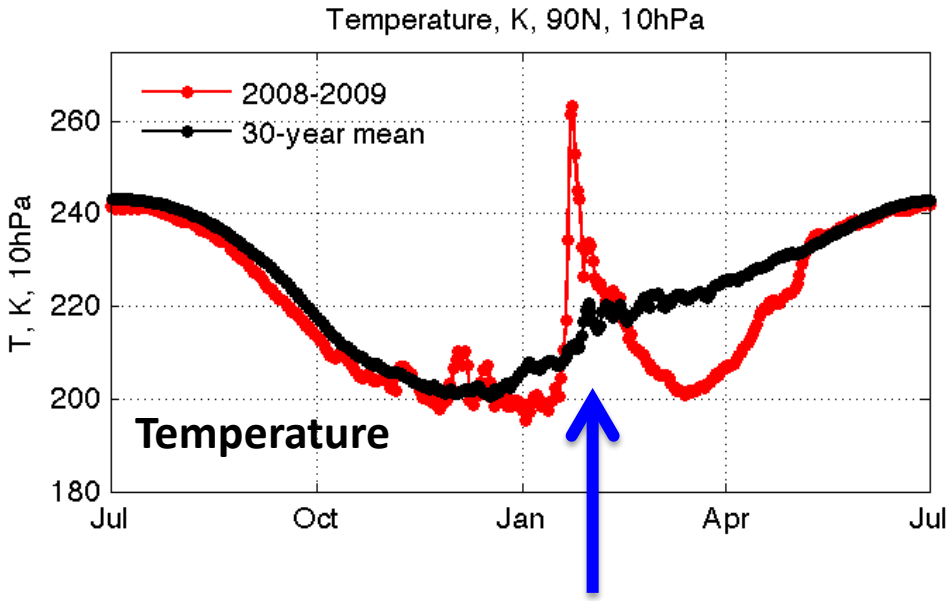
Waves motion in the atmosphere



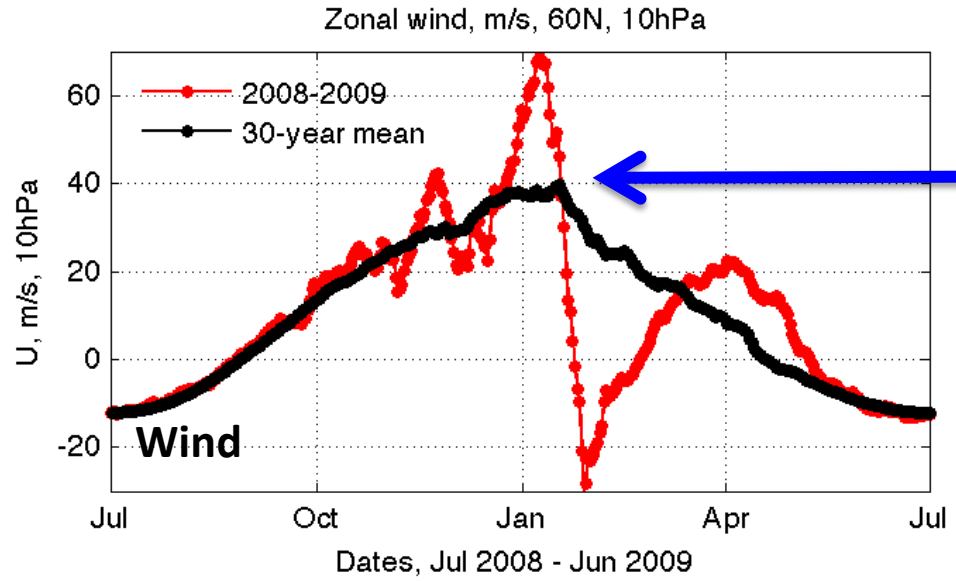


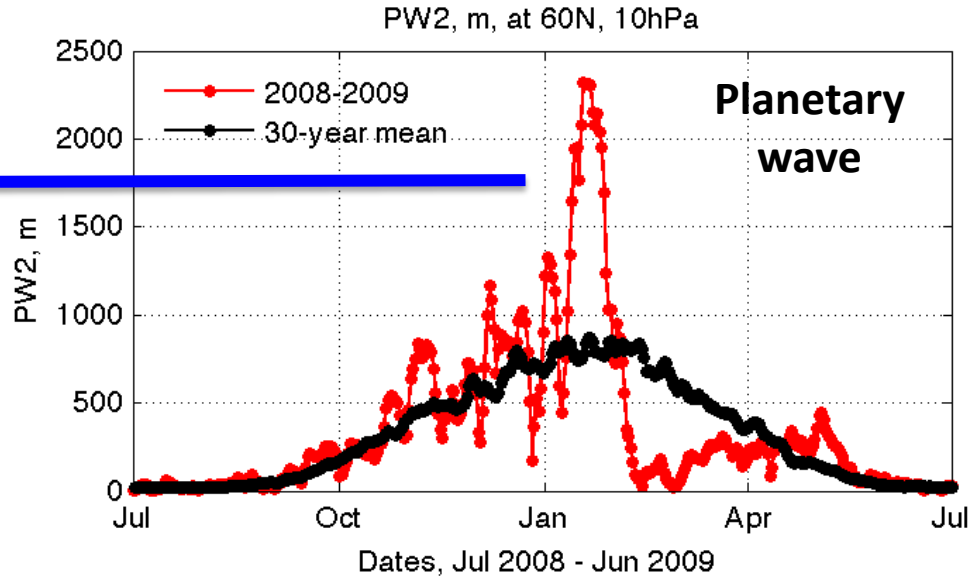
- Large variety of sources
- Strongly affected by propagation conditions – latitudinal and seasonal variation
- Amplitudes of waves exponentially increase with altitude
- Deposit momentum and energy at the altitude of “break” or dissipation

Long-term forcing of atmospheric waves

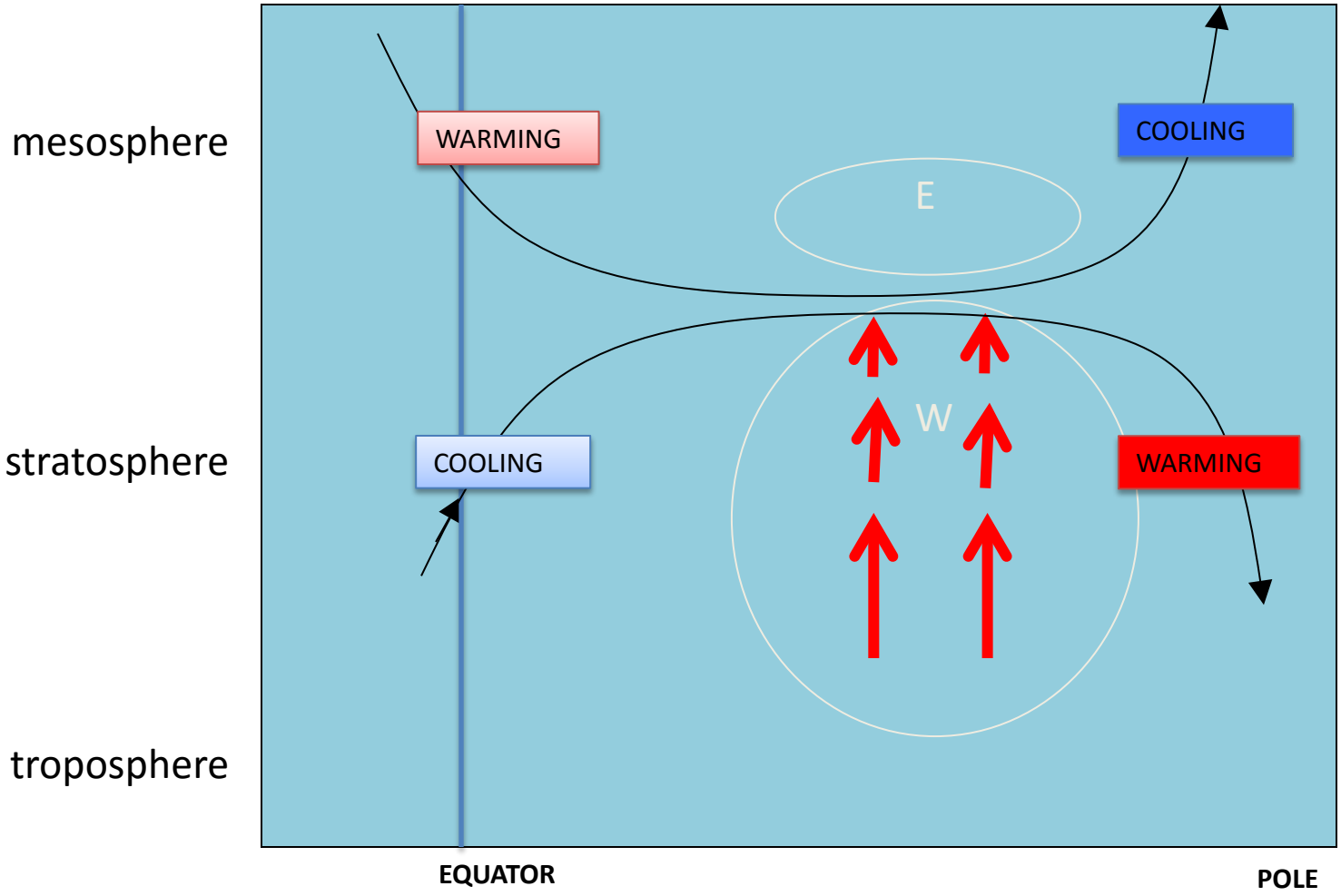


- Largest known meteorological disturbance
- Rapid increase in temperature in the high-latitude stratosphere (25K+); from winter-time to summer-time
- Accompanied by a change in the zonal mean wind
- **Caused by anomalously strong quasi-stationary planetary waves**





Planetary wave forcing and residual circulation



Warming and cooling lead to circulation changes in the stratosphere and mesosphere

Current hypotheses and possible mechanisms of coupling between the polar stratosphere and low latitude ionosphere

Mechanism	Point	References
Nonlinear interaction of planetary wave and tide	PW + SW2 migrating tide -> SW1 nonmigrating tide	Liu et al., 2010; Pedatella and Forbes, 2010
Lunar tide amplification	Tidal phase variation	Fejer et al., 2010, 2011; Yamazaki, 2012; Forbes, 2012; Fejer and Tracy, 2013; Pedatella et al., 2014
TW3 amplification	DW1 + SW2 -> TW3	Fuller-Rowell et al., 2010, Wang et al., 2012
Temperature + wind dynamo	Temperature increase at high-latitude MLT -> dynamo effects	Pancheva and Mukhtarov, 2011; Korenkov et al., 2012
Ozone variations	Variations in stratospheric ozone -> increase in migrating and non-migrating 12-h tides	Goncharenko et al., 2012, Sridharan, 2012
SW2 amplification	Change of propagation conditions	Jin et al., 2012

- Relative importance of each mechanism is not known
- All mechanisms can work simultaneously and create complex variations from the stratosphere to the ionosphere

Some connections already established between Solar quiet (Sq) currents and SSW

Vineeth et. al (2009) – Modification of CEJ and EEJ

Fejer et al. (2010) – Modification of CEJ and EEJ associated with zonal mean wind reversal and enhancement of lunar semidiurnal tidal winds.

Yamazaki et al. (2012a) – Amplification in geomagnetic lunar tides at Addis-Ababa

Yamazaki et al. (2012b) – Amplification in EEJ associated with CEJ when zonal mean wind reverses

Yamazaki et al (2012c) – Increase in Sq over the southern hemisphere compared to the Northern hemisphere

Experimental evidences over Africa

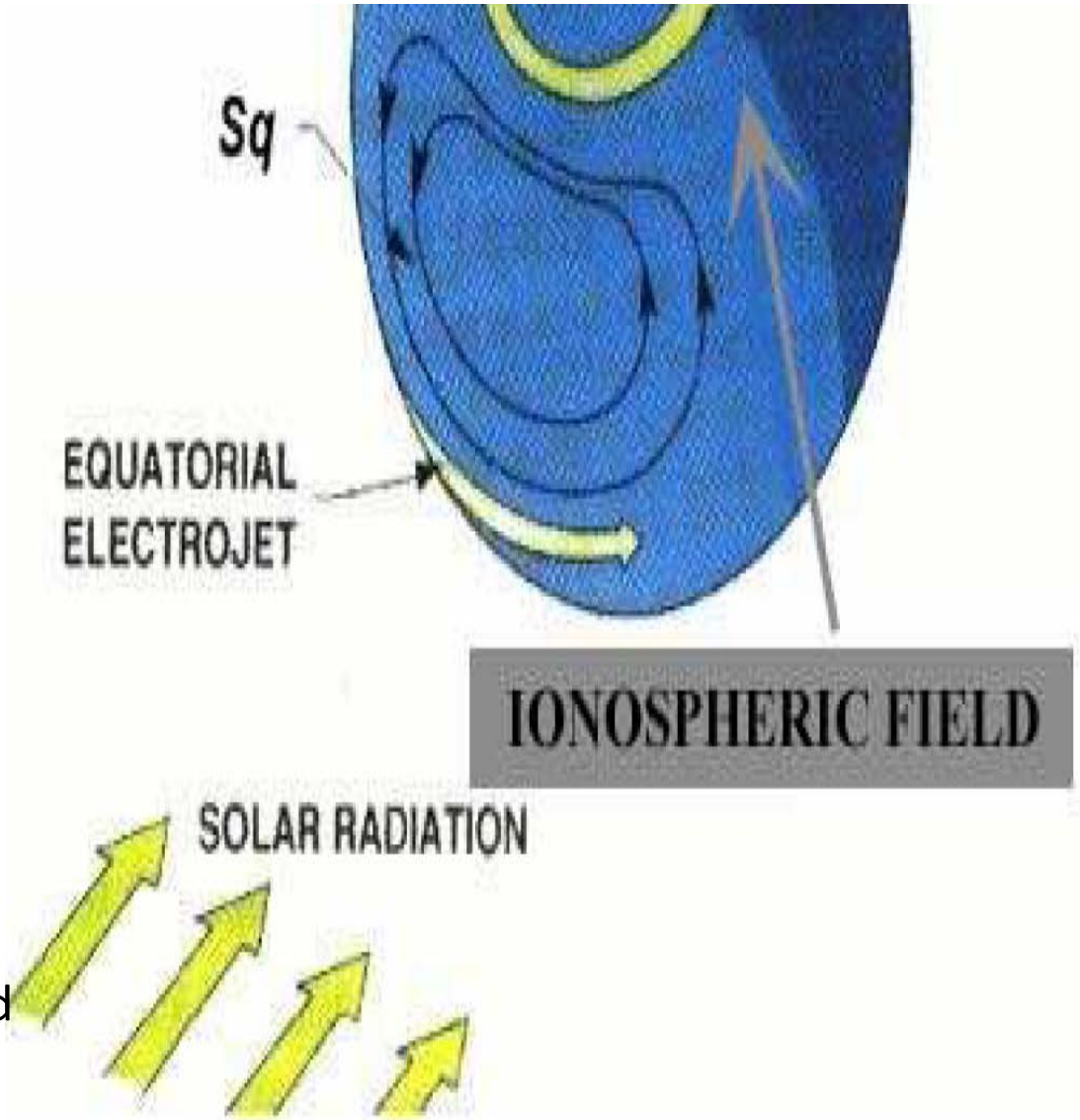
Sq currents briefly

Due to the effect of solar extreme ultra-violet radiation, the E-Layer is conducting electrically as well.

Tidal wind (v) moves conducting matter across the field lines of the main field (Bo).

This result to an electric field (VxBo), electric currents and magnetic field variation recorded on the surface of the Earth.

The equatorial electrojet (EEJ) is an intense narrow band of solar quiet (Sq) currents at E-region altitudes of the Ionosphere around 3^0N and ^{0}S flowing eastward along the dayside dip equator.



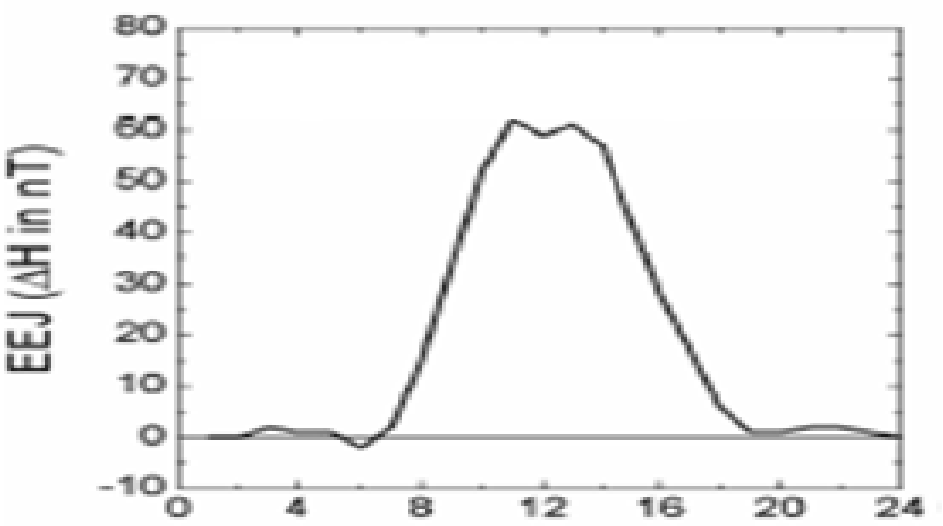
Sq currents characteristics

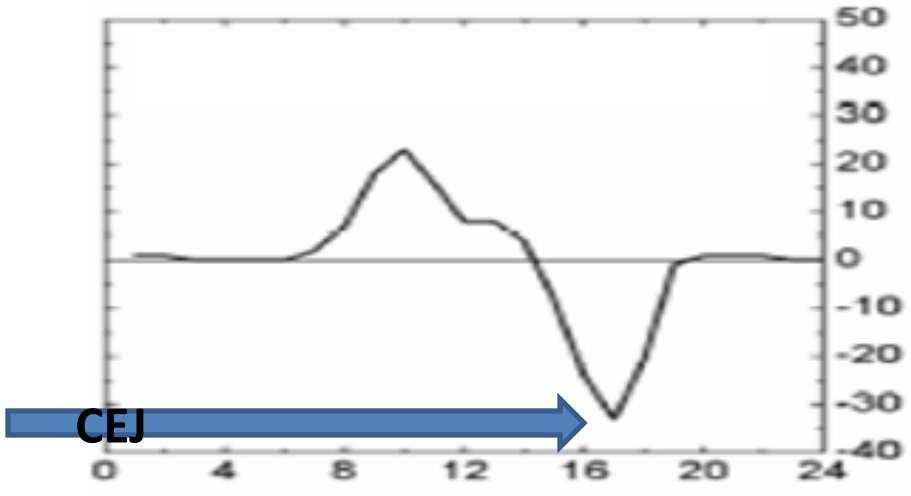
Sq field is an eastward electric field at the equatorial day-side of the ionosphere.

Manifests itself from the horizontal (H) magnetic field intensity.

Intense Sq currents at the magnetic equator result to an EEJ currents.

Sometimes, at the equatorial day-side of the ionosphere, the intense Sq currents reverses (westward electric field) and result to counter electrojet (CEJ) currents.





African geomagnetic stations investigated

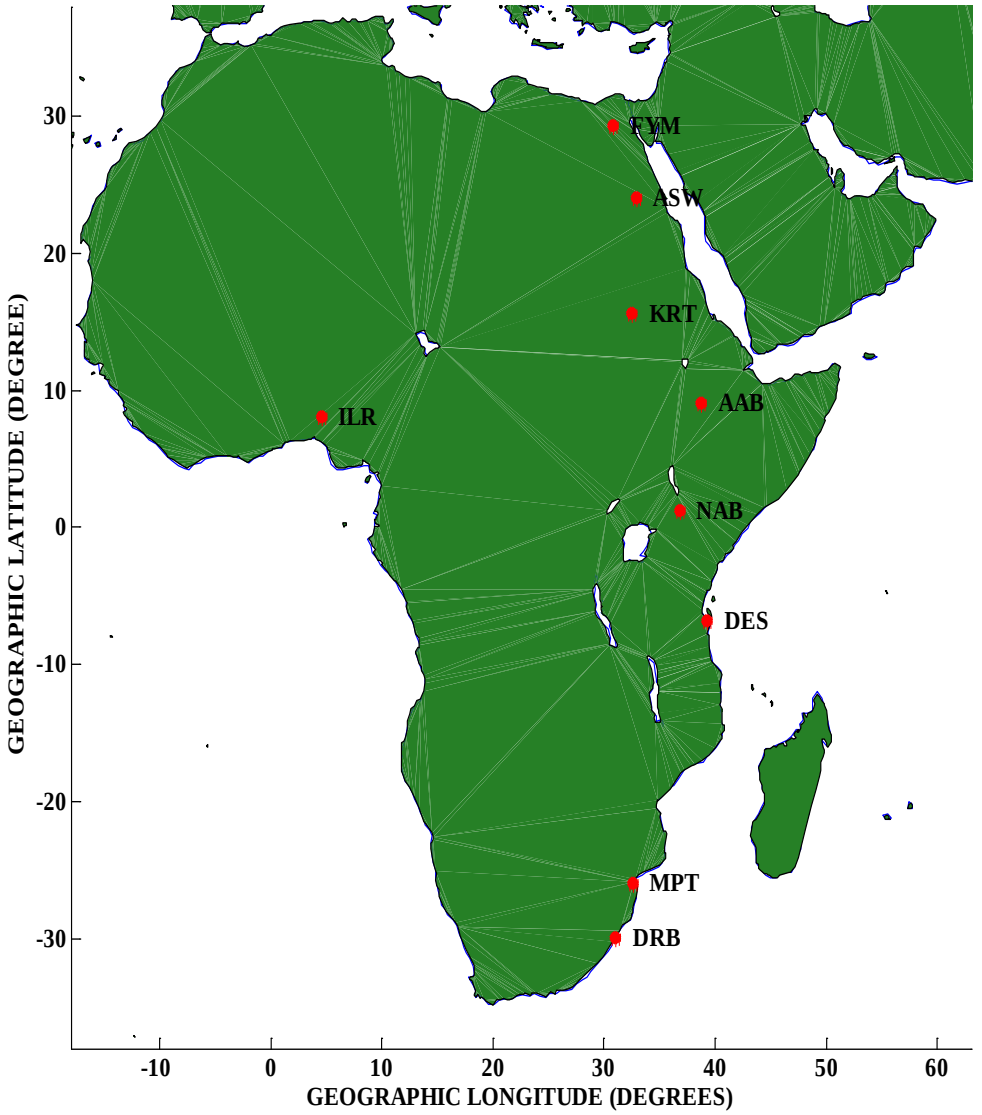
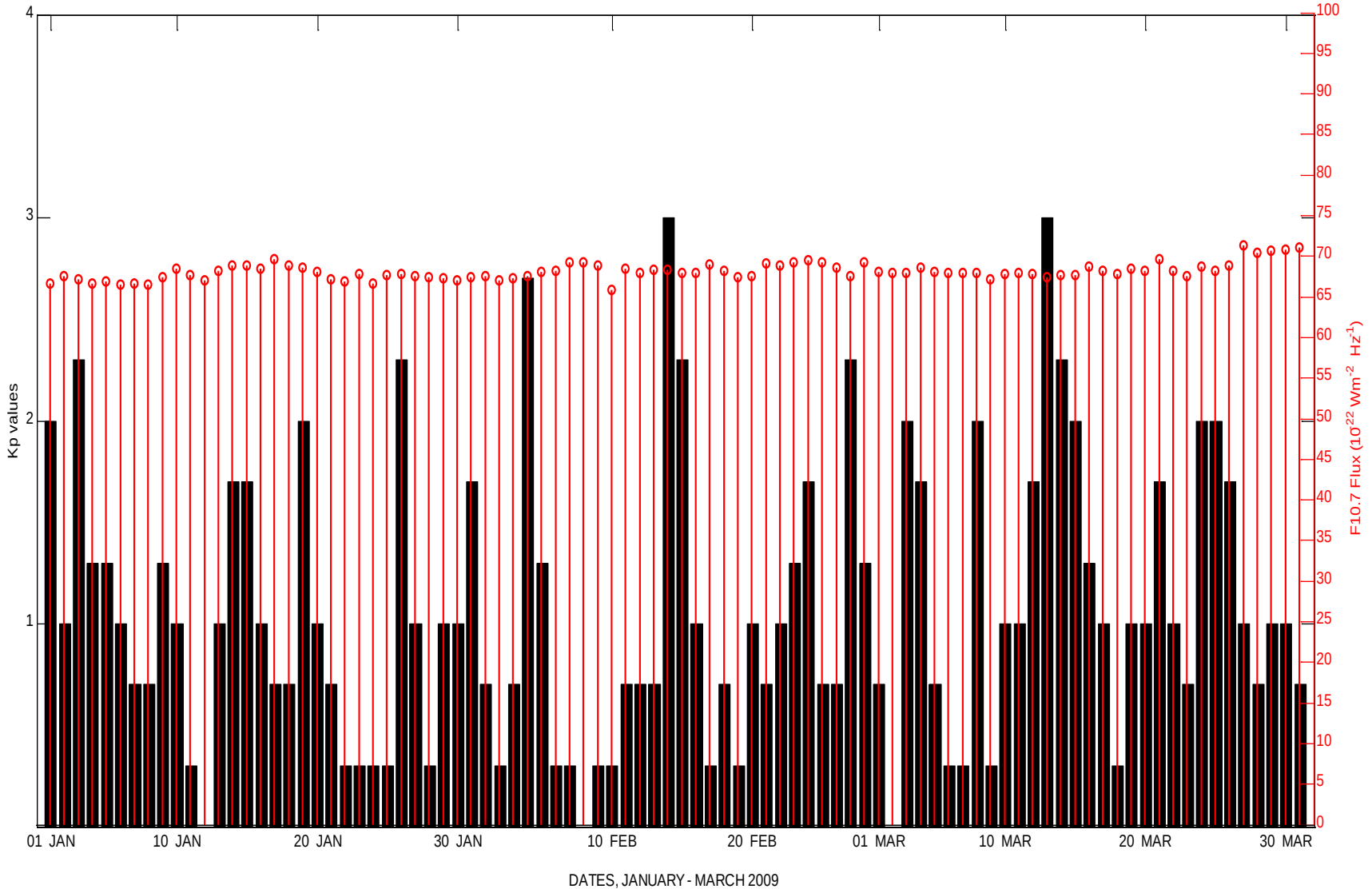


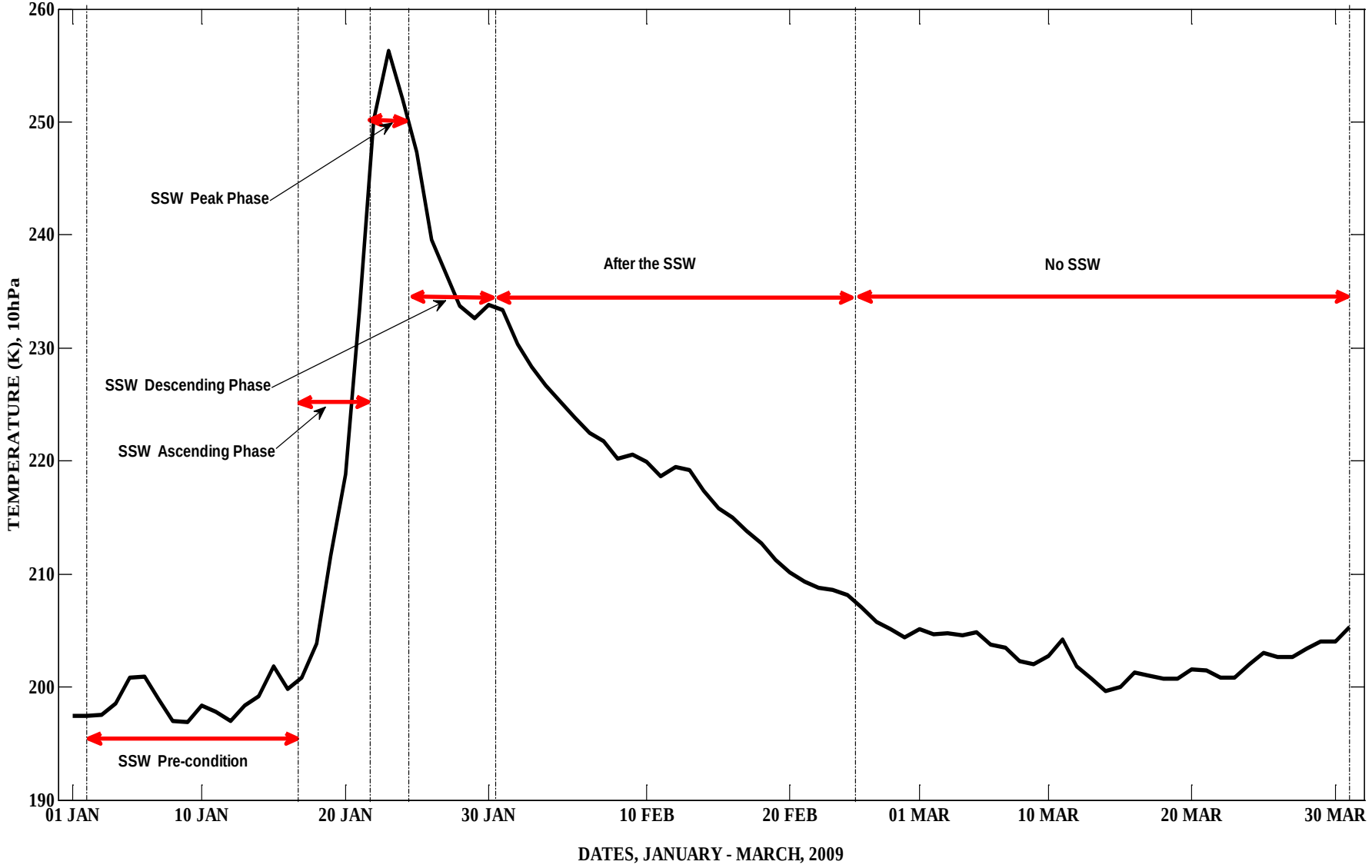
Table 1: Geographic and geomagnetic coordinates of the stations investigated.

Station	Codes	Geographic Coordinates		Geomagnetic Coordinates	
		Latitude	Longitude	Latitude	Longitude
Fayum	FYM	$29.30^{o}N$	$30.84^{o}E$	$21.13^{o}N$	$102.34^{o}E$
Aswan	ASW	$24.08^{o}N$	$32.89^{o}E$	$15.31^{o}N$	$104.77^{o}E$
Khartoum	KRT	$15.63^{o}N$	$32.53^{o}E$	$6.03^{o}N$	$104.00^{o}E$
Addis Ababa	AAB	$9.03^{o}N$	$38.74^{o}E$	$0.16^{o}N$	$110.44^{o}E$
Ilorin	ILR	$8.50^{o}N$	$4.55^{o}E$	$1.82^{o}S$	$76.68^{o}E$
Nairobi	NAB	$1.28^{o}S$	$36.81^{o}E$	$10.76^{o}S$	$108.51^{o}E$
Dal Es Salaam	DES	$6.80^{o}S$	$39.28^{o}E$	$16.62^{o}S$	$110.72^{o}E$
Maputo	MPT	$25.96^{o}S$	$32.58^{o}E$	$36.61^{o}S$	$99.64^{o}E$
Durban	DRB	$29.88^{o}S$	$31.05^{o}E$	$39.51^{o}S$	$96.41^{o}E$

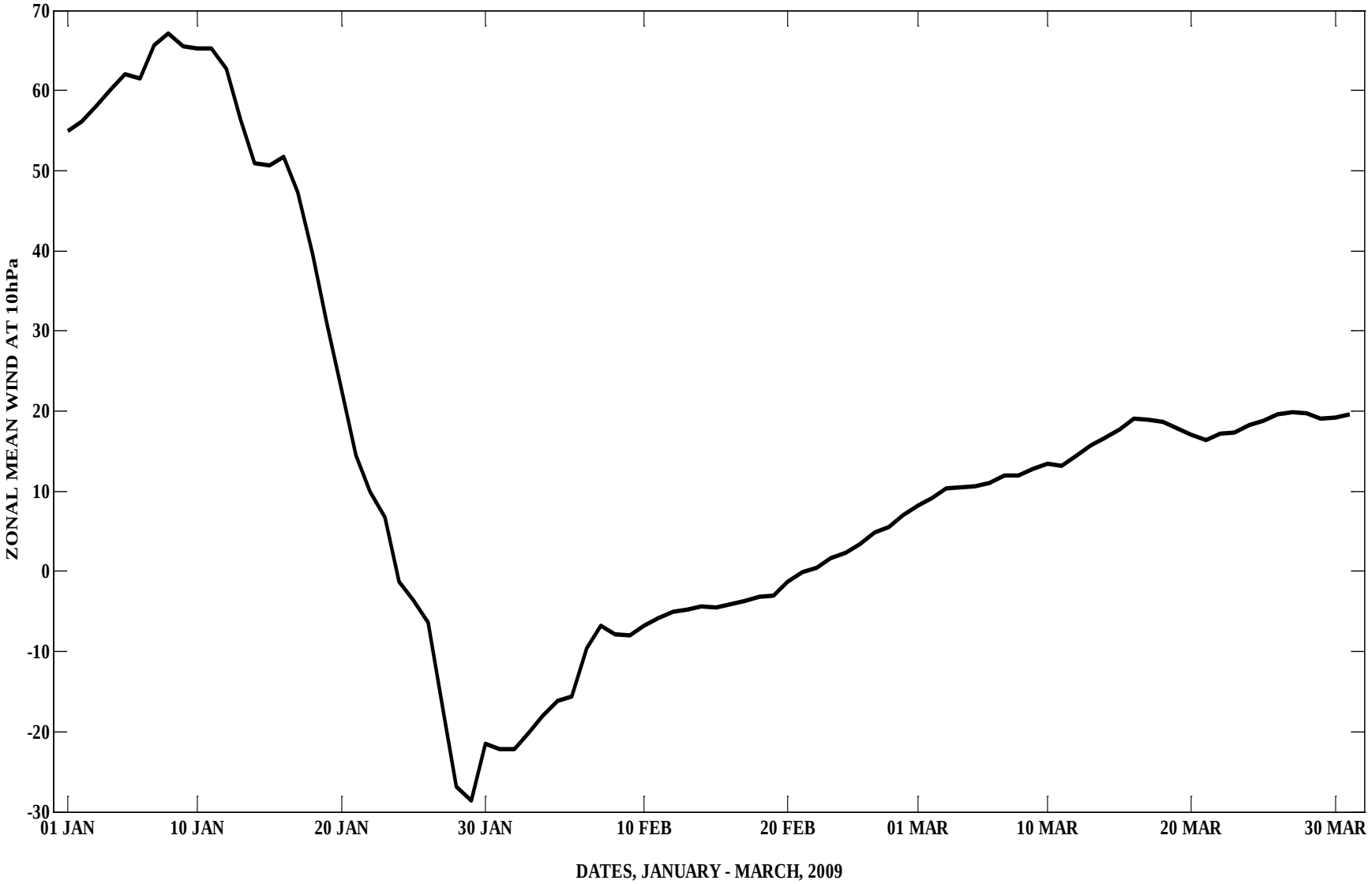
January 1 - March 31st, 2009 geomagnetic and solar flux conditions



Stratospheric Air Temperature at Different Phases (http://www.esrl.noaa.gov/psd/)



Stratospheric zonal mean wind



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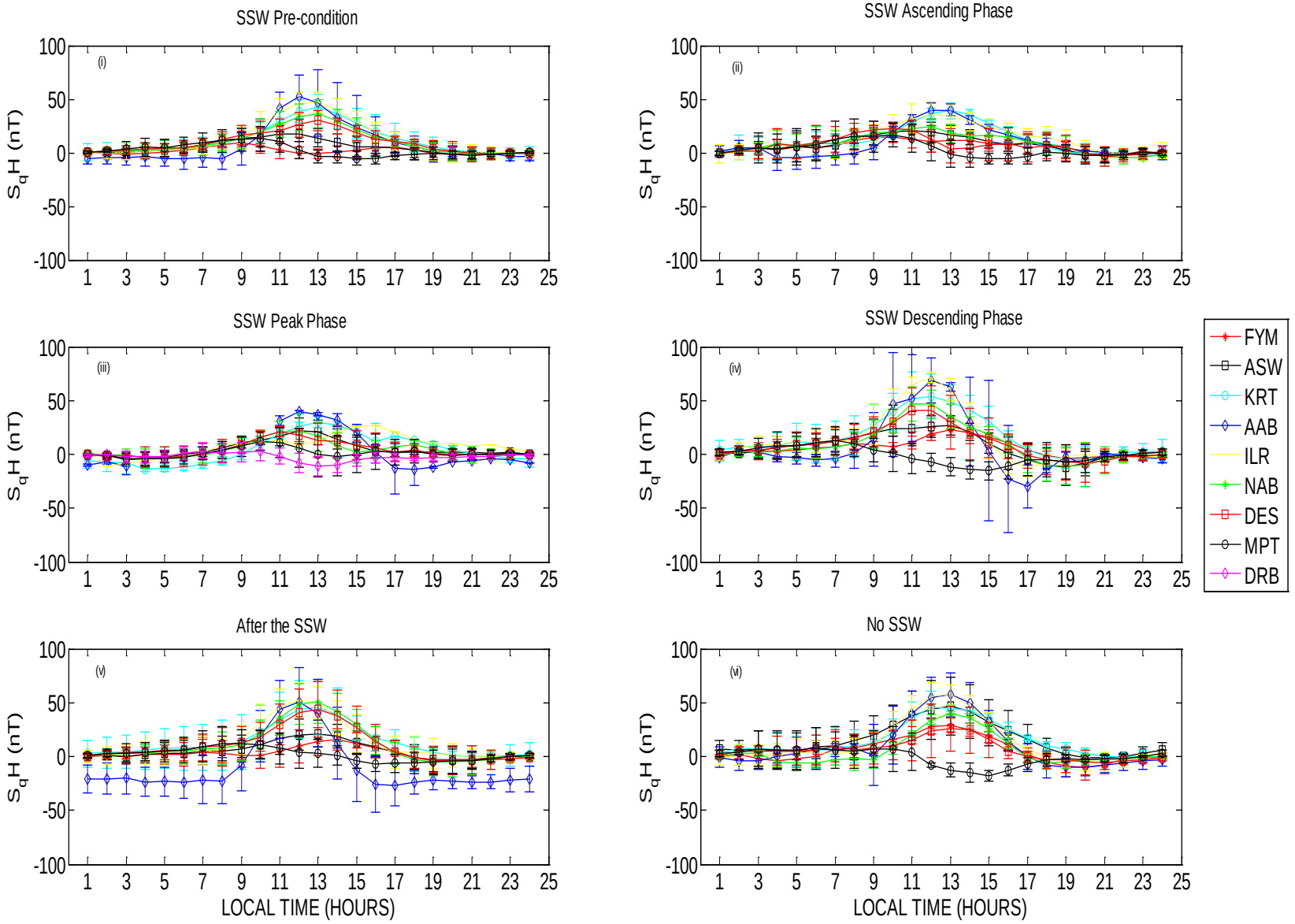
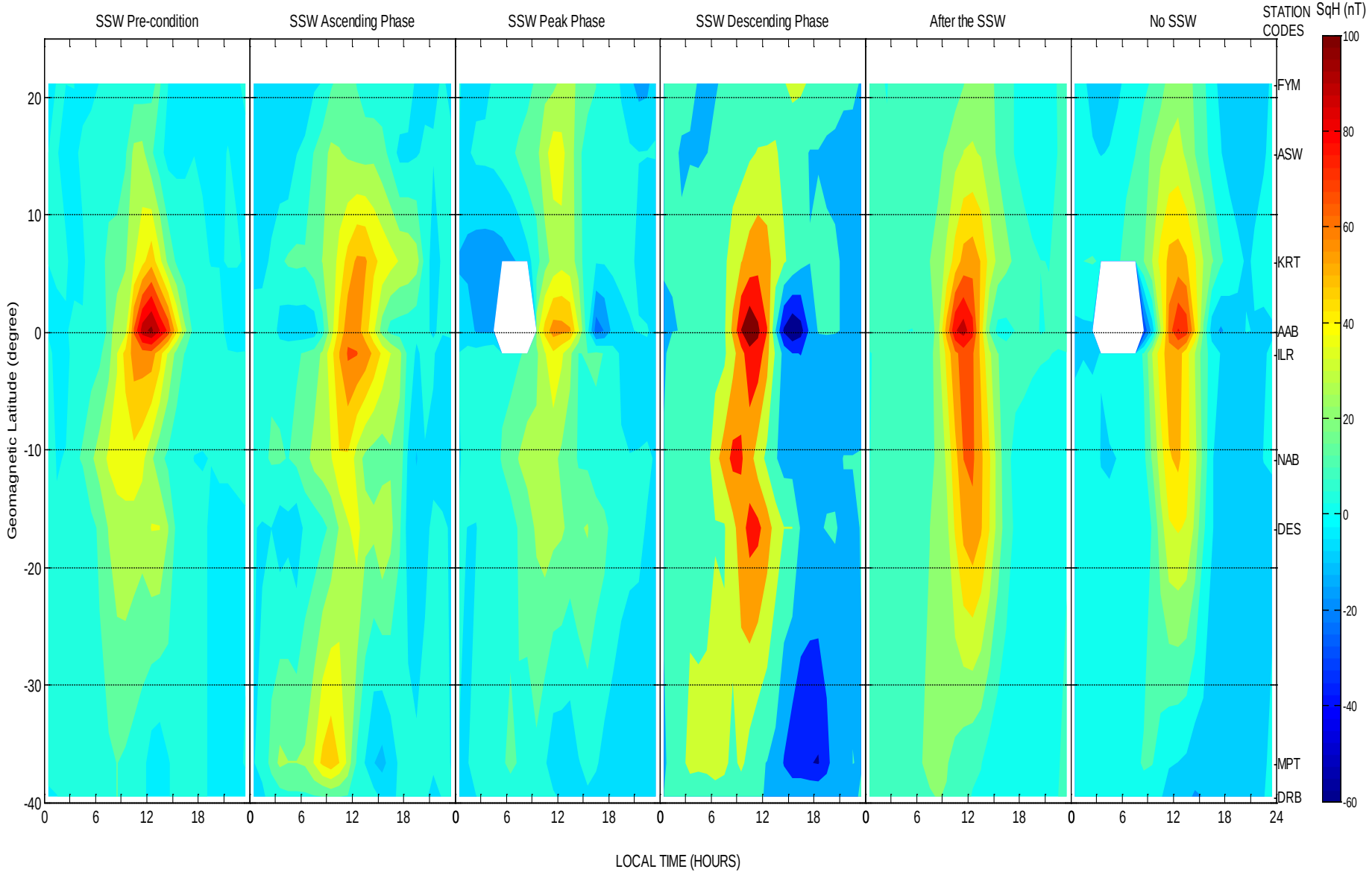
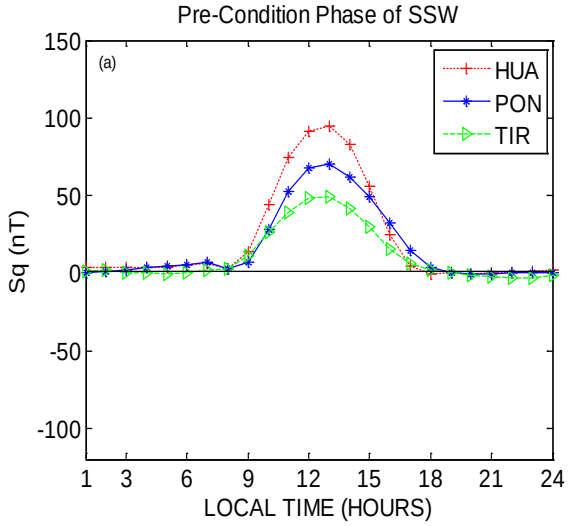
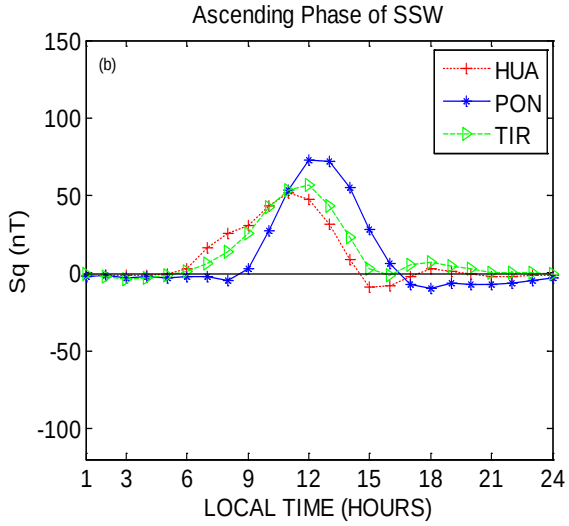


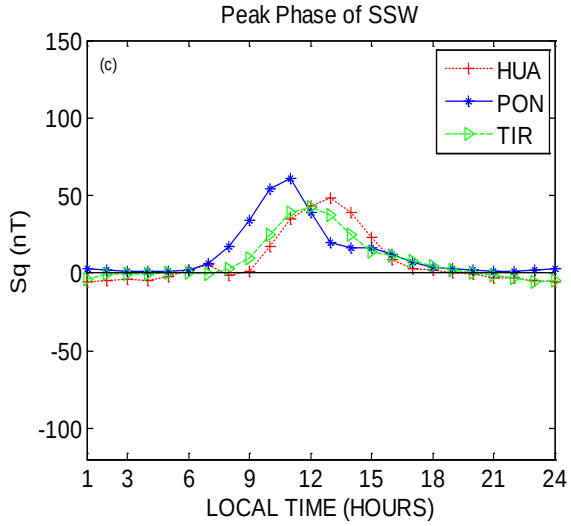
Phases of SSW investigated in Africa in 2009

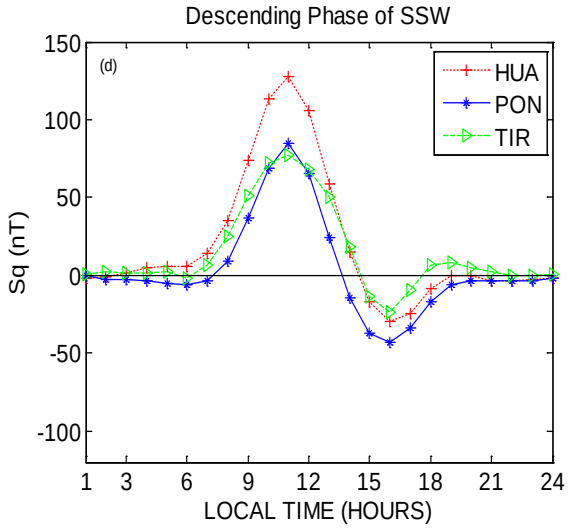


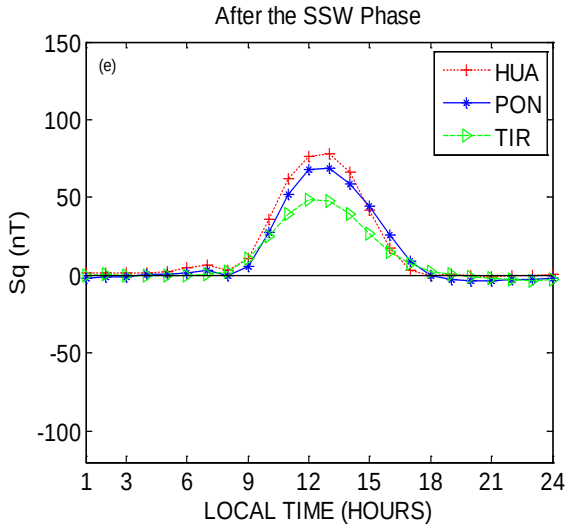
Longitudinal variability of SqH at different sectors during different phases of SSW

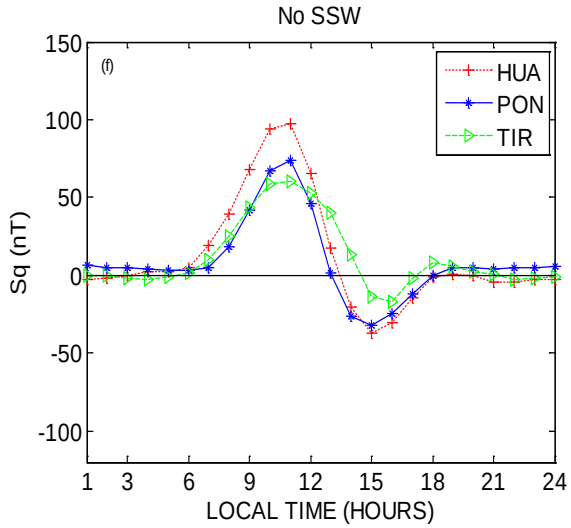












Conclusions

A reduction in the S_qH magnitude that enveloped the African hemispheres was observed while the stratospheric polar temperature was increasing and got strengthened when the stratospheric temperature reached its maximum.

There is a reversal in the north-south asymmetry of the S_qH, which is indicative of higher S_qH magnitude in the Northern hemisphere compared to the Southern hemisphere during SSW peak phase.

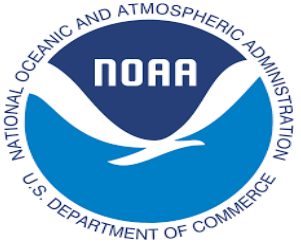
The reversal of the equatorial electrojet (EEJ) or the counter electrojet (CEJ), was observed after the polar stratospheric temperature reached its maximum.

Similar changes were observed in the EEJ at the South America, Pacific Ocean and Central Asia sectors. The effect of the SSW is largest in the South American sector and smallest in the Central Asian sector.

Accepted JGR, August 2016:

[1]O.S. Bolaji, [1]E.O. Oyeyemi, [1]O.P. Owolabi, [2]Y. Yamazaki,[3,4]A.B. Rabiu, [3]D. Okoh, [5]A. Fujimoto, [6]C. Amory-Mazaudier, [7]G. K. Seemala, [5]A. Yoshikawa and [9]O.K. Onanuga

Acknowledgements



Thank you for Listening