Regional S4 index variations observed using FORMOSAT-3/COSMIC GPS RO technique during Stratospheric Sudden Warmings in recent years

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ABSTACT

Stratospheric sudden warmings (SSW) occur mostly in the northern winter high latitudes. During an SSW, the temperature in the stratosphere abnormally and rapidly increases, causing a reversal in the latitudinal temperature gradient, and a reversal in the zonal mean zonal winds during major warmings. This change in background temperatures and winds has been shown in past studies to result in ionospheric variability due to atmospheric coupling effects between different regions and is maintained for several days.

In this poster, we present the variations of the S4 index (scintillation index) measured over Siberia and Taiwan from the signal-to-noise ratio (SNR) of GPS radio occultation (RO) signals in the L1 C/A channel using FORMOSAT-3/COSMIC satellites during SSWs in 2016 and 2017. The SSW time period S4 results are compared to climatological values to identify if any anomalies occur during the time of the SSW.

Stratospheric Sudden Warming (SSW)

According to Paula, E. R., et al. [2015], the scintillation intensity (represented by the S4 index) might be weakened significantly at low latitudes during SSW events, so we tried to observe other regions (including low and high latitudes) to find whether there is a similar phenomenon.

The occurrence of a stratospheric sudden warming is defined by the following two characteristics:

(1) The average stratospheric temperature rises at 90°N and a geopotential height of 10 hPa (~32 km).

(2) The stratospheric polar vortex is displaced from the pole or the vortex splits into two or more vortices, and during major warmings, the west wind of the polar region even shifts to east wind. Some SSWs are a combination of both types.

The stratospheric vortex breakdown can be classified into three categories:

(1) Major SSW (2) Minor SSW (3) Final SSW

Compared with the minor SSW, a major SSW results in the vortex disintegrating when the zonal mean zonal wind is suddenly reduced and reversed to the easterly winds.

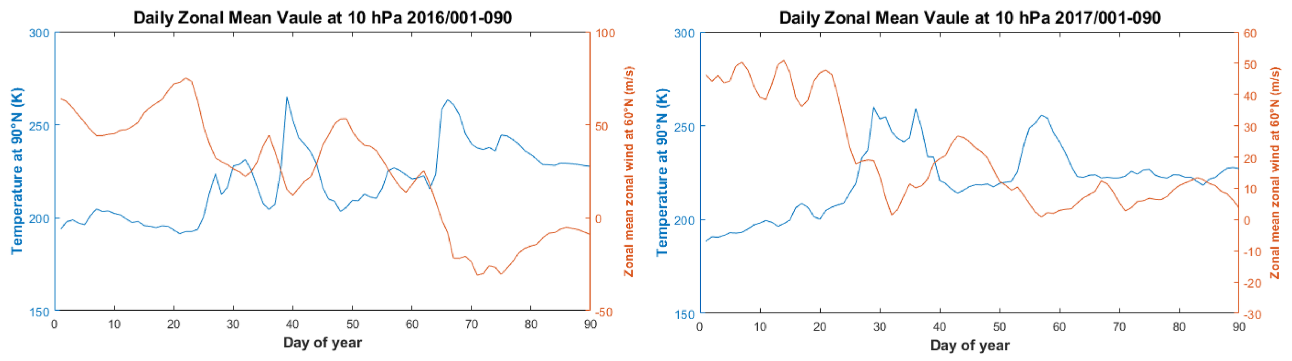


Figure 1. Daily zonal mean zonal wind and temperature of the plots. Blue line is average stratospheric temperature at 90 °N, and orange line is zonal mean zonal wind at 60°N. Left is the 2016 SSW event; Right is 2017 SSW event.

DATA

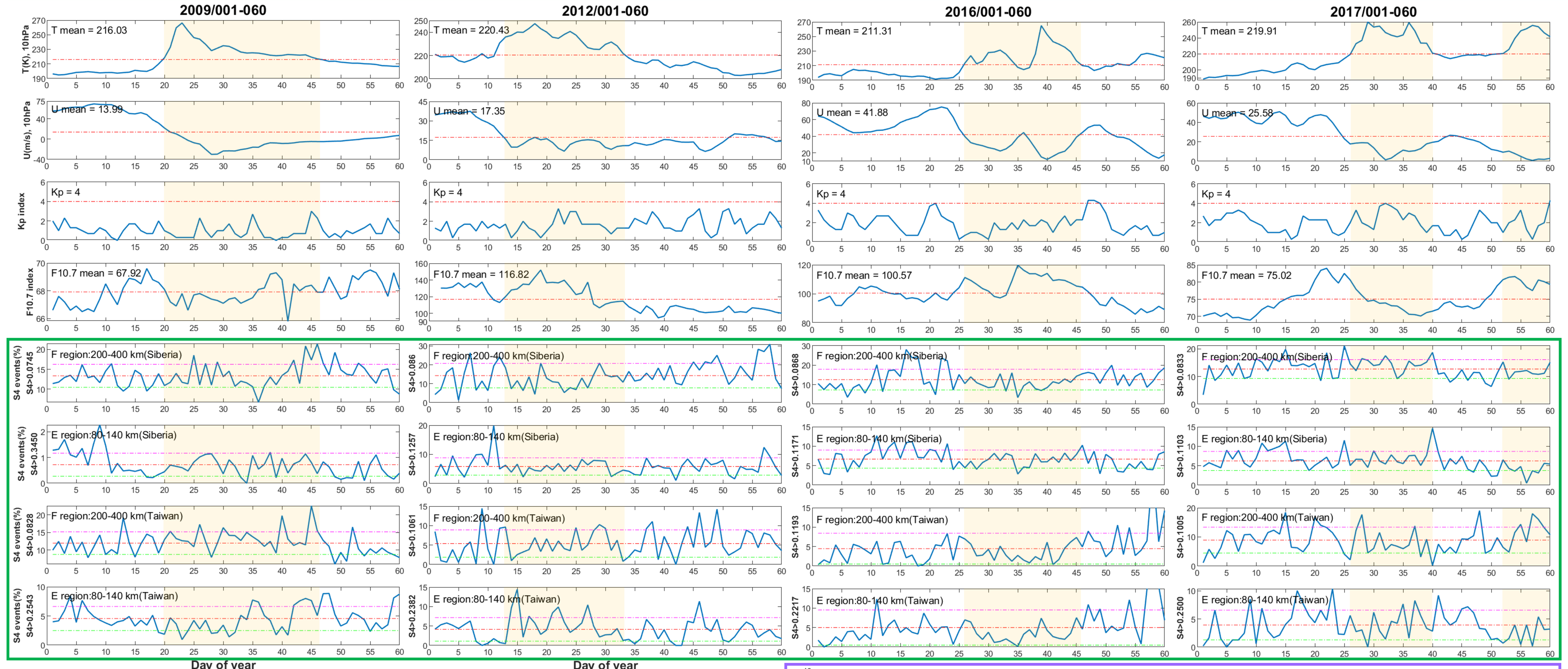
Time 2009001-060, 2012001-060, 2016001-060, 2017001-060

Location Siberia (40-85°N, 50-180°E),
Taiwan and near East Asia (15-30°N, 60-180°E)

Grid Resolution Latitude: 10° Longitude: 10°
Altitude: 200-400 km (F region)
80-140 km (E region)

Time Resolution	**Number of Data (S4 indices)**	
18:00-06:00 LT	3,796,524 (2009001-060)	1,299,485 (2016001-060)
20:00-06:00 LT	960,694 (2012001-060)	1,546,220 (2017001-060)

Data Comparison – Major Scintillation Event Occurrence Rates



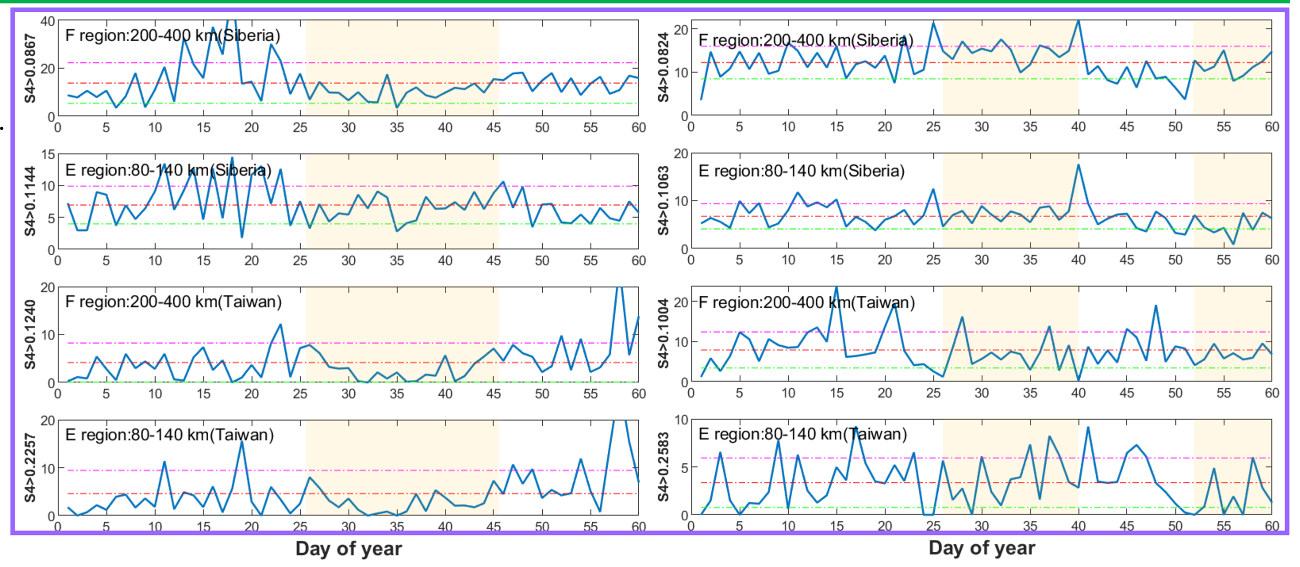


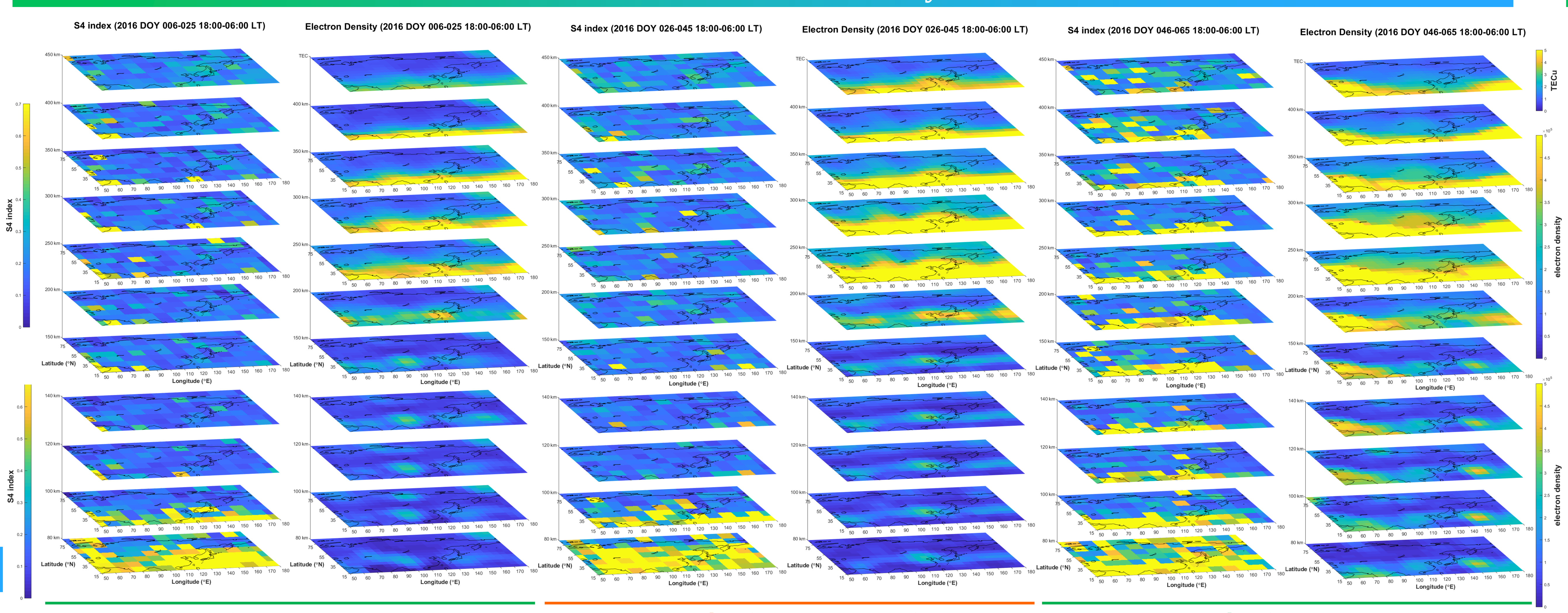
Figure 2. **1800-0600 LT** **2000-0600 LT**

The red dash-dot line: the 60-day average of each occurrence rate data set.
The magenta dash-dot line: the third quartile (average plus one standard deviation value) of the occurrence rates (%).
The green dash-dot line: the first quartile (average minus one standard deviation value) of the occurrence rates (%).
Kp = 4 is a reference line for judging whether a magnetic storm is occurring.

T(K): the average stratospheric temperature at 90°N at geopotential height of 10 hPa
U(m/s): zonal mean zonal wind (m/s) at 60°N at geopotential height of 10 hPa

The occurrence rate of major scintillation events for each day is calculated using the mean and standard deviation of all S4 indices observed during the 60 days, and the third quartile (average plus one standard deviation value) is used as the threshold value.
The occurrence rate of major scintillation events (%) is based on the percentage of S4 values that are greater than the threshold value per day.

S4 Index / Plasma Density



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https://omniweb.gsfc.nasa.gov/ow.html

RESULTS

All SSW events observed don't coincide with magnetic storms.

2009 (solar minimum):

(1) There are slightly lower occurrence rates during the SSW.

(2) Occurrence rates events are lower than the baseline of the first quartile many times especially at E region in Taiwan.

2012 (solar maximum):

(1) There does not seem to be a obvious the weakening of the occurrence rates during SSW.

2016:

(1) There are obviously lower occurrence rates, especially in Siberia.

(2) Long-lasting weak occurrence rates at E and F region in Siberia, Taiwan and near East Asia were observed.

(3) With the onset of the SSW, a long period of weakening in the occurrence rates started from the 26th day of 2016; however, the simultaneous solar activity increase didn't seem to obviously affect the S4 index.

(4) When 1800-0600 LT and 2000-0600 LT are compared, the overall trend remains unchanged even if the time of the prereversal enhancement is excluded.

(5) Compared with the occurrence rates and plasma density, higher plasma density doesn't necessarily correspond to higher scintillation occurrence rates. The relation to vertical plasma drifts should be further examined.

2017:

(1) There are only slightly lower occurrence rates during the 26th-40th and 52th-60th days of 2017 in Siberia at E region, Taiwan and East Asia at F region.

(2) The weakening of the S4 index was not as obvious as it in 2016.

SUMMARY

1. During the SSW events in 2016, the stratospheric temperature increase and the zonal mean zonal wind decrease seem to have more effects than F10.7 index.

2. Occurrence rates at high latitudes and low latitudes in 2016 are all weakened in the specific regions examined.

3. During the SSW in 2017, the occurrence rates did not change significantly, and more variables may need to be explored.

4. We should divide more regions to analyze those regions where S4 indices are more affected by SSW events.

5. We should compare more years to analyze whether there are similar phenomena like the changes of S4 indices in 2016.

(a) the growth rate of the instability process due to the evening vertical plasma drifts
(b) the flux tube modified by thermospheric meridional winds
(c) the wave of the F layer caused by atmospheric gravity waves traveling upward
The above conditions will be the items that need to be considered in the future.

ACKNOWLEDGMENTS

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