Intraseasonal and Interannual Variability of the Winter Monsoon Cold Surges over the South China Sea (SCS) and Its Relationship to Convection over Southern SCS

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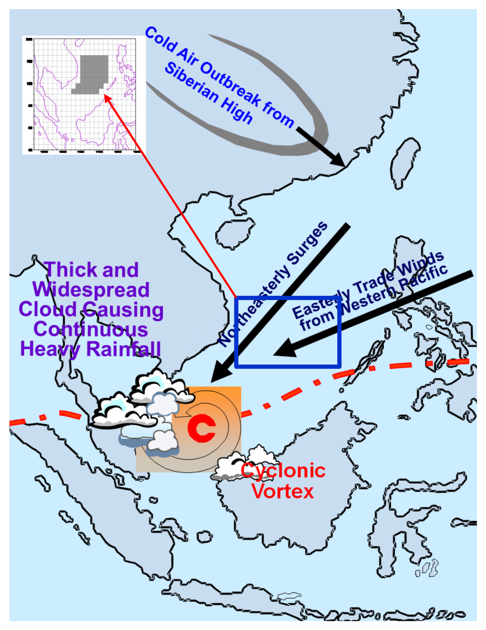
Introduction

The East Asian winter monsoon, which is associated with a strong Siberian High (SH) pressure system and active cold surges is one of the most energetic monsoon circulation systems. During periods of intensification of the SH a strong pressure gradient establishes between the SH and Southern China which causes outbreaks of cold air mass from the East Asiatic landmass that intensifies the northeasterly winds over the South China Sea (SCS). Maximum winds are observed over central SCS and downstream over southern SCS the cyclonic vortices located within the monsoon trough gets intensified due to increases in relative vorticity and mass convergence. This causes widespread rainfall, lasting for a few days that affect the coastal regions of Malaysia facing the SCS during the winter monsoon season. There is however large variability in the intensity and occurrences of cold surges within the season and between different years. This study aims to examine in detail the intraseasonal oscillation of these surges and its relation to large-scale convection over southern SCS. The interannual variability is also being examined together with other atmospheric parameters that may influence the intensity of cold surges on seasonal timescales.



Data and Methodology

The main data used in this study is the six-hourly JRA-25 atmospheric parameters at 1.25-deg resolution and OLR at 2.5-deg resolution. The period of study covers 32 boreal winters (November 1979 – February 2011). The domain of the cold surge index (CSI) is shown in the enclosed blue rectangular box. Average Mean Sea Level Pressure (MSLP) for SH, Hong Kong and Peninsular Malaysia were computed from the region of (40N-50N, 90E-100E), (22.5N-27.5N, 115E-120E) and (EQ-5N, 100E-105E) respectively. Daily rainfall data was obtained from 7 meteorological stations namely Kota Bharu, Kuala Krai, Kuala Terengganu 1, Kuala Terengganu 2, Kuantan, Mersing, and Kuching (Borneo side). In defining a cold surge from the reanalysis, average 1000-hPa resultant wind at central SCS as mentioned above is used. Using information from this region, a cold surge (CS) is defined as follows:

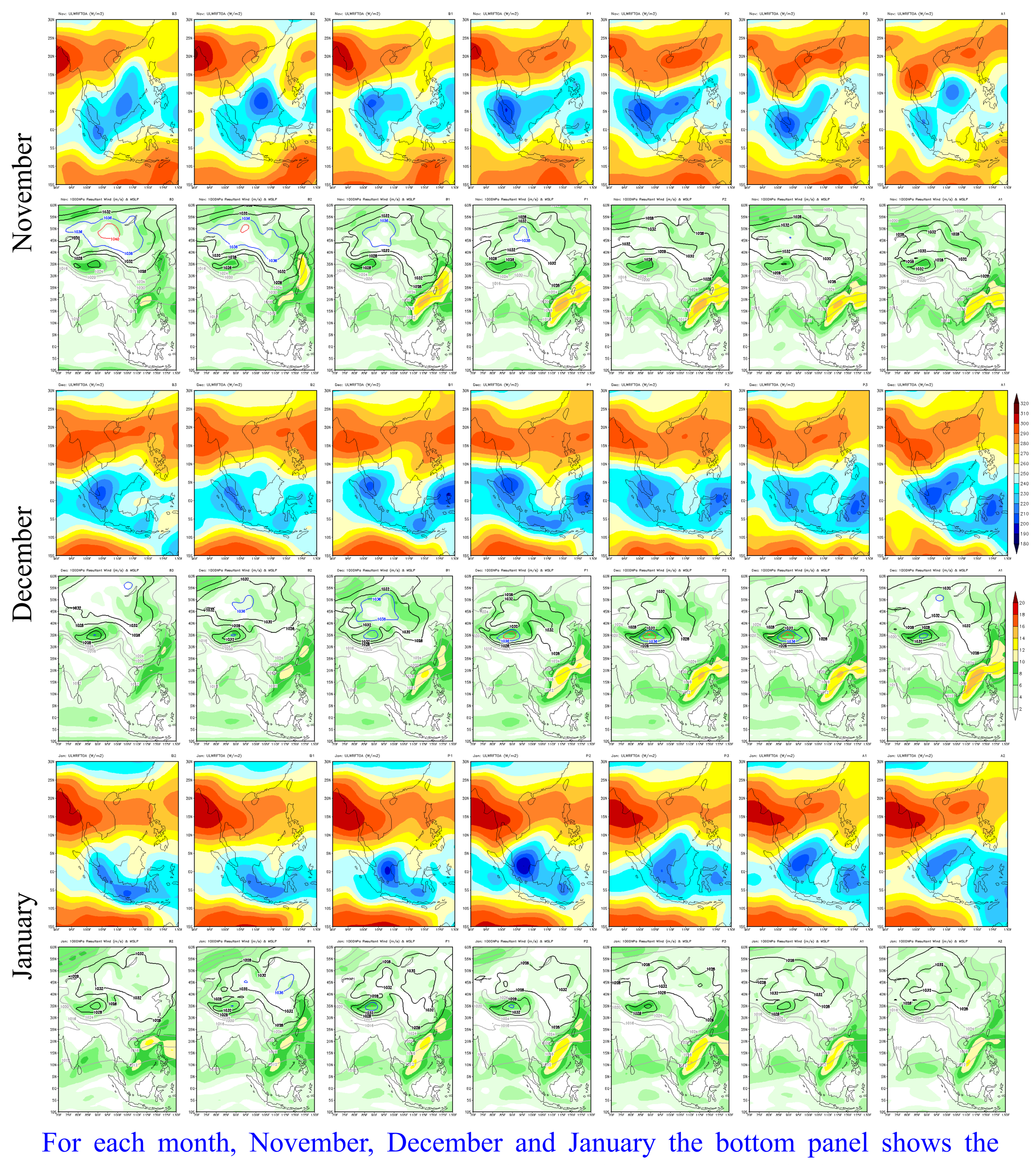
- Onset: Wind speed at 1000-hPa, $W1000 \geq 10.0$ m/s and sustained for at least 3 days. In the case of first surge of the season, the episode is counted as CS, if the difference in wind speed within the last 5 days exceeds 5m/s even though the W1000 is sustained less than 3 days.
- Withdrawal: $W1000 < 10.0$ m/s

Spectral analysis is carried out on the daily data to determine the significant modes of oscillation. The daily time series are then band pass filtered to examine the relationship between the different indices. The spectral density of the seasonally averaged data for 32 seasons is also computed to determine significant oscillations on the interannual time scale.

Results

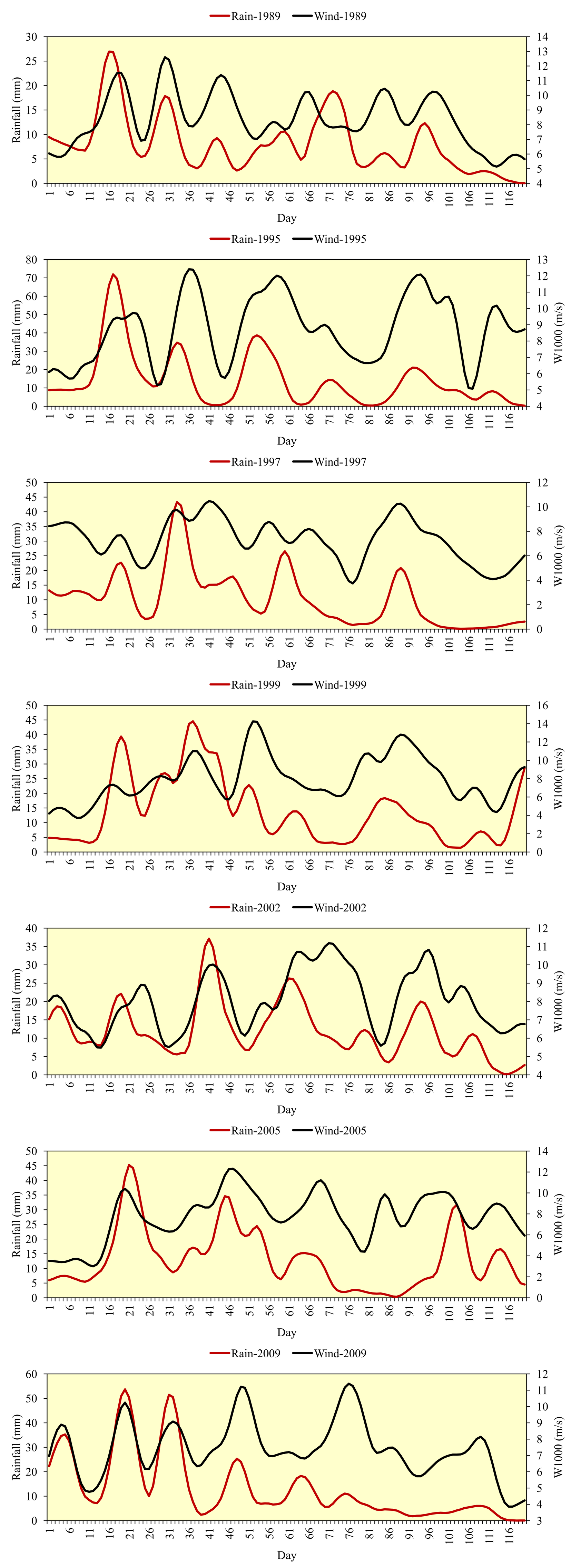
Intraseasonal Variability

During the season it is observed that the surge typically last for about 4 to 5 days and the core of the strong winds is located over northern and central SCS. However, in November the major convective system occurs more towards the northeastern Peninsular Malaysia region, whereas in December it gets shifted towards southern Peninsular Malaysia. In January the whole system is now located over the sea between Peninsular Malaysia and Borneo coast and partly affecting western Sarawak. In February, the trough has moved to the southern hemisphere and strong cross-equatorial flow dominates the Malaysian and southern SCS region resulting in dry weather conditions. The main reason for the southward shift of the convective system is the steady southward movement of the monsoon trough from around 5N in November to south of the equator in February.



For each month, November, December and January the bottom panel shows the isotachs (shaded) for wind at 1000-hPa and isobars (solid line) for seven consecutive days showing one surge cycle. The top panel is the OLR distribution for the corresponding days. The maps are a composite of several surge events falling within each month respectively.

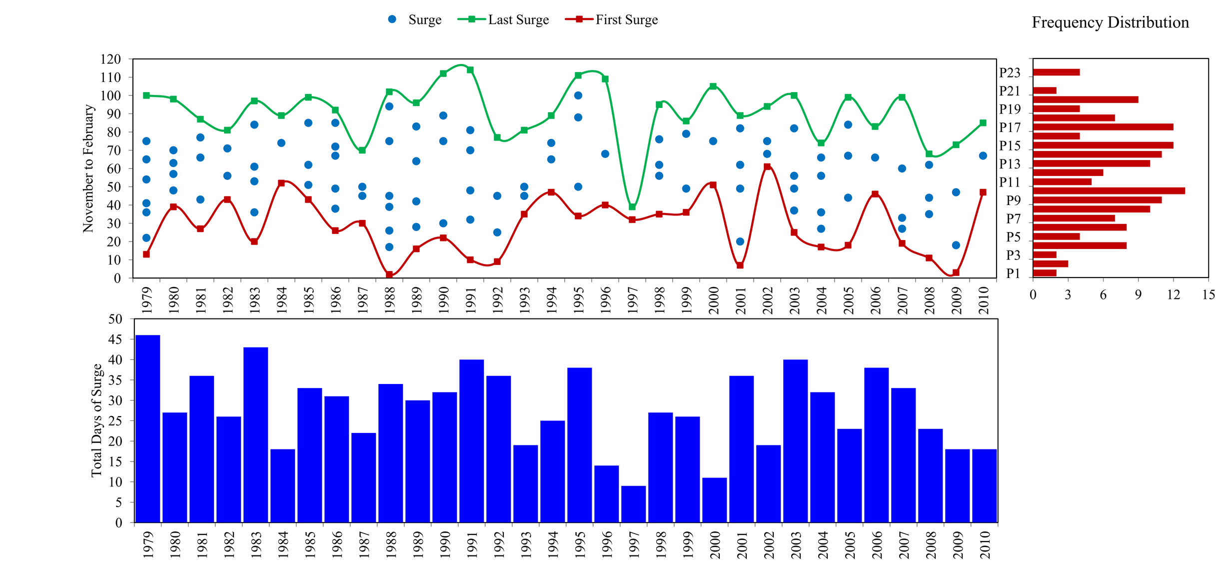
The time series of wind and rainfall for 7 stations along the east coastal regions of Peninsular Malaysia and western Sarawak after filtering using a band pass filter shows strong relationship between the surge and heavy rainfall. Typically the first onset of heavy rain almost always coincides with the onset of the surge. Towards the end of the season, the relationship becomes poorer because the trough has moved further south of Peninsular Malaysia, shifting the convection southwards and eastwards.



Time series of band pass filtered wind and rainfall data for selected years.

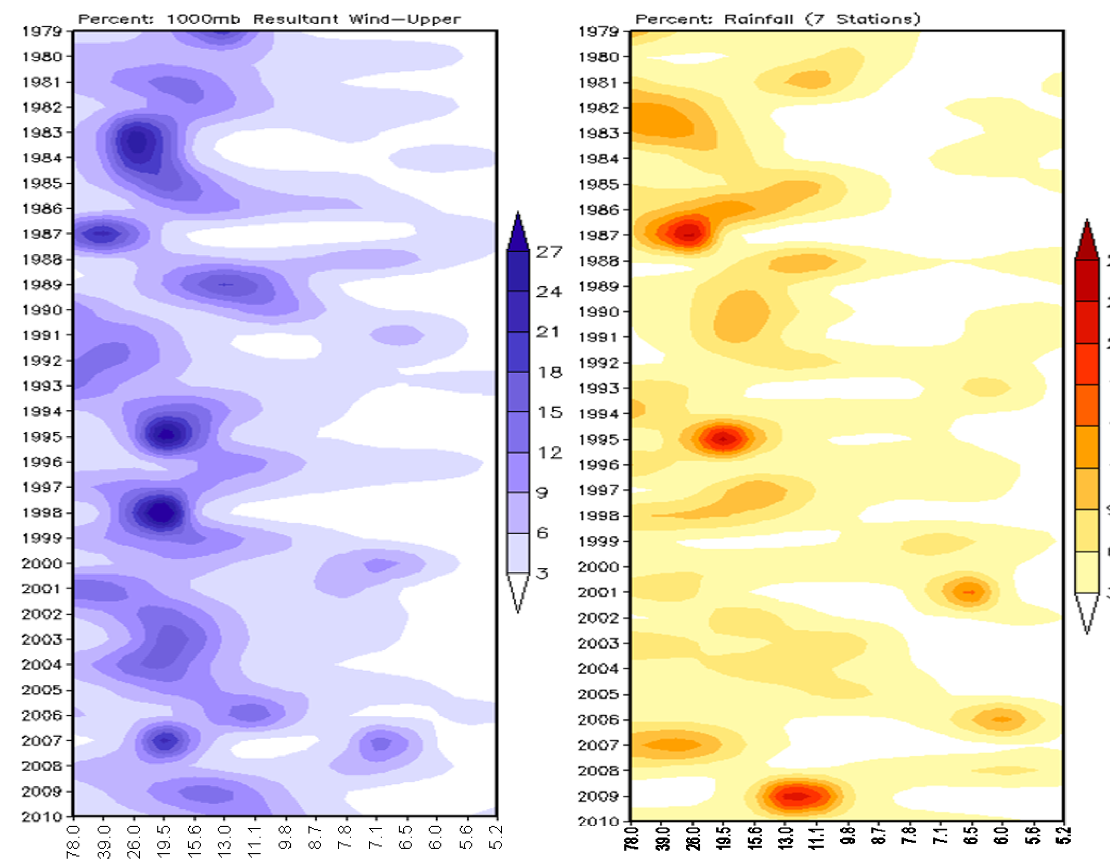
Climatology

The number of surges varies from 2 to 8 per season with an annual average of 6. El Nino years have fewer surges with an average of 4. During 1997, when the most intense El Nino was recorded there was only 2 surges and the total number of surge days was 9, the lowest recorded. The highest number of surge days was in 1979 with 46 days. The average number of surge days per season is 28 days. The onset of the first surge could be as early as 1 November or as late as 30 December. The average onset date is around the last week of November. The last surge can occur till the end of February but on average fewer surges occurs after the first week of February. The frequency of occurrences of surges shows a bimodal peak with first and second peak occurring during the second decade of December and January respectively.



Top left panel: Blue circle indicates the beginning date of occurrence of northeasterly surge over the SCS. The red and green squares are the first and last occurrences of surge respectively for the season.
Top right panel: The frequency of occurrences of northeasterly surges grouped into pentads from 1 Nov – 28 Feb (120 days) for the 32 seasons from 1979 to 2010.
Bottom panel: The total lifespan of surges for each season (1 Nov – 28 Feb) for the period 1979 to 2010.

Results



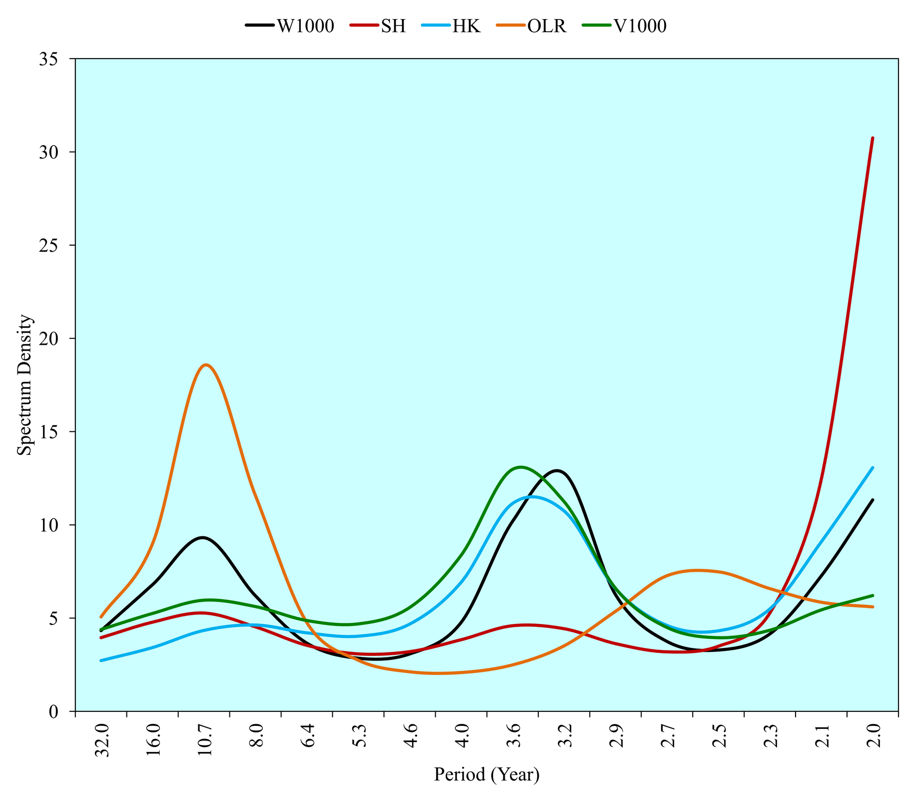
The wind exhibits strong intraseasonal oscillation (ISO) with a majority of seasons showing strong oscillation in the 15 to 25 day time scale. The strongest intraseasonal oscillation in this time scale is mainly observed during the La Nina years. The next most prominent intraseasonal oscillation are in the 10 to 20 day time periods. In 1991, 2001 and 2008, oscillations with period centered around 7 days are also observed. The rainfall too exhibits dominant ISO in the 15 to 25 day time period for most of the monsoon seasons.

The left panel is the contour plot of the spectral density estimates of daily wind speed at 1000-hPa for the 32 seasons from 1979 – 2010.

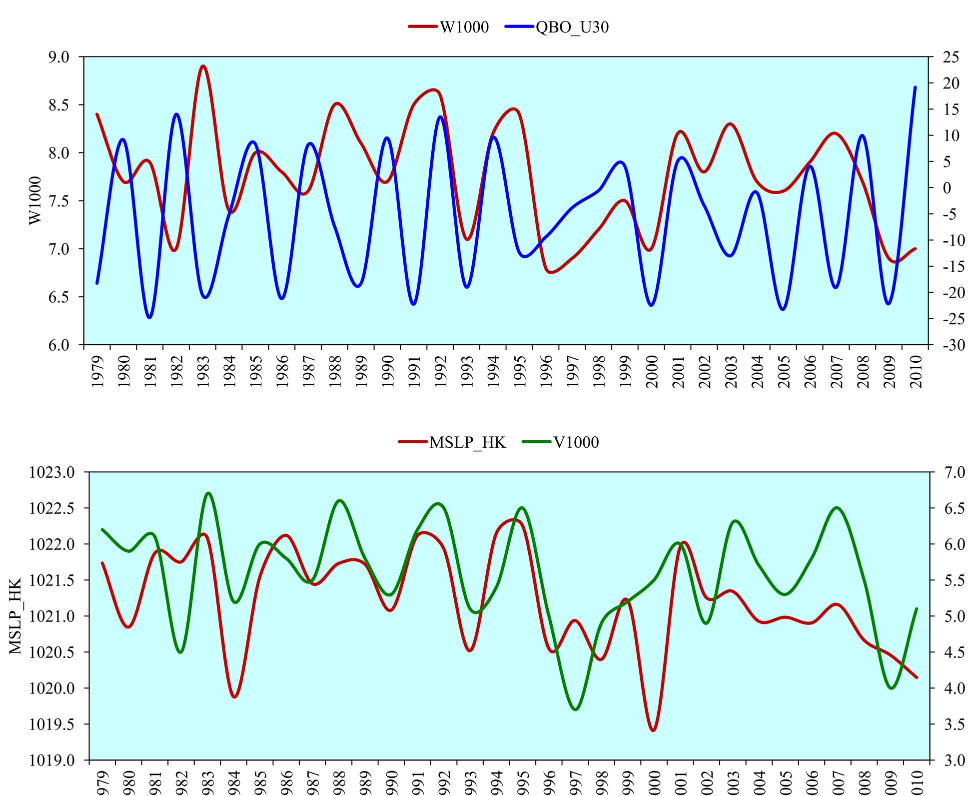
The right panel is the contour plot of the spectral density estimates of daily rainfall averaged over 7 stations for the 32 seasons from 1979 – 2010.

Interannual Variability

The spectrum for the MSLP over Siberia shows a single dominant mode on the biennial time scale whereas the MLSP over Hong Kong has a dominant signal on the biennial time scale and another prominent mode with a 3 to 4 years cycle. The resultant wind at 1000-hPa (W1000) has strong signals with 2 and 3 year cycles, whereas the meridional component (V1000) has a single dominant mode with periods centered at 3.6 years. The OLR however, has a signal with 2.6 years period and another low frequency oscillation with a 10 year period, indicating that on the inter annual time scale the convection over the southern SCS region is not only influenced by the cold surges but also by other planetary scale forcings.



The spectral density function for the seasonal average; MSLP over Siberia and Hong Kong, Resultant and Meridional Wind at 1000-hPa and OLR.



Top Panel: Time series of seasonal averaged wind at 1000-hPa and the zonal wind at 30-hPa.

Bottom Panel: Time series of seasonal averaged meridional component (absolute value) of wind at 1000-hPa and MSLP at Hong Kong.

The seasonal wind during the winter monsoon season near the earth's surface and the zonal wind at 30-hPa in the stratosphere display QBO modes. These two winds are in opposite phase for most of the years. The seasonal pressure at Hong Kong and the meridional component of the wind near the surface of the earth has strong positive relationship.

Conclusions

A detailed analysis on the cold surges over the SCS with respect to its onset, withdrawal, life cycle and distribution has been carried out. The driving mechanism for these surges have also been examined. Through power spectrum analysis the dominant intraseasonal oscillation modes have been identified which is found to be between 15 and 25 days. The heavy rain over east coastal areas of Peninsular Malaysia and western Sarawak is found to be closely related to the surges. On the interannual variability, the intensity of the cold surge has a biennial mode which is in opposite phase with the stratospheric zonal wind QBO at 30-hPa. The meridional component of the surge is more highly correlated to the pressure at Hong Kong in the interannual variability.