

MINISTRY OF NATURAL RESOURCES
AND ENVIRONMENT
**VIET NAM INSTITUTE OF METEOROLOGY,
HYDROLOGY AND CLIMATE CHANGE**

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**INTRASEASONAL VARIABILITY OF
METEOROLOGICAL, OCEANIC ELEMENTS IN
WESTERN EAST SEA (BIỂN ĐÔNG)**

Specialization: Oceanography

Code: 62440227

SUMMARY DOCTORAL THESIS

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The Thesis was completed in:
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Change

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The PhD dissertation can be found at:

- Vietnam National Library;
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Change Library

Abbreviations

| | |
|----------|--|
| BSISO | Boreal Summer Intraseasonal Oscillation |
| ECCO | Estimating the Circulation & Climate of the Ocean |
| EEMD | Ensemble Empirical Mode Decomposition |
| EMD | Empirical Mode Decomposition |
| ENSO | El Niño Southern Oscillation |
| EOF | Empirical Orthogonal Function |
| IMF | Intrinsic Mode Functions |
| ISO | IntraSeasonal Oscillation |
| MEEMD | Multidimension Ensemble Empirical Mode Decomposition |
| MJO | Madden-Julien Oscillation |
| OLR | Outgoing Longwave Radiation |
| ONI | Oceanic Niño Index |
| PC1, PC2 | Principal Component of EOF |
| QBWO | Quasi Biweekly Oscillation |
| SST | Sea Surface Temperature |
| WSTR | Surface wind stress |
| TC | Tropical cyclones |

PREFACE

1. Scientific Background

Intraseasonal oscillation has two dominant scales including the 10-20 days and 30-60 days period. The 30-60 days period oscillation is derived from equatorial Indian Ocean area. In winter, this oscillation tends to propagate eastward towards western Pacific Ocean. It was first discovered in 1971 by Madden-Julian and called the Madden-Julian Oscillation (MJO) (Madden and Julian, 1971, 1994; Wang and Rui, 1990; Salby and Hendon, 1994; Zhang and Dong, 2004). In summer, the 30-60 days period oscillation tend to propagate north and northwest to the northern Indian Ocean and north of western Pacific Ocean. This component is also called the boreal summer intraseasonal oscillation (BSISO (Yasunari, 1979; Krishnamurti and Subramanian, 1982; Lau and Chan, 1986; Kemball-Cook and Wang, 2001; Annamalai and Sperber, 2005). The 10-20 days period oscillation (some refers to as disturbance) appear in the Western Pacific. This oscillation tends to propagate north-west into the East Sea (Biển Đông). This oscillation is recently referred to as the quasi biweekly oscillation (QBWO). Bien Dong is the region on the propagation axis of these intraseasonal oscillations, which is affected evidently by the attached convective and circulation area. These effects are reflected in the meteorological and oceanic elements such as cyclone/anticyclone of the atmosphere, the summer monsoon onset, moisture transport and precipitation, the formation of tropical cyclones and storms, sea surface temperature, ocean circulation and sea surface height. Extreme weather events, such as droughts or heavy rains on the continent have been studied in detailed to identify the related impact. However, the source of the impact associated with intraseasonal oscillation has not been extensively studied (especially in Viet Nam). Therefore, studying the intraseasonal variability of meteorological and oceanic elements in the Western Bien Dong to assess the role of

intraseasonal oscillations in global and regional scales for climate and weather of coastal areas in Viet Nam is extremely necessary.

2. Purpose of the Study

- To further clarify the intraseasonal variability of meteorological and oceanic elements in the western Bien Dong area.
- Clearly determine the relationship between intraseasonal variability of meteorological and oceanic elements in western Bien Dong with ENSO.

3. Object and scope of the study

Object of the study

- To study the intraseasonal variability of sea surface temperature and wind stress in the western Bien Dong
- To study the effect of ENSO on the intraseasonal variability of sea surface temperature and wind stress in western Bien Dong.

Scope of study

- Sea surface temperature and wind stress in western Bien Dong, bounded by 102°E - 116°E and 6°N - 22°N.
- Data of meteorological elements that reflects the mechanism of action and propagation of the large-scale convection and circulation (OLR and 850 mb wind) bounded by 80°E -150°E và 15°N - 45°N.

4. New scientific contributions

- Base on observed data at monitoring stations, the thesis analyzed the presence and effect of intraseasonal oscillation and ENSO on meteorological and oceanic variability in western Bien Dong.
- The thesis applied the EEMD and Fast MEEMD method for the one dimensional and two-dimensional data - this is the adaptive method useful for non-stop and non-linear data.
- The thesis has contributed to confirm correlation between intraseasonal variability in the Bien Dong and ENSO.

5. Theses

Thesis 1: The intraseasonal variability in western Bien Dong is influenced by two intraseasonal oscillation (10-20 days and 30-

60 days period), varying from winter to summer due to the different characteristics of intraseasonal oscillations in different seasons.

Thesis 2: ENSO has a significant impact on intraseasonal variability in the study area.

6. Scientific and practical significance

- The thesis clarifies the impact of large-scale global intraseasonal oscillations on intraseasonal variability in western Bien Dong. The intraseasonal variability in the study area are influenced by two intraseasonal oscillation (10-20 days and 30-60 days period). These oscillations have different shifting characteristics in winter and summer. From there, the extent of their impact on the study area is different.

- Although there are different views on the influence of ENSO on the intraseasonal variability in Bien Dong, the thesis has clarified the influence of ENSO on meteorological conditions in western Bien Dong.

- Thus, it can be seen that changes in weather and climate conditions in western Bien Dong and on mainland in Viet Nam are due to the increase and decrease of activities of intraseasonal variability due to the influence of ENSO.

6. Structure of thesis

The content of the thesis is presented in three chapters:

Chapter 1: Introduction studies on intraseasonal oscillation in Bien Dong and some concepts

Chapter 1 presents some concepts of intraseasonal oscillations, mechanisms of action and structure of global intraseasonal oscillations. Overview of national and international studies related to intraseasonal variability in Bien Dong and its relationship with ENSO.

Chapter 2: Data and methods.

Describe the data sources and methods used in the study.

Chapter 3: Intraseasonal Variability of SST and wind stress on Western Bien Dong and relation with ENSO.

Presentation of study results on the mechanism and time-varying of intraseasonal variability of SST and wind stress in the study area under the effect of intraseasonal oscillations such as MJO, BSISO, QBWO.

Provide some information on relation of intraseasonal variability in the study area with the ENSO

CHAPTER 1

OVERVIEW OF INTRASEASONAL OSCILLATION

STUDIES IN BIEN DONG

1.1. Overview of intraseasonal oscillation Studies

1.1.1. International Studies

1.1.1.1. Studies on QBWO

The northwestward propagation of the 10 – 20 day mode is associated with the weakening of the subtropical high over the western Pacific (Zhou and Chan, 2005). Horizontal structure of the 10 – 20 day mode exhibits a slight southwest-northeast tilt but mainly longitudinal elongation (Guanghua Chen and Chung Hsiung Sui, 2010). Statistical analyses indicated that the QBWO over the Asian monsoon region originated from the equatorial western Pacific and moves northwestward to the Bay of Bengal and northern India, and then northwards to the Tibetan Plateau area (Meirong Wang, Jun Wang and Anmin Duan, 2017).

1.1.1.2. Studies on MJO and BSISO

Oceanic circulation in Bien Dong has an intraseasonal oscillation responding to MJO. During its westerly phase, MJO produces positive (negative) wind stress curl over the northern (southern) SCS and thus induces an enhanced cyclonic (anticyclonic) circulation in northern (southern) Bien Dong (Guihua Wang et al, 2013). ISO process in Bien Dong summer monsoon exhibits as the east-west oscillation of the western Pacific subtropical high, coupled together with the northward-propagating MJO, creating alternating dry and wet phases with a period of 40 days (Chen Guanjun và nnk, 2014).

1.1.2. Studies in Viet Nam

In summer (May-Oct), MJO's major effect is seen in the formation of tropical cyclone in north-western Pacific and has no significant effect on the Pacific center (Nguyen Duc Ngu, 2013). Northward propagation of variation of the zonal wind in the South Asia region leads to the active and break phase of rainfall in North and South Vietnam with the period of 30-40 days (Bui Minh Tuan et al, 2016).

1.2. Studies on the relation between Intraseasonal Oscillation and ENSO

Although some studies have reported an increase in intraseasonal activity during El Nino events, some authors suggested that MJO tends to be less active during the El Nino years and more active during the La Nina years (J. M. Slingo et al, 1996). Interannual variability of MJO is not associated with ENSO (W. S. Kessler et al, 2000; Hendon et al, 1999). MJO were enhanced in boreal summer during the development of El Nino events. Cold tongue of East Pacific not appear in time which to support MJO propagate futher to east and Maintain its intensity longer (Hendon, 2005).

CHAPTER 2: DATA AND METHOD

1.3. Data

1.3.1. Station data

Data were used in study are time series of SST and wind speed in the 1993-2015 period of 4 stations including: Bai Chay, Son Tra, Phu Quy, Phu Quoc. These are daily average data, hence, should be suitable for use in analyzing intraseasonal variability.

1.3.2. Grided reanalysis data

Daily mean grided reanalysis data were used in this study including: SST and wind stress from the ECCO2 project. Data spatial resolution is 0.25 degree; OLR and wind components at 850 mb level are obtained from NCEP with a spatial resolution

of 2.5 degree. Period of wind data is taken for the period of 1993-2015 and OLR for 1993-2013.

1.3.3. Oscillation indices

1.3.3.1. Intraseasonal oscillation indices

Intraseasonal oscillation indices were built by Kikuchi et al (2012). The data could be obtained from the following website: http://iprc.soest.hawaii.edu/users/kazuyosh/Bimodal_ISO

1.3.3.2. Oceanic Niño Index

ONI (Oceanic Niño Index) were obtained from NOAA. <http://ggweather.com/enso/oni.htm>

1.4. Study methods

Methods were applied in this study are as shown in the following diagram:

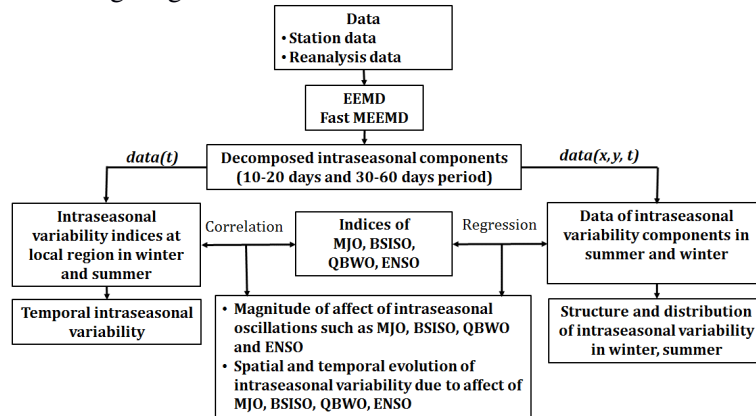


Figure 0.3. Study diagram

1.4.1. EEMD method

EEMD method was improved by Z.H. Wu and N.E. Huang (2009) based on EMD to rectify the mode mixing problem. Accordingly, the original white noise series data with finite amplitude is added (Gaussian noise). Data were then decomposed into IMFs by the EMD method from new time series. The IMFs received from EEMD method is of a significantly reduced mode mixing phenomena. Usually, the amplitude of the white noise is 0.2-0.4 times the standard

deviation of the original data and number of repetitions of the filtering process is several hundred times.

The steps of the EEMD method are as follows:

- i) Add a white noise series to the original data
- ii) Decompose the data with added white noise into IMFs by EMD
- iii) Repeat steps 1 and 2 as many times as is required until the envelopes are symmetric with respect to zero (note that each time a different white noise series is added)
- iv) Obtain the ensemble means of the corresponding IMFs of the decompositions as the final result.

1.4.2. Fast MEEMD methods

Fast MEEMD were proposed by Zhaohua Wu et al (2016) to analyze large data set.

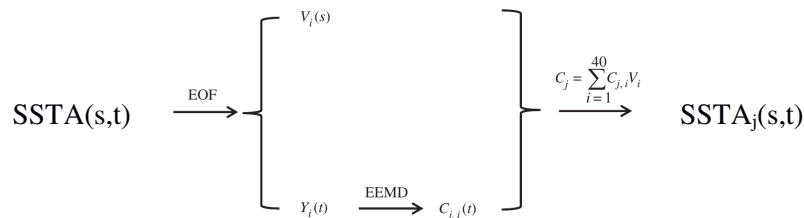


Figure 2.4. MEEMD method diagram

1.4.3. Construct intraseasonal variability of SST and the corresponding wind probability in the Bien Dong

QBWO index were constructed from the 10-20 day period OLR data which is decomposed by the MEEMD method. The similar approach was used in the studies of P.Chatterjee and B.Goswami (2004), Chan et al (2002), J.Mao and J.Chan (2005).

1.4.4. Statistical significance test

Student's t test were applied in this study, according to the study of K. Ye and R. Wu (2015). The degrees of freedom were calculated by:

$$DOF=(TDS/MD)*YS - 2 \quad (6)$$

with, TDS as number of days from May to September (153 days), number of days from December (this year) to March (next year)

is either 151 or 152 days; MD is mean number of days of intraseasonal oscillation (15 days for 10 - 20 day period and 45 days for 30 - 60 day period) and YS is length of data (years), this study used 23 years data (1993 - 2015).

Student's t test formula:

$$t = \frac{r}{\sqrt{(1 - r^2)/DOF}} \quad (7)$$

95% confidence interval for 10 - 20 days and 30 - 60 days variation is 0.13 and 0.22 respectively

CHAPTER 3. INTRASEASONAL VARIABILITY OF SEA SURFACE TEMPERATURE AND SURFACE WIND IN WESTERN BIEN DONG

1.5. Intraseasonal Variability under the influence of MJO

1.5.1. Variability over time of the 30-60 day period in the winter

A MJO' life cycle of activity undergoes 8 spatial-varying phases: Phase 1 is when enhanced convective area exist in the equatorial India Ocean; phase 8 is when this convective area weakens in the Western Pacific (Kikuchi et al., 2012). This study selected 4 cases representing the MJO phase shift: A - phase 1 and 2; B - phase 3 and 4; C - phase 5 and 6; D - phase 7 and 8. Where A has PC1 > 0 and PC2 > 0; Case B has PC1 < 0 and PC2 > 0; Case C has PC1 < 0 and PC2 < 0; Case D has PC1 > 0 and PC2 < 0.

Thus, in order to examine the variation of SST and wind speed at observational stations during the MJO phases, the study selected SST and wind velocities values at times when PC1 and PC2 values of MJO satisfy A, B, C cases above, respectively. The PC1 and PC2 components are MJO's indexes according to the study of Kikuchi (2012) that was introduced in Chapter 2.

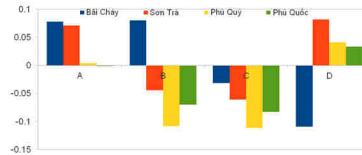


Figure 0.11. Intraseasonal variability of mean SST value in 30 – 60 day period at stations according to spatial phases of MJO in winter

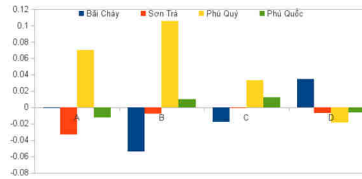


Figure 0.12. Similar figure 3.12 for wind speed.

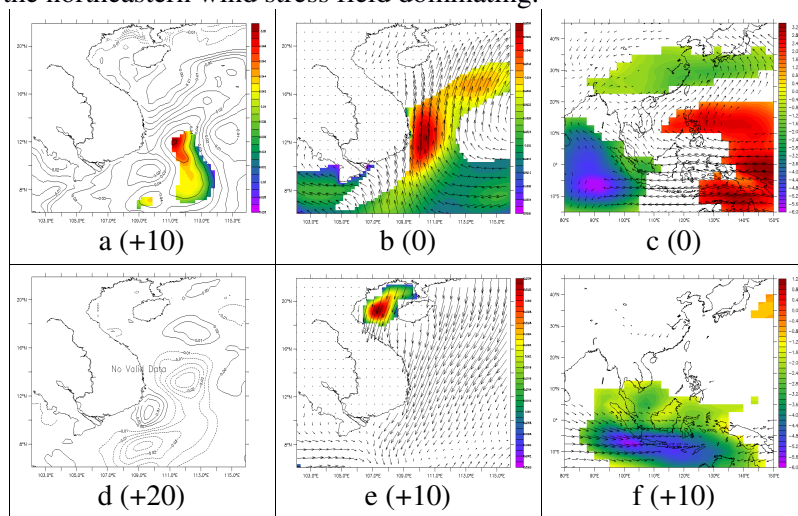
The intraseasonal variability of SST at observational stations are more pronounced than wind speed. In A, D cases, the average intraseasonal value of SST at observational stations was positive. In B, C cases when convections developed in the Indonesian region affecting the West Bien Dong area, the average intraseasonal values of SST at the stations was negative (Figures 3.12 and 3.13).

1.5.2. Spatial structure and evolution over time of 30 - 60 days period in winter

The study used a single variable regression analysis method to estimate or to predict the value of dependent variables (ie, ors of in-season) according to the variation of the independent variable (the intraseasonal oscillation indexes) on all grid points from reanalysis data. The regression equation at each grid point is constructed from two time series: The first is the time series of the intraseasonal variability index of the elements; Second- the time series of the intraseasonal oscillation index. Whereas the time series of intraseasonal oscillation index would be shifted lead or lag in a specific time step compared to the time series of intraseasonal variability index. This time-step shift is used to calculate the cross-correlation between two time series. The minus sign (-) shows the time series of intraseasonal

oscillation index moving lead a time step compared to time series of intraseasonal variability index. Opposite, the plus sign (+) shows the lag of the time series of intraseasonal oscillation index compared to the time series of intraseasonal variability index. The regression coefficients at all grid points would produce a regression map of the elements on the index of intraseasonal oscillation. These regression maps also carry information of cross-correlation coefficients (only cross correlation coefficients at grid points which reaching the 95% significance level was showed).

During the wet phase, enhanced convective area is indicated by negative OLR anomaly (Figure 3.16-f). Characteristics of intraseasonal variability of elements in the West of the Bien Dong are exist of negative SST anomaly and the northeastern wind stress field dominating.



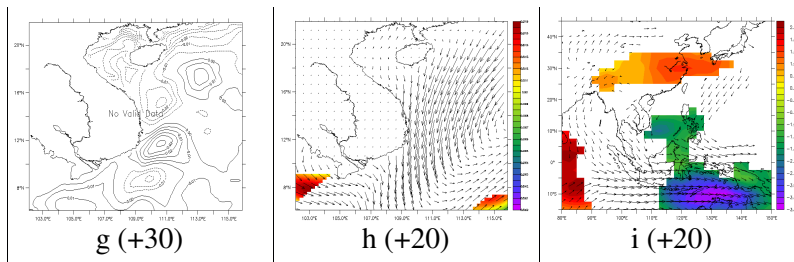
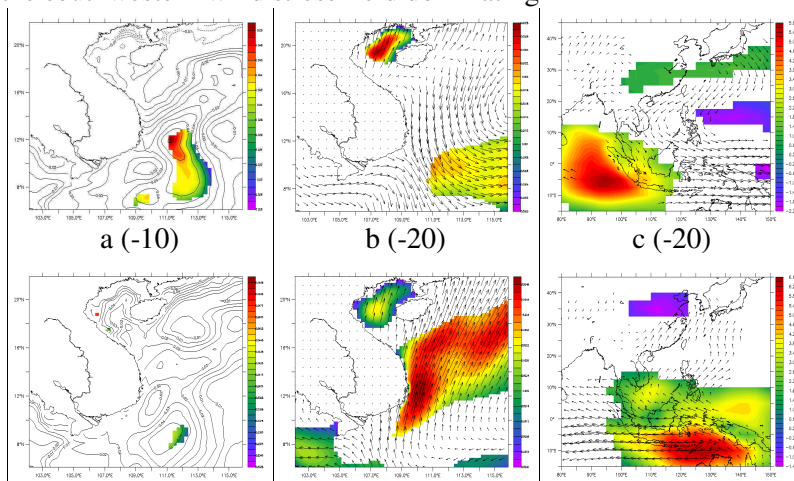


Figure 3.16. Distribution of SST (a, d, g), WSTR (b, e, h), OLR và 850 mb wind speed (c, f, i) in 30-60 day period in wet phase from lead 0 day to lag 30 day when regression to MJO index in winter (1993 – 2015)

Numbers from 0 to +30 correspond to the number of days that MJO lead/lag compared to the intraseasonal variability of the elements (minus sign - is lead, plus sign + is lag). The color background area is the correlation coefficient area which reached 95% significant level.

In the dry phase, the West of Bien Dong is affected by the suppressed convective area represented by the negative OLR anomalies and anticyclone circulation of low-level wind (figure 3.17-i). Characteristics of intraseasonal variability of elements in the West of the Bien Dong are exist of positive SST anomaly and the southwestern wind stress field dominating



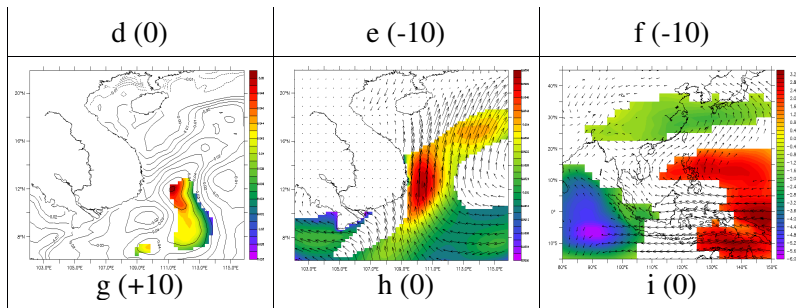


Figure 0.17. Similar figure 3.16 for dry phase

1.6. Intraseasonal Variability under the influence of BSISO

1.6.1. Variability over time of 30-60 day period in the summer

To evaluate intraseasonal variability of 30-60 day period in the summer according to BSISO phases. Case A has PC1 > 0 and PC2 > 0; Case B has PC1 > 0 and PC2 < 0; Case C has PC1 < 0 and PC2 < 0; Case D has PC1 < 0 and PC2 > 0. The mean SST value at stations is positive in cases A, D (phase 1-2, 7-8); Negative in cases B, C (phase 3-4, 5-6). Average values of wind speed are almost opposite to SST (Fig. 3.20, Fig. 3.21).

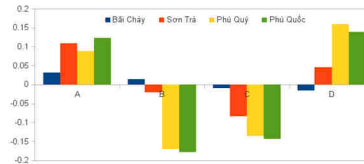


Figure 0.20. Intraseasonal variability of mean SST value in 30 – 60 day period at stations according to spatial phases of BSISO in summer.



Figure 0.21. Similar figure 3.20 for wind speed.

1.6.2. Spatial structure and evolution over time of 30 - 60 days period in summer

In the wet phase, the intraseasonal variability of the elements in the Western Bien Dong are influenced by the enhanced convective area that moves up from the south. Characteristics of intraseasonal variability of elements in the West of the Bien Dong are exist of negative SST anomaly dominating in the South and middle of the study area, along with a cyclone of wind stress (Figure 3.23). Opposite, anticyclone exist in the Bien Dong in dry phase. At the same time, positive SST anomalies appear in the dry phase replacing the negative SST anomalies in the wet phase in the southern part of the study area (Figure 3.24). Intraseasonal variability of SST and wind stress are strongly active in the south and then tend to move north in the study area.

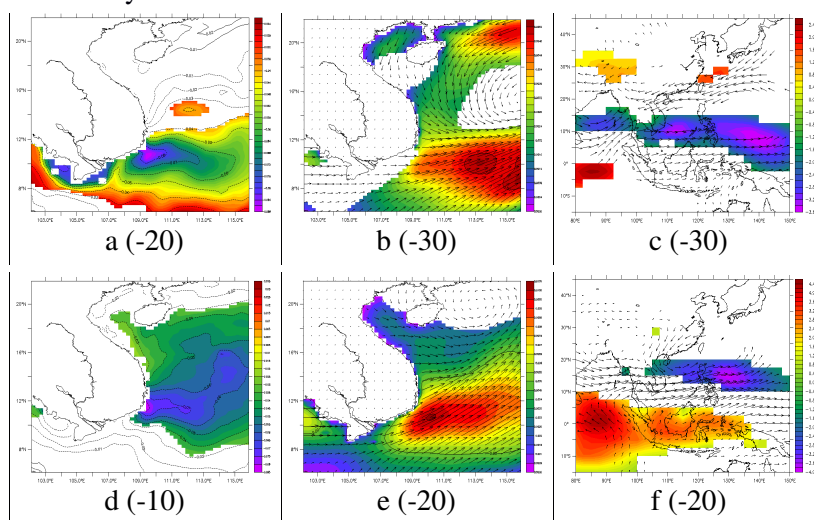


Figure 0.23. Distribution of SST (a, d, g), WSTR (b, e, h), OLR và 850 mb wind speed (c, f, i) in 30-60 day period in wet phase from lead 0 day to lag 30 day when regression to MJO index in summer (1993 – 2015).

Numbers from -30 to -10 correspond to the number of days that BSISO lead compared to the intraseasonal variability of the

elements. The color background area is the correlation coefficient area which reached 95% significant level

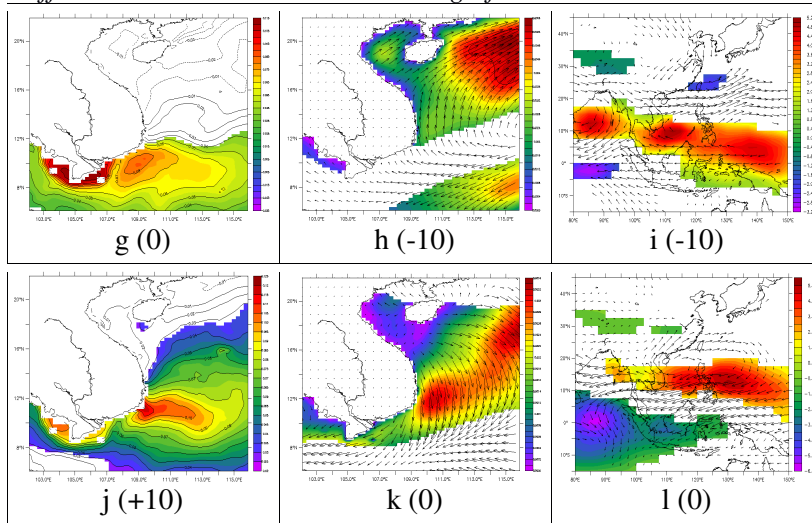


Figure 0.24. Similar figure 3.23 for dry phase

1.7. Intraseasonal Variability under the influence of QBWO in winter

1.7.1. Variability over time of 10 - 20 day period in the winter

In winter, during the wet phases (cases A and D), the mean values of the SST in 10-20 day period at the stations tend to decrease, whereas the values of wind velocity tend to increase

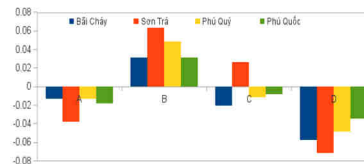


Figure 0.27. Intraseasonal variability of mean SST value in 10 – 20 day period at stations according to spatial phases of QBWO in winter.

During the dry phases (cases B and C), the mean values of the elements are almost reversed in comparison to the wet phases. This means that the SST value increases while the wind speed decreases. Except for Case C, the remaining cases show a

phase inverse relationship between the SST and the wind speed at the stations under the influence of QBWO

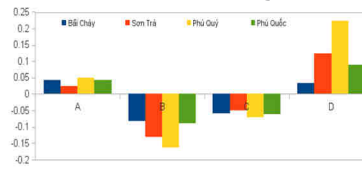
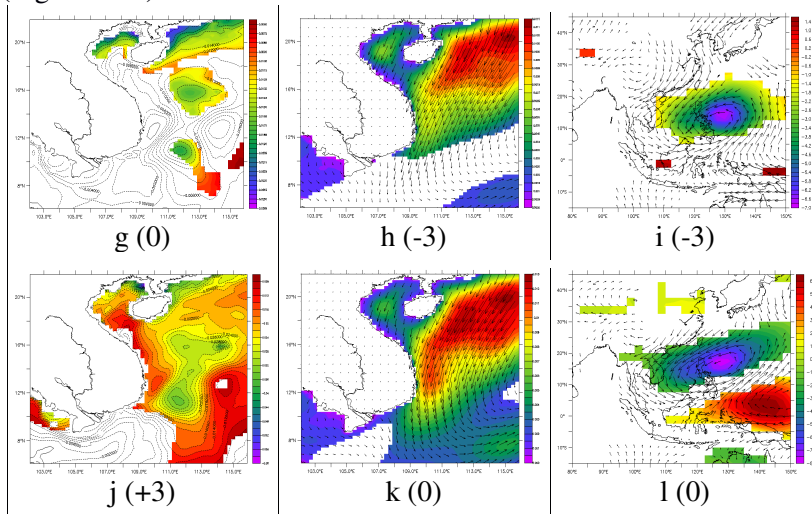
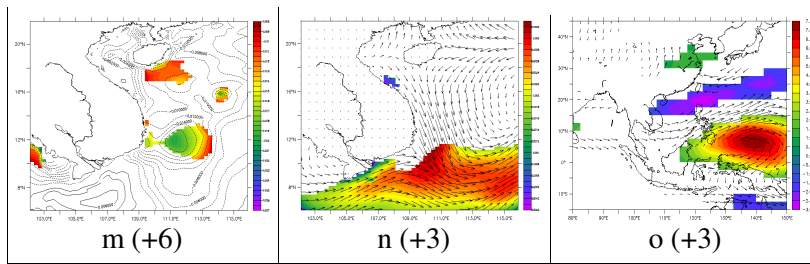


Figure 0.28. Similar figure 3.27 for wind speed

1.7.2. Spatial structure and evolution over time of 10 - 20 days period in winter

In the wet phase, when the enhanced convection area from the western Pacific equator then it moves the North and begins to affect the Bien Dong. Characteristics of intraseasonal variability of elements in the West of the Bien Dong are exist of negative SST anomaly and northeastern wind stress dominates (Figure 3.30)

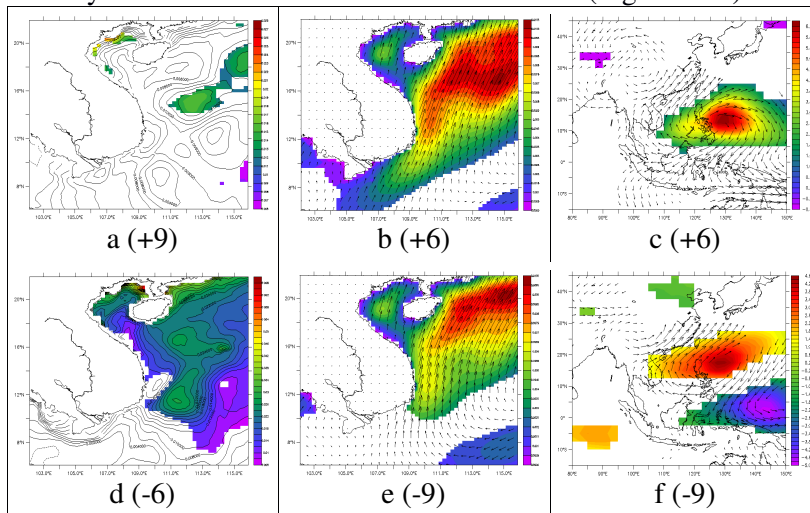




Hình 0.30. Distribution of SST (a, d, g), WSTR (b, e, h), OLR và 850 mb wind speed (c, f, i) in 10 - 20 day period in wet phase from lead 3 day to lag 6 day when regression to QBWO index in winter (1993 – 2015).

Numbers from -3 to +6 correspond to the number of days that QBWO lead/lag compared to the intraseasonal variability of the elements (minus sign - is lead, plus sign + is lag). The color background area is the correlation coefficient area which reached 95% significant level

During the dry phase, suppressed convective area from the western Pacific equator moves the Northwest and begins to affect the Bien Dong. Characteristics of intraseasonal variability of elements in the West of Bien Dong are exist of positive SST anomaly and southwestern wind stress dominantes (Figure 3.31)

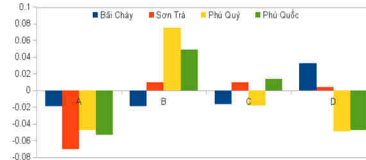


Hình 0.31. Similar figure 3.30 for dry phase.

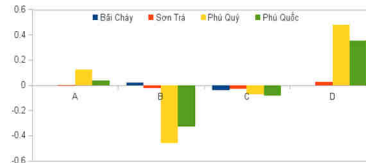
1.8. Intraseasonal Variability under the influence of QBWO in summer

1.8.1. Variability over time of 10 - 20 day period in summer

The average values of SST at south stations are increase/decrease reverse phase with the wind speed. In most phases of QBWO, the SST value and the wind speed of intraseasonal variability at Phu Quy station is more fluctuate than other stations.

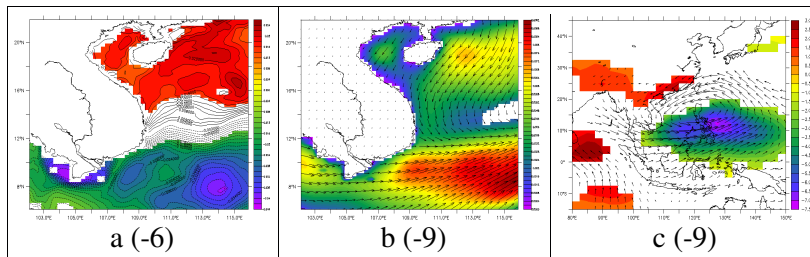


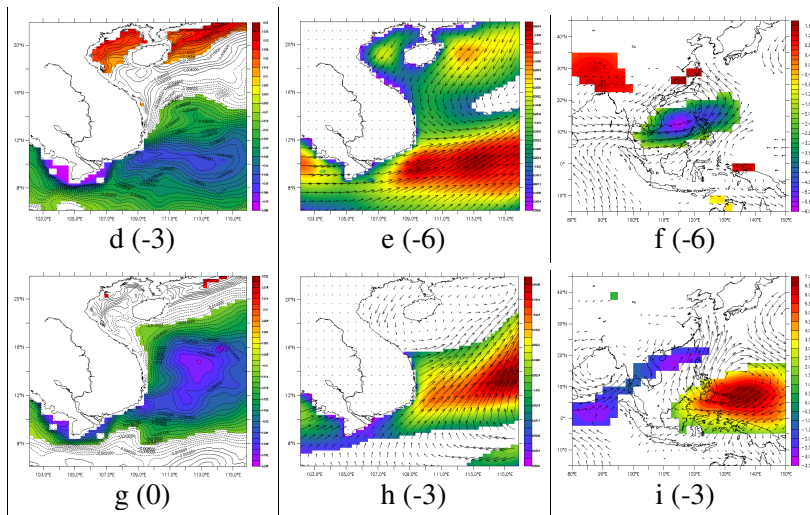
Hình 0.34. Intraseasonal variability of mean SST value in 10 – 20 day period at stations according to spatial phases of QBWO in summer.



Hình 0.35. Similar figure 3.34 for wind speed.

1.8.2. Spatial structure and evolution over time of 10 - 20 days period in summer

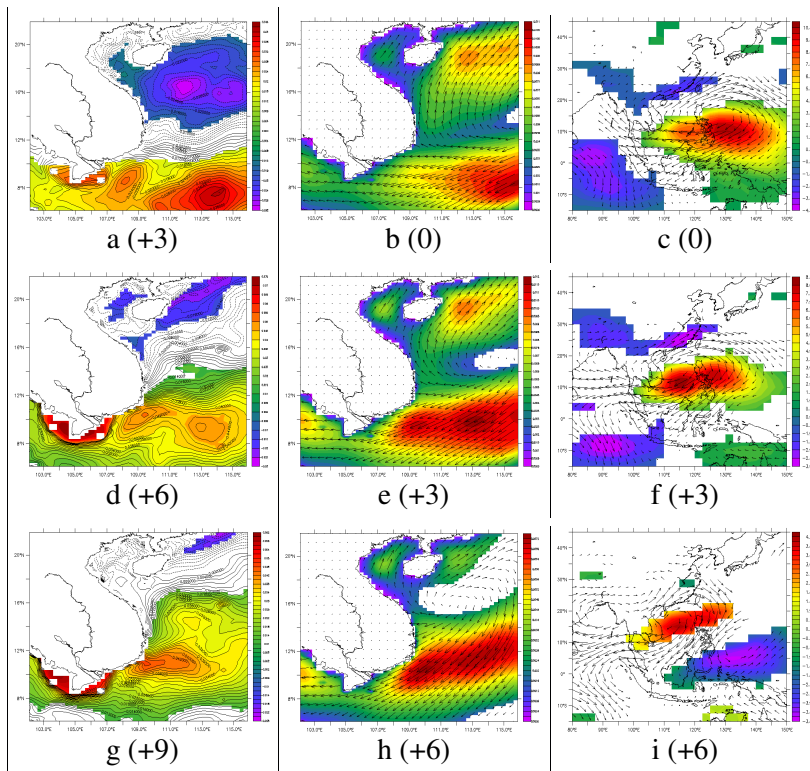




Hình 0.37. Distribution of SST (a, d, g), WSTR (b, e, h), OLR và 850 mb wind speed (c, f, i) in 10 - 20 day period in wet phase from lead 9 day to lead 3 day when regression to QBWO index in summer (1993 – 2015).

Numbers from -9 to -36 correspond to the number of days that QBWO lead compared to the intraseasonal variability of the elements. The color background area is the correlation coefficient area which reached 95% significant level

In the wet phase, enhanced convective area is indicated by negative OLR anomalies exist in the Bien Dong (TGT = -9, -6, -3) (Figure 3.37). The prominent characteristic of intraseasonal variability in wet phases is the distinct distribution between the northern and southern of the study area. Specifically, in the North there are positive SST anomaly and northeastern wind stress, in the South, there are positive SST anomaly and western wind stress.



Hình 0.38. Similar figure 3.37 for dry phase

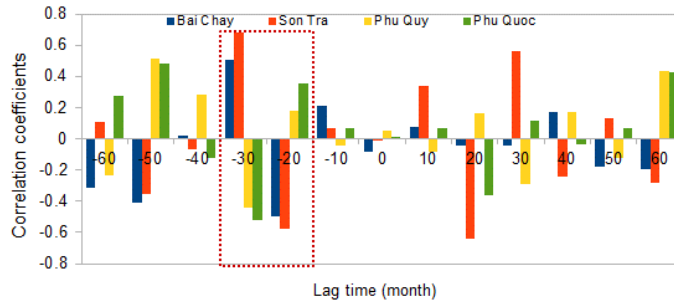
In the dry phase, Bien Dong is affected by suppressed convection, which are indicated by positive OLR anomaly area (TGT = 0, +3, +6 days) (Figure 3.38). Characteristics of the intraseasonal variability in the dry phase are in contrast to those in the wet phase. In the North, there is negative SST anomaly and southwest wind stress. In the South, there is positive SST anomaly and north and northeast wind stress.

1.9. The impact of ENSO on intraseasonal variability of the Bien Dong

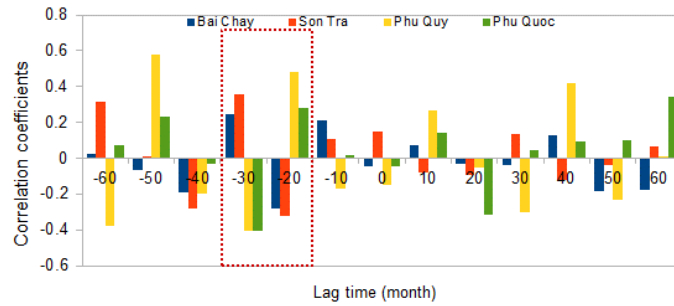
ENSO has a significant relationship with the intraseasonal variability of the SST in western Bien Dong after the occurring of ENSO approximately 20-30 months. There is a

reverse phase between the north and south stations in the 10-20 day period. Northern stations also exhibit a reverse phase between 10-20 days and 30-60 days period. Moreover, in the 10-20 days period, the correlation coefficients of the northern stations are larger than in the south, the opposite is true for the 30-60 days period.

At the time of TGT = 0 days, ENSO has an effect on the intraseasonal variability of wind speed in western Bien Dong with a positive correlation coefficients at all stations. The correlation coefficients at the stations show that the affect of ENSO decreases from north to south for 10-20 days period and increases from north to south for 30-60 days period.

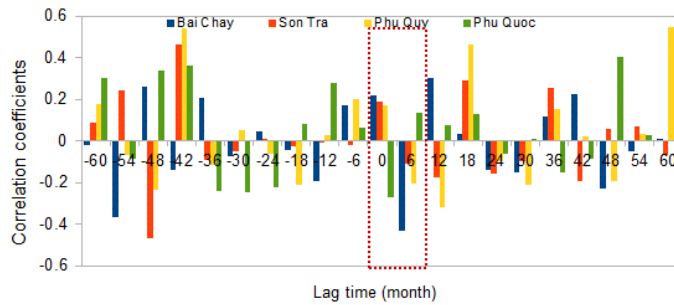


a) Summer

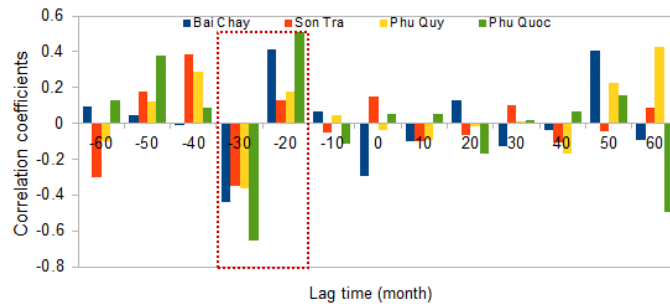


b) Winter

Figure 0.40. Correlation coefficient between SST10 and SST Nino3.4



a) Summer



b) Winter

Figure 0.41. Correlation coefficient between SST30 and SST Nino3.4

CONCLUSION AND RECOMMENDATION

Conclusion

1) 10-20 days intraseasonal variability

- In winter, during the wet phase, cyclonic circulation prevails, causing the northeast wind stress and the negative anomalies of SST to exist across the entire study area. In contrast, in the dry phase, the anticyclonic circulation prevails, causing the southwest wind stress field and the positive SST anomaly field to exist in the study area.
- In summer, during the dry phase, in the north western Bien Dong area, there is negative SST anomaly under forcing of the southwestern wind stress field. Meanwhile, in the south west of

Bien Dong, the positive SST anomaly exist under the development of the eastward wind. In the wet phase of QBWO, in the north west of the Bien Dong, there are positive SST anomaly under forcing of the northeast wind stress field. Meanwhile, in the south west of Bien Dong, the negative SST anomaly exists under the development of the westward wind.

2) 30-60 days intraseasonal variability

- In winter, intraseasonal variability of sea surface temperatures and winds in the 30-60 days period in Western Bien Dong are influenced by MJO. Due to the influence of the East Asian monsoon, the distribution of intraseasonal variability in winter has the northeast-southwest axis in the study area. The area most affected is located offshore of the South Central Coast. In the dry phase, the positive SST anomaly appears along with the southwestern wind stress anomalies. Conversely, in wet phase, the negative SST anomaly and the northeast wind stress exists in the study area.

- In summer, the intraseasonal variability of SST and wind stress tend to be contradictory in each phase caused by the northward propagation of wet and dry phases of QBWO. Cyclonic anomaly of wind stress often occurs in wet phase. This cyclone enhances the west and southwest winds in the south of the study area. Intensification of southwest wind increased the activity of upwelling South Central region, forming a cold tongue from coastal moving to the northeast. Conversely, anticyclonic anomaly exist in the Bien Dong in the dry phase. At the same time, positive SST anomaly appear to replace the negative SST anomaly in the wet phase in the southern part of the study area. The correlation coefficient between SST and wind speed at observing stations also shows that the impact of BSISO to the southern half is higher for the northern half of the study area.

3) The impact of ENSO on intraseasonal variability on the study area

- ENSO affects the intraseasonal variability of the SST in western Bien Dong after the occurring of ENSO approximately 20-30 months. There is a reverse phase between the north and south stations in the 10-20 days period. In Northern stations, there is a reverse phase between 10-20 days and 30-60 days period. Moreover, in the 10-20 days period, the correlation coefficients for the northern stations are larger than those in the south and opposite in the 30-60 days period.

- ENSO affects the intraseasonal variability of the wind speed in the western Bien Dong at the time of operation. The impact of ENSO decreases from north to south for intraseasonal variability of wind speed in 10-20 days period and increases from north to south in 30-60 days period.

Recommendations

1) Large scale intraseasonal oscillations has a significant effect on the entire meteorology system of the western Bien Dong area and on the mainland of Viet Nam. However, this study only looked at two specific elements of SST and wind. Therefore, it is necessary to continue studying the intraseasonal variability of other elements such as humidity and rainfall; intensity, number of tropical depressions, storms; currence; sea surface height and sea surface heat and moisture flux.

2) The issue of the relationship between ENSO and intraseasonal variability in Bien Dong should be further studied. In particular, there should be a clear distinction in the different effects of the regular El Nino and El Niño Modoki.

3) From the information of the evolution, the rule of intraseasonal variability of the meteorological elements, medium-scale forecasts for these elements is necessary. Medium-scale forecasting will contribute to improving capacity of weather forecasts for meteorological and marine areas in Vietnam. Therefore, it is necessary to continue studying in the modeling of intraseasonal variability of meteorological and oceanic fields by ocean-atmosphere coupled models.

LIST OF PUBLICATIONS

1. **Le Quoc Huy**, Tran Thuc, Dinh Van Uu (2013), *Application of coupled model for studying the variation of sea surface temperature (SST) in the Western Bien Dong*. Conference Report of the 16th, Scientific and Technical Publisher vol.II, pp. 250-256.
2. **Le Quoc Huy**, Tran Thuc, Dinh Van Uu, Nguyen Xuan Hien (2014), *Specify the intraseasonal variability of sea surface temperature over upwelling area in South Central of Viet Nam*. Conference Report of the 17th, Scientific and Technical Publisher, pp. 319-324.
3. Tran Thuc, Nguyen Xuan Hien, **Le Quoc Huy**, Doan Thi Thu Ha (2015), *Updating trend of sea level change in Viet Nam sea area*. Conference Report of the 18th, Scientific and Technical Publisher, pp. 365-371.
4. **Le Quoc Huy**, Nguyen Xuan Hien, Tran Thuc, Pham Tien Dat (2017), *Analysis of the variation in sea surface temperatures and the influence of enso in the coastal region of the South Central of Viet Nam*. Journal of Climate change science, No 1, 3/2017, pp 68-76.
5. **Le Quoc Huy**, Tran Thuc, Dinh Van Uu, Nguyen Xuan Hien (2017), *Effects of quasi biweekly oscillation on the sea surface temperature and wind field in Viet Nam' coastal areas in summer*. Scientific and Technical Hydro - Meteorological Journal, No 679, 07/20017, pp 19-26.
6. **Quoc Huy Le**, Thuc Tran, Xuan Hien Nguyen, Van Uu Dinh (2017), *Effects of ENSO on the intraseasonal oscillations of sea surface temperature and wind speed along Vietnam's coastal areas*. Vietnam Journal of Science, Technology and Engineering, Vol 59, number 3, 9/2017, 85-90.