Spectral analysis of circulation derived from HF Radar data installed in the upper Gulf of Thailand

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Introduction

The results from numerical experiments in our previous studies reveal that circulation in the upper Gulf of Thailand changes seasonally due to monsoonal winds. The circulations turn clockwise and counter-clockwise during the southwest and the northeast monsoon, respectively. The seasonal variations of wind and current affect eutrophication to be severe in different area in the gulf throughout the year. Red tide is usually intense during the southwest monsoon when river discharge is very large, and wind directs landward. Strong sub-surface hypoxic water mass was developed from late southwest monsoon to the onset of the northeast monsoon season. These facts address the importance of seasonal circulation.

The simulated circulation results agree well with the data derived from High Frequency (HF) Radar system installed along the coastline around the upper Gulf of Thailand. Although the role of monsoonal wind on seasonal circulation is well clarified, other factors and mechanisms probably related to temporal and spatial variations are still unknown. Such information can be achieved from the application of spectral analysis on time series data extracted from HF Radar measurement. With the use of Wavelet Analysis, the frequency of hidden phenomena embedded in the time series data can be revealed. More understanding in circulation patterns and related phenomena are expected to be the outcomes of this study.

Procedure

Time series HF Radar data in the upper Gulf of Thailand at 2 points as shown in Figure 1 are extracted and analyzed for Wavelet power spectrum. The data in year 2014, provided by GISTDA, Thailand, are used. FORTRAN source codes are used for data extraction and the application of bandpass filter on the circulation data. R programming is applied for Wavelet analysis based on Package 'WaveletComp' (https://cran.r-project.org/web/packages/WaveletComp/WaveletComp.pdf).

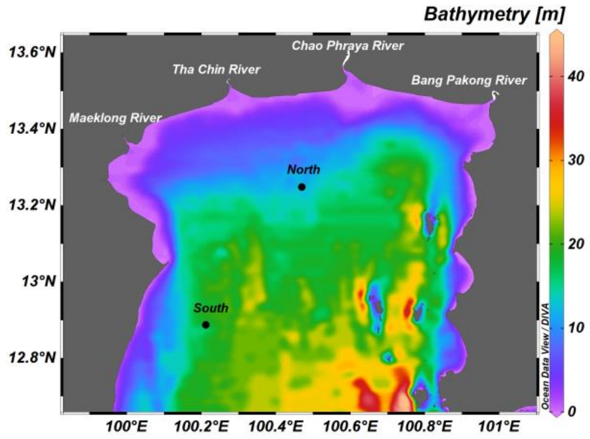

Figure 1 The upper Gulf of Thailand showing water depth in meter and dots present the points to extract time series data for spectral analysis.

Results and discussion

The wavelet power spectrum of current velocities in u and v components at the points in the north and the south of the upper Gulf of Thailand is shown in Figure 2 and Figure 3, respectively. The distribution patterns of the spectrum in u and v components are different but in almost the same way in both locations. High spectrum of about 10 – 14 Hrs. and 28 – 32 Hrs. occurs twice a month, but mostly in different phases, throughout the year. This signal addresses diurnal and semi-diurnal tidal dominance during half lunar cycle or half monthly period. The spectrum in v component seems to be larger and more continuous than that in u component because tidal current in north-south direction is stronger than that in east-west direction. The responses of current in north-south direction to tidal phases are then more dominant than the other one.

High spectral energy for the period of 5-10 days during days 250-350 (August – November) is also observed. The spectrum in u component is stronger than that in v component at both points in this case. This suggests that the variations in u during the changing season be larger than those in v. Bandpass filter for current variation between 5 and 10 days is therefore applied to investigate the current pattern in that period, which covers from the late southwest to the early northeast monsoon season. It is calculated from the difference of velocity running means between 5 and 10 days from August to November. The results of bandpass calculation are shown as horizontal distribution of surface current vectors in some selected times shown in Figure 4.

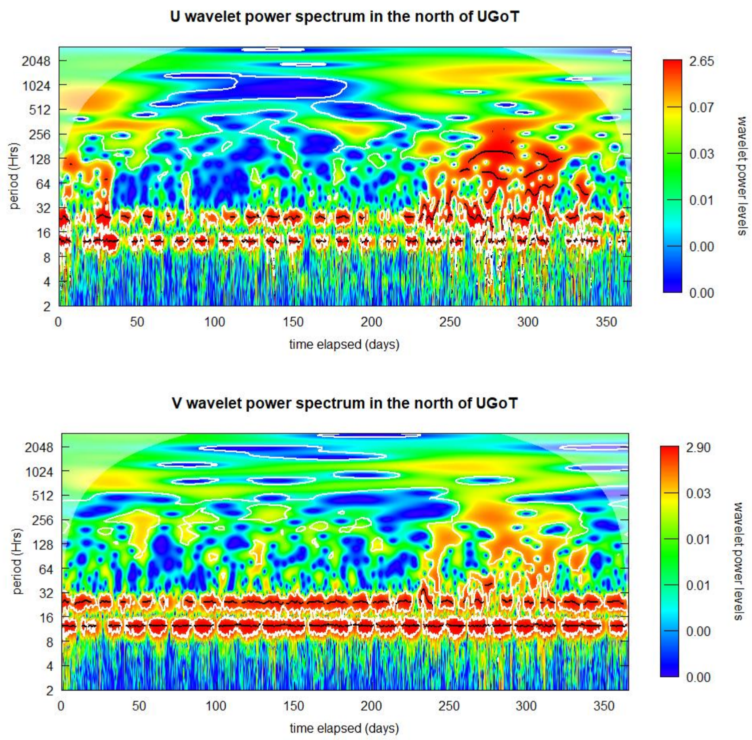

Figure 2 Wavelet power spectrum of HF current velocities in u (upper) and v (lower) components at the point in the north of the Gulf of Thailand.

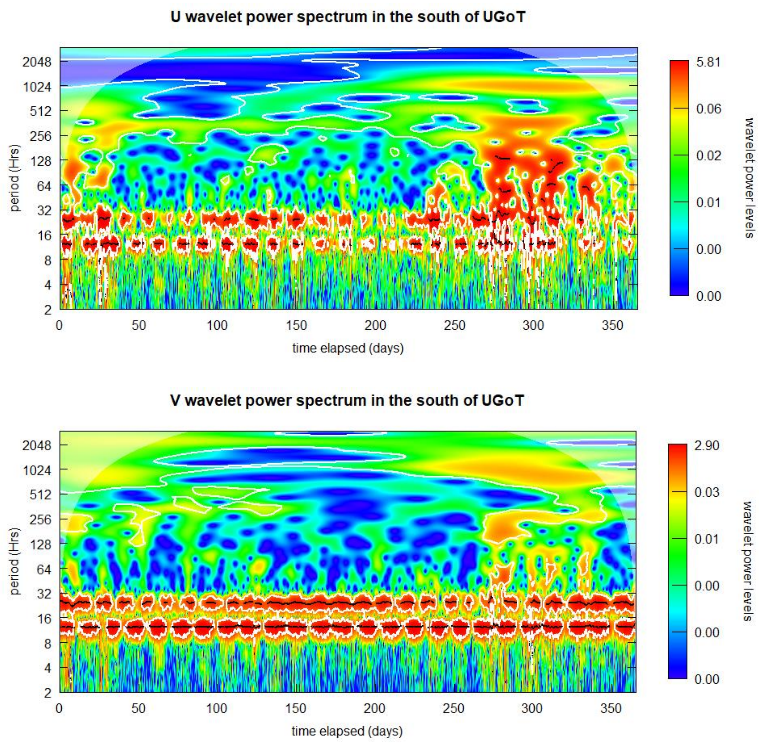

Figure 3 Wavelet power spectrum of HF current velocities in u (upper) and v (lower) components at the point in the south of the Gulf of Thailand.

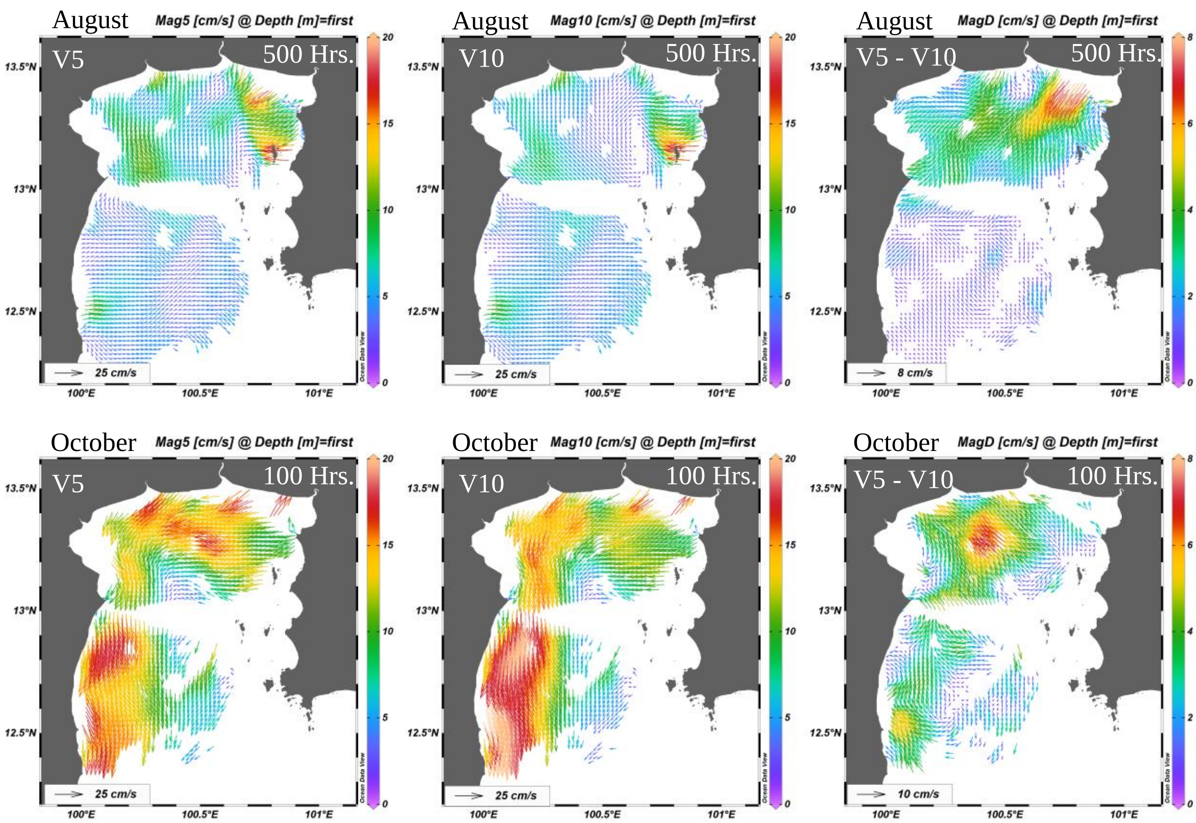

Figure 4 Mean surface current for 5 day (V5) and 10 day (V10), and the bandpass filter of current data between 5 and 10 days (V5-V10) in August 2014 at 500 Hrs. (upper) and in October 2014 at 100 Hrs. (lower) from start.

Horizontal distributions of mean surface current for 5 and 10 days, and the bandpass filter of the current data between 5 and 10 days in August 2014 at 500 Hrs. (late August) and in October 2014 at 100 Hrs. (early October) from start are shown in Figure 4. Those times are selected to present here because the current patterns are quite complete and the spatial variation in current fields is clearly observed. They are also used to show as examples of high spatial variation in current fields during the periods of 5 – 10 days. Mean currents in both times mostly direct from the northwest to the northeast direction in late August. Current variations are low in the southern part and high in the northern part of the gulf. High variation in current patterns in the northern part may come from wind or discharge variations, or both.

Mean currents are strong especially in the west of the gulf during late October showing the influence of the northeast monsoon (lower panel of Figure 4). Counter clockwise circulation is developed with strong southward flow along the west coast. Current variations between 5 and 10 days are also low in the southern part and high in the northern part in the same way as those in early August. High temporal and spatial variations in current patterns are expected to occur because this is the critical period for continually changes in wind direction from the southwest to the northeast. The variation in current patterns seem to occur greater in east-west direction than in north-south direction when the circulation starts to reverse form clockwise to counter-clockwise direction.

This analysis reveals that the frequency of current variation takes between 5 and 10 days, and the variation is large in the north of the upper gulf of Thailand. We still do not exactly know how this phenomenon relates to other coastal environments. However, this is the same period when sub-surface hypoxia is developed, observed from our previous studies, in the area of high current variation. Their relationship will be continually investigated for more understanding in the mechanism of eutrophication in this coastal sea.

Conclusion

Surface current data measured by HF Radar in the upper Gulf of Thailand were spectrally analyzed using Wavelet analysis. The power spectrum was found to be high in half-lunar cycle throughout the year addressing the importance of tidal current phases. High spectral energy for the period of 5-10 days during days 250-350 is also observed. This variation is related to the transition period from the southwest to the northeast monsoon when circulation stars to change from clockwise to counter-clockwise direction. The phenomenon may be related to sub-surface hypoxia developed in the same time.

Publication/conference presentation

It was planned to publish the complete results in a scientific journal in the near future on the title of "Seasonal circulation and spectral analysis of circulation derived from HF Radar data installed in the upper Gulf of Thailand"

Perspectives in the future

We will continue investigate the relationship between variation in surface current power spectrum and sub-surface hypoxic water development together with their interannual variations.