#### ACTA OCEANOGRAPHICA TAIWANICA SCIENCE REPORTS OF THE NATIONAL TAIWAN UNIVERSITY No. 14, PP. 75-87, 11 FIGS., DEBEMBER, 1983

# ON THE CHARACTERISTICS OF CURRENT AT THE OFFSHORE REGION OF SUAO

### CHING-SHENG CHERN<sup>1</sup>

(Received September 9, 1983; accepted in revised form December 20, 1983)

#### ABSTRACT

Under the influences of coastline and offshore ridge at SuAo, the longshore wind is the main driving force for the sub-tidal frequency current fluctuation. The dominant period of the current fluctuation is about 3-4 day. The wind-driven current has rotary behavior, its major axis is toward north and very stable. The mean current field is determined by the incoming Kuroshio from the south and the local topography. The isothermal lines are roughly following the depth countour in this region.

# INTRODUCTION

Taiwan stands on the edge of the East China continental shelf. To its right is the deep Pacific basin The 2000 meter depth contour comes very near shore along most portion of the east coast of the island. At SuAo coastal area, there exists a shallow water ridge. The bathymetry of this region is shown in Fig. 1.

Kuroshio is the western intensified current flows northward along the east coast of Taiwan. There exists quite extensive literature on its structure, e.g. Stommel and Yashida (1972). But most of them are concerns to the flow at region south of Japan. Chu (1976) studied the transport of Kuroshio from Hualien to Ishigakijima. He found the main axis of Kuroshio locates very near Hualien coast. As the current flows toward the shallow ridge at SuAo, it should separate from the coast, since the geostrophic current tending to flow along the depth contour. Tominaga (1972) also showed that the geostrophic current turns clockwise in front of a shallow ridge due to the topographic  $\beta$ -effect. The mean current field in the SuAo coastal region is determined by the interaction between the bottom topography and incoming Kuroshio from the south.

Wind is another major factor to affect the ocean current. Due to the blocking effect of the Central mountain ridge, which has an average height over 3000 meter, the wind at the east coastal region of Taiwan is mainly in the longshore direction.

In this paper, we study the characteristics of ocean current on the limited shelf around SuAo. Cheng and Chu (1976) studied the tidal currents in this place. we are concern to the mean field and subtidal frequency variation.

# **DATA COLLECTION**

A self-recording current meter was deployed at the offshore region of SuAo from October 25 to December 23, 1975. The instrument was moored 65 meter below sea surface at a site about 200 meter deep. The sea level record at SuAo harbour and the meteorological data from Peng-Chia-Yu and Hualien for the same period were obtained from the

<sup>1.</sup> Institute of Oceanography, National Taiwan University, Taipei, Taiwan, Republic of China.

Ching-Sheng Chern



Fig. 1. Bathymetric chart of SuAo offshore area depths are in meters.



Fig. 2. Locations of STD station, tide gauge station, current meter mooring site and the weather stations.



Fig. 3. Low-passed time series of atmospheric pressure and wind stresses at Peng-Chia-yu and Hualien.

Ľ



Fig. 4. The ellipse orientation, stability and rotary coefficients of wind stress at Peng-Chia-Yu and Hualien.

Central Weather Bureau. All data were low-passed using a cosine taper filter to remove the fluctuations at tidal periods. The sea level record at SuAo was adjusted to remove the atmospheric pressure effect from the pressure measurement at Hualien.

The R/V Chiu-Lien occupied 32 stations around the shallow ridge at SuAo from April 9 to 13, 1983. The station pattern, tide gauge location and the weather stations are shown in Fig. 2. Stations were occupied at intervals of 10 n miles. The STD data were digitized at 10 m intervals from their analog format.

#### SUB-TIDAL FREQUENCY VARIATION

Fig. 3 shows the low-passed atmospheric pressure and wind stress at Hualien and Peng-Chia-Yu, from October 6 to December 25, 1975. The pressure signals at these two places are almost the same. This indicates they are always under the same weather system. The signals of wind stress at these two locations are similar only during period of strong wind. Following Gonella (1972), we decompose the wind stress fluctuations into Fourier components and regard the signal at each frequency forms an ellipse. Fig. 4 shows their ellipse orientation, stability and rotary coefficients as function of frequency.

At Peng-Chia-Yu, the wind has rotary behavior and is dominated by the NNE monsoon. But there is no preferred permanent direction, as indicated by the low stability coefficient. In contrast, the wind at Hualien is unidirectional and its direction is very stable. This due to the blocking effects of the Central Mountain Ridge. Therefore the wind











Frequency (cycle per day)

- Fig. 7. (a) The ellipse orientation, stability and rotary coefficients of current at SuAo offshore.
  - (b) Log-log plot of power spectral density of current and sea level at SuAo.



#### Frequency ( cycle per day )

Fig. 8. The cohernce squared between the current at SuAo offshore/sea level at SuAo and the wind stresses at Peng-Chia-Yu.

hasonly the longshore component at Hualien' as illustrated in Fig. 3. The rotary spectrum of wind stress at the two places are shown in Fig. 5. The variance spreads over the low frequency band and there is no pronounced peak. Since the wind at Hualien is contaminated by the land effects, we choose the wind data at Peng-Chia-Yu to represent the offshore condition around SuAo.

Fig. 6 shows the lowpassed record of the adjusted sea level at SuAo harbour and the current at SuAo offshore. (The? mark on the sea level record at November 19 indicates that big sea level change is unreliable. Since during that period, wind is calm and atmospheric pressure is steady. There is no reason to expect 30 cm sea level change in 2 day). The current is dominated by the 3-4 day period fluctuation, while the period of the sea level fluctuation is about 6 day. This can also be seen from the spectrum estimate, as shown in Fig. 7. In Fig. 8. we also show the coherence squared between the coaltal sea level and offshore current at SuAo. Both the longshore and cross-shore current components are highly coherent with the sea level around 4 day period. But there is no connection between sea level and the current field at 6 day period. The reason for the occurrence of the 6-day period coastal sea level fluctuation is not clear. The data only shows it is a localized phenomena. This may be due to the complicated topographic effects. Cheng and Chu (1976) also found there is a poor correlation between the offshore diurnal tidal current and the corresponding coastal tide at this place.

Fig. 7 also shows the ellipse orientation, stability coefficient and the rotary coefficient of the current at SuAo offshore as a function of frequency. The current has rotary behavior, its major direction is northward and very stable around 3-4 day period. Fig. 8 shows

#### On the Characteristics of Current at the Offshore Region of SuAo

the coherence squared between the wind stresses at Peng-Chia-Yu and the sea level/current at SuAo. Both the longshore and offshore currents are coherent with the longshore component of wind stress around 4 day period, while their coherence with the offshore wind stress is poor. The sea level is also coherent with the longshore wind stress around 4 day period. This indicates the longshore wind is the main driving force for the sub-tidal frequency variation of the current and sea level at SuAo offshore.

At an ordinary continental shelf, the longshore wind will mainly drive the longshore current. This is due to the constraint that the net onshore and offshore transport is zero at solid boundary. The rotary nature of current at SuAo will be the combined effects of both the coastal line and the submarine ridge influences.

## MEAN CURRENT FIELD

Fig. 9 shows the progressive vector diagram of the current at SuAo offshore. The mean current flows toward NEE direction at a rate about 12 cm/sec. Since Kuroshio flows northward at Hualien offshore, Chu (1976). This indicates the current separates from the coast and turns clockwise in front of the shallow ridge at SuAo. There are two possible reasons. Under the shallow water approximation, the barotropic geostrophic current flows along the depth contour, Pedlosky (1979). From the conservation of potential vorticity, the current will also induce clockwise vorticity as it flows toward a shallow region.

Figs. 10, 11 show the temperature an density distributions at four different depths at SuAo offshore on April 9-13, 1983. The constant value lines are roughly follow the depth contour. Since the hydrographic and the current meter data are collected at different seasons, and both results indicate current separating from the coast and following the bottom topography. We may regard it as a general truth.



Fig. 9. Progressive Vector Diagram of current at SuAo offshore.





4



Fig. 11. Horizontal at distribution in April, 1983 at four different depths. ———— depth contour ———— isopycnal line

S.

#### Ching-Sheng Chern

# DISCUSSION AND CONCLUSION

The current at the offshore of SuAo is influenced by the special topography of that region. Both the coastline and the submarine ridge have strong effects on the current structure. At a coastally bounded continential shelf, the longshore wind is usually the main driving force of the coastal circulation. The water moves alongshore, with the wind, in the coastal zone. The Coriolis force associated with the longshore current is balanced by the offshore pressure gradient.

A submarine ridge is dynamically similar to a continental shelf except the absence of the constraining effect of a coastal boundary. From a simplified linear model, Brink (1983) studied the wind-driven motions over an infinitely long submarine bank. One of his conclusions is as follows: "The primary driving mechanism is related to the disruption of surface Ekman transport by bottom friction. Alongbank stress is shown to be fairly ineffect driving agent, while crossbank winds drive geostrophic current relatively effectively."

At the offshore of SuAo, the submarine ridge is perpendicular to the coast. Therefore longshore wind is the dominanting factor for both the coast and bottom topography effects. And both the longshore and offshore currents are coherent with the longshore wind. The detailed structure of current field in this region is further complicated by the presence of Kuroshio. More current meter measurements are needed to reveal the characteristics of ocean current in this region.

#### **ACKNOWLEDGEMENTS**

This research was supported by the National Science Council of Republic of China, under the contract No. NSC-72-0407-M002a-03.

The author wishes to thank the Central Weather Bureau for providing the weather and tide gauge data.

# **REFERENCES CITED**

BRINK, K. H. (1983) Low-frequency free wave and wind-driven motions over a submarine bank. J. Phys. Oceanogr., 13: 103-116.

CHENG, K. and T.Y. CHU (1976) Tidal currents in the offshore area of Su-aou in relation to tides of land station along the east coast of Taiwan. Acta Oceanographica Taiwanica, 6: 39-51.

CHU, T.Y. (1976) Study of the Kuroshio current between Taiwan and Ishigakijima. Acta Oceanographic Taiwanica 6: 1-24.

GONELLA, J. (1972) A rotary-component methos for analyzing meteorological and oceanographical vector time series. Deep Sea Research 19: 833-846.

PEDLOSKY, J. (1979) Geophysical Fluid Dynamics, Springer-Verlag Press, New York.

STOMMEL, H. and K. YASHIDA (1972) Kuroshio, University of Tokyo Press.

TOMINAGA, M. (1972) Brief analyses of the upwelling phenomena near the eastern coast of Taiwan. Acta Oceanographic Taiwanica 2: 25-38. On the Characteristics of Current at the Offshore Region of SuAo

# 蘇澳海域之海流特性

# 陳慶生

# 摘 要

受到海岸線與離岸淺水地形的雙重影響,蘇澳外海的低頻率海水運動主要是佔沿岸風所造成,此 地區風吹流主要的周期大約為 3~4 天,而且具有旋轉性,橢圓主軸向北而且非常穩定,本區平均流 場則由黑潮與當地地形來決定,等溫線大抵上與等深線一致。