A Sea of Change: JGOFS Accomplishments and Future of Ocean Biogeochemistry. May 5-8, 2003. Washington D.C., USA

Seasonal variation of volume transport in the major inflow region of the Taiwan Strait: The Penghu Channel

Sen Jan, Institute of Physical Oceanography, National Sun Yat-Sen University, 70 Lien-Hai Rd., Kaohsiung 80424, Taiwan, R.O.C.,
Email: senjan@mail.nsysu.edu.tw, Phone: 886-7-5252000x5353, Fax: 886-7-5255359
Shenn-Yu Chao, Horn Point Laboratory, University of Maryland Center for Environmental Science, Cambridge, MD 21613-775, USA
Email: chao@hpl.umces.edu, Phone: 410-221-8200, Fax: 410-221-8490

Abstract

Eight cruises of current measurements along a zonal transect (~31.84 km) across the major inflow region of the Taiwan Strait, the Penghu Channel, were carried out using the shipboard Acoustic Doppler Current Profiler (ADCP) during 1999-2001. On each cruise, the measurement was repeated twice along the transect with a time lag of 6 hours and 12 minutes, and the repeated data were averaged to eliminate the dominant semidiurnal tidal currents. Velocities, after removing semi-diurnal tides, suggest that there is a strong northward flow in the channel, with a speed of about 100 cm/s in the upper 50 m in summer. The northward flow becomes much weaker in winter. The calculated through-flow transports vary seasonally and are correlated with the change of the East Asia monsoon. The estimated transport is around 0 during the peak northeast monsoon in winter, increases from 0.5 to 1 Sv (1 Sv = 106 m3/s) as the northeast monsoon weakens in spring, peaks to 1.5 Sv at the end of southwest monsoon in summer, and decreases rapidly from 1.5 to 0 Sv when the northeast monsoon intensifies in fall. The error, mostly induced by unfiltered diurnal tidal currents, is estimated to be +- 0.20 Sv in the transport calculation.

The Penghu Channel

The Penghu Channel (*PHC* in Fig. 1), about 40 km wide and 100 m deep to the north and 80 km wide and 200 m deep to the south, is a funnel-shaped deep channel. It is well-known that there is a persistent northward sub-tidal flow in the PHC through-out a year, which is often speculated to be the origin of the so-called "*Taiwan Warm Current*". The throughflow transport in the PHC is important not only for the circulation in the Taiwan Strait, but also for the balance of biogeochemical budget in the East China Sea (Jan et al., 2002; Chung et al., 2001). Unfortunately, estimates of the PHC transport are scanty in the open literature. In light of this deficiency, this study is simply aimed at measuring the currents and calculating the volumetric fluxes through the PHC.

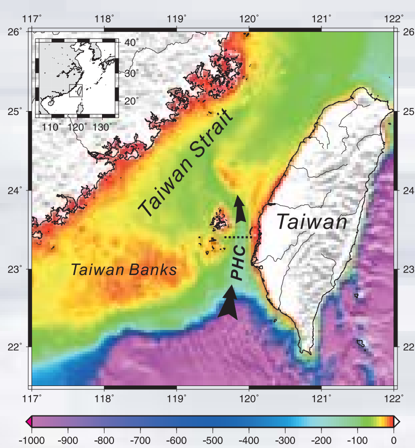

Fig. 1 A map showing topography in the Penghu Channel (PHC).

Velocity Measurement

Eight cruises for current measurements were conducted on board Ocean Research I (Fig. 2) and III (OR-1 and OR-3) along a zonal transect (32 km long) across the width of the PHC during 1999-2001. Table 1 lists the period of each measurement. The velocities were measured using the ship-board ADCP. The ship track was designed so as to eliminate the semidiurnal tidal currents.

Fig. 2 Ocean Research I

Table 1 Shipboard ADCP measurement periods and calculated transports (Sv) in the PHC

R/V	Cruise no.	Period	Q(Sv)
OR-1	558	1999/8/15/14:00-22:42	1.58
OR-3	569	1999/10/15/19:00-16/4:23	0.76
OR-1	569	1999/11/19/4:00-13:30	-0.11
OR-1	578	2000/3/24/21:00-25/7:46	0.56
OR-1	585	2000/6/18/1:50-11:10	1.26
OR-3	646	2000/8/18/13:15-22:40	1.72
OR-1	602	2001/2/12/9:22-19:00	0.02
OR-3	702	2001/5/24/9:38-18:56	1.10

Detide by Phase Averaging

The sb-ADCP measurements were made along the same transect twice, i.e. the first and third tracks as illustrated in Fig. 3. The two repeat are separated by 6 h and 12 min so that they are out of phase by half a cycle of the dominant semidiurnal tides. The measured velocities along the transect are separated to eight segments and averaged over each segment. The averaged data are gridded every 4 m in the vertical. The gridded data of the first and third tracks were averaged to eliminate the semidiurnal tidal currents, the so-called "phase averaging".

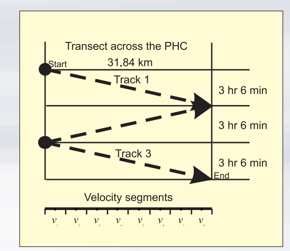

Fig. 3 Ship track of measurements.

Subtidal Flow Structure

The semidiurnally averaged currents (subtidal currents) distributions of the u- and v- components in the PHC transect are shown in Fig. 4. The subtidal flow are essentially northward (v) and vary seasonally. The zonal currents (u) are relatively much weaker. Started from winter, the northward flow is weak (Fig. 4(c) and (g)), and its velocity is less than 10 cm/s. During winter-spring transition period, the flow develops a core structure centered in the upper 50 m layer of PHC (Fig. 4(d)); the flow speed increases thereafter. In late summer, the northward flow core is fully developed with a speed as high as 100 cm/s (Fig. 4(a) and (f)). After summer, the flow strength drops rapidly, and the core speed is reduced to about 50 cm/s (Fig. 4(b)). The depth-averaged subtidal flow distributions are shown in Fig. 5.

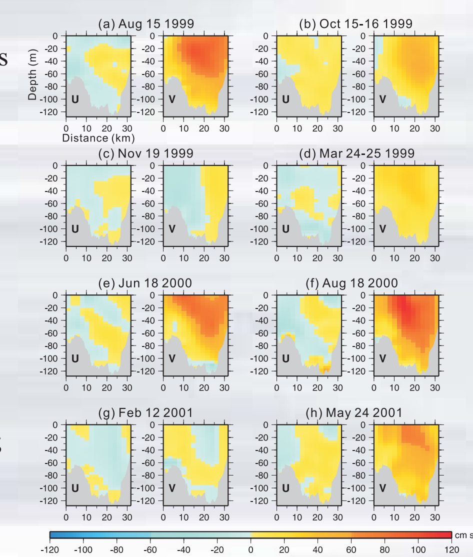

Fig. 4 Semidiurnal-averaged velocity distributions (u and v) in the PHC transect for the eight measurement periods.

The strength of velocity vectors clearly peaks over the deepest region of PHC in summer (Fig. 5(a), (e) and (f)), and decreases in spring and autumn to about half of the summer peak (Fig. 5(b), (d) and (h)). In contrast, the winter flow is much weaker and less coherent (Fig. 5(c) and (g)).

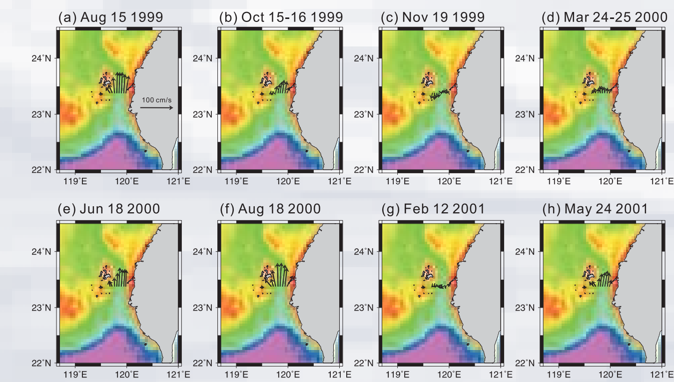

Fig. 5 Horizontal distribution of the depth-averaged subtidal flow.

Volume transport calculation

The flow volume transport through the transect (Q) is calculated using the semidiurnally averaged velocity (v) perpendicular to the transect as

$$Q=\Sigma \Sigma v(\Delta z\, d)$$

where d=3.98 km is the width of each segment and Δz=4 m is thelayer thick-ness. The calculated Q through PHC listed in Table 1suggests the through-flow in PHC is generally northward but with strong seasonal variations. Fig. 6 shows the calculated Q as a function of the month regardless of the year of measurement, along with the monthly mean wind-speed vectors at an islet near the transect, and the northward sea-level gradients.

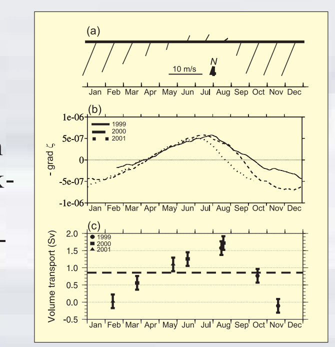

Fig. 6 (a) Monthly mean wind speed, (b) sea-level gradients, and (c) flow transports over a one-year time scale regardless the year of measurement.

Concluding remarks

The seasonal variation of the transport appears to be highly cor-related with changes of the along-channel sea level gradients as well as the change of East Asia monsoon (Fig. 6). The transport is quite small (~0 Sv) during the strongest northeast monsoon in winter, increases as the monsoon weakens in spring (0.5-1 Sv), peaks after the southwest monsoon in summer (~1.5 Sv), and de-creases rapidly when the northeast monsoon starts in fall.

References
Chung, S.-W., S. Jan, and K.-K. Liu (2001) Nutrient fluxes through the Taiwan Strait in spring and summer 1999, J. of Oceanography, 57, 47-53
Jan, S., J. Wang, C.-S. Chern, and S.-Y. Chao (2002) Seasonal variation of the circulation in the Taiwan Strait. J. of Mar. Systems, 35, 3-4, 249-268