Internal tide and its associated cooling system in Genka Bay, Okinawa, Japan

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Introduction

Genka Bay is located on the main island of Okinawa, situated in the subtropics of southern Japan. The physical environment that affects the flow regime and therefore, changes the water temperature was highlighted as one of the factors influencing the sustainability of corals in the Ryukyu Islands (Heron et al., 2004). Internal tide is one of the key processes in dynamics of coastal ocean that might have influence on that flow regime and temperature change (Nakaza et al., 2006). Considering the above fact, a comprehensive field observation was carried out for the first time to explore the characteristics of the internal tidal current and its associated cooling system in Genka Bay.

Observations

Profiling and mooring measurements were carried out in the three observation sites of Genka Bay by using ADCPs (up-ward looking modes,10-min time ensemble and a 2-meter depth bin) and TPM chlorotech sensors during September-Novenmber, 2007. Water depth was 110, 60 and 50 m for the site St.1, St.2, and St.3 respectively.

Results

The depth-averaged currents at all sites flow nearly parallel to the coastline during the study period. Time series of bottom water temperatures at all sites follow a semi-diurnal oscillation pattern, and indicate the temperature transmission from offshore even to near-shore shallow water regions with the strong group velocity (*Cg*=0.54 m/s) of internal wave during summer (Fig.3). The vertical structures of the horizontal current as well as the bottom temperature trends show the existence of a cross-shore internal tide that decreases (increases) the bottom water temperature with its ingoing (outgoing) phase (Figs. 4 and 5). These temperature fluctuations influence the vertical profile and control the temperature stratification at the bottom layer(Fig.6). Spectra of the baroclinic and bottom water temperature also congruent the internal tide based cooling system in Genka Bay.

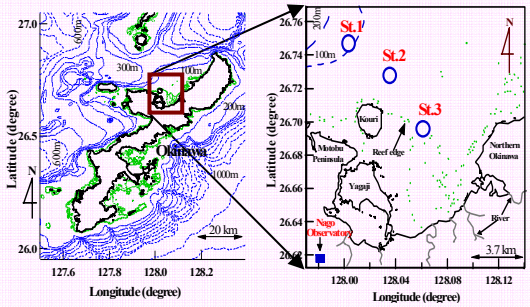


Fig.1 Seabed topography around Okinawa Island

Fig.2 Location of the measuring points

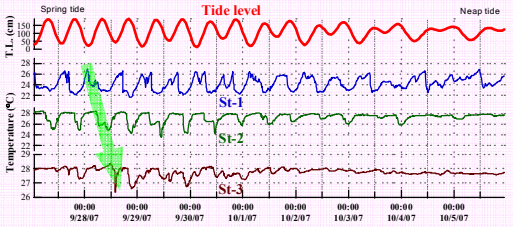


Fig.3 Time series of the bottom water temperature at Sts.1-3 and sea level. Green arrow shows representative phase speed of internal tide

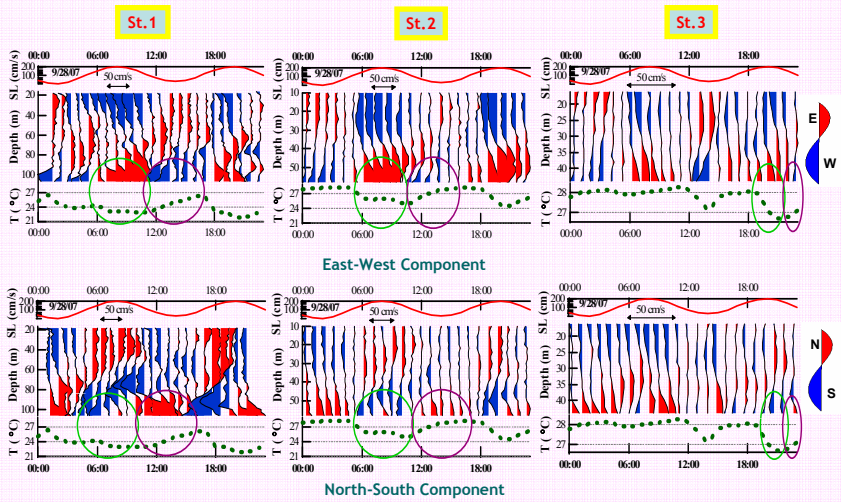
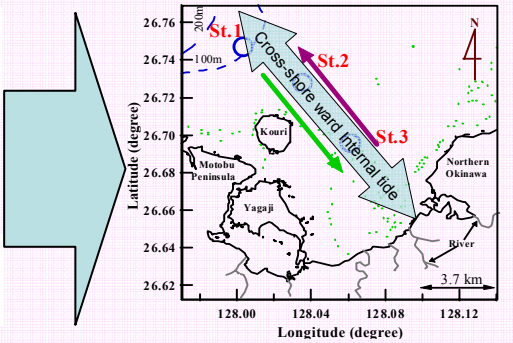


Fig.4 Vertical structure of horizontal current and bottom water temperature trend at Sts. 1-3

Southeast (**shore**-ward) current transmission propagates with time and decrease bottom water temperature



Northwest (**offshore**-ward) current transmission propagates with time and decrease bottom water temperature

Fig.5 Temperature fluctuation mechanism at the bottom layer

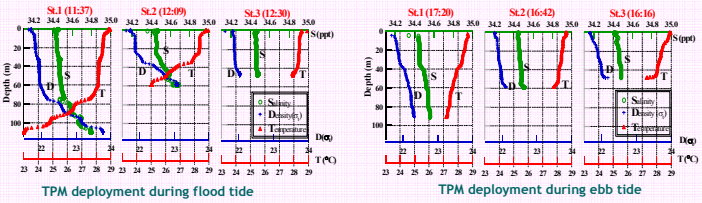


Fig.6 Vertical profile of temperature, salinity and density during the TPM deployment in Sts. 1-3 on September 28, 2007

Conclusions

A cross-shore ward internal tide is revealed in Genka Bay even though the depth-averaged current flows nearly parallel to the coast. This internal tide decreases (increases) the bottom water temperature with its ingoing (outgoing) phase and hence maintain a unique water cooling system in summer. The results are not complete enough to reveal all the characteristics of internal tides throughout the year. The study, however, should provide a platform in order to understand and predict the behavior of the internal tides with considerable background when developing sustainable coastal management initiatives in Genka Bay.

References

Heron, Skirving, and Heron (2004): Coral bleaching limitations by wave-induced vertical mixing at the Reef Front, 10th International Coral Reef Symposium, Okinawa Convention Center, Okinawa, Japan.
Nakaza, Rahaman, Kitamura, Pawlak, and Tsukayama (2006): Cross-shore internal waves in Zanpa coastal region of Okinawa Island, Journal of Waterway, Port, Coastal, and Ocean Engineering, ASCE, Vol. 132, No. 1, pp. 36-46.