

**Real-Time Drifter and ADCP V(z) Observations of Kuroshio Intrusions
on East China Sea Shelf
and
A New Littoral Ocean Observing System**

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LONG TERM GOALS

The long-term objective is to improve our understanding of the interactions between the Kuroshio and the East China Sea with the coordinated use of several tools, some of which already developed by ONR: a Surface Velocity Program (SVP) drifters array and a modified version of the ADOS-V used for the ONR sponsored NLIWI experiment. Our long-term goal is to investigate the dynamical processes that govern this interaction and to develop inexpensive operational tools to provide real-time physical observations in a variety of marine environments. To achieve this goal, new observations are being obtained. This research contributes to a more realistic prediction of this complex physical environment in area of strategic importance for PACFLEET operations.

OBJECTIVES

The first objective is to measure the strength and the surface structure of the Kuroshio along the east coast of Taiwan and to the north east of the island, and to observe the intrusion of the Kuroshio onto the southern East China Sea's continental shelf.

The second objective is to measure the circulation and physical processes on the southern East China Sea's continental shelf on a variety of spatial and temporal scales during the joint predictability experiment (Intensive Observing Period) in FY '09.

APPROACH

To accomplish the first objective, two SVP drifters are being released each week by Taiwan's coast

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guard off Taidong (south east Taiwan). The deployments began on April 7, 2007 and are scheduled to continue for approximately 70 weeks. The data are being made available to the QPE investigators at: <http://www-pord.ucsd.edu/~yykim/drifters/WPAC/> . The drifter's tracks are routinely overlaid to maps of satellite altimetry observations of meso-scale eddies computed by AVISO.

To accomplish the second objective, a new instrument, called the R-ADOS-V (Restrained Autonomous Drifting Ocean Station with Velocity profile measurements capability) has been built and deployed in the southern East China Sea continental shelf in September 2008, together with an array of SVP drifters fitted with GPS receivers. Funds from the DURIP award "A New Littoral Ocean Observing System" (award #N00014-07-1-0897) were used for the construction of the first R-ADOS-V's prototype.

WORK COMPLETED IN YF'08

Task 1: weekly releases of SVP drifter pairs in the Kuroshio

To date, 50 SVP drifters have been deployed in the Kuroshio south-east of Taiwan by the Taiwanese coast guard.

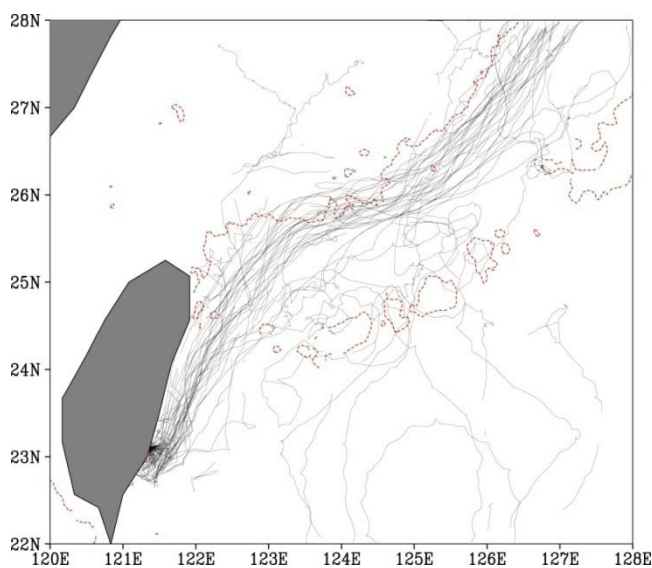


Figure 1: Spaghetti diagram of the 48 SVP drifters released in the Kuroshio by the Taiwanese coast guard. From April 7, 2008 to October 12, 2008.

Task 2: test of the R-ADOS-V prototype and deployment of a 5 element SVP-GPS drifters array during the QPE pilot cruise

Two 130 m long restrained drifters were assembled at the Scripps Institution of Oceanography by Mr Chris Mc Call under the supervision of Drs. Luca Centurioni and Peter Niiler (See Figure 2 for a schematic of the R-ADOS-V).

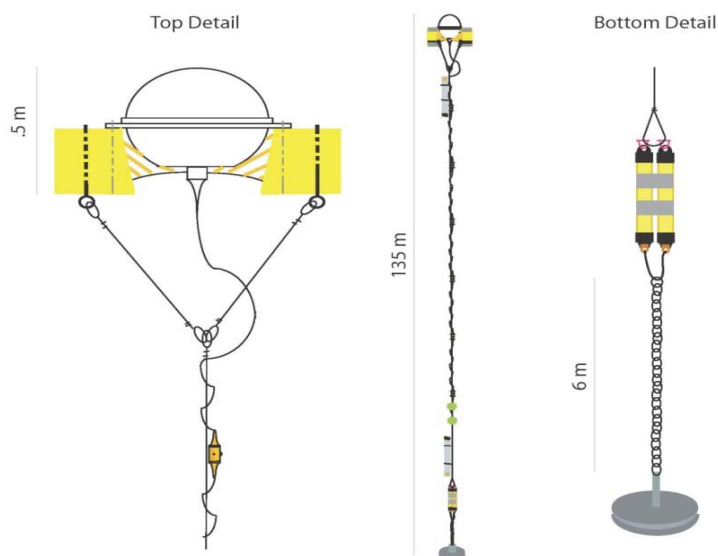


Figure 2: Schematic of the R-ADOS-V. The top detail shows the spherical ABS buoy that contains the batteries and the electronics. The ABS buoy is mounted onto the yellow “doughnut” shaped foam ring for extra buoyancy. Underneath is a schematic of the cables assembly and of a thermistor/pressure pod. The mid picture shows two ADCP’s clamped on the cable. However, only one ADCP was used for the QPE pilot cruise. The bottom details show the assembly of the shallow water acoustic releases.

The self deployment capabilities of the R-ADOS-V were tested extensively off Point Loma (San Diego, CA) during the months preceding the QPE pilot cruise until the correct cable configuration was identified. One restrained drifter with the ADCP (R-ADOS-V) and one with thermistor chain only were then shipped to Keelung (Taiwan) to be deployed during the QPE pilot cruise (Figure 3).



Figure 3: Two restrained drifters are being prepared for deployment in the Keelung harbor warehouse. The cable is hold in the correct deployment configuration with water soluble paper tape and cardboard board and tubes.

Dr. Luca Centurioni and Mr Chris Mc Call sailed on board of OR1 on September 2nd and successfully deployed one R-ADOS-V during leg 1 of the pilot cruise (Figure 4 and Figure 6). The R-ADOS-V was deployed on September 2, 2008, 18:10 UTC at 25° 56.64'N, 122° 27'E . The instrument was successfully recovered on September 4, 2008 at 9:47 UTC. The two restrained drifters were then re-deployed during leg 2 of the pilot cruise (Figure 4). The R-ADOS-V was redeployed at the same location of leg 1 on September 9, 2008 at 16:40 UTC (Figure 6). The restrained drifter with the thermistor chain only was deployed on September 9, 2008 14:19 UTC at 25° 55.54'N, 122° 34.66'E (Figure 6). The R-ADOS-V was vandalized by a Taiwanese fishing boat on September 9 one hour before recovery (Figure 5)



Figure 4: the box with the R-ADOS-V is deployed from the stern of R/V OR1 on September 2, 2008. The black straps which are holding the cardboard in place are secured to the bottom pallet with salt blocks.



Figure 5: The fishing vessel that vandalized the R-ADOS-V. The red circle shows the surface expression of the R-ADOS-V on the deck of the boat.

The fishermen cut the cable just underneath the buoy. The sub-surface expression of the buoy was lost. The fishermen loaded the buoy on their vessel and began steaming north-east. The position of the fishing vessel was known in real time and with great accuracy since our buoying kept transmitting GPS positions every minute. The R/V OR1 steamed on an interception course and we were able to recover the surface buoy a few hours later. The second restrained drifter (thermistor chain only) was successfully recovered on September 9.

Five GPS drifters were deployed from OR1 (Table 1 and Figure 6)

Table 1: ARGOS ID, location and times of the five SVP/GPS drifters deployed during the QPE pilot experiment.

ARGOS ID	LONGITUDE	LATITUDE	DATE AND TIME
75438	122° 46.40'E	25° 47.08'N	9/7/2008 3:31 UTC
75439	122° 40.53'E	25° 44.40'N	9/7/2008 4:33 UTC
75440	122° 28.67'E	25° 39.88'N	9/7/2008 12:30 UTC
75441	122° 38.21'E	25° 42.64'N	9/7/2008 4:59 UTC
75442	122° 34.57'E	25° 42.21'N	9/7/2008 13:09 UTC

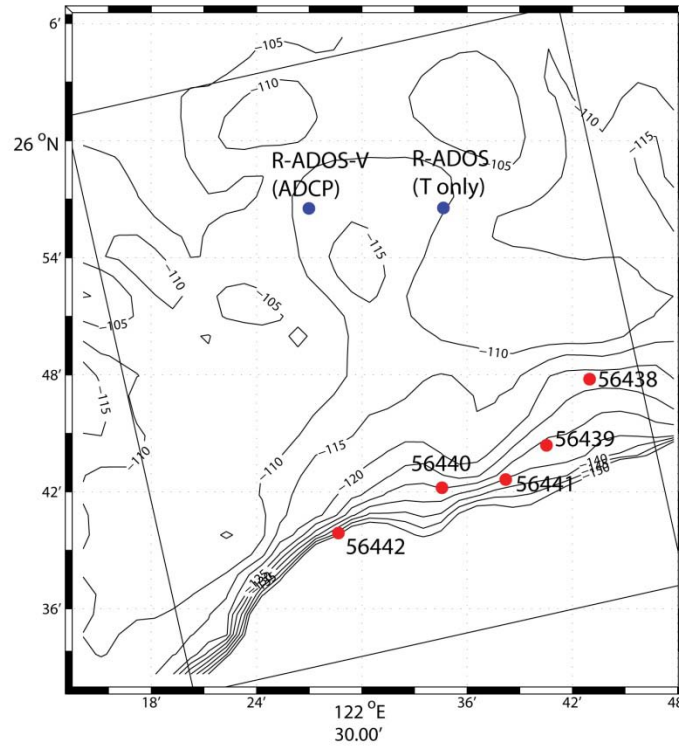


Figure 6: Bathymetry map of the QPE pilot experiment region: The blue dots mark the deployment location of the restrained drifters (the R-ADOS, with thermistor chain only and the R-ADOS-V, with the profiling ADCP). The red dots mark the deployment location of the SVP-GPS drifters).

RESULTS

Task 1: Intrusion of the Kuroshio on the south East China Sea continental shelf

A regime of intruding Kuroshio onto the South East China Sea (SECS) shelf was observed in April 2008 (Figure 7). A cyclonic eddy moved near the east coast of Taiwan, sustaining a flow directed against the Kuroshio, which then intruded onto the continental shelf, as shown by the track of the drifter released on April 7, 2008 (Figure 7) from south-eastern Taiwan.

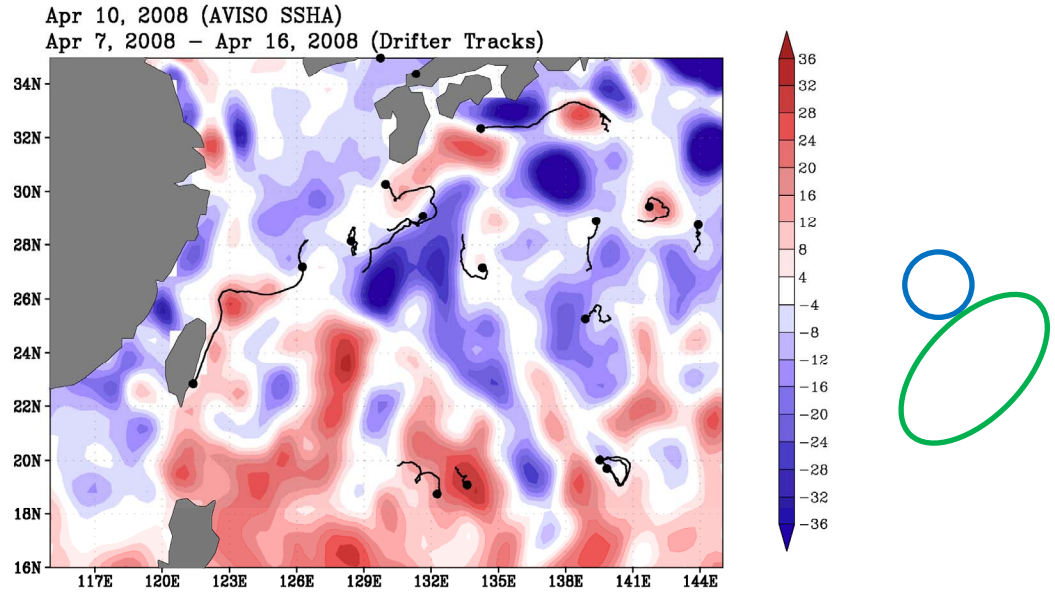


Figure 7: Sea Level Anomaly and drifter tracks (April 7 through April 16, 2008). The green oval marks the position of the cold cyclonic eddy that moved near Taiwan. The track of the first drifter released on April 7, 2008, the day in which our experiment began, showed an excursion of the Kuroshio onto the continental shelf (blue circle).

The drifter tracks from subsequent releases (from May through September 2008) did not show any Kuroshio intrusion during the following months. Figure 8 shows a typical non-intruding regime. In October 2008 another cold eddy moved near the east coast of Taiwan. The drifter tracks then began again to show a deep intrusion of the Kuroshio on the shelf of the SECS.

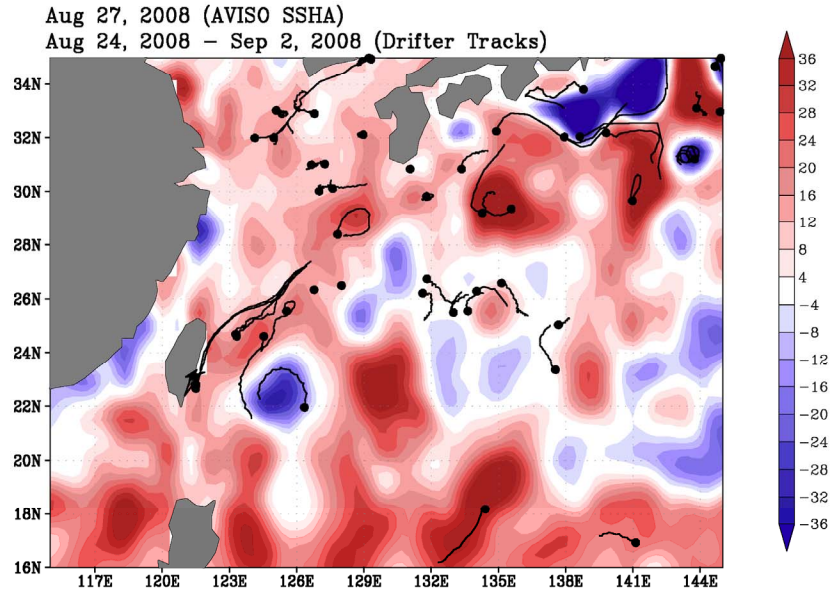


Figure 8: Non intruding regime. This timeframe correspond to the week preceding the QPE pilot experiment.

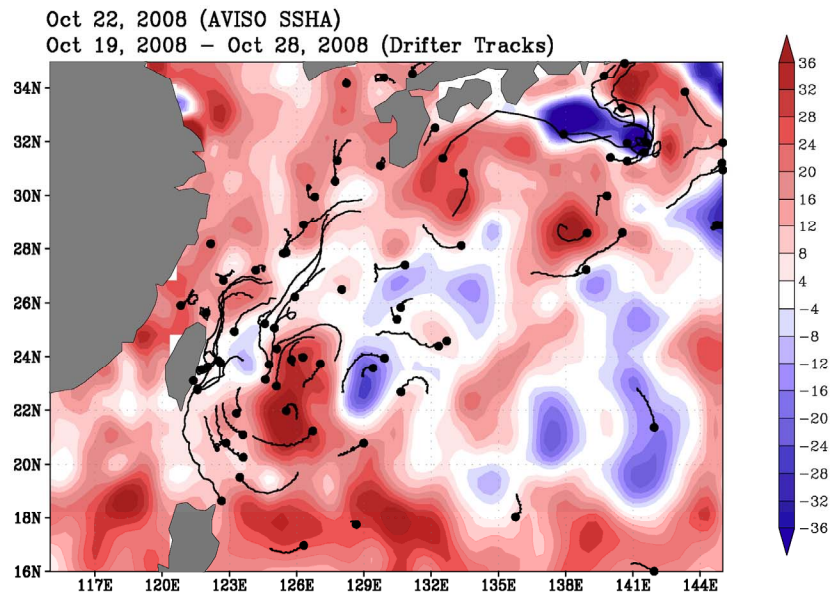


Figure 9: As figure 7. A cold cyclonic eddy is leaning against the eastern coast of Taiwan and the tracks of the drifters released off Taidong show a deep intrusion of the Kuroshio into the SECS shelf.

Those results are suggesting that by tracking the cold cyclonic eddies that approach Taiwan from the interior of the Pacific Ocean, predictions of the onset of the intrusion of the Kuroshio onto the SECS shelf are possible.

Task2: Results from the QPE Pilot Cruise

A succession of tidal waves with amplitudes in excess of 30 m can be seen in the time series of the temperature profiles obtained from the R-ADOS-V (Figures 10 and 11). For the QPE pilot experiment we used old temperature pods that had been already deployed during the Non-Linear Internal Wave experiments in the South China Sea in 2005 and 2007. The reason for the numerous gaps in the data record is now under investigation. No such problem was encountered during the NLIWI '05 and '07 experiments, where the same thermistor chain was used without such problem

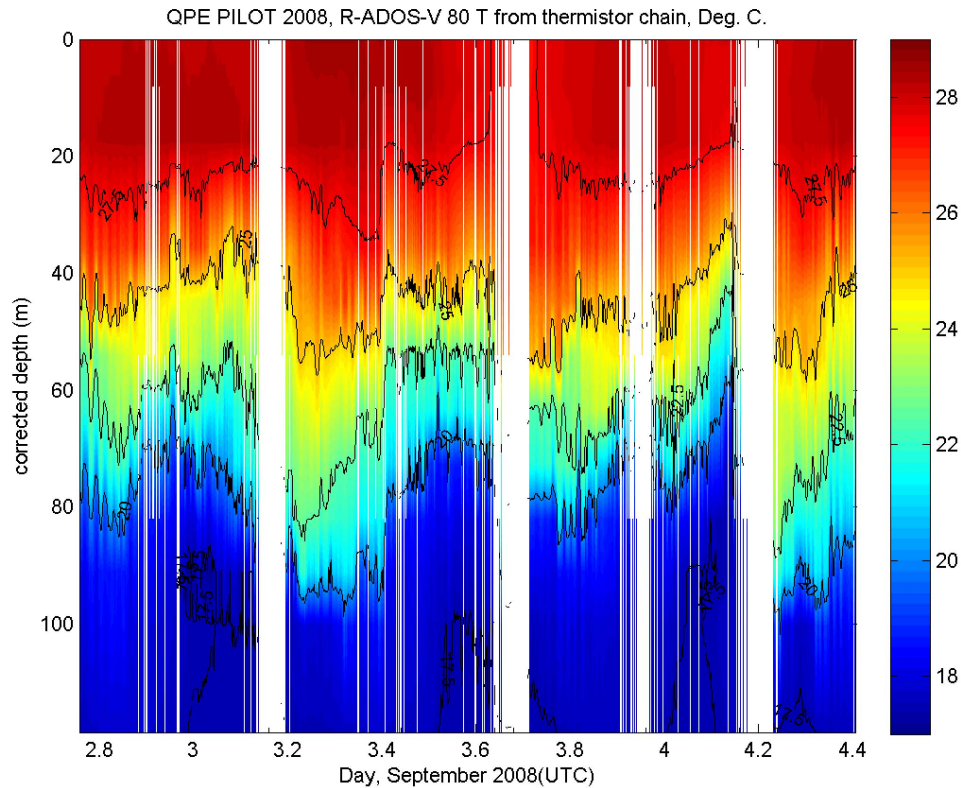


Figure 10: Temperature profiles time series from the R-ADOS-V thermistor chain (25° 56.64'N, 122° 27'E). Leg 1.

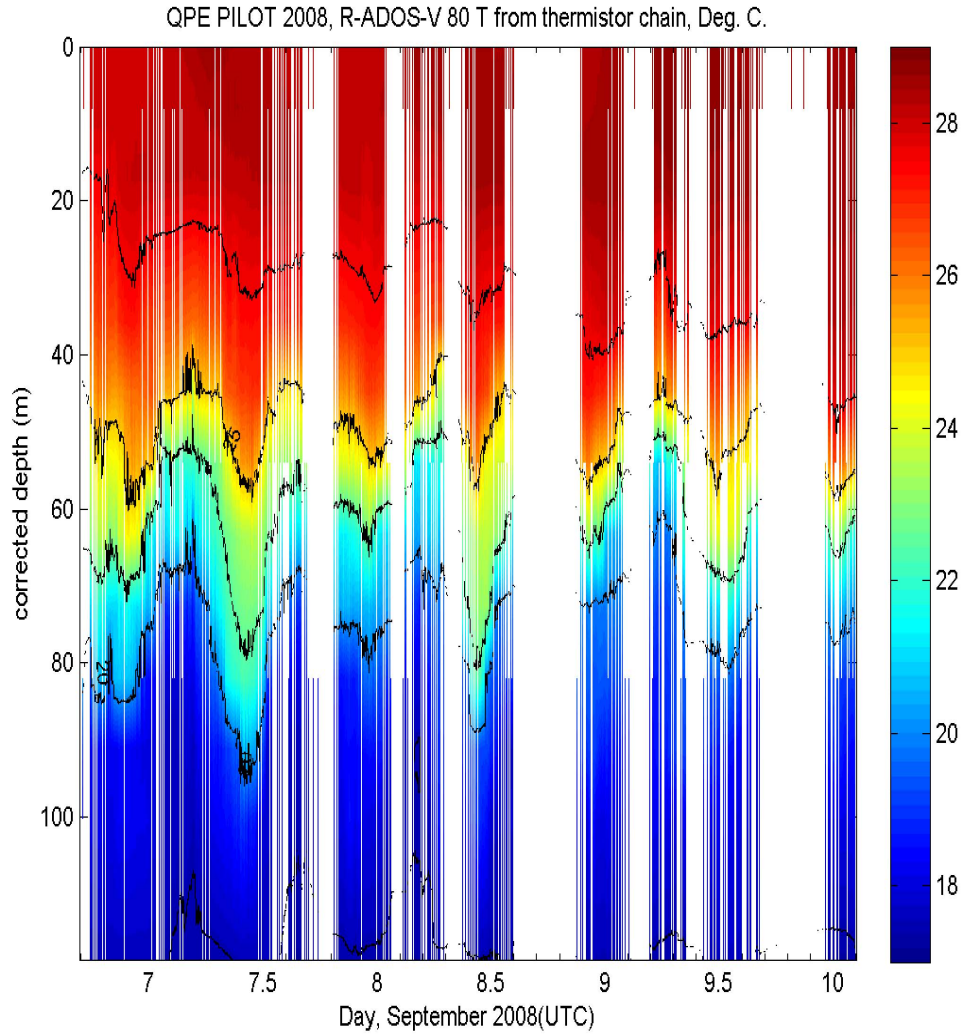


Figure 11: Temperature profiles time series from the R-ADOS-V thermistor chain (25° 56.64'N, 122° 27'E). Leg 2. The gaps in the data are due to the aging battery cells of the temperature pods.

The 27.5° C isotherm deepened from approximately 20 m depth at the beginning of leg 1 to more than 40 m depth at the end of leg 2.

The current profile time series (Figure 12), which is available only for leg 1 due to the vandalism episode reported in the previous section, show that the tidal currents be in excess of 1 ms⁻¹.

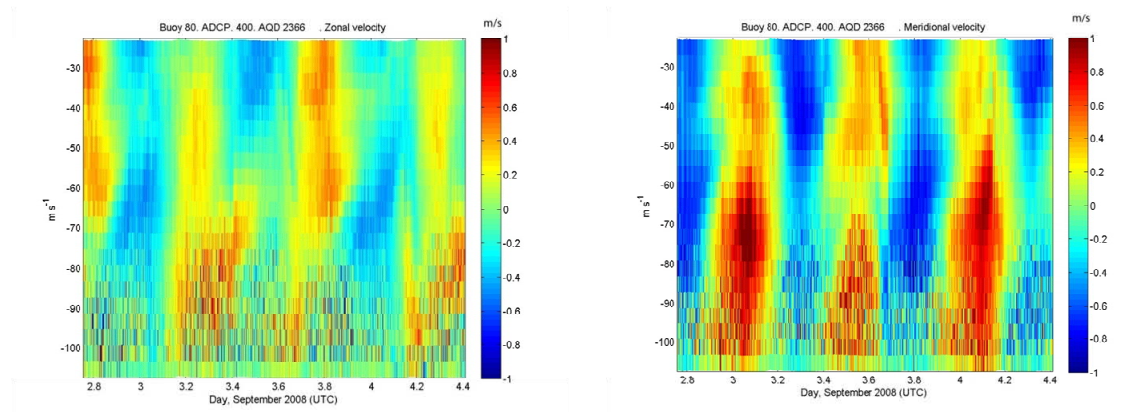


Figure 12: Horizontal current profiles time series from the R-ADOS-V ($25^{\circ} 56.64'N$, $122^{\circ} 27'E$). Leg 1.

The two SVP-GPS drifter deployed at the northernmost locations (blue and yellow tracks in Figure 13) moved very rapidly (with speeds of the order of 1m/s) to the north-west.

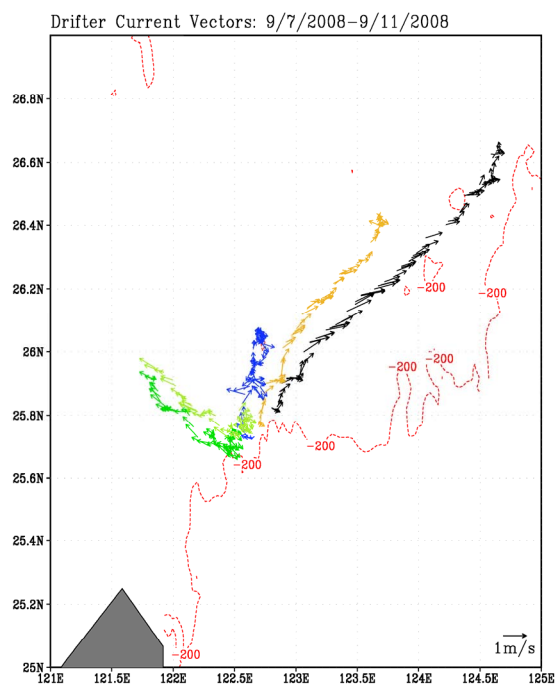


Figure 13: Tracks of the SVP-GPS drifters deployed during the QPE pilot cruise on September 7, 2008.

The remaining three drifters moved with slower speeds to the north and north-east. Those results suggest the occurrence of a frontal structure and enhanced horizontal shear across the region sampled by the SVP drifters.

Overall, the QPE pilot experiment enabled us to prove that the R-ADOS-V can be successfully deployed from within a box with minimal effort and no need of technical staff with mooring operations skills. The real-time transmission of temperature, current and geographical position data is now being implemented and will be used during the 2009 QPE IOP experiment.

IMPACT/APPLICATIONS

The R-ADOS-V design will be upgraded. Newly built instruments will be delivering data in real time and will be used during the QPE IOP experiment in 2009.

The SVP drifter data (ARGOS positions) were placed on the GTS for use by global scientific community.

TRANSITIONS

N/A

RELATED PROJECTS

NOAA/OGP funded the “Global Drifter Program”. ONR funded “Non Linear Internal Wave Dynamics in the South China Sea- a Lagrangian View”