Mean Flow and Variability at the Upper Portion of the East Sea Proper Water in the southwestern East Sea with APEX Floats

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16 APEX floats, autonomous profiling floats deployed as part of the Array for Real-time Geostrophic Oceanography (ARGO) program, are used to understand the currents at 800 m underwater in the southwestern East Sea. The flow penetrates into the Ulleung basin (UB) through two paths: an extension of the southward flowing the North Korean Cold Water along the east coast of Korea and between Ulleung Island and Dok island. Flows at 800 m are observed range 0.2 to 4.29 cm/sec and the variability in the north in the UB is stronger than that in the south. The eddy kinetic energy is found a few $cm^2 s^{-2}$. In the UB, cyclonic flows from 0.3 - 1.6 cm/sec are observed with the bottom topography.

Key words: Autonomous profiling float, Deep current, Ulleung Basin, East/Japan Sea

1. Introduction

The deep water in the East Sea is characterized by the homogeneity in temperature and salinity. This character makes a difficulty in deducing the deep flow field from the dynamics. A large number of studies have been carried out to investigate the water circulation in this area from the hydrographic data [7, 12]. However, most of these studies focused on the circulation in the surface or near surface; consequently, we need to do more study on the circulation not only in the subsurface but in the deep water as well. Recently, [1] have studied the mean circulation pattern in the East Sea from direct current measurements. And a schematic diagram of the deep water circulation in the East Sea was suggested by [13] from lots of deep sea current data directly observed by current meter moorings.

New observation instrument, called the Autonomous Lagrangian Circulation Explorer (ALACE), is developed for the measurement of the current in the submerged water [3-4].

Some researches used these neutrally buoyancy floats, for example, RAFOS float for deep cross equatorial flow in the Atlantic [11], ALACE for mid-depth circulation in the tropical and South Pacific [5] and for the intermediate depth circulation in the tropical Atlantic [14]. In the East Sea, [10] devised a new method to remove the errors in the estimated location and time from APEX, and estimated the velocity at the depth of 800 m after processing to minimize some kinds of errors.

In this paper, APEX floats launched by Meteorological Research Institute (METRI) of Korea Meteorological Administration (KMA) have been used to describe the mean flow and variability of the Upper East Sea Proper Portion of the Water (about 800 meter) in the southwest of the East Sea.

2. Data

As part of ARGO Program, METRI launched 3 floats in 2001, and 5 floats in 2002 in the southwestern East Sea. Two floats of them ran aground on the continental shelf within the span of about 3 months and another two floats launched in 2002 ran out the UB. And eleven floats, equipped with SBE-41, were deployed by the Ministry of Maritime Affairs & Fisheries (MOMAF) through the Korea Ocean Research & Development Institute (KORDI). In this study,

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APEX data obtained in and around the UB within about 2 years have been analyzed (Table 1).

METRI-APEX floats were programmed to surface after six and half a day periods of dritr at depth of approximately 800 dbar but KORDI-

Table 1. Information of APEX floats and data used in this study.

Argos ID (WMO ID)	Date of Deployment	Location of Deployment		Period of Data (month)	Drifting depth (m)	Cycle (day)	Launched by
24890(2900170)	Oct. 22, 2001	37.58	130.52	12	800	7	METRI
24892(2900171)	Oct. 22, 2001	37.58	129.90	22	800	7	"
24680(5900193)	Aug. 2, 2002	38.28	129.40	11	800	7	"
24681(5900194)	Jul. 30, 2002	38.10	130.37	11	800	7	"
24682(5900195)	Jul. 31, 2002	35.59	131.51	11	800	7	"
24683(5900196)	Jul. 31, 2002	37.30	131.73	11	800	7	"
23734(2900204)	Oct. 19, 2001	38.52	129.50	21	700	10	KORDI
18543(-)	Oct. 13, 2001	37.3	131.43	10	700	10	"
18544(2900202)	Oct. 14, 2001	37.23	131.90	19	700	10	"
18545(2900203)	Oct. 14, 2001	37.30	131.72	16	700	10	"
04664(2900205)	"	36.00	130.00	20.5	700	10	"
04665(2900206)	"	36.17	130.17	16.5	700	10	"
04666(2900207)	"	36.17	130.33	20.5	700	10	"
04684(2900209)	Sep. 02, 2002	36.00	130.33	10	700	10	"
04252(2900225)	Sep. 02, 2002	36.00	130.50	10	700	10	"

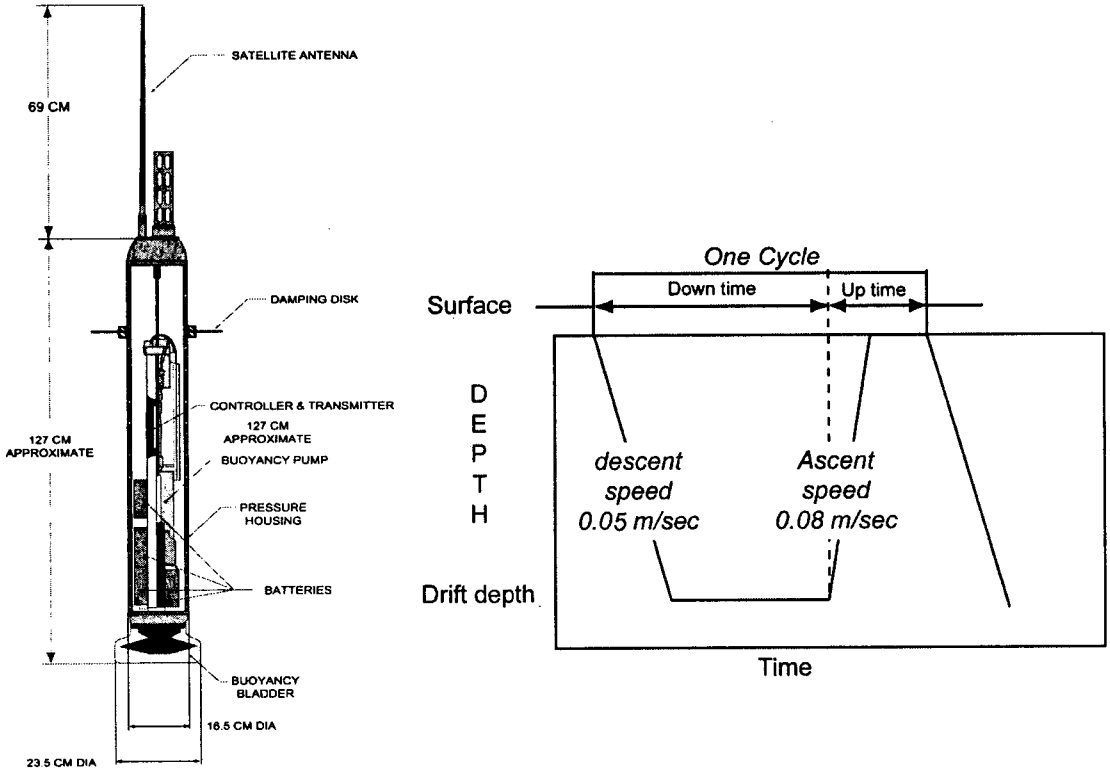

Fig 1. APEX schematic (left panel) and an observation cycle of the profiling float (right).

APEX float 700 dbar. During their ascent to the surface from the parking depth, temperature and salinity profiles are obtained at preset pressures and transmitted during half a day surface period. The transmitted data including the float status information as well as the location information are collected from the ARGOS data transmission system [2].

Afterwards they return to the parking depth for the next mission.

3. Flow Pattern

3.1. General pattern

From the pattern of flow on Plate 1, it is apparent that flows at 800 m are spatially complex. Flows at 800 m generally are parallel to the coast with southward or southeastward flow and are directed through between Ulleung island and Dok island after sinking around the polar front.

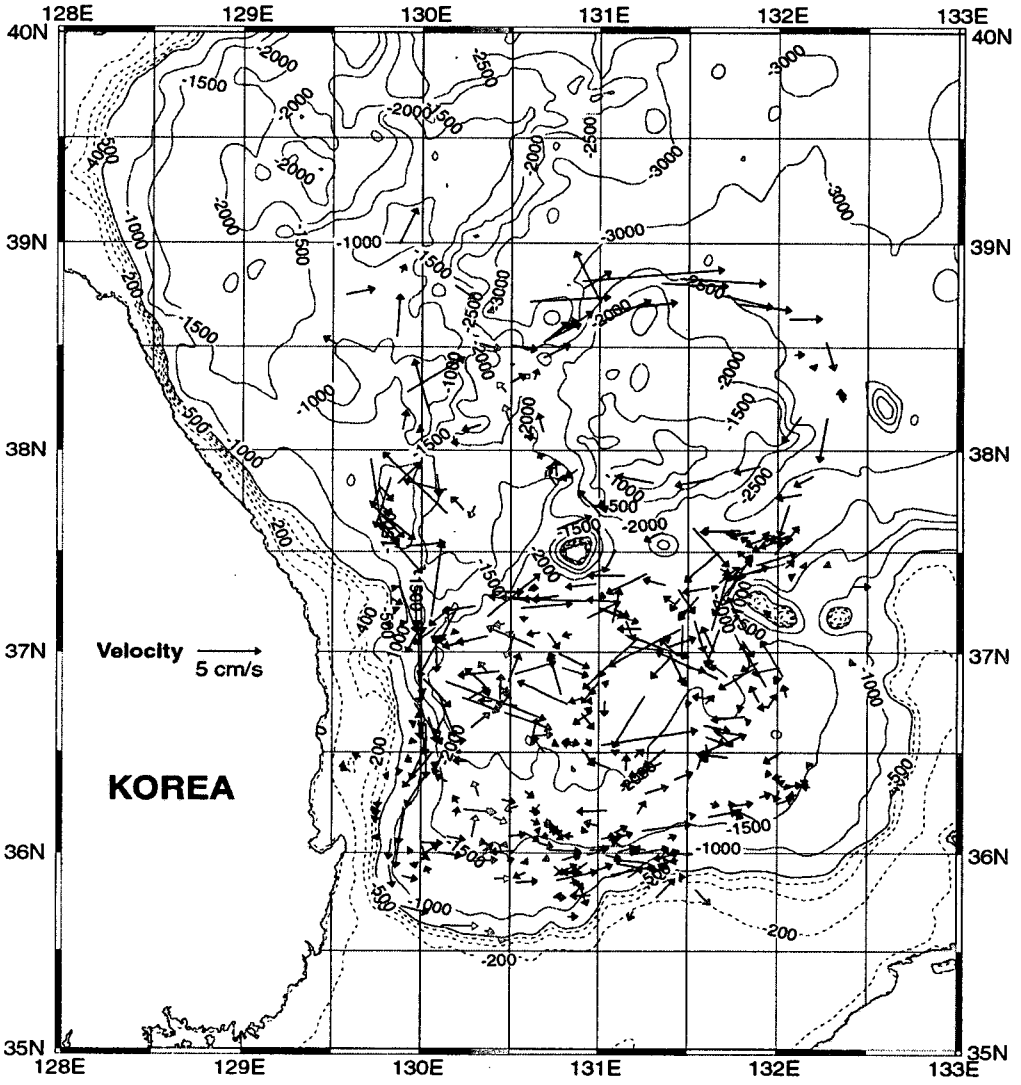

Plate 1. Deep current field at 800 m observed by APEX profiling floats.

The mean flows entering into through the off coast and east of the Ulleung island have a mean speed of 2.4 cm/sec and 0.8 cm/sec over the period of observation, respectively. In the UB cyclonic flows from 0.3 - 1.6 cm/sec are observed with the bottom topography.

Floats 24680 and 13544 looped in an anti-cyclonic flow centered near the Korea Plateau during the summer season.

3.2. Mean circulation and variability

To compute mean vectors and variability of the Lagrangian flow at 800 meter, we group to bin the data in 0.5° x 0.5° square grids. We calculate vector averages and kinetic energy of mean velocity on all boxes containing more than 2 vector values and represent mean velocity in each box on Plate 2. The mean kinetic energy (MKE) and eddy kinetic energy (EKE) are calculated in

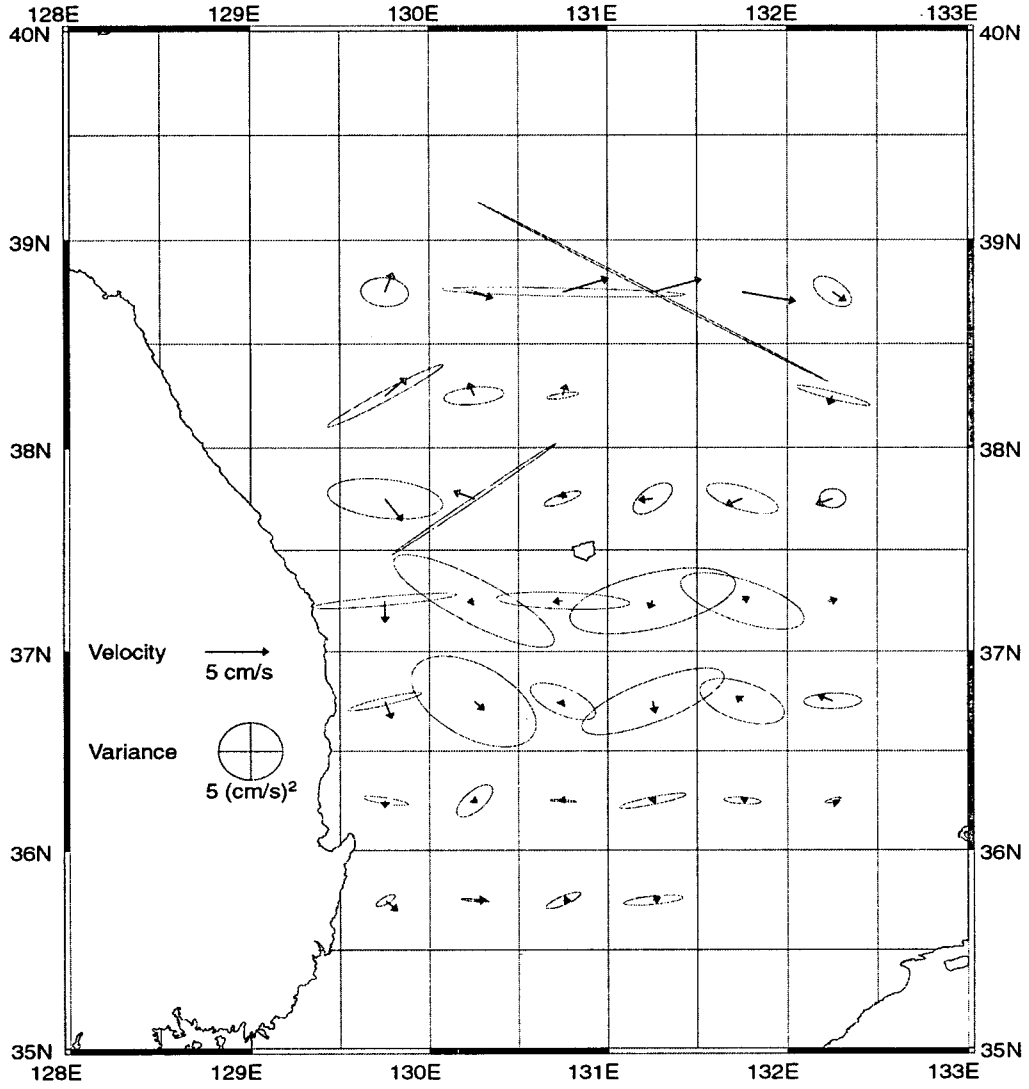

Plate 2. Mean velocity vectors (cm/s) and principal standard variation ellipses (cm^2/s^2) at 800 m from 0.5° x 0.5° binned.

the same way as [16] did in the North Atlantic and [8] in the Oregon coast. For each box, the deviation u' (west-east direction) and v' (S-N direction) from the mean (u, v) allow to determine the MKE and EKE per unit mass as follows:

$$MKE = (u^2 + v^2) /2$$
$$EKE = (u'^2 + v'^2) /2$$

It is found that mean MKE and mean EKE are just a few $cm^2 s^{-2}$ of 1.3 and 2.1 respectively. The variation of deep currents in the west part of the UB is revealed stronger than that of the east part.

4. Discussion and conclusions

The circulation of the Upper portion of the East Sea Proper Wate (UESPW) was studied using the profiling floats in the southwestern part of the East Sea during November 2001 to July 2003.

The UESPW in the Ulleung basin was formed from two intrusion; extending to the southward North Korea Cold Current flowing parallel to the coastline off the east coast of Korea, and westward flows, probably formed at the polar front parallel to 40N, between Ulleung Island and Dok Island. The entering speeds are mean speed of 2.4 cm/sec and 0.8 cm/sec in the northwest and east part of the Ulleung basin, respectively. The UESPW entering in the Ulleung basin flowed the cyclonic direction along the bottom topography and had the mean speed of 0.9 cm/s. It is found that mean MKE and mean EKE are just a few $cm^2 s^{-2}$. In addition, weak flows are found to the southward in the south of the UB, and eastward and northeastward in the east of the UB. These passages are identical to those suggested by [6] and predicted by the numerical model [15], and the mean speed is a little weaker than that of [1, 9].

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