The Dok Cold Eddy

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ABSTRACT

Remotely sensed data from a variety of sources, including inverted echo sounder travel-time measurements, satellite measured sea-surface temperature and TOPEX/Poseidon (T/P) sea-surface height anomalies, are combined with historical hydrography to examine the current and temperature patterns in the Ulleung Basin (UB) of the Japan/East Sea. The focus here is the formation and behavior of a persistent cold eddy observed south of Dok Island. This eddy, referred to as the Dok Cold Eddy (DCE), is about 60 km in diameter and originates from the pinching-off of a Subpolar Front meander. The DCE typically dwells south of Dok Island for 1-6 months before propagating westward towards Korea. When the DCE is stationary it resides between T/P ground tracks and is undetectable. However, when the DCE propagates it crosses a T/P ground track and is detectable. The DCE impacts the formation of fronts and eddies in the UB and may be related to the occasional disappearance of the East Korean Warm Current.

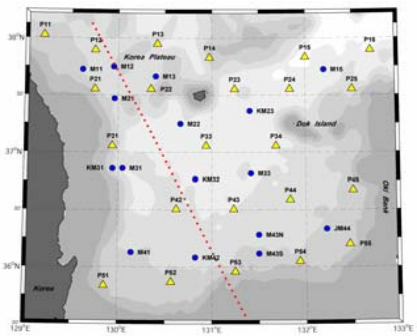


Figure 1: Bathymetry of southwestern JES and the locations of the PIES (yellow triangles) and current meters (blue circles) are shown. The ground track of TOPEX/Poseidon line 56 is marked by small red squares. Contour interval is 500m.

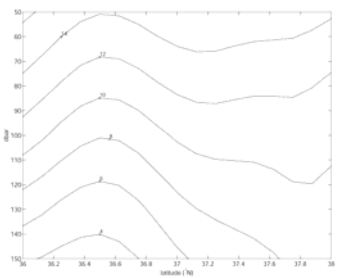


Figure 2: Average temperatures along the vertical section at 131.5° E, for the June 15 to December 11, 1999 time period. The center of the DCE is located near 36.5° N.

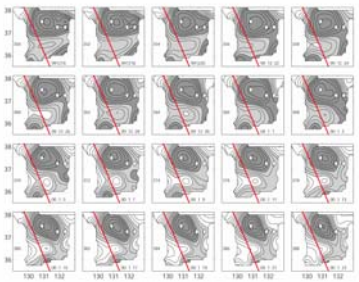


Figure 3: Maps of Geopotential height (m^2s^{-2}) (at the surface relative to 500 dbar) are shown for December 1999-January 2000 (2-day interval). Contour interval is 0.2 m^2s^{-2}. Geopotential height < 6 m^2s^{-2} is shaded white. Geopotential height > 6 and < 7 m^2s^{-2} is shaded light gray. Geopotential height > 7 m^2s^{-2} is shaded dark gray. The DCE propagated westward towards Korea in December 1999 and was absorbed by the EKWC in January 2000. The thick line is the TOPEX/Poseidon sub-orbital track. Numbers on the left are the days since Jan 1, 1999. Numbers on the lower right are the date (year-month-day).

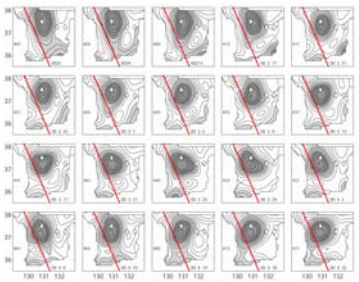


Figure 4: Same as Figure 3 for February -April 2000 (4-day interval). The DCE re-formed and remained nearly stationary until it began to propagate towards Korea on about March 25, reaching the coast of Korea on April 6, 2000.

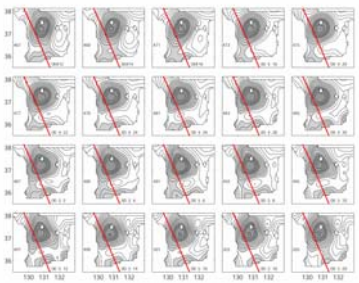


Figure 5: Same as Figure 3 for April-May 2000 (2-day interval). The DCE re-formed on April 14 and immediately propagated westward, reaching the Korean coast on about May 18, 2000.

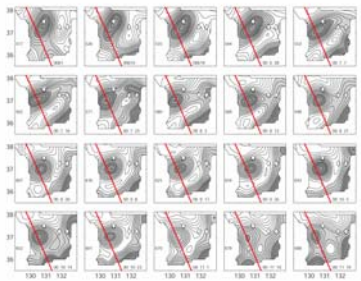


Figure 6: Same as Figure 3 for June -November 2000 (9-day interval). An extreme deepening of a meander trough of the Subpolar Front, that nearly extended to the coast of Korea in June 2000, resulted in the absence the EKWC from its northward path along the Korea coast.

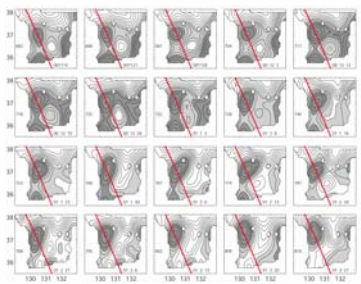


Figure 7: Same as Figure 3 for November 2000 -March 2001 (7-day interval). The DCE re-formed on about 15 November. Steep troughs in the Subpolar Front enveloped the DCE (January 29 and March 12, 2001).

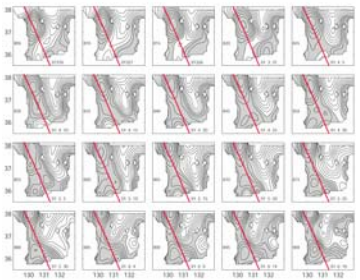


Figure 8: Same as Figure 3 for January -June 2001 (5-day interval). A steep trough in the Subpolar Front persists.

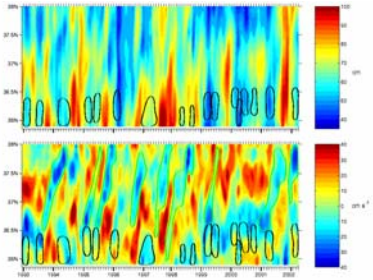


Figure 9: Top panel: geopotential height at the surface relative to 500 dbar (cm). Bottom panel: geostrophic velocity normal to T/P line 56 (positive crosses line to northeast). Black ellipses indicate the presence of the Dok Cold Eddy. Green polygons mark the presence of strong Subpolar Front meandering.

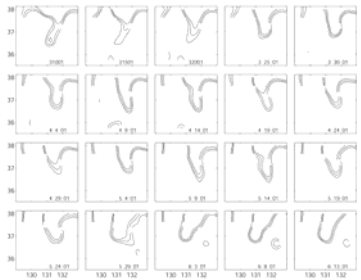
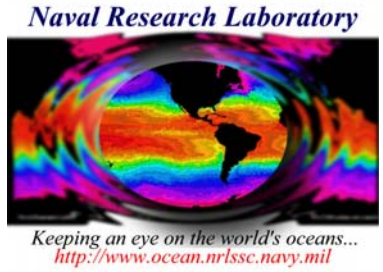


Figure 10: Geopotential height (at surface relative to 500 dbar) contours (45 cm, 47.5 cm, and 50 cm) plotted every four days from 3/10/01 through 6/13/01, showing an oscillatory, meandering trough of the Subpolar Front.

Conclusions

Meandering of the SF and resulting formation of the DCE are common occurrences in the UB. The DCE, with a mean diameter of 60-80 km, typically forms when a large meander of the SF between Ulleung and Dok Islands pinches off. The DCE, though highly variable in space and time, is a semi-permanent feature generally located southwest of Dok Island.

The shedding of a DCE likely occurs due to a combination of baroclinic and barotropic instabilities. The baroclinic instability process appears to be initiated in either of two ways: (1) the growth of the Ulleung Eddy, due to transport increases through the Korea/Tsushima Strait, narrows the meander neck; (2) the separation angle of the EKWC, which may be determined by the ratio of momentum transport of the EKWC to the NKCC, approaches 90° when the transport of the NKCC becomes much greater than that of the EKWC. The large separation angle causes the meander neck to narrow because the eastern side of the meander is constrained by the Oki Spur and the western side, due to inertial considerations, can not turn south soon enough to maintain the meander width. In both cases, the beta-Rossby number (the ratio of relative vorticity advection to planetary vorticity advection, given by $Q = v/\beta L^2$, where v is a typical particle speed through the meander, β is the northward gradient of the Coriolis parameter, and L is the width of the meander (~60-100 km), which is determined by the meander width here, increases to a value greater than eight indicating that baroclinic instabilities are likely a contributing factor to the shedding of the DCE. Nine years of T/P data indicate that the development of a large separation angle of the EKWC is the more likely means for initiating the instability processes (seven out of nine occurrences between 1993 and 2001 as seen in Figure 9).

The DCE either propagates westward until it meets the EKWC off the coast of Korea, or remerges with a meander of the SF. However, when the meander retreats, another DCE may be shed. The DCE was more variable during the second measurement year than during the first year and on several occasions propagated westward, eventually merging with waters off Korea. The DCE can deflect the EKWC, sometimes stopping the northward flow entirely, and hence strongly affecting the circulation of the entire UB (seen in 1993 and 2000 by T/P, see Figure 9).

The meandering of the SF, transport fluctuations of the NKCC, and flow through the Korea/Tsushima Strait clearly have a strong impact on the circulation of the UB. The DCE can have a large impact on the path of the EKWC and the Ulleung Eddy. Hence, westward propagation of the DCE and SF meandering are expected to have a large effect on UB circulation and fisheries. Monitoring of the DCE through a combined analysis of in situ observations with satellite altimetry could lead to forecasting capability for oceanographic conditions off the coast of Korea and in the southern JES.