Seasonal variability of Eulerian tracer dispersal in an estuary and a continental shelf margin

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Abstract. Coastal marginal seas and estuaries are generally dumpsites for wastewater from sewage and power plants (e.g., Uchiyama *et al.*, 2014). Accidental leakage of toxic materials may result in serious hazardous incidents that should be predicted and assessed urgently upon the occurrence. We thus develop an offline passive tracer model by exploiting oceanic reanalysis outcomes and analyze differences in spatiotemporal variability of the leaked tracers in an estuary and a continental shelf margin on the Pacific side of Japan. In the estuary, tidal oscillations enhance short-term dilution locally, while the month-long transport is dominated rather by inter-seasonal variability of the clockwise circulation of the estuarine through flow. On the marginal coast, the Kuroshio and associated secondary lateral circulation readily traps the tracer, leading to immediate transport mostly in the alongshore direction. The seasonal difference in the tracer dispersal is apparent such as sporadic offshore tracer eruption episodes, depending on the locations of the Kuroshio axis.

Keywords: ROMS, coastal dispersal, offline tracer model, Eulerian passive tracer

1. Introduction

It is generally true in Japan that nuclear power plants and sewage treatment plants are located mostly in the coastal areas. If accidental leakage of toxic materials occurs, it may cause hazardous influences on marine environment. We therefore develop an offline passive tracer model that computes 3-D dispersal of arbitrary Eulerian tracers with a point source capability by exploiting 3-D oceanic model reanalysis and prediction such as JCOPE2 (Miyazawa *et al.*, 2009) as an urgent oceanic assessment tool. An advantage of the offline tracer model over simultaneous (*viz.*, online) simulations of hydrodynamics and tracer transport is its computational efficiency that is requisite for immediate forecasts. The offline model is applied to investigate seasonal variability of tracer dispersal released from two particular sites as test cases. We choose 1) Ikata in Ehime Prefecture located on the Iyo Sea coastline in the western part of the Seto Inland Sea (hereinafter SIS), and 2) Hamaoka in Shizuoka Prefecture is on the Pacific coast which is an open coast affected by the transient Kuroshio. Mimicking the oceanic leakage upon the accident occurred at the Fukushima Dai-ichi Nuclear Power Plant in

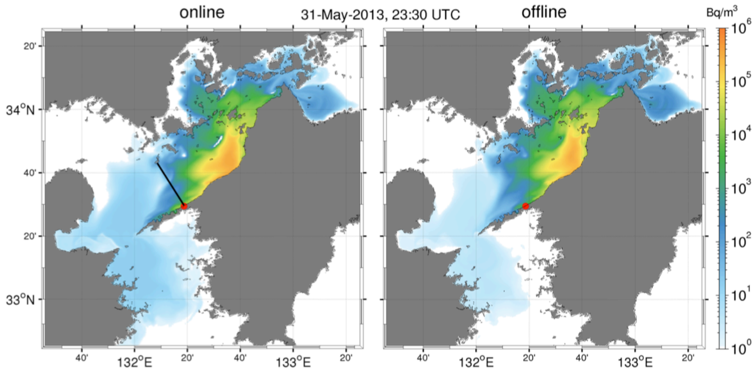

Fig.1 Surface tracer concentrations in Bq/m^3 for the online (left) and the offline (right) cases on the 31st days since May 1st, 2013. The release site (red circle mark) corresponding to the Ikata NPP in the Iyo Sea. The black line denotes the transect used in **Fig.2**.

the spring 2011, the tracer is discharged for 11 days in 4 different seasons since the 1st days in Feb., May, Aug., and Nov., 2013, and is tracked for 31 days after each release.

2. Reproducibility of the offline tracer model

The offline computation is carried out for each site by using the pre-computed 3-D flow field with a double-nested JCOPE2-ROMS oceanic downscaling model of the SIS. **Figure 1** shows comparison of the surface tracer concentration in Bq/m^3 on the 31st model day in the spring (May) condition in the Iyo Sea by the online tracer model (left) and that by the offline tracer model (right). Both the cases exhibit a similar dispersal pattern where the northeast-ward transport is dominant, demonstrating that the offline model agrees well with the online model. The offline computational cost is significantly reduced by about 1/20 compared to the online model. The offline model is suitably run on a single quad-core CPU workstation, whereas the online model needs a LINUX cluster for a reasonably short computational time.

3. Seasonal tracer variability in the SIS

In May (spring) and August (summer), the tracer is mainly transported northeastward while the southwestward transport is predominant in November (fall) and February (winter). In general, the subtidal mean circulation in the SIS is persistently clockwise (e.g., Uchiyama et al., 2012) that leads to the northeastward transport. The monthly mean temperature along the transect off Ikata (the black line in **Fig.1**) represents that a cold core water mass exists at depth within 5-60 m below the surface in May (**Fig. 2**). This structure corresponds to the so-called “cold dome” (Chang *et al.*, 2009) which is the remainder from the cold water formed in winter and has regularly observed in the Iyo Sea (as well as the Harima Sea and the Suo Sea where the basins are semi-isolated by shallow straights) during spring and summer. A counter-clockwise lateral circulation near the surface is thus developed geostrophically by this density structure (**Fig.2**), promoting the northeastward tracer transport. The cold dome

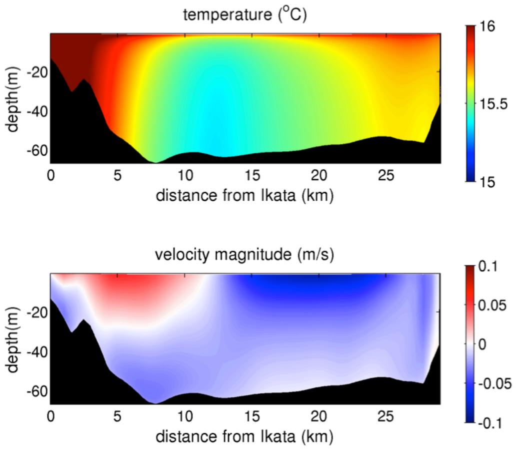

Fig.2 Cross-sectional plots of the monthly-mean temperature (upper) and northeastward velocity (lower) along the transect (the black line in **Fig.1**) in May, 2013.

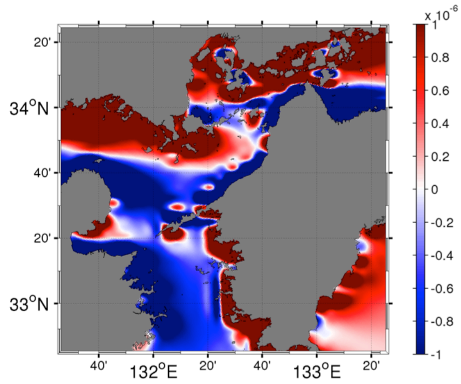

Fig.3 Monthly-averaged wind stress curl (N/m^3) in the western part of the SIS in Nov., 2013.

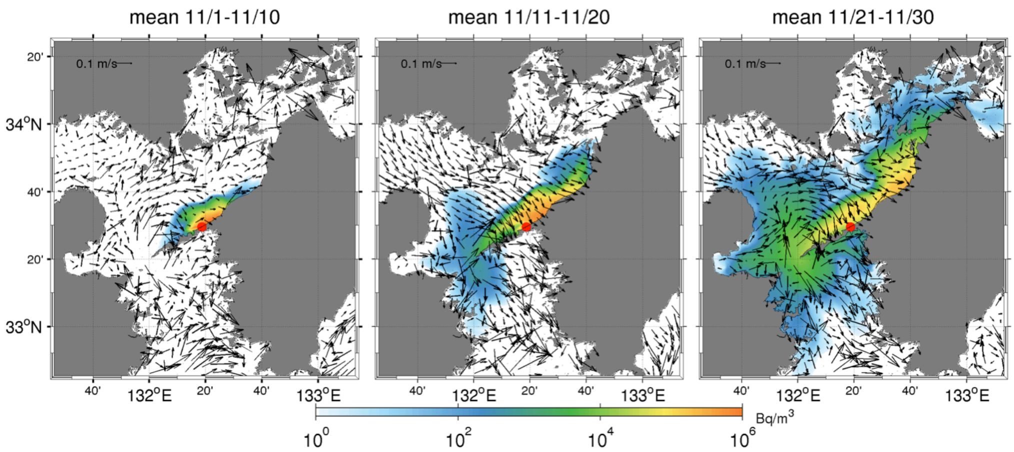

Fig.4 Sequential plots of the 10 days-averaged results from the offline case in Nov. (fall), 2013. Surface velocity vectors are plotted on surface tracer concentration in color.

keeps staying in the Iyo Sea to maintain the counter-clockwise circulation until summer (Aug.). In contrast, in fall and winter, seasonal southeastward wind is predominant and southwestward Ekman transport is developed accordingly. In November (**Fig. 4**), a divergent pattern in the surface wind is formed near the shore characterized by a partial northeastward dispersal, while it is not that obvious in February when the southwestward transport is evident. The tracer bifurcation occurred in the middle of the Iyo Sea is affected by the bifurcating wind stress curl (**Fig. 3**). Change of the sign occurs in the Iyo Sea that promotes the separating dispersal pattern in November, whereas the weak and positive stress curl is widely distributed in the entire Iyo Sea in February (not shown).

4. Seasonal tracer variability in the Pacific coast

The comparative offline tracer computation is conducted for the open coast condition affected significantly by the Kuroshio. The tracer is released from Hamaoka near Cape Omaezaki in the same way as the SIS cases. The location of the transient Kuroshio axis near the coast lines plays a key role in the tracer dispersal (**Fig. 5**). The secondary circulation develops between the Kuroshio and the coastline readily traps the released tracer, promoting the eastward transport with sticking to the shore around the release site in May. In the late May, a cyclonic gyre is enhanced off Hamaoka, resulting in the westward transport with inflowing flux into the Ise and Mikawa Bays. However, once the Kuroshio largely meanders in November, the secondary circulation grows seaward to form a large gyre and standing mesoscale eddies, inducing predominant eastward transport along with sporadic diluted southward transport far to the offshore by about 32^{o}N. The shore-attached transport is found also in February, although the offshore episode is dominant in August, depending on the locations of the Kuroshio axis relative to the shore.

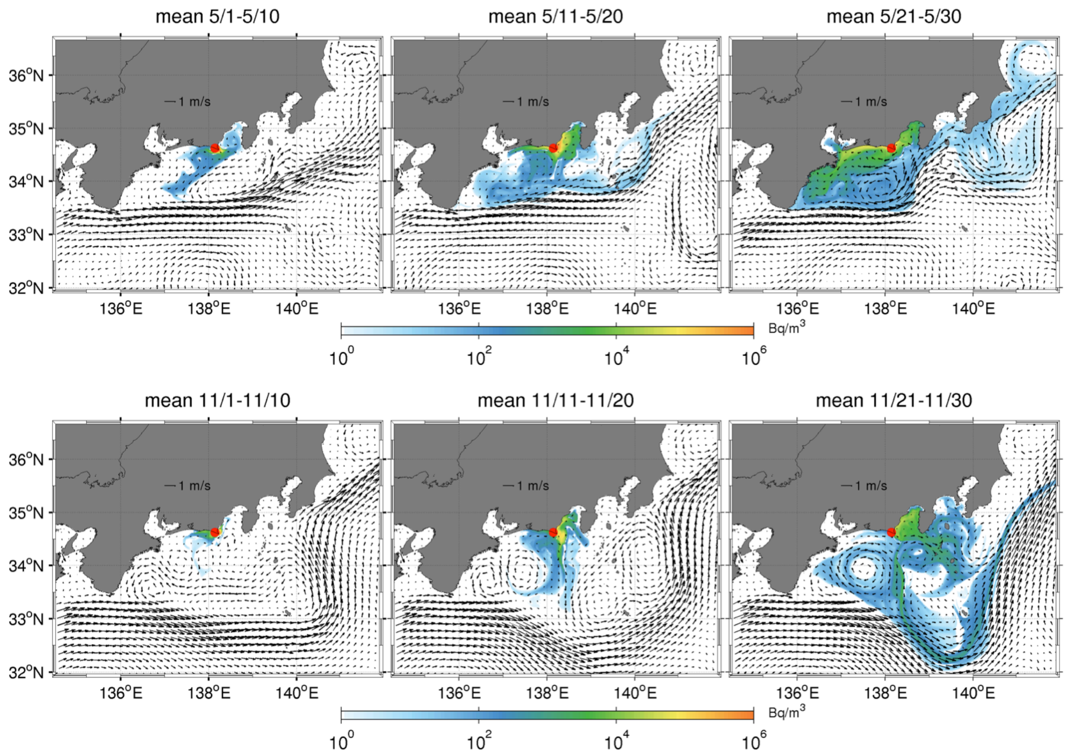

Fig.5 Same as Fig. 4 but for the Pacific offline case. May (upper row) and November (lower row) are presented.

References

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