SPILLED OIL TRAJECTORY ASSESSMENT BY USING TOPEX/POSEIDON

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KEY WORDS: Oil spill, Satellite altimetry, Along-track gradient, Geostrophic current, Ekman drift, Stokes drift

ABSTRACT

Spilled oil trajectory from the sunken tanker Nakhodka is assessed by the combination of in situ wind data and sea surface topography derived from TOPEX/POSEIDON altimeter data. Geostrophic velocities derived from along-track altimeter height gradients reveal the effect of small scale cyclonic eddy on the drifting path of Nakhodka bow section during the period of negligible wind influence. Assuming that the surface current is composed of three parameters, namely Ekman drift, geostrophic current and Stokes drift, the sum of these parameters could explain 75% of the east-west component and 86% of the north-south component of the observed drifting speed.

1 INTRODUCTION

On January 2, 1997 the Russian tanker Nakhodka sunk in the southern part of Japan Sea, which caused the worst oil spill disaster ever before along the coast of Japan Sea. At the time of the accident the tanker was divided into the bow section and the other part. The latter sunken at the depth of 2500 meters contained about 10000 kilolitre of heavy oil and continued to spill afterward. The bow section with spilled oil drifted in the southeast direction and arrived at the coast of Japan Sea within a week. It is urgently needed that the spilled oil trajectory should be estimated with good accuracy so that the countermeasures to conserve the water quality and the ecosystem along the coast of Japan Sea must be taken. The purpose of the study is to evaluate the path of Nakhodda bow section based on the in situ and the along-track altimeter-derived geostrophic velocities.

2 SATELLITE ALTIMETER AND SHIPBOARD DATA

Figure 1 shows the study area (132E-137E, 36N-40N) with four TOPEX/POSEIDON (hereafter called T/P) orbits (pass 10,25, 188, 203 as indicated as arrows) and three observation lines of Seifu-maru (D, PM, F) of Maizuru Marine Observatory. X and △ indicate the location of sunken tanker Nakhodka and the Japan Meteorological Agency (hereafter called JMA) buoy 21002, respectively. According to the Maritime Safety Agency report (Maritime Safety Agency, 1997), the sunken part of the tanker is located at the southern part of Yamato Basin at the depth of 2500 meters. In general the collinear method is used in order to calculate the dynamic sea surface height from the satellite altimeter data (for example Kuragano and Shibata(1997), Jacobs et al.(1999)). In this study the dynamic sea surface height is derived from the sum of the mean sea surface height from the model (GFDL MOM) (Hirose,N.,1999) and the temporal anomaly from the mean sea surface height from the altimeter (Kozai, 1999). Precise corrections for the altimeter data such as tidal and atmospheric corrections are

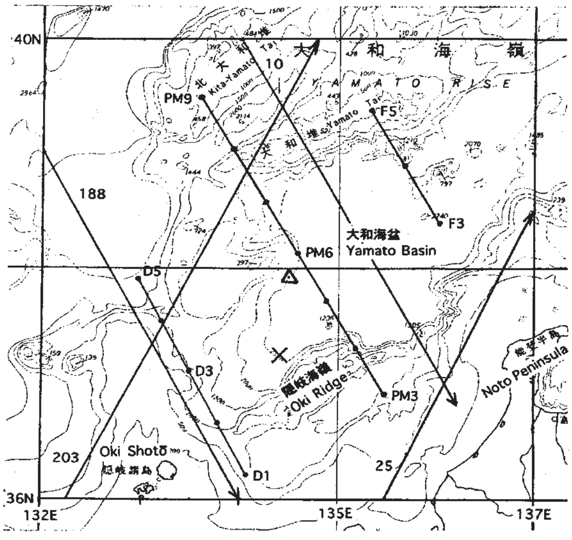

Figure 1. Study area

3 ESTIMATION OF SEA SURFACE TOPOGRAPHY

Based on the dynamic sea surface height along the four T/P orbits sea surface topography of the study area is estimated. Though the dynamic sea surface height along the orbits is available every 6.5 km, the distance between the orbit extends more than 200 km. Furthermore the time difference of one week exists between the pass 10 and 203. An objective analysis using the distance function (Thiebaux and Pedder, 1987) is carried out to estimate sea surface topography for the study area. It is of characteristics that the estimated sea surface topography is an average in terms of spatial and temporal scales. Figure 2 shows the estimated dynamic sea surface topography derived from T/P during the drifting period of Nakhodka bow section. It can be seen that the sea surface height increases toward the coast of Japan Sea and the sea surface gradient is large around the location of the sunken tanker (X in Figure 2).

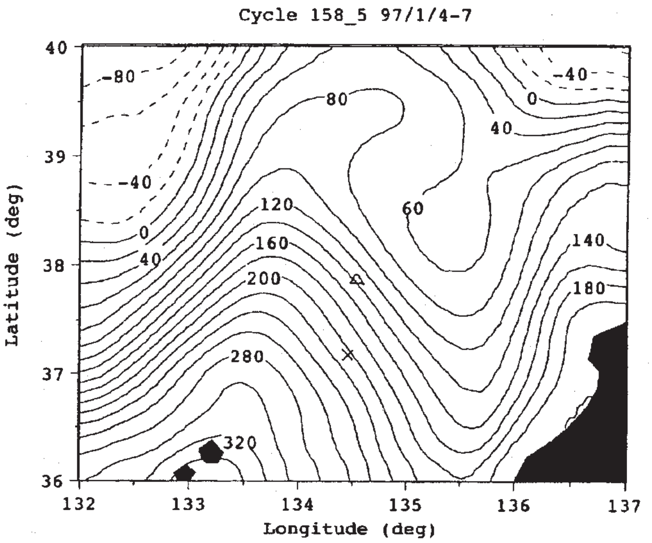

Figure 2. Estimated sea surface topography (Jan.4-7, 1997) (contour unit:mm)

4 DRIFTING TRAJECTORY AND GEOSTROPHIC CURRENT

Figure 3 illustrates the field of T/P cross-track velocities from the cycle 159 (pass 10, 25, Jan.7-8, 1997) and the drifting path of the Nakhodka bow section connected by six X along with the average wind vectors for each path observed at the JMA buoy 21002 indicated as △. Cross-track velocity Vc can be calculated as follows (Strub et al, 1997).

$$Vc(i) = -\frac{g}{f}\frac{\partial h}{\partial s} = -\frac{g}{f}\left[\frac{h(i+n)-h(i-n)}{2n\Delta s}\right] \qquad (1)$$

where Vc is the cross-track surface velocity, g is the acceleration of gravity, f is the Coriolis parameter, h is the sea surface height, s is the along-track coordinate, i is the index of the along-track grid point, and n is the half span of the centered difference. In this study a span of 10 T/P intervals (n=5) is used to produce a 65km difference.

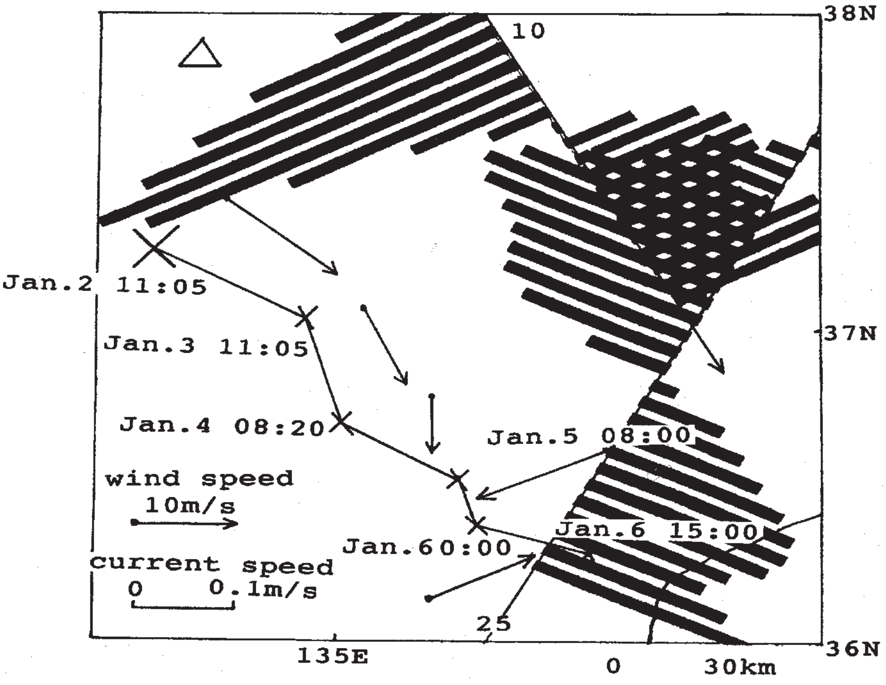

Figure 3. T/P cross-track velocities and the drifting path of Nakhodka bow section with average wind vectors.

According to the Figure 3, the drifting path of the bow section follows the wind direction from January 2 to 4, while the other paths do not necessarily obey the wind direction during the rest of the drifting periods. Especially the bow section flows toward the southeast direction though the wind speed is recorded less than 10m/s at the buoy from January 4 to 5. This is attributable to the presence of small-scale cyclonic eddy centered at 37 degrees north and 136 degrees east, which may influence most on the drifting path of January 6. In order to quantitatively evaluate these drifting paths of the bow section the surface current is assumed to be consisted of three parameters, namely Ekman drift, geostrophic current and Stokes drift(Kubota, 1994) described as follows.

$$\text{Surface current} = \text{Ekman drift} + \text{geostrophic current} + \text{Stokes drift} \tag{2}$$

Ekman drift at the sea surface is calculated following Ekman's theory and geostrophic current is derived from the cross-track velocity in the equation (1). Stokes drift is important for estimating the drifting path of the bow section. In this study 1% of the surface wind speed is used to estimate Stokes drift (Kinsman, 1965). Figure 4 shows the contribution of each parameter to the observed drifting speed in the u-component (east-west direction) and the v-component (north-south direction) during each drifting period. It is clearly seen that the contribution of Ekman drift is very small in both components and especially gives negative effects in the u component. The sum of Ekman drift and the geostrophic current is indicated at the third bar from the left of each drifting period. Compared with the Ekman drift alone, these sums contribute to the greater proportions in both components. Last of all the sum of Ekman drift, geostrophic current and Stokes drift is given at the right bar of each drifting period. Except the period from January 5 to 6 where the wind speed decreases less than 10m/s and the wind direction becomes variable, these sums could explain 75% of the u component and 86% of the v component of the observed drifting speed.

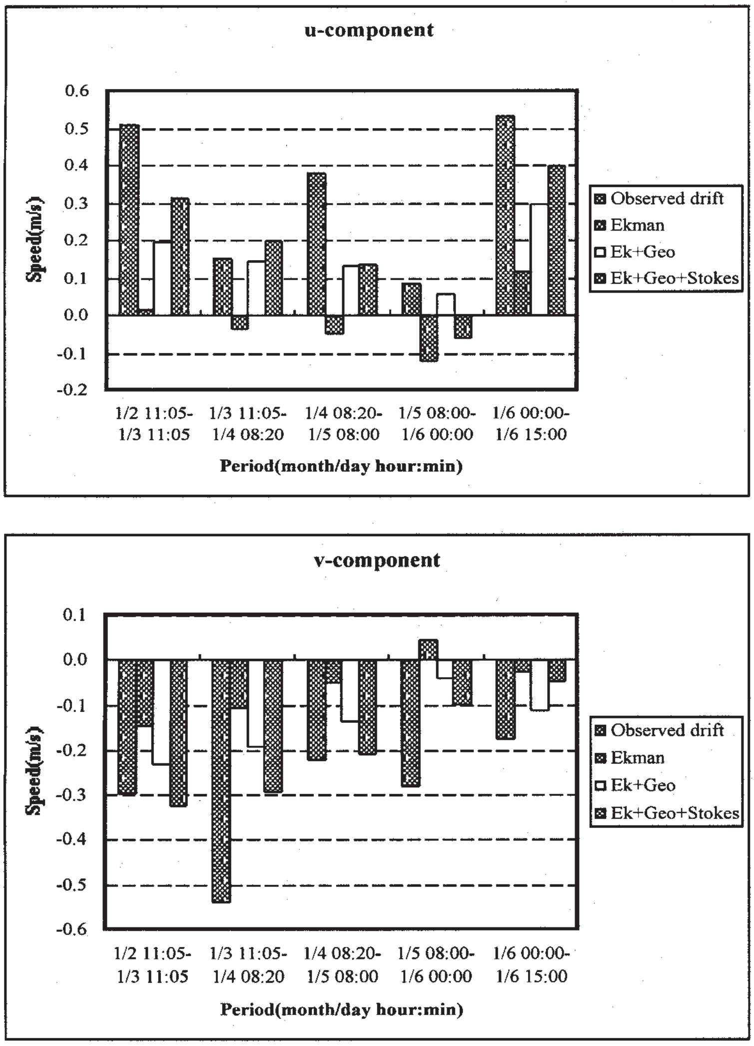

Figure 4. Contribution of Ekman drift, geostrophic current and Stokes drift to the observed drifting speed in the u-component (east-west direction) and the v-component (north-south direction).

5 CONCLUSIONS

Based on the results and discussions above the summary is given as follows.
(1) Spilled oil trajectory from the sunken tanker Nakhodka is assessed by the combination of in situ wind data and sea surface topography derived from TOPEX/POSEIDON altimeter data.
(2) Geostrophic velocities derived from along-track altimeter height gradients reveal the effect of small scale cyclonic eddy on the drifting path of Nakhodka bow section during the period of negligible wind influence.
(3) Assuming that the surface current is composed of Ekman drift, geostrophic current and Stokes drift, these sums could explain 75% of the u component and 86% of the v component of the observed drifting speed.

ACKNOWLEDGEMENTS

The author would like to express sincere gratitudes to the following institutions and personnels for their helpful assistance in providing various datasets; the oceanographic department of Maizuru Marine Observatory, JMA, Mr.Oku of Maritime Safety Agency, the buoy robot team of JMA, Mr.Nishizawa of Kobe Marine Observatory, NASA/JPL/PODAAC and Dr.Hirose of NASA/JPL. This study is supported by a Grant-in-Aid for Scientific Research 10680503 from the Ministry of Education, Science, Sport and Culture, Japan.

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