6.9 Oil Spill Prediction Model

6.9.1 Introduction

A large-scale oil spill from the Russian tanker "Nakhodka" occurred in the Japan Sea in January 1997. It brought heavy damage to the environment along the western coastline of the Japanese major island Honshu. After the incident, countermeasures against large-scale oil spill events were examined in the Japanese Government. The importance of oil spill prediction accompanied by information on meteorological and oceanographic conditions was widely recognized.

Accordingly, an oil spill prediction model for the offshore deepwater seas where tidal current is negligible was developed in JMA, to help the Japan Coast Guard conduct emergency response operations for an actual oil spill event. The prediction model is applicable to the entire western North Pacific. The domain of calculation is variable between 0.8×0.8 degree and 12×12 degree, which is determined under the incident circumstances. The model is based on particle tracking technique, i.e., spilled oil is represented with multiple particles.

6.9.2 Governmental equation

An oil spill prediction model is generally described in the following equation including the terms of advection and diffusion,

$$\frac{dC}{dt} = \frac{\partial C}{\partial t} + \boldsymbol{V} \bullet \nabla C = \nabla \bullet (K \nabla C) + S \tag{6.9.1}$$

where C is the concentration of the pollutant, t is time, $\boldsymbol{V}$ the advection velocity, K the turbulent diffusion coefficient, and S (called the source term) represents processes to change the total amount of the spilled oil through the change of oil properties.

In the advection term, effects of the surface wind, the ocean wave, and the ocean current should be taken into account. Ekman drift current is generated by the sea surface wind, and given as 2.5% of the wind speed with an angle of 15 degree clockwise with respect to the wind direction. The Stokes drift, which is net movement of particles at the sea surface to the traveling direction of the wave with back and forth motion in each wave cycle, is calculated by the following equation.

$$u_w(z) = \frac{\omega k a^2 \cosh(2k(H-z))}{2\sinh^2(kH)} c_p \tag{6.9.2}$$

where H is the water depth, $\omega = 2\pi/T_w$ the angular frequency, $k = 2\pi/L_w$ the wavenumber, $a = H_w/2$, $c_p = g/2\pi f = gT_w/2\pi$ the phase velocity of the wave, with H_w (m) the wave height, T_w (s) the wave period, L_w (m) the wavelength, f (s^{-1}) the wave frequency and g (m/s^2) the acceleration due to gravity.

In the source term, the processes of evaporation and emulsification are taken into consideration. The process of vertical mixing is also included in the model as a part of the diffusion term. Specifications of the oil spill prediction model and references are shown in Table 6.9.1.

Table 6.9.1 Specification of the oil spill prediction model.

Applicable area		10S-65N, 120E-180E
Domain of calculation		Variable (0.8×0.8 – 12×12 degrees)
Grid spacing		Variable (2-30 km), according to the domain of calculation
Number of grids		41×41
Prediction period		192 hours
Physical and chemical process	Advection	Ekman drift (estimated from wind field of Global Spectrum Model) Stokes drift (estimated from wave field of Global/Coastal Wave Models) Ocean current (Ocean Comprehensive Analysis System)
	Diffusion	Elliott (1986) etc.
	Evaporation	Fingas (1997)
	Emulsification	Reed (1989)

6.9.3 Products

The model for the western North Pacific is to be operated in the case of a large-scale oil spill in the offshore deepwater seas where tidal current is negligible. The result of oil spill prediction is provided to the Japanese Government and/or the Japan Coast Guard with the other various marine meteorological charts. An example of the prediction is shown in Fig. 6.9.1.

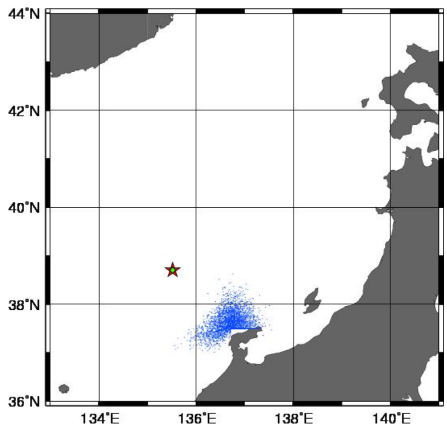

Fig. 6.9.1 An example of oil spill prediction in the Japan Sea. The star and the diamond (located at the same position in this figure) show the locations of incident site and drain source of oil, respectively, and the dots show the predicted distribution of spilled oil.

References

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