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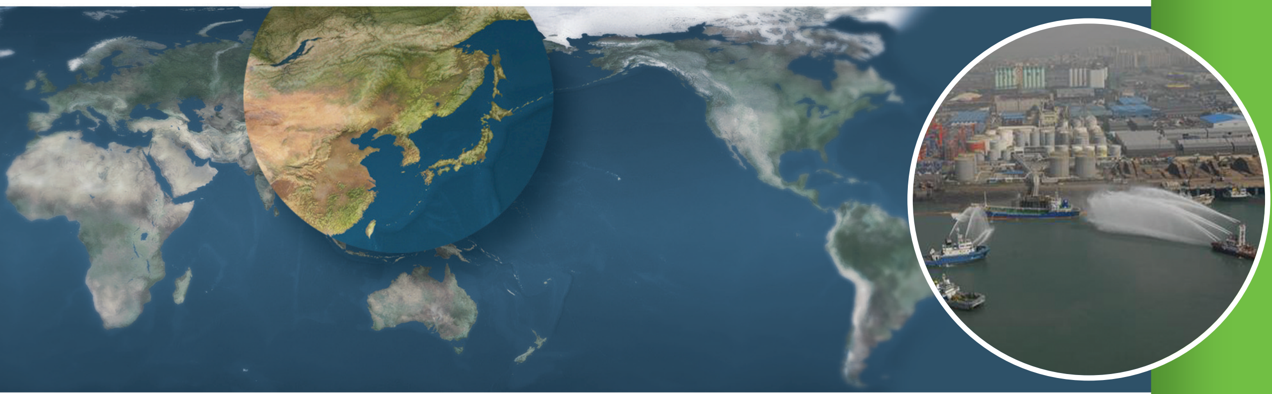
NOWPAP REGIONAL OIL SPILL PREDICTION MODEL



MERRAC Technical Report No. 4

Regional Seas

NOWPAP MERRAC

Northwest Pacific Action Plan
Marine Environmental Emergency Preparedness and Response
Regional Activity Centre

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Foreword

MERRAC, the Marine Environmental Emergency Preparedness and Response Regional Activity Centre, is one of four Regional Activity Centres of the Northwest Pacific Action Plan (NOWPAP) which was adopted in 1994 as a Regional Seas Programme of the United Nations Environment Programme (UNEP) by the People's Republic of China, Japan, Republic of Korea, and Russian Federation. MERRAC is responsible for regional co-operation on marine pollution preparedness and response in the region.

With technical support from the International Maritime Organization (IMO), MERRAC is currently functioning as secretariat for the NOWPAP MERRAC Focal Points Meeting, Expert Meeting, Competent National Authorities Meeting for NOWPAP Regional Oil Spill Contingency Plan (CNA meeting). The Centre also carries out other special activities including the management of a regional information system, organization of training and exercise, capacity building, co-ordination of research and development on the technical aspects of oil and Hazardous & Noxious Substances (HNS) spills.

As one of main outcomes of MERRAC activities, the NOWPAP Regional Oil and HNS Spill Contingency Plan (NOWPAP RCP) and its relevant Memorandum of Understanding (MoU) were developed and officially came into effect as being signed by all NOWPAP member states. The purpose of the NOWPAP RCP is to provide an operational mechanism for mutual assistance through which the member states will co-operate during major marine oil and HNS pollution incidentsin the region

In order to provide practical and technical guidelines to promptly and effectively respond to major marine pollution accidents within the framework of the NOWPAP RCP, it was agreed to carry out the series of MERRAC Specific Projects related to oil spill prediction model, minimum level of preparedness for response to oil spill in the NOWPAP region, HNS response operation guidelines, HNS database in the NOWPAP region.

Through MERRAC Specific Projects, the technical report was developed by NOWPAP MERRAC based upon the decision of 10th MERRAC Focal Points Meeting (May 2007). The Expert Group consisted of 4 experts who were nominated by MERRAC Focal Points as follows: Mr. Zhao Ruxiang (China), Mr. Taiji Imoto(Japan), Dr. Moonjin Lee (Korea, Leading Expert), Dr. Sergey Moninets (Russia), and contributed to developing the technical report. MERRAC staffs (Dr. Jeong-Hwan Oh, and Ms. Hyon-Jeong Noh) finalized and edited the report with technical support of MERRAC Focal Points, NOWPAP Regional Coordinating Unit (RCU), and IMO.

As Director of MERRAC, I would like to thank the MERRAC Focal Points and all experts of the Expert Group for their support and contributions to finalizing the MERRAC Technical Reports.

Seong-Gil Kang
Director of MERRAC

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Chapter 1. Introdution

It is crucial to predict the trajectory of spilt oil accurately for successful response operation and protection of the marine environment. The trajectory is mainly dependent on surface drift due to wind and surface current. Based on this practical need, each of the member states of NOWPAP has developed their own oil spill prediction models to respond to oil spill accidents occurring in their own regions, as reported at the Third Forum Meeting (Yuzhno-Sakhalinsk, Russian Federation, July 1999). Ten models developed in the NOWPAP Member States, three models from Japan, the People's Republic of China, and the Republic of Korea, respectively, and one from the Russian Federation, were reported together with particulars of the models such as the model name, owner, company of production, operating system, language, hardware, ocean environment database, and its covering database map.

At the Fourth Forum Meeting (Qingdao, People's Republic of China, May 2001), the lead country of this specific project, the Republic of Korea, presented an outline of the draft standard input format to an oil spill prediction model in the NOWPAP region, as agreed. The objective of this work was to develop a database to provide standardized input into the above models. At the Fourth Forum Meeting, it was recommended that MERRAC with member states develop in the next two years an integrated oil spill prediction model covering the whole NOWPAP region. For this purpose, it was also the establishment of a special group of national experts (hereinafter referred to Expert Group) for developing a NOWPAP Oil Spill Prediction Model (hereinafter referred to as OSPM) was also recommended at the same meeting. After the fourth meeting, the Republic of Korea as the lead country has continued to prepare the plan on the arrangement of an Expert Group. At the Fifth NOWPAP MERRAC Focal Points Meeting (Daejeon, Republic of Korea, May 2002), the Republic of Korea suggest a working plan for the establishment and operation of the Expert Group, including its personnel organization, purposes, missions, budget, etc.

After the Fifth NOWPAP MERRAC Focal Points Meeting, an Expert Group consisting of National Experts of OSPM nominated by each NOWPAP member was established. The purposes of the Expert Group are to collect detailed information on existing OSPMs in the NOWPAP Member States, and to analyze this information from a technical viewpoint. The Expert Group also compared and analyzed the results of the member states' OSPMs under the same scenarios of oil spill incident. After collection and analysis of information on existing OSPMs, the Expert Group will recommend one model or several models to be widely applicable for the NOWPAP region. Or, if necessary, the Expert Group will suggest guidelines for developing a new model for the NOWPAP region.

Chapter 2. General Features of OSPM

2.1. Behavior of spilt oil at sea

Oil spilt at sea is usually transported by the movement of the surface seawater due to wind, wind-driven currents, tidal currents, and quasi-steady currents, and simultaneously it diffuses by turbulence, as described in Fig. 1. Furthermore, the oil is decayed over time by weathering via complicated physical, chemical, and biological processes. The present model was established upon consideration of these behaviors of spilt oil at sea.

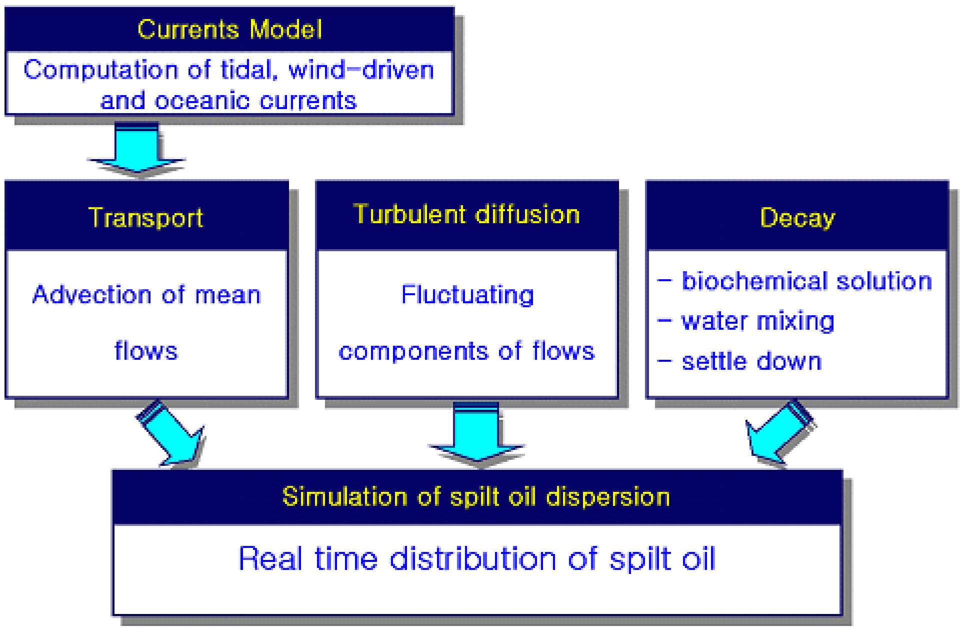

Fig. 1. *Schematic diagram of OSPM.*

2.2. Transportation

Transportation is characterized by the movement of the center of mass of the spilt oil and is independent of spreading and spill volume. The slick will move in the same direction and at same speed as the surface water. Tidal currents move the surface water, but they are cyclic with only a small residual movement of surface water in any direction. The movement of a thin layer of oil is affected to a far greater extent by wind. The exact dependence is not known with high accuracy, but movement at a rate of approximately 3% of the wind speed in the direction of the wind is to be expected. Another import factor is oceanic currents, which strongly impact residual movement in certain regions. The center of mass of the spilt oil also moves as a function of winds: this is called the leeway. Therefore, the center of mass of the spilt oil drifts as a vector sum of the surface currents and a fraction of the wind velocity.

2.3. Spreading and Diffusion

2.3.1. Spreading

Spreading of the spilt oil is generally considered in three stages in which different driving and resisting parameters play important roles: gravity-inertia stage, inertia-viscosity stage, and interfacial tension-viscosity stage. The spreading determines the initial process of the spilt oil and also is related to the following processes, such as evaporation, advection, etc. Based on Fay (1969) who experimentally suggested an empirical equation for spreading of spilt oil, we assume that the spreading processes are dominated by balances between gravity and inertia for < 5 mm thickness, and between inertia and viscosity for 5 - 10 mm thickness of the spilt oil. In cases where the thickness is greater than 10 mm, we follow the Mackay et al. (1980) model in which interfacial tension and viscosity prevails in the spreading process.

2.3.2. Diffusion

Turbulence is always present in coastal waters and oceans. It interchanges the fluid properties through fluctuations about their mean values. Where the density of the water increases strongly with depth, the strong hydrostatic equilibrium introduces different eddy sizes in the horizontal and in the vertical directions. Fluids with marked density stratification, with light fluids on top of dense fluids, are very stable; however, if there is relative motion between two layers, then the boundary between the two will deform. If the relative motion is strong, then the boundary may become unstable and turbulence ensues and mixing will occur. The process of vertical circulation being driven by vertical density differences is called convection, whereas horizontal circulation of water is called advection. Convection occurs when the air temperature drops below the temperature of the surface water. The surface water cools and sinks and is replaced by subsurface water, which also cools and sinks.

2.4. Weathering

2.4.1. Evaporation

Once an oil spill occurs, the most dominant weathering phenomenon during the first several days is evaporation, as shown in Table 1. Consequently, a significant amount of oil mass is transported into the atmosphere, and, therefore, the remaining oil mass on the sea surface gradually decreases with its properties changed. We followed the evaporation formula of Stiver and Mackay (1984), who analytically calculated evaporation using oil distillation data. The consequent change in oil's viscosity was determined using the evaporation fraction (Mackay et al., 1980).

2.4.2. Emulsification

Emulsification of oil refers to the process whereby sea water droplets become suspended in the oil, affecting the oil's properties such as density and viscosity. The emulsion thus formed is usually very viscous and more persistent than the original oil. The formation of these emulsions causes the volume of pollutants to increase between three and four times. This slows and delays other processes that would allow the oil to dissipate. Emulsification of oil depends on the relative amounts of oil components such as asphaltene, resin, and wax (Bobra, 1991). Generally, oils containing a lower percentage of asphaltene are less likely to form emulsions and are more likely to disperse. The Mackay et al. (1980) model was used in the present study for predicting this effect, in which emulsification is defined as a function of wind speed, the water content of oil, and an oil specific constant. The change in viscosity associated with emulsification is also taken into account (Mooney, 1951).

Chapter 3. Current Status of OSPMs of NOWPAP Members

In order to review and analyze the existing OSPMs of NOWPAP Members, the following information on the existing OSPMs were collected from national experts of the Expert Group in NOWPAP Members (see Annex A).

- Development of database for OSPM
- Techniques of real time prediction of currents
- Techniques of spilt oil dispersion modeling
- Display methods and items of OSPM output
- Operating system, developing language, etc.

After collection of information on the existing OSPMs, analysis and comparison of the existing OSPMs of each member state were carried out. The collected information is arranged in Annex B in detail. The results of the review and analyses of the OSPMs of NOWPAP Members are summarized below.

3.1. Japan

In conjunction with the marine accident (oil spill accident) of the Nakhodka in January 1997, a new understanding of the importance of trajectory prediction was obtained. In response to this situation, the Japan Coast Guard constructed a trajectory prediction system and a real-time database to perform accurate and prompt trajectory prediction for spilled oil.

The trajectory prediction system calculates the trajectory of drifting matter, by using the wind and current data corrected in the real-time database. This system can be operated within the limits of 15° N to 55° N in latitude and 120° E to 180° E in longitude, as shown Fig. 2. In calculating the trajectory of drifting oil, this system prepares five kinds of oil property tables (crude oil, gasoline, naphtha, A type heavy oil, and C type heavy oil.). Fig. 3 shows the oil spill prediction results of OSPM of Japan.

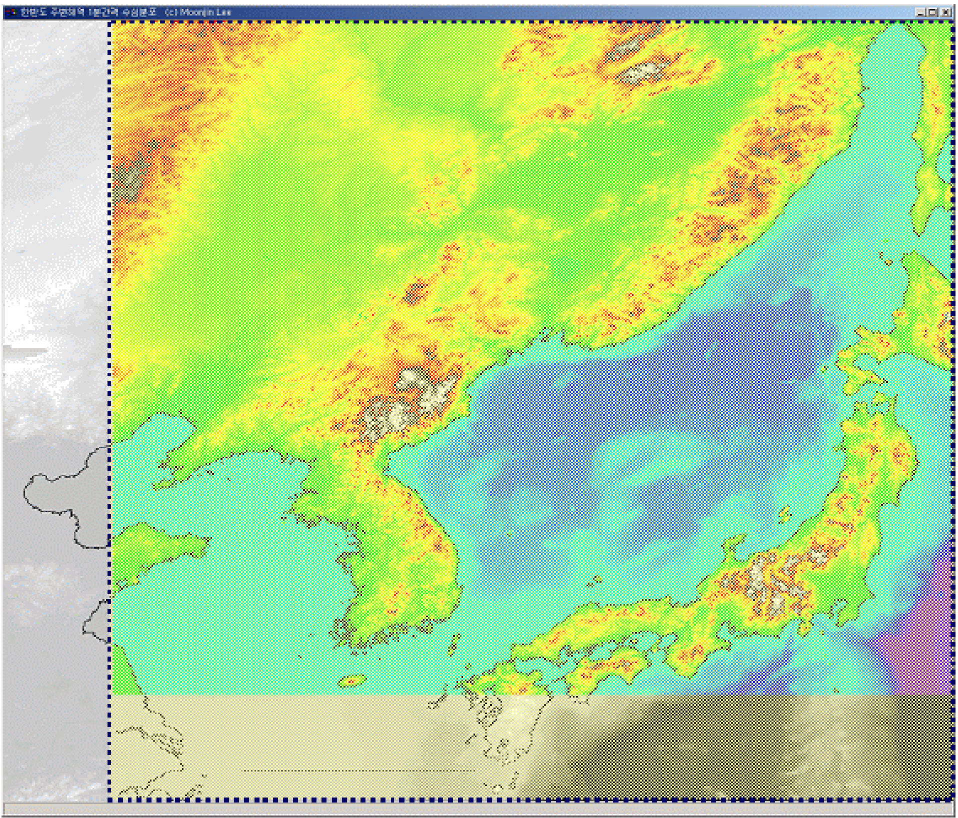

Fig. 2. *Areas of the existing OSPM of Japan.*

The real-time database was constructed in 1998, in order to collect and manage in-situ wind and ocean current data observed from vessels via anemometers, ADCP, etc. These raw data are automatically transmitted from vessels to the database, and processed to the grid data for the trajectory prediction with data from other cooperating organizations.

The features of the database are listed as follows:

1. The grid size is 10' and the data set is updated every day.
2. Blank grids are covered with monthly climatological mean data in order to fill the grids.
3. The wind forecast data over the sea are provided to the database by the Japan Meteorological Agency (JMA). JMA's forecast data contains 30'x30' grid data of wind direction and speed taken every 6 hours for 3 days.
4. In the area where the tidal current is dominant, the tidal current is calculated using the harmonic constant.

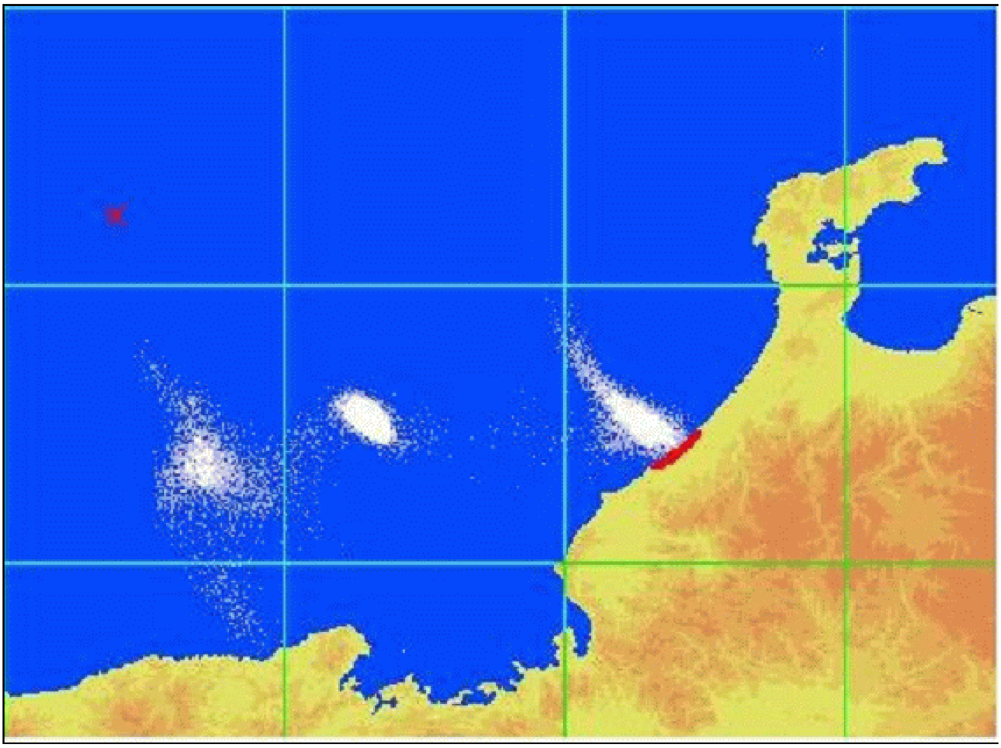

Fig. 3. *Oil spill prediction results of OSPM of Japan.*

3.2. People's Republic of China

The People's Republic of China has several OSPMs for the sea off the coast of Shandong and Jiangsu, as shown Fig. 4.

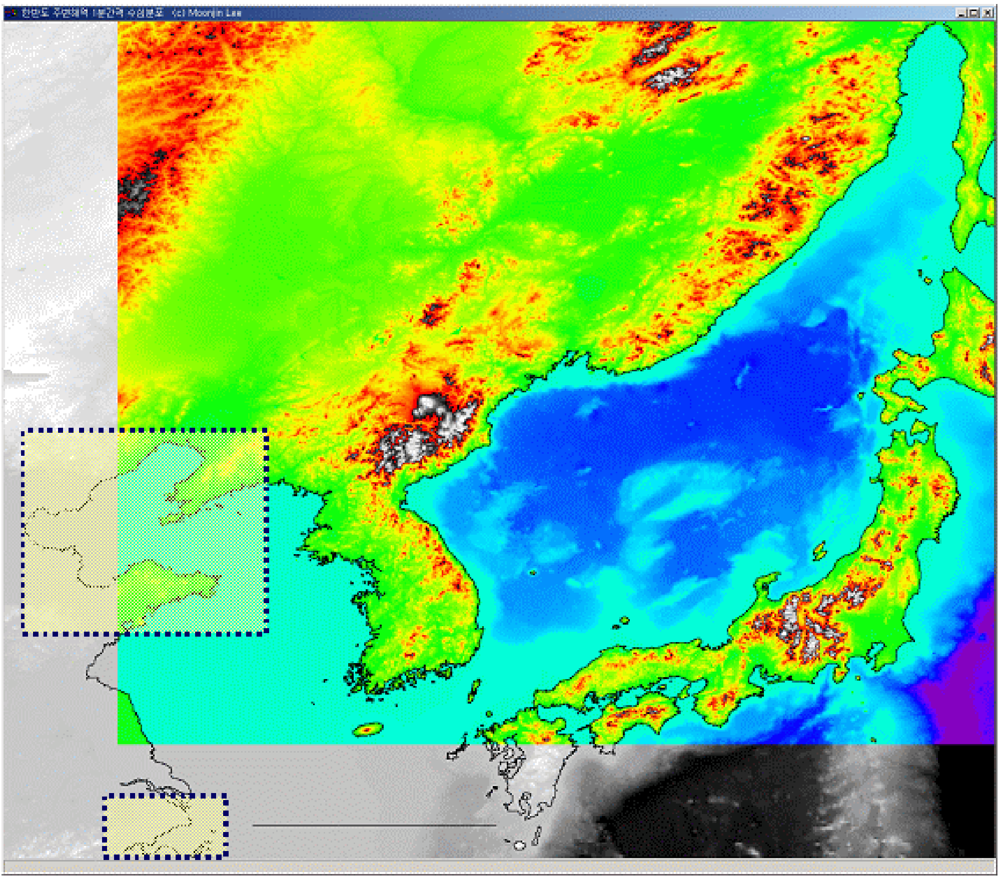

Fig. 4. *Areas of the existing OSPM of People's Republic of China.*

The Yantai oil trajectory prediction model system, one of the existing OSPMs of China, consists of three parts: an oil trajectory model system, GIS, and a notification system. It is valid in scope, as shown Fig. 5.

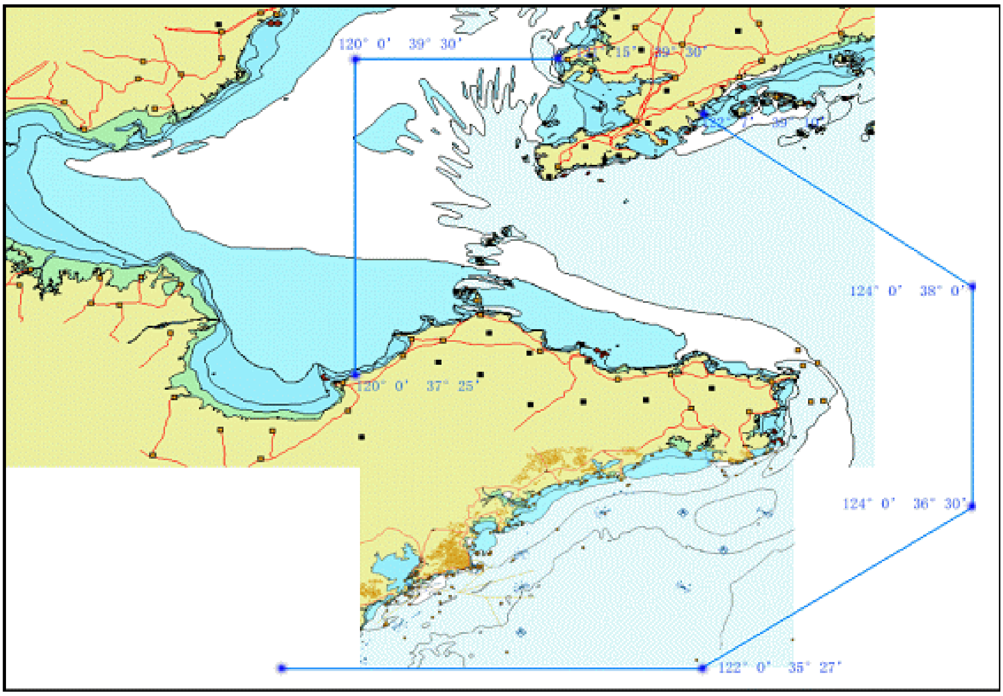

Fig. 5. *Areas of the Yantai OSPM.*

The hydrodynamic model established using the finite element method can be used to compute tidal, pressure gradient, and wind-driven motion of the water. These water currents are in turn used to calculate transport of an oil spill in and on the water. Tidal current harmonic constants (phase and amplitude) are stored in the database. Current driven oil spill transport can easily be predicted using the harmonic constant database and wind database.

A three-dimensional stochastic random-walk method and Lagrangian particle-tracking technique, wherein a certain number of particles simulate the oil on the water and move due to ocean currents and spreading or dispersion mechanisms, are used to simulate and calculate the oil spill diffusion results from turbulence and trajectories results from sea currents.

Other processes, including physical emulsification, chemical evaporation and biological degradation, are considered in the model. These processes dealt with in the model are mainly parameterized according to algorithms from the literature and laboratory.

The model system developed by China Ocean University has been applied to a variety of marine environments for use in response and contingency planning, risk assessment, and training. The system is delivered with environmental data tools and an interactive GIS that allows the user to view and enter data, run the model, and view model output. Geographical data and model output are mapped and animated on a color screen and may be printed. Tabular information may also be viewed. Locations of site-specific information (such as critical habitats or response equipment) are indicated on a map and stored in a database. An example of this system is displayed in Fig. 6.

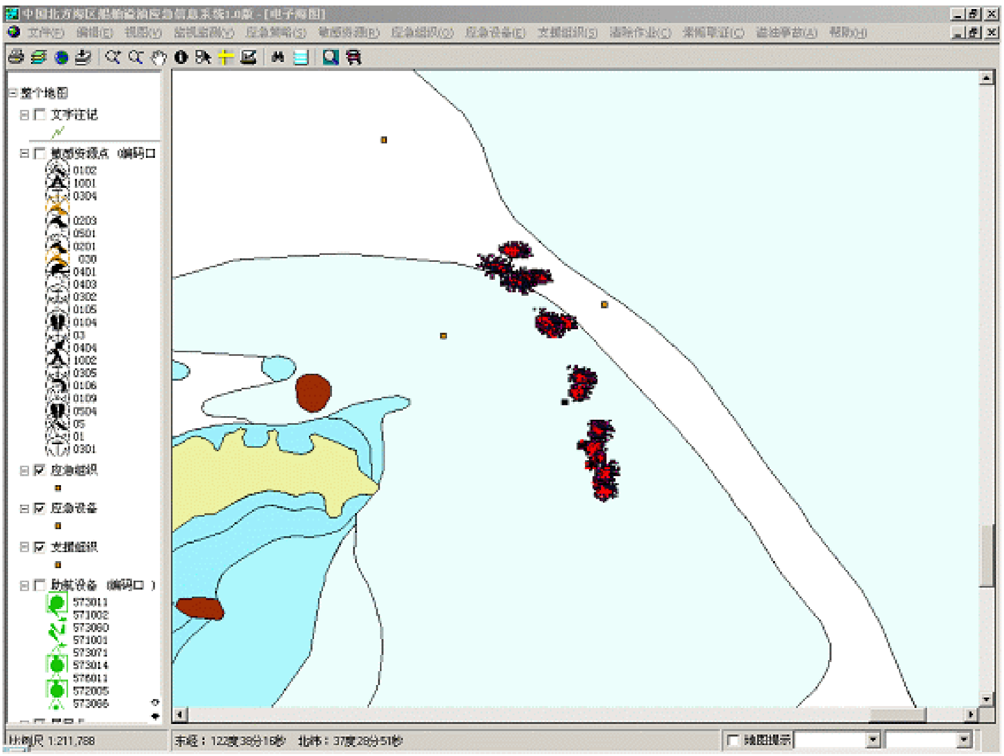

Fig. 6. *Oil spill prediction results of Yantai OSPM.*

3.3. Republic of Korea

As shown in the cases of several accidents in the mid- and late 1990s such as the Sea Prince, Honam-Sapire, and 1st Yu-il, which largely polluted the coastal zones of the Korean southern region, the Korean marine environment has been frequently threatened by large oil spills. Following the occurrence of such oil spills, the OSPM of Korea was developed for accurate prediction of the real-time trajectory of the spilt oil with the geographical scope of all Korean seas (Lee et al., 2002). The OSPM of Korea has been applied to several areas, as shown Fig. 7.

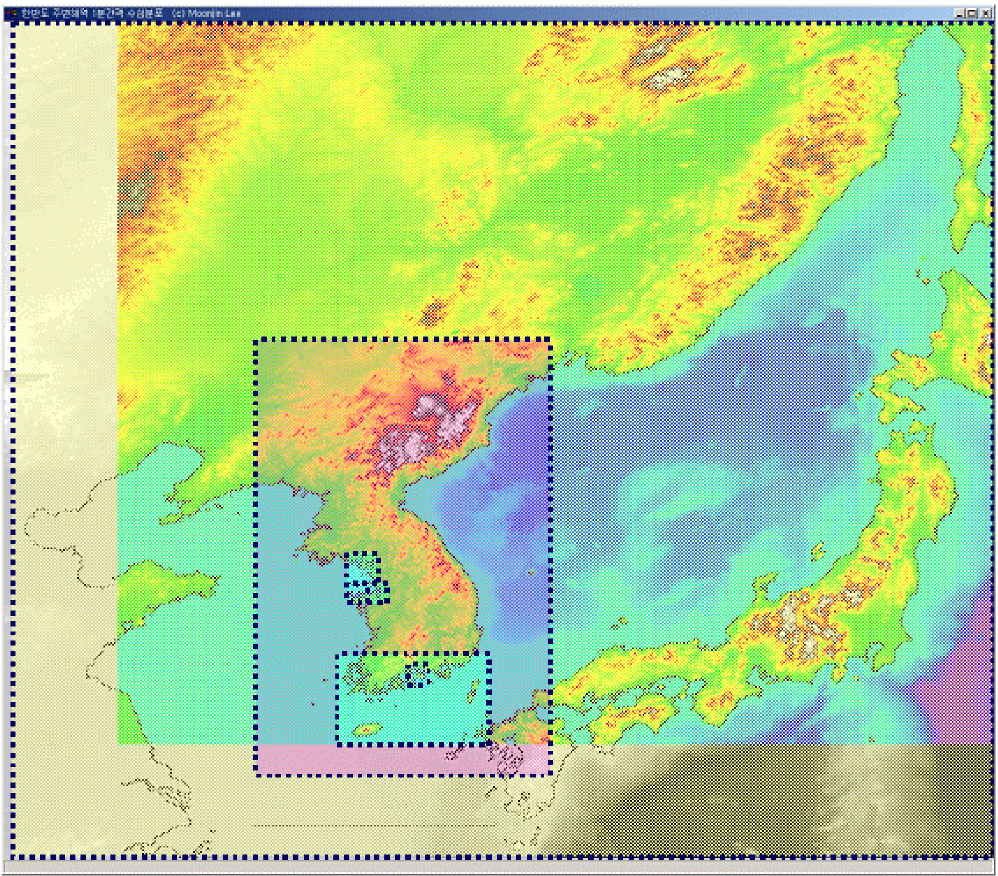

Fig. 7. *Areas of the existing OSPM of Republic of Korea.*

For the OSPM of Korea, environmental factors such as wind, wind-driven current, tidal current, and quasi-steady current were produced in the target areas by solving Navier-Stokes equations. From the computed currents, harmonic constants and a response function are extracted for prediction of real time tidal current and real time wind-driven current, respectively. Oil dispersion was predicted with the generated real-time currents based on harmonic constants and the response function. In the dispersion model, the turbulent diffusion of spilt oil was simulated by a Monte Carlo technique based on fractal Brown motion. The weathering process of the spilt oil was also considered as multi-processes with three components, evaporation, solution, and sinking. Finally, a comparison between the observed and simulated trajectories of the spilt oil was made in order to assess the utilization of this OSPM in the Korean environment. The simulated results give a reasonable estimation of the observed spilt oil behavior. Currently, the model is being used by the Korea National Maritime Police Agency for the oil spill response operation of the Korean government. The format of the input/output data of this system can be used for developing an oil spill prediction model covering the whole Northwest Pacific Region within the framework of the Northwest Pacific Action Plan (NOWPAP). An example of this system is displayed in Fig. 8.

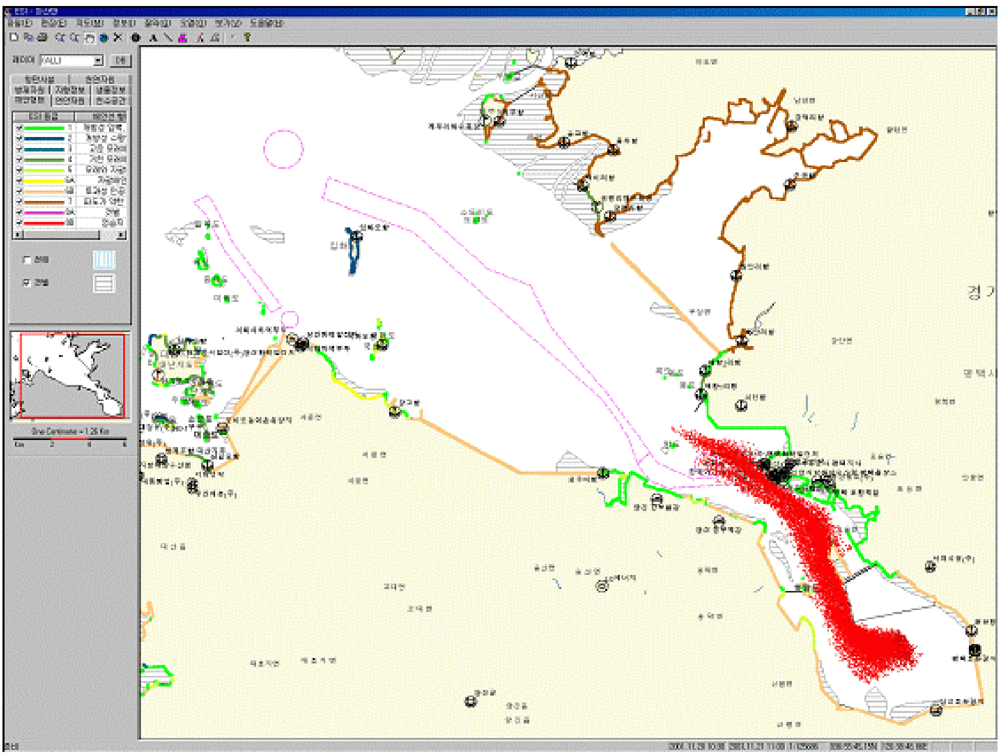

Fig. 8. *Oil spill prediction results of OSPM of Republic of Korea.*

3.4. Russian Federation

The OSPM of the Russian Federation is being developed by the Far Eastern Regional Hydrometeorological Research Institute (FERHRI). FERHRI has applied the following six models to the sea off the coast of Vladivostok and Sakhalin, as shown in Fig. 9.

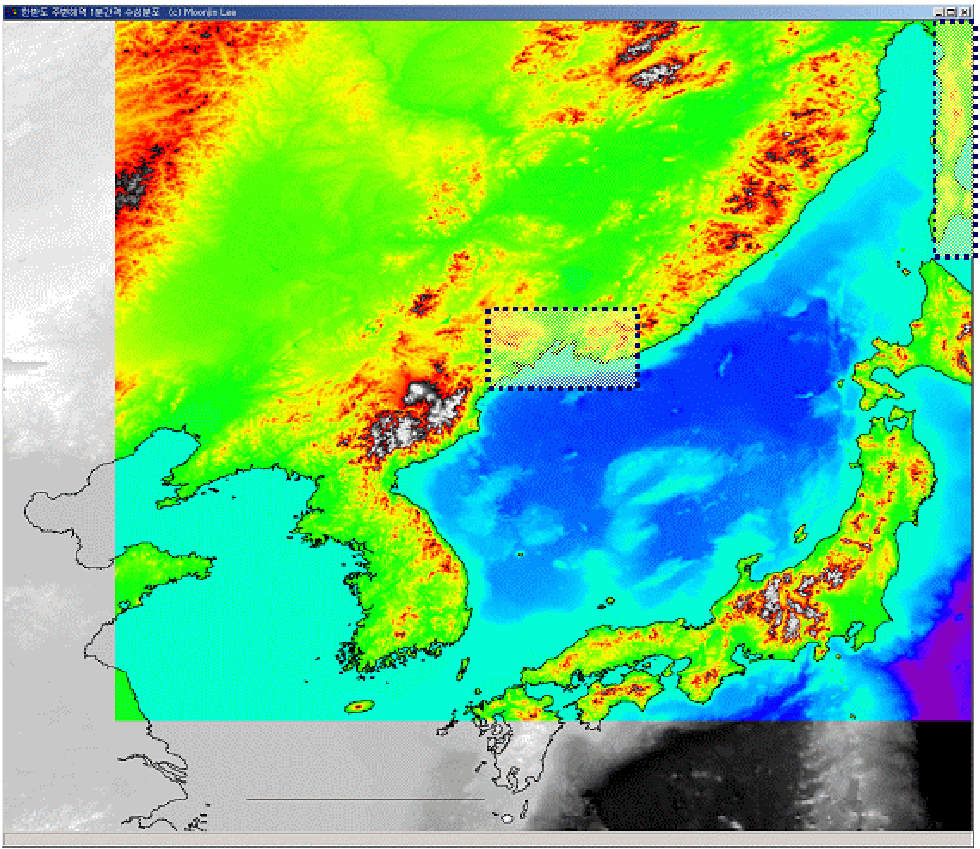

Fig. 9. *Areas of the existing OSPM Russian Federation.*

- OSA/OILMAP: SOI, Moscow
- GNOME 1.1.6: NOAA OR&R, USA
- VOS 3.2: FERHRI, Vladivostok
- VOS-RT 2: FERHRI, Vladivostok
- OILMAP and others (COASTMAP, CHEMMAP, SIMAP): Applied Science Associates, USA
- OSIS BMT: Marine Information Systems Limited, Great Britain

VOS 3.0 and VOS-RT 1.2 models are integrated into the on-line VOS-RT model, which uses simplified techniques developed for statistical purposes (VOS model). Two foreign models, OILMAP and OSIS have the most powerful functional capabilities among all the models considered. They can be referred to as the oil models of the new generation. The Russian models VOS/VOS-RT are considered the next most capable models. With regard to support with hydrometeorological data on the Sakhalin shelf, VOS and VOS-RT models (developed by FERHRI) are the most advantageous. These models were widely used in operations on the Sakhalin shelf and their executors have experience in calculating oil spills on the south-eastern, eastern, north-eastern, and northern Sakhalin shelf. OSA/OILMAP and OSIS models were not as widely used in the Sakhalin projects and the SOI model operation revealed its non-competitiveness in this region. At present, FERHRI models are the most effective in fulfilling projects on oil spills. The oil spill VOS model is highly advanced and the VOS-RT model is the only on-line model that operates on the north-eastern Sakhalin shelf within the limits of 51° 10' N to 54° 30' N in latitude and 142° 40' E to 144° 50' E in longitude. Fig. 10 shows the oil spill prediction results of the OSPM of the Russian Federation

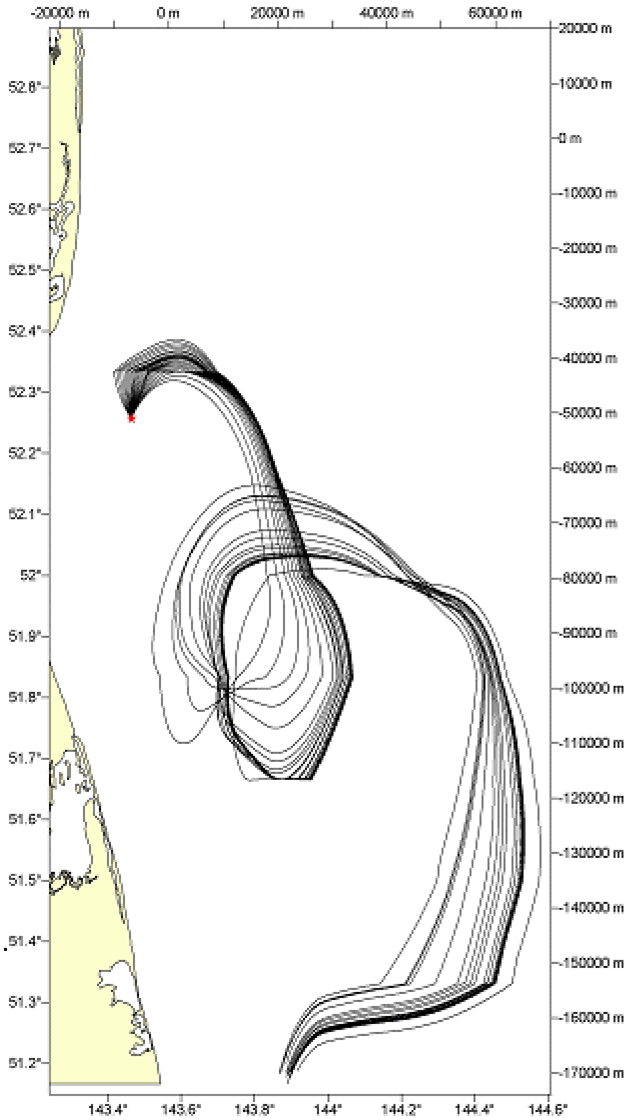

Fig. 10. *Oil spill prediction results of OSPM of Russian Federation.*

Chapter 4. Comparison and analysis of the results of existing OSPMs of NOWPAP Members

4.1. The Incident Scenario for Member States' OSPM Calculations

To compare and to analyze the NOWPAP member states' OSPM, oil spill incident scenarios under identical conditions were sent to experts in each member state and calculations based on their respective OSPM and the scenarios thus notified as the input conditions were requested. Although the OSPM calculations were requested in January 2006, only Japan provided the results and China and Russia did not do so. In February, March, and April 2006, the incident scenarios were repeatedly sent to China and Russia, and these two members were again requested to send their calculations. However, there has been no reply to date (May 2006). The present report therefore compares and analyzes the OSPM results only of Korea and Japan to verify the need to develop a standard OSPM for the NOWPAP region.
The two following hypothetical oil spill incident scenarios were selected to compare and to analyze the member states' calculations based on their respective OSPM.

1. Scenario A
   - Incident date/time: 01:00 May 1, 2006
   - Incident point: 36° 46' 51.53"N, 124° 18' 26.98"E (see Fig. 11)
   - Spilled oil type: Bunker C
   - Predicted term: 3 days

2. Scenario B
   - Incident date/time: 01:00 May 1, 2006
   - Incident point: 38° 49' 41.46"N, 131° 02' 10.63"E (see Fig. 11)
   - Spilled oil type: Bunker C
   - Predicted term: 3 days

Experts in each country carried out the oil spill prediction for each scenario based on their own OSPM. In the oil spill prediction for each scenario, they computed and used the data on currents and winds needed for their own OSPM.

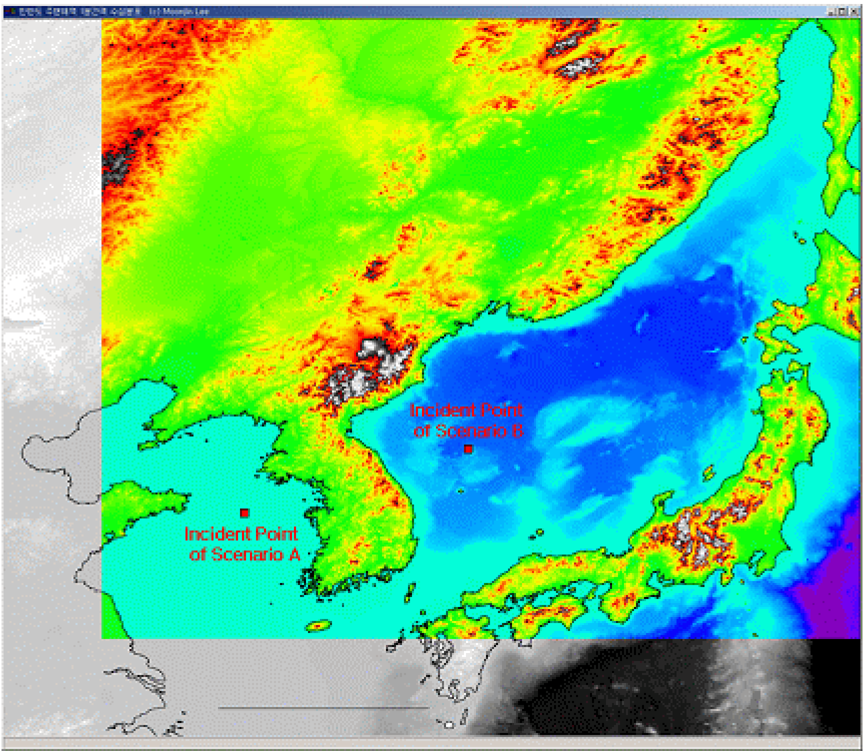

Fig. 11. *Incident points of scenario A and B.*

4.2. Comparison and Analysis of OSPMs Results

As presented in Fig. 12 and Fig. 13, respectively, the calculations regarding oil spill incident scenario A made by Japanese and Korean experts based on their own OSPM differed considerably. As shown in Fig. 12, according to the Japanese OSPM calculation regarding the hypothetical oil spill incident scenario, the spilled oil moved approximately 24 miles to the south and the average speed of the spilled oil based on the drift distance was inferred to be 0.67 knots. On the other hand, according to the Korean OSPM calculation regarding the same scenario under identical conditions, which is presented in Fig. 13, the oil moved approximately 10 miles to the north-northeast. The average speed of the oil based on the drift distance based on the Korean OSPM calculation was inferred as approximately 0.14 knots.

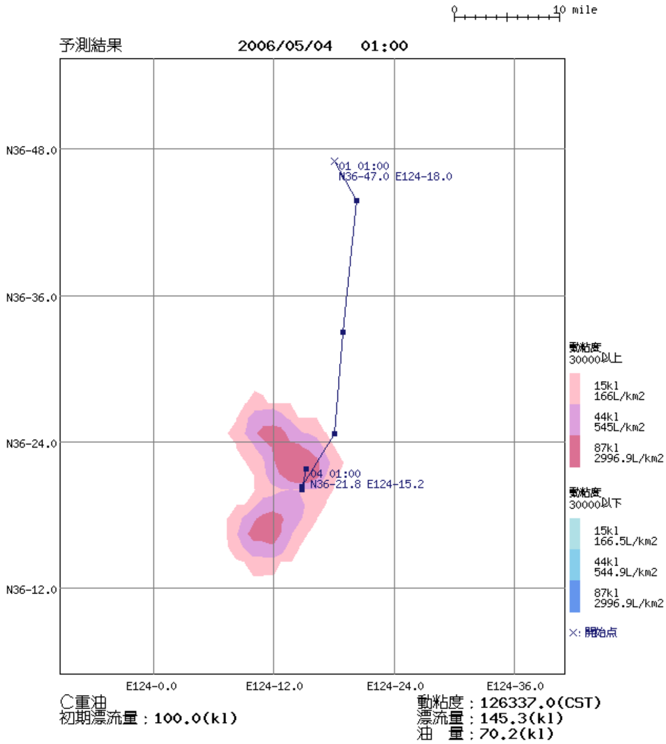

Fig. 12. *Predicted trajectories of spilt oil for scenario A by OSPM of Japan.*

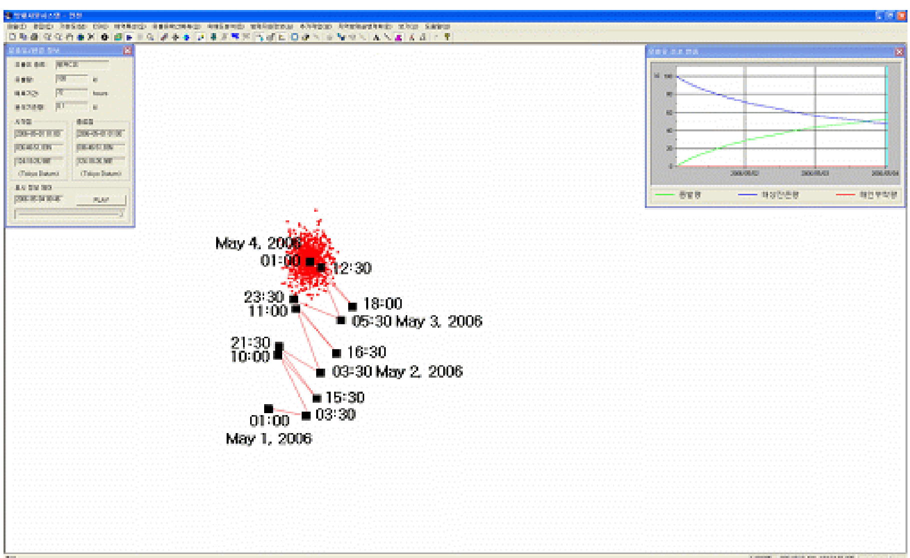

Fig. 13. *Predicted trajectories of spilt oil for scenario A by OSPM of Korea.*

As shown in Fig. 14 and Fig. 15, the Japanese and Korean OSPM calculations for hypothetical oil spill incident scenario B are comparatively similar. According to these calculations, regarding oil spill incident scenario B, the spilled oil moved to the northeast and drifted approximately 36 miles and approximately 50 miles, respectively, in the Japanese and Korean calculations. According to predictions regarding oil spill incident scenario B, average moving speeds of the spilled oil in the Japanese and Korean OSPM calculations were approximately 0.5 knots and approximately 0.7 knots, respectively. In other words, the Japanese and Korean OSPM calculations for the two oil spill incident scenarios were similar for scenario B but considerably different for scenario A, even yielding opposite directions. Because such differences can be made by the winds and currents used in the OSPM, the data on currents used in the Japanese and Korean OSPM regarding scenario A were compared for analysis. The data on currents used in the two states' OSPM were real-time predictions using independent databases. From among the prediction data, the currents for 03:00 May 1, 2006 are as shown in Fig. 16 and Fig. 17. The data on currents used in the Japanese and Korean OSPM were 10 miles and 0.25 mile, respectively, in terms of the computational grid size, thus differing considerably. As a result, there was a difference in the spatial distribution of the currents. Likewise, the two states' data on winds were 30 miles and 0.25 mile, respectively, in terms of the grid size, also differing considerably. As a result, the results differed considerably with respect to the spatial distribution of the direction of wind. At 03:00 May 1, 2006, the wind used in the Japanese OSPM was a northerly wind of approximately 8 m/sec; the wind used in the Korean OSPM at the same time, however, was a southwesterly wind of approximately 8 m/sec. As these figures shown, the results of the OSPM differed considerably depending on the winds and currents used. The accuracy of winds and currents is determined by the prediction methods and the structure of the computational grid. Although scenario B had problems identical to scenario A, oceanic currents which has minor local changes were dominant in the sea area of scenario B so that the effect of differences in the grid size on the currents was minimal and the OSPM calculations turned out to be similar.

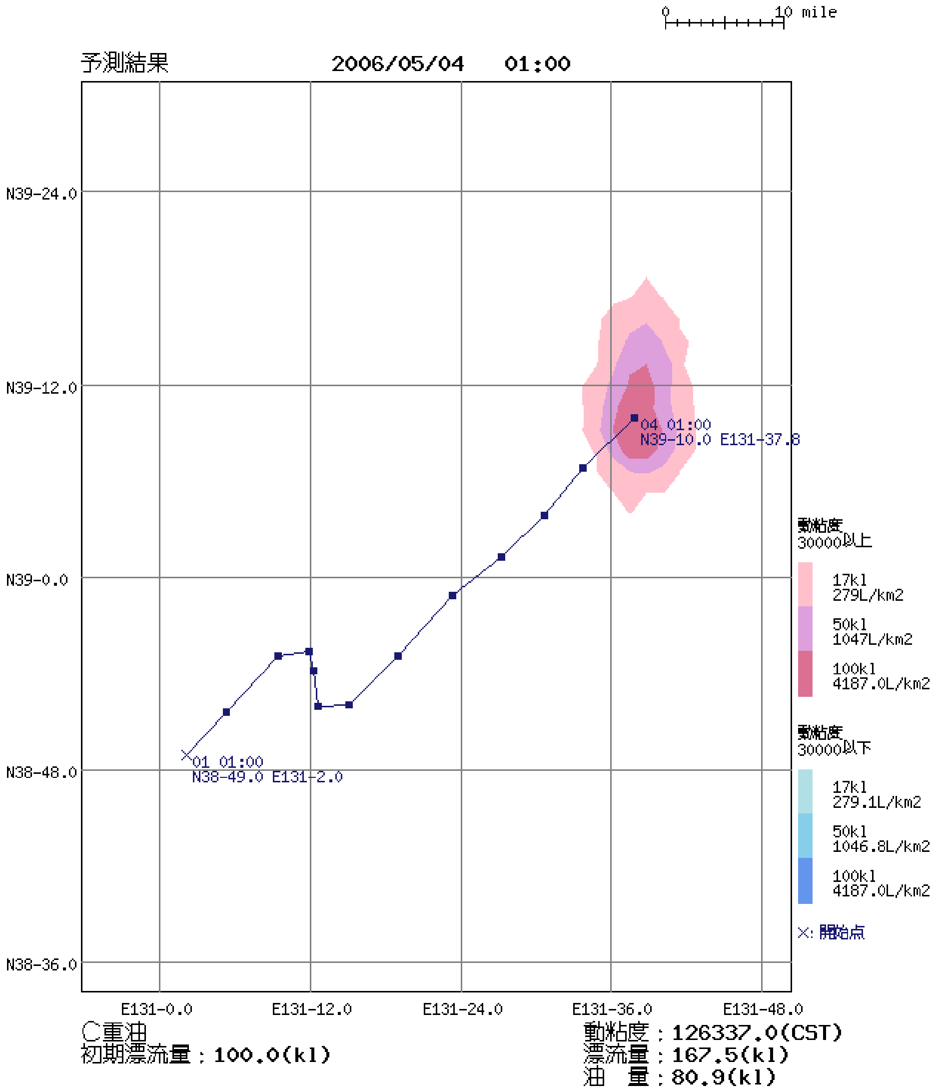

Fig. 14. *Predicted trajectories of spilt oil for scenario B by OSPM of Japan.*

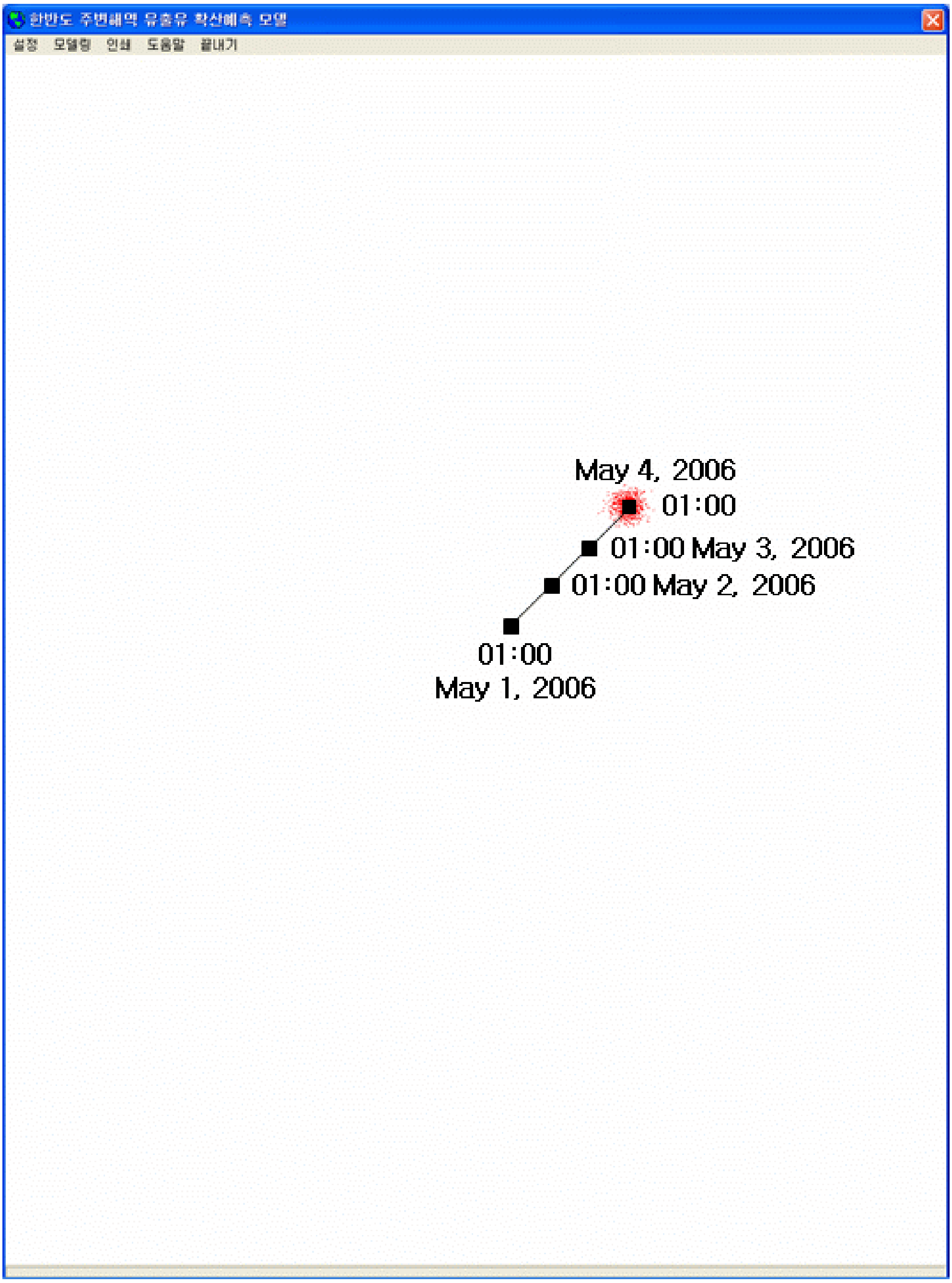

Fig. 15. *Predicted trajectories of spilt oil for scenario B by OSPM of Korea.*

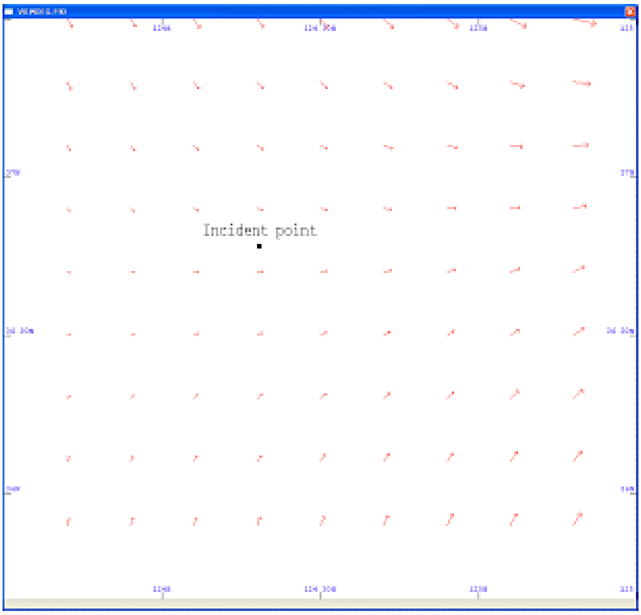

Fig. 16. *Predicted currents of Yellow Sea adopted into OSPM of Japan (03:00 May 1, 2006).*

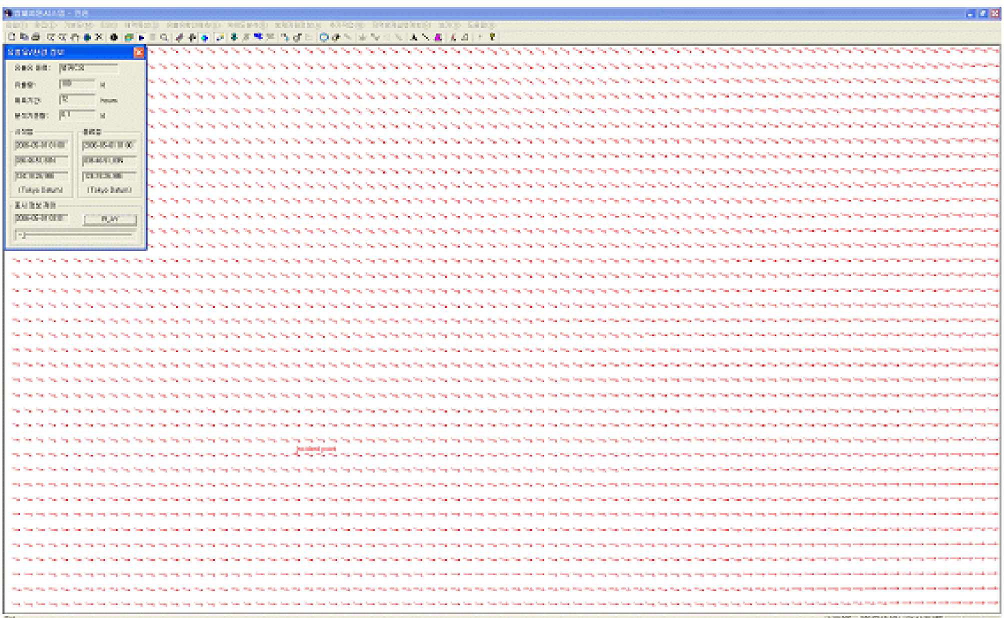

Fig. 17. *Predicted currents of Yellow Sea adopted into OSPM of Korea (03:00 May 1, 2006).*

Chapter 5. Summary

It is crucial to predict the trajectory of spilt oil accurately for successful response operation and protection of the marlrine environment. The trajectory is mainly dependent on surface drift due to wind and surface current. Based on this practical need, each of the member states has developed their own oil spill prediction models to respond to oil spill accidents occurring in their own region. In order to review and analyze the existing OSPMs of NOWPAP Members, information on the existing OSPMs was collected from national experts of the Expert Group in NOWPAP Members. After collection of information on the existing OSPMs, analyses and comparison of the existing OSPMs of each member state were carried out. The results are summarized in Table 1. In the analysis and comparison, commercial OSPMs are excluded as they cannot consider detailed environments of regional seas. Since most commercial OSPMs are developed for wide application, they request user input for detailed information on the environment for respective regional seas. It is not a simple undertaking for users to prepare detailed information on the environments for regional seas according to the manner of commercial OSPMs, despite that they are exported.

From the review and analysis of the OSPMs of NOWPAP Members, the following technical characteristics of the OSPMs of NOWPAP Member States are noted:

1. Each of the NOWPAP Members operates their own oil spill prediction models to respond to oil spill accidents occurring in their own region. However, no model has been developed to cover the whole NOWPAP Region in detail.
2. While some commercial OSPMs have been introduced from other nation, they cannot be applied in regional seas effectively as they cover only general features of the OSPM and exclude special characteristics of regional seas for wide application. In order to operate such OSPMs in regional seas, real-time currents and winds have to be determined by the user according to their acceptable input form. It is difficult to determine real-time currents and winds due to limitations of their acceptable input form, even if the user is exported.

Table 1. *Analysis and comparison of existing OSPMs of NOWPAP Member States.*

Member of States	Japan	People's Republic of China	Republic of Korea	Russian Federation
No. of OSPMs (excluding commercial OSPMs)	1	3	3	2
Real time currents	Tidal currents, Oceanic currents	Tidal currents, Wind-driven currents	Tidal currents, Wind-driven currents, Oceanic Currents	Tidal currents, Oceanic currents
Real time wind	Using JMA's forecasting		Using KMA's forecasting	Using JMA's forecasting
Weathering process of Oil	Spreading	Spreading, Emulsification, Evaporation, Biological degradation	Spreading, Emulsification, Evaporation, Biological Degradation	Spreading, Emulsification, Evaporation, Biological degradation
Oil types	Generalized 5 types oil	Generalized Several types oil based on database of its characteristics	Generalized 10 types oil based on decay factor(e-folding time)	5 types oil for region
Shoreline interaction	Beaching	Beaching	Beaching, Reflection	Beaching, Reflection
Protection and removing effect	None	None	Protection	None
Application of GIS	Display on ENC	Display on ESI Map	Display on ENC and export to ESI Map	Developing
Web Service	Yes	No	No	Yes

3. The existing OSPMs of NOWPAP members have some unique features according to the oceanic characteristics of each nation, developing environments of the OSPM, basic concepts of OSPMs of the developer, etc. The real-time currents are represented by tidal currents, wind-driven currents or oceanic currents according to the dominant components of each regional sea. Weathering process of oils is modeled for common oil types in regional seas by using concepts based on the database of characteristics of oil. Some existing OSPMs of NOWPAP members can directly display the trajectories of oil on an ESI map and/or can export outputs for representation with the ESI map. Some existing OSPMs are supported on website using the Internet, while others are operated on personal computers.

As represented in the technical characteristics, the existing OSPMs of NOWPAP members have been developed with various features for optimized consideration of the environment of each state. For this reason, the existing OSPMs cannot be applied to the entire NOWAP region. In order to use an OSPM for the entire NOWPAP region, a more widely applicable OSPM must be developed. Another problem of existing OSPMs is that the resolution of the existing OSPMs is too crude. Japan and the Republic of Korea have OSPMs covering the whole NOWPAP region. However, their OSPMs do not precisely represent the geometry of the coastal region. To test the applicability of existing OSPMs in the NOWPAP region, the member states' OSPM calculations on the same oil spill incident scenarios were compared and analyzed. These countries' OSPM calculations for identical scenarios differed in the direction and distance of the movement of the spilled oil. Such differences were attributed to the following reasons:

1) Differences in the spatial distribution of currents and winds due to differences in computational grid sizes
2) Time gap among the data on currents and winds used in the OSPM
3) Differences in designating the input data for OSPM calculations

Based on the results of technical analysis and applicability verification, it is difficult that an existing OSPMs is used for the whole NOWPAP region. In order to establish the efficient information system on the movements of spilled oil in the whole NOWPAP region, a standard OSPM for the NOWPAP region should be developed. The advantages and disadvantages of development of a standard OSPM are summarized in Table 2.

Table 2. Advantages and disadvantages regarding the development of a standard OSPM for NOWPAP region.

	Advantages	Disadvantages
Use of a commercial OSPM	− Rapid and easy establishment of OSPM	− Difficulties of preparedness of environmental data − Unrealistic real-time simulation of oceanic conditions
Modification of an existing OSPM	− Reduction of funds and time	− Difficulties of consideration of special environment of each states − Difficulties of establishment of advanced and expansible concepts
Development of standard OSPM	− Considerable special environment of each NOWPAP member − Realistic simulation of oil dispersion by using advanced concepts − Various applications of OSPM by using standard input/output such as risk assessment, response planning, training and etc. − Simple and easy operation due to automatic generation of some features by using voluminous database instead of user's input − Easy expansion and update according to requirements of NOWPAP members	− Need of funds and time

Chapter 6. Guidelines for Development of NOWPAP OSPM

As explained in the summary, it is necessary to develop a standard oil spill prediction model (OSPM) covering the whole NOWPAP region in order to facilitate prompt and effective responses to mass oil spills. However, since NOWPAP Members have their own OSPMs that have been developed with consideration of pertinent oceanographic characteristics, these OSPMs cannot be easily applied to the whole NOWPAP region. Therefore, the Expert Group have suggested necessity of development of a standard OSPM for the NOWPAP region.

The requirements in developing a standard OSPM for the NOWPAP region are as follows:

1. Establishment of a computational grid system that can reflect the characteristics of the NOWPAP region and development of an OSPM based on it
   - Selection of a computational grid size to simulate characteristics of the currents in each sea area
   - Adoption of a standard grid system for the NOWPAP region
2. Establishment and use of a standard wind data database
   - Networking between the member states for the exchange of real-time wind data
   - Establishment of a database for normal wind distribution
3. Development of real-time prediction system based on advanced techniques
   - Development of currents prediction system based on advanced techniques
   - Prediction and use of currents using advanced techniques
4. Development of a standard operating environment for OSPM
   - Simplification of input conditions to minimize OSPM input errors
   - Development of a user-friendly operating environment

In order to support various information for the response of oil spill accident, the following functions will be needed in the standard OSPM.

1. Standard formats to input environmental conditions such as currents, winds, waves, water temperatures, etc.
2. Loading of common map data such as Electric Nautical Chart (eg. S57 format), Environment Sensitivity Index Map (eg. Shape file format of ArcInfo), etc.

3. Databases for maps, real-time prediction of currents, and modeling of oil weathering process
4. Output in common GIS formats for application to other systems
5. User friendly operating environment as well as commercial OSPM
6. Reverse tracking of oil trajectories
7. Consideration of response such as protection by booms, removal by skimmers, effects of dispersants, etc.
8. Validation and modification of real-time oil trajectories by using observed trajectories

A standard OSPM for the whole NOWPAP region will be used for oil spill accident occurred in inter-country sea area, and it will support information on movement of spilled oil going to coastal area of NOWPAP Member States. NOWPAP Members could then use their existing OSPMs, respectively, for detailed prediction in coastal areas. To this end, a standard OSPM should be developed that can link with the existing OSPMs of NOWPAP Members. However, if necessary, the existing OSPMs should be modified in combination with a standard OSPM. In order to develop a standard OSPM of NOWPAP, we proposed the following working plan:

1. Design of the standard OSPM to be developed by consensus of experts from the member states
   - Collection and estimation of techniques on the OSPM
   - Technical design of the standard OSPM
   - Collection and review of physical oceanographic data and other data required for the model operation
   - Collection of relevant data necessary for the standard OSPM
   - Technical design of a standard database format that can link with the existing OSPMs of NOWPAP Members
2. Establishment of a large draft OSPM
   - Establishment of a database of the current existing data in the NOWPAP Member States
   - Development of a real time prediction system for marine environments such as tidal currents, wind-driven currents, oceanic currents, wind, etc.
   - Development of a draft model using the real time prediction system of marine environments
   - Initial operation and revision of the model
3. Update and revision of the standard OSPM
   - Review and revision of the developed model (including the database) for improvement of accuracy

- Development of oil spill response strategies based on the developed standard OSPM
- Field tests and updates

The development of the standard OSPM that covers the whole NOWPAP region would require much time and a large budget. Hence, we first prepare a standard data format to exchange data between the existing OSPMs of NOWPAP Member States. The prepared a standard data format is presented in Annex B. A standard data format is used to correct data for calculation of the existing OSPMs. The accuracies of the existing OSPMs can be improved by adoption of standard data, but the development of standard OSPM is necessary to extract the best outputs of OSPM in the whole NOWPAP region. Therefore, we strongly recommend that the development of a standard OSPM of NOWPAP region should be carried out as soon as possible.

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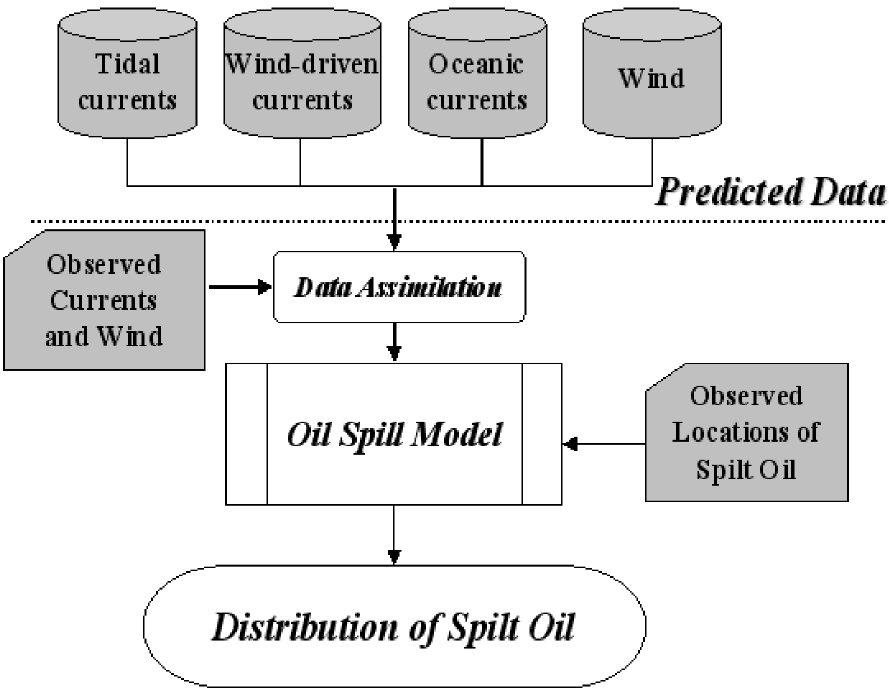
Annex B. Standard data format of OSPM of NOWPAP Region

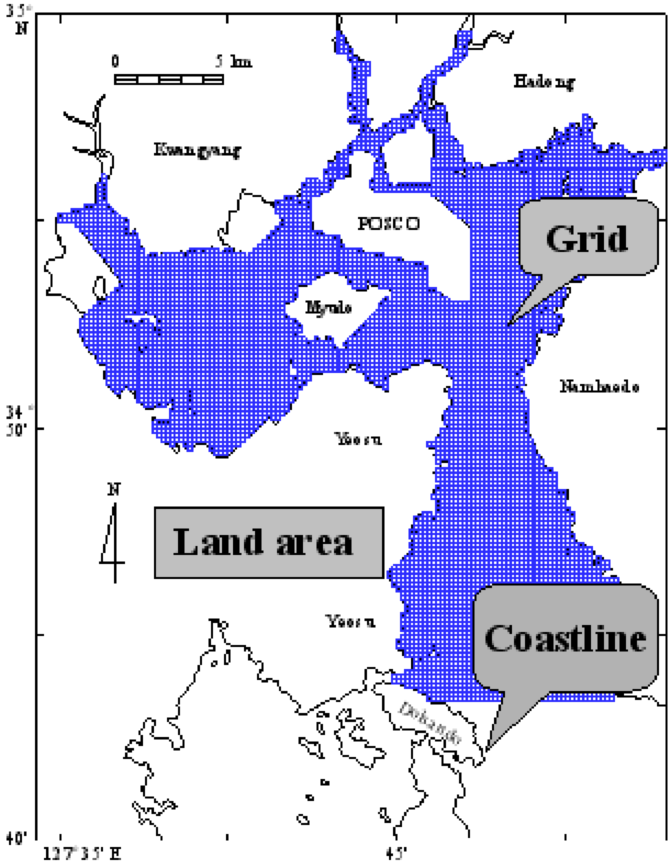
1. Structure of Oil Sill Prediction Model



2. Descriptions of input data file

2.1. basic input data files

- CNTR.DAT − Control parameter of oil spill model for specificaition of coputational grid numbers, grid size, computational time step, starting time, runtime, spill locacion, spill duration, amount of spilt oil, and etc.
- CST.DEG − Coastline position data for specification of land area in polygon type.
- DMAP.DAT − Depths data on computational grid.



2.2. Predicted data files

- TCUR.PRD − Predicted tidal current speed and direction data on computational grid.
- WCUR.PRD − Predicted wind-driven current speed and direction data on grid
- OCUR.PRD − Predicted oceanic current speed and direction data on grid
- WND.PRD − Predicted wind speed and direction data on grid

2.3. Observed data files

- CURS.OBS − Observed current speed and direction data at observed positions
- WND.OBS − Observed wind speed and direction data at observed positions
- OILP.OBS − Observed amount of spilt oil at observed positions

3. Contents of input data file

3.1. Computational grid

1, 1	2, 1	. . .	NX-1, 1	NX, 1
. . .	. . .	. . .	. . .	. . .
1, NY	2, NY	. . .	NX-1, NY	NX, NY

3.2. Headlines of all files

- Accident name (30 column)
- Creating date and time of file (30 column)
- Operator name (30 column)
- Country name (30 column)

3.3. Basic input data files

Filename	Parameter	Description	Format
CNTR.DAT		**Control parameter of oil spill model**	
	NX NY DX DY DT IYEAR IMONTH IDAY IHOUR IMIN IETIM SRCX SRCY IDUR AMTS KASEOIL	Grids number in x Grids number in y Grid size in x (deg) Grid size in y (deg) Computational time step (sec) Starting year of spill model Starting month of spill model Starting day of spill model Starting hour of spill model Starting minute of spill model Runtime of model (hours) Spill location in longitude (deg) Spill location in latitude (deg) Spill duration (hours) Amount of spilt oil (ton) Type of spilt oil (1: light oil, 2: Bunker C, 3: crude oil)	I5 I5 F10.5 F10.5 F10.5 F10.5 F10.5 I4 I2 I2 I2 I2 I5 I5 F10.2 I5
CST.DEG		**Coastline data of model domain**	
	BLAT, BLON TLAT, TLON NSEG ALON, ALAT	Lower-left position of domain (deg) Upper-right position of domain (deg) Number of segments of each polygon Position of segment (deg)	F10.5 F10.5 I5 F10.5
DMAP.DAT		**Depths data of model domain**	
	DMAP	Array of depths (m) − Data numbers: NX*NY − Depths on land: -999.99999	NX*F1 0.5

3.4. Predicted data files

Filename	Parameter	Description	Format
TCUR.PRD		**Predicted tidal currents data**	
	DATE, TIME TCSPD, TCDIR	• Real time of prediction • Arrays of current speed (m/s) and current direction (deg) − Data numbers: NX*NY − Values on land: -999.99999	yyyy/mm/dd, hh:mm NX*F10.4, NX*F10.2
WCUR.PRD		**Predicted wind-driven currents data**	
	DATE, TIME WCSPD, WCDIR	• Real time of prediction • Arrays of current speed (m/s) and current direction (deg) − Data numbers: NX*NY − Values on land: -999.99999	yyyy/mm/dd, hh:mm NX*F10.4, NX*F10.2
OCUR.PRD		**Predicted oceanic currents data**	
	DATE, TIME OCSPD, OCDIR	• Real time of prediction • Arrays of current speed (m/s) and current direction (deg) − Data numbers: NX*NY − Values on land: -999.99999	yyyy/mm/dd, hh:mm NX*F10.4, NX*F10.2
WND.PRD		**Predicted wind data**	
	DATE, TIME WSPD, WDIR	• Real time of prediction • Arrays of wind speed (m/s) and wnid direction (deg) − Data numbers: NX*NY − Values on land: -999.99999	yyyy/mm/dd, hh:mm NX*F10.4, NX*F10.2

3.5. Observed data files

Filename	Parameter	Description	Format
CUR.OBS		**Observed currents data**	
	DATE, TIME ALON, ALAT, CSPD, CDIR	• Observation time • Location of observation and observed current speed (m/s) and direction (deg)	yyyy/mm/dd, hh:mm:ss 4F10.5
WND.OBS		**Observed wind data**	
	DATE, TIME ALON, ALAT, WSPD, WDIR	• Observation time • Location of observation and observed wind data speed (m/s) and direction (deg)	yyyy/mm/dd, hh:mm:ss 4F10.5
OILP.OBS		**Observed oil distribution**	
	DATE, TIME ALON, ALAT, ASO	• Observation time • Location of observation and observed amount of spilt oil (ton)	yyyy/mm/dd, hh:mm:ss 3F10.5

4. Examples of input file

4.1. Headline of all files

OCEAN	! *Accident name (30 column)*
1997 12 24	! *Creating date and time of file (30 column)*
Moonjin Lee	! *Operator name (30 column)*
Korea	! *Country name (30 column)*

4.2. Basic input files

4.2.1. CNTR.DAT

Headline

10	! *Grids number in x*
10	! *Grids number in y*
0.05000	! *Grid size in x (deg)*
0.05000	! *Grid size in y (deg)*
18.53233	! *Computational time step (sec)*
2000	! *Starting year of spill model*
1	! *Starting month of spill model*
14	! *Starting day of spill model*
16	! *Starting hour of spill model*
59	! *Starting minute of spill model*
48	! *Runtime of model (hours)*
129.42517	! *Spill location in longitude (deg)*
35.47751	! *Spill location in latitude (deg)*
12	! *Spill duration (hours)*
100.50	! *Amount of spilt oil (ton)*
1	! *Type of spilt oil*

4.2.2. CST.DEG

Headline

129.22500	35.20000	! *Lower-left position of domain (deg)*
129.64200	35.72170	! *Upper-right position of domain (deg)*
2		! *Number of following positions*
129.22500	35.20000	! *Position of coastline (deg)*
129.33500	35.88000	

```
3
129.33500  35.88000
129.44500  35.48000
129.23200  35.37000
```

4.2.3. DMAP.DAT

Headline

```
-999.99999  30.10000  . . .   20.53000   ! depths(m) on grid
      30.30000  20.70000  . . . -999.99999     2
      . . .     . . .     . . .    . . .      . . .
      50.30000-999.99999  . . . -999.99999    NY-th row of grid
        1        2     . . .    NX-th column of grid
```

4.3. Predicted data files

4.3.1. TCUR.PRD

Headline

```
2000 01 10 14 30   ! Real time of prediction (14 Jan., 2000, 14:30)
-999.99999  0.10000  . . .   0.53000   ! Tidal current speeds
      0.30000   0.70000  . . . -999.99999     2
      . . .     . . .    . . .    . . .      . . .
      0.50000-999.99999  . . . -999.99999    NY-th row of grid

-999.99999 360.10000  . . .  359.53000   ! Tidal current directions
     355.30000   0.70000  . . . -999.99999     2
      . . .     . . .    . . .    . . .      . . .
     357.50000-999.99999  . . . -999.99999    NY-th row of grid
        1        2     . . .    NX-th column of grid

2000 01 10 15 30
-999.99999  0.20000  . . .   0.43000
      0.30000   0.50000  . . . -999.99999
      . . .     . . .    . . .    . . .
      0.60000-999.99999  . . . -999.99999

2000 01 10 16 30
-999.99999 360.10000  . . .  359.53000
```

```
355.30000   0.70000  . . .  -999.99999
 . . .     . . .    . . .     . . .
357.50000-999.99999  . . .  -999.99999
```

4.3.2. WCUR.PRD

Use the same format of tidal current data file (TCUR.PRD)

4.3.3. OCUR.PRD

Use the same format of tidal current data file (TCUR.PRD)

4.3.4. WND.PRD

Use the same format of tidal current data file (TCUR.PRD)

4.4. Observed data files

4.4.1. CUR.OBS

Headline

2000 01 14 14 30 50 ! *Observed time (14 Jan., 2000, 14:30:50)*
129.44500 35.48000 1.50000 359.30000 ! *location, current speed and direction*

2000 01 14 14 40 30
129.33500 35.23000 0.50000 10.20000
2000 01 14 14 40 30
129.33500 35.23000 0.50000 10.20000

4.4.2. WND.OBS

Use the same format of current data file (CUR.OBS)

4.4.3. OILP.OBS

Headline

2000 01 14 14 30 50 ! *Observed time (14 Jan., 2000, 14:30:50)*
129.44500 35.48000 7.50000 ! *location, amount of oil*
2000 01 14 15 30 50
129.34500 35.58300 3.50000
2000 01 14 16 00 20
129.33200 35.43200 2.50000

NOWPAP MERRAC

Northwest Pacific Action Plan
Marine Environmental Emergency Preparedness and Response
Regional Activity Centre

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