2. Atmospheric and Oceanic Environment Modeling

Numerical modeling of ocean circulation in the Asian adjacent seas

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Keywords global ocean circulation model, surface mixed layer, chlorophyll, satellite ocean color data, bloom, Asian adjacent seas

1. Introduction

Necessity of evaluating natural variability and anthropogenic effects in the Asian adjacent seas is increasing in considering their role in the global material cycles and ecosystems. In the previous studies by use of ocean circulation models, hydrographic data, and satellite ocean color data (Endoh et al., 1994a), we discussed that the annual surface chlorophyll distribution depends on the upwelling distribution in the surface layer and that the seasonal variation of chlorophyll is well explained by the seasonal variation of surface mixed-layer depth (Endoh et al., 1995; Obata et al., 1996). Based on these *basin-scale* studies, we focus on regional phenomena in the Asian adjacent seas as a first step to verify any relationship between physical conditions and biochemical cycles.

2. Method

A numerical model employed is a standard global ocean circulation model introduced by Endoh et al.(1994a). In the previous study (Endoh et al., 1994b), the model was integrated to a quasi-steady state with seasonal variation driven by the monthly climatological wind stress (Hellerman and Rosenstein, 1983), monthly sea surface temperature and seasonal sea surface salinity (Levitus, 1982).

Endoh et al. (1995) discussed the global climatological relationship between seasonal variations of the mixed-layer depth in the model and chlorophyll concentrations from satellite ocean color data. The discussion was concentrated to basin-scale spring bloom in the middle and high latitudes. Here, in this report, we examine the similar regional-scale relationship including lower latitudes, especially in the Asian adjacent seas around Japan.

3. Results

Monthly mixed-layer depths in the Asian adjacent seas (100°E to 170°E, 0°N to 60°N) derived from the seasonal climatology-driven model (Endoh et al., 1994b) are shown in Fig. 1. For comparison, monthly chlorophyll concentrations from the satellite ocean color data (CZCS data) (Ishizaka, 1993) for the same region are shown in Fig. 2.

In the winter season from January to March, deep mixed layer forms south and east of Japan and in the Japan Sea by the cooling convection of the saline water advected by the Kuroshio. Phytoplankton pigment in winter is denser (>0.1 mg m^{-3}) compared with its summer value in the deeper mixed layer region south of Japan (<35°N). The mixed layer in this region is generally euphotic in all seasons (Endoh et al., 1995; Obata et al., 1996) and nutrient-limited because of the Ekman downwelling (Endoh et al., 1994a; Polovina et al., 1995). The intense winter convection supplies nutrients from deeper levels to the surface water and bloom occurs south of Japan. This winter blooming mechanism of the euphotic and nutrient-limited mixed layer in the subtropical region can be seen not only south of Japan but also in the whole Philippine basin and further in the East and South China Sea. In these regions, more phytoplankton pigments from autumn to winter corresponding to the mixed-layer deepening by surface cooling are found (Fig. 2).

In the subarctic region, on the other hand, the mixed layer is abundant with nutrients because of the Ekman upwelling throughout the year (Endoh et al., 1994a), while it is aphotic in the winter season (Endoh et al., 1995; Obata et al., 1996). Chlorophyll concentrations change very little in winter. They increase from April north of 40°N (including the Japan Sea), which synchronize with euphotic conditioning for photosynthesis caused by the shallowing of the mixed layer.

4. Summary

Monthly surface mixed-layer depth in a global ocean circulation model with climatological seasonal forcing and monthly chlorophyll concentration from the satellite ocean color data are compared for the Asian adjacent seas. It is shown that deepening of the mixed-layer depth explains the winter bloom in the euphotic subtropical region, and shallowing of the mixed-layer depth explains the spring bloom in the aphotic subarctic region.

In future study, interannual variation of the mixed-layer depth in the Asian adjacent seas of the model will be compared with that of primary productivity in these regions to understand how the climate change affects regional ocean ecosystems.

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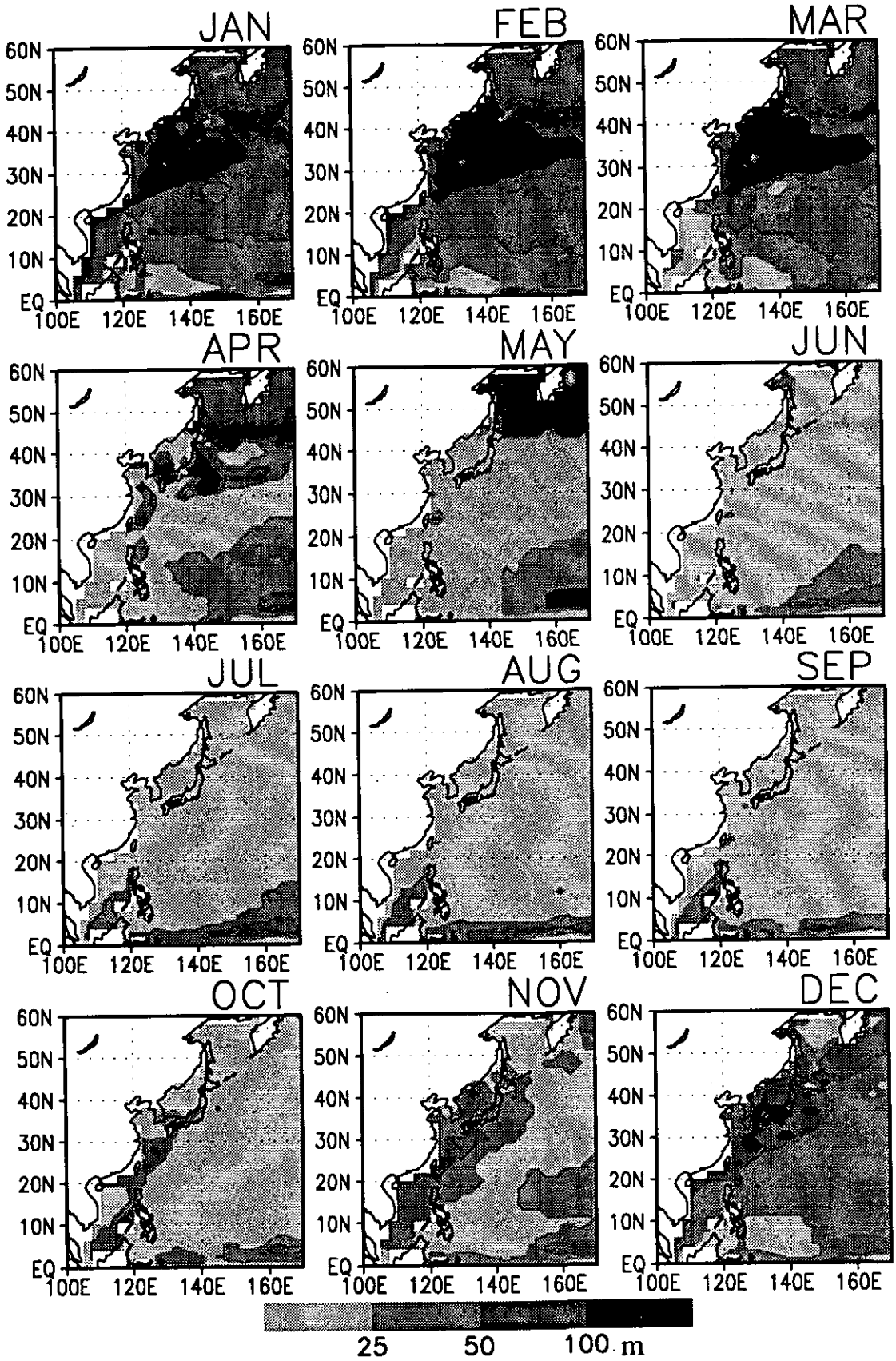

Fig. 1 Monthly mixed-layer depths in the Asian adjacent seas of the model.

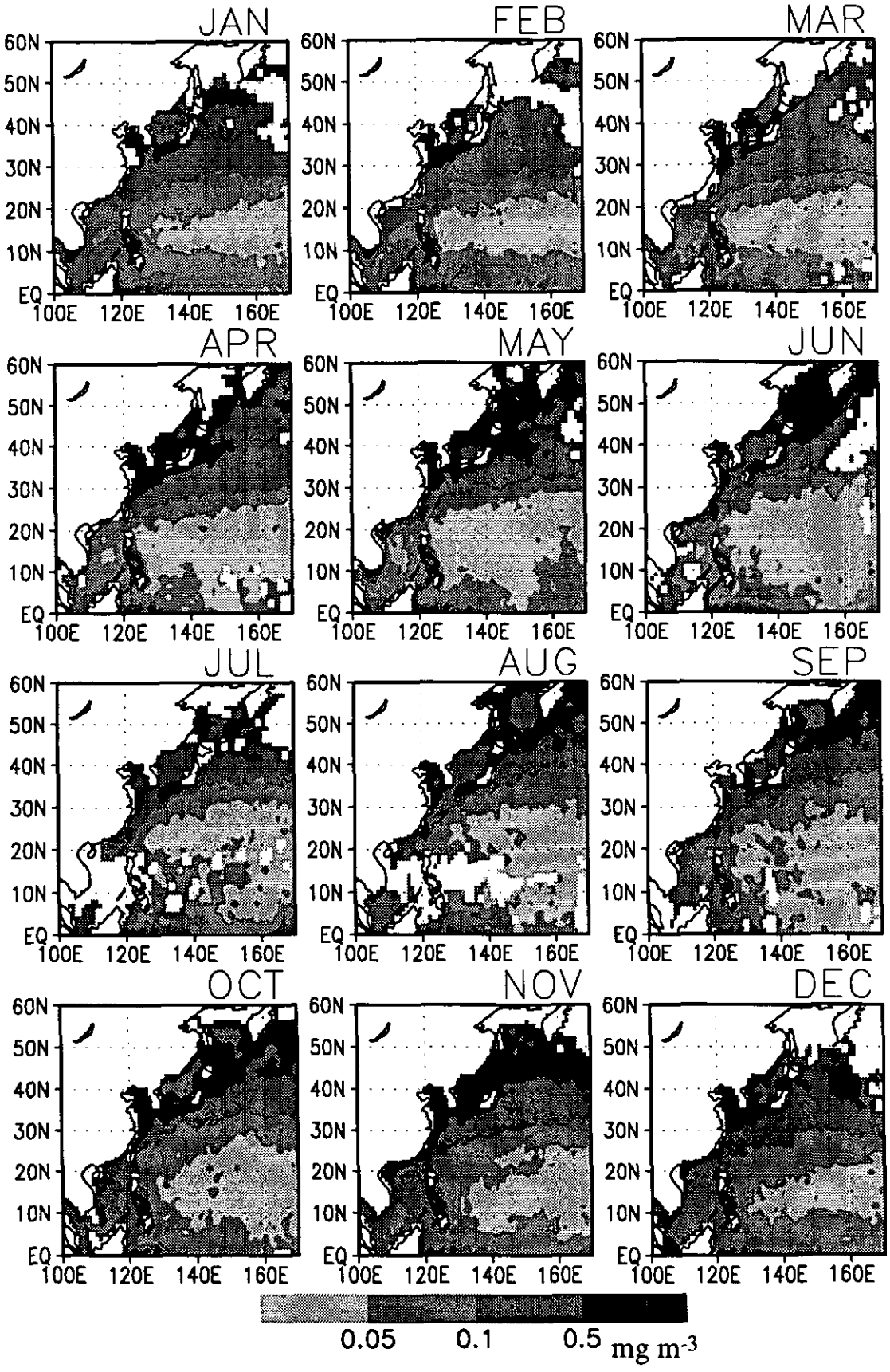

Fig. 2 Monthly phytoplankton pigment concentrations in the Asian adjacent seas from satellite ocean color data (CZCS data). The unit is mg m^{-3}.

Development of a Simulation System for Runoff and Material Transport Processes through a River Catchment

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Keywords Catchment, Runoff, GIS, and HSPF

1. Introduction

In order to manage and preserve the marine environmental system, one of the important things is to evaluate the quantity and quality of the inflow rate of loading from the river catchment to the sea. Most of the loading produced in the river catchment are conveyed to the sea through the river network. Because the mechanism of the transport process of the loading is quite different depending on the properties of the segments which constitute the catchment, we should consider the segment to be as a minimum unit and construct the mathematical framework made up of the segment and river network to develop a simulation system for runoff and material transport processes through a river catchment. Inevitably this framework requires not the lumped runoff model of the loading but the distributed one to which the spatial and temporal databases concerning the catchment are indispensable. The recent remarkable development of remote sensing and geographic information system (GIS) enables us to construct the database. Furthermore, several mesoscale catchment model have been proposed as the powerful tool which enables us to understand the dynamics of transport process of loading. In this study we investigated the response of a river catchment to precipitation by simulating the hydrological runoff and sediment transport in the catchment by using the HSPF (Hydrological Simulation Program-FORTRAN) which has been developed by EPA (Environmental Protection Agency, USA).

The total cyclic system of the water and materials in the catchment consists of many subsystems which are themselves quite complicated. Thus, our first step is to understand the response of the total system itself according to the change of the characteristics of the catchment segment before the investigation of the mechanism of subsystems in detail. It will be the next step to examine the mechanism. Namely, this study deals with the framework of the coupling the GIS with the simulation model.

2. Model Site (Hinuma River Catchment)

So as to indicate the applicability of the HSPF, we have applied it to the Hinuma River Catchment in central Japan as shown in Figure1. The main Hinuma River is 65 km long and has the catchment area of 459km^2. The western part of the catchment is the mountain side with 300 - 500 m height, while the eastern part has the flat geographical feature. The soil matrix in the western part contains the sand and sandy loam, while that in the eastern part is Kuroboku (ando) soils. National Institute for Environmental Studies (NIES)[1)] measured

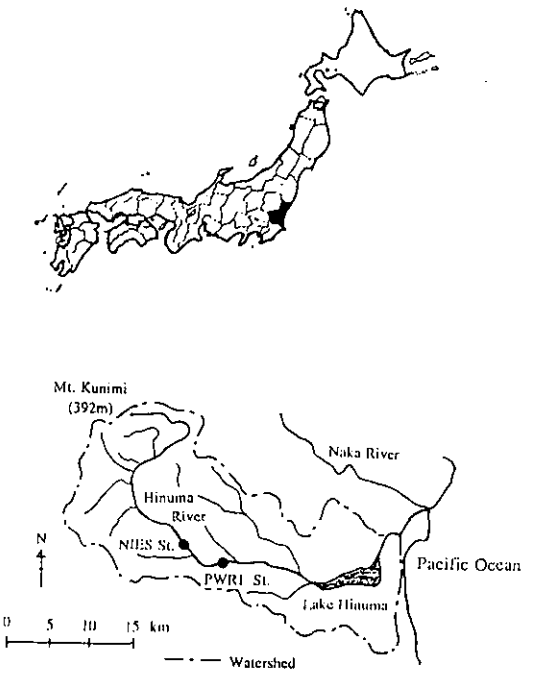

Figure 1. Location of study and stations in the Hinuma River Catchment

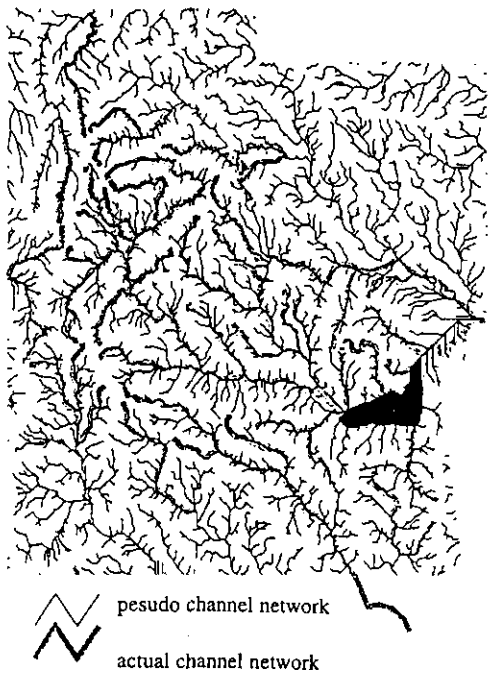

Figure 2. Comparison of the generated and real channel network

flow discharge, sediment load and several water quality indices from 1987 to 1990, while Public Works Research Institute (PWRI) [2] of Ministry of Construction observed the flow discharge and the three type of sediment load from 1987 up to now. PWRI also surveyed the sediment sources, the channel dimension, flow resistance and the properties of bed material particles in the whole river catchment. When the flow was calculated, the information about the river bed was important in this simulation. The measuring station of NIES was 33km upstream from the river mouth, and that of PWRI is 28km upstream respectively.

3. Results

(Pseudo Channel network and Segment)

The pseudo channel network was generated by applying GIS (ARC/INFO) to the Grid-based digital elevation model (DEM) of which resolution is 50m. By comparing the generated pseudo channel network with the actual one, we concluded that the generated one is quite similar except for the flat zone near the coastal line (Figure-2). The segment of catchment along which the runoff processes of water and loading should be considered were categorized based on the landuse. In this study, the landuses were classified into 8 group i.e. forest, paddy field, field, orchard, bare land, urban area, etc. Besides, the information about the spatial distribution of soil matrix was added as the segment information to improve the accuracy in simulating the runoff processes. The gradients of the channel and segment which primarily determine the flow intensity were also calculated by using GIS. The geophysical databases which describes the catchment characterized structurally by the segment and channel network were mostly constructed by using GIS.

(Application of Catchment Model)

For the purpose of the calibration of many constants and parameters concerning the runoff processes (infiltration capacity, percolation intensity, storage capacity in each layers and so on), the relationships were investigated among these parameters, the landuses and the soil matrix in Japan, and the mean values and its

variance were obtained. The period for which the model was calibrated extenuated from January 1, 1987 through January 1, 1988. The time step is 1 hour. The flow discharge was measured by PWRI. The parameter tuning was developed by considering their mean value and variance and specifying the segment by using GIS. The databases constructed by GIS supported this rapid estimation. By using the calibrated parameters, the hydrologic simulation was accomplished for one year of 1989. Figure 3 shows the comparison between the simulated results and measured ones. The responses of calculated and measured hydrograph to major precipitation events happened in August are shown in Figure 4. The fairly well agreement means that the constants and parameters of runoff process could be approximately estimated based on the land use and soil matrix.

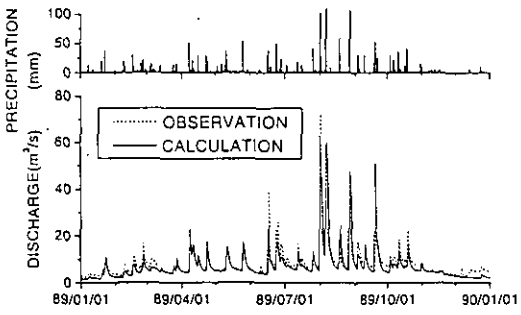

Figure 3 Comparison between observed and calculated discharge for 1989.

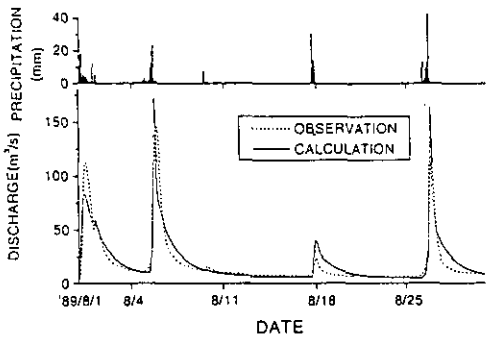

Figure 4 Discharge response to major precipitation events in August

Since one of our primary concerns among pollutant loadings is the sediment, as the first step we applied HSPF to simulate the sediment transport. The data of suspended solid (SS) measured by NIES was used for the calibration. In HSPF the sources of sediment was divided into the overland flow erosion and washoff by raindrops. Because the mechanism of these two has not been clarified, the parameter tuning for the sediment production was made by using the standard values for the land cover and soil matrix in HSPF. The degree of accuracy in estimating sediment transport rate depends on the estimation of flow intensity and the appropriate choice of representative diameter of transported matter. Figure 5 shows the measured and simulated concentration variations of SS. The calculated results indicate that the major source for the variation is the rainfall events. There are discrepancies between calculated and measured values in the middle of August. One reason for this may be attributed to the fact that the number of sampling was not sufficient. The other reason why the calculated values seem much larger can be the re-suspension of the vast amount of sediment which was generated and deposited on the rived bed by the preceding lager rainfall.

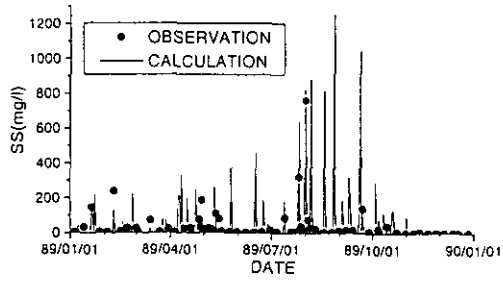

Figure 5 Comparison between observed and calculated suspended solids concentrations for 1989

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Study on the Transport and Transformation Model for the Environmental Acidification Substances

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Keywords Acid deposition, East Asia, Numerical model, Cloud process, Scavenging

1. Background

The anthropogenic emission of air pollutants has been increasing in the east Asian region, recently, more than 24 million tonnes of sulfur oxides are emitted in the atmosphere. Thus, the environmental acidification due to deposition of acidic substances originating in continental emission source is recognized as most serious problem. It is difficult to estimate the transboundary long range transport of acidic substances because of the no monitoring network has been developed.

2. Research Objective

The Lagrangian-based long range transport model of sulfur oxides was developed (the MRI-LTM) to evaluate the acid deposition due to transboundary long range transport from the Asian continent emission sources (Sato et al., 1995). Since the liquid phase oxidation of pollutants plays important role in wet deposition process (Schwaltz, 1988), the MRI-LTM, however, has no function of chemical reaction. Then, in order to make the models on acid deposition synthesize not only atmospheric process but also critical loads of soil, effects on ecosystem and materials, the Eulerian long range transport model including the meteorological prediction module has been developed under the collaboration between the National Institute for Environmental Studies (NIES) and the Meteorological Research Institute (MRI). The amounts of acidic deposition estimated by the transport model must be delivered to the model to express in critical loads of soil.

3. Method

In order to provide meteorological variables such as winds, temperature, humidity for the Eulerian-based transport model, the meteorological prediction model has been developed Owing to have wider calculation domain over the east Asian region and to gain higher spatial resolution over the focused area, two meteorological prediction models were combined; the Japan Meteorological Agency's operational spectral limited area model around Japan (JSM) was nested in the modified fine mesh limited area model over the east Asian region (FLM). The nesting method was used the spectral boundary coupling (Sasaki et al., 1995). The center of the inner model was put on the longitude of 130 degrees east. The global objective analysis data sets (GANL) created by the JMA were used for initial and boundary conditions for outer model. And the inner model was improved to have the additional function expressing cloud and precipitation at each vertical layer.

4. Result

Since to obtain the spatial distribution of some chemical species transported from the east Asian continent, the intensive field survey, IGAC/APARE /PEACAMPOT was carried out in the period of early in March 1994, the meteorological simulation was performed on this period.

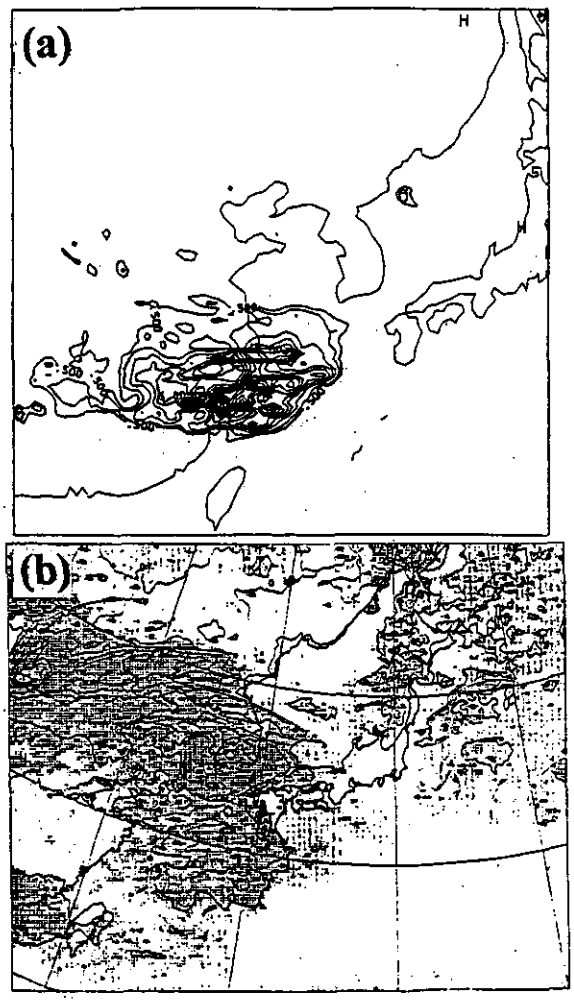

Fig. 1 An example of the predicted horizontal distribution of ground level precipitation (a) and cloud distribution observed by GMS for March 11, 1994, (b).

Furthermore, the model performance on the distribution of sea level pressure, clouds and precipitation was analyzed. Those distributions were compared with weather cart, infrared radiation cloud imagery of the geostationary meteorological satellite (GMS) and observed precipitation by the AMeDAS data, respectively.Figure 1 shows an example of the model verification on ground level precipitation (a) and horizontal distribution of cloud observed by the GMS (b). It is seen from Fig. 1 that the results of model prediction agree with observed cloud location. In order to verify the model performance on precipitation, the six regions are set over the Japan region, and the predicted amount of precipitation at ground level is preponderantly verified for Kyushu western part of Japan by using AMeDAS data set. Figure 2 shows the comparison of time series between predicted and observed 24-hr precipitation amount averaged over the Kyushu area.

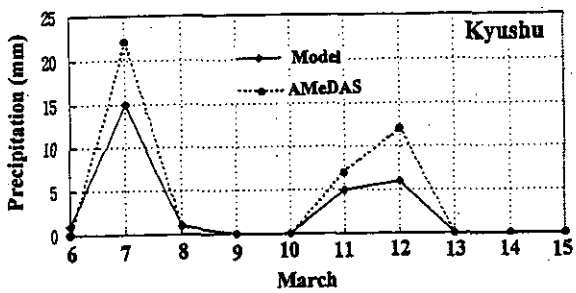

Fig. 2 The time series of predicted and observed precipitation for Kyushu region.

And results of the score calculation between prediction and observation are shown in Table 1. Since the regions of Hokkaido, Toholu and Kanto locate near the lateral boundary of the inner model domain, these regions are under direct influence of the lateral boundary effect, then the accuracy of prediction is inferior to the other regions. However, it is clear from Fig. 2 and Table 1 that the model makes under prediction for precipitation.

Table 1. Results of the score calculation between predicted and observed precipitation.

Region	Obs.	Pred.	Corre.	RMS	Bias
Hokkaido	16.78	1.11	0.6232	1.76	-1.42
Tohoku	21.00	3.42	0.9777	2.80	-1.59
Kanto	45.72	12.33	0.9182	6.95	-3.03
Kannsai	56.52	22.30	0.8928	6.16	-3.11
Kyushu	46.84	31.55	0.9927	2.95	-1.39
Okinawa	74.04	53.04	0.7302	7.08	-1.87

Furthermore, in order to examine the model performance on the expression of cloud and precipitation in each vertical layer, the comparative transport simulation of sulfur oxides was performed by including and excluding liquid phase oxidation process in the cloud. In other words, the additional function on wet deposition due to precipitation and liquid phase oxidation in each layer was examined. The result shows the increase of wet deposition and production of sulfate in compare with the case of excluding cloud process.

5. Concluding Remarks

In order to provide the grid node values of the meteorological variables including precipitation and cloud for the Eulerian based transport model, a flame of the nested meteorological prediction model has been made up, and the model was verified. It is found that the inner model has the characteristic to predict slightly lower precipitation in compare with observed precipitation. Since the precipitation process plays an important role in wet deposition process, the nested meteorological prediction model must improve to express the cloud and precipitation processes with higher accuracy.

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Development of Local CO_2 Circulation Models and Elucidation of Role of Land Ecosystem

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Key Words

Regional climate model,Biosphere-atmosphere interaction model,CO_2 flux

1.Introduction

It is an especially important and basic issue to make clear the mechanism of carbon dioxide (CO_2) circulations and budgets in the study of global warming. The so-called "CO_2 missing sink issue" shows that we have not had sufficient knowledge of CO_2 circulations. Unless we can make clear the problem, it is difficult to draw the future image of the global warming phenomenon.

The CO_2 circulations are deeply influenced by ecosystems, and especially through local weather and climate. Thus,we need to simulate CO_2 circula -tions after modeling local weather and climate

In this study, we firstly construct the model of the relationship between local weather and surface hydrology processes including land ecoystem. Secondly, we numerically simulate daily variations of atmospheric CO_2 concentration by estimating CO_2 fluxes in the model. As a result,we can estimate the atmospheric CO_2 concentration at each level. By doing so,it will be possible to evaluate the role of processes associated with so-called " CO_2 missing sink" and their relative degree of importance.

2.Research Method

Firstly,we develop a high-quality nested regional climate model,which has 23 levels in the vertical and its horizontal resolution is 30 km.

Secondly, we develop a simple surface hydrology model including plant physiological processes for use in a 3-dimensional regional climate model. In the model, we treat explicitly CO_2 fluxes between the atmosphere and land ecosystems according to daily variations of local weather.

Lastly,we simulate the local CO_2 circulations and budgets with use of the developed model (Mabuchi et al.,1996; Y. Sato et al.,1996).

Initial and boundary values of meteorological variables are given by the Global Analysis(GANAL) data set,which was used as the initial values twice a day in the operational numerical weather prediction. Those of atmospheric CO_2 concentration are given as a spatially-constant value of about 345 ppmv at all the grids. However, a several-year trend is assigned to fit the model to a trend of atmo -spheric CO_2 concentration over Japan observed by the Tohoku University (Nakazawa,T. et al.,1993).

3. Results and Discussion

Figure 1 shows time evolution of atmospheric CO_2 concentration at 850 hPa calculated by use of the regional CO_2 circulation model including the

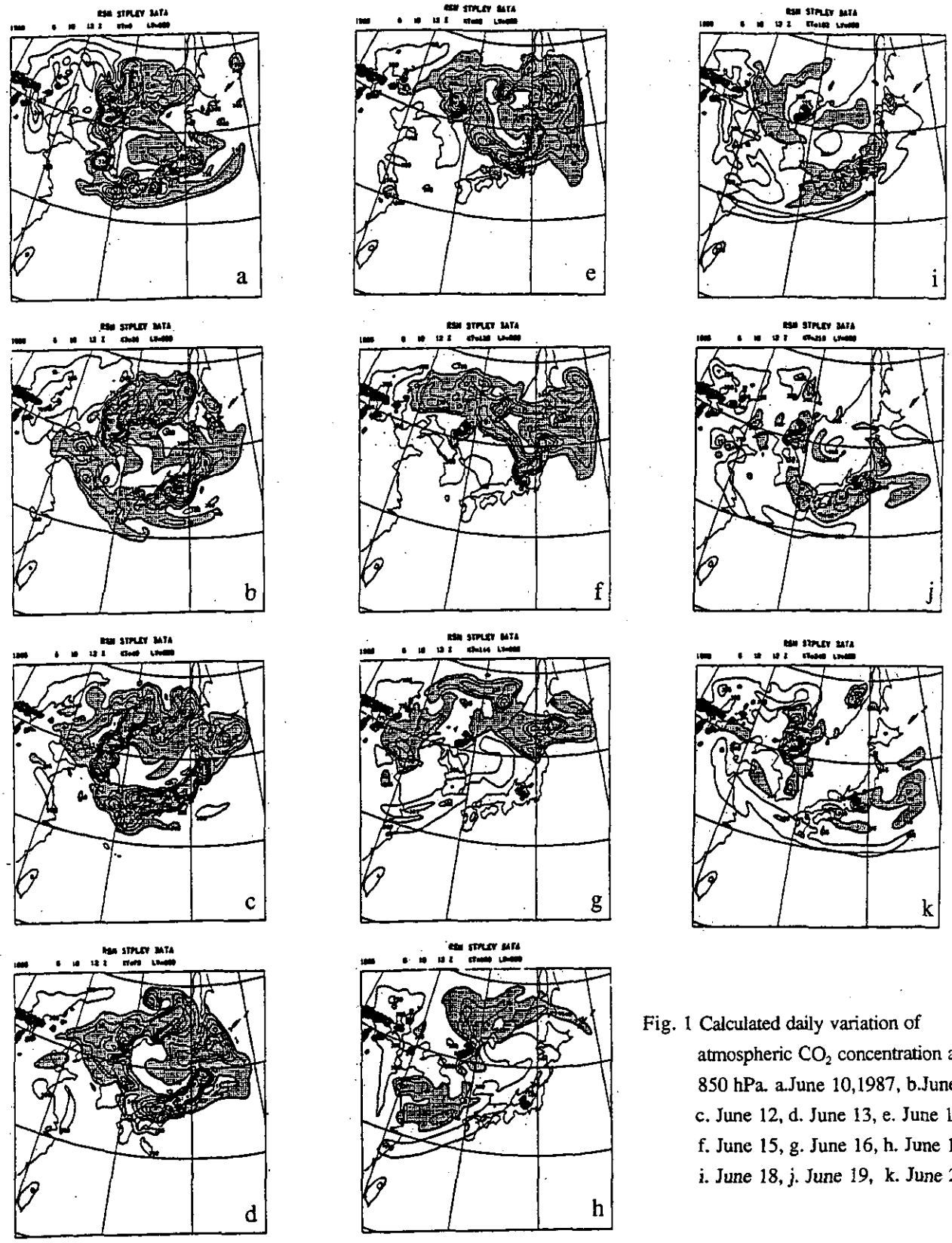

Fig. 1 Calculated daily variation of atmospheric CO_2 concentration at 850 hPa. a.June 10,1987, b.June 11, c. June 12, d. June 13, e. June 14, f. June 15, g. June 16, h. June 17, i. June 18, j. June 19, k. June 20.

Biosphere-Atmosphere Interaction Model (BAIM). A selected initial day for display is at 12 UTC on June 10,1997. Each panel is shown at intervals of 1 day. A contour interval is 5 ppmv. Values less than 345 ppmv are shaded. As the former-half of the period is fine weather,photosynthesis is active, thus less atmospheric CO_2 concentration areas predominate. In the latter-half of this period, it becomes rainny weather, thus photosynthesis is not active, but plant and soil respiration are still active.

Thus, much atmospheric CO_2 concentration areas predominate.

Figure 2 shows time evolution of CO_2 budgets through one year. AAT denotes the CO_2 absorption by photosynthesis,RES the respiration of land ecosystems, NET≡AAT-RES the net primary production of CO_2, RDM the soil respiration, respectively. Leaf area index(LAI) of plants is assigned to be an annual variation based upon Dorman and Sellers (1989). We see that plant is active from mid-April to mid-September. After May, we see some high frequency variation about AAT and RES. This feature corresponds to variation of weather. It is noted that in the middle part of June the Net Primary Production(NPP) approaches to zero, since AAT and RES are almost balanced each other. If this model results have a certain degree of reality, a determination of NPP by using remote-sensing data from satellites may be erroneous.

Figure 3 shows variations of atmospheric CO_2 concentration at each level below 500 hPa. Atmo-spheric CO_2 concentration at the 500 hPa level has no variation, but has a constantly-increasing trend, which was prescribed in this model to be the trend over Japan observed by Nakazawa et al.(1993). Through May to September, photosynthesis of plants is active, thus you can see relatively low atmospheric CO_2 concentration. It is interesting that photosynthesis/respiration due to land eco-systems has some phase lag of variation from the surface to higher level: 500 hPa. It seems in this model that CO_2 concentration at 500 hPa does not influenced by surface ecosystems except a little effect. In a glimpse,phase lag of variation of atmo-spheric CO_2 concentration can be seen at each level. We see that we have some gap between 850 and 700 hPa. Note that atmospheric CO_2 concentra-tion has been averaged with respect to a constant pressure level. Thus, below 850 hPa a part of this calculation domain was occupied by the orography. This analyses at a constant prssure level may make it difficult to interpret exactly a time variation of atmospheric CO_2 concentration at each level.

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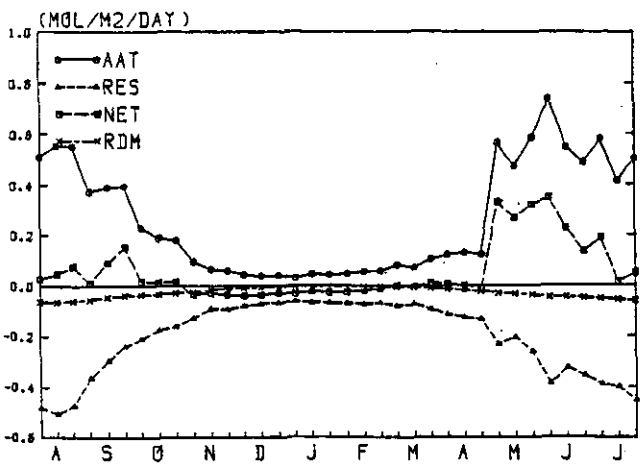

Fig.2 CO_2 budgets averaged over the central domain :3000 km×3000 km. AAT denotes the CO_2 absorption by photosynthesis of plants, RES the respiration by plants and soil,NET≡AAT - RES : NPP of CO_2,RDM the soil respiration.

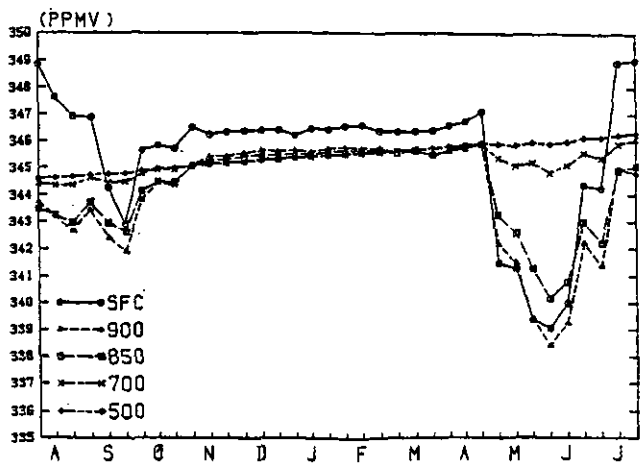

Fig. 3 Annual variation of calculated atmospheric CO_2 concentration at each level. SFC denotes the earth's surface.

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Keywords

bridge pier island, oil spill, residual currents wind driven currents

1. Introduction

The scale of oil transport by tankers is rapidly increasing to meet the demands, and there is a growing concern about possible large-scale environmental damage occurring due to tanker accidents. This concern is, in part, well founded, because most of tankers have single bottom plate and a few have double bottom plate, as well as the size of individual tankers are continually increasing. Thus, the damage associated with the accidental loss of one tanker increases.

In June 2, 1997, an oil tanker, Diamond Grace (contained 38,000 ton crude oil produced in Umshaiff of UAE.) was stranded on the Nakano-se shoal in Tokyo Bay (10:05 in the morning.) Immediately the tanker was anchored but crude oil was spilled from cracks (later it was reported that about 1550kl of crude oil was spilled). At 17:54 the tanker was towed and at 20:00 arrived at Kawasaki-sea berth.

Since Tokyo Bay is enclosed sea and coastal zone is heavily industrialized, there is an immediate need to determine how rapidly the oil will spread and where it will go in a given time, when oil-spill accident occurred. A knowledge of where the oil goes after it is spilled and the area covered by the oil thus forms a basis for decisions concerning the best method of oil treatment. In this paper prediction method of oil spreading in Tokyo Bay is presented.

2. Model description

Spread of an oil slick may be approximately viewed as composed of two parts, the first consisting of convection by winds and current, and the second of the increase in area of the oil due to gravitationary spreading in calm water. Since tidal currents are dominant in Tokyo Bay, the drift due to wind and tidal currents were considered. The center of mass of the oil is given by Hoult (1972) as follows,

$$dx/dt = Ucurrent + 0.035Uwind \qquad (1)$$

where x is the coordinate of the center of mass of oil, *Ucurrent* is tidal current and *Uwind* is the wind velocity.

The properties of the oil vary with time and the most important cause of this variation is the evaporation of the lighter components of the oil into the air. Other causes are dissolution of the soluble components into sea water and the changes brought by biological degradation. These changes all tend to make the oil denser and more viscous. In this model those effects are not considered. Crude oil is a mixture of a very large number of components, each with its own properties. As the different components generally have quite different spreading coefficients, a bulk model may be the first approximation of the details of the flow.

The three dimensional circulation model was used to calculate *Ucurrent* in eq. (1). The circulation model which describes velocities (u, v, w) and salinity (S) originally developed by Blumberg and Mellor (1997). The second-order turbulence closure scheme of Mellor and Yamada (1982) was used in order to express the variation of vertical mixing due to wind and surface cooling.

The major sources of freshwater inputs were from the rivers of Tsurumi, Tama, Sumida, Arakawa, Edo, and 10km upstream was included as computational domain. Daily averaged freshwater discharges from these rivers (River Flow Table, Ministry of Construction) was imposed. Tidal forcing was given from harmonic constants obtained at Jogashima and Iwaibukuro tide gauge stations. Daily averaged air temperature, solar radiation, cloud cover, relative humidity were obtained from Chiba meteorological station for computation of heat flux through the water surface Hourly averaged wind velocity was obtained from the same station for computation of oil spreading in eq. (1). Boundary conditions of temperature and salinity at open ocean were obtained from water quality date-base at Fishery Station in Kanagawa Prefecture

Initial condition of temperature and salinity were obtained from water quality date-base in Environment Agency. Simulation was conducted from May 1, 1997 to July 5, 1997 in order to give the velocity field of *Ucurrent* an time step of Δt = 10 sec was used. Oil spill was simulated by imposing particles at spilled point (10:05 AM, July 2, 1997) at distribution of particles were simulated.

3. Results.

In July 2, 1997, strong wind persisted from SW to NE direction (Fig.1).

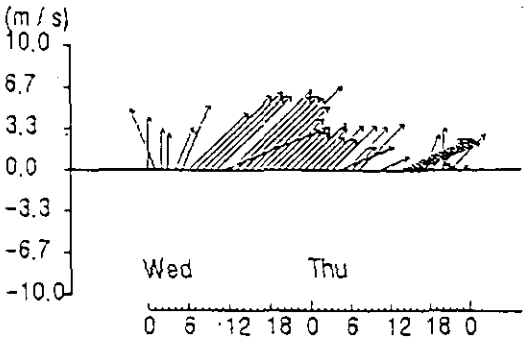

Fig.1 Wind direction during July 2~3, 1997

In the case of south-west wind, the contour lines of salinity and temperature spread across the longitudinal axes of the bay. The surface water is transported toward northern shoreline by the wind-driver surface stress and confronted with inflows of river water along the western coast. On the other hand, north-east wind yields that the contour lines of salinity and temperature become parallel to the eastern coastline (Chiba , Prefecture) of the bay.

Distribution of spilled oil particles in the surface (Fig.2) at 11:00 AM on July 3, 1997 shows an excellent agreement with satellite image of SPOT II obtained at 10:54 AM on July 3, 1997. Spilled oil tended to spread across the longitudinal axes of the bay (toward Kawasaki city in Kanagawa Prefecture and Futtsu in Chiba Prefecture). The residual currents determined by integrating flows during two tidal period on July 2, 1997 (Fig. 3-a,b) indicated that flow directions were from Yokohama-city toward Futtsu, and part of flow went north-east direction along the coast of Chiba Prefecture toward Chiba Harbor. Eddies around the islands constructed for a road across Tokyo Bay were clearly shown, in particular large eddies were generated in the 5th layer (Fig. 3-b).

In order to evaluate the effects of these islands on the residual current, the simulation without islands were conducted for same period. Distribution of spilled oil particles (Fig. 4)tended to spread in much broader area, in particular more oil particles were transported along the coast of Chiba Prefecture toward Chiba Harbor.

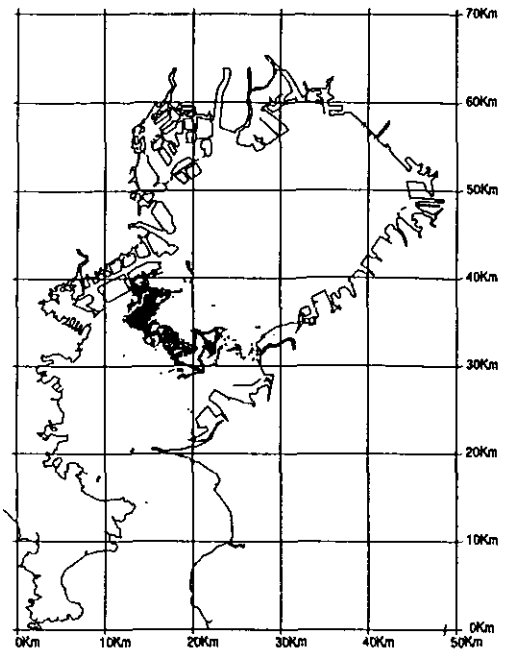

Fig.2. Distribution of spilled oil particles in the surface at 11:00 AM on July 3, 1997.

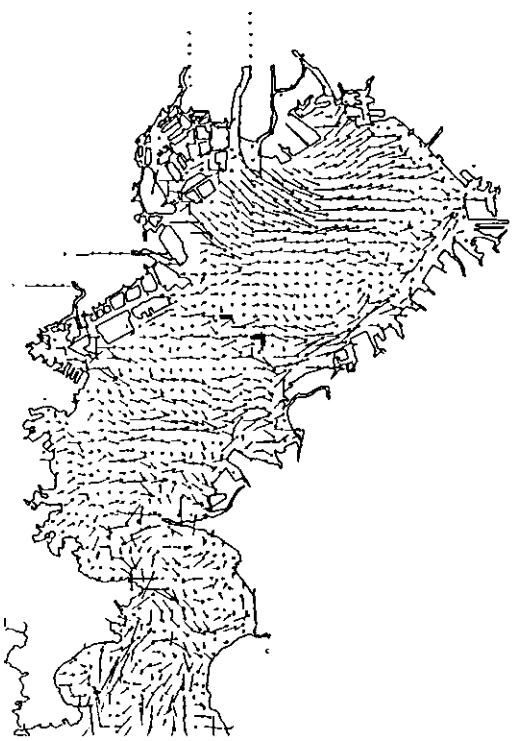

Fig.3-a. The residual currents in the surface on July 2, 1997

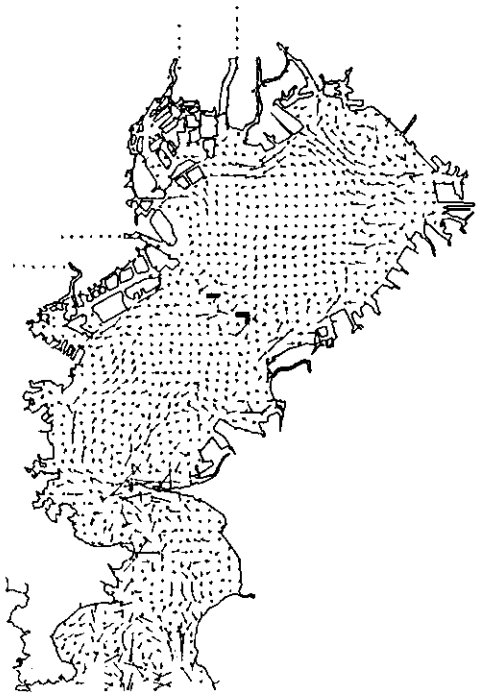

Fig.3-b. The residual currents in the 5th layer on July 2, 1997

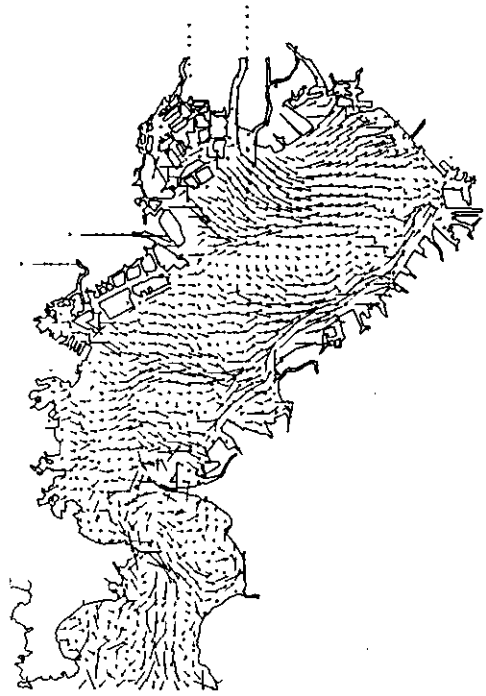

Fig.5-a. The residual currents without islands in the surface on July 2, 1997.

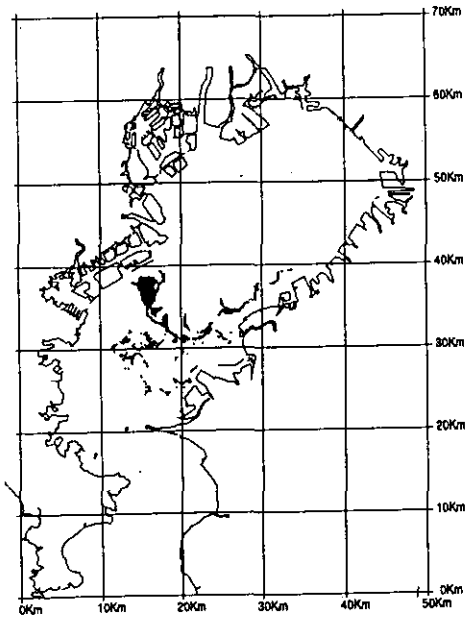

Fig.4. Distribution of spilled oil particles without islands at 11:00 AM on July 3, 1997

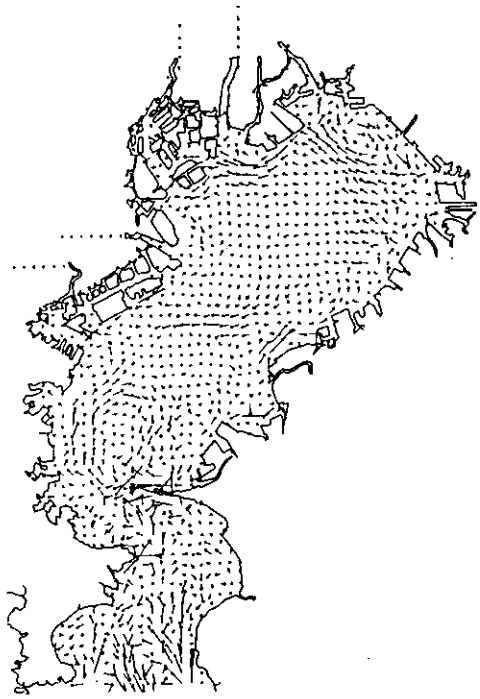

Fig.5-b. The residual currents without islands in the 5th layer on July 2, 1997.

The residual currents without inlands (Fig.5-a,b) exhibit strong stream from Yokohama-city toward Kisarazu-city in Chiba Prefecture and these currents were extended along the coast of Chiba Prefecture toward Chiba Harbor. These currents carried oil particles toward Chiba Harbor, promoting broader spread of oil particles. Existence of these islands blocked the water exchange between inner bay and outer bay by generating large eddies around the islands.

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