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Numerical Research of Regional Environment on IT Based Laboratory

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Abstract - A software system is developed to study regional environment. The system, SPEEDI-MP, aims to the body to produce various environmental assessment systems as well as numerical research tool to treat inclusive and successive behaviors of pollutant materials in the atmospheric, oceanic and terrestrial region. This paper describes models, system and some application.

I. Introduction

The progress of environmental studies has been revealing the complex behavior of pollutant materials in the environment. In the nuclear field, the pass way of radionuclides to the public has a wide variety due to the increase of nuclear facilities in Asia, the call port of nuclear ships, the possibility of terrorist attack, etc.

The development of a software tool, SPEEDI-MP, has started from 2001 to resolve such complex environmental problems under the idea that new numerical simulation basis is necessary to treat the 'inclusive and successive' behaviors of pollutant materials in the atmospheric, oceanic and terrestrial regions. This system is the third generation of SPEEDI (System for Prediction of Environmental Emergency Dose Information) [1], following SPEEDI practically used as a national nuclear emergency response system and WSPEEDI (Worldwide version of SPEEDI) [1], [2] for large-scale nuclear accidents in the world. The name SPEEDI-MP (Multi-model Package) means an assembly of multi-purpose numerical models for various kinds of environmental problems.

II. Outline of SPEEDI-MP

SPEEDI-MP aims to the body to produce various environmental assessment systems as well as numerical research tool to treat 'inclusive and successive' behaviors of pollutant materials in the atmospheric, oceanic and terrestrial environment. Furthermore, by the introduction of SPEEDI-MP onto ITBL (IT Based Laboratory)[3], effective cooperation studies are expected by various communities from environmental research to countermeasures for natural hazards. ITBL is a project started in 2001 with the objective of realizing a virtual joint research environment using information technology (IT).

In the first five-year program, the following development has started to resolve environmental pollutant problem in the local and the Asian regions.

A. Development of atmospheric, oceanic and terrestrial models

Atmospheric, oceanic and terrestrial models are prepared to provide environmental pollution models with environmental data, e.g., wind field, ocean current, water circulation, etc. The models are MM5 [4], POM [5] and SOLVEG [6] for atmospheric, oceanic and terrestrial environment, respectively.

MM5 is a non-hydrostatic meteorological model developed by the Pennsylvania State University and the National Center for Atmospheric Research (NCAR), which has many functions such as the choice of various physical options, the domain nesting calculation, and the four-dimensional data assimilation of analysis and observation data. MM5 calculates meteorological fields with high resolution in time and space based on atmospheric dynamic equation. The Princeton Ocean Model (POM) is a three-dimensional hydrodynamic model developed by Princeton University. The model solves the time dependent, primitive equations of motion in a bottom-following sigma-coordinate system. It contains a free surface formulation and complete thermodynamics, with an embedded level 2.5 turbulence closure sub-model to provide vertical mixing coefficients. SOLVEG is a new atmosphere-soil-vegetation model developed at JAERI to study heat, water, and CO_2 exchanges between the atmosphere and land surface. The model consists of one-dimensional multi-layer sub-models for atmosphere, soil, and vegetation and radiation schemes for the transmission of solar and long-wave radiation fluxes in the canopy. It simulates diurnal variations and seasonal changes of variables in the atmosphere, soil, and vegetation by using initial and boundary conditions from observations or other model's outputs.

Environmental pollution models developed in present are for air pollution problem, nuclear accident, oil spill, volcanic gas dispersions and migration of harmful insects.

B. Vectorization, parallelization and model coupling

Numerical models in SPEEDI-MP need much computation time. Furthermore, the inclusive model coupling simulations require more time. Thus, in addition to the vectorization and parallelization of each model programs, model couplers are developed for the exchanges of heat, wind stress, precipitations, etc. at the sea and/or ground surface during the parallel calculations of above models. By the dynamic coupling of numerical models operated in heterogeneous computers, computation time needed for combined simulations of multi-models can be shorten. In present, MM5 and POM are coupled by a Message Passing Library, Stampi[7]. The coupling of MM5 and SOLVEG is also underway.

C. Systematization

For the model operations, on-line global meteorological data acquisition function, global geological databases, graphical user interface (GUI) and visualization function are constructed. Numerical models in the atmospheric, oceanic and terrestrial environments are operated on the common supporting software base. The principle of common supporting software base is the easy access to the system by many users. Thus, Web-based GUI, 2-D and 3-D graphics commonly used in environmental researches, e.g., the Generic Mapping Tool (GMT), the Grid Analysis and Display System (GrADS), AVS, and the NetCDF format files for data transfer by network are selected.

Fig. 1 shows a current structure of SPEEDI-MP.

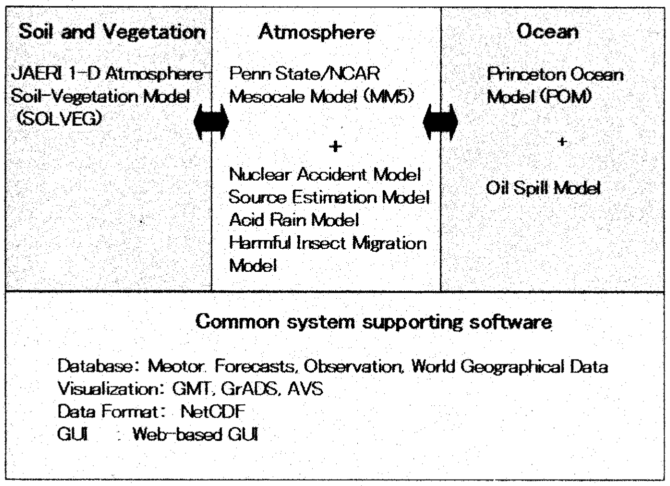

Fig. 1. Current structure of SPEEDI-MP.

III. Numerical Research on Regional Environment

A. Air pollutions and volcanic gas dispersion

It is a normal expectation to use parallel computers for achieving large scale and long term evaluation of environmental problems in reasonable CPU time. In SPEEDI-MP, the target is an air pollution problem. Air pollution problem, in particular acid rain problem, is treated in the scale of 5000 km x 5000 km with the grid of 500x500. Evaluation period is normally one or several years. MM5 needs about 11 days for one- year simulations by 32 processors of VPP5000, Fujitsu Co. Furthermore, an acid rain model needs more computation time for chemical reaction processes. Thus, vector and parallel computers in ITBL computer plat home will make simulations with huge computer resource possible.

As a part of this study, the dispersion simulation of volcanic gas erupted from Miyake Island is put into practice. After the stench incident at West Kanto District on 28 August 2000 caused by volcanic gas from Miyake Island, the following simulations dealing with atmospheric dispersion of volcanic gas from Miyake Island have been carried out.

(1) Retrospective simulation to analyze the mechanism of the transport of high concentration volcanic gas to West Kanto District on 28 August and to estimate the release amount of volcanic gas.
(2) Automated real-time simulation from the acquisition of meteorological data to the output of figures for operational prediction of the transport of volcanic gas to Tokai and Kanto districts.

B. Parallel simulation for nuclear accident and migration of rice plant hoppers

In practical aspects, when a catastrophic nuclear accident like Chernobyl occurs, multi-size real-time simulations from local scale to hemispheric scale are required.

Fig. 2 shows an example of multi-size simulations for hypothetical nuclear accidents assumed at a nuclear power plant near Hong Kong. Meteorological fields in two domains of local and regional areas are calculated simultaneously by the nesting function of MM5. Because variables at the boundary of both domains are exchanged each other, wind fields consistent in both domain are calculated. Fig. 2 is the distributions of 3 hour averaged air concentrations of noble gases. Because wind fields calculated for each nested domain are consistent, concentration distributions are also reasonable in the both domains.

Another parallel simulation for nuclear accident is a source term estimation for environmental discharges from unknown source point. When domestic monitoring posts alarm in spite of no domestic accident, we must consider the accident in abroad. In fact, a clue of finding the accidental release from Chernobyl at other countries was the detection of extraordinary air doses in Sweden. In Eastern Asia, the transports of radionuclides from possible plants, e.g., more than 10 sites must be calculated quickly to find the release point by comparing simulations with monitoring. Such a case, the release starting time is also unknown. Thus, if we assume 10 cases of release starting times, totally 100 cases of simulations are needed. Our idea is to allot 100 case simulations to CPUs of parallel computer and, then, predicted results are gathered to one processor and compared with observed data by statistical analysis. The concept of this idea is shown in Fig. 3.

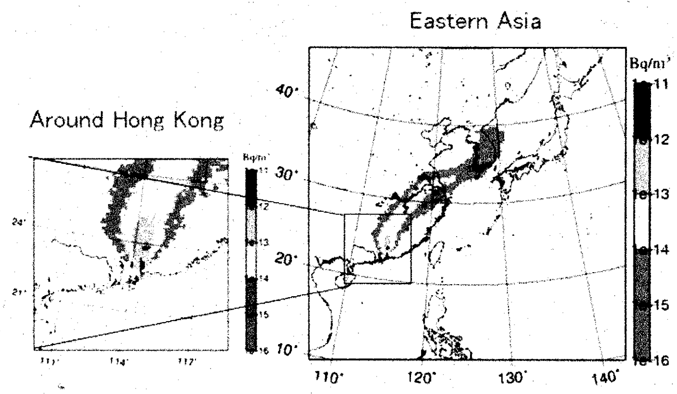

Fig. 2. Example of multi-size simulations for hypothetical nuclear accidents assumed at a nuclear power plant near Hong Kong.

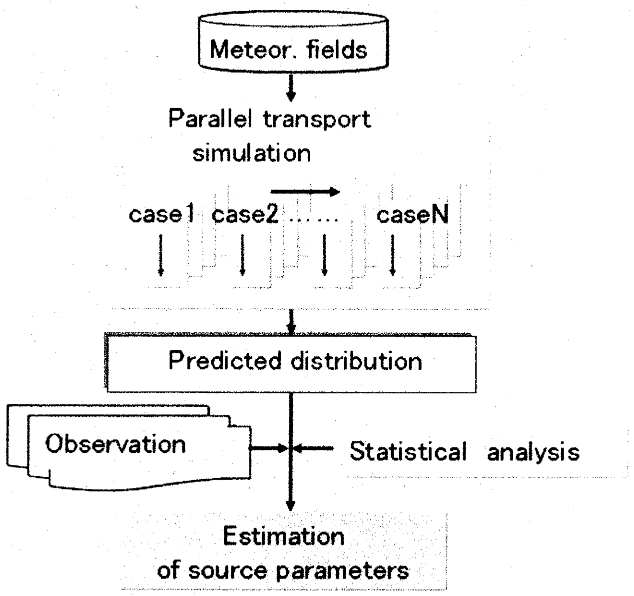

Fig. 3. The computational flow to estimate source conditions by parallel computing.

This idea is also applied to find the propagation area of rice plant hoppers which are harmful insect to rice plant. It is known that rice plant hoppers migrate from the Asian continent in the rainy season. But the determination of exact propagation area and forecasts of migration to Japan were difficult. The simulation of migration is separated to processors with release areas, and carried out in the same time. Fig. 4 shows the migration of rice plant hoppers from various areas in the eastern Asia. This simulation aims to finding the generation area of plant hoppers in Asia by the comparison of simulation results with observation in Western Japan. The computation time is considerably shorten by allotting many migration simulations to parallel processors.

In the figure, particles represent rice plant hoppers flying to the western Japan from various areas of the eastern Asia.

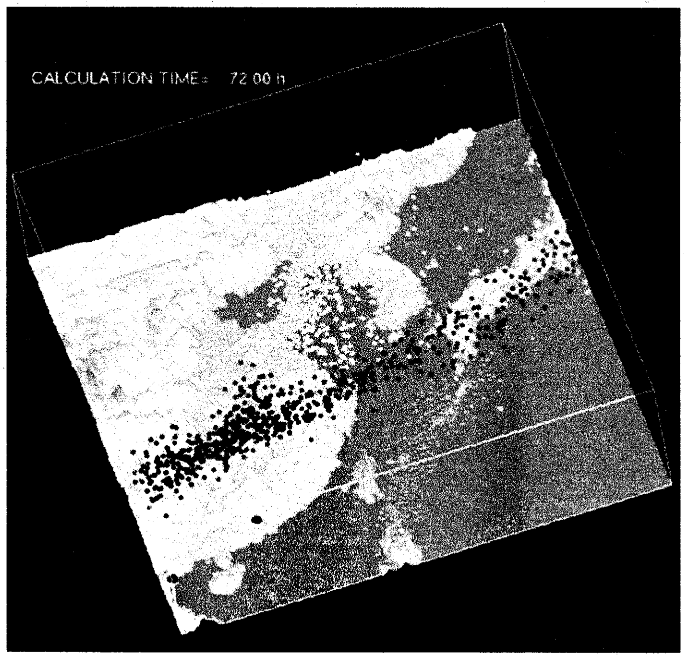

Fig. 4. Simulation of migration of rice plant hoppers from various areas in the eastern Asia.

C. *Model coupling simulation*

A model coupling simulation using different types of computers is carried out for air and oceanic pollution simulation. The models coupled are meteorological model MM5, Oceanic model POM, air pollution model GEARN and oceanic pollution model S-GEARN. These models are allotted to four computers according to the computer resources models need. By the network, necessary boundary data are dynamically delivered to other machine. In this manner, model coupler processes data considering the difference of grid and time step, etc. in each model. For example, 3-D meteorological data are processed to 2-D sea-surface data for POM and 3-D grid data for air pollution models.

Fig. 5 shows oil spill simulation from Tanker Nahotoka in 1997 at the Japan Sea. This simulation can be done by coupling of MM5 and POM, because the sea-surface current which transports float oil is strongly affected by wind stress. In this simulation, atmospheric and oceanic simulations start simultaneously in Fujitsu VPP5000 and AP3000, respectively, and wind stress and surface temperature are exchanged every 10 minutes in model time by data network. By this network computing, sea-surface currents affected by wind stress are calculated precisely.

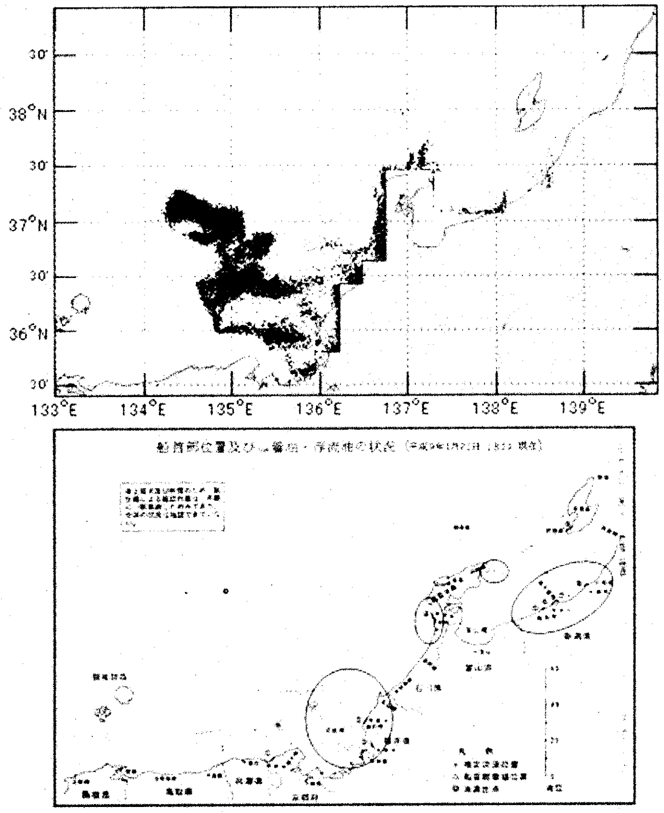

Fig. 5. Oil spill simulation from Tanker Nahotoka in 1997 at the Japan Sea.

The top of Fig. 5 shows the oil distribution after 20days predicted using ocean currents from the coupling simulation of MM5 and POM. We compared the result with observations shown in the bottom of Fig.5. According to the observation, strong northwest winds in winter season generated sea-surface currents toward south-east and, consequently, the oil reached the seacoast of the Japan Sea of the Honsyu Island (circled areas). It is clear that the predicted distribution agreed well with observation.

IV. Concluding Remarks

The ultimate goal of this research is to develop a simulation tool for the 'inclusive and successive' behaviors of pollutant materials in the atmospheric, oceanic and terrestrial environment in the Asian and local regions. For this purpose, the effective coupling of multi models is important from the physical and computational aspects. In the computational aspect, we will continue the vectorization and parallelization of models, development of model coupler and operational system.

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