Development of a submodel of global material transport via surface water circulation

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1. Background and Objective

Recently, global environmental issues become important problems not only from the point of environment conservation but also political and economic point of views. These phenomena have their fundaments on natural, social as well as economical aspects, and should be analyzed with comprehensive and integrative approach of these view points. Based on the recognition, we are developing a comprehensive global environmental model. A model described in this paper is also one of the effort, and this is a submodule focused on material transport via surface water runoff and ocean circulation. The model is composed with basin scale watershed runoff part and global scale ocean circulation part. Both are supported by a global scale geographical information system and organically connected with other modules. Though the submodules written here are in preliminary stage and expected to be refined by fine tuning effort, global environmental crisis of these day requires strongly such a detailed but comprehensive approach.

2. Surface runoff module

In order to describe surface runoff via rivers, watersheds/basins are fundamental units of analysis. Location of rivers and other inner-waters, slopes of terrain are basic factors to calculate the transport paths of surface water. Tracking the paths with accumulating regional effective precipitation we can calculate down-stream waterflow intensity and pouring load of water quality and material loads into ocean. Several basic dataset used should be mentioned. As digital elevation data of the world, we used ETOPO5 obtained from NOAA's National Geophysical Data Center. This data is based on a cell size of 5 arc minutes and also polluted with noise. we worked this runoff calculation with 5 arc minutes cells following the resolution of ETOPO5 dataset, however, we augmented it with stream line data and inner-water surface area data to enforce surface

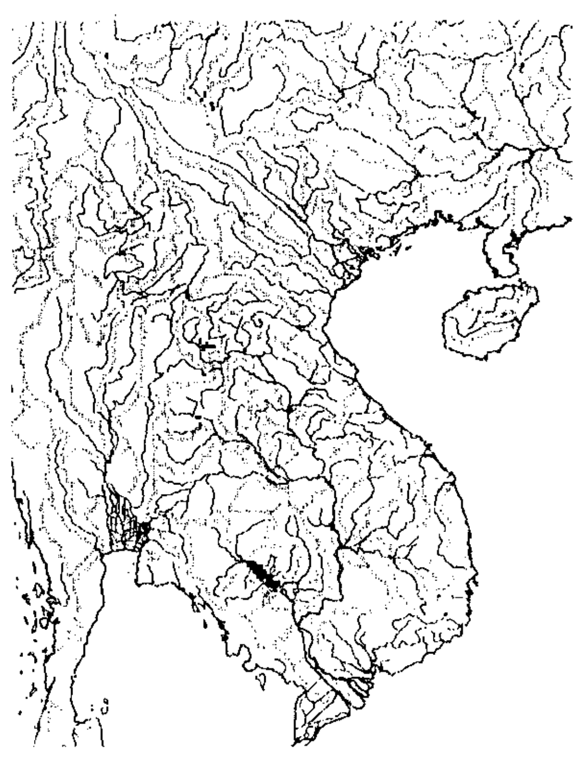

Figure 1 Drainage basin analysis, an example of Indo-China peninsula

water to be accumulated to river/inner water cells. A group of programs was developed to conduct this mission on a UNIX workstation, and executed for the whole globe. Figure 1 shows a partial result of watershed delineation of Indo-China peninsula. Solid lines denote streams and vague dotted lines denote boundary of sub-watershed. Integrating the inter-cell transport within watersheds and also inter-watershed transport of water, we can calculate material loads poured into ocean, which are discharged distributionaly at each 5 arc minutes inland and coastal cells. Cogley's global runoff intensity dataset (GGHYDRO) and simple country /population based discharged model were coupled with the above surface water transport model.

3. Ocean transport module

Much of the load poured at river mouths are trapped in coastal regions, however some are conveyed to offshore and are involved in

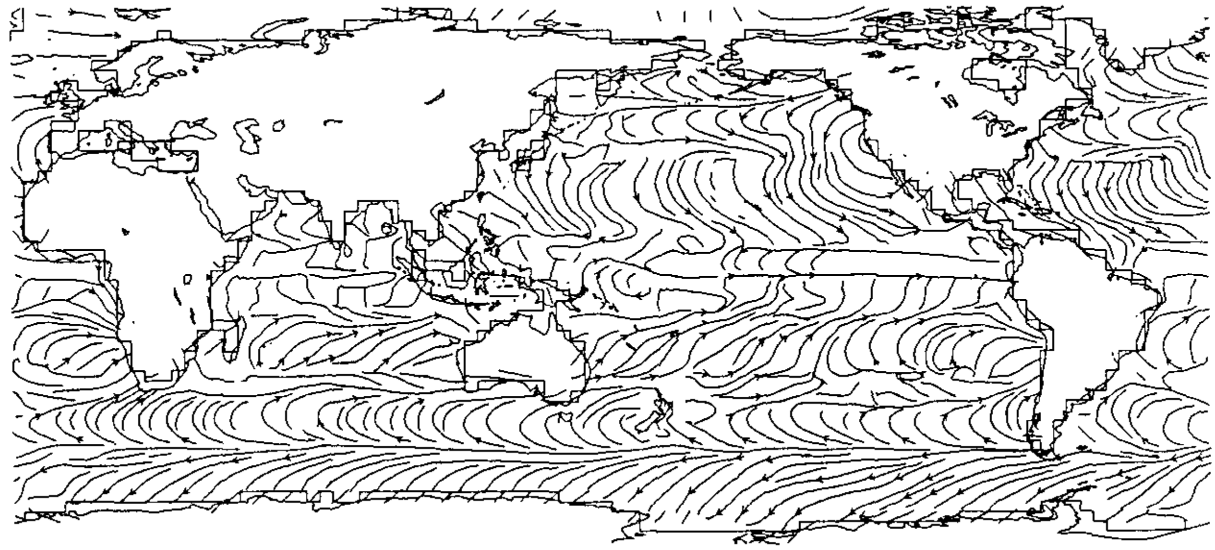

Figure 2 Snapshot of calculated streamline of upper layer, year 99, October 17

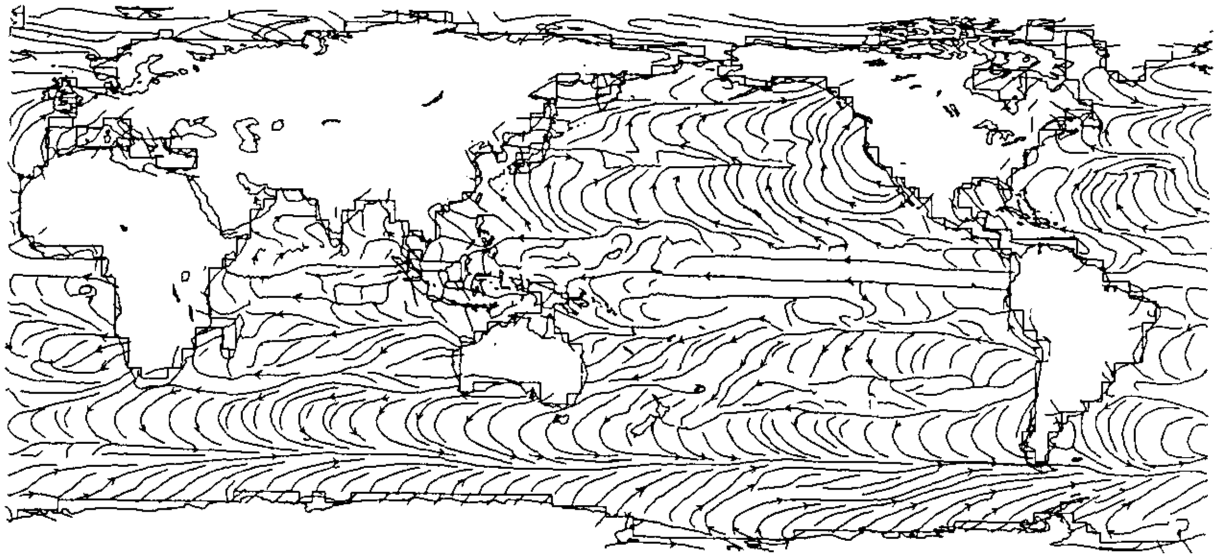

Figure 3 Snapshot of calculated streamline of subsurface layer, depth 1819 m, year 99, October 17

general circulation of ocean current. A primitive equation world ocean general circulation model (MOM) developed by the Geophysical Fluid Dynamic Laboratory, NOAA, Princeton University was used in order to track the fate of the anthropogenic discharge. The model's spacing between grid points is 4.0 degree of latitude and 3.75 degree of longitude. The maximum depth is 5700 m, and there is 15 vertical layers. Temperature, salinity, and chemical concentrations are defined at the center of grids. The u and v components of velocity are defined at the center of the corner points. Coastal boundaries coincide with the edges of the grids. Scripps 1 degree topography was interpolated to get the ocean's bathymetry. Grids of which three faces are coastal boundaries were omitted. The observed potential temperatures, salinities (Levitus, 1982) as well as wind stress field (Hellerman and Rosenstein, 1983) were applied every month as boundary conditions of upper layer, which represent an average of upper 30 m. Linear second order lateral mixing of momentum, heat and chemicals is applied with constant eddy coefficients $1.0\times10^9 cm^2s^{-1}$ for momentum and $2.0\times10^7 cm^2s^{-1}$ for heat and chemicals. Also the same is vertical mixing scheme and $20.0 cm^2s^{-1}$ and $1.0 cm^2s^{-1}$ were used in this case. Convective adjustment handles regions of gravitational instability. Figure 2 and 3 are snapshots of calculated surface and middle depth streamlines after 100 years of integration.

4. Circulation of anthropogenic concentration of chemicals in global waters

Figure 4 is a estimated discharge intensity of DDT, a typical anthropogenic chemical with a high persistence in the environment and an extensive global distribution. Every year estimations of such discharge were inputted to the surface water transport submodule and ocean circulation submodule. And global distributions of the chemical were estimated. Figure 5 shows an example concentration profile of the chemicals in upper layer of the world ocean. Also, figure 6 shows an anthropogenic imaginary load discharged propotional with population density.

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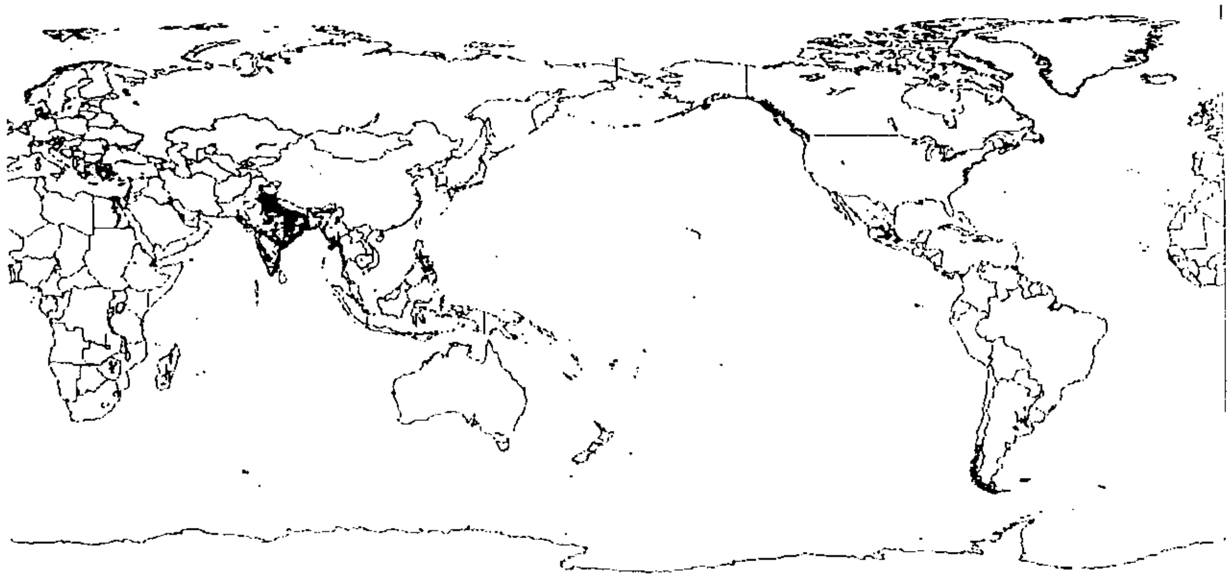

Figure 4 Estimated discharge intensity of DDT, year 1985

erous supply of the GFDL Modular Ocean Model (MOM).

References

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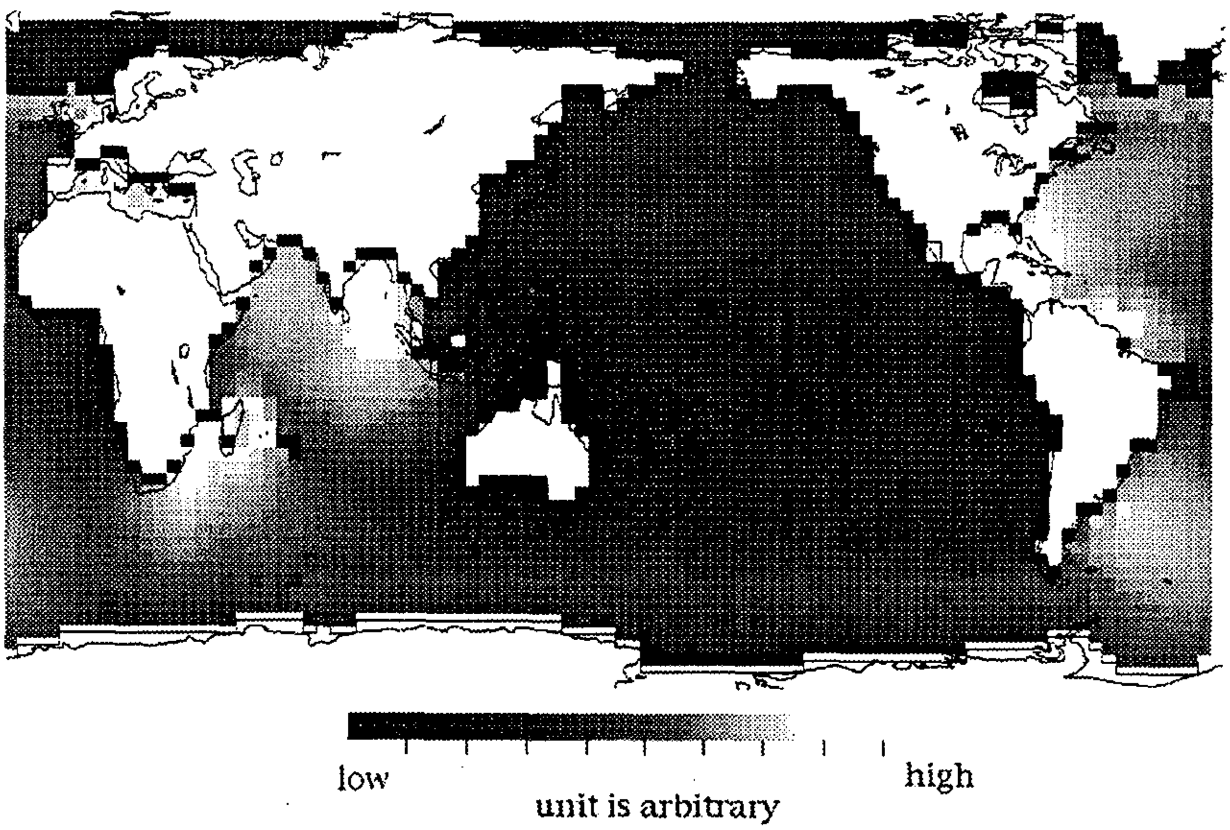
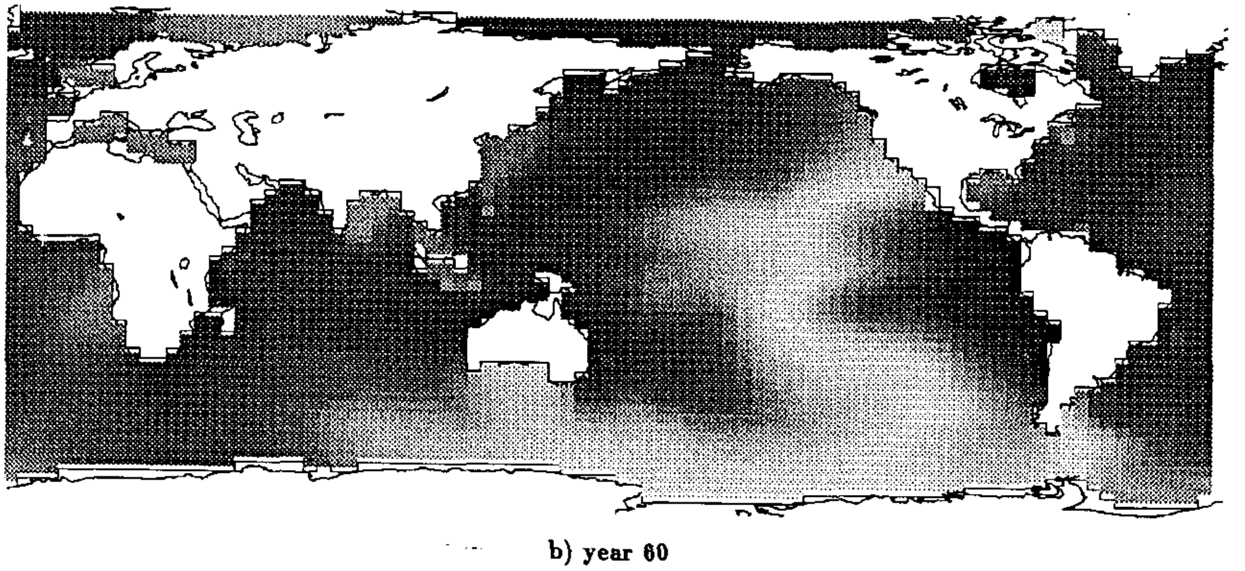


Figure 5 Calculated concentration profile of DDT, surface water, year 1980

a) year 10

Figure 6 Calculated concentration profiles of anthropogenic material discharged propotional with population density



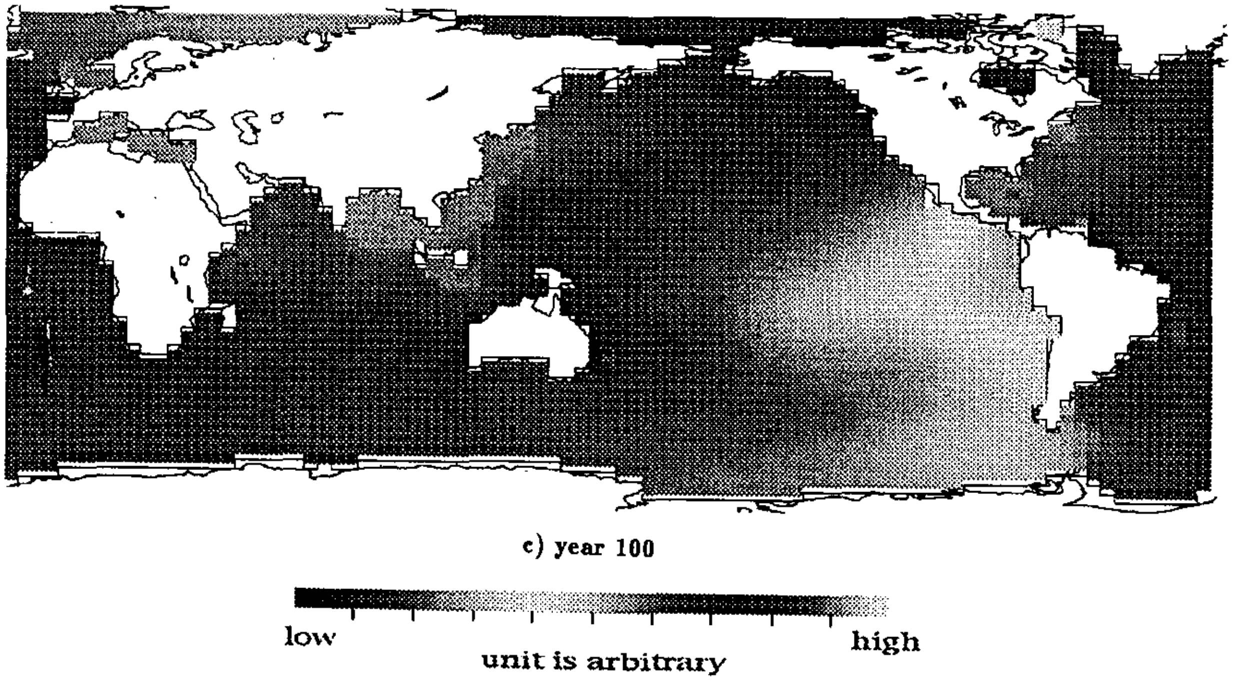


Figure 6 Calculated concentration profiles of anthropogenic material discharged propotional with population density