Atmospheric and Oceanic Environment Modeling

Study of Oceanic Surface Mixed Layer and Current System for Evaluation of Satellite Ocean Color Data

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1. Background

Recently, effects of human activity are expanding to the global ocean scale. Necessity of evaluating anthropogenic effects is increasing. In the ocean, phytoplankton is the most fundamental element which is exposed to environmental deterioration. Satellite ocean color data is one of the most efficient indicators of ocean surface content of chlorophyll or phytoplankton, and is becoming a more and more important measure of global link between natural/anthropogenic physical and biological change. Therefore we need to develop useful satellite ocean data in order to evaluate the ocean environment.

2. Objective

Satellite global data set accumulating in daily basis so far reveals a clear relationship with physical environment such as upwelling of ocean water and change of sun light in the ocean surface layer. Anticipating future massive storage of ocean color data through SeaWiFS (1994-) and OCTS/ADEOS (-1995), it is urgent to prepare assimilation system which provides near-operational mapping of global chlorophyll. Simulation of the past data set should precedes this.

In the present study, the goal is set to re-evaluate quantitatively the discussion of cause and effect of phytoplankton to physical environment such as ocean water upwelling and surface mixing with the use of global water circulation numerical models. Present advantage is in our availability of the past/near future ocean color data of several years as seasonal climatology of global chlorophyll distribution.

3. Method

A numerical model employed is a standard global ocean circulation model driven by the climatological wind stress (Hellerman & Rosenstein,1983(1)), temperature and salinity (Levitus,1982(2)) with realistic bottom and coastal topography (Fig.1) and resolution of 2.5° x 2° x 21 levels. The distribution of vertical levels is shown in Fig.2. Embedded in the model is a turbulent mixed layer model which has a closure scheme of level 2 (Mellor & Yamada, 1982(3)) with 5 meters resolution in the upper 20 meters. It gives a set of turbulent mixing coefficients of temperature/salinity and momentum, which actually mixes water in the vertical direction and predicts new temperature/salinity and current. As references, climatological wind stress, temperature and salinity data used to drive this model are shown in Fig.3,4 and 5, respectively.

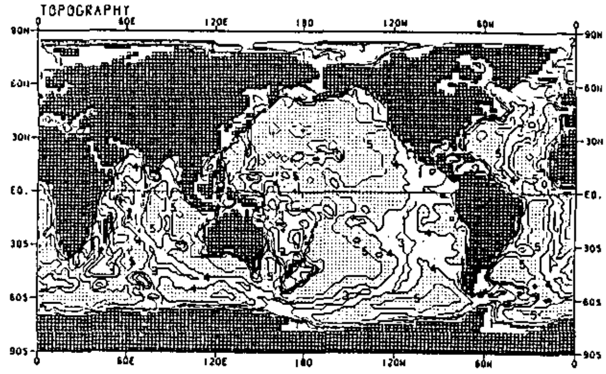

Fig.1 Bottom and coastal topography of the model. Contour interval is 1000m.

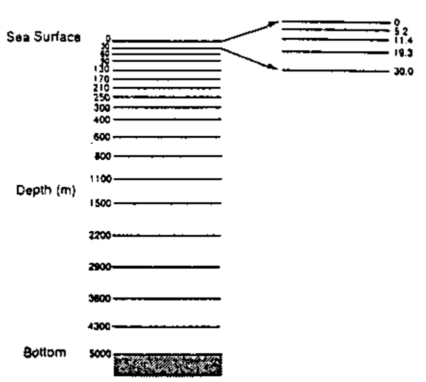

Fig.2 The distribution of vertical levels of the model.

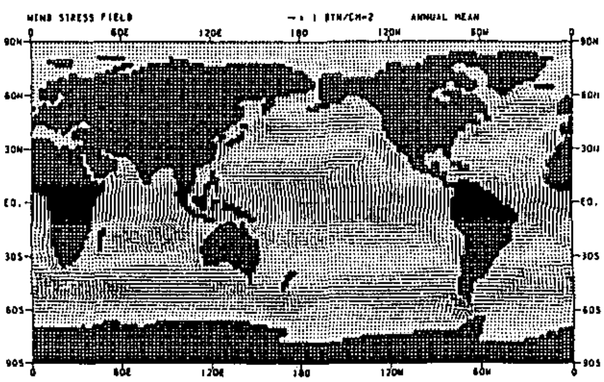

Fig.3 Annual mean wind stress field used in the model. (Hellerman & Rosenstein,1983)

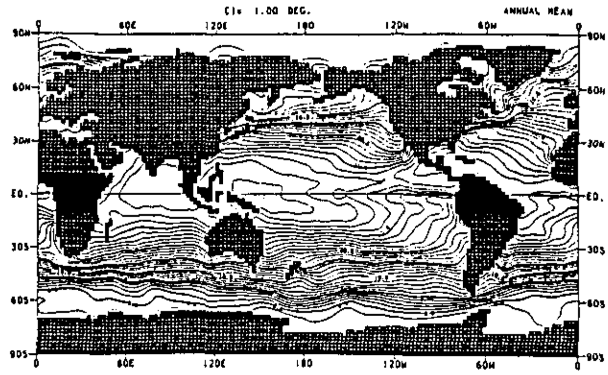

Fig.4 Annual mean temperature distribution in the ocean surface. (observed : Levitus,1982) Contour interval is 1°C.

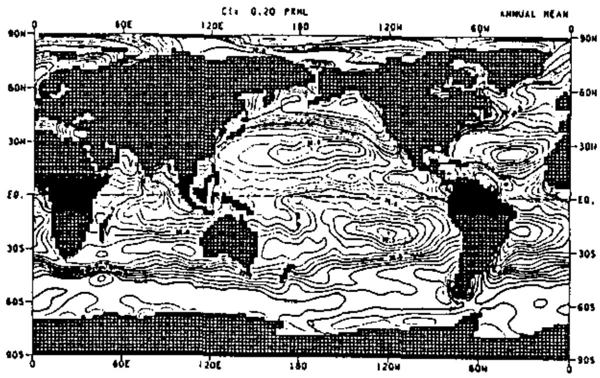

Fig.5 Annual mean salinity distribution in the ocean surface. (observed : Levitus,1982) Contour interval is 0.2 psu.

4. Results

As a preliminary calculation, the model with annual forcing as mentioned above is integrated with time for about 1000 years until it reaches to a quasi-steady state. Fig.6 indicates a global distribution of surface upwelling. This is practically determined by the local Coriolis parameter (, a function of latitude) and the wind stress distribution. Fig.6 corresponds very well to the global view of the ocean chlorophyll concentration, for example, produced from scenes of CZCS sensor aboard the satellite Nimbus7. Especially, upwelling in the equatorial and high latitude area explains the concentrated chlorophyll in each corresponding area of the real ocean. Conversely, downwelling in the middle latitude explains poor chlorophyll region.

Fig.7 shows a distribution of vertical mixing coefficient produced in the mixing closure scheme in the model. In general, the large value around 20 to 60 cm^2/s, is found along the latitudinal belt of strong easterlies and westerlies.

Surface temperature and salinity distribution and stream function are shown in Fig.8,9 and 10, respectively. These and other variables such as horizontal currents, convective mixing frequency and depth of surface mixed layer show reasonable distributions. Relatively small value for the mixing is indicated due to the use of annual mean wind stress. High latitude overshooting of the western boundary currents in the model northern hemisphere results in the too strong convective mixing in the high latitude.

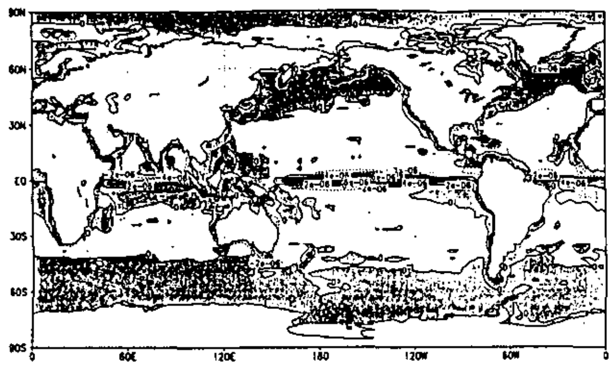

Fig.6 Upwelling (positive) distribution in the ocean surface with the annual mean wind stress. Contour interval is 2×10^{-6}m/s. Shaded areas indicate upwelling regions. Downwelling in the middle latitude and upwelling in the equatorial and high latitudinal area are evident.

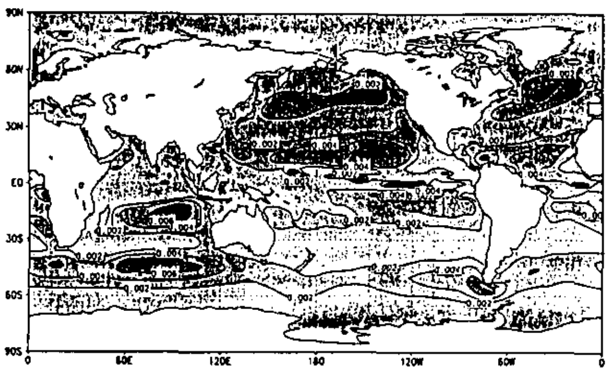

Fig.7 Vertical mixing coefficients in the ocean surface. Contour interval is $2\times10^{-3}m^2/s$. Large values are indicated in the latitudinal belts of strong easterlies and westerlies of wind.

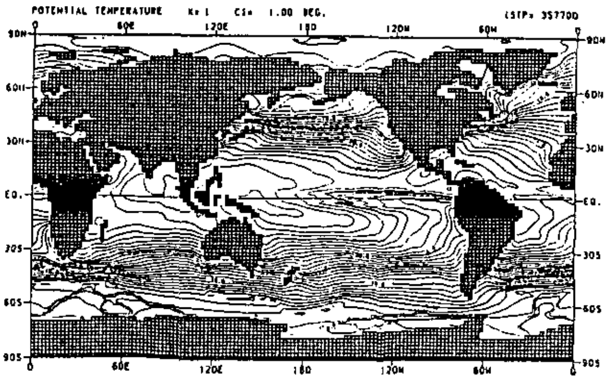

Fig.8 Temperature distribution in the ocean surface.

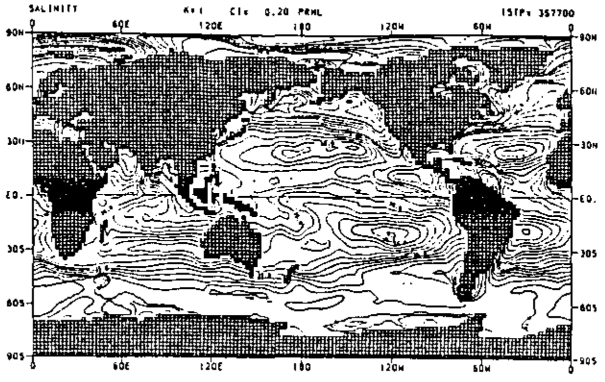

Fig.9 Salinity distribution in the ocean surface.

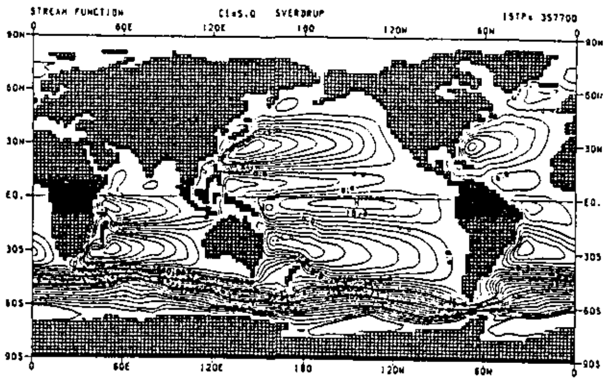

Fig.10 Stream function. Contour interval is $5\times10^6 m^3/s$.

For improvements in the future, preliminary calculation with seasonal forcing will be conducted. Improvement in the closure scheme in the mixed layer model to level 2.5 is planned. Closer study of related physical variables is made along with preparation of the global ocean color digital data to be compared directly with the model results.

References

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