New modeling approach with probability distribution functions as a guideline for high resolution models: application for future states of the Arctic Ocean

*Motoyoshi Ikeda[1,2]

1. Hokkaido University, 2. JAMSTEC

A new modeling approach for simulation of the future is proposed on the basis of a simple box model, with one active box for the surface layer, which interacts with the warmer and saltier box to the south and the lower box for the heavier subsurface layer. The new component to the simple model is a probability distribution function (PDF) defined at discrete grids on the temperature–salinity (*T*–*S*) plane, representing horizontal heterogeneity as shown in the attached figure. A *T*–*S* distribution retains only the probabilities of different water types, while their locations are discarded. Time progressions of the PDF are calculated as the basic equations. The mechanisms to increase and reduce heterogeneity are represented by divergence and convergence of the PDF, respectively. The heterogeneity is generated by the intrusion of exterior water and forcing variability, and reduced by horizontal diffusion within the box. Convection with the lower box tends to concentrate the PDF to the lower box (*T, S*).
This approach has provided the way to develop and use a medium resolution model, in each grid of which the PDF is implemented by representing sub-grid processes. The model results can provide guidelines about the basic behavior and performance of the high resolution models which resolve explicitly the heterogeneity represented by the PDF.
The box model with PDF has been applied for the Arctic Ocean, in which sea ice formation is decreasing under the global warming. The Atlantic Water, which flows into the Arctic Ocean partly modified under ice formation in the Barents Sea, will reduce the density of the subsurface layer (200 to 500-m depth) due to the warming. The active box of the surface layer (0 to 200-m depth) has sea ice and receives atmospheric forcing and freshwater flux, and interacts with the Greenland Sea.
The simple box model possesses a salinity-driven state, at which the saltier water enters the active box, is freshened, and becomes lighter, along with another solution, a convected state with the subsurface layer. Under the exterior condition that could produce both salinity-driven and convected states in the simple model, there are two partly convected solutions in the probability model near by the two states in the simple model, caused by the heterogeneity. As either the heterogeneity is doubled, or the subsurface layer is freshened by 0.1, the solution near the salinity-driven state has a convected portion increased, merging with the one near by the convected state. Thus, it is a possible consequence that the Arctic surface layer will be partly convected and have sea ice reduced significantly in the near future.
Our urgent issue is to clarify what consequences will occur due to the global warming. Under a horizontally uniform surface layer, convection hardly occurs with the subsurface layer, while heterogeneity associated with mesoscale variability, convective chimneys and sea ice leads tends to induce high density portions in the surface layer and expands convected areas. We certainly need a high resolution model with ice growth in open leads as well as convective chimneys in order to provide the future projection.
The reference is given as Ikeda (1997), *J. Phys. Oceanogr.*, **27**, 2576-2589.

Keywords: modeling guideline, probability distribution function, convection

$$(T_i, S_j) = (T_{ref}, S_{ref}) + (i\Delta T, j\Delta S)$$

$$([T],[S]) = (T_{ref}, S_{ref}) + \sum_{i}\sum_{j}(P_{ij}T_i, P_{ij}S_j)$$