Deep Convection Simulated by OGCM with Different Types of Atmospheric Forcing

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An adequate simulation of the processes responsible for deep water formation is a primary requirement for suitable modeling of the World Ocean itself, as well as of the climate system as a whole. The deep convection confined within few restricted areas occupying only several percents of the overall World Ocean area is a basic mechanism for interchange of sea water properties between the surface and deep ocean layers.

A series of numerical experiments with a primitive equations ocean general circulation model (OGCM) has been performed in an effort to analyze the geography and temporal variability of deep convection events. The OGCM used in the experiments (*Resnyansky and Zelenko, 1999*) includes a parameterization of small scale mixing generated by wind and buoyancy flux in the upper ocean layers, which is implemented in the framework mixed-layer schemes. The vertical exchange due to density convection in the ocean interior is parameterized through the "convective adjustment" scheme, which is actuated every time as soon as static instabilities emerge in the vertical potential density profile. The computations were performed in the global domain (excepting the Arctic basin to the north of 77.5° N) with a fairly coarse horizontal resolution (2°×2° in the most part of the domain and 2°×1° near the equator) and 32 levels in the vertical.

The set of experiments consisted of the basic integration (run ***BASE***) and of three further computations: ***SDAY, SMON*** and ***RELX***. The run ***BASE*** started from rest with climatological January distributions of sea water temperature and salinity specified from data of the WOA-98 atlas. The length of the integration is 24 years (1979–2002), during which the model was forced by actual 6-hourly data on surface fluxes of heat, fresh water and momentum from the NCEP-DEO AMIP-II reanalysis (*Kanamitsu et al., 2002*). Three further computations started from the state reached in run ***BASE*** by 01/01/1999 and differed from it only in structure of atmospheric forcing fed into OGCM. In runs ***SDAY*** and ***SMON*** the initial 6-hourly forcing was transformed into series smoothed over time with one day and one month sliding window respectively. In run ***RELX*** 6-hourly forcing (surface fluxes of heat, fresh water and momentum) was applied in association with restoring sea surface temperature and salinity computed in the model to actual values with characteristic time of about 1 month.

The events of deep convection were identified using a convection mask registering at each time step the computational cells, in which convection penetrated down to a specified depth. The major areas of deep convection in all of the runs were observed during the cold season (from December to March) in the Greenland and Labrador Seas. Convective mixing penetrated there down to 1200–1600 m and not infrequently down to bottom. Winter convection in the South Ocean, as obtained in the experiments, appeared much weaker with characteristic mixing depths less than 100 m. The exception was run ***RELX*** , in which convection events expanded over substantially broader areas, and mixing penetrated down 500–800 m. In particular, spatially localized and steady in time area with bottom-reaching convection was traced in the Weddell Sea.

In run ***BASE*** with actual 6-hourly atmospheric forcing location of convection events is rather versatile in time (Fig. 1, left panels). The areas of static instabilities in a matter of days may move in space by several computational cells, disappear and once again appear. Nevertheless their geography remains similar in large-scale localization confined for the most part to the Greenland and Labrador Seas. In run ***SMON*** (Fig. 1, right panels) the pattern of convection events is quite stable at these time scales and more extensive in space as against run ***BASE***. Thus the experiments suggest that smoothing over time of atmospheric forcing results in the overestimated role of convection processes.

In line with the OGCM design, including the parameterization of the upper mixed layer and the convective adjustment scheme, the development of convective events affects the evolution of mixed layer depth h (Fig. 2). Removal of daily and synoptic variations of atmospheric forcing in run ***SMON*** brings about the disappearance of the corresponding fluctuations in h , but have no appreciable influence on the general shape and on the amplitude of the seasonal cycle. Anyhow, maximum seasonal mixed layer deepening in runs ***BASE***, ***SDAY*** and ***SMON*** remains roughly the same. The greatest transformation of temporal variability of h is noticeable in run ***RELX***, in which deep convection in the Greenland Sea is severely suppressed (Fig. 2b). In the Southern Hemisphere the situation is reverse, as was mentioned above.

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References

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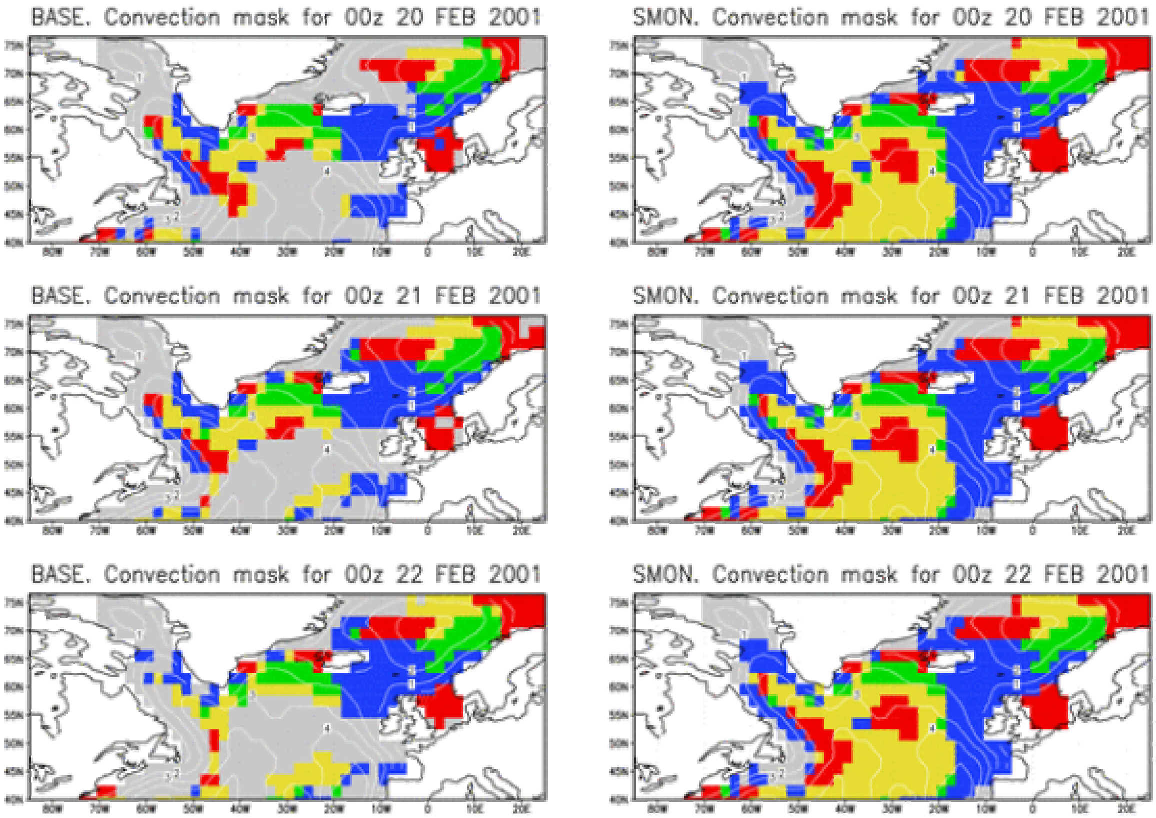

Fig. 1. Horizontal structure of convection events in the North Atlantic during February, 20–22, 2001 in runs ***BASE*** with 6-hr atmospheric forcing (left panels) and ***SMON*** with monthly smoothed forcing (right panels).

Cells coloring indicate the depth of convection penetration: down to 100 m and more (blue), down to 500 m and more (green), down to 1000 m and more (yellow), and down to bottom (red). Contours display OGCM's depth with 1-km interval.

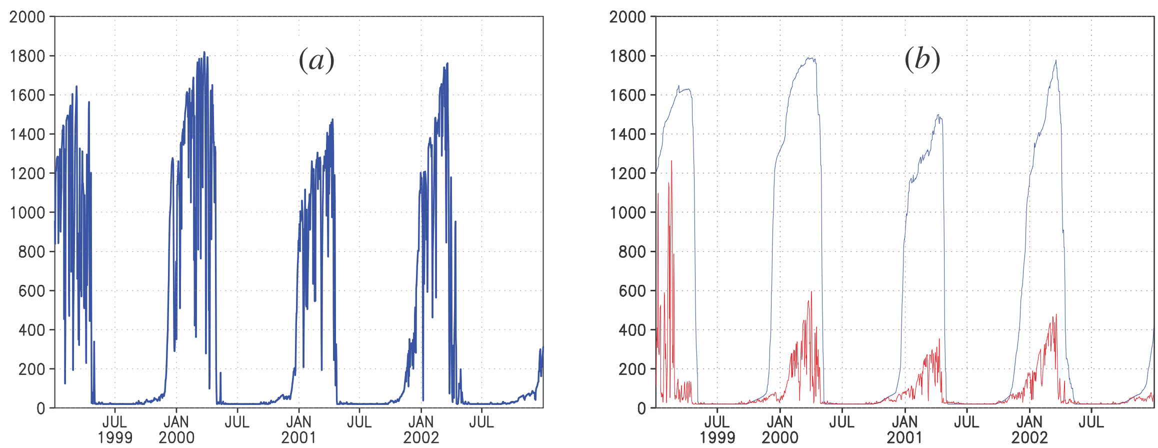

Fig. 2. Temporal changes of the mixed layer depth *h* (meters) in the Greenland Sea (averaged over 67°–75° N, 25°–10° W) in experiments with different types of atmospheric forcing (AF).
(*a*) run ***BASE*** (6-hr AF); (*b*) runs ***SMON*** (monthly smoothed AF, blue line) and ***RELX*** (6-hr AF in association with restoring SST an SSS fields, red line).