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On the importance of surface mixing in an OGCM

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Abstract

An ocean general circulation model is coupled with a bulk mixed layer model and a sea ice model. It is forced both by daily varying fluxes and by the monthly means derived from these daily data. Comparing the respective results reveals the importance of high-frequency forcing. The incorporation of a sea ice model allows to study the interaction between the mixed layer and the sea ice. Sea ice extent appears to be very sensitive to mixing. Daily varying forcing makes it possible to analyse the mechanisms of mixed layer dynamics.

1. INTRODUCTION

Recently, Sterl & Kattenberg (1994) (hereafter SK) showed that coupling a mixed layer model (MLM) to an OGCM improves the thermodynamic performance of the OGCM. Using monthly mean climatological forcing, they obtained better agreement with climatological sea surface temperature (SST) and needed a smaller correction to the applied heat flux than without MLM. Here these findings are extended by investigating the impact of using daily-varying forcing instead of the monthly means. The interaction between mixed layer and sea ice is also studied.

2. EXPERIMENTAL SETUP

The HOPE ocean model (Wolff & Maier-Reimer, 1994), which includes a Hibler-type sea ice model, and the MLM of SK are used. The model is forced by a one-year set of daily values of air/sea fluxes obtained from an integration of the ECMWF atmosphere model at T63 resolution (Janssen, 1994). These fluxes are used as a new 'climatology', i.e., each year the model is forced by the same fluxes. The importance of high-frequency forcing is investigated by comparing runs forced by daily fluxes with runs forced by the corresponding monthly means. In all cases, SST and surface salinity are relaxed toward climatology to prevent model drift.

Figure 1 shows wind stress (as a proxy of wind stirring energy available), mixed layer depth (MLD), and heat flux at 40°W, 43°N to illustrate the working of the MLM. Clearly, heat flux and wind stress are highly anti-correlated, so that their respective impact on MLD is hard to separate. The mixed layer (ML) mainly deepens as a response to negative heat flux (cooling), but during summer deepening is possible with positive heat flux if wind stirring is high enough. During such episodes of ML deepening the heat flux error

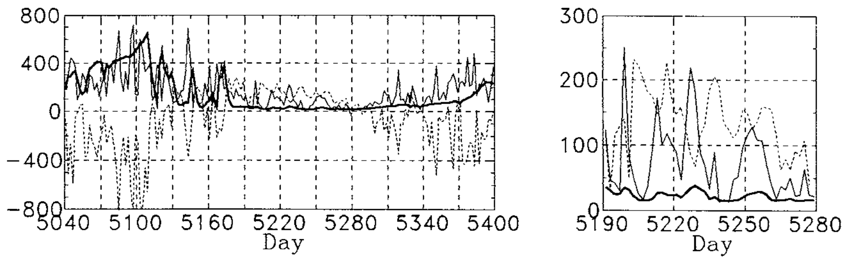

Figure 1: MLD (thick solid, in m), wind stress (thin solid, in mPa), and heat flux (thin dashed, in mW/m^2) at 40°W, 43°N. Left: year 15, right: summer (JJA) enlarged.

(the relaxation term for heat flux, see SK) decreases and the heat content increases (not shown), highlighting the importance of the ML as a sink for the atmospheric heat flux.

3. DAILY VERSUS MONTHLY FORCING

SK used climatological fluxes to force their model when investigating the impact of the MLM on model performance. To test whether the values for the MLM parameters they recommended are also suited if daily forcing is used, the model has been run with and without MLM for both kinds of forcing. Figure 2 shows the rms SST and heat flux errors, respectively, from these four runs, averaged over the subtropics (10°N $\cdots$ 30°N) and the subartic (50°N $\cdots$ 70°N). As explained in Sterl (1994), the model fails to produce enough ice, which leads to large errors in areas that are affected by ice. Excluding subarctic winter from the analysis, Figure 2 confirms the finding of SK that the MLM mainly improves the model during summer, i.e., when ML formation is governed by wind-stirring. Furthermore, the improvement gained from adding the MLM is roughly the same for both forcings. Thus the parameter values recommended by SK are also suited for daily varying (high-frequency) forcing.

4. INTERACTION BETWEEN MIXED LAYER AND ICE

Figure 2 also shows that the errors are smaller with daily forcing than they are with monthly forcing. The differences are enhanced if the MLM is present. Although they seem to be small, Figure 3 shows that these differences correspond to a large change in meridional overturning. Its maximum is situated at about 60°N, the approximate latitude of the sea ice edge in the Labrador Sea (Figure 4). Further investigation indeed shows that the differences displayed in Figure 3 originate in the Labrador Sea and are related to the amount of sea ice there.

Figure 4 shows the sea ice compactness for the two runs with MLM, obtained with daily and with monthly forcing, respectively. Although in both cases the model does not succeed in reproducing the actual sea ice distribution (see Sterl, 1994) it appears that the kind of forcing (daily/monthly) alters the sea ice compactness to some extend. This is also true for runs without MLM, even though for them the differences are smaller (not shown). With daily forcing, instantaneous fluxes can be much larger than the monthly average,

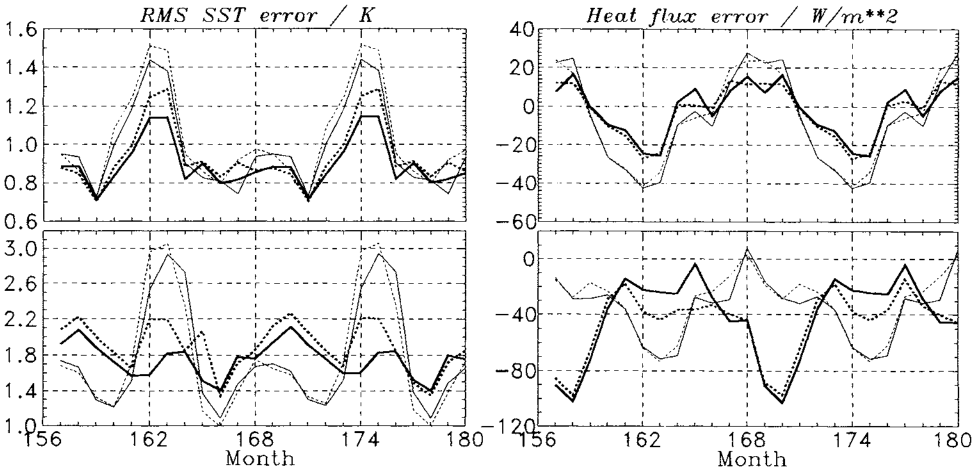

Figure 2: Two years of rms SST error (left) and heat flux error (right), averaged over the areas between 10°N and 30°N (top) and 50°N and 70°N (bottom). (Thick: with MLM, thin: without; solid: daily forcing, dashed: monthly.)

leading to mixing reaching deeper at times. Warm water is brought to the surface, melting the thin ice at the ice edge. These changes in ice cover induce the changes in overturning shown in Figure 3. Without sea ice model there are hardly any such differences. This again shows the great sensitivity of the sea ice model with respect to changes in mixing and the subsequent impact on overturning that was already described in Sterl (1994).

5. CONCLUSIONS

The HOPE OGCM with and without MLM has been forced with both daily and monthly varying fluxes. The results show that the MLM deals with both kinds of forcing

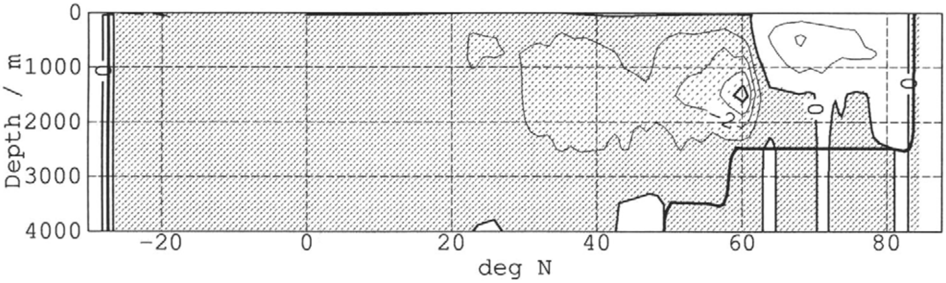

Figure 3: Difference in annual-mean meridional overturning stream function between a run with daily and one with monthly forcing, both with MLM. Contour interval is 1 Sv, negative values are stippled.

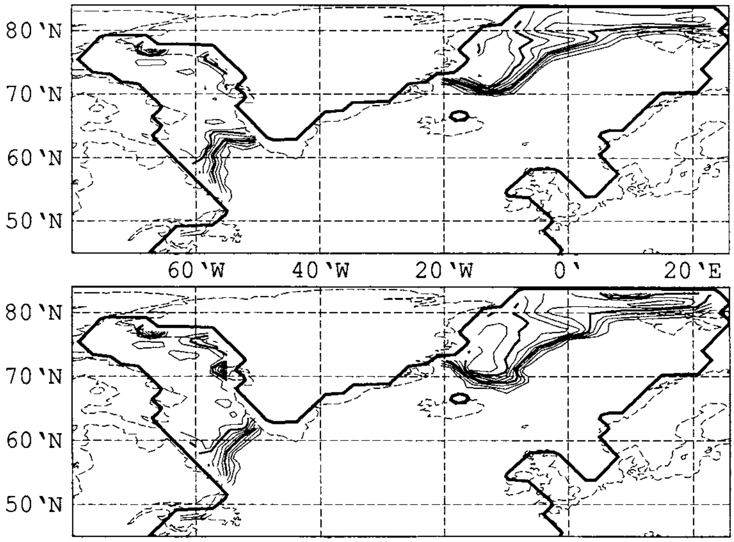

Figure 4: Sea ice compactness for run with daily (top) and monthly (bottom) forcing; MLM included. Contour interval is 10%.

in the same way, i.e., it is not necessary to use different values for the parameters of that model if high-frequency forcing is used. This conclusion is important for the use of the MLM in a coupled ocean-atmosphere model, where the oceanic part is exposed to the high-frequency variability of the atmosphere.

The results show further that the difference between daily and monthly forcing result in substantial differences in meridional overturning. At least in part, these differences correspond to and may be caused by changes in sea ice distribution. The sensitivity of overturning and sea ice distribution to the frequency characteristics of the forcing calls for care when testing OGCMs in stand-alone mode, which is usually done with monthly (climatological) forcing.

6. REFERENCES

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