Toward a natural boundary condition for the freshwater fluxes in HYCOM

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ABSTRACT

The lack of a quantitative knowledge of nearly all the components of the surface fresh water fluxes (evaporation, *E*, Precipitation, *P*, and runoff, *R*), has justified the use of a "relaxation condition" at the surface as the crudest representation for the surface fluxes. In this case the sea surface salinity of the model is linearly restored to the climatological observations. The virtual salt flux formulation ("mixed boundary condition") introduces a non physical salt flux through the air-sea interface allowing the concentration dilution effect to be represented. Huang (1993), introduced the "natural boundary" condition according to which the real fresh water flux across the upper surface is specified as the vertical velocity boundary condition for the continuity equation, while the salinity flux is set identically to zero at the sea surface. The barotropic signals due to the different amount of water at the surface is thus retained and the global ocean salt content is perfectly conserved. Details of the three different conditions are summarized in the Table 1. Different papers presented numerical evidences of the importance of the freshwater flux forcing and of their corrected representation (Weaver et al.,1991; Huang, 1993; Wadley et al., 1995; Tartinville et al., 2001; Oka and Hasumi, 2004).
The HYbrid Coordinate Ocean Model (Bleck, 2002) has already implemented a new surface formulation. Testing, assessing and improving this formulation are the final goals of this study.

MODEL SETUP

- closed basin at rest, uniformly 5700 m deep;
- extension: 0°N to 60°N, 0°E to 60°E;
- resolution: 0.5°x 0.5°, only 1 layer;
- uniform *T*=12.5°C and uniform *S*=35psu;
- salt flux artificially set to zero;
- horizontal diffusion velocity = 2 m/s;
- forcing: only a "linear" meridional freshwater flux (see Fig. 2).

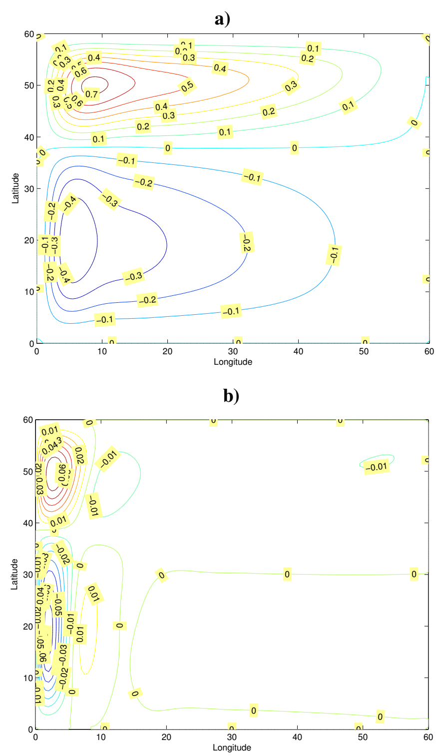

Fig. 1(a) Barotropic nondivergent streamfunction in Sv.

(b) Integrated meridional volume flux through each box in Sv.

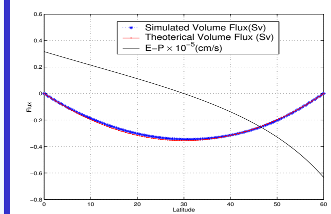

Fig. 2. Meridional distribution of the fluxes: *E-P* forcing (in 10^{-5} cm/s) and total poleward volume fluxes, simulated and theoretical (in Sv)

"Linear" freshwater forcing

$$E - P = \frac{W_0}{\cos\phi}\left(1 - \frac{2\phi}{\phi_N}\right)$$

where W_0=1 m/yr;

RESULTS

- the Goldsbrough-Stommel gyres (Goldsbrough, 1933; Stommel, 1957) are reproduced (Fig 1);
- the gyres are in general negligible if compared with the ones driven by the wind stress but at high latitudes they can be an important part of the total volume flux in the subpolar basin (Huang and Schmitt, 1993);
- the results are comparable with previous studies (Huang, 1993 and Griffies et al., 2001);
- at the equilibrium, the northward atmospheric flux due to the forcing (≈0.35 Sv) has to be balanced by a southward motion in the ocean. The simulated southward flux is in good agreement with the one predicted by the theory (Fig. 2).

CONCLUSIONS and FUTURE WORK

- the new code implemented in HYCOM is able to reproduce the barotropic circulation systematically neglected by the other formulations;
- thanks to the relation between η and the baroclinic thicknesses dp_k', it is possible to inflate or deflate locally each layer affected by the freshwater flux; this is important for the natural formulation of the river runoff;
- extension to shallower areas: the hypothesis $\eta<<1$ fails in shallow regions and it is required to keep the splitting variable η in the equations of motions and in the conservation of mass;
- the input of the temperature and salinity of the freshwater added to or subtracted from the system will require the advection of the barotropic thickness. The results presented here are just the first step toward the complete and correct implementation of the freshwater forcing in HYCOM.

TABLE 1

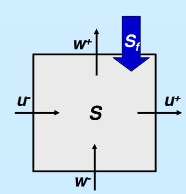

Fig. 3. A surface grid box in the *xz*-plane

Relaxation	Mixed (Virtual Salt flux)	Natural
• $w^+ = 0$; so $(wS)^+$ vanishes • $S_f = \Gamma(S^*-S)$; where S^* is the climatological salinity value Γ is the relaxation coeff.	• $w^+ = 0$; so $(wS)^+$ vanishes • $S_f = S(E-P)$; where S is the salinity in the value in the box	• $w^+ = E-P$; • $S_f = 0$; and this means $(wS)^+ - k_s(\partial_z S^+) = 0$; where $(wS)^+$ is the advective flux and $k_s(\partial_z S^+)$ is the "antiadvective" flux

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