ABSTRACT

Optimal surface salinity perturbations influencing the meridional overturning circulation maximum are exhibited and interpreted on a stable steady-state of a 2D latitude-depth ocean thermohaline circulation model. In spite of the stability of the steady state the non-normality of the dynamics is able to create some transient growth and variability through stimulation by optimal perturbations. It is found that the response to the optimal initial sea surface salinity perturbation involves a transient growth mechanism leading to a maximum modification of the circulation intensity after 67 yr. Then, looking for the optimal stochastic surface salinity flux perturbation, it is established that the variance of the circulation intensity is controlled by an oscillation of 150 yr period. These optimal initial perturbations leading to explicit solutions (e.g. eigenvalue problems), their determination in more realistic 3D models should be straightforward.

INTRODUCTION

Recent observations and modeling studies have stressed the influence of surface salinity perturbations on the Atlantic circulation. The sensitivity of the meridional overturning circulation to initial, constant or stochastic perturbations can be estimated objectively through the analysis of optimal perturbations. As a first methodological step, we look for these optimal perturbations in a 2D model of the thermohaline circulation.

MODEL AND STEADY STATE

The latitude-depth 2D model (Sévellec et al. 2006) is based on the zonal-average approximation of Marotzke et al. (1988). Wright and Stocker (1991), for a single hemisphere North Atlantic size basin. Mixed boundary conditions are used at the surface, i.e. restoring sea surface temperature and prescribed freshwater flux.

OPTIMAL INITIAL SSS PERTURBATION

We look for the optimal sea surface salinity perturbation influencing the oceanic circulation in a linearized approach. Optimality is defined with respect to the MOC maximum – a discussion on the choice of the norm is available in Sévellec et al. (2007). The optimal SSS for this measure is obtained by propagation of the cost function relative to the measure, through the adjoint of the linear tangent model. In addition we constrain the solution (1) to be SSS only, (2) to conserve salt and (3) to be normed (in such optimal linear problem a quadratic norm must be used). The optimal solution can be explicitly written in terms of the two constraints, the adjoint of the linear tangent model and the cost function.

Maximisation problem: $\max (\langle F|u(\tau)|,|u(0)\rangle)$. Constraints: (1) & (2) $|u(0)| = P|u|^2$ and (3) $\langle u(0)|S|u(0)\rangle = 1$.

Perturbation propagation: $|u(\tau)| = M|\tau| |u(0)|$.

$\Rightarrow$ Explicit solution: $|u| = (2\tau)^{-1/2} |N^{-1} P^T M^T |F|, |N P|$.

The solution depends on the integration time of the adjoint model: we choose to examine the most efficient growth in time in agreement with our 2D model 'adjusted' dynamics, found for a delay of 67 yr. The corresponding pattern is a large-scale dipole perturbation. The time integration of the linear model perturbed by this optimal SSS triggers an oscillation of 150 yr (Sévellec et al., 2006) leading to a transverse growth of the MOC intensity after 67 yr.

CONCLUSIONS

In order to validate the linear approach, we have compared the linear and nonlinear time integrations initialized by the optimal SSS perturbation for different amplitudes ranging from -0.1 to 0.1 psu (confined in the upper 50 m). A strong correspondence exists between the linear and nonlinear integrations, although the latter show a weak asymmetry between positive and negative perturbations.

References

