CHAOCEAN Project Report

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Chapitre 1

Introduction

1.1 The project

The goal of this project is to disentangle the low-frequency oceanic variability in the subtropcial North Atlantic as locally generated through intrinsic ocean processes, locally driven by the atmosphere or controlled by remote signals.

Chapitre 2

The configuration

2.1 Description

This configuration is a regional configurations of the North Atlantic [20S-55N ; 98W-14E] using the MITgcm [Marshall et al, 1997]. The horizontal resolution is $\frac{1}{12}^{\circ}$, and the 46 vertical layers range from 6m at the surface to 250m at depth. To avoid too shallow grid cell, the shallowest grid cell is set to 6m. The topography has been linearly interpolated from the ORCA12 [Molines et al, 2014] . The geometry of the basin has been modified in order to reduce computation needs, leading to a 1000x900 grid point horizontal grid instead of 1301x900 (reduction of about $\frac{1}{4}$). For this purpose, the Mediterranean sea sea has been removed, and is now consider throught the use of open boundary conditions at the strait of Gibraltar. The Pacific is not considered.

2.2 Parameters

The ocean model uses a modified UNESCO equation of state [Jackett et McDougall, 1995], which uses the model variable potential temperature as input. The background model viscosity is parametrized as a Laplacian and a bi-Laplacian, with constant coefficients $A_h = 20$ m^2 s^{-1} and $A_4 = 10^{10}$ m^4 s^{-1}, respectively. Horizontal tracer diffusion is parametrized identically and with the sane coefficients. The vertical viscosity and diffusion are set to 10^{-5} m^2 s^{-1}. These parameters are those used by Dr Schoonover in his Gulf Stream configuration (/tank/groups/climode/schoonover/GS-68C/terraforming/control/input/). A Nonlocal K-Profile Parameterization [Large et al, 1994] is use to achieve vertical mixing. A free sleep condition is applied at both the bottom and the horizontal boundaries. The model is integrated forward in time on an Arakawa C-grid with a third order direct space time (DST) Flux limiter (finite volume method) and a time step of 200 sec.

2.3 Computational ressources

All simulations have been performed with the NCAR supercomputer Cheyenne. The domain has been devided in 360 tiles, such that 1 year of simulation is completed in 9 hours, representing about 3240 core.hours of machine time.

2.4 Spin-up

We have first integrated the model for 5 years (1958-1962) for a spin-up, and then run it for 50 years (1963-2012) to produce 4 ensembles of 12 members each. The 4 ensembles differ in their opend boundaries and surface conditions, which will either be fully varying or yearly repeating. They are referred to as ORAR (Ocean Real - Atmosphere Real), OCAR (Ocean Climatologic - Atmosphere Real), ORAC (Ocean Real - Atmosphere Climatologic), and OCAC (Ocean Climatologic - Atmosphere Climatologic). All ensemble have been completed succesfully (jan 2019) and stored under /tank/chaocean/qjamet/RUNS/. 5-day averaged model output have been generated for 6 oceanic variables (T, S, U, V, W, Eta) and 9 atmospheric variables (t2, q2, sensible latent and net heat flux, freshwater flux, u10, v10, precipitations), leading to about 61 GB of data for a single year and 36.6 TB for a 12-member, 50-yr long ensemble.

Chapitre 3

Forcing the model

3.1 Open boundaries

The model is forced at southern and northern boundaries, as well as at the strait of Gibraltar, using 5-day averaged model outputs of the the $\frac{1}{12}^{\circ}$ global, ocean-only simulation ORCA12.L46-MJM88 [Molines et al, 2014]. For the northern boundary and the strait of Gibraltar, velocities have been rotated from the initial NEMO curved grid to the regular lat/lon chaocean grid. Accordinly, the forcing at the boundaries is applied every 5 days. Forcing files are available under /tank/chaocean/boundary_conditions_12/.

Figures below show the interpolated volume transport across the three ocean boundaries for a given year (1986), and compare the interpolated net volume transport across the boundary with the net volume transport of the original NEMO data. The lower correlation at the northern boundary is due to the higher curvature of the NEMO grid at that location.

3.2 Atmospheric forcing

A simple, atmospheric boundary layer model [Deremble et al, 2013] is use to force the surface ocean. It is here composed of prescibed zonal and meridional wind at 10 meters (u10, v10), precipitations (precip), longwave and shortwave radiations (radlw, radsw), while air temperature and relative humidity humidity at 2 meters (t2, q2) are prescibed over land, but free to evolve with the underlying ocean state.

The atmospheric variables q2, t2, radsw, radlw, u10 and v10 are extracted from DFS4.4 [Brodeau et al, 2010, Molines et al, 2014], and precipitations come from DFS5.2 due to a better time resolution (daily for DFS5.2 *vs* monthly for DFS4.4). This forcing set is made upon ERA-40 before 31 December 2001 and ERA-Interim afterward for q2, t2, u10 and v10. Precipitations and radiative heat fluxes are made upon satellite observations for the period 1979-2012, and the 1979-2012 climatology is applied for the period 1958-1978.

Daily long wave radiations and precipitations are linearly interpolated to 6-hourly, and daily short wave radiations are interpolated to 6-hourly values as a step function, with zeros at the first and last (4th) time records of a day, and doubling the daily value for the two other time records. These variables are linearly interpolated onto the regular lat/lon chaocean grid. The transition over land (i.e. over the reshaped american continent) has been smoothed to avoid abrupt transitions. (Note : The linearly interpolated winds induce 'triangle' patterns in precipitations computed by cheapaml due to the divergence operator. This is finally out the scope since precipiations are prescribed rather than beeing computed by cheapaml).

Note that no albedo correction are currently accounted for in CheapAML, such that the solar radiations have to be corrected prior application (in hard in the forcing file). This has not been made in this configuration, where SolarFile='radsw.box' referres to the 'radsw' of DFS4.4. The appropriate solar file from DFS4.4 is referred to as Qsw instead, where a constant sea surface albedo correction is made with a coefficient of a = 0.066 [Brodeau et al, 2010].

All atmospheric focing files are available under /tank/chaocean/atmospheric_conditions_12/.

3.3 Using yearly forcing files with the MITgcm

To avoid large forcing files, the 55-year boundaries and atmospheric times series have been sub-sampled into 55 yearly time series. To achieve a correct time interpolation at first and last model time steps, yearly forcing files are extended with 2 additional time records placed at the end, yelding to 75 (1462) time records for the 5-days (6-hours) boundary (atmospheric) forcing files. The last (second last) time record of the extended forcing files corresponds to the last (first) time record of the preceding (following) year. To handle an interpolation between the last and the first time-record at the begin of a year, and between the third last and the second last time record at the end of a year, the script get_periodic_interval.F, and those which call it, have been modified (see the ./code/ directories). The external forcing cycle and external forcing period are kept the same, i.e. externForcingCycle=31536000 (365 days), externForcingPeriod=432000 (5 days), externForcingPeriod_cheap=21600 (6 hours), but additional parameters useYearlyField and useYearlyField_cheap are added to the data and data.cheapaml in order to discriminate either or not the forcing files are extended (i.e. =TRUE -> extended 'realistic' forcing, =FALSE -> regular yearly repeating forcing). Other part of the model that make use of external forcing (i.e. MITgcm packages blin, bulk, cfc, ...) have been modified accordingly. Those files can be found in /tank/chaocean/qjamet/Config/run_testPerdForcing/

Chapitre 4

Ensemble strategy

4.1 Initial considerations

Fig. 4.1 illustrates our strategy to generate the 12 Initial Conditions (ICs). They consist in 1 'unperturbed' IC as the model state at 01/01/1063 after 5 years of spin up, and 11 'perturbed' ICs, generated by integrating the model for 1 year, initialized with the model state at the date 01/04/1963, 01/05, 01/08, etc. We initially thought to integrate the 1 year runs used to generate the 11 perturbed ICs with climatological (atm & obcs) forcing. Under such conditions, the perturbed ICs present large (in both amplitude and scale) anomalies in the subtropical north Atlantic due to the too weak variance of the climatological winds. It is thus integrated under fully foced (atm & obcs) conditions. In order to avoid 'background' differences between perturbed ICs and the unperturbed IC, the latter is also integrated 1 additional year. All the ICs are thus integrated twice under 1963 forcing conditions. Comparable results are obtained by perturbing the oceanic 3D temperature with a Gaussian white noise with a standard deviation of 3.5 10^{-3} K as in Germe et al [2017]. This test has been integrated for 1 year under the year 1963 forcing. This indicates the saturation of the initial uncertainties impact.

To extend the 'realistic' ensemble ORAR, we have generated 12 additional initial conditions with the same procedure described above, but starting from 12, 2-day appart days within December, 1962, i.e. 12/30, 12/28, 12/26, ...

Initial conditions are available under /tank/chaocean/initial_conditions_12/ensemble_ic/

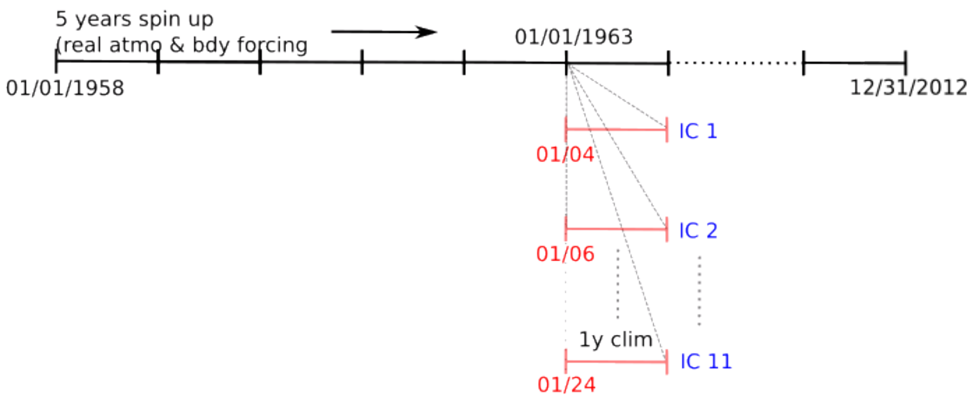

Figure 4.1 – Diagram illustrating the method used to generate the 12 Initial Conditions (IC). It consists in 1 'unperturbed' IC as the model state at 01/01/1063 after 5 years of spin up, and 11 'perturbed' ICs, generated by integrating the model for 1 year, initialized with the model state at the date 01/04/1963, 01/05, 01/08, etc.

4.2 Extending the ensemble size

4.3 Maco Initial Conditions

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