Rapport Technique

TR/CMGC/03/87

CERFACS OCEAN ANALYSIS AND SEASONAL FORECASTING SYSTEM: UNASSIMILATED REFERENCE HINDCAST EXPERIMENTS

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CERFACS Contribution to the DEMETER final report

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September 2003

We present here some results obtained in the framework of the DEMETER project. A series of coupled seasonal hindcasts has been produced and archived at ECMWF on the period 1987-2001. The way they were constructed is first described in section 1. Some results are detailed for the tropics and the extratropics in section 2. A global ocean data assimilation system has also been developed and is described in section 3, along with early investigations of the analyses produced for initialising coupled hindcasts.

1. Production of hindcasts

1-1 The unassimilated ocean analyses

The ocean initial conditions (ICs) have been obtained by running the ORCA model in forced mode. It was spun up from Levitus (1998) for temperature and salinity and rest for the velocities, using a blended climatology of ERS and in situ (mostly TAO) observed winds, ERA15 heat fluxes and Xie and Arkin (1996). After this two-year spin up, during which the model remained close to the climatology, the model was forced with ERA40 daily fluxes, winds, and with a 200 Watt/m^2/°C restoring SST term from November 1st, 1986 onwards. The strategy used to produce perturbed ensembles of ocean ICs (shown in figure 1) is as follows: every three months, an IC from the unperturbed forced ocean run is used to start two wind-perturbed forced runs (using positive and negative daily wind perturbations provided by ECMWF); 14 days before the target date, four SST perturbations (again provided by ECMWF) are linearly added and subtracted during 7 days to the restored SST, and then persisted.

Restarting every three months from unperturbed experiments (instead of running perturbed experiments over long periods, as done by other DEMETER partners) ensures that the long term climate drift in the ocean is the same for all ocean ICs. Conversely, restoring the model towards perturbed SSTs (rather than imposing a temperature perturbation extrapolated from the surface to some depth all at once, as done by other DEMETER partners) preserves the water column properties (salinity, currents, mixing) in equilibrium through the model's equations. On the other hand, wind perturbations have less time to produce ocean perturbations, thus potentially leading to a smaller spread inside the IC ensemble. The restoring timescale associated with a flux "correction" term of 200 Watt/m^2/°C is about 7 days for a 50-meter-deep mixed layer, so that the model surface perturbation in temperature after 14 days is of the same order of magnitude as the SST perturbation itself, and the spread is thus probably not reduced. Note also that the choice of combining both sources of perturbations has no symmetry.

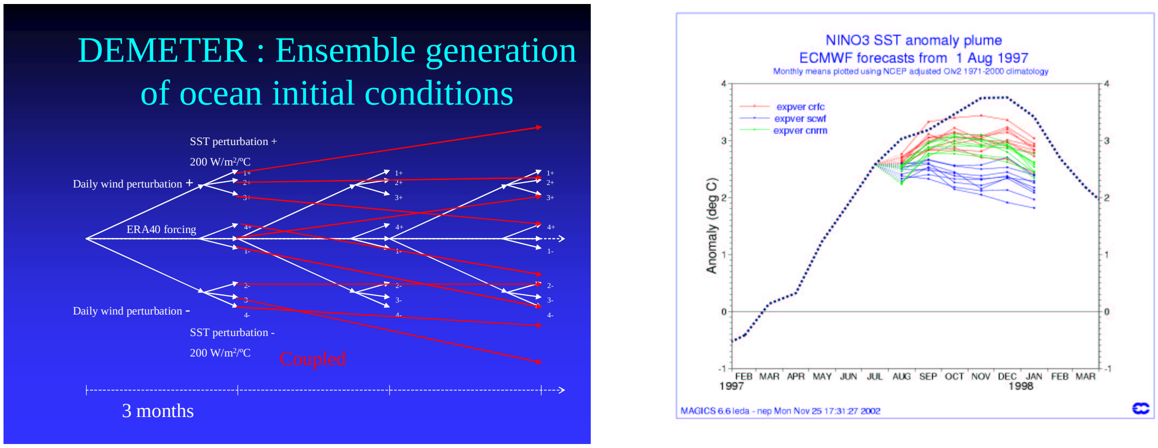

Figure 1: left, schematics of the ocean initial conditions production using wind and temperature Perturbations; right, CERFACS prediction of the “nino3” temperature anomaly peak of late 1997 (in red) along with other models results.

1.2 The coupled hindcasts

CERFACS model couples the atmosphere model from CNRM (ARPEGE) and the ocean model from LODyC (ORCA) through the OASIS coupler (OASIS, 2000). Both atmosphere and ocean model versions are rigorously the same as CNRM and LODYC respectively; the atmosphere initialisation is the same as done at CNRM; the ocean initial conditions have been produced at CERFACS following the strategy described above, and have been used by LODyC. The main differences between the global OPA model used at Météo-France and the more recent ORCA version concern the grid (different stretching of the north hemisphere grid avoiding pole singularities), the treatment of the sea surface elevation (prognostic in ORCA but not in OPA), the lateral physics (isopycnal diffusion on tracers and dynamics, Gent and McWilliams parameterization in ORCA), and the restoring towards Levitus climatology in some particular areas (semi-closed seas, poleward of 60°). Hindcasts have been produced from 1980 to 2001 following the DEMETER standards (6-month lead, 9 members, initialised in February, May, August and November). We will focus on the 1987-2001 period in the following.

2. Some performances of the system

2.1 The tropics

As an illustration of the model ability to predict important climate features, figure 1 shows the prediction of the peak phase of the 1997 ENSO event. The maximum phase is correctly simulated, though its amplitude is slightly underestimated. Figure 2 shows the prediction of the seasonal-averaged temperature one month in advance, and shows that the ensemble almost always includes the actual anomaly, especially during the 1997 event. The ability of the model to predict the major interannual phenomenon is also confirmed by looking at other time-scales (monthly anomalies), other variables (especially atmospheric pressure and precipitation in the tropics), but also subsurface temperature anomaly.

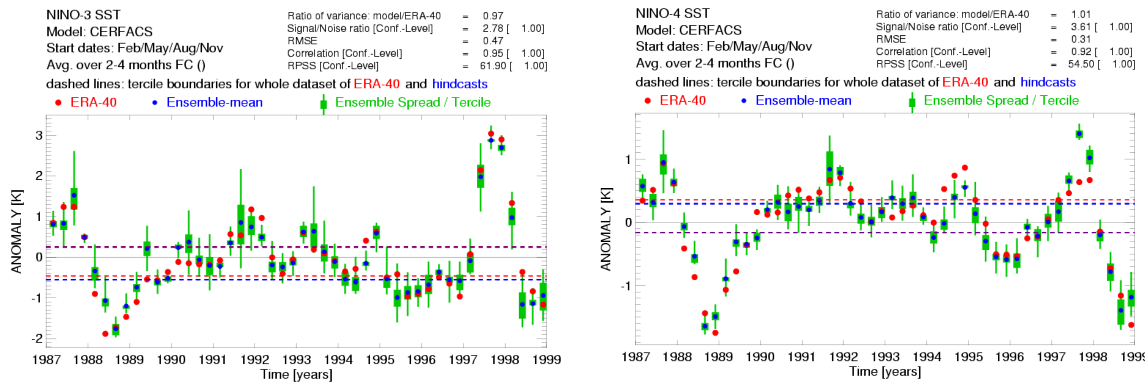

Figure 2 : Seasonal prediction one month in advance of “nino3” and “nino4” season-averaged indices of surface temperature, as outcoming from the Cerfacs system:

2.2 The extratropics

In general, a good tropical skill is necessary for improving seasonal prediction over the globe, but not sufficient. Looking through verification diagnostics on the DEMETER web site, it appears, as shown in figure 3, that winter prediction (e.g. temperature, but also precipitations) over Northern Hemisphere, and particularly over Europe, is one strength of CERFACS model. Indeed, RPSS (shown in figure 3), which represents a rather rigorous test over these regions, is positive, which is not the case for all models (but the multi-model). This is confirmed by all other scores (ACC, ROC, Value). On the other hand, summer predictions over the same region are clearly a weakness of the model. Again, RPSS shown in figure 3 corroborate results obtained with other scores, and results over the whole northern subtropics are in agreement.

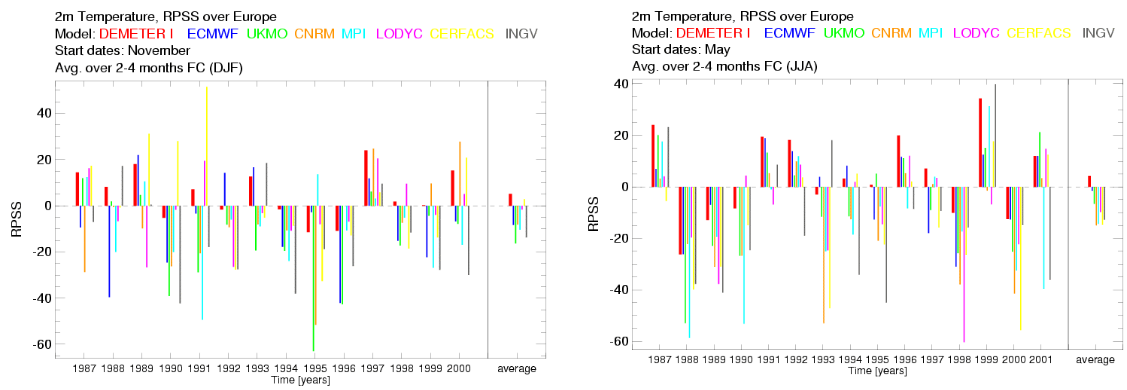

Figure 2 : Ranked Probability Skill Scores of winter (left) and summer (right) temperature over Europe; Cerfacs is in yellow.

2.3 Brief discussion

It would be a whole study to explain the differences between those coupled models which share some components. In particular, comparison of CERFACS, CNRM and LODyC results brings some surprising features. For example, in the tropics, CERFACS and CNRM results are rather close, with slightly better ACC scores for CERFACS during the first 4 months, and the reverse for months 5 and 6 (not shown here). A possible explanation is the smoother process by which we introduce perturbations in SST. In the northern subtropics, scores favour significantly CERFACS versus CNRM, though the atmosphere model (which is thought to be the most important component for these regions) is rigourously the same, as well as the atmospheric intial conditions. Here we could think that the coupled drift, which is significantly different (not shown here), may have a significant impact on the variability.

3. The global ocean data assimilation system and its results

One CERFACS goals in the DEMETER project project was to develop a global ocean data assimilation system and test its impact on seasonal predictions. The system, based on a pre-existing variational 3D and 4D system for the tropics, has been completed, and we show in the following what were the developments, and what are its results. Unfortunately, the production of seasonal forecasts with those results is still underway.

3.1 The improved 3D-Variational system

Starting from the existing tropical variational assimilation system, several modules were developed or modified to be able to cope with the representation of the global ocean. Among those modules, there was in particular the observation operator, compatible with the stretched grid of ORCA. Important resources have been devoted to the development, the evaluation and the tuning of a specific treatment of the background error covariance term inside this variational system, which takes advantage of several balance relationships between all modelled variables increments. In particular, a multivariate balance operator for the dynamics (i.e. the relationship between temperature and current and sea level elevation increments) has been developed. This task was absolutely needed for the ocean analysis system to be able to take into account altimeter data, and we show in the next paragraph that it has a huge impact on the estimated ocean state.

3.2 Ensembles of ocean reanalyses

The developed system has been integrated for more than 10 years (1990-2000) using ECMWF quality controlled in-situ temperature observations, and figure 4 shows some results averaged over this period. This figure shows that the interannual temperature variance has been significantly improved, leading to a better agreement with in-situ observations. The top right figure has roughly the same shape whether assimilation is univariate or multivariate. Note that in the Pacific, the pattern is almost the same as the forced one, but the amplitude has changed, partly because the mean temperature state has a steeper thermocline gradient. Note also the dramatic improvement in the tropical Atlantic and, in a lesser extent, in the tropical Indian oceans. If the temperature mean state and variability is almost unchanged, switching from univariate to multivariate has a dramatic impact on other modelled variables. As an example, salinity mean fields for both assimilation experiments is shown here. In the multivariate case, many salinity structures are conserved (with respect to the forced run) and even improved. The same arises for zonal and vertical currents (not shown here).

Additional developments have been carried out to produce ensembles of ocean initial conditions in the presence of data assimilation. In particular, in order to preserve in some way the same procedure for perturbing the ocean state as described above, and also to avoid any inadequacy between the perturbed SST and the observed temperature underneath, we have constructed sets of perturbed observations, by interpolation of the SST perturbations onto the observed locations, that preserve the shape of the mixed layer. We have verified (not shown here) that this could create higher amplitude perturbations even at the thermocline level. This procedure has been used to create ensembles of ocean initial conditions.

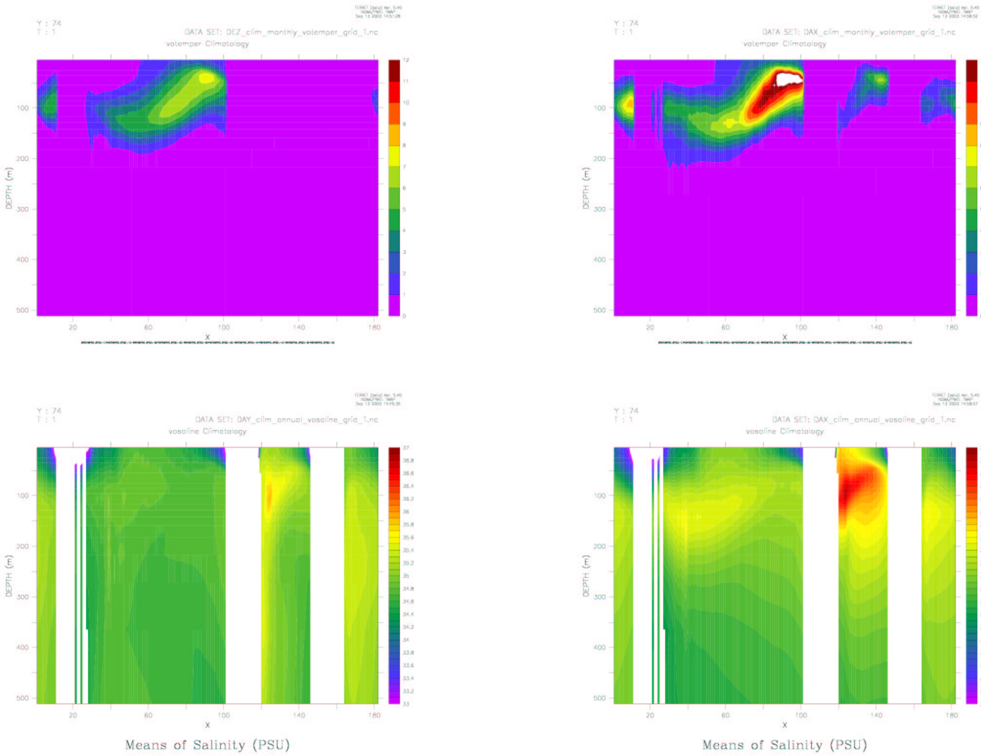

Figure 4: top: variance of the interannual temperature anomalies (°C2) of the forced ocean experiment (used to initialise DEMETER hindcasts shown earlier), left, and of a multivariate 3D-Var experiment, right. Bottom: mean salinity of a univariate 3D-Var experiment, left, and a multivariate 3D-Var experiment. All are vertical section along the equator, in the three oceans.

Acknowledgments:
The following people at CERFACS have strongly contributed to the work summarised above: A. Weaver, E. Machu, S. Ricci, N. Daget. F-J Doblas-Reyes, R. Hagedorn and D. Lucas have been of great help in the set up of the CERFACS coupled model, the use of ECMWF computing facilities, and the disposal of diagnostics.