Initialising ocean currents for multi-annual climate forecasts

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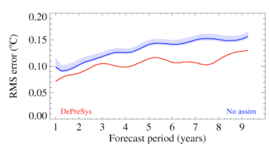
Background

The Hadley Centre has developed a Decadal Prediction System (DePreSys) with the purpose of providing multi-annual climate forecasts to the industrial and commercial sectors.

Skill from our initialisation process has been measured using two large hindcast sets. Both sets include external forcings, but only one is initialised from analyses of observation. It has been found that initial conditions contribute significantly to skill (see Figure 1).

Figure 1: results from 10 year hindcasts starting from the 1st of March, June, September and December in every year from 1982 to 2001 inclusive, where the forecast from each start date comprises an ensemble of four members. The rms errors for the ensemble mean forecast of the global and annual mean near-surface air temperature for various forecast periods are shown. The blue curve represents forecasts which are identical to DePreSys, except they do not assimilate atmosphere and ocean observations into their initial conditions.



An abrupt decrease in ocean forecast skill occurs near the initialisation time, which is associated with noise in the forecasts (see Figure 2)
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The aim of this work is *to introduce ocean currents into the initial conditions of forecasts to provide a more accurate and better balanced initial state of the ocean for climate forecasts.*

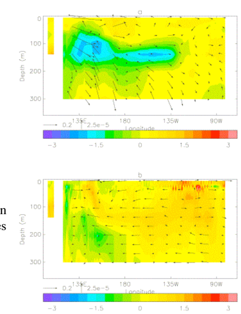

Figure 2: a vertical cross-section of monthly mean ocean temperature (shaded) and current anomalies (arrows) for (a) an assimilation run and (b) a random HadCM3 month.

Method of creating ocean analyses

There are insufficient observations of ocean currents so an indirect method must be used.

Scale analysis of equations of motion show that the total ocean currents on annual timescales largely consist of Ekman and geostrophic components.

The total current has been estimated using a fit dependent on 3 variables, namely the wind stress in the *x* and *y* direction, and the corresponding geostrophic current:

$$U_A = C_0 + C_1 U_g + C_2 \tau_x + C_3 \tau_y \qquad (1)$$
$$V_A = D_0 + D_1 V_g + D_2 \tau_x + D_3 \tau_y \qquad (2)$$

where U_A and V_A are the analysed currents in the zonal and meridional directions respectively.

Geostrophic currents are estimated using altimeter data to specify the pressure at the surface, and our 3D analyses of *T* and *S* to specify ϱ. Wind stresses are obtained from ERA-40 reanalyses.

The fit coefficients are calibrated using HadCM3 data. The resulting ocean currents will therefore be in balance with data currently used to initialise the ocean.

Figures 3 and 4 show an estimate of the accuracy of the fits at two different ocean depths.

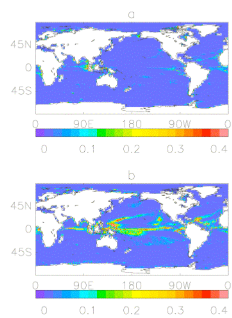

Figure 3: maps of the error variance of the fit normalised by the climatological error variance at 35m depth for the JJA seasonal mean of (a) U and (b) V. The error variance is calculated by comparing analysed currents computed from equations (1) and (2) with the actual HadCM3 currents.

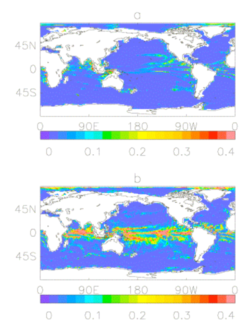

Figure 4: as Figure 3, at 301m depth

Results

On the 1st March and September of every year from 1994 to 2001 a seven member ensemble of forecasts has been run for the Control and the Test of initialising ocean currents.

Figure 5 shows the anomaly correlation coefficient (*acc*) of both the Test and Control for the global and annual average of near-surface air temperatures, as a function of lead time. The results suggest that the initialisation of ocean currents has increased the skill in predictions of this quantity.

Figure 5: the skill of predictions of the global and annual mean near-surface air temperatures for the control and test set of hindcasts. The skill is measured using *acc*, and is plotted for lead times up to the first few seasons when a discernible signal can be seen. The dotted lines represent the estimated 5 and 95% confidence levels.

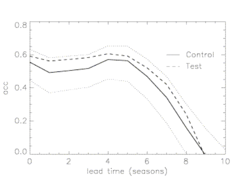

Figure 6 shows that the annual mean near-surface air temperature in the Nino3 region is more accurately predicted by the Test ensemble of hindcasts in the first few seasons.

Figure 7 shows very similar improvements in upper ocean heat content. It is plausible that the improvements in upper ocean heat content cause the corresponding changes in near-surface air temperature.

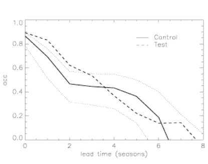

Figure 6: as Figure 5, but for the Nino3 region.

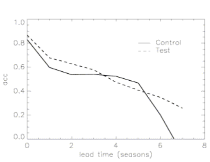

Figure 7: as Figure 6, assessing the heat content of the top 242 m of the ocean.

Figure 8 shows a map of the change in *acc* between the Test and Control for zonal currents at 5m depth. Small improvements can be seen over large regions of the ocean.

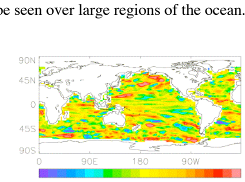

Figure 8: a map of the *acc* of (Test minus Control) for the annually averaged zonal currents at 5m depth, and at 1 season lead time. The area averaged *acc* for the Control and Test is 0.178 and 0.213 respectively. The analyses of ocean currents has been used for verification purposes.

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