Tendency Error in a Climate Model: iterative estimation

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BACKGROUND

Traditionally, systematic error in a climate model is evaluated as:

$$\overline{X} - \overline{X_o}$$

i.e. a difference between a climatology of the model at equilibrium (e.g. mean of an AMIP run) and of an observed climatology. This approach leads to error compensations and it is difficult to eveluate where the true error is.

In the POTENTIALS European project, we proposed to analyze the tendency error, rather than the equilibrium (or asymptotic) error. The model is run with a relaxation towards observed variables (e.g. 6-hourly analyses):

$$\frac{dX}{dt} = model(X) + k(X_o - X)$$

Then, the mean tendency error is:

$$-\overline{k(X_o - X)}$$

REFINEMENT

Ideally, this tendency error represents the drift of the model from the observed to its own climatology and reinjecting it into the model equations would reduce strongly the model bias. But the model reacts to this forcing and the result of a perturbed simulation is not the expected one.

A solution is to be more stuborn than the model and attempt to correct its own corrections

Step 1: $\frac{dX^1}{dt} = model(X^1) + k(X_o - X^1)$

Step 2: $\frac{dX^2}{dt} = model(X^2) + k/2(\overline{X_o - X^1}) + k/2(X_o - X^2)$

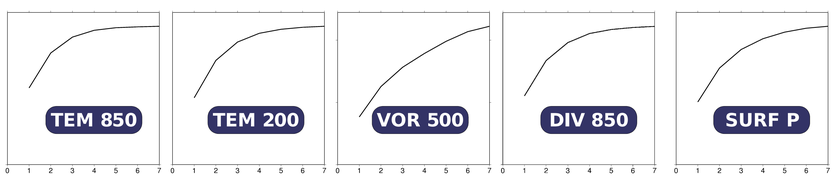
...

Step n: $\frac{dX^n}{dt} = model(X^n) + k/2(\overline{X_o - X^1}) + k/4(\overline{X_o - X^2}) + ... + k/2^{n-1}(X_o - X^n)$

It appears that the correction term (or the tendency error which is its opposite) increases in the first steps, then stabilizes.

EXPERIMENT

The model ARPEGE/IFS (climate version 4) has been integrated in 7 steps in TL63l31 geometry. Each step is a 44-year integration driven by ERA40 6-hourly data for the atmospheric prognostic variables and surface temperature (SST is imposed). The tendency error for each variable is the sum of 7 terms. The figure below shows for a few variables the global RMS of the tendency error (arbitrary units) as a function of step.



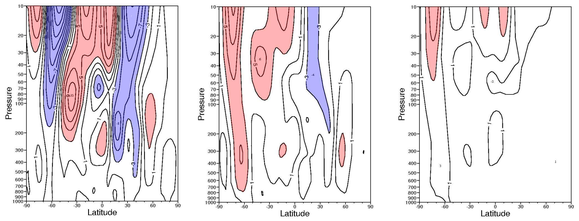
VALIDATION 1

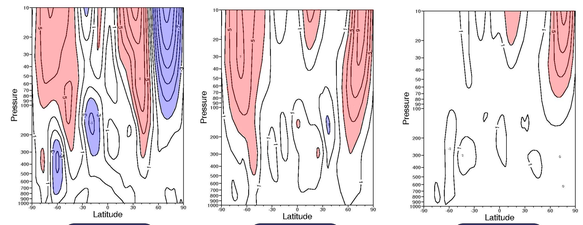
To prove that the method is efficient, a first approach consists of running the ARPEGE GCM with the correction term added to its equations for 44 years (1958-2001) with observed SST, and to compare the mean climate with ERA40 data. Three experiments are considered here:

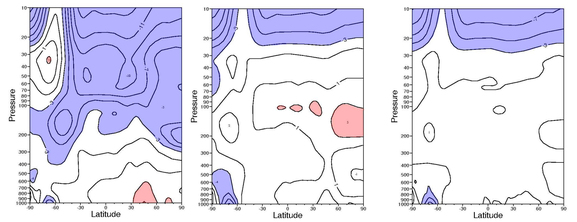
E1: no correction

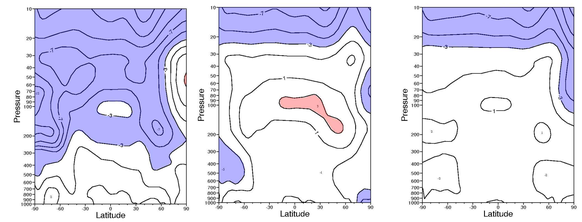
E2: correction from the first step (as in POTENTIALS)

E3: correction after 7 steps









VALIDATION 2

In a second phase, the model with the correction term (7 steps) is used in a DEMETER-like experiment, i.e. 44-winter reforecasting in coupled ocean-atmosphere mode with 9 members (lagged average). The scores below concern anomaly correlations for DJF, i.e. month 2-4 averages, over the northern hemisphere.

Without correction:

precipitation: **0.16** Z500: **0.14** T850: **0.15**

With correction:

precipitation: **0.16** Z500: **0.17** T850: **0.17**