The impact of a new simple SST slab model on a monthly forecasting system.

C. Rendina[1,2], Buzzi A.[1], Malguzzi P.[1], Mastrangelo D.[1], Drofa O.[1]

1) Institute of Atmospheric Sciences and Climate – Italian National Research Council – Bologna. E-mail : c.rendina@isac.cnr.it

2) Physics Department – University of Ferrara

Introduction

Monthly forecast is intermediate between medium range forecast, an initial value problem, and seasonal forecast, essentially a boundary value problem. Therefore, there are different approaches in modelling the ocean in order to simulate the contribution of sea surface temperature (SST) to the atmospheric forcing in the time range of 10-40 days.

The atmospheric model GLOBO is used to issue monthly atmospheric ensemble forecasts at ISAC-CNR (Mastrangelo et al., 2012). It contains a slab mixed layer model to simulate SST that includes a relaxation term to a SST climatology, derived from ERA-Interim dataset, and a climatological mixed layer. A flux correction term is used in the new version of the model in order to improve SST simulation.

Model and data

GLOBO model: grid point atmospheric global circulation model, 1.0° x 0.75° lon-lat horizontal resolution, 50 vertical levels. (Malguzzi et al., 2011).

ERA-Interim Dataset: 1989-2008 SST climatology and sea ice cover climatological tendency (10-day averages, Berrisford et al., 2009).

Ocean Mixed Layer climatology: 1941-2008 (10-days averages, de Boyer Montégut et al., 2004).

Current SST equation

$$\frac{\partial T}{\partial t}=\frac{F_{net}}{\rho C_p h(x,y)}-\tau(T-T_{clim}) \qquad \tau\approx\frac{1}{2.3}\,days^{-1},\ \rho=10^3\frac{Kg}{m^3},\ C_p=4186\frac{J}{KgK}$$

New equation

$$\frac{\partial T}{\partial t}=\frac{F_{net}+O_{res}}{\rho C_p h(x,y)}-\tau(T-T_{clim}) \qquad \tau\approx\frac{1}{23}\,days^{-1},\ \rho=1026\frac{Kg}{m^3},\ C_p=3930\frac{J}{KgK}$$

Model and experiment setup

Reforecast mode ensemble is run forcing GLOBO with daily observed SST and sea ice cover from ERA-Interim dataset, for the period 1989-2009. It consists of 42 members, half from 00UTC and half from 12 UTC of the initialization day. O_{res} represents all contributions to SST tendency due to internal ocean dynamics. They have been obtained by subtracting the contribution of modelled surface net heat fluxes (F_{net}) from climatological heat changes between consecutive 10-day SST averages. Forecast mode ensemble is run like the current operational mode but with the new SST equation. Initial SST is persisted until calendar day 5 of the month and then evolution starts. O_{res} then is updated at calendar days 15 and 25. SST and mixed layer climatology, together with sea ice climatological tendency, are updated at calendar days 1, 11 and 21. Up to now 7 months of 2011 have been simulated, creating 32 member ensembles, using initial and perturbed conditions derived from the GFS-NCEP ensemble forecasting system.

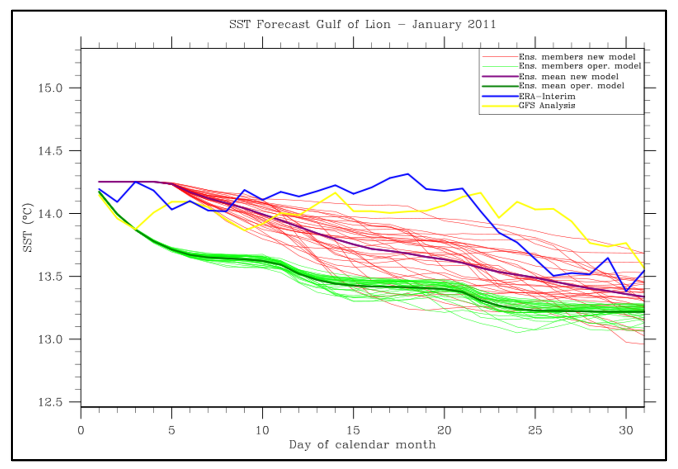

Figure 1. Example of SST forecast for January 2011 in the Gulf of Lion (Mediterranean Sea). Green lines refer to the operational SST equation, red lines to the new equation. The blue and yellow lines represent daily SST observations derived from ERA-Interim and from m GFS-NCEP analysis, respectively.

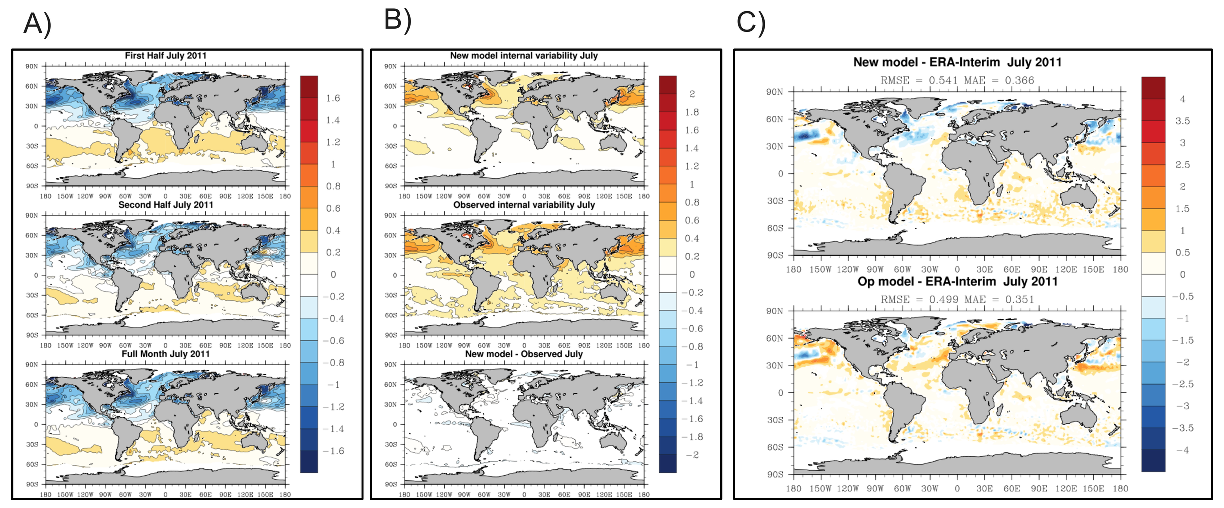

Figure 2. A) Global distribution of SST forecast ensemble mean differences between the run with the new ocean model and the operational run for July 2011. The top panel shows the first part of the month, the middle panel the second part, the bottom panel the entire month. B) Global distribution of the SST internal variability for July: in the top panel simulated by the new model, in the middle panel the observed one, in the bottom the difference. C) Global distribution of the monthly SST forecast error for the new model (top) and operational one (bottom). Values are in degree Celsius.

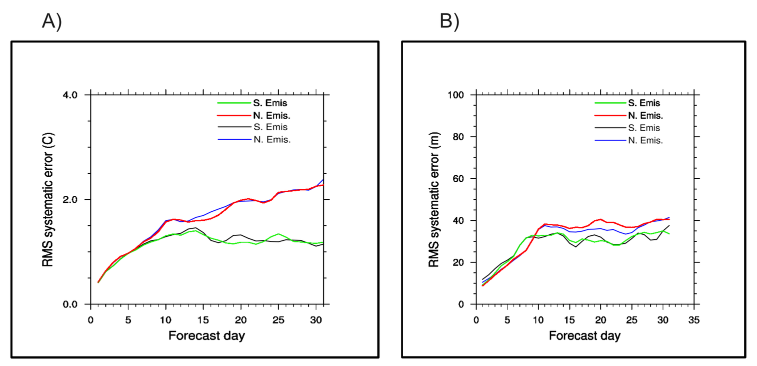

Figure 3. Systematic forecast error in reforecast mode for March in the Northern (20-80N) and the Southern hemisphere (20-80S). a) Temperature at 850 hPa. b) Geopotential height at 500 hPa. Red and green lines refer to the model forced with daily SST and sea ice cover, blue and black lines refer to the operational reforecast.

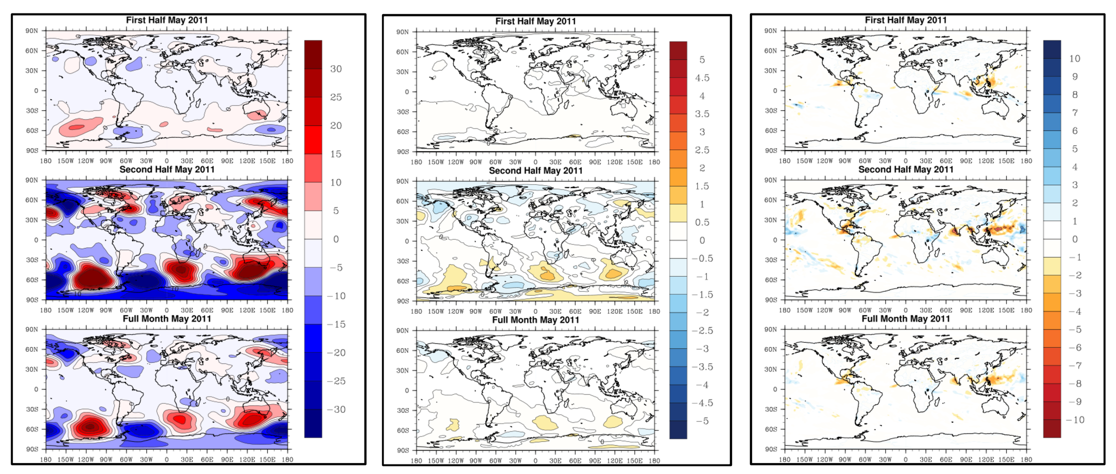

Figure 4. Same as in fig. 2 A), but for Z500 (left), T850 (center) and precipitation (right) for May 2011. Values are in meters, degree Celsius and mm/day.

First Results

In forecast mode the new equation produces a larger spread, more similar to the observed variability (fig. 2B), and a smoother-in-time evolution of the SST than in the operational model (fig. 1). For the 7 months considered, the new SST is colder in the equatorial belt and summer hemisphere, and warmer in the winter hemisphere (see, for example, fig. 2A). The global distribution of forecast errors of the monthly averaged ensemble mean of SST is similar to the operational one (fig. 2C). However the global mean forecast performance in terms of root mean square error (RMSE) and mean absolute error (MAE) depends on the SST analysis used as reference (see blue and yellow line in fig. 1). Predicted atmospheric fields show differences in absolute values and patterns, especially in the precipitation over the equatorial belt and in general in the second part of the month (fig. 4), but the forecast anomaly patterns remain similar to the operational case. Some differences appear in the second part of the individual months, but not so relevant except for March 2011 (fig. 5). In reforecast mode, using daily observed fields of SST, in place of the SST equation, has little impact on the systematic error (fig. 3).

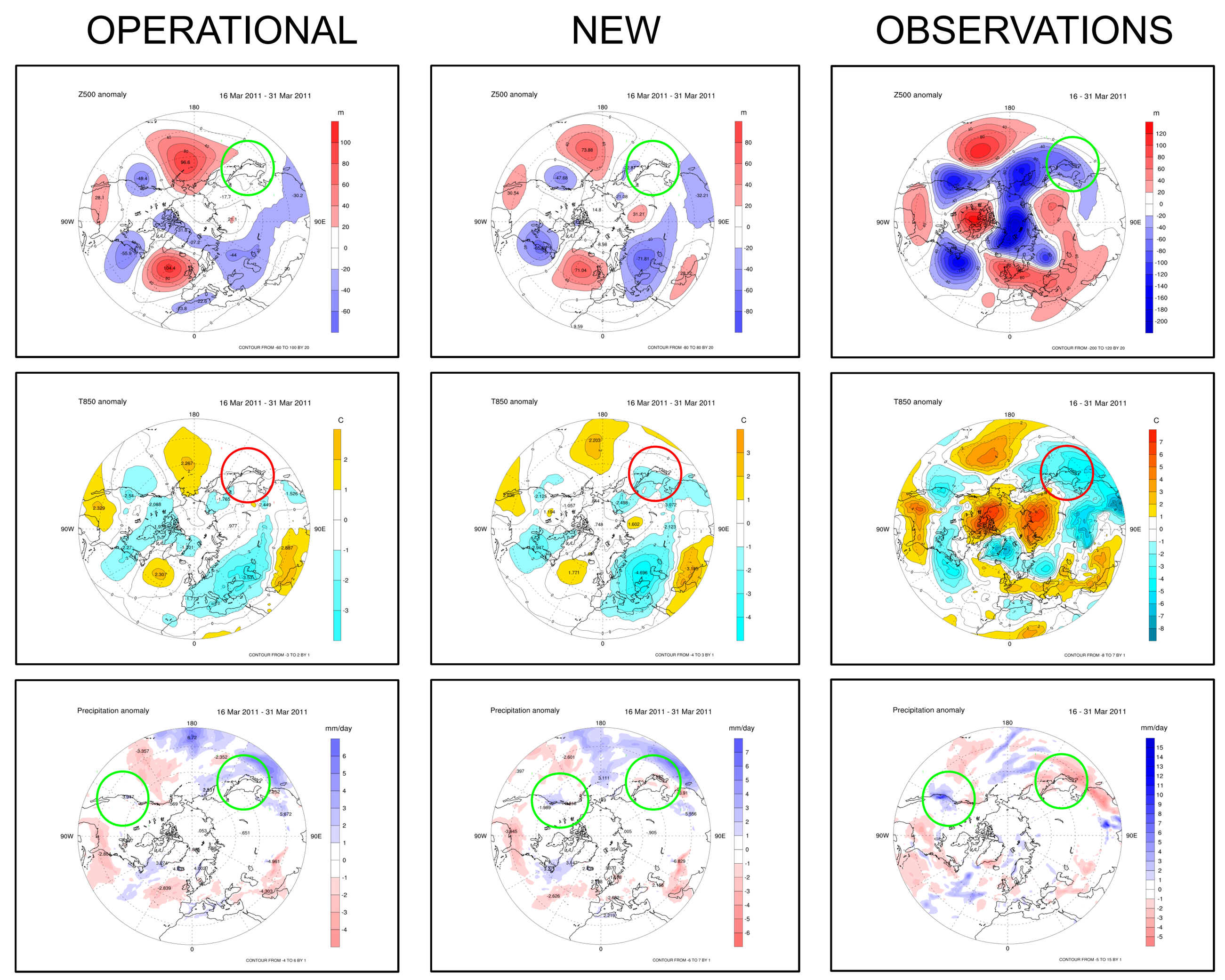

Figure 5. Predicted anomalies (left and middle column) and observations (right column) for the second part of March 2011 of Z500 (top row), T850 (middle row), and precipitation (bottom row). The left column refers to operational forecast, the middle to forecast with the new SST equation, the right to observed anomaly from ERA-Interim. The coloured circles indicate the areas exhibiting the most important differences.

Conclusions

The new version of the equation for the SST evolution implemented in the GLOBO model provides more realistic sea surface temperatures on a monthly time scale, with a larger spread than the operational version, more similar to the observed variability. However, the performance of the model is sensitive to the SST analysis used as reference, due to analysis errors comparable to forecast errors. The effects of SST on the atmospheric mean variables do not show significant improvements of anomaly patterns in experiments limited to a few of monthly forecasts. Precipitation over the Maritime Continent and the equatorial belt in general is the variable mostly influenced by the different SST formulations. The use of daily observed SST and sea ice fields, tested in the reforecasts, does not seem to ameliorate the systematic error of the atmospheric model. However, too few simulated monthly forecasts have been tested so far, so a larger set of simulations will be provided to generalize the present preliminary results. Moreover, the capability of the model to properly simulate the Madden-Julian Oscillation, that is the most important source of predictability for monthly time scale (Vitart and Molteni, 2010), will be examined.

References

Berrisford, P., D. Dee, K. Fielding, M. Fuentes, P. Kallberg, S. Kobayashi and S. Uppala (2009), The ERA-Interim archive. *ERA report series*, 1, pp 16

de Boyer Montégut, C., G. Madec, A. S. Fisher, A. Lazar, and D. Iudicone (2004), Mixed layer depth over the global ocean: an examination of profile data and a profile-based climatology, *J. Geophys. Res.*, 109, C12003, doi:10.1029/2004JC002378.

Malguzzi, P., A. Buzzi and O. Drofa (2011): The meteorological global model GLOBO at the ISAC-CNR of Italy: assessment of 1.5 years of experimental use for medium range weather forecast. *Wea. Forecasting*.

Mastrangelo, D., Malguzzi, P., Rendina, C., Drofa, O., and Buzzi, A.(2012): First outcomes from the CNR-ISAC monthly forecasting system, Adv. Sci. Res., 8, 77-82, doi:10.5194/asr-8-77-2012.

Vitart F, Molteni F. 2010. Simulation of the Madden–Julian Oscillation and its teleconnections in the ECMWF forecast system. *Q. J. R. Meteorol. Soc.* 136: 842–855. DOI:10.1002/qj.623.