Atlantic Tropical Cyclone Activity in EC-Earth Full Field Initialized Decadal Forecasts

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Seasonal forecasts of tropical cyclone activity are routinely performed, with relative success, in various centers around the world (Zhao et al., 2010). However, predictions of Atlantic tropical cyclone statistics beyond a one-year horizon still remain elusive. At the decadal timescale, Atlantic TC activity is modulated by the Atlantic Multidecadal Oscillation (AMO), a fluctuation in Atlantic SSTs (Goldenberg et al., 2001). A recent study has found some level of predictability of the AMO at the multi-annual timescale (García-Serrano and Doblas-Reyes, 2012), thus suggesting potential predictability of Atlantic TCs over a similar timescale. Here, we describe the first steps in our attempt to move beyond the seasonal horizon towards making skillful multi-annual forecasts of Atlantic TC activity.

Using the CGCM EC-Earth, we performed a series of five-member ensemble re-forecasts, starting on November 1st, for every five years of the 1960-2005 period. Each forecast is run for a 10-year period. The atmosphere and land surface initialization was taken from the ERA-40 reanalysis for all start dates before 1989 and from ERA-Interim (Dee et al., 2011) afterwards. The ocean initial conditions have been taken from the 3D-Var five-member ensemble ocean re-analysis known as NEMOVAR-COMBINE (Balmaseda et al., 2010). EC-Earth is a coupled atmosphere-ocean model developed by a number of meteorological services and research groups in Europe. More information about EC-Earth can be found in Hazeleger et al. (2010).

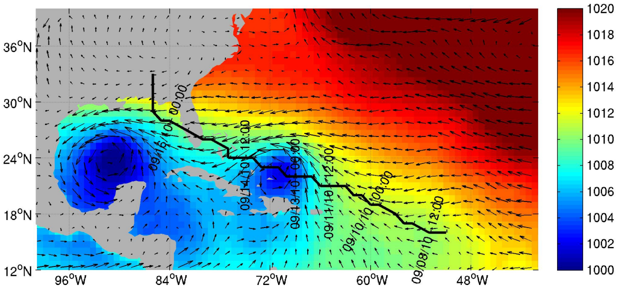

Figure 1: Mean sea level pressure in EC-Earth during a month of September. The arrows represent the surface wind. A tropical cyclone is seen in the Gulf of Mexico while another one is seen approaching the U.S.

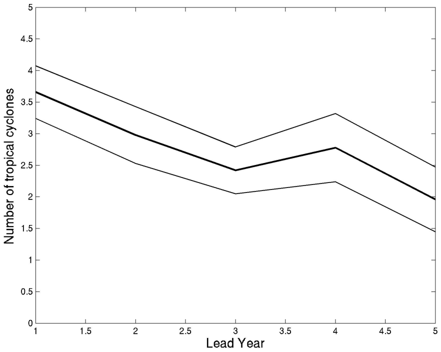

Figure 2: Downward trend in the number of tropical cyclones present in the first years of the forecasts. The thick black line represents the ensemble mean while the thin black lines represent 1 std. dev. above and below the ensemble mean.

The tracking of tropical cyclones in EC-Earth data is performed using a tracking algorithm developed during a previous series of studies (Caron and Jones, 2011; Caron et al., 2012) where it was shown to skillfully detect and track tropical cyclones present in model simulations. The detection criteria are based on Walsh et al. (2007) and include:

- a minimum in surface pressure (considered the center of the storm).
- strong surface (10 m) winds in the vicinity of the storm center.
- a warm core in the mid- to upper-troposphere.
- the number of consecutive, detected centers cover at least a 24 h period.

In EC-Earth hindcast integrations, tropical cyclones are seen forming over the Atlantic basin, including the area referred to as the Main Development Region (region limited by 8°N, 20°N, 80°W and 20°W; see figure 1). However, the mean annual number of storms (∼2-3) detected is well below the 1960-2010 climatological average (∼8). Given previous results obtained by other GCMs integrated at similar resolutions (Camargo et al., 2005), a low bias in the total storm count over the Atlantic is not unexpected. In this case however, the bias appears to be strengthened by a downward drift in tropical Atlantic SSTs. This appears to be supported by a significant downward trend in TC numbers as a function of lead year in the first five years of the hindcasts (figure 2). The low number of TCs in the simulations compared to observations makes it difficult to draw any conclusions regarding the ability of the hindcasts to capture TC activity.

This observed drift is inherent to decadal prediction using full field initialization. Standard procedures exist to correct for continuous fields such as temperature. However, this drift in SSTs has a particularly profound impact on simulated tropical cyclones since these storms require ocean temperature to be above a certain threshold (∼26°C) for their formation. Any drift in SSTs below that value will significantly reduce, if not completely shut down, TC formation. Figure 3 compares the climatological mean SSTs over the Atlantic for the August-October season between observation and the series of hindcasts. It is clear that EC-Earth SSTs have drifted below the required threshold over a significant portion of the basin, most likely hindering cyclogenesis.

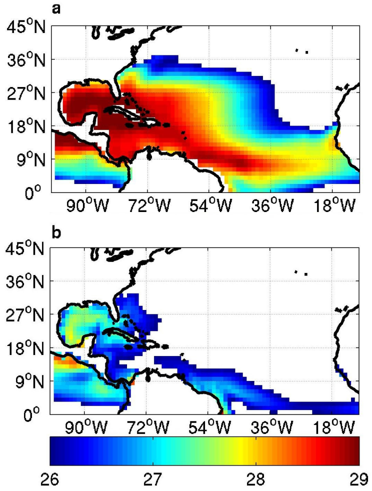

Figure 3: Mean a) observed and b) hindcasat simulated SSTs during the ASO season over the North Atlantic region.

There is no substitute to compensate for the absence of TCs caused by low model SSTs in EC-Earth hindcasts. However, it is possible that, if SSTs were to remain above the 26°C threshold required for TC formation, TC activity would rise sufficiently for comparison with observations to become feasible. It is worth mentioning that most of the model drift that we suspect is partly responsible for the low bias in TC numbers occurs during the first months of the hindcasts, which are all initialized on November 1st. The official start of the hurricane season is on August 1st. This suggests that i) the impact of the drift on TC formation is likely stronger than what is shown in figure 2, since most of the drift in SST has already occurred by the start of the first hurricane season and that ii) if no drift were present in the simulation, the mean number of tropical cyclones during a given season would be much closer to the observed climatological average.

We thus plan to re-run the atmosphere component of EC-Earth using the hindcast-derived SST anomalies superimposed onto observed climatological SSTs. In doing so, we will ensure that SSTs remain above the required threshold for TC formation while also retaining the SST anomalies derived from the individual hindcasts. Furthermore, because the computational cost of running EC-Earth is significantly reduced in this configuration, this will also allow us to increase the model resolution to ∼0.7°, which should further contribute to increasing cyclogenesis over the MDR. These results will be available in the upcoming months.

References:

Balmaseda, M.A., K. Mogensen, F. Moteni and A.T Weaver, *NEMOVAR Technical reports No. 1*, (2010).
Camargo, S. J., A. G. Barnston and S. E. Zebiak, *Tellus*, **57A**, 589-604 (2005).
Caron, L.-P., C. G. Jones, P. A. Vaillancourt and K. Winger, *Clim. Dyn.* (2012). doi: 10.1007/s00382-012-1311-6
Caron, L.-P. and C. G. Jones, *Clim. Dyn.* (2011). doi: 10.1007/s00382-011-1160-8
Dee, D. P. and co-authors, *Q.J.R. Meteorol. Soc.*, **137**, 553-597 (2011).
Goldenberg, S. B., C. W. Landsea, A. M. Mestas-Nuñez and W. M. Gray, *Science*, **293**, 474-479 (2001).
Hazeleger W. and co-authors, *Bull. Amer. Meteorol. Soc.*, **91**, 1357-1363 (2010).
García-Serrano, J. and F. J. Doblas-Reyes, *Clim. Dyn.*, (2012). (under review)
Uppala, S. M., and co-authors, *Q. J. R. Meteorol. Soc.*, **131**, 2961-3012 (2005).
Walsh K. J. E., M. Fiorino, C. W. Landsea and K. L. McInnes, *J. Clim.*, **20**, 2307-2314 (2007).
Zhao, M., I. M. Held and G. A. Vecchi, *Mon. Wea. Rev.*, **138**, 3858-3868 (2010).