Overview of the Ability of the Canadian Regional Climate Model to Simulate recent North-Eastern Pacific Tropical Cyclone Activity

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Introduction

In comparison with other ocean basins, and despite showing the highest cyclogenesis density, comparatively little research has been undertaken regarding tropical cyclone (TC) activity in the Eastern Pacific (EPAC). This is likely a consequence of a lack of reliable historical records and the fact that only a small portion of these storms make landfall. Interestingly enough, TC activity in the EPAC shows a downward trend over the recent past (Kossin et al., 2007), a feature unique amongst basins where TC activity is observed. Conversely, TC activity in the Atlantic is on the rise (Emanuel, 2005). The out-of-phase relationship between these two ocean basins has been discussed by (Wang and Lee, 2010).

The Canadian Global Environmental Multiscale model (GEM; Zadra et al., 2008) has been shown to produce realistic TC activity in the Atlantic (Caron et al, 2011; Caron and Jones, 2012), both in terms of geographical distribution and interannual variability. The aim of the present study is to evaluate the capability of that same model, run in three different configurations, at reproducing TC activity in the Eastern Pacific.

Three different ensembles were created for this experiment:

- Two simulations were run in limited-area mode, at 0.3° fixed resolution over a domain covering the area between the Eastern Pacific Ocean and Arabian Sea. In this configuration, the lateral boundary conditions (LBCs) were provided by ERA-40. This ensemble will be referred to as LAM-ERA.
- Three simulations were run using the same LAM domain, but in this case, the LBCs were provided by a GCM. More specifically, the LBCs originated from previous runs of GEM performed at (global) fixed resolutions of 2° (2) and 1° (1). This ensemble will be referred to as LAM-GEM.
- Two simulations were performed using a variable resolution configuration, with a 0.3° resolution domain covering the same area as the LAM domain. This ensemble will be referred to as GVAR.

The simulations were performed over the 1979-2006 period using observed sea surface temperature (SST) and sea-ice fraction provided by the Atmospheric Model Intercomparison Project v2 (AMIP2; Glecker, 1996) as lower boundary conditions. The TCs are tracked, using an automated procedure, during the months of June-October, inclusively. More details on the model configuration, domain and tracking procedure can be found in Caron et al. (2011). Simulated tropical cyclones are compared with historical data taken from the International Best Track Archive for Climate Stewardship (IBTrACS) database (Knapp et al., 2010).

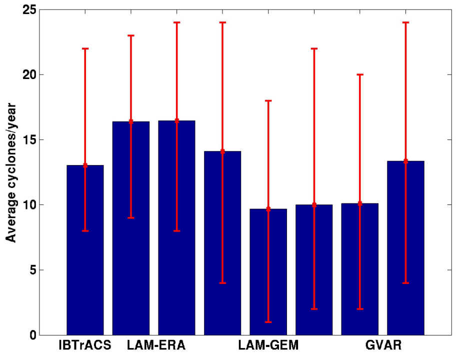

Figure 1: Average annual number of TCs for each configuration. The error bars mark the seasonal minimum and maximum.

Results

Figure 1 shows the average annual number of TCs in each of the different configurations, together with the seasonal minimum and maximum that occurred over the 28-year period. Large differences can be observed, with ERA-driven runs overestimating the activity, the LAM driven by GEM 2° showing the weakest activity and the LAM driven by GEM 1° and GVAR situated somewhere between the two. While the differences in the level of activity in the LAM configuration can be attributed to different boundary conditions, the difference in activity between the two GVAR members results from the fact that one member uses a slightly different version of the same model, one that has a slightly different lapse rate over the tropics (Caron et al., 2013).

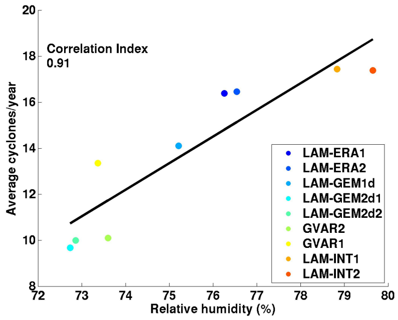

Figure 2: Relationship between mean seasonal (JAS) mid-tropospheric humidity (600 hPa) and mean number of TCs in GEM.

To understand the main factor driving the differences in the number of simulated TCs in the EPAC, the climatological values of large-scale fields known to influence cyclogenesis (Emanuel and Nolan, 2004) were computed during the most active season from July to September (JAS), over a region covering 95°-110°W and 8°-12°N of the EPAC domain. The correlation between the mean annual number of TCs and each of the individual large-scale fields was estimated. The only positive correlation was found to be between the number of TCs and the mid-tropospheric humidity at 600 hPa. This result is shown in figure 2. The correlation is very high (0.91) and significant at the 99% level.

Figure 3 shows the difference in cyclogensis density between the LAM-ERA ensemble and the LAM-GEM ensemble. Cyclogenesis in LAM-ERA is generally seen to be higher than in LAM-GEM, in agreement with figure 1. The distribution of LAM-ERA is more realistic than LAM-GEM (not shown), in large part because LAM-GEM (and GVAR) produces very few storms along the coast of Central America. This is clearly visible in figure 3. The higher cyclogenesis density over the centre of the basin and near the coast in LAM-ERA is the direct result of higher mid-tropospheric humidity (as shown in figure 2).

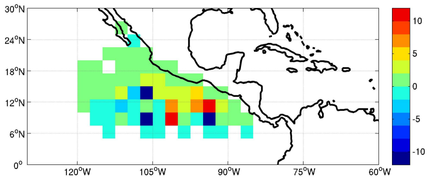

Figure 3: Difference in cyclogenesis density between the LAM-ERA ensemble and LAM-GEM ensemble. Units are number of TCs/(2.5°x2.5°)/decade.

Figure 3 also shows an area of lower cyclogenesis density in LAM-ERA (compared to LAM-GEM), between ∼6°-10°N. This appears to be the result of significantly higher vertical wind shear over that region in ERA-40 driven simulations. These higher wind shear values are likely related to the difference in the representation of the ITCZ, although whether this is due to a stronger ITCZ or a shift in its mean position is unknown at this time.

Figure 4 shows the timeseries of the annual number of TCs for the LAM-ERA ensemble for the 1979-2006 period. The LAM-ERA ensemble is the only one of the three ensembles showing a significant correlation with respect to observations over the given period. The correlation coefficient for this ensemble is estimated at 0.43, which is much lower than the correlation coefficient over the Atlantic for the same ensemble, which is ∼0.8. In fact, it is even lower than the correlation coeffecient of the LAM-GEM ensemble over the Atlantic, which is ∼0.5. This is somewhat surprising, given that the EPAC is much closer to the lateral boundary than the Atlantic basin, which points to a reduced role of SST in modulating TC activity in that region.

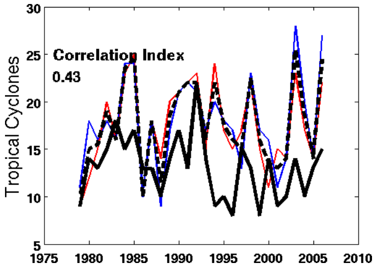

Figure 4: Timeseries of TCs for the LAM-ERA ensemble for the 1979-2006 period. Each member is in color, the ensemble mean is represented by the dash black line while the observations are represented by the full black line.

Finally, while the LAM-ERA ensemble was successful at simulating the observed upward trend in TC activity over the Atlantic, it completely fails to simulate the downward trend over the EPAC. It is not clear at this stage why this is so. Wang and Lee (2010) attributed the out-of-phase relationship between the Atlantic and the EPAC to simultaneous variations in vertical wind shear. Given the obvious sensitivity of the model to mid-tropospheric humidity, it is possible that other large-scale fields "override" the influence of the vertical wind shear and prevent the model from capturing the downward trend. This issue is currently under investigation.

References:
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