Prospects of hurricane variability analysis in dynamically downscaled tropical cyclone simulations

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North Atlantic tropical cyclone (TC) activity has been observed to vary over a wide range of timescales, from sub-seasonal to decadal (and possibly longer), and multiple attempts have been made to relate these variations to a large array of climate variables. The lower frequency variations are generally considered to be related to the slowly varying thermodynamic conditions, driven in large part by changes in local sea surface temperatures (SSTs), whereas higher frequencies tend to be driven by teleconnections from factors external to the tropical Atlantic. For instance, North Atlantic TC activity is modulated at the interannual time scale by El Niño Southern Oscillation (ENSO): El Niño (La Niña) years are usually associated with lower (higher) TC activity in the North Atlantic. At slightly longer time scales, the North Atlantic TC activity is strongly tied to the Atlantic Multidecadal Oscillation (AMO), a slow oscillation in Atlantic SSTs linked to the Atlantic meridional overturning circulation. Changes in the AMO are often used to explain the heightened TC activity observed since the mid-1990s.

An approach to quantifying the relationship between climate and tropical cyclone activity is to use modeling. Among the models, downscaled models are often used as they can provide the necessary high-resolution to accurately simulate tropical cyclone activity. Such technique is capable of resolving tropical cyclones using boundary conditions supplied by the reanalysis datasets. This combines the advantage of relatively robust estimates of large-scale conditions by the reanalysis with the high fidelity simulation of tropical cyclones by the embedded high-resolution models.

In this study, we will use a series of tropical cyclone tracks produced by randomly seeding (in space and time) weak, warm-core vortices in different reanalysis datasets. The tracks of the resulting storms are then given by a beta-and-advection model driven by the flows derived from the reanalysis wind fields whereas the intensity of the storm is evaluated from a high-resolution atmosphere-ocean coupled tropical cyclone intensity model (Emanuel, 2006). It should be noted that most of the disturbances seeded in the environment dissipate before they can intensify to tropical storm status.

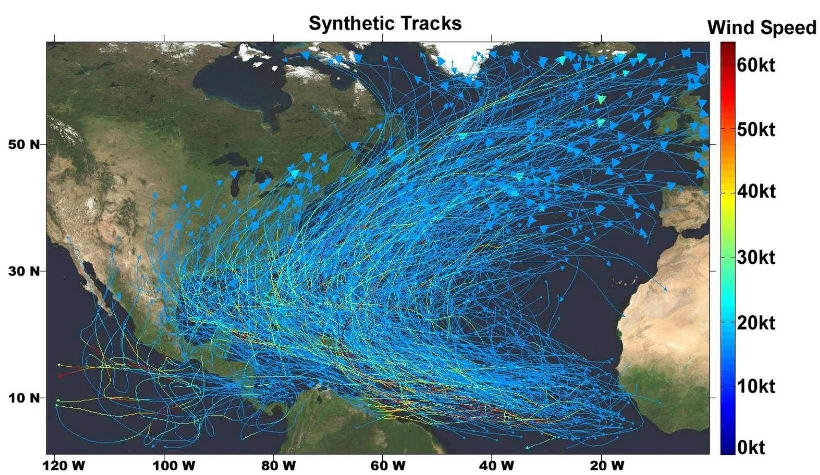

Figure 1: 500 synthetic tracks produced using MERRA reanalysis dataset.

We show in figure 1 the geographical distribution of 500 synthetic tracks obtained with the downscaling technique, which produce randomly seeding disturbances evolving in the environmental conditions provided by MERRA reanalysis. The tracks follow a relatively realistic trajectory, with many storms forming off the coast of Africa (where so-called Cape Verde storms tend to form) and propagating westward towards Central and South America. There is a small bias over the Gulf of Mexico and the storms tend to live longer than the real world counterpart, but overall, the trajectory of the tracks and their geographical distribution tend to be fairly realistic. The tracks also have a realistic intensity distribution (not shown) and a realistic seasonal cycle (figure 2), with most storms forming in the August-October period.

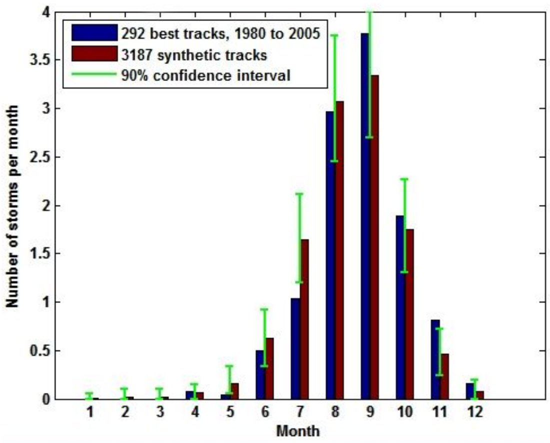

Figure 2: Average number of storms per season for observed (blue) and synthetic (red) tracks. The green bars represent the 90% confidence interval (synthetic tracks).

The synthetic tracks have thus been shown to have a fairly realistic geographical, seasonal and intensity distribution. Their interannual variability has also been studied (Emanuel, 2010) and was shown to be highly correlated to the observed variability (see figure 3 for an example derived from MERRA reanalysis). What is unknown at this time is which of the observed climate-hurricane connections were captured by this technique. This is what we plan to investigate. We will use Poisson regression, which is a classical approach to analyze count data, in conjunction with the full list of climate factors previously identified as influencing cyclone variability over the North Atlantic basin. This list of climate influences will include influences such as ENSO, the North Atlantic Oscillation and the precipitation over the Western Sahel region, to name a few.

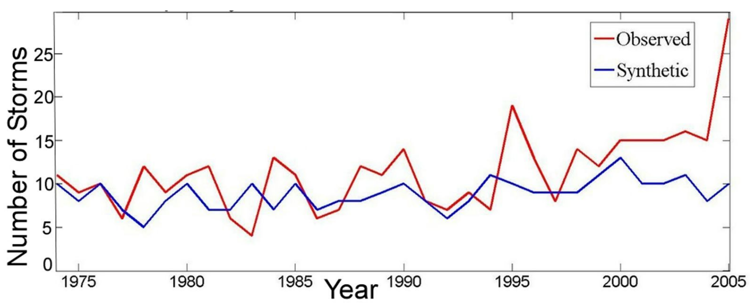

Figure 3: Observed (red) and simulated (blue) time series of Atlantic Tropical cyclones. The synthetic tracks were produced using MERRA reanalysis.

By analyzing the statistical significance of the regressions resulting from downscaled reanalysis, we will be able to identify the climate-cyclones links that are captured in the downscaled TC. Furthermore, we will compare the statistical significance of results obtained by downscaling typical reanalysis product with a reanalysis product that assimilates only surface information (NOAA-CIRES 20th Century Reanalysis). Because the latter only assimilates surface information, we expect the results to be somewhat degraded compared to the former. By comparing the relationship observed in both downscaling exercises, we hope to learn more about the processes controlling North Atlantic TC variability and which of these processes the downscaling model manage or fail to capture. This will suggest possible modifications/improvements to models used for dynamical forecasts.

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References

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