Simulating High-Resolution Atlantic Tropical Cyclones with GEM-Climate

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Since 1995, tropical cyclone (TC) activity in the Atlantic has increased markedly in contrast to the quieter period of the 1970's and 1980's. The recent years have seen many records broken in the Atlantic, such as the largest number of tropical cyclones in a given season and the most powerful storm ever recorded. As well, the accumulated cyclone energy index has been above the 1951-2000 median for all years from 1995-2005, except in 1997 and 2002 (Bell and Chelliah, 2006), years during which an El-Niño, known to suppress TC activity in the Atlantic, was observed. Whether this upswing in activity is due to a multi-decadal natural variability, to a long-term rising trend caused by anthropogenically forced global warming or to a combination of the two is still unclear. This uncertainty has its root in the relatively limited number of years of hurricane data available and the reliability of these historical data.

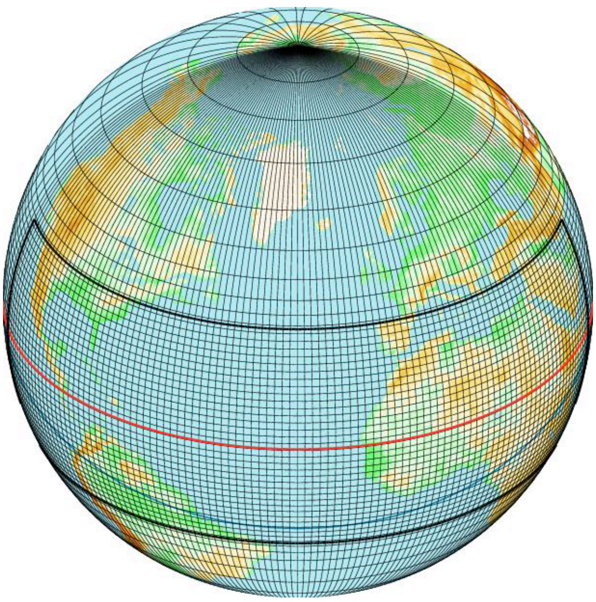

Figure 1: Variable resolution grid used in this study.

Climate models offer an alternative by which to explore TC activity and the factors controlling interannual variability. However, so far, Global Climate Model (GCM) studies of future TC activity have shown widely different conclusions. One major cause of this is the low resolution of GCMs and their inability to simulate the important processes controlling TC genesis and intensification. The physical realism of these simulated TCs improves with increasing model resolution. Running a high-resolution model (20-30 km) over the whole globe is presently not feasible except on the most powerful supercomputers currently available. An alternative approach to achieving locally enhanced resolution (e.g. over the tropical Atlantic) to study resolution benefits on TC simulation is to run a GCM in variable resolution mode, whereby resolution is locally increased within a predefined region of the continuous global domain. In this study, we exploit this variable resolution option in the Global Environmental Multiscale (GEM) model (Côté et al., 1998) using a 2° global domain with telescoping up to 0.3° over the entire tropical Atlantic TC tracks (figure 1).

Initially, we concentrate on the ability of GEM to simulate past observed Atlantic TC activity. In the first step of this evaluation, GEM in variable GCM mode (GVAR) has been integrated for the period 1979-2004 using observed sea surface temperatures (SSTs). Simulated TCs were identified according to a scheme suggested by Walsh et al. (2007). Accordingly, a TC is detected if a system displays for 24h the following characteristics:

- a minimum pressure in the center.
- surface winds of at least 17 $m\ s^{-1}$ (65 $km\ h^{-1}$) in the vicinity of the center.
- a warm core in the mid- to upper-troposphere.

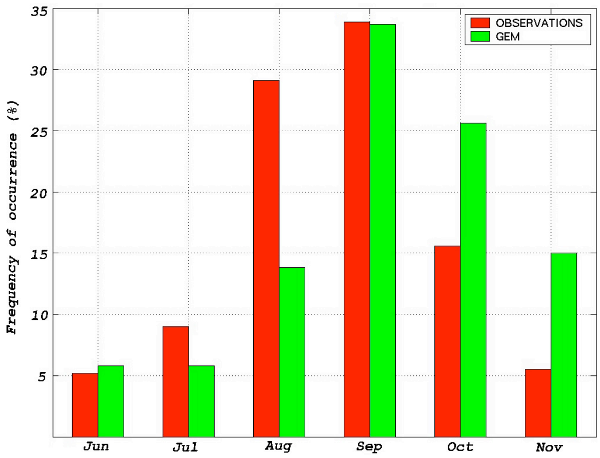

Figure 2: Relative monthly distribution of Atlantic tropical cyclones, 1979-2004.

Results

A comparison of simulated TC activity between the GVAR run and observations allows a direct comparison of TC statistics on climate timescales. For example, the majority of Atlantic tropical storms are observed from August to October. Figure 2 shows the relative monthly distribution of TC formation for the period 1979-2004 for both observed and simulated tropical storms. We notice that GEM reproduces fairly well the intra-annual distribution of TCs, with a maximum during the peak of hurricane season (September). However, its overall distribution is biased toward a too large proportion of TCs at the end of the year to the detriment of the beginning of hurricane season. In absolute numbers, GEM tends to systematically overestimate the monthly production of TCs; the reasons as to why this is the case are currently under investigation.

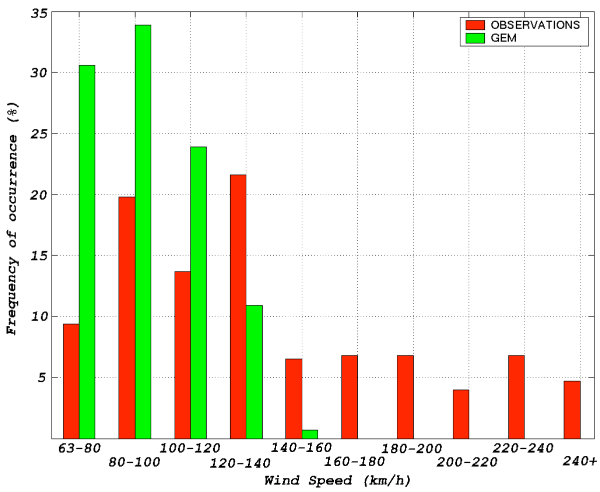

Figure 3: Relative wind speed distribution of Atlantic tropical cyclones, 1979-2004.

A recurrent problem with low-resolution GCMs when studying TCs is the low intensity of the system produced: GCMs produce systems that are reminiscent of TCs, but which are too weak to be considered so. The wind speed threshold of 65km/h is rarely reached with low-resolution GCM. By increasing the resolution to 0.3°, we witness the formation of tropical storms and category 1 hurricanes (threshold of 119km/h). Figure 3 shows that GEM comes short of producing the most intense storms (Cat 3+); further increases in resolution seem to be necessary for detecting these most destructive storms. This is not entirely surprising since 0.3° appears insufficient resolution for eye development, a key process to reaching very high wind speed.

References:

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