Simulation of Past, Present, and Future Climates

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From the severe droughts that gripped the horn of Africa in the 1980’s to extreme winters that Europe experienced around the 17th century, climate plays a very important role in our society. Understanding the causes and predictability of such fluctuations in climate, and how the climate system may evolve in the future is the underlying aim of this project. Climate models, which have proved an essential tool in such research, are at the heart of our project and thus, our work is only possible with access to significant computer resources. Here an overview of our most recent work on tropical storms is given.

The hurricane season of 2005 in the Atlantic sector was the most intense on record, with 28-recorded tropical storms and 15 of them reaching hurricane intensity. In contrast, in 2006 there were only 9 named tropical storms. Why was 2005 season so different to 2006? What role did sea surface temperature (SST) play? Was there an anthropogenic influence? We have investigated these type of question with the ECHAM5 (Roeckner et al., 2003) atmospheric general circulation model. With sufficiently high resolution (50-100km horizontally), the structure and strength of tropical storms can be reasonably simulated (Fig. 1). In particular, the agreement with observations is much better than can be simulated with the horizontal resolution (200-300km) typically used in current models (Bengtsson et al., 2007), such as used in the latest IPCC report on climate change (IPCC, 2007).

To understand the causes of Atlantic hurricane variability and whether an anthropogenic influence is detectable, ensemble simulations with ECHAM5 at high-resolution were performed, with observed SST and sea ice prescribed. The simulations revealed two important results: First, multi-decadal fluctuations in vertical wind shear in the Atlantic sector (Fig. 2), which is a key parameter for hurricane development, explain most of the variability in hurricane activity during the last century; and second, variations in vertical wind shear are forced by the SST difference between the Atlantic and Indo-Pacific regions (Latif et al., 2007). The SST in 2005 and 2006 were consistent with different hurricane activity in the two years. Taken together these results argue that most of the observed variability, even the most recent, is driven by internally forced climate variability.

The impact of anthropogenic driven global warming was further studied in two high-resolution (50km horizontally) time-slice experiments for present day (1960-1990) and projected future (2070-2100) conditions. Simulations were performed with SST and sea ice conditions from climate change experiments performed by the Max Planck Institute for Meteorology. Consistent with previous studies performed at lower resolution, the total number of storms is projected to decrease into the future (Fig. 3), due to increased atmospheric stability. In contrast to these previous studies, however, the number and intensity of the strongest storms is projected to increase (Fig. 3), due to the increased atmospheric water vapour. This has important consequence for people living in regions with tropical storms. (see Bengtsson et al., 2007 for further details.)
Our knowledge of the real climate system is limited by observations. This in turn has lead to a big reliance on models, particularly in the study of low frequency variability. Paleo-reconstructions offer one possibility for extending back our knowledge of the climate system, and in turn for improving the models. This is one area where our future activities will focus. A nice example of our initial work in this area, also relevant here, is the interpretation of a corral record from the Caribbean. With simulations (Fig. 1) and observations of rainfall and SST, we were able to explain why this corral was able to track observed hurricane record, much better then any existing proxies or SST observations (Hetzinger et al., 2008).

The above provides a small flavour of our activities at HLRN. In the future we will work more on simulating past variability, understanding extreme weather and the impact of climate change on it, as well as in the area of decadal prediction.

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References


Refereed publications

