NOTES AND CORRESPONDENCE

Comments on "Impacts of CO_2-Induced Warming on Simulated Hurricane Intensity and Precipitation: Sensitivity to the Choice of Climate Model and Convective Scheme"

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ABSTRACT

In a simulation of enhanced tropical cyclones in a warmer world, Knutson and Tuleya make several assumptions that are not borne out in the real world. They include an unrealistically large carbon dioxide growth rate, an overly strong relationship between sea surface temperature and hurricane intensity, and the use of a mesoscale model that has shown little to no useful skill in predicting current-day hurricane intensity. After accounting for these inaccuracies, a detectable increase in Atlantic hurricane intensity in response to growing atmospheric greenhouse gas levels during this century becomes unlikely.

1. Introduction

In a signal paper on atmospheric chemistry, Ellsaesser (1982) asked the question: "Should we trust models or observations?" A recent paper by Knutson and Tuleya (2004; hereafter KT04) on prospective tropical cyclone changes in a warming world recalls the complexities of Ellsaesser's question.

KT04 used a suite of general circulation models from the Coupled Model Intercomparison Project (CMIP2+) study to investigate prospective changes in tropical cyclone activity in a warmer world. They found that a near century of warming from the atmospheric buildup of greenhouse gases would result in tropical cyclones with a 14% increase in central pressure fall, a 6% increase in the peak surface wind, and a 7% increase in the average rate of precipitation within about 300 km of the storm center by the equivalent of model year 2080.

These increases are shown to primarily result from a strong association, within the models employed, between sea surface temperatures (SSTs) in the tropical cyclone formation regions and maximum storm intensity. The positive response to increases in SSTs dominate the negative (weakening) storm response to model-projected increases in the upper-tropospheric temperatures relative to the surface. The models are perturbed with a 1% (compounded) annual increase in the concentration of atmospheric carbon dioxide. No changes in vertical shear were assumed.

We examined real-world observations of these same elements and found that they are substantially different from the way that they are characterized in the KT04 analysis. When real (rather than modeled) hurricanes are examined, the correspondence between intensity and SST drops by a factor of 5. The real rate of carbon dioxide increase (which has been quite constant for the last three decades) suggests that the prospective increases in intensity are halved in model year 2080. Fi-

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nally, we have concerns in the use of the Geophysical Fluid Dynamics Laboratory (GFDL) hurricane model to address future intensity questions because of its lack of predictive skill in current-day hurricane intensity forecasts.

2. CO_2 forcing scenario

KT04 uses as a determinate of the background climate in the future the 80-yr trends of SSTs, air temperature, atmospheric humidity, and surface pressure from the output from nine different climate models driven with 1% yr^{-1} increases in atmospheric carbon dioxide concentrations. This forcing scenario is used out of convenience as the results from many climate models run under this CO_2 growth scheme are available from CMIP2+. CMIP2+ sought a common, easily handled scenario for all its participating models so that intercomparisons of model output could readily be made (Covey et al. 2003). However, a 1% yr^{-1} increase in atmospheric carbon dioxide is not a realistic scenario for the future evolution of the atmospheric concentration of greenhouse gases—neither for carbon dioxide alone, nor in combination with other greenhouse gases. A warning to this effect is made by Covey et al. (2003) when summarizing CMIP results. This warning is often overlooked or ignored by both researchers describing their results and, in what is more often the case, by media outlets reporting results that they may feel bear climate change implications. Thus, it is worth repeating here, from Covey et al. (2003):

> The rate of radiative forcing increase implied by 1% per year increasing CO_2 is nearly a factor of two greater than the actual anthropogenic forcing in recent decades, even if non-CO_2 greenhouse gases are added in as part of an "equivalent CO_2 forcing" and anthropogenic aerosols are ignored (see, e.g., Figure 3 of Hansen et al. 1997). Thus the CMIP2 increasing-CO_2 scenario cannot be considered as realistic for purposes of comparing model-predicted and observed climate changes during the past century. It is also not a good estimate of future anthropogenic climate forcing, except perhaps as an extreme case in which the world accelerates its consumption of fossil fuels while reducing its production of anthropogenic aerosols.

Further evidence that the actual growth rate of the climate forcing (from greenhouse gases) is less than half the rate implied by a 1% yr^{-1} increase in CO_2 is given by Michaels et al. (2002) and most recently by Hansen and Sato (2004).

The percentage increase in atmospheric CO_2 levels in 80 yr under a 1% yr^{-1} scenario is nearly 2.5 times the increase under a scenario of a 0.5% yr^{-1} increase—a rate consistent with current trends. The concentration reached in 80 yr under the 0.5% yr^{-1} scenario is equivalent to the concentration reached in about year 40 of the 1% yr^{-1} scenario.

Since the rate of global temperature increase is nearly constant in the CMIP2+ model runs (Covey et al. 2003, their Fig. 20), research using the CMIP2+ model output, such as that performed by KT04, should focus on conditions in model years 40–50 for a more reasonable representation of the greenhouse gas environment at the end of the twenty-first century.

Because the aggregate warming rate in the CMIP2+ models is linear, the model aggregate results for hurricane intensity increases found by KT04 with more realistic carbon dioxide increments should be reduced by nearly a factor of 2, or to a 7% increase in central pressure fall, a 3% increase in peak wind speed, and a 4% increase in precipitation rate within about 300 km of the cyclone center. Given these reduced estimates and the highly variable nature of tropical cyclone characteristics, both on annual and decadal time scales (Landsea et al. 1999; Goldenberg et al. 2001), this reduces the likelihood that detection of these model-derived intensity increases will occur within the next several decades or even within this century.

3. SST–storm intensity relationship

The primary reason that KT04 report greater future storm intensities is that SSTs in the tropical cyclone genesis regions are greater in the high-CO_2 model environment than in the control runs. The models grow tropical cyclones in an idealized environment that is absent the myriad factors, such as vertical wind shear, that also act to inhibit tropical cyclone development. As such, KT04's focus is on potential intensity, that is, the theoretical maximum intensity that a tropical system may obtain absent influences other than SST and large-scale atmospheric temperature and moisture conditions. Under such a scenario, SST is the dominant influence on storm development, and ultimately on storm intensity. However, it is not the potential intensity, but the actual intensity, that a storm attains that is relevant to the community of individuals who are impacted by tropical weather systems, and thus it is instructive to examine actual storm behavior under real-world conditions.

The strong dependence on SST in KT04's model is clearly evident in KT04's Table 2, which shows that the correlation between genesis region SSTs and storm intensity (as measured by minimum central pressure) ranges from -0.64 to -0.84, with an average value over the control and high-CO_2 runs of -0.74, or an overall explained variance between SST and intensity of 55%.

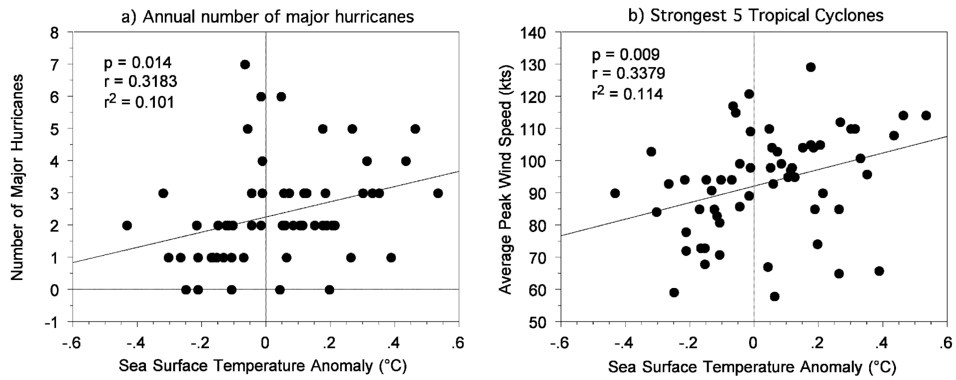

FIG. 1. Scatterplots showing the observed relationship between SSTs and two measures of hurricane intensity: (a) the number of major hurricanes (tropical cyclones of category 3, 4, or 5 on the Saffir–Simpson hurricane scale) each year and (b) the average peak wind speed in the five strongest storms in each year, for the period 1944 to 2002 in the Atlantic basin.

Observations, rather than models, argue that this relationship is not so well defined in the actual environment. We averaged monthly SST anomalies from the extended 5º × 5º Kaplan SST dataset (Kaplan et al. 1998; Reynolds and Smith 1994) for the region spanning 10º–25ºN and 15º–80ºW for the season July through November, 1944–2002. We then relate the average SST anomalies to two measures of tropical cyclone intensity: 1) the peak wind speed averaged across the five strongest storms each year and 2) the total annual number of major hurricanes (tropical cyclones of category 3, 4, or 5 on the Saffir–Simpson hurricane scale; data updated from Landsea et al. 1996). We chose to use the average peak wind speed across the five strongest systems rather than across all tropical systems to reduce the influence of annual frequency variations on the data values, as KT04's methodology was not developed to analyze frequency variations in an altered climate.

Figure 1 shows the observed relationship between SSTs and storm intensity. While statistically significant ($p < 0.05$), it is much less strong than in the KT04 models. The observed correlation between Atlantic SSTs and average peak wind speed in the five strongest storms is 0.34, and the correlation between SSTs and the annual number of major hurricanes is 0.32, or an overall explained variance of about 10%. The model-derived KT04-explained variance (based instead upon pressure, which is obviously proportional to maximum wind) of 55% is a five-fold inflation of explained variance over real-world data. Our result is consistent with other investigations such as Landsea et al. (1999), who report correlations between local SSTs and storm intensity measures in the Atlantic basin of between 0.16 and 0.29—values that are approximately equal to, or in many cases, less than their reported correlations between intensity and other factors such as SSTs in the ENSO region of the tropical Pacific Ocean, the state of the stratospheric quasi-biennial oscillation, rainfall in the African Sahel, and regional sea level pressure and 200-hPa zonal wind speeds. Clearly, the assumption made in KT04 that only the thermodynamical changes are important for determining upper-limit intensities in hurricanes is too simplistic in the real world.

It is important not to read too much into the actual value of slopes in the relationships depicted in Fig. 1. In both cases, while the slope is statistically significant ($p < 0.05$) across the observed range of SSTs, it becomes statistically insignificant if the analysis is limited only to the subset of warmer than normal SSTs—conditions more representative of a potentially warmer SST state in the future. This behavior, coupled with the low overall level of explained variance, indicates that there is little, if any, reliability in using the slope of these relationships as a predictive tool.

4. GFDL model intensity forecasting skill

KT04's mesoscale model that provides the hurricane change estimates is the atmospheric component of the operational GFDL hurricane coupled model used for day-to-day hurricane predictions at the National Hurricane Center (NHC). This model has shown no actual predictive skill in forecasting hurricane intensity during the last two hurricane seasons in official NHC post-season evaluations (J. Gross 2004, personal communication). {Skill in hurricane intensity predictions is based upon a comparison of absolute wind speed errors against a "no-skill" benchmark model [statistical hurricane intensity forecast (SHIFOR)] that uses only climatological and persistence predictors.} The performance of the GFDL model in an operational mode can be influenced by such factors as model physics and model specification, as well as the quality and the quantity of the observational data used to initialize the model. While one may argue that the errors in the model are consistent whether operating in a high-CO_2 environment or in a control environment, and that therefore differences between the two environments serve as a useful diagnostic for potential changes, the concession must be made that the difference represents only the change in theoretical model-derived storms in different environments. In actuality, the theoretical storms generated by the model do not behave as their real-world counterparts as demonstrated by the lack of predictive skill. Therefore, it is hard to imagine what utility, if any, remains for a tool that fails to demonstrate useful information on the storms of today, when used to project the storms of the future.

5. Conclusions

KT04 admittedly performed their study in an idealized setting, both in terms of their selection of a CO_2-growth scenario as well as in the environmental conditions in their hurricane model. However, while idealized conditions may be appropriate in didactic application such as investigations into model behavior, they are inappropriate for making real-world projections, especially when observations are substantially different than the behavior in the idealized system, as we have demonstrated is the case in this instance. Therefore, statements such as those made by KT04 that "one implication of the results is that if the frequency of tropical cyclones remains the same over the coming century, a greenhouse gas-induced warming may lead to a gradually increasing risk in the occurrence of highly destructive category-5 storms" should be avoided. Instead, the combination of observed greenhouse gas forcing trends, weak correlation between SSTs and tropical cyclone intensities, high interannual and interdecadal variation in tropical cyclone characteristics, and the use of a mesoscale model that shows difficulties in predicting current-day hurricane intensity changes suggests that the influence of atmospheric composition changes on future hurricane intensities will be undetectable in the foreseeable future and, in fact, may never be manifest.

Press coverage of KT04's results as published (Revkin 2004) has left the public with the impression that a perceptible increase in hurricane strength is likely in coming decades as a result of planetary warming. That is the modeled result given in KT04. But, when driven by real-world observations rather than unrealistically parameterized and constrained model conditions, the prospects for a detectable increase in hurricane strength in coming decades are reduced to the noise level of the data.

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