Draft science plan for Tropical Cyclone Climate Model Intercomparison Project (TC-MIP).

Numerous groups worldwide are currently simulating the formation and evolution of tropical cyclones using climate models. The main applications to date are for the forecasting of tropical cyclone numbers several months in advance and for the prediction of the effects of climate change on tropical cyclones. Best results are obtained with the finest possible resolutions, since tropical cyclones are small compared with the resolution of most current climate models.

The modeling groups involved in this effort use a number of different models, all of which employ different representations of the climate system. There has been no systematic attempt to compare the results of the different models in order to try to understand the reasons for their differences, an important step towards improving their simulations. Indeed, modeling groups have used different methods for assessing the performance of their models, so published results are not easily compared.

As a consequence, there is a need for a project that compares and analyses the results of a number of climate models to determine their performance in simulating tropical cyclones and to investigate systematically the reasons for differences in model results. This should include comparisons of the output of coarser-resolution models, as they can simulate large-scale climate parameters important for tropical cyclones, such as vertical wind shear.

A proposal has already been submitted by Siegfried Schubert of NASA/Goddard to establish an intercomparison project for groups that perform seasonal predictions of tropical cyclones using climate models. A second group, comprising modelers who mostly use climate models to predict the effects of climate change, held a meeting in Orlando on Apr. 30, 2008 to determine how they might best interact with the first group.

It is clear from this meeting and other discussions that whatever final form the intercomparison project takes, it will consist of a number of essential elements:

(1) common metrics will be used for the assessment of model quality;
(2) common detection criteria, appropriately adjusted for resolution, will be applied to the output of all models;
(3) the simulation by coarser-resolution models of large-scale climate variables of relevance to tropical cyclone formation and intensification will be examined;
(4) the generation and evolution of tropical cyclone-like lows by finer resolution models will be evaluated;
(5) modeling groups will be encouraged to perform and analyse common experiments, such as runs with specified sea surface temperatures.

This document gives more details of the scientific questions to be addressed as part of this project, along with specific analyses and simulations to be performed to answer these questions.

1. What is the native ability of each climate model to generate tropical vortices and how does this depend on resolution? By comparing the characteristics of the models, can we determine other factors that govern simulated formation rates?

This issue will be addressed by performing ensemble simulations in which all models were run with climatological SSTs supplied by the coordinating team. Preferably, 10-year runs should be performed with 3 ensemble members each. It is suggested that a "standard" resolution set of runs be performed for all models to enable easy intercomparison. It is suggested that this resolution be 1 degree. In addition, other runs should be performed using the same SSTs and the same model but with resolution as high as feasible for that particular model. Runs are also encouraged using the same model but with different convection schemes or different dynamical cores.

Detailed lists of important model features will be compiled so that reasons for differences in model results can be identified. Such features would include the details of the convective parameterization employed, horizontal diffusion representation, air-sea interaction representation (e.g. transfer coefficients) and cloud schemes. To test the impact of the convection scheme, it is proposed that high-resolution runs (at least 0.5 degrees) be performed with the model convection scheme turned off.

In addition, in order to examine the ability of the models to respond to interannual variations in climate, AMIP-style runs should be performed, using SSTs supplied by the coordinating team for the years 1950-2006, with 3 ensemble members. Runs should be made at 1 degree resolution, or coarser if this is not possible.

The proposed experiments, required and optional, are summarized in Table 1:

2. Why do almost all climate models simulate too few tropical cyclones in the north Atlantic basin? In contrast, why do a number of models simulate too much formation in the south Atlantic, where observed formation is rare? Why do models also have such a poor simulation of formation in the eastern N. Pacific?

Comparison between the model simulations of large-scale fields, using genesis parameters (e.g. Emanuel and Nolan 2004; Camargo et al. 2007), will be made to determine relationships between formation and atmospheric climatology. Comparisons between models will identify systematic factors that would explain the simulated formation rates. It has been suggested that the lack of formation in the Atlantic is caused by an inadequate simulation of easterly waves and that this may depend on resolution. This hypothesis could be tested in simulations with the same model but using different resolutions. For the eastern N. Pacific, topography may be a factor. This could be tested with an experiment in which topography in this region were either raised or lowered, to see if this would affect the formation rate, or an experiment using a higher-resolution model with a better representation of topography in this region.

3. Is there general agreement between the predictions of genesis parameters and direct simulation of tropical lows by climate models, or are there systematic differences between the two? In other words, what is the relationship between the quality of the model simulation of large-scale fields and actual simulated tropical cyclone formation? What model parameters govern these links?

A considerable amount of work has already been performed on this topic (e.g. McDonald et al. 2005; Chauvin et al. 2006; Camargo et al. 2007). We aim to build on this work and clarify some of its conclusions, through the use of common, consistent metrics for the diagnosis of simulated cyclone formation, such as those suggested by Camargo and Zebiak (2002) and Walsh et al. (2007). These metrics could include the following:

- Resolution-dependent absolute detection criteria based on 10 m wind speed (Walsh et al. 2007)
- Basin-dependent detection criteria based on statistical distributions (Camargo and Zebiak 2002)
- Occurrence statistics in cyclone days, based on a consistent definition of storm lifetime
- Probability distributions of 10m wind speed, central pressure and storm rainfall.
- Large scale parameters such as vertical wind shear, sea surface temperature,

4. What factors influence the extratropical transition of simulated storms, and does this occur at realistic locations?

There are existing well-known factors that influence extratropical transition (ET), such as vertical wind shear. Measures of cyclone structure such as the phase diagram of Hart (2003) will be applied to establish quantitative comparisons between model ET and real ET as represented in reanalyses.

5. How do simulated tropical cyclone rainfall rates compare with available observations, and what factors govern intermodel differences?

Model simulations of tropical cyclone rainfall rates will be compared with aggregated TRMM tropical cyclones rainfall amounts (e.g. Lonfat et al. 2004). The difficulty here is that the TRMM estimates are limited by sampling issues, since not all storms are sampled at all times by the TRMM instruments. The purpose of the intercomparison in this context would be to identify major biases in model simulations of this quantity and to determine whether such biases are related to specific aspects of model formulation. The blended precipitation data set CMORPH (Joyce et al. 2004) will also be compared for individual tropical cyclones.

6. Do the models simulate the correct relationship between the MJO and observed tropical cyclone formation? What is the role of air/sea interaction and SST anomalies in TC formation?

A number of existing climate models of tropical cyclone formation are coupled-ocean atmosphere models. No new runs are proposed here, but existing coupled runs could examine the role that this coupling plays in the climatological formation of tropical cyclones. Simulations using coupled and specified-SST runs with the same atmospheric model will be compared to investigate the influence of the MJO, its relationship with tropical cyclone formation, and the influence of air-sea interaction on the simulated climatological aspects of tropical cyclone formation and occurrence. Crucial to this comparison will be an assessment of the quality of the MJO simulation in each climate model, building on previous work by the US CLIVAR working group on the MJO.

Personnel and Equipment

It is envisaged that model groups who chose to participate in this project will store their raw model output at their own supercomputing sites but will use personnel hired by the project to help analyse their data using the common metrics proposed. Therefore it is envisaged that funding will be sought for the following:

- a research associate to provide the main scientific contact with the groups, to lead the data analysis and intercomparison project, and to assist in the analysis of each group's model output using the common metrics of the intercomparison project.
- A web site where a selection of group model outputs, including intercomparison results, would be stored for use by all members of the intercomparison project.
- Funding to support attendance by invited speakers at meetings of the intercomparison group

Initial tasks

An important initial task would be to compile an inventory of suitable model runs already archived by each group. A brief list of future runs that are relevant to this project should also be provided. In addition, it is recommended that each group archive a number of crucial variables in future runs that will aid their analysis for the presence of tropical cyclones. These variables are as follows (fields saved every 6 hours):

- SST
- Mean sea level pressure
- Accumulated precipitation
- 10 metre u,v,T and q
- u,v,T,q,omega at 850, 700, 500, 400, 300, 250 and 100 hPa.
- Z from 1000 to 200 hPa at 50 hPa intervals

References

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Table 1. Suggested experiments for intercomparison project.

Experiment	Resolution	Required, Optional or Existing
Climatological SSTs, 3x10 years	1 deg.	R
Climatological SSTs, 3x10 years	As high as possible	R
Climatological SSTs, 3x10 years, convection off	0.5 deg.	O
AMIP-style SSTs, 1950-2006, 3 ensemble members	1 deg	R
Coupled model SSTs, 30 years	Existing resolution	E