WORKSHOP ON TROPICAL CYCLONES AND CLIMATE

BY SUZANA J. CAMARGO AND ADAM H. SOBEL

Tropical cyclones (TCs) are among the most destructive of natural disasters. The statistics of TC occurrence and intensity are influenced by variations in the large-scale climate, but many aspects of this influence are poorly understood. Even less is known about the influence of tropical cyclones on the large-scale climate. These problems have been studied relatively little, considering their importance, perhaps because TCs and climate are for the most part studied by separate groups of scientists who have tended to interact less than they might. As debate about the possibility of an influence of anthropogenic climate change on TCs has heated up in the last year, it has become clear that the relationship between TCs and climate needs much more sustained and serious study.

In response to this need, the International Research Institute for Climate and Society (IRI) hosted a two-and-a-half-day workshop in March 2006 on "Tropical Cyclones and Climate." The centerpiece of the workshop was a set of invited lectures, with a modest number of contributed oral presentations and a small poster session. Relatively lengthy discussion periods were built into the schedule (the complete agenda can be found online at http://iri.columbia.edu/outreach/meeting/TropicalCyclones/agenda.html) allowing in-depth discussion of the presentations and related issues. A special issue of *Tellus A* (the Swedish Geophysical Society's publication on dynamical meteorology and oceanography) is currently in preparation, featuring papers based on presentations given at the workshop.

TROPICAL CYCLONES AND CLIMATE WORKSHOP

WHAT: Experts assembled to provide a unique assessment of the current knowledge and problems with the influence of climate on tropical cyclones, and vice versa, to provide new insights and form new collaborations in this rapidly evolving area of research.
WHEN: 27–29 March 2006
WHERE: Palisades, New York

The planning for the workshop began in late 2004. At that time, the relationship between TCs and climate did not appear to be a hot topic. The extreme Atlantic hurricane season of 2005, and the disastrous consequences of Katrina in particular, as well as two high-profile papers published during the summer of 2005 (Emanuel 2005; Webster et al. 2005) changed that. Presumably due at least in part to these developments, the workshop attracted more interest than we had expected. Eighty-three registered attendees participated, mainly from universities (76%) and government (13%), with some representatives from the insurance industry (6%) and the press (4%). Of the registrants, 23% were female, and 12% were from foreign institutions; 20 were graduate students and one was a high school student. In addition to these

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registered participants, a small number of scientists from the Columbia University community informally attended some or all of the workshop.

Presentations were loosely classified into the following four areas: the influence of climate on TCs, the influence of TCs on climate, paleotempestology, and risk management and impacts. The second and third areas are those in which little research has been done, and one goal of the workshop was to stimulate interest in these areas.

The influence of climate variability on TCs was emphasized on the first day. Fréderic Vitart (European Centre for Medium-Range Weather Forecasts), Lennart Bengtsson (University of Reading), and Kevin Hodges (University of Reading) discussed the simulation of TCs in general circulation models (GCMs). This is a thorny issue because GCMs, particularly when run in climate mode, have resolutions that are too low to represent TC physics with high fidelity. Yet, such low-resolution models are the only ones that are usable for long climate simulations, and they do form TC-like vortices whose statistics (such as the climatological annual cycle in some basins, and some aspects of interannual variability) can, to some degree, resemble those of the observed TCs. The models discussed in both studies show a small but significant impact of increasing greenhouse gases on simulated TC activity, with a slight decrease of TC frequency in most regions. Both models showed no significant increase in TC intensity in spite of a SST warming of 2°–3°C.

Suzana Camargo (International Research Institute for Climate and Society) analyzed various aspects of the TC activity in response to ENSO, including typhoon intensity; track changes in the western North Pacific, using a novel cluster analysis; and an index of the likelihood of tropical cyclogenesis, based on large-scale environmental factors (sea surface temperature, wind shear, etc.) developed by Kerry Emanuel. The importance of each of these environmental factors to the TC response to ENSO was explored using the genesis index. Specific factors were identified as having more influence than others, with different factors being more important in different regions. Vertical shear and midlevel relative humidity are consistently important in many regions, especially the western North Pacific near the Asian continent and the North Atlantic. Vorticity anomalies contribute most significantly in the central Pacific (both north and south), especially during El Niño events when tropical cyclones tend to form closer to the equator.

Johnny Chan (City University of Hong Kong) discussed the interannual and interdecadal variability of typhoon activity in the western North Pacific. Chan showed that ENSO influences typhoon activity in this basin mainly through the atmosphere, rather than through the ocean, because the interannual variations in intensity that have been observed are opposite in sign to what would be expected based on the local SST anomalies in the region of TC genesis.

The recent spurt of hurricane landfalls in the United States shows that the impacts of TCs are not only devastating to individuals, communities, and property, but also to our economy, both directly and indirectly. Richard Murnane (Risk Prediction Initiative) provided the perspective of the insurance industry, for whom TCs are the most important natural disasters. One topic of interest to the insurance industry is extratropical transition, because this is difficult to predict and can lead to large impacts in New England and Europe. Roger Pielke Jr. (Colorado State University) analyzed the roles that urban development and population increases in coastal areas have on the losses resulting from hurricanes. Pielke argued persuasively that long-term increases in economic damage have been and will continue to be overwhelmingly due to these factors, with the influence of climate change a distant second. María Uriate (Columbia University) studied the impacts of TCs on ecology, rather than economy. Uriarte used data from field work in Puerto Rico, as well as an individual-based model of a tropical forest ecosystem, to show how hurricanes influence forests by setting them back to an earlier successional stage.

The afternoon of the second day focused on TCs in past climates. This session featured three presentations on paleotempestology, which is the study of past hurricane activity using proxies in the geologic record. Kam-biu Liu (Louisiana State University) analyzed coastal lake sediments, which record past hurricane strikes through microfossil data. Using proxy records from the Gulf Coast, Liu finds that the return period for catastrophic Atlantic hurricanes is approximately 300 years, and that a very active period occurred 1,000–3,800 years ago. Jeffrey Donnelly (Woods Hole Oceanographic Institution) described new proxies that his group has been developing, such as fossil trees, which may be able to provide high-resolution archives of tropical cyclone strikes dating back many thousands of years. Amy Frappier (University of New Hampshire) proposed a new methodology to obtain a high-resolution proxy record of TC events from stalagmites using stable isotopes. Using this methodology, she was able to identify 80% of all intense storms striking Belize in the observational record in the last 30 yr, validating the technique.

In addition to paleotempestology, the influence of TCs on climate was the other underinvestigated area

that the workshop specifically targeted. Most climate research implicitly assumes that TCs are irrelevant to the larger-scale climate, but it is not clear that this is necessarily the case. Robert Korty (California Institute of Technology) described a mechanism by which TCs may influence the thermohaline circulation of the ocean by promoting vertical mixing in the upper ocean, and argued that this mechanism could explain the warm climate of the Eocene. Claudia Pasquero (California Institute of Technology) discussed a possible mechanism for positive feedback between hurricanes and upper-ocean warming, involving year-to-year persistence of warm anomalies at the base of the thermocline that are produced by TCs. These same anomalies can allow the next season's TCs to become stronger, because further vertical mixing will not cool the surface as much a it would without the anomalies.

Finally, the workshop featured a set of talks on the possible influence of climate change, including anthropogenically induced trends, on TCs.

Kerry Emanuel (Massachusetts Institute of Technology) showed that various measures of TC activity have been increasing since the mid-1970s, particularly in the Atlantic. Emanuel found no evidence for a natural multidecadal cycle in the tropical Atlantic SST. When the trend is included, the time series associated with the spatial structure of multidecadal oscillation tracks the Northern Hemisphere (NH) surface temperature. Emanuel thus argued that the NH surface temperature and late-summer tropical Atlantic SST variations are both part of the climate system's response to natural and anthropogenic forcings, including solar variability, volcanoes, and anthropogenic emissions of aerosols and greenhouse gases.

Thomas Knutson (Geophysical Fluid Dynamics Laboratory) analyzed the TC intensity response to global warming using simulations with a high-resolution regional nonhydrostatic hurricane model whose boundary conditions were provided from coupled GCM simulations forced by increasing greenhouse gases. Using a variety of different GCMs for the forcing and different convection schemes in the hurricane model, Knutson finds a robust increase in storm intensity in a warmer climate, though one significantly smaller than that implied by Emanuel's observational analysis (which increases the numbers of storms substantially per degree of SST warming). The sources of this disagreement were the subject of considerable discussion. Christopher Landsea (National Hurricane Center) addressed the quality of the TC best-track data, especially in the Atlantic, with particular attention to what can and cannot be inferred about trends in intensity during the twentieth century as discussed in recent papers (Emanuel 2005; Webster et al. 2005). Landsea pointed out the increase in the number of in situ measurements per storm over time as one factor confounding the detection of trends. Other issues are the evolution of the Dvorak technique, which makes the intensity estimates inhomogeneous, and the variable amount of satellite coverage throughout the years. All of these problems point to the strong necessity for a reanalysis to be performed over all basins, leading to a new best-track dataset appropriate for climate studies.

This workshop brought together scientists working on different aspects of the relationship of TCs to climate, including segments of the community who typically have little contact with each other. Discussions were stimulated between climate scientists and TC experts, modelers and paleoclimatologists, and physical and social scientists. The workshop focused on issues of great interest to the media, the public, and the broader scientific community, but also drew attention to relatively unexplored areas where much more attention is warranted. We hope that some of the graduate students and postdoctorates who attended the workshop will constitute part of the next generation of scientists who will tackle these important problems.

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