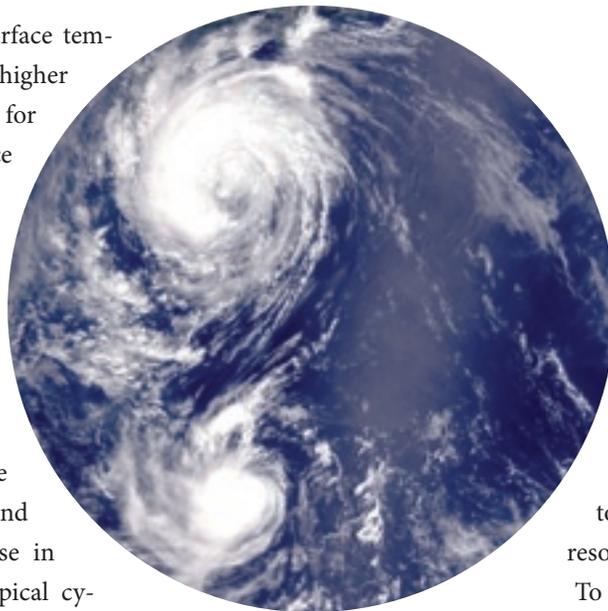


More Typhoons over the South China Sea?

Warm oceans with surface temperatures of 26°C or higher provide the fuel for tropical cyclones. Since sea surface temperatures in the tropics have risen on average about 0.5°C over the last decades, it is reasonable to ask if this corresponds to any clear trends in tropical cyclone frequency or intensity. In a recent observational study, **Peter Webster** (Georgia Institute of Technology) and colleagues found no statistically significant increase in the world-wide frequency of tropical cyclones over the last 30 years. He did note, though, significantly more storms at category 4 and 5 levels, an indication that storms have become stronger. For the western North Pacific, a region of great relevance to the IPRC focus on Asian-Pacific climate, the number of category 4 and 5 storms has grown from 5.7 per year during the first 15-year period studied, to 7.7 per year during the second period.

We can anticipate further surface warming. This would, by itself, be expected to increase cyclone frequency and intensity. Other factors, however, are known to affect tropical cyclone genesis and development, for example, moisture content, vertical wind shear, and atmospheric convective stability. **Markus Stowasser**, in collaboration with **Yuqing Wang** and **Kevin Hamilton**, has been applying the IPRC Regional



Climate Model (IPRC-RegCM) to studying the effects of global climate change on tropical cyclones in the Pacific. In this project, the IPRC-RegCM is run for a region extending from 100°E to 160°W and from 15°S to 55°N, and with a 0.5° horizontal resolution and 28 vertical levels.

To see how well the IPRC-RegCM is able to simulate present-day tropical cyclone statistics, the model was first run for the July–October period in 10 consecutive years (1991–2000) with horizontal boundary conditions and sea surface temperatures taken from observations. The model simulated 17.9 typhoons per year, which is close to the 20.1 per year recorded in the Joint Typhoon Warning Center (JTWC) best-track data set. The simulated storms have a larger radius (peak winds typically 150 km from the center) than observed typhoons. Other features typically observed in tropical cyclones, however, such as cyclonic inflow in the lower troposphere and anticyclonic outflow above 300 hPa, the pronounced warm core around 350 hPa, and the very high relative humidity (up to 100%) in the inner core of the storm are well simulated. Figure 1a

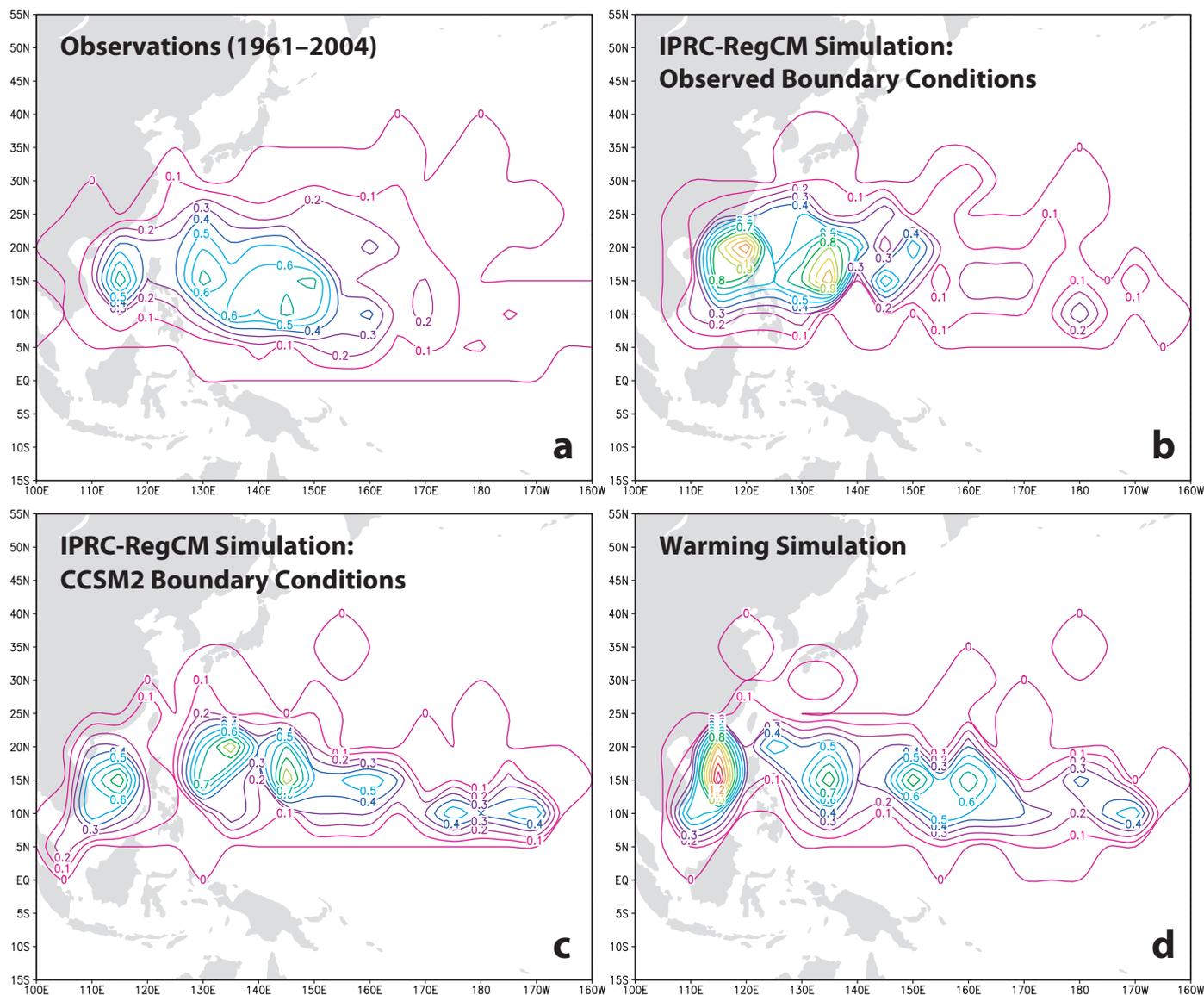


Figure 1. Comparison of tropical storm genesis locations in the western North Pacific during July–October in (a) JTWC best-track data (1961–2004) and the IPRC–RegCM integrations driven by boundary conditions obtained from (b) observed data (1991–2000), (c) CCSM2 present-day control run data, and (d) CCSM2 integration with 6 times present-day CO₂ levels. Results shown as number of storms per 5° latitude–longitude box per year.

shows the number of storms that formed in each 5° box per year computed from the JTWC data; Figure 1b shows the same variable for the simulation. The geographic distribution of the simulated storms is in reasonable agreement with the

data. In both observation and simulation, the region of most frequent tropical storm formation is the South China Sea.

To use the regional model to study the effects of increased levels of CO₂, the model was nested within the NCAR coupled global climate model CCSM2. First, the regional model was run for ten July–October periods with boundary and sea surface temperature forcing from ten consecutive years of a present-day control run of the CCSM2; the regional model was then forced for ten more July–October periods, in which the forcing fields were taken from ten consecutive years from the end of a long CCSM2 run with six times the present day atmospheric CO₂ concentration. The fairly large increase in CO₂ concentration was chosen because the CCSM2 is one of the climate models with the least sensitivity to increased CO₂ concentration levels.

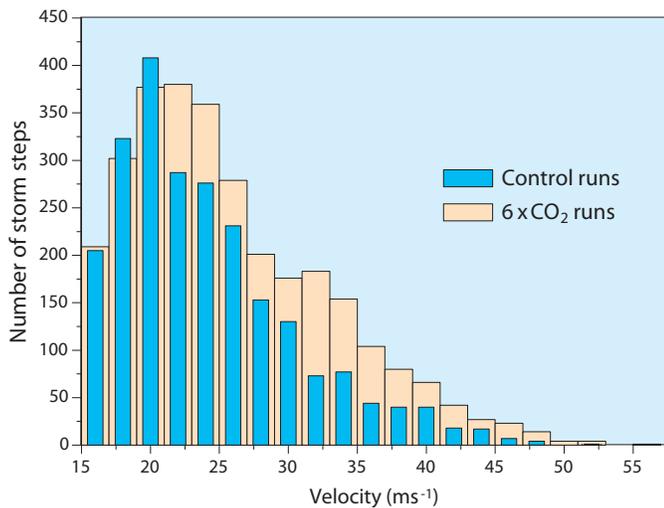


Figure 2. A histogram of western North Pacific tropical cyclone frequency with different maximum surface wind speeds. The frequency is given in numbers of 12-hour time-steps during which a tropical cyclone was present in the domain under present-day levels of CO₂ (blue) and under global warming conditions (6 times present-day CO₂ levels, in yellow). The number of tropical cyclones over the whole domain does not increase significantly in the global warming case; however, the average strength of the storms does increase significantly.

During the July–October period of the present-day control runs, the model simulated an average of 19.6 tropical cyclones. In the 6-fold CO₂ runs, the sea surface temperature in the tropical western North Pacific run rose roughly 3°C, and the number of average storms per season rose to 23.3, a number not statistically significantly higher than in the unperturbed control simulation. The storm genesis locations simulated by the IPRC–RegCM with control CCSM2 forcing are shown in Figure 1c and for forcing taken from the 6-fold CO₂ run with the CCSM2 in Figure 1d. Although the total number of storms over the region did not increase significantly, the increase in storms in the South China Sea is statistically significant. Moreover, those storms that formed in the warming experiment were, on average, significantly stronger. Thus, in the control run 21% of the storms had wind speeds between 30 and 40 m/s, and 8% had peak winds above 40 m/s. In the global warming runs, 32% had wind speeds between 30 and 40 m/s, and 13% had peak winds above 40 m/s. Figure 2 shows the distribution of the peak surface winds for all the storms (computed at 12-hour intervals during the lifetime of each storm) simulated in the present-day and warming runs.

Analyses of the global-warming runs reveal that the large-scale atmospheric environmental conditions over the South China Sea change to favor more tropical cyclone formation: the relative humidity in the mid-troposphere increases

and the vertical wind shear decreases compared to the present-day runs. Fewer tropical cyclones formed in most other regions of the western North Pacific, a result consistent with lower relative humidity, higher stability and vertical shear found in the warm-climate simulation over these areas.

The results of this study demonstrate the utility of applying the IPRC–RegCM to the tropical cyclone climate sensitivity problem. By using a regional model forced by output from coarse resolution global coupled models, the area to be studied can be represented at fairly high spatial resolution. Different global models produce different changes in the circulation in the tropical Pacific in response to the same large-scale climate forcing, so it will be interesting to repeat the present IPRC–RegCM simulations with boundary forcings taken from other global climate models for which control and global warming simulations are available.

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