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Rainfall hazard from tropical cyclones

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The assessment of rainfall hazard from tropical cyclones (TCs) typically relies on empirical models, which estimate the rainfall field for a given TC intensity and motion category as the ensemble average over the historical storms in that category. The coarseness of the classification, the exclusion of other relevant storm parameters (most notably the radius of maximum winds), and the paucity of the historical data make the estimates rather inaccurate. Moreover, ensemble averaging suppresses the all-important fluctuations due to rainbands and local convection and severely underestimates the rainfall maxima.

We have developed an alternative approach to evaluate the probability distribution of the maximum rainfall intensity in a period d at a geographical point due to passage of a tropical cyclone. This maximum rainfall intensity, $I_{max}(\theta, r, d)$, depends on the duration d, the distance r of the point from the storm center, and several storm parameters θ: the maximum tangential wind velocity at gradient level V_{max}, the radius of maximum winds R_{max}, Holland's B parameter for the wind profile, the storm translation velocity u_t, and the average temperature and saturation ratio inside the boundary layer.

We obtain the distribution of $I_{max}(\theta, r, d)$ as follows. First, under an assumption of the frozen turbulence type, we equate the temporal maximum $I_{max}(\theta, r, d)$ to the spatial maximum $I_{max}(\theta, r, l = d/u_t)$. We find the distribution of $I_{max}(\theta, r, l)$ as $F_{I_{max}(\theta,r,l)}(i) = \{F_{I(\theta,r,l)}(i)\}^{L/l}$ where L is a suitable length that depends on r and $I(\theta, r, l)$ is the rainfall intensity in a generic l-interval inside L. This relationship strictly holds under the assumption of independence, but we have found that it produces accurate results also in cases with dependence. We write $I(\theta, r, l)$ as $I(\theta, r, l) = \hat{I}(\theta, r, l) \cdot Z \cdot \varepsilon(l)$ where $\hat{I}(\theta, r, l)$ is a deterministic estimate of $I(\theta, r, l)$

based on horizontal wind convergence in the TC boundary layer (see below), Z is a random correction factor for bias and storm-to-storm variability, and $\varepsilon(l)$ is a random unit-mean factor that accounts for intensity fluctuations due to rainbands and local convection .

The distributions of $Z$and $\varepsilon(l)$ are obtained from the precipitation radar (PR) snapshots of TRMM. The distribution of $\varepsilon(l)$ includes an atom at zero representing the probability of zero or negligible rainfall inside segments of length l. Our main interest is however in the upper tail of the distribution, which has approximately lognormal shape and depends little on distance r from the TC center. The estimate $\hat{I}(\theta, r, l)$ is obtained from Langousis *et al*. (2008a,b), who use basic thermodynamics and a relatively simple numerical model to calculate the vertical moisture flux inside the TC boundary layer due to horizontal wind convergence. In this model, the tropical cyclone is characterized by the radial profile of the tangential wind speed at gradient level, the storm translation velocity, and the average temperature and saturation ratio inside the boundary layer. Model rainfall field predictions closely match smoothed TRMM measurements and MM5 simulations, but the model does not resolve rainfall fluctuations due to rainbands and local convection.

The calculated distributions of $I_{max}(\theta, r, d)$ are in good agreement with maximum rainfall intensities estimated from TRMM measurements.