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Extreme Rainfall Intensities and Long-term Rainfall Risk from Tropical Cyclones

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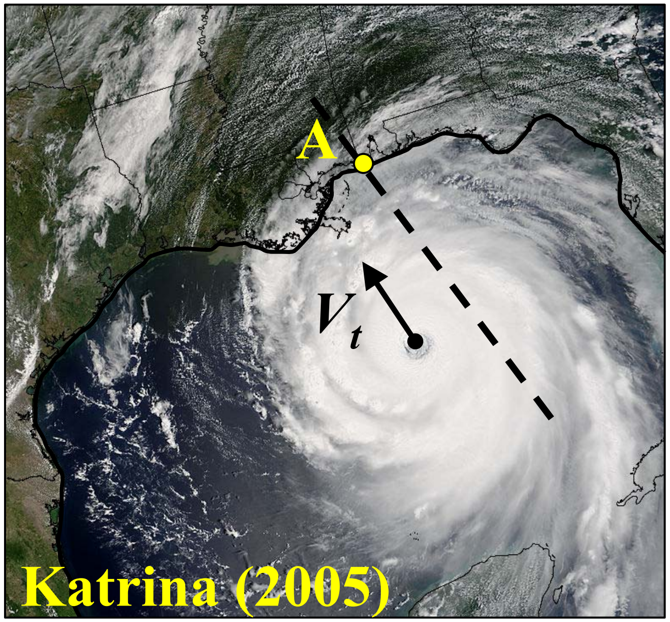
Objective

Long-term rainfall risk from TCs at location A:



$\lambda_D(i)$: rate at which $I_{max}(D)$ exceeds i at location A (events/year)

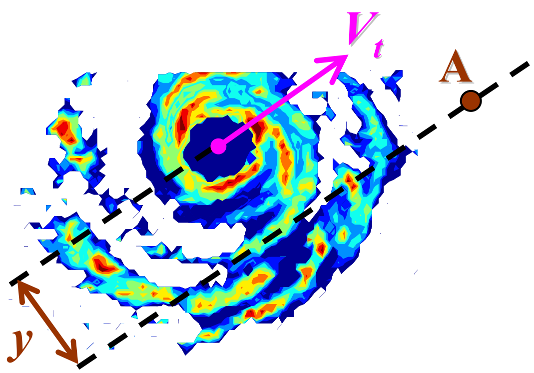
$I_{max}(D)$: maximum rainfall intensity at location A for averaging duration D

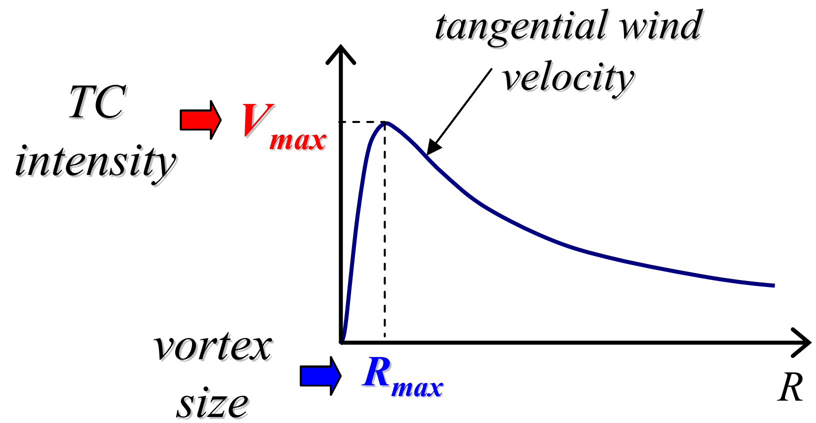
Risk analysis ⇨ $\lambda_D(i) = \lambda \int_{\text{all } \boldsymbol{\omega}} P[I_{max}(D) > i|\boldsymbol{\omega}]\, P[\boldsymbol{\omega}]\, d\boldsymbol{\omega}$

- λ: *TC arrival rate* [events/yr]
- $P[I_{max}(D) > i|\boldsymbol{\omega}]$: ***focus***
- $P[\boldsymbol{\omega}]$: *local recurrence (literature)*; *TC characteristics*

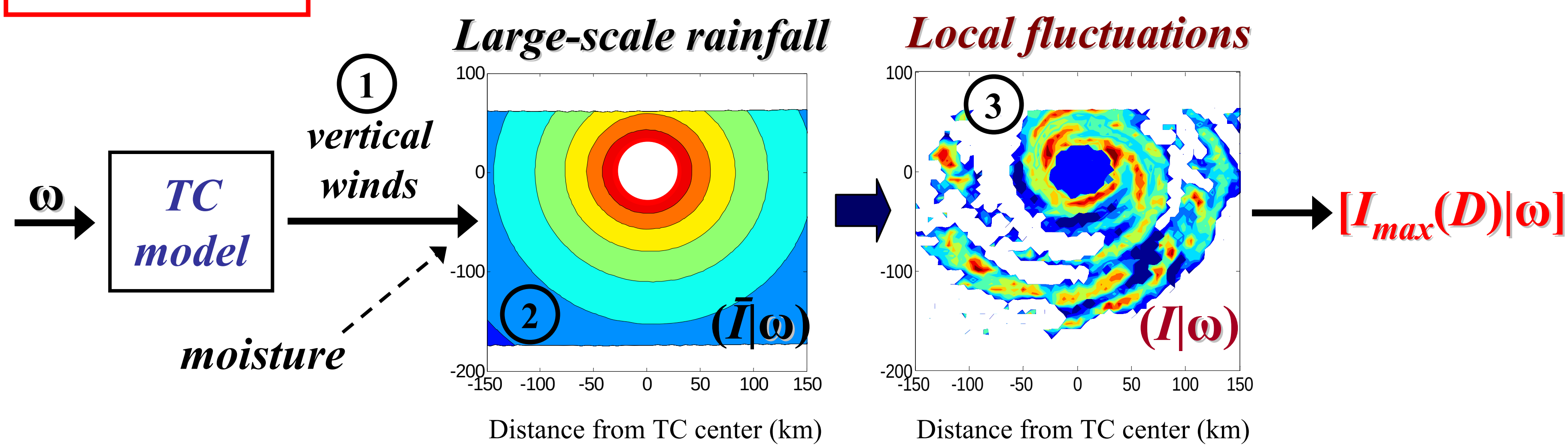
Implementation

➢ **parameters** $\omega = [V_{max}, R_{max}, V_t, y]$

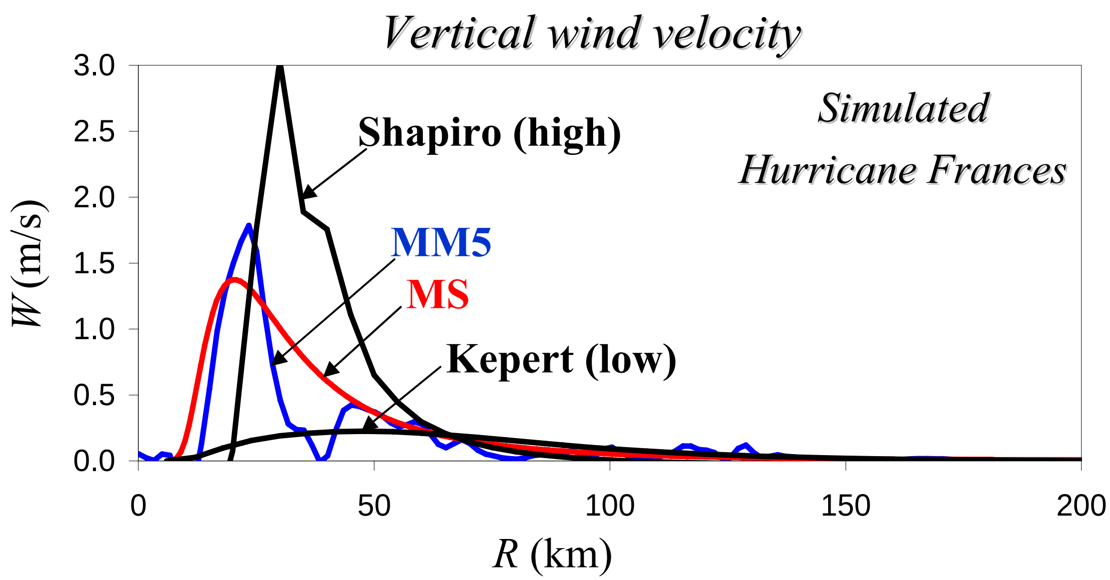




$[I_{max}(D)|\omega]$



TC Model: Vertical winds and Rain



Vertical winds

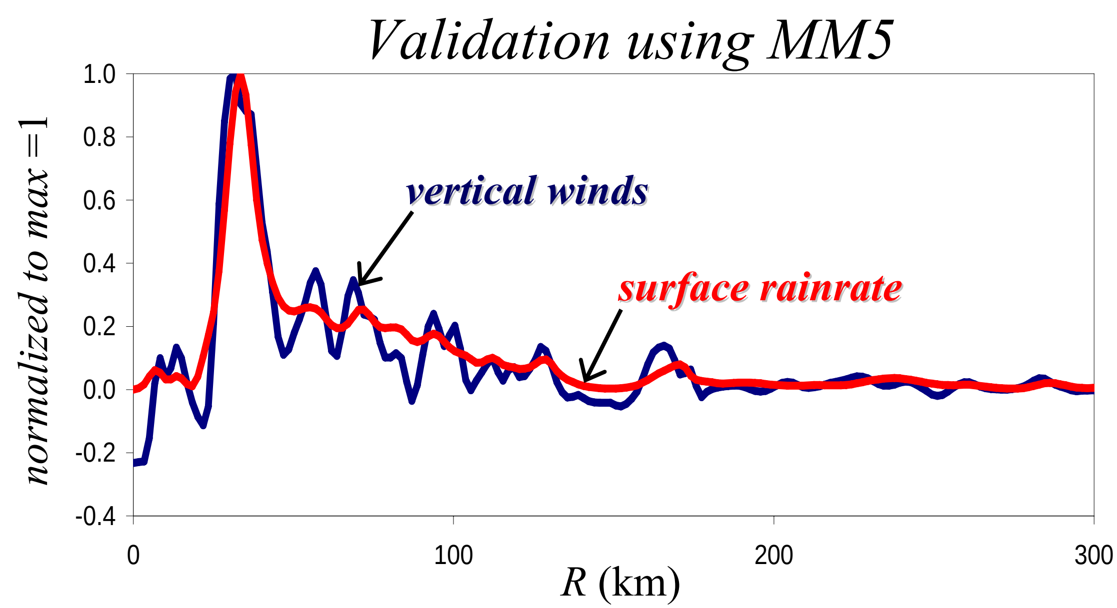
Rain:

$$\bar{I} = c\,W$$

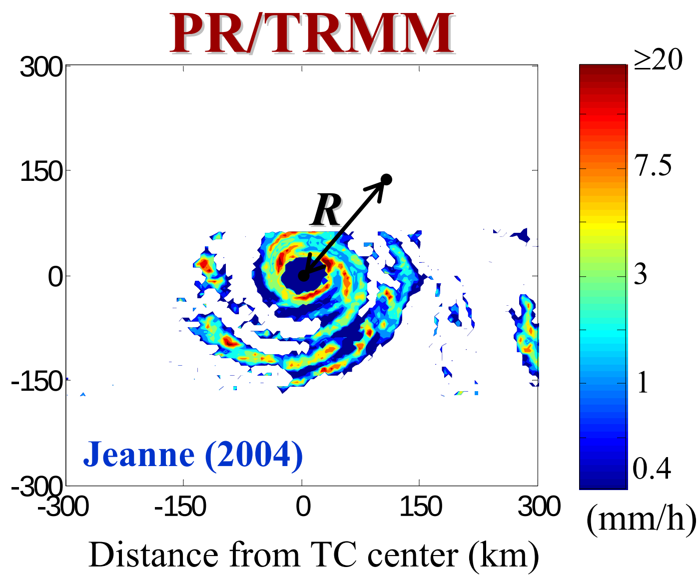
rainrate

moisture content of air

vertical wind speed



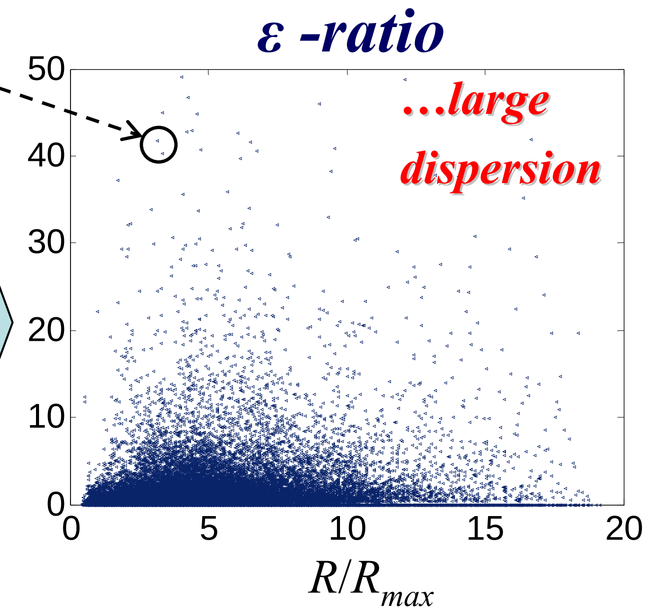
Validation using PR/TRMM data



$$\varepsilon = \frac{I_{PR}}{I_{model}}$$

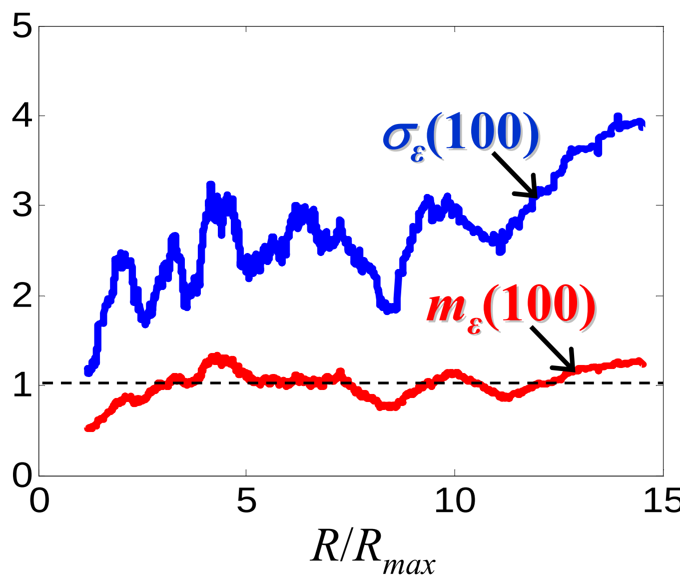
38 storms

48483 *points*

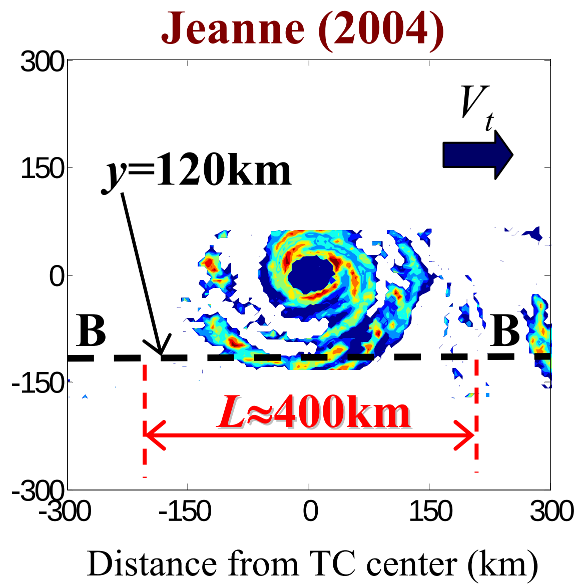


...model rainfall variability at different scales

...almost ***unbiased*** *estimation*



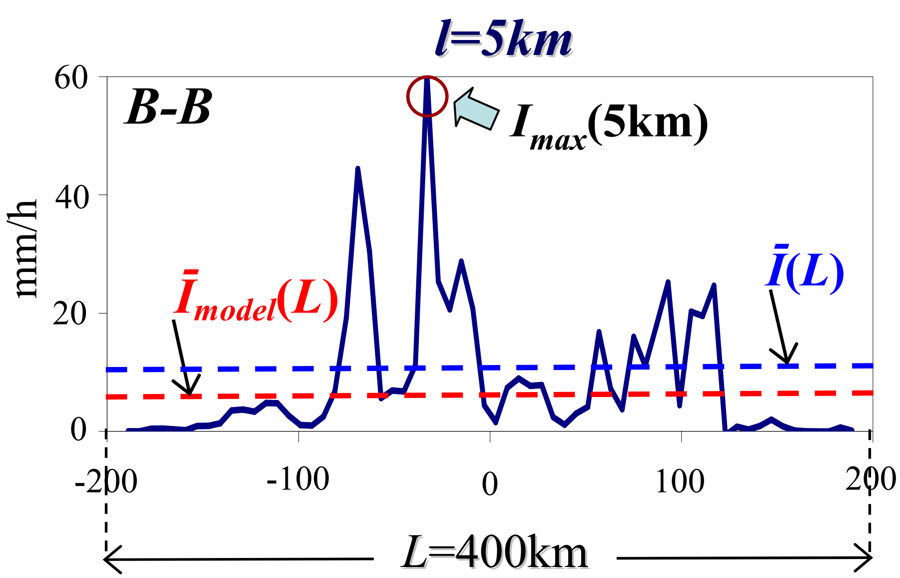
Statistical model of $[I_{max}(l)|\omega]$

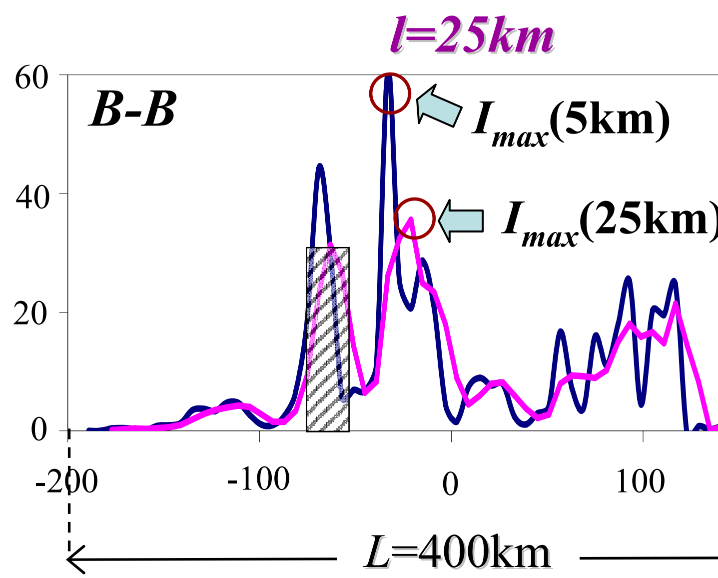


(large-scales) (small-scales)

$$I_{max}(l) = \underbrace{\bar{I}_{model}(L)\ \beta}_{\text{(large-scales)}}\ \underbrace{\gamma_{max}(l)}_{\text{(small-scales)}}$$

- $\bar{I}_{model}(L)$: ***model** estimate for the mean **rainfall intensity** inside **L***
- β: *corrects the **model** mean relative to the **empirical** mean*
- $\gamma_{max}(l)$: ***amplification factor** for the maximum inside l*





Statistical models for $[\beta|\omega]$ and $[\gamma_{max}(l)|\omega]$

Model for $[\beta\,|\omega]$

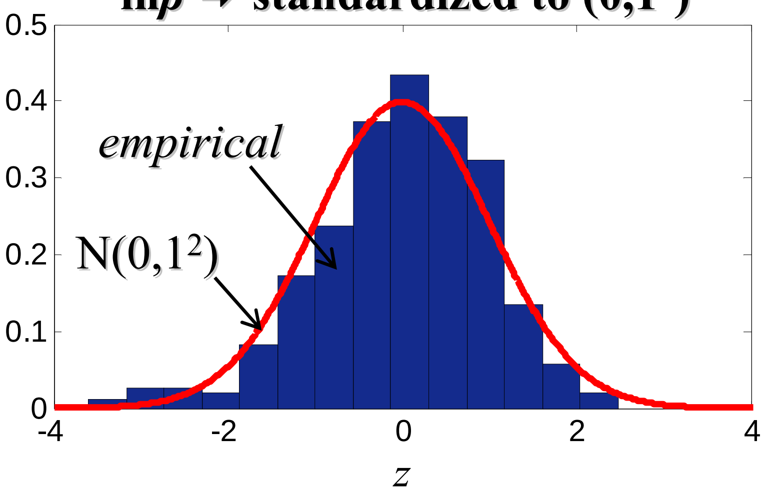
$$\beta = \frac{\bar{I}(L)}{\bar{I}_{model}(L)}$$

$\bar{I}(L)$ → ***empirical*** *mean inside L*

$\bar{I}_{model}(L)$ → ***model*** *estimate*

… $\beta\,(y, \bar{I}_{model}) \sim$ lognormal

lnβ ⇨ standardized to $(0,1^2)$

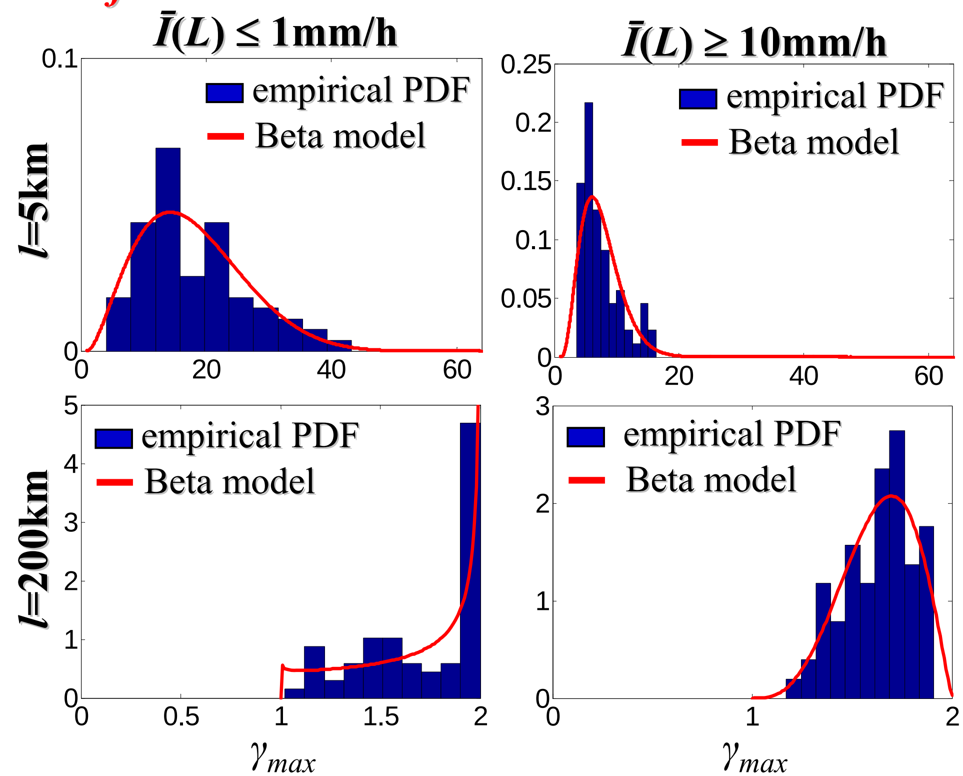


Model for $[\gamma_{max}(l)|\omega]$

$$\gamma_{max}(l) = \frac{I_{max}(l)}{\bar{I}(L)}$$

$I_{max}(l)$ → ***maximum*** *rainfall intensity at scale l*

$\gamma_{max}(l)$ → ***parameterize in terms of $\bar{I}$***



Application to New Orleans

➢ **Recurrence model for** $\omega = [V_{max}, R_{max}\ V_t, y]$

$[V_{max}|\Delta P]$ (m/s) ~ { **lognormal** with $m = 4.8\ \Delta P^{0.559}$, $\sigma = 0.15\ m$ (Willoughby and Rahn, 2004) }

$[R_{max}|\Delta P]$ (km) ~ { **lognormal** with $m = 3.962\text{-}0.00567\Delta P$, $\sigma = 0.313$ (Vickery *et al*., 2000) }

(ind.)

ΔP(mb) ~ { **shifted lognormal** with $m_{ln\Delta P} = 3.15$, $\sigma_{ln\Delta P} = 0.68$, *Shift par.* = 18mb (IPET, 2006) }

⇩

$P[V_{max}, R_{max}]$

⇩

V_t ~ { **LN with m = 6m/s & σ = 2.5m/s** (Vickery *et al*., 2000, Chen *et al*. 2006) } → $P[V_t]$

z ~ **U[-500km, 500km]**

α ~ **N[-5.4°,(34.9°)²]** (IPET, 2006)

(ind) ⇨ $y = -z\cos(\alpha)$ → $P[y]$

***Joint density P*[ω]**

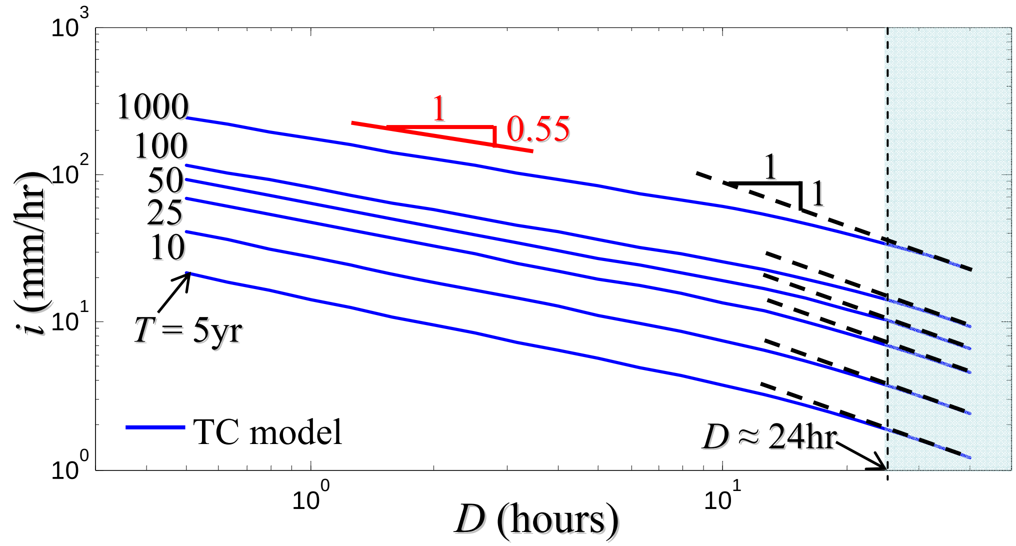
(assuming ind.)

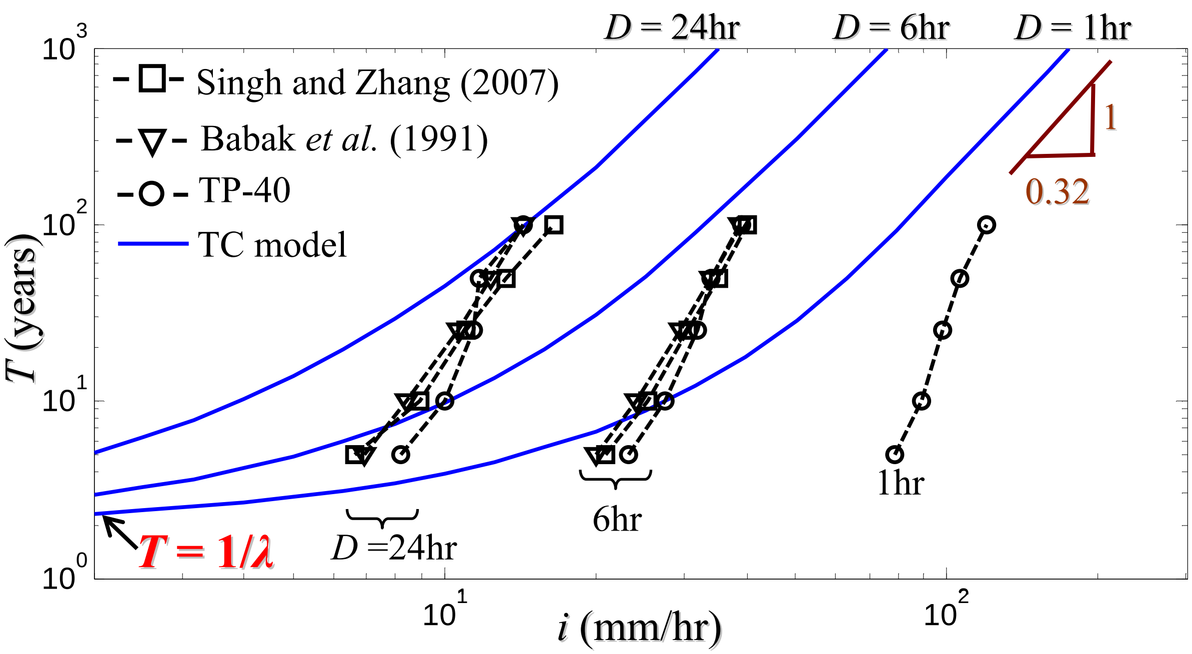
Application to New Orleans: IDF curves

Rainfall Risk and IDF curves:

$$\lambda_D(i) = \lambda \int_{\text{all } \omega} P[I_{max}(D) > i|\omega]\ P[\omega]d\omega$$

IDFs: *plots of i against **D** and* $T = 1/\lambda_D(i)$ (years)





- For ***large D*** and ***T*** TCs dominate risk.
- For ***small D*** applies the rule: *"convection is convection"*

Conclusions

➢ *We developed a* ***physical-statistical framework*** *for* ***peak TC rainfall intensities***

$[I_{max}(D)|\omega]$

- *Explicit parameterization of the hurricane:* $\omega=[V_{max}, R_{max}, V_t, y]$
- *Physical model to obtain* ***large-scale rainfall*** *given* **ω**

  (*inter*-storm variability)
- *Statistical model for* ***rainfall fluctuations***

  (*intra*-storm variability)

➢ *Model* ***validation*** *using PR/TRMM data*

➢ ***Application to New Orleans***

TCs dominate rainfall risk for
$D \geq$ **24h** and $T \geq$ **100 years**

Future work

- *effect of landfall and topography*
- *areal reduction*
- *TC wind maxima*