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

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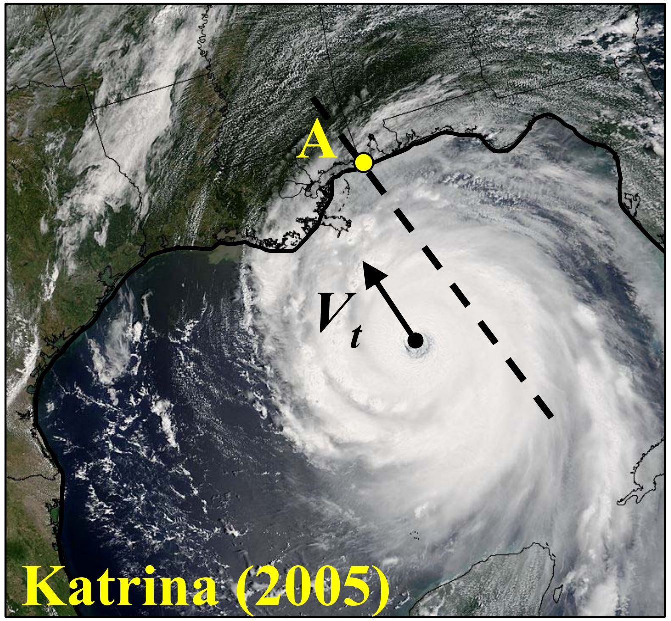
Objective

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

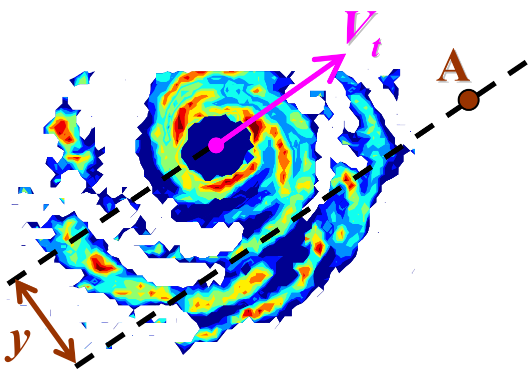
Risk analysis ⇨ $$\lambda_D(i) = \lambda \int_{\text{all } \omega} \underbrace{P[I_{max}(D) > i|\omega]}_{\textit{focus}} \underbrace{P[\omega]}_{\textit{local recurrence (literature)}} d\omega$$

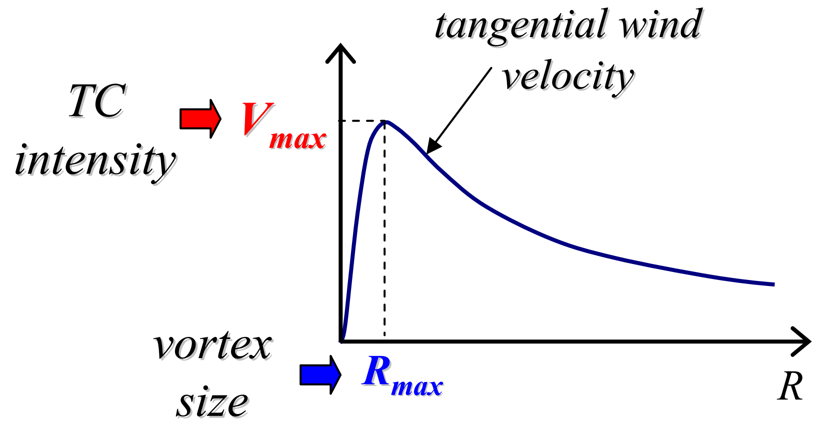
λ: *TC arrival rate* [events/yr]

$P[\omega]$: *TC characteristics*

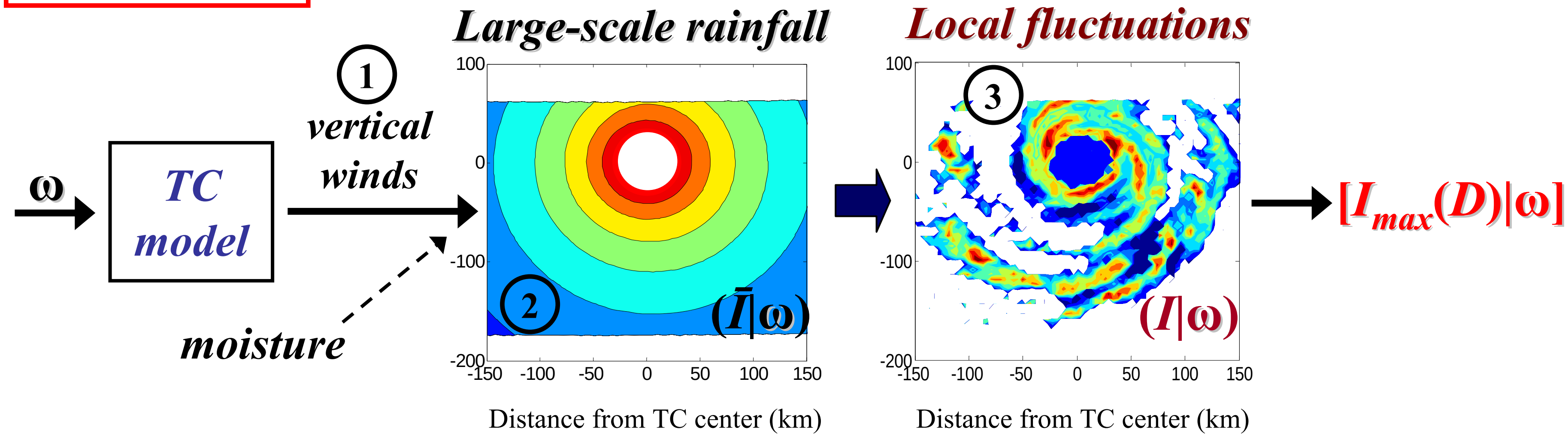
Implementation

- **<u>parameters</u>** $\omega = [V_{max}, R_{max}, V_t, y]$

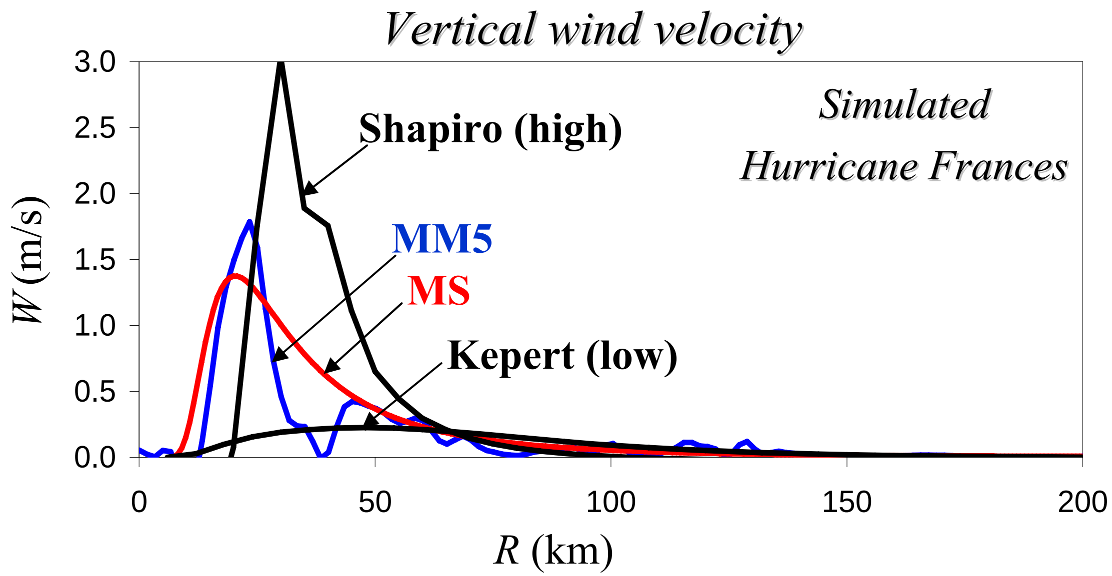




$[I_{max}(D)|\omega]$



TC Model: Vertical winds and Rain

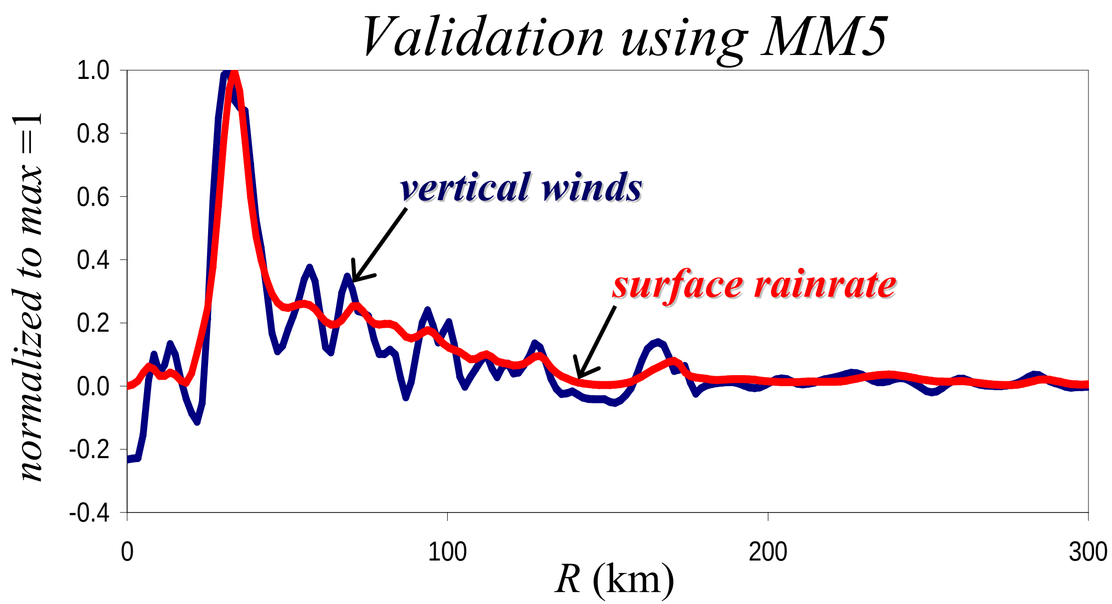


Vertical winds

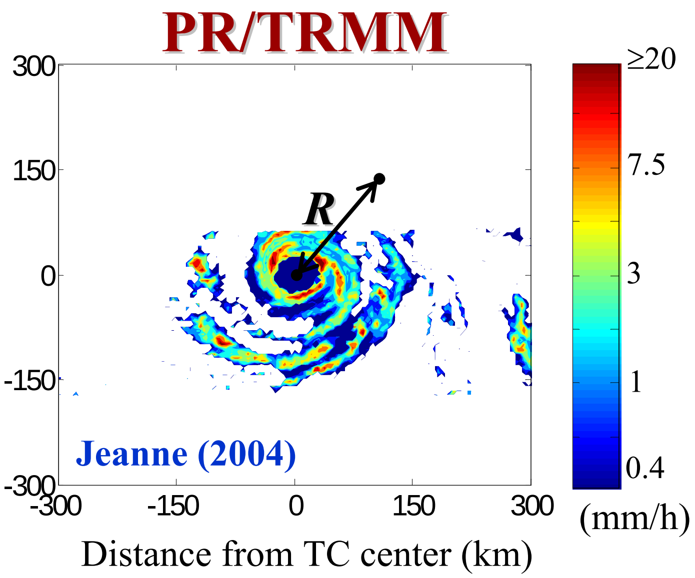
Rain:

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

rainrate ($\bar{I}$), *moisture content of air* (c), *vertical wind speed* (W)



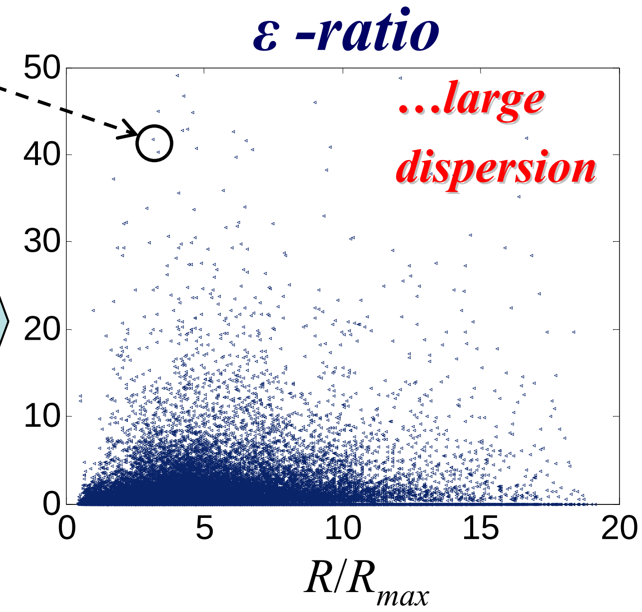
Validation using PR/TRMM data



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

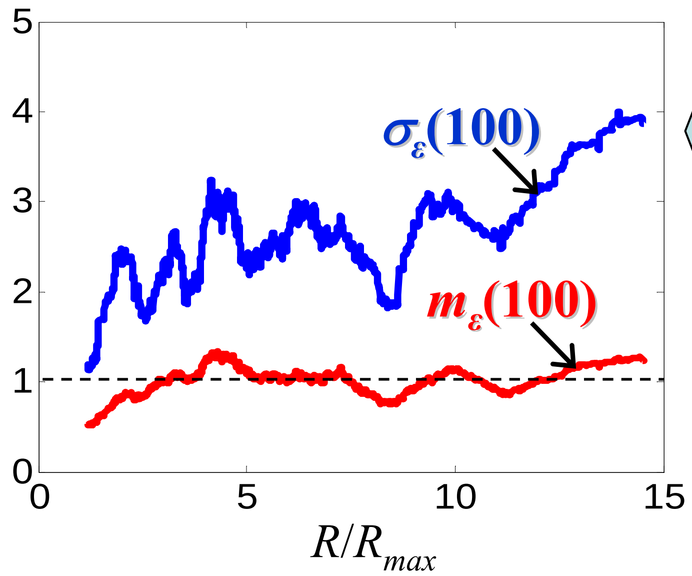
38 frames

48483 points

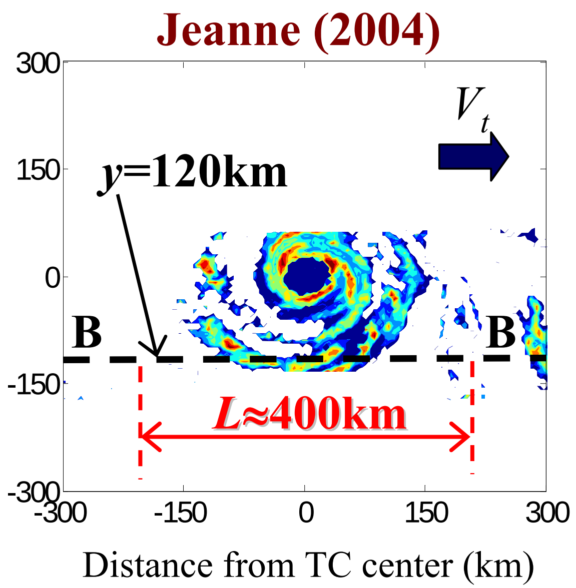


…model rainfall variability at different scales

…almost ***unbiased*** *estimation*



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



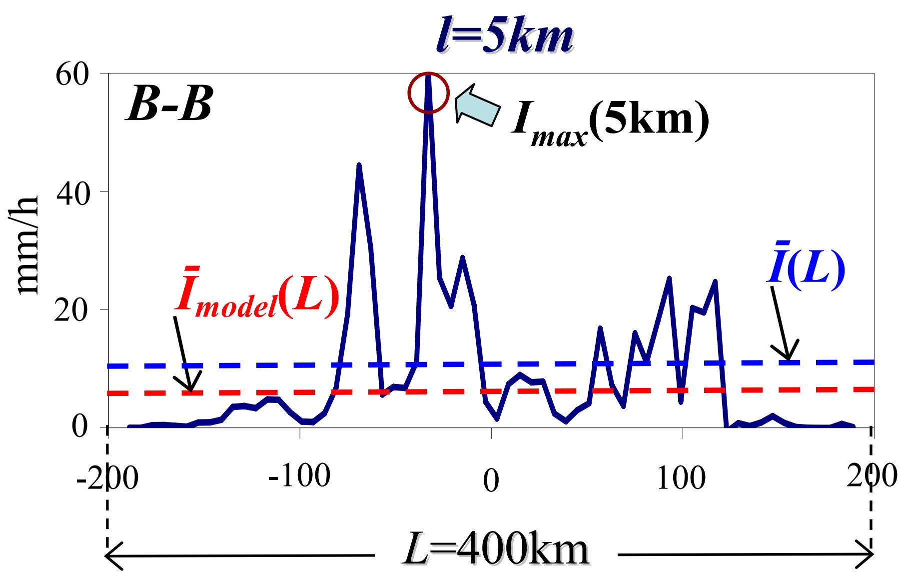
(large-scales) (small-scales)

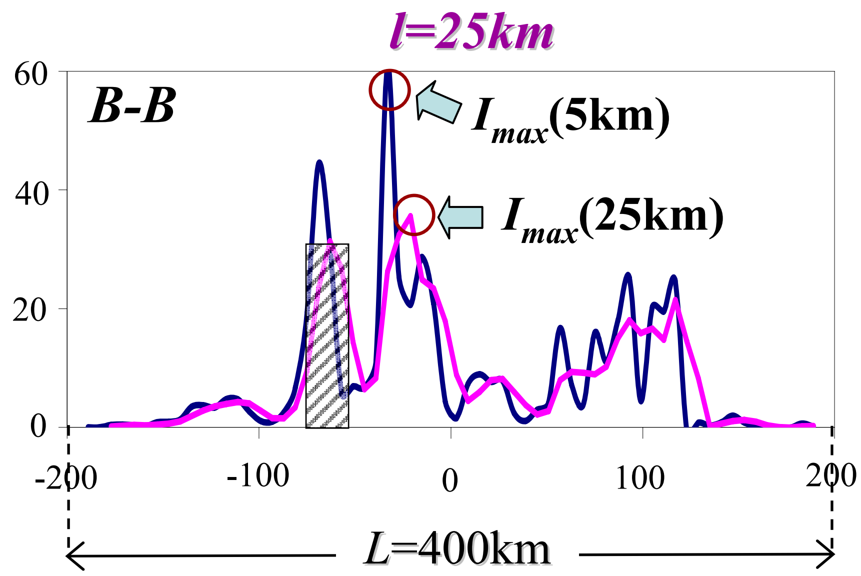
$$I_{max}(l) = \underbrace{\bar{I}_{model}(L)\ \beta}_{\text{(large-scales)}}\ \underbrace{\gamma_{max}(l)}_{\text{(small-scales)}}$$

model *estimate for the mean* ***rainfall intensity*** *inside* ***L***

corrects the ***model*** *mean relative to the* ***empirical*** *mean*

amplification factor *for the maximum inside l*





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

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

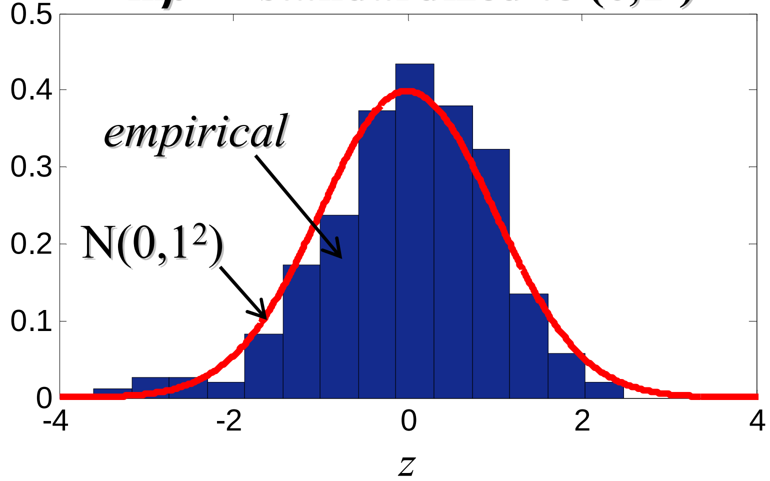
$$\beta = \frac{\bar{I}(L)}{\bar{I}_{model}(L)}$$

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

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

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

lnβ ⇨ standardized to $(0,1^2)$

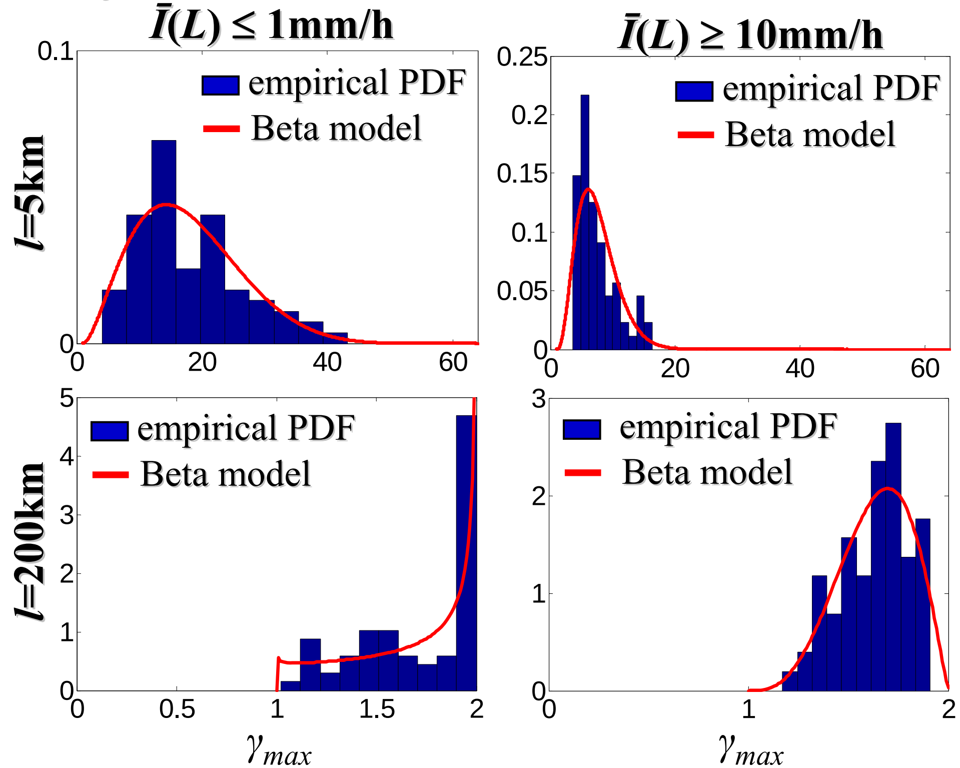


Model for $[\gamma_{max}(l)|\omega]$

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

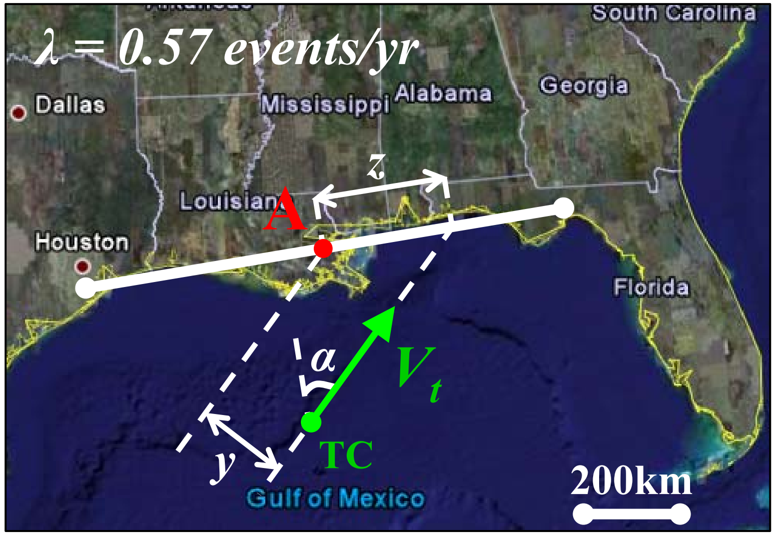
$I_{max}(l)$ → ***maximum*** *rainfall intensity at scale l*

$\gamma_{max}(l)$ → ***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[-5.4º,(34.9º)²]** (IPET, 2006)

(ind) ⇨ $y = -z\cos(\alpha)$

$P[y]$

Joint density $P[\omega]$

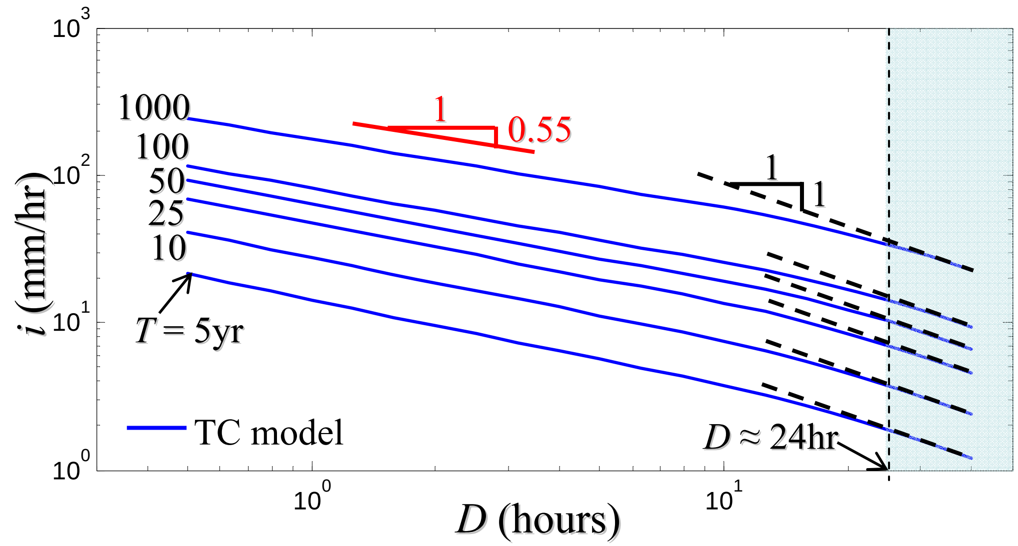
(assuming ind.)

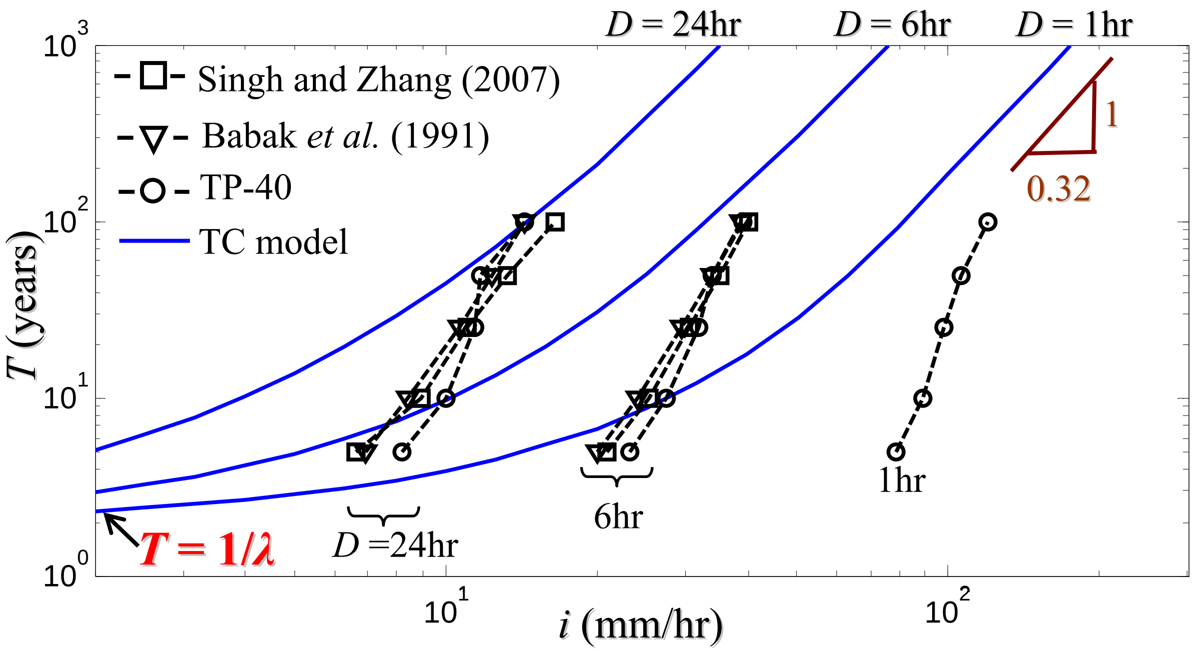
Application to New Orleans: IDF curves

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***

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

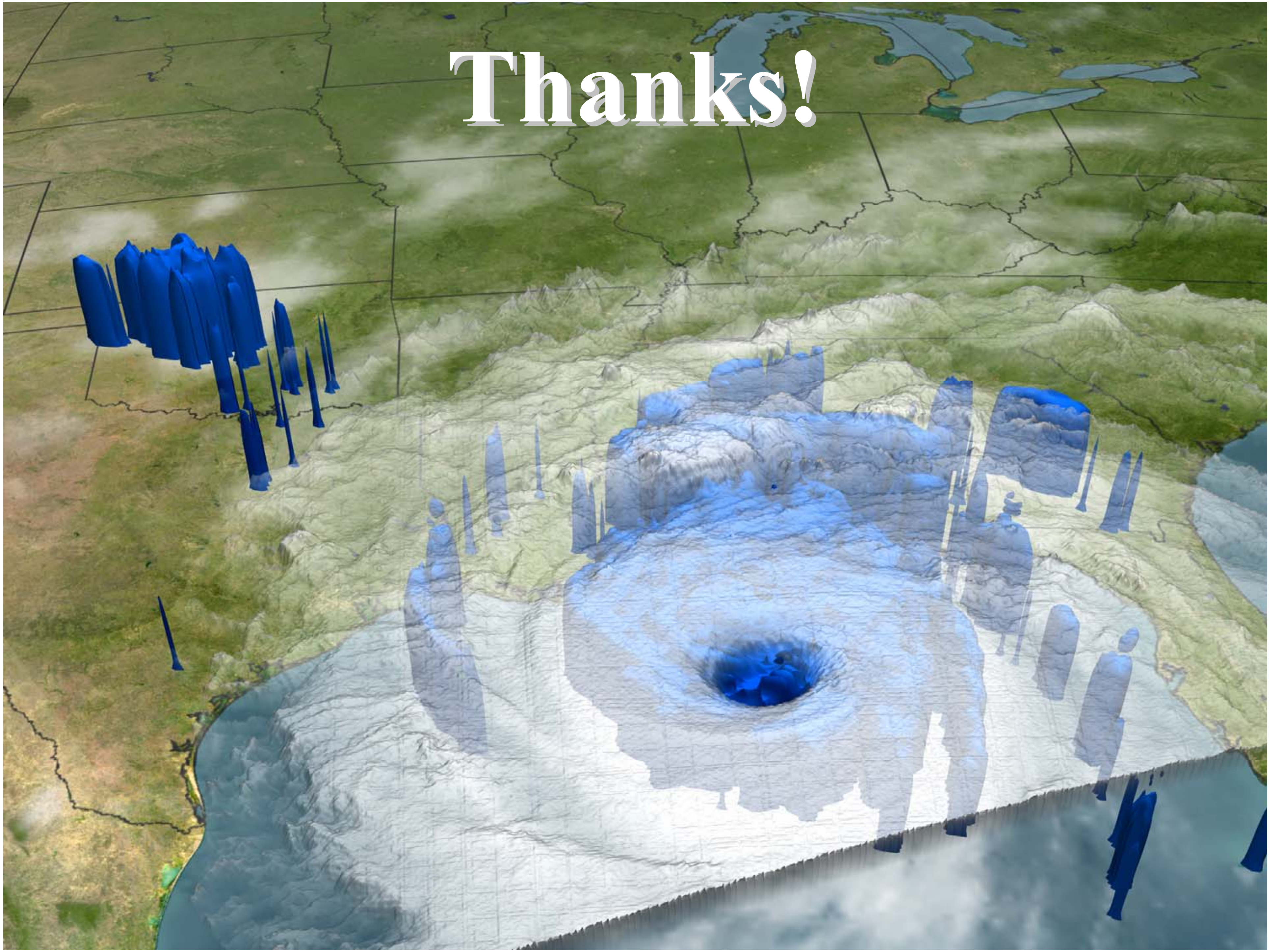
- *Explicit parameterization of the hurricane:* $\omega=[V_{max}, R_{max}, V_t, y]$
- *Physical model to obtain **large-scale rainfall** given* ω (*inter*-storm variability)
- *Statistical model for **rainfall fluctuations*** (*intra*-storm variability)

- *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*


Thanks!