Development of a Probabilistic Tropical Cyclone Rainfall Model

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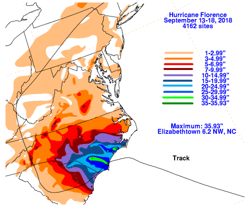
BACKGROUND: Heavy precipitation is a major hazard in landfalling tropical cyclones (TCs). Historically, heavy rainfall has induced freshwater floods and mudslides during TC landfalls, accounting for 27% of deaths and devastating property. Hence, improving current TC quantitative precipitation forecasts is indispensable. A new tropical cyclone rainfall probability model is described that provides five-day probabilistic forecasts of extreme rainfall accumulation above a selected threshold, e.g., 1", 3", 6", etc..



Florence (2018) – 35.9/26.6 inches N Carolina/S Carolina Record

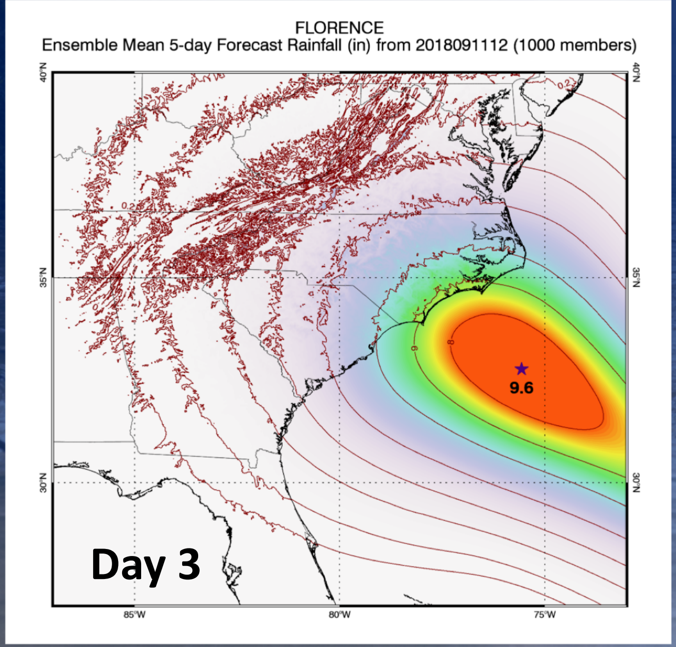
METHODS

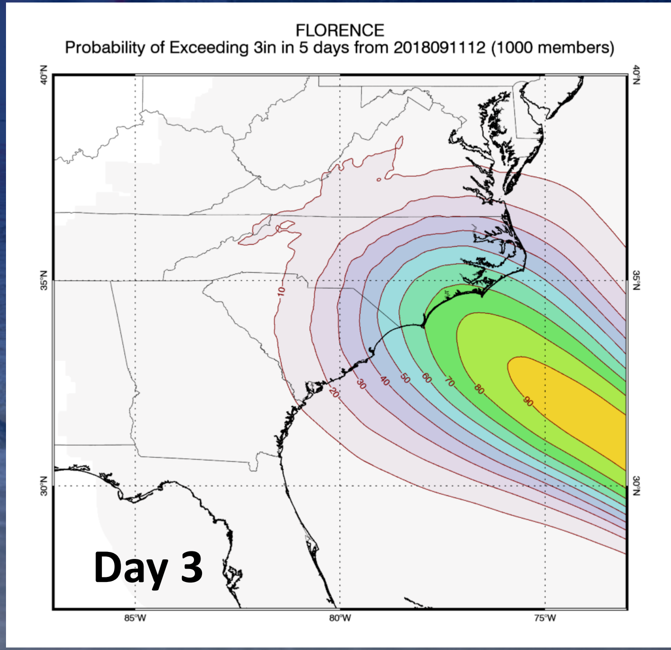
- **R-CLIPER**: Rainfall CLImatology & PERsistence
  - Marks & DeMaria (2003), Tuleya et al. (2007)
  - Accounts for intensity, size, speed, land, but not asymmetry or topography
  - Run experimentally at NHC 2001-2003, operationally since 2004
- **PHRaM**: Parametric Hurricane Rainfall Model
  - Lonfat et al. (2007)
  - Builds on R-CLIPER framework, but adds asymmetry and topography
  - Intensity and shear dependent parameterization of rainfall derived from TRMM data (Lonfat et al. 2004, Chen et al 2006)
- **Rainfall Probability**: Probabilistic PHRaM
  - Utilizes NHC's 1000-member Monte Carlo ensemble used for wind speed probabilities (DeMaria et al. 2009)
  - PHRaM is run on the 1000 members to get probabilistic information
  - Includes uncertainties in track, intensity, & size randomly selected from NHC error distributions over past 5 years
  - R_{max} values calculated using Knaff et al. (2015) empirical relationship which is function of V_{max}, & latitude
  - Computationally reasonable to run in real-time

RESULTS

- Ensemble-based products include:
  - Ensemble mean,
  - Probability of exceeding a fixed amount
  - Probability of exceeding deterministic forecast by some amount,
  - Area with % chance of exceeding deterministic forecast

A new **probabilistic TC Rain Model** produces the **probability of rain exceeding** certain accumulation **thresholds** over a 5-day forecast.





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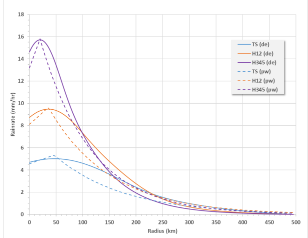
R-CLIPER

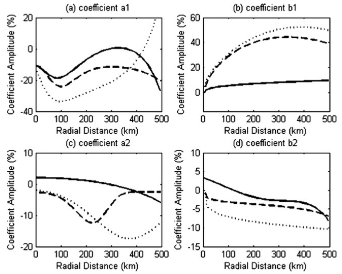


- Rain rate scales continuously with intensity, $V_{max} \geq$ 35kt, $R_{max} \leq$ 100km

PHRaM

$$R_{\text{PHRaM}} = R_{\text{R-CLIPER}} + R_{\text{shear mod}} + R_{\text{topography}},$$

$$R_{\text{shear mod}}(r, \theta) = \sum a_i(r)\cos(i\theta) + \sum b_i(r)\sin(i\theta),$$



$$R_{\text{topography}} = c\mathbf{V}_s \cdot \nabla h_s,$$

- c constant of proportionality, V_s 10 m wind field, & h_s is elevation. Use Willoughby et al. (2006) wind model

$$V(r) = V_{\max}\left(\frac{r}{R_{\max}}\right)^n, \quad (0 \leq r \leq R_{\max}),$$

$$V(r) = V_{\max}\exp\left(-\frac{r - R_{\max}}{X_1}\right), \quad (R_{\max} \leq r),$$

- *n* is exponent for power law inside R_{max} (=1), X_1 is an exponential decay length in outer vortex (=250 km).
- Wind field reduced to 10-m by taking 85% of estimates
- Inflow angle is not accounted for

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