Precipitation Intensity-Duration-Frequency Analysis in the Face of Climate Change and Uncertainty

Supporting Casco Bay Region Climate Change Adaptation RRAP

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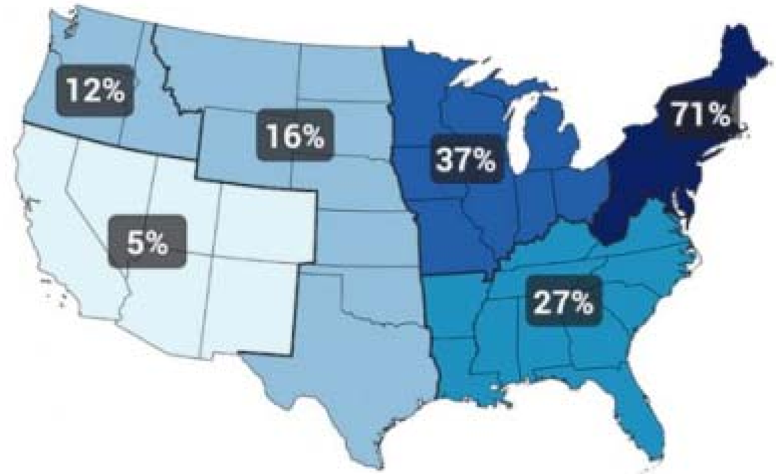
Need to Update IDF Curve Development

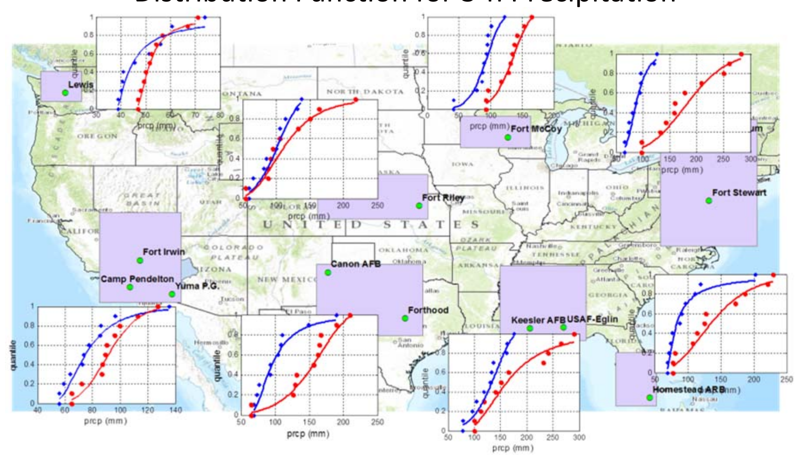
- Challenges in quantifying extreme events
  - The most extreme precipitation events (or heaviest 1% of all daily events) have increased in every region of the contiguous states since the 1950s
  - Climate change projections suggest increased likelihood of extreme precipitation events
  - Uncertainty in quantifying extreme events
- Regional resilience assessment requires improved understanding of:
  - Non-uniform spatial and temporal distribution of potential climate-induced changes in intensity and variability of extreme events
  - Adaptation responses to these changes
  - Uncertainty, source of uncertainty, and associated risks
- Cities/regions need this information to inform design of precipitation-affected infrastructure

Observed change in heavy precipitation from 1958 to 2012



Source: National Climate Assessment Report, 2014

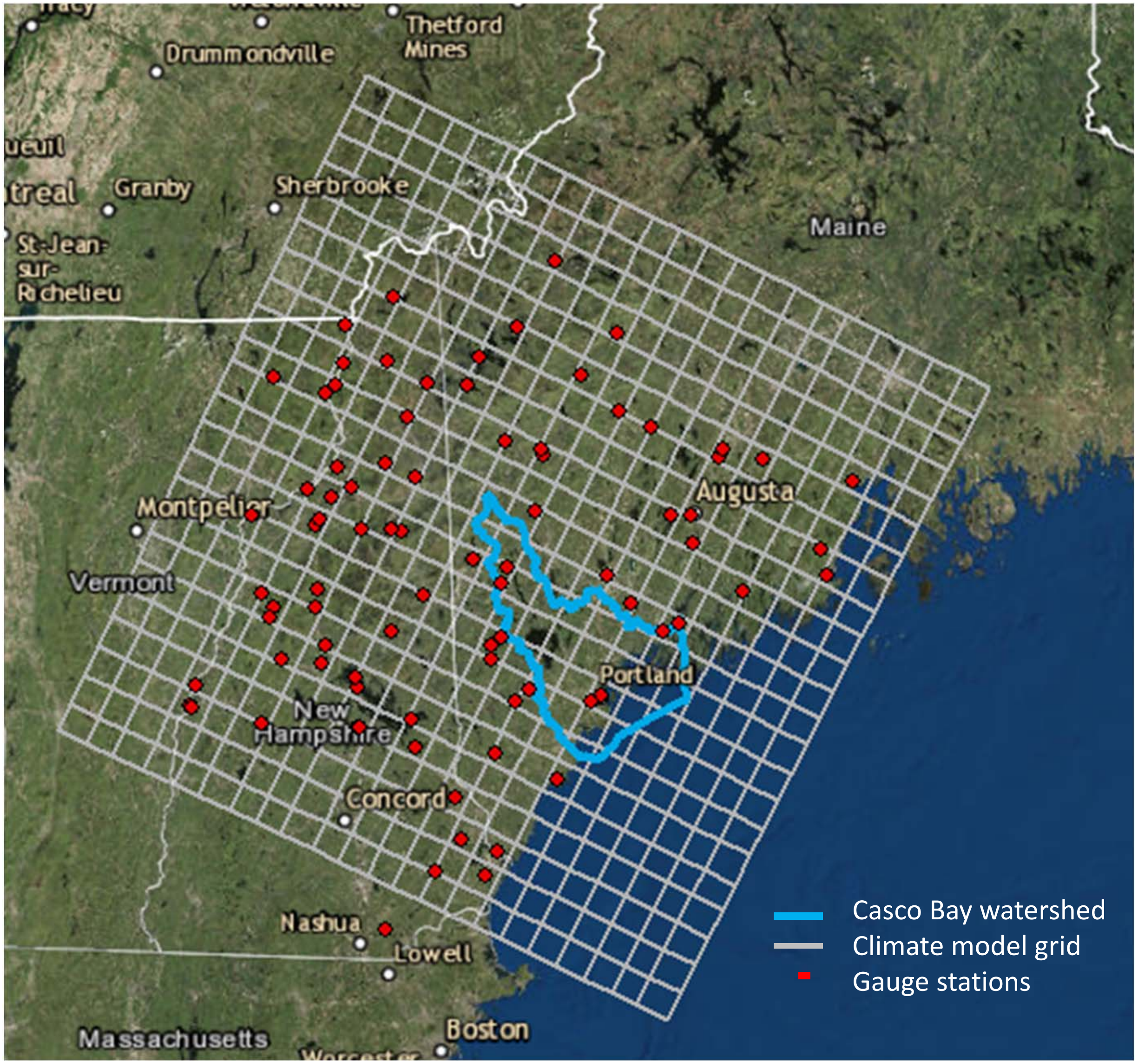
Historical (blue) and Forecasted (red) Cumulative Distribution Function for 3-h Precipitation



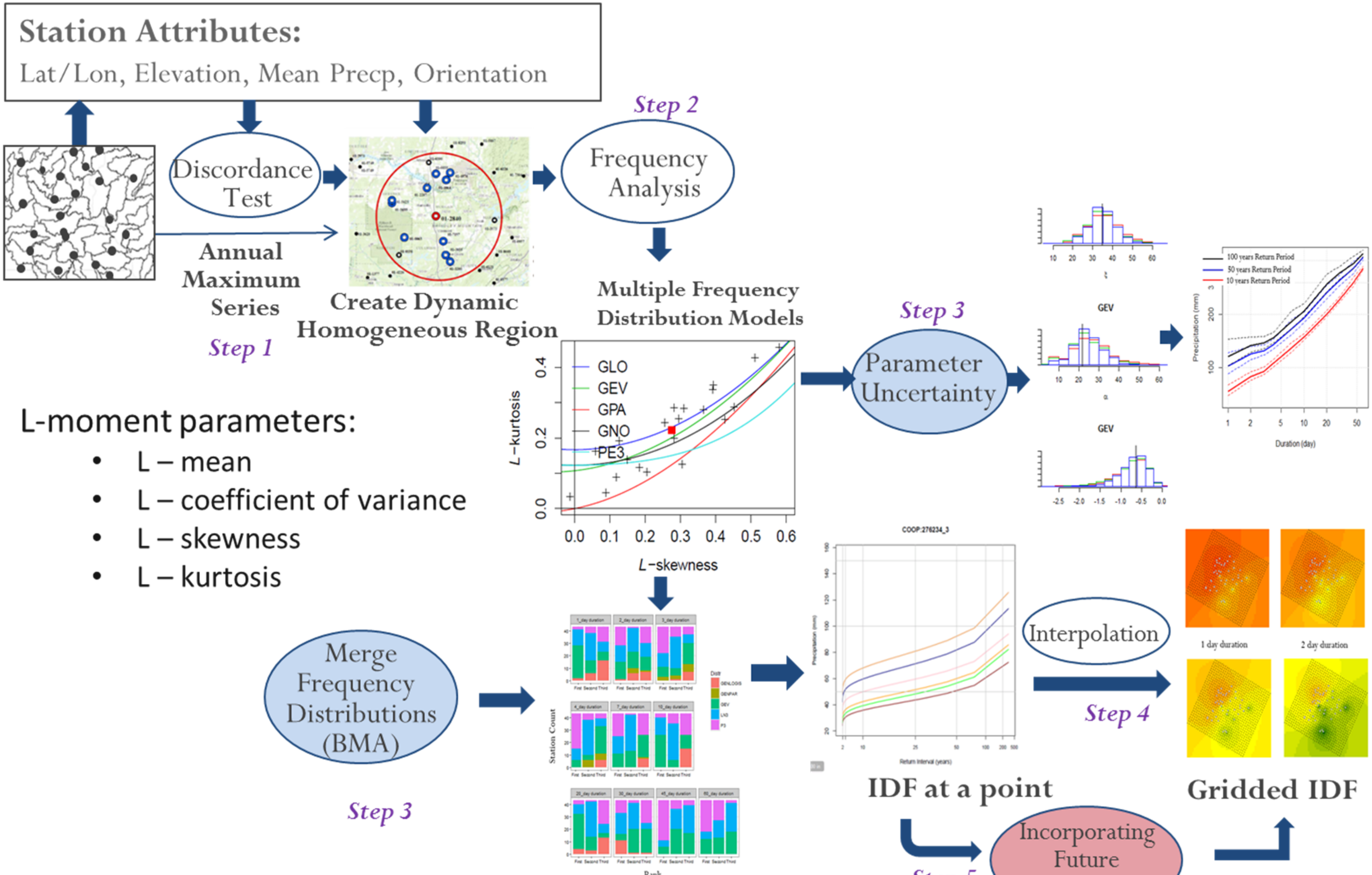
Source: Argonne National Laboratory

Casco Bay Region

- Casco Bay watershed
  - City of Portland located downstream of the watershed
  - Recent flooding in 2007 impacted by both stream flow and costal storm
- Data sources:
  - Precipitation records from 85 daily rain gages and 15 hourly gages from NOAA
  - Precipitation projections (shown as grid) extracted from regional climate modeling results by Argonne using WRF (1965-2004; 2035-2065)



Processes for IDF Development

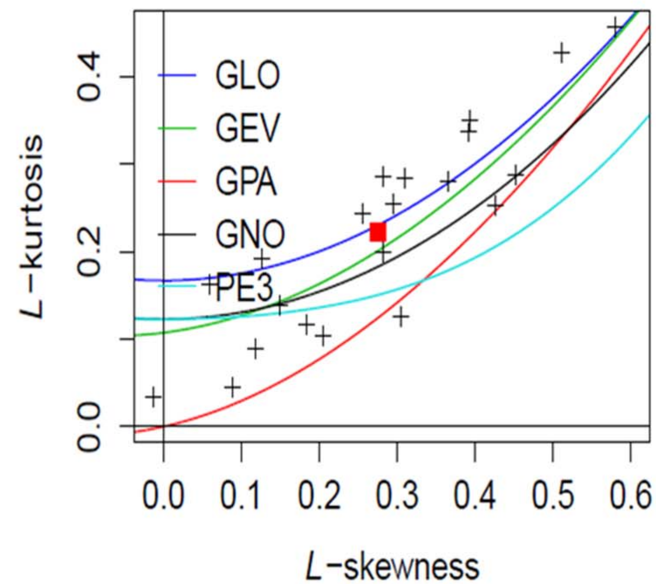


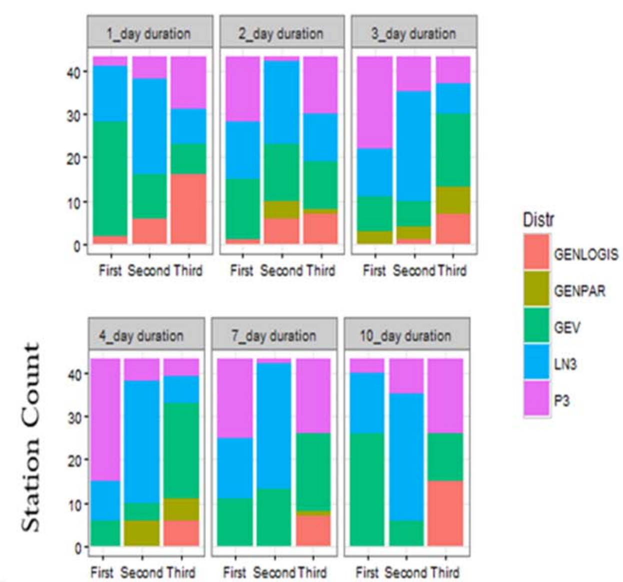
L-moment parameters:

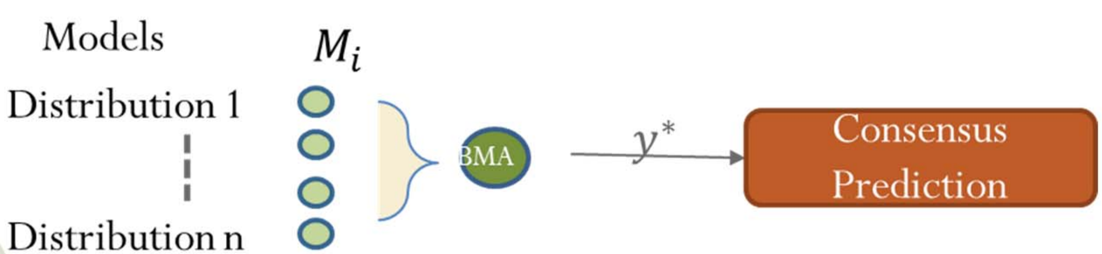
- L – mean
- L – coefficient of variance
- L – skewness
- L – kurtosis

Model Selection and Uncertainty

- Distribution model
  - Five distributions considered
  - Ranked by goodness-of-fit measure using L-skewness and L-kurtosis
- Model uncertainty
  - Wide range of preferred distribution models for each of 10 durations in Casco Bay region
  - Best model could not be confidently identified
- Bayesian model averaging (BMA) method
  - Combine a number of plausible models together through weighting
  - Derive the weights from models' posterior performances
  - provides deterministic forecast with the associated forecast distribution

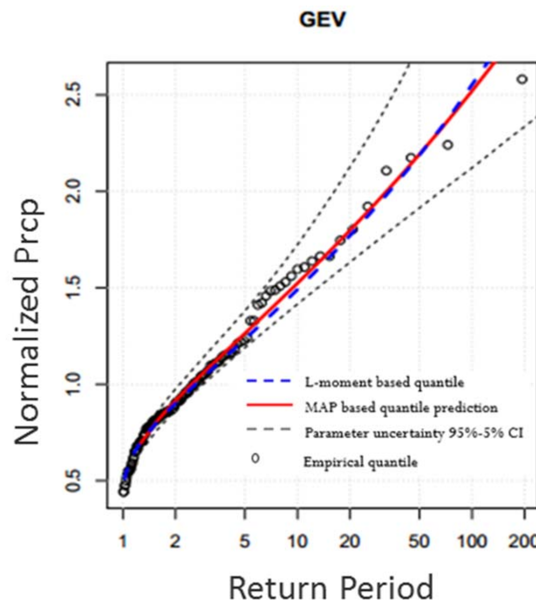


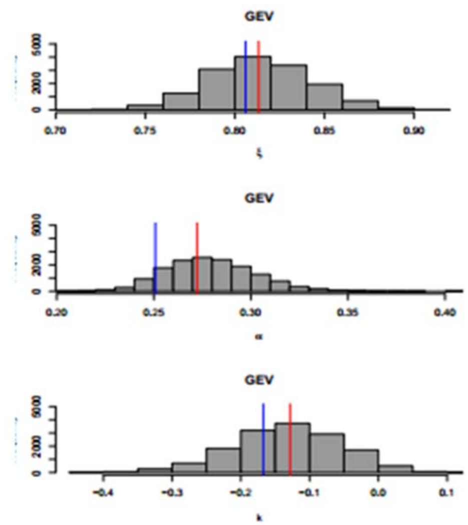




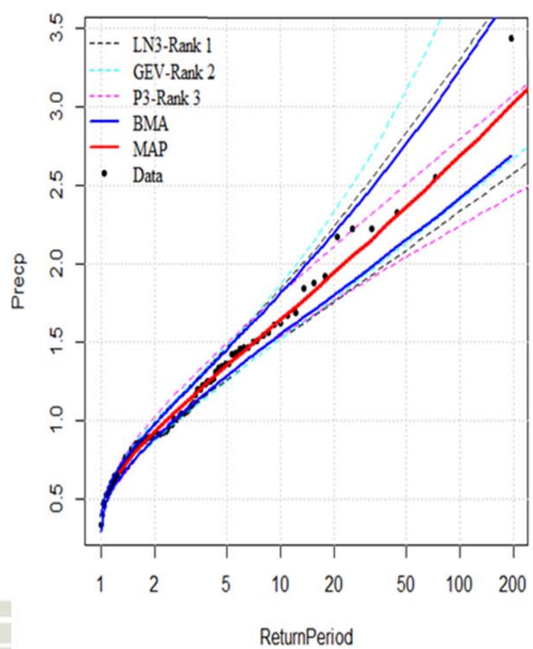
Identification of Parameter Uncertainties

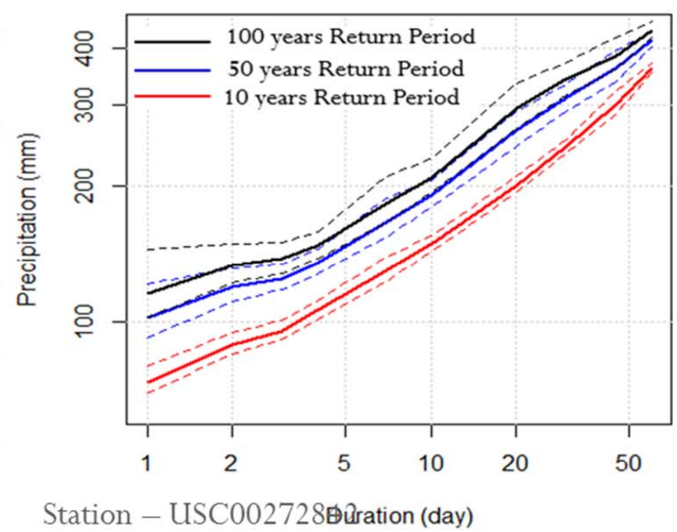
- Bayesian approach
  - Sample the entire parameter posterior distribution
  - Determine distribution parameters (location, scale, and shape) using MAP vs. L-moment estimates
  - Provide uncertainty band (95% - 5%) based on parameter posterior distribution
- Predictive uncertainty
  - Incorporate both parameter and model uncertainties
  - Reduced predictive uncertainty under BMA
  - Uncertainty implication – risk probability





USC00172238 duration of 2 days

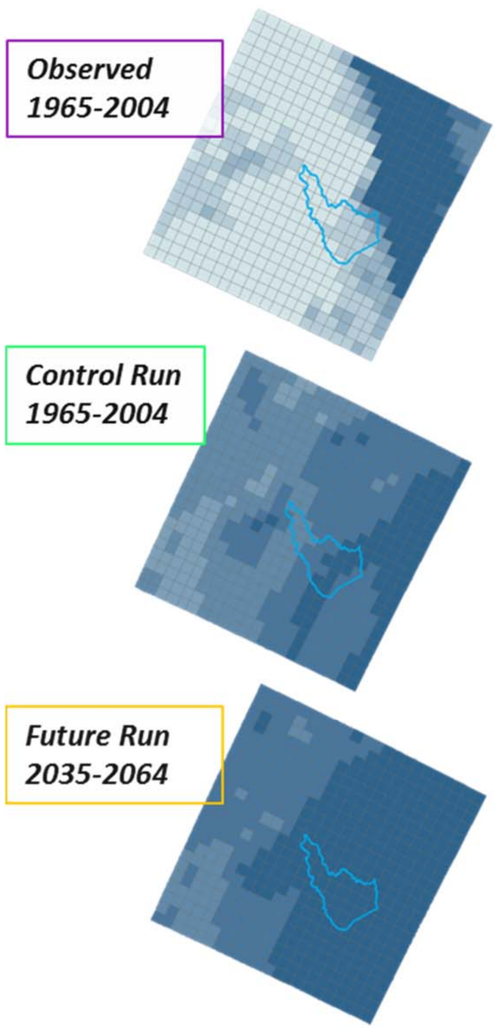




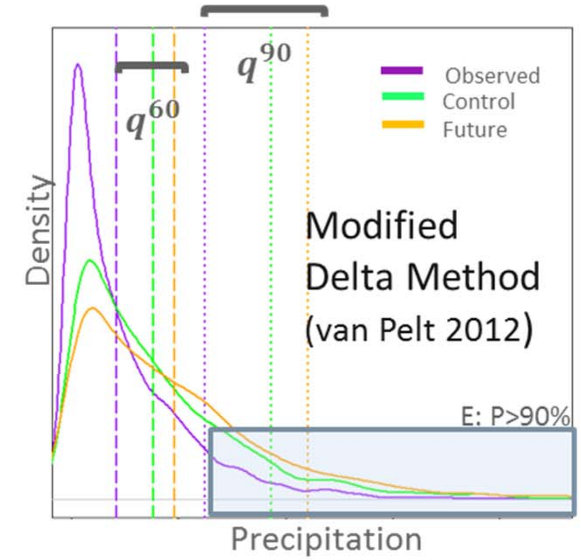
Station – USC002728

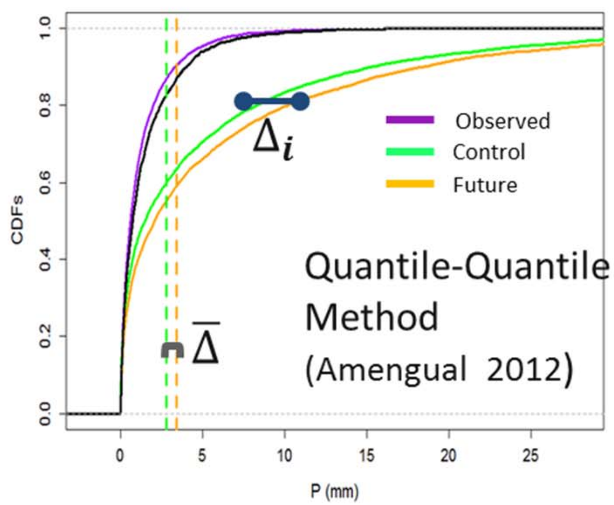
Incorporating Future Projections in IDF

1. DATA



2. TRANSFORMATION FACTORS





3. TRANSFORMED DATA

(A) Apply changes in the means:

$$for\ P_{obs} < q^{90}_{obs} : \quad P_{trans} = \alpha P_{obs}{}^{\beta}$$

(B) Apply changes in the extremes:

$$for\ P_{obs} > q^{90}_{obs} :$$

$$P_{trans} = \frac{E_{fut}}{E_{control}} * (P_{obs} - q^{90}_{obs}) + \alpha (q^{90}_{obs})^{\beta}$$

(C) Transformed observation data including future signal

Apply quantile factors:

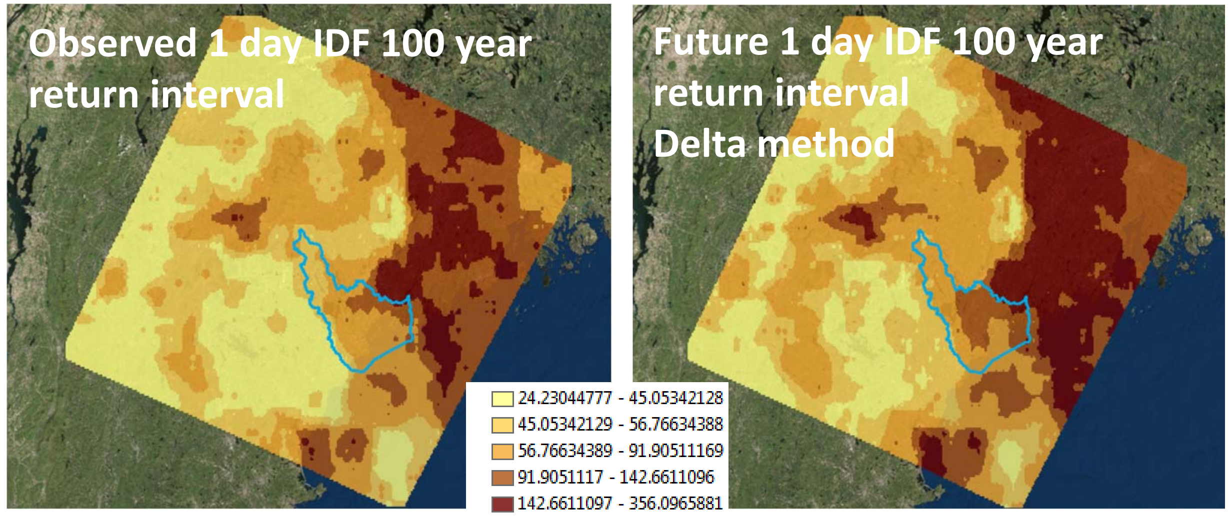
$$P_{trans} = P_{obs} + g\bar{\Delta} + f(\Delta_i - \bar{\Delta})$$

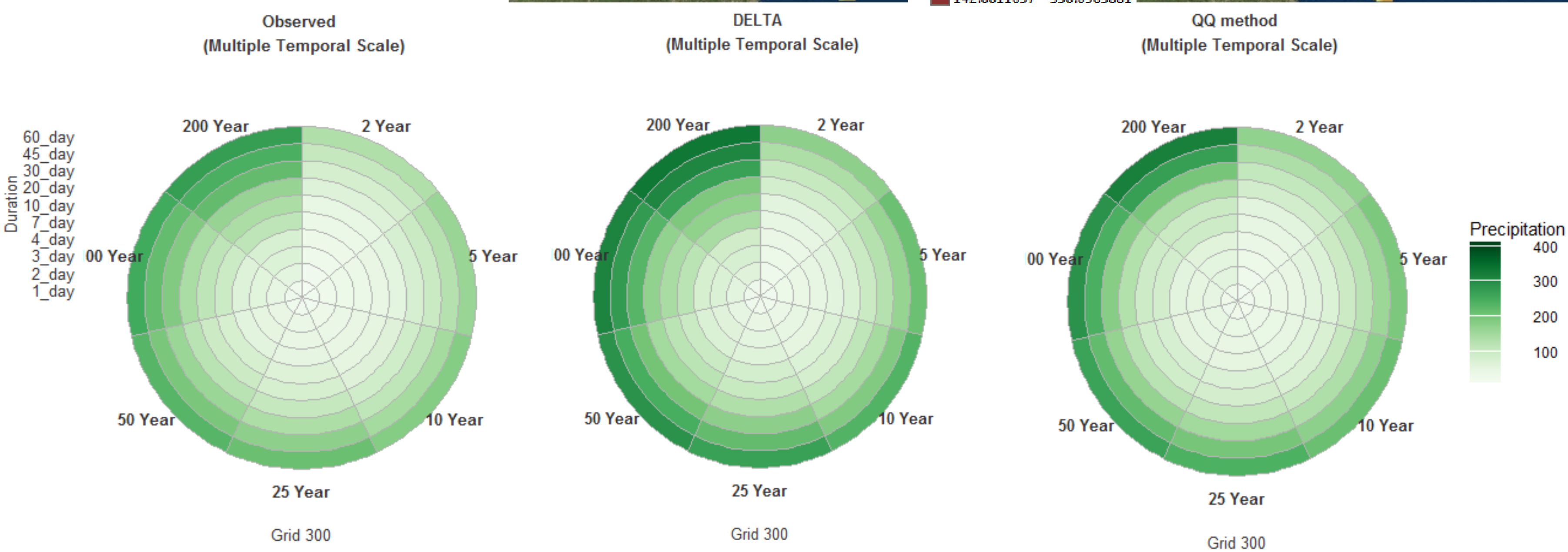
g – mean adjustment
f – scale adjustment

Remove difference between controlled and observed quantile

Results of IDF Analysis Incorporating Future Projections

- Increased intensity for all durations and return period events
- More increase in high return-period events
- Spatial variations in change of IDF





Future Work

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- Identify and incorporate uncertainties from regional climate models
- Develop Runoff IDF for Casco Bay region
- Explore feasibility to include radar data in development of sub-daily IDF and improve the quality of sub-daily IDF due to vary limited number of hourly rain gage stations.

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