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

Supporting Casco Bay Region Climate Change Adaptation RRAP

Eugene Yan, Alissa Jared, Edom Moges
Environmental Sciences Division
Argonne National Laboratory
July 28, 2016
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

Source: National Climate Assessment Report, 2014
Casco Bay Region

- Casco Bay watershed
  - City of Portland located downstream of the watershed
  - Recent flooding in 2007 impacted by both stream flow and coastal 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

Station Attributes:
- Lat/Lon, Elevation, Mean Precip, Orientation

Step 1
Annual Maximum Series

Step 2
Discordance Test
Create Dynamic Homogeneous Region
Frequency Analysis

Step 3
Multiple Frequency Distribution Models
Parameter Uncertainty

Step 4
Interpolation
IDF at a point

Step 5
Gridded IDF
Incorporating Future Projections

L-moment parameters:
- L – mean
- L – coefficient of variance
- L – skewness
- L – kurtosis

Merge Frequency Distributions (BMA)
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
Incorporating Future Projections in IDF

1. DATA

- Observed 1965-2004
- Control Run 1965-2004
- Future Run 2035-2064

2. TRANSFORMATION FACTORS

- Modified Delta Method (van Pelt 2012)

3. TRANSFORMED DATA

A. Apply changes in the means:
   \[ P_{trans} = \alpha P_{obs}^\beta \]
   for \( P_{obs} < q_{obs}^{90} \)

B. Apply changes in the extremes:
   \[ P_{trans} = \frac{E_{fut}}{E_{control}} \times (P_{obs} - q_{obs}^{90}) + \alpha (q_{obs}^{90})^\beta \]
   for \( P_{obs} > q_{obs}^{90} \)

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

- 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.

Acknowledgements

- Work is sponsored by Department of Homeland Security Regional Resiliency Assessment Program
- Argonne National Laboratory
  - Duane Verner
  - Scott Collis
  - Thomas Walls
  - Bob Johnson
- Washington State University
  - Yonas Demissie

Contact: Eugene Yan
eyan@anl.gov