Impact of Non-Stationary Climate Conditions on Extreme Precipitation Frequency Estimates Needed for Engineering Design

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Hydrometeorological Design Study Center (HDSC)


- Main HDSC responsibility: preparing national standards and updating Precipitation Frequency (PF) estimates for various parts of the USA and affiliated territories.

- Since 2004, updates are published online as Volumes of NOAA Atlas 14: hdsc.nws.noaa.gov/hdsc/pfds/index.htm
Where is NOAA Atlas 14 used?

- To estimate severity of real or forecasted storm events

- Infrastructure design
  - Control of water: flood mitigation, land development and construction, storm water drainage (roads, parking lots, airports, land, roofs), culverts, bridges,...
  - Utilization of water for beneficial purposes: water supply, irrigation, navigation, hydroelectric-power development, ...
  - Water-quality management, etc.
Where to get NOAA Atlas 14 estimates?

FOR A SELECTED LOCATION:

**DDF curves**

**Frequency**

**Depth (Intensity)** for a given

**Duration** associated with specific **Frequency**
Current NOAA Atlas 14 process

**Approach:** Region-of-influence regional frequency analysis approach based on GEV distribution with parameters calculated based on L-moment statistics from annual maximum series (AMS).

**Main steps:**
- Annual maximum series (AMS) extraction and QC (durations: 15 min - 60 days)
- Regionalization
- Calculation of regional L-moments and distribution fitting (based on AMS stationarity assumption)
- Derivation of DDF curves and confidence limits
- Interpolation to 30 arc-sec grid
Current trend testing on NOAA Atlas 14

REGIONAL ANALYSIS:
Testing $H_0$: no serial correlation at 5% level in normalized AMS regressed against time

AT-STATION ANALYSIS:
1. Applying parametric and non-parametric statistical tests for trends in AMS mean and variance
2. Investigating spatial patterns in tests’ results

If statistical tests indicate positive trends in AMS (PDS) in less than 10-20% of randomly scattered stations, should we still try to account for non-stationary climate effects at stations where tests indicate trends?

Background  Current NA14  Non-stationary NA14  Preliminary Results  Collaboration
Accounting for non-stationary climate in NA14 requires:

- **Change in distribution parameterization**
  - Replacing L-moment approach with Maximum likelihood approach

- **Change in time series used in frequency analysis**
  - Replacing AMS with PDS (AMS-based analysis not sensitive to changes in frequency of heavy precipitation events)

Hypothetical example:

- No difference in AMS
- No difference in DDF

AMS vs PDS

- PDS threshold

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**Background**

**Current NA14**

**Non-stationary NA14**

**Preliminary Results**

**Collaboration**
In 2015, Federal Highway Administration (FHWA) tasked HDSC to conduct a pilot project on effects of non-stationary climate on NOAA Atlas 14 precipitation frequency estimates.

A pilot project looked at the effects of change in methodology on estimates.

Preliminary findings are inconclusive (see next pages)

As a result of this project, HDSC and FHWA expanded the project into the collaborative effort between the federal government and academia.
Pilot project’s preliminary findings

- **Change in methodology vs. inclusion/exclusion of non-stationarity**
  a) Difference due to methodology change

<table>
<thead>
<tr>
<th>Methodology</th>
<th>LMOM (in)</th>
<th>MLE (in)</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15.0</td>
<td>20.0</td>
<td><strong>33%</strong></td>
</tr>
</tbody>
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b) Difference due to inclusion of non-stationarity

<table>
<thead>
<tr>
<th>Time Period</th>
<th>MLE (in)</th>
<th>MLE(t) (in)</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20.0</td>
<td>20.7</td>
<td><strong>4%</strong></td>
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c) Difference in 24-hr 100-yr estimate

<table>
<thead>
<tr>
<th>Methodology</th>
<th>LMOM (in)</th>
<th>MLE(t) (in)</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15.0</td>
<td>20.7</td>
<td><strong>38%</strong></td>
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- **Selection of non-stationary model**

Need to ensure we are not doing more harm than good!
Selection of the start of record period, the end of extrapolation time period, and the forecast of the future trend may significantly affect estimates

- What period of record to use in the analysis?
- How much extrapolation (to account for a design lifetime) is reasonable?
- Should we assume that the trend from the past will continue into the future or infer the future trend from climate projections?
Collaborative effort with academia on enhancing NA14 methods/products to account for non-stationary climate

- **TASK 1: Development of non-stationary methods**
  In 2016, HDSC partnered with the Penn State University (Dr. Benjamin Shaby, Gregory Bopp)

- **TASK 2: Using information from projected climate outlooks**
  HDSC is partnering with the University of Illinois, Urbana-Champaign/Illinois State Water Survey (Dr. Momcilo Markus, Dr. James Angel)
THANK YOU!

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