Changes in Heavy Rainstorm Characteristics with Time and Temperature - PRESENTATION

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CHANGES IN HEAVY RAINSTORM CHARACTERISTICS WITH TIME AND TEMPERATURE
INTRODUCTION

• Consensus that frequency of high intensity extreme rainfall events will rise with warming induced by increasing GHG

• Wide variety of measures of rainfall; accumulation measured over moving windows, both measured and modeled

• We use an individual event definition, so as to measure storm depth, $V$, storm duration $T$, and peak intensity $I_p$
STORM EVENT DEFINITION AND ANALYSIS

• Application of threshold excess techniques to examination of climate change impacts upon extreme rainstorms:
  • Hourly-archived rainfall data is divided into individual storm events:
    – Minimum time interval of 6 hours between hourly accumulations; this is known as the Inter-Event Time Definition (IETD)
    – For each event, storm depth, duration and peak-hour accumulation are identified
Storm Event Definition

- IET < 6 hr
- IET ≥ 6 hr
- $t_1$, $t_2$
# Rainfall Data

<table>
<thead>
<tr>
<th>Description</th>
<th>Springfield</th>
<th>Peoria</th>
<th>O’Hare</th>
<th>Pearson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name/Sta. ID</td>
<td>IL8719</td>
<td>IL6711</td>
<td>IL1549</td>
<td>6158733</td>
</tr>
<tr>
<td>Latitude, degrees N</td>
<td>39.848°</td>
<td>40.668°</td>
<td>41.995°</td>
<td>43.677°</td>
</tr>
<tr>
<td>Longitude, degrees W</td>
<td>89.664°</td>
<td>89.684°</td>
<td>87.934°</td>
<td>79.631°</td>
</tr>
<tr>
<td>Total no. rainstorms, $m$</td>
<td>4567</td>
<td>4615</td>
<td>3777</td>
<td>3172</td>
</tr>
</tbody>
</table>
STORM EVENT DEFINITION AND ANALYSIS

- Storms with a depth exceeding a threshold value are chosen for analysis, with storm duration, $T \leq 24$ hrs
  - The threshold, $u_v \leq V$, is chosen so that on average, about 4 events per year are selected
  - Storm depth and duration $(v, t)$ are identified for each event
  - Peak intensity is converted to a dimensionless index, $I_{pf}$,

$$i_{pf} = \frac{i_p - v/t}{v/1 - v/t} = \frac{(i_p/v)t - 1}{t - 1}, t > 1$$

$$Pr\{(V > v)(I_{pf} > i_{pf})(T \leq t)\} = J_u \exp[-(v - u_v)/\sigma_v]$$

$$\left\{ 1 - F_i - F_{ct} - \frac{1}{\alpha} \ln \left[ 1 + \frac{\exp(-\alpha F_i) - 1}{\exp(-\alpha) - 1} \right] + 1/t_{max} \right\}$$
Storm Event Parameter values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Springfield IL8719</th>
<th>Peoria IL6711</th>
<th>O’Hare IL1549</th>
<th>Pearson 6158733</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storm depth threshold, $u_v, mm$</td>
<td>39</td>
<td>37</td>
<td>37</td>
<td>25</td>
</tr>
<tr>
<td>Total no. of rainstorms, $n, v &gt; u_v$</td>
<td>184</td>
<td>238</td>
<td>172</td>
<td>144</td>
</tr>
<tr>
<td>Average storm depth, $\bar{v}$</td>
<td>58.298</td>
<td>51.543</td>
<td>52.881</td>
<td>34.962</td>
</tr>
<tr>
<td>Standard deviation, $\hat{\sigma}_v$</td>
<td>19.298</td>
<td>15.543</td>
<td>15.881</td>
<td>9.962</td>
</tr>
<tr>
<td>Average duration, $\bar{t}$</td>
<td>13.201</td>
<td>12.036</td>
<td>12.034</td>
<td>11.927</td>
</tr>
<tr>
<td>Standard deviation, $\hat{\sigma}_t$</td>
<td>6.091</td>
<td>8.668</td>
<td>5.800</td>
<td>6.287</td>
</tr>
<tr>
<td>Average intensity peak factor, $i_{pf}$</td>
<td>0.294</td>
<td>0.299</td>
<td>0.296</td>
<td>0.339</td>
</tr>
<tr>
<td>Standard deviation, $\hat{\sigma}_{pf}$</td>
<td>0.187</td>
<td>0.191</td>
<td>0.171</td>
<td>0.229</td>
</tr>
</tbody>
</table>
ANALYSIS - TIMESPANS

• Storm events were split into 2 time blocks split at 1980-01-01, 0001, at each of the 4 meteorological stations

• Comparisons between two successive time blocks of:
  • Statistical moments
  • Empirical distributions
  • Correlations between storm event variables
ANALYSIS – TIME SPANS

• STATISTICAL MOMENTS
  – Changes in means of \( v, t, \) and \( i_{pf} \) between the earlier and later time blocks did not reveal any significant changes.

• EMPIRICAL DISTRIBUTIONS; that is, no attempt is made to fit or force a distribution:
  – \( X^2 \) test was used to determine if there was a significant change in empirical distributions for storm variables
ANALYSIS - TIMESPANS

a) Springfield

- Expected (from 1949-1979 dist)
- Observed, 1980-2006

b) Peoria

- Expected (from 1949-1979 dist)

c) O'Hare

- Expected (from 1963-1979 dist)
- Observed, 1980-2006

d) Pearson

- Expected (from 1960-1979 dist)
ANALYSIS - TIMESPANS

- Does the “Shape” of the probability distribution change, even if mean values of variables show no significant changes?

<table>
<thead>
<tr>
<th>Variable</th>
<th>Equation/test</th>
<th>Springfield IL8719</th>
<th>Peoria IL6711</th>
<th>O’Hare IL1549</th>
<th>Pearson 6158733</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storm Depth, V</td>
<td>$\chi^2$</td>
<td>9.080</td>
<td>2.790</td>
<td>12.822</td>
<td>5.678</td>
</tr>
<tr>
<td></td>
<td>p-value</td>
<td>0.106</td>
<td></td>
<td>0.025</td>
<td></td>
</tr>
<tr>
<td>Storm Duration, T</td>
<td>$\chi^2$</td>
<td>17.552</td>
<td>5.476</td>
<td>24.192</td>
<td>9.16</td>
</tr>
<tr>
<td></td>
<td>p-value</td>
<td><strong>.007</strong></td>
<td></td>
<td><strong>0.0005</strong></td>
<td>0.156</td>
</tr>
<tr>
<td>Intensity Peak Factor, $I_{pf}$</td>
<td>$\chi^2$</td>
<td>1.141</td>
<td>9.998</td>
<td>13.961</td>
<td>10.421</td>
</tr>
<tr>
<td></td>
<td>p-value</td>
<td><strong>0.040</strong></td>
<td><strong>0.007</strong></td>
<td><strong>0.034</strong></td>
<td></td>
</tr>
</tbody>
</table>
ANALYSIS – TIME SPANS

Summary

• From periods before and after 1980:
  – Significant change in distributions for storm depth at O’Hare, storm duration at Springfield and O’Hare, and intensity at Peoria, O’Hare, and Pearson.
  – No change in frequency of extreme events at 3 of 4 stations
  – No change in mean values of storm depth, duration, and intensity
  – Correlations between storm variables; only one significant change in correlations between storm variables pre and post 1980; V – T at Springfield
ANALYSIS - TEMPERATURES

• The 2 time blocks of data were reviewed for the influence of Mean-Monthly Temperature (MMT) upon storm characteristics:

  - Duration, $T$ ↓ with ↑MMT
  - Intensity $I_{pf}$ ↑with ↑MMT

  Under all conditions, irregardless of time span

  – Storm depth $v$ is less correlated with MMT post 1980
Analysis - Temperatures
Storm Frequency and Temperature

Significant increase in frequency of storms in highest MMT range post-1980.
CONCLUSIONS

• More storms occurring at higher temperatures
  – Attention must be paid to changing probability distributions of storm variables, not otherwise revealed from a review of statistical parameters

• Increasing temperature leads to shorter duration, higher intensity events
  – Temperature correlations with storm duration and intensity are constant over time
  – Correlation of temperature with storm depth weakens at most stations
CONCLUSIONS

• Greater granularity of rainstorm data produced by Event-Definition permits:
  – Identification of trends
  – Sensitivity of change of storm variables with temperature