
Vulnerability assessment of precipitation extremes

Eylon Shamir, Ph.D.  Eshamir@hrcwater.org

Collaborators:
Konstantine P. Georgakakos Sc.D. & Theresa Modrick Ph.D.

Hydrologic Research Center, San Diego, California, U.S.A.
www.hrcwater.org
Established in 1993 as a nonprofit research, technology transfer, and training organization. HRC’s objectives are to help bridge gaps between scientific research in hydrology and applications for the solution of important societal problems that involve water.

www.hrcwater.org
Extreme events with extreme impact
- Analysis of the very extreme (un-observed) events and their water resources impacts: an example from the Panama Canal watershed

Non extreme events with extreme impact
- Analysis of frequently occurring events with extreme impact: Climate change assessment of flash flood frequency in Southern California
Study Objectives: Estimate very low frequency rainfall events and assess their impact and potential damage on the canal operation.
Panama Canal Watershed
[~3,300 km²]
The idea of predicting events with a magnitude that is not yet observed

Steps:
• Analysis of the observed record
• Fitting an extreme value distribution (e.g. GEV)
• Assess the tail of the distribution

Augmenting the observed record:
- Paleo-climatic flood records
- Stochastic weather generator to simulate likely to occur events
- Simulating events that occurred in similar setting and/or neighboring watersheds
- Simulating possible synoptic conditions that may lead to extreme events
Rare but probable [Foreseen] versus Unforeseen Events

Return Level in a given year [Percent]

Observed Data
~100 year

Foreseen

Unforeseen

Return Period [Years]

0 1 10 100 1000 10000

Probability of being exceeded

0 10 20 30 40 50 60

1% 0.1% 0.01%
Likely extreme rainfall event
Stream inflow into Gatun Lake
Lake Gatun level
Economic analysis of Expected damage
December 6-12, 2010

NASA Tropical Rainfall Measuring Mission [TRMM]

Madden Lake Gamboa Bridge
Annual Maxima Series
24 –Hour Mean Areal Rainfall over the Canal Watershed

Dec 7-8, 2010
276 mm/24-hr
Was the 2010 rainfall event a probable one?

Generalized Extreme Value (GEV) Distribution
## Daily rainfall over the Canal Watershed

<table>
<thead>
<tr>
<th>Date</th>
<th>Precipitation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7-8 December, 2010</td>
<td>276 mm</td>
</tr>
<tr>
<td>Max. Previously Observed [1908-2007]</td>
<td>124 mm</td>
</tr>
<tr>
<td>Max. Stochastic Weather Generator Model</td>
<td>315 mm</td>
</tr>
<tr>
<td>Maximum Probable Precipitation [PMP]</td>
<td>130 mm</td>
</tr>
<tr>
<td>Max. Atmospheric model (e.g. WRF) Weather Simulations (1 out of 20)</td>
<td>326 mm</td>
</tr>
</tbody>
</table>

*Wang, Shamir, and Georgakakos, 2007*
The Revised Risk Study
Simulations of Gatun Lake Level with Existing Spillway

Critical Lock & Hydropower Closure

Likely extreme rainfall Event

streamflow into Gatun Lake

Lake Gatun level

Economic analysis of Expected damage

Return Period [Years]

Gatun Lake Level [Feet]

10,000-YEAR SIMULATION ANNUAL MAXIMA (WEBULL): EXISTING SPILLWAY

Median

10 & 90 Percentiles

Failure
Climate Change assessment on Flash Flood Frequency
In Southern California

Dr. T. Modrick (UCSD/Scripps Ph.D. Dissertation)

Number of sub-watersheds: 975
Average Local drainage area: 26 km$^2$

“Recent findings of the WMO (2008) country-level survey where of the 139 countries, 105 indicated that flash floods were among the top two most important hazards around the world and require special attention”

“On the average, these events kill more people worldwide than any other natural disaster – in an average year, flash floods kill over 5,000 unsuspecting people and cause millions of dollars of property damage
Increase in Precipitation and Streamflow during “El Nino–favorable” conditions
CCSM3 climate model for “control” and “A1B” climate change scenarios

Define two periods:
- 20th Century (control, 1970-1999)
- 21st Century (A1B, 2070-2099)

CCSM3 model output provides input to Simplified Orographic Precipitation model

Hydrology and geomorphology models remain the same.
Simulated Precipitation Differences

Wet Season (October – April) Total Climatology

CCSM3 IPCC-SRES A1B Scenario – Middle of the road emission scenario.

End of 20th Century

End of 21st Century

~15%

~20%
Model 1: Slope of Linear Fit = 1.32
Model 2: Slope of Linear Fit = 1.49

Increase flash flood frequency at the end of the 21st century.

The cause of projected changes:
- Increase in rainfall magnitude
- Increase in event duration
- Decrease in number of events
Take Home messages

- Prediction of extreme events with extreme impact MUST consider uncertainty bounds

- Climate change impact on the frequency of flash floods occurrence has to consider properties that dominate the local hydrologic processes.
THANKS !!!

Eylon Shamir, Ph.D.  Eshamir@hrcwater.org

Hydrologic Research Center, San Diego, California, U.S.A.
www.hrcwater.org