Projected Changes in Rainfall Extremes in Southeast Asian Cities: Implications for Flood Risk Assessment

Pradeep Mandapaka
Institute of Catastrophe Risk Management

04 August 2017
Outline

- Motivation: Flood risk assessment
- Data characteristics and indices employed
- Future projections of rainfall (and trends?)
- Regional analysis
- Future projections of discharge: A case study in Jakarta
- Summary and final remarks
Motivation

- 600 million people
- Many densely populated cities
- Long coastlines
- Low elevation coastal regions
- High vulnerability to extreme events

(e.g. 10/2011 floods in Thailand, 01/2007 and 01/2013 floods in Jakarta)
Current Knowledge and Gaps

**Warming climate**

Intensification of hydrologic cycle

**Changes in precipitation characteristics**

- Are changes in precipitation extremes more prominent than annual totals?
- Regional heterogeneity in changes in precipitation characteristics?

**Dry versus wet**

- Dry get drier and wet gets wetter?

**Quantification of changes in hydrologic cycle in Southeast Asia** → high-resolution climate model output because of complex land-sea organization and long coastlines

**Objectives:** To assess future changes in rainfall structure in Southeast Asia using high-resolution climate model output

- For different geographical subsets such as urban regions, wet/dry regions and low elevation coastal (LEC) regions
- Changes in river flows and implications for flood risk
Data

Global climate model (GCM) projections
NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP)
20 GCMs (From CMIP5)
Spatial resolution → 0.25° (~27 km)
Temporal resolution → Daily
Historical → 1951 – 2005
Future projections → 2006 – 2099
(RCP 4.5 and RCP 8.5 scenarios)

Topography
NOAA ETOPO1 Global Relief Model
Spatial resolution → 1-min (~2 km)

Night-time light data
Spatial resolution → 30-sec (~1 km)
Year → 2010

All datasets regridded to a common spatial resolution of 0.25°

RCPs: Set of greenhouse gas emissions, concentration and land use pathways

<table>
<thead>
<tr>
<th>Representative Concentration Pathways</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCP2.6</td>
<td>Low emission scenario; Rise and decline in radiative forcing levels; Ambitious greenhouse gas emission reductions required over time.</td>
</tr>
<tr>
<td>RCP4.5</td>
<td>Intermediate emission scenario; Stabilization without overshoot after 2100; A future with relatively ambitious emissions reductions.</td>
</tr>
<tr>
<td>RCP6.0</td>
<td>Intermediate emission scenario; Stabilization without overshoot after 2100; Application of a range of technologies and strategies for reducing greenhouse gas emissions.</td>
</tr>
<tr>
<td>RCP8.5</td>
<td>High emission scenario; Rising pathway; A future with no policy changes to reduce emissions.</td>
</tr>
</tbody>
</table>

Study Region

Top panel
CSEA: Continental Southeast Asia
SRMP: Sumatra and Malay Peninsula
BORS: Borneo and Sulawesi

Bottom panel
Dry: 0 – 20 percentile annual rainfall
Wet: 80 – 100 percentile annual rainfall
Stippled pixels (bottom panel): Urban
## Indices Employed

<table>
<thead>
<tr>
<th>Index</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRCPTOT</td>
<td>Annual precipitation</td>
<td>mm</td>
</tr>
<tr>
<td>R10</td>
<td>Number of days per year when daily rainfall is ≥ 10 mm</td>
<td>-</td>
</tr>
<tr>
<td>R95P</td>
<td>95\textsuperscript{th} percentile of daily rainfall</td>
<td>mm d\textsuperscript{-1}</td>
</tr>
<tr>
<td>Rx1day</td>
<td>Annual maximum daily rainfall</td>
<td>mm d\textsuperscript{-1}</td>
</tr>
</tbody>
</table>

All indices computed for each 0.25° pixel and normalized with base (1980 – 2000) climatology
Daily Rainfall Extremes

CSEA: Continental Southeast Asia
SRMP: Sumatra and Malay Peninsula
BORS: Borneo and Sulawesi
PHIL: Philippines
NGUI: New Guinea
Decadal Trends

Stippled region → At least 15 (out of 20) models agree with the sign of ensemble
Decadal Trends (regional averages)

- **PRCPTOT**
  - RCP4.5 mean ± std
  - RCP8.5 mean ± std

- **R95P**

- **Rx1day**

**Mask/Region**
- CSEA: Continental Southeast Asia
- SRMP: Sumatra and Malay Peninsula
- BORS: Borneo and Sulawesi
- PHIL: Philippines
- NGUI: New Guinea
- L-Dry: Driest land region
- L-Wet: Wettest land region
- LEC: Low elevation coastal region

Institute of Catastrophe Risk Management
Flood Risk Management: Jakarta Case Study

- PRCPTOT
- R95P
- R×1day

Yearly normalized index comparison between RCP 4.5 and RCP 8.5 from 1950 to 2100.
Rainfall for Different Return Periods

Fitted a GEV distribution to RX1day values for each 31 year moving window and GCM.
Future Discharge Patterns: Jakarta Case Study

Rainfall discharge curves

Projections of discharge for Ciliwung River
(Land use land cover changes not taken into account)

RCP 4.5

RCP 8.5

50 years

100 years

(Adapted from Daksiya et al. 2017)
Future Overflow Patterns: Jakarta Case Study

Rainfall-overflow curve

Overflows in the central basin bounded by Ciliwung and Cengkareng
(Land use land cover and levee heights assumed to be constant)
Summary and Remarks

- Analysed high-resolution (bias-corrected statistically downscaled) climate model output to quantify changes in precipitation characteristics
- Overall, centennial change in precipitation totals is slightly lower (~17%) compared to extremes (~22%) for RCP 8.5 scenario
- Changes in precipitation smaller for Java and higher for Continental Southeast Asia and Philippines
- No significant differences were observed for urban versus non-urban, and dry versus wet regions
- Climate model variability found to be large

- A hydrologic case study on Ciliwung River, Jakarta is conducted and future discharge and overflow patterns analysed.
- Centennial change in discharge for 100-yr return period rainfall and RCP 8.5 scenario is about 27% (under current conditions of land use)

Thank you