NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE | Institute of Catastrophe Risk Management

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

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INTRODUCTION

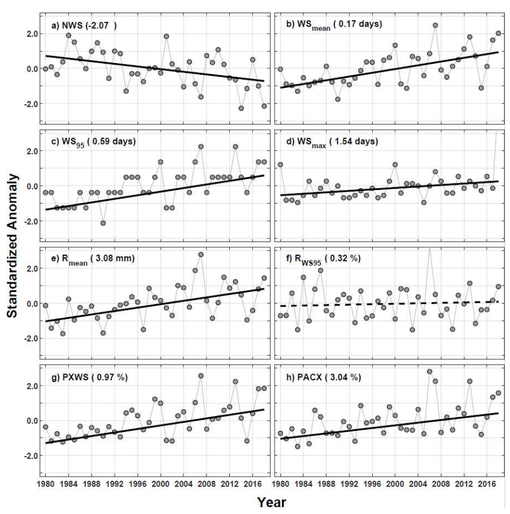
Extreme precipitation and associated flooding cause severe damage to society and the environment. Southeast Asia (SEA) is highly vulnerable to extreme events (e.g. 2011 Thailand flood, 2012 flood in Peninsular Malaysia, and 2013 flood in Jakarta) and it is home to about 620 million people with many densely populated cities and low elevation coastal regions. Rapid urbanization in SEA further exacerbates the flood risk.

GOALS: To quantify historical and future changes in precipitation in SEA cities at a resolution finer than the typical GCM resolution. To integrate information about the changes in precipitation extremes and urban growth into an in-house flood risk assessment framework and assess flood risk as demonstrated for Jakarta.

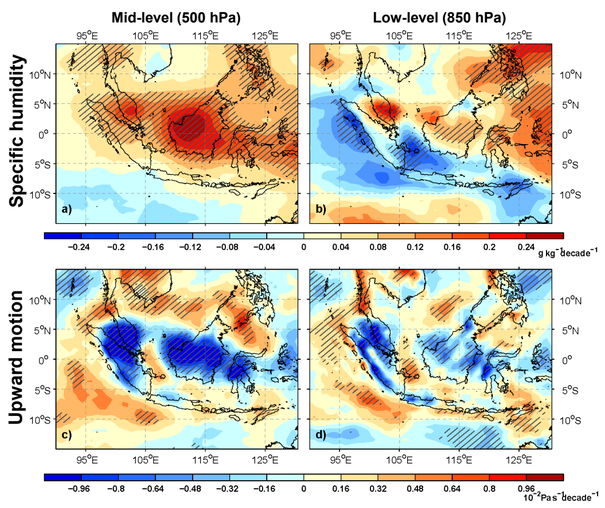
1. HISTORICAL RAINFALL TRENDS

Analyzed wet spells (defined as the number of consecutive rainy days) in Singapore during 1980 to 2016 and examined if the observed trends can be explained by the behaviour of large-scale dynamic and thermodynamic variables over the region.

Datasets: Rain gauge data from Singapore and reanalysis data from ERA-Interim.



Wet spell indices over Singapore estimated using rain gauge data. Significant trends (solid lines) were observed in wet spell indices. Numbers in parenthesis indicate decadal change

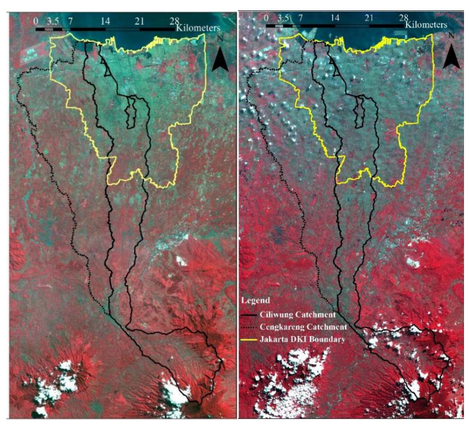


Decadal trends in specific humidity and upward motion at two pressure levels estimated using reanalysis data. Significant increase in humidity and upward motion is observed over Borneo, Malay Peninsula and Philippines

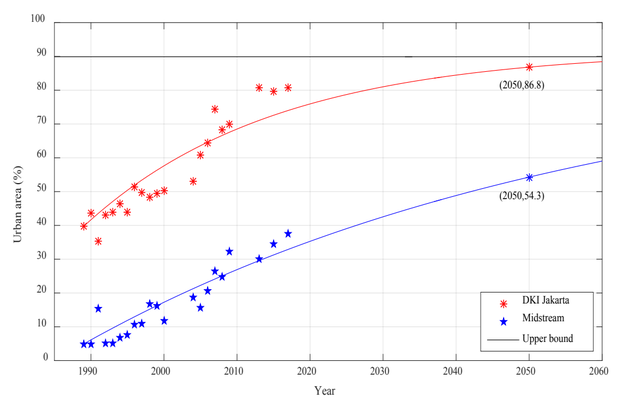
3. URBANIZATION TRENDS FROM LANDSAT IMAGERY

Extracted urban areas in Jakarta region using supervised classification of Landsat imagery in ArcGIS environment and parameterized and extrapolated to year 2050.

Datasets: Landsat 4-5 Thematic Mapper (TM) for 1989-2009 and Landsat 8 Operational Land Imager (OLI) for years 2013, 2015 and 2017.



Changes in landuse-landcover for Jakarta region as evident in Landsat false color composite images for years 1989 and 2017

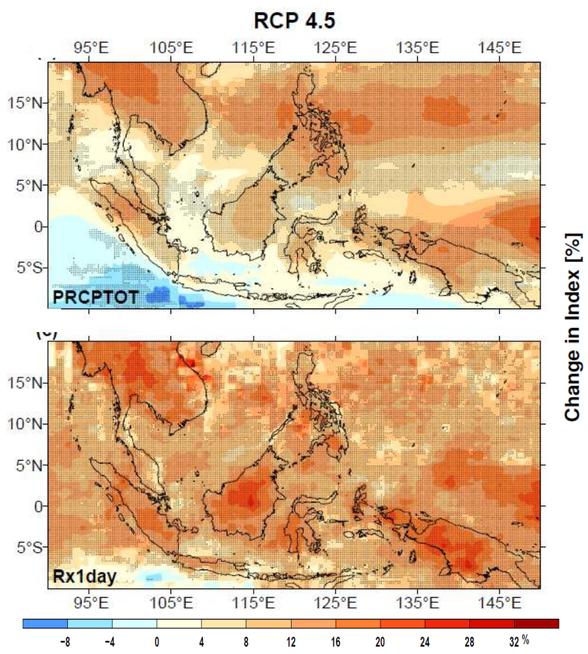


Percentage urban extent for DKI Jakarta and midstream regions extracted from Landsat imagery and corresponding future (year 2050) projections are derived from the fitted models. The percentage urban extent for midstream region is projected to increase from 38% in 2017 to 54% in 2050

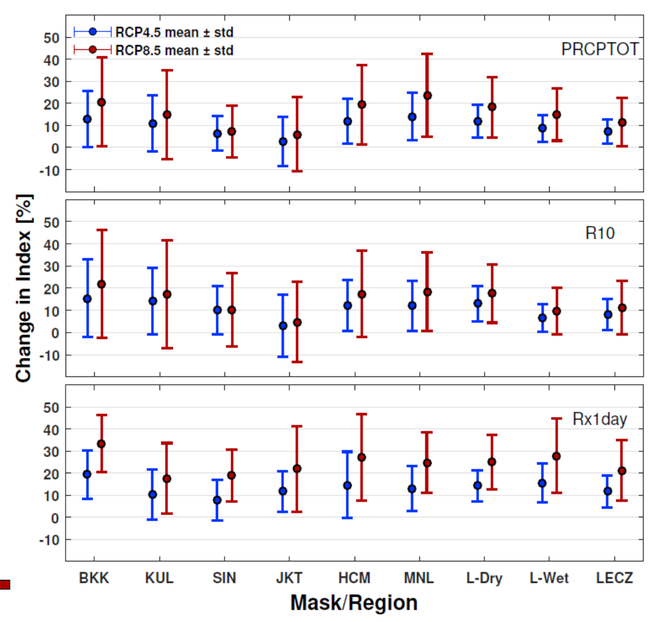
2. FUTURE RAINFALL PROJECTIONS AND TRENDS

Analysed high resolution future projections from an ensemble of 20 climate models under two emission scenarios RCP4.5 and RCP8.5 and trends (if any) are quantified.

Datasets: NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) with a spatial resolution of 0.25°.



Spatial distribution of centennial changes (i.e., 2070-2099 vs. 1970-1999) in annual total rainfall (PRCPTOT) and maximum daily rainfall (RX1DAY). Stippling indicates that at least 15 models agree with the sign of ensemble mean change

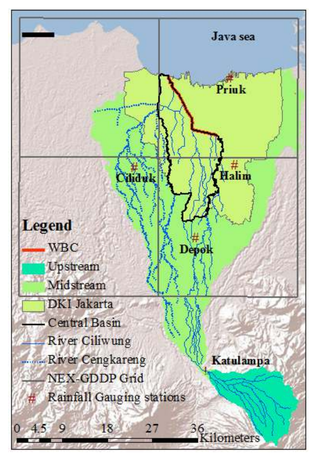


Changes in precipitation indices averaged over each city and three regional masks (dry, wet and low elevation coastal zones) for the 2070-2099 period relative to 1970-1999 period. Vertical bars depict intermodel variability (standard deviation)

4. FLOOD RISK ASSESSMENT

Integrate the information about precipitation extremes and urbanization into a flood risk assessment framework developed in ICRM, and demonstrate it over Jakarta.

Data and models: Rain gauge data, surveys, loss curves from ICRM, Jakarta flood model



Three study regions in Jakarta along with rain gauges and NEX-GDDP grids used

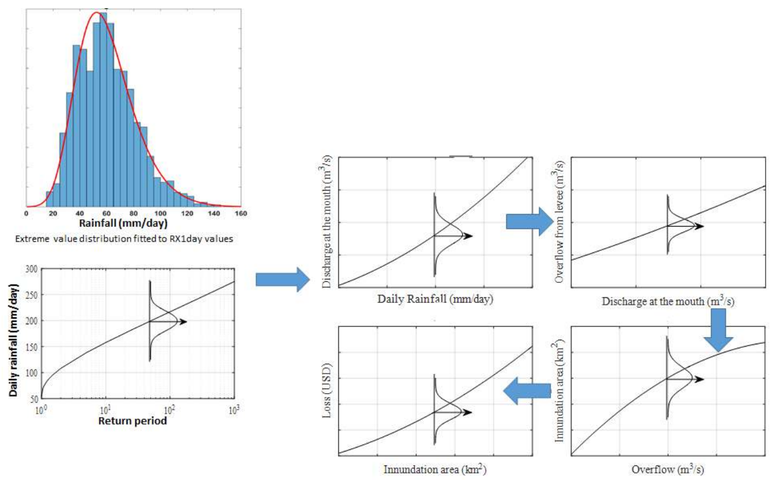
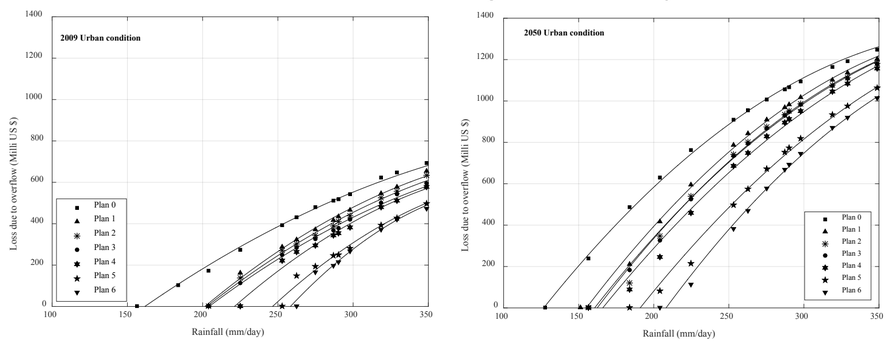


Illustration of propagation of uncertainty from rainfall to annual expected loss



Flood loss values for different daily rainfall values (2-5000 year return period) under current (year 2009) and future (year 2050) projected urban conditions

KEY CONCLUSIONS

- Significant trends in wet spell indices observed for Singapore. Mean and the maximum wet spell length increased at 0.17 and 1.54 days per decade, respectively.
- Strengthening of low-level convergence, vertical motion, increase in moisture availability and instability explain the upward trends observed in wet spells over Singapore.
- Projected centennial increase in total annual precipitation relative to 1970-1999 period when averaged over all coastal areas in SEA is about 12% under RCP8.5 scenario.
- The flood loss in Jakarta for 100-year return period rainfall is projected to increase by 172% in year 2050 compared to the year 2009 value.

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