Climate projections downscaling and inundation modeling over Jakarta, Indonesia

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March 14, 2016

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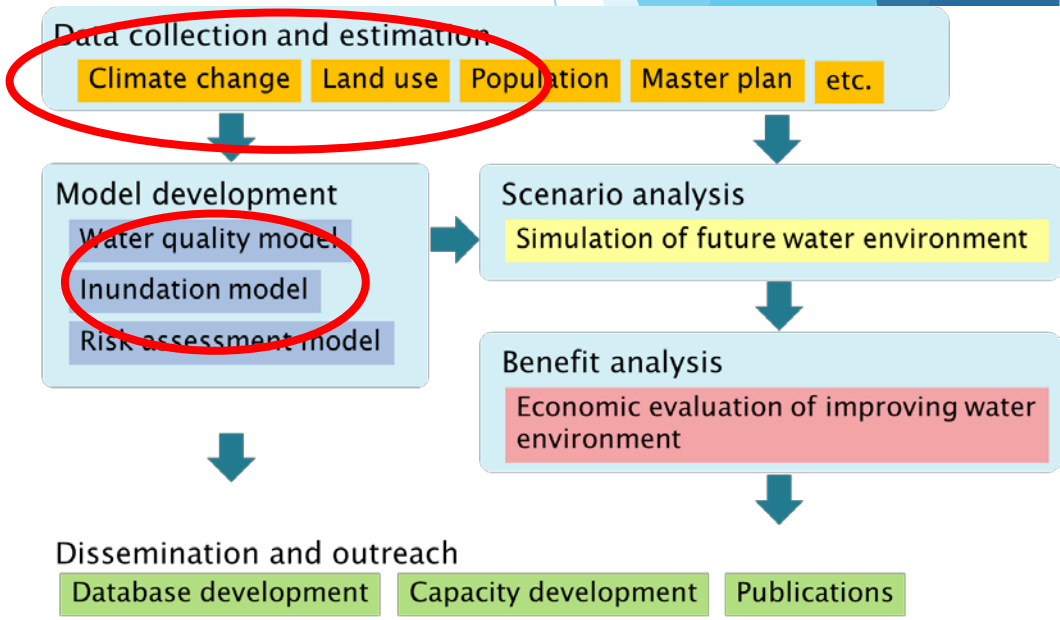
Water & Urban Initiative

Outline

- Introduction: Urban flood in changing context
- Flood inundation modeling
- Climate projections downscaling and adaptation



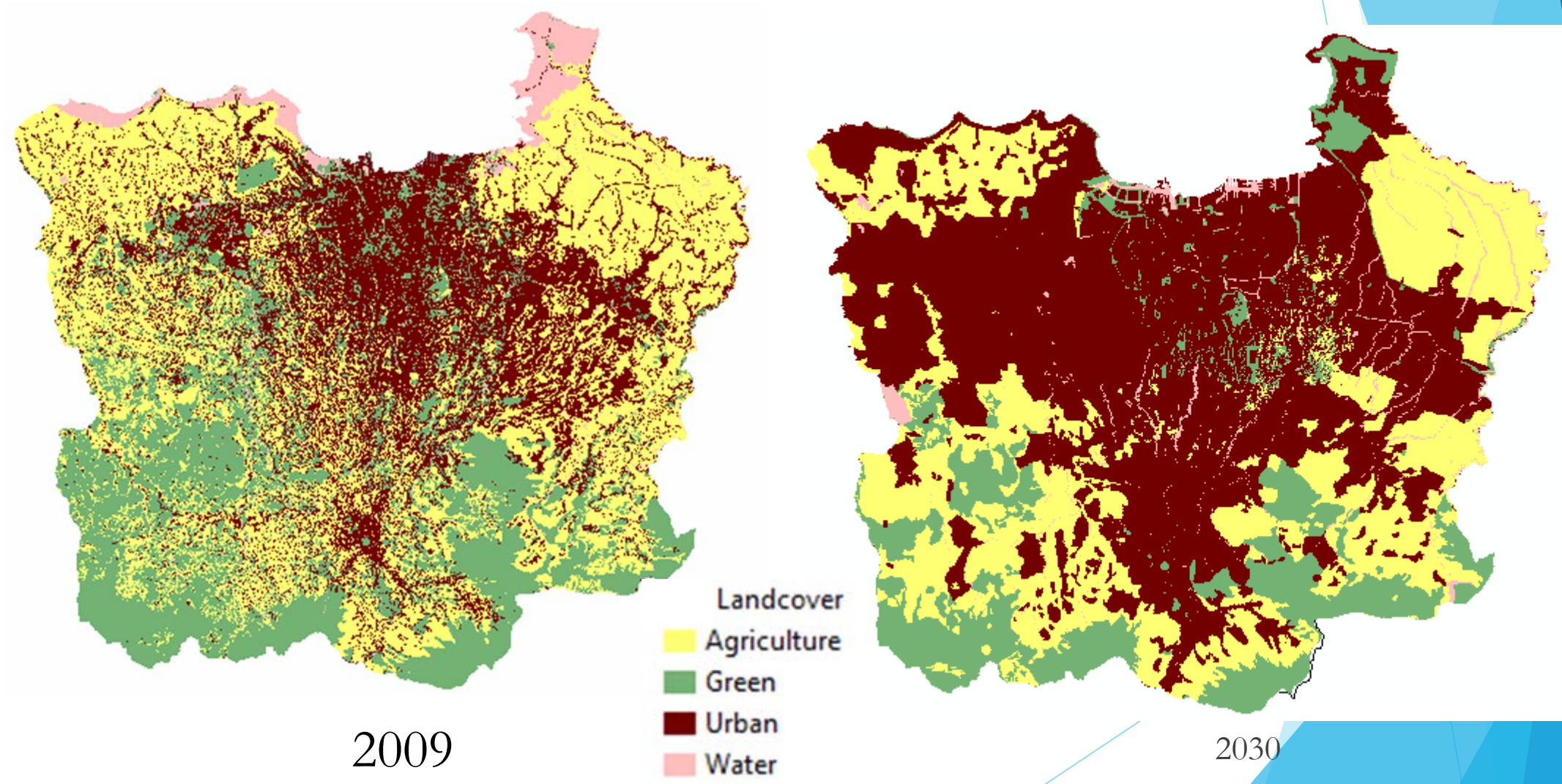
Introduction

- Flooding occurs frequently in Jakarta during the rainy season, causing huge losses.
- Flooding (due to heavy rainfall and overflowing of river water) is identified as a significant risk for conception and transmission of water-borne illness (e.g., diarrhea).
- Flood simulation under changing scenario is required for the human health risk assessment of the flood-affected population.

http://www.abc.net.au/am/content/2013/s3672587.htm

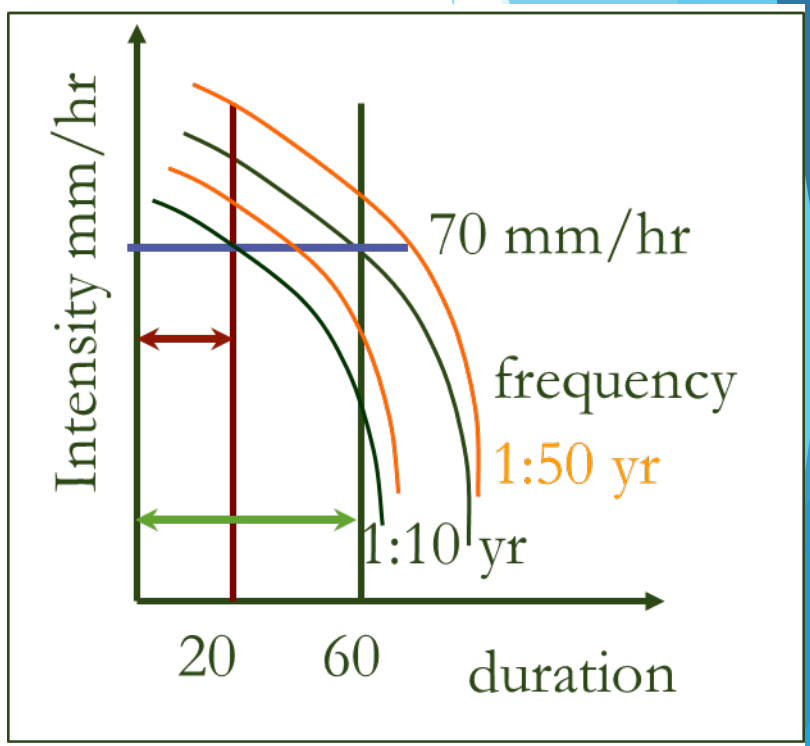
http://contemporarycity.org/2014/04/jakarta/

Urban expansion in Greater Jakarta



Climate change

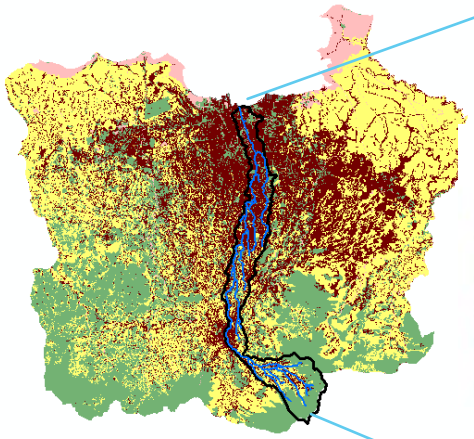
- Climate change exacerbates the frequency and intensity of hydro-meteorological disasters
- The incidence of extreme precipitation events is expected to increase, resulting frequent intense flood disasters

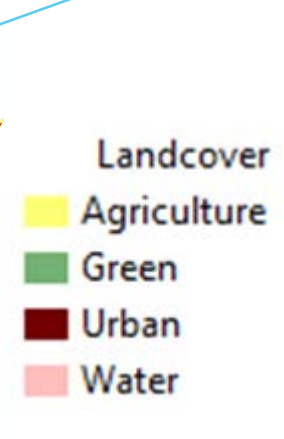


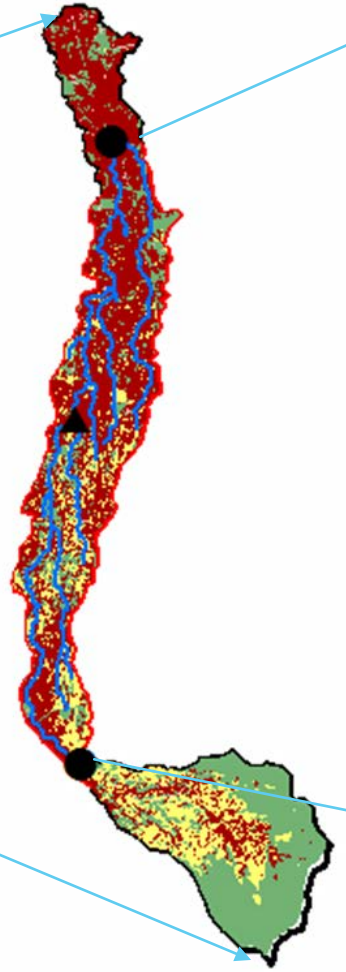
Modeling area: Ciliwung river basin

- High flow rates in the Ciliwung River flowing through Jakarta regularly causes extensive flooding in the rainy season.
- Inundation occurs because of the Ciliwung River overflowing when it is unable to accommodate flood discharge from upstream.
- The case study area encompasses the floodplain along the Ciliwung River from upstream of Manggarai Gate to Katulampa hydrological station.
- The case study area comprises dense population, rapid urbanization and flood-prone locations in Grater Jakarta.

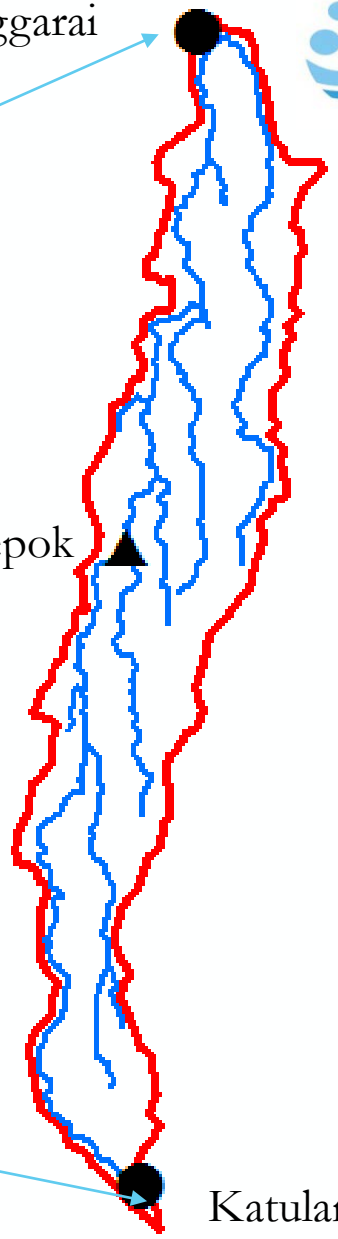
Modeling area: Ciliwung river basin







Catchment area = 438 km2



Simulation area = 238 km2

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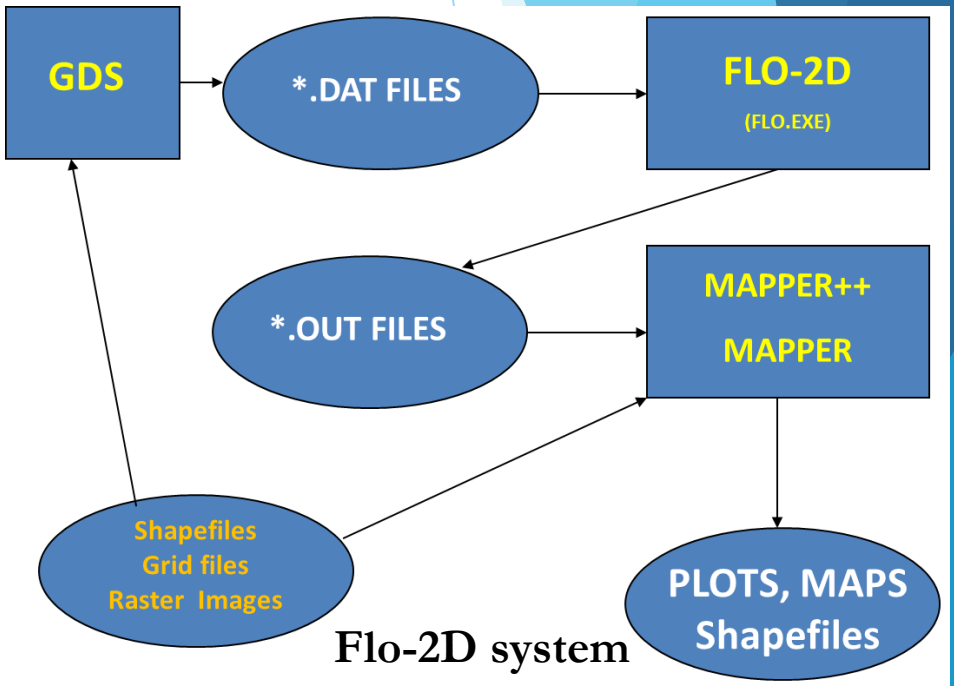
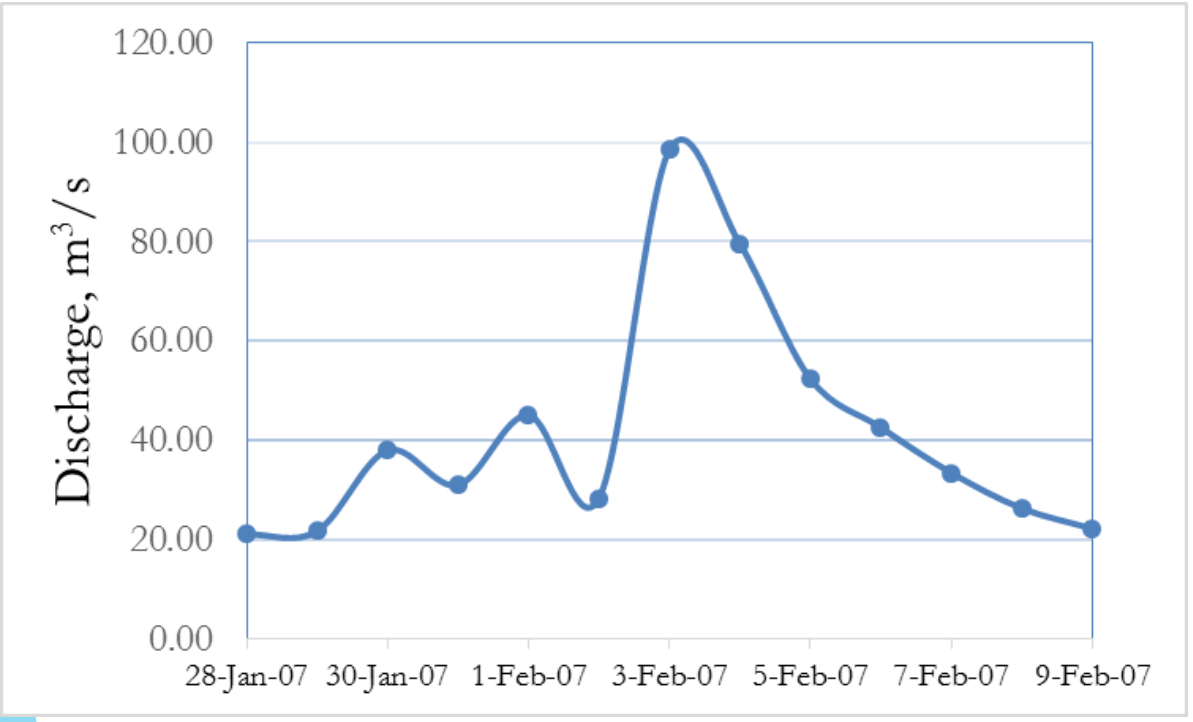
Inundation model set-up

- This study uses Flo-2D, a two-dimensional hydrologic-hydraulic model, to analyze characteristics (area, depth, time of occurrence, flow velocity) of urban flooding.
- A flood event of February 2007 was used for the inundation model set-up.
- River network and floodplain delineation is based on SRTM 90 m elevation data.
- Daily inflow (discharge) and rainfall at Katulampa and Depok stations respectively were used for the model set-up.
- Urban stormwater flow is governed by natural flow (due to lack of pipe network data)

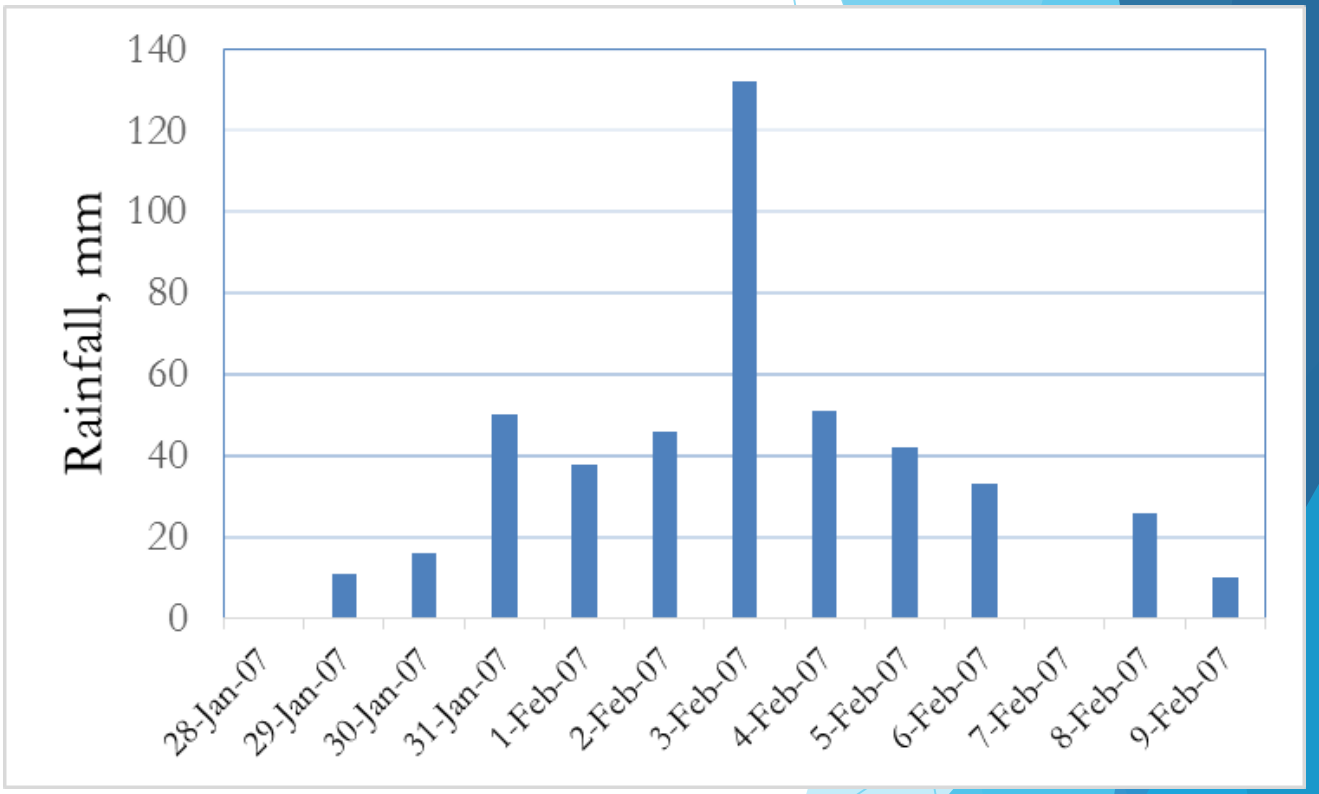


Flo-2D system

Input data

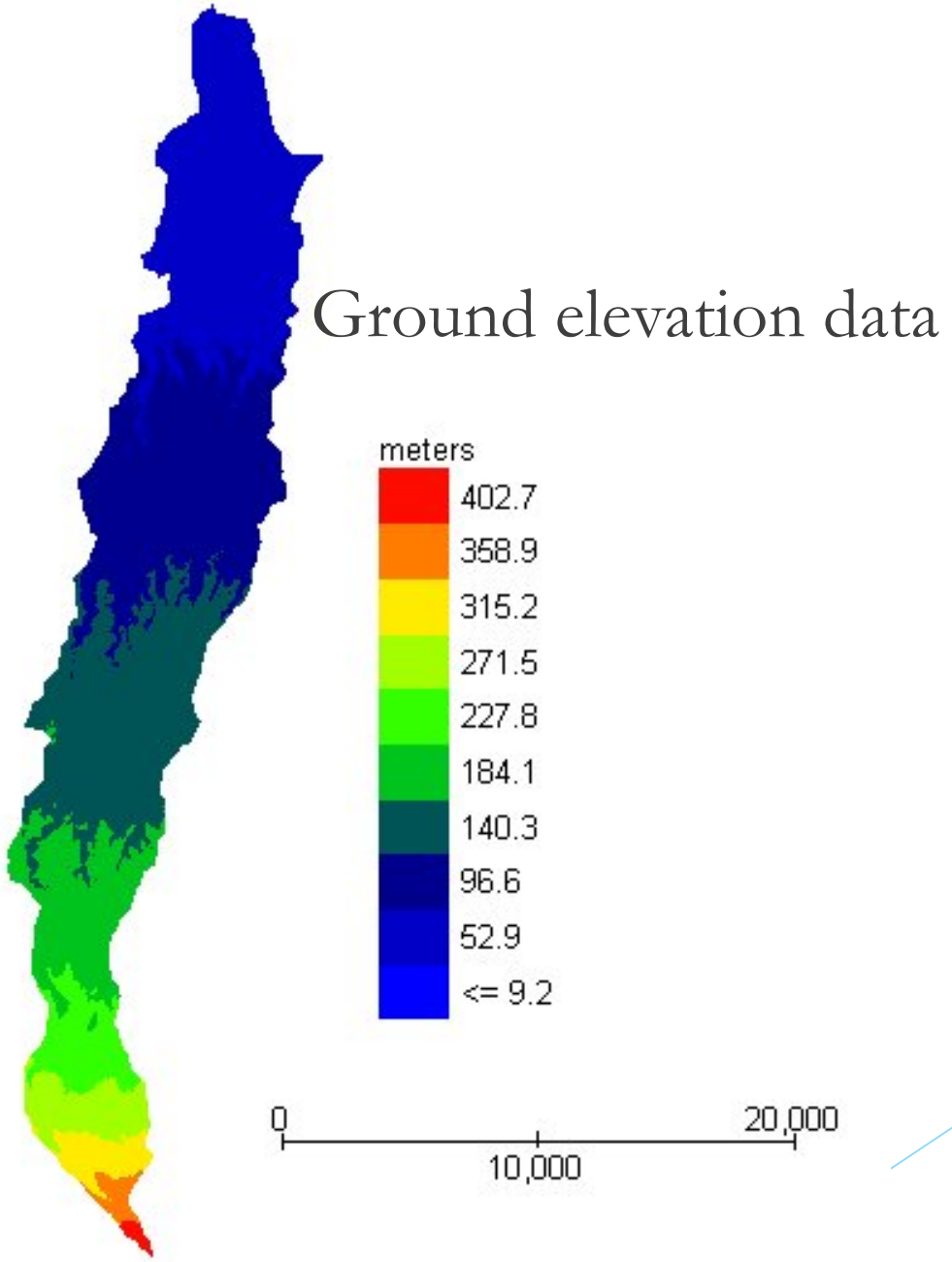


Inflow at Katulampa station



Rainfall at Depok station

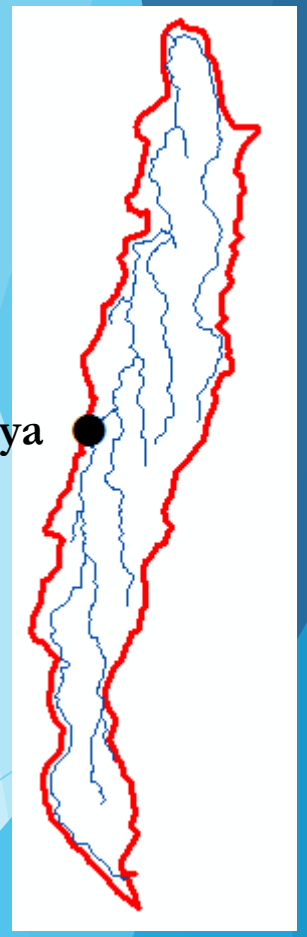
Input data



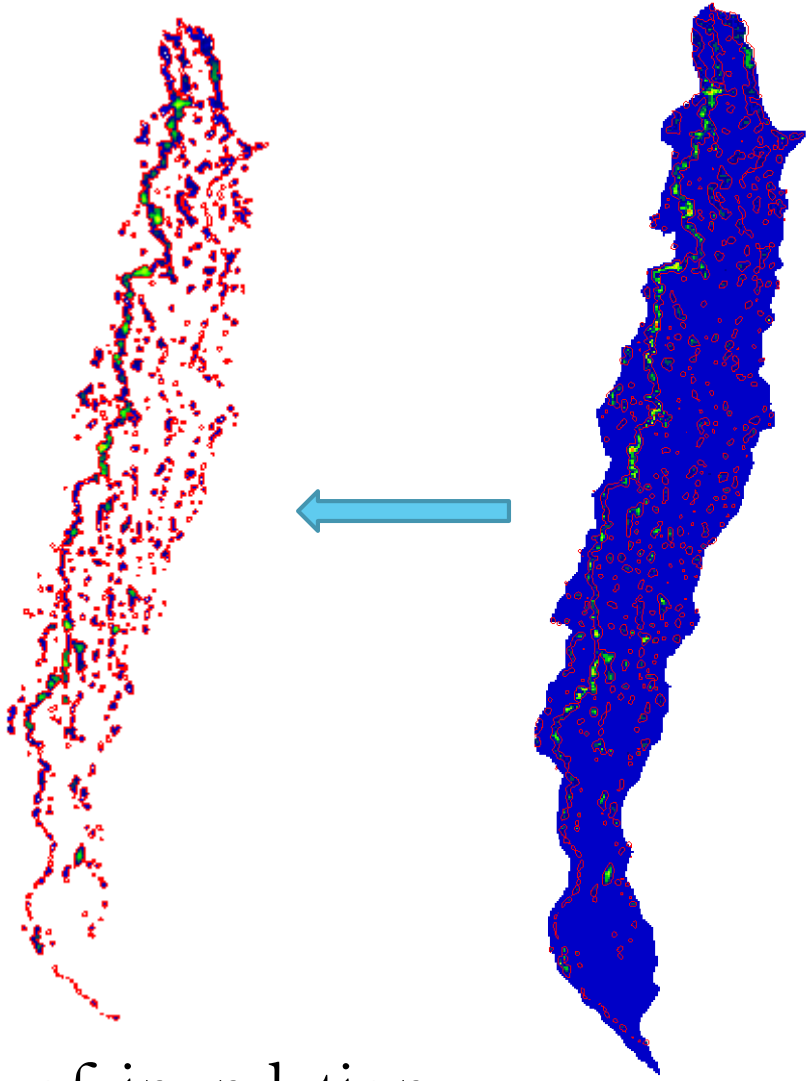
Ground elevation data

Model Calibration/validation

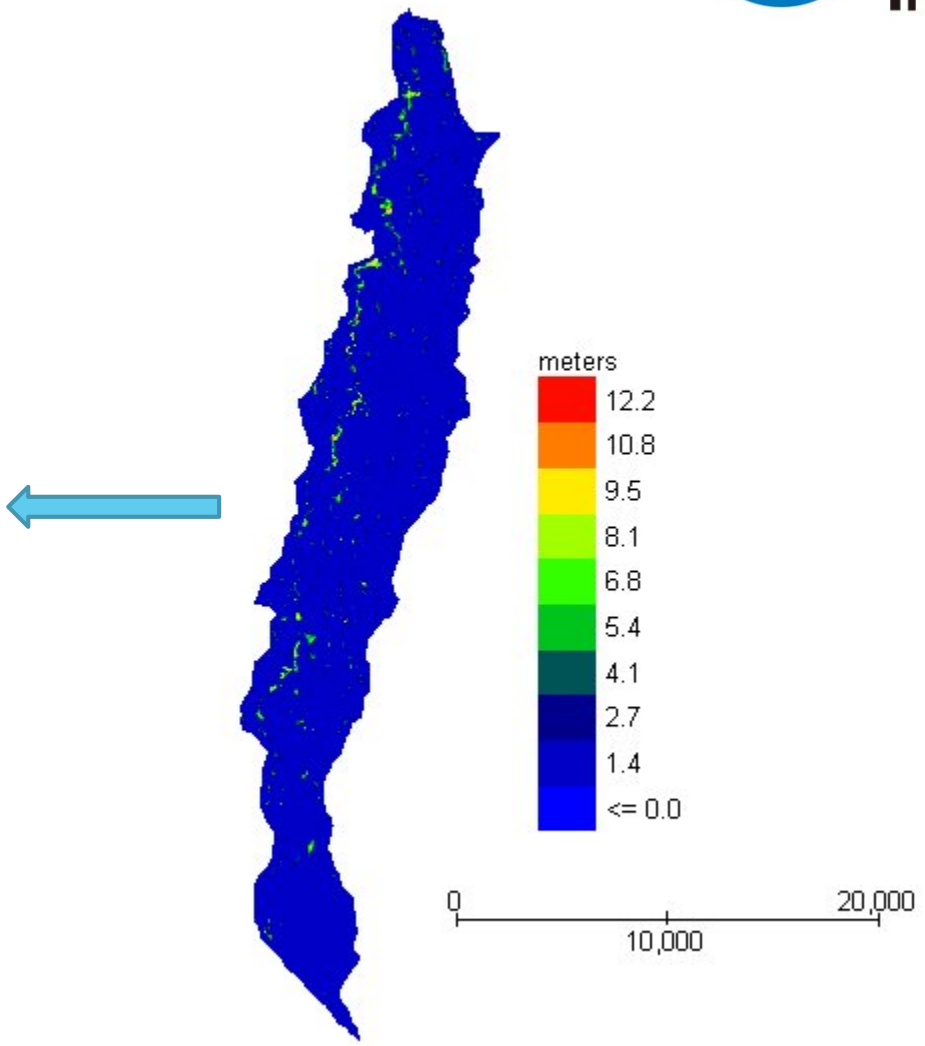
- Reference data for the calibration were flood value passing at Ratu Jaya section of Ciliwung river.
- Observation flood at Ratu Jaya on 3rd February, 2007 was used for calibrating model parameters
- The most sensitive model parameter was the Manning's roughness
- Based on the modeling results, the inundation is mapped onto detailed topographic maps.
- The inundation map will be verified using the data of the inundation area and depths from secondary data and survey.



Results



Area of inundation

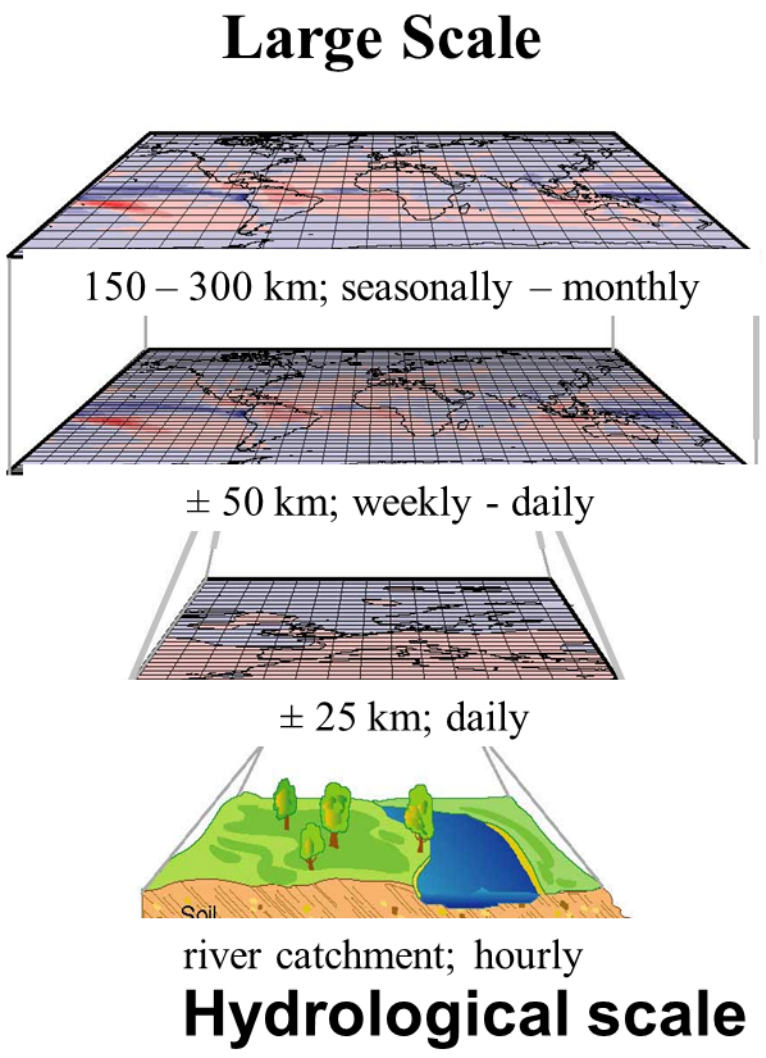


Maximum flow depths

Climate projections

- Climate projections are widely employed to understand the likely impact of climate change.
- Global climate models (GCM) simulate the response of greenhouse gas concentrations, and provide estimates of climate variables such as temperature, precipitation etc.
- Climate projections derived from GCM consists of biases, and hence not suitable for direct use at regional/local climate change studies.
- Downscaling is the process of deriving finer resolution (i.e., regional/local) climate data from GCM climate data.

Climate projections downscaling



Methods

- Dynamical
- Statistical

Types

- Spatial
- Temporal

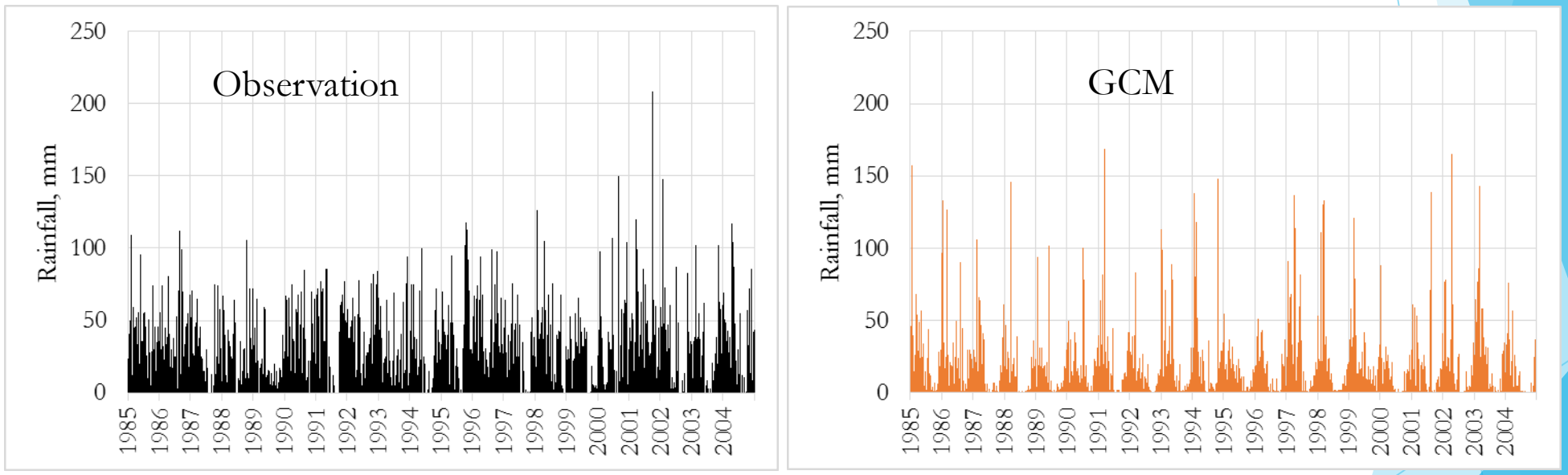
Climate data: MRI-CGCM3

- MRI-CGCM3 is composed of atmosphere-land, aerosol, and ocean-ice models
- Horizontal resolution: 120 km
- Temporal resolution: daily
- RCP 4.5 and 8.5 were used as the future scenario to obtain future precipitation form MRI-CGCM3
- Download:

http://cera-www.dkrz.de/WDCC/ui/Entry.jsp?acronym=MRMC

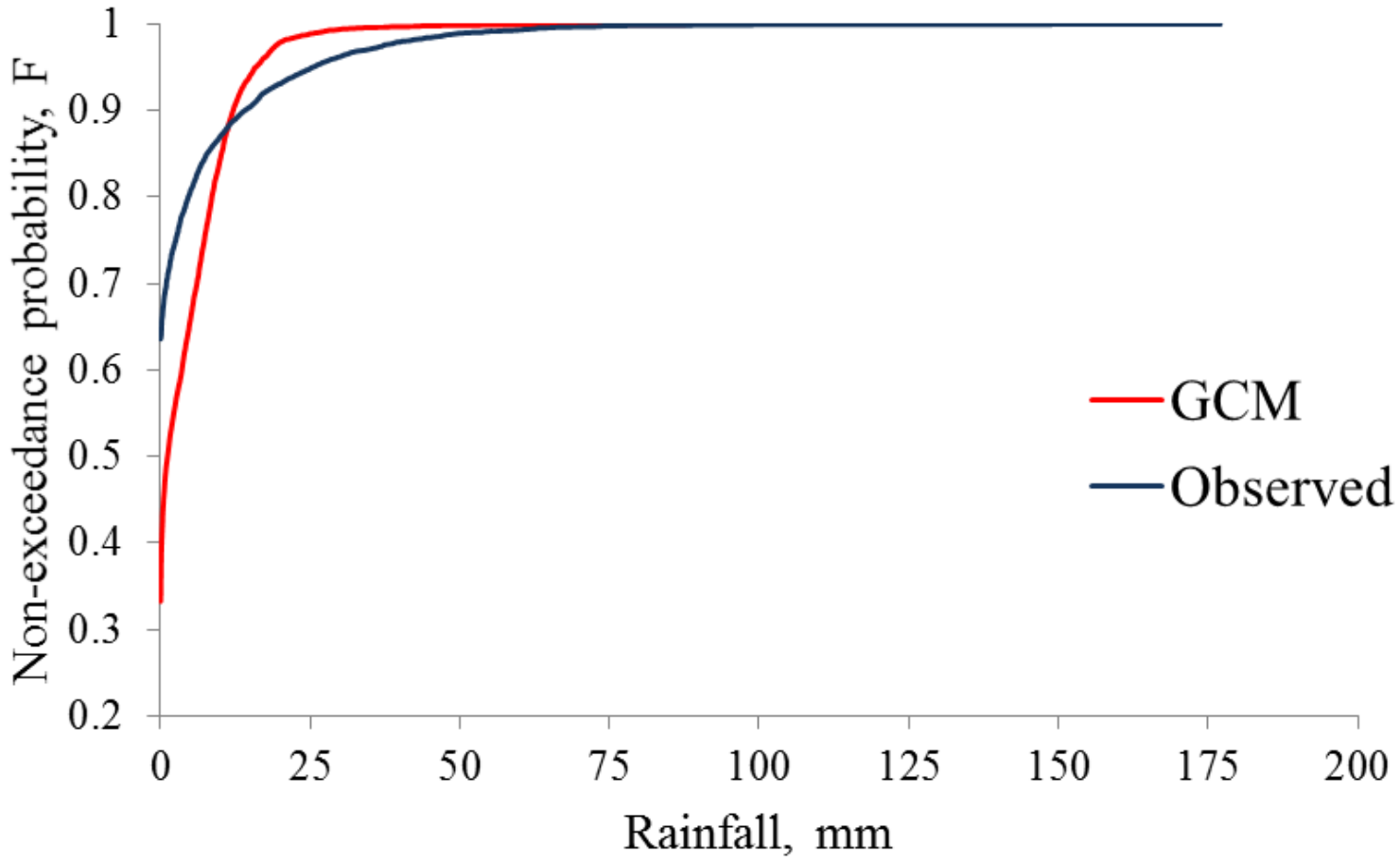
Bias identification

Comparison of observation and MRI-GCM daily rainfall over Jakarta



- Bias in frequency (too many rainy days for GCM data)
- Bias in intensity (largely underestimated rainfall for GCM data)

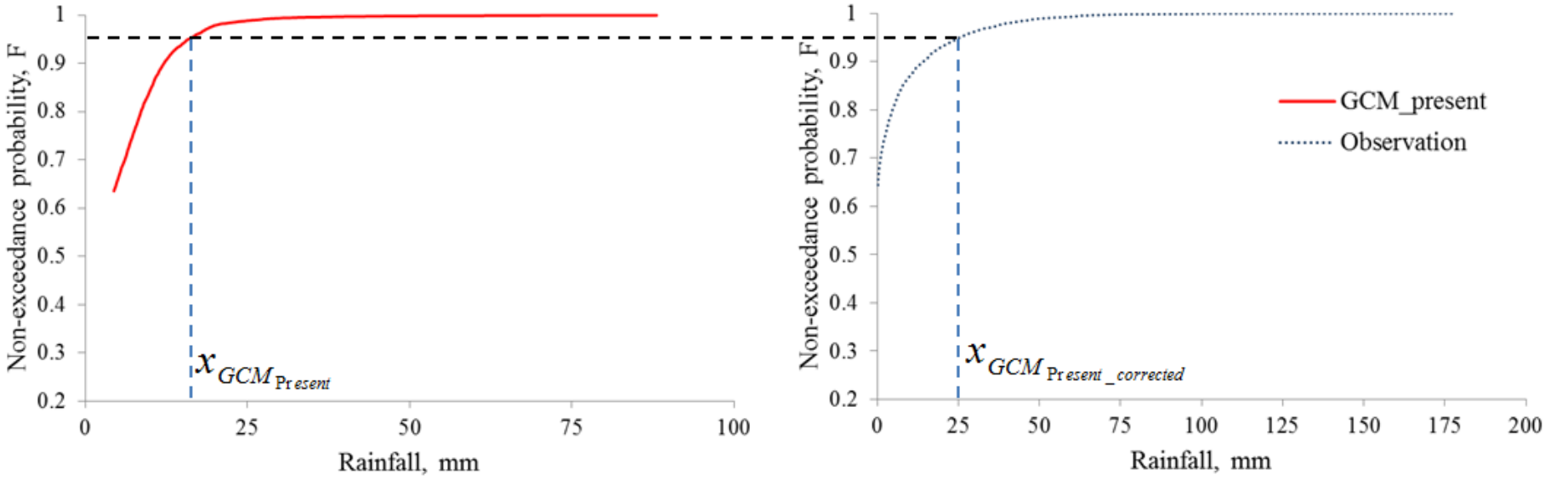
Bias correction (frequency)



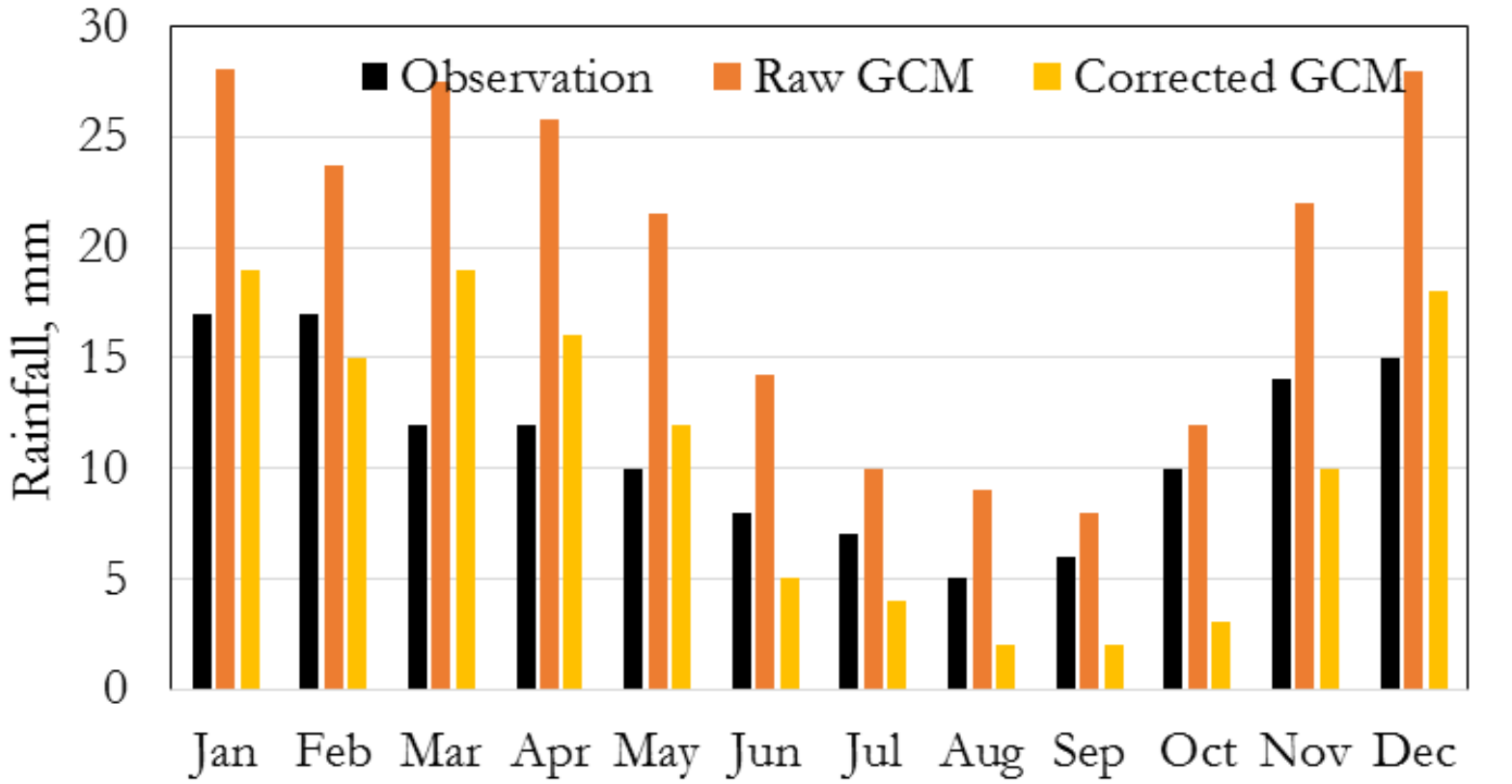
Bias correction (intensity)

$$x_{GCM_{\Pr esent\_corrected}} = F_{obs}^{-1}(F_{GCM_{\Pr esent}}(x_{GCM\,20_{\Pr esent}}))$$

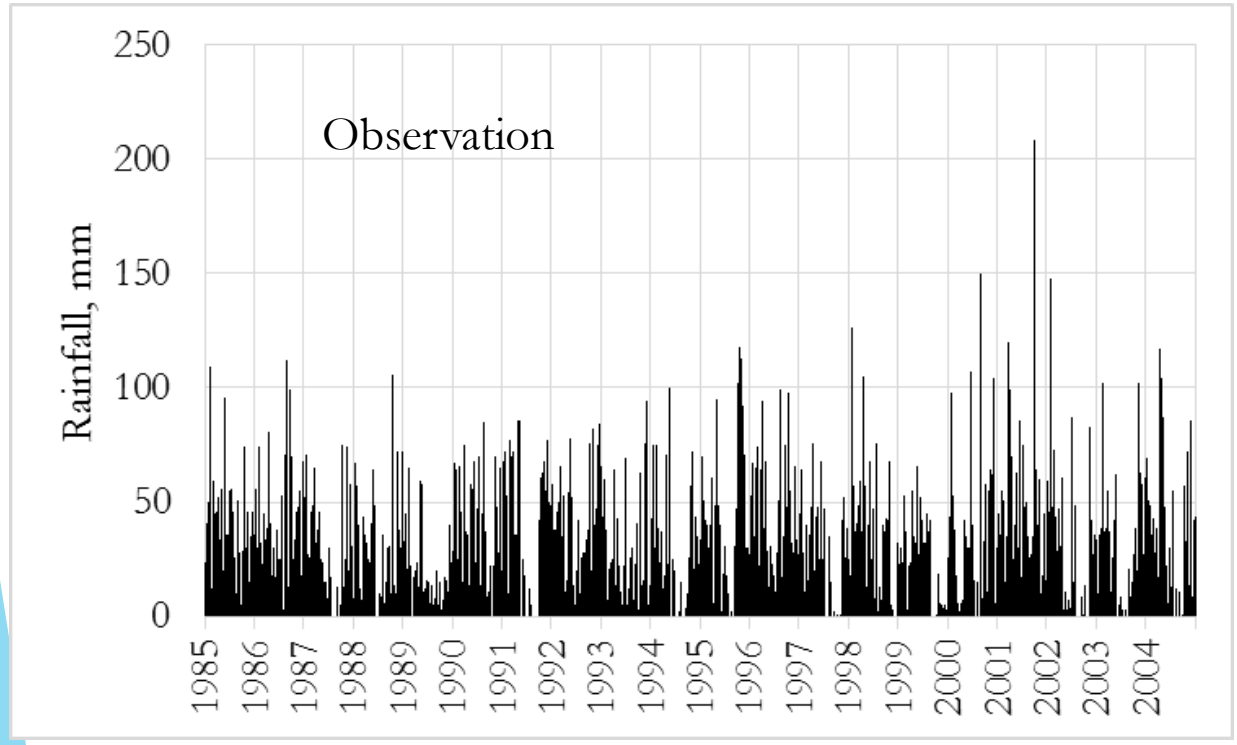
$$x_{GCM_{Future\_corrected}} = x_{GCM_{Future}} \frac{F_{obs}^{-1}(F_{GCM_{Future}}(x_{GCM_{Future}}))}{F_{GCM_{\Pr esent}}^{-1}(F_{GCM_{Future}}(x_{GCM_{Future}}))}$$

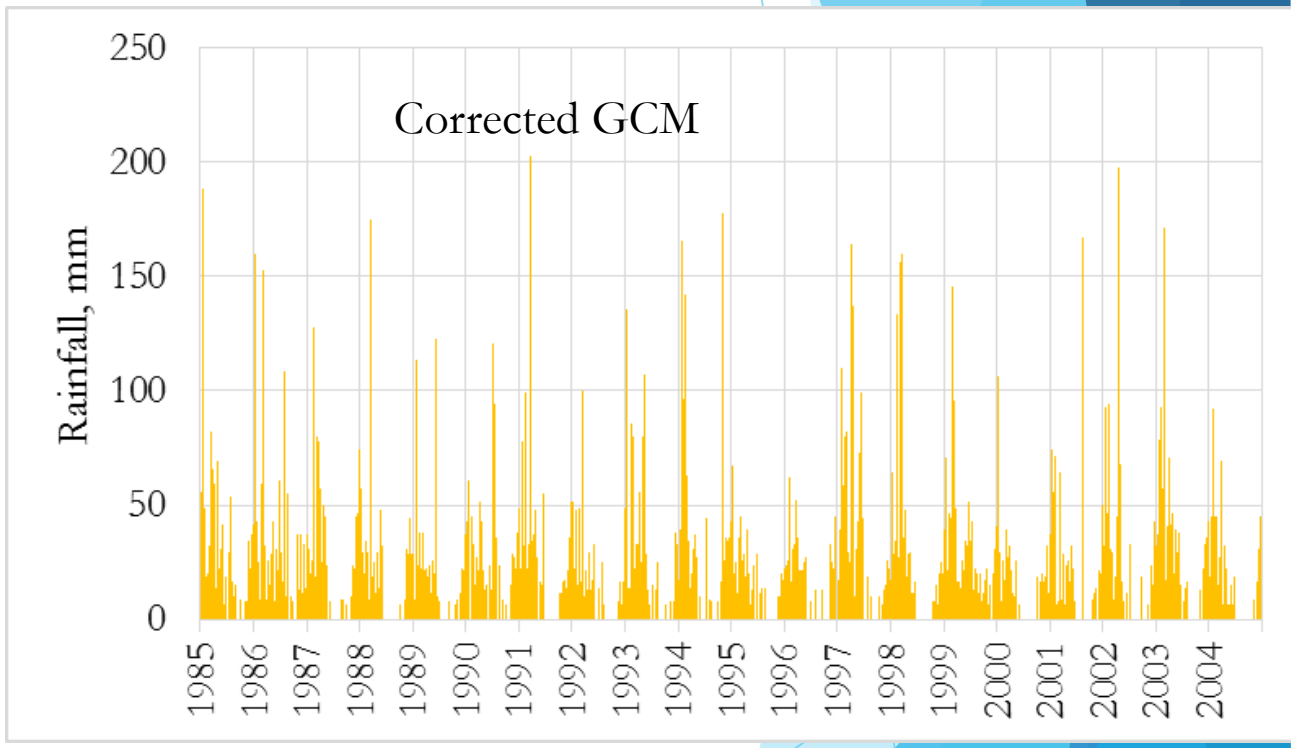


Results: Frequency correction



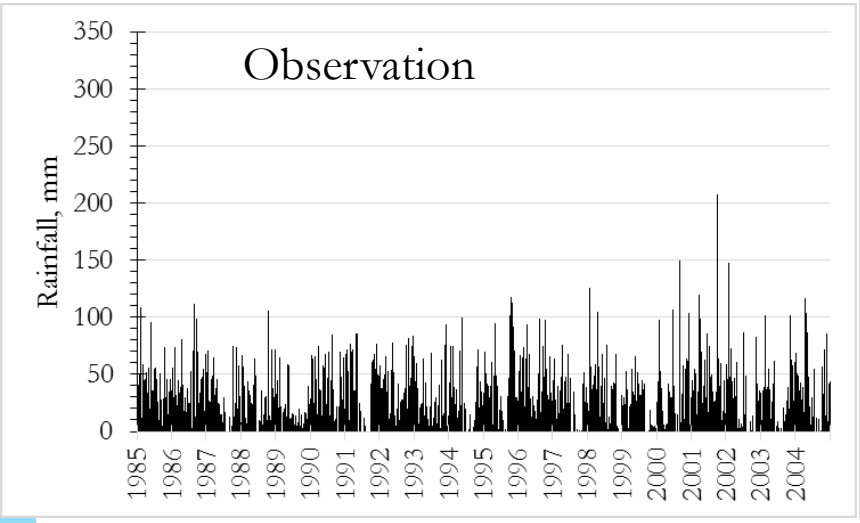
Results: Intensity correction

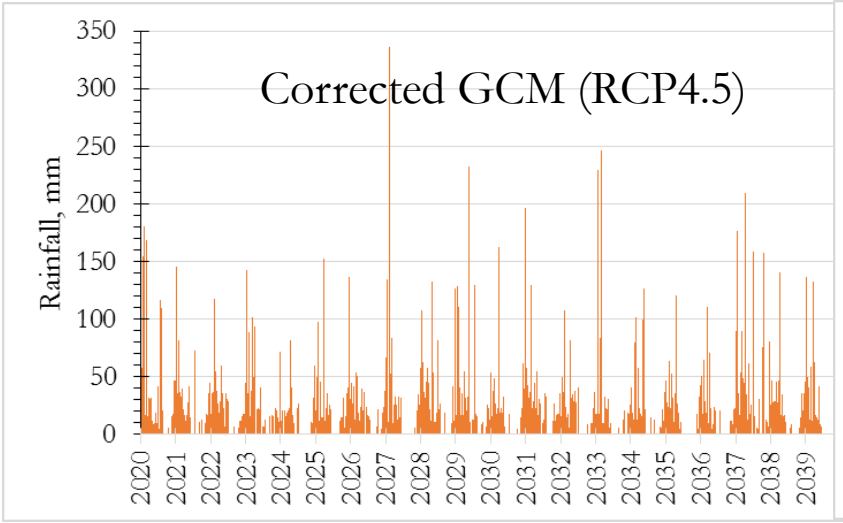


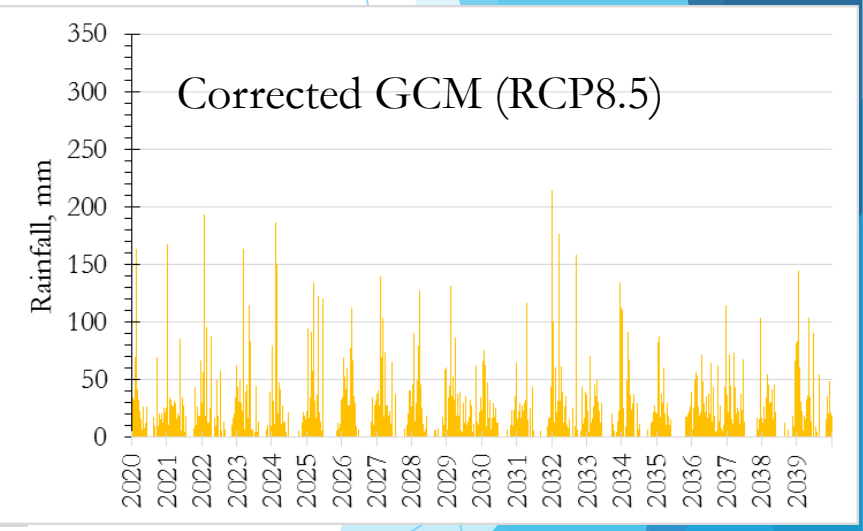


Results

Comparison of current (observation) and future bias corrected GCM daily rainfall over Jakarta region



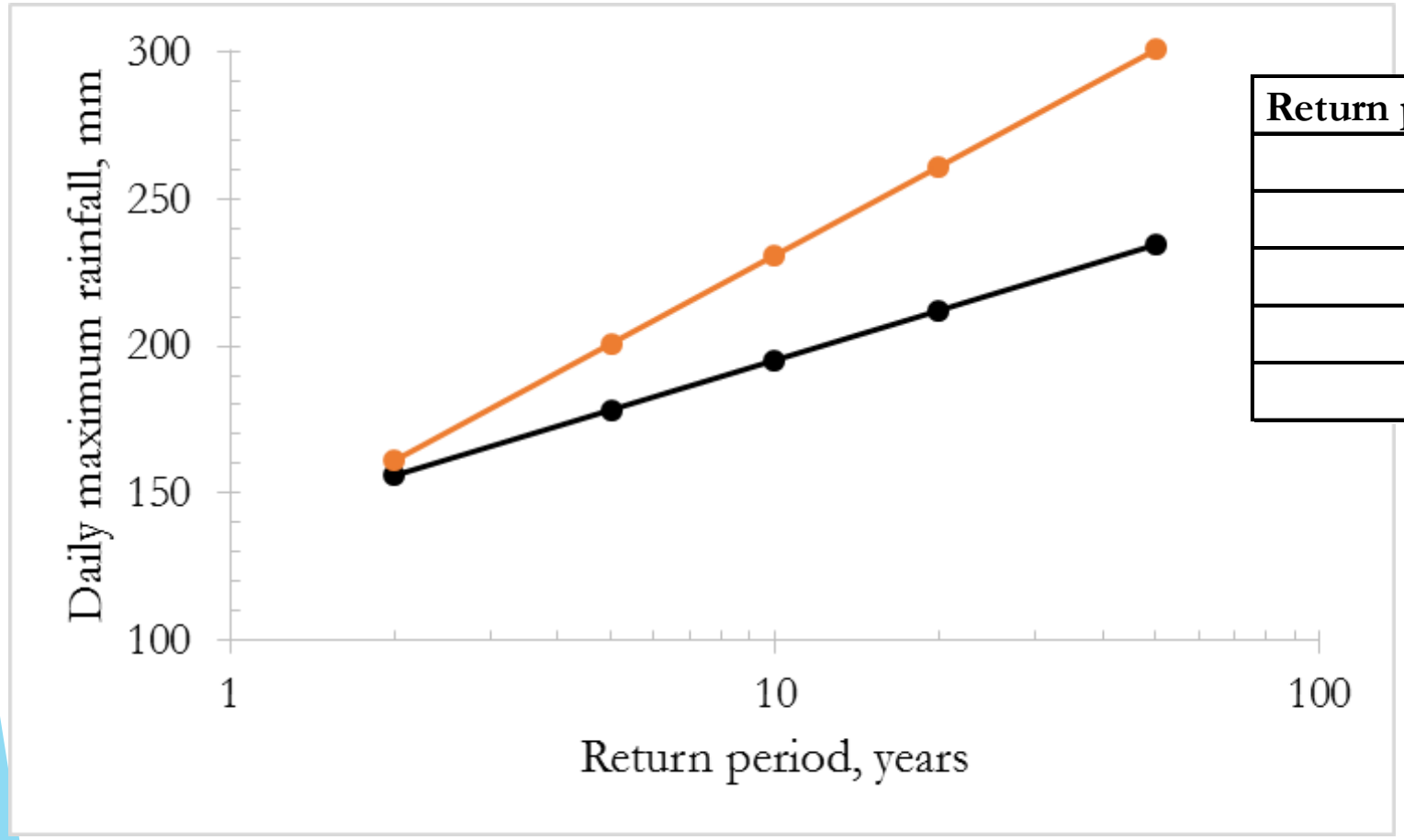




- Significantly higher peaks in GCM data
- Frequent and intense rainfall

Results

Comparison of current (observation) and future bias corrected GCM daily rainfall over Jakarta



Return period, yrs	Present	Future	Increase (%)
2	155	161	3
5	178	200	12
10	195	230	18
20	212	261	23
50	234	300	28

Conclusive remarks

- Haphazard Urbanization and Climate Change are the greatest challenges for urban flood disaster risk reduction.
- The climate projections revealed **significant increase in rainfall magnitude (intensity)** for a range of durations and return periods.
- The increase in rainfall intensity and magnitude has major implications on ways in which current (and future) municipal wastewater management infrastructure is designed, operated, and maintained.
- The **design standards and guidelines** currently employed **needs to be reviewed** in the lights of the results of this research **to reflect the impacts of climatic change**.
- Flexible adaptive measures should be mainstreamed.