A Monte Carlo Framework to Evaluate the Benefits of Flood Warnings in an Urban Flood-Prone Polder Area, China

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1. Introduction

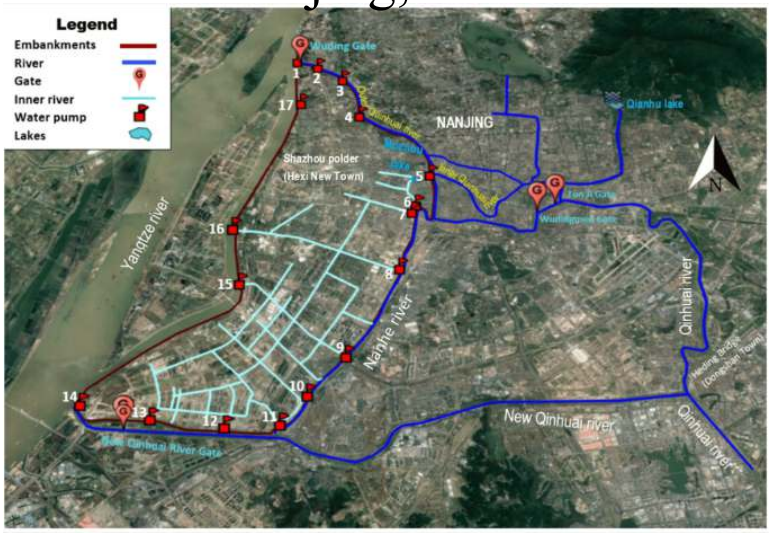
Nanjing is a city with urban flood risk due to the urbanisation of its polder areas and the increased frequency of intense rainstorms.

Source: https://www.china360online.org, Beijing and Nanjing: China's Capital Cities Resources

Urban flooding in Nanjing city on 1 July 2016

Wang et al. (2020).Cities: https://doi.org/10.1016/j.cities.2020.102884

Shazhou polder (Hexi New Town), Nanjing, China



Duque et al. 2023, Hydrology: https://doi.org/10.3390/hydrology10120238

1. Introduction

Principles of how a FEWS can monitor and warn in a flood-prone polder area

Reactive pumping

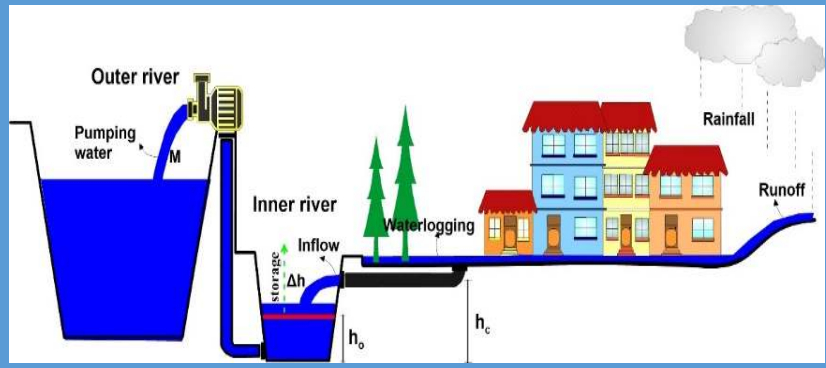
- Based on observed runoff (inflow) entering the inner rivers.
- Storage capacity defined by the level of the inner rivers prior to storm arrival.

Proactive pumping

- A FEWS can provide time in advance to pump.
- Increase the storage capacity prior to storm arrival.
- Decrease the probability of the critical condition events

Characteristics of a flood-prone polder area during a storm event

- Poor drainage storage
- Pumping capacity < urban drainage capacity



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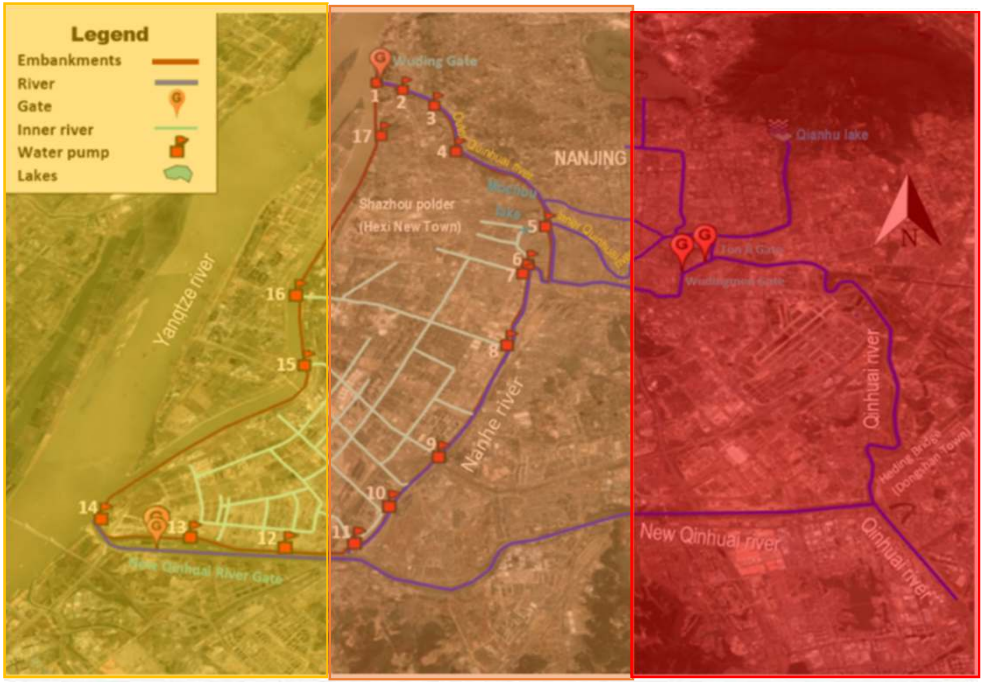
1. Introduction

Colour-coded rainstorm warning system in Mainland China (based on forecasts)

Colour	Meaning
Yellow	Rainfall exceeds 50 mm in 6 h and is likely to continue
Orange	Rainfall exceeds 50 mm in 3 h and is likely to continue
Red	Rainfall exceeds 100 mm in 3 h and is likely to continue

Wang et al. (2020).Cities: https://doi.org/10.1016/j.cities.2020.102884



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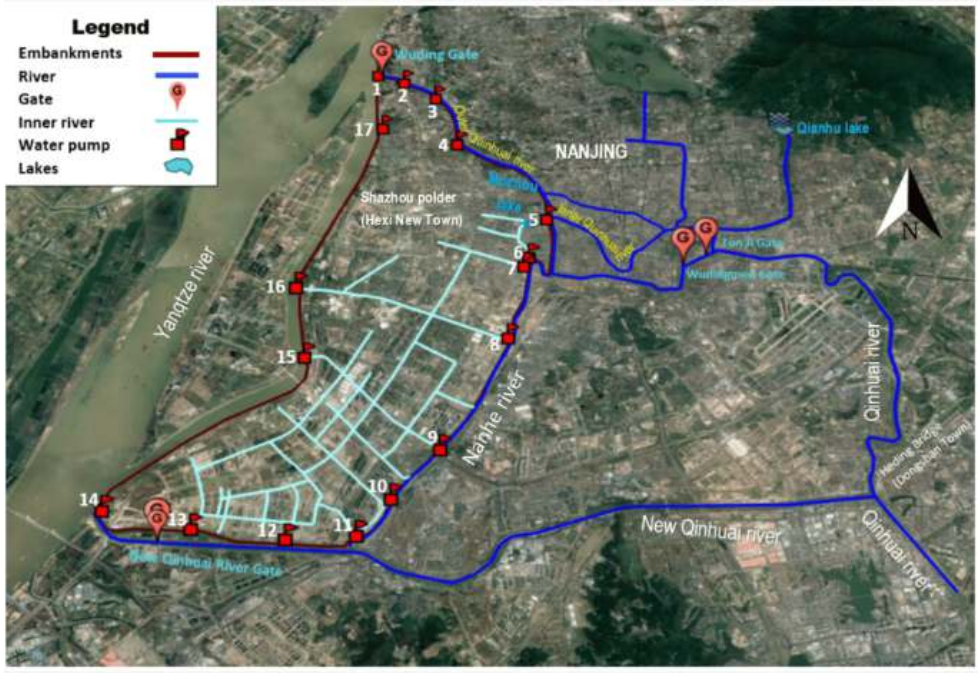
Even though the existing colour-coded-based storm warnings in Nanjing, polders are in practice operated in reactive mode!

2. AIM

To demonstrate the use of flood forecasts and warnings in the operation of a polder system to mitigate urban flooding.

Reactive pumping => Proactive pumping

Case study: Shazhou polder (Hexi New Town), Nanjing, China



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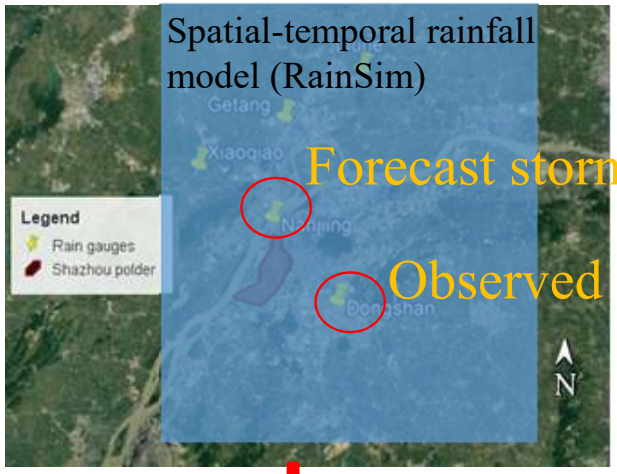
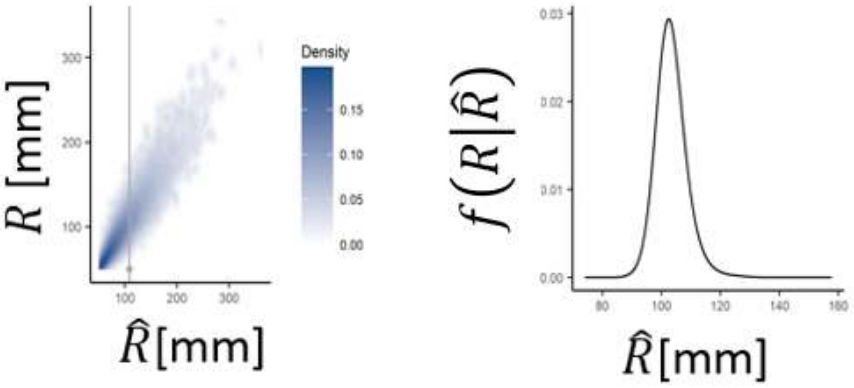
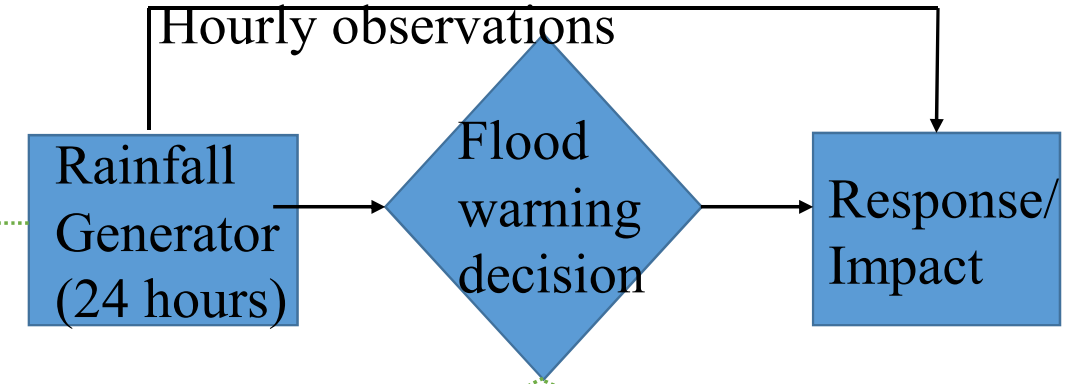
3. FRAMEWORK



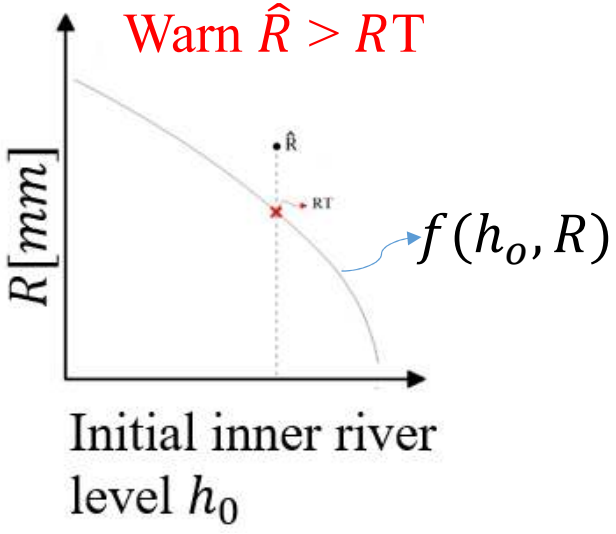
Joint distribution of R and $\hat{R}$





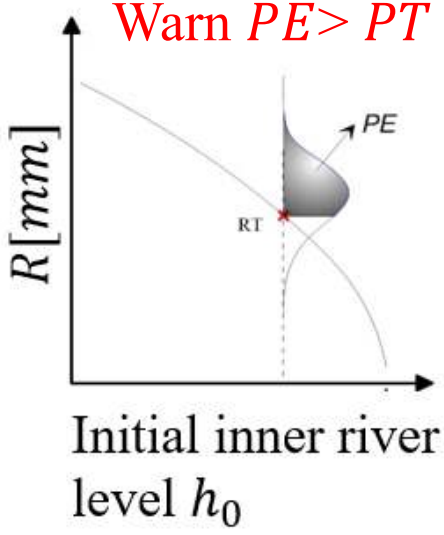
Deterministic

Warn $\hat{R} > RT$



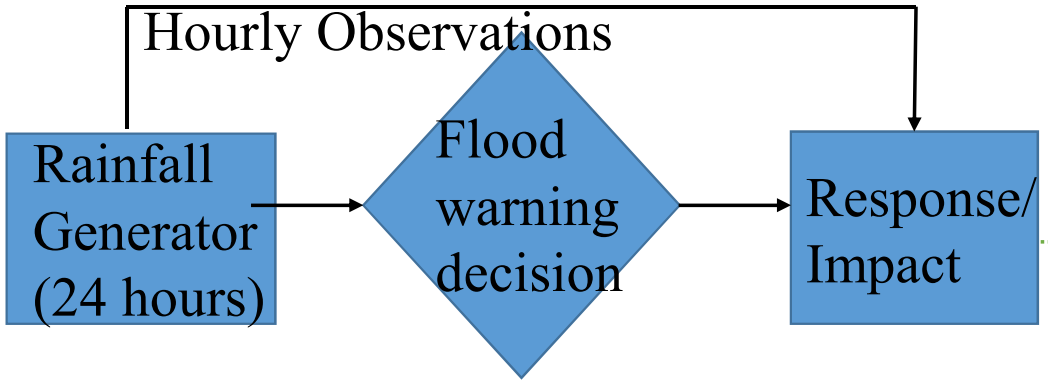
Probabilistic

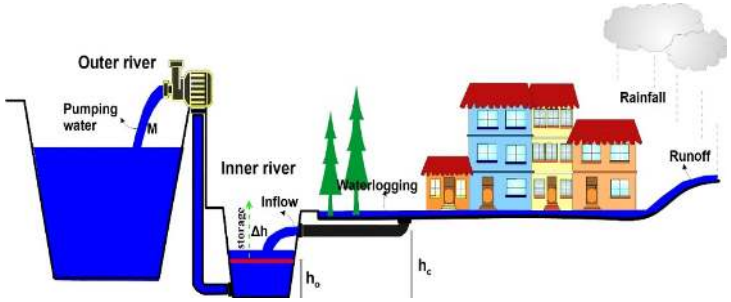
Warn $PE > PT$



RT based on past events

3. FRAMEWORK





Forecasting Scenario=
proactive pumping + reactive pumping

Metrics computed based on 8730 daily rainfalls of July

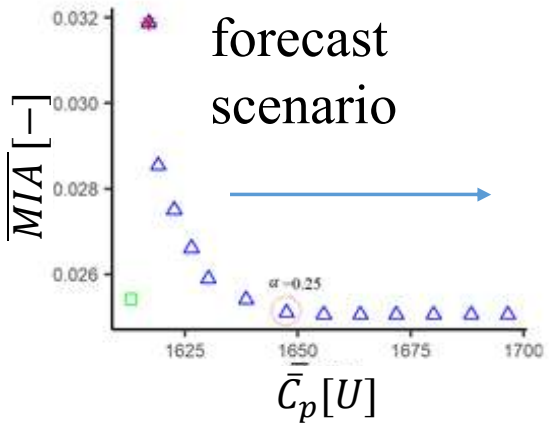
Metric	Meaning
$\overline{MIA}$	Average Maximum Inundated Area
$\overline{D}_w$	Average waterlogging duration
$\bar{C}_p$	Average Pumping costs

Parameters to be explored

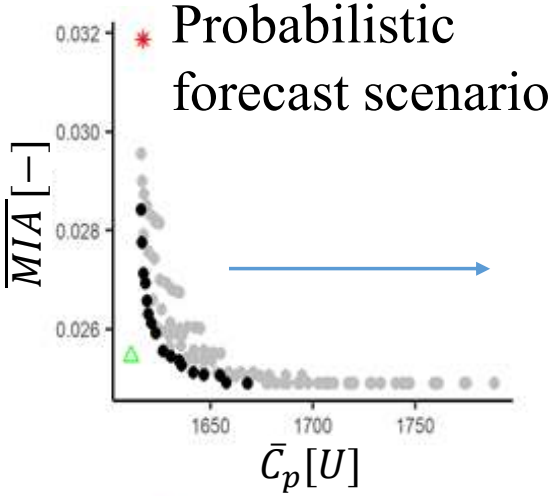
Scenario	Parameter	Range
Deterministic	α	0-0.5
Probabilistic	α, PT	α=0-0.5 PT=0.1-1

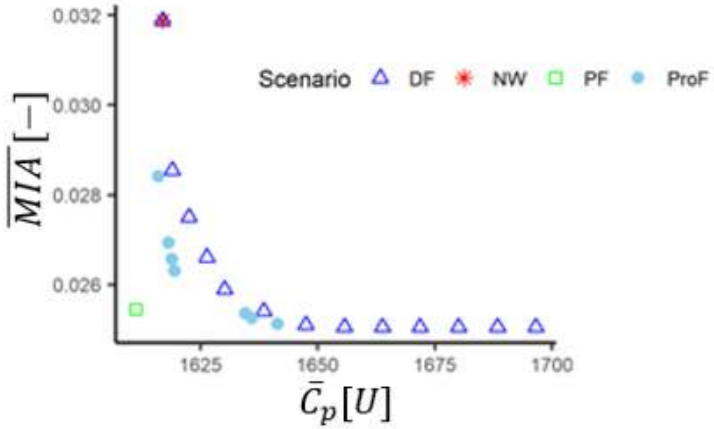
4. Results

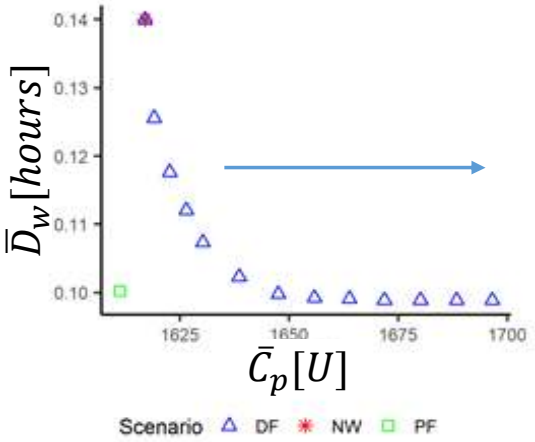
Deterministic forecast scenario

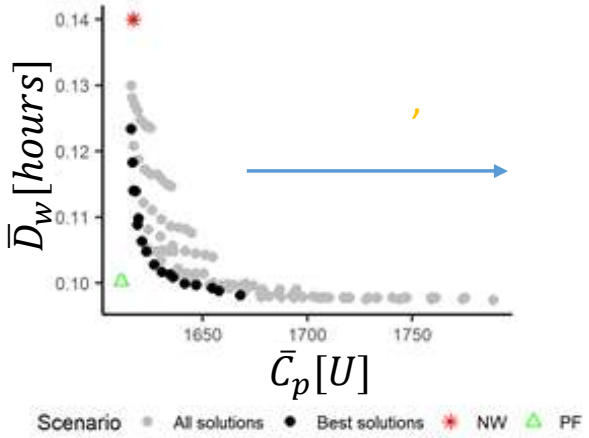


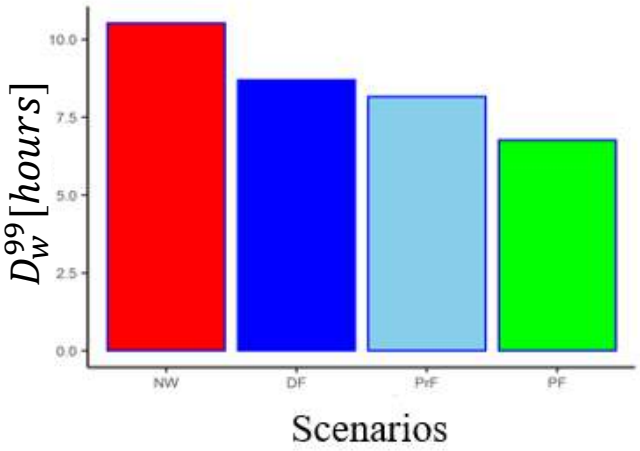
Probabilistic forecast scenario











5. Conclusions and future work

- Monte Carlo simulation can be used to evaluate flood warning systems in flood-prone areas.
- It includes design principles for flood warnings in polder regions.
- The operation of polder based on forecasts (proactive actions) improve the current situation, with probabilistic forecasts performing better than deterministic.
- A Pareto curve shows trade-off between flooding metrics, allowing a polder manager to choose an operating strategy that meets a stated objective.
- The framework assumes stationarity in forecast performance; future work should examine how future change in rainfall and flood extremes affect this.