

Reparametrizing rainfall generators with convective-permitting models to generate high-resolution rainfall for climate impact studies

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1. Introduction



Source: Google

- Changes in many extreme weather and climate events have been observed since about 1950.
- In urban areas climate change is projected to increase risks from extreme precipitation, inland and coastal flooding ... (very high confidence).

(source: IPCC, 2014)

1. Introduction

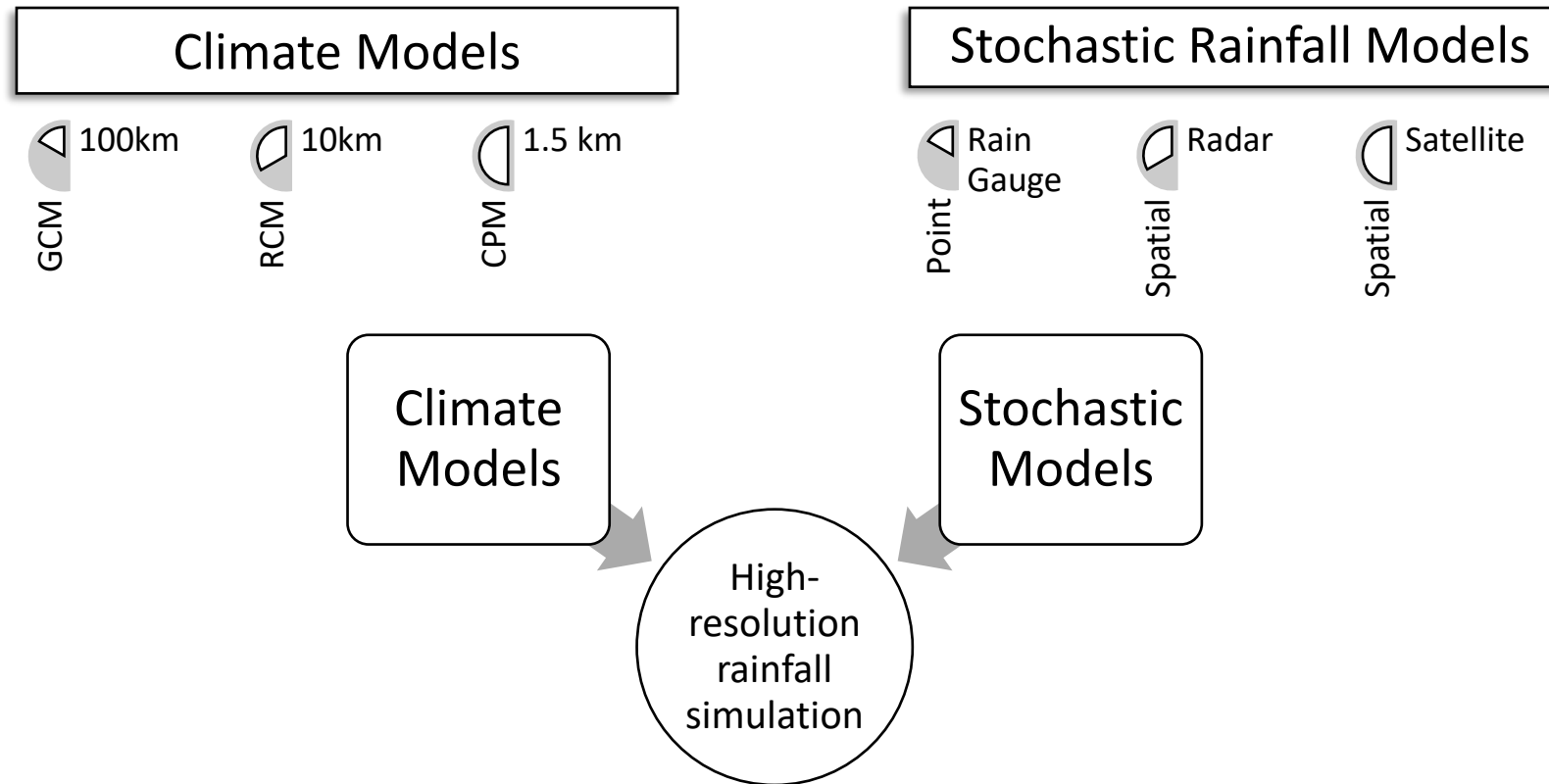


Source: https://en.wikipedia.org/wiki/2007_United_Kingdom_floods

Climate models have been widely used in the recent decade but are generally not directly applicable to estimating the future flood risk for urban catchments and drainage systems:

- We need high-resolution rainfall data at a 1km (or finer) and sub-hourly scales.
- Projected time-series of precipitation for future climates, as produced by climate models, are not long/numerous enough for reliable estimation of high percentiles of future precipitation

1. Introduction



Can we combine the information from high-resolution climate models with stochastic rainfall generators to simulate rainfall at hydrologically relevant scales (5min, 1×1km)?

2. Data and Methods

UKCP18 Local (2.2km) projections

- Convection-permitting models (CPM)
- Resolution: 1hour, 2.2km
- Period: 1980-2000, 2020-2040, 2060-2080. (RCP8.5)
- 12 ensemble members

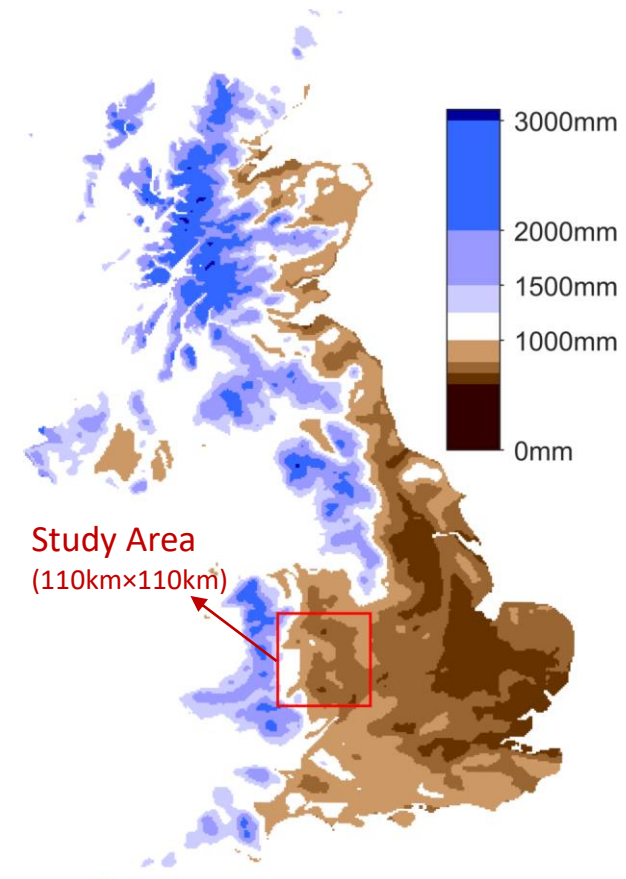


Figure 1. Annual-average CPM precipitation from 1980-2000

2. Data and Methods

Radar Observation

- 1 km Resolution UK Composite Rainfall Data (Met Office, 2003)
- Resolution: 5min, 1km
- Period: 2008-2018

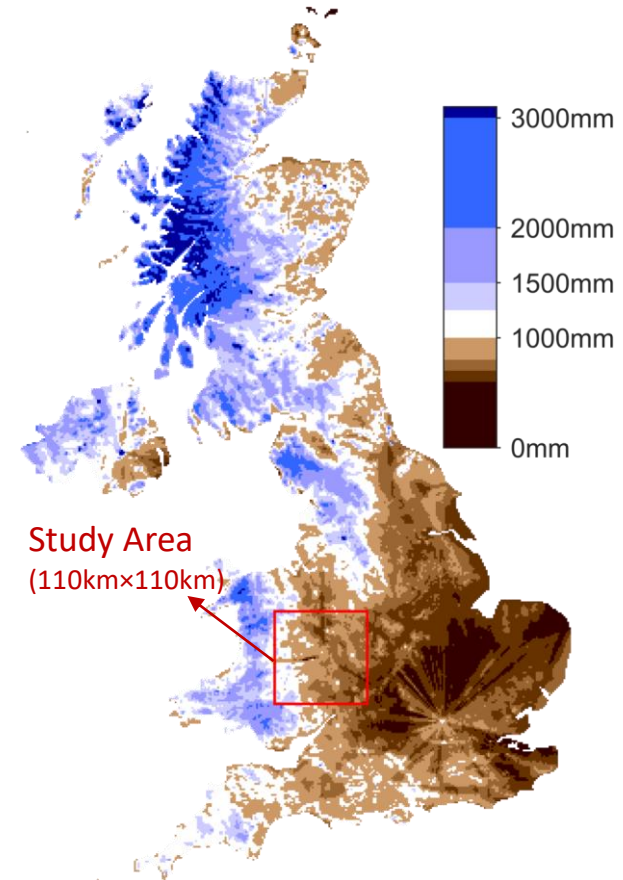


Figure 2. Annual-average radar-derived precipitation from 2008 to 2018, where missing data is excluded

2. Data and Methods

- **Stochastic rainfall generator**

Tool development is based on:

STREAP model (Paschalis, 2013)

Space-Time Realizations of Areal Precipitation

The model combines well established ideas in the analysis of time series and spatial fields (spanning from point processes to multidimensional random fields).

Alteration in this version

- 1) Model adapted to a downscaling mode
 - 2) A more realistic temporal correlation
- (Added dependence of temporal correlation on its spatial scale).

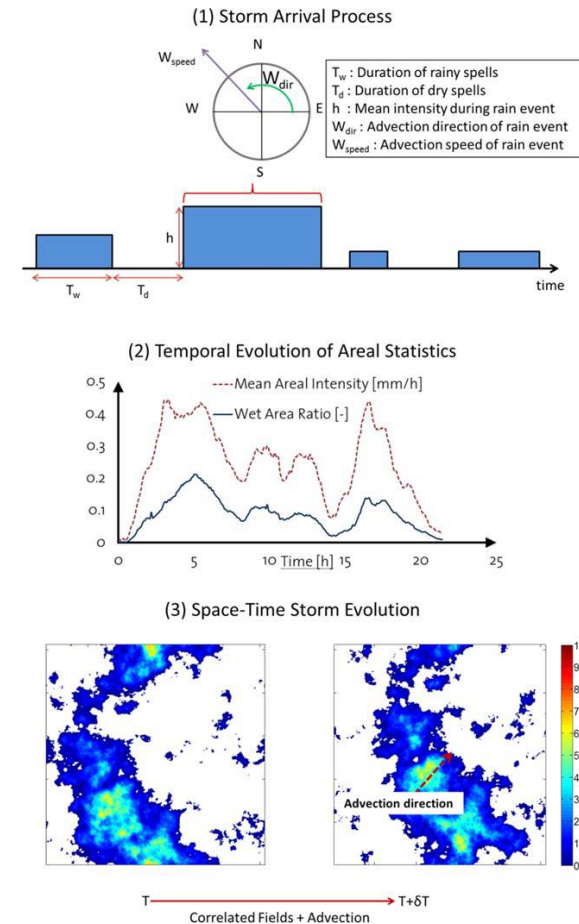


Figure *. Schematic representation of the STREAP model. (Paschalis, 2013)

2. Data and Methods

- What potential changes of rainfall properties in future projections can be included in the model?
 - ✓ Changing distribution of rainfall intensity (at both areal and point scales)
 - ✓ Changing seasonality
 - ✓ Changing distribution of wet/dry spell duration
 - ✓ Changing spatial extent of storms
 - ✓ Changing storm advection speed
- What potential changes have not been included?
 - × Changing autocorrelation of point rainfall (5min resolution)

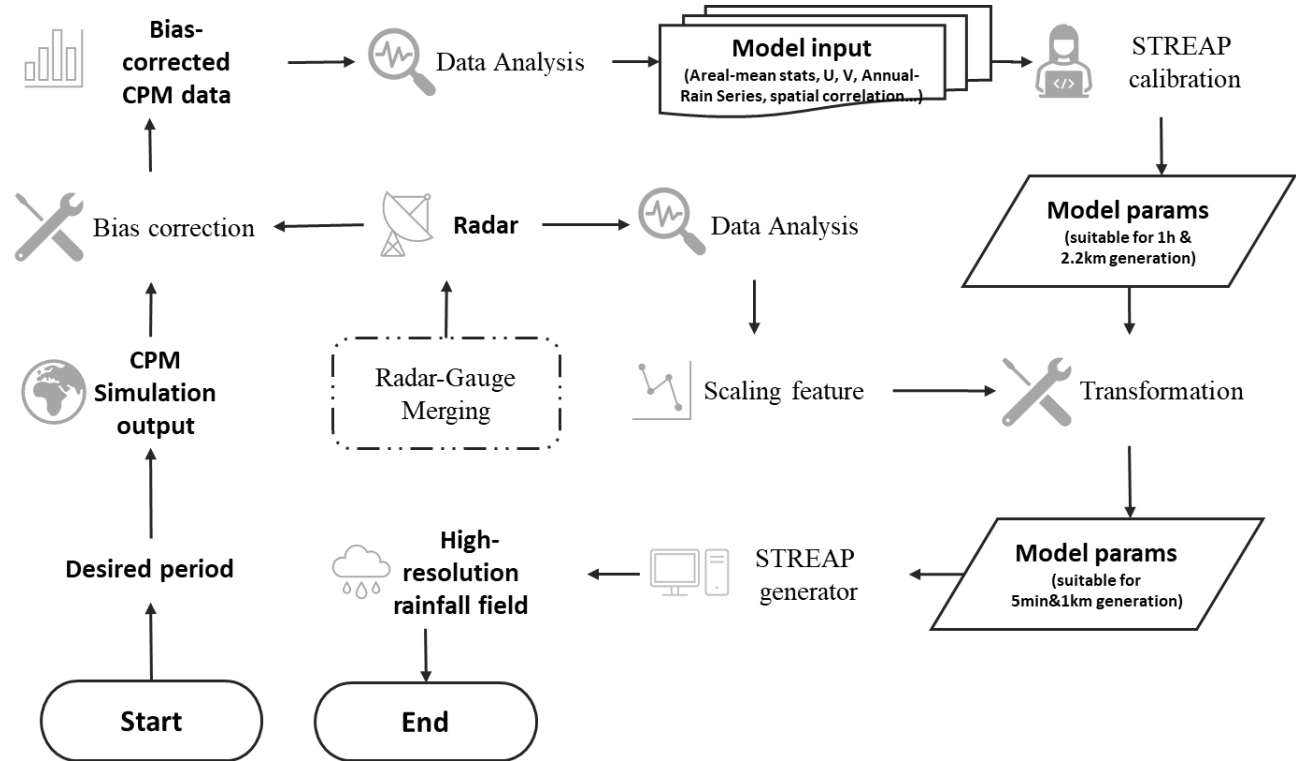


Figure 3. Flowchart of Modelling procedure

2. Data and Methods

- **Modelling procedure**

(Figure 3)

- **Modelling Period:**

CPM data in the current climate (1980-2000) is used for validating the model (by comparing the simulated rainfall with observed rainfall).

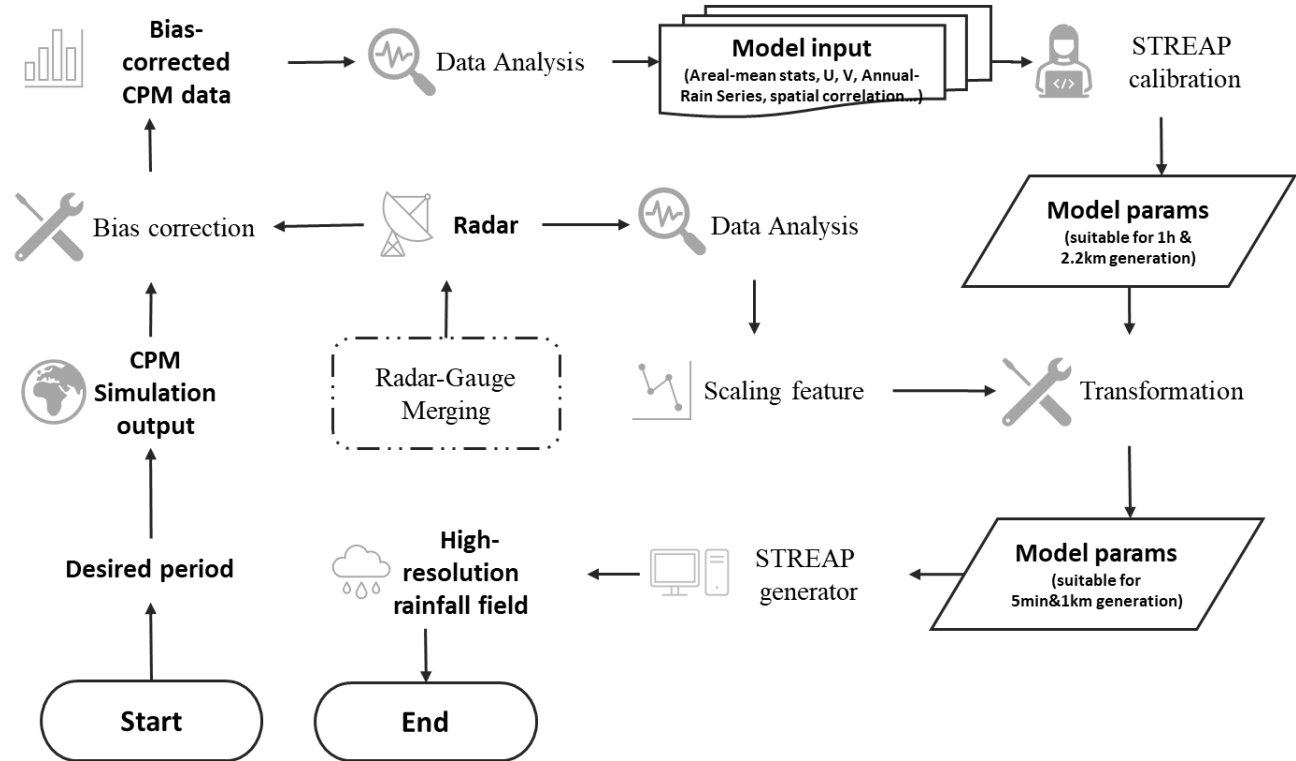


Figure 3. Flowchart of Modelling procedure

3. Model Validation

- **Model Calibration**

Based on climate data output

- **Model Generation**

- **Model Validation**

Analysis at both areal and point scales.

Comparisons of rainfall statistics of generated rainfall and radar observations

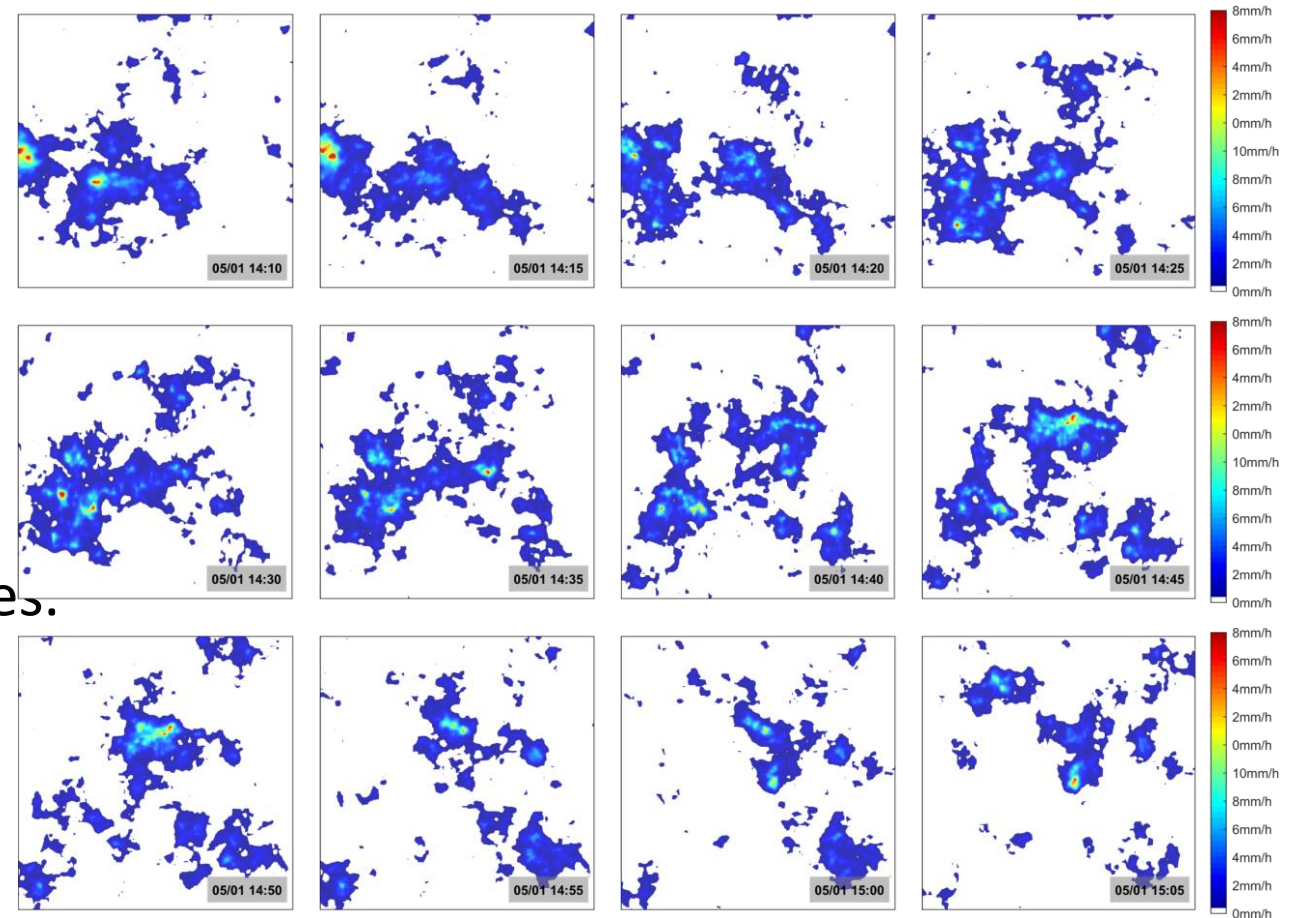


Figure 4. A series of STREAP-generated rainfall field at 5min resolution

3. Model Validation

- Evaluation at areal scale (exceedance probability)

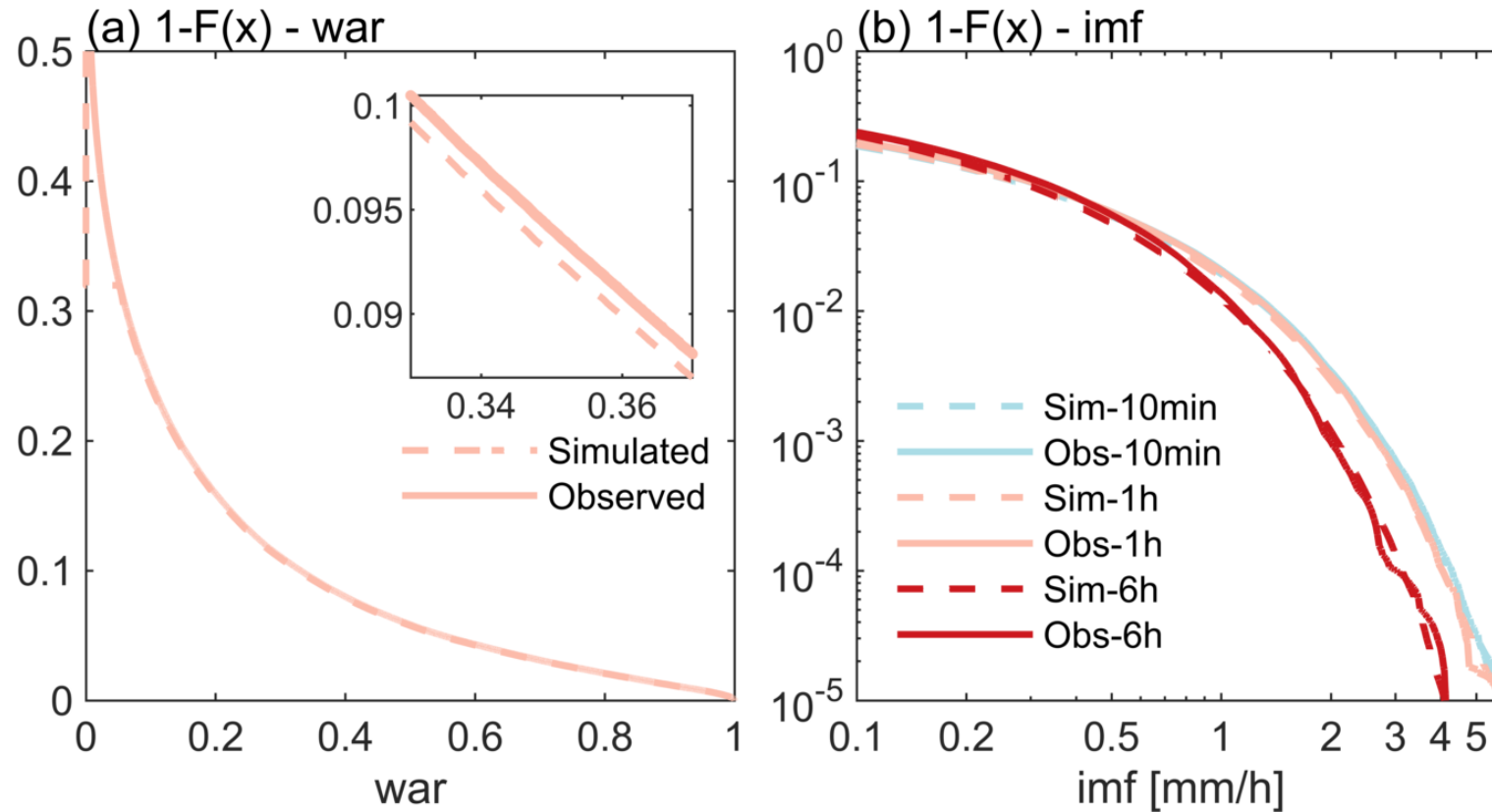


Figure 5. A comparison between observed (obs) and simulated (sim) mean areal statistics. The radar data covers 11 years (2008–2018); simulations represent the mean of 20 realizations of 11 years each.

* war: wet area ratio
imf: areal mean precipitation

3. Model Validation

- Evaluation at areal scale

(auto-correlation & cross-correlation) We simulate 5min rainfall field and then compute areal-scale time series (imf series, war series) at different aggregation levels (10min, 1h, 6h).

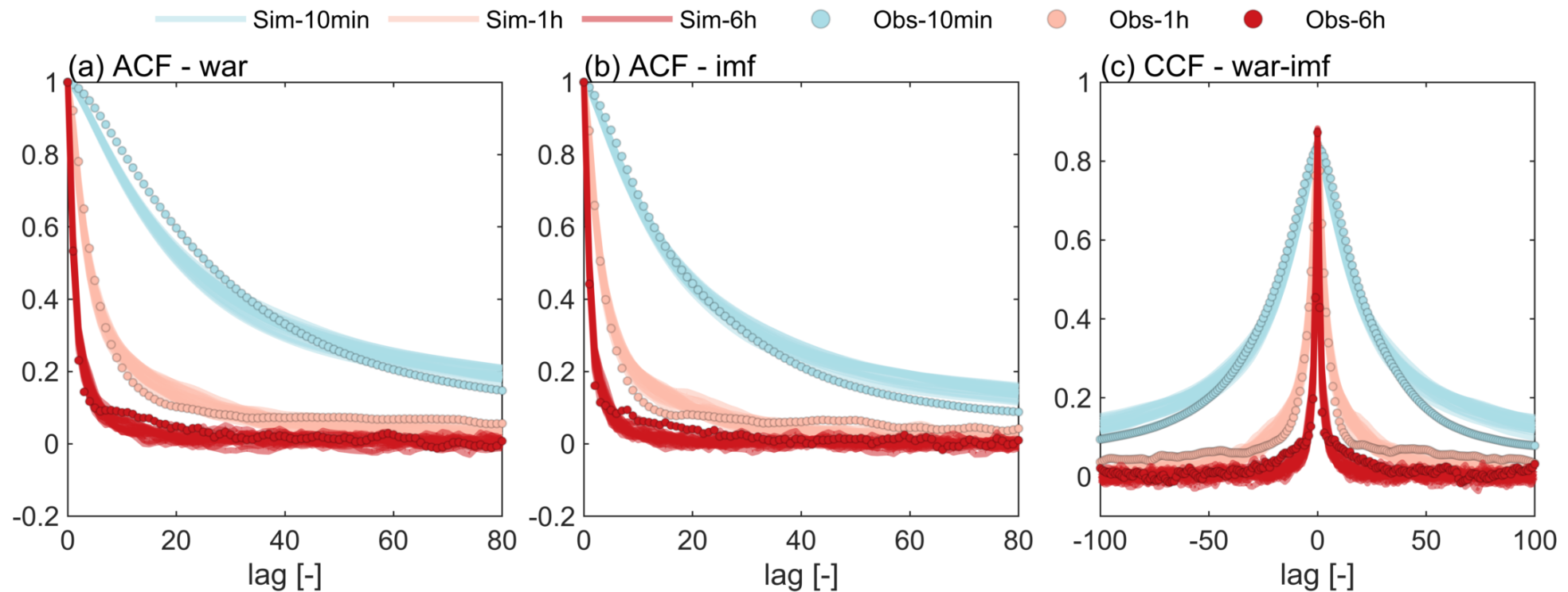


Figure 6. A comparison between observed (Obs) and simulated (Sim) correlation at 10min, 1h and 6h temporal scales. (a) autocorrelation of WAR series (b) autocorrelation of IMF series (c) cross-correlation between WAR series and IMF series.

3. Model Validation

- **Evaluation at point scale**

(spatial structure of rainfall intensity)

This metric (Bell, 1987) is the probability distribution of the length of an arbitrary cross section that is covered with precipitation across a radar image.

It addresses the ability of a model to simultaneously capture the spatial correlation of precipitation, the size of the generated rain cells and the distribution of the wet area ratios.

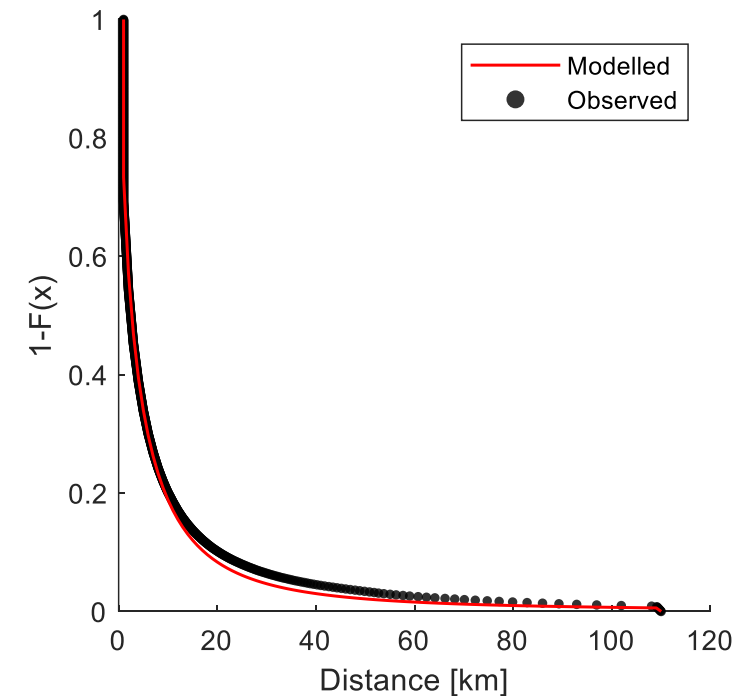


Figure 7. Exceedance probability of the length of an arbitrary cross section covered with rain for the STREAP model. Dots correspond to observation and lines to the mean value of a 40-year realization of 5min field.

3. Model Validation

- Evaluation at point scale
(auto-correlation)

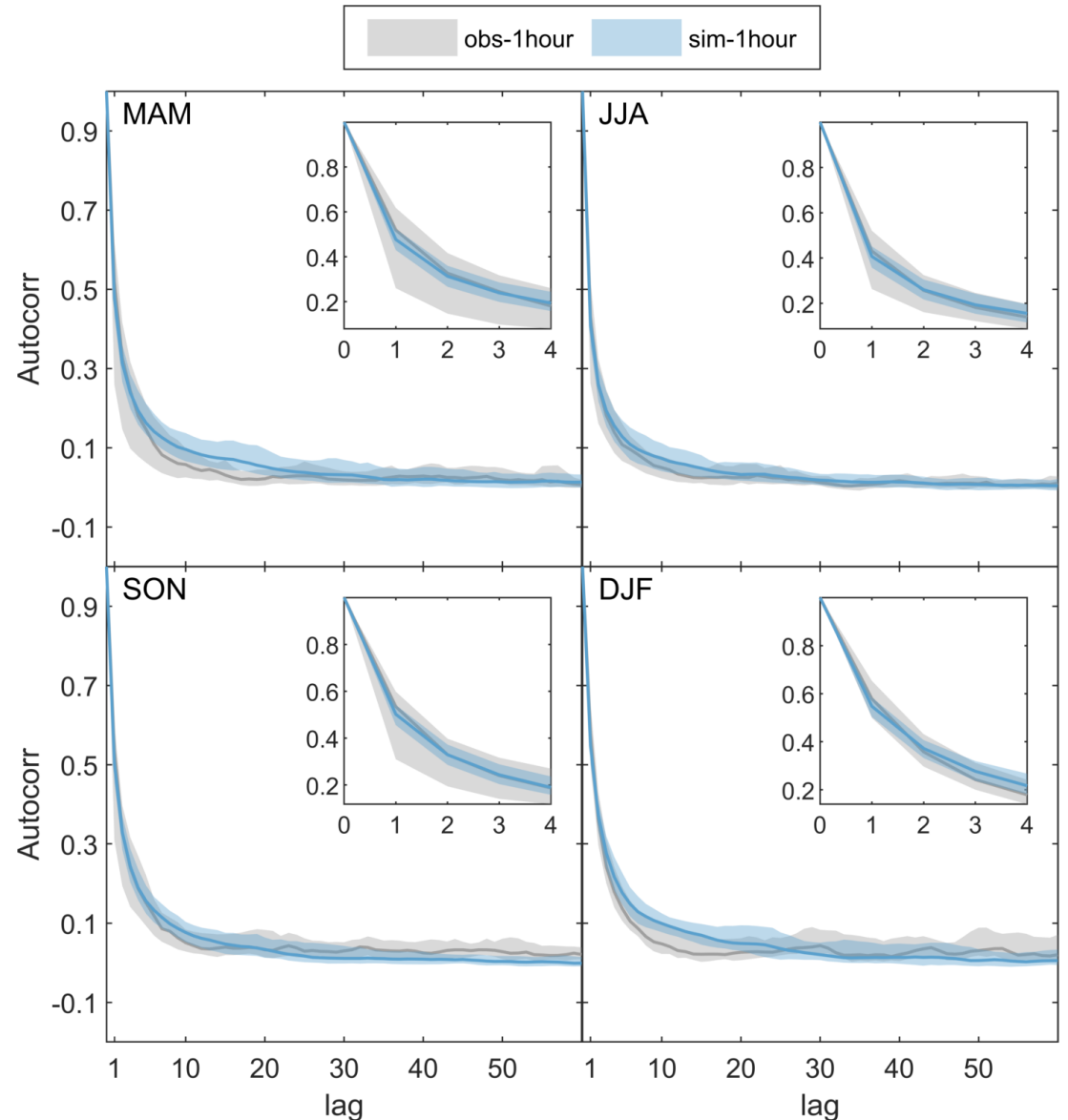


Figure 8. A comparison of observed (grey) and simulated (blue) autocorrelation of point rainfall at several random-selected locations, in different seasons

3. Model Validation

- Evaluation at point scale
(distribution of rainfall intensity)

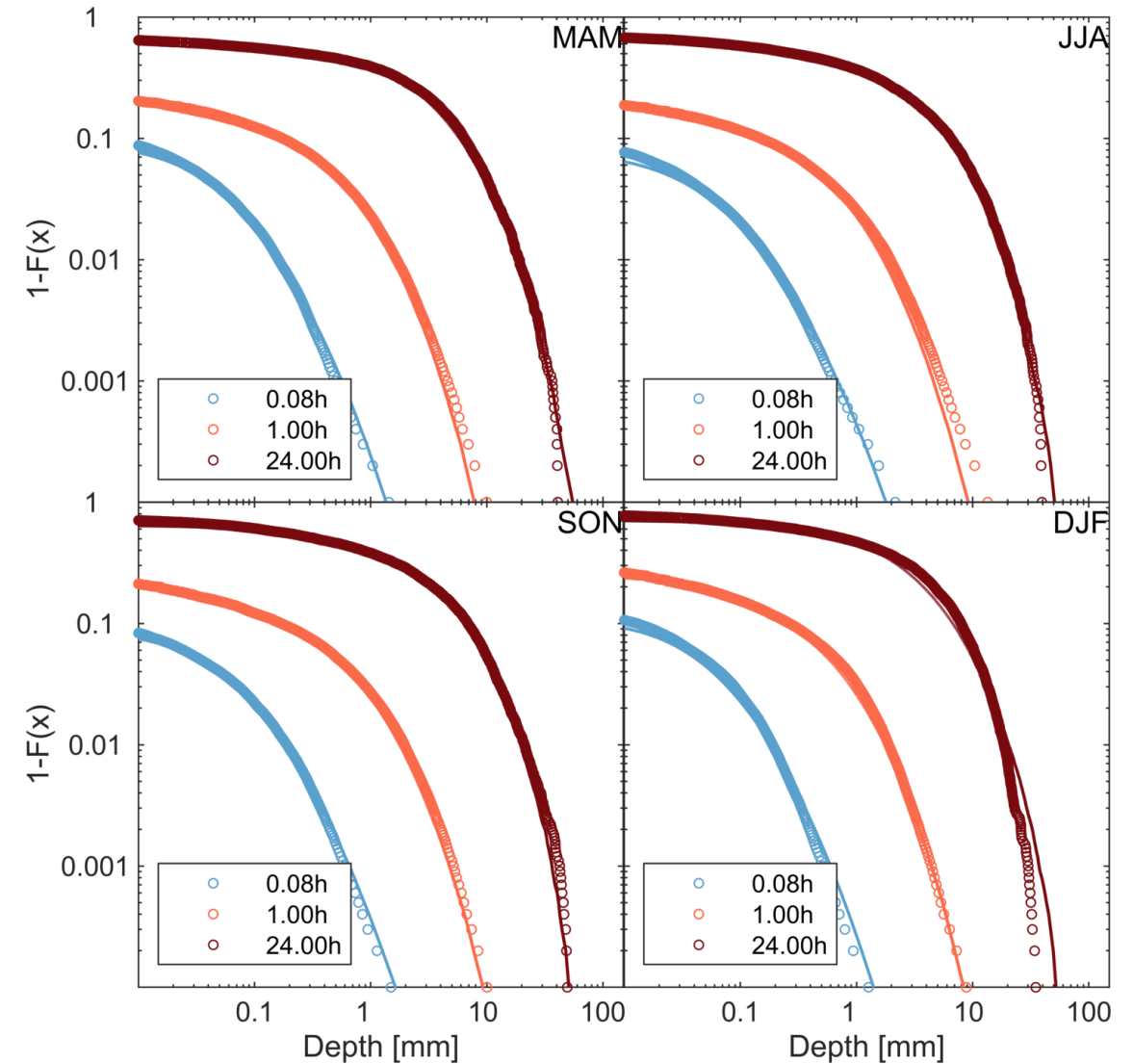


Figure 9. A comparison of observed (circle) and simulated (line) exceedance probability of point rainfall at several random-selected locations, in different seasons

4. Summary

- A well-established rainfall generator is further developed for climate impact studies
- The generator is able to simulate more and longer spatial-temporal rainfall ensembles at a higher resolution than the climate model
- The generator has been successfully validated at both areal and spatial scales.
- The computational cost of simulating rainfall is very minimal.

Computational duration: Simulating 1-year 110km×110km 5min-resolution data takes less than 15min with a PC equipped with Intel Core i7 (2.9GHz).