3rd SWITCH Scientific Meeting
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# Predicting rainfall for the city of the future

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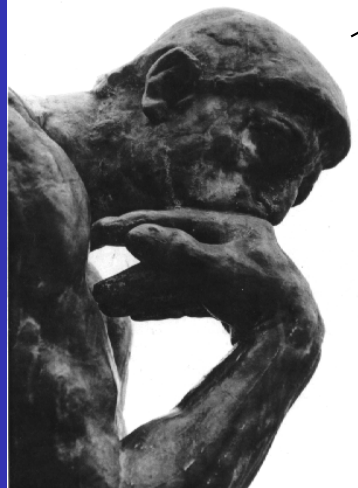
December 2008

Flood in western France
10 Mars 2008

Fullscreen Acrobat Reader

# Planning for the city of the future



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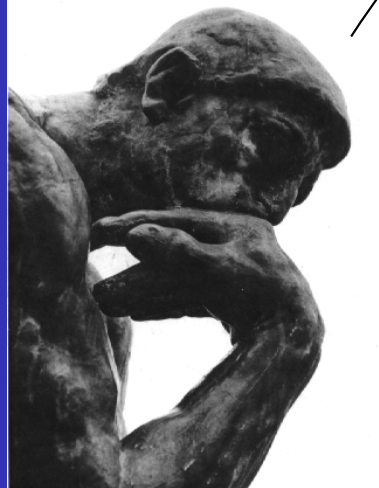
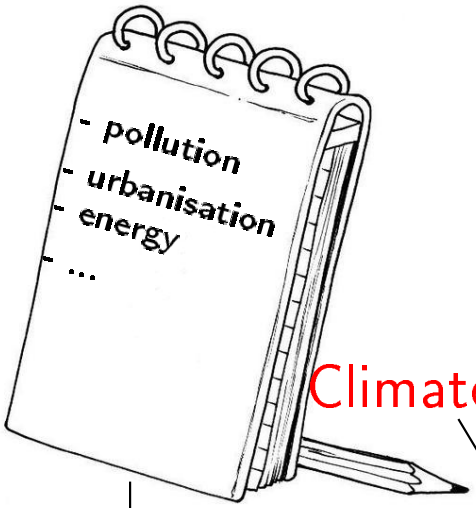


Economic crisis

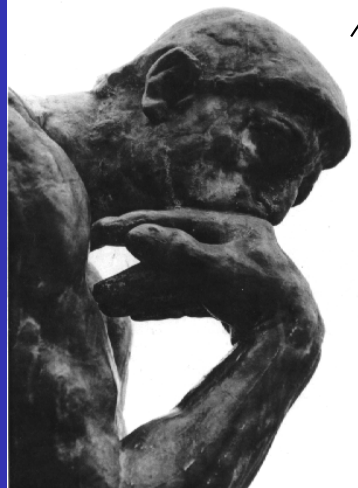
# Planning for the city of the future






Climate change

Economic crisis



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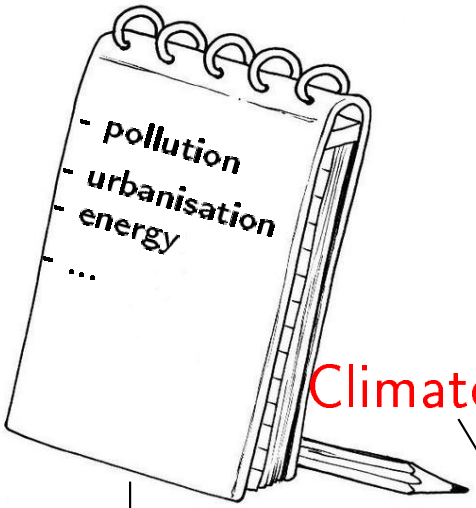


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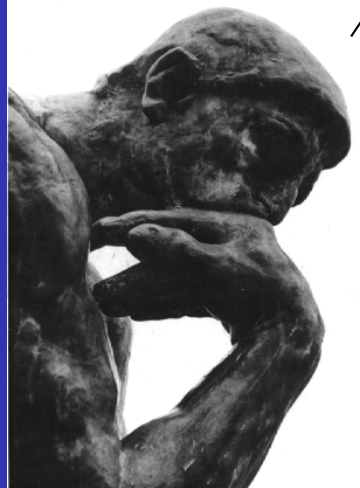

Strategies should be flexible or robust!

# Why climate change should be taken into account?



- There is now evidence that climate change may perturb global water cycle
- Climate change prediction are uncertain
- Classical stormwater managment may not be adequate (neither flexible nor adaptable)
- Alternative strategies BMP, SUDS may be more valuable

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## Objectives of the work

- Modelling rainfall for the city of the futur, taking uncertainties into account
- Using predicted rainfall series as input in a rainfall-runoff model
- Testing different strategies to mitigate impacts of climate change

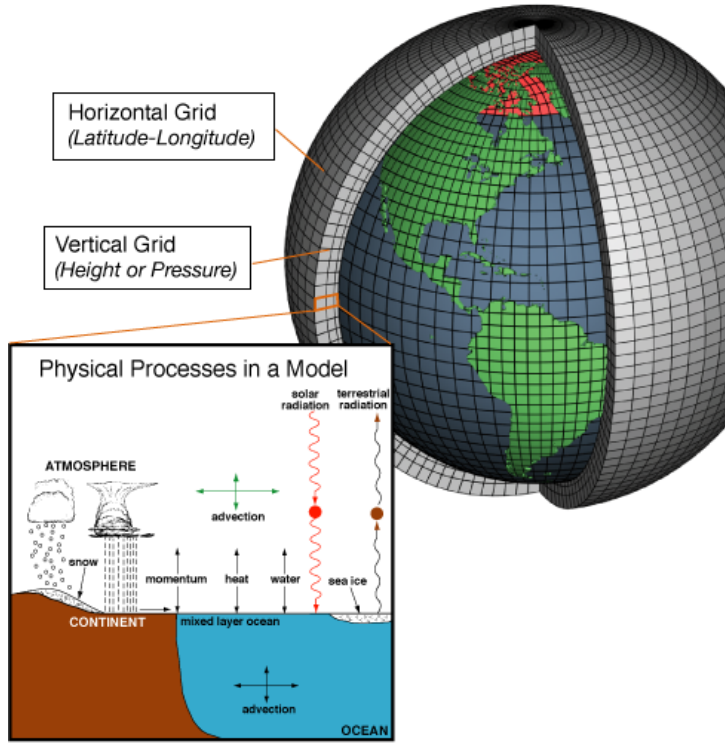
# Problem of scales!



## Global Climate Models (GCMs) prediction are coarse.

Typically:

- 2,5° latitude and 3,75° longitude
- Monthly time step

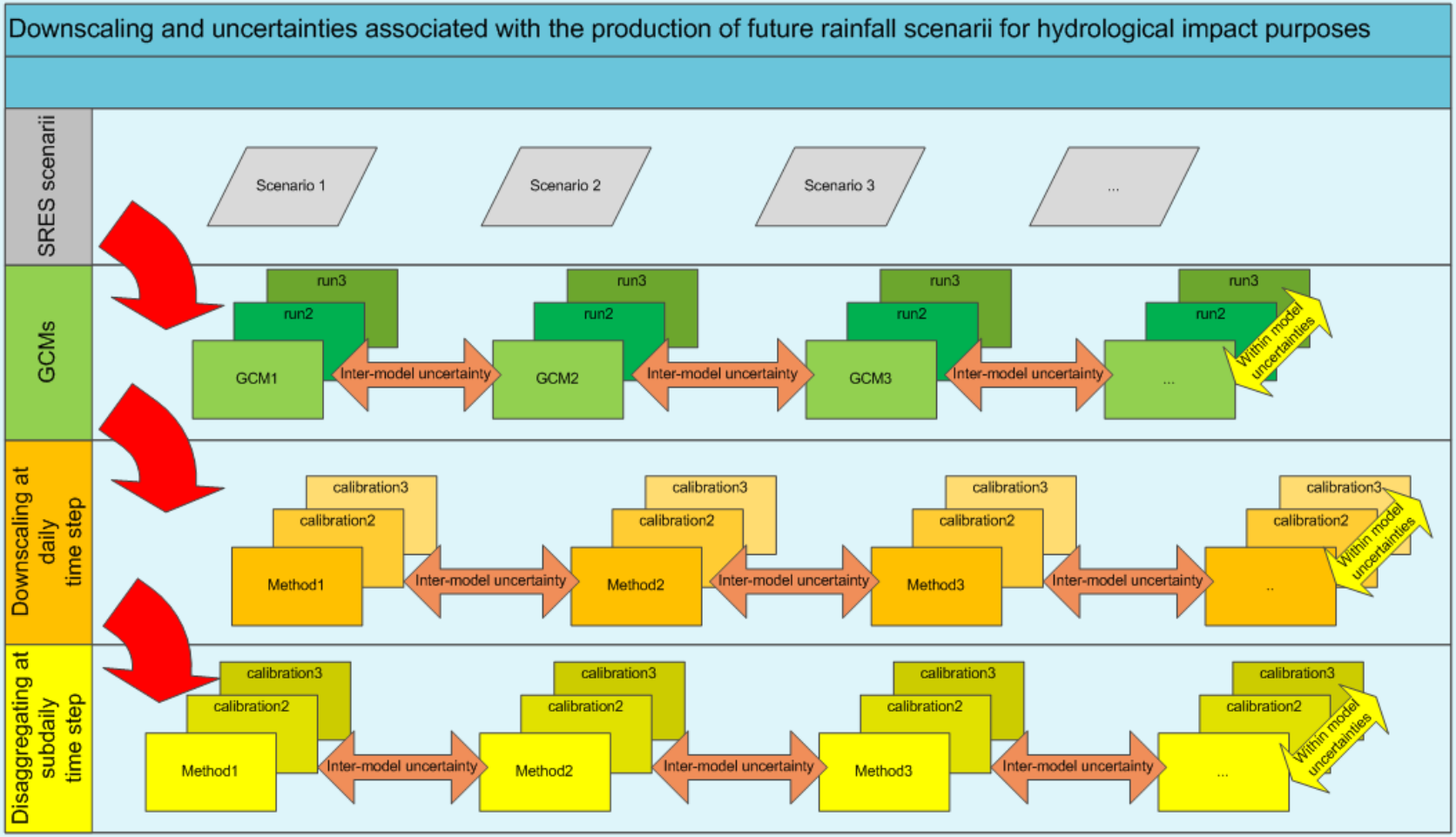



## Urban hydrology

- Spatial variability is especially important
- Temporal resolution can be 10 minutes depending on the phenomenon we want to model

# Downscaling





# Theoretical framework for producing probabilistic rainfall scenarios for the city of the future



- Approach based on the pilot methodolgy developped within the DEFRA project FD2113: "single and multi-site rainfall generation with climate model uncertainty"(ended september 2006)
- Modelling and simulation of daily rainfall time series at a single or multiple sites

## Methods

- Generalized Linear Models (GLMs) are used to downscale rainfall at daily time step from GCMs outputs
- Disagregation to hourly data is then achieved via methods based on Poisson cluster models

# Using GLMs to downscale rainfall at a daily time step (1)



Basically, GLMs derive relationships between a variable of interest, $\mathbf{Y} = (Y_1, \ldots, Y_n)^t$, called the *predictand* and a set of $p$ temporally varying predictor variables, or *covariates*, whose values can be arranged in a $n \times p$ matrix $\mathbf{X}$. The relationships between the predictand and the predictors are assumed to be given by

$$g(\mu) = \mathbf{X}\beta \qquad ; \qquad \mu = \mathbf{E}(\mathbf{Y}) \tag{1}$$

Moreover, the distribution of each $Y_i$ is assumed to belong to the exponential family. That is

$$f_Y(y; \theta, \phi) = \exp\left[\frac{y\theta - b(\theta)}{a(\phi)} + c(y, \phi)\right] \tag{2}$$

where $a$, $b$ and $c$ are some specific functions and $\phi$ is called the *dispersion* parameter.

# Using GLMs to downscale rainfall at a daily time step (2)



**Here,**

- Predictand ← rainfall series
- Predictors ← terms relating to seasonality, terms relating to the history of the series itself (autocorrelations, intensity of previous rain events...) and external covariates such as coarse-scale atmospheric variables.

# Using GLMs to downscale rainfall at a daily time step (3)



- Models are fitted using historical data (rainfall and large scale atmospheric variables derived from NCEP reanalysis) to describe relationships.
- Then, for future scenarios, one may simulate from the fitted models driven by GCM-generated atmospheric variables.
- Actually, the modelling framework is composed of two components: first, an *occurrence model* based on logistic regression is used to model the pattern of wet and dry days, and second, an *amount model* based on gamma distributions allows the simulation of rainfall amounts on wet days.
- Simulating nonstationary rainfall sequences is achieved by allowing some predictors to modulate the effect of other predictors incorporated via interactions (alternative to, e.g., fitting separate models in each month of the year).

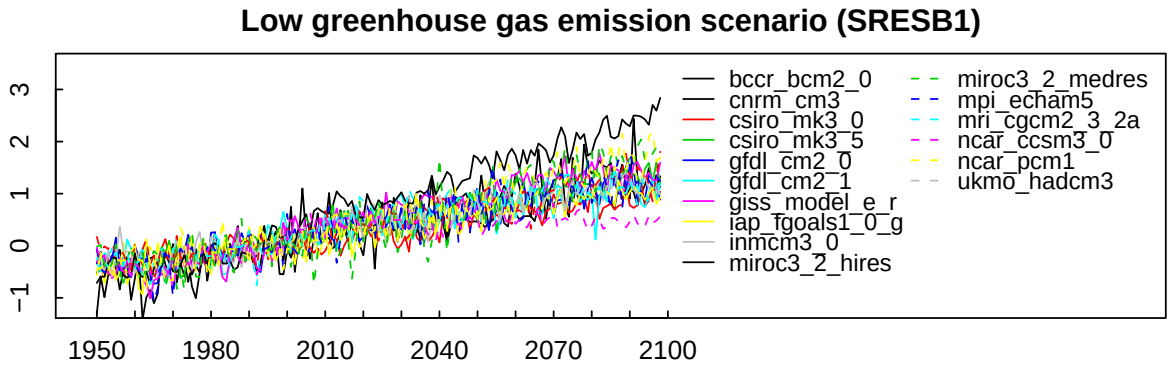
# Case study: Geneva, Switzerland

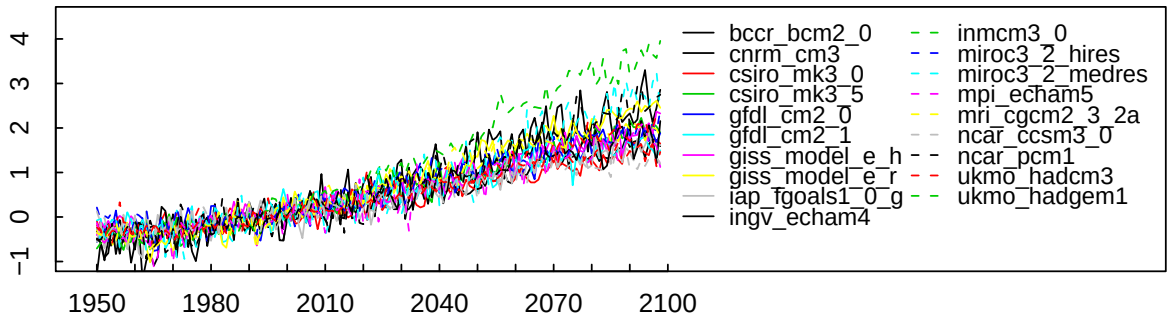


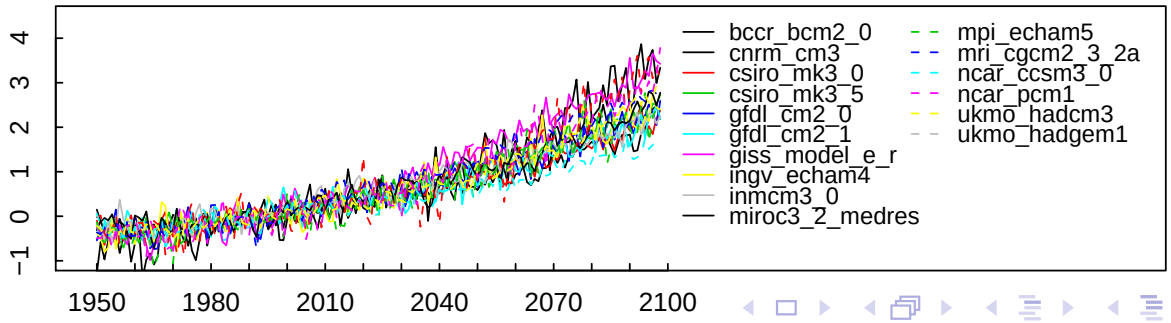
| Station | Genève-Cointrin | Genève-Aïre | Croix-de-Rozon | Jussy |
|---|---|---|---|---|
| Northings [km] | 508 810 | 498 580 | 499 480 | 495 800 |
| Eastings [km] | 120 310 | 122 320 | 111 080 | 116 900 |
| Altitude [m] | 420 | 375 | 478 | 465 |
| Data availability | 1900–. . . | 1968–. . . | 1974–2005 | 1900–. . . |
| Type | Auto. since 1980; TB before | TB | TB | TB |

# Evolution of surface air temperatures



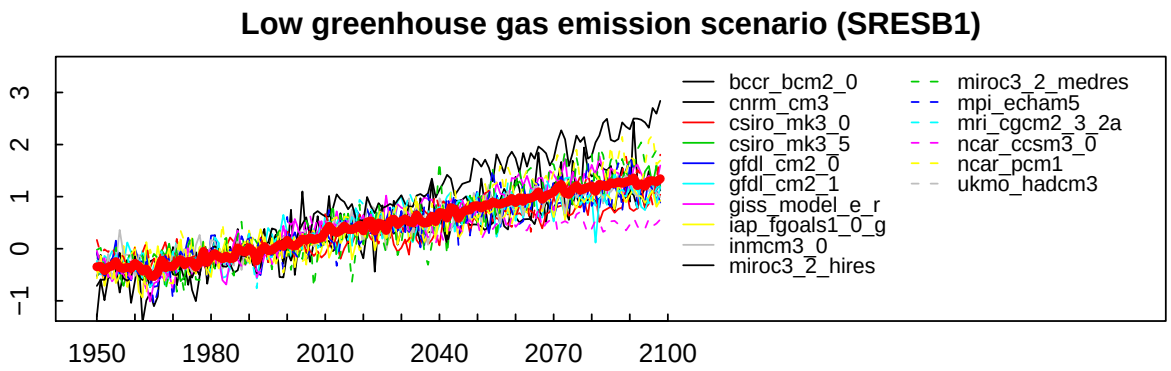


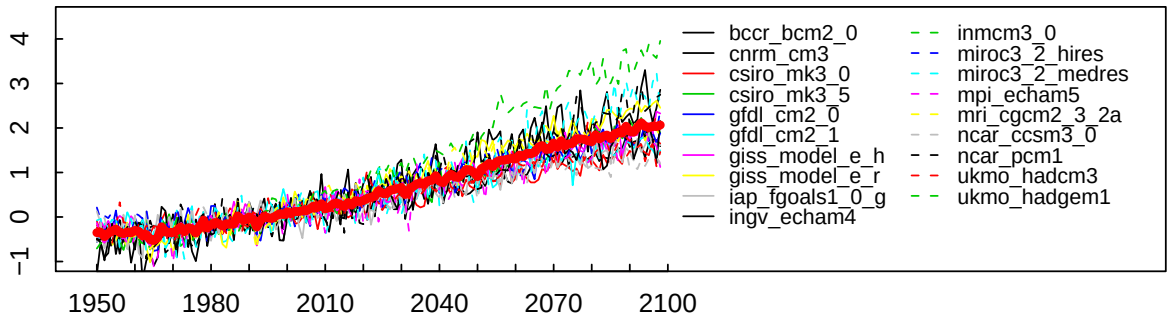



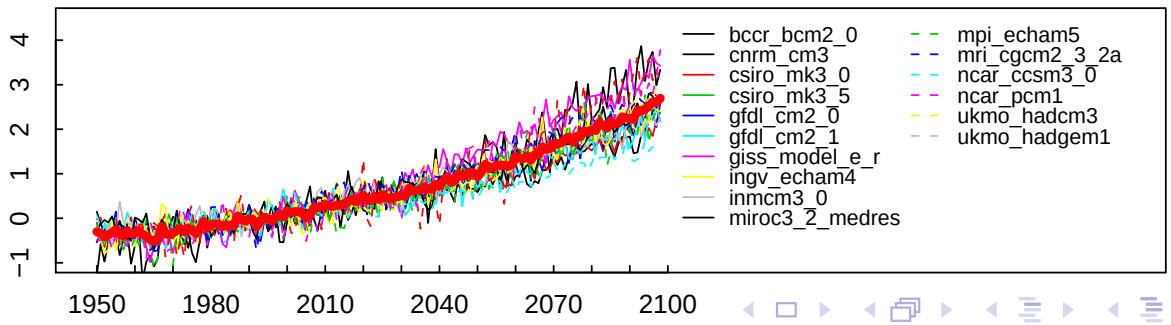



# Evolution of surface air temperatures





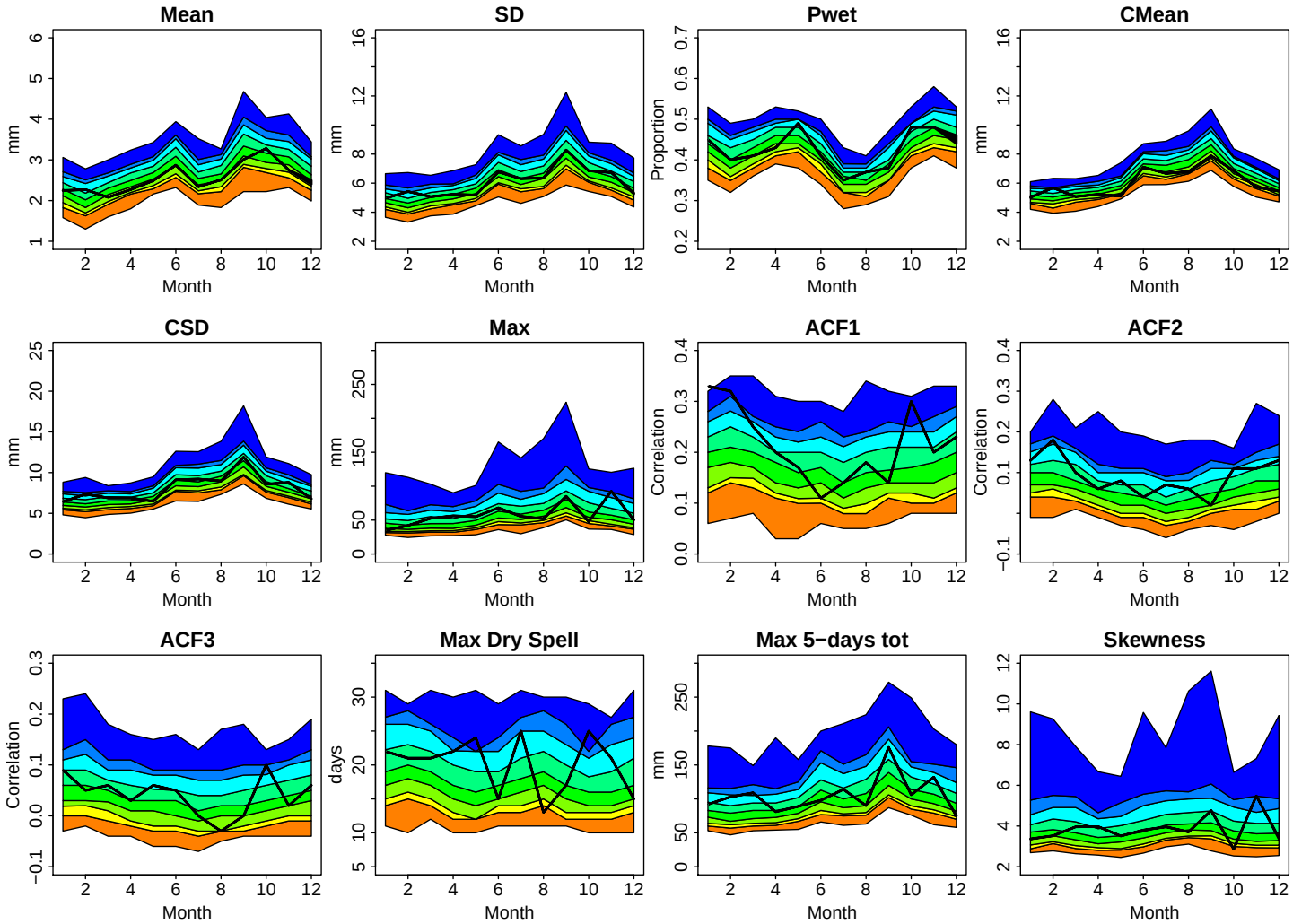
# Summary



- Models were fitted using observed rainfall series and NCEP predictors during the period 1982-2007.
- Fitting and simulations were carried out simultaneously for the all the four sites.
- Three SRES scenarios were considered: A2 (high), A1B (medium), B1 (low)
- Around 20 different GCMs were considered per scenario.
- The period 1956-1981 has been used for validation.
- The future period used for simulation is 2072-2098.

# Summary monthly statistics of 200 simulations for the site *Genève-Cointrin* during the fitting period





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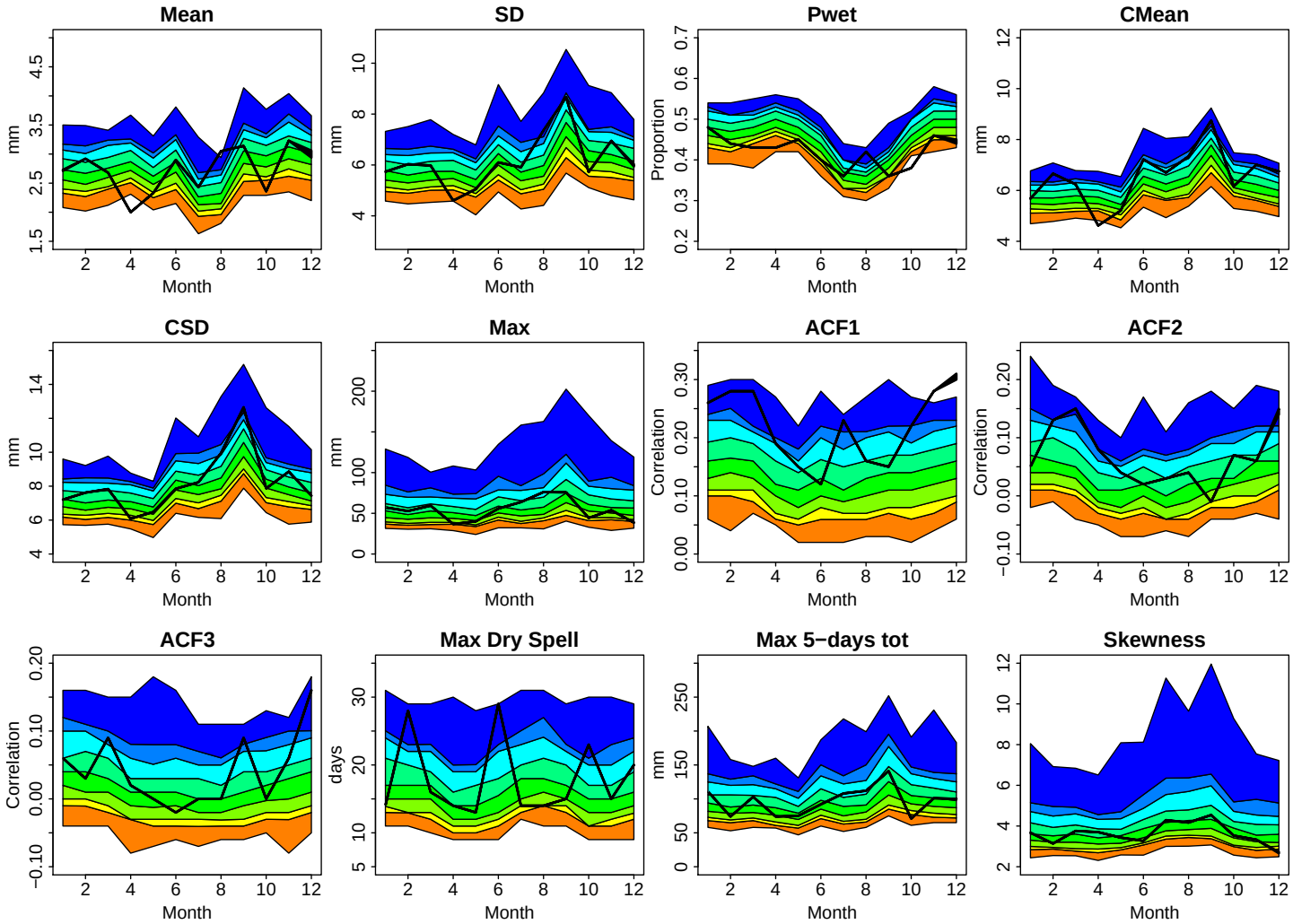
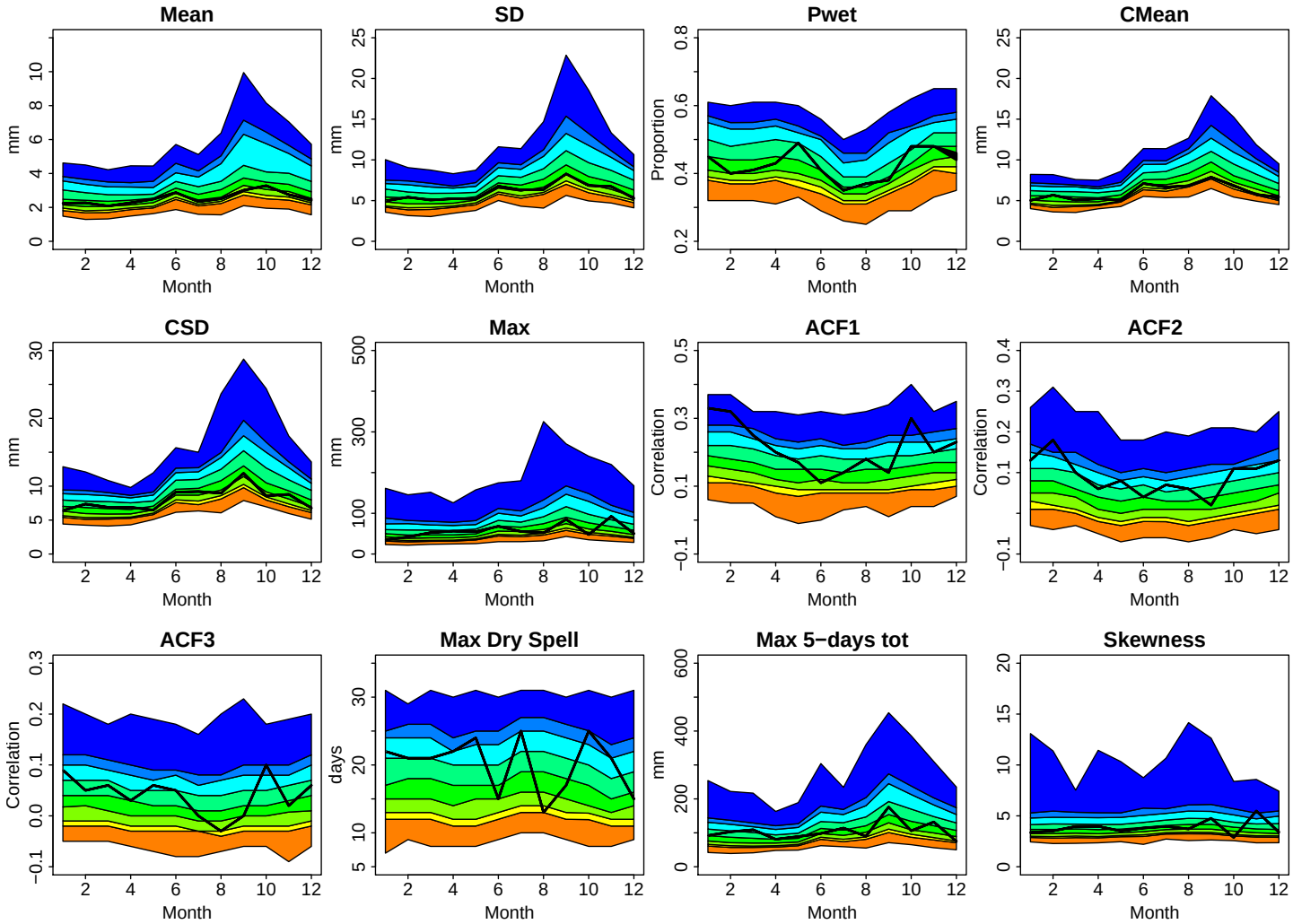


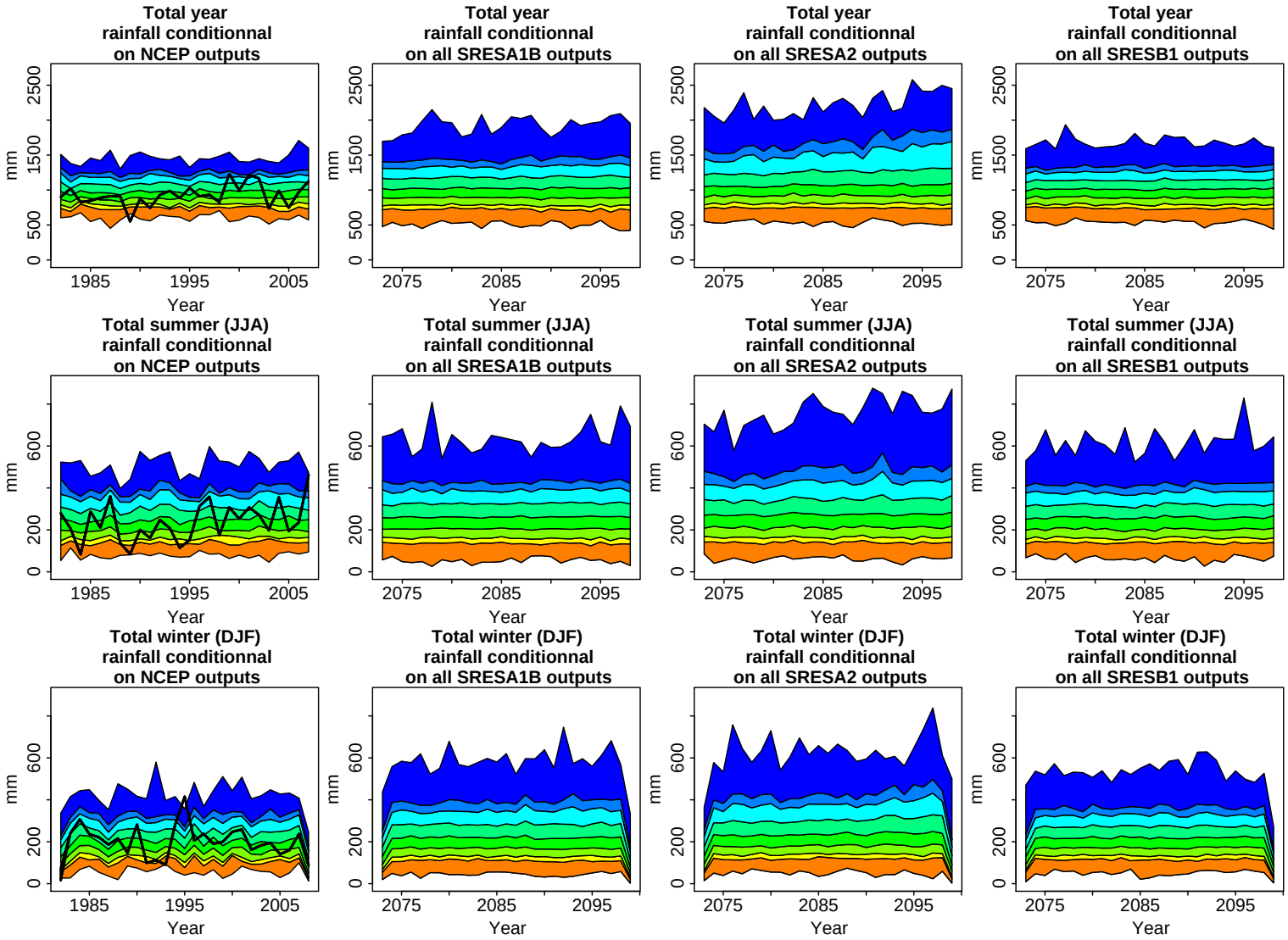
# Summary monthly statistics of 200 simulations for the site *Genève-Cointrin* during the future period (scenario A2)





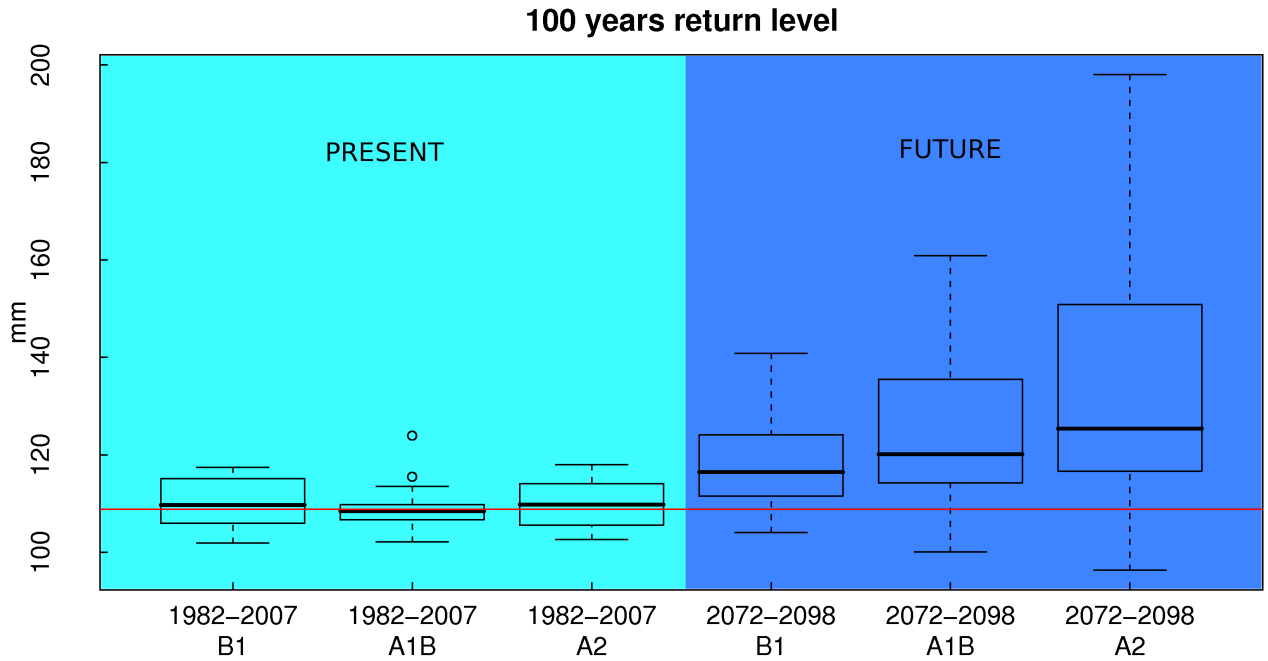
# Annual total rainfall simulated by the models





# Extreme value analysis






- Independently of the SRES scenario considered, the average forecasted 100-year return level for the future period is higher than for the fitting period.
- The higher the forcing is, the higher the average 100-year return level is (SRESB1: 117.71 mm, SRESA1B: 124.40 mm, SRESA2: 133.97 mm).

# Perpsectives



**Futur tasks**

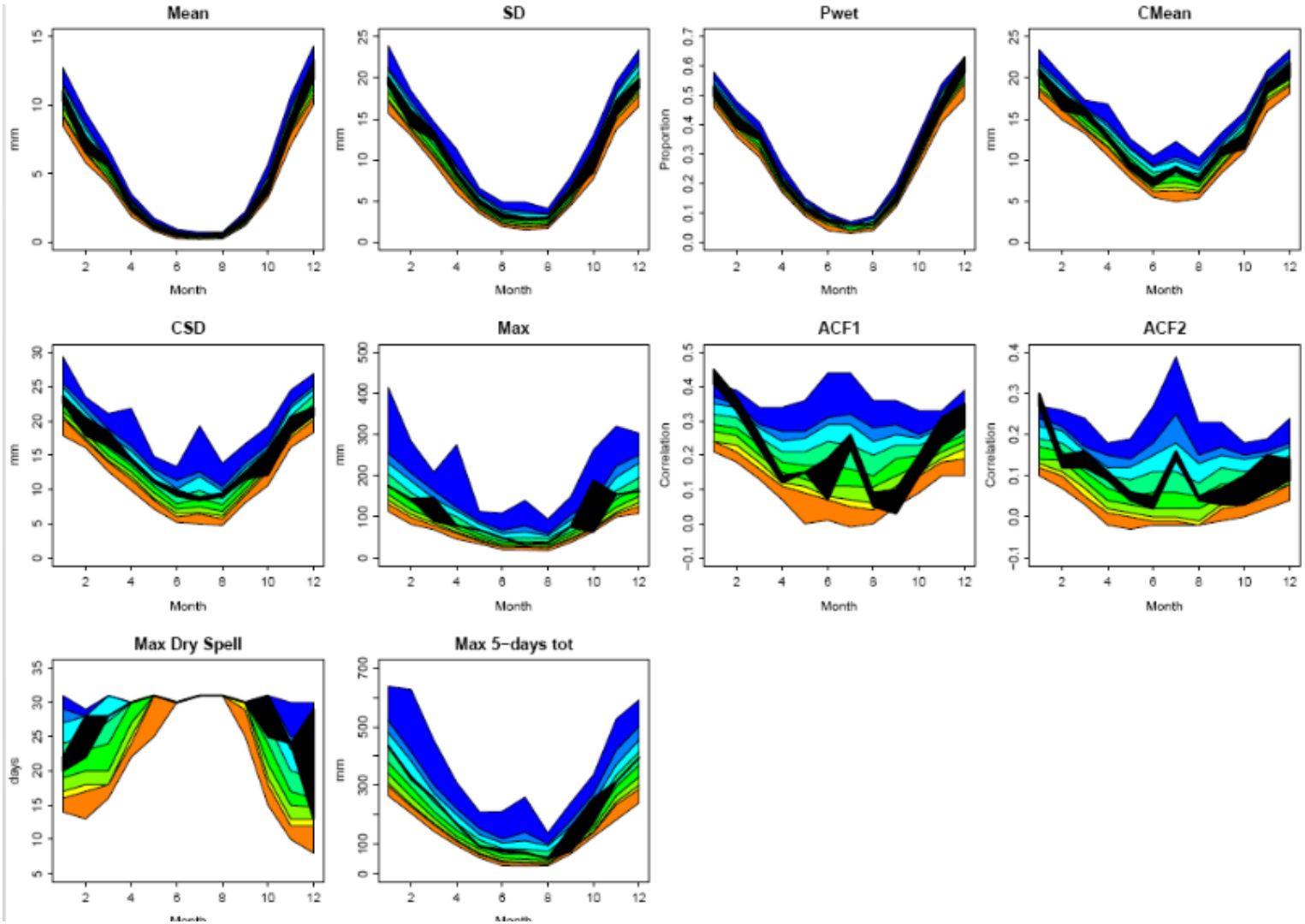
- make the methodology more robust and easy to use
- go on with subdaily simulations
- for a given city:
  - build a detailed rainfall-runoff model
  - assess impacts of perturbed rainfall sceanrios on stormwater mangement
  - quantify these impacts against other potential threads (population increase...)
  - test different strategies to mitigate these impacts.

**Demo cities**

- on demand, provide them with scenarios of rainfall for the future
- I need for that at least 20 years of observed rainfall series at (sub)daily time step, for one or more stations.

# Example: a model for Belo Horizonte (1961-1999)





# Example: a model for Belo Horizonte (2061-2099)