Workshop "Rencontres Lyon-Grenoble autour des extrêmes"
26 septembre 2012

Méthode SCHADEX : Présentation Application à l'Atnasjø (NO), Etude de l'utilisation en contexte non-stationnaire

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Mistis

EDF
CHANGER L'ÉNERGIE ENSEMBLE

Outline

1. SCHADEX methodological overview
2. Application to Atnasjø catchment
3. Sensitivity analysis for non-stationary assessment

1. SCHADEX methodological overview

SCHADEX extreme flood estimation method

Main features

- Probabilistic method based on rainfall-runoff simulation
- Provides dam design flood estimations up to 10^4 return period
- Up to 10^4 km^2 catchments, adapted to moutainous areas

Data required

Local rainfall and runoff time-series, air temperature, flood hydrographs

Outputs

Complete distributions of areal rainfall, flood volumes and flood peaks, up to extreme quantiles

SCHADEX methodological overview

Main components

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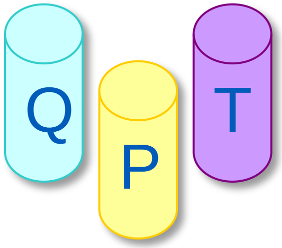
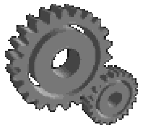


Rainfall probabilistic model

Hydrological model

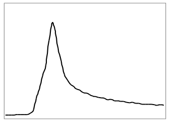
Climatological records

Rainfall-runoff simulation



Q_{100}, Q_{1000}
Extreme flood volumes
(at the study timestep)

Peak-to-volume ratio



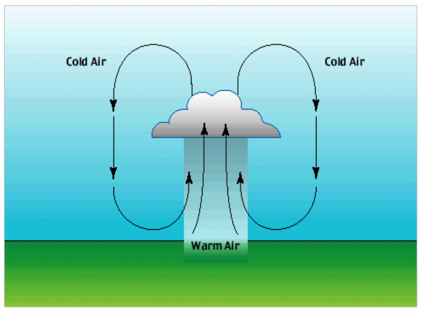
QX_{100}, QX_{1000}
Extreme flood peaks

Design flood

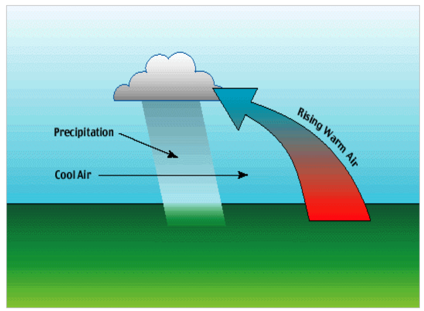
Rainfall probabilistic model : MEWP distribution

An observation:

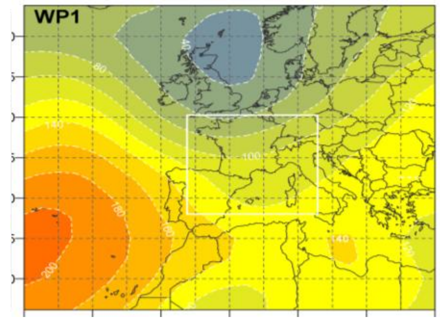
In France (but not only…), heaviest rainfalls have various atmospheric genesis



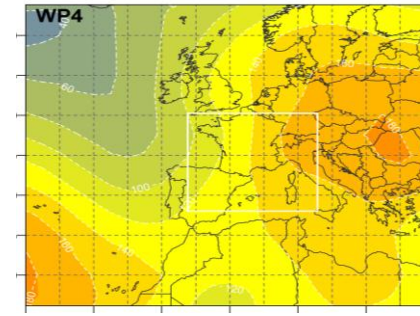
Convective rainfall



Frontal rainfall



Atlantic circulation



Mediterrean circulation

Hypothesis :

A rainfall observations sampling based on days having similar atmospheric circulation patterns will give more homogeneous sub-samples

…and probably closer to the « i.i.d. » asumption

Seasonal and weather patterns sub-sampling

Weather patterns for Norway

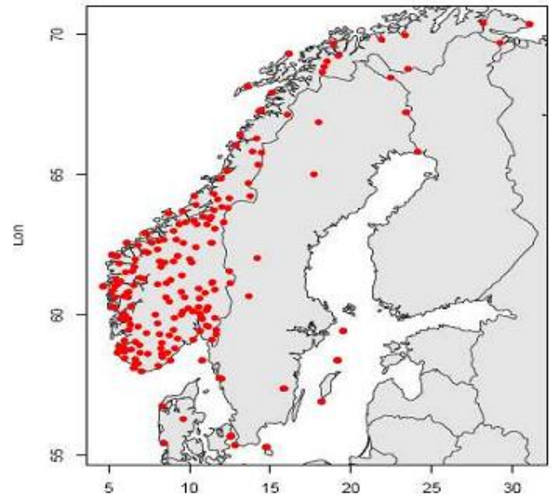
•Several classifications built during a FloodFreq STSM (A. Fleig, 2011) and compared to existing ones

•Precipitation dataset for rainfield shape analysis :
204 stations (175 in Norway) – data from 1970 to 2008

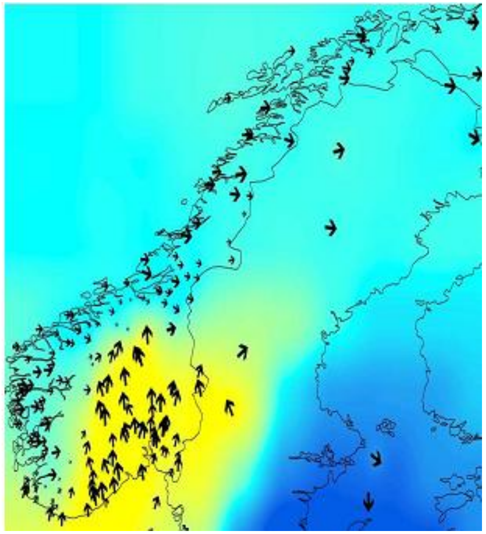
•Synoptic situations identified on 700 and 1000 hPa geopotential fields on a NW Atlantic domain

•Classifications assessed on their discriminating power for rainy days (Cramer test on rain/no rain)

•Selected classifications had 8 classes, grouped to keep only 4 classes to gain robustness in heavy rainfall analysis



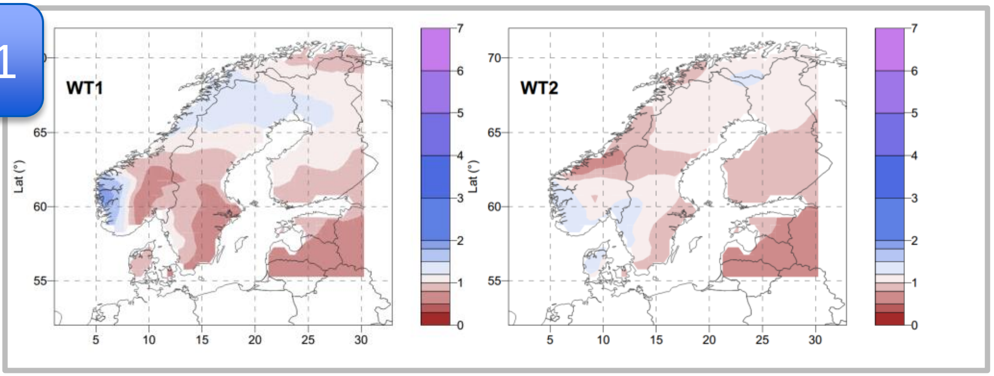
Precipitation dataset


Dominating wind direction on the 30 days with highest precipitation at each station

Weather patterns for Norway

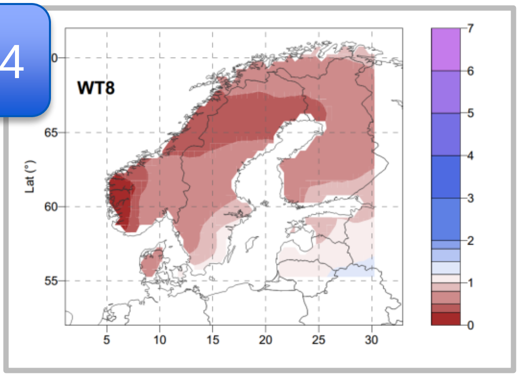
WP1

22%



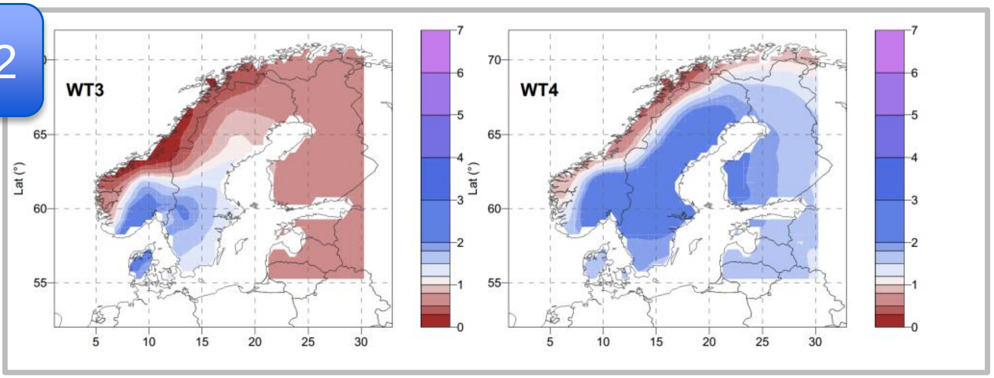
WP4

17%



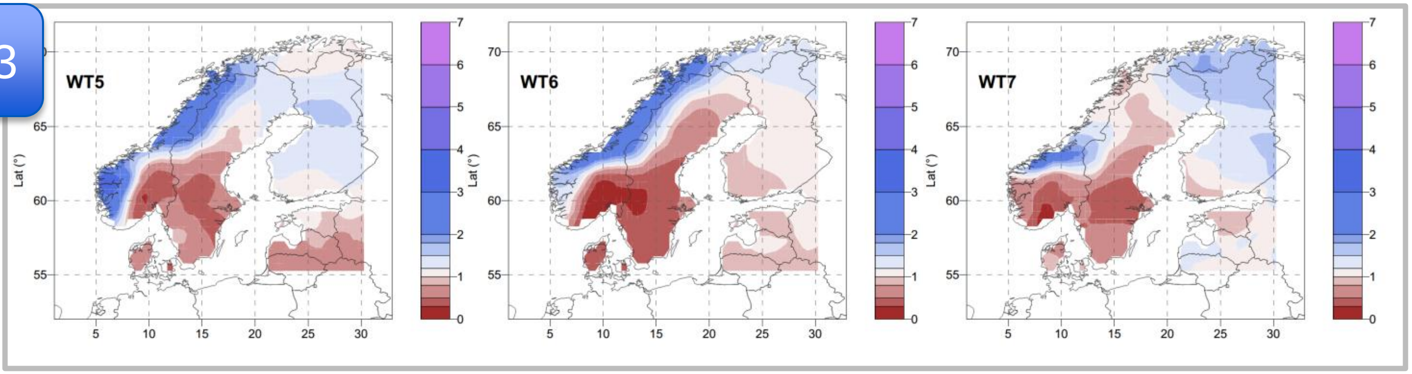
WP2

33%

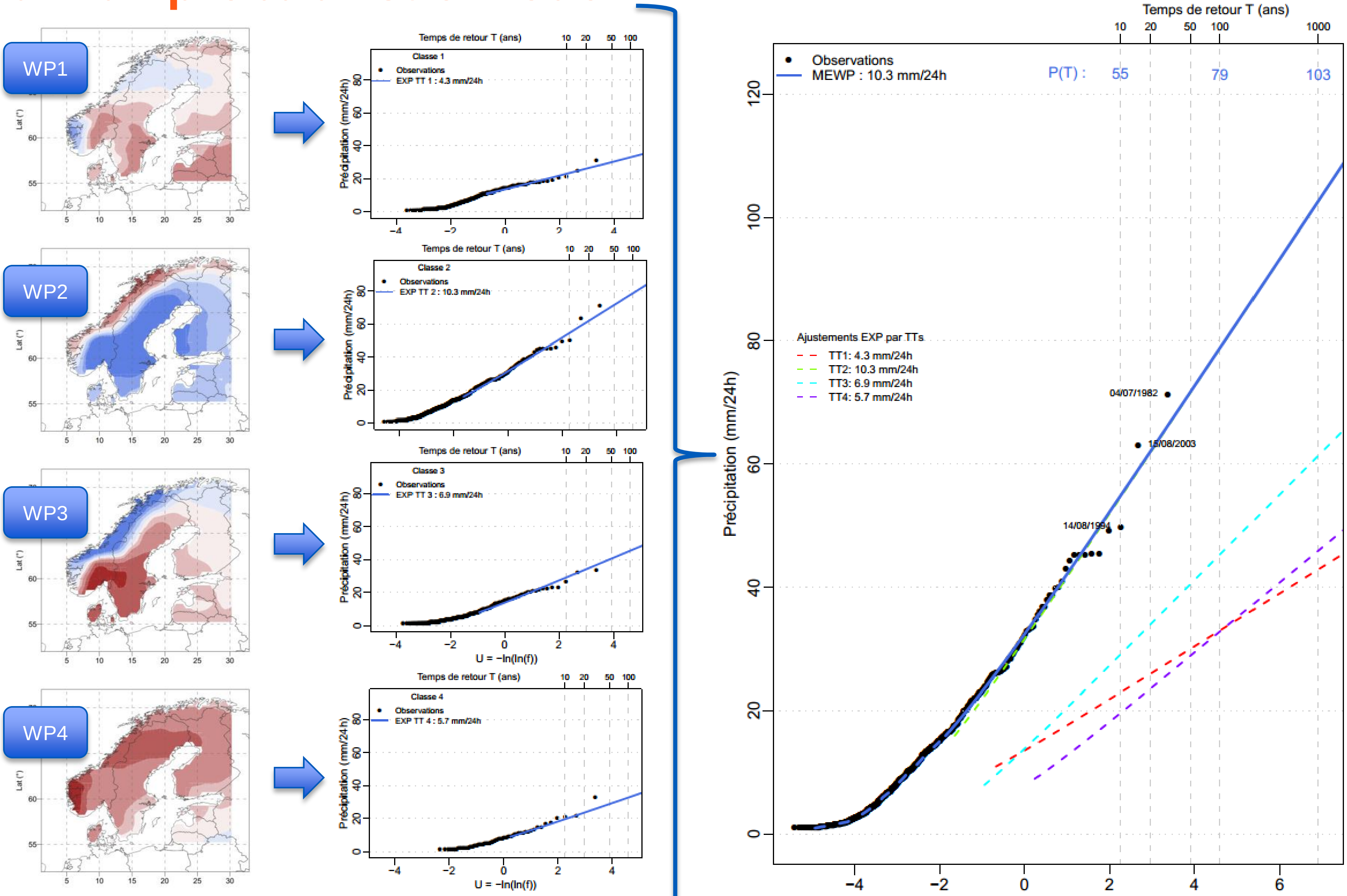


WP3

28%



Rainfall probabilistic model : MEWP distribution



WP sub sampling | EXP fit | Composite seasonal distribution (MEWP)

SCHADEX rainfall-runoff simulation process

Main features

1. A significant climatological record is used to generate a great variety of hydrological states through the hydrological model

2. The simulation process allows an exhaustive combination between heavy rainfall events and hydrological states

A so-called « semi-continuous » simulation process

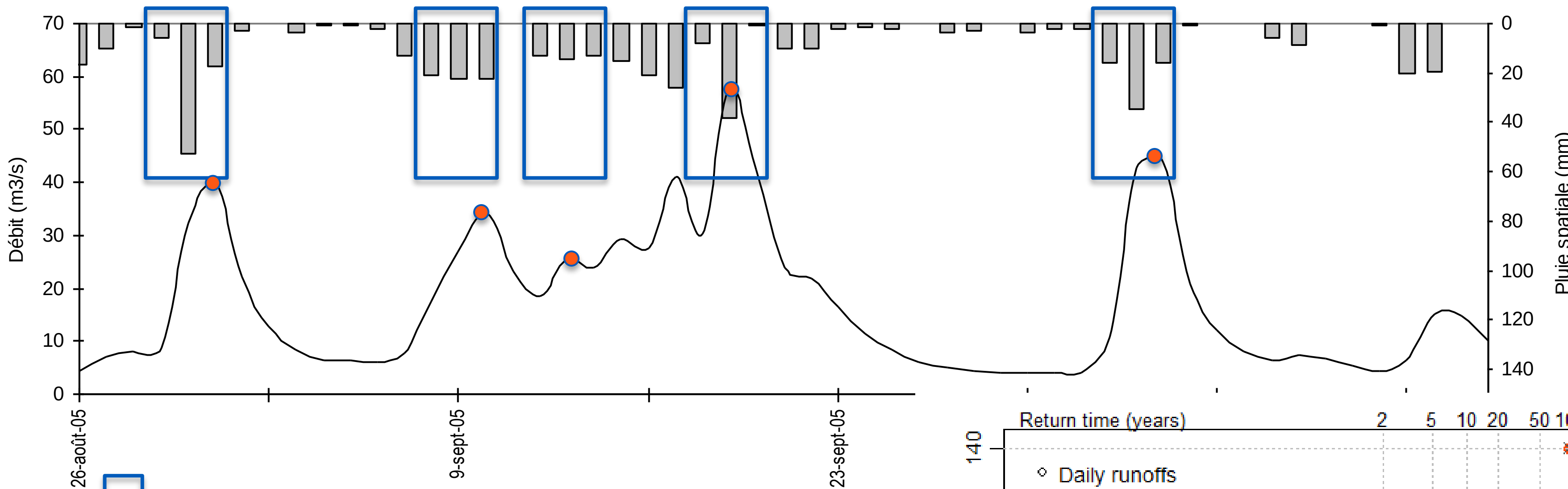
- Continuous description of the hydrological state of the watershed

- But event-based rainfall generator

→ Around 2.10^6 events are simulated

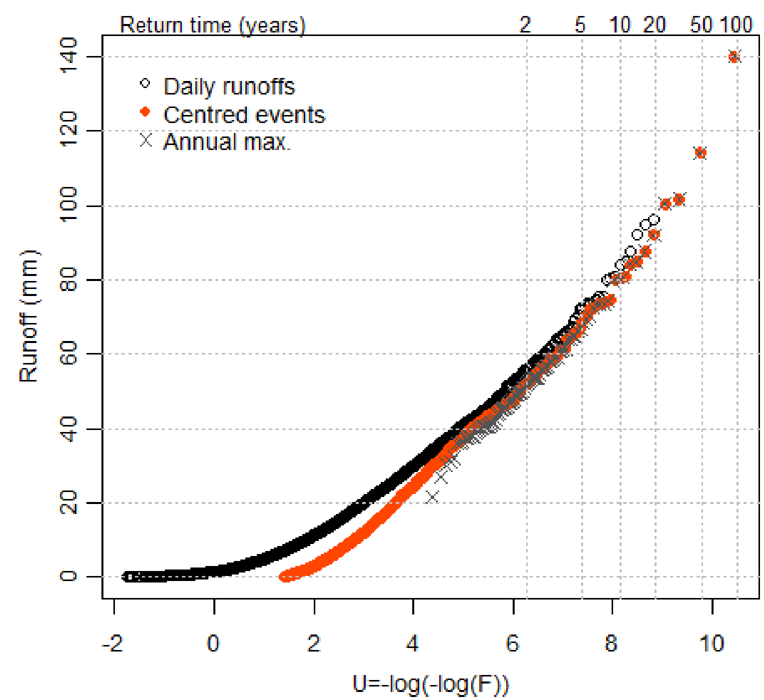
An original sampling process

Centred rainy events

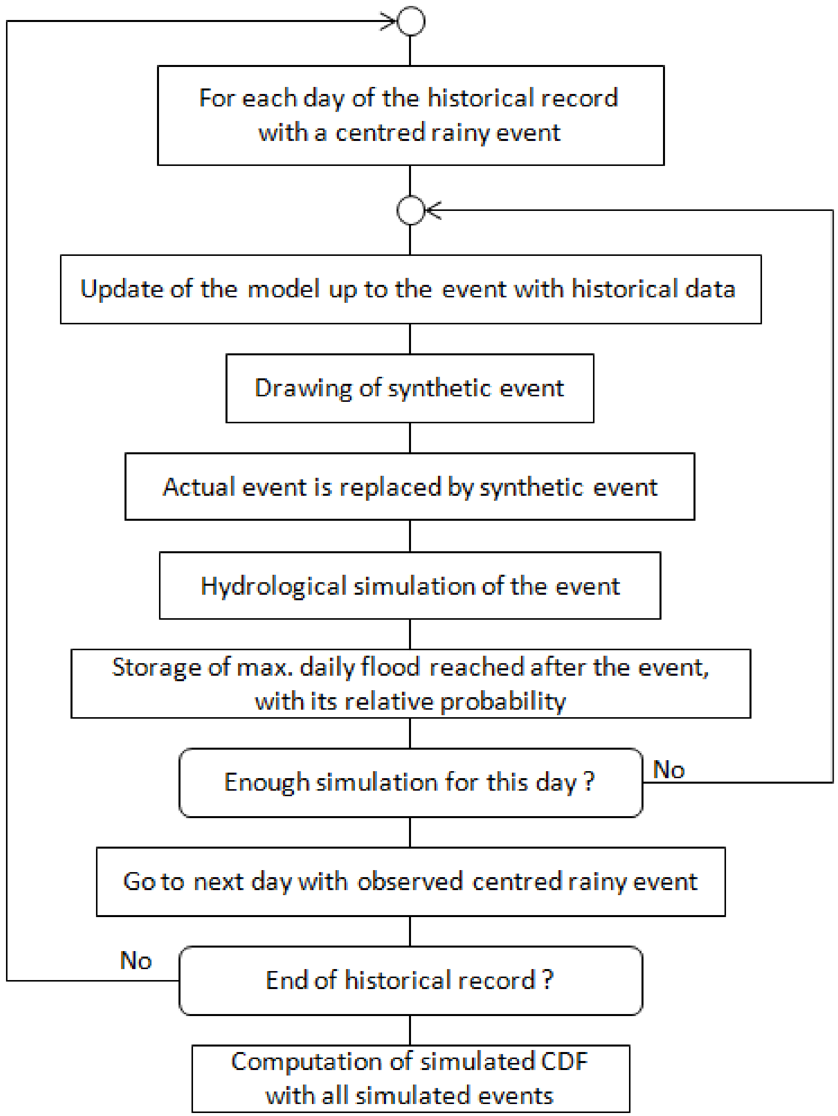


Centred rainy event

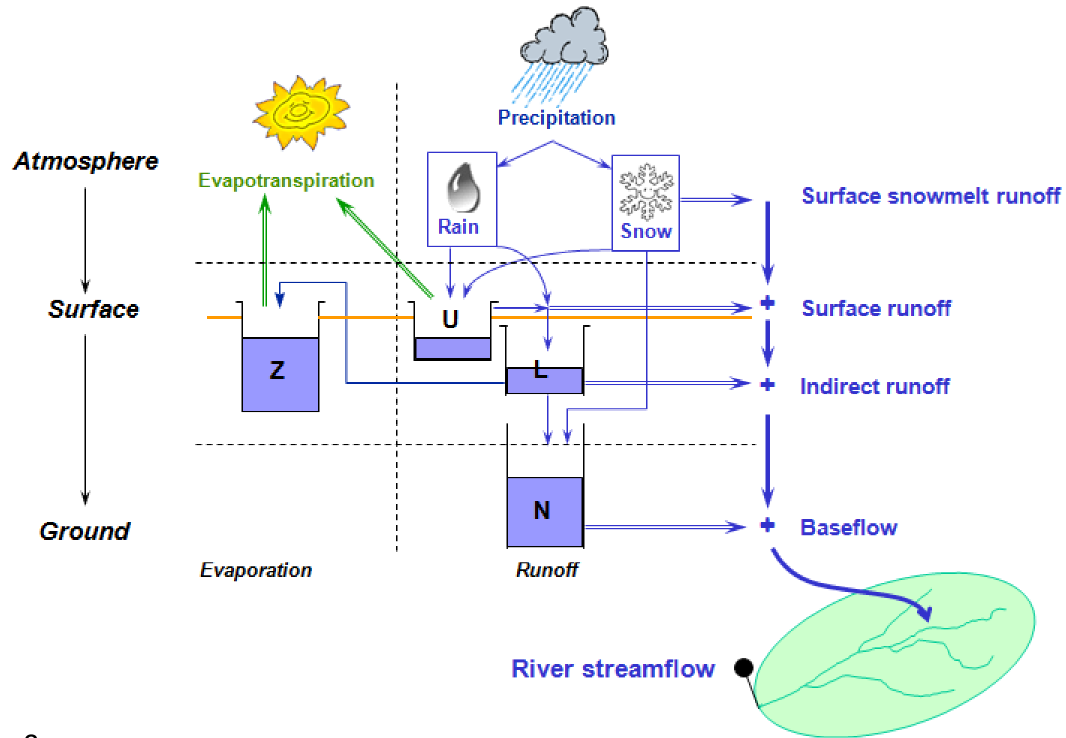
Associated discharge



SCHADEX rainfall-runoff simulation process



MORDOR hydrological model



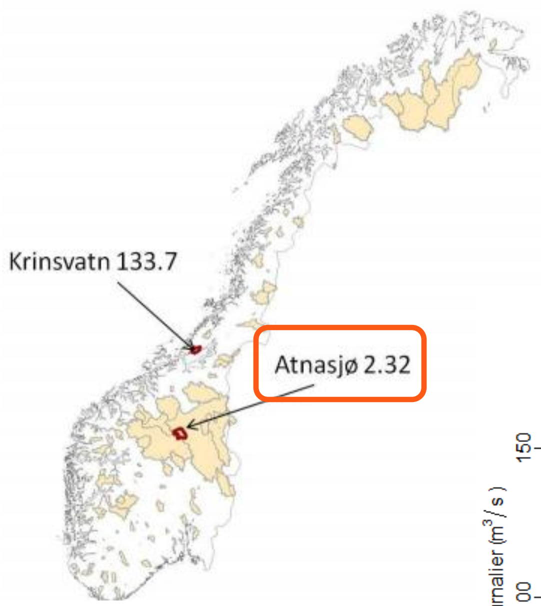
Overview of MORDOR

- Lumped, continuous model
- Hourly to daily time step
- Watershed area from 10 to 10^4 km²
- Adapted to moutain hydrology (snowpack model)
- Data input : rainfall (mean areal precipitation), air temperature
- Automatic calibration (genetic algorithm on historical data)
- More than 80 models for operational forecast at EDF

2.
Application to Atnasjø catchment

Atnasjø catchment

Main features



Atnasjø (2.32) – Inland catchment in south-central Norway dominated by snowmelt flooding during spring/early summer. The largest recorded flows occurred in June 1995, May 1966 and May 1973, representing rainfall during peak snowmelt periods. Winter periods are dominated by low flows due to sub-zero conditions throughout the catchment.

Station owner – NVE

Period of discharge record – 1916 until today's date

Catchment area = 463 km^2

H_{50} (Median elevation) = 1204 m.a.s.l.; **H_{10} =** 803; **H_{90} =** 1593

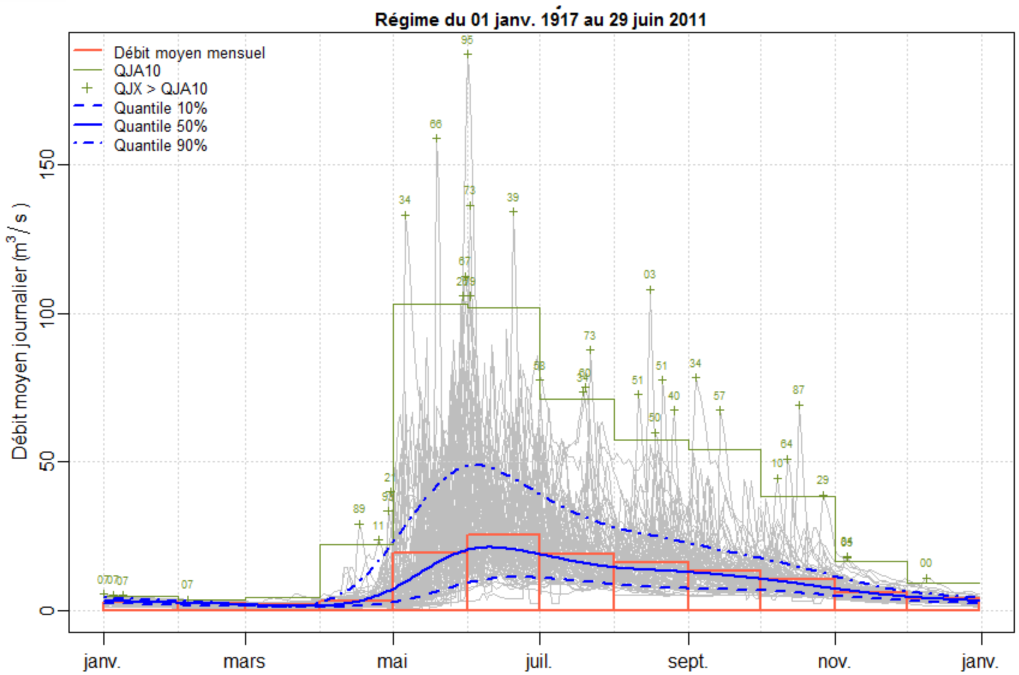
River hierarchy – Atna/Glomma

Average annual runoff – 696 mm/yr

Mean annual flood (1916-2010) – 71 m^3/s

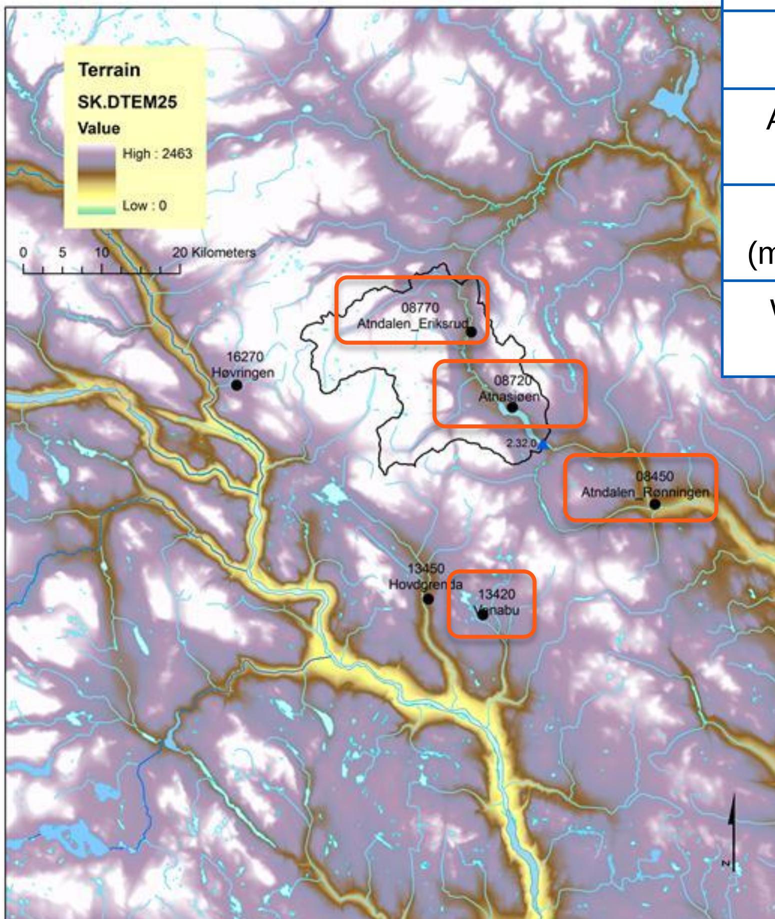
Highest recorded discharge – 187 m^3/s (01.jun.1995)

Land cover: Lake – 3%; Forest – 21%; Marsh/Bog – 3%; Glacier < 1%; Agricultural < 1%; Bare rock – 71% (Also have land cover data for each of 10 equal area elevation zones.)



Atnasjø catchment

Areal precipitation

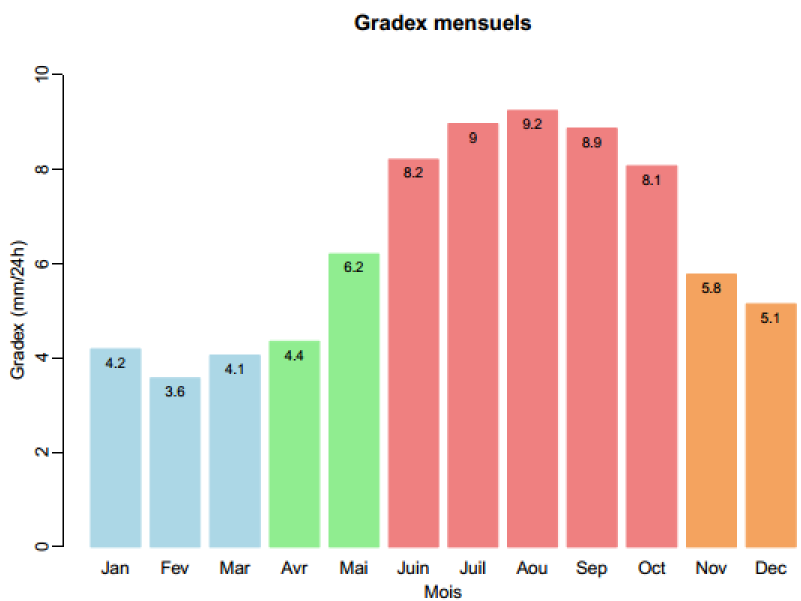


Reference	08450	08720	08770	13420
Name	Rønninngen	Atnasjøen	Eriksrud	Venabu
Altitude (m)	535	749	731	930
MAP (mm/year)	511	571	504	688
Weight	0.19	0.29	0.10	0.80

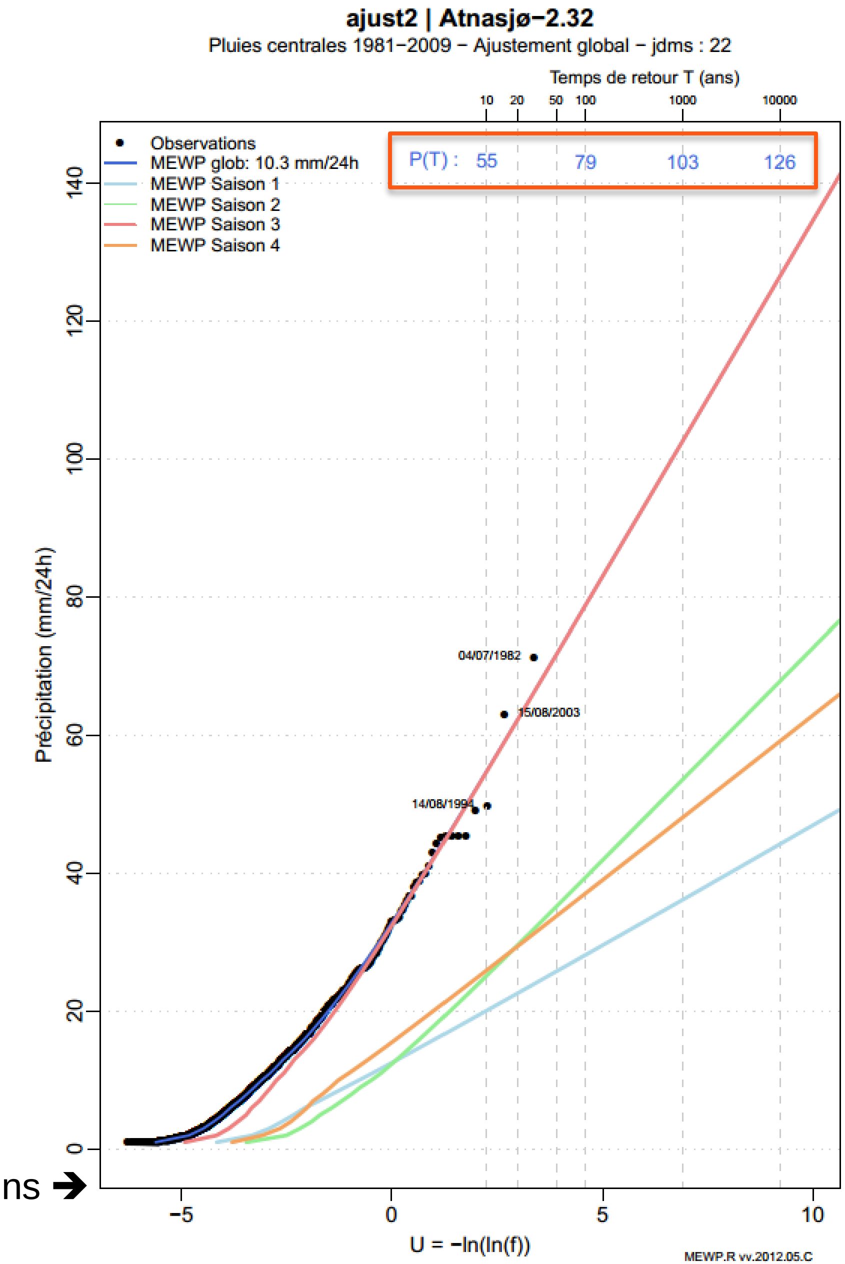
Water budget (1973-2010) :

Mean annual precip. : 852 mm/y
Mean annual runoff : 655 mm/y
ETP losses : 197 mm/y

MEWP areal rain fit - annual

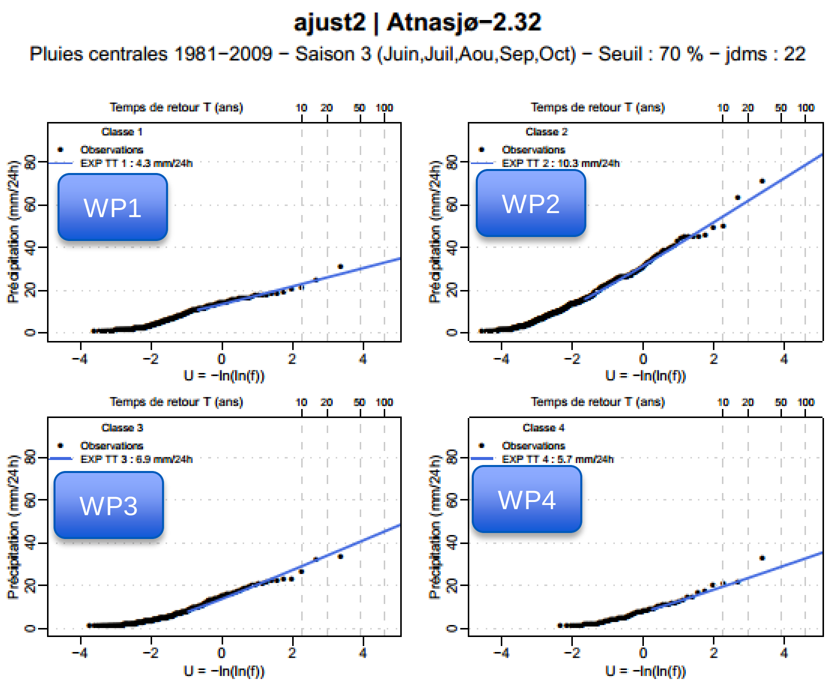


↑ Monthly gradex and seasons



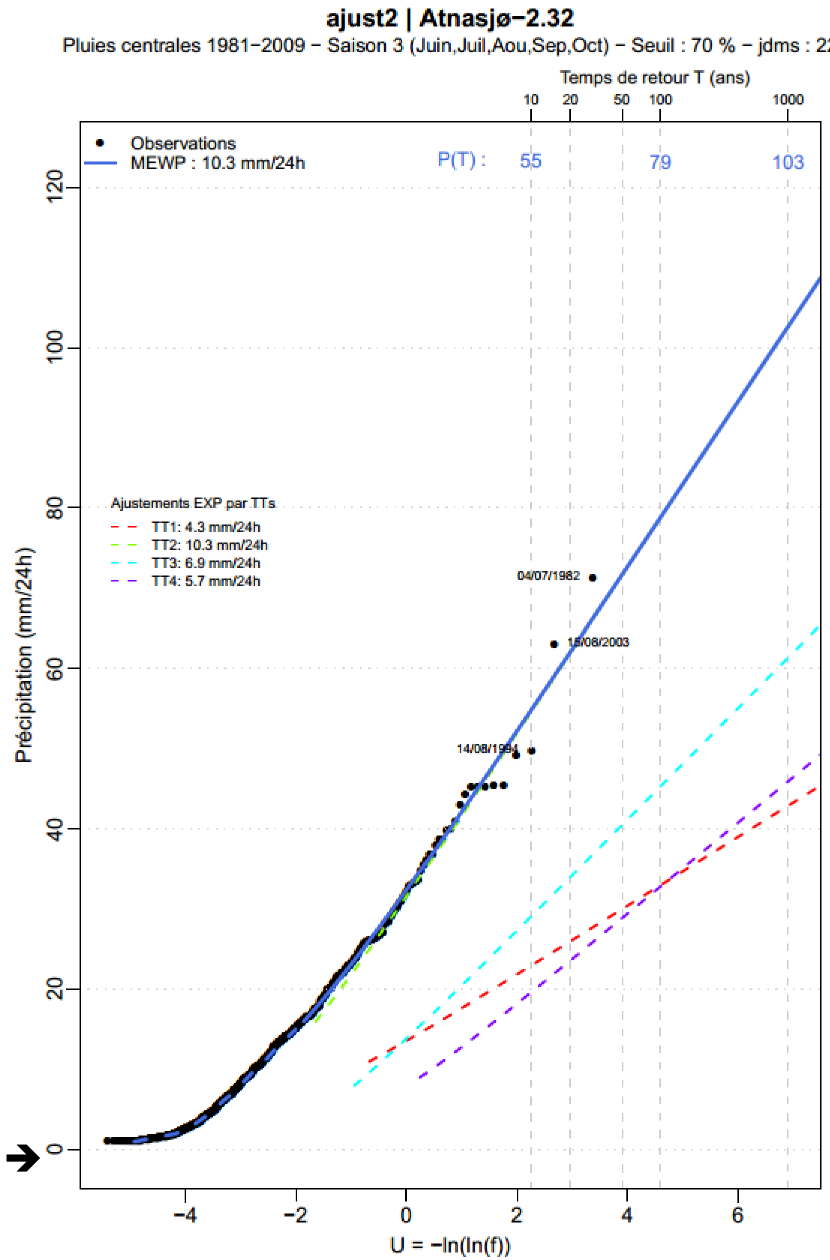
Annual and seasonal distributions →

MEWP areal rain fit – June to October



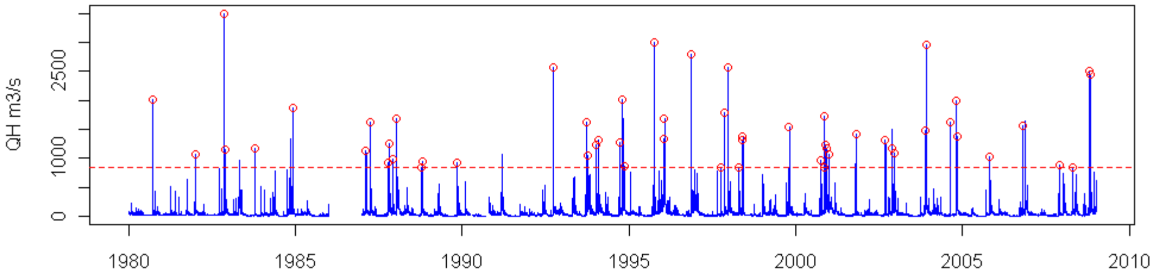
↑ WP sub-sampling and EXP fit

Jun to Oct MEWP distribution →

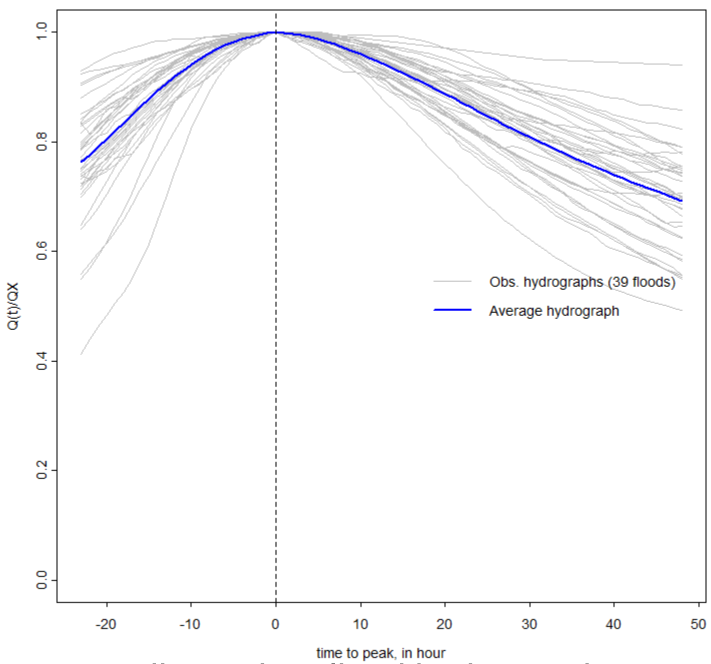


Peak-to-volume ratio

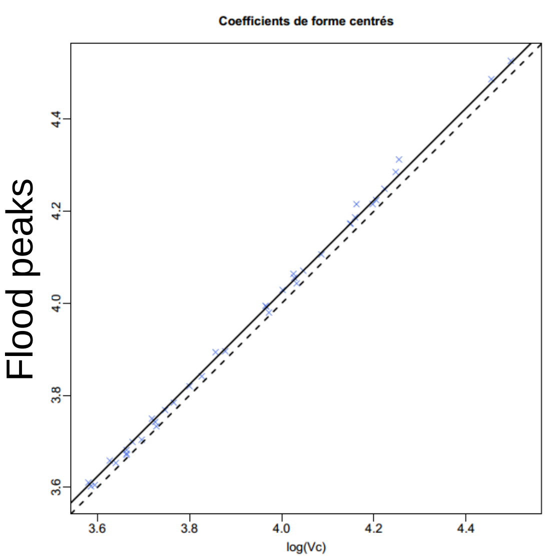
Based on 1987-2011 hourly discharges



selection of hydrographs (POT selection)



Adimensionalized hydrographs



Flood volumes

$$K_c = \frac{1}{n} \sum_i \frac{QX_i}{VX_i}$$

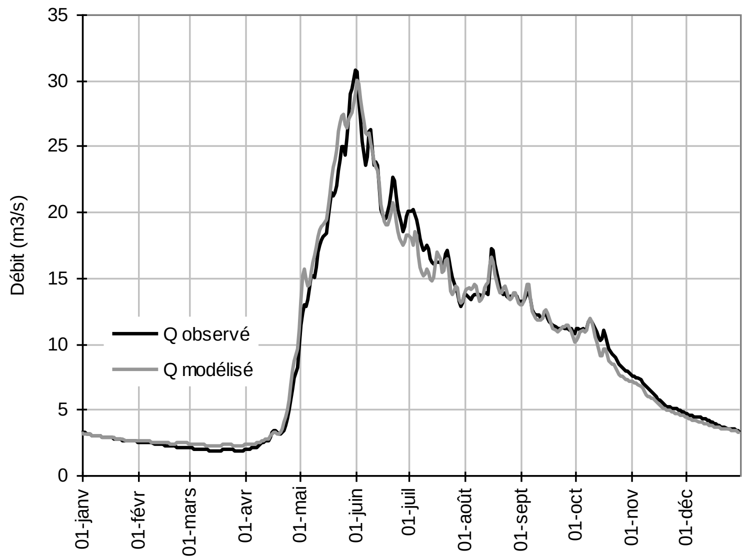
Average peak-to-volume ratio

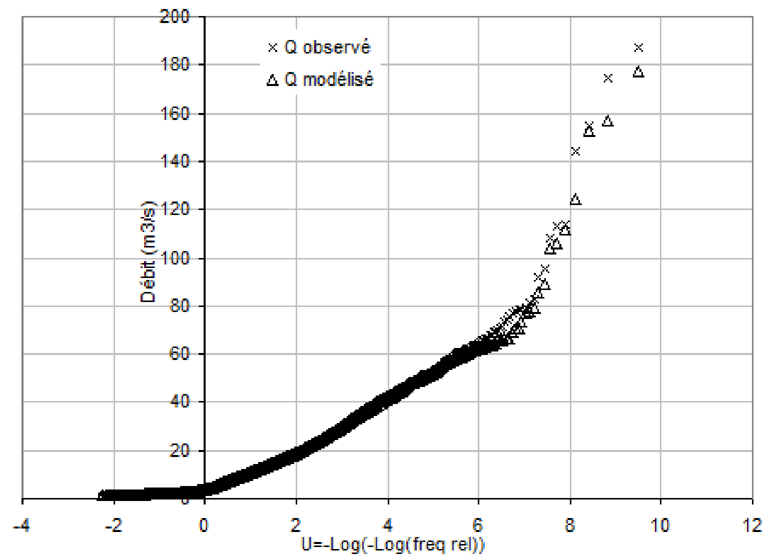
K_c=1.02
K_{nc}=1.04

MORDOR hydrological model

Calibrated at daily timestep, on a selection of 20 years within the 1973-2010 period

Statistics for 1973-2010



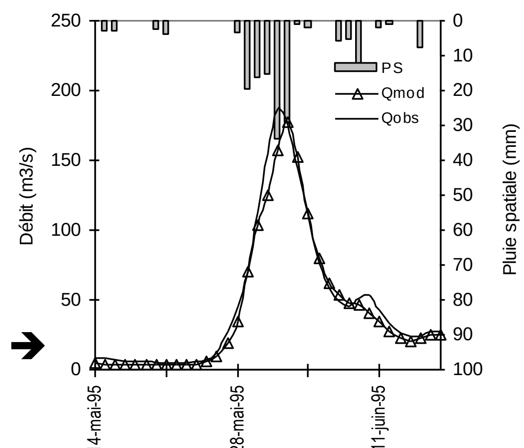


↑ Regime

Daily discharges CDF ↑

	Calibration	Validation
NSE	0.86	0.82

June 1995 flood ➔

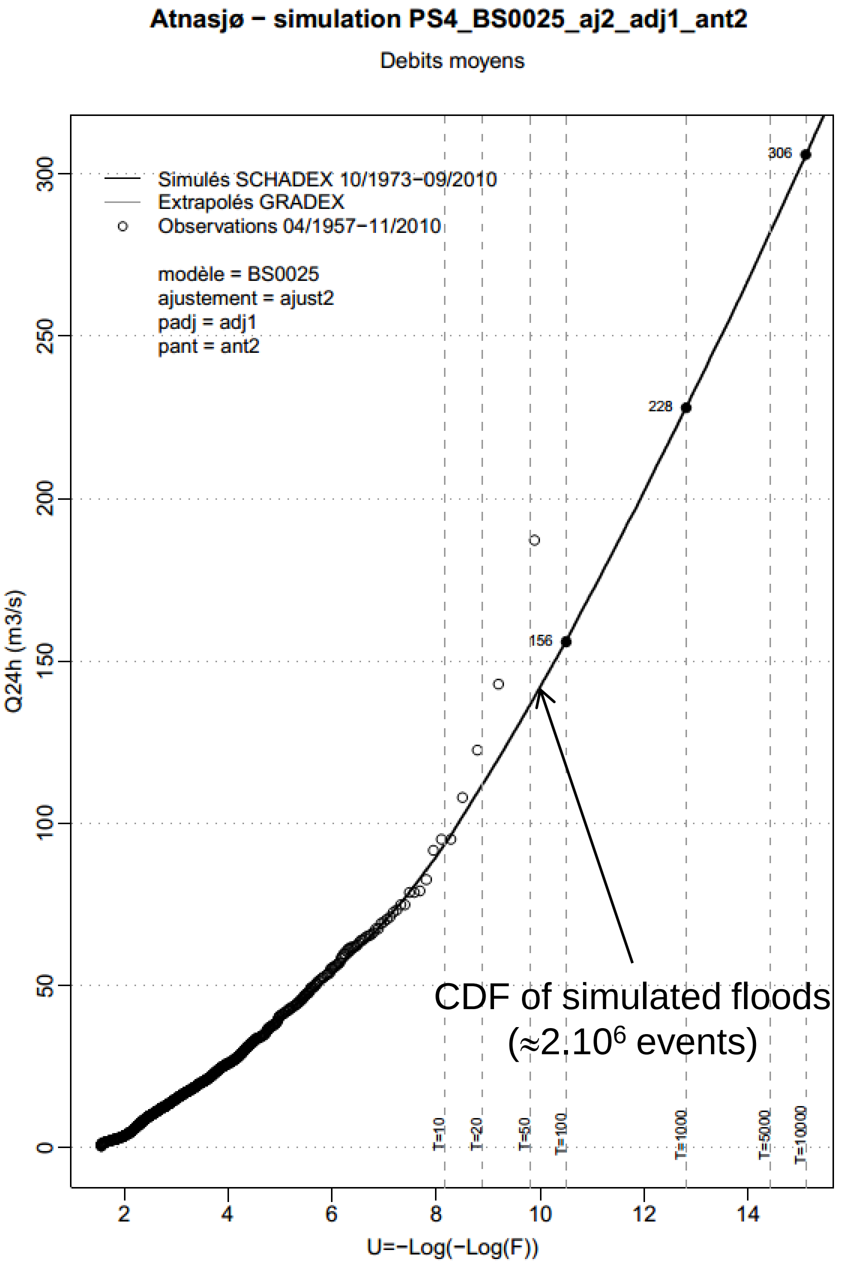


SCHADEX simulation results

Daily discharges

Compared to rain-based POT sampling of observed discharges (about 19% of daily values)

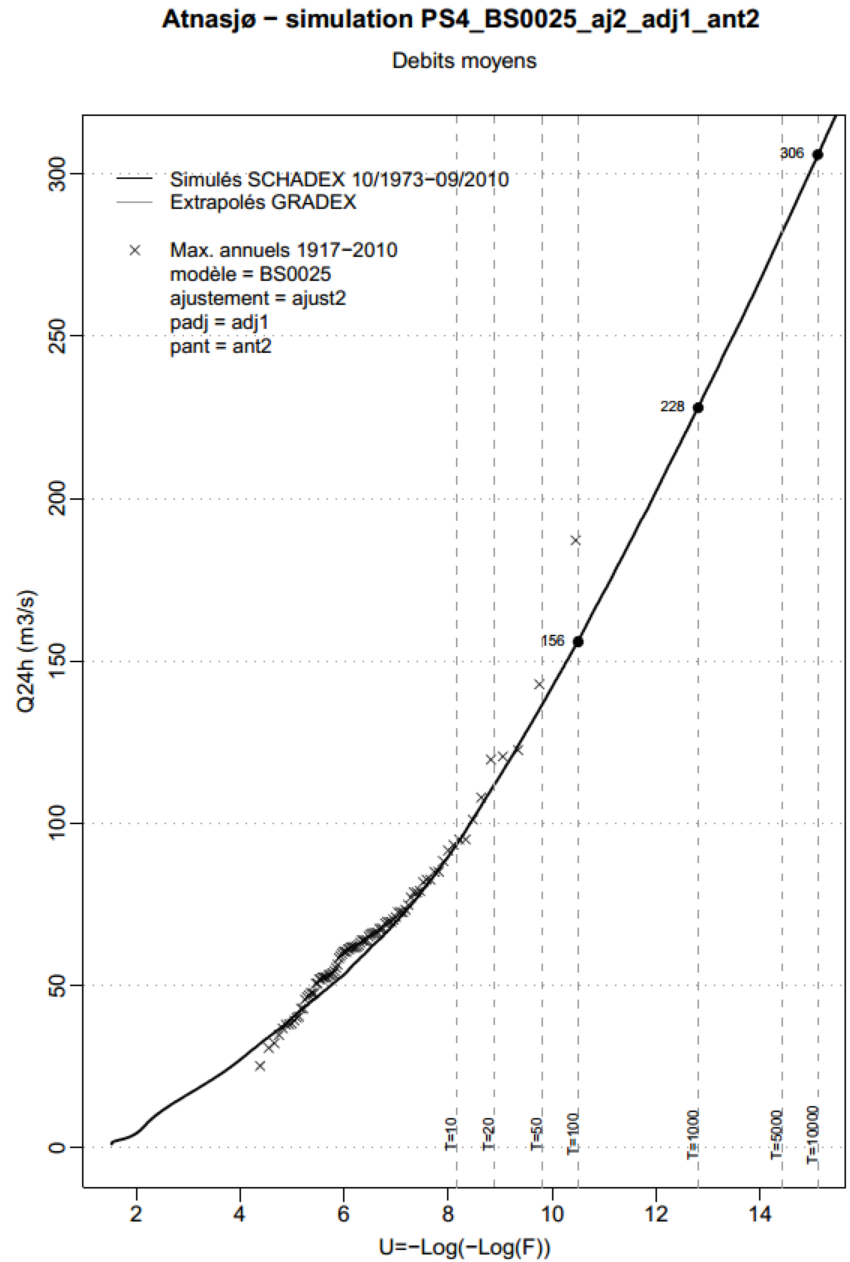
QJ_{1000} = 228 m³/s
$QJ_{10\,000}$= 306 m³/s



SCHADEX simulation results

Daily discharges

Compared to annual maxima (1917-2010)

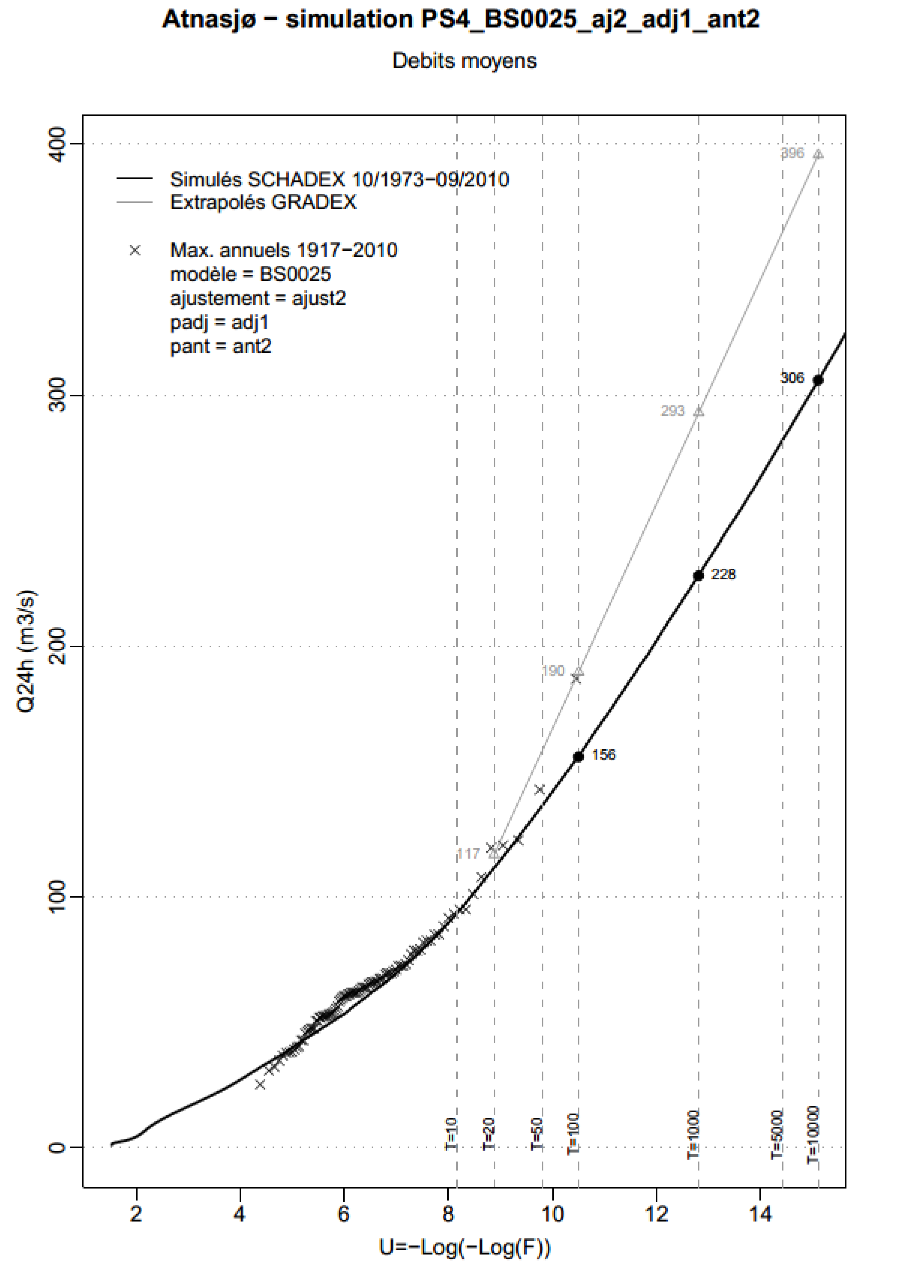


SCHADEX simulation results

Daily discharges

Compared to annual maxima (1917-2010)

Plotted against GRADEX estimations



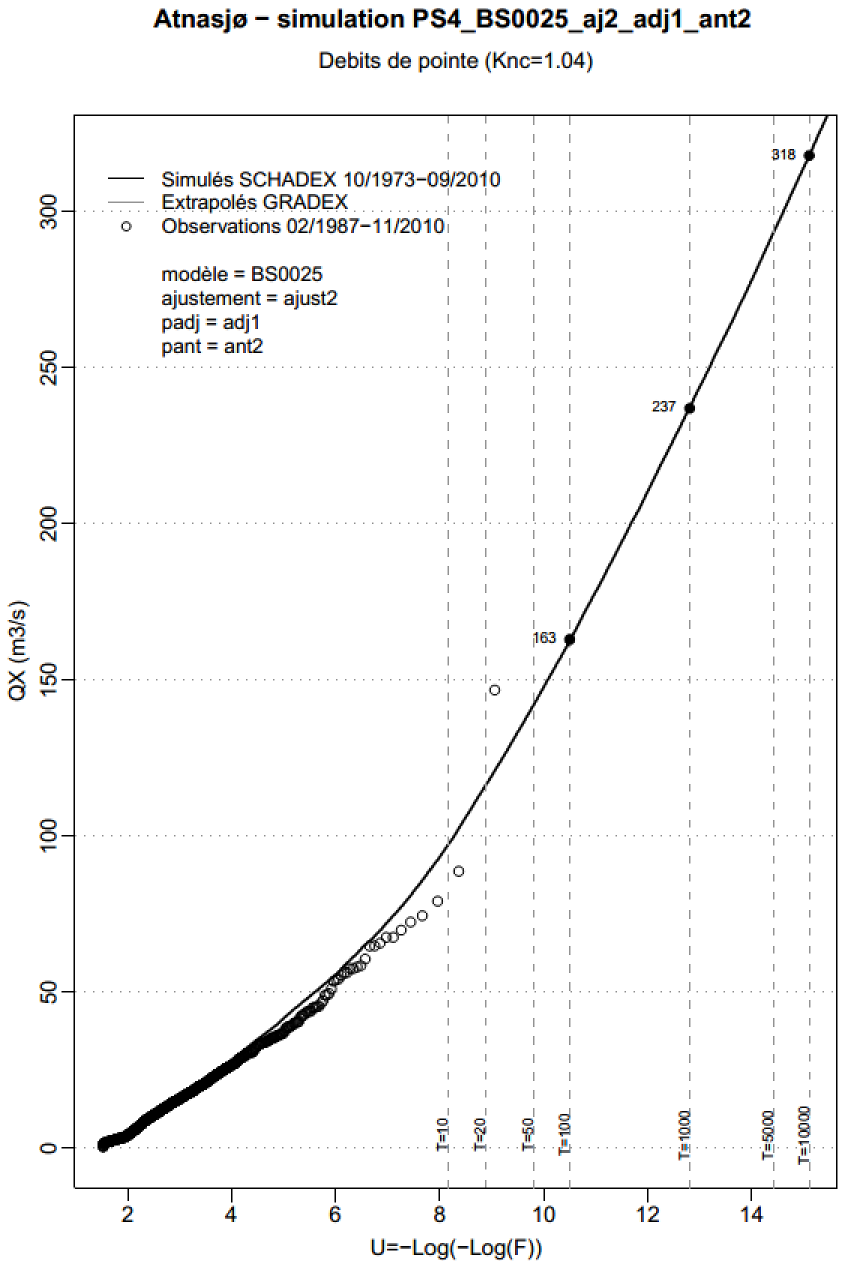
SCHADEX simulation results

Peak discharges

Peak-to-volume ratio of 1.04

Compared to annual maxima (1987-2010)

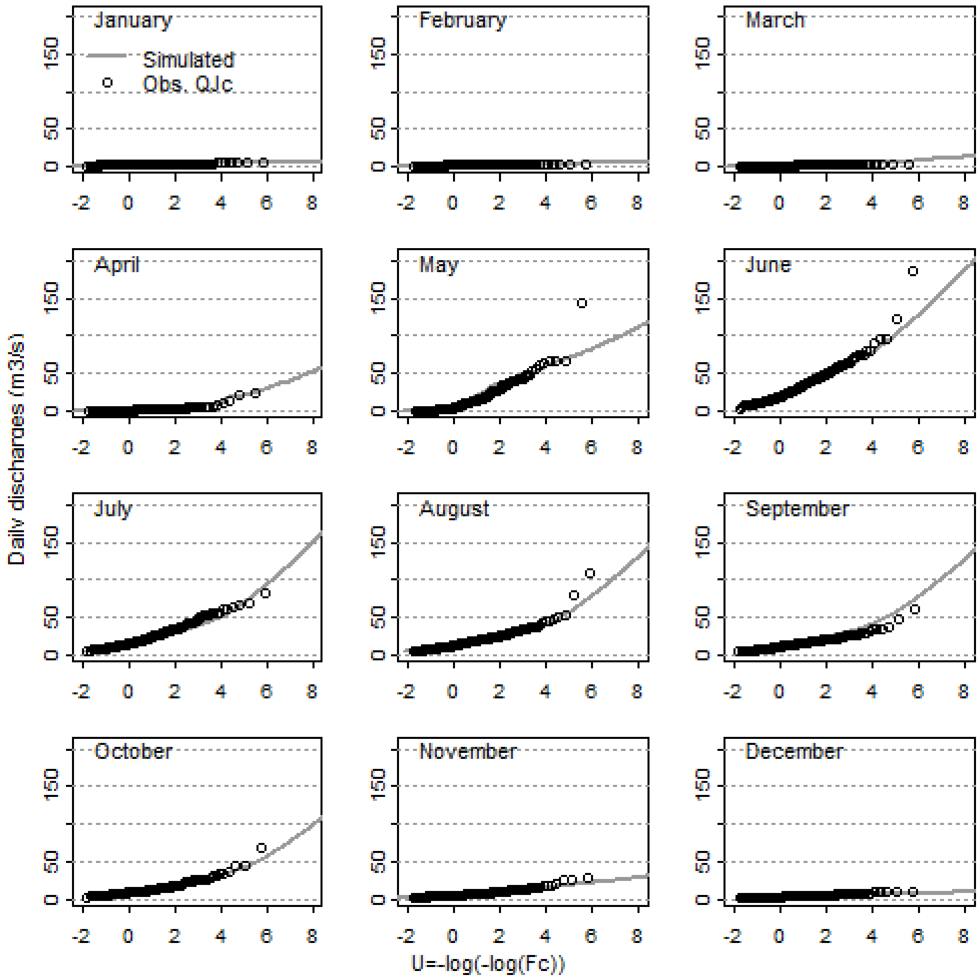
QX_{1000} = 237 m^3/s
$QX_{10\,000}$= 318 m^3/s



SCHADEX simulation results

Daily discharges – monthly sub-distributions

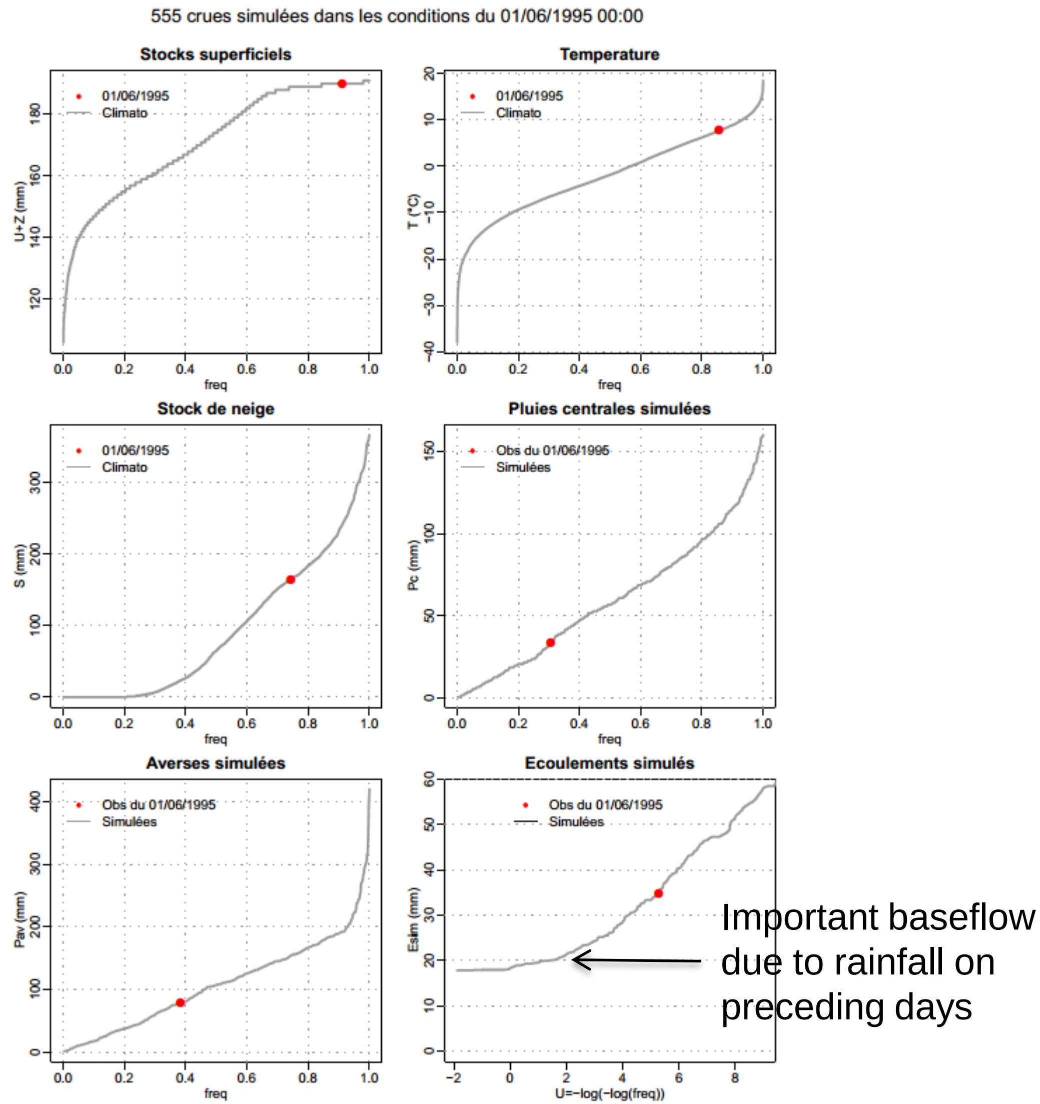
Compared to rain-based POT sampling of observed discharges of the month



A zoom into the simulated floods

Events simulated in the conditions of 6 June 1995 flood

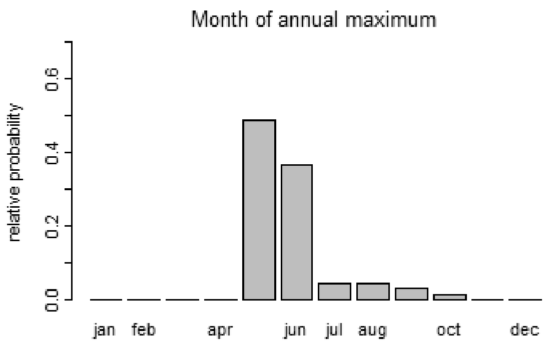
555 events simulated in the conditions of that particular day

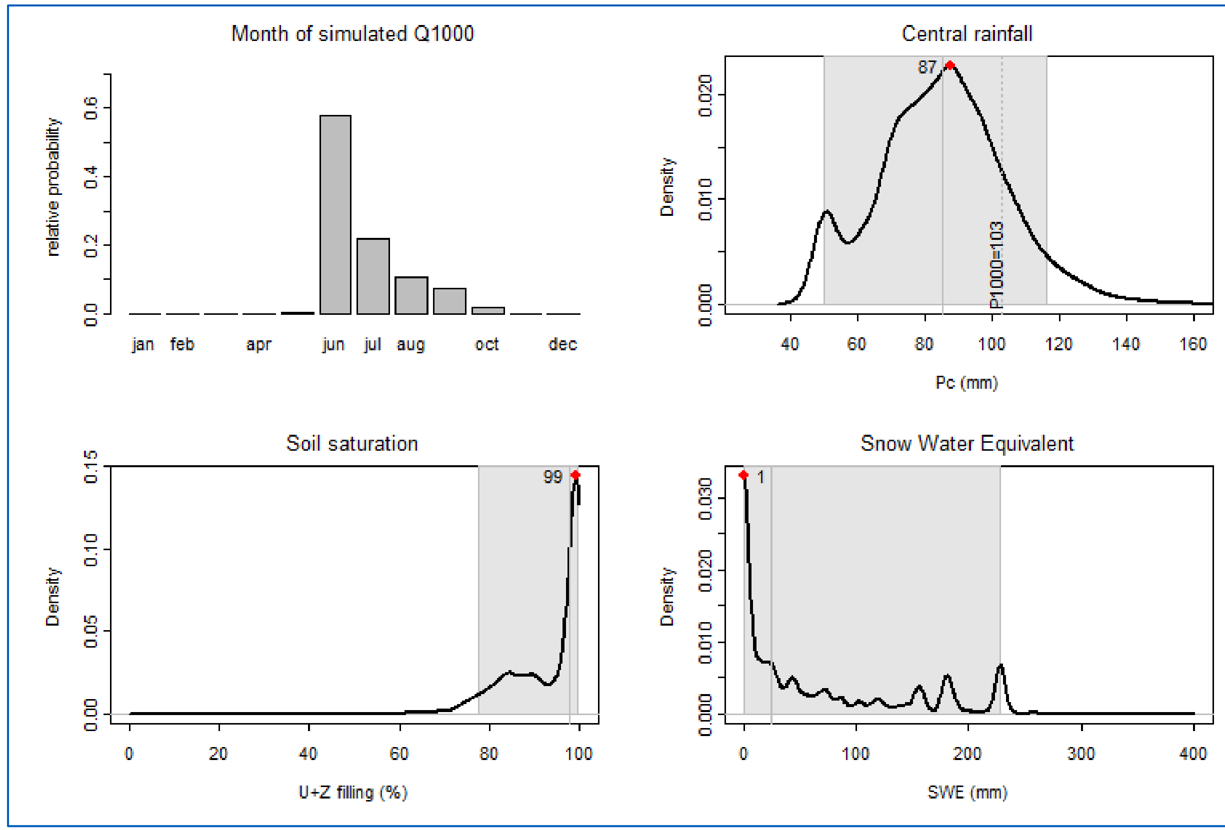


A zoom into the simulated floods

Daily discharges – Return time 1000 y.

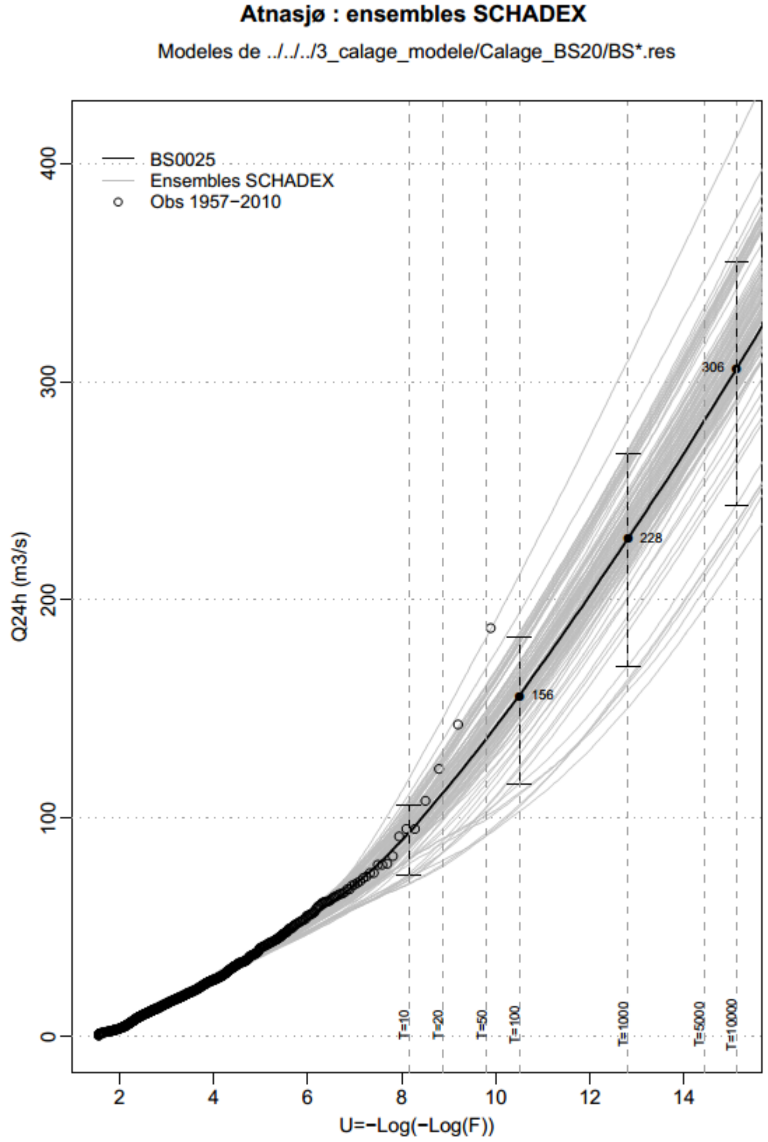
Statistics of 10^4 simulated events reaching ±1% around the QJ_{1000} value

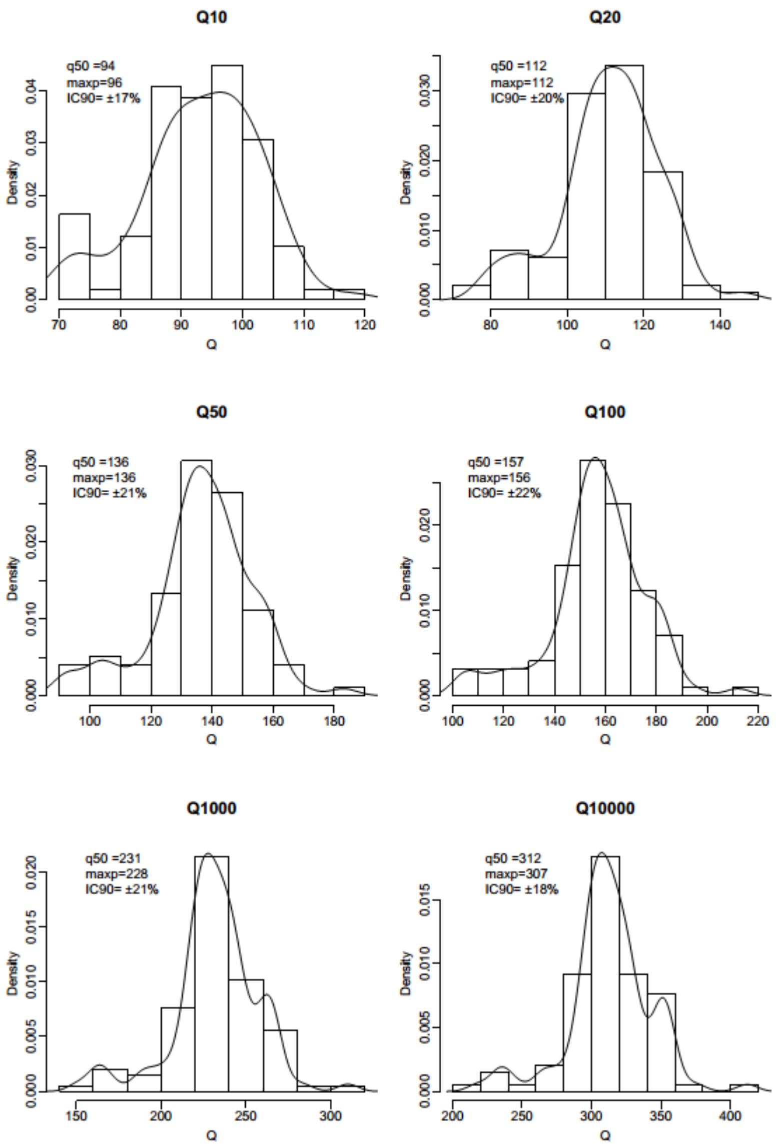


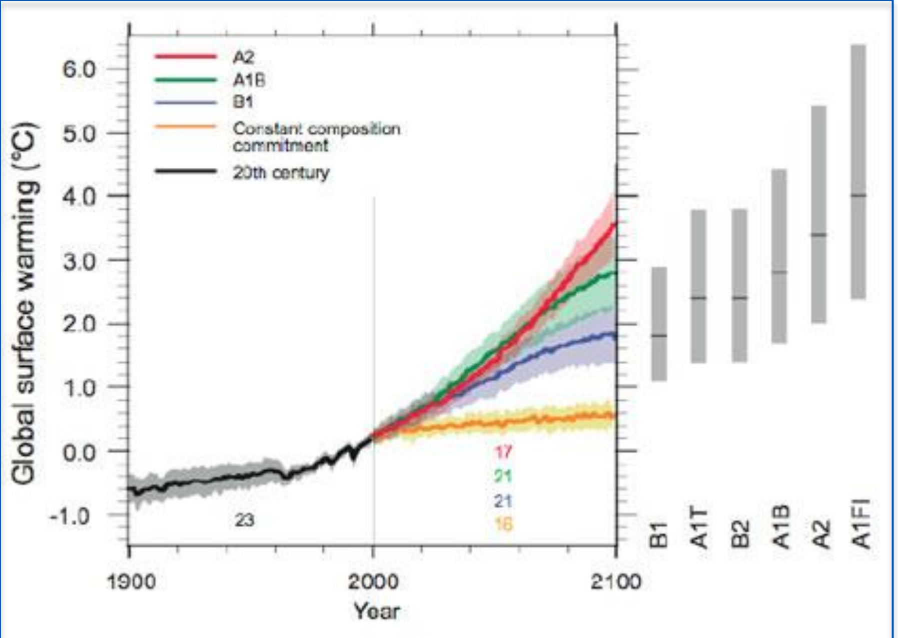


Sensitivity analysis to rainfall-runoff model calibration

Simulations ran with100 models calibrated on 20 years bootstrapped within1973-2010







3.
Assessing non-stationarity of extremes with SCHADEX ?

Thèse de P. Brigode (UPMC)

CC and flood hazard through SCHADEX?

Before using GCM outputs, performing a sensitivity analysis of the SCHADEX method on each catchment is needed:

- Use of observed datasets;
- Which SCHADEX parameters are the most sensitive to climatic changes?
- Which are the most influencing SCHADEX parameters on extreme streamflow?
- Is SCHADEX able to capture natural variability of extreme streamflow?

Additional question assessed:

- Is there any trends captured over the past years?

Methodology

Sensitivity analysis of the SCHADEX results:

- Construction of several sub-sets of observed years.
- SCHADEX estimation on each of the different constructed sub-sets.
- Comparison of these estimations with the reference SCHADEX estimation;
- Analysis of the SCHADEX estimations spread.

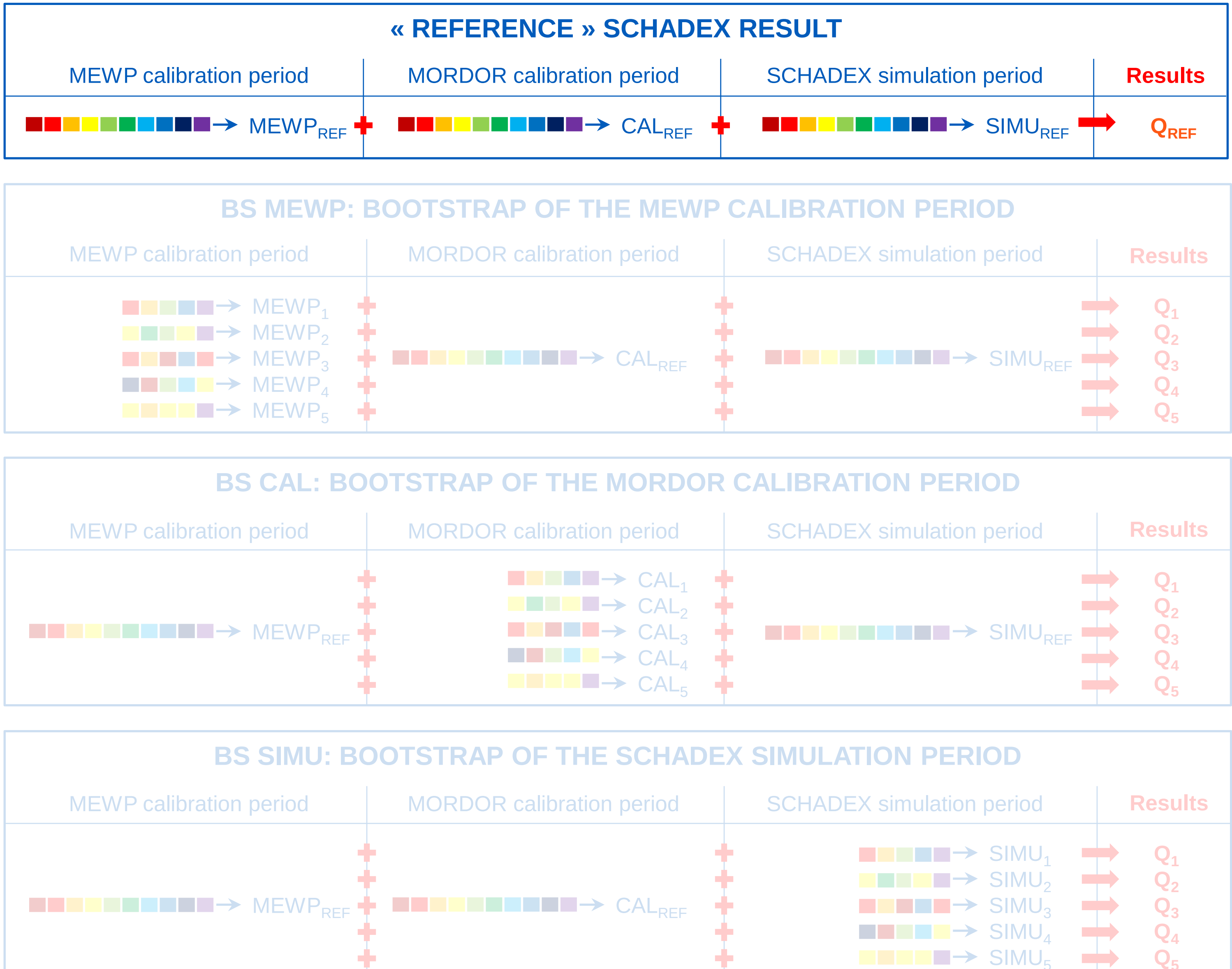
Tests performed for each component of SCHADEX:

- MEWP rainfall probabilistic model
- MORDOR rainfall-runoff model
- Rainfall-runoff simulation climatology

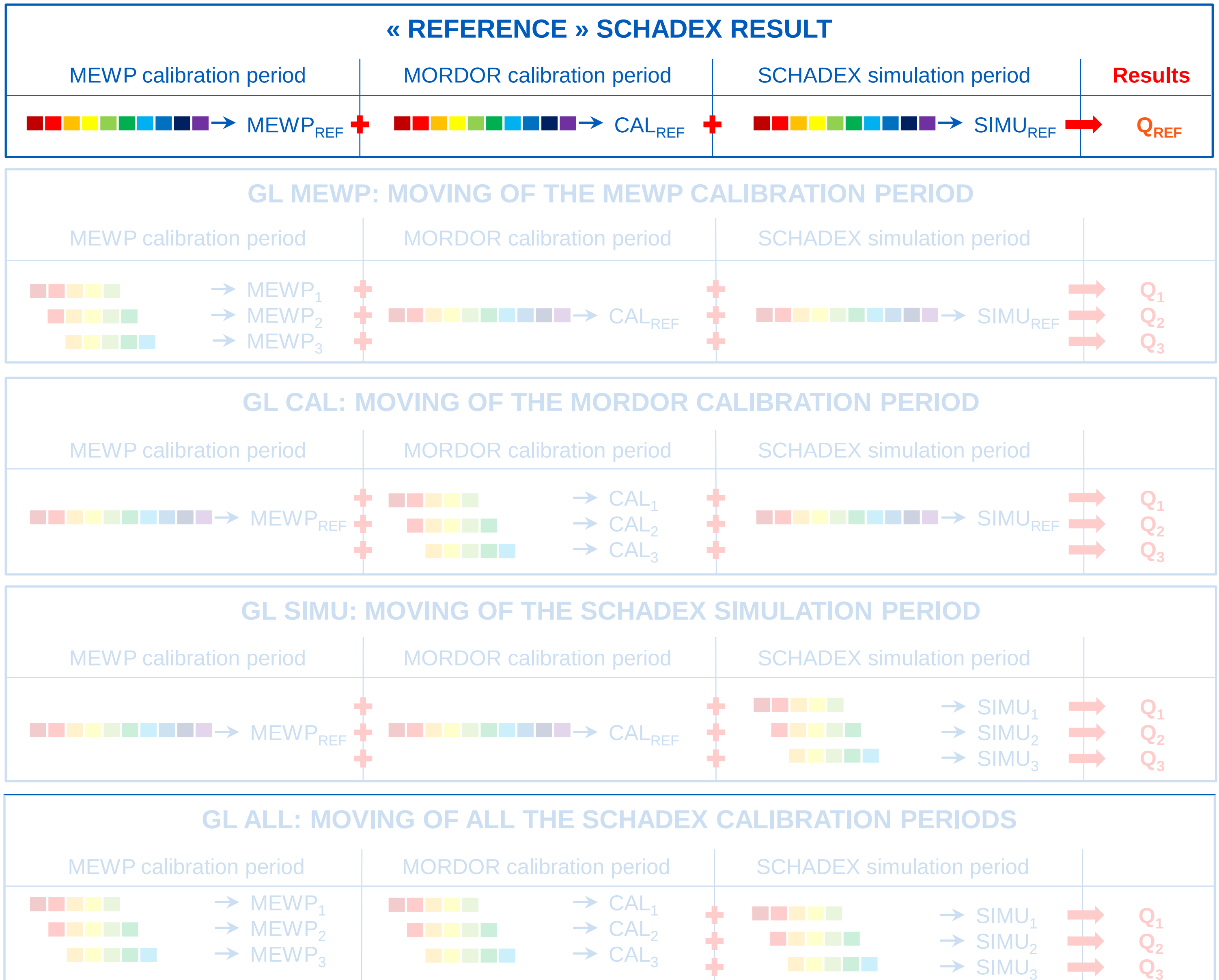
Two types of datasets :

- **BS** = Sub-samples bootstraped within the available data (100 boot. of 25 years w/o replacement)
- **GL=** Moving window sub-samples (20 years window)

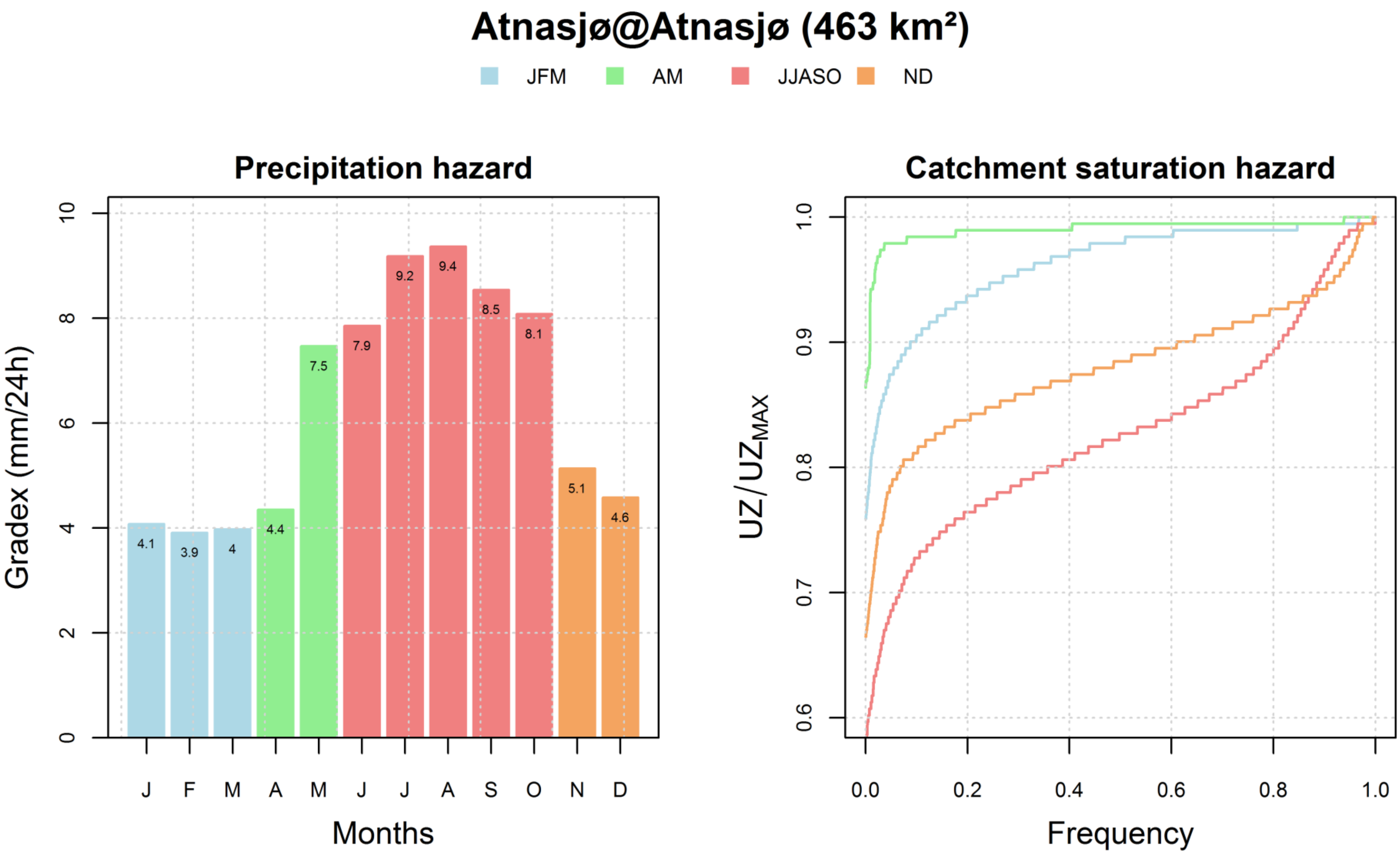
Methodology – BS experiments



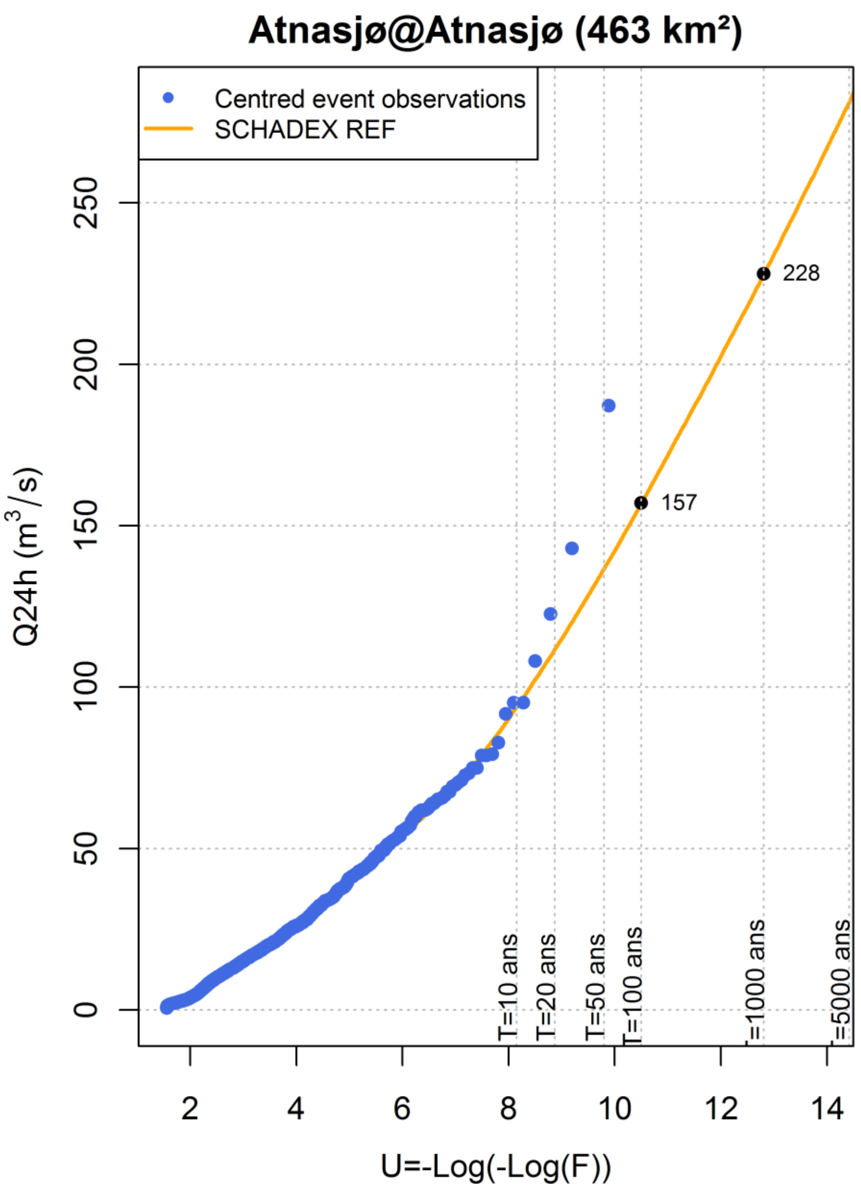
Methodology – GL experiments



Atnasjø catchment : « full data » analysis



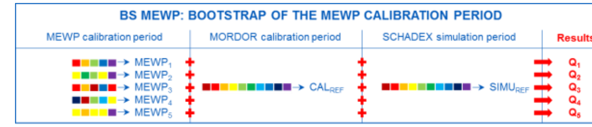
Atnasjø catchment : « full data » analysis



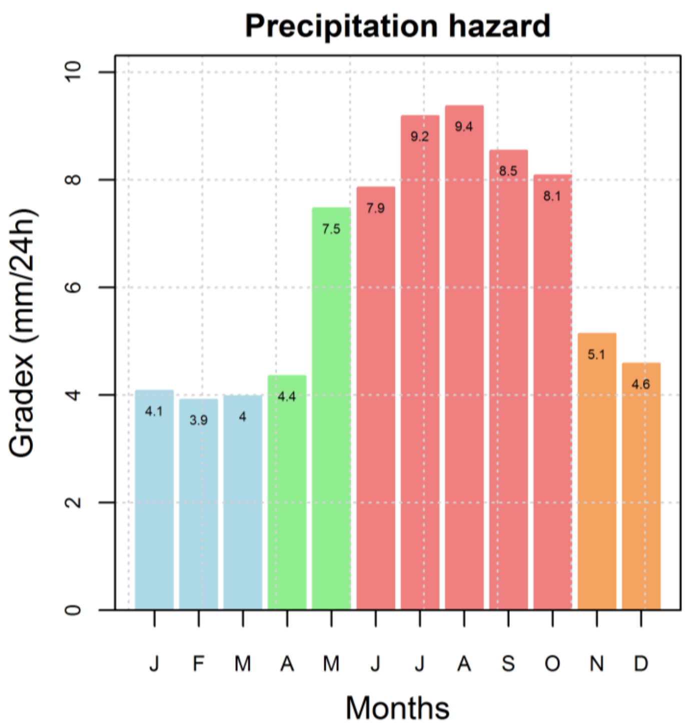
Atnasjø catchment : « full data » analysis

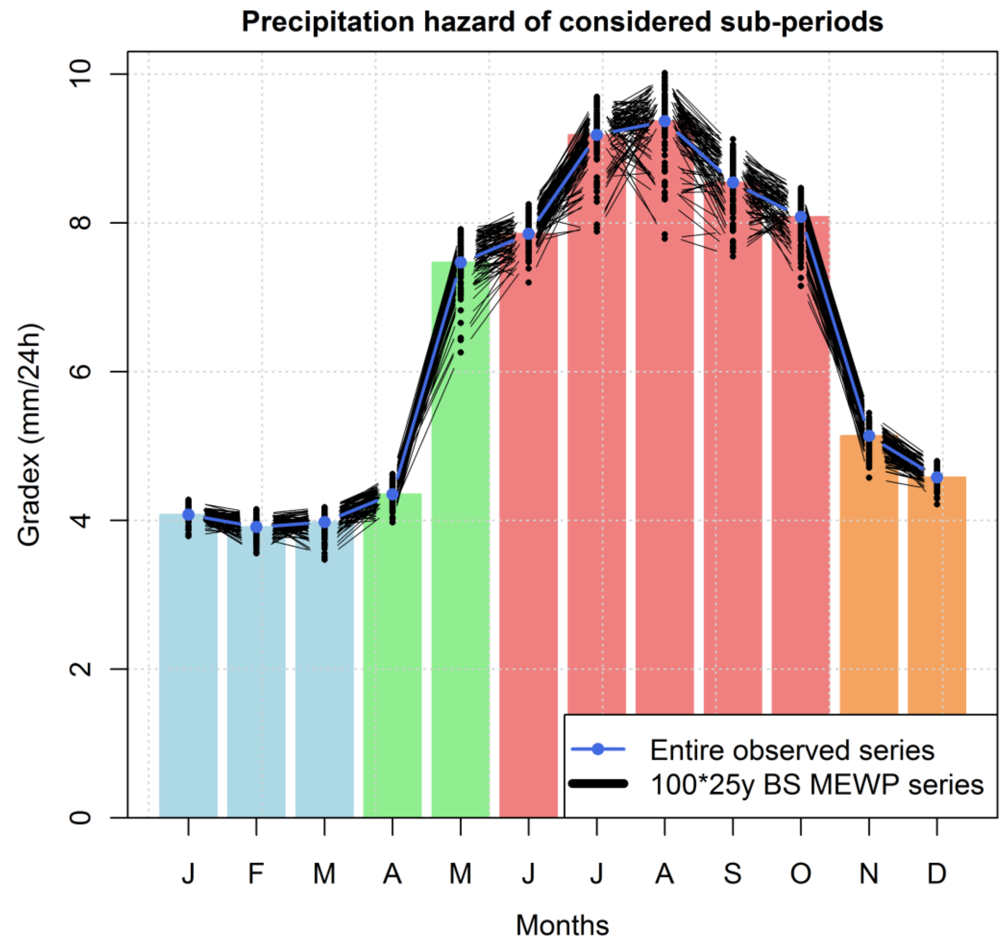
	Data used	Model options
PROBABILISTIC RAINFALL MODEL	1981-2009 (29 years)	**MEWP model:** - 4 seasons (JFM, AM, JJASO, ND) - Use of a weather pattern (4) classification;
RAINFALL-RUNOFF MODEL	1972-2010 (39 years)	**MORDOR model:** - 25 free parameters, snow-component; - (NSE + Qsorted) objectifve function for calibr.
SIMULATION PROCESS	1972-2010 (39 years)	**Common SCHADEX simulation options.**

BS experiments - MEWP

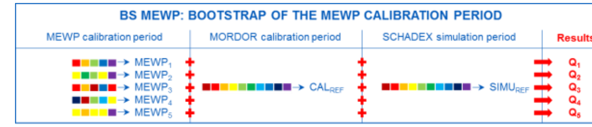


100 BS periods of 25 years among 29

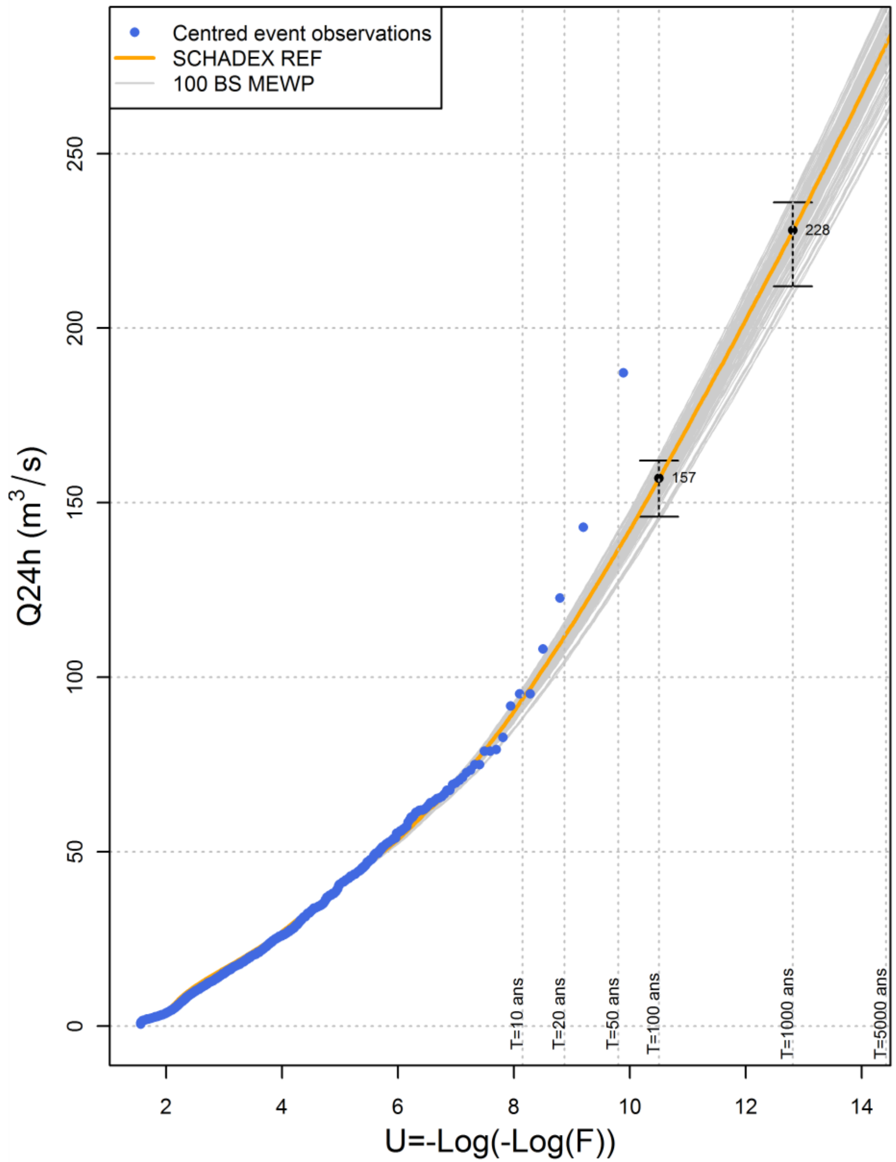


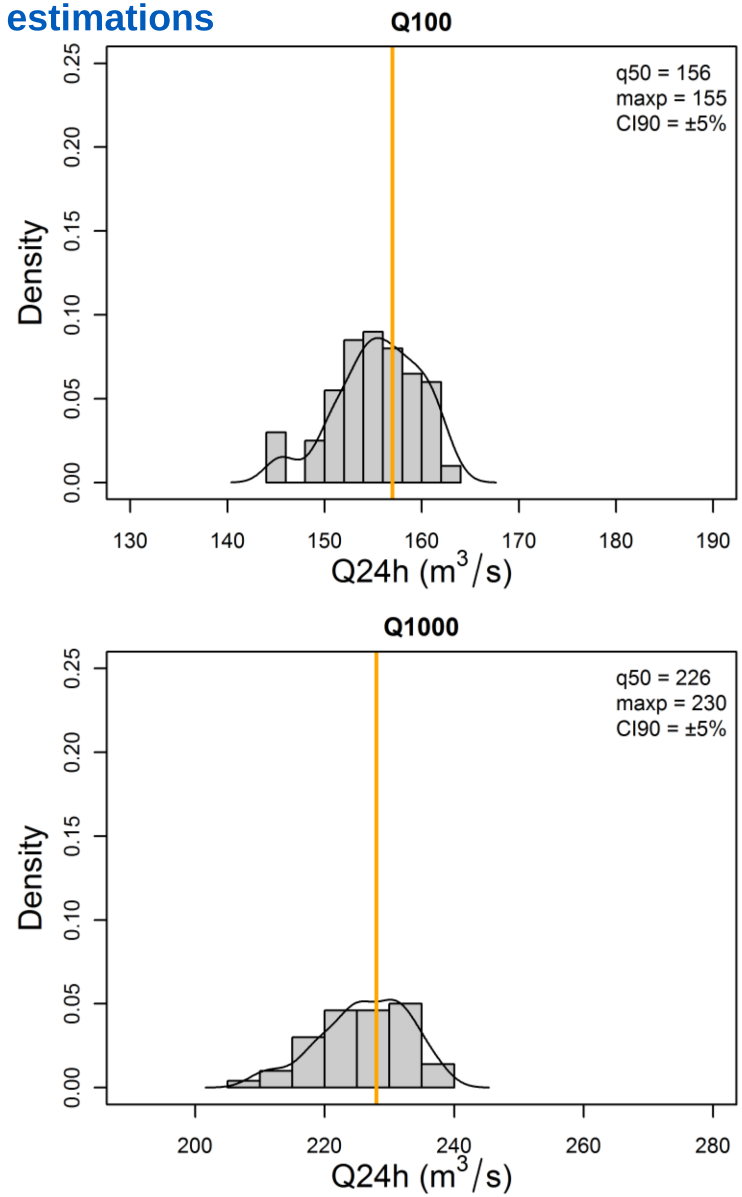


BS experiments - MEWP

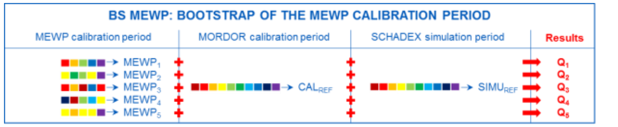


100 BS periods of 25 years among 29: 100 SCHADEX estimations

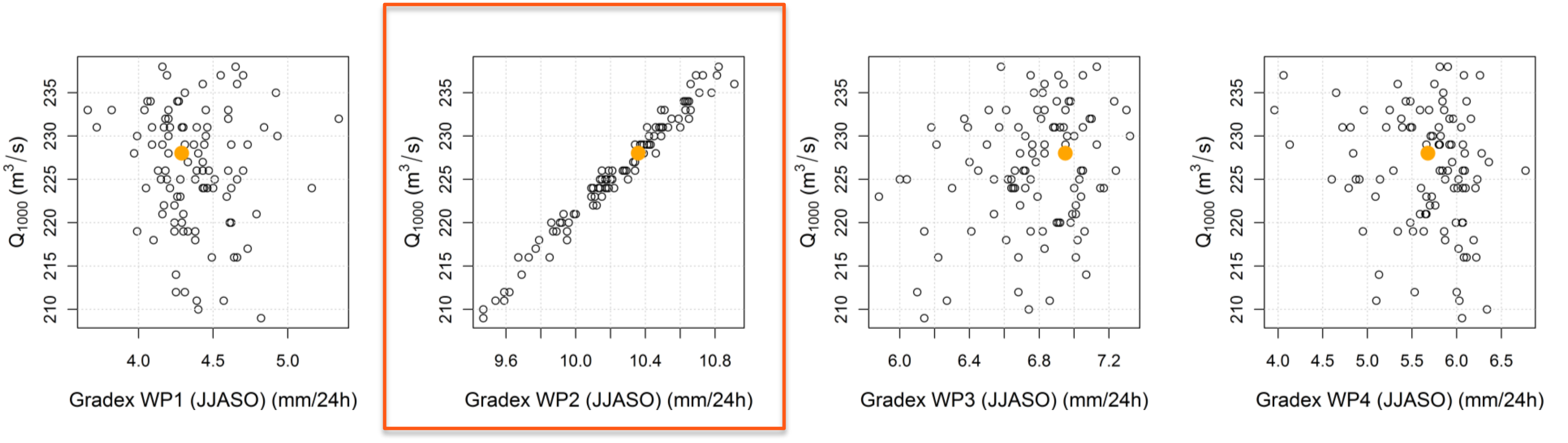




BS experiments - MEWP

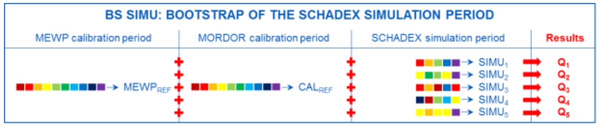


100 BS periods of 25 years among 29

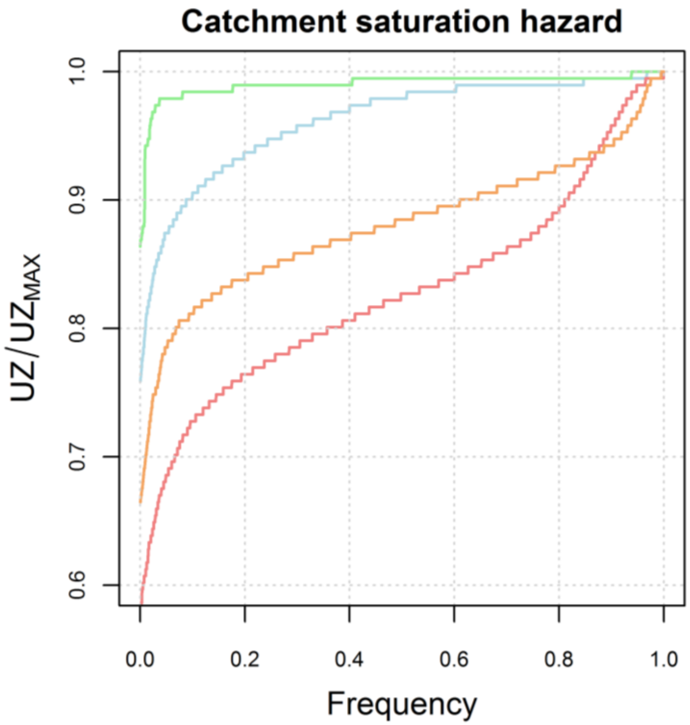


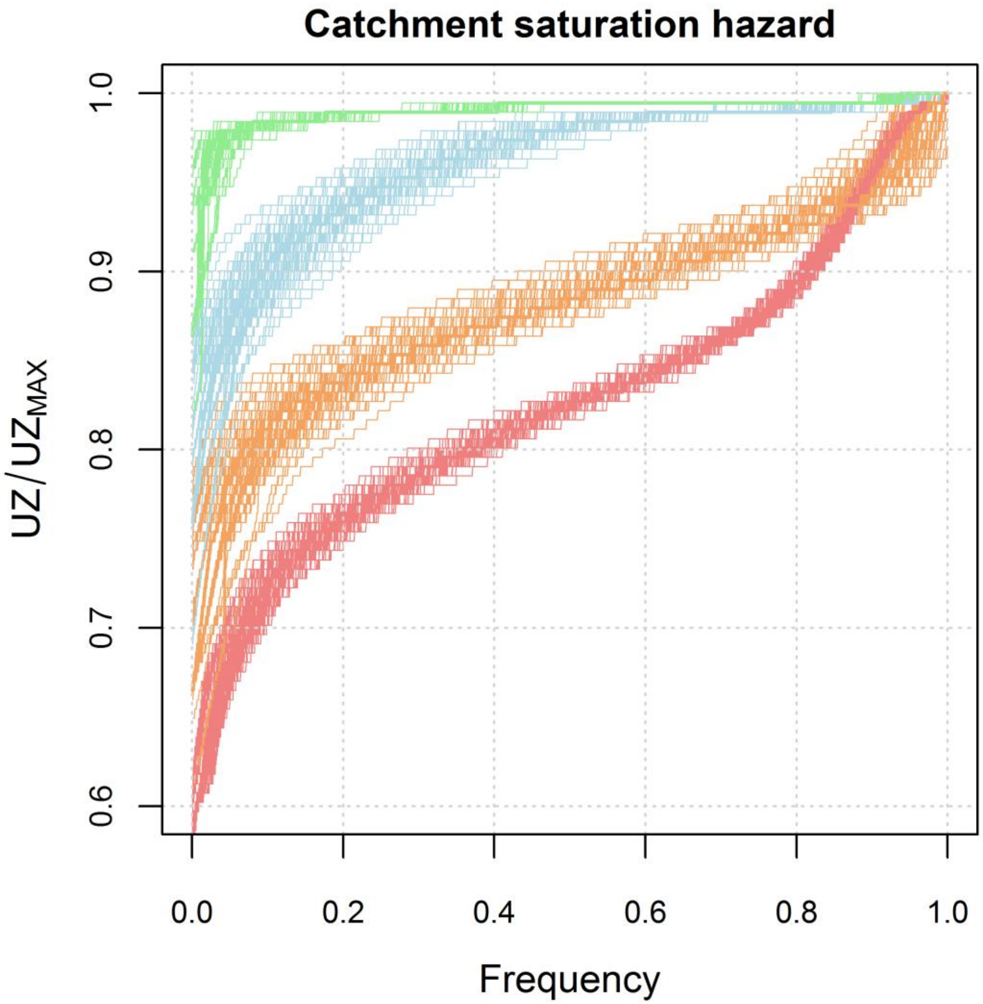
⇨ WP2 gradex is the influent parameter

BS experiments – simulation climatology

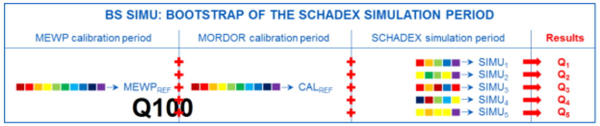


100 BS periods of 25 years among 39

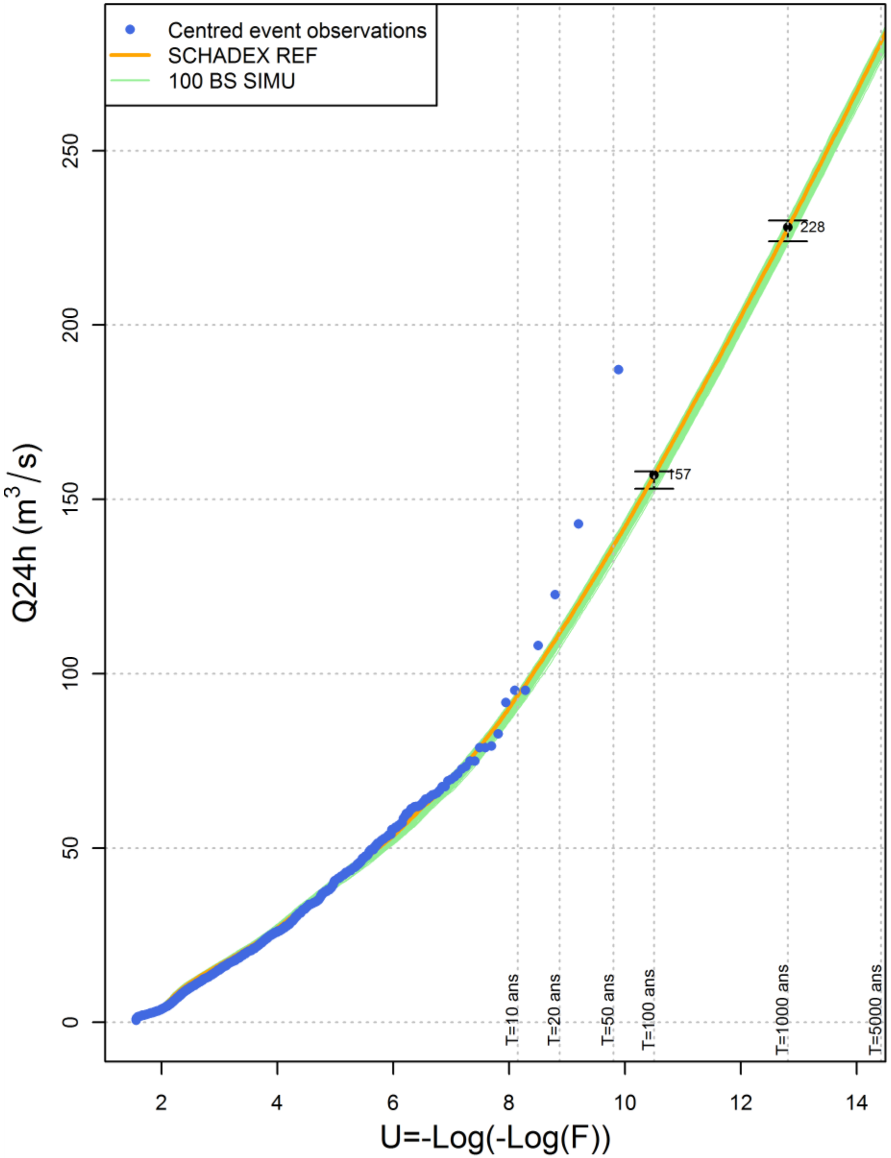


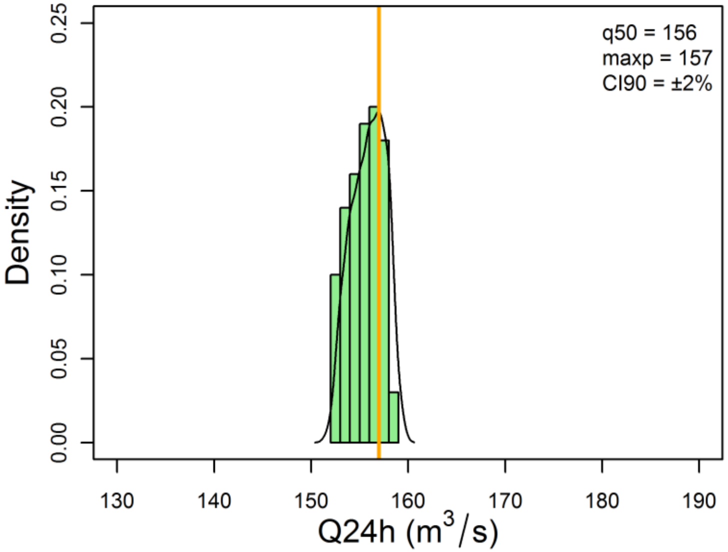


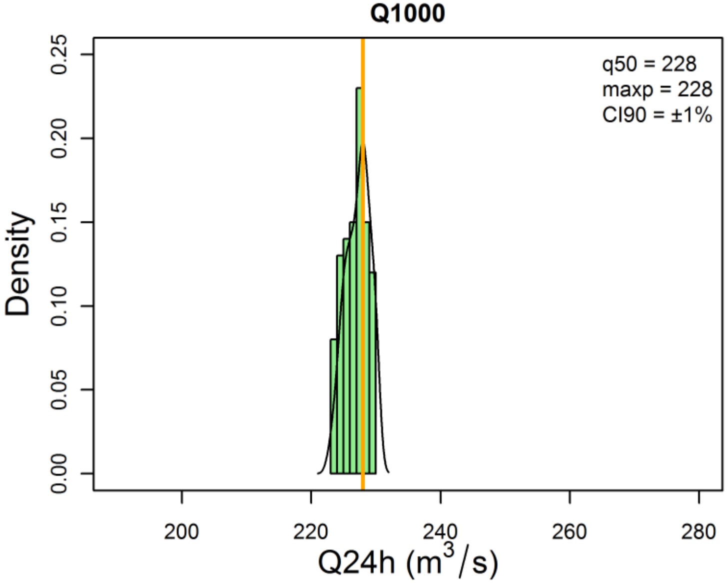
BS experiments – simulation climatology



100 BS periods of 25 years among 39

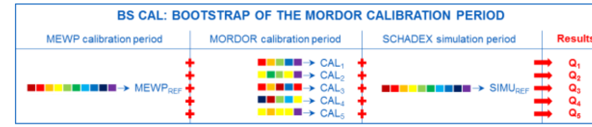


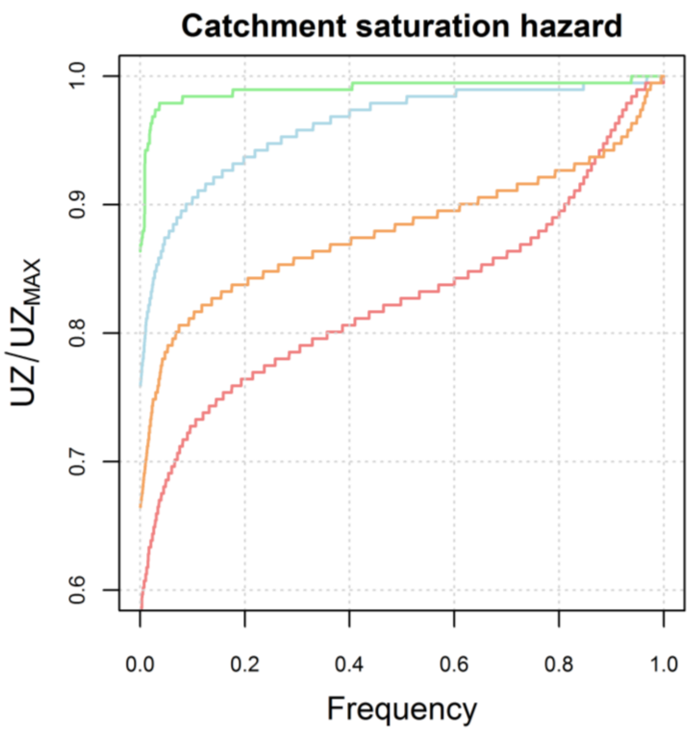


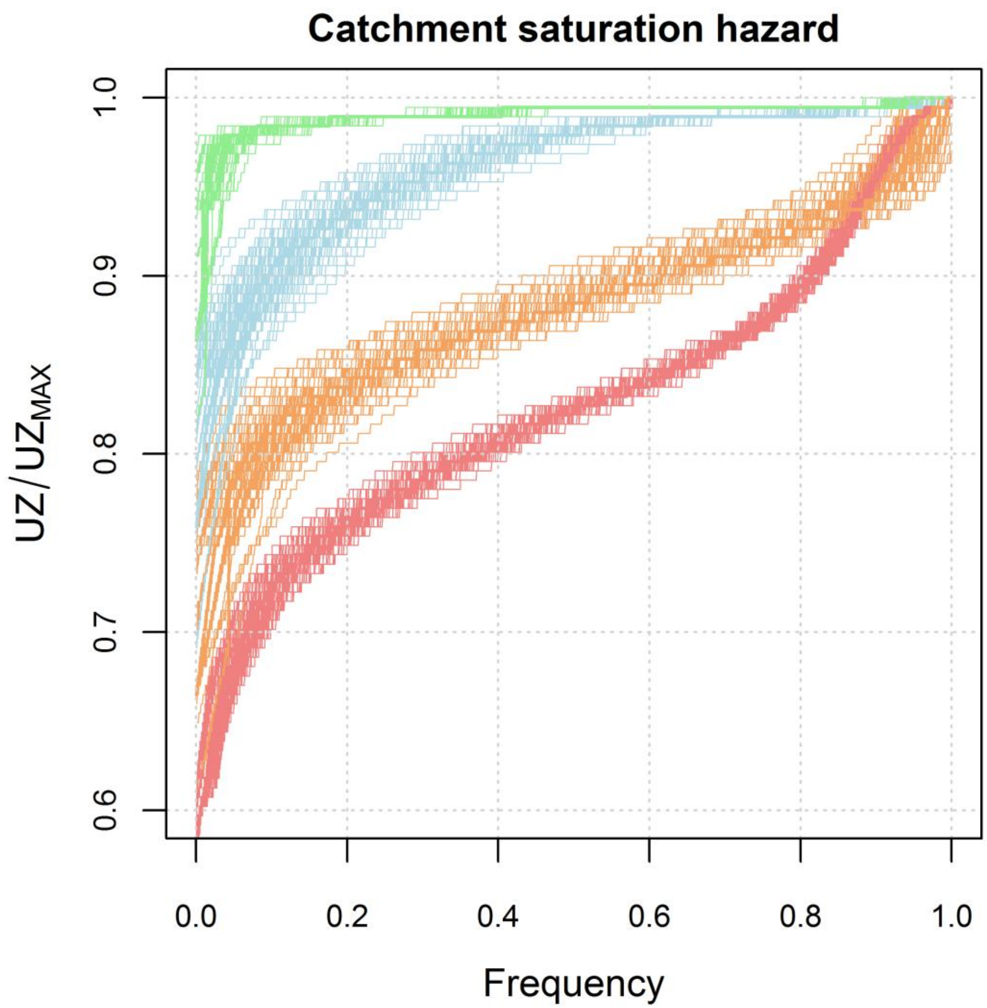


BS experiments – model calibration

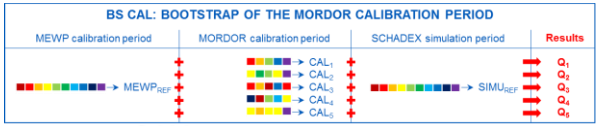
100 BS periods of 25 years among 39



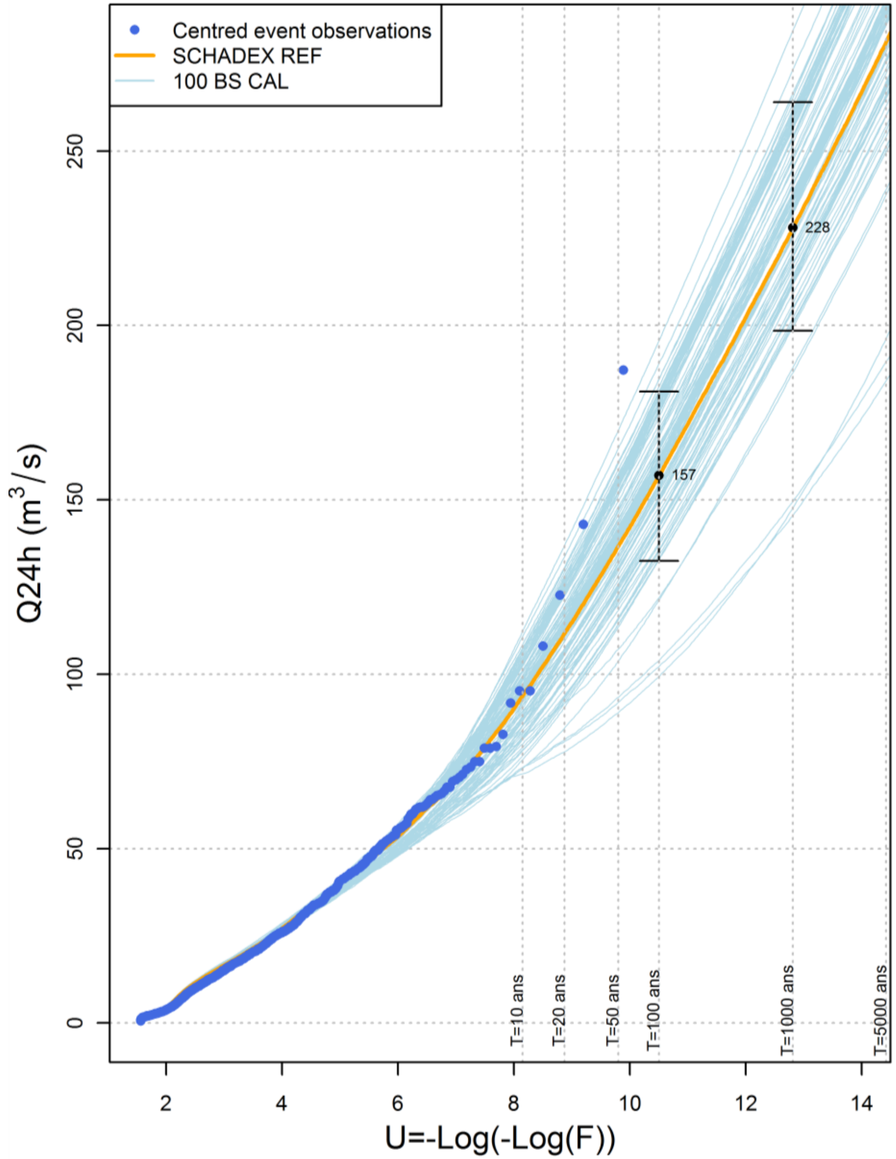


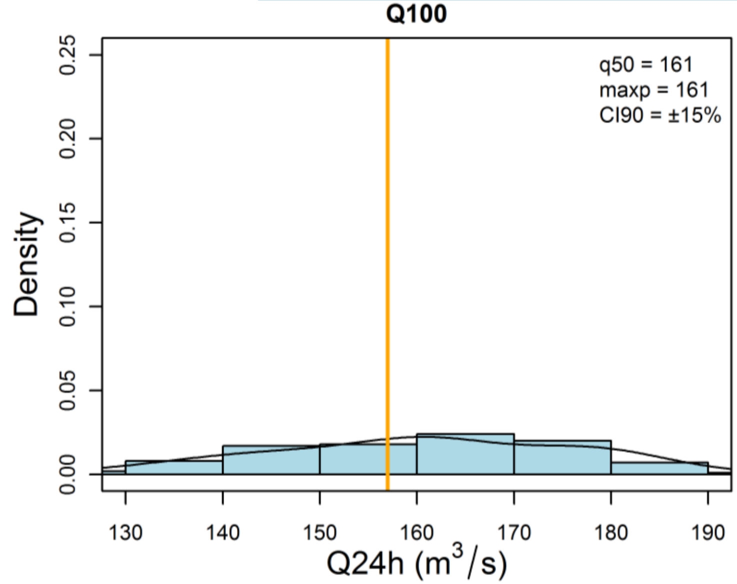


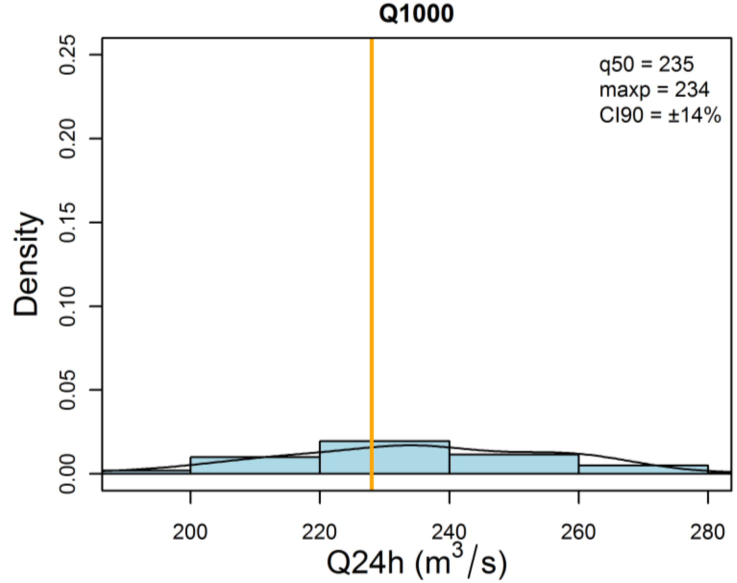
BS experiments – model calibration



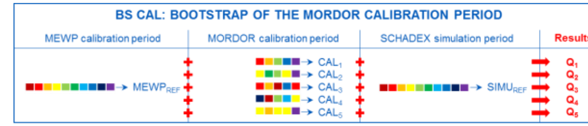
100 BS periods of 25 years among 39 ⇨ 100 models







BS experiments – model calibration

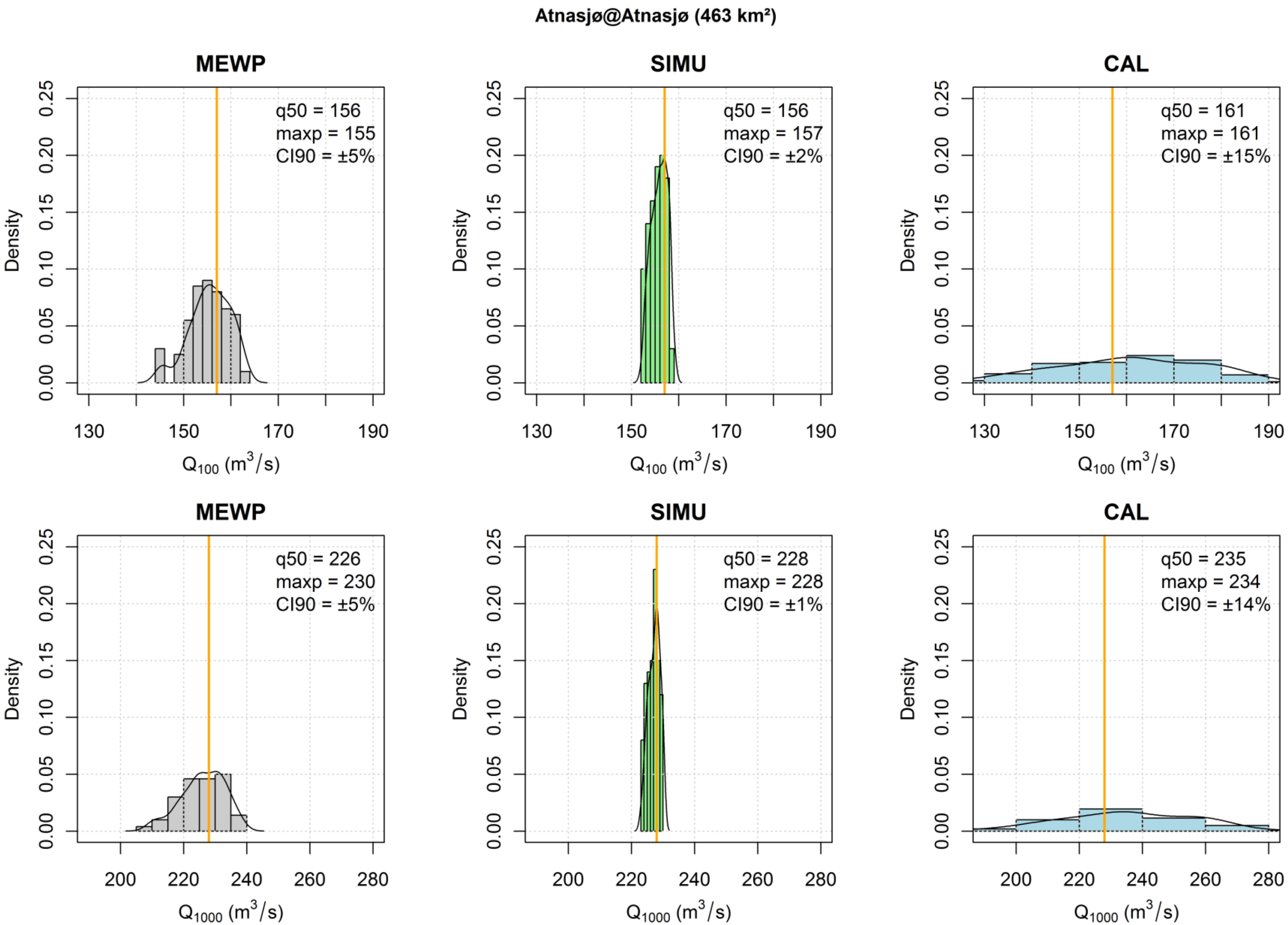


100 BS periods of 25 years among 39 ⇨ 100 models

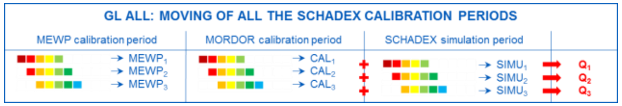
```
PARAMETRES OPTIMISES:
   sbv:    463.0   pdt:   24 h      Modèle neige
    cp:   1.0000
   fp1:   1.2000    fp2:   2.5472    fp3:   1.0035   fp4:   2.1827
 ptjp1:   0.0000   pnfr:   8.0000    ltm:   0.8000
  prft:   1.0000    efp:   3.7971    eft:   0.5450   dbt:   0.1840
    kf:   5.0479    kfs:   0.3000     es:   0.7500   ztn:   1.0000
 fnts0:   0.0000
   fe1:   0.0058    fe2:   2.0000    fe3:  -7.8929
   kl1:   0.1000    kl2:   0.4769     dn:     544.   exn:   4.7842
  ftr1:    2.104   ftr2:    2.188   rtr0:  9999.00    aq:   0.0000
  Umax:      199   Lmax:       30   Zmax:       30

    U1:        0     L1:      124     Z1:        1    N1:       34
    S1:        0    ts1:    0.000  tft1:    0.000
   rti:   1.0000

Simulation du  1/10/1972 au 30/ 9/2010
Calcul des critères du  1/10/1973 au 30/ 9/2010
------------------------------------------------------------------------
CRITERES (Q24h)      Nash : 0.8425
                      R2Q : 0.8470
                     R2dO : 0.5536
```

Lot of parameters conditioning extrapolation within the model
Equifinality of some of them
… to be simplified !

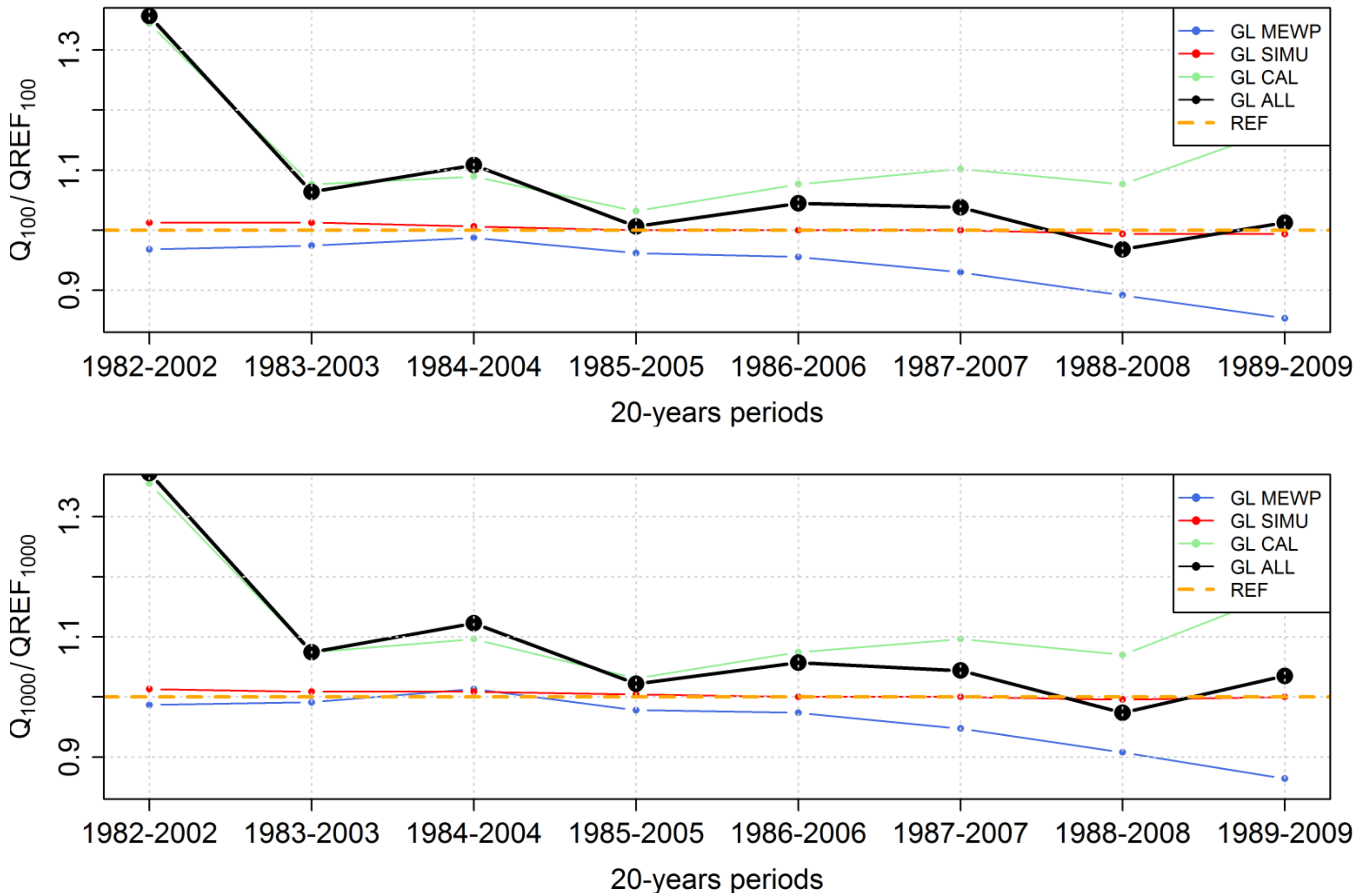
Summary of BS experiments



Summary of GL experiments



Atnasjø@Atnasjø (463 km²)



Summary of all experiments

	Q_{100}	Q_{1000}
BS MEWP	157 m^3/s ± **5%**	228 m^3/s ± **5%**
BS SIMU	157 m^3/s ± **2%**	228 m^3/s ± **1%**
BS CAL	157 m^3/s ± **15%**	228 m^3/s ± **14%**
GL MEWP	15% spread	16% spread
GL SIMU	2% spread	2% spread
GL CAL	26% spread	27% spread
GL ALL	33% spread	34% spread

Conclusions

- SCHADEX combines most of climatic and hydrologic data available on the catchment
- Lot of factors taken into account in extreme flood estimations

  Weather type, season, soil saturation, snowmelt…
- It provides a flexible simulation framework

  MEWP and MORDOR can be substituted easily by other models (e.g. GPD for rain)
- Detailed assessment of flood risk : volume, peak, annual or seasonal, processes…
- The sensitivity analysis allows to point out the most influent parameters / data for extreme flood estimation
- « Future flood » estimation through SCHADEX will focus on these parameters / data