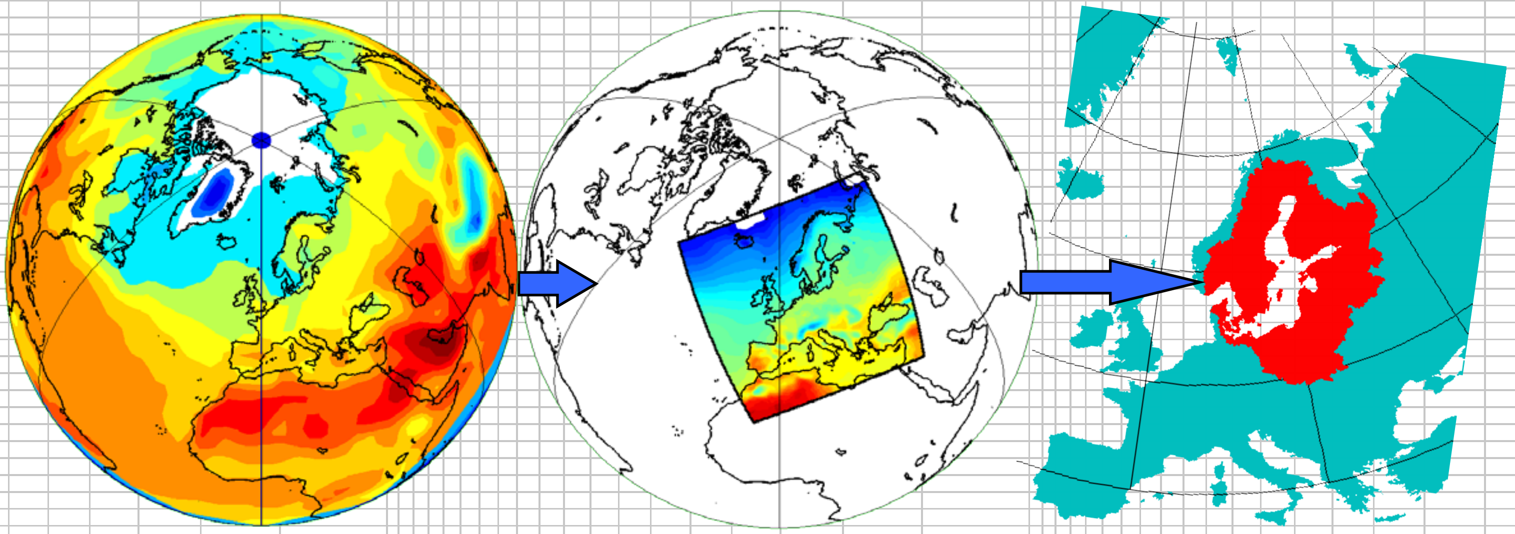
Distribution-based scaling (DBS) for better utilizing outcomes of regional climate models (RCMs)



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Research & Development unit, SMHI

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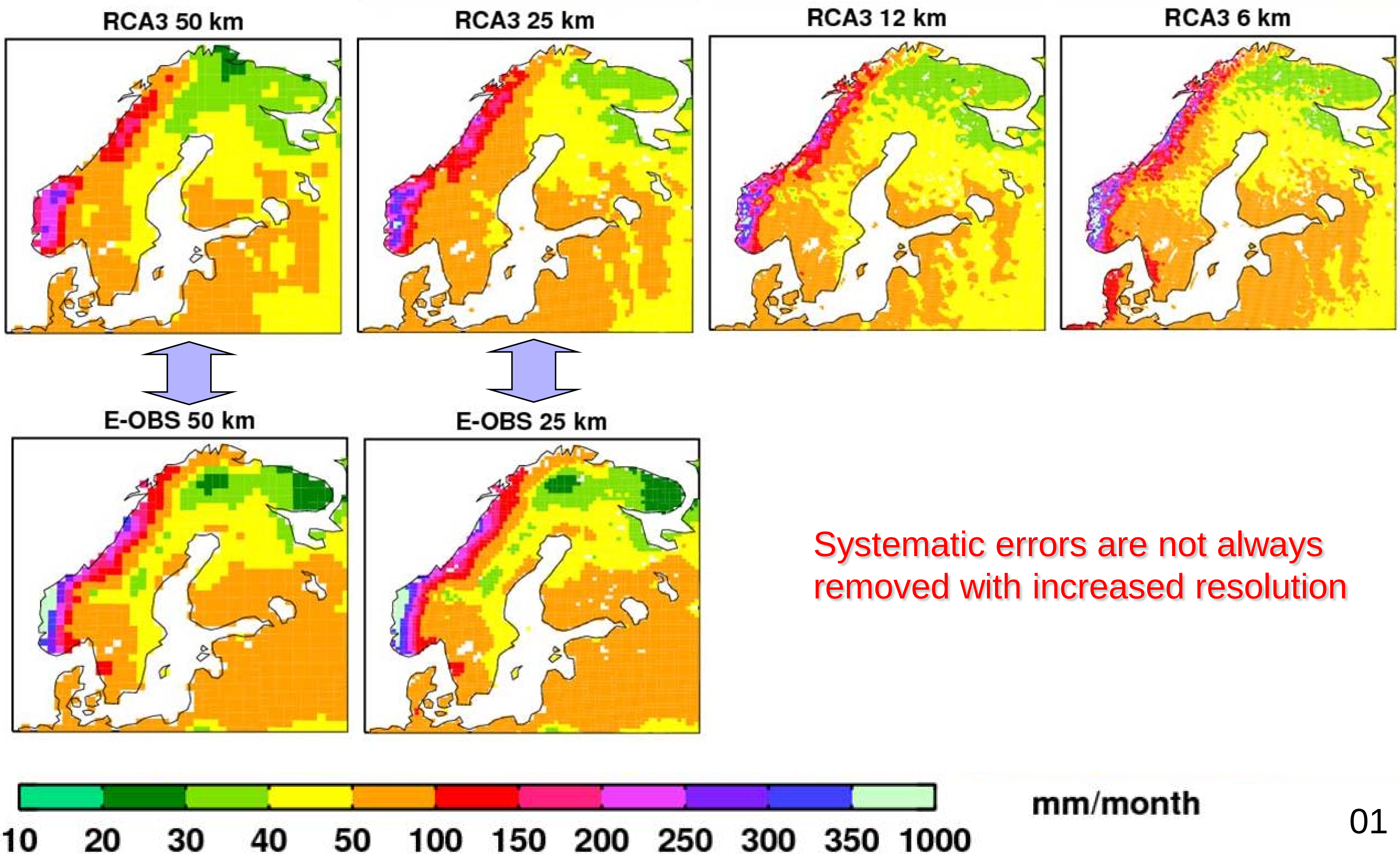
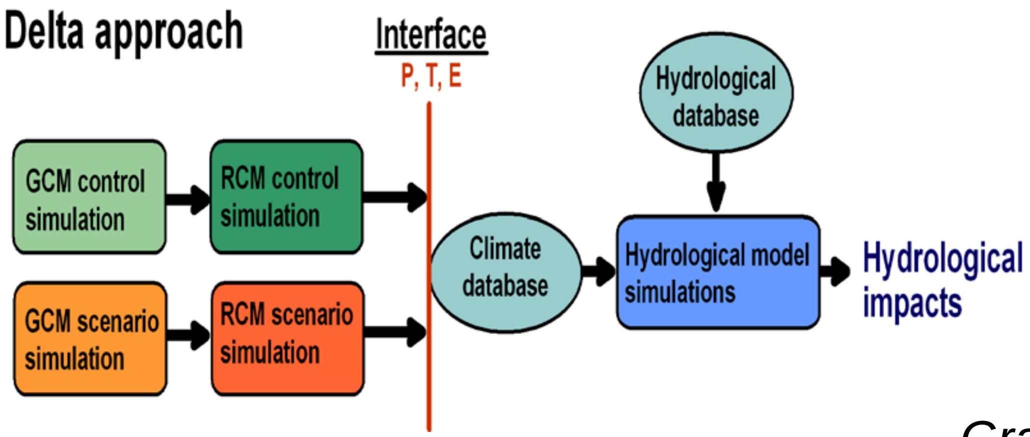
Precipitation (DJF, 1987-2007) as a function of resolution

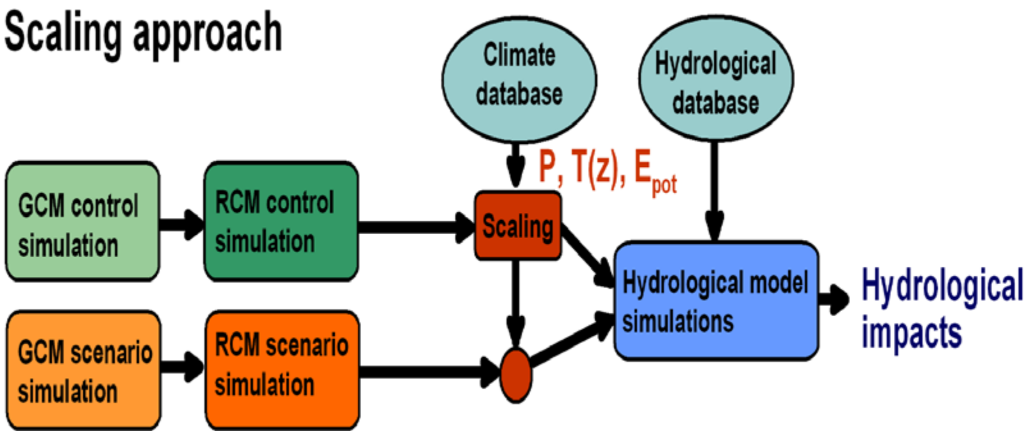


Systematic errors are not always removed with increased resolution



- Adjusts present climate to the future
- Variability remains in the present (observations)

Graham et al., 2007; Olsson et al., 2009



- Adjusts control climate to the present
- Variability comes from the future (RCM)

Yang et al., 2009

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Current status of method development:

Meteo. Variables to be scaled [unit]	Temp.	Probablility distribution	Remark
Precipitation [mm]	Daily	Gamma Distribution $$f(x\|\alpha,\beta)=\frac{(x/\beta)^{\alpha-1}\exp(-x/\beta)}{\beta\Gamma(\alpha)},\quad x,\alpha,\beta\succ 0.$$	▪ **Identify a threshold value to remove drizzle days** ▪ **normal rainfall and extrem rainfall events are adjusted differently per season**
Temperature [º C]	Daily	Normal Distribution $$f(x\|\mu,\sigma)=\frac{1}{\sqrt{2\pi\sigma^2}}e^{-\frac{(x-\mu)^2}{2\sigma^2}},\qquad \beta\succ 0.$$	▪ **Dependent on weather state of being rainy or non-rainy** ▪ **Fourier series used to describe annual cycle**
Wind velocity [m/s]	Daily	Weibull Distribution $$f(x\|a,b)=\frac{b}{a}\left(\frac{x}{a}\right)^{b-1}e^{-\left(\frac{x}{a}\right)^b},\qquad x\succ 0.$$	▪ **adjusted per season and dependent on weather state**
Relative humidity [%]	Daily	Beta Distribution $$f(x\|a,b)=\left[\frac{\Gamma(a+b)}{\Gamma(a)\Gamma(b)}\right]x^{a-1}(1-x)^{b-1},\qquad 0\le x\le 1 \qquad a,b\succ 0$$	▪ **adjusted per season and dependent on weather state**

DBS for precipitation:

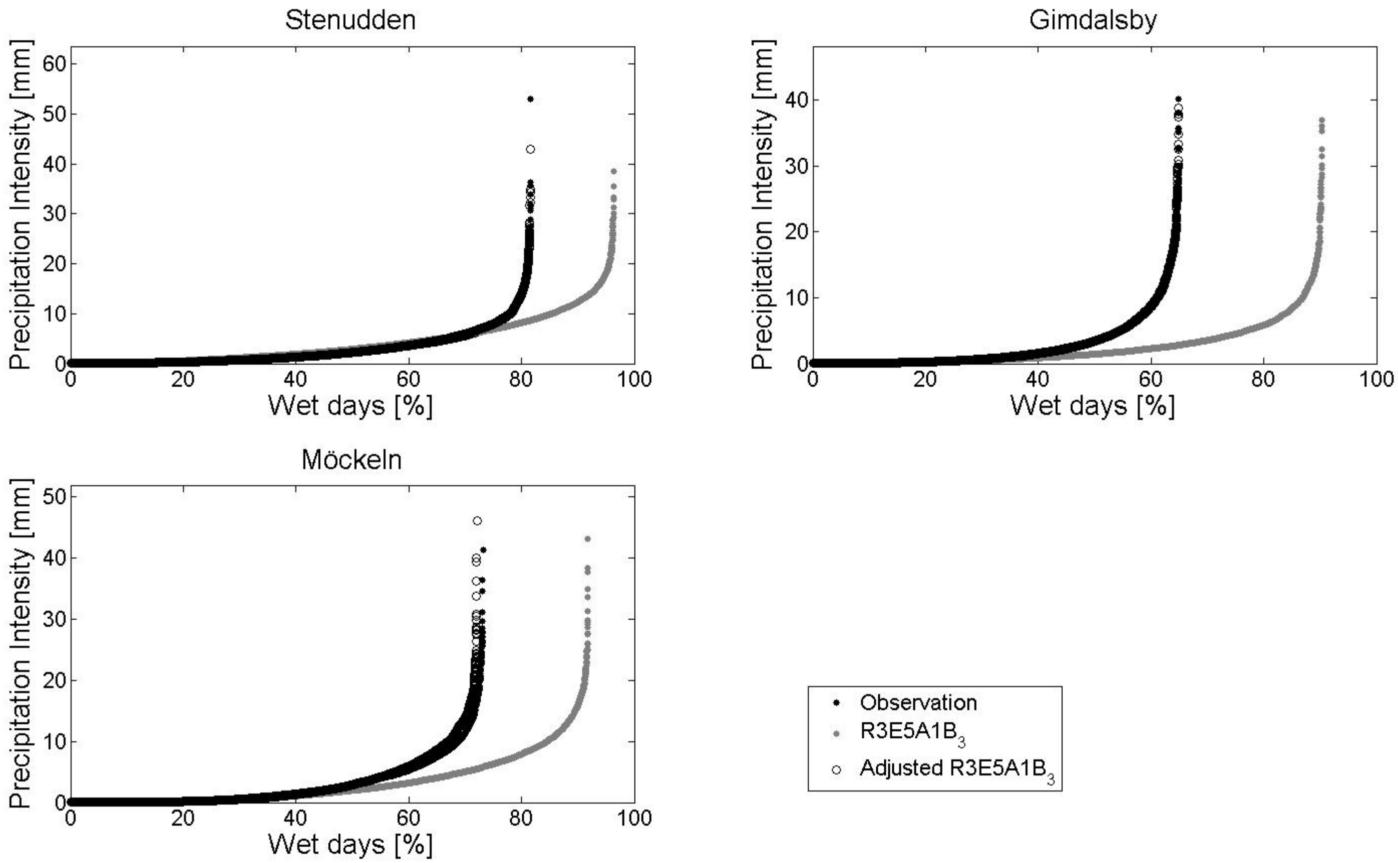

Fig: Distribution of precipitation intensities for all three study basins calculated from observations (1961-1990), and raw R3E5A1B3 output and DBS-adjusted R3E5A1B3 output for the control period.

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DBS for temperature:

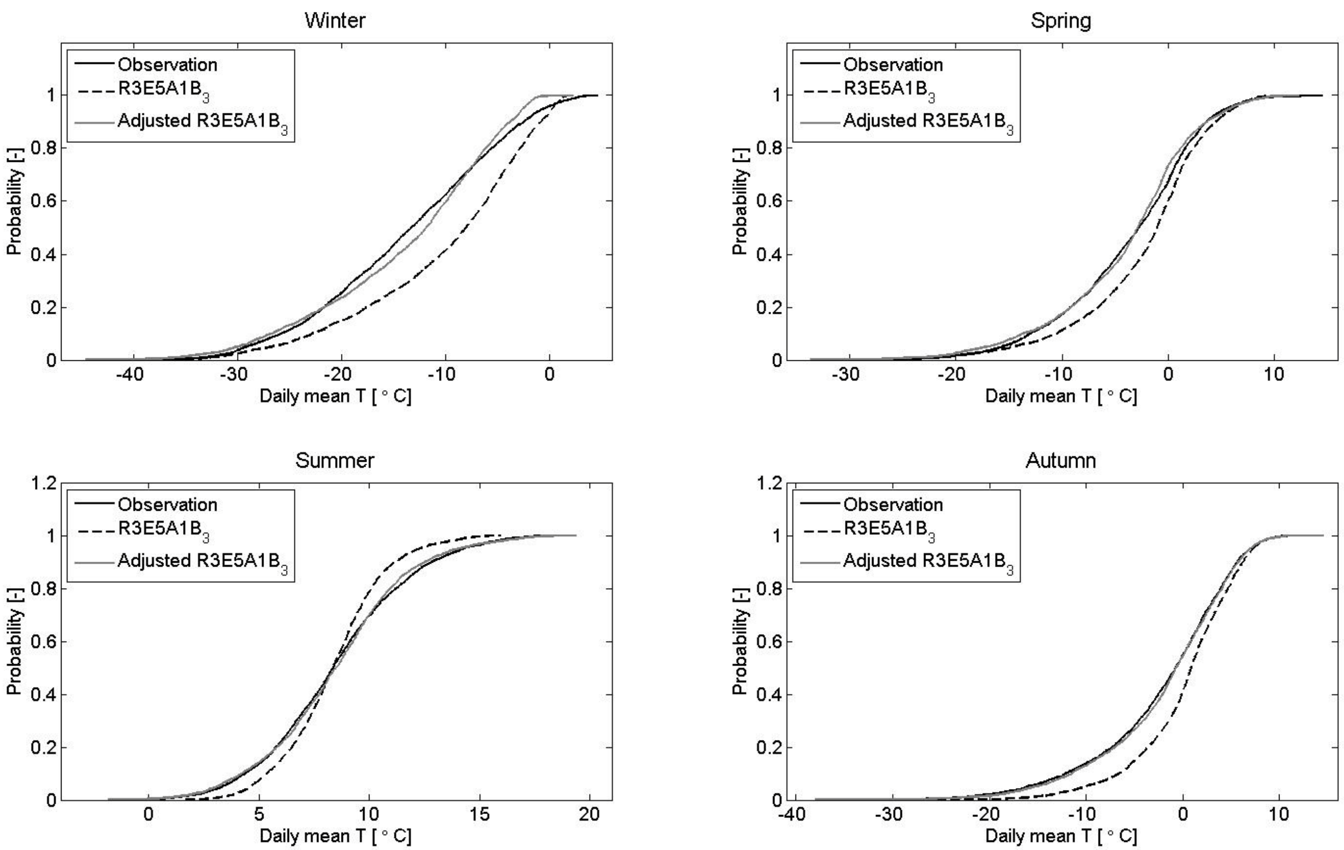

Fig.: Distribution of daily temperature from observations (1961-1990), and raw R3E5A1B3 and DBS-adjusted R3E5A1B3 projection outputs for the control period for each season in the Stenudden basin.

DBS for relative humdity (Rh) & wind speed (W):

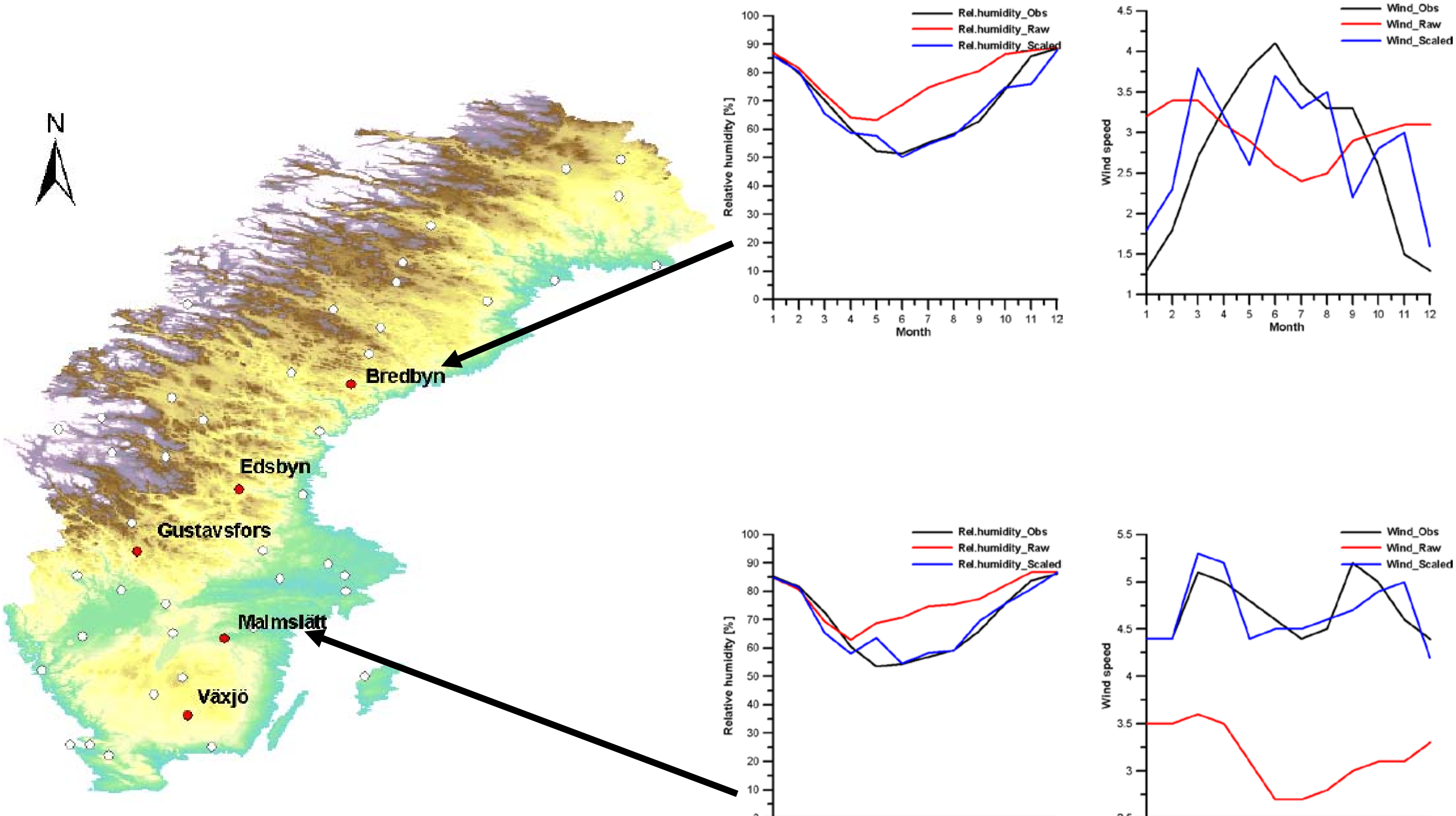

Fig:
DBS method to adjust relative humidity
and wind speed at stations in Sweden using R3E5A1B3 output for the control period

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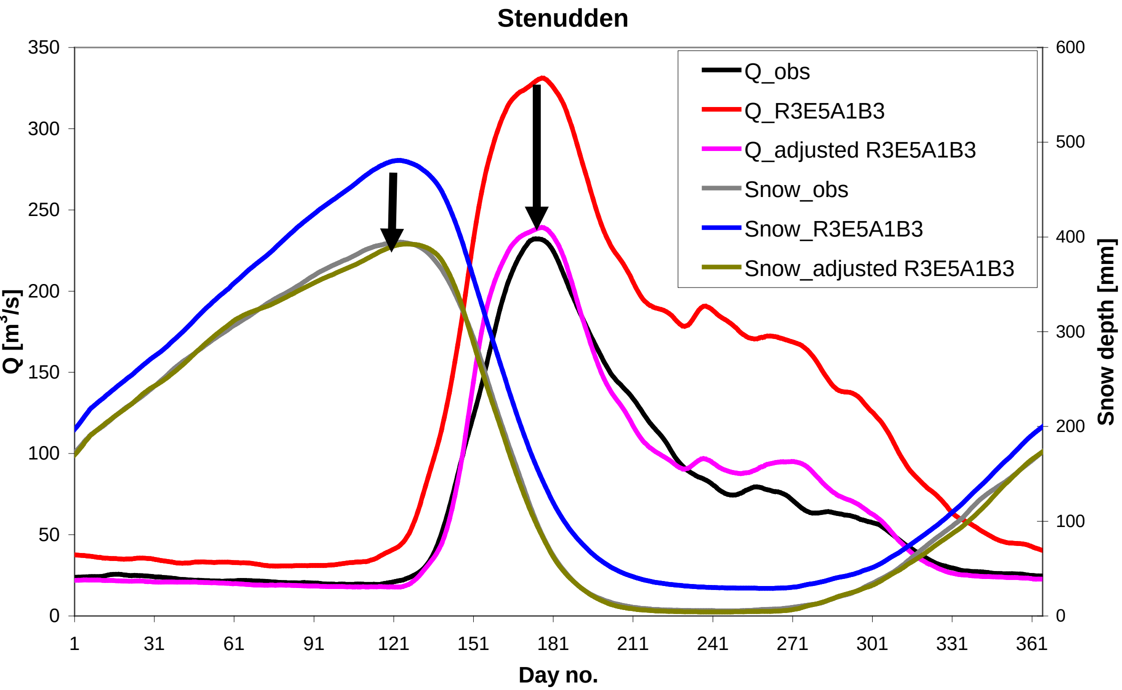
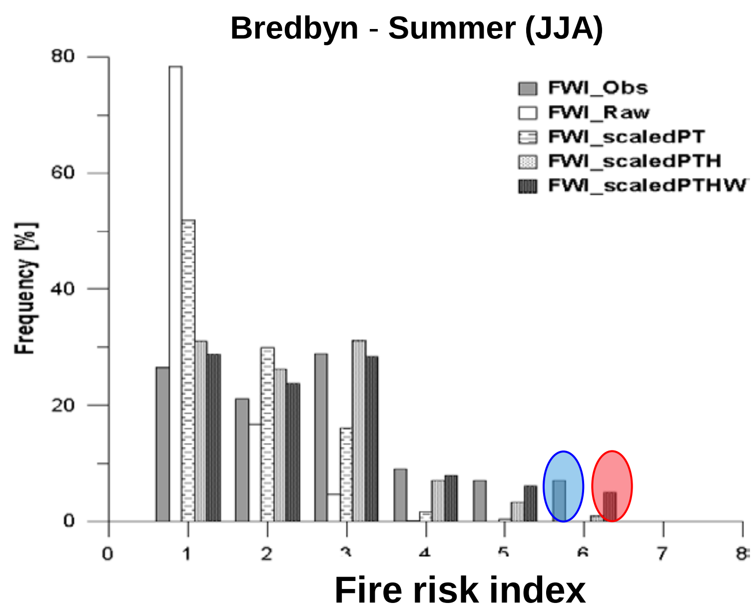


Hydrological response (P, T) Using HBV

Fig:
Mean daily runoff (Q) and snow depth (Snow) simulated with the HBV Model using precipitation and temperature from observations (1961-1990), raw R3E5A1B3, and DBS-adjusted R3E5A1B3 projection outputs for the control period.
(*Yang et al, 2009; Olsson et al, 2010*)

Forest fire risk (P,T, Rh, W) using Fire Weather Index (FWI)

Fig:
Seasonal forest fire risk simulated with FWI model using Precipitation, temperature, relative humidity and wind speed from observations (1961-1990), raw R3E5A1B3, and DBS-adjusted R3E5A1B3 projection.
(*Yang et al., manuscript, 2010*)



About Classification:

- **Classification algorithm**
  - Fuzzy rule based classification (*Bardossy et al, 2002*)
    --- Extreme floods analysis (*Filiz et al, 2004*)
    --- statistical downscaling *(Wetterhall et al, Yang et al, 2008)*

- **Predictor & Predictand**
  - Predictor: Mean sea level pressure (SLP)
  - Predictand: Daily precipitation **p** at 20 stations

- **Spatial Domain**
  - 40º N - 75º N
  - 30º W - 40º E

- **Number of types**
  - 12

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Fuzzy rule based classification

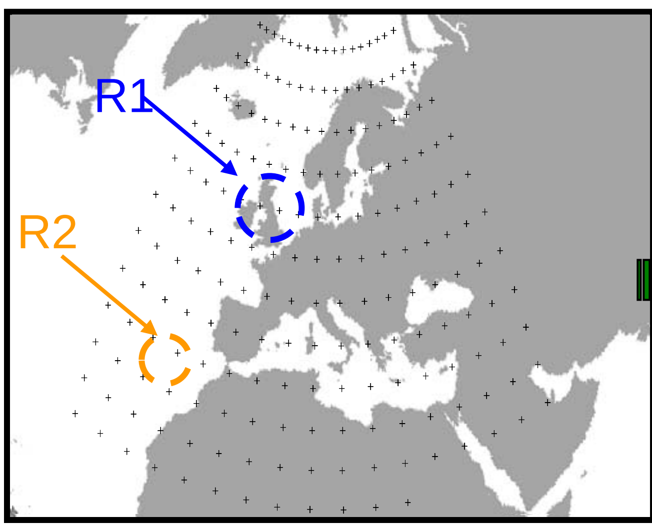
Using anomaly of sea level pressure (SLP)

$$g(i,t) = \frac{h(i,t) - \mu(i,t')}{\sigma(i,t')}$$

Very high (++) High (+) Low (-) Very low (--)

at each grid point i from 1961 to 1990:

h (i,t): Observed pressure at time t
μ (i,t'): **Mean** of SLP over annual cycle
σ (i,t'): **Standard deviation** of SLP over annual cycle

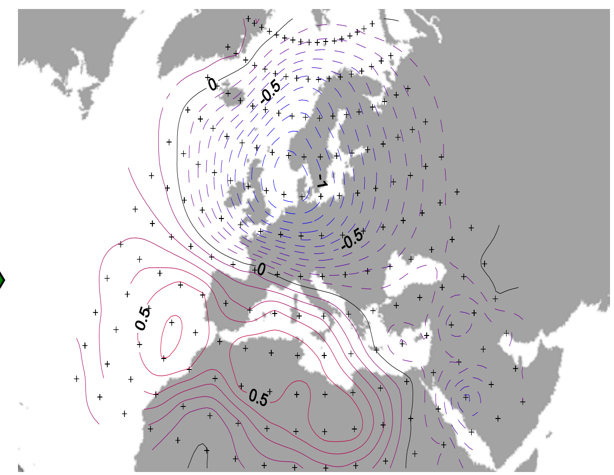


Fuzzy rule:

IF **R1 "Very low"**
AND **R2 "High"**
AND **R3**…AND **R4…**
THEN **CT 11**

…

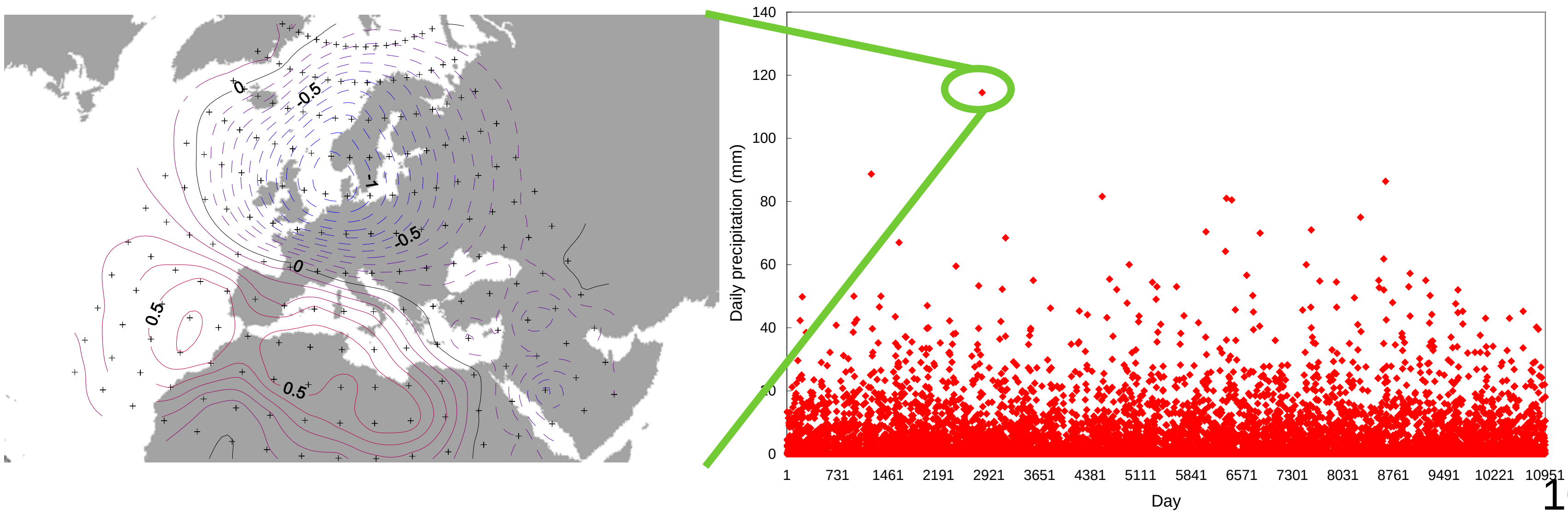
IF **R1 ...**
AND **R2 …**
AND **R3**…AND**R4…**
THEN **CT 02**



Fuzzy rule based classification

- maximize dissimilarities amongst different CT group
- seasonal hydrological response

Objective function → **Simulated Annealing** → **Representative CTs**



Some results:

Wetness Index, I_w :

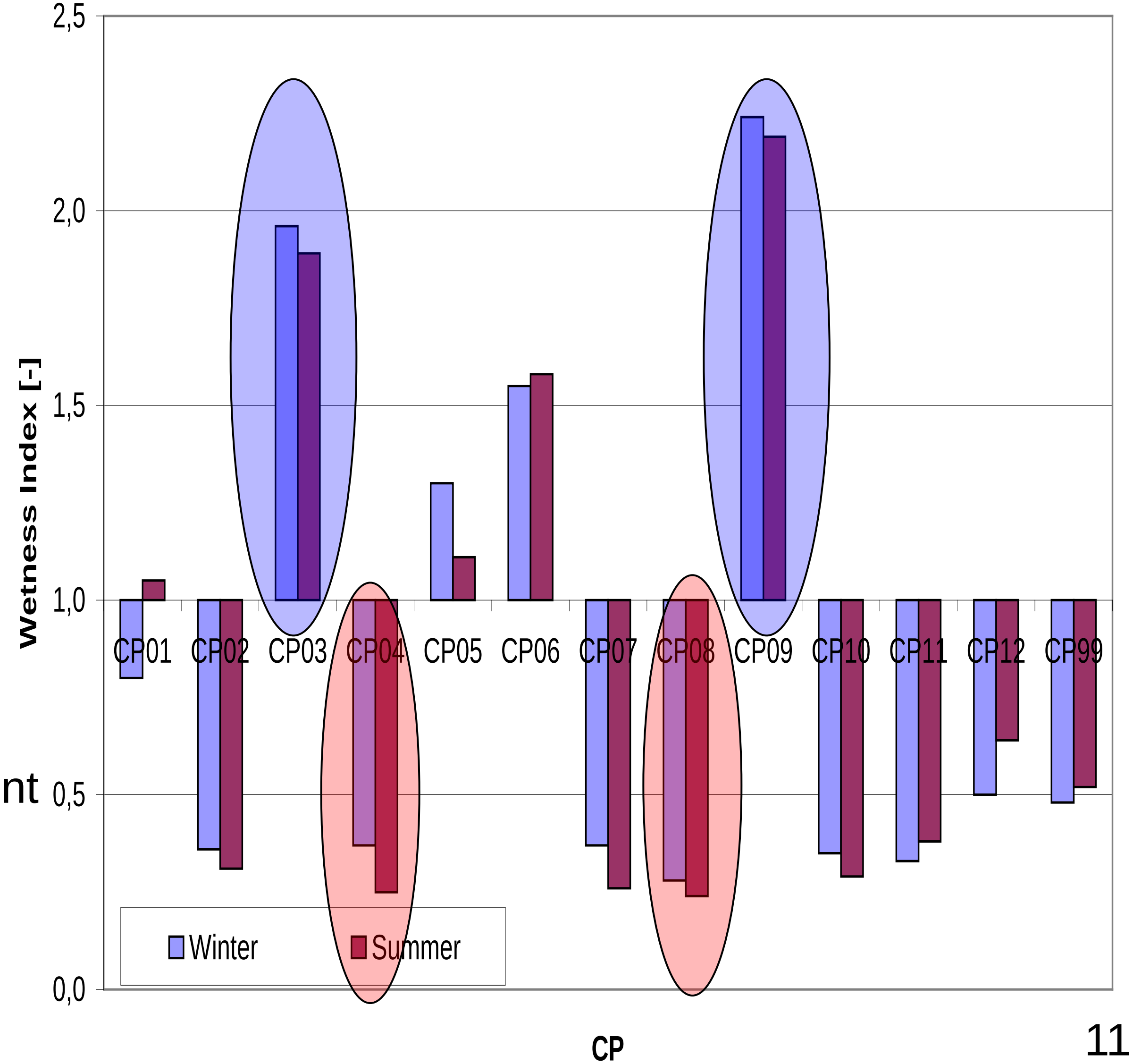
$$I_w = \frac{R_i}{N_i}$$

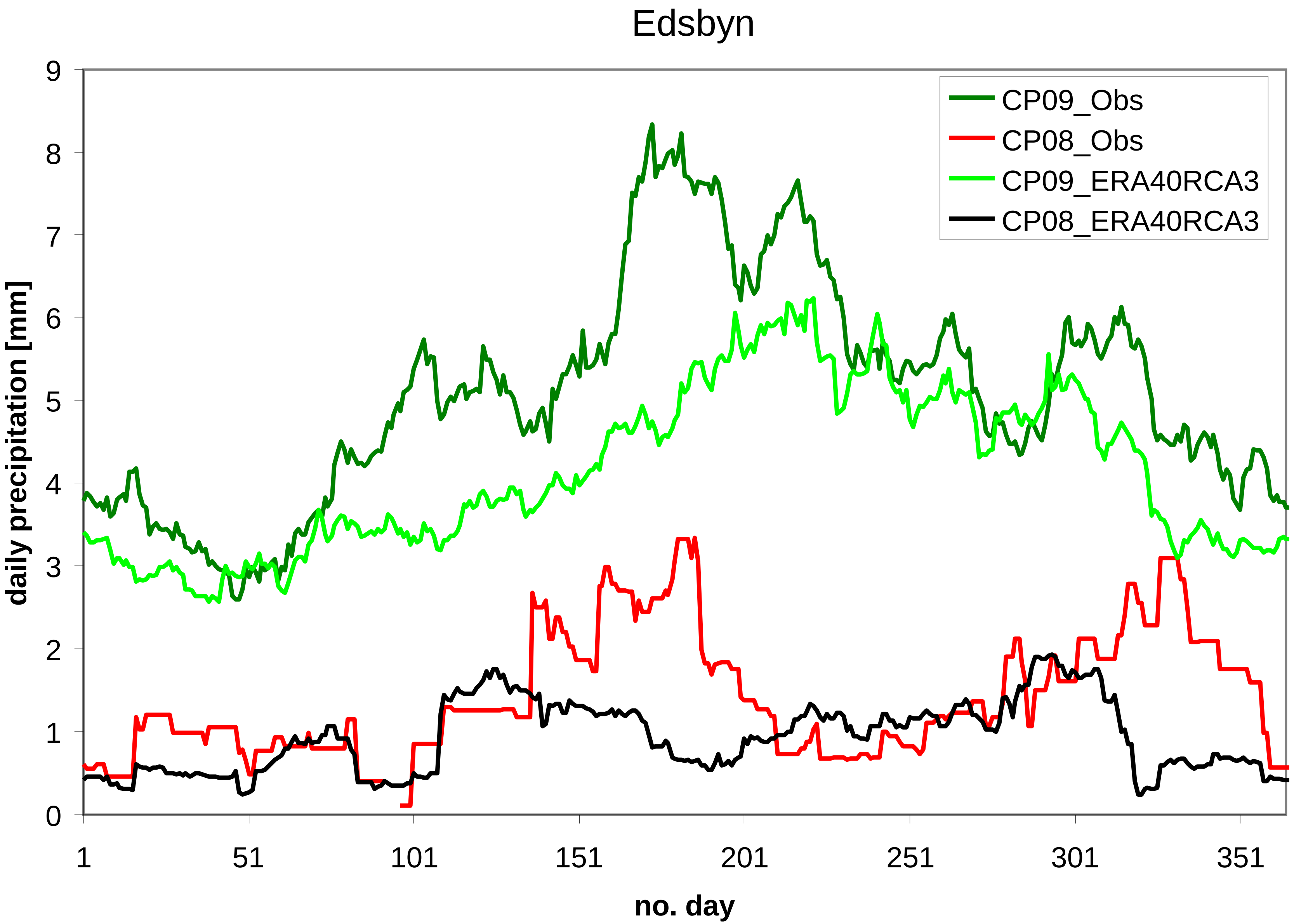
Where,

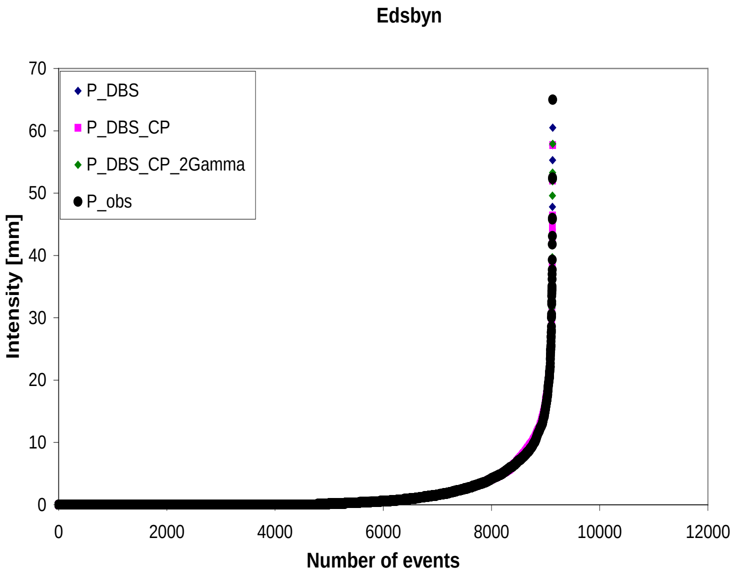
i --- CT

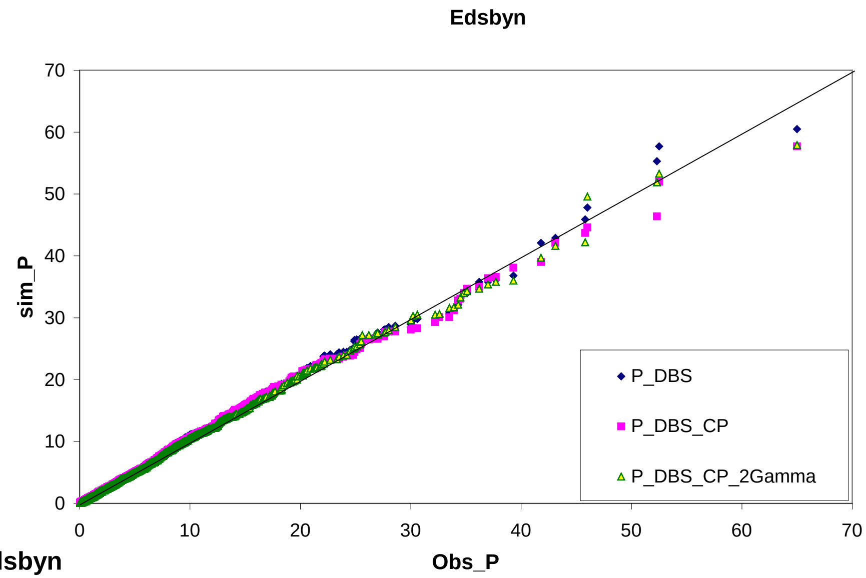
R_i - Rainfall contribution in percent [%]

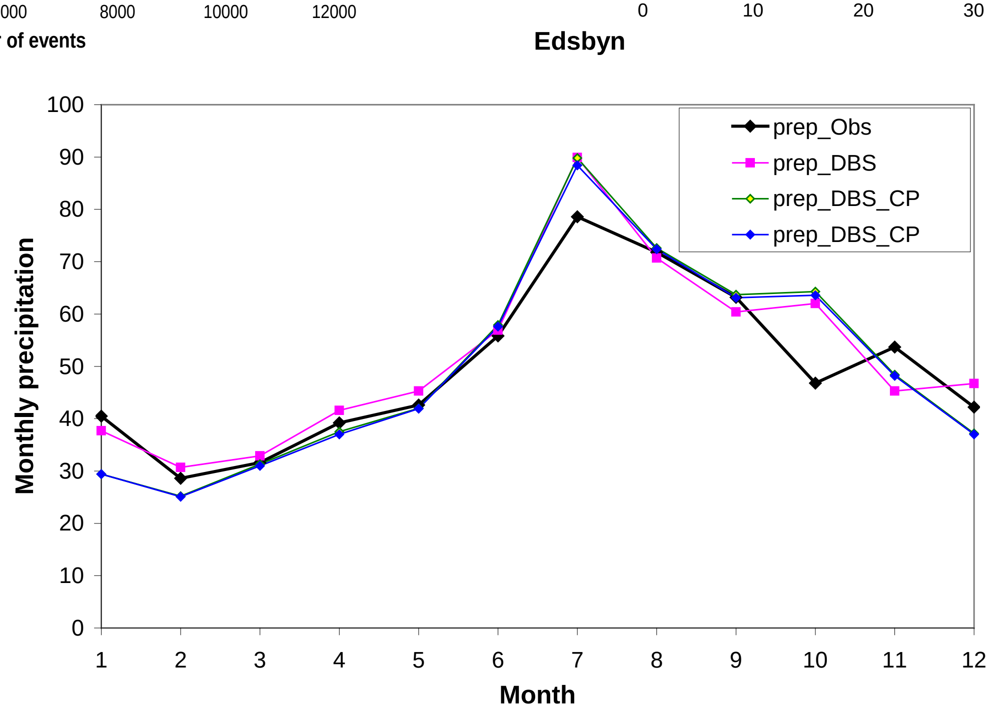
N_i - CT occurrence in percent [%]




Edsbyn
CP09_Obs
CP08_Obs
CP09_ERA40RCA3
CP08_ERA40RCA3
daily precipitation [mm]
0
1
2
3
4
5
6
7
8
9
1
51
101
151
201
251
301
351
no. day


Edsbyn
Intensity [mm]
Number of events
P_DBS
P_DBS_CP
P_DBS_CP_2Gamma
P_obs
0
10
20
30
40
50
60
70
0
2000
4000
6000
8000
10000
12000


Edsbyn
sim_P
Obs_P
P_DBS
P_DBS_CP
P_DBS_CP_2Gamma
0
10
20
30
40
50
60
70


Edsbyn
Monthly precipitation
Month
prep_Obs
prep_DBS
prep_DBS_CP
prep_DBS_CP
0
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7
8
9
10
11
12

Conclusion & Future work:

- Bias correction is required to remove systematic error from climate model;

- DBS method show its promising uses in adjusting bias for impact studies; It helps to better use outcome from climate models without interfering their climate change signal;

- Circulation types proved useful in capturing synoptic property in atmosphere.

- Testing COST733 package for CT classification to find out most appropriate classification for climate condition in Sweden;

- Improve DBS method to follow dynamic evolution in climate model (*by spring, 2011*)

- Using classified CTs to evaluate RCMs' performance in hydrological aspect;

Thank you!

Delta Change & DBS:

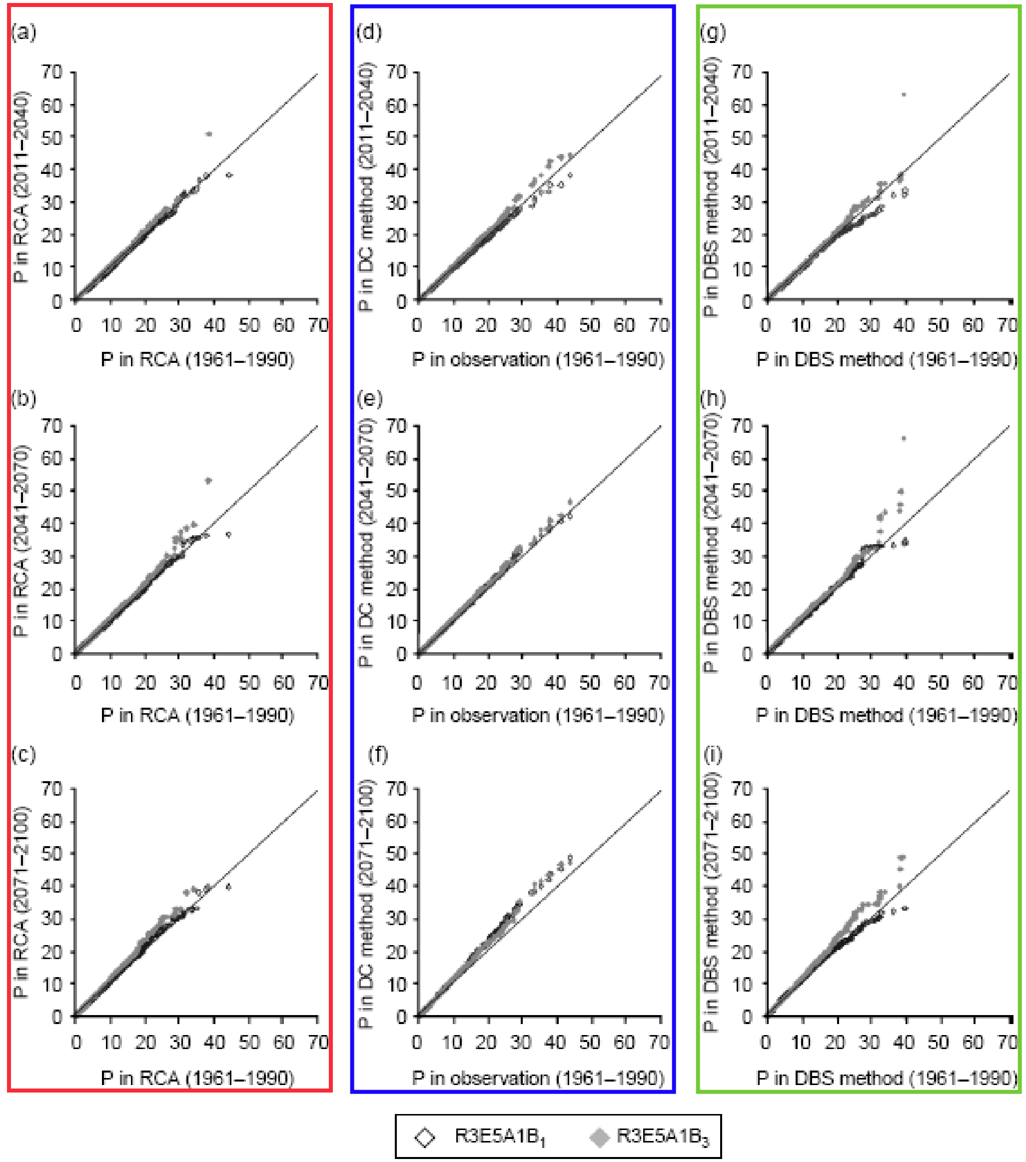


Fig.:
Comparison between precipitation in the control or baseline period (x axis) and in future periods (y axis; 2011–2040 in the upper row, 2041–2070 in the middle row, 2071–2100 in the bottom row) for both the R3E5A1B1 and R3E5A1B3 projections in the Stenudden basin. The left column shows raw RCA3 outputs, the middle column shows DC-adjusted RCA3 outputs and the right column shows DBS-adjusted RCA3 outputs.

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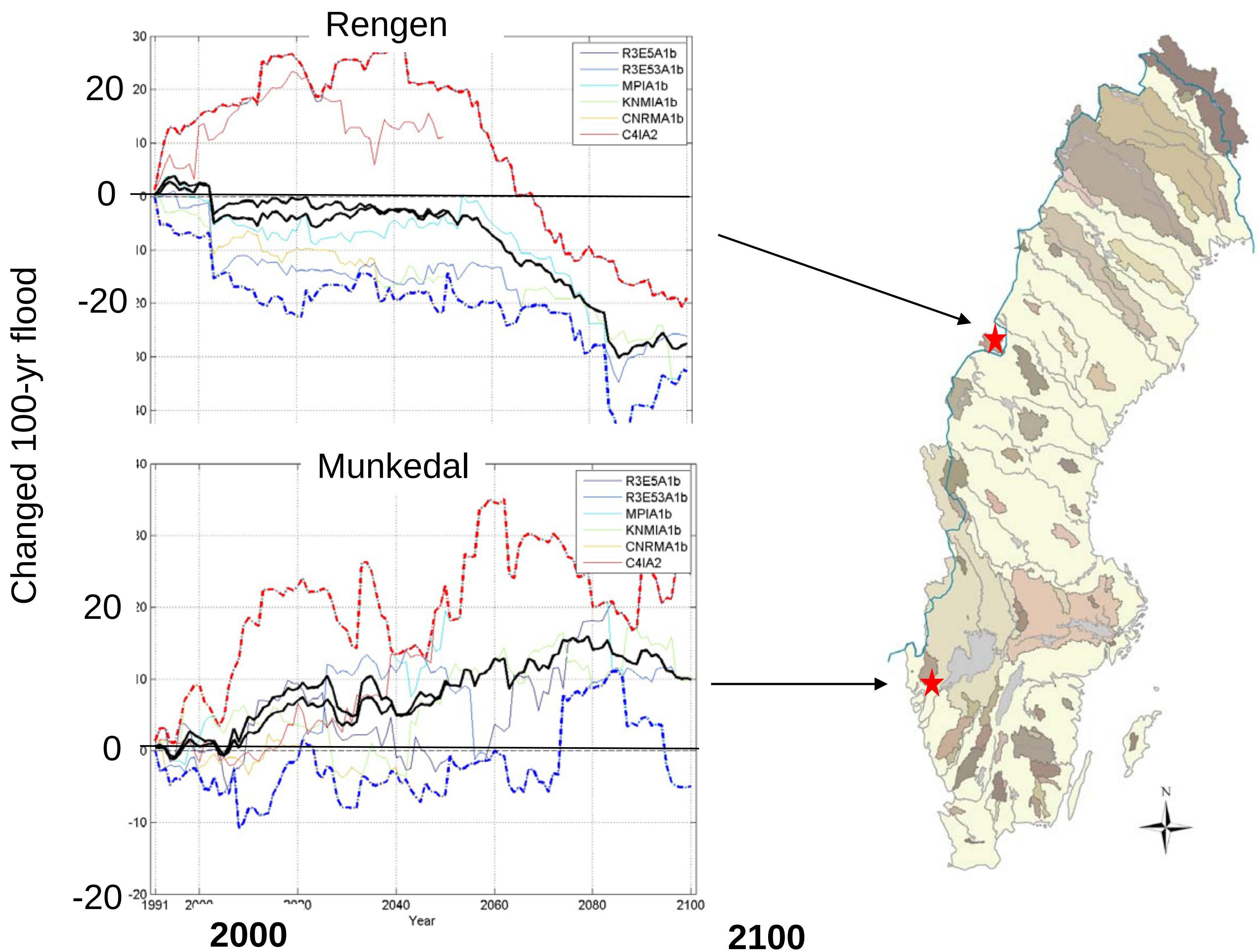
CC study: changed 100-year discharge 2071-2100 (P, T)



CC study: Hydrological response (P, T) – Climate Impact