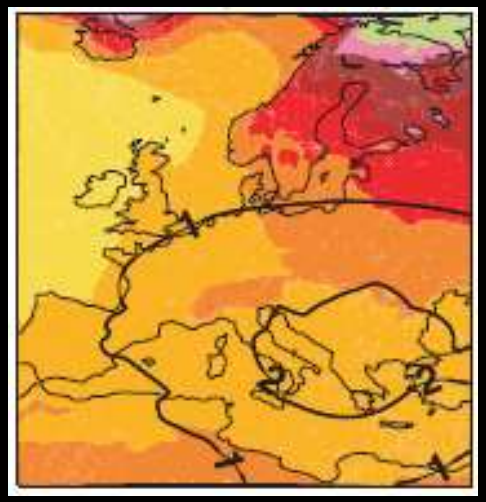
SMHI

Regional Climate Model (RCM) data evaluation and post-processing for hydrological applications

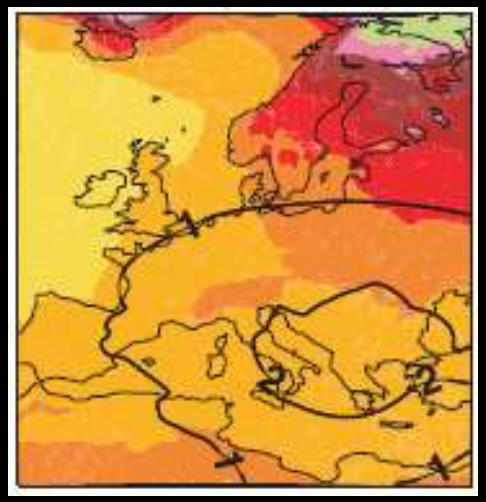


Jonas Olsson

Research & Development (hydrology)
Swedish Meteorological and Hydrological Institute

SMHI

Hydrological climate change impact assessment at SMHI: overview / issues / future



Jonas Olsson

Research & Development (hydrology)
Swedish Meteorological and Hydrological Institute

People

Coordinator of hydrological climate change impact research at SMHI

Chantal Donnelly

Peter Berg

Thomas Bosshard

Wei Yang

Lennart Simonsson

Outline

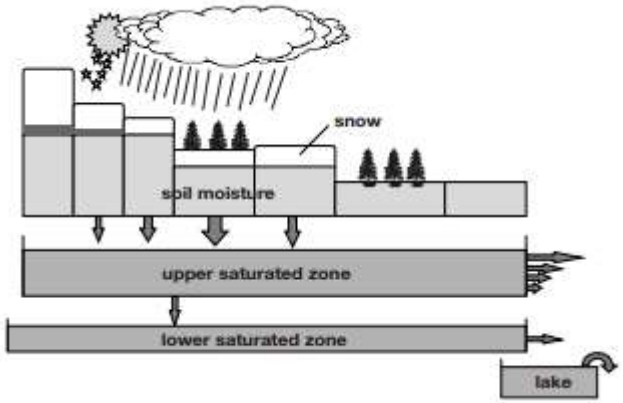
- Hydrological climate change impact assessment at SMHI: a brief history + overview of current methods, tools and applications
- Selected issues: what scientific questions are we struggling with?
- Future directions

History

- The SWECLIM programme 1997-2003

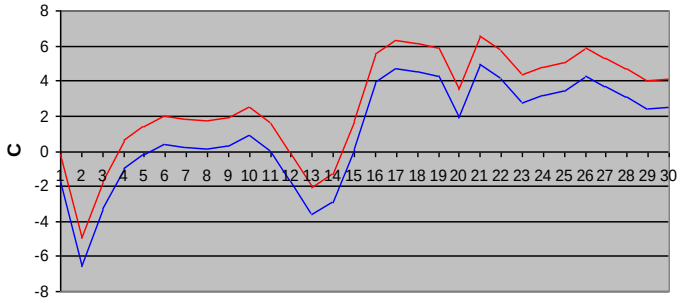
Rossby Centre

- HBV model



- Delta Change

T



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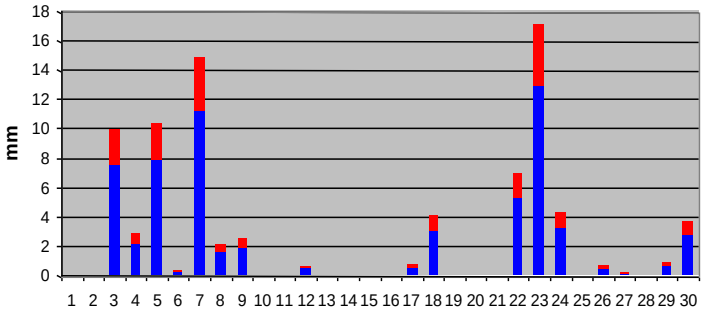


Early results

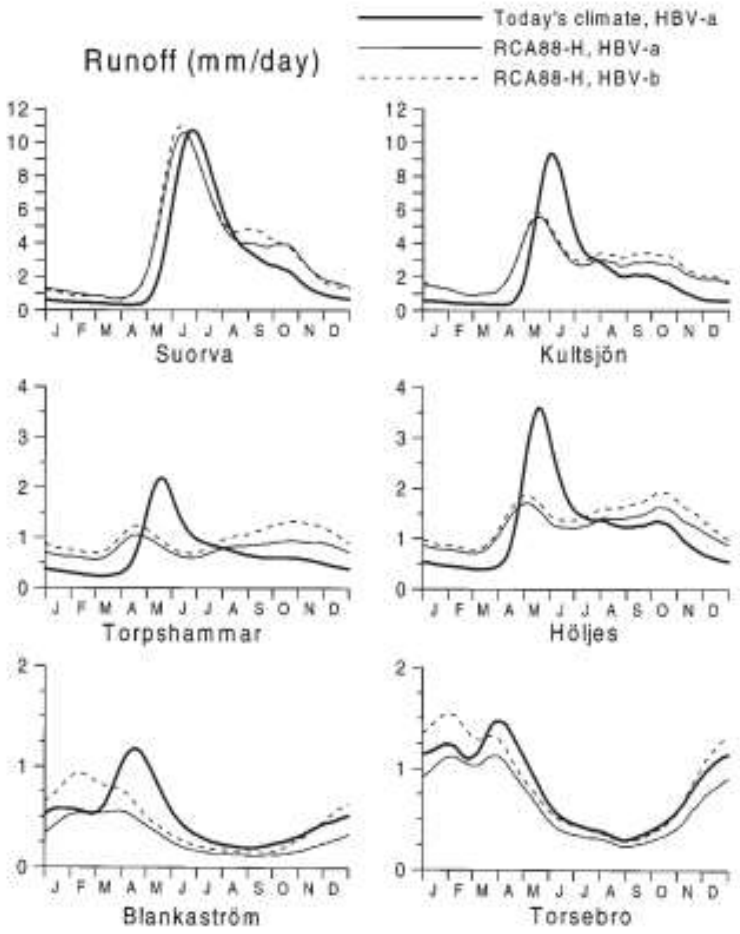


Fig. 7. Annual cycle of river runoff in 6 test basins today and according to the RCA88-H regional climate scenario and 2 versions of the HBV model. The curves have been smoothed

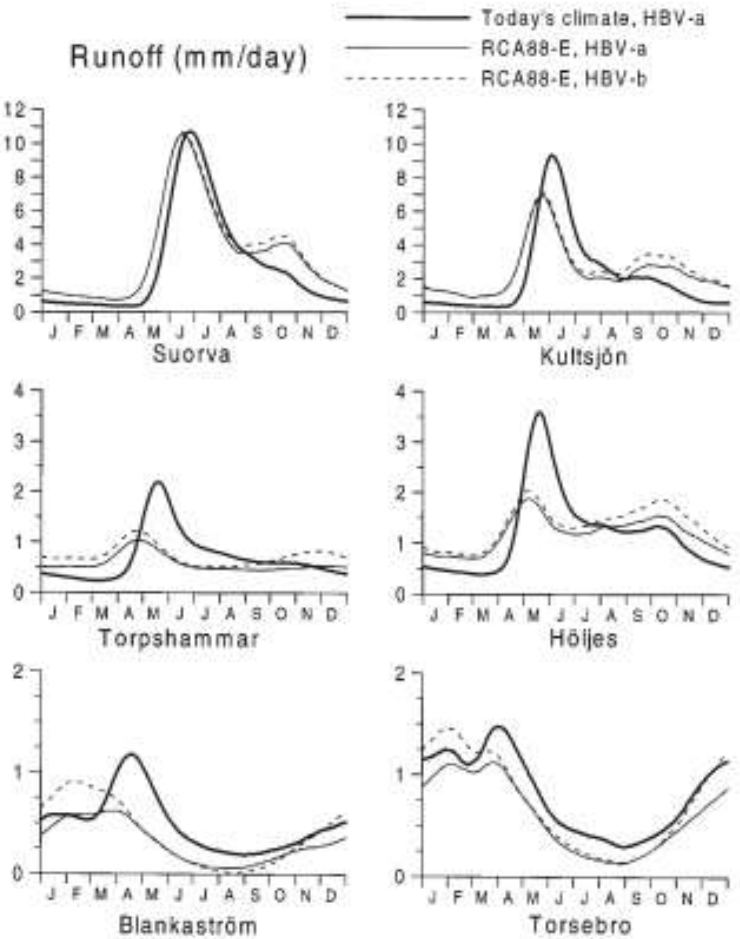
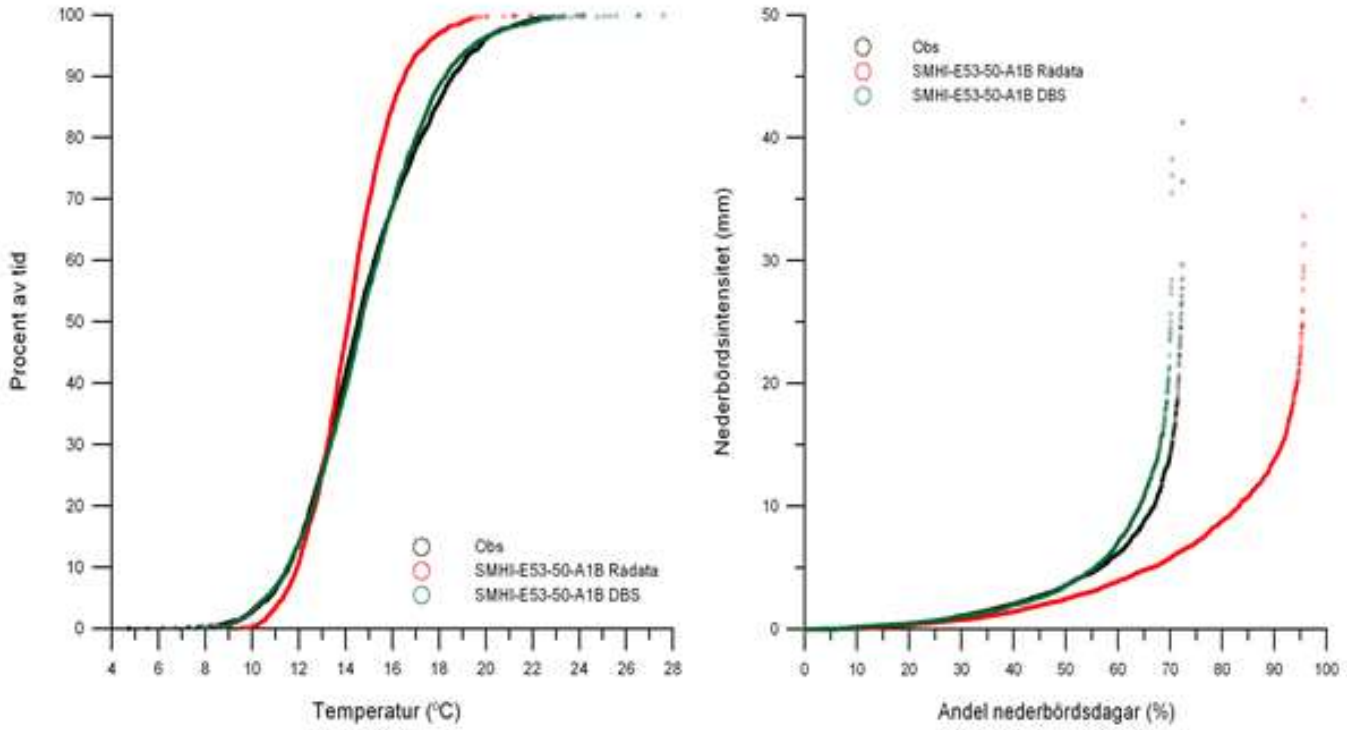


Fig. 8. Annual cycle of river runoff in 6 test basins today and according to the RCA88-E regional climate scenario and 2 versions of the HBV model. The curves have been smoothed

Bergström, S., B. Carlsson, M. Gardelin, G. Lindström, A. Pettersson, and M. Rummukainen. 2001. Climate change impacts on runoff in Sweden - assessments by global climate models, dynamical downscaling and hydrological modelling. Clim.Res 16:101–112.

Distribution-Based Scaling (DBS)

- Bias correction of daily time series by distribution mapping using a Gamma (double) distribution for precipitation and a Gaussian for temperature



Figur 2.4. Jämförelse mellan rådata från klimatmodeller och data som anpassats med DBS-metoden samt observationer. Till vänster dygnsmedeltemperatur (procent av tiden som viss dygnsmedeltemperatur underskrids och till höger nederbörd (andel dagar med olika nederbördsintensitet).

Yang, W., Andréasson, J., Graham, L.P., Olsson, J., Rosberg, J., and F. Wetterhall (2010) Distribution-based scaling to improve usability of regional climate model projections for hydrological climate change impact studies, Hydrol. Res., 41, 211-229.

Updated guidelines for dam design

- A lot of calculations needed!

Nation	Institut	Scenario	GCM	RCM	Upplösning	Period
	SMHI	A1B	ECHAM5(1)	RCA3	50 km	1961-2100
	SMHI	A1B	ECHAM5(2)	RCA3	50 km	1961-2100
	SMHI	A1B	ECHAM5(3)	RCA3	50 km	1961-2100
	SMHI	A1B	ECHAM5(3)	RCA3	25 km	1961-2100
	SMHI	B1	ECHAM5(1)	RCA3	50 km	1961-2100
	SMHI	A1B	CNRM	RCA3	50 km	1961-2100
	SMHI	A1B	CCSM3	RCA3	50 km	1961-2100
	CNRM	A1B	ARPEGE	Aladin	25 km	1961-2050
	KNMI	A1B	ECHAM5(3)	RACMO	25 km	1961-2100
	MPI	A1B	ECHAM5(3)	REMO	25 km	1961-2100
	C4I	A2	ECHAM5(3)	RCA3	25 km	1961-2050
	HC	A1B	HadCM3(Q0)	HadRM3	25 km	1961-2100
	C4I	A1B	HadCM3(Q16)	RCA3	25 km	1961-2100
	METNO	A1B	BCM	HIRHAM	25 km	1961-2050
	METNO	A1B	HadCM3(Q0)	HIRHAM	25 km	1961-2050
	DMI	A1B	ECHAM5(3)	HIRHAM	25 km	1961-2100

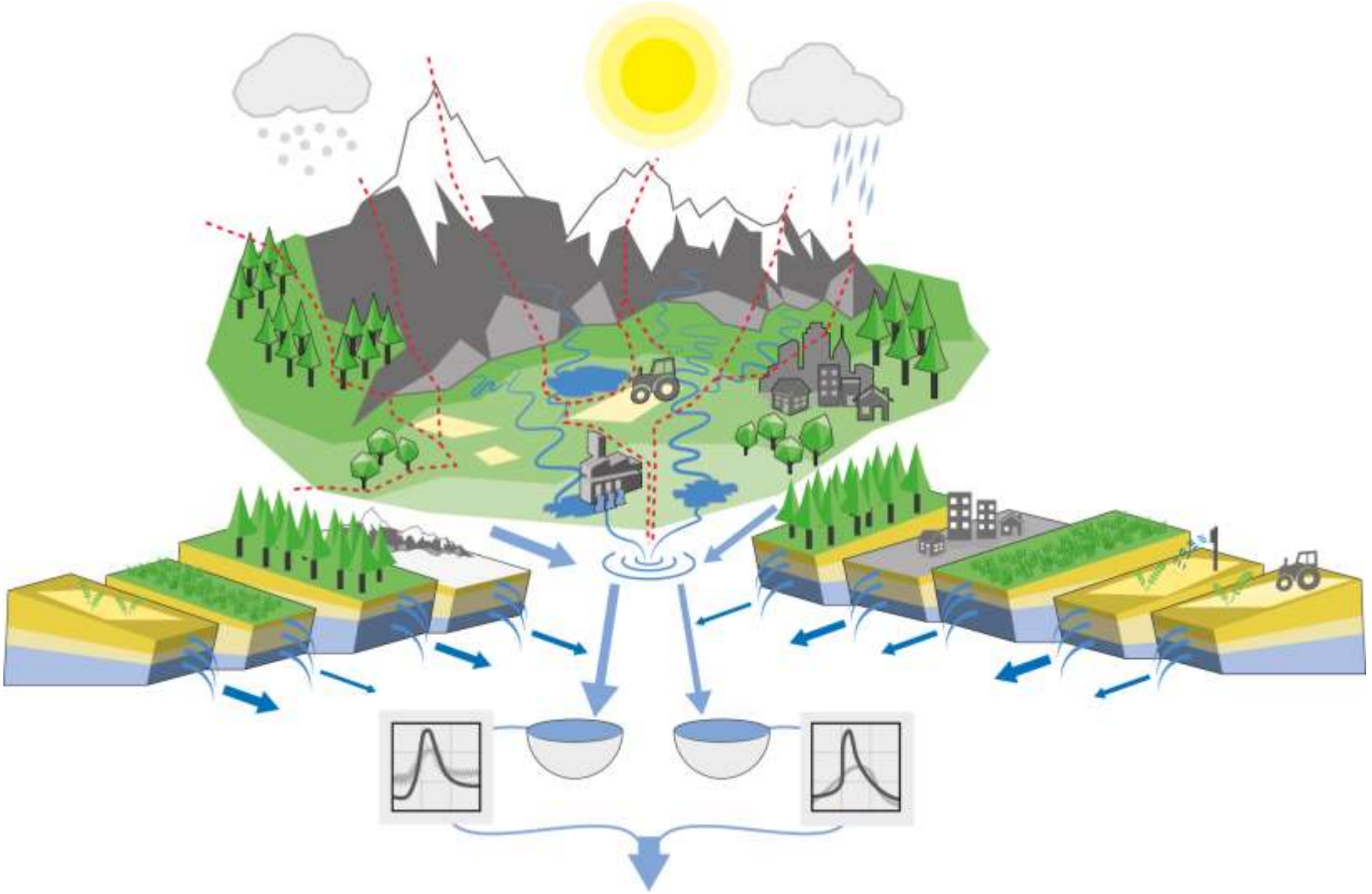
The factory for hydrological climate change impact calculations was born!

Andréasson, J., S. Bergström, M.Gardelin, J. German, H. Gustavsson, K. Hallberg och J. Rosberg 2011. Dimensionerande flöden för dammanläggningar för ett klimat i förändring - metodutveckling och scenarier. Elforsk rapport 11:25.

Hydrological Predictions for the Environment

SMHI

- The HYPE model

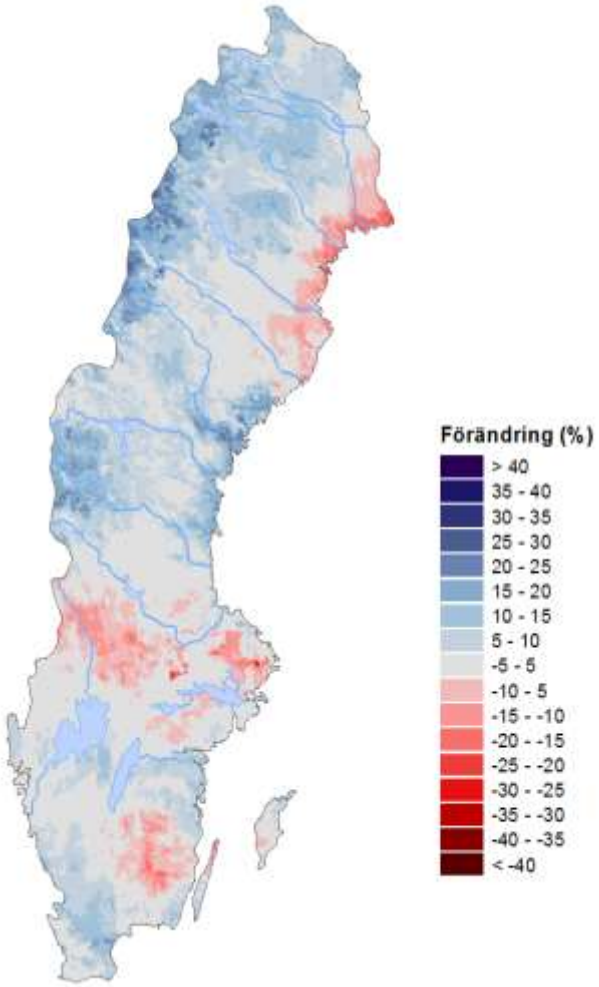


Lindström, G., Pers, C.P., Rosberg, R., Strömqvist, J., Arheimer, B. 2010. Development and test of the HYPE (Hydrological Predictions for the Environment) model – A water quality model for different spatial scales. Hydrology Research 41.3-4:295-319.

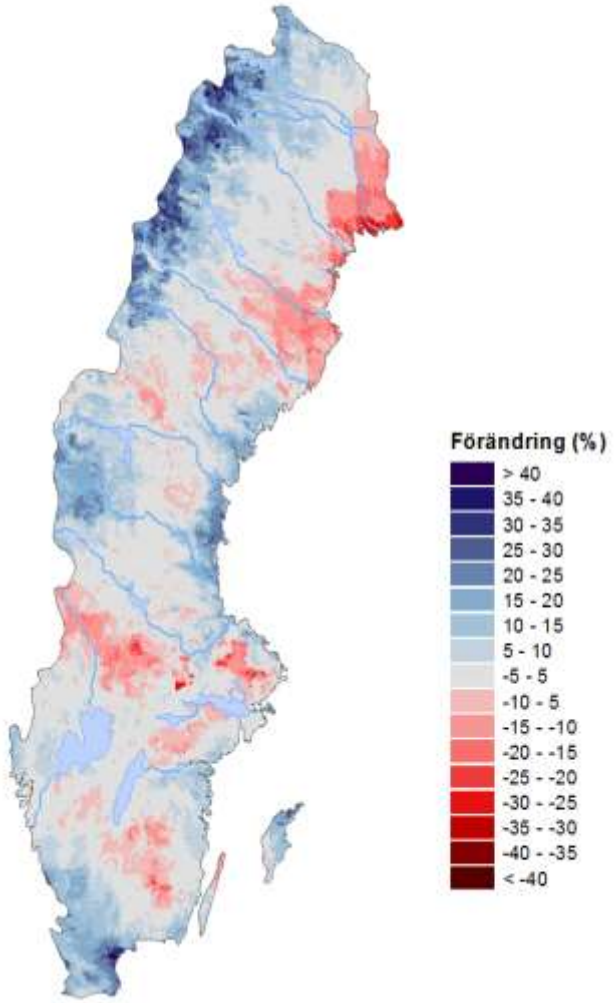
HYPE climate projections: Sweden

SMHI

Change in local 100-year runoff (%) 1963-1992 to 2069-2098



RCP4.5



RCP8.5

HYPE climate projections: global

SMHI

SMHI HypeWeb — Regions with HYdrological Predictions for the Environment (HYPE)

Find world-wide water information!

Download computed data for free, and visualize various hydrological variables and how they vary in time and space for each region.

The data can be used in decision-support systems for environmental management and awareness.

Read more

Tailor your service

Please, contact us to get customized development tailored to your specific needs!

e-mail

Arctic Europe Sweden Baltic Sea

La Plata Basin Niger River MENA India

Explore the HYPE

See how water flow is calculated in the model by using the HYPE Runoff Explorer!

Read more

HYPE large-scale applications

The HYPE model

HYPE open source community

Usefulness of open data in water modelling (SWITCH-ON)

Other Open Data from SMHI

About us

Swedish Meteorological and Hydrological Institute (SMHI)

Hydrology Research at SMHI

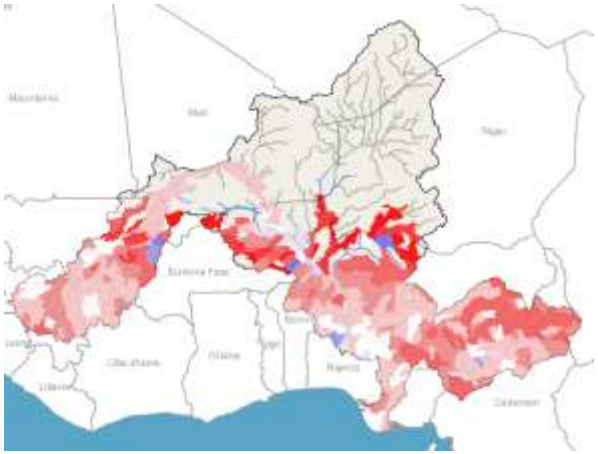
Feedback

Please, give us your response on the HYPE data and this website!

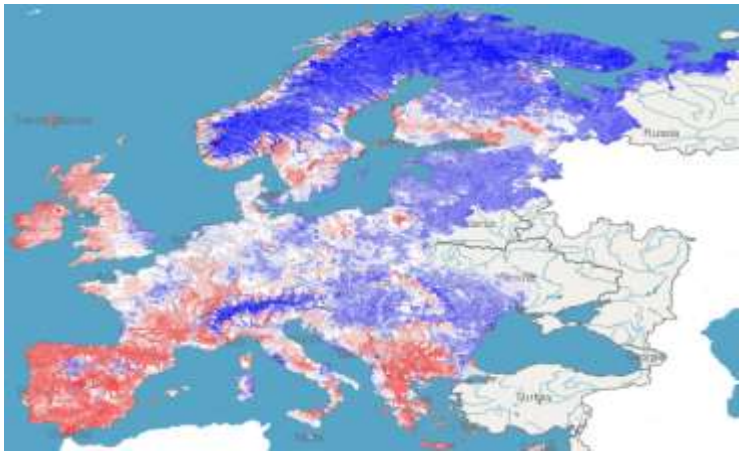
e-mail

HYPE climate projections: global

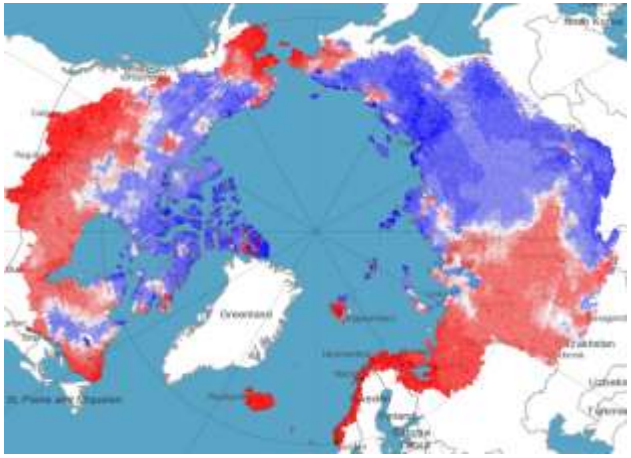
Drought intensity in Niger



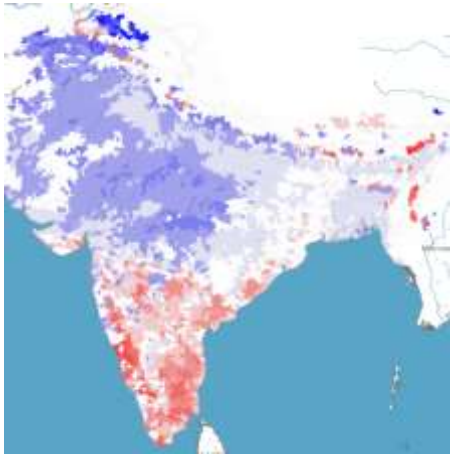
Low flows in Europe



Snow Water Equivalent in the Arctic



Irrigation demand in India



Selected issues (in random order)

SMHI

Q: How confident can we be in the HBV projections?

Q: What is the impact of scale/resolution of model and reference data?

Q: How to deal with bias in precipitation frequency?

Q: How can we bias-correct precipitation from high-resolution RCM projections with only lower-resolution reference data available?

Q: Do un-biased precipitation and temperature distributions ensure also un-biased internal hydrological variables?

Q: How can we bias-correct other hydrologically important variables than precipitation and temperature?

Q: How can we select a subset of representative projections from a large ensemble?

Selected issues

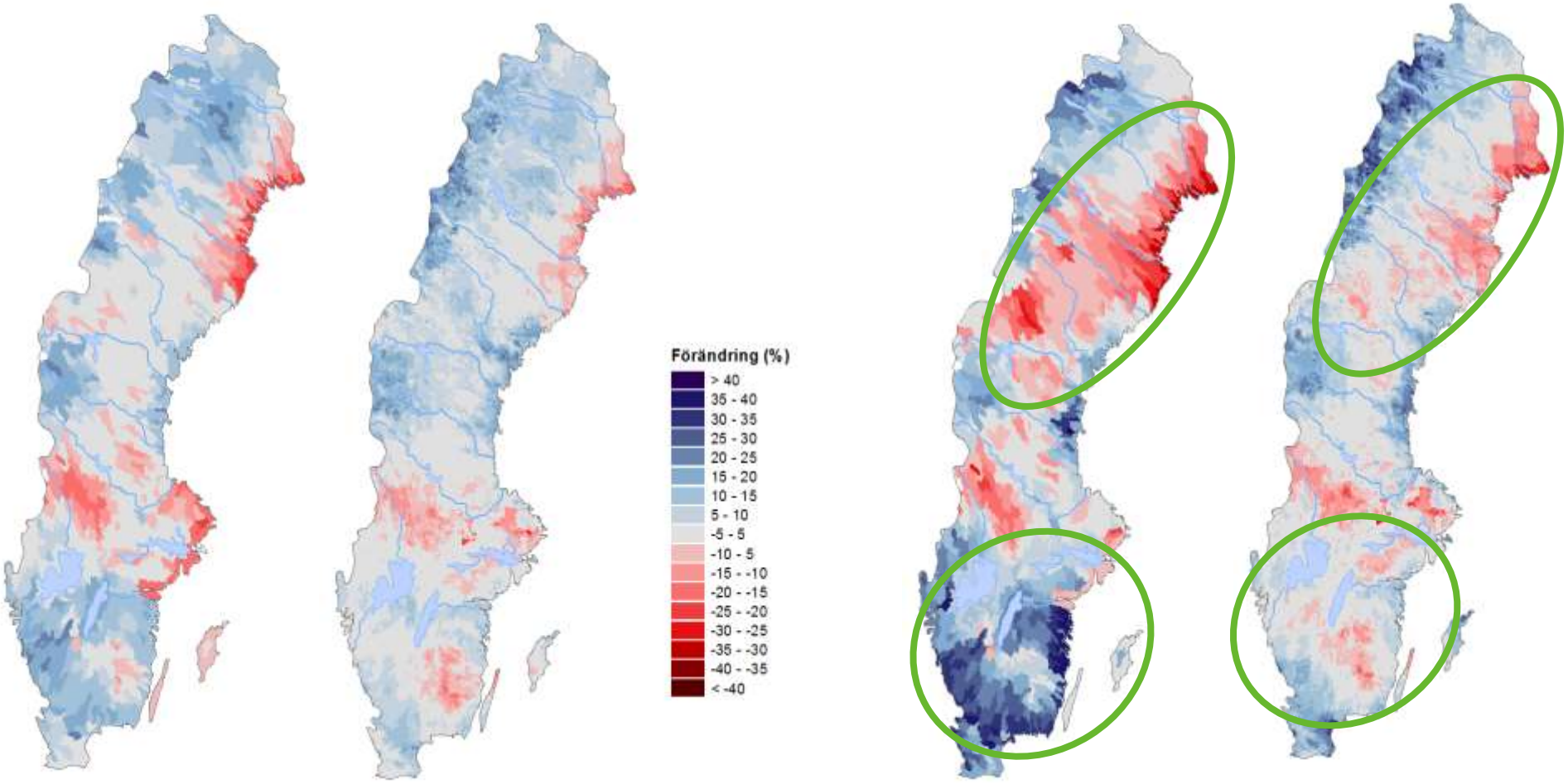
Q: How confident can we be in the HBV projections?

A: Compare HBV and HYPE.

HBV vs. HYPE

SMHI

Change in local 100-year runoff (%) 1963-1992 to 2069-2098



HBV HYPE

RCP4.5

HBV HYPE

RCP8.5

Selected issues

Q: How confident can we be in the HBV projections?

Q: What is the impact of scale/resolution of model and reference data?

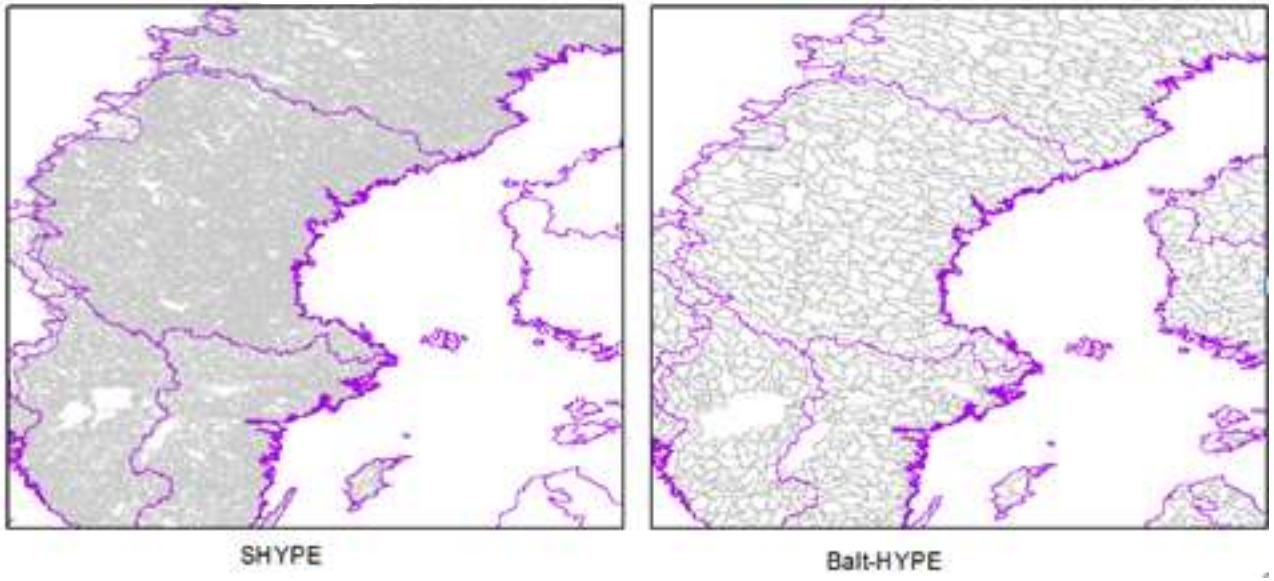
A: Compare different model set-ups for the same region.

HYPE projections: impact of resolution

- Two applications of the same hydrological model (HYPE) at different scales:
  - S-HYPE: all of Sweden, 37786 subbasins, mean size ~ 7 km^2
  - Balt-HYPE: Baltic Sea catchment, 5128 subbasins, mean size ~ 325 km^2

- Each application has different forcing data, landcover and soil-type data

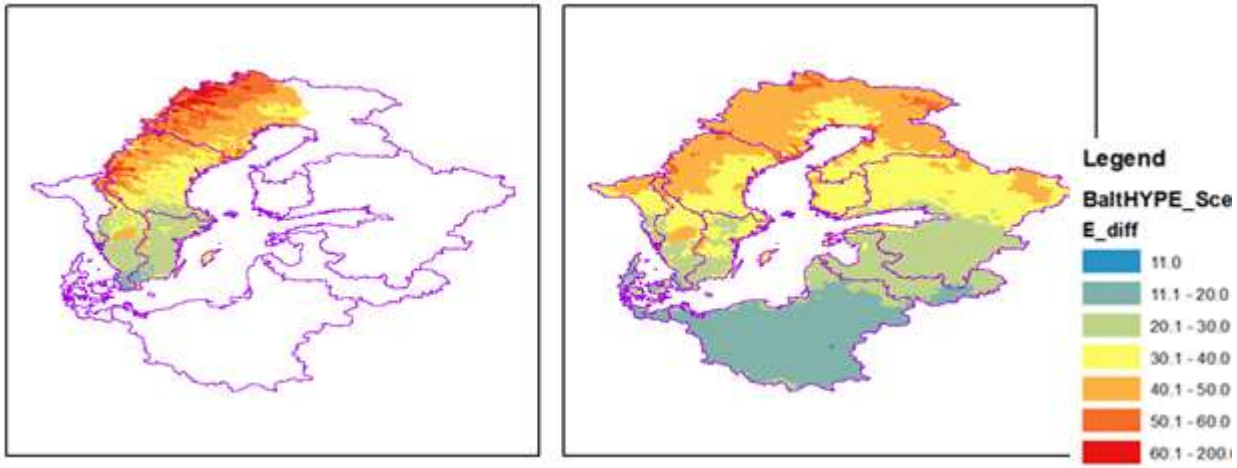
- Performance varies between applications



HYPE projections: impact of resolution

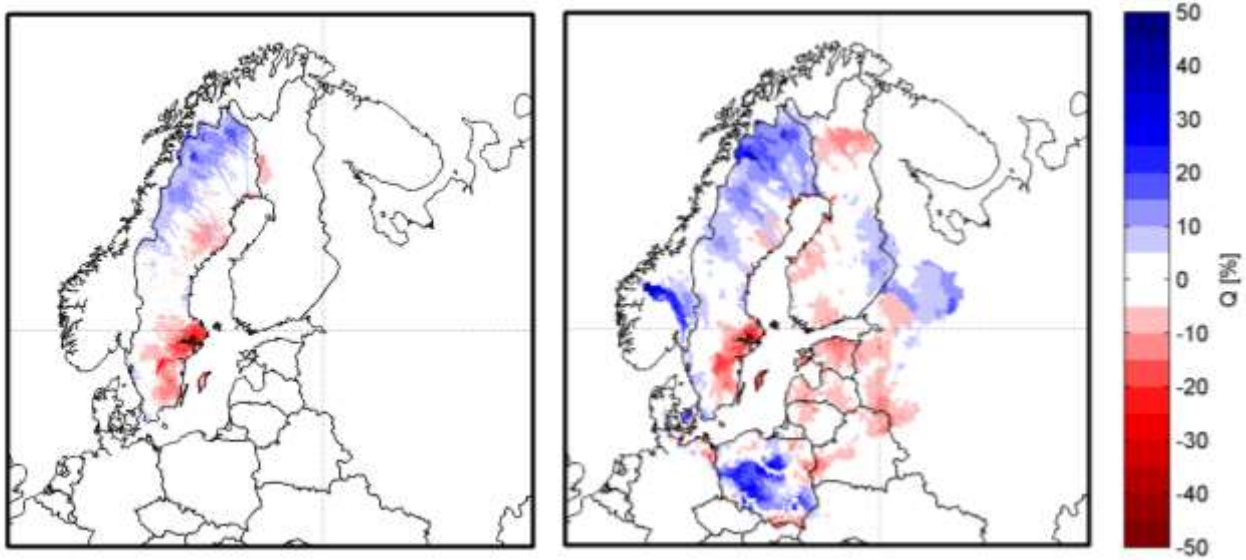
SMHI

Change in evapotranspiration (%)



- Obvious difference is that increases in evapotranspiration at higher elevations not captured in Balt-HYPE
- Precipitation patterns are similar

Change in discharge (%)



- General pattern for Sweden is similar
- For local areas more intense changes in local runoff are seen over larger areas in Balt-HYPE (i.e. scale)
- This leads to larger increases in discharge in the northern Swedish rivers from Balt-HYPE

Selected issues

Q: How confident can we be in the HBV projections?

Q: What is the impact of scale/resolution of model and reference data?

Q: How to deal with negative bias in precipitation frequency?

A: ?

Precipitation frequency bias

- In north/central Europe usually a positive bias (too often precipitation in RCM)
- This is usually solved by a cut-off threshold, eliminating low intensities

Precipitation frequency bias

- In north/central Europe usually a positive bias (too often precipitation in RCM)
- This is usually solved by a cut-off threshold, eliminating low intensities
- In parts of south Europe and elsewhere (e.g. India) often a negative bias
- How to add precipitation?
  1/ randomly?
  2/ extend existing events?
  3/ in line with ”weather situation analysis”?

Selected issues

Q: How confident can we be in the HBV projections?

Q: What is the impact of scale/resolution of model and reference data?

Q: How to deal with bias in precipitation frequency?

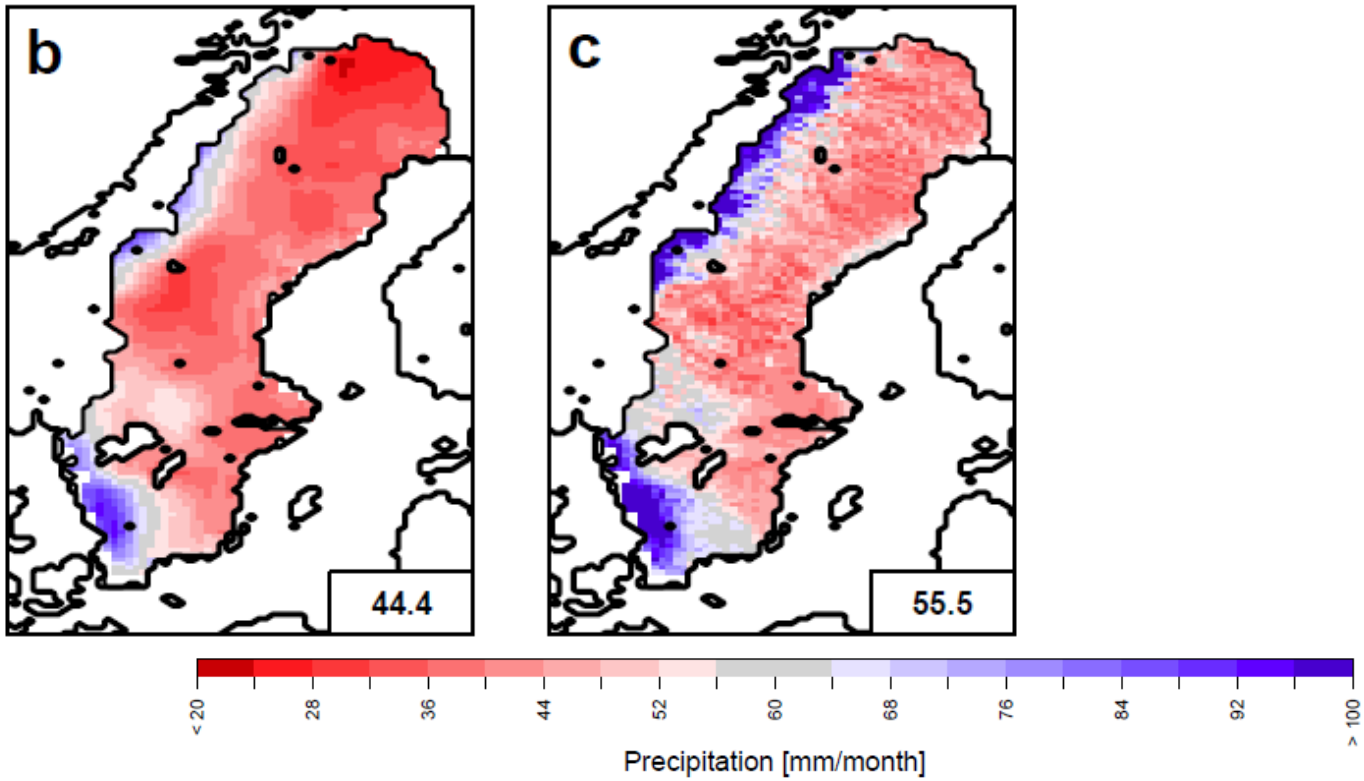
Q: How to bias-correct precipitation from high-resolution RCM projections with only lower-resolution reference data available?

A: Construct high-resolution “pseudo-reference data” (“pseudo-observations”).

Pseudo-observations

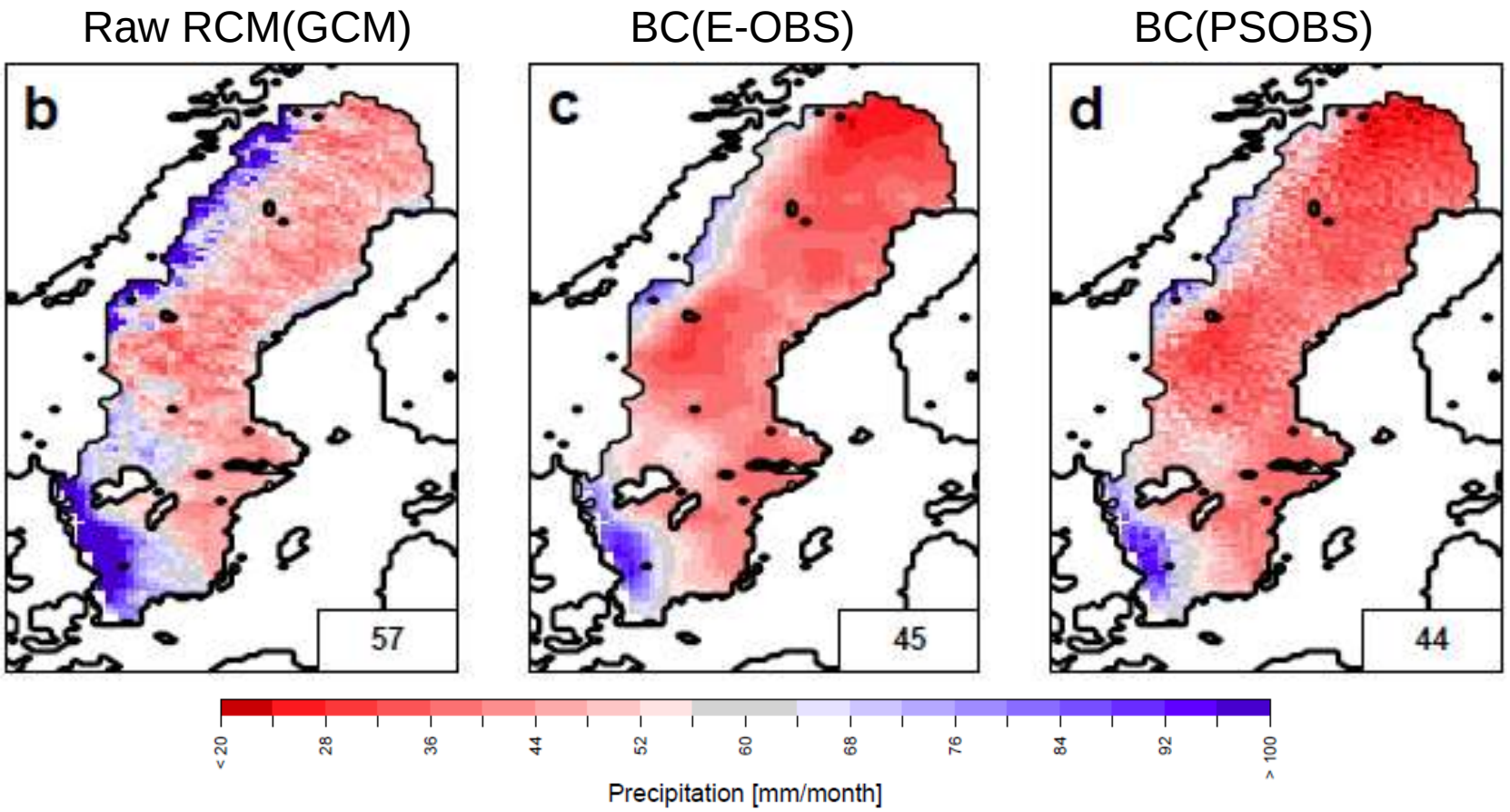
- Construction of high resolution pseudo-reference data (PSOBS):
  1. Use an RCM with constrained large scale flow to re-analysis data
  2. Perform a spatial smoothing of the observations and RCM fields to have a common resolution that you trust
  3. Correct each timestep of the model for each single month to that of the observational data by scaling by the monthly ratio

E-OBS RCM(ERA-boundaries)



Pseudo-observations

- Clear difference in bias-corrected RCM projections



Berg, P.; Bosshard, T.; Yang, W. (2015) Model Consistent Pseudo-Observations of Precipitation and Their Use for Bias Correcting Regional Climate Models. Climate, 3, 118-132.

Selected issues

Q: How confident can we be in the HBV projections?

Q: What is the impact of scale/resolution of model and reference data?

Q: How to deal with bias in precipitation frequency?

Q: How can we bias-correct precipitation from high-resolution RCM projections with only lower-resolution reference data available?

Q: Do un-biased precipitation and temperature distributions ensure also un-biased internal hydrological variables?

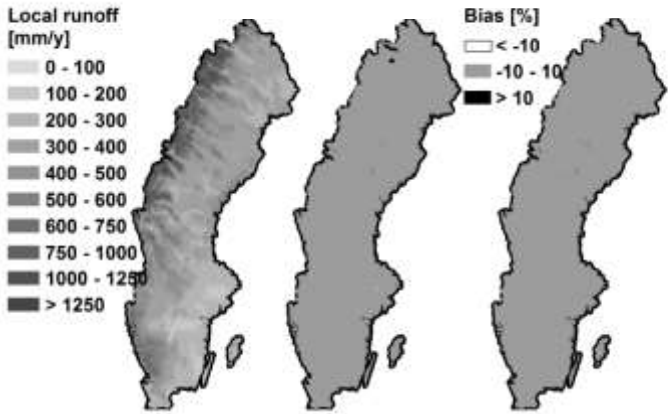
A: Evaluate reference-period simulations against observations.

HYPE results

- HYPE simulations with bias-corrected T and P in two RCM projections

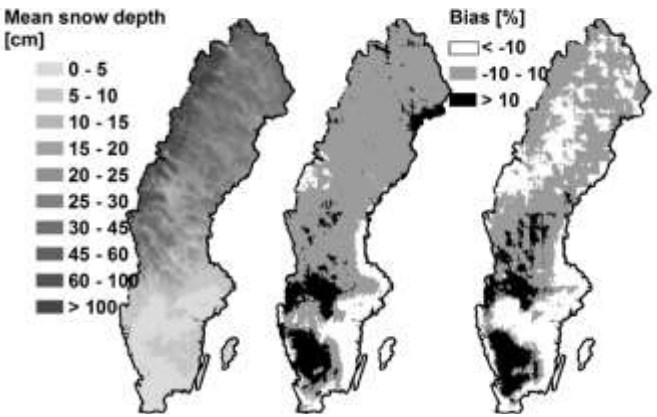
Runoff

OBS RCM1 RCM2



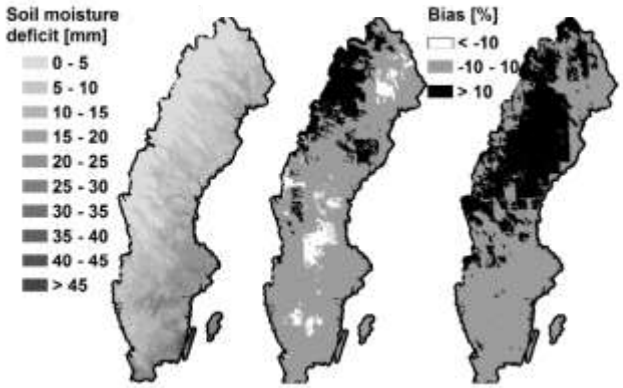
Snow depth

OBS RCM1 RCM2



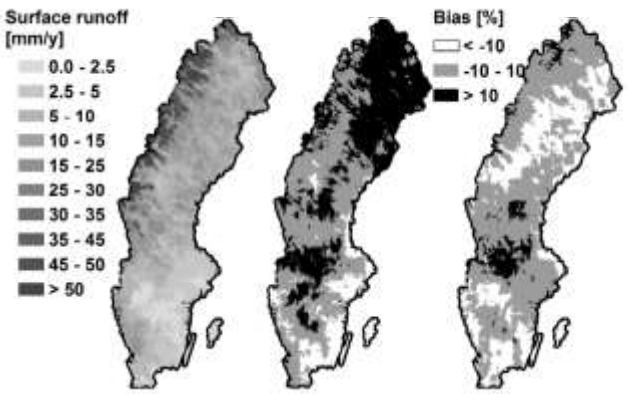
Soil moisture deficit

OBS RCM1 RCM2



Surface runoff

OBS RCM1 RCM2



Dahné, J. Donnelly, C., and Olsson, J. Post-processing of climate projections for hydrological impact studies, how well is reference state preserved? Proceedings of IAHS-IAPSO-IASPEI Assembly, Gothenburg, Sweden, July 2013 (IAHS Publ., 2013).

Selected issues

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Q: Do un-biased precipitation and temperature distributions ensure also un-biased internal hydrological variables?

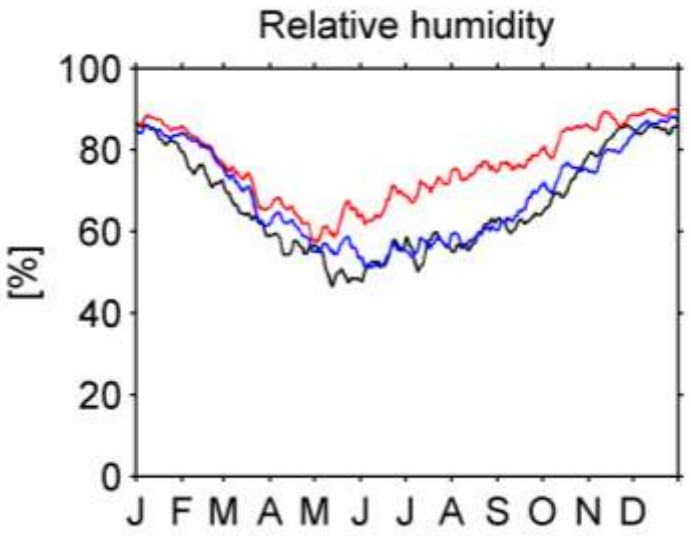
Q: How can we bias-correct other hydrologically important variables than precipitation and temperature?

A: Extend DBS to other variables, e.g. wind speed and relative humidity.

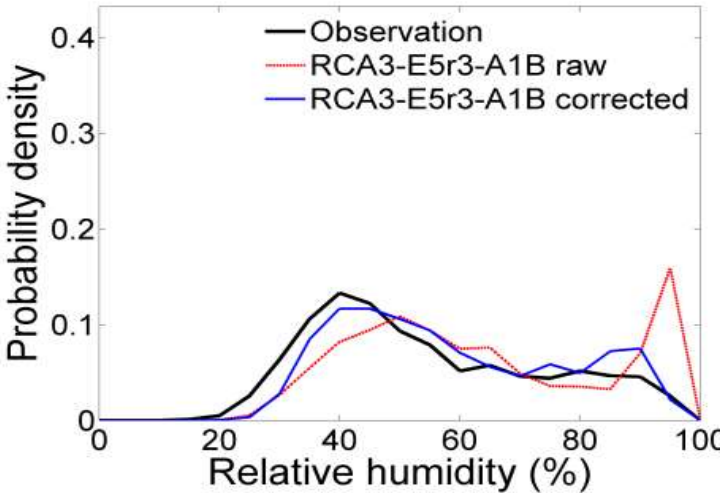
Relative humidity in DBS

- Assume a Beta distribution

Annual cycle



PDF

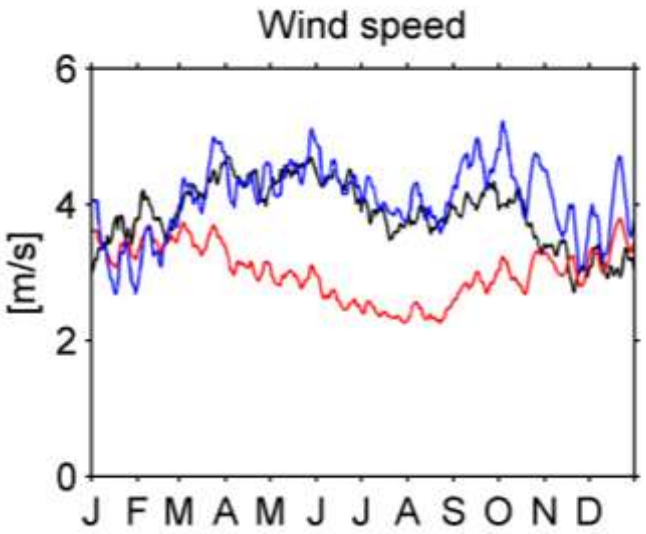


Yang, W., Gardelin, M., Olsson, J. and T. Bosshard (2015) Forest fire risk assessment in Sweden using climate model data: bias correction and future changes. Nat. Hazards Earth Syst. Sci. Discuss., 3, 837-890.

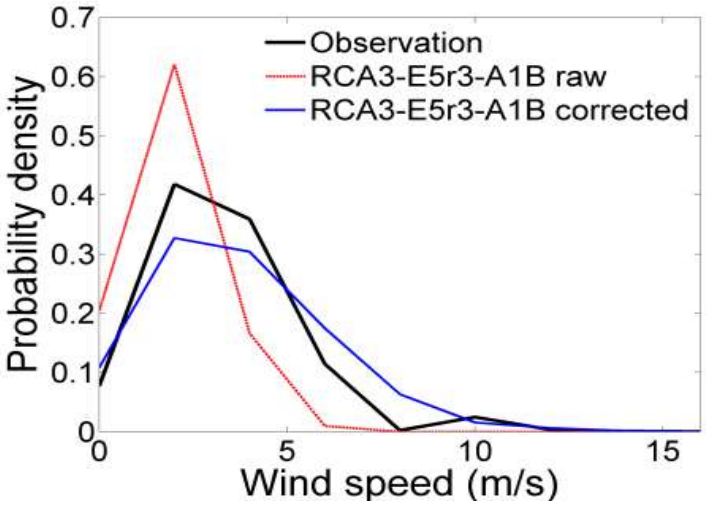
Wind speed in DBS

- Assume a Weibull distribution

Annual cycle



PDF



Selected issues

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Q: Do un-biased precipitation and temperature distributions ensure also un-biased internal hydrological variables?

Q: How can we bias-correct other hydrologically important variables than precipitation and temperature?

Q: How can we select a subset of representative projections from a large ensemble?

A: Pdf skill score analysis.

Ensemble subset analysis

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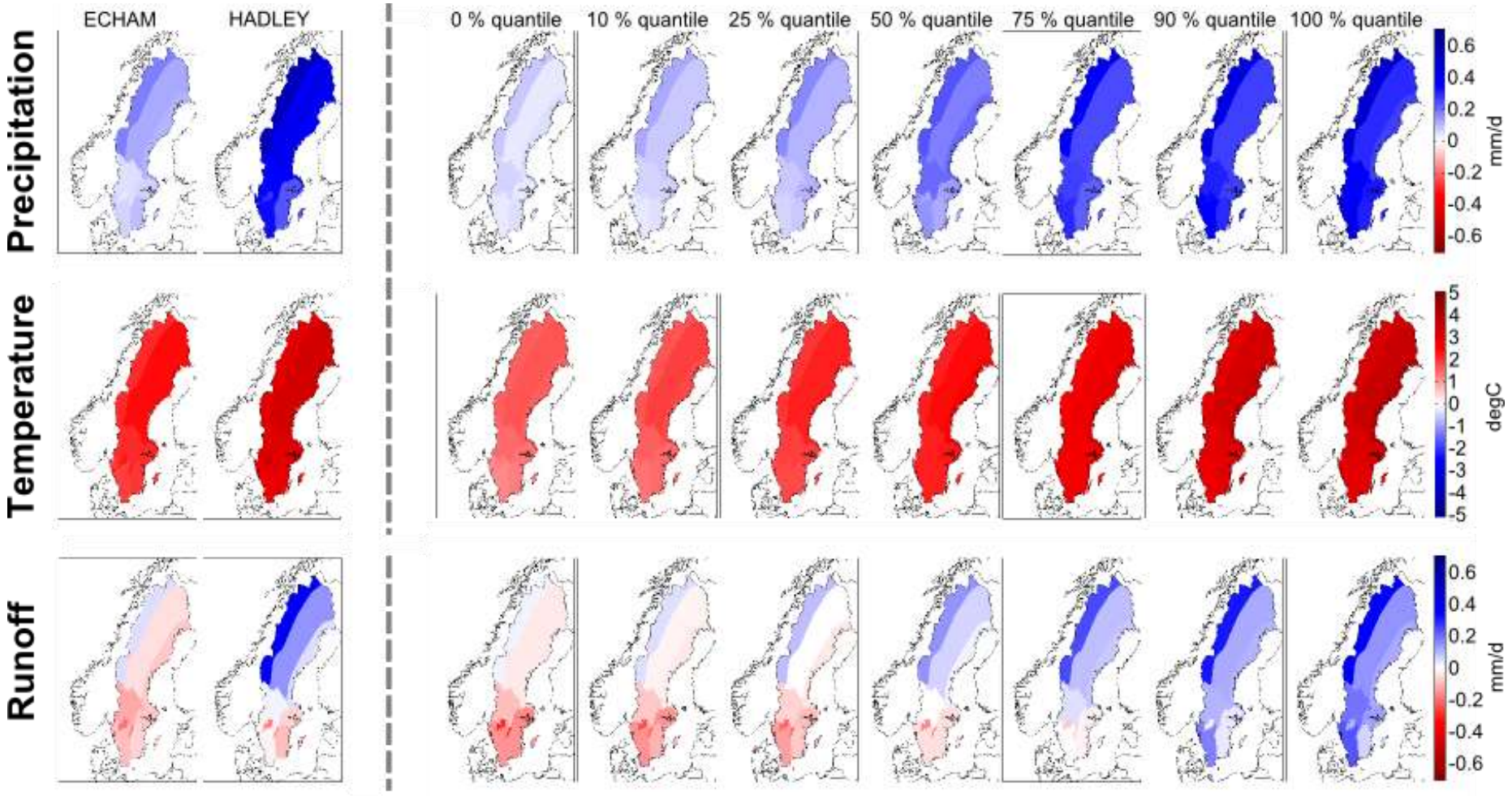
Two projections

Full ensemble (quantiles)



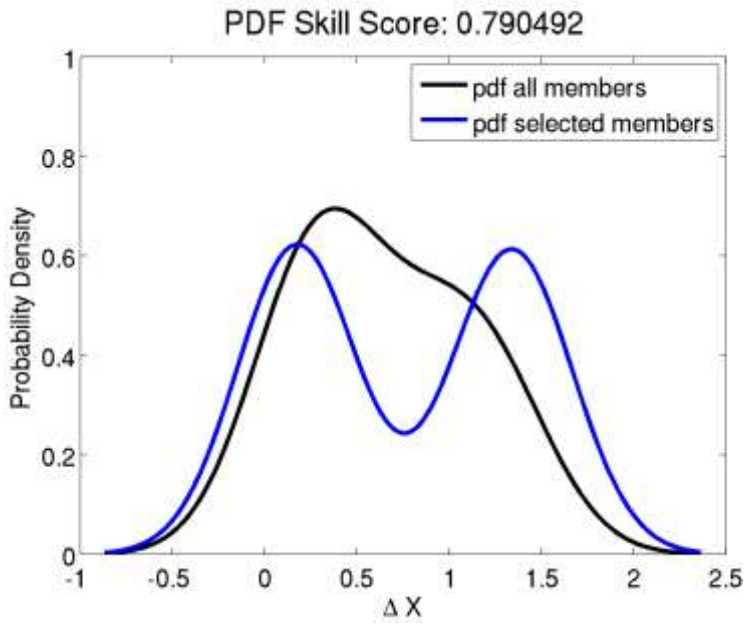
Ensemble subset analysis

SMHI

Principle of subset selection

- Subset generation algorithm:
  - **Resampling (bootstrapping)** of all possible 2^N combinations (N=ensemble size)

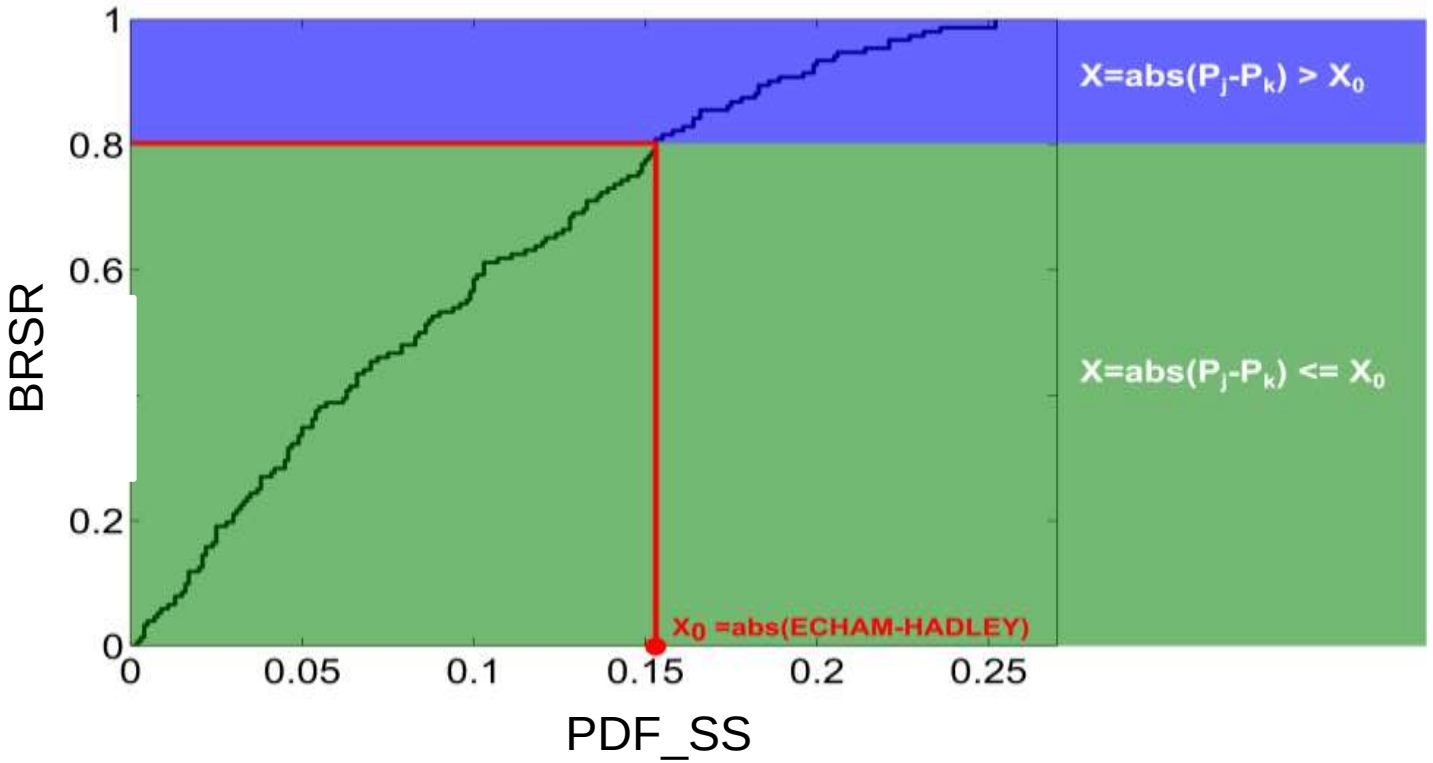
- Criterion:
  - **Best uncertainty spread representation, measured by the PDF Skill Score (PDF_SS)**



The PDF_SS is equal to the overlapping area of two PDFs.

Ensemble subset analysis

- Bootstrapped Representative Subset Ratio (BRSR)



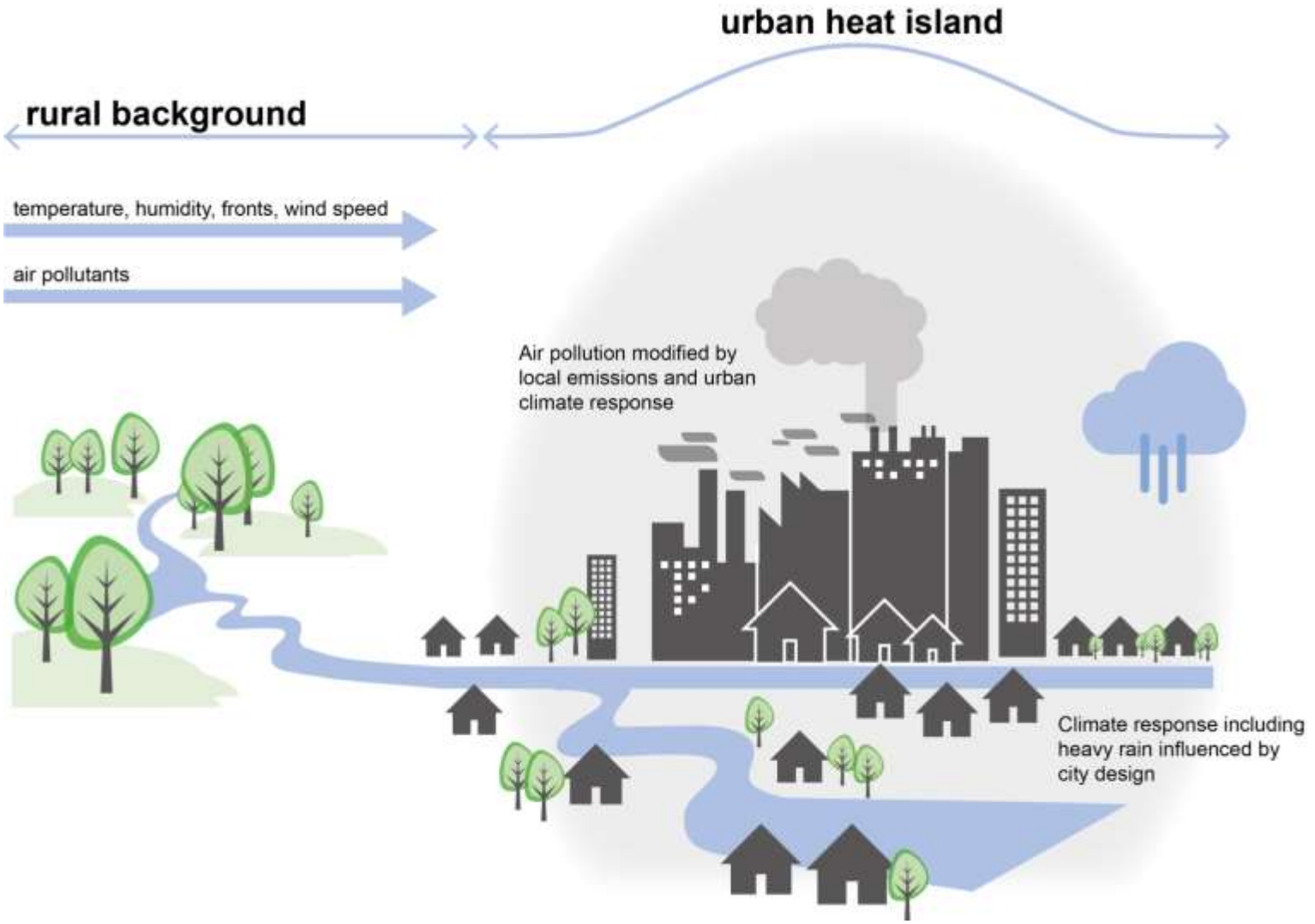
Order all Subsets according to their PDF_SS in increasing order.
BRSR = 0.8 → 80 % of all possible subsets have equal or lower PDF_SS than the chosen subset

Future directions

- Local short-duration rainfall extremes and flash flood risk in very high-resolution climate projections

Urban Sectoral Information System (SIS)

SMHI

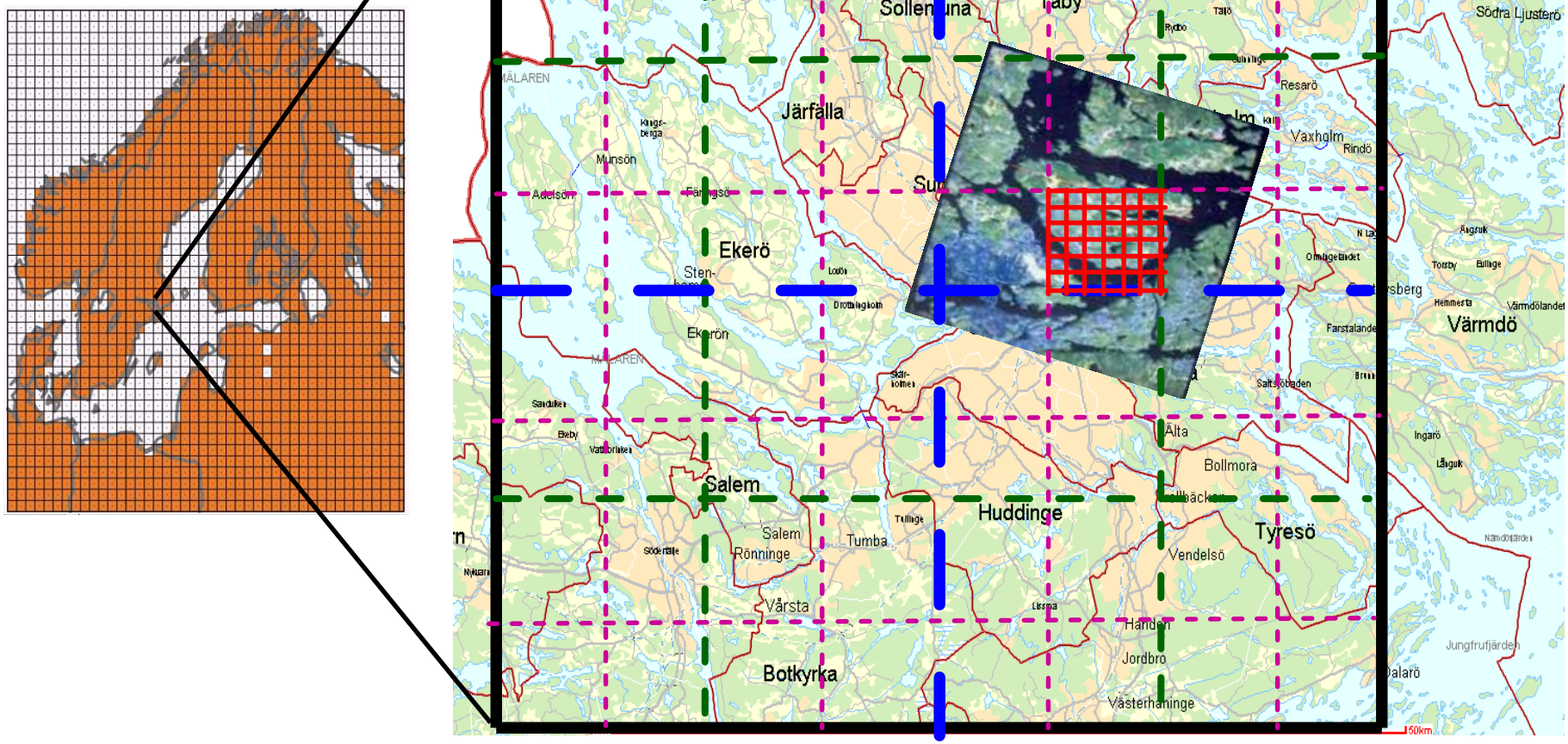


Very high-resolution downscaling

SMHI

50 km ➔ **25 km** ➔ **12 km** ➔ **6 km** ➔ **1 km**

PRUDENCE **ENSEMBLES** **Euro-CORDEX** **C3S boundary** **C3S urban scale**



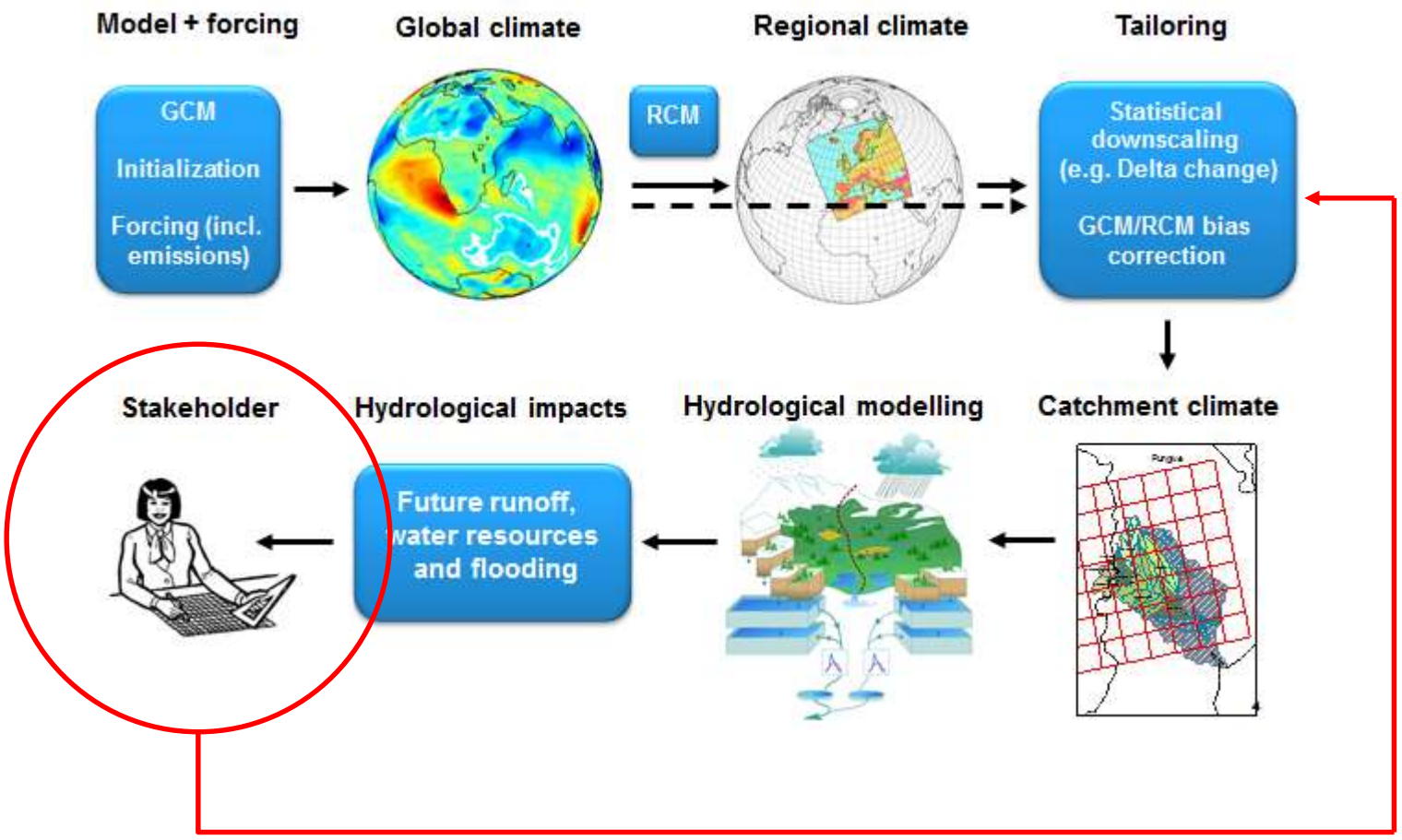
Future directions

- Short-duration rainfall extremes and flash flood risk in very high-resolution climate projections

- ”New” approaches to modeling and decision support for adaptation

”New” approaches

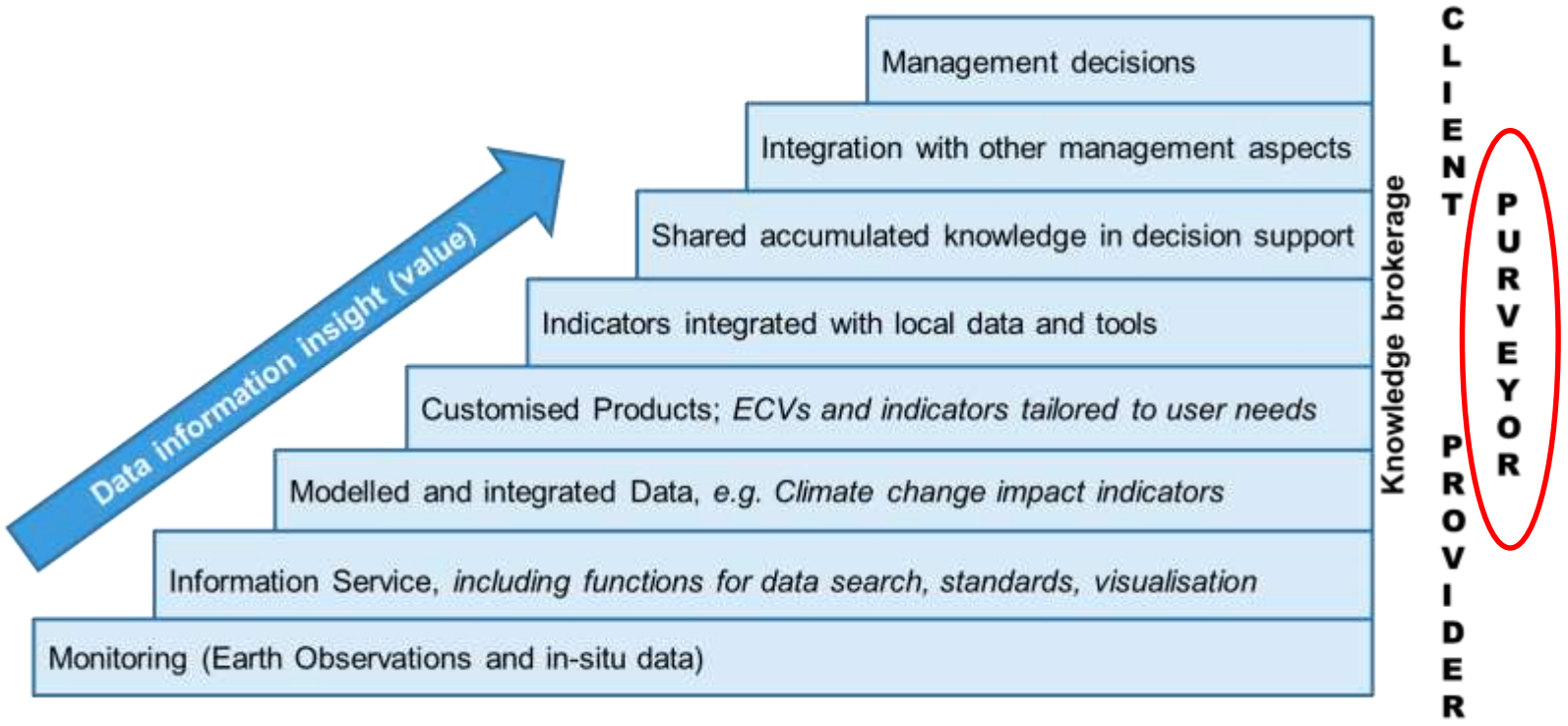
- From top-down to bottom-up: start with catchment analysis / climate sensitivity & threshold effects / end-user needs, then do tailored impact modelling



”New” approaches

- From top-down to bottom-up: start with catchment analysis / climate sensitivity & threshold effects / end-user needs, then tailored impact modelling

- Improved interface between climate data providers and local clients (end-users)



Future directions

- Short-duration rainfall extremes and flash flood risk in very high-resolution climate projections
- ”New” approaches to modeling and decision support for adaptation

Thanks for your attention!

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