Future climate change

# Skill of methods for describing regional climate futures

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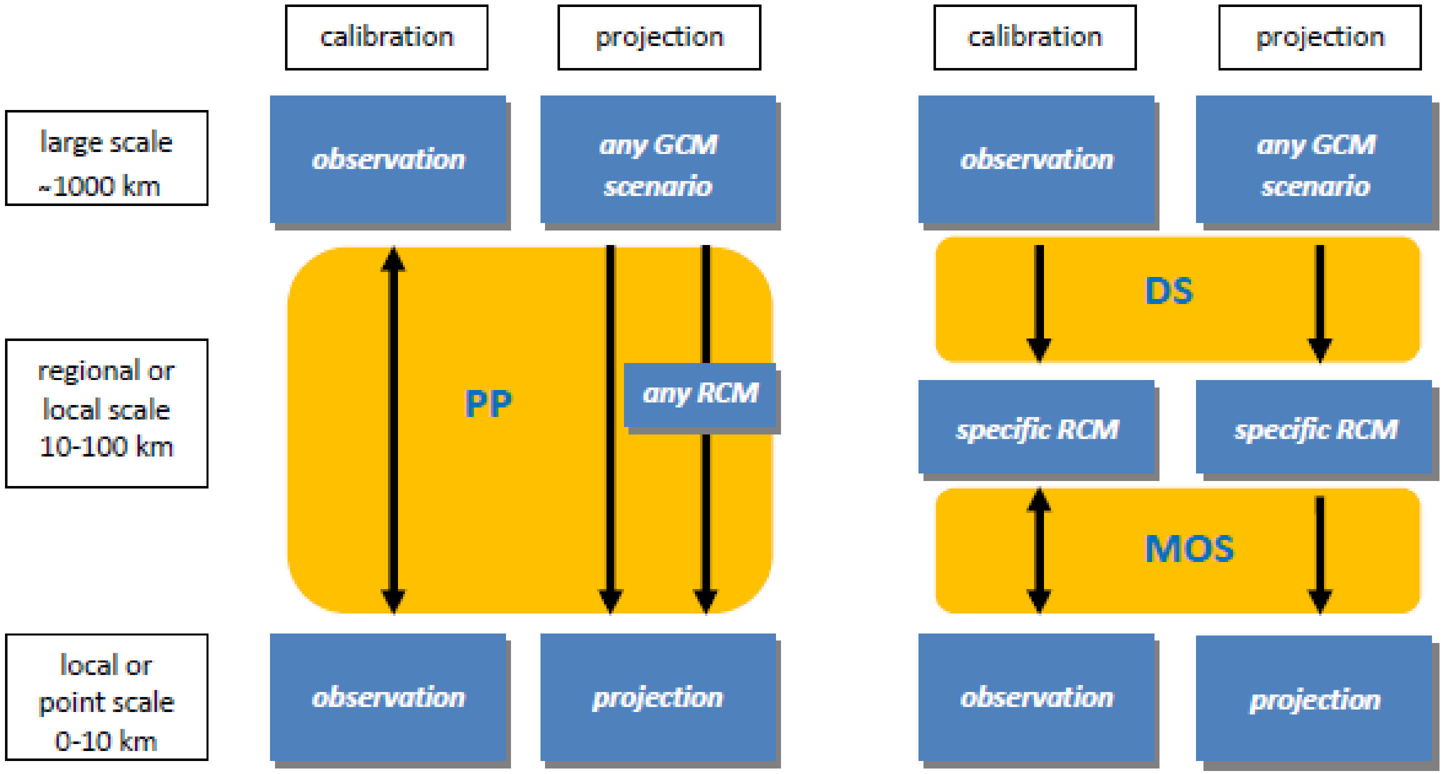
Tallin, 6-7 September 2012

# TYPES OF DOWNSCALING METHODOLOGI

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## *SKILL OF DOWNSCALING*

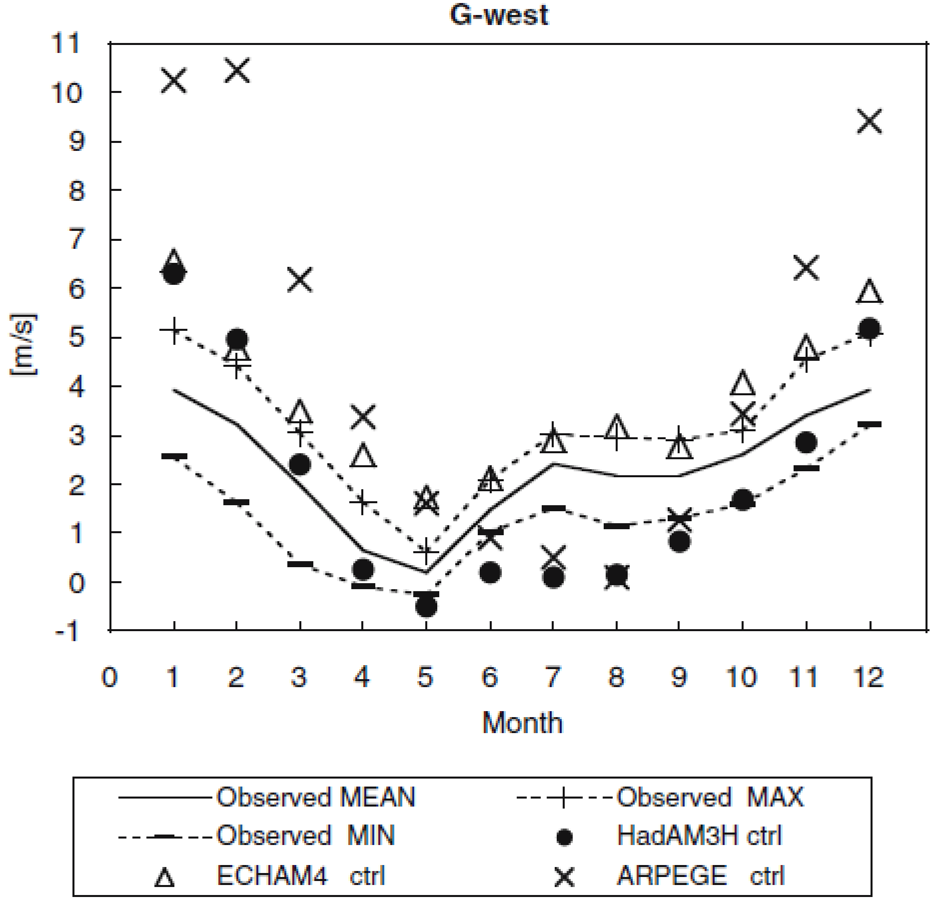
***The quality of a downscaling product stands and falls with the ability of the forcing GCM to provide meaningfull large scale boundary conditions***

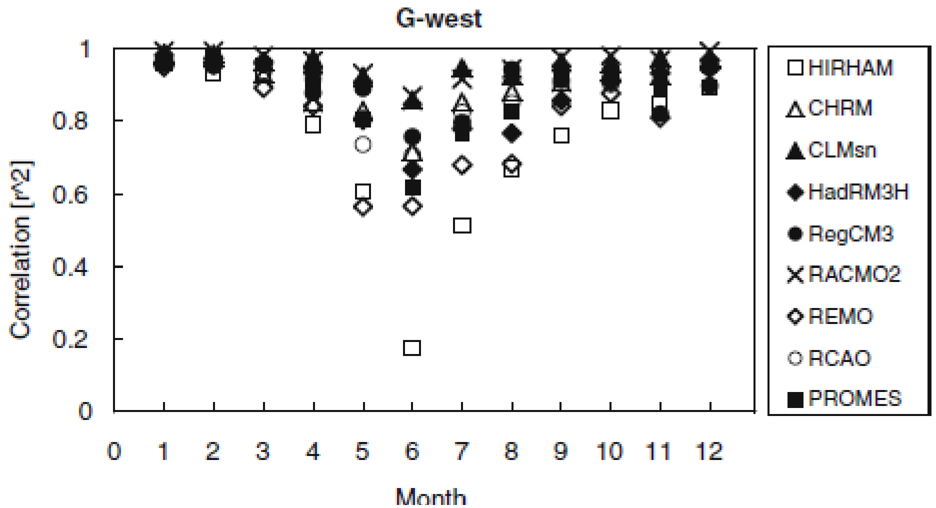
***<u>The main shortcomings of GCMs in Europe:</u>***

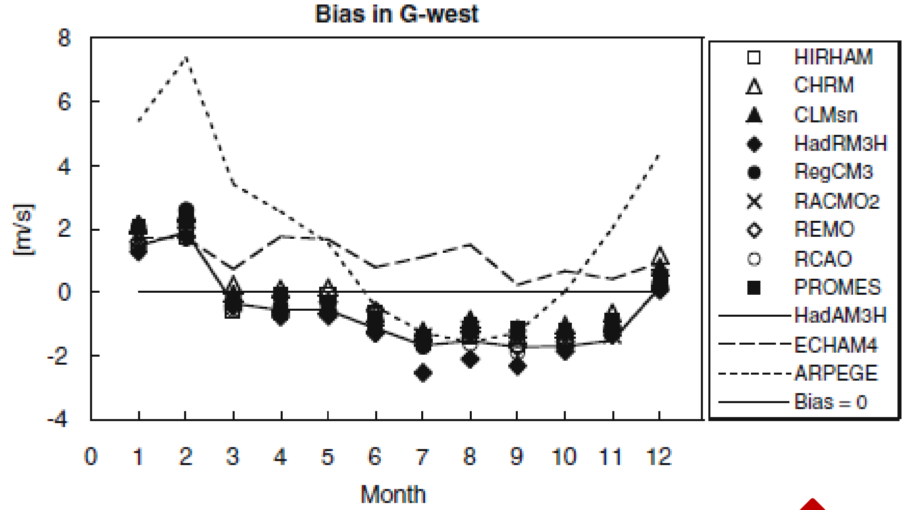
***Circulation in many GCMs is too zonal in winter (van Ulden et al., 2007)***

***Large part of uncertainty in Northern and Central European temperature and precipitation stems from driving GCM (Déqué et al., 2007)***

## *Too zonal in winter*




***van Ulden et al., 2007***

# SKILL OF DOWNSCALING

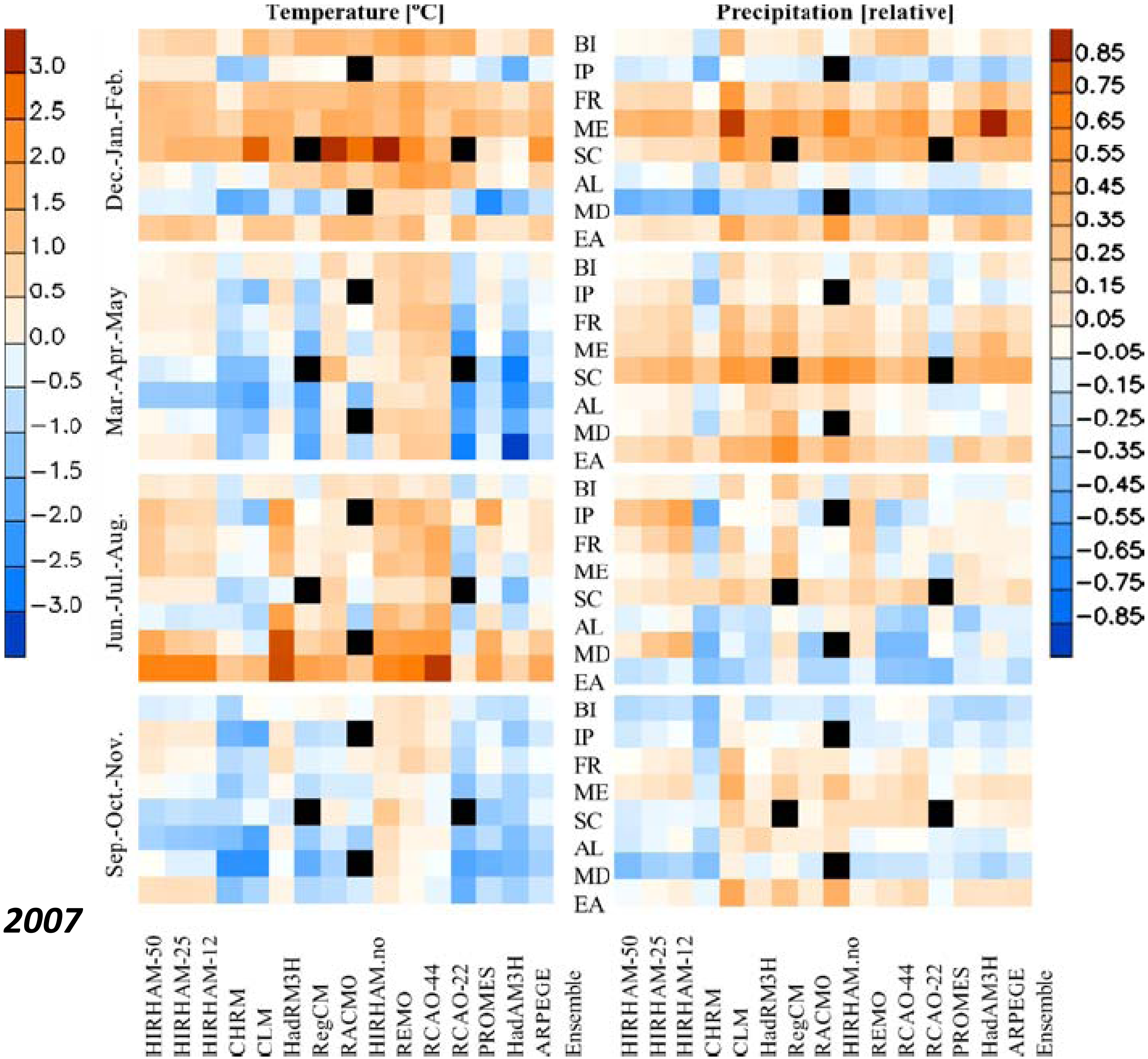
## RCMS

*The parametrisations are developed and tuned for specific climates and might be at least slightly misspecified under future climate conditions.*

*RCMs have been shown to adequately simulate European daily temperature and precipitation intensities , although considerable biases have to be expected (e.g. Jacob et al., 2007)*

*RCMs are able to simulate spatially coherent fields.*

*The biases in one variable may propagate into strong biases in dependent variables (e.g. Yang et al. 2010).*




*Jacob et al. 2007*

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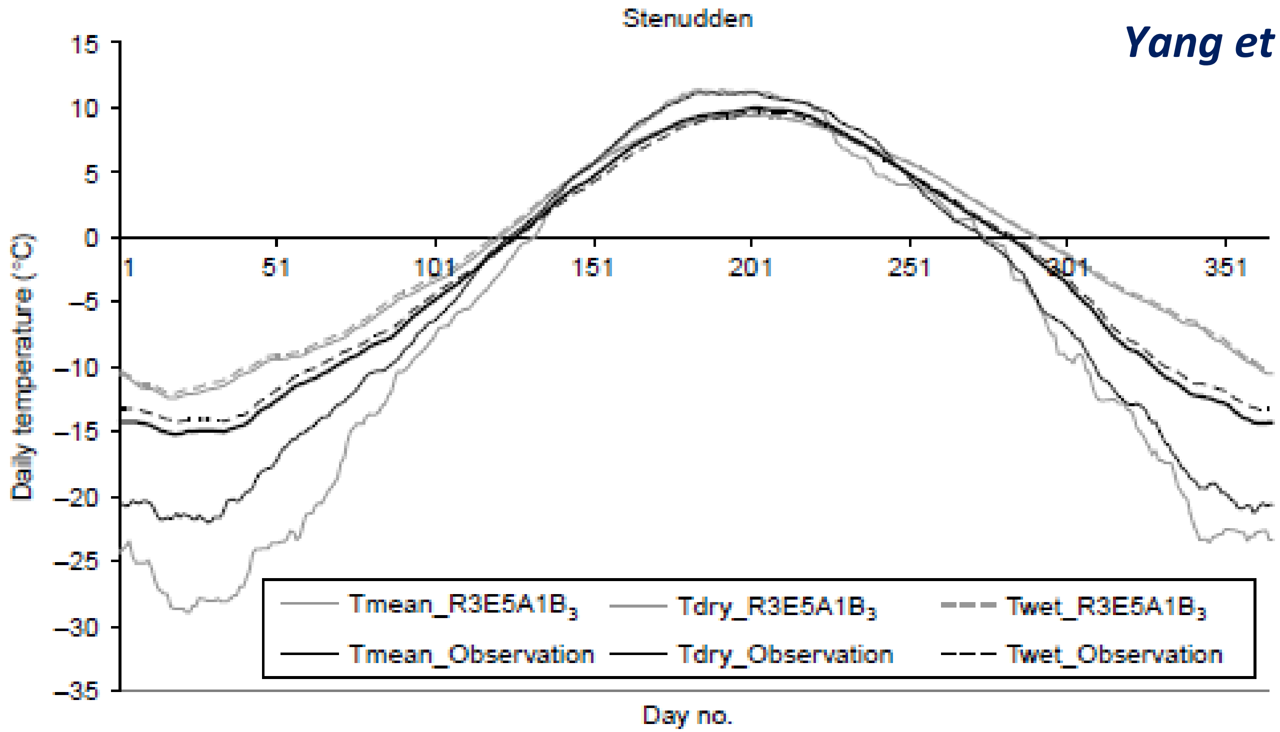
***SKILL OF DOWNSCALING***

***RCMS***




***Yang et al., 2010***

# *SKILL OF DOWNSCALING RCMS*

***Distribution based bias***

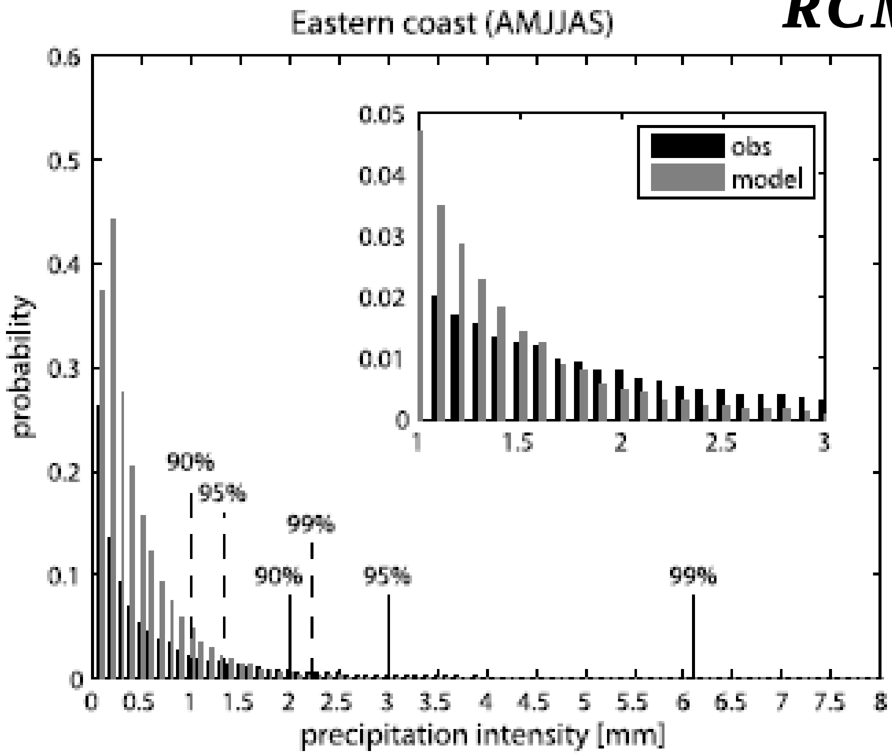



*Fig. 8.* Probability density of precipitation intensity over the three representative regions: northern mountains (upper panel), southern plains (middle panel) and Eastern coast (bottom panel). Inner boxes highlight the probability of precipitation intensity from 0.1–1 mm $h^{-1}$. The 90th, 95th and 99th percentiles are marked for the observations (solid vertical lines) and the RCA3 simulation (dashed vertical lines).

***JH Jeong et al., 2011***

## *SKILL OF DOWNSCALING* ## *ENSEMBLES*

***A way of filtering the occasional errors and an indicator of uncertainty***

***Sharing codes – are the models independent?***

***Ensemble design***

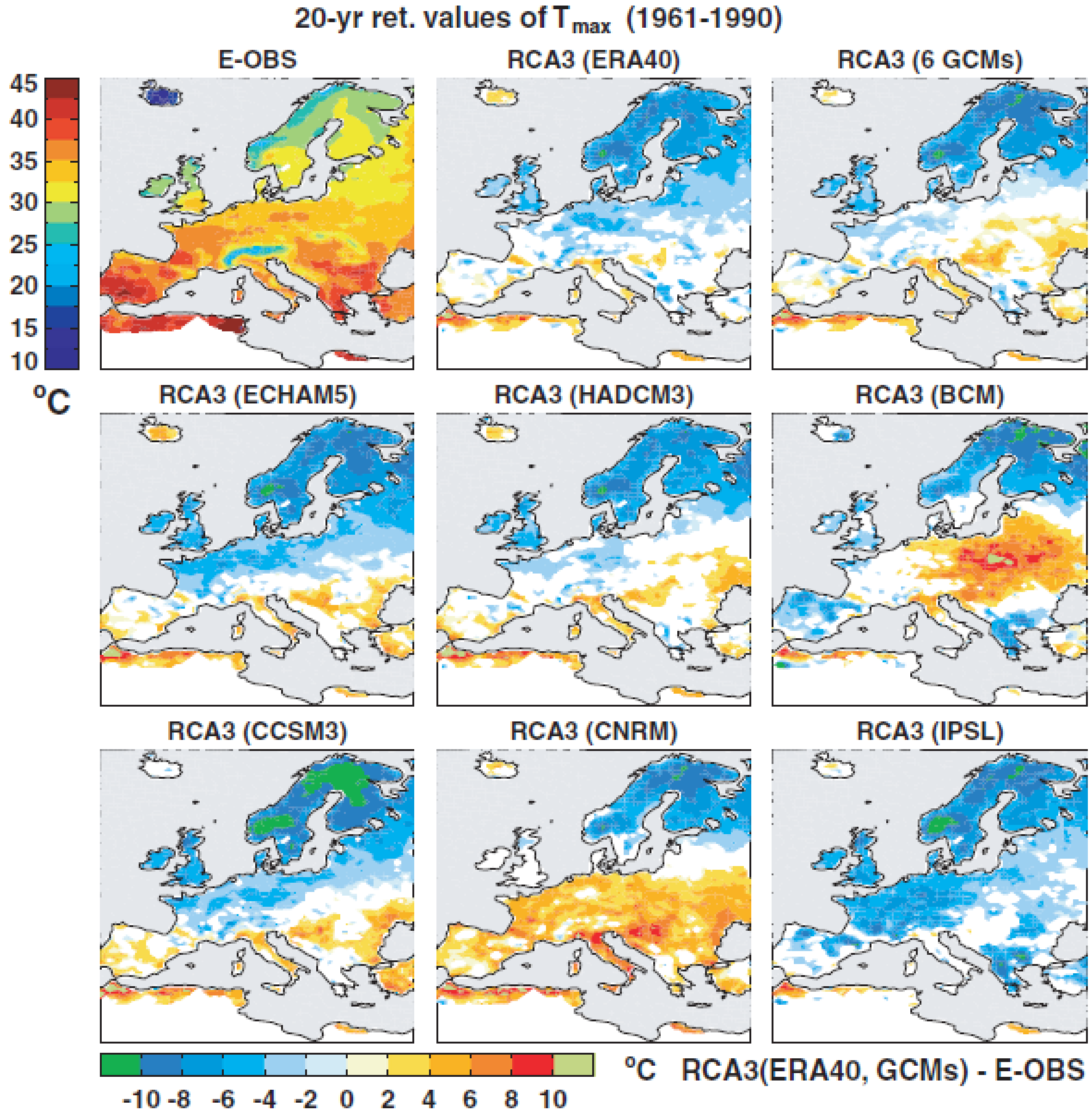
- ***multi-model ensembles***
- ***perturbed physics ensembles***

***Is it possible to distinguish between uncertainty related to model formulation and that related to initial conditions?***

***Ensemble projections or single climate projections?***

***To weight or not to weight?***

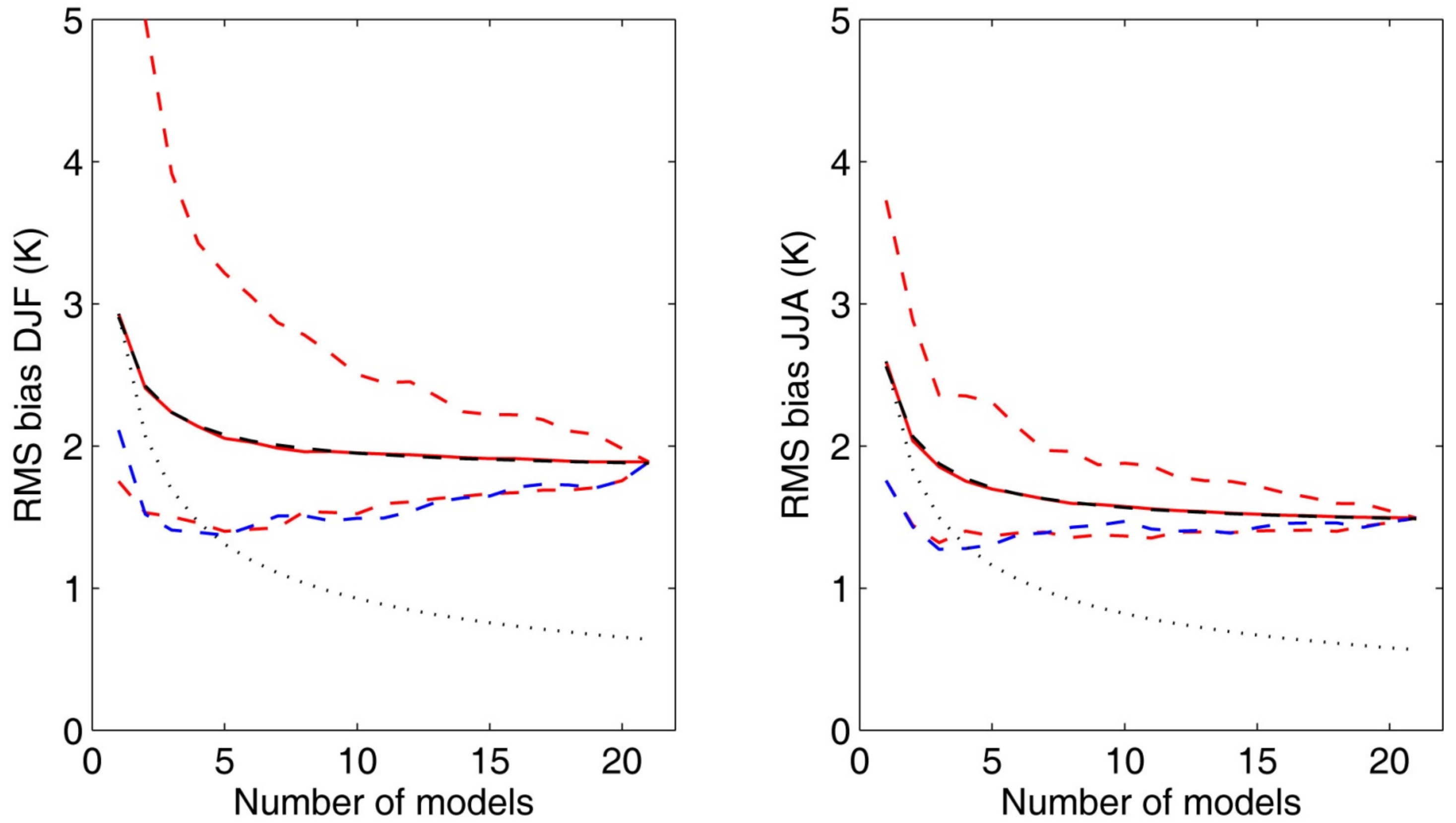
# SKILL OF DOWNSCALING




*Nikulin et al. 2011*

## *SKILL OF DOWNSCALING*

## *RCMS*




Knutti et al, 2010

## SKILL OF DOWNSCALING ENSEMBLES

A way of filtering the occasional errors and an indicator of uncertainty

Sharing codes – are the models independent?

Ensemble design

multi-model ensembles

perturbed physics ensembles

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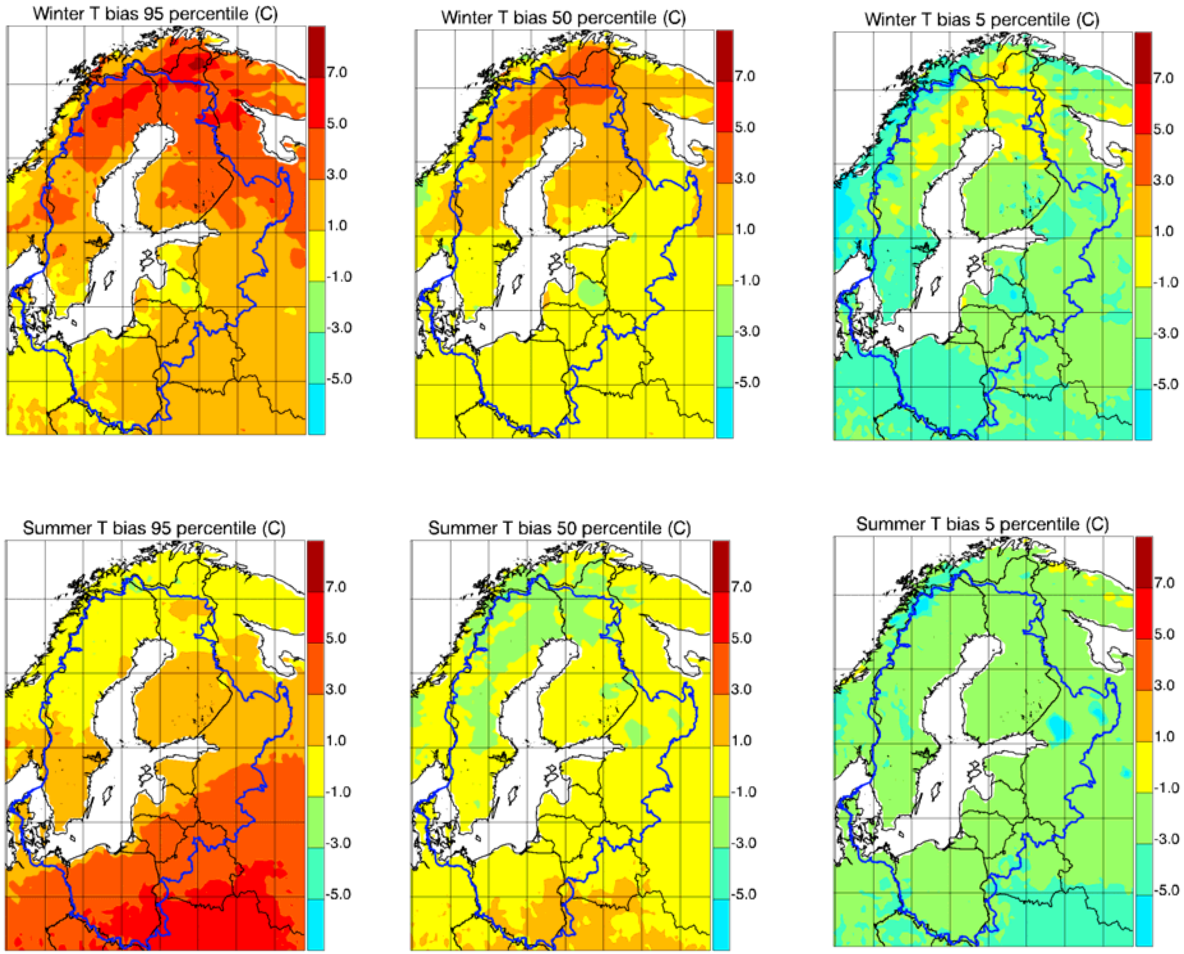
Ensemble projections or single climate projections?

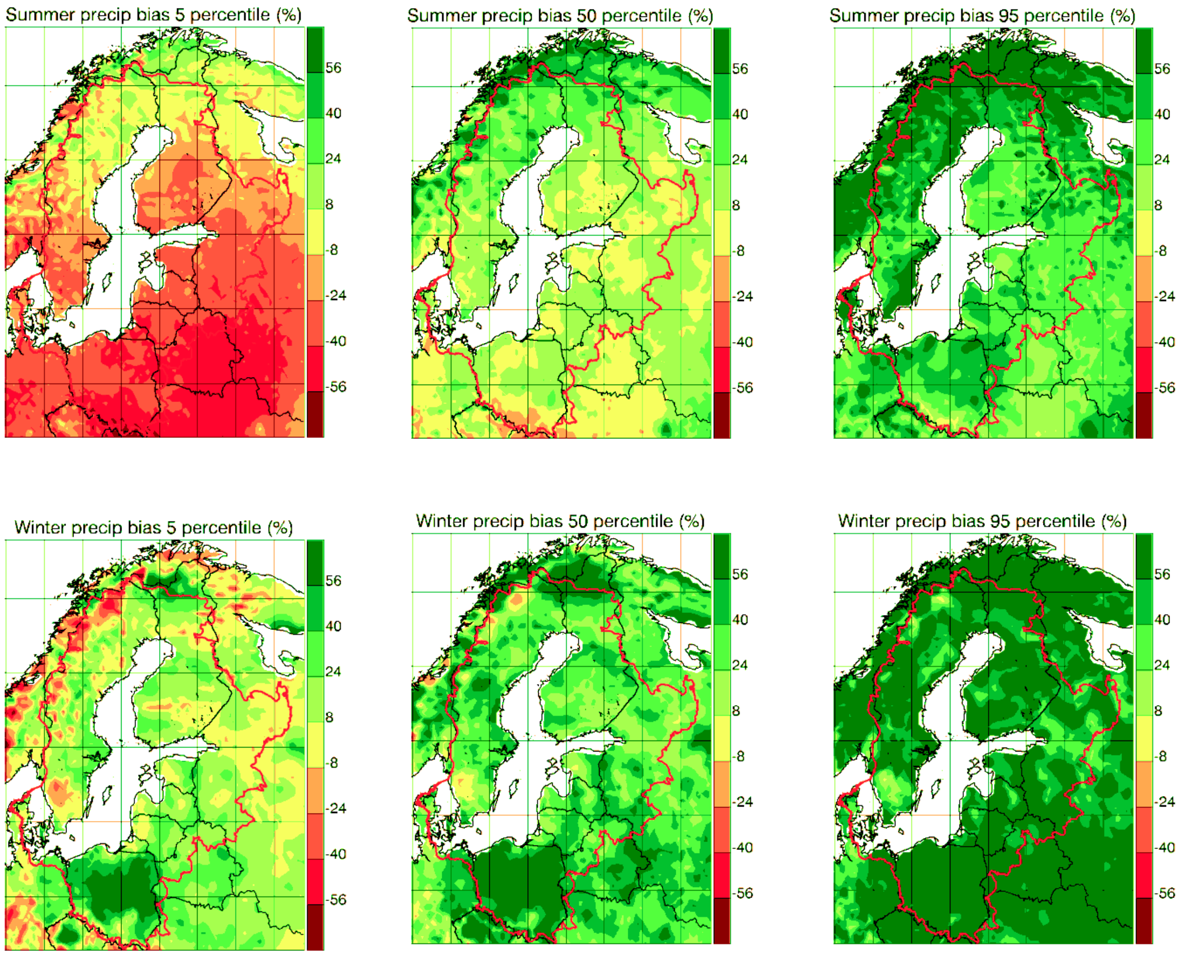
To weight or not to weight?

# *PERFORMANCE OF RCMS IN REPRODUCING THE CLIMATE*




***Simulated temperature bias (◦C) w.r.t. E-OBS for 1961-2000. The maps show the pointwise smallest (left), median (middle) and largest (right) bias taken from an ensemble of 10 RCMs with lateral boundary conditions taken from ERA40***

# PERFORMANCE OF RCMS IN REPRODUCING THE CLIMATE




***Simulated precipitation bias (%) w.r.t. E-OBS for 1961-2000. The maps show the pointwise smallest (left), median (middle) and largest (right) bias taken from an ensemble of 10 RCMs with lateral boundary conditions taken from ERA40.***

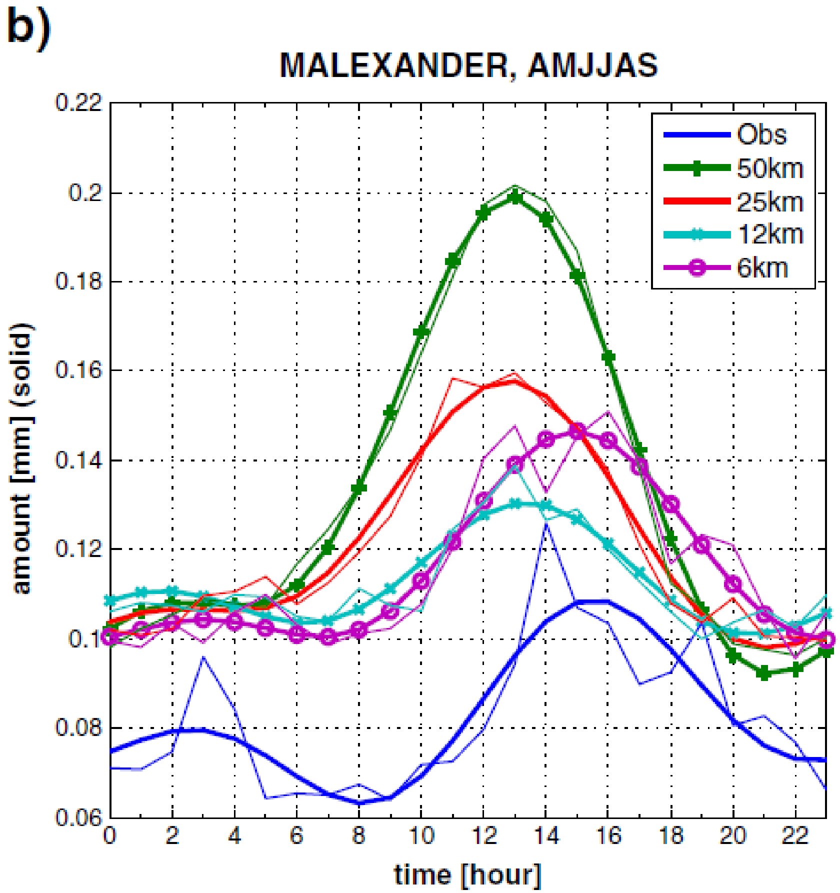
## *SKILL OF DOWNSCALING* *RCMS*

***A few RCM validation studies consider sub-daily scales. Jeong et al. 2011 have shown that diurnal precipitation cycle in Sweden is reasonably captured by RCM at SMHI, but afternoon peak occurs too early and is spatially too uniform.***

***Increasing model resolution in general improve model simulations, in particular precipitation in complex terrain (Salathé et al., 2003)***

# *SKILL OF DOWNSCALING*

***Fig. 4.2-7: An example of the estimated diurnal cycle of precipitation amount [hourly precipitation amount] from observation and from the RCA3 (RCM developed by the Rossby Centre of SMHI) simulations with 4 different resolutions for the station 'Malexander' in central southern Sweden (picture taken from Walther et al, 2011).***



# RECENT DEVELOPMENTS AND EXTENSION OF RCMS

*Oceans - the aspect of boundary conditions in RCMs*

*Nudging procedure*

*Hydrostatic and nonhydrostatic solutions*

*Lakes in the RCMs*

*Dynamics of vegetation*

*Biogeochemistry*

# *SKILL OF DOWNSCALING*

## *MOS*

***MOS has been shown to successfully correct temperature biases as well as biases in precipitation intensities and the number of wet days (Piani et al. 2010)***

***Widmann et al. 2003 developed a non-local MOS that corrects systematic spatial displacements of precipitation.***

***Yang et al. 2010 applied MOS to improve correlation between simulated temperature and precipitation.***

***MOS is not capable of correcting the misrepresentation of temporal structure of a simulated variable (cannot correct errors in the lenght of dry, wet or hot spells).***

# *SKILL OF DOWNSCALING*

## *MOS*

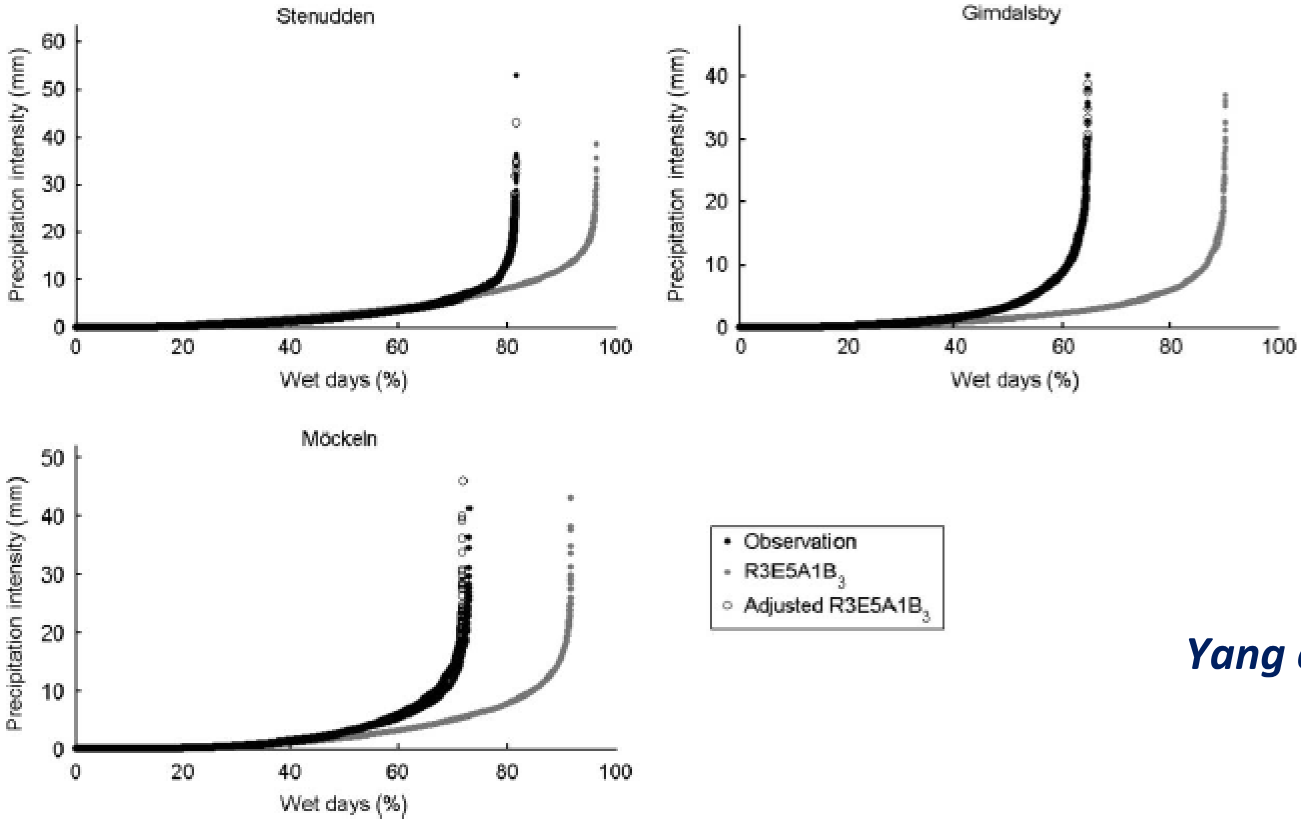
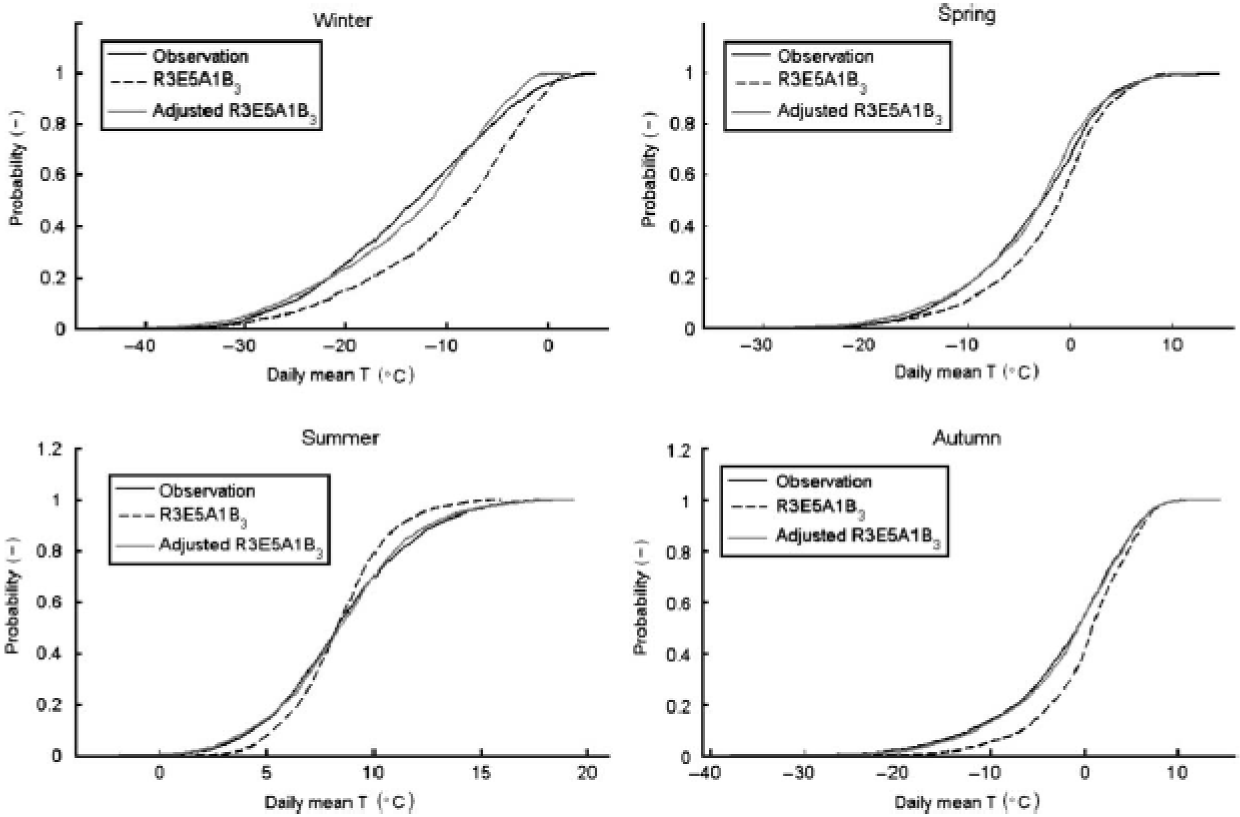



**Figure 4** | Distribution of precipitation intensities for all three study basins calculated from observations (1961–1990) and raw R3E5A1B$_3$ output and DBS-adjusted R3E5A1B$_3$ output for the control period. Note that the observations are difficult to see as the DBS-adjusted values closely overlie them.

*Yang et al., 2010*

# SKILL OF DOWNSCALING

## MOS




*Yang et al., 2010*

**Figure 7** | Distribution of daily temperature from observations (1961–1990) and raw R3E5A1B$_3$ and DBS-adjusted R3E5A1B$_3$ projection outputs for the control period for each season in the Stenudden basin.

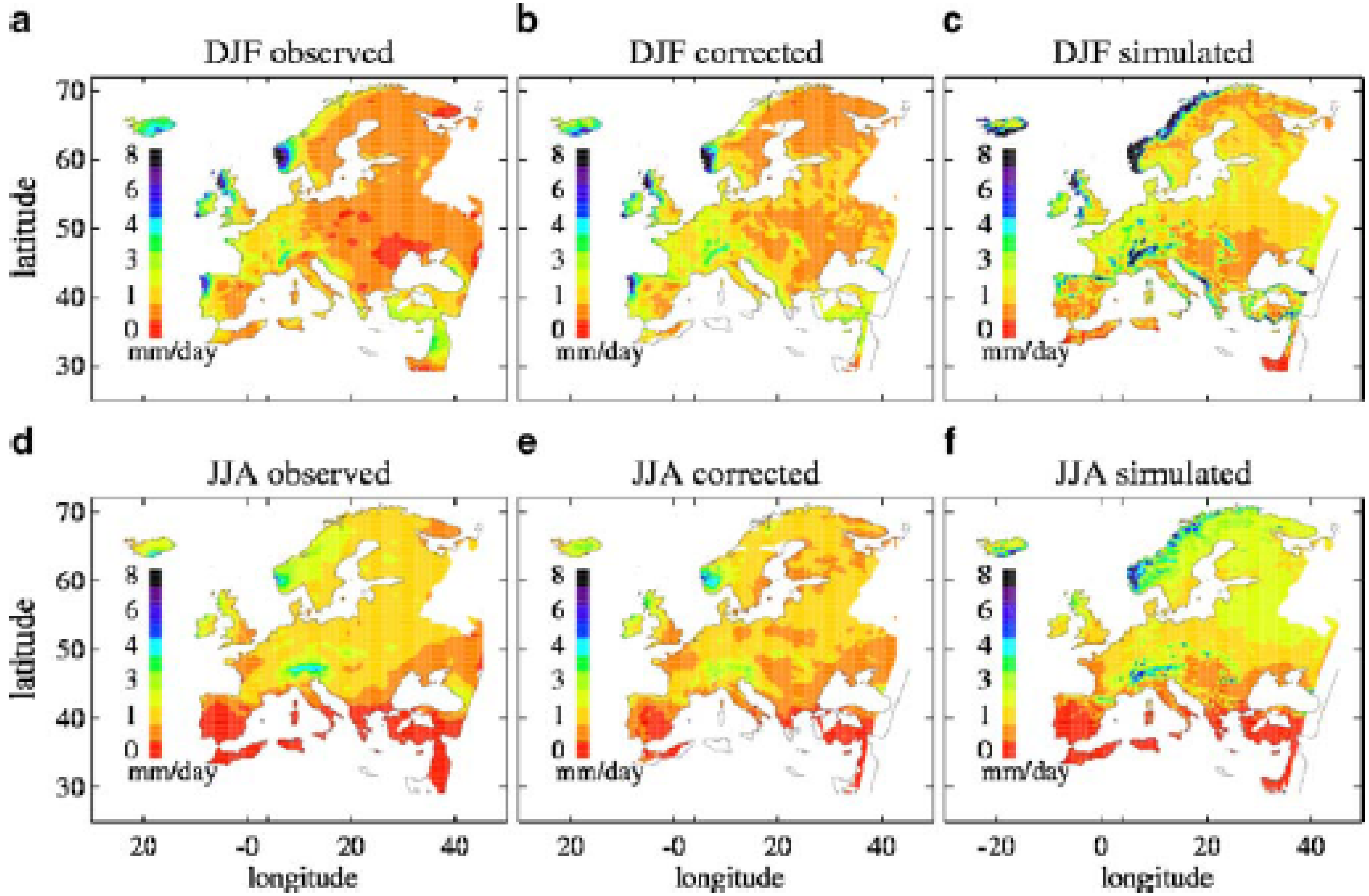



*Fig. 4.2-5. Application of bias correction, derived from simulated and observed data from 1961 to 1970, to model data from 1991 to 2000. a Mean observed daily precipitation for winter (DJF) 1991 to 2000, b same as a but for corrected simulated data, c same as a but for uncorrected simulated data. d–f Same as a–c but for summer (JJA) (Piani et al., 2010, Fig.2)*

## *SKILL OF DOWNSCALING*

***PP***

***PP explicity uses an empirical knowledge by inclusion of observational data into statistical models. A simulated predictands are bias free.***

***If the predictors do not capture the climate change signal, nonstationarities may arise.***

***Underrepresentation of temporal variability***

***Problems with variability around the mean. There are methods to deal with it: inflation or randomisation, but it is impossible to evaluate their quality in the scenarios for future.***

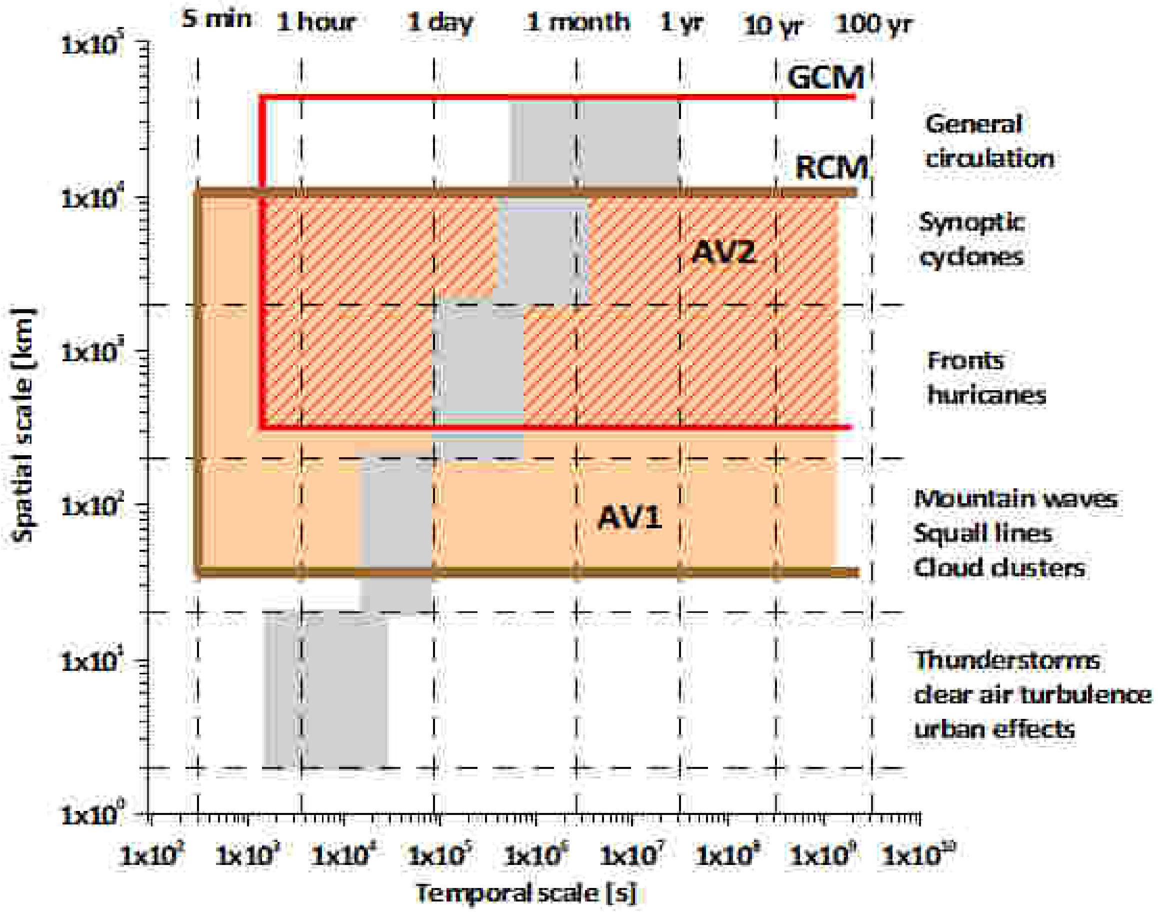
## *SKILL OF DOWNSCALING*

## *PP*

***A main disadvantage of PP is a handling of spatial coherence.***

***The development of downscaling methods to full spatial fields for climate change studies is still in its early stages (Onibon et al. 2004 disggregation of areal rainfall by the Gaussian process).***

# Concept of *added value*




*Orlanski, 1975*
*Laprise, 2004*
*von Storch, 2005*
*Feser, 2006*
*Di Luca, 2012*

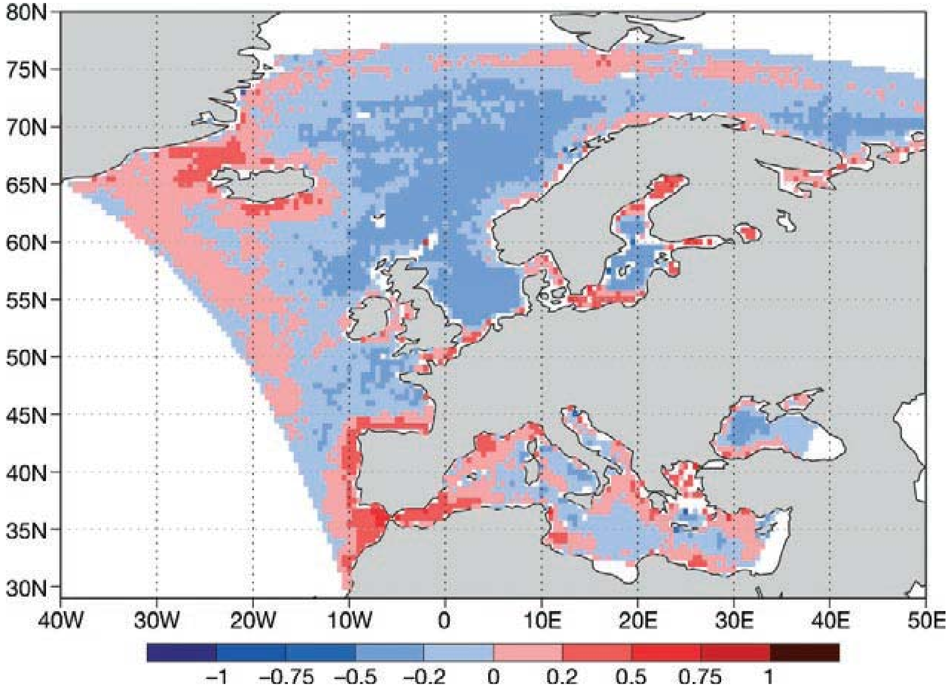



***Fig. 4.2-8. Brier skill score using QuikSCAT level 2B12 as the truth, global reanalysis (NCEP reanalysis) as the reference forecast, and a regional model (SN-REMO) as the forecast, after Winterfeldt et al. (2010).***

## *SUMMARY*

***RCMs are able to improve quality and precission of GCMs, but with some limitations.***

***RCMs simulations are biased and these biases are partly common to all models (they are not excluded by ensembles)***

***MOS is able to correct a considerable part of biases, the distribution based corrections should be implemented in majority of cases.***

***PP explicity uses an empirical knowledge by inclusion of observational data into statistical models. A simulated predictands are bias free.***

***If the predictors do not capture the climate change signal, nonstationarities may arise.***

## *STATISTICAL-EMPIRICAL DOWNSCALING METHODS*

***Model Output Statistics***

- ***bias correction***
- ***delta change or scaling***

***Perfect Prognosis***

- ***regression methods***
- ***weather classification methods***

***Weather Generators***

## *VALIDATION TECHNICS*

***Errors of driving global climate model***

***Errors inherent in the downscaling approach***

***Perfect Boundary Condition***

***Big Brother Experiments***

# VALIDATION INDICES

*Mean, variation, extremes, spatial and temporal structure*

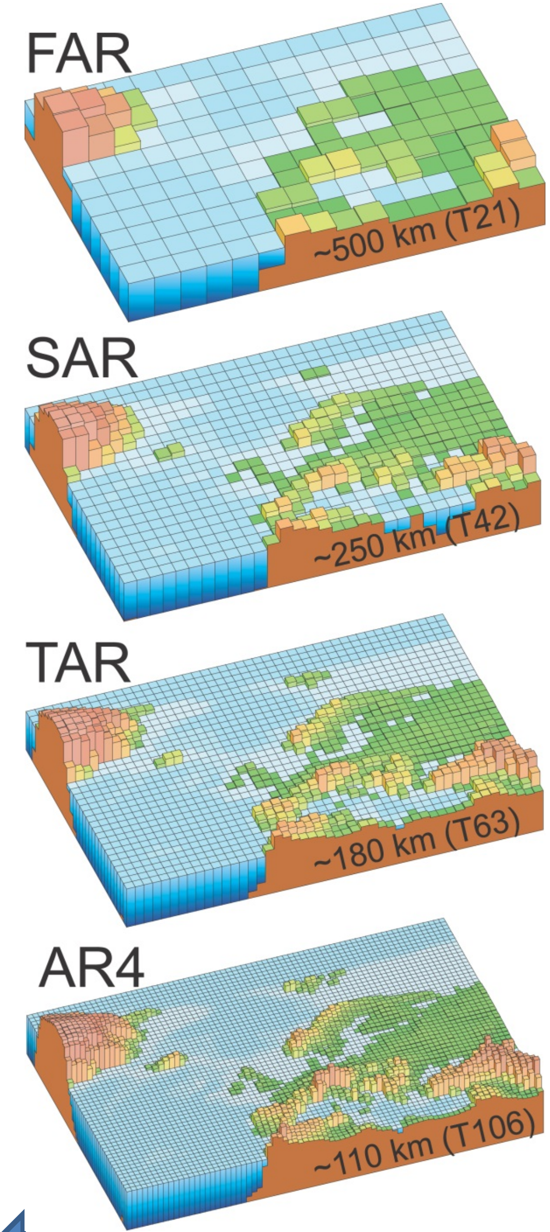
*Perfect Boundary Condition*

*Big Brother Experiments*

*Should the validation use the data directly with grid box resolution or should data be smoothed in advance?*

*Distribution-wise and event –wise validation*

*Validation in climate change context (nonstationarity of skill and/or biases)*




# *INTRODUCTION*

***Grid scale: 100-300 km***

***Skillful scale: 100-2500 km***

***Downscaling:***
***a process linking large scale variables with small scale variables***

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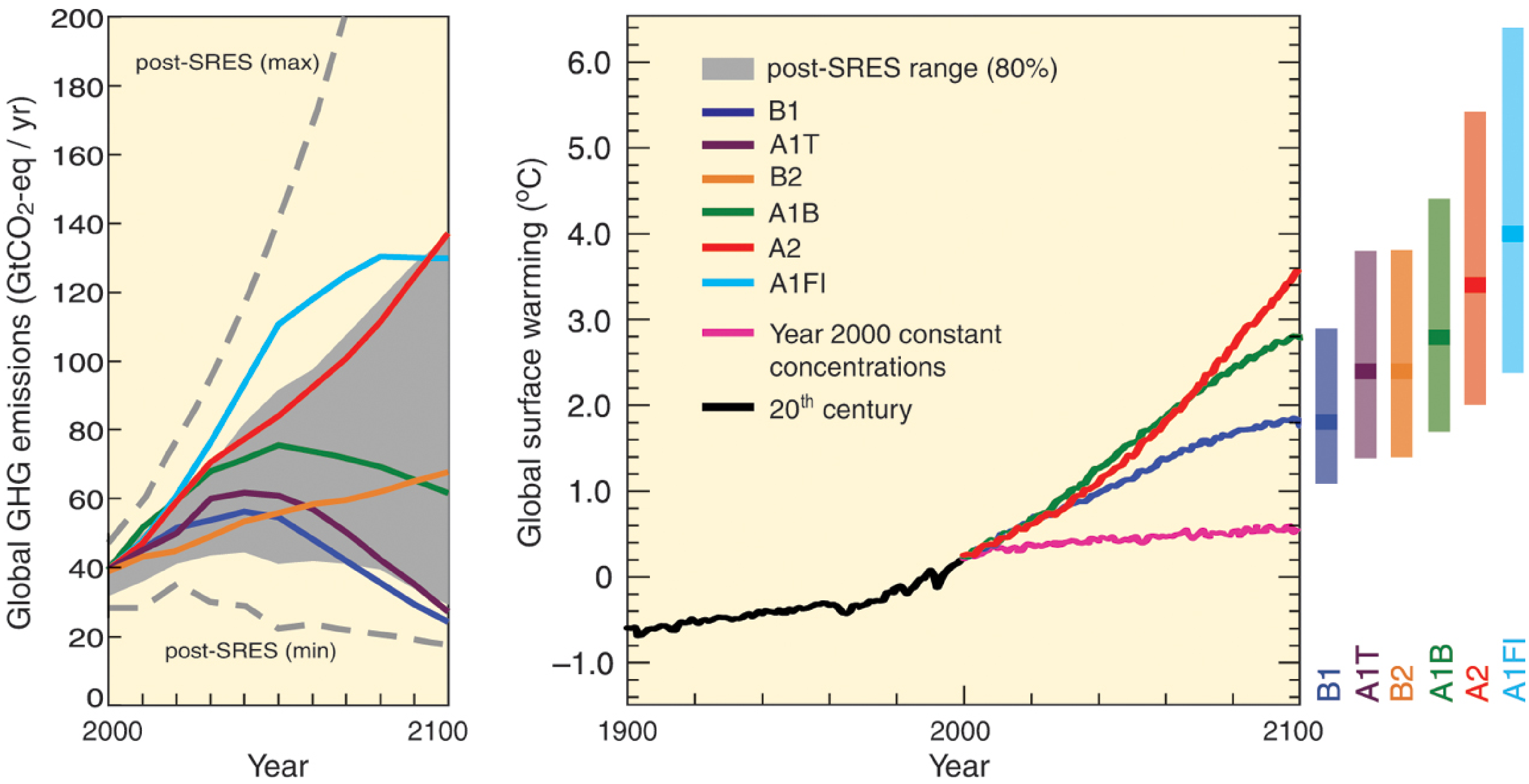
# ***DRIVERS OF CLIMATE VARIABILITY AND CHANGE***

- ***Solar radiance***
- ***Oceanic processes***
- ***Biosphere with its annual cycle and long-term changes***
- ***Criosphere with its annual cycle and long-term changes***
- ***Volcanic processes***
- ***Biogeochemical cycles and their long-term changes***

❑ ***GHG concentration***

❑ ***Aerosols***

❑ ***Sulphur compounds***

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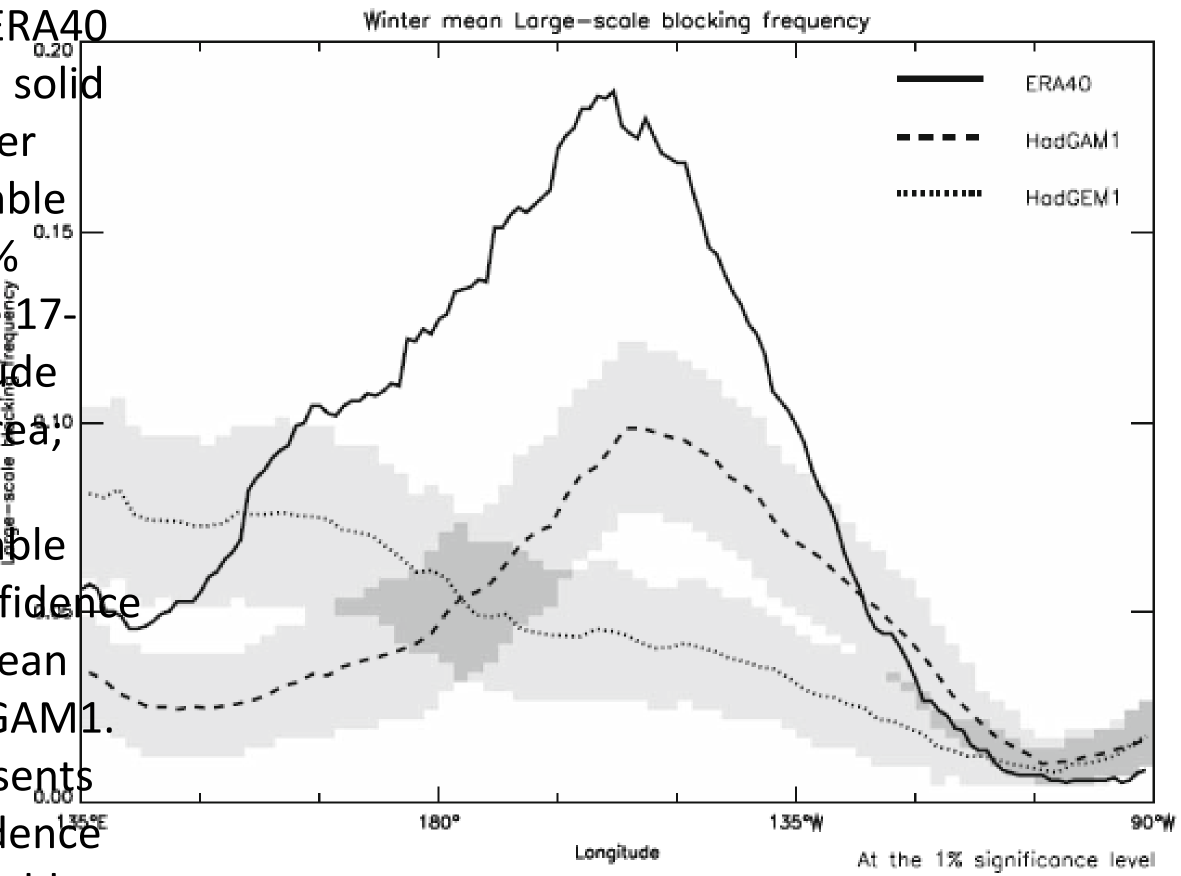
# *SKILL OF DOWNSCALING*

Hinton et al., 2009

Winter (DJF) mean blocking frequencies for ERA40 (Dec 1978 to Feb 1995) in solid line; HadGAM1 six member ensemble with the ensemble mean dashed and the 99% confidence interval of the 17-year mean at each longitude denoted by the shaded area; HadGEM1 three member ensemble with the ensemble mean dotted and the confidence interval on the 17-year mean represented as with HadGAM1. The darker shading represents the area where the confidence intervals of the two ensembles overlap



# SELECTED SOURCES OF UNCERTAINTY

| Effects of low spatial resolution | Results of methodological assumption | Sources of uncertainty |
|---|---|---|
| Sub-grid processes like cloud formation, convection, precipitation and many others are not explicitly simulated<br><br>Real coastline and land cover can significantly differ from that in the model.<br><br>Low resolution flatens the orography influencing not only local climate conditions predicted by the model but also the atmospheric circulation which has an impact on climate in wider spatial scale. | Effects of nonstationarity of empirical and statistical relationships between large scale predictors and local or point scale predictands.<br><br>Effects of nonstationarity of biases.<br><br>Effects of systematic errors in climate models or their groups on ensembles statistics | Uncertainty according to natural drivers of climate variability like solar or volcanic activity.<br><br>Uncertainty according to anthropogenic drivers of climate change like emissions and concentrations of aerosols and greenhouse gases and changes in land use.<br><br>Input data to climate models - their quality, precision and limited temporal and spatial distribution. |