

C2CCC Marathonmøde Grenå 25. april

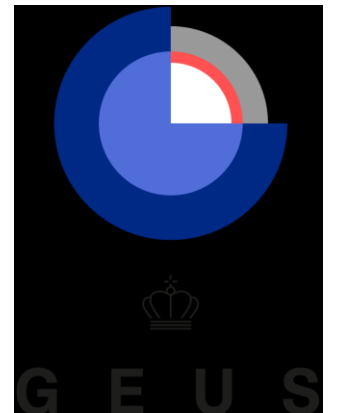
Anvendelse af klimafremskrivninger i hydrologisk sammenhæng

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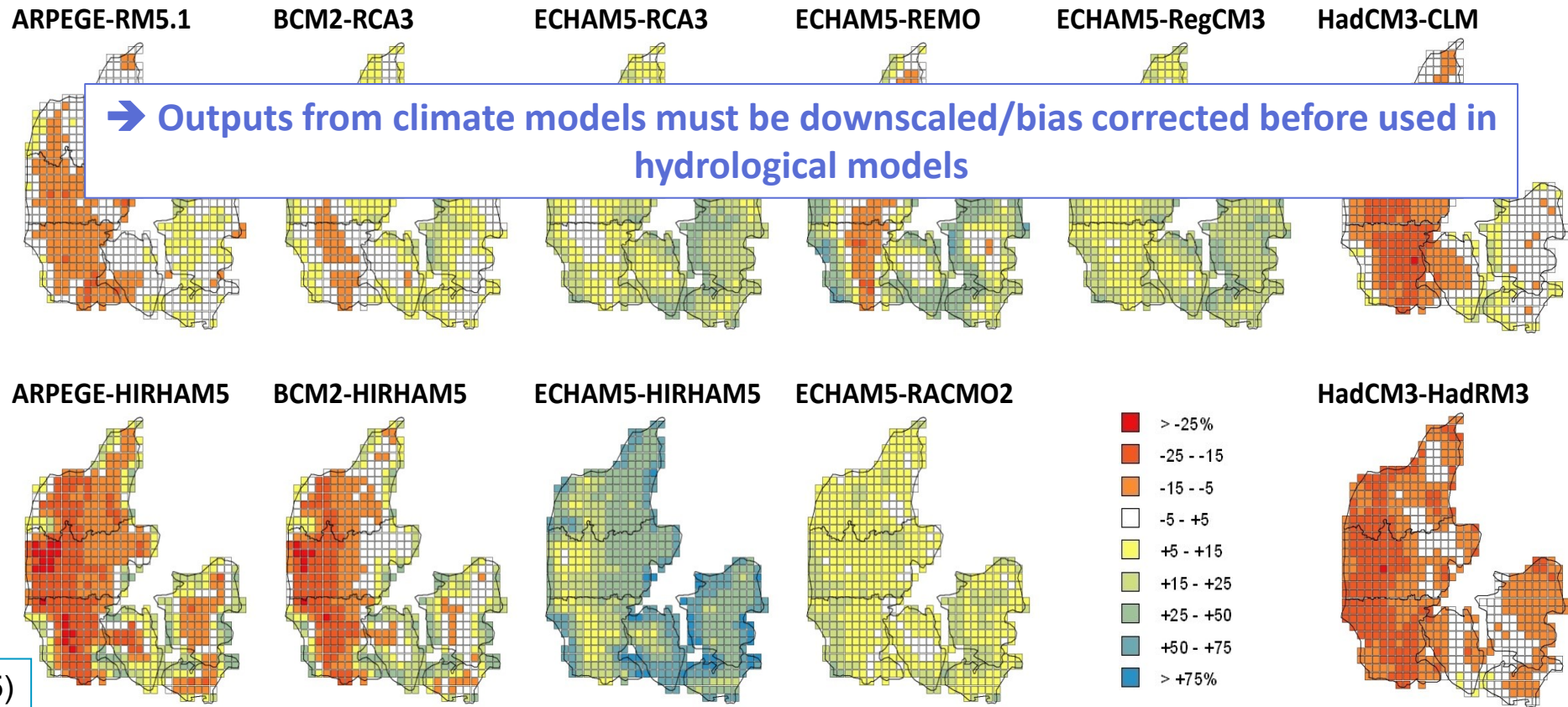
Outline

- Recap af usikkerheder på klimafremskrivninger (klimatilpasnings.dk / AR4)
- Klimafremskrivning og hydrologiske effekter (AquaClew /AR5)
 - Fremskrivning for 2071-2100 i forhold til 1981-2010 reference for RCP 8.5 og RCP 4.5 scenarierne, med biaskorrektion af 21/5 klimamodeller fra AR5 ud fra perioden 1990-2009
- Tidligere eksempler på vurdering af klimaeffekter i hydrologisk sammenhæng (AR4)
 - Klimatilpasning.dk (3 – 9 klimamodeller 2021-2050/1961-1990 landsdækkende)
- Opsamling på usikkerheder (reference, fremskrivning, bias-korrektion)
- Konklusion



Usikkerhed på forskellige klimamodeller og bias korrektion (AR4)

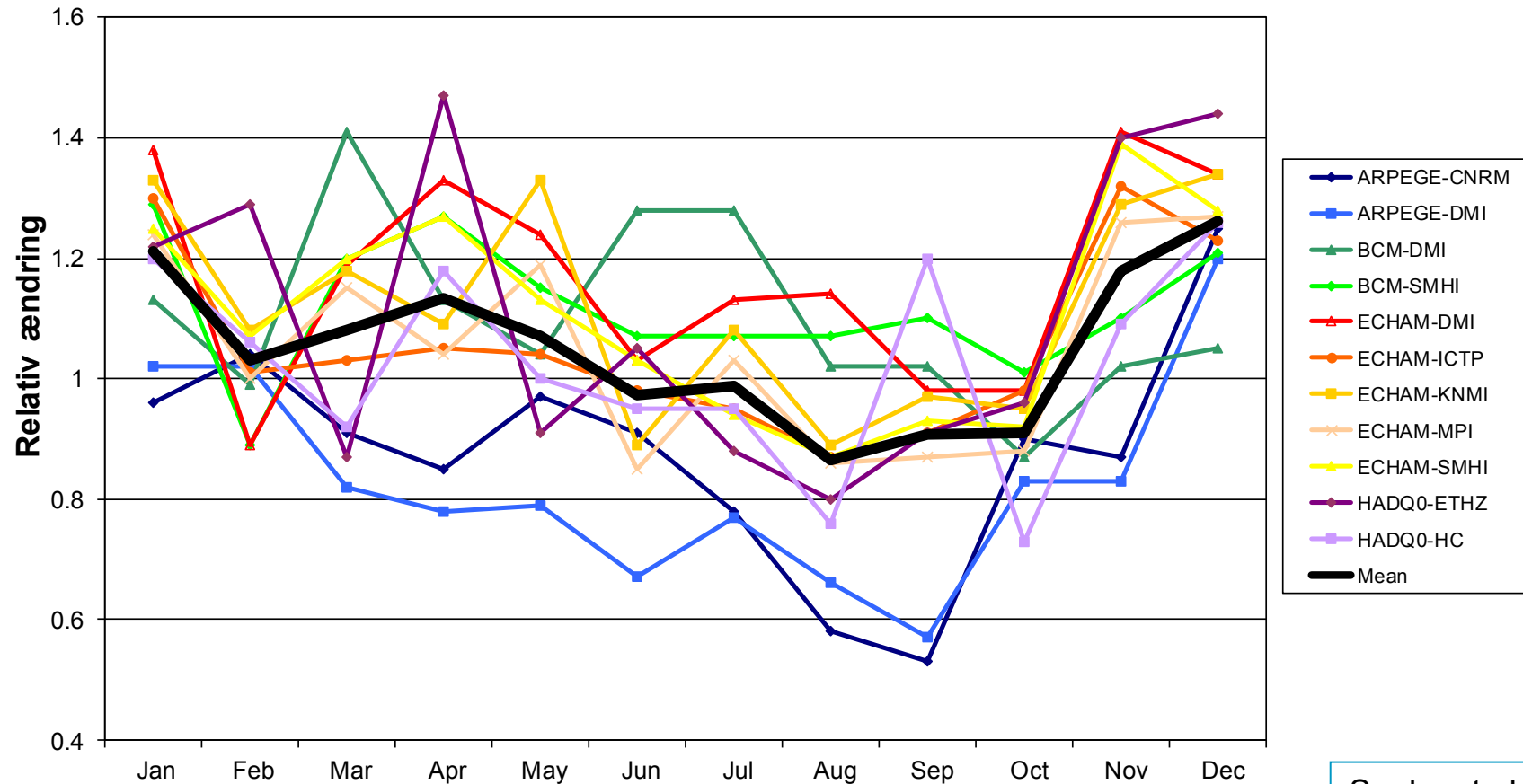
Bias (model - observed) in annual precipitation for 1991-2010



Seaby et al. (2015)

Fremtidig nedbørsudvikling (AR4)

Ændring i månedlig nedbør i DK 2071-2100
sammenlignet med 1991-2010



Seaby et al. (2015)

Forudsigelse af klimaet og effekter på grundvand

Periode
(Reference: 1961-90; 1981-2010, Fremtid: 2021-50; 2071-2100)

Emissions-scenarie
(B2, A2, A1B, RCP4.5, RCP 8.5)

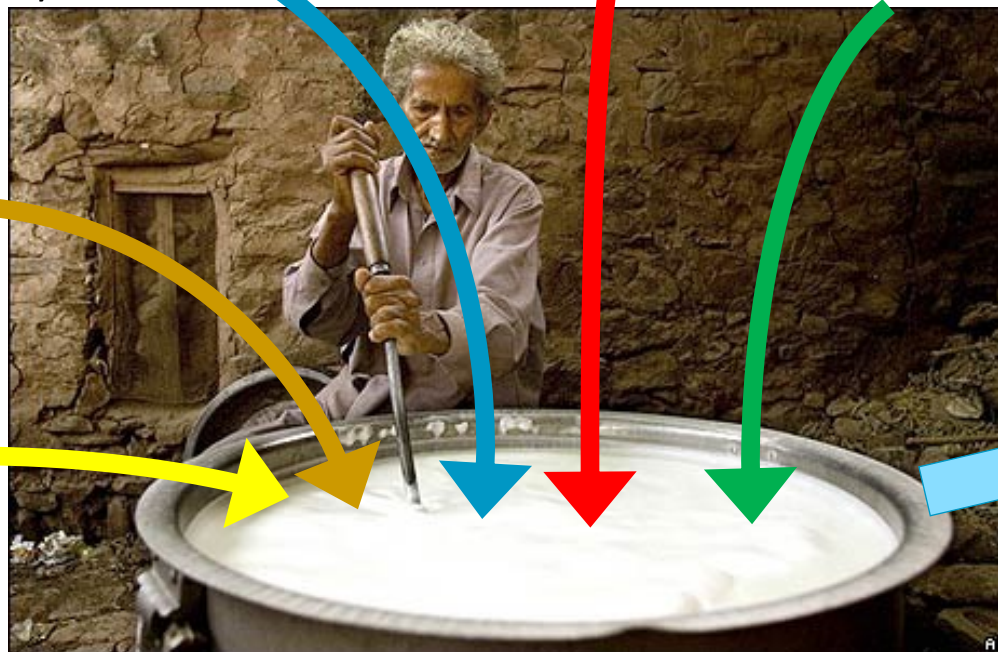
Klimamodel
(HIRHAM, ECHAM, HadGEM2-ES etc.)

Bias korrektion

(Delta change,
Distribution
Based Scaling)

Hydrologisk model

(MIKE SHE/MIKE Hydro,
konceptuel/lumped)

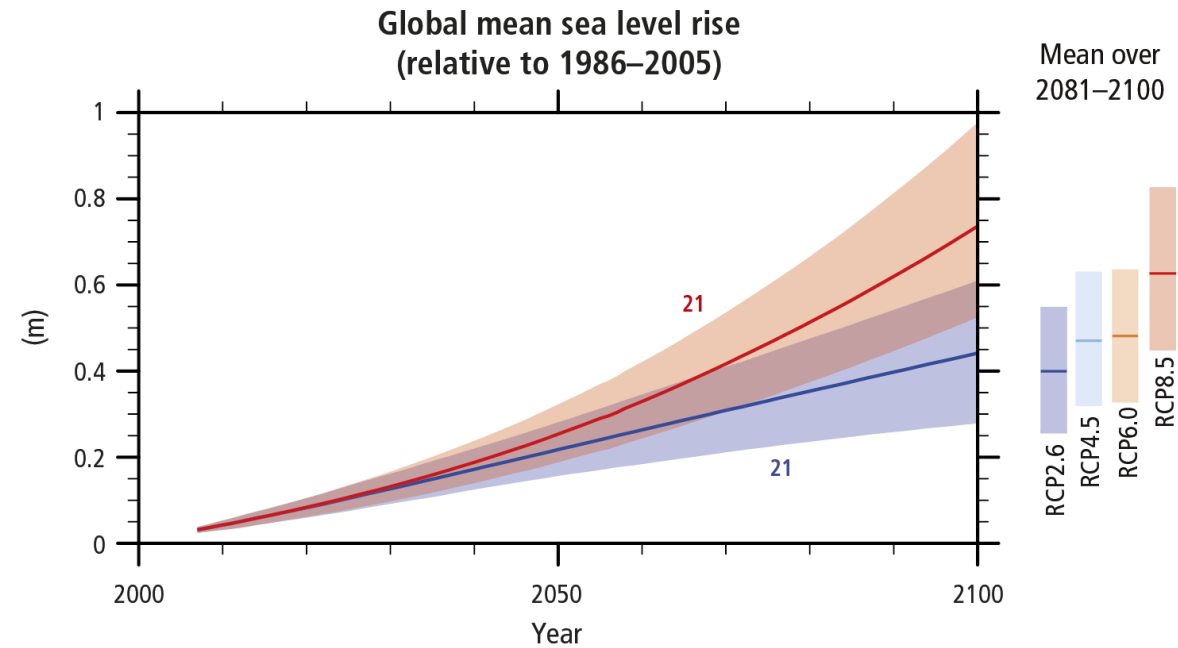
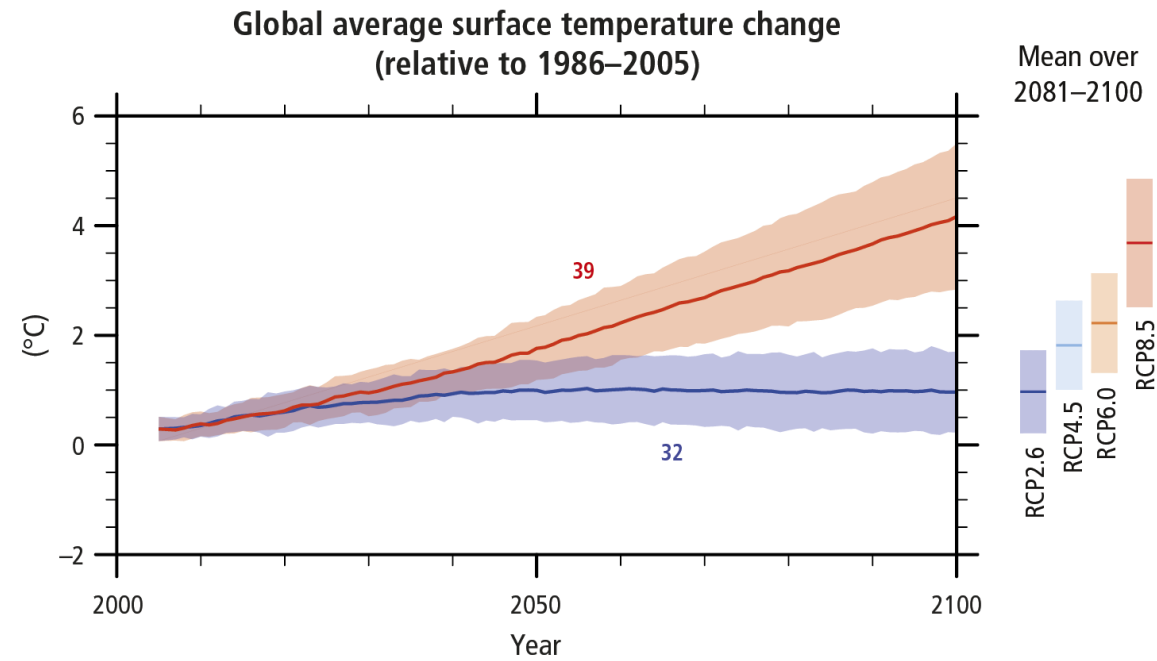
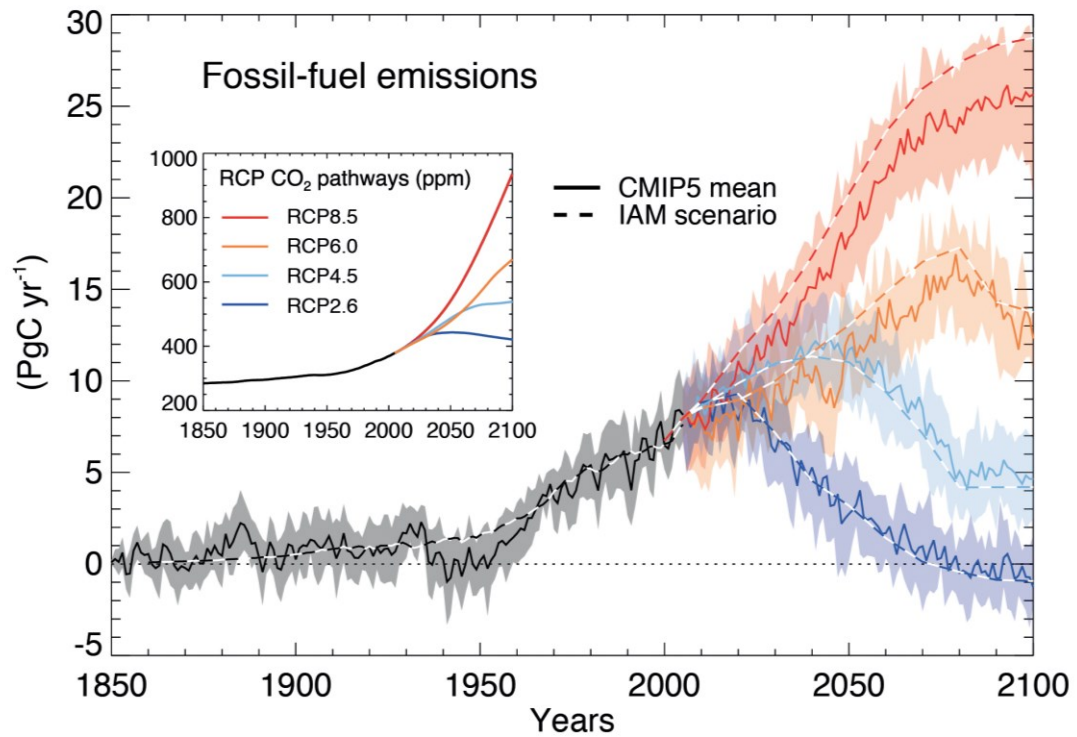


**Klimaprognose og
hydrologisk prognose**



Klimafremskrivning

IPCC Emission Scenarios (RCPs)



IPCC – AR5 (2014)

Bias korrektionsmetoder

Delta change method (perturbations to observed values)

$$P_{fut} = P_{obs} \frac{M_{fut}}{M_{cont}}$$

M: Mean monthly precipitation (e.g. 30 years period)

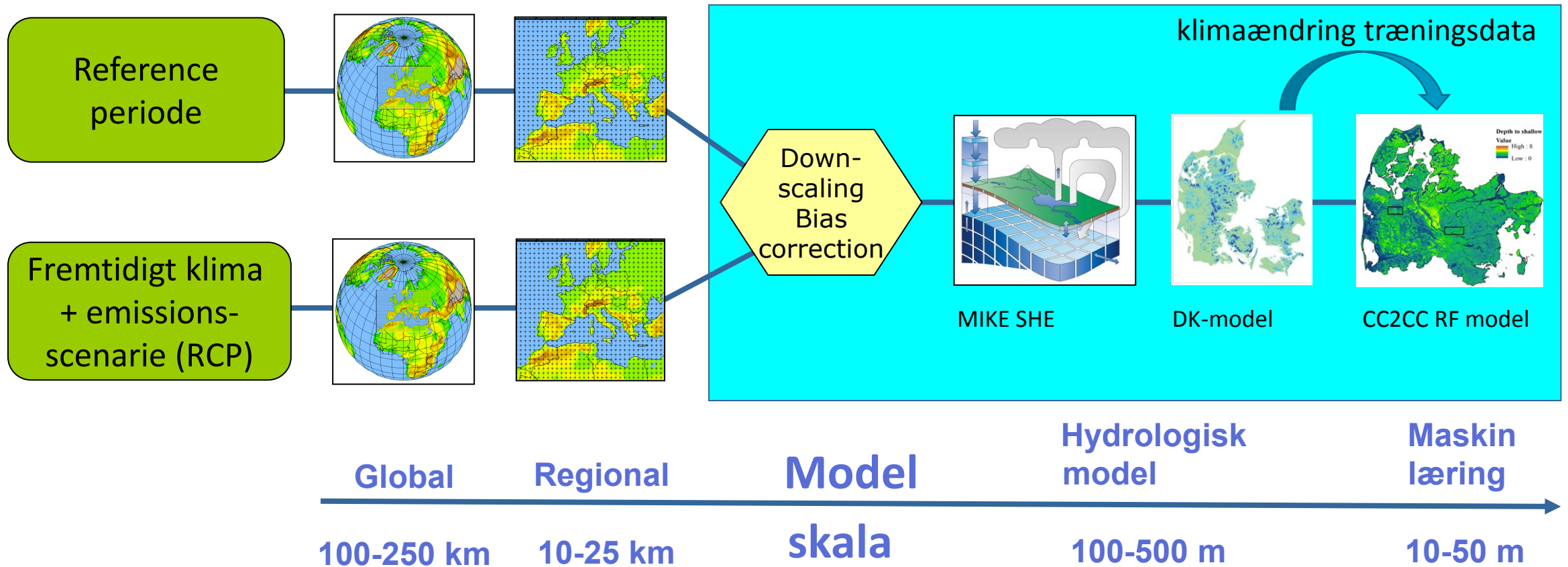
M_{fut} : Future climate

M_{cont} : Present climate (control period)

More comprehensive methods (perturbations to climate model simulated values)

- Distribution based scaling
- Quantile mapping
- ➔ *Preserve climate model simulated structure, changes in variability and intensities*

Metodik



Fremskrivninger af temperatur, nedbør og potentiel fordampning

Temperatur

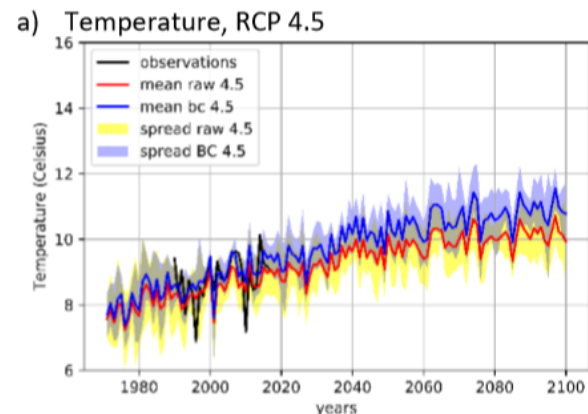
På hver figur:

- Observeret (sort)
- Uden biaskorrektion (rød)
- Med biaskorrektion ("dobbelt gamma", blå)
- Spredning (uden biaskorrektion, gulskraveret)
- Spredning (med biaskorrektion, blågråskraveret)

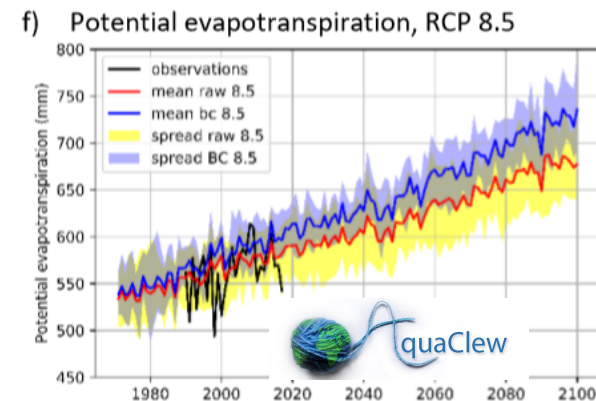
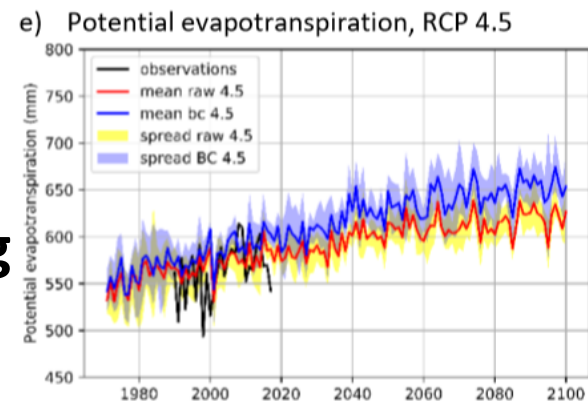
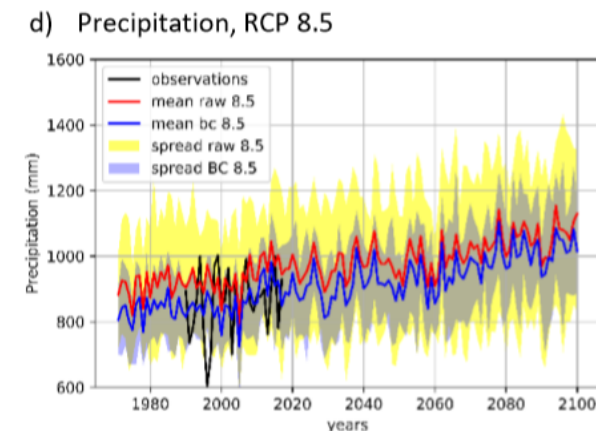
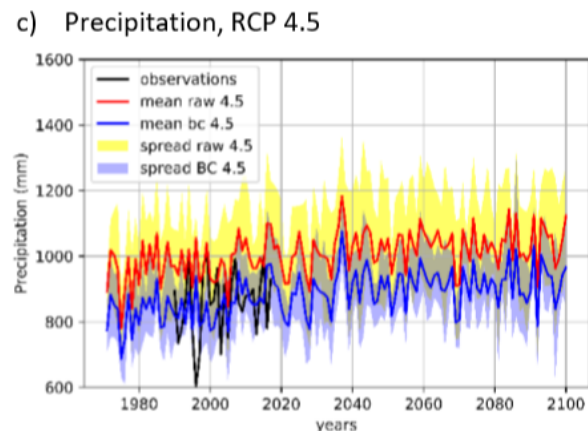
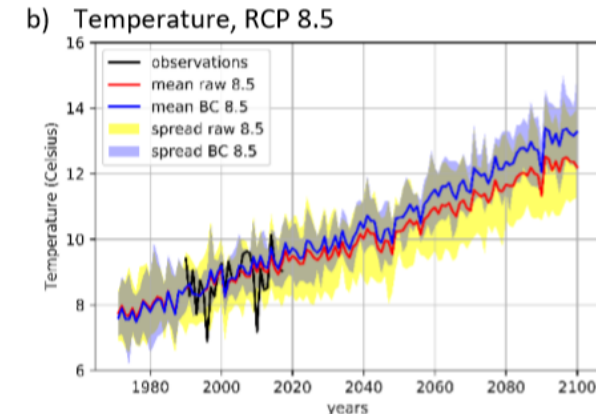
Nedbør

Potentiel fordampning

RCP 4.5



RCP 8.5



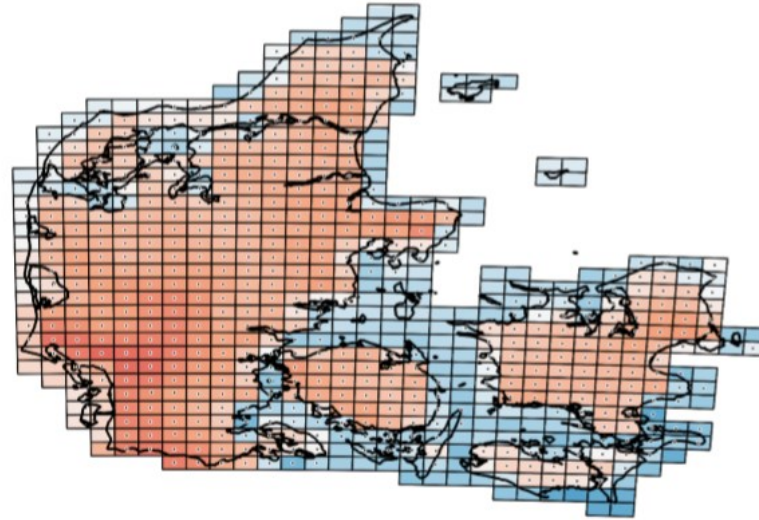
RCP 8.5 Ændring i årsnedbør (%) for 2071-2100 sammenlignet med 1981-2010

Middel og standardafvigelse
for 16 klimamodeller
(RCM/GCM) hhv. uden og med
biaskorrektion

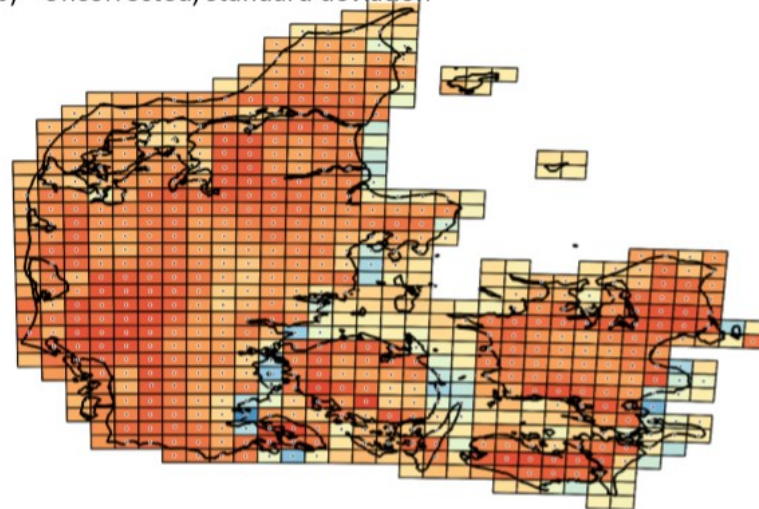
Paten-Zapata og Sonnenborg 2019 - ROSA

Ukorrigeret - middel ændring

d) Uncorrected, mean change



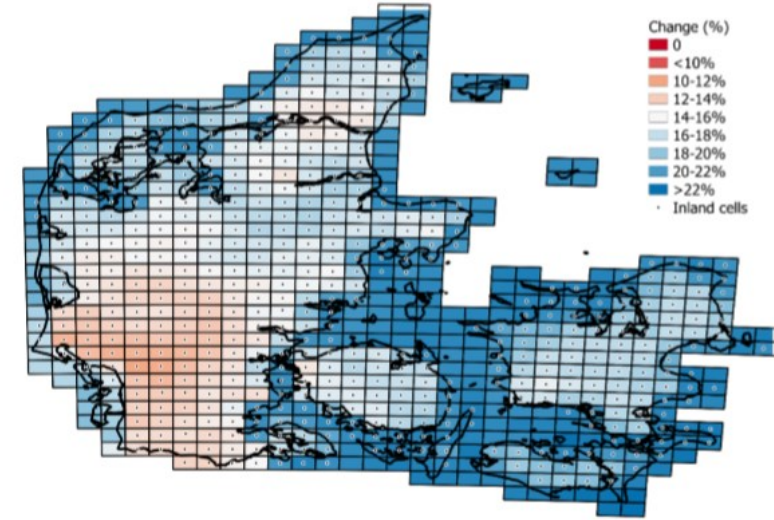
b) Uncorrected, standard deviation



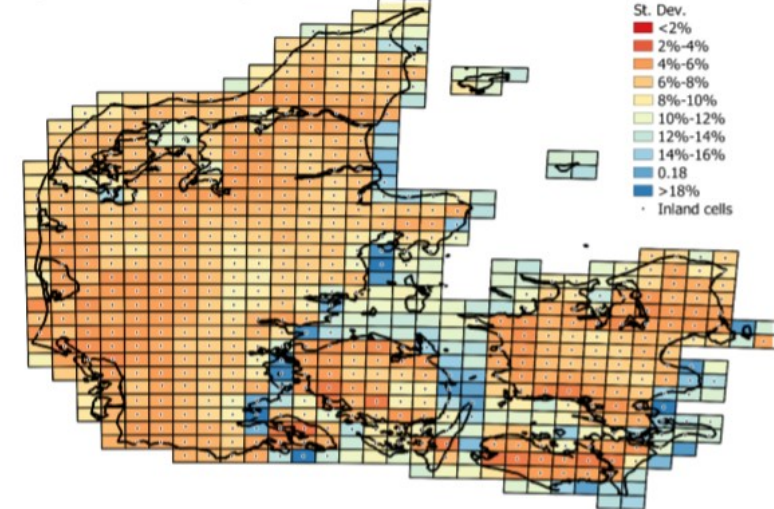
Ukor. standardafvigelse

Bias korrigeret - middel ændring

c) Bias-corrected, mean change



a) Bias-corrected, standard deviation



Bias. Kor. standard afvigelse

Change (%)

- 0
- <10%
- 10-12%
- 12-14%
- 14-16%
- 16-18%
- 18-20%
- 20-22%
- >22%
- Inland cells

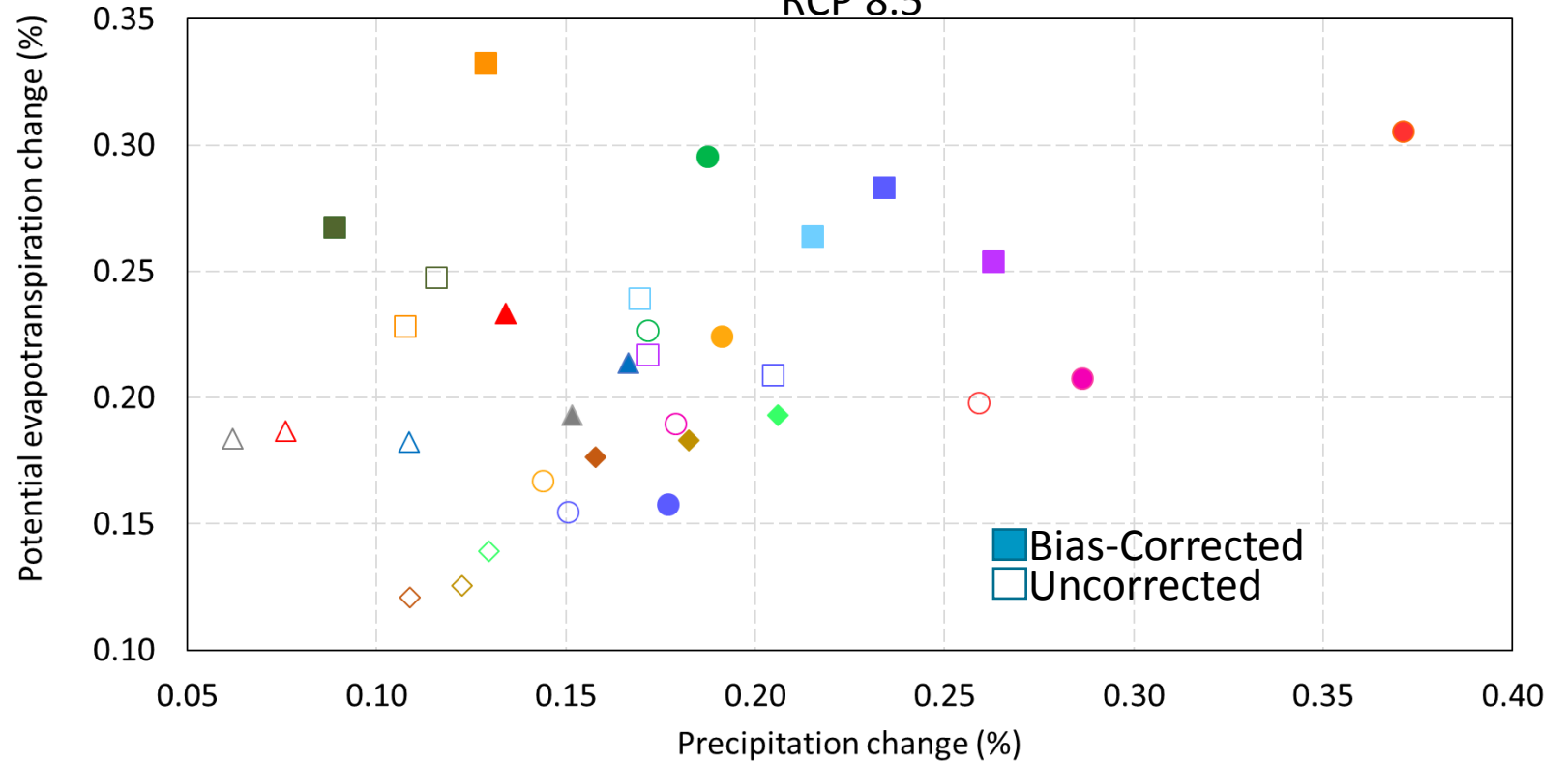
St. Dev.

- <2%
- 2%-4%
- 4%-6%
- 6%-8%
- 8%-10%
- 10%-12%
- 12%-14%
- 14%-16%
- 0.18
- >18%
- Inland cells

Fremskrevne ændringer i nedbør og potentiel fordampning

Projected change 2071-2100 compared to 1981-2010

RCP 8.5



- | | |
|------------------------------|--------------------------------|
| ● CanESM2-REMO2015r1i1p1 | ● CNRM-CM5-CCLM 4.8.17r1i1p1 |
| ▲ EC-EARTH-HIRHAM5r3i1p1 | ● IPSL-CM5A-MR-RCA4r1i1p1 |
| ▲ EC-EARTH-RACMO 2.2r12i1p1 | ● MIROC5-REMO2015r1i1p1 |
| ▲ EC-EARTH-RACMO 2.2r1i1p1 | ◆ MPI-ESM-LR-REMO2009r1i1p1 |
| ◆ MPI-ESM-LR-RCA4r1i1p1 | ◆ MPI-ESM-LR-REMO2009r12i1p1 |
| ● NorESM1-M-HIRHAM5r1i1p1 | ■ HadGEM2-ES-CCLM 4.8.17r1i1p1 |
| ■ HadGEM2-ES-HIRHAM5r1i1p1 | ■ HadGEM2-ES-REMO2015r1i1p1 |
| ■ HadGEM2-ES-RACMO 2.2r1i1p1 | ■ HadGEM2-ES-RCA4r1i1p1 |

Pasten-Zapata, Sonnenborg, Refsgaard 2019 - ROSA



Usikkerhed på fremskrivning

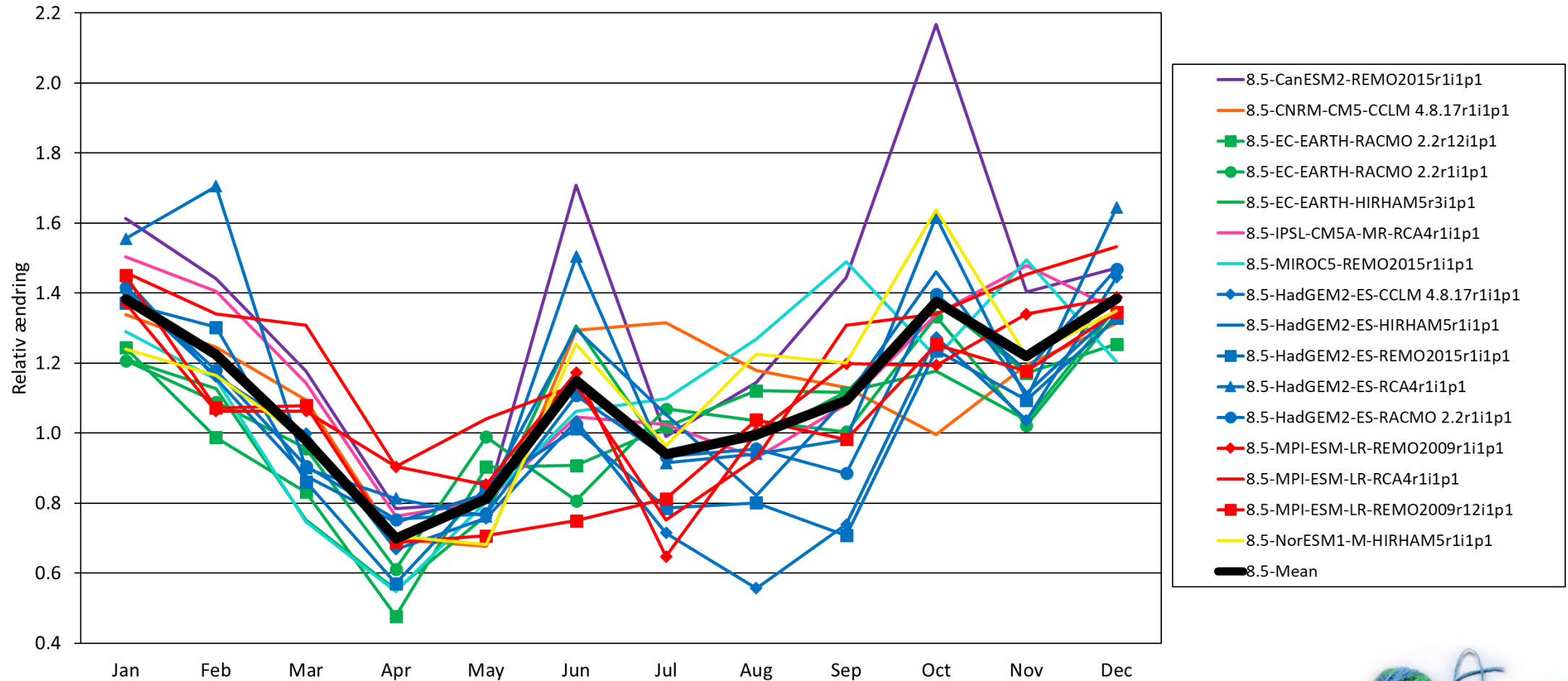
GCM: global klimamodel
 RCM: regional klimamodel
 RCP: emissions scenarie
 NV: naturlig variabilitet

Signal to noise ratio

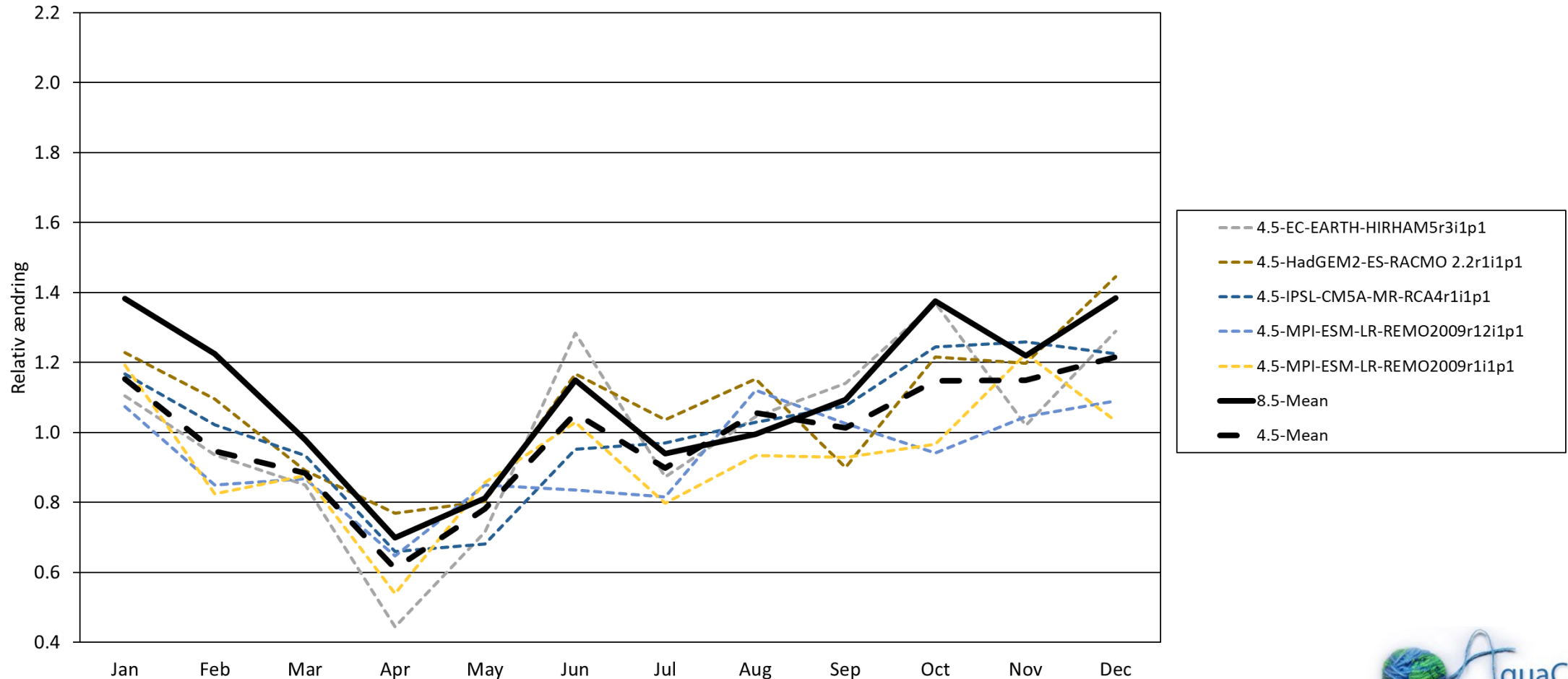
Uncertainty	TEMPERATUR		NEDBØR	
	2041-2070	2071-2100	2041-2070	2071-2100
GCM	●	●	●	●
RCM	●	●	●	●
RCP	●	●	●	●
NV	●	●	●	●

- Largest source of uncertainty
-
-
- Smallest source of uncertainty

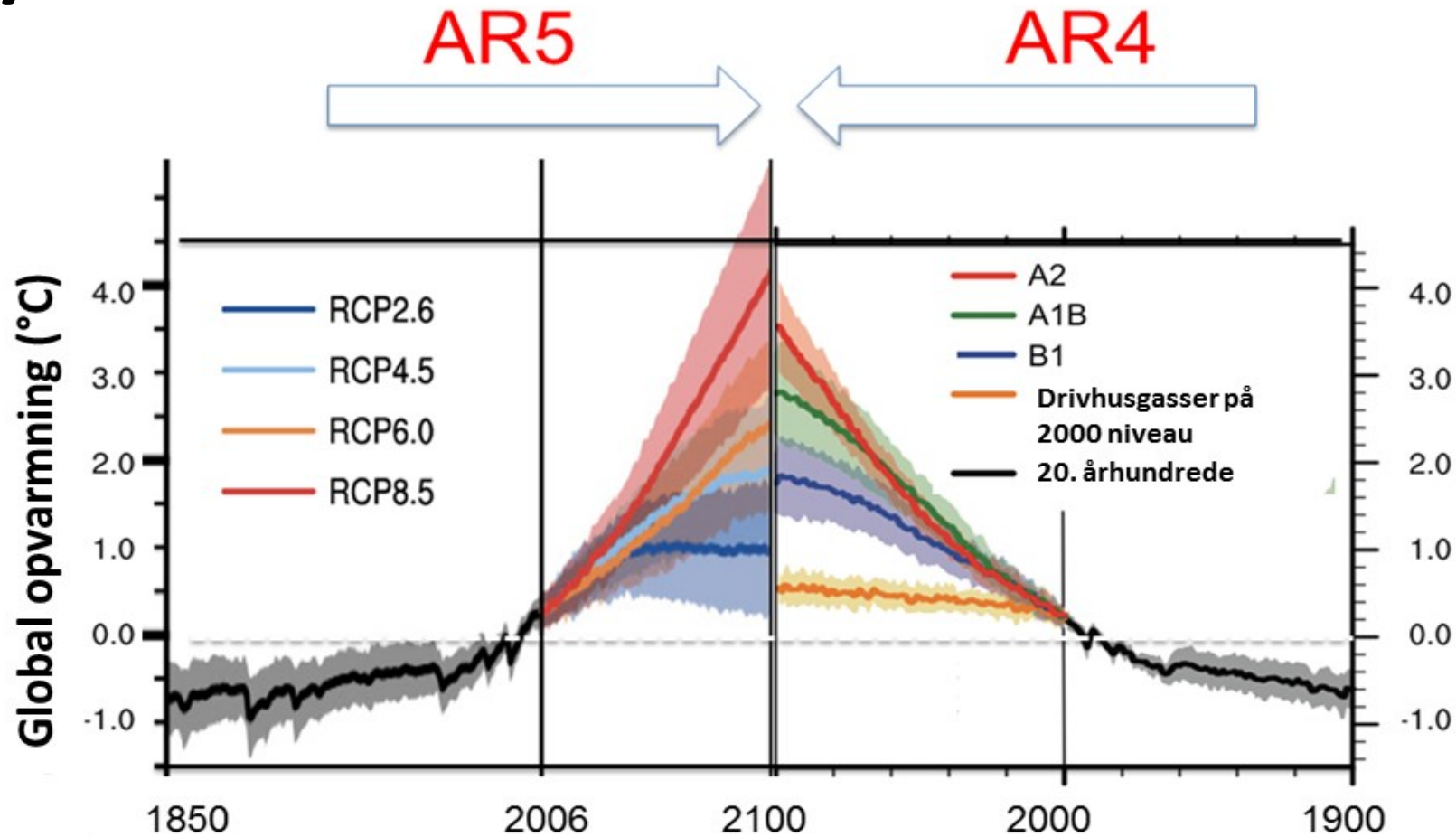
New projections AR5 2071-2100 versus 1981-2010 (RCP 8.5)



New projections AR5 2071-2100 versus 1981-2010 (RCP 4.5)

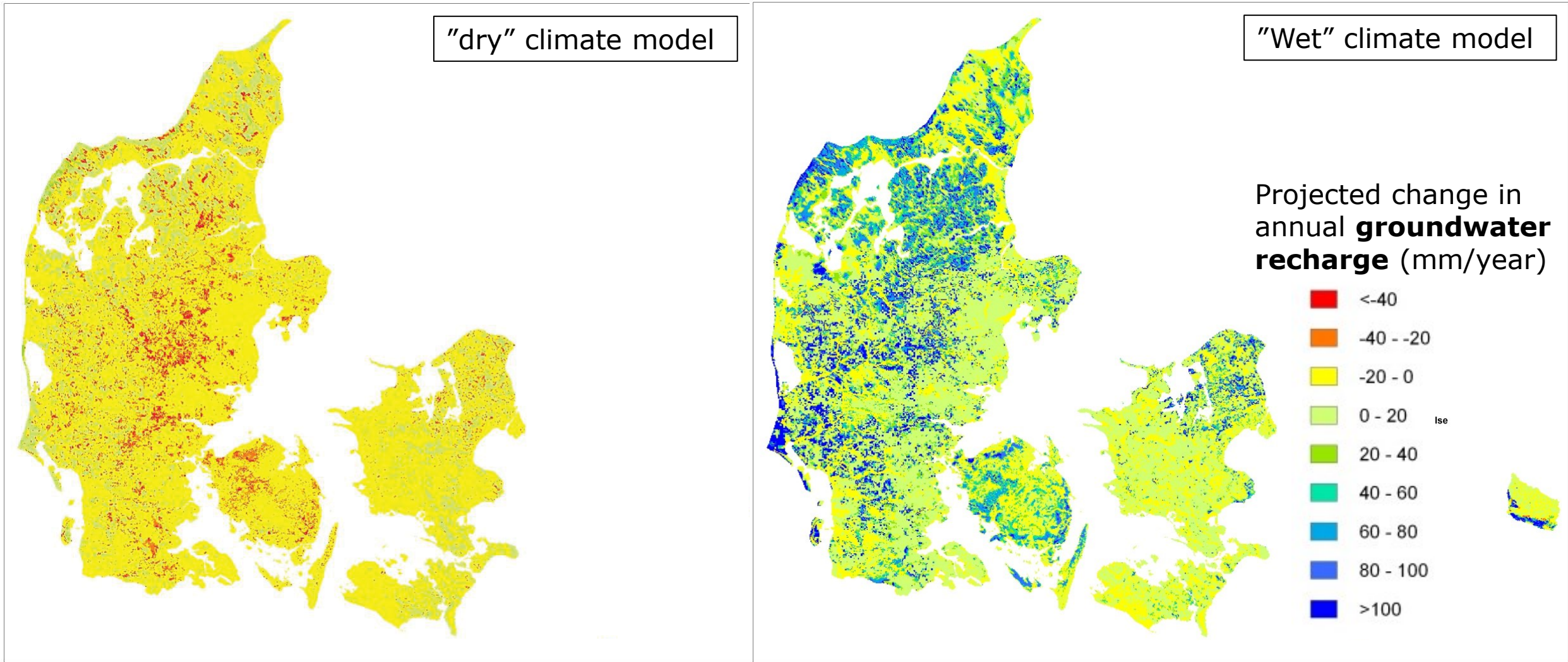


Tidligere eksempler på klimafremskrivning (AR4)



CC impacts on groundwater (Example 2/4)

Change in available groundwater [1961-90] to [2021-50]



Eksempel på fremskrivning klimatilpasning.dk

Våd

Median

Tør klimamodel

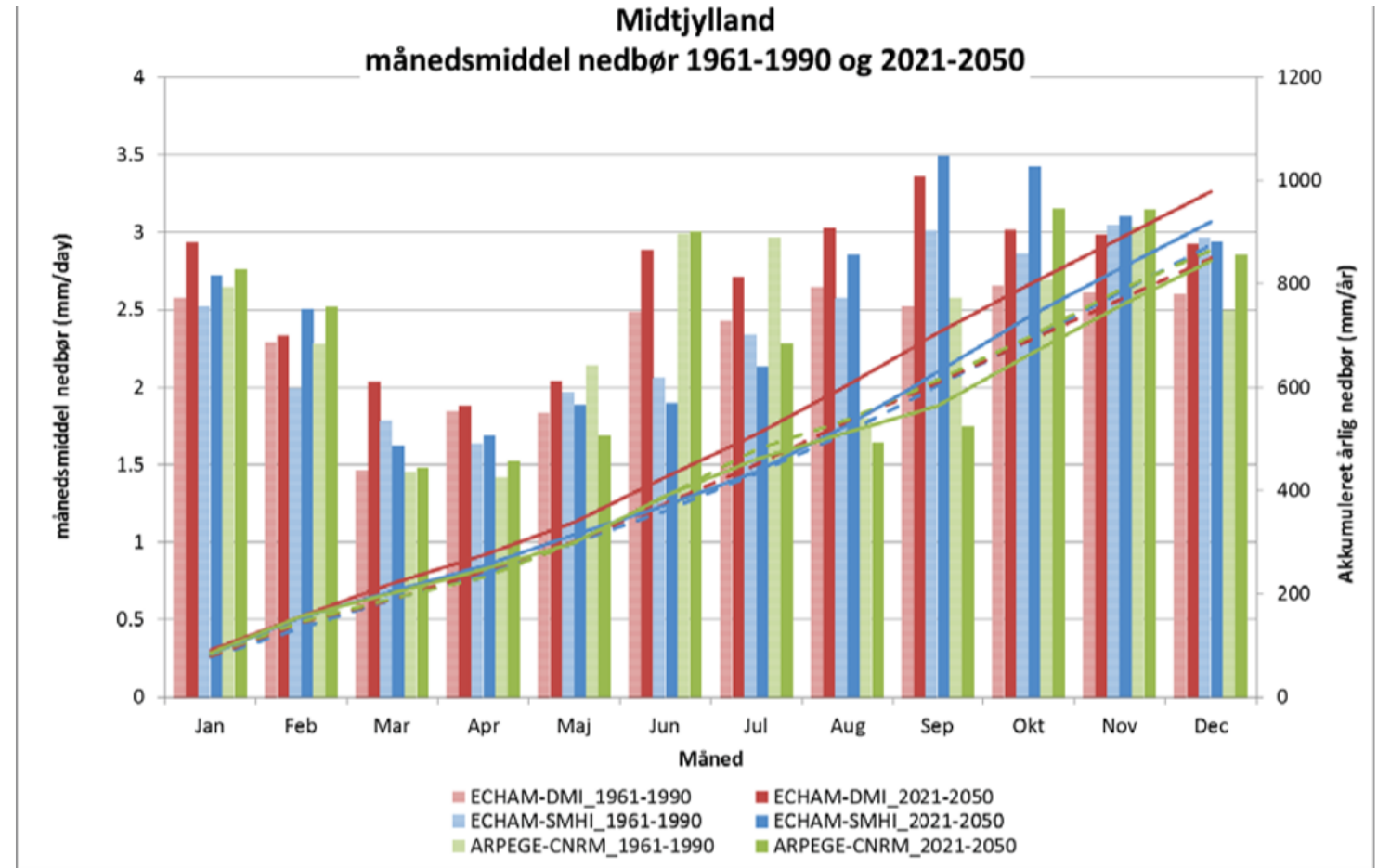
Reference er rimelig ens (1961-1990)

(stiplet kurve akkumuleret for året)

Fremskrivning er meget forskellig

(2021-2050) for våd, median og tør

(vist med optrukket linie akkumuleret)



Figur 4.7 Ændringer i månedsnedbør for de tre udvalgte klimamodeller (ECHAM-DMI, ECHAM-SMHI og ARPEGE_CNRM) for referenceperioden 1961-1990 (tonede søjler) og fremtidsperioden 2021-2050 (udfyldte søjler). Desuden er vist akkumulerede værdier på stiplede kurver (1961-1990) og optrukne linjer (2021-2050).

Ranking af klimamodeller

Sjælland

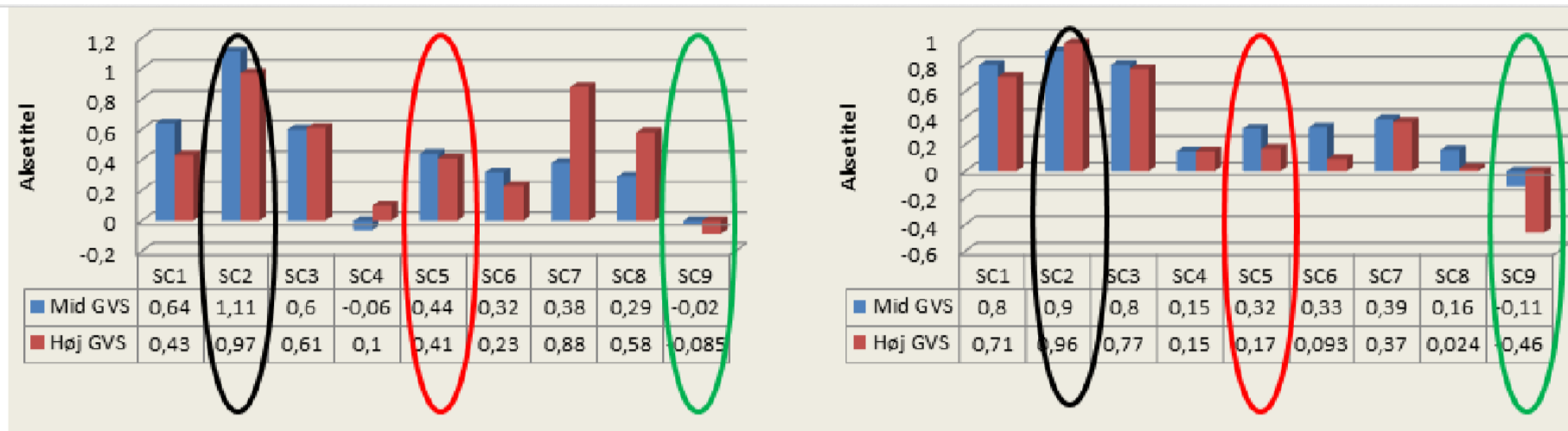
Ringkøbing fjord opland

Fremtid: 2021-2050
Reference: 1961-1990
Biaskorrektion:
1991-2010

VÅD
MEDIAN
TØR

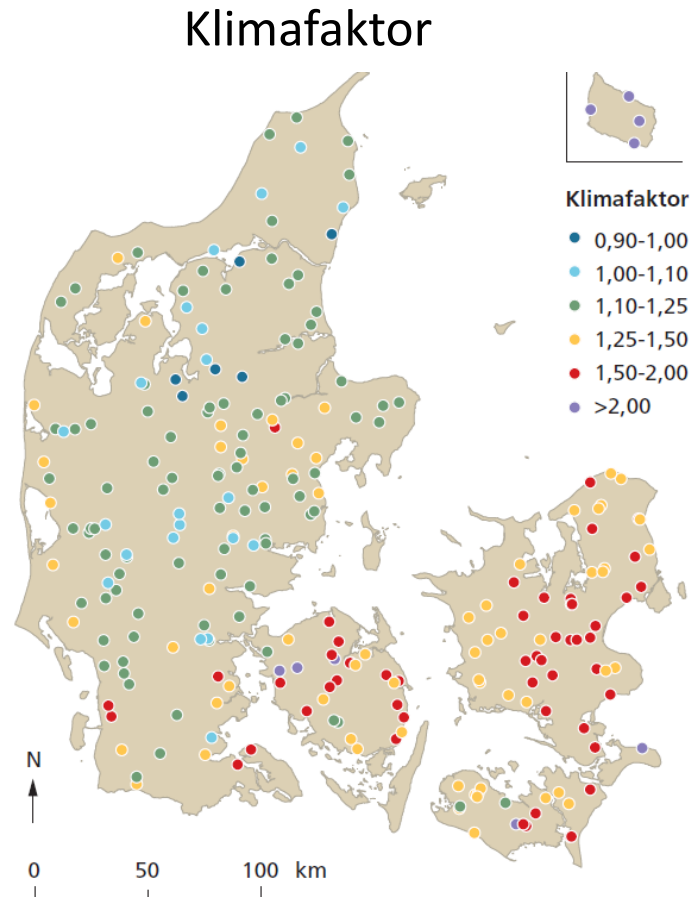
(3/9 klima modeller)

Klimatilpasning.dk

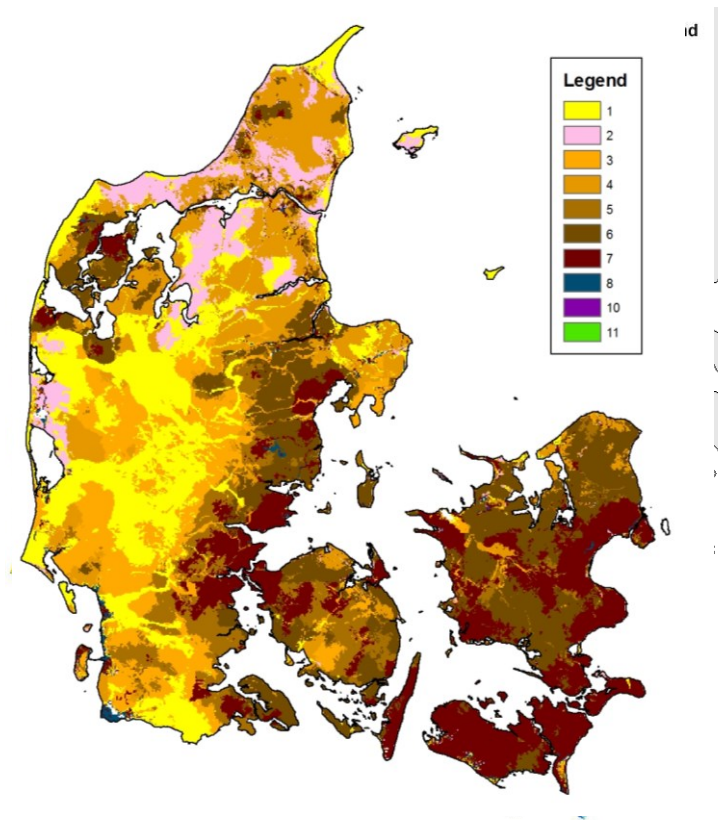


Figur 3.6 Ændringer i middel grundvandsstand (Mid GVS) og karakteristisk høj grundvandsstand (Høj GVS) i gennemsnit (m) for Sjælland (område 1) og Ringkøbing Fjord oplandet (del af område 5). Kombination 2 (SC2-sort: ECHAM-DMI, våd) giver størst stigning. Kombination 5 (SC5-rød: ECHAM-SMHI, median) giver en medianstigning. Kombination 9 (SC9 – grøn: ARPEGE-CRNM) giver mindst stigning i grundvandsstand for begge områder (der ses et begrænset fald i grundvandsstanden for Sjælland og Ringkøbing Fjord med kombination 9, tør). Tilsvarende analyse er gennemført for grundvandsdannelse.

Afstrømning og grundvand



Dybde til grundvand (B) tid



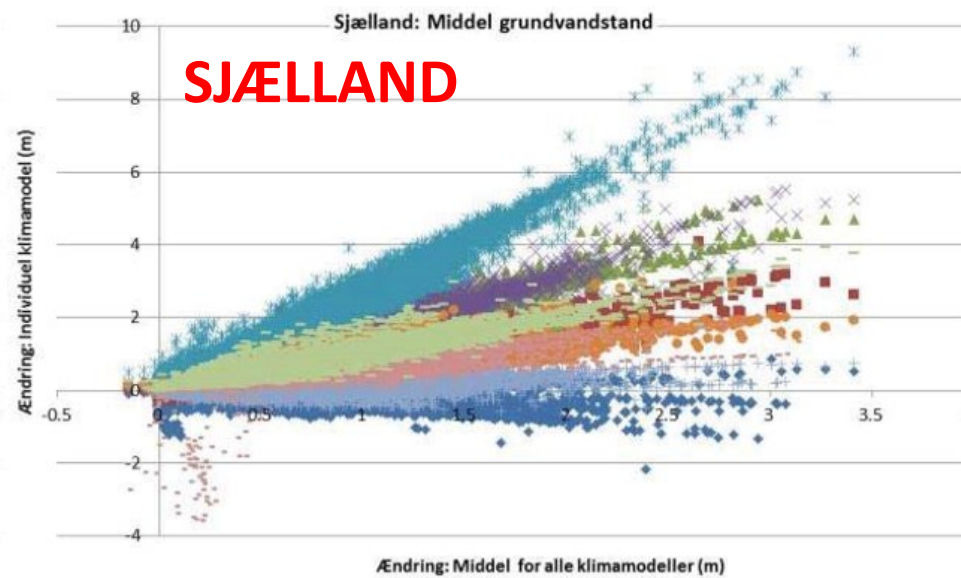
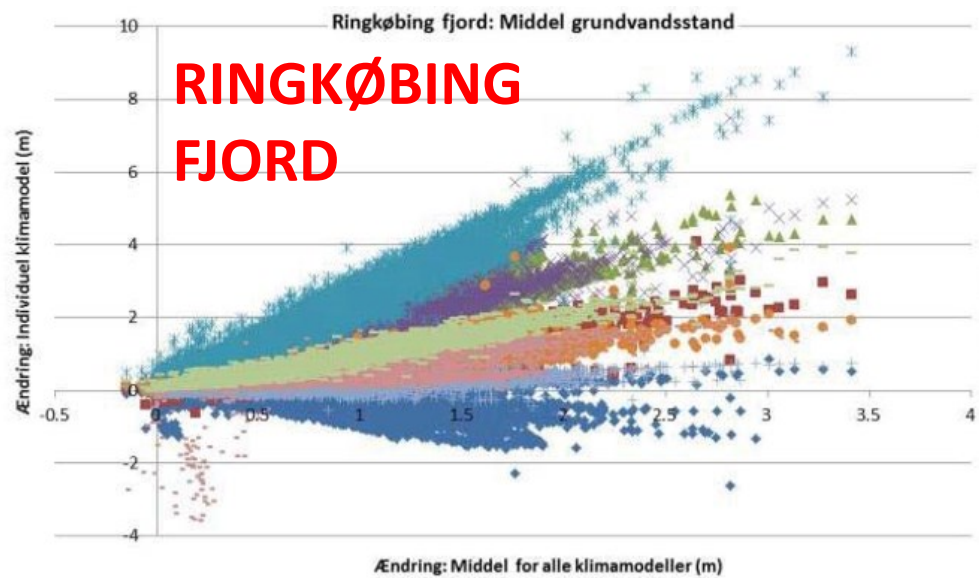
Max afstrømning i vandløb

- Klimafaktor for 100 års hændelse opdelt på områder og periode

Klimafaktor 100 årshændelse	Sjælland	Øerne	Fyn	Syddjylland	Midtjylland	Nordjylland	Bornholm
Hele året	1,55	1,54	1,60	1,24	1,19	1,10	2,98

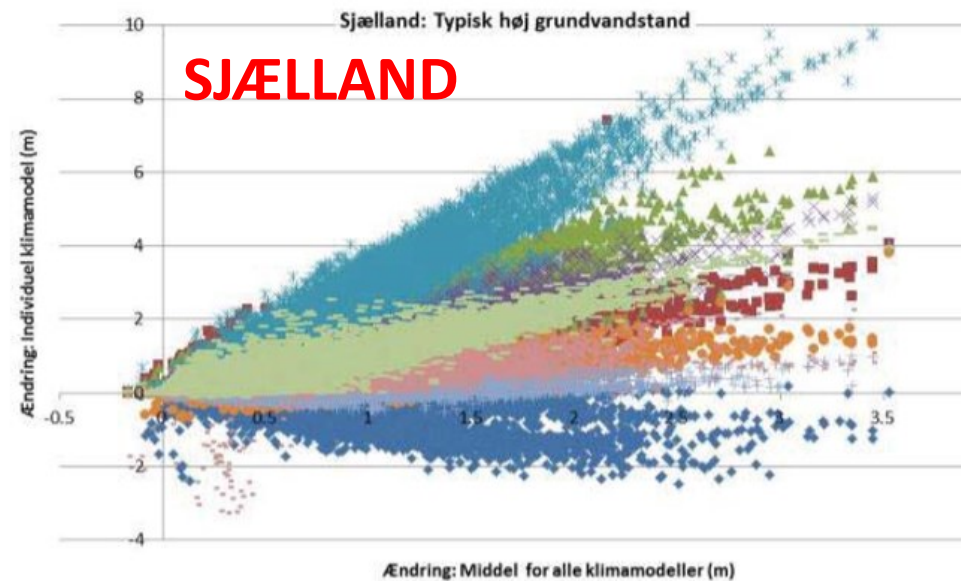
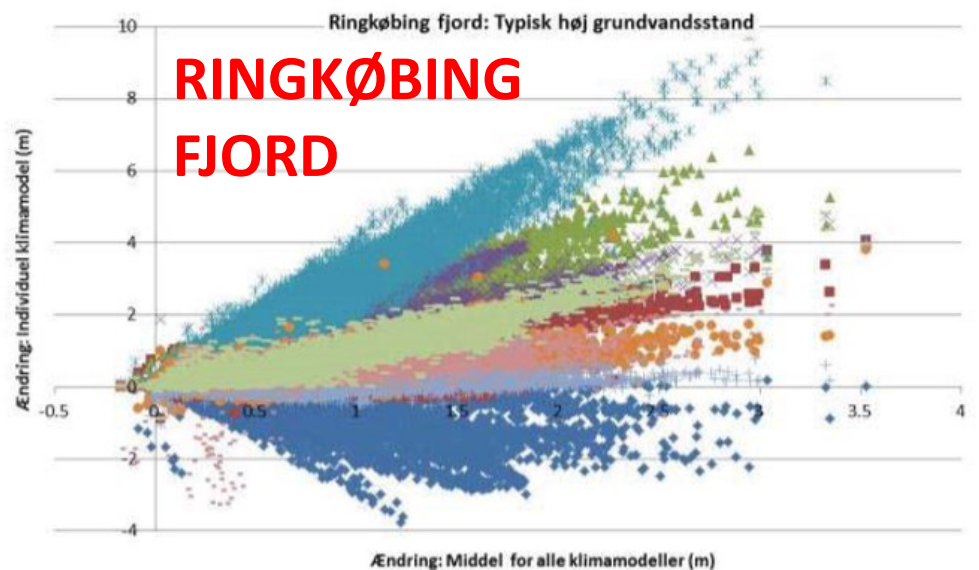
Fremskrivning 2021-2050 versus 1961- 1990

Middel



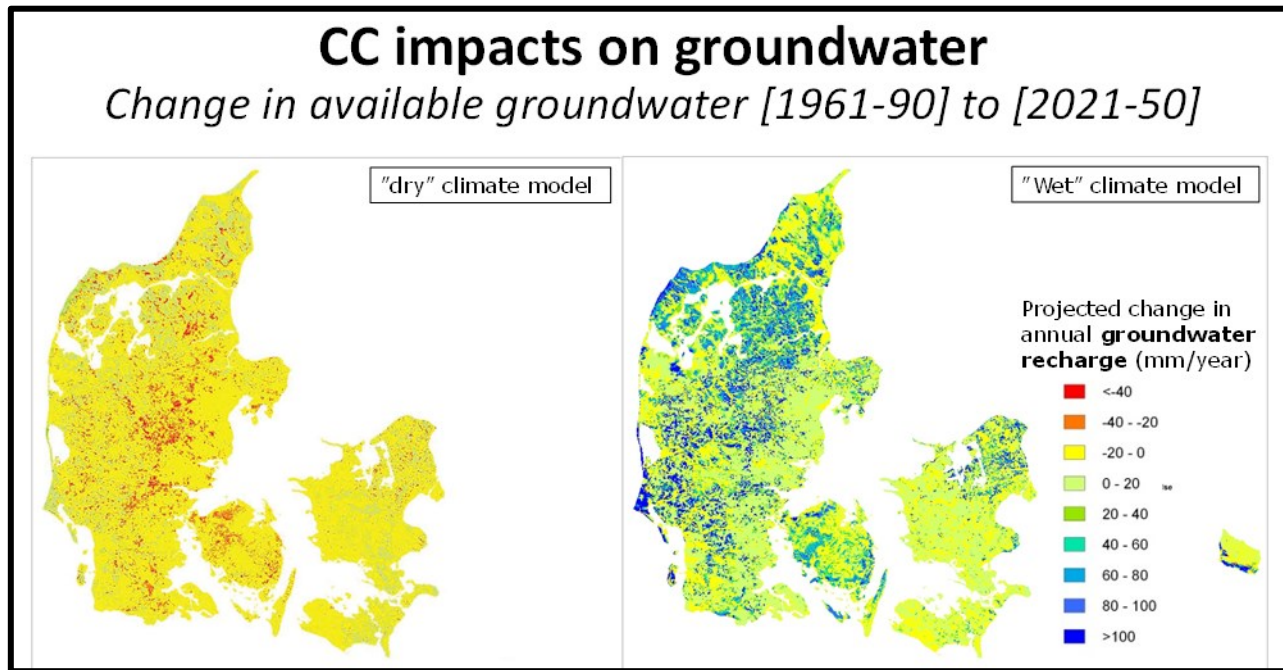
◆ ARPEGE-CNRM ◆ ARPEGE-DMI ▲ BCM-DMI × BCM-SMHI × ECHAM-DMI ● ECHAM-ICTP + ECHAM-KNMI - ECHAM-MPI - ECHAM-SMHI ◆ ARPEGE-CNRM ◆ ARPEGE-DMI ▲ BCM-DMI × BCM-SMHI × ECHAM-DMI ● ECHAM-ICTP + ECHAM-KNMI - ECHAM-MPI - ECHAM-SMHI

Typisk høj grundvands- stand

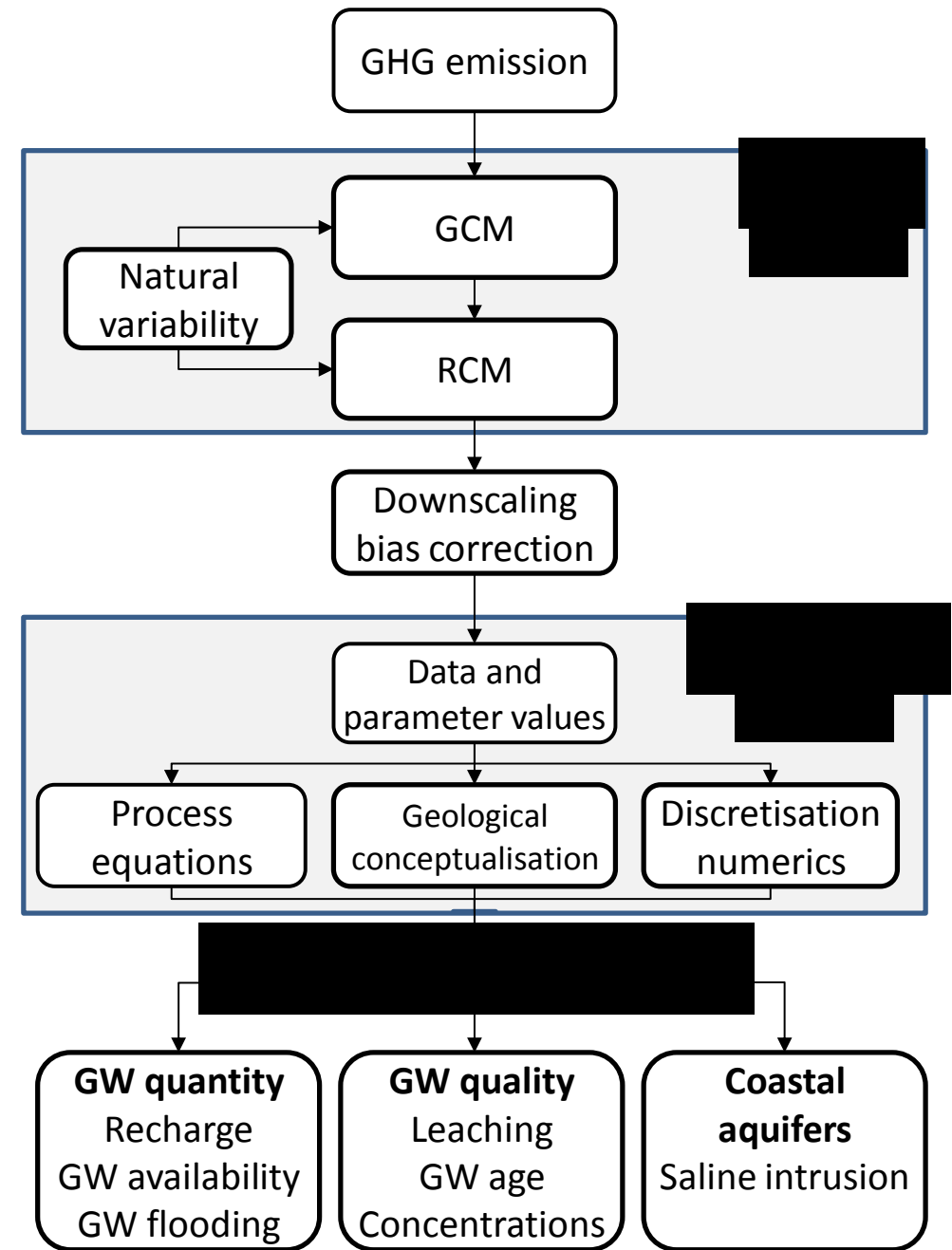


Uncertainties in climate change impact assessments

Uncertainty cascade



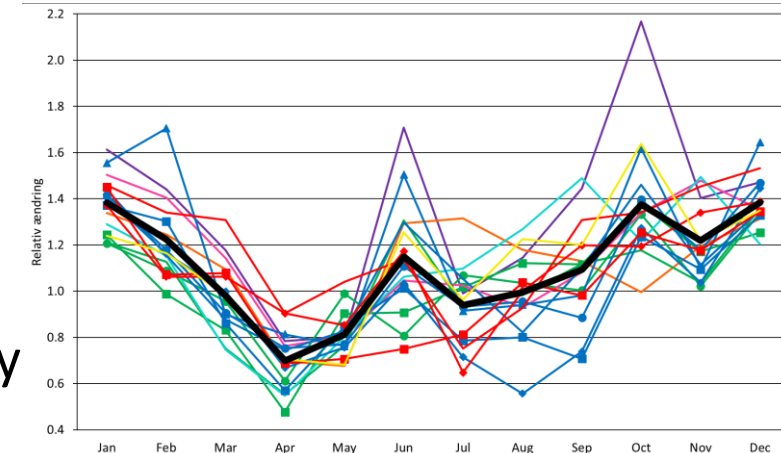
Refsgaard et al. (2016)



Conclusions

Key challenges for groundwater management

- Impacts, e.g.
 - Groundwater flooding
 - Groundwater recharge
 - Groundwater quality
 - Meteorological-Agricultural-Groundwater drought
- Large uncertainties on climate impacts
 - ➔ Uncertainties must be accounted for in water management (e.g. by adaptive management)
 - ➔ Try to reduce uncertainties
 - Improved models and data
 - Discard ensemble model members with low reliability (see e.g. Climate JPI project <http://aquaclew.eu/>)



Pasten-Zapata, E., Sonnenborg T., Refsgaard, J.C. (In Review) Assessing the uncertainty of precipitation and temperature projections for Denmark as basis for evaluating the impacts of climate change on hydrology. Review of Survey activities (RoSa).

