

# Past and Future snow conditions in Europe calculated by the EURO-CORDEX regional climate model ensemble

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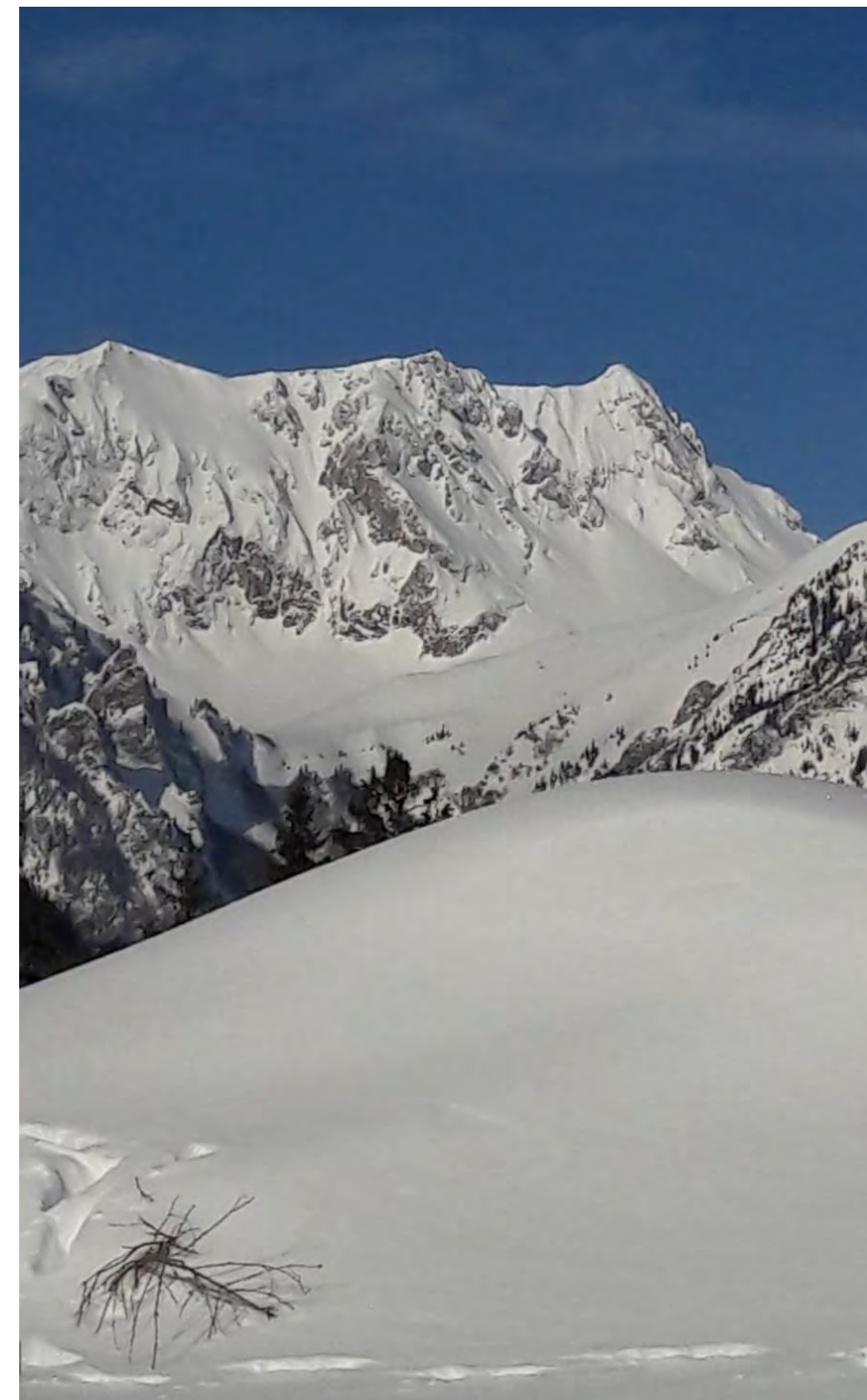
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October 2019

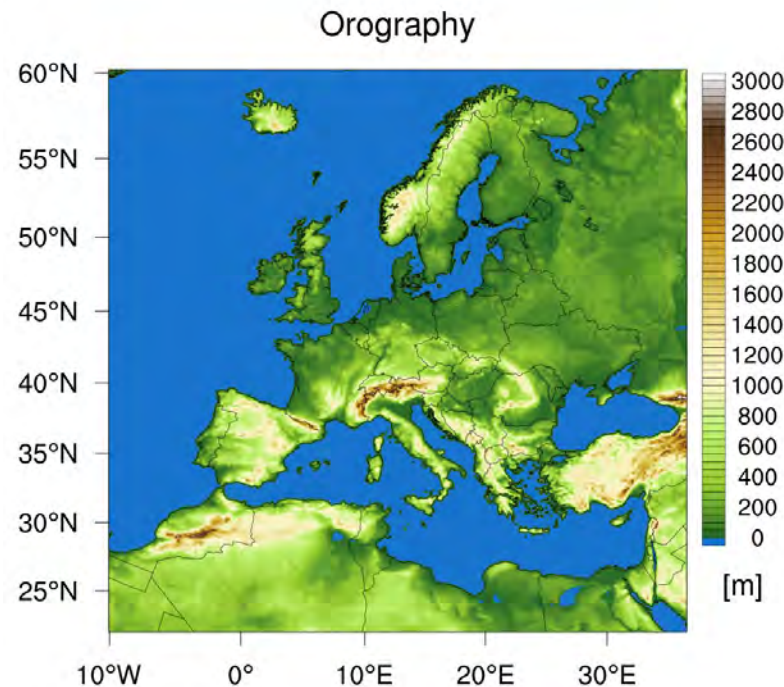
# ■ The future evolution of snow is relevant.....

- Future snow projections are relevant for numerous sectors:
  - Important natural water resource:  
hydropower, water supply ...Water management
  - Agriculture (length of snow cover)
  - Ecology
  - High importance for tourism and recreation in many regions
  - Road maintenance
  - Surface energy balance (e.g. snow-albedo feedback)
- Validierung 1989-2008:  
Assess the ability of state of the art RCMs to reproduce observed snow cover
- Analysis of 21<sup>st</sup> century RCM snow cover projections

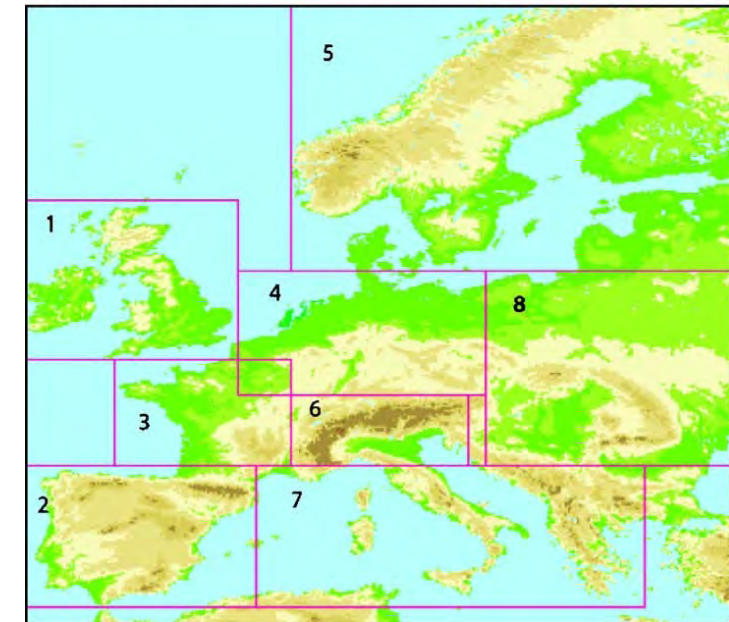


# ■ Simulations, variables and European analysis domain

- **EURO-CORDEX** RCM ensemble at 12 km resolution EUR-11:  
Reanalysis- and GCM-driven simulations
- Variable: **surface snow water equivalent (SWE) and snow depth (SND)**  
(if not available: surface snow depth; conversion by constant density rough estimate of 333 Kg/m<sup>3</sup>)
- Snow cover day has the threshold of 3 cm snow depth
- **European analysis domain** with focus on **Scandinavia** and **Alps**



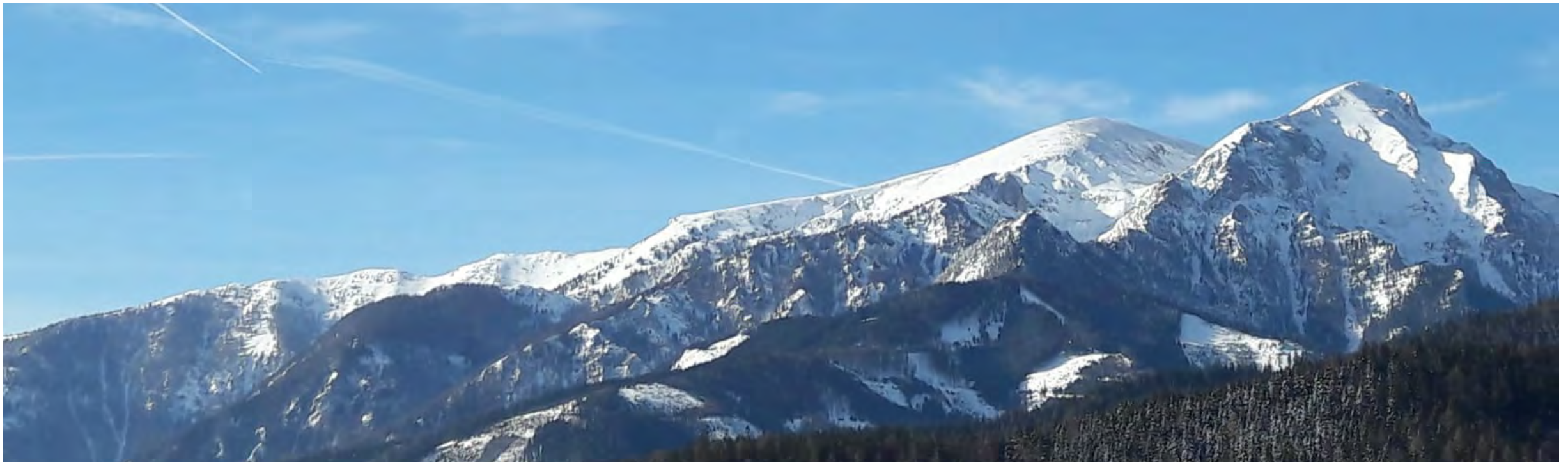
Area	West	East	South	North
1 (BI) British Isles	-10	2	50	59
2 (IP) Iberian Peninsula	-10	3	36	44
3 (FR) France	-5	5	44	50
4 (ME) Mid-Europe	2	16	48	55
5 (SC) Scandinavia	5	30	55	70
6 (AL) Alps	5	15	44	48
7 (MD) Mediterranean	3	25	36	44
8 (EA) Eastern Europe	16	30	44	55





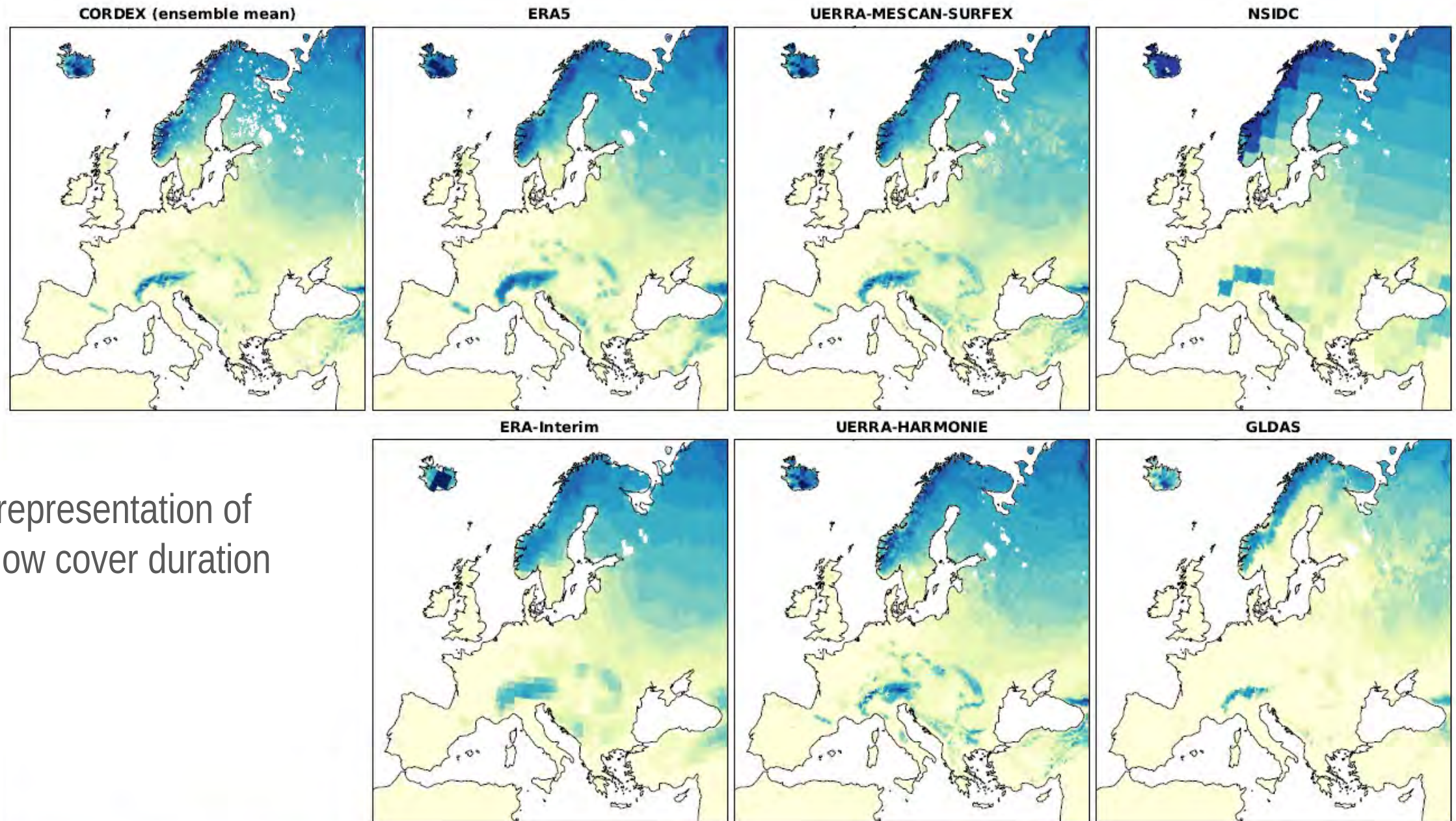
# ■ Evaluation

- **10 ERA-Interim driven EURO-CORDEX RCMs:**  
ALADIN, CLM, HIRHAM, RACMO, RCA4, RegCM, REMO, WRF
- **Datasets:** ERA5, GLDAS, UERRA-MESCAN, NSIDC

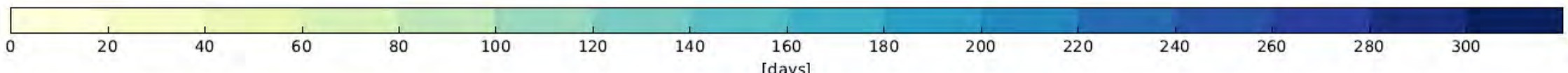




# Mean snow cover duration 1989 - 2008

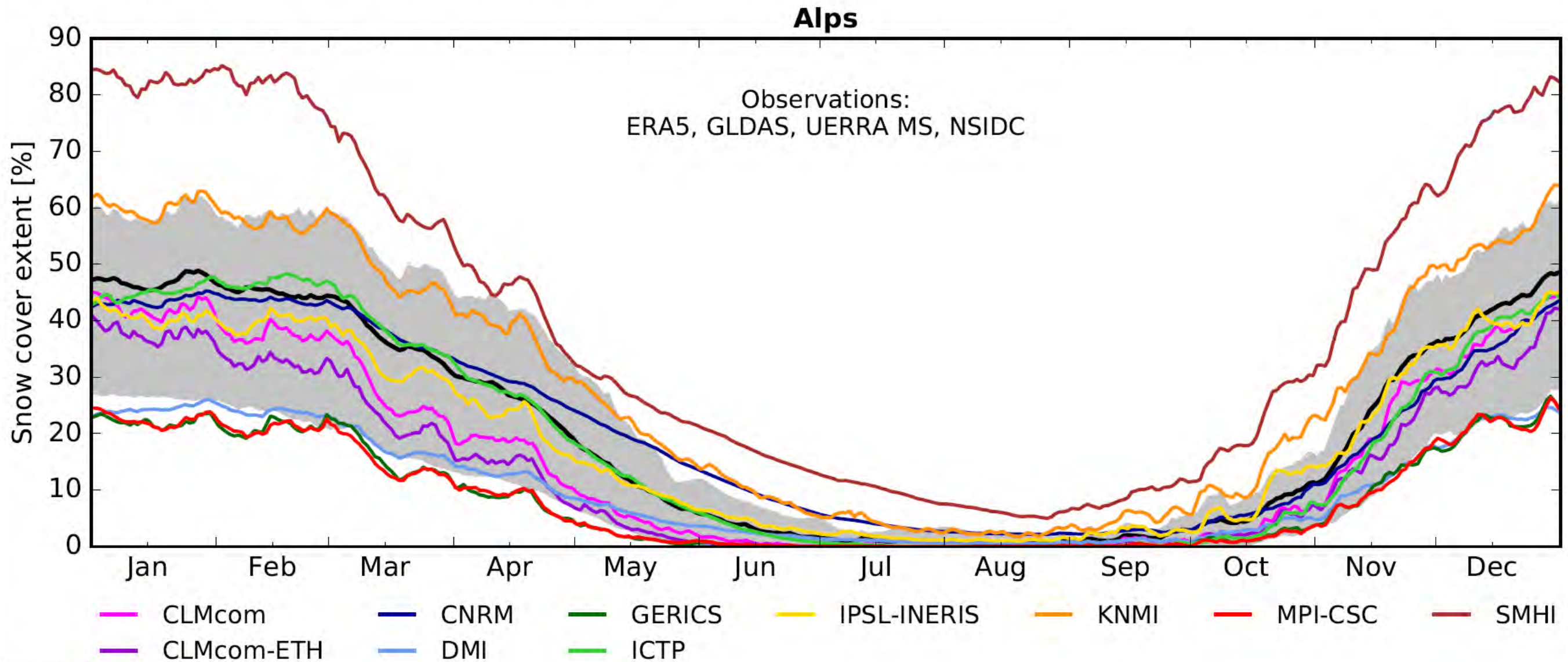


- Differences in representation of present day snow cover duration

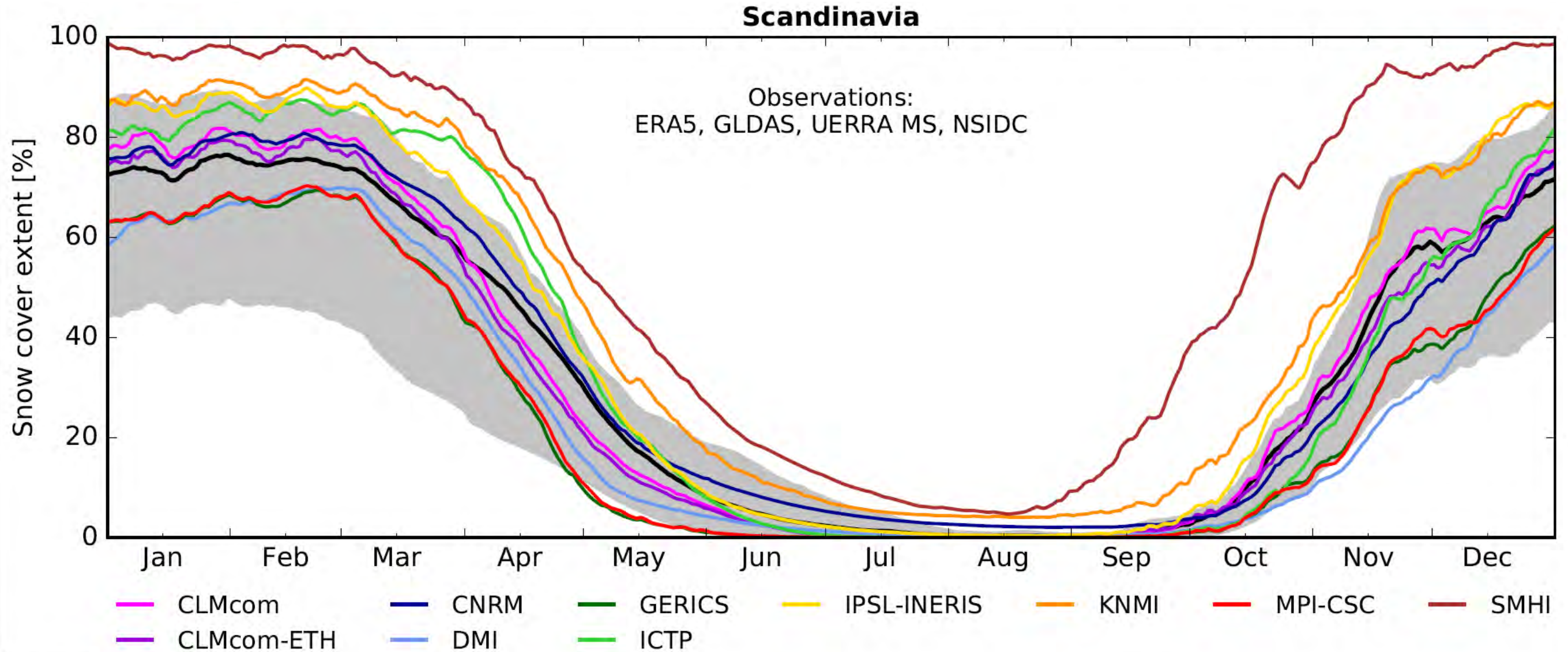




## Alps: Snow cover extent [%] 1998 -2008

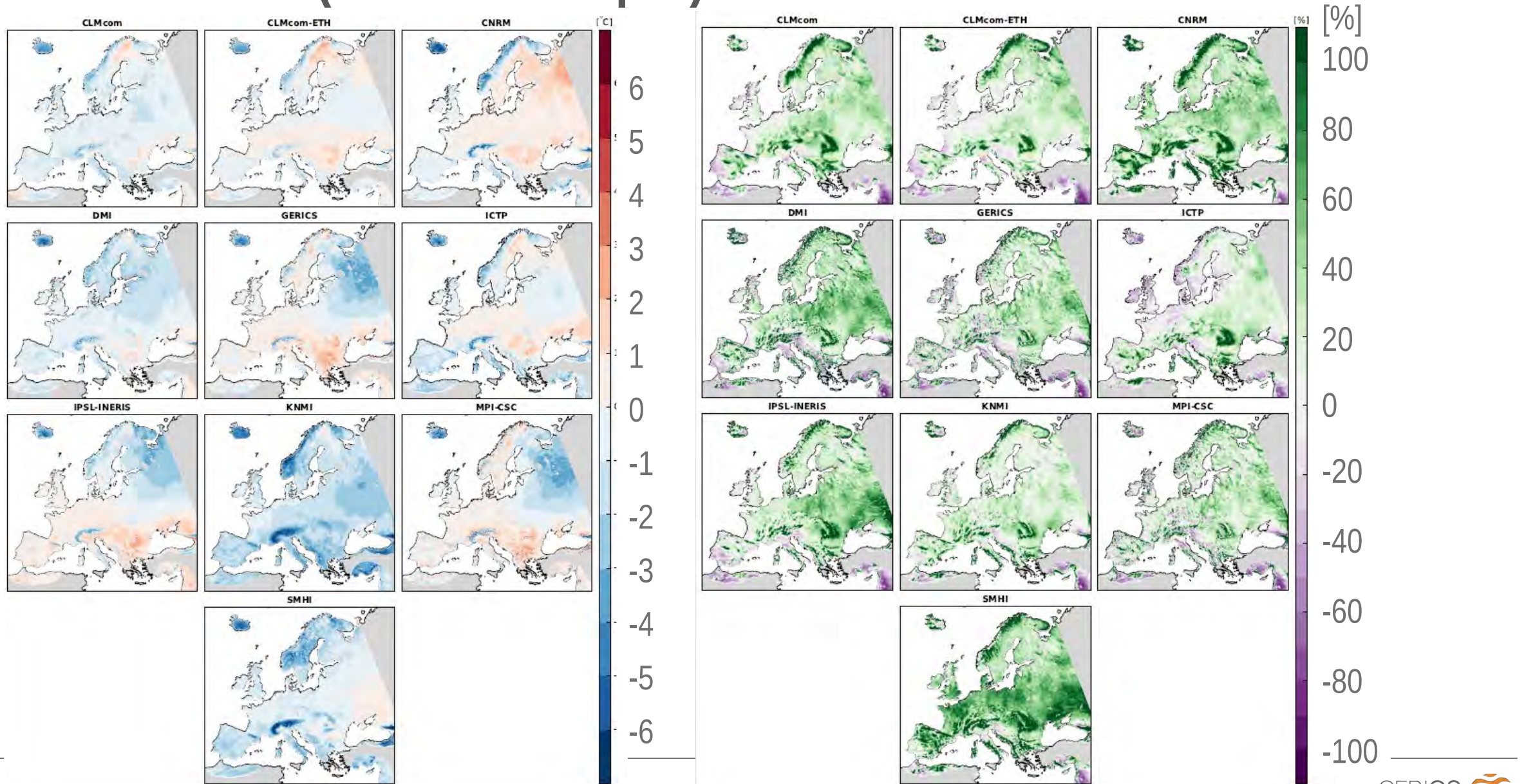


# ■ Scandinavia: Snow cover extent [%] 1998 -2008



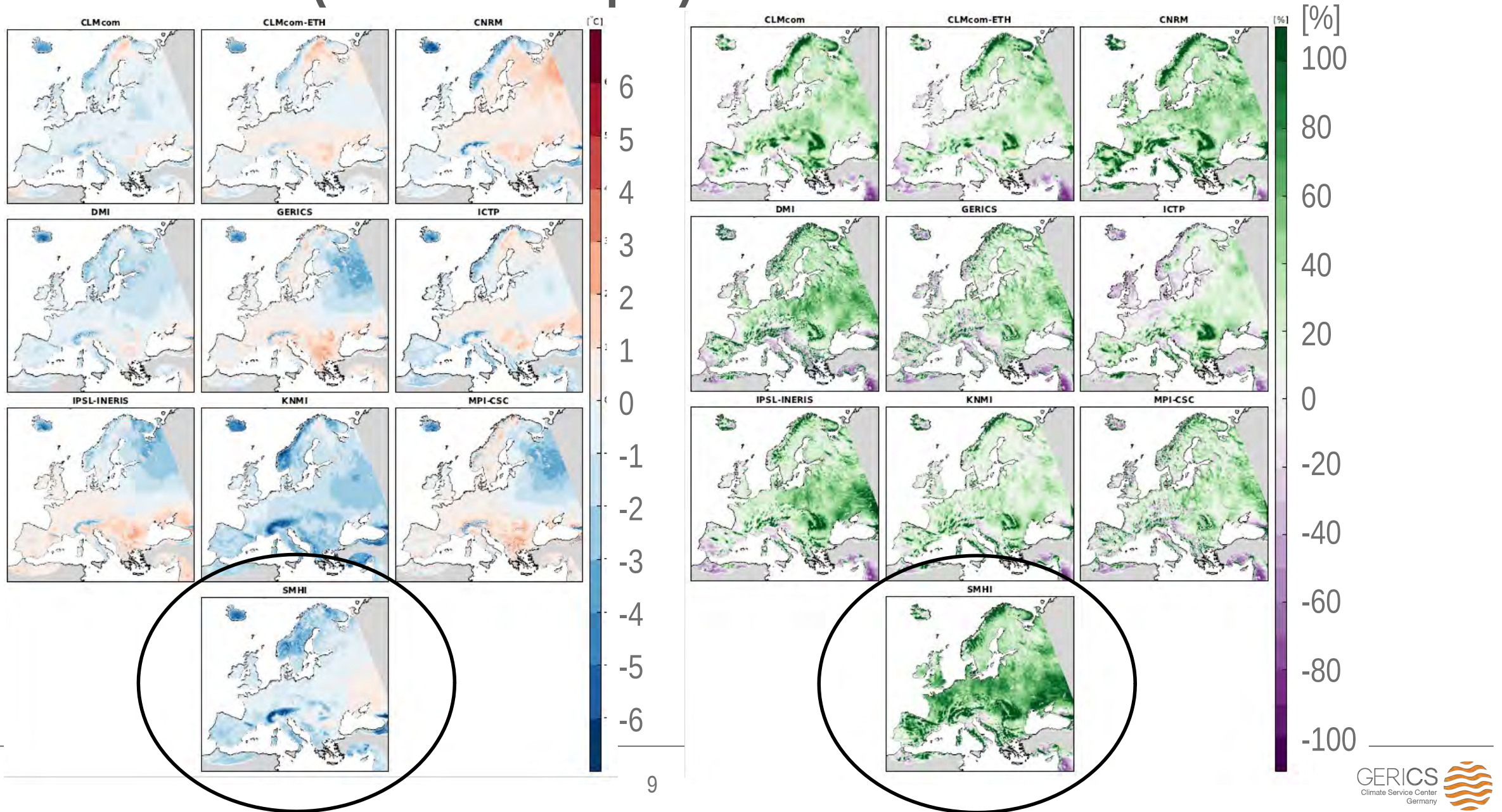


# 1989-2008 Temperature and precipitation bias of individual RCMs compared to EOBS (November-April)



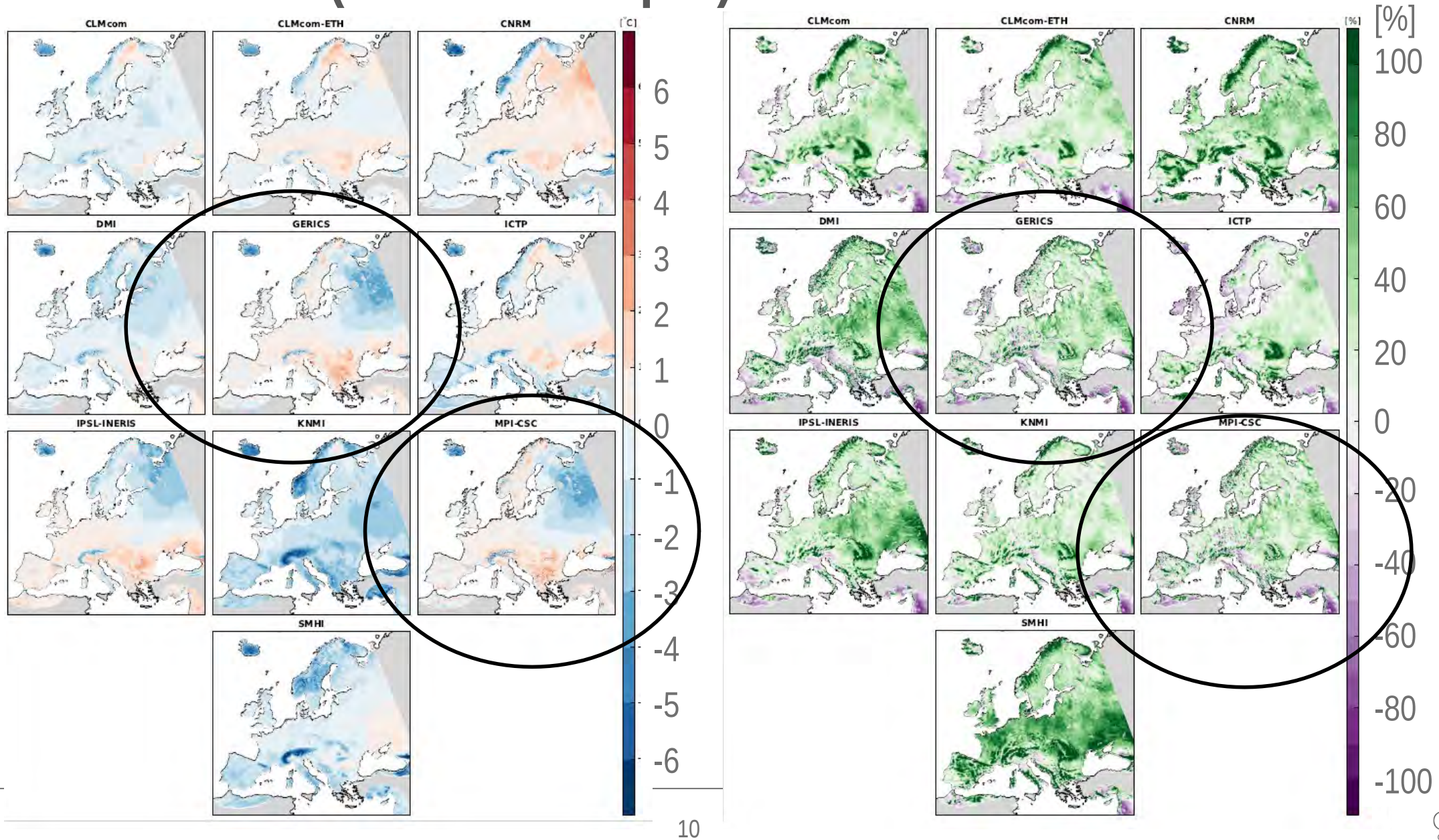


# 1989-2008 Temperature and precipitation bias of individual RCMs compared to EOBS (November-April)





# 1989-2008 Temperature and precipitation bias of individual RCMs compared to EOBS (November-April)





# ■ Climate Scenario Simulations



# Climate scenario simulations

RCM

9

GCM

12

GCM/RCM (realisation)	RCA	CLM	REMO	RACMO	HIRAM	Aladin63	RegCM
CanESM2 (r1)	, ,	, , X	, , X	, ,	, ,	, ,	, ,
CNRM-CM5 (r1)	, ,	, ,	, ,	X, , X	, , X	, , X	, ,
GFDL-ESM2G (r1)	, ,	, ,	X, ,	, ,	, ,	, ,	, ,
HadGEM2-ES (r1)	X,X,X	,X,X	X, , X	X,X,X	, , X	, ,	, ,
EC-EARTH (r1)	, ,	, ,	, ,	,X,X	, , X	, ,	, ,
EC-EARTH (r3)	, , X	, ,	, ,	, , X	X,X,X	, ,	, ,
EC-EARTH (r12)	X,X,X	X,X,X	X, , X	X,X,X	, , X	, ,	, ,
MIROC5 (r1)	, ,	X, , X	X, , X	, ,	, ,	, ,	, ,
MPI-ESM-LR (r1)	X,X,X	X,X,X	X,X,X	, ,	, ,	, ,	, ,
MPI-ESM-LR (r2)	, ,	, ,	X,X,X	, ,	, ,	, ,	, ,
MPI-ESM-LR (r3)	, ,	, ,	, , X	, ,	, ,	, ,	, ,
NorESM (r1)	X, , X	, ,	X, , X	, , X	,X,X	, ,	, ,
IPSL-CM5A-MR (r1)	,X,X	, ,	, ,	, ,	, ,	, ,	, ,
IPSL-CM5A-LR (r1)	, ,	, ,	X, ,	, ,	, ,	, ,	, ,



# Climate scenario simulations

RCM

9

GCM	GCM/RCM (realisation)	RCA	CLM	REMO	RACMO	HIRAM	Aladin63	RegCM
12	CanESM2 (r1)	/ /	/ / X	/ / X	/ /	/ /	/ /	/ /
	CNRM-CM5 (r1)	/ /	/ /	/ /	X / X	/ / X	/ / X	/ /
	GFDL-ESM2G (r1)	/ /	/ /	X /	/ /	/ /	/ /	/ /
	HadGEM2-ES (r1)	X,X,X	/X,X	X / X	X,X,X	/ / X	/ /	/ /
	EC-EARTH (r1)	/ /	/ /	/ /	X,X	/ X	/ /	/ /
	EC-EARTH (r2)	/ / X	/ /	/ /	/ /	/ /	/ /	/ /
	EC-EARTH (r1)	/ / X	/ /	/ /	X /	/ /	/ /	/ /
	MIROC5 (r1)	/ /	/ /	/ /	/ /	/ /	/ /	/ /
	MPI-ESM-LR (r1)	X,X,X	X,X,X	X,X,X	/ /	/ /	/ /	/ /
	MPI-ESM-LR (r2)	/ /	/ /	/ /	/ /	/ /	/ /	/ /
	MPI-ESM-LR (r1)	/ /	/ /	/ /	/ /	/ /	/ /	/ /
	NorESM (r1)	X / X	/ /	/ /	/ / X	/ /	/ /	/ /
IPSL-CM5A-MR (r1)	/ / X	/ /	/ /	/ /	/ /	/ /	/ /	
IPSL-CM5A-LR (r1)	/ /	/ /	/ /	/ /	/ /	/ /	/ /	

rcp26

rcp45

rcp85

18

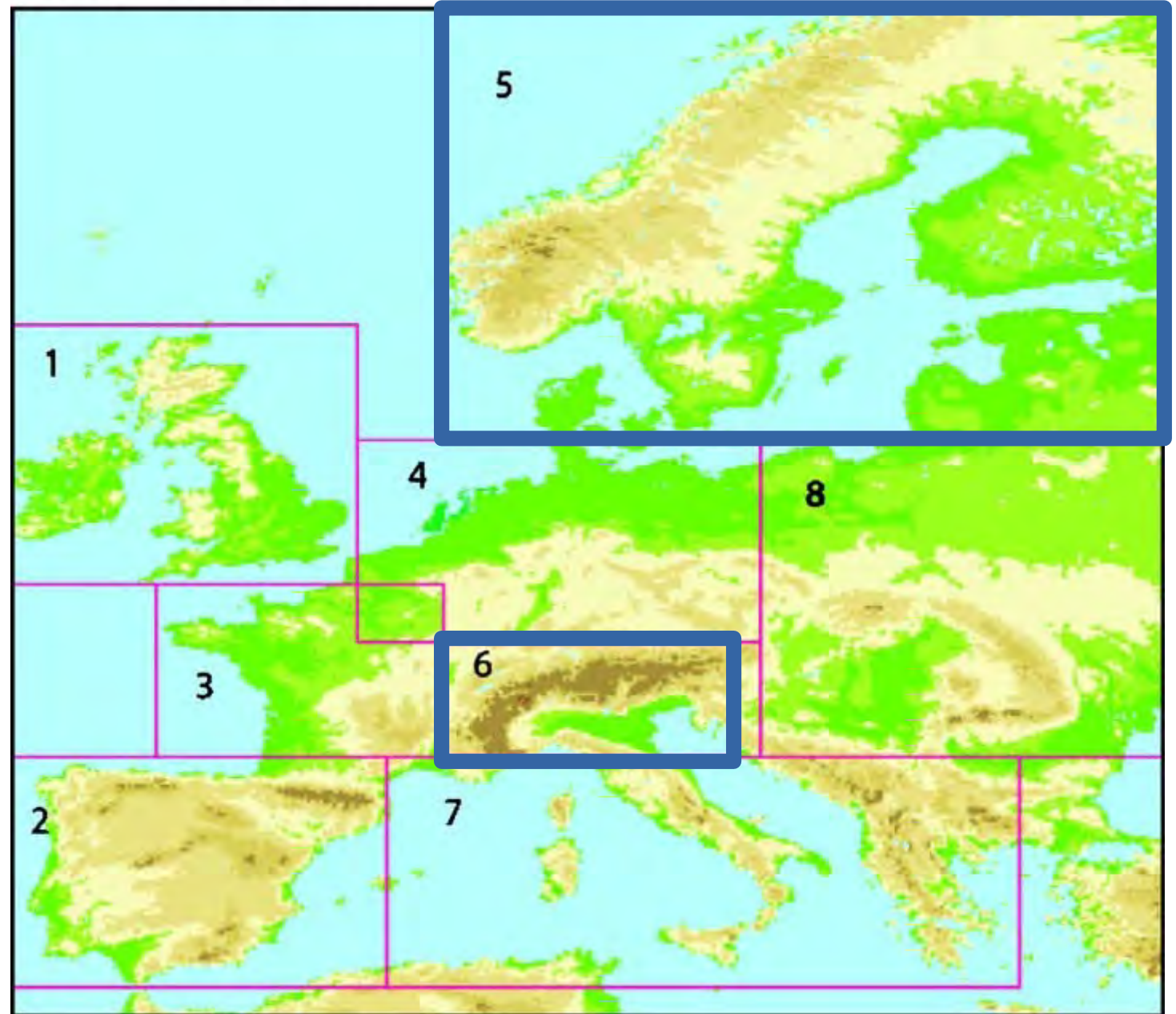
12

31

# Study Focus Regions

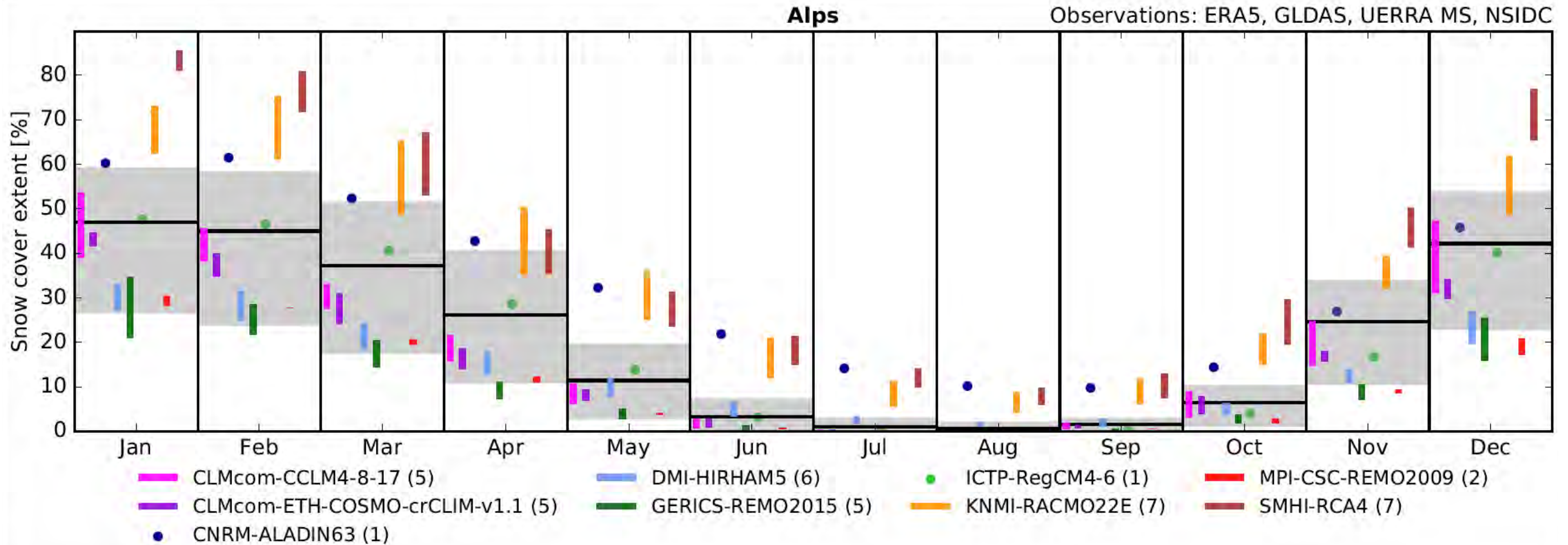
Scandinavia

Alps

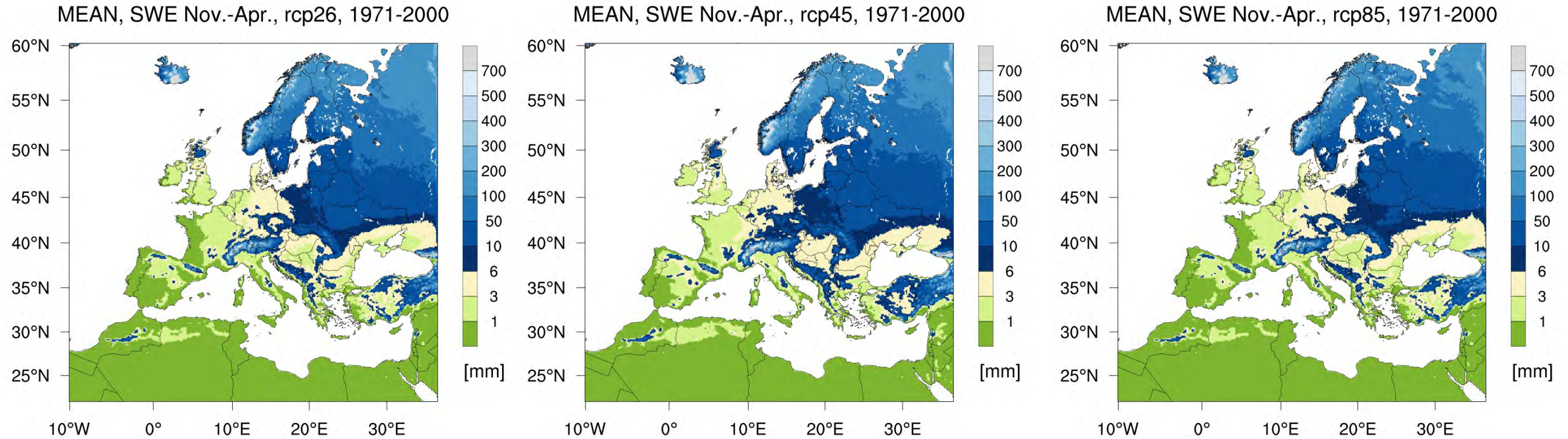




# ■ Alps: Historical snow cover extent [%] 1989-2008 (snow day=3 cm snd)



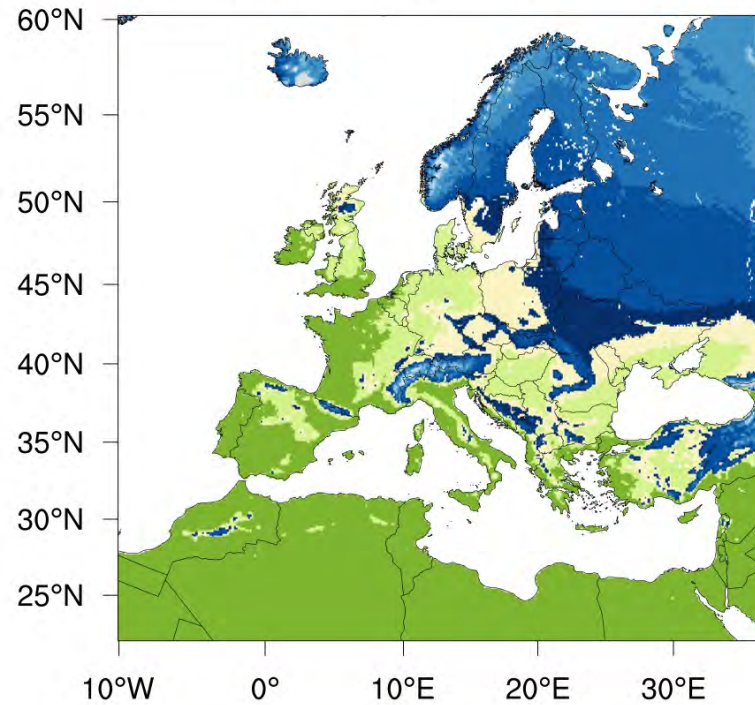
# ■ Snow water equivalent [mm] 1971-2000 (November-April)



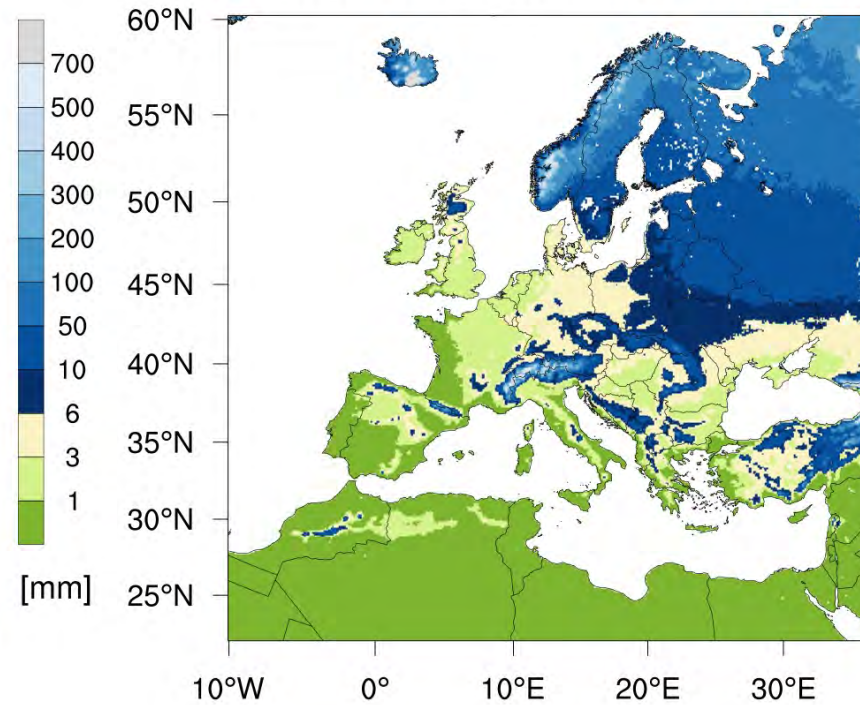


# ■ Snow water equivalent [mm] 2021-2050 (November-April)

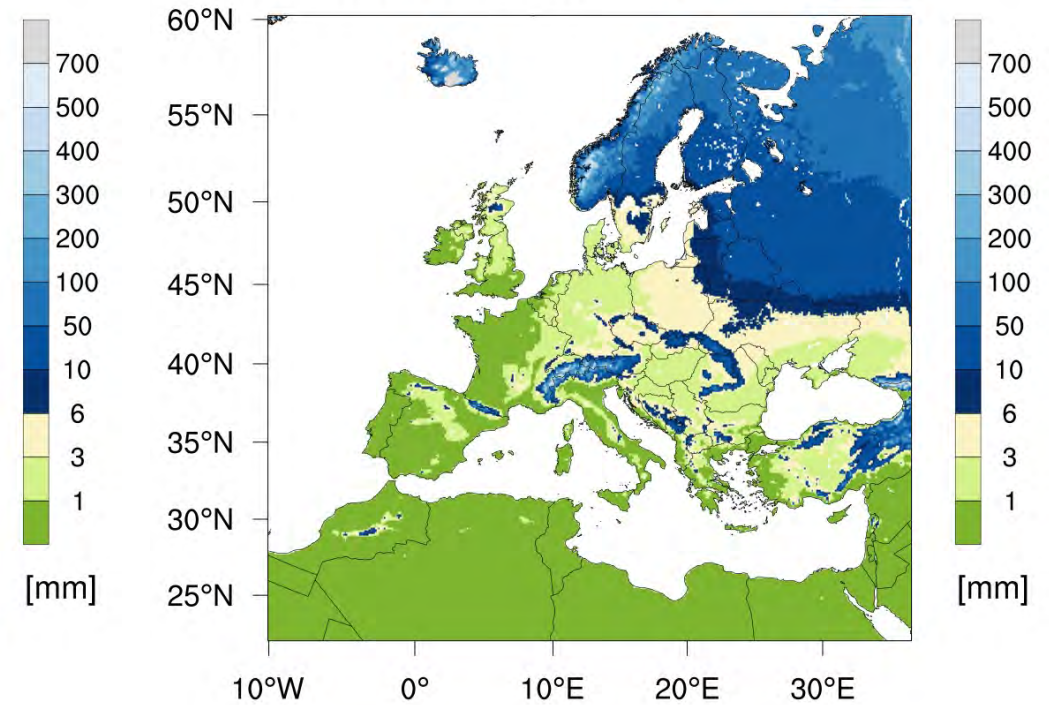
MEAN, SWE Nov.-Apr., rcp26, 2021-2050



MEAN, SWE Nov.-Apr., rcp45, 2021-2050

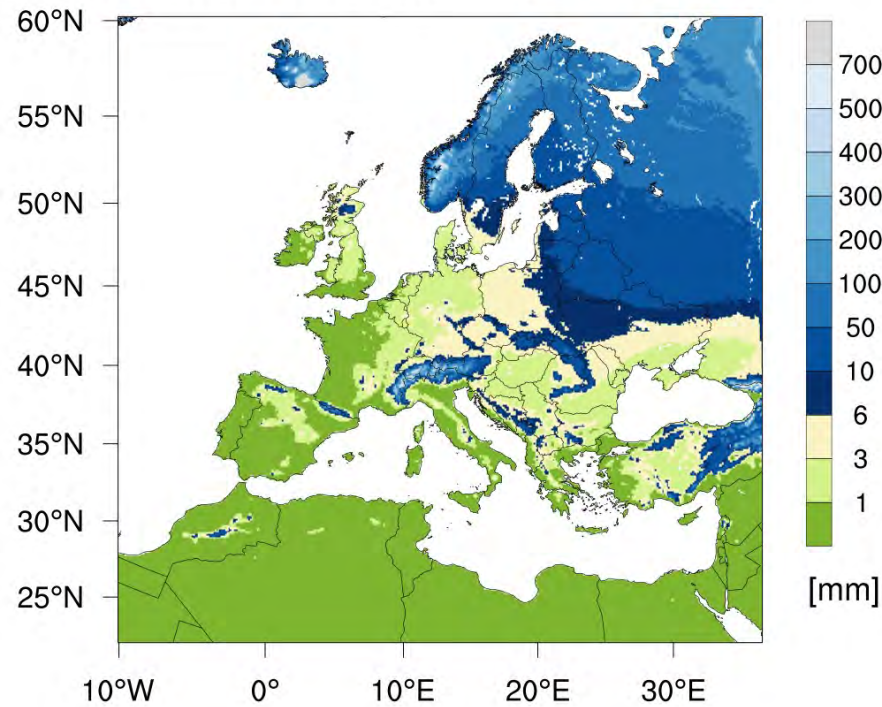


MEAN, SWE Nov.-Apr., rcp85, 2021-2050

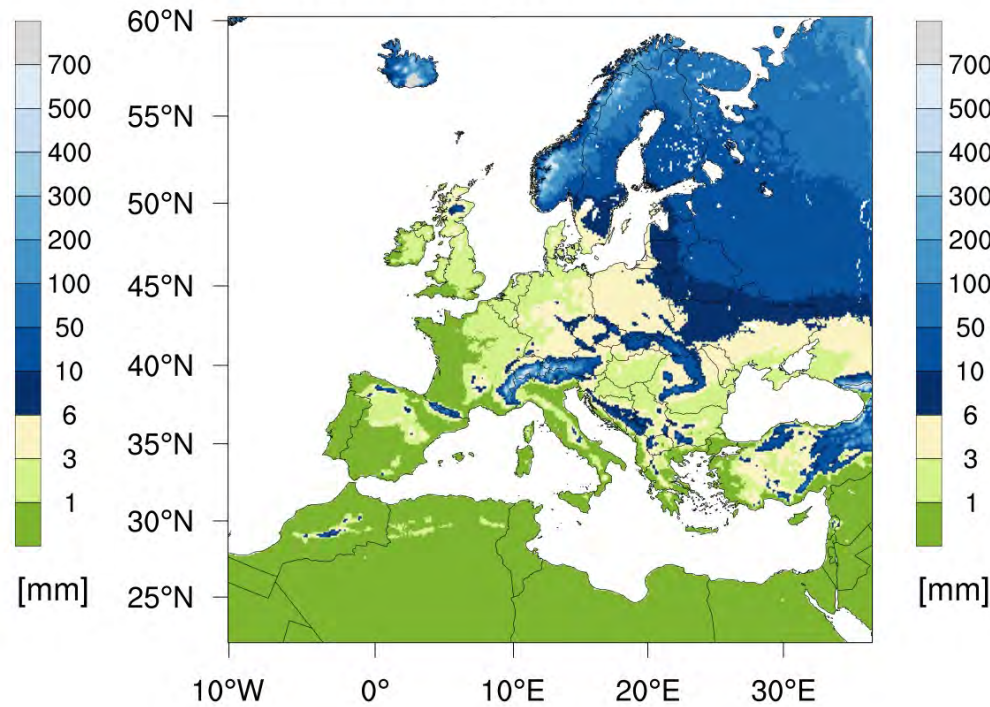


# ■ Snow water equivalent [mm] 2070-2099 (November-April)

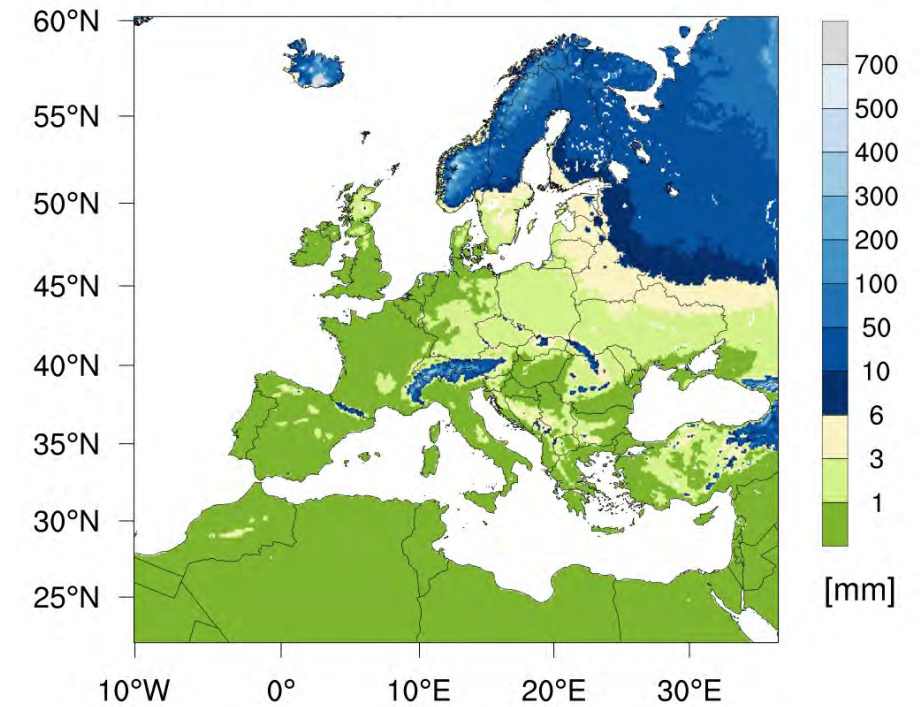
MEAN, SWE Nov.-Apr., rcp26, 2070-2099



MEAN, SWE Nov.-Apr., rcp45, 2070-2099



MEAN, SWE Nov.-Apr., rcp85, 2070-2099





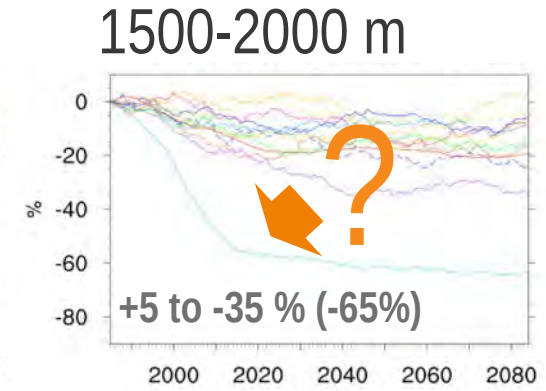
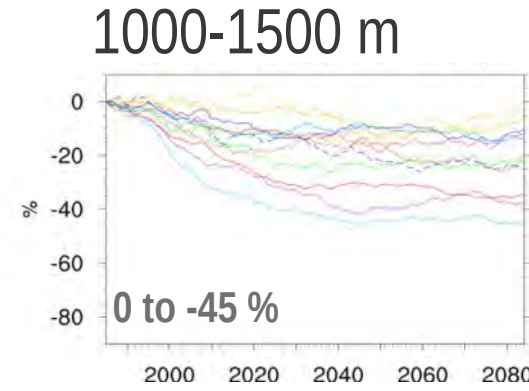
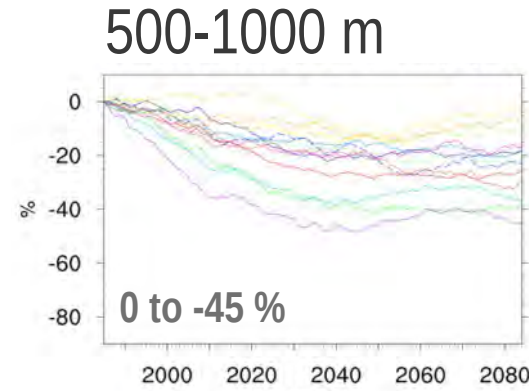
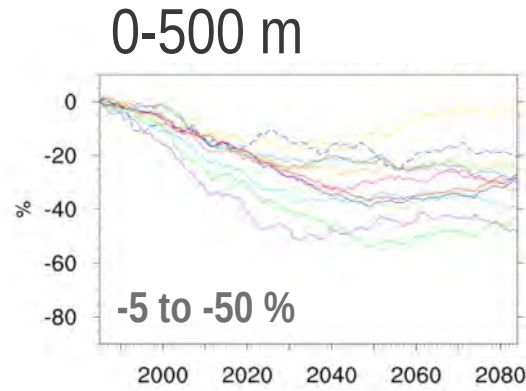
# ■ Snow water equivalent: relative change to 1971-2000 [%]

Scandinavia, 30-year running mean

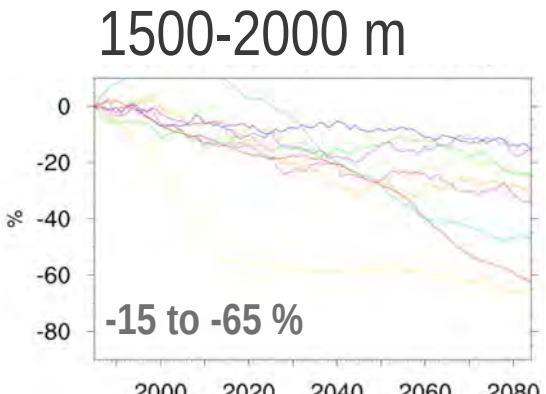
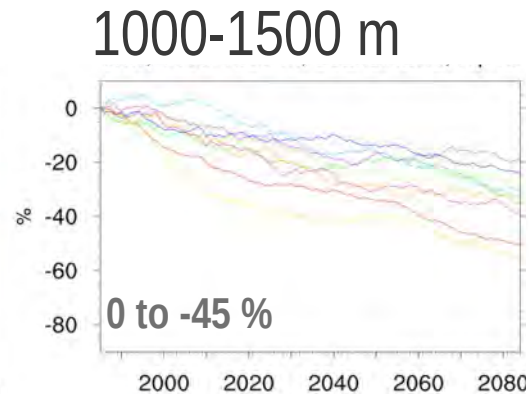
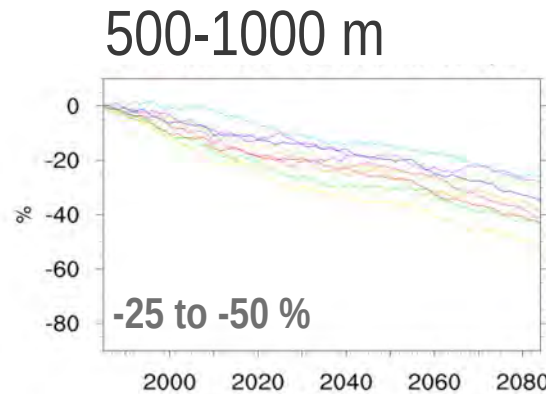
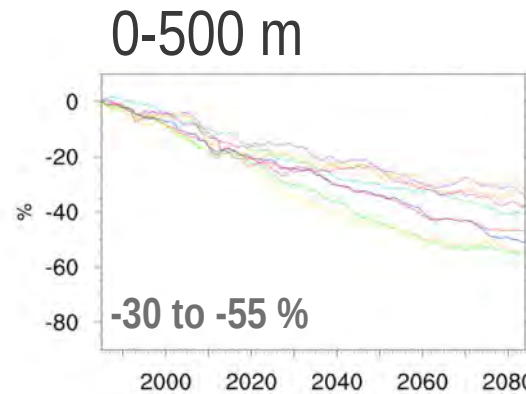
numbers:

Relative change by 2070-2099

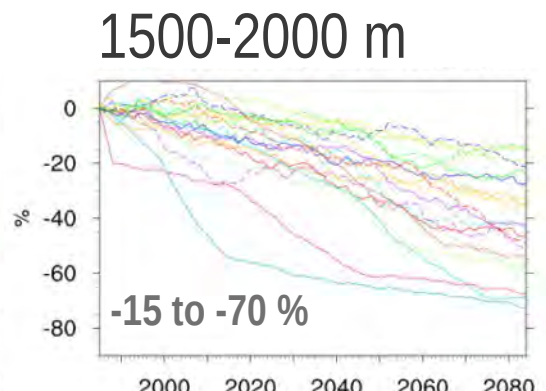
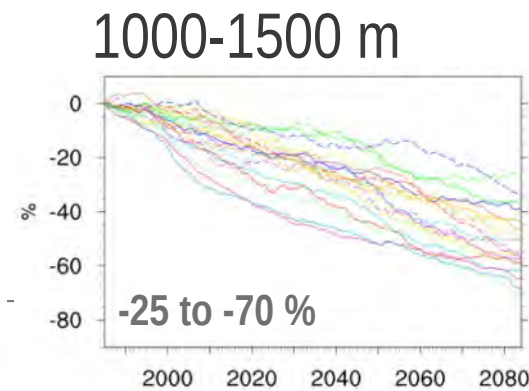
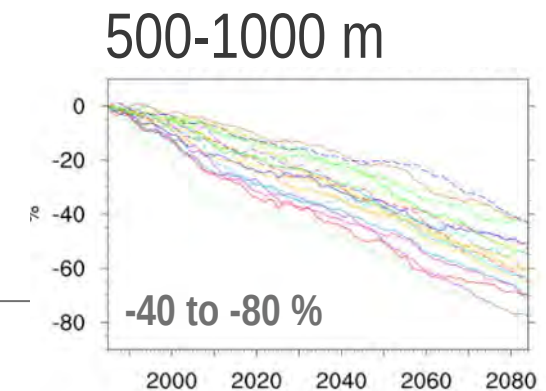
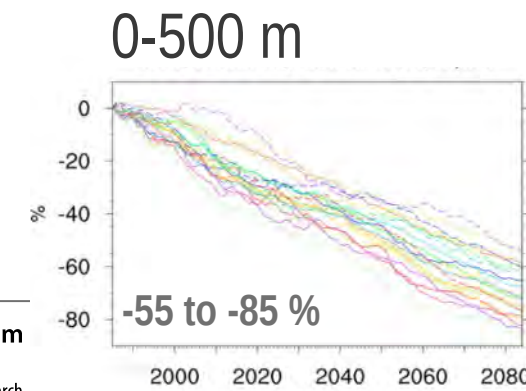
RCP2.6



RCP4.5



RCP8.5



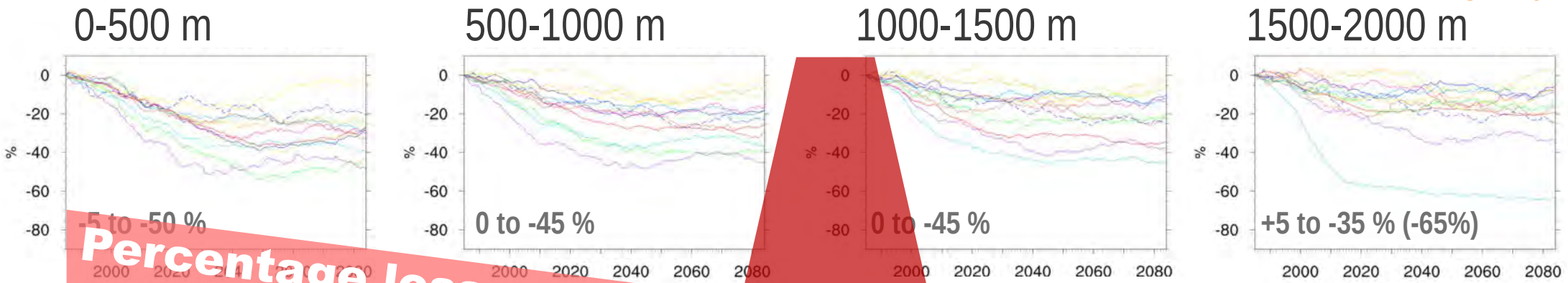
# ■ Snow water equivalent: relative change to 1971-2000 [%]

Scandinavia, 30-year running mean

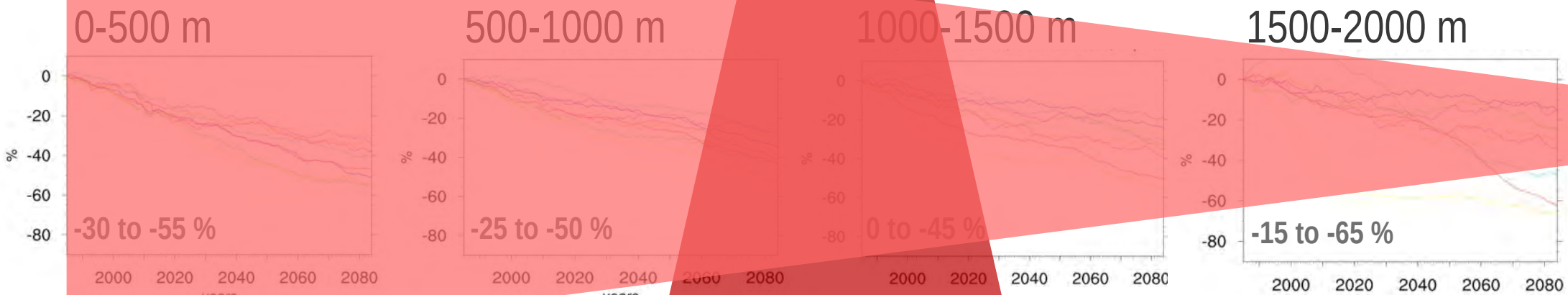
numbers:

Relative change by 2070-2099

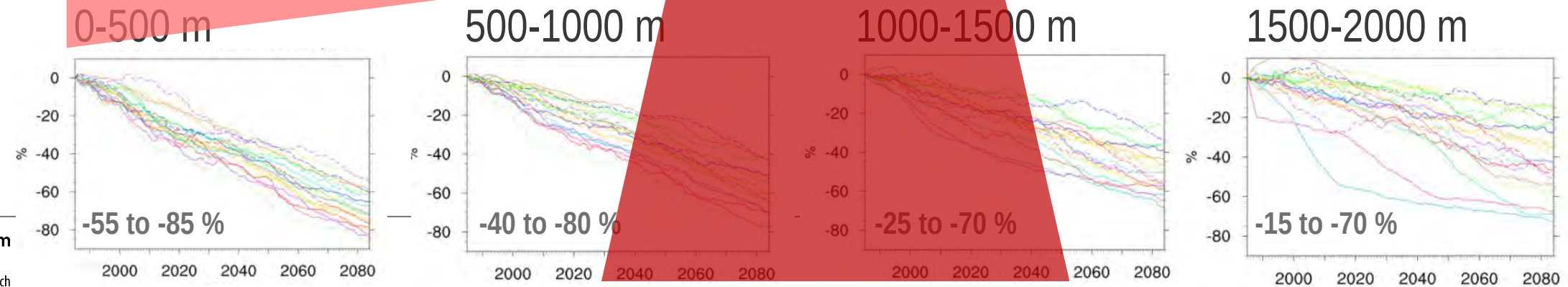
RCP2.6



RCP4.5



RCP8.5





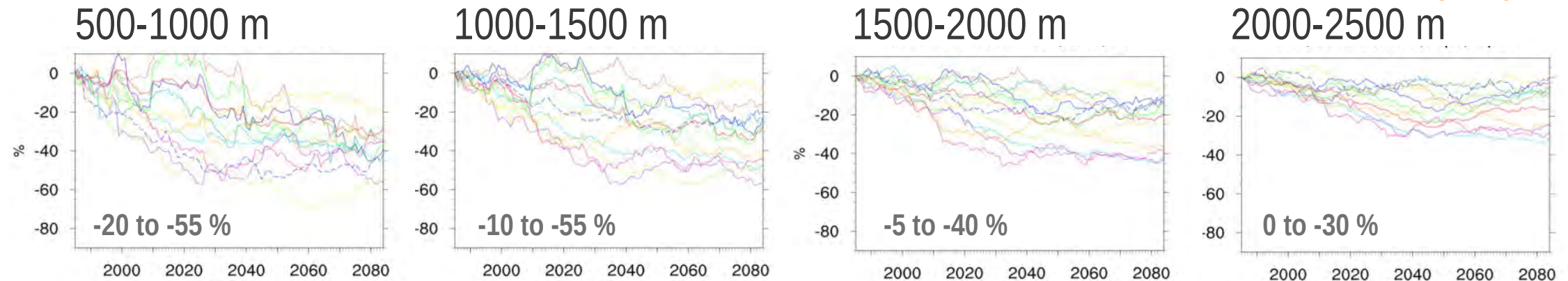
# ■ Snow water equivalent: relative change to 1971-2000 [%]

Alps, 30-year running mean

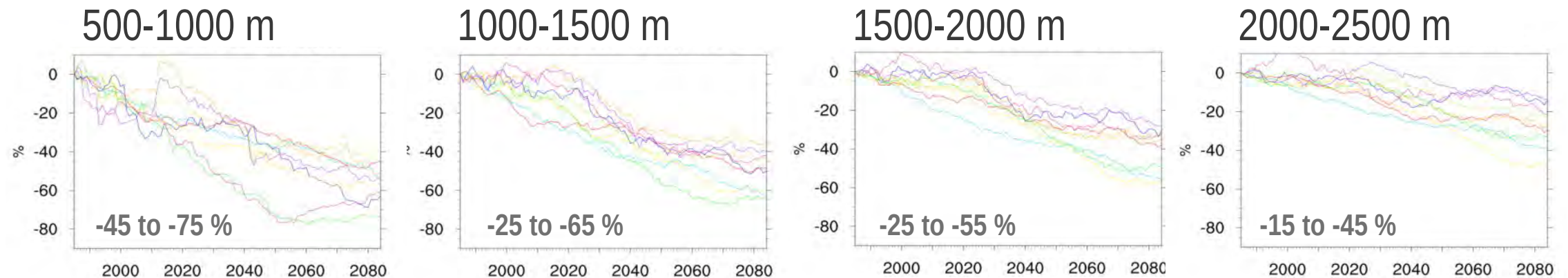
numbers:

Relative change by 2070-2099

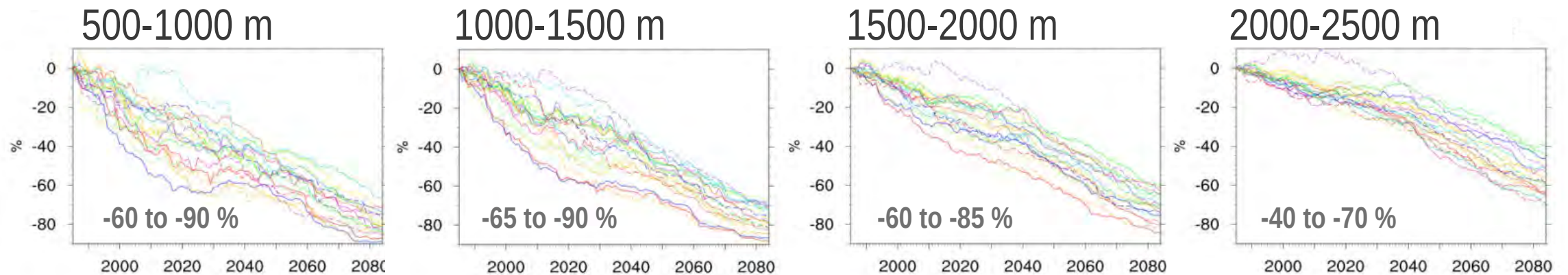
RCP2.6



RCP4.5



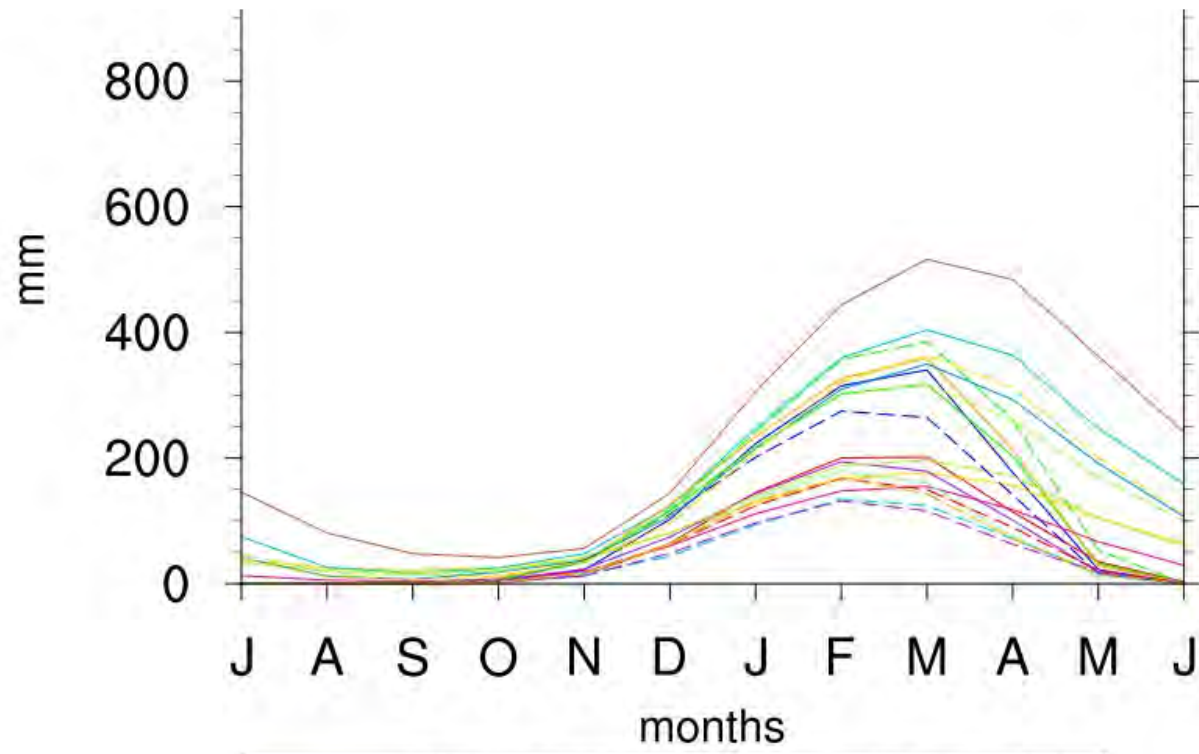
RCP8.5



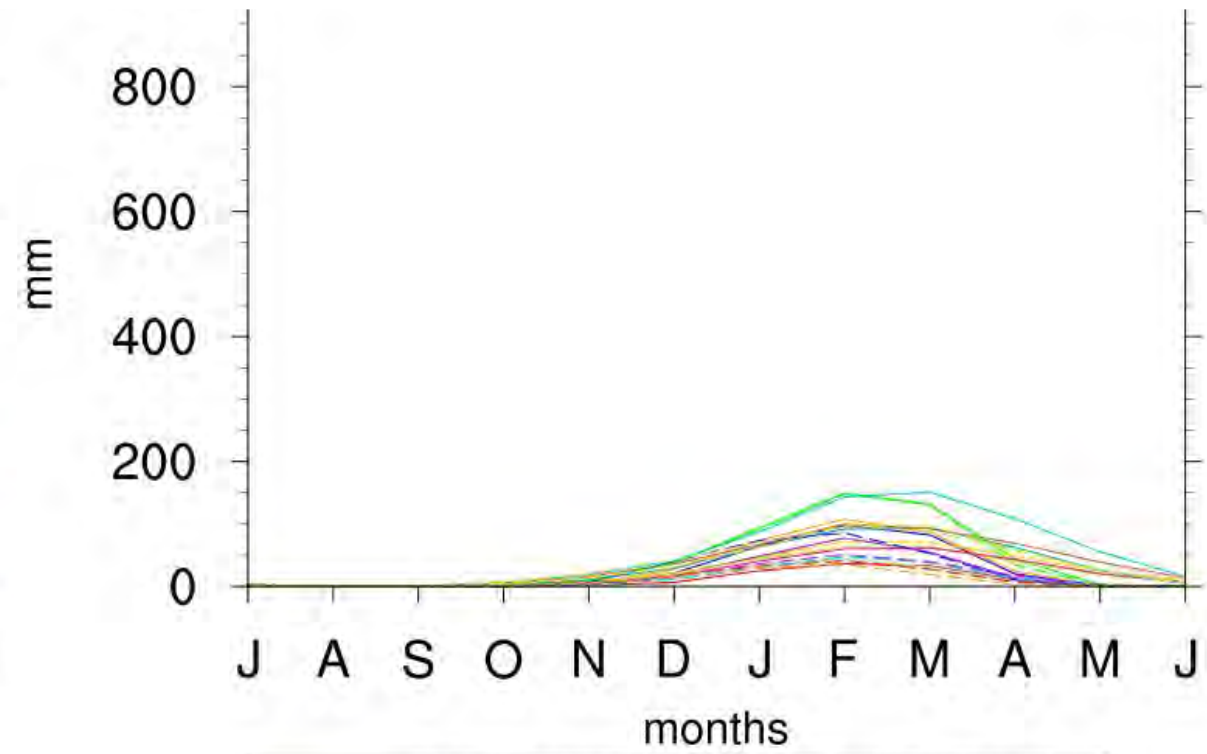
# Annual cycle of snow water equivalent [mm]

## Alps 1500-2000 m, RCP8.5

1971-2000



2070-2099

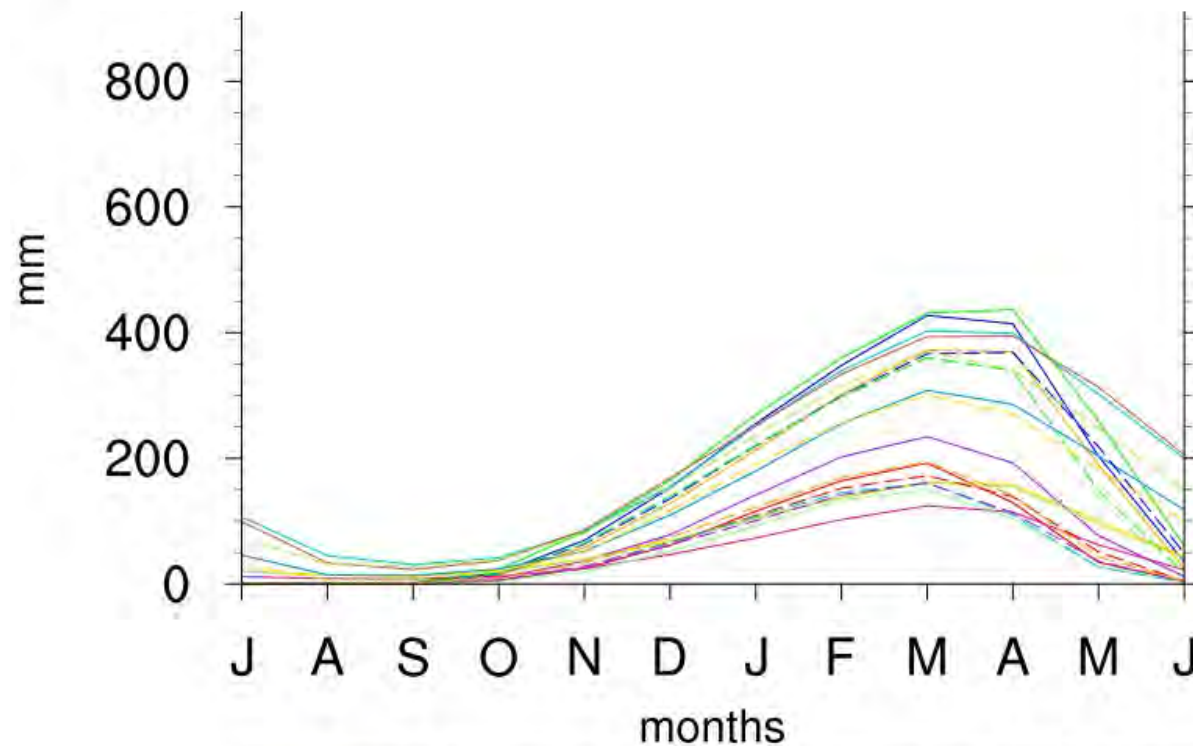


no snow left in July, August, September

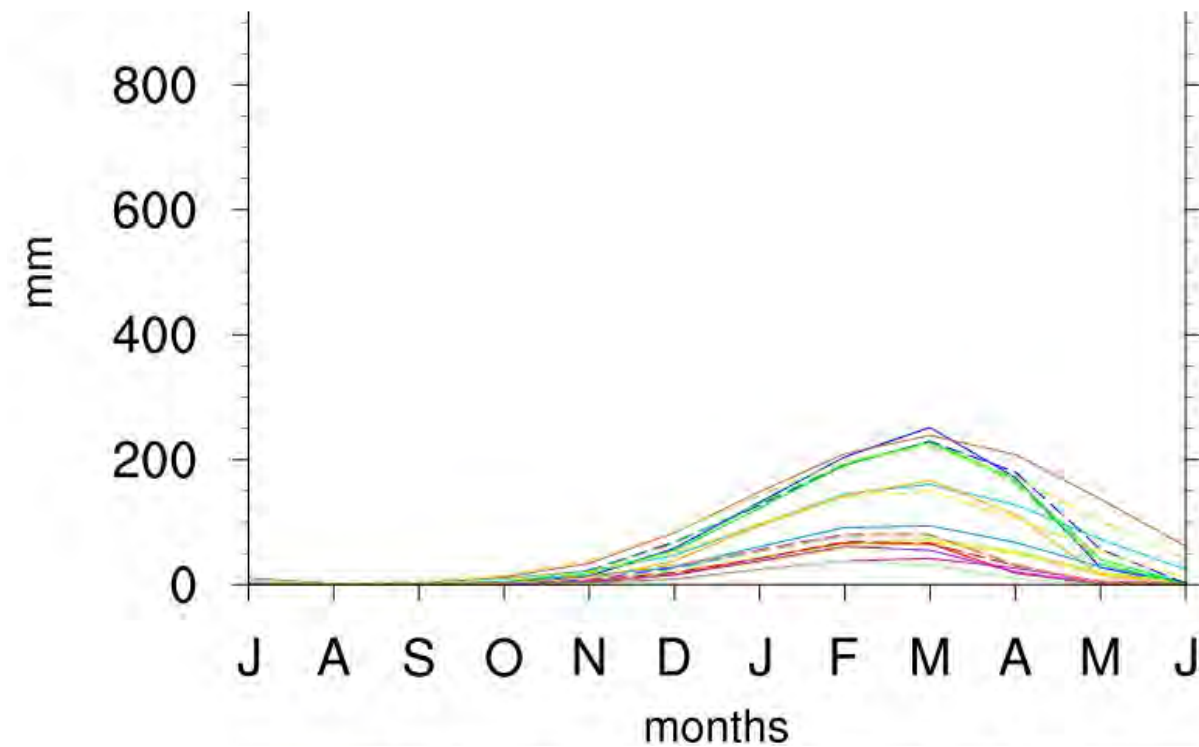


# Annual cycle of snow water equivalent [mm] Scandinavia 500-1000 m, RCP8.5

1971-2000



2070-2099



no snow left in July, August, September

## ■ Summary and outlook:

- RCM-simulated snow cover is overall realistic.
  - Climate scenarios indicate **important reduction of European snow cover** by end of 21<sup>st</sup> Century, even for RCP2.6
  - Scandinavia/Alps: **strong loss (55%-90%)** at low elevations for RCP8.5
  - Scandinavia/Alps: strong reduction of snow cover duration at low elevations for RCP8.5
- 
- Snow atmosphere feedbacks
  - Complete study of climate scenario simulations





# Mean snow cover duration 1998 -2008

