What can we say about future conditions in the Nordic area at global mean temperature increases of 1.5 and 2°C above pre-industrial conditions based on regional climate model scenarios?

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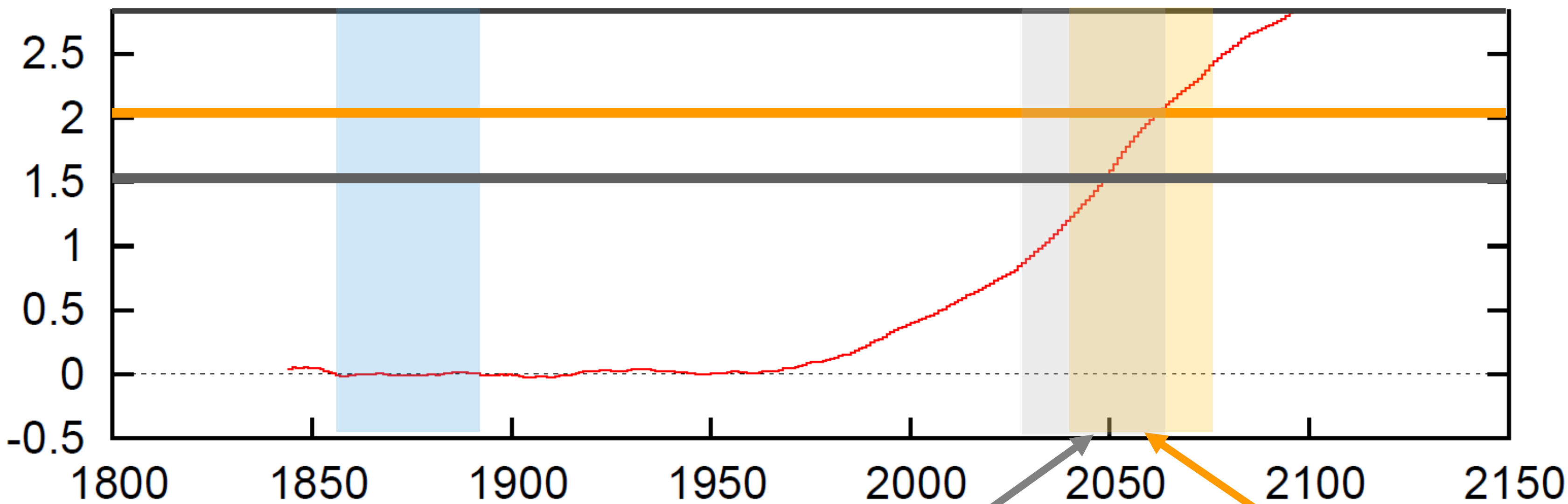
When do we reach 2(1.5)˚C warming?

Global annual mean 2m-temperature

30-year running mean anomaly w.r.t. 1861-1890
in one simulation by one global climate model



”Preindustrial” conditions (1861-1890)

1.5°C warming (2033-2062)

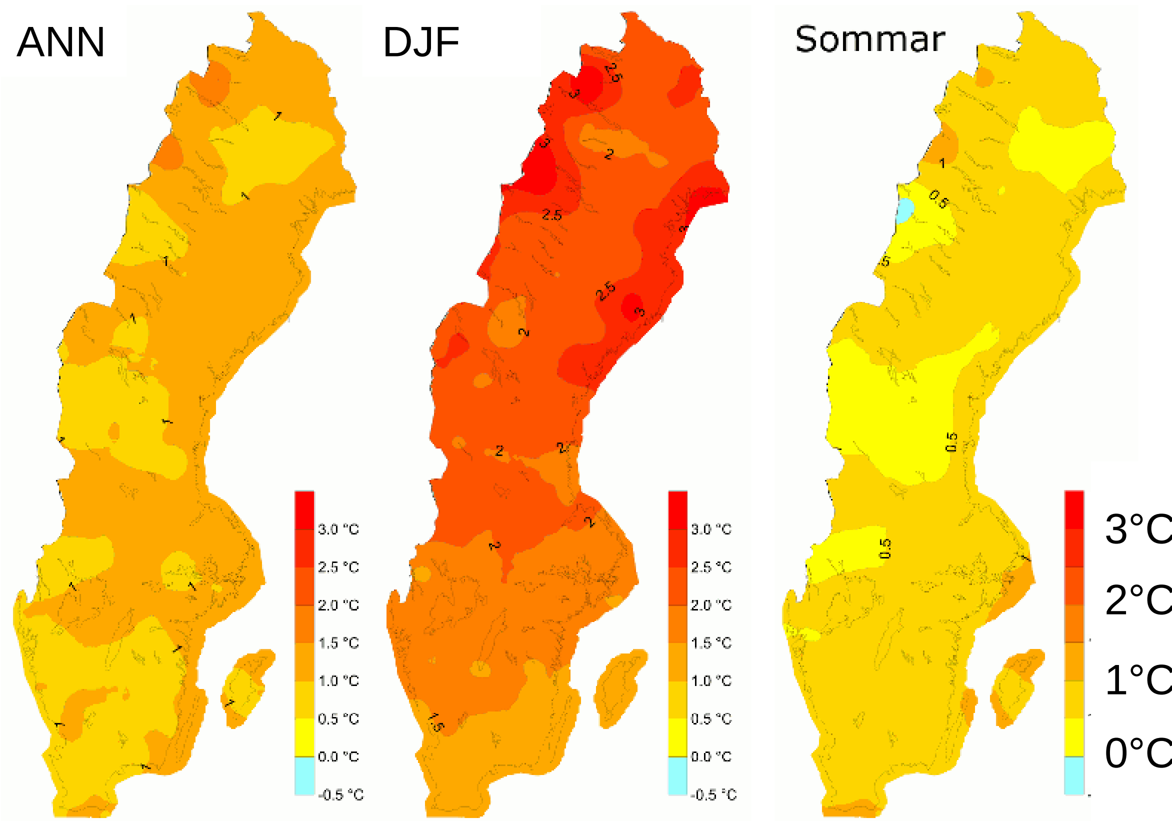
2°C warming (2046-2075)

Where are we now?

1880-1899 to 1998-2017

Global mean + 0.87°C

Iceland+ 1.49°C
Denmark + 1.57°C
Sweden + 1.64°C
Norway + 1.68°C
Finland + 1.74°C



1991-2017 compared to 1861-1890 (SMHI)

Goals of the study

- Addressing Nordic climate change at +1.5°C or +2°C global warming in a large set of RCM simulations at 12.5 km grid spacing

- At which of the two warming levels can we detect statisticant significant climate change

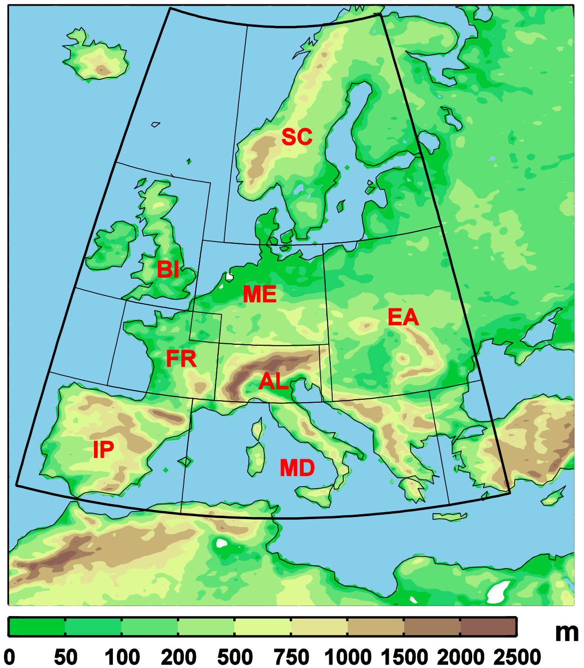
- To what extent are changes at the two warming levels different?

- How different sources of uncertainty influence the climate change signal?

RCM simulations

24 EURO-CORDEX simulations with 7 RCMs under RCP8.5 (available at ESGF in October 2018)

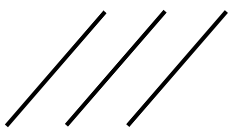
GCMs from CMIP5



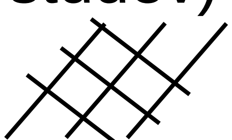
No	Institute	RCM	GCM
1	SMHI	RCA4	EC-EARTH-r12
2			HadGEM2-ES
3			MPI-ESM-LR-r1
4			NorESM1-M
5			IPSL-CM5A-MR
6	BTU Cottbus	CCLM4-8-17	EC-EARTH_r12
7			MPI-ESM-LR-r1
8			CanESM2
9			MIROC5
10	ETH	CCLM4-8-17	HadGEM2-ES
11	HZG-GERICS	REMO2009	MPI-ESM-LR-r1
12			MPI-ESM-LR-r2
13		REMO2015	EC-EARTH_r12
14			HadGEM2-ES
15			CanESM2
16			MIROC5
17	KNMI	RACMO2.2	EC-EARTH-r1
18			EC-EARTH-r12
19			HadGEM2-ES
20	DMI	HIRHAM5	EC-EARTH-r3
21			HadGEM2-ES
22			NORESM1-M
23	IPSL	WRF3.3.1	IPSL-CM5A-MR
24		WRF3.6.1	HadGEM2-ES

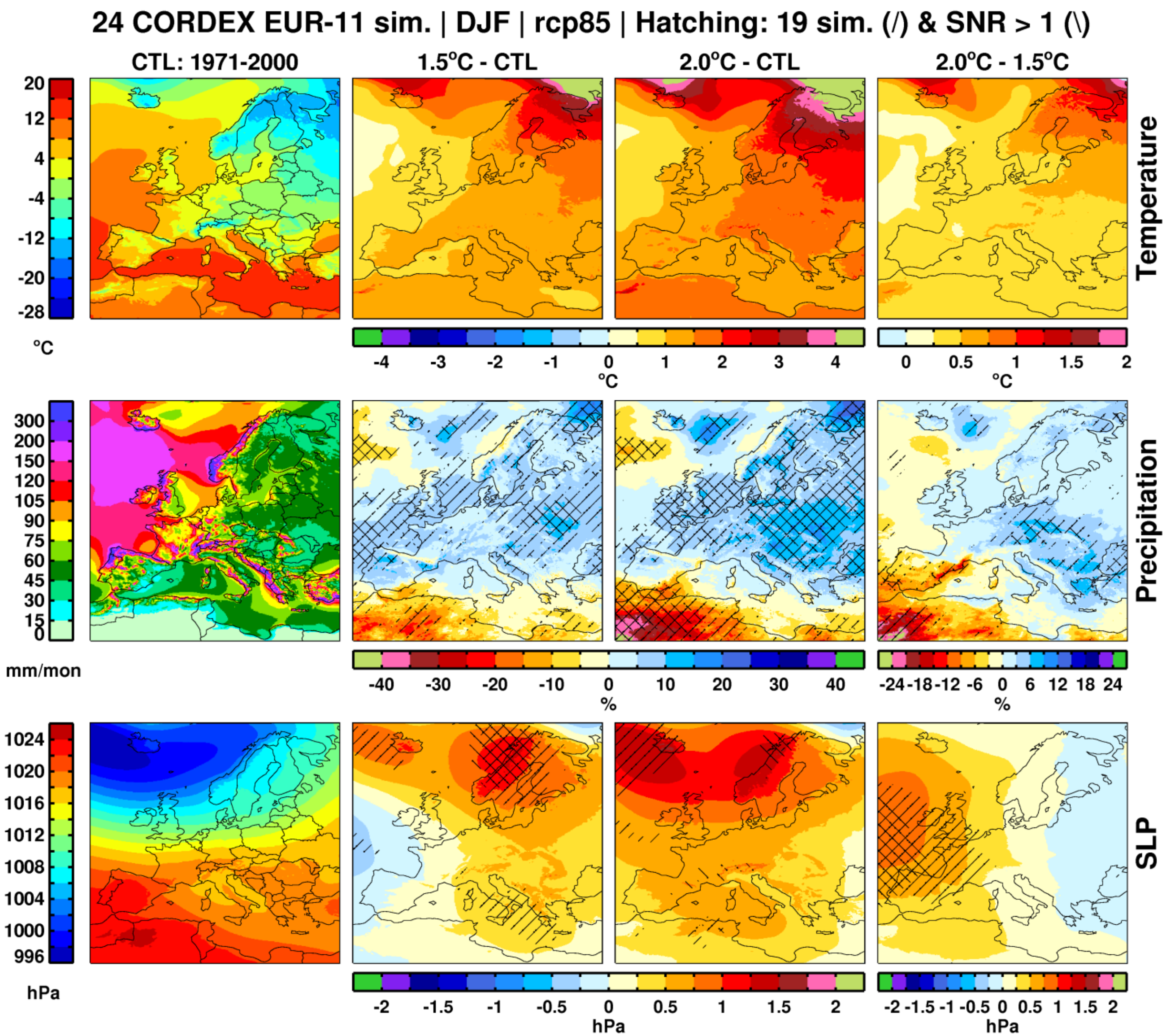
Ensemble mean climate change (DJF)

Robustness indicated when 80% of the models agree on sign of change



Significance in these areas when SNR (mean / stddev) > 1



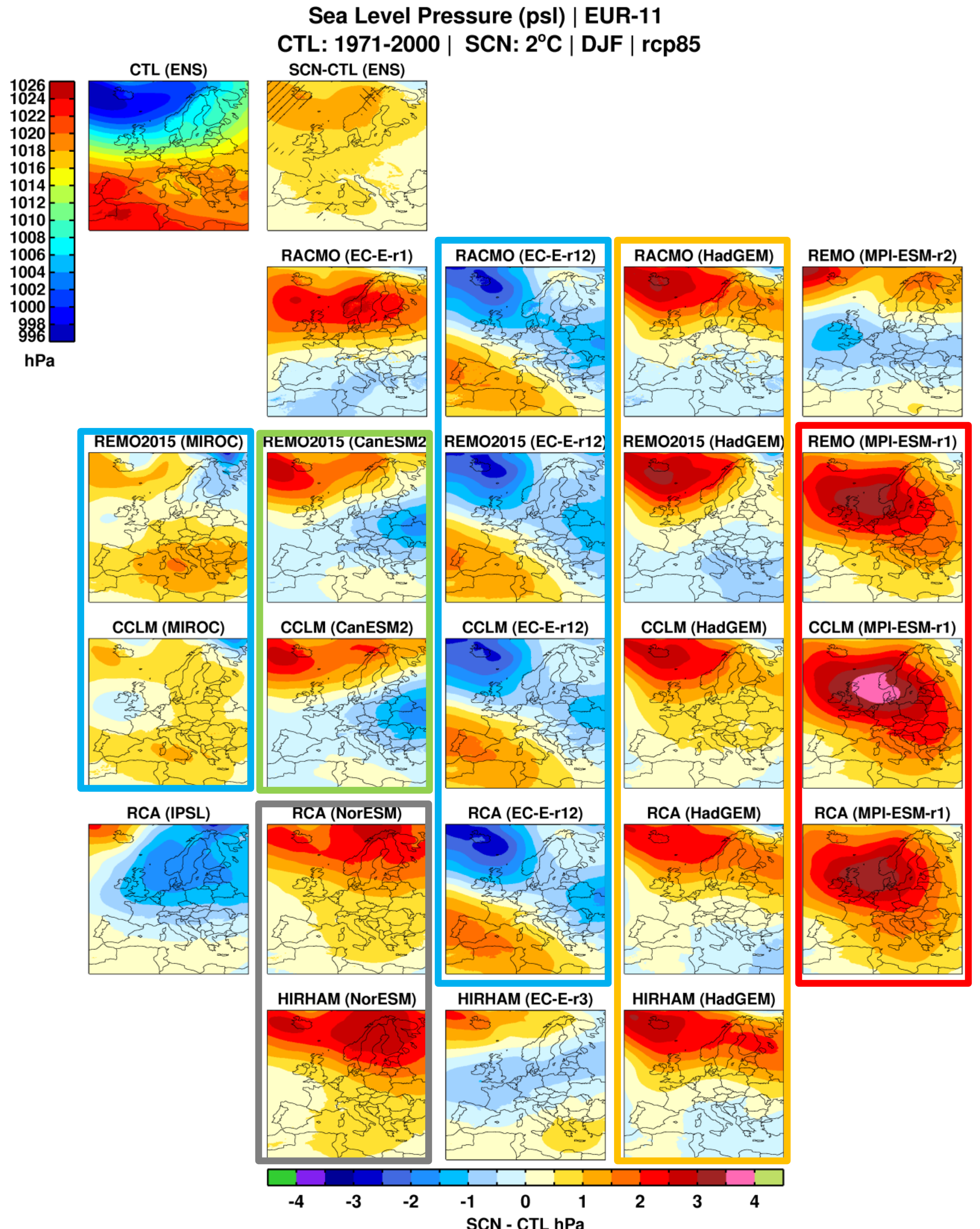


MSLP (DJF)

Strong dependency on forcing GCM and ensemble members

Apparent signs of internal variability

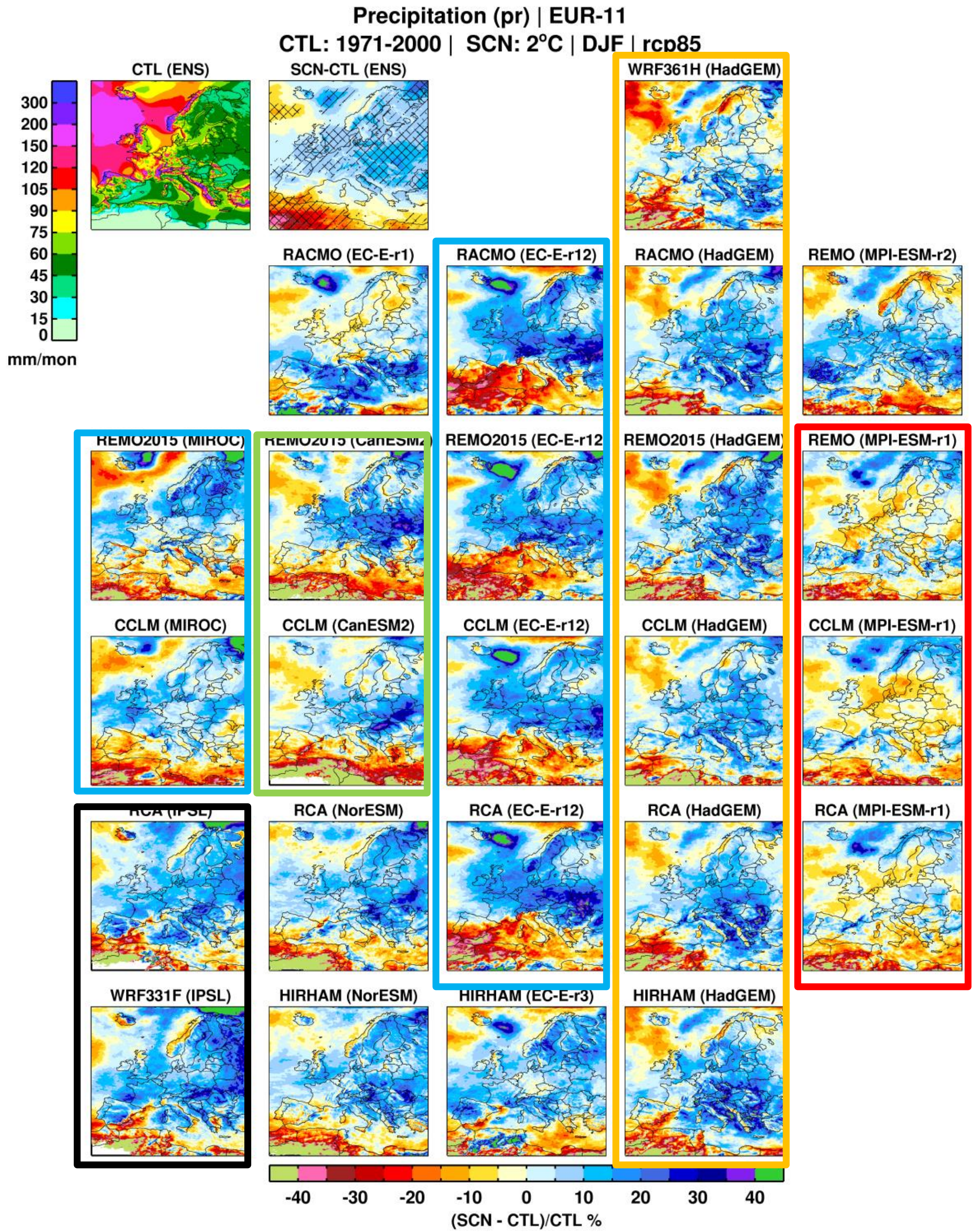
Variability is large and the signal is clearly smoothed by averaging



Precipitation (DJF)

Generally increasing precipitation in most of Europe in winter

But, strong dependency on forcing GCM/natural variability - e.g. Norwegian coastline

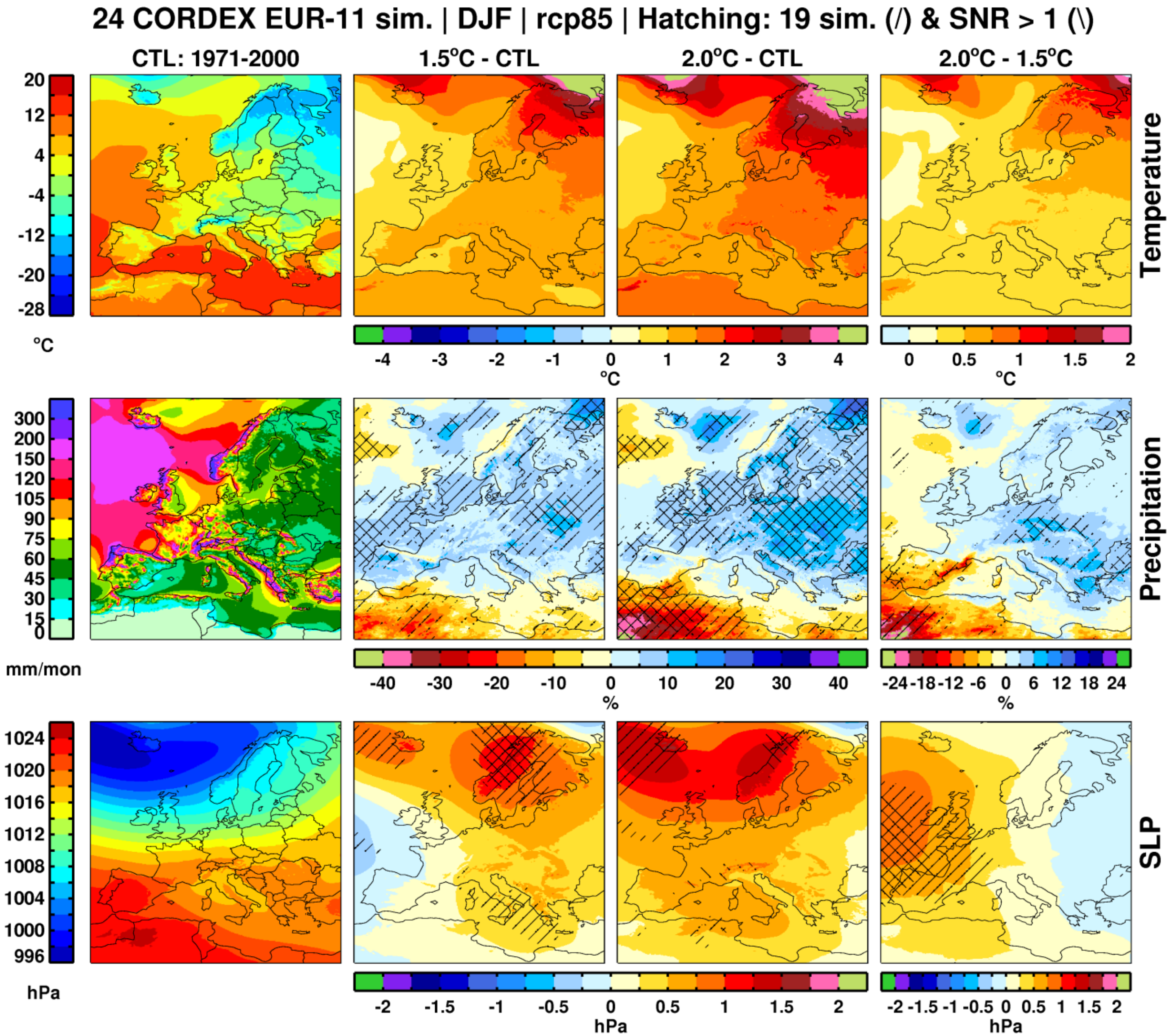


Ensemble mean climate change (DJF)

Temperature increase highly significant and robust

Precipitation increase is less robust with large regional uncertainties

Tendencies for some decrease in the N-S pressure gradient over the N. Atlantic

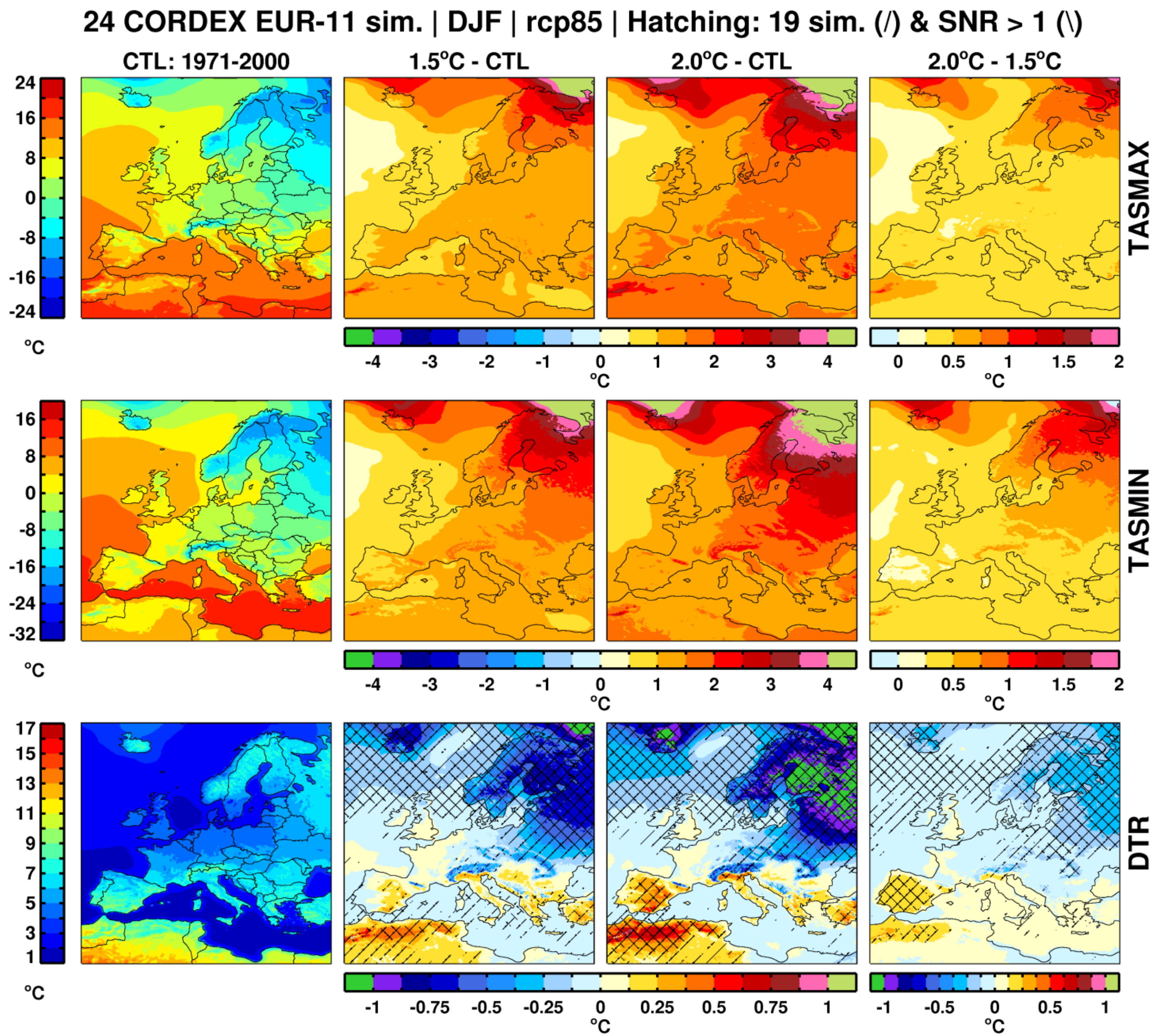


Temperature climate (DJF)

Temperature increases most significant in the Nordic countries

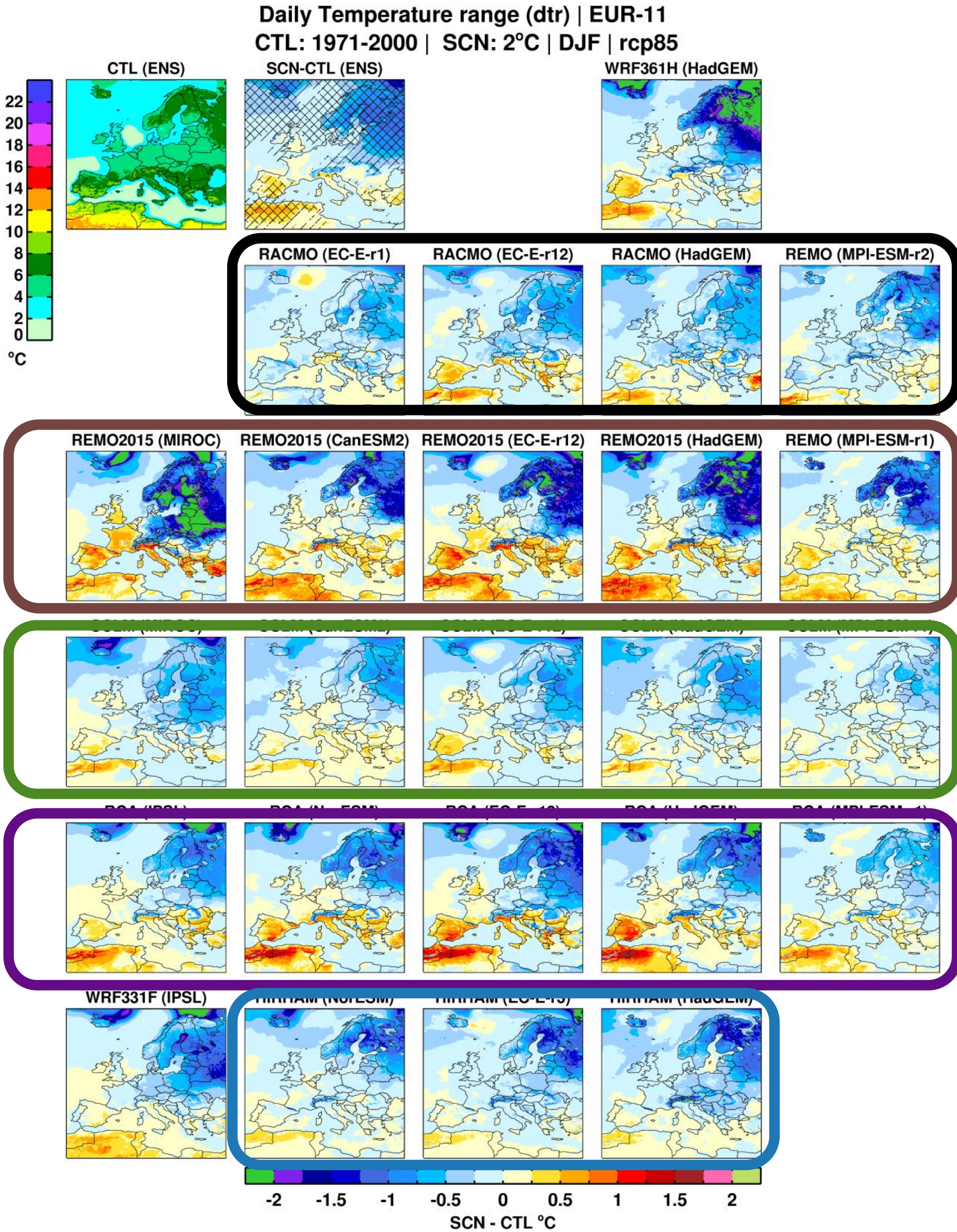
Minimum temperatures increase more than maximum (less variability)

Reduced diurnal temperature range



Diurnal Temperature Range (DJF)

Strong dependency on RCM

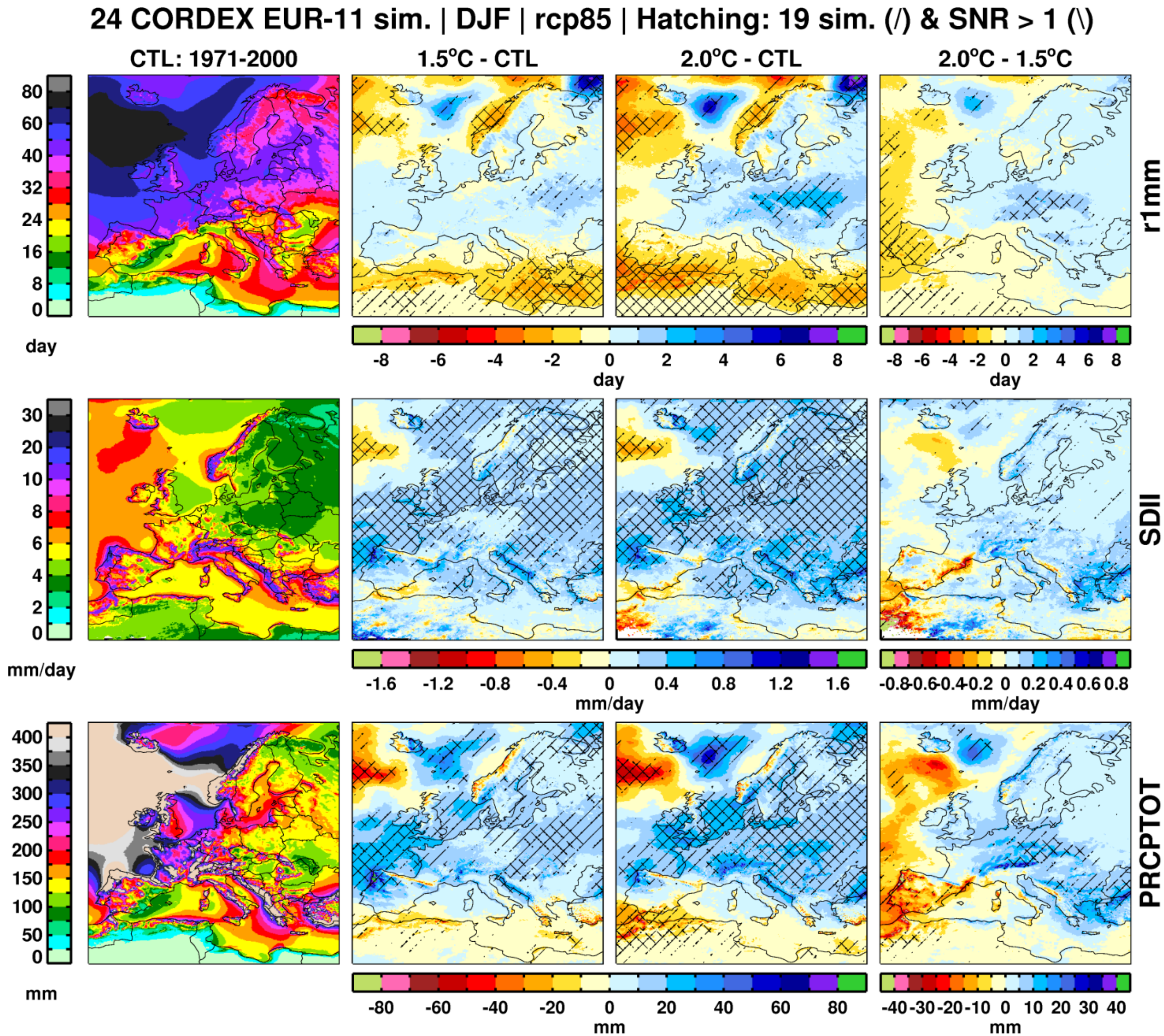


Rainy/snowy days (DJF)

Number of wet days similar as today

Precipitation increase on the wet days (intensification)

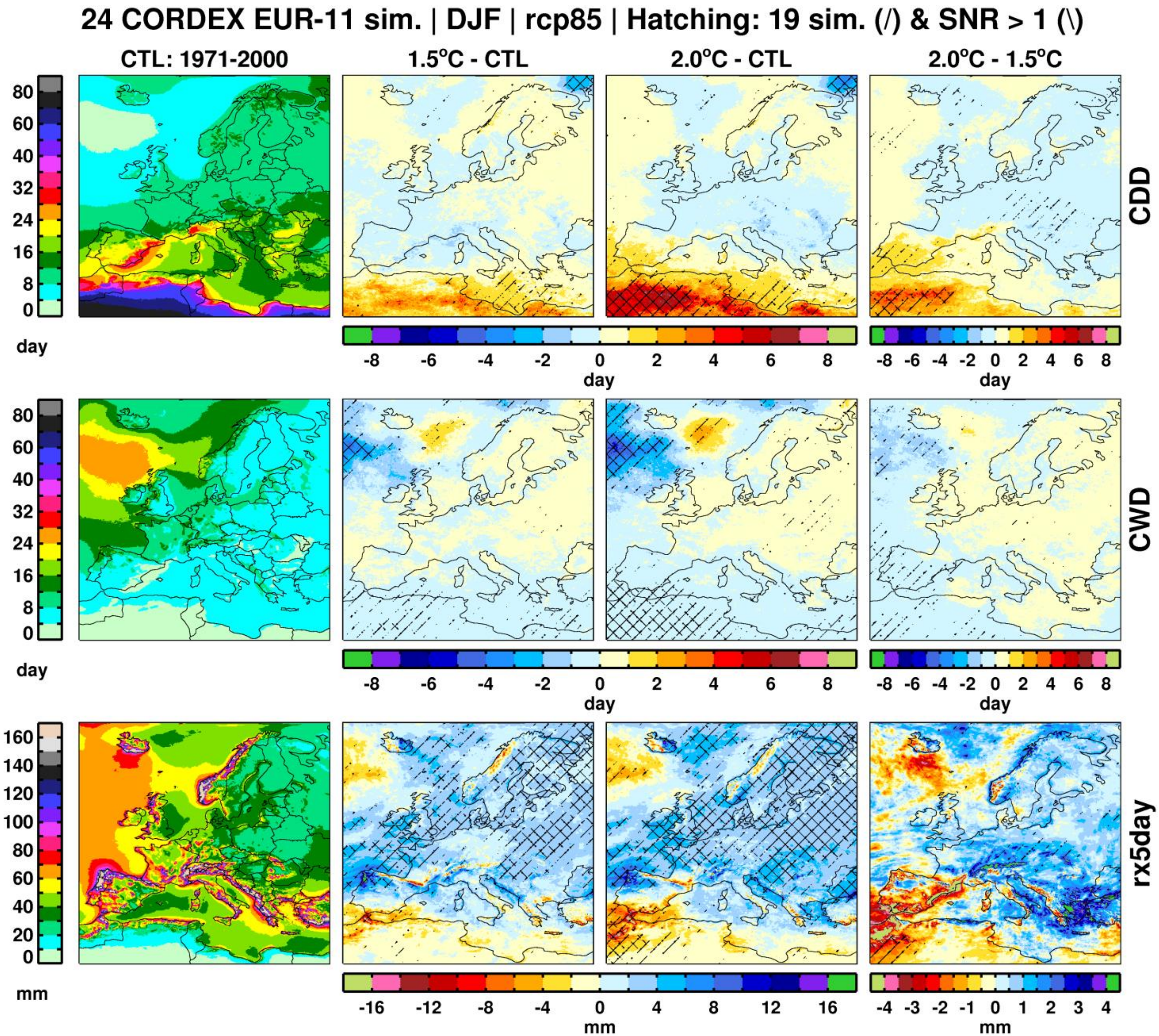
Exception to these findings possibly over parts of Norway with sligthly fewer rainy days



Wet and dry periods (DJF)

Consequtive number of dry and wet days is not changing

Max. five-day precipitation increases in most areas

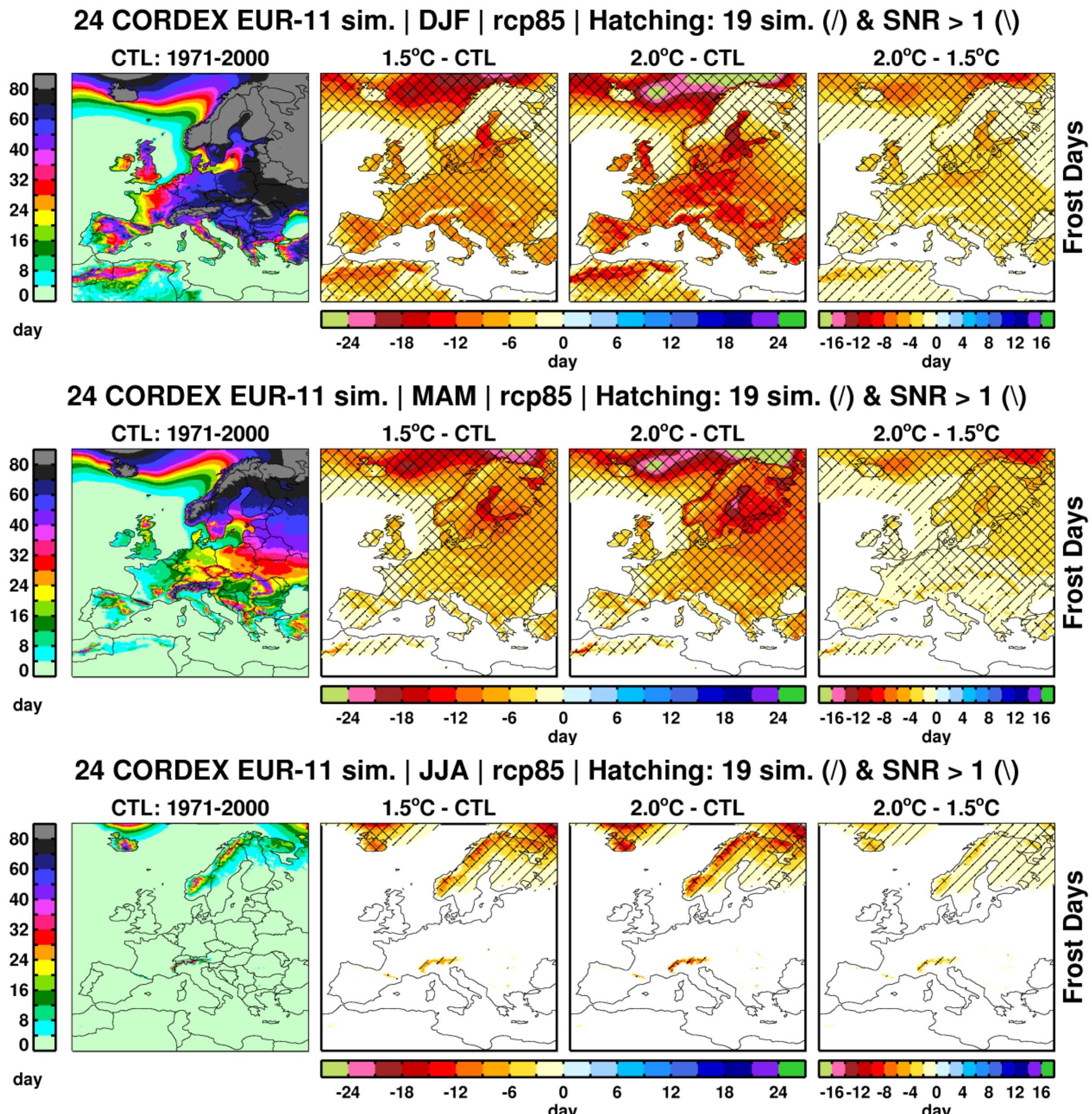


Frost days

Frost days generally decreasing

Wintertime changes small in the ”cold” northernmost regime

Notable changes over the ocean

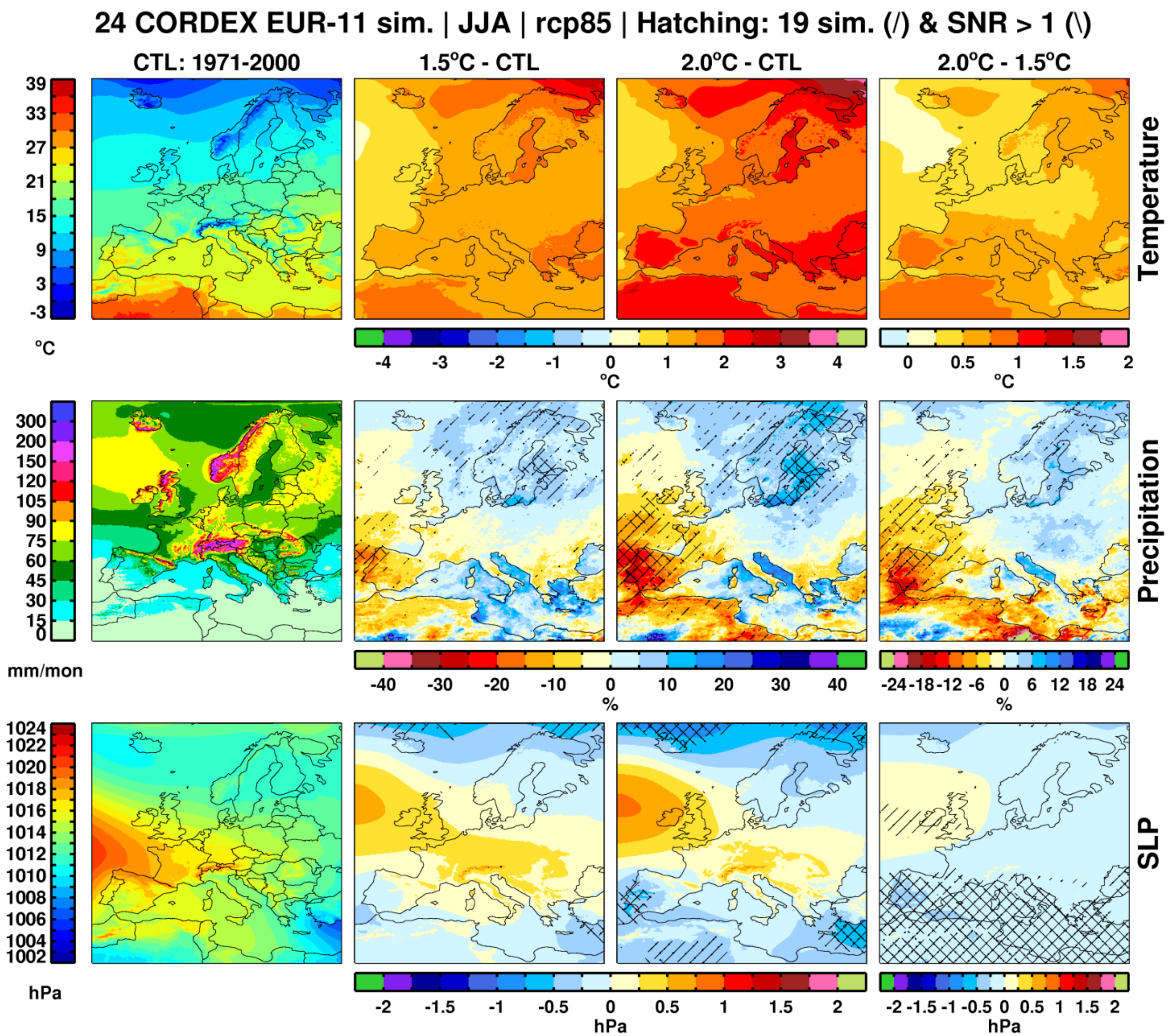


Summary

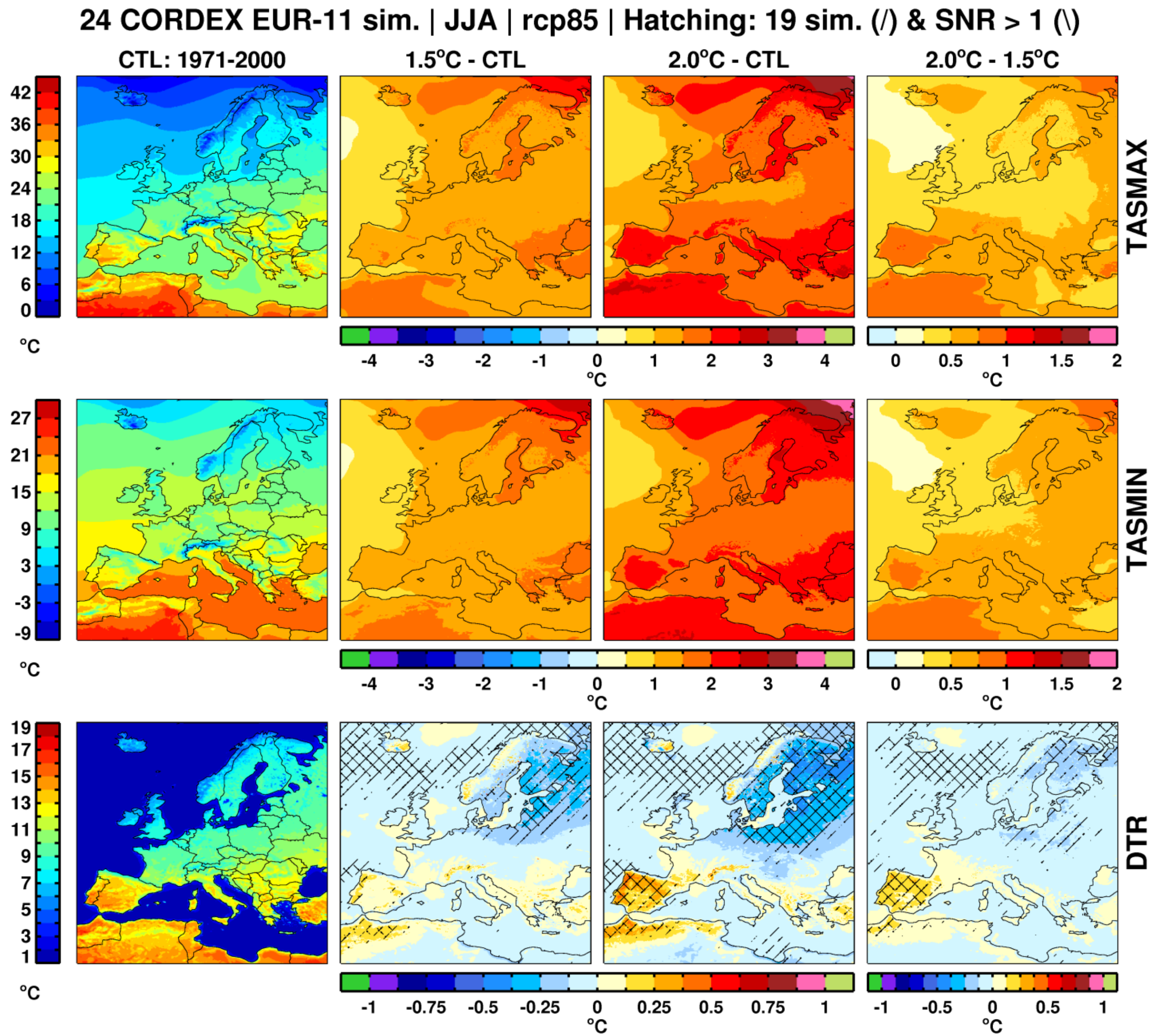
- Warming in all seasons in the future that is highly significant and robust over the ensemble
- The simulated temperature changes in the Nordic region are mostly larger than the global mean warming
- Precipitation will increase in the Nordic region, mostly in winter
- Already at SWL1.5 many changes are significant while at SWL2 stronger and more robust changes are found
- Undertainties related to choice of GCM, RCM and ensemble members varies with variable
- Generally, there is a large impact of natural variability

Kjellström et al., 2018. European climate change at global mean temperature increases of 1.5 and 2 °C above pre-industrial conditions as simulated by the EURO-CORDEX regional climate models, *Earth Syst. Dynam*., 9, 459-478, https://doi.org/10.5194/esd-9-459-2018.

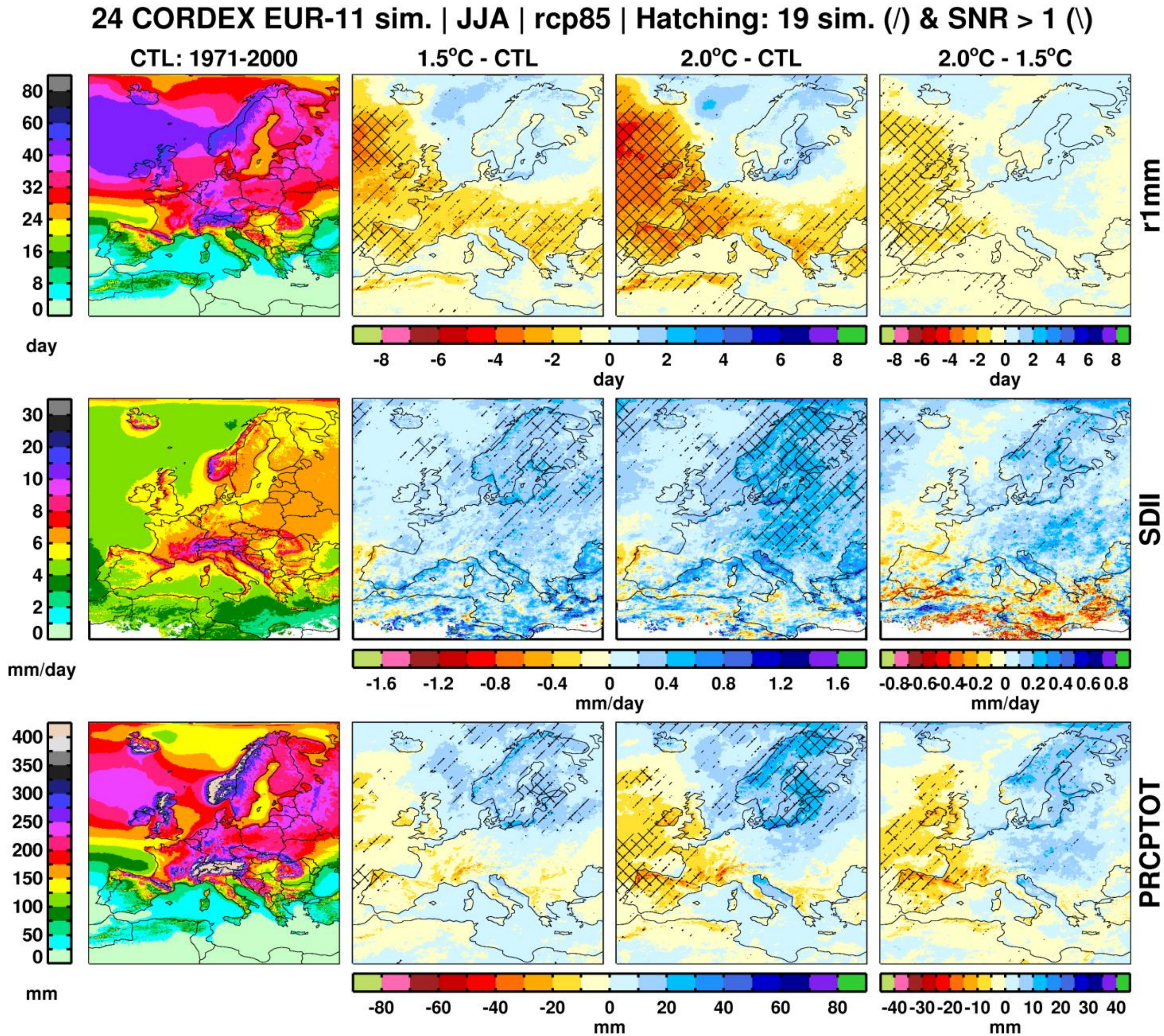
Ensemble mean climate change (JJA)



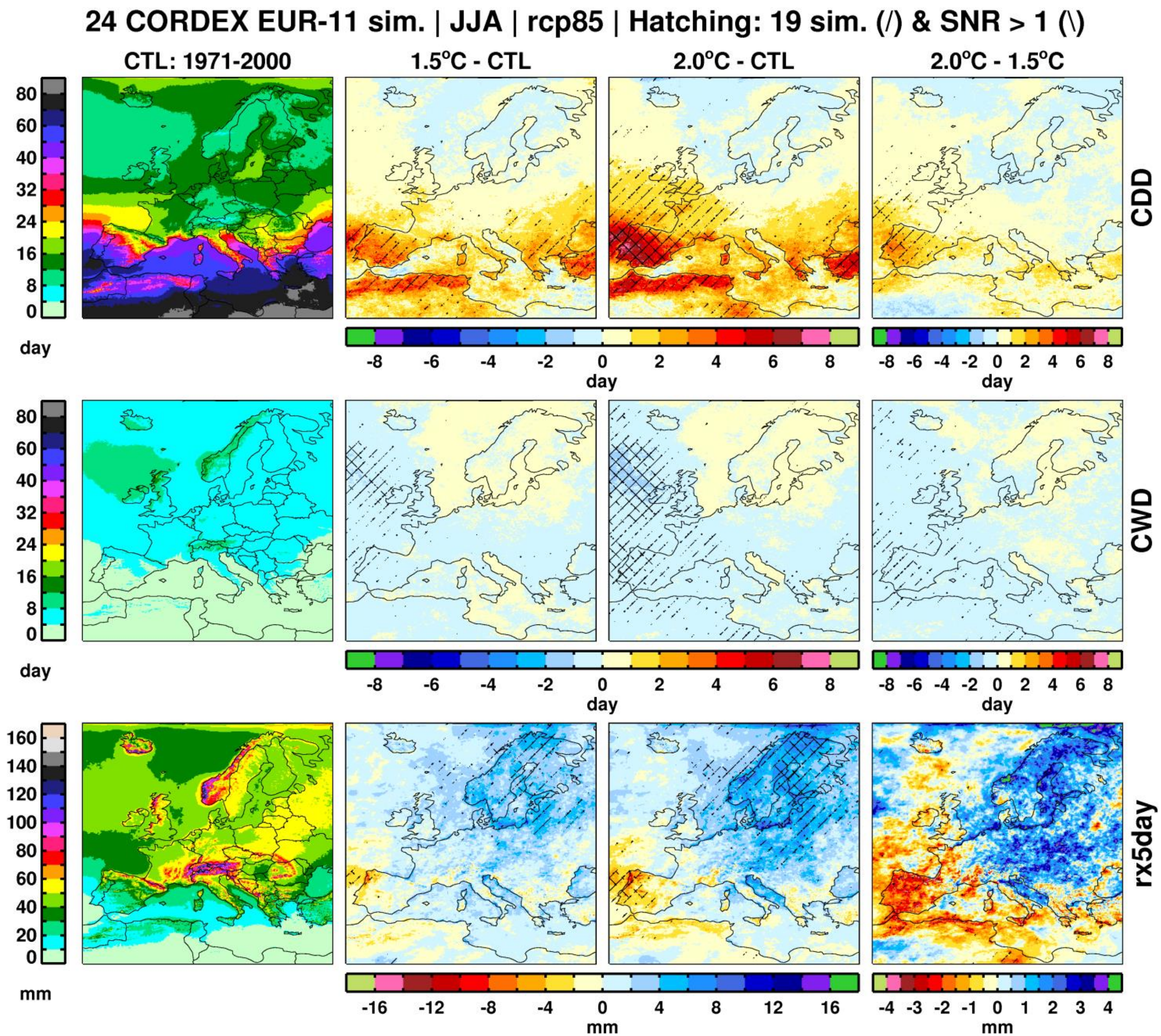
Changes in the temperature climate (JJA)



As many wet days as today, but wetter (JJA)



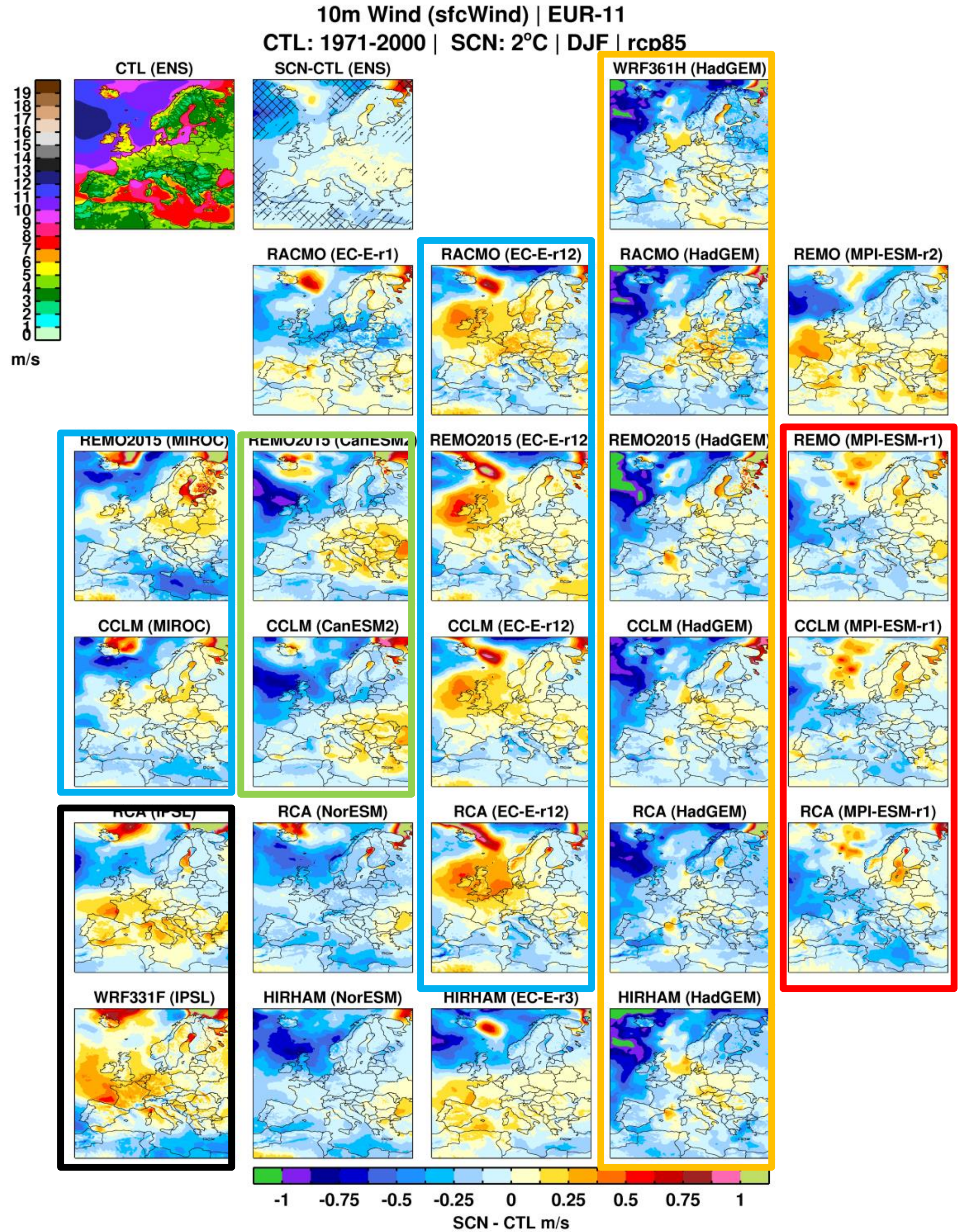
Wet/dry periods (JJA)



10m wind (DJF)

Strong dependency on forcing GCM and ensemble member

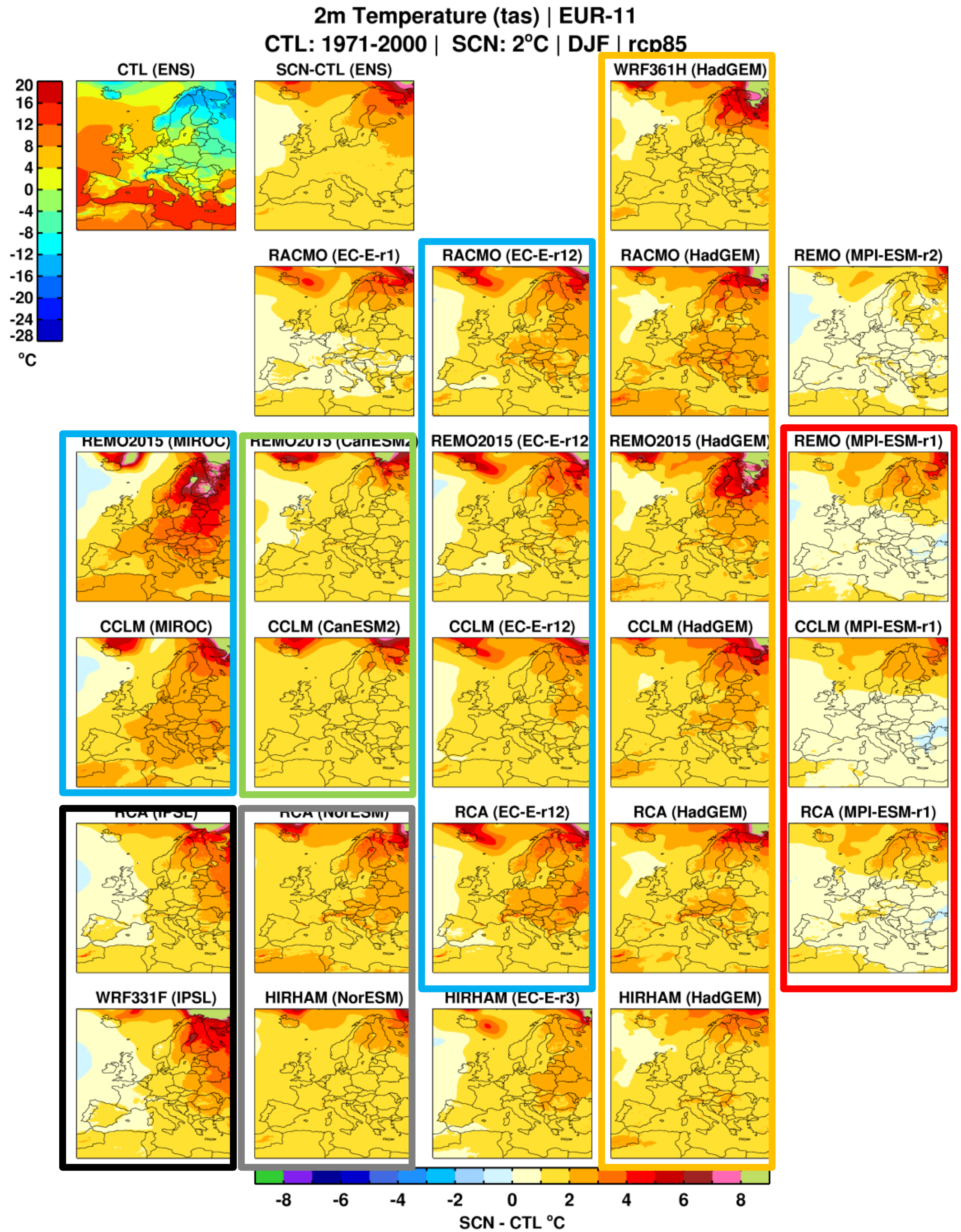
Coherent structures of increase only over parts of the Atlantic and in the far north (likely due to decreasing sea ice and changing stability conditions)



T2m (DJF)

Strong dependency on forcing GCM and ensemble members

RCMs modifies the CC signal from a GCM differently



Definition of 1.5&2°C

10 CMIP5 GCM simulations have been downscaled by EURO-CORDEX RCMs

- The simulated GCM climate for 1861-1890 taken as a proxy for preindustrial conditions
- SWL1.5 and SWL2 are the first periods when the 30-year running mean global temperature reaches 1.5 or 2.0˚C above that of the pre-industrial period
- CC signal compare SWL1.5 and SWL2 to 1971-2000

No	GCM name	SWL1.5	SWL2
1	BNU-ESM	2009	2023
2	*CanESM2*	*2013*	*2026*
3	IPSL-CM5A-LR	2011	2027
4	MIROC-ESM	2020	2030
5	MIROC-ESM-CHEM	2018	2030
6	CCSM4	2013	2030
7	*IPSL-CM5A-MR*	*2016*	*2030*
8	*MPI-ESM-LR (r2)*	*2016*	*2032*
9	GISS-E2-H-CC	2017	2035
10	*EC-EARTH (r1)*	*2017*	*2035*
11	GFDL-CM3	2023	2035
12	*MPI-ESM-LR (r2)*	*2018*	*2035*
13	*EC-EARTH (r12)*	*2019*	*2035*
14	GISS-E2-H	2020	2036
15	*EC-EARTH (r3)*	*2020*	*2037*
16	IPSL-CM5B-LR	2022	2037
17	*HadGEM2-ES*	*2024*	*2037*
18	MPI-ESM-MR	2020	2038
19	HadGEM2-CC	2029	2041
20	FIO-ESM	2027	2042
21	CNRM-CM5	2029	2043
22	CSIRO-Mk3-6-0	2032	2044
23	HadGEM2-AO	2034	2046
24	NorESM1-ME	2032	2046
25	GISS-E2-R-CC	2031	2048
26	*NorESM1-M*	*2033*	*2048*
27	*MIROC5*	*2033*	*2048*
28	GFDL-ESM2M	2034	2051
29	MRI-CGCM3	2040	2052
30	GFDL-ESM2G	2037	2054
31	inmcm4	2043	2058

Earliest occurence:
1995-2024 (SWL1.5)
2009-2038 (SWL2)

Latest occurence:
2026-2055 (SWL1.5)
2038-2067 (SWL2)

No	GCM name	SWL1.5	SWL2
1	BNU-ESM	2009	2023
2	*CanESM2*	*2013*	*2026*
3	IPSL-CM5A-LR	2011	2027
4	MIROC-ESM	2020	2030
5	MIROC-ESM-CHEM	2018	2030
6	CCSM4	2013	2030
7	*IPSL-CM5A-MR*	*2016*	*2030*
8	*MPI-ESM-LR (r2)*	*2016*	*2032*
9	GISS-E2-H-CC	2017	2035
10	*EC-EARTH (r1)*	*2017*	*2035*
11	GFDL-CM3	2023	2035
12	*MPI-ESM-LR (r2)*	*2018*	*2035*
13	*EC-EARTH (r12)*	*2019*	*2035*
14	GISS-E2-H	2020	2036
15	*EC-EARTH (r3)*	*2020*	*2037*
16	IPSL-CM5B-LR	2022	2037
17	*HadGEM2-ES*	*2024*	*2037*
18	MPI-ESM-MR	2020	2038
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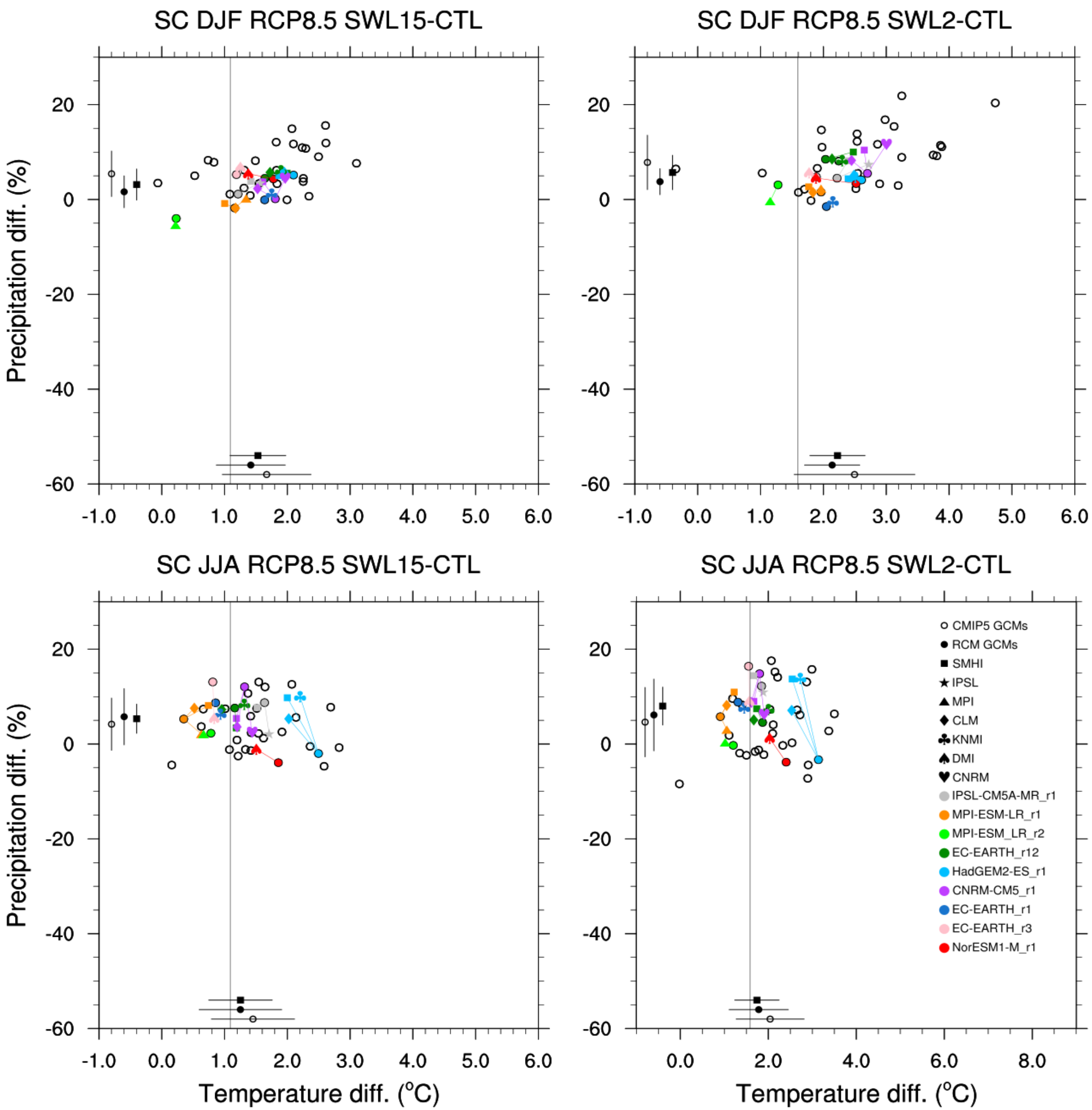
A wider perspective: Scandinavia



RCMs can either amplify or attenuate the CC signal in the underlying GCMs

the chosen subset of GCMs is giving a weaker increase in temperature compared to that of the full CMIP5 ensemble