Changes in Extreme climates of the greater Baltic Sea region since 1851: observations versus simulations

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- Climatology and change over the great Baltic Sea region
- Can global climate models capture the climatology and change?

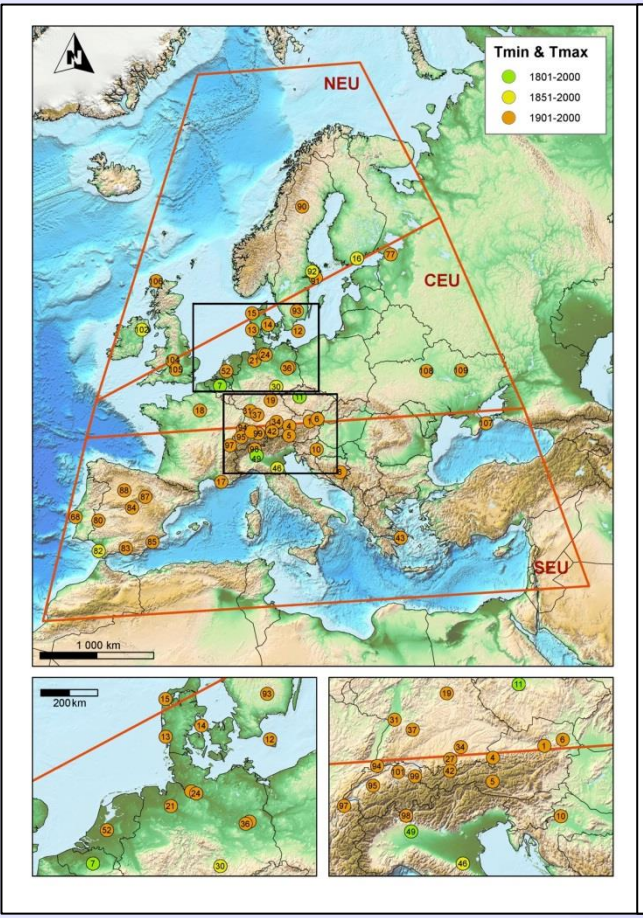
Trends of extreme temperature and precipitation climates in Europe: A trend atlas of the EMULATE indices

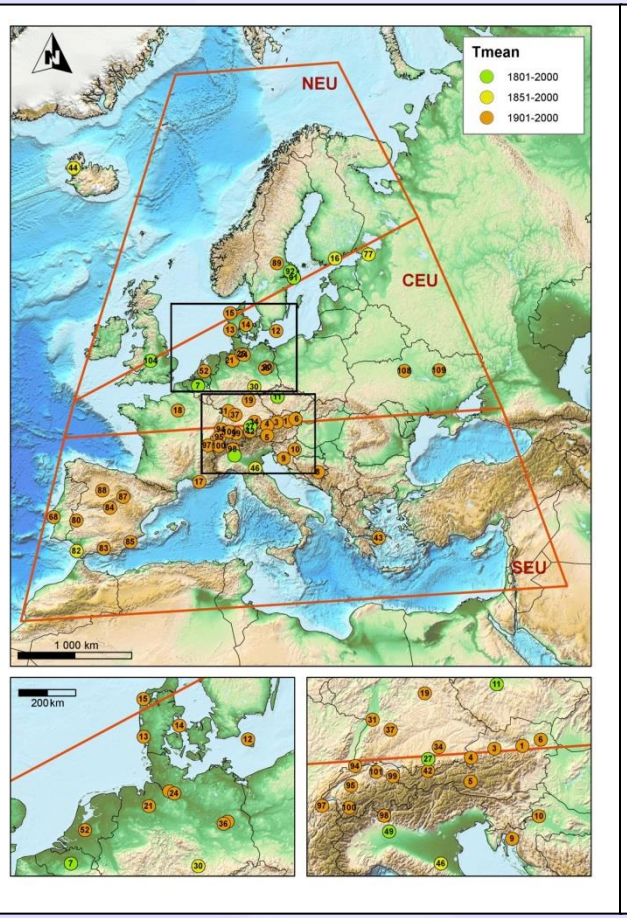
Chen, D., Walther, A., Moberg, A., Jones, P.D., Jacobeit, J., Lister, D.

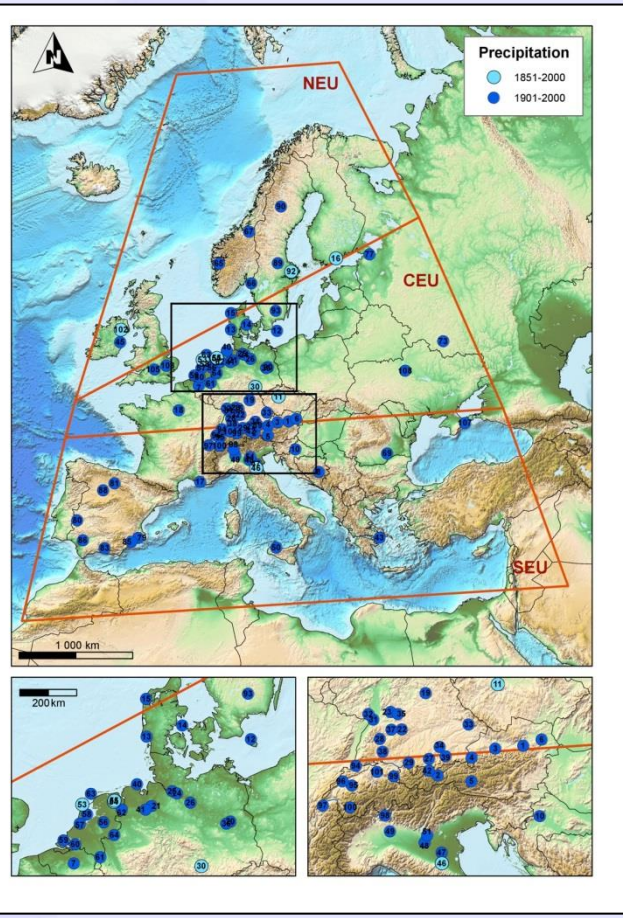
- Originally Published as internal report 2006
  - Systematic mapping of seasonal extreme climate conditions
  - over Europe
  - during the past 2 centuries (1801-, 1851-, 1901-2000) using
  - 64 climate indices (2014: 27 indices, to be published by Springer)
  - maps, time-series, tables

Observation for different periods and regions for

T_{min}, T_{max} 1801-2000, 1851-2000, 1901-2000 T_{mean} Prec







Summary tables: Here, linear trends for regions during 1901-2000 for all indices. **Warming**/**cooling** indicated with **red**/**blue** colors, **wetting**/**drying** with **green**/**brown**.

	unit	MAM						JJA						SON						DJF					
	100 yr^{-1}	NEU		CEU		SEU		NEU		CEU		SEU		NEU		CEU		SEU		NEU		CEU		SEU	
MEANTN	[°C]	1,09	**	0,85	**	0,46	*	0,70	**	0,92	**	0,75	**	1,11	**	1,04	**	0,60	**	0,48		1,19	*	0,99	**
MEANTX	[°C]	0,94	**	0,65		1,63	**	0,85	*	0,59		1,63	**	0,85	**	1,00	**	1,66	**	0,48		1,11	*	1,41	**
TN2P	[°C]	1,50		1,26		0,83		0,60		0,24		0,76	*	1,12		0,92		0,68		0,12		1,53		1,36	*
TN98P	[°C]	0,23		0,02		0,19		0,75	*	1,17	**	0,62	**	0,84	**	0,71	*	0,17		0,98	**	1,46	**	0,75	*
TX2P	[°C]	1,61	*	0,89		1,66	**	0,93	**	-0,08		1,65	**	1,13		0,90		1,45	**	0,34		1,03		1,22	*
TX98P	[°C]	0,40		-0,33		0,86		0,96		0,98	*	1,62	**	0,22		0,11		1,57	**	1,20	**	1,94	**	1,87	**
TN2N	[d]	-2,01	**	-2,05	**	-1,82	**	-1,50	**	-2,09	**	-2,52	**	-2,11	**	-2,70	**	-1,48	**	-0,07		-1,28		-1,64	*
TN98N	[d]	1,83	**	1,57	**	1,30	*	1,71	**	2,44	**	1,81	**	1,76	**	1,12	**	1,09	*	2,46	**	2,03	**	1,48	**
TX2N	[d]	-2,08	**	-0,96	*	-2,89	**	-2,48	**	-0,52		-2,87	**	-2,96	**	-2,03	*	-2,39	**	-0,21		-0,77		-1,97	**
TX98N	[d]	1,13		0,75		2,44	**	1,54	*	0,64		2,93	**	0,92		0,29		1,90	**	2,58	**	2,69	**	2,50	**
HWDI	[d]	0,94		2,21	*	2,94	*	1,32		0,31		1,51	**	0,12		-0,14		1,17	*	2,40	*	3,49	**	1,02	**
WSDI90	[d]	1,34		1,33		3,13	**	1,14		0,24		2,72	**	0,58		0,00		1,80	**	2,59	**	2,64	**	1,75	**
CSDI10	[d]	-1,29		-2,05	**	-0,75		-1,87	**	-1,20	**	-1,58	**	-2,10	**	-2,68	**	-1,05	*	-0,11		-1,97		-1,71	
MEANTG	[°C]	0,85	*	0,82	*	1,04	**	0,73	*	0,96	**	1,19	**	0,97	**	1,15	**	1,11	**	0,33		1,16	*	1,25	**
TG2P	[°C]	1,52		1,21		1,36	**	0,89	**	0,40		1,25	**	1,29		0,97		1,13	*	-0,13		1,27		1,55	**
TG98P	[°C]	0,04		-0,27		0,51		0,81		1,15	**	1,17	**	0,51		0,44		0,85	*	1,05	**	1,52	**	1,29	**
TG2N	[d]	-2,18	*	-1,85	**	-2,50	**	-2,47	**	-1,59	**	-2,23	**	-3,38	**	-3,24	**	-1,71	**	0,17		-0,82		-1,94	*
TG98N	[d]	1,66	*	1,51	*	2,35	**	1,91	*	2,15	**	3,14	**	1,35	*	1,02	*	1,97	**	2,73	**	2,48	**	2,39	**
PRECTOT	[mm]	15,15		23,99		-5,92		-2,23		2,14		1,89		47,21	**	16,61		-14,98		28,14	*	34,99	*	14,90	
PREC98P	[mm]	1,07		2,22	*	0,09		0,06		1,49		0,11		2,49	**	2,08	*	-2,32		1,69	*	2,64	**	1,50	
R98N	[d]	0,40		0,40		0,02		0,07		0,19		0,23		0,77	**	0,37		-0,07		0,60	*	0,53	*	0,42	*
R98T	[%]	2,80		3,27	*	2,66		0,79		3,69	**	5,67		4,28	**	3,67	**	0,20		4,34	**	3,99	*	5,47	**
SDII98p	[mm]	1,20		2,28		0,20		-0,31		4,34	**	0,28		3,13	**	3,81	**	-1,08		2,60	**	3,88	**	2,64	
SDII	[mm]	0,32	**	0,69	**	0,01		0,09		0,52	**	-0,22		0,57	**	0,63	**	0,07		0,49	**	0,94	**	0,39	
R5d	[mm]	3,68	*	5,35	*	-0,37		0,91		6,80	*	-0,15		7,44	**	4,03		1,52		5,55	**	9,04	**	4,57	
R1d	[mm]	1,77	*	3,34	**	0,72		0,26		4,02	**	-0,64		2,72	*	3,26	*	0,50		2,60	**	3,52	*	2,07	
CDD	[d]	0,55		0,25		1,65		1,05		0,89		-1,19		-0,75		0,97		2,43		-0,09		0,28		-0,63	

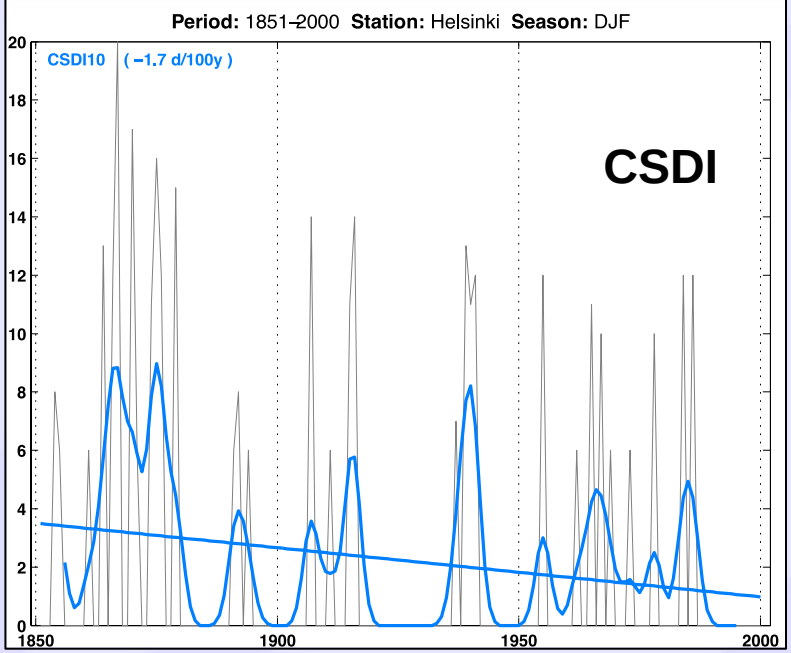
Data and indices

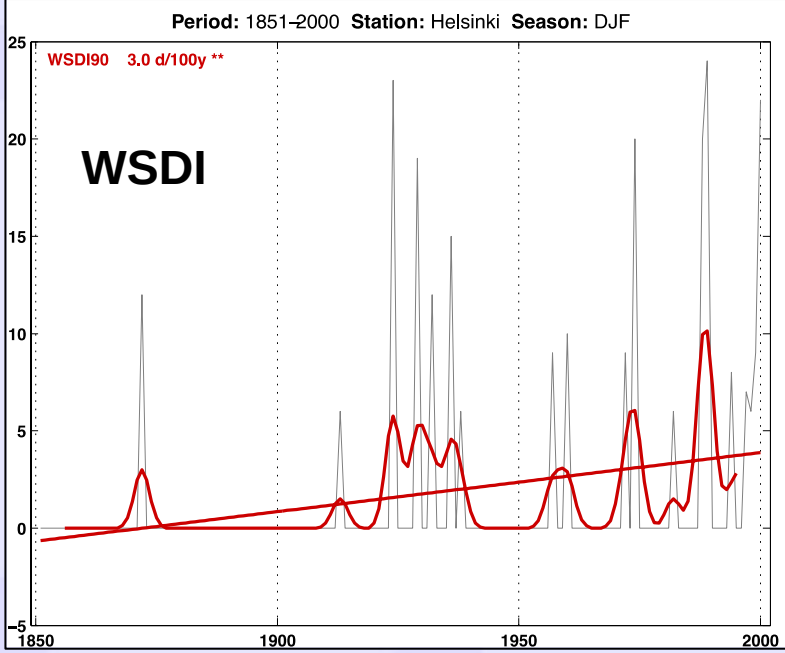
- Data: E-ObsV9.0 daily 0.5x0.5 degree Tmax, Tmin and Prep during 1951-2005 (Haylock *et al.*, 2008)
- 4 annual extreme indices (Donat *et al.*, 2013) with reference period set to 1961-1990 (except for CDD)
  - Consecutive dry days (CDD): Maximum number of consecutive days when precipitation<1mm/day (days)
  - Extremely wet days (R99p): Total precipitation from days >99th percentile (mm)
  - Cold spell duration index (CSDI): Number of days when at least six consecutive days of min temperature <10th percentile (days)
  - Warm spell duration index (WSDI): Number of days when at least six consecutive days of max temperature >90th percentile (days)

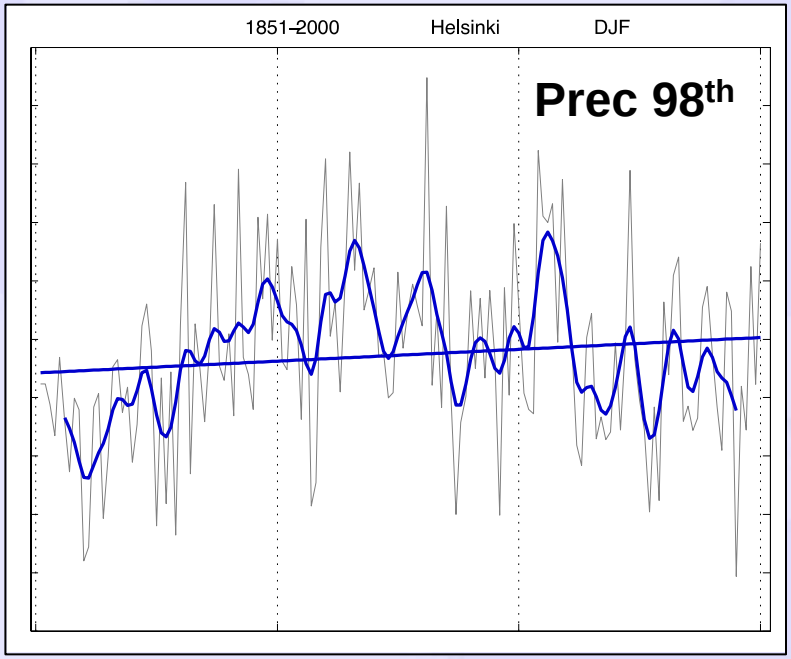
1851-2000

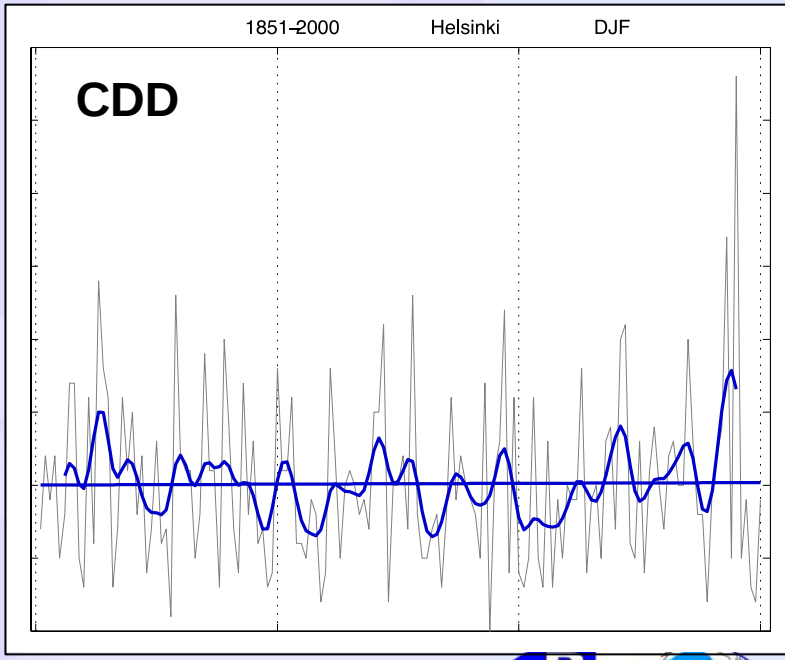
Helsinki

DJF





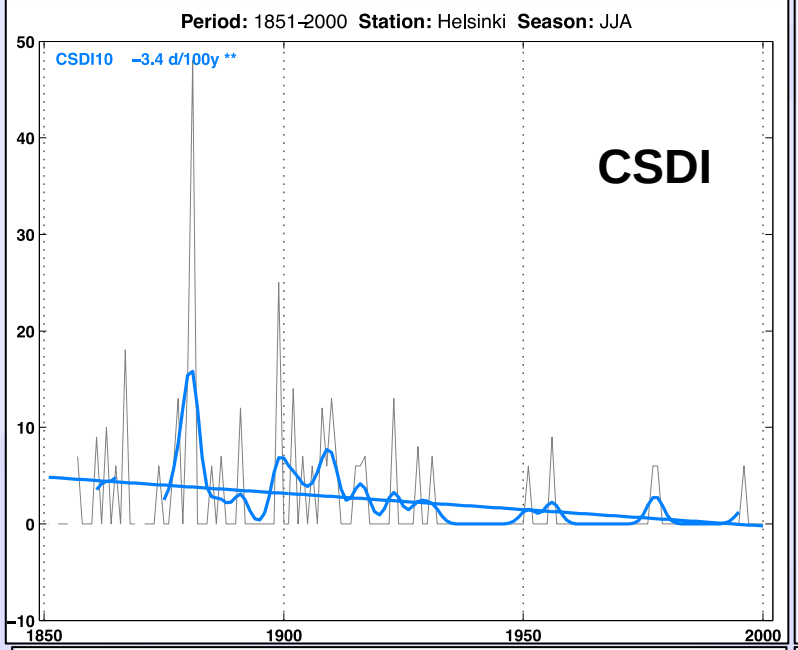


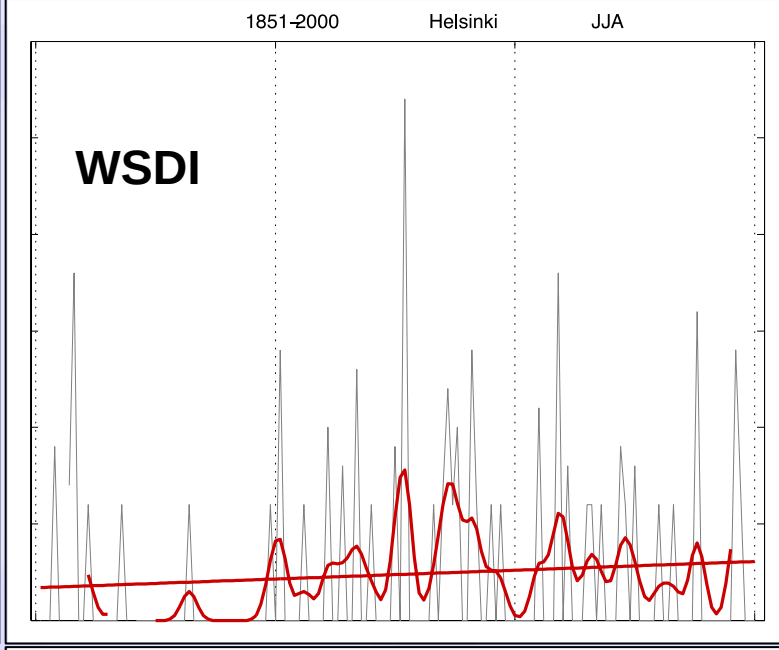


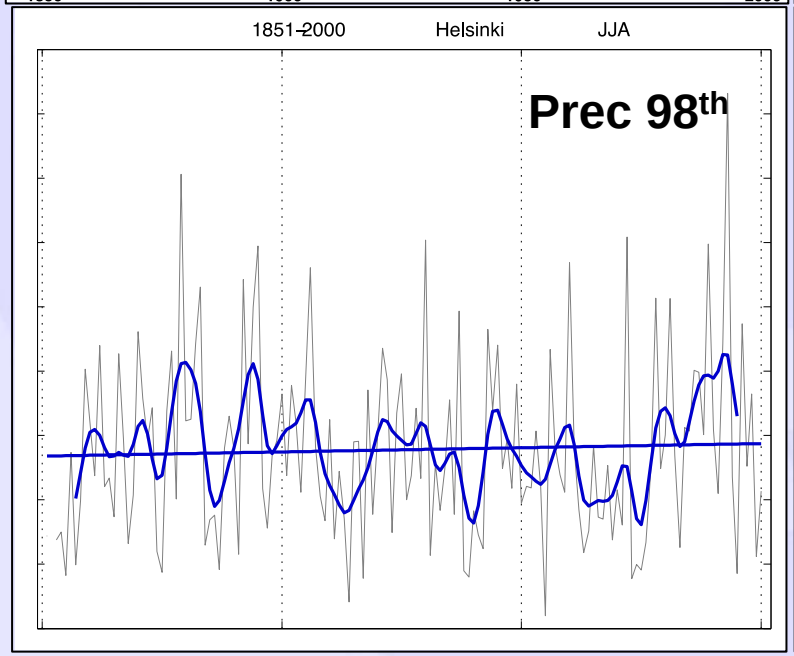
1851-2000

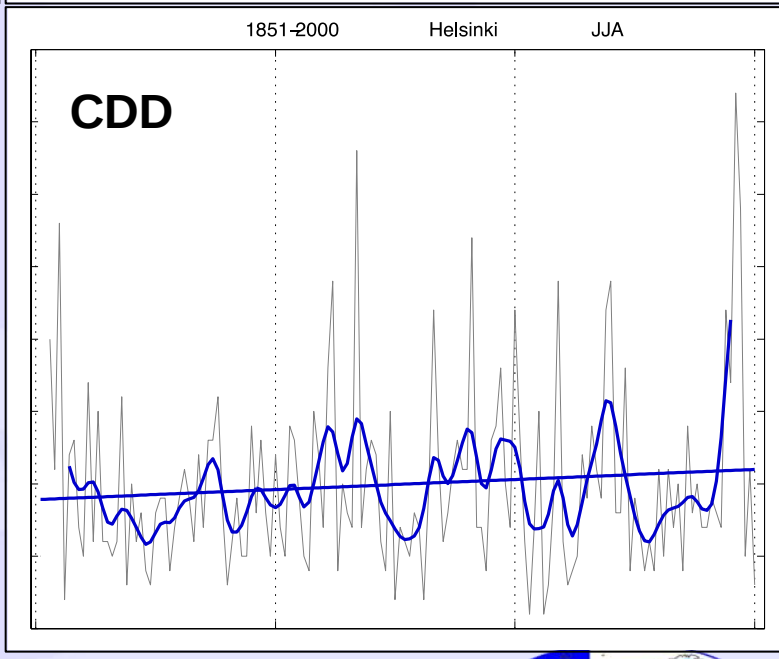
Helsinki

JJA

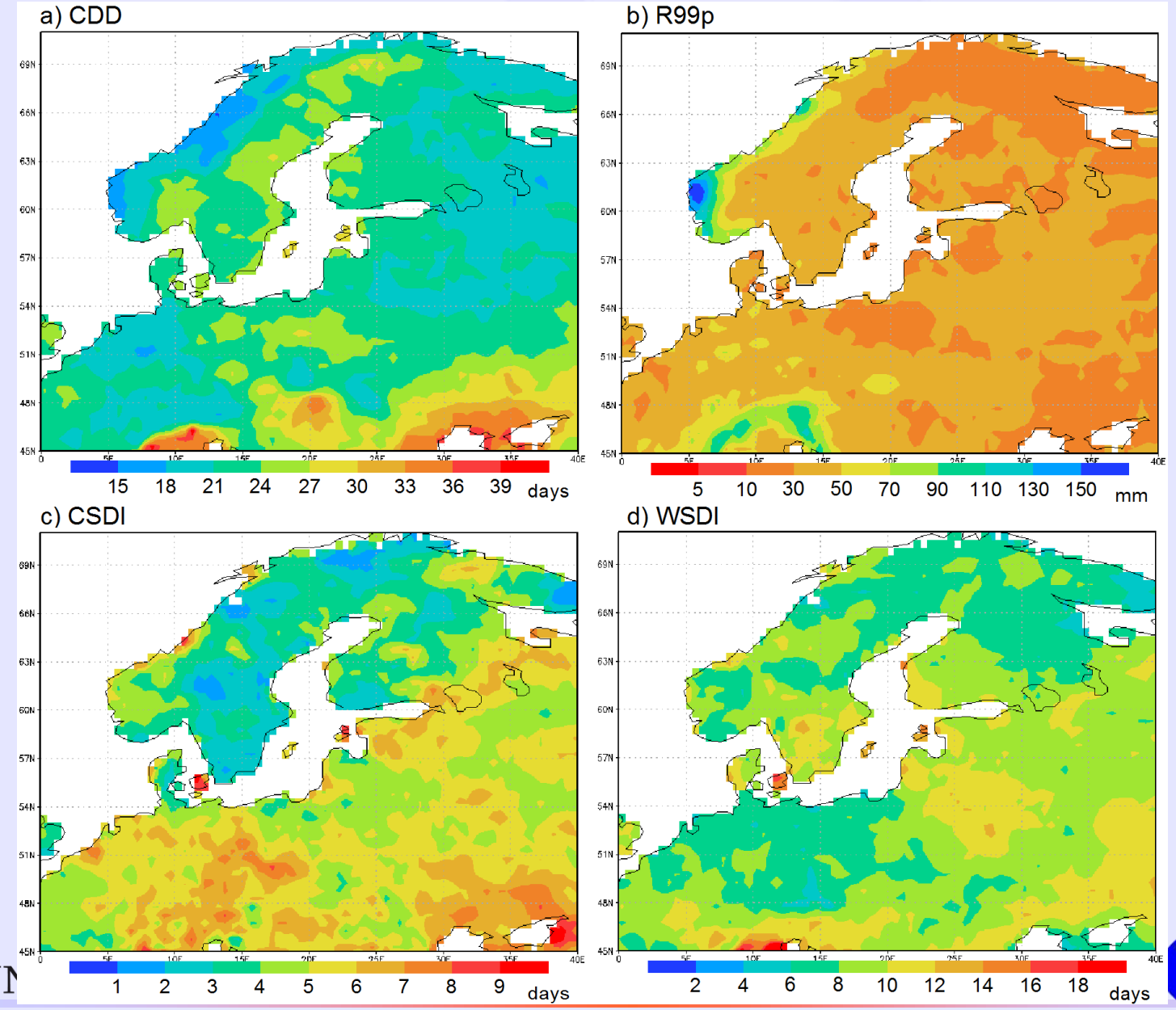








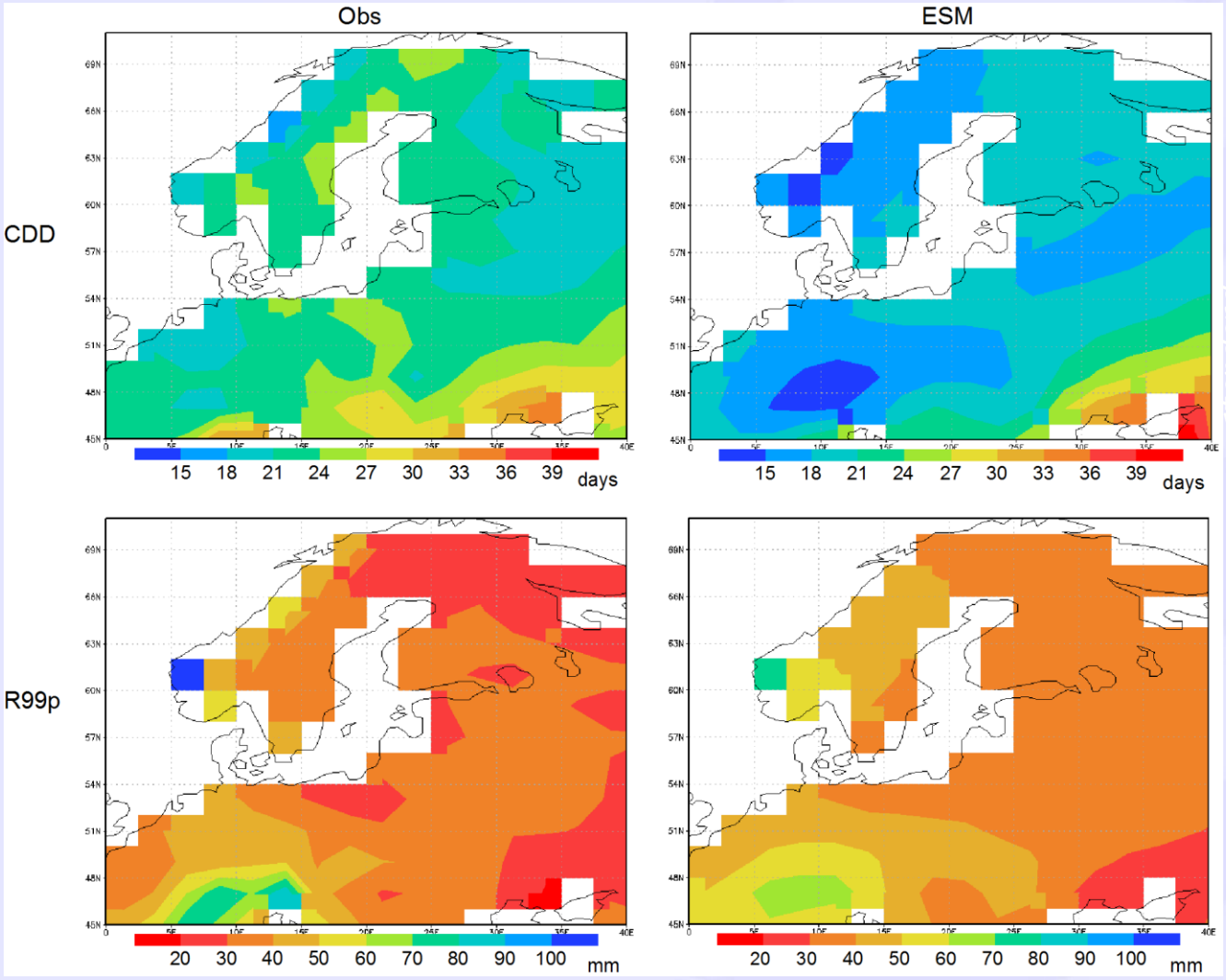
Observed indices averaged during 1951-2005

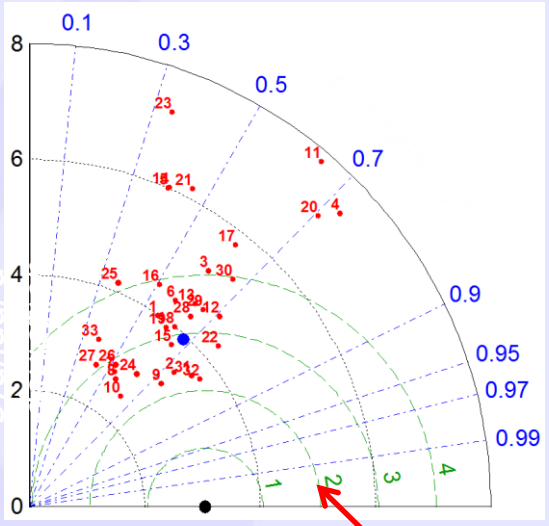


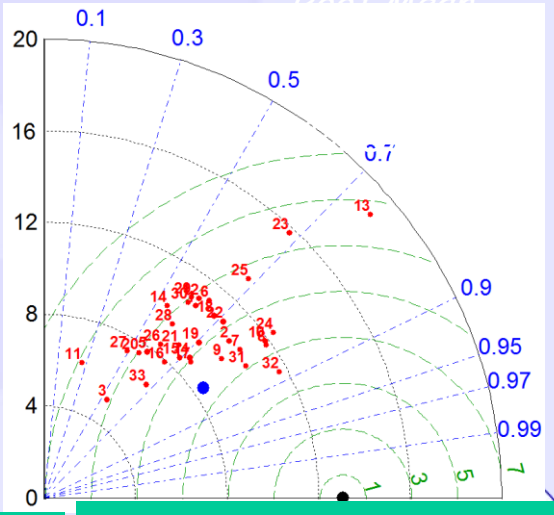
Model name, center and the number in the Taylor diagram

Modeling Center	No.	Model	Modeling Center	No.	Model	Modeling Center	No.	Model
CSIRO-BOM	1	ACCESS1-0	CNRM-CERFACS	13	CNRM-CM5	MIROC	24	MIROC4h
	2	ACCESS1-3	CSIRO-QCCCE	14	CSIRO-Mk3-6-0		25	MIROC5
BCC	3	bcc-csm1-1	NOAA GFDL	15	GFDL-CM3		26	MIROC-ESM
	4	bcc-csm1-1-m		16	GFDL-ESM2G		27	MIROC-ESM-CHEM
GCESS	5	BNU-ESM	MOHC	17	HadCM3	MPI-M	28	MPI-ESM-LR
CCCma	6	CanESM2		18	HadGEM2-CC		29	MPI-ESM-MR
NCAR	7	CCSM4		19	HadGEM2-ES		30	MPI-ESM-P
NSF-DOE-NCAR	8	CESM1-BGC	INM	20	inmcm4	MRI	31	MRI-CGCM3
	9	CESM1-CAM5	IPSL	21	IPSL-CM5A-LR		32	MRI-ESM1
	10	CESM1-FASTCHEM		22	IPSL-CM5A-MR	NCC	33	NorESM1-M
CMCC	11	CMCC-CESM		23	IPSL-CM5B-LR			
	12	CMCC-CMS						

Mean 1951-2005 -- Obs vs. Multi-model ESM focus on spatial distribution



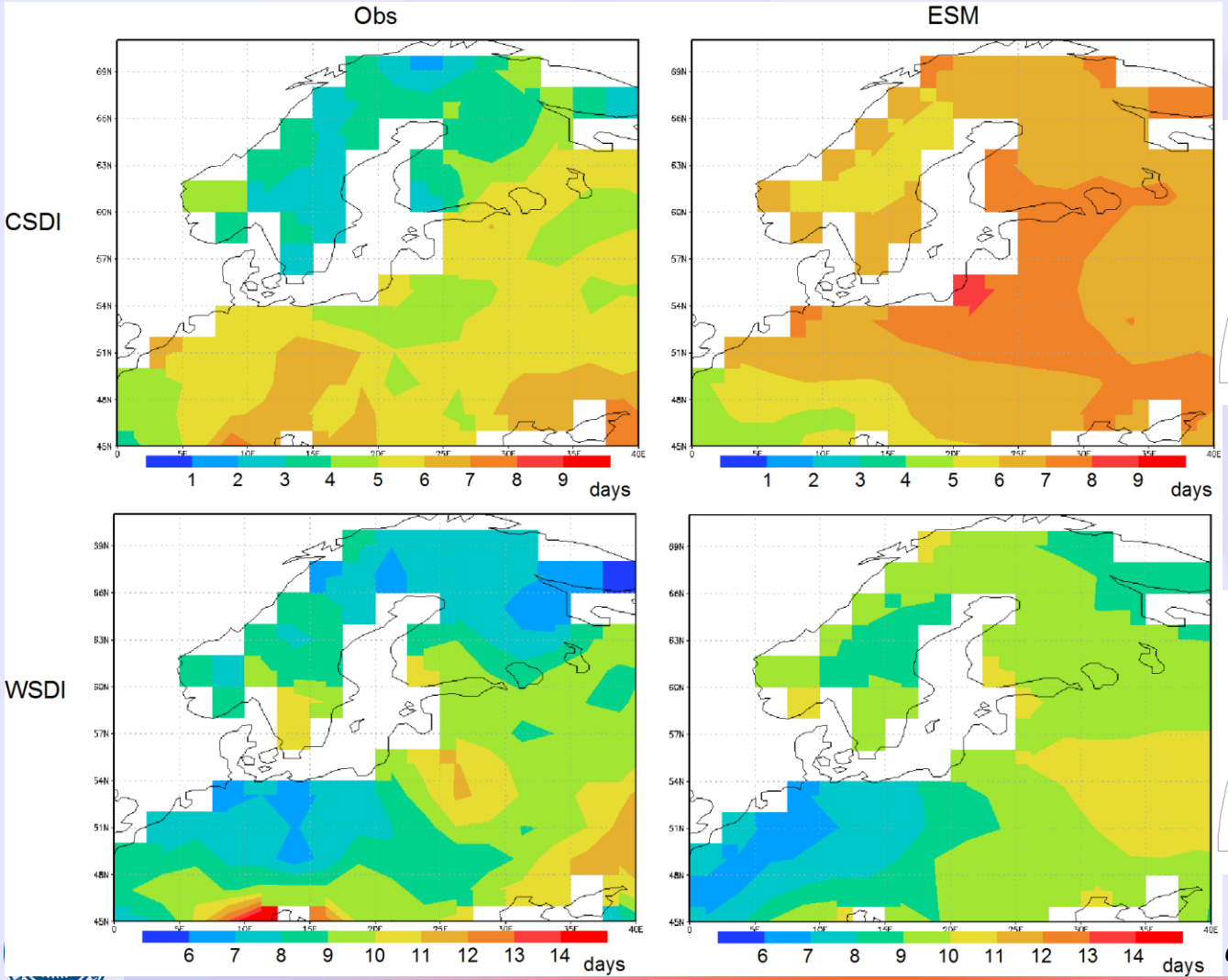


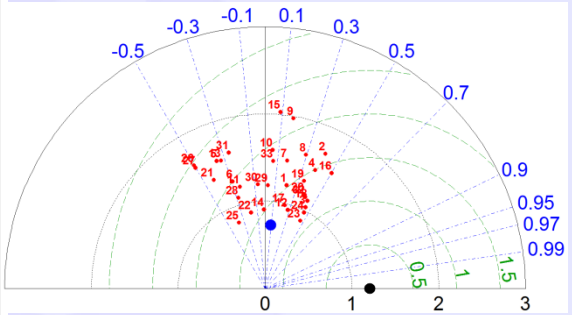


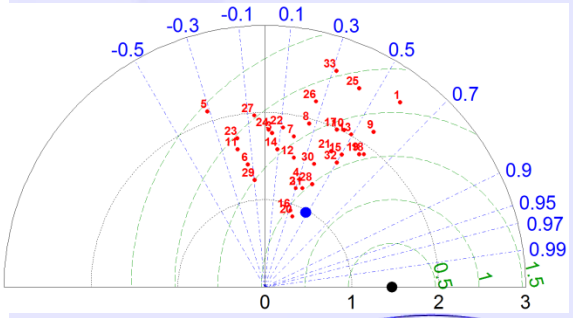
All the data has been regridded onto 2.5x2 (LonxLat) degree resolution

Black: Obs; Blue: ESM

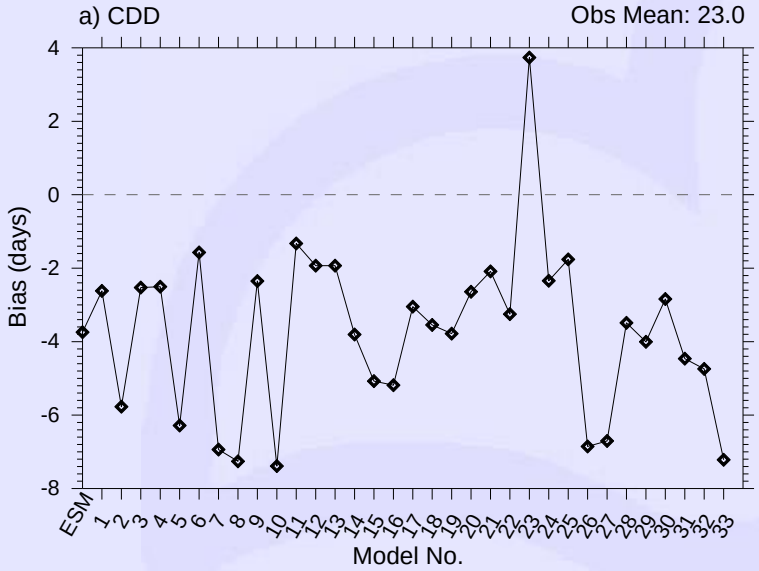
Mean 1951-2005 -- Obs vs. Multi-model ESM

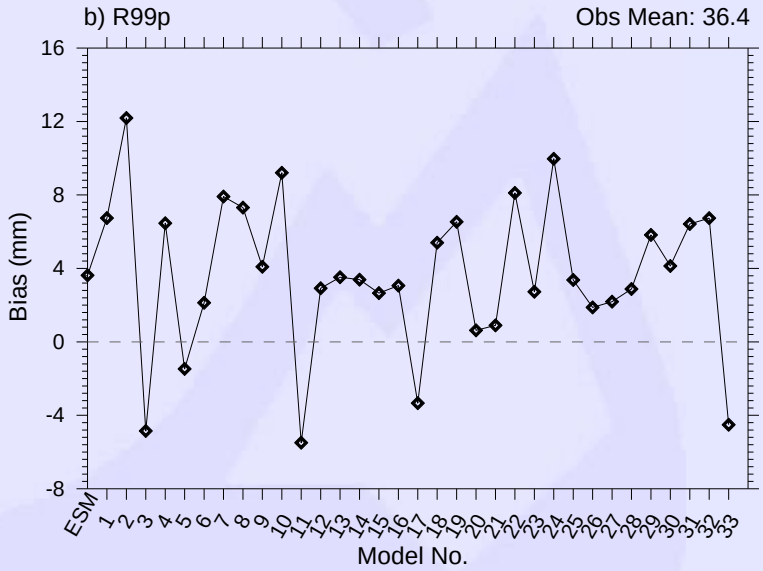


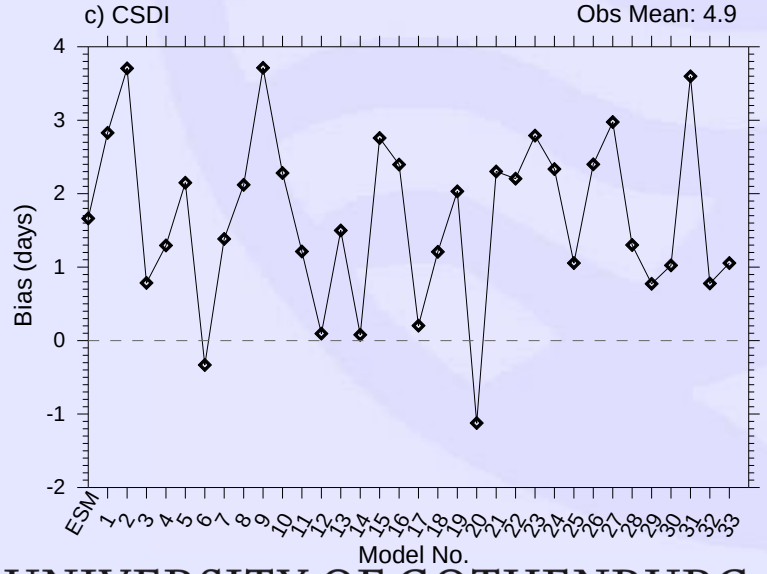


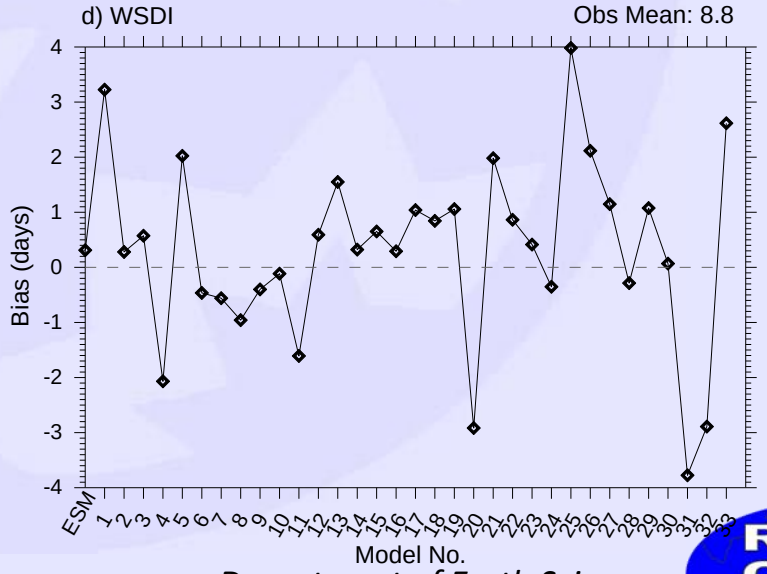


Model bias over GBS during 1951-2005

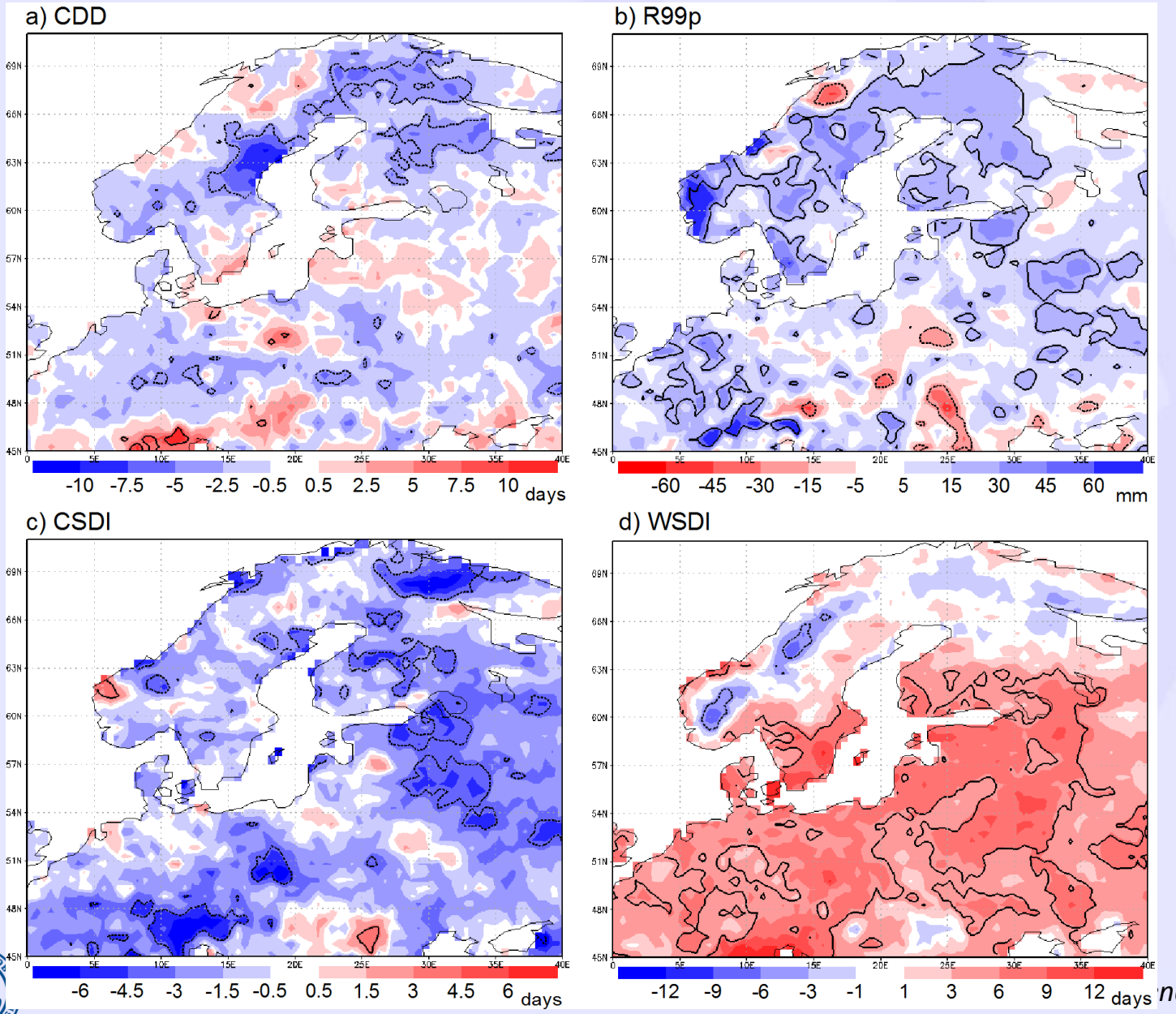






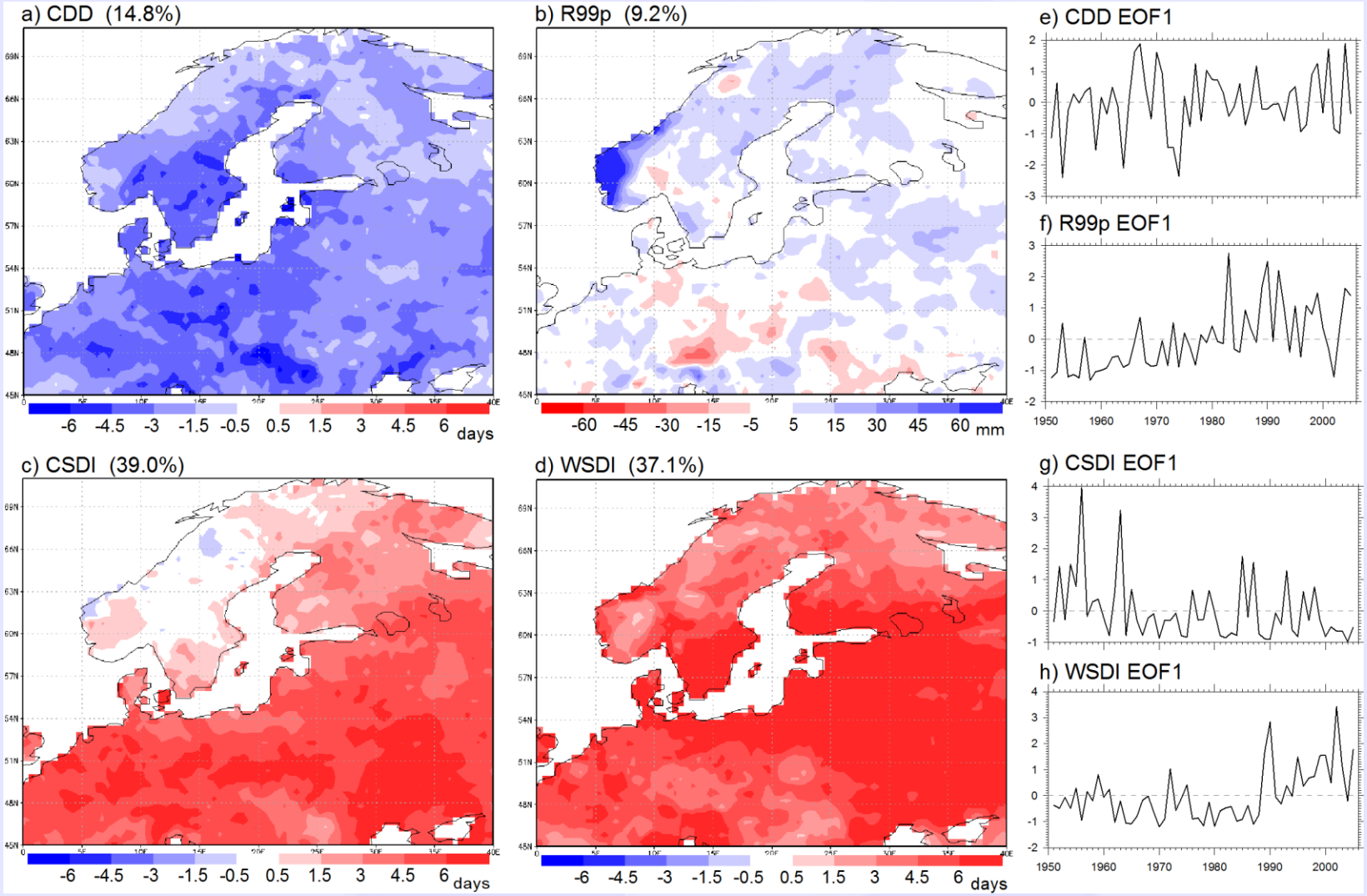


Observed change: [1979-2005] – [1951-1978]



Black lines indicate the regions where the change is significant at the 0.05 level (t-test)

1st EOF pattern



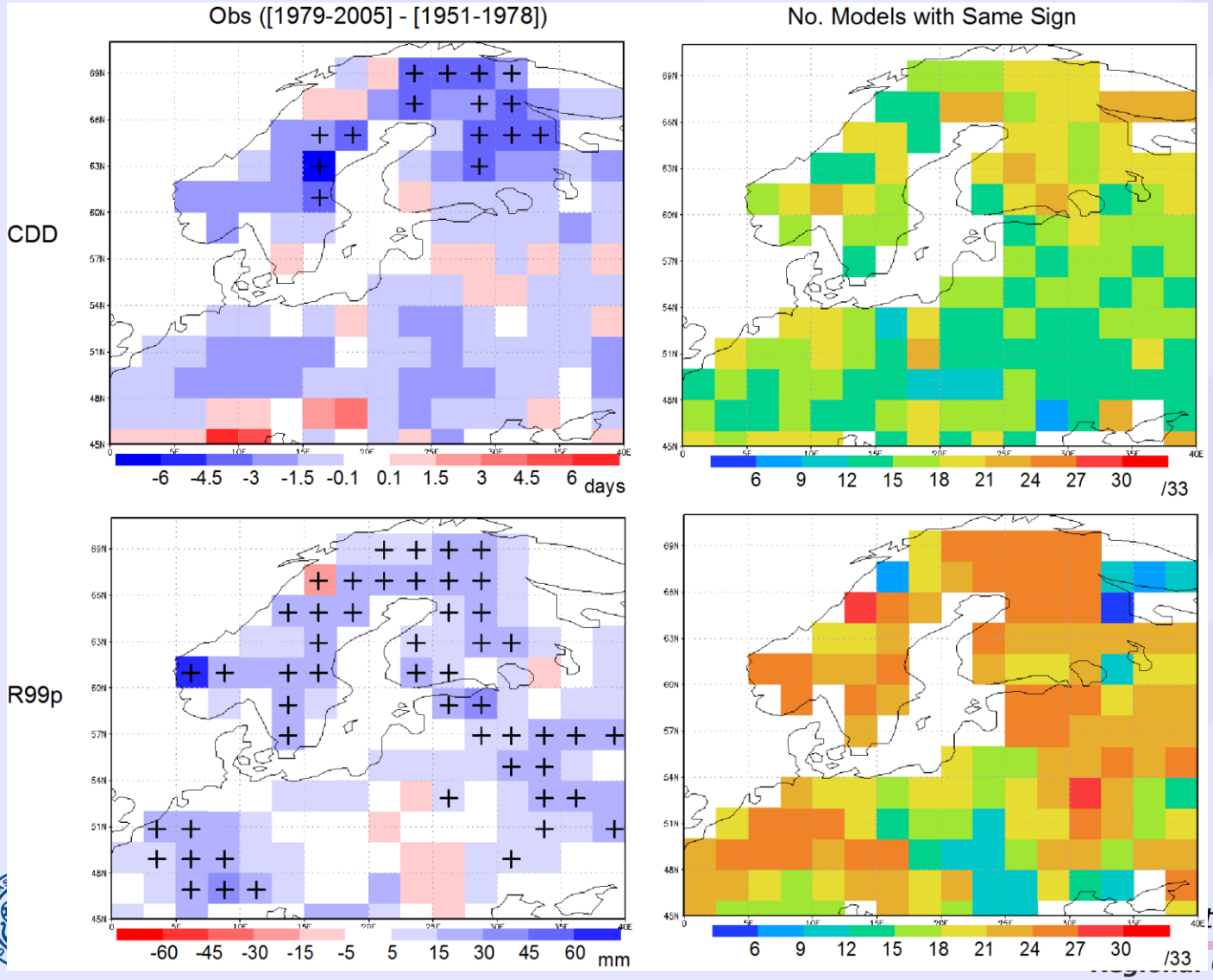
Explained variances for the first 3 EOFs (%)

	CDD	R99p	CSDI	WSDI
EOF1	14.8	9.2	39.0	37.1
EOF2	9.7	6.4	12.1	12.5
EOF3	5.9	4.9	7.0	8.5

Top five models in terms of different annual statistical indicators

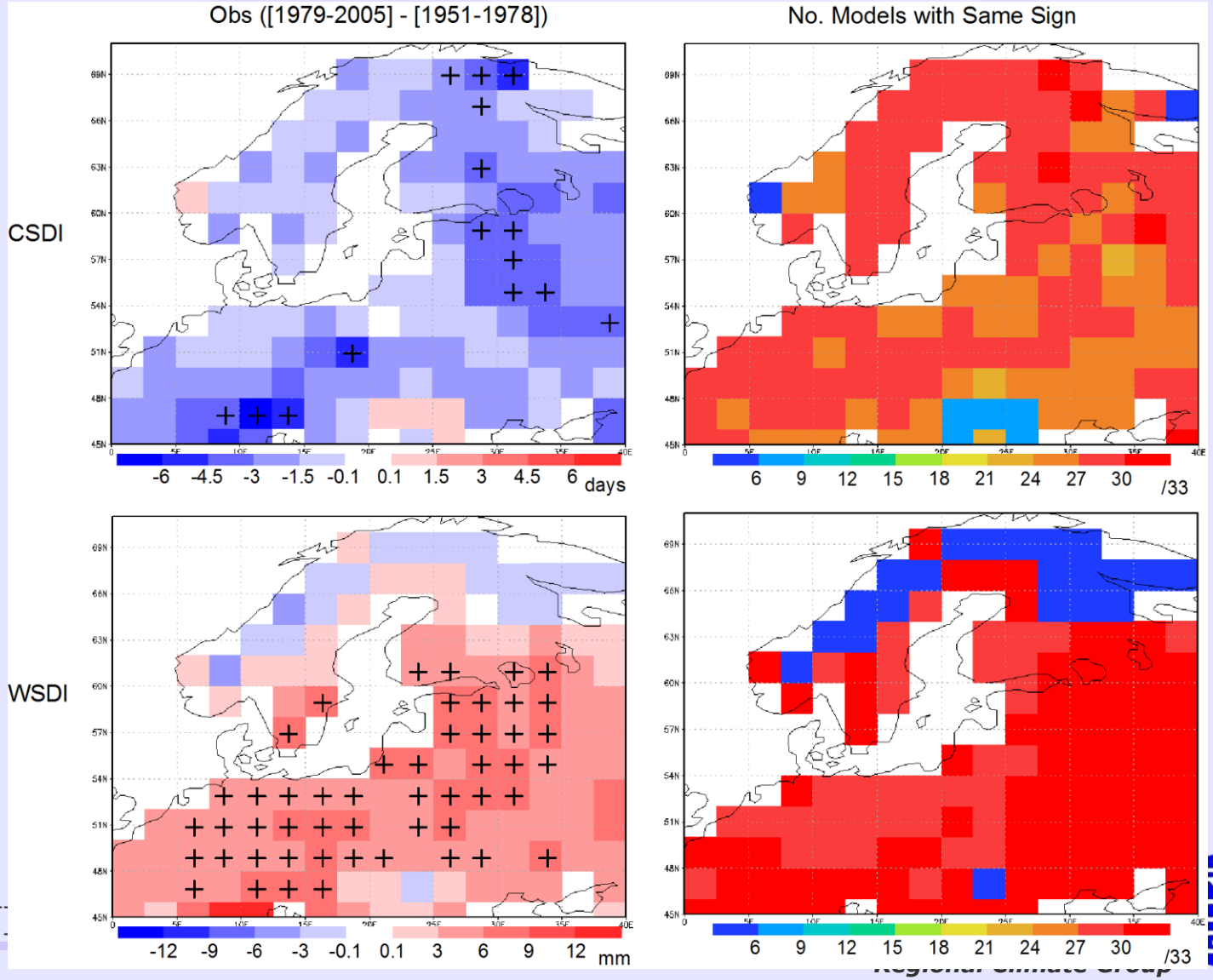
	Rank	1	2	3	4	5
CDD	Bias	CMCC-CESM	CanESM2	MIROC5	CMCC-CMS	CNRM-CM5
	RMSD	MRI-ESM1	CESM1-CAM5	MRI-CGCM3	ACCESS1-3	CESM1-FASTCHEM
	Cor	MRI-ESM1	MRI-CGCM3	IPSL-CM5A-MR	ACCESS1-3	CESM1-CAM5
R99p	Bias	inmcm4	IPSL-CM5A-LR	BNU-ESM	MIROC-ESM	CanESM2
	RMSD	MRI-ESM1	MRI-CGCM3	CESM1-BGC	CESM1-FASTCHEM	MIROC4h
	Cor	MRI-ESM1	MRI-CGCM3	CESM1-BGC	CESM1-FASTCHEM	MIROC4h
CSDI	Bias	CSIRO-Mk3.6.0	CMCC-CMS	HadCM3	CanESM2	MPI-ESM-MR
	RMSD	IPSL-CM5B-LR	MIROC4h	bcc-csm1-1	HadGEM2-CC	MRI-ESM1
	Cor	GFDL-ESM2G	IPSL-CM5B-LR	MIROC4h	bcc-csm1-1	HadGEM2-CC
WSDI	Bias	MPI-ESM-P	CESM1-FASTCHEM	ACCESS1-3	MPI-ESM-LR	GFDL-ESM2G
	RMSD	inmcm4	GFDL-ESM2G	MPI-ESM-LR	MRI-CGCM3	HadGEM2-CC
	Cor	HadGEM2-CC	ACCESS1-0	HadGEM2-ES	CESM1-CAM5	GFDL-CM3

Number of models have the same sign for the change of extreme indices



Cross indicates grid at which the change ([1979-2005] - [1951-1978]) is significant at the 0.05 level (t-test)

Number of models have the same sign for the change of extreme indices



Conclusion

- CDD significantly decreased in the northern part of GBS with the significantly increased extreme precipitation; Cold events significantly decreased in the east and southwest of GBS and warm events significantly increased over middle to south of GBS;
- The observed climatology of precipitation extremes can be reasonably reproduced by multi-model ESM while that of temperature extremes is poorly reproduced;
- Most models can capture the increased extreme precipitation over northern part of GBS.

Reference

- Donat, M. G., et al. (2013), Updated analyses of temperature and precipitation extreme indices since the beginning of the twentieth century: The HadEX2 dataset, J. Geophys. Res. Atmos., 118, doi:10.1002/jgrd.50150.
- Haylock, M.R., N. Hofstra, A.M.G. Klein Tank, E.J. Klok, P.D. Jones, M. New. 2008: A European daily high-resolution gridded dataset of surface temperature and precipitation. J. Geophys. Res (Atmospheres), 113, D20119, doi:10.1029/2008JD10201.