



# Combining global and regional models to “fill the matrix”

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## PRINCIPLES (COPERNICUS C3S\_34b\_Lot2)

- Aim of supplementing existing EUR-11 ensemble for the benefit of the COPERNICUS Climate Data Store
- 9 RCM partners:
  - SMHI RCA4
  - DMI HIRHAM5
  - ETHZ CcrCLM
  - KNMI RACMO22E
  - MF ALADIN63
  - ICTP RegCM4.6.1
  - UKMO HadGEM3-RA
  - IPSL WRF381P
  - GERICS REMO2015
- Budget of around 60-70 new (single-RCP) simulations, or a rough doubling of the existing amount in 4 years.



## Design of the PRINCIPLES matrix

- ECMWF asked for a high degree of completely filled sub-matrices, as opposed to homogeneous filling
  - Good and bad sides: less approximations in filling out holes, but lesser representation of variability
- Complication: Model versions change, so what is a filled matrix??
- Ad-hoc decision was made:
  - REMO 2009 = REMO2015
  - CCLM4-8-17  $\neq$  CcrCLM
  - WRF361H  $\neq$  WRF381P
  - ALADIN53  $\neq$  ALADIN63



RCP8.5	RCA4	CCLM4-8-17	CcrCLM	REMO09,15	RACMO22E	HIRHAM5	WRF361H	WRF381P	ALADIN53	ALADIN63	RegCM4.6.1	HadRM3-GA7.05	Total now
MOHC-HadGEM2-ES	1	1		1	1	1	1	1		1	1	1	8
ICHEC-EC-EARTH	3	1	(3)	1	3	3	1						12
CNRM-CERFACS-CNRM-CM5	1	1		1	1	1			1	1			7
NCC-NorESM1-M	1		1	1	1	1		1					6
MPI-M-MPI-ESM-LR	1(+2)	1	3	2+1	1		1				1		10
IPSL-IPSL-CM5A-MR	1							1					2
CCCma-CanESM2		1		1									2
MIROC-MIROC5		1		1									2
Current status	8	6	4	9	7	6	3	3	1	2	2	1	52
Remaining	2	0	5	1	1	2	0	3	0	2	3	4	23
RCP4.5	RCA4	CCLM4-8-17	CcrCLM	REMO09,15	RACMO22E	HIRHAM5	WRF361H	WRF381P	ALADIN53	ALADIN63	RegCM4.6.1	HadGEM3-RA	Total now
MOHC-HadGEM2-ES	1	1			1								2
ICHEC-EC-EARTH	1	1			2	1							4
CNRM-CERFACS-CNRM-CM5	1	1			1				1				3
NCC-NorESM1-M					1	1							2
MPI-M-MPI-ESM-LR	1	1		2									3
IPSL-IPSL-CM5A-MR	1						1	1					3
Current status	5	4	0	2	5	2	1	1	1	0	0	0	17
Remaining	0	0	0	3	0	1	0	0	0	1	0	0	5
RCP2.6	RCA4	CCLM4-8-17	CcrCLM	REMO09,15	RACMO22E	HIRHAM5	WRF361H	WRF381P	ALADIN53	ALADIN63	RegCM4.6.1	HadGEM3-RA	Total now
MOHC-HadGEM2-ES	1			1	1						1		3
ICHEC-EC-EARTH	1	1		1	1	1							5
CNRM-CERFACS-CNRM-CM5					1				1	1			3
NCC-NorESM1-M	1			1									2
MPI-M-MPI-ESM-LR	1	1		2			1						5
IPSL-IPSL-CM5A-MR													0
Current status	4	2	0	5	3	1	1	0	1	1	1	0	18
Remaining	1	0	0	1	2	1	0	0	0	0	2	2	8
Total remaining in project	3		5	5	3	4		3		3	5	6	37



Climate  
Change

## PRINCIPLES

# Many sub-matrices filled this way

- -But, some holes remain.

RCP8.5	RCA4	CCLM4-8-17	CcrCL M	REMO 09,15	RACMO2 2E	HIRHA M5	WRF36 1H	WRF38 1P	ALADIN 53	ALADIN 63	RegCM4. 6.1	HadRM3-GA7.05	Total now
MOHC-HadGEM2-ES	1	1		1	1	1	1	1		1	1	1	10
ICHEC-EC-EARTH	3	1	(3)	1	3	3	1						12
CNRM-CERFACS-CNRM-CM5	1	1		1	1	1			1	1			7
NCC-NorESM1-M	1		1	1	1	1		1					6
MPI-M-MPI-ESM-LR	1(+2)	1	3	2+1	1		1				1		11
IPSL-IPSL-CM5A-MR	1				1			1					3
CCCma-CanESM2		1		1									2
MIROC-MIROC5		1		1									2
Current status	8	6	4	9	8	6	3	3	1	2	2	1	53
Remaining	2	0	5	1	0	2	0	3	0	2	3	4	22
RCP4.5	RCA4	CCLM4-8-17	CcrCL M	REMO 09,15	RACMO2 2E	HIRHA M5	WRF36 1H	WRF38 1P	ALADIN 53	ALADIN 63	RegCM4. 6.1	HadGEM3-RA	Total now
MOHC-HadGEM2-ES	1	1			1								2
ICHEC-EC-EARTH	1	1			2	1							4
CNRM-CERFACS-CNRM-CM5	1	1			1				1				3
NCC-NorESM1-M					1	1							2
MPI-M-MPI-ESM-LR	1	1		2									3
IPSL-IPSL-CM5A-MR	1						1	1					3
Current status	5	4	0	2	5	2	1	1	1	0	0	0	17
Remaining	0	0	0	3	0	1	0	0	0	1	0	0	5
RCP2.6	RCA4	CCLM4-8-17	CcrCL M	REMO 09,15	RACMO2 2E	HIRHA M5	WRF36 1H	WRF38 1P	ALADIN 53	ALADIN 63	RegCM4. 6.1	HadGEM3-RA	Total now
MOHC-HadGEM2-ES	1												3
ICHEC-EC-EARTH	1												5
CNRM-CERFACS-CNRM-CM5													3
NCC-NorESM1-M	1			1									2
MPI-M-MPI-ESM-LR	1	1		2			1						5
IPSL-IPSL-CM5A-MR													0
Current status	4	2	0	5	3	1	1	0	1	1	1	0	18
Remaining	1	0	0	1	2	1	0	0	0	0	2	2	8
Total remaining in project	3		5	5	3	4		3		3	5	6	37

(SGRE)=1x4x4x1

First results shown in a minute

RCP8.5	RCA4	CCLM4-8-17	CcrCL M	REMO 09,15	RACMO2 2E	HIRHA M5	WRF36 1H	WRF38 1P	ALADIN 53	ALADIN 63	RegCM4. 6.1	HadRM3-GA7.05	Total now
MOHC-HadGEM2-ES	1	1		1	1	1	1	1		1	1	1	10
ICHEC-EC-EARTH	3	1	(3)	1	3	3	1						12
CNRM-CERFACS-CNRM-CM5	1	1		1	1	1			1	1			7
NCC-NorESM1-M	1		1	1	1	1		1					6
MPI-M-MPI-ESM-LR	1(+2)	1	3	2+1	1		1				1		11
IPSL-IPSL-CM5A-MR	1				1			1					3
CCCma-CanESM2		1		1									2
MIROC-MIROC5		1		1									2
Current status	8	6	4	9	8	6	3	3	1	2	2	1	53
Remaining	2	0	5	1	0	2	0	3	0	2	3	4	22
RCP4.5	RCA4	CCLM4-8-17	CcrCL M	REMO 09,15	RACMO2 2E	HIRHA M5	WRF36 1H	WRF38 1P	ALADIN 53	ALADIN 63	RegCM4. 6.1	HadGEM3-RA	Total now
MOHC-HadGEM2-ES	1	1			1								2
ICHEC-EC-EARTH	1	1			2	1							4
CNRM-CERFACS-CNRM-CM5	1	1			1				1				3
NCC-NorESM1-M					1	1							2
MPI-M-MPI-ESM-LR	1	1		2									3
IPSL-IPSL-CM5A-MR	1						1	1					3
Current status	5	4	0	2	5	2	1	1	1	0	0	0	17
Remaining	0	0	0	3	0	1	0	0	0	1	0	0	5
RCP2.6	RCA4	CCLM4-8-17	CcrCL M	REMO 09,15	RACMO2 2E	HIRHA M5	WRF36 1H	WRF38 1P	ALADIN 53	ALADIN 63	RegCM4. 6.1	HadGEM3-RA	Total now
MOHC-HadGEM2-ES													3
ICHEC-EC-EARTH													5
CNRM-CERFACS-CNRM-CM5													3
NCC-NorESM1-M	1			1									2
MPI-M-MPI-ESM-LR	1	1		2			1						5
IPSL-IPSL-CM5A-MR													0
Current status	4	2	0	5	3	1	1	0	1	1	1	0	18
Remaining	1	0	0	1	2	1	0	0	0	0	2	2	8
Total remaining in project	3		5	5	3	4		3		3	5	6	37

$$(SGRE) = 1 \times 5 \times 9 \times 1 - 1$$



RCP8.5	RCA4	CCLM4-8-17	CcrCLM	REMO09,15	RACMO22E	HIRHAM5	WRF361H	WRF381P	ALADIN53	ALADIN63	RegCM4.6.1	HadRM3-GA7.05	Total now
MOHC-HadGEM2-ES	1	1		1	1	1	1	1		1	1	1	10
ICHEC-EC-EARTH	3	1	(3)	1	3	3	1						12
CNRM-CERFACS-CNRM-CM5	1	1		1	1	1			1	1			7
NCC-NorESM1-M	1		1	1	1	1		1					6
MPI-M-MPI-ESM-LR	1(+2)	1	3	2+1	1		1				1		11
IPSL-IPSL-CM5A-MR	1				1			1					3
CCCma-CanESM2		1		1									2
MIROC-MIROC5		1		1									2
Current status	8	6	4	9	8	6	3	3	1	2	2	1	53
Remaining	2	0	5	1	0	2	0	3	0	2	3	4	22
RCP4.5	RCA4	CCLM4-8-17	CcrCLM	REMO09,15	RACMO22E	HIRHAM5	WRF361H	WRF381P	ALADIN53	ALADIN63	RegCM4.6.1	HadGEM3-RA	Total now
MOHC-HadGEM2-ES	1	1			1								2
ICHEC-EC-EARTH	1	1			2	1							4
CNRM-CERFACS-CNRM-CM5	1	1			1				1				3
NCC-NorESM1-M													
MPI-M-MPI-ESM-LR	1	1											
IPSL-IPSL-CM5A-MR	1												
Current status	5	4											
Remaining	0	0											
RCP2.6	RCA4	CCLM4-8-17	M	09,15	2E	M5	1H	1P	53	63	6.1	-RA	now
MOHC-HadGEM2-ES	1			1	1						1		3
ICHEC-EC-EARTH	1	1		1	1	1							5
CNRM-CERFACS-CNRM-CM5					1				1	1			3
NCC-NorESM1-M	1			1									2
MPI-M-MPI-ESM-LR	1	1		2			1						5
IPSL-IPSL-CM5A-MR													0
Current status	4	2	0	5	3	1	1	0	1	1	1	0	18
Remaining	1	0	0	1	2	1	0	0	0	0	2	2	8
Total remaining in project	3		5	5	3	4		3		3	5	6	37

(SGRE)=1x1x4x3

Internal variability of GCM

RCP8.5	RCA4	CCLM4-8-17	CcrCL M	REMO 09,15	RACMO2 2E	HIRHA M5	WRF36 1H	WRF38 1P	ALADIN 53	ALADIN 63	RegCM4. 6.1	HadRM3-GA7.05	Total now
MOHC-HadGEM2-ES	1	1		1	1	1	1	1		1	1	1	10
ICHEC-EC-EARTH	3	1	(3)	1	3	3	1						12
CNRM-CERFACS-CNRM-CM5	1	1		1	1	1			1	1			7
NCC-NorESM1-M	1		1	1	1	1		1					6
MPI-M-MPI-ESM-LR	1(+2)	1	3	2+1	1		1				1		11
IPSL-IPSL-CM5A-MR	1				1			1					3
CCCma-CanESM2		1		1									2
MIROC-MIROC5		1		1									2
Current status	8	6	4	9	8	6	3	3	1	2	2	1	53
Remaining	2	0	5	1	0	2	0	3	0	2	3	4	22
RCP4.5	RCA4	CCLM4-8-17	CcrCL M	REMO 09,15	RACMO2 2E	HIRHA M5	WRF36 1H	WRF38 1P	ALADIN 53	ALADIN 63	RegCM4. 6.1	HadGEM3-RA	Total now
MOHC-HadGEM2-ES	1	1			1								2
ICHEC-EC-EARTH	1	1			2	1							-
CNRM-CERFACS-CNRM-CM5	1	1			1								
NCC-NorESM1-M					1	1							
MPI-M-MPI-ESM-LR	1	1		2									
IPSL-IPSL-CM5A-MR	1												
Current status	5	4	0	2	5	2							
Remaining	0	0	0	3	0	1							
RCP2.6	RCA4	CCLM4-8-17	CcrCL M	REMO 09,15	RACMO2 2E	HIRHA M5	WRF36 1H	WRF38 1P	ALADIN 53	ALADIN 63	RegCM4. 6.1	HadGEM3-RA	Total now
MOHC-HadGEM2-ES	1			1	1						1		3
ICHEC-EC-EARTH	1	1		1	1	1							5
CNRM-CERFACS-CNRM-CM5					1				1	1			3
NCC-NorESM1-M	1			1									2
MPI-M-MPI-ESM-LR	1	1		2			1						5
IPSL-IPSL-CM5A-MR													0
Current status	4	2	0	5	3	1	1	0	1	1	1	0	18
Remaining	1	0	0	1	2	1	0	0	0	0	2	2	8
Total remaining in project	3		5	5	3	4		3		3	5	6	37

(SGRE)=3x2x4x1  
Effects of scenario on GCM-RCM results

RCP8.5	RCA4	CCLM4-8-17	CcrCL M	REMO 09,15	RACMO2 2E	HIRHA M5	WRF36 1H	WRF38 1P	ALADIN 53	ALADIN 63	RegCM4. 6.1	HadRM3-GA7.05	Total now
MOHC-HadGEM2-ES	1	1		1	1	1	1	1		1	1	1	10
ICHEC-EC-EARTH	3	1	(3)	1	3	3	1						12
CNRM-CERFACS-CNRM-CM5	1	1		1	1	1			1	1			7
NCC-NorESM1-M	1		1	1	1	1		1					6
MPI-M-MPI-ESM-LR	1(+2)	1	3	2+1	1		1				1		11
IPSL-IPSL-CM5A-MR	1				1			1					3
CCCma-CanESM2		1		1									2
MIROC-MIROC5		1		1									2
Current status	8	6	4	9	8	6	3	3	1	2	2	1	53
Remaining	2	0	5	1	0	2	0	3	0	2	3	4	22

RCP4.5	RCA4	CCLM4-8-17	CcrCL M	REMO 09,15	RACMO2 2E	HIRHA M5	WRF36 1H	WRF38 1P	ALADIN 53	ALADIN 63	RegCM4. 6.1	HadGEM3-RA	Total now
MOHC-HadGEM2-ES	1	1			1								2
ICHEC-EC-EARTH	1	1			2	1							4
CNRM-CERFACS-CNRM-CM5	1	1			1				1				3
NCC-NorESM1-M					1	1							2
MPI-M-MPI-ESM-LR	1	1		2									3
IPSL-IPSL-CM5A-MR	1						1						1
Current status	5	4	0	2	5	2	1						18
Remaining	0	0	0	3	0	1	0						8

(SGRE)=3x4x5x1 -8

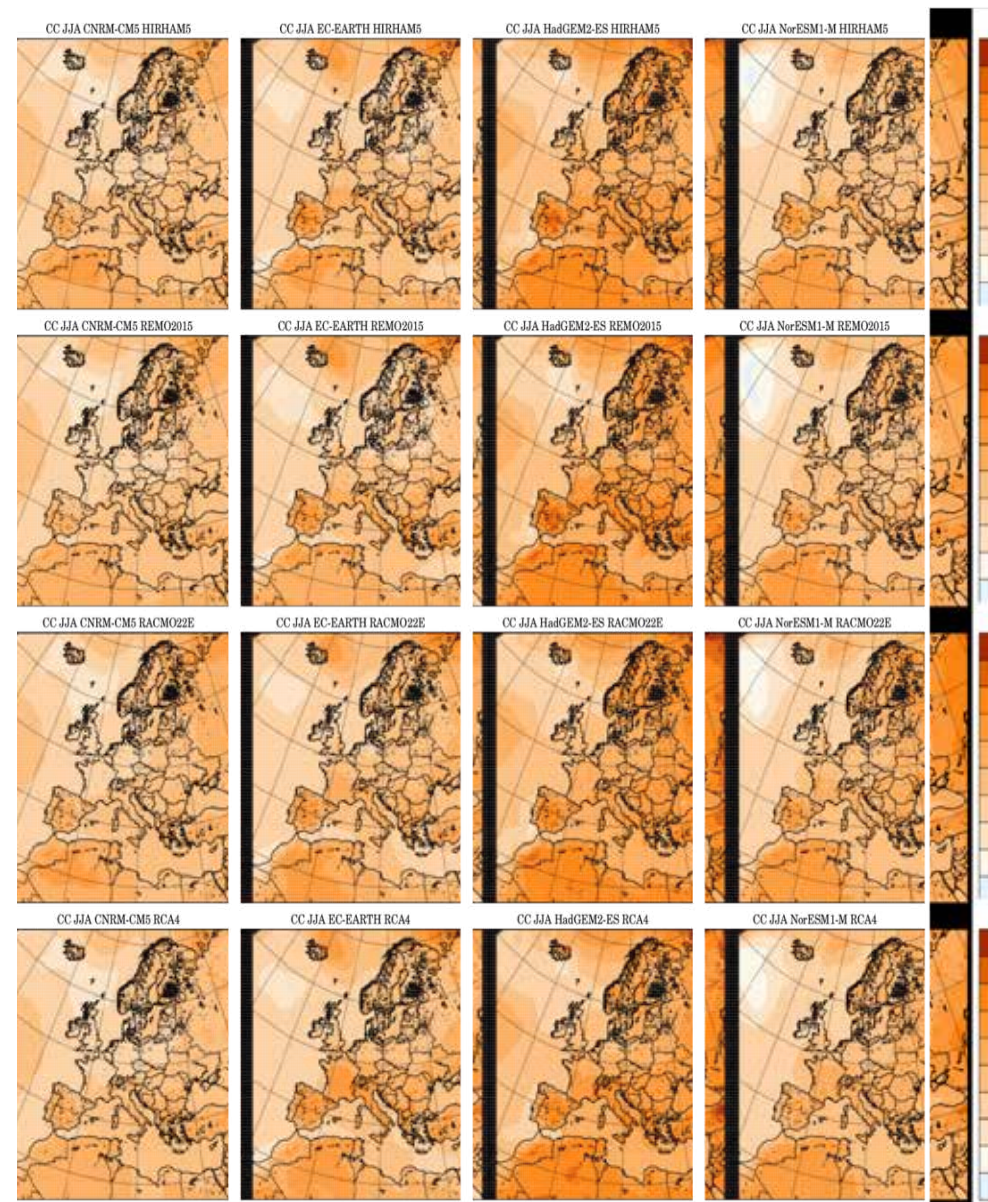
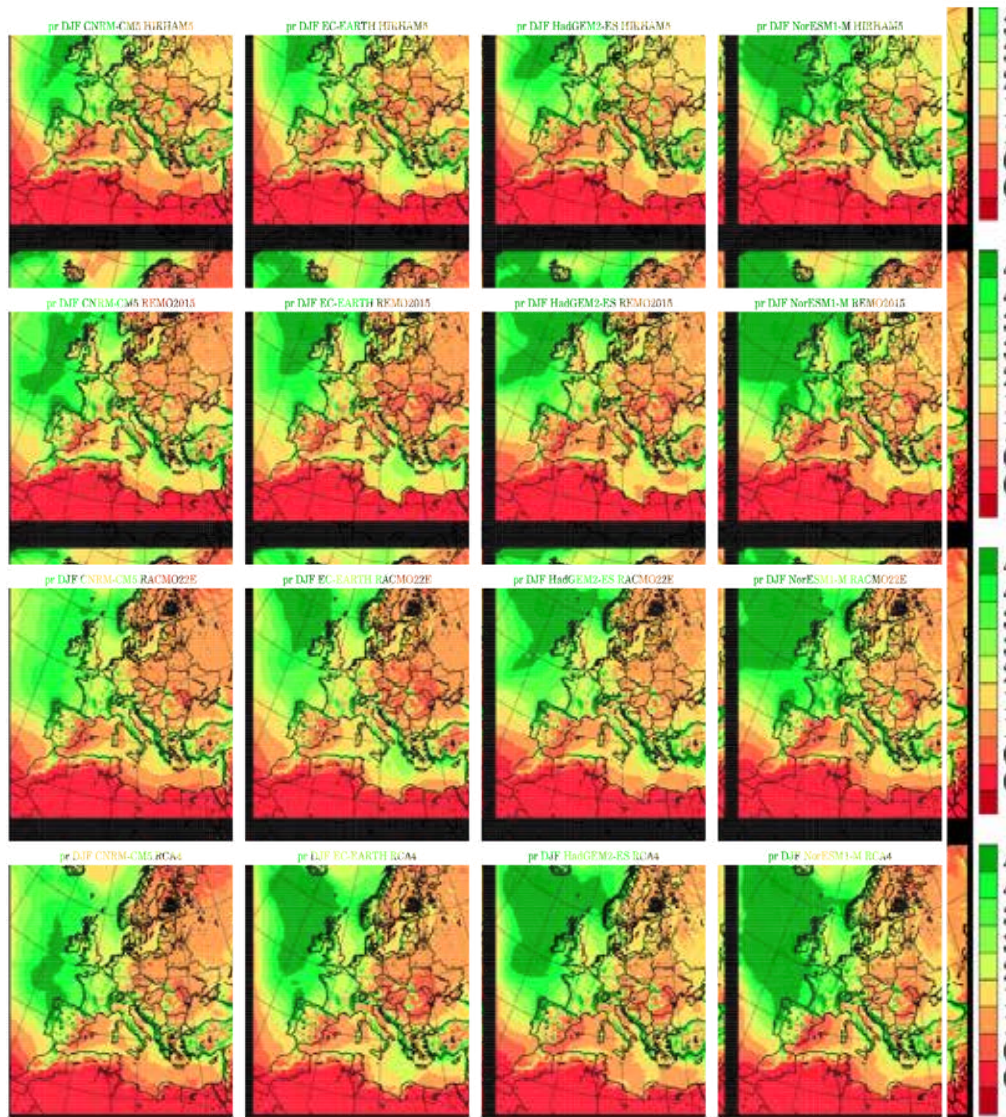
RCP2.6	RCA4	CCLM4-8-17	CcrCL M	REMO 09,15	RACMO2 2E	HIRHA M5	WRF36 1H	WRF38 1P	ALADIN 53	ALADIN 63	RegCM4. 6.1	HadGEM3-RA	Total now
MOHC-HadGEM2-ES	1			1	1						1		3
ICHEC-EC-EARTH	1	1		1	1	1							5
CNRM-CERFACS-CNRM-CM5					1				1	1			3
NCC-NorESM1-M	1			1									2
MPI-M-MPI-ESM-LR	1	1		2			1						5
IPSL-IPSL-CM5A-MR													0
Current status	4	2	0	5	3	1	1	0	1	1	1	0	18
Remaining	1	0	0	1	2	1	0	0	0	0	2	2	8
Total remaining in project	3		5	5	3	4		3		3	5	6	37

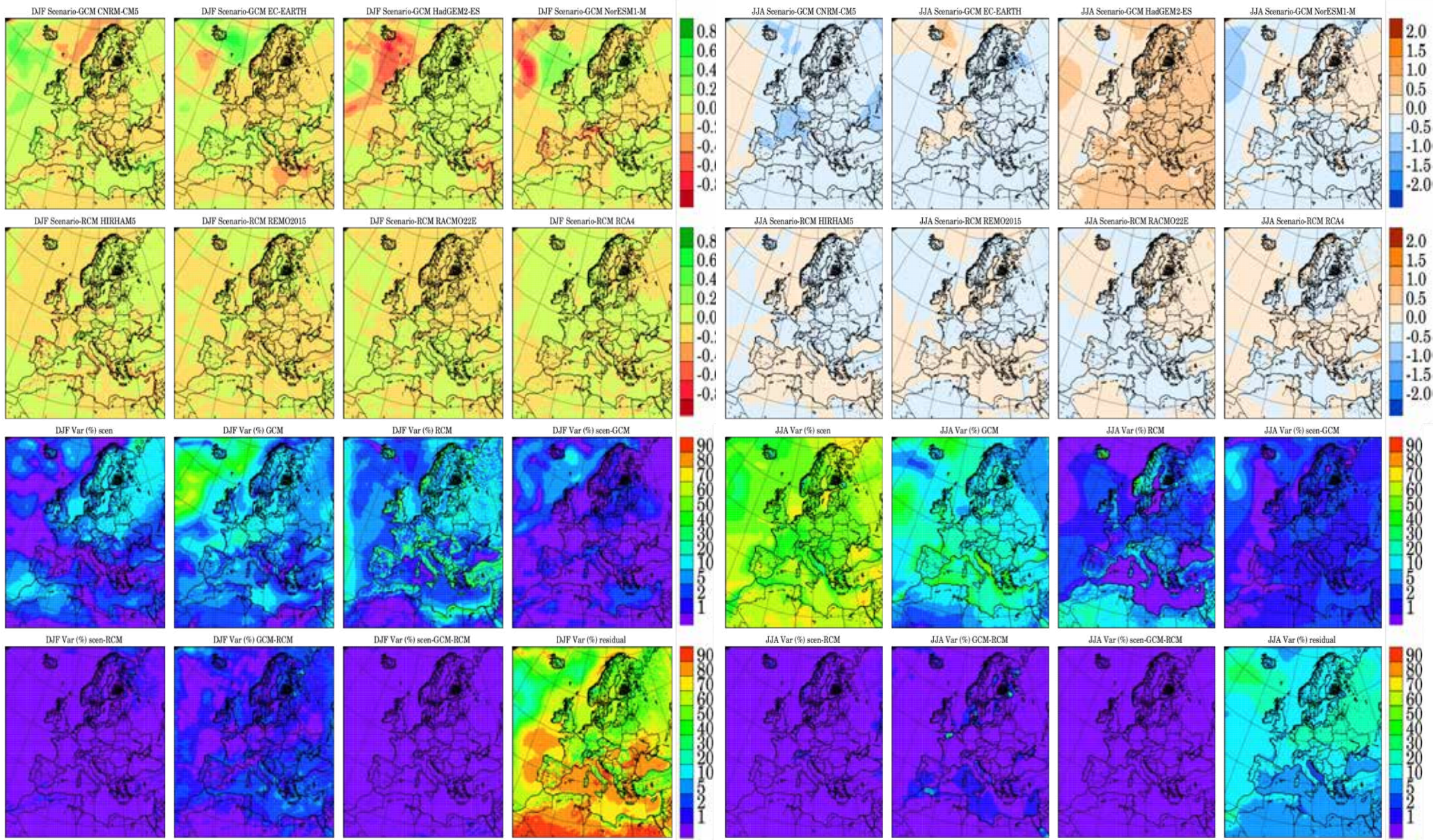


Climate  
Change

## PRINCIPLES

# **ANOVA analysis of Temperature for 4x4 matrix**







## Conclusions

- A lot of sub-matrices have been filled, with stuff for a lot of investigations
- A few holes could still be filled to achieve much larger sub-matrices
- Some promising combinations can already be studied; preliminary results presented
  - Only average fields at the moment
  - T and pr very different behaviour; RCMs proven to be more important for DJF pr than for JJA T.

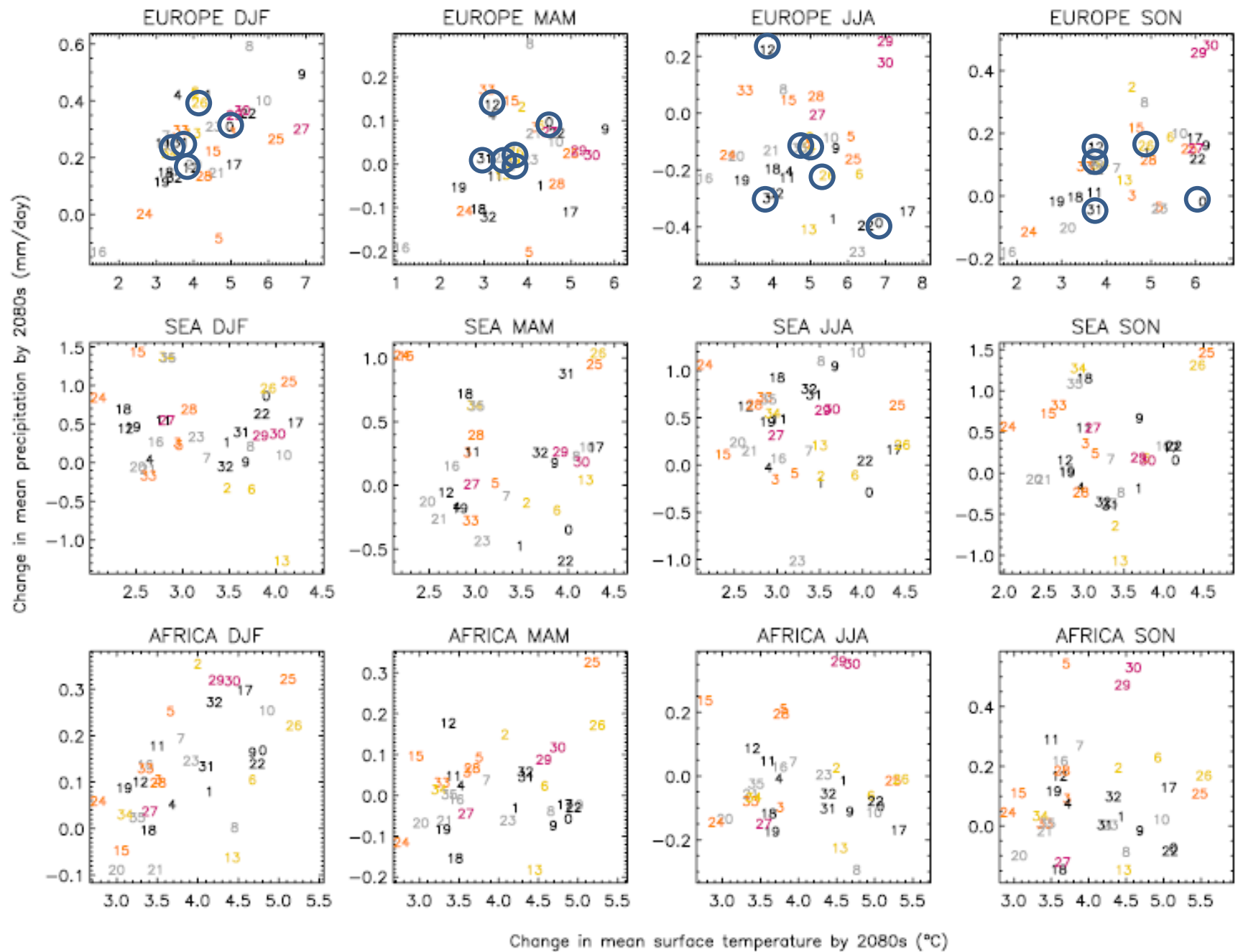
RCP8.5	RCA4	CcrCLM	REMO 09,15	RACMO22E	HIRHAM5	WRF381P	ALADIN63	RegCM4.6.1	HadGEM3-RA
MOHC-HadGEM2-ES	E	4	E	E	1	2	2	1	1
ICHEC-EC-EARTH	EEE	333	E	EE2	E22	3	3	3	2
CNRM-CERFACS-CNRM-CM5	E	4	E	1	2	3	1	3	4
NCC-NorESM1-M	E	E	1	2	E	2		4	4
MPI-M-MPI-ESM-LR	E33	EEE	EE2	3	3	4	4	2	3
IPSL-IPSL-CM5A-MR	E		3	3	4	1			
CCCma-CanESM2			E						
MIROC-MIROC5			E						
Before PRINCIPLES	8	4	7	3	2				
PRINCIPLES	2	5	3	5	6	6	4	5	5
RCP4.5	RCA4	CcrCLM	REMO 09,15	RACMO22E	HIRHAM5	WRF381P	ALADIN63	RegCM4.6.1	HadGEM3-RA
MOHC-HadGEM2-ES	E		3	E	3				
ICHEC-EC-EARTH	E		4	EE	E				
CNRM-CERFACS-CNRM-CM5	E						3		
NCC-NorESM1-M			4		E				
MPI-M-MPI-ESM-LR	E		EE						
IPSL-IPSL-CM5A-MR	E								
Before PRINCIPLES	5		2	3	2				
PRINCIPLES			3		1		1		
RCP2.6	RCA4	CcrCLM	REMO 09,15	RACMO22E	HIRHAM5	WRF381P	ALADIN63	RegCM4.6.1	HadGEM3-RA
MOHC-HadGEM2-ES	E		E	E	4			2	3
ICHEC-EC-EARTH	E		E	E	E				3
CNRM-CERFACS-CNRM-CM5	4		3				2		
NCC-NorESM1-M	2		2	4				4	
MPI-M-MPI-ESM-LR	E		EE	4				3	
Before PRINCIPLES	3		4	2	1				
PRINCIPLES	2		2	2	1		1	3	2
Total outside PRINCIPLES	13	1	13	8	5				
Total SC1	1	1	1	1	1	1	1	1	1
Total SC2	3	2	2	2	3	2	2	3	1
Total SC3	2	3	3	2	2	2	2	3	3
Total SC4	1	2	2	2	2	1	1	1	2
Total PRINCIPLES	7	8	8	7	8	6	6	8	7





# PRINCIPLES

- 0 HadGEM2-ES
- 1 ACCESS1-0
- 2 ACCESS1-3
- 3 bcc-csm1-1
- 4 bcc-csm1-1-m
- 5 BNU-ESM
- 6 CanESM2
- 7 CESM1-CAM5
- 8 CMCC-CESM
- 9 CMCC-CM
- 10 CMCC-CMS
- 11 CCSM4
- 12 CNRM-CM5
- 13 CSIRO-Mk3-6-0
- 14 EC-EARTH
- 15 FGOALS-g2
- 16 FIO-ESM
- 17 GFDL-CM3
- 18 GFDL-ESM2G
- 19 GFDL-ESM2M
- 20 GISS-E2-R
- 21 GISS-E2-H
- 22 HadGEM2-CC
- 23 HadGEM2-AO
- 24 Inmcm4
- 25 IPSL-CM5A-LR
- 26 IPSL-CM5A-MR
- 27 IPSL-CM5B-LR
- 28 MIROC5
- 29 MIROC-ESM
- 30 MIROC-ESM-CHEM
- 31 MPI-ESM-LR
- 32 MPI-ESM-MR
- 33 MRI-CGCM3
- 34 NorESM1-M
- 35 NorESM1-ME



Change in mean surface temperature by 2080s (°C)



## Assessment of internal variability

- What does the project want:
  - ...two sources of internal variability are identified ... driving GCM or RCM... we will assess internal climate variability based on the resulting new simulations from [WP2] and from already existing additional information.
  - The lessons learned from [Task 1.3] are analysed and reported to give final recommendation for future needs of filling up the RCP/GCM/RCM-matrix
- The PRINCIPLES simulations will provide an excellent basis for this:
  - ECEARTH, 3 ensemble members downscaled by 4 RCMs each
  - MPI-ESM 3 members by 3 RCMs
  - 4 GCMS (HadGEM2, ECEARTH, MPI-ESM, CNRM-CM5) downscaled by all 9 RCMs
- Also, we can do "emergence" studies, comparing RCM variability, GCM variability and CC signals in different RCP's having a 4x2x3 filled and several larger almost-filled 3d matrices.
- REMEMBER we have to make recommendations about future filling projects!
- Thoughts? We are in this together...