### Assessment of multiple daily precipitation statistics in ERA-Interim driven Med-CORDEX and EURO-CORDEX experiments against high resolution observations

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 Météo-France and Mercator Océan, France,
 Universidad de Castilla-La Mancha, Toledo, Spain
 CETEMPS and University of L'Aquila, Italy

### Assessment of multiple daily precipitation statistics in ERA-Interim driven Med-CORDEX and EURO-CORDEX experiments against high resolution observations

- Assessing the performance of an ensamble of RCMs over various EU regions against HR observations using both Med- and EURO-Cordex, with focus on extremes
- Does increased resolution (0.44  $\rightarrow$  0.11 deg) provide real benefits compared to HR OBS?
- Do modelled precipitation climate extremes show significant Added Value?

## DATASETS AND SETUP

- 9 ERA-Interim driven, double nested Med- and EURO-CORDEX Regional Climate Models
- 3 common analysis grids at 0.11, 0.44, 1.50 degrees resolution
- HR observation datasets over 9 different European regions
- Precipitation undercatch correction with UDEL dataset (Matsuura and Willmott 2010, UDEL V3.01) when applicable



Dataset	Institution	Region	Period	~Res	Reference
EURO4M-APGD *	MeteoSwiss	Alps	1971-2008	5km	Isotta et al. (2013)
Spain02 <sup>+</sup>	Santander Meteorology Group	Spain	1971-2010	0.11 deg	Herrera et al. (2010)
SAFRAN	Meteo-France	France	1958-2013	8km	Vidal et al. (2010)
UK gridded dataset °+	UK Met Office	United Kingdom	1990-2010	0.11 deg	Perry et al. (2009)
KLIMAGRID °	METNO	Norway	1957-2013	1km	Mohr (2009)
PTHBV °	SMHI	Sweden and part of Finland	1961-2010	4km	Johansson (2002)
CARPATCLIM *	Hungarian Met Service	Carpathians	1961-2010	0.10 deg	Szalai et al. (2013)
REGNIE °+	DWD	Germany	1961-2009	1km	Rauthe et al. (2013)
CETEMPS gridded dataset <sup>+</sup>	CETEMPS, University of L'Aquila	Italy	2000-2014	0.11 deg	Not released yet

o = covered by EURO-CORDEX only

+ = undercatch-corrected with UDEL data



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o = covered by EURO-CORDEX only

+ = undercatch-corrected with UDEL data

## 9 Regional Climate Models @ 0.11 and 0.44 deg resolution

Model		Institution
CCLM4-8-17	CLMcom	
HIRHAM5	DMI	
INERIS-WRF331F	IPSL	EURO-CORDEX
RACMO22E	KNMI	
RCA4	SMHI	
ALADIN5.2	CNRM	
RegCM4.4	ICTP	
CCLM4-8-18	GUF	WIEU-CONDEX
PROMES	UCLM	

Analysis period: 1989-2008; 1990-2008 (UK); 2000-2010 (Italy)

# Precipitation performance indices with emphasis over extremes

Index	Description
RMSE, mean, bias	Standard statistics.
TAYLOR	Taylor diagrams: spatial correlation, std.dev. and centered RMSE.
PDF, KL	Symmetrized Kullback-Leibler divergence for PDFs *. (>1mm / day)
SDII *	Mean daily precipitation intensity. (mm / day)
DDF *	Mean frequency of dry days. (%)
CDD95 *	95th percentile of dry spell length. Replaces CDD. (No. days / year)
Psum>R95 obs *	Total precipitation above the reference 95th percentile of observed daily precipitation. Replaces R95p. (mm / year)

\* = daily precipitation indices

### Example for mean precipitation (DJF)



### Example for mean precipitation (DJF)



## Example for mean precipitation (SON)



## Example for mean precipitation (SON)



### Results for mean precipitation

![](_page_11_Figure_1.jpeg)

![](_page_11_Figure_2.jpeg)

### Results for mean precipitation

![](_page_12_Figure_1.jpeg)

![](_page_12_Figure_2.jpeg)

## Results for mean precipitation

Annual cycle

![](_page_13_Figure_2.jpeg)

## **Results for daily PDFs**

![](_page_14_Figure_1.jpeg)

## **Results for daily PDFs**

![](_page_15_Figure_1.jpeg)

![](_page_16_Figure_0.jpeg)

![](_page_17_Figure_0.jpeg)

![](_page_18_Figure_0.jpeg)

![](_page_19_Figure_0.jpeg)

Selected maps: Psum>R95obs

![](_page_20_Figure_2.jpeg)

Selected maps: Psum>R95obs

![](_page_21_Figure_2.jpeg)

Taylor plots (0.11deg)

![](_page_22_Figure_2.jpeg)

![](_page_22_Figure_3.jpeg)

![](_page_23_Figure_1.jpeg)

![](_page_23_Figure_2.jpeg)

Models: - EURO ···· MED

![](_page_24_Figure_1.jpeg)

![](_page_25_Figure_1.jpeg)

#### Increasing model resolution

#### Decreasing grid resolution

													Cor	relati	on w	th Of	3S (D	JF)													>
	0 1	1		С	urrent.r	esol: 01	1				04	.4		С	urrent.r	esol: 04	4				1.5	50		С	urrent.re	esol: 15	60				
AVERAGE-	0.74	0.7	0.71	0.76	0.82	0.51	0.87	0.83	0.87	0.92	0.77	0.7	0.72	0.74	0.86	0.68	0.87	0.84	0.86	0.91	0.77	0.75	0.8	0.7	0.83	0.5	0.93	0.87	0.89	0.97	
RCA4-	0.79	0.65	0.69	0.77	0.87	0.53	0.88	0.87	0.91	0.96	0.81	0.65	0.71	0.75	0.88	0.73	0.88	0.87	0.91	0.95	0.81	0.71	0.75	0.75	0.9	0.41	0.93	0.9	0.91	0.98	
RACMO22E-	0.81	0.8	0.73	0.8	0.79	0.63	0.87	0.91	0.84	0.88	0.84	0.79	0.75	0.8	0.83	0.86	0.87	0.92	0.82	0.88	0.85	0.86	0.86	0.76	0.83	0.68	0.93	0.92	88.0	0.95	
WRF331F-	0.79	0.68	0.7	0.81	0.86	0.46	0.87	0.88	0.9	0.95	0.81	0.65	0.71	0.8	0.89	0.6	0.87	0.9	0.89	0.95	0.81	0.65	0.71	0.8	0.89	0.46	0.94	0.92	0.9	0.97	orig
HIRHAM5-	0.73	0.66	0.69	0.72	0.74	0.51	0.83	0.79	0.82	0.86	0.75	0.65	0.71	0.69	0.78	0.68	0.83	0.78	0.8	0.83	0.79	0.76	0.83	0.64	0.7	0.56	0.91	0.88	88.0	0.96	.res
CCLM-	0.78	0.67	0.75	0.79	0.84	0.45	0.89	0.84	0.89	0.94	0.81	0.67	0.74	0.78	0.88	0.6	0.89	0.86	0.89	0.95	0.8	0.64	0.79	0.78	0.83	0.52	0.92	0.85	0.86	0.96	<u></u>
PROMES-	0.67	0.68	0.64	0.64		0.59		0.78			0.71	0.68	0.65	0.6		0.82		0.8			0.78	0.9	0.86	0.47		0.83		0.85			011
RegCM4 -	0.62	0.56	0.65	0.66		0.52		0.7			0.65	0.58	0.64	0.67		0.65		0.72			0.71	0.64	0.74	0.63		0.77		0.77			0
GUF-CCLM-	0.73	0.76	0.79	0.83		0.42		0.83			0.77	0.76	0.79	0.82		0.58		0.86			0.72	0.72	0.84	0.73		0.46		0.84			<u>`</u>
ALADIN-	0.74	0.83	0.78	0.79		0.44		0.85			0.76	0.82	0.77	0.76		0.58		0.87			0.62	0.85	0.81	0.74		-0.18		0.9			_
8 AVERAGE-	0.62	0.46	0.66	0.61	0.61	0.31	0.85	0.75	0.86	0.89	0.64	0.5	0.67	0.62	0.63	0.38	0.86	0.77	0.85	0.89	0.72	0.53	0.76	0.68	0.77	0.5	0.93	0.84	0.89	0.95	
E RCA4-	0.6	0.24	0.53	0.59	0.59	0.26	0.78	0.66	0.85	0.89	0.6	0.25	0.5	0.57	0.57	0.33	0.79	0.68	0.85	0.89	0.7	0.33	0.64	0.63	0.78	0.37	0.89	0.79	0.87	0.98	
RACMO22E-	0.72	0.54	0.76	0.69	0.64	0.39	0.89	0.82	0.87	0.9	0.74	0.57	0.77	0.71	0.63	0.55	0.91	0.84	0.83	0.9	0.82	0.64	0.84	0.71	0.81	0.68	0.96	0.88	0.9	0.94	
WRF331F-	0.66	0.45	0.59	0.63	0.63	0.2	0.87	0.78	0.87	0.89	0.67	0.5	0.63	0.63	0.7	0.17	0.88	0.8	0.84	0.89	0.74	0.5	0.69	0.7	0.77	0.4	0.94	0.89	0.91	0.91	ori
HIRHAM5-	0.65	0.39	0.63	0.62	0.66	0.27	0.87	0.65	0.88	0.92	0.66	0.42	0.59	0.62	0.7	0.3	0.86	0.67	0.87	0.91	0.73	0.45	0.67	0.74	0.76	0.35	0.94	0.8	0.88	0.98	g.re
CCLM-	0.69	0.55	0.71	0.62	0.54	0.47	0.86	0.76	0.83	0.88	0.72	0.6	0.73	0.61	0.57	0.57	0.87	0.79	0.84	0.87	0.8	0.63	0.82	0.71	0.72	0.68	0.95	0.86	0.9	0.96	SO:
PROMES-	0.59	0.5	0.75	0.68		0.26		0.75			0.61	0.52	0.75	0.69		0.31		0.76			0.66	0.58	0.9	0.69		0.32		0.83		_	044
RegCM4 -	0.51	0.43	0.5	0.48		0.41		0.74			0.55	0.47	0.55	0.49	-	0.5		0.75			0.67	0.43	0.67	0.62		0.83		0.78			0
GUF-CCLM-	0.57	0.53	0.69	0.53		0.32		0.76			0.62	0.58	0.71	0.53		0.5		0.79			0.7	0.56	0.79	0.6		0.7		0.85			.~
ALADIN-	0.59	0.55	0.76	0.65		0.18		0.82		-	0.61	0.6	0.76	0.69		0.16		0.83			0.63	0.63	0.78	0.7		0.14		0.91			1
ERAIN-	0.64	0.45	0.67	0.42	0.5	0.36	0.86	0.81	0.85	0.83	0.66	0.49	0.69	0.42	0.47	0.45	0.88	0.82	0.85	0.83	0.79	0.59	0.81	0.55	0.73	0.7	0.94	0.95	0.94	0.91	esc
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#### Increasing model resolution

													Co	relati	on w	ith Ol	3S (C	JF)													5
	$0^{1}$	11		c	urrent.r	esol: 01	11				04	.4		С	urrent.r	esol: 04	4				1.5	50		С	urrent.re	esol: 15	50				
AVERAGE-	0.74	0.7	0.71	0.76	0.82	0.51	0.87	0.83	0.87	0.92	0.77	0.7	0.72	0.74	0.86	0.68	0.87	0.84	0.86	0.91	0.77	0.75	0.8	0.7	0.83	0.5	0.93	0.87	0.89	0.97	
RCA4-	0.79	0.65	0.69	0.77	0.87	0.53	0.88	0.87	0.91	0.96	0.81	0.65	0.71	0.75	0.88	0.73	0.88	0.87	0.91	0.95	0.81	0.71	0.75	0.75	0.9	0.41	0.93	0.9	0.91	0.98	
RACMO22E-	0.81	0.8	0.73	0.8	0.79	0.63	0.87	0.91	0.84	0.88	0.84	0.79	0.75	0.8	0.83	0.86	0.87	0.92	0.82	0.88	0.85	0.86	0.86	0.76	0.83	0.68	0.93	0.92	0.88	0.95	
WRF331F-	0.79	0.68	0.7	0.81	0.86	0.46	0.87	0.88	0.9	0.95	0.81	0.65	0.71	0.8	0.89	0.6	0.87	0.9	0.89	0.95	0.81	0.65	0.71	0.8	0.89	0.46	0.94	0.92	0.9	0.97	orig
HIRHAM5-	0.73	0.66	0.69	0.72	0.74	0.51	0.83	0.79	0.82	0.86	0.75	0.65	0.71	0.69	0.78	0.68	0.83	0.78	0.8	0.83	0.79	0.76	0.83	0.64	0.7	0.56	0.91	0.88	0.88	0.96	.res
CCLM-	0.78	0.67	0.75	0.79	0.84	0.45	0.89	0.84	0.89	0.94	0.81	0.67	0.74	0.78	0.88	0.6	0.89	0.86	0.89	0.95	0.8	0.64	0.79	0.78	0.83	0.52	0.92	0.85	0.86	0.96	.∺ 
PROMES-	0.67	0.68	0.64	0.64		0.59		0.78			0.71	0.68	0.65	0.6		0.82		0.8			0.78	0.9	0.86	0.47		0.83		0.85			1
RegCM4 -	0.62	0.56	0.65	0.66		0.52		0.7			0.65	0.58	0.64	0.67		0.65		0.72			0.71	0.64	0.74	0.63		0.77		0.77			C
GUF-CCLM-	0.73	0.76	0.79	0.83		42		0.83			0.77	0.76	0.79	0.82		0.58		0.86			0.72	0.72	0.84	0.73		0.46		0.84			<u> </u>
ALADIN-	0.74	0.83	0.78	0.79	K K		<b>_</b>	0.85			0.76	0.82	0.77	0.76		0.58		0.87			0.62	0.85	0.81	0.74		-0.18		0.9			_
AVERAGE-	0.62	0.46	0.66	0.61	0.6	31	0.85	0.75	0.86	0.89	0.64	0.5	0.67	0.62	0.63	0.38	0.86	0.77	0.85	0.89	0.72	0.53	0.76	0.68	0.77	0.5	0.93	0.84	0.89	0.95	
► RCA4-	0.6	0.24	0.53	0.59	0.5	26	0.78	0.66	0.85	0.89	0.6	0.25	0.5	0.57	0.57	0.33	0.79	0.68	0.85	0.89	0.7	0.33	0.64	0.63	0.78	0.37	0.89	0.79	0.87	0.98	
RACMO22E-	0.72	0.54	0.76	0.69	0.6	39	0.89	0.82	0.87	0.9	0.74	0.57	0.77	0.71	0.63	0.55	0.91	0.84	0.83	0.9	0.82	0.64	0.84	0.71	0.81	0.68	0.96	0.88	0.9	0.94	
WRF331F-	0.66	0.45	0.59	0.63	0.6	2	0.87	0.78	0.87	0.89	0.67	0.5	0.63	0.63	0.7	0.17	0.88	0.8	0.84	0.89	0.74	0.5	0.69	0.7	0.77	0.4	0.94	0.89	0.91	0.91	orig
HIRHAM5-	0.65	0.39	0.63	0.62	0.66	0.27	0.87	0.65	0.88	0.92	0.66	0.42	0.59	0.62	0.7	0.3	0.86	0.67	0.87	0.91	0.73	0.45	0.67	0.74	0.76	0.35	0.94	0.8	0.88	0.98	I.reg
CCLM-	0.69	0.55	0.71	0.62	0.54	0.47	0.86	0.76	0.83	0.88	0.72	0.6	0.73	0.61	0.57	0.57	0.87	0.79	0.84	0.87	0.8	0.63	0.82	0.71	0.72	0.68	0.95	0.86	0.9	0.96	ĕ.
PROMES-	0.59	0.5	0.75	0.68		0.26		0.75			0.61	0.52	0.75	0.69		0.31		0.76			0.66	0.58	0.9	0.69		0.32		0.83			044
RegCM4-	0.51	0.43	0.5	0.48		0.41		0.74			0.55	0.47	0.55	0.49		0.5		0.75			0.67	0.43	0.67	0.62		0.83		0.78			$\mathbf{C}$
GUF-CCLM-	0.57	0.53	0.69	0.53		0.32		0.76			0.62	0.58	0.71	0.53		0.5		0.79			0.7	0.56	0.79	0.6		0.7		0.85			
ALADIN-	0.59	0.55	0.76	0.65		0.18		0.82			0.61	0.6	0.76	0.69		0.16		0.83			0.63	0.63	0.78	0.7		0.14		0.91			1
ERAIN-	0.64	0.45	0.67	0.42	0.5	0.36	0.86	0.81	0.85	0.83	0.66	0.49	0.69	0.42	0.47	0.45	0.88	0.82	0.85	0.83	0.79	0.59	0.81	0.55	0.73	0.7	0.94	0.95	0. <del>9</del> 4	0.91	eso
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#### Increasing model resolution

													Co	relati	on w	ith Of	3S (C	JF)													5
	$0^{1}$	11		C	urrent.r	esol: 01	1				04	.4		С	urrent.r	esol: 04	4				1.5	50		С	urrent.re	esol: 15	50				
AVERAGE-	0.74	0.7	0.71	0.76	0.82	0.51	0.87	0.83	0.87	0.92	0.77	0.7	0.72	0.74	0.86	0.68	0.87	0.84	0.86	0.91	0.77	0.75	0.8	0.7	0.83	0.5	0.93	0.87	0.89	0.97	
RCA4-	0.79	0.65	0.69	0.77	0.87	0.53	0.88	0.87	0.91	0.96	0.81	0.65	0.71	0.75	0.88	0.73	0.88	0.87	0.91	0.95	0.81	0.71	0.75	0.75	0.9	0.41	0.93	0.9	0.91	0.98	
RACMO22E-	0.81	0.8	0.73	0.8	0.79	0.63	0.87	0.91	0.84	0.88	0.84	0.79	0.75	0.8	0.83	0.86	0.87	0.92	0.82	0.88	0.85	0.86	0.86	0.76	0.83	0.68	0.93	0.92	0.88	0.95	
WRF331F-	0.79	0.68	0.7	0.81	0.86	0.46	0.87	0.88	0.9	0.95	0.81	0.65	0.71	0.8	0.89	0.6	0.87	0.9	0.89	0.95	0.81	0.65	0.71	0.8	0.89	0.46	0.94	0.92	0.9	0.97	orig
HIRHAM5-	0.73	0.66	0.69	0.72	0.74	0.51	0.83	0.79	0.82	0.86	0.75	0.65	0.71	0.69	0.78	0.68	0.83	0.78	0.8	0.83	0.79	0.76	0.83	0.64	0.7	0.56	0.91	0.88	0.88	0.96	.res
CCLM-	0.78	0.67	0.75	0.79	0.84	0.45	0.89	0.84	0.89	0.94	0.81	0.67	0.74	0.78	0.88	0.6	0.89	0.86	0.89	0.95	0.8	0.64	0.79	0.78	0.83	0.52	0.92	0.85	0.86	0.96	
PROMES-	0.67	0.68	0.64	0.64		0.59		0.78			0.71	0.68	0.65	0.6		0.82		0.8			0.78	0.9	0.86	0.47		0.83		0.85			11
RegCM4 -	0.62	0.56	0.65	0.66		0.52		0.7			0.65	0.58	0.64	0.67		0.65		0.72			0.71	0.64	0.74	0.63		0.77		0.77			C
GUF-CCLM-	0.73	0.76	0.79	0.83		42		0.83			0.77	0.76	0.79	0.82		9,58		0.86			0.72	0.72	0.84	0.73		0.46		0.84			<u>`</u>
ALADIN-	0.74	0.83	0.78	0.79				0.85			0.76	0.82	0.77	0.76	4			0.87			0.62	0.85	0.81	0.74		-0.18		0.9			<u> </u>
AVERAGE-	0.62	0.46	0.66	0.61	0.6	81	0.85	0.75	0.86	0.89	0.64	0.5	0.67	0.62	0.	38	0.86	0.77	0.85	0.89	0.72	0.53	0.76	0.68	0.77	0.5	0.93	0.84	0.89	0.95	
► RCA4-	0.6	0.24	0.53	0.59	0.5	26	0.78	0.66	0.85	0.89	0.6	0.25	0.5	0.57	0.	33	0.79	0.68	0.85	0.89	0.7	0.33	0.64	0.63	0.78	0.37	0.89	0.79	0.87	0.98	
RACMO22E-	0.72	0.54	0.76	0.69	0.6	39	0.89	0.82	0.87	0.9	0.74	0.57	0.77	0.71	0.	55	0.91	0.84	0.83	0.9	0.82	0.64	0.84	0.71	0.81	0.68	0.96	0.88	0.9	0.94	
WRF331F-	0.66	0.45	0.59	0.63	0.6	2	0.87	0.78	0.87	0.89	0.67	0.5	0.63	0.63	0	17	0.88	0.8	0.84	0.89	0.74	0.5	0.69	0.7	0.77	0.4	0.94	0.89	0.91	0.91	orig
HIRHAM5-	0.65	0.39	0.63	0.62	0.66	0.27	0.87	0.65	0.88	0.92	0.66	0.42	0.59	0.62	0.7	0.3	0.86	0.67	0.87	0.91	0.73	0.45	0.67	0.74	0.76	0.35	0.94	0.8	0.88	0.98	I.res
CCLM-	0.69	0.55	0.71	0.62	0.54	0.47	0.86	0.76	0.83	0.88	0.72	0.6	0.73	0.61	0.57	0.57	0.87	0.79	0.84	0.87	0.8	0.63	0.82	0.71	0.72	0.68	0.95	0.86	0.9	0.96	ő.
PROMES-	0.59	0.5	0.75	0.68		0.26		0.75			0.61	0.52	0.75	0.69		0.31		0.76			0.66	0.58	0.9	0.69		0.32		0.83			044
RegCM4-	0.51	0.43	0.5	0.48		0.41		0.74			0.55	0.47	0.55	0.49		0.5		0.75			0.67	0.43	0.67	0.62		0.83		0.78			C
GUF-CCLM-	0.57	0.53	0.69	0.53		0.32		0.76			0.62	0.58	0.71	0.53		0.5		0.79			0.7	0.56	0.79	0.6		0.7		0.85			
ALADIN-	0.59	0.55	0.76	0.65		0.18		0.82			0.61	0.6	0.76	0.69		0.16		0.83			0.63	0.63	0.78	0.7		0.14		0.91			T
ERAIN-	0.64	0.45	0.67	0.42	0.5	0.36	0.86	0.81	0.85	0.83	0.66	0.49	0.69	0.42	0.47	0.45	0.88	0.82	0.85	0.83	0.79	0.59	0.81	0.55	0.73	0.7	0.94	0.95	0.94	0.91	eso
	ė	-sd	-su	-eo	- Âui	aly-	/ay-	ain-	en-	÷	ġ.	-sd	-su	-e-o	-Yu	aly-	/ay-	ain-	en-	÷	ų.	-sd	-su	-e-	-Yn	aly-	/ay-	ain-	en-	¥	
	RA(	A	thia	Fran	rme	#	lorv	Sp	wed		RA(	$\triangleleft$	thia	Fran	rme	11	lorv	Sp	wed		RA(	$\triangleleft$	uthia	Lar	rma	1t	lorv	Sp	wed		
	AVE		arpa		Ge		2		٥		AVE		arpa		Ge		2		٥		AVE		arpa		Ge		2		٥		
			0										0		rec	lion							0								
				E		aid	h	C			cor	r																			
				_ F	16	yı	JII	3						0.05				0.75		1.00											
						-						0.00		0.25		0.50		0.75		1.00											

#### Increasing model resolution

													Cor	relati	on w	ith Ol	3S (D	JF)													>
	0 1	1		c	current.	esol: 01	1				04	4		С	urrent.r	esol: 04	4				1.5	50		С	urrent.re	esol: 15	50				
AVERAGE-	0.74	0.7	0.71	0.76	0.82	0.51	0.87	0.83	0.87	0.92	0.77	0.7	0.72	0.74	0.86	0.68	0.87	0.84	0.86	0.91	0.77	0.75	0.8	0.7	0.83	0.5	0.93	0.87	0.89	0.97	
RCA4-	0.79	0.65	0.69	0.77	0.87	0.53	0.88	0.87	0.91	0.96	0.81	0.65	0.71	0.75	0.88	0.73	0.88	0.87	0.91	0.95	0.81	0.71	0.75	0.75	0.9	0.41	0.93	0.9	0.91	0.98	
RACMO22E-	0.81	0.8	0.73	0.8	0.79	0.63	0.87	0.91	0.84	0.88	0.84	0.79	0.75	0.8	0.83	0.86	0.87	0.92	0.82	0.88	0.85	0.86	0.86	0.76	0.83	0.68	0.93	0.92	0.88	0.95	
WRF331F-	0.79	0.68	0.7	0.81	0.86	0.46	0.87	0.88	0.9	0.95	0.81	0.65	0.71	0.8	0.89	0.6	0.87	0.9	0.89	0.95	0.81	0.65	0.71	0.8	0.89	0.46	0.94	0.92	0.9	0.97	orig
HIRHAM5-	0.73	0.66	0.69	0.72	0.74	0.51	0.83	0.79	0.82	0.86	0.75	0.65	0.71	0.69	0.78	0.68	0.83	0.78	0.8	0.83	0.79	0.76	0.83	0.64	0.7	0.56	0.91	0.88	0.88	0.96	.res
CCLM-	0.78	0.67	0.75	0.79	0.84	0.45	0.89	0.84	0.89	0.94	0.81	0.67	0.74	0.78	0.88	0.6	0.89	0.86	0.89	0.95	0.8	0.64	0.79	0.78	0.83	0.52	0.92	0.85	0.86	0.96	.∺ ⊙
PROMES-	0.67	0.68	0.64	0.64		0.59		0.78			0.71	0.68	0.65	0.6		0.82		0.8			0.78	0.9	0.86	0.47		0.83		0.85			011
RegCM4 -	0.62	0.56	0.65	0.66		0.52		0.7			0.65	0.58	0.64	0.67		0.65		0.72			0.71	0.64	0.74	0.63		0.77		0.77			0
GUF-CCLM-	0.73	0.76	0.79	0.83		42		0.83			0.77	0.76	0.79	0.82		58		0.86			0.72	0.72	0.84	0.73		9.46		0.84			<u>`</u>
ALADIN-	0.74	0.83	0.78	0.79	4		•	0.85			0.76	0.82	0.77	0.76	4			0.87			0.62	0.85	0.81	0.74	4			0.9			
AVERAGE-	0.62	0.46	0.66	0.61	0.6	31	0.85	0.75	0.86	0.89	0.64	0.5	0.67	0.62	0.	38	0.86	0.77	0.85	0.89	0.72	0.53	0.76	0.68	0.	.5	0.93	0.84	0.89	0.95	
E RCA4-	0.6	0.24	0.53	0.59	0.5	26	0.78	0.66	0.85	0.89	0.6	0.25	0.5	0.57	0.	33	0.79	0.68	0.85	0.89	0.7	0.33	0.64	0.63	0.	37	0.89	0.79	0.87	0.98	
RACMO22E-	0.72	0.54	0.76	0.69	0.6	39	0.89	0.82	0.87	0.9	0.74	0.57	0.77	0.71	0.	55	0.91	0.84	0.83	0.9	0.82	0.64	0.84	0.71	0.	68	0.96	0.88	0.9	0.94	
WRF331F-	0.66	0.45	0.59	0.63	0.6	2	0.87	0.78	0.87	0.89	0.67	0.5	0.63	0.63	0	17	0.88	0.8	0.84	0.89	0.74	0.5	0.69	0.7	0	.4	0.94	0.89	0.91	0.91	orig
HIRHAM5-	0.65	0.39	0.63	0.62	0.66	0.27	0.87	0.65	0.88	0.92	0.66	0.42	0.59	0.62	0.7	0.3	0.86	0.67	0.87	0.91	0.73	0.45	0.67	0.74	0.76	0.35	0.94	0.8	0.88	0.98	.res
CCLM-	0.69	0.55	0.71	0.62	0.54	0.47	0.86	0.76	0.83	0.88	0.72	0.6	0.73	0.61	0.57	0.57	0.87	0.79	0.84	0.87	0.8	0.63	0.82	0.71	0.72	0.68	0.95	0.86	0.9	0.96	음 ()
PROMES-	0.59	0.5	0.75	0.68		0.26		0.75			0.61	0.52	0.75	0.69		0.31		0.76			0.66	0.58	0.9	0.69		0.32		0.83			44
RegCM4 -	0.51	0.43	0.5	0.48		0.41		0.74			0.55	0.47	0.55	0.49		0.5		0.75			0.67	0.43	0.67	0.62		0.83		0.78			0
GUF-CCLM-	0.57	0.53	0.69	0.53		0.32		0.76			0.62	0.58	0.71	0.53		0.5		0.79			0.7	0.56	0.79	0.6	_	0.7		0.85			'n
ALADIN-	0.59	0.55	0.76	0.65		0.18		0.82			0.61	0.6	0.76	0.69		0.16		0.83			0.63	0.63	0.78	0.7		0.14		0.91			4
ERAIN-	0.64	0.45	0.67	0.42	0.5	0.36	0.86	0.81	0.85	0.83	0.66	0.49	0.69	0.42	0.47	0.45	0.88	0.82	0.85	0.83	0.79	0.59	0.81	0.55	0.73	0.7	0.94	0.95	0.94	0.91	eso
	GE	Aps	ans	nce	any	taly	way	ain	den	¥	GE	Aps	ans	nce	any	taly	way	Jain	den	¥	GE	Aps	ans	nce	any	taly	way	Jain	den	¥	
	ERA	4	athi	Fra	erm	_	Nor	S,	Swe		ERA	~	athi	Fra	erm	_	Nor	5	Swe		ERA	4	athi	Fra	erm	_	Non	S,	Swe		
	AVI		Carp		G				0)		AVI		Carp		G				0)		AVI		Carp		Ō				0)		
		1	0										0		reg	jion							0								
				F	20	aid	n	S			cor	r																			
						9.0		J				0.00		0.25		0.50		0.75		1.00											
												5.00																			

#### Increasing model resolution

													Cor	relati	ion w	ith Ol	BS (C	JF)													5
	01	11		C	urrent.r	esol: 01	1				04	4		С	urrent.r	resol: 04	14				1 !	50		С	urrent.re	esol: 15	60				
AVERAGE-	0.74	0.7	0.71	0.76	0.82	0.51	0.87	0.83	0.87	0.92	0.77	0.7	0.72	0.74	0.86	0.68	0.87	0.84	0.86	0.91	0.77	0.75	0.8	0.7	0.83	0.5	0.93	0.87	0.89	0.97	E.
RCA4 -	0.79	0.65	0.69	0.77	0.87	0.53	0.88	0.87	0.91	0.96	0.81	0.65	0.71	0.75	0.88	0.73	0.88	0.87	0.91	0.95	0.81	0.71	0.75	0.75	0.9	0.41	0.93	0.9	0.91	0.98	E.
RACMO22E-	0.81	0.8	0.73	0.8	0.79	0.63	0.87	0.91	0.84	0.88	0.84	0.79	0.75	0.8	0.83	0.86	0.87	0.92	0.82	0.88	0.85	0.86	0.86	0.76	0.83	0.68	0.93	0.92	0.88	0.95	
WRF331F-	0.79	0.68	0.7	0.81	0.86	0.46	0.87	0.88	0.9	0.95	0.81	0.65	0.71	0.8	0.89	0.6	0.87	0.9	0.89	0.95	0.81	0.65	0.71	0.8	0.89	0.46	0.94	0.92	0.9	0.97	orig
HIRHAM5-	0.73	0.66	0.69	0.72	0.74	0.51	0.83	0.79	0.82	0.86	0.75	0.65	0.71	0.69	0.78	0.68	0.83	0.78	0.8	0.83	0.79	0.76	0.83	0.64	0.7	0.56	0.91	0.88	0.88	0.96	.res
CCLM-	0.78	0.67	0.75	0.79	0.84	0.45	0.89	0.84	0.89	0.94	0.81	0.67	0.74	0.78	0.88	0.6	0.89	0.86	0.89	0.95	0.8	0.64	0.79	0.78	0.83	0.52	0.92	0.85	0.86	0.96	0::0
PROMES-	0.67	0.68	0.64	0.64		0.59		0.78			0.71	0.68	0.65	0.6		0.82		0.8			0.78	0.9	0.86	0.47		0.83		0.85			)11
RegCM4 -	0.62	0.56	0.65	0.66		0.52		0.7			0.65	0.58	0.64	0.67		0.65		0.72			0.71	0.64	0.74	0.63		0.77		0.77			0
GUF-CCLM-	0.73	0.76	0.79	0.83		42		0.83			0.77	0.76	0.79	0.82		3.58		0.86			0.72	0.72	0.84	0.73		9.46		0.84			<u>`</u>
ALADIN-	0.74	0.83	0.78	0.79				0.85			0.76	0.82	0.77	0.76	4			0.87			0.62	0.85	0.81	0.74	4			0.9			<b>_</b>
AVERAGE-	0.62	0.46	0.66	0.61	0.6	81	0.85	0.75	0.86	0.89	0.64	0.5	0.67	0.62	0.	38	0.86	0.77	0.85	0.89	0.72	0.53	0.76	0.68	0.	.5	0.93	0.84	0.89	0.95	
E RCA4-	0.6	0.24	0.53	0.59	0.5	26	0.78	0.66	0.85	0.89	0.6	0.25	0.5	0.57	0.:	33	0.79	0.68	0.85	0.89	0.7	0.33	0.64	0.63	0.	37	0.89	0.79	0.87	0.98	
RACMO22E-	0.72	0.54	0.76	0.69	0.0	39	0.89	0.82	0.87	0.9	0.74	0.57	0.77	0.71	0.	55	0.91	0.84	0.83	0.9	0.82	0.64	0.84	0.71	0.	68	0.96	0.88	0.9	0.94	E.
WRF331F-	0.66	0.45	0.59	0.63	0.0	2	0.87	0.78	0.87	0.89	0.67	0.5	0.63	0.63	0	17	0.88	0.8	0.84	0.89	0.74	0.5	0.69	0.7	0.	.4	0.94	0.89	0.91	0.91	orig
HIRHAM5-	0.65	0.39	0.63	0.62	0.66	0.27	0.87	0.65	0.88	0.92	0.66	0.42	0.59	0.62	0.7	0.3	0.86	0.67	0.87	0.91	0.73	0.45	0.67	0.74	0.76	0.35	0.94	0.8	0.88	0.98	.res
CCLM-	0.69	0.55	0.71	0.62	0.54	0.47	0.86	0.76	0.83	0.88	0.72	0.6	0.73	0.61	0.57	0.57	0.87	0.79	0.84	0.87	0.8	0.63	0.82	0.71	0.72	0.68	0.95	0.86	0.9	0.96	ë:
PROMES-	0.59	0.5	0.75	0.68		0.26		0.75			0.61	0.52	0.75	0.69		0.31		0.76			0.66	0.58	0.9	0.69		0.32		0.83			044
RegCM4 -	0.51	0.43	0.5	0.48		0.41		0.74			0.55	0.47	0.55	0.49		0.5		0.75			0.67	0.43	0.67	0.62		0.83		0.78			0
GUF-CCLM-	0.57	0.53	0.69	0.53		0.32		0.76			0.62	0.58	0.71	0.53		0.5		0.79			0.7	0.56	0.79	0.6		0.7		0.85			<u>``</u>
ALADIN-	0.59	0.55	0.76	0.65		0.18		0.82			0.61	0.6	0.76	0.69		0.16		0.83			0.63	0.63	0.78	0.7		0.14		0.91			4
ERAIN-	0.64	0.45	0.67	0.42	0.5	0.36	0.86	0.81	0.85	0.83	0.66	0.49	0.69	0.42	0.47	0.45	0.88	0.82	0.85	0.83	0.79	0.59	0.81	0.55	0.73	0.7	0.94	0.95	0.94	0.91	eso
	Ц.	bs	ans	joe	any	taly	vay	ain	Jen	X	GE	bs	ans	jce	any	taly	vay	ain	den	¥	В	sdp	ans	JCe	any	taly	vay	ain	den	¥	
	RA	4	athia	Frai	Brmg	-	Vor	S	wed		RA	4	athia	Frai	ST M	-	Vor	S	wed		RA	4	athi	Frai	erm(	-	Vor	S	wed		
	AVE		arpi		g		2		S		AVE		arpi		ğ		2		S		AVE		arpi		g		2		S		
			0										0		rec	gion							0								
																-															
					20	aid	h	C			cor	r																			
				_ f	16	yı	JI	3				0.00		0.05		0.50		0.75		1.00											
												0.00		0.25		0.50		0.75		1.00											

## CONCLUSIONS

The model ensembles show **remarkable performance** in simulating the **spatial patterns and annual cycle of all metrics analyzed**, with a substantial improvement going from the low resolution of the ERA-interim data to the medium resolution RCM44ensemble and the high resolution RCM11. This conclusion is **retained** even when the data are **upscaled** to the lower resolution (confirms Torma et al., 2015)

EURO-CORDEX and Med-CORDEX models have similar performance; both ensembles are of sufficient quality to be applied in climate projections

Some metrics (e.g. **DDF and CCD95** in some regions) still indicate **deficiencies** in the model's description of precipitation processes mainly due to the **drizzle phenomenon** that is **not solved** only by **increasing resolution**, but there are indications that this problem might be ameliorated which cloud and **convection** processes are **explicitly described**.

Need to develop a homogeneous and internally consistent **high resolution, quality checked, observation dataset** for the entire European territory which can be used for future development of very high resolution, European-wide models.

## THANKS!

#### Paper reference:

Fantini A., Raffaele F., Torma C., Bacer S., Coppola E., Giorgi F., Ahrens B., Dubois C., Sanchez E., Verdecchia M.
Assessment of multiple daily precipitation statistics in ERA-Interim driven Med-CORDEX and EURO-CORDEX experiments against high resolution observations.

Submitted to Climate Dynamics, 2016

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Supervisor: Erika Coppola, ICTP, Trieste

Contact: afantini@ictp.it

### Results for mean precipitation (JJA)

![](_page_33_Figure_1.jpeg)

# Results for daily PDFs Kullback-Leibler divergence

![](_page_34_Figure_2.jpeg)

# Results for daily PDFs Kullback-Leibler divergence

![](_page_35_Figure_2.jpeg)

# Results for daily PDFs Kullback-Leibler divergence

![](_page_36_Figure_2.jpeg)

RCM11-EURO RCM44-EURO RCM11-MED RCM44-MED

#### Selected maps: Psum>R95obs

![](_page_37_Figure_2.jpeg)

### Results for daily precipitation indices Selected maps: DDF

![](_page_38_Figure_1.jpeg)

![](_page_39_Figure_1.jpeg)

				с	urrent.r	esol: 01	1							С	urrent.r	esol: 04	4							С	urrent.re	esol: 15	0				
AVERAGE-	0.74	0.7	0.76	0.83	0.87	0.38	0.82	0.87	0.76	0.91	0.75	0.7	0.76	0.81	0.89	0.53	0.81	0.86	0.74	0.9	0.81	0.8	0.83	0.8	0.91	0.75	0.86	0.82	0.7	0.92	
RCA4 -	0.77	0.68	0.71	0.83	0.82	0.47	0.81	0.89	0.85	0.92	0.79	0.69	0.71	0.83	0.8	0.67	0.79	0.87	0.84	0.91	0.82	0.84	0.8	0.79	0.81	0.8	0.84	0.86	0.81	0.87	E.
RACMO22E-	0.82	0.83	0.77	0.9	0.91	0.47	0.84	0.94	0.8	0.91	0.84	0.8	0.78	0.89	0.93	0.71	0.83	0.93	0.77	0.92	0.87	0.89	0.86	0.89	0.93	0.77	0.9	0.9	0.74	0.96	
WRF331F-	0.8	0.72	0.77	0.84	0.9	0.47	0.8	0.91	0.81	0.94	0.83	0.69	0.79	0.82	0.93	0.75	0.81	0.92	0.79	0.94	0.84	0.76	0.84	0.79	0.95	0.77	0.88	0.9	0.77	0.93	orig
HIRHAM5-	0.71	0.61	0.73	0.78	0.81	0.31	0.78	0.82	0.69	0.85	0.71	0.63	0.74	0.75	0.82	0.37	0.78	0.78	0.66	0.83	0.79	0.77	0.83	0.79	0.88	0.65	0.83	0.86	0.59	0.93	.res
CCLM-	0.78	0.68	0.83	0.86	0.93	0.37	0.85	0.9	0.68	0.92	0.8	0.69	0.83	0.83	0.95	0.53	0.85	0.9	0.67	0.93	0.82	0.72	0.89	0.82	0.97	0.81	0.87	0.83	0.6	0.91	0:: C
PROMES-	0.66	0.71	0.66	0.71		0.38		0.83			0.68	0.7	0.68	0.7		0.51		0.82			0.79	0.88	0.81	0.7		0.75		0.83			11
RegCM4 -	0.63	0.54	0.71	0.78		0.32		0.8			0.64	0.56	0.7	0.77		0.36		0.79			0.77	0.76	0.76	0.84		0.69		0.78			
GUF-CCLM-	0.73	0.77	0.83	0.87		0.32		0.88			0.76	0.77	0.82	0.85		0.47		0.89			0.81	0.75	0.88	0.81		0.86		0.75			
ALADIN-	0.73	0.78	0.81	0.86		0.33		0.85			0.74	0.77	0.82	0.83		0.45		0.83			0.76	0.82	0.84	0.78		0.66		0.7			
AVERAGE-	0.63	0.44	0.72	0.73	0.75	0.25	0.74	0.78	0.68	0.84	0.65	0.48	0.7	0.72	0.74	0.34	0.74	0.8	0.66	0.84	0.77	0.56	0.79	0.77	0.91	0.77	0.83	0.83	0.66	0.92	
E RCA4-	0.54	0.19	0.66	0.62	0.55	0.2	0.51	0.68	0.68	0.72	0.53	0.21	0.62	0.59	0.52	0.25	0.51	0.69	0.67	0.71	0.7	0.46	0.71	0.71	0.78	0.77	0.66	0.75	0.66	0.82	-
RACMO22E-	0.74	0.55	0.72	0.81	0.84	0.34	0.86	0.86	0.75	0.9	0.76	0.59	0.7	0.82	0.83	0.54	0.87	0.88	0.72	0.91	0.85	0.62	0.78	0.83	0.95	0.89	0.93	0.93	0.74	0.98	
WRF331F-	0.7	0.51	0.66	0.69	0.83	0.32	0.82	0.83	0.77	0.91	0.73	0.57	0.67	0.69	0.86	0.5	0.83	0.85	0.74	0.92	0.82	0.66	0.71	0.75	0.95	0.86	0.89	0.89	0.77	0.96	ori
HIRHAM5-	0.61	0.33	0.69	0.72	0.7	0.19	0.67	0.73	0.68	0.81	0.6	0.35	0.62	0.67	0.68	0.22	0.65	0.73	0.67	0.79	0.76	0.56	0.77	0.85	0.91	0.69	0.77	0.83	0.59	0.86	g.re
CCLM-	0.67	0.48	0.7	0.74	0.81	0.26	0.83	0.79	0.53	0.86	0.68	0.52	0.71	0.73	0.81	0.34	0.84	0.81	0.52	0.86	0.75	0.54	0.83	0.77	0.96	0.39	0.92	0.85	0.56	0.97	so!:
PROMES-	0.62	0.49	0.73	0.74		0.35		0.77			0.66	0.55	0.72	0.74		0.5		0.78			0.75	0.57	0.86	0.7		0.84		0.79			044
RegCM4 -	0.57	0.39	0.74	0.74		0.16		0.82			0.6	0.44	0.75	0.73		0.25		0.83			0.78	0.56	0.83	0.83		0.84		0.84			
GUF-CCLM-	0.6	0.49	0.73	0.73		0.25		0.79			0.62	0.54	0.72	0.73		0.29	_	0.82			0.75	0.47	0.82	0.73		0.91		0.81			
ALADIN-	0.61	0.49	0.82	0.77		0.21		0.77			0.62	0.53	0.81	0.77		0.21		0.78			0.75	0.65	0.8	0.74		0.74		0.8			
ERAIN-	0.66	0.42	0.68	0.67	0.76	0.21	0.84	0.76	0.74	0.84	0.67	0.47	0.68	0.69	0.74	0.24	0.85	0.77	0.73	0.84	0.83	0.55	0.85	0.71	0.94	0.77	0.93	0.9	0.81	0.98	eso
	AVERAGE -	-Alps-	Carpathians-	France-	Germany-	Italy-	Norway-	Spain-	Sweden -	- XN	AVERAGE-	Alps-	Carpathians-	France-	Germany-	ltaly-	Norway-	Spain-	Sweden -	- XU	AVERAGE-	- Alps -	Carpathians-	France -	Germany-	Italy-	Norway-	Spain-	Sweden -	-NK-	U

Correlation with OBS (MAM)

![](_page_40_Figure_3.jpeg)

													00	reial	ULL W		00 (0	JA)													_
				C	urrent.r	esol: 01	1							С	urrent.r	esol: 04	4							С	urrent.r	esol: 15	0				
AVERAGE-	0.74	0.83	0.79	0.84	0.77	0.31	0.72	0.89	0.73	0.87	0.72	0.82	0.8	0.81	0.78	0.24	0.72	0.88	0.72	0.88	0.78	0.88	0.86	0.87	0.81	0.43	0.77	0.89	0.69	0.88	
RCA4-	0.7	0.76	0.78	0.81	0.47	0.29	0.74	0.85	0.77	0.86	0.67	0.76	0.78	0.78	0.45	0.14	0.73	0.82	0.77	0.85	0.76	0.84	0.91	0.86	0.31	0.79	0.83	0.82	0.68	0.79	
RACMO22E-	0.84	0.9	0.9	0.9	0.9	0.46	0.84	0.93	0.77	0.93	0.83	0.88	0.9	0.88	0.9	0.43	0.84	0.94	0.76	0.94	0.88	0.92	0.97	0.92	0.93	0.67	0.89	0.96	0.76	0.94	
WRF331F-	0.77	0.85	0.81	0.88	0.82	0.34	0.67	0.93	0.71	0.87	0.78	0.83	0.82	0.84	0.86	0.43	0.69	0.92	0.7	0.88	0.81	0.91	0.9	0.9	0.93	0.35	0.64	0.95	0.84	0.89	orig
HIRHAM5-	0.69	0.77	8.0	0.82	0.74	0.26	0.61	0.83	0.61	0.78	0.66	0.77	0.79	0.8	0.76	0.02	0.59	0.8	0.62	0.79	0.77	0.86	0.86	0.86	0.92	0.61	0.72	0.82	0.45	0.86	l.res
CCLM-	0.81	0.88	0.85	0.85	0.93	0.4	0.76	0.94	0.77	0.9	0.81	0.87	0.87	0.84	0.95	0.35	0.78	0.93	0.76	0.91	0.79	0.9	0.89	0.84	0.98	0.15	0.77	0.96	0.71	0.93	ě:
PROMES-	0.72	0.83	0.78	0.82		0.3		0.89			0.7	0.83	0.8	0.77		0.21		0.86			0.8	0.89	0.81	0.84		0.53		0.95			011
RegCM4 -	0.64	0.78	0.56	0.77		0.22		0.86			0.65	0.78	0.59	0.76		0.25		0.87			0.66	0.83	0.67	0.87		0.16		0.78			
GUF-CCLM-	0.76	0.89	0.82	0.86		0.27		0.95			0.73	0.87	0.83	0.83		0.19		0.95			0.74	0.87	0.88	0.84		0.16		0.94			
ALADIN-	0.72	0.8	0.86	0.82		0.27		0.84			0.67	0.77	0.86	0.79		0.14		0.8			0.77	0.85	0.88	0.88		0.43		0.81			
AVERAGE-	0.7	0.77	0.8	0.79	0.63	0.38	0.55	0.85	0.68	0.78	0.7	0.76	0.79	0.79	0.62	0.4	0.58	0.84	0.66	0.78	0.79	0.84	0.82	0.85	0.78	0.66	0.69	0.82	0.66	0.89	
E BCA4-	0.55	0.56	0.82	0.69	0.14	0.3	0.38	0.74	0.66	0.66	0.54	0.53	0.77	0.66	0.15	0.31	0.41	0.68	0.65	0.66	0.65	0.73	0.81	0.8	0.46	0.47	0.56	0.61	0.62	0.77	
BACM022E-	0.8	0.85	0.86	0.87	0.89	0.43	0.75	0.9	0.76	0.86	0.81	0.85	0.86	0.88	0.88	0.5	0.79	0.91	0.74	0.86	0.87	0.9	0.89	0.92	0.97	0.67	0.86	0.89	0.72	0.96	
WRF331E-	0.72	0.82	0.76	0.83	0.74	0.41	0.55	0.91	0.61	0.87	0.73	0.81	0.77	0.83	0.75	0.47	0.59	0.9	0.58	0.88	0.8	0.9	0.82	0.88	0.78	0.73	0.67	0.89	0.59	0.97	9
HIBHAM5-	0.62	0.66	0.82	0.77	0.5	0.29	0.44	0.79	0.63	0.66	0.59	0.64	0.76	0.72	0.49	0.25	0.45	0.74	0.62	0.65	0.72	0.83	0.82	0.84	0.73	0.45	0.62	0.81	0.63	0.77	ig.re
CCLM-	0.76	0.84	0.78	0.79	0.86	0.47	0.64	0.92	0.71	0.83	0.77	0.84	0.78	0.8	0.85	0.53	0.67	0.91	0.72	0.83	0.85	0.87	0.83	0.84	0.95	0.76	0.76	0.94	0.74	0.97	los
PROMES-	0.74	0.82	0.85	0.8		0.39		0.84			0.75	0.83	0.85	0.81		0.44		0.83			0.83	0.86	0.92	0.8		0.77		0.8			04
BegCM4-	0.7	0.78	0.72	0.76		0.39		0.85			0.7	0.77	0.72	0.77		0.41		0.85			0.79	0.8	0.67	0.84		0.89		0.75			4
GUF-CCI M-	0.73	0.82	0.72	0.76		0.43		0.92			0.73	0.82	0.71	0.78		0.41		0.92			0.82	0.8	0.75	0.84		0.76		0.93			
ALADIN-	0.72	0.8	0.84	0.83		0.33		0.81			0.71	0.8	0.85	0.82		0.32		0.78			0.76	0.86	0.88	0.87		0.41		0.78			
																															n,
ERAIN-	0.74	0.83	0.67	0.8	0.87	0.48	0.61	0.87	0.76	0.76	0.75	0.83	0.69	0.82	0.85	0.5	0.64	0.87	0.76	0.75	0.85	0.87	0.87	0.88	0.97	0.82	0.73	0.87	0.76	0.93	so
	AVERAGE	Alps	Carpathians	France	Germany	Italy	Norway	Spain	Sweden	ž	AVERAGE	Alps	Carpathians	France	Germany	Italy	Norway	Spain	Sweden	Ϋ́	AVERAGE	Alps	Carpathians	France	Germany	Italy	Norway	Spain	Sweden	Ϋ́	
															reg	ion															

Correlation with ORS (11A)

![](_page_41_Figure_3.jpeg)

				CI	urrent.r	esol: 01	1							С	urrent.r	esol: 04	4							CL	urrent.re	esol: 15	0				
AVERAGE-	0.72	0.63	0.71	0.79	0.86	0.4	0.85	0.84	0.81	0.93	0.74	0.6	0.7	0.78	0.87	0.63	0.85	0.84	0.8	0.92	0.79	0.68	0.78	0.82	0.84	0.71	0.89	0.85	8.0	0.95	
RCA4-	0.77	0.6	0.71	0.73	0.87	0.45	0.83	0.86	0.88	0.95	0.79	0.59	0.71	0.75	0.86	0.71	0.82	0.86	0.88	0.95	0.81	0.68	0.76	0.74	0.85	0.75	0.86	0.87	0.88	0.92	
RACMO22E-	0.83	0.82	0.77	0.89	0.88	0.48	0.89	0.91	0.86	0.93	0.86	0.8	0.77	0.9	0.89	0.8	0.89	0.91	0.84	0.93	0.86	0.85	0.85	0.9	0.78	0.74	0.93	0.85	0.87	0.97	
WRF331F-	0.78	0.63	0.71	0.82	0.89	0.5	0.84	0.88	0.8	0.94	0.8	0.59	0.7	0.81	0.91	0.77	0.85	0.87	0.79	0.94	0.86	0.68	0.72	0.86	0.94	0.97	0.91	0.9	0.77	0.96	orig.
HIRHAM5-	0.69	0.5	0.64	0.73	0.79	0.32	0.81	0.78	0.74	0.87	0.71	0.5	0.65	0.73	0.79	0.53	0.81	0.76	0.73	0.86	0.74	0.57	0.73	0.75	0.73	0.44	0.85	0.86	0.75	0.94	.resc
CCLM-	0.76	0.56	8.0	0.82	0.87	0.35	0.87	0.84	0.76	0.94	0.78	0.55	0.79	0.8	0.9	0.57	0.88	0.85	0.75	0.94	0.78	0.6	0.84	0.83	0.9	0.49	0.88	0.8	0.72	0.96	0:10
PROMES-	0.65	0.72	0.6	0.67		0.43		0.83			0.68	0.65	0.58	0.65		0.68		0.83			0.81	0.77	0.75	0.72		0.96		0.86			=
RegCM4-	0.6	0.45	0.62	0.75		0.44		0.76			0.64	0.45	0.59	0.73		0.66		0.76			0.75	0.62	0.72	0.88		0.75		0.78			
GUF-CCLM-	0.69	0.68	0.76	0.83		0.33		0.86			0.72	0.66	0.76	0.83		0.49		0.88			0.78	0.66	0.82	0.81		0.77		0.82			
	0.68	0.68	0.78	0.83		0.29		0.83			0.72	0.64	0.78	0.83		0.5		0.83			0.76	0.7	0.81	0.86		0.55		0.86			
AVERAGE-	0.55	0.25	0.61	0.65	0.7	0.18	0.77	0.74	0.71	0.86	0.57	0.29	0.6	0.63	0.69	0.29	0.78	0.75	0.7	0.86	0.68	0.38	0.66	0.71	0.84	0.58	0.86	0.8	0.72	0.93	
C RCA4-	0.52	0.1	0.58	0.53	0.62	0.14	0.59	0.62	0.65	0.84	0.52	0.1	0.54	0.49	0.59	0.27	0.6	0.62	0.65	0.84	0.64	0.29	0.61	0.63	0.79	0.49	0.72	0.68	0.64	0.91	
RACMO22E-	0.7	0.46	0.68	0.76	0.78	0.21	0.87	0.83	0.81	0.91	0.73	0.51	0.67	0.78	0.77	0.42	0.89	0.84	0.79	0.91	0.81	0.57	0.75	0.82	0.9	0.57	0.94	0.87	0.84	0.98	
WRF331F-	0.64	0.29	0.56	0.6	0.73	0.33	0.82	0.8	0.74	0.86	0.65	0.36	0.57	0.58	0.76	0.4	0.83	0.81	0.71	0.86	0.77	0.51	0.61	0.66	0.82	0.89	0.9	0.87	0.79	0.9	orig.
HIRHAM5-	0.55	0.17	0.57	0.59	0.65	0.05	0.74	0.63	0.7	0.85	0.55	0.2	0.52	0.53	0.65	0.14	0.73	0.64	0.7	0.84	0.66	0.27	0.6	0.7	0.85	0.39	0.83	0.77	0.64	0.91	reso
CCLM-	0.62	0.23	0.71	0.68	0.69	0.17	0.85	0.77	0.63	0.86	0.64	0.29	0.71	0.67	0.7	0.26	0.87	0.78	0.62	0.85	0.72	0.39	0.71	0.7	0.87	0.39	0.93	0.83	0.7	0.96	0::0
PROMES-	0.51	0.33	0.62	0.65		0.18		0.78			0.55	0.39	0.6	0.65		0.32		0.79			0.61	0.37	0.7	0.68		0.44		0.86			44
RegCM4-	0.5	0.28	0.47	0.71		0.33		0.72			0.52	0.31	0.49	0.68		0.42		0.71			0.66	0.42	0.56	0.84		0.84		0.63			
GUF-CCLM-	0.46	0.16	0.59	0.6		0.17		0.77			0.5	0.22	0.59	0.59		0.28		0.79			0.59	0.23	0.62	0.59		0.69		0.82			
ALADIN-	0.49	0.24	0.74	0.7		0.03		0.74			0.5	0.27	0.72	0.69		0.08		0.75			0.64	0.39	0.73	0.75		0.49		0.86			
ERAIN-	0.63	0.23	0.7	0.65	0.71	0.16	0.85	0.8	0.74	0.84	0.64	0.23	0.71	0.64	0.7	0.2	0.87	0.81	0.73	0.84	0.8	0.49	0.81	0.67	0.91	0.69	0.94	0.95	0.84	0.94	ose
	AVERAGE	Alps	Carpathians	France	Germany	Italy	Norway	Spain	Sweden	N	AVERAGE	Alps	Carpathians	France	Germany	Italy	Norway	Spain	Sweden	N	AVERAGE	Alps	Carpathians	France	Germany	Italy	Norway	Spain	Sweden	N	
															109																

Correlation with OBS (SON)

![](_page_42_Figure_3.jpeg)

## Model by model bias

	DJF bias % <mod obs="" –="">/<obs></obs></mod>																											
	current.resol: 011									current.resol: 044										current.resol: 150								
AVERAGE-	0.04	6.73	14.11	-5.36	-26.29	-16.51	-12.87	8.89	-21.83	-0.76	7.32	13.95	-5.92	-25.02	-17.51	-13.6	9.25	-21.87	-3.48	8.29	13.6	-5.6	-27.63	-21.8	-14.9	14.31	-23.69	
RCA4-	19.9	14.71	47.87	10.67	-13.53	-13.73	8.23	19.33	-5.19	18.63	15.24	47.2	9.91	-10.36	-14.88	6.32	19.77	-5.16	17.31	17.6	45.94	10.82	-15.53	-17.83	1	23.19	-5.88	
RACMO22E-	-0.8	2.68	14.34	-12.78	-18.21	-16.46	-14.92	0.22	-24.73	-2.25	3.31	14.15	-13.3	-18.37	-17.1	-15.79	0.78	-24.15	-6.19	6.37	12.85	-13.07	-22.26	-21.37	-18.32	7.83	-27.86	
WRF331F-	-7.93	7.54	4.38	-8.65	-38.67	-22.68	-29.72	6.6	-27.1	-9.24	8.54	4.07	-9.26	-40.44	-23.02	-30.49	6.89	-27.14	-12.34	9.77	2.81	-10.07	-38.08	-28.46	-29.62	11.6	-28.01	
HIRHAM5-	9.17	9.1	16.8	-1.55	-20.6	-3.1	-6.54	7	-19.57	11.7	9.33	17.68	-1.4	-14.27	-5.63	-8.28	6.6	-20.04	6.99	7.22	18.32	-0.85	-24.06	-12.08	-14.59	13.79	-24.03	
CCLM-	0.21	8.63	-0.9	-14.49	-42.6	-26.59	-17.21	11.31	-32.56	-1.85	9.77	-0.85	-15.55	-42.06	-26.92	-17.68	12.22	-32.85	-4.61	11	-2.9	-14.81	-44.09	-29.26	-18.74	15.14	-32.66	
PROMES-	-15.89	-22.29	24.66		-24.46		-6.56			-17.27	-22.29	24.15		-20.47		-7.07			-19.09	-20.6	28.04		-39.36		-8.91		011	
RegCM4 -	13.41	28.23	0.97		-7.36		-10.34			11.85	28.16	1.1		-10.33		-10.18			9.18	27.62	0.09		-0.65		-6.92			
GUF-CCLM-	2.45	23.54	20.55		-35.25		-18.07			0.76	25.26	20.2		-34.28		-18.24			-2.8	27.31	17.84		-38.23		-18.84			
ALADIN-	-20.14	-11.55	-1.68		-35.9		-20.72			-19.2	-11.39	-2.17		-34.6		-20.98			-19.81	-11.7	-0.6		-26.38		-19.19			
& AVERAGE-	-8.8	3.24	6	-10.14	-39.94	-27.73	-17.62	11.46	-30.94	-10.71	4.25	5.76	-11.06	-38.62	-27.82	-18.38	11.61	-30.79	-9.45	6.69	2.67	-8.21	-38.22	-30.64	-19.82	14.74	-30.63	
Ē RCA4-	-2.5	10.59	14.07	-10.52	-36.01	-31.06	-11.73	17.82	-28.75	-4.96	11.23	14.4	-11.7	-32.56	-31.24	-13.21	18.26	-28.8	-2.33	12.57	9.32	-7.67	-36.53	-34.94	-19.9	19.33	-28.62	
RACMO22E-	-6.71	-2.78	9.57	-13.17	-28.45	-27.96	-18.52	0.89	-31.43	-8.06	-1.88	9.26	-14.16	-25.5	-27.92	-18.89	0.81	-31.12	-8.47	0.75	5.53	-11.43	-29.15	-30.81	-19.71	5.48	-31.56	
WRF331F-	-10.69	6.33	2	-7.7	-52.11	-30.06	-34.72	6.8	-33.72	-13.16	7.6	1.35	-8.51	-53.71	-30.08	-35.6	6.83	-33.48	-11.53	11.52	-1.46	-5.52	-48.26	-32.26	-35.57	10.48	-32.99 3	
HIRHAM5-	8.11	15.3	19.95	0.45	-27.88	-17.7	-2.94	22.38	-25.37	5.64	16.32	20.96	-0.32	-23.83	-17.6	-4.65	22.43	-25.23	6.19	18.11	17.53	1.95	-25	-22.19	-11.4	26.76	-24.19	
CCLM-	-16.24	-2.27	-4.75	-19.79	-52.52	-31.87	-24.62	9.39	-35.43	-17.52	-1.11	-5.27	-20.61	-52.56	-32.24	-25.06	9.69	-35.33	-16.72	1.91	-8.39	-18.4	-51.2	-32.98	-23.56	11.64	-35.77	
PROMES-	-9.66	-8.95	13.64		-35.31		0.8			-11.56	-8.5	13.21		-32.44		0.37			-11.01	-6.71	9.91		-35.14		-1.99		044	
RegCM4 -	1.51	18.27	0.42		-34.1		-19.36			-0.95	19.64	0.21		-34.94		-19.51			1.14	23.6	-2.24		-29.81		-19.69			
GUF-CCLM-	-24.01	-1.92	-0.95		-55.75		-30.2			-25.51	-0.57	-1.71		-55.06		-30.67			-24.63	2.26	-5.18		-56.34		-29.49			
ALADIN-	-18.97	-5.46	0.04		-37.28		-17.3			-20.34	-4.48	-0.56		-36.98		-18.18			-17.68	-3.78	-1		-32.52		-17.1			
ERAIN-	-32.23	-11.95	-6.77	-24.96	-41.53	-39.94	-27.06	-3.25	-41.86	-33.51	-10.86	-7.61	-25.89	-41.19	-40.47	-27.44	-2.94	-41.92	-31.03	-8.46	-9.51	-23.46	-39.53	-41.16	-27.33	-1.63	-41.85	
	Alps-	Carpathians-	France-	Germany-	Italy-	Norway-	Spain-	Sweden -	-YU	Alps-	Carpathians-	France-	Germany-	- Italy	Norway-	Spain-	Sweden -	- NU	Alps-	Carpathians-	France-	Germany-	Italy-	Norway-	Spain-	Sweden -	- NN	
														region														

![](_page_43_Figure_3.jpeg)

## Model by model bias

							140.4	wi biu	0 /0		. 00	027.50	002																		
	current.resol: 011											current.resol: 044										current.resol: 150									
A	VERAGE-	10.78	19.97	18.35	4.64	-10.47	0.4	-7.4	26.36	-5.65	11.08	19.67	18.78	4.17	-8.05	-0.46	-8.72	26.59	-6.05	8.33	19.67	17.11	3.83	-9.32	-6.01	-13.11	29.8	-7.44			
	RCA4-	31.54	45.89	54.33	35.01	4.06	-0.39	10.45	36.79	17.43	33.79	44.3	54.79	34.58	9.18	-1.27	7.95	37.02	17.15	35.08	46.29	53.19	32.63	2.36	-5.16	-0.07	38.28	17.31			
RA	CMO22E-	-5.9	-4.75	9.01	-12.59	-20.78	-6.2	-9.87	1.64	-12.26	-6.73	-4.93	9.25	-13.13	-20.37	-6.59	-11.02	1.89	-12.04	-9.04	-4.17	7.22	-14	-18.88	-11.79	-15.86	7	-15.75			
V	VRF331F-	8.06	28.93	19.64	12.81	-12.3	-4.88	-16.16	23.11	-10.53	7.31	28.73	19.36	12.27	-14.28	-5.18	-17.36	23.49	-10.88	5.2	29.35	18.06	11.68	-10.27	-12.15	-20.13	26.91	-11.38	orig		
ŀ	HRHAM5-	6.36	-1.47	6.61	-8.53	-24.74	21.96	-13.63	41.09	-5.4	12.24	-2.8	8.4	-8.47	-15.25	19.36	-15.61	40.73	-6.58	9.74	-4.68	8.81	-7.09	-21.32	11.48	-23.79	44.58	-8.7	.res		
	CCLM-	12.97	10.01	2.97	-3.48	-28.28	-8.48	-20.76	29.15	-17.49	10.79	10.3	3.37	-4.37	-27.57	-8.59	-21.64	29.83	-17.9	6.14	9.99	0.42	-4.06	-29.02	-12.44	-25.61	32.23	-18.69	<u>0</u>		
ł	PROMES-	5.98	21.06	24.85		5.34		-2.14			5.99	21.19	25.22		10.43		-3.41			3.16	21.24	26.91		-5.99		-7.88			11		
	RegCM4-	7.54	17.79	4.74		10.2		-9.88			8.06	17.3	5.35		7.49		-10.08			4.07	16.84	3.03		26.39		-10.11					
GU	JF-CCLM-	15.61	29.84	13.56		-28.55		-21.41			14.12	30.3	13.95		-27.53		-22.19			8.13	30.44	11.04		-28.28		-26.2					
-	ALADIN-	14.84	32.47	29.49		0.78		16.76			14.14	32.66	29.3		5.47		14.92			12.49	31.7	25.32		1.11		11.66					
δ A	VERAGE-	3.48	13.51	8.53	-0.66	-27.68	-10.18	-15.51	27.76	-15.73	2.04	13.91	8.94	-1.28	-25.22	-9.87	-16.89	27.82	-15.8	3.02	14.4	4.62	0.06	-25.24	-14.55	-22.14	30.26	-14.29	-		
E	RCA4-	8.71	25.5	16.61	6.42	-26.39	-7.98	-10.15	37.7	-2.48	7.16	25.26	17.87	5.27	-21.69	-7.83	-12.48	38.03	-2.67	9.67	22.66	11.5	8.01	-23.02	-14.42	-23.42	39.2	-0.85			
RA	CMO22E-	-5.43	-2.79	6.68	-6.48	-27.42	-20.44	-19.26	3.32	-18.56	-6.43	-2.62	6.82	-7.16	-24.76	-20.07	-20.14	3.18	-18.42	-6.4	-2.84	2.67	-6.23	-27.03	-23.81	-26.02	6.72	-18.15	-		
V	WRF331F-	5.51	21.48	12.32	9.14	-26.49	-12.71	-28.01	21.64	-18.82	4.04	22.14	12.1	8.63	-26.83	-12.33	-29.45	21.6	-18.91	4.3	24.13	8.63	9.62	-19.84	-16.29	-32.31	24.35	-17.64	orio		
ŀ	HRHAM5-	10.33	10.29	6.26	-1.99	-28.68	5.01	-15.75	53	-13.62	8.91	10.37	8.08	-2.44	-24.38	5.61	-18.57	53.06	-13.8	9.94	9.18	3.42	-1.2	-25.91	-1.6	-29.47	56.04	-9.84	g.re		
	CCLM-	2.4	2.58	-4.08	-10.39	-46.41	-14.76	-29.62	23.1	-25.15	0.8	3.05	-4.05	-10.69	-45.51	-14.74	-30.47	23.23	-25.17	0.02	4.55	-8.49	-9.91	-47	-16.63	-31.96	24.97	-24.94	<u>80</u>		
I	PROMES-	13.68	29.49	21.7		-21.47		7.16			11.58	30.15	21.8		-17.4		5.92			14.32	31.53	16.66		-22.77		-0.49			044		
	RegCM4-	-2.37	7.44	0.17		-5.09		-15.79			-3.12	8.04	0.61		-3.81		-16.36			-2.38	9.25	-1.91		5.51		-21.07					
GU	JF-CCLM-	-6.52	7.29	-1.48		-50.98		-33.73			-7.98	7.88	-1.61		-49.67		-34.56			-8.42	9.37	-5.88		-52.83		-36.19					
	ALADIN-	4.98	20.3	18.62		-16.21		5.55			3.41	20.9	18.84		-12.91		4.08			6.15	21.81	14.95		-14.31		1.67					
	ERAIN-	-15.83	1.75	-2.68	-12.71	-26.63	-26.35	-18	5.85	-26.29	-16.74	2.33	-2.91	-13.29	-25.43	-26.61	-18.62	6.04	-26.41	-14.42	3.78	-5.85	-12.07	-24.33	-28.15	-20.27	7.57	-25.47	esc		
		Alps-	Carpathians-	France-	Germany-	Italy-	Norway-	Spain-	Sweden -	- YU	Alps-	Carpathians-	France-	Germany-	region	Norway-	Spain-	Sweden -	-YU	Alps-	Carpathians-	France-	Germany-	Italy-	Norway-	Spain-	Sweden -	- NU			
															-																

MAM bias % <mod – obs>/<obs>

![](_page_44_Figure_3.jpeg)

## Model by model bias

	current.resol: 011											current.resol: 044								current.resol: 150									
AVERAGE-	-9.9	-12.6	0.07	0.61	-24.4	-6.49	-10.95	7.62	-4.1	-9.37	-12.52	0	0.12	-21.74	-6.5	-12.76	7.74	-4.22	-11.08	-12.26	-0.01	0.63	-12.52	-10.04	-17.09	8.61	-4.8		
RCA4-	-18.95	-9.9	17.22	22.53	-33.76	4.92	-1.92	27.02	27.73	-15.17	-10.44	17.23	22.21	-26.81	4.9	-4.8	26.89	28.13	-11.7	-9.91	19.85	20.44	-27.18	2.23	-11.08	26.95	30.14		
RACMO22E-	-16.81	-21.44	-0.96	-8.03	-34.46	-17.08	-10.4	-5.33	-8.56	-17.7	-21.18	-1.05	-8.64	-32.61	-17.09	-11.54	-5.09	-8.28	-18.25	-20.7	-0.41	-8.84	-28.25	-19.38	-19	-4.92	-10.7		
WRF331F-	3.63	6.52	27.52	17.55	16.63	-11.57	16.31	14.45	-4.74	2.97	6.82	26.92	16.79	15.85	-11.79	14.07	14.99	-5.13	2.29	8.62	28.57	17.48	33.4	-14.91	14.29	15.85	-8.36	orig	
HIRHAM5-	-17.18	-21.55	-17.34	-10.13	-66.16	0.16	-45.44	5.7	-11.37	-11.72	-21.94	-17.11	-10.32	-60.34	0.04	-47.28	5.46	-12.29	-13.64	-22.47	-15.67	-7.49	-57.29	-5.26	-51.41	6.75	-9.47	l.res	
CCLM-	-14.53	-36.04	-31.23	-18.9	-50.67	-8.89	-59.29	-3.75	-23.58	-16.23	-35.68	-31.04	-19.43	-50.94	-8.56	-59.95	-3.54	-23.52	-18.06	-36	-32.14	-18.42	-39.89	-12.88	-62.7	-1.57	-25.63	Ö:	
PROMES-	6.14	9.41	13.01		8.36		2.23			6.19	9.49	12.69		15.33		-1.19			-0.07	9.03	15.05		8.1		-7.75			011	
RegCM4 -	-31.79	-26.16	-7.02		-22.79		-8.05			-31	-26.05	-7.1		-27.72		-7.77			-32.45	-25.71	-8.63		12.72		-14.42				
GUF-CCLM-	-13.24	-13.94	-18.67		-55.35		-48.13			-13.93	-13.82	-18.43		-55.01		-48.96			-19.14	-13.81	-19.85		-45.44		-50.13				
ALADIN-	13.59	-0.34	18.08		18.58		56.15			12.22	0.09	17.93		26.55		52.58			11.28	0.61	13.12		31.14		48.38				
AVERAGE-	-21.86	-25.33	-14.21	-11.54	_49.55	-14.15	-19.1	1.44	-17	-23.48	-24.91	-14.38	-12.19	-47.33	-13.51	-21.58	1.55	-16.99	-21.34	-24.61	-15.79	-10.75	-44.18	-18.34	-28.29	2.22	-15.19		
E BCA4-	_33.39	-29.45	-24.22	-15.88	_47.42	-7.89	-15.32	10.65	-4.03	-34.68	-29.5	-23.66	-16.97	-42.56	-7.24	-19.09	10.71	-3.96	-31.92	-31.15	-26.27	-14.77	-43.11	-14	-29.13	10.95	-0.68		
BACMO22E-	-22.83	-27.38	-13.89	-15.33	-45.6	-22.9	-15.76	-10.12	-18.18	-24.25	-26.94	-14.2	-15.93	-43.36	-22.2	-17.23	-9.98	-17.94	-22.49	-26.79	-15.51	-14.89	-45.75	-25.56	-26.43	-9.19	-17.22		
WRE331E-	-9.6	-1.51	15.13	11.05	-25.85	-16.75	-1.15	6.85	-16.2	-11.11	-0.63	14.35	10.28	-24.18	-16.23	-4.78	7.13	-16.33	-9.67	1.03	13.21	11.71	-16.15	-19.95	-8.7	8.27	-16.26	9	
HIBHAM5-	-24.42	-17.45	-27.98	-11.74	-70.79	-5.06	-45.99	8.81	-12.18	-25.77	-17.22	-27.6	-12.36	-69.14	-4.21	-50.27	8.9	-12.41	-24.16	-17.74	-28.64	-10.37	-66.53	-11.61	-56.33	9.38	-7.89	ig.re	
CCLM-	-26.1	-47.22	-37.95	-25.82	-79.5	-18.15	-63.73	-8.97	-34.43	-27.91	-46.85	-38.3	-25.99	-79.55	-17.7	-64.72	-8.98	-34.31	-26.51	-45.99	-39.04	-25.4	-79.11	-20.58	-65.01	-8.33	-33.9	los	
PROMES-	-7.06	-10.84	6.44		-58.29		4.66			-9.46	-10.22	6.07		-55.61		2.22			-6.8	-9.91	3.83		-55.7		-11.82			24	
ReaCM4-	-32.08	-27.19	-5.71		-25.03		-0.62			-32.86	-26.76	-5.93		-23.31		-2.27			-30.49	-26.43	-6.94		-9.44		-15.47			4	
GUF-CCLM-	-32.38	-46.15	-33.3		-83.3		-62.88			-34.39	-45.57	-33.89		-82.29		-64.07			-33.07	-44.92	-34.31		-86.24		-65.18				
ALADIN-	-8.89	-20.73	-6.37		-10.14		28.88			-10.91	-20.46	-6.3		-5.96		25.96			-6.92	-19.62	8.4		4.44		23.47				
ED AINI	0.7	0.00	0.47	44.40	00.00	01.01	10.04	0.00	00.04	7 70	0.00	0.00	10.04	00.00	00 F	10.07	0.50	00.54	0.00		10.04	10.01	477	00.4	47.00	0.07	10.0	g	
ERAIN-	-6.7	3.36	-8.17	-11.49	-22.29	-21.01	-10.91	-0.68	-20.61	-7.72	3.83	-8.63	-12.04	-20.06	-20.5	-12.67	-0.52	-20.51	-6.69	5	-10.34	-10.81	-17.7	-22.4	-17.36	0.67	-18.6	SO	
	Alps	Carpathians	France	German)	Italy	Norway	Spair	Sweder	Š	Alps	Carpathians	France	Germany	Italy	Norway	Spair	Sweder	Ň	Alps	Carpathians	France	Germany	Italy	Norway	Spair	Sweder	Ň		
		÷												region						-									

JJA bias % <mod – obs>/<obs>

![](_page_45_Figure_3.jpeg)

## Model by model bias $_{\scriptscriptstyle{\rm SON}}$

	current.resol: 011										current.resol: 044										current.resol: 150								
AVERAGE-	-10.61	1.29	-3.13	-5.11	-19.97	-11.47	-19.25	13.19	-19.44	-10.34	1.39	-3.24	-5.64	-19.24	-12.28	-19.69	13.58	-19.31	-11.5	2	-3.35	-4.8	-22.32	-16.86	-19.72	16.65	-20.02		
RCA4-	7.71	16.88	22.33	17.59	1.94	-7.52	-1.46	30.2	-0.59	8.36	16.31	21.77	17.03	5.48	-8.58	-2.99	30.6	-0.21	10.77	17.08	21.18	16.93	-2	-12.01	-6.05		-0.03		
RACMO22E-	-10.81	-8.24	-0.4	-9.31	-7.08	-12.35	-14.4	6	-19.19	-11.29	-8.02	-0.5	-9.91	-6.55	-12.84	-14.92	6.47	-18.62	-13.13	-6.68	-1.64	-9.5	-14.9	-16.9	-15.34	10.79	-21.22		
WRF331F-	-20.7	-10.23	-14.95	-15.92	-30.27	-19.97	-35.12	2.69	-29.69	-21.49	-9.71	-15.24	-16.5	-33.19	-20.33	-35.02	3.15	-29.28	-22.02	-8.17	-12.89	-15.64	-34.92	-26.14	-33.1	5.93	-29.67	orig	
HIRHAM5-	-4.71	1.68	-0.32	0.12	-25.5	3.77	-17.03	22.14	-16.2	-1.1	0.86	0.34	0	-18.03	1.76	-18.4	22.05	-17.01	-3.03	-0.5	0.68	2.17	-29.66	-4.69	-21.6	25.97	-17.81	J.res	
CCLM-	-16.64	-7.76	-15.93	-18	-41.01	-21.28	-27.8	4.91	-31.53	-17.93	-7.39	-15.86	-18.84	-40.35	-21.39	-28.02	5.62	-31.43	-20.14	-7.1	-18.25	-17.96	-43.61	-24.55	-27.34	8.54	-31.38	0 : 0	
PROMES-	-12.6	5.68	4.22		-6.88		-8.51			-12.16	6.18	3.89		-2.61		-9.13			-12.31	7.52	6.97		-24.58		-11.55			011	
RegCM4-	-12.44	15.77	-13		-7.78		-21.04			-11.84	15.64	-12.87		-15.76		-20.47			-13.12	16.19	-13.66		5.68		-18.16				
GUF-CCLM-	-10.97	6.66	-3.71		-37.93		-33.39			-12.04	7.4	-3.86		-37.48		-33.28			-15.57	8.51	-5.21		-38.73		-32.54				
ALADIN-	-14.3	-8.81	-6.45		-25.22		-14.45			-13.55	-8.76	-6.87		-24.65		-15.03			-14.94	-8.87	-7.36		-18.17		-11.81				
AVERAGE-	-17.46	-5.57	-9.41	-10.95	_31.24	-20.88	_24 95	13.97	-26.48	-18.21	-5.04	_9.37	-11.67	_29.53	_20.77	_25.87	14 17	-26.37	-17 57	-3.47	_12 57	_9.25	_31.74	-24 74	-26.89	16.43	_25.82		
E BCA4-	-18.83	-2.44	-6.82	-10.91	-28.65	-18.52	-20.78	24.39	-19.03	-19.69	-2.31	-6.02	-11.98	-24.1	-18.46	-22.3	24.75	-19	-17.72	-2.53	-10.33	-8.67	-30.95	-24	-28.4	25.56	-18.49		
BACM022E-	-13.94	-12.15	-1.01	-11.61	-19.15	-23.26	-16.23	4.43	-24.77	-14.28	-11.85	-1.16	-12.48	-16.17	-23.01	-16.67	4.57	-24.46	-15.38	-10.85	-5.17	-10.15	-23.88	-26.66	-17.7	7.74	-24.74		
WRE331E-	-23.68	-8.87	-18.07	-13.07	-41.92	-25.72	-40.71	9.37	-32.88	-24.07	-8.04	-18.6	-13.68	-43.73	-25.62	-41.64	9.53	-32.78	-23.76	-5.13	-19.93	-11.33	-37.65	-28.46	-39.47	12.34	-31.7	9	
HIBHAM5-	-3.22	10.59	1.42	2.66	-27.98	-9.2	-18.41	30.71	-19.55	-4.65	10.97	2.54	2.09	-24.1	-8.92	-20.87	30.87	-19.65	-3.44	11.66	-2.27	4.48	-27.71	-15.04	-25.59	33.14	-17.82	ig.re	
CCLM-	-24.09	-21.26	-18.89	-21.83	-51.99	-27.7	-36.78	0.97	-36.18	-24.88	-20.77	-19.16	-22.33	-51.43	-27.84	-37.34	1.12	-35.99	-25.1	-19.15	-22.25	-20.57	-54.75	-29.52	-36.09	3.36	-36.34	lose	
PROMES-	-10.97	-1.45	-2.23		-21.82		-11.25			-12.3	-0.91	-2.38		-18.03		-11.92			-9.43	1.04	-6		-26.38		-13.92			24	
ReaCM4-	-15.3	9.8	-13.34		-6.34		-22.66			-15.27	10.57	-13.14		-6.2		-22.62			-16.3	13.28	-15.6		1.06		-23.69			4	
GUF-CCLM-	-29.19	-15.13	-16.02		-51.72		-41.87			-30	-14.29	-16.42		-51.06		-42.43			-30.43	-11.63	-19.7		-55.26		-41.55				
ALADIN-	-17.9	-9.21	-9.72		-31.56		-15.89			-18.76	-8.73	-10		-30.98		-17.08			-16.54	-7.88	-11.88		-30.11		-15.58				
ED AINI	00.00	5.40	10.10	17.01	00.00	00.50	00.54		05.75	07.44	4.04	10.07	10.50	00.40	00.04	07.05	1.05	05.00	05.00	0.00	15.50	17.05	07.50	00.00	00.04	0.00	05.00	g	
ERAIN-	-26.62	-5.46	-12.16	-17.81	-29.09	-36.56	-26.54	-2.2	-35.75	-27.11	-4.91	-12.6/	-18.56	-28.42	-36.81	-27.05	-1.85	-35.88	-25.82	-3.23	-15.52	-17.05	-27.53	-38.22	-26.94	-0.68	-35.86	ő	
	Alps	thians	rance	many	Italy	orway	Spair	veder	Š	Alps	thians	rance	many	Italy	orway	Spair	veder	Š	Alps	thians	rance	many	Italy	orway	Spair	veder	Š		
		ırpa	uL.	Ge		Z		Ś			ırpa		Ge		Z		Ś			ırpa		Ge		z		Ś			
		ö									ö			reales						ö									
														region															

SON bias % <mod – obs>/<obs>

![](_page_46_Figure_3.jpeg)