

Evaluation AROME 500 m Simulations in the Framework of DE On-Demande-Extremes

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1.AROME 500 m – Setup and Tested Cases

2. Methodology for Gridded Verification

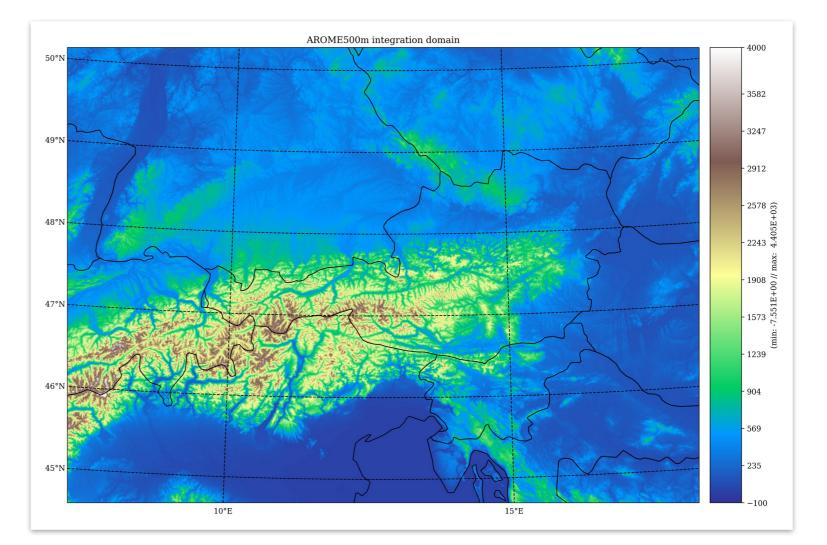
3.Results in Detail

4.Summary



Case Selection

- Selection based on station data
- 65 days with observed rr > thres selected from 2016 -2023
- 48 h forecasts with AROME 500m
- Inits one day before and on the day of the observed peak
- Overall approx. 130 model runs performed on ECMWF ATOS
- Fixed domain covering the (eastern) Alpine region





AROME 500m and AROME

AROME 500m setup (Deode prototype v.03):

- AROME cy48t3_deode
- dx, dy= 1km, linear truncation
- 1728 x 1250 grid points
- 90 Levels (lowest 5m)
- Time step: 30s
- Initialization: IFS HRES (3D + surface)
- Coupling: IFS HRES (hourly)
- Modified dyn setup w.r.t. AROME-Aut (e.g. comad, p/c nsiter=2, no slhd, tuning spectral nudging)

AROME-Austria setup:

- AROME cy43t2
- dx, dy= 2.5km, / linear truncation
- 600 x 432 grid points
- 90 Levels (lowest 5m)
- Time step: 60s
- Initialization: 3DVar, OI
- Counting: IFS HRES (hourly) time

AM <mark>DYN</mark> :	1 0 1 0 1	
LADVF: True	NAM <mark>DYN</mark> A:	
LQMPD: False	LCOMADH: True	
LQMT: False	LCOMADV: False	
LQMVD: False	LCOMAD_GFL: True	NEMELBC0B:
LRHDI_LASTITERPC: True	LCOMAD_SP: True	NEFRSPCPL: 1
NITMP: 4	LCOMAD_SPD: True	NEK0: 220 NEK1: 255
NSITER: 2	LCOMAD_SVD: True	NERI: 233 NENI: 4
NSPDLAG: 3	LCOMAD_T: True	NEN2: 8
NSVDLAG: 3	LCOMAD_W: True	SPNUDDIV: 0.3
NTLAG: 3	LGWADV: True	SPNUDQ: 0.
NVLAG: 3	LNESC: True	SPNUDT: 0.3
NWLAG: 3	LPC_CHEAP: True	SPNUDVOR: 0.3
RDAMPDIV: 20.0	LPC FULL: True	<pre>TEFRCL: \${namelist.tefrcl}</pre>
RDAMPPD: 20.0	LRDBBC: False	
RDAMPQ: 0.0	LSETTLS: False	gridtype = "linear"
RDAMPT: 0.0	LSETTLST: True	name = "AUSTRIA CASES"
RDAMPVD: 20.0	LSLHD_GFL: False	nimax = 1717
RDAMPVOR: 20.0	LSLHD_OLD: False	njmax = 1239
REPS1: 0.0	LSLHD_SPD: False	tstep = 30
REPS2: 0.0	LSLHD_SVD: False	
REPSM1: 0.0	LSLHD_T: False	xdx = 500.0
REPSM2: 0.0	LSLHD_W: False	xdy = 500.0
REPSP1: 0.0	ND4SYS: 2	xlat0 = 47.5
SDRED: 1.0 SIPR: 60000.0	NPDVAR: 2	xlatcen = 47.5
SIFR: 350.0	NVDVAR: 4	xlon0 = 12.75
SITRA: 50.0	SLHDEPSH: 0.08	xloncen = 12.75
SLHDA0: 0.25	SLHDKMAX: 6	

Warning: Comparing AROME-500 vs. AROME-Aut is not fair, but we want to know where we stand compared to operational systems

SLHDD00: 6.5e-05 VESL: 0.05

XIDT: 0.0 ZSLHDP1: <u>1.7</u>

ZSLHDP3: 0.6

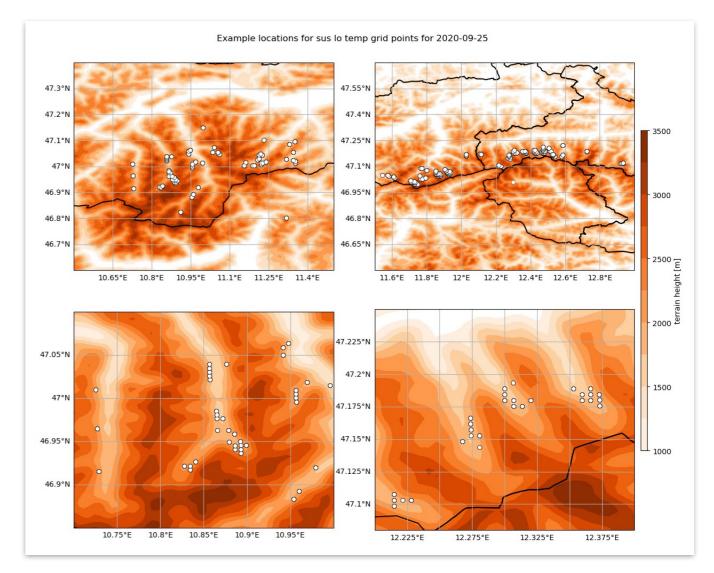
Evaluation of AROME 500 m in DE On-Demande-Extremes 4



Notable Experiences

- No crashes* observed during 130 model runs
- But: SMILAG/ETADOT messages ocurred (more during wintertime)
- Indicates that references setup, in particular tstep=30 is close to the limit for stability
- But no obvious problems seen so far in the output fields (visual checks, fields look reasonable)
- Changing to quadratic/cubic truncation and/or reduction of tstep (15-20s) removes SMILAG/ETADOT

* problems with explicit snow scheme (ABORT with "suspicious low temp in layer ..." has to be commented).





- 5

Verification Methodology

- Each selected day was covered with two 500 m simulations:

 init 00 UTC the same day
 init 00 UTC the day before
- Verified variable: 24 hour accumulated precipitation of the marked period

-24 h	00 UTC HPE Day	+24 h	+48 h
AROME 500 m	Day of observed HPE		
	AROME 500 m		•
AROME Aut			_
	AROME Aut		
I <mark>FS Highres</mark>			_
	FS Highres		+



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AROME 500 m	Day of observed HPE		
	AROME 500 m		
AROME Aut			>
	AROME Aut		
I <mark>FS Highres</mark>			
	FS Highres		

- Each run of Panelification compares these 6 runs, FSS is aggregated over all 65 days.
- 130 runs of AROME 500, AROME-Aut, and IFS Highres (390 model runs compared in total)



Verification Methodology

- Each selected day was covered with two 500 m simulations:

 init 00 UTC the same day
 init 00 UTC the day before
- Verified variable: 24 hour accumulated precipitation of the marked period
- Verification metric: Fraction Skill Score Aggregated FSS Relative Aggregated FSS
- Consecutive days of one longer HPE are verified as two separate days

-24 h	00 UTC HPE Day	+24 h	+48 h
AROME 500 m	Day of observed HPE		
	AROME 500 m		
AROME Aut			>
	AROME Aut		
I <mark>FS Highres</mark>			
	IFS Highres		

- Each run of Panelification compares these 6 runs, FSS is aggregated over all 65 days.
- 130 runs of AROME 500, AROME-Aut, and IFS Highres (390 model runs compared in total)



Fraction skill score for one threshold and window siz

$$FSS = \frac{2f_o f_m}{f_o^2 + f_m^2}$$

 $f_{\rm o} \ldots$ observed frequency summed over all grid points

 $f_{\rm m} \ldots$ simulated frequency summed over all grid points

Lowest value:0Perfect value:1Useful/skillful threshold: $0.5 * (1 + f_o)$



Using the FSS for more than one period

Fraction skill score for one threshold and window siz

$$FSS = \frac{2f_o f_m}{f_o^2 + f_m^2}$$

 $FSS_{Averaged} = \sum_{t=0}^{t_n} \frac{2f_{o,t}f_{m,t}}{f_{o,t}^2 + f_{m,t}^2}$

 $f_{\rm o} \ldots$ observed frequency summed over all grid points

 $f_{\rm m} \ldots$ simulated frequency summed over all grid points

Lowest value:0Perfect value:1Useful/skillful threshold: $0.5 * (1 + f_o)$

Averaging the FSS gives **equal weight to all events** (periods), which means that weaker precipitation periods can heavily distort results for higher precipitation thresholds.



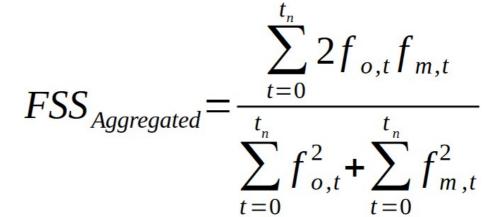
Using the FSS for more than one period

Fraction skill score for one threshold and window siz

$$FSS = \frac{2f_o f_m}{f_o^2 + f_m^2}$$

 $FSS_{Averaged} = \sum_{t=0}^{n} \frac{2t_{o,t} t_{m,t}}{f_{o,t}^2 + f_{m,t}^2}$

Aggregating the FSS weights per grid point, at which the threshold is **exceeded**. However, this weights more widespread events more heavily.





f_o ... observed frequency summed over all grid points

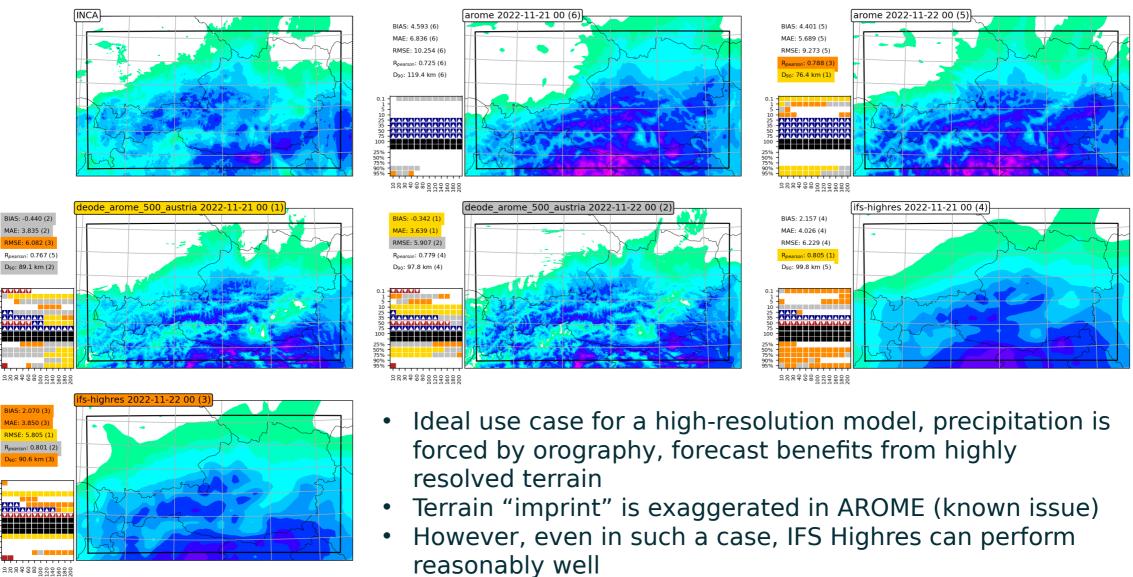
 f_m ... simulated frequency summed over all grid points

Lowest value: Perfect value: Useful/skillful threshold:

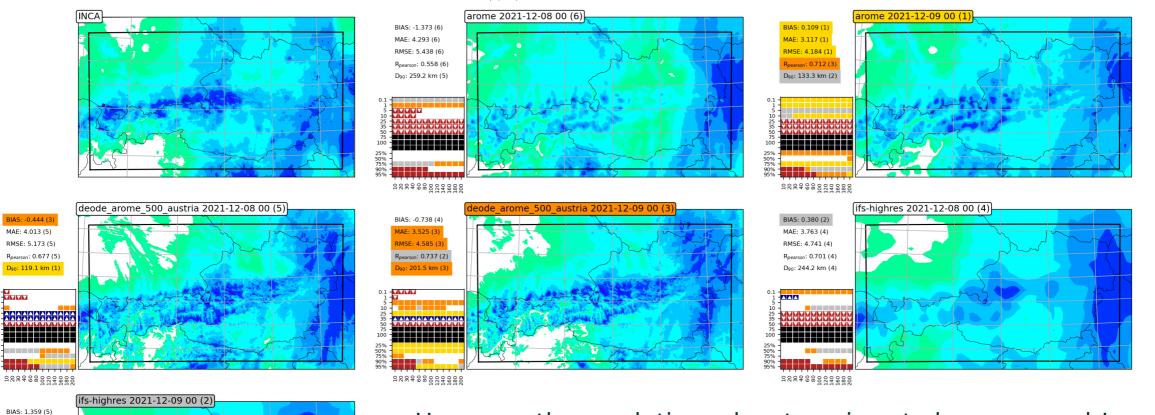
 $0.5 * (1 + f_{o})$

Evaluation of AROME 500 m in DE On-Demande-Extremes

21 November 2022 - large scale, orographically forced



9 December 2022 - large scale, orographically forced

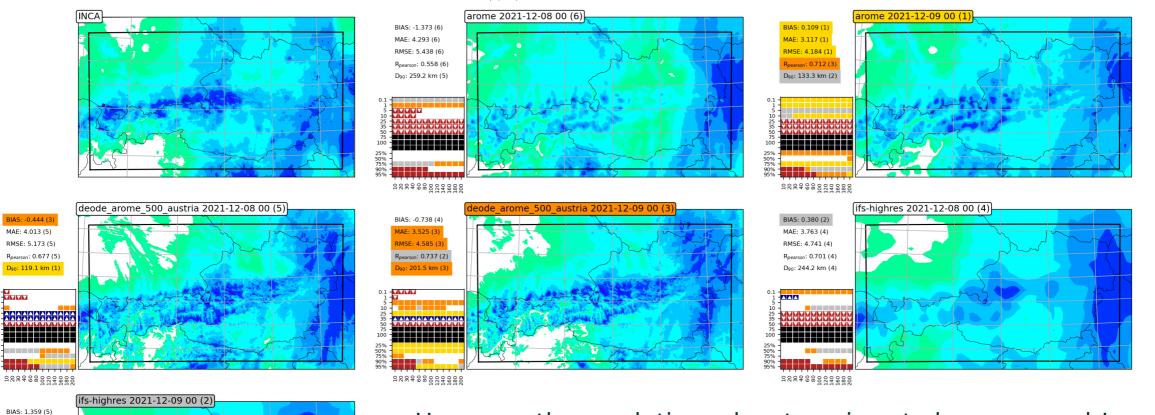


Acc. Precip. [mm] from 20211209 00 to 20211210 00 UTC

• However, the resolution advantage is not always enough!

MAE: 3.292 (2) RMSE: 4.340 (2) R_{pearson}: 0.765 (1) D₉₀: 274.9 km (6)

9 December 2022 - large scale, orographically forced



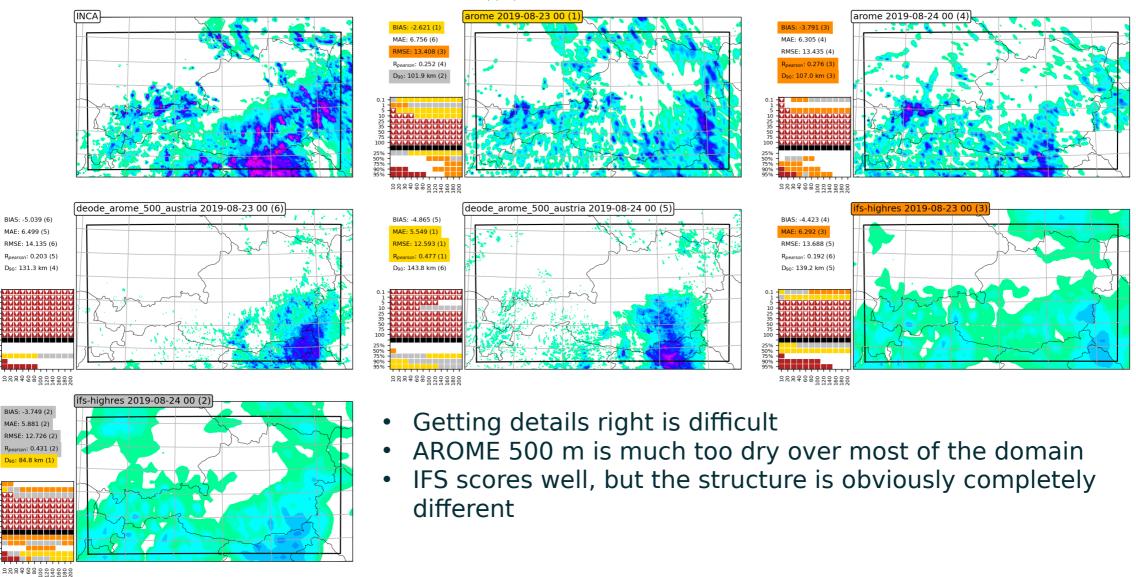
Acc. Precip. [mm] from 20211209 00 to 20211210 00 UTC

• However, the resolution advantage is not always enough!

MAE: 3.292 (2) RMSE: 4.340 (2) R_{pearson}: 0.765 (1) D₉₀: 274.9 km (6)

24 August 2019 - scattered convection

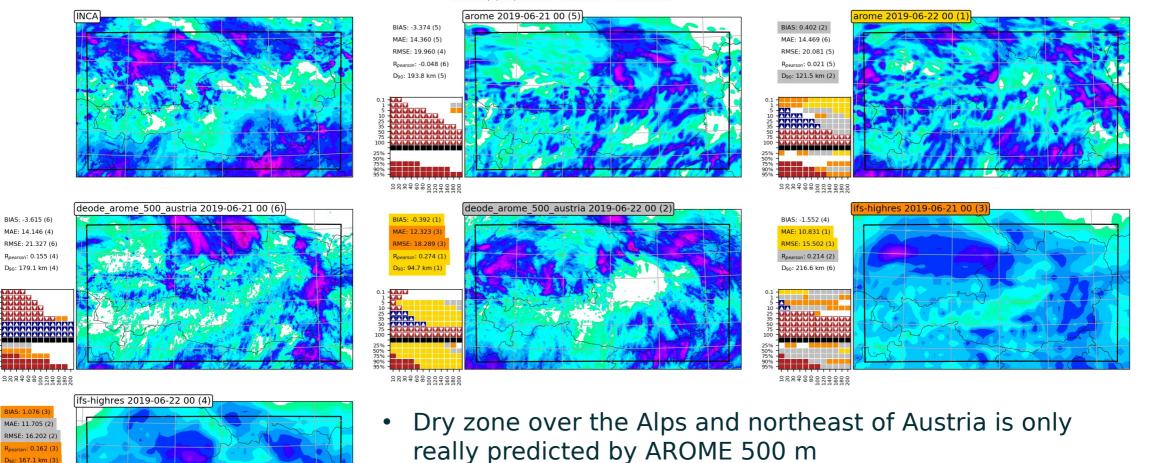
90% 95%



Acc. Precip. [mm] from 20190824 00 to 20190825 00 UTC

22 June 2019 - widespread convection

D₉₀: 167.1 km (3)



Acc. Precip. [mm] from 20190622 00 to 20190623 00 UTC

	a) AROME-Aut Deterministic 2.5 km operational 00 UTC +00h														b) AROME-Aut Deterministic 2.5 km operational 00 UTC +24h											
0.1 -	0.94	0.95	0.95	0.96	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.97	- 0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99		
1 -	0.91	0.93	0.93	0.94	0.95	0.95	0.96	0.96	0.96	0.96	0.96	0.97	- 0.92	0.94	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.98	0.98	0.98		
5 -	0.84	0.87	0.88	0.89	0.91	0.92	0.93	0.94	0.94	0.94	0.95	0.95	- 0.83	0.86	0.87	0.89	0.91	0.92	0.93	0.94	0.94	0.95	0.95	0.96		
10 -	0.77	0.80	0.82	0.84	0.86	0.88	0.89	0.90	0.91	0.92	0.92	0.93	- 0.75	0.78	0.81	0.82	0.85	0.87	0.89	0.90	0.91	0.92	0.93	0.94		
25 -	0.56	0.61	0.65	0.68	0.72	0.75	0.78	0.80	0.81	0.83	0.84	0.85	- 0.54	0.59	0.63	0.66	0.71	0.74	0.77	0.79	0.81	0.83	0.84	0.85		
35 -	0.46	0.53	0.57	0.61	0.67	0.71	0.74	0.77	0.79	0.81	0.83	0.84	- 0.46	0.52	0.56	0.60	0.66	0.70	0.73	0.76	0.78	0.79	0.81	0.82		
50 -	0.38	0.45	0.50	0.54	0.59	0.64	0.67	0.70	0.73	0.75	0.76	0.78	- 0.36	0.42	0.47	0.51	0.57	0.61	0.64	0.66	0.68	0.70	0.72	0.74		
75 -	0.29	0.35	0.40	0.43	0.48	0.52	0.54	0.57	0.59	0.60	0.62	0.63	- 0.29	0.36	0.41	0.45	0.51	0.55	0.58	0.61	0.63	0.64	0.66	0.67		
100 -	0.15	0.19	0.22	0.25	0.30	0.34	0.38	0.41	0.43	0.45	0.47	0.48	- 0.15	0.20	0.25	0.28	0.34	0.39	0.43	0.47	0.51	0.53	0.56	0.57		
	c) Deo	de Pro	, totype	(500 r	m ARO	ME) 00	UTC +	, ⊦00h	'	'	'	1	d) Deo	de Pro	, totype	(500 r	n ARO	ME) 00) UTC -	+24h	'	'	'	'		
0.1 -	0.95	0.96	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.99	- 0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98		
[-4 1- mu] 5-	0.92	0.93	0.94	0.94	0.95	0.96	0.97	0.97	0.97	0.97	0.98	0.98	- 0.90	0.92	0.92	0.93	0.94	0.95	0.95	0.96	0.96	0.97	0.97	0.97		
<u>u</u> 5 -	0.84	0.86	0.88	0.89	0.91	0.92	0.93	0.94	0.94	0.95	0.95	0.95	- 0.80	0.82	0.84	0.85	0.87	0.88	0.90	0.90	0.91	0.92	0.92	0.93		
월 10 -	0.76	0.79	0.81	0.83	0.86	0.88	0.89	0.90	0.91	0.92	0.93	0.93	- 0.70	0.73	0.75	0.77	0.80	0.82	0.84	0.85	0.86	0.87	0.88	0.89		
on Threshold 5 - 32 - 32 -	0.57	0.62	0.66	0.69	0.73	0.76	0.78	0.80	0.81	0.83	0.84	0.85	- 0.48	0.53	0.57	0.59	0.64	0.68	0.70	0.73	0.75	0.76	0.77	0.79		
F 35 -	0.51	0.57	0.61	0.64	0.69	0.73	0.75	0.77	0.79	0.80	0.81	0.82	- 0.39	0.43	0.47	0.50	0.55	0.59	0.61	0.64	0.66	0.68	0.69	0.70		
ecipitati	0.41	0.47	0.52	0.55	0.61	0.65	0.68	0.71	0.73	0.76	0.78	0.79	- 0.25	0.29	0.31	0.33	0.37	0.39	0.42	0.44	0.46	0.48	0.50	0.52		
- 75 -	0.26	0.31	0.35	0.38	0.41	0.44	0.47	0.48	0.50	0.51	0.53	0.54	- 0.16	0.19	0.21	0.22	0.24	0.26	0.27	0.28	0.29	0.30	0.31	0.32		
لط 100 -	0.08	0.10	0.11	0.12	0.14	0.16	0.17	0.18	0.19	0.20	0.20	0.21	- 0.13	0.15	0.17	0.18	0.20	0.21	0.22	0.22	0.23	0.23	0.23	0.23		
	e) IFS I	, Highre	s 00 U	TC +0	0h	'		'	'	'	'	'	f) IFS ⊦	lighres	, oo u	'C +24	h '	'		'	'		'	'		
0.1 -	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	- 0.96	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.99	0.99		
1 -	0.94	0.95	0.96	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.99	- 0.93	0.94	0.95	0.95	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98		
5 -	0.88	0.90	0.91	0.92	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.97	- 0.84	0.86	0.88	0.89	0.91	0.92	0.93	0.93	0.94	0.94	0.95	0.95		
10 -	0.80	0.83	0.85	0.87	0.89	0.91	0.92	0.93	0.94	0.95	0.95	0.95	- 0.74	0.77	0.80	0.81	0.84	0.86	0.88	0.89	0.90	0.91	0.91	0.92		
25 -	0.56	0.61	0.65	0.67	0.72	0.75	0.78	0.80	0.82	0.83	0.84	0.85	- 0.47	0.52	0.55	0.58	0.62	0.65	0.68	0.70	0.72	0.74	0.75	0.77		
35 -	0.46	0.52	0.56	0.60	0.65	0.69	0.72	0.74	0.76	0.77	0.79	0.80	- 0.34	0.38	0.42	0.45	0.49	0.53	0.56	0.58	0.60	0.62	0.64	0.65		
50 -	0.31	0.36	0.40	0.43	0.49	0.53	0.57	0.60	0.62	0.64	0.66	0.67	- 0.14	0.16	0.18	0.19	0.22	0.23	0.25	0.27	0.28	0.30	0.31	0.33		
75 -	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	- 0.06	0.07	0.09	0.10	0.12	0.14	0.15	0.15	0.16	0.17	0.18	0.19		
100 -	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	- 0.07	0.08	0.09	0.10	0.12	0.13	0.13	0.13	0.13	0.14	0.15	0.16		
	10	20	30	40	60	80	100	120	140	160	180	200 Window	10 Size [km]	20	30	40	60	80	100	120	140	160	180	200		

- Full tables are tedious to compare
- Useful/skillful threshold is not obvious for aggregated values, average over all cases would be an option
- For high thresholds, scores are often well below 0.5
- So what can we do?



Evaluation of AROME 500 m in DE On-Demande-Extremes

- 0.8

- 0.6

- 0.4

- 0.2

a) AROME-Aut Deterministic 2.5 km operational 00 UTC +00h b) AROME-Aut Deterministic 2.5 km operational 00 UTC +24h																									
0.1	0.02	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
1	0.03	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	0.01	-0.01	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	
5	- 0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.02	0.01	-0.01	-0.00	-0.00	-0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	
10	0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	- 0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	-0.00	-0.00	-0.01	-0.01	- 0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	Ē
35	0.00	0.01	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	- 0.11	0.13	0.15	0.15	0.16	0.17	0.18	0.18	0.18	0.17	0.17	0.17	F
50	- 0.07	0.09	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	- 0.22	0.26	0.29	0.32	0.35	0.37	0.39	0.40	0.40	0.40	0.41	0.41	- 10 ⁻
75	- 0.27	0.33	0.38	0.41	0.46	0.49	0.52	0.54	0.56	0.58	0.59	0.60	- 0.23	0.29	0.33	0.35	0.39	0.41	0.44	0.45	0.47	0.47	0.48	0.48	Ē
100	- 0.15	0.19	0.22	0.25	0.30	0.34	0.37	0.40	0.43	0.45	0.46	0.48	- 0.08	0.12	0.15	0.18	0.22	0.26	0.31	0.34	0.37	0.39	0.41	0.42	Ē
	c) Dec	de Pro	totype	(500 i	m ARO	ME) 00	UTC -	+00h	'	'	'	I	d) Dec	de Pro	, totype	, (500	m ARO	ME) 00	UTC ·	+24h	'	'	'	1	-1
0.1	0.01	-0.01	-0.01	-0.01	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00	Ē
[4 mm] 5	0.02	-0.02	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.03	-0.03	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	F
	0.04	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.02	-0.02	0.04	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.02	
ploy 10	0.04	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03	
10 Threshold	- 0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	-0.00	-0.00	-0.01	-0.01	- 0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	
L 35	- 0.04	0.05	0.05	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	- 0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	
oc ati	- 0.10	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	- 0.11	0.13	0.13	0.14	0.15	0.16	0.17	0.17	0.18	0.19	0.19	0.19	
Precipitation 52 52 53	0.24	0.29	0.33	0.36	0.39	0.42	0.44	0.46	0.47	0.48	0.50	0.51	- 0.10	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	
[≞] 100	- 0.08	0.09	0.11	0.12	0.14	0.16	0.17	0.18	0.19	0.19	0.20	0.21	0.06	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.08	0.08	
	e) IFS	Highre	s 00 U	TC +0	0h								f) IFS I	lighre	s 00 UT	rc +24	lh .								
0.1	- 0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	- 0.96	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.99	0.99	
1	- 0.94	0.95	0.96	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.99	- 0.93	0.94	0.95	0.95	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	- 0.8
5	- 0.88	0.90	0.91	0.92	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.97	- 0.84	0.86	0.88	0.89	0.91	0.92	0.93	0.93	0.94	0.94	0.95	0.95	
10	- 0.80	0.83	0.85	0.87	0.89	0.91	0.92	0.93	0.94	0.95	0.95	0.95	- 0.74	0.77	0.80	0.81	0.84	0.86	0.88	0.89	0.90	0.91	0.91	0.92	- 0.6
25	- 0.56	0.61	0.65	0.67	0.72	0.75	0.78	0.80	0.82	0.83	0.84	0.85	- 0.47	0.52	0.55	0.58	0.62	0.65	0.68	0.70	0.72	0.74	0.75	0.77	- 0.4
35	- 0.46	0.52	0.56	0.60	0.65	0.69	0.72	0.74	0.76	0.77	0.79	0.80	- 0.34	0.38	0.42	0.45	0.49	0.53	0.56	0.58	0.60	0.62	0.64	0.65	0.4
50	- 0.31	0.36	0.40	0.43	0.49	0.53	0.57	0.60	0.62	0.64	0.66	0.67	- 0.14	0.16	0.18	0.19	0.22	0.23	0.25	0.27	0.28	0.30	0.31	0.33	- 0.2
75	- 0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	- 0.06	0.07	0.09	0.10	0.12	0.14	0.15	0.15	0.16	0.17	0.18	0.19	
100	- 0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	- 0.07	0.08	0.09	0.10	0.12	0.13	0.13	0.13	0.13	0.14	0.15	0.16	
	10	20	30	40	60	80	100	120	140	160	180	200 Window	10 Size [km]	20]	30	40	60	80	100	120	140	160	180	200	

- Look at the differences between the models!
- With the right coloring, improvement and deterioration are easily visible



Evaluation of AROME 500 m in DE On-Demande-Extremes

a) AROME-Aut Deterministic 2.5 km operational 00 UTC +00h b) AROME-Aut Deterministic 2.5 km operational 00 UTC +24h																										
0.	1 - •	-0.02	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	1	-0.03	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	0.01	-0.01	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	
	5	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.02	0.01	-0.01	-0.00	-0.00	-0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	
1	0	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	- 0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	
2	5	-0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	-0.00	-0.00	-0.01	-0.01	- 0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	Ē
3	5	-0.00	0.01	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	- 0.11	0.13	0.15	0.15	0.16	0.17	0.18	0.18	0.18	0.17	0.17	0.17	F
5	0 -	0.07	0.09	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	- 0.22	0.26	0.29	0.32	0.35	0.37	0.39	0.40	0.40	0.40	0.41	0.41	- 10 ⁻¹
7	5 -	0.27	0.33	0.38	0.41	0.46	0.49	0.52	0.54	0.56	0.58	0.59	0.60	- 0.23	0.29	0.33	0.35	0.39	0.41	0.44	0.45	0.47	0.47	0.48	0.48	E F O
10	0 -	0.15	0.19	0.22	0.25	0.30	0.34	0.37	0.40	0.43	0.45	0.46	0.48	- 0.08	0.12	0.15	0.18	0.22	0.26	0.31	0.34	0.37	0.39	0.41	0.42	Ē
	c)) Deo	de Pro	totype	(500 i	m ARO	ME) 00	UTC -	+00h	'	1	'	I	d) Dec	de Pro	totype	(500	m ARO	ME) 00	utc -	+24h	I	I	1	'	10 ⁻¹
	1 - •	-0.01	-0.01	-0.01	-0.01	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00	E.
[mm h ⁻¹	1 - •	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.03	-0.03	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	F
nm]	5	-0.04	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.02	-0.02	0.04	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.02	
plor 1	0 - •	-0.04	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03	
nresl	5 -	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	-0.00	-0.00	-0.01	-0.01	- 0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	
on Threshold 8 7 1	5 -	0.04	0.05	0.05	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	- 0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	
itati	0 -	0.10	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	- 0.11	0.13	0.13	0.14	0.15	0.16	0.17	0.17	0.18	0.19	0.19	0.19	
Precipitati	5 -	0.24	0.29	0.33	0.36	0.39	0.42	0.44	0.46	0.47	0.48	0.50	0.51	- 0.10	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	
آ 10	0 -	0.08	0.09	0.11	0.12	0.14	0.16	0.17	0.18	0.19	0.19	0.20	0.21	- 0.06	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.08	0.08	
	e) IFS I	, Highre	s 00 U	TC +0	0h		1	1	'	1	1	'	f) IFS H	lighres	s 00 UT	rc +24	↓h ′	1	1	'	1	1	1		
0.	1 -	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	- 0.96	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.99	0.99	
	1 -	0.94	0.95	0.96	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.99	- 0.93	0.94	0.95	0.95	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	- 0.8
	5 -	0.88	0.90	0.91	0.92	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.97	- 0.84	0.86	0.88	0.89	0.91	0.92	0.93	0.93	0.94	0.94	0.95	0.95	
1	0 -	0.80	0.83	0.85	0.87	0.89	0.91	0.92	0.93	0.94	0.95	0.95	0.95	- 0.74	0.77	0.80	0.81	0.84	0.86	0.88	0.89	0.90	0.91	0.91	0.92	- 0.6
2	5 -	0.56	0.61	0.65	0.67	0.72	0.75	0.78	0.80	0.82	0.83	0.84	0.85	- 0.47	0.52	0.55	0.58	0.62	0.65	0.68	0.70	0.72	0.74	0.75	0.77	- 0.4
3	5 -	0.46	0.52	0.56	0.60	0.65	0.69	0.72	0.74	0.76	0.77	0.79	0.80	- 0.34	0.38	0.42	0.45	0.49	0.53	0.56	0.58	0.60	0.62	0.64	0.65	0.4
5	0 -	0.31	0.36	0.40	0.43	0.49	0.53	0.57	0.60	0.62	0.64	0.66	0.67	- 0.14	0.16	0.18	0.19	0.22	0.23	0.25	0.27	0.28	0.30	0.31	0.33	- 0.2
7	5 -	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	- 0.06	0.07	0.09	0.10	0.12	0.14	0.15	0.15	0.16	0.17	0.18	0.19	
10	0 -	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	- 0.07	0.08	0.09	0.10	0.12	0.13	0.13	0.13	0.13	0.14	0.15	0.16	
		10	20	30	40	60	80	100	120	140	160	180	200 Window	10 Size [km]	20	30	40	60	80	100	120	140	160	180	200	

- Look at the differences between the models!
- With the right coloring, improvement and deterioration are easily visible
 - AROME 500 m performs much better than IFS Highres for higher precipitation thresholds
 - In comparison, only a small deterioration is seen for lower values.



a) AROME-Aut Deterministic 2.5 km operational 00 UTC +00h b) AROME-Aut Deterministic 2.5 km operational 00 UTC +24h																									
0.1	0.02	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
1	- 0.03	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	0.01	-0.01	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	
5	0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.02	0.01	-0.01	-0.00	-0.00	-0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	
10	0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	- 0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	-0.00	-0.00	-0.01	-0.01	- 0.07		0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09			Ē
35	0.00	0.01	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	- 0.11	0.13	0.15		0.16								-
50	- 0.07	0.09	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	- 0.22	0.26		11	1.35							0.41	- 10 ⁻¹
75	- 0.27												0.23		د 0`		0.39							0.48	Fo
100	- 0.15					0.34	0.37	0.40	0.43	0.45	0.46	0.48	- 0.22 0.23	101		0.18				0.34	0.37	0.39	0.41	0.42	E
	c) Deo	ode Pro	totype	(500 i	m ARO	ME) 00		+00h		1			C	. 10	totype	(500 i	m ARO	ME) 00	UTC ·	+24h	I	1	1	1	10-1
0.1	-0.01	-0.01	-0.01	-0.01	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00		-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00	E .
۔ د 1	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.03	-0.03	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	F
٤ <u>5</u>	-0.04	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.02	-0.02	0.04	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.02	
plou	-0.04	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03	
Sell 25	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	-0.00	-0.00	-0.01	-0.01	- 0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	
L 35	0.04	0.05	0.05	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	- 0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	
Precipitation Threshold [mm h ⁻¹⁻ 05 22 05 25 20 10	0.10	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	- 0.11	0.13	0.13	0.14									
Leci	0.24	0.29	0.33	0.36	0.39	0.42	0.44	0.46	0.47	0.48	0.50	0.51	- 0.10	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	
^L 100	0.08	0.09	0.11	0.12	0.14	0.16	0.17	0.18	0.19	0.19	0.20	0.21	- 0.06	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.08	0.08	
	e) IFS	Highre	es 00 U	TC +0	0h								f) IFS I	lighre	s 00 UT	TC +24	ŀh								_
0.1	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	- 0.96	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.99	0.99	
1	- 0.94	0.95	0.96	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.99	- 0.93	0.94	0.95	0.95	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	- 0.8
5		0.90	0.91	0.92	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.97	- 0.84	0.86	0.88	0.89	0.91	0.92	0.93	0.93	0.94	0.94	0.95	0.95	
10		0.83	0.85	0.87	0.89	0.91	0.92	0.93	0.94	0.95	0.95	0.95	- 0.74	0.77	0.80	0.81	0.84	0.86	0.88	0.89	0.90	0.91	0.91	0.92	- 0.6
25		0.61	0.65	0.67	0.72	0.75	0.78	0.80	0.82	0.83	0.84	0.85	- 0.47	0.52	0.55	0.58	0.62	0.65	0.68	0.70	0.72	0.74	0.75	0.77	- 0.4
35		0.52	0.56	0.60	0.65	0.69	0.72	0.74	0.76	0.77	0.79	0.80	- 0.34	0.38	0.42	0.45	0.49	0.53	0.56	0.58	0.60	0.62	0.64	0.65	
50	- 0.31	0.36	0.40	0.43	0.49	0.53	0.57	0.60	0.62	0.64	0.66	0.67	- 0.14	0.16	0.18	0.19	0.22	0.23	0.25	0.27	0.28	0.30	0.31	0.33	- 0.2
	- 0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	- 0.06	0.07	0.09	0.10	0.12	0.14	0.15	0.15	0.16	0.17	0.18	0.19	
100	- 0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	- 0.07	0.08	0.09	0.10	0.12	0.13	0.13	0.13	0.13	0.14	0.15	0.16	_
	10	20	30	40	60	80	100	120	140	160	180	200 Window	10 Size [km]	20]	30	40	60	80	100	120	140	160	180	200	

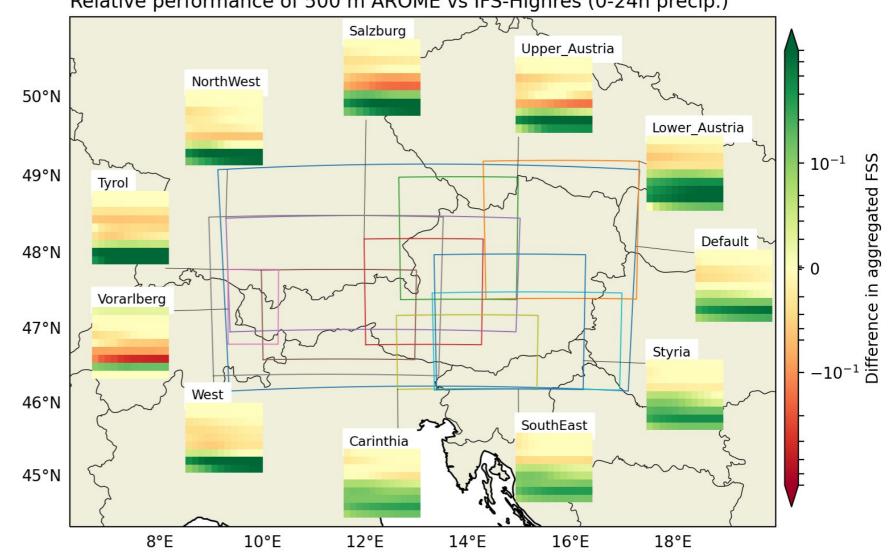


Evaluation of AROME 500 m in DE On-Demande-Extremes

Precipitation Threshold [mm h⁻¹]

Results for smaller regions: 0 - 24 h forecasts

- Verification was repeated for multiple subdomains to examine the added value
- Smaller sample (of grid points) shows higher variability
- South and southeast is captured better than West and North.



Relative performance of 500 m AROME vs IFS-Highres (0-24h precip.)

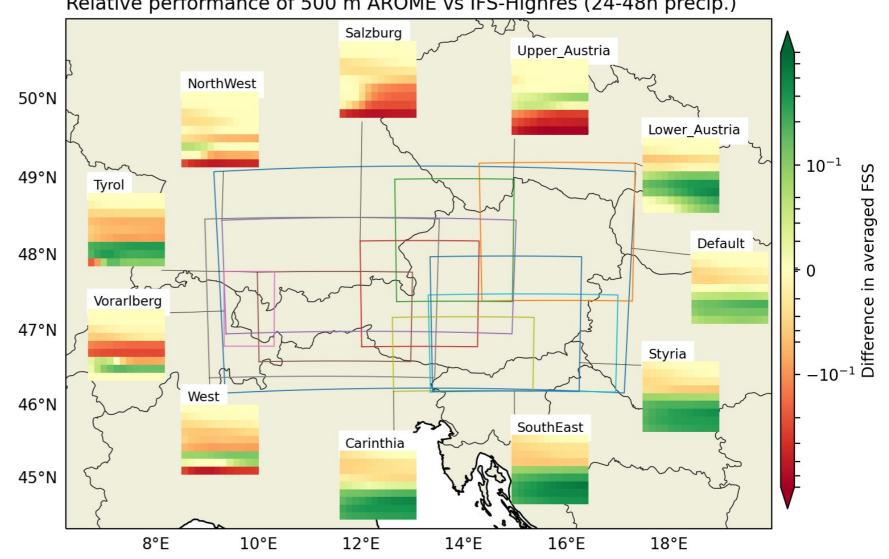
Evaluation of AROME 500 m in DE On-Demande-Extremes

(GeoSphere

Austria

Results for smaller regions: 24 - 48 h forecasts

- East-west contrast is more pronounced for 24 – 48 h predictions
- Some regions clearly do not benefit from 500 m resolution at these leadtimes
- Larger sample will be needed for definitive results



Relative performance of 500 m AROME vs IFS-Highres (24-48h precip.)

Evaluation of AROME 500 m in DE On-Demande-Extremes

(GeoSphere

Austria

The AROME 500 m simulations have a qualitative and quantitative added value compared to IFS Highres for heavy precipitation forecasts.

Since the sample is still low at 65, the numbers for smaller regions are less clear.

Added value for the evaluated sample is **lower in the west and north but higher in** the south and southeast of Austria.

The results of the operational AROME-Aut 2.5 km deterministic model are still better. While this comparison is not entirely fair, it should still be used as ultimate benchmark (+ IFS HRES, GDT).



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