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Fuzzy verification of precipitation forecasts during the DOP – on the benefit of high resolution models with explicit convection

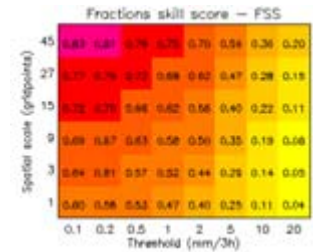
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Mathias Rotach¹, Mattis Schütze²

¹ MeteoSchweiz ² Universität Hamburg



Fuzzy verification settings

(Fuzzy verification package by E. Ebert, 2008)

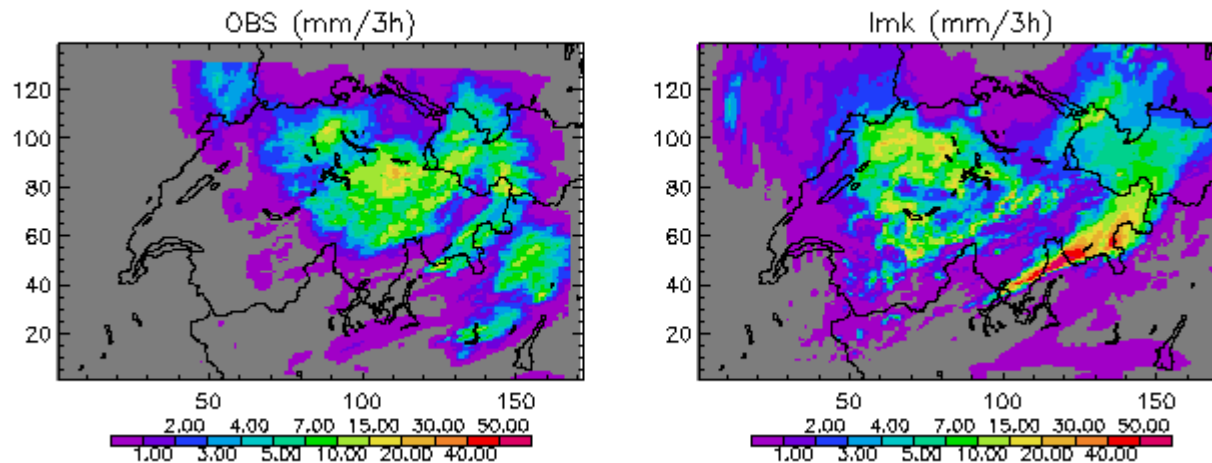


- Verification against Swiss national radar data
- D-PHASE region: basically Switzerland
- D-PHASE Observation Period: June – November 2007
- 3 h precipitation accumulation, all situations together
- Models: COSMO-EU (7 km), COSMO-DE (2.8 km), COSMO-7 (7 km), COSMO-2 (2.2 km)
- Take always latest model run (exclusive a cutoff of 3 h)



Concept of Fuzzy Verification

- Suitable especially for high resolution forecast and observations (e.g. radar)
- Instead of only evaluating point-by-point match, consider larger growing boxes around region of interest
- Choose different thresholds to define event and no-event
- Calculate statistics for all window sizes and thresholds



8. August 2007,
00 – 03 UTC



Concept of Fuzzy Verification

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- Instead of only evaluating point-by-point match, consider larger growing boxes around region of interest
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- Calculate statistics for all window sizes and thresholds

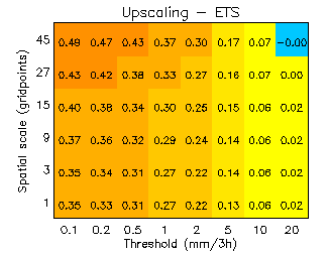
Applied two methods:

Upscaling and Fraction Skill Score



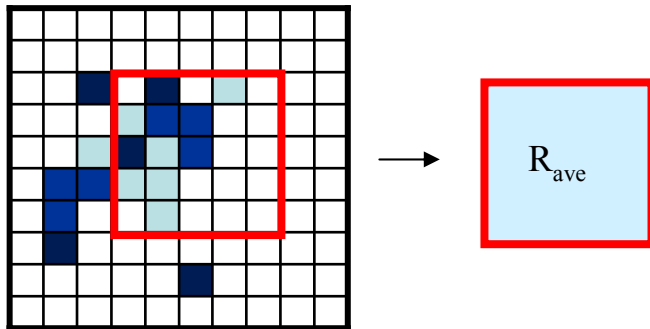


... Upscaling (UP)



1. Concept:

Averaging forecast and observation data over respective window.



2. Contingency Table

Event if $R_{ave} \geq \text{threshold}$
 No-Event if $R_{ave} < \text{threshold}$

observation

		observation	
		yes	no
forecast	yes	Hit	False Alarm
	no	Miss	Correct negative

3. Equitable Threat Score

$$ETS = \frac{hits - hits_{random}}{hits + misses + false\ alarms - hits_{random}}$$

$$hits_{random} = \frac{(hits + misses)(hits + false\ alarms)}{total}$$

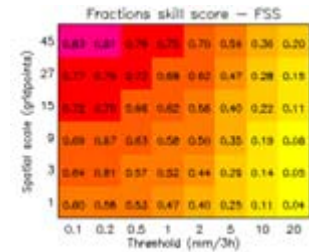
Q: Which fraction of observed yes events has been accurately forecast?





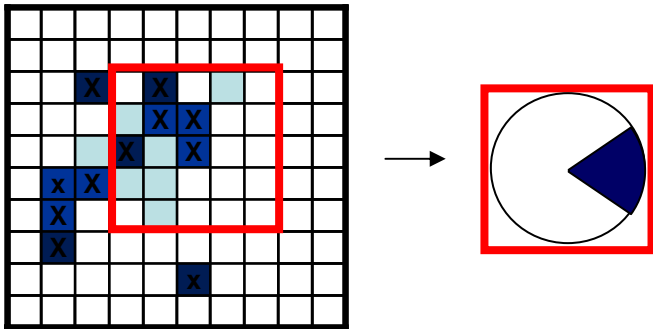
... Fraction Skill Score (FSS)

(Roberts and Lean, 2005)



1. Concept:

Determine fractional coverage P of grid points with R > threshold.



2. Probabilities

P_{obs} = fraction of obs grid points > threshold

P_{fcst} = fraction of fcst grid points > threshold

3. Skill score for fractions/probabilities

$$FSS = 1 - \frac{\frac{1}{N} \sum_{i=1}^N (P_{fcst} - P_{obs})^2}{\frac{1}{N} \sum_{i=1}^N P_{fcst}^2 + \frac{1}{N} \sum_{i=1}^N P_{obs}^2}$$

Q: What are the spatial scales at which the forecast resembles the observations?



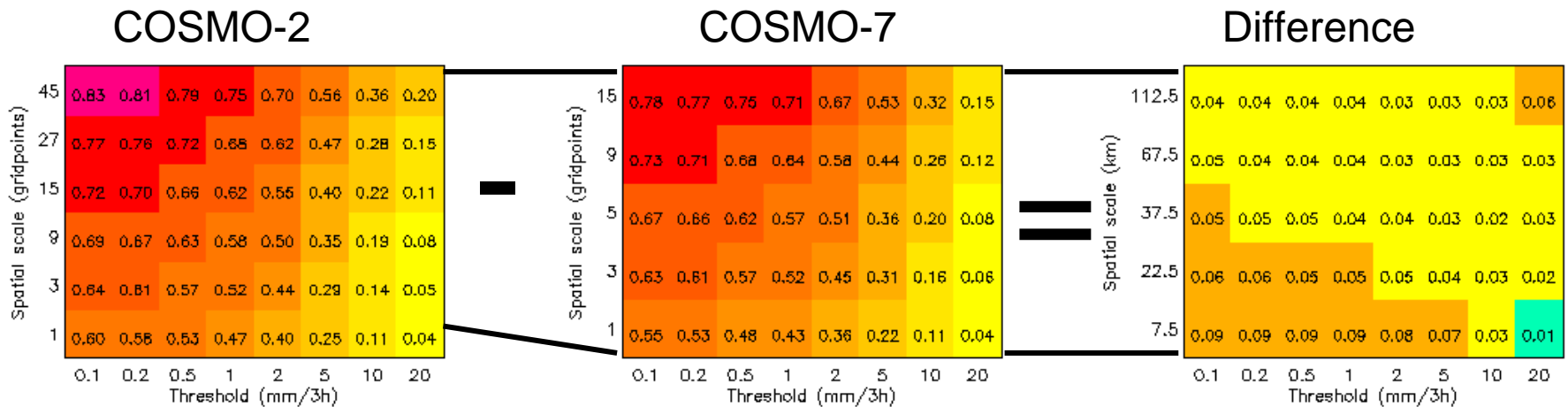
Fuzzy verification COSMO-2 – COSMO-7

DOP (June – November 2007), 3h acc., vs. Swiss radar

Upscaling



Fraction Skill Score



bad good

COSMO-7 better COSMO-2 better





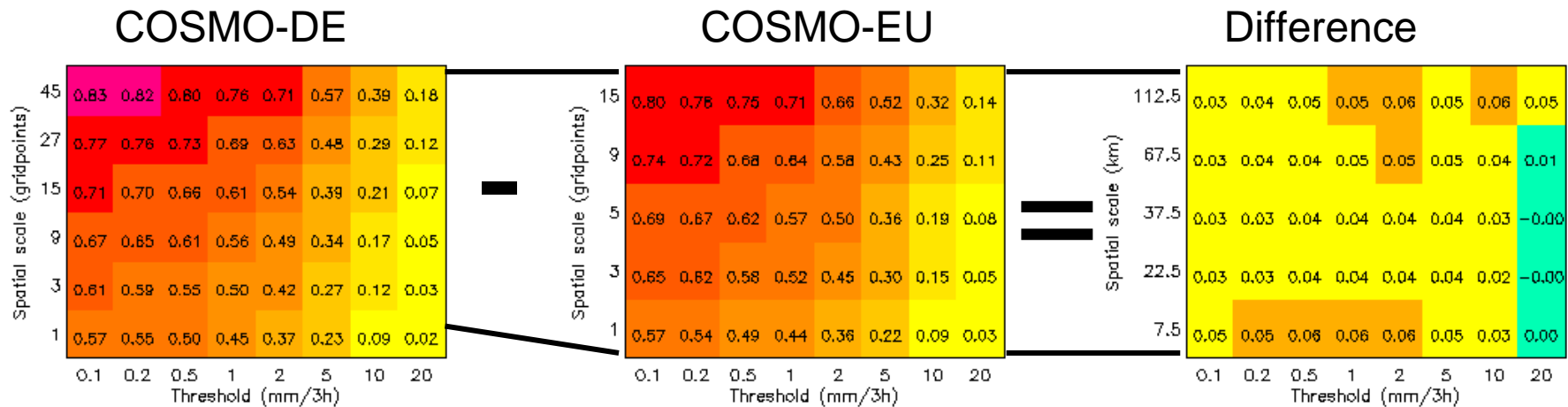
Fuzzy verification COSMO-DE – COSMO-EU

DOP (June – November 2007), 3h acc., vs. Swiss radar

Upscaling



Fraction Skill Score



bad good

COSMO-EU better COSMO-DE better





Evaluate shorter time periods

- Summer (JJA)
- Autumn (SON)
- June, July and August
- Daily timeseries

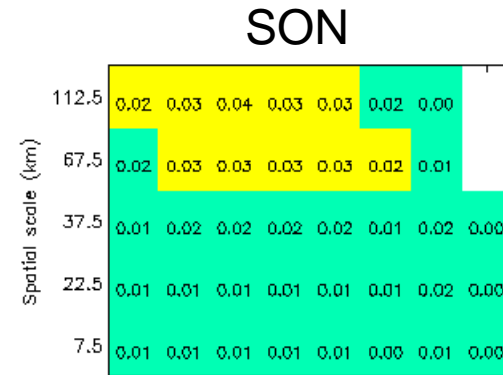
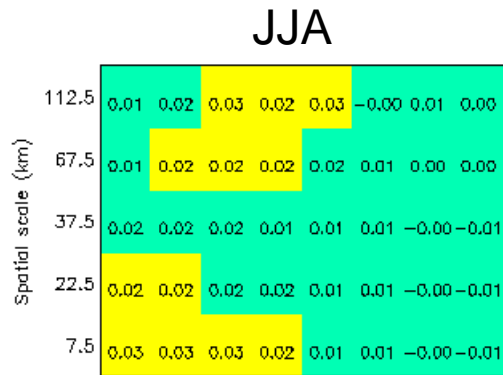
→ Concentrate on **German COSMO models**



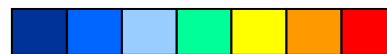
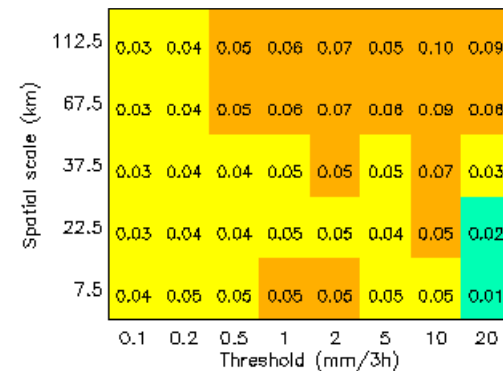
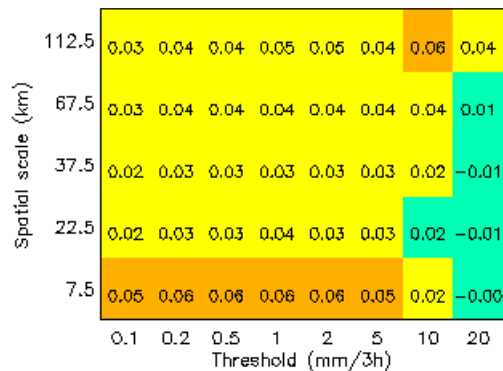
Differences COSMO-DE - COSMO-EU

JJA and SON

Upscaling



Fraction Skill Score



COSMO-EU better COSMO-DE better

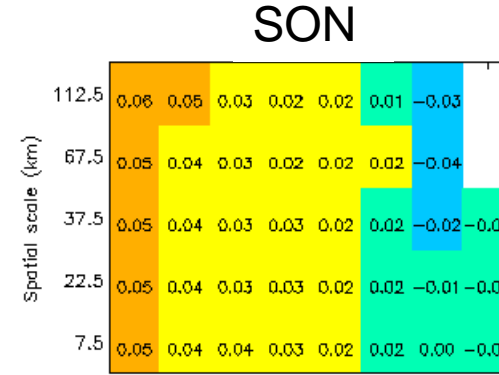
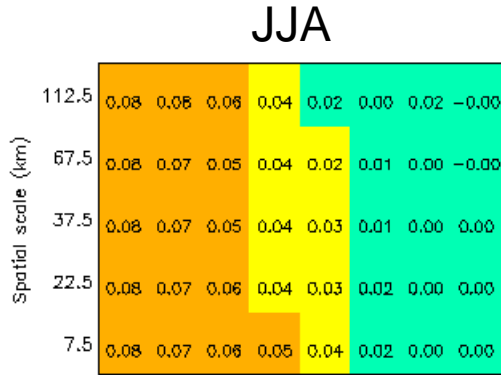




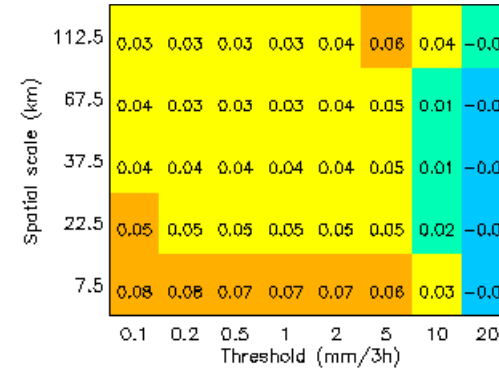
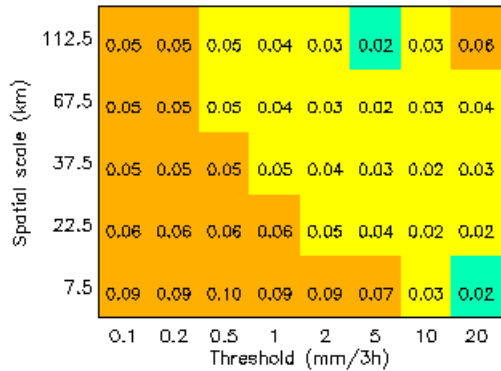
Differences COSMO-2 - COSMO-7

JJA and SON

Upscaling



Fraction Skill Score



COSMO-7 better

COSMO-2 better

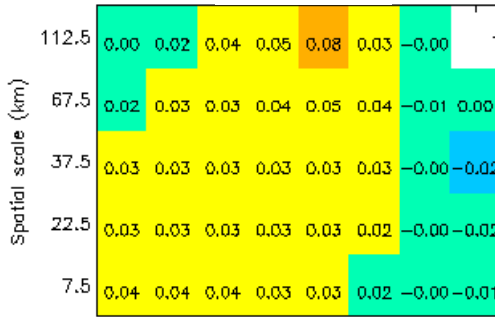




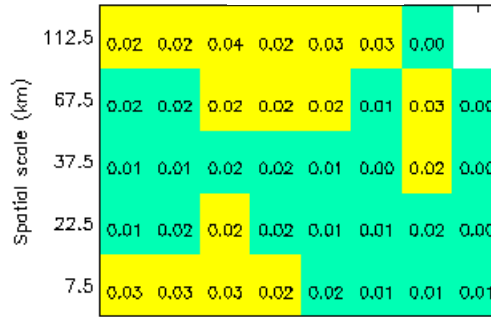
Differences COSMO-DE - COSMO-EU

Upscaling

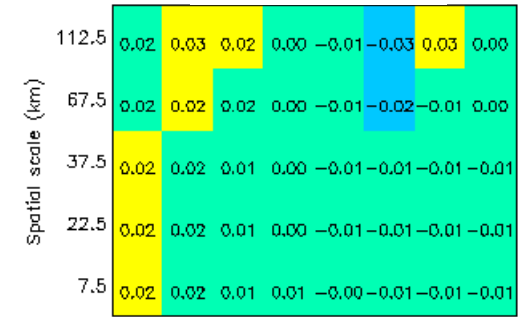
June



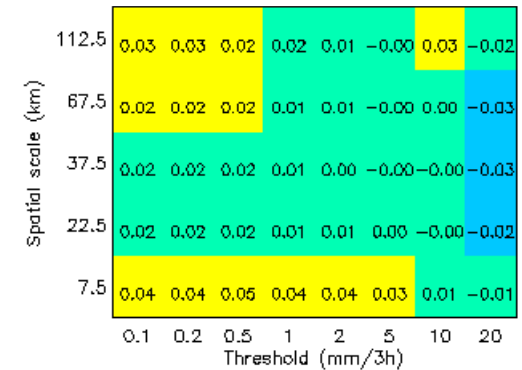
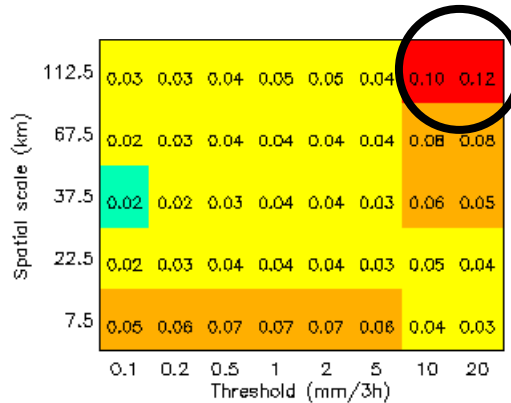
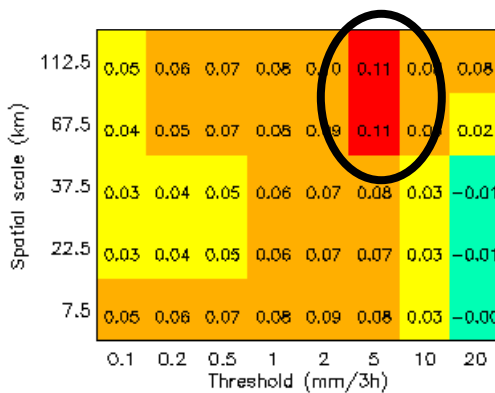
July



August



Fraction Skill Score



COSMO-EU better COSMO-DE better





Differences COSMO-DE - COSMO-EU

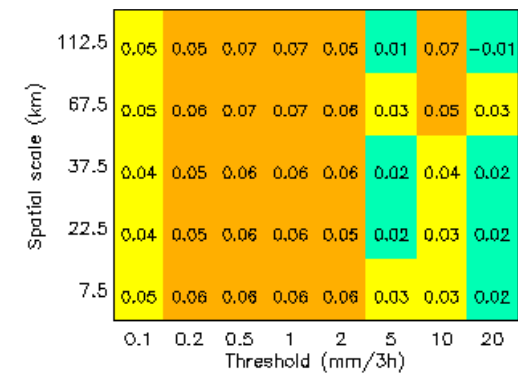
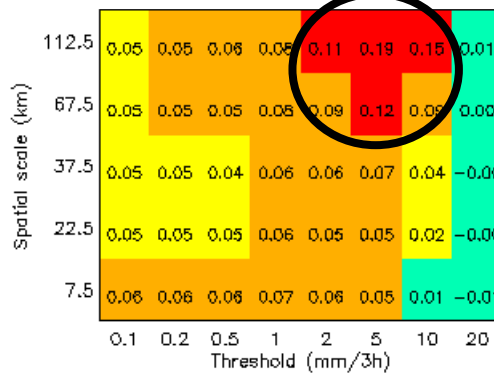
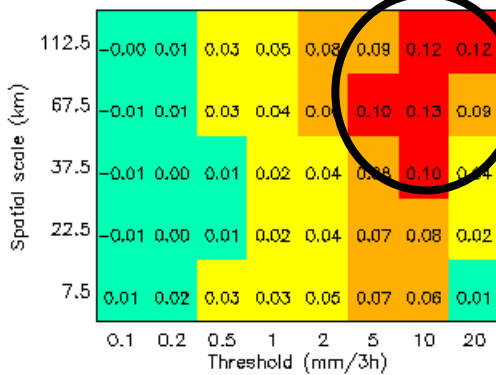
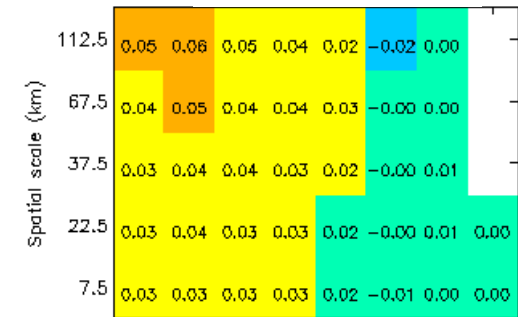
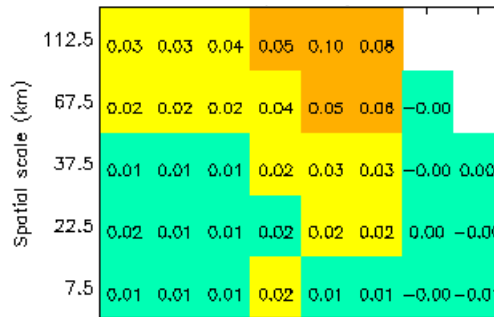
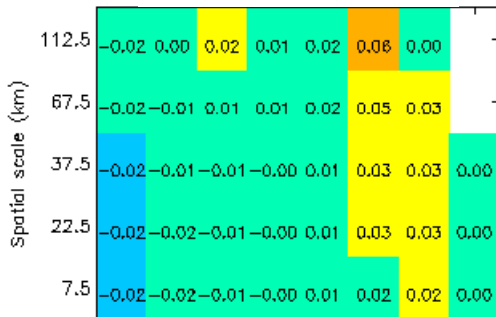
Upscaling

Fraction Skill Score

September

October

November



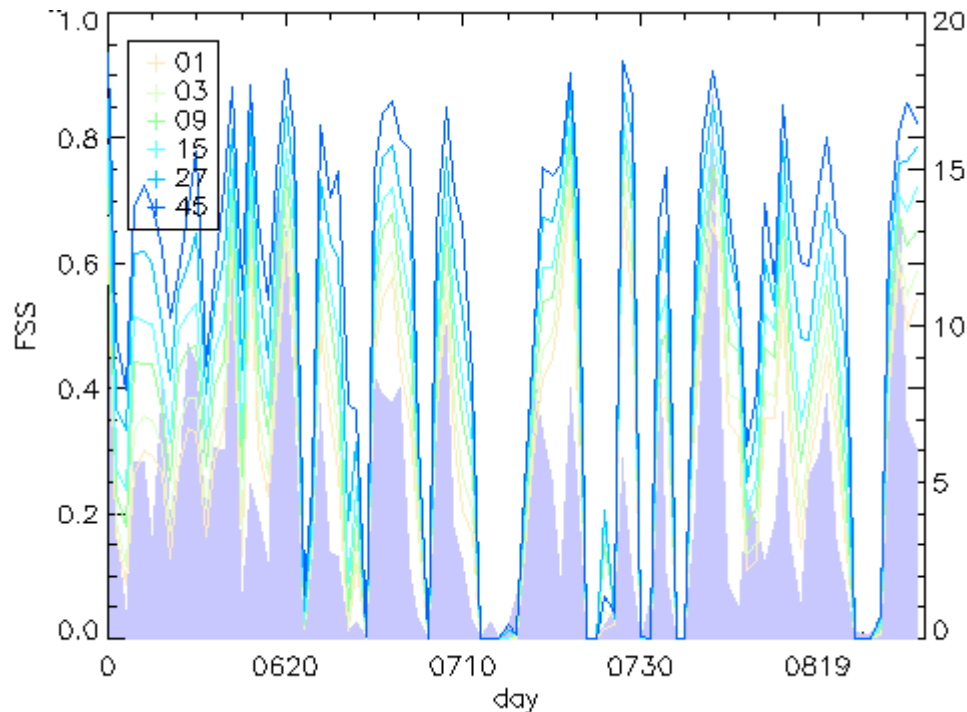
COSMO-EU better COSMO-DE better





Timeseries of scores for JJA COSMO-DE

Fraction Skill Score, Threshold = 1.0 mm,
3 h acc., daily aggregated



→ large day-to-day
variations for all
window sizes

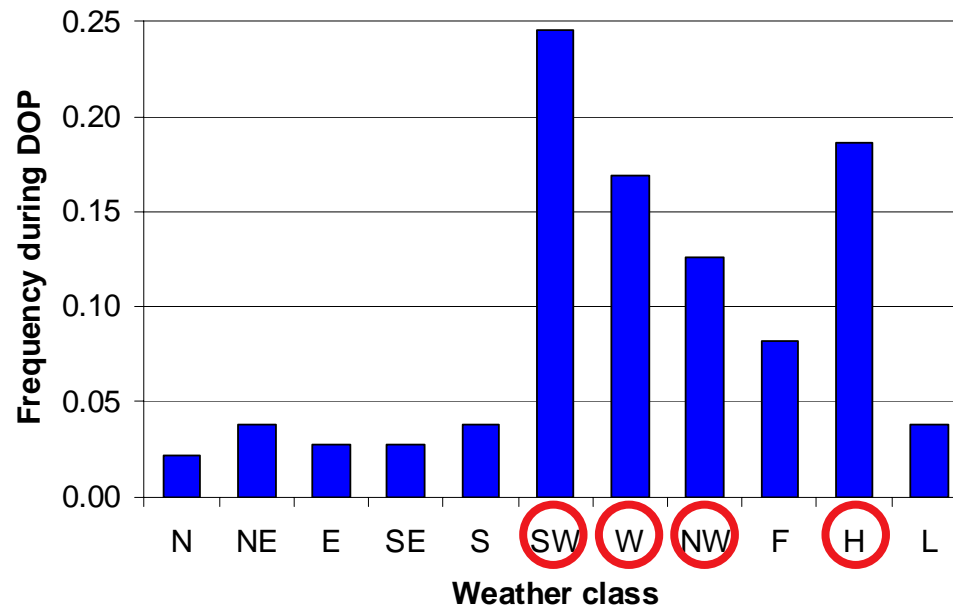
→ score = 0 if
either $P_{obs} = 0$ or
 $P_{fcst} = 0$

$$FSS = 1 - \frac{\frac{1}{N} \sum_{i=1}^N (P_{fcst} - P_{obs})^2}{\frac{1}{N} \sum_{i=1}^N P_{fcst}^2 + \frac{1}{N} \sum_{i=1}^N P_{obs}^2}$$



Weather type dependant verification

- 11 weather classes (subjective classification):
 - Main wind directions: N, NE, E, SE, S, SW, W, NW
 - F, H, L (pressure)



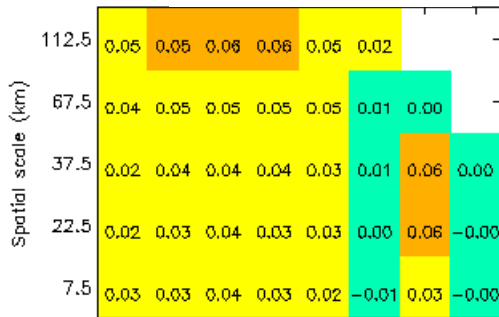


Main Weather classes

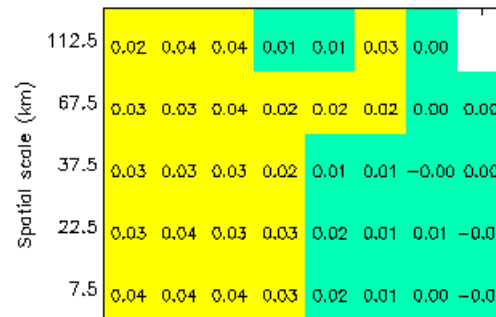
COSMO-DE – COSMO-EU

Upscaling

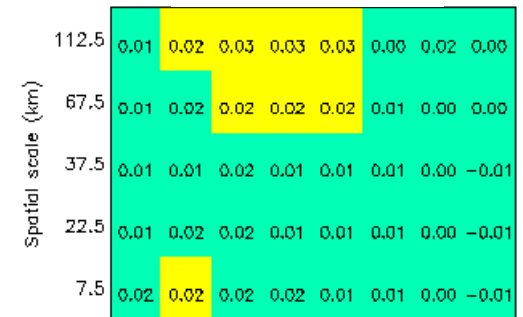
NW (12%)



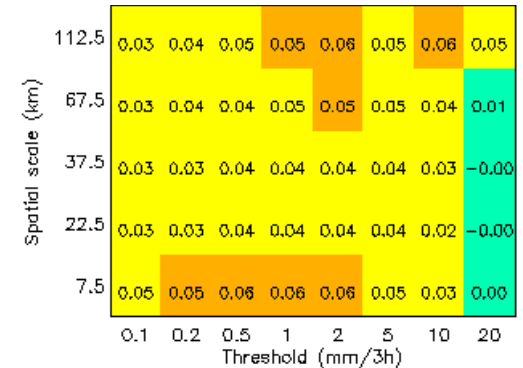
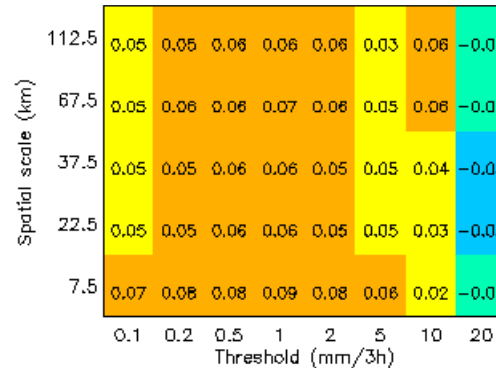
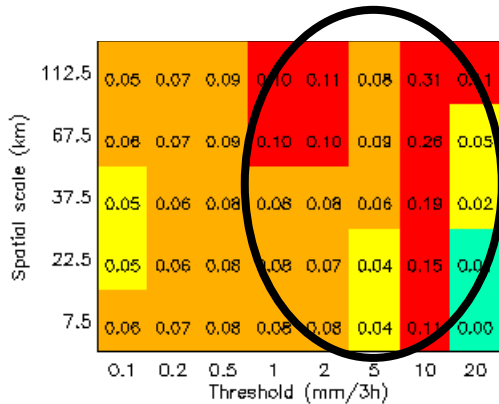
W (17%)



all cases



Fraction Skill Score



COSMO-EU better

COSMO-DE better



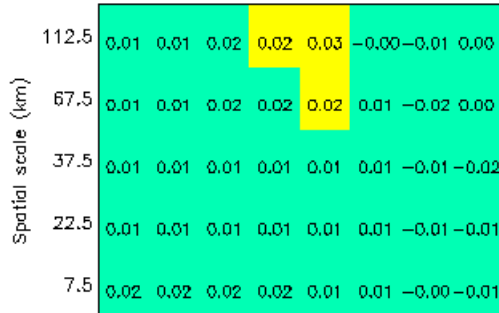


Main Weather classes

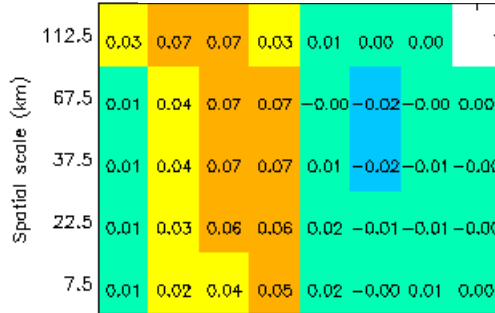
COSMO-DE – COSMO-EU

Upscaling

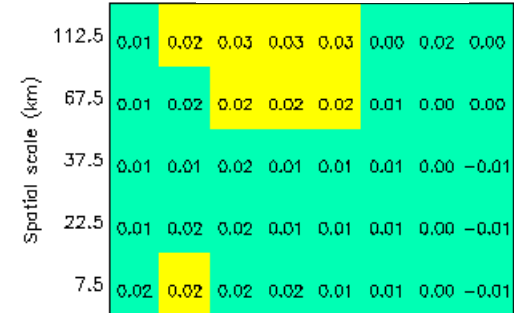
SW (25%)



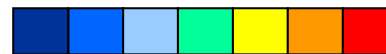
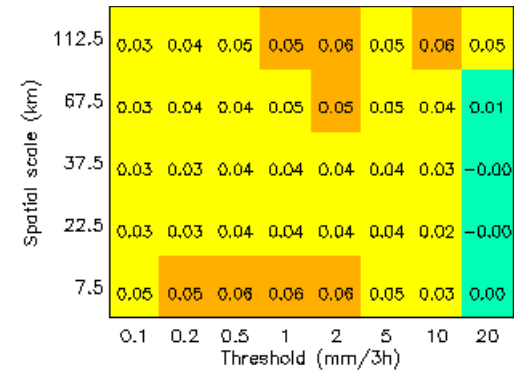
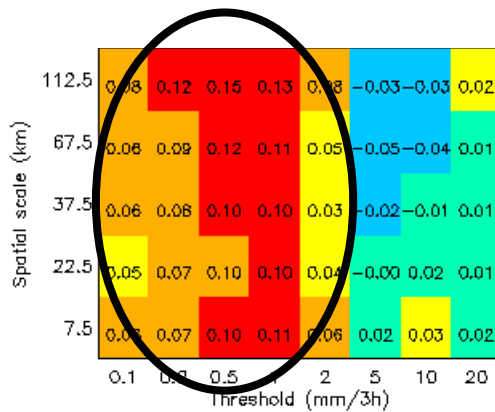
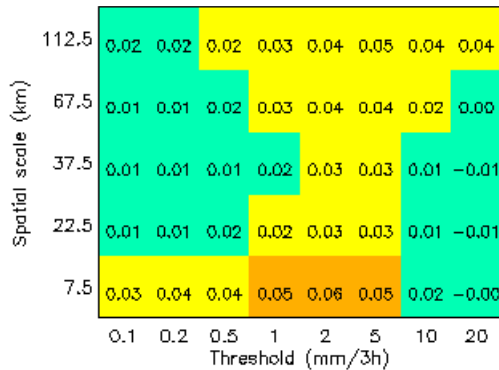
H (18%)



all cases



Fraction Skill Score



COSMO-EU better

COSMO-DE better





Conclusions and Outlook

- Evaluation by means of fuzzy verification reveals a better performance of high resolution models compared to models with parameterised convection.
- For a more detailed evaluation it is meaningful to perform weather type dependant verification.
- Upcoming
 - Fuzzy Verification for COPS-Domain
 - Apply other verification measures (e.g. Intensity scale)
 - Take into account the number of cases contributing to each „fuzzy field“
 - Bootstrapping to test robustness of results
 - Look not only in space but also in time





D-PHASE model zoo



Name	Δx (km)	Runs per day	Forecast range (h)
COSMO-2, Swiss	2	8	24-30
COSMO-I2, Italy	2	1	30
CSOMO-DE, Germany	2	8	21
ISACMOL, Italy	2	1	39
ISACMOL2, Italy	2	1	39
ARPAMOL, Italy	2	1	36
MM5_2_CT, Germany	2	1	24
MM5_2_4D, Germany	2	1	24
MM5_325, Germany	3	1	60
AROME, France	4	1	30
CMCGEMH, Canada	2	1	18

- High-resolution deterministic models (11)
- Driving deterministic models (10)
- Ensemble prediction systems (7)

Name	Members	Δx (km)	Runs per day	Forecast range (h)
CLEPS, Italy	16	10	1	132
MOGREPS, UK	24	25	2	54
INMSREPS, Spain	20	27	2	72
CSREPS, Italy	16	10	1	72
LAMEPSAT, Austria	17	18	2	48
PEPS, SRNWP	varying	7	4	42
MPEPS, S	varying	2	8	18

Name	Δx (km)	Runs per day	Forecast range (h)
COSMO-7, Germany	7	2	72
COSMO-IT, Italy	7	2	72
COSMO-EU	7	4	78
QBOLAM33, Italy	33	1	60
QBOLAM11, Italy	11	1	48
ALADFR, France	12	1	54
MM5_60, Germany	60	2	72
MM5_15, Germany	15	2	72
ALADAT, Austria	9	2	48
CMCGEML, Canada	15	1	24

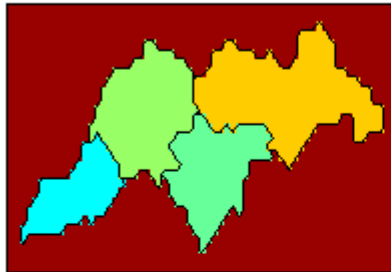




Catchment verification vs. Swiss radar

ACD – total precip. [mm]

Sum: 443 mm; Space100%, Time 100%



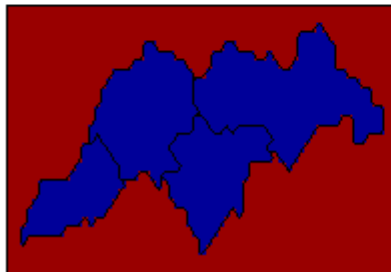
ACD – relative BIAS [%]

Global 0%; local +/-0%



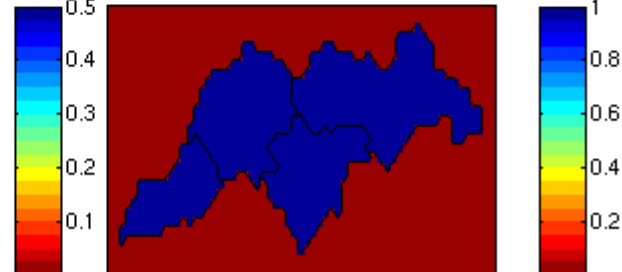
ACD – ETS (RR > 1mm)

Mean 1.00



ACD – correlation

Mean 1.00



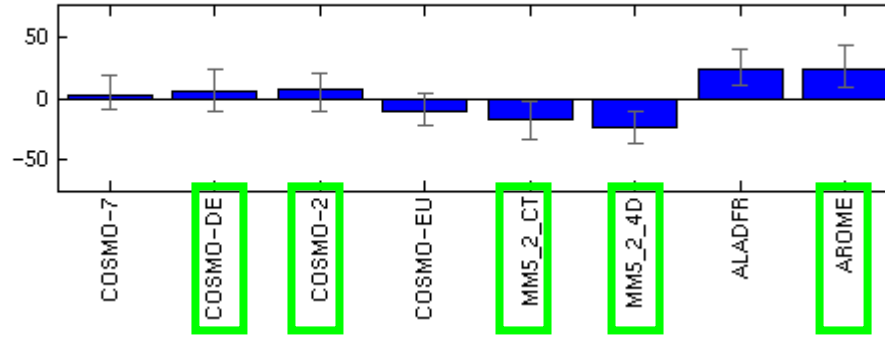
Regions: Bodensee, Hochrhein, Eastern Jura, Eastern Mittelland



Verification versus Swiss Radar, 2007060100 – 2007083100

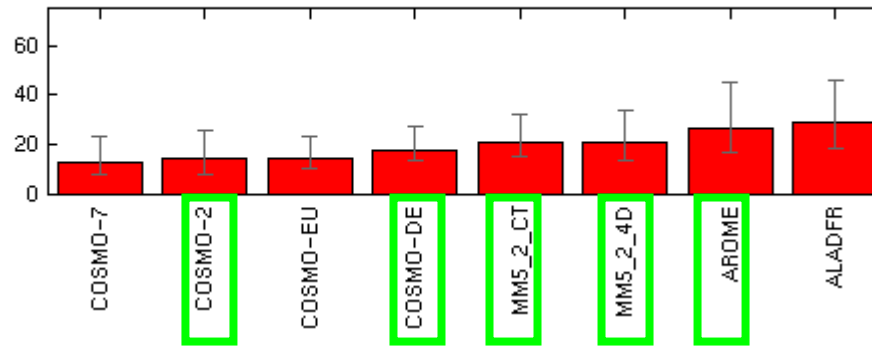
JJA

Relativ BIAS
full domain
(%)



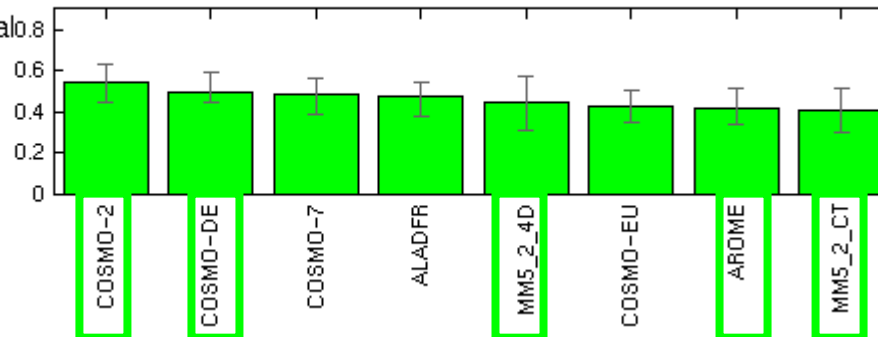
Overall over- /
underestimation?

Mean
|rel. BIAS|
of a region
(%)



Ability to resolve mean
spatial patterns.

Mean temporal
correlation
in a region
(hourly)



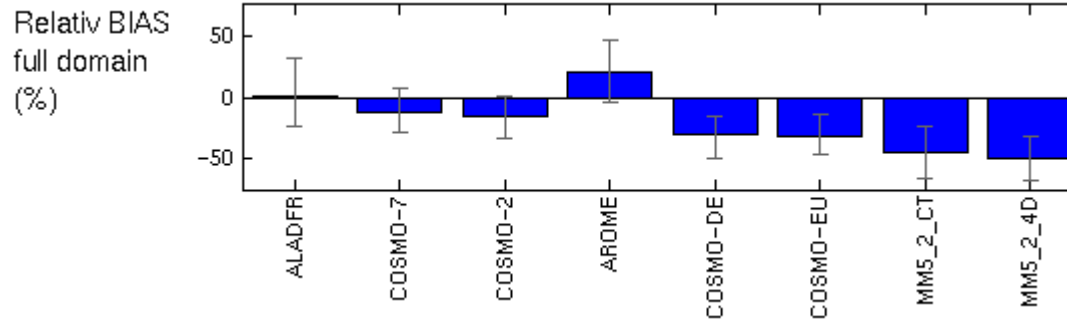
Timing



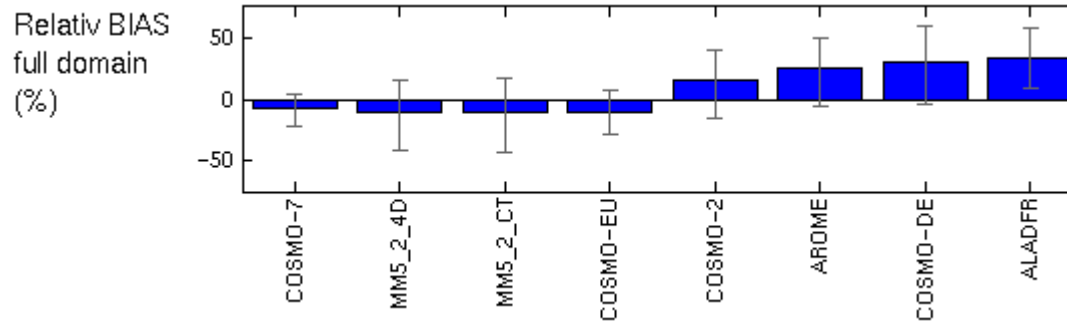


Verification vs Swiss Radar – relative bias full domain

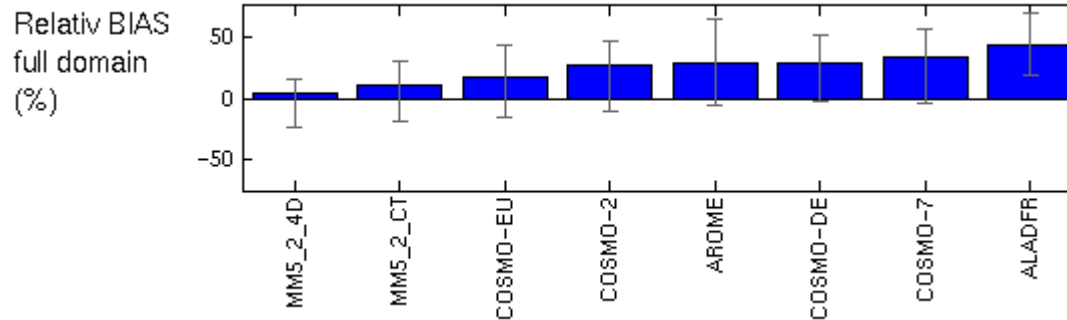
June



July



August



Fuzzy verific:
Weusthoff et :

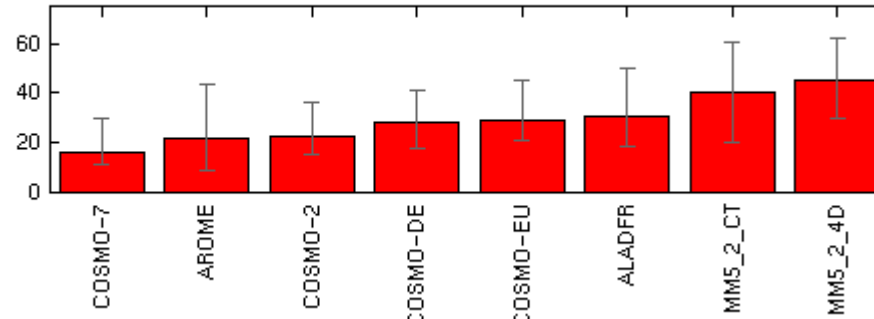




Verification vs Swiss Radar – mean relative bias of a region

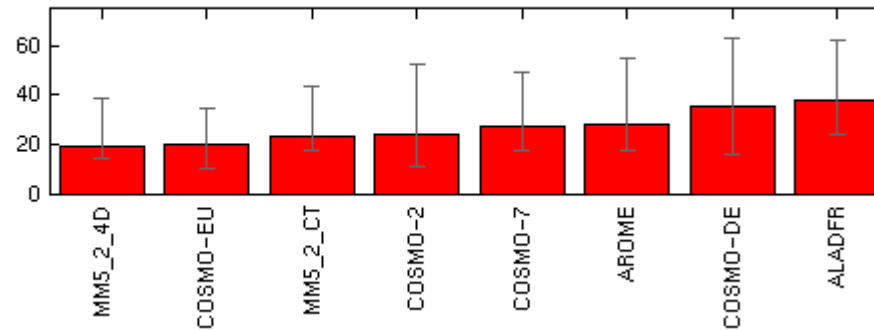
June

Mean
|rel. BIAS|
of a region
(%)



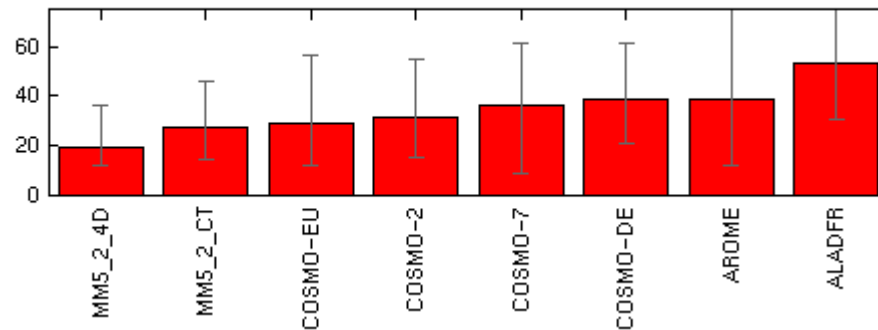
July

Mean
|rel. BIAS|
of a region
(%)



August

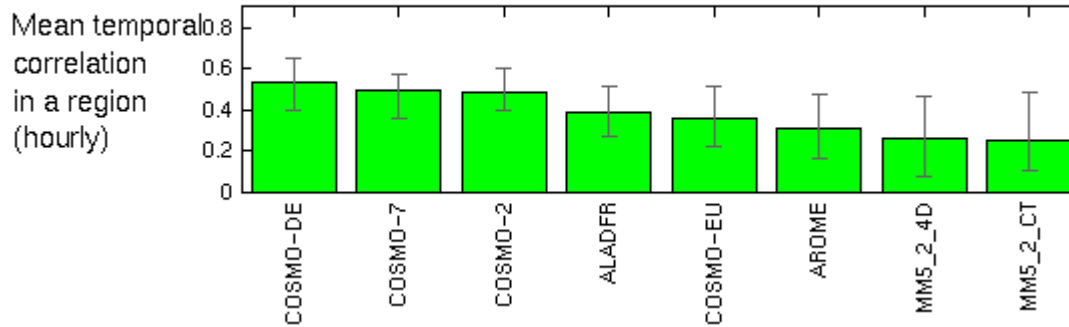
Mean
|rel. BIAS|
of a region
(%)



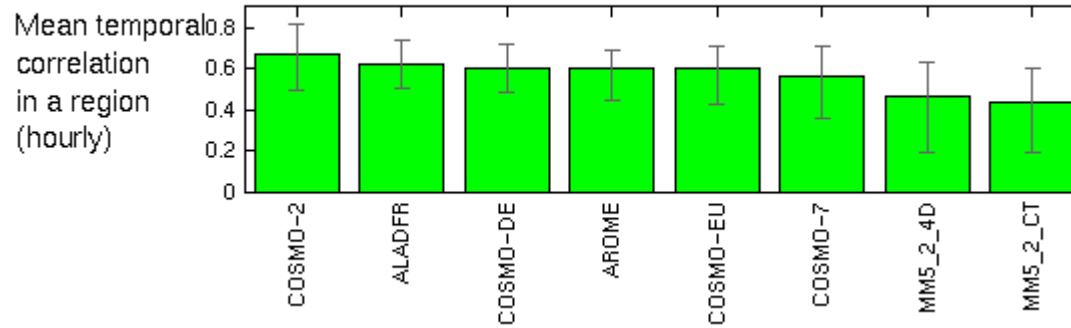


Verification vs Swiss Radar – mean temporal correlation in a region

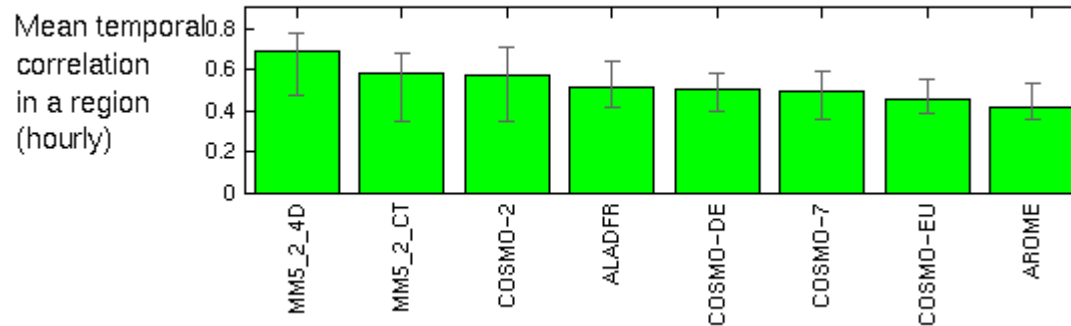
June



July



August





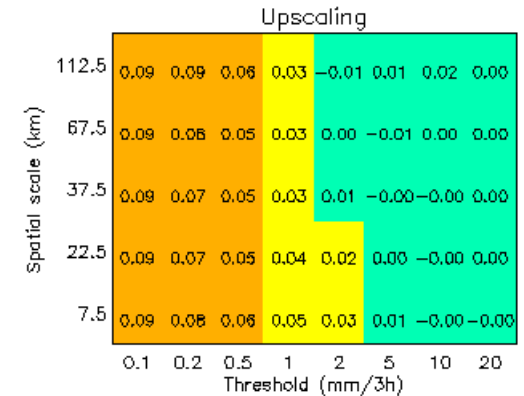
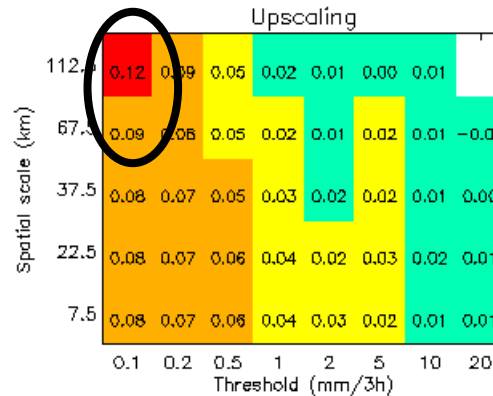
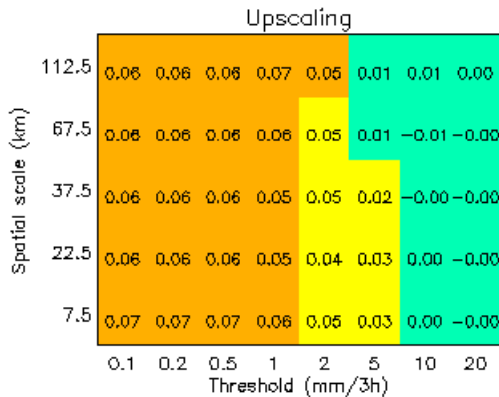
Differences COSMO-2 - COSMO-7

June

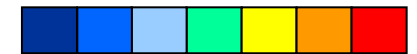
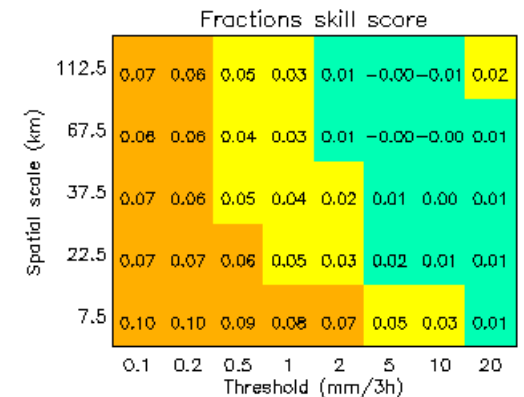
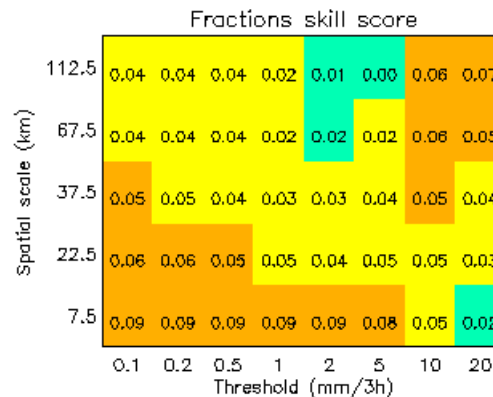
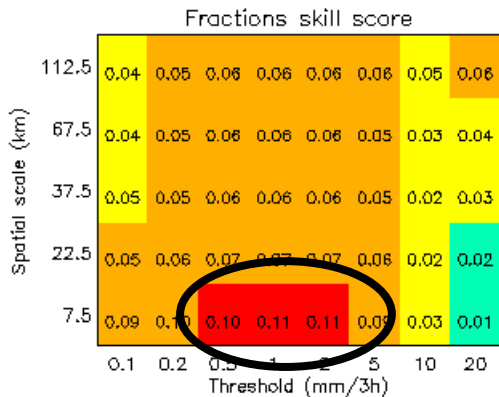
July

August

Upscaling



Fraction Skill Score



COSMO-7 better

COSMO-2 better





Main Weather classes

COSMO-2 – COSMO-7

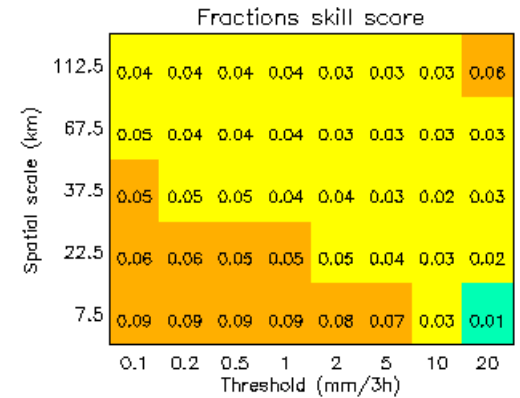
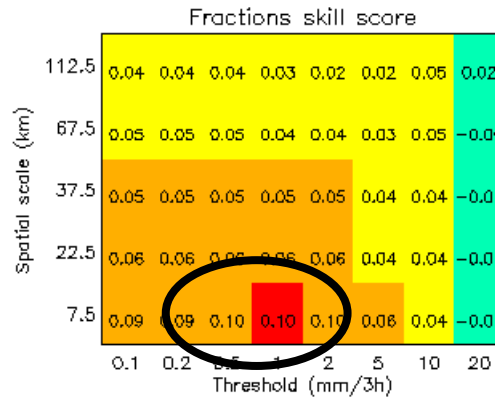
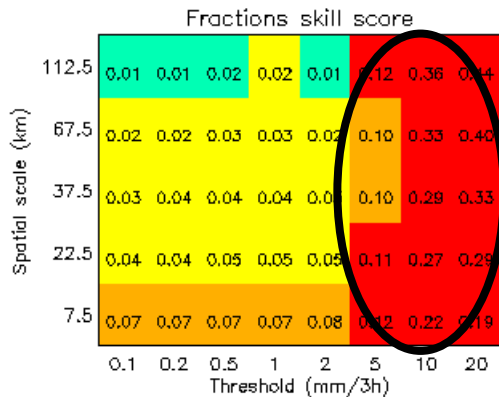
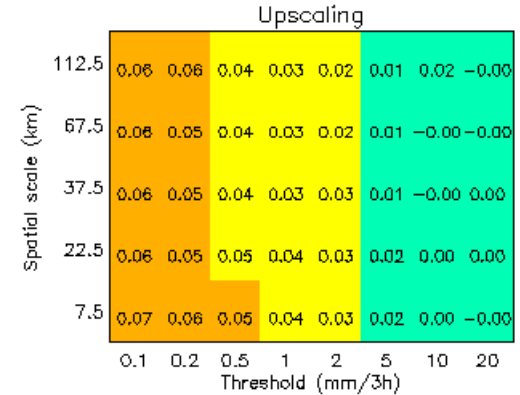
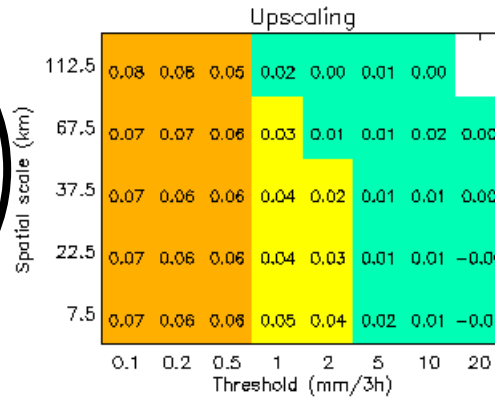
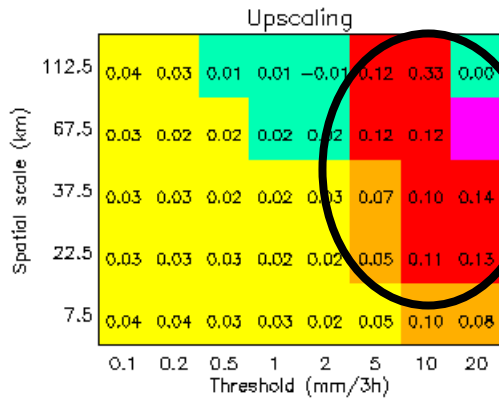
Upscaling

Fraction Skill Score

NW (12%)

W (17%)

all cases



COSMO-7 better

COSMO-2 better





Main Weather classes

COSMO-2 – COSMO-7

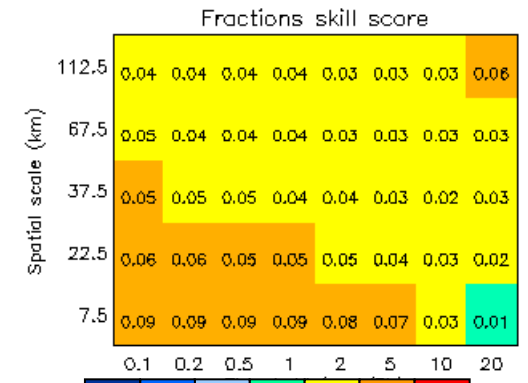
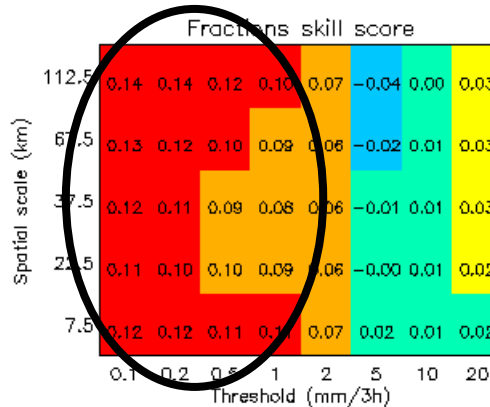
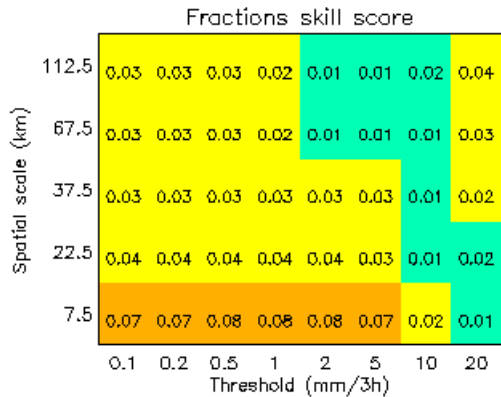
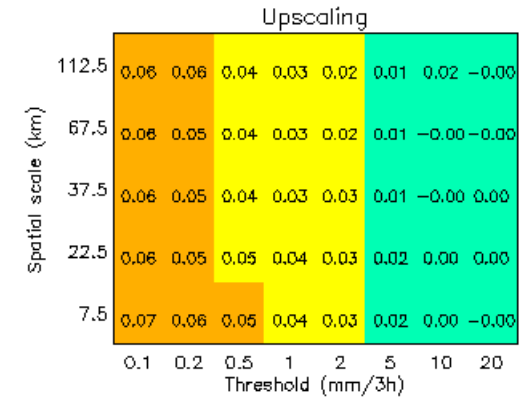
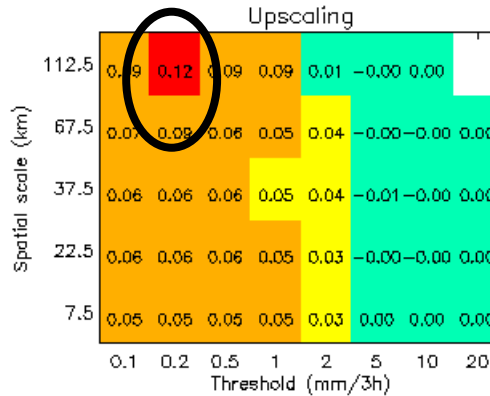
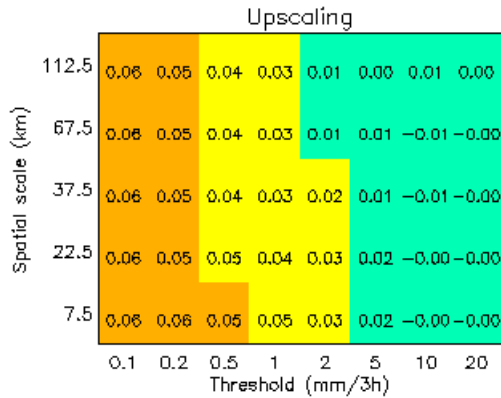
Upscaling

Fraction Skill Score

SW (25%)

H (18%)

all cases



COSMO-7 better

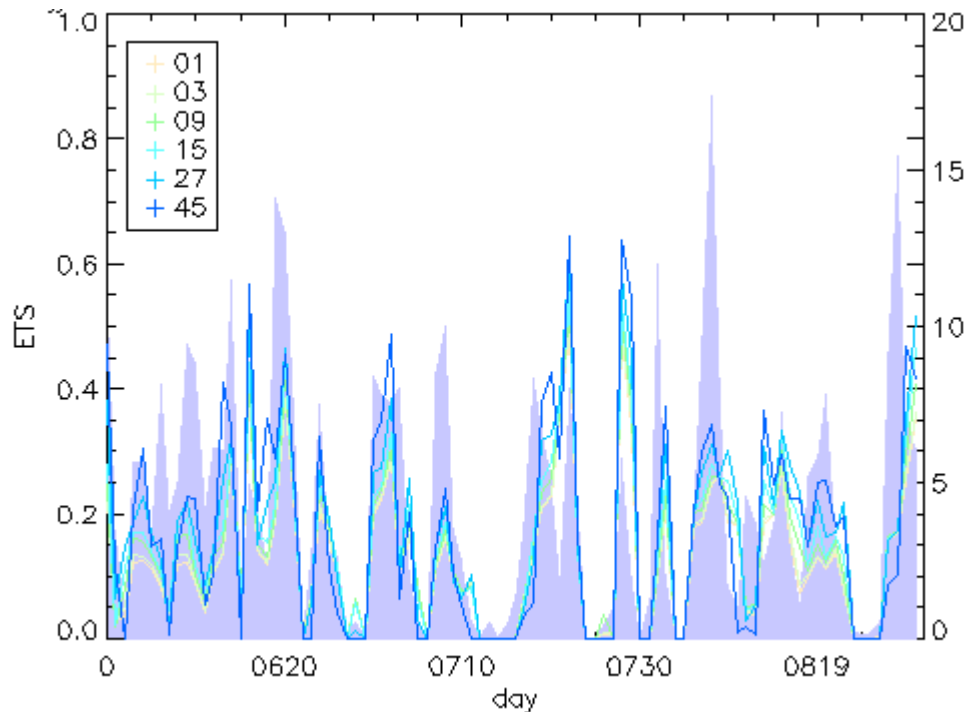
COSMO-2 better





Timeseries of scores for JJA COSMO-DE

Upscaling (ETS), Threshold = 1.0 mm, 3 h acc.,
daily aggregated



→ Strong day-to-day
variation for all
window sizes

→ correct negatives
are not accounted for

$$ETS = \frac{hits - hits_{random}}{hits + misses + false\ alarms - hits_{random}}$$

$$hits_{random} = \frac{(hits + misses)(hits + false\ alarms)}{total}$$

