Focus on Spatial Verification
Filtering techniques

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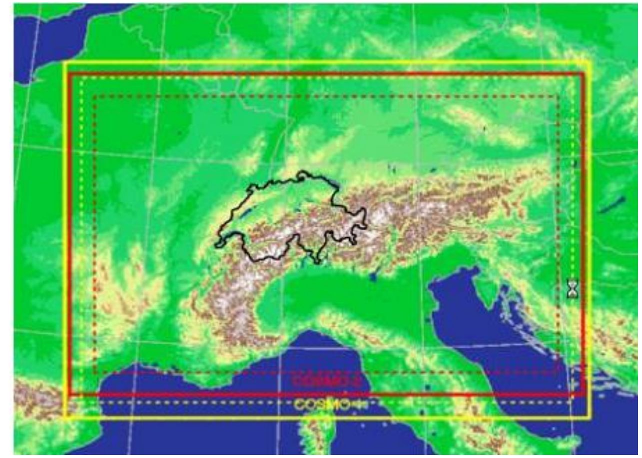
Approach

- Attempt to introduce alternative methods for verification of spatial precipitation forecasts and study their relative benefits
- Techniques that allow to diagnose the skill of a system as a function of the **spatial scale of the forecast error and intensity** of the precipitation events
- Aim is to compare the performance of precipitation forecasts for two different resolutions of COSMO model over the core MesoVICT case
- Precipitation events on different spatial scales are caused by different physical processes and the evaluation of forecast skill on various scales becomes important

Preparation/Adaptation of MesoVICT datasets as input for VAST

MesoVICT datasets



Forecast Data:

1. Model Data interpolated on the VERA grid (<u>resolution 8 km</u>)

ASCII format on a Cartesian grid (non regular)

Models available:

COSMO-2 (old runs – version of model):

COSMO-1 (new runs)

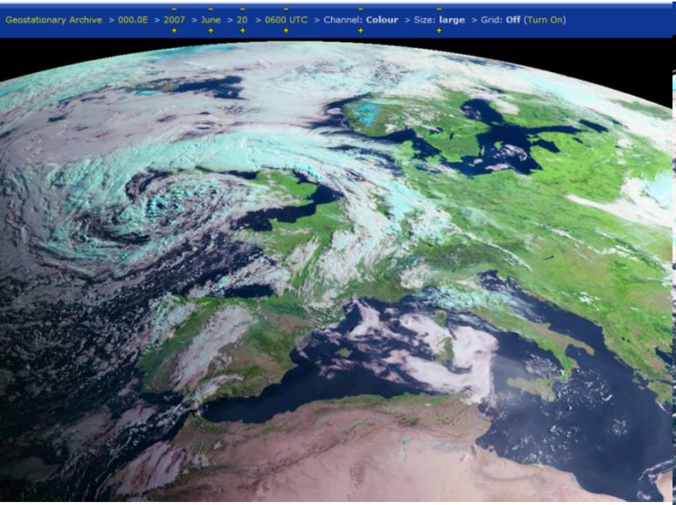
Data:20, 21,22.06.07:00-24UTC. Precipitation, 1h accumulation

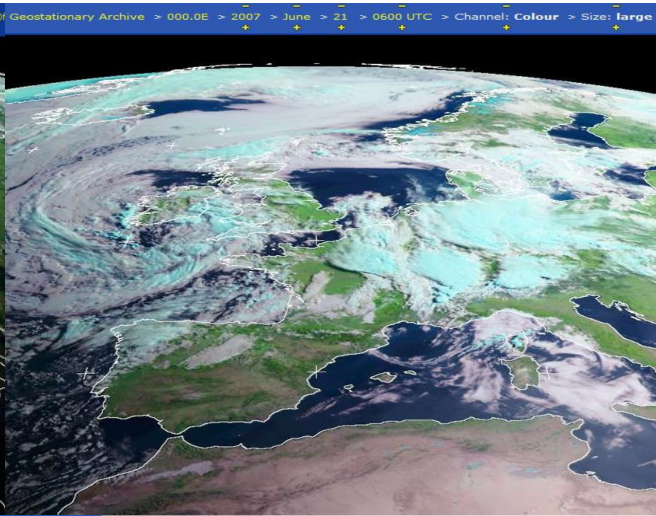
- VAST can process only regular lat-lon files so these data will have to be interpolated for a second time (!) on a regular grid, to be usable by software

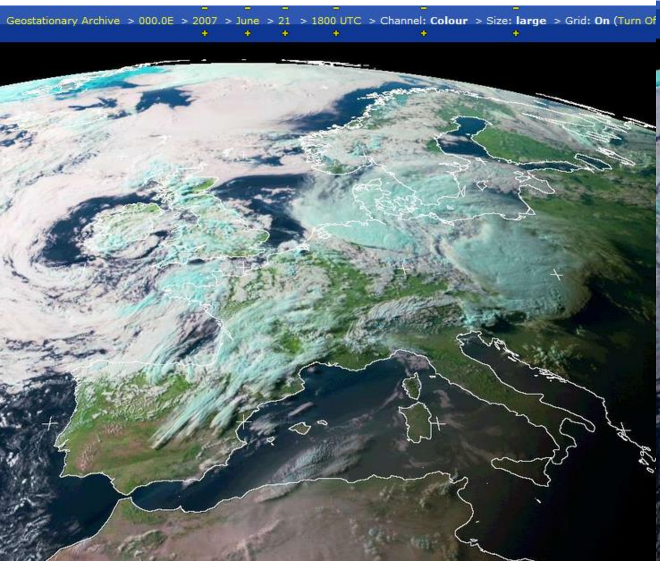
- <u>Observation data used</u>: VERA analysis in ~8km resolution

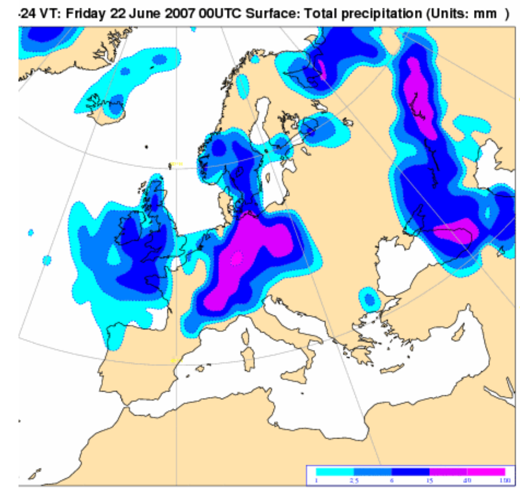
Case 1 (core case): 20-22 June 2007

Ahead of a trough, located over the British Isles, warm moist air is advected towards the Alpine Region. This leads to strong convective events in the evening of 20 June, in the area north of the main mountain range. On the next day (21st) a cold front is reaching the Alps from the west and moves to the east rather quickly. Ahead of the front again convective events are observed. With the passage of the front strong westerly winds occurred.



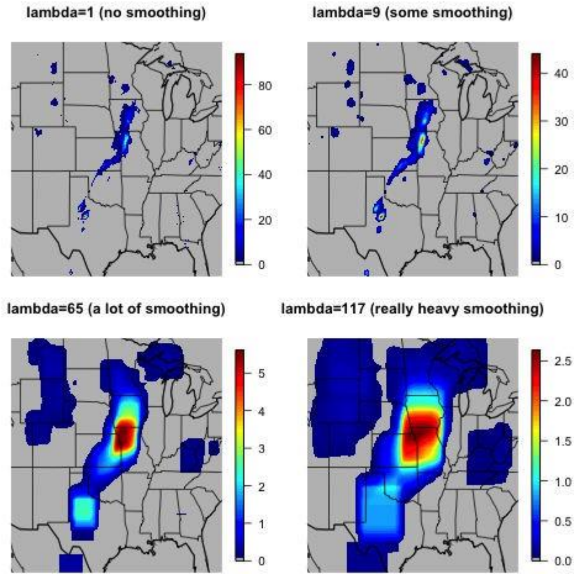


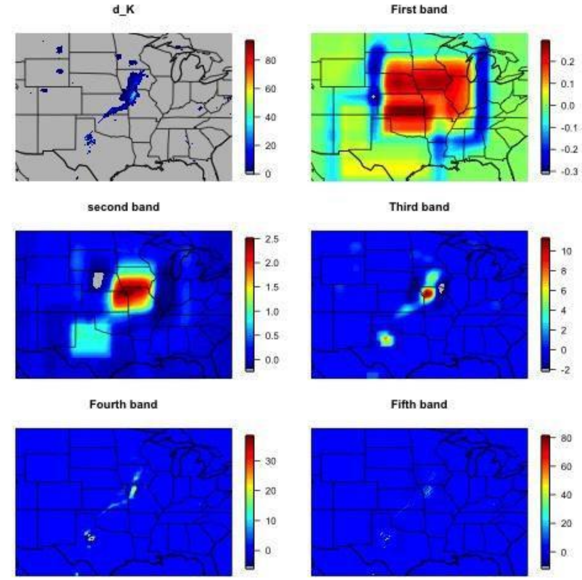




smoothing / neighborhood

Filter

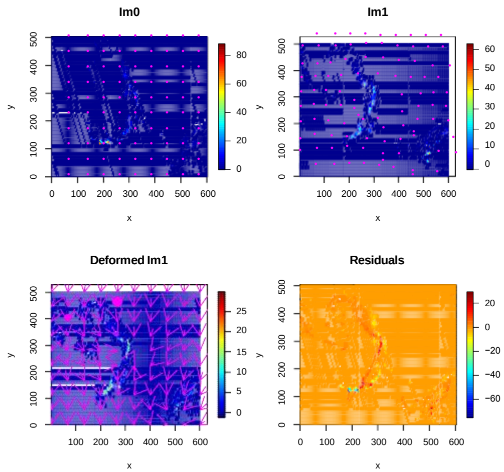




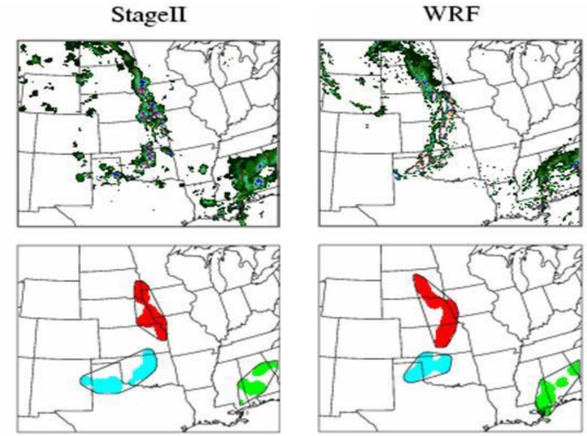
Scale Separation

Entire field

Spatial Displacement



specific features



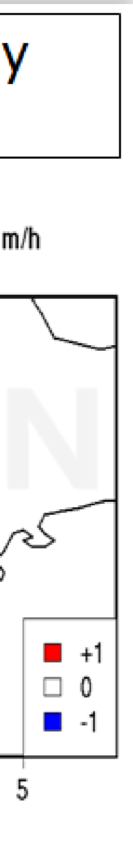
Intensity-scale verification

B. Casati, G. Ross and D.B. Stephenson (2004) "A New intensity-scale verification approach for the verification of spatial precipitation forecasts", Meteorol Appl, vol 11, 141-154 pp

Evaluate the forecast skill as a function of the precipitation **intensity** and the **spatial scale** of the error

NOTE: **scale** = single band spatial filter → features of different scales → feedback on different physical processes and model parameterizations

In the neighborhood based (fuzzy) verification, the **scale** is the neighborhood size (low band pass filter): as the scale increases the exact positioning requirements are more and more relaxed



Steps in IS verification

Binary error decomposition: Thresholding is used to convert the forecast and analysis into binary images for each of the rainfall rates. Binary error is the difference of this $Z=I_{y'}-I_{x}$

Binary error image is then expressed as the sum of components on different spatial scales by performing a 2-dimentional discrete Haaer wavelet decomposition $Z=\sum_{l=1}^{L} Z_l$

Most substantial binary error image of the mother wavelet components are calculated for various spatial scales (ℓ=1,..L=7). The spatial scales refer to the spatial scale of the error and not that of the precipitation features or their displacement as it happens in the neighborhood methods

- The MSE of the binary error image is calculated from $\mathrm{MSE}=\sum_{i=1}^{L}\mathrm{MSE}_l$ $\mathrm{MSE}_l=\overline{Z_l^2}$ while for each threshold the skill score can be calculated from $SS=\frac{\mathrm{MSE}-\mathrm{MSE}_{random}}{\mathrm{MSE}_{best}-\mathrm{MSE}_{random}}$, where and MSE_{random} is associated with a random forecast calculated from the bias and the base rate at each threshold
- Intensity scale verification technique is a spatial generalization of traditional binary verification (HSS)
- Application using SpatialVx: waveIS routine

Two-dimensional discrete Haar wavelet filter (Casati et al, 2004)

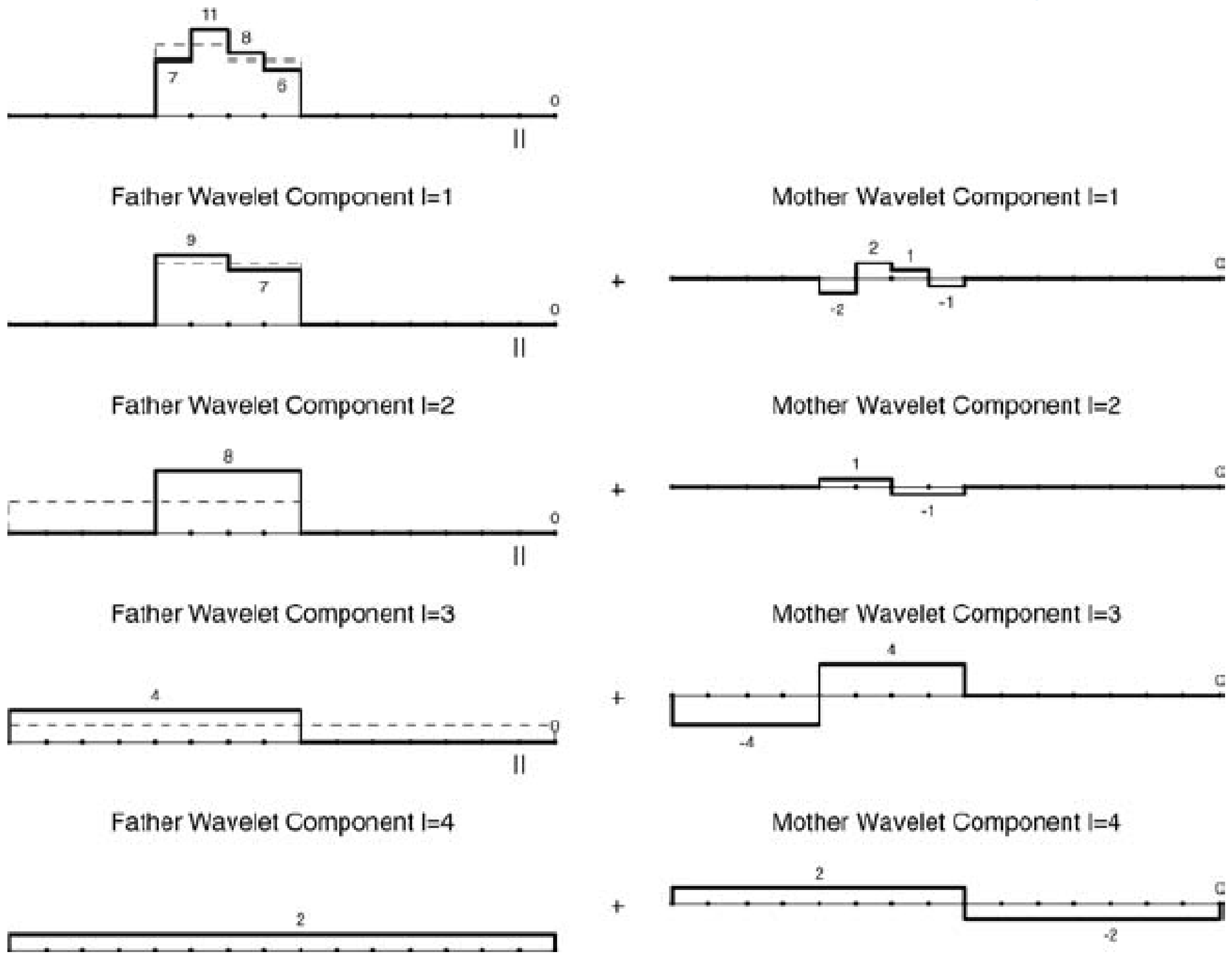
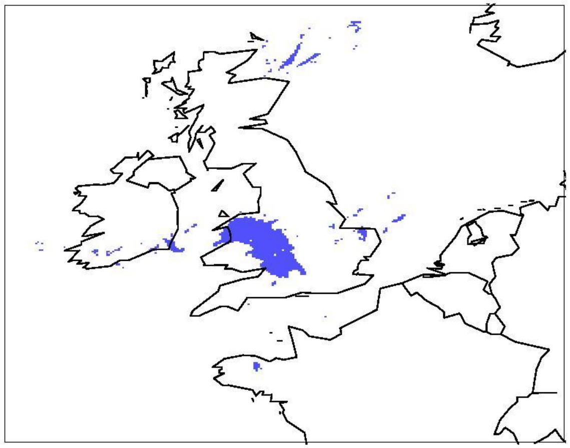


Figure 11. *Example of the one-dimensional discrete Haar wavelet filter applied to an example function (top left panel). At the first step the function is decomposed into the sum of a coarser* mean *function (the first father wavelet component) and a* variation-about-the-mean *function (the first mother wavelet component). At each step the Haar wavelet filter decomposes the father wavelet component obtained from the previous step into the sum of a coarser* mean *function (the l^{th} father wavelet component) and a* variation-about-the-mean *function (the l^{th} mother wavelet component). The l^{th} father wavelet component is obtained from the initial function by a spatial averaging over 2^l pixels. The process stops when the largest father wavelet component (mean over the whole domain) is found.*

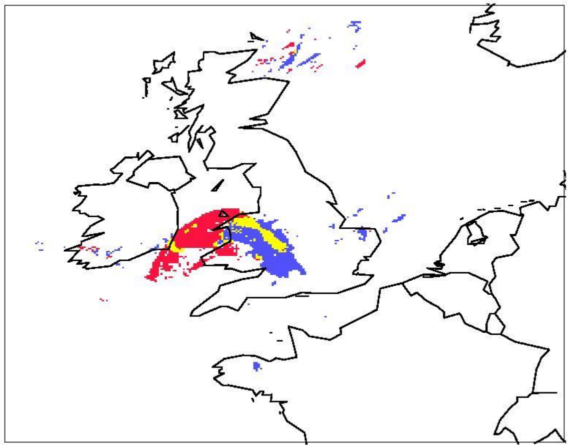
Links with categorical verification

Binary Analysis



Binary Forecast

Overlapping



$$MSE_u = \frac{b+c}{n}$$

$$SS_u = HSS$$

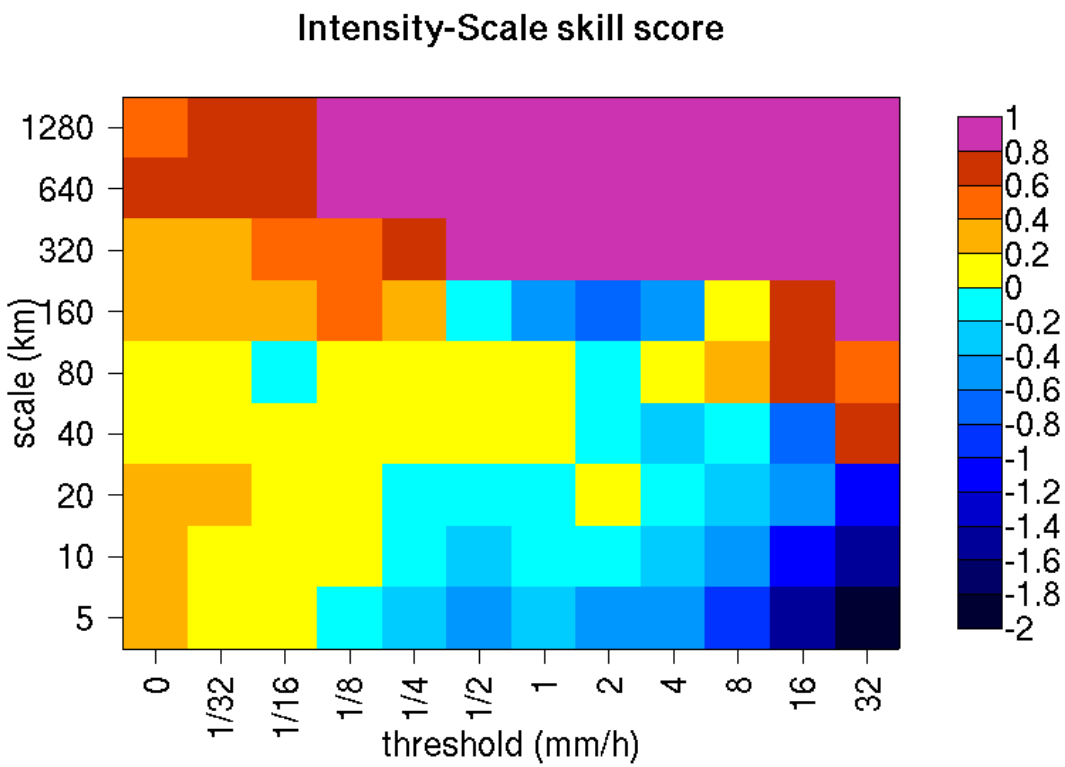
	X > u	X < u	
Y > u	Hits a	False Alarms b	a+b
Y < u	Misses c	Correct Rejections d	c+d
	a+c	b+d	a+b+c+d=n

Casati, 2007

Intensity-scale skill score (SS)

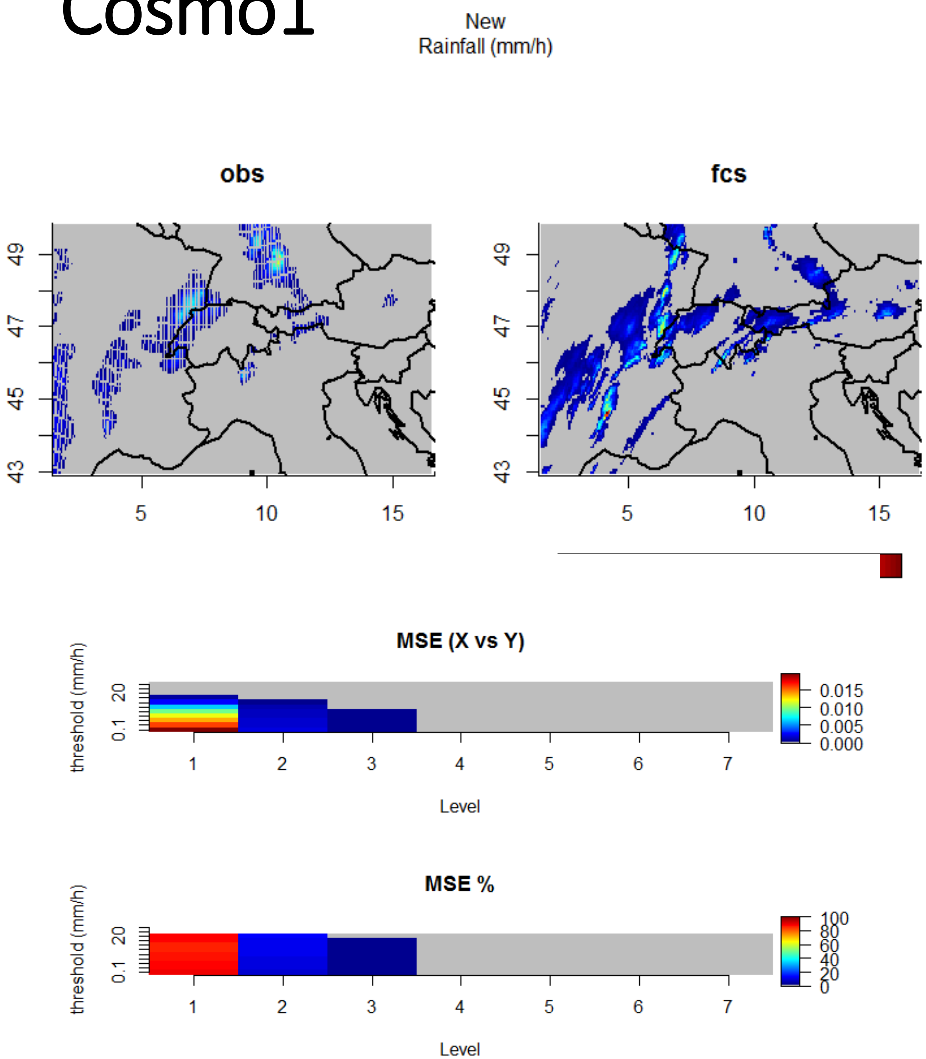
For each threshold and scale component: skill score associated to the MSE of binary images (= HSS) . Skill versus random chance, equally partitioned across the scales. The IS skill score is capable of isolating specific scale-dependent errors.

Usually, small scales exhibit negative skill, whereas large scales exhibit positive skill

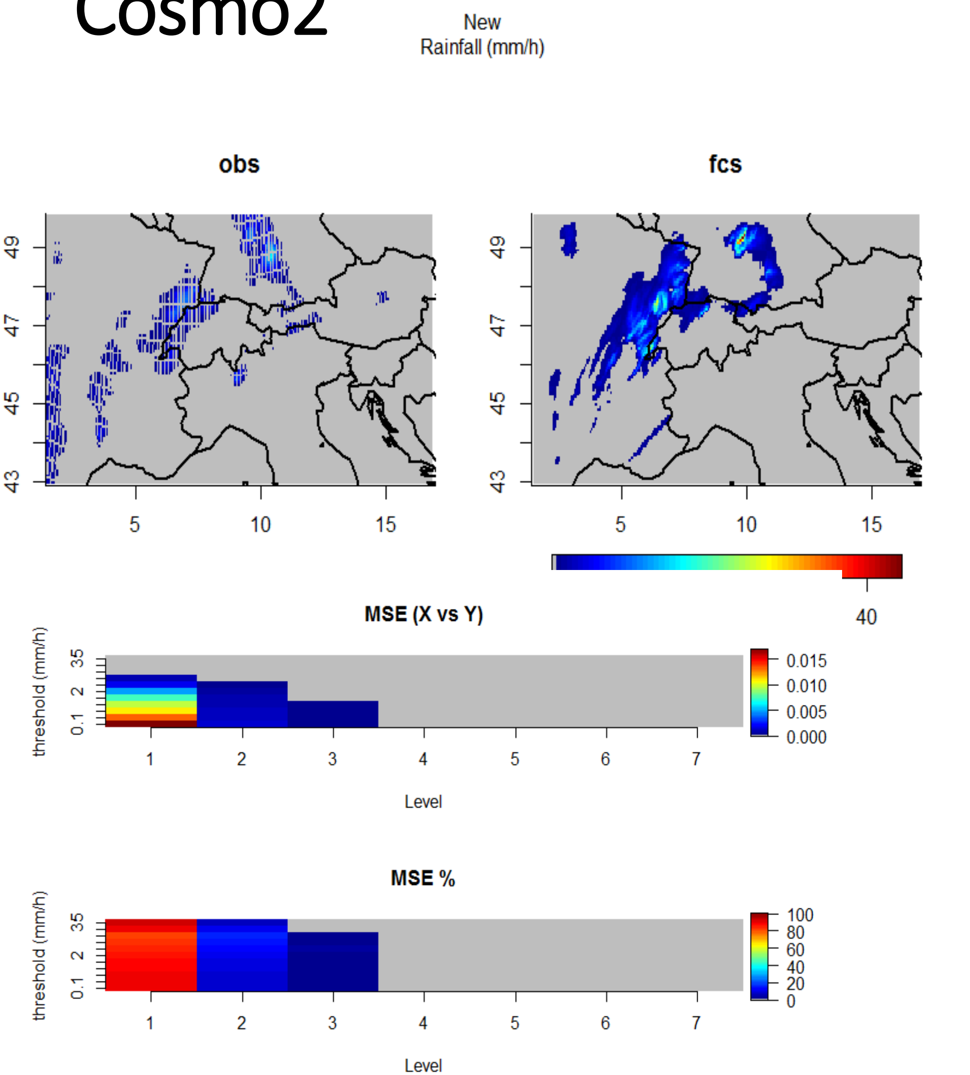


20070621-01:map

Cosmo1

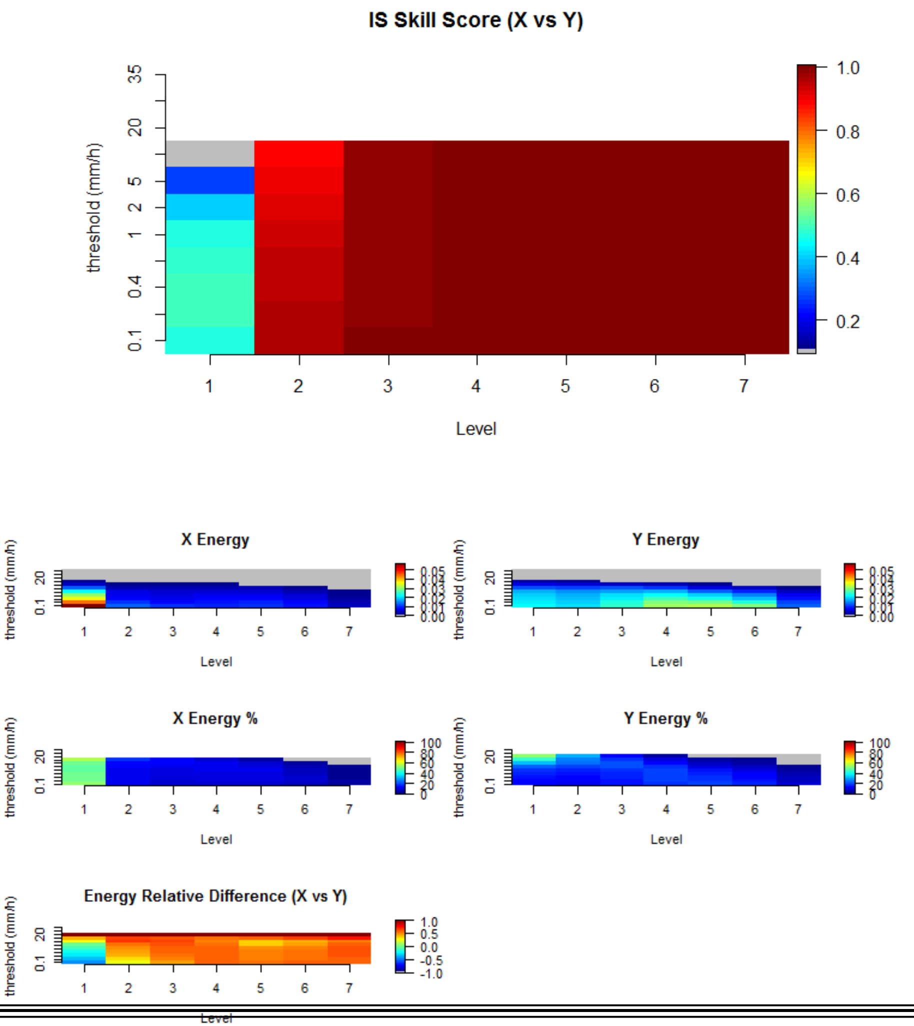


Cosmo2

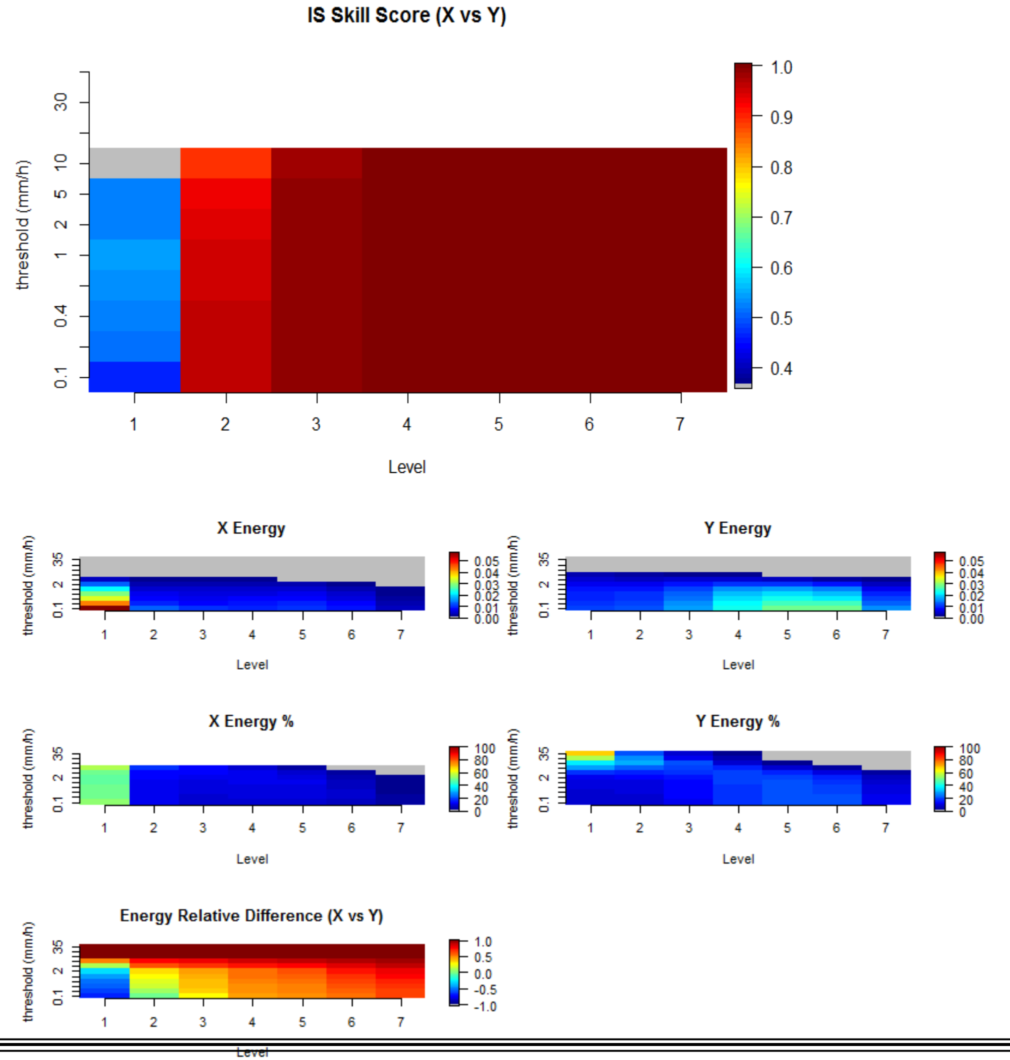


20070621-01: Skill

Cosmo1

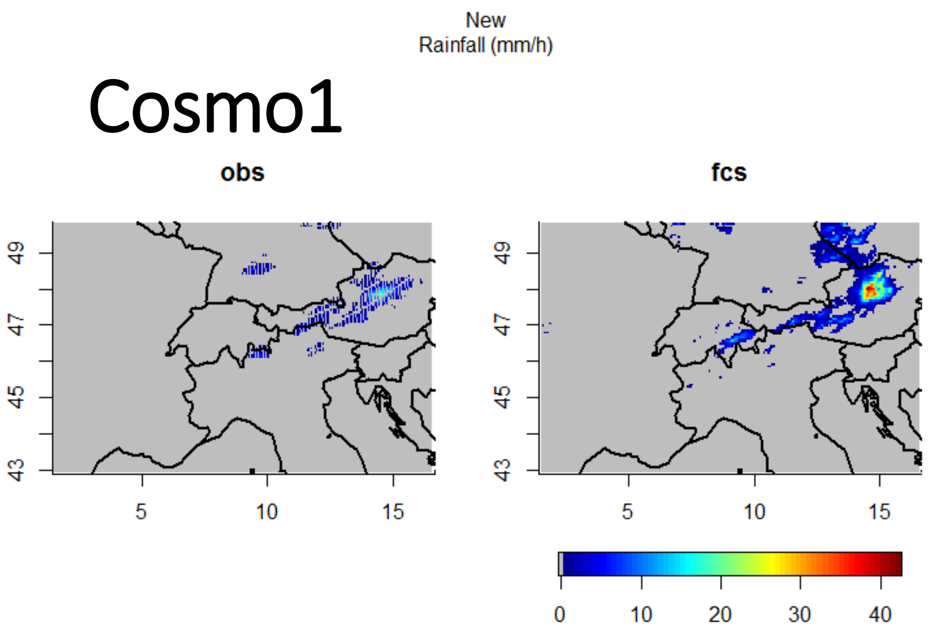


Cosmo2

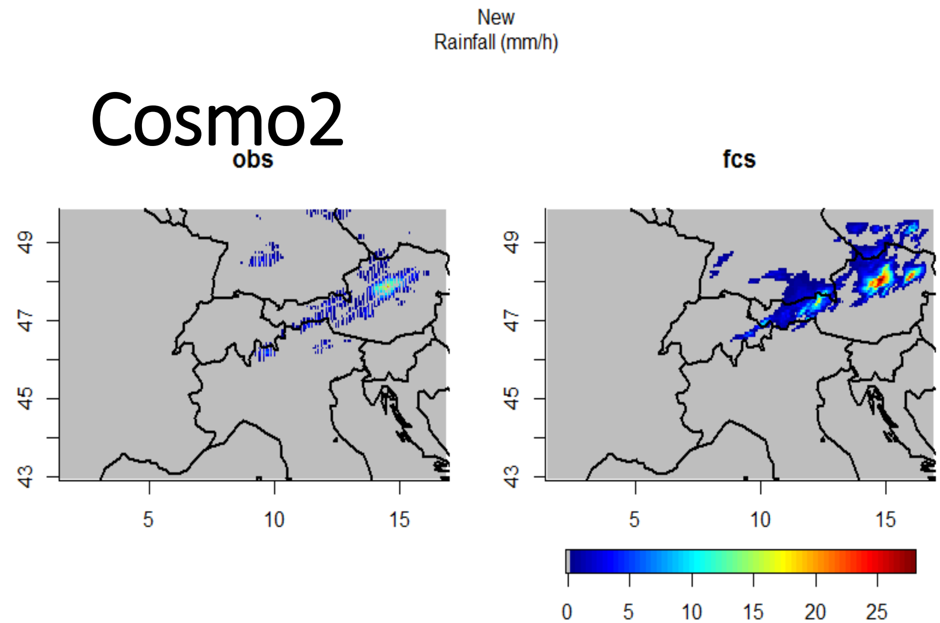


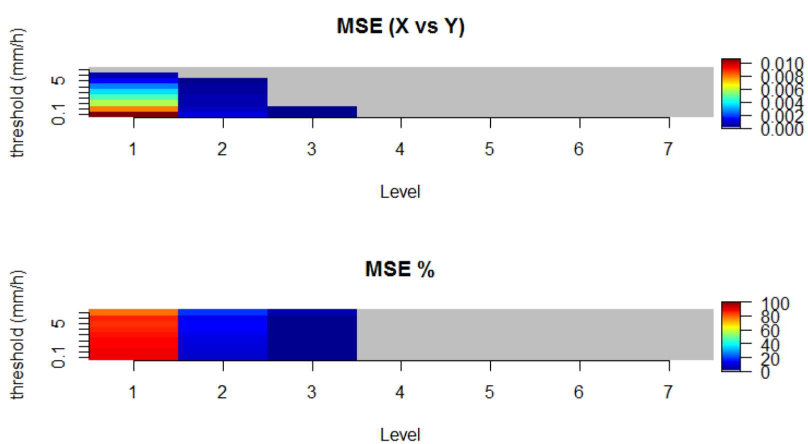
20070621-15:map

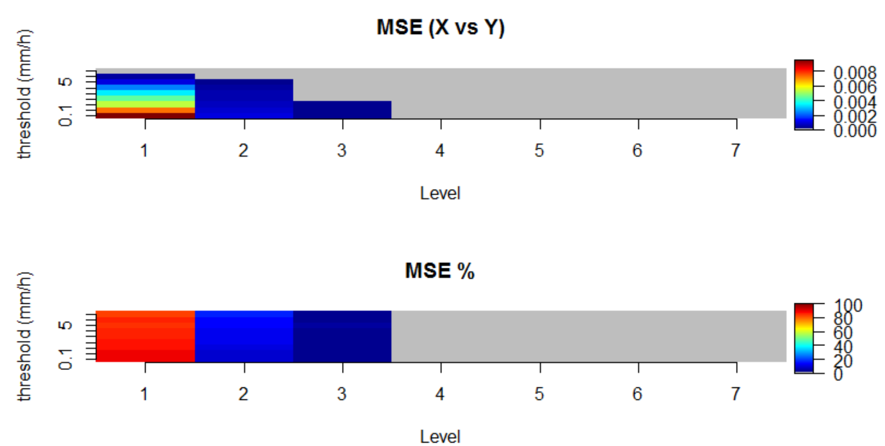
Cosmo1



Cosmo2

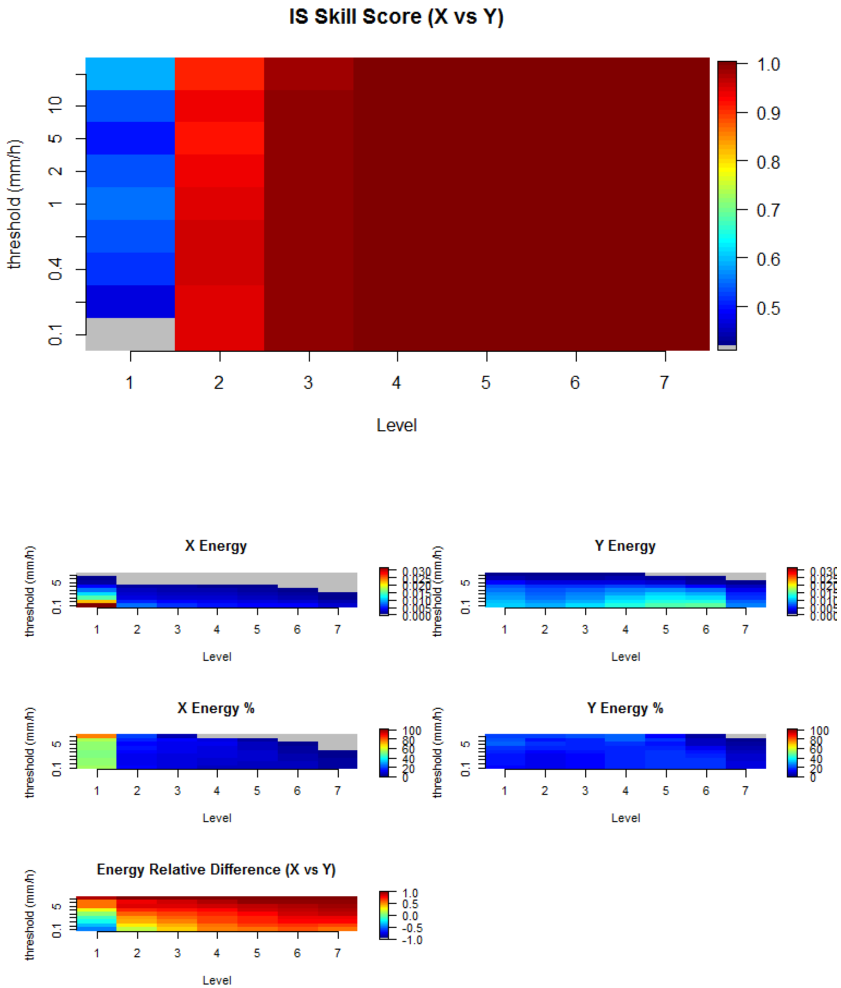




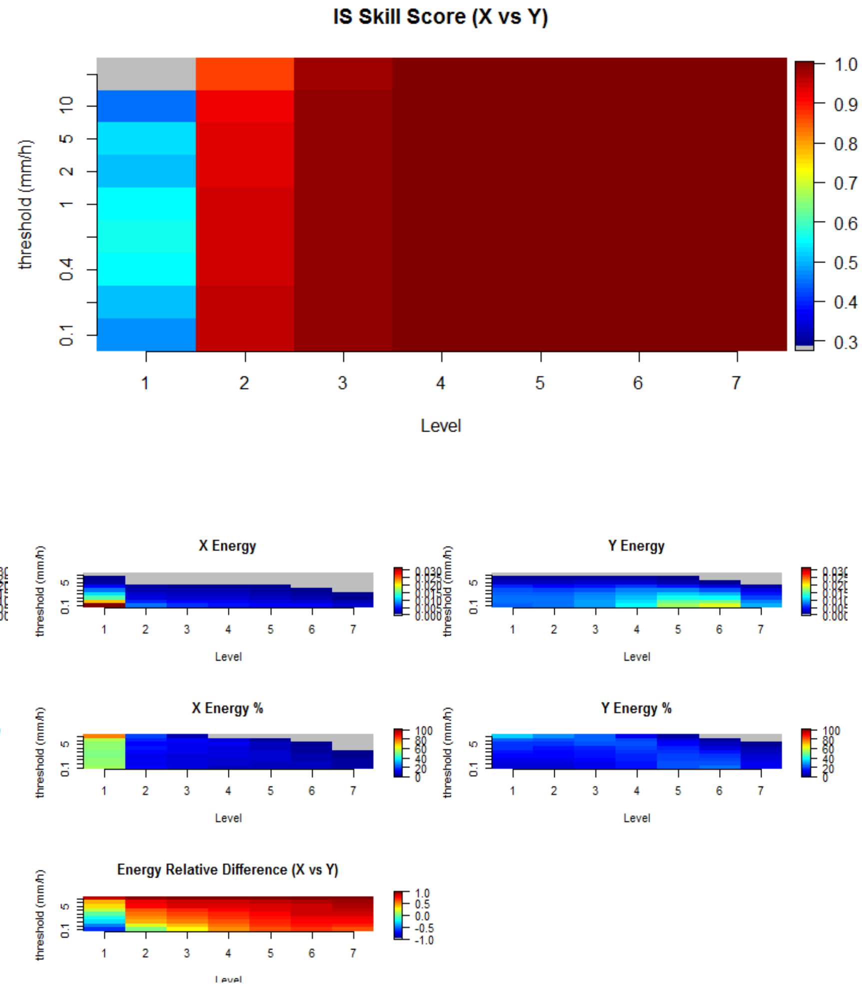


20070621-15: Skill

Cosmo1

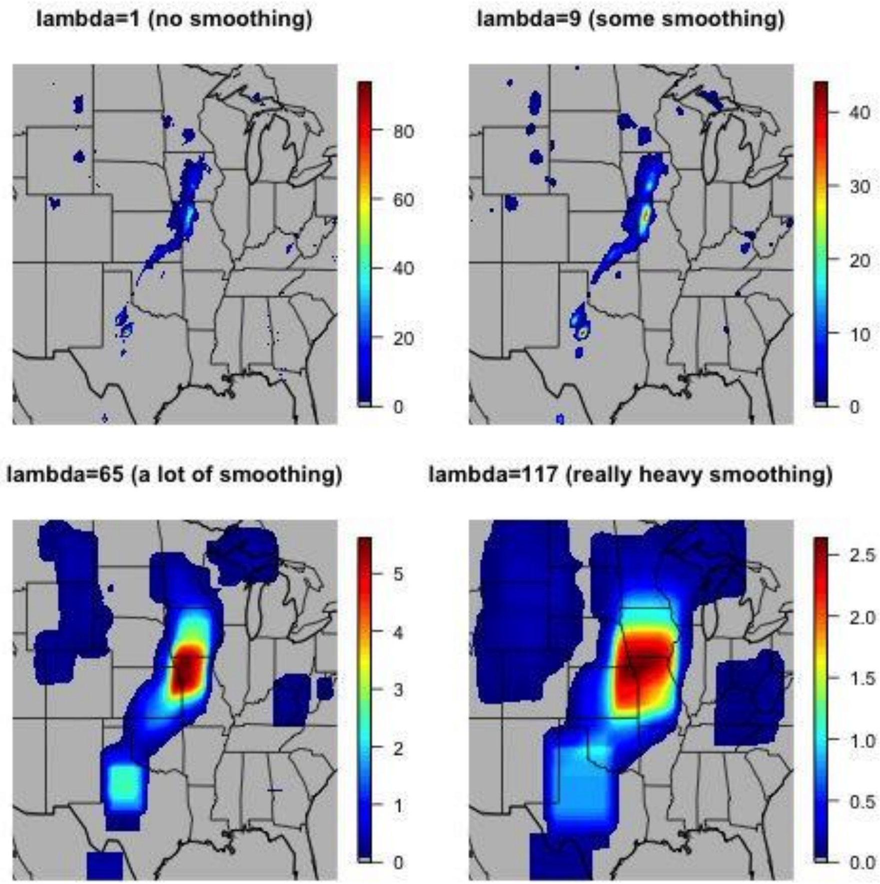


Cosmo2



Recalling the ICP

smoothing filter / Neighborhood Methods

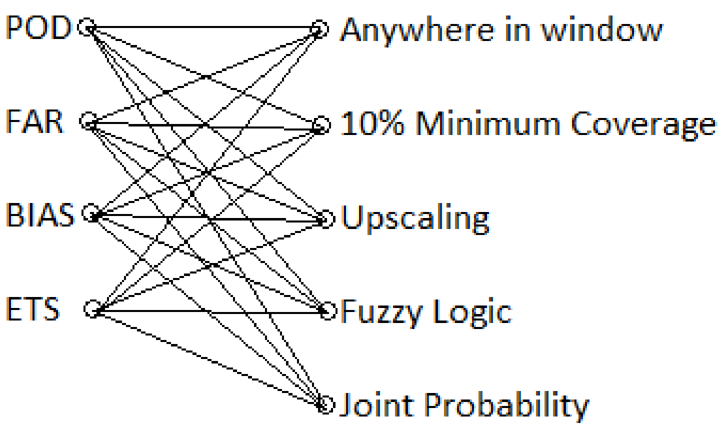


Apply filter to:
- raw field
- binary "thresholded" field (event field)

Apply filter to:
- both fields
- forecast only
- observations only

Ebert, 2008, Meteorol. Appl., 15, 51 – 64

- # Neighborhood methods/scores :VAST



Pragmatic approach με BSS

Fractions Skill Score

Practically Perfect Hindcast

Area Related Root Mean Square Error

- # Categorical verification

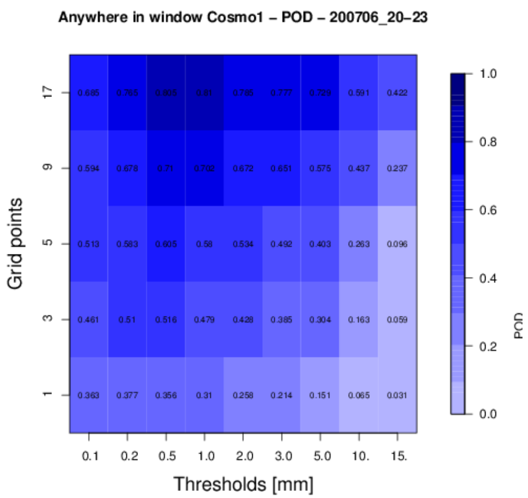
BIAS

FAR

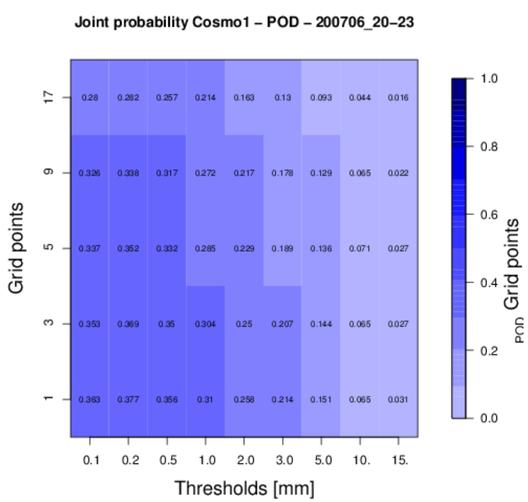
POD

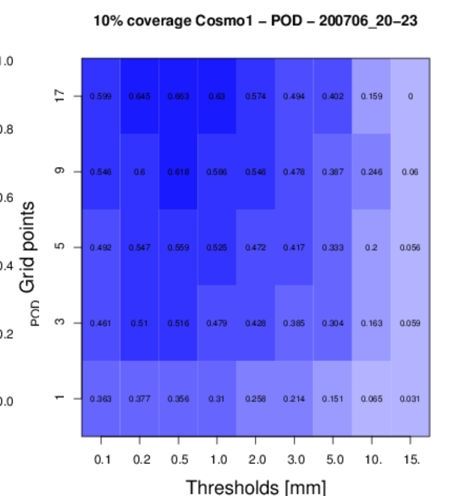
COSMO-1

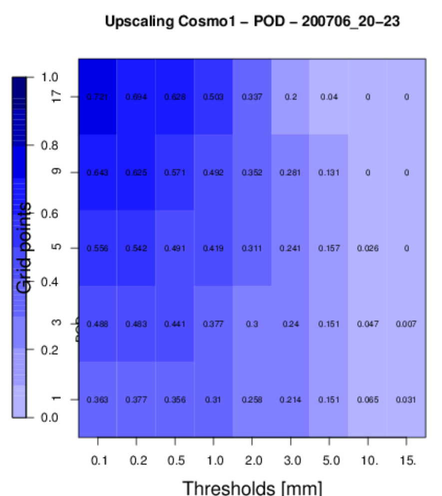
- **POD**

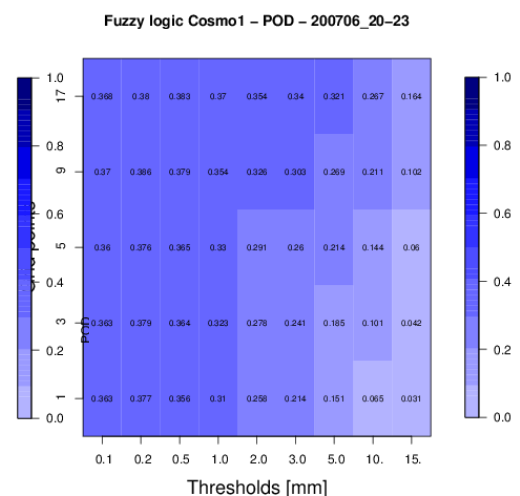


Neighborhood method	Decision Model
Upscaling	In a good forecast it is predicted the same average value of precipitation with the predicted
Fraction Skill Score	A forecast is useful when the frequency of forecasted events is similar with the frequency of the observed events
Minimum coverage	A forecast is useful if the event is forecasted in a minimum fraction of the area of interest
Anywhere in the window	A forecast is useful if it is more true than untrue, characterizing the events as probabilities
Pragmatic approach	A useful forecast has higher probability to discriminate the events and the non events.(in reference with the climatological value derived from the observations
Area related RMSE	A useful forecast has the same distribution of intensity as the observations









COSMO-1

- **FAR**

Neighborhood method	Decision Model
Upscaling	In a good forecast it is predicted the same average value of precipitation with the predicted
Fraction Skill Score	A forecast is useful when the frequency of forecasted events is similar with the frequency of the observed events
Minimum coverage	A forecast is useful if the event is forecasted in a minimum fraction of the area of interest
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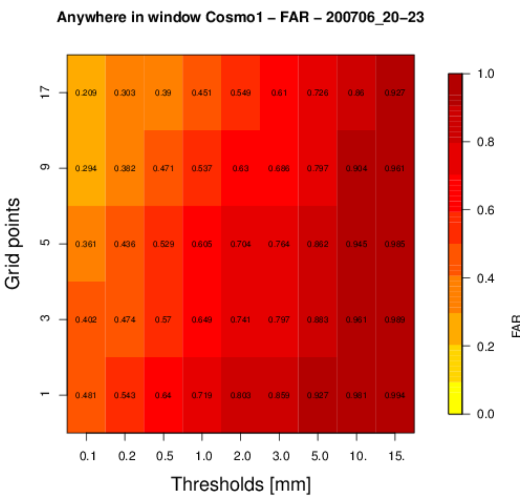
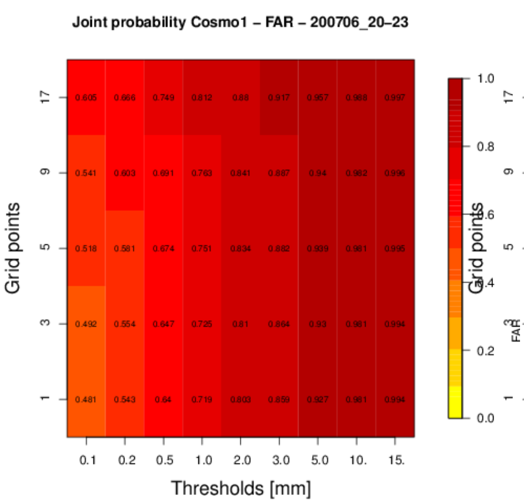
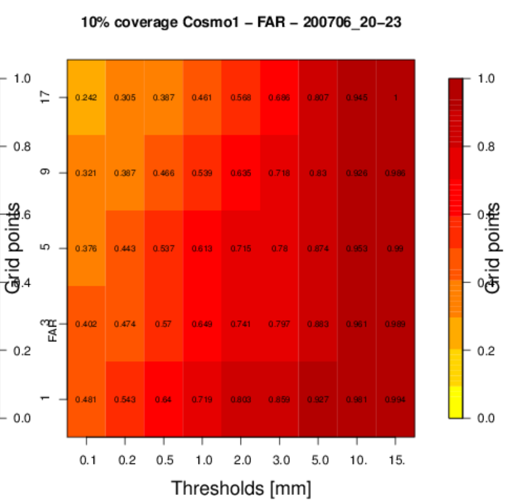
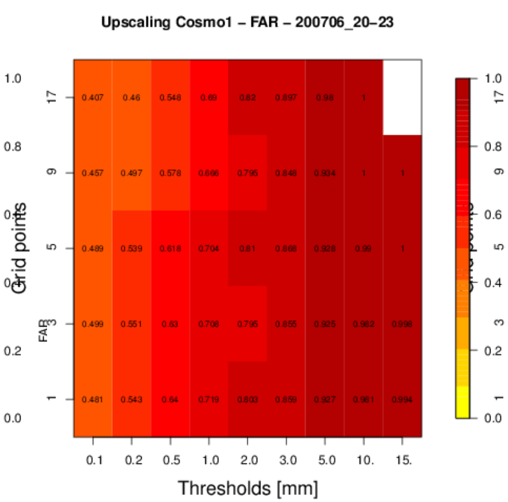
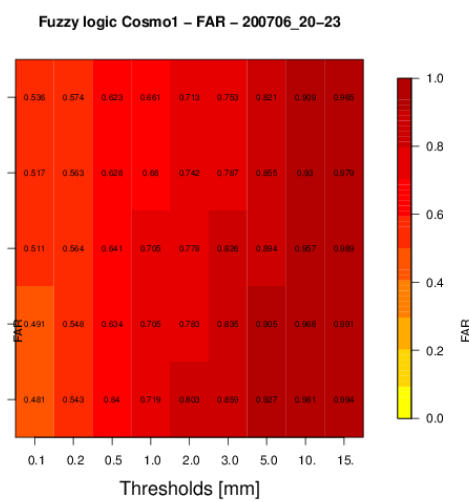




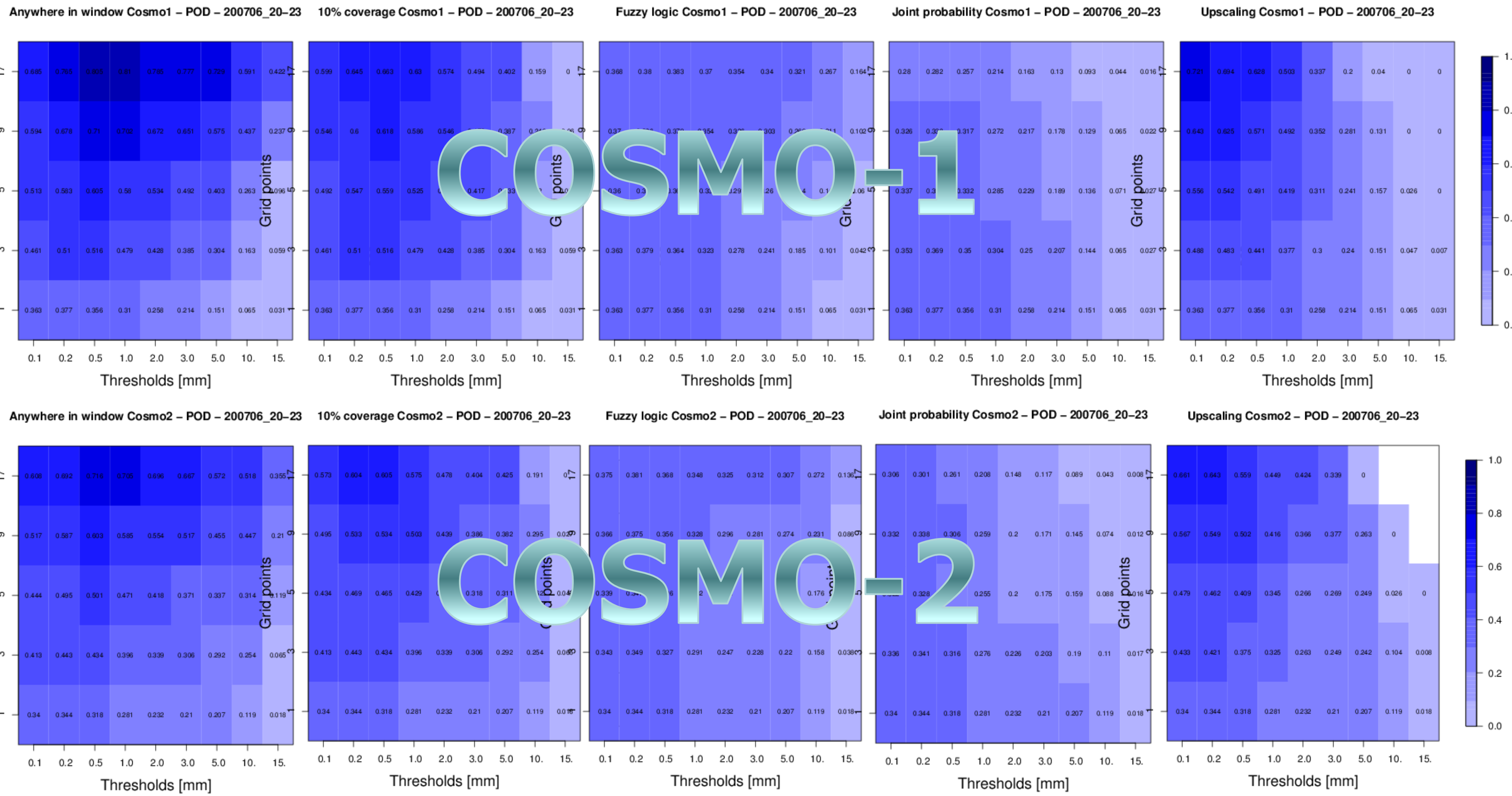






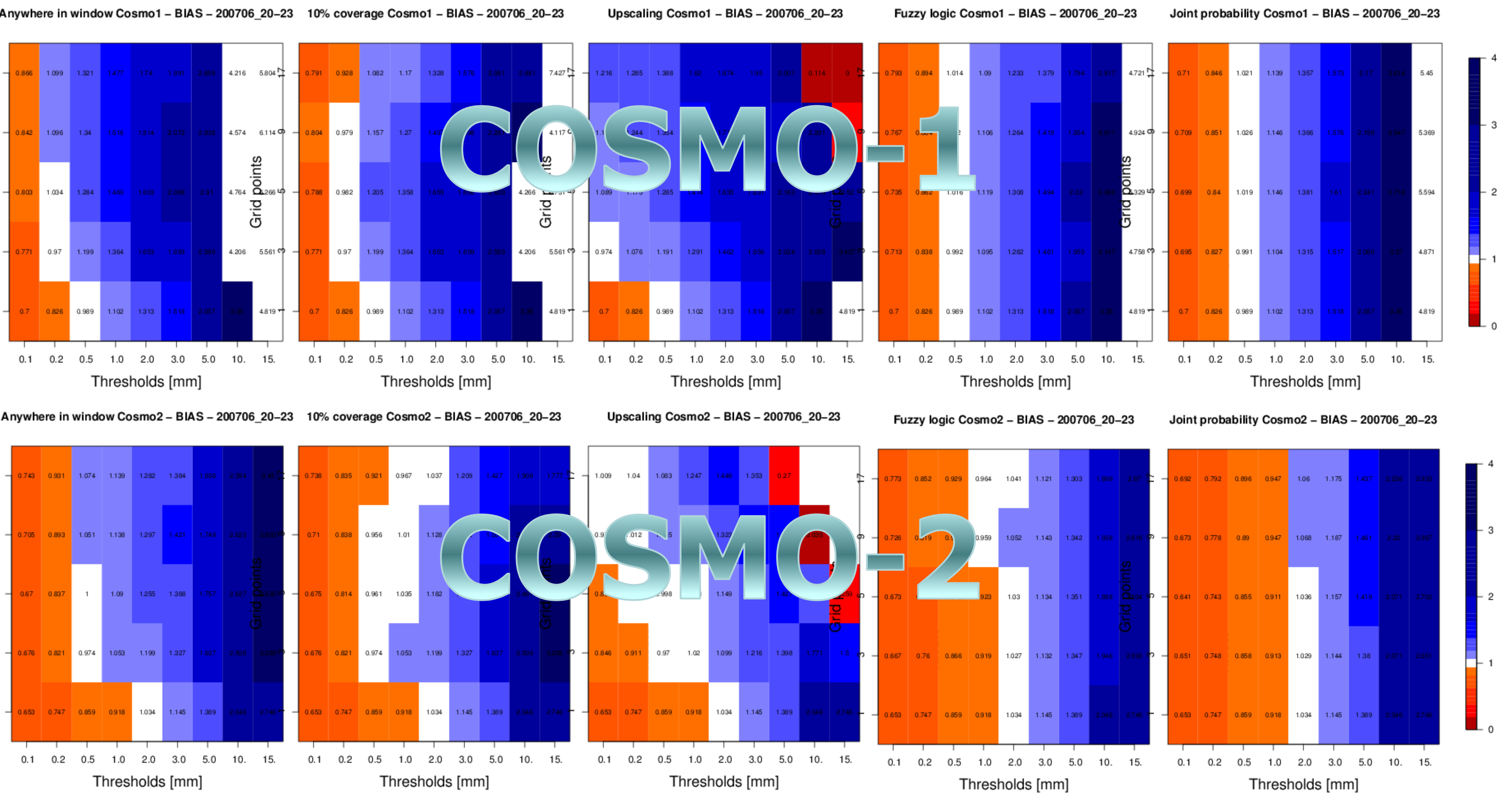
Neighborhood method scores COSMO-1 vs COSMO-2

- POD



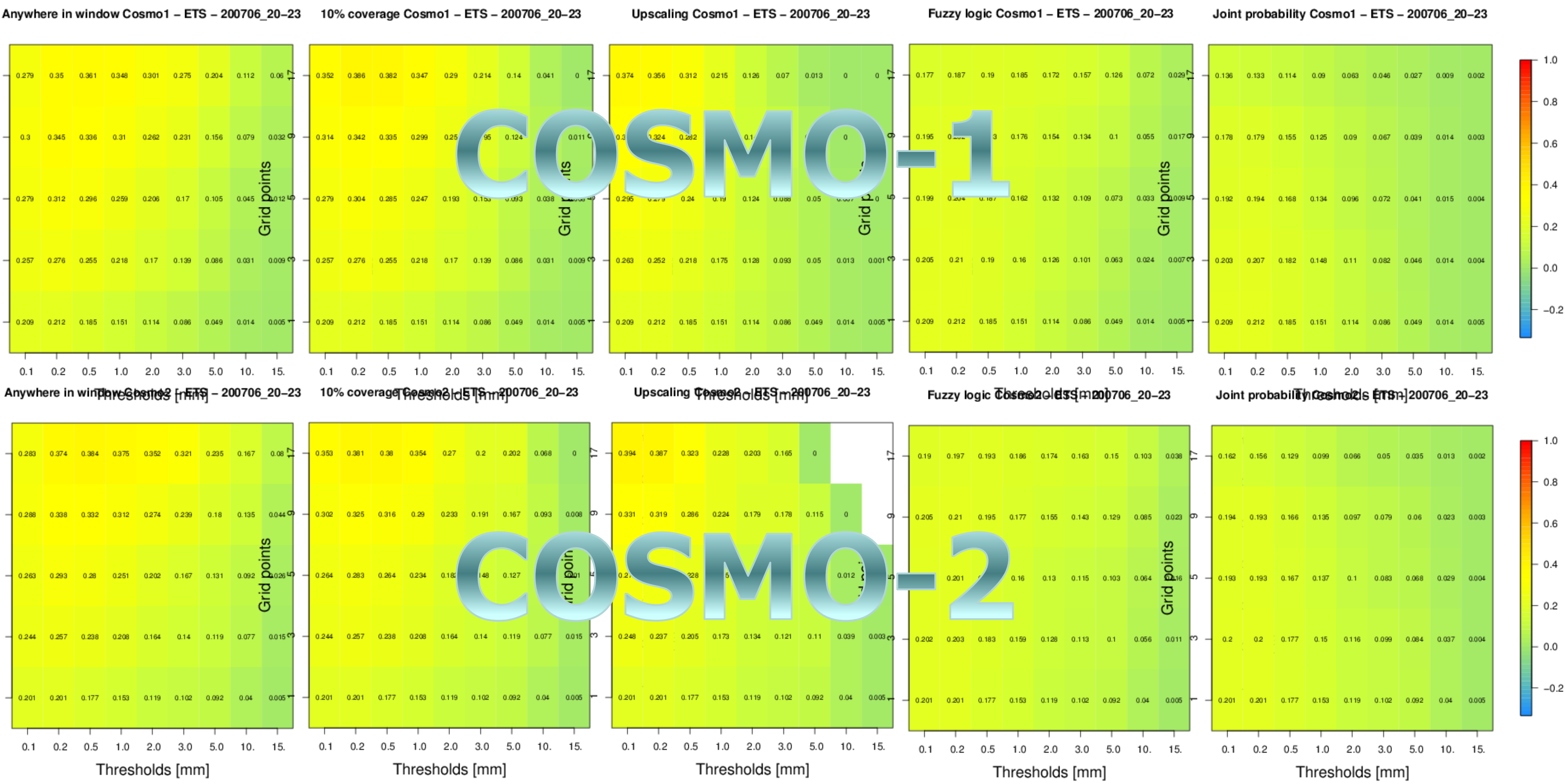
Neighborhood method scores COSMO-1 vs. COSMO-2

- **BIAS**

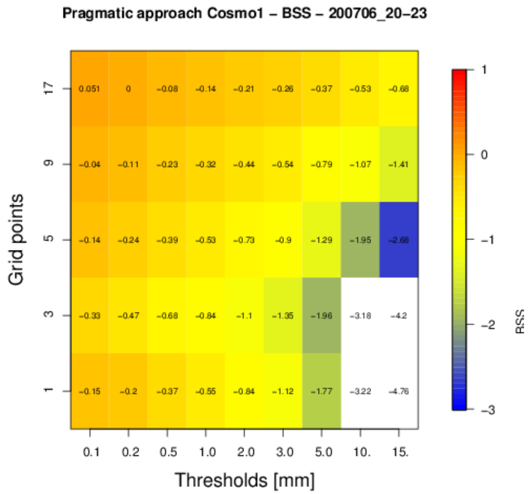


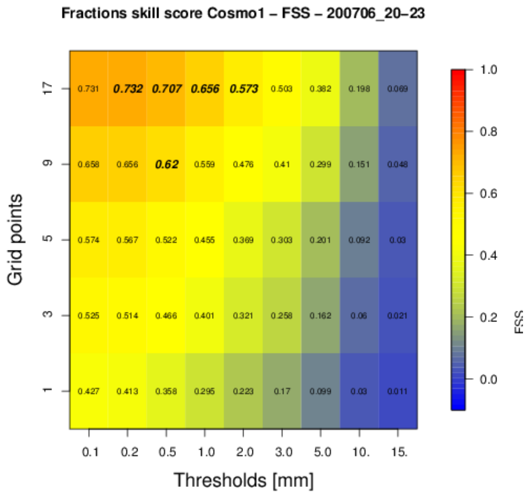
Neighborhood method scores COSMO-1 vs COSMO-2

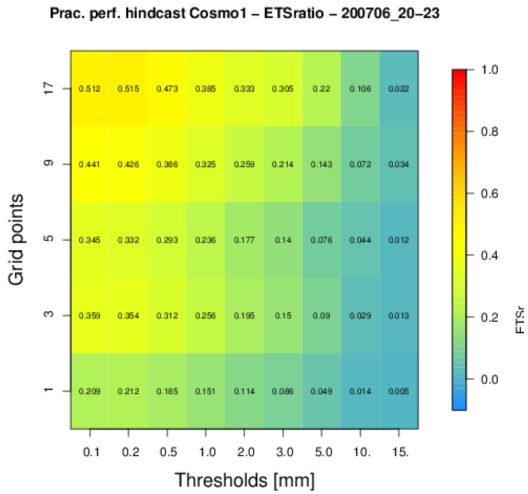
- **ETS**

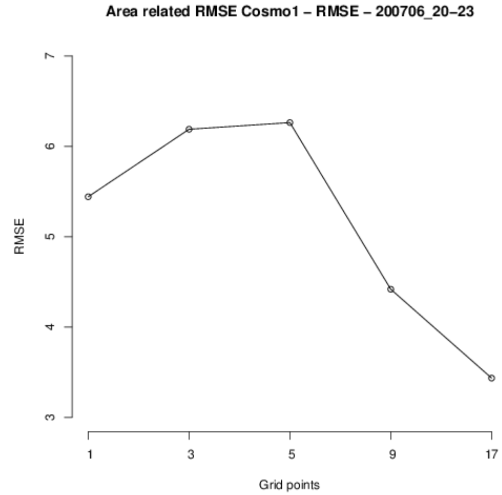


Neighborhood method scores COSMO-1

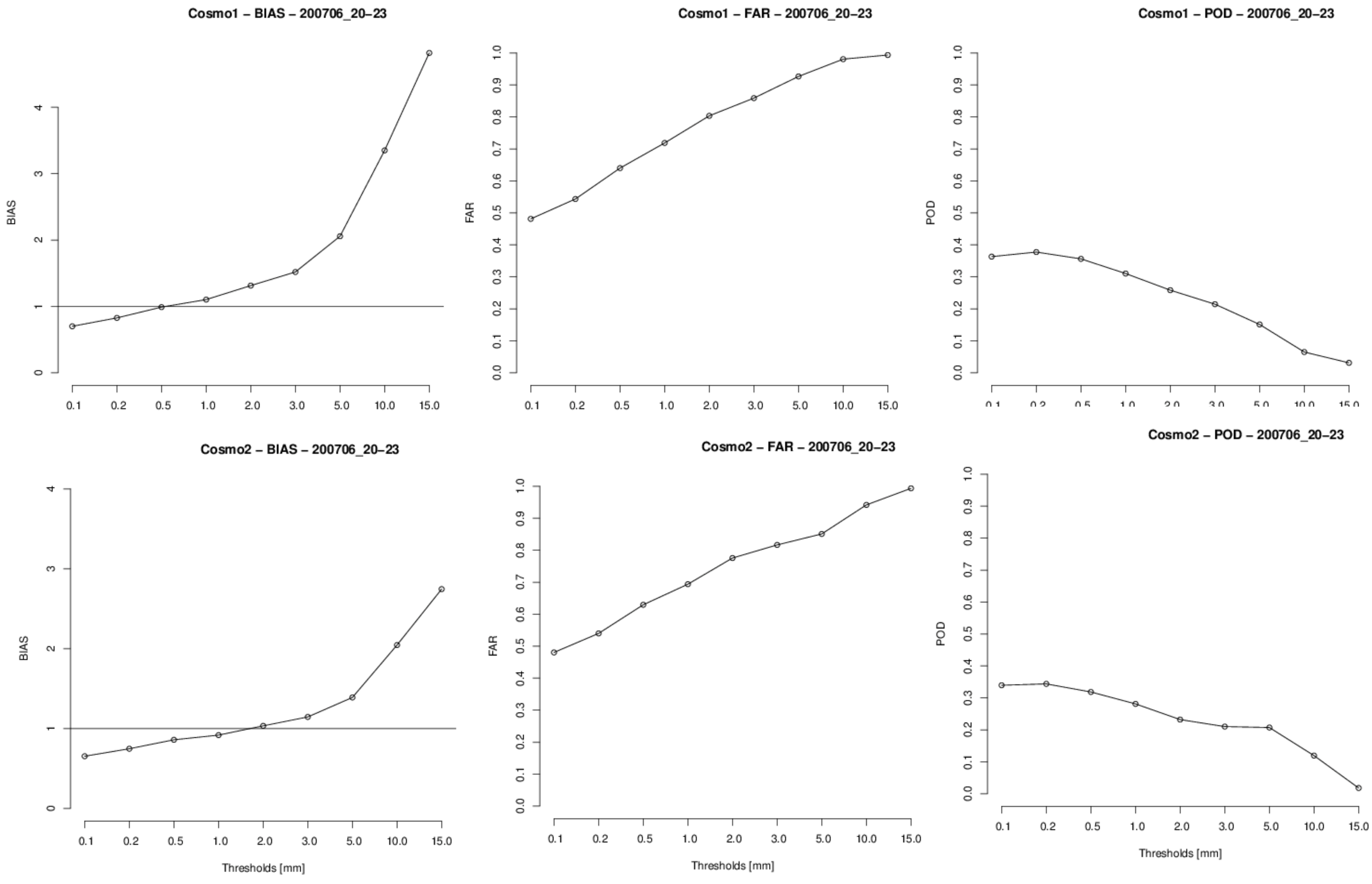








Categorical scores: COSMO-1 vs. COSMO-2



Few thoughts/comments for filtering method applications

- Application of IS spatial method was attempted over a few instances related to the MesoVICT core case of 21-23/06/2007
- Main issue was the shift of the frontal system which was well described by the small (even negative) skill score in the pertinent scales
- Both models have negative skills at the smallest scale but skill improves when considering larger spatial scales.
- ISS decreases as the precipitation threshold is increased and this is due to the poor ability of the model to go beyond just the yes/no rain discrimination
- IS method constraints are related to the request to have precipitation analysis available for each grid point of the forecast field, and to the fact that Haar wavelet decomposition is designed for a square domain defined by a grid $\mathbf{2^l x 2^l}$

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Few thoughts/comments for filtering method applications

- IS kind of analysis and graphical representation of scores is not suitable for the operational verification as it is not concentrated in the average behavior of the model over areas but on single forecast. Neighborhood methods however with the right choice of decision model and aggregation on several timesteps/runs can provide a more operationally “useful” type of information
- While all methods measure intensity bias, no single method addresses all types of errors and so it is necessary to either prioritize which types of errors are most important to the user and choose the appropriate verification approach, or preferably apply more than one type of verification method.

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