Cosmo model validation through precipitation data coming from radar-based estimation and rain gauges measures

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September 2, 2013

Contents

About the work

The aim of the work is to realise a new type of verification for COSMO I7

- The verification is made against a precipitation field estimated by the Italian radar mosaic corrected with the data coming from the Italian rain gauges network
- Two phases:
  - Relative error
  - Fuzzy verification
- Case study: October 24-25-26-27, 2010
- Finding a useful methodology for different kind of studies

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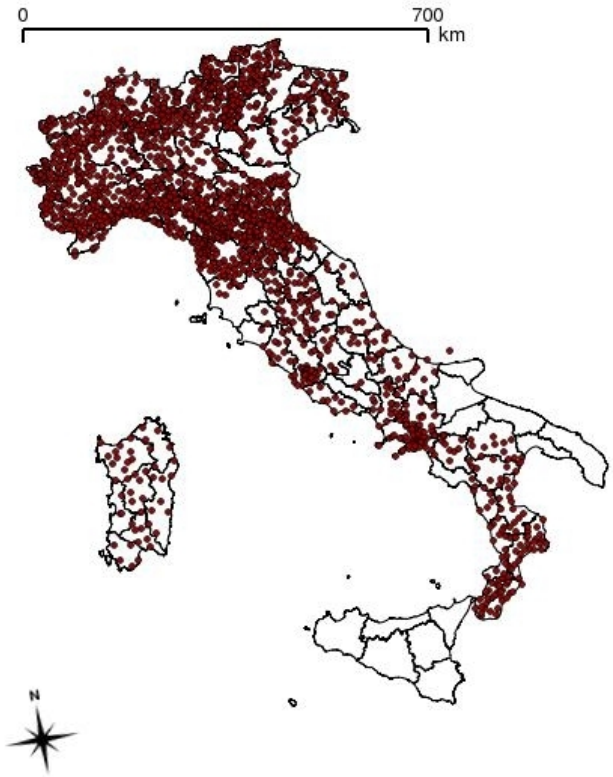
Future developement

- Complete the study by applyng the same methodology to COSMO I2 (or other models)

Rain gauges

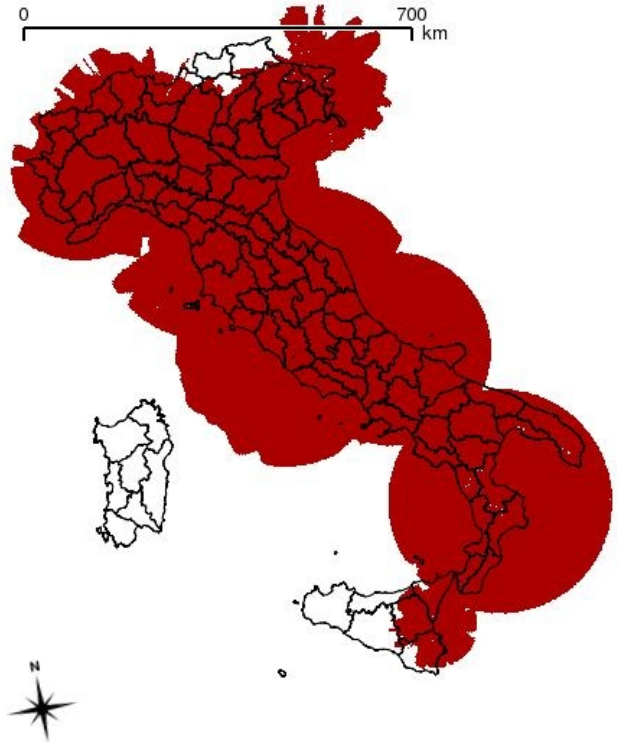
- Unevenly distributed through the Italian territory with the exception of the Puglia and Sicily regions
- The data delivered within the COSMO Project are used together with those observed by the rain gauges belonging to the different Regional Centres and made available through the Italian Civil Protection Department



Radar

24 operative machines

- 10 are installed and managed by Regions
- 4 are owned by the Air Force
- 2 are owned by ENAV (Air Traffic Control Agency)
- 8 are installed by Civil Protection Departement (6 emitting in C band, 2 in X band)



Case analysis

Reason for the choice

- Preponderance of advective precipitation (against a short convective phase at the beginning)
- The precipitation is well spread over the entire Italian territory
- Advective precipitation is better because:
  - has slow evolution and a greater spatial extent
  - the precipitation is more uniform with respect to a phenomenon of convection

Radar/Rain gauges: calculation of the difference (deviation)

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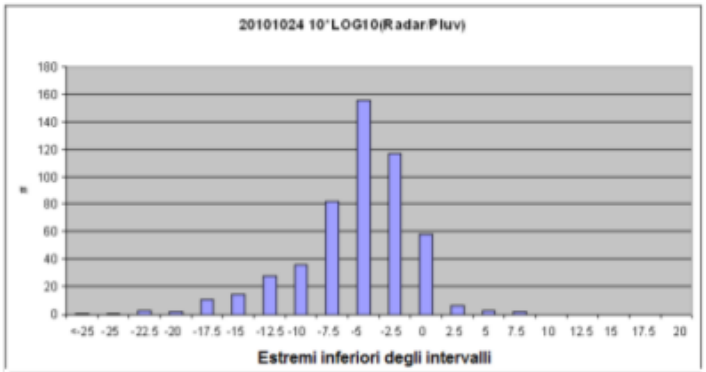
- The median value among the 9 radar grid points is coupled with the rain gauge one
- The difference (or deviation) between the two data is calculated as follows:

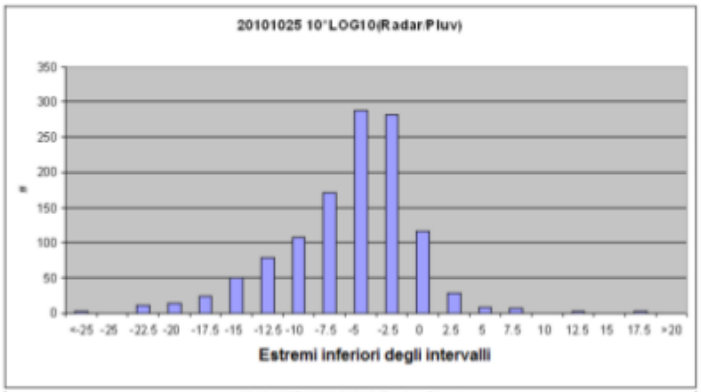
$$Difference = 10 * \log_{10}\left(\frac{r}{rg}\right) \quad (1)$$

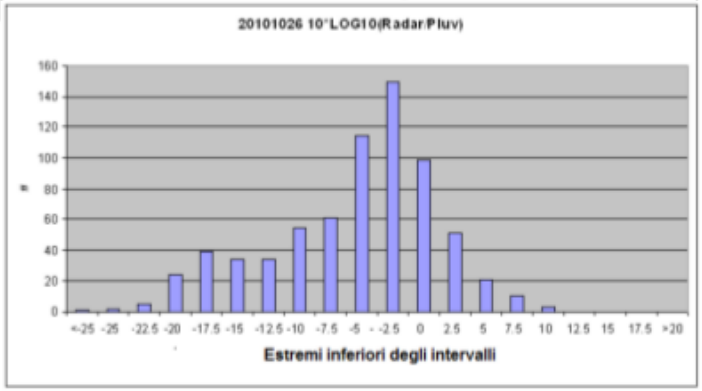
r: precipitation estimated by the radar
rg: rain gauge measurement

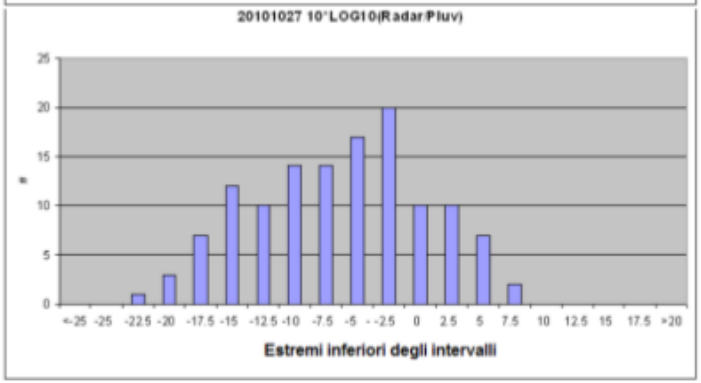
Radar/Rain gauges: calculation of the difference (deviation)

The overall mean difference between the rain gauge measurements and the radar data falls between -5 and -2.5 dB









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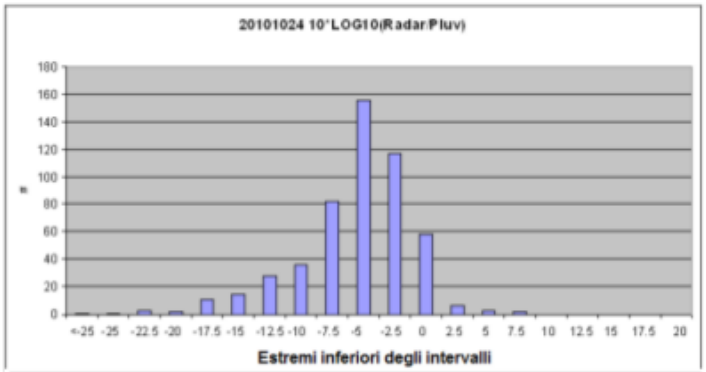
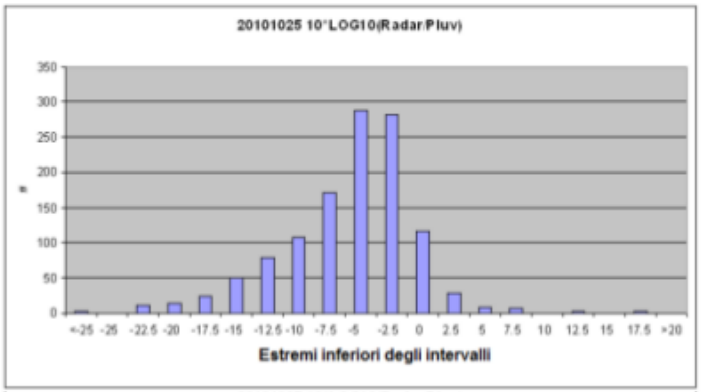
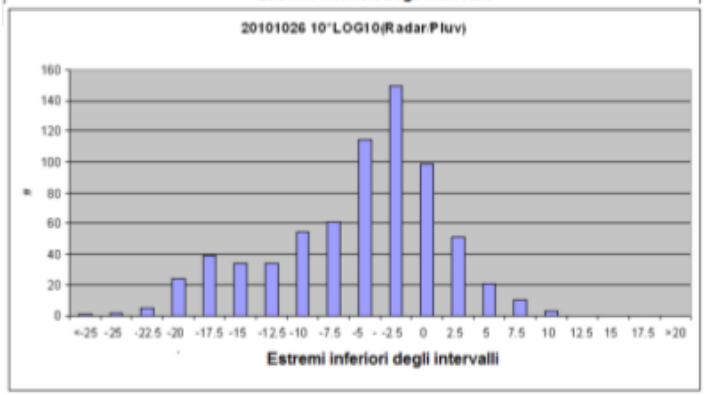
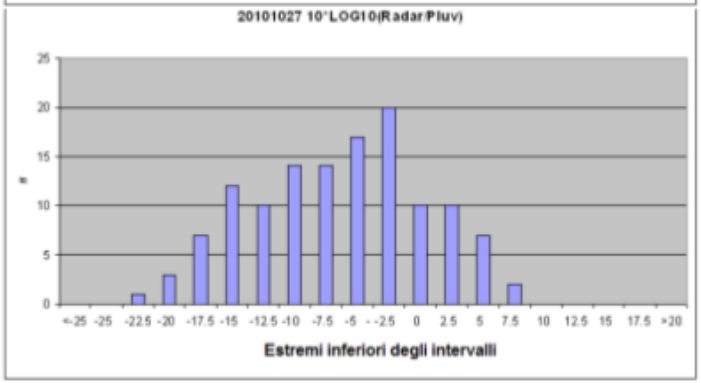




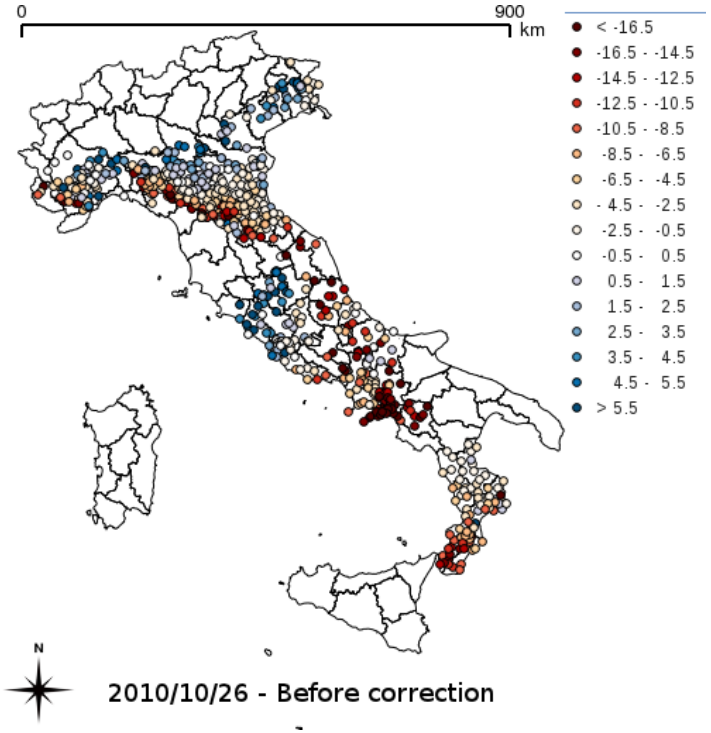




Hypothesis: the radar seems to underestimate the precipitation

Calculation of the difference: spacial distribution

- Differences due to the intensity of the precipitation
  - The radar seem to underestimate strong precipitation and overestimate weak precipitation
- Differences due to the orography
  - The radar seem to underestimate the precipitation close to the mountains



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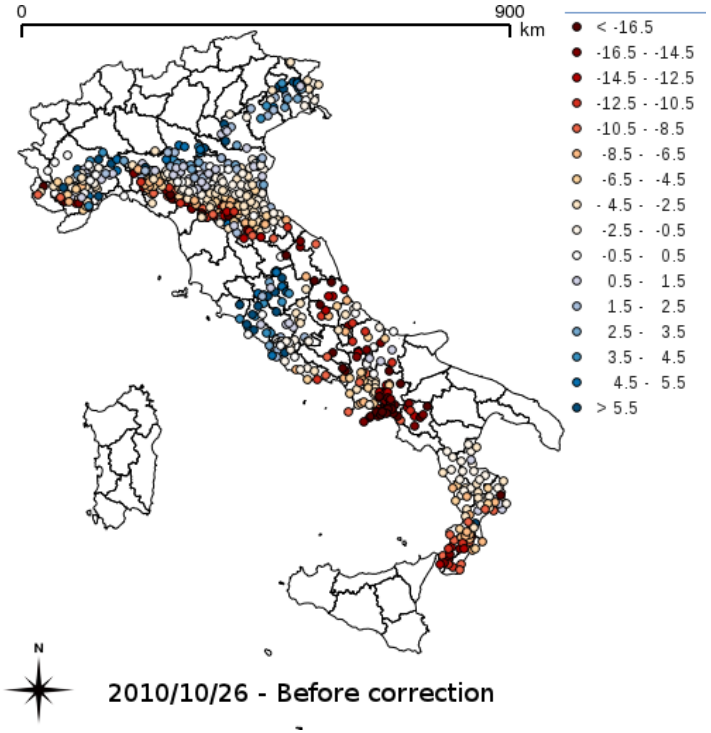

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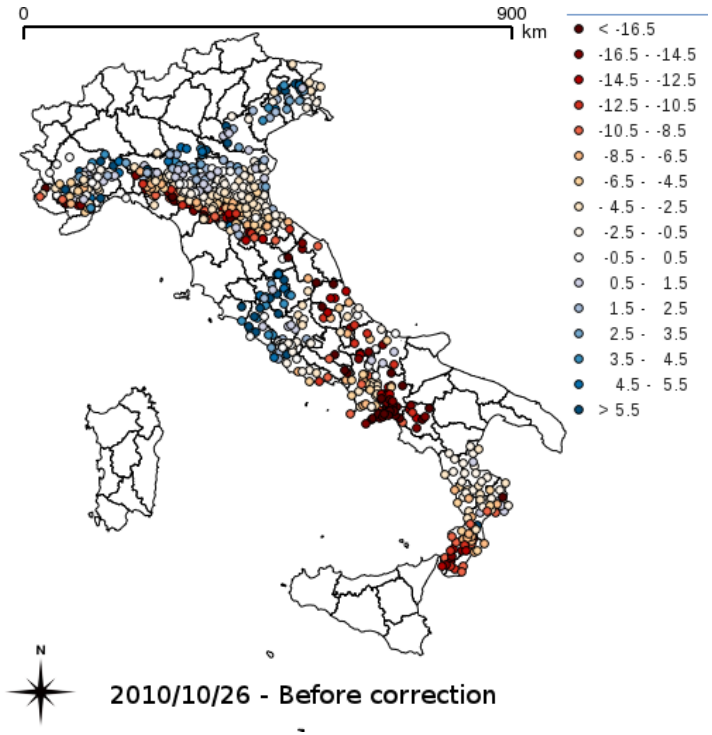


There might be a correlation between the amount of precipitation and the measurement technique

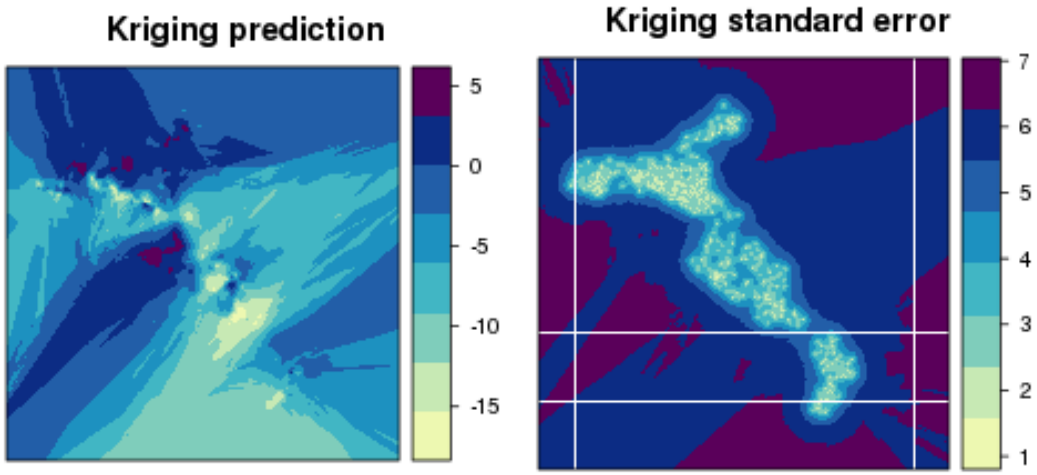
So

It seems legitimate to use the rain gauges data to correct the rarad estimation

Ordinary Kriging

2010/10/26 - Example

- The difference (expressed in dB) between the pluviometric radar data and the rain gauge measurements is then used to correct the radar itself
- The ordinary kriging is used for this operation
  - Left: kriging prediction for the difference between the radar and the rain gauges network
  - Right: the associated kriging standard error



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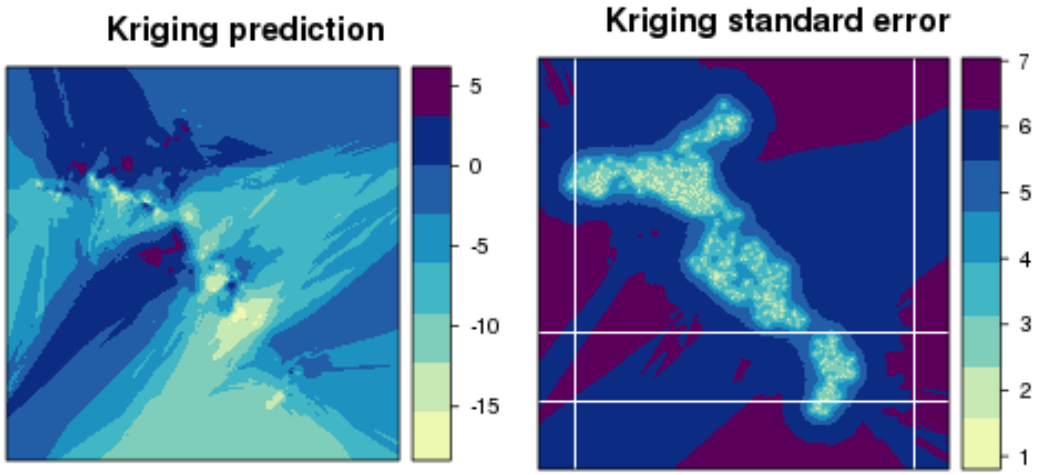

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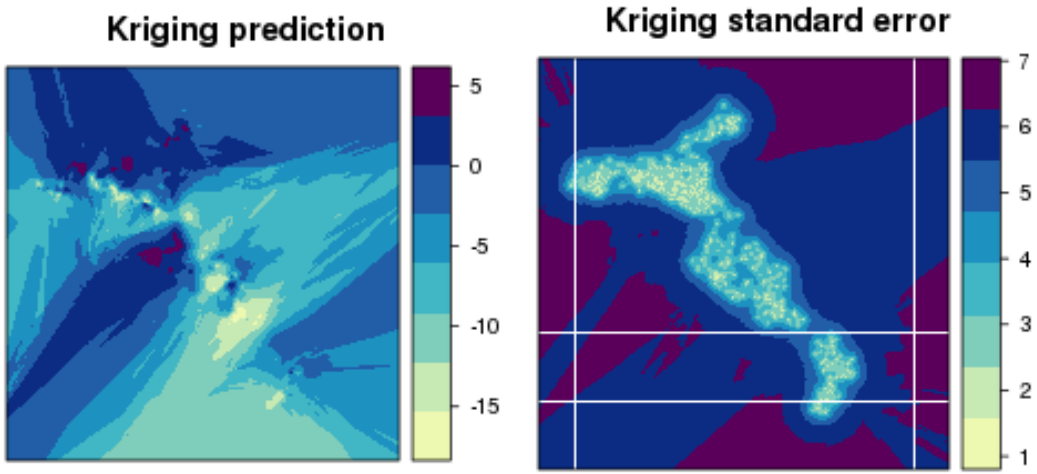
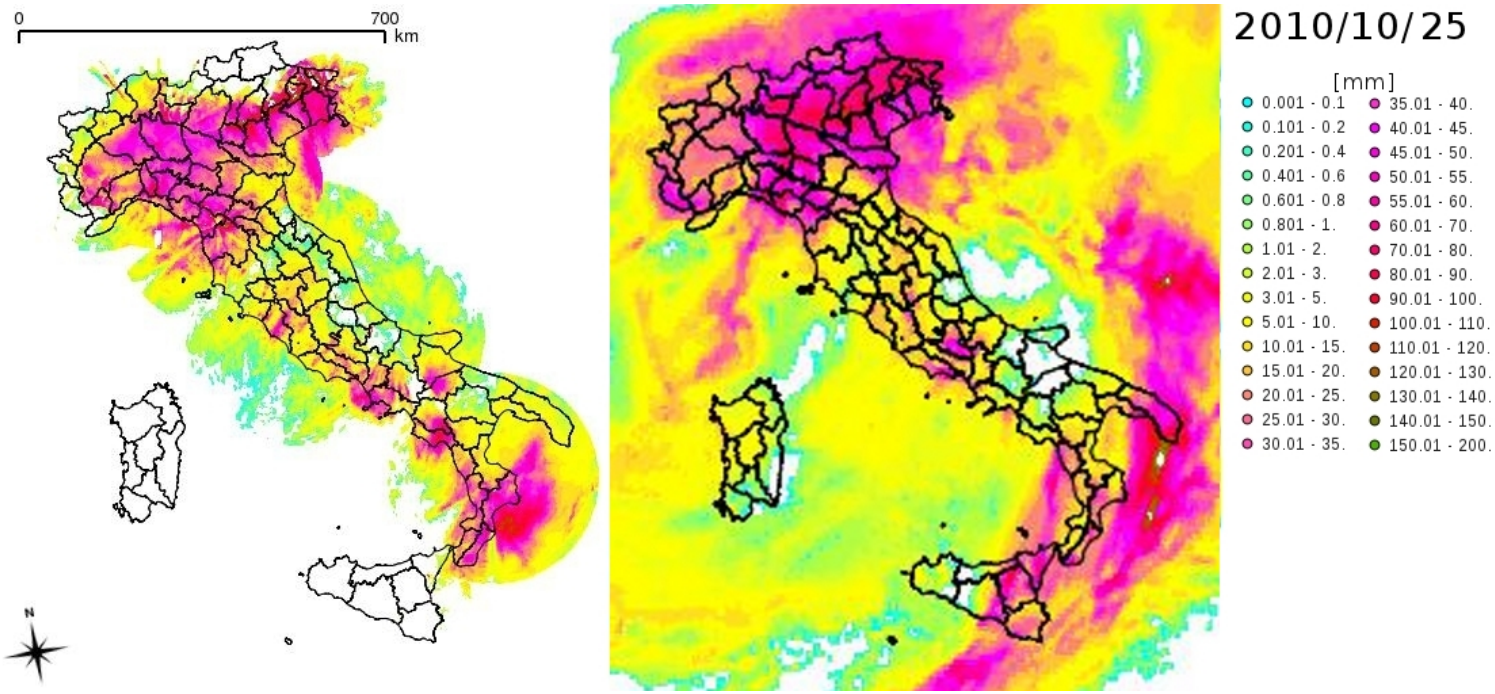


- The standard error is small where the rain gauge network is thicker
- The standard error gets bigger where there are fewer of them (beyond Italy borders, over the sea, in Puglia and Sicily regions)

Preliminary analysis (eyeball)

The first step in the verification is an eyeball comparison between the modified radar field and the COSMO-I7 forecast (October the 25^{th})



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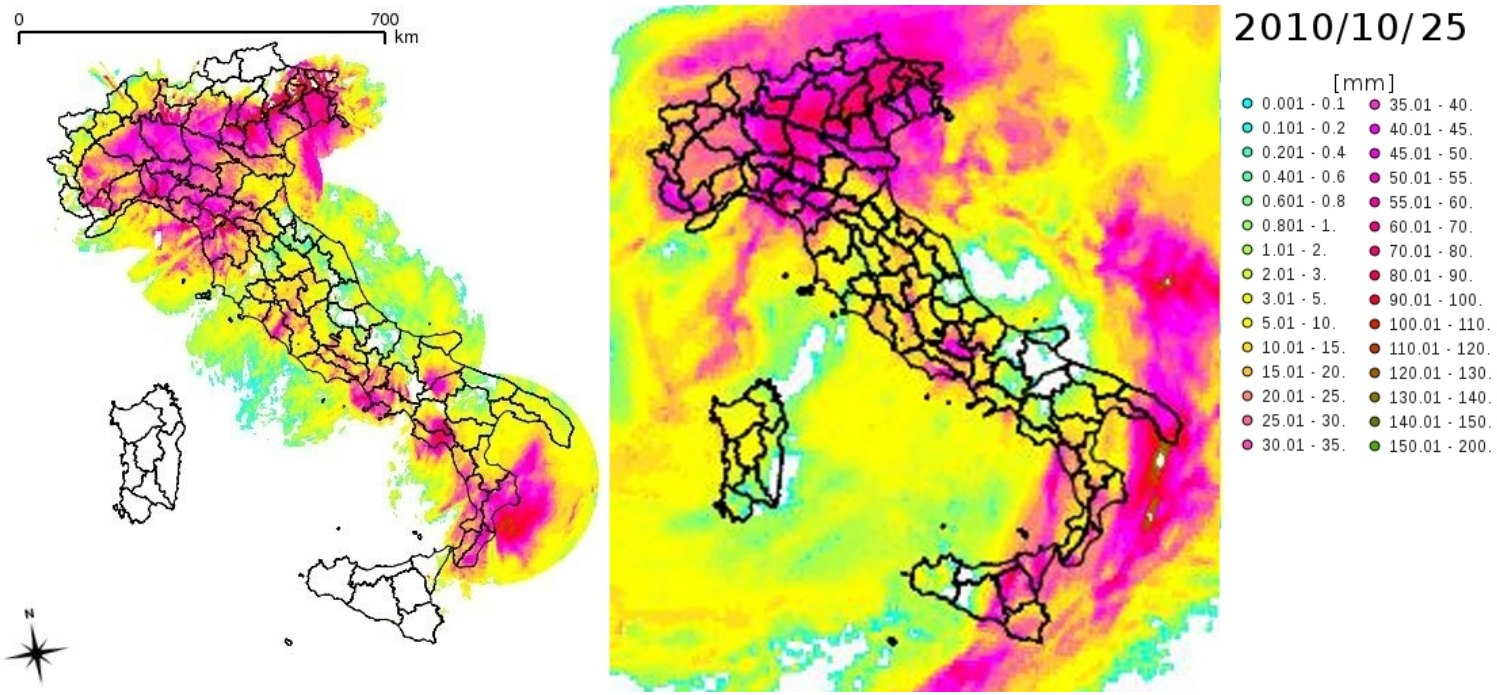

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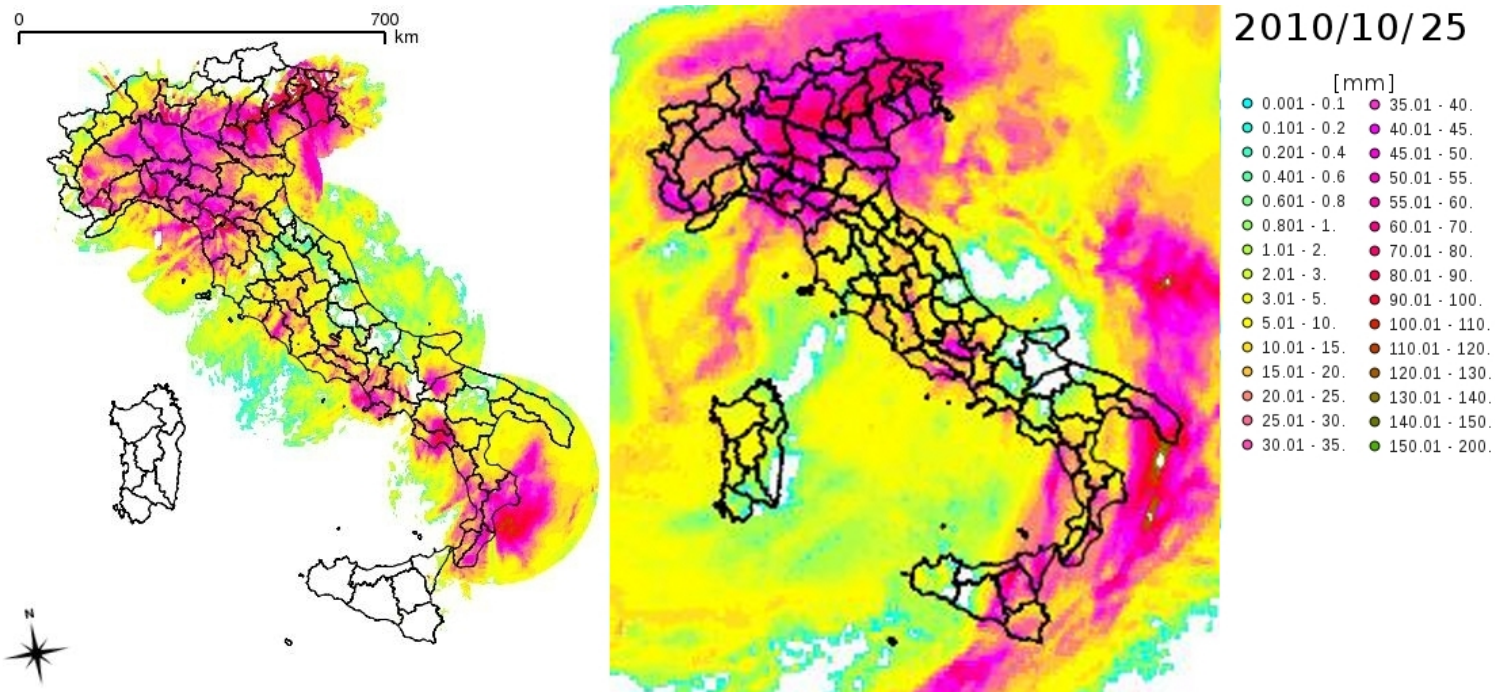

- It is possible to notice a good agreement between the two fields
- The agreement is good for what concerns the dislocation of the precipitation patterns, a little worst if we look at the intensity of the precipitation

Relative error

- The relative error is calculated as follows:

$$E_{rel} = \left[\frac{F - O}{O}\right] * 100 \quad (2)$$

E_{rel}: relative error
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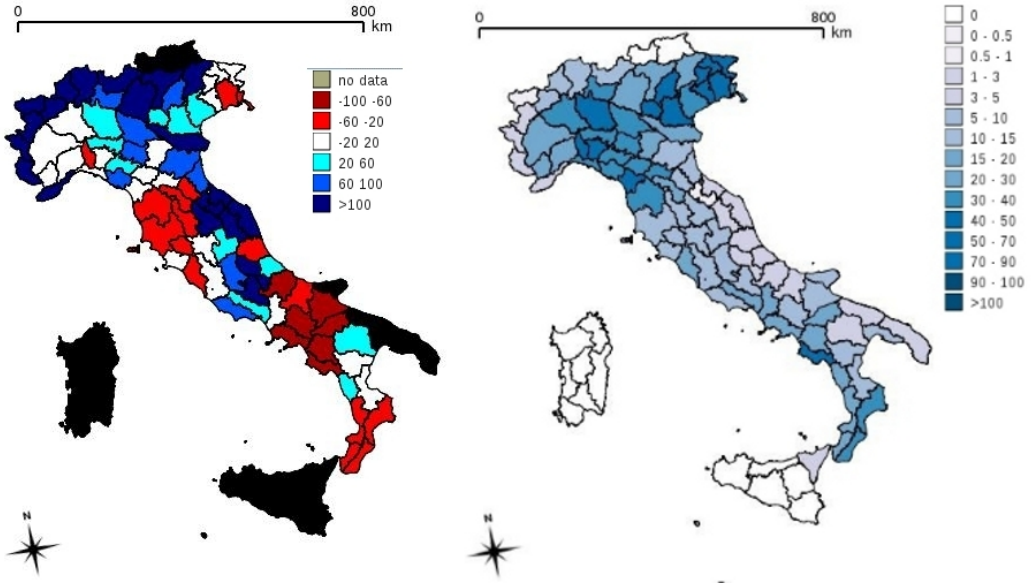
Relative error - October 25, 2010

- October the 25^{th}: the precipitation almost covers the entire Italy



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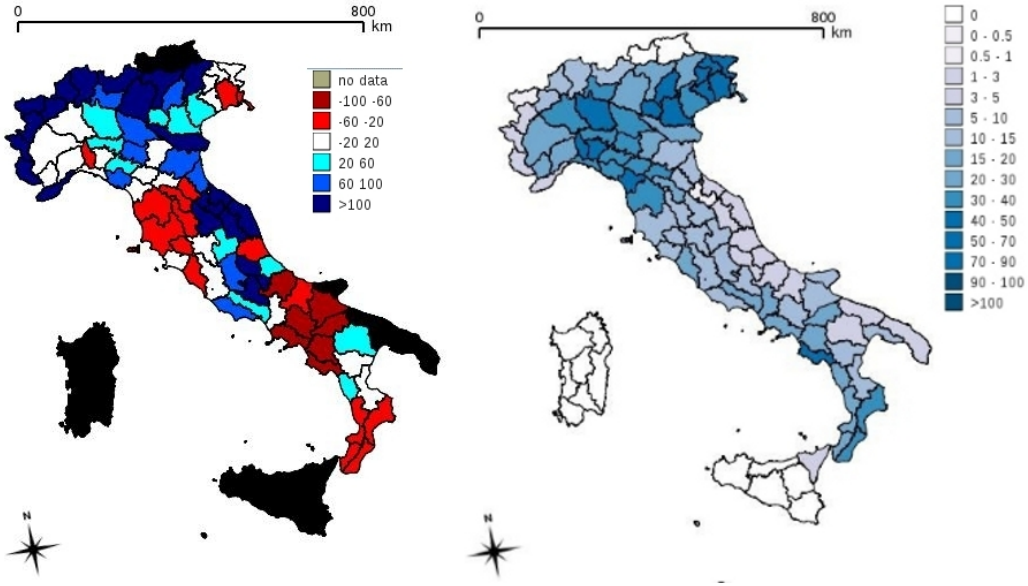

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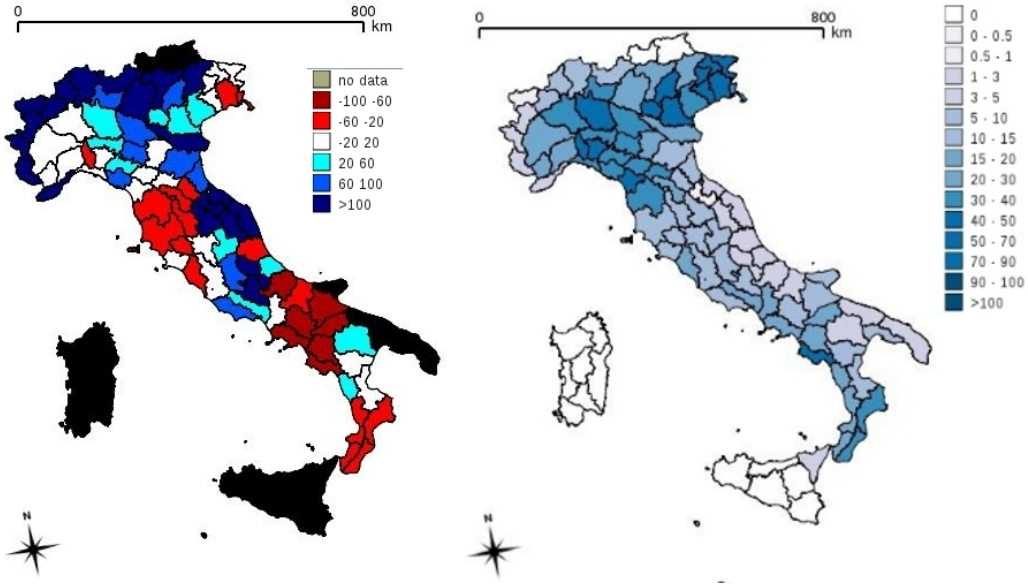

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- General overestimation of the model over northern Italy, more marked in the alpine region
- For what concerns the peninsula, the model underestimates almost everywhere, with the exception of the Marche and part of the Lazio regions

Fuzzy Verification

Witch is the link between spatial forecast and a combination of the intensity of the precipitation and the scale of the event?

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Fraction Skill Score (FSS)

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

Equitable Threat Score (ETS)

How well did the forecast "yes" events correspond to the observed "yes" events (accounting for hits due to chance)?

Method

Re-sampling of the domain

The domain is divided in boxes with a side of 10 km

- Observed: 1 km $\Rightarrow$ 10 km
- Forecast: 7.5 km $\Rightarrow$ 10 km

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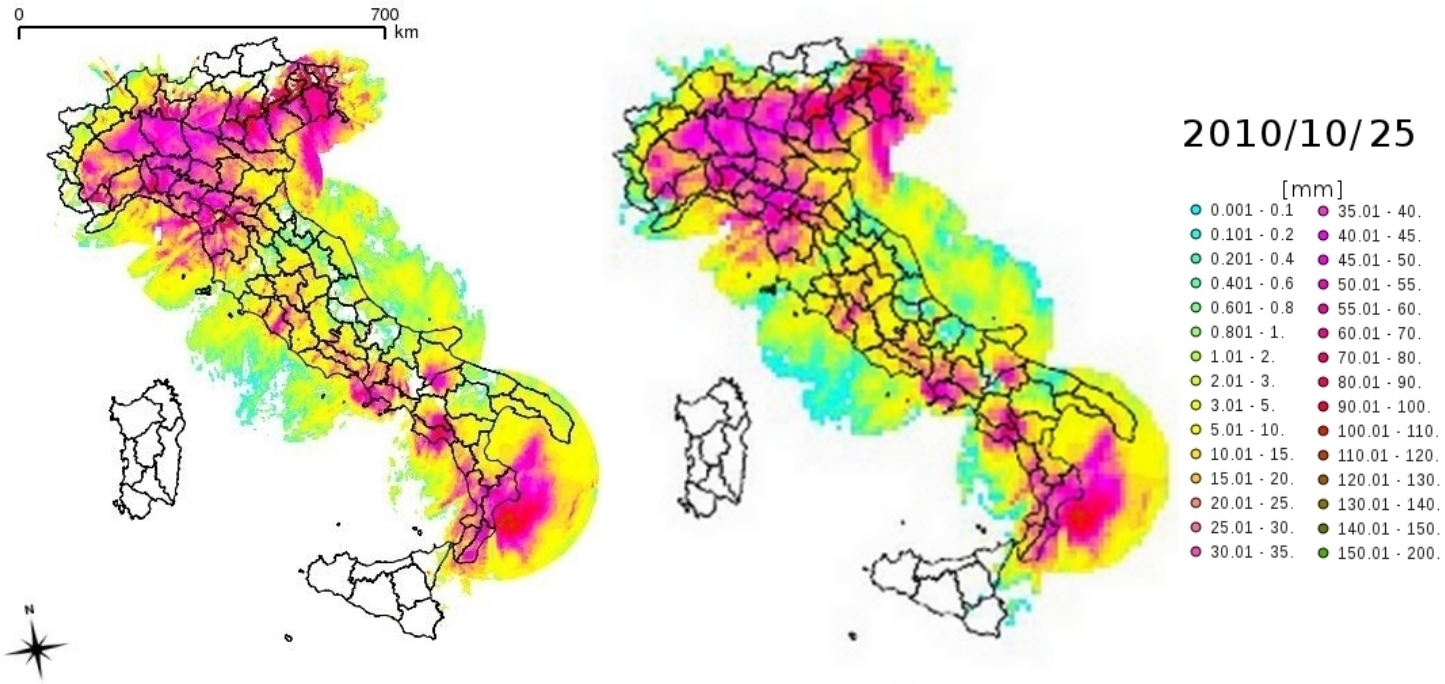
Tresholds identification and analysis boxes

- Thresholds: 0.2 mm (instrumental error), 1, 2, 5, 10, 20, 40, 50, 75 mm/24h
- Boxes: 20, 30, 40, 50, 60, 70, 80, 90 e 100 km sides

Re-sampling (observation)

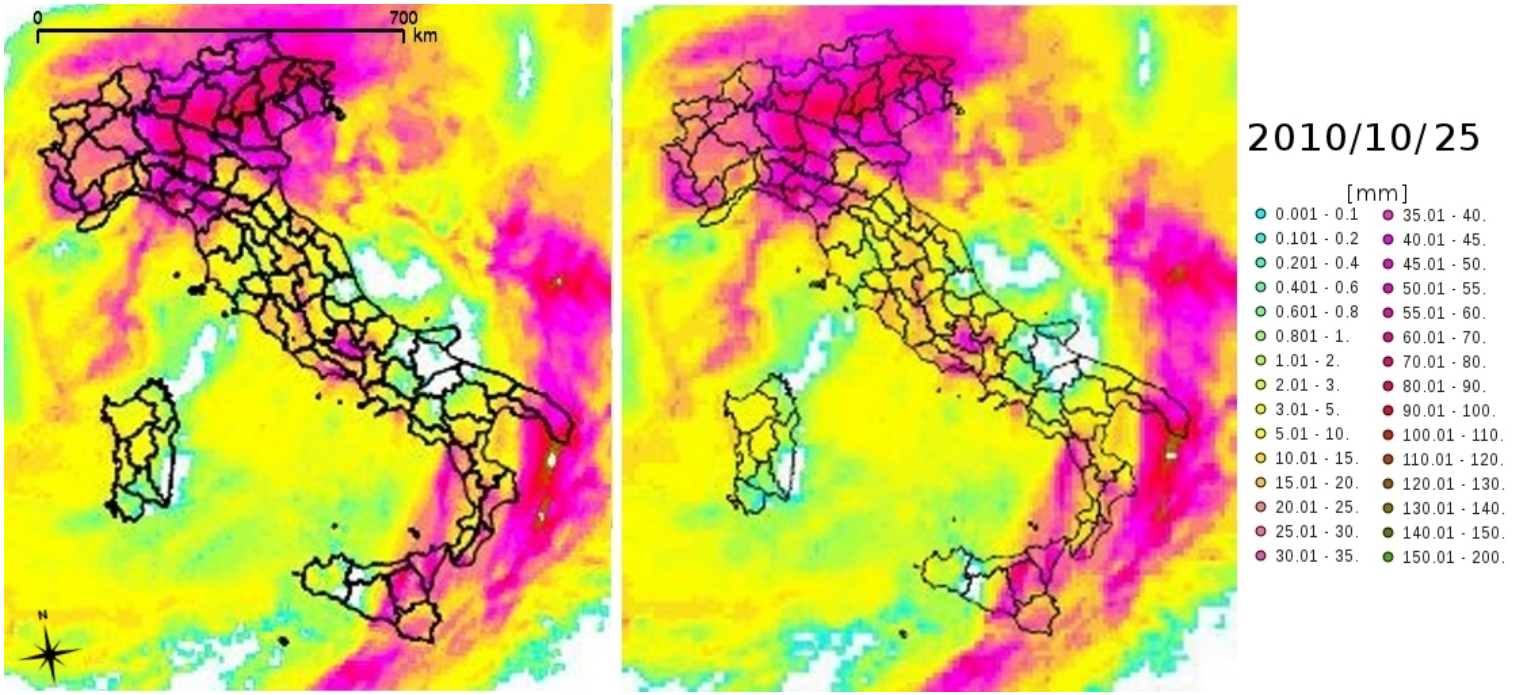
October the 25^{th}: pluviometric radar field after the rain gauge correction (mm/24h)



Left: Original resolution (1 km) **Right:** Re-sampling (10 km)

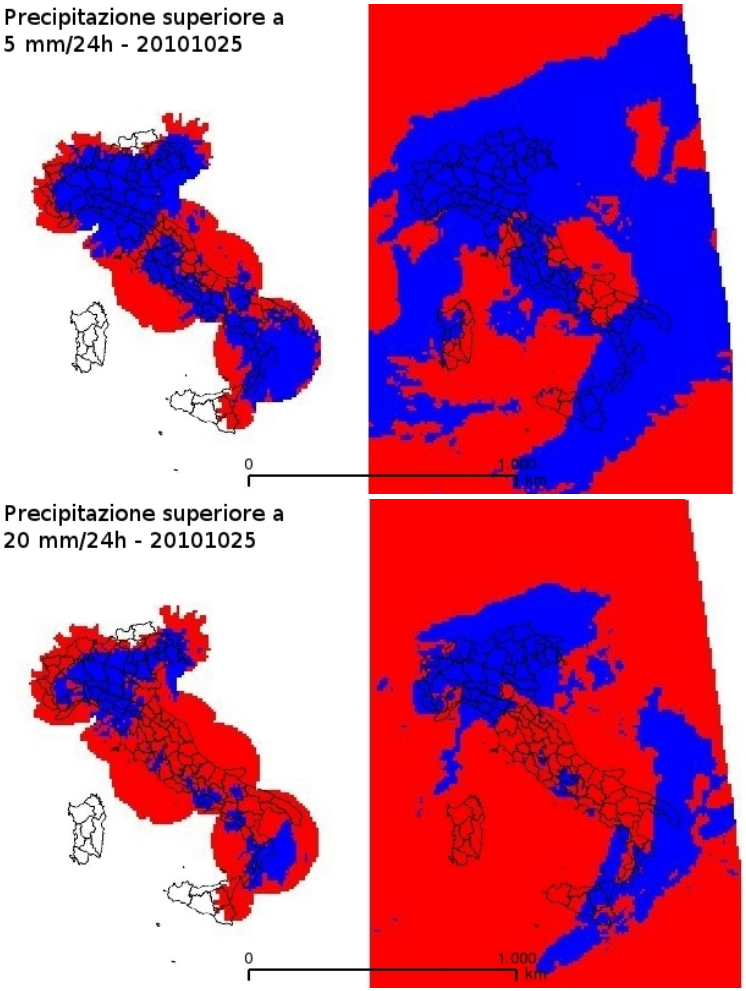
Re-sampling (forecast)

October the 25^{th}: COSMO-I7 forecast cumulated (24h) precipitation



Left: Original resolution (7.5 km) **Right:** Re-sampling (10 km)

Precipitation thresholds analysis



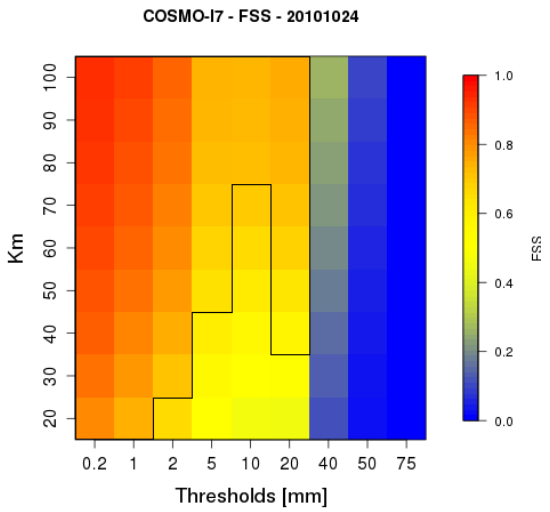
Observed (corrected radar field) (left) and forecast (right)

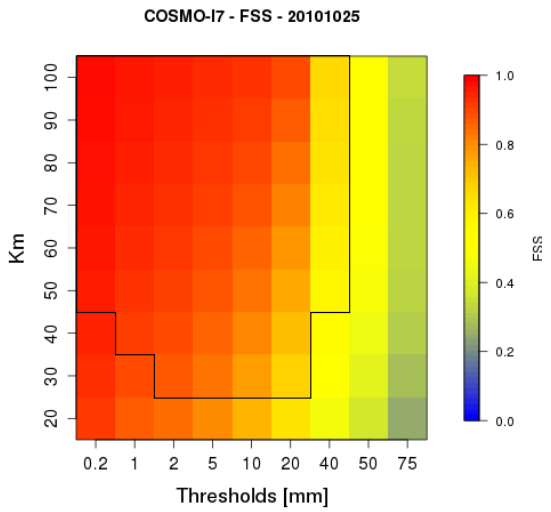
Example: 5mm and 20mm

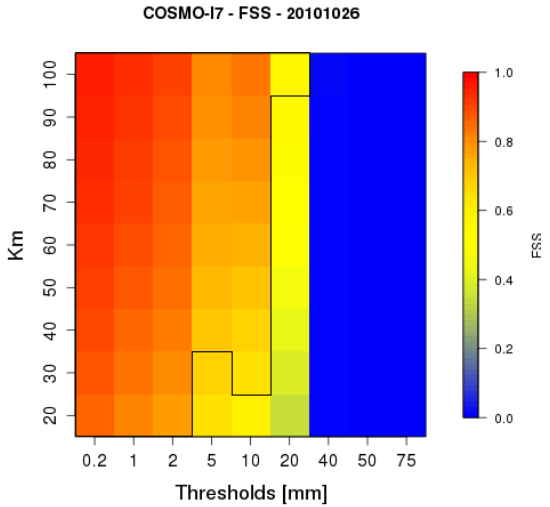
The precipitation exceeding determined thresholds is elaborated after the re-sampling operation

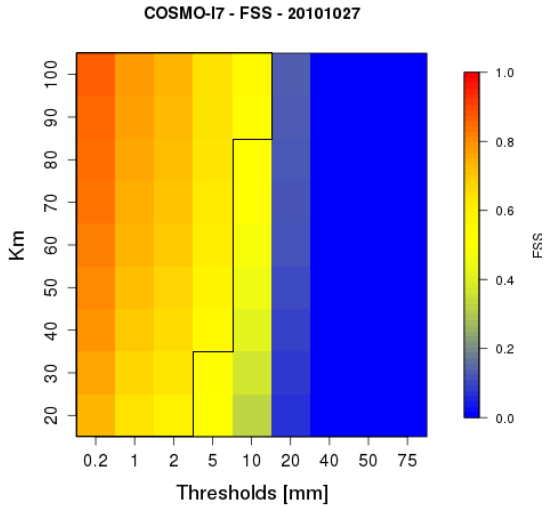
- White: no data
- Red: precipitation not exceeding the threshold
- Blue: precipitation exceeding the threshold

FSS calculation









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- Y: box side [km]
- Z: FSS [0 - 1]

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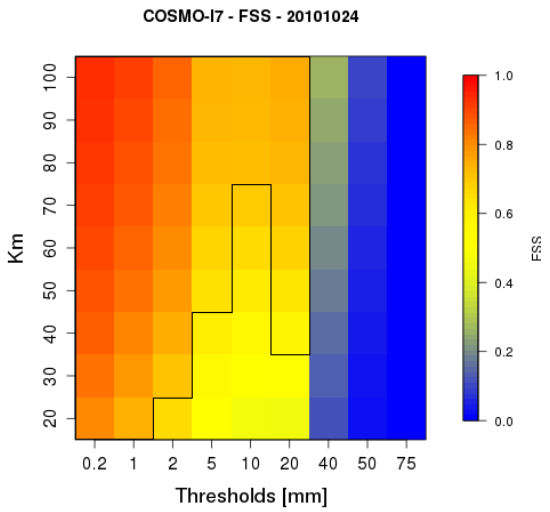

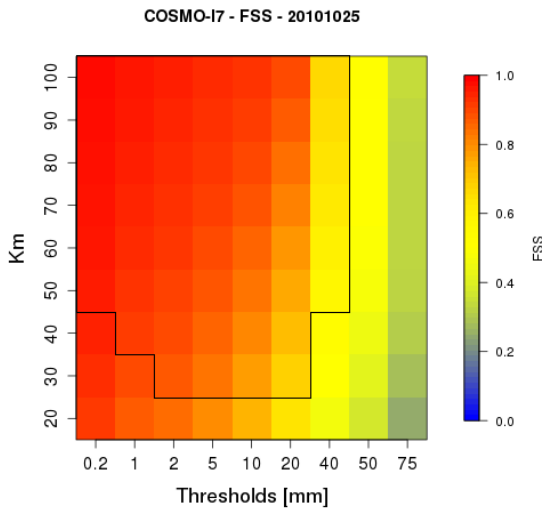

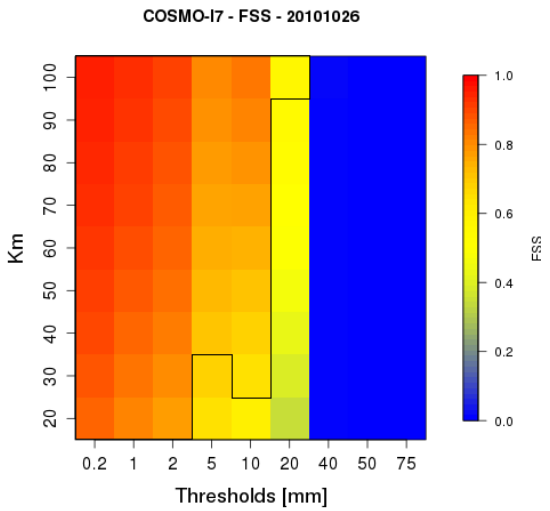

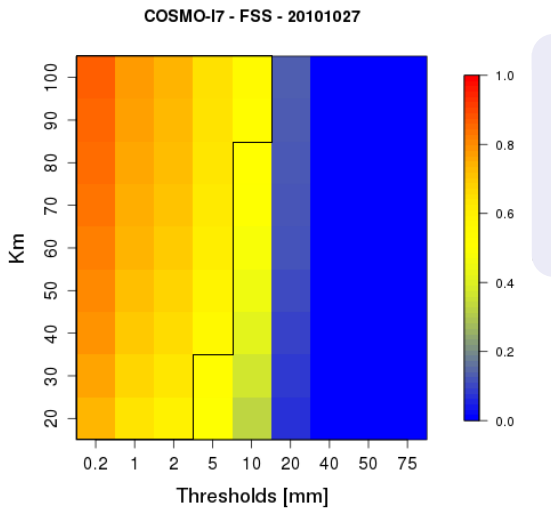

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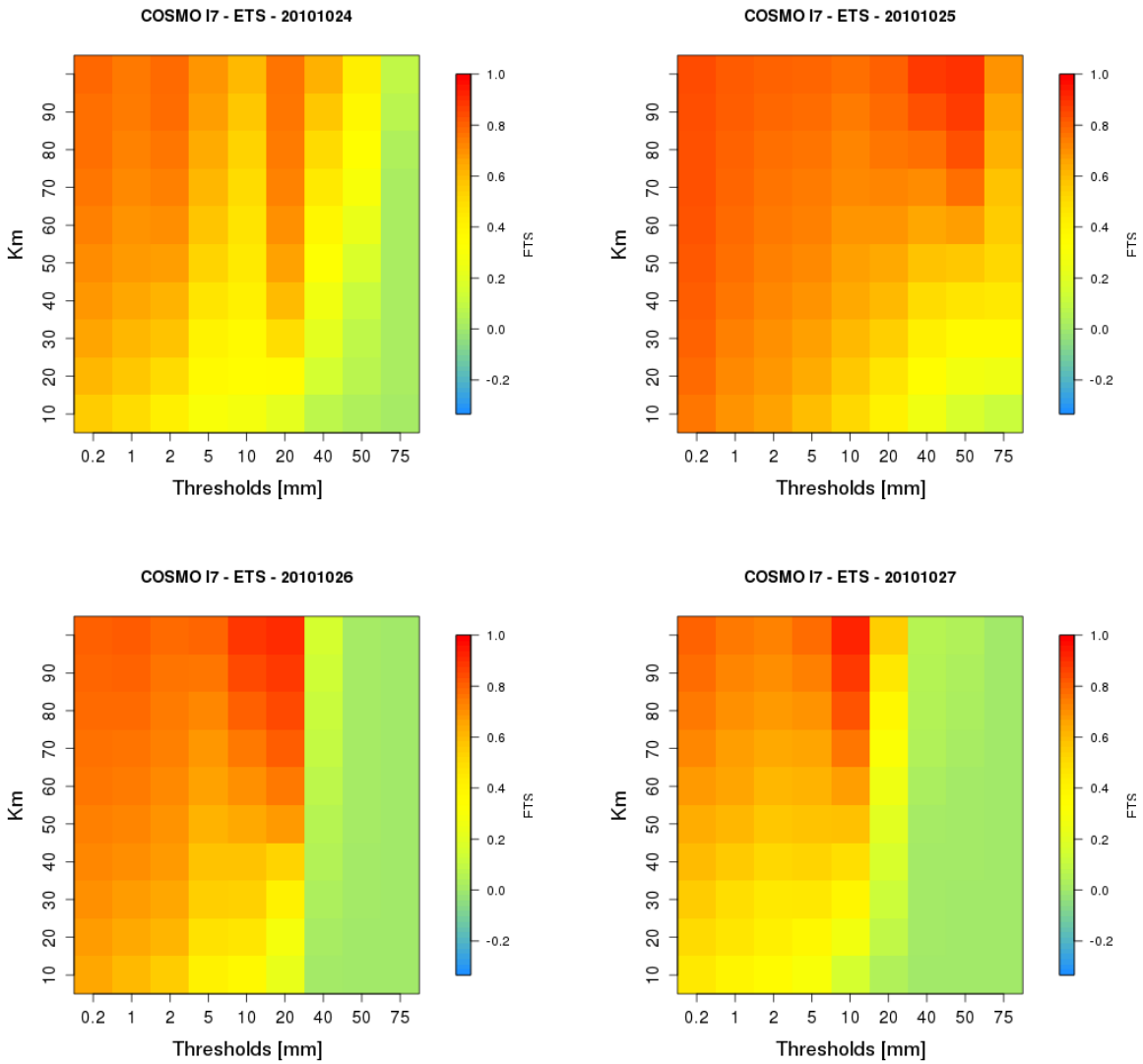
The black line surrounds the values witch are higher than the FSS_{useful}

ETS calculation



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  - The rain estimated by the radar is affected by errors coming from the characteristics of the precipitation, the orography and the geometry of the beam itself
  - the rain gauges show some problems when displaced at higher altitude and do not supply a regular field
- For the above reasons we decided to perform an ordinary kriging of the differences between the radar precipitation field and the rain gauge network measurements, and then to use the latter to correct the first

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- The evaluation of the relative error has been done by dividing the Italian territory into the 102 alert areas used by the Civil Protection Department. The mean forecast and observed precipitation has been calculated for each area (with the exception of those where the kriging standard error was too high)
- The results are concordant with those coming from a more classic verification (rain gauges only)
  - COSMO-I7 tends to overestimate the precipitation over the Alpine area and underestimates (or overestimates less) over the plains

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- The ETS also shows good skills for the middle thresholds (on large areas)

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- This kind of verification lets us know what are the conditions in witch COSMO-I7 can be trusted for different types of forecasts (from the local to the large scale ones)

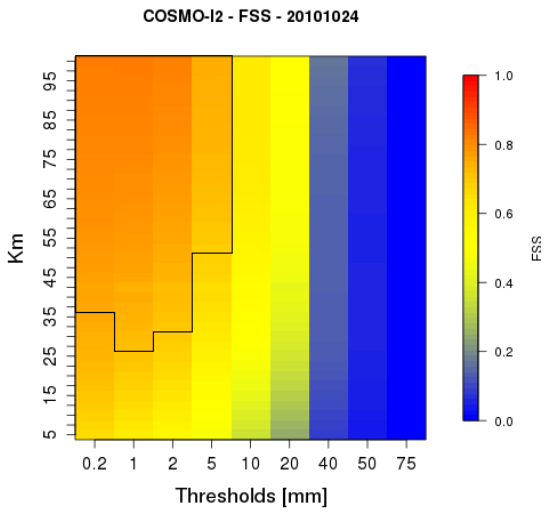
Future developments

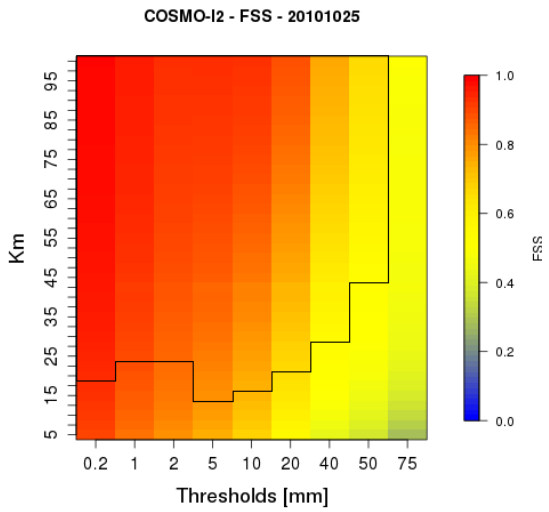
This work, although it refers to a single case study, shows some potentiality and some promising result. The idea is to extend the approach to other case studies (or longer periods) using the model COSMO-I2 which probably is more suitable for this kind of analysis due to its higher horizontal resolution

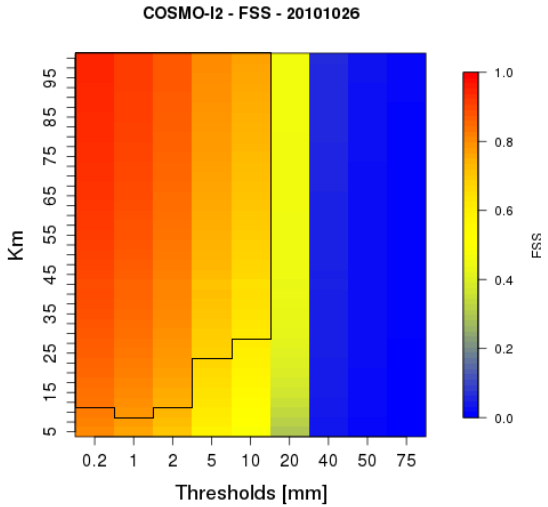
Software

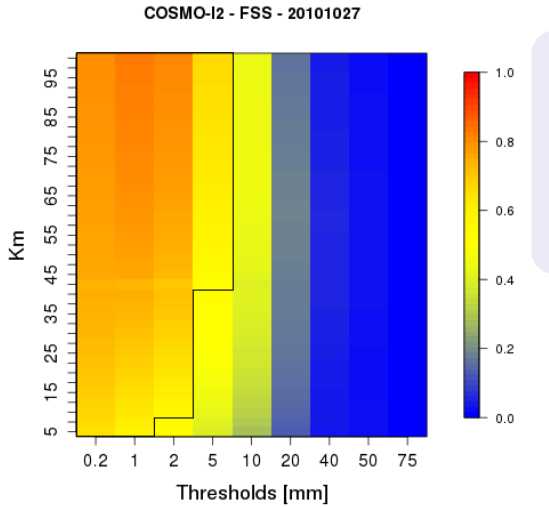
- QGIS: Map display and grid (forecast and observed) georeferencing
- GRASS: Data distribution over alert areas and cumulate precipitation calculation (relative error)
- R: Raster elaboration and fuzzy verification graphics

FSS





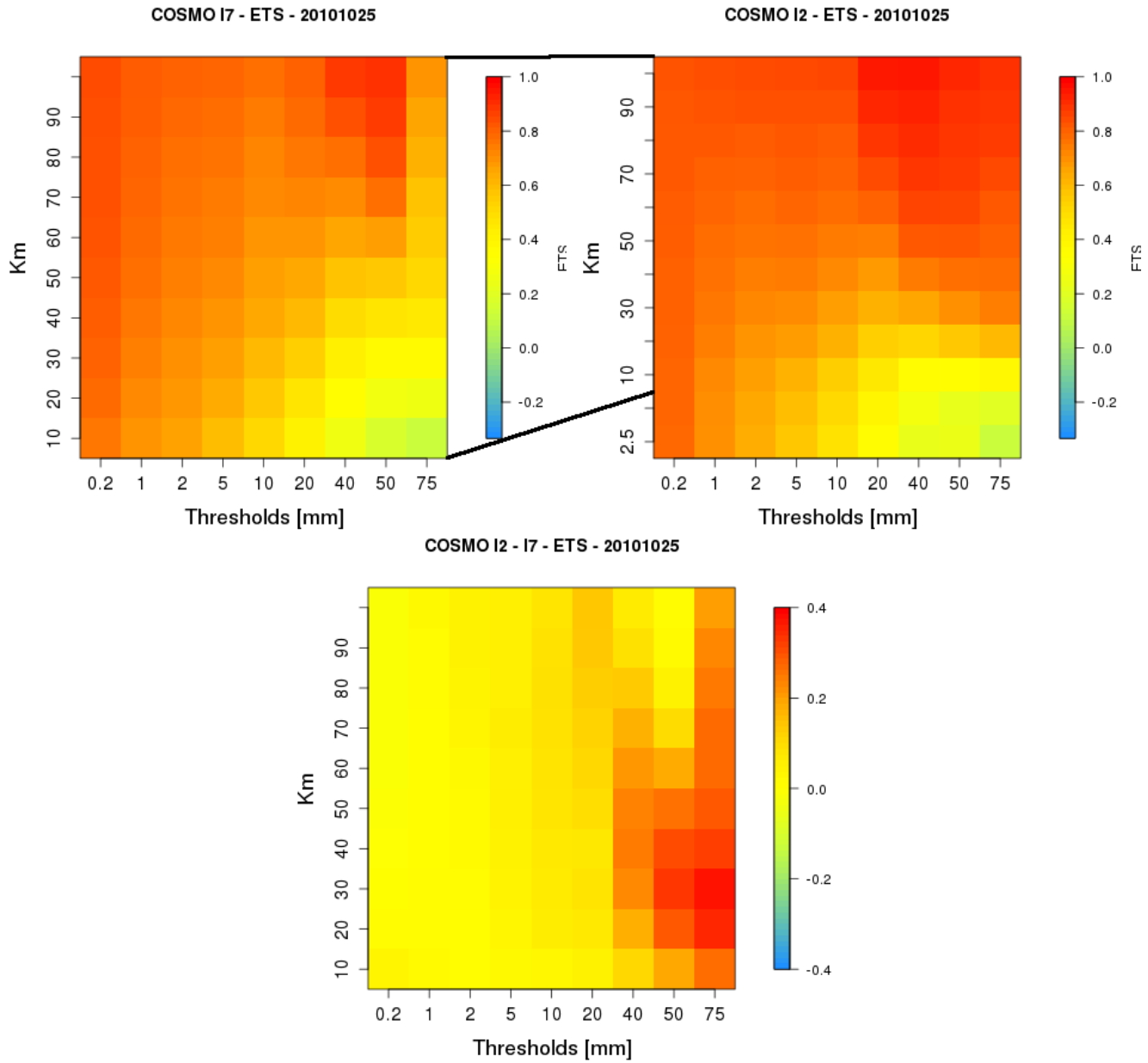




- X: thresholds [mm]
- Y: box side [km]
- Z: FSS [0 - 1]

The black line surrounds the values witch are higher than the FSS_{useful}

ETS


COSMO I7 - ETS - 20101025
COSMO I2 - ETS - 20101025
COSMO I2 - I7 - ETS - 20101025
Km
Thresholds [mm]
ETS
0.2 1 2 5 10 20 40 50 75
10 20 30 40 50 60 70 80 90
2.5 10 30 50 70 90
1.0 0.8 0.6 0.4 0.2 0.0 -0.2
0.4 0.2 0.0 -0.2 -0.4

THANK YOU FOR YOUR ATTENTION