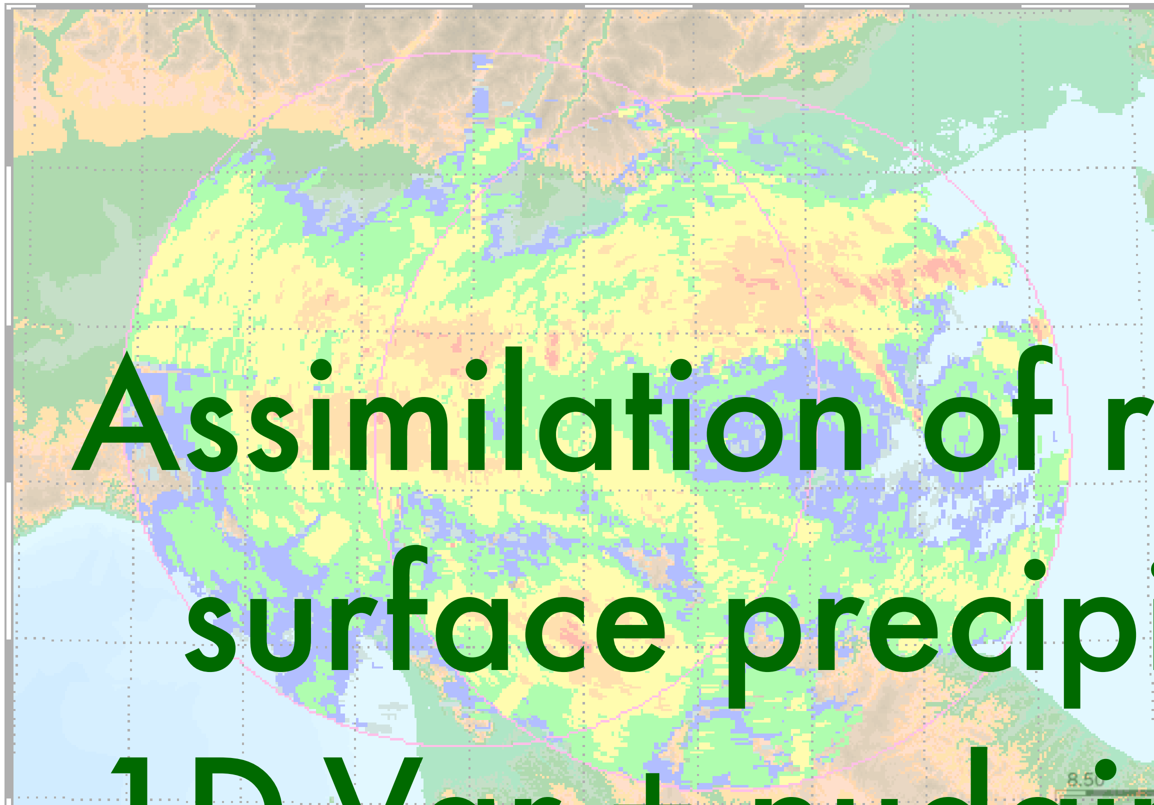
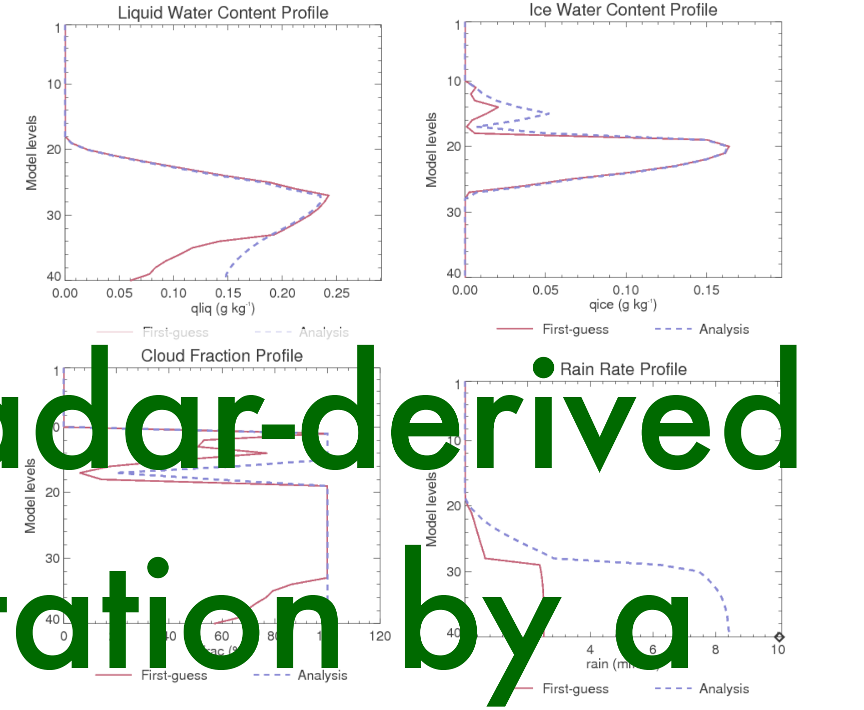
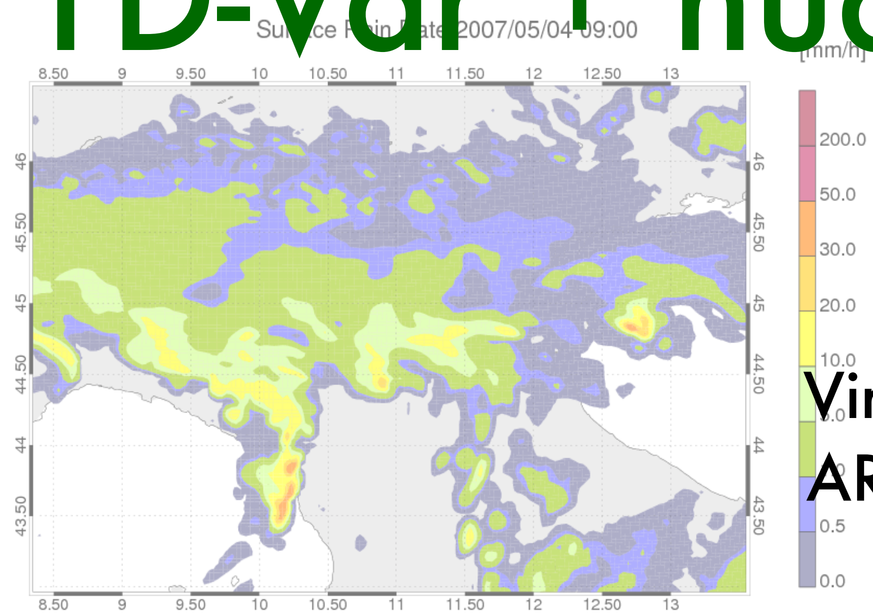
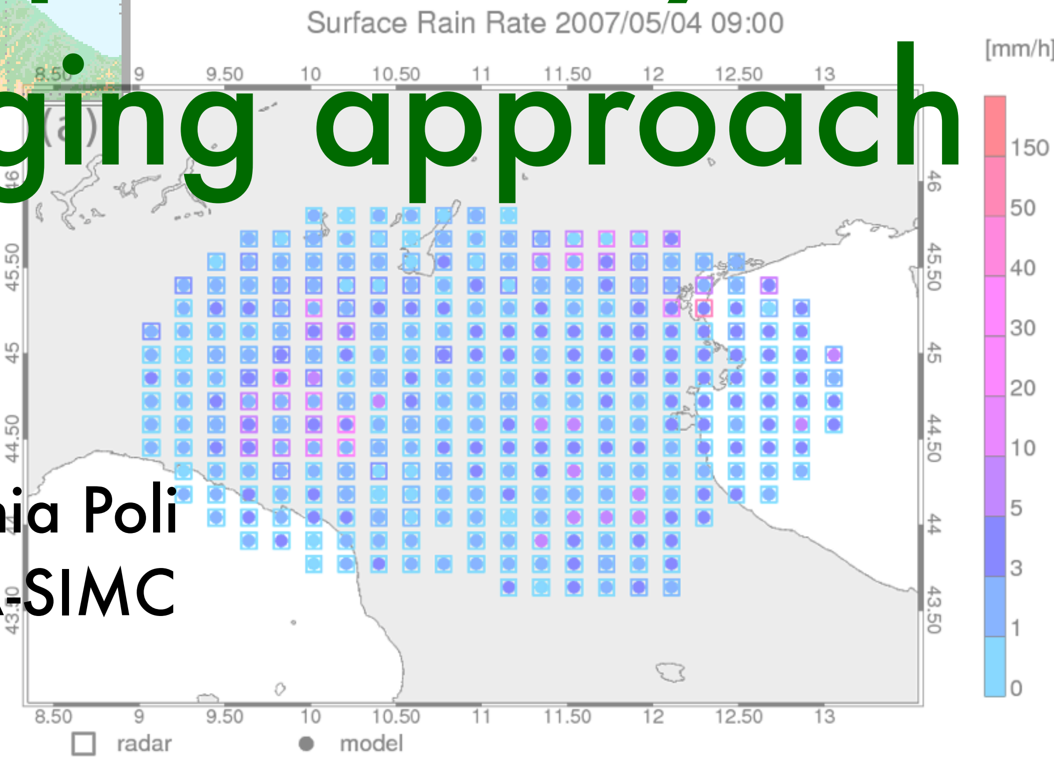
Assimilation of radar-derived surface precipitation by a 1D-Var + nudging approach





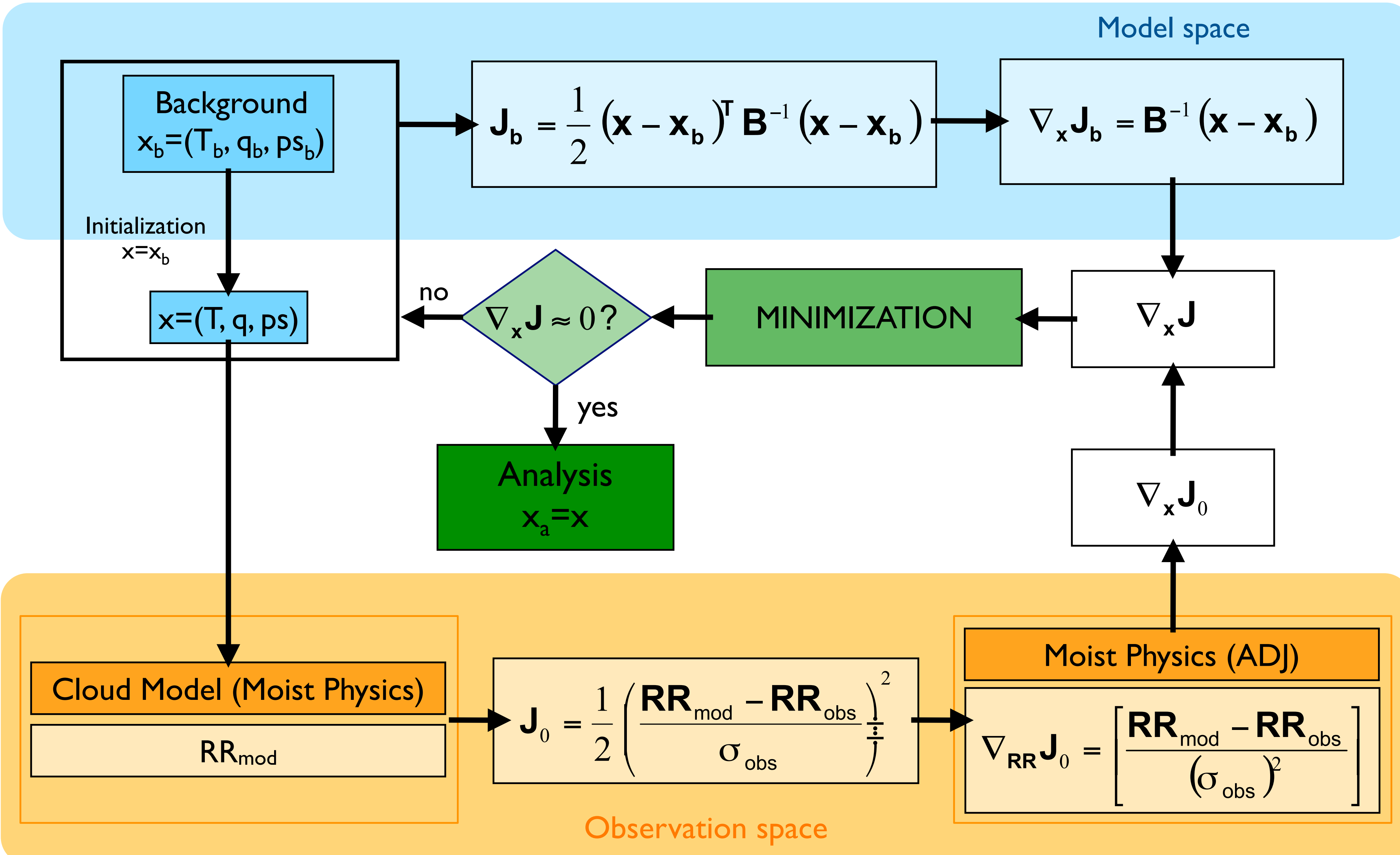




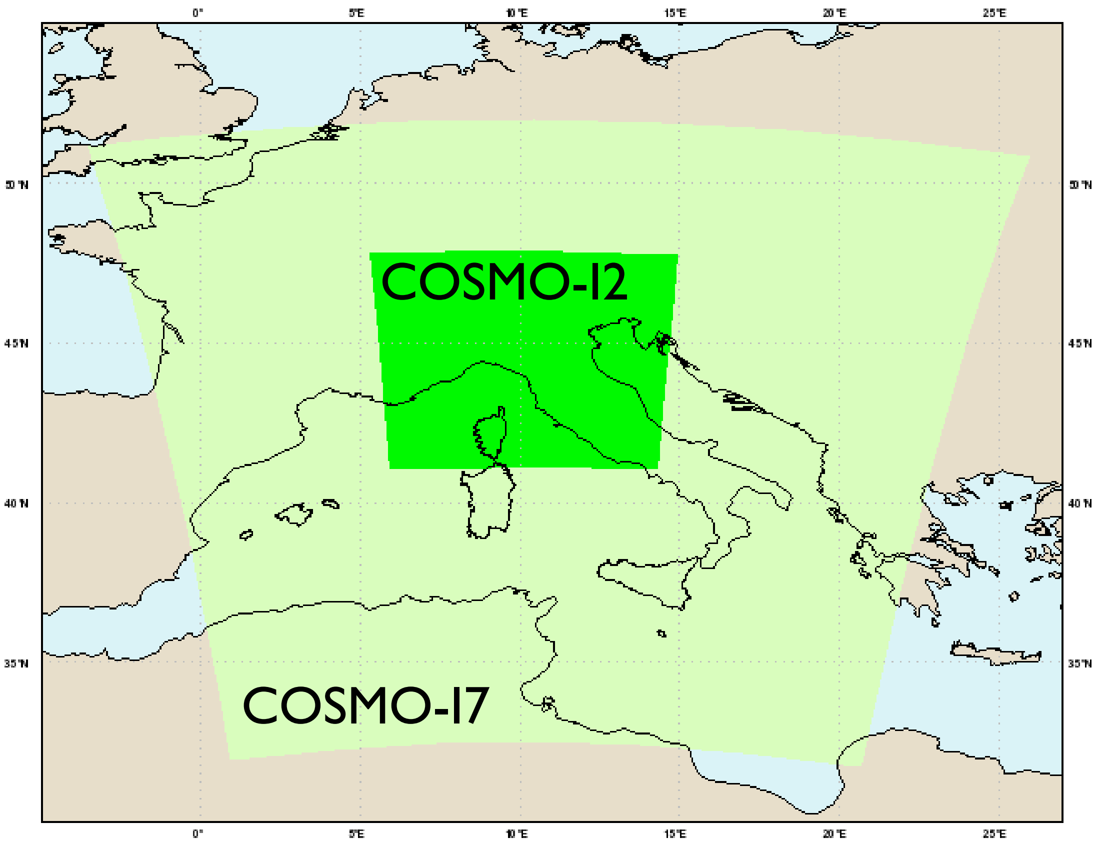
Virginia Poli
ARPA-SIMC

Variational assimilation

Convert observations (radar RR) in profiles of temperature and humidity and nudge them as “pseudo”-observations.



Numerical Model

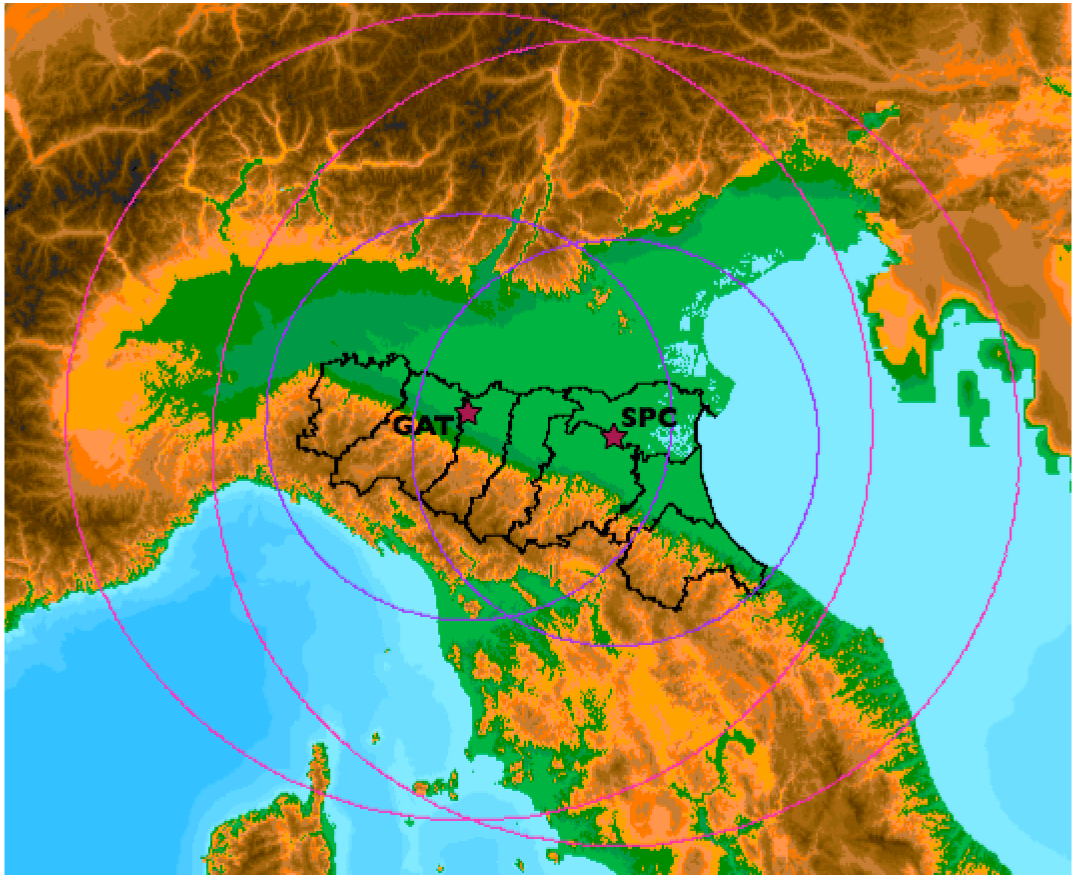


Numerical weather prediction model:

- COSMO-I2, version 4.0 (grid resolution = 2.8 km)
- nested on COSMO-I7 domain (grid resolution = 7 km)
- observations assimilation through nudging

Every 15 minutes, in the assimilation cycle, some parameters are selected (temperature profiles, humidity profiles, pressure profiles, sensible and latent heat fluxes at the surface) to be used as input in the variational algorithm.

Observations



Radar rain rates are derived from the two Emilia-Romagna polarimetric doppler C-band radars. Reflectivity measures are acquired from each radar with a repetition cycle of 15 minutes and a horizontal resolution of 1 km. Reflectivities values are then converted in instantaneous surface rain rate. The observational error has been estimated, as a first approximation, at about 30% of the measure.

The use of very high spatial and temporal data resolution should guarantee some improvements in the initial condition knowledge. Moreover, highly correlated observations can introduce not expected errors in the analysis, generating spurious structures.

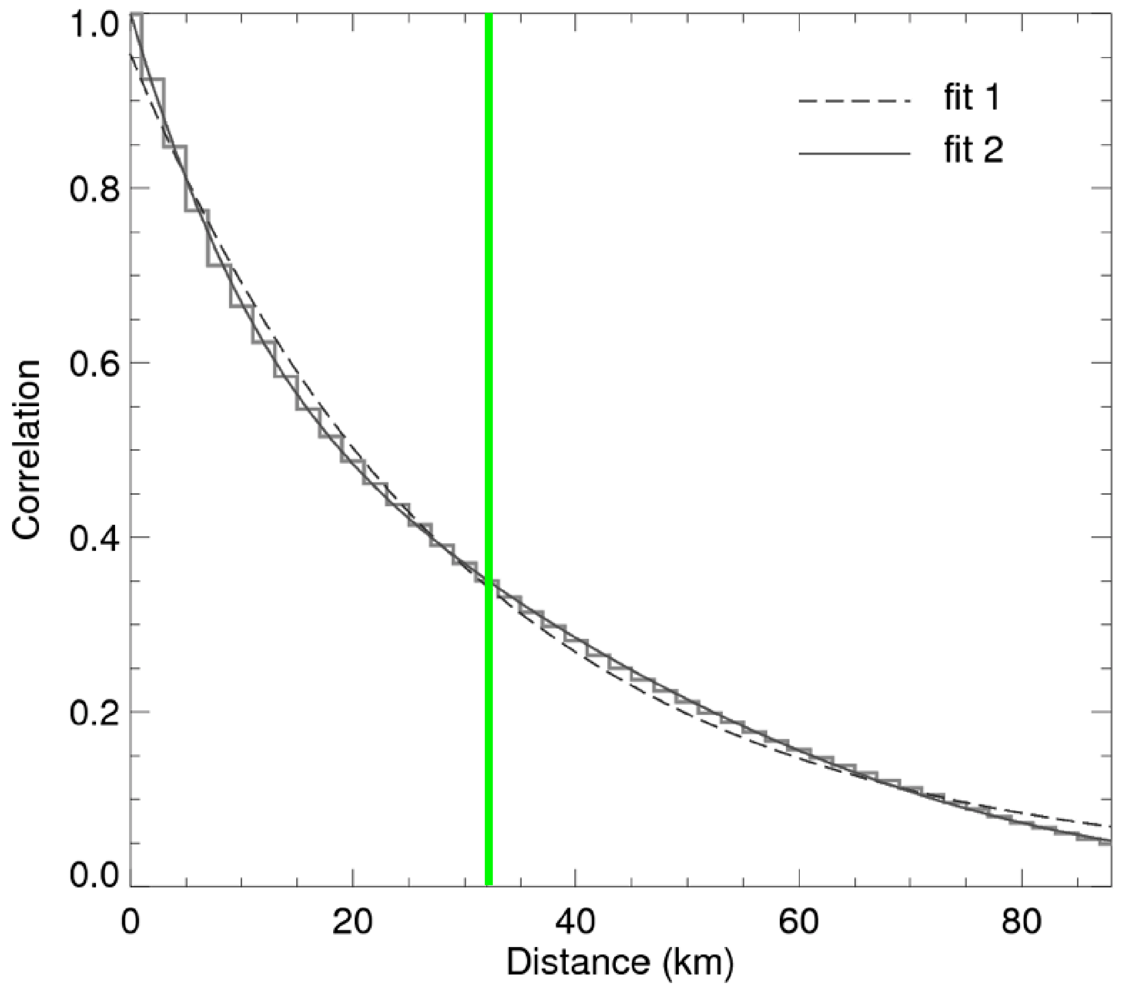
To reduce the total amount of data a thinning procedure is chosen.

Data thinning (I)

The spatial sampling is determined by the decorrelation length of the reflectivity auto-correlation field.

Using the data acquired over the whole test case period the auto-correlation histogram as a function of the distance has been generated. Smaller the distance higher the correlation between two points, being the correlation at zero distance equal to one by definition.

The trend is a monotonically decrease with no clear cut-off. The e-folding distance of 32 km could be chosen as decorrelation length as first approximation.

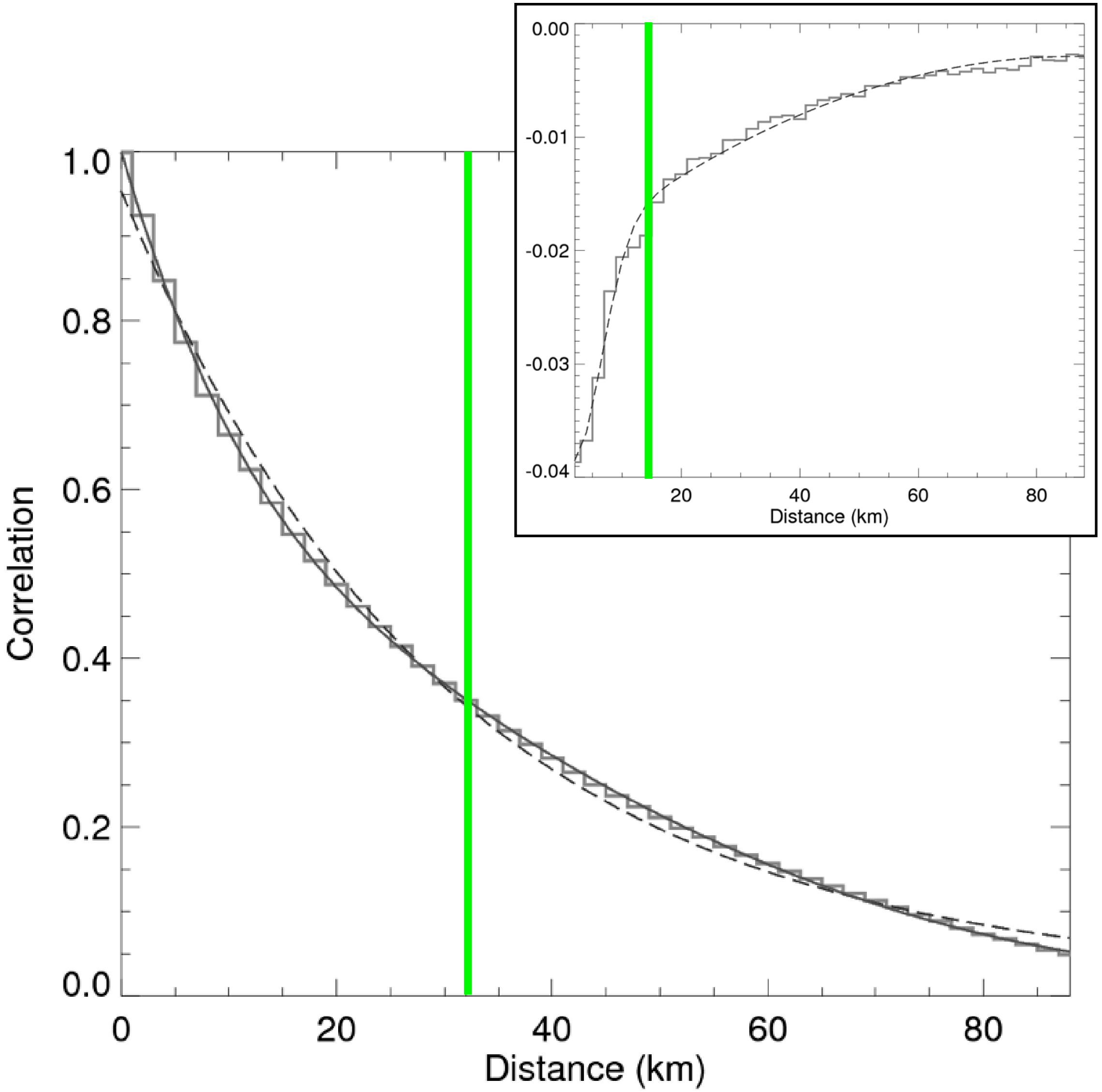


Data thinning (II)

The spatial sampling is determined by the decorrelation length of the reflectivity auto-correlation field.

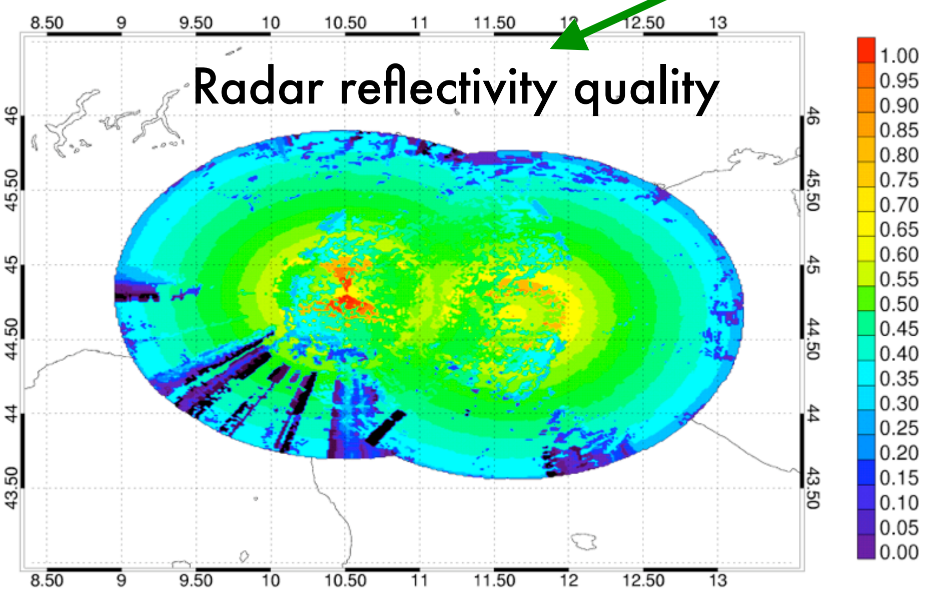
Using the data acquired over the whole test case period the auto-correlation histogram as a function of the distance has been generated. Smaller the distance higher the correlation between two points, being the correlation at zero distance equal to one by definition.

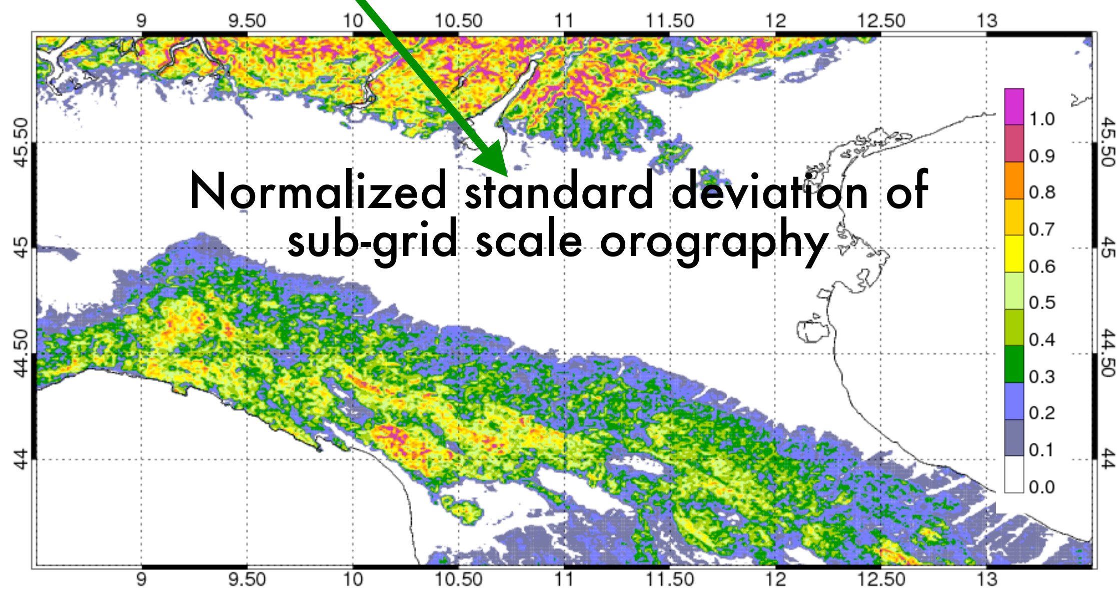
The trend is a monotonically decrease with no clear cut-off. The e-folding distance of 32 km could be chosen as decorrelation length as first approximation. The derivative of the auto-correlation reveals discontinuity at about 15 km, which is chosen as new decorrelation length.



Observational error definition

$$Err = (1\text{-}quality) + 0.2\left(\frac{\sigma}{\sigma_{\max}}\right) quality$$





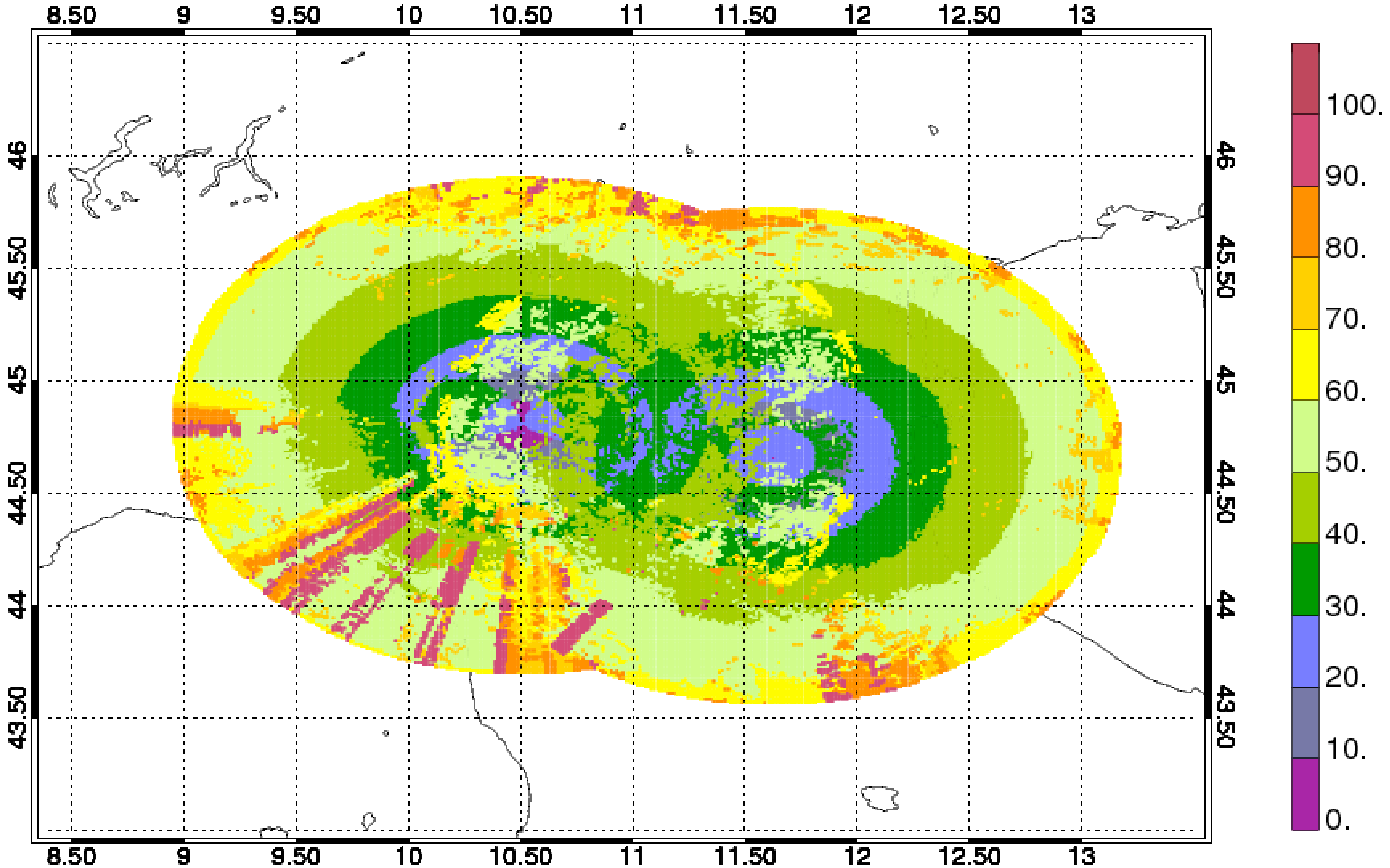
The quality is a single value that characterizes the final reliability of each radar datum (Fornasiero, 2006). It takes into account:

- Distance from radar
- Anomalous propagation
- Beam Blocking
- Path Integrated Attenuation

The dataset used to calculate the normalized sub-grid scale orography standard deviation is a NASA high resolution DEM (~90 m).

The maximum standard deviation used for normalization is chosen in the region of interest.

Error map



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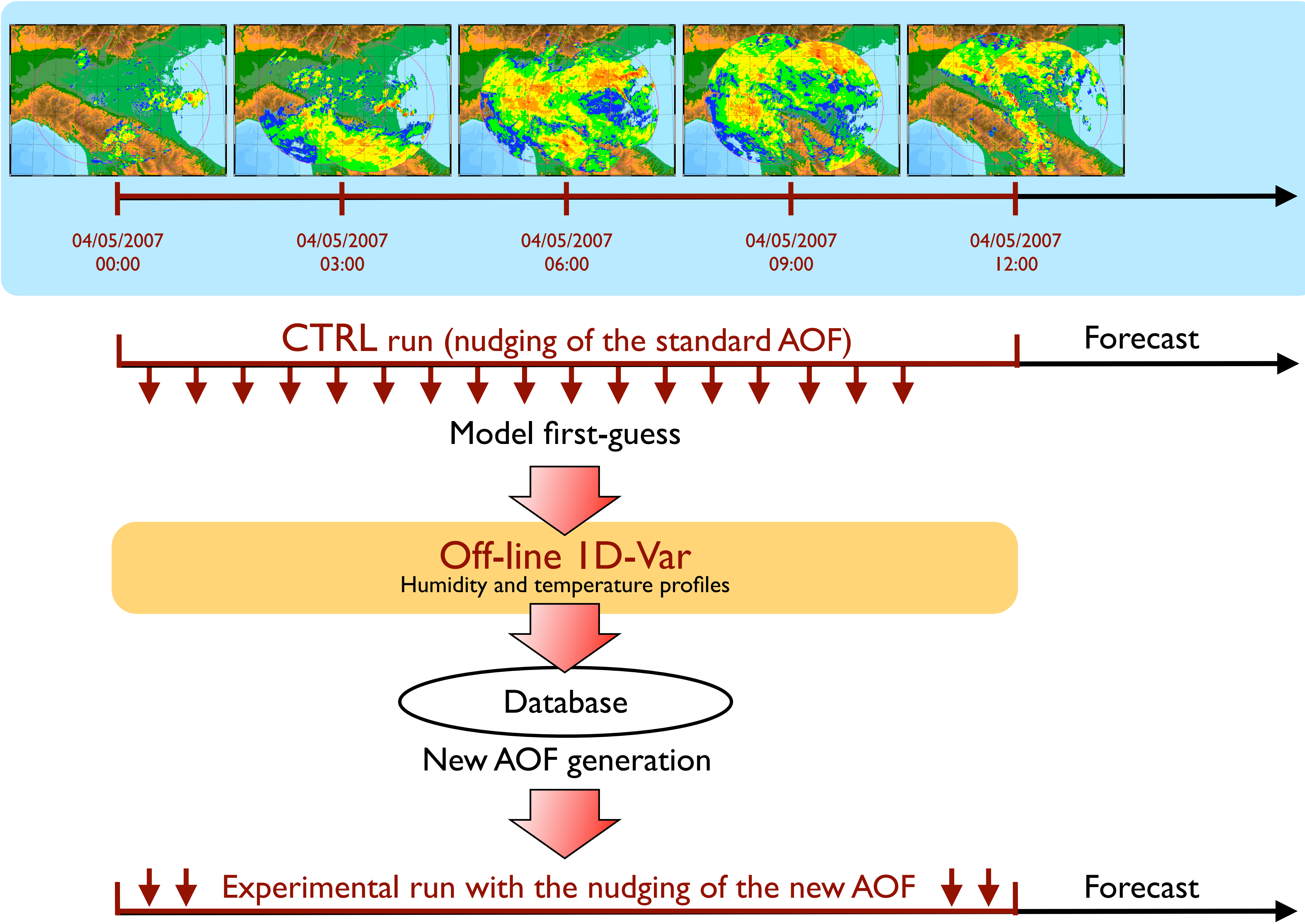
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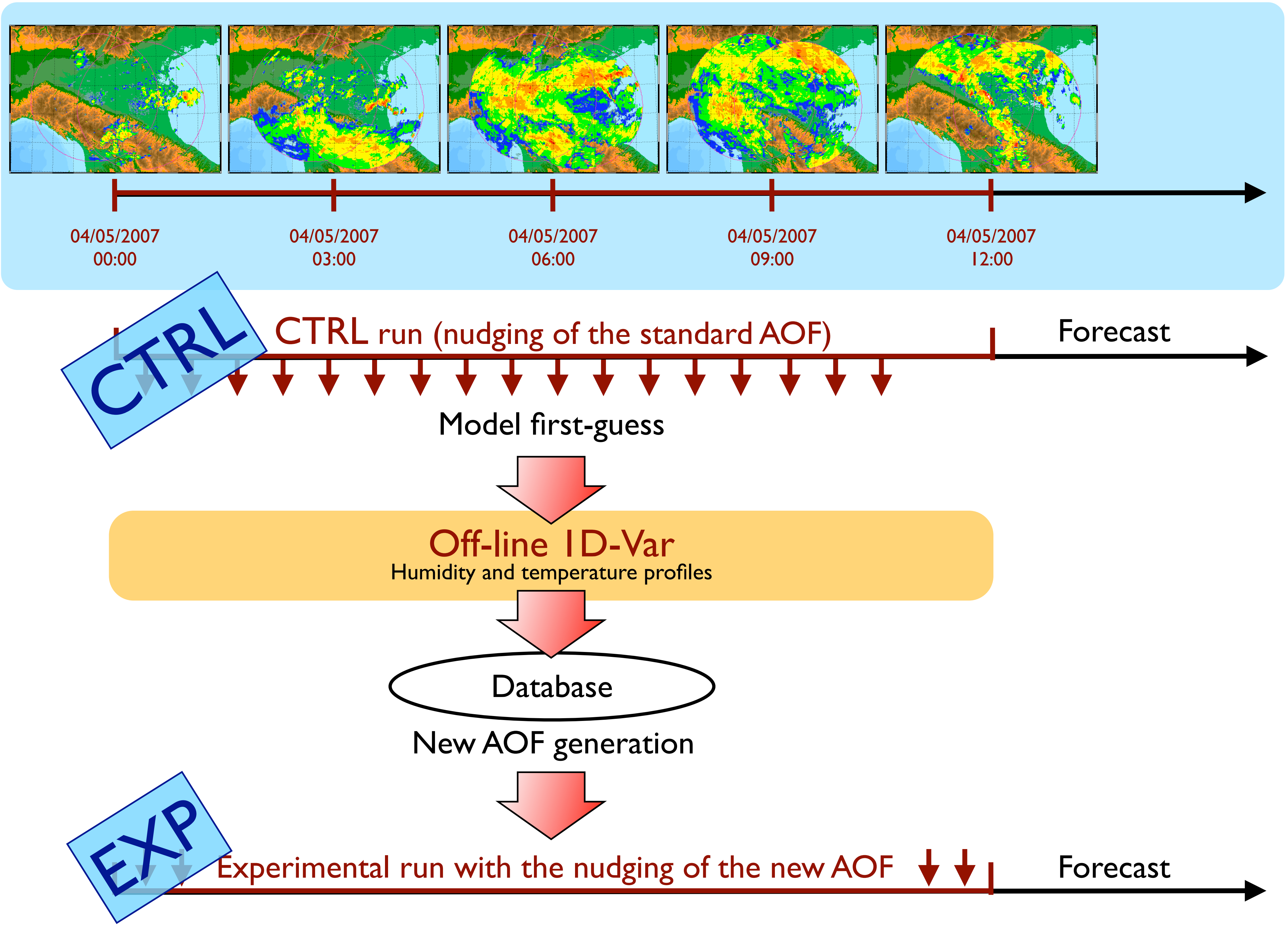
04/05/2007 12:00
CTRL run (nudging of the standard AOF)
Forecast
Model first-guess
Off-line 1D-Var
Humidity and temperature profiles
Database
New AOF generation
Experimental run with the nudging of the new AOF
Forecast



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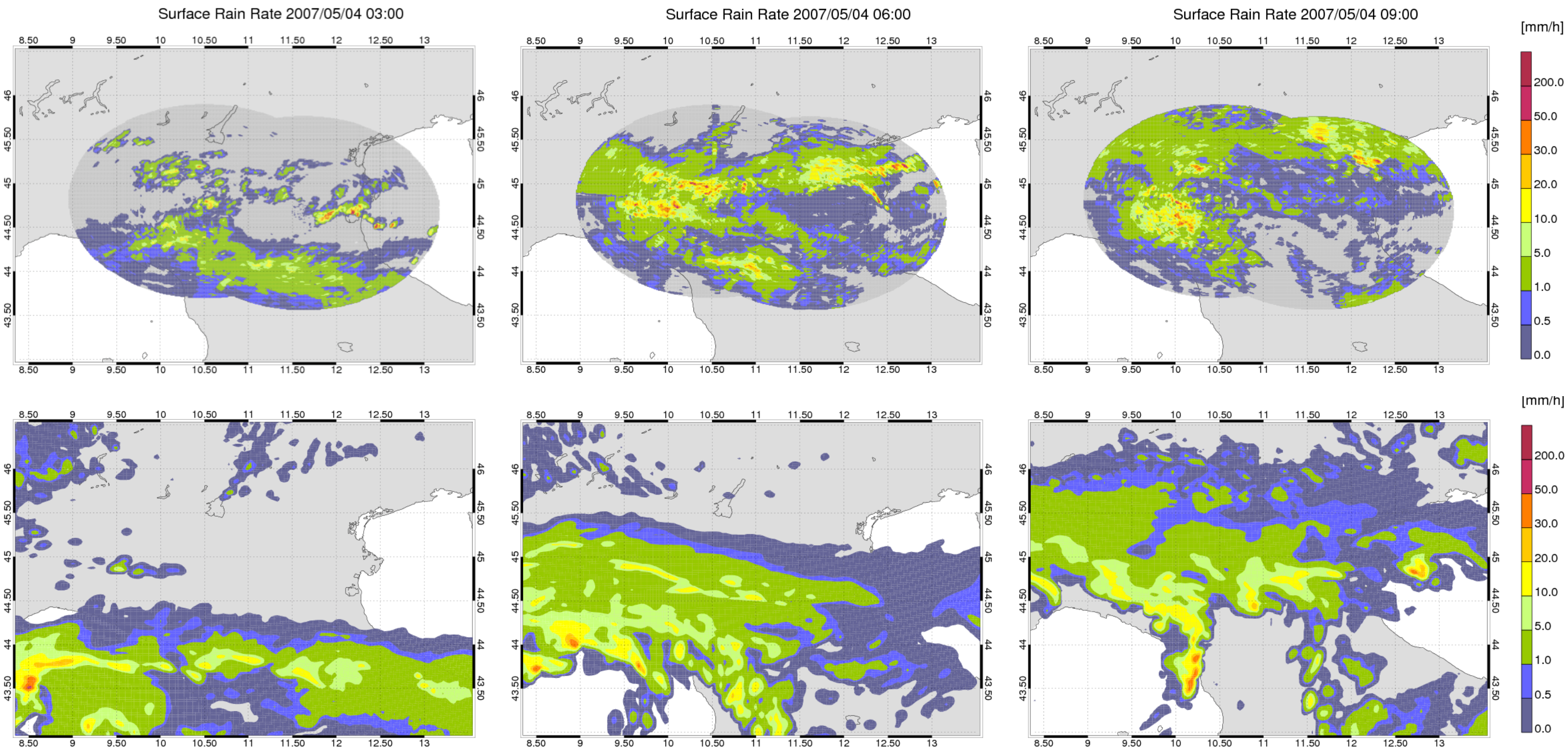
CTRL run (nudging of the standard AOF)
Forecast
Model first-guess
Off-line 1D-Var
Humidity and temperature profiles
Database
New AOF generation
EXP
Experimental run with the nudging of the new AOF
Forecast

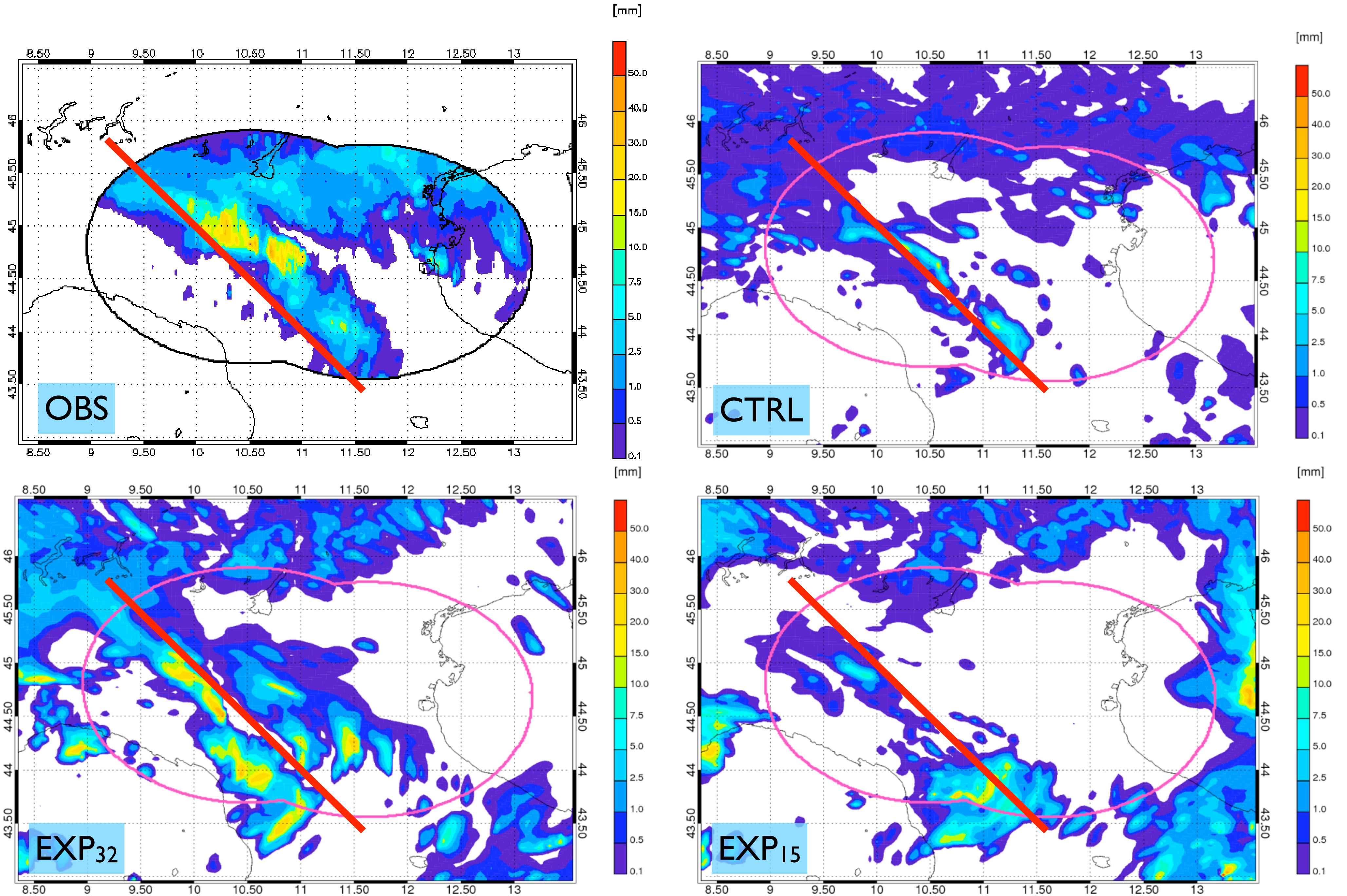
Case study

The selected case study is a convective episode in the Po valley which occurred between the 2nd and the 6th of may 2007. The strongest precipitation events occurred on the 4th of May and for this reason this day has been chosen for the assimilation experiment.



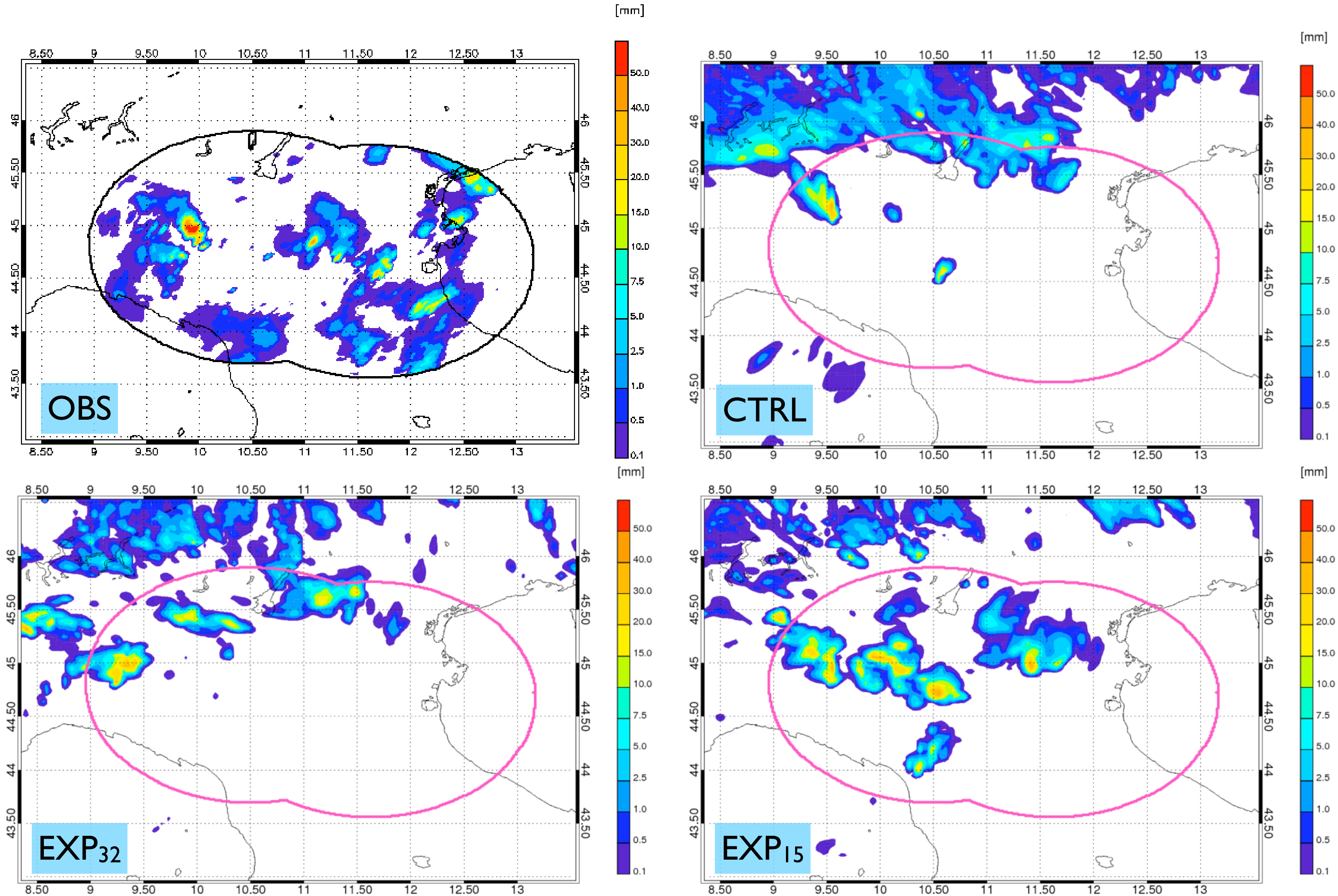
“Data thinning” impact

ASSIMILATION CYCLE: hourly precipitation at +12 hrs



“Data thinning” impact

FORECAST CYCLE: hourly precipitation at +6 hrs



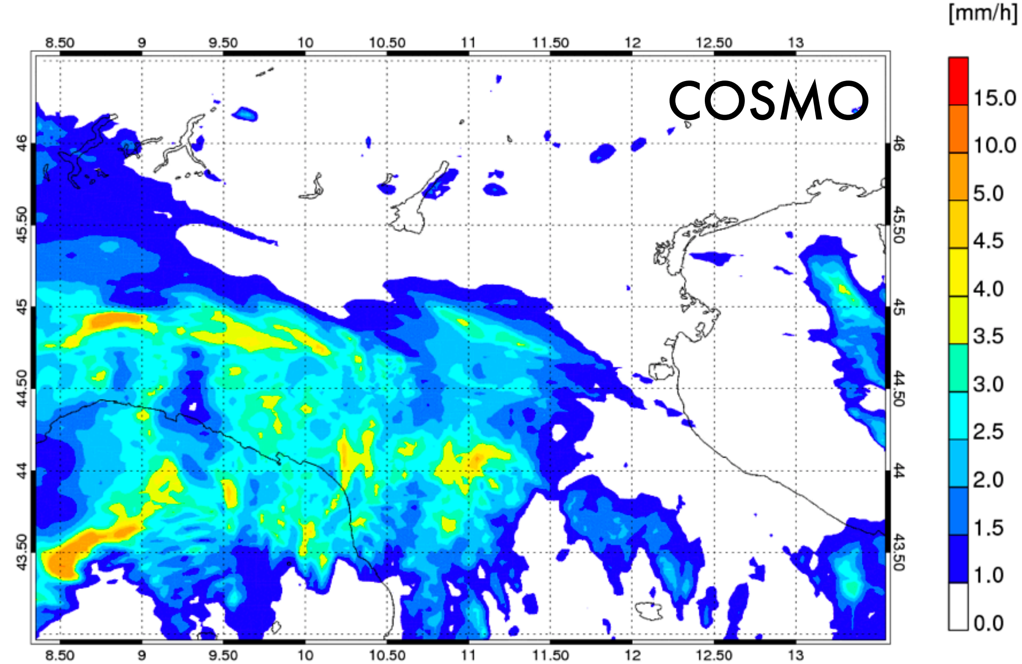
Model calibration (I)

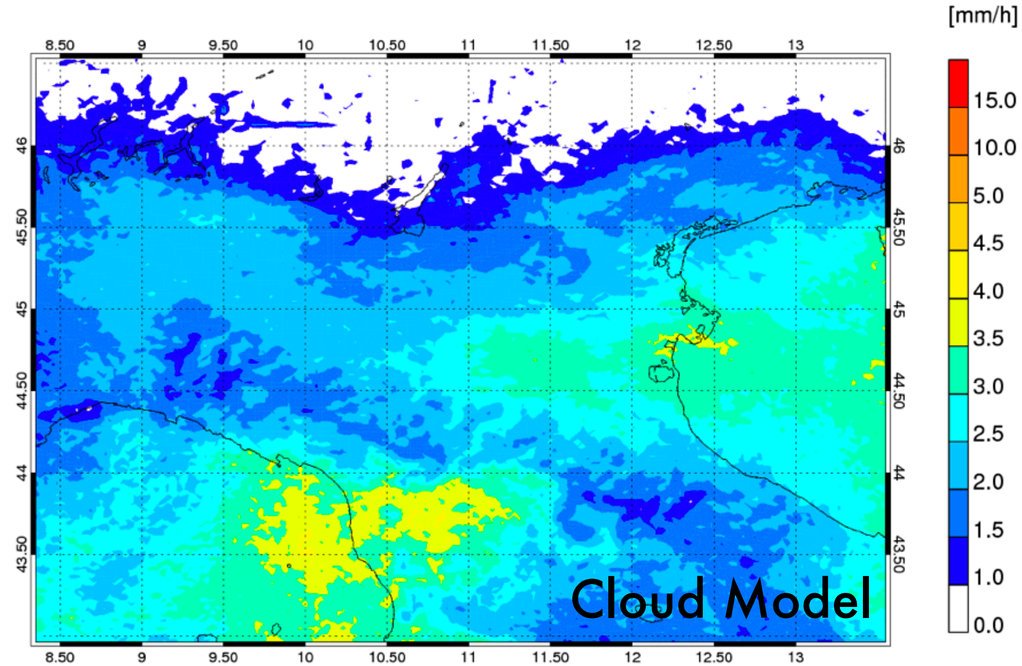
The variational approach works in a statistically optimal way if observations and model errors are unbiased.

In our system cloud model has a different physics with respect to the actual one implemented into the COSMO model.

To quantify the difference between the two models the instantaneous surface rain rate has been analyzed.

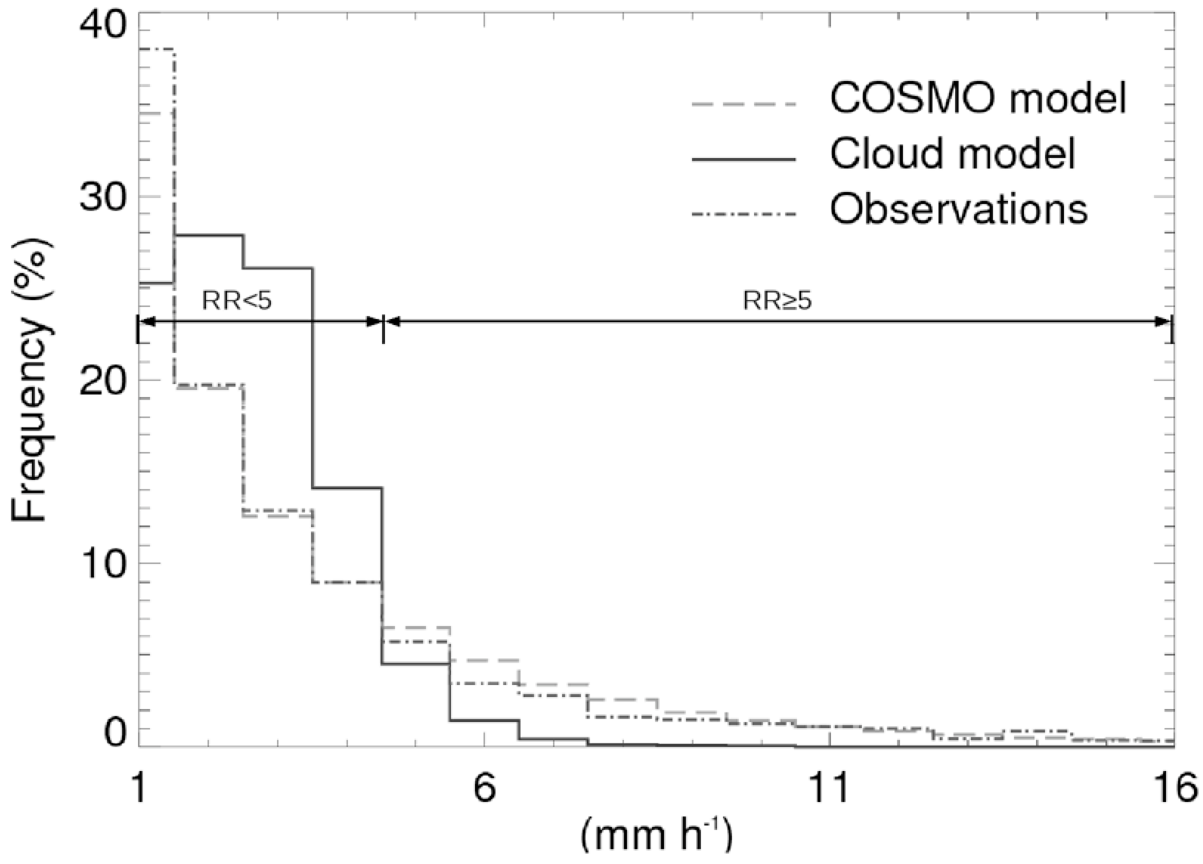
Given a set of temperature and humidity profiles the mean properties of the cloud model generated precipitation field diverge from the ones which would be produced by the COSMO model. Precipitation is not only determined by the "physical" balance of the total water contained in a 1D column but it also depends on dynamical driven processes. The simplified cloud model cannot take these effects into account.





Model calibration (II)

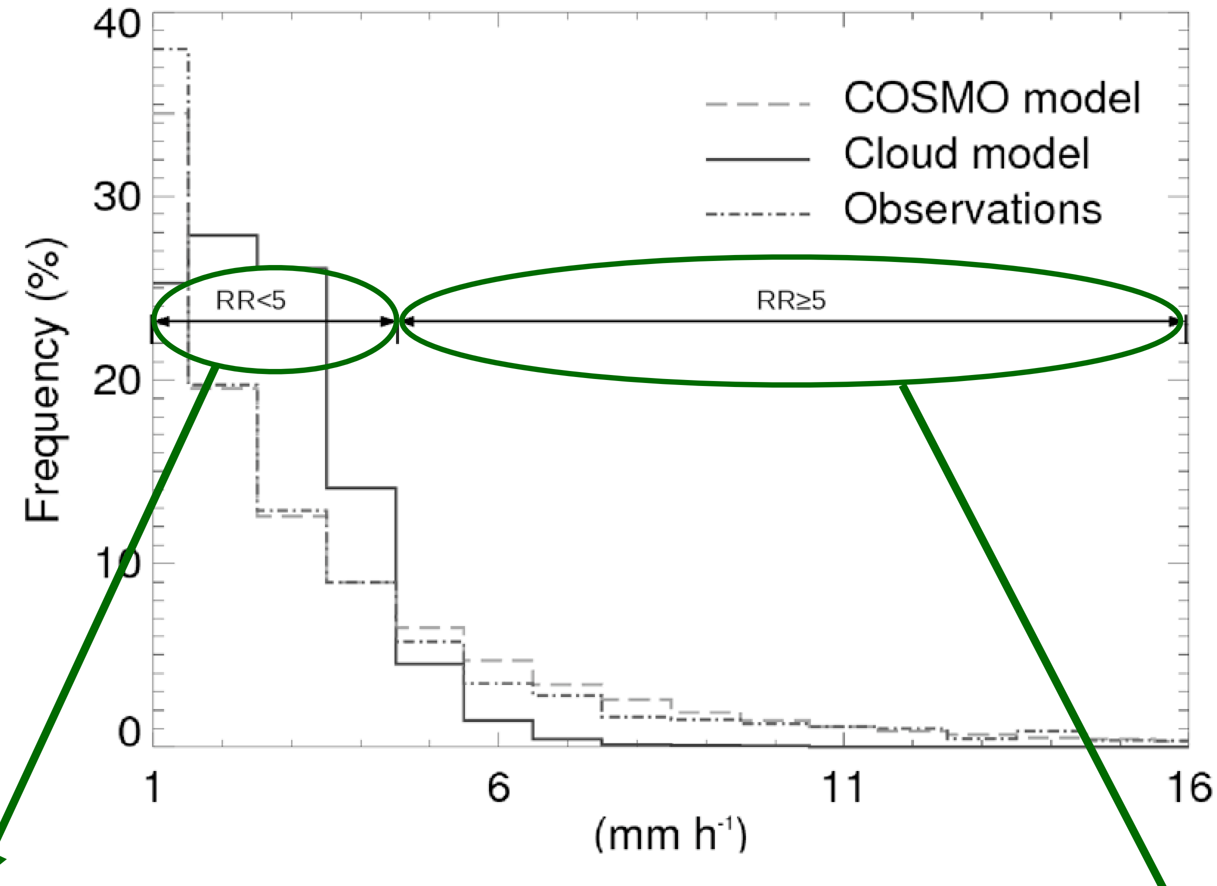
RR frequency histogram for cloud model, COSMO and radar observations.
Only precipitation data greater than 1 mm h^{-1} are considered.



Bias correction on observations: $\overline{RR_{fg} - RR_{obs}} = \overline{RR_{cosmo} - RR_{obs}}$

Model calibration (II)

RR frequency histogram for cloud model, COSMO and radar observations. Only precipitation data greater than 1 mm h^{-1} are considered.



$RR_{fg} > RR_{COSMO} \cong RR_{obs}$

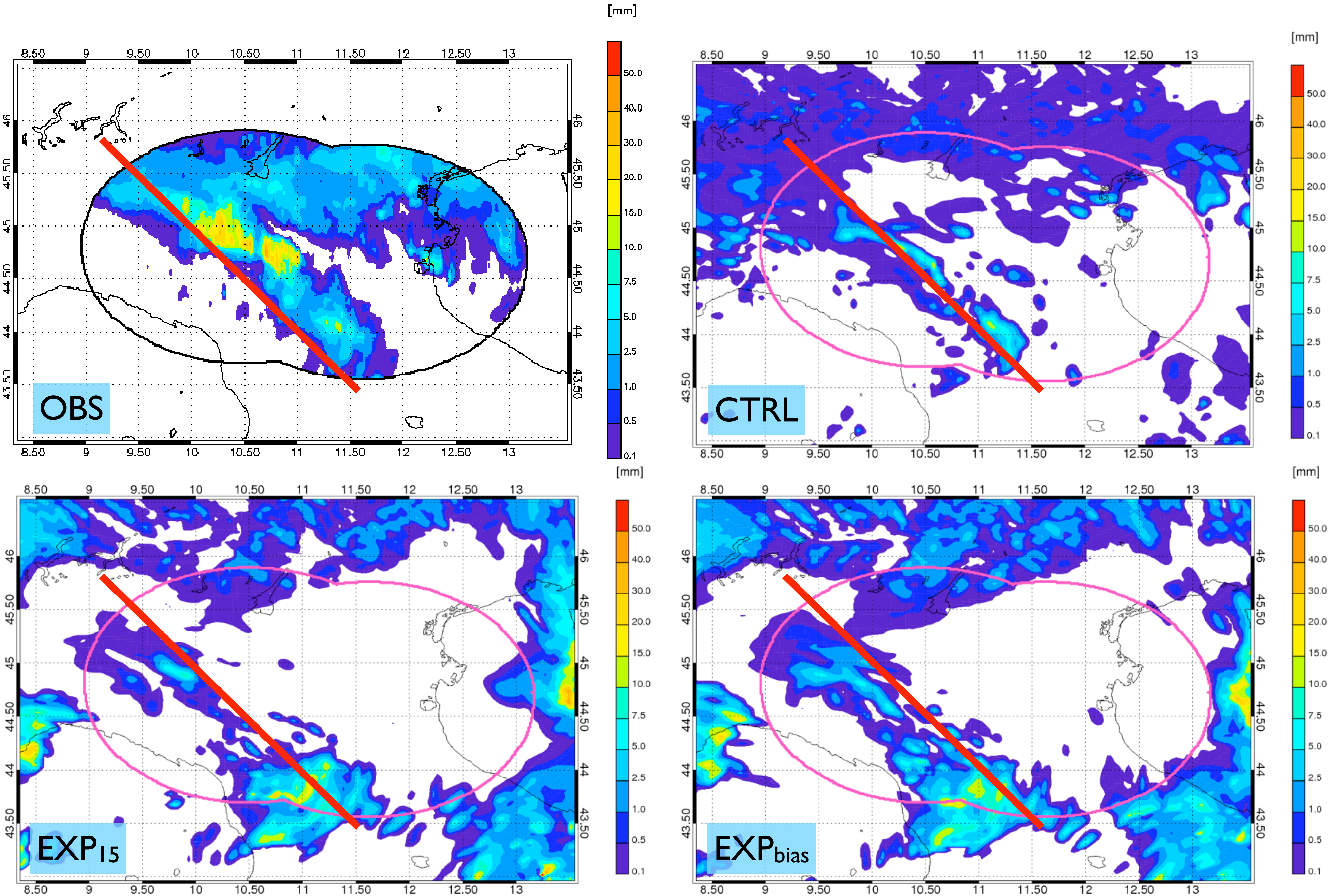
$RR'_{obs} = RR_{obs} + 0.5$ mm h^{-1}

$RR_{fg} < RR_{COSMO} \cong RR_{obs}$

$RR'_{obs} = RR_{obs} - 2$ mm h^{-1}

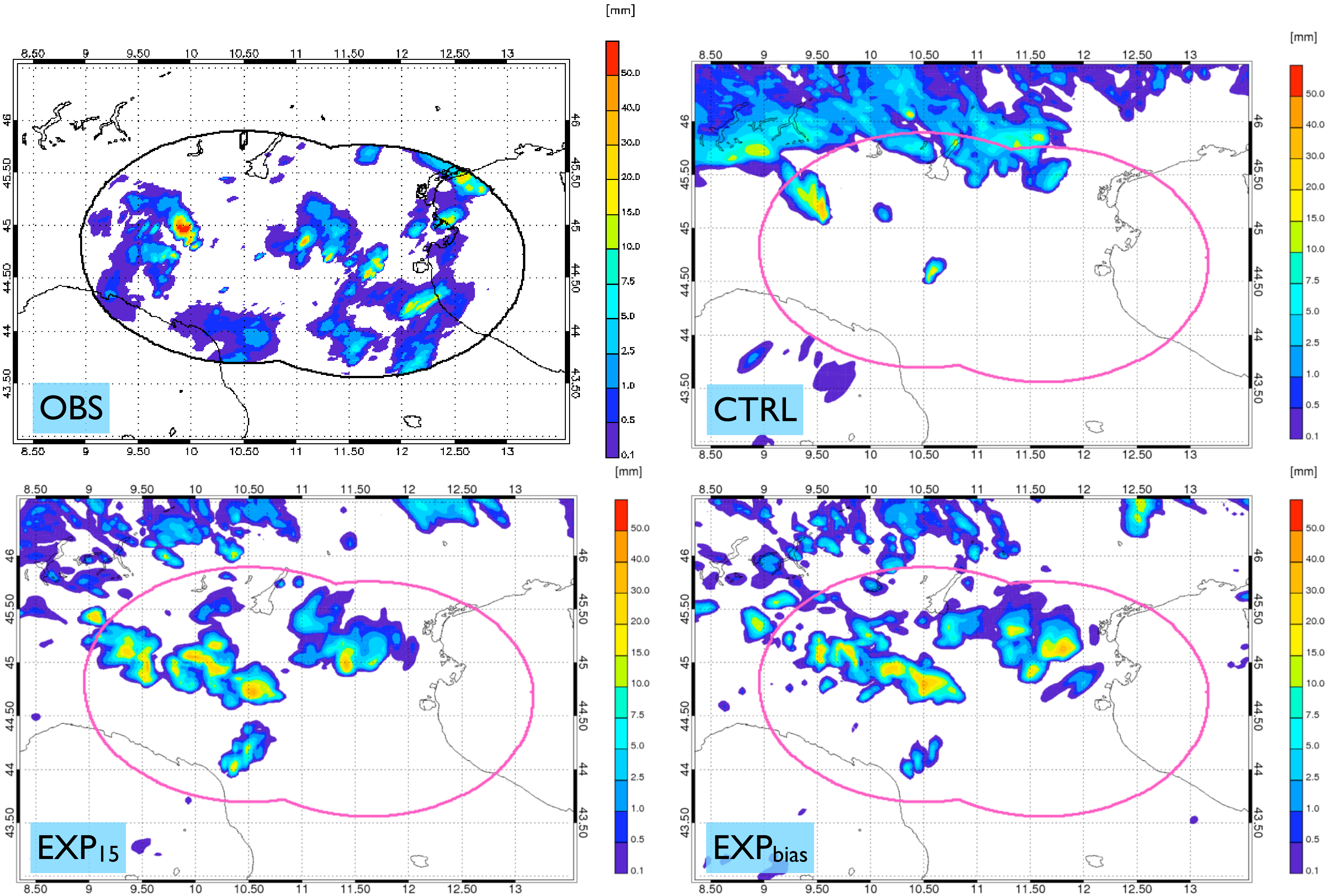
Calibration impact

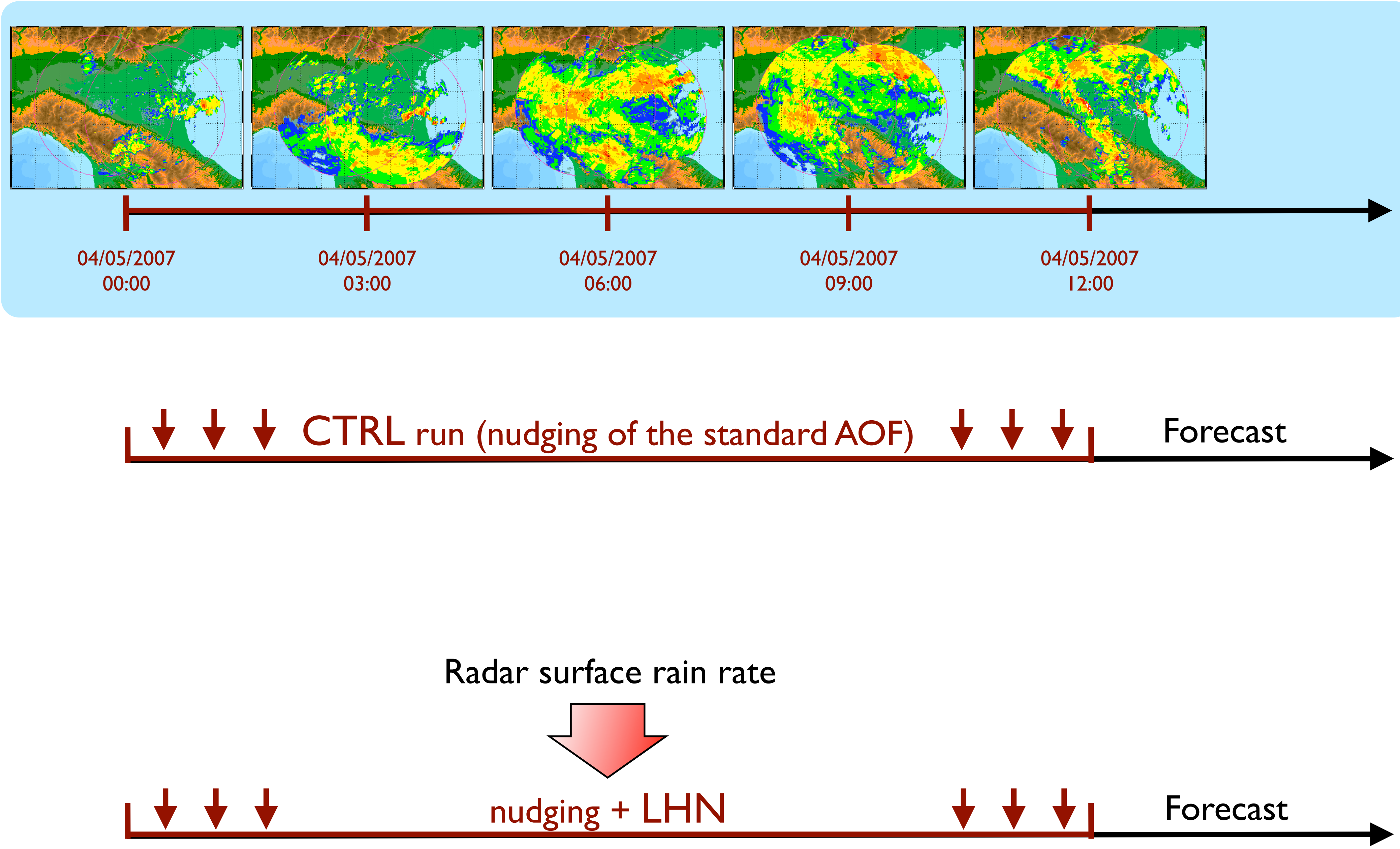
ASSIMILATION CYCLE: hourly precipitation at +12 hrs



Calibration impact

FORECAST CYCLE: hourly precipitation at +6 hrs

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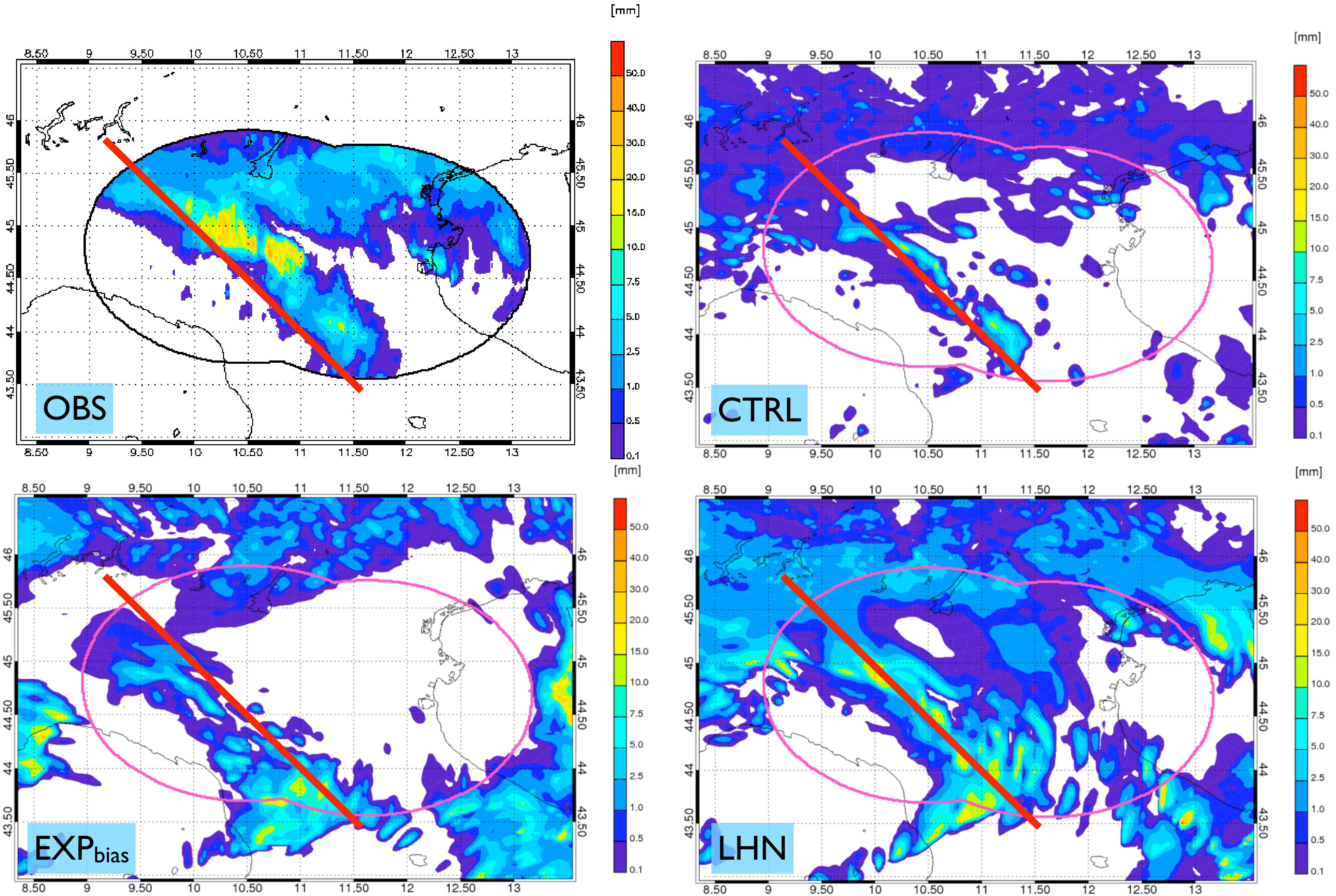
CTRL run (nudging of the standard AOF)
Forecast
Radar surface rain rate
nudging + LHN
Forecast

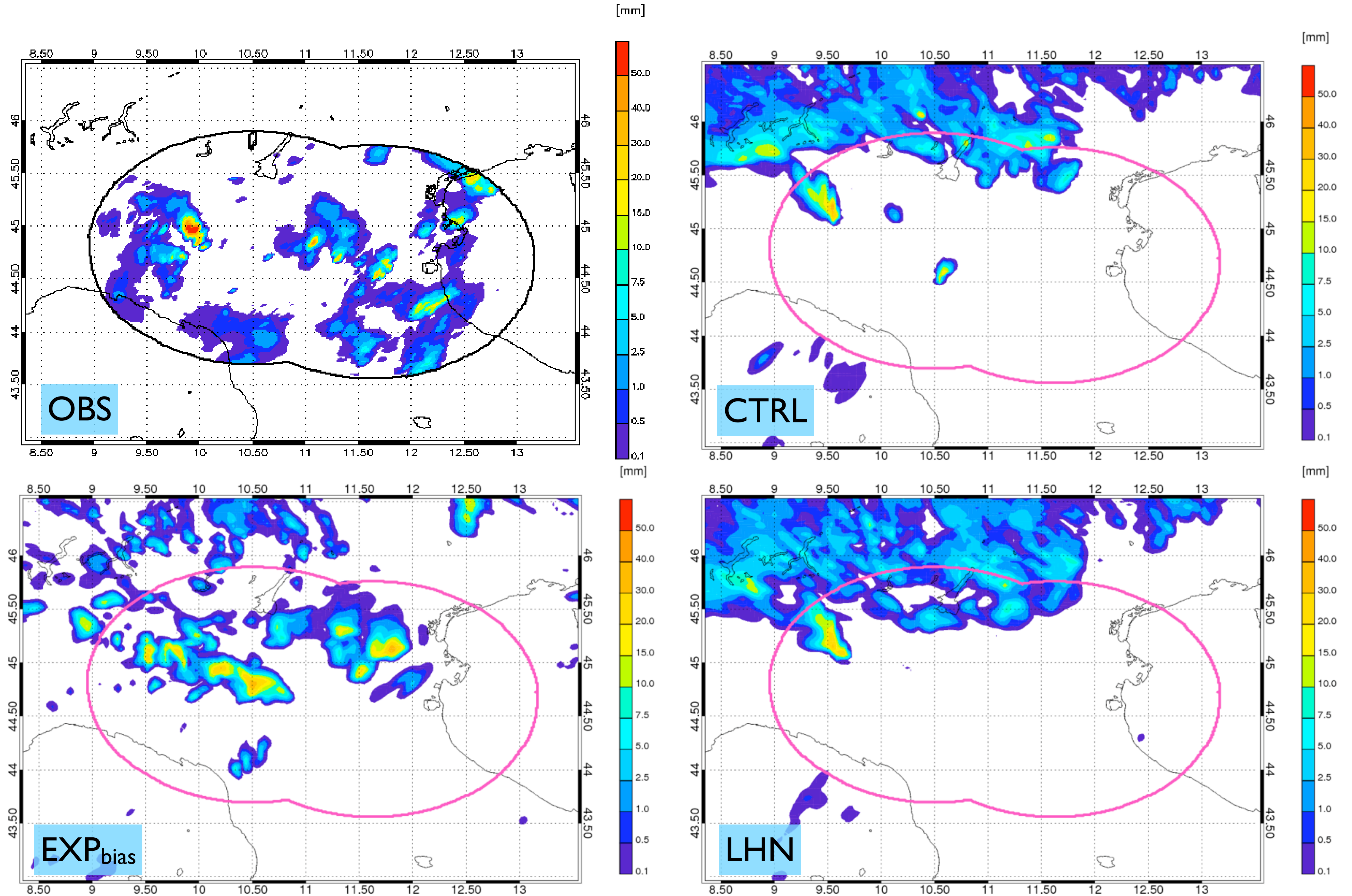
1D-Var vs LHN

ASSIMILATION CYCLE: hourly precipitation at +12 hrs



1D-Var vs LHN

FORECAST CYCLE: hourly precipitation at +6 hrs



Conclusions

- A 1D-var + nudging system has been developed in order to assimilate radar surface rain rate

- The system has been optimized:
  - making observations "data thinning"
  - estimating the observational error
  - calibrating the model

- Tests made show that the system shows promising results even if
  - results are strongly dependent on parameters used in nudging
  - in those areas where precipitation is observed, but not forecasted, the introduction of precipitating profiles do not trigger the model towards a precipitating condition

- A preliminary comparison with LHN has been made

Future plans

- COSMO 4.0
  - Switch to the newest COSMO release
- Emilia Romagna radar composite
  - Test methods using italian radar composite (provided by the National Department of Civil Protection)
- Only one case study
  - Validation of methods using a test bed
- Qualitative verification of results
  - Quantitative verification of forecasts using independent observations
- 1D-Var: application of a mean bias
  - Definition of a case dependent bias