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Radar and lightning data assimilation: the impact of different setting options discussed for a heavy precipitation event occurred in Italy

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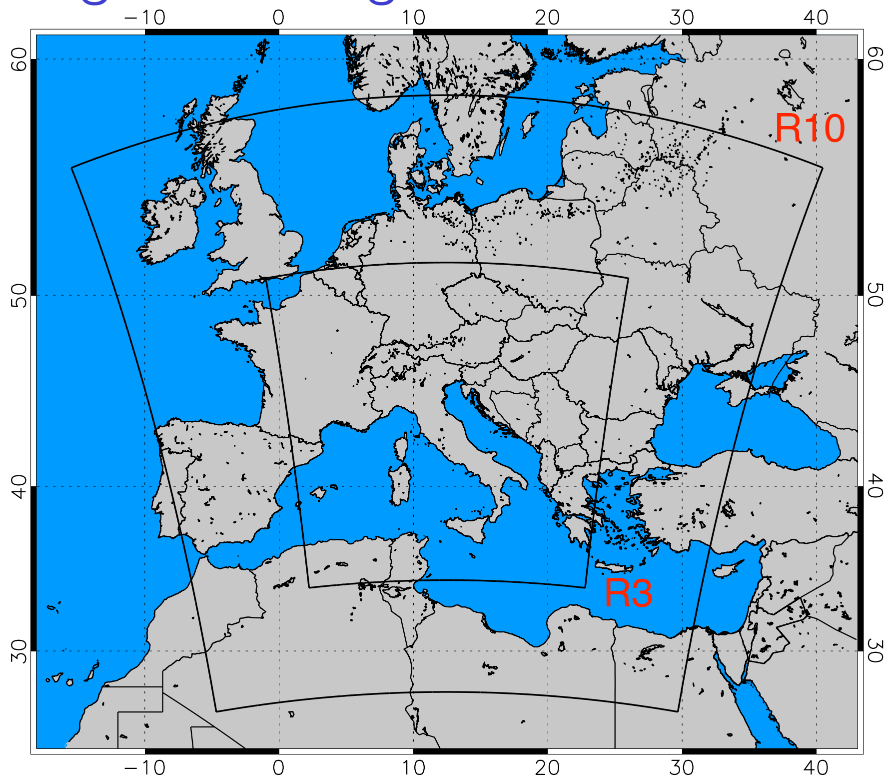
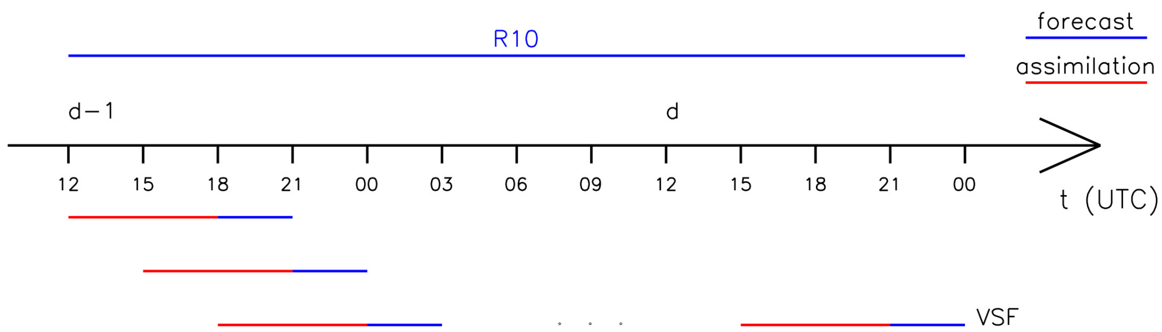
RAMS@ISAC grids configuration

	R10	R3
NNXP	351	635
NNYP	351	635
NNZP	42	42
Lx (km)	3510	1905
Ly (km)	3510	1905
Lz (km)	23.1	23.1
DX (km)	10	3
DY (km)	10	3
CENTLAT	43N	43N
CENTLON	12.5E	12.5E



Very Short-term Forecast (VSF) configuration

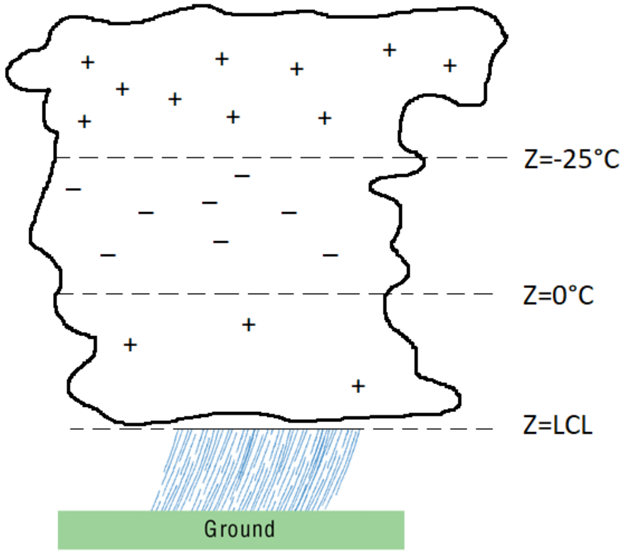
8 forecast for every day, lasting 9 hours each. Each forecast consists of an assimilation period of 6 hours followed by a VSF period 3 hours long.



Lightning assimilation – 3DVar

A relative humidity pseudo-profile is generated when/where lightning is observed:

$$RH: \begin{cases} NO\ DATA & z < z_{LCL} \\ 100\% & z_{LCL} \leq z \leq z_{-25°C} \\ NO\ DATA & z > z_{-25°C} \end{cases}$$



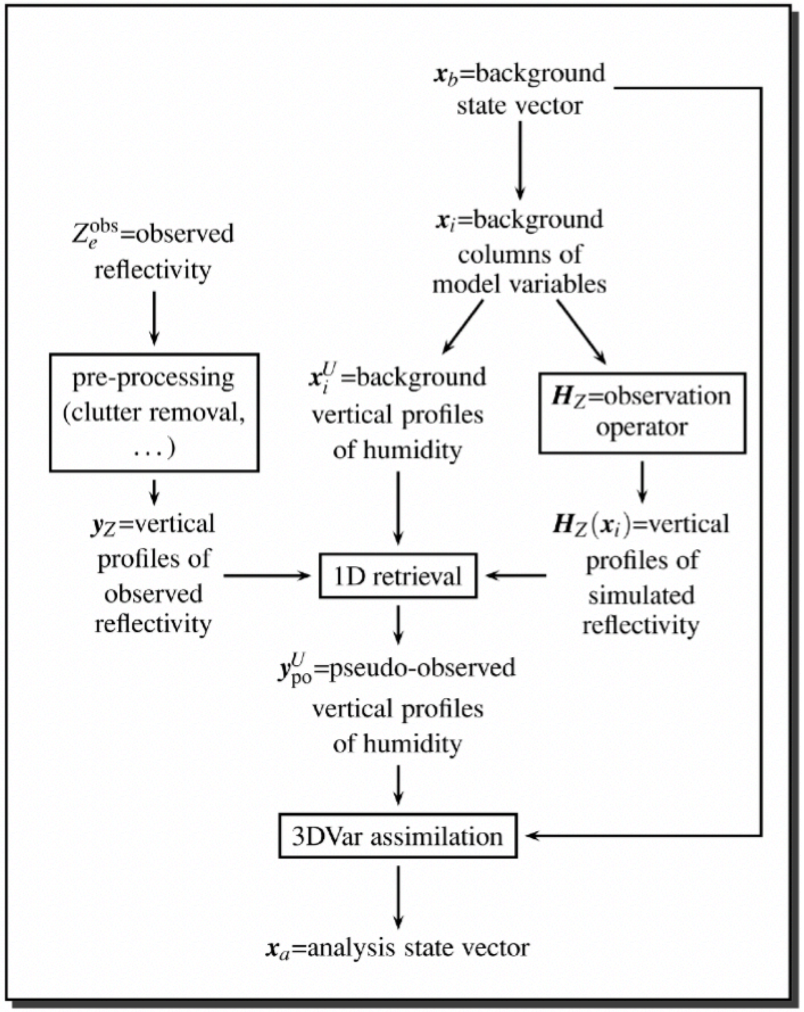
This relative humidity pseudo-profile is assimilated by RAMS-3DVar once the relative humidity has been converted in water vapor mixing ratio:

$$J(x) = \frac{1}{2}(x - x_b)^T B^{-1}(x - x_b) + \frac{1}{2}[H(x) - y_o]^T R^{-1}[H(x) - y_o]$$

The background error matrix is computed by the NMC method which considers one month of simulations.

Radar reflectivity data assimilation – 3DVar

Caumont et al., 2010, Tellus 62A

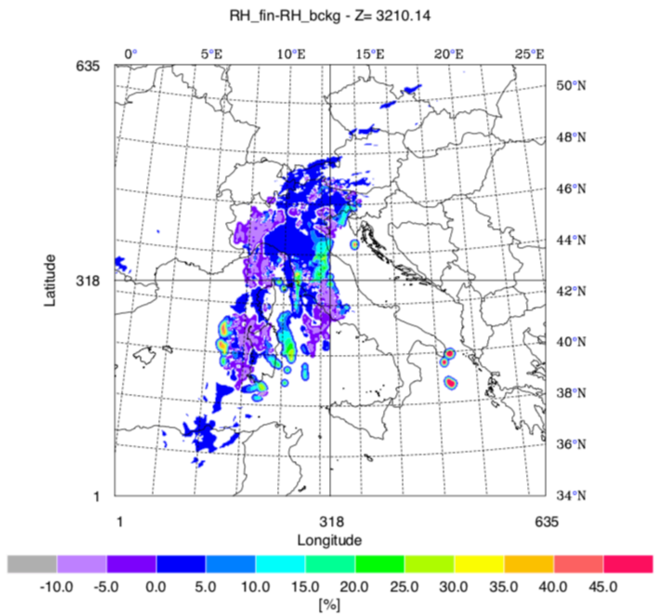


$$y^U_{\mathrm{po}} = \sum_i x^U_i \frac{W_i}{\sum_j W_j}$$

$$W_i \equiv \exp\left\{-\frac{1}{2}[y_0 - h(x_i)]^{\mathrm{T}} \mathbf{R}^{-1} [y_0 - h(x_i)]\right\}$$

$$J(X) = \frac{1}{2}(X - X_b)^{\mathrm{T}} \mathbf{B}^{-1} (X - X_b) + \frac{1}{2}[Y - H(X)]^{\mathrm{T}} \mathbf{R}^{-1} [Y - H(X)]$$

An example:
00 UTC 17/11/2019



RADAR CAPPI of the national radar composite at 2000m, 3000m, 4000m and 5000m are assimilated.

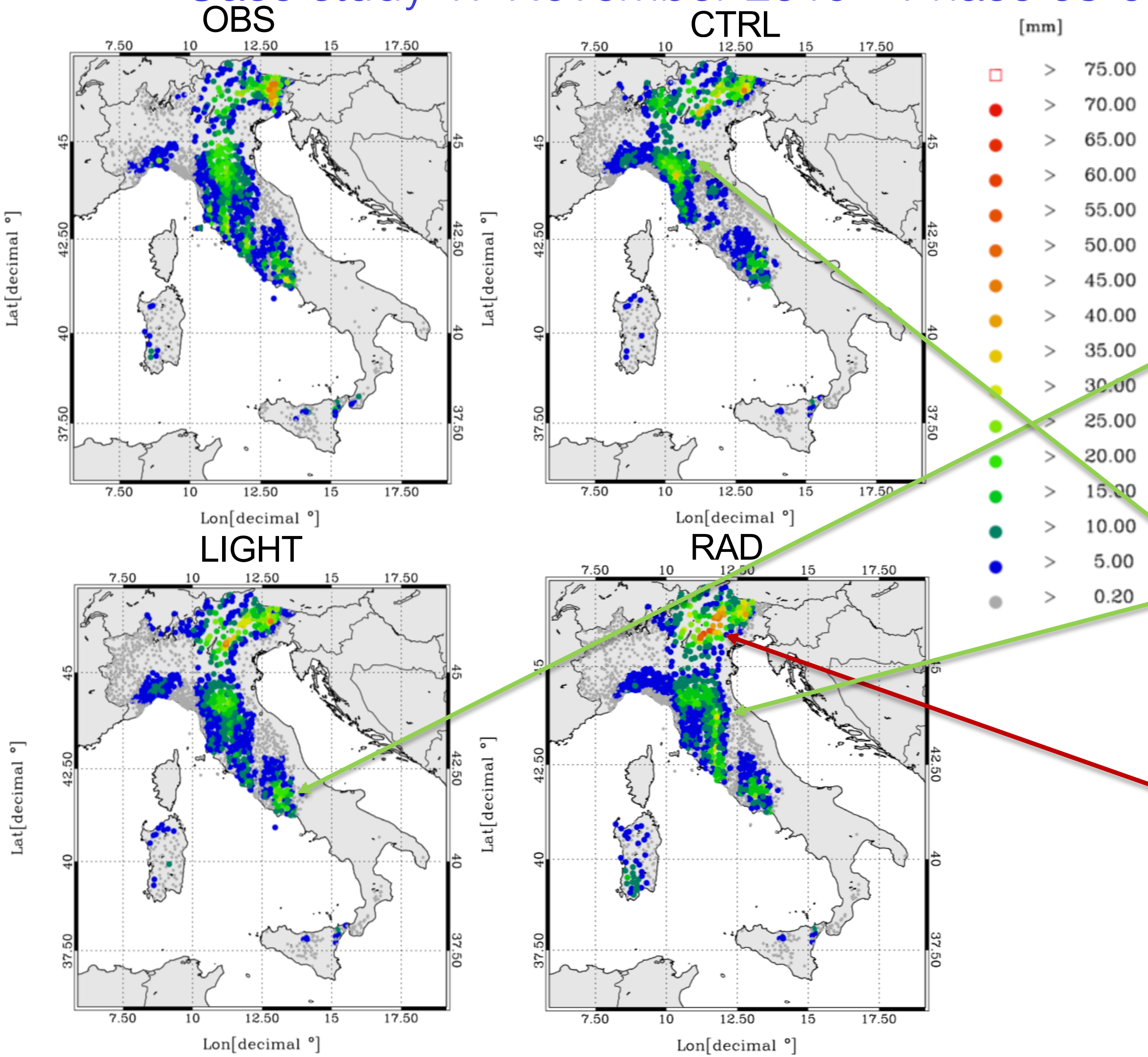
Simulations considered for this case study

Experiment	**Description**	**Data assimilated**	**Model variable impacted**
CTRL	Control run	None	None
RAD	RADAR data assimilation	Reflectivity factor CAPPI (RAMS-3DVar)	Water vapour mixing ratio
LIGHT	Lightning data assimilation	Lightning density (RAMS-3DVar)	Water vapour mixing ratio
RADLI	RADAR + lightning data assimilation	Reflectivity factor CAPPI (RAMS-3DVar) + Lightning density (RAMS-3DVar)	Water vapour mixing ratio

OBS: observations

Forecasted and observed precipitation have been compared using the nearest neighborhood method employing a search radius of $2 \cdot \Delta x \cdot \sqrt{2}$~8.5 km

Case study 17 November 2019 – Phase 03-06 UTC



Data assimilation impact on the precipitation forecast.

Positive aspects:

- Better precipitation forecast in southern Lazio for lightning and radar data assimilation
- Eastern shift of the precipitation pattern in northern Italy

Negative aspect:

- Tendency to overestimate rainfall in Lombardia (especially for radar reflectivity data assimilation)

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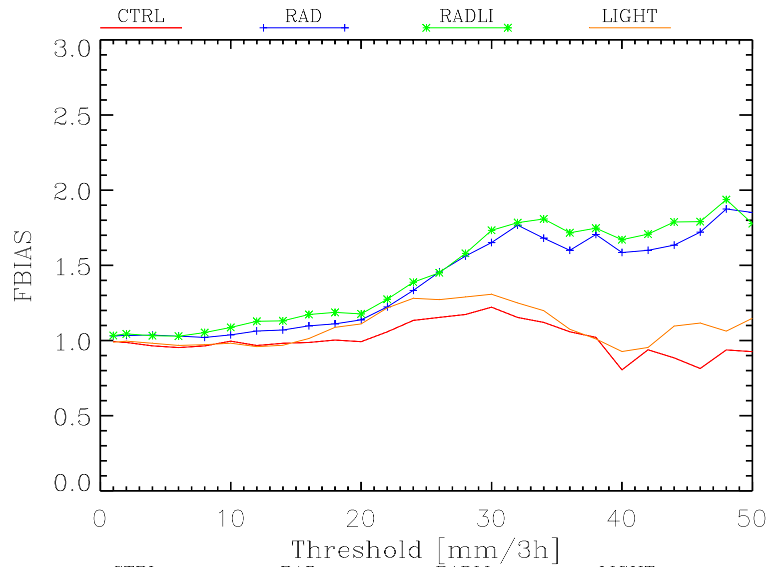
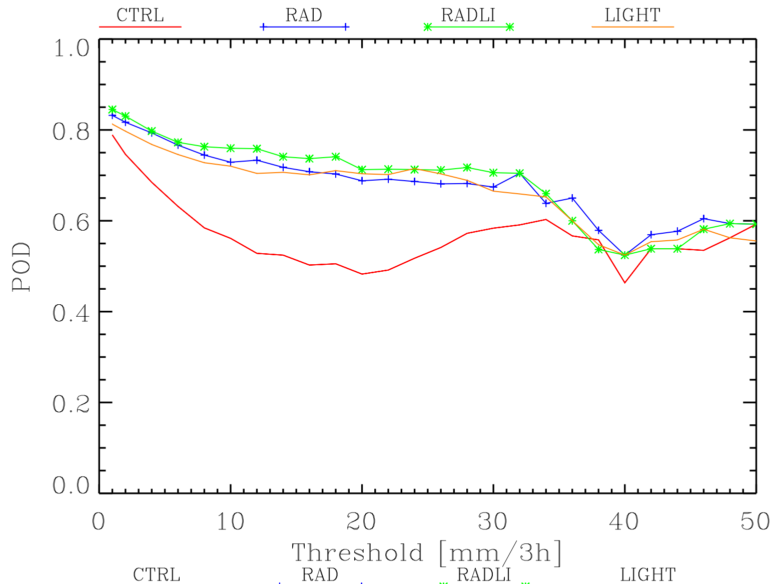
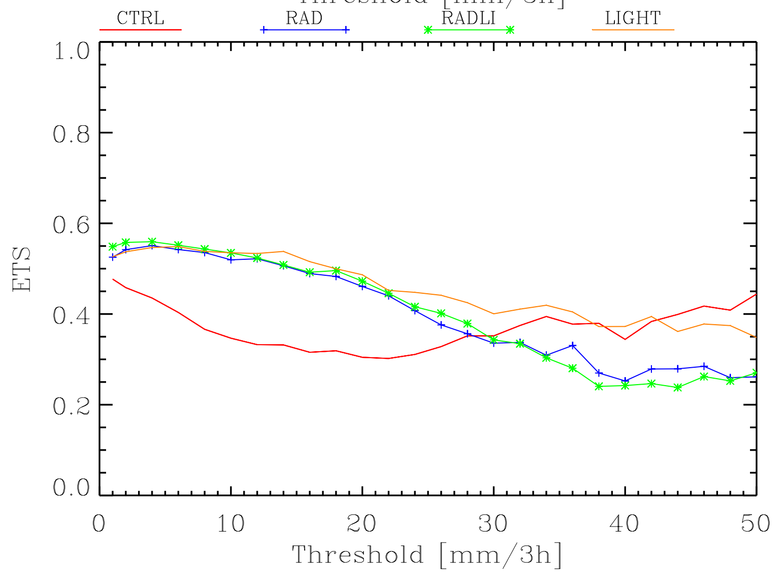
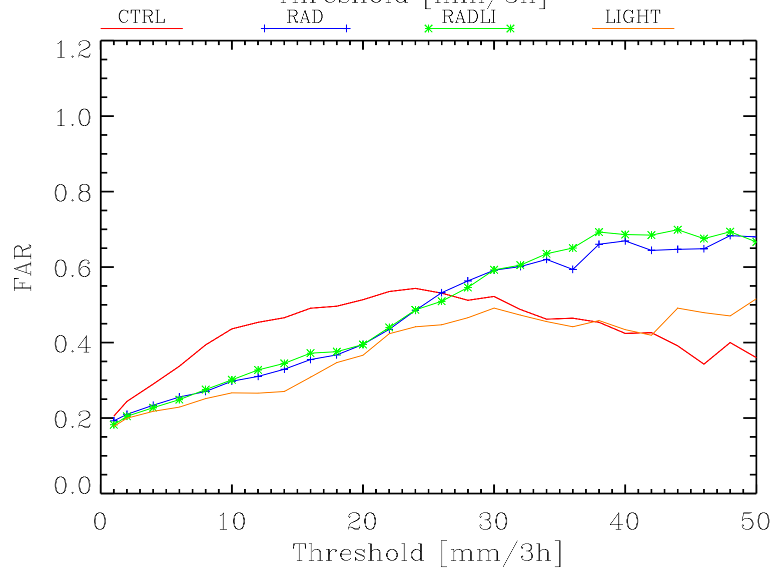
Scores for the event

The performance of RAMS@ISAC model has been evaluated using qualitative score (FBIAS, POD, ETS, FAR) computed from dichotomous contingency computed for all the 8 VSF of the 17 November 2019.









Conclusions

This case study shows the impact of lightning and radar reflectivity data assimilation on the very short-term forecast of RAMS@ISAC model for a case study reasonably predicted by the CTRL forecast. Both data are assimilated using 3DVar.

Despite the good performance of the CTRL forecast:

- lightning and radar reflectivity improve the forecast (ETS) up to 40 mm/3h and 30 mm/3h respectively, while for largest thresholds the impact is smaller;
- the result for the simulation assimilating both radar and lightning is similar to that for radar data assimilation.

The worsening of the performance of for LIGHT, RAD and RADLI at the largest thresholds is caused by the increase in false alarms.
All simulations with lightning and/or radar reflectivity data assimilation have a better POD in comparison with CTRL.

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