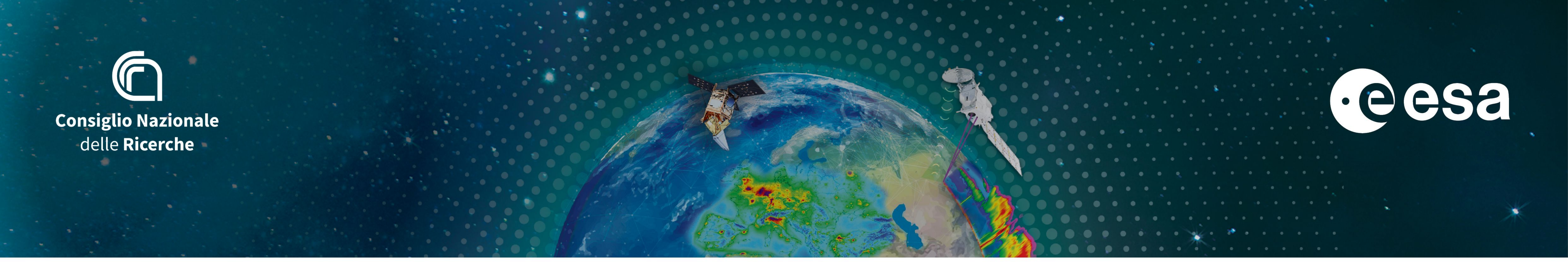


Towards the assimilation of MTG-IRS and all-sky microwave radiances in the convection-permitting ICON model

Marcello Grenzi [a] , Thomas Gastaldo [b],[d] , Virginia Poli [b],[d] , Chiara Marsigli [c],[d] , Carlo Cacciamani [d] , Alberto Carrassi [a]

[a] University of Bologna, [b] Arpae Emilia-Romagna, Hydro-Meteo-Climate Service, Bologna, Italy, [c] Deutscher Wetterdienst (DWD), Offenbach am Main, Germany, [d] ItaliaMeteo Agency, Bologna, Italy

MOTIVATION

1. Data assimilation of all-sky radiances

Dealing with complex optical properties of clouds requires accurate forward operator and model forecast. Many NWP centers nowadays assimilate satellite data in **clear-sky** and only gradually also in **all-sky** conditions mainly in global models.

2. Humidity is highly undersampled in conventional data

The data assimilation (DA) of **water vapor-sensitive microwave (MW) sounders** (e.g. MHS) on polar satellites provides a large impact on the forecast quality. However, the contribution of MW data is still poorly investigated in Limited Area Models (LAM). Furthermore, the geostationary Meteosat Third Generation Infrared Sounder (**MTG-IRS**) will soon provide radiances at infrared wavelengths at a resolution never attained before.

Accurate humidity assimilation is important for improving the representation of **convective system** dynamics, especially the processes of Convection Inhibition (CIN) removal and Convective Available Potential Energy (CAPE) enhancement, driven by moisture convergence.

1. METHOD

The ICON model

The new ICOsahedral Non-hydrostatic (ICON) model[1], developed in a collaboration between the German Weather Service (DWD) and Max-Planck Institute for Meteorology (MPI-M), represents a powerful tool for investigating the atmospheric dynamics at **convection-permitting** scale. ICON is now run operationally by different NWP centers in Europe in ICON-LAM, replacing the previous COSMO model.

The data assimilation system

Analysis is provided by the **KENDA**[2] data assimilation system based on a Local Ensemble Transform Kalman Filter (**LETKF**[3]). It solves a quadratic cost function in the ensemble space (H is the forward operator, $\mathbf{R}$ the observation error matrix, $\mathbf{y^o}$ the observation vector, $\mathbf{X^b}$ the background perturbation matrix, L the number of LETKF members):

$$\tilde{J}(\mathbf{w}) = (L-1)\mathbf{w}^T\mathbf{w} + [\mathbf{y}^o - H(\bar{\mathbf{x}}^b + \mathbf{X}^b\mathbf{w})]^T\mathbf{R}^{-1}[\mathbf{y}^o - H(\bar{\mathbf{x}}^b + \mathbf{X}^b\mathbf{w})]$$

Simulation setup

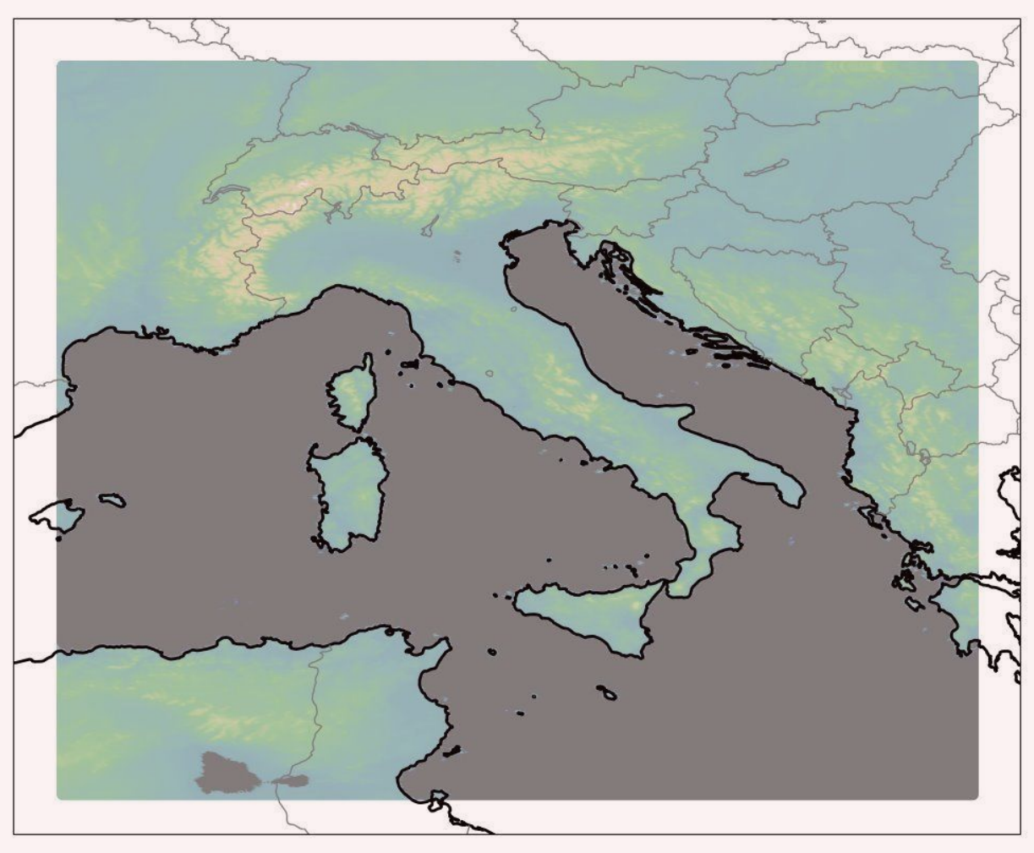
- ICON-LAM resolution: **2.2km, 65 vertical levels**
- Forecasts every **12h** (init. at 00 and 12 UTC)
- Forecasts lead time: **24h**
- ECMWF-IFS HRES boundary conditions for deterministic forecast
- ECMWF-ENS boundary conditions for LETKF
- **Convection-permitting**: only shallow convection parametersation
- KENDA analysis every **1h**
- LETKF with ***L* = 40 members** + deterministic

Scheme of the ICON unstructured triangular grid

Data currently assimilated

- **conventional** observations (AIREP, SYNOP, TEMP)
- radar-estimated precipitation with Latent Heat Nudging (**LHN**)
- **radar volumes** (reflectivity and radial winds)

For the future assimilation of satellite data is necessary to run ICON and KENDA with the fast radiative transfer model **RTTOV v13.2**[4], used as forward operator for DA.



ICON-LAM domain used for this study

2. CASE STUDY

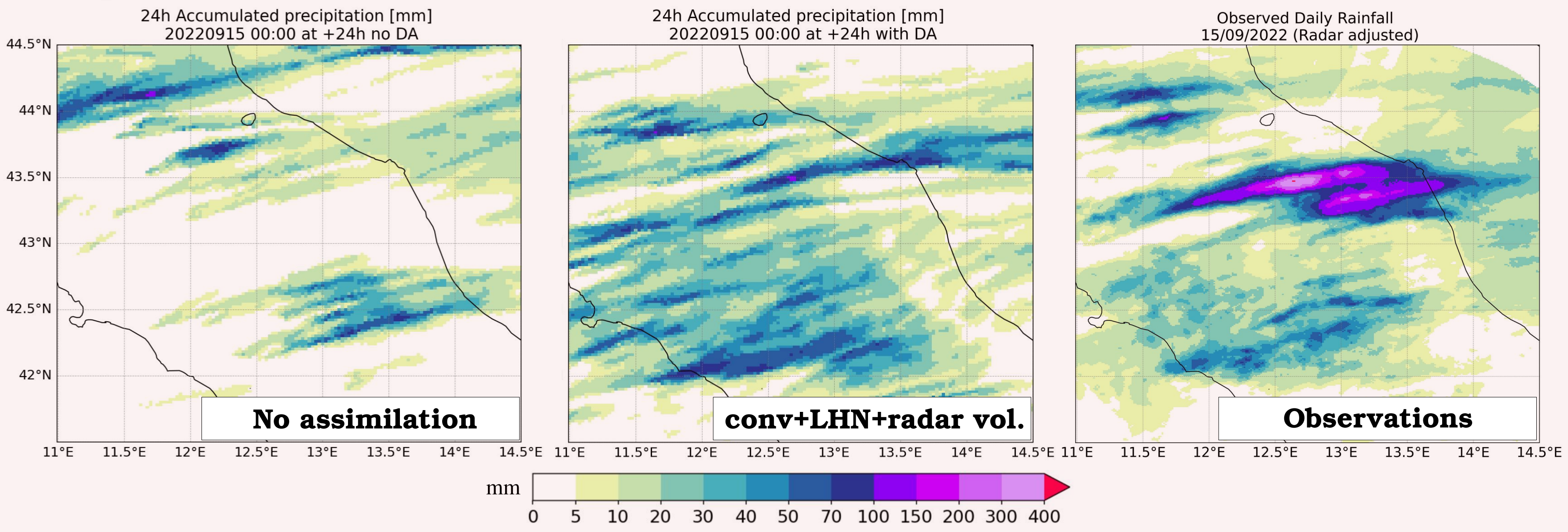
On the 15th September 2022 a stationary convective system caused huge flooding over Marche region, in Central Italy. The maximum rainfall measured was more than **400mm in 7h**. The event was very **poorly predicted** by the main NWP models, both in location and intensity.

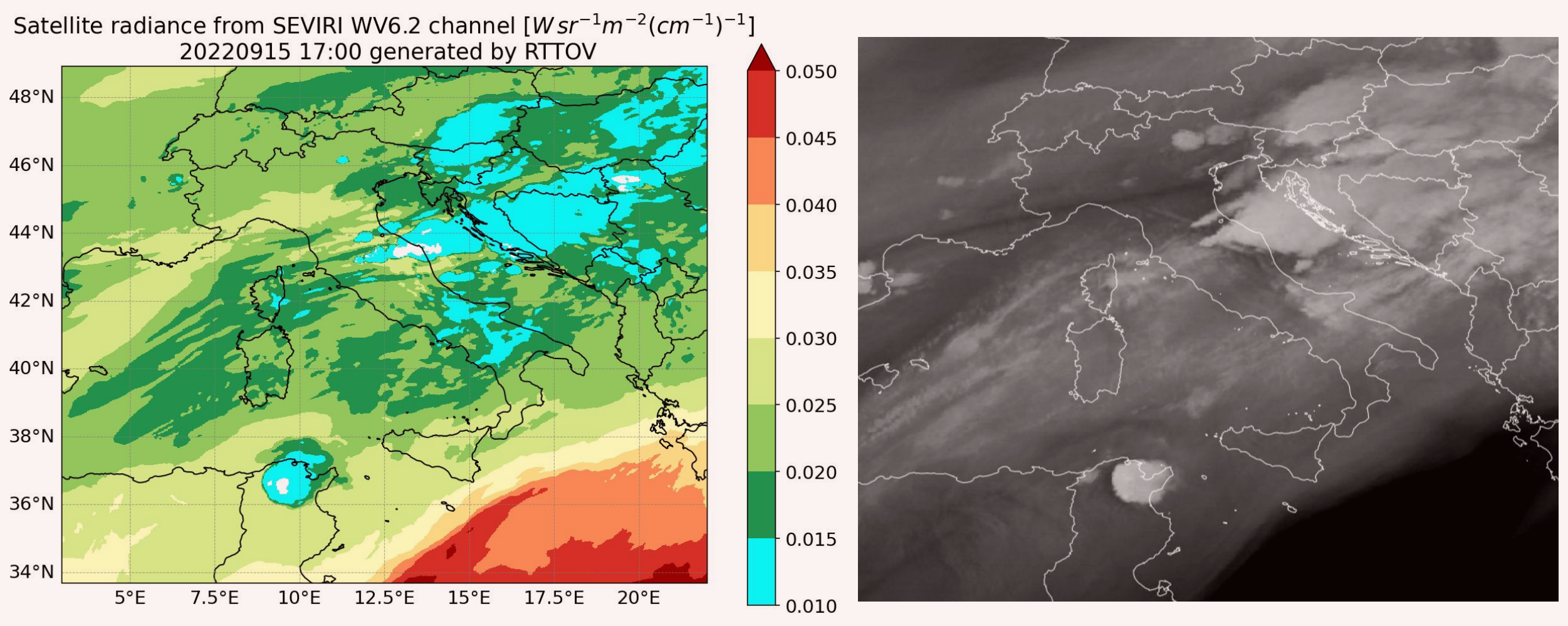
In this preliminary work we proceed by:

- Testing ICON performance in the period 12th - 16th Sept. (10 forecasts), comparing the results **with and without assimilation**
- Checking consistency of synthetic RTTOV output based on KENDA analysis

3. RESULTS

Forecast initialised on 15/09/2022 at 00UTC. Daily cumulated precipitation and comparison with radar-estimated rainfall:

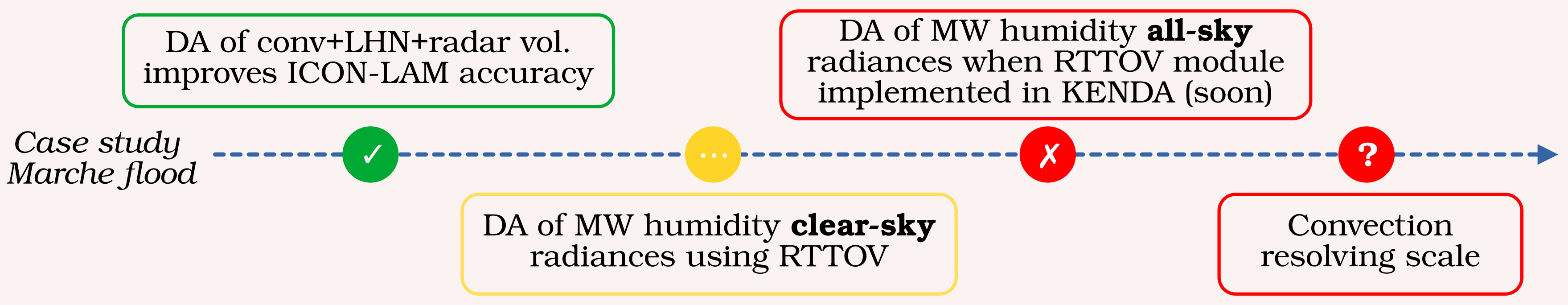




Consistency check after compilation with RTTOV:

- On the left, **simulated radiance of MSG SEVIRI WV channel at 6.2µm**, generated by RTTOV from the KENDA analysis at 17UTC.
- On the right, SEVIRI real measurement at 17UTC.

CONCLUSIONS AND NEXT STEPS



DA of conv+LHN+radar vol. improves ICON-LAM accuracy

DA of MW humidity **all-sky** radiances when RTTOV module implemented in KENDA (soon)

Case study Marche flood

✓ … ✗ ?

DA of MW humidity **clear-sky** radiances using RTTOV

Convection resolving scale

A comprehensive study of the relative impact of all these different sources of data will be carried out. In parallel, the additional (potential) benefit of high spatial and temporal resolution **MTG-IRS** data is thought to be tested employing synthetic observations.

References

[1] Zängl, G., Reinert, D., Rípodas, P. and Baldauf, M.: The ICON (ICOsahedral Non-hydrostatic) modelling framework of DWD and MPI-M: Description of the non-hydrostatic dynamical core. Q.J.R.M. Soc., 2015.
[2] Schraff, C., Reich, H., Rhodin, A., Schomburg, A., Stephan, K., Periáñez, A. and Potthast, R.: Kilometre- scale ensemble data assimilation for the COSMO model (KENDA). Q.J.R.M.S.., 142: 1453-1472, 2016.
[3] Hunt, B. R., Kostelich, E. J., and Szunyogh, I.: Efficient data assimilation for spatio-temporal chaos: A local ensemble transform Kalman filter, Physica D, 230, 112–126,2007.
[4] Saunders, R., Hocking, J., Turner, E., Rayer, P., Rundle, D., Brunel, P., Vidot, J., Roquet, P., Matricardi, M., Geer, A., Bormann, N., and Lupu, C.: An update on the RTTOV fast radiative transfer model (currently at version 12), Geosci. Model Dev., 11, 2717-2737, 2018

ATMOS 2024 | 1–5 July 2024 | Bologna, Italy