Impact of the variation of model domain size and native resolution on the applicability of the CRA analysis on QPF verification: A MesoVICT study

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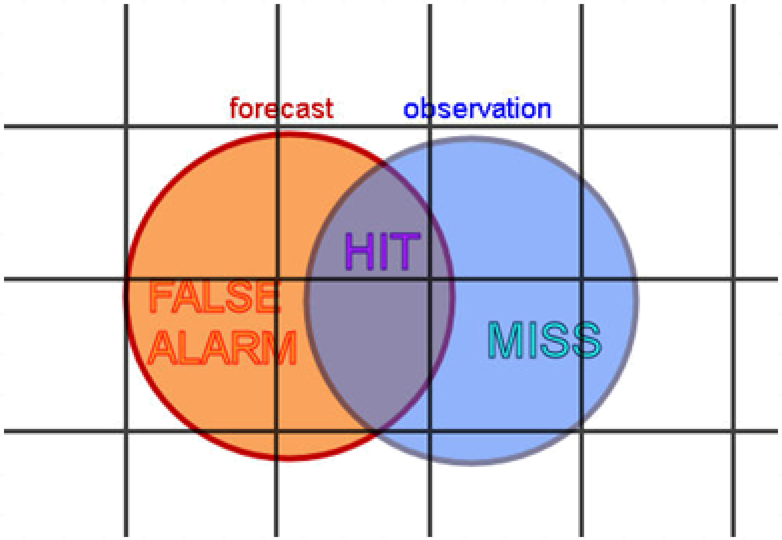
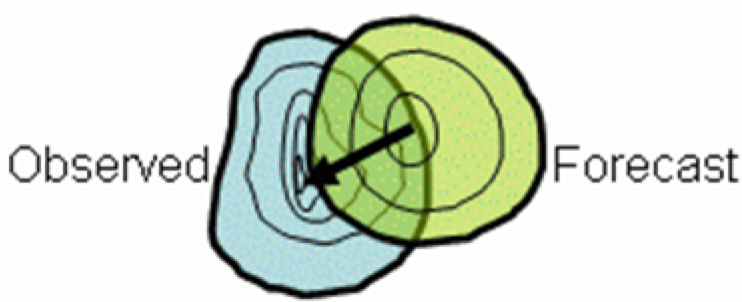
- The feature-oriented approach investigated in MesoVICT: the CRA analysis
- The ‘problem’: assessing the CRA sensitivity to model domain size and native resolution over a complex region
  - What about QPFs over complex terrain at convection-permitting resolution?
- Data: QPFs vs. observational analyses
- How the CRA is applied and tuned for this study
  - Advantages to perform an additional eyeball assessment of the results using the 2-D CRA shift analysing plot
- Conclusion and final findings





Double penalty effect:
the event is correctly simulated, but it is misplaced with respect to the original position.

The forecast is **penalized twice**:

- once for missing the event in the correct position; and
- once for producing a false alarm where the event is not observed.

The contiguous rain area analysis (**CRA**; Ebert and McBride 2000) is an feature-oriented technique based on a **pattern-matching** of two contiguous areas delimited by a chosen isohyet.

THE 'PROBLEM' ADDRESSED IN THE STUDY

Investigating how the variation of the model domain size and native resolution can affect the application of the CRA analysis on quantitative precipitation forecast (QPF) verification over the a complex terrain region, the MesoVICT area, characterized by the presence of the Alps (i.e., complex orography) and the Mediterranean Sea (i.e., lack of observations, coastlines).

Aim of the ISPRA work

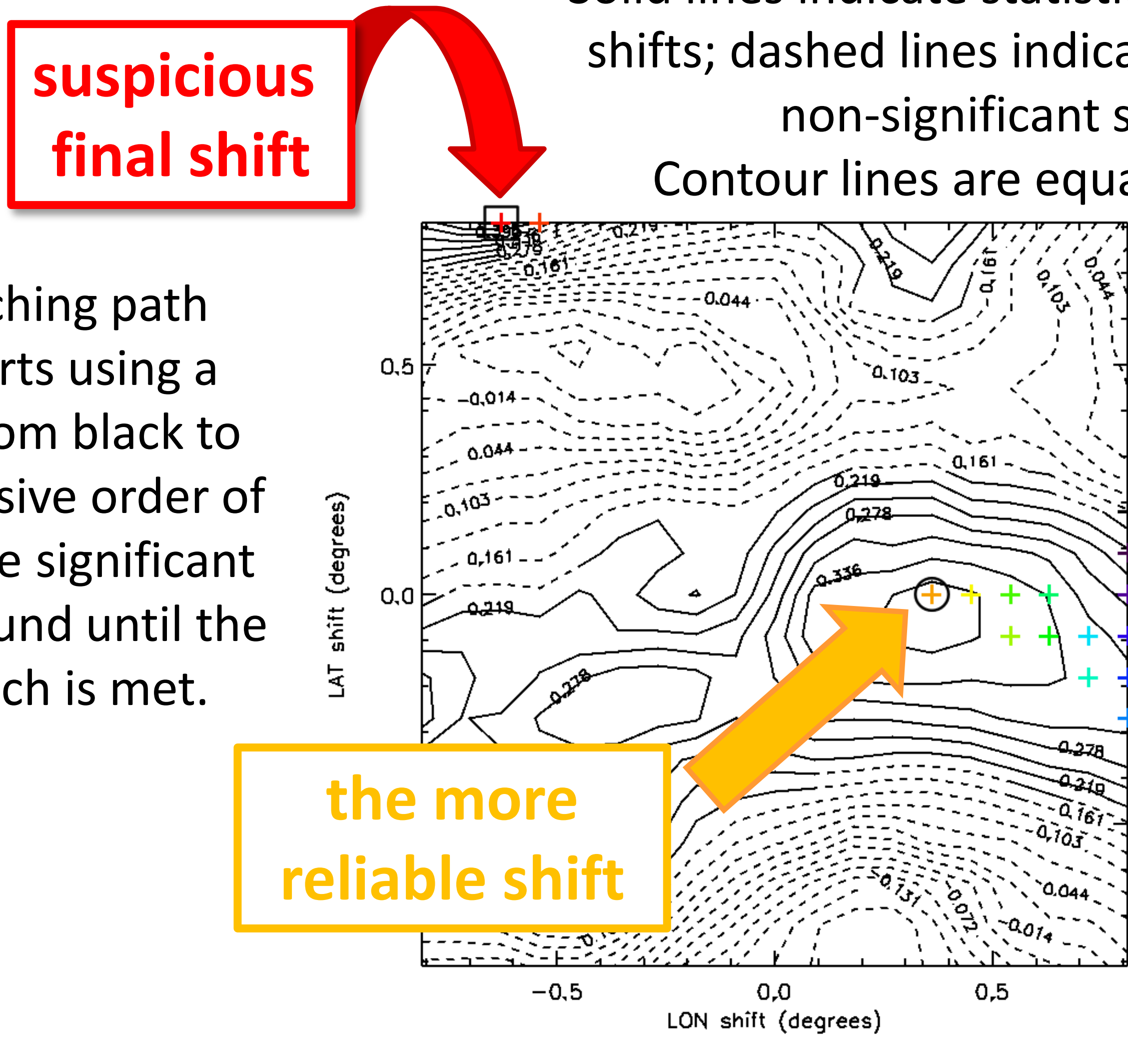
- Inter-comparing results obtained by using different NWP models (w. different spatial resolutions, different model domains, among others), different observational analysis and different verification domains.
- Verify whether the use of constraints and analysing tools is a mandatory requirement for the application of this feature-based approach over such a complex region.
- **Assessing pros and cons** in applying the CRA analysis to verify high-resolution deterministic QPFs, in particular at convection-permitting resolution.

CRA analysis (Ebert and McBride, 2000; Grams et al., 2006) using "traditional" pattern matching criteria (max CORR; min MSE) and imposing some additional checks/constraints

- Max **shifting value** (search distance): 15, 20, 30 grid points in both LON & LAT
- Check on **No. of effective grid points** (**N_{eff}**), i.e., the smaller N_{eff} is, the greater the min CORR is to have a statistical significant shift → considering only **statistical significant shifts**
- Check on % of precipitation out of the verification domain (**domain jumping**)
- Check on ratio between "max forecast after best shift" and "max forecast before the best shift"
- A (final) **eyeball comparison** by using the **2-D CRA analysis shift plot** to compare the "best pattern match" against the "intermediate matches" found during the CRA application (aka **CRA matching path**), obtained through minim. MSE or maxim. CORR, to **determine whether** the best pattern match found **is a correct, reasonable match or is an isolated result obtained by chance** that does not represent a realistic assessment of the forecast displacement error.

Solid lines indicate statistically significant shifts; dashed lines indicate statistically non-significant shifts.
Contour lines are equally spaced.

The CRA matching path (crosses) reports using a colour scale, from black to red, the progressive order of the intermediate significant best matches found until the final best match is met.



After Mariani and Casaioli, *Meteorologische Zeitschrift* , **27**, 2018

Case

- Case 1: 20-22 June 2007 – core case/mandatory
- Case 3: 25–28 September 2007 – core case
- Extra case: 22–25 November 2007 – tier 3 case

Field tested

QPFs – mapped over verification domains – from:

- COSMO-2 (@ 2.2 km) from MeteoSwiss
- GEM-LAM (@ 2.5 km) from Environment Canada
- BOLAM from ISPRA, with 3 low-res (@ 10 km) & 1 hi-res (@ 7.5 km) config.
- MOLOCH from ISPRA, with a higher-res (@ 2.5 km) non-hydrostatic config.

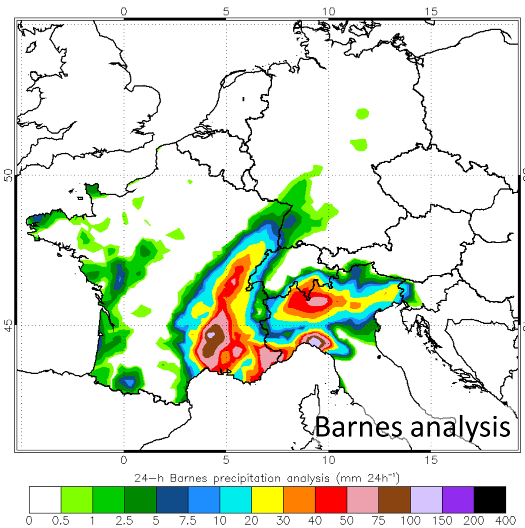
Observations (accumulated on a daily basis)

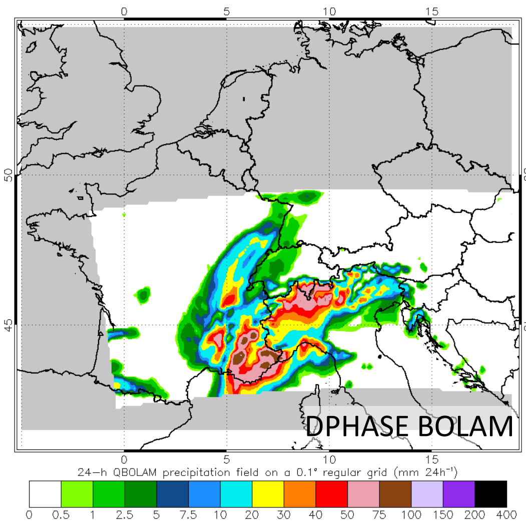
- VERA analysis @ 8 km
- Barnes objective analysis @ 10 km

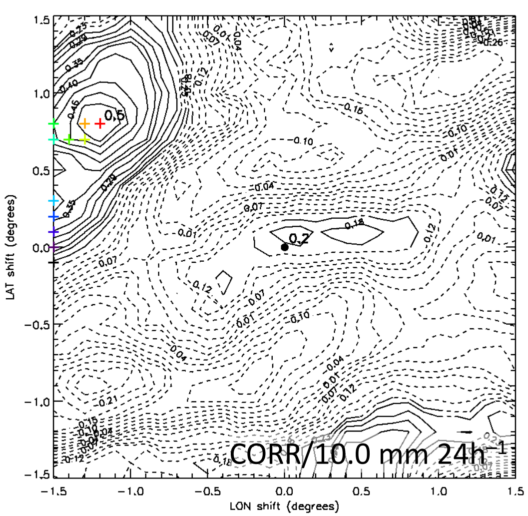
Rain rate contours

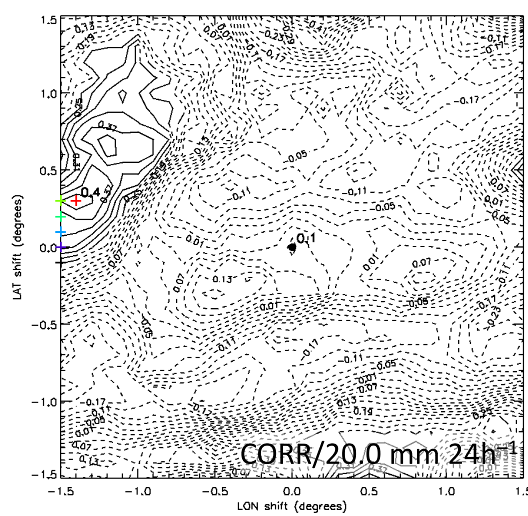
- 0.5, 5.0, 10.0 and 20.0 mm 24 h^{-1}

22 NOV 2007





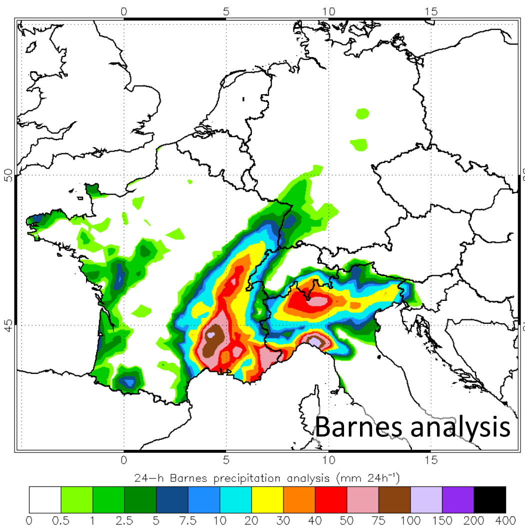


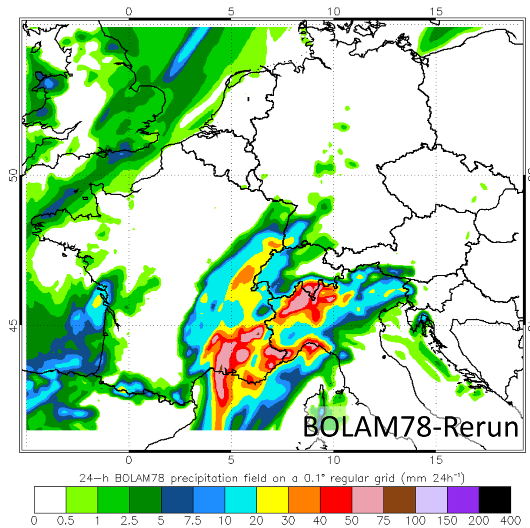


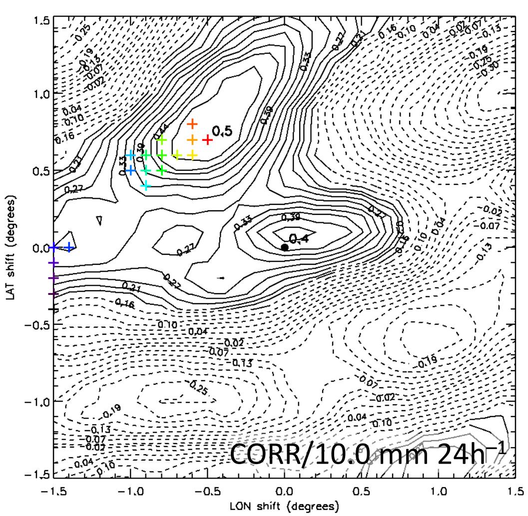
- ✓ Part of the precipitation feature is predicted over a data-void region.
- ✓ The best match found is driven by the match of the “marine” branch of the forecast band with the bulk of the precipitation observed over the Massif Central area
- ✓ This issue is emphasized by the under-prediction of the rainfall band over South-eastern France

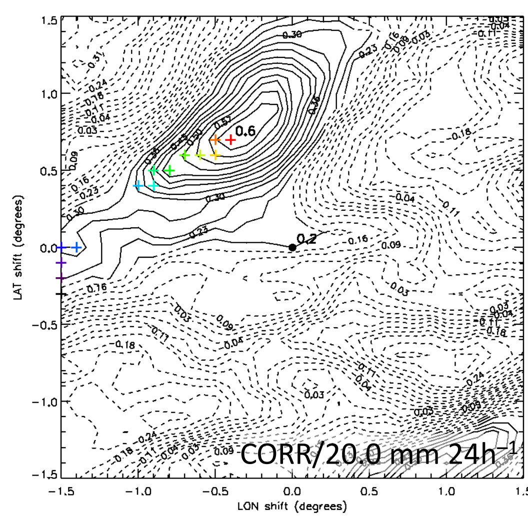
LACK OF OBSERVATIONS OVER THE MEDITERRANEAN SEA / MODEL DOMAIN OVER THE ENTIRE MESOVICT AREA

22 NOV 2007





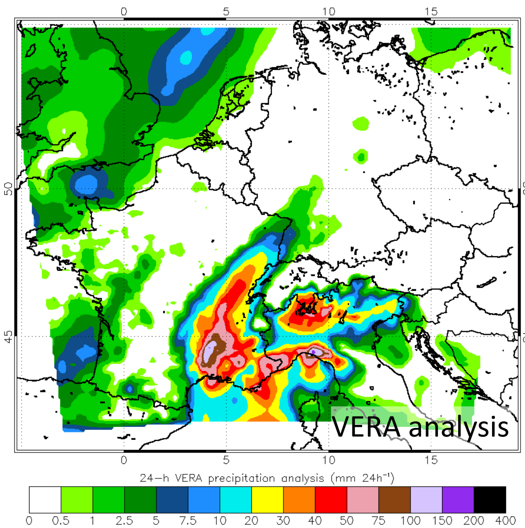


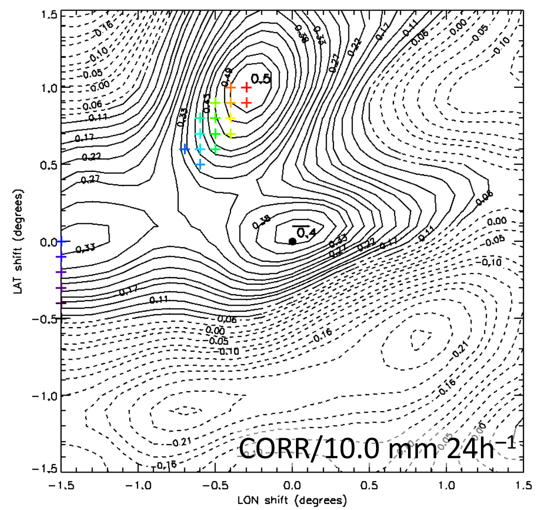


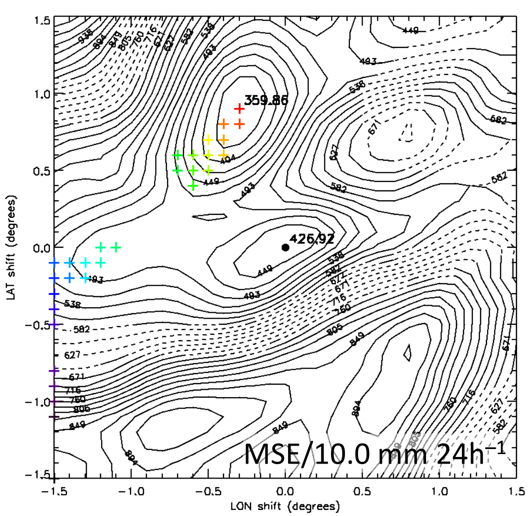
- ✓ The vector displacement is equal to [−0.5° E, 0.7°N] for the 10.0 mm 24 h^{-1} rain rate contour and [−0.4° E, 0.7°N] for the 20.0 mm 24 h^{-1} rain rate contour.
- ✓ Pattern error represents resp. around 75% and 50% of the total forecast error.
- ✓ The CORR value associated with the best match reaches about 0.5/0.6, depending on the rain rate contour considered.
- ✓ Increasing the maximum shifting value to 20 and 30 grid points, nonrealistic matches are instead obtained.

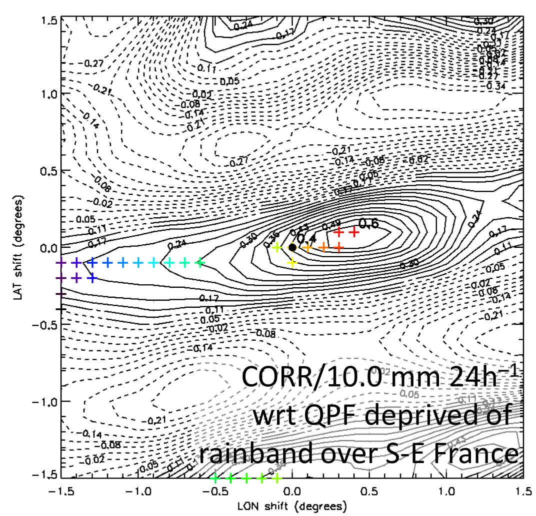
OBSERVATIONS OVER THE MEDITERRANEAN SEA (BOGUS STATIONS)/ MODEL DOMAIN OVER THE ENTIRE MESOVICT AREA

22 NOV 2007



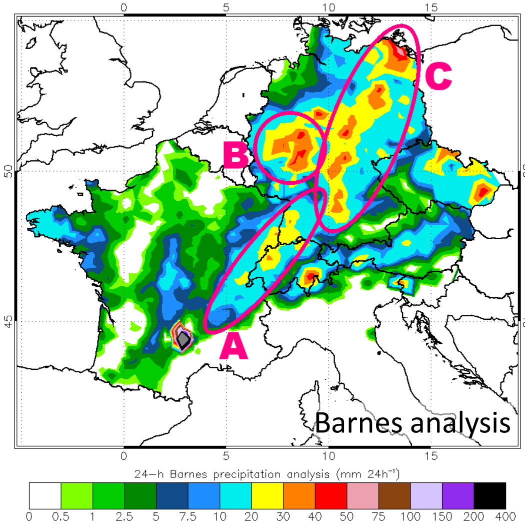


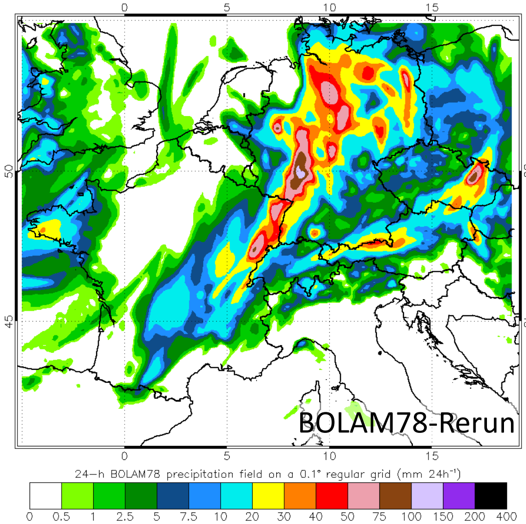


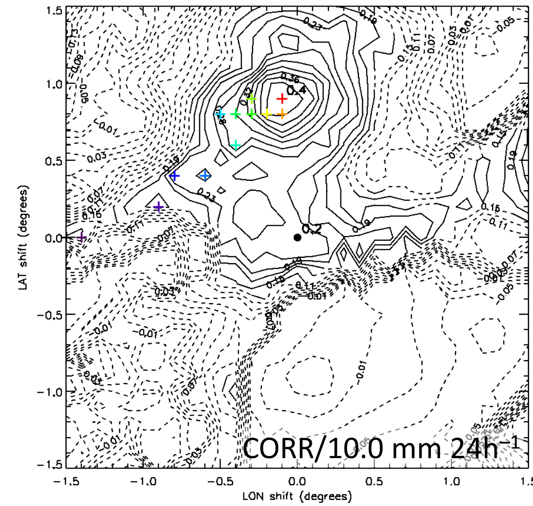


- ✓ The eyeball comparison between the VERA analysis and the BOLAM78 QPF highlights some differences, especially in terms of the position of the precipitation pattern over the MED Sea and, as expected, of the precipitation accumulation over S-E France.
- ✓ The suggested N-W shift of the forecast feature is not reliable: it implies a non-correct match against what was observed over N-W Italy and Switzerland.
- ✓ Why? **CRA uses translation but no distortion**.

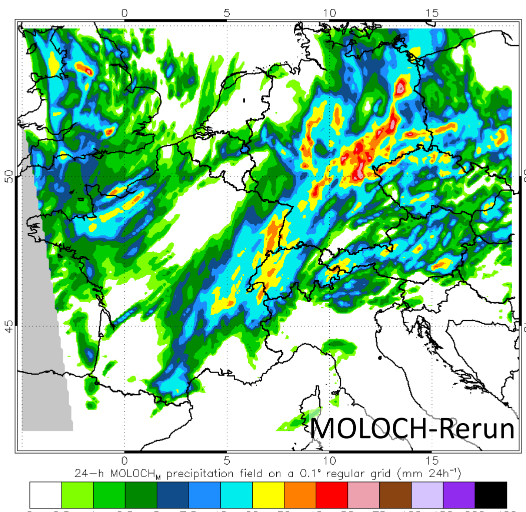
21 JUN 2007

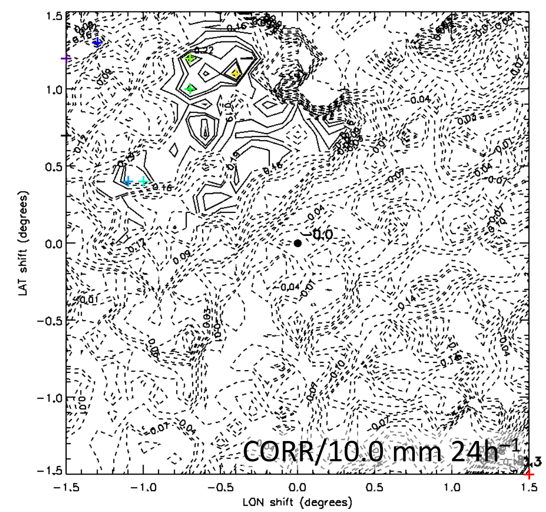




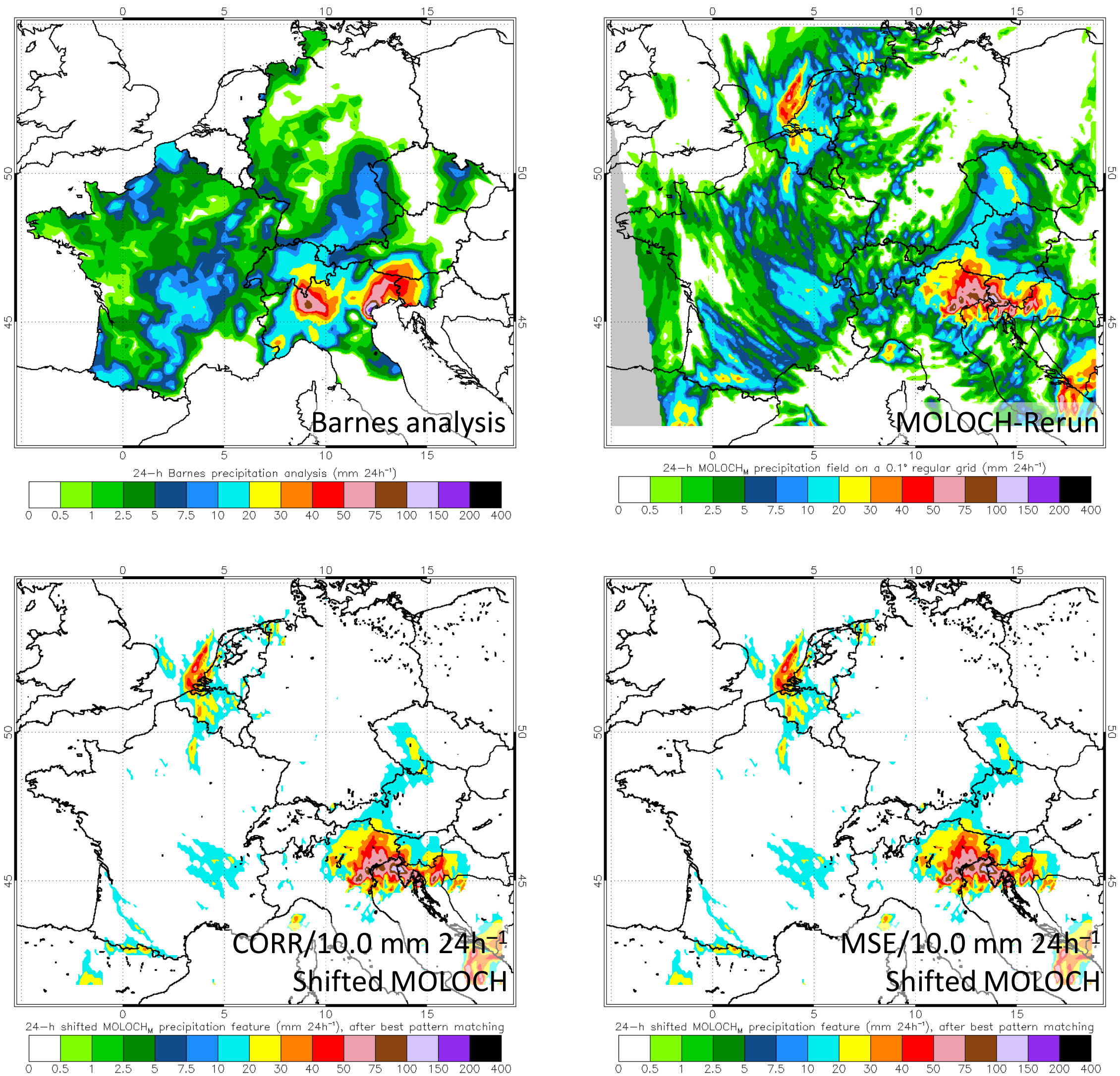


Both models provide a good forecast of the large-scale structure of the event, while differing in reproducing the single sub-structures and, as it is obvious, the rainfall small-scale details.
This has an impact on the CRA analysis.



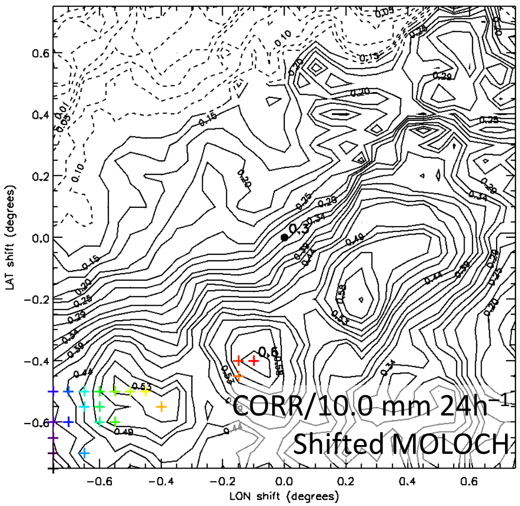


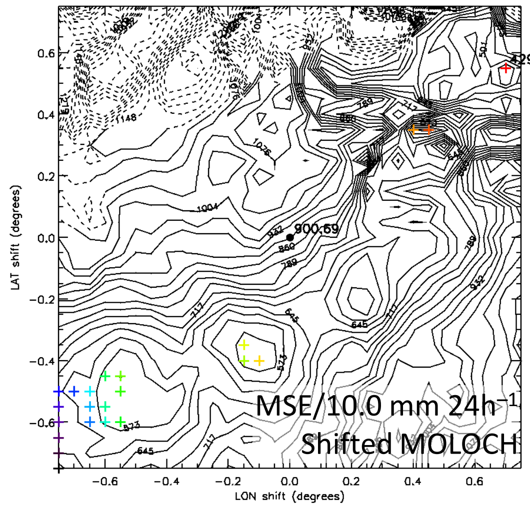
26 SEP 2007



In this case, increasing the model resolution does not introduce any additional issue about the CRA applicability. This is likely due to the lesser spatial complexity of the meteorological event under investigation.

26 SEP 2007



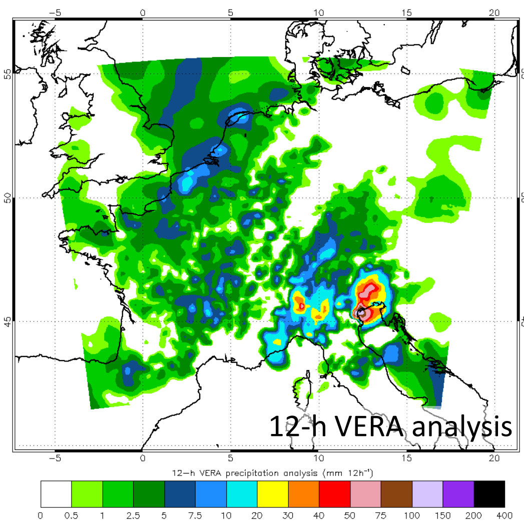


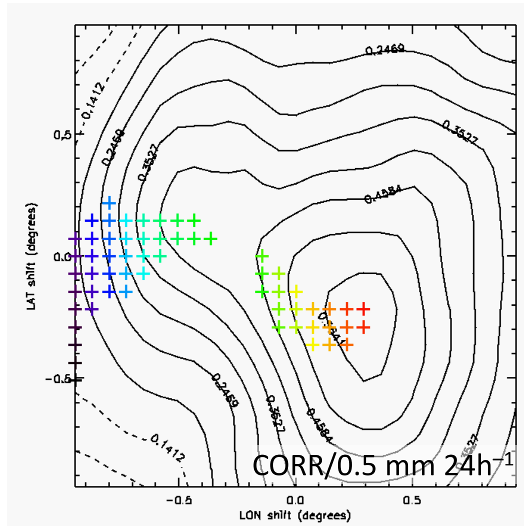
Results differ when the verification unsing the MSE-based CRA analysis is performed over the finer 0.05° grid.

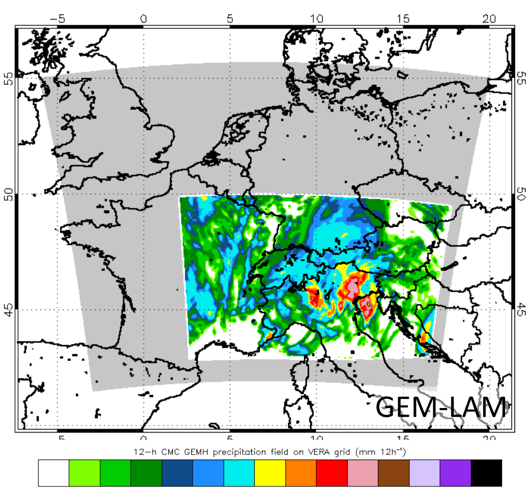
The result found with a CRA rain rate contour equal to both 10.0 mm 24 h^{-1} and 20.0 mm 24 h^{-1} suggests that the forecast feature has to be shifted north-eastward, that is [0.7° E, 0.55° N], to spatially match the observed feature.

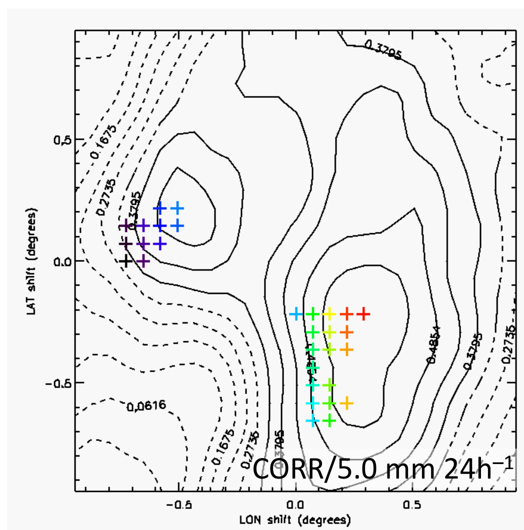
Visually, this result is less realistic: in particular, the resulting shifted forecast predicts high precipitation (≥ 50.0 mm 24 h^{-1}) over Southern-central Austria, in a region where it did not occur.

26 SEP 2007, 1800 UTC



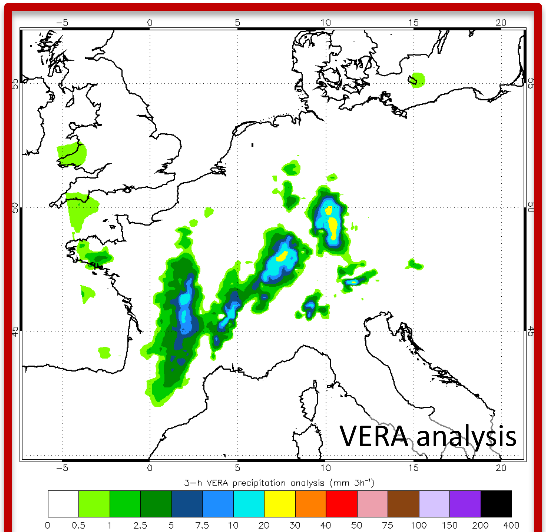


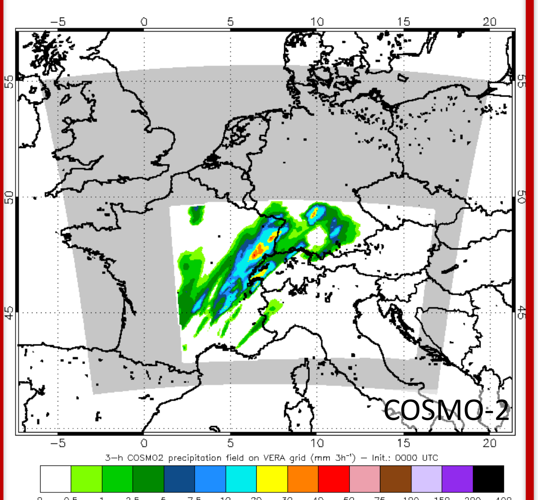


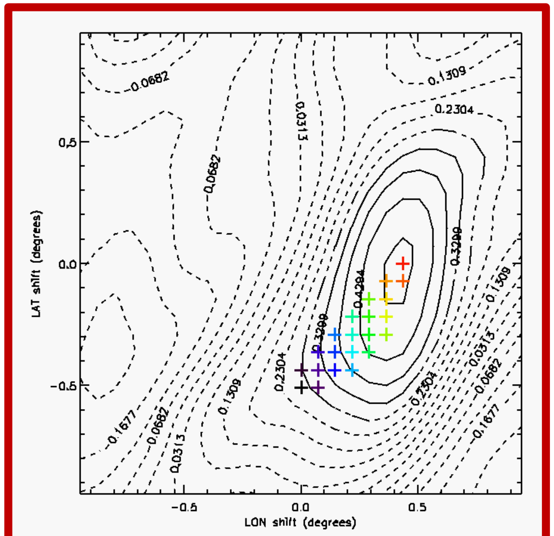


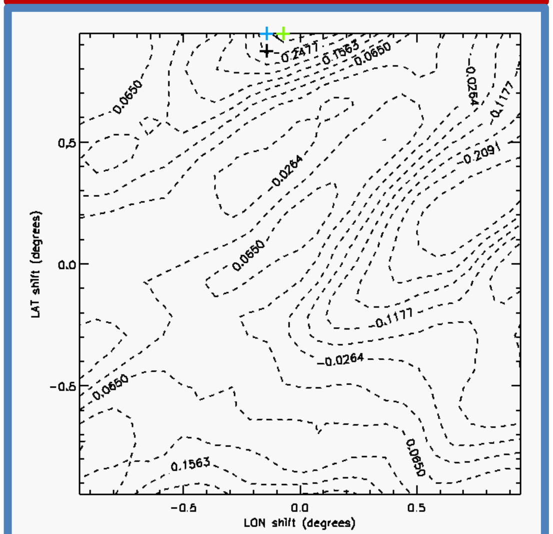
…AND WHEN QPF ARE VERIFIED ON A SHORTER TIME SCALE?

21 JUN 2007, 0300 UTC

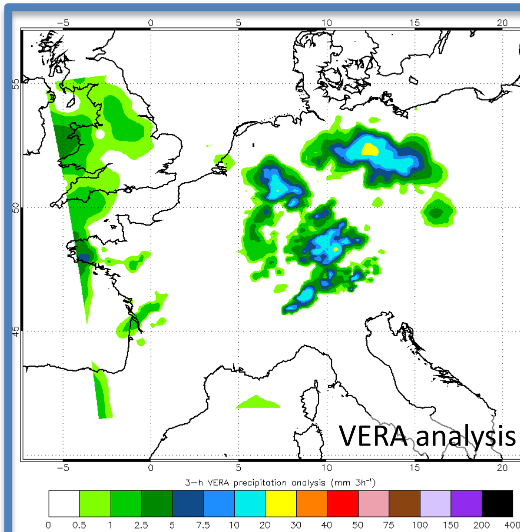


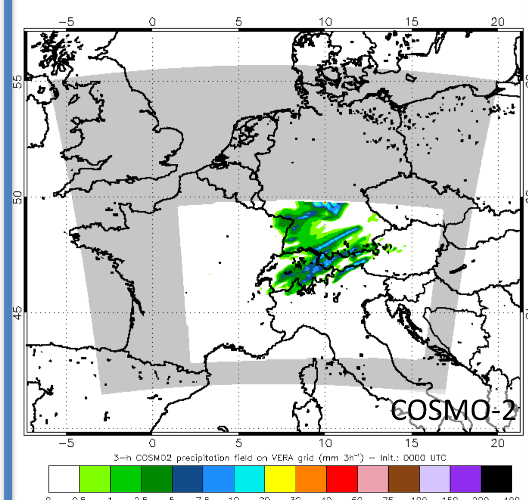






21 JUN 2007, 1200 UTC





Conclusions 1/2

- ✓ The CRA analysis has the **advantage of easily provide information on forecast error**, but **its unsupervised use might produce misleading results**.
- ✓ Some care has to be taken when evaluating the best matches achieved with the CRA analysis to distinguish reliable results from the suspicious, unphysical ones.
- ✓ **Quality checks to assess the statistically significance of the results** as a function of the No. of verification grid points **could be effective** (but non always sufficient) **to detect non-realistic pattern matches** and, in some case, to correct them.
- ✓ It is **highly suggested using a tool like the 2-D CRA shift analysis plot**. This plot, together with the CRA matching path, turns out to be useful to correctly evaluate the diagnosed spatial forecast errors. This is **particularly true when evaluating deterministic QPFs over complex terrain at convection-permitting resolution**.
- ✓ The CRA analysis is **sensitive to the model resolution** and it is found to be strongly dependant on the event and its physical characteristic.
- ✓ **For the spatial verification of the higher-res. QPFs, it could be also useful to apply an iterative approach**: the CRA analysis could be first applied over a coarse grid to get close to the right best pattern match – identifying this way a first guess of the best match; then a comparison over a finer resolution grid could be performed to refine the match.

CONCLUSIONS 2/2

- ✓ Results confirms that CRA tends to provide **more robust and reliable results when using the CORR maximization as pattern matching criterion**.
- ✓ **Min MSE should be avoid** or used in conjunction with either max CORR or other additional constraints or check (e.g., % of grid points out of the verif. domain), to discriminate the CRA results.
- ✓ **Results can be influenced by the difference in resolution** (spatial scales resolved) between observation and forecast fields, even if comparison is performed on a coarser verification grid, especially when considering higher entity threshold and/or convective events.
- ✓ **Verification at short accumulation time could be problematic** since either entities are defined over a reduced number of grid points or results are associated to erroneously matches.
- ✓ **The CRA could be sensitive to lack of information in the observed entity** (e.g., over MED) **and/or in the forecast entity** (e.g., when the rainfall band under investigation is partially observed outside the model domain), since it could be conditioned by the "domain jumping" issue.

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THANKS FOR YOUR KIND ATTENTION!

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