SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	2018
Project Title:	Development of a perturbation strategy for convection-permitting ensemble forecasting over Italy
Computer Project Account:	spitconv
Principal Investigator(s):	Chiara Marsigli
Affiliation:	Arpae SIMC, Bologna, Italy
Name of ECMWF scientist(s) collaborating to the project (if applicable)	………………………………………………………………..…… ………………………………………………………………..……
Start date of the project:	01/01/2016
Expected end date:	31/12/2018

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Previous year		**Current year**	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	5,500,000	5,722,234	3,000,000	728,229
Data storage capacity	(Gbytes)	200	500	200	100

Summary of project objectives

(10 lines max)

The aim of this project is to develop a complete perturbation strategy for the convention-permitting ensemble over Italy based on the COSMO model (COSMO-2I-EPS, called COSMO-IT-EPS in the experimental phase). This project represents the third step of a work which has been performed thanks to previous the SPITCONV Special Project (2010-2012 and 2013-2015).
The third phase (2016-2018, this SP) is aimed at:
1) further developing the use of the LETKF scheme for providing perturbed Initial Conditions to the ensemble
2) testing the combination of the different perturbations which are being developed in COSMO (physics and soil).
The ensemble is now pre-operational at Arpae, on Supercomputing resources of CINECA.
The tests for the further developments and upgrades of the system will be carried out on ECMWF resources, thanks to this SP and to Italian resources.

Summary of problems encountered (if any)

(20 lines max)

-

Summary of results of the current year (from July of previous year to June of current year)

This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project

Summary.

During this reporting period (second half of 2017 and first half of 2018) the work has focused on further testing Initial Conditions to the COSMO-2I-EPS ensemble provided by a KENDA-based data assimilation system for thunderstorm events over Italy and to further testing the physics perturbations in the COSMO model:
- test of KENDA with COSMO-ME-EPS Boundary Conditions
- test of COSMO-2I-EPS ensemble with KENDA IC
- test of COSMO-2I-EPS ensemble with Parameter Perturbations

The testing period chosen was from 19th of June 2018 to 6th of July 2018, when several thunderstorms has interested different areas of Italy.
The SBUs provided by the SPITCONV SP for these tests have been complemented by those provided by the SPITSREP SP (see the correspondent final report).

Set-up of the experiments.

The experiments object of this Project were run on a period of summer 2016 selected for the occurrence of several thunderstorms on different areas of the Italian peninsula and over the Alps.

- Period: 19th of June 2018 to 6th of July 2018
- Runs only of the days with thunderstorms somewhere in the domain (Italy)
- Starting day of the runs (8 events):
  - 19/06 (Central Italy, Apennines)
  - 20/06 (Marche region)
  - 23/06 (south-east Italy, Basilicata-Puglia region)
  - 25/06 (Piemonte region)
  - 26/06 (north-east Italy, Friuli region)

- 02/07 (northern Italy, Alps)
- 05/07 ()
- 06/07 ()

- Each day a run of the ensemble was started at 00 UTC, for 48 h.

The domain of the COSMO-2I-EPS ensemble is shown in Figure 1.

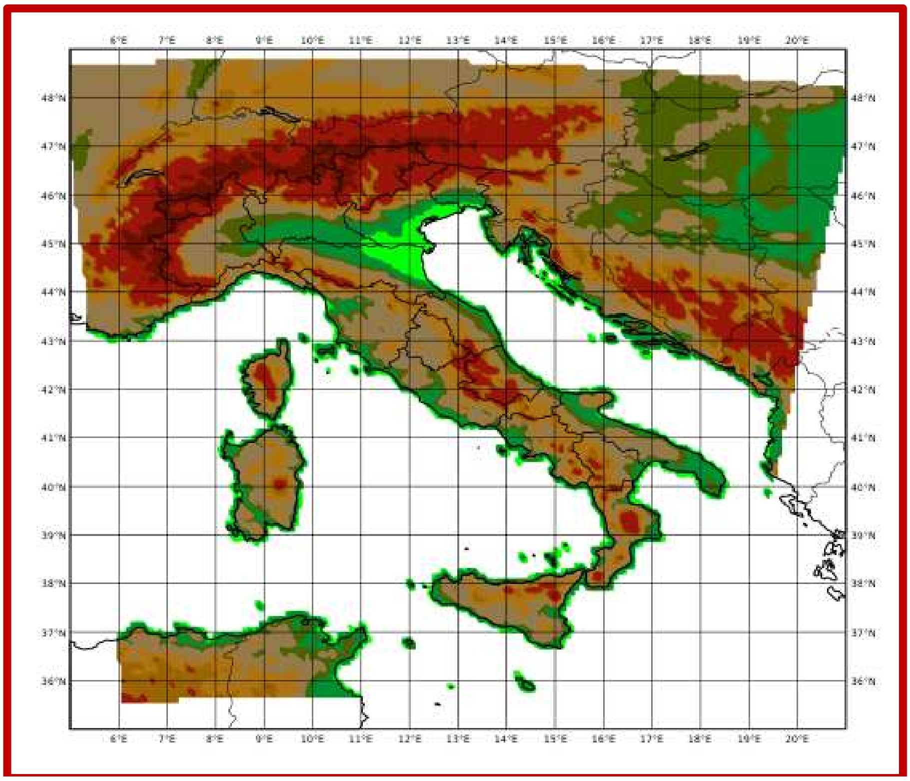

Figure 1. Orography of the COSMO model at 2.2 km resolution, on the domain of the COSMO-2I-EPS ensemble.

In all the experiments the COSMO model has been run over this domain, with an horizontal resolution of **2.2 km** and **65 levels** in the vertical. The COSMO model is run in the convection-permitting scale and the parametrisation of the deep convection is switched off.
The COSMO-2I-EPS has now in its pre-operational configuration 20 members, but in the experiments it had only **10 members**.
In all the experiments here reported the Boundary Conditions to the 10 runs were provided by the first 10 members of the COSMO-ME-EPS ensemble of COMET, a 10-km ensemble over the Mediterranean area with ICs provided by an ensemble data assimilation system based on LETKF operated also by COMET.

The COSMO-2I-EPS ensemble was run in 3 different configurations:

- **noPP**: Downscaling from COSMO-ME-EPS, no physics perturbations
- **PP**: Downscaling from COSMO-ME-EPS, physics perturbations (Parameter Perturbation)
- **kendaIC_PP**: Initial conditions from the KENDA analyses, physics perturbations (Parameter Perturbation)

KENDA is a data assimilation scheme based on the LETKF approach, developed in the COSMO Consortium and implemented by Arpae-SIMC on the ECMWF computing facilities.
In order to have the initial conditions from the KENDA analyses, a KENDA cycle has also been run, with 20 members and 3-hourly cycles. Conventional observations (SYNOP, TEMP, AIREP) have been assimilated, together with a Latent Heat Nudging of the surface rain rate estimated by the Italian radar network. A scheme of the KENDA cycle is shown in Figure 2, while the Italian radar network is shown in Figure 3.

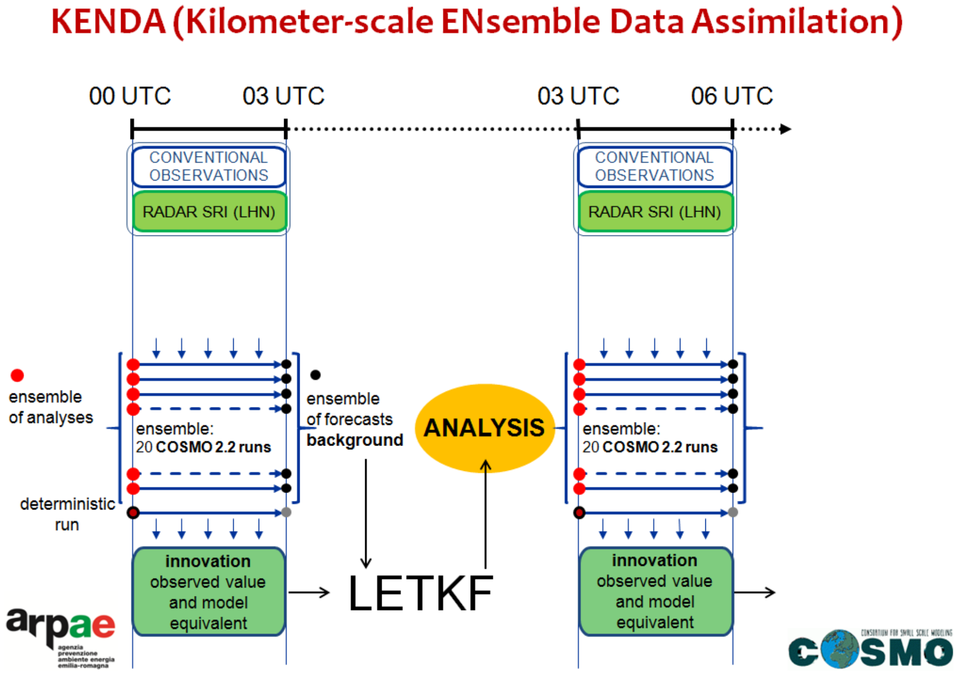

Figure 2. Schematic representation of the KENDA ensemble data assimilation cycle.

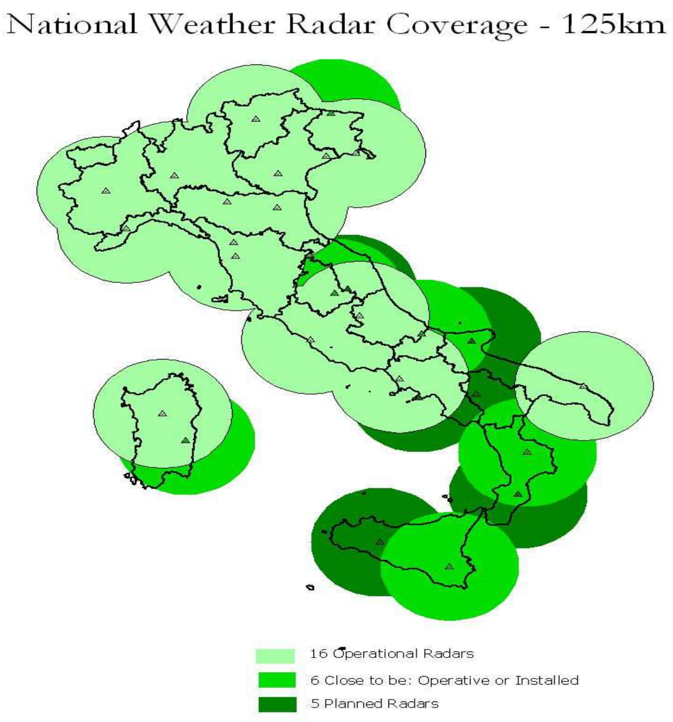

Figure 3. Italian radar network.

The assimilation has been run from 19th of June 2018 at 00 UTC to 8th of July 2018 at 00 UTC.

Evaluation of the results.

The main issues subjected to evaluation are:

- test of KENDA with COSMO-ME-EPS Boundary Conditions

- test of COSMO-2I-EPS ensemble with KENDA IC
- test of COSMO-2I-EPS ensemble with Parameter Perturbations

In order to show how the selected perturbations influence the performance of the ensemble in the prediction of the thunderstorms, COSMO-2I-EPS with only parameter perturbations (**PP** exp) and with also KENDA Initial Conditions (**kendaIC_PP** exp) are compared.

The comparison is carried out both as examination of single cases and as statistical evaluation over the entire set of cases. In this way, also the performance of the ensemble data assimilation is evaluated, indirectly, through the quality of the forecast initialized with the KENDA Analyses.

An objective verification of the quality of the precipitation forecasted by the ensemble is carried out by comparing the forecasts with observations from two different sources: against data recorder by a dense raingauge network and against precipitation estimated by radar and then adjusted with the raingauge data. Both sets of data cover the entire Italian territory.

Precipitation is considered as accumulated over 6 hour periods. The verification method is a simple spatial verification method called DIST (Marsigli et al, 2008). According to this method, the verification domain is first covered with boxes of selected size (here 0.2 x 0.2 deg). Then both forecasts (each ensemble member separately) and observations are aggregated in each box, by computing the average or the maximum (or other parameters of the precipitation distribution). Finally, common probabilistic verification scores are computed for both the average and maximum values belonging to each box and aggregated over the whole domain.

In Figure 4, the Brier Skill Score (left column) and the ROC area (right column) are computed for average precipitation over each box exceeding 1 mm in 6 h (top row) and for maximum precipitation over each box exceeding 5 mm in 6 h (bottom row). The scores are shown as a function of the forecast range.

Forecasts are compared with precipitation estimated from the Italian radar network and adjusted with the raingauge values of the Italian network.

In each panel, **kendaIC_PP** experiment (red line) is compared against **PP** experiment (black line).

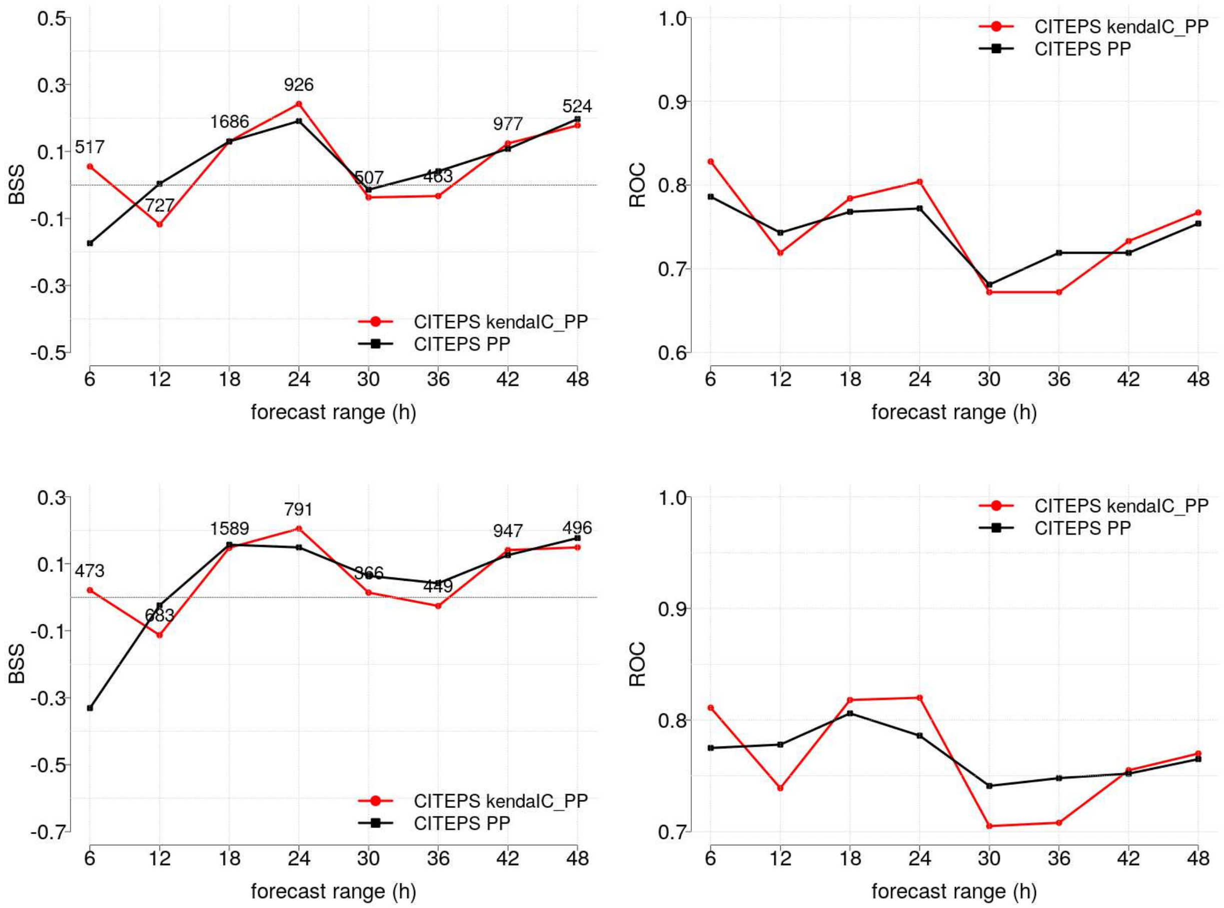

Figure 4. Brier Skill Score (left column) and the ROC area (right column) for average precipitation over each box exceeding 1 mm in 6 h (top row) and for maximum precipitation over each box exceeding 5 mm in 6 h (bottom row), computed against precipitation estimated from the Italian radar network, adjusted with raingauge values.

Forecasts are compared with precipitation estimated from the Italian radar network and adjusted with the raingauge values of the Italian network.

In all the plots is particularly evident the gain in skill in the first 6 hours of forecast determined by the use of Initial Conditions from the KENDA assimilation cycle.

Generally, scores are not very high, showing the difficulty of forecasting thunderstorm events at high resolution (the verification boxes are of the order of 20 x 20 km).

In order to show the quality of the ensemble members and how this is affected by the different initial conditions, a deterministic verification of the individual members is presented in Figure 5.

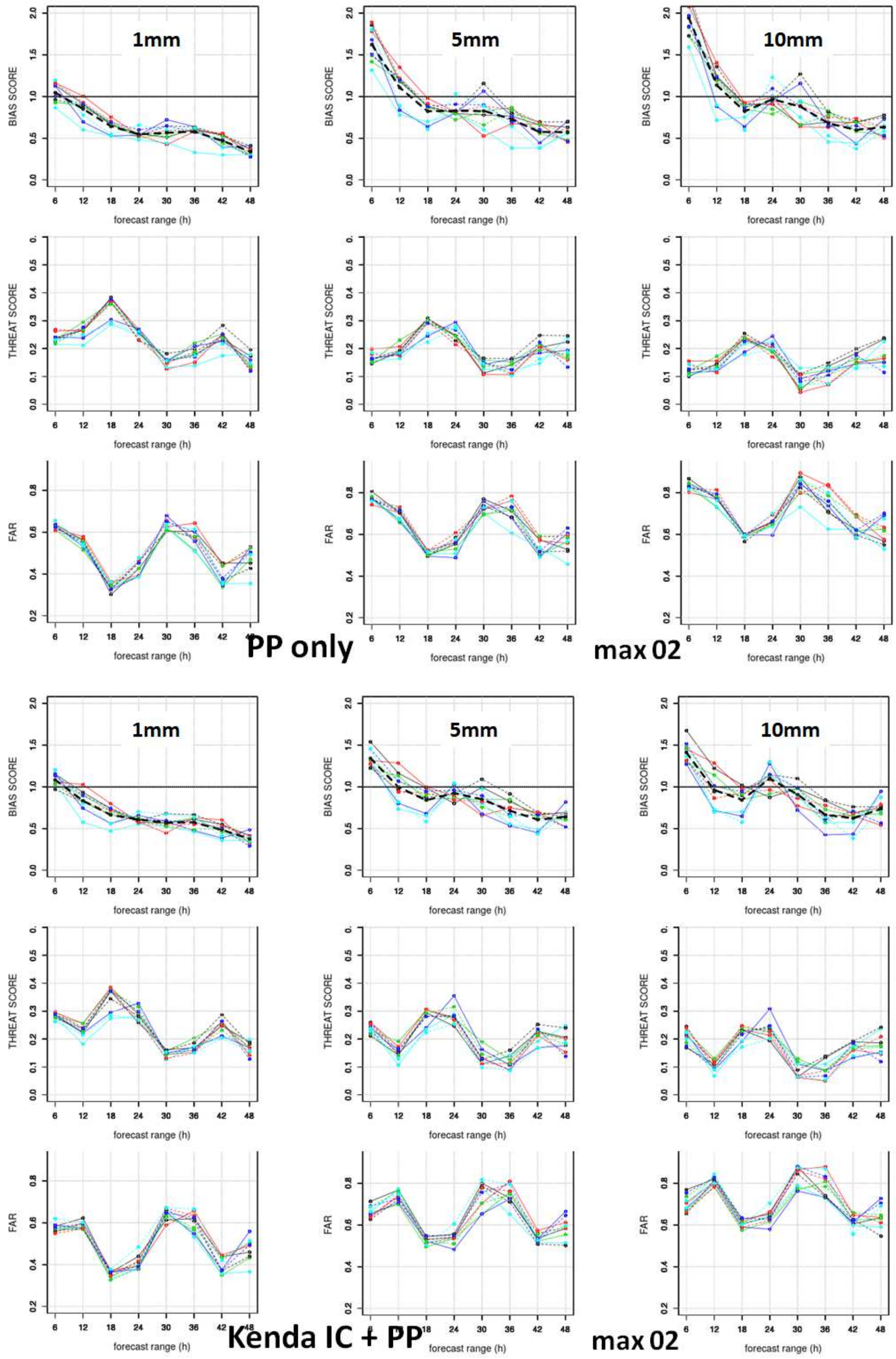

Figure 5. Frequency Bias (top row), Threat Score (middle row) and False Alarm Rate (bottom row) for the maxiumum precipitation over each box exceeding 1 mm in 6 h (left column), 5 mm in 6 h (central column) and 10 mm in 6 h (right row), computed against adjusted radar data for the PP (upper panels) and kendaIC_PP (lower panels) experiments.

The Frequency Bias indicates that the precipitation is generally underestimated by the ensembles, particularly the lower threshold. It is interesting to notice that instead precipitation is overestimated for the first 6 hours for the 5 and 10 mm thresholds and that this bias is partly cured by the Initial Conditions from the KENDA analysis cycle. The other two scores do not vary much between the two ensemble configurations, with the exception of the first 6 hours as already noticed.

In order to provide a clearer indication of what kind of events the 2.2 km ensemble is able to forecast in presence of thunderstorms, probability maps for selected cases are also shown.

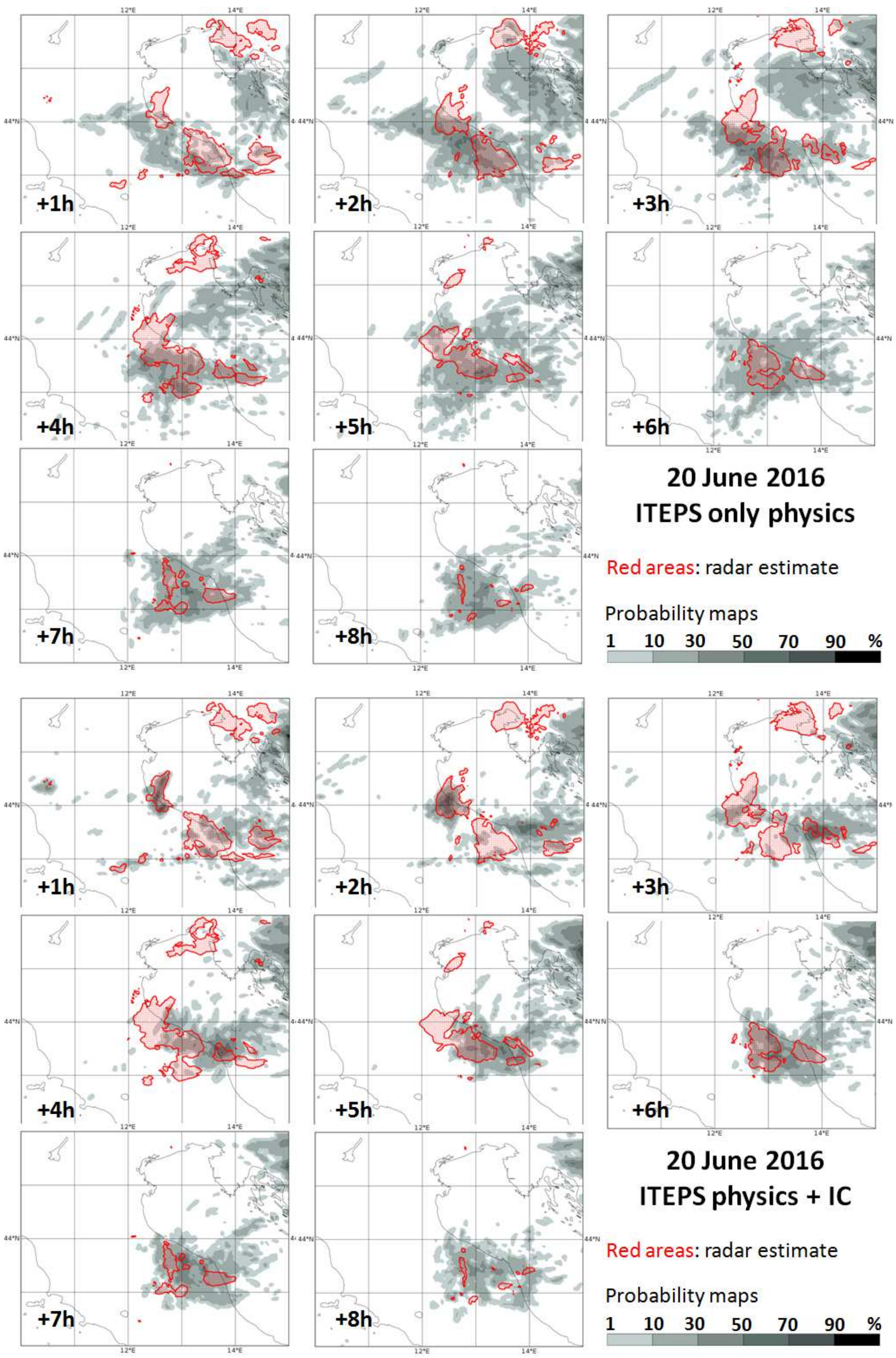

Figure 6. Probability maps (gray shaded) of precipitation exceeding 5 mm/1h generated by the ensemble, relative to the PP (upper panels) and kendaIC_PP (lower panels) experiments, and filled contours (red areas) of precipitation estimated by radar exceeding 1mm/1h for the event of the 20th of June 2018, first 8 hours.

Inspecting figure 6, where the probability of precipitation exceeding 5 mm in 1 hour as forecasted by the ensemble in the two different configurations (PP and kendaIC_PP) is plotted against the contour relative to the precipitation exceeding 1mm in 1 hour as estimated by the radar network, it is possible to see that indeed the 2.2 km ensemble is generally able to indicated the probable occurrence of thunderstorms in the area where it was occurred. The level of spatial agreement between the forecast, issued in terms of probability and hence not really suitable for a 1 to 1 comparison with observations, is shown by the match or mismatch between the gray shaded areas and the red area.

In this kind of evaluation, little can be said about the accuracy of the forecast of the precipitation amount, since the focus has been put on the capability of the ensemble to issue a forecast of thunderstorm at all, as a valuable tool to assist the forecasters in their daily task. On top, the level of spatial agreement or disagreement is what the forecaster should keep in mind for a profitable usage of the information provided by the ensemble. It is underlined that the different thresholds chosen for the probabilities and for the radar contouring are selected on purpose in order to take into account the detected tendency of the radar estimate to underestimate the precipitation (in analogy with what is done in a verification based on thresholds defined as percentiles instead of values).

Considering the first 2-3 hours of forecast, it is evident that the data assimilation at 2.2 km with the KENDA cycle is able to provide initial conditions which greatly improve the position of the precipitation at the beginning of the forecast. This is believed to be due largely to the Latent Heat Nudging which is applied to each member of the KENDA ensemble, which had proven to increase the skill of the precipitation in the first few hours of the forecast. In this case, the forecast by the kendaIC_PP ensemble remains better than the PP one for the entire period shown.

As a second example, the same plots for the event of the 2nd of July are shown in Figure 7. Also for this event, where thunderstorms developed from the first hours of the day over different parts of the Alps, it is possible to see that the ensemble is able to indicate the occurrence of thunderstorms approximately in the correct areas. On top, the positive impact of the KENDA Initial Conditions is visible in the first hours, when the signal has a very good localization.

Also in this case the better performance of the kendaIC_PP ensemble is persistent over the entire period considered.

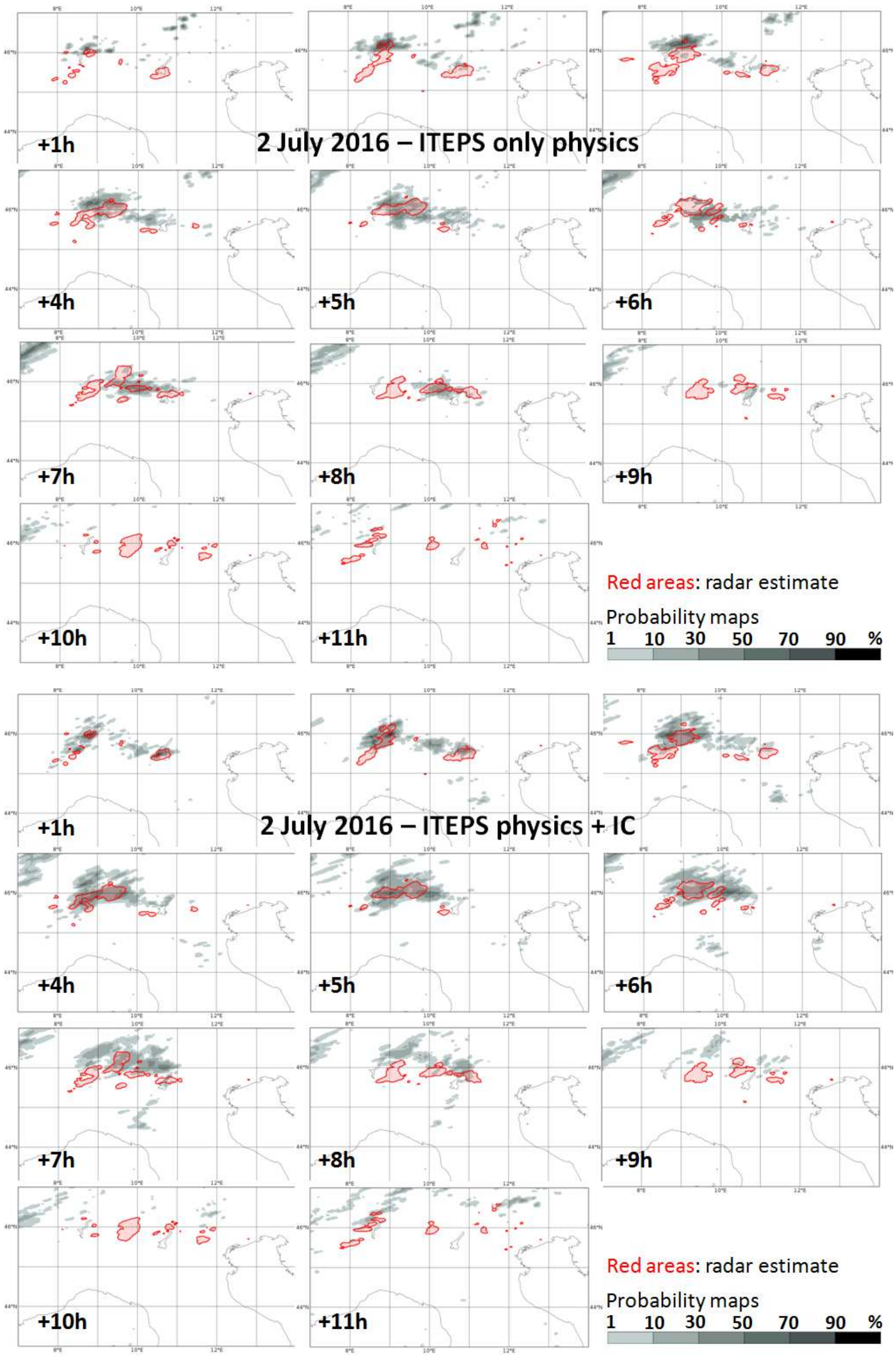

Figure 7. Probability maps (gray shaded) of precipitation exceeding 5 mm/1h generated by the ensemble, relative to the PP (upper panels) and kendaIC_PP (lower panels) experiments, and filled contours (red areas) of precipitation estimated by radar exceeding 1mm/1h for the event of the 2nd of July 2018, first 11 hours.

List of publications/reports from the project with complete references

Summary of plans for the continuation of the project

In order to complete this phase of the SPITCONV Special Project, verification of the prediction of thunderstorms will be performed also with spatial / object based methods.
In terms of the runs to be performed, it will be further studied the impact of physics perturbations.
On top, a different phenomenology will be studied, by selecting different events over which to repeat the run of the ensembles, including cases of fog.