

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 2011

Project Title: Limited Area Ensemble Kalman Filter

Computer Project Account: SPITLEKF

Principal Investigator(s): Lucio TORRISI, Francesca MARCUCCI

Affiliation: CNMCA - Italian Met. Service

Name of ECMWF scientist(s) collaborating to the project (if applicable) Massimo BONAVITA

Start date of the project: 2007

Expected end date: 2011

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)	1500000	100%	2500000	36%
Data storage capacity	(Gbytes)				

Summary of project objectives

(10 lines max)

The SPITLEKF main goal is to investigate methodologies to improve analysis and forecast skill of operational limited area NWP models through the use of an ensemble data assimilation algorithm based on a variation of the Ensemble Kalman Filter approach (LETKF). This is an important current research topic in meteorology and many competing approaches are currently under study and experimentation.

Summary of problems encountered (if any)

(20 lines max)

No real problem was encountered, neither technical nor conceptual.

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

A data assimilation algorithm based on the LETKF approach (Hunt *et al.*, 2007) has been implemented and tested in the CNMCA NWP suite.

An a-posteriori perspective has been assumed as regards the treatment of random model error. A combination of additive and adaptively-varying multiplicative covariance inflation techniques is used. This methodology seems effective and, most notably for operational applications, is able to avoid filter divergence and instability. Model uncertainty representation through a stochastic physics scheme (Buizza *et al.*, 1999; Palmer *et al.*, 2009) has been also implemented in the prognostic model in a preliminary version, but it was recently switched off. Sea surface temperature perturbations derived from randomly selected, scaled consecutive analysis differences has been daily inserted.

Using the project resources two multiplicative inflation techniques have been tested:

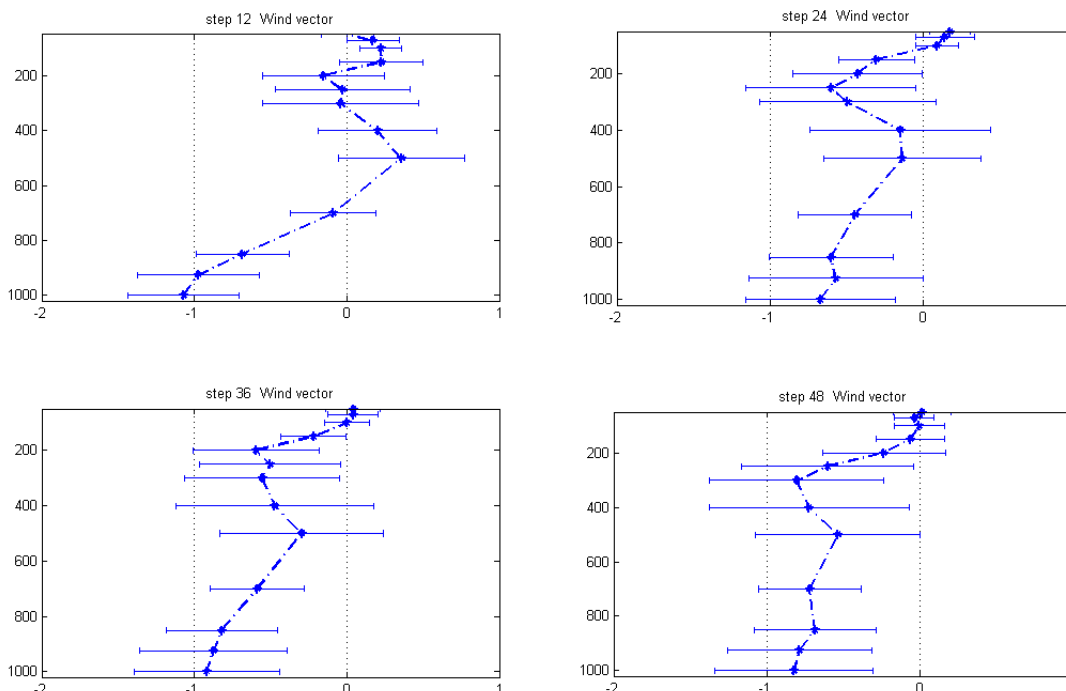
- 3D Adaptive Multiplicative Inflation with temporal smoothing according to Li *et al.* (2009) acting on background perturbations

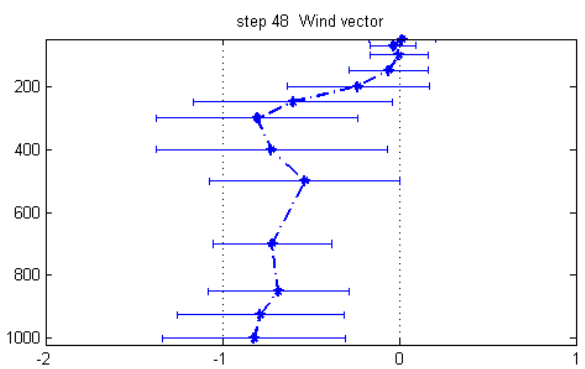
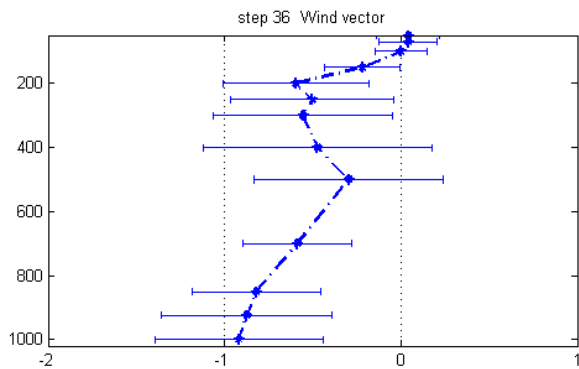
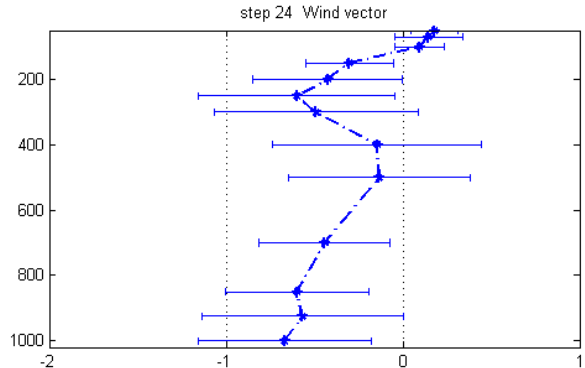
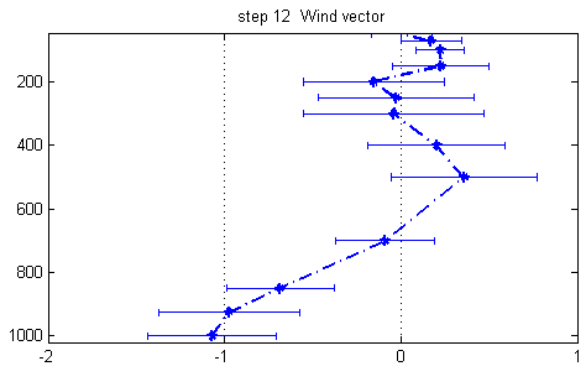
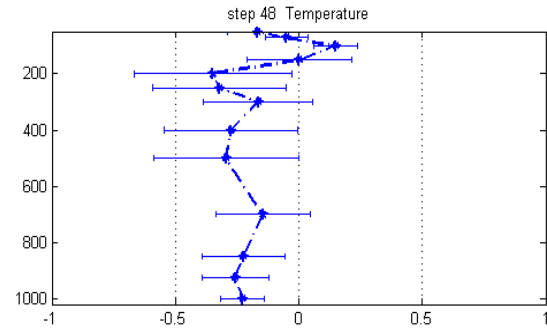
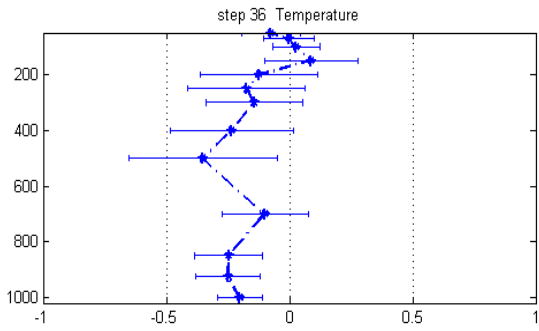
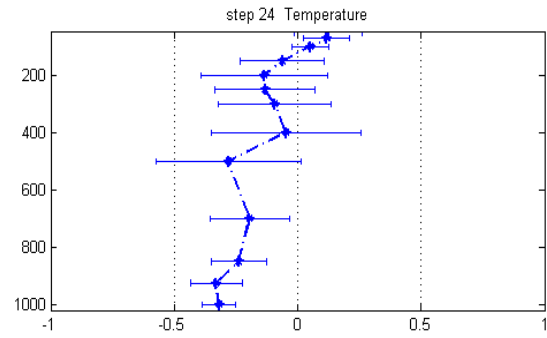
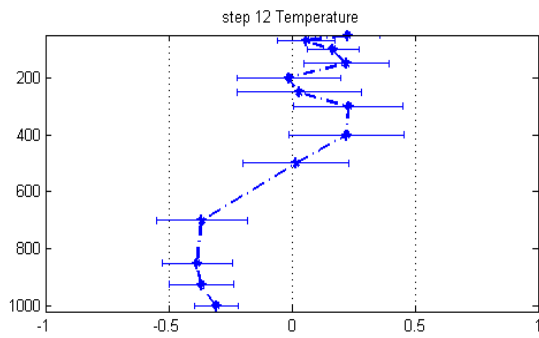
$$\mathbf{x}_i^b \leftarrow r \left(\mathbf{x}_i^b - \bar{\mathbf{x}}_i^b \right) + \bar{\mathbf{x}}_i^b \qquad r = \frac{\mathbf{d}_{o-b}^T \mathbf{d}_{o-b} - Tr(\mathbf{R})}{Tr(\mathbf{H} \mathbf{P}^b \mathbf{H})} \qquad \mathbf{d}_{o-b} \text{ Innovation vector}$$

- State Dependent Covariance Inflation according to Whitaker and Hamill (2010) acting on analysis perturbations

$$\mathbf{x}'_a = \mathbf{x}'_a \sqrt{\alpha \frac{\sigma_b^2 - \sigma_a^2}{\sigma_b^2} + 1}$$

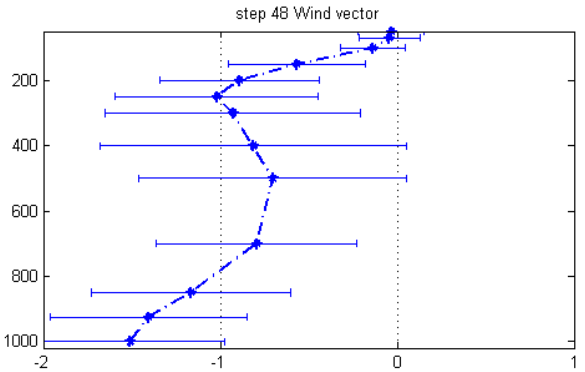
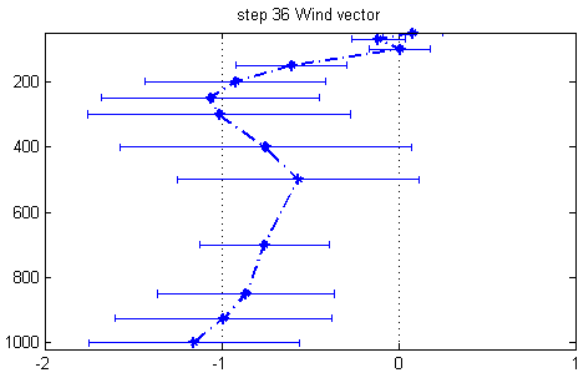
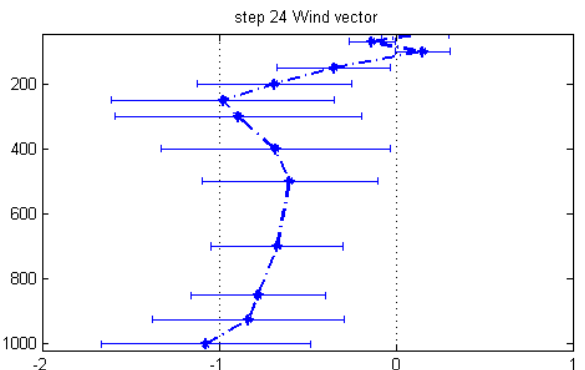
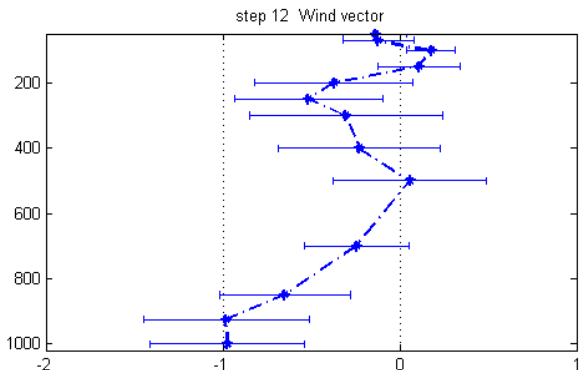
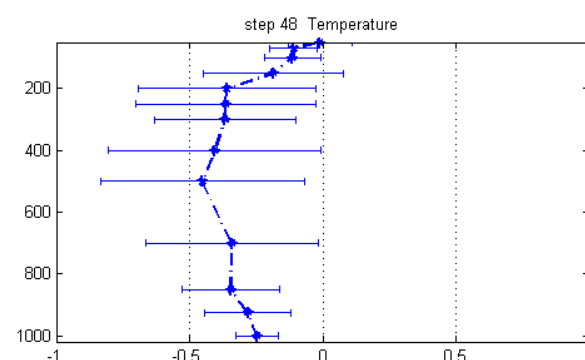
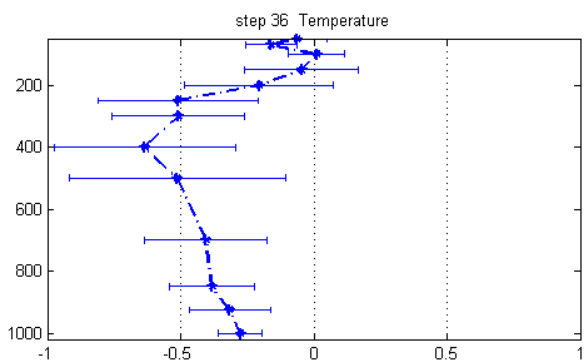
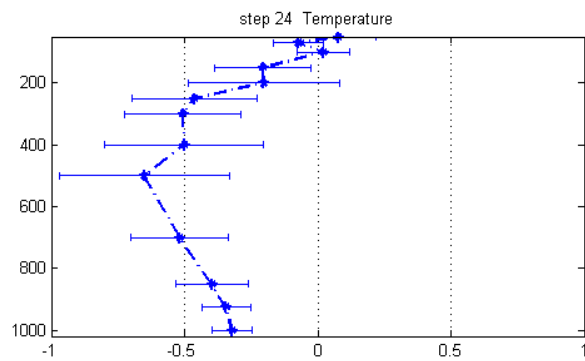
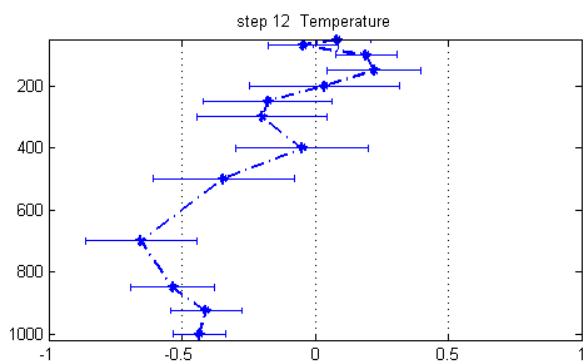
A comparison study between the previous inflation schemes has been done. Verification results of relative difference (%) in RMSE computed against IFS analysis for 00 UTC EuroHRM (28km) runs from 11-10-2009 to 10-11-2009 are reported below. A clear improvement has been found using the state dependent covariance inflation with $\alpha=0.95$.





Moreover, the importance of the climatological additive inflation used at CNMCA (randomly selected, 48-24h or 36-12h forecast differences) has been confirmed by another experiment for the 00 UTC EuroHRM (28km) runs in the period 11-10-2009 / 10-11-2009. The relative difference (%)

in RMSE computed against IFS analysis (reported below) is decreased by using the climatological additive inflation.



The LETKF performance has been evaluated in comparison with CNMCA operational 3DVar on the same observational dataset and IFS 4DVar. The EnKF-based assimilation cycle has proved to be of superior quality with respect to the operational 3DVar and of slightly lesser quality with respect to the IFS 4DVar. In the last evaluation you have to take into account the reduced number of observation types (no radiances in this experiment) used in the CNMCA LETKF system in comparison with IFS 4DVar.

Treatment of non-linearities through *quasi outer-loop /running in place* technique (Yang and Kalnay, 2010) was also investigated. Preliminary results do not show any positive impact. Since 1 June 2011 the CNMCA has been using operationally the LETKF system (40 members) to initialise the deterministic COSMO-ME model (7km).

List of publications/reports from the project with complete references

Bonavita M, Torrisi L, Marcucci F. 2008. The ensemble Kalman filter in an operational regional NWP system: Preliminary results with real observations. *Q. J. R. Meteorol. Soc.* **134**: 1733-1744.
Bonavita M, Torrisi L, Marcucci F. 2010. Ensemble data assimilation with the CNMCA regional forecasting system. *Q. J. R. Meteorol. Soc.* **136**: 132-145.

Summary of plans for the continuation of the project

(10 lines max)

Plans for the continuation of the project envisage the LETKF trial with a more complete subset of the operational observational dataset comprising nonlocal observations (I.e., radiances and precipitation), the use of which is not computationally straightforward to implement in a local algorithm such as LETKF. The workplan includes also a detailed investigation of model error representation in the filter (i.e. evolved additive noise, stochastic physics) and the tuning of the Filter parameters in this new scenario.

Treatment of non-linearities through *quasi outer-loop /running in place* technique will be further investigated.