SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2020
Project Title:	Investigating the impact of radar data assimilation using 3D-Var, 4D-Var and ensemble Kalman Filter into the high resolution weather forecast
Computer Project Account:	Spitferr
Principal Investigator(s):	Prof. Rossella Ferretti
Affiliation:	CETEMPS – Department of Physical and Chemical Sciences, University of L'Aquila. Italy
Name of ECMWF scientist(s) collaborating to the project (if applicable)	…… ……
Start date of the project:	March 19, 2019
Expected end date:	December 31, 2021

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)	5000000	5000000	10000000	6896030.61
Data storage capacity	(Gbytes)	20000	550	20000	400

Summary of project objectives (10 lines max)

The impact of assimilation methods (3D-Var, 4D-Var, ENKF) will be evaluated in terms of Short term Quantitative Precipitation Forecasts (SQPF). In this respect three different approaches will be used: traditional, grid to grid and spatial. The traditional approach compares the observed and forecasted rain at the exact location through several statistical indexes, derived from a contingency table. The second approach compares the rainfall fields using a neighbourhood technique. And lastly, the spatial approach, identifies the spatial patterns (or objects) in observed/predicted precipitation fields and compare them through a number of attributes, e.g. distance between centroid, area of intersection, orientation, that are calculated using a fuzzy logic based approach. The aforementioned statistical analyses will be performed with the Model Evaluation Tools (MET) verification package (Brown et al. 2009), developed by the National Center for Atmospheric Research (NCAR) Developmental Testbed Center (DTC).

Summary of problems encountered (10 lines max)

WRFDA Version 3.9.1 has been compiled successfully thanks to the support of help desk and Mr. Bojan Kasic. The assimilation with 3DVAR and 4DVAR works well with good computational performance now. We also tested the impact of 3DVAR technique for the simulation of a tornado event, using a heavy configuration with 3 domains from 4.5km to 300m. Unfortunately, the simulation stopped on reaching the job time limit (48 hours). We have tried to resolve this technical issue using a WRF restart file, but the simulation ended again with a SIGTERM error. The problem has been resolved only with the aid of Mr. Bojan Kasic and his colleague that have disabled the time limit for the job submitted on Cray CCB.

Summary of plans for the continuation of the project (10 lines max)

The preliminary comparison between a cycling 3D-VAR and 4D-VAR assimilation methods will be finalised later this year. The reached results will be compared against the WRFDA-ETKF to further improve the representation of the mesoscale environment. In this context the ETKF will be applied to a previous ensemble forecast, assimilating radar data and conventional observations for several hours ahead of the event with the aim of updating the ensemble members. Finally, a comparison between forecasts with cycling 3D-Var, 4D-Var and ETKF with and without radar observations, will be made to better understand the predictability of extreme rainfall events with varying observations and assimilation methods.

List of publications/reports from the project with complete references

There are not yet publications but two oral presentations:

▪ Mazzarella, V. and Ferretti, R.: A comparison between 4D-VAR and cycling 3D-VAR methods for the simulation of a severe weather event in Central Italy. Preliminary results. EGU2020: Sharing Geoscience Online.

▪ Capozzi, V., Mazzarella, V., Maiello, I., Cotroneo, Y., Ferretti, R., Miglietta, M.M., Budillon, G.: Observation and simulation of a tornadic supercell over the plain of Caserta (Southern Italy) using X band weather radar and WRF model in LES mode, EMS Annual Meeting, 2019.

Summary of results

If submitted **during the first project year**, please summarise the results achieved during the period from the project start to June of the current year. A few paragraphs might be sufficient. If submitted **during the second project year**, this summary should be more detailed and cover the period from the project start. The length, at most 8 pages, should reflect the complexity of the project. Alternatively, it could be replaced by a short summary plus an existing scientific report on the project attached to this document. If submitted **during the third project year**, please summarise the results achieved during the period from July of the previous year to June of the current year. A few paragraphs might be sufficient.

The second year of the special project has been devoted to the comparison between a cycling 3D-VAR and 4D-Var data assimilation methods using WRFDA. This activity aims to investigate the impact of these techniques in rainfall forecast over a complex orography region. Nowadays, the use of 4D-VAR assimilation technique has been investigated in several scientific papers showing positive results in the estimation of precipitation but the need to resolve the tangent linear and adjoint model makes this method computationally too expensive. Hence, it is used operationally only in large forecast centres. To the aim of exploring a more affordable method, a preliminary comparison between a cycling 3D-VAR, that needs less computational resources, and 4D-VAR techniques is performed for a severe weather event occurred in Central Italy. The study case, 3 May 2018, is characterized by a strong south easterly flow over central Italy that carried moist and warm air mass toward Adriatic regions. This flow, associated with a cut-off low (992 hPa) located in western side of Sicily region (Southern Italy), produced moderate and heavy rainfall along the Adriatic coast with rainfall maxima that reached 60mm/12h in Abruzzo region (Fig.1).

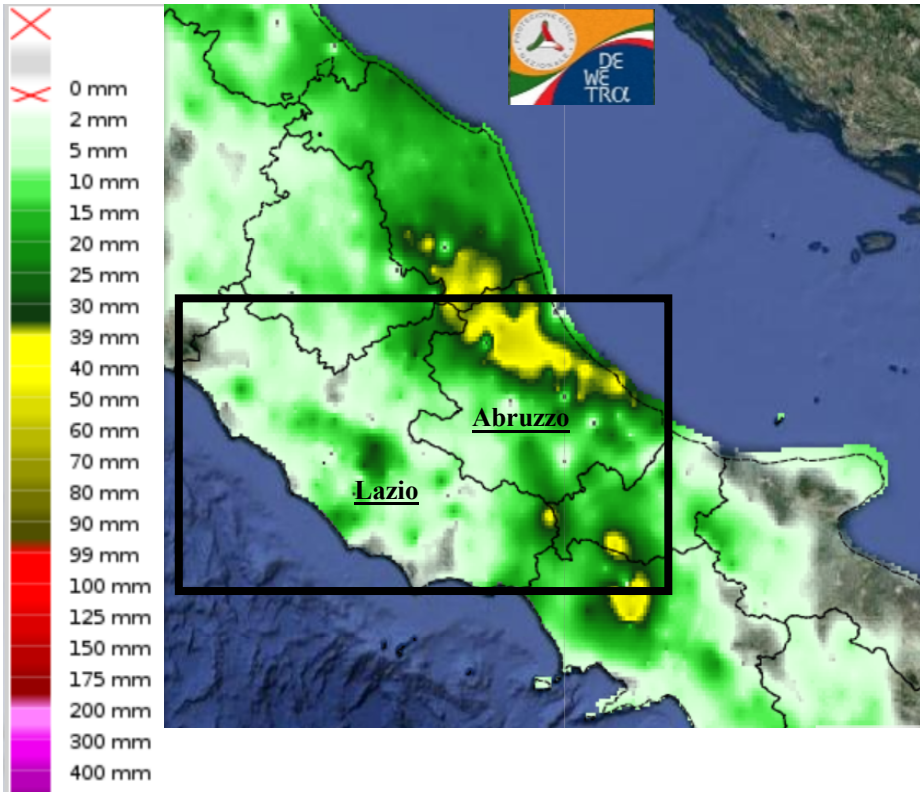

Figure 1: Precipitation amount (mm) from 0900 to 2100 UTC on May 3, 2018. Courtesy of Italian Civil Protection Department, DEWETRA platform.

A one-way nesting configuration with two domains has been used for this comparison. The mother domain covers the Italy with a spatial resolution of 3km, whereas the inner domain covers the central

Italy with a spatial resolution of 1 km. Both domains used 40 terrain following vertical levels from the ground up to 50 hPa. Reflectivity and radial velocity, measured by Mt. Midia (Central Italy) and San Pietro Capofiume (Po Valley, Northern Italy) C band weather radars have been assimilated in combination with the conventional observations (SYNOP and TEMP) provided by the Global Telecommunication Network of the World Meteorological Organization (WMO). A total of five experiments are carried out for evaluating the impact of the two different assimilation methods: one experiment without assimilation, namely the CTL run, two simulations with cycling 3D-VAR and two others with 4D-VAR. The hourly reflectivity, radial velocity and conventional observations are assimilated in the mother domain (3km) from 0300 UTC to 0600 UTC on 3 May. A more detailed description of the experiments is presented in Fig. 2.

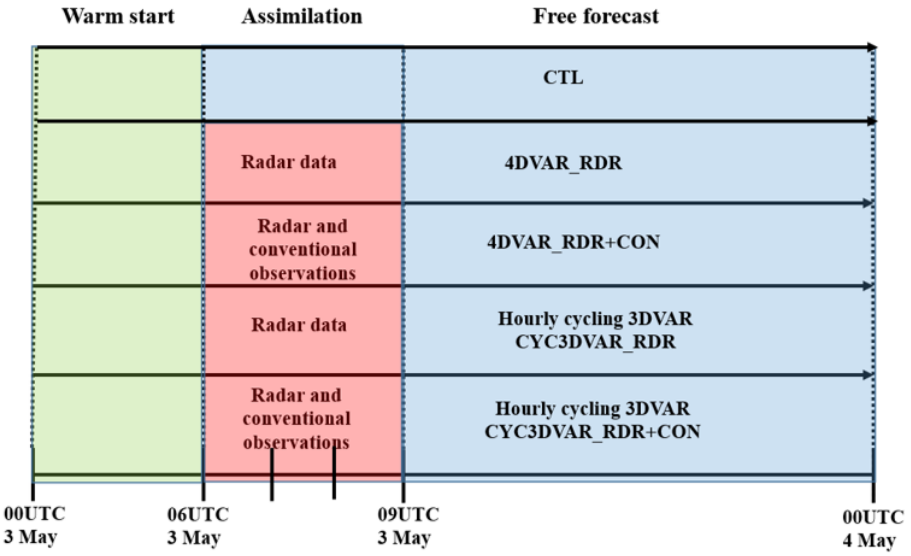

Figure 2: A brief description of the simulation carried out. A 6h warm start is used to reduce the initial precipitation spin-up.

The simulations are evaluated in Lazio and Abruzzo subregion (highlighted by black rectangle in Fig. 1) which identifies the area covered by Mt. Midia radar. The 3-hourly rainfall measured by the rain gauge network of the Italian Civil Protection Department (DPC) from 1200 UTC to 0000 UTC are used for the statistical evaluation. In this context, a comparison between the observed and forecast precipitation fields has been performed by using the Fractions Skill Score (FSS). This score has been calculated over both domains (3km and 1km) for two different threshold values: >3mm/3h and >5mm/3h. The results, related to 3km domain, show the positive impact of assimilation compared to CTL experiment and that the FSS values of cycling 3D-VAR are comparable with those of 4D-VAR (Fig. 3) when a one-way nesting is used.

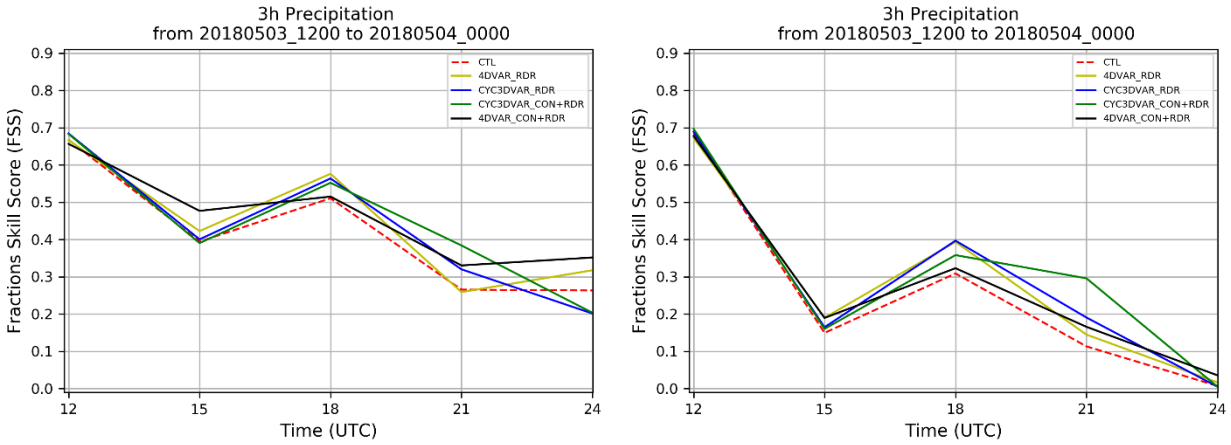

Figure 3: Evolution of FSS calculated in Lazio-Abruzzo subregion over 3km domain for the threshold 3mm/3h (left panel) and 5mm/3h (right panel).

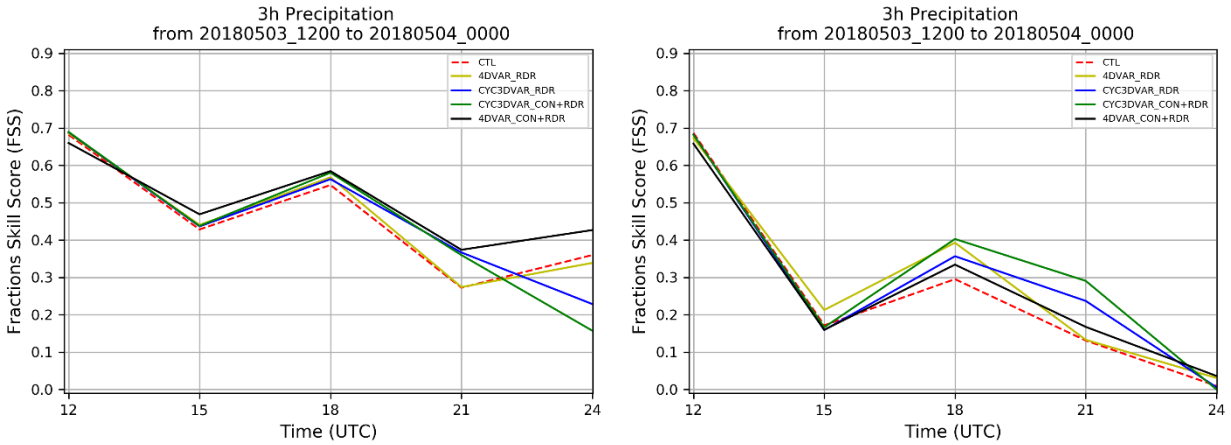

Figure 4: Figure 5: Evolution of FSS calculated in Lazio-Abruzzo subregion over 1km domain for the threshold 3mm/3h (left panel) and 5mm/3h (right panel).

A similar behaviour of FSS is also obtained for the high-resolution domain, proving the good impact of the cycling 3D-VAR for both threshold values (Fig. 4). However, the FSS is influenced by the threshold value, hence we decided to strength the statistical analysis by adding the RMSE and the Mean Error. These scores confirm that both assimilation methods reduce the error in the precipitation forecast, but unlike the analysis with FSS, the impact is limited to the interval 15 UTC to 21 UTC (Fig. 5).

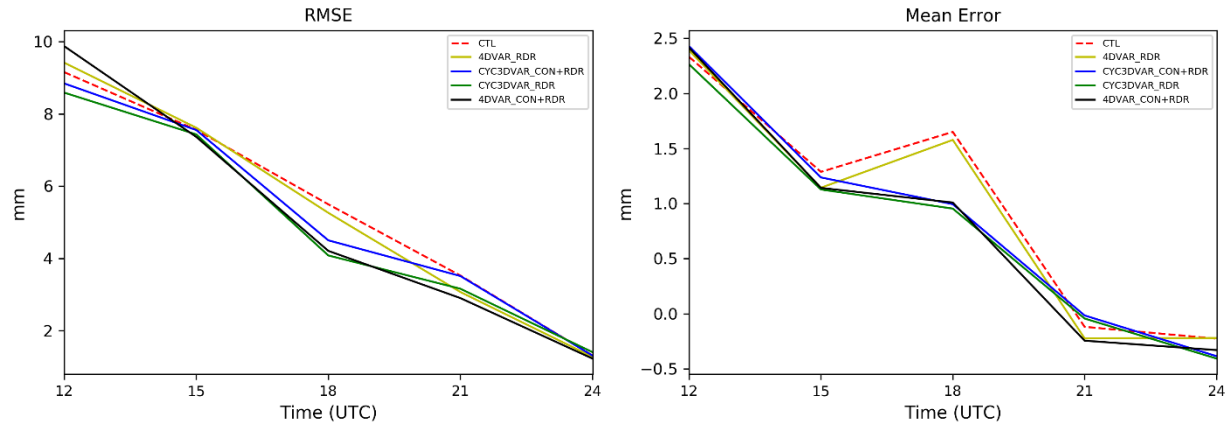

Figure 6: Figure 7: Evolution of RMSE and Mean Error (ME) calculated in Lazio-Abruzzo subregion over the low resolution domain.

During the second part of the year, to the aim of better understanding the impact of the cycling assimilation and the 4DVAR, we repeated the experiments using a two-way nesting technique. The simulations show a worsening in terms of FSS compared with CTL (Fig. 6). Probably, the continuous interaction between inner and mother domains produces noise in the analysis field reducing the performance of assimilation. This unexpected behaviour will be further investigated in the next six months before we start the last year of the project devoted to the ETKF assimilation.

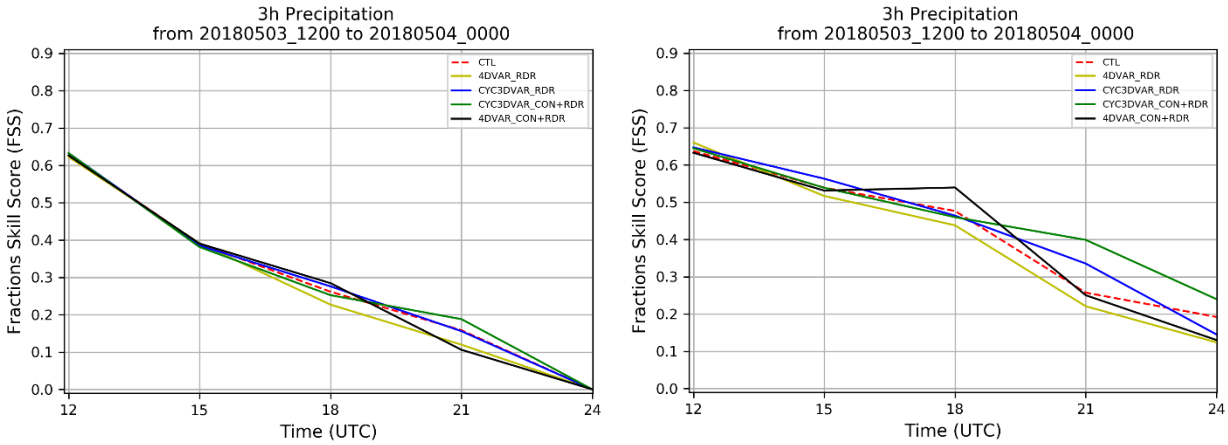

Figure 8: Evolution of FSS calculated in Lazio-Abruzzo subregion over 3 km domain for the threshold 3mm/3h (left panel) and 5mm/3h (right panel) for the simulations with two-way nesting.