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	2021
Project Title:	AWARE - Assimilating Water vapor during African heavy Rainfall Events
Computer Project Account:	spitmero
Principal Investigator(s):	dr. Agostino N. Meroni
Affiliation:	University of Milano-Bicocca and CIMA Research Foundation
Name of ECMWF scientist(s) collaborating to the project (if applicable)	N/A
Start date of the project:	19th March 2021
Expected end date:	31st December 2022

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)	N/A	N/A	850000	~150000
Data storage capacity	(Gbytes)	N/A	N/A	5000	0

Summary of project objectives (10 lines max)

Using the state-of-the-art numerical weather prediction model WRF (Weather Research and Forecasting), at cloud resolving grid spacing, and the 3DVAR code provided in the WRF Data Assimilation tool, a set of simulations is outlined to investigate the effects of changing the spatial and the temporal resolution of the observational data in the assimilation experiments of a heavy rainfall experiment in South Africa.

The numerical setup and the heavy rainfall experiments are described in Meroni et al., *Q. J. R. Meteorol. Soc.* (2021). The observational data are ZTD (Zenith Total Delay) products, that contain information on the columnar water vapour, coming from GNSS (Global Navigation Satellite System) receivers and SAR (Synthetic Aperture Radar) satellite measurements. Examples of such products are described in Lagasio et al., *Remote Sens.* (2019).

Summary of problems encountered (10 lines max)

No particular problem was encountered in these first three months of the project. Most of the effort was concentrated on the compilation of the WRF and WRFDA codes, the preparation of the inputs for the simulations and the first experiments. During the compilation, small issues with the choice of one of the configure.wrf options were encountered and solved.

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

Now that the codes are ready, experiments assimilating GNSS data every 3 and 6 hours and SAR data at different spatial resolution (4.5, 13.5 and 40.5km) can be performed. The GNSS_NRT experiment described in the proposal does not seem to be relevant and, thus, we are considering running experiments with different background covariance matrices, to better understand the preliminary results described below.

List of publications/reports from the project with complete references

No publication has been produced so far. A peer-review publication is surely foreseen with the results of the experiments to be performed. The tentative title is: “Water vapour assimilation experiments for heavy rainfall simulations in South Africa: sensitivity to the data spatio-temporal resolution”.

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.

After compiling the codes, two preliminary assimilation experiments were performed, using the background covariance matrix option CV5. In the first one, GNSS ZTD observations were assimilated every 12 hours over the three numerical domains. In the second experiment, SAR ZTD measurements were assimilated at 1700UTC on the 21st of March 2018 at 13.5 km grid spacing, in the innermost domain only.

The comparison with ground station observations, shown in the figure below, indicates that the assimilation procedure is excessively drying and cooling the atmosphere. Several hypotheses have to be tested with the next experiments to understand this behaviour.

For example, the approach to assimilate over all WRF domains has already been followed in other parts of the world, but it is questionable and is thought to be a limitation of the present results. Secondly, the use of very-high resolution observations, such as in the SAR experiments introduces large innovation vectors during the assimilation, which likely make the simulation unrealistic. In a recent paper, we used another background covariance matrix (CV7) with a constraint on the large scale dynamics to prevent the model going unstable (Lagasio et al., *Remote Sens.*, 2020). We suggest that the use of an alternative background covariance matrix might improve the issue. Thirdly, while assimilating the ZTD the temperature changes instantaneously. As the temperature variations appear quite strong, in order to mitigate such abrupt changes, we propose to simultaneously assimilate ZTD and temperature recordings from the weather ground stations.

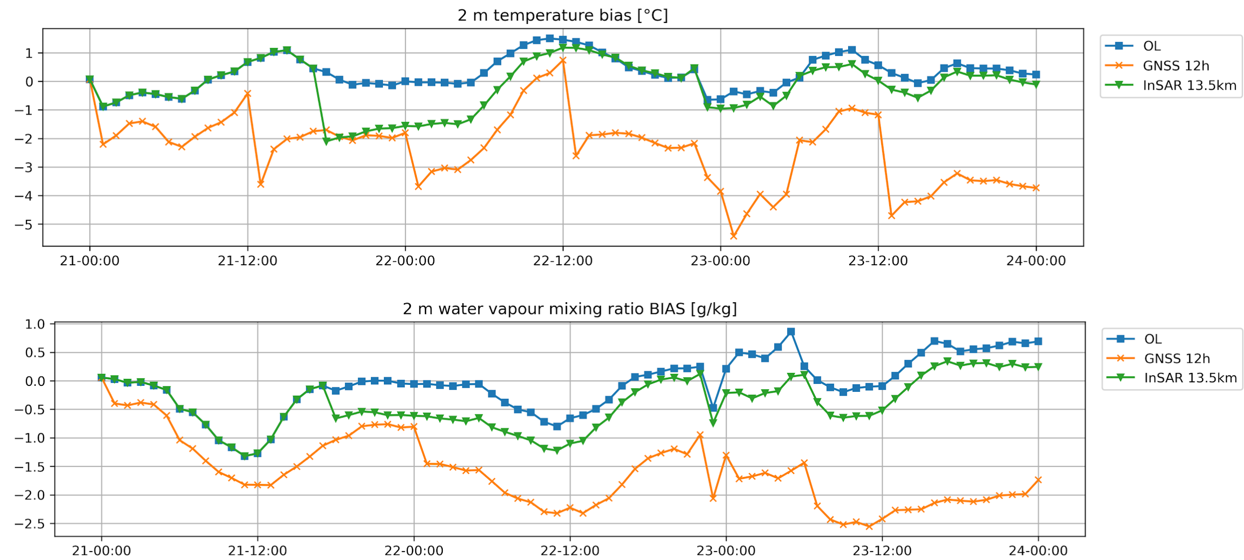

Figure: (a) 2 m temperature bias and (b) 2 m water vapour mixing ratio of the OL (Open Loop, no assimilation), GNSS 12 and InSAR 13.5km experiments. The reference observations are the meteorological ground stations operated by SAWS (South African Weather Service), which is acknowledged for providing the data. There are roughly 200 stations, except for in a few hours around 0000 UTC 23rd March 2018, when there are between 10 to 20 stations available. This gap in recordings is to be filled in the near future with an updated set of observations.