EMI R&D 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	2026
Project Title:	Assimilation of 2-meter temperature with Hybrid-3DEnVar over the Alps in AROME-Austria and testing the scale-dependent localization
Computer Project Account:	spatjyot
Principal Investigator(s):	Kaushambi Jyoti
Affiliation:	Department of Meteorology and Geophysics, University of Vienna, Austria
Name of ECMWF scientist(s) collaborating to the project (if applicable)	…… ……
Start date of the project:	01-01-2026
Expected end date:	31-12-2028

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)			**35,000,000**	**13,587,675**
Data storage capacity	(Gbytes)				

Summary of project objectives (10 lines max)

We aim to improve the 2-meter temperature (T2m) forecast of GeoSphere Austria's convective-scale limited-area numerical weather prediction model, AROME. Currently, GeoSphere Austria uses the 3DVar data assimilation scheme in operations. This special project provides us with resources to assimilate SYNOP observations using the Hybrid-3DEnVar method with a 32-member convection-permitting ensemble (CLAEF Alpe Adria, 1 km horizontal resolution) in AROME-Austria. We aim to determine whether T2m forecasts generated with Hybrid-3DEnVar improve upon operational 3DVar forecasts, particularly in complex Alpine terrain.

Summary of problems encountered (10 lines max)

No problems have been encountered so far, and the project is proceeding largely as planned.

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

a) We will run Hybrid-3DEnVar and 3DEnVar with higher inflation and larger localization settings.
b) We will perform OSE data denial excluding SYNOP observation with 3DVar, 3DEnVar, and Hybrid-3DEnVar.
c) We will run another set of experiments where stations with larger differences between station height and model orography will be assigned a higher observation error.
d) We will apply scale-dependent localization on Hybrid-3DEnVar and 3DEnVar.

List of publications/reports from the project with complete references

No publications have resulted directly from the current project.

The current project builds upon a previously published paper, "Jyoti, K., Griewank, P., Meier, F. & Weissmann, M. (2026). The benefits of a hybrid-3DEnVar data assimilation scheme for the convection-permitting NWP model AROME–Austria. Quarterly Journal of the Royal Meteorological Society, e70207. Available from: https://doi.org/10.1002/qj.70207"

Some computational resources were used to implement revisions and to conduct additional experiments during the peer-review process.

Summary of results

We conducted three assimilation experiments: 3DVar (fully climatological background error covariance matrix, B), Hybrid-3DEnVar (HYB-50; using equal weights for the climatological and ensemble-derived B matrices), and 3DEnVar (using a fully ensemble-derived B matrix). All experiments assimilated the same set of observations within a 3-hourly assimilation cycle over 11 days from 26 July to 5 August 2025. Assimilation of T2m was turned off at night from 18 UTC to 03 UTC and resumed at 06 UTC. We use a 32-member ensemble consisting of 16 lagged forecasts with a 6-hour lead time and 16 forecasts with a 3-hour lead time. We apply a 30% deflation to the original ensemble spread at analysis time and a 30 km localization at the surface, which increases linearly to 150 km at the model top.

We evaluated the improvement in first-guess departures across all assimilation experiments over 44 assimilation cycles, corresponding to daytime periods when T2m were assimilated. For that, we computed the percentage change in the root-mean-square deviation (ΔRMSD) of first-guess (FG) departures relative to the 3DVar experiment. Positive values indicate a reduction in ΔRMSD, corresponding to an improvement in FG departures of that experiment compared to 3DVar.

We verified upper-air FG departures for temperature and zonal wind against a combined dataset of aircraft and radiosonde observations. The HYB-50 experiment showed a reduction in ΔRMSD of FG departures compared to 3DVar for zonal wind in both the 500–200 hPa and 800–700 hPa layers (see Fig. 1). For temperature, improvements were limited to the 500–200 hPa layer, likely due to the high density of aircraft observations at these altitudes. In contrast, the 3DEnVar experiment demonstrated poorer performance for both temperature and zonal wind at all heights. We also verified the FG departures of T2m at Austrian stations across different terrain types, as shown in Fig. 2. A station is categorized as a valley, mountain, or flat station based on the surrounding elevation. The RMSD of experiment HYB-50 was found to be higher than 3DVar, and the 3DEnVar underperformed both 3DVar and HYB-50 in all terrain categories.

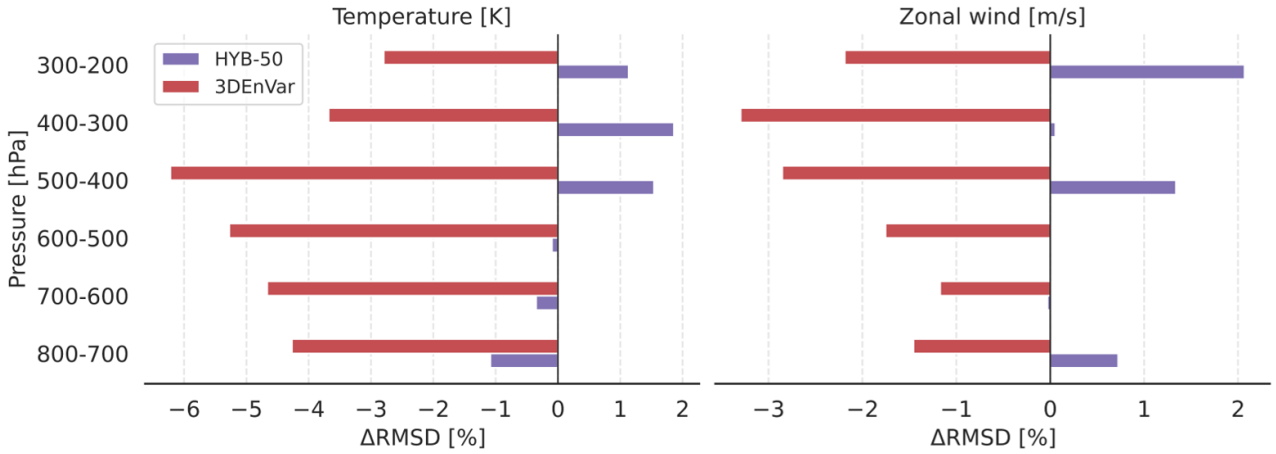

Fig. 1 Percentage change in the root-mean-square deviation (ΔRMSD) of first-guess (FG) departures relative to the 3DVar experiment for temperature and zonal wind. The scores are calculated against combined observations from aircraft and radiosonde. Positive values indicate a reduction in ΔRMSD, corresponding to an improvement in FG departures of that experiment compared to 3DVar.

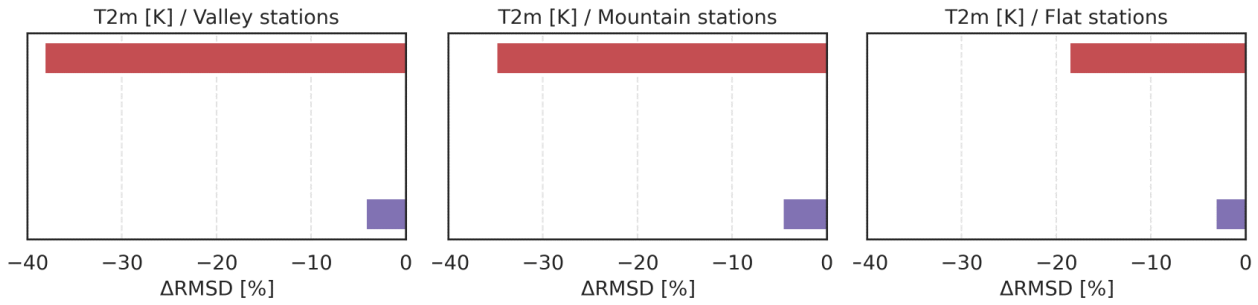

Fig. 2 Same score as in Fig. 1, but now shown for T2m observations for Austrian valley, mountain, and flat stations. The stations are categorized based on surrounding elevation.

Although the HYB-50 outperforms 3DVar in terms of reducing the ΔRMSD of FG departures for both temperature and zonal wind at upper air, the poor performance of the 3DEnVar experiment can be due to the following reasons. Our further investigation showed that the ensemble is under-dispersive, with ensemble spreads for both T2m and upper-air temperature substantially smaller than the prescribed observation errors. Moreover, applying ensemble deflation further reduces variance, thereby decreasing the relative influence of observations on the analysis update and, consequently, shifting the analysis farther from the observations. We also use very small localization settings at the surface. Taken together, these factors are likely to degrade the performance of the 3DEnVar configuration.