A. REQUEST FOR A SPECIAL PROJECT 2026–2028

MEMBER STATE:	Austria
Principal Investigator[1]:	Kaushambi Jyoti
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Project Title:	Assimilation of 2-meter Temperature (T2m) with Hybrid-3DEnVar over the Alps in AROME-Austria and testing The Scale-Dependent Localization

To make changes to an existing project please submit an amended version of the original form.)

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ………….	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2026	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for project year:		**2026**	**2027**	**2028**
High Performance Computing Facility	[SBU]	50M	50M	50M
Accumulated data storage (total archive volume)[2]	[GB]	97600	140000	200000

EWC resources required for the project year:		**2026**	**2027**	**2028**
Number of vCPUs	[#]			
Total memory	[GB]			

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.
[2] These figures refer to data archived in ECFS and MARS. If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.
[3]The number of vGPU is referred to the equivalent number of virtualized vGPUs with 8GB memory.

Storage [GB]			
Number of vGPUs[3] [#]			

Continue overleaf.

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Extended abstract

From a scientific perspective within the framework of weather and climate, forecasting T2m is important because it reflects the complex interaction between the atmosphere, land surface, and boundary layer processes. Moreover, for practical purposes, an accurate T2m forecast helps plan outdoor and recreational activities for humans, etc. Despite its significance, T2m forecasts are known to exhibit biases in NWP models. During the night, the forecast tends to be warmer; during the day, it tends to be colder than the measurements. These biases are contributed from various sources, such as model resolution, the boundary layer scheme, complex terrain, and misrepresentation of surface processes (radiation heat fluxes), etc.

Surface measurement stations (SYNOP observation) provide the measurements on T2m, 2-meter relative humidity (RH2m), surface pressure (Ps), and 10-meter U and V components. However, if T2m or, in general, the SYNOP observations are not assimilated carefully, they can degrade forecast accuracy, especially in complex terrains like the Alps.

GeoSphere Austria currently assimilates SYNOP for operational assimilation with the 3DVar method in the AROME model. T2m observations are only assimilated during the day and switched off at night. Since the domain of AROME at GeoSphere Austria includes the Alps, assimilating T2m with 3DVar can be problematic in the complex terrain, as the horizontal and vertical covariances of climatological background error covariances can produce unrealistic increments when nearby valleys and mountain tops have different weather, which then leads to different degrees of small-scale correlation, even negative correlations in atmospheric variables.

State-of-the-art ensemble variational methods use ensemble-based covariances in the variational framework, such as the 3DEnVar or hybrid-3DEnVar method. Variance and covariances in the ensemble-based error-covariance matrix depend on the recent atmospheric flow.

To illustrate the importance of ensemble information in the mountainous terrain, Figure 1 shows the increment from a single temperature observation assimilation from Mode-S aircraft data at 1600 m height above sea level at Innsbruck. Three assimilation experiments were conducted: 3DVar (only climatological errors), hybrid-3DEnVar (both types of errors), and 3DEnVar (only ensemble errors). Increments from 3DVar resulting from assimilating one temperature observation are smooth and extend even beyond 300 km from the observation location. In contrast to 3DVar, the 3DEnVar increments are negative north of the observation. These increments are affected by the alpine orography following the terrain. This property can be particularly beneficial in complex terrain, as the ensemble covariances can be representative of the local weather in the valleys, hence contributing to realistic increments, unlike 3DVar.

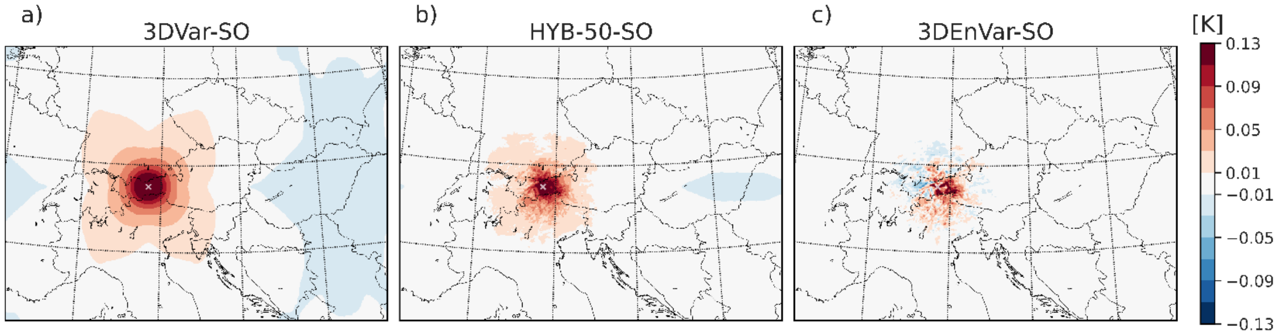

Figure 1: Analysis increments at approximately 835 hPa (model level 64) on assimilation of a single Mode-S observation of temperature. The observation was assimilated at 1600 m above sea level at 1200 UTC, 22-06-2022. The figure shows increments from a) 3DVar (climatological covariances), b) hybrid-3DEnVar (both climatological and ensemble-based covariances), and c) 3DEnVar (ensemble-based error covariances).

In addition, localization restricts the influence of long-distance covariances, limiting the extent of increments. Our research has shown that the analysis resulting from the hybrid approach (Figure 1b) is more accurate than the other two, but we have not studied whether the forecasts are improved. Hence, this special project will assimilate SYNOP observation with the Hybrid-3DEnVar method with a 50-member convection-permitting ensemble in AROME-Austria and then test if this improves T2m forecasts over complex Alpine terrain.

Apart from SYNOP assimilation as mentioned above, we plan to test the Scale-dependent localization (SDL) methods. So far, in our research, we are applying localization to every variable with the same length scale, which is not optimal as it can cut the meaningful correlations of synoptic weather and keep the spurious correlation associated with convective systems. SDL opens up the pathway to apply different length scales depending on the spatial scale of atmospheric phenomena. Ensemble perturbations are filtered on large-scale, medium-scale, and small scales to filter the synoptic, mesoscale, and convective phenomena.
The SDL method is currently used in the operational 3DEnVar system at Meteo-France. We want to test the efficiency of SDL in AROME-Austria and understand if this can be a better choice than only applying a single length scale to all variables.

Technical setup

The domain of AROME at GeoSphere Austria, as shown in Figure 1, is set over central Europe and has the Alps at its centre. AROME runs at a 2.5 km horizontal resolution with 600 x 432 (589 x 421 + 11 grid-points extension zone in the west-east and north-south directions and 90 terrain-following vertical coordinates.
We run AROME cycle 46t1 for research purposes on the ECMWF-ATOS machine under the atvinar project since July 2022. To date, atvinar has used resources allocated to GeoSphere Austria, which are insufficient to run the proposed forecasts.

Work plan

a. **SYNOP assimilation with hybrid-3DEnVar:** We plan to assimilate SYNOP observations in three sets of assimilation experiments. These three sets differ in which surface observations they assimilate; the non-surface observations are assimilated in all three. In the first set of experiments, we will assimilate 2-meter temperature with 3DVar, Hybrid-3DEnVar, and 3DEnVar every 3 hours. After assimilation, a forecast with a 24-hour lead time will be generated from 00 UTC, 06 UTC, 12 UTC, 18 UTC, and a 3-hour lead time forecast from intermediate assimilation steps. In the second set of experiments, T2m and RH2m will be assimilated, and finally, all surface variables (T2m + RH2m + Ps+ UV10m) will be assimilated in the third set of experiments. 3-hour and 24-hour lead time forecasts will be generated for the second and third sets of experiments just as for the first. All three sets of experiments will be carried out for a 1-month summer period and a 1-month winter period. Our surface dataset includes the Austrian TAWES network and SYNOP observations from neighbouring countries. To date, we have set up the assimilation framework for a single cycle, assimilated T2m with 3DVar, hybrid-3DEnVar, and 3DEnVar, and run a 3-hour forecast for all DA configurations.

b. **Scale-dependent localization:** Five assimilation experiments will be run: 3DVar, 3DEnVar, and hybrid-3DEnVar with SDL, 3DEnVar, and hybrid-3DEnVar with a single length scale for all variables (as done currently). These experiments will be repeated by applying different length scales within the SDL approach.

Required resources

Sr. No.	Work plan	SUB estimate	Storage requirement
1	3DEnVar assimilation and a 3-hour forecast	3000	5 GB
2	3DEnVar assimilation and a 24-hour forecast	20000	35 GB + 3-hr 50-member ensemble forecast is 700 GB
3	Miscellaneous test (sensitivity to localization scales and weight to ensemble-B)	3000000	
4	SDL initial tests with different wavebands	1000000	
5	SDL for a 1-month period with 3-hr and 24-hr forecasts	24800000	
6	Miscellaneous test for SDL	20000000	

Total number of experiments = DA-configuration (3DVar, Hybrid-3DEnVar, 3DEnVar) x obs (T2m,T2m+RH2m, full SYNOP) x exp-per-day (3-hour, and 24 hour forecasts) x time-period = 3x3x8x60 = 4,320
SBU consumption for SYNOP = 2160x3000 + 2160x20000 = 49680000

References

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