NWP related activities in AUSTRA

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1. Operational NWP systems at GeoSphere

All NWP systems (AROME-Aut, C-LAEF, AROME-RUC) operated by GeoSphere Austria (formerly ZAMG) are currently based on AROME. Since 2019, C-LAEF has been running on the same resolution as AROME-Aut (2.5km/L90). The C-LAEF control run and AROME-Aut are running with an identical setup on two different HPC platforms, such that the C-LAEF control run can be used as a backup for AROME-Aut, if necessary.

	AROME-Aut/C-LAEF ctrl	C-LAEF	AROME-RUC
Model version	cy43t2bf11	cy43t2bf11	cy43t2bf11
Resolution	2.5km	2.5km	1.2km
Area / centered over	600x432 / Alpine region	600x432 / Alpine region	900x576 / Austria
Members	1	16 + 1	1
Levels (lowest/highest)	90 (5m / 35km)	90 (5m / 35km)	90 (5m / 35km)
Starting times	00, 03, … 21 UTC	00, 03, … 21 UTC	00, 01,…,22,23 UTC
Forecast range	60 hours	60 hours (00 and 12), 3 h	12 hours
Time step	60s	60s	30s
Output Frequency	1h 2D/3D	1h 2D/3D	15min 2D/1h 3D
Orography / physiography	GMTED2010 ECOCLIMAP 1	GMTED2010 ECOCLIMAP 1	SRTM 90m ECOCLIMAP 1
LBC model	IFS HRES	IFS ENS (first 16) + HRES (ctrl)	AROME-Aut / C-LAEF ctrl
LBC update	1h	1h	1h
Surface scheme	SURFEX 8.0	SURFEX 8.0	SURFEX 8.0
Initial conditions (3D / Surf.)	3DVAR / OI	Ens 3DVAR+Jk / Ens OI	3DVAR / OI +IAU+Nudging/LHN
Cycle interval	3 hours	3 hours	1 hour
Assimilation Window	-90min-+90min	-90min-+90min	-90min-+30min
B-Matrix	C-LAEF EDA climatologic	C-LAEF EDA climatologic	AROME-RUC EDA climatologic
Hardware	HPE Apollo 8600 (GeoSphere)	Cray XC40 (ECMWF)	HPE Apollo 8600 (GeoSphere)

Table 1: Setup of the operational NWP systems at GeoSphere Austria

The last upgrade of C-LAEF took place in September 2023 with the main changes being:

- Model physics perturbation scheme: The hybrid perturbation scheme (acting on tendencies and selected parameters) was replaced by a pure stochastic parameter perturbation scheme (SPP)
- Ceilometer observations: Cloud cover observations (converted to RH) were introduced into the ensemble 3DVar system. Tests have shown that these observations can improve low stratus forecasts during autumn and winter.

The rapid update system (AROME-RUC) is running on higher resolution (1.2km) and uses significantly more observations than AROME-Aut/C-LAEF. Table 2 lists all observations currently integrated into the assimilation system.

Observation Type	Parameter assimilated	Source	AROME/C-LAEF	AROME-RUC	research mode
SYNOP/TAWES	U10m, V10m, Z, T2m,RH2m	OPLACE/GeoSphere/GTS	x	x	
AMDAR, MODE-S	U,V,T,Q	OPLACE/EUMADDC/ACG	x	x	
MODE-S MRAR	U,V,T	EUMADDC/OPLACE		x	
GEOWINDMSG3	U,V	OPLACE/GTS	x	x	
GEOWIND-HR MSG3	U,V	OPLACE/NWC-SAF		x	
TEMP (radiosonde)	U,V,T,Q,Z	GTS/OPLACE/GeoSphere	x	x (bufr)	
PILOT	U,V	GTS/GeoSphere		x	
WINDPROFILER, SODAR	U,V	OPLACE/GTS/GeoSphere		x	
SCADA	U,V,T	Energie Burgenland		x	
MSG3-SEVIRI	WV-radiances	OPLACE	(x)	x	
NOAA18/19/20/SNPP/Met Op-B-C AMSU-A, MHS, ATMS	radiances	OPLACE	(x)	x	
MetOp-B-C IASI	radiances	OPLACE	(x)	x	
ASCAT wind	U10m,V10m	OPLACE/EUMETSAT	x (25km)	x (12,5km)	
RADAR	reflectivity / radial winds	various		x	
INCA-RR	RR 5min LHN	GeoSphere		x	
SNOWGRID snow analysis	snowheight/density	GeoSphere	x	x	
GNSS	ZTD (optional STD)	EPOSA/E-GVAP	(x)	x	
Radio Occultation	GPSRO bending angles	OPLACE/ROMSAF		x	
Ceilometer	N -> RH	GeoSphere	x	x	
Microwave Links	(estimated RR)	DREI Hutchison			x
Sentinel-1 InSAR	(STD)	ESA/Joanneum R./EOG			x
ZTD on trains	(ZTD)	ÖBB/TU-Vienna			x
T-LAKE	T Water	Hydrol. Service/ZAMG	x	x	

Table 2: Overview observation (types) used in operational NWP systems

2. Towards C-LAEF 1k

As one of the major upcoming upgrades, the new "C-LAEF 1k" system is being developed for operations starting in 2025. From summer 2023 until February 2024 a full 16+1 member suite of C-LAEF 1k was running as Esuite on ECMWF ATOS-HPC. The integration domain covers the same area as the current operational systems, which results in a horizontal grid with 1489x1500 gridpoints. The C-LAEF 1k Esuite includes all features regarding perturbations and observations used in the assimilation scheme as the operational C-LAEF system but only the 00 UTC run was implemented with a forecast range of +60h while all other runs were only calculated up to +3h. From October 2023 until end of January a second control member where 3D-Var was replaced by 3D-Envar (see also section 4) was included int the Esuite. Overall performance of the C-LAEF 1k Esuite was comparable to operational C-LAEF. For most parameter the performance of C-LAEF 1k was similar to operational C-LAEF (example for 10m wind speed in Fig. 1). For more details see talk of Clemens Wastl (*LACEPS activities*).

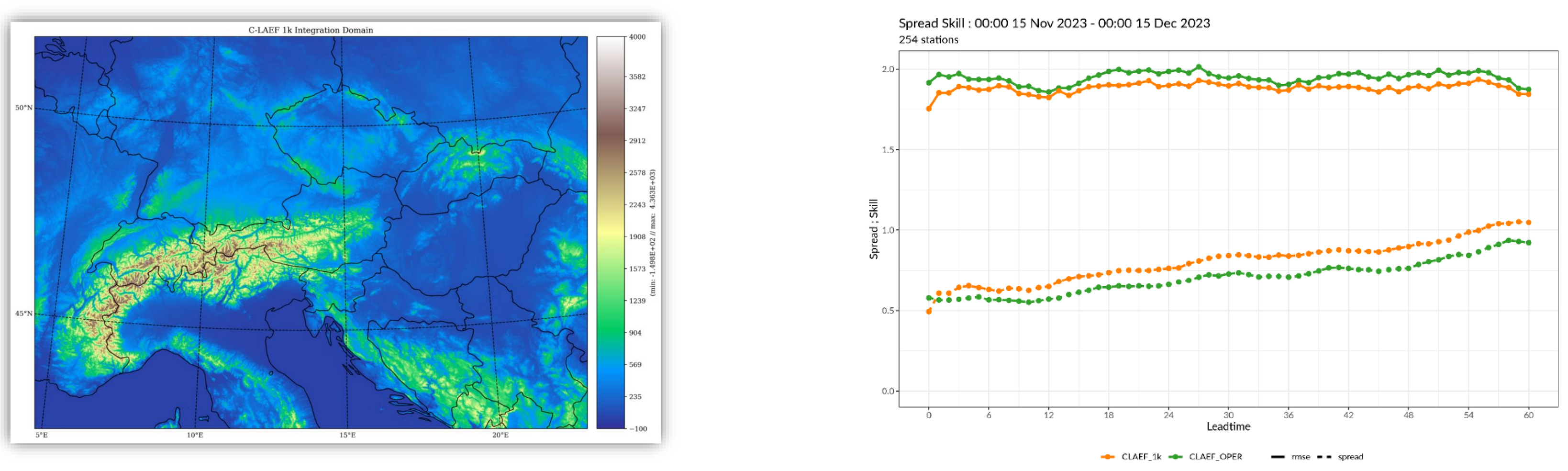

Fig.1 : Integration domain of the new C-LAEF 1k system and spread/skill of 10m wind speed for C-LAEF (CLAEF_OPER) and C-LAEF 1k)

3. ARA – high resolution Austrian Re-analysis ensemble with Arome

The high resolution Austrain Re-analysis ensemble with AROME (ARA) aims to generate a limited area ensemble reanalysis data set with a spatial resolution of 2.5 km and 90 vertical levels.

Based on the operational C-LAEF system a 10+1 Member reanalysis ensemble is created with a 3-hourly assimilation cycle. Coupling files are created from ERA5 data set with a time resolution of 3h for the perturbed member and 1h for the control run. The system runs on ECMWF ATOS-HPC system targeting to cover the time span from 2013 – 2023. Further details can be found in the ACCORD-NL No. 5 (Creation of high-resolution Austrian regional reanalysis ensemble with AROME, Awan et al.).

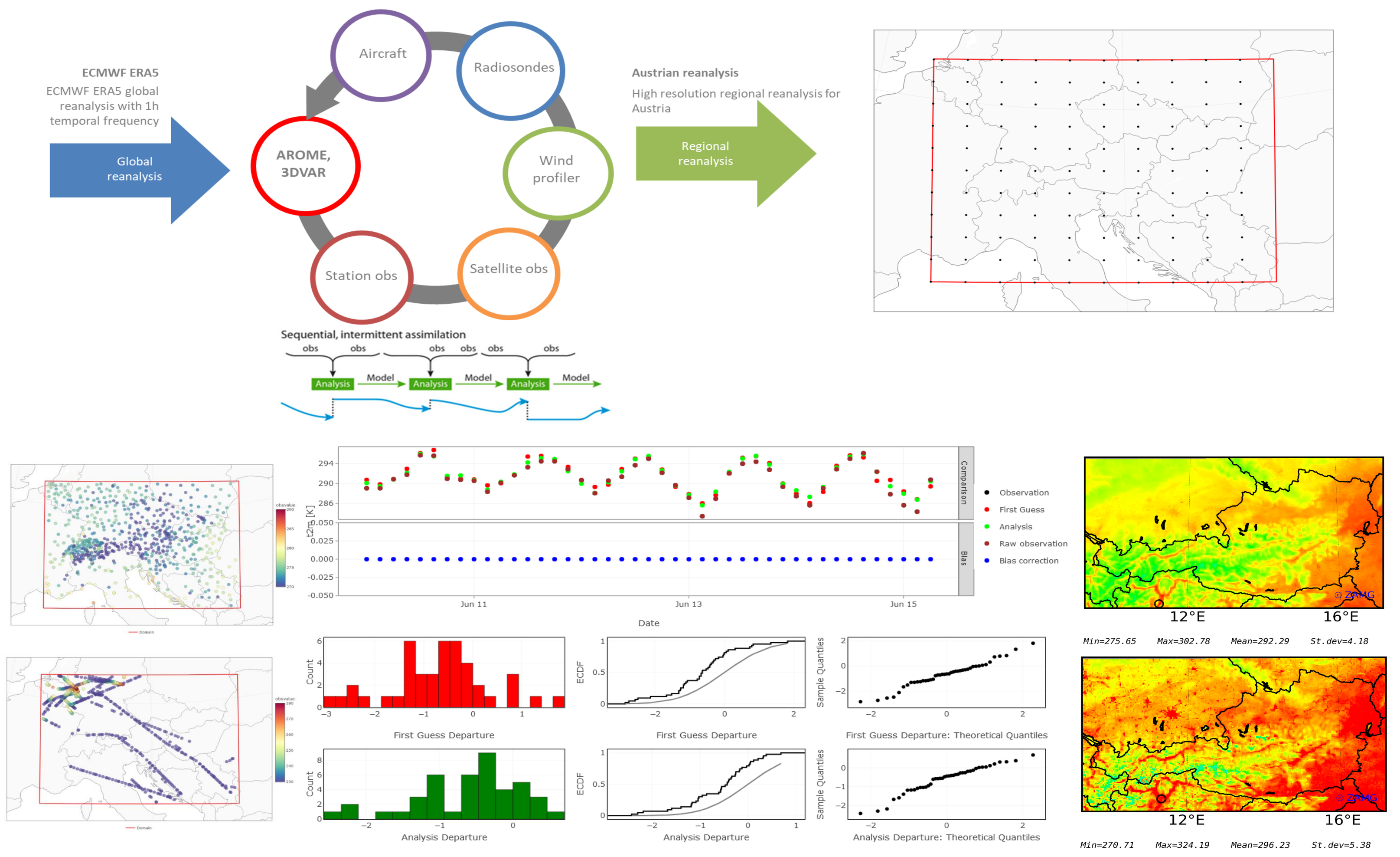

Figure 2: Schematic representation of ARA reanalysis system along with the extent of target model domain, and example of station observations and 3D observations from Aircraft used within 3D-Var.

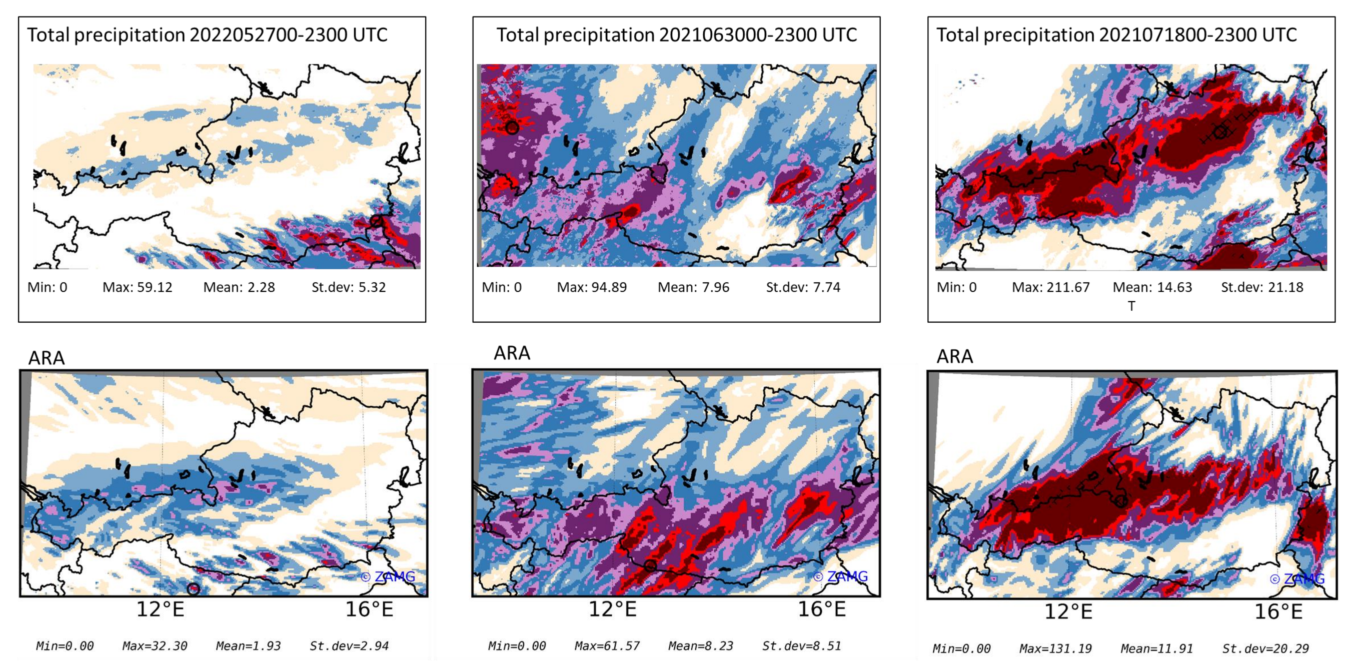

Figure 3: Accumulated precipitation for three selected extreme precipitation events. Top row: Gridded observational reanalysis INCA, bottom row: ARA reanalysis

4. 3D-EnVAR

For C-LAEF we test different options with 3D-EnVar approach (Montmerle et al. 2018) of AROME on the AROME-Aut domain (see table 1). As the number of EPS members in C-LAEF is rather limited we tried C-LAEF lagged (2x16+1+1) vs downscaled lagged ECMWF-ENS (2x16+1+1) vs a combination of ECMWF-ENS and lagged C-LAEF 34 LAM +16 global members in a single obs and multi obs experiment.

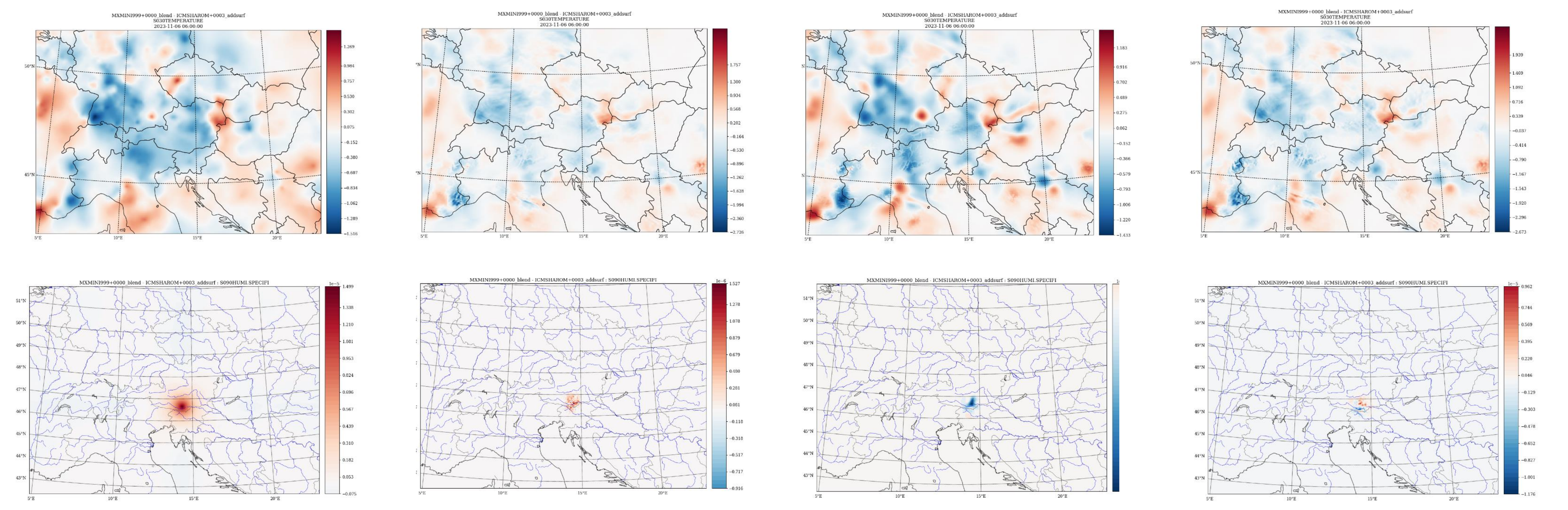

Figure 4: Increments from multi observation experiment (about 540hPa at the top) and single RH2m observation at Klagenfurt (bottom; lowest model level) on 6th November 2023 06 UTC. 3D-Var, C-LAEF lagged 3D-EnVar, pure and mixed C-LAEF+ECMWF-ENS (from left to right).

The increments in Fig. 4 show some flow dependent deformation in case of 3D-EnVar and for low model level also some impact of orography while mostly isotropic structures as expected in 3D-Var. In case of application of global EPS instead of C-LAEF the increments are more similar to 3D-Var, but still some flow dependency can be seen. Interestingly, also the sign of the single obs increment changes. In the mixed EPS (Fig. 4 right) an in-between solution is achieved. As we struggled with stability using pure lagged C-LAEF EPS we chose the hybrid EPS approach for a deterministic C-LAEF 1k 3D-EnVar parallel experiment in autumn 2023. Localization was set as proposed by Voigt for AROME-FR code version cy46t1. Even if some scores like T2m bias (Fig. 5) were promising the overall performance regarding clouds and humidity compared to 3D-Var was not.

For further studies regarding 3DEnVar we will move to cy48t2 also allowing VARBC application.

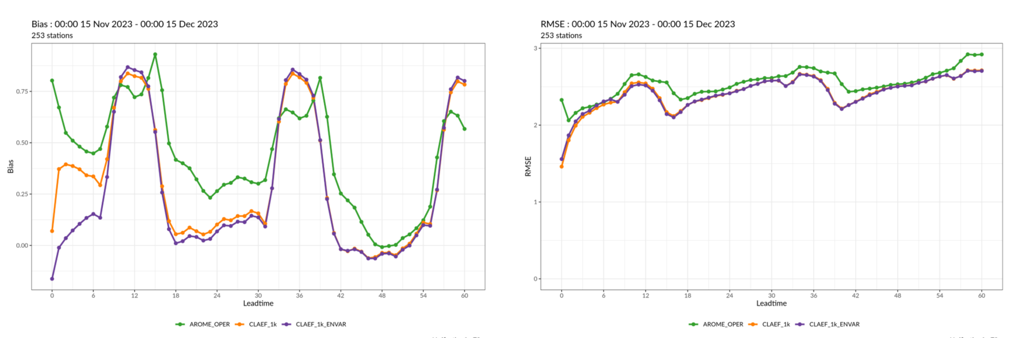

Figure 5: T2m bias (left) and RMSE (right) from 1 month 3D-Var (yellow), 3D-EnVar (violett) C-LAEF1k comparison. Green is operational 2.5km control run.

T. Montmerle, Y. Michel, E. Arbogast, B. Menetrier, P. Brousseau, 2018: A 3D ensemble variational data assimilation scheme for the limited-area AROME model: Formulation and preliminary results, Q. J. R. Met. Soc. 144,716, 2196-2215, DOI:10.1002/qj.3334

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