

Assimilation of Sentinel-1 delays into AROME



 Bundesministerium
Bildung, Wissenschaft
und Forschung

Austrian Space Applications Programme

GeoSphere Austria, NWP
Florian Meier

Projects: SAME-AT and ACHILLES with
Joanneum Research Graz and EOG Vienna

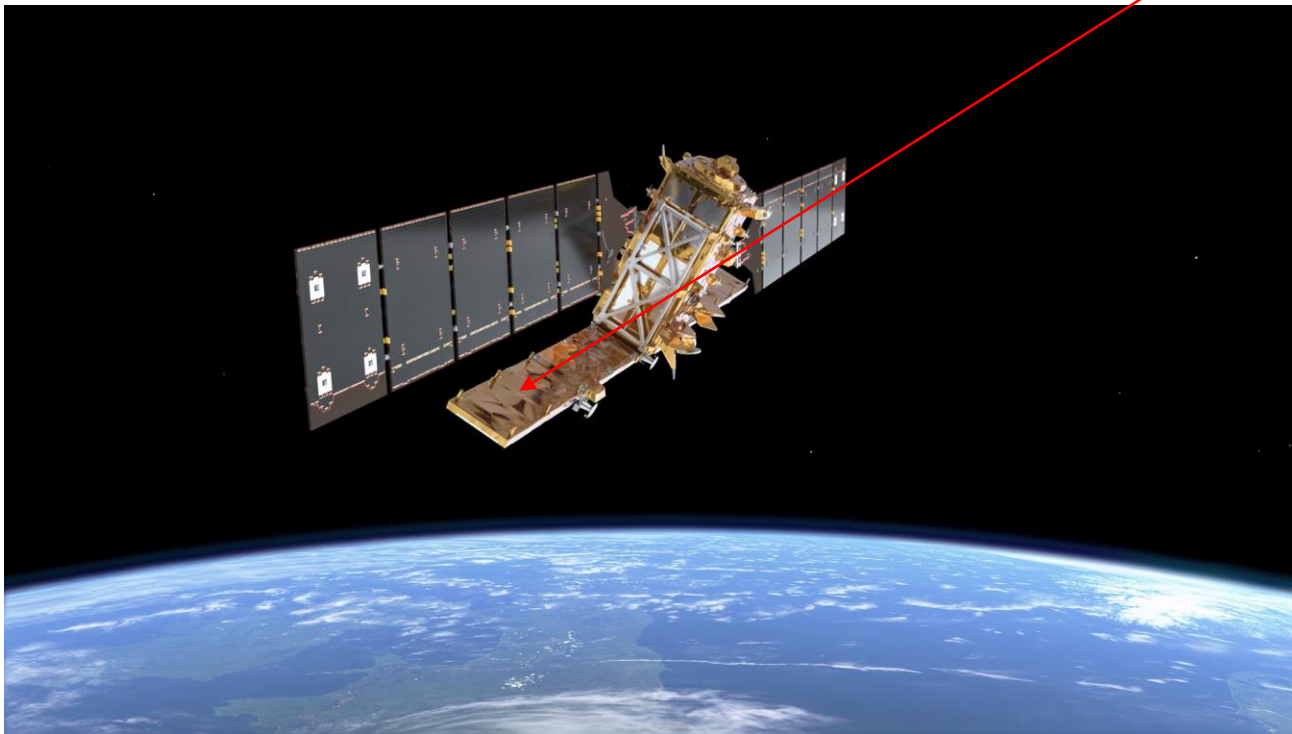


1st April 2025

Sentinel 1 radar satellites EU Copernicus space program

Observation of soil movements with InSAR C-band radar and observation of oceans (ships/sea level) and ice

- Polar orbiting satellites orbit 693km; return period 12 days; (ASC 146 ~17UTC over Austria)
- Sentinel 1 A-D launched on April 2014/2016/Dez 2024/ autumn2025
- Sentinel 1 B switched off electrical issue in december 2021
- weight: 2.1t; size: 21x2.5x4m; 12m radar antenna; several scan modes up to 5m res.



$$\Delta r = -\frac{\lambda}{4\pi} \Delta\varphi$$

relative delay from phase shift

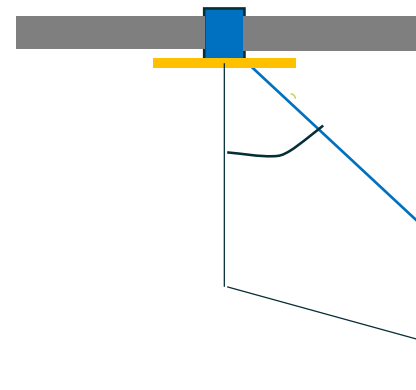
delay has several components

- noise
- Ionosphere
- lower atmospheric component
- soil movements

Model: AROME/C-LAEF 2.5km L90 cy43t2 Austrian operational domain

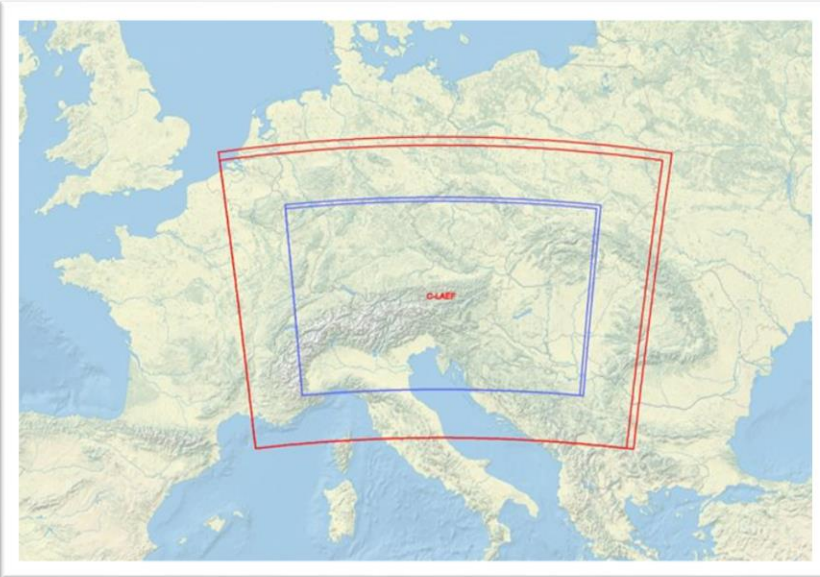
Observations provided by project partners:

interferograms
data with ~200m resolution on WGS84
netcdf format with relative delays, latitude, longitude,
azimuth and incidence angle of satellite, coherence
altitude of footpoints from high resolution DEM

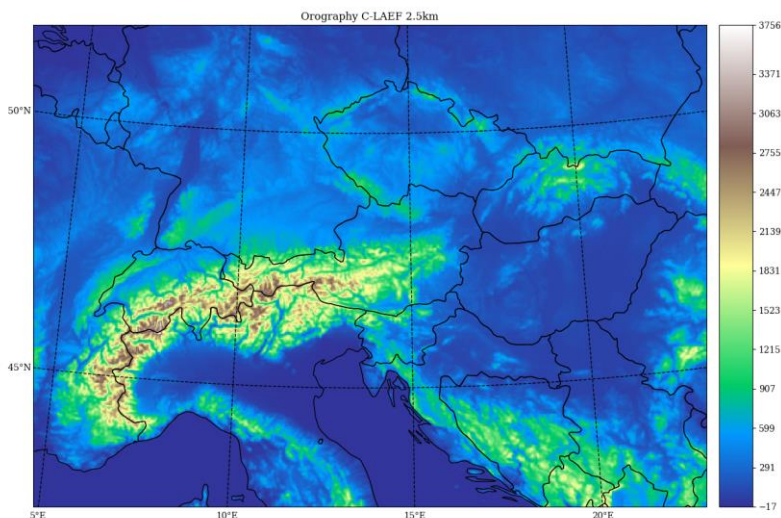


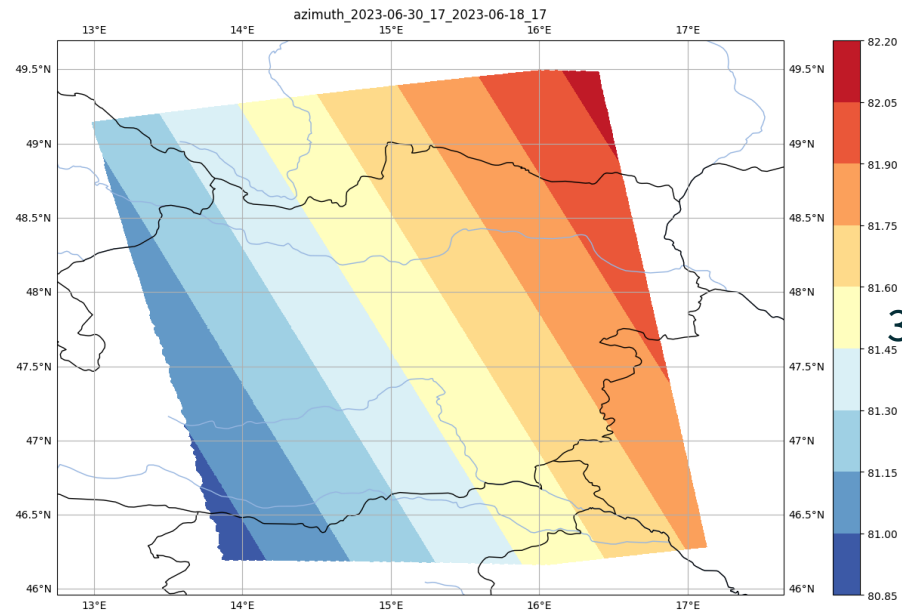
- high spatial resolution
- low temporal resolution
- Relative observation between two overpasses

using slant delay operator
De Haan & Imrisek 2019



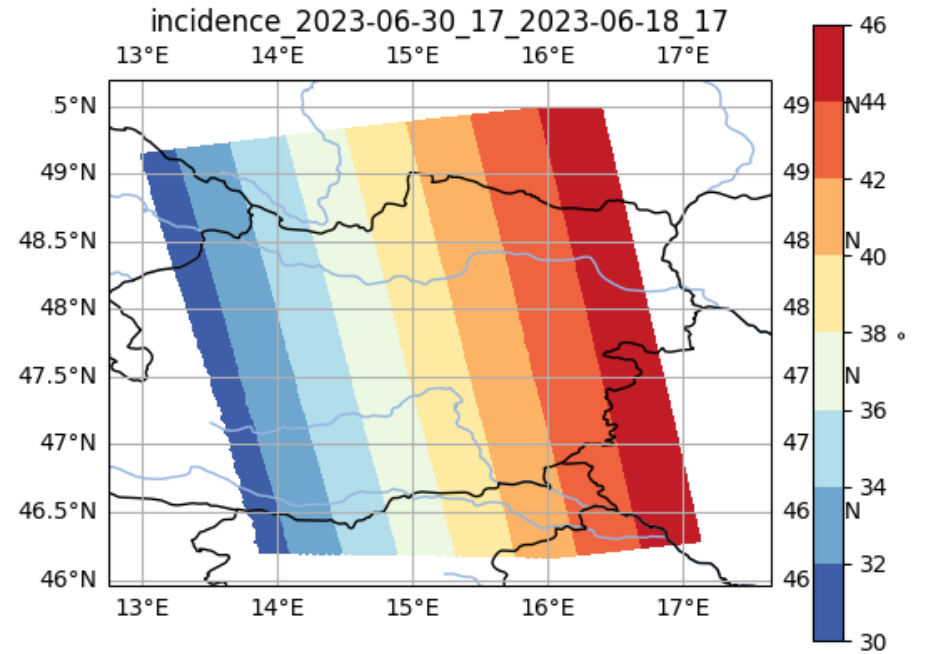
3h assimilation cycle 3D-Var
MODE-S, AMV, conventional obs



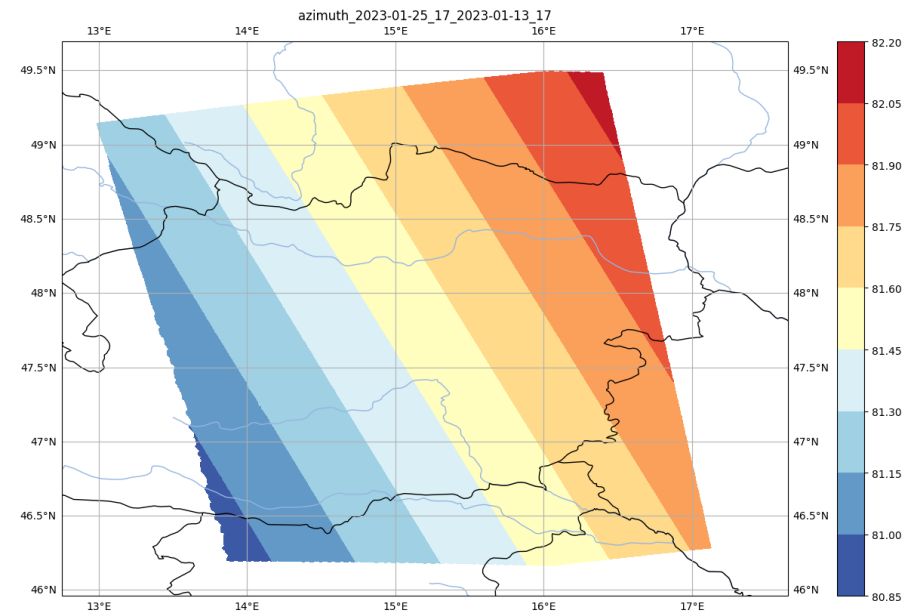


30th June
2023

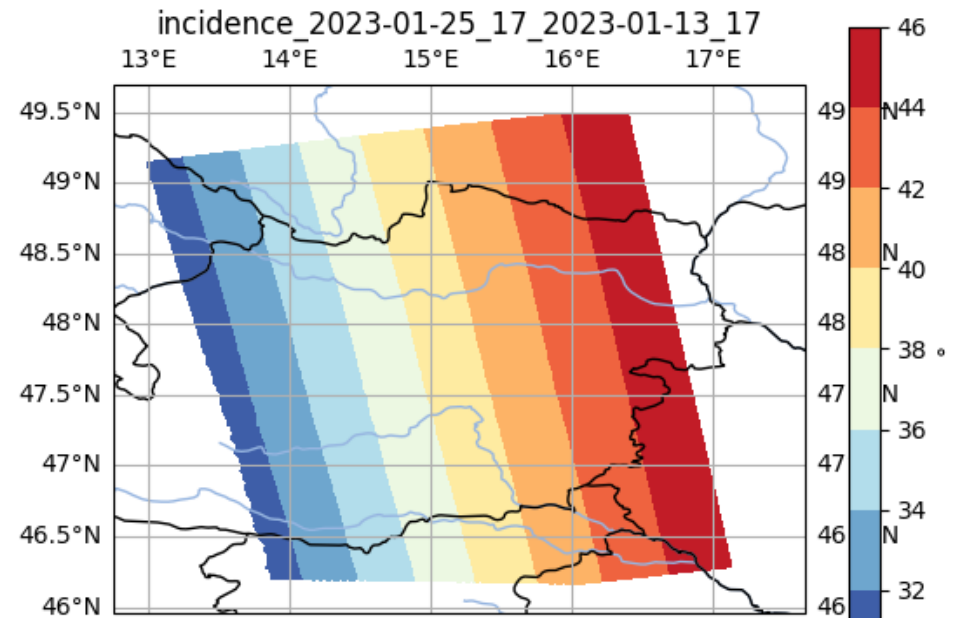
azimuth



incidence=90°-elevation

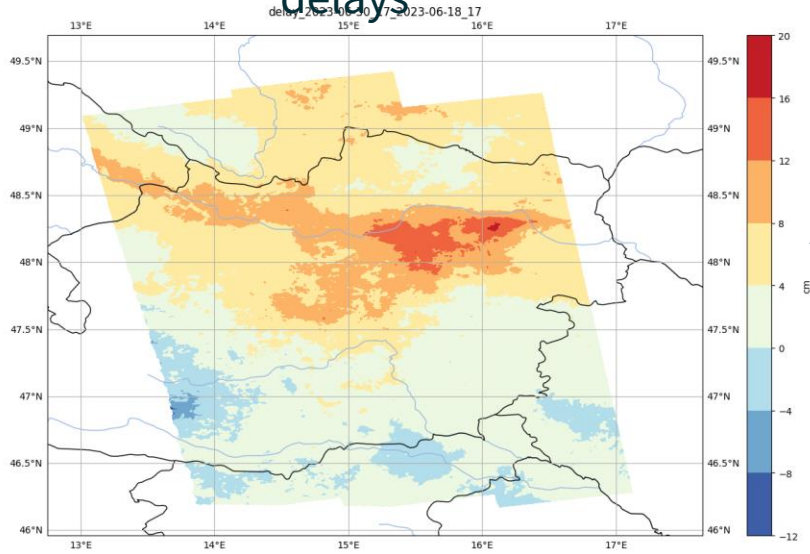


25th Jan.
2023



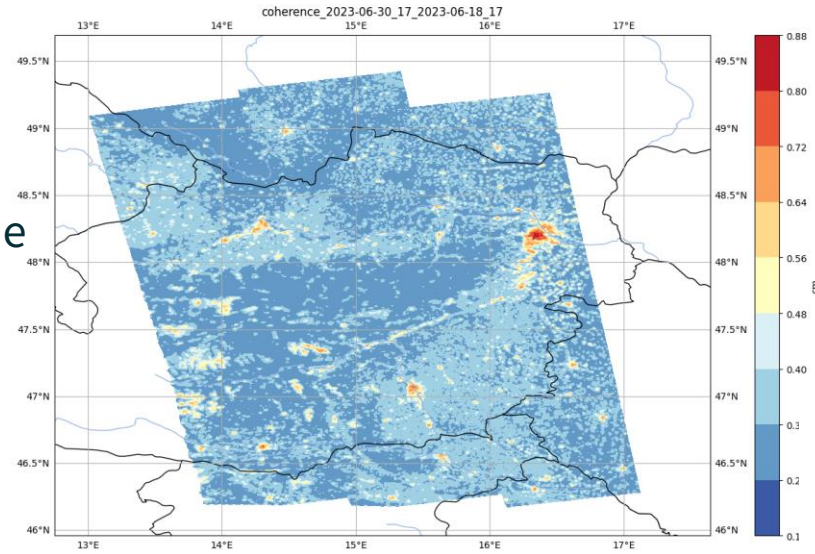
observation data

delays

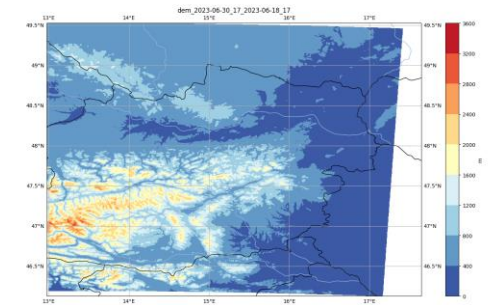


30th June
2023

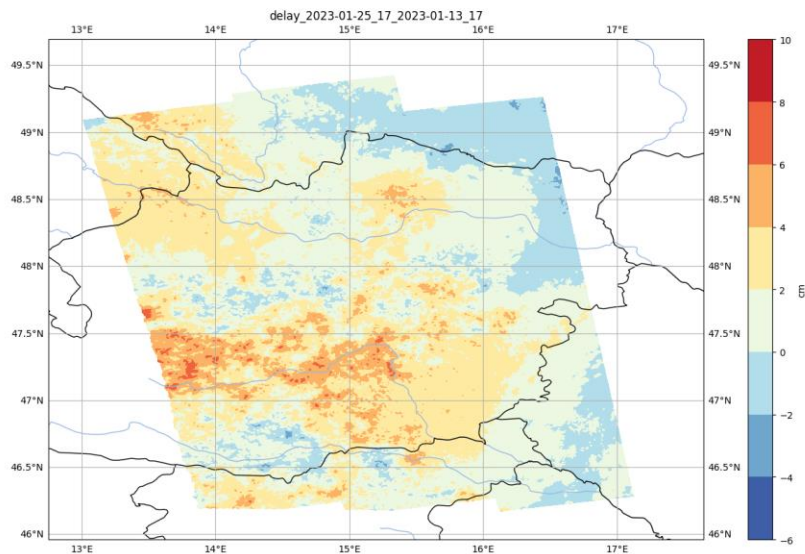
coherence



orography

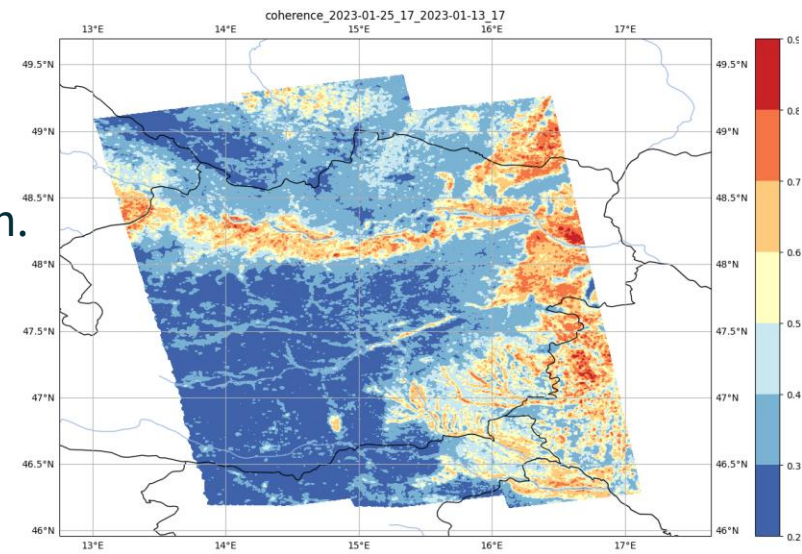


delays



25th Jan.
2023

coherence

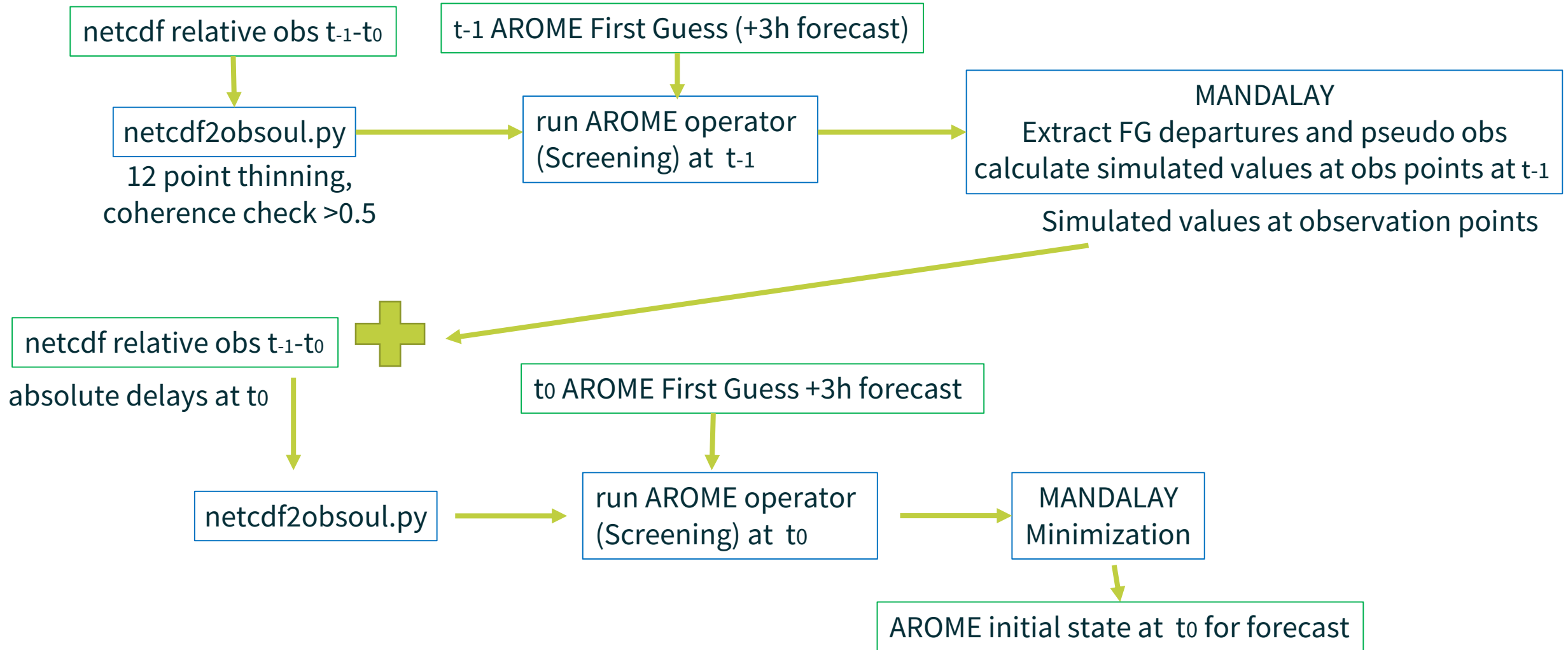


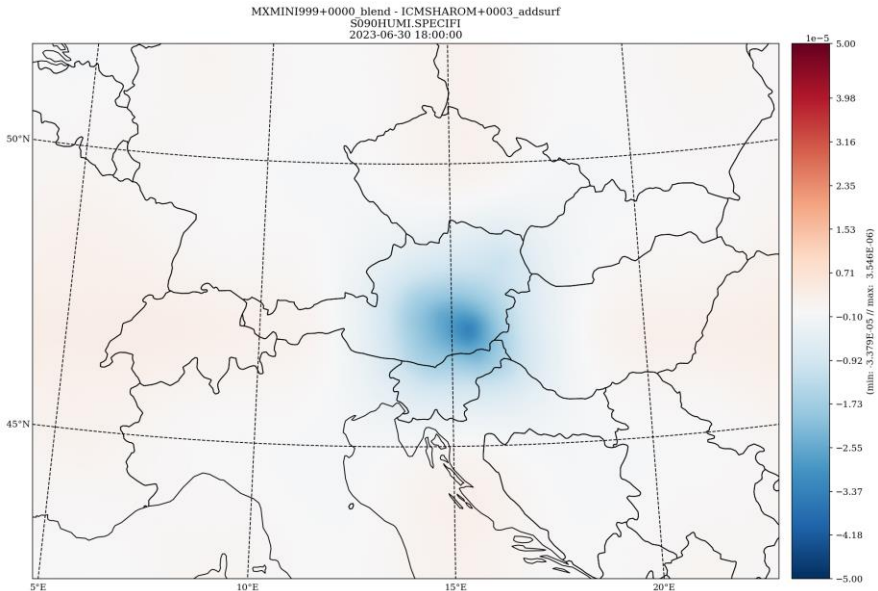
How to get absolute observations?

- Put relative observation at first timeslot into bator-screening
- Take observations-FG departures (OBS-FG) from ODB to get absolute delays
- add all relative delays to get absolute delays at all observation times
- failed as fields are too noisy

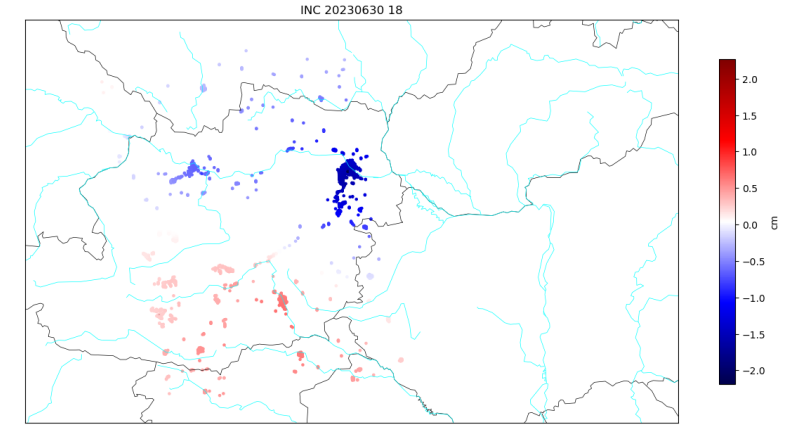
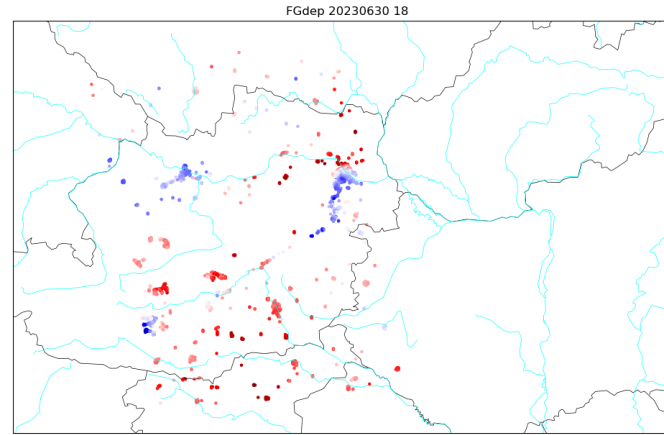


scheme of Sentinel 1 INSAR delay assimilation into AROME

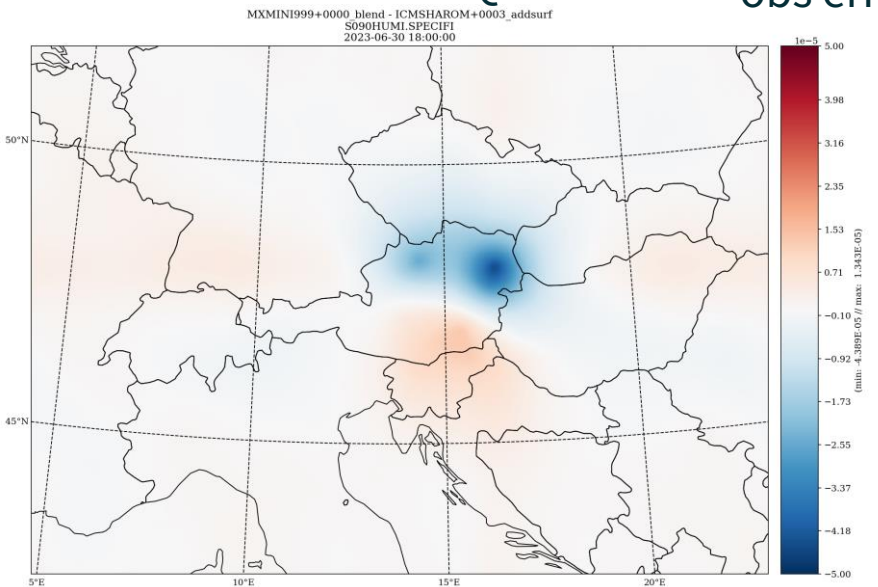




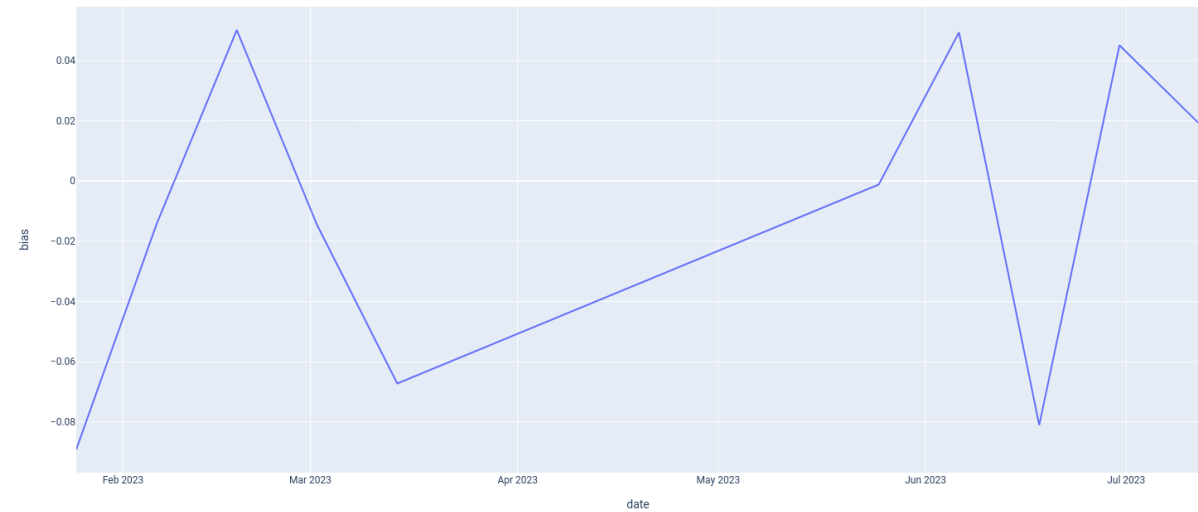
increment Q90



Several bias correction approaches failed due to temporal inconsistency -> take domain average departure as bias

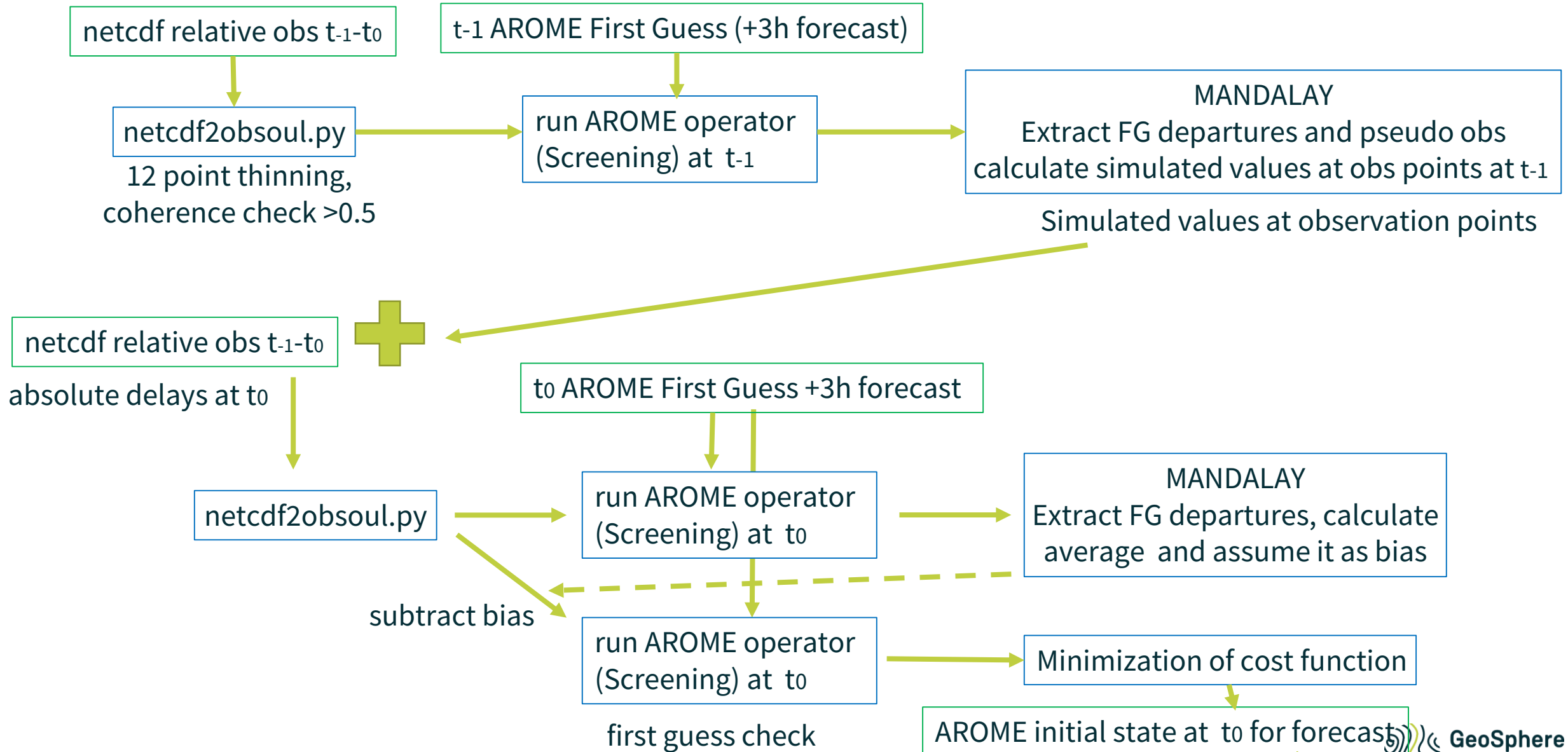


obs error 1.4cm

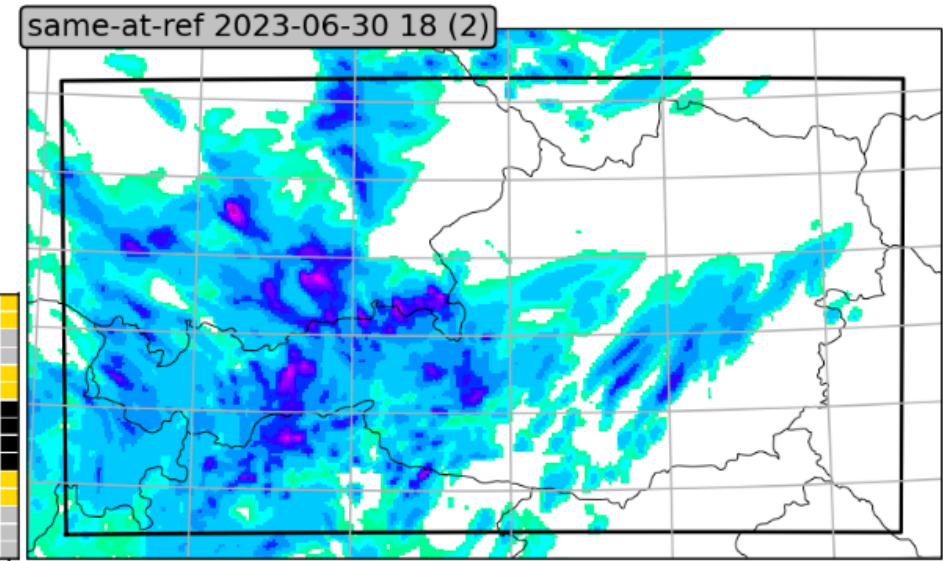
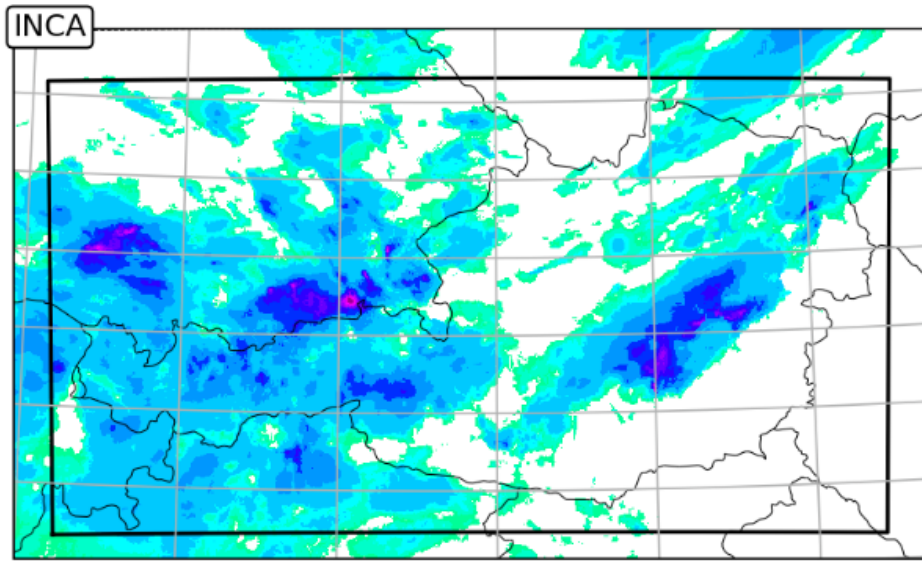


Time series of domain averaged FG departure

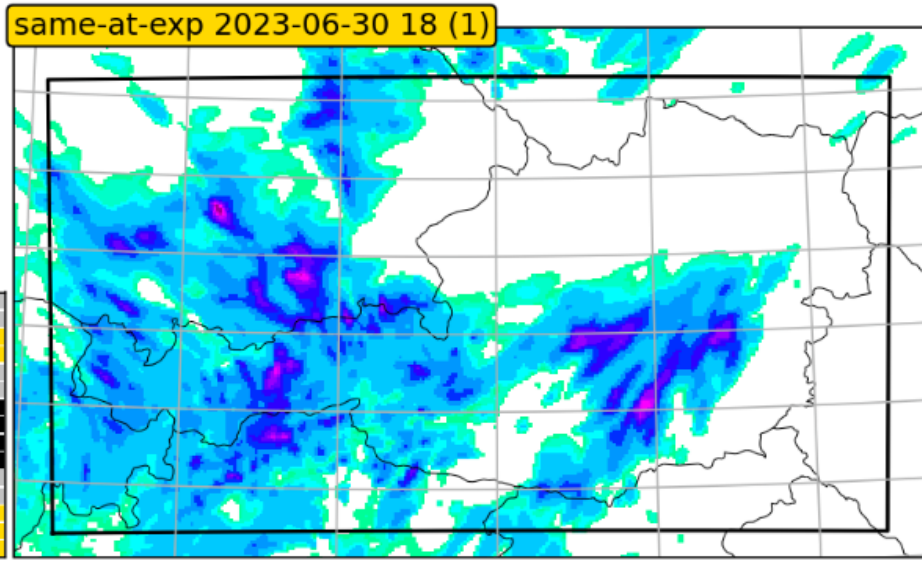
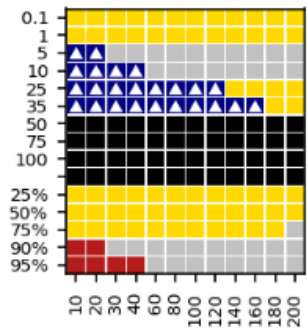
scheme of Sentinel 1 INSAR delay assimilation into AROME



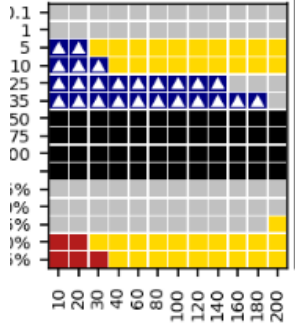
Acc. Precip. [mm] from 20230630 18 to 20230630 21 UTC



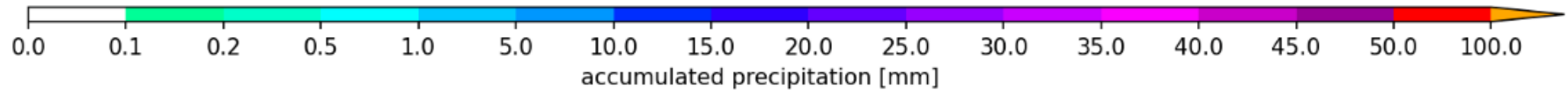
BIAS: 0.344 (1)
 MAE: 2.140 (1)
 RMSE: 4.318 (1)
 $R_{pearson}$: 0.348 (2)
 D_{90} : 34.1 km (2)



BIAS: 0.599 (2)
 MAE: 2.300 (2)
 RMSE: 4.604 (2)
 $R_{pearson}$: 0.352 (1)
 D_{90} : 27.5 km (1)



case study 30th June 2023 3h precipitation



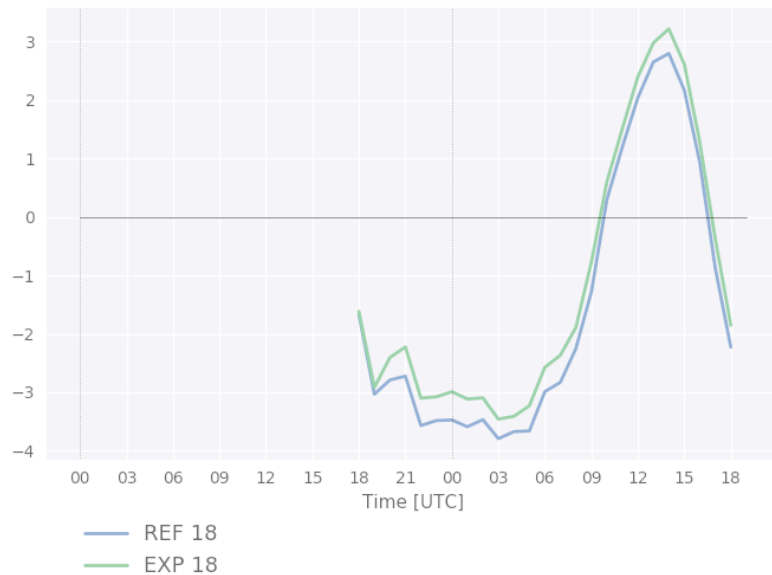
test period

Observation error 1.4

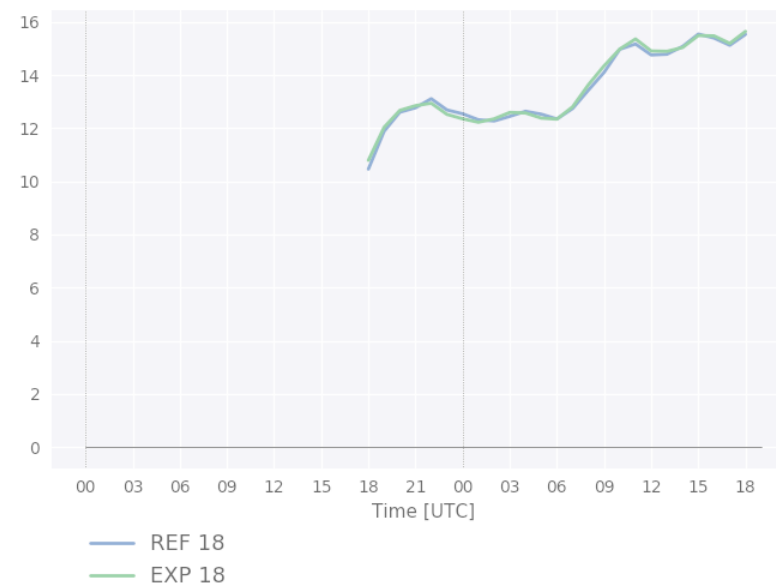
Reference REF: AROME 2.5km with 3h cycle 3D-Var no Sentinel-1

Experiment EXP: open loop 3D-Var based onFG from REF and +24h forecast including S1 data
January-July 2023

2m_relative_humidity: Mean BIAS from: 20230125 to 20230724



2m_relative_humidity: Mean RMSE from: 20230125 to 20230724

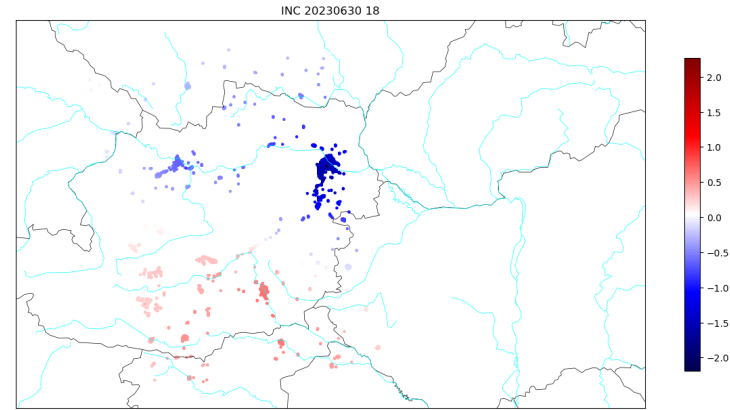
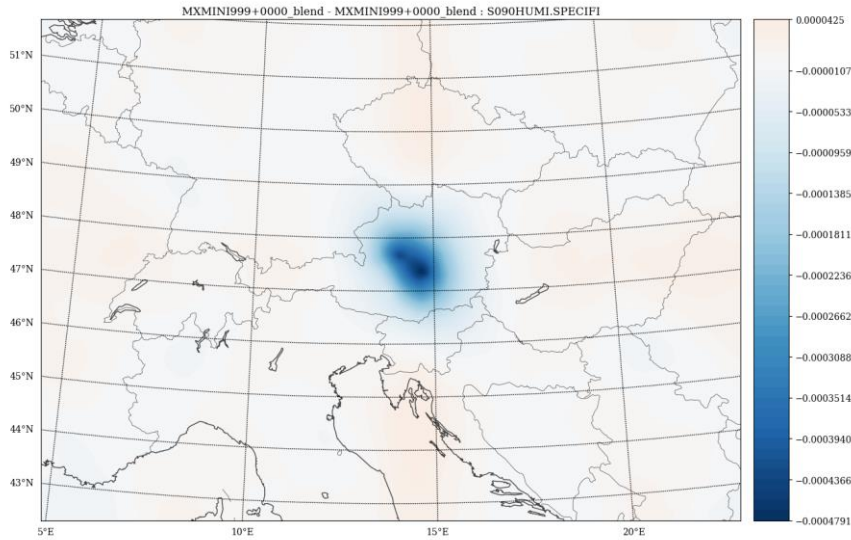


other scores
neutral

- Relative delays from Sentinel 1 assimilated
- low temporal resolution (12d) and coherence
- data and assimilation approach limits the impact
- improvement in RH2m bias otherwise mostly neutral impact on scores; mixed impact on precipitation
- Improve thinning
- combine Sentinel-1 with ZTD of reference stations to derive absolute delay values and several ASC/DSC data

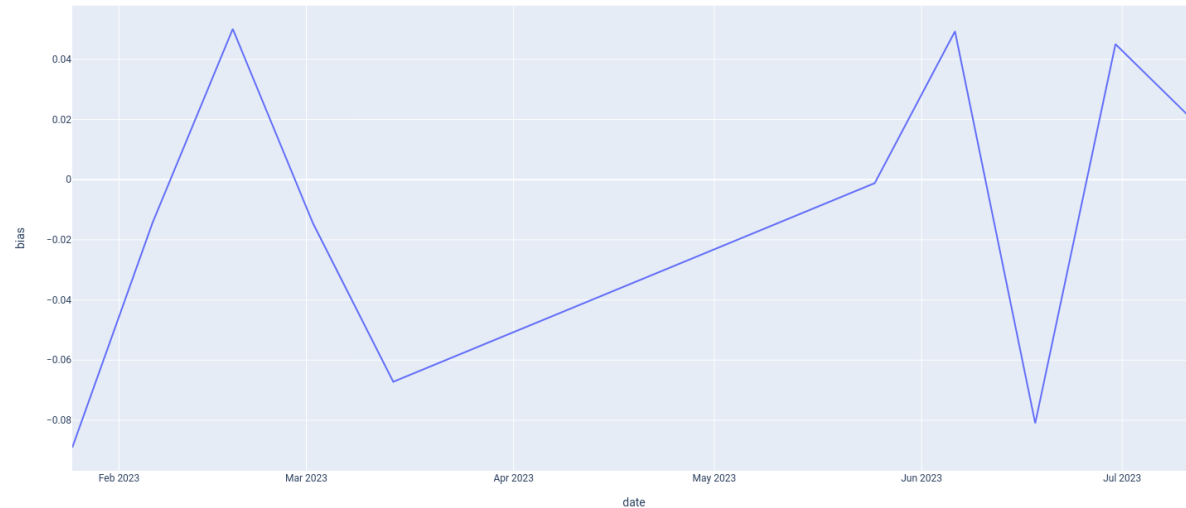
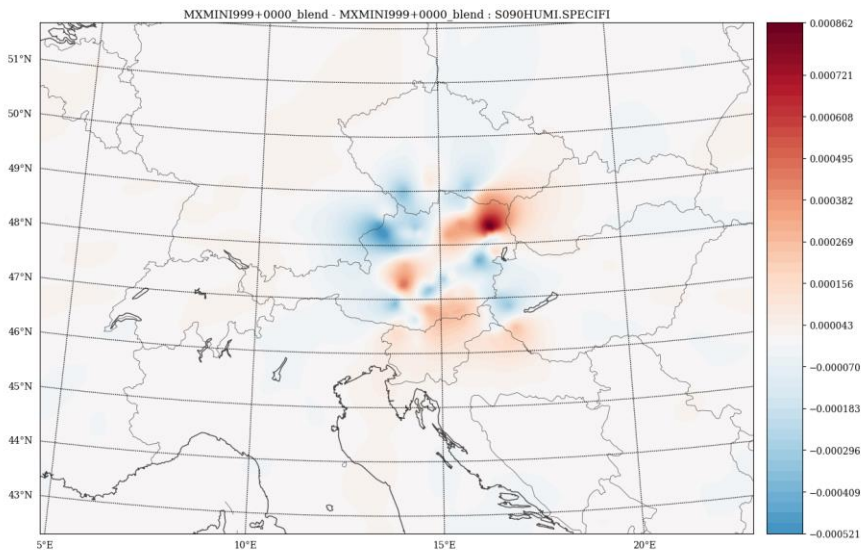


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observation impact Q90 obs error 1.4cm



Time series of domain averaged FG departure

