Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Progress towards new variational surface analyses at DWD

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Deutscher Wetterdienst

1 New surface analyses at DWD

As part of its operational assimilation cycles for the global and regional domains, DWD calculates analyses for sea surface temperature (SST), snow depth, two-metre temperature, and soil moisture.

Currently, the implementations of our surface analyses are unrelated to each other and to the atmospheric analysis (DACE). But recent developments (see section 2 Generic variational analysis) allow us to **implement new surface analyses** which will make use of parts of DACE. (Fig. 1).

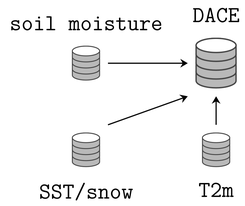

Figure 1: At the moment, each surface analysis has its own source code. In future, we want the surface analyses to be integrated with DACE.

We expect the new surface analyses to

- **reduce maintenance efforts** because there will be less duplicated functionality,
- **improve diagnostic and monitoring capabilities** because of shared tools for feedback files,
- **facilitate new developments** like new algorithms (Table 1) or additional observations because of more re-usable code.

	current	*planned*
SST analysis	Cressman	2D-(En)VAR
Snow analysis	Cressman	
T2m analysis	optimal interpolation (OI)	
Soil moisture analysis	SEKF	tbd

Table 1: Current and future planned surface analysis methods.

2 Generic variational analysis ("Omnivar")

Recent efforts of DWD's data assimilation groups (T. Hüther, S. Hollborn, R. Potthast et al.) have provided generic tools for ensemble-variational minimization in DACE according to:

$$\min_{\mathbf{x}} J(\mathbf{x}) = \frac{1}{2}(\mathbf{x}-\mathbf{x}^b)^T\mathbf{B}^{-1}(\mathbf{x}-\mathbf{x}^b) + \frac{1}{2}(\mathbf{y}-H(\mathbf{x}))^T\mathbf{R}^{-1}(\mathbf{y}-H(\mathbf{x})) = \frac{1}{2}(\mathbf{x}-\mathbf{x}^b)^T(\mathbf{B}_{\text{clim}}+\mathbf{B}_{\text{ens}})^{-1}(\mathbf{x}-\mathbf{x}^b) + \frac{1}{2}(\mathbf{y}-H(\mathbf{x}))^T\mathbf{R}^{-1}(\mathbf{y}-H(\mathbf{x})),$$

where $\mathbf{B}_{\text{clim}}$ and $\mathbf{B}_{\text{ens}}$ are application-specific implementations.

3 A prototype for two-metre temperature (T2m)

We have completed a prototype for the two-dimensional analysis (2DVAR) of T2m, including

- identical parallelization and I/O as the atmospheric analysis, including feedback files,
- use of independent grids for $\mathbf{x}$, $\mathbf{B}_{\text{clim}}$, and $\mathbf{B}_{\text{ens}}$ (global & regional)
- multivariate analysis, currently used for separate treatment of land and water points in H and $\mathbf{B}$ (Fig. 2),
- several options for $\mathbf{B}_{\text{clim}}$ (Table 2).

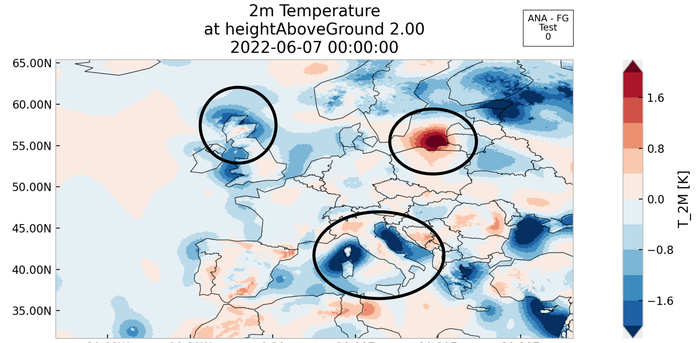

Figure 2: Analysis increments reflect the land-sea mask.

We used the **untuned prototype** to calculate a T2m analysis from 1–14 June 2022 with identical observations as the operational OI (Table 2).

	FG [K]	*ANA [K]*
operational OI (no minimization) separate analysis for land and water grid points	1.60	1.02
$\mathbf{B}_{\text{clim}} = \mathbf{B}_{\text{OI}}$ joint analysis for land and water grid points	1.62	1.17
$\mathbf{B}_{\text{clim}}(i,j) = \exp\left(\frac{-d_{\text{hor}}(i,j)^2}{2\sigma_{\text{hor}}}\right)\cdot\exp\left(\frac{-d_{\text{vert}}(i,j)^2}{2\sigma_{\text{vert}}}\right)$ joint analysis for land and water grid points	1.62	1.18
$\mathbf{B}_{\text{clim}}(i,j) = \text{lsc}(i,j)\cdot\exp\left(\frac{-d_{\text{hor}}(i,j)^2}{2\sigma_{\text{hor}}}\right)\cdot\exp\left(\frac{-d_{\text{vert}}(i,j)^2}{2\sigma_{\text{vert}}}\right)$ correl. between land and water points (lsc) set to 0.5, interpolation uses only matching land/water points	1.79	1.43

Table 2: First guess and analysis RMSE for T2m.

4 Operational OI vs. 2DVAR with $\mathbf{B}_{\text{OI}}$

Figure 3 shows the RMSD over 14 days between analyses from the operational OI and the 2DVAR with $\mathbf{B}_{\text{OI}}$, highlighting the main differences in coastal regions.

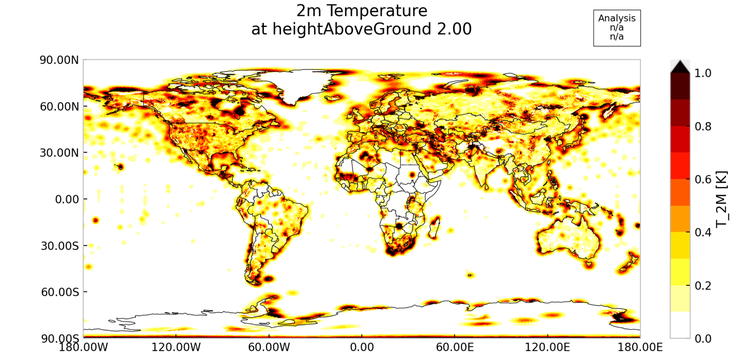

Figure 3: RMSD between OI and 2DVAR analysis.

Our first attempt to improve on this with a multivariate analysis for land and water points has not succeeded yet because of differences in the interpolation (Table 3). With only one or two points left for interpolation, the model equivalent (FG) deteriotates (last row of Table 2).

operational OI	10 points
2DVAR	3 points (to be increased to 6)

Table 3: Number of points for interpolation before removing mismatched land/water points.

5 Next steps and outlook

The last **missing piece** of the puzzle is **observation quality control**, which we are working on at the moment. Besides that,

- parameters controlling $\mathbf{B}$ and interpolation are all available in namelists and allow to **start tuning**,
- $\mathbf{B}_{\text{ens}}$ is in its last stages of development,
- the prototype is already prepared for other variables than T2m, and
- a NUMEX experiment with the prototype binary and its new files has been prepared and tested (expid 11547).