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Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Developments in Surface Analysis at DWD

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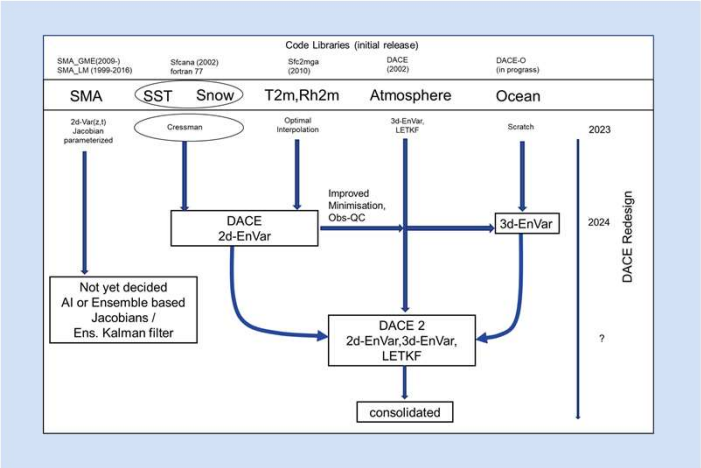
A new surface analysis system is under development at DWD, aiming at the implementation of a 2d EnVar data assimilation scheme based on DACE, the Data Assimilation Coding Environment platform used for the atmospheric global 3d EnVar and for the regional LETKF based analysis. The development is driven for three main reasons:

1. *Code unification: There are three code branches for the analysis of SST and Snow, screen level variables, and soil moisture in addition to the atmospheric analysis. Unified code improves maintainability. Common updates (e.g. I/O, parallelization, observation processing, …) are done only once, not for each analysis package separately, and code responsibility can be shared by more developers.*
2. *There is a need to get rid of persistent problems, e.g. patterns of the structure function in data sparse regions. No parallelisation of SMA, snow and SST analysis package. Single processor implementation.*
3. *A modern analysis scheme like 2d-Var allows to include more observation types (satellite data). Abstract data types in the minimisation part allow easier implementation of new algorithms. Full parallelisation and scalability.*



Redesign of DA system at DWD

The figure shows the present Data assimilation methods used in the weather forecast system at DWD and the future developments towards a unified redesigned system. As a first step towards the 2d variational surface analysis the screen level temperature analysis is replaced. Additional variables as Rh2m and SST are added stepwise when the scheme is consolidated. Snow analysis is prepared in the frame of the CERISE project. The new analysis is based on existing DACE code, with more flexible implementation of the minimisation part and improvement in organisation of qc for obs. processing. An Ocean 3d-EnVar is developed in parallel as completely new code following object oriented principles, which builds the new platform for the redesign of the full DA system. The redesign of the atmospheric analysis, as a major long term effort, is coordinated from early stage, improvements in surface analysis are adopted. The surface analysis package is planned to be merged continuously, finally leading to the new DACE2 coding environment.

2d EnVar Algorithm

Minimisation of cost function

$$J(x) = (x-x^b)^T B^{-1}(x-x^b) + (y-Hx)^T R^{-1}(y-Hx)$$

$$\nabla J = 0$$

Solution for x in model space

$$x^a - x^b = BH^T(HBH^T + R)^{-1}(y - Hx^b)$$

Rearrange to solve minimisation efficient in observation space

$$\underbrace{(R+HBH^T)}_{A}\underbrace{(BH^T)^{-1}(x-x^b)}_{z} = \underbrace{y-Hx^b}_{b}$$

A is symmetric and positiv definit. Linear equation system can be solved iteratively by standard conjugate gradient method to find solution for z that minimizes J in observation space .

Solution in model space is obtained by post multiplication

$$x^a - x^b = BH^T_{spec} z$$

$$B = H^T_{clim} B_{clim} H_{clim} + H^T_{ens} B_{ens} H_{ens}$$

B lives in a common „interpolation space“ for B_{clim} and B_{ens}, e.g. on climatological or ensemble or any other appropriate grid. H_{spec} transforms B from interpolation to observation space.
No operation in full model resolution is required.Only for calculation of the observation equivalent HX_b model gridpoints around observation locations are involved.

NWP model forecast system

Global
– ICON (Icosahedral Nonhydrostatic model)
– Deterministic: 13 km, 120 layer, 7 day fc, 0:00,12:00 UTC
– 40 member ensemble, 26 km

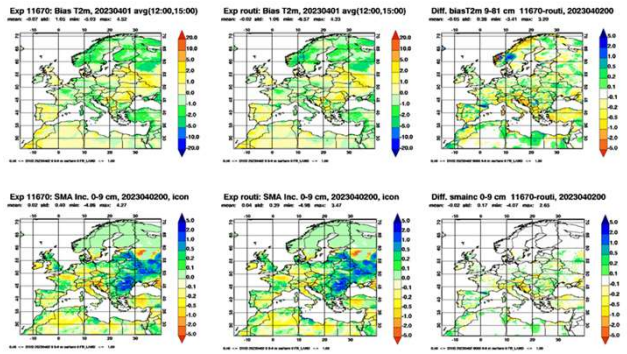
European nest:
- ICON-EU, deterministic 6.5 km, 74 layer, 5 day fc
- 40 member ensemble, 13 km

Regional model:
– ICON-D2, deterministic 2.2 km, 65 layers, 72 hours fc, 6 hour update
– 40 member ensemble, same model resolution as deterministic.

Overview present surface analysis system

Analysis	Analysis scheme	Observations used	Background field, external data sources	Update frequency (hrs), time, model
SST-analysis	Cressman scheme	Synop observations of sea temperature from buoys and ships	Background SST from Ostia foundation temperature, max. 36 hours ago, 5 km resolution, updated by latest synop reports. Ostia Sea Ice cover based on OSI-SAF sea ice analysis.	24 hour, 0 UTC ICON-global, ICON-EU, ICON-D2
Snow analysis	Cressman scheme	Synop observations of snow depth, Precipitation reports in combination with T2m, WW reports converted to snow depth increments using empirical fct	IMS snow cover global, 25 km resolution, AFWA snow depth analysis in data sparse regions, presently not used due to product changes.	3 hour, 0,3,6… ICON-global, ICON-EU 6 hour, 0,6,12,… (ICON-D2)
T2m analysis	Optimal Interpolation	T2m reports from synop stations over land, and from ships and buoys over sea, Amips	None, Background from 3 hour model forecast of assimilation run.	24 hours, 0 UTC 3 hourly analysis for previous day, to be used as gridded observations for Soil Moisture Analysis.
Soil Moisture analysis	2d var (z,t) extended Kalman filter using parameterized Jacobians for calculation of dT2m/dwb	Gridded observations for 12:00, 15:00 UTC local time from T2m analysis.	Background soil moisture analysis from previous day 0:00 UTC.	24 hour, analysis for 0 UTC previous day, actual analysis calculated using 24 hour model increment wb(t,0:00) – wb(t-24hr,0:00). Incremental analysis update in 0:00 UTC model forecast

Impact of new T2m-Analysis on Soil moisture analysis (SMA)



The figure shows 2m temperature forecast errors (fc-ana) for an assimilation experiment using the 2d-Var T2m analysis compared to the operational scheme for a selected day over Europe (top panels), and the corresponding soil moisture increments in the upper 3 soil layers (bottom panels). The differences are shown in the right column. There is generally overall agreement between both, which indicate the technical readyness of the new scheme. However differences indicate different observation selection, and differences in the choice of the observation error
(1 K for the new scheme vs. 1.6 K in the old OI scheme).

Summary

A new 2D EnVar surface analysis scheme is developed at DWD. This is based on present DACE code, but it is coordinated with the redesign of the whole DA system. A first version for 2m temperature analysis is evaluated and scores for a 7 week experiment are close to the present system (not shown). Rh2m, SST, and snow are added stepwise until the present system is replaced by a unified surface analysis.

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