Snow analysis at DWD
- Status and plans

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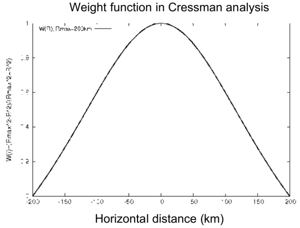
Current snow analysis scheme

- based on Cressman interpolation, ie. distance-weighted, successive correction towards observations
- 3 h (global) and 6 h (regional) analysis cycles
- background fields:
  - `W_SNOW`, `RHO_SNOW` → `H_SNOW`
  - `FRESHSNW`, `T_SNOW`
- observations:
  - snow depth from SYNOP
  - temperature and precipiation as snow depth proxies
  - NOAA snow cover and depth in NH (if no other data available)
- analysis fields:
  - `H_SNOW`, `FRESHSNW` (diagnosed)
  - `W_SNOW`, `RHO_SNOW`, `T_SNOW`



Current snow analysis scheme

Motivation for revision

- no error-weighted use of observations in Cressman interpolation
- no possibility to use other observations than snow depth (no forward operators)
- use with multilayer snow schemes is unclear

Where are we now?

We are currently working with two independent code bases:

- surface analyses (SNW, SST, SMA)
- Fortran 90 (77)
- SVN behind some custom set of scripts at DWD

- DACE (atmospheric analysis)
- Fortran 2003
- Git & Gitlab hosted at DKRZ Hamburg

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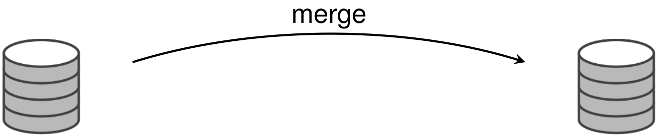

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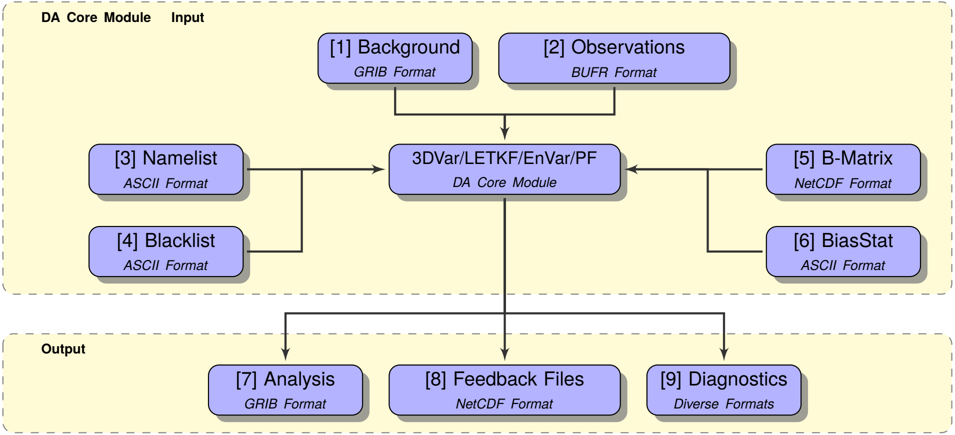
Our goal is to integrate the surface analyses into DACE.

- main data assimilation code at DWD



DACE - Data Assimilation Coding Environment

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

- DACE provides several analysis algorithms:
  - PSAS/3DVar, LETKF (operational), EnVar (operational), particle filter

⇒ better (statistically optimal) use of observations

- the DACE code is…
  - organized around derived datatypes for state, observations, grids, etc.
  - employs encapsulation and generic interfaces (eg. observation operators)
  - highly parallel

⇒ easier to maintain and to extend

- DACE handles observation preprocessing
  - I/O, metadata handling
  - various quality checks
  - preprocessing

Using 3DVar for the snow analysis

- 3DVar cost function:

$$J = (x^b - x)^T B^{-1}(x^b - x) + (y - H(x))^T R^{-1}(y - H(x))$$
$$\frac{\partial J}{\partial x} = B^{-1}(x - x^b) + H^T R^{-1}(H(x) - y)$$

$\Rightarrow$ set $\frac{\partial J}{\partial x}$ to zero, solve for x

- linearize $H(x) \approx H(x^b) + Hx - Hx^b$, plus some linear algebra:

$$(HBH^T + R)z = y - H(x^b) \qquad \Rightarrow \text{minimization, solve for } z$$
$$x = x^b + BH^T z \qquad \Rightarrow \text{postmultiplication to get } x$$

- in DACE, B is implemented as a concatenation of operators/subroutines for
  - interpolation
  - transposition (move data between processors)
  - correlation functions

Snow analysis in DACE using 3DVar

- analysis fields: `H_SNOW` (analyzed) `FRESHSNW` (diagnosed)
- observations: snow depth
  - either directly from SYNOP
  - or diagnosed from SYNOP precip + temperature + previous snow depth
  - or diagnosed from NOAA snow depth analysis or IMS snow mask
- actually a 2DVar but surface height of observations and background enters covariance matrix B

Snow analysis in DACE using 3DVar

- use a factorized ansatz for horizontal and vertical correlation functions as part of the *B* matrix

$$B_{ij} = \sigma_i \sigma_j c_h(i,\ j;\ l_h) c_v(i,\ j;\ l_v)$$

- start with Gaussian/Gaspari-Cohn correlation functions
- l_h and l_v will be based on current Cressman length scales

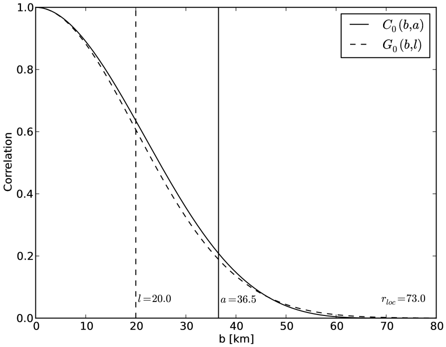


Figure 1: Gaspari-Cohn (solid) and Gaussian (dashed) correlation functions

Steps to implement the snow analysis in DACE

1. enable input of observations
   - adapt data types and tables for new observation types and their metadata
2. implement current observation preprocessing
   - derive pseudo snow depth obs. where necessary
3. add required first guess fields to data structures
4. implement B matrix
   - implement horizontal and vertical correlation functions dependent on observation locations
   - link snow depth to this type of new B matrix
5. diagnose fresh snow factor
6. write increments
7. write feedback files (for diagnostic purposes)

Time line

- started technical work in Q1/2021
- target for Q4/2021: finish core development work
  - have a working implementation that is technically complete and can perform analyses similar to the current operational system
- 2022: further testing, tuning and configuration

- possible further technical developments (with increasing complexity):
  - include ensemble information in the B matrix to complement the horizontal and vertical correlation functions (EnVar-like)
  - trials with LETKF or particle filter
  - include forward operators for satellite observations (eg. SWE)