Snow analysis at DWD
- Integration into DACE

G. Geppert, M. Lange, R. Potthast, C. Schraff, et al.
Deutscher Wetterdienst

Where are we now?

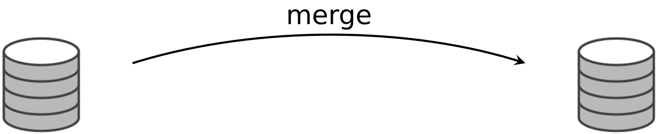
At DWD, we are currently working with two independent code bases:

- 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

Where are we now?

At DWD, we are currently working with two independent code bases:



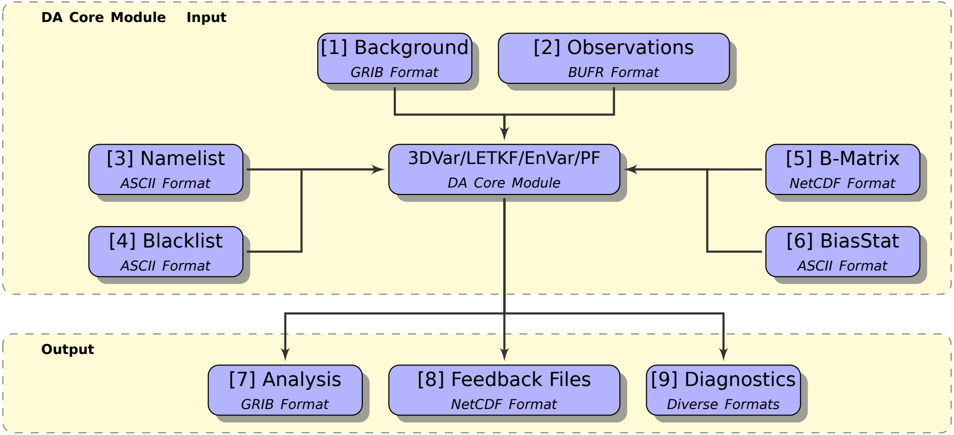
- surface analyses (SNW, SST, SMA)
- Fortran 90 (77)
- SVN behind some custom set of scripts at DWD

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

Our goal is to integrate the surface analyses into DACE.

DACE - Data Assimilation Coding Environment

- main data assimilation code at DWD
- used for global and regional analyses
- closely linked with ICON in case of LETKF



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
- the code is...
  - organized around derived datatypes for state, observations, grids, etc.
  - employs encapsulation and generic interfaces
  - sufficiently generic to use 'atmospheric' analysis code for surface analyses with little extensions and 'namelist' control
- DACE handles observation preprocessing
  - read cdfin files, ie. converted BUFR files
  - perform various quality checks, also in relation to the first guess
  - store data and metadata in generic data structure

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

- targeted variables: snow depth (analyzed) fresh snow factor (diagnosed)
- observations used in the analysis: 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
- analysis sees only snow depth - both in first guess and observations
- actually a 2DVar but with height information for observations and grid points

Snow analysis in DACE using 3DVar

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

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

- initial approach will use Gaussian/Gaspari-Cohn correlation functions
- l_h and l_v will be based on current Cressman length scales

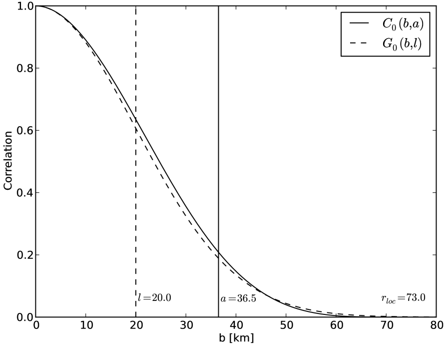


Figure 1: Gaspari-Cohn (solid) and Gaussian (dashed) correlation functions

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)

All steps have recently been done in other contexts or for other variables (eg. a preliminary two-dim. temperature analysis and trials with Gaussian B matrices).

Time line

- end of 2021: finish core development work
  - have a working implementation that is technically complete and can perform analyses similar to the current operational analyses
- possibly beyond 2021: further testing, tuning and configuration

- possible further technical developments (with increasing complexity):
  - include current ensemble information in the B matrix to complement the horizontal and vertical correlation functions (EnVar-like)
  - trials with LETKF or PF
  - include satellite observations of SWE

Open questions

- do we need to consider multilayer aspects now?
- are there ideas yet for how SNOWPOLINO is supposed to ingest a snow analysis and what kind of analysis?
- is there already any experience with multilayer analyses in any context?
- are there possible other contributions we need to consider early on?