Snow analysis for NWP at Meteo France and recent developments for land surface analysis

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Outline

- Current land surface data assimilation system
- Snow analysis:
  - AROME limited-area model
  - ARPEGE global model
  - First steps towards the use of satellite observations
- Future plans for the assimilation system over land and preliminary steps towards coupled assimilation: Diagnostics using ARPEGE EDA for surface analysis
- Conclusions and future work

Land surface data assimilation system

- Météo France global model ARPEGE and limited area model AROME are coupled to the surface modelling platform SURFEX.

- Each grid point is divided into 4 tiles which have their own prognostic variables (and analysed variables):

  - Nature: ISBA-3L (3 layers) for NWP (Noilhan and Mahfouf, 1996; Boone et al., 1999), prognostic variables in the three superficial layers (liquid and solid fractions for soil water content, SWE for snow on the ground) → : T_s, T_2, T_3, w_g, w_2, w_3.

  - Town: TEB (Masson, 2000) → T_{roof}, T_{wall}, T_{road}

  - Lake → LST (FLake)

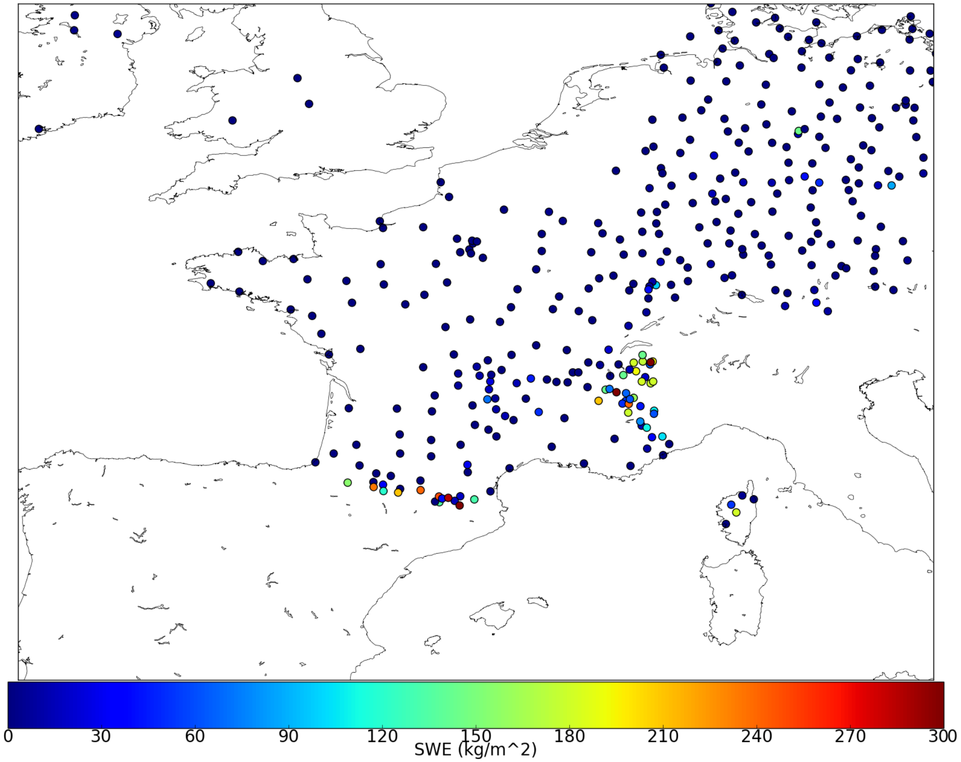
  - Sea → SST (CMO 1D)

- We use screen level observations of T_{2m} and RH_{2m} to compute gridded analysed fields using 2D Optimal Interpolation (OI) (CANARI)

- 1D OI scheme using the increments of T_{2m} and RH_{2m} (Giard and Bazile, 2000) to obtain increments of soil temperature and moisture T_s, T_2, w_g, w_2.

Snow analysis

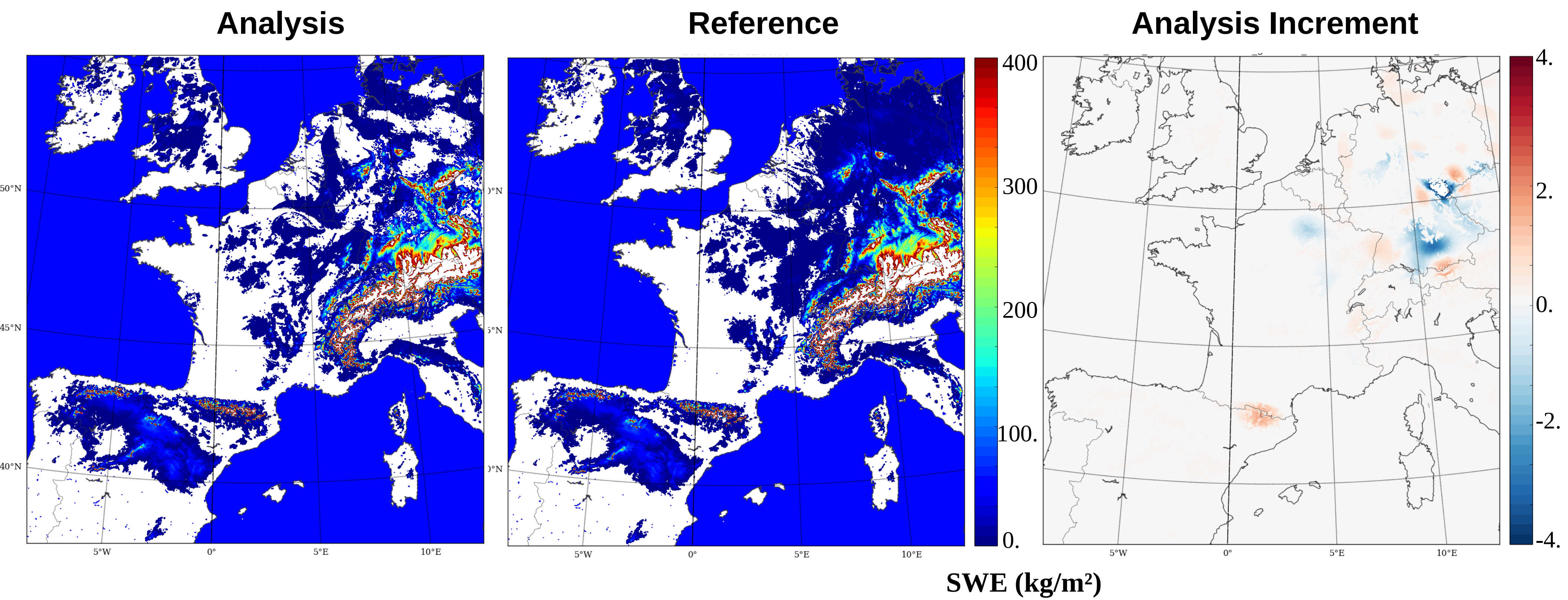
- Snow analysis over plains: necessary to correct for insufficient snow melt in the model
  - 2 periods of study: winter 2018 (February-March) and 2019 (January-February)



Snow depth observations over the AROME-France domain

- Heterogeneous observation network over the AROME-France domain
- Snow analysis performed using CANARI 2D OI
- Prognostic variable: SWE → use of model density to transform snow depth observations into snow water equivalent for the assimilation
- Tuning of observation and background errors and length scales

Snow analysis: case study on 20th January 2019, 12:00



Observation error: $\sigma_o = 2.5$ kg/m²

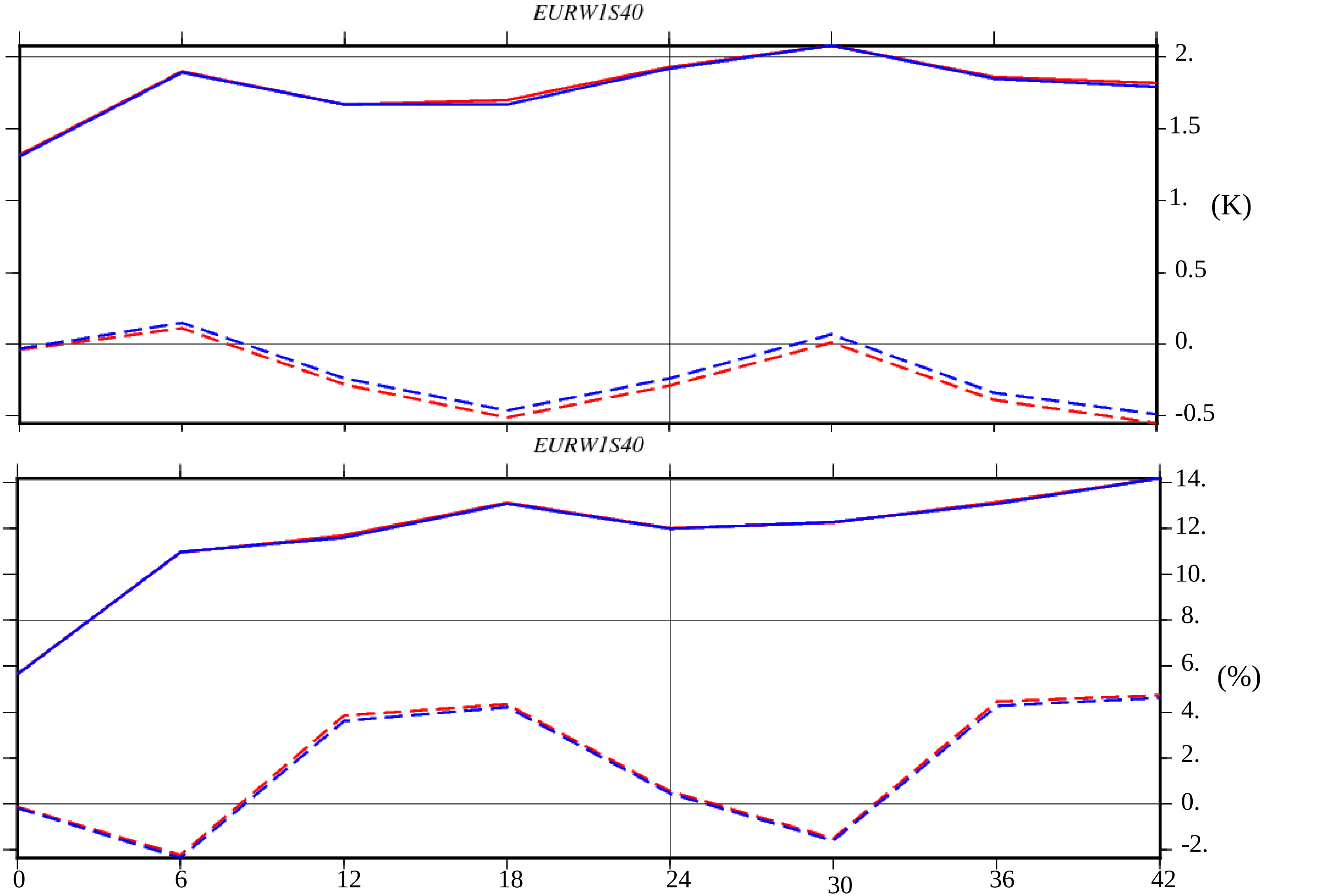
Background error: $\sigma_b = 5.0$ kg/m²

Length scale: d = 50 km (Model resolution: 1.3 km)

Snow analysis: bias and MSE on February-March 2019 with respect to Synop stations

T2m
(σ_o = 2.5 kg/m²)

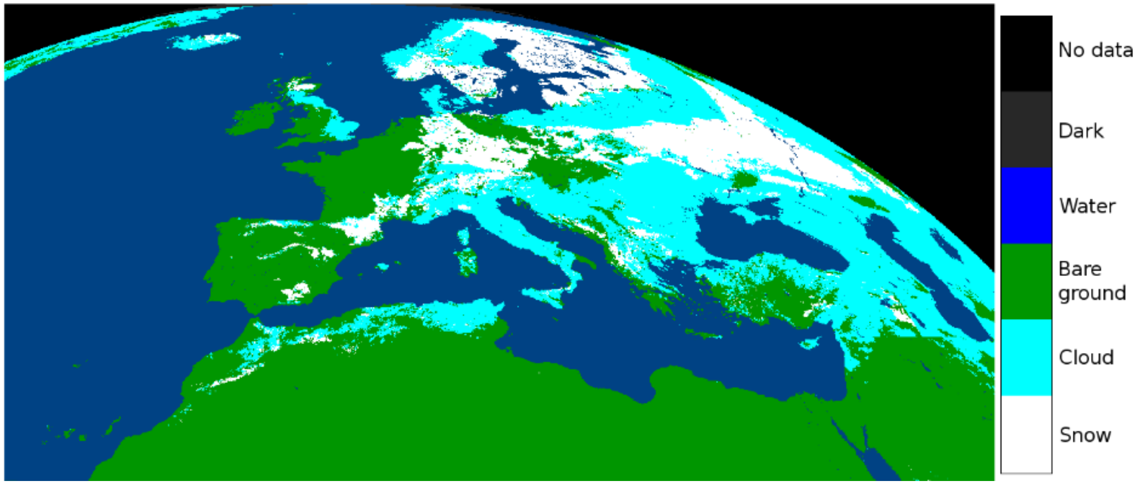
Hu2m
(σ_o = 2.5 kg/m²)



Bias (dashed line) and Mean Square Error (solid line) of 2 metre temperature and 2 metre relative humidity forecasts as a function of the forecast range, with snow analysis and without snow analysis

Snow analysis: use of satellite observations

- Daily snow cover product H10 from H-SAF (http://hsaf.meteoam.it/snow.php)
  - Resolution 0.05° over Europe, computed from SEVIRI multichannel analysis

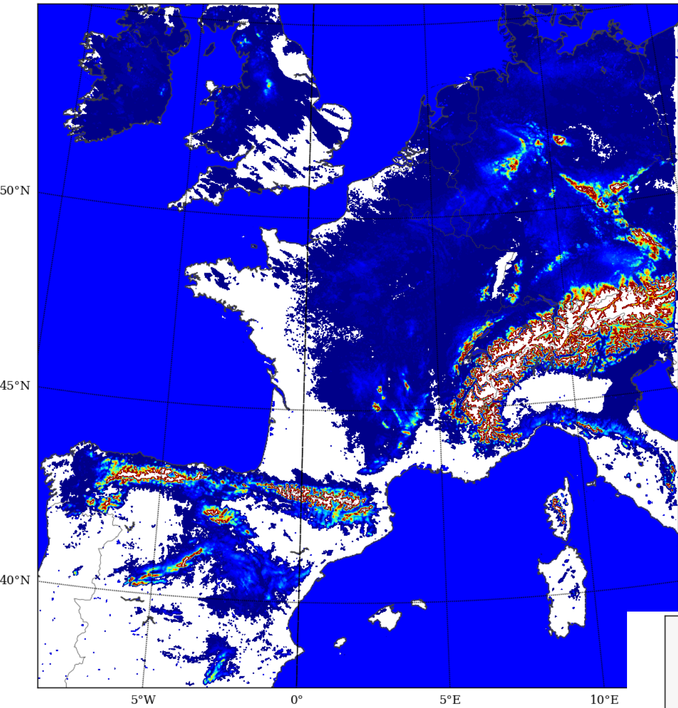


H-SAF H10 snow product on March 9, 2010

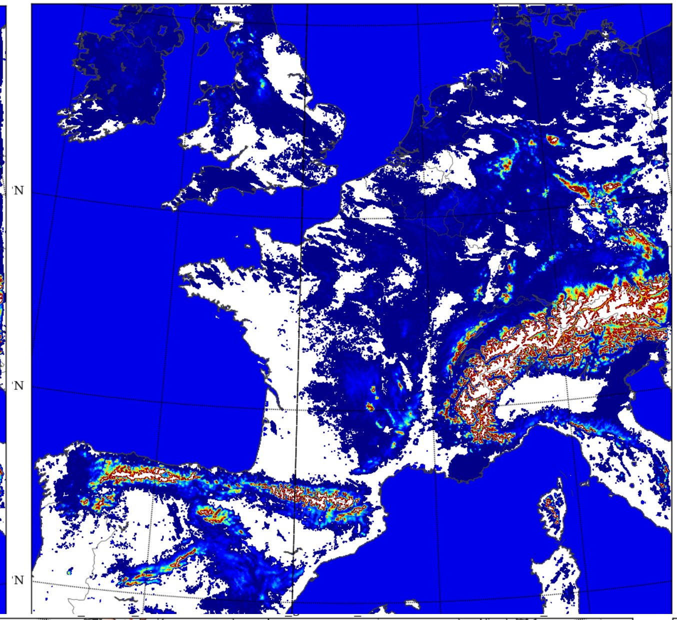
- The snow mask (values 0 or 1) is converted into values that can be ingested in the assimilation :
  - 0 kg/m² (no snow) or 5 kg/m² (snow on the ground)
- Tuning of observation errors and length scale:
  - σ_o = 8 kg/m² (H-SAF) instead of 5 kg/m² (Synop)
  - d = 5 km (H-SAF) instead of 50 km (Synop)

Snow analysis: case study on 12th February 2018, 12:00

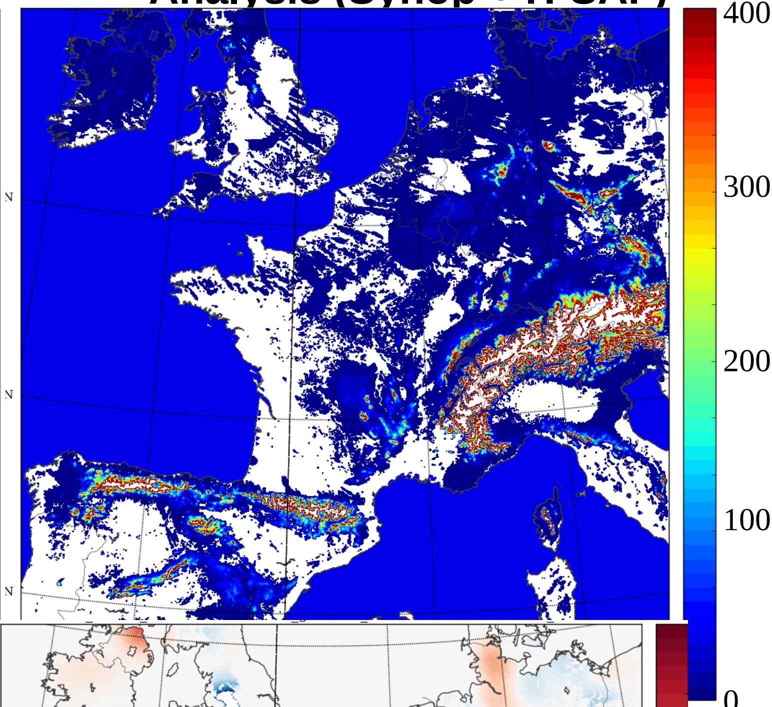
Reference



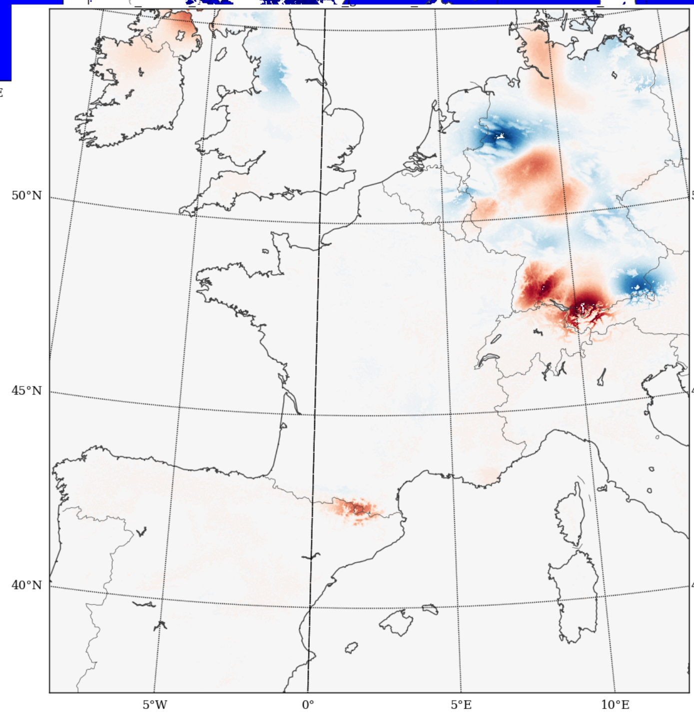
Analysis (Synop only)

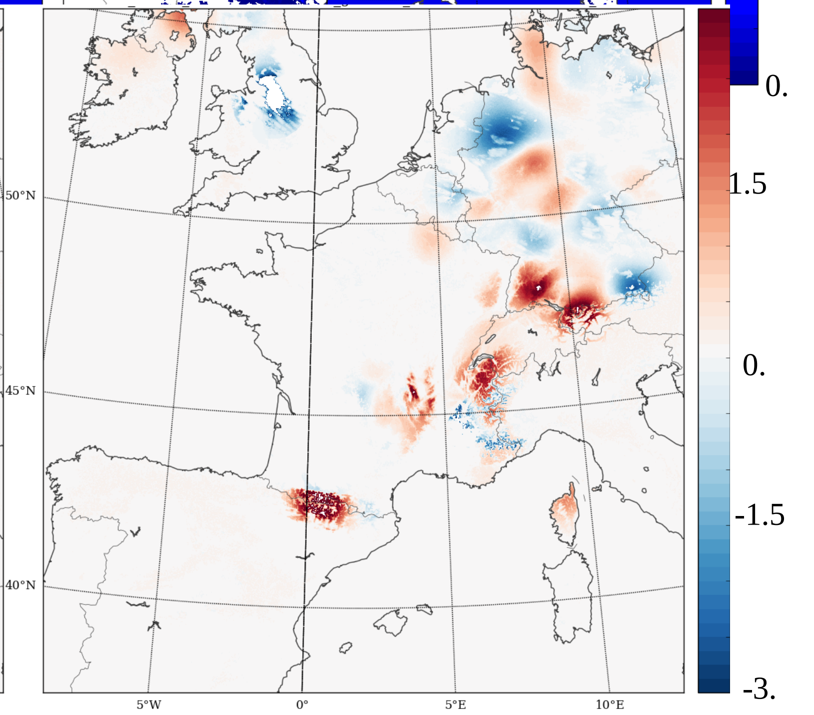


Analysis (Synop + H-SAF)



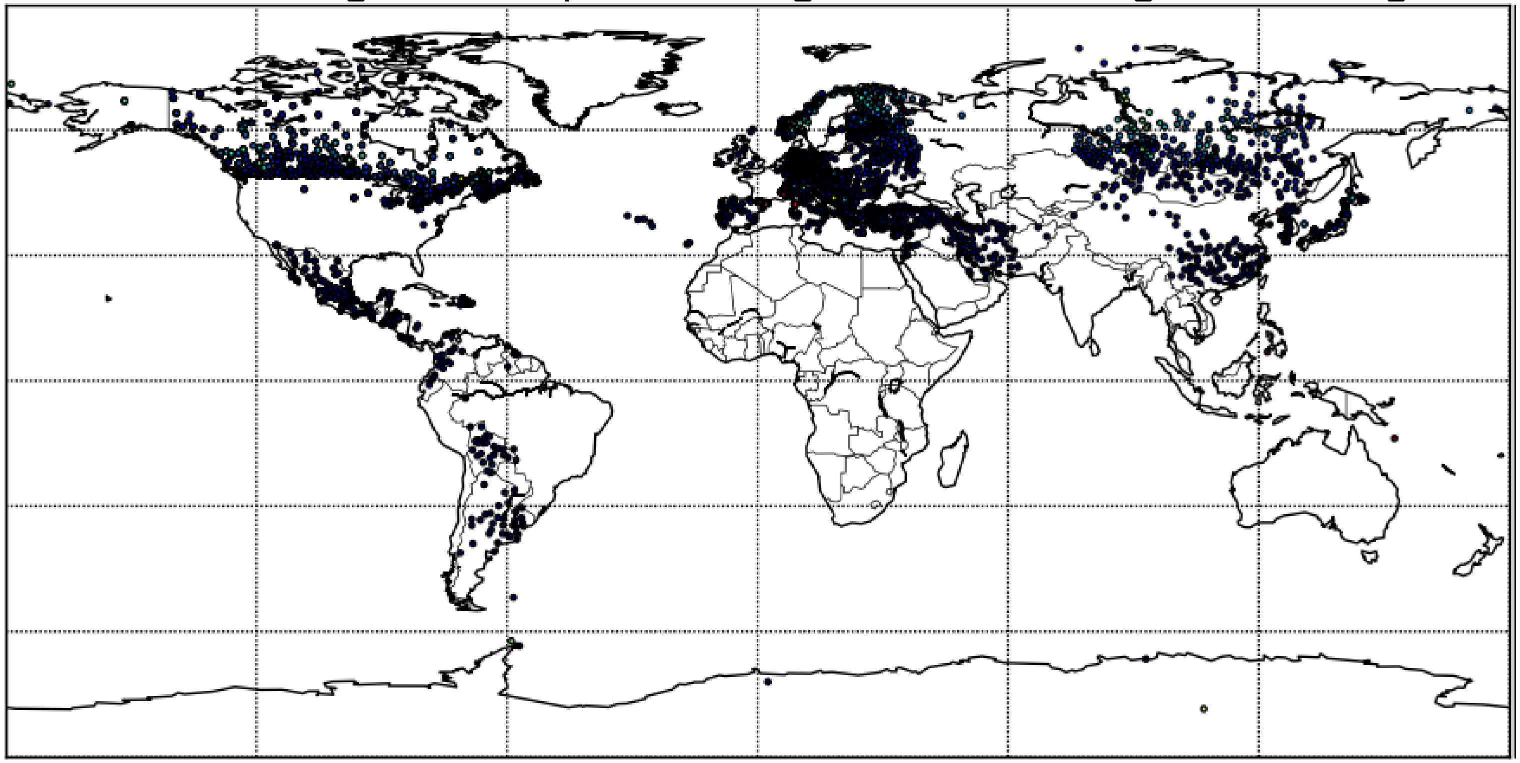
Analysis Increment
(SWE kg/m²)





Snow analysis in ARPEGE

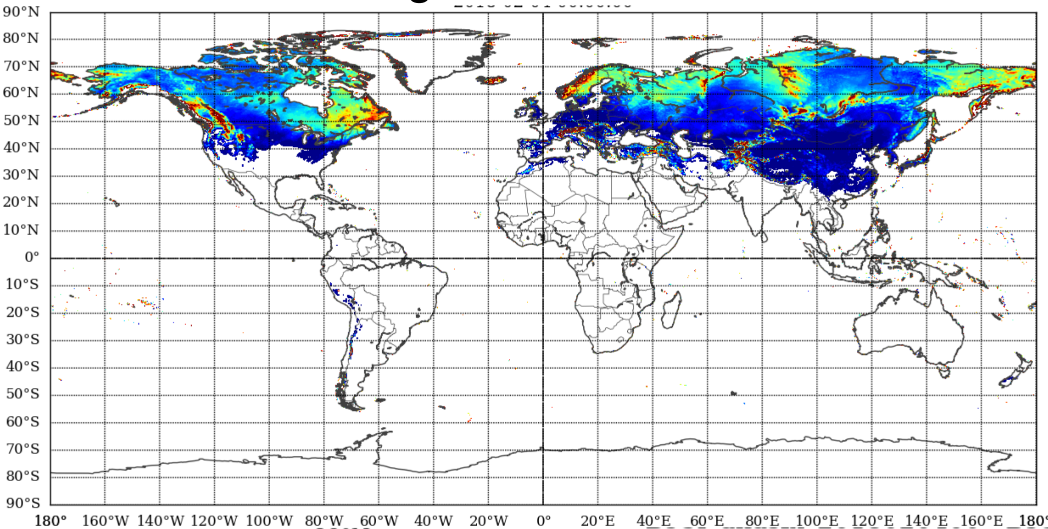
- Synop stations measuring snow depth: heterogeneous coverage over the globe



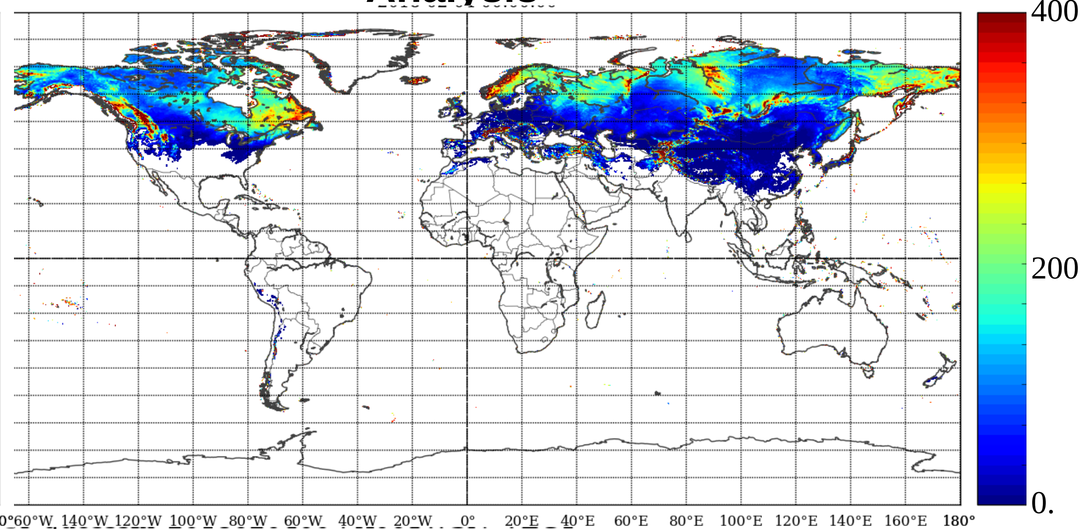
- Same principle as in AROME: 2D-OI with a struture function accounting for the distance and the difference of elevations between observation and grid point
- Tuning of observation errors and length scale:
  - σ_o = 5 kg/m², d = 100 km

Snow analysis: case study on 4th February 2018, 00:00

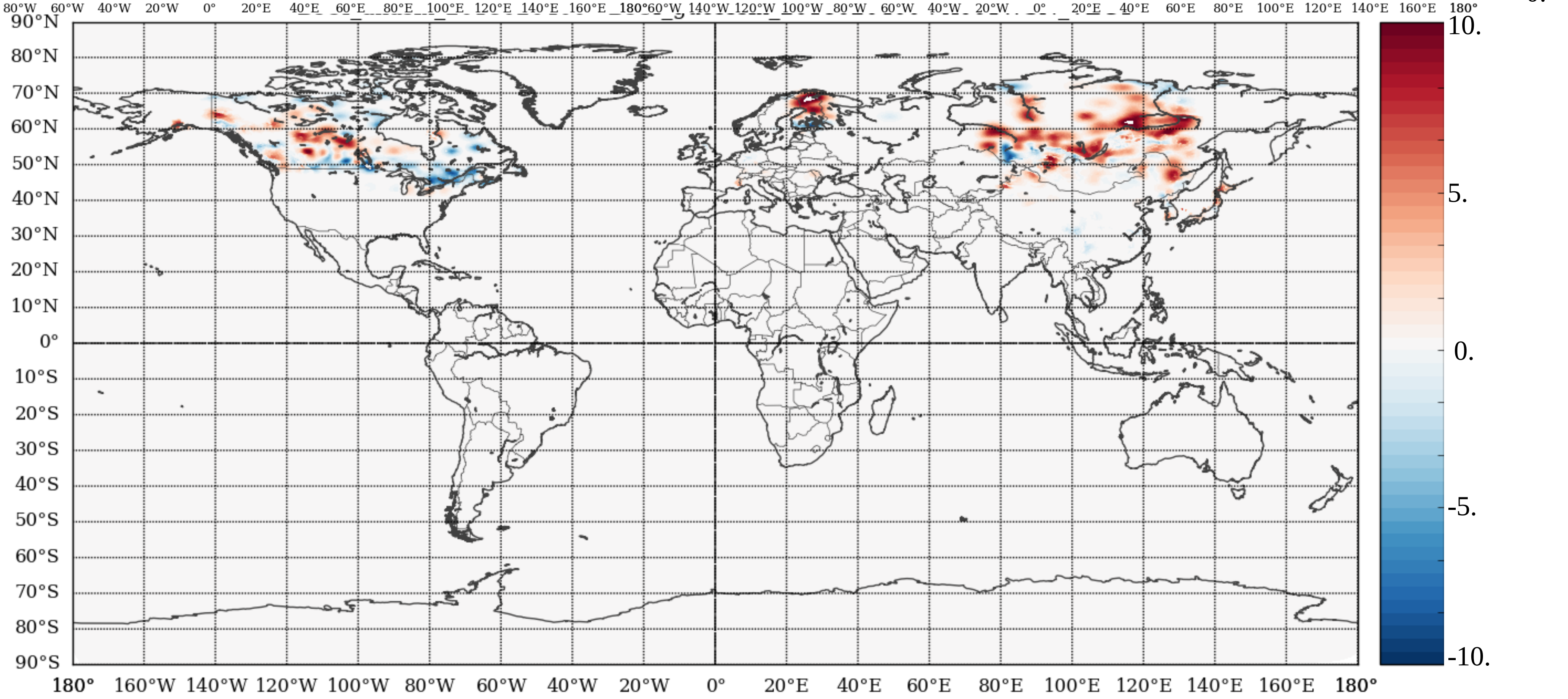
Background



Analysis



Analysis Increment (SWE kg/m²)



Snow analysis in ARPEGE: use of satellite data

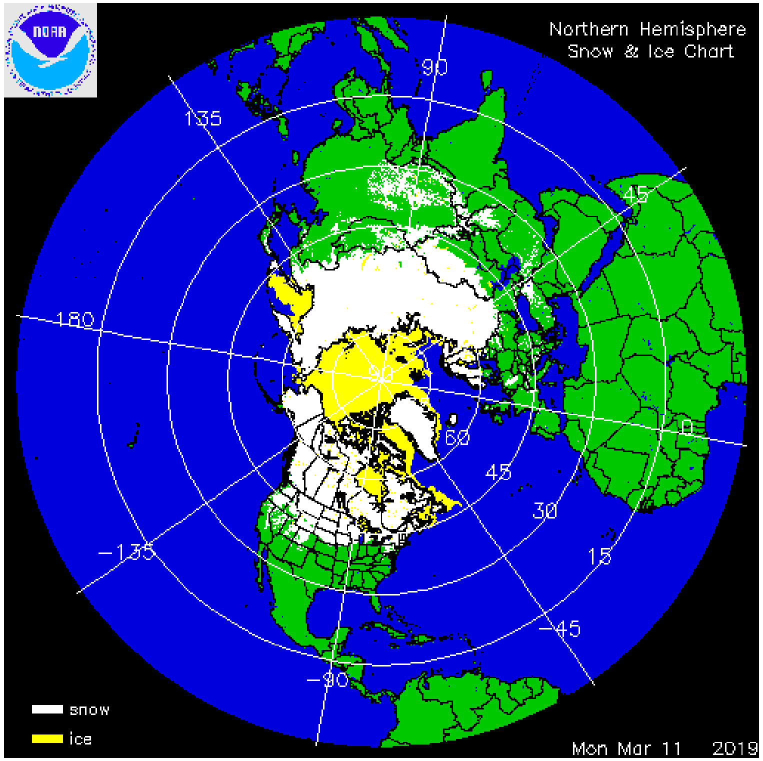
- IMS NOAA-NESDIS snow product over Northern Hemisphere: derived from AVHRR, AMSU, GOES/Imager, Himawari (AHI), Meteosat (SEVIRI)

- Daily product, 4 km resolution

- The snow mask (values 0 or 1) is converted into values that can be ingested in the assimilation :
  - 0 kg/m² (no snow) or 5 kg/m² (snow on the ground)

- Thinning of observations: ~1 observation every 30 km is kept

- Tuning of observation errors and length scale:
  - σ_o = 8 kg/m² (IMS) instead of 5 kg/m² (Synop)
  - d = 10 km (IMS) instead of 100 km (Synop)



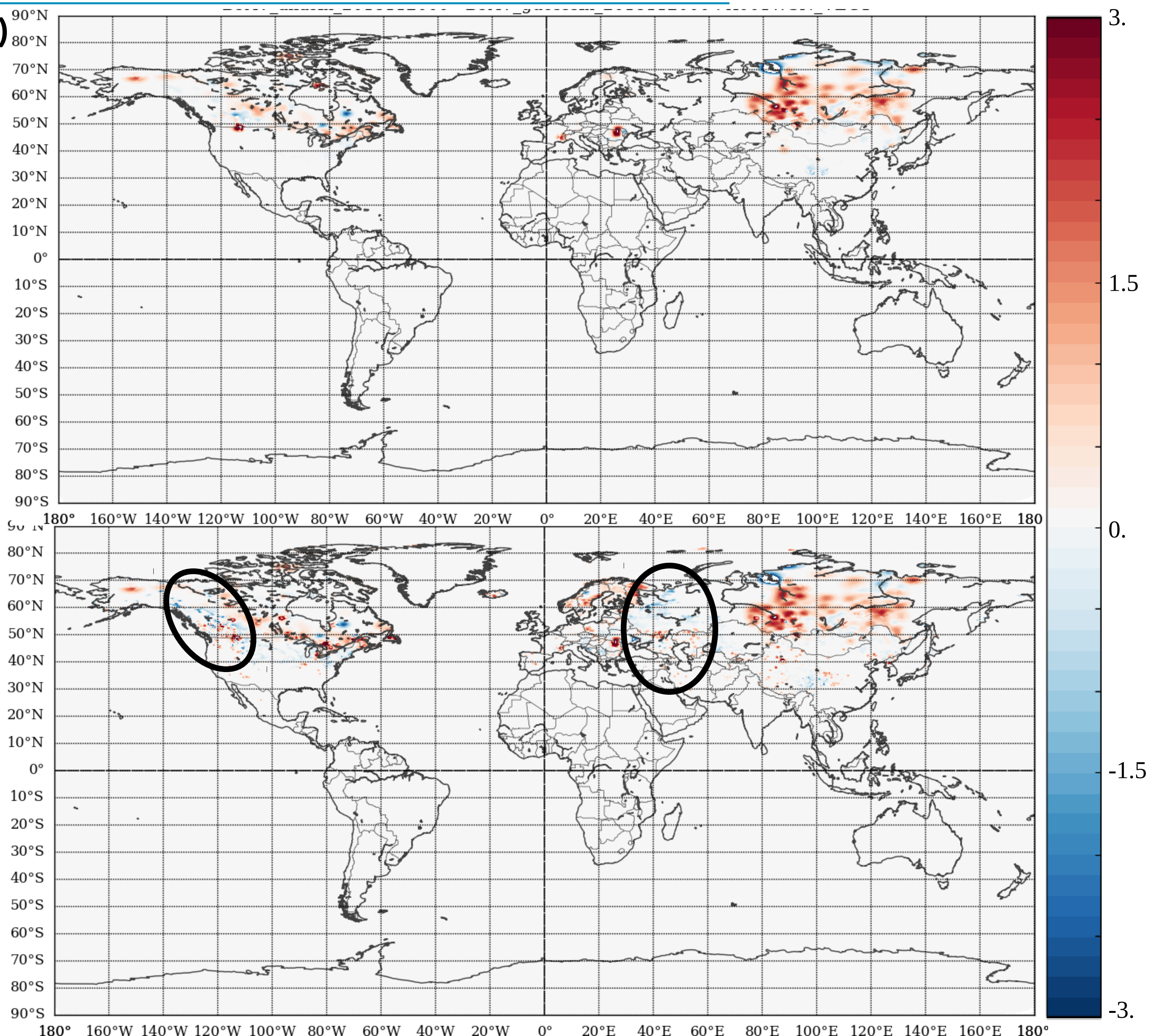
IMS snow and ice product over Northern Hemisphere on March 11, 2019

Snow analysis: case study on 20th November 2018, 00:00

Analysis increment (kg/m²)

Synop only

Synop + IMS



Increments in regions where there is a lack of in-situ data

Diagnostics using ARPEGE EDA for surface analysis

- The optimal interpolation coefficients (covariances between the forecast errors of T_{2m} and RH_{2m} and the soil moisture values w_g and w_2) were obtained from a set of 100 single column model integrations where the initial soil moisture content was perturbed, in conditions of maximum coupling between soil and atmosphere.

- The coefficients are constant in space and time and several empirical coefficients are applied to account for the local conditions (diurnal cycle, presence of wind, snow on the ground, precipitation…) and decrease the increments.

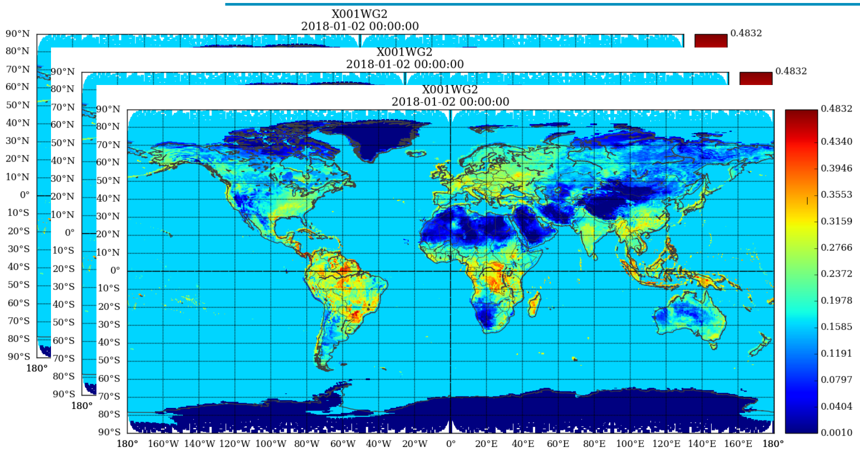
- The goal of the present study is to use the Ensemble Data Assimilation to compute covariances between soil variables (T_s, T_2, w_g and w_2) and observed variables (T_{2m} and RH_{2m}).

$$\Delta \mathrm{x} = \mathrm{BH}^{\mathrm{T}}(\mathrm{HBH}^{\mathrm{T}} + \mathrm{R})^{-1}\Delta \mathrm{y}$$

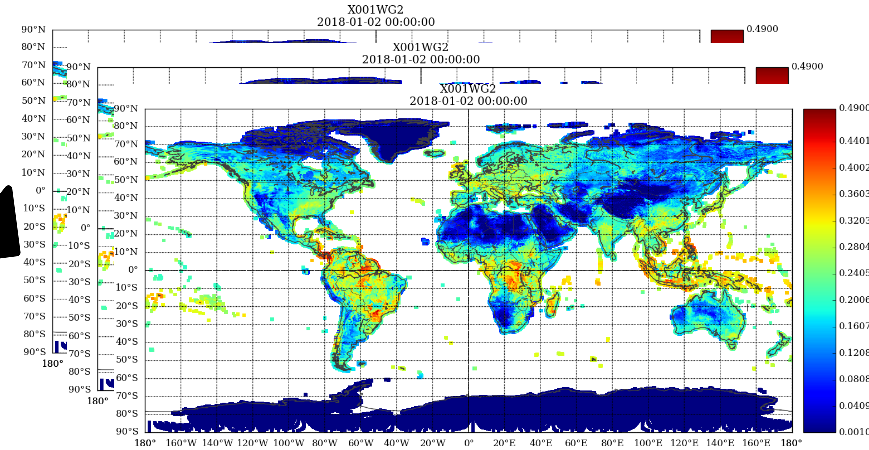
$$\Delta \mathbf{x} = \mathbf{cov}(\mathbf{x}^b,\mathbf{y}^b)\left[(\mathbf{cov}(\mathbf{y}^b,\mathbf{y}^b) + \mathbf{cov}(\mathbf{y}^o,\mathbf{y}^o)\right]^{-1}\Delta \mathbf{y}$$

- Météo France operational global EDA has 50 members at lower resolution than ARPEGE model.

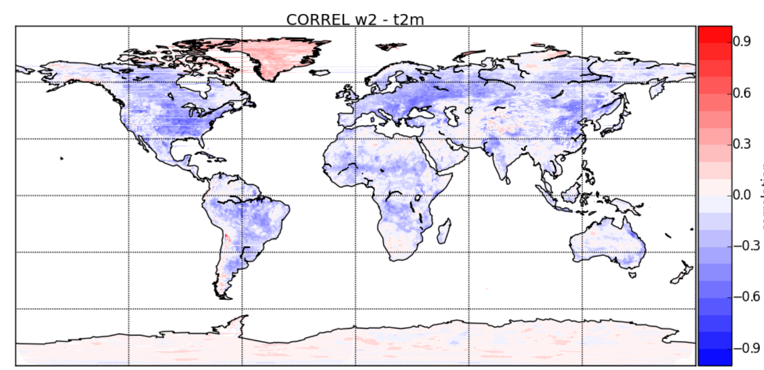
Diagnostics using ARPEGE EDA for surface analysis



Surface fields at **low resolution** from EDA (50 members)



Surface fields at **high resolution** (50 members)



Correlations and standard deviations at **high resolution**

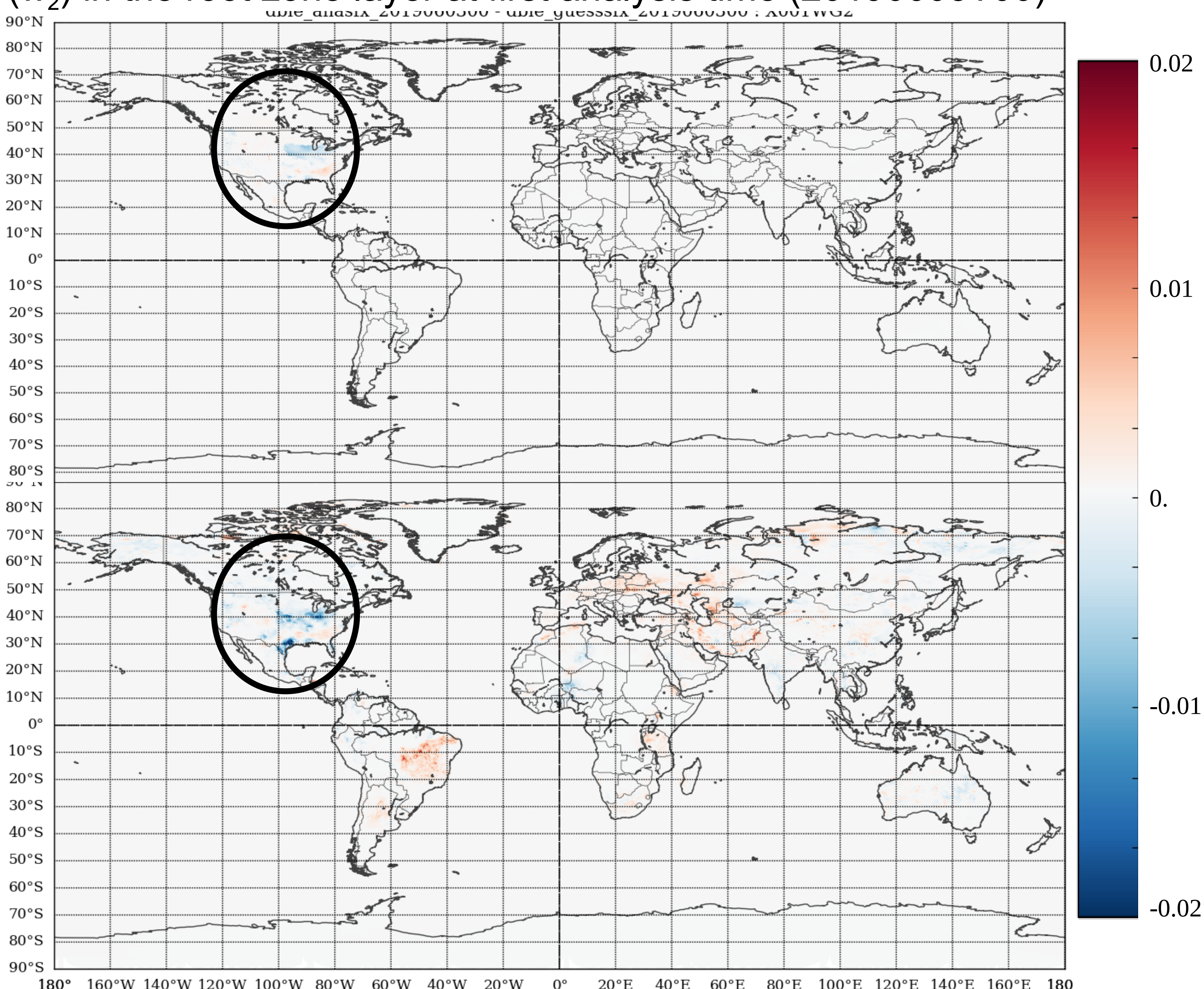
Soil analysis of w_g and w_2

Diagnostics using ARPEGE EDA for surface analysis

- Analysed surface fields computed with diagnostics from the EDA: increments of soil moisture (w_2) in the root zone layer at first analysis time (20190603T00)

OI increments

(m³/m³)



EDA increments

Similar main increments over Northern America
Smaller increments over other regions

Conclusions and future work

- Snow analysis in AROME and ARPEGE models with a 2D Optimal Interpolation, using Synop observations
- Current studies to include satellite products of snow cover in the assimilation
  - Nesdis-IMS snow cover product for ARPEGE
  - H-SAF products for AROME
- Improvement of the land surface data assimilation system: ensemble methods (EnKF, particle filter…) and use of atmospheric ensembles produced by ensemble data assimilation systems
  - AEARP for global model ARPEGE
  - AEARO for limited area model AROME