Recent developments for land surface analysis at Météo-France

Camille Birman, Jean-François Mahfouf, Zied Sassi, Nadia Fourrié, Vincent Guidard, Adrien Napoly, and other colleagues from GMAP

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Outline

- Current land surface data assimilation system
- Snow analysis:
  - AROME limited-area model
  - ARPEGE global model
- Land surface temperature analysis using satellite observations in AROME model
- 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)

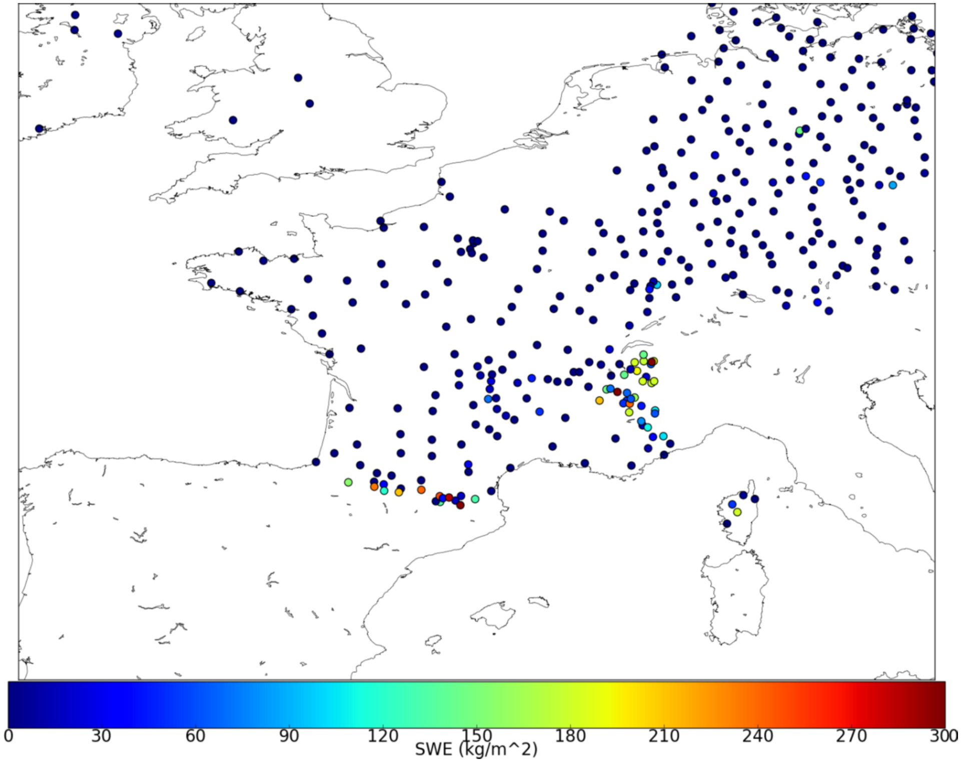
    - Sea → SST (CMO 1D)

- 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 in AROME model: operational since January 2020
  - 2 periods of study for validation: winter 2018 and 2019

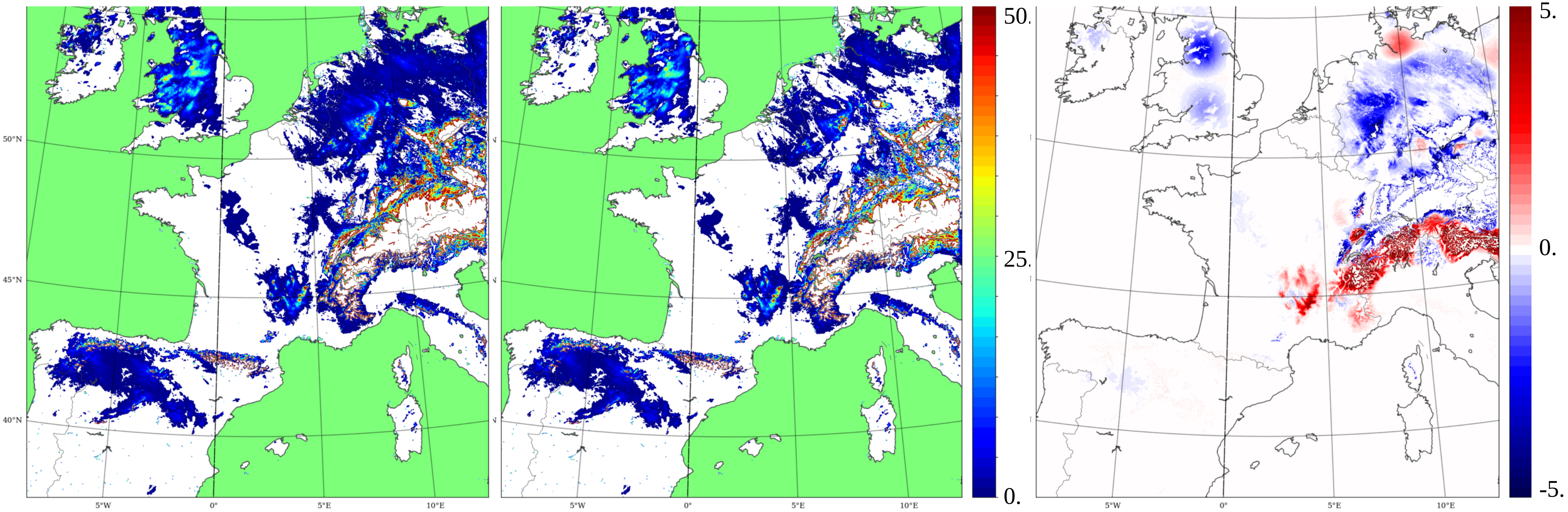


Snow depth observations over the AROME-France domain (19th March 2018, 06h)

- Heterogeneous observation network over the AROME-France domain
- Snow analysis is performed using CANARI 2D OI and SURFEX OI assimilation
- Prognostic variable: SWE → use of model density (from the guess) 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 19th January 2019, 06:00

Guess **Analysis** **Increment**



SWE (kg/m²)

Observation error: σ_o = 4.0 kg/m²

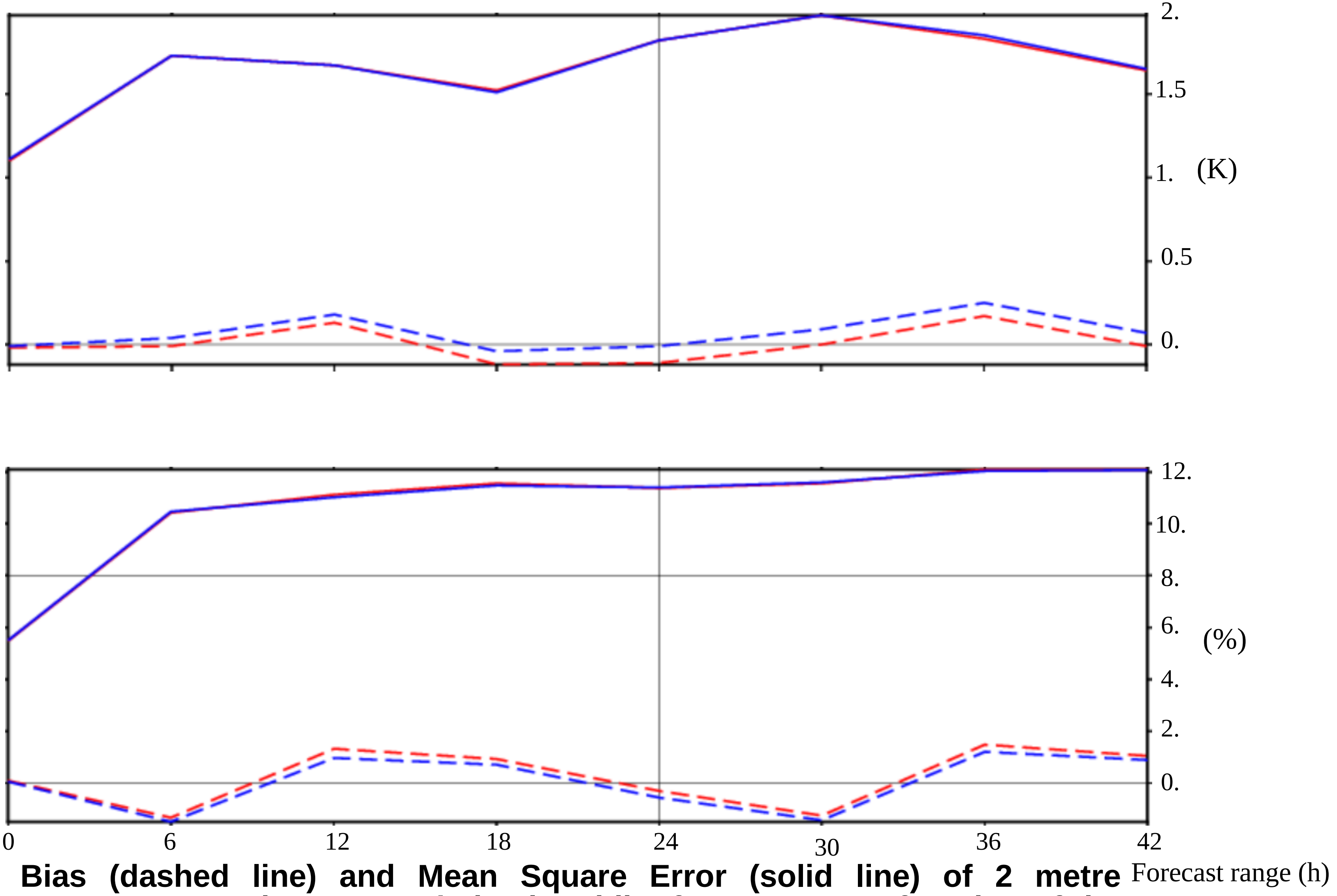
Background error: σ_b = 5.0 kg/m²

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

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

T2m
(σ_o = 4.0 kg/m²)

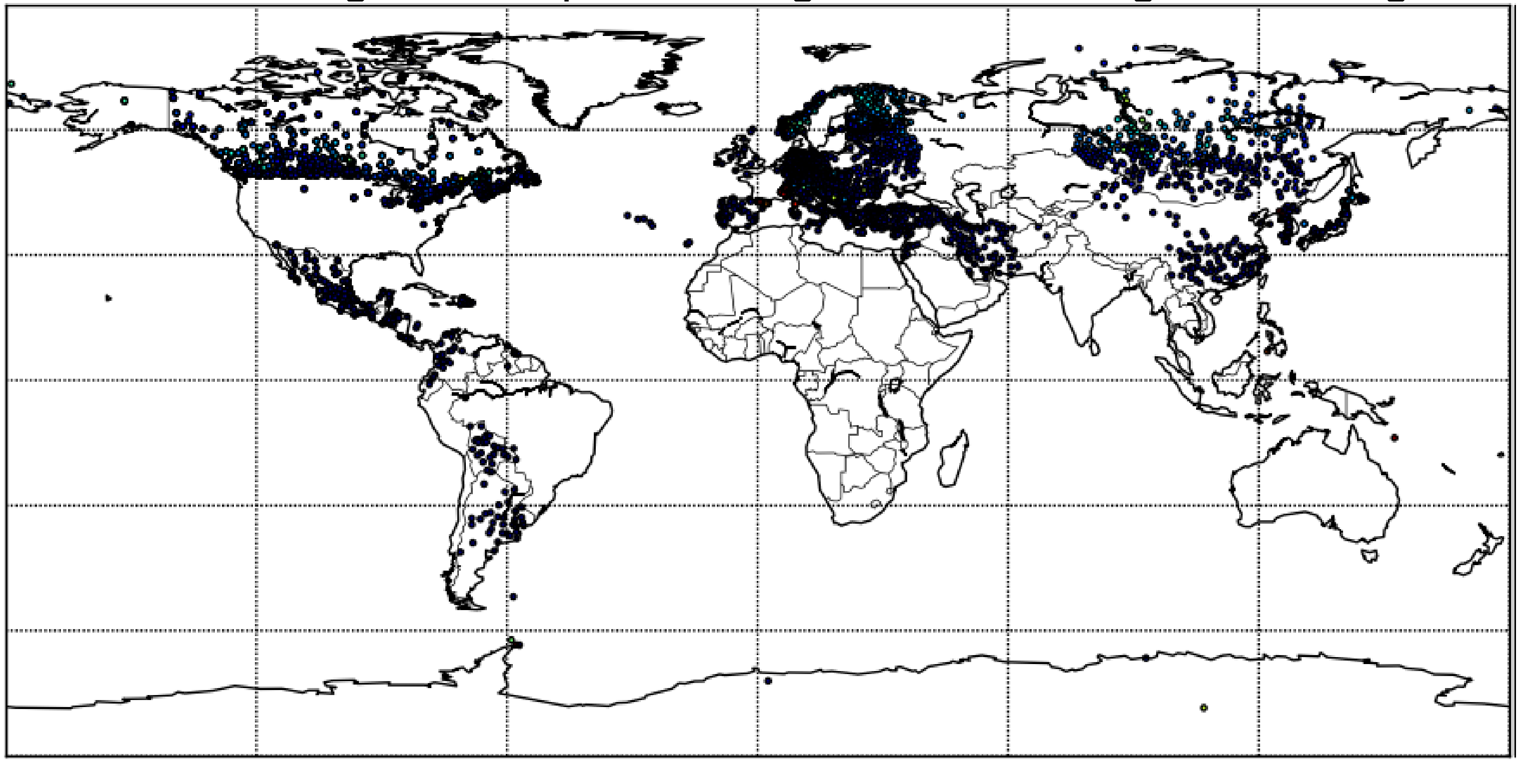
Hu2m
(σ_o = 4.0 kg/m²)



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 in ARPEGE

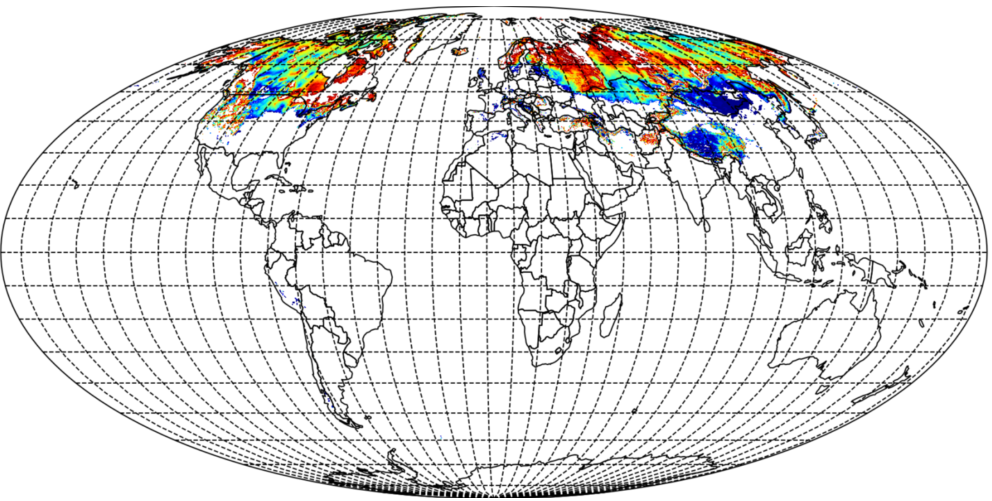
- Synop stations measuring snow depth: heterogeneous coverage over the globe



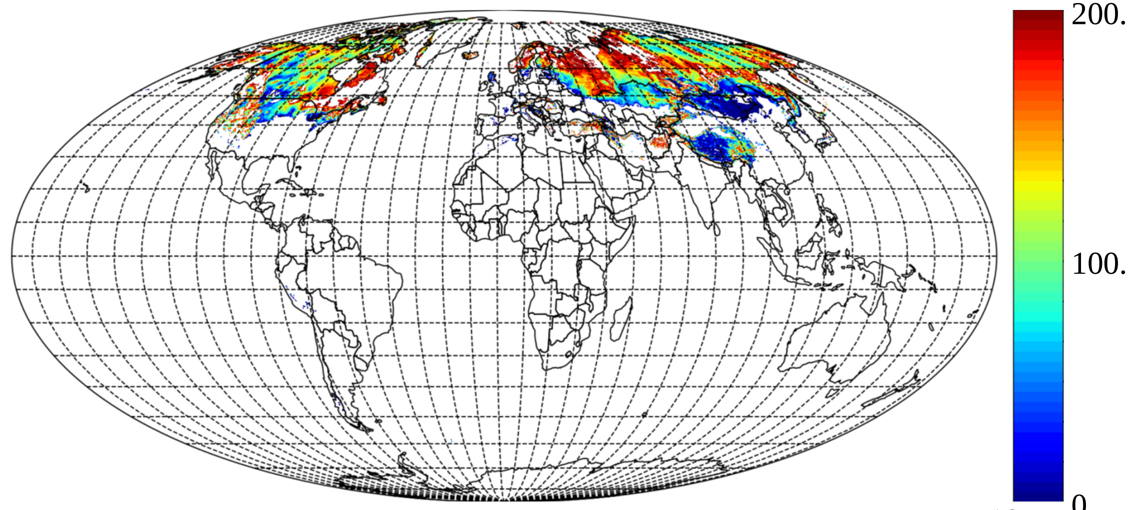
- Same principle as in AROME: 2D-OI with a struture function accounting for the distance and the difference of elevations between observation and grid point
- Observation errors and length scale:
  - σ_o = 5 kg/m², d = 100 km

Snow analysis: case study on 20th March 2019, 06:00

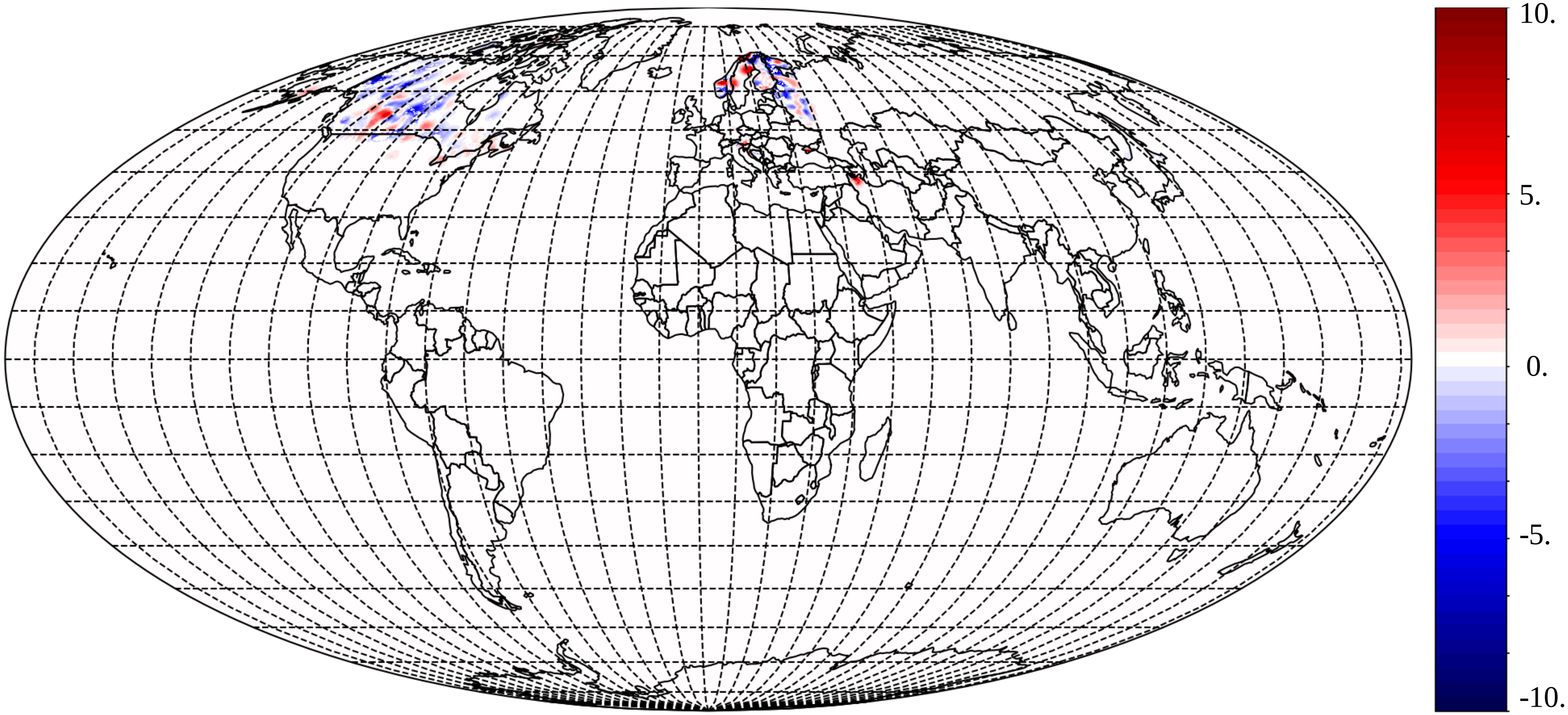
Background



Analysis

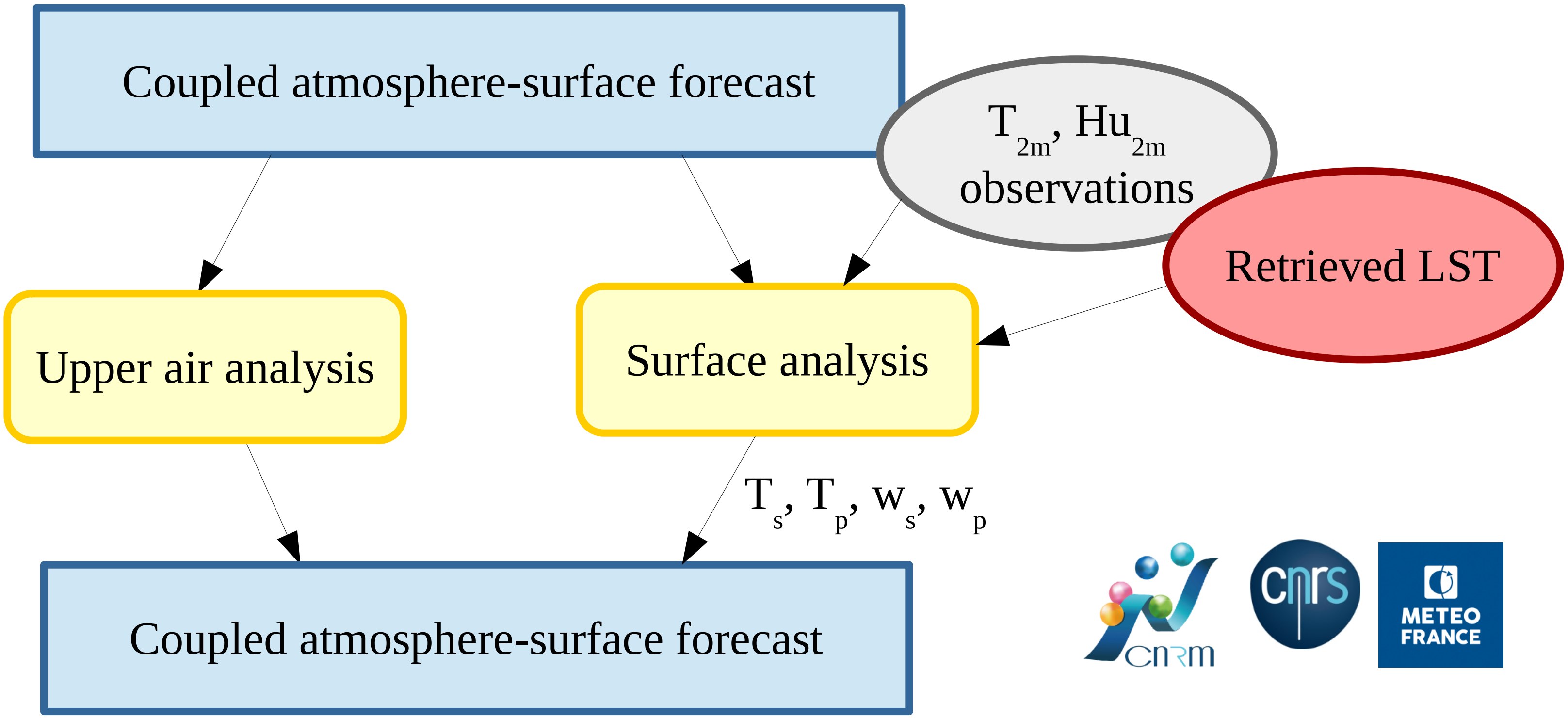


Analysis Increment
(SWE kg/m²)



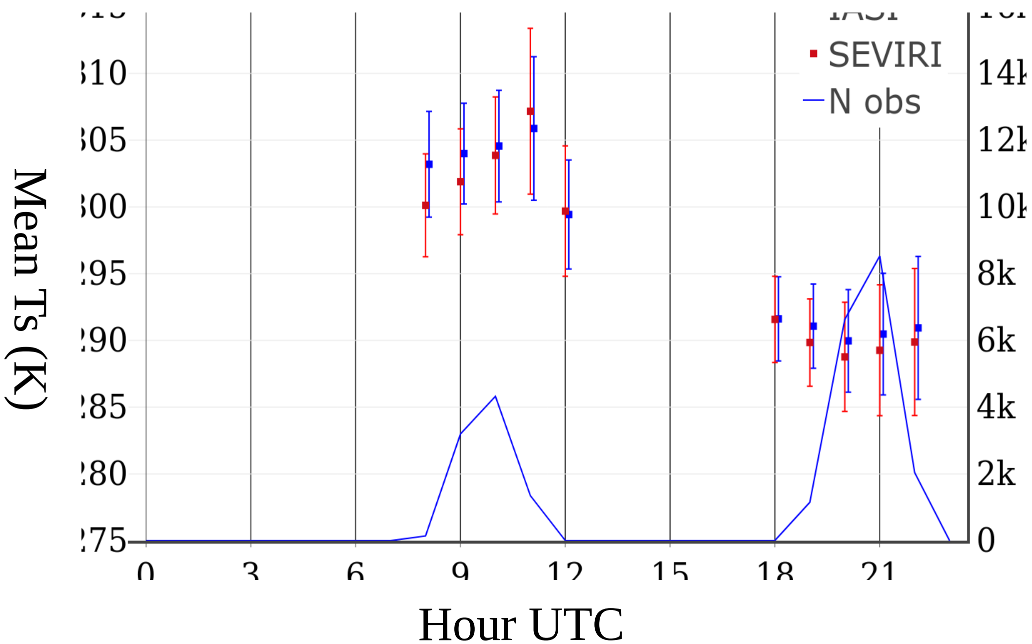
Land surface temperature analysis

- A realistic descritpion of surface properties is necessary for the assimilation of surface and lower atmosphere sensitive channels (emissivity for MW and temperature for IR).
- At Météo France a window channel is used to retrieved the land surface temperature (LST) for infrared channels (or the emissivity for microwave channels)
- However this retrieved land surface temperature is not used afterwards and the model land surface temperature is analysed using 2 metre temperatures
- The goal of the study is to use the retrieved land surface temperature in the infrared channels to analyse the AROME model land surface temperature. (PhD Zied Sassi)



Land surface temperature analysis

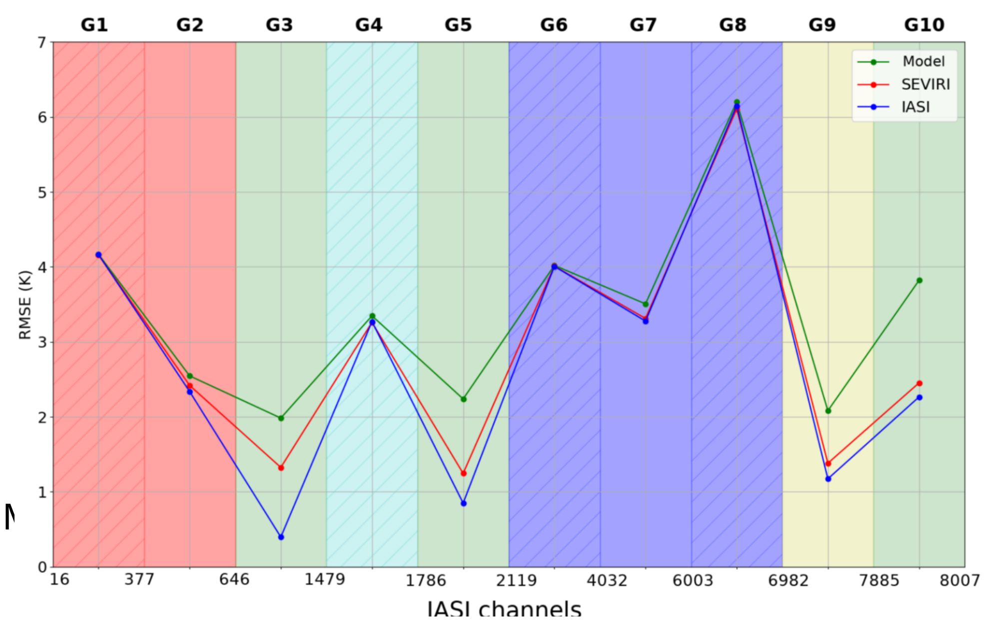
- Comparison of SEVIRI and IASI LSTs: mean and standard deviation of retrieved LSTs (summer 2018) (figs Zied Sassi)



Consistent diurnal cycles between IASI and SEVIRI, lower bias (0.9 K) and standard deviations (1.7 K) by night time

- Radiative transfer simulations

RMSE of simulated Tbs with respect to observations

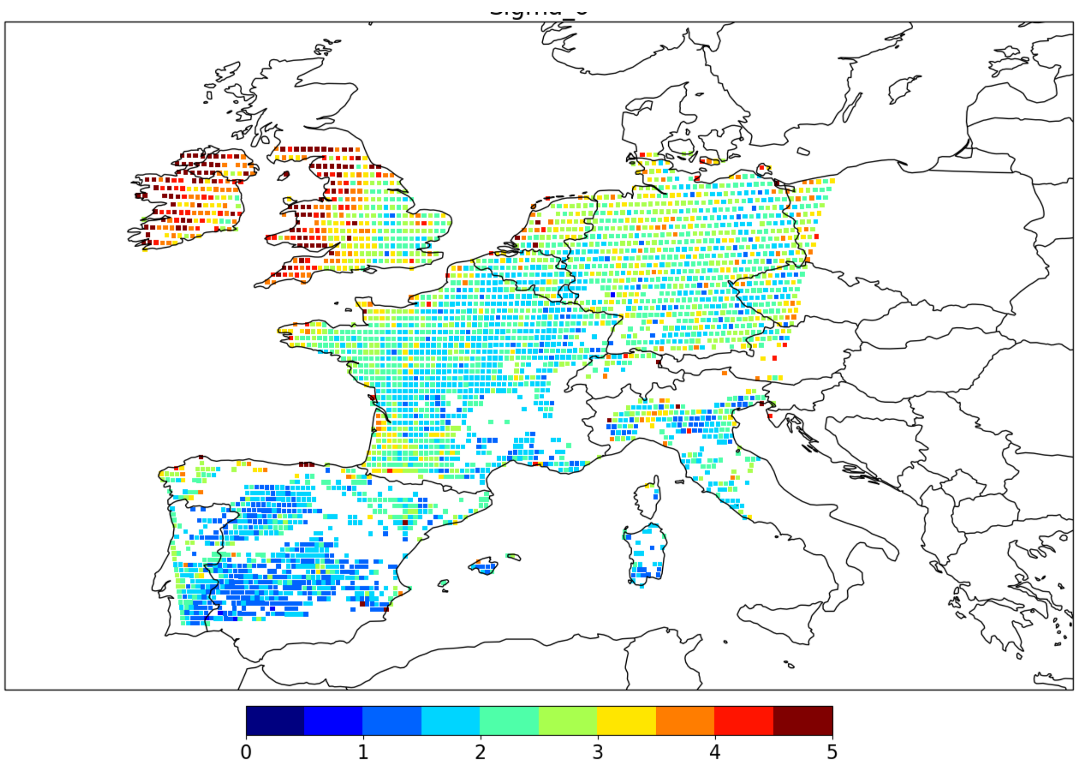


The use of retrieved LST improves simulated Tbs in surface sensitive channels

Sassi et al., 2019: Use of infrared satellite observations for the surface temperature retrieval over land in a NWP context, *Remote Sensing*

Land surface temperature analysis

- First experiments of assimilation of LST retrieved from SEVIRI in AROME model during July 2019 by night time
  - Experiment setup: assimilation of a new variable in the surface data assimilation system
  - Diagnostics of assimilation parameters: observation and background error, and correlation lengths
  - Experiment with the assimilation of LST during July 2019 and assessment of the impact on forecasts and assimilation of other satellite sensors



Observation standard deviations diagnosed for analysis times 00, 03, 06 over AROME france domain during July and August 2019 (fig. Zied SASSI)

2020

Diagnostics using ARPEGE EDA for surface analysis

- Optimal interpolation coefficients (covariances between the forecast errors of T_{2m} and RH_{2m} and the soil moisture values w_g and w_2) are constant in space and time, and were obtained in conditions of maximum coupling between soil and atmosphere.

- 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.

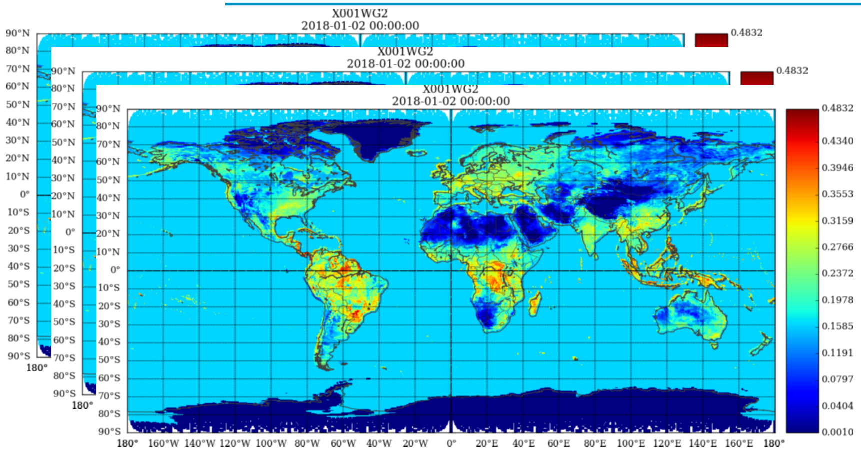
- The goal of the present study is to use the Ensemble Data Assimilation to compute covariances between soil variables (T_s, T_2, w_g and w_2) and observed variables (T_{2m} and RH_{2m}).

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

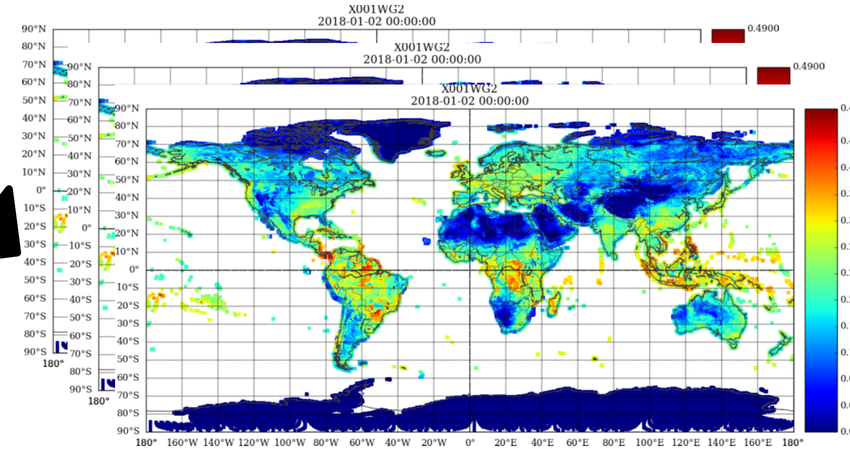
$$\Delta \mathrm{x} = \mathrm{cov}(\mathrm{x}^b,\mathrm{y}^b)\left[(\mathrm{cov}(\mathrm{y}^b,\mathrm{y}^b) + \mathrm{cov}(\mathrm{y}^o,\mathrm{y}^o)\right]^{-1}\Delta \mathrm{y}$$

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

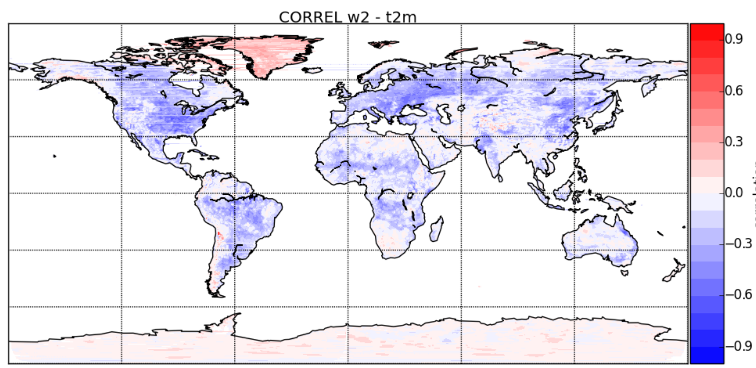
Diagnostics using ARPEGE EDA for surface analysis



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



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



Correlations and standard deviations at **high resolution**

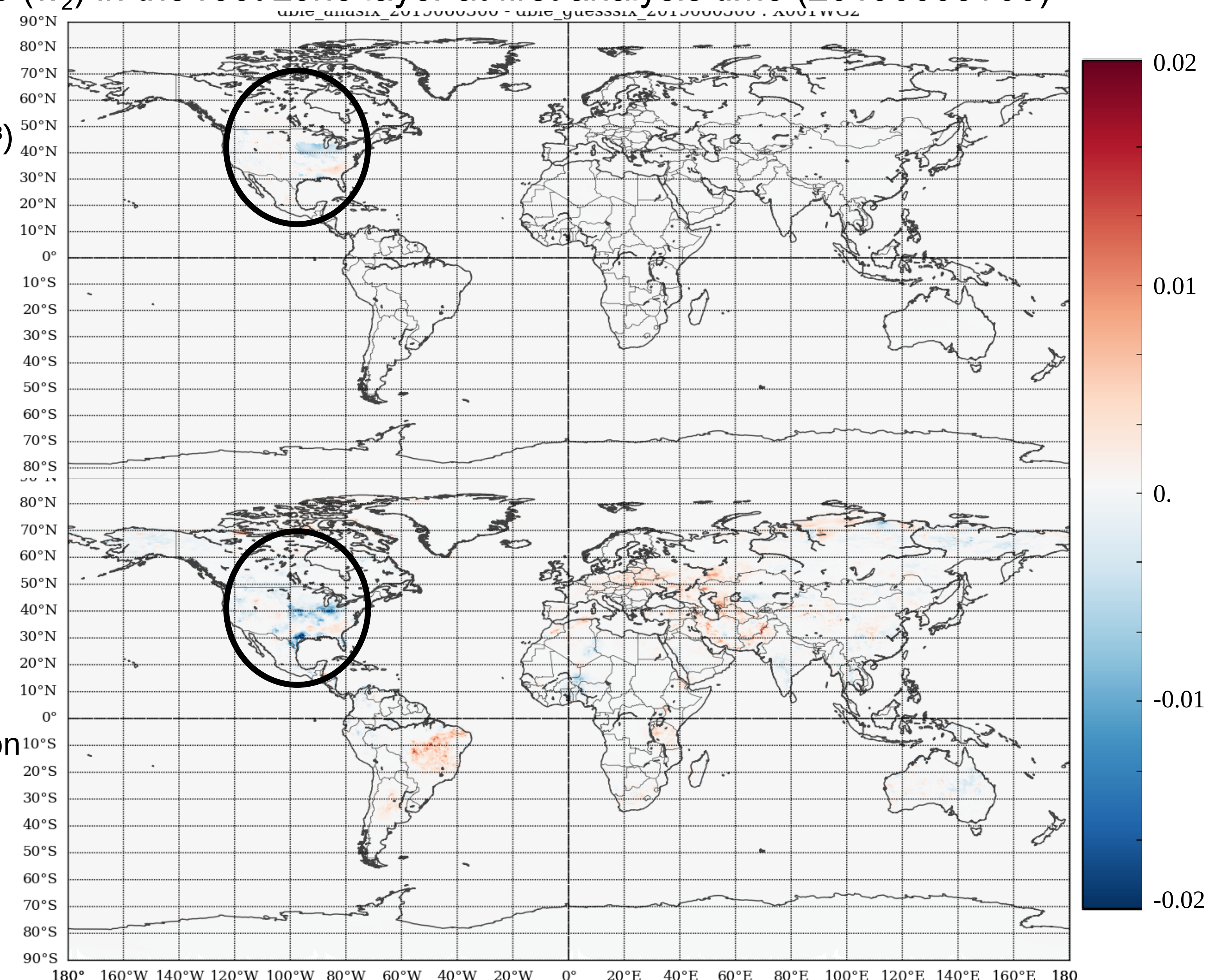
Soil analysis of w_g and w_2

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

(m^3/m^3)



EDA increments

Similar main increments over Northern America
Smaller increments but non zero over other regions

Conclusions

- Snow analysis in AROME and ARPEGE models with a 2D Optimal Interpolation, using Synop observations

- Assimilation of satellite land surface temperature retrieved from SEVIRI (PhD Zied Sassi):

  Impact on forecasts and on the assimilation of other sensors

- Current work on the use of ISBA-DIF in AROME model: development of an adapted OI in SURFEX

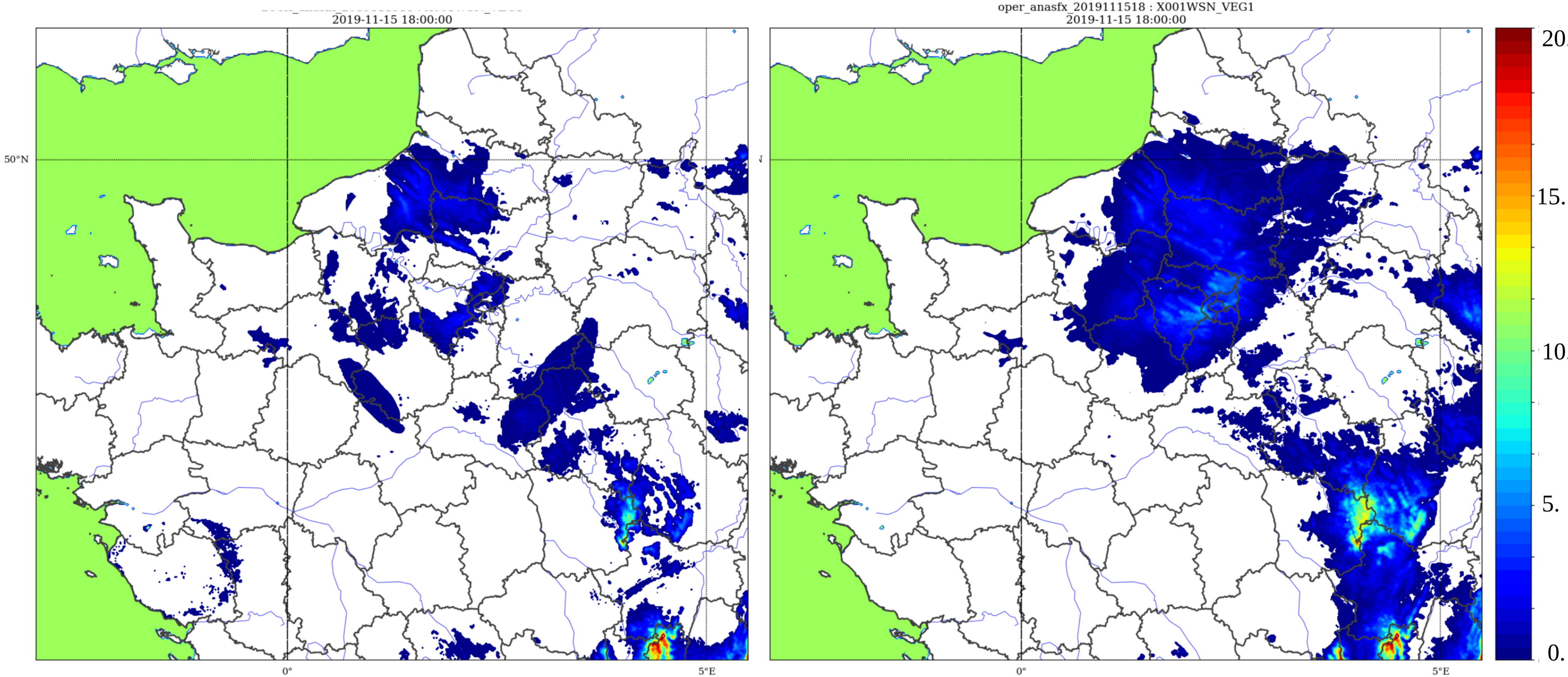
- Improvement of the land surface data assimilation system: use of atmospheric ensembles produced by Ensemble Data Assimilation systems (AEARP for global model ARPEGE, AEARO for AROME)

Future work and perspectives

- Current studies to include satellite products of snow cover in the assimilation
  - Nesdis-IMS snow cover product for ARPEGE
  - H-SAF products for AROME
- Assimilation of satellite land surface temperature retrieved from SEVIRI:
  - Assimilation of LSTs retrieved from different sensors and synergy between sensors
  - Introduction of a dependancy between surface and upper air analyses
- Studies to improve CANARI tool: inclusion into OOPS framework while maintaining the 2D tool in the IFS/ARPEGE code (ODB, I/O, parallelization...)

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

Analysis **Reference**



SWE (kg/m²)

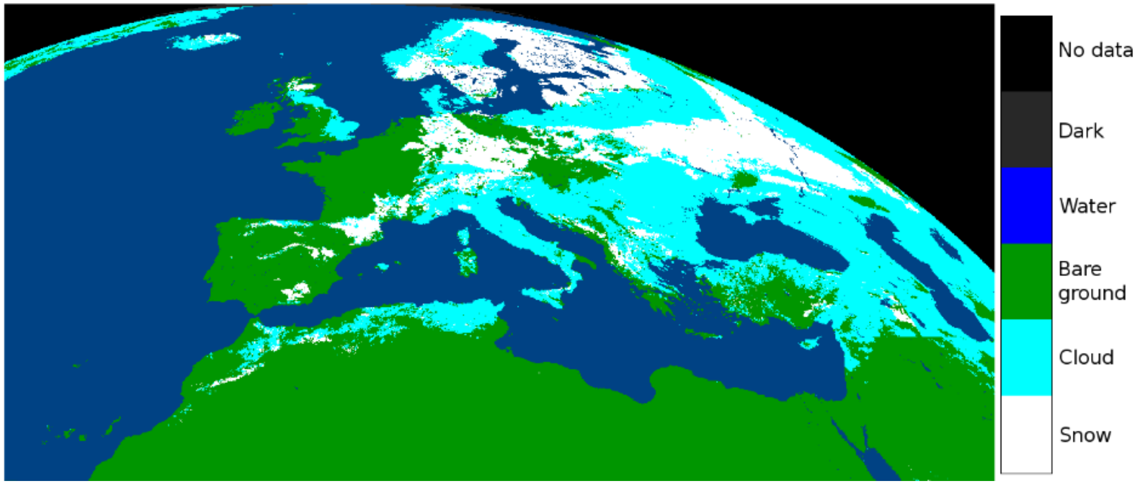
Observation error: σ_o = 4.0 kg/m²

Background error: σ_b = 5.0 kg/m²

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

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

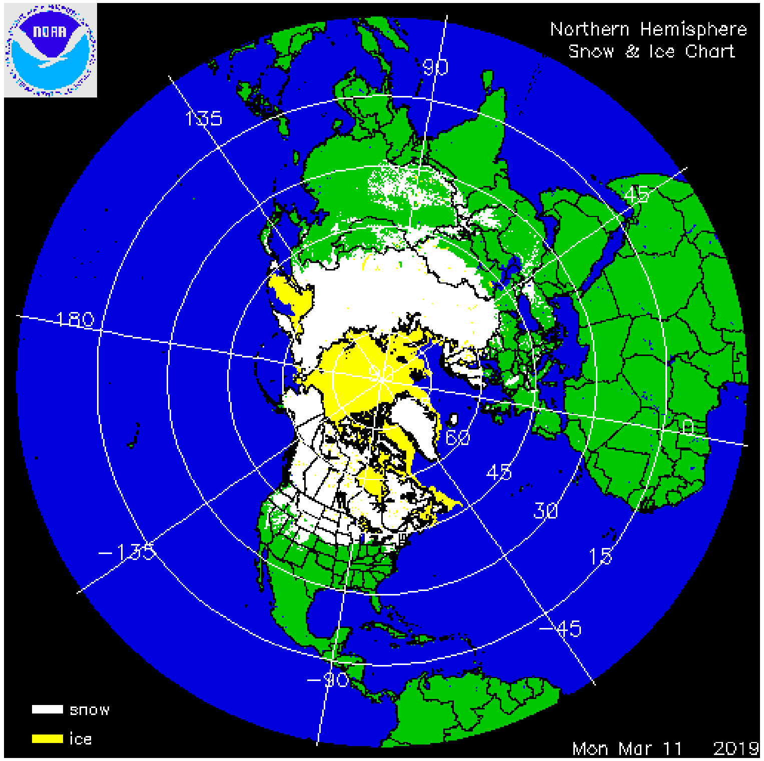


H-SAF H10 snow product on March 9, 2010

- 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 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