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

Camille Birman, Jean-François Mahfouf...

SURFEX User Workshop, 18-20 March 2019, Toulouse, France
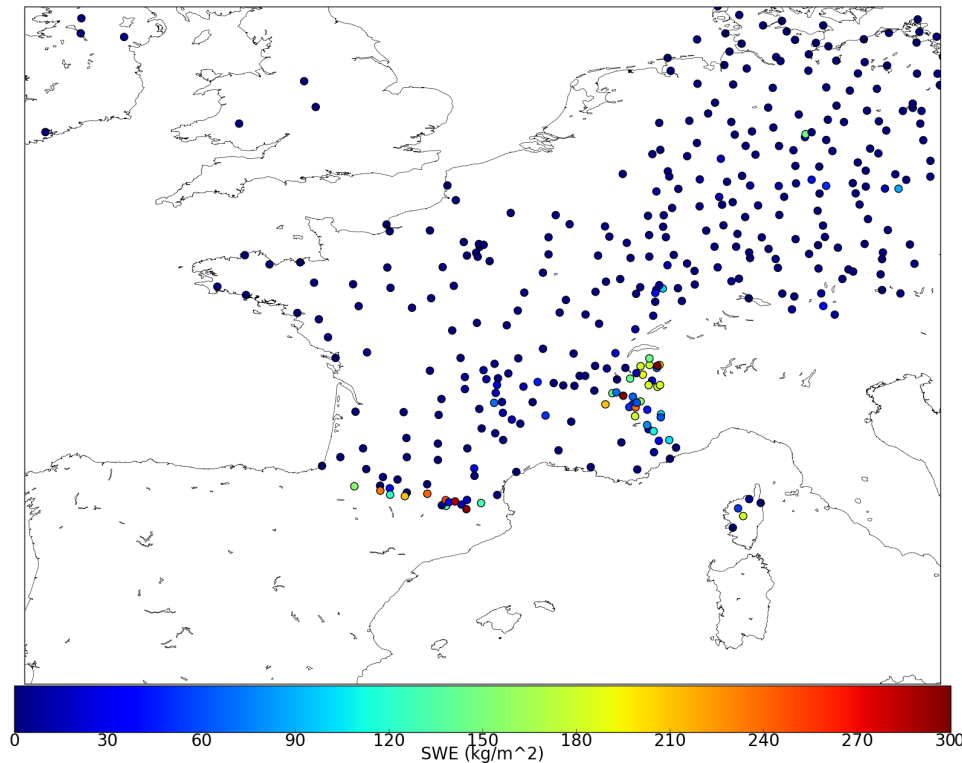
Outline

- Current land surface assimilation system

- Snow analysis:

  - AROME model

  - ARPEGE model

  - First steps toward 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 assimilation system

- Météo France global model ARPEGE and limited area model AROME are coupled to SURFEX.

- The 4 tiles 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) $\rightarrow$: T_s, T_2, T_3, w_g, w_2, w_3.

  - Town: TEB (Masson, 2000) $\rightarrow$ T_{roof}, T_{wall}, T_{road}

  - Lake $\rightarrow$ LST (FLake)

  - Sea $\rightarrow$ 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

 - Case study February 2018 and January-February 2019

- Observations extracted over France

- Snow analysis performed using CANARI 2D OI

- Transfer of snow increments into SURFEX

- 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 scale

Snow depth observations over the AROME-France domain
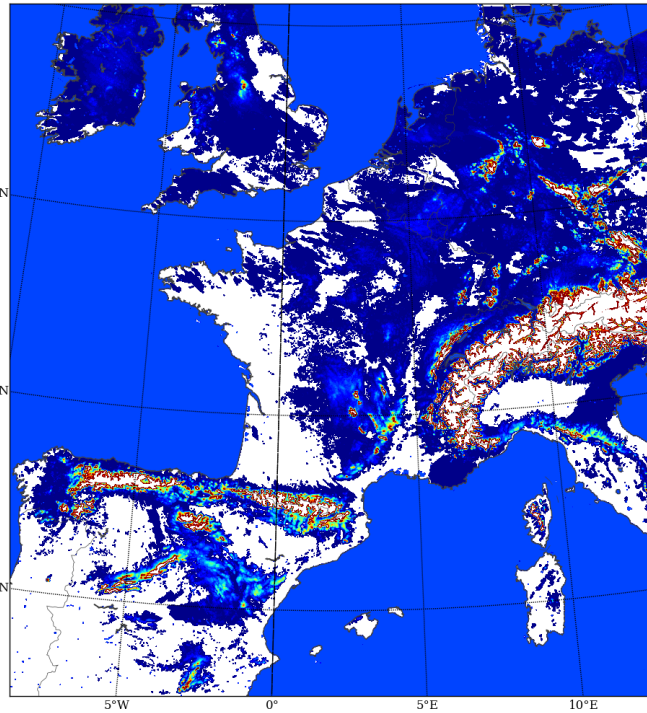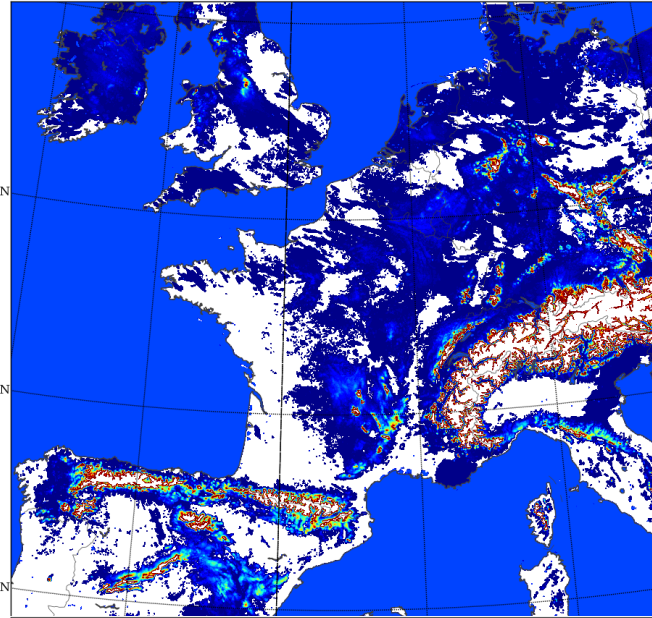
Snow analysis: case study on 12th February 2018, 12:00

Background

Analysis

Reference

Analysis Increment (σ_o = 5 kg/m²)

(kg/m²)

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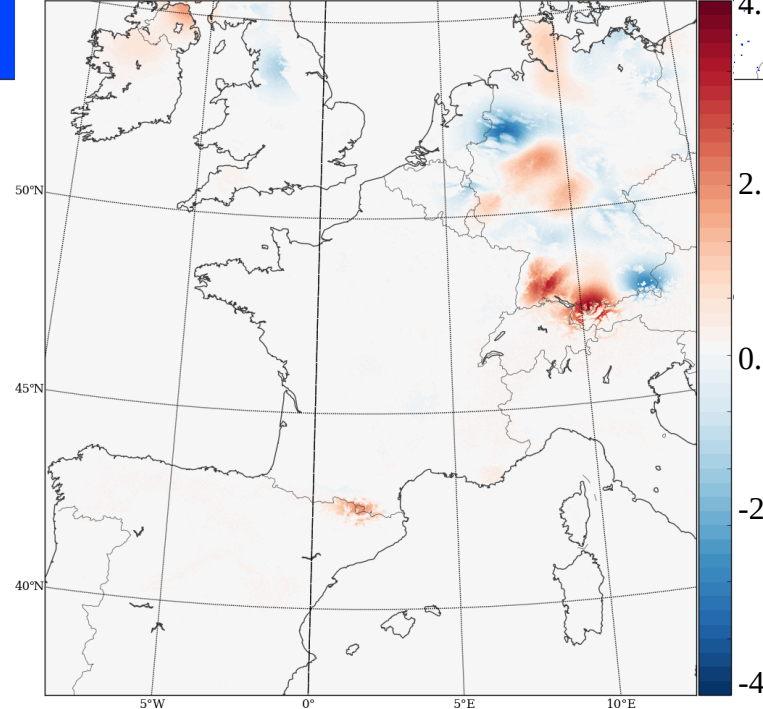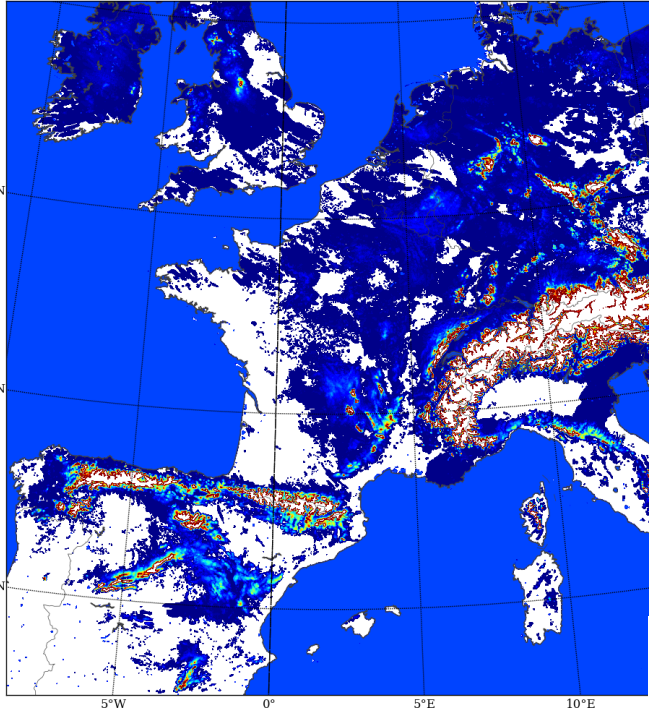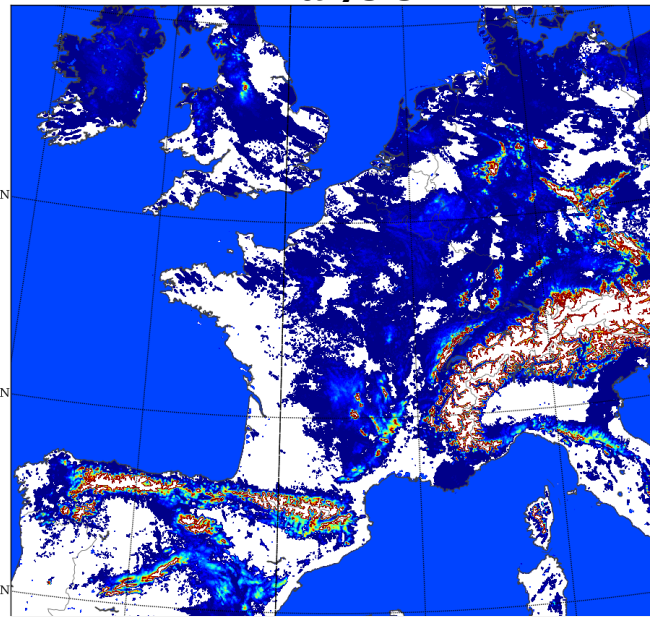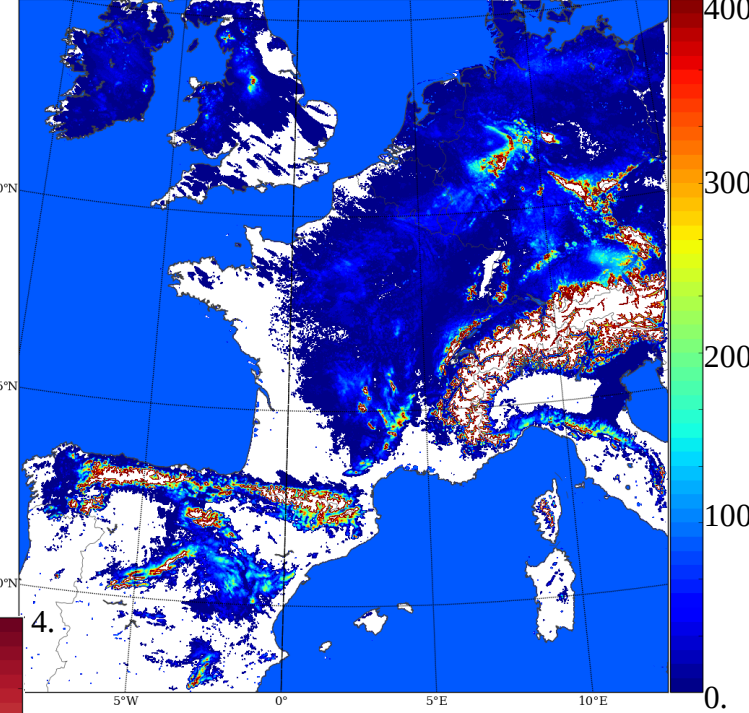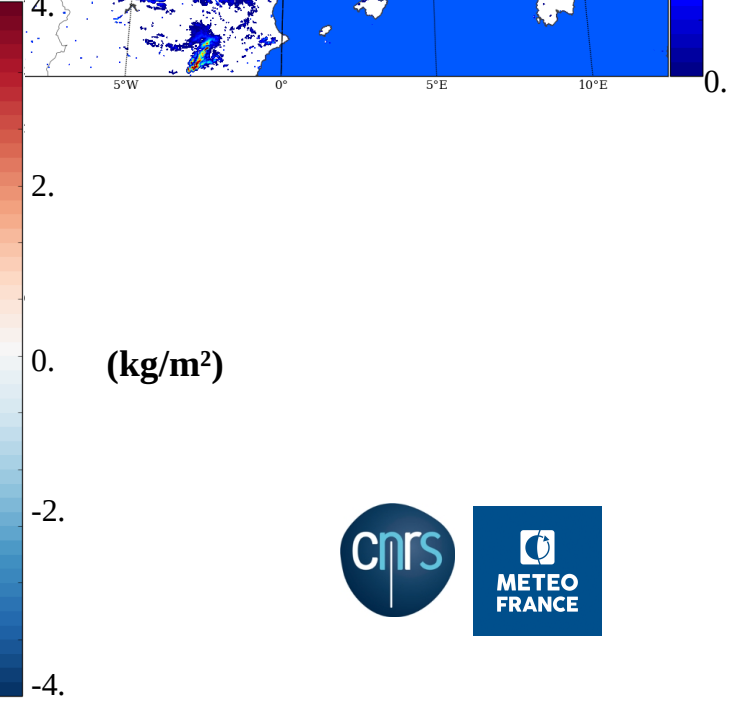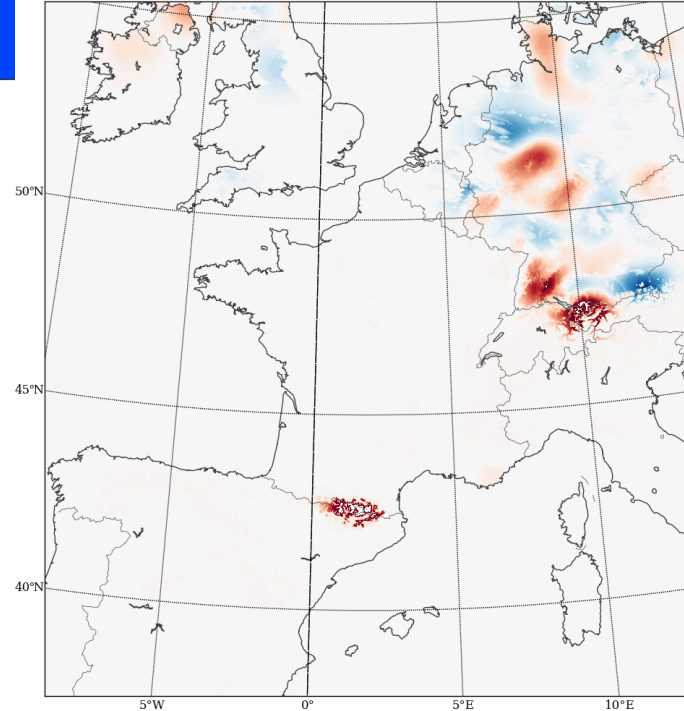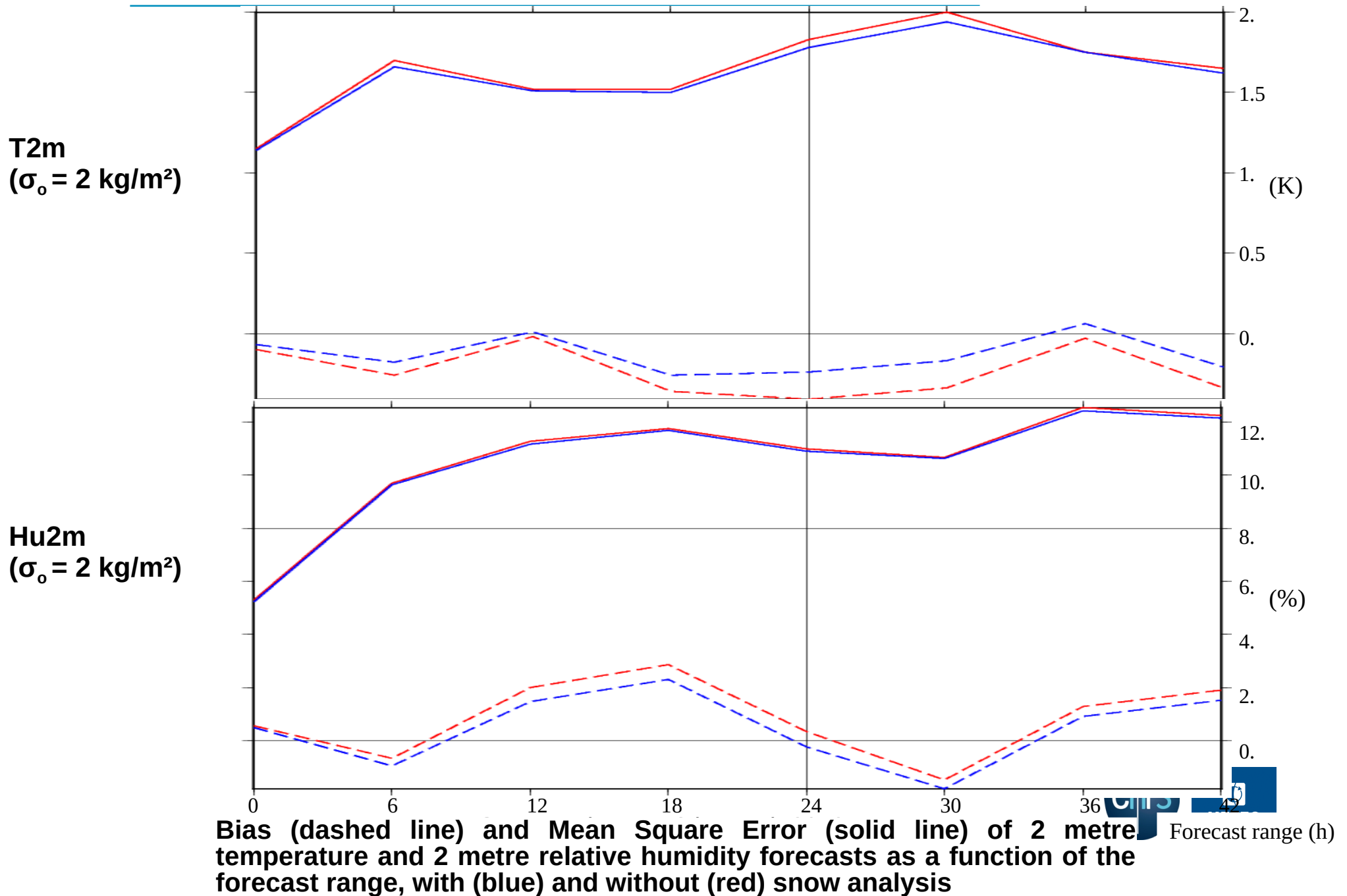

Background

Analysis

Reference

Analysis Increment (σ_o = 2 kg/m²)

(kg/m²)

Snow analysis: bias and MSE on February 2018 with respect to Synop stations

T2m
(σ_o = 2 kg/m²)

Hu2m
(σ_o = 2 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 (blue) and without (red) snow analysis

Forecast range (h)

Snow analysis: use of satellite observations

- Daily snow product H10 from H-SAF (http://hsaf.meteoam.it/snow.php)
 - Resolution 0.05° over Europe, computed from SEVIRI multichannel analysis
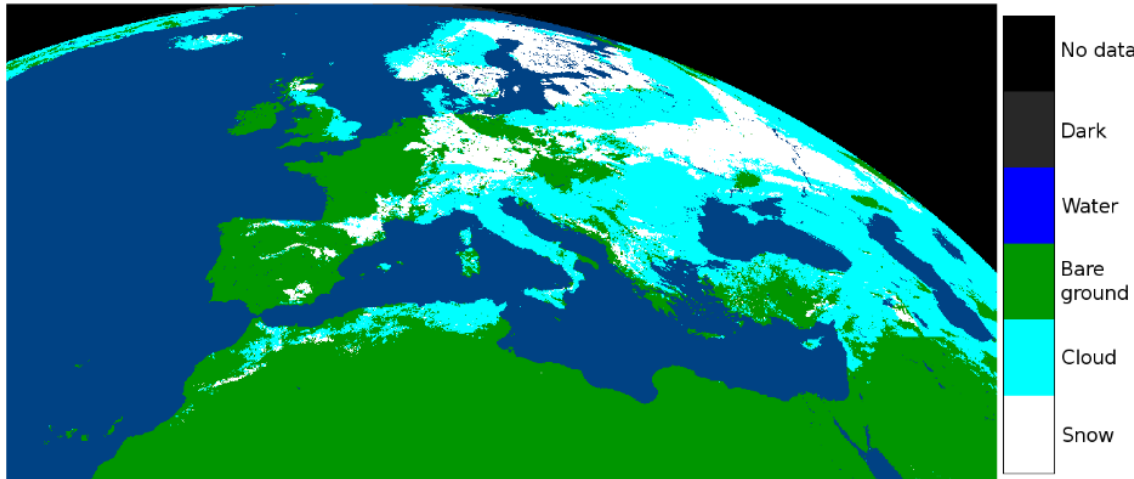
H-SAF H10 snow product on March 9, 2010

- 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)
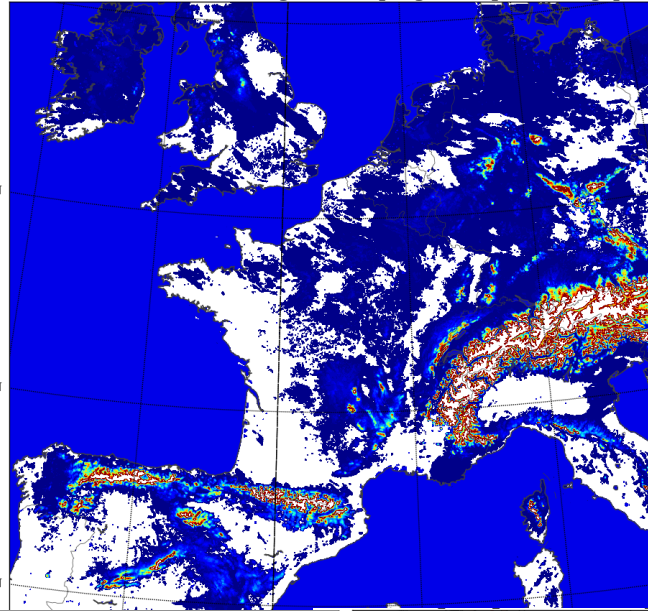 - d = 5 km (H-SAF) instead of 50 km (Synop)

SUW, Toulouse, 18th March 2019
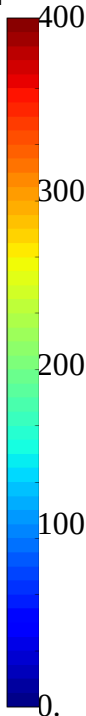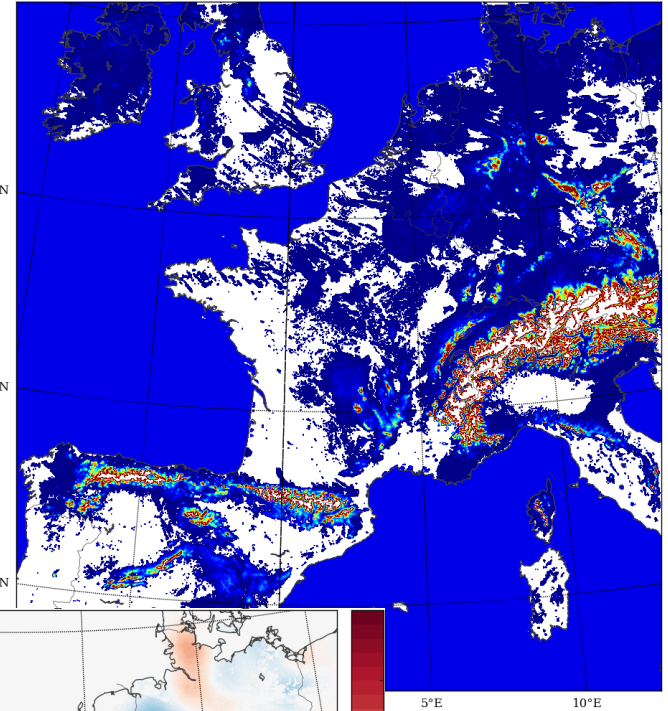
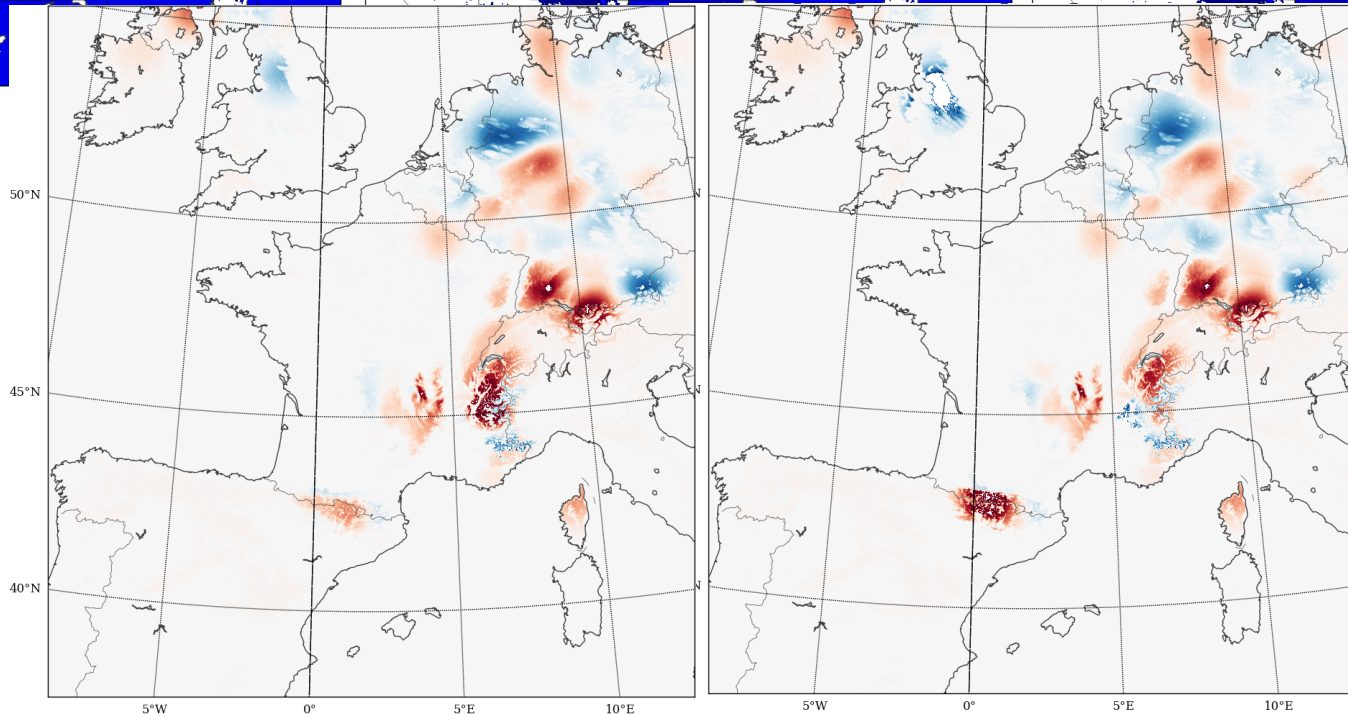# Snow analysis: case study on 12th February 2018, 12:00
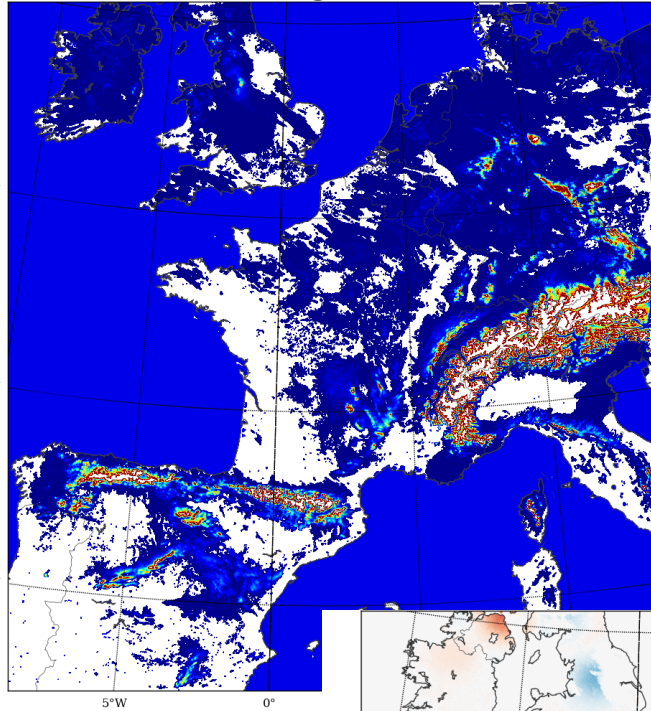
Background **Analysis (Synop only)** **Analysis (Synop + H-SAF**

Analysis Increment

Synop only

Synop + H-SAF

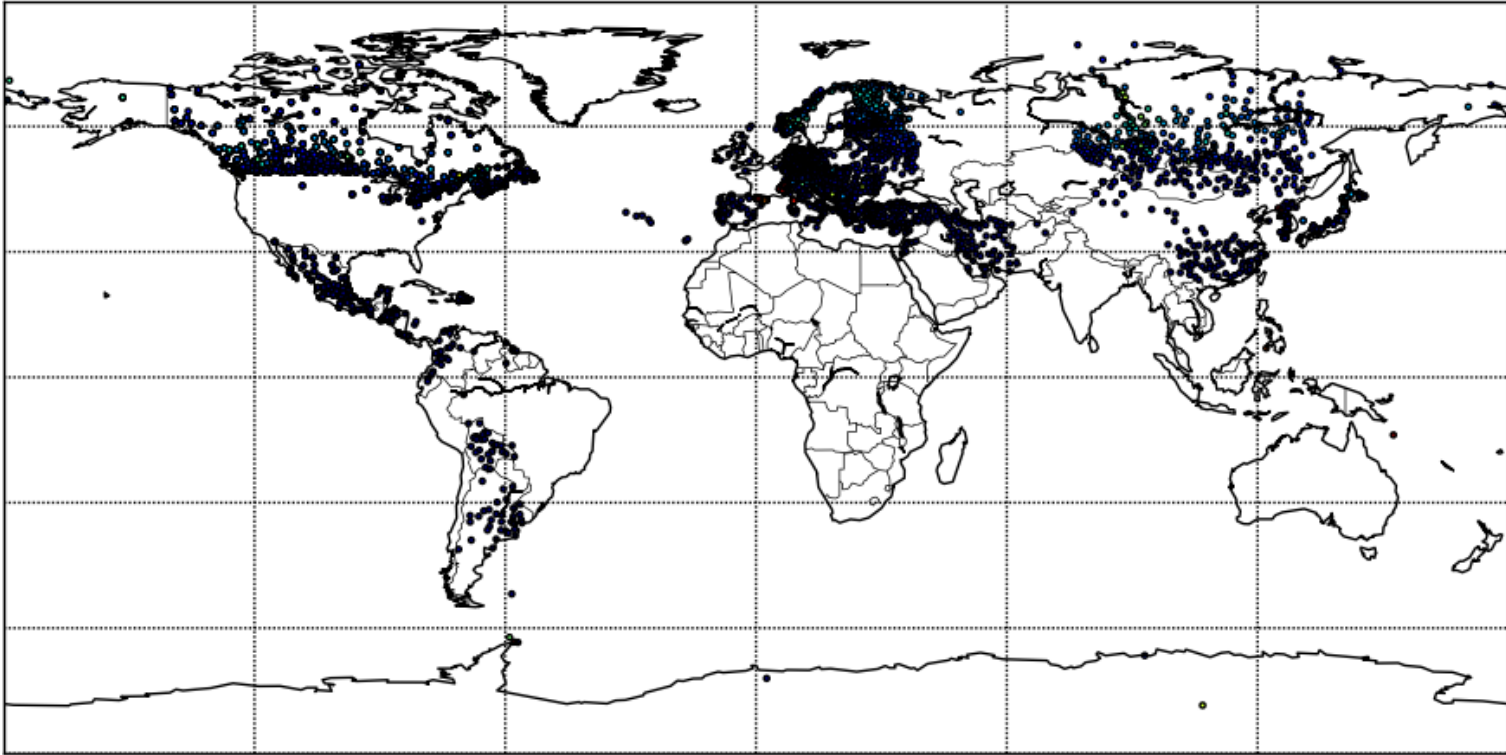**(kg/m²)**

Snow analysis in ARPEGE
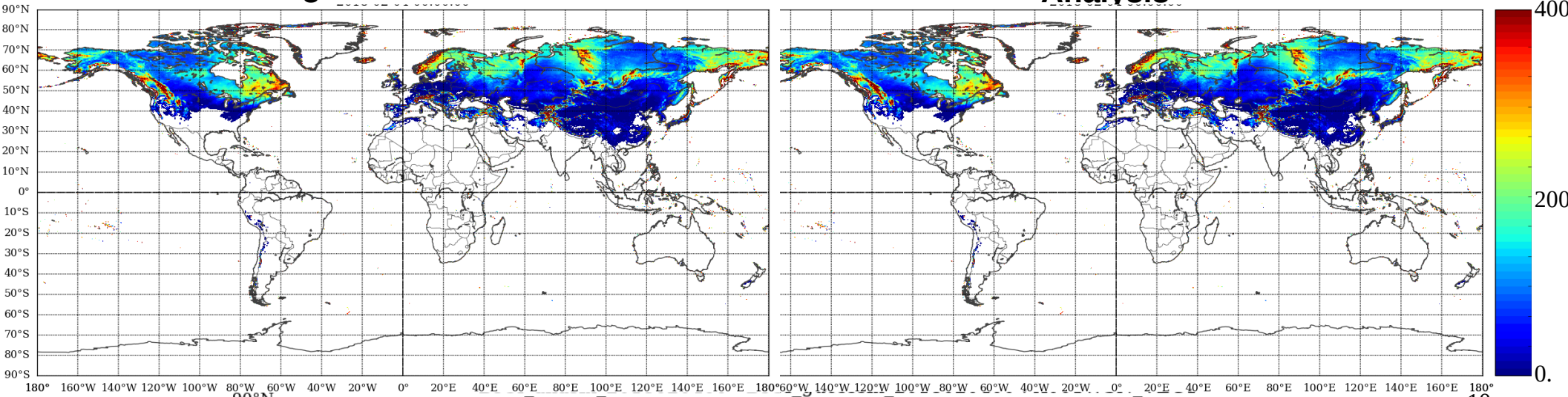
- Synop stations: heterogeneous coverage over the globe

- 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

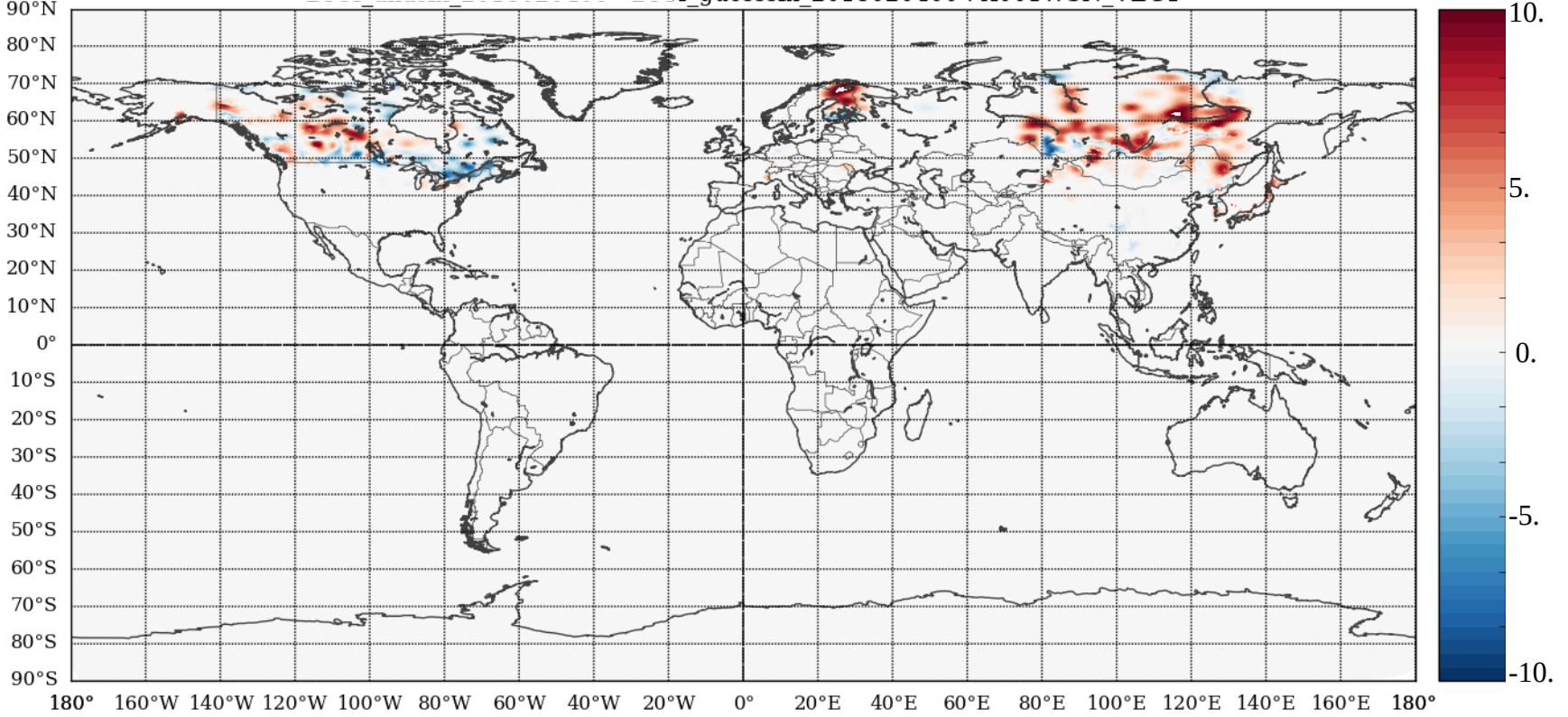# Snow analysis: case study on 4th February 2018, 00:00

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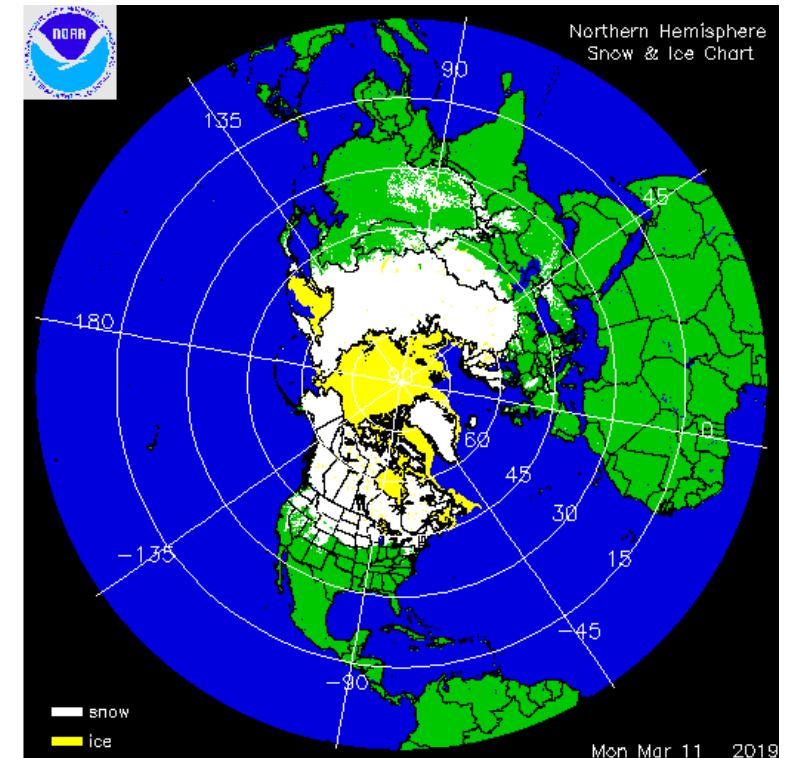
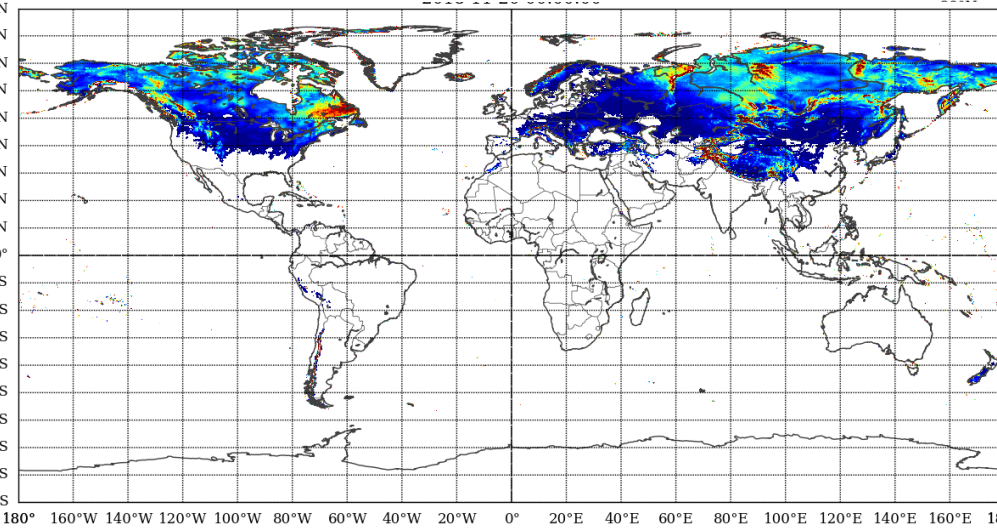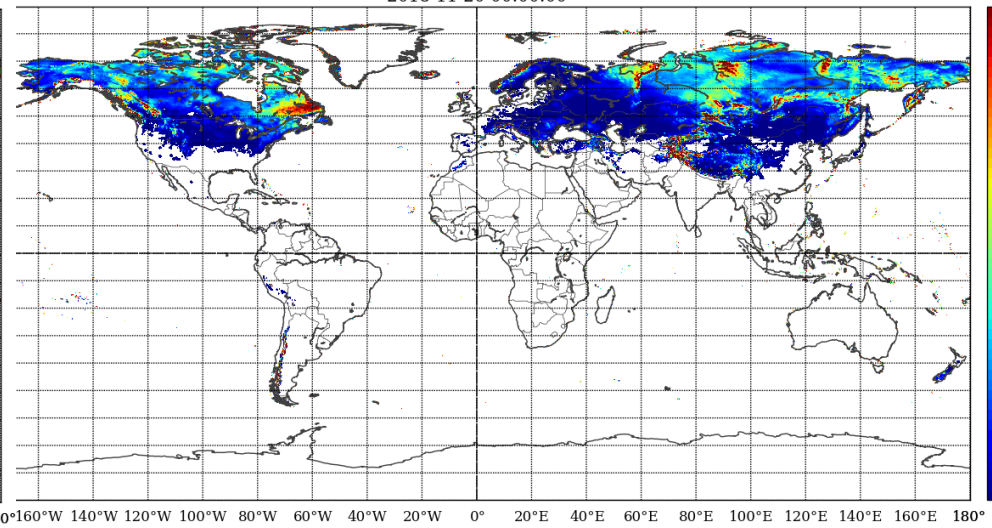IMS snow and ice product over Northern Hemisphere on March 11, 2019

SUW, Toulouse, 18th March 2019

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

Analysis
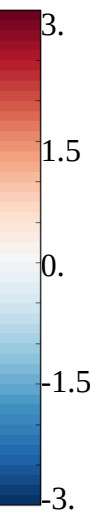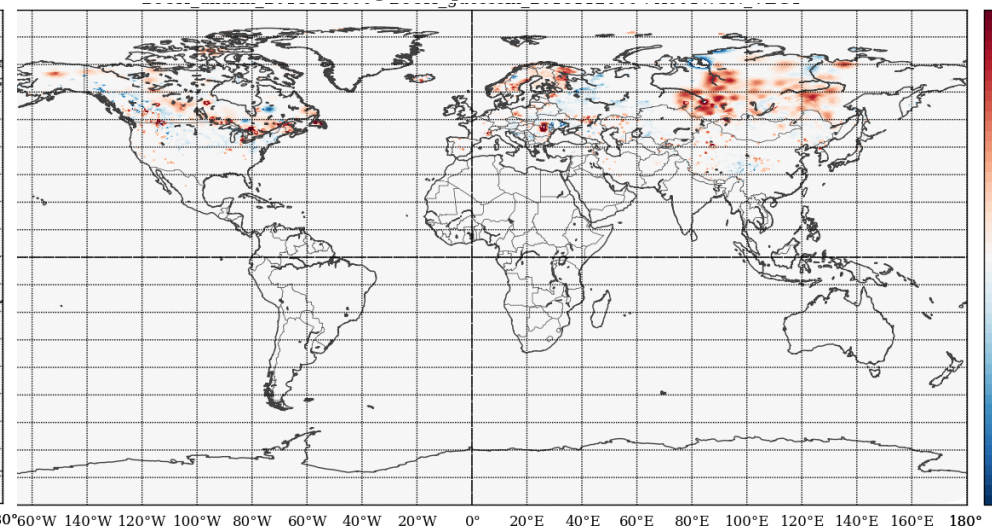

Synop only

Synop + IMS
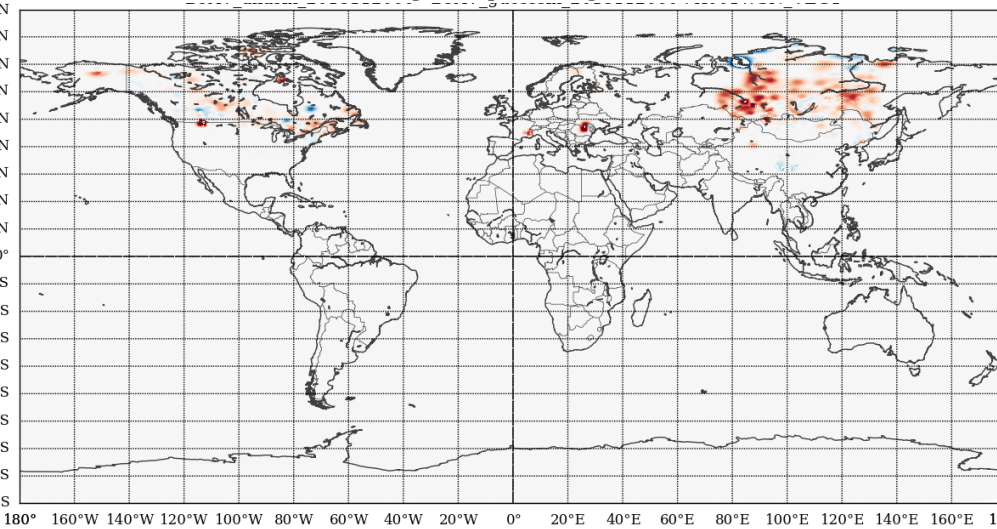
Analysis increment (kg/m²)

Synop only

Synop + IMS

Diagnostics using ARPEGE EDA for surface analysis

- Optimal interpolation coefficients:

  - Covariances between the forecast errors of T_{2m} and RH_{2m} and the perturbed 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.

$$w^a - w^b = \alpha(T^o - T^b) + \beta(RH^o - RH^b)$$

$$\alpha = \frac{\sigma_w}{\Phi \sigma_T} \left\{ \left[1 + \left(\frac{\sigma_{RH}^o}{\sigma_{RH}^b} \right)^2 \right] \rho_{T,w} - \rho_{T,RH} \rho_{RH,w} \right\}$$

$$\beta = \frac{\sigma_w}{\Phi \sigma_{RH}} \left\{ \left[1 + \left(\frac{\sigma_T^o}{\sigma_T^b} \right)^2 \right] \rho_{RH,w} - \rho_{T,RH} \rho_{T,w} \right\}$$

$$\Phi = \left[1 + \left(\frac{\sigma_T^o}{\sigma_T^b} \right)^2 \right] \left[1 + \left(\frac{\sigma_{RH}^o}{\sigma_{RH}^b} \right)^2 \right] - \rho_{T,RH}^2$$

- Kalman filter approach:

$$\Delta \mathbf{x} = \mathbf{B} \mathbf{H}^T (\mathbf{H} \mathbf{B} \mathbf{H}^T + \mathbf{R})^{-1} \Delta \mathbf{y}$$

- Use of EDA (AEARP, 25 members) to compute standard deviations and covariances between surface variables and observed variables.

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

Diagnostics using ARPEGE EDA for surface analysis
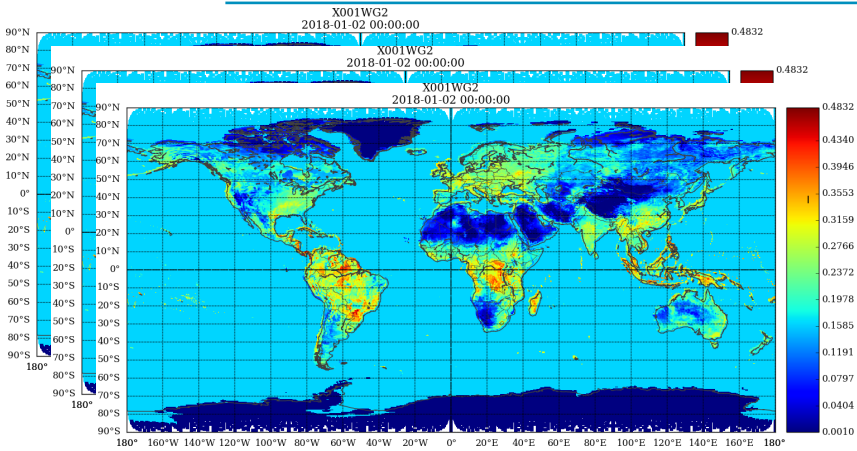
Surface fields at **low resolution** from EDA
(25 members)
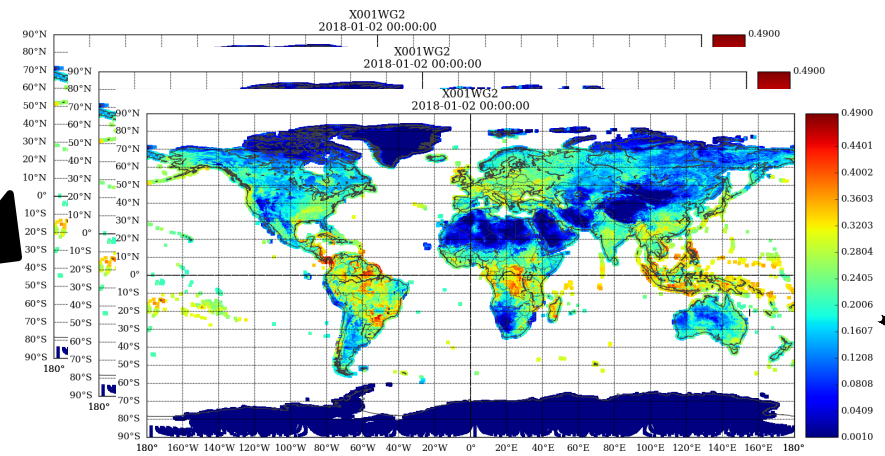
Surface fields at **high resolution**
(25 members)
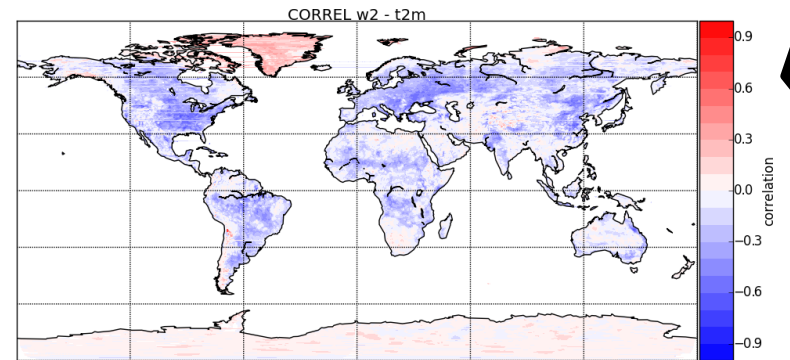
Soil analysis

Correlations and standard deviations at **high resolution**

ISWG, Lisbon, 26th June 2018

Diagnostics using ARPEGE EDA for surface analysis

- Cycling of analysed surface fields computed from the EDA over assimilation cycles: increments in the 2nd layer of the soil at first analysis time (20180102H00)

OI increments   TG2   EDA increments

WG2

Conclusions and future work

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

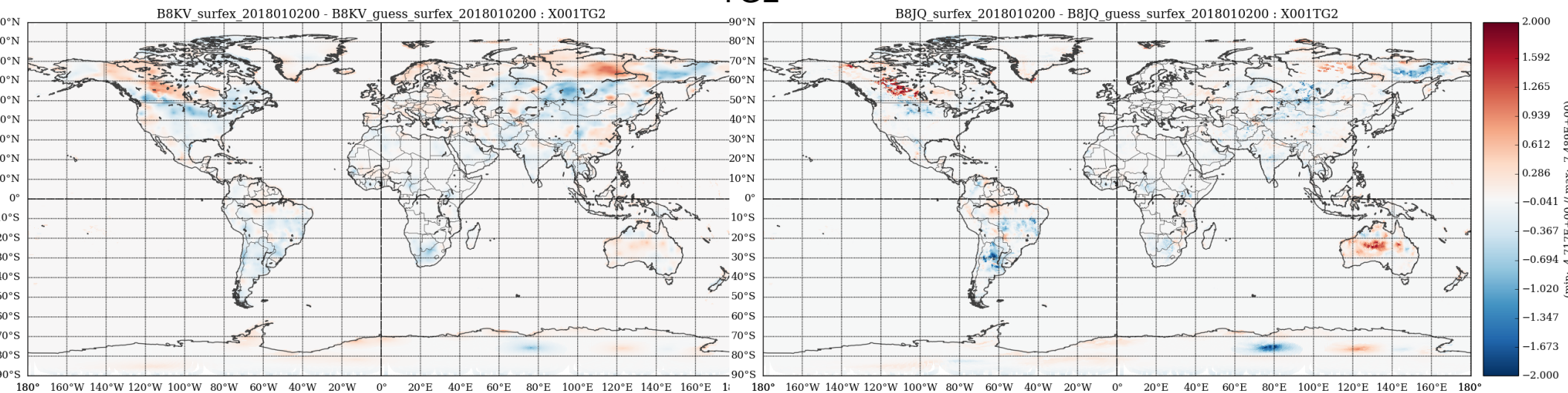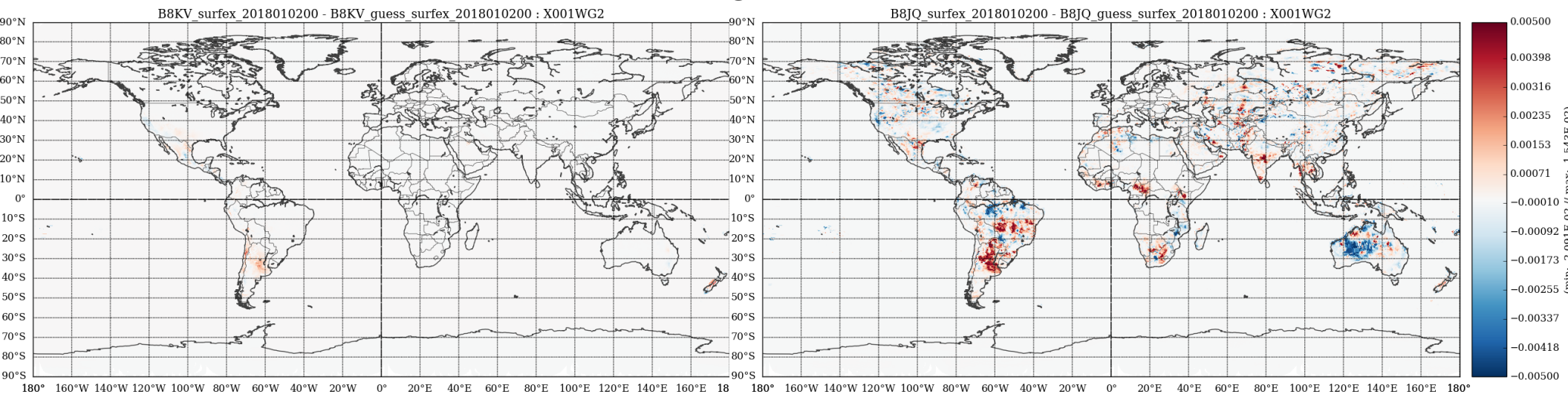- Improvement of the land surface data assimilation system: ensemble methods (EnKF, particle filter…) and use of atmospheric ensembles produced by ensemble data assimilation systems (AEARP → global model ARPEGE, AEARO → limited area model AROME)

- Assimilation of satellite products, in particular for surface temperature (PhD Zied Sassi) and for snow (Nesdis-IMS snow cover product for ARPEGE, H-SAF products for AROME)

- Future plans for the assimilation of soil moisture products (soil moisture product from ASCAT, and/or from L-band sensors SMOS/SMAP), and albedos (LSA-SAF products)

Land surface assimilation system

- Météo France global model ARPEGE and limited area model AROME are coupled to the surface modelling platform SURFEX, which represents the exchanges between the atmosphere and the surface.

- Each grid box is divided into 4 tiles for nature, sea, lake and town fractions. The 4 tiles recieve the same atmospheric forcing and the surface fluxes computed on each tile are averaged over the grid box.

- The 4 tiles 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) $\rightarrow$: T_s, T_2, T_3, w_g, w_2, w_3.

  - Town: TEB (Masson, 2000) $\rightarrow$ T_{roof}, T_{wall}, T_{road}

  - Lake $\rightarrow$ LST (FLake)

  - Sea $\rightarrow$ SST (CMO 1D)
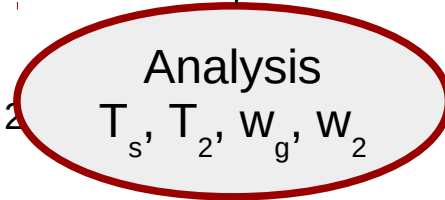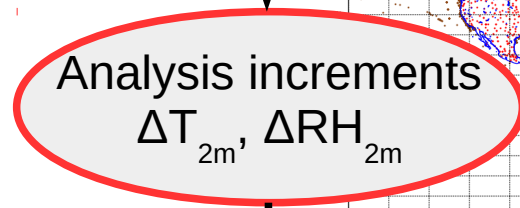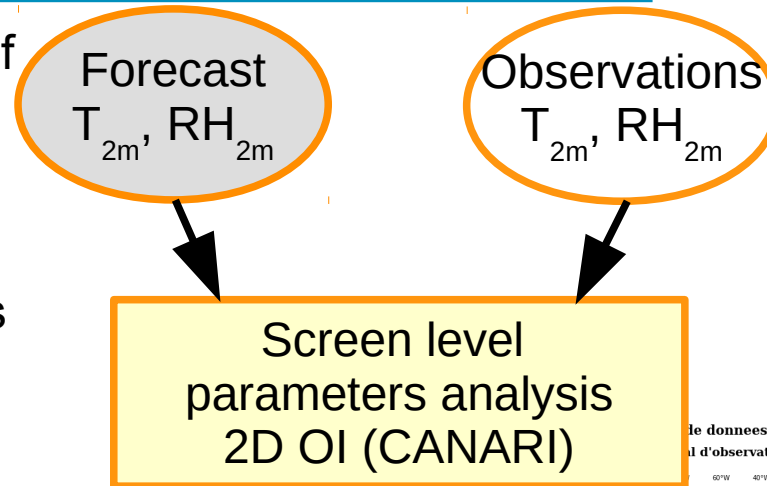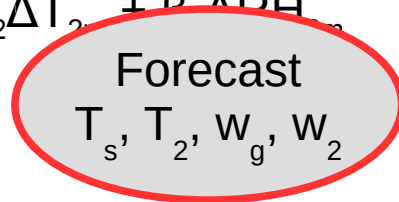
Land surface assimilation system

- 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):

  - $\Delta T_s = \Delta T_{2m}$

  - $\Delta T_2 = \Delta T_{2m}/2\pi$

  - $\Delta w_g = \alpha_1 \Delta T_{2m} + \beta_1 \Delta RH_{2m}$

  - $\Delta w_2 = \alpha_2 \Delta T_{2m} + \beta_2 \Delta RH_{2m}$

Forecast T_{2m}, RH_{2m}

Observations T_{2m}, RH_{2m}

Screen level parameters analysis 2D OI (CANARI)

de donnees - SYNOP/SHIP - 2018/06/11 00H UTC cut-off long
l d'observations avant screening : 39135

Analysis increments ΔT_{2m}, ΔRH_{2m}

Forecast T_s, T_2, w_g, w_2

Soil analysis 1D OI

Analysis T_s, T_2, w_g, w_2

ISWG, Lisbon, 2

CNRS   METEO FRANCE
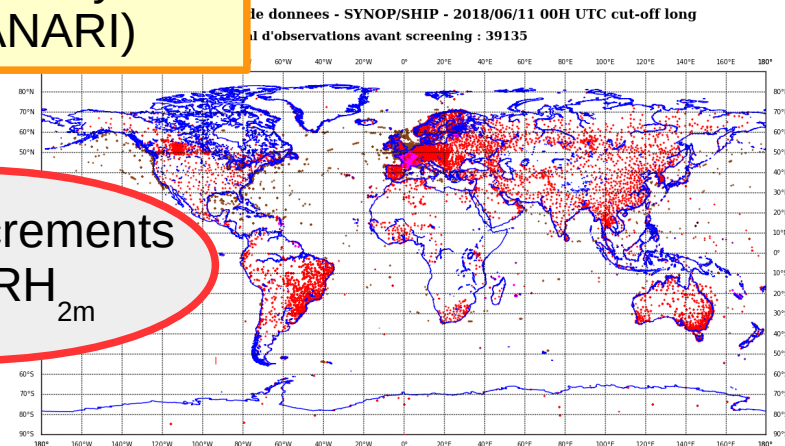
Snow analysis: case study on 22th January 2019, 12:00

Background
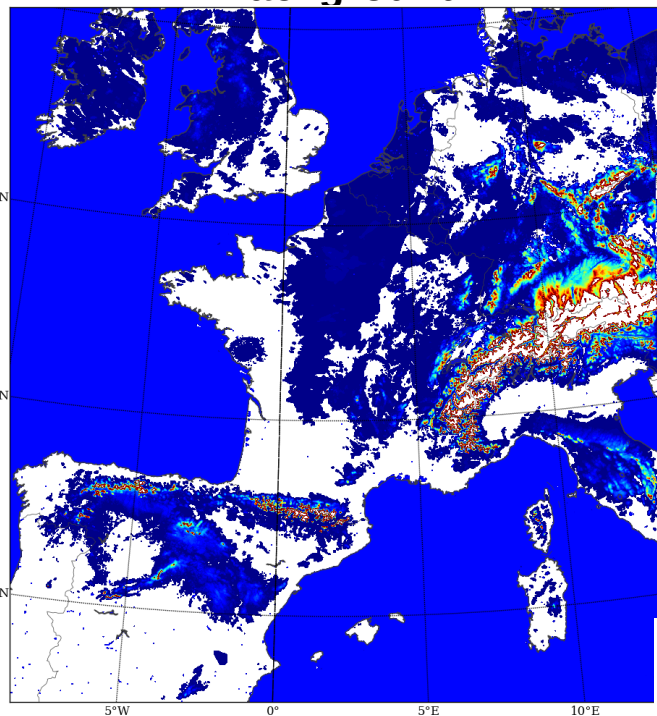
Analysis
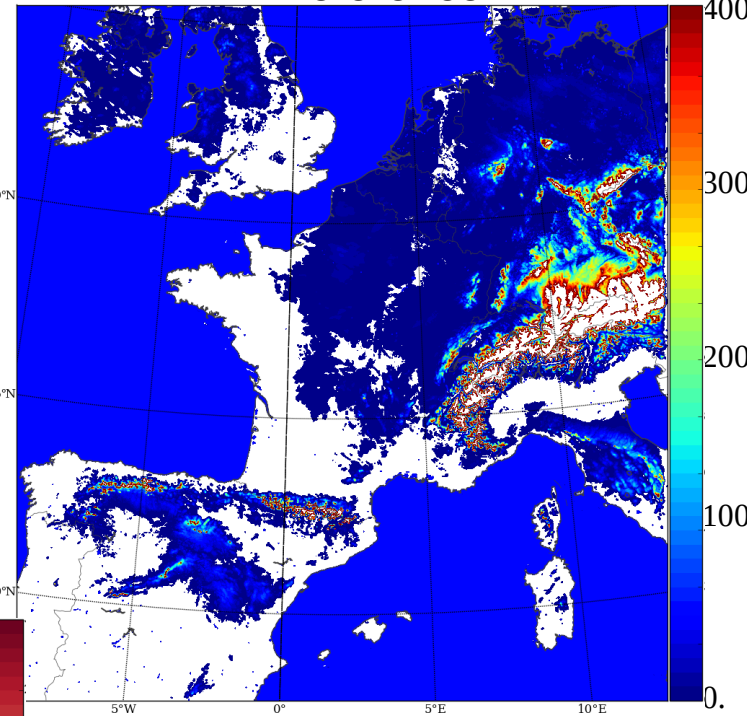
Reference

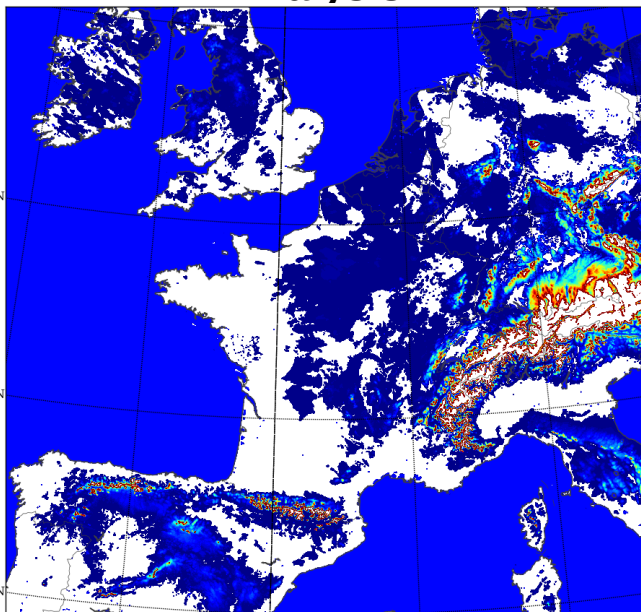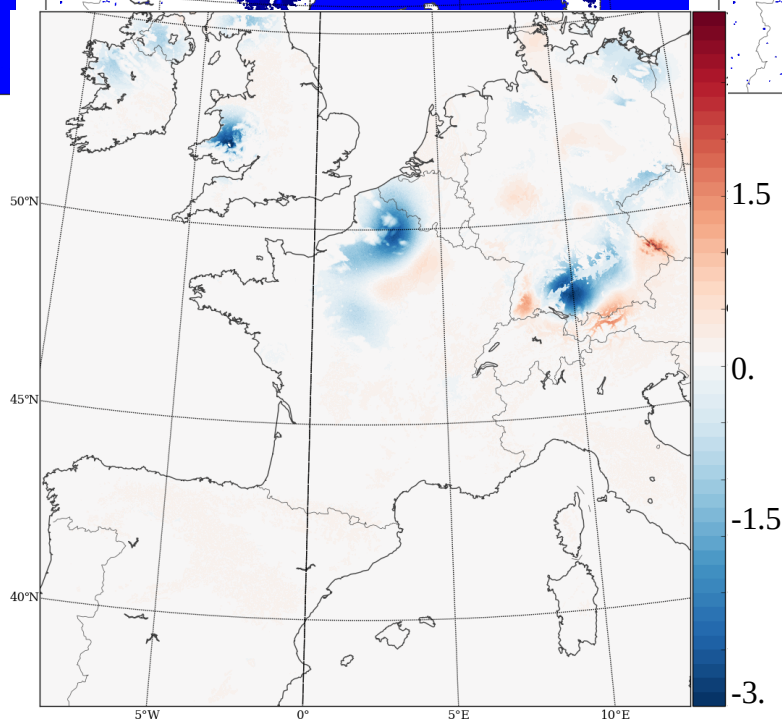**Analysis Increment (σ_o = 5 kg/m²)**

(kg/m²)

Snow analysis: bias and MSE on February 2018 with respect to Synop stations (9 simulations)
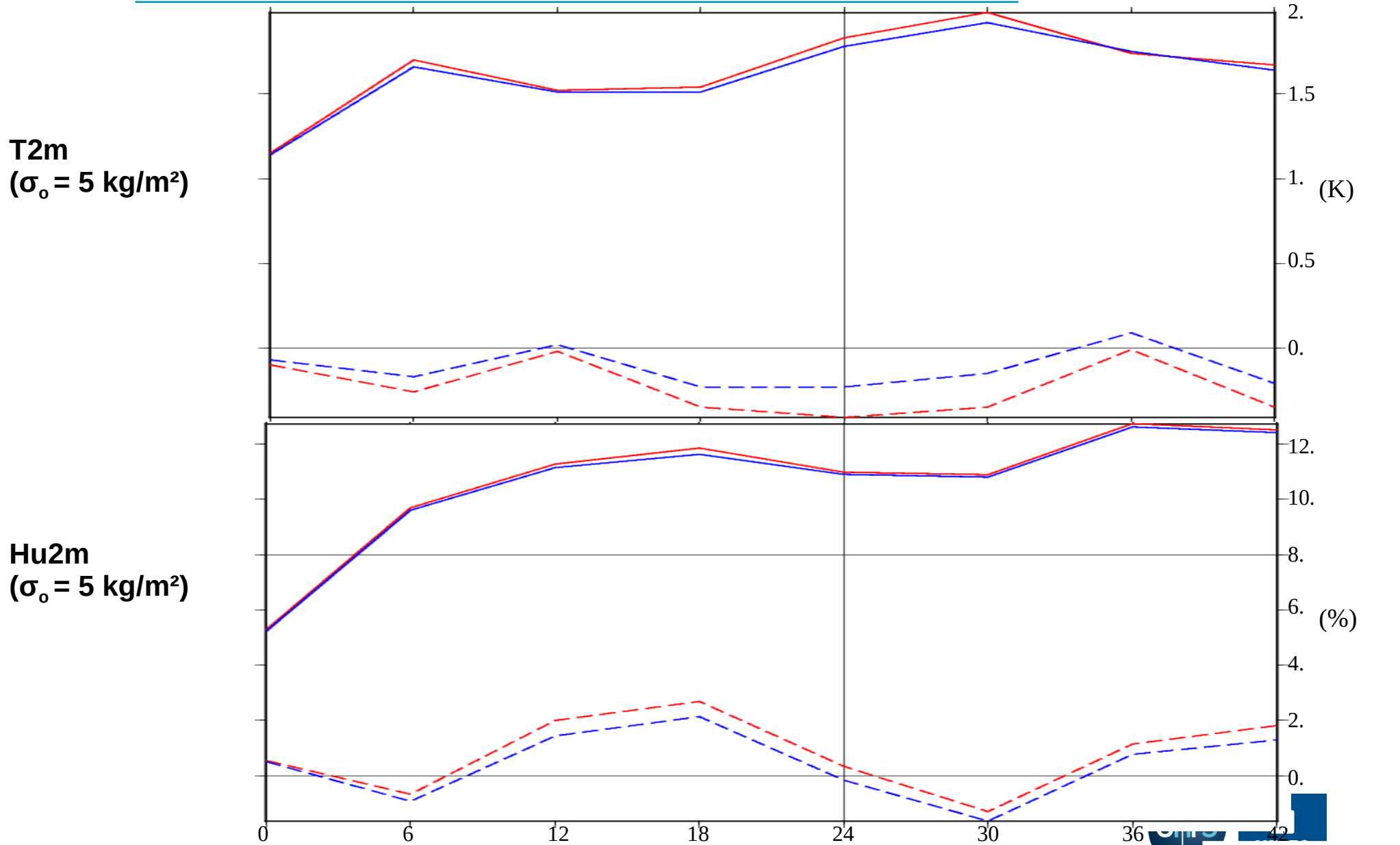
T2m
(σ_o = 5 kg/m²)

(K)

Hu2m
(σ_o = 5 kg/m²)

(%)

SUW, Toulouse, 18th March 2019

Forecast range (h)

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 (blue) and without (red) snow analysis

Diagnostics using ARPEGE EDA for surface analysis

- Diagnostics on a summer period (August 2017): Correlations between w_2 and T_{2m} averaged ove the period. Coll. with ECMWF (Patricia de Rosnay)

CORREL w2 - t2m
AEARP

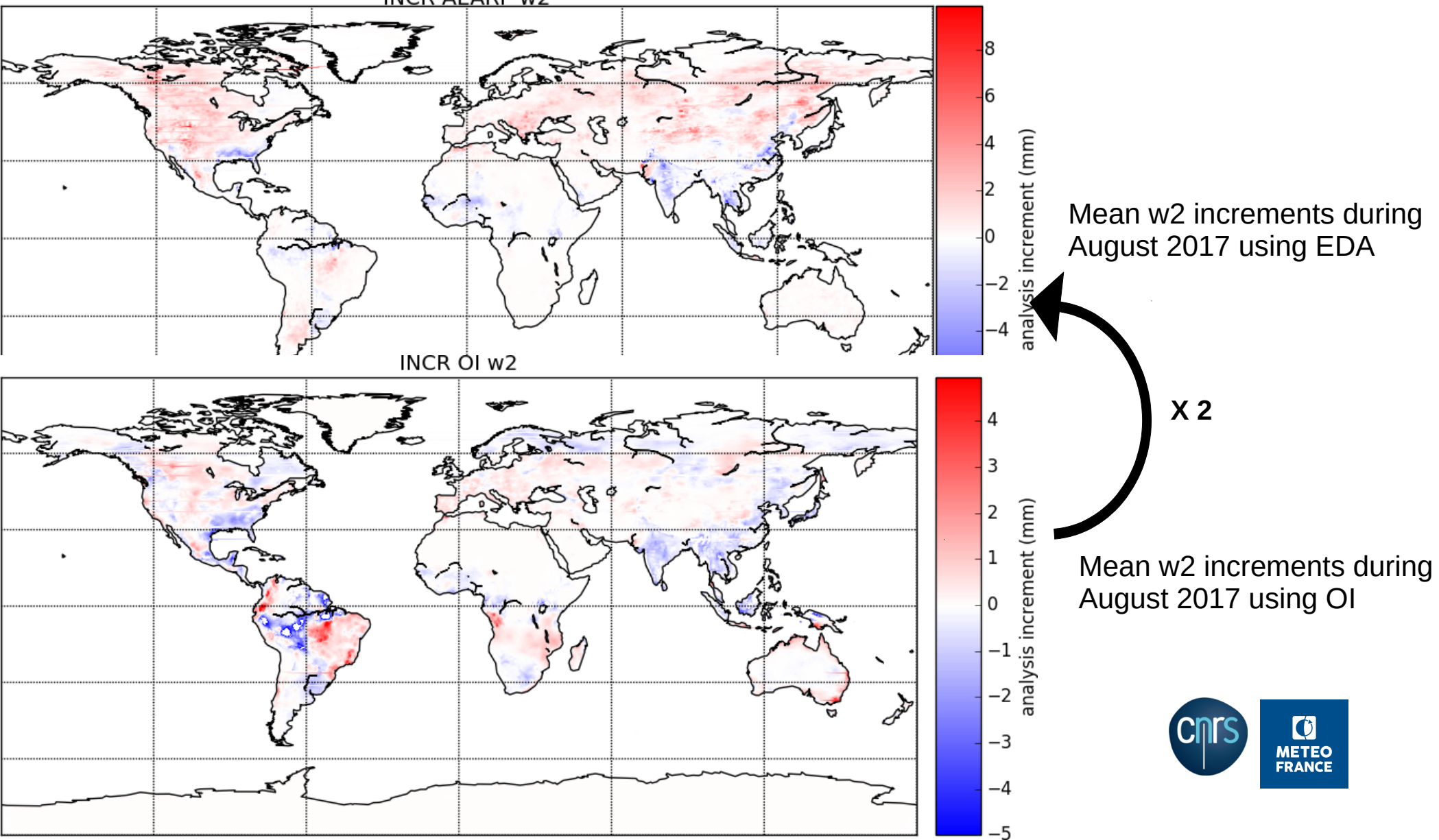Correlations between w2 and T2m computed over a 3-weeks period (August 2017, all analysis times)

CORREL swvl2 - 2t
EDA ECMWF

22
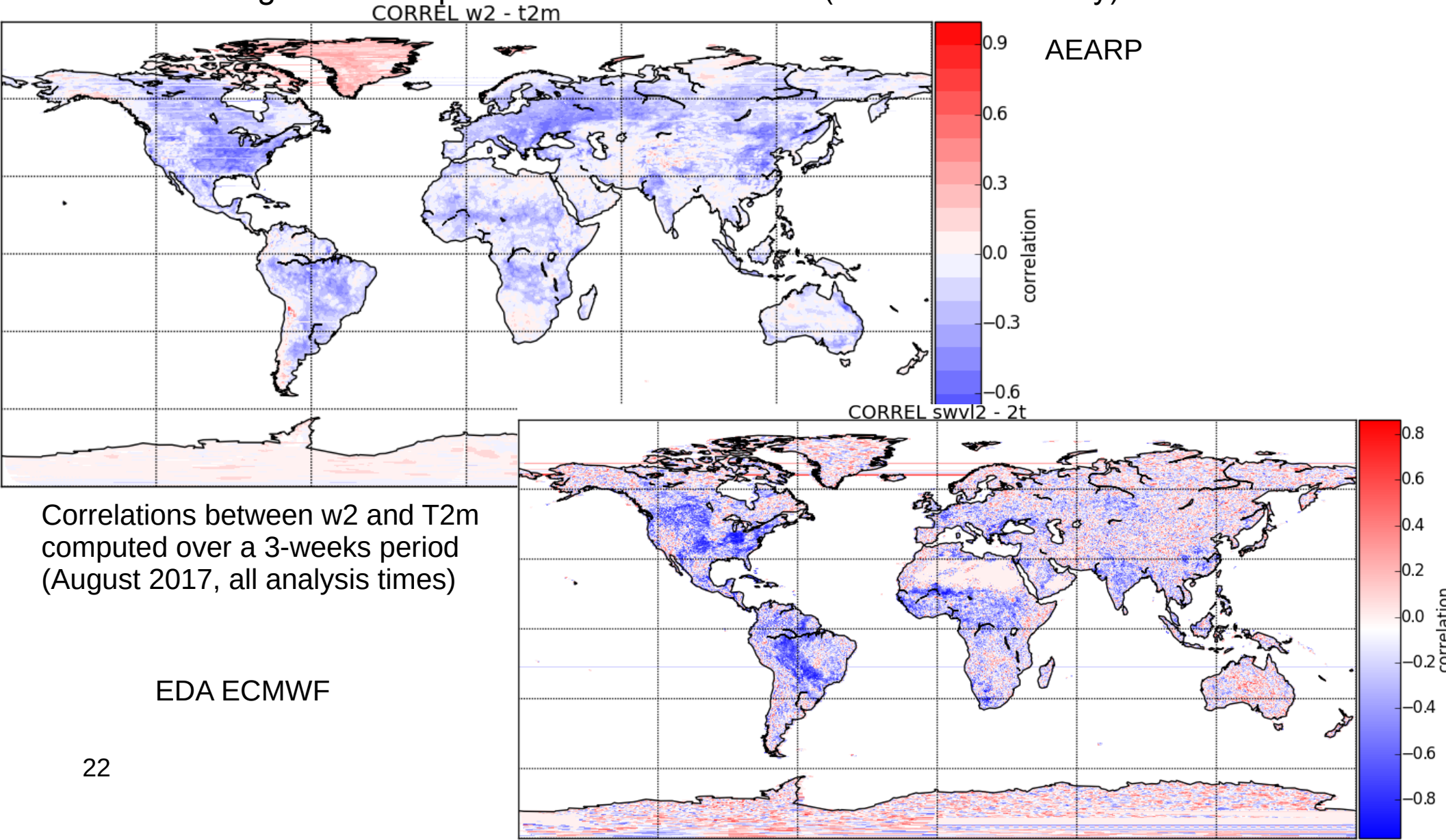
Diagnostics using ARPEGE EDA for surface analysis

- Analysis increments for soil variables and comparison with OI increments (operationnal T_{2m} and RH_{2m} increments)

INCR AEARP w2

Mean w2 increments during August 2017 using EDA

X 2

INCR OI w2

Mean w2 increments during August 2017 using OI

Conclusions and future work

- Analysis of surface parameters: snow depth, precipitation (2D optimal interpolation), ...(LAI); improvement of analysis techniques, in particular in areas of complex orography (MESCAN)

- 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 → global model ARPEGE, AEARO → limited area model AROME)

- Assimilation of satellite products, in particular for surface temperature (PhD Zied Sassi), for soil moisture (soil moisture product from ASCAT, and/or from L-band sensors SMOS/SMAP), for snow (snow cover products Nesdis-IMS/H-SAF product/Modis?) and for albedos (products from LSA-SAF)