Review of surface modeling and data assimilation in ALADIN

http://www.umr-cnrm.fr/aladin/

Outline of this talk
(according the HIRLAM-ALADIN Rolling Work Plan)

- Algorithms for surface assimilation (SU1)
- Use of observations in surface assimilation (SU2)
- SURFEX: validation of existing options for NWP (SU3)
- Assess/improve quality of surface characterization (SU5)
- Coupling with sea surface/ocean SU6) (mentioned by Martina on Monday, I will not present material here)

See also poster of Balazs, presented later

Algorithms for surface assimilation

- Some tests were preformed while using structure function for T2m of the MESCAN scheme in the AROME surface data assimilation. This led to some realistic increments of mountain regions.
- Snow analysis over plains is necessary to correct for insufficient snow melt in the AROME model. Last year efforts were made to extract more data over France. The snow analysis is done relying on codes from the CANARI scheme while transferring the increments to SURFEX in AROME. A French case study (12/2/2018) showed some slight improvements. This work has to continue.

Optimum Interpolation

1) Optimum Interpolation of T_{2m} and RH_{2m} using 2m observations interpolated at the model grid-point by a 2m analysis **(2-D CANARI OI)**

$$\Delta T_{2m} = T_{2m}^{a} - T_{2m}^{b} \qquad \Delta RH_{2m} = RH_{2m}^{a} - RH_{2m}^{b}$$

2) Correction of 4 surface parameters (T_s, T_p, W_s, W_p) using 2m increments between analysed and forecasted values.

$$T_p^a - T_p^b = \Delta T_{2m} / 2\pi \qquad T_s^a - T_s^b = \Delta T_{2m}$$

$$W_s^a - W_s^b = \alpha_{WsT} \Delta T_{2m} + \alpha_{WsRH} \Delta RH_{2m}$$

$$W_p^a - W_p^b = \alpha_{WpT} \Delta T_{2m} + \alpha_{WpRH} \Delta RH_{2m}$$

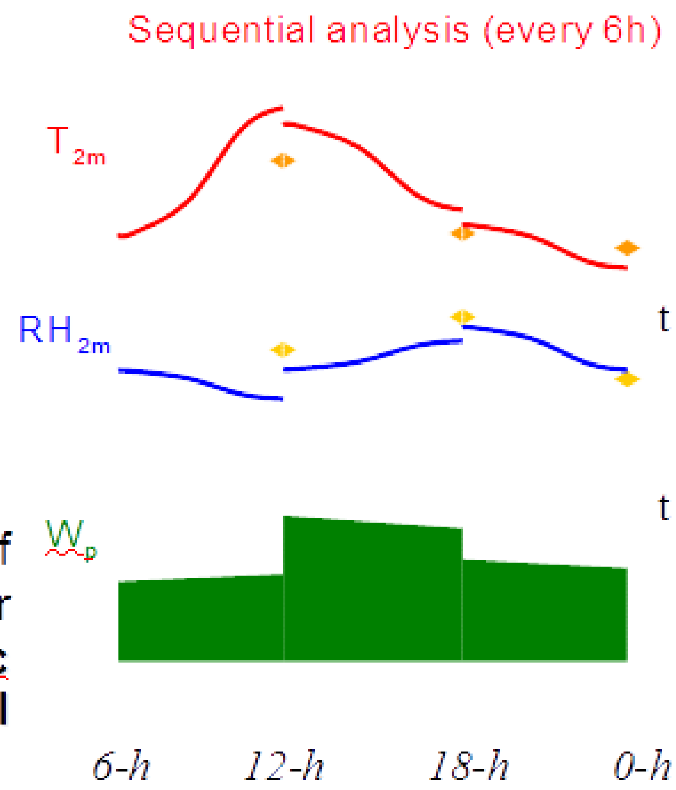
OI coefficients

$$\alpha_{Ws/pT} = \frac{\sigma^b_{Ws/p}}{\Phi\sigma^b_{T2m}} \left\{ \left[1 + \left(\frac{\sigma^a_{RH2m}}{\sigma^b_{RH2m}} \right)^2 \right] \rho_{T2m,Ws/p} - \rho_{T2m,RH2m}\rho_{RH2m,Ws/p} \right\}$$

$$\alpha_{Ws/pRH} = \frac{\sigma^b_{Ws/p}}{\Phi\sigma^b_{RH2m}} \left\{ \left[1 + \left(\frac{\sigma^a_{T2m}}{\sigma^b_{T2m}} \right)^2 \right] \rho_{RH2m,Ws/p} - \rho_{T2m,RH2m}\rho_{T2m,Ws/p} \right\}$$

$$\Phi = \left[1 + \left(\frac{\sigma^a_{T2m}}{\sigma^b_{T2m}} \right)^2 \right] \left[1 + \left(\frac{\sigma^a_{RH2m}}{\sigma^b_{RH2m}} \right)^2 \right] - \rho^2_{T2m,RH2m}$$

- Very strong dependency of these background error statistics to **physiographic** properties and **meteorological conditions.**



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) → : T_s, T_2, T_3, w_g, w_2, w_3.

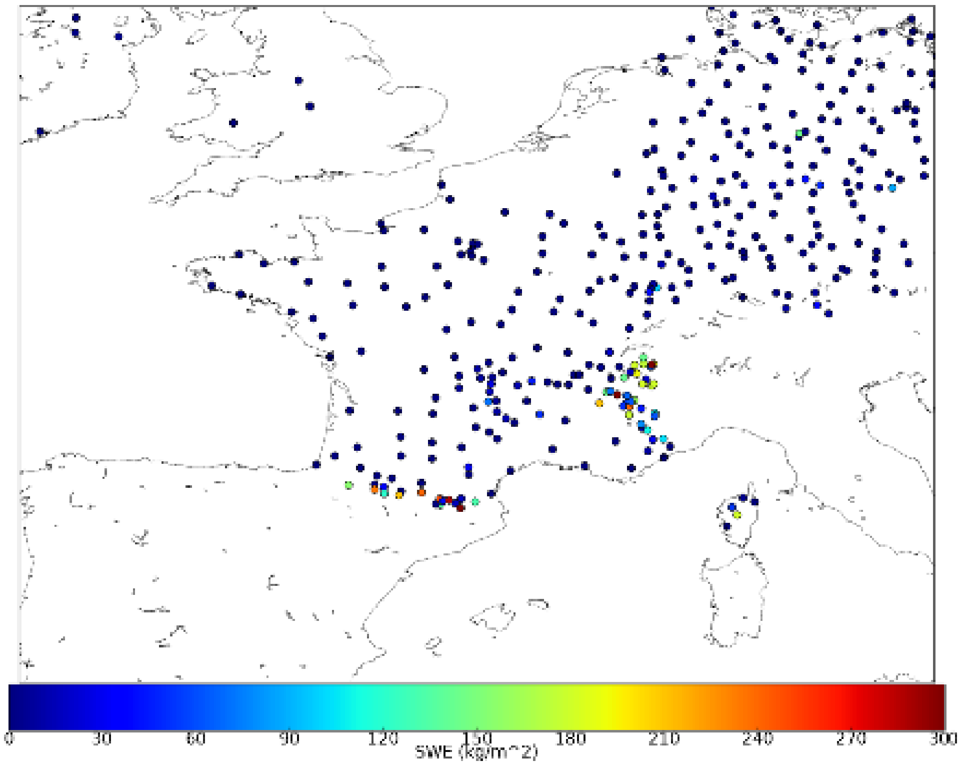
  - Town: TEB (Masson, 2000) → T_{roof}, T_{wall}, T_{road}

  - Lake → LST (FLake)

  - Sea → SST (CMO 1D)

Snow analysis

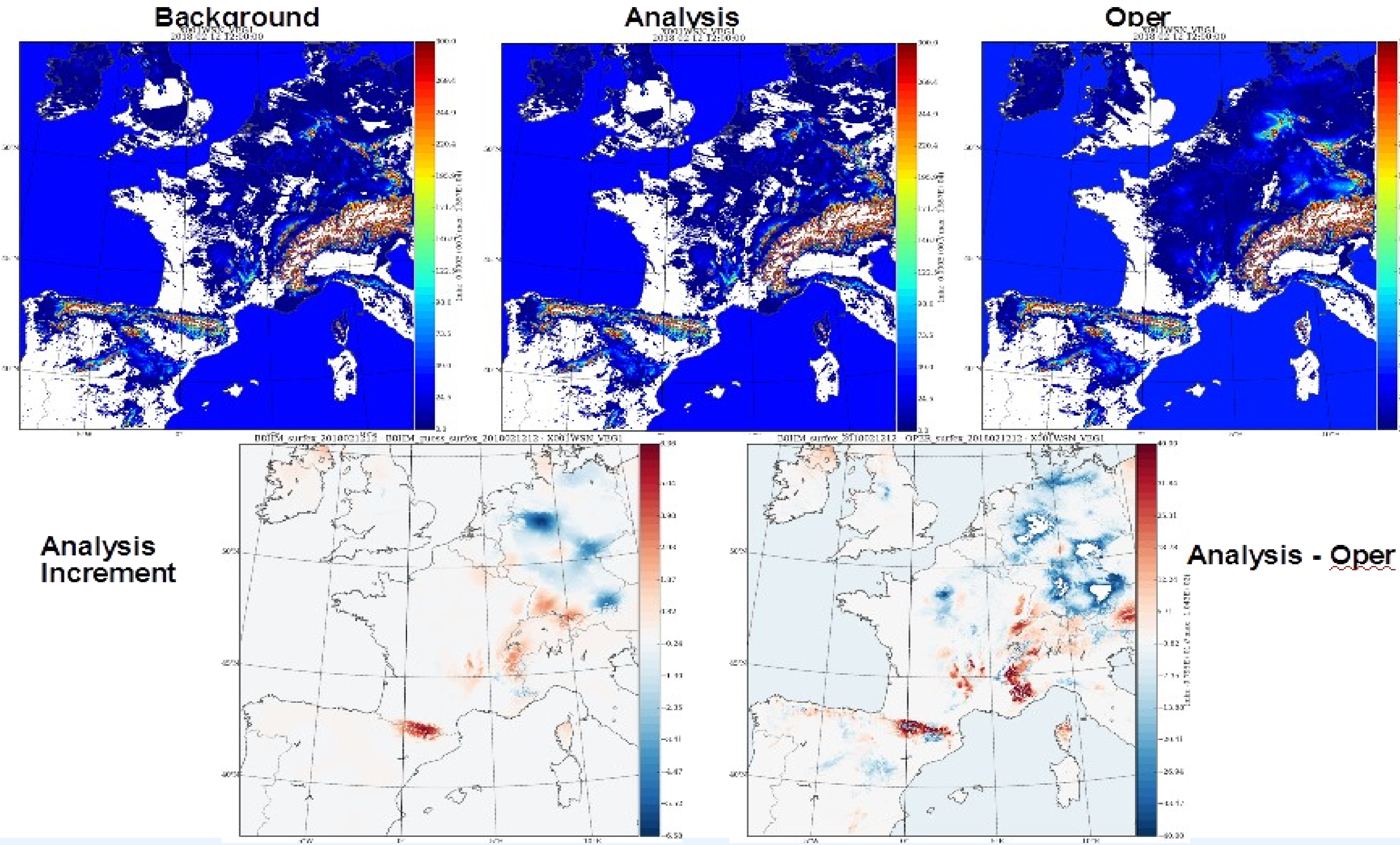
- Snow analysis over plains: necessary to correct for insufficient snow melt in the model
  - Case study February 2018



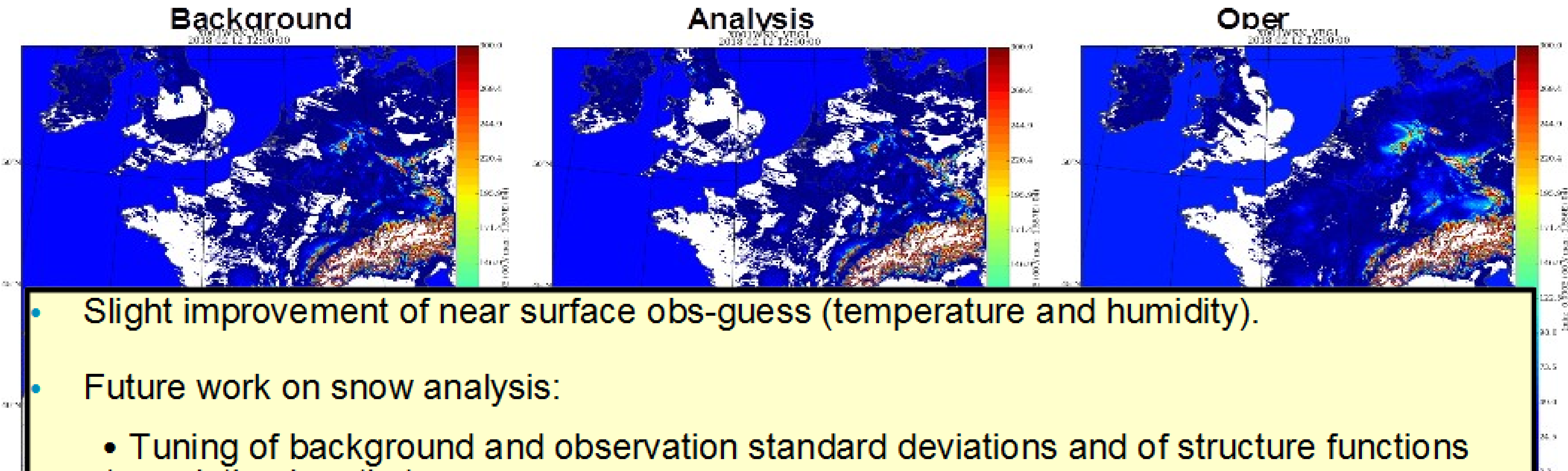
Snow observations over the AROME-France domain

- Observations extracted over France
- Snow analysis performed using CANARI 2D OI
- Transfer of snow increments into SURFEX
- Prognostic variable: SWE → use of model density

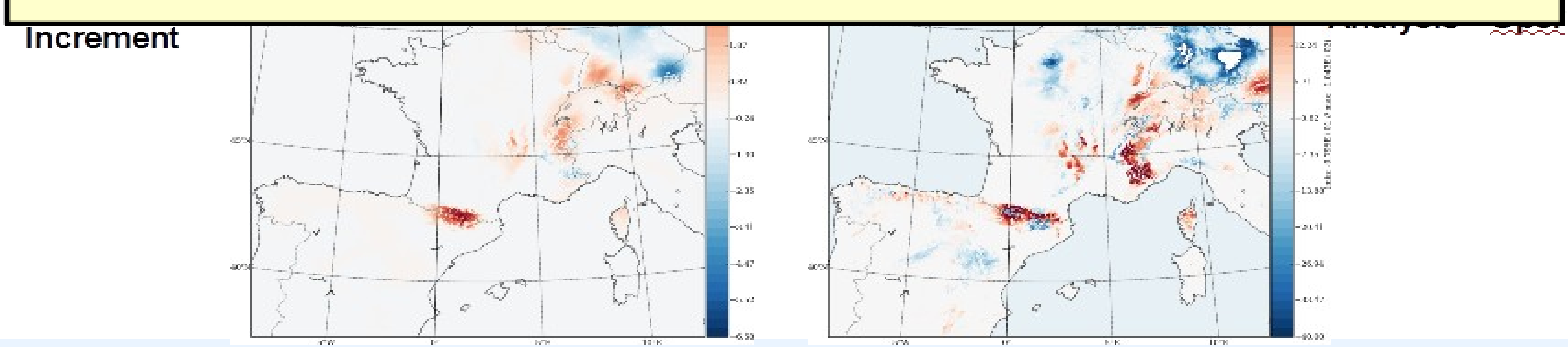
Snow analysis: case study on 12th february 2018, 12:00



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



- Slight improvement of near surface obs-guess (temperature and humidity).
- Future work on snow analysis:
  - Tuning of background and observation standard deviations and of structure functions (correlation lengths)
  - Use of satellite products of snow cover



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.

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

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

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

$$\Phi = \left[1+\left(\frac{\sigma^o_T}{\sigma^b_T}\right)^2\right]\left[1+\left(\frac{\sigma^o_{RH}}{\sigma^b_{RH}}\right)^2\right] - \rho^2_{T,RH}$$

- Kalman filter approach:

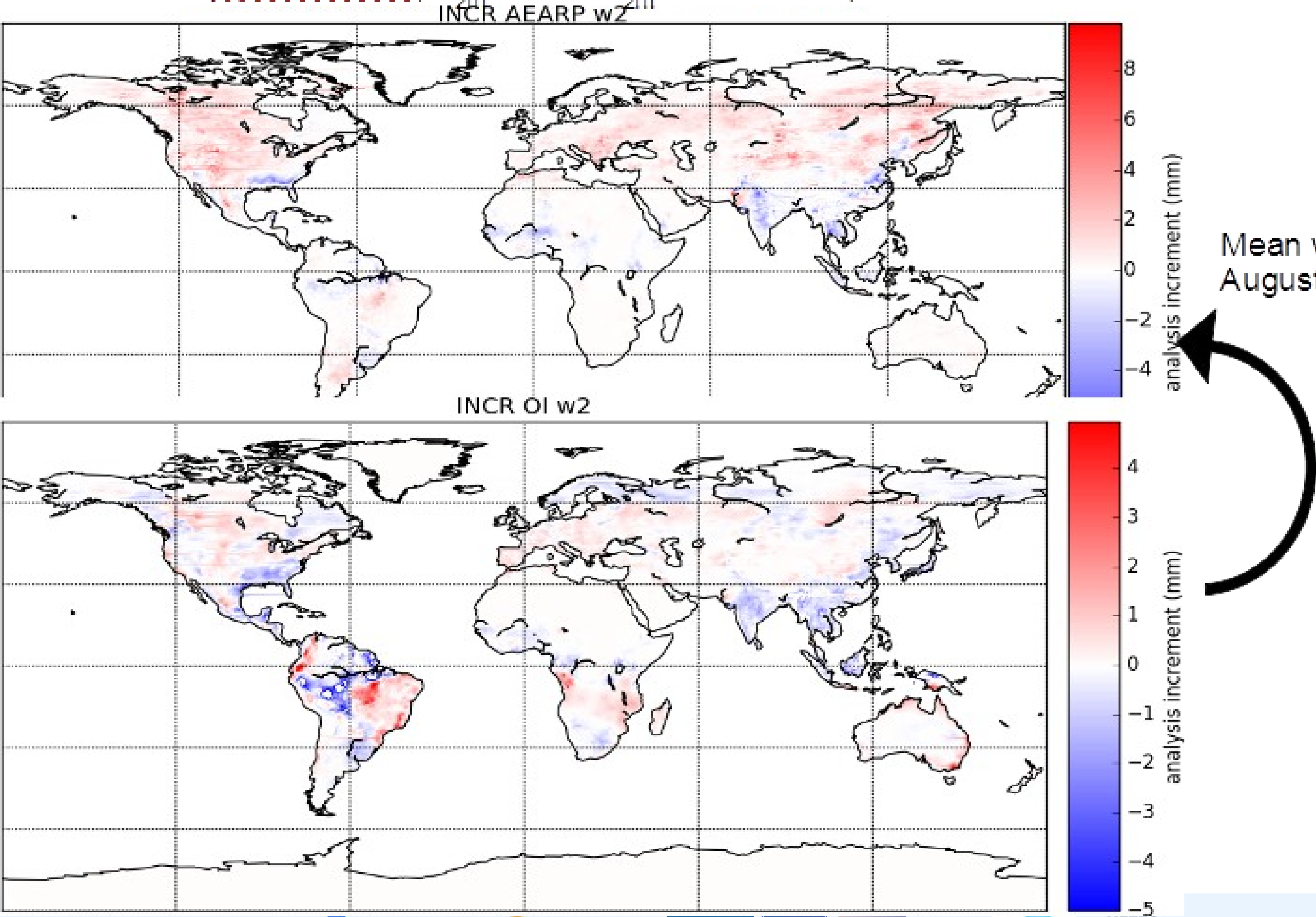
$$\Delta\mathrm{x} = \mathrm{BH^T(HBH^T + R)^{-1}}\Delta\mathrm{y}$$

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

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

Diagnostics using ARPEGE EDA for surface analysis

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



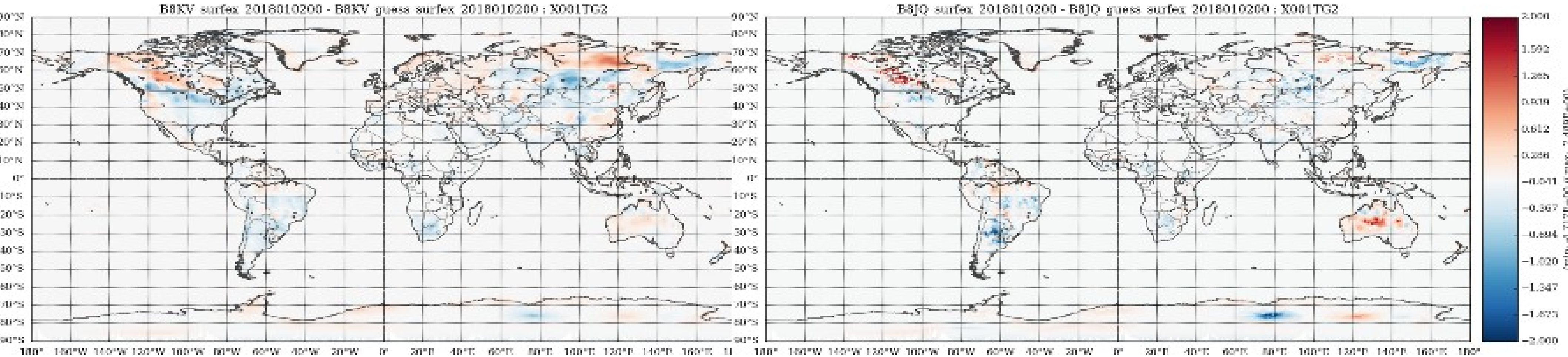
Mean w2 increments during August 2017 using EDA

X 2

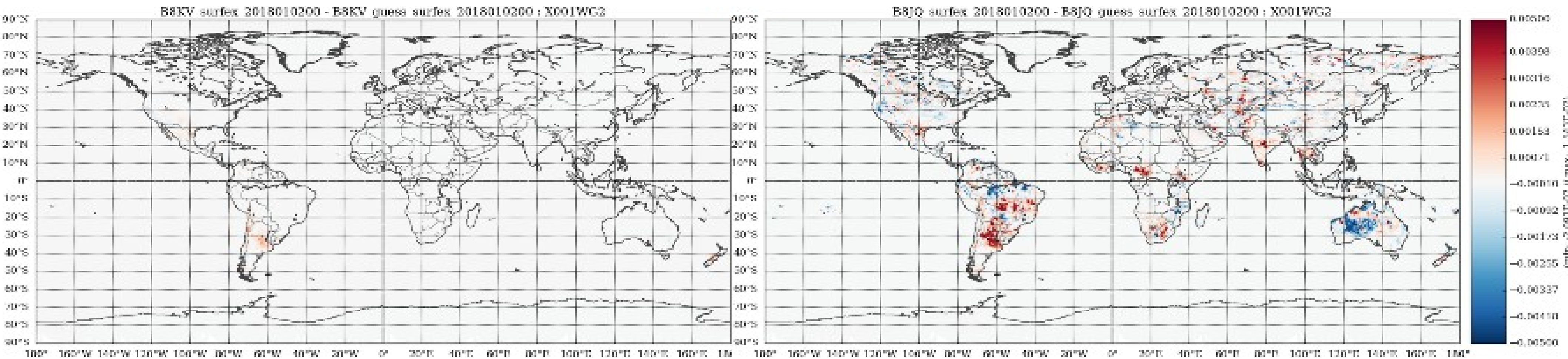
Diagnostics using ARPEGE EDA for surface analysis

- 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

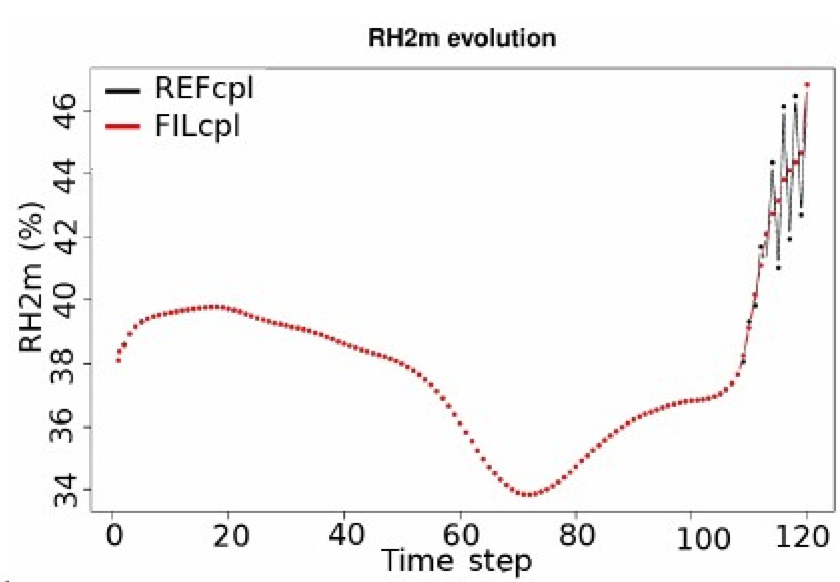


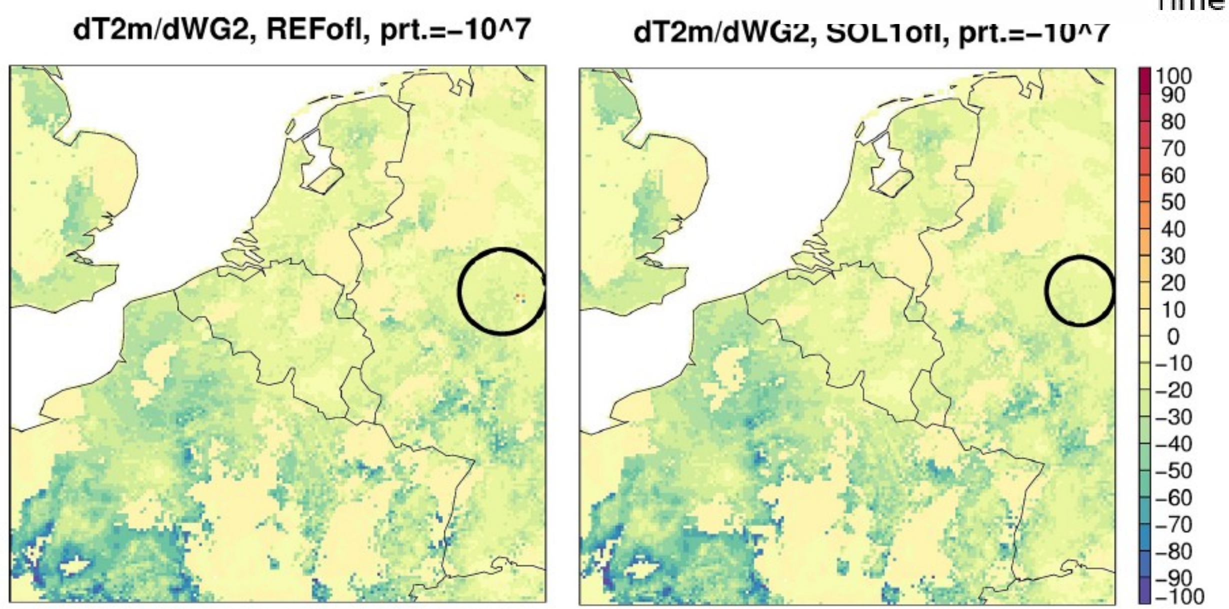
Extended Kalman Filter (Annelies Duerinckx)

$$\boldsymbol{x}_{\mathrm{a}}^{t} = \boldsymbol{x}_{\mathrm{b}}^{t} + \mathbf{B}\mathbf{H}^{T}(\mathbf{H}\mathbf{B}\mathbf{H}^{T} + \mathbf{R})^{-1}[\boldsymbol{y}_{\mathrm{o}}^{t} - \mathcal{H}(\boldsymbol{x}_{\mathrm{b}}^{t_0})]$$

$$\mathbf{H} = \frac{\delta y^{t}}{\delta x^{t_0}} = \frac{y_i^{t}(x^{t_0} + \delta x_j) - y_i^{t}(x^{t_0})}{\delta x_j}.$$

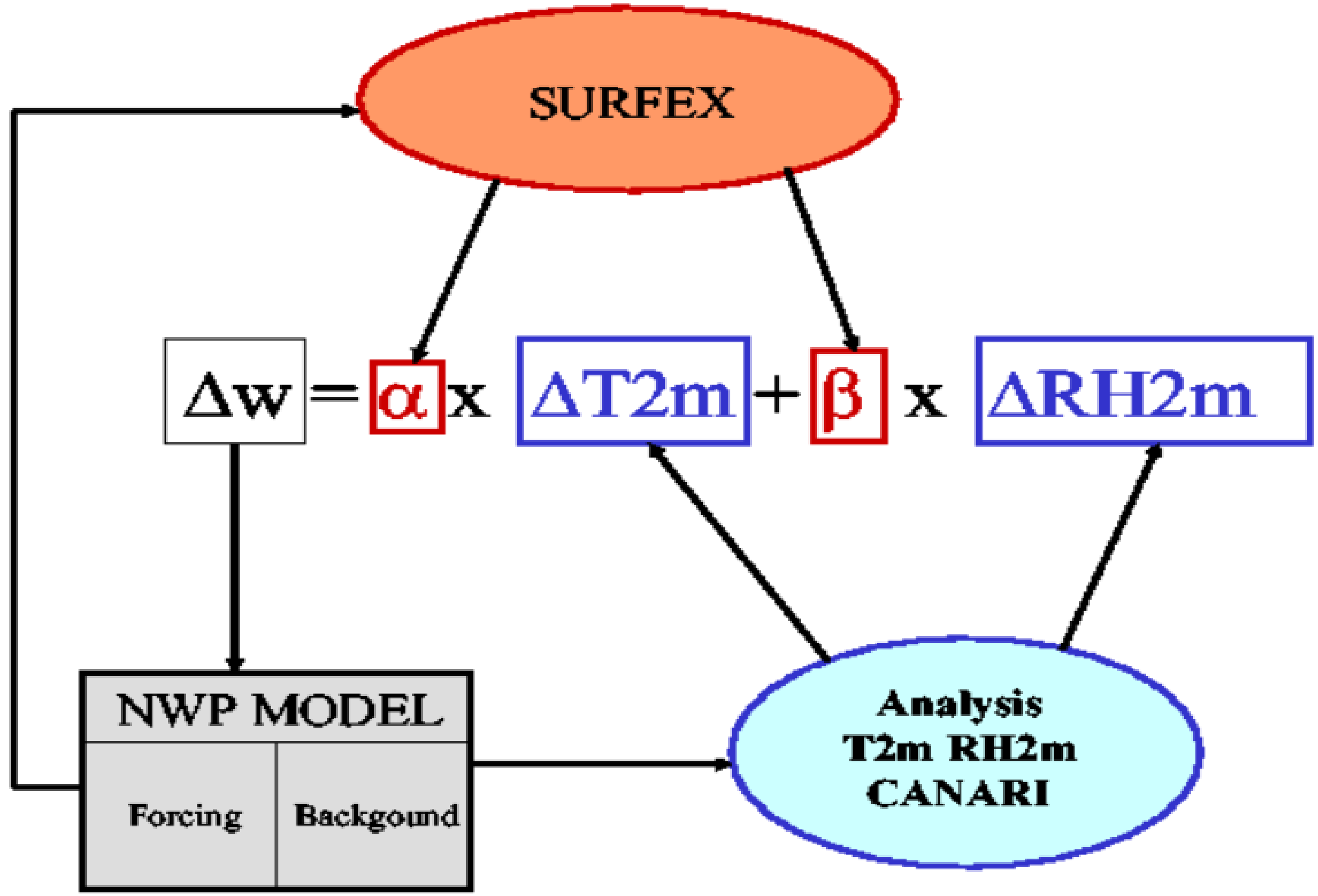
$$x_{\text{filtered}} = 0.5 \times w \times x_{t-1} + (1-w)x_t + 0.5 \times w \times x_{t+1}$$





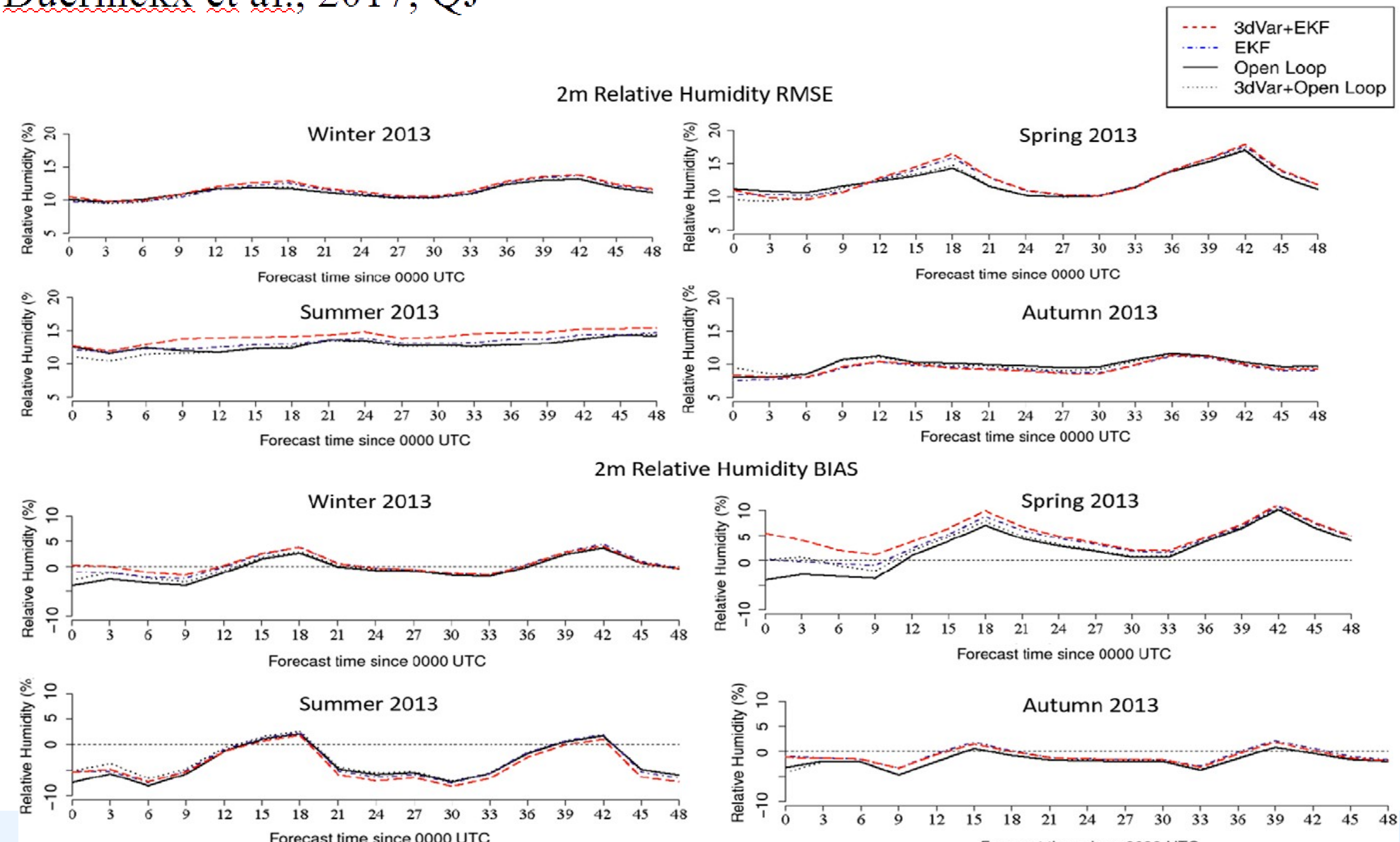
Offline surface DA

Coupling between atmospheric model and offline SURFEX



3D-VAR coupled to EKF (Annelies Duerinckx, Arab Djebbar)

Duerinckx et al., 2017, QJ



New SODA-EKF based assimilation suite (ViTa)

- Analysis of soil water content (WG), temperature (TG), and later also snow cover
- Spatial domain: INCA-SK 501 x 301 @ 1 km
- Gridded observations: Standard CANARI analysis is replaced by hi-res analysis of T2M & RH2M from INCA-SK system (see figure)
- Forcing: ~20m above surface,
  - surface fields: INCA-SK precipitation analysis + global radiation analysis -> improved calculation of Jacobians
  - other fields: from ALARO-SK 4.5km
- SURFEX and SODA executables from cy40t1 pack
- Future plans:
  - Test and optimize current setup
  - Compare EKF with OI_MAIN
  - Switch to SURFEX v8.1
  - Snow cover analysis

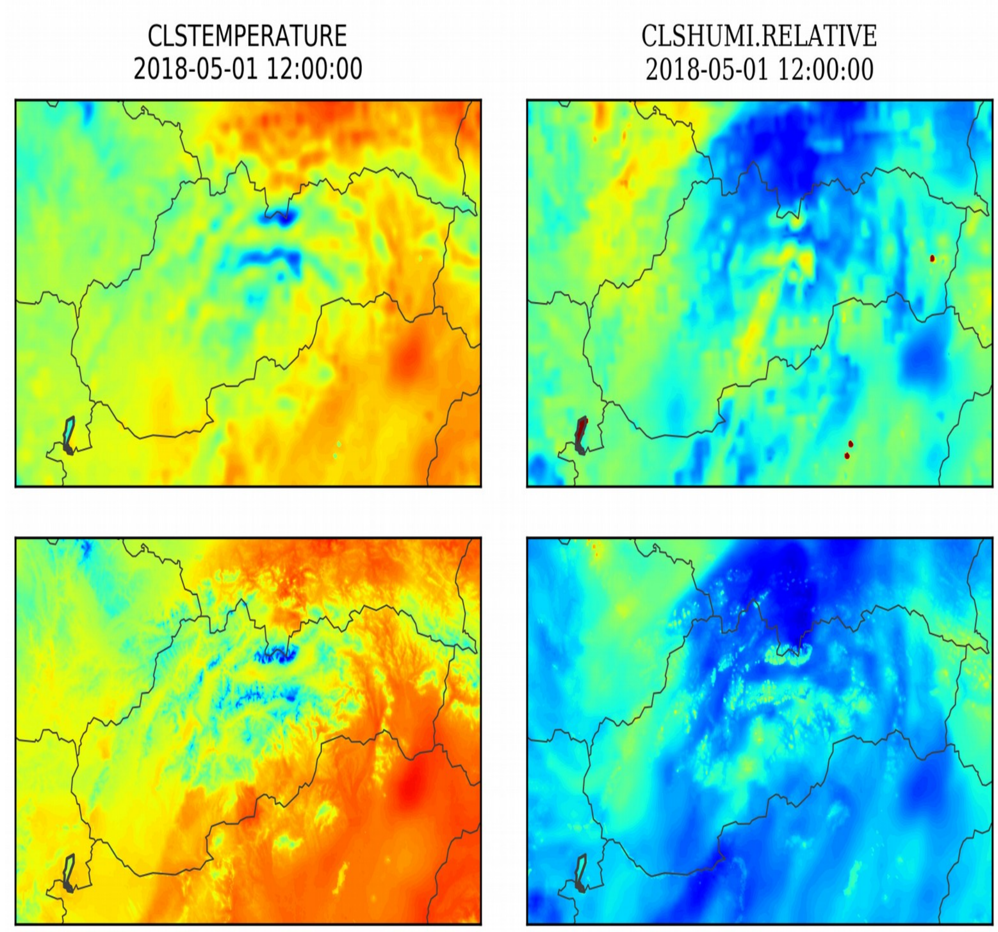
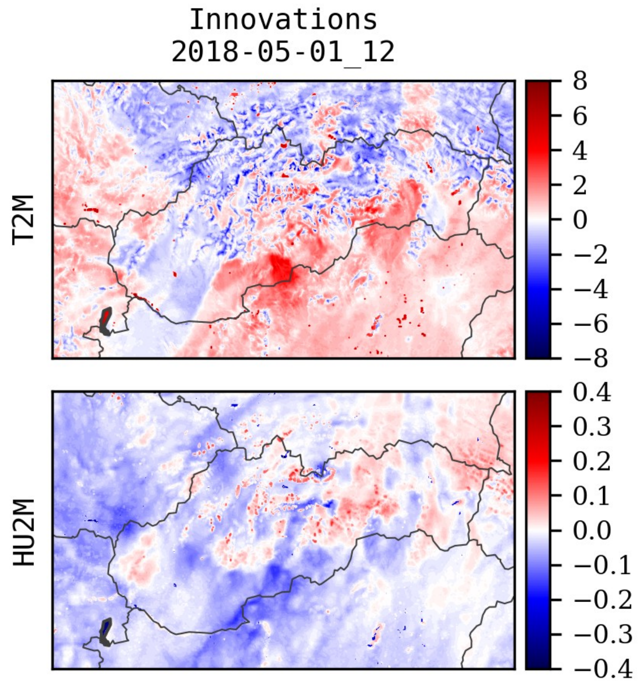


Fig: Downscaled CANARI (top) vs INCA-SK (bottom) analysis of T2M and RH2M used in SODA-EKF

SODA-EKF soil analysis pilot experiment (ViTa)

- Analysis increments for soil water content (WG2, WG1) and soil temperature (TG2, TG1) – shown in figure on the right
- Observation innovations for T2M, HU2M – shown in figure on the left
- Analysis calculated over INCA-SK spatial domain (501 x 301 @ 1 km)
- Surface scheme: ISBA 3-L (force-restore) without CANOPY model
- 4 control variables used: WG2, WG1, TG2, TG1
- 2 observation types used: – T2M, HU2M
- Vertical interpolation scheme: N2M=2 (Geleyn)
- Perturbations amplitude and variances: default values used
- Time interval for Jacobians calculation: 6 hours immediately before analysis time (here 2018-05-01 12:00)
- Background covariance treatment: For the moment LBEV=F, LBFIXED=T
    - B matrix is fixed, i.e. at each cycle B is reset to prescribed value
- SODA crashed when file format was set to FA, with LFI format there was no problem
- SURFEX and SODA executables: from cy40t1_bf06 pack



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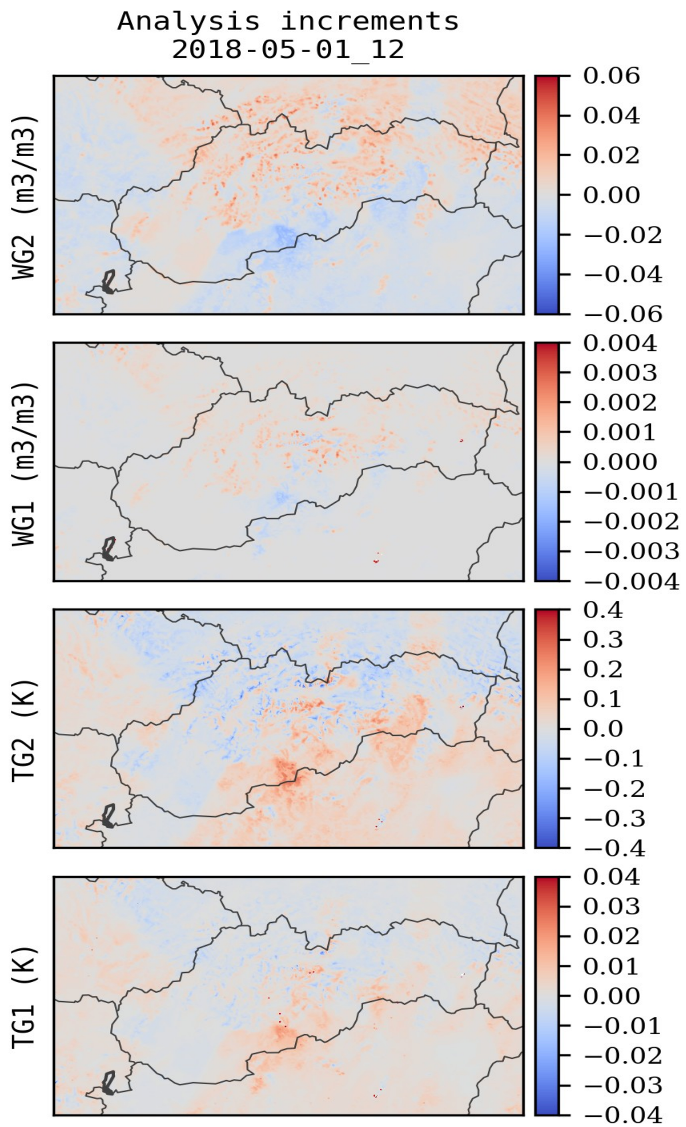


Use of observations in surface DA

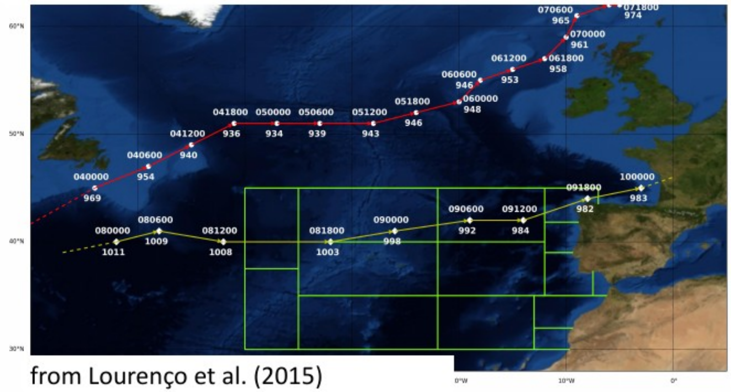
- SU2.2: Currently in the operational applications only T2m and RH2m are assimilated. Nevertheless quite some efforts are being made to assimilated satellite derived surface variables (e.g. the leaf-area index and surface soil moisture estimates). These activities mostly take place in Météo-France (see e.g. Albergel, C., et al. 2017), IPMA and ZAMG.

Assimilating wind from ASCAT

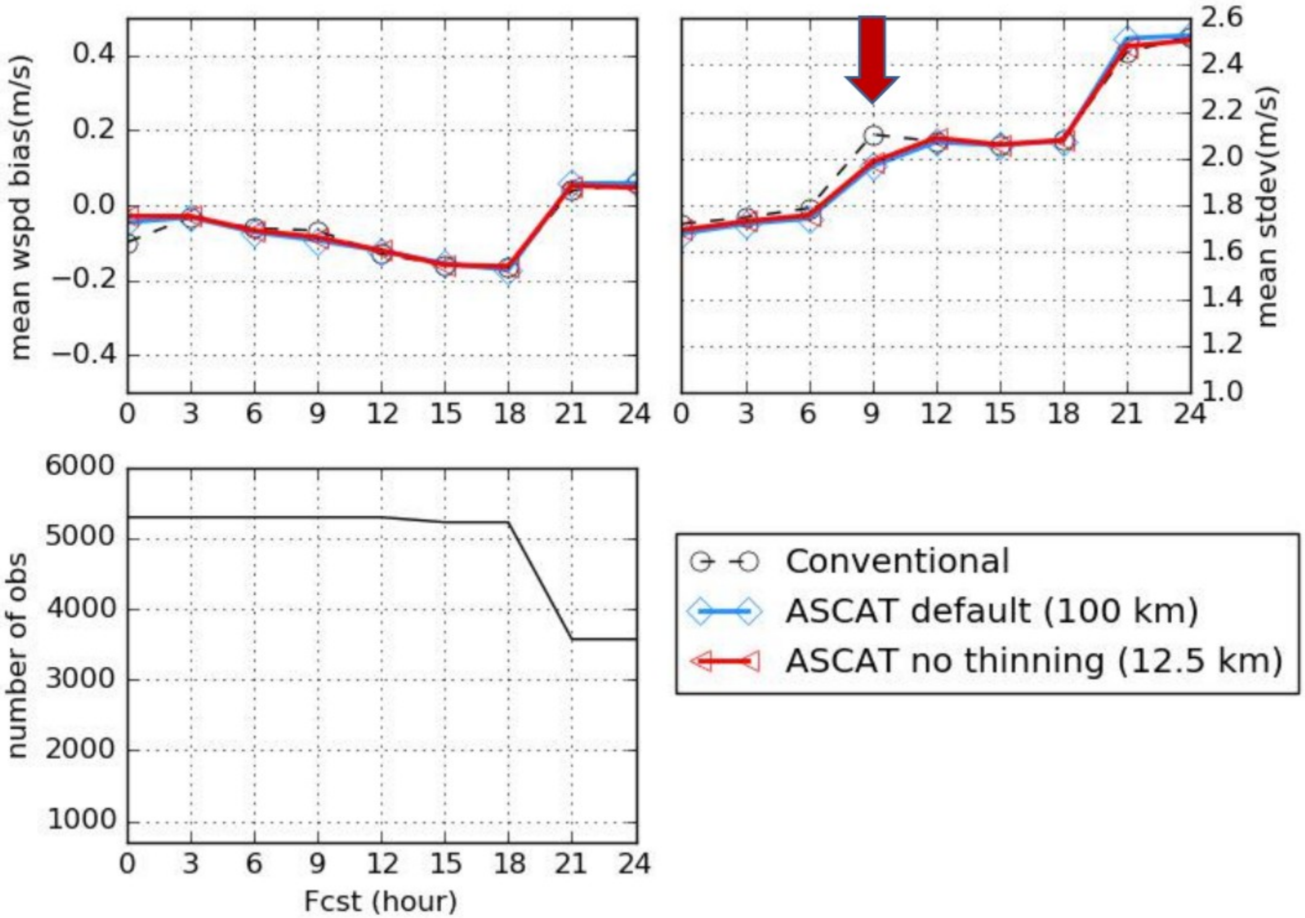
Impact on forecasts over the ocean

10 m wind spd verified against **HSCAT+OSCAT**

Experimentation period 6 to 11 Feb 2014 period during stormy 2013-2014 winter. Including "**Stephanie storm**" (9-10 Feb).



from Lourenço et al. (2015)

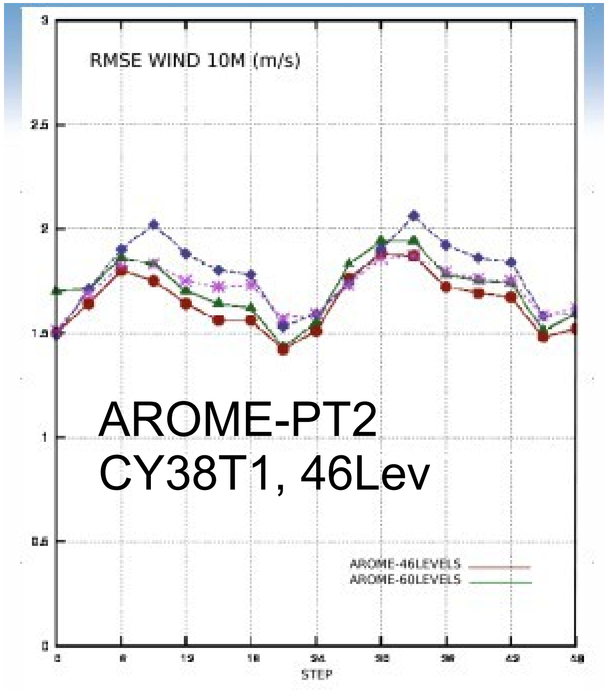


Courtesy, Isabel Monteiro

SURFEX: Validation of existing options for NWP

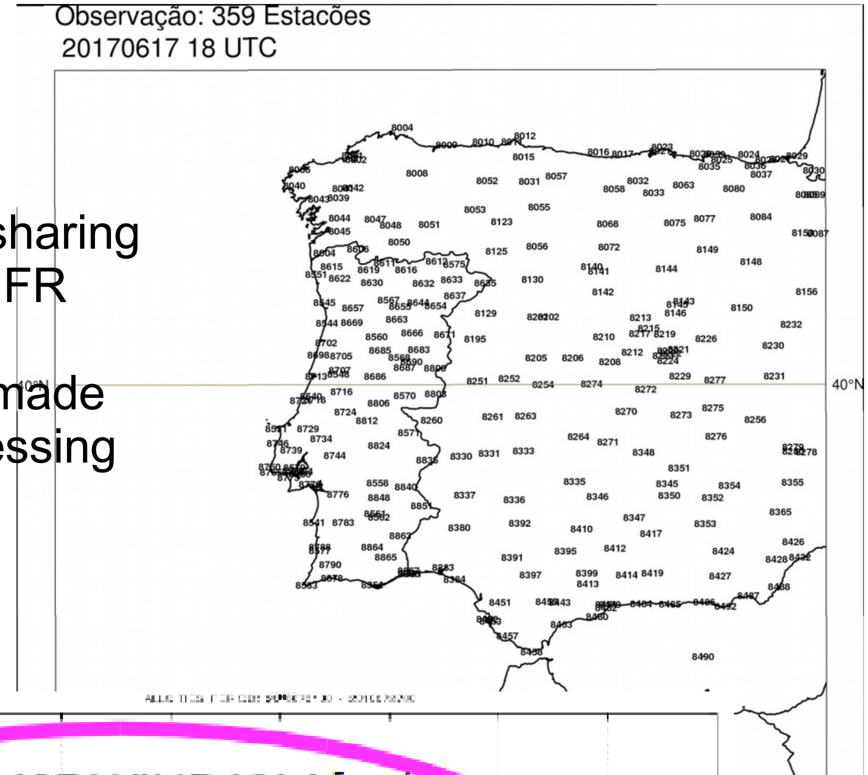
- SU3.1 The performance of the snow model Crocus (offline SURFEX) was evaluated by ARSO (Slovenia) over the winter 2016/2017. This included two versions of Crocus, one coupled to ALADIN forecast an another with INCA analysis. In both cases snow analysis and forecast was produced for each grid point o those models. Results are generally encouraging. The model will be used primarily as a snow product for hydrology and as a tool in snow avalanche risk diagnosis and forecasting, but could be later also used as snow analysis for ALADIN.
- SU3.6 Test of FLake in the Hungarian AROME-

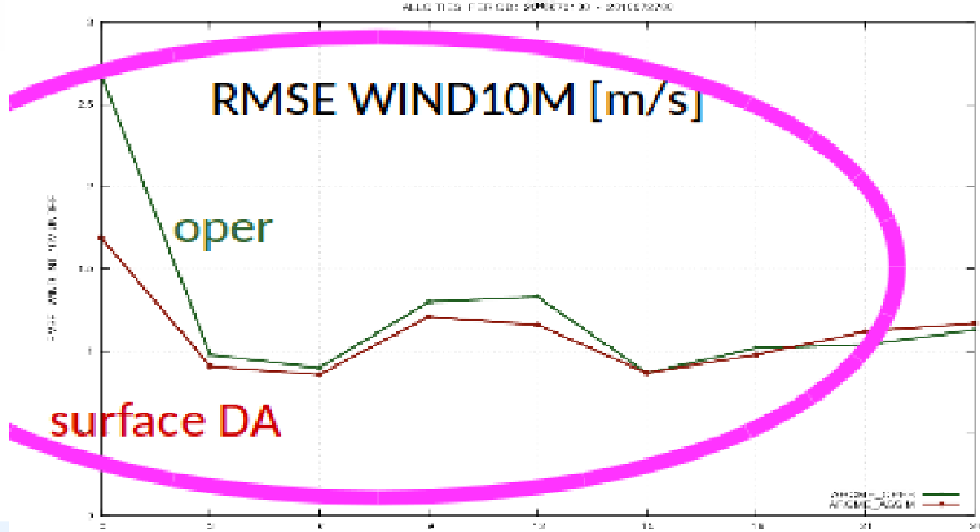
6-hour surface DA with Iberian conventional data (2016-2017)



> 6-hour regional sharing WMO BUFR SYNOP

> Home-made pre-processing





3-hour surface DA with Iberian conventional data (2016-2017)

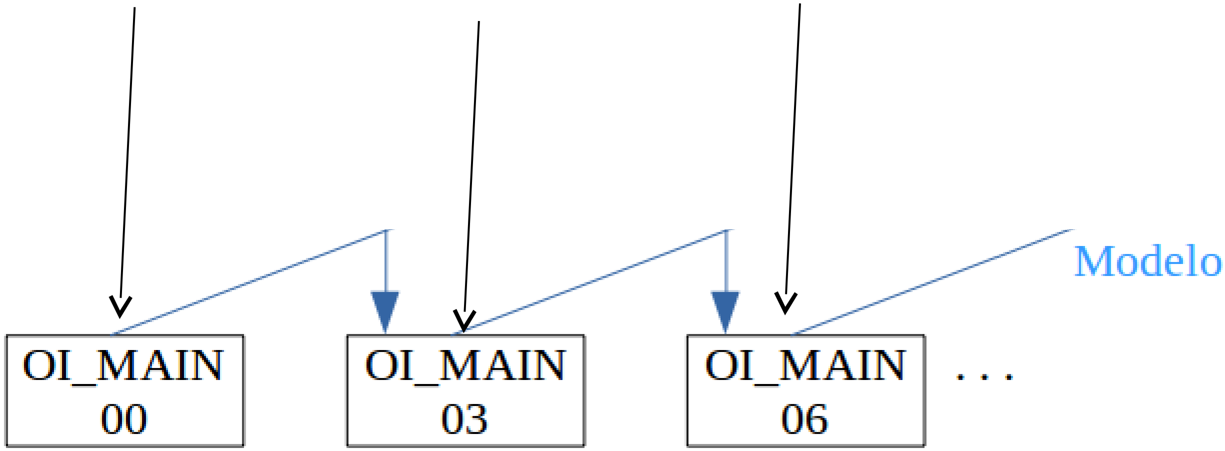
2018 upgrade

AROME-PT2 (CY38T1, 46Lev.)
> 3-hour regional sharing WMO BUFR SYNOP

> home-made pre-processing

> SST update each 6-hour cycle

Surface observation: T2m + HR2m



1-hour surface DA with Iberian conventional data (2016-2017)

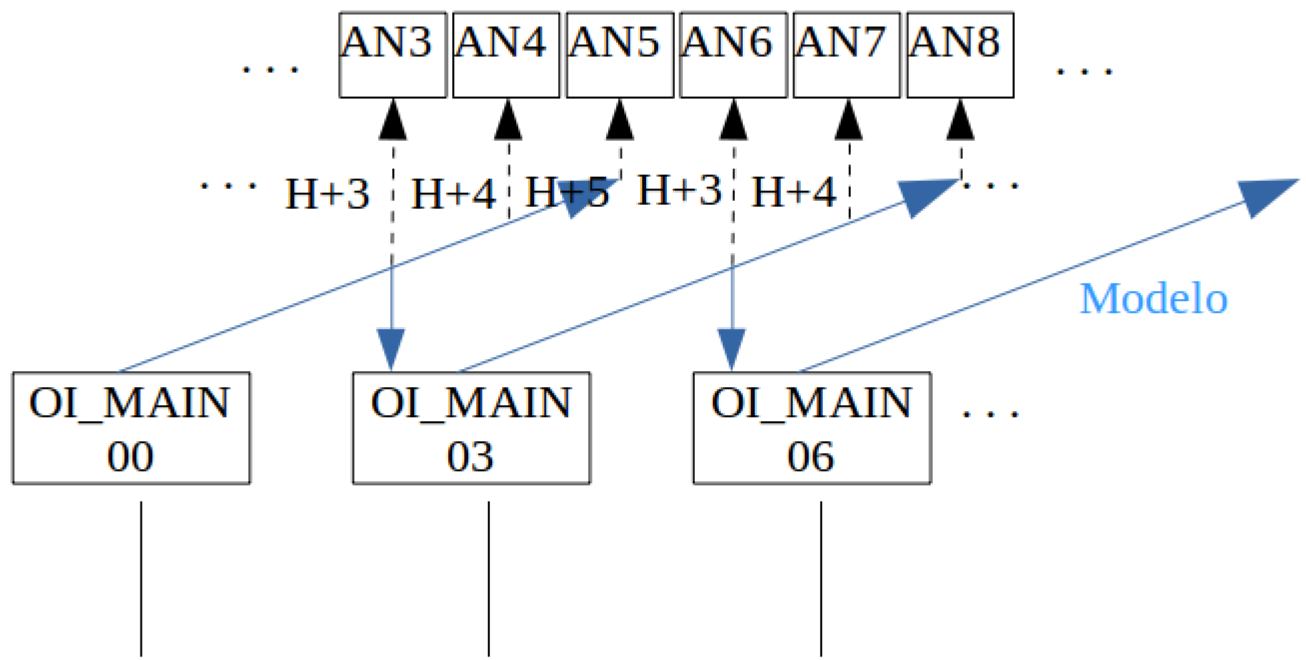
AROME-PT2 (CY38T1, 46Lev.)

> 1-hour regional sharing WMO BUFR SYNOP

> home-made pre-processing (emoslib, ECMWF):
. retards & ammends,
. duplicates,
. choose WMO IDs overlaps between Portugal and Spain (922, 912, 927, 960 at least)
. Rem. obs records with ambiguos metadata.

Hourly analysis by OI (CANARI standalone, Taillefeur, 2000)

Surface observation: T2m + HR2m + V10m



Surface observation: T2m + HR2m

1-hour surface DA with Iberian conventional data (2016-2017)

Hourly CANARI-AROME validation (00UTC *network*):
Summer (20170801 – 20170815)
Winter (20170110 - 20170207)
Table - RMSE and BIAS of screen level parameters analysis over Mainland for Portugal CAN-ARO and
CAN-ALA *vs*. ARO-OP initial fields

	T2M		H2M		V10M	
EXP	RMSE (C)	BIAS (C)	RMSE (%)	BIAS (%)	RMSE (m/s)	BIAS (m/s)
CAN-ARO(Summer)	1.52	0.18	8.86	-0.70	1.37	0.18
CAN-ARO(Winter)	1.63	-0.01	8.58	-1.36	1.35	0.03
CAN-ALA(Summer)	1.78	0.43	10.95	-0.76	2.18	0.92
CAN-ALA(Winter)	1.85	-0.09	10.66	-0.72	2.25	0.82
ARO-OP (Summer)	2.07	0.90	11.79	-4.69	2.50	1.63
ARO-OP (Winter)	2.06	0.27	12.69	-5.26	2.16	1.24

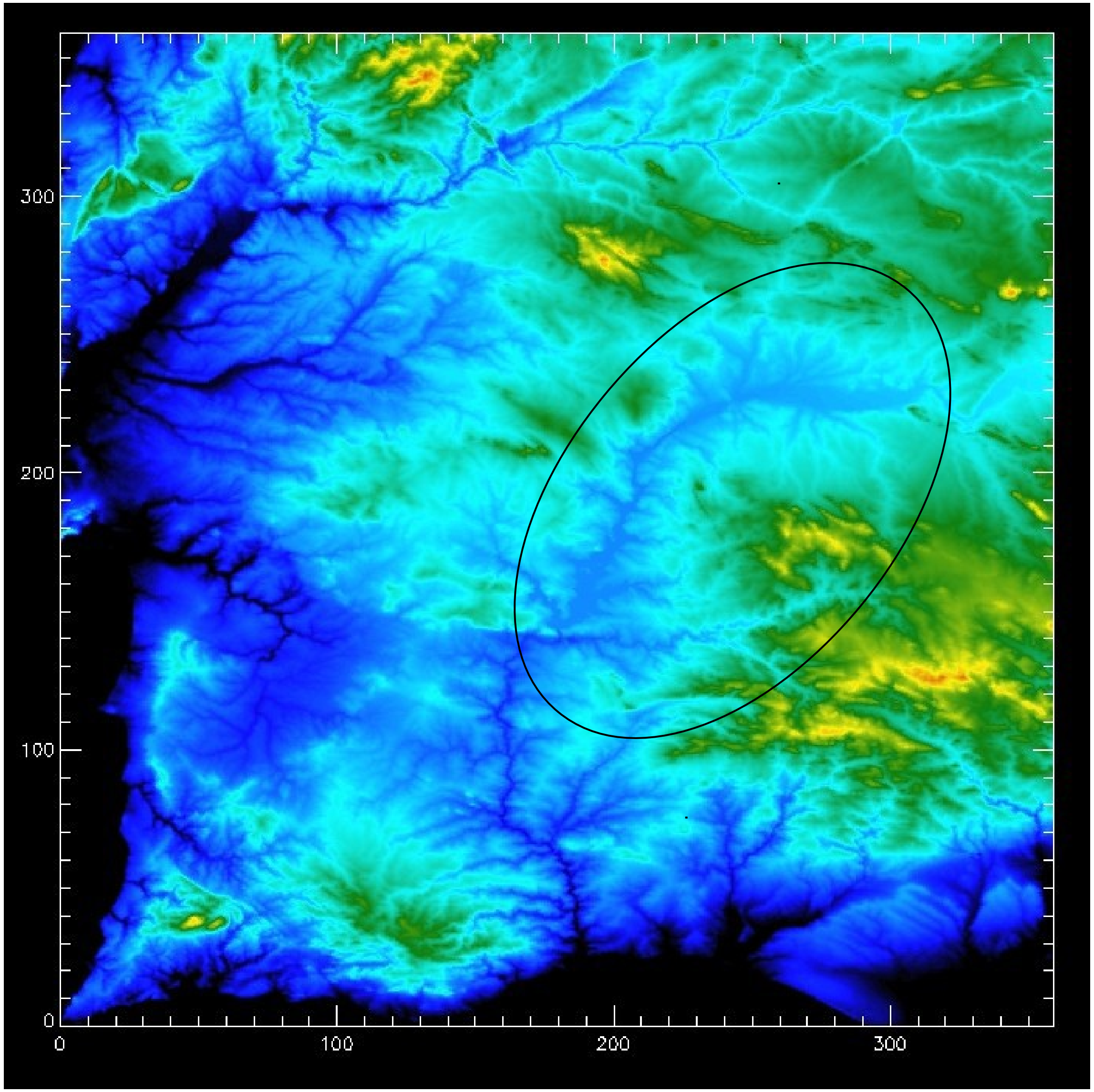
. CAN-ARO is closer to observations than any other product at 00UTC and 12UTC;

. daily analysis monitoring shows the results are consistent at any hour of the day.

Assess/improve quality of surface characterization

- SU5.5: In 2017 the new version of ECOCLIMAP database, called ECOCLIMAP Second Generation, has been realized. It is a global data set at 300m-resolution, with LATLON geographic projection. 1 pixel corresponds 1 type (surface type or vegetation type). It is based on ESA-CCI Land Cover version 1.6.1 (2016), epoch 2008-2012, satellites MERIS FR && RR et SPOT/VGT. Some first tests have been performed in AROME-France for 2 months in 2016 showing encouraging improvements but more tests are needed to understand the sensitivities (to tree heights and roughness lengths).

Implementing Alqueva Lake physiography



Assuncao, S. et al. (2017) IMPACT OF THE INTRODUCTION OF ALBUFEIRA ALQUEVA IN AROME FORECASTING MODEL, APMG

. Alqueva is the largest artificial Lake in Europe
. The Lake physiography was implemented in AROME-PT2 surface representation through an upgrade on:
ECOCLIMAP_II_v2.3
GMTED2010_30

Case-studies:
. Alqueva Lake-breeze
. Advected low cloudiness over the Lake

There is a positive impact when introducing the Alqueva Lake physiography, on the forecasts of temperature, relative humidity, wind and cloudiness !