Review of surface modeling and data assimilation in ALADIN

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

Outline of this talk
cfr. HIRLAM-ALADIN Rolling Work Plan

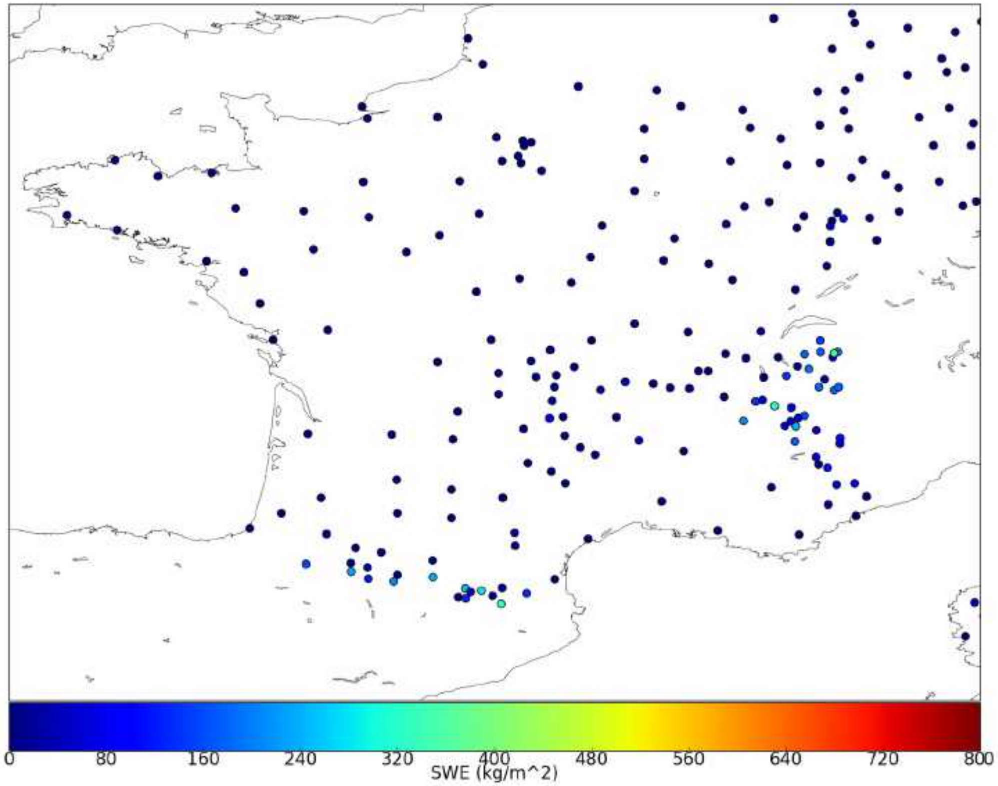
- Algorithms for surface assimilation (SU1)
- Use of observations in surface assimilation (SU2)
- SURFEX: validation of existing options for NWP (SU3)
- SURFEX: development of model components (SU4)
  see http://www.umr-cnrm.fr/aladin/IMG/pdf/lemoigne_asm_tls.pdf
- Assess/improve quality of surface characterization (SU5)
- Coupling with sea surface/ocean (SU6) (work by ARSO, mentioned by Martina on Monday)

Algorithms for surface assimilation

- tests 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.
- At IPMA (Portugal) local progress in data assimilation: the AROME surface data assimilation cycling by the formalism OI_MAIN locally implemented according to a more recent description in Monteiro et al. (2017) was validated for the Iberian domain with a clear positive impact on the screen level parameters forecasts up to a 24-hour range; these short-range forecasts are now feeding an operational hourly CANARI surface analysis. The verification showed a positive impact for T2m and RH2m.
- Validation of EKF surface assimilation with SYNOP observations using force-restore method (SHMU)
- Using the ARPEGE EDA for diagnostics for surface analysis (MF)

Snow analysis

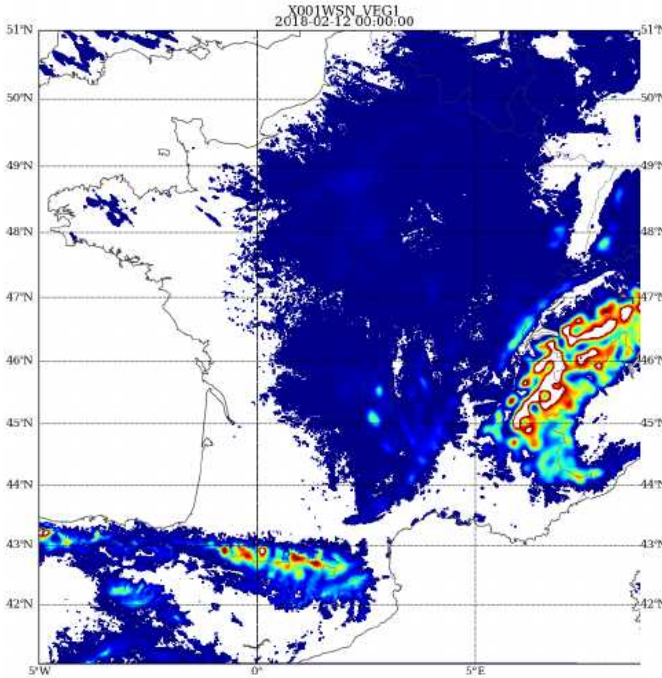
- Snow analysis over plains: necessary to correct for insufficient snow melt in the model
  - Case study February 2018



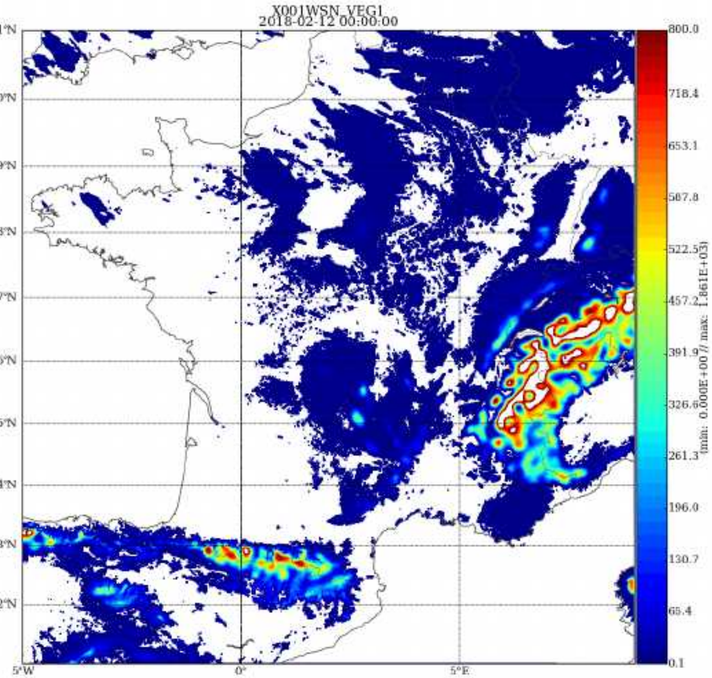
Snow observations over the AROME-France domain

- More observations extracted over France
- Snow analysis performed in Canari routines (casnas)
- Tranfer of snow increments into Surfex

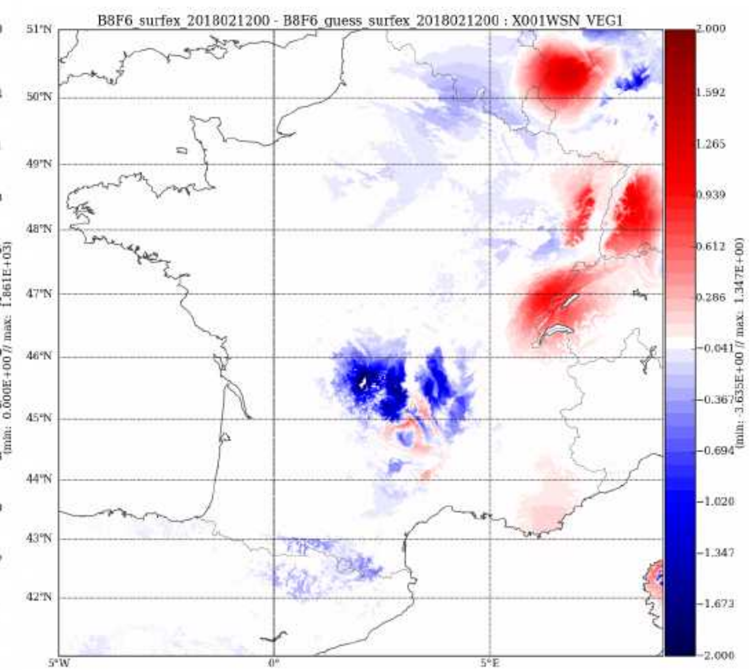
- Case study on 12 February 2018, 00:00



Snow cover over the Arome-France domain without snow analysis



Snow cover over the Arome-France domain with snow analysis



Analysis increments

- Slight improvement in near surface agreement between model and observations

- Future plans for snow analysis:
  - Adjust observation and background errors and structure functions
  - Use Surfex snow density
  - Use satellite products of snow cover
  - Activate snow analysis in ARPEGE

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.

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

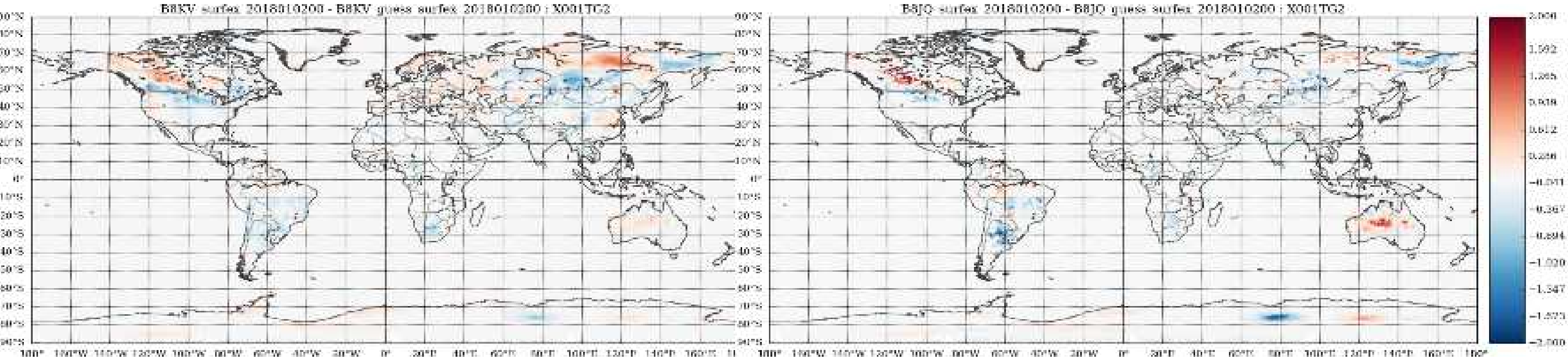
Diagnostics using ARPEGE EDA for surface analysis

- 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)

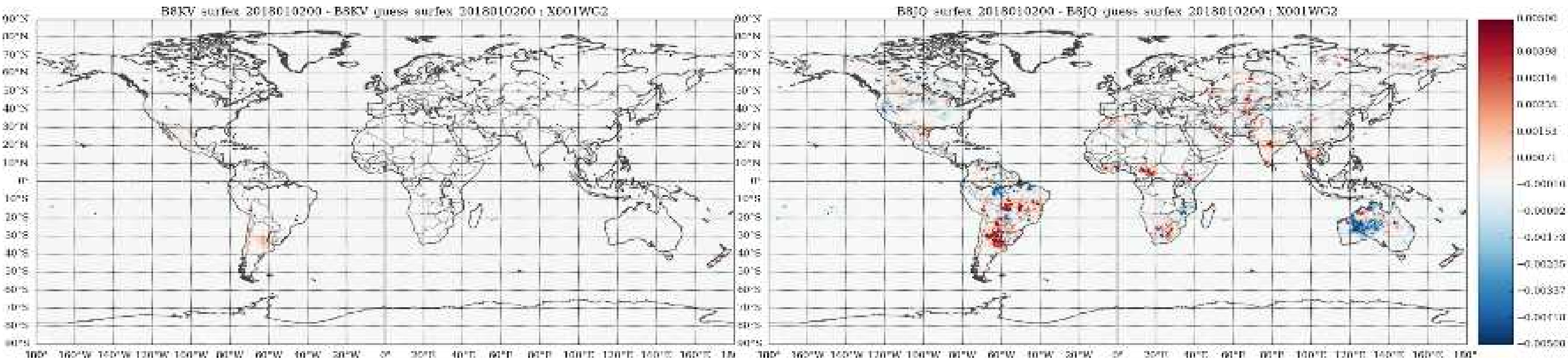
OI increments

TG2

EDA increments



WG2

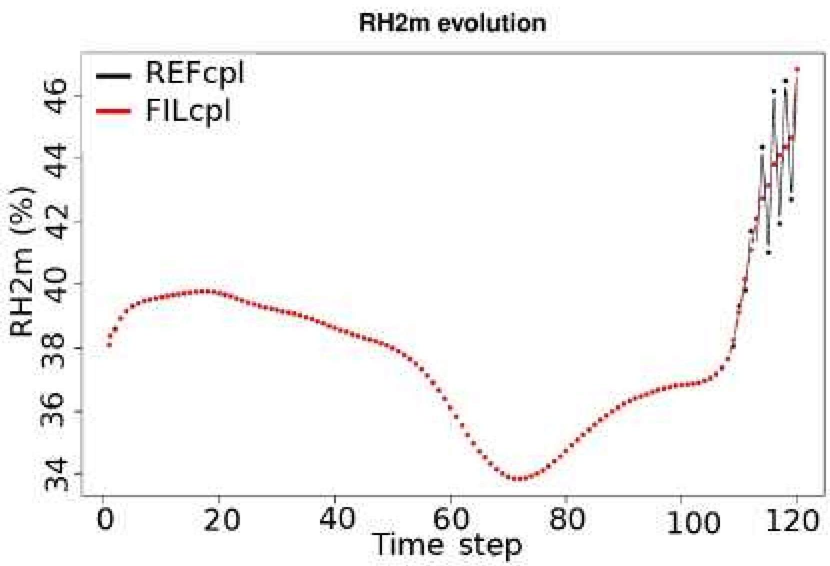


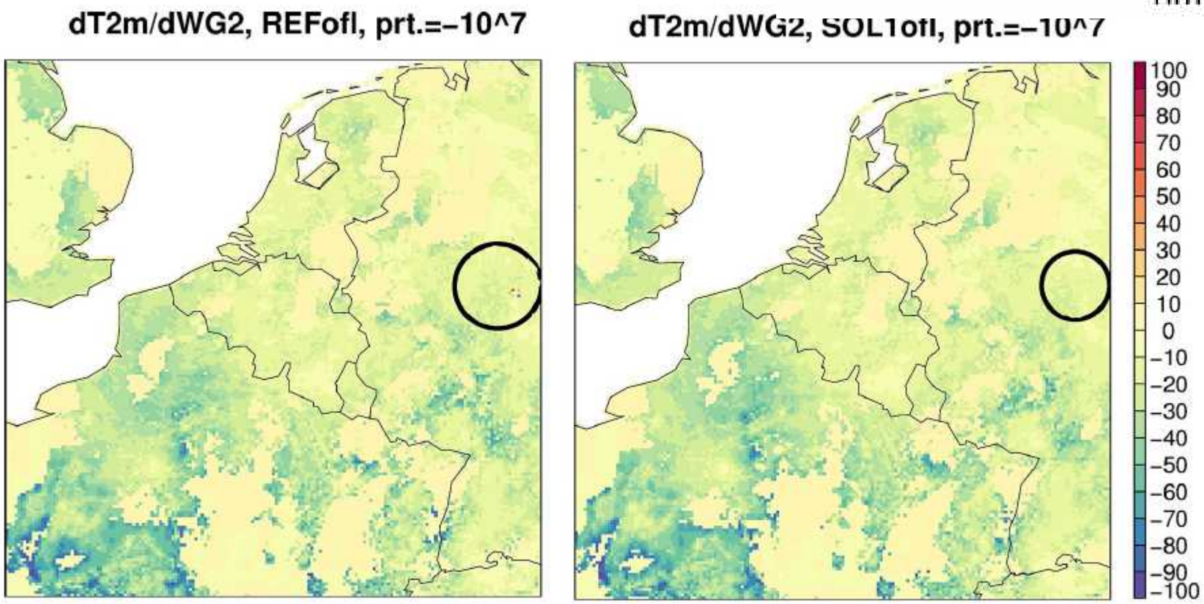
Extended Kalman Filter (Annelies Duerinckx)

$$\mathbf{x}_a^t = \mathbf{x}_b^t + \mathbf{B}\mathbf{H}^T(\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R})^{-1}[\mathbf{y}_o^t - \mathcal{H}(\mathbf{x}_b^{t_0})]$$

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

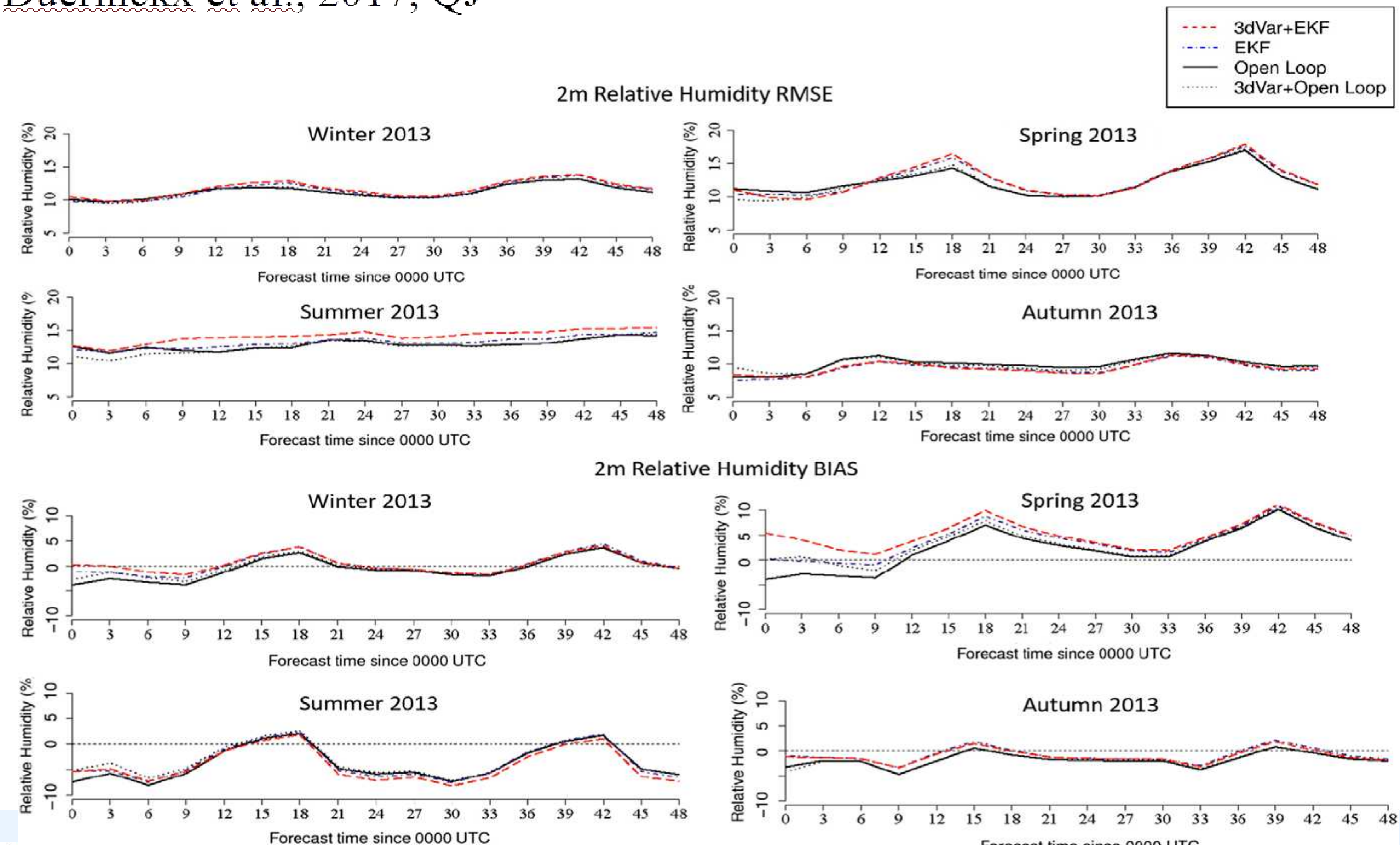
$$x_{\text{filtered}} = 0.5 \times w \times x_{t-1} + (1-w)x_t + 0.5 \times w \times x_{t+1}$$





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

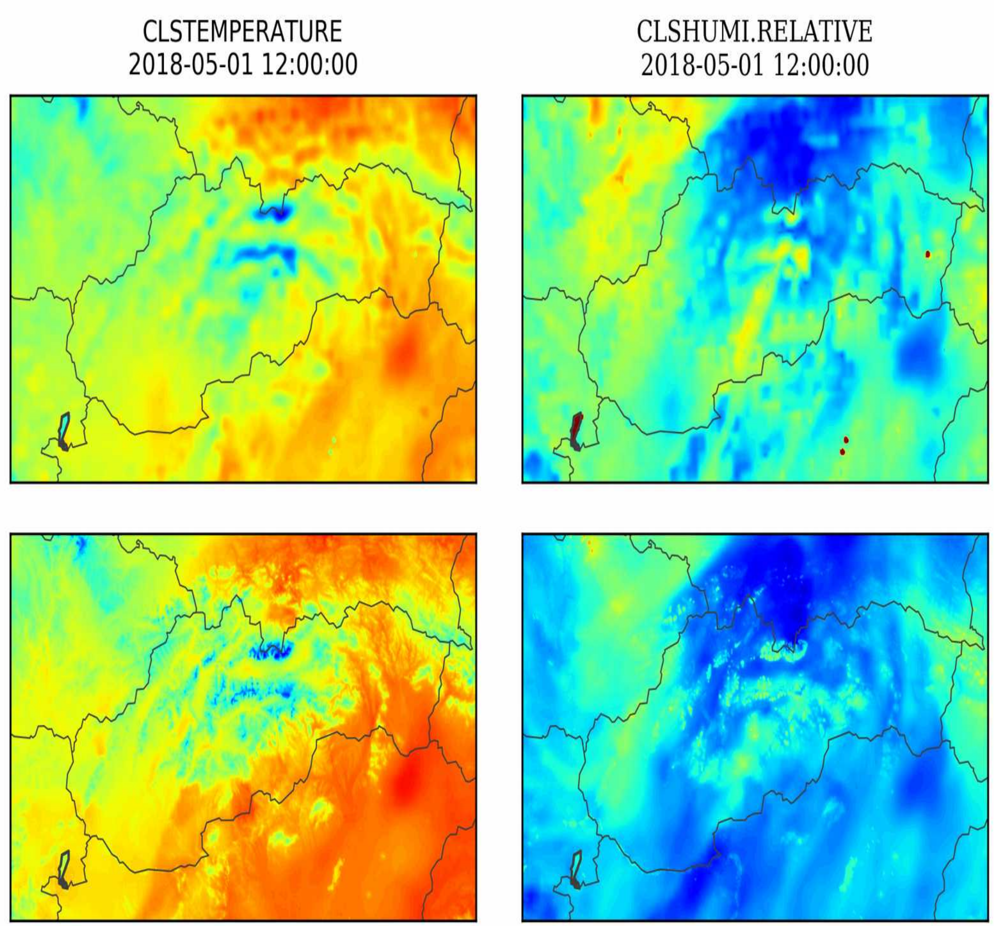
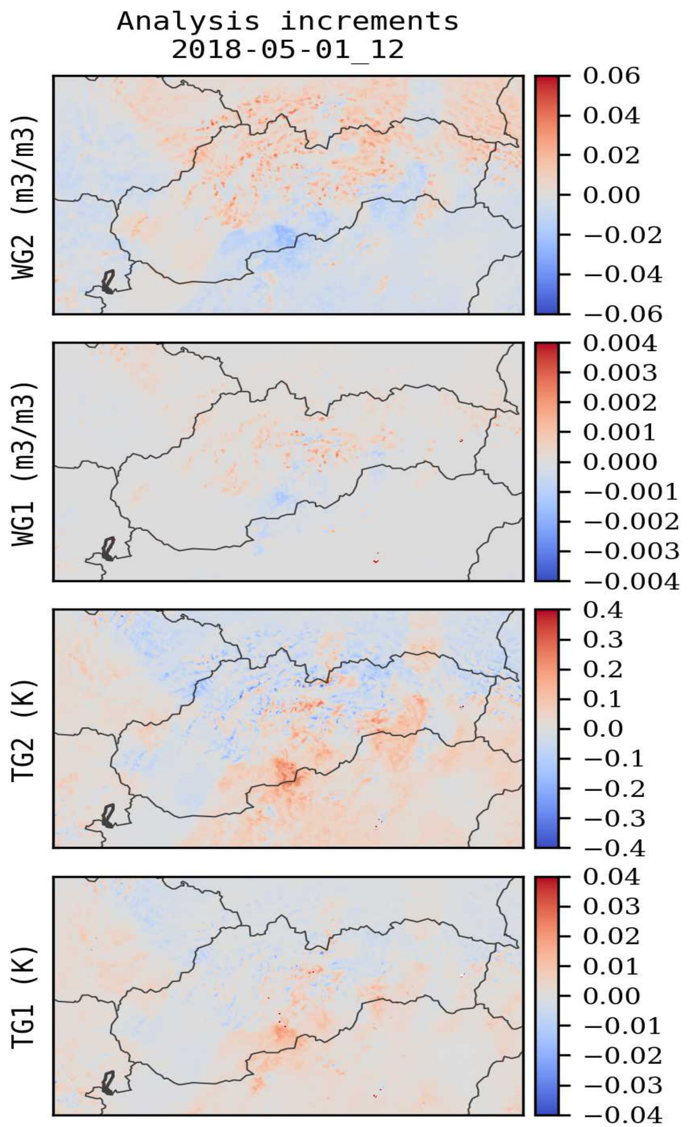


Fig: Downscaled CANARI (top) vs INCA-SK (bottom) analysis of T2M and RH2M used in SODA-EKF

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
- SURFEX and SODA executables: from cy40t1_bf06 pack



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.

Data Assimilation: LDAS system

Open-loop & Analysis experiments over 2000-2012
Spin-up (20 times 1990 + 1990-1999)

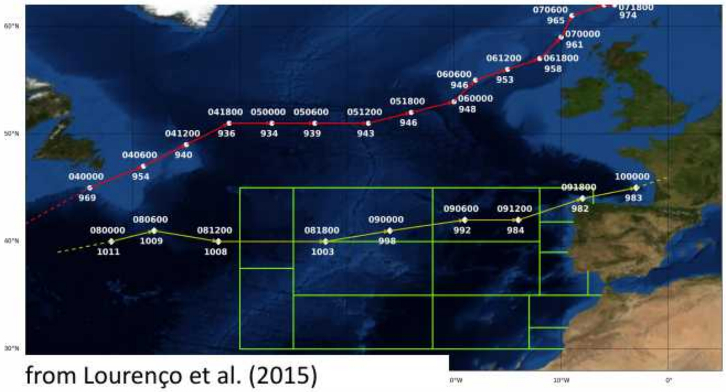
Model	Domaine	Atm. Forcing	DA Method	Assimilated Obs.	Observation Operator	Control Variables	Additional Option
ISBA-DF CO_2-responsive version (Interactive veg.)	Europe and the Mediterranean basin (0.5°)	Earth2Observe WRR1 (Schellekens et al., 2017)	SEKF	SSM (ESA-CCI) LAI	Second layer of soil (1-4cm) LAI	Layers of soil 2 to 8 (1-100cm) LAI	Coupling with CTRIP (0.5°)

Assimilating wind from ASCAT

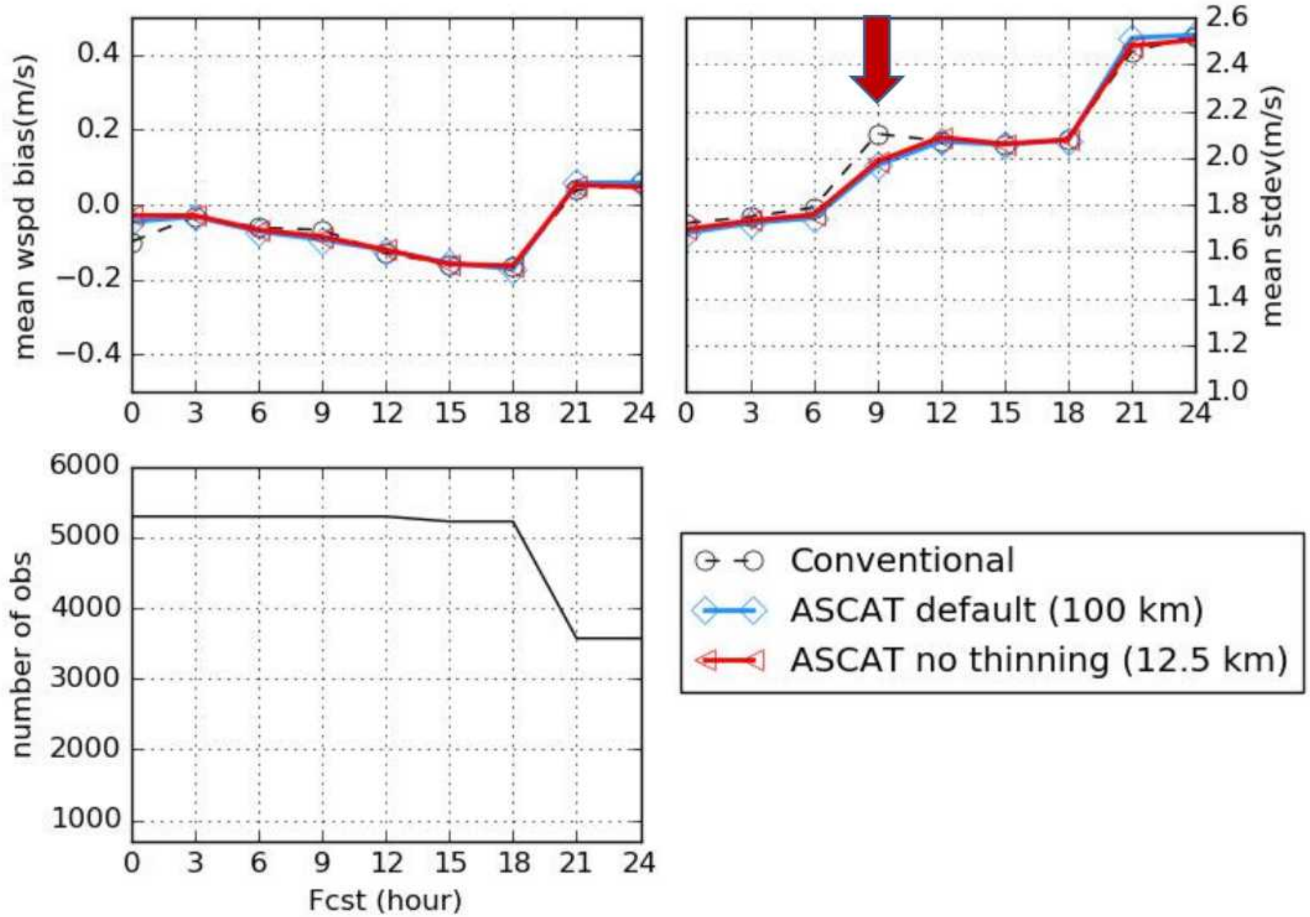
Impact on forecasts over the ocean

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.
- 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.

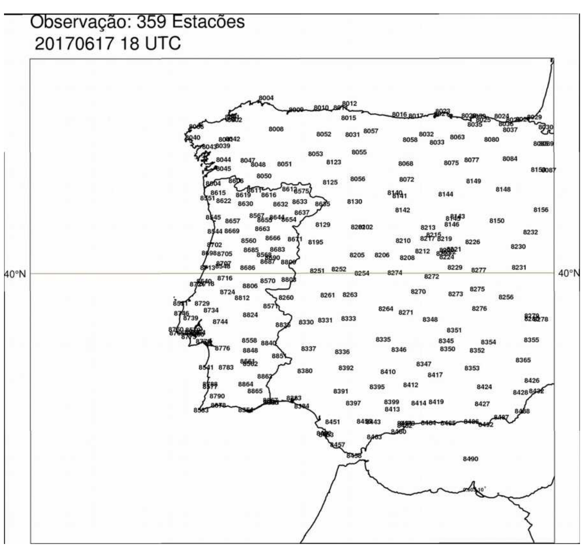
3-hour surface DA with Iberian conventional data (2016-2017)

2018 upgrade

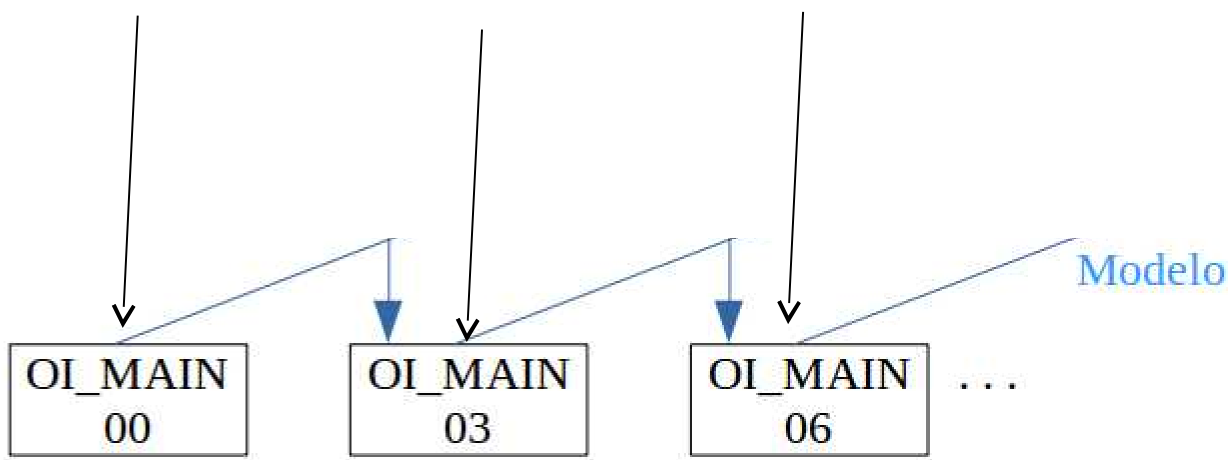
AROME-PT2 (CY38T1, 46Lev.)
> 3-hour regional sharing WMO BUFR SYNOP

> home-made pre-processing

> SST update each 6-hour cycle



Surface observation: T2m + HR2m



1-hour surface DA with Iberian conventional data (2018)

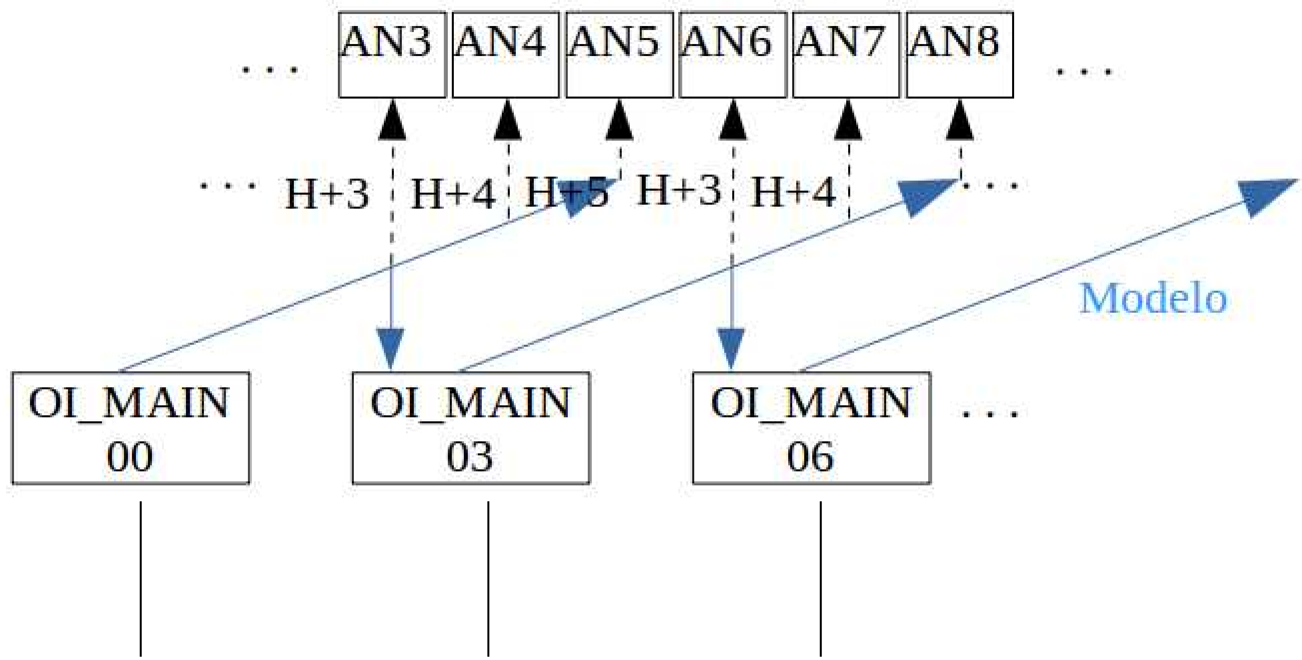
AROME-PT2 (CY38T1, 46Lev.)

> 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)

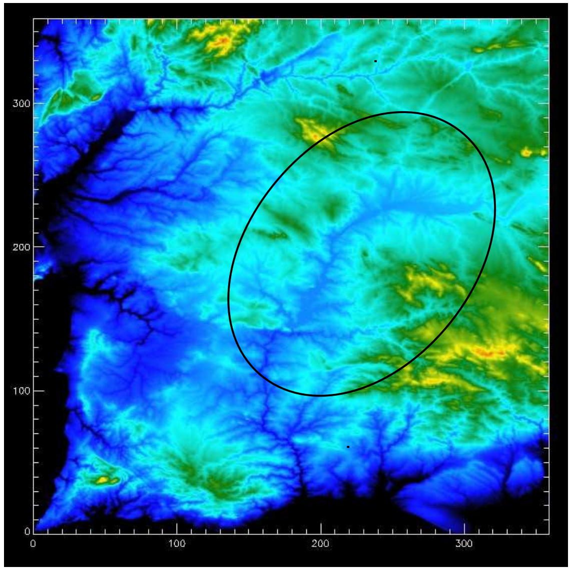
Surface observation: T2m + HR2m + V10m



Surface observation: T2m + HR2m

Assess/improve quality of surface characterization

- SU5.5: In 2017 the new version of ECOCLIMAP database, called ECOCLIMAP Second Generation, has been realized.
  - 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).
- SU5.1: In order to take advantage of the most recent surface knowledge available, the Alqueva physiography was locally introduced and tested in IPMA (Portugal). The version of AROME with ECOCLIMAP_I_GLOBAL_v1.5 provided forecasts closer to the observations. This will be used in operations.



Thank you for your attention