Meteo-France operational land surface analysis for NWP: current status and perspectives

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Outline

- The current land surface assimilation system
- Recent developments for T2m analysis
  - Use of T2M_ISBA
  - Activation of MESCAN structure functions
- Ongoing work on snow analysis
- Future plans for the assimilation system over land and preliminary steps towards coupled assimilation
  - Towards the assimilation of retrieved Ts from satellite observations
  - Diagnostics using ARPEGE EDA for surface analysis
- Conclusions

Land surface assimilation system

- Both global model ARPEGE and regional model AROME are now coupled to the surface modelling platform SURFEX to represent the exhanges between the surface and atmosphere.

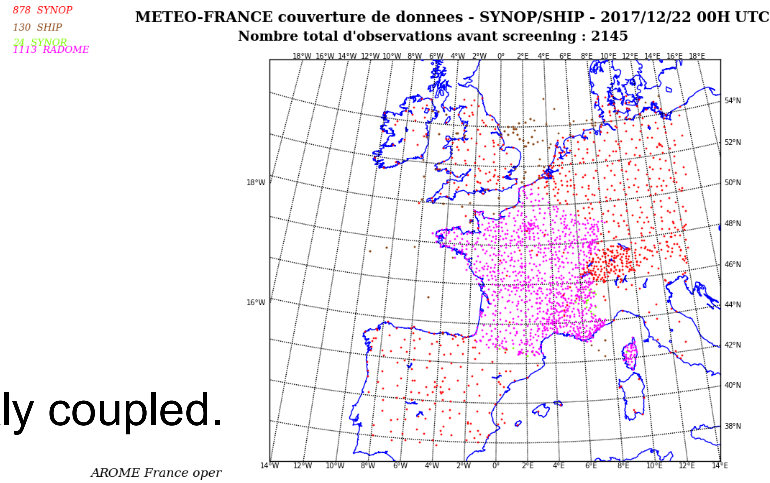
- Each grid point is divided into 4 tiles for nature, sea, lake and town with the same atmospheric forcing, with pronostic variables for each type of cover:

  - Nature: ISBA-3L (3 layers) for NWP (Noilhan and Mahfouf, 1995; Boone et al., 1999), pronostic variables in the two superficial layers (liquid and frozen parts for water, snow water equivalent for snow on the ground) → : T_s, T_2, w_g, w_2.

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

  - Lake

  - Sea → SST



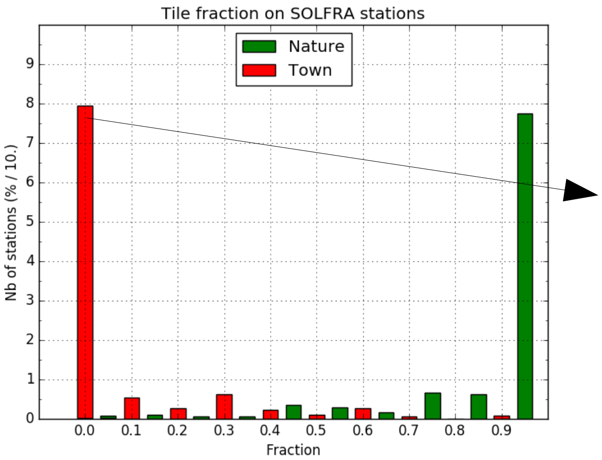
- The surface and atmospheric assimilation are currently weakly coupled.

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

- 1D OI scheme for the soil analysis using the increments of T_{2m} and RH_{2m} (Giard and Bazile, 2000)

T2m analysis: use of T2M_ISBA

- T2M_ISBA instead of T2M_mean for assimilation and scores



20 % of SYNOP+RADOME stations have a town fraction > 0

Positive impact on forecasts for T2m/Hu2m scores:

TEMPERATURE CORRIGEE (K)

(K)

26 simulations de 42h valides du 20170801 au 20170827

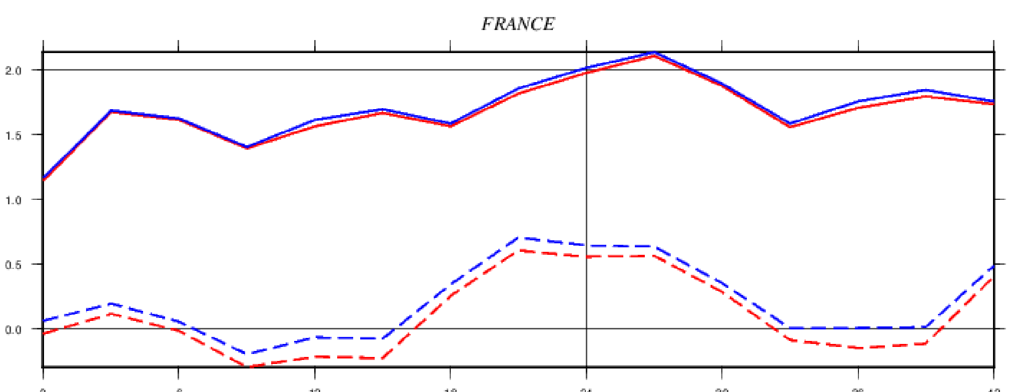
HUMIDITE (%)

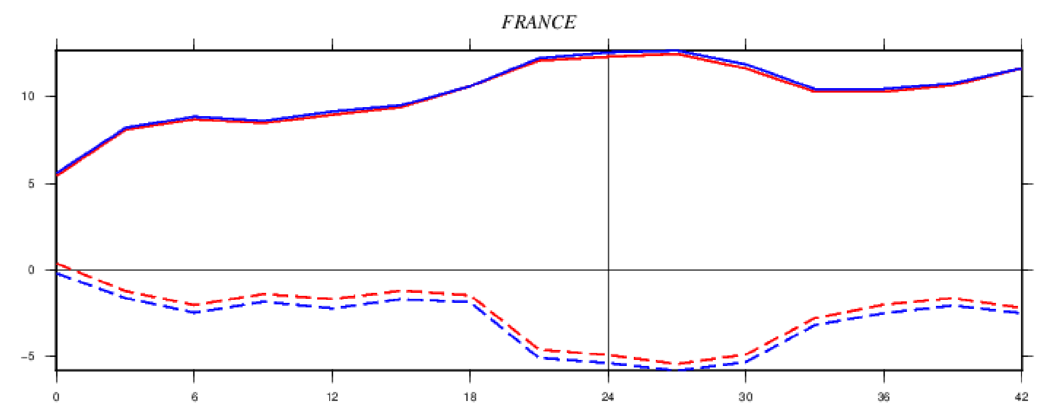
(%)

26 simulations de 42h valides du 20170801 au 20170827

OPER EXP

OPER EXP





(Figures from Y. Seity)

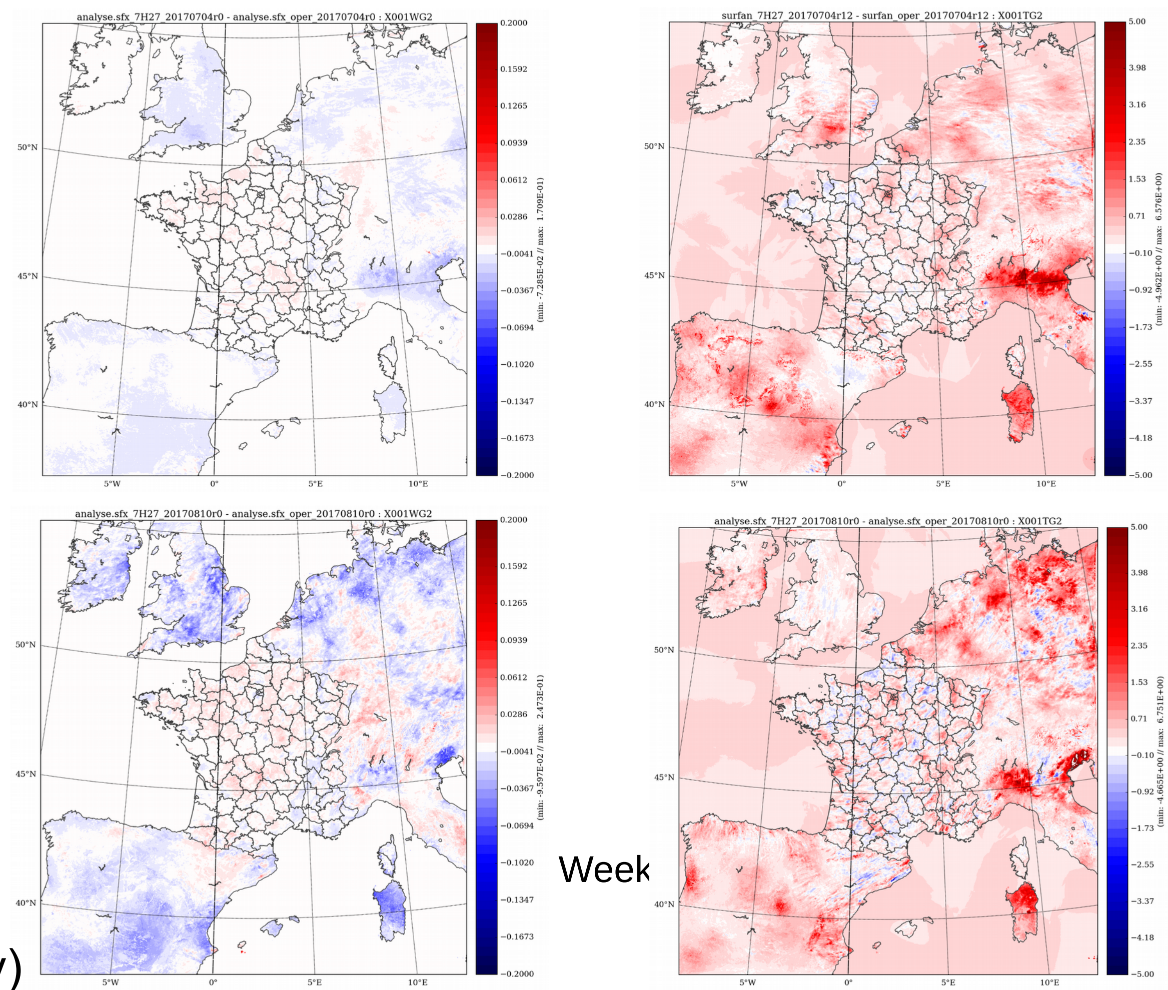
Adjustment of surface assimilation

- EXP: adjustments in surface assimilation + use of T2M_ISBA instead of T2M_mean
- After N days of 3D-Var assimilation cycles (from 20/01/2018), the soil is dryer and warmer (in relation with the overestimation of latent flux observed on various stations)

Soil water content (EXP-oper) | Soil temperature (EXP-oper)

N = 20

N = 57

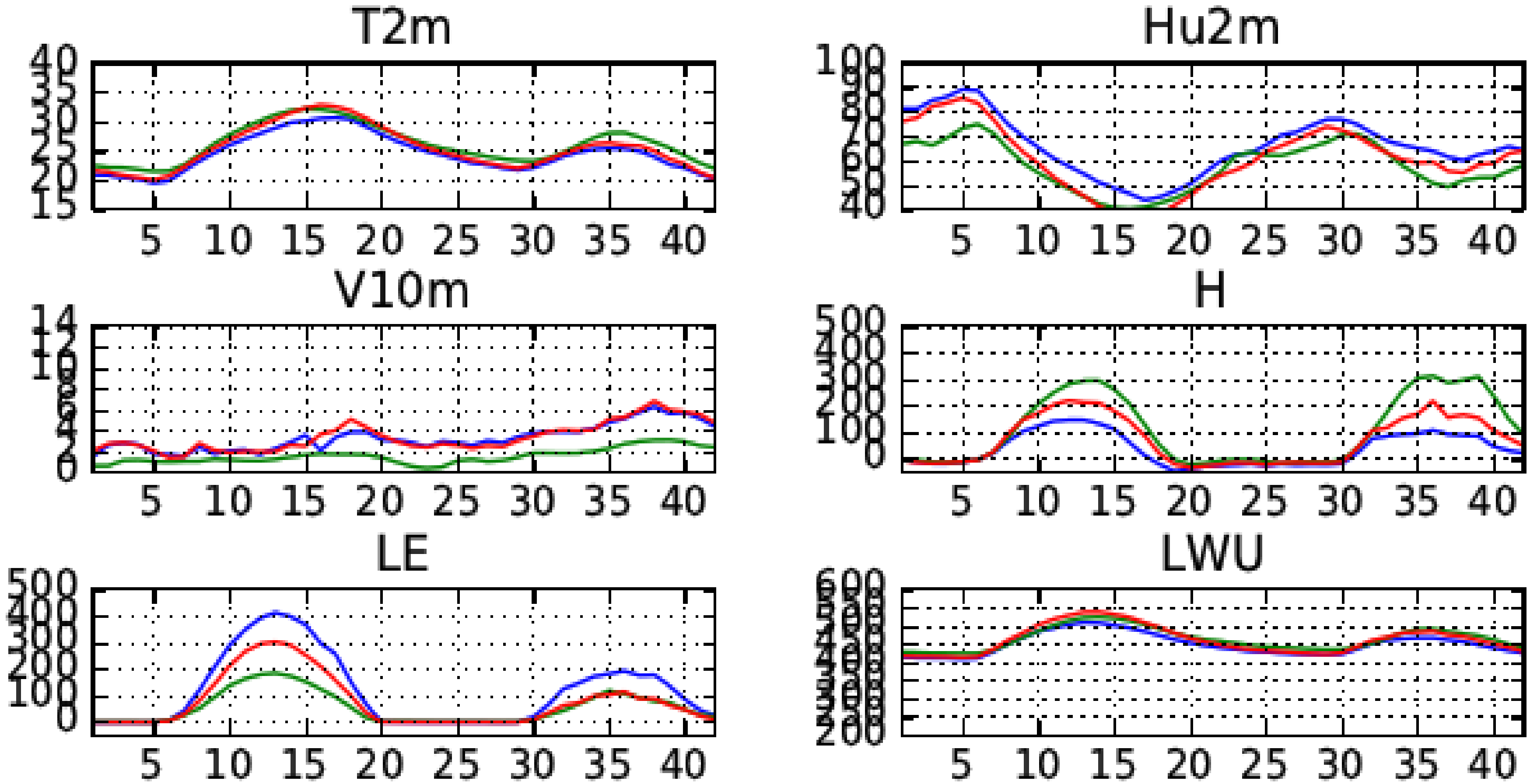


Week

(Figures from Y. Seity)

Adjustment of surface assimilation

- After 51 days, a clear-sky day in Toulouse on 04/08/2017
  ARPEGE / AROME-OPER / EXP
- The experiment corrects half of the error on the latent/sensible fluxes:



(Figures from Y. Seity)

Activation of MESCAN structure functions

1. **MESAN**

$$Corr(r, d_p, d_z) = 0.5\left[e^{-\frac{r}{d}} + \left(1 + \frac{2r}{d}\right)e^{-\frac{2r}{d}}\right] \cdot F_p(d_p)F_z(d_z)$$

where,

- $d = 190km$ is the horizontal scale;
- $F_p(d_p)$, and $F_z(d_z)$ empirical functions for land-fraction and difference of height respectively.

2. **SAFRAN**

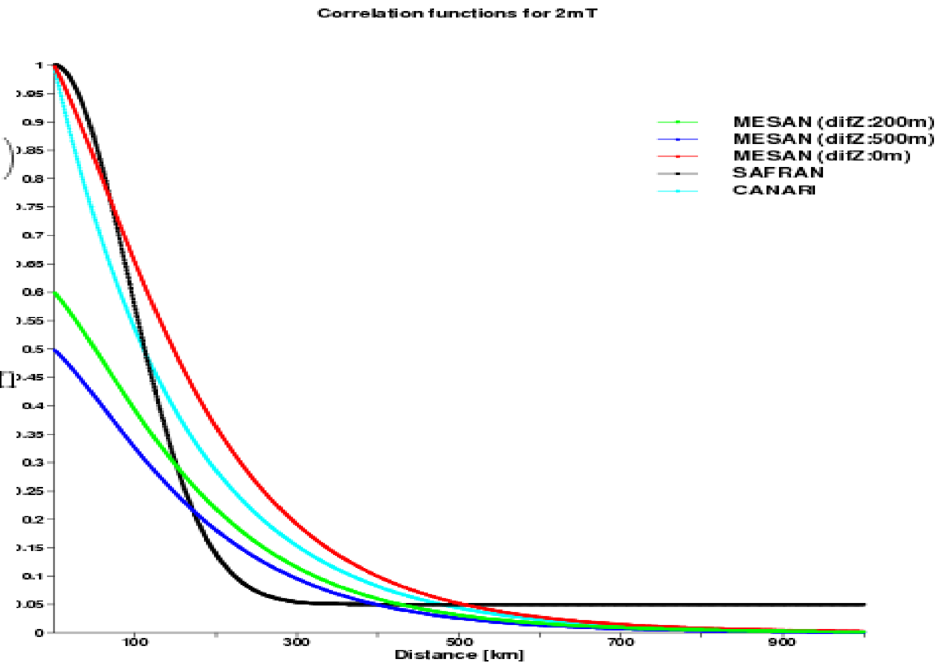
- $Corr(r) = f + (1 - f) \cdot e^{-\frac{r^2}{d^2}}$

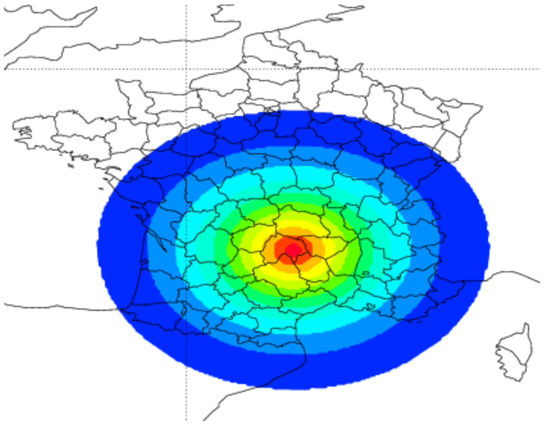
f=0.05 denotes the large scale part of the signal, and d=130km.

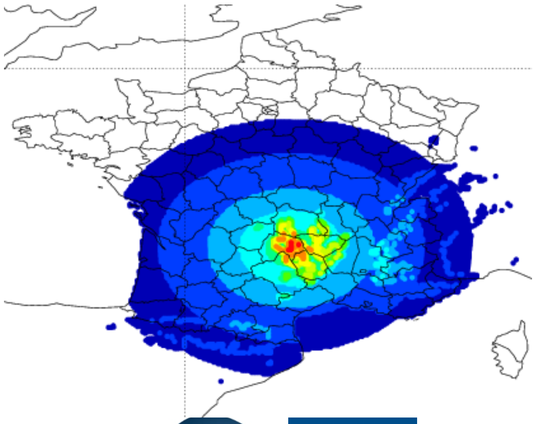
3. **CANARI**

- $Corr(r) = e^{-0.5\frac{r}{d}}$

where, d=80km.

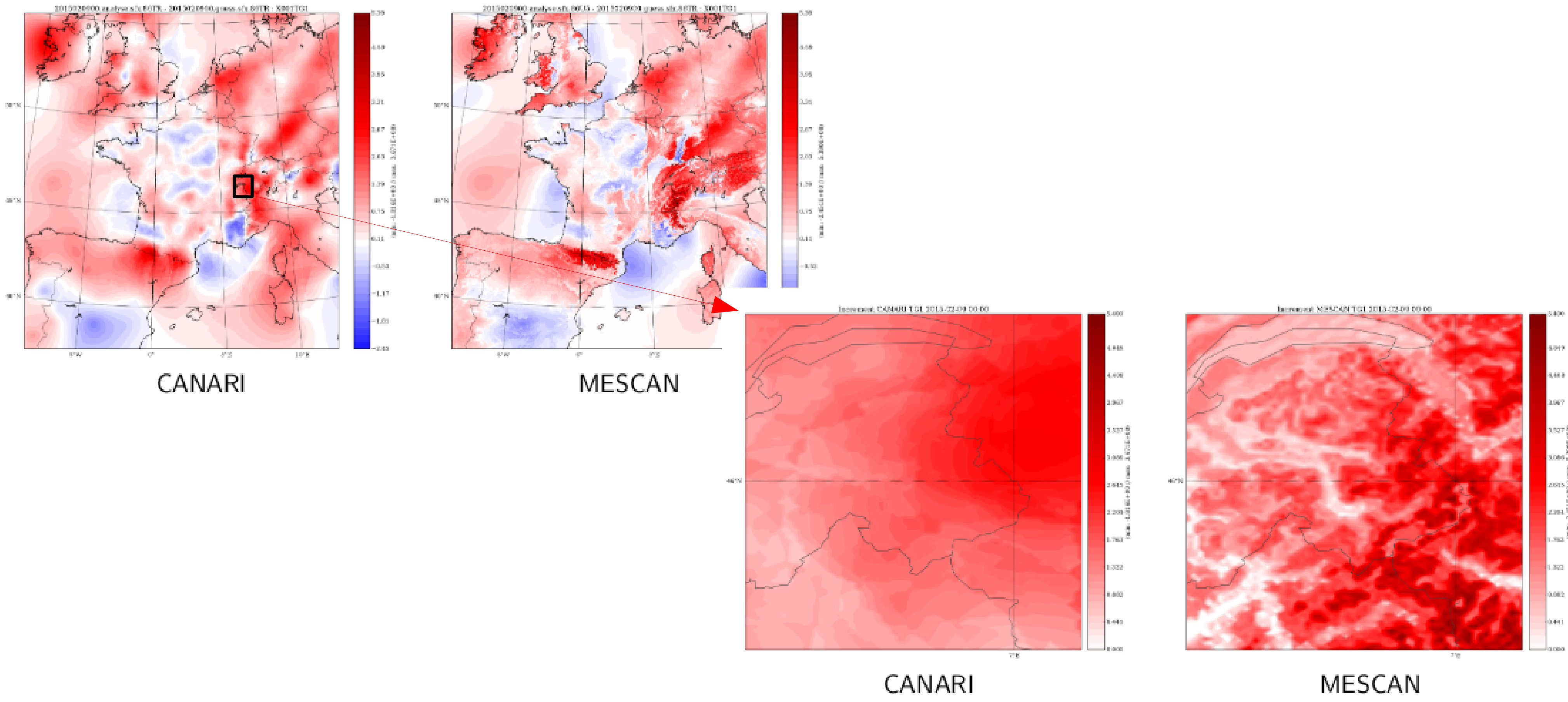






Activation of MESCAN structure functions

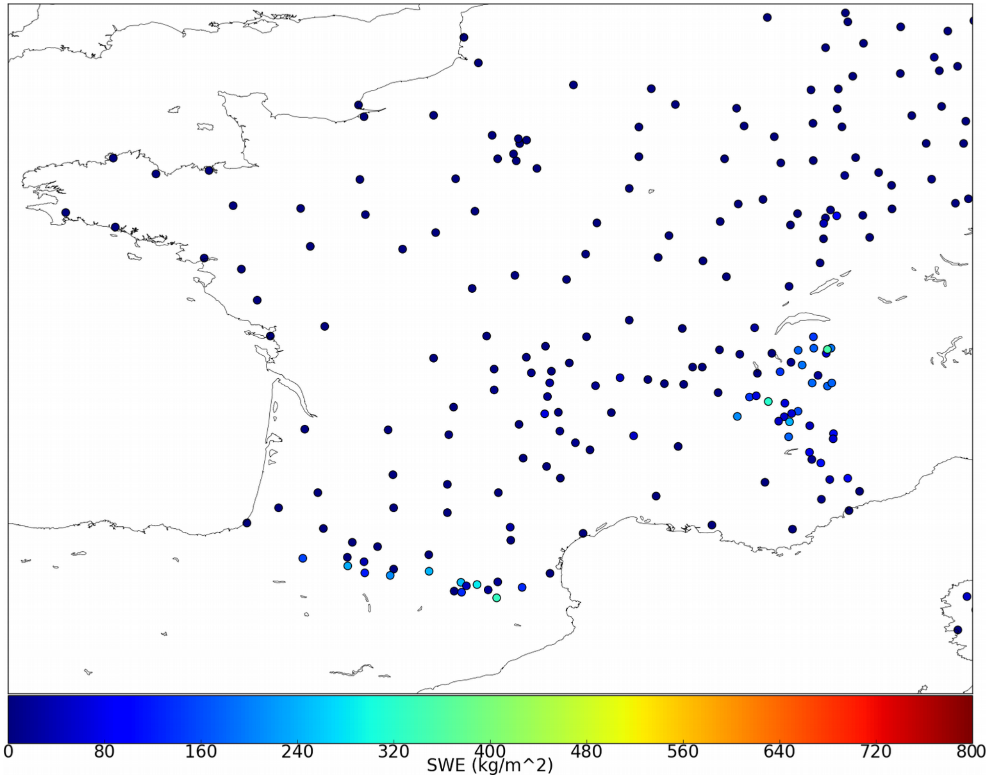
- Modification of structure functions for T2m analysis (OI)
- Impact on relief with more realistic increments



(Figures from A. Mary)

Snow analysis

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

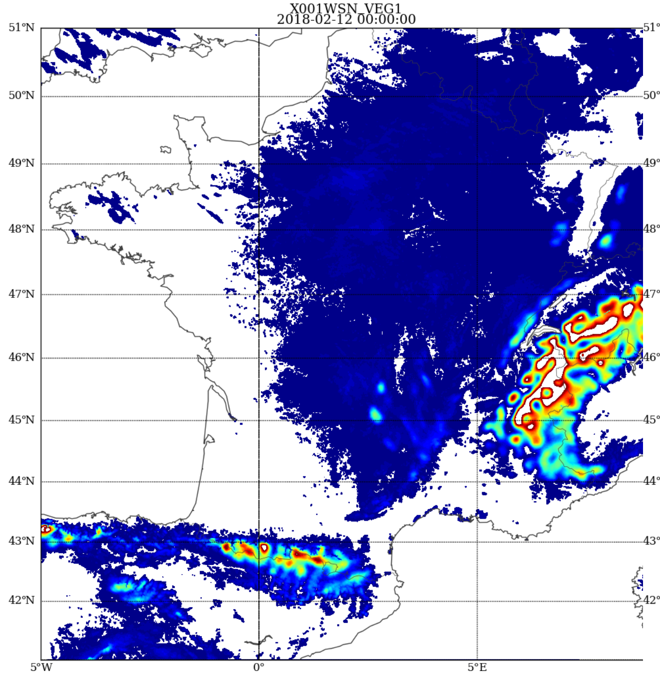


- More observations extracted over France
- Snow analysis performed in Canari routines (casnas)
- Tranfer of snow increments into Surfex

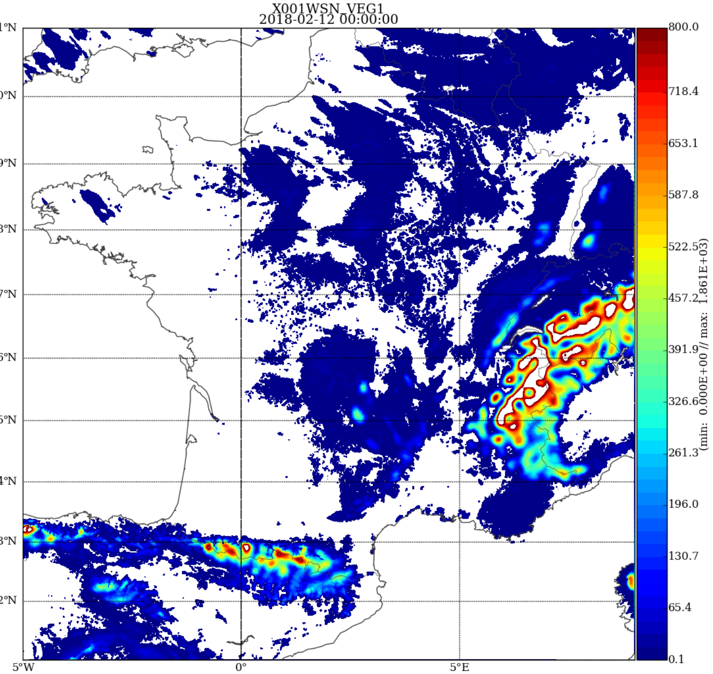
Snow observations over the AROME-France domain

Snow analysis

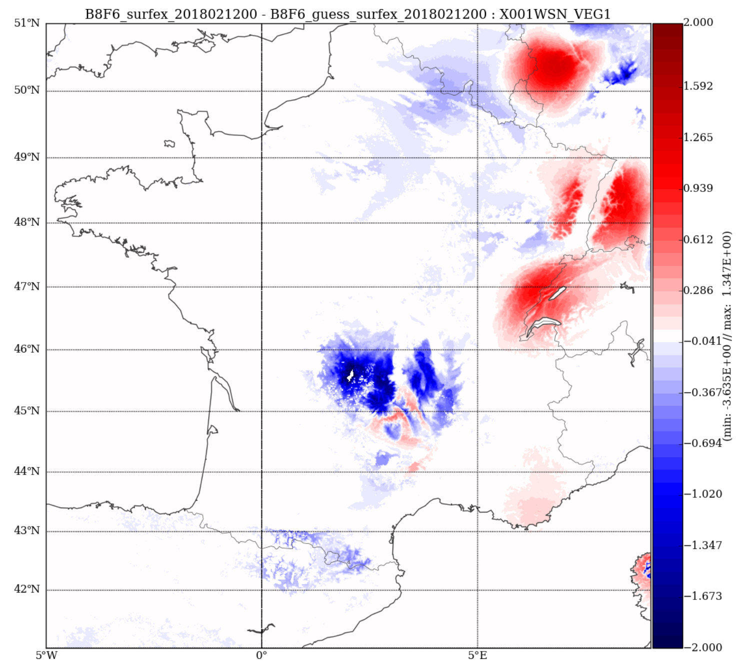
- Case study on 12 February 2018, 00:00



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

Towards coupled land-atmosphere assimilation: assimilation of Ts over land

- A realistic description of surface properties (emissivity and surface temperature) is necessary to assimilate near-surface channels (MW AMSU-A, MHS,… + IR SEVIRI, IASI) over land.
- In the current systems, we use emissivity atlases or an inversion of emissivity (MW) or of surface temperature (IR). This methodology can be extended to other hyperspectral infrared sounders such as CrIS, IASI-NG, IRS…
- However the retrieved surface temperature is not used to update the surface temperature in the model and the inversion is performed at each assimilation cycle.

- **<u>Towards coupled land-atmosphere assimilation</u>**

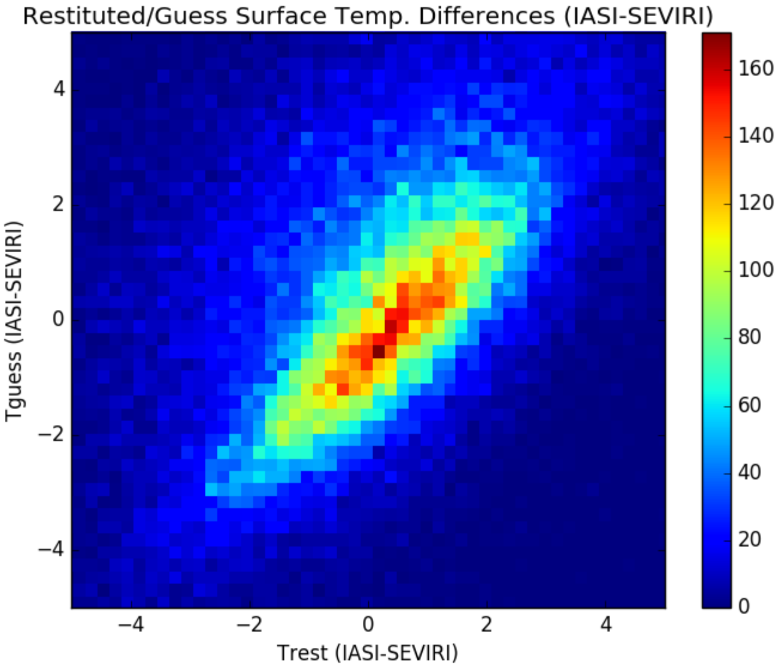
Zied Sassi (PhD student 2017-2020) on the synergy of satellite observations for the definition of surface temperature.

- Comparisons of the surface temperatures retrieved from various sensors (microwave and infrared) onboard various platforms (geostationnary and polar orbiting satellites).
- Assimilation of the retrieved Ts from satellite observations (preliminary studies with IR observations) in the surface model.

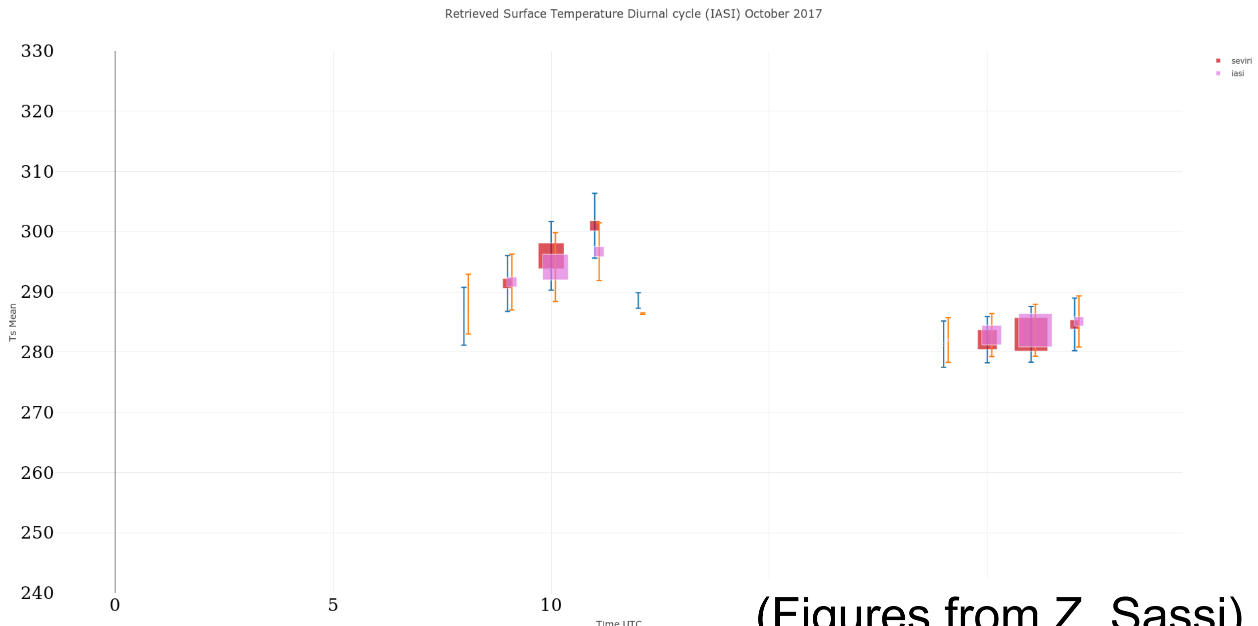
Towards coupled land-atmosphere assimilation: assimilation of Ts over land

- Comparison of surface temperature retrieved from SEVIRI channel 6, from IASI channel 1194 (IR) and from AMSU-A and -B channels 2 (MW) over the month of October 2017:
  - Good agreement between SEVIRI and IASI retrieved temperatures (bias less than 0.6 K, standard deviation less than 2 K, dropping to 0.5 K and 1.2 K respectively by night-time)
  - Better agreement by night-time for the IR sensors and by daytime for MW sensors

Retrieved Ts – guess anomalies for IASI and SEVIRI sounders



Diurnal cycle of retrieved Ts from IASI and SEVIRI over the AROME-France domain



(Figures from Z. Sassi)

- Future work will include the use of the Ts retrieved from one sensor for the assimilation of surface sensitive channels of other sensors.
- Assimilation of retrieved surface temperature to update land surface temperature in the model

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:

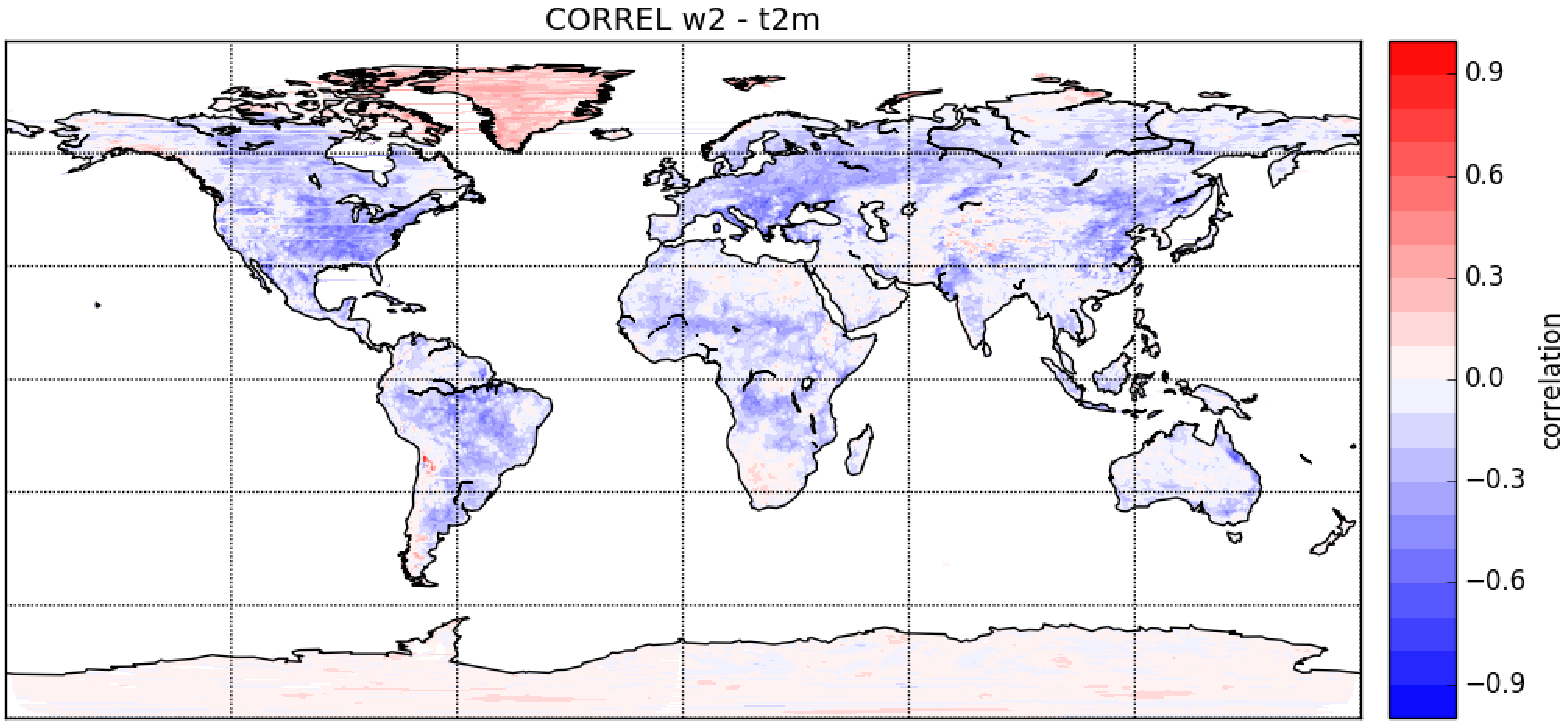
$$\Delta \mathrm{x} = \mathrm{BH^T(HBH^T + R)^{-1}}\Delta \mathrm{y}$$

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

$$\frac{\partial y}{\partial x} = \frac{\mathbf{cov}(x,y)}{\sigma_x^2}$$

Diagnostics using ARPEGE EDA for surface analysis

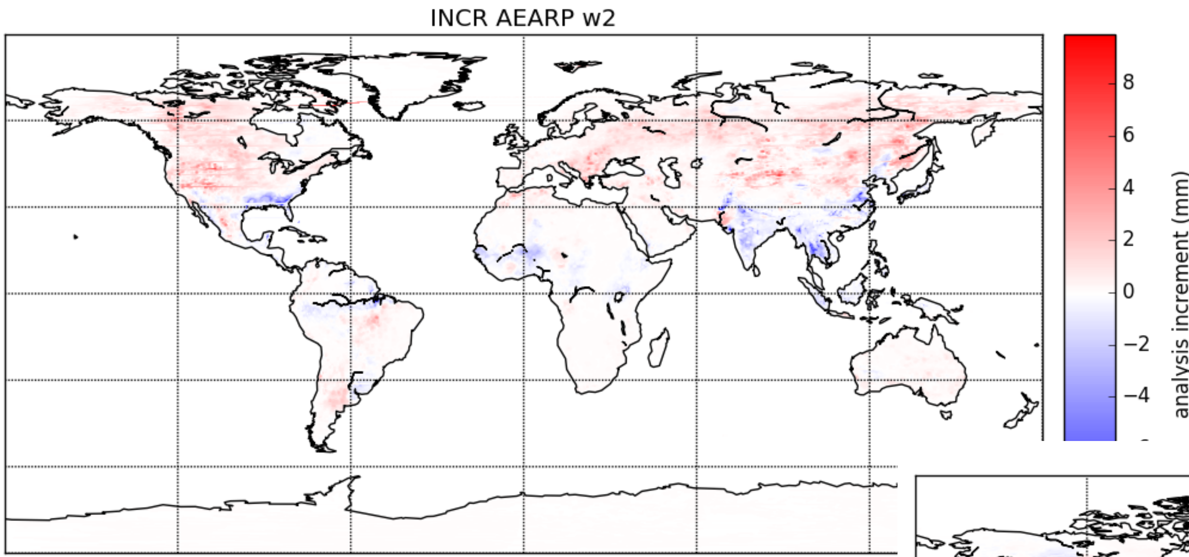
- Use of EDA (AEARP, 25 members) to compute standard deviations and covariances between surface variables and observed variables.
  - 3-weeks period (August 2017) (double suite)
  - Diagnostics computed for the whole period and for each analysis time separately



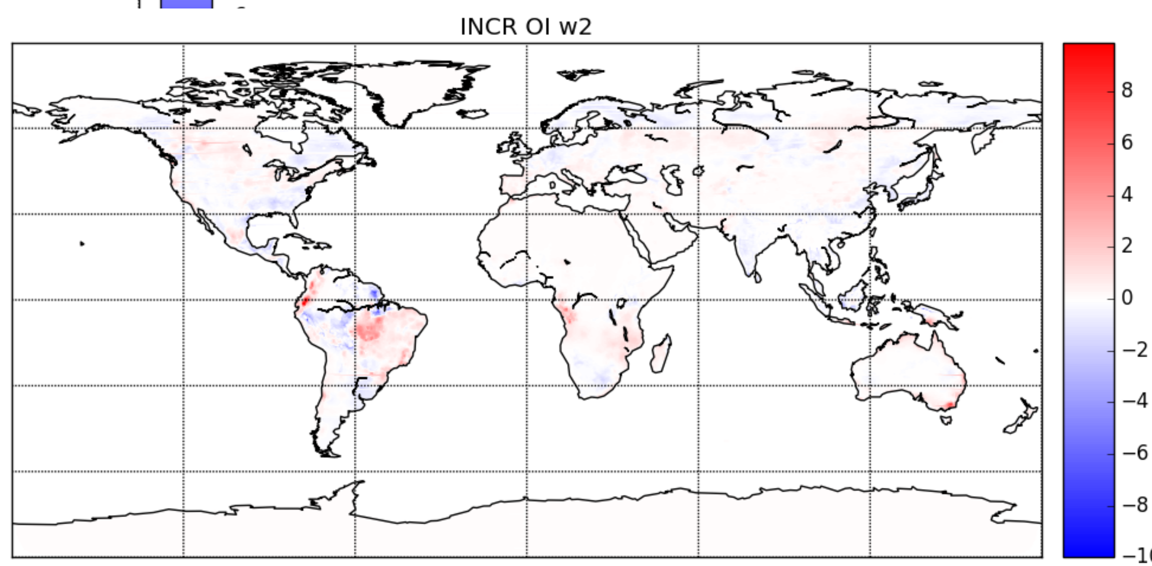
Correlations between w2 and T2m computed over a 3-weeks period (August 2017) using ARPEGE EDA (all analysis times)

Diagnostics using ARPEGE EDA for surface analysis

- Analysis increments of soil variables, and comparison with OI increments
  - Increments of T_{2m} and RH_{2m} from the operational suite
  - Mean soil increments over 1 month



Mean increments of w2 computed over a 3-weeks period (August 2017) using ARPEGE EDA (all terms)



Mean increments of w2 computed over a 3-weeks period (August 2017) with OI coefficients

- Next step: cycling of the increments of soil temperature and humidity over several assimilation cycles

Conclusions and future work

- Analysis of surface parameters: precipitation, snow depth (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, AEARO)

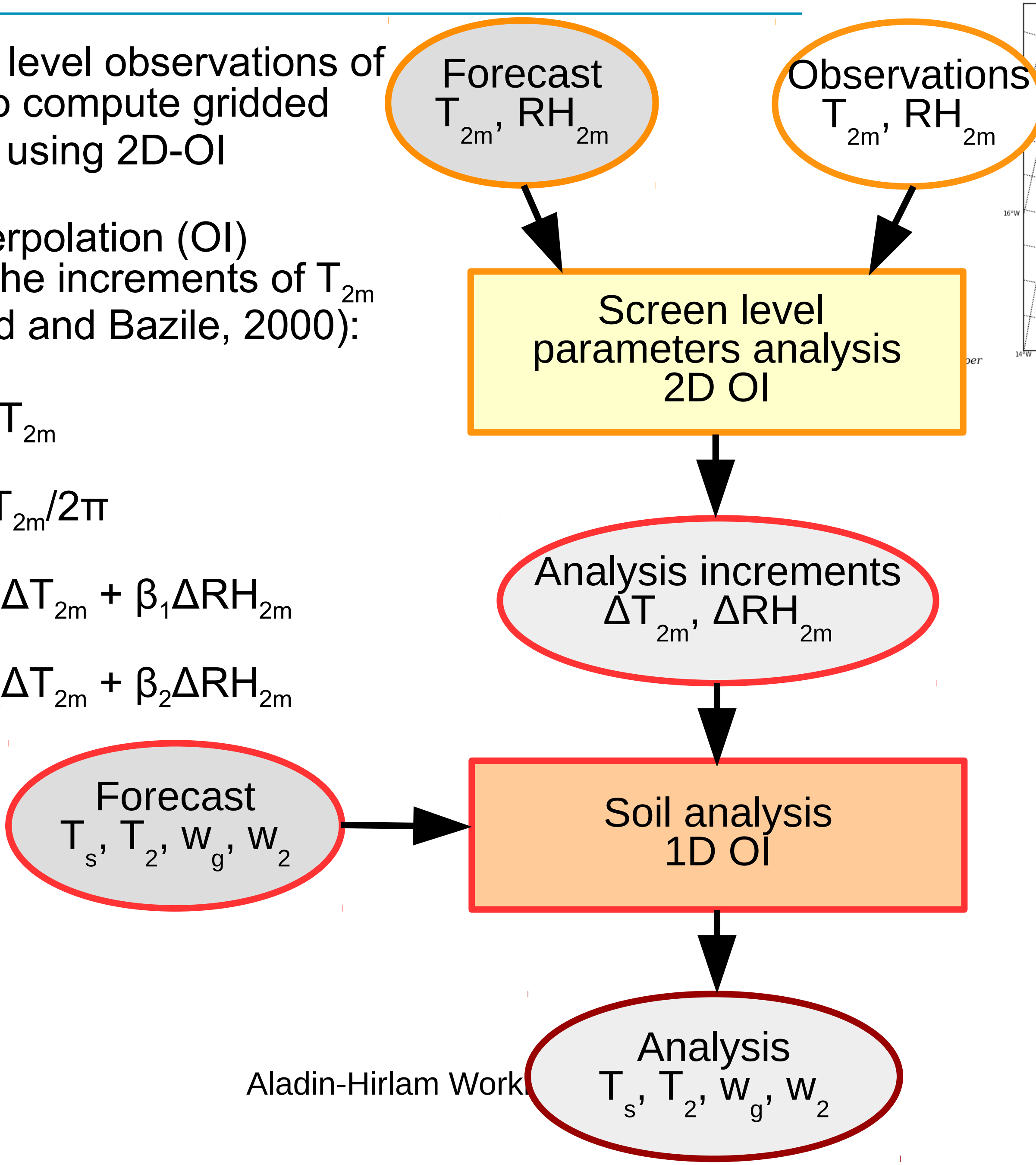
- Development of a surface analysis system compatible with the evolutions of the surface schemes (increase of the number of soil layers, diffusion version of ISBA), and with a potentiel evolution towards a strong coupling between surface and atmosphere (one control variable for surface and atmosphere)

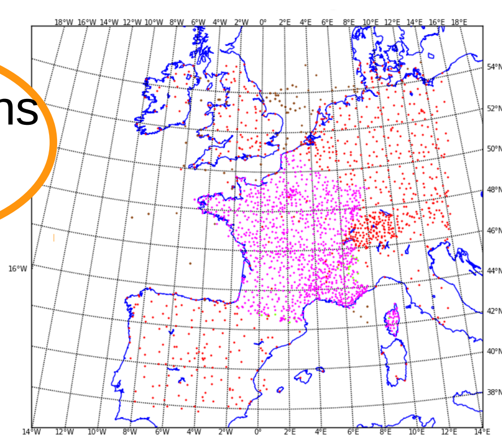
- Assimilation of satellite products, in particular for surface temperature (PhD Zied Sassi), for soil moisture (soil moisture product from ASCAT, and/or from L-band sensors SMOS/SMAP) and for snow (snow cover products Nesdis-IMS/H-SAF product/Modis?)

Land surface assimilation system

- We use screen level observations of T_{2m} and RH_{2m} to compute gridded analysed fields using 2D-OI
- 1D Optimal interpolation (OI) scheme using the increments of T_{2m} and RH_{2m} (Giard and Bazile, 2000):

  - $\Delta T_s = \Delta T_{2m}$
  - $\Delta T_2 = \Delta T_{2m}/2\pi$
  - $\Delta w_g = \alpha_1 \Delta T_{2m} + \beta_1 \Delta RH_{2m}$
  - $\Delta w_2 = \alpha_2 \Delta T_{2m} + \beta_2 \Delta RH_{2m}$

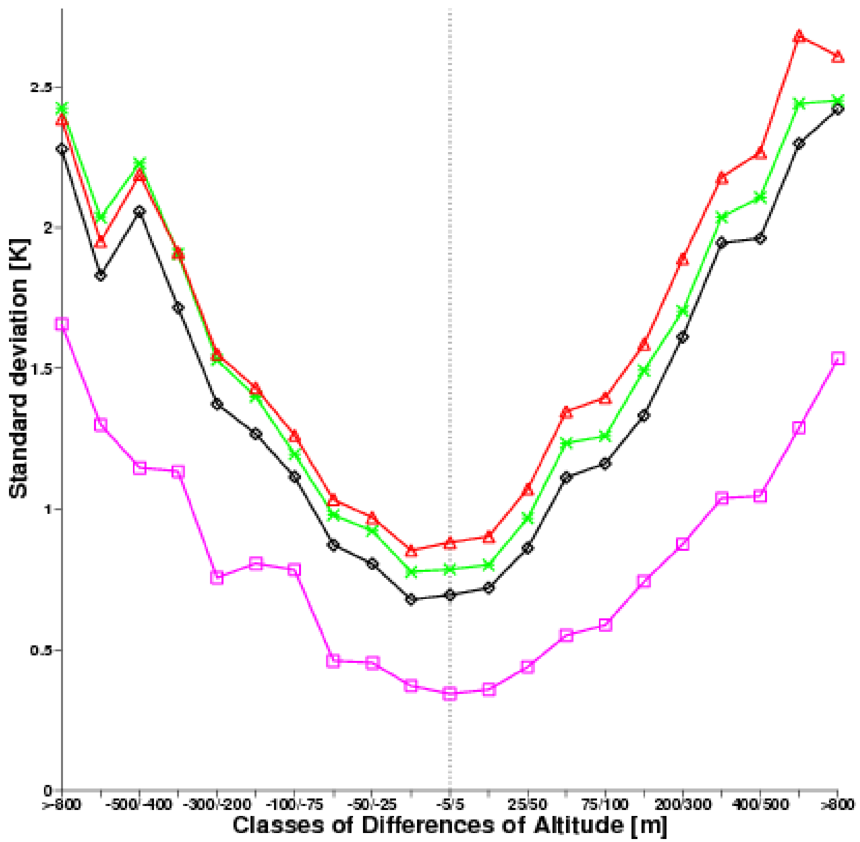




Activation of MESCAN structure functions

- The MESCAN analysis is closer to the observations on average.

Dependence on the altitude difference
T2m December 2009



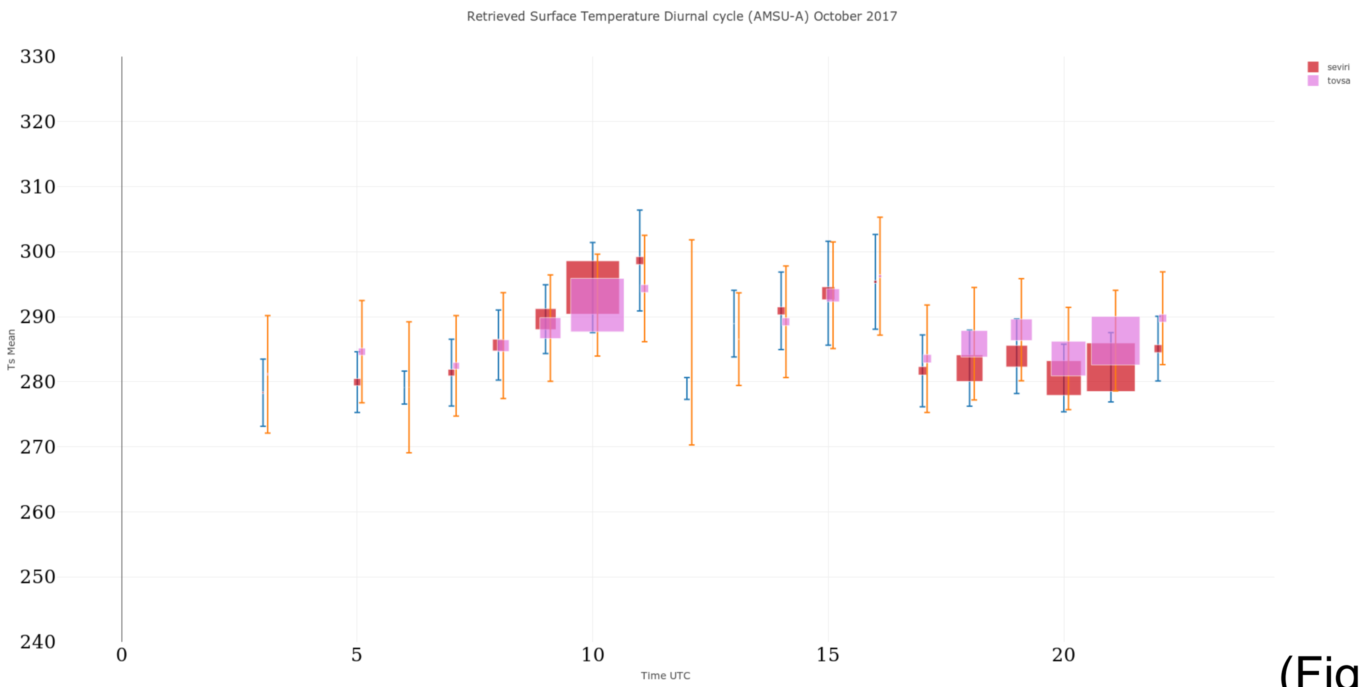
3-month evaluation
(Dec 2009-Jan 2010, June 2010)

	Biais	RMS	Nombre d'observation pour la vérification
CANARI Avec 1290 Obs	-0.008	1.077	~1290
CANARI Avec 430 Obs	-0.003	1.070	~430
	-0.006	1.366	~860 indépendantes
	-0.005	1.274	~1290
MESCAN Avec 1290 Obs	0.026	0.656	~1290
MESCAN Avec 430 Obs	0.024	0.553	~430
	0.027	1.393	~860 indépendantes
	0.026	1.180	~1290
SAFRAN Avec 1290 Obs	0.001	0.838	~1290

Towards coupled land-atmosphere assimilation: assimilation of Ts over land

- Better agreement by daytime than by night-time for the MW sensors

Diurnal cycle of retrieved Ts from AMSU-A and SEVIRI over the AROME-France domain



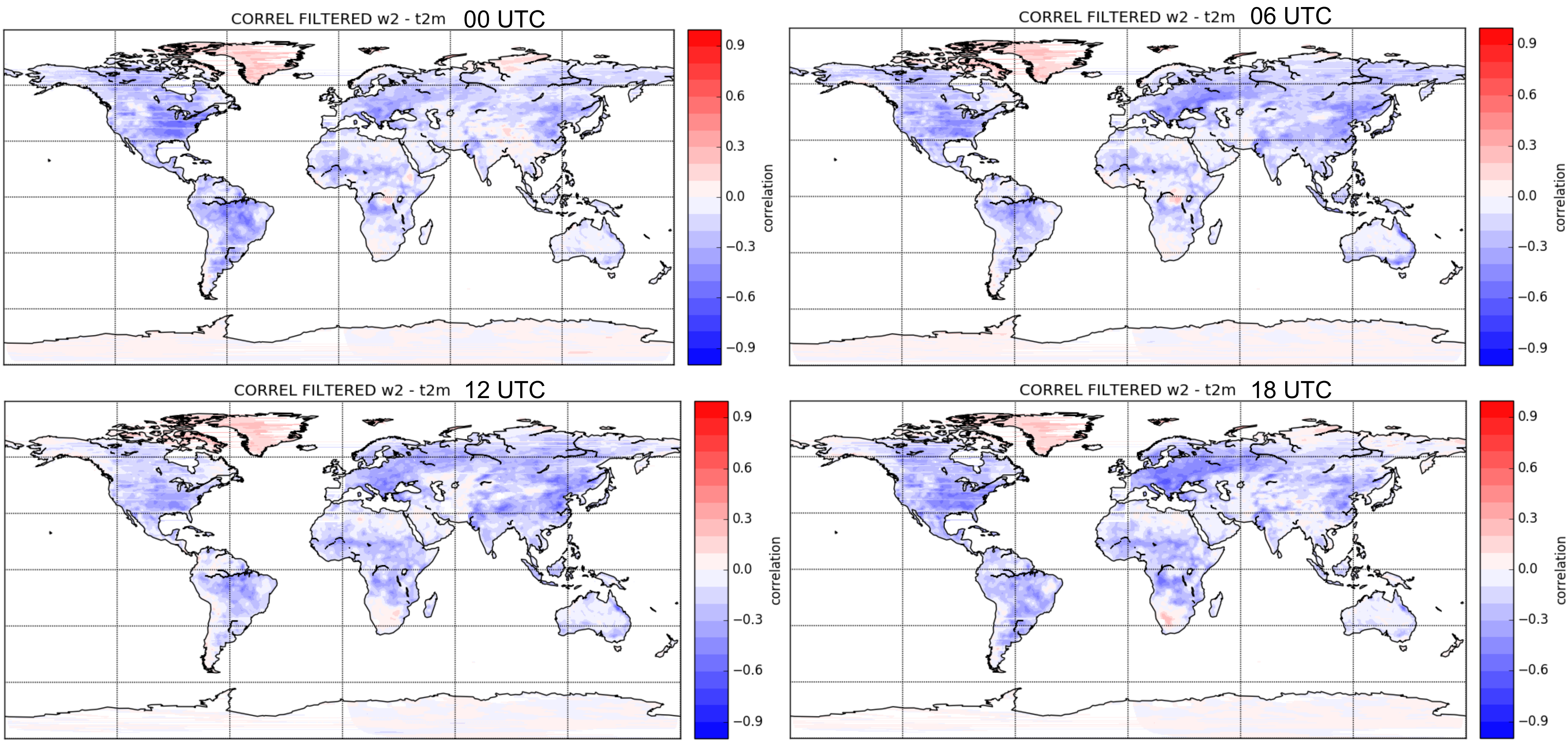
(Figure from Z. Sassi)

- Future work will include the use of the Ts retrieved from one sensor for the assimilation of surface sensitive channels of other sensors.

- Assimilation of retrieved surface temperature to update land surface temperature in the model

Diagnostics using ARPEGE EDA for surface analysis

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



Correlations between w2 and T2m computed over a 3-weeks period (August 2017) using ARPEGE EDA