Assimilation of satellite retrieved land surface temperature, and future plans at Météo France for earth surface assimilation

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Outline

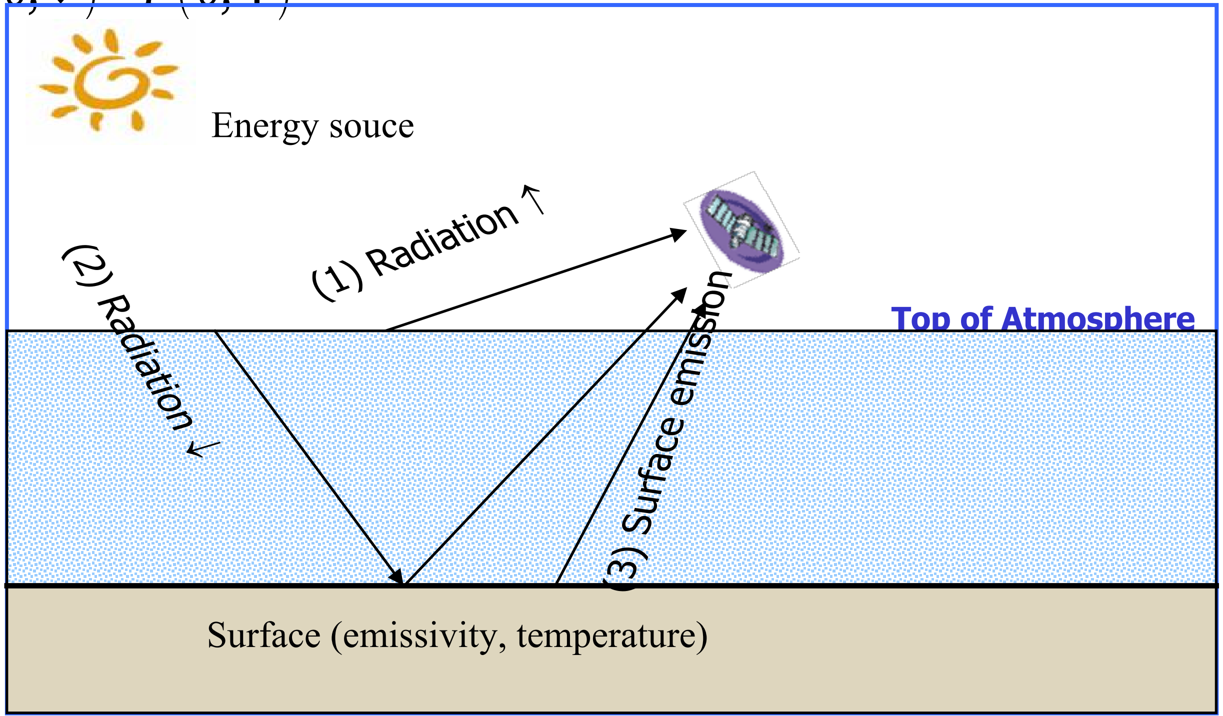
- Introduction
- Land surface temperature assimilation
- Conclusions and future work for land surface assimilation for NWP

Introduction

- Near surface atmospheric layers are crucial in NWP to simulate heat and water fluxes between surface and atmosphere
- Satellite radiances are informative on surface and near surface atmosphere, but are not assimilated in surface model
- The assimilation of satellite radiance needs realistic surface conditions:
  - Surface temperature retrieval for infrared sensors (surface emissivity for microwave sensors)
  - Retrieval at each assimilation time

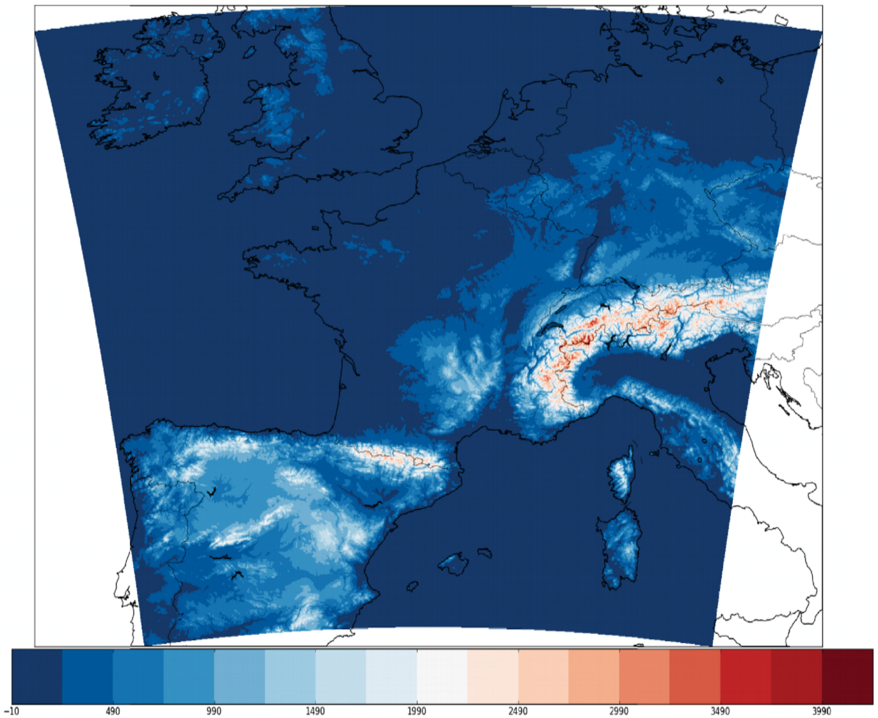
$$T(p,\upsilon)=\varepsilon(p,\upsilon).Ts.\tau+(1-\varepsilon(p,\upsilon)).\tau.T(\upsilon,\downarrow)+T(\upsilon,\uparrow)$$

$T(p,v)$: brightness temperature
$\varepsilon(p,v)$: surface emissivity
Ts: surface temperature
τ: atmospheric transmittance
$T(v,\downarrow)$: downward radiation
$T(v,\uparrow)$: upward radiation



Introduction

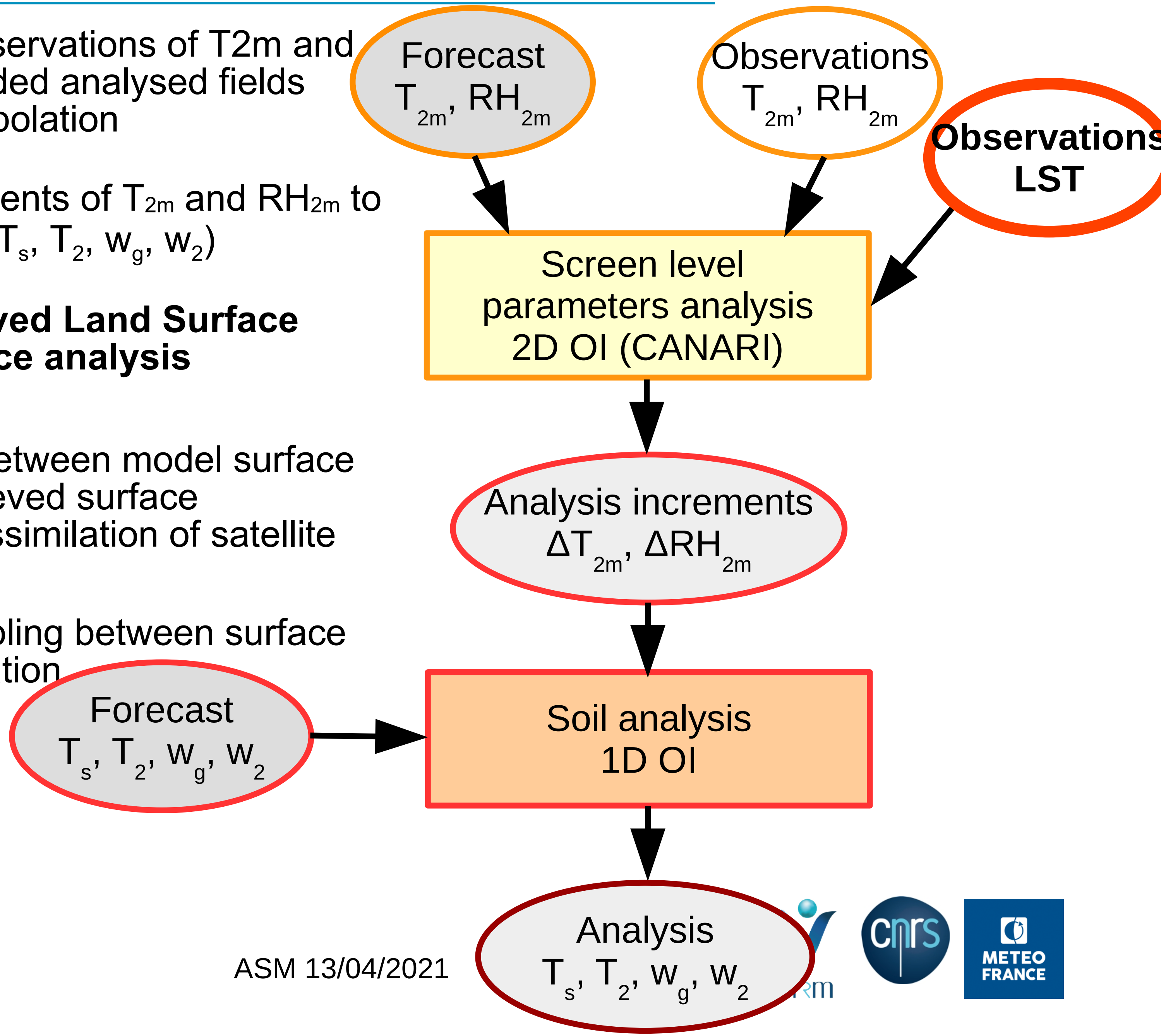
- AROME limited-area model:
  - Spectral limited area non-hydrostatic model with explicit moist convection (since 12/2008)
  - Horizontal resolution : 1.3 km, 90 vertical levels (from 5 m up to 10 hPa)
  - 3D-Var assimilation (1-h window) + IAU for upper air
  - Optimal Interpolation with 3h window for surface assimilation
  - Coupled to hourly forecasts from global model ARPEGE
  - Forecast range : from 7 to 48 hours (8 times a day)
  - Physical parametrizations (Seity et al., 2010): mixed-phase microphysics (3-class ice parametrization, ICE3 scheme), turbulence parametrization, radiation scheme (RRTM), explicit convection



AROME France domain and orography

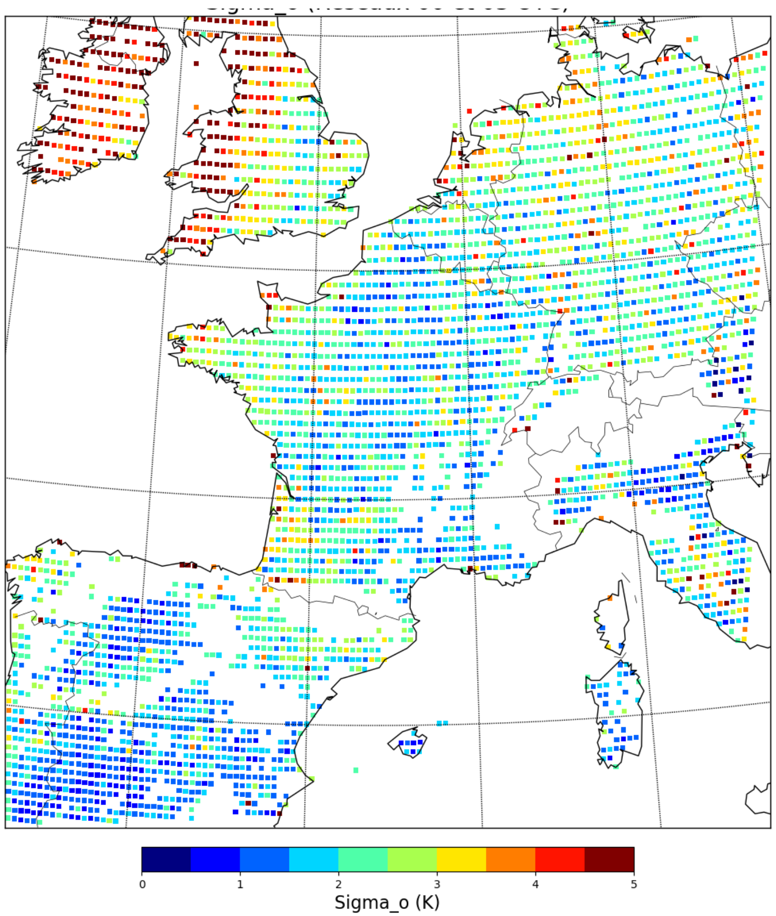
Introduction

- Use of screen level observations of T2m and Hu2m to compute gridded analysed fields using 2D Optimal Interpolation
- 1D OI using the increments of T_{2m} and RH_{2m} to analyse soil variables (T_s, T_2, w_g, w_2)
- **Use of satellite retrieved Land Surface Temperature in surface analysis**
  - Better consistency between model surface temperature and retrieved surface temperature for the assimilation of satellite radiances
  - Improvement of coupling between surface and upper air assimilation

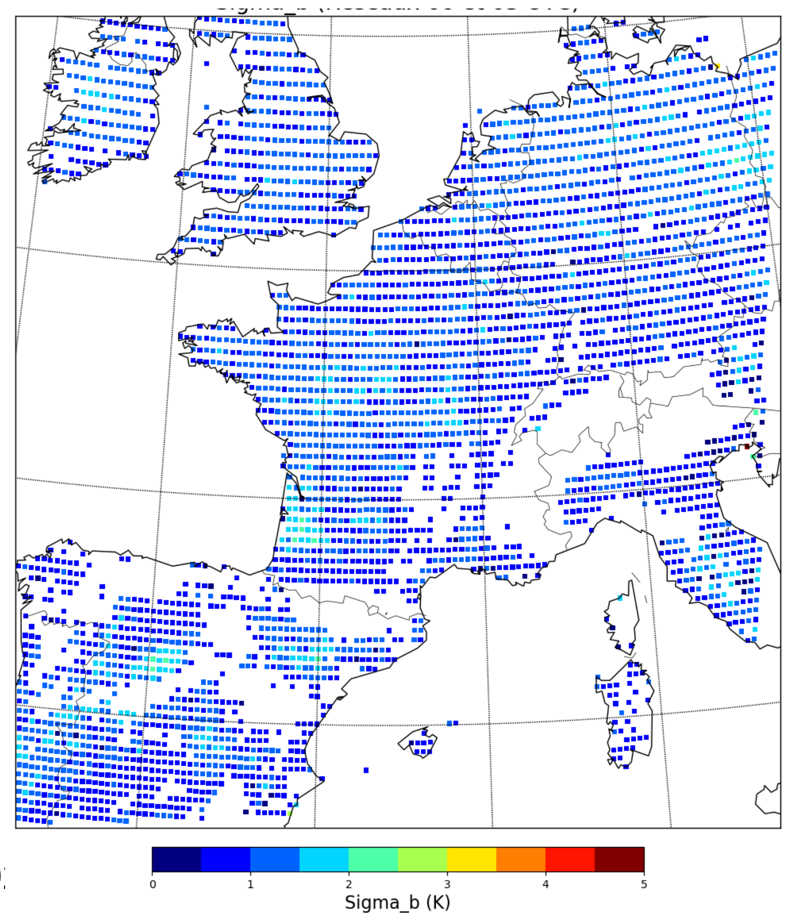


Land surface temperature assimilation: implementation

- Assimilation of SEVIRI retrieved land surface temperature in AROME model
- Assimilation of LST at 0h and 3h assimilation times
- Diagnostics of observation and background errors using Desroziers method
  - σ_o = 3 K, σ_b = 1.8 K, L_b = 30 km



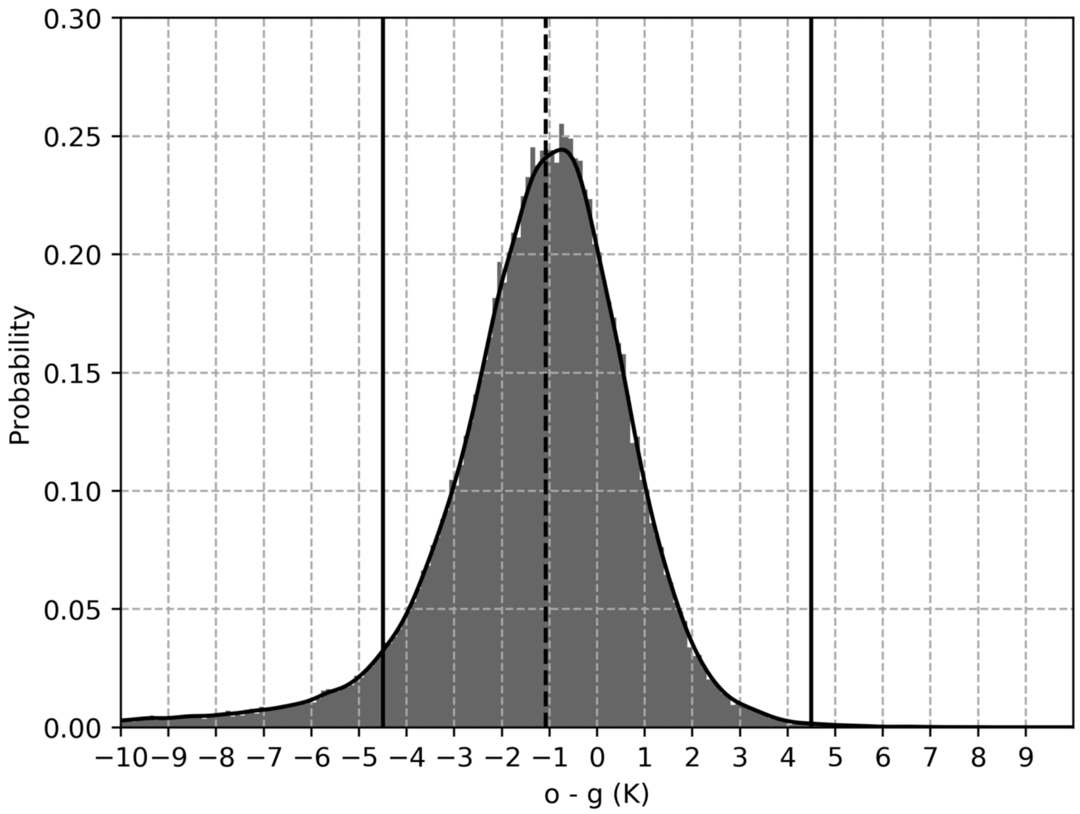
Observation standard deviations



Background standard deviations

Land surface temperature assimilation: implementation

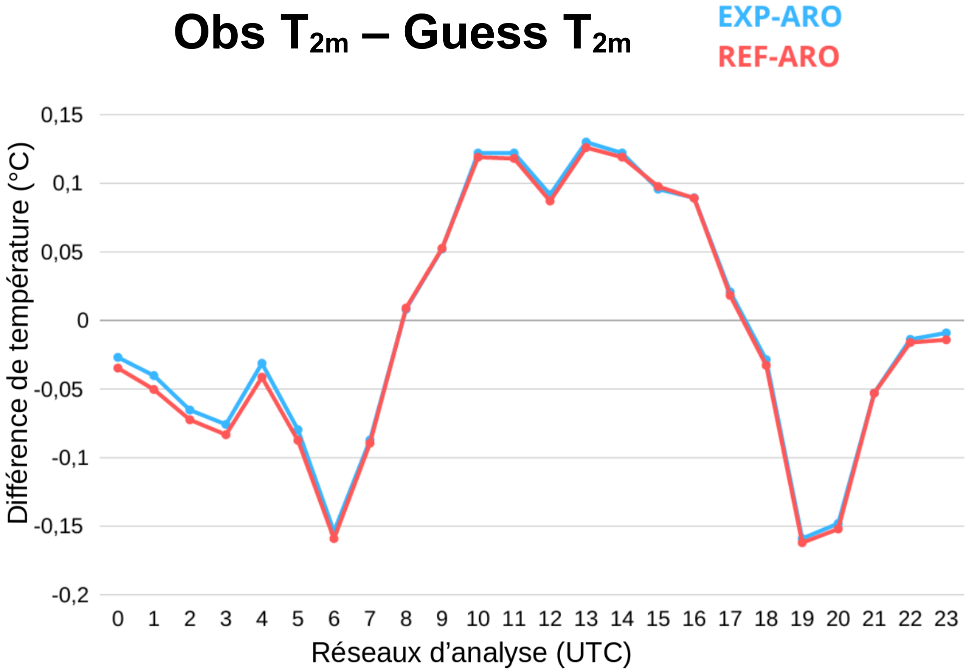
- Case studies
  - Threshold on innovations: obs – guess lower than -4.5 K removed to avoid undetected clouds

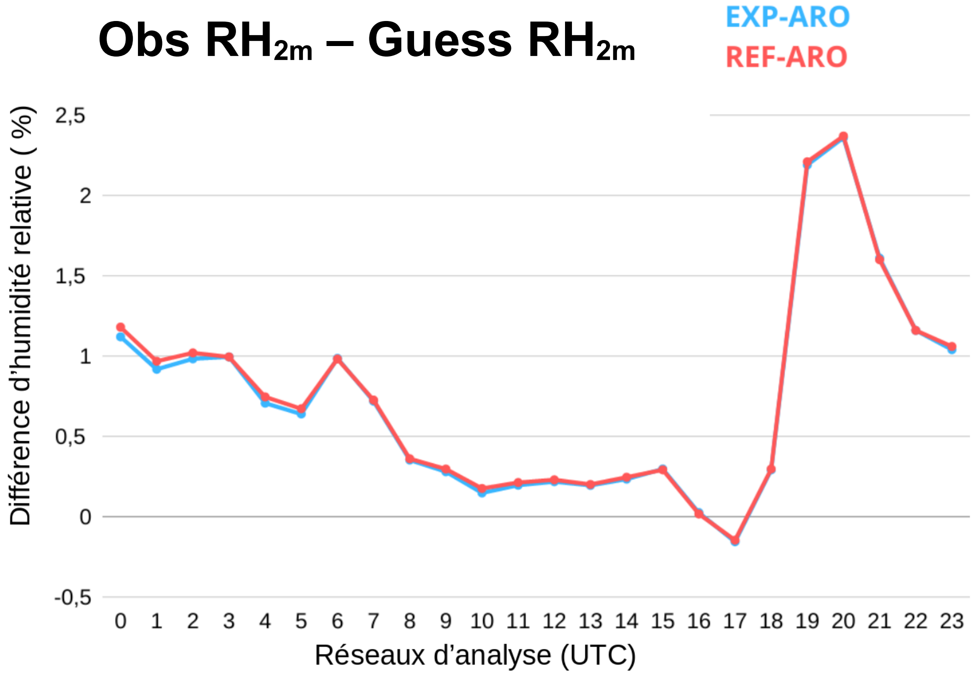


Obs LST – guess LST distribution

Land surface temperature assimilation: results

- Assimilation of SEVIRI LST at 0h and 3h in an AROME experiment over 2 months in 2019 (July and August)
- Evaluation of land surface temperature assimilation on assimilation





Mean differences between observations of T_{2m} (left) and RH_{2m} (right) and background for each analysis time, for EXP-ARO and EXP-REF experiments

Smaller differences between observations and background for the first assimilation times (up to 6h)

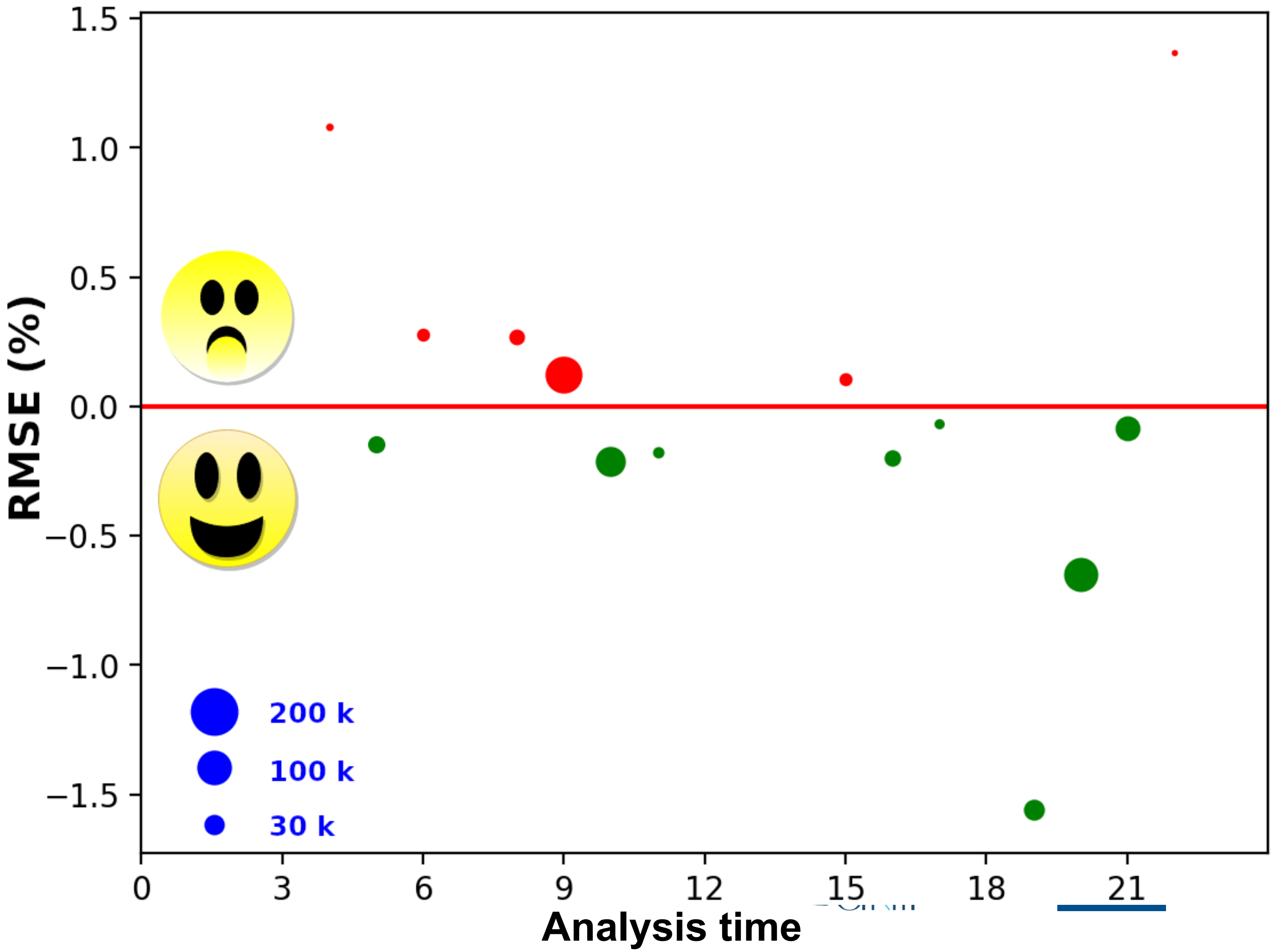
Land surface temperature assimilation: results

- Evaluation of land surface temperature assimilation on assimilation

Impact on emissivity retrieval for MW sensors

Average decrease of RMSE: 0.29 %

Differences of RMSE for MHS channel 5 between observed and simulated radiances from background (1h forecasts) for EXP-ARO and EXP-REF



Land surface temperature assimilation: results

- Evaluation of land surface temperature assimilation on AROME forecasts: impact on Synops

Forecast ranges	0h	6h	12h	18h	24h	30h	36h	42h	48h
T_{2m} (K)	**-0.01**	0	0	0	**0.01**	0.01	0	0.01	0.01
RH_{2m} (%)	-0.02	0.01	0.04	0.08	0.06	0.06	-0.02	0.01	0.07

Relative difference of mean quadratic errors for T_{2m} and RH_{2m} with respect to observations for forecast ranges up to 48h
0.01: significant with 99.5 % confidence
0.01: significant with 95 % confidence

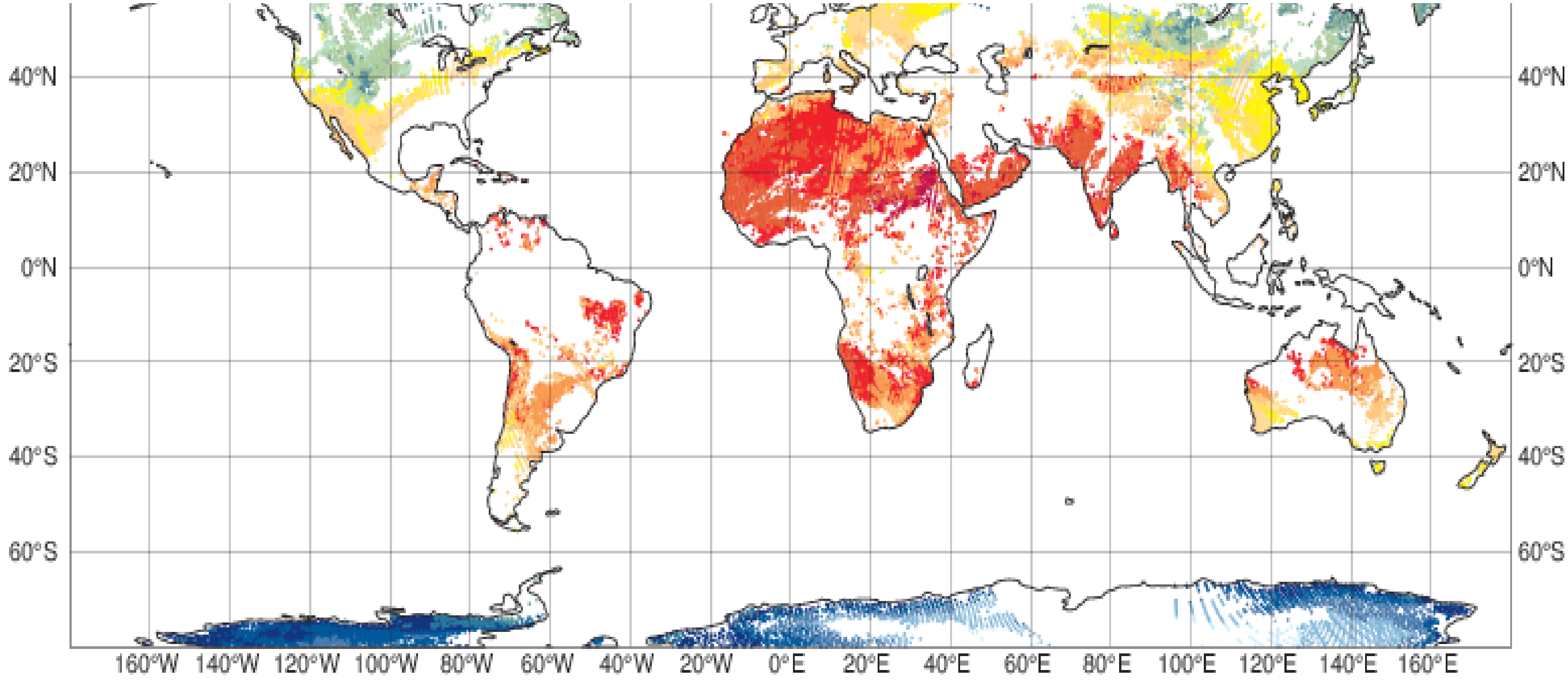
- Improvement of forecasts of T2m and Hu2m up to 48h, with significant impact by nighttime
- Improvement of forecasts of temperature and specific humidity below 400 hPa up to 24h

Land surface temperature assimilation: conclusions

- The assimilation of SEVIRI land surface temperature in land surface model ISBA improves the assimilation of 2 metre and satellite observations
- Improvement in temperature and humidity forecasts up to 36h in low atmospheric layers
- Sassi et al, 2021: Assimilation of satellite retrieved land surface temperature in AROME NWP model, *submitted*
- Future work: contribution of coupled surface and atmosphere assimilations for the representation of fluxes between surface and atmosphere in AROME model
  - Use of ensembles of data assimilation for T_{2m}, RH_{2m} and LST analyses
  - Evaluation on other types of observations: precipitation, albedo, radiation…
- Experiments of assimilation of land surface temperature at all analysis times, and over different periods in AROME

Land surface temperature assimilation: conclusions

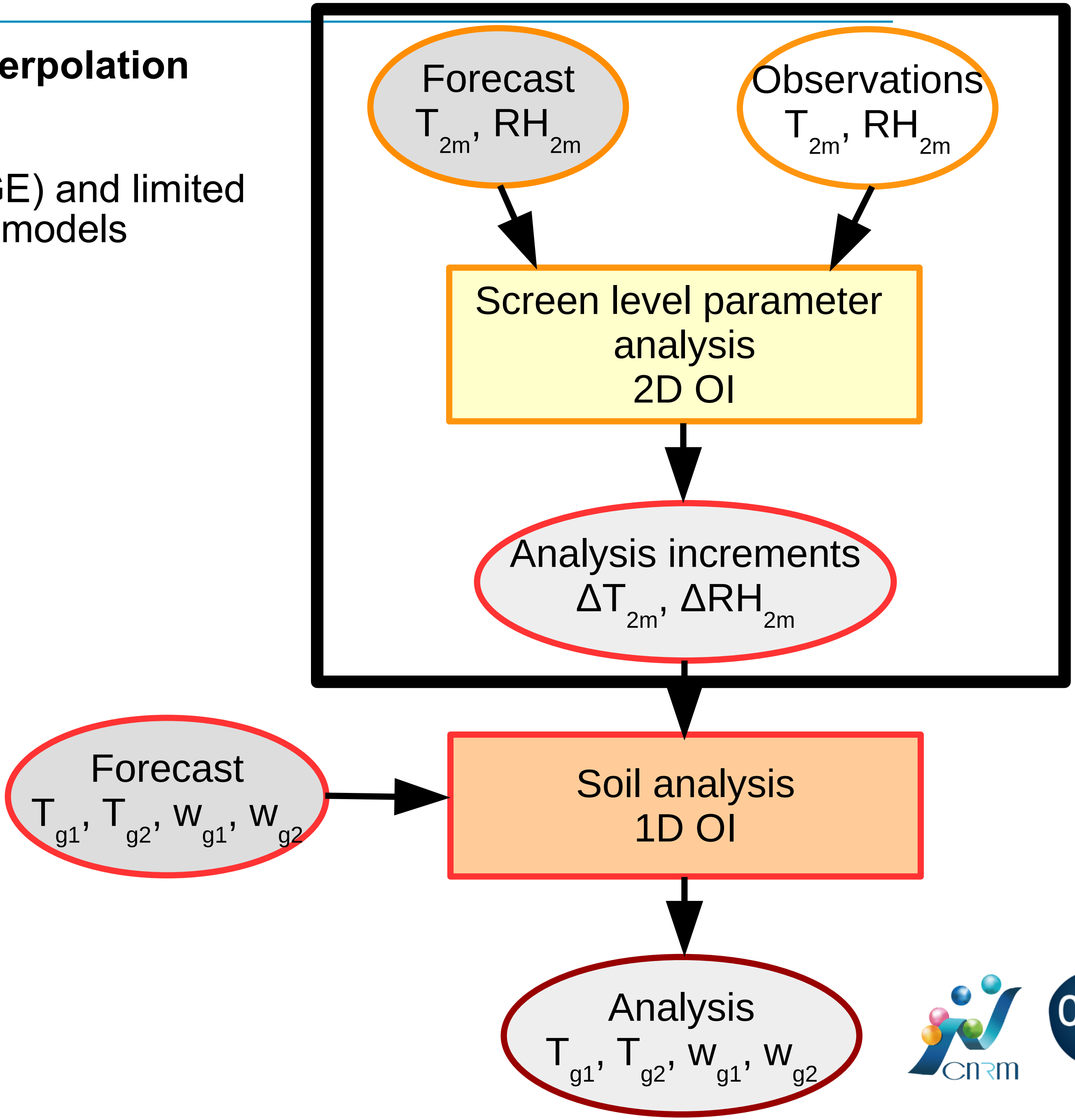
- Application of the methodology to IASI observations: land surface temperature retrieval and assimilation in ARPEGE for land surface analysis



Land surface temperatures retrieved from IASI instrument (canal 10.8 µm)

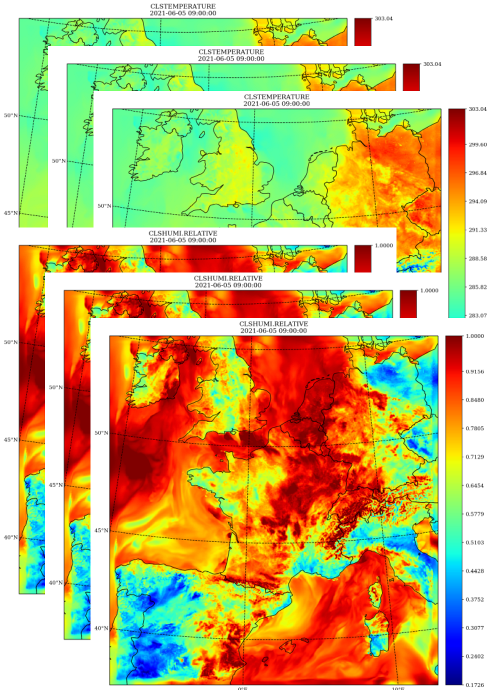
Future work for land surface assimilation: Use of data assimilation ensembles for the 2D part

- **2D Optimal Interpolation CANARI**
- Global (ARPEGE) and limited area (AROME) models



Future work for land surface assimilation: Use of data assimilation ensembles for the 2D part

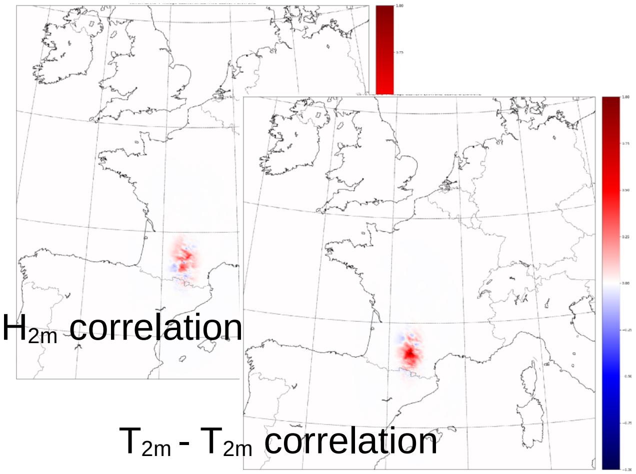
- 2022-2025: PhD activity «Toward an ensemble approach for surface AROME model surface assimilation»



Low resolution T_{2m} and RH_{2m} fields from AEAR0 (25 members)

Ensemble B matrix

T_{2m} and RH_{2m} analysed fields



T_{2m} - RH_{2m} correlation

T_{2m} - T_{2m} correlation

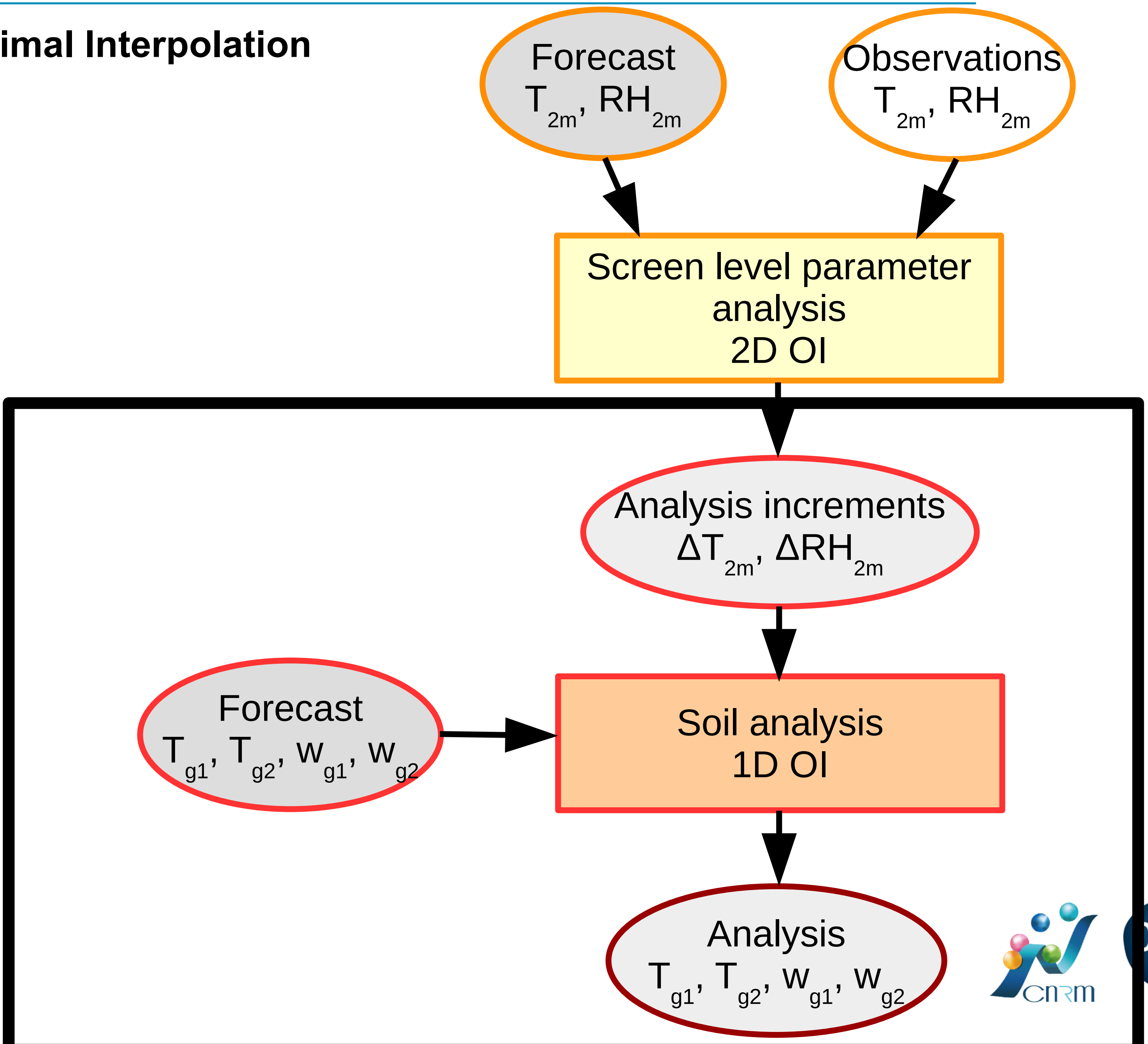
Ex: T_{2m}-T_{2m} correlations, and T_{2m}-RH_{2m} correlations with a T_{2m} observation in Toulouse

- Building of a new tool for 2m variables spatialisation using an ensemble method (eg 2D-EnVar) to benefit from operational ensemble data assimilation

- Extend to other types of observations (satellite observations, precipitation...)

Future work for land surface assimilation: Use of data assimilation ensembles for the 1D part

- **1D Optimal Interpolation**



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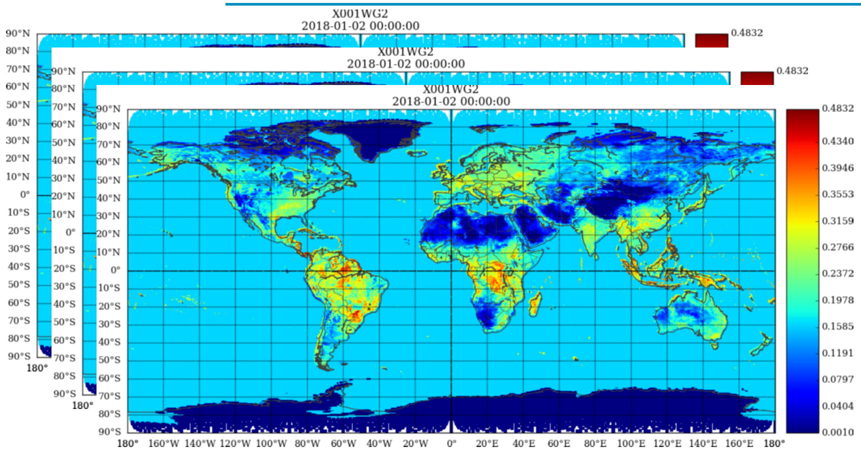
Future work for land surface assimilation: Use of data assimilation ensembles for the 1D part

- The optimal interpolation coefficients (covariances between forecast errors of T_{2m} et RH_{2m} and soil water content w_g et w_2) are constants in time and space.
- A set of coefficients is then applied to account for local conditions at the analysis time (diurnal cycle, wind, precipitation, snow...)
- The objective is to use ensembles of 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}).

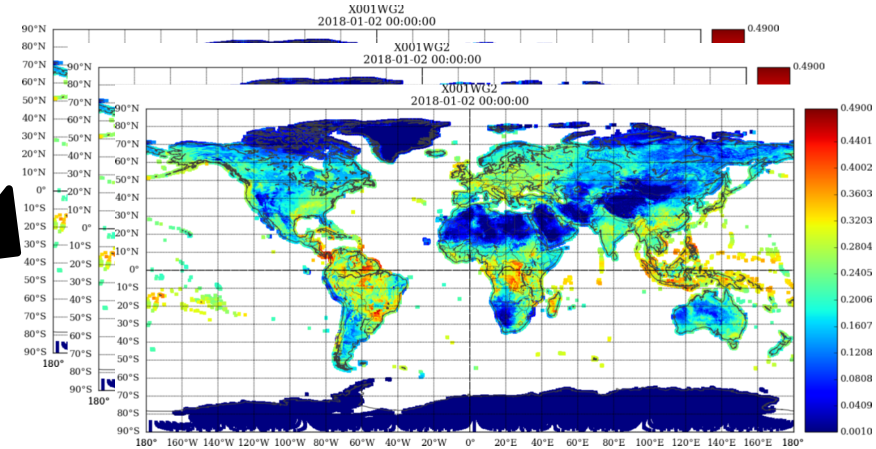
$$\Delta \mathrm{x} = \mathrm{BH}^{\mathrm{T}}(\mathrm{HBH}^{\mathrm{T}} + \mathrm{R})^{-1}\Delta \mathrm{y}$$

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

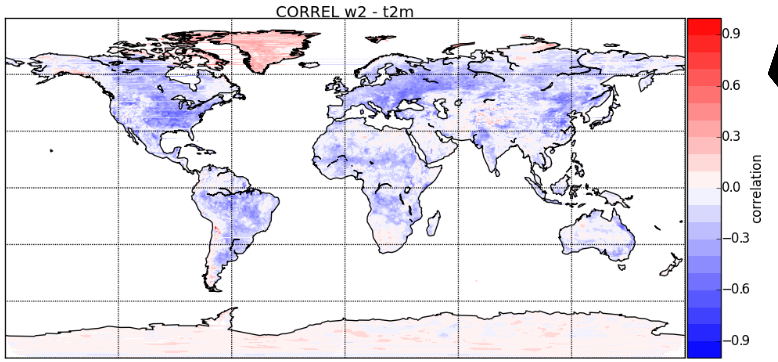
Future work for land surface assimilation: Use of data assimilation ensembles for the 1D part



Suface fields at **low resolution** from ARPEGE EDA (AEARP, 50 members)



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



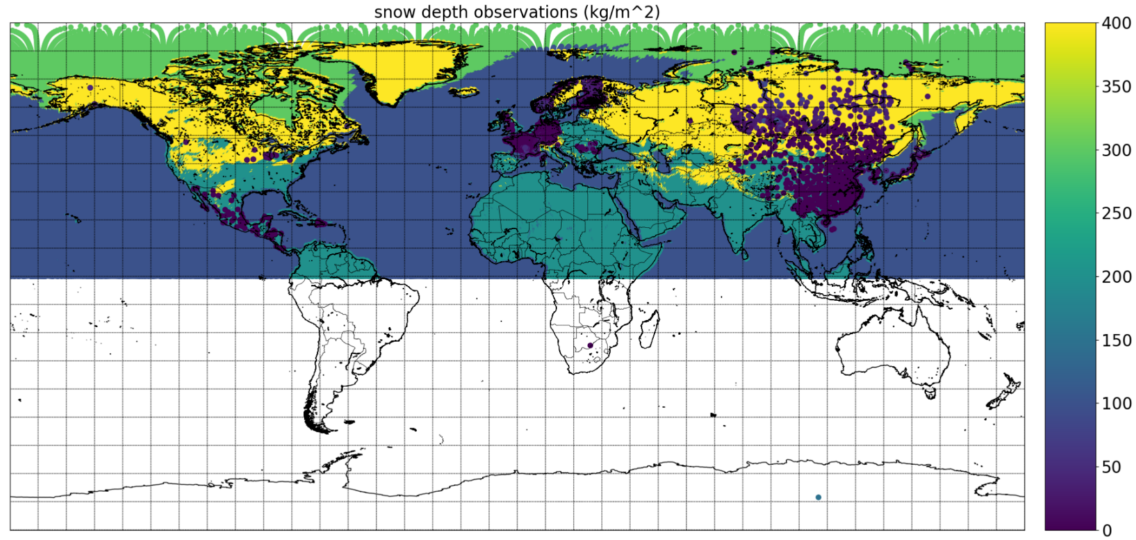
Correlations and standard deviations at **high resolution**

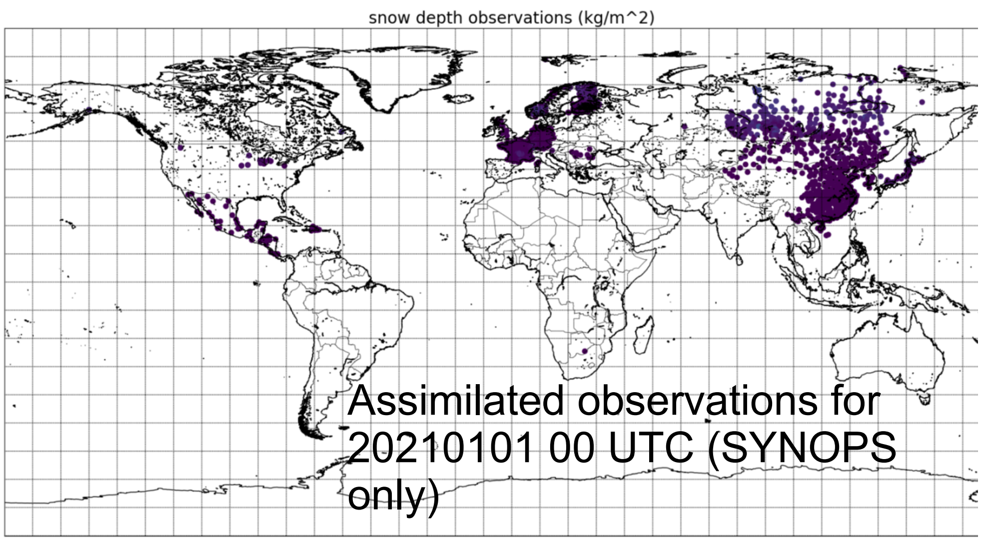
Soil analysis for w_g and w_2

Future work for land surface assimilation: Snow depth assimilation

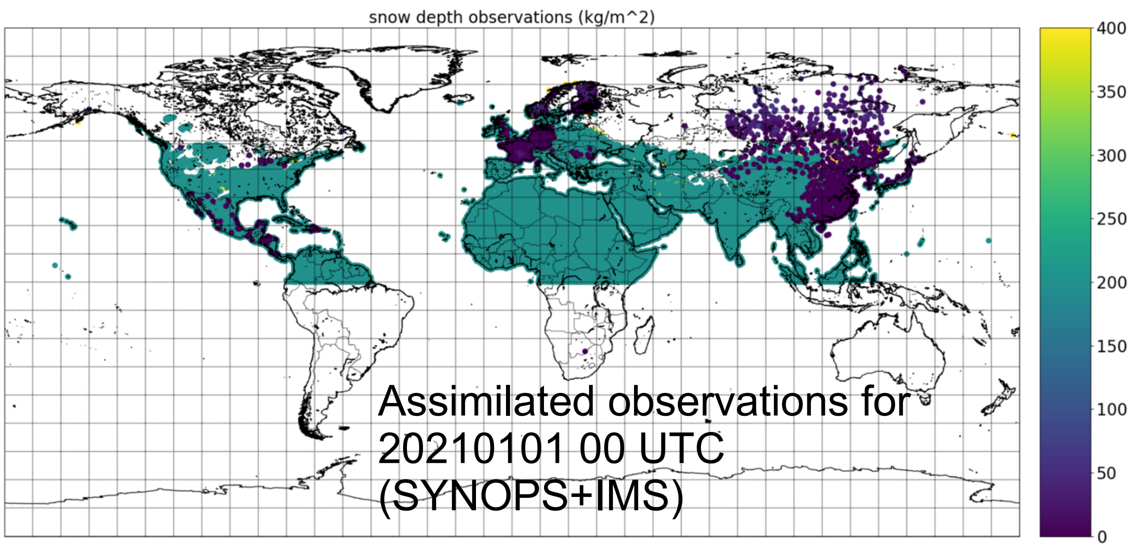
- Snow depth analysis in global model ARPEGE and limited-area model AROME
- Assimilation of SYNOP observations + first tests to assimilate IMS snow cover product (4 km, 1 per day)

Available observations for 20210101 00 UTC (SYNOPS+IMS)





Assimilated observations for 20210101 00 UTC (SYNOPS only)

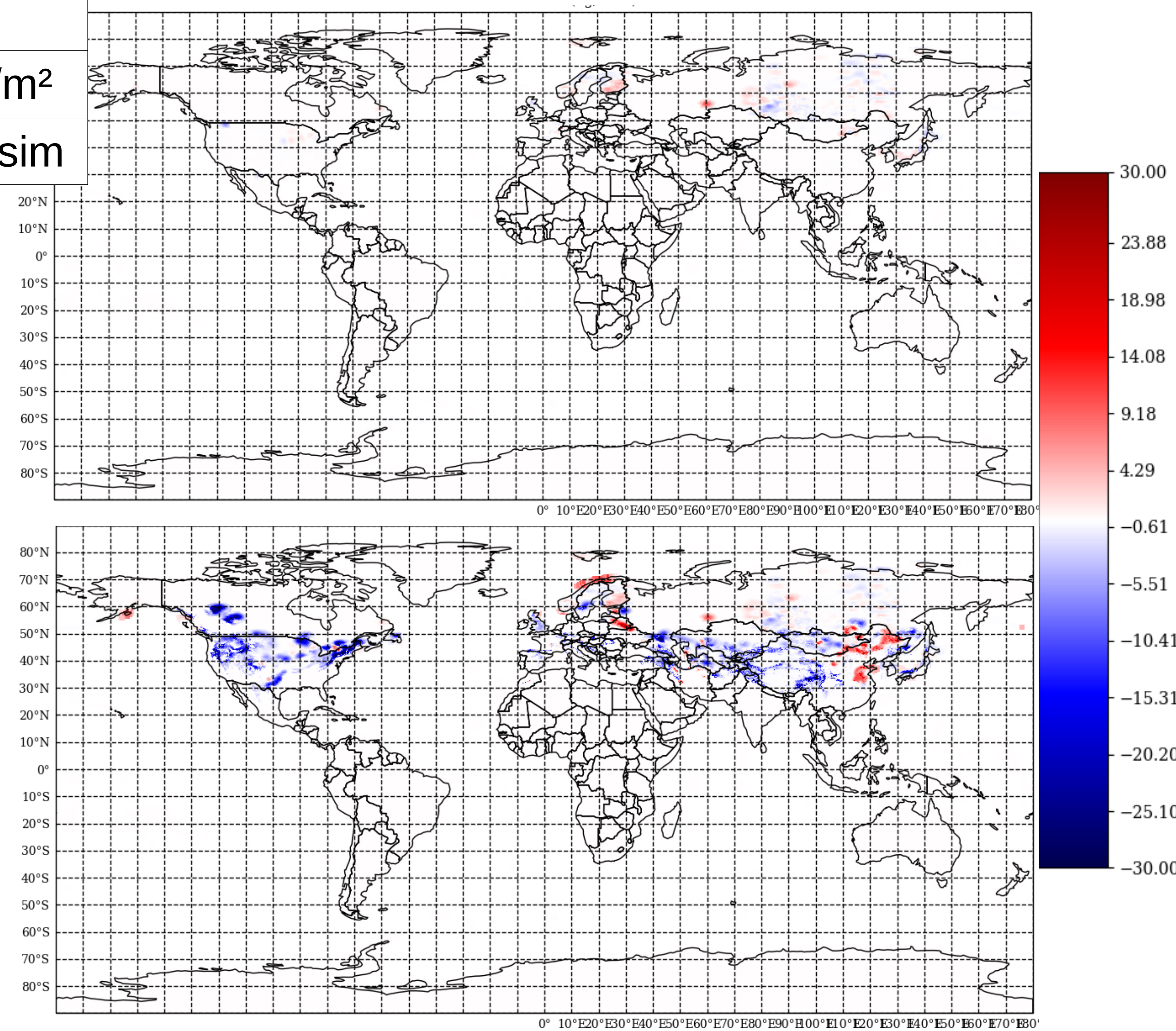


Assimilated observations for 20210101 00 UTC (SYNOPS+IMS)

Future work for land surface assimilation: Snow depth assimilation

- Assimilation of IMS snow cover product (4 km, 1 per day)

		IMS snow cover	
		0	1
Model background	0	0 kg/m²	10 kg/m²
	≠ 0	0 kg/m²	No assim



Snow water equivalent increments with SYNOP observations for 20210101 00 UTC (kg/m²)

Snow water equivalent increments with SYNOP observations + IMS snow cover for 20210101 00 UTC (kg/m²)

Conclusion and future work

- Assimilation of satellite observations
  - Snow analysis: snow cover products
  - Land surface temperature: LST retrieved from infrared instruments
  - (Soil moisture)
- Improvement of surface analysis techniques: use of ensembles of data assimilation for 2D + 1D
  - 2D part: use of EDA in a 2D-EnVar framework, assimilation of other variables
  - 1D part: use of EDA to diagnose coefficients for 1D OI in the soil
- Progress towards coupled surface-atmosphere assimilations through the use of information from EDA, and the assimilation of observations sensitive to the interface between surface and atmosphere (e.g. LST)