Current practice at Météo-France on land data assimilation for NWP

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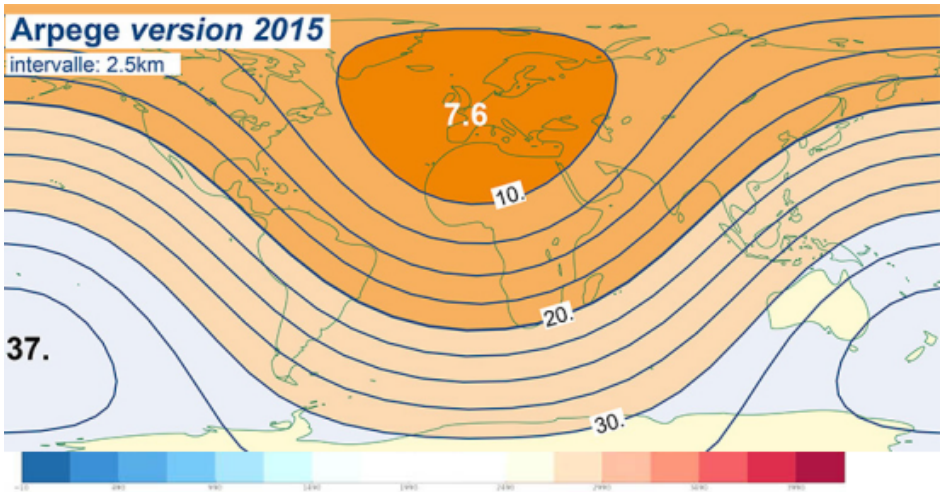
Outline

- Météo France NWP models: the global model ARPEGE and regional model AROME
- The surface modelling platform SURFEX
- Land surface assimilation system
- Future plans for assimilation system over land

Global model ARPEGE



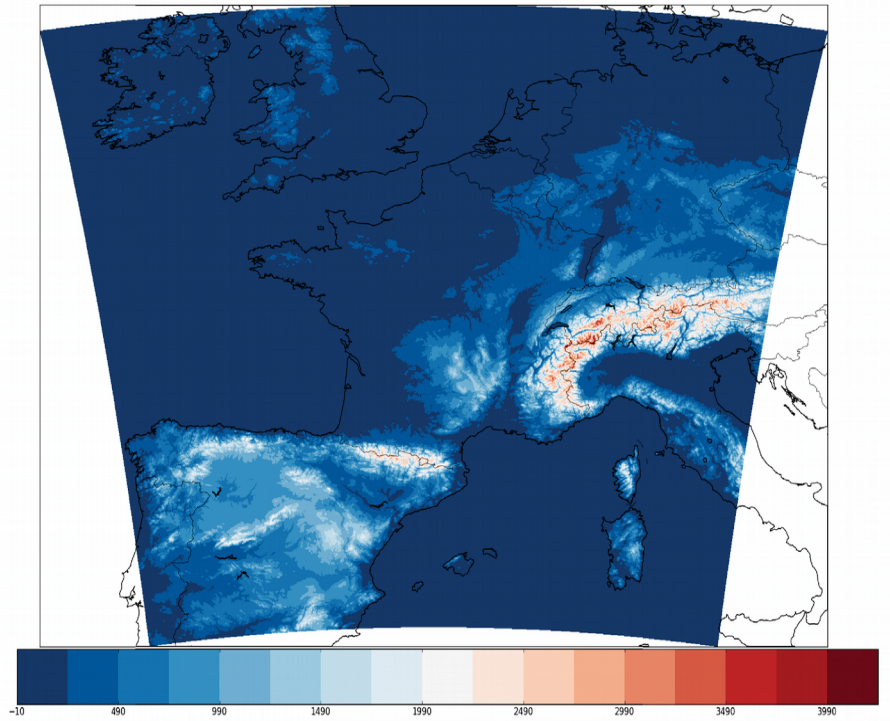
Spectral model with variable resolution:
T_L1198c2.2L105

Δx from 7.5 to 36 km
105 vertical levels from 10 m to 0.1 hPa

- Incremental 4D-Var assimilation (6-h window and 30 min time-slots):
  - 2 loops of minimization: T_L149c1L105 (40 iterations) + T_L399c1L105 (40 iterations)
  - Background error variances and correlation lengths from an Ensemble Data Assimilation system (4D-Var at lower resolution: T_L499/T_L149) with 25 members
- Forecast (cut-off and ranges):
  - 00 UTC (1h10/54h), 00 UTC (2h15/102h), 06 UTC (3h/72h), 12 UTC (1h50/144h), 18 UTC (3h/60h)
- Physical parametrizations
  - Lopez microphysics (Lopez, 2002; Bouteloup et al., 2006)
  - RRTM/FM radiation scheme
  - Parametrization of convection and subgrid effects (Bougeault, 1985)
  - Turbulence scheme (Bougeault and Lacarrère, 1999; Cuxart, Bougeault and Redelsperger, 2000)

Regional model AROME

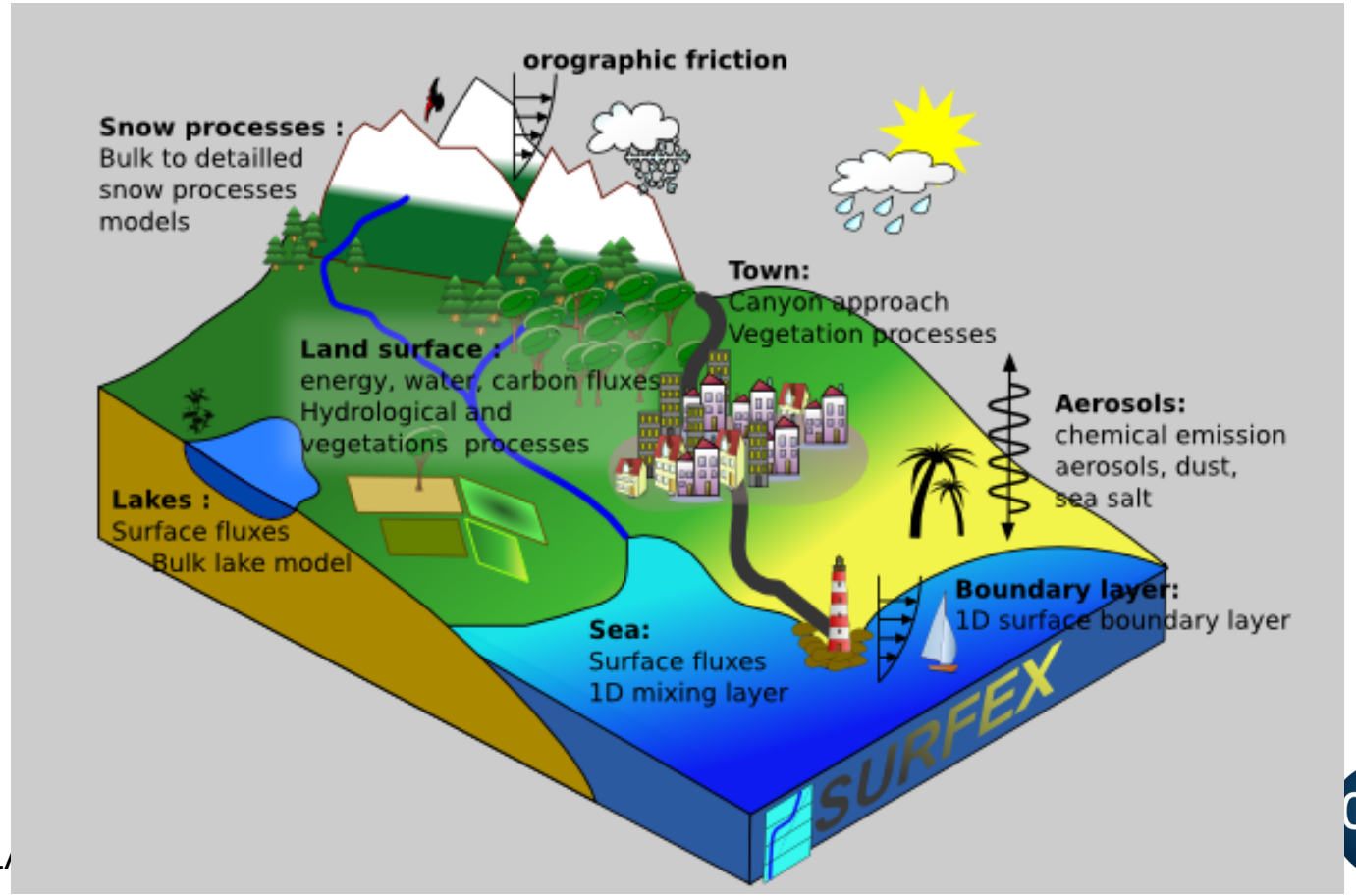
- Spectral limited area non-hydrostatic model with explicit moist convection (since 12/2008)
- Horizontal resolution : 1.3 km (*)
- 90 vertical levels (from 5 m up to 10 hPa) (*)
- 3D-Var assimilation (1-h window) + IAU (*)
- Coupling files : hourly forecasts from global model ARPEGE
- Forecast range : from 7 to 42 hours (8 times a day)
  - cut-off: between 20 min and 3.5 h
- Physical parametrizations (Seity et al., 2010):
  - Mixed-phase microphysics (3-class ice parametrization, ICE3 scheme)
  - Turbulence parametrization
  - Radiation scheme (RRTM)
  - Explicit convection



(*) since 04/ 2015

Surface modelling platform SURFEX

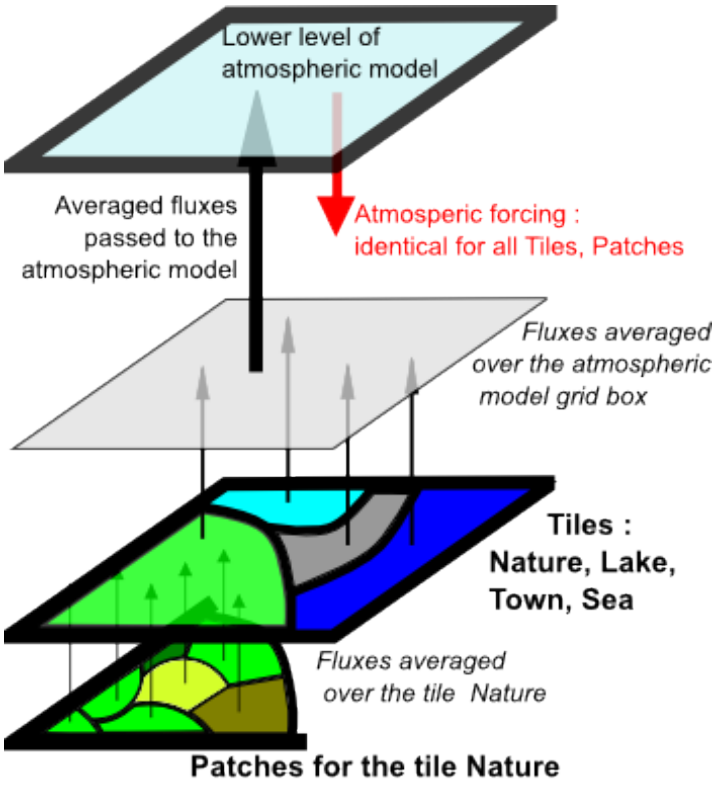
- SURFEX platform to modelise the exchanges of water and energy between land surface and atmosphere.
- Several schemes available for nature, sea, lake and town



Surface modelling platform SURFEX

- Atmospheric forcing (air temperature, specific humidity, wind components, pressure, rain rate, snow rate, CO2, chemical species, aerosol concentration)
  and radiative forcing (solar radiation, infrared radiation)

- Surface radiative properties (albedo, emissivity, surface radiative temperature) and surface fluxes (momentum, sensible heat, latent heat, CO2, chemical species, aerosols)



SURFEX tiling and coupling with an atmospheric model

Surface modelling platform SURFEX

- 4 types of covers and associated pronostic variables

  - Nature: ISBA-3L (3 layers) for NWP (Noilhan and Mahfouf, 1995; Boone et al., 1999), diffusion version for research applications. Pronostic variables in the two superficial layers → temperature and humidity of the superficial and root-zone reservoirs (liquid and frozen parts for water, snow water equivalent for snow on the ground):

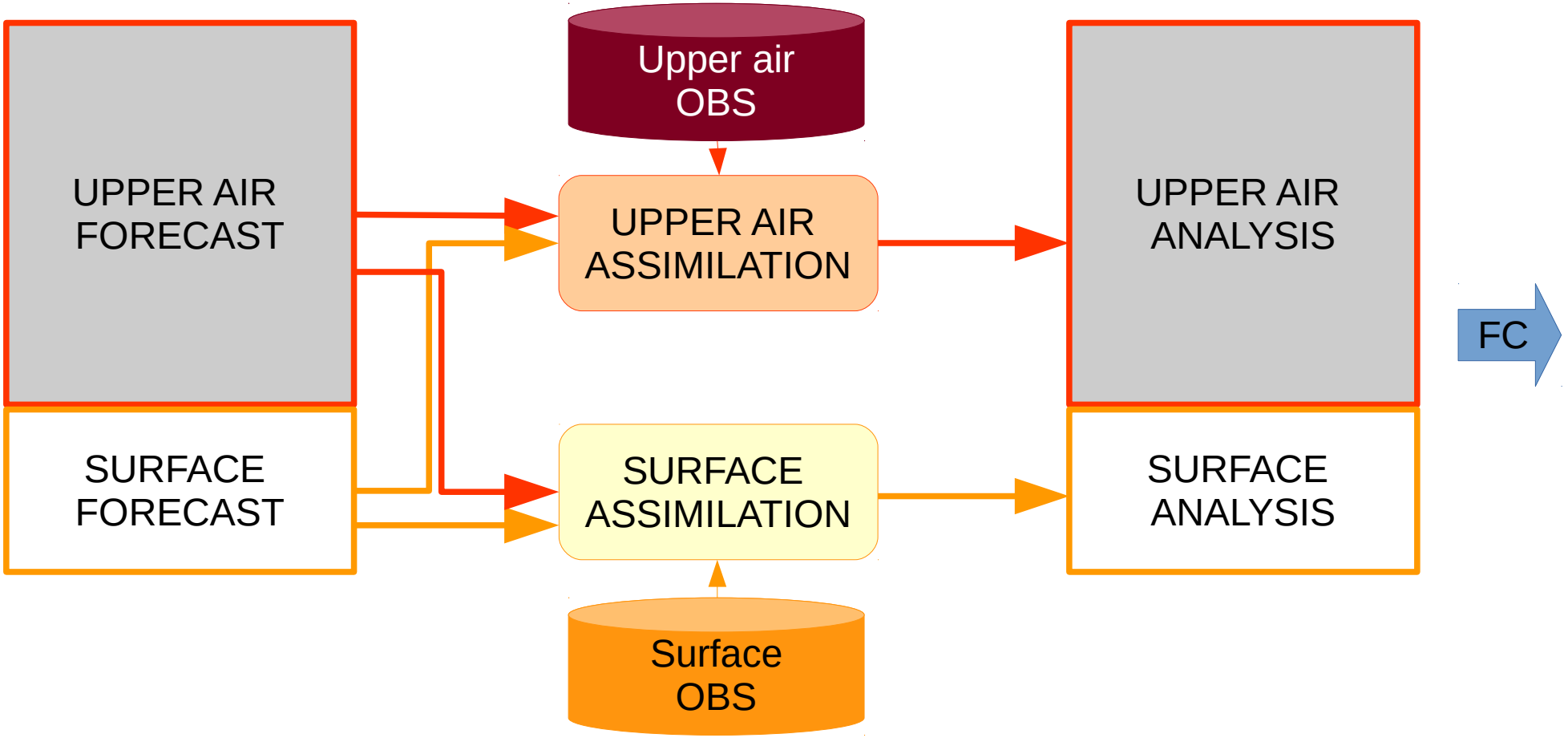
    - Surface temperature (soil+vegetation): T_s
    - Deep soil temperature: T_2
    - Superficial soil moisture content: w_g
    - Root zone soil moisture content: w_2

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

  - Lake

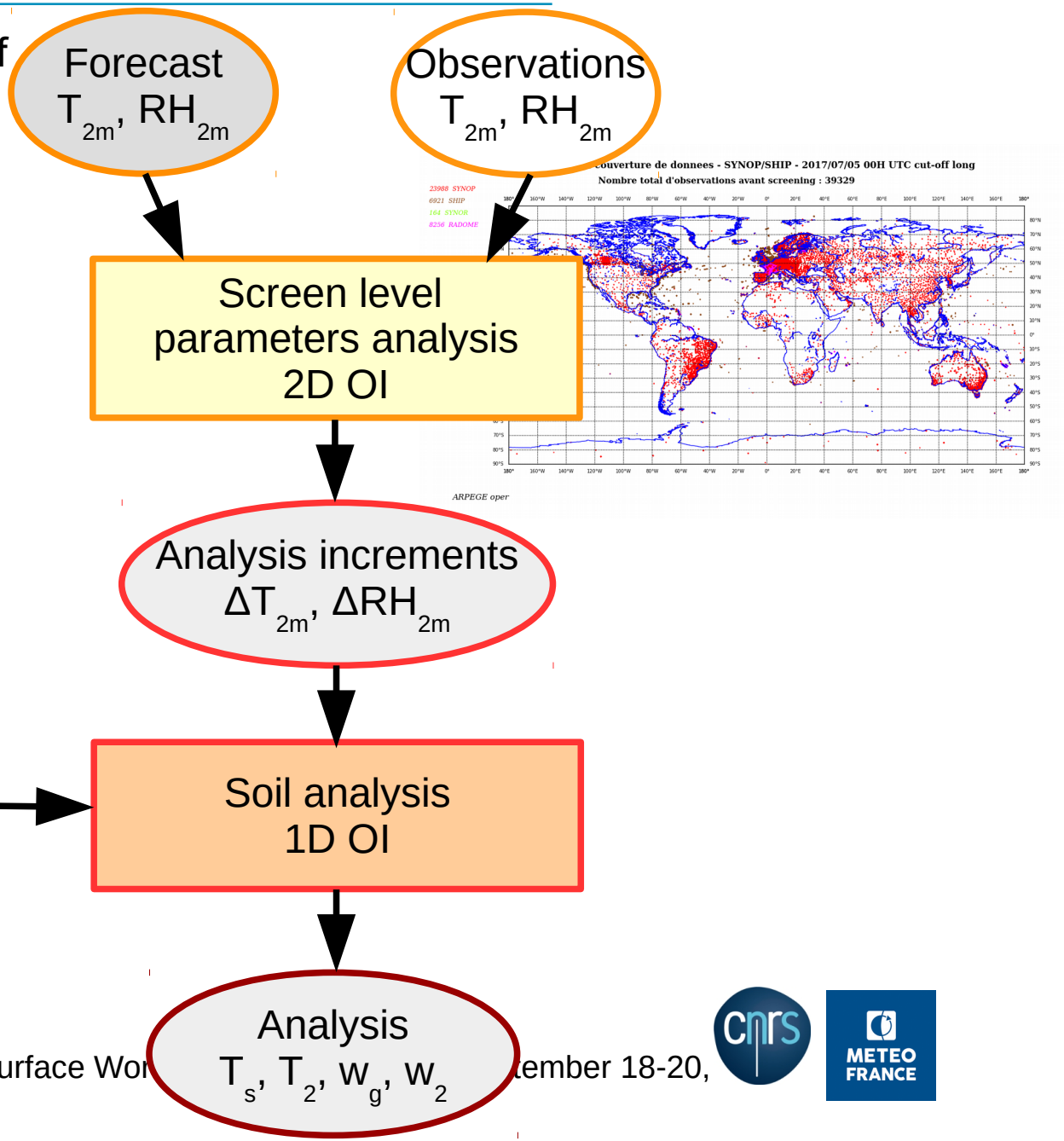
  - Sea → SST

Surface modelling platform SURFEX



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

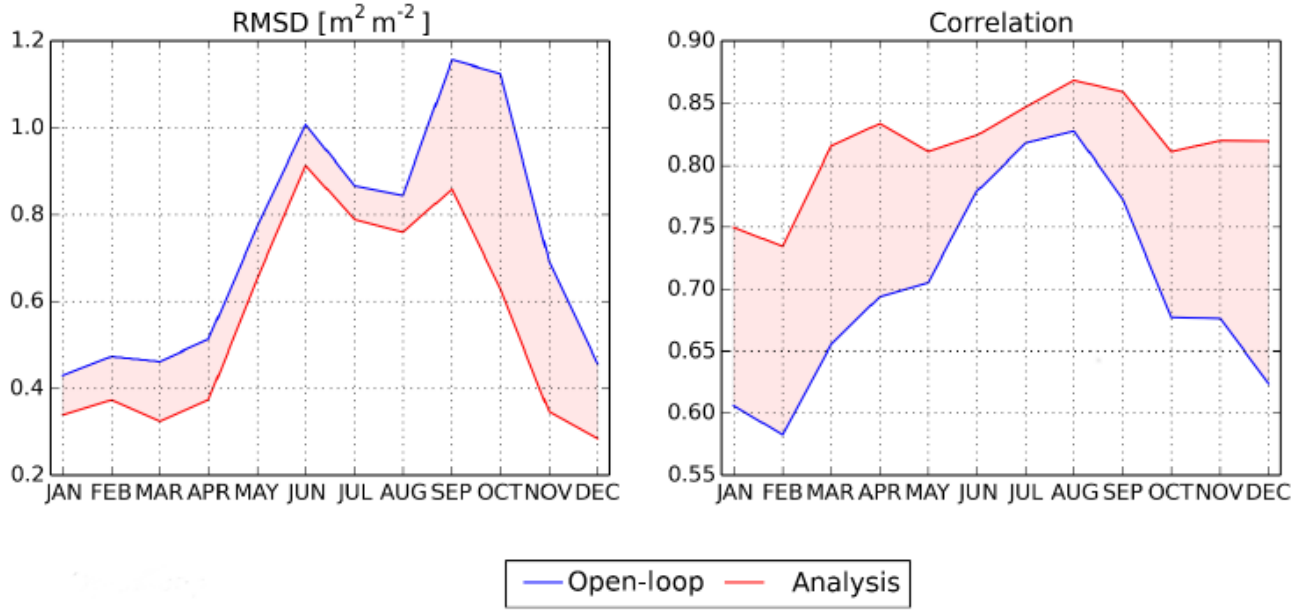


Ongoing developments and future plans

- Assimilation of superficial soil moisture satellite products (L2)
  - ASCAT: L2 products of soil moisture in a NWP framework (Mahfouf 2010)
    - $\Delta w_g = \alpha_1 \Delta T_{2m} + \beta_1 \Delta RH_{2m} + \gamma_1 \Delta w_g^o$
    - $\Delta w_2 = \alpha_2 \Delta T_{2m} + \beta_2 \Delta RH_{2m} + \gamma_2 \Delta w_g^o$
  - SMOS / SMAP (L-band): L2 products (no assimilation of Tbs) in near-real time (3h cutoff)

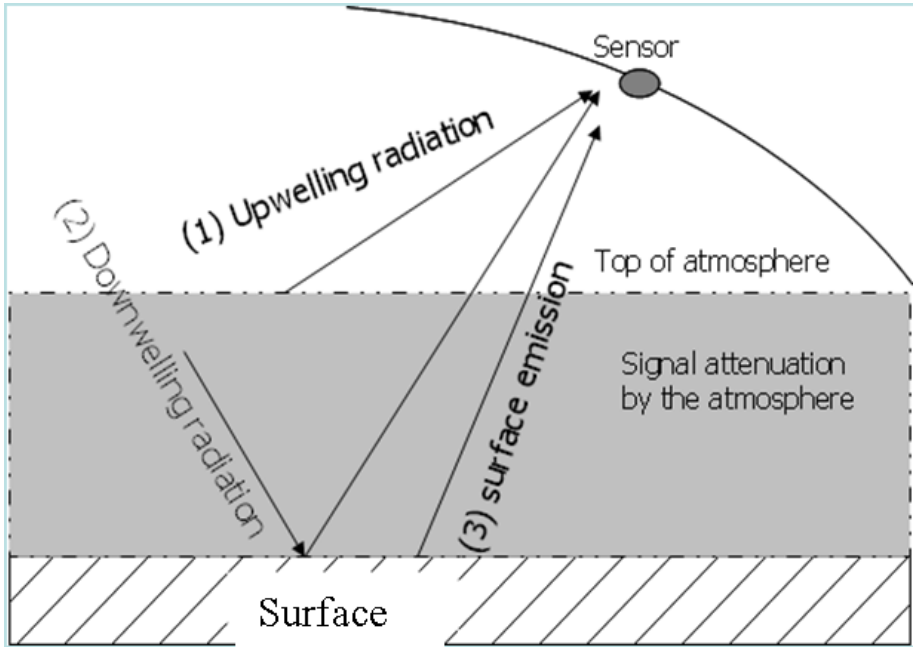
In a research context, Albergel et al., 2017 assimilate ESA-CCI-SSM and LAI in Surfex (diffusion version) using an SEKF in offline mode.

Monthly RMSD and correlation values between leaf area index (LAI) from the open-loop (blue line), analysis (red line) and GEOV1 LAI estimates from the Copernicus Global Land Service project over 2000-2012 (Albergel et al., 2017).



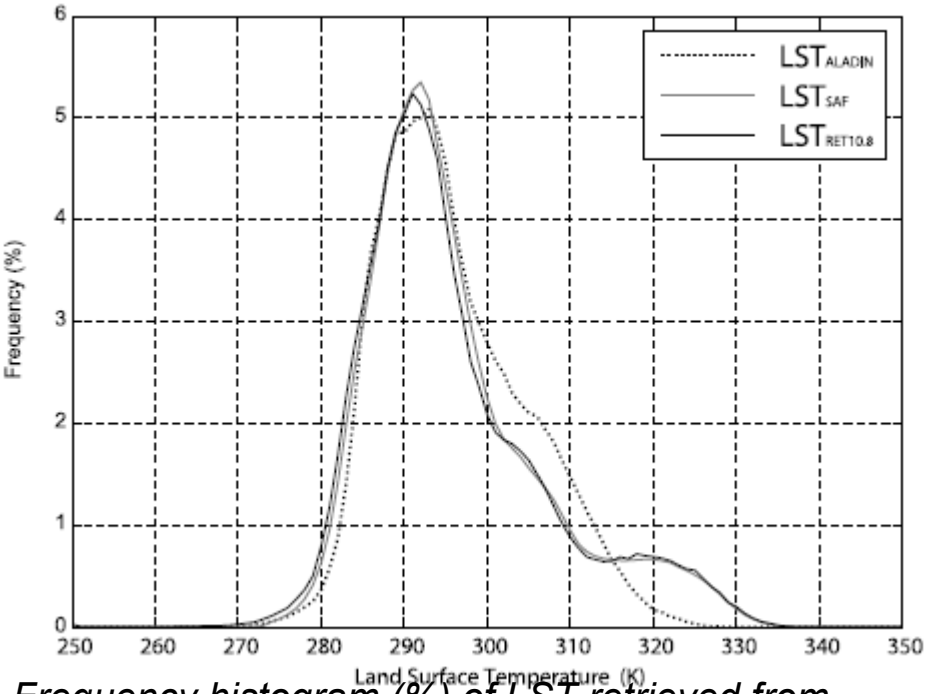
Ongoing developments and future plans

- Assimilation of IR land surface temperature (LST) (Guedj et al., 2011 (SEVIRI in ALADIN model), Vincensini, 2013 (IASI in ARPEGE model), Boukachaba et al., 2017 (IASI in AROME model))



Simplified scheme of the radiative transfer

$$T_s = B\left[\frac{T(p,\nu) - T(p,\uparrow) - \tau(1-\epsilon(p,\nu))T(p,\downarrow)}{\tau\epsilon(p,\nu)}\right]^{-1}$$



Frequency histogram (%) of LST retrieved from SEVIRI channel at 10.8 µm (black line), LST_{SAF} from EUMETSAT Land-SAF (grey line) and LST from analyses of land surface temperature from the operational runs of the Météo France model ALADIN (dotted line) from 15 July to 15 August 2009 (Guedj et al., 2011)

- PhD on the synergy of satellite observations for the definition of surface temperature

Ongoing developments and future plans

- Snow analysis: 2D-OI using in-situ observations
  - satellite products of snow cover (Nesdis-IMS/H-SAF product/Modis?)
- Analysis of other surface parameters (precipitation, LAI, radiation...)
- Evolution of the land data assimilation system using ensemble (EnKF or another ensemble technique)
  - Use of atmospheric ensembles from atmospheric ensemble data assimilation systems (information about Jacobians) (e.g. Fairbairn et al. (2015) compare EnKF and SEKF in research framework)
- Develop a land surface data assimilation system compatible with the evolution of surface schemes (increase of the number of layers, diffusive version...)

Conclusions

- In NWP the ISBA-3L scheme is used with pronostic variables in the two upper layers
- Assimilation of T2m and RH2m to analyse soil variables
- Satellite observations: preliminary studies using L2 products
  - ASCAT surface soil moisture in a NWP context
  - ESA-CCI-SSM product in a research mode using a diffusion version of ISBA
- Assimilation of LST retrieved from satellite observations (preliminary studies with IR observations)
- SMAP / SMOS and L-band observations: L2 products of soil moisture in real time
- Plans to use ensemble techniques for land surface data assimilation