Preliminary steps towards the assimilation of satellite derived soil moisture in the Météo-France NWP models

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11 June 2009

A short history on land data assimilation for NWP (1)

- 1980's :
  - Developments of improved land surface schemes for NWP and climate models (e.g. the ISBA scheme [Noilhan and Planton, 1989] at Météo-France)
  - Need for soil moisture initialization in NWP models (sensitivity experiments)
  - Feasibility studies using IR skin temperature for GEO satellites and screen-level observations from surface networks
- 1990's :
  - Simple soil analysis schemes based on OI with screen-level observations used in a number of operational weather centres (ECMWF : Douville et al., 2000; Météo-France : Giard and Bazile, 2000)
  - Use of IR satellite products not very successful

A short history on land data assimilation for NWP (2)

- 2000's :
  - Availability of low frequency MW products informative about soil moisture (AMSR-E, TMI, ERS, ASCAT, ...)
  - Plans for future satellite missions (SMOS, HYDROS [SMAP])
  - Feasibility studies on the information content of superficial soil moisture on root-zone soil moisture
  - Development of improved soil analysis schemes suitable for the assimilation of satellite microwave products and/or radiances.
- 2010's
  - Operational assimilation of satellite information about land surfaces in NWP models (positive impacts on forecast scores ?).
  - "Suitable" observational data set : ASCAT superficial soil moisture (availability in BUFR format in operational weather centres and temporal continuity on MetOp)
  - Improved land data assimilation systems : offline EKF (ECMWF, Météo-France) or EnKF (MetOffice, CMC, NASA)

Current developments at Météo-France

- Land data assimilation system : Extended Kalman filter developed within the externalized land surface platform SURFEX (currently coupled to the limited area NWP models AROME (2.5 km) and ALADIN(9.5km)) - OI also available.
- Land surface scheme : 2-layer version of ISBA (force-restore method) [4 main prognostic variables]
- Observations : screen-level observations (T_{2m}, RH_{2m}), satellite derived superficial soil moisture w_g (AMSR-E, ERS, ASCAT)
- Methodology : short assimilation window (6-h) - Jacobians of the observation operator estimated in finite differences (local analysis)
- New additional components :
  - EnKF and PF : developed at NILU/Met.No
  - EKF version allowing the assimilation of LAI observations using ISBA-Ags (dynamical vegetation)

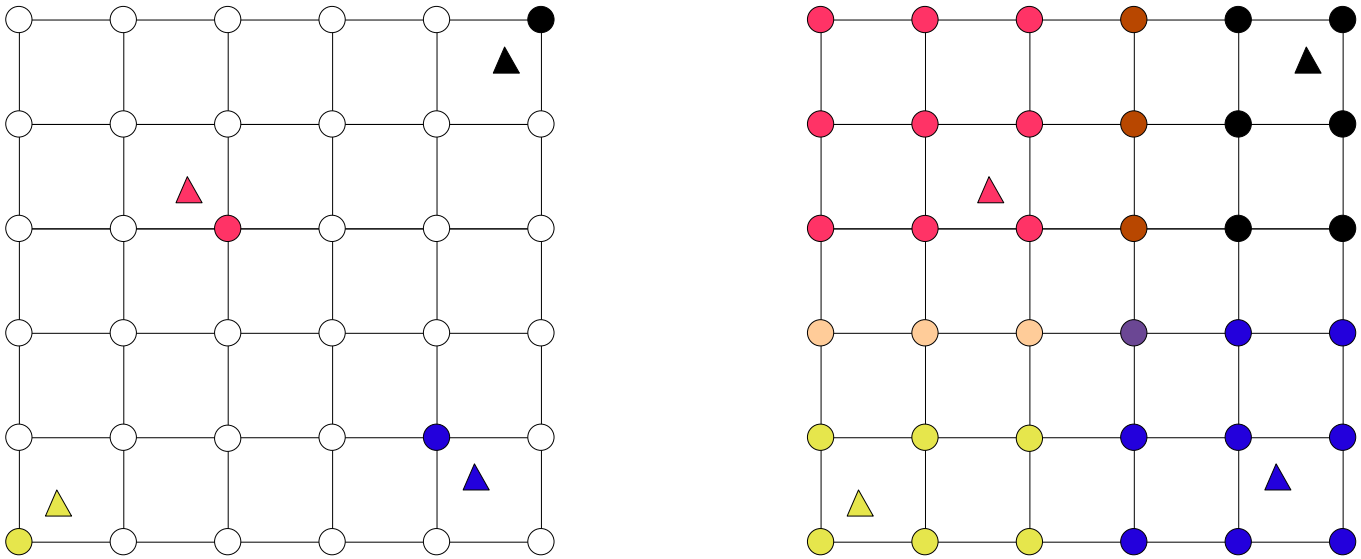
Steps towards the assimilation of satellite soil moisture in NWP models

- Interpolation of observations on model grid (analysis done in model space)
- Use of a bias correction scheme for observations
- Specification of observation errors
- Examine the link between the control variable and the observation (Jacobians)
- Definition of the data assimilation system (assimilation length, background errors, quality controls, ...)

Illustration : assimilation of ERS superfical soil moisture retrievals

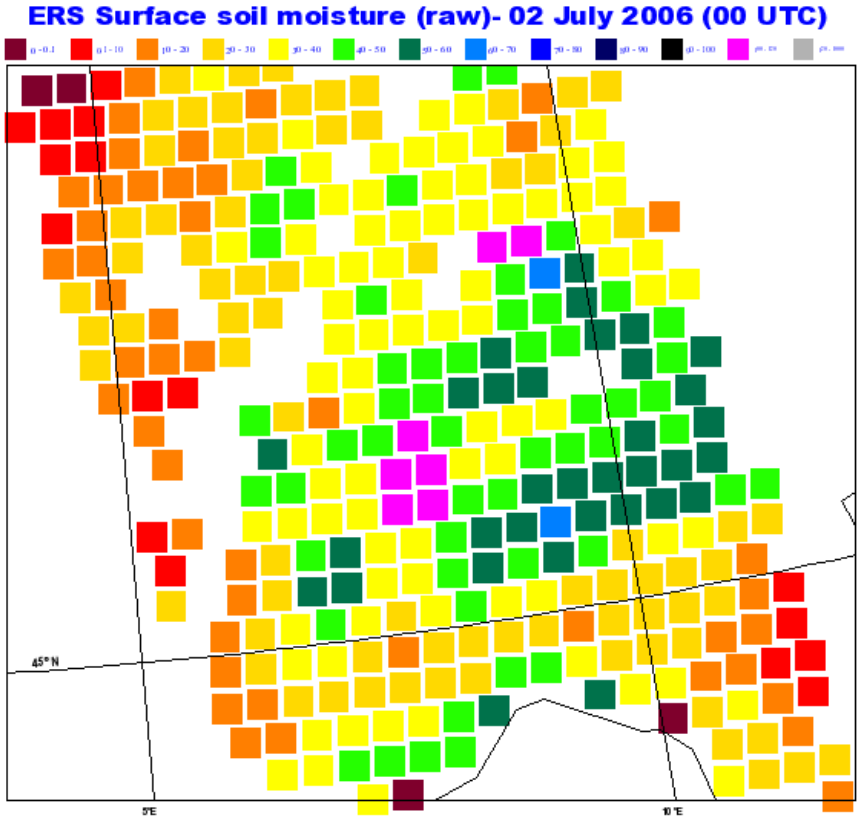
- Period : July 2006
- Data : w_g derived from C-band scatterometer ERS2 (change detection method) - available on a 27 km grid
- Technique : Extended Kalman Filter (with constant background error)
- Assimilation window : 6h
- Control variables : w_2 (root-zone soil moisture content)
- Error specification : σ^b_{w2}=0.01 m^3/m^3, σ^o_{wg}=0.02 m^3/m^3
- Numerical model : ALADIN-France with ISBA 2-L (9.5 km resolution)

Projection on model grid

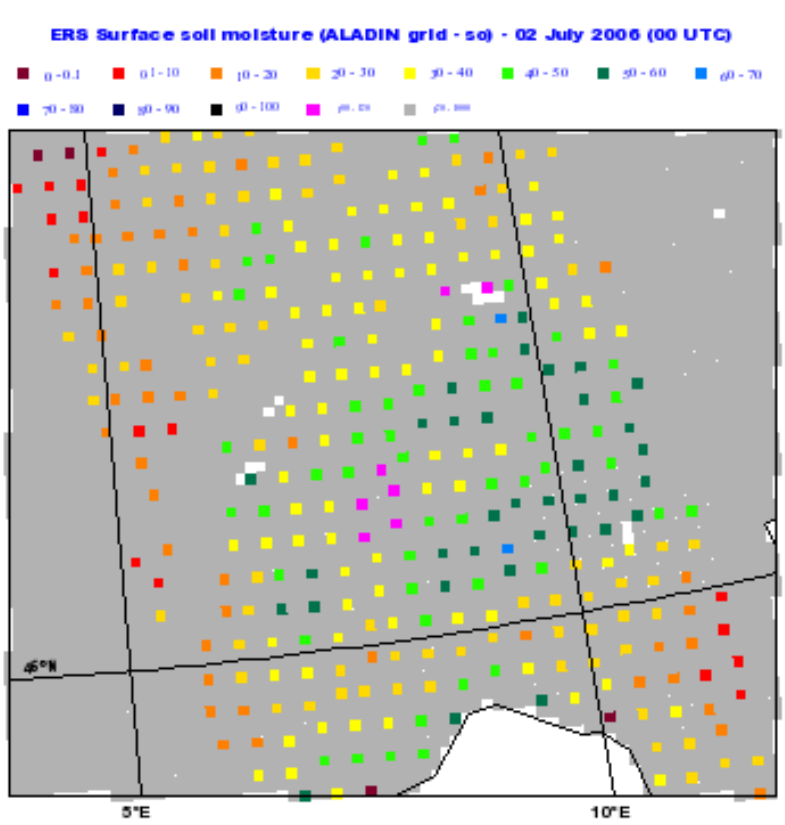


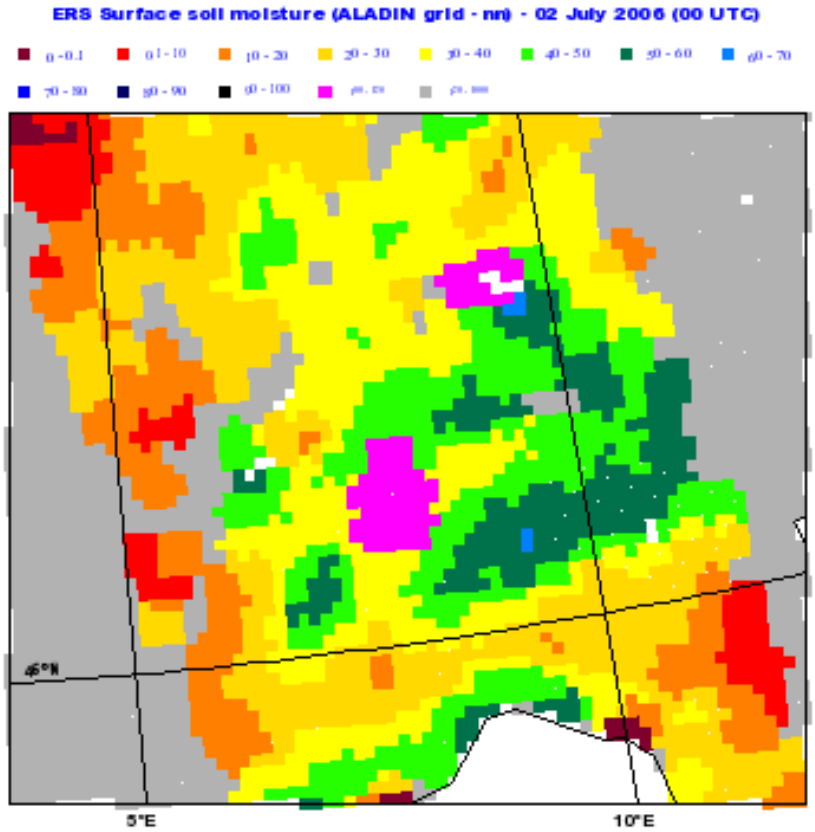
Nearest neighbour (nn) - Oversampling (os)

Raw data



Projected data

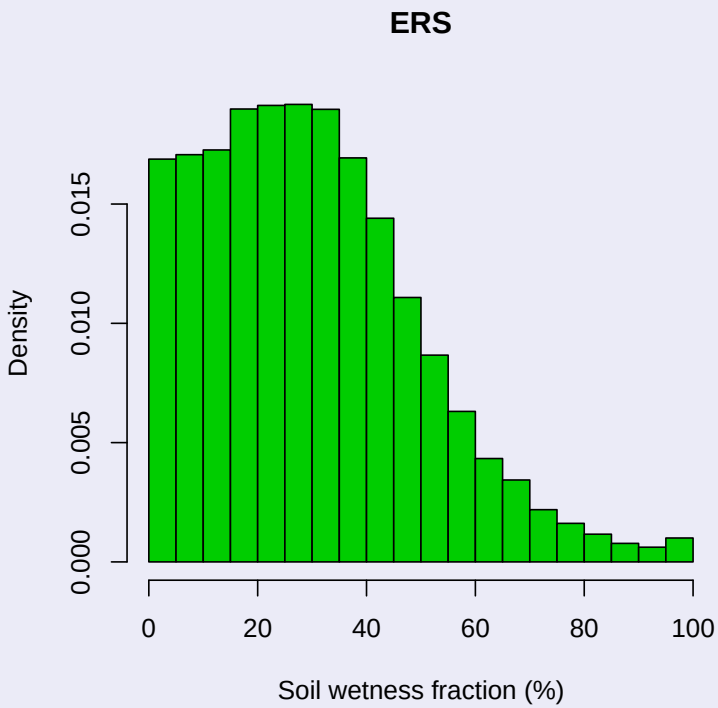


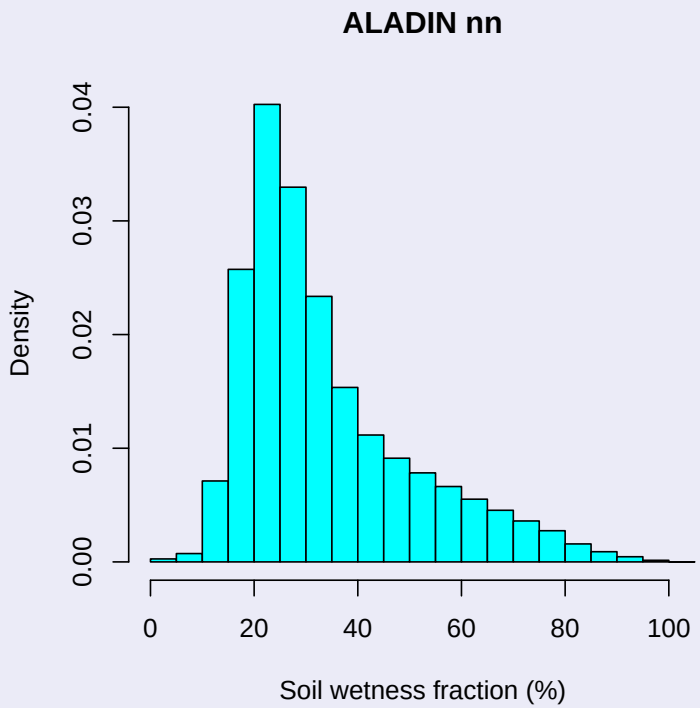


Nearest neighbour (nn) - Oversampling (os)

Comparison w_g/w_{sat} ERS vs. w_g/w_{sat} ALADIN (nn)

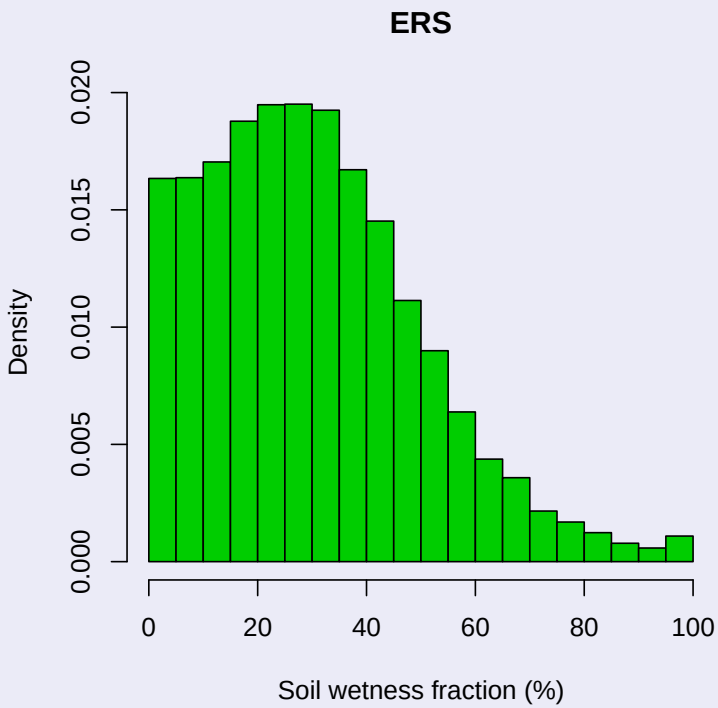
Raw observations without bias correction

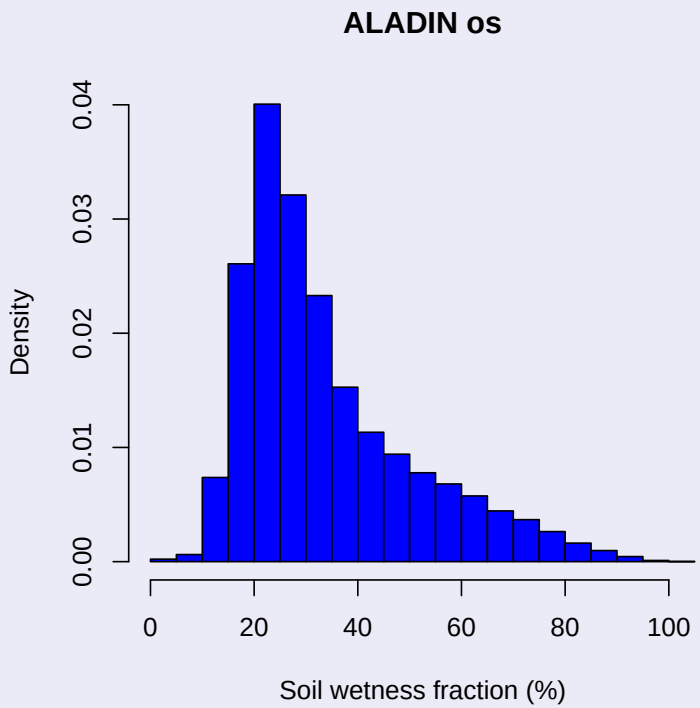




Comparison w_g/w_{sat} ERS vs. w_g/w_{sat} ALADIN (os)

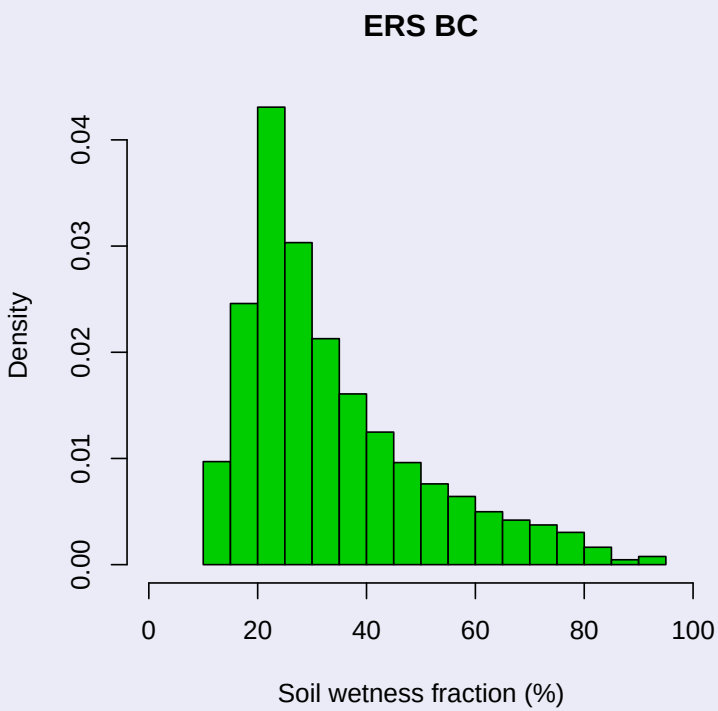
Oversampled observations without bias correction

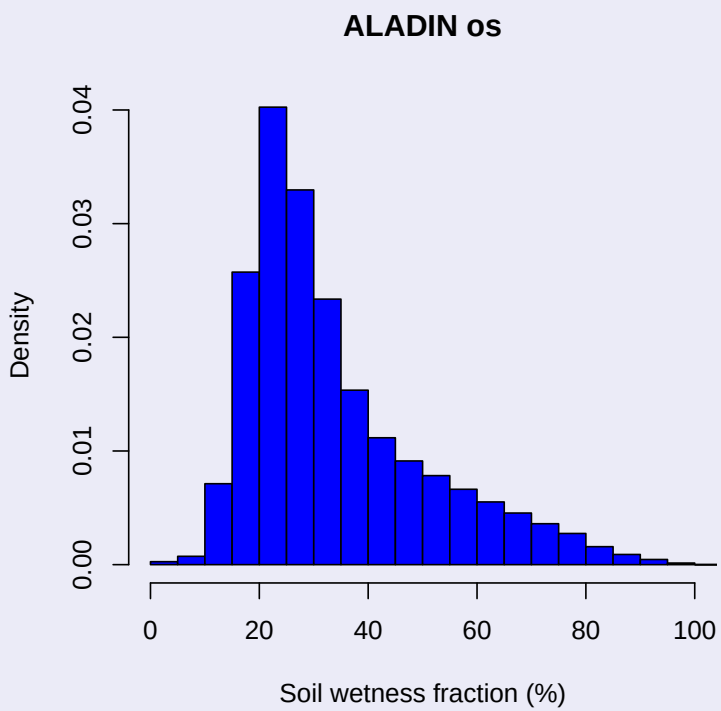




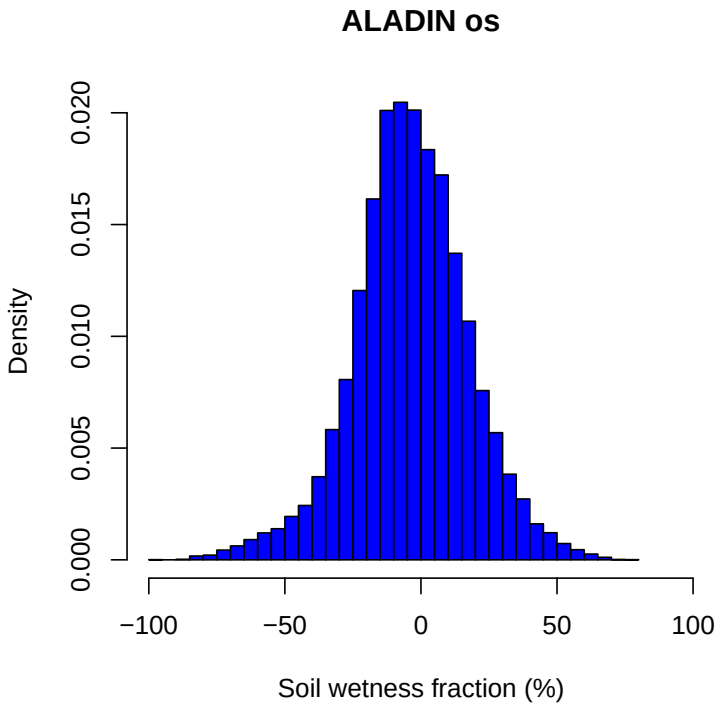
Comparaison w_g/w_{sat} ERS vs. w_g/w_{sat} ALADIN (os)

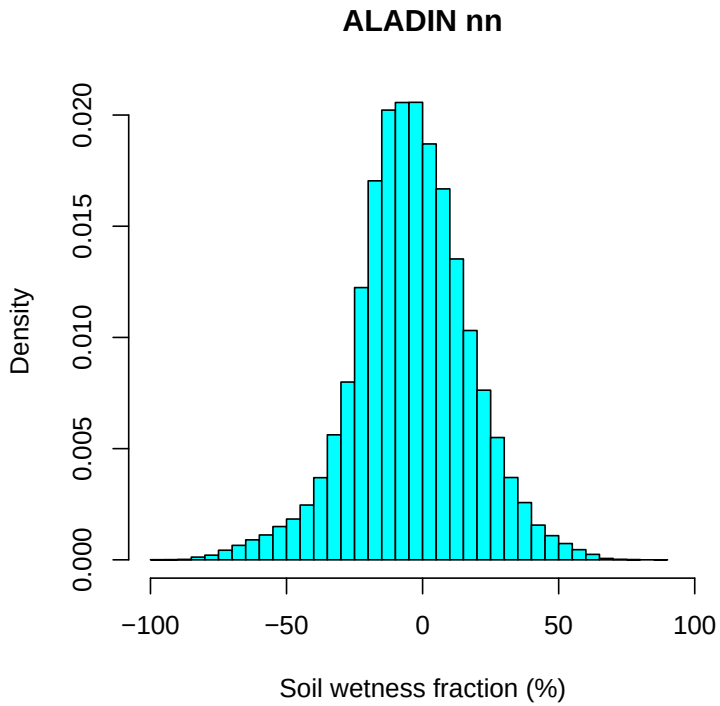
Bias corrected observations using CDF matching





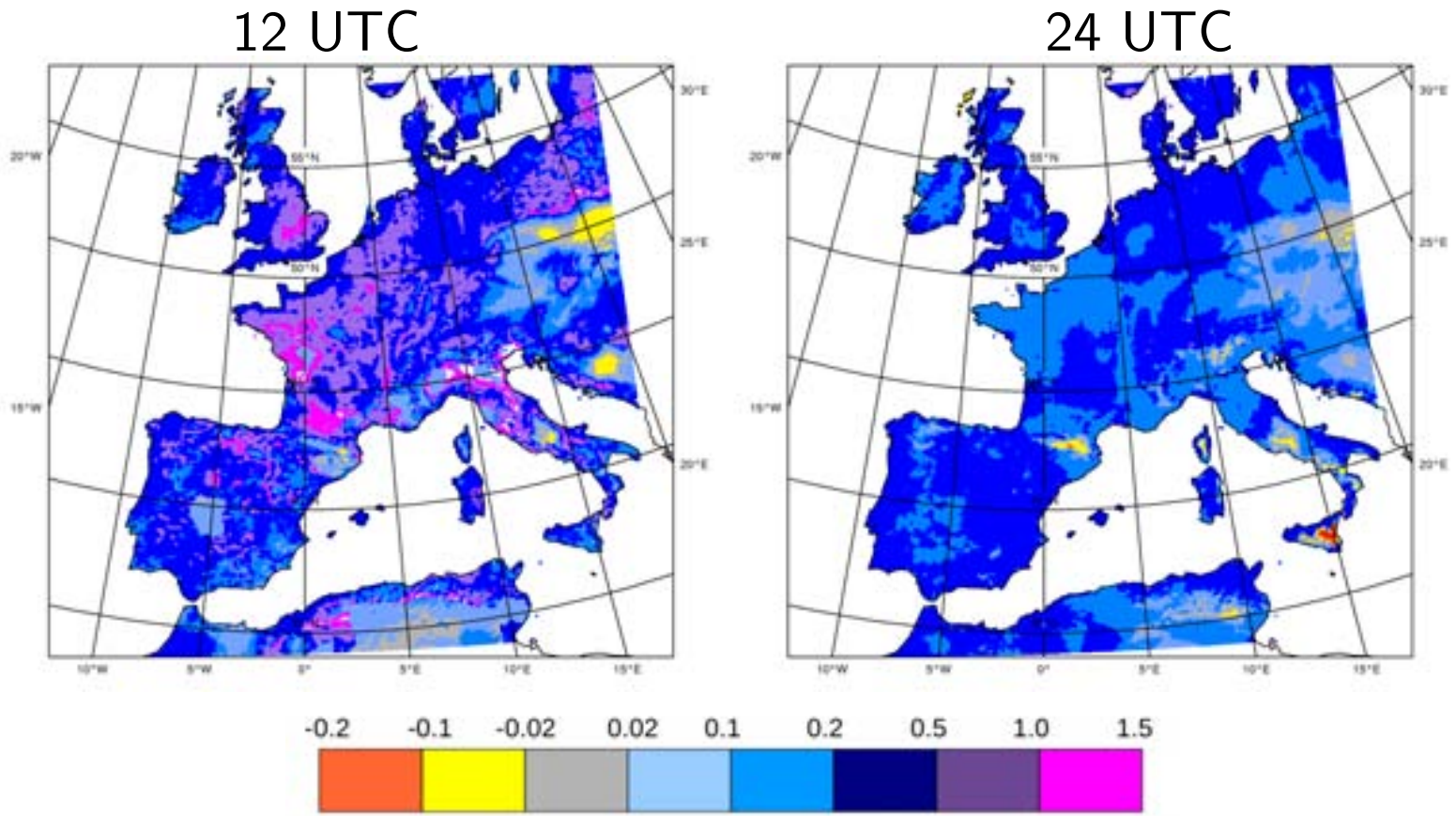
Distribution of innovations





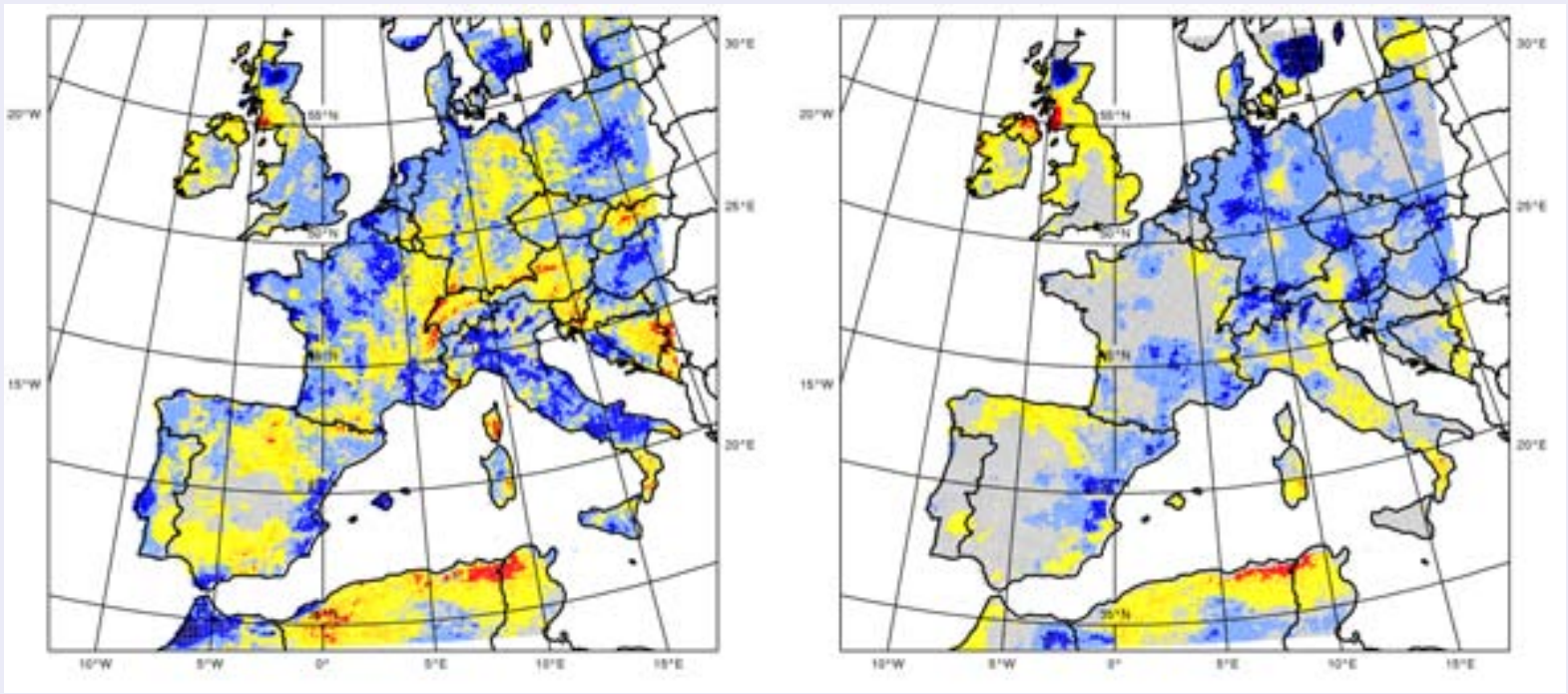
$$\sigma_o = \sigma_b = 13\ \% \quad => \quad 0.06\ m^3/m^3$$

Jacobian $\partial w_g / \partial w_2$



Root-zone soil moisture increments (mm) July 2006

assimilation (T_{2m}+RH_{2m}+w_g) - assimilation (w_g)



Conclusions

- Development of an externalized land data assimilation system based on an EKF for the analysis of soil prognostic variables in numerical weather prediction models at Météo-France
- This new system allows the assimilation of satellite derived superficial soil moisture currently available from a number of microwave instruments (AMSR-E, ERS, ASCAT)
- Encouraging results over ALADIN-France domain for the assimilation of screen-level observations (Mahfouf et al., 2009; JGR), ERS and AMSR-E satellite soil moisture (Draper et al. 2009; JGR). In particular, NWP soil moisture products at 10 km can be compared to oversampled satellite derived products at 30/50 km. The assimilation can be performed over short assimilation windows (compatible with NWP atmospheric analyses).

Some selected remaining issues

- Assimilation issues (Jacobian of observation operator) :
  - The 2-layer force-restore method provides a (too ?) strong link between superficial soil moisture and root-zone soil moisture.
  - The use of one single surface temperature (bare soil and vegetation) provides a daytime spurious link between superficial and root-zone soil moisture contents.
  - The Jacobian in weak forcing conditions (no precipitation flux, no evaporation) could be estimated analytically with ISBA-2L.
- Observation error specification : "realistic" observation errors are significantly higher than background errors projected in observation space !
- The bias correction for ERS w_g has to be improved using longer time series (done for AMSR-E)
- Examine the impact in terms of NWP forecast scores (so far ECMWF experiments have either shown neutral or negative impacts w.r.t. to the assimilation of screen-level variables)