Surface analyses for NWP model initialization at Météo-France

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Plan

- Introduction
- Soil moisture and soil temperature analysis
- Others analyses: snow, sea surface temperature, sea ice, ...

Introduction

Introduction

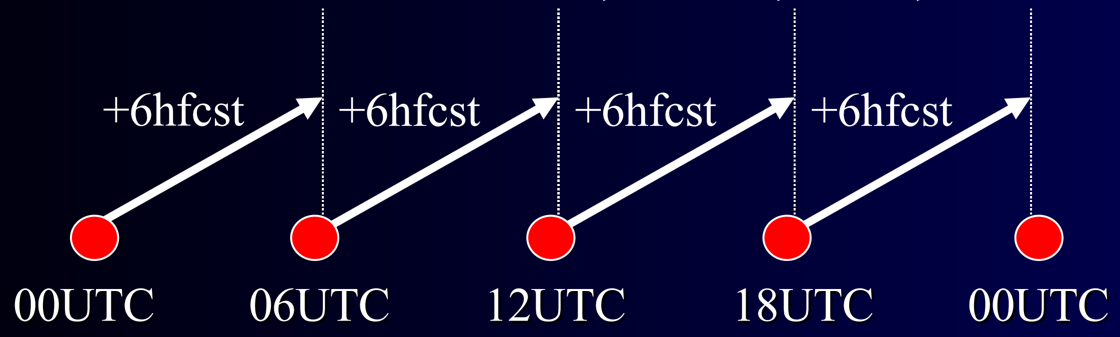
- Surface fluxes : key role in the evolution of meteorological fields near the ground, in the boundary layer and in the troposphere

- These fluxes depend strongly on surface variables which have strong variabilities in time and space (pronostic variables)

  ⇒ Necessity of same degree of sophistication between surface scheme, physiographic database, surface analysis

- Surface analyses are performed separately from upper air analysis

- Several surface analyses are used for different surface parameters (Soil temperature and Soil moisture, Snow, SST, Sea ice, ...)

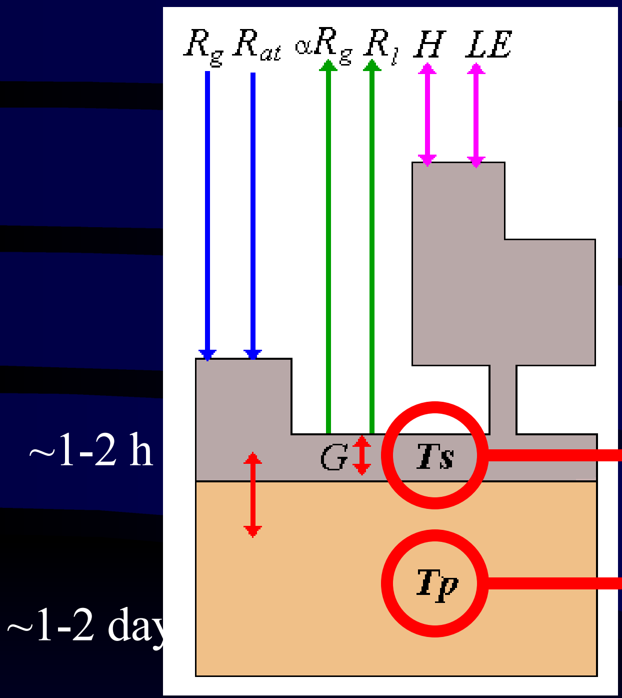


Soil moisture and soil temperature analysis

Surface Parameterization scheme (ISBA)

Operational version : Noilhan & Planton (1989), Noilhan & Mahfouf (1996), Bazile (1999), Giard & Bazile (2000)

Energy



Analysis

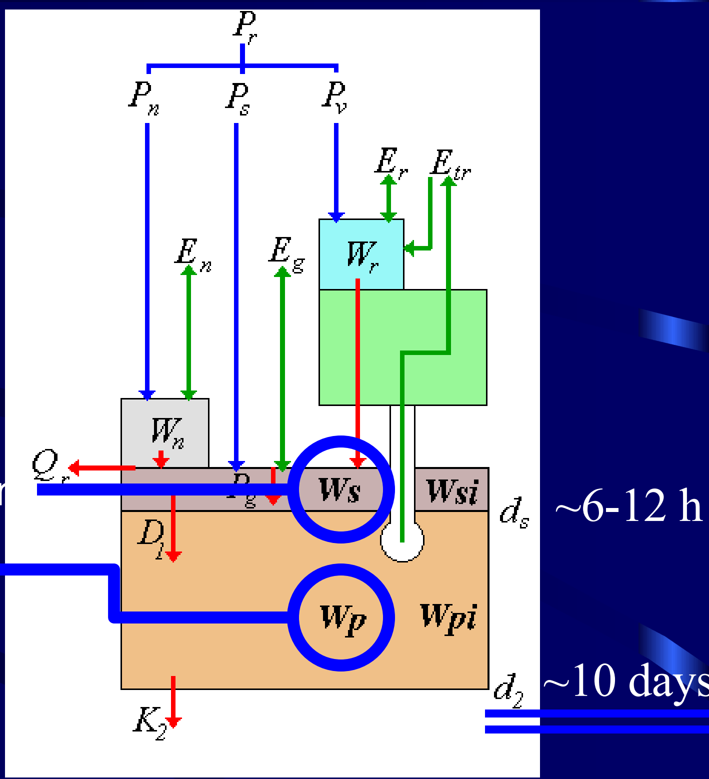
surface temperature

mean soil temperature

superficial soil water content

total soil water content

Water



Research versions : interactive vegetation module (Calvet et al. 1998),

sub grid-scale runoff and sub-root layer (Boone et al 1999),

explicit 3-layers snow scheme (Boone & Etchevers 2001), tiling,

multi-layer soil scheme, urban scheme

Importance of soil moisture and temperature analysis

- Stable surface conditions : Low surface fluxes. Influence of surface limited near the ground.

- Neutral/instable surface conditions : Strong surface fluxes. Influence on PBL evolution and sometimes more (trigger deep convection)

Soil moisture initialization is very important under strong solar radiation (determines Bowen ratio).
Wr << Ws << Wp according time scale evolution.
Accumulation of model error may degrade significantly the forecast during long period

Optimum Interpolation method

Coiffier 1987, Mahfouf 1991, Bouttier 1993, Giard and Bazile 2000

1) Optimum Interpolation of T_{2m} and RH_{2m} using SYNOP observations interpolated at the model grid-point (by a 2m analysis)

$$\Delta T_{2m} = T_{2m}{}^{a} - T_{2m}{}^{b} \qquad \Delta RH_{2m} = RH_{2m}{}^{a} - RH_{2m}{}^{b}$$

2) Correction of surface parameters (T_s, T_p, W_s, W_p) using 2m increments between analysed and forecasted values

$$\boxed{\mathbf{x}^{a} = \mathbf{x}^{b} + \mathbf{BH}^{T}(\mathbf{HBH}^{T} + \mathbf{R})^{-1}(\mathbf{y} - H(\mathbf{x}^{b}))}$$

$$T_s{}^{a} - T_s{}^{b} = \Delta T_{2m}$$

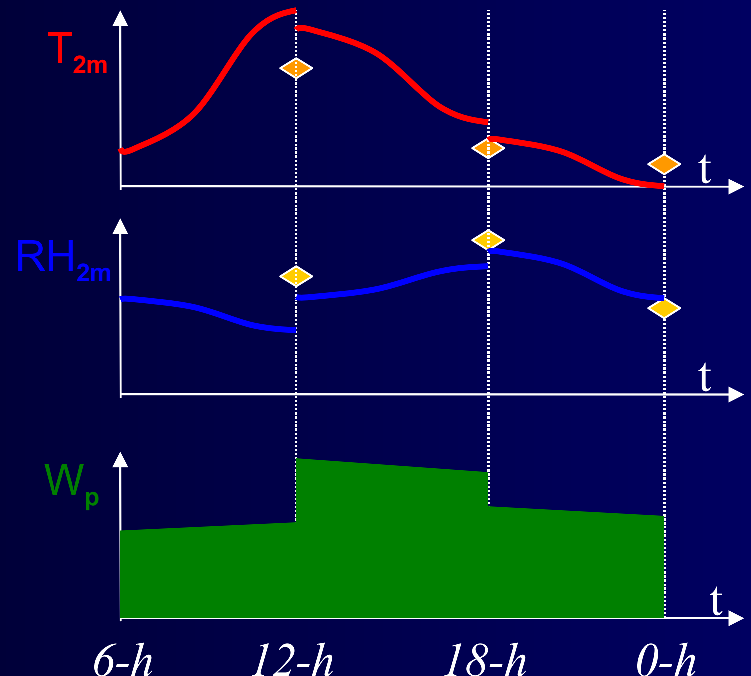
$$T_p{}^{a} - T_p{}^{b} = \Delta T_{2m} / 2\pi$$

$$W_s{}^{a} - W_s{}^{b} = \alpha_{WsT} \Delta T_{2m} + \alpha_{WsRH} \Delta RH_{2m}$$

$$W_p{}^{a} - W_p{}^{b} = \alpha_{WpT} \Delta T_{2m} + \alpha_{WpRH} \Delta RH_{2m}$$

OI coefficients

Sequential analysis (every 6h)



Optimum Interpolation coefficients

$$\alpha_{Ws/pT} = \frac{\sigma^{b}_{Ws/p}}{\Phi\sigma^{b}_{T2m}}\left\{\left[1+\left(\frac{\sigma^{a}_{RH2m}}{\sigma^{b}_{RH2m}}\right)^{2}\right]\rho_{T2m,Ws/p} - \rho_{T2m,RH2m}\rho_{RH2m,Ws/p}\right\}$$

$$\alpha_{Ws/pRH} = \frac{\sigma^{b}_{Ws/p}}{\Phi\sigma^{b}_{RH2m}}\left\{\left[1+\left(\frac{\sigma^{a}_{T2m}}{\sigma^{b}_{T2m}}\right)^{2}\right]\rho_{RM2m,Ws/p} - \rho_{T2m,RH2m}\rho_{T2m,Ws/p}\right\}$$

$$\Phi = \left[1+\left(\frac{\sigma^{a}_{T2m}}{\sigma^{b}_{T2m}}\right)^{2}\right]\left[1+\left(\frac{\sigma^{a}_{RH2m}}{\sigma^{b}_{RH2m}}\right)^{2}\right] - \rho^{2}_{T2m,RH2m}$$

Very strong dependency of these backgroung error statistics to physiographic properties and meteorological conditions

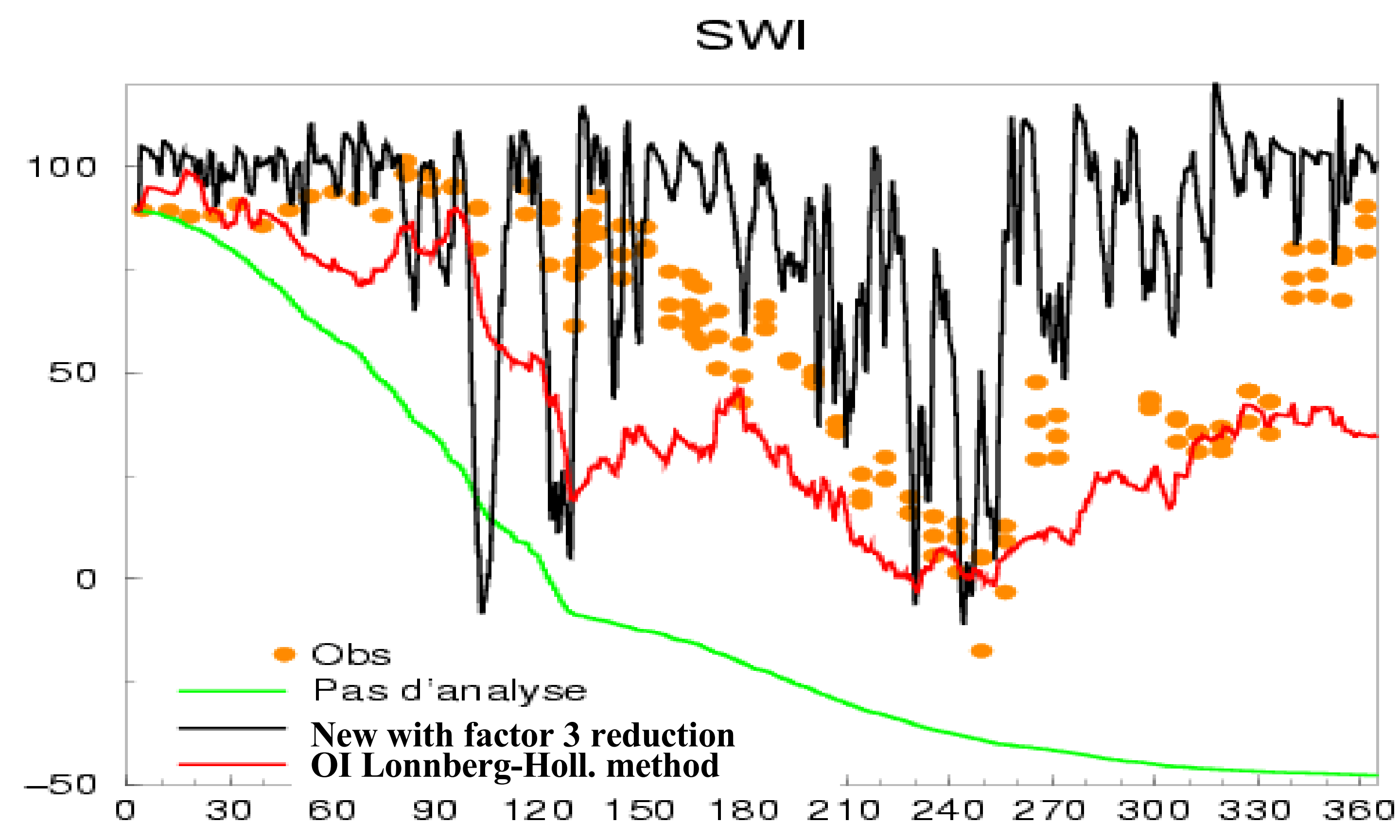
MonteCarlo method under summer anticyclonic conditions to get the dependency to physiography (deriving analytical formulation of OI coefficients) + empirical additional dependency to meteorological conditions

$$\boxed{\alpha_{Wp/sT/RH} = f\,(t,\ veg,\ LAI/Rs_{min},\ texture,\ atmospheric\ conditions)}$$

Long and difficult work (in principle should be redo with model or physiography evolutions!)

Optimum Interpolation method

- March 98:
  - Operational implementation with ISBA
- October 99:
  - Factor 3 reduction of OI coefficients on Wp
  - Continuous formulations for OI coefficients
  - Cloudiness is taken into account in OI coefficients



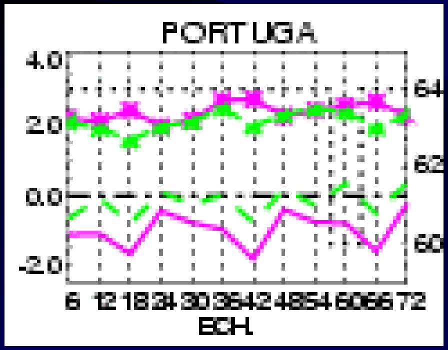
Optimum Interpolation method

- May 03:
  - Spatial smoothing of Soil Wetness Index (SWI)
  - Improved 2m background error statistics (smaller scales)
  - Factor 2 reduction of OI coefficients on Wp
  - Zenith solar angle is taken into account
  - Remove temporal smooting of Wp analysis increments
  - No bias correction on T2m analysis increments

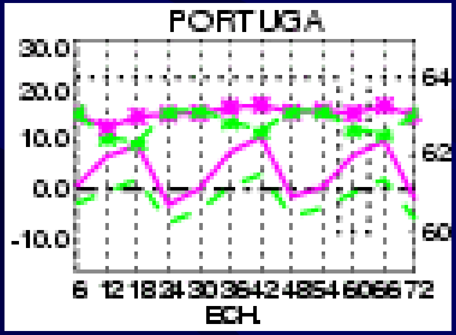
⇒ Improvments of SYNOP scores on T2m and H2m in winter

⇒ More realistic soil moisture

T2m

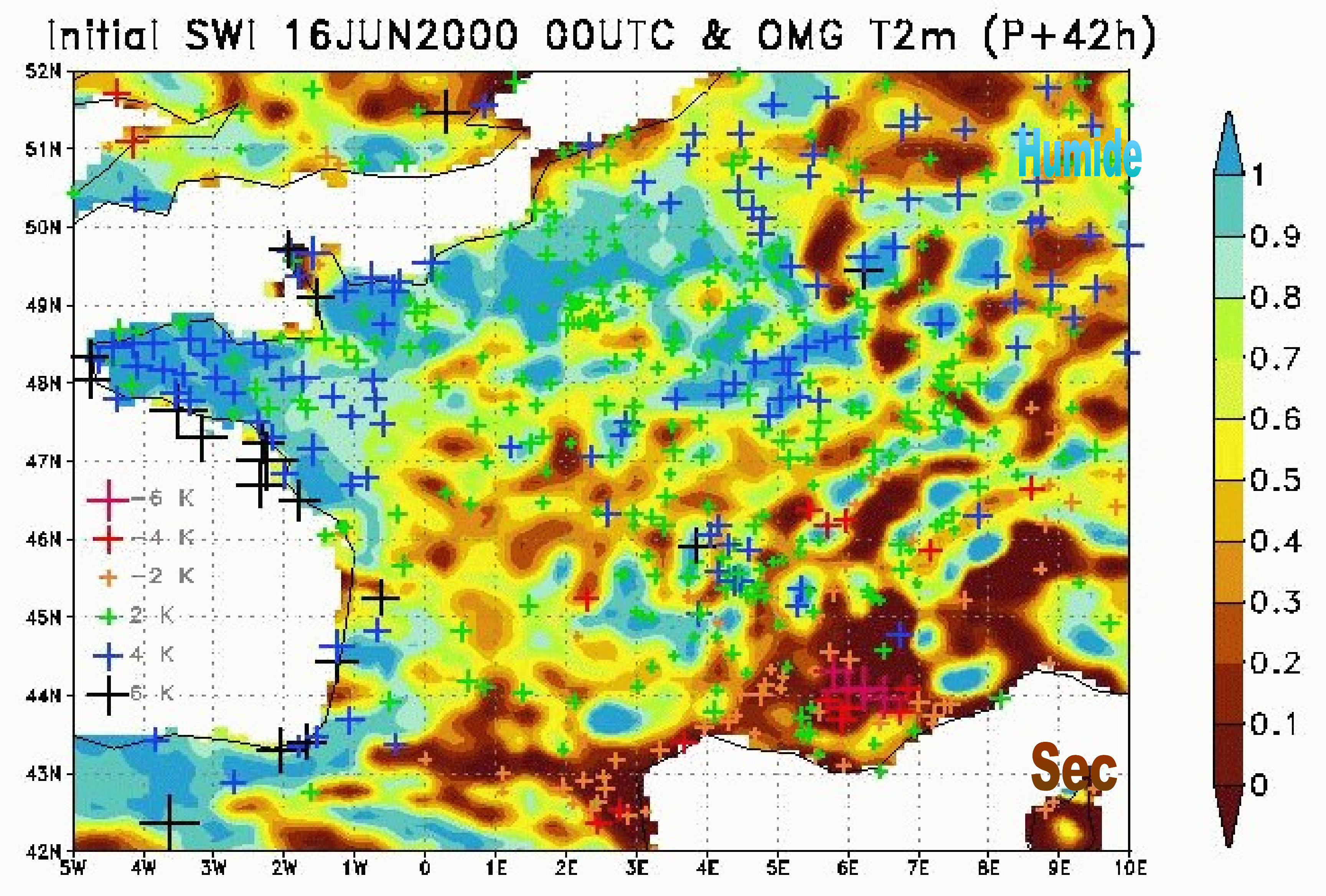


H2m



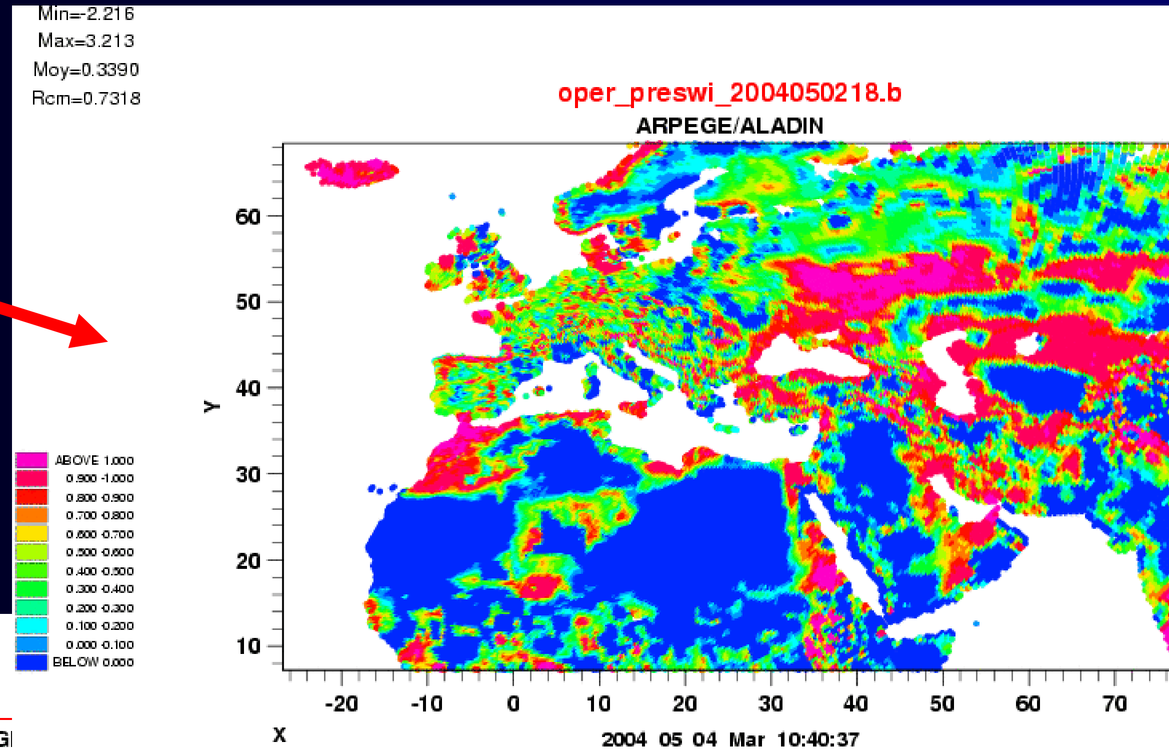
OPER / NEW

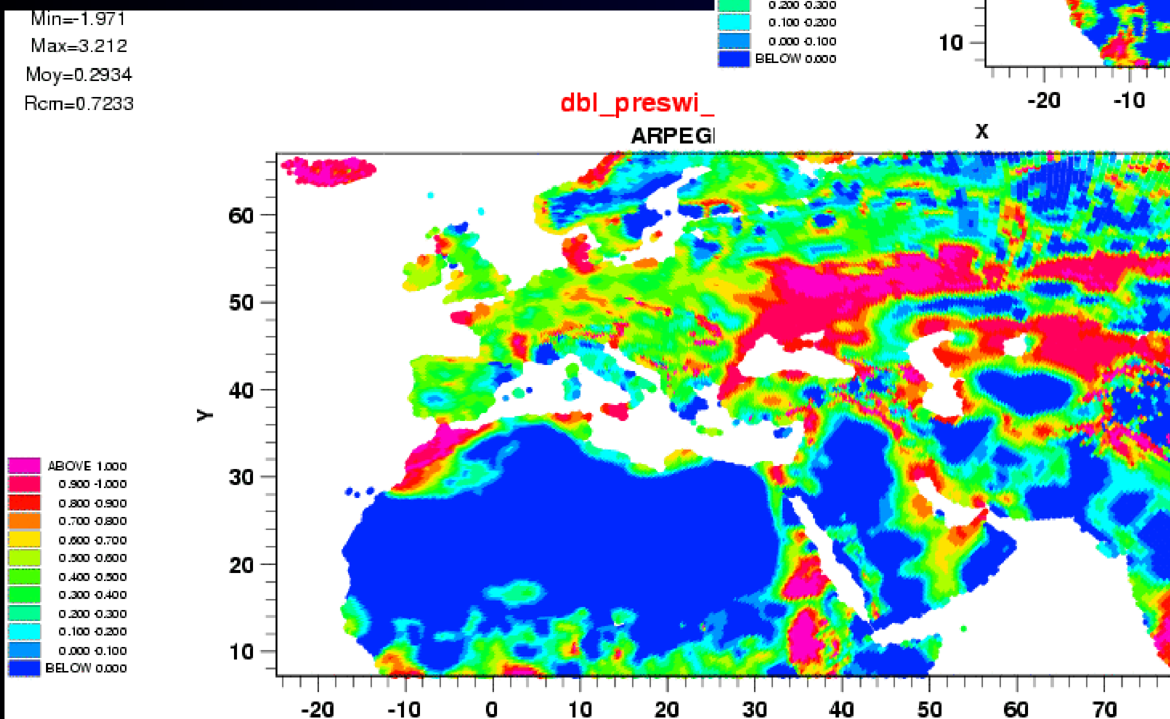
Illustration of problem with first implementation:
42h ALADIN forecast for 17th June 2000 at 18h UTC



Soil wetness index (SWI) pour le 2 mai 2004

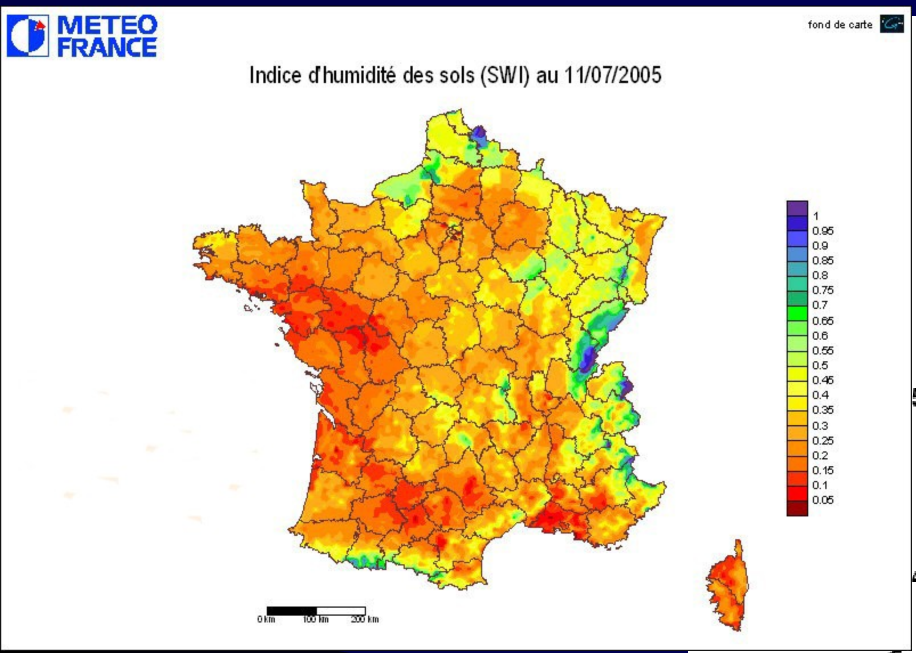
OPER

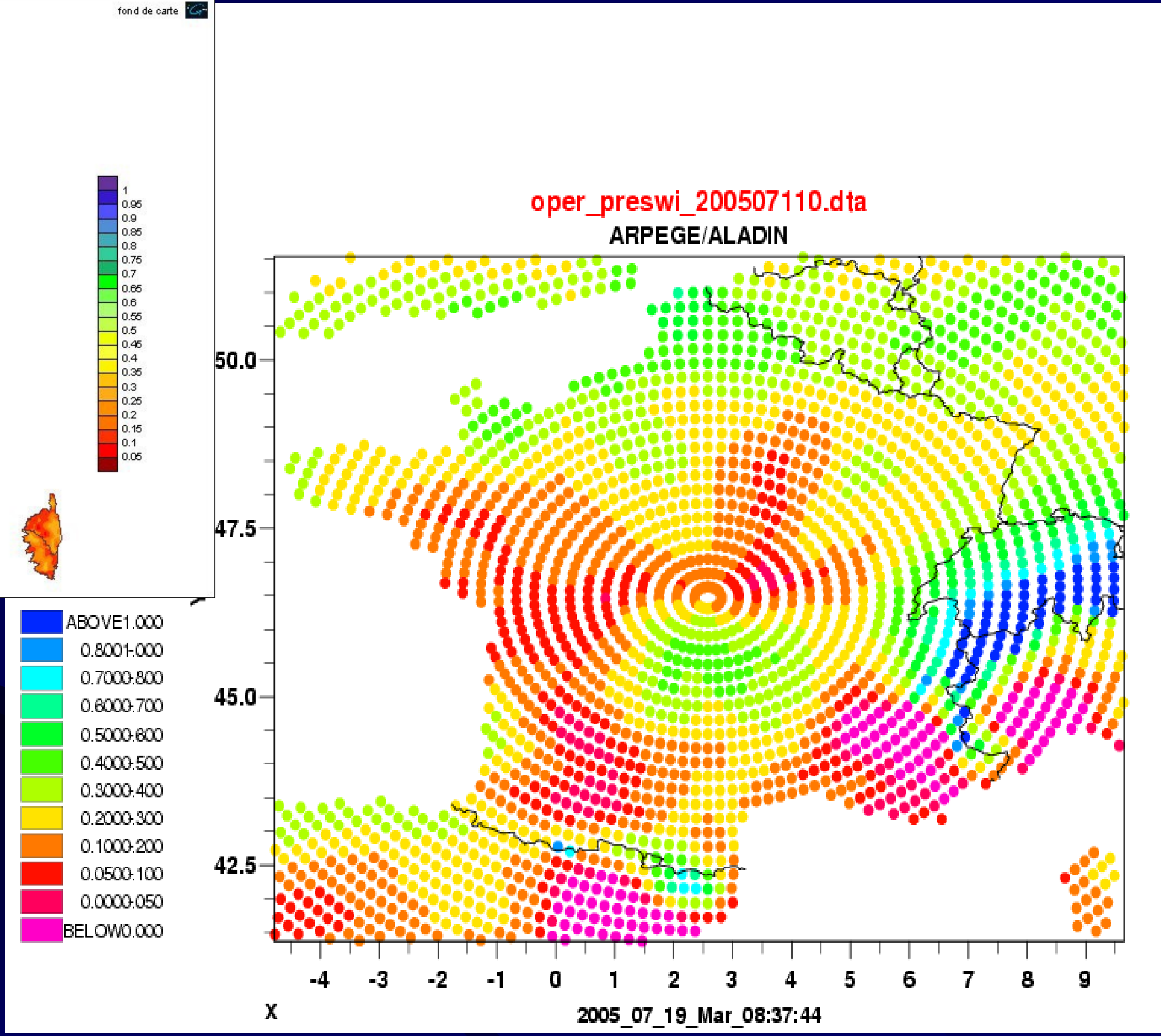




NEW

Soil Wetness Index in SIM (left) et in ARPEGE (right)
11 July 2005

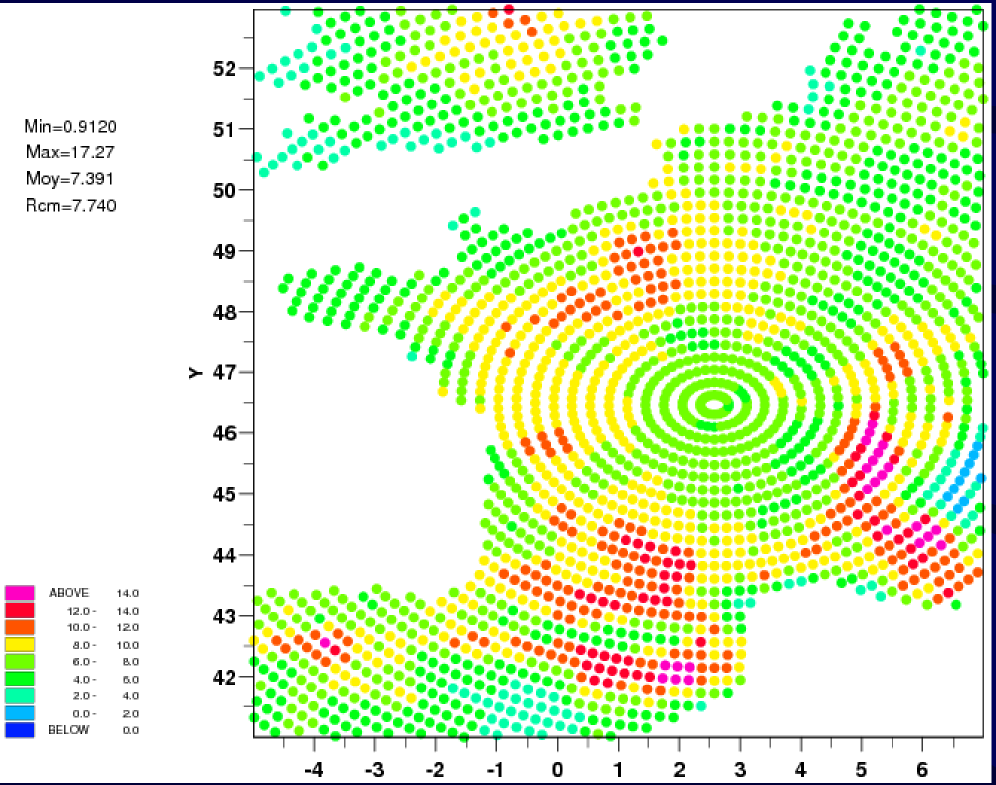




Analysis increments (May-June 2006)

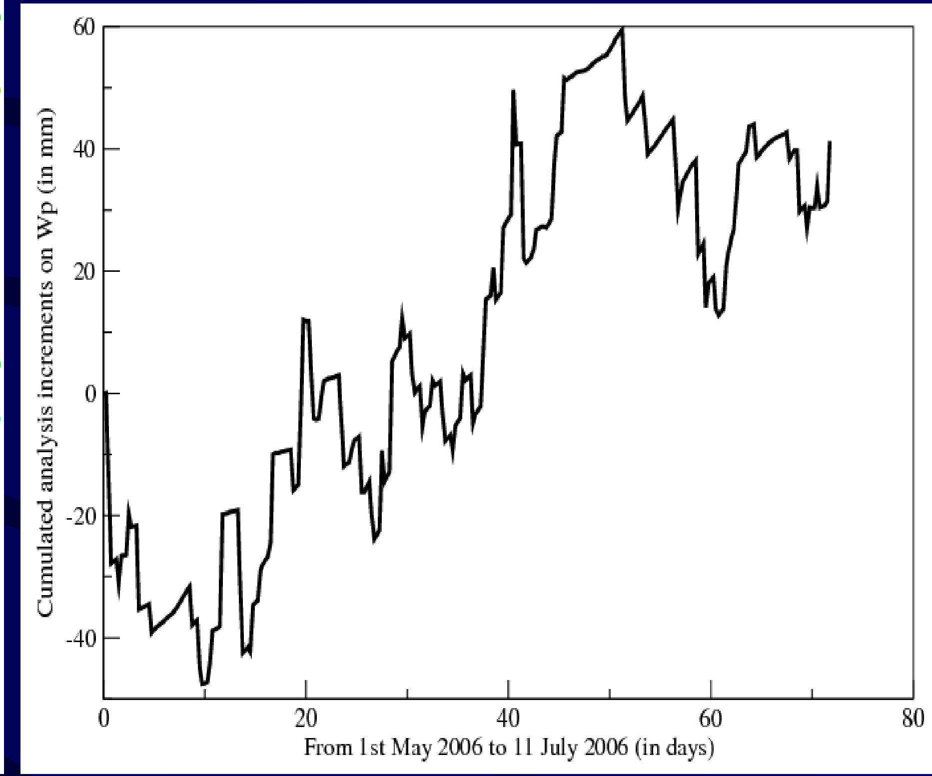
Daily mean of absolute analysis increments

|ΔT2m|



Cumulated analysis increments on Wp

(in mm)



Variational surface analysis

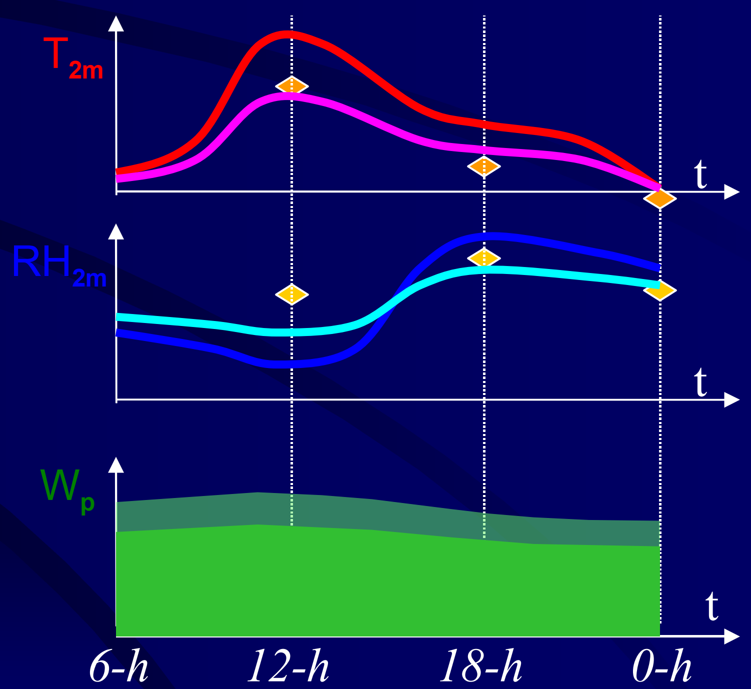
Mahfouf (1991), Callies et al. (1998), Rhodin et al. (1999), Bouyssel et al. (2000)

- Formalism:

$$J(\mathbf{x}) = J^{b}(\mathbf{x}) + J^{o}(\mathbf{x}) = \tfrac{1}{2}(\mathbf{x}-\mathbf{x}^{b})^{T}\mathbf{B}^{-1}(\mathbf{x}-\mathbf{x}^{b}) + \tfrac{1}{2}(\mathbf{y}-H(\mathbf{x}))^{T}\mathbf{R}^{-1}(\mathbf{y}-H(\mathbf{x}))$$

x is the control variables vector
y is the observation vector
H is the observation operator
B is the background error covariance matrix
R is the observation error covariance matrix

Continuous analysis

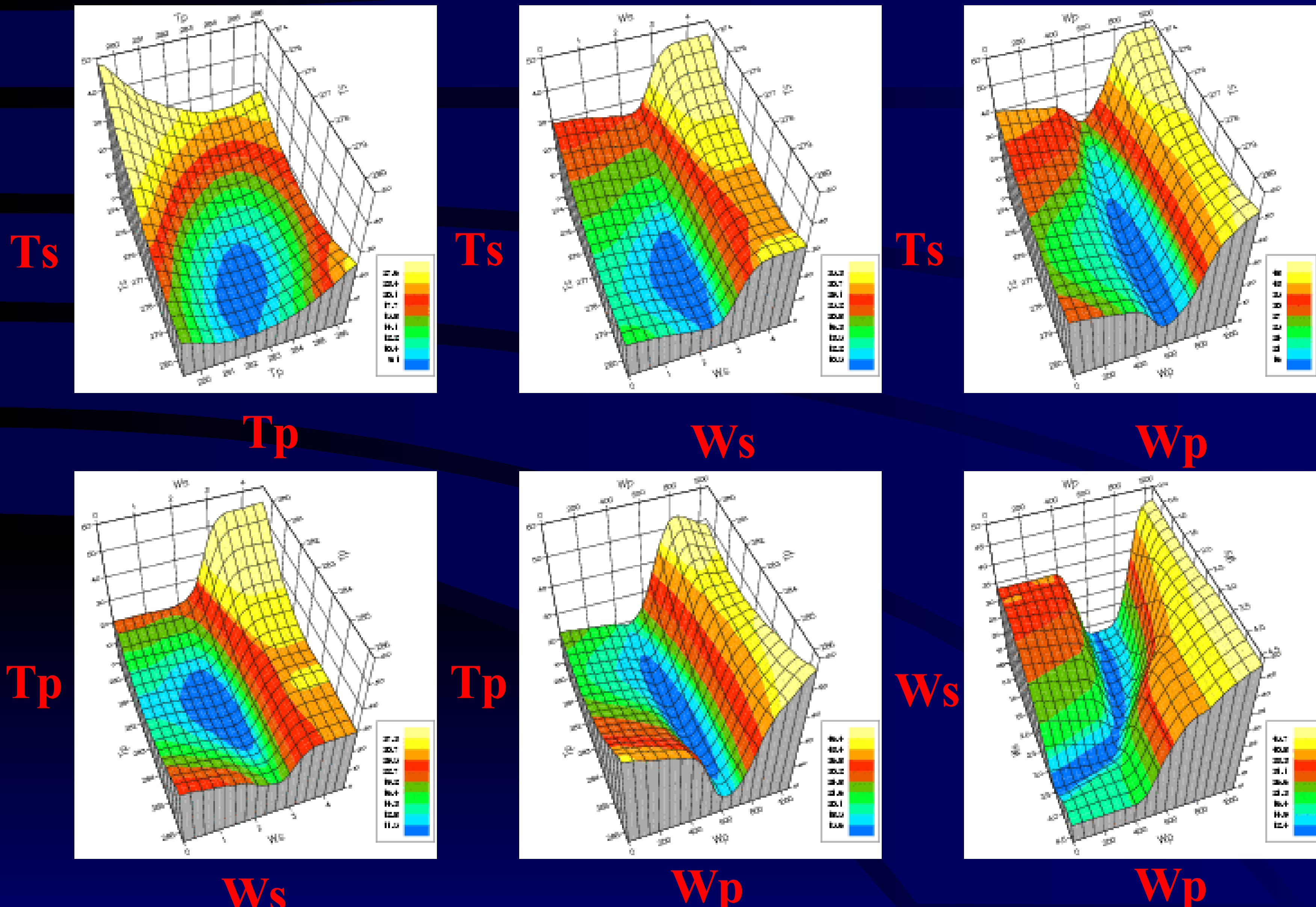


The analysis is obtained by the minimization of the cost function $J(\mathbf{x})$

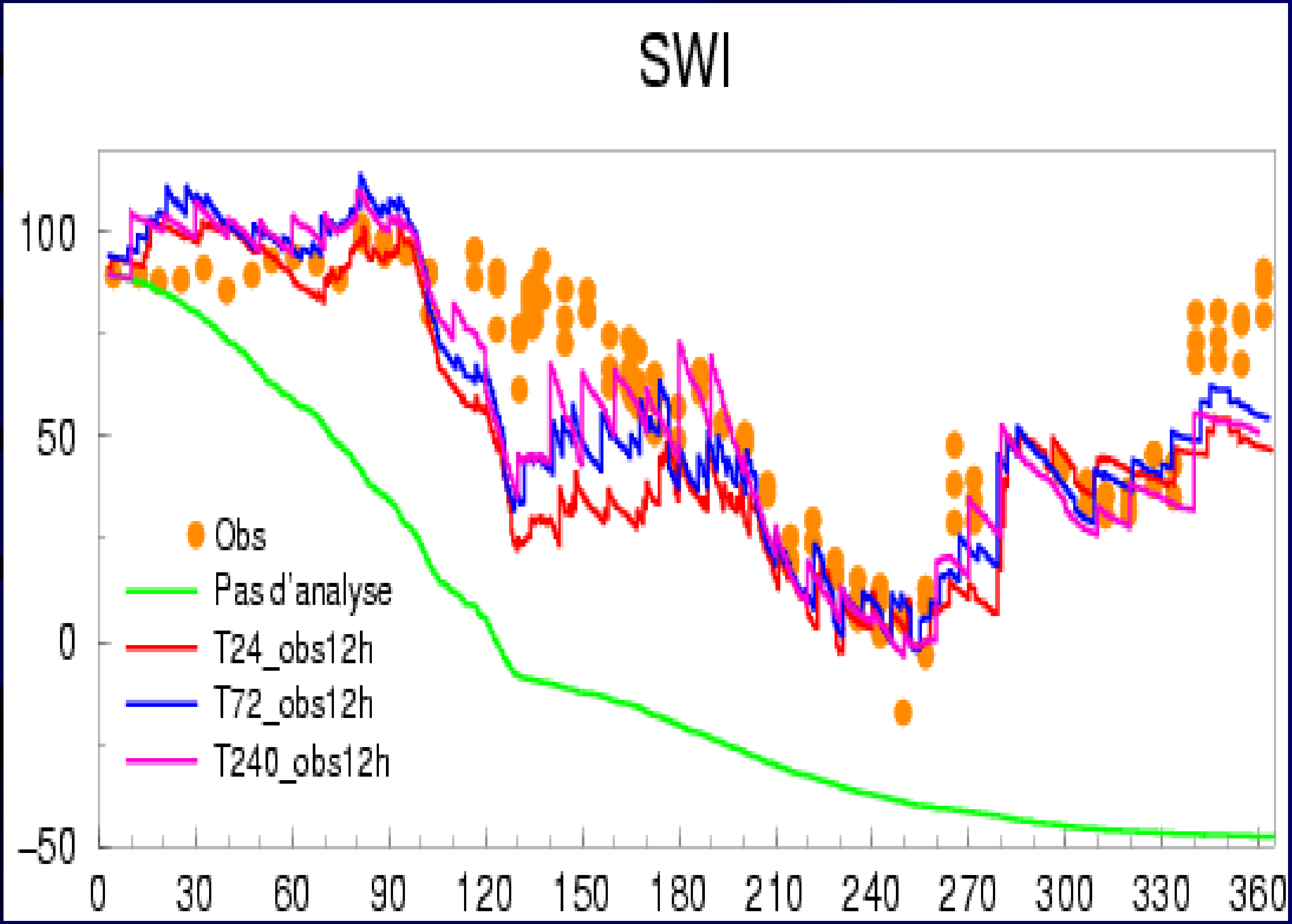
For high dimensional problems: TL/AD models

For low dimensional problems: finite differences

Visualisation of cost function



Variational Analysis on MUREX experiement



SWI

Julian days

Dynamical optimal interpolation or Simplified 2D-Var

Hess (2001), Balsamo et al. (2002)

- TL hypothesis : $H(\mathbf{x}+\mathrm{d}\mathbf{x}) \cong H(\mathbf{x}) + \mathbf{H}.\mathrm{d}\mathbf{x}$ (acceptable for Wp)

$$\mathbf{x}^a = \mathbf{x}^b + \mathbf{B}\mathbf{H}^T(\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R})^{-1}(\mathbf{y} - H(\mathbf{x}^b))$$

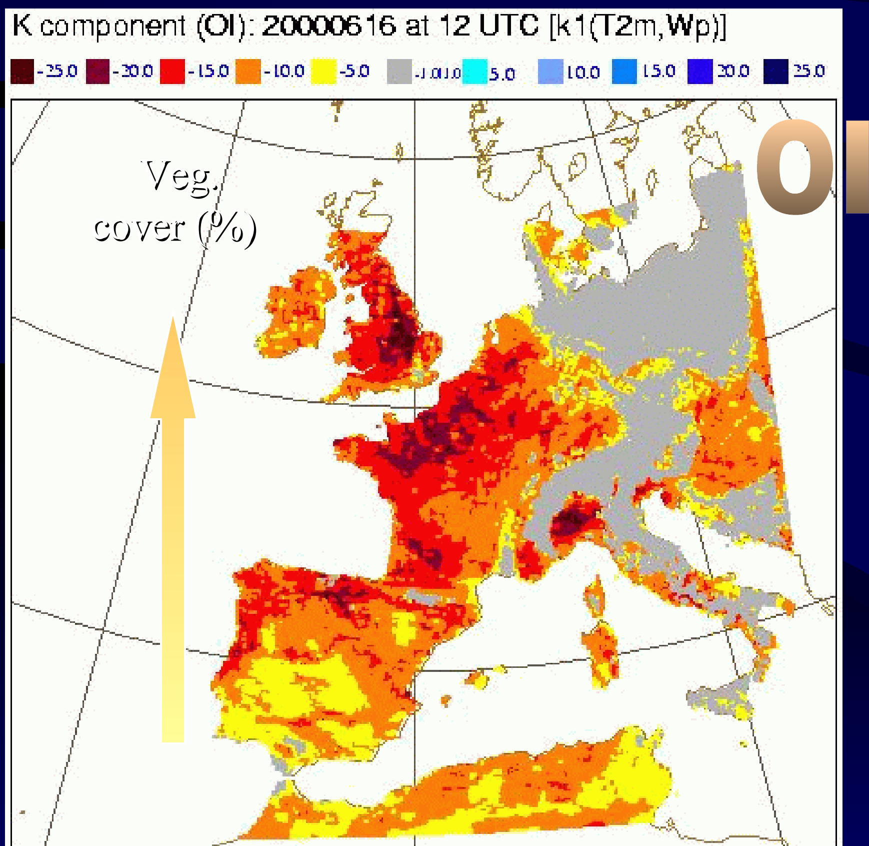
$$W_p^{\,a} - W_p^{\,b} = \alpha_{WpT}\,\Delta T_{2m} + \alpha_{WpRH}\,\Delta RH_{2m}$$

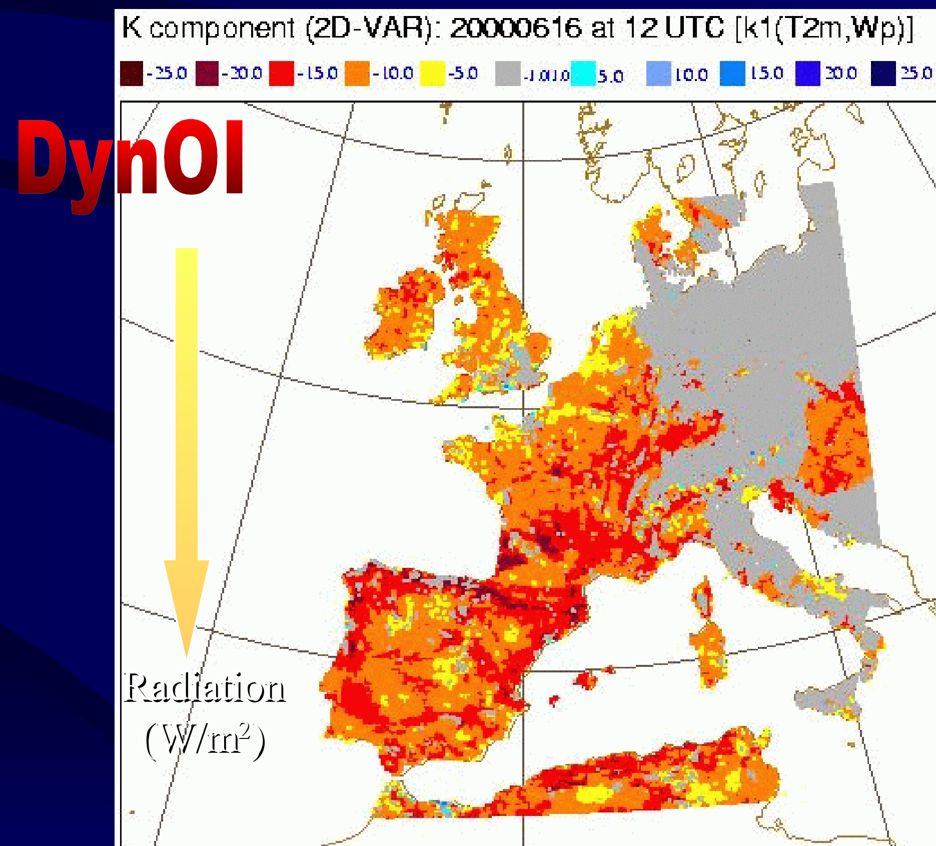
- “Normal” OI coefficient α_{WpT} and α_{WpRH} are evaluated statistically (once)
- Dynamical OI coefficients α_{WpT} and α_{WpRH} are evaluated dynamically (each time)

Comparison of statistical and dynamical OI

A comparison with OI (Gain Matrix and OI coefficients) is useful to point out some properties of the variational approach

- masking of low sensitivity grid-points (coherence of masked areas)
- dependency from radiation rather than vegetation
- evaluation of the overall correction of the OI

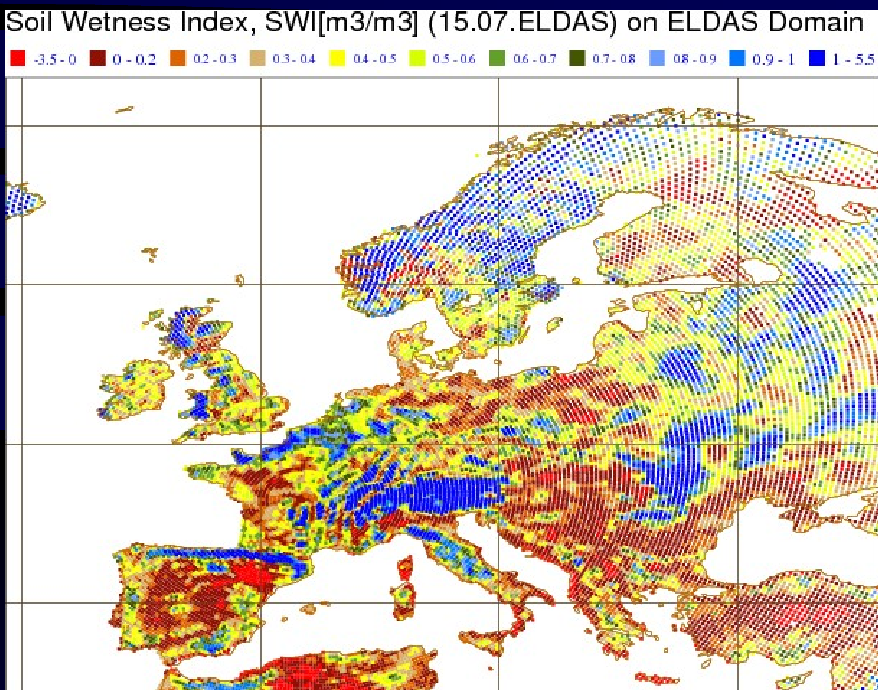


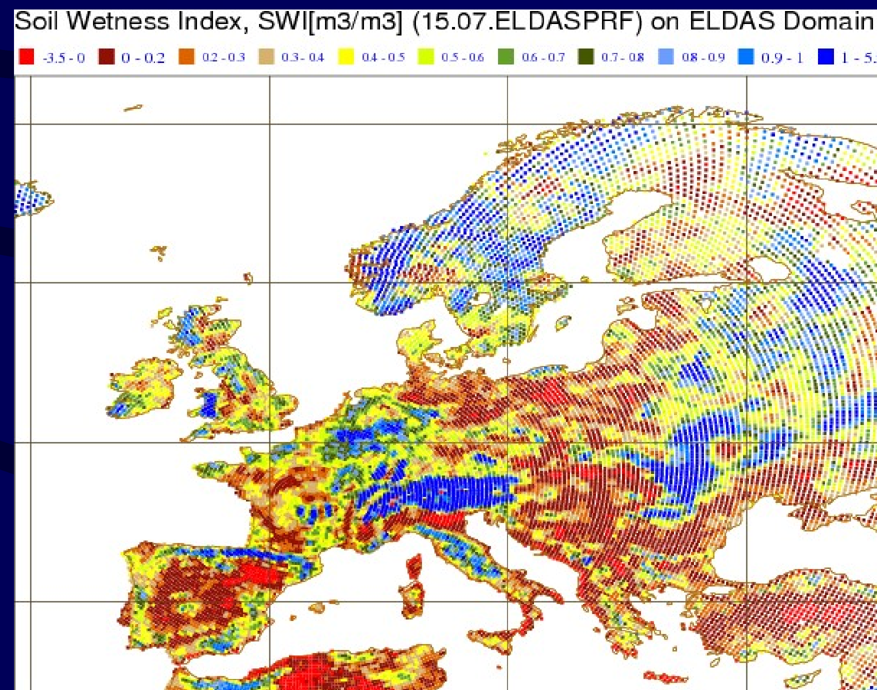


Dyn OI tested in ELDAS (two 6 months assimilations)

the two cycles without and with Precipitation readjustment are compared

2D-Var | **2D-Var + p24h**

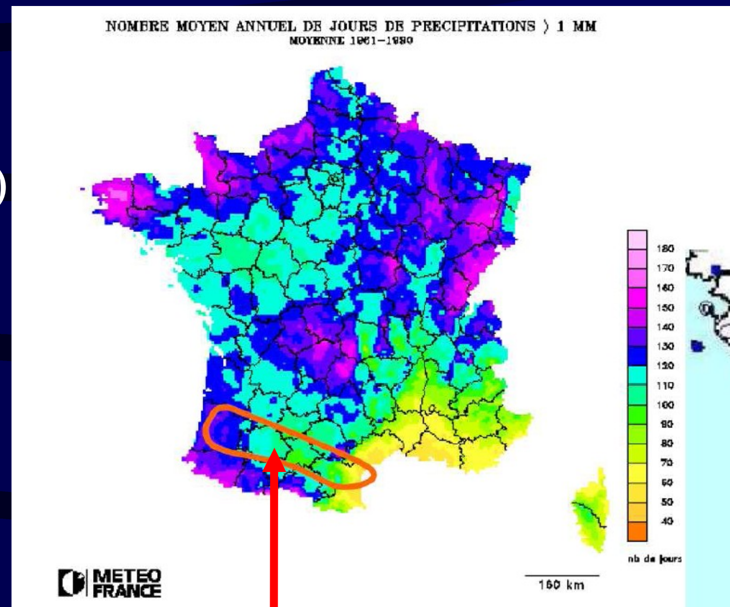


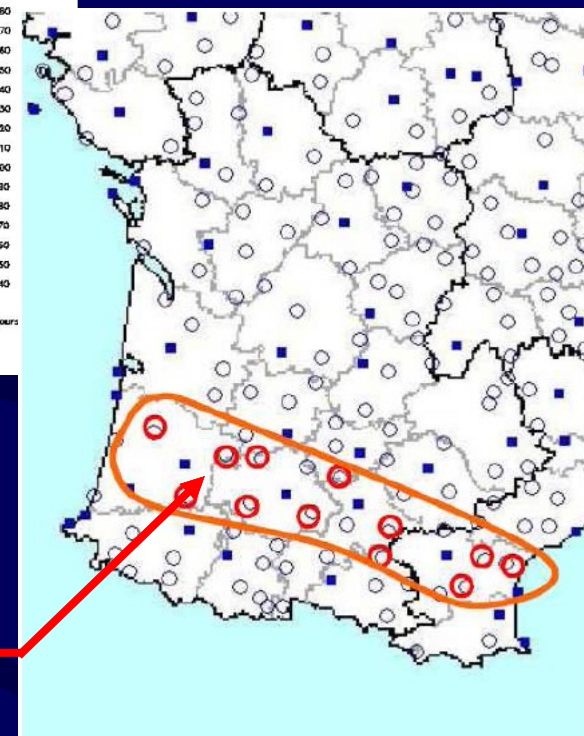


$\Rightarrow$ Differences of small scales : temporal and spatial

Soil Moisture Validation in France

- A national project (Météo-France / CNES)
- Soil moisture networks are needed
  - Validation of Land Surface Models
  - Assimilation: to help characterise/reduce the bias between SMOS products and the model wg
- A 12 station network in SW France
  - Atlantic-Mediterranean
  - RADOME operational network of Météo-France, delivering real-time data





Others analyses:

Sea surface temperature

Sea ice

Snow

…

SST and Sea Ice cover analysis

Optimal interpolation assimilating buoys and ships (~1300 obs by rXX)

Relaxation towards SST NESDIS analysis 0.5°*0.5° (~5 days time scale)

Use SSMI observations to determine Sea Ice (once a day). Temporal consistency in sea ice cover analysis.

No lake temperature analysis

Snow correction

Snow analysis developed in CANARI, but never operational

Research study to use either IFS or NESDIS snow cover analysis

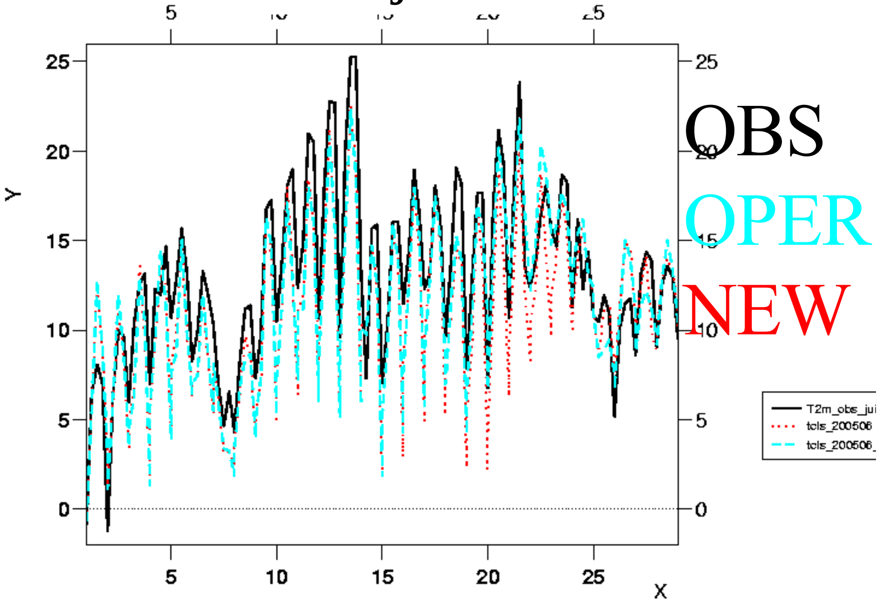
Snow melting in case of warm T2m observations

Frozen soil correction

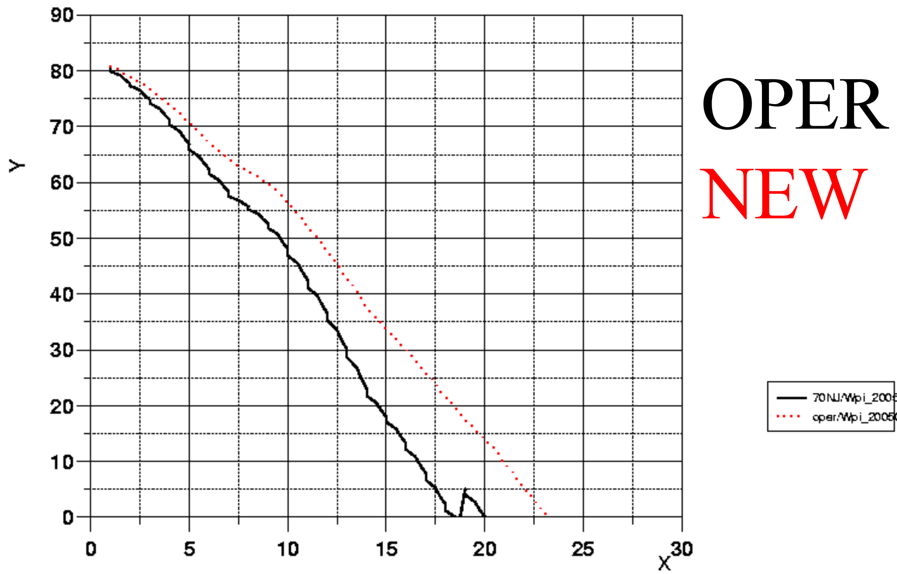
Melting of frozen soil in case of warm T2m observations

1D simulation over Sodankyla (Finland)

T2m juin 05

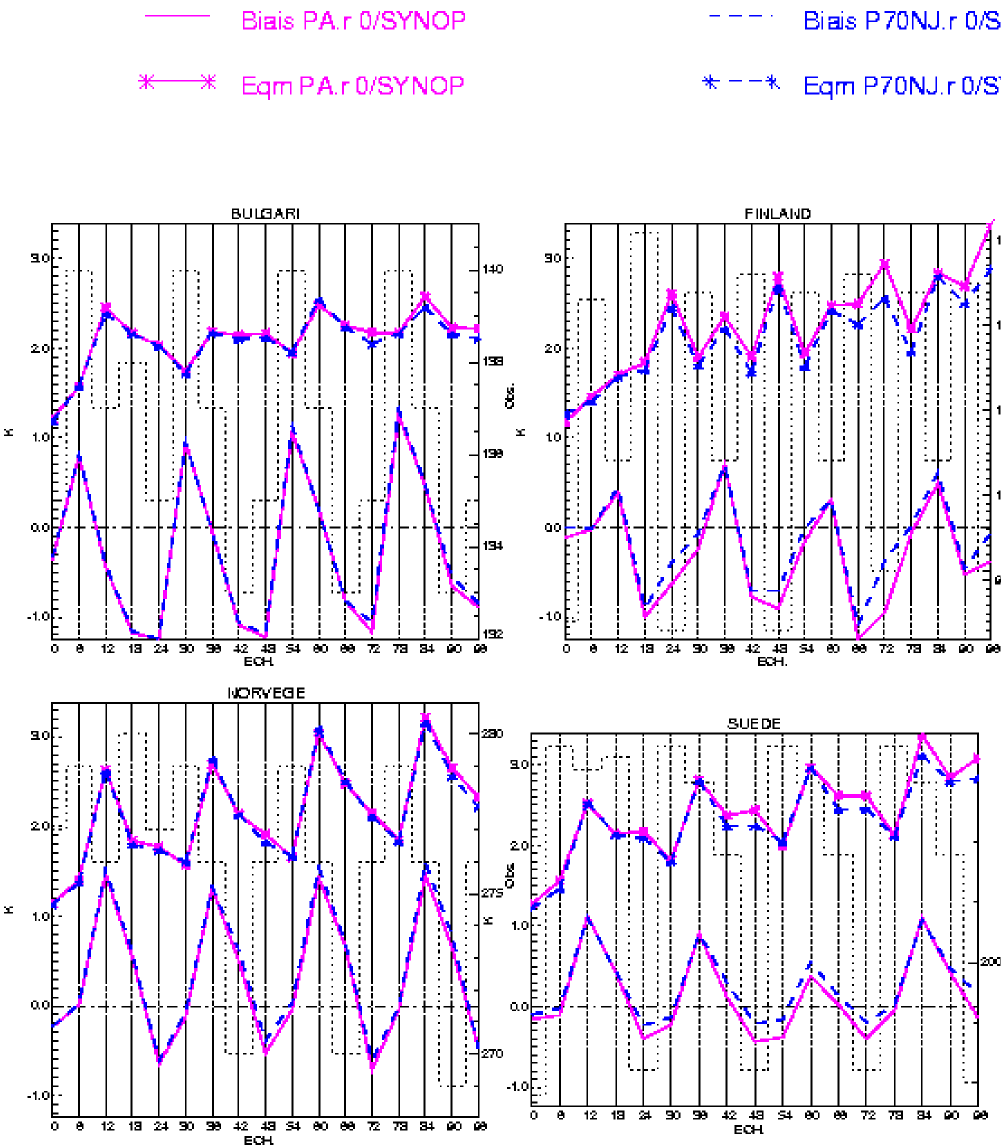


Eau du sol gelée



TEMPERATURE CORR.

28 cas, 01/06/2005_00UTC -> 02/07/2005_00UTC



Conclusions

- Surface analyses implemented for ARPEGE, not yet in ALADIN or AROME (technically and scientifically working) -> CHMI
- Important effort on soil moisture analysis (including satellite obs)
- New algorithms (2D-Var, Dyn-OI) but two costly for the time being
- Importance of 2m observations
- Potential of better atmospheric forcings (radiation, precipitations)
- How to combine in a reasonable cost system analysed/observed forcings, 2m obs, satellite obs? Link with upper analysis? Is the spatialisation of observation a good solution?