Summary of activities with SURFEX data assimilation at Météo-France

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Outline

- Status at Météo-France in 2008
- Developments undertaken during 2009-2011 :
  - Extended Kalman Filter within SURFEX
  - Assimilation of satellite derived soil moisture (AMSR-E, ASCAT)
  - Feasibility studies in NWP context
  - OI soil analysis for the AROME convective scale NWP model
  - Assimilation of satellite derived surface albedo (SEVIRI-MSG)
  - Assimilation of ASCAT superficial soil moisture in hydrological models (H-SAF funded study)
  - Land carbon and water monitoring (FP7-GEOLAND2) : assimilation of LAI and soil moisture within ISBA A-gs
- Conclusions on ongoing activities

Soil analysis at Météo-France (2008)

- Global model ARPEGE : soil analysis based on OI (Giard and Bazile, 2000) for water contents and temperatures using screen-level SYNOP observations (T2m, RH2m)
- Limited area models ALADIN and AROME : interpolation of the ARPEGE soil analysis
- Limitations :
  - New observations are becoming available => difficult to include in the OI framework
  - New land surface models are being developed => OI is structured for the 2-layer version of the ISBA scheme (Noilhan and Planton, 1989)
  - Soil analysis is « model dependent » => not always beneficial when used in a different model

Strategy

- Development of a new land data assimilation system with the externalized land modelling platform SURFEX (to be used by all Météo-France NWP models; currently ALADIN and AROME)
- Methodology : Extended Kalman Filter (compromise between OI and EnKF)
- Heritage : studies undertaken at DWD (Hess, 2001), Météo-France (Balsamo et al., 2004), ECMWF (Seuffert et al., 2004) during the FP5-ELDAS project and Environment Canada (Balsamo et al., 2007)
- Preliminary studies : comparisons between OI, EKF, EnKF for screen-level observation assimilation with a « toy model » (Mahfouf, 2007; Mahfouf et al. 2009)

Summary of developments

- Developments on the EKF :
  - Combined assimilation of AMSR-E soil moisture and screen-level observations (collaboration with University of Melbourne)
  - Inclusion of precipitation information in the EKF (additional observations, estimation of model errors) (collaboration with University of Prague)
  - Assimilation of ASCAT soil moisture in the hydrometeorological model SIM – coupling with routine model (validation on river discharges)
- Assimilation of ASCAT soil moisture using an EKF coupled to the ALADIN 3D-Var (internal collaborations + ZAMG)
- Development of a soil analysis based on OI for the operational AROME model (internal collaborations)
- Other developments at CNRM to be presented by Alina Barbu and Dominique Carrer

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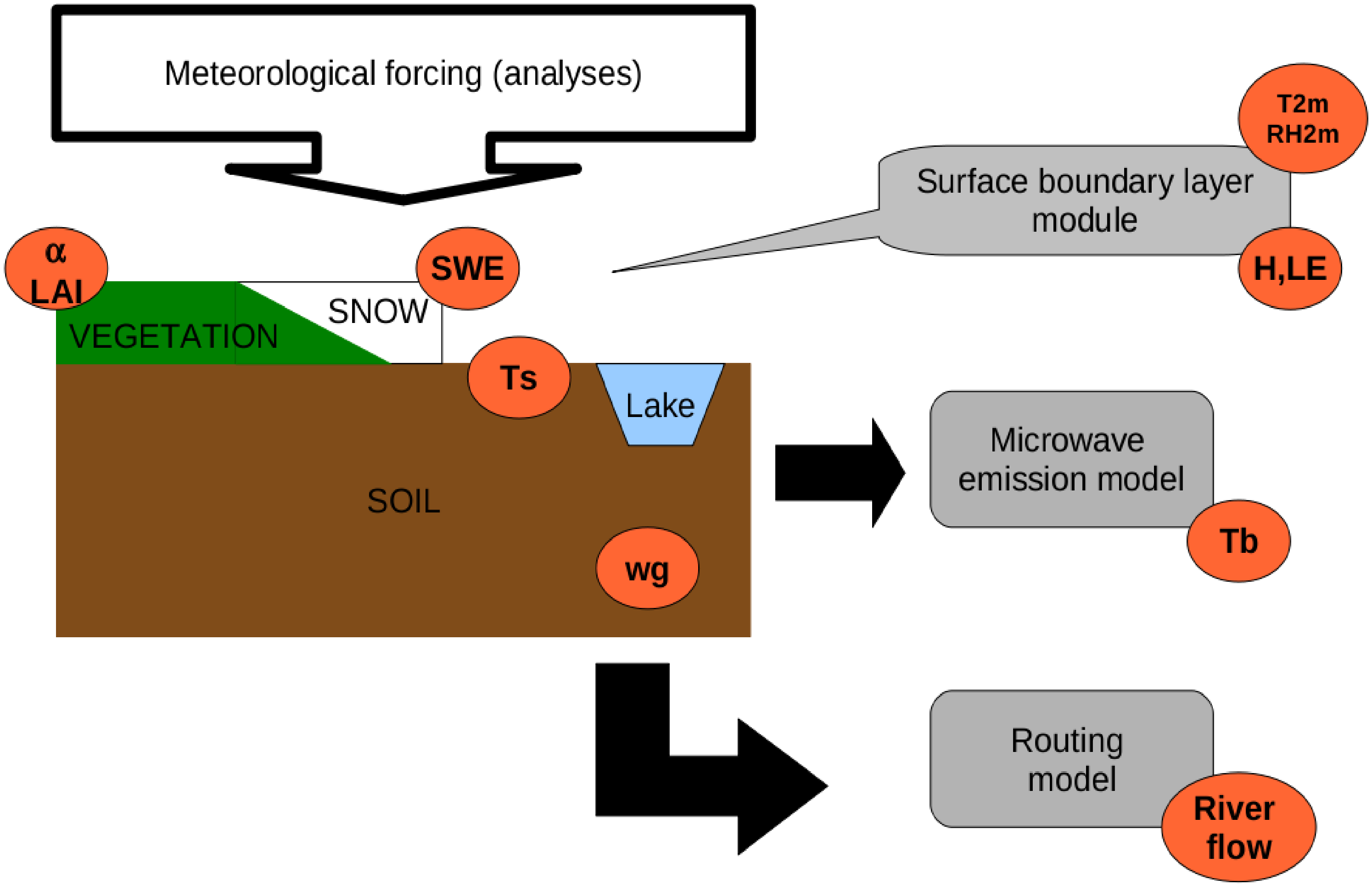
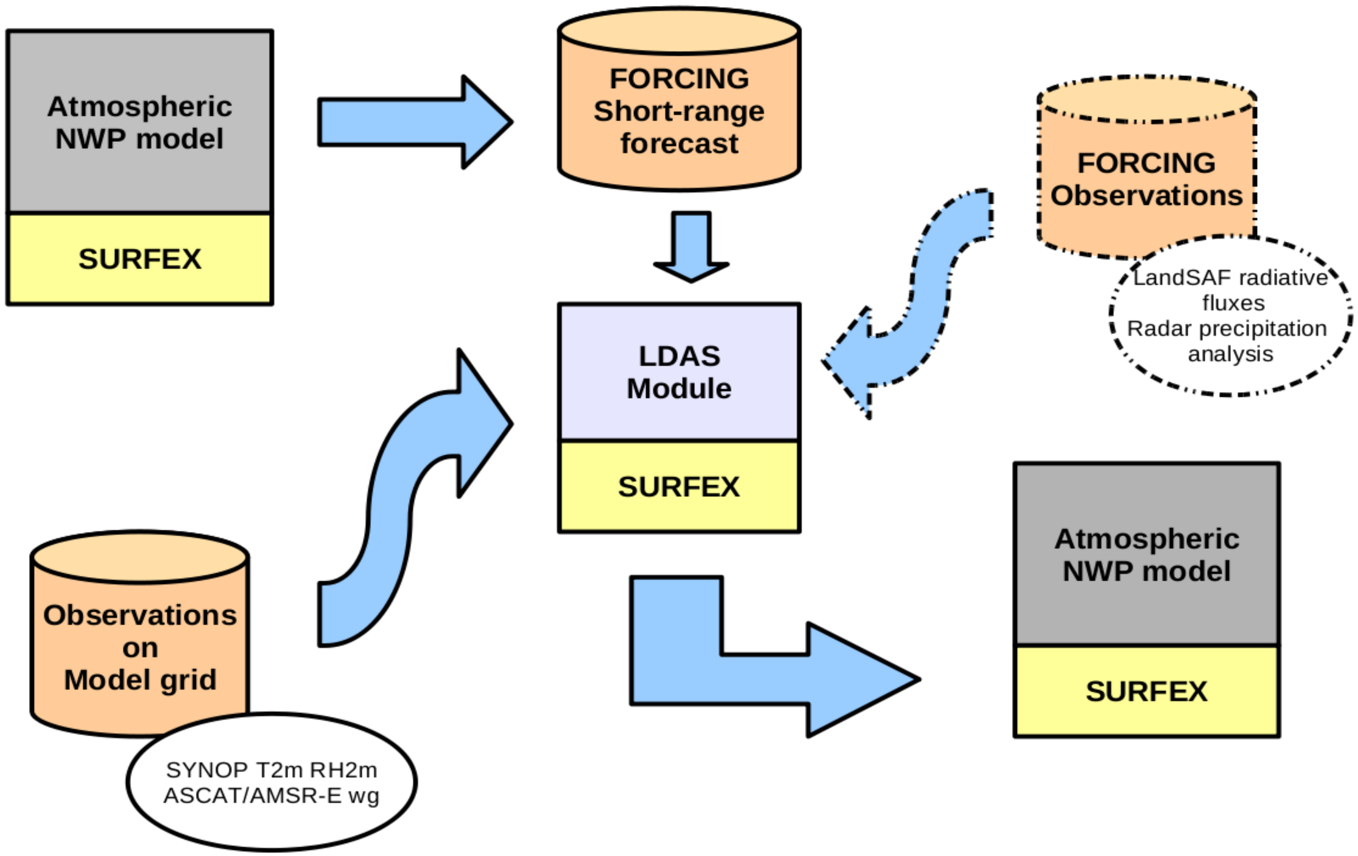
Externalized surface modelling platform



Externalized land data assimilation



Semi-coupled mode : the atmosphere can be corrected by the land data assimilation

Improved background error statistics in the EKF

- Assumption : the primary source of errors in land surface modelling comes from the precipitation forcing
- Use of ALADIN short-range lagged forecasts to estimate the model errors statistics (Q matrix of the EKF)
- From the spread of a « poor's man » ensemble : variance of model errors for soil moisture contents and correlation between the two soil moisture reservoirs
- Test period : May 2009 over the ALADIN France domain – EKF with two control variables :
  - WG1 : superficial soil water reservoir (1 cm)
  - WG2 : deep soil water reservoir (~ 2 m)

The Extended Kalman Filter

Analysis equations

$$x^b = M(x^a)$$

$$\mathbf{P}^b = \mathbf{M}\mathbf{P}^a\mathbf{M}^T + \mathbf{Q}$$

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

$$\mathbf{P}^a = (\mathbf{I} - \mathbf{K}\mathbf{H})\mathbf{P}^b$$

Covariance matrix of model errors:

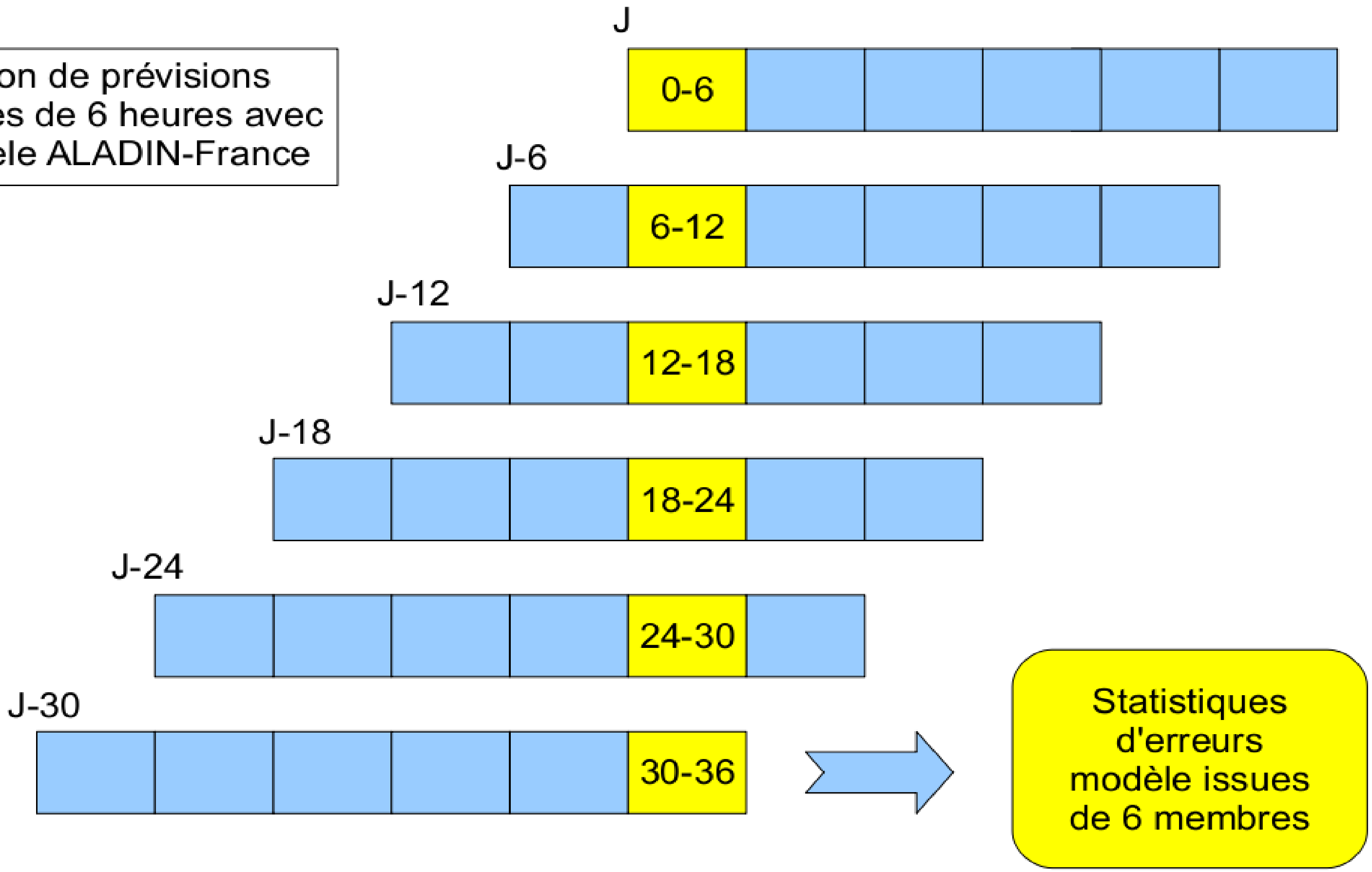
$$\mathbf{Q} = \begin{bmatrix} \sigma^2_{wg1} & \rho\sigma_{wg1}\sigma_{wg2} \\ \rho\sigma_{wg1}\sigma_{wg2} & \sigma^2_{wg2} \end{bmatrix}$$

M=land surface scheme ISBA and *x*=(wg1,wg2)

H is estimated in finite differences **H** = {*H*(x+Δx) – *H*(x)}/Δx

Lagged forecasts with ALADIN model

Utilisation de prévisions décalées de 6 heures avec le modèle ALADIN-France



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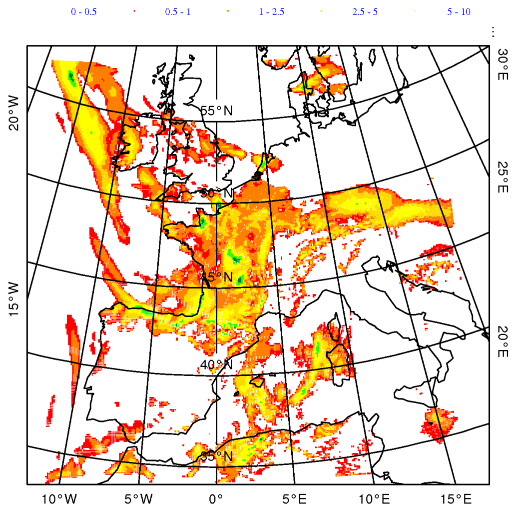
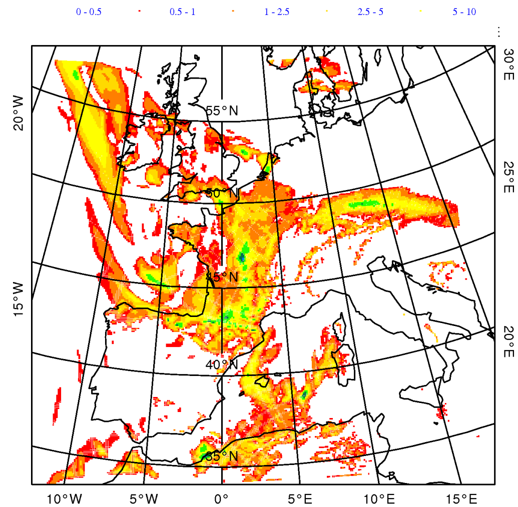
Ensemble of precipitation forecasts

RAIN Member 1 2009051412



RAIN Member 2 2009051412



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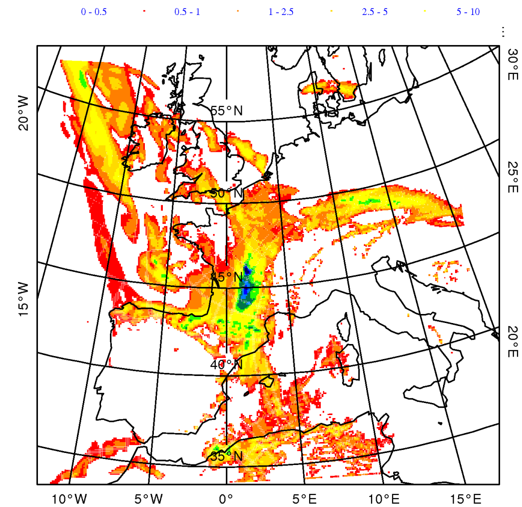
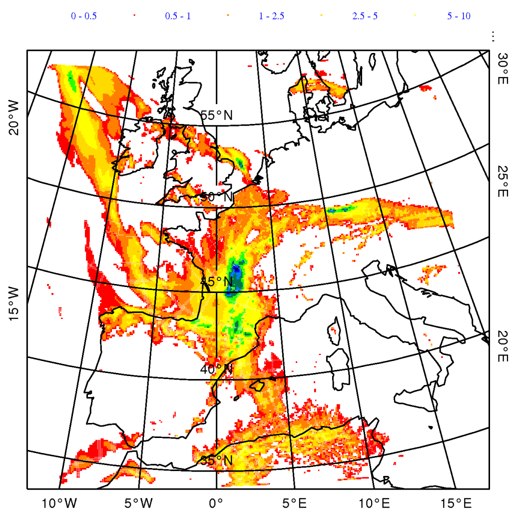
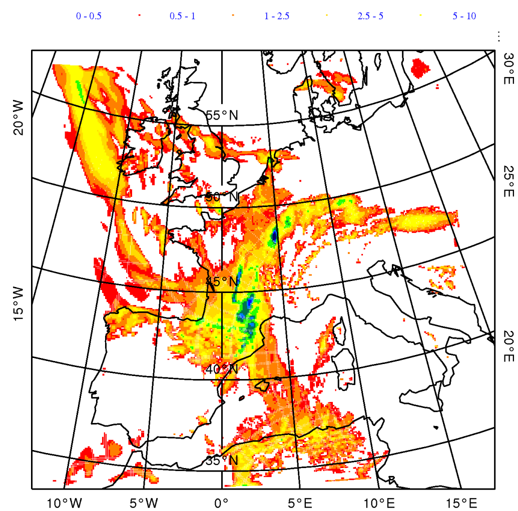


RAIN Member 4 2009051412



RAIN Member 5 2009051412



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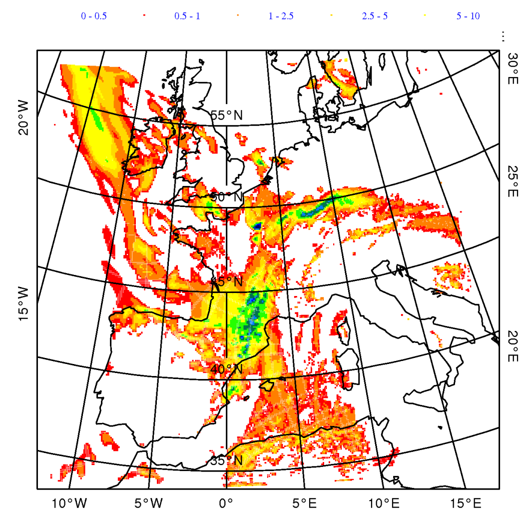
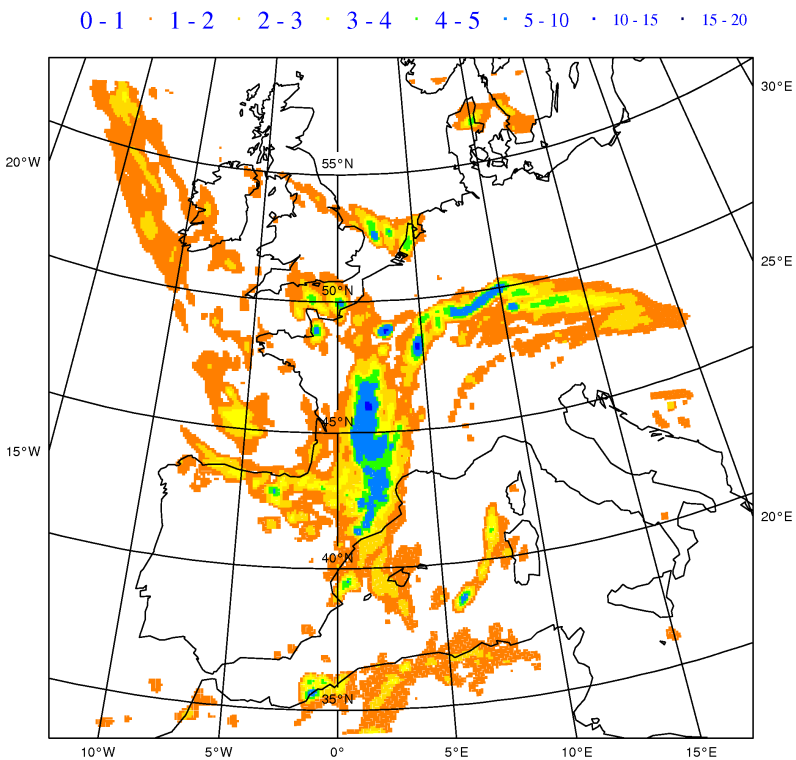
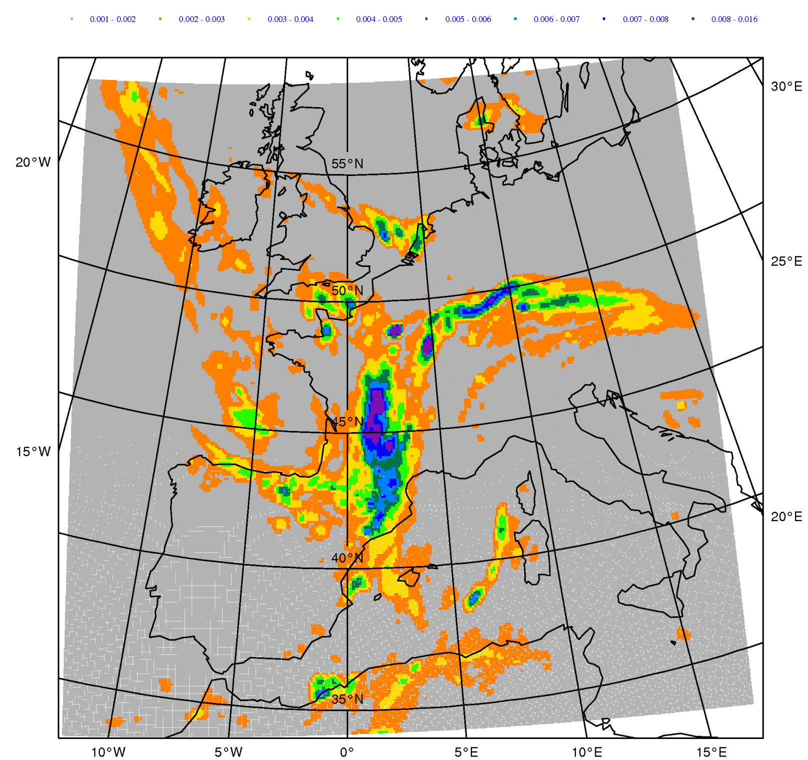


Model error std for soil moisture

STD RAIN ERROR (mm) 2009051412



STD WG2 ERROR (vol/vol) 2009051412



$$\sigma_{WG} = 0.002 \times (\sigma_{rain} + 1)$$

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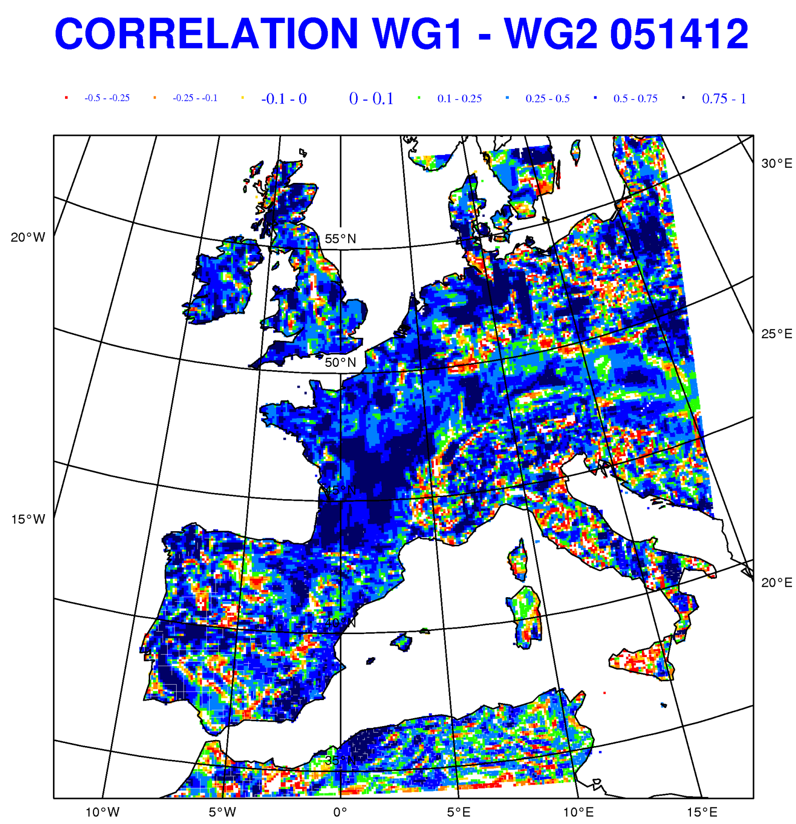
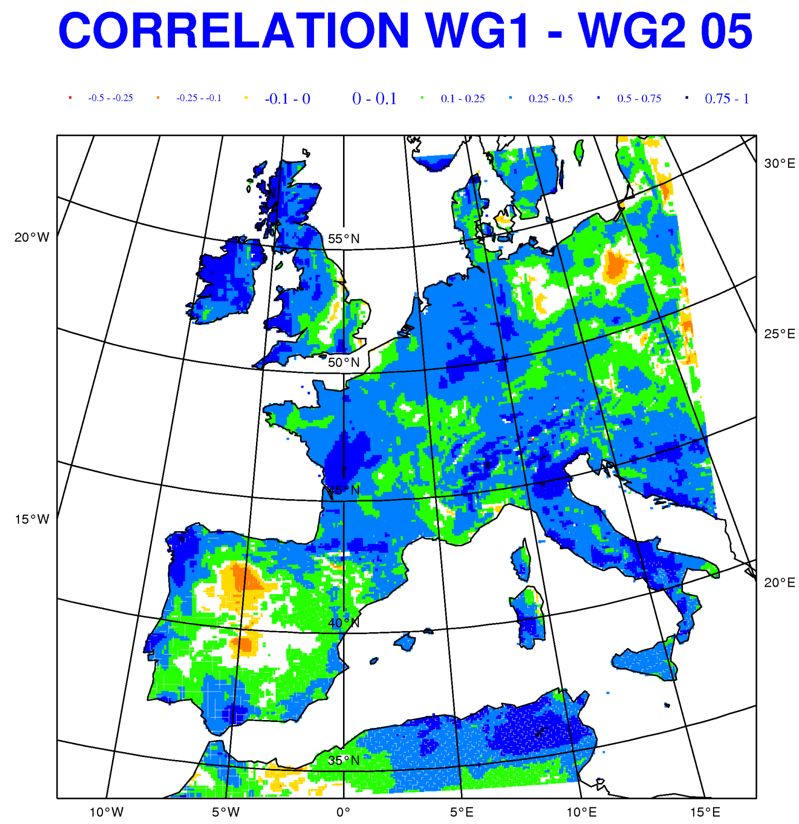
Error correlation between WG1 and WG2



Size = 6 forecasts



Size = 6x31 forecasts

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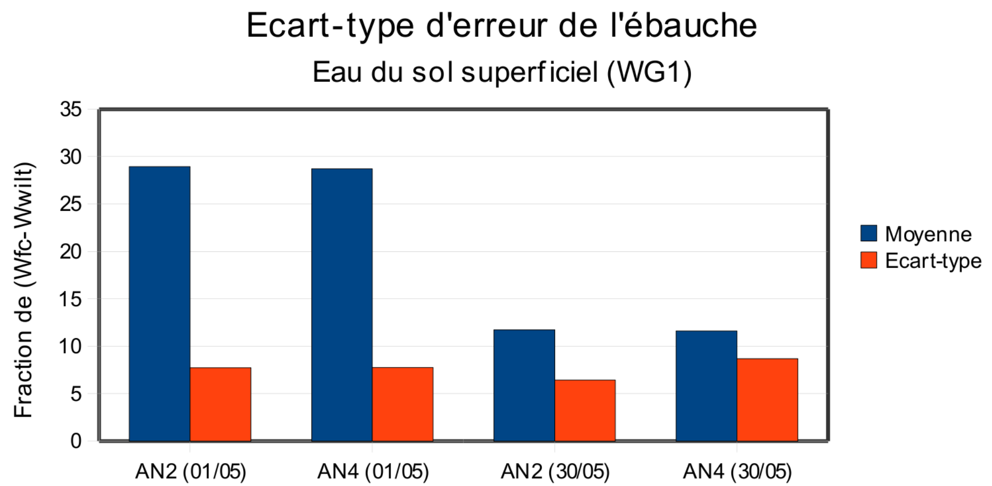
Evolution of B matrix (one month)

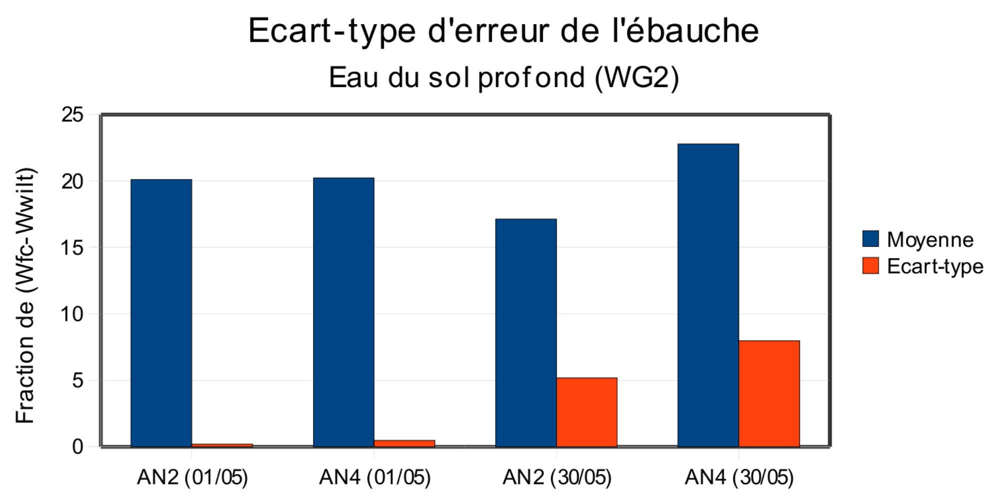
Superficial
Soil moisture
WG1



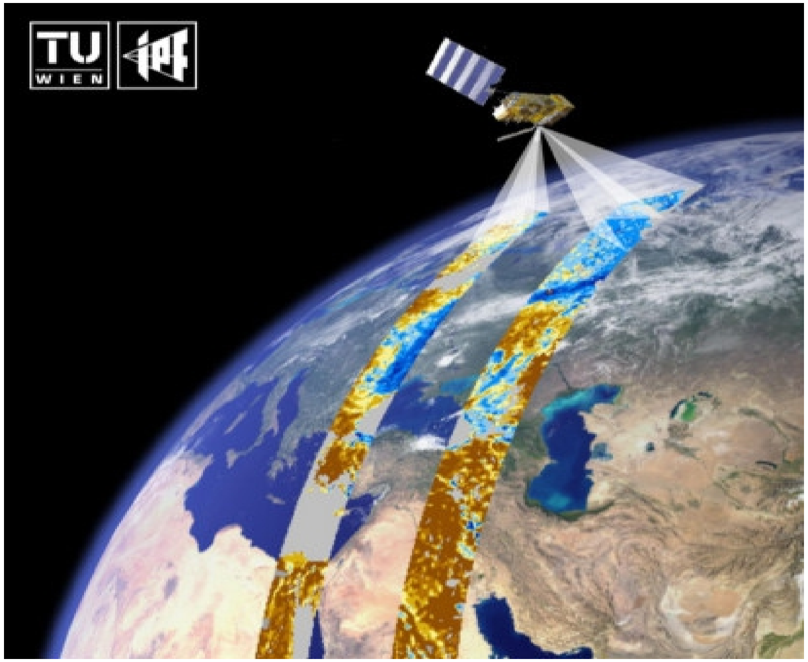
AN2 : Q=0.125xBo

AN4 : Q=derived from ensemble forecasts

Deep
Soil moisture
WG2



Assimilation of ASCAT soil moisture



ASCAT : C-band scatterometer on board MetOp

Real-time superficial soil moisture product since end 2008 (change detection method, Wagner, 1998)

Product resolution : ~ 25 km

Revisit time : ~ 1 day

- Atmospheric model : NWP LAM ALADIN
- Data assimilation : 3D-Var 6h
- Land surface assimilation : simplified EKF (analytical Jacobians)
- Test period : May 2009
- Data preprocessing :
  - Bias correction (CDF matching)
  - Data rejection (towns, orography, frozen soils, snow)
  - Background check
  - Obs error = 0.06 m3/m3

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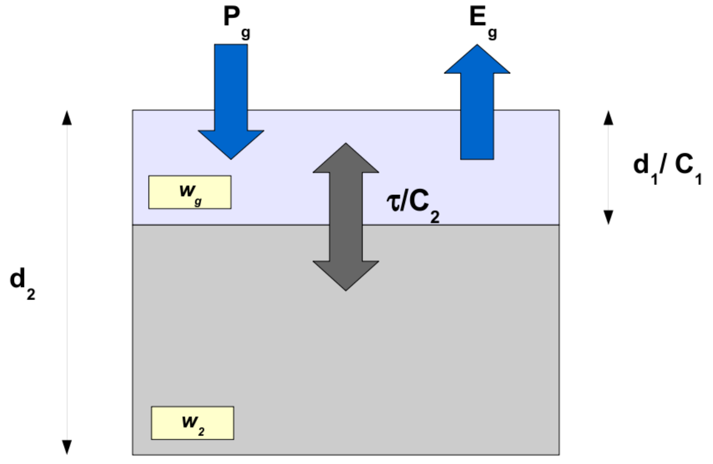
Analysis equation

$$\Delta \mathbf{x}^t = \mathbf{B}^t \mathbf{H}^T (\mathbf{HBH}^T + \mathbf{R})^{-1} [\mathbf{y}_o{}^t - H(\mathbf{x}^t)]$$

$$\mathbf{x} = \begin{pmatrix} w_g \\ w_2 \end{pmatrix} \qquad \mathbf{B}^t = \mathbf{MBM}^T \qquad H = (1,0)$$

$$\mathbf{M} = \begin{pmatrix} \frac{\partial w_g{}^t}{\partial w_g{}^0} & \frac{\partial w_g{}^t}{\partial w_2{}^0} \\ \frac{\partial w_2{}^t}{\partial w_g{}^0} & \frac{\partial w_2{}^t}{\partial w_2{}^0} \end{pmatrix}$$



$$\frac{\partial w_g{}^t}{\partial w_g{}^0} = \exp\left(-\frac{C_2 t}{\tau}\right)$$

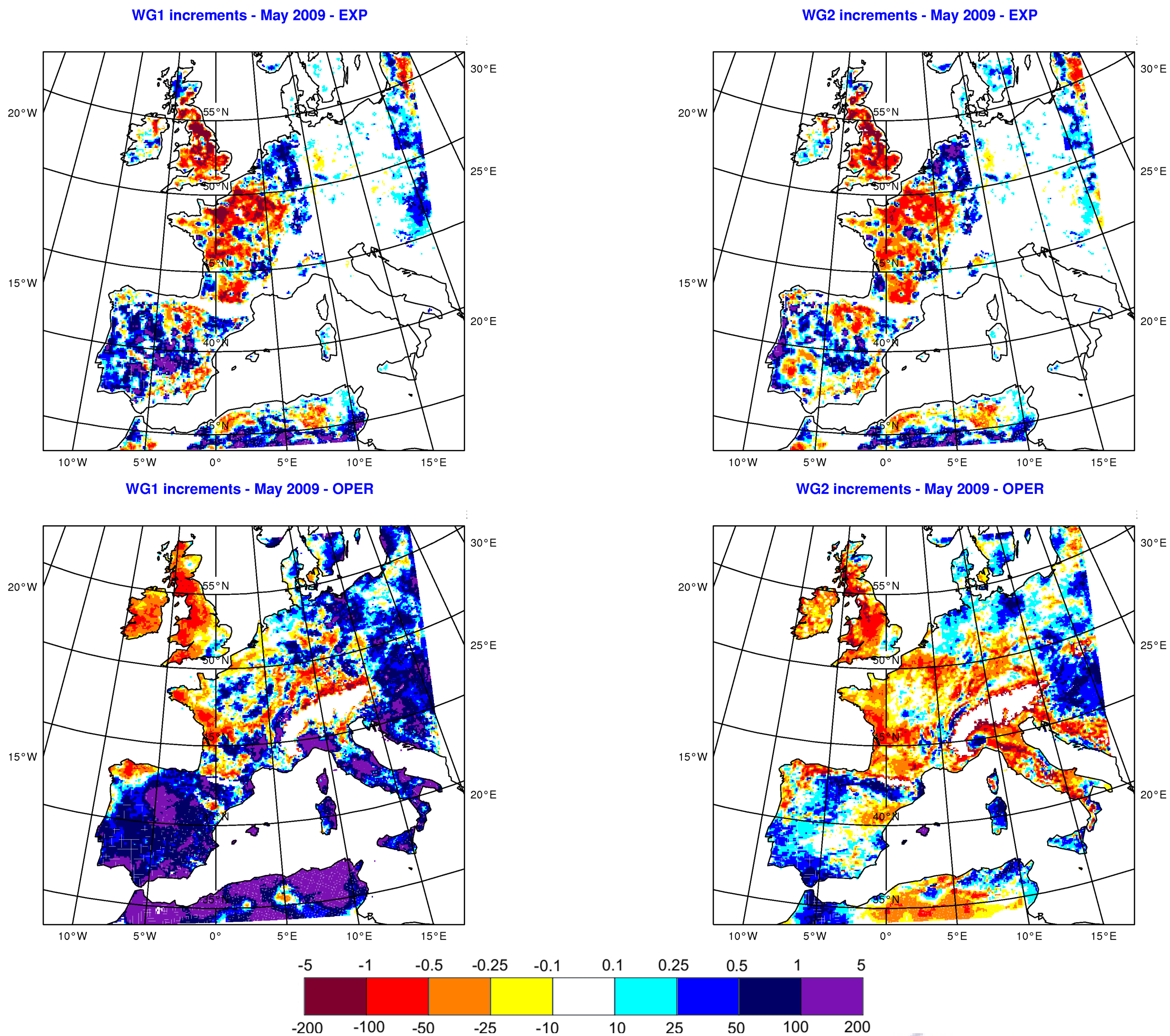
$$\frac{\partial w_g{}^t}{\partial w_2{}^t} = 1 - \exp\left(-\frac{C_2 t}{\tau}\right)$$

$$\frac{\partial w_2{}^t}{\partial w_g{}^0} = 0 \qquad \frac{\partial w_2{}^t}{\partial w_2{}^0} = 1$$

Soil moisture increments

WG1
EXP

WG1
OPER

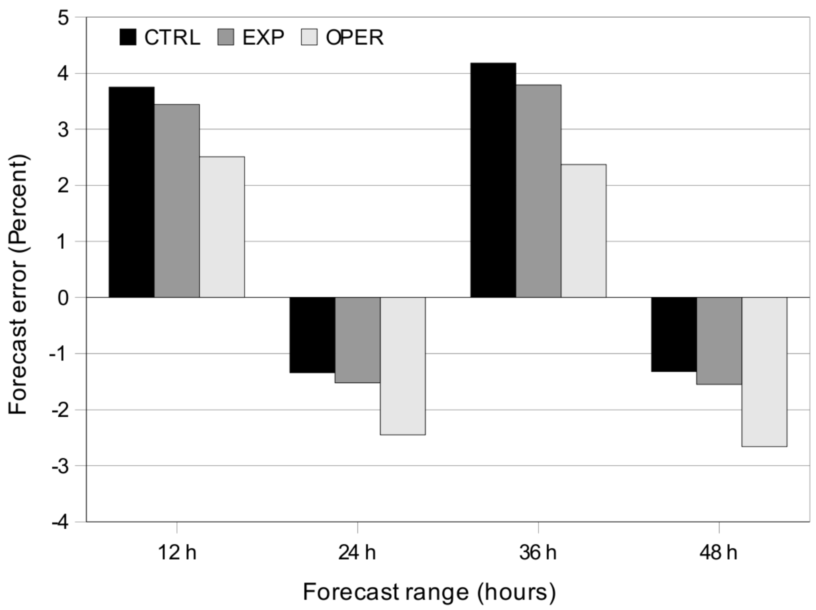


WG1
EXP

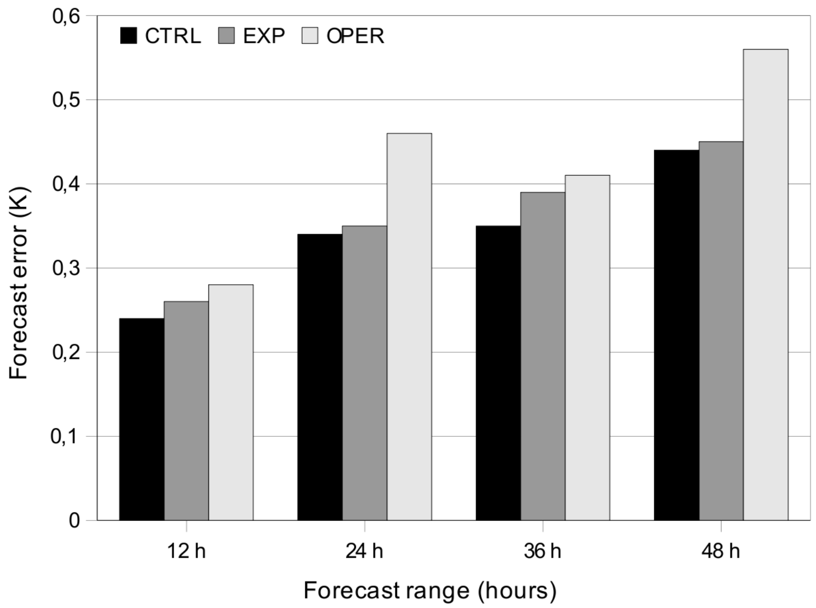
WG2
OPER

Impact on forecast scores

Mean biases over one month



Relative humidity at 2m



Temperature at 2m

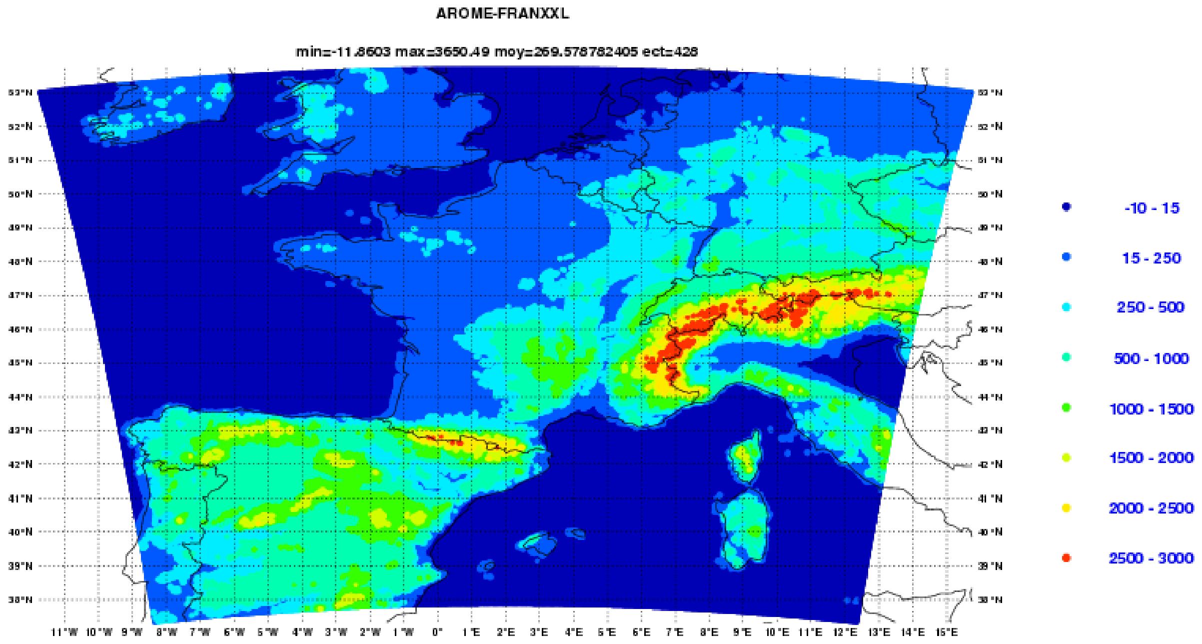
CTRL=no soil analysis

EXP = soil analysis assimilation using ASCAT

OPER = soil analysis using T2m RH2m

Soil analysis for AROME

- Implementation of soil analysis for AROME based on OI (Giard and Bazile 2000) with SURFEX
- The soil analysis has been put in operation in 11/2011 with a wider AROME domain and an increased usage of observations (SSMIS/aircrafts/IASI/radar Doppler winds)
- Preliminary AROME 3D-Var with soil analysis (3 weeks)



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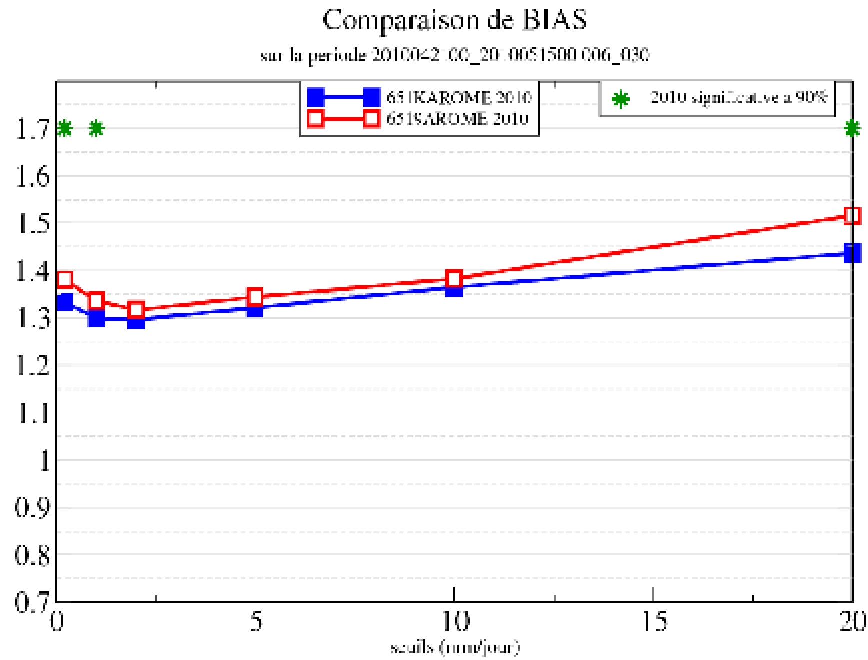
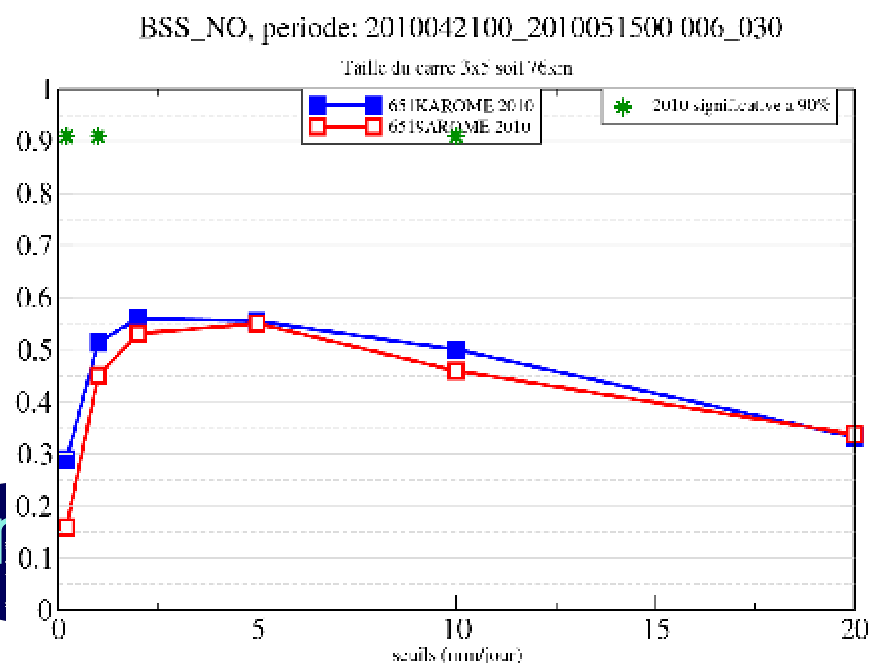
Precipitation scores

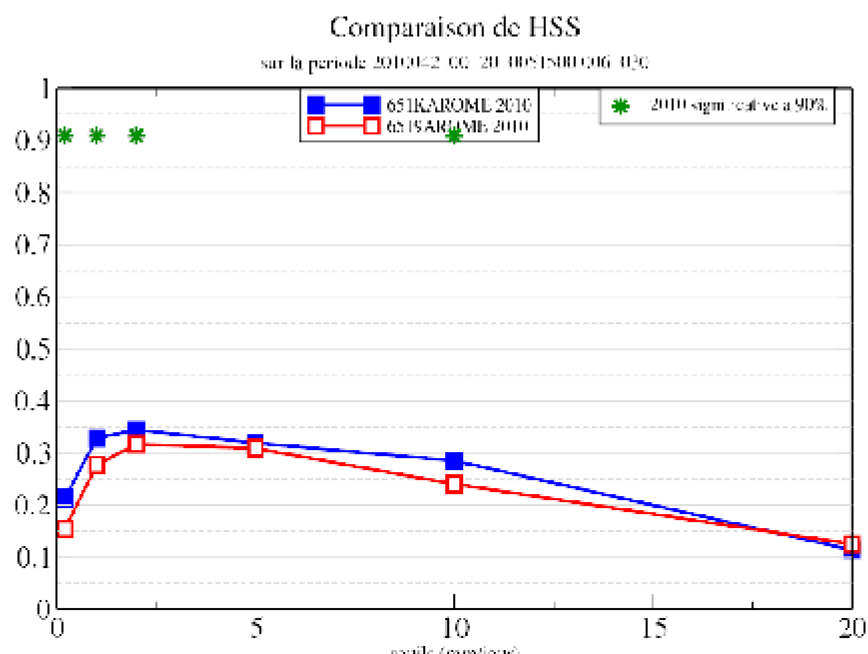
With surface analysis

Without surface analysis

3 weeks (15/05 – 21/04/2010)

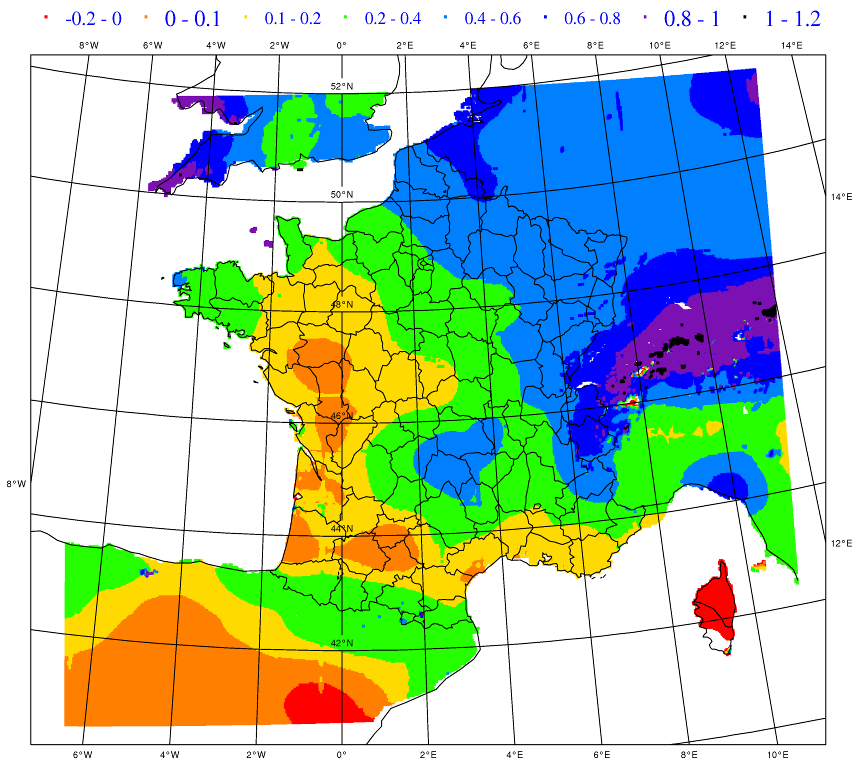




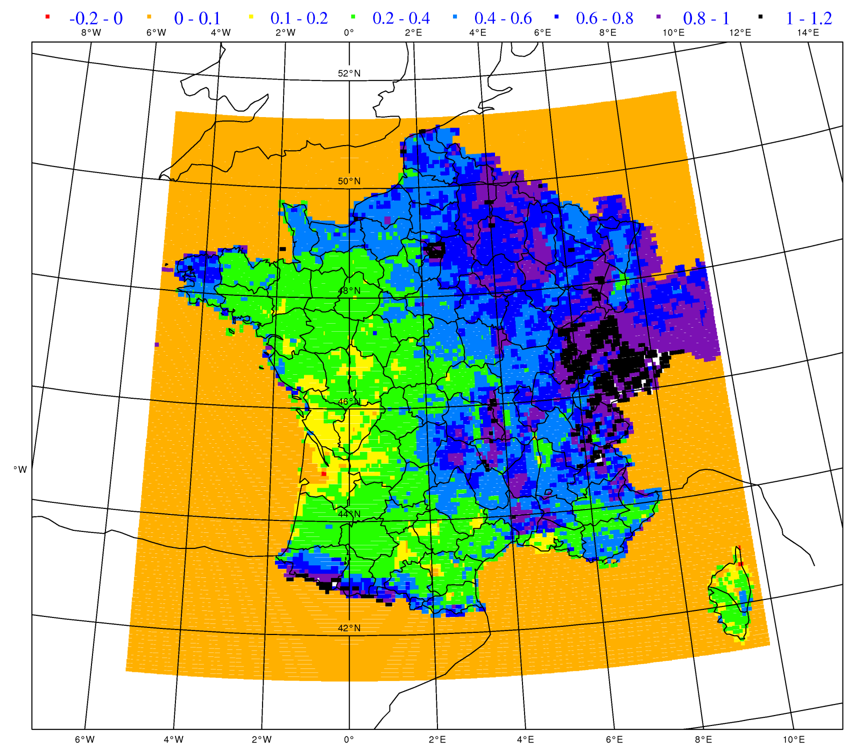


Soil wetness index (*SWI*)

AROME **OPER**



SIM (ISBA with observed forcing)



$$SWI = \frac{w_2 + w_3 - w_{wilt}}{w_{fc} - w_{wilt}}$$

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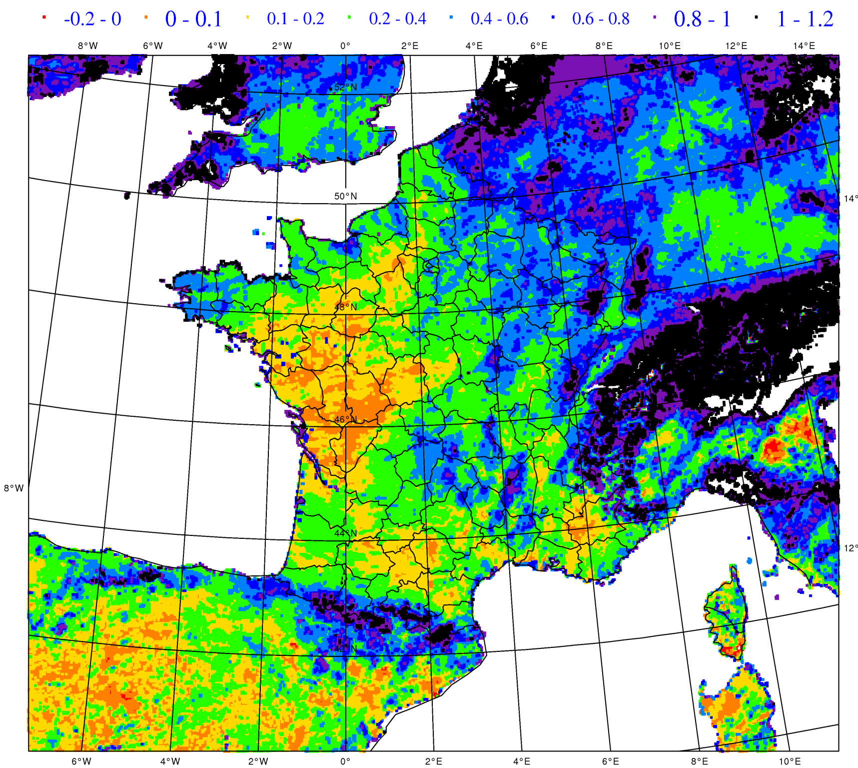
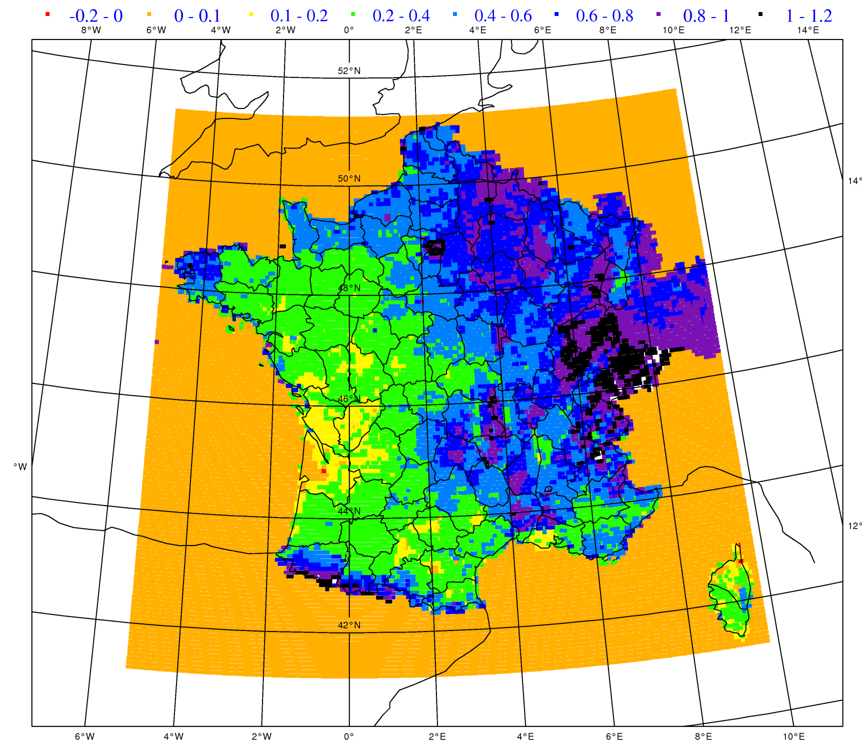
Soil wetness index (*SWI*)

AROME **DBL**



SIM (ISBA with observed forcing)



$$SWI = \frac{w_2 + w_3 - w_{wilt}}{w_{fc} - w_{wilt}}$$

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Ongoing activities

- Use of OI SURFEX and EKF SURFEX in ALADIN and HIRLAM consortia
- Interest of the CEN for snow data assimilation
- Use of LSA SAF products (albedo, surface emissivity) for improved surface specification (assimilation of SEVIRI radiances)
- Participation to EU funded projects (FP7-GEOLAND2 and FP7-EURO4M)
- Towards the assimilation of SMOS data in EKF SURFEX (PhD thesis)
- Interest in the Project for Intercomparison of Land Data Assimilation Systems (PILDAS)
- Areas of improvements (non exhaustive) : bias correction of observations, specification of model errors, computational efficiency, data formats

THANKS FOR YOUR ATTENTION