Soil analysis scheme for AROME within SURFEX

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AROME features

- Current status : Every 6 hours the surface prognostic variables of AROME are interpolated from an ARPEGE analysis
- Differences between ARPEGE and AROME forecasting systems relevant for surface analysis :
  - Higher spatial resolution (2.5 km vs 10 km)
  - Shorter assimilation cycle (3h vs 6h)
  - Improved description of surface processes :
    - Fractional grid coverage : nature / *towns* / *lakes* / oceans
    - ECOCLIMAP land cover / FAO soil type data bases
    - Town Energy Budget (Masson, 2000) = 9 prognostic variables for temperature
    - Three-layer version of ISBA (Boone et al., 2000) = 3 prognostic soil water reservoirs
    - CANOPY surface boundary layer scheme (Masson and Seity, 2009) = 4 prognostic variables (temperature, wind, specific humidity, TKE) on 5 levels

Surface analysis scheme

- Scientific objective : Initialisation of the prognostic variables from the surface schemes available within SURFEX for the NWP model AROME (Soil temperatures and moisture contents of the land surface scheme ISBA + road and building temperatures of the town model TEB)
- Main choices :
  - Variables with long equilibrium time scales = dedicated analysis procedure (e.g. root zone soil moisture)
  - Variables with fast equilibrium times cales = cycling (e.g. prognostic variables of CANOPY)
  - Assignment of temperature from water bodies (lake, oceans) using an SST analysis (CANARI OI scheme)
  - Method : same as one used for ALADIN since Feb.2009 at Météo-France (Optimum Interpolation scheme described in Giard and Bazile (2000))

Surface and soil analyses for AROME

- Adapation of the OI CANARI for screen-level analysis (and SST analysis) to AROME : use background values for T2m and RH2m computed by CANOPY (no vertical interpolation in CANARI) – conservative approach (same statistical model as in ALADIN and ARPEGE)
- Reduction of the OI coefficients for soil moisture corrections by a factor of two in order to account for the reduction of the assimilation window by the same factor
- Initialisation of the same soil water reservoirs as in ALADIN : Ws and Wp. *The deeper reservoir W3 does not act directly on evapotranspiration and has a smaller depth than the root zone.*
- Initialisation of the deep road temperature (1 m depth) using increments of the deep soil temperature analysis
- Consistency checks for snowmelt and soil freezing
- All other prognostic variables are simply cycled => Analysis = 3h forecast

Soil analysis equations

Analysis increments for the volumetric soil water contents (ws and wp) and the soil temperatures (Ts and Tp) :

$$\Delta w_s = \alpha_1 (T_{2m}{}^a - T_{2m}{}^b) + \alpha_2 (HU_{2m}{}^a - HU_{2m}{}^b)$$

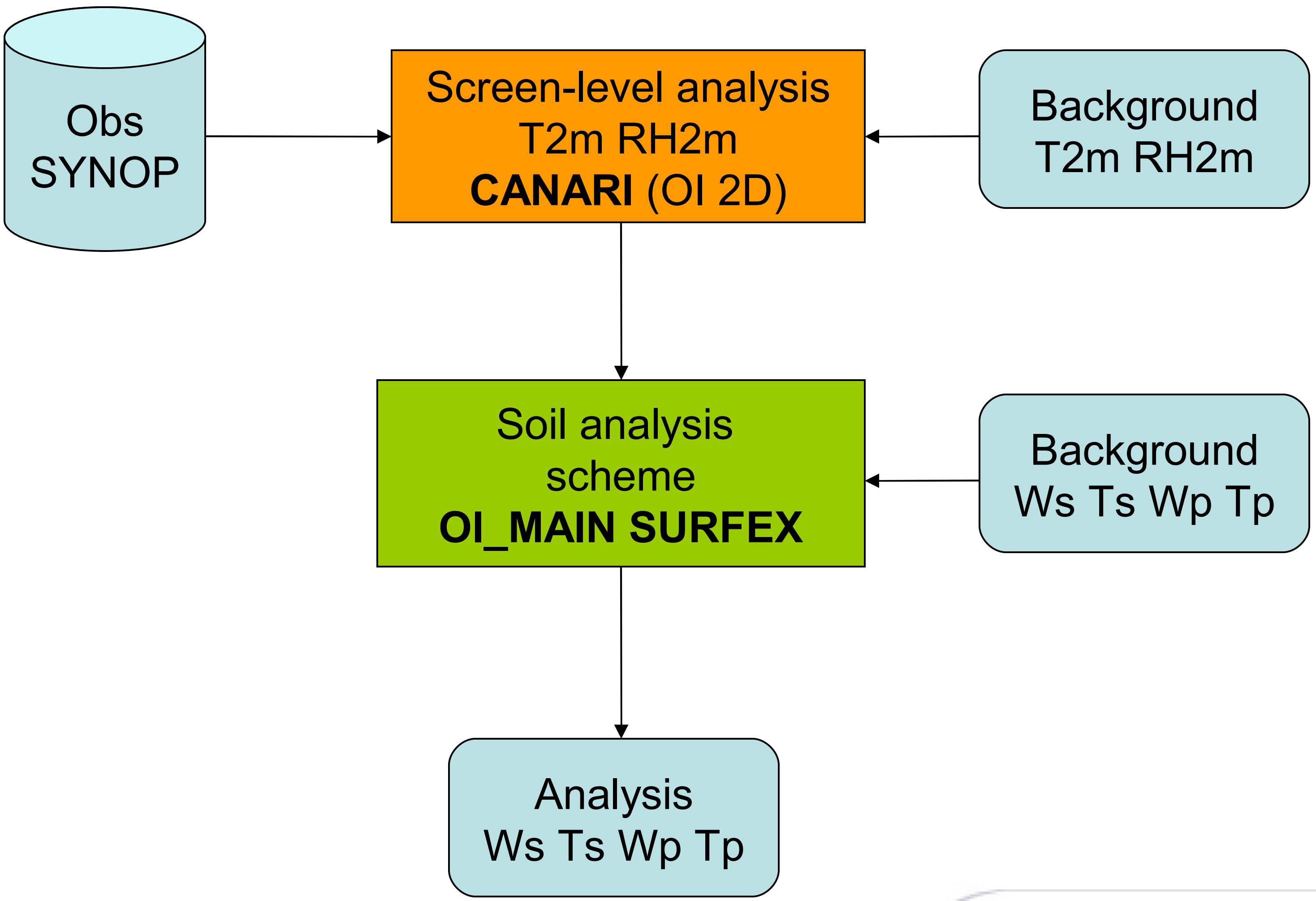
$$\Delta w_p = \beta_1 (T_{2m}{}^a - T_{2m}{}^b) + \beta_2 (HU_{2m}{}^a - HU_{2m}{}^b)$$

$$\Delta T_s = \mu_1 (T_{2m}{}^a - T_{2m}{}^b)$$

$$\Delta T_p = \nu_1 (T_{2m}{}^a - T_{2m}{}^b)$$

Giard and Bazile (2000)
[Monthly Weather Review]

Soil analysis scheme

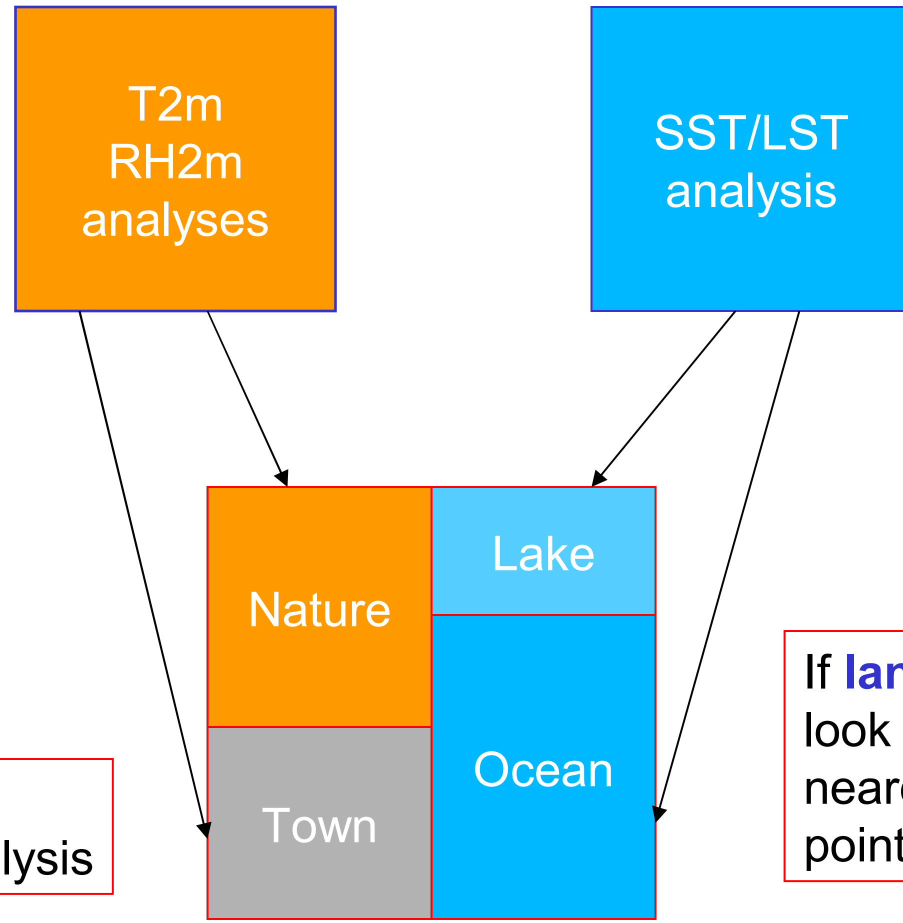


Few thoughts

- Screen-level analyses of T2m and RH2m over all surface types (nature/towns/sea/water)
- Despite being performed on a 2.5 km grid, the correlation lengths of the OI scheme and the density of the surface network prevent small scale heterogeneities (< 50 km) from being provided by the observations => they do not contain enough information to initialise all surface types
- What to do with small scale and sub-grid scale surfaces ?
  - Do not perform any analysis – are the models good enough ?
  - Impose a climatology – if available for slow evolving variables
  - Use screen-level observations that are influenced by other tiles or other grid points (smoothing effect)
- Current observation operator not satisfactory for heterogeneous tiles (weighted average)

Correspondence atmosphere-surface

Atmosphere
Land/sea : binary



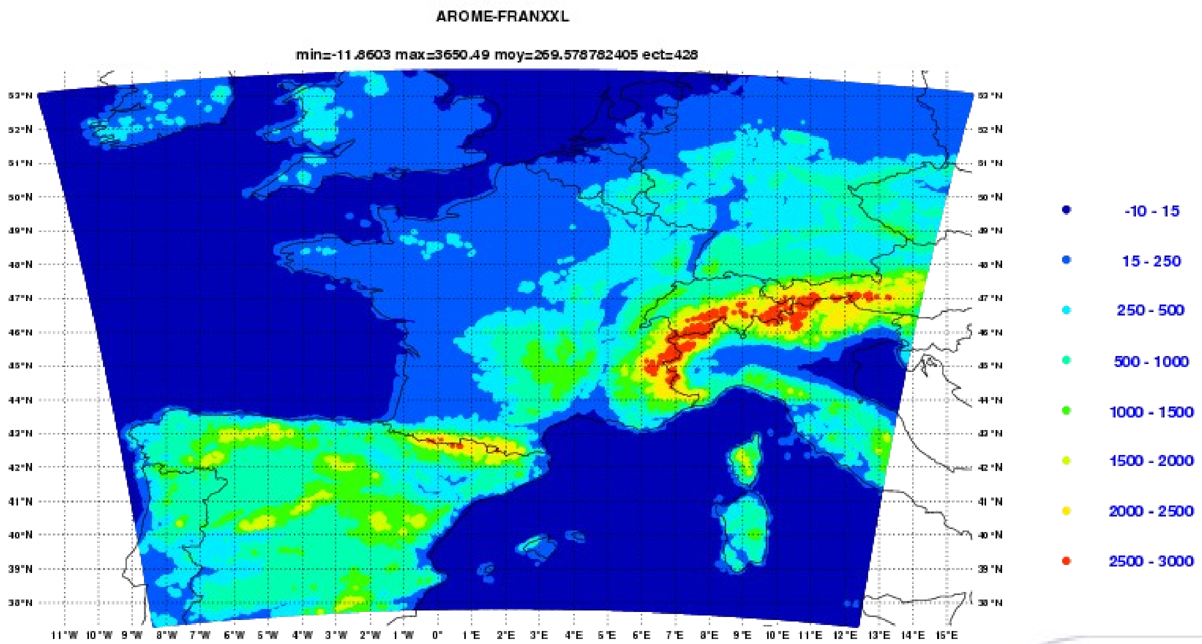
Surface
Tiling approach

If **sea** point :
Still perform analysis

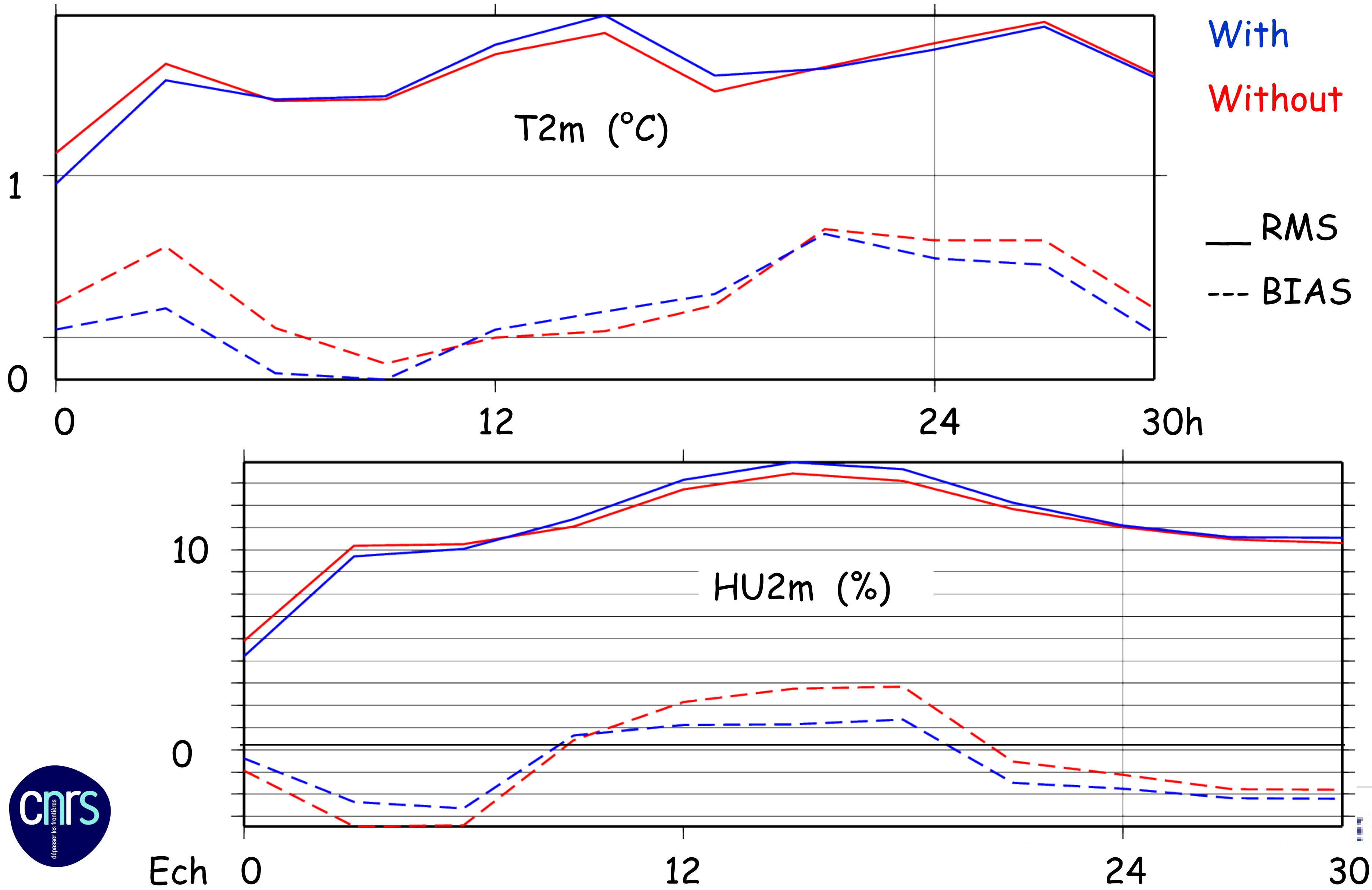
If **land** point :
look for the nearest sea point

Experiments

- The soil analysis is in parallel suite since the end of June 2010 that includes a wider AROME domain with an increased usage of observations (SSMIS/aircrafts/IASI/radar Doppler winds)
- Preliminary AROME 3D-Var with only the soil analysis (3 weeks)



Surface analysis – 3 week evaluation

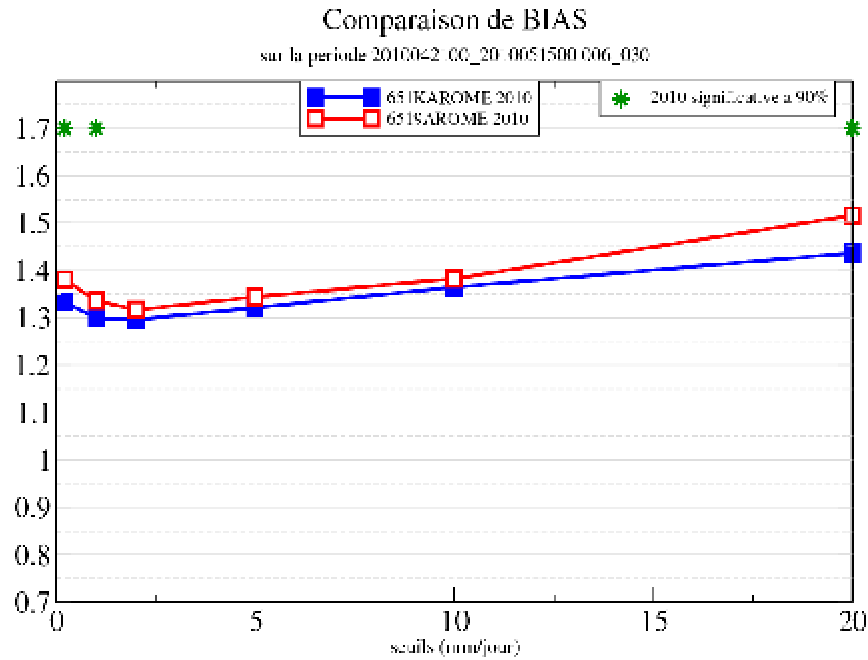


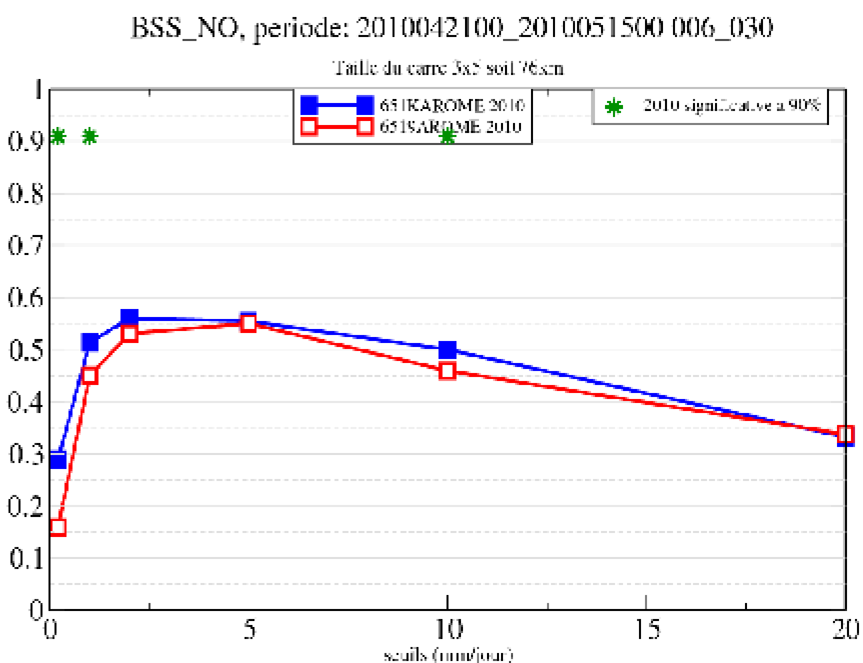
Precipitation scores

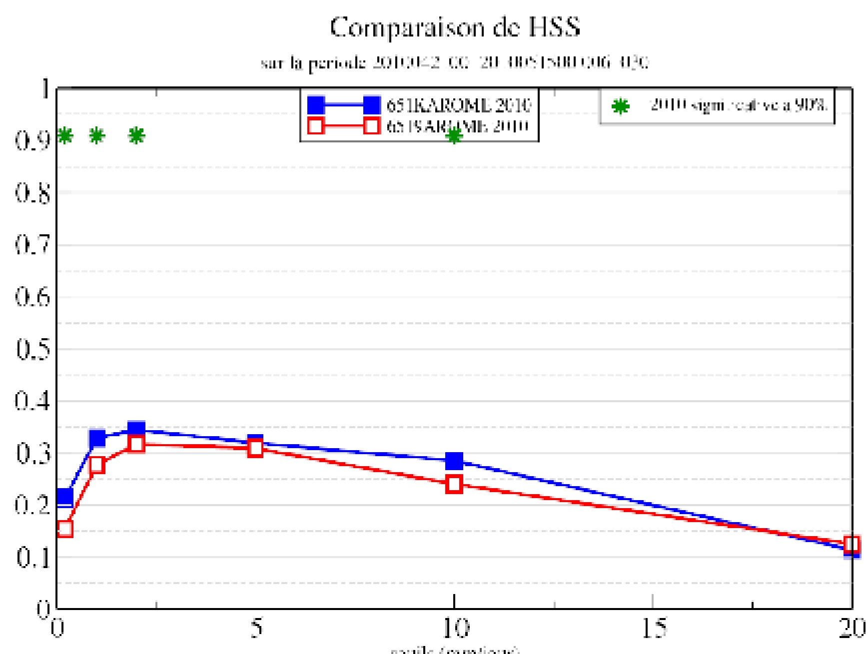
With surface analysis

Without surface analysis

3 weeks (15/05 – 21/04/2010)

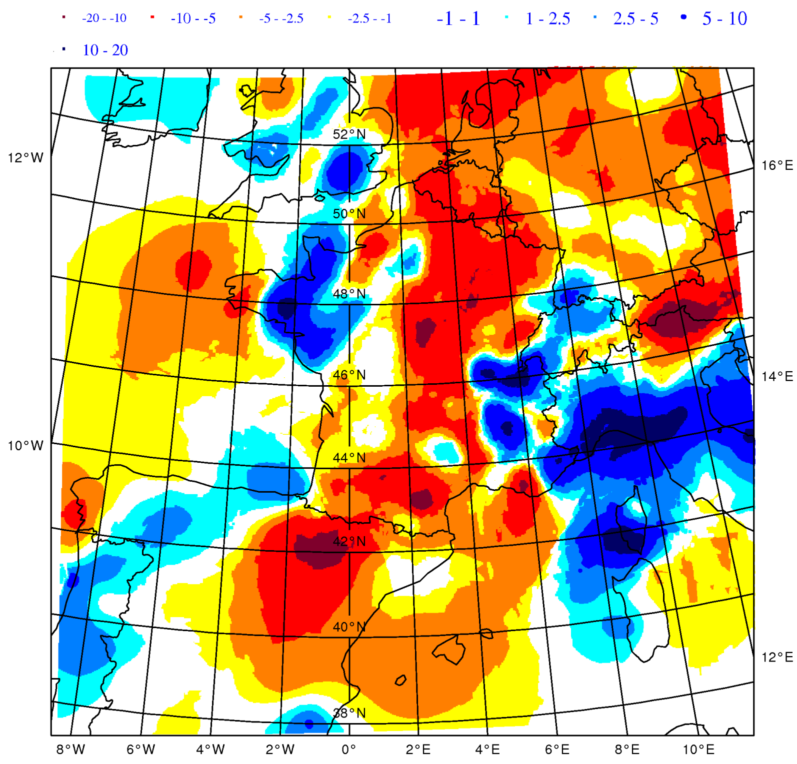




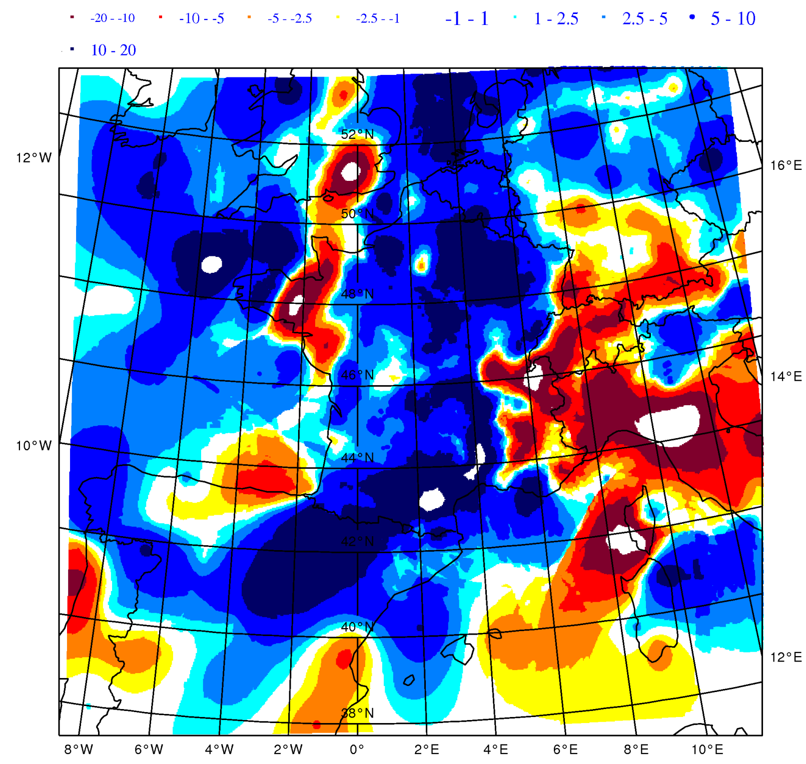


T2m and RH2m analysis increments

RH2M increments 12 Z - 20 August 2010 - DBL



T2M increments 12 Z - 20 August 2010 - DBL



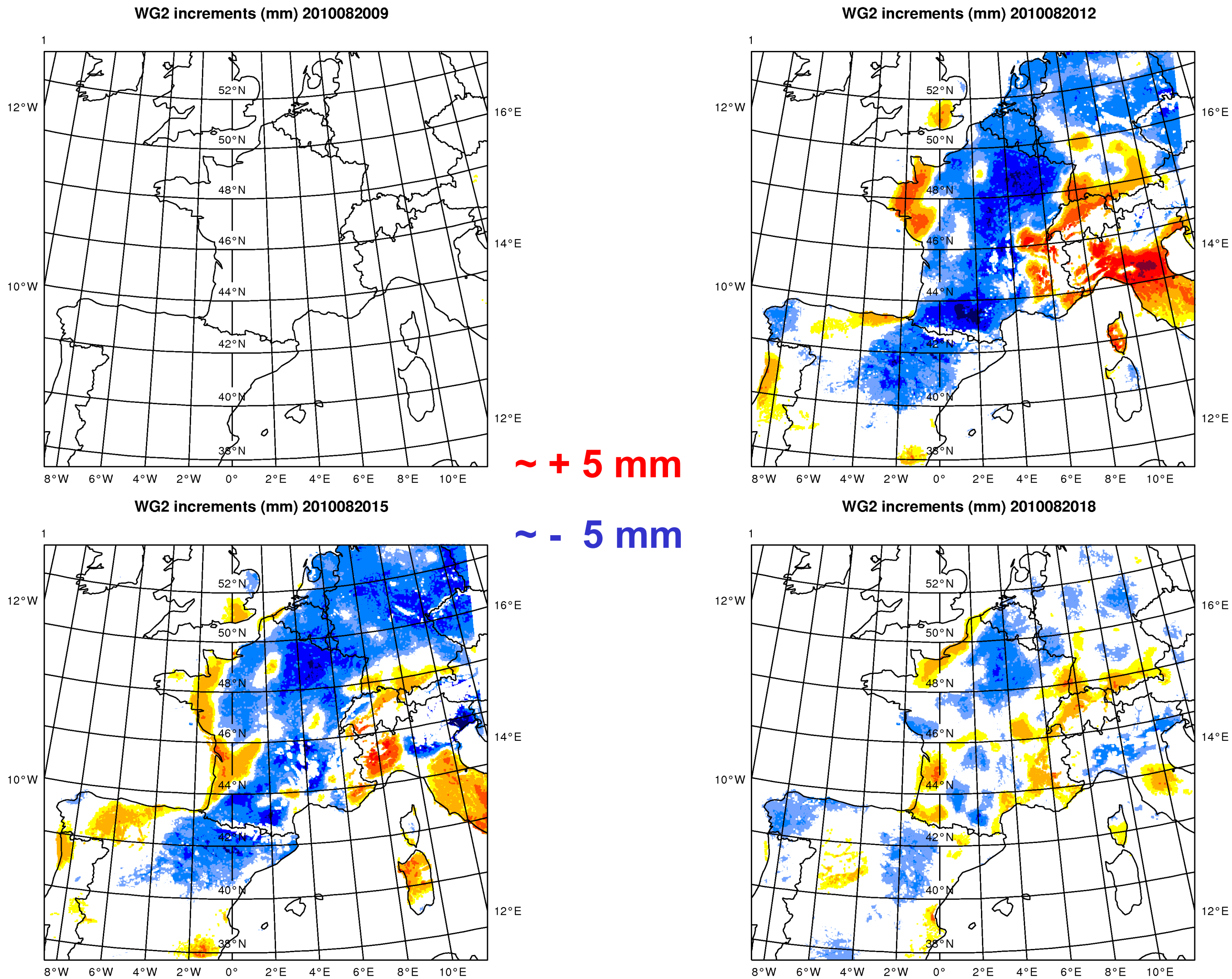
Negative increments : model too moist

Positive increments : model too cold

Soil moisture increments (diurnal cycle)

09 UTC

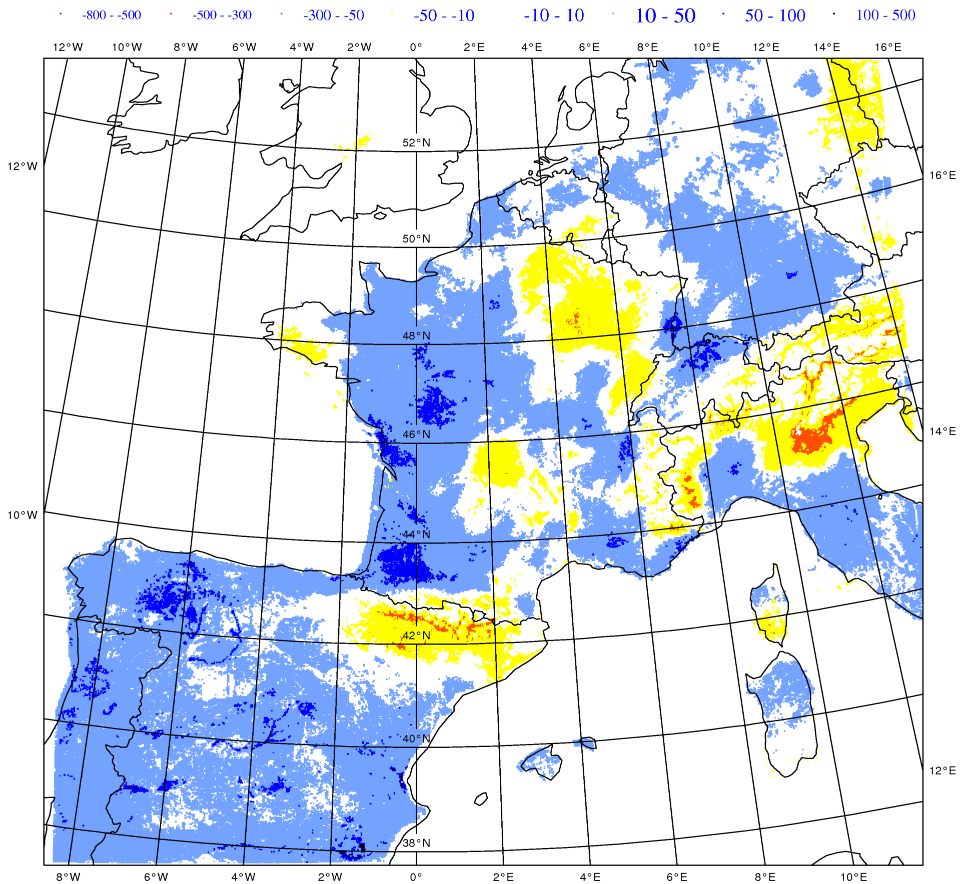
12 UTC

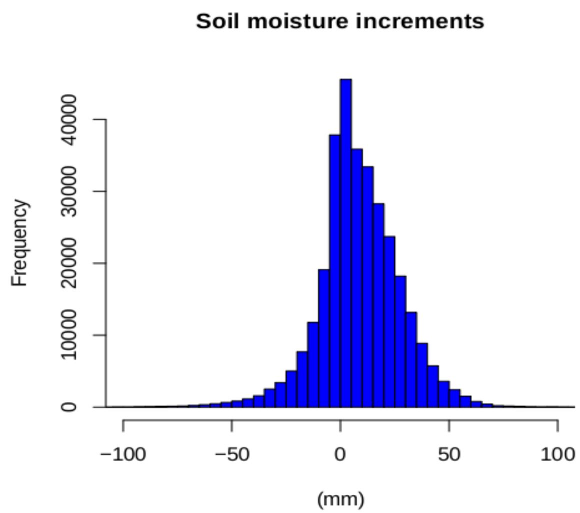


15 UTC

18 UTC

Soil moisture increments (accumulated)





Mean=8.7 mm

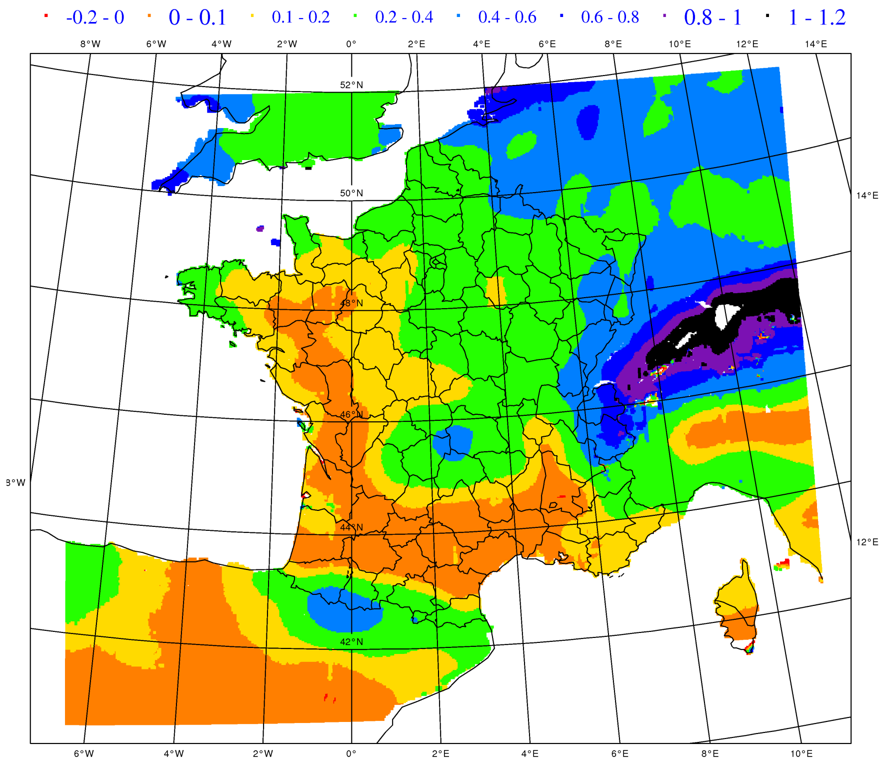
Stdev=19 mm

12/08/2010 -> 11/09/2010

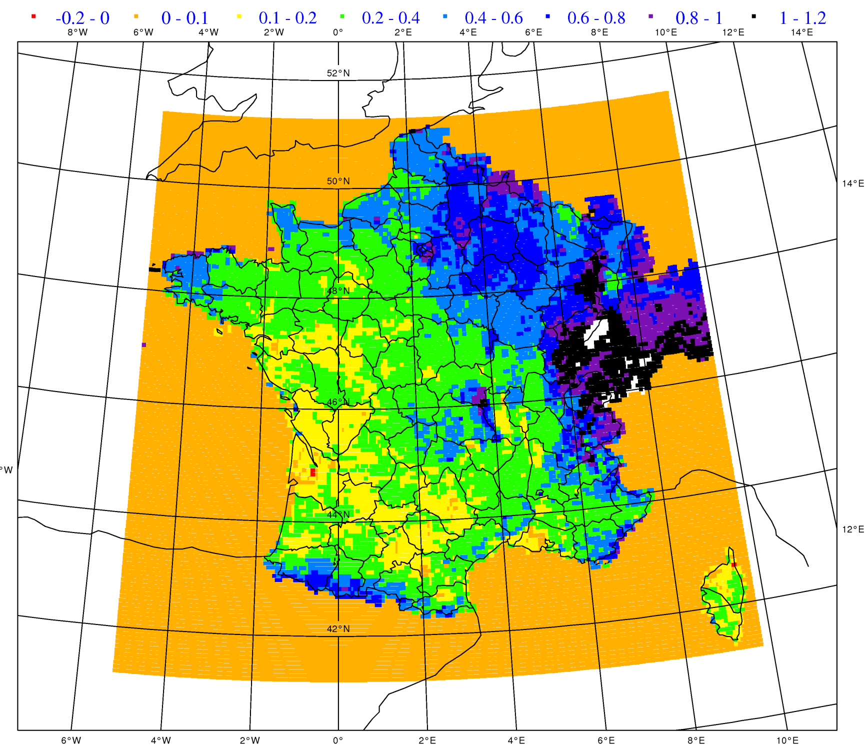
Color convention changed !!

Soil wetness index (*SWI*)

AROME **OPER**



SIM (ISBA with observed forcing)



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

01 September 2010

cnrs dépasser les frontières

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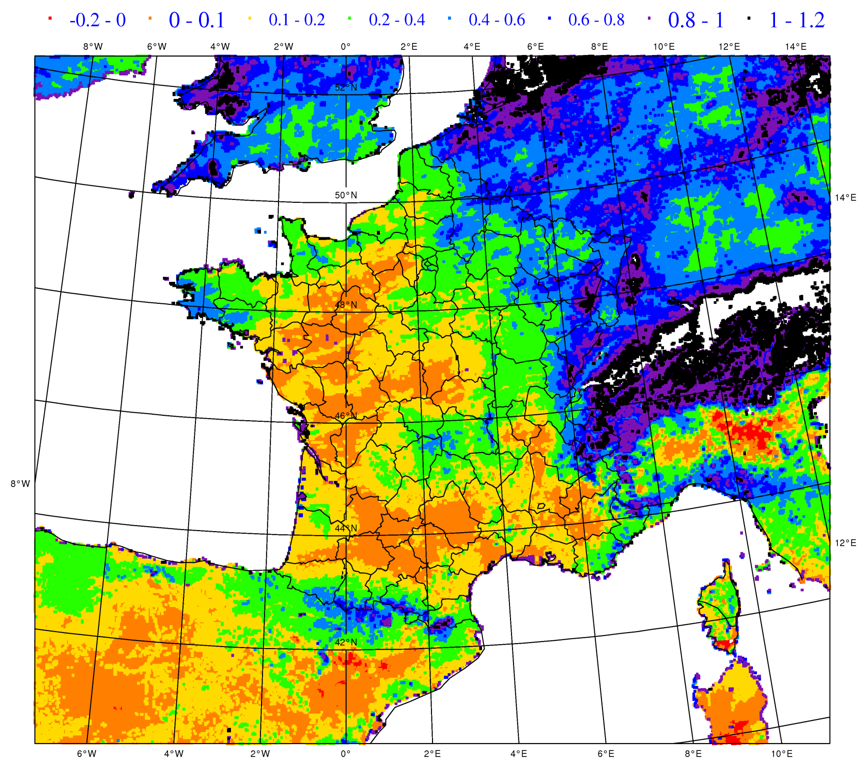
Soil wetness index (*SWI*)

AROME **DBL**



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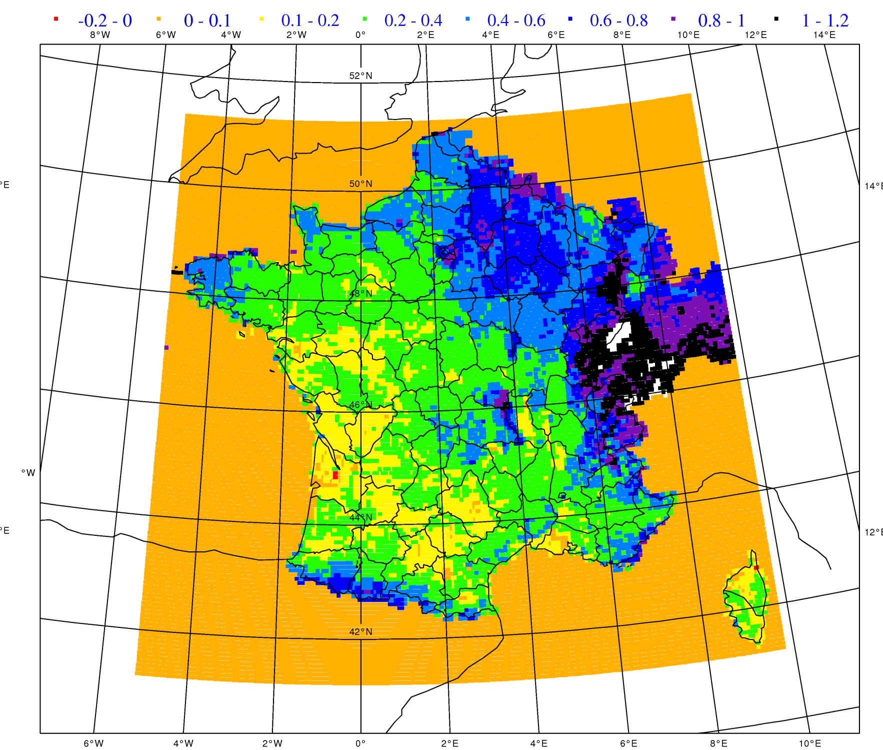

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01 September 2010

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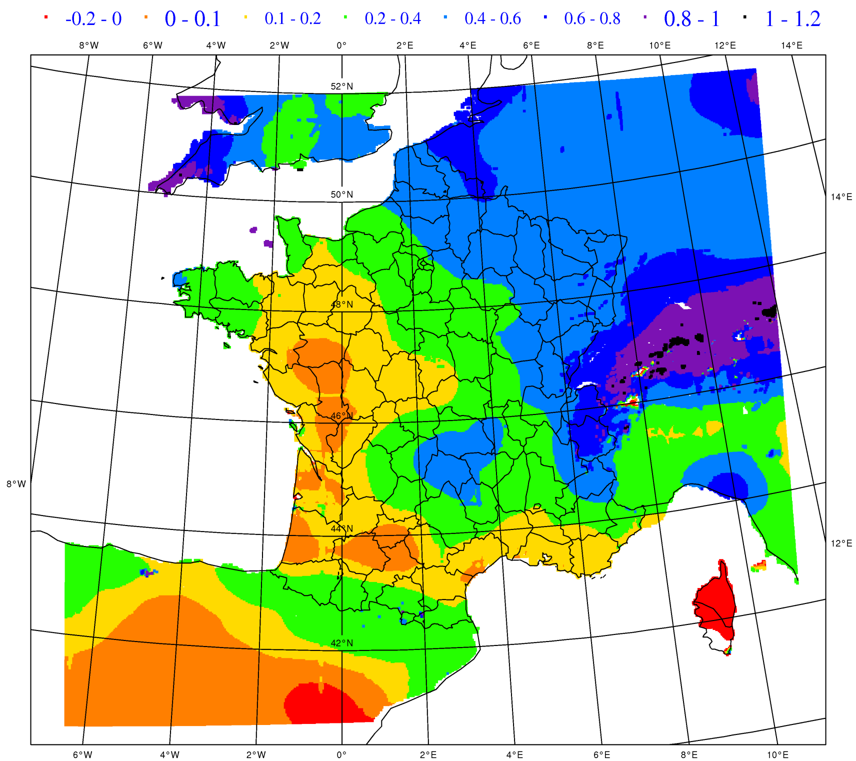

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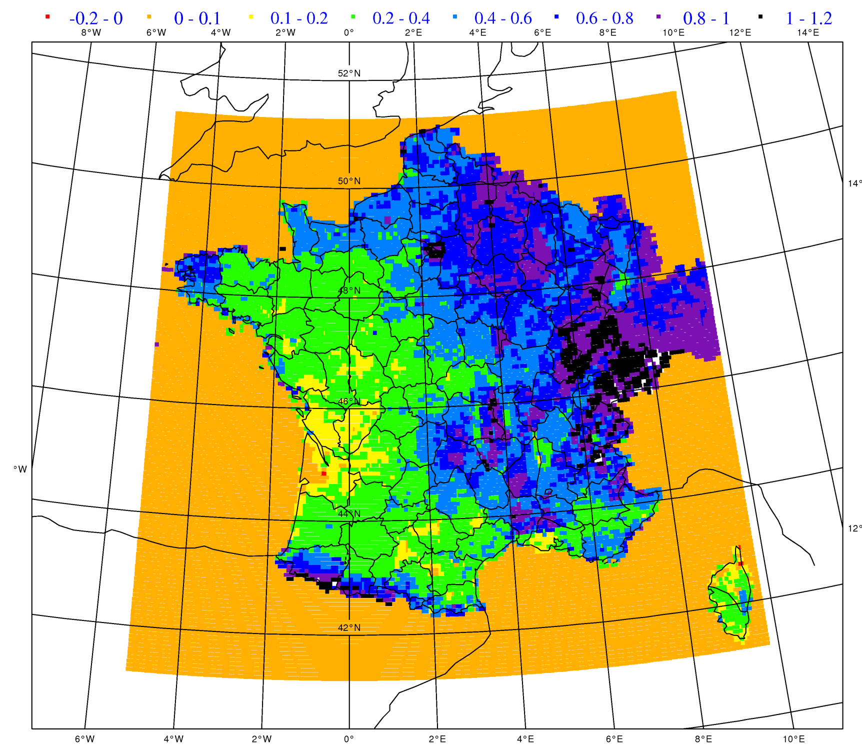

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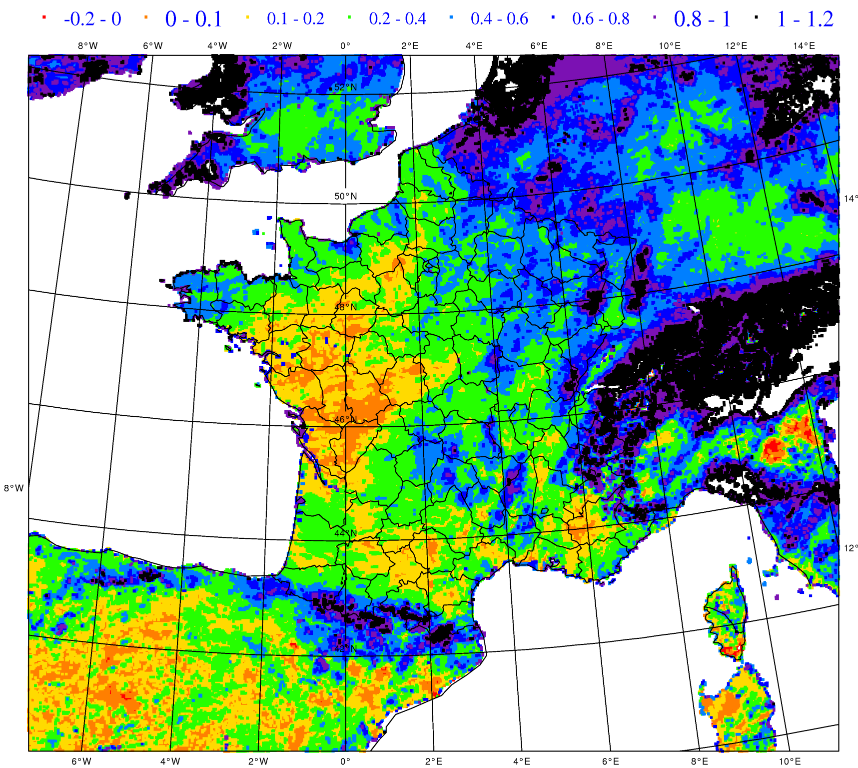
01 October 2010

Soil wetness index (*SWI*)

AROME **DBL**



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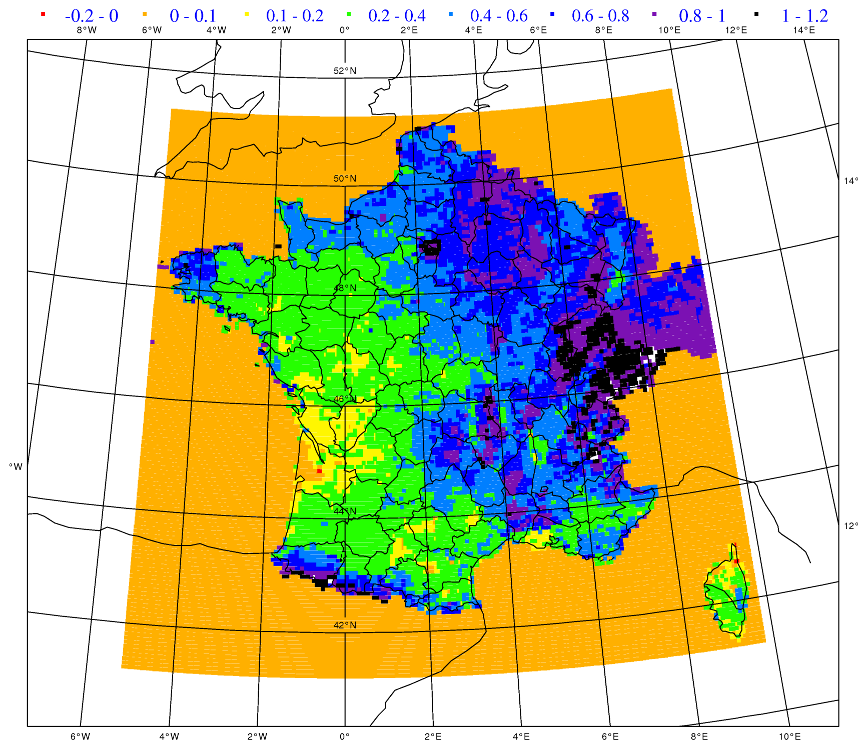

$$SWI = \frac{w_2 + w_3 - w_{wilt}}{w_{fc} - w_{wilt}}$$

01 October 2010

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Conclusions

- Soil analysis scheme is available within SURFEX (OI_MAIN) and is suitable for AROME and also ALADIN/ALARO
- 3D-Var assimilation experiments in summer have shown a reasonable behaviour of the soil analysis (size of increments).
- Precipitation scores are improved and biases in screen-level parameters are reduced
- The SWI compares better with the hydrological system SIM – in particular small scales features induced by orography
- This soil analysis should go in operations with the next AROME version.

Possible improvements

- Reduction of the OI coefficients for the superficial reservoir Ws as it has been done for the deep reservoir Wp (Mahfouf et al., 2009)
- Improve the soil temperature analysis : diurnal cycle of the OI coefficients (larger values during the night and for the deep soil temperature) (Mahfouf et al., 2009)
- Use a lake surface temperature climatology (Kourzeneva, 2010) instead of an inaccurate SST analysis over lake surfaces (provided or extrapolated).
- Replace the OI scheme by a (Simplified) Extended Kalman Filter

Thanks for your attention

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