SURFEX in ALADIN (and ARPEGE) NWP models

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METEO FRANCE
Toujours un temps d'avance

PLAN

- ARPEGE and ALADIN operational NWP configurations
- Operational surface physical parameterizations
- SURFEX implementation in ALADIN (and ARPEGE)
- Validation status and some results
- Perspectives

ARPEGE configurations

- "ARPEGE" : stretched global model with 4D-Var data assimilation

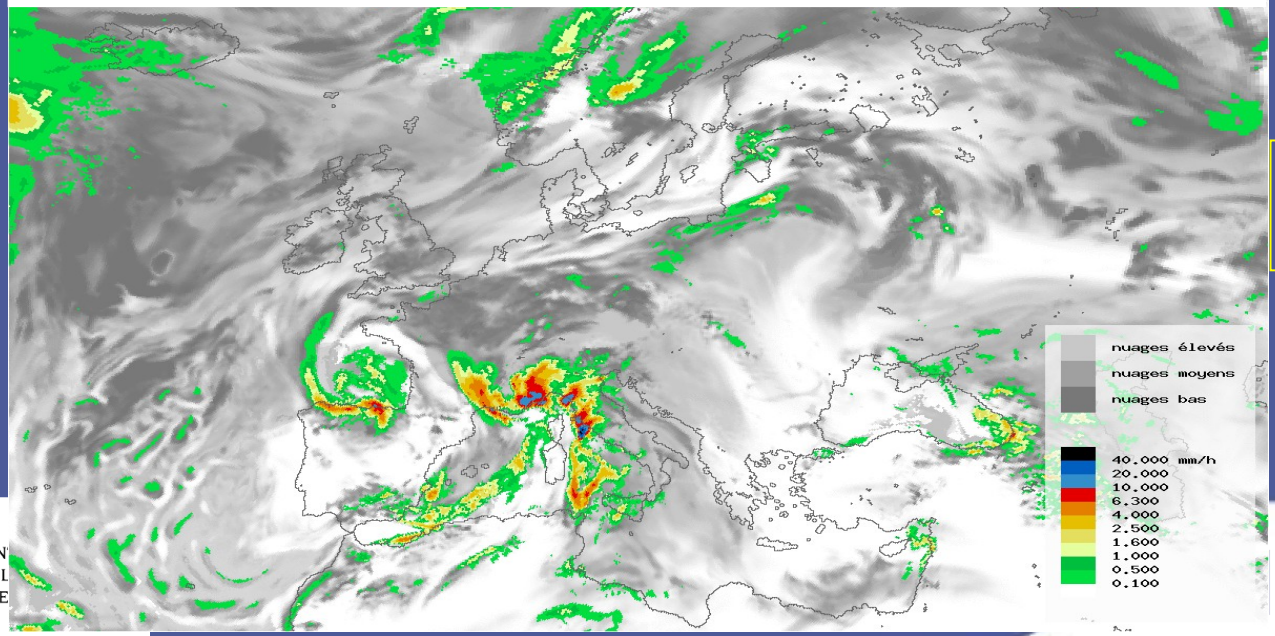
  oper: 15<Δx<90, 60 vertical levels, Analysis increments = 90km

  test: 10<Δx<60, 70 vertical levels, Analysis increments = 60km
- "AEARP" : ensemble of assimilations 3D-Fgat/4D-Var

  6 members, Δx=55km, 60/70 vertical levels
- "PEARP" : short range ensemble forecasting system

  11/35 members, 23<Δx<130, 55/65 vertical levels

ARPEGE 30h forecast from 20090915r0 analysis
1-h cumulated precipitations and L/M/H cloudiness



ARPEGE
New resolution

ALADIN configurations

- "ALADIN-France" : LAM with 3D-Var data assimilation

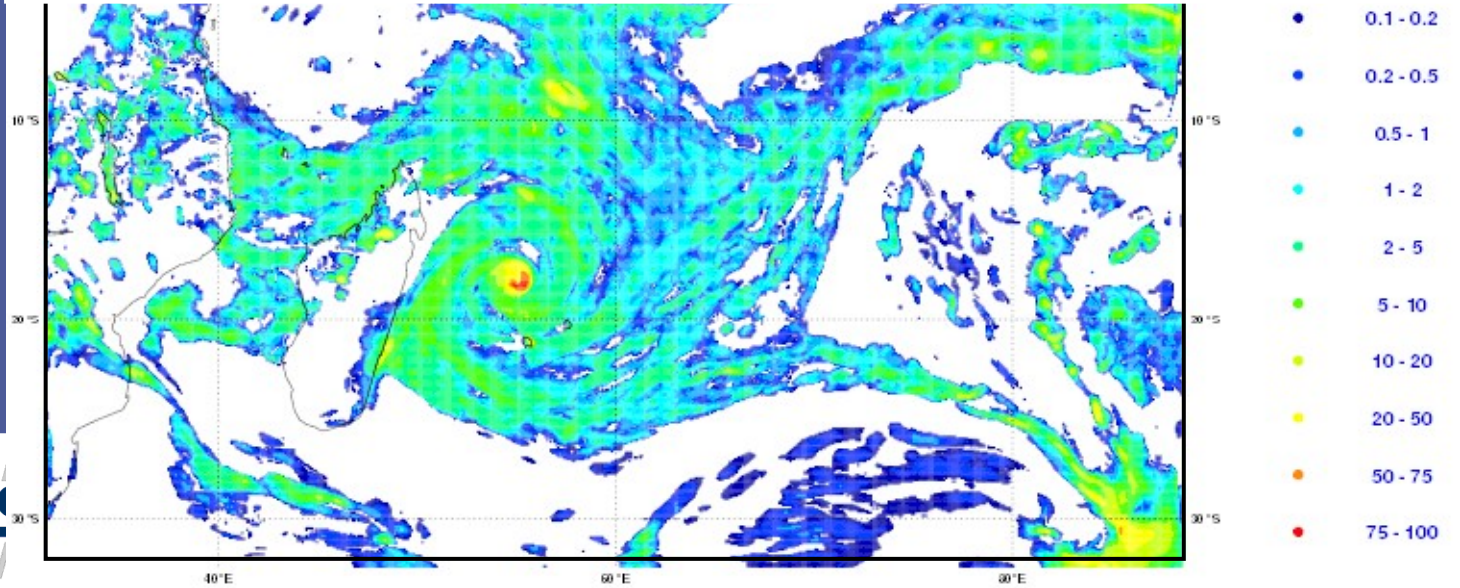
  oper: Δx=9.5km, 60 vertical levels

  test: Δx=8km, 70 vertical levels
- "ALADIN-Réunion" : LAM with 3D-Var data assimilation

  oper: Δx=10km, 60 vertical levels

  test: Δx=8km, 70 vertical levels
- By end 2010: "ALADIN-OM" with 3D-Var data assimilation over 3 new domains : New Caledonia, French Polynesia, Antilles

"ALADIN-Réunion" 24h forecast from 20090205r0 analysis
3-h cumulated surface precipitations



ARPEGE and ALADIN characteristics

- ARPEGE (global) and ALADIN (LAM): same dynamics and physics
- Dynamics: Hydrostatic shallow-atmosphere approximation, pressure-based hybrid vertical coordinate, two-time-level semi-lagrangian semi-implicit time integration scheme, spectral horizontal representation, finite-element vertical representation, spectral horizontal diffusion
- Atmospheric physics:
  - Prognostic TKE turbulence scheme (Cuxart et al., 2000)
  - Mass flux moist shallow convection (Bechtold et al., 2001)
  - Mass flux deep convection scheme (Bougeault, 1985)
  - PDF based cloud scheme (Smith, 1990)
  - Microphysics with 4 prognostic hydrometeors (Lopez, 2002)
  - Radiation scheme RRTM & FM6 (Mlawer et al., 1997, Morcrette et al, 2001)
  - Gravity wave drag scheme (described in annexe of Catry et al. 2008)
- Upper air analyses: 4D-Var (ARPEGE) / 3D-Var (ALADIN)

Surface characteristics

Physiography: - GTOPO30 database (5' resolution), - Binary land sea mask

- Soil types: NASA database 1° - Soil depths: ISLSCP 1°

- Land covers: AVHRR NDVI classification over Europe (res. 2km), Wilson and Henderson Sellers (1985) classification elsewhere (res. 1°) : Lookup tables between ecotypes and model parameters, « effective roughness length »

ISBA scheme (Noilhan & Planton 1989, Noilhan & Mahfouf 1996, Giard & Bazile 2000)

- Surface energy balance one single surface temperature (bare soil/vegetation/snow)

- Soil transfers 2-layers force-restore method (1st layer= 1 cm, 2nd layer = 1m<d2<3m)

- Vegetation 1-layer. Canopy resistance formulation for transpiration (Jarvis).

Frozen soils 2-layers: surface and deep frozen water contents (Bazile, 1999)

Snow model 1-layer: snow water equivalent, snow albedo (Bazile et al., 2001)

Bulk iterative parameterisation "ECUME" for ocean fluxes

Constant surface temperatures over open sea, sea-ice and lake

Surface analyses: Assimilation of T_{2m}, H_{2m} obs for soil temperatures and soil moistures initialization based on Optimal Interpolation, SST and Sea-ice cover analyses

Benefits of surface externalization in atmospheric models

- Surface models become more and more sophisticated and so their development, initialization, dataflow, diagnostics should be preferably separated from atmospheric models : surface and atmospheric modelling communities will be likely more and more separated in the future

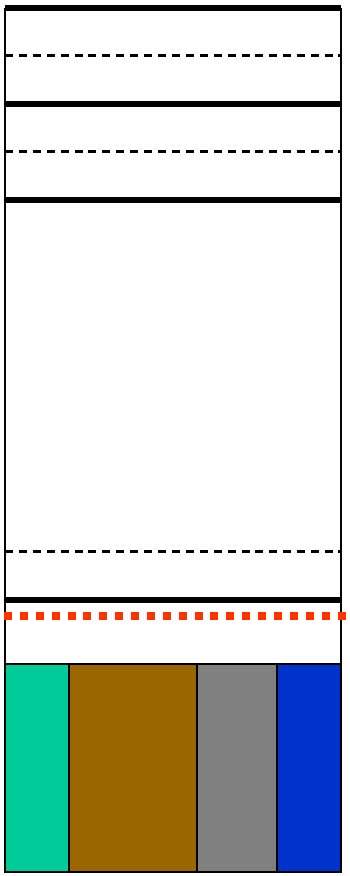
- Make easier the implementation of new surface parameterizations in atmospheric models (general interface surface/atmosphere : Polcher et al. 1998)

- The use of identical surface parameterizations in « in line » and « off line » modes open new perspectives for surface modelling and surface analysis (advanced analysis algorithms, use of analysed precipitation and radiation fluxes, …)

SURFEX implementation in ALADIN / ARPEGE (specific aspects compared with AROME)

- Implicit coupling required for long time step (ALADIN~500s, ARPEGE~1000s)
- Specific surface variables are needed for atmospheric parameterizations : Qs, Z_0, Z_{0h}, fraction of sea, snow fraction, ...
- Ascendant compatibility implies :
  - use of operational physiographic databases (not ECOCLIMAP)
  - specific developments done in ISBA not present in initial SURFEX :
    snow scheme, frozen soil scheme, surface exchange turbulent coefficients, thermal inertia of vegetation, ...
  - consistency issues between atmospheric and surface computations (L, Cp, …)
- Parameterization of subgrid scale orographic effects (« GWD »)
- Digital Filter Initialization
- Surface analysis
- For ARPEGE : gaussian grid, longer time step, meteorological conditions, 4D-Var compared with 3D-Var

Implicit coupling with the atmosphere



Vertical diffusion

$$X \equiv u, v, \theta, q$$

$$X_i^+ - X_i^- = -\omega_{i,i}\left(X_{i+1}^+ - X_i^+\right) + \omega_{i-1,i}\left(X_i^+ - X_{i-1}^+\right)$$

$$F_{X,\cdot} = \cdot$$

Downward sweep

$$X_i^+ = A_{X,i}^- X_{i+1}^+ + B_{X,i}$$

$$A_{X,i} = f\left(\omega_{i-1,i}, \omega_{i,i}, A_{X,i-1}\right)$$

$$B_{X,i} = f\left(\omega_{i-1,i}, \omega_{i,i}, B_{X,i-1}, X_{X,i-1}\right)$$

Lower atmospheric level

$$X_N^+ = A_{X,N}^- F_{X,S}^+ + B_{X,N}^-$$

Surface Ts + Fluxes on each tiles, Average fluxes

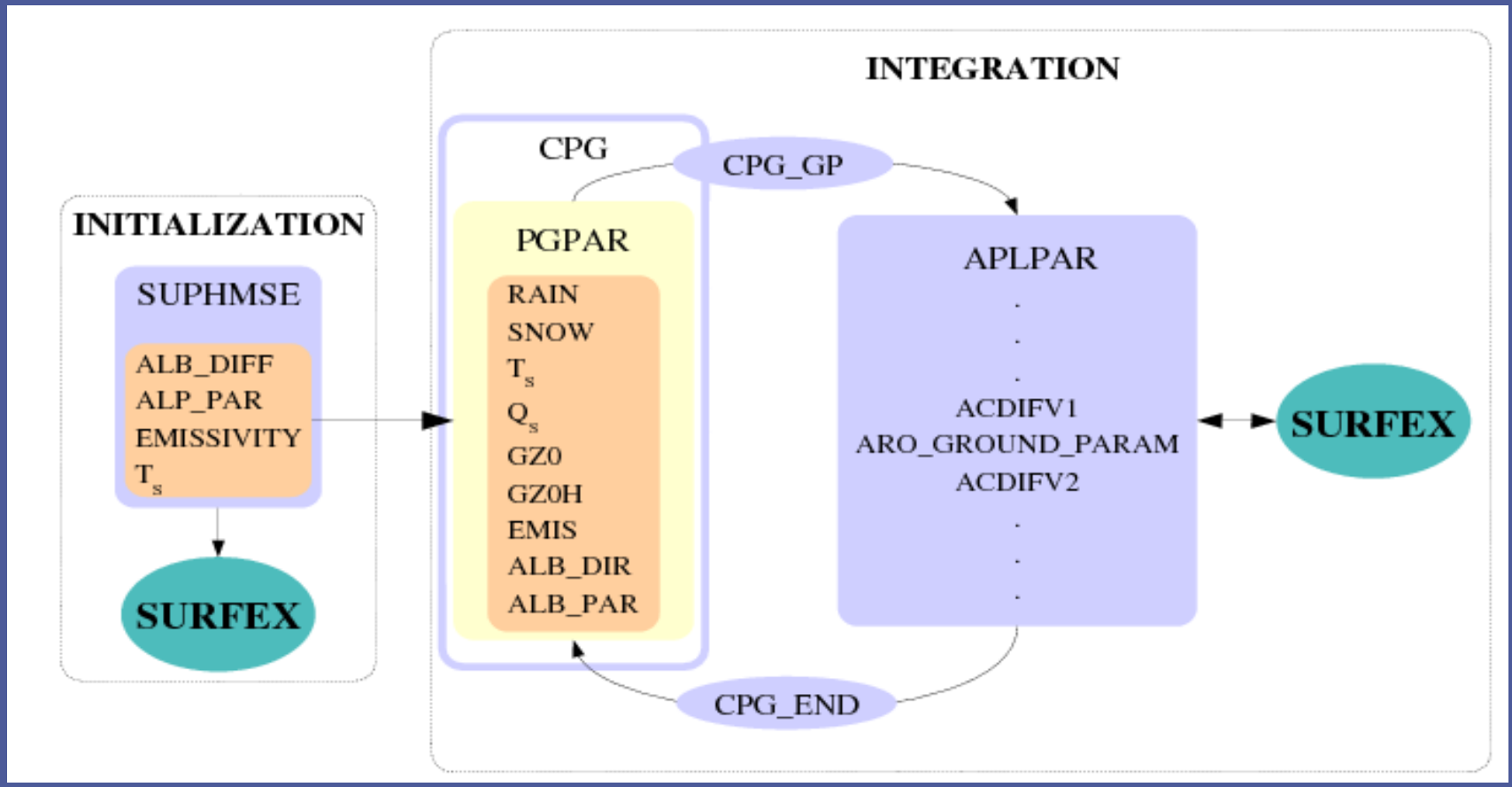
$$H^+ = \rho C_p V_N^- C_H^- \left(\beta_S T_S^+ - \beta_N T_N^+\right)$$

$$\frac{C_s}{\Delta t}\left(T_S^+ - T_S^-\right) = R_n^+ - H^+ - LE^+ - G^+$$

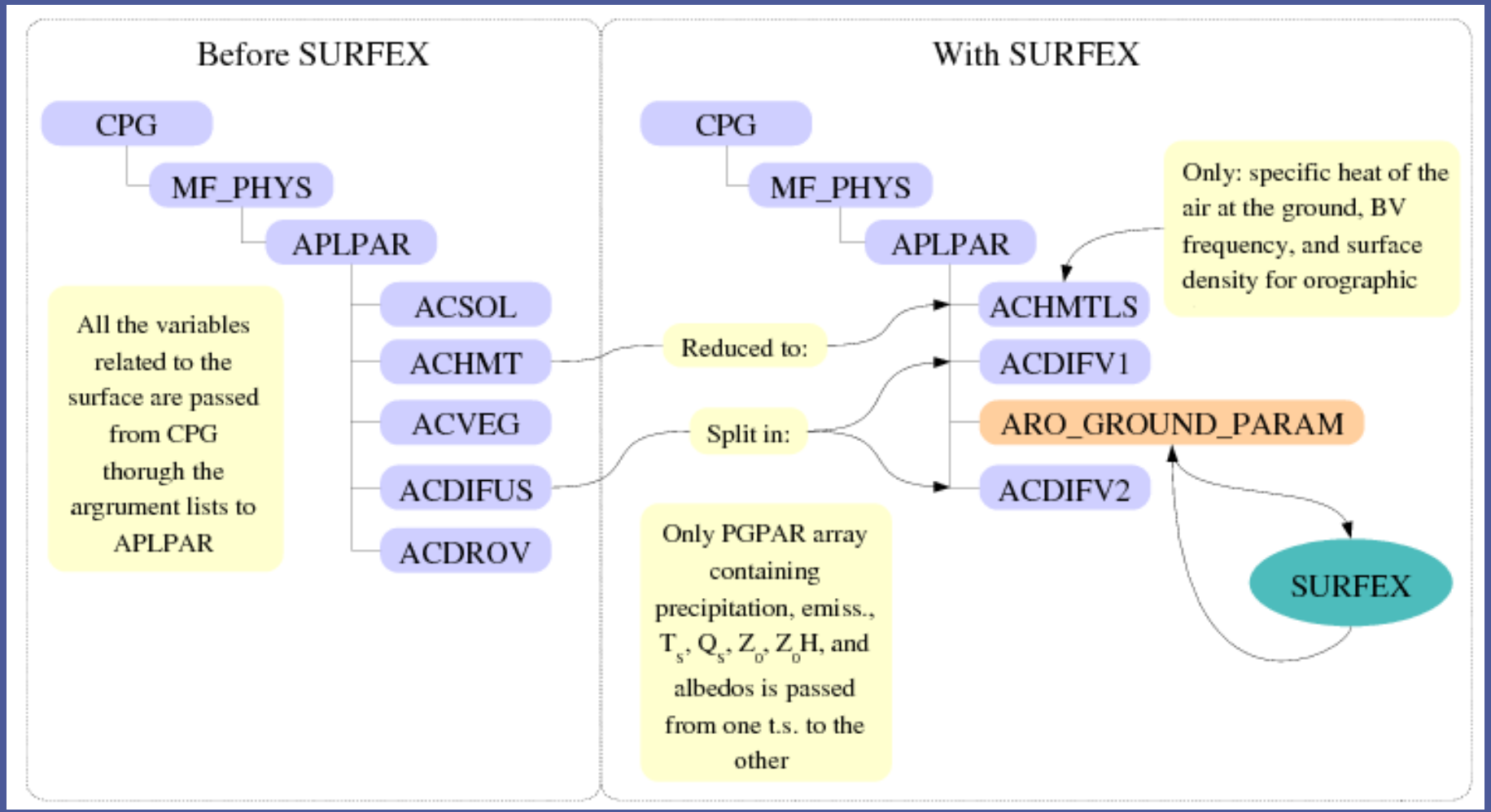
Upward sweep

(Best et al. 2004)

Implementation of SURFEX in ARPEGE / ALADIN (1)



Implementation of SURFEX in ARPEGE / ALADIN (2)



Model validation (1)

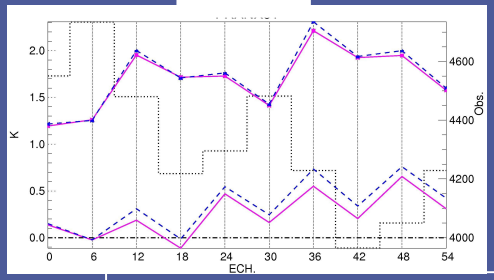
- Reproducibility tests of ALADIN with and without SURFEX are very useful to find remaining bugs, interfacing and parameterization discrepancies
- There are “small” differences remaining :

  - Initialization of some prognostic variables, like water content over vegetation or snow albedo

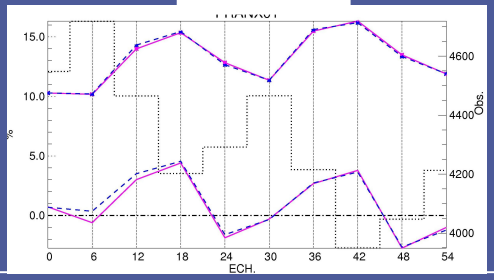
  - Location of surface processes is not the same in the physics with and without SURFEX : for instance the precipitation fluxes computed in the time-step are not available when calling SURFEX and should be pseudo-historical variables

  - Operational frozen soil parameterization not coded in SURFEX

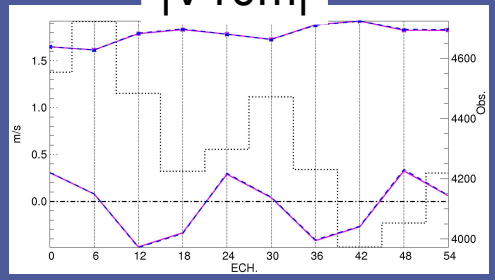
T2m



RH2m



|V10m|

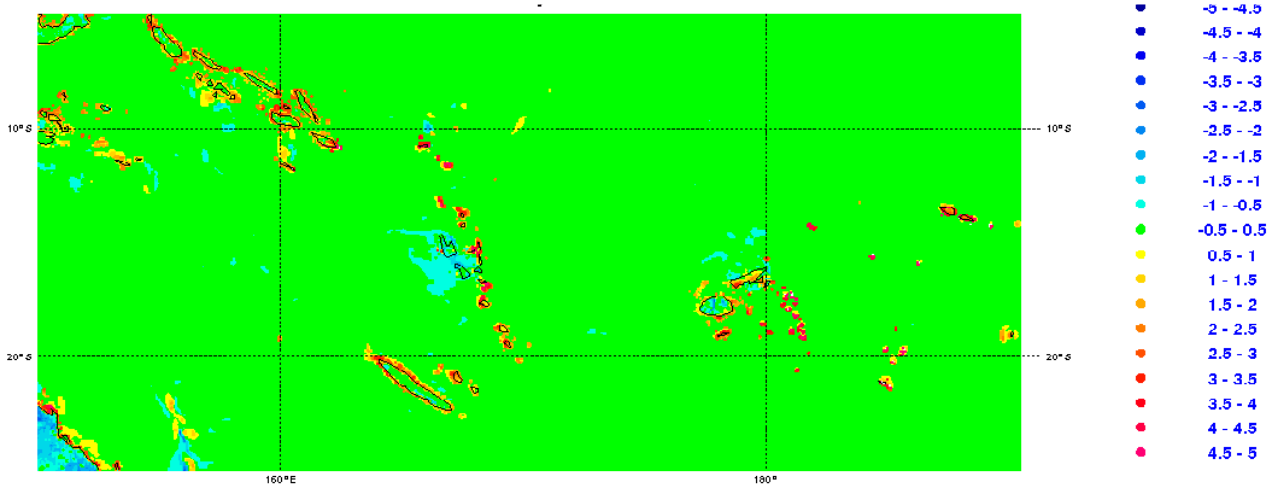


SYNOP scores for T2m, H2m, |V10m| over France for the period 1-20/07/2008
ALADIN oper (blue), ALADIN with SURFEX)

Model validation (2)

- Preliminary evaluation of ALADIN with SURFEX in forecast experiments, using similar SURFEX configuration as in AROME : ECOCLIMAP, ISBA-3L, Snow scheme (Douville, 1995), Frozen soil scheme (Boone et al, 2000), *but not TEB and CANOPY schemes (not tested yet for long time-steps)*
- Example showing the impact of fractional surface representation (sea, lake, nature, town):

12h forecast differences on T2m (SURFEX-OPER) with ALADIN_New_Caledonia

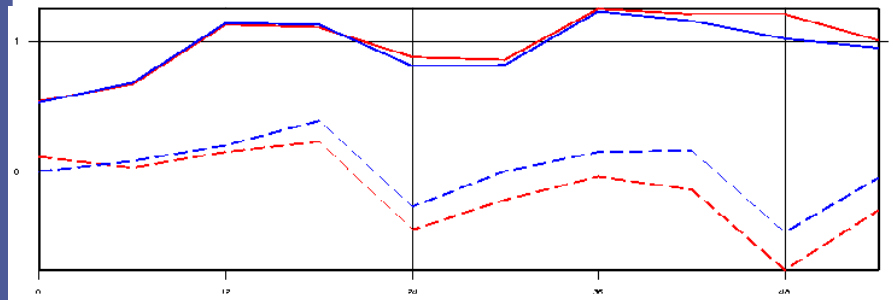


Objective scores on 54h forecasts (July 2008)

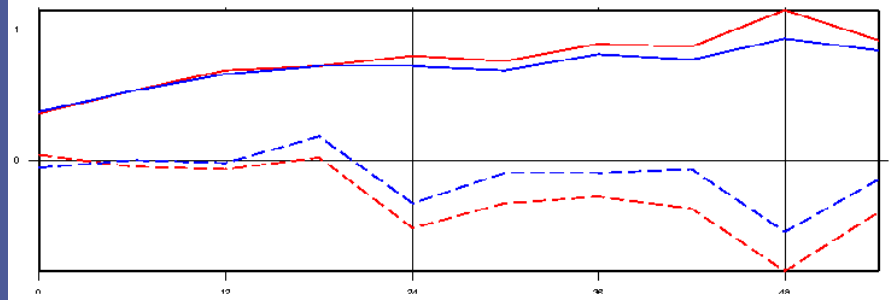
Surface pressure (hPa)

ALADIN oper ALADIN surfex

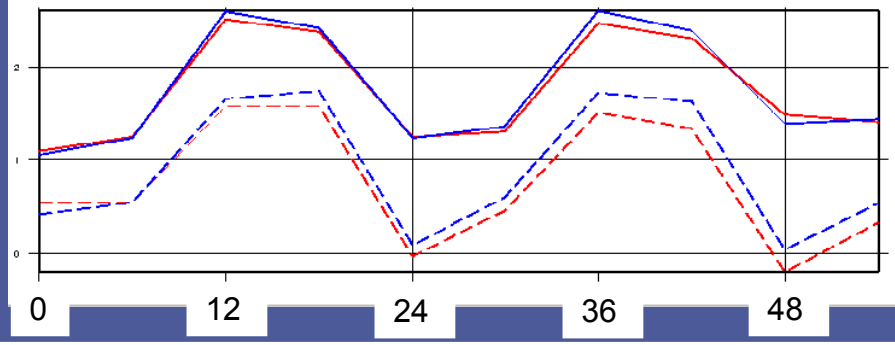
scores over France: all stations



stations –300m



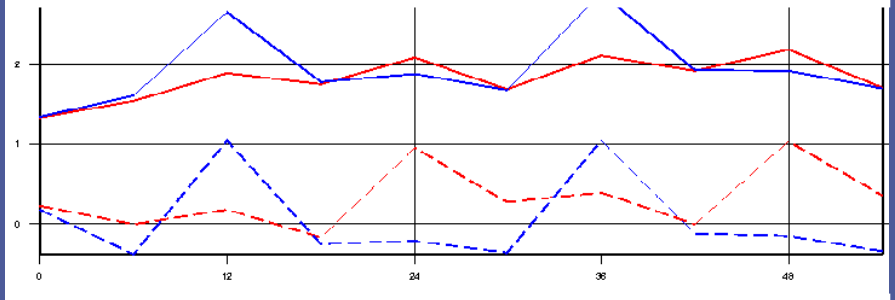
stations +300m



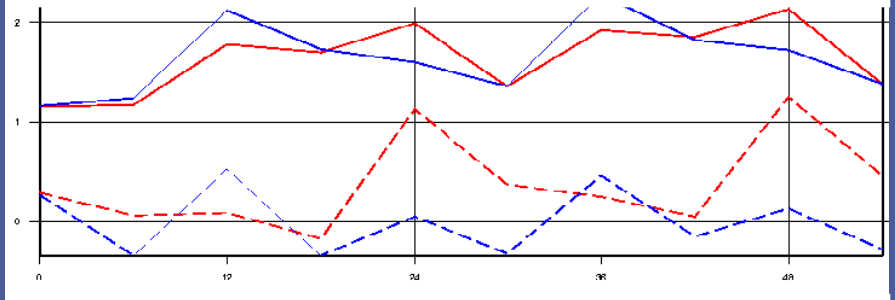
T2m (K)

ALADIN oper ALADIN surfex

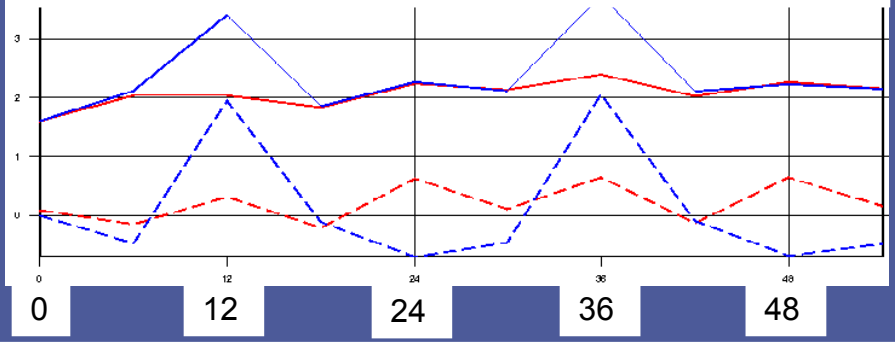
scores over France: all stations



stations –300m



stations +300m



Slight improvement for Ps and T2m during night

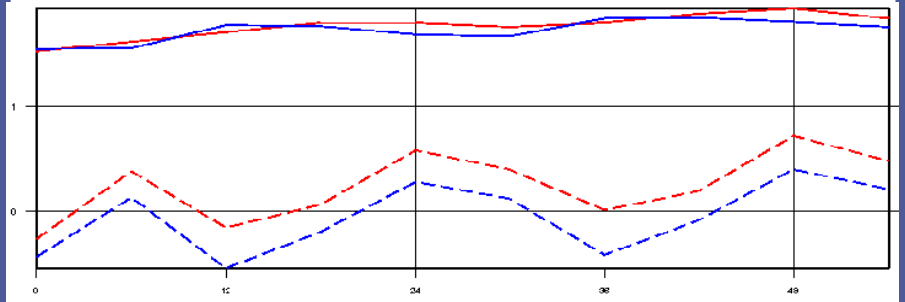
Overestimation of T2m at 12h UTC (probably the consequence of a too dry soil moisture in summer -> test with surface analysis)

Objective scores on 54h forecasts (July 2008)

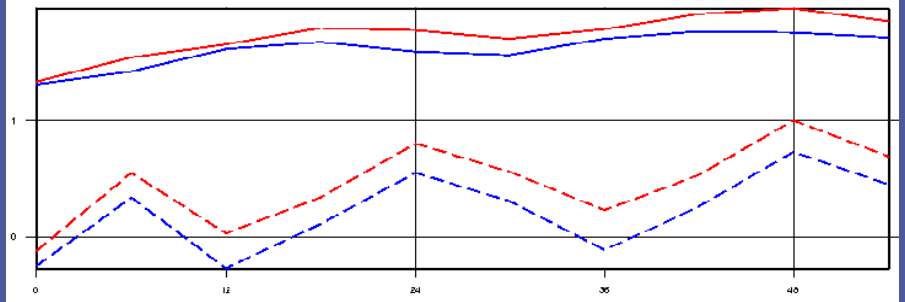
V10m (m/s)

ALADIN oper ALADIN surfex

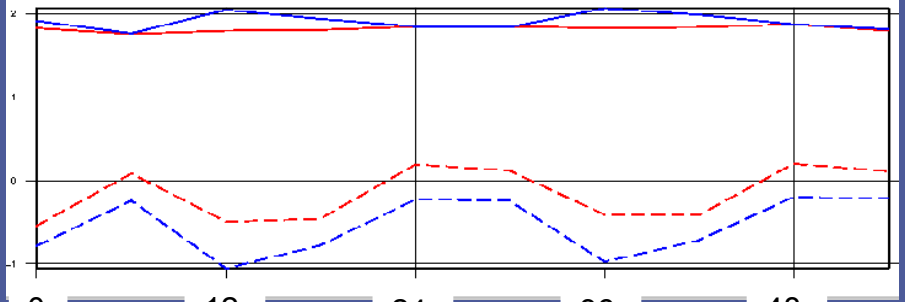
scores over France: all stations



stations –300m



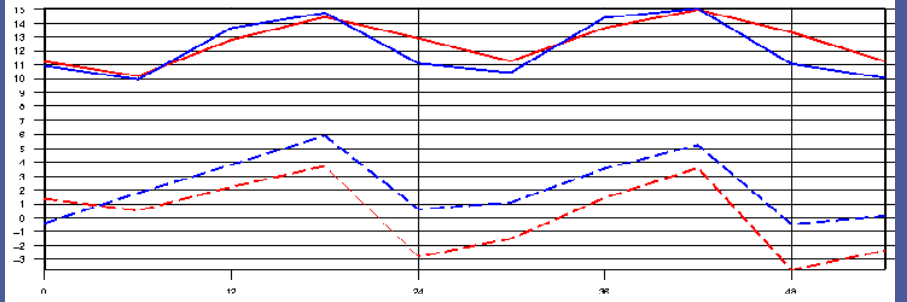
stations +300m



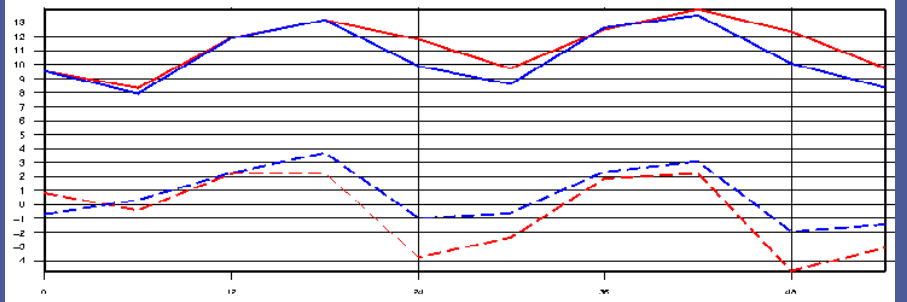
HU2m (%)

ALADIN oper ALADIN surfex

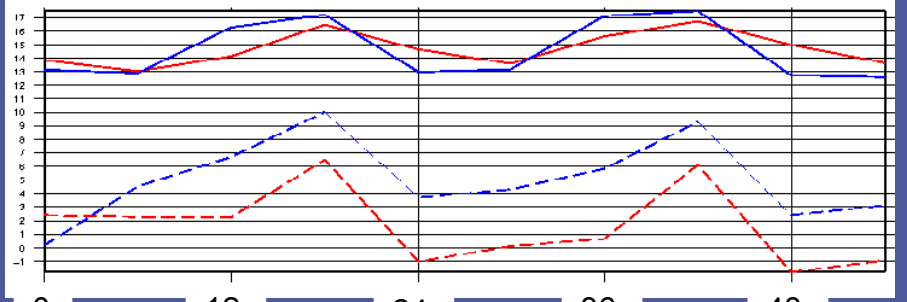
scores over France: all stations



stations –300m



stations +300m



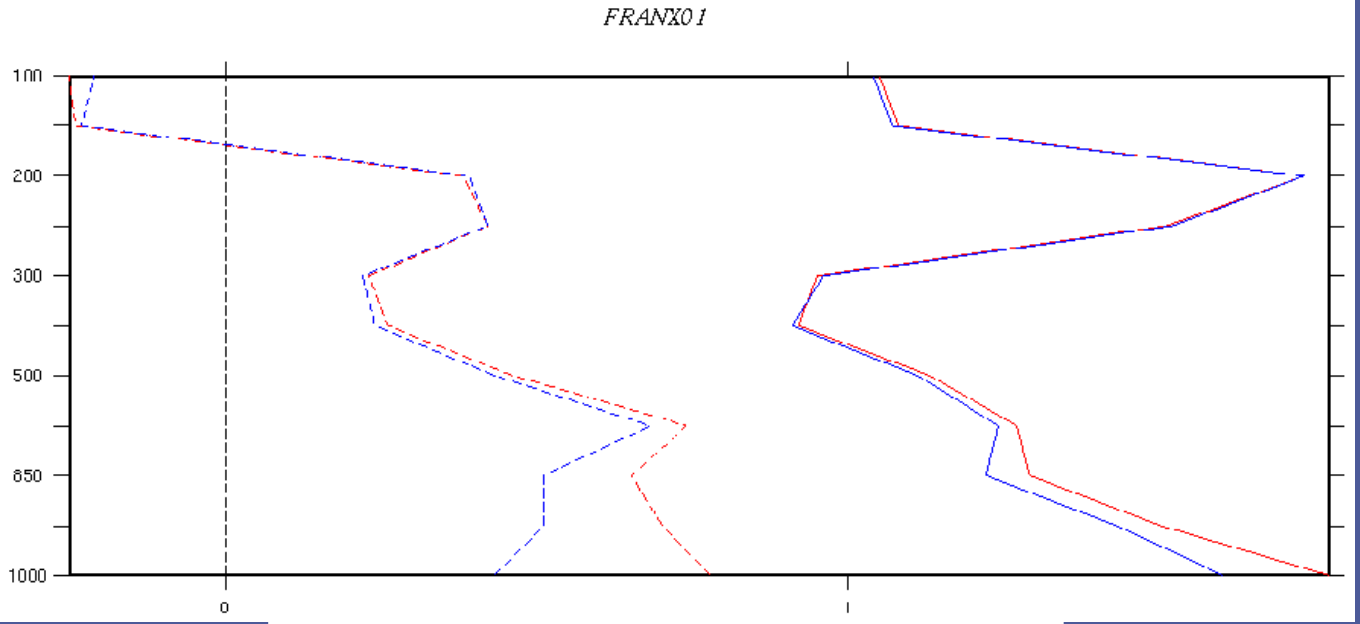
Improvement of wind in plains, degradation over mountains

Degradation of bias for RH2m and improvement of RMS (to be investigated)

Objective scores versus RS on 54h forecasts (July 2008)

Temperature (K)

ALADIN oper ALADIN surfex



Improvement of temperature in the PBL
Neutral impact on wind and temperature

- Similar validation has been performed on January 2008

Problem on T2m due to frozen soil parameterization: need to be evaluated in long assimilation experiment

Assimilation

- ALADIN 3D-Var upper air analysis works with SURFEX

  - CLS fields (T2m, H2m, V10m) interpolated to the observation location and not recomputed at observation location

  - TL and AD perturbations of CLS fields are supposed to be at the lowest model level. Linear version of CLS observation operator would be better (plan to develop simplified versions of current TL and AD codes of CLS observation operator ("achmt") by using Qs computed in SURFEX)

- ARPEGE 4D-Var upper air analysis not yet tested with SURFEX

- Surface analysis (Jean-François's talk)

Perspectives

- Validation of surface analysis with SURFEX
- Validation of full ALADIN assimilation experiments on several periods and domains, parallel suite in ALADIN planned in 2010
- SURFEX validation in ARPEGE-PNT
- Evaluation of new schemes (TEB, CANOPY, diffusion scheme, …)
- Post-processing : more and more surface fields need to be post-processed. Currently they are written to the atmospheric historical files to be post-processed by “fullpos” configuration (to be replaced by “PREP” ?)
- Optimisation issues : Open-MP, I/O, FA format, improving efficiency of PGD, PREP

Thank you
for your attention