Development and test of a 4D-Var assimilation for the convective-scale model AROME-France

Pierre Brousseau
Météo-France/CNRM-GAME

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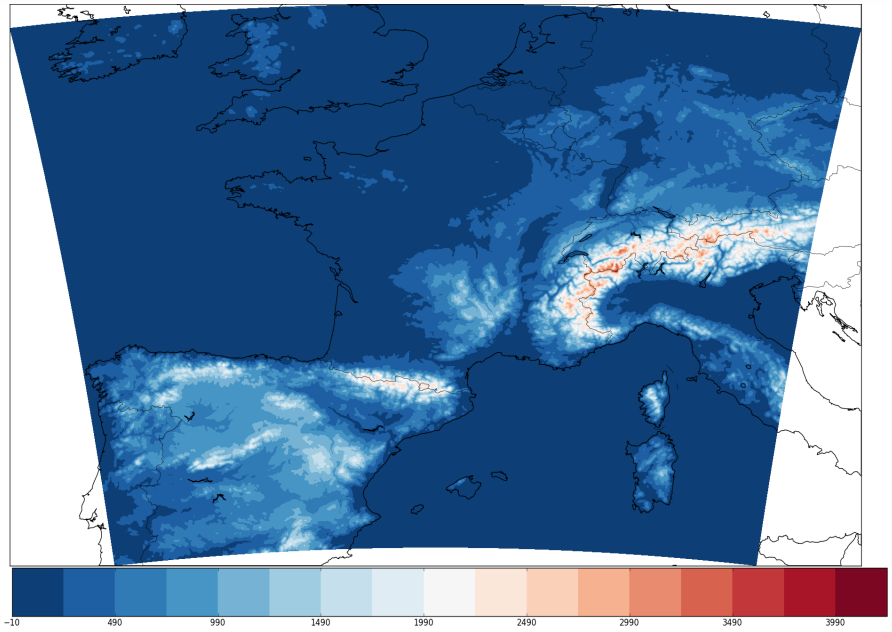
Outlines

- Context : AROME-France NWP system, evolution,...
- Description of the 4D-Var system
- Some results.

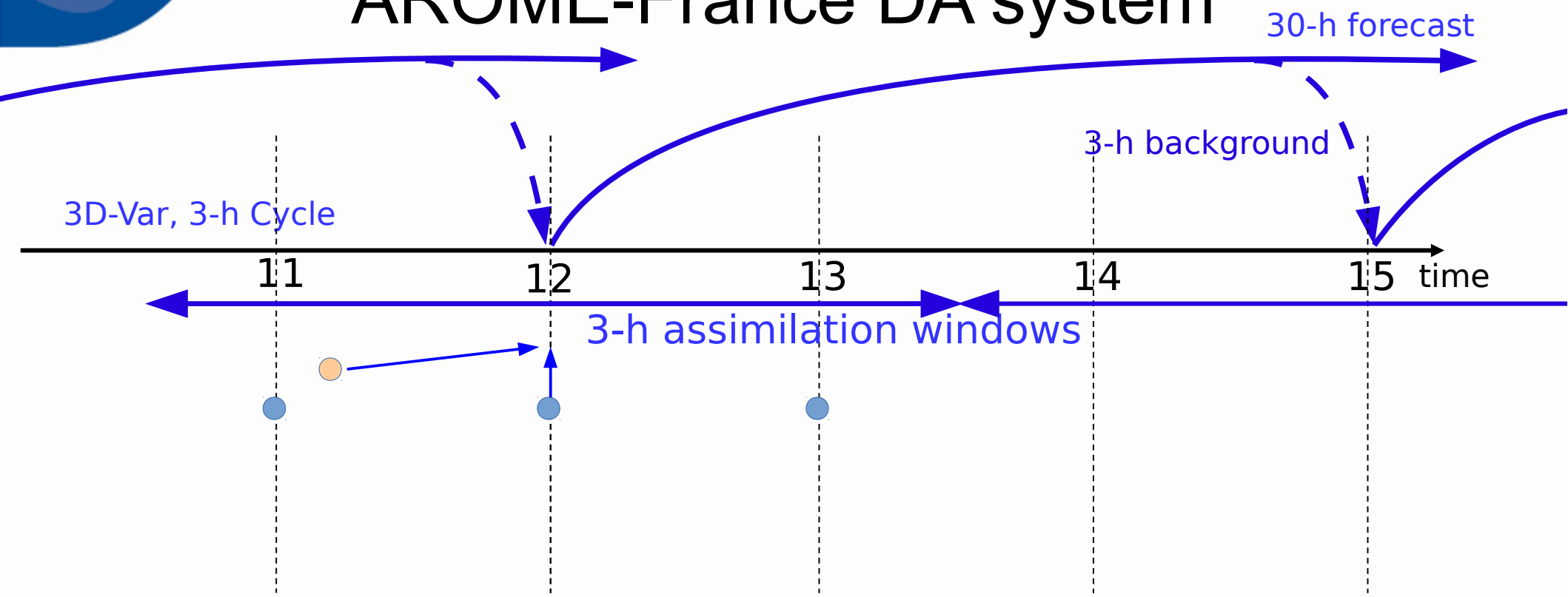
AROME-France

- Spectral limited area non-hydrostatic model with explicit moist convection, in operations since decembre 2008.
- 2.5 km horizontal resolution and 60 vertical levels (increased to 1.3 km and 90 lev. in april 2015)
- 30-h range forecasts (8 times a day)
- Coupling files : hourly forecasts from global model ARPEGE



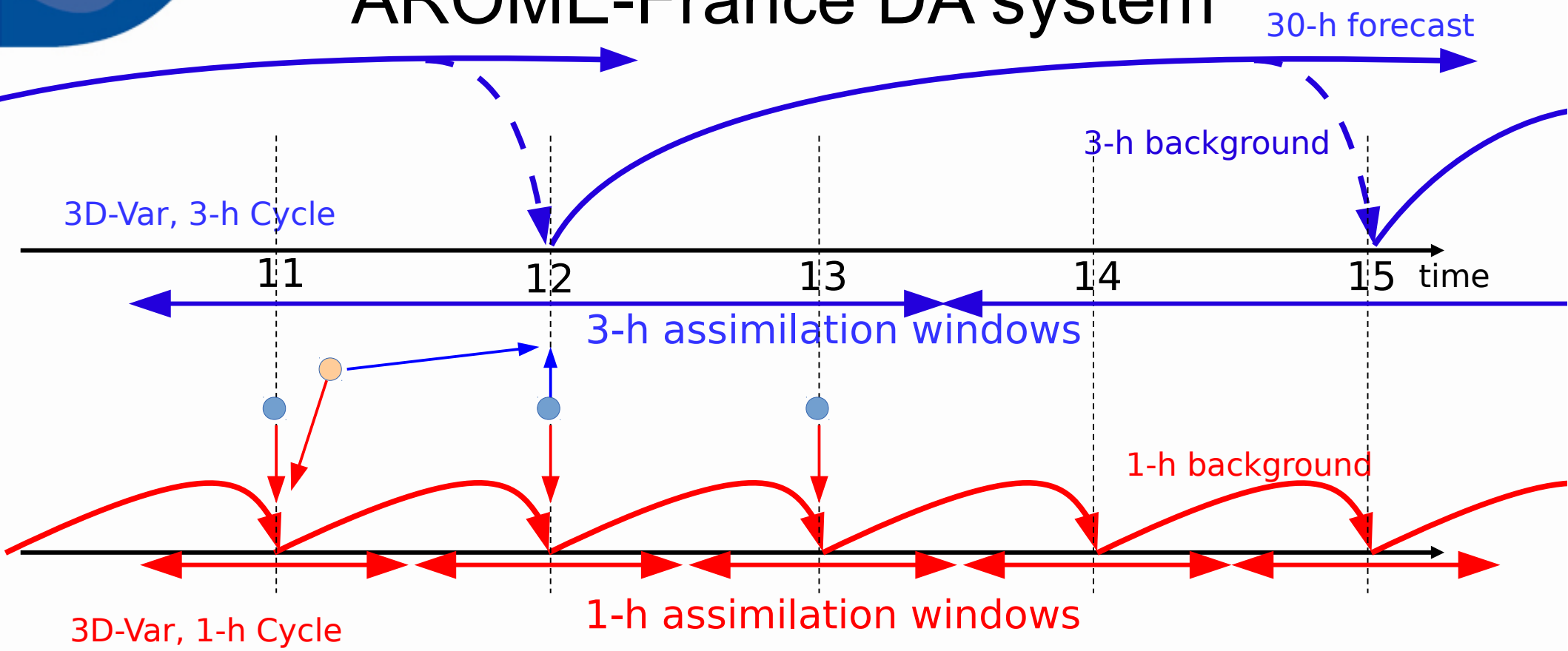
- Initial Conditions : 3D-Var at the model resolution in a 3-h continuous assimilation cycle :
  - U, V, T, q and Ps analyzed
  - hydrometeors, TKE and non-hydrostatic fields copied from the background
  - observations assimilated in the global model ARPEGE + radar observations (doppler winds and reflectivities) + screen-level measurements (T2m, Hu2m)
  - Climatological B matrix (horizontally homogeneous ans isotropic) estimated from an « off-line » AROME ensemble assimilation.

AROME-France DA system



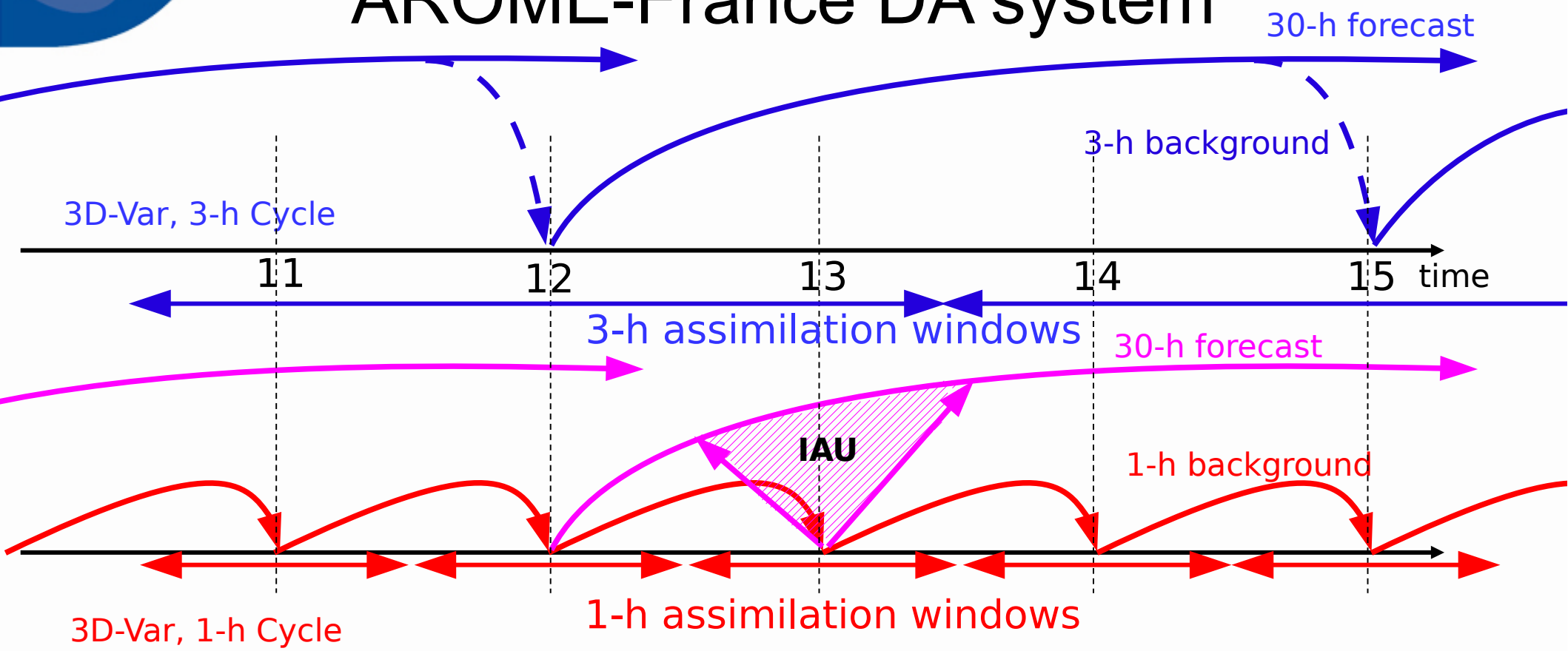
- **3D-Var** :
  - Leads to crude approximations (observations are considered at the analysis time)
  - Observations performed at a high frequency rate at a given location are under-used (only one per assimilation window)
- **Planned evolutions for AROME :**
  - At long-term : development of a 4D-Envar system (as for the global model ARPEGE)

AROME-France DA system



- **3D-Var** :
  - Leads to crude approximations (observations are considered at the analysis time)
  - Observations performed at a high frequency rate at a given location are under-used (only one per assimilation window)
- **Planned evolution for AROME :**
  - At long-term : development of a 4D-Envar system (as for the global model ARPEGE)
  - At short-term : use of 3D-Var in a 1-h assimilation cycle (april 2015)

AROME-France DA system



- **Long range forecasts** (up to 30 h) using the analysis valid at H, also wait for the lateral boundary conditions provided by the global model ARPEGE forecast of the same analysis time.
- These forecasts are also able to benefit from the **analysed information at H+1** using the Incremental Analysis Update (IAU)
- IAU is not used for its filtering properties in the assimilation cycle

What about a 4D-Var for AROME ?

- **No plan at Météo-France to develop a 4D-Var at convective-scale for operations :**
  - Difficulties to develop and maintain tangent Linear and Adjoint models of a complex system
  - high numerical cost due to the numerous calls to the TL and AD : should not allow to perform minimization at the model resolution.

- **But, existing tools for ALADIN model (10~7 km) :**
  - Development of TL/AD models (Soci et al. 2006)
  - Experimentation of an incremental 4D-Var system (B. Chapnik Météo-France)

- **HIRLAM consortium** : test and development of a 4D-Var for AROME in the HARMONIE system (M. Lindskog (SMHI), J. Barkmeijer (KNMI),...)

- **Idea : to develop and evaluate** (interest, numerical cost,...) **a 4D-Var for AROME** in a research framework as a reference to the planned 4D-Envar development.

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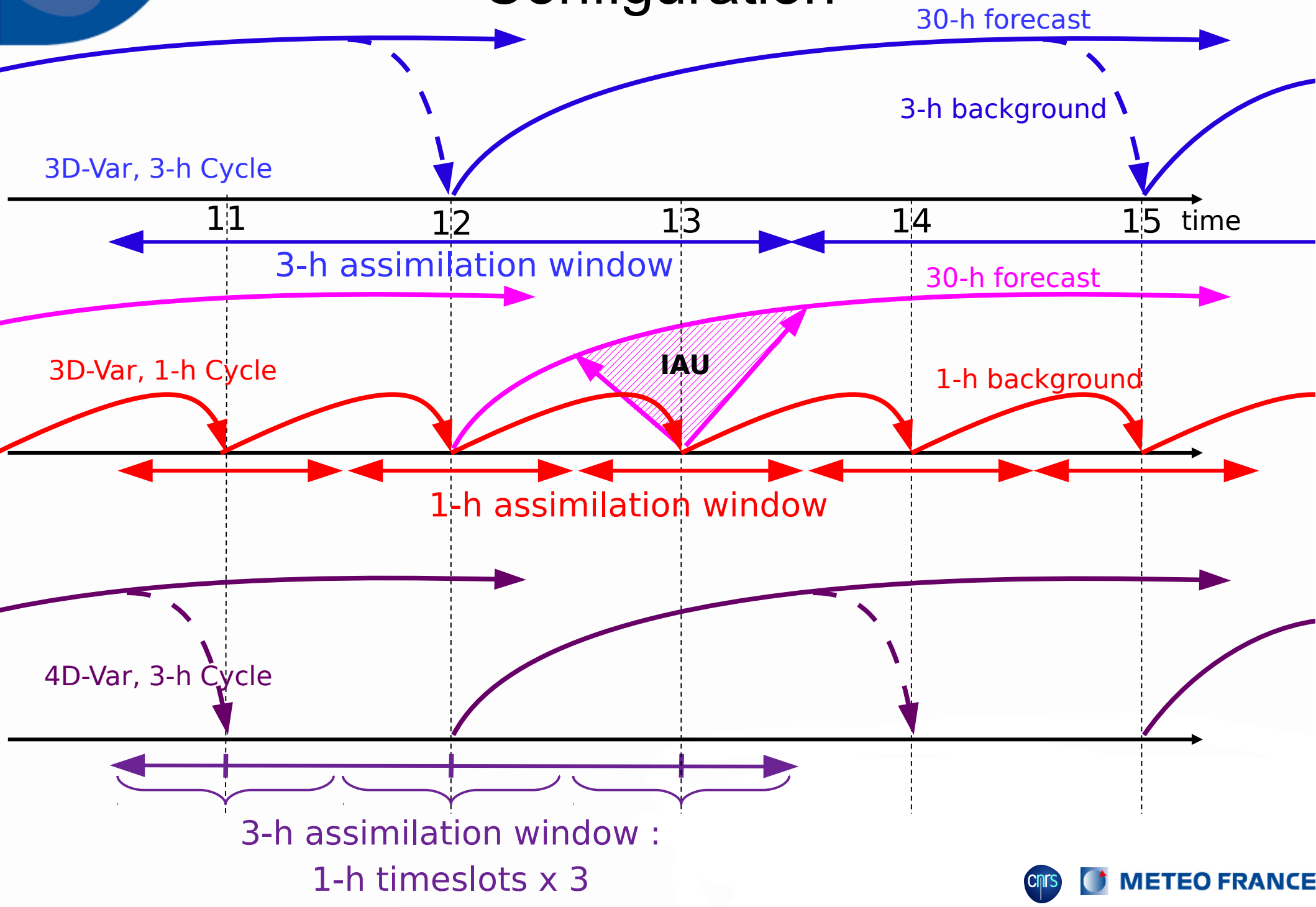
- **Description of the 4D-Var system**
- Some results.

Configuration



Configuration

- **AROME 4D Screening at full resolution :** full AROME microphysic needed for radar reflectivity observation operator : reflectivity observations => relative humidity pseudo-observations (Wattrelot 2014)

- **4D-var minimization (resolution : 2,5 km or 5 km)**
  - direct model (trajectory) : simplified model
    - non-hydrostatic or **hydrostatic** dynamic
    - simplified microphysic : only 4 hydrometeors (whitout graupel)
    - simplified surface scheme
      => longer timestep : 120 s (Vs 60 s)

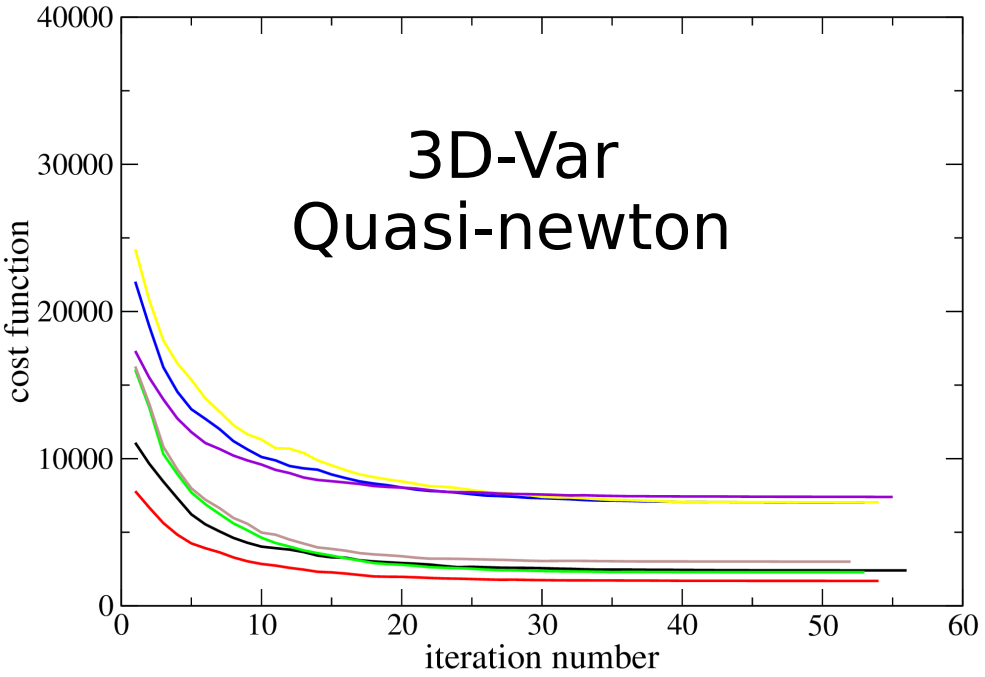
  - hydrostatic ALADIN TL/AD model (Soci et al. 2006)
    (+ MF simplified physic)

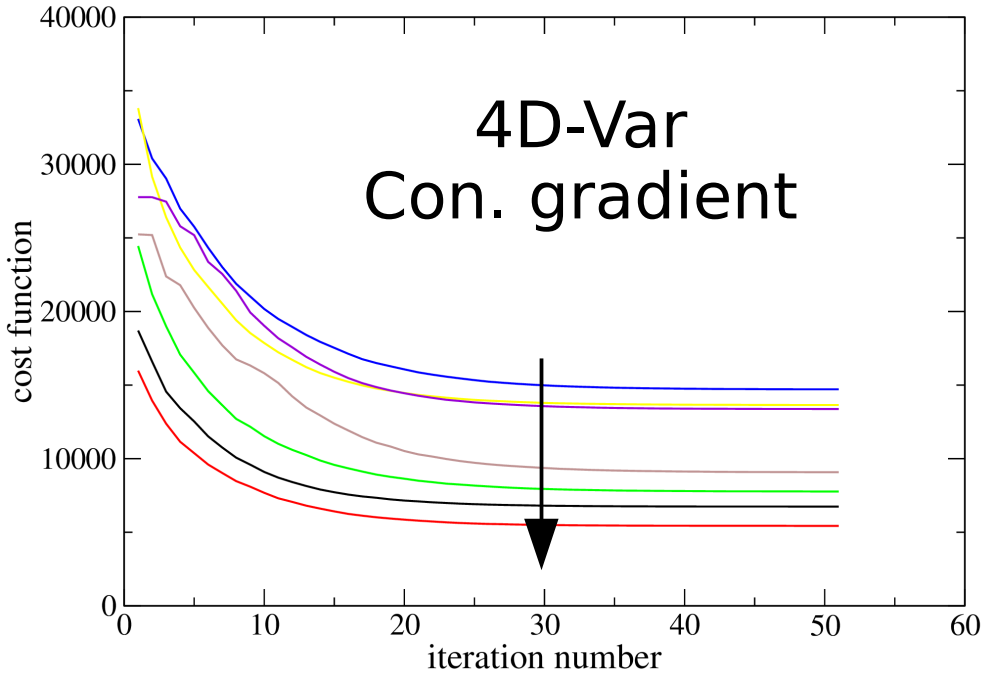
- **B Matrix : same as in 3D-Var but sigma-b x 0,85**

- **Observations : same as in 3D-Var**

Numerical Cost of the minimization

- **2.5 km Configuration (operational geometry) :**
  - domain «France » (750*720 points), 60 vertical levels
  - minimization : dt=120s, 30 iterations

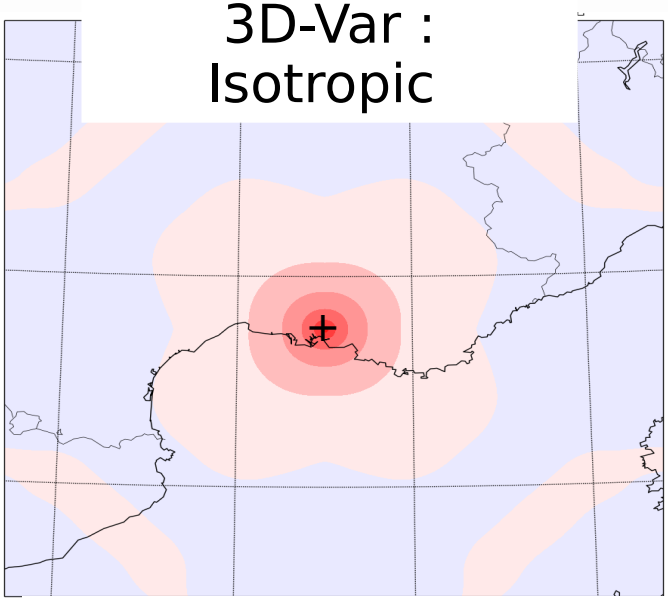




- **Elapse time : ~3h on 120 nodes** on MF's Bull calculator (~900 nodes)
  - a 3D-Var minim : 3 min on 8 nodes
  - a 3h AROME forecast : 3 min on 24 nodes

Single obs T experiment :
4° K innovation at 800 hPa (middle of the window)

3D-Var :
Isotropic



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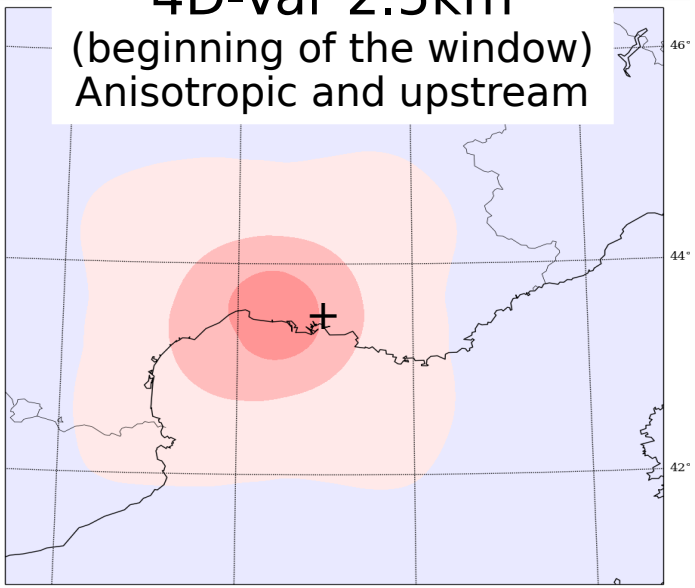
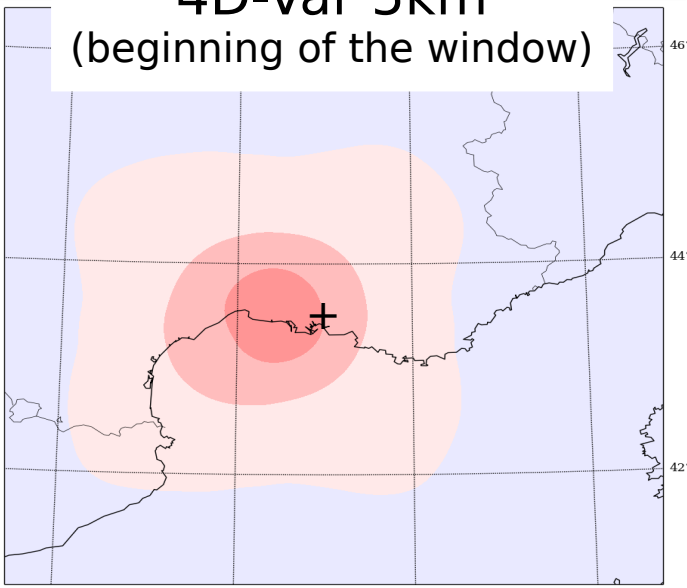
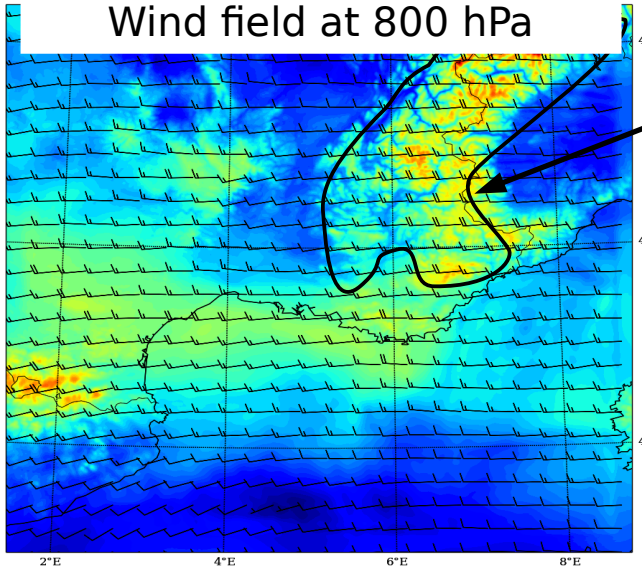
4D-Var 2.5km
(beginning of the window)
Anisotropic and upstream



4D-Var 5km
(beginning of the window)

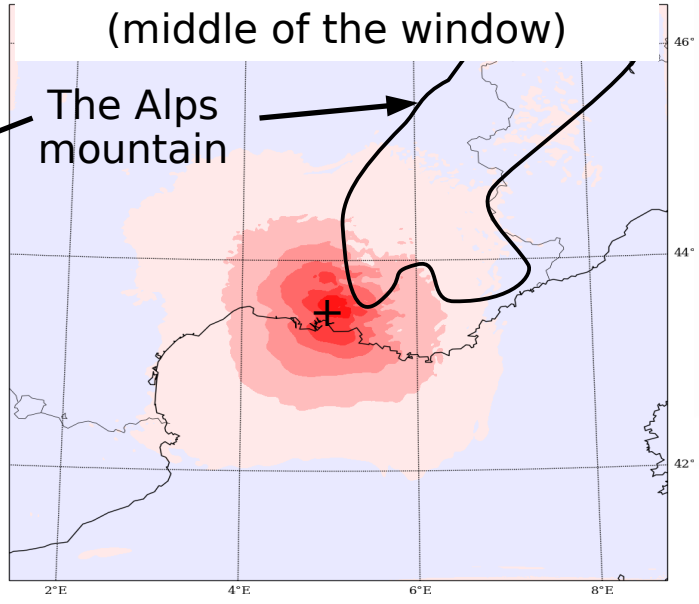


Wind field at 800 hPa

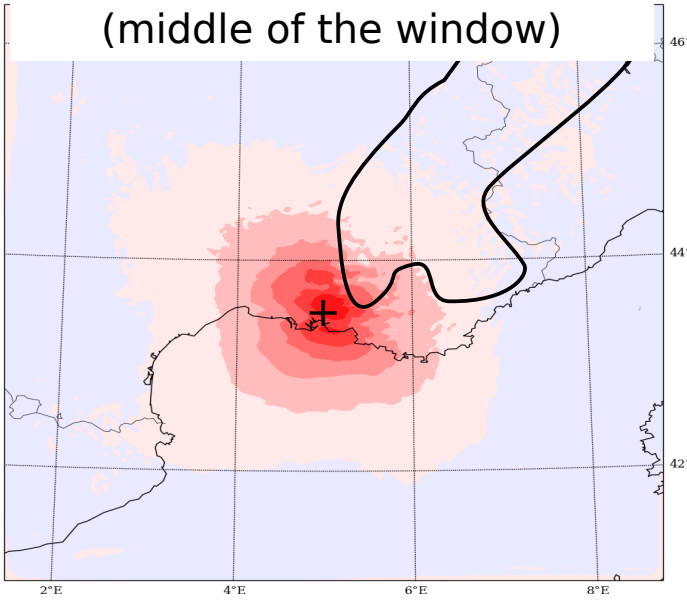


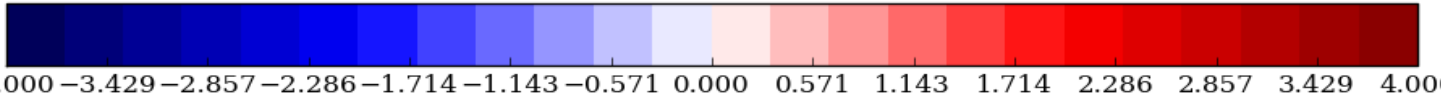
(middle of the window)

The Alps
mountain



(middle of the window)





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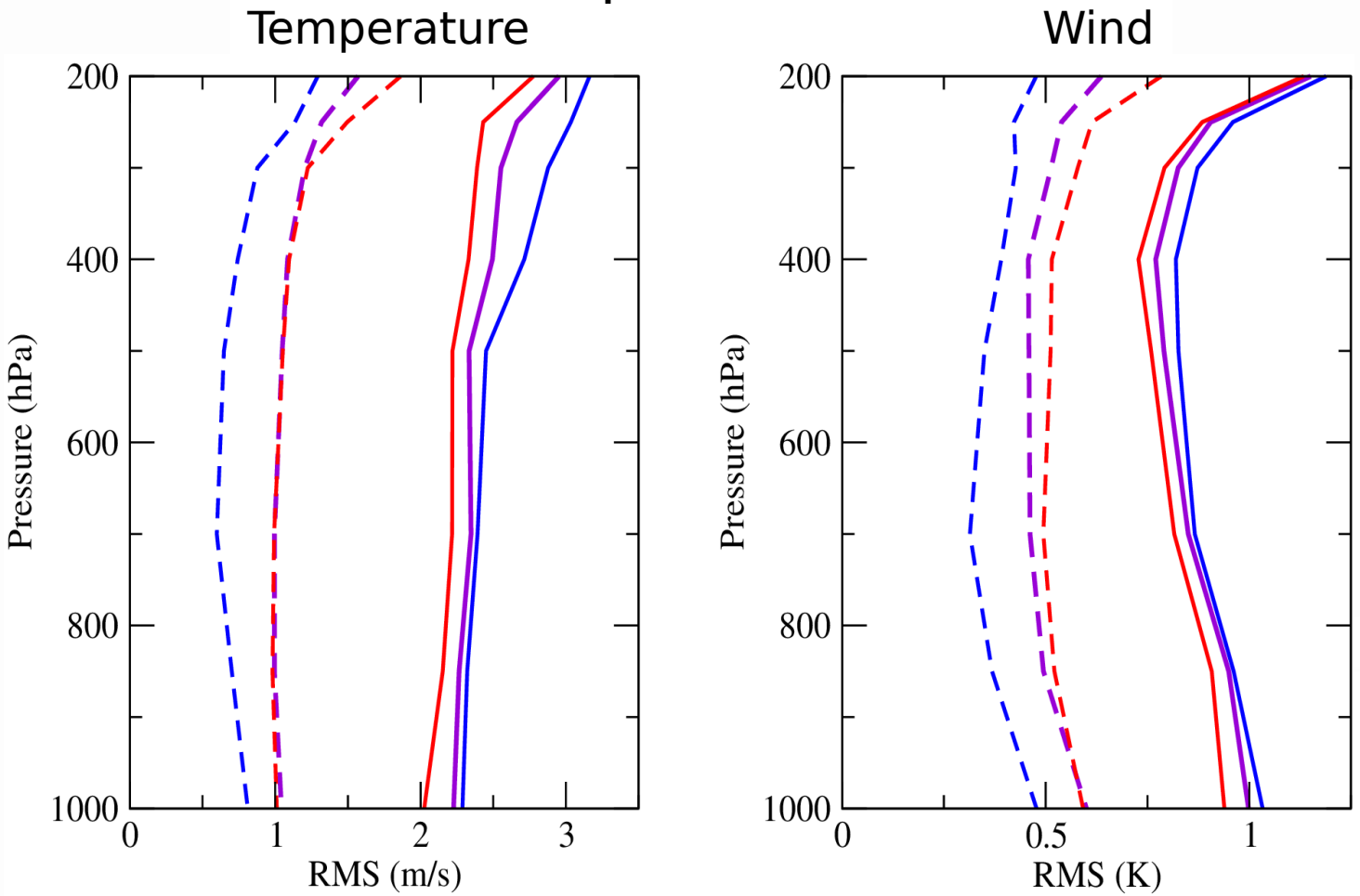
- Description of the 4D-Var system
- **Some results : 25 days assimilation experiments (05/09/2013 - 30/09/2013)**

Plane observations

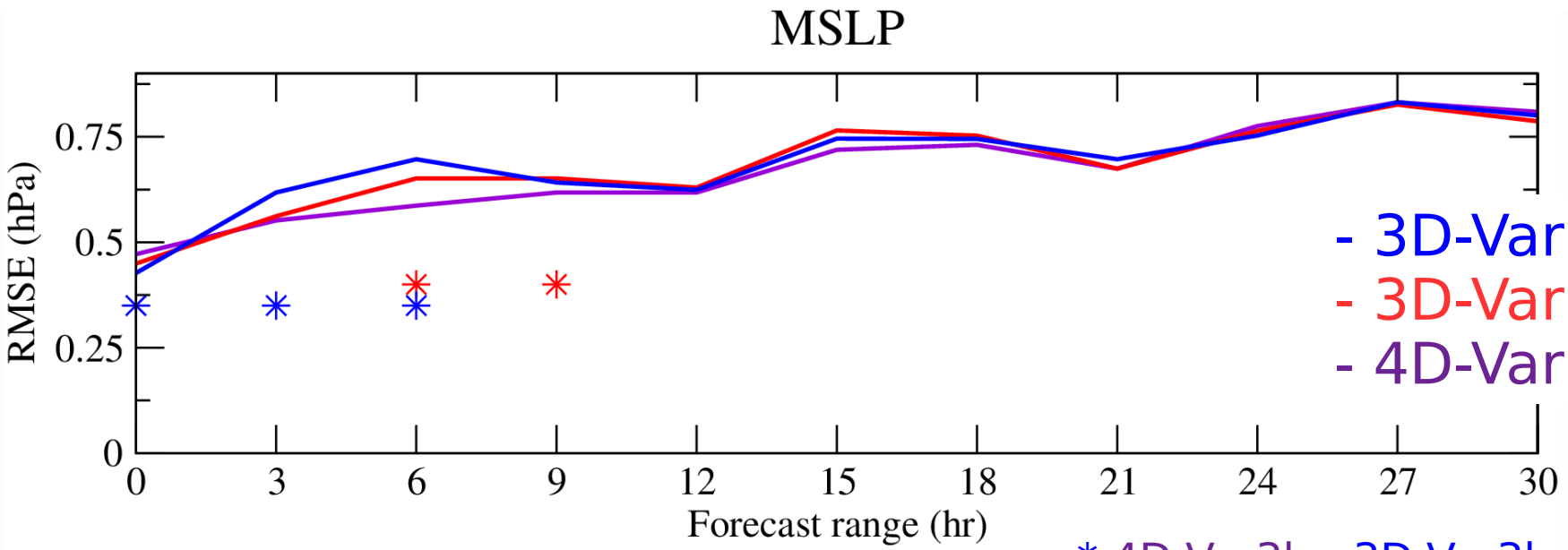
- **Observations spread during the assimilation windows :**
  - RMS(Obs-guess) smaller in 4D-Var 3-h and 3D-Var 1-h
  - number of assimilated observations x 15 % and x 10 % due to a better first-guess check

Vertical profiles of RMS



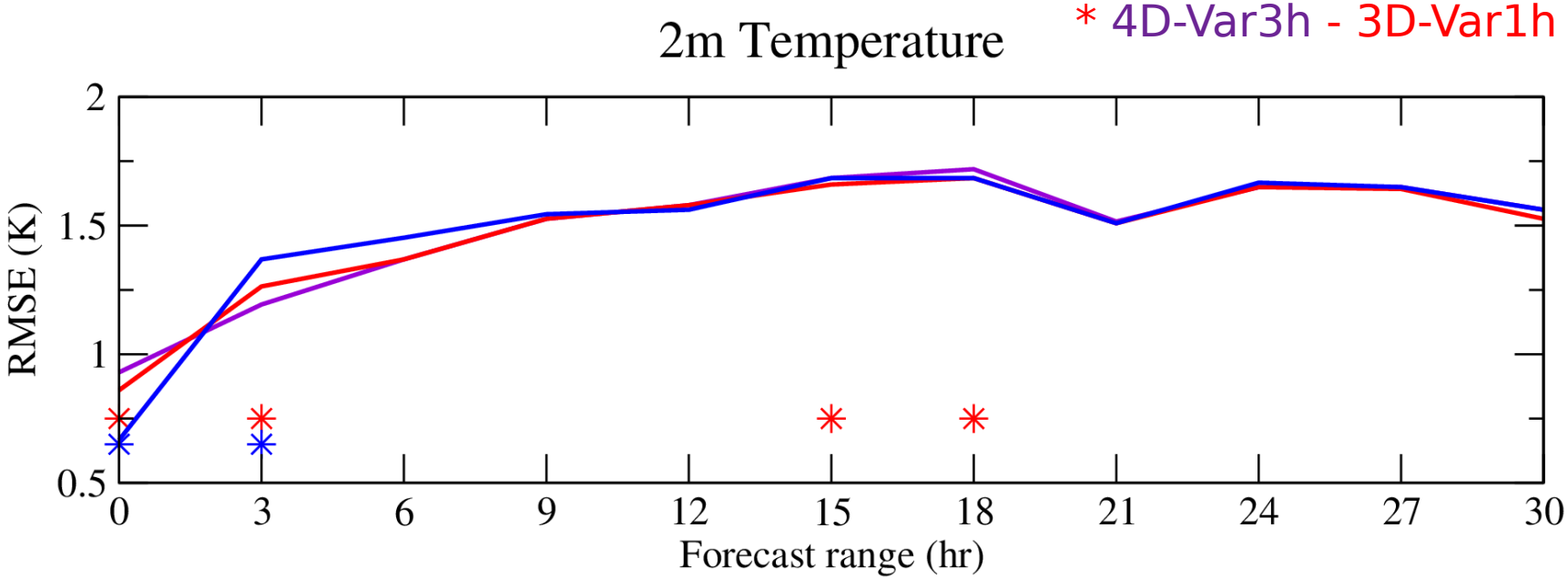
Forecast scores

- **MSLP and T2m RMSE : 30-h forecast initialized at 00 UTC**



- 3D-Var 3h
- 3D-Var 1h + IAU
- 4D-Var 3h

* 4D-Var3h - 3D-Var3h significative
* 4D-Var3h - 3D-Var1h significative



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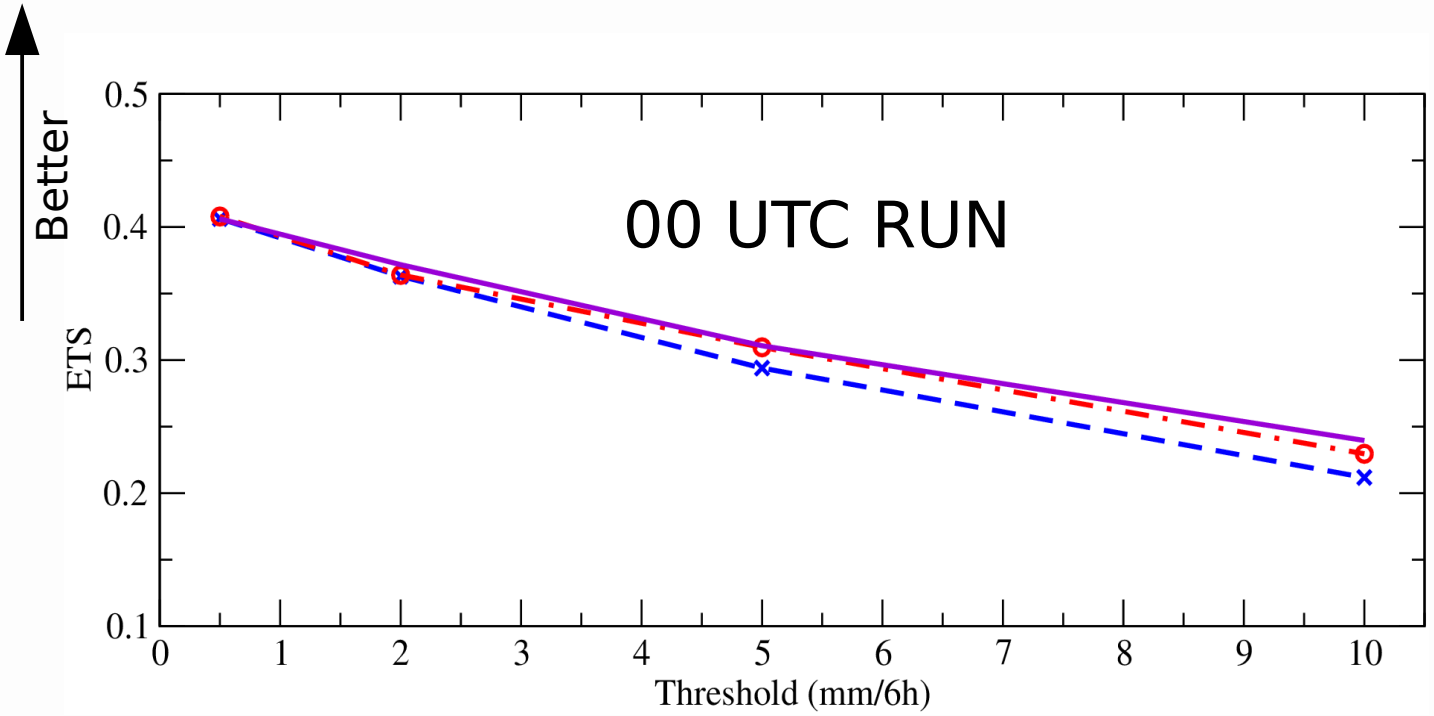
Precipitation scores

- **Averaged Equitable Threat Score** for 6-h cumulative précipitation forecasts for different threshold excedances :
  - 00 UTC runs 4D-Var 3h ~ 3D-Var 1h > 3D-Var 3h

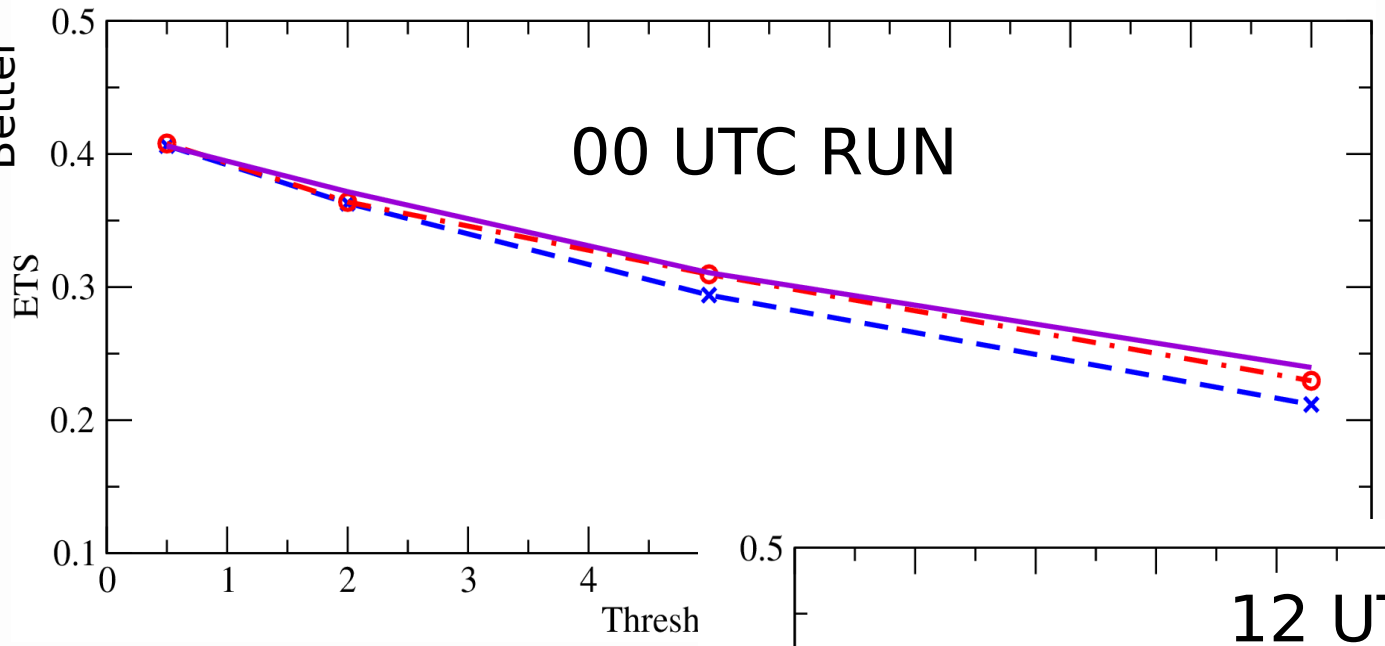


- 3D-Var 3h
- 3D-Var 1h
- 4D-Var 3h

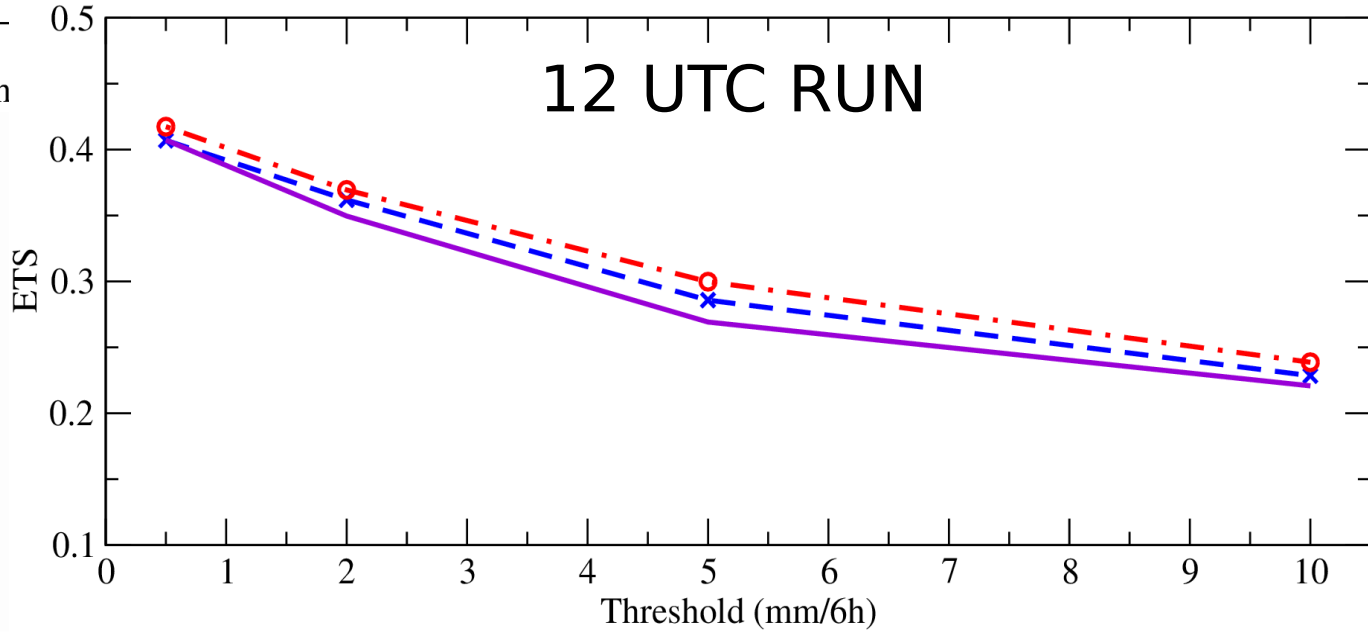
Precipitation scores

- **Averaged Equitable Threat Score** for 6-h cumulative précipitation forecasts for different threshold excedances :
  - 00 UTC runs 4D-Var 3h ~ 3D-Var 1h > 3D-Var 3h
  - 12 UTC runs 3D-Var 1h > 3D-Var 3h > 4D-Var 3h

Better

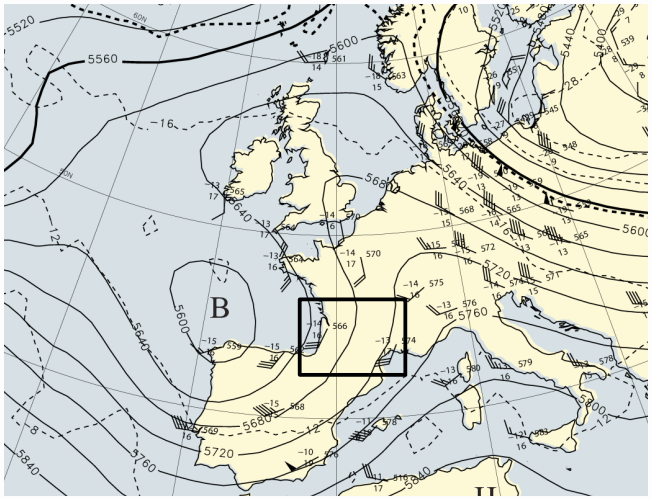


- 3D-Var 3h
- 3D-Var 1h
- 4D-Var 3h

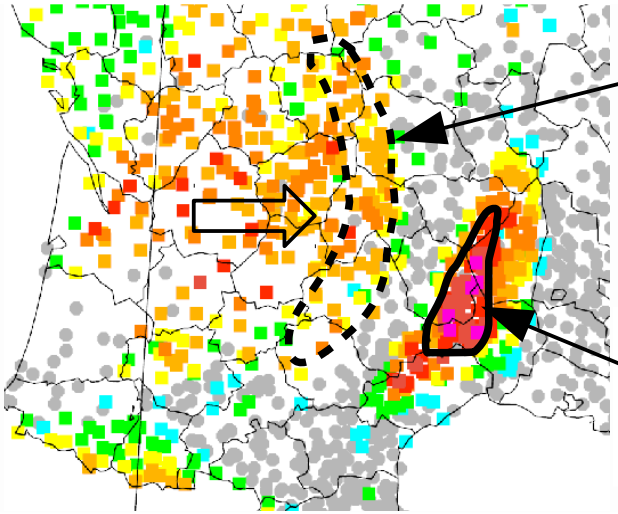


Problem for the convection forecasting : convection maximum at 17 UTC

28/09/2013 case



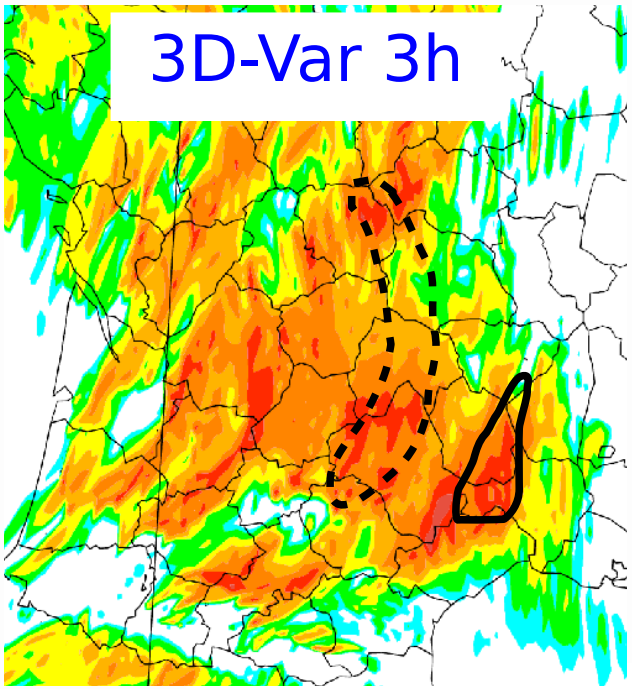
Raingauge measurements

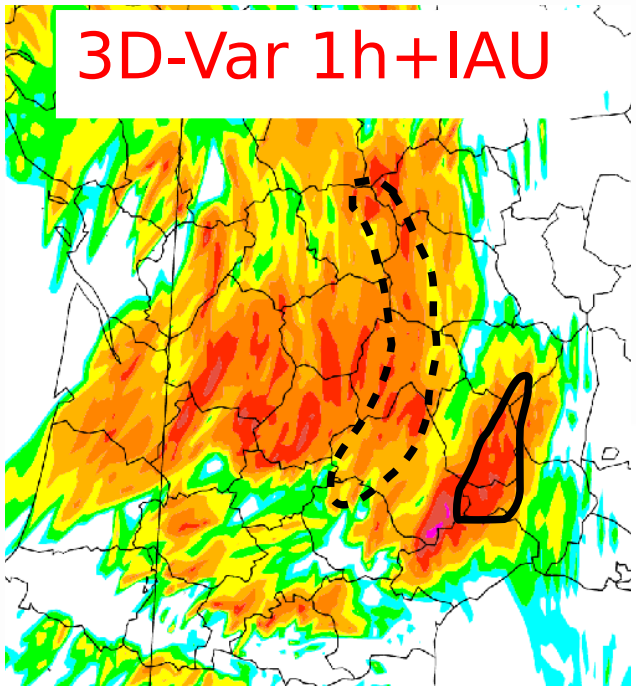


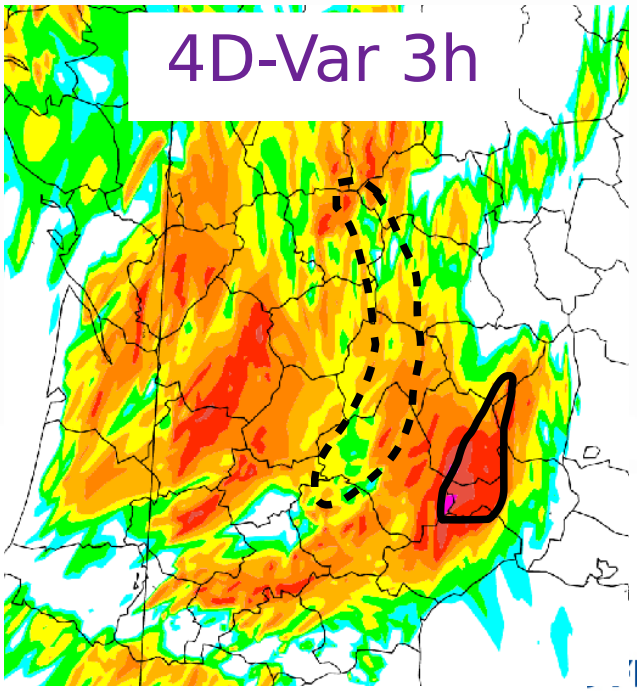
Squall line

orographically
induced convection :
More than 60mm in 12 h

12 UTC run : 0-12 h cumulative precipitations







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Conclusion

- Developement of a 4D-Var prototype for AROME-france :
  - providing somme interesting results with few tuning, certainly to be improved, ans some problems to be solved
  - numerically expensive

- Non operationnal use but interesting for case study

- Perspectives :
  - in a research framework, reference for the 4D-Envar development planned at Météo-France
  - on going works : minimization at lower resolution for convective scales, increase of the timeslot number (i.e. increase of the number of assimilated radar observation)

Thank you for your attention...

- P. Brousseau, L. Berre, F. Bouttier et G. Desroziers.(2011) Background-error covariances for a convective-scale data-assimilation system : AROME-France 3D-Var. Quart. J. Roy. Meteor. Soc., vol. 137, pages 409–422.

- Y. Seity, P. Brousseau, S. Malardel, G. Hello, P. Bénard, F. Bouttier, C. Lac et V. Masson.(2011) The AROME-France convective-scale operational model. Monthly Weather Review, vol. 139, no. 3, pages 976–991.

- Soci, C., Fischer, C., & Horányi, A. (2006). Sensitivity of high-resolution forecasts using the adjoint technique at the 10-km scale. Monthly weather review, 134(3), 772-790.

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