Recent experience at Météo-France on the assimilation of observations at high temporal frequency

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6th WMO workshop on the impact of various observing systems on NWP

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Outline

- The global ARPEGE model and its 4D-Var DA system
- Impact of using 30 min time-slots in 4D-Var
- The regional AROME model and its 3D-Var DA system
- Impact of 3D-Var hourly cycling
- Conclusions and perspectives

Computing facilities at Météo-France

- New HPC computers since mid-2013 : **BULLX 710DLC**
- Two clusters (research and operations)
- Each cluster 24 000 CPUs (Ivy Bridge) – 1Pflops (peak perfornance)

14 January 2014 : Migration of the NWP suites on the new HPC

13 April 2015 : Significant upgrade of the NWP suites : increases in horizontal and vertical resolutions of the models + changes to the data assimilation systems + more observations

2016 : New HPC upgrade (x3) : Intel processors Ivy Bridge -> Broadwell
Each cluster : 24*1000 (32 Gb) -> 40*1800 CPUs (64 Gb)

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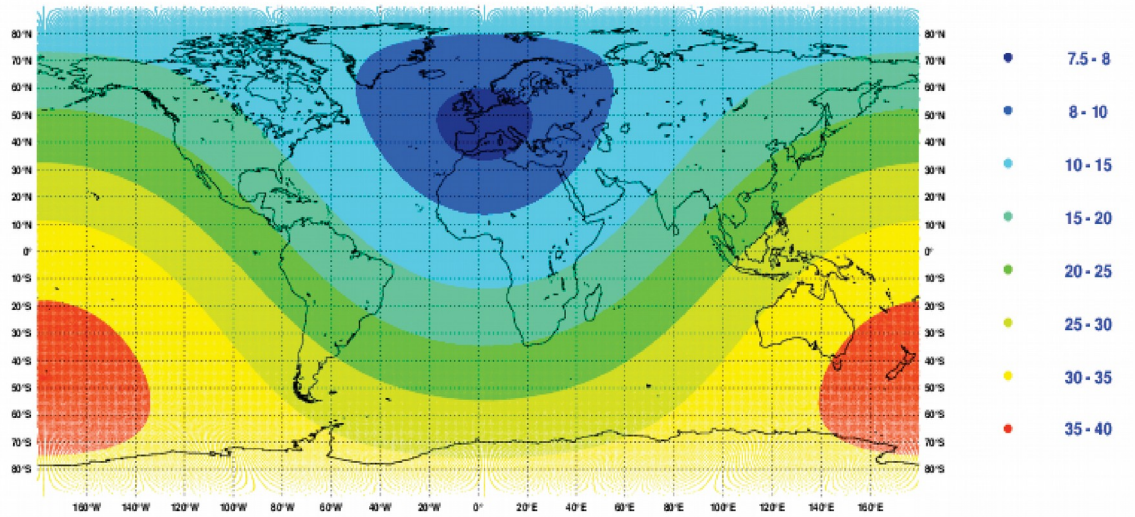
Global model ARPEGE

Spectral model with variable resolution : T_L1198c2.2L105
(resolution from 7.5 km to 36 km, 105 levels from 10 m to 0.1 hPa)
Forecasts up to 104 hours



Previous configuration:
T_L798c2.4L70
4D-Var 1 hour time slots
Minimisation (25/25)
EDA : 6 members

4D-Var assimilation (6-h window and 30 min time-slots) :

- 2 loops of minimization : T_L149c1L105 (40 iterations) + T_L399c1L105 (40 iterations)
- Background error variances and correlation lengths from an Ensemble Data Assimilation system (4D-Var at lower resolution: T_L479/T_L149) with 25 members

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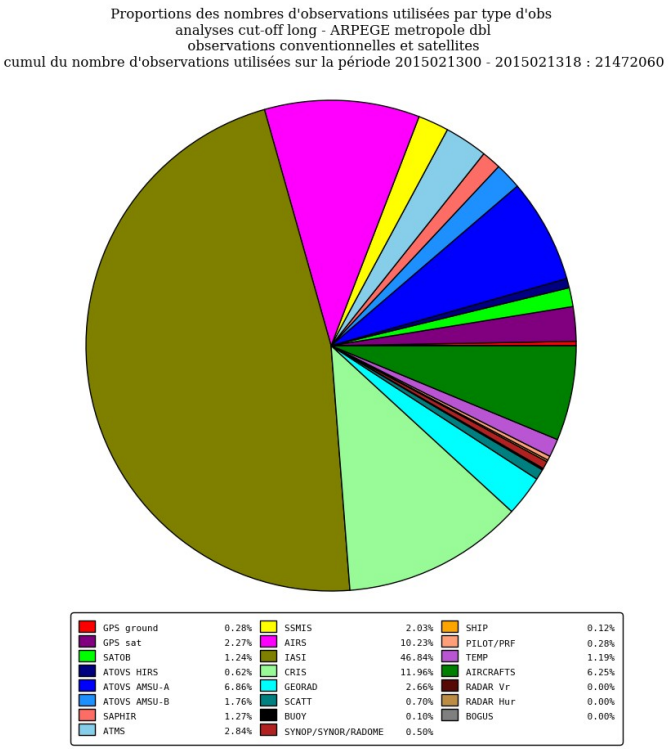
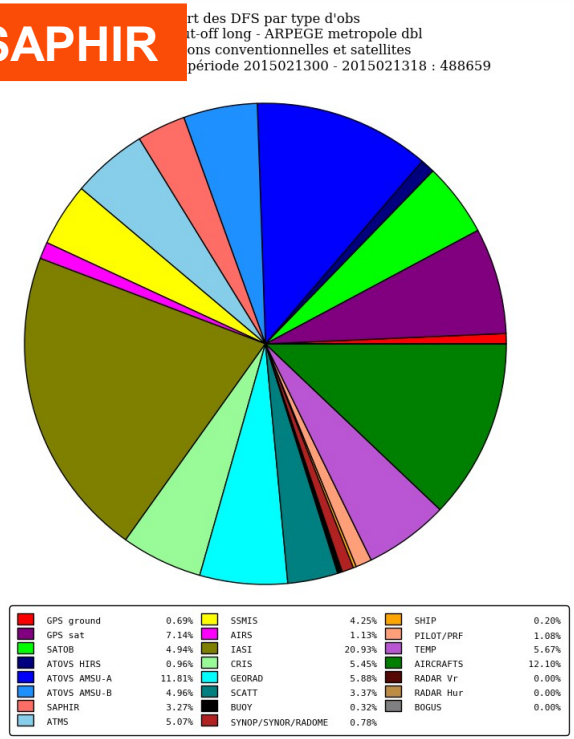
Information content in ARPEGE



IASI (x2)
AIRS
CRIS
ATMS
AMSU-A (x6)
AMSU-B/MHS (x4)
GPS-RO
AIRCRAFTS

SAPHIR



Number of observations

Information content $DFS=Tr(I-AB^{-1})$

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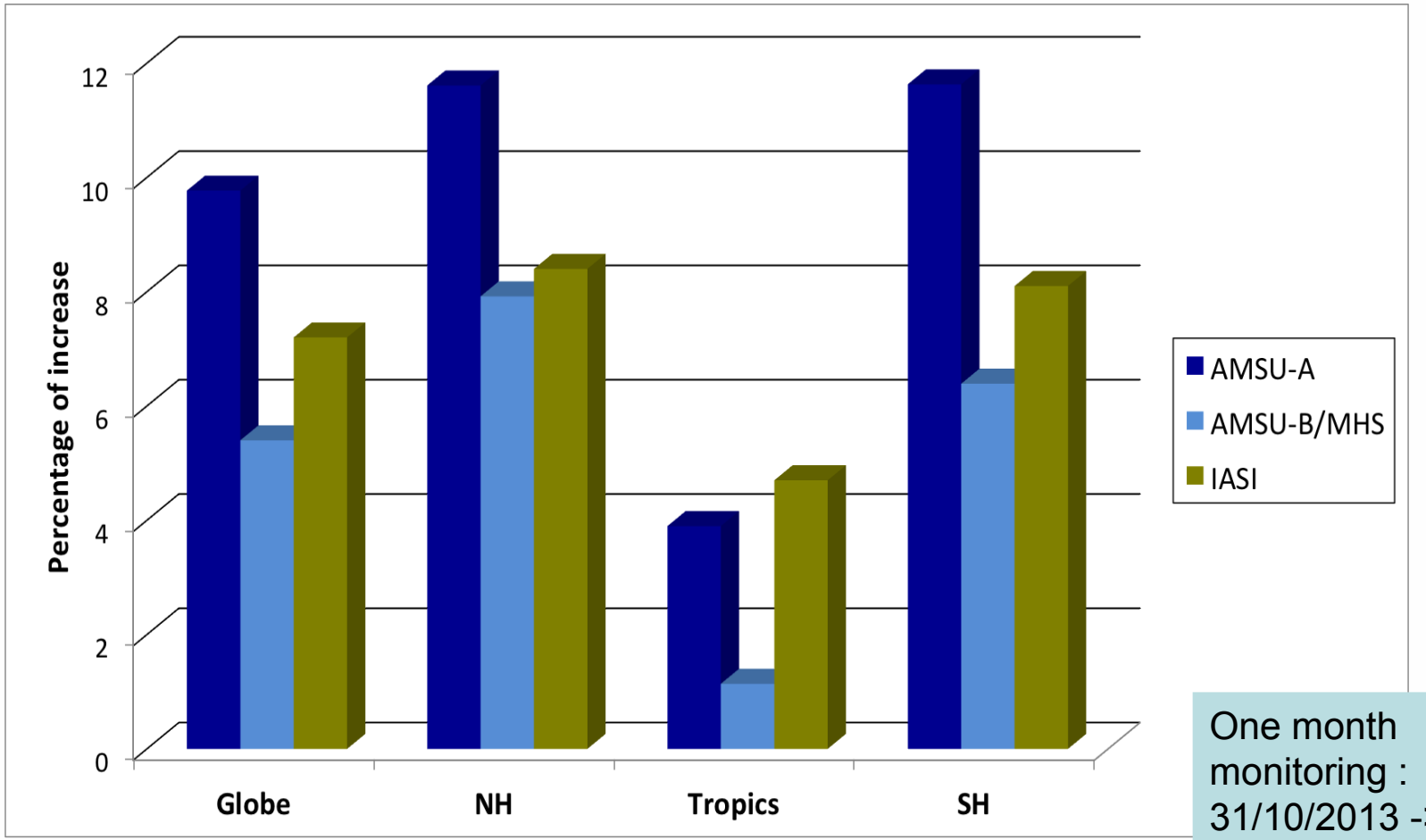
Change in observation usage



One month monitoring : 31/10/2013 -> 25/11/2013

Most significant increases for AMSU-A (x7), AMSU-B/MHS (x4) and IASI (x2)

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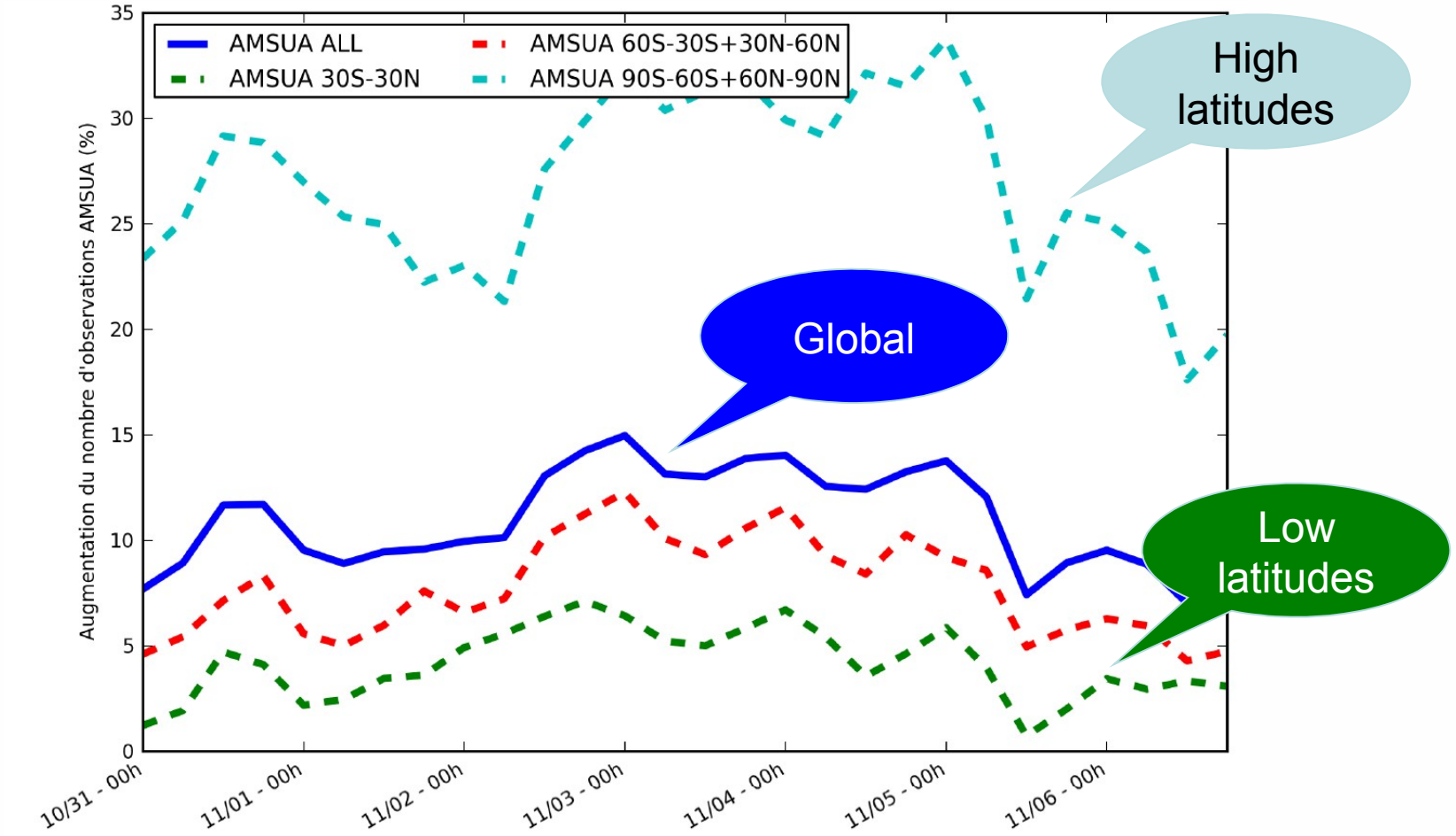
Latitudinal dependency of observation increase



AMSU-A temperature sounders
31 October 2013 -> 06 November 2016

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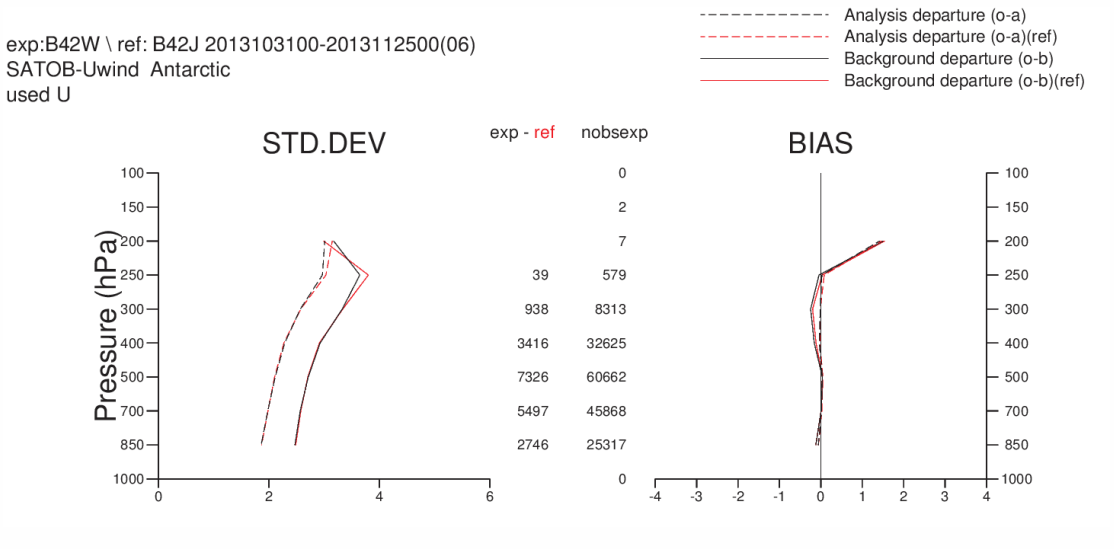
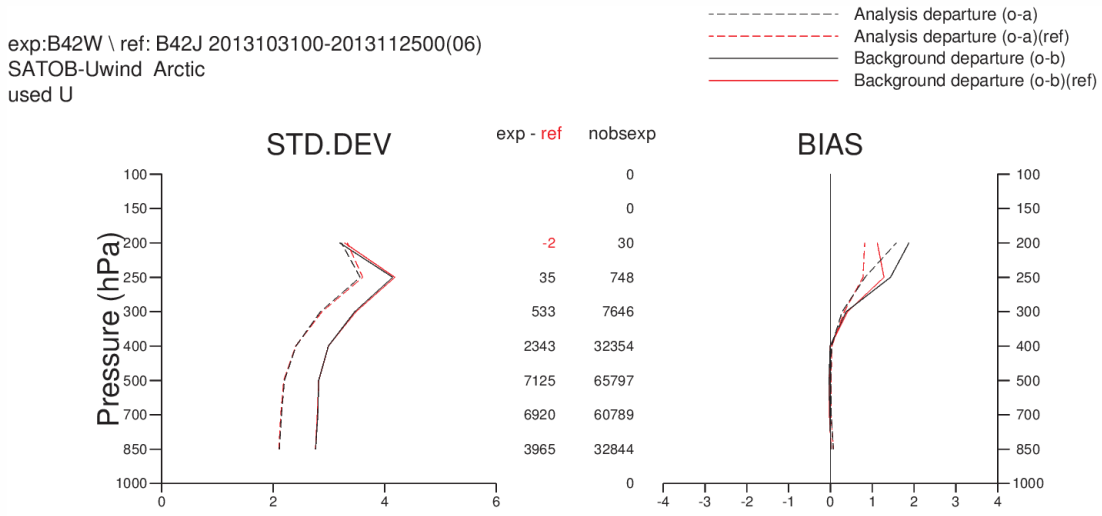
Moving platforms





30 min time slots
60 min time slots

AMVs (U)
Arctic region
10.4 % increase

AMVs (U)
Antarctic region
11.5 % increase

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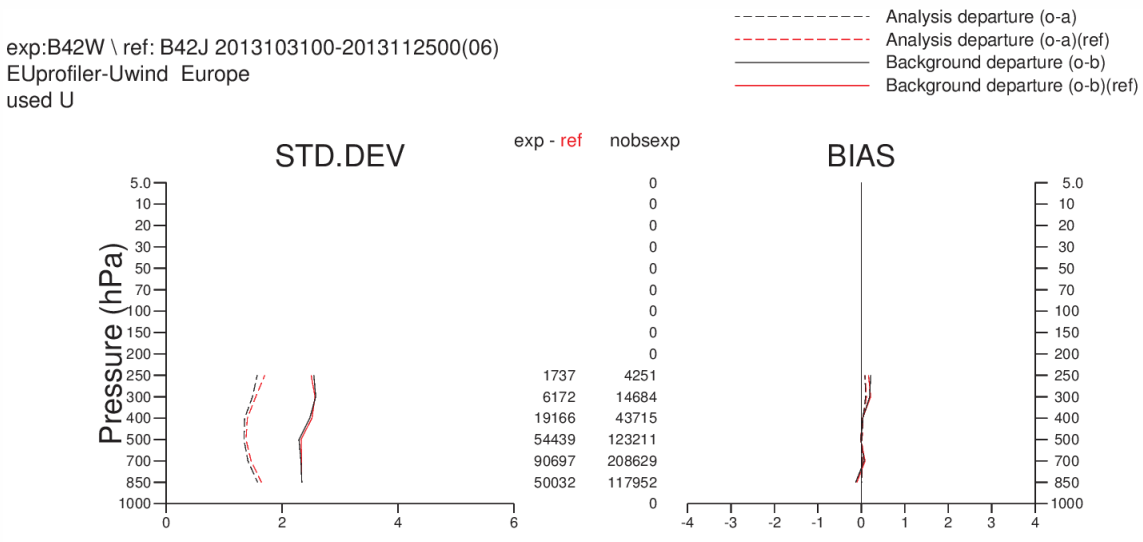
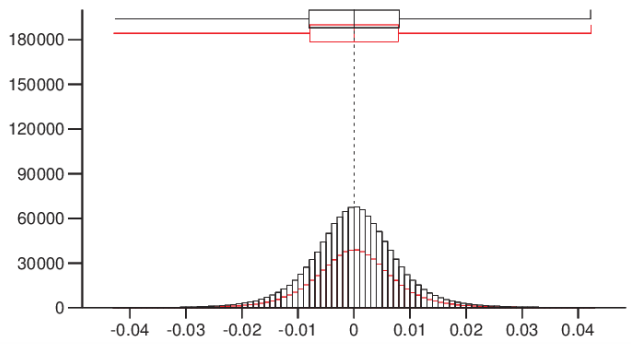
Fixed platforms at high frequency

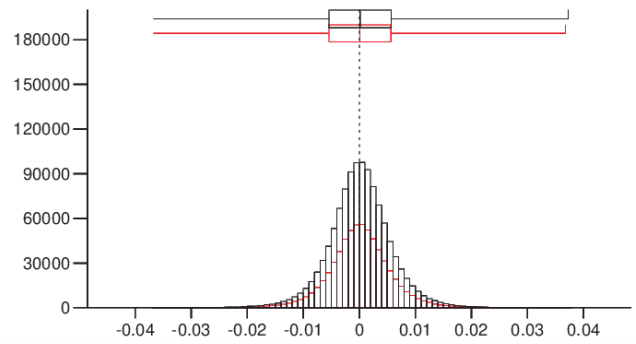
30 min time slots
60 min time slots



Euro profilers
43 % increase



ZTD (OmB)



ZTD (OmA)

Ground-based GPS
77 % increase

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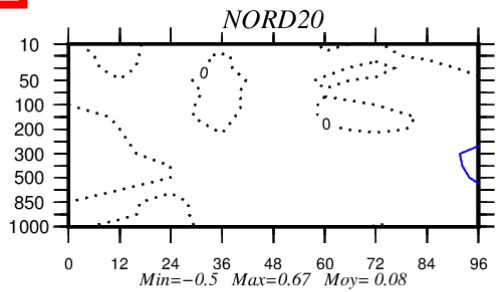
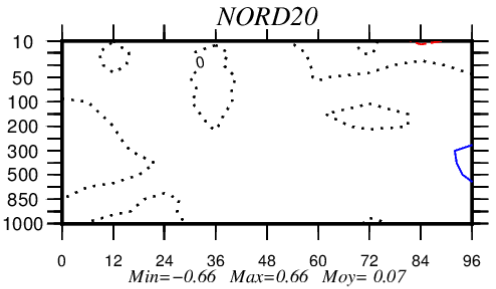
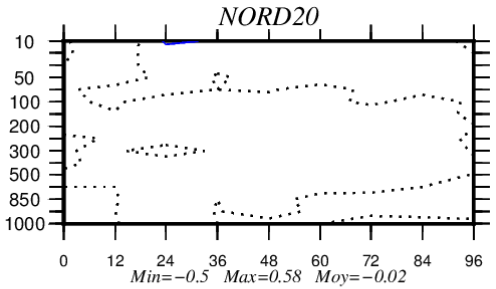
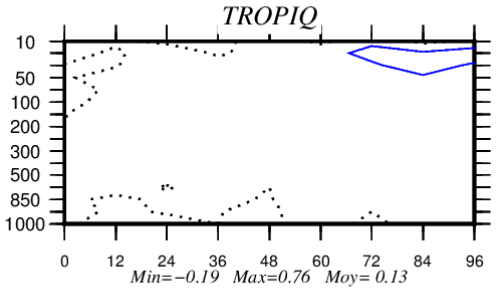
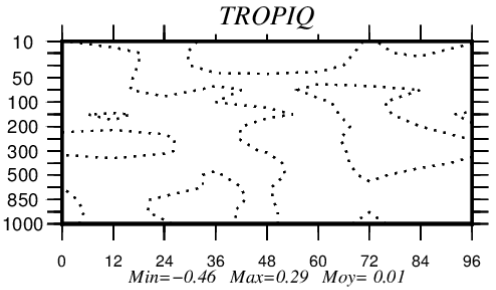
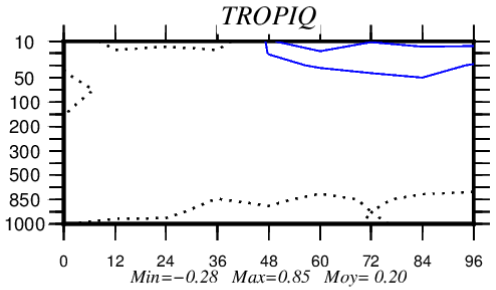
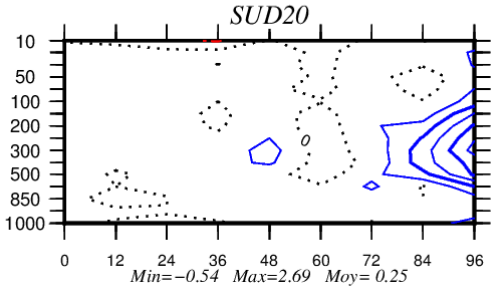
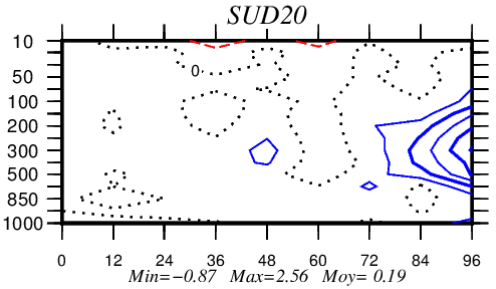
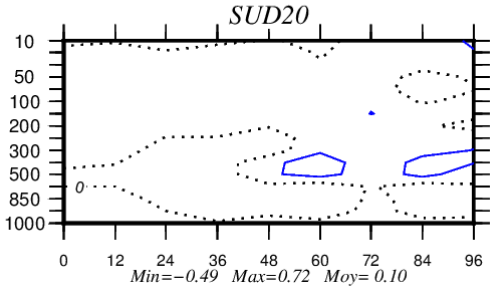
Forecast scores against ECWMF (1)

31/10/2013 – 30/11/2013

	RMS	STD	BIAS
North20			
Tropics			
South 20			

96 h

Blue isolines => (30min TS) better than (1h TS) ☺

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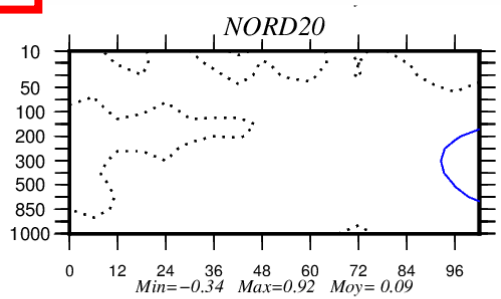
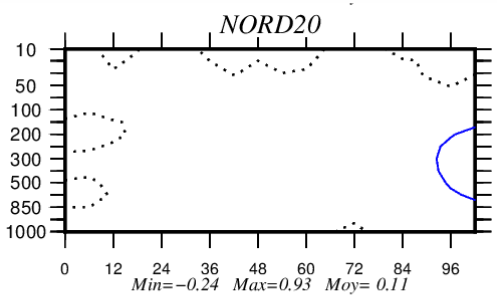
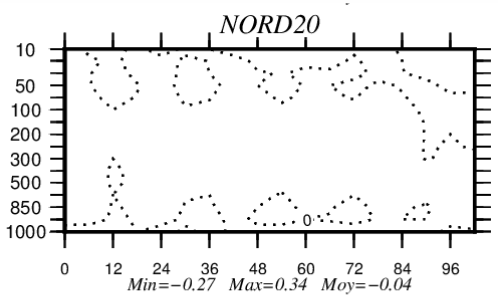
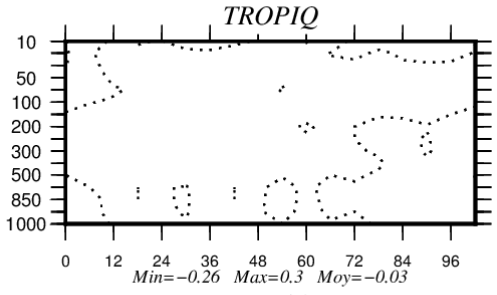
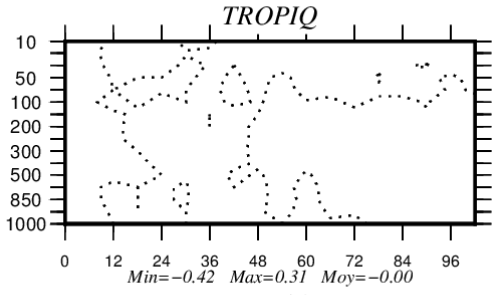
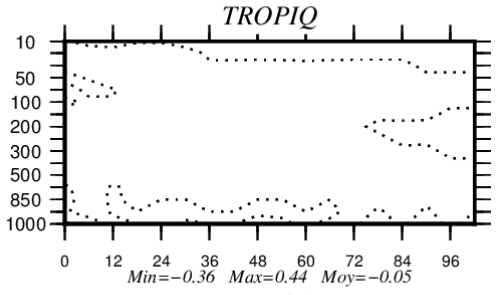
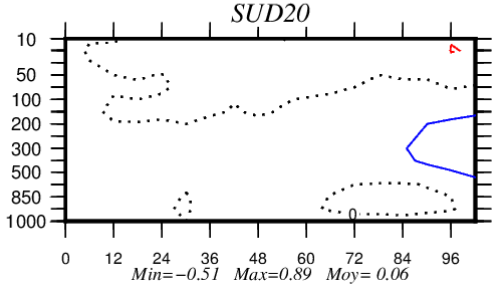
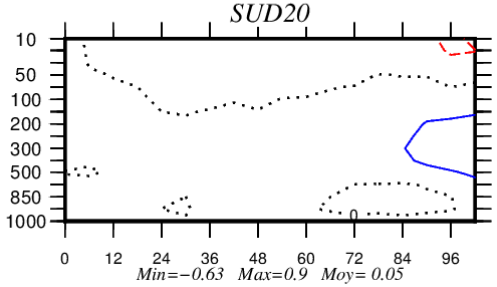
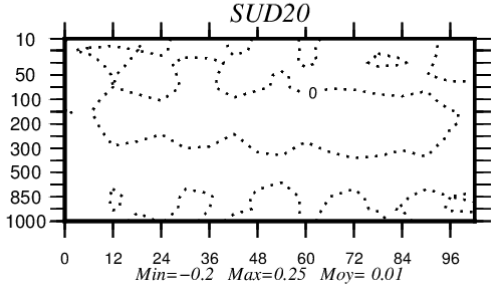
Forecast scores against RAOB (2)

31/10/2013 – 30/11/2013

	RMS	STD	BIAS
North20			
Tropics			
South 20			

96 h

Blue isolines => (30min TS) better than (1h TS) ☺

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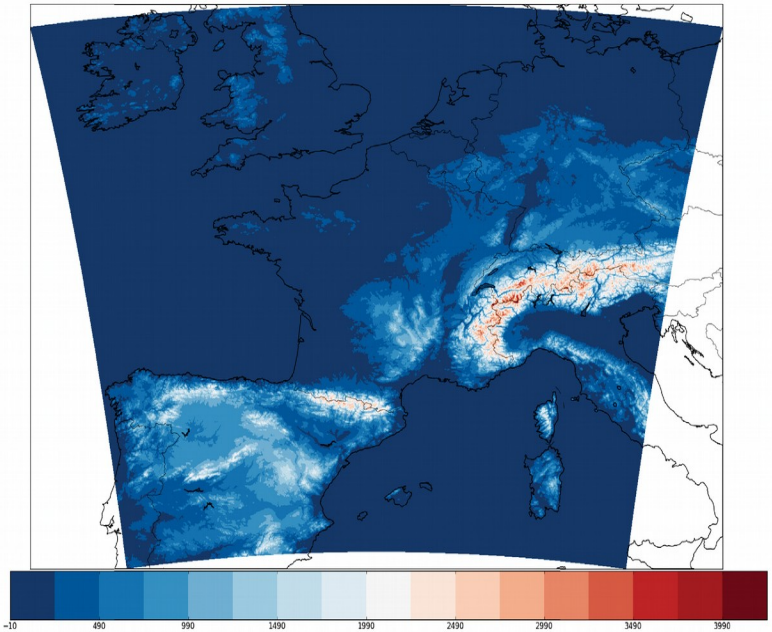
Regional model AROME

- Spectral limited area non-hydrostatic model with explicit moist convection (since 12/2008)
- Horizontal resolution : 1.3 km
- 90 vertical levels (from 5 m up to 10 hPa)
- 3D-Var assimilation (1-h window)
- Observing system : same as ARPEGE (+) 5 SEVIRI/MSG radiances (with Ts inversion) (+) radar DOW and Z (RH) (–) GNSS RO (+) IR and MW sounders with a different set of channels
- Coupling files : hourly forecasts from global model ARPEGE
- Forecast range : up to 42 hours



Previous configuration:
2.5 km resol. and L60 with top at 1 hPa
3D-Var with 3-h assimilation window

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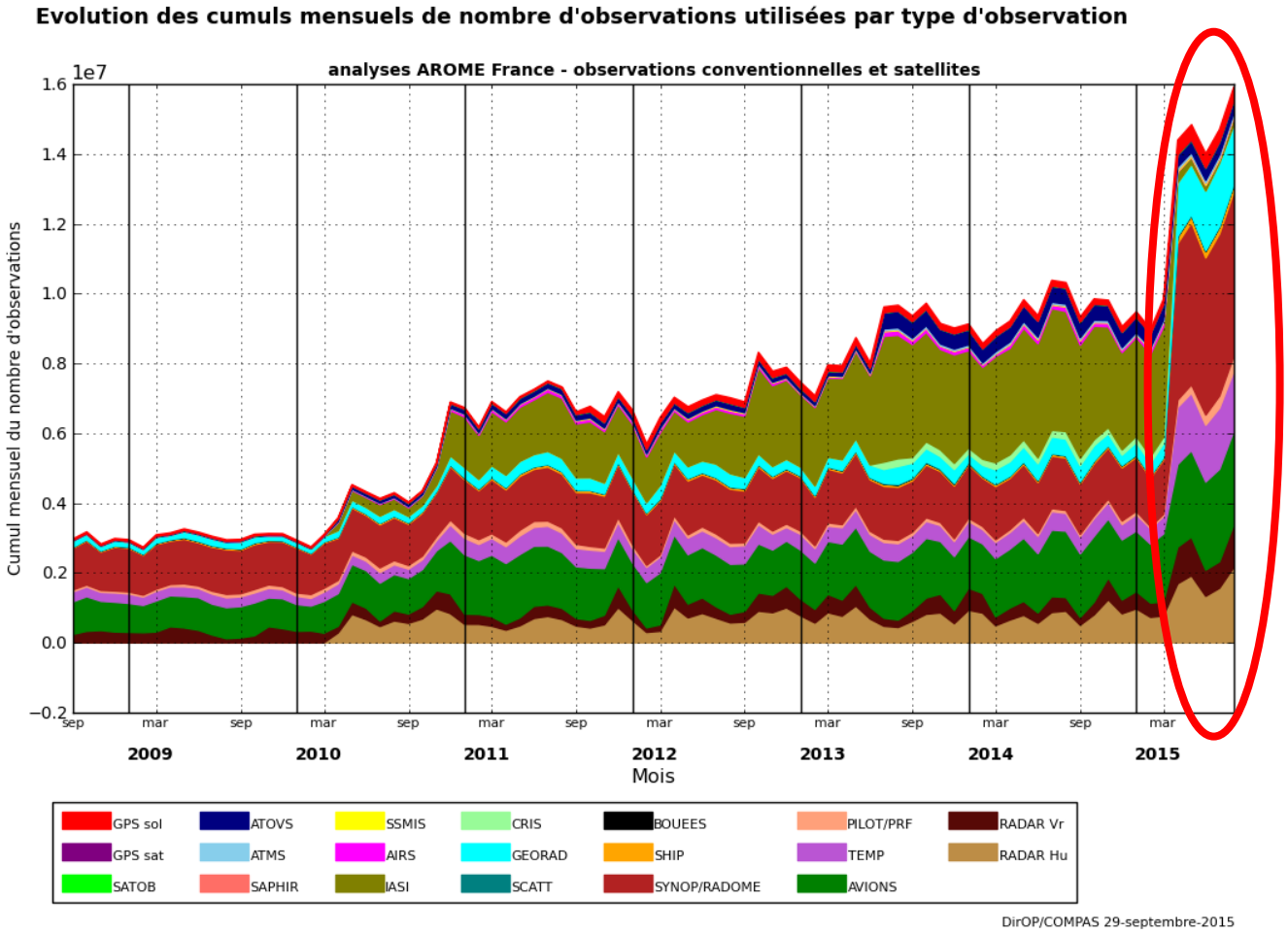
Observations in AROME 3D-Var

IASI
AIRCRAFTS
SURFACE
RADARS
SEVIRI
ATOVS
TEMP



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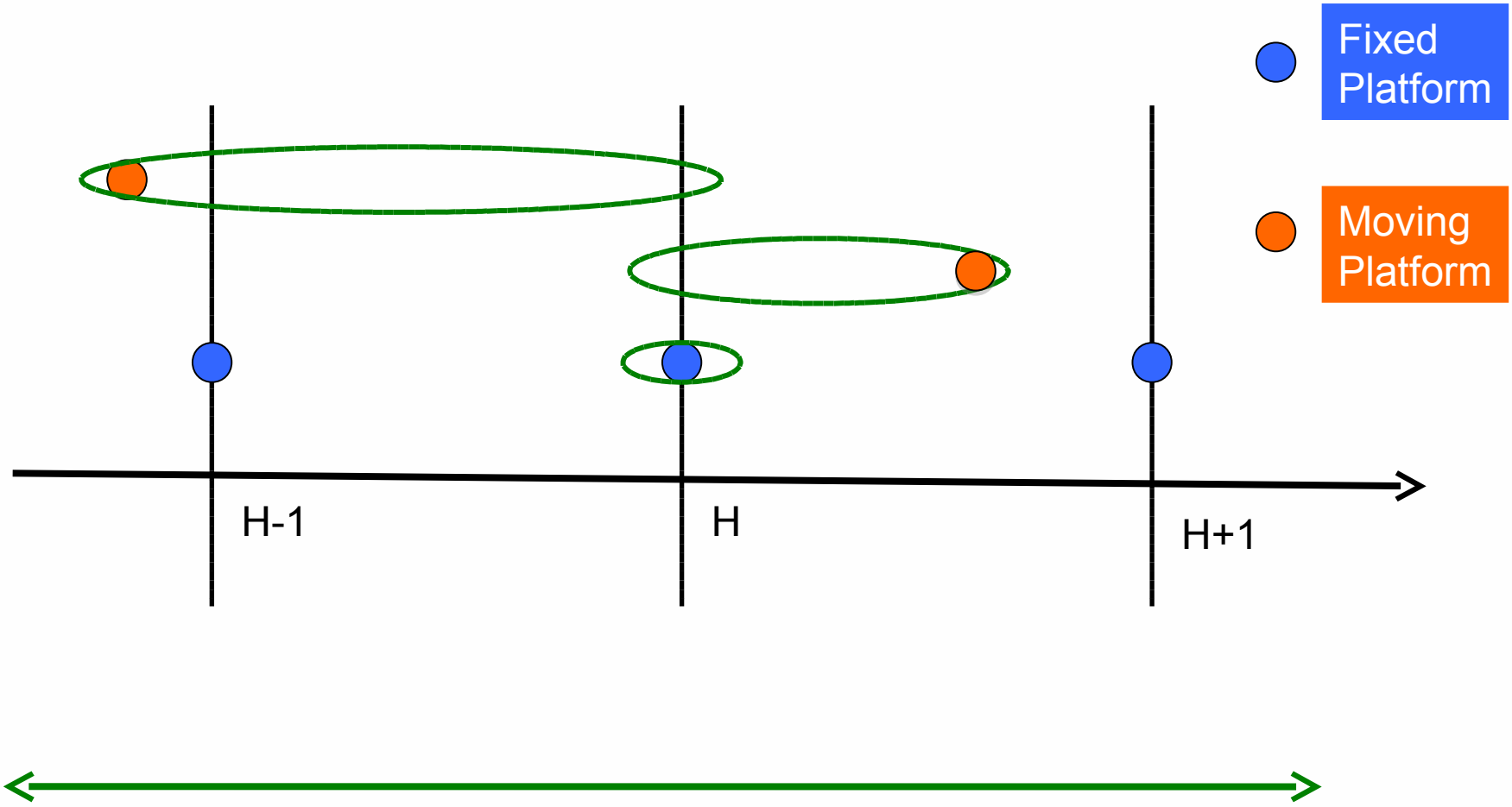
3D-Var : use of observations in the time window



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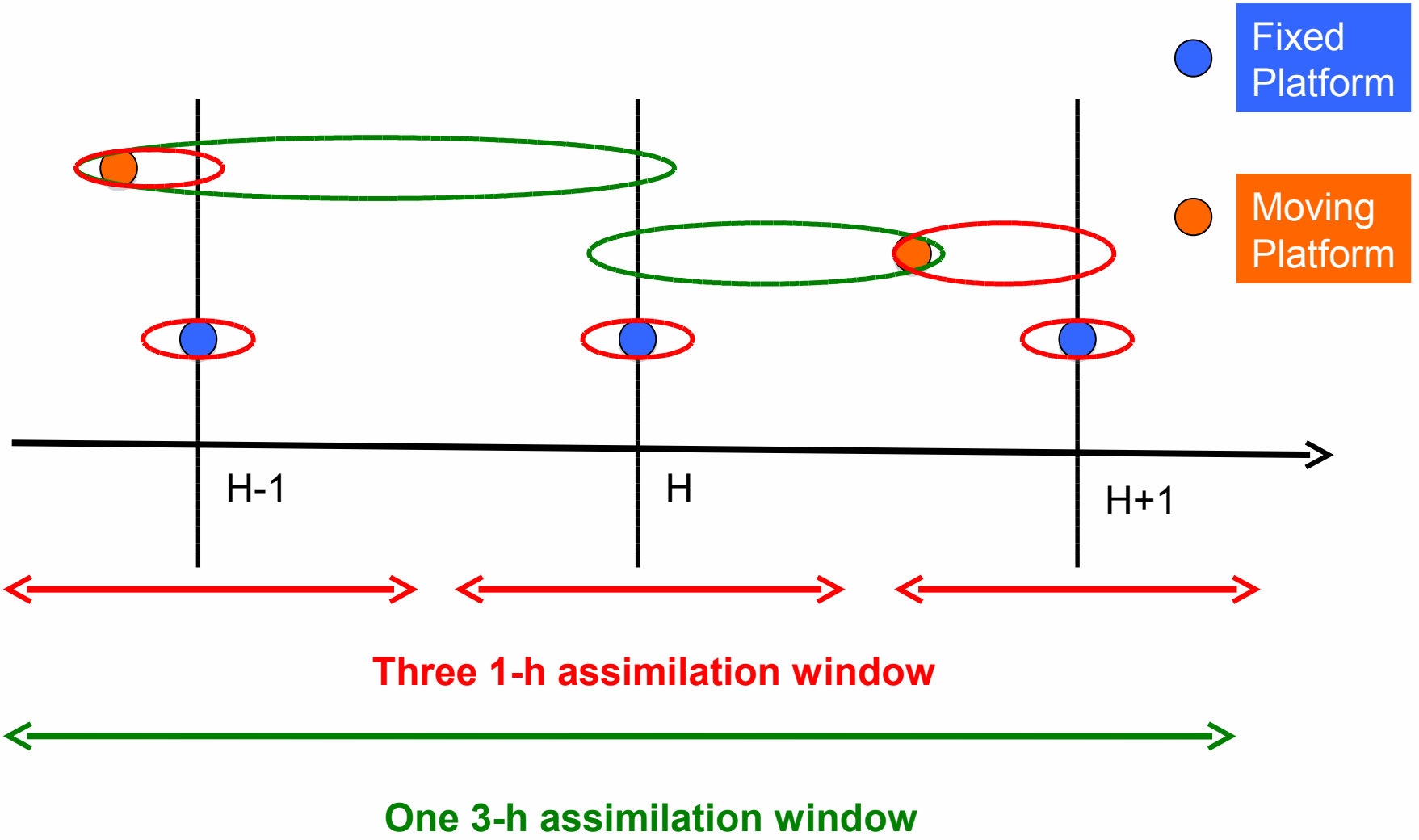
3D-Var : use of observations in the time window



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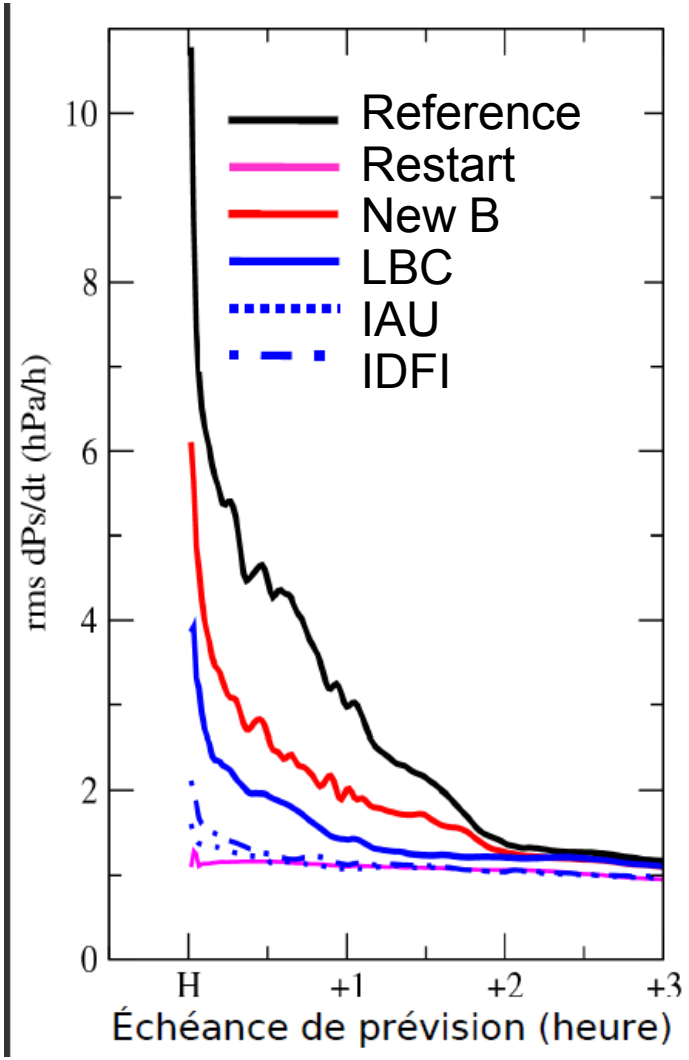
Issues with 3D-Var one-hour cycling (1)



Spin-up problem : presence of unrealistic gravity waves at the beginning of the forecast to reach model equilibrium

Too frequent assimilation cycles => accumulation of imbalances

Features helping to reduce the spin-up:

1) New B matrix based on EDA (improved balance of the small scales)
2) Lateral boundary at initial time taken as AROME analysis
3) *Incremental DFI or Incremental Analysis Update (not used operationally)*

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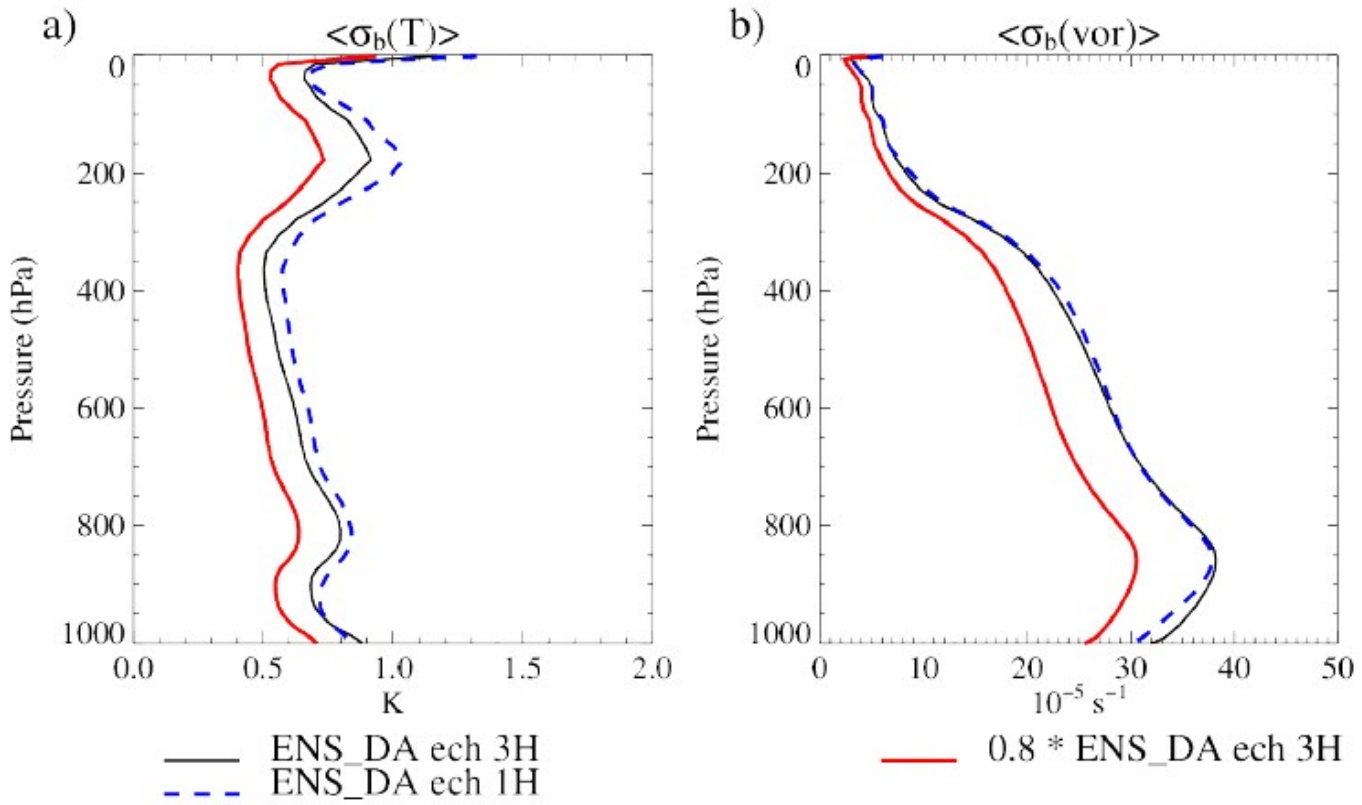
Issues with 3D-Var one-hour cycling (2)



B matrix from EDA for 1-h forecast is larger than for 3-h forecast !
⇒ Use of B matrix from 3-h forecast with reduction factor

Tuning with Desroziers diagnostics : 0.8 ☹
Empirical tuning : 0.6 ☺

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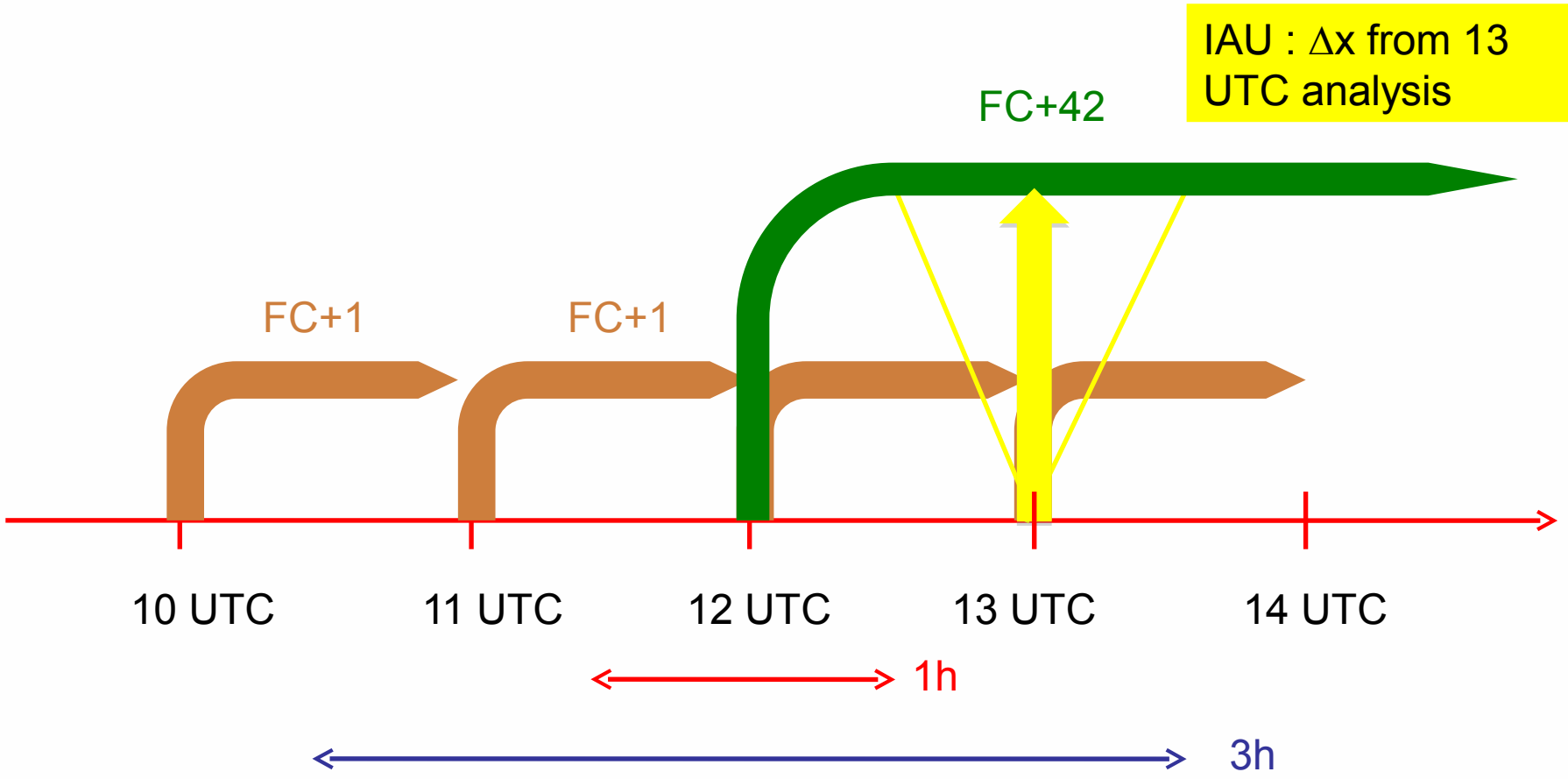
Practical implementation

How to keep the same quality of the 42-h forecasts of AROME with 1-h cycling ?



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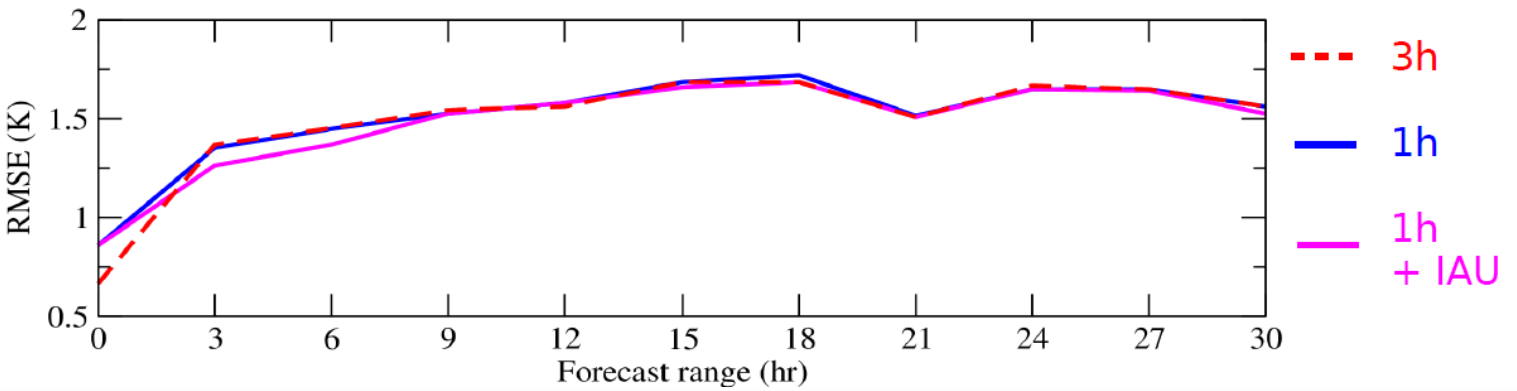
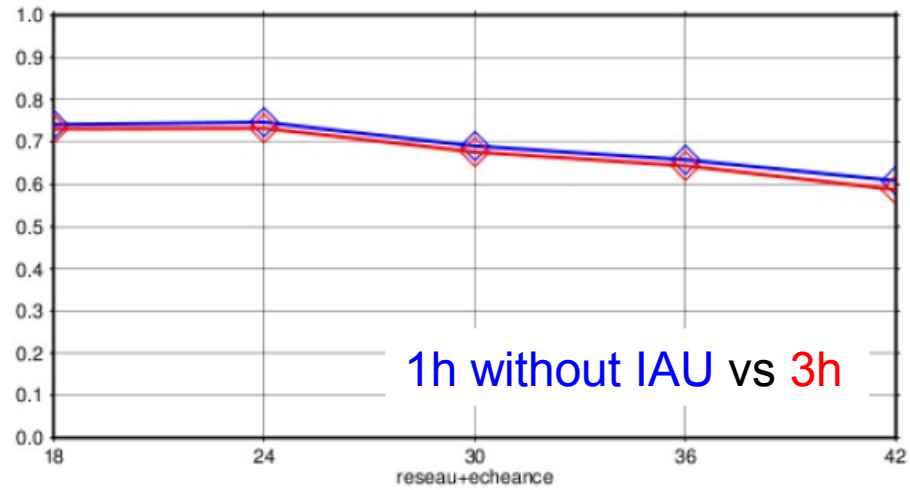
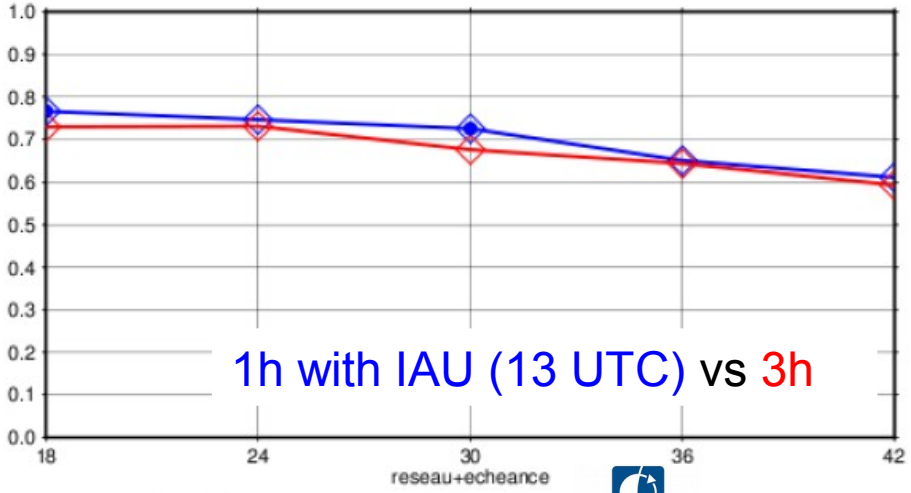
Objective scores (FC from 12 UTC)

RMS T_{2m} (from 01/09/2013 to 30/09/2013)



BSS for 6-h rainfall accumulation for 5mm/6h threshold (15/07 -> 30/09/2013)





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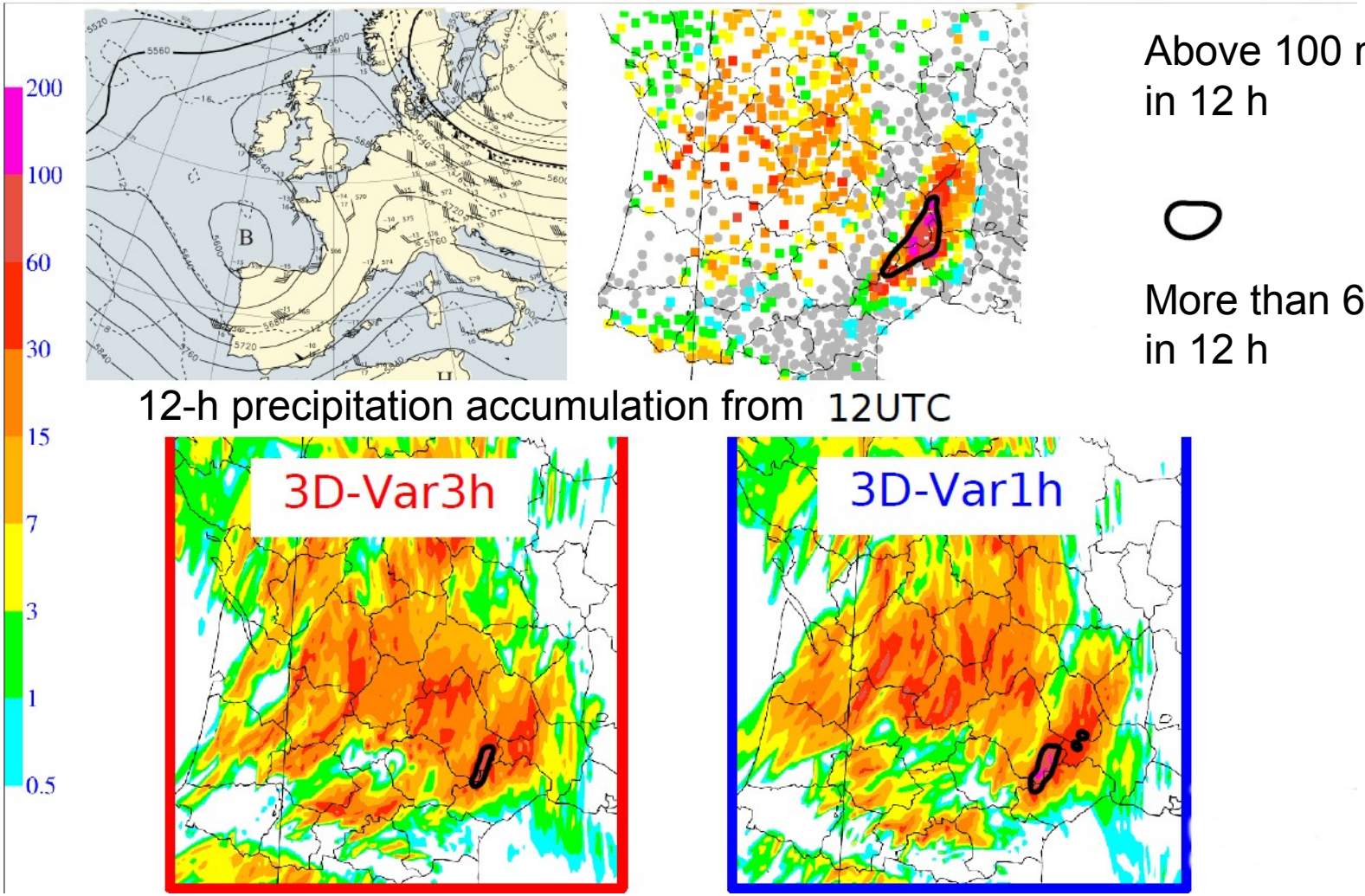
Case study : 28 september 2013



Brousseau et al. (2016) – QJRMS (accepted)

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Conclusions and perspectives

- The assimilation of observations at higher temporal frequency improves the quality of numerical forecasts (at global and regional scales)
- In the global model ARPEGE, the increase of observations is noticeable over polar regions for satellite data (up to 20 %) and for specific observing systems (wind profilers, ground based GPS)
- In the regional model AROME, more observing systems can benefit from a higher temporal frequency (surface observations, radar data, geostationnary radiances)
- The number of observation assimilated in AROME has increased by a factor of 2 when going from a 3-h cycle to a 1-h cycle, and some observations are now assimilated (almost) at the appropriate time (radiosoundings, aircrafts data)
- Such usage is straightforward in a 4D-Var system but less obvious in a 3D-Var system
- Importance of developing 4D mesoscale DA schemes for a more efficient use of observations at high temporal frequency (4D-Var, 4D-EnVar)

Thank you for your attention !

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