

Use of ground based GNSS data in NWP models at Météo-France

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Outline

1. The operational models at Météo-France
2. (historical) implementation method of ground based GNSS ZTD
3. Monitoring and use of ground based GNSS ZTD
4. Impact of the ground based GNSS ZTD in the operational models
5. Overview of current situation and work in progress...



1. The operational models at Météo-France



The operational models at Météo-France

■ Global model and 4DVAR assimilation system **ARPEGE**

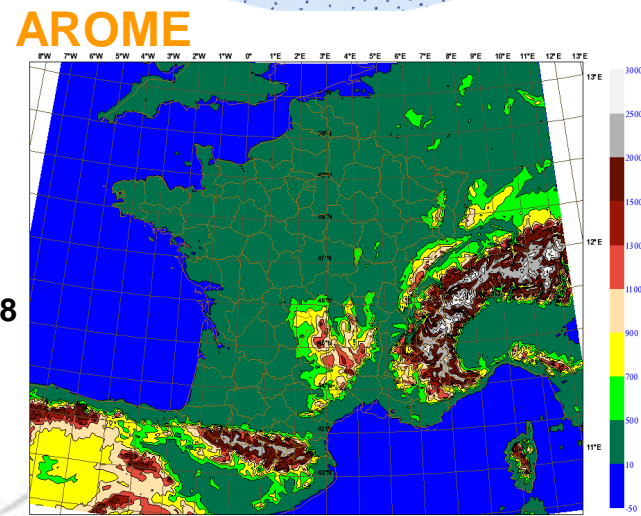
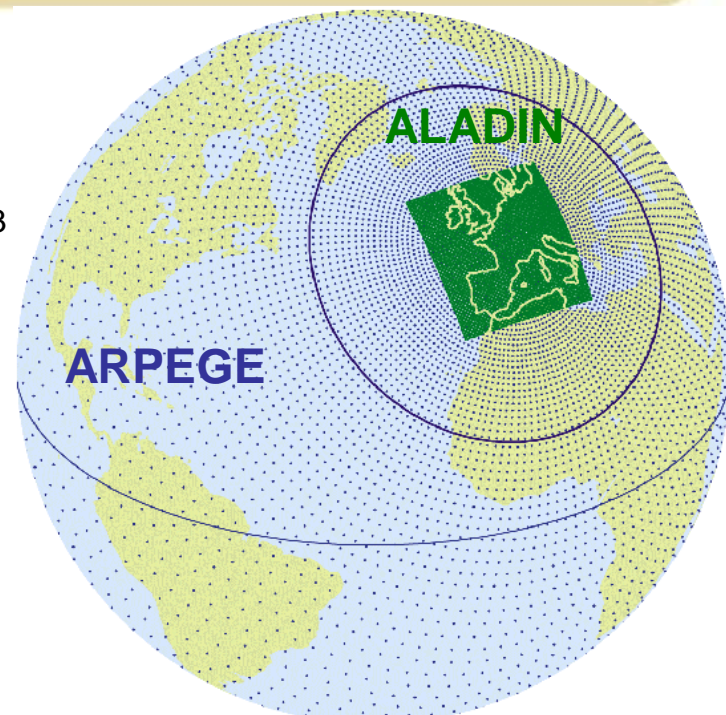
- Vertical: 70 levels, model top at 0.1 hPa (~65 km altitude)
- Horizontal: T798, stretched model: highest horizontal resolution over France (~10 km)
- 4DVAR assimilation (non-stretched) with two minimizations: T107 / T323
- Analysis horizontal resolution is about 60 km (globally)
- **Assimilates European GNSS ZTD data since 19 September 2006**
- Note: there are still operational runs of our non-stretched global model

■ European limited-area model and 3DVAR assimilation system **ALADIN**

- Horizontal resolution 7.5 km, same vertical levels as ARPEGE
- 3DVAR assimilation with 1 minimization at full resolution (6h period)
- One version running over France
- **Assimilates European GNSS ZTD data since 19 September 2006**

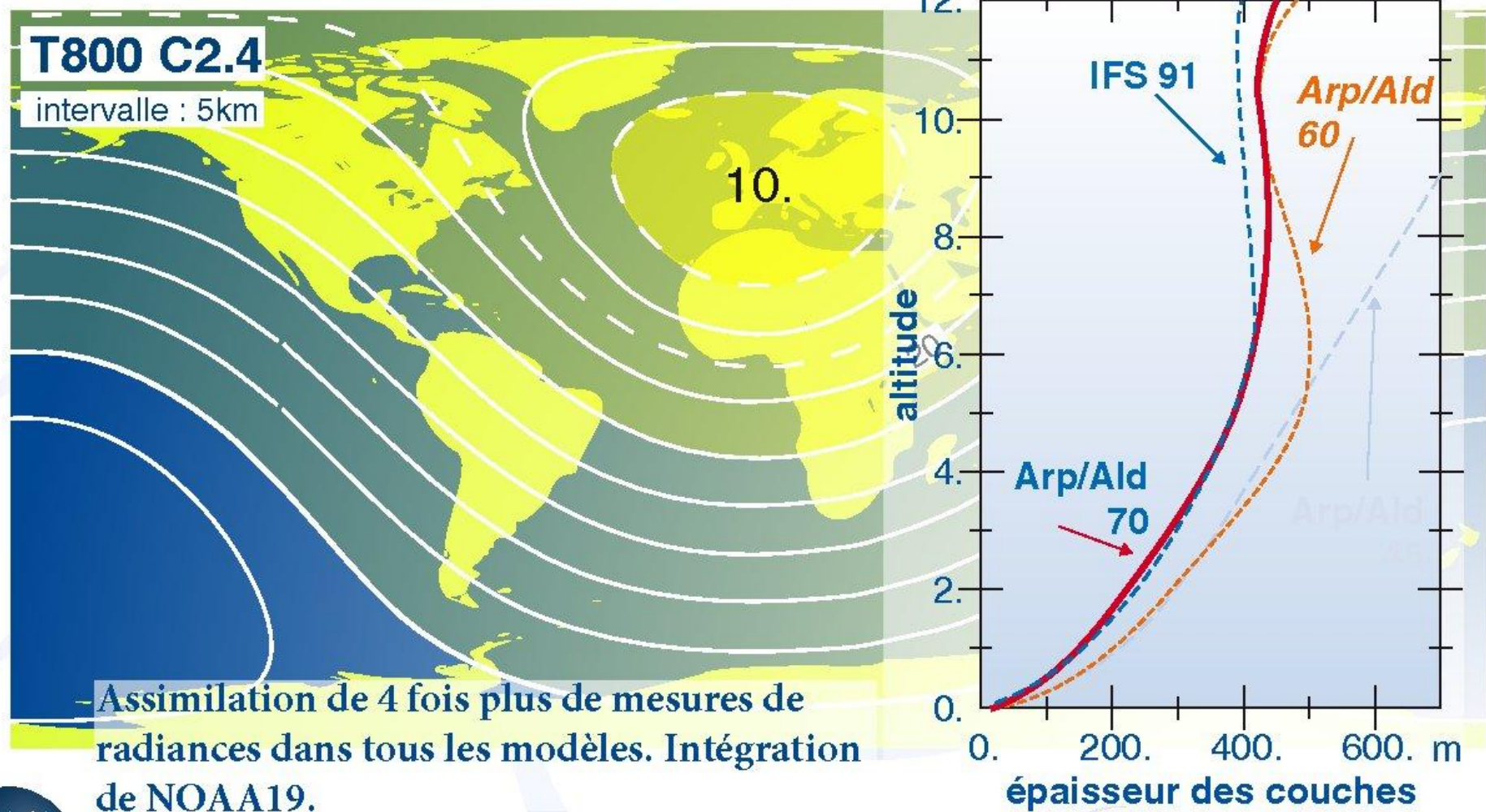
■ High-resolution mesoscale non-hydrostatic model and 3DVAR assimilation system **AROME** over France

- Horizontal resolution 2.5 km, 60 levels
- 3DVAR assimilation with 1 minimization at full resolution (3h period)
- **Assimilates European GNSS ZTD data over France since 22 April 2008**



Evolutions 2009-2010

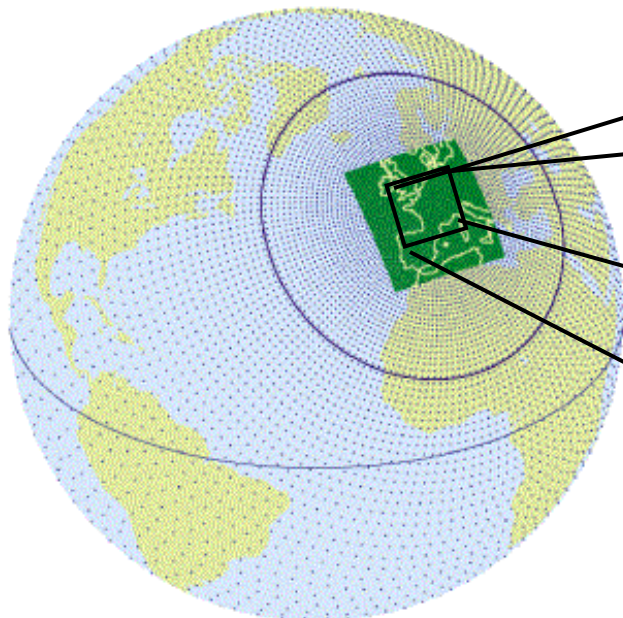
Nouvelle résolution horizontale pour Arpege, nouveau découpage vertical en 70 niveaux pour Arpege, Aladin et autres.



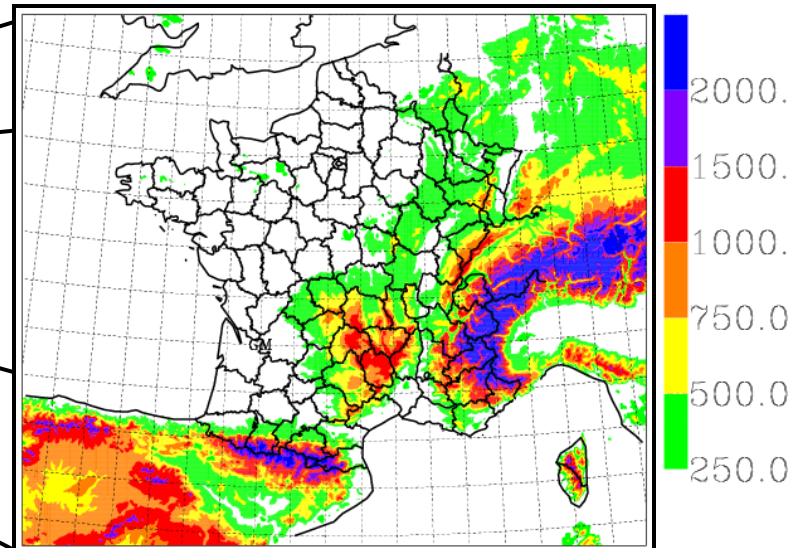
The AROME operational model

- AROME model has completed the french NWP system, which is since 2008 :
 - ARPEGE : global model (10 km over Europe)
 - ALADIN France : regional model (7.5 km)
 - AROME : mesoscale model (2.5 km)
- Aim : to improve local meteorological forecasts of potentially dangerous convective events (storms, unexpected floods, wind bursts...) and lower tropospheric phenomena (wind, temperature, turbulence, visibility...).

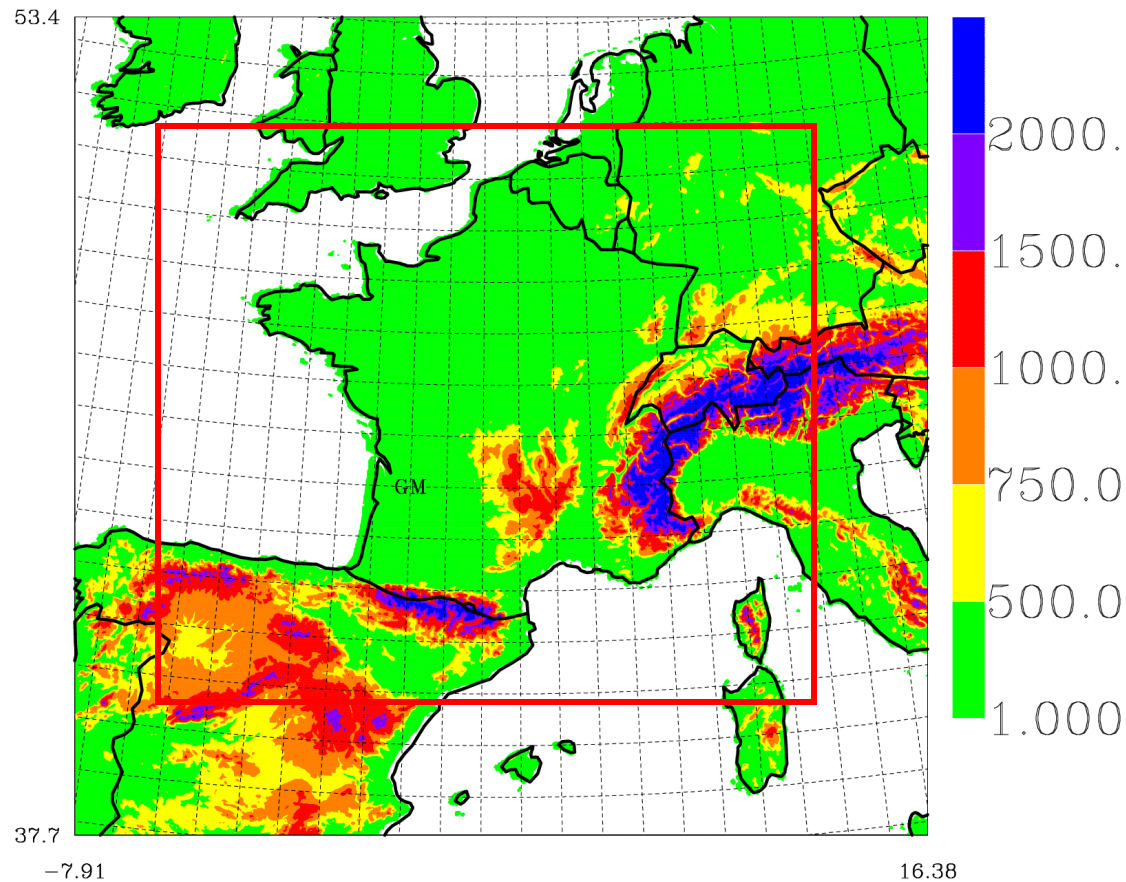
ARPEGE stretched grid and ALADIN-FRANCE domain



AROME France domain

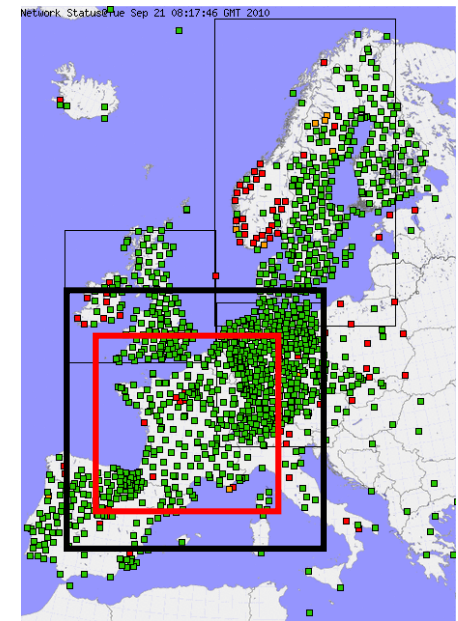


The next AROME operational model



Domain 750x720 points

Boundary conditions :
Arpege instead of Aladin



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2. (historical) Implementation method of ground-based GNSS ZTD assimilation



E-GVAP ZTD data in the M-F operational models

- **1st period : 2005 - 2006**
 - First experiments to evaluate the impact of GPS data in the operational models (Paul Poli)

- **2nd period : 2006 - 2008**
 - Implementation in the operational models : Arpege, Aladin (in 2006) and finally Arome (in 2008) using a white list approach

- **3rd period : 2008 - 2010**
 - No major changes for ZTD data in the operational models, except a new white list for Arome. Experiments in research mode.

- **4th period : 2010 -**
 - Recoding from scratch the operational code to make the GNSS data become “normal” data, with classical black-list method, and variational bias correction.



The specificity of E-GVAP ZTD data in 2006-2008

- **E-GVAP ZTD data are a special kind of meteorological data :**
 - Processing upgrades, strategy changes, network expansion, analysis centers appearing/disappearing...
 - List of station identifiers evolves all the time
 - Quantity and quality of data can change abruptly
- **Objectives :**
 1. Be able to use GPS ZTD data operationally
 2. Be able to monitor the improvements in GPS ZTD data
- **Corresponding requirements**
 - Objective 1: approximately stable data quality and quantity (we cannot assimilate data whose data quality and quantity evolve all the time)
 - Objective 2: acceptance by the screening phase of ALL ZTD data arriving to us (we want to compare all the data to our model in order to build up statistics and follow evolutions)
- **Problem:**
 - Requirements to reach objectives 1 and 2 present irreconcilable differences...



Usual data filtering solutions at MF

■ « Black list method »

- Default behaviour is that **all data are active**, that is, intended for assimilation
- Black list:
 - Filter that makes data originating from suspicious sites/sources **passive**
- Typically used for
 - Radiosonde data
 - Ground data
 - Satellite remote sensing channels/frequencies which we cannot model properly
- Problem with that method
 - Only works if one knows the complete list of data providers **beforehand**

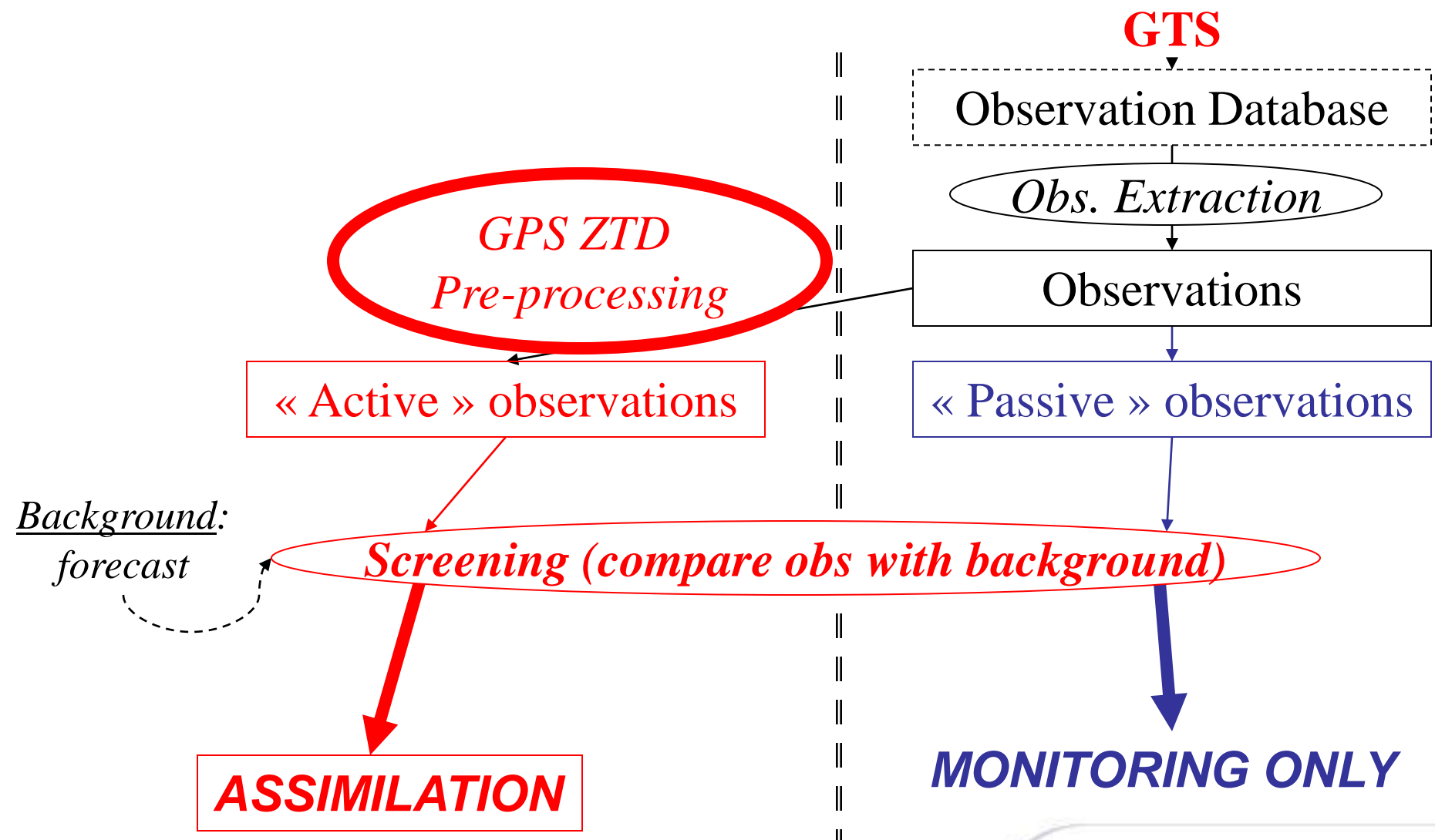
■ **Because of the increasing number of sites, GPS ZTD data required a different approach**

■ « White list method »

- Default behaviour is that **all data are passive**, that is, excluded from assimilation
- White list:
 - Filter that makes data originating only from trusted sites **active**
- First and only application so far : GPS ZTD
- Problem with that method
 - Only works if one knows the complete list of data providers **beforehand**



Current GPS ZTD data flow at Météo-France



Selection rules for European ZTD

■ Station location

- Station is located in, or close to, Europe (i.e. no isolated stations outside Europe)
- Station altitude is below xx meters altitude, within yy meters of the model orography
- Next closest station is located more than zz km away, and station coordinates do not change over time

■ Quantity

- Data from the station are present more than 50% of the time

■ Quality

- Observation minus background departures for the station are gaussian with a χ^2 -test
 - Parameters: threshold: 0.1%; nbins=70, or less if ndata in any bin < 10
- Absolute bias must be less than 20 mm and stdev less than 30 mm

■ Timeseries considered to carry out this selection

- At least 10 days long
- Must contain different weather types, ideally a combination of dry and wet events
- Avoid really wet events because our models are not such good references then

■ Notes:

- Thresholds xx, yy, zz are model-dependent
- For the 4DVAR assimilation, we exclude data at 60 minute freq. (not sure of the exact time of these data)
- If there are several analysis centers meeting all the criteria for a given station:
 - Retain the one for which observation minus background standard deviation is the smallest, if the difference is more than 0.2 mm with the other centers, otherwise:
 - Retain the one for which max (observation minus background standard) minus min (observation minus background standard) per period is smallest, if the difference is more than 5 mm with the other centers, otherwise: (last resort)
 - Retain the one which presents the most stable bias (smallest stdev of the mean as calculated per period)

GPS ZTD Pre-processing

Pre-processing input:

- GNSS ZTD data
- Selection list

Pre-processing steps:

1. Selection of the observations coming from stations in the map
 - ❖ Check all values within physical range
 - ❖ Verify that latitude, longitude, altitude, time significance have not changed (*)
2. Time thinning:
 - ❖ In 4DVAR: average observations by time-slot (30 minutes or 1 hour)
 - ❖ In 3DVAR: retain only the 'most central' obs (closest to analysis time)
3. Observation minus background bias correction (*)
4. Observation standard deviation error assignment (*)

(*) = relies on information stored in the station selection list



3. Monitoring and use of ground-based GNSS ZTD



Short cut off of ARPEGE & AROME

- Short cut off ARPEGE and for AROME

	00	03	06	09	12	15	18	21
ARPEGE	2h10		9h00		13h50		21h00	
AROME	1h20	6h30	9h20	12h30	14h10	18h30	21h25	24h30

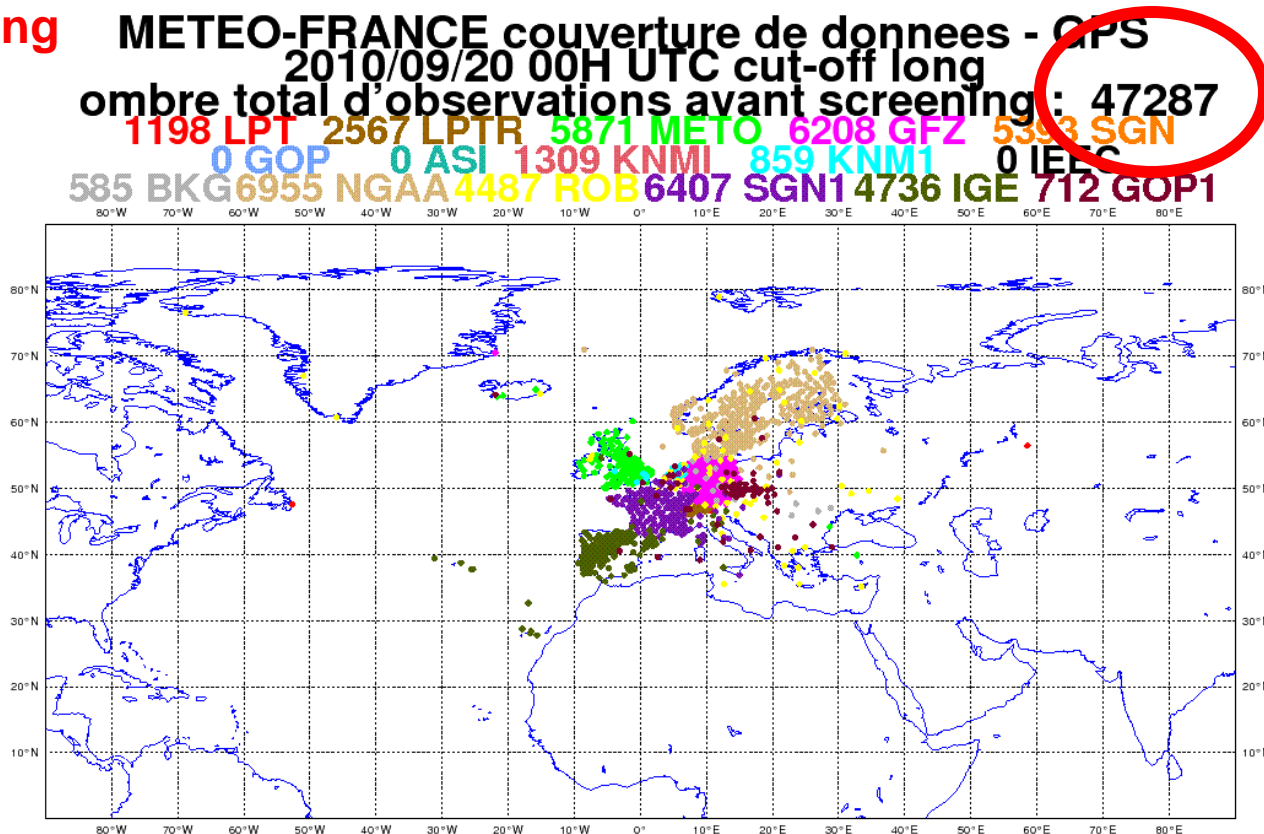
- There is no delay problem for the long cut off (between 6h55 and 8h05 after the network time).
- It is important that ZTD data arrive early enough for the ARPEGE short cut off and for AROME.



Example of data usage (ARPEGE)

ARPEGE at 00H

(6h period, long
cut-off)



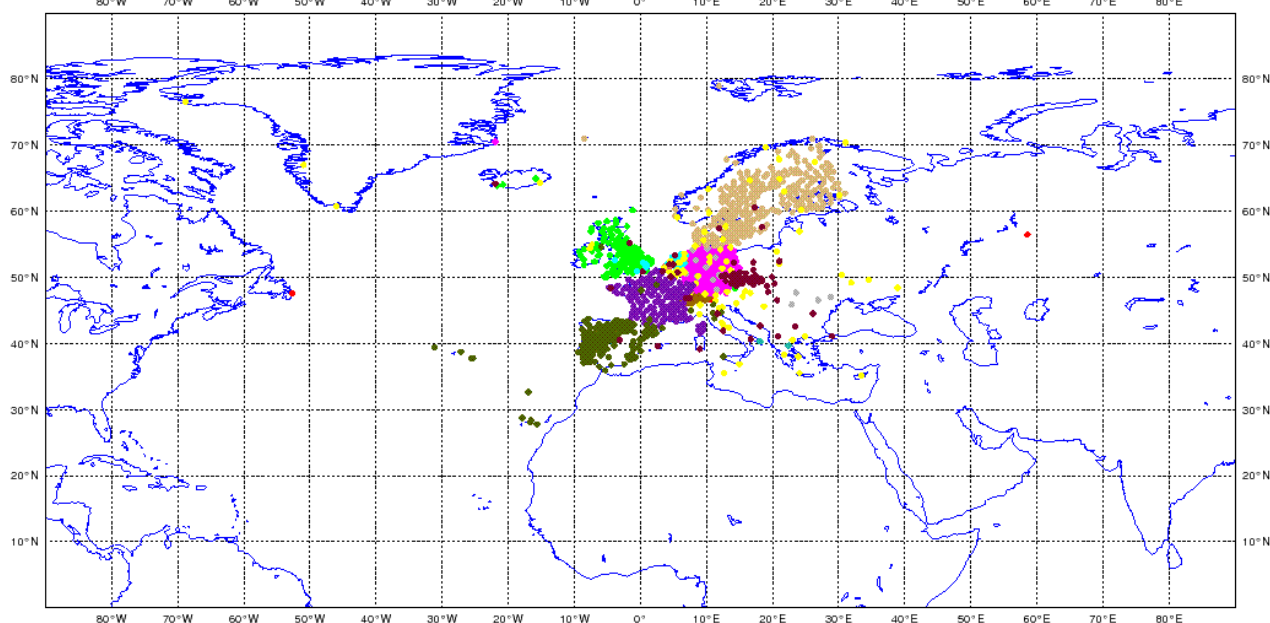
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Example of data usage (ARPEGE)

ARPEGE at 00H

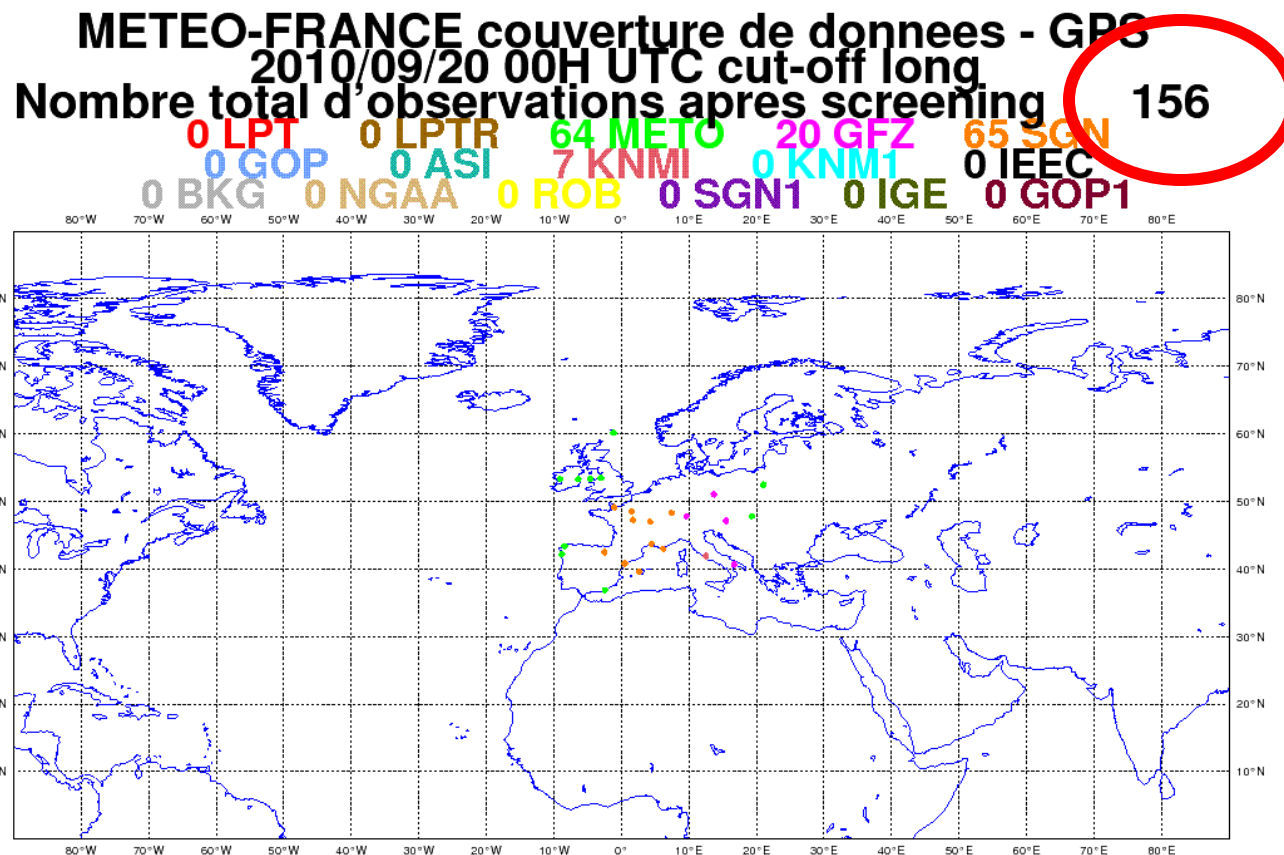
**(6h period,
short cut-off)**

METEO-FRANCE couverture de donnees - GPS
2010/09/21 00H UTC cut-off court
ombre total d'observations avant screening: 25936
 780 LPT 1710 LPTR 2977 METO 4060 GFZ 2492 SGN
 0 GOP 568 ASI 690 KNMI 580 KNM1 0 ILEC
 351 BKG 3322 NGAA 2412 ROB 2318 SGN1 3234 IGE 442 GOP1



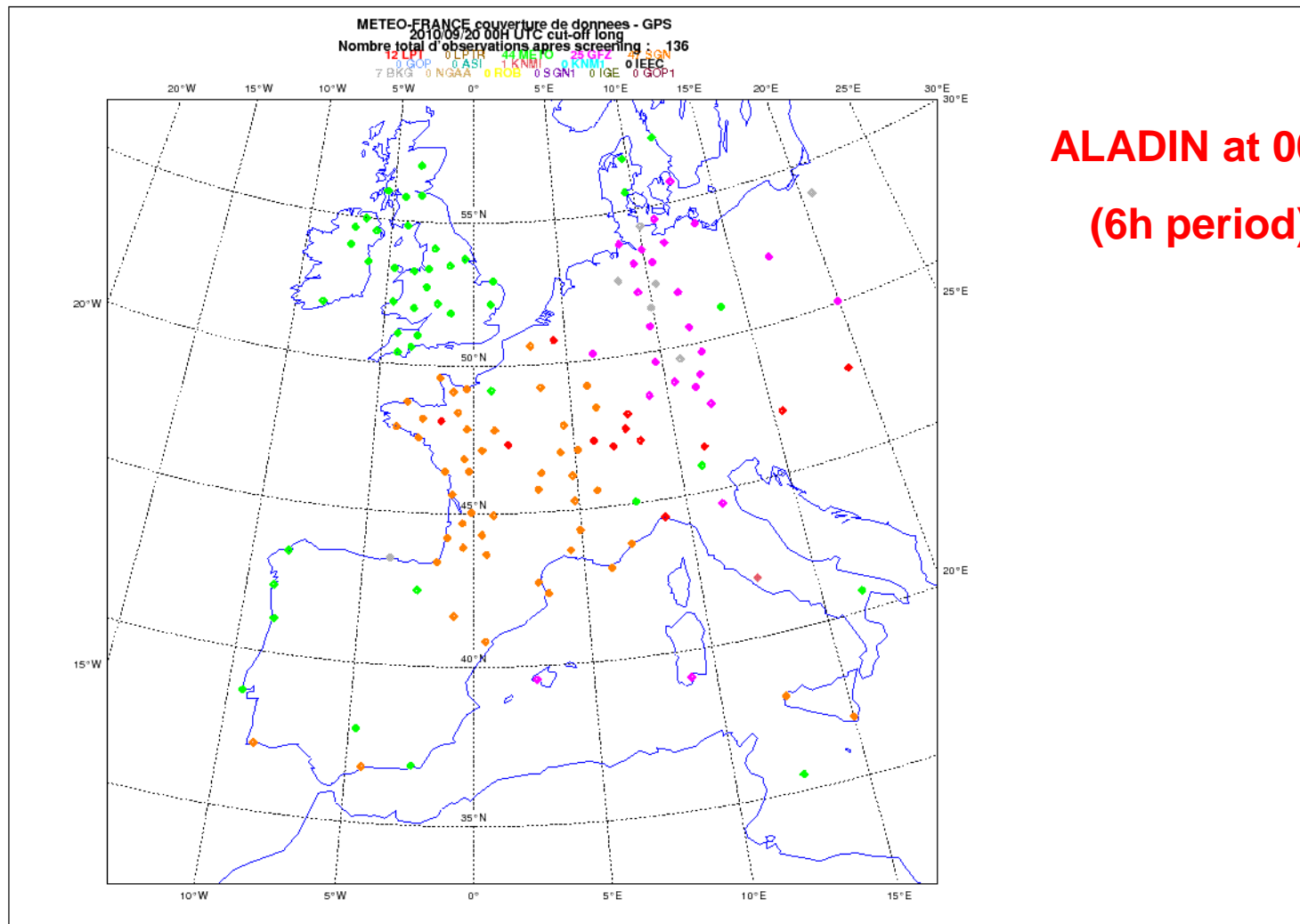
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Example of data usage (ARPEGE)



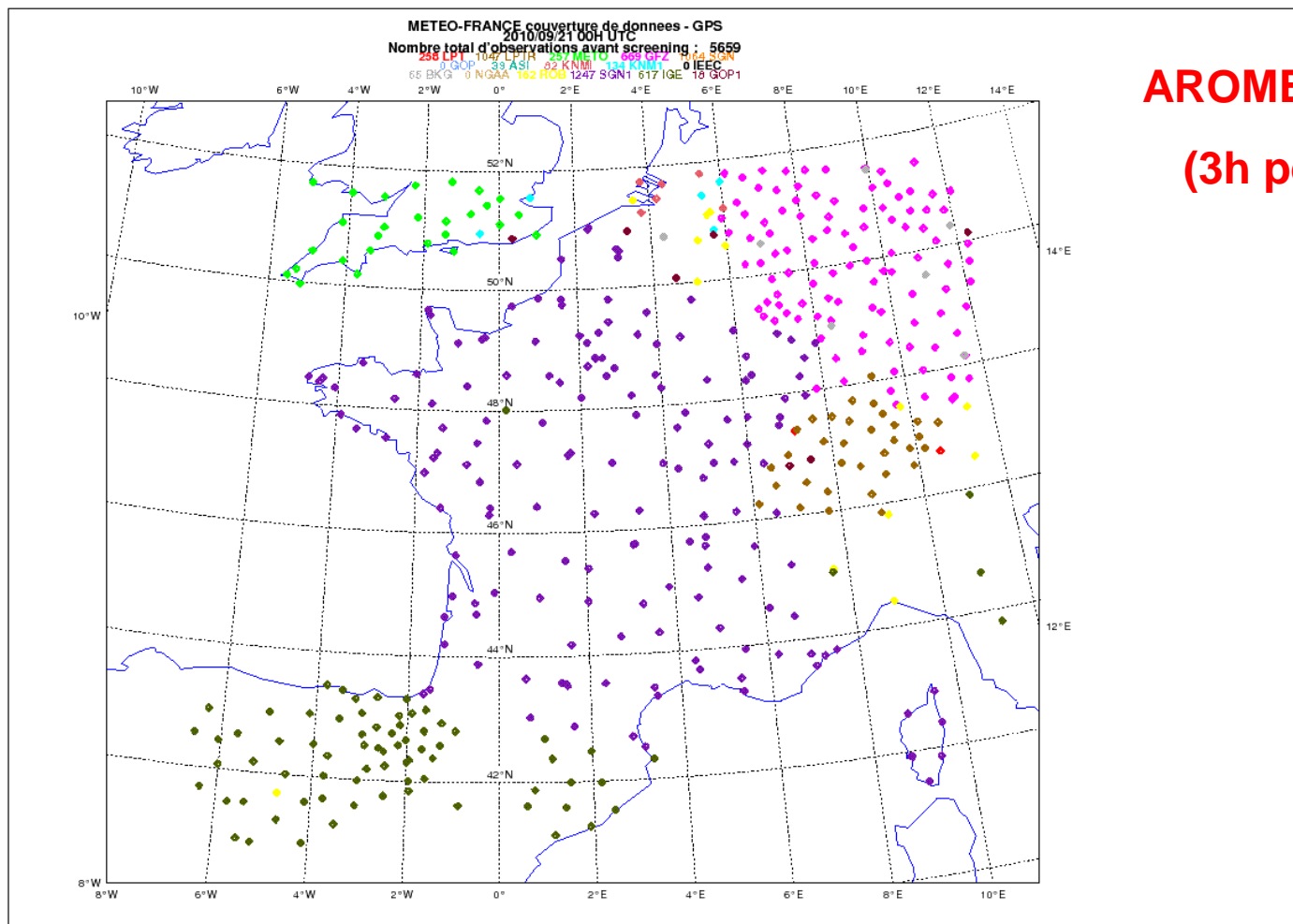
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Example of data usage (ALADIN)



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Example of data usage (AROME)



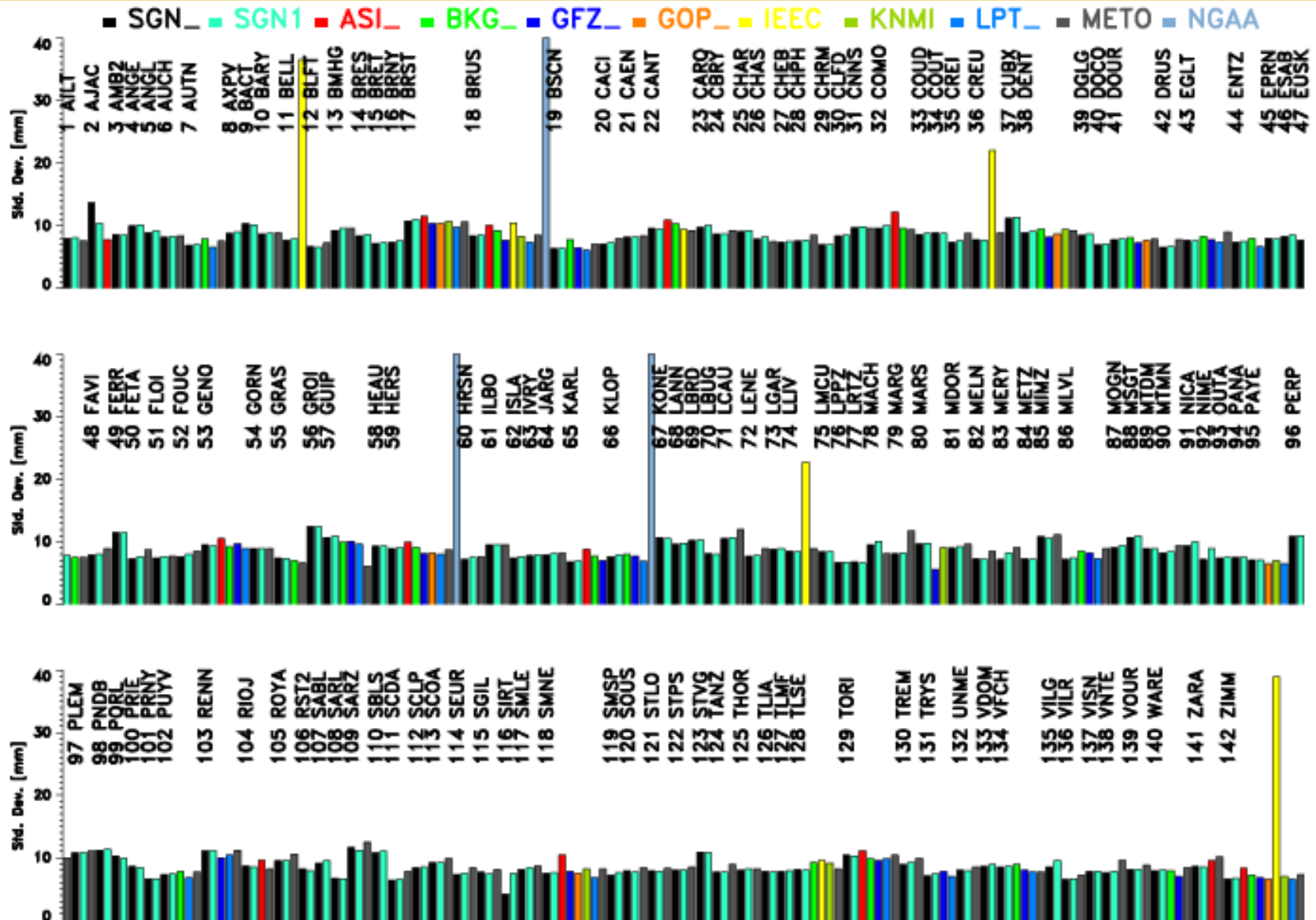
AROME at 00H
(3h period)



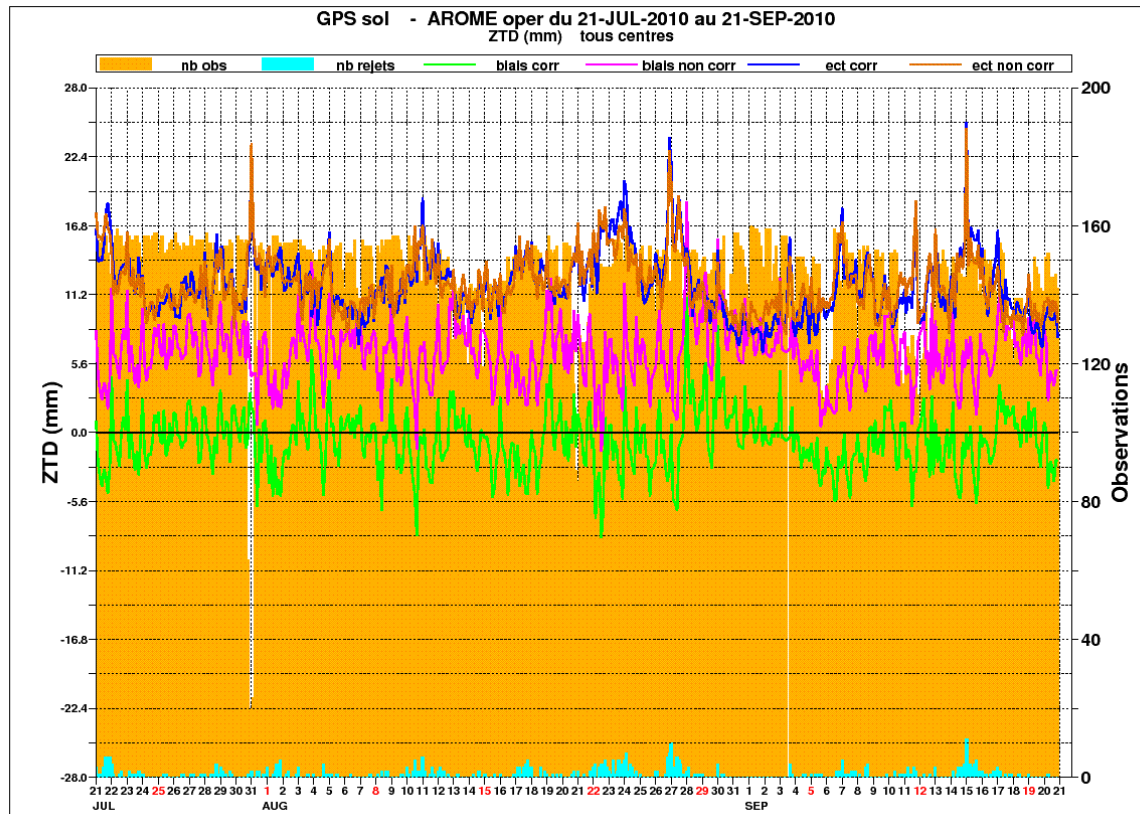
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Monitoring of stations solutions over ~France

Example: standard deviations



Monitoring example (time-series)

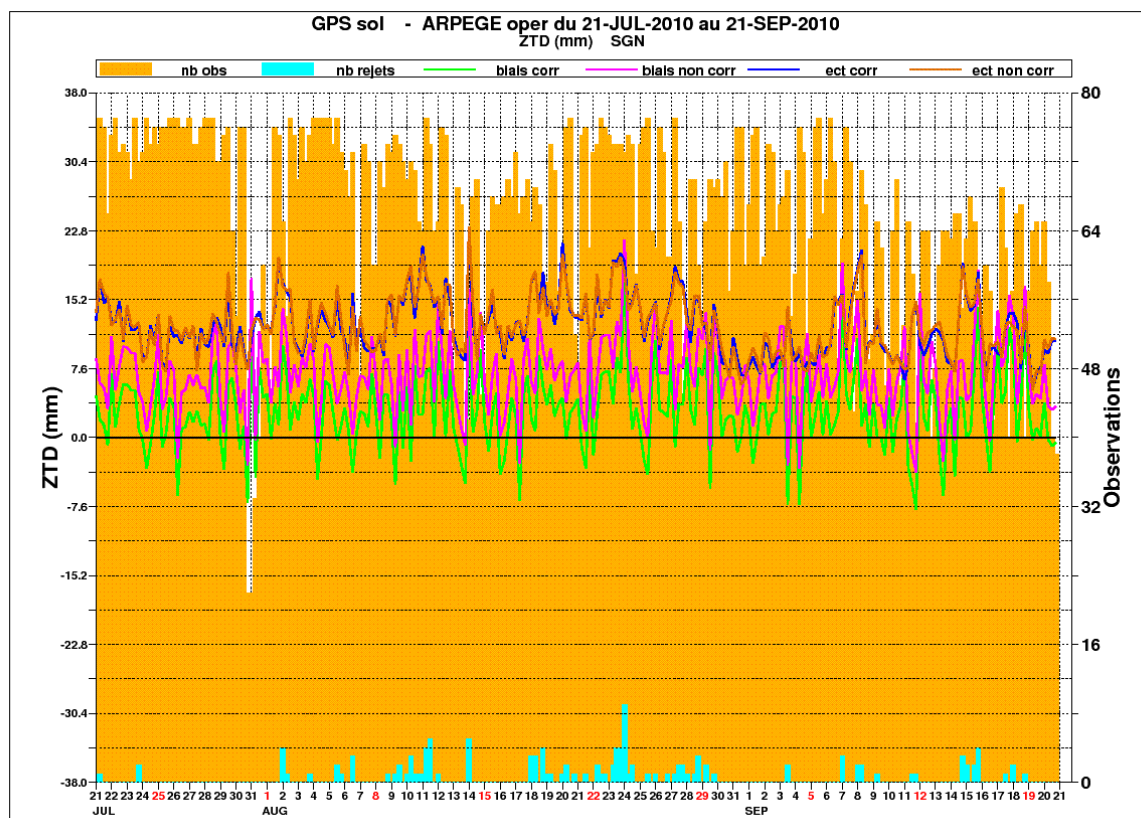


DPREVI/COMPAS



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Monitoring example (time-series)

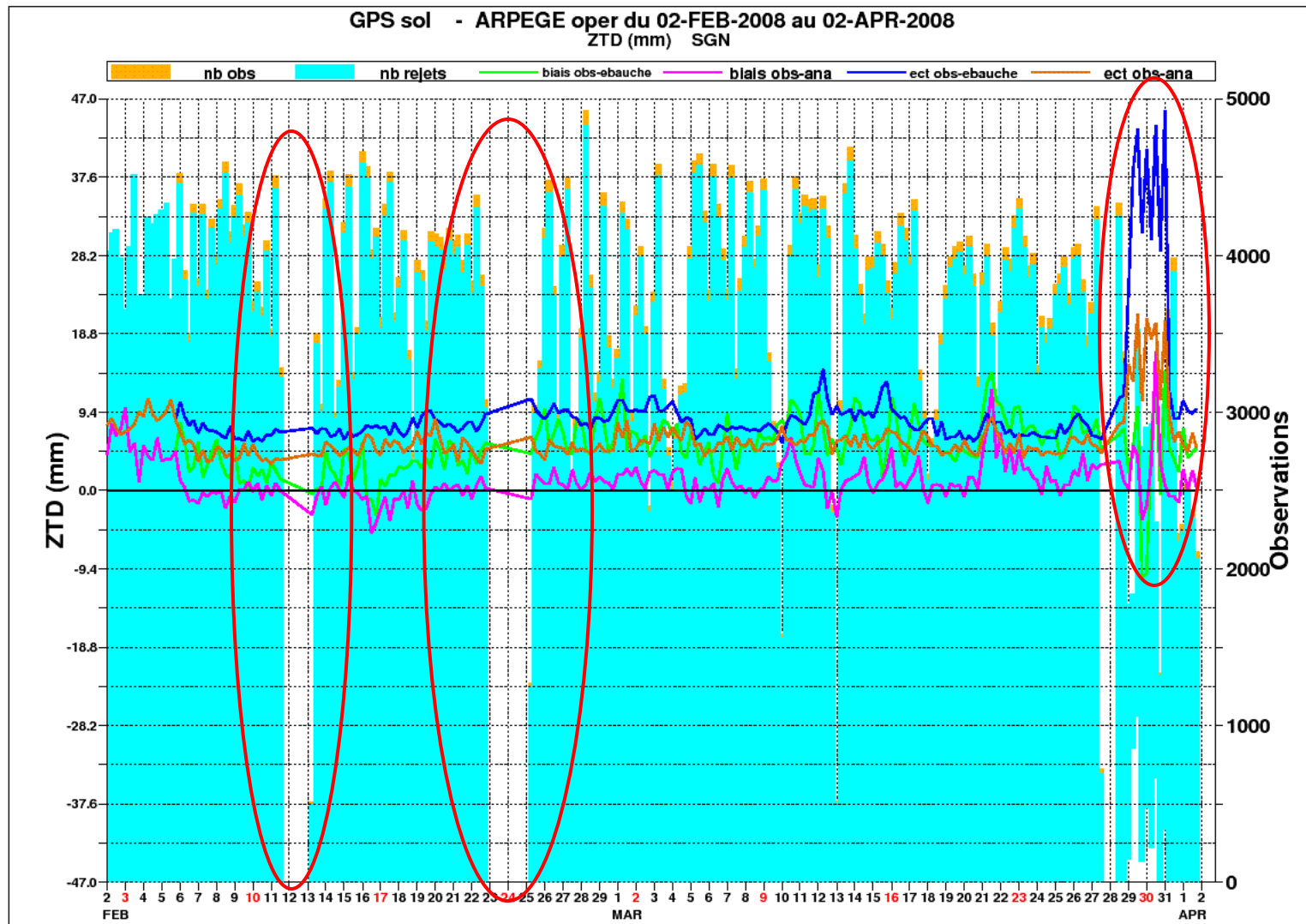


DPREVI/COMPAS



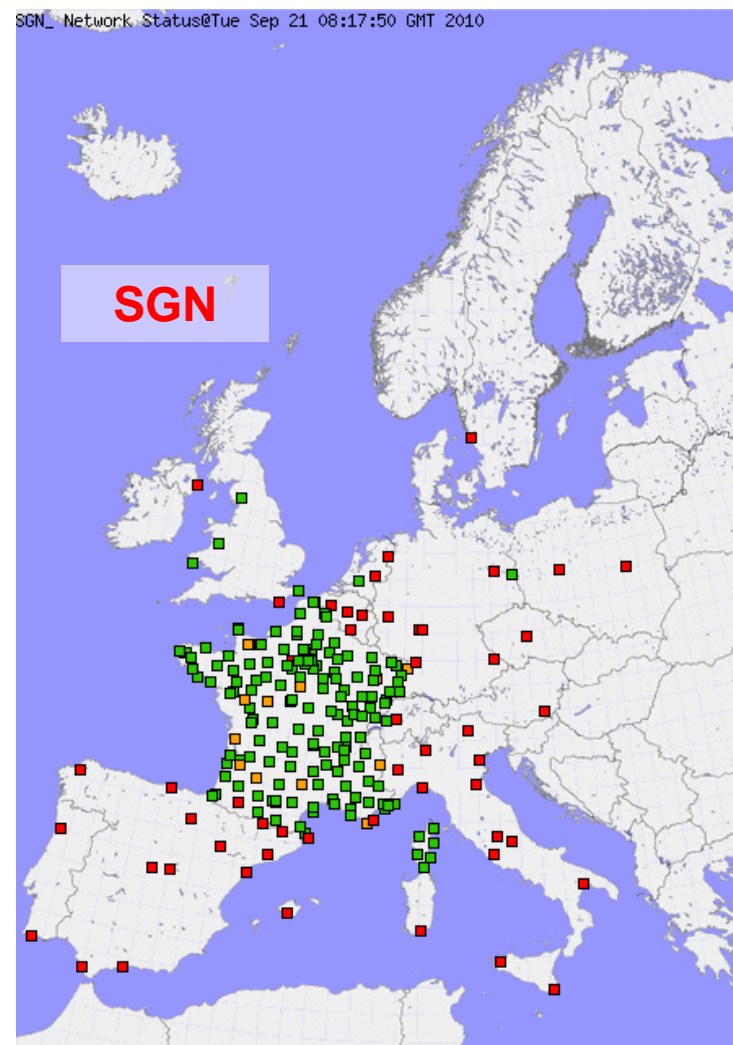
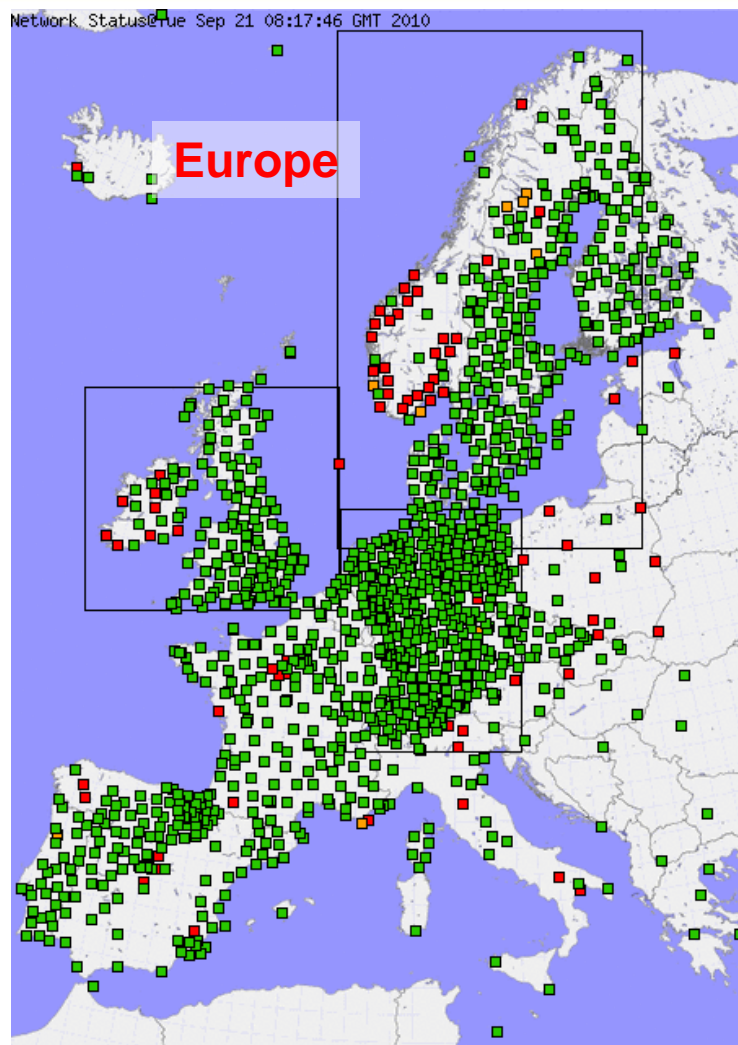
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Monitoring example (problem detection)



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The EGVAP monitoring

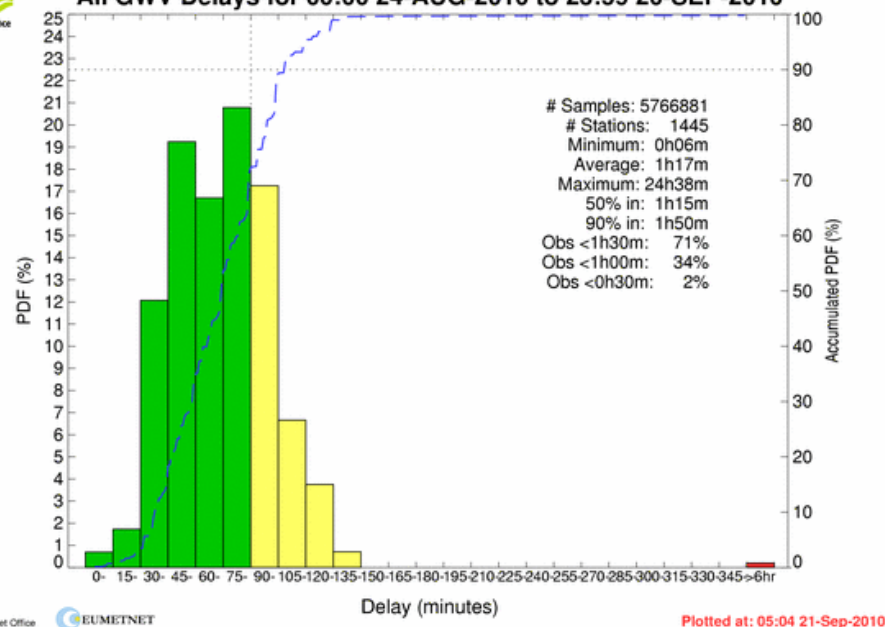


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The EGVAP monitoring

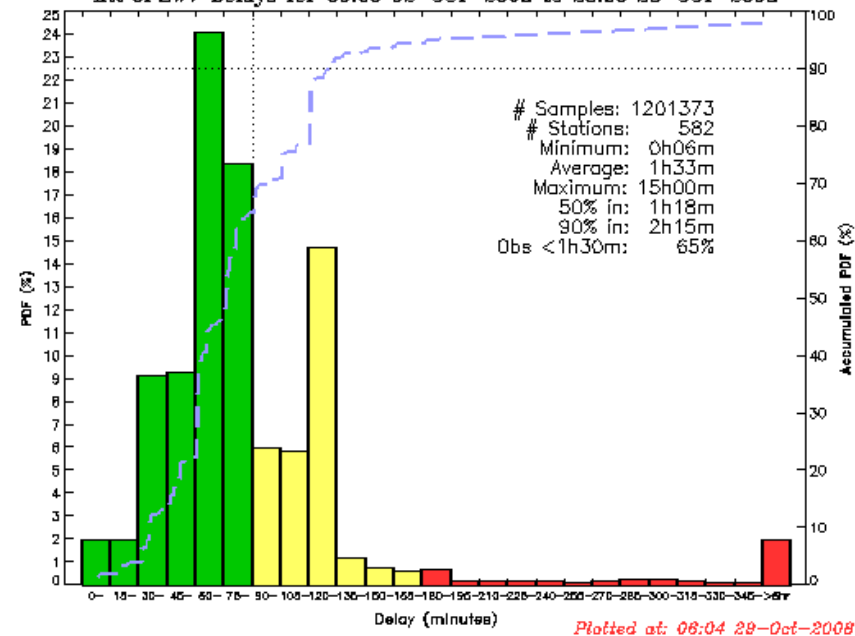


All GWV Delays for 00:00 24-AUG-2010 to 23:59 20-SEP-2010



Oslo, 2010

All GPS/V Delays for 00:00 02-OCT-2008 to 23:59 26-OCT-2008



Copenhagen, 2008



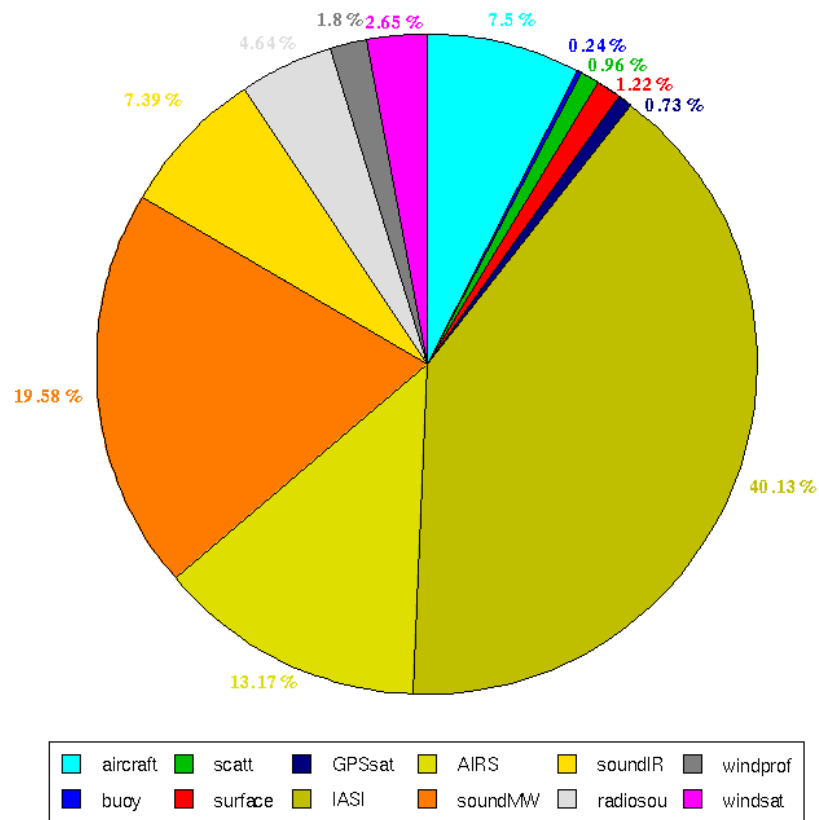
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4. Impact of the ground-based GNSS ZTD in the operational models



Relative weight of GPS ZTD data in Arpege assimilation system

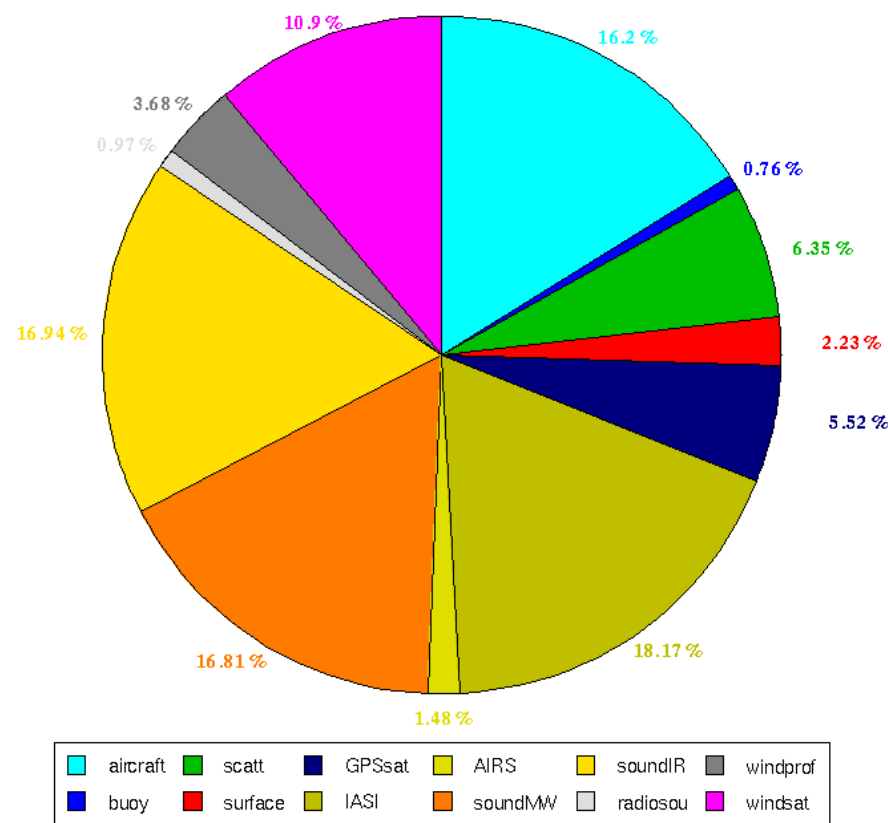
Nombre d'observations
1752107



DFS_96YY_2010071512_ensemble_traP

GNSS ZTD = 0.06 %

DFS
40879.94



DFS_96YY_2010071518_ensemble_traP

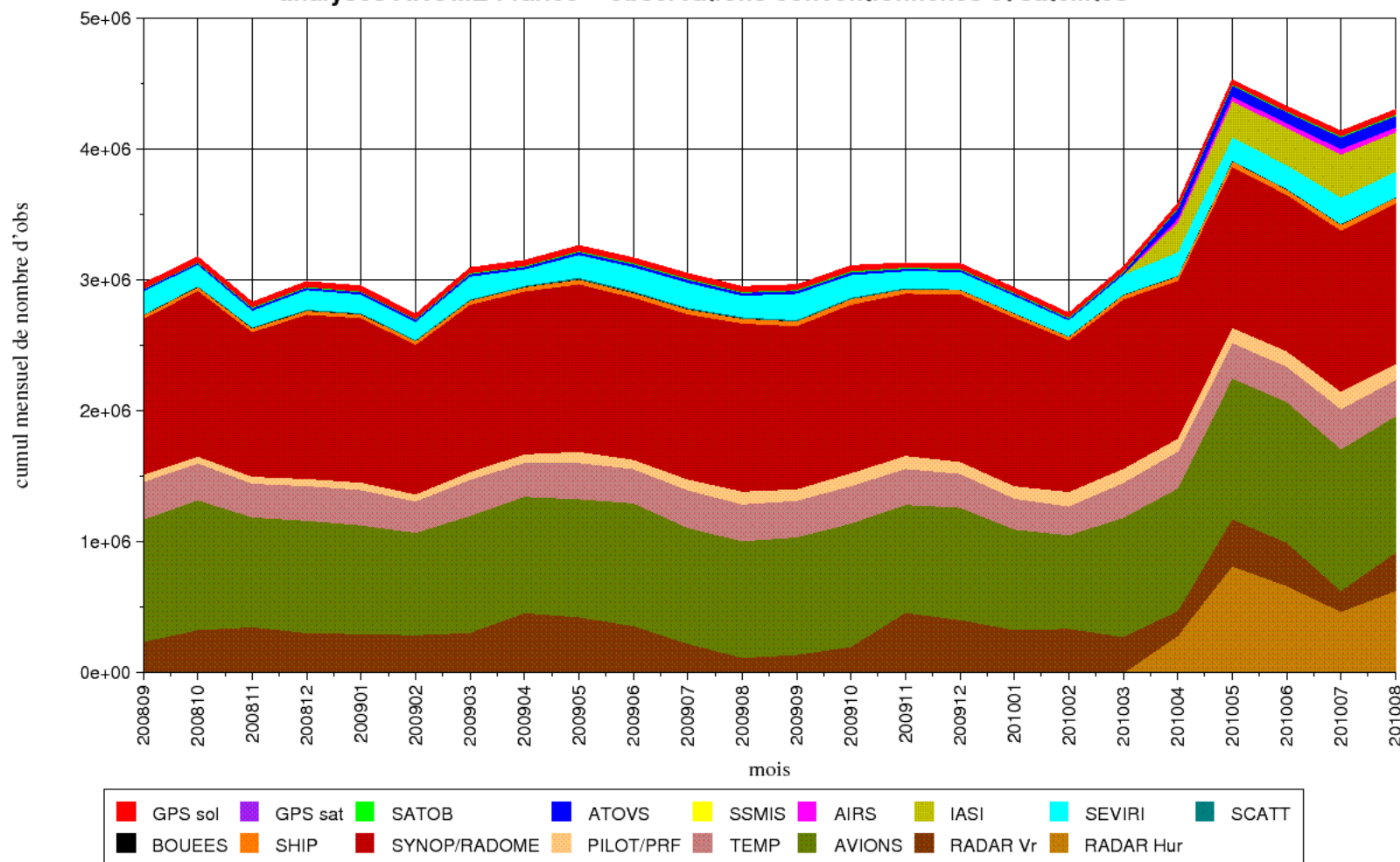
GNSS ZTD = 0.17 %



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Relative weight of GPS ZTD data in Arôme assimilation system

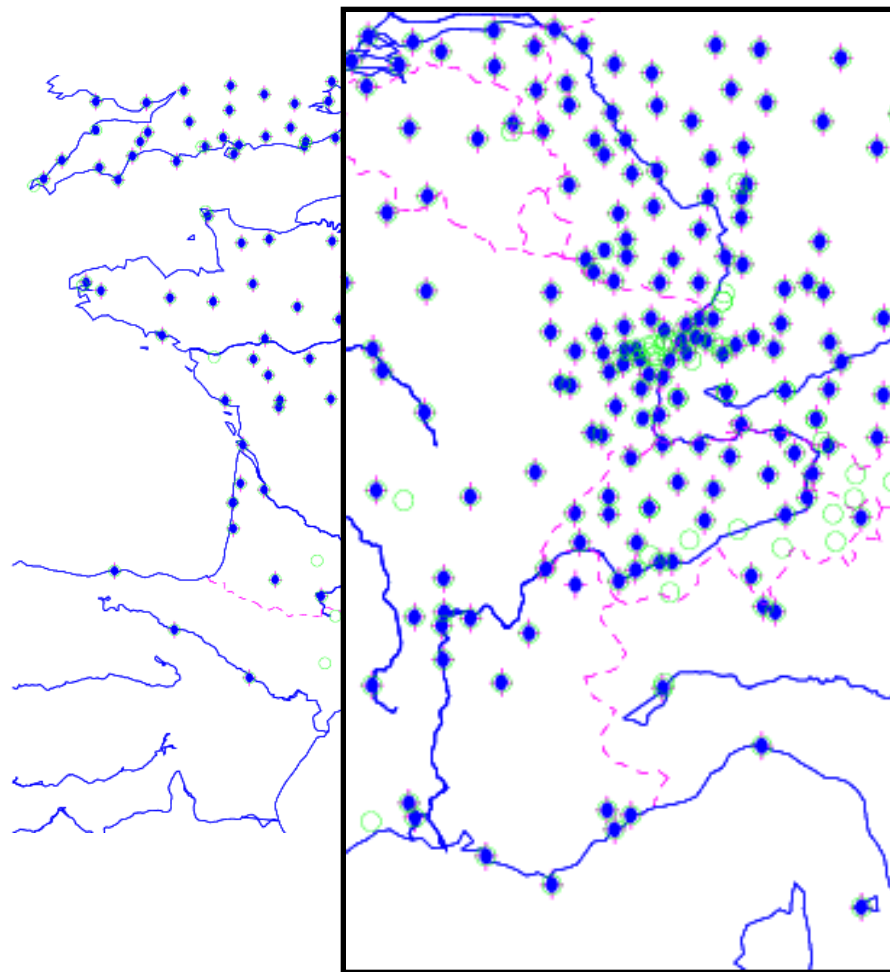
Evolution des cumuls mensuels de nombre d'observations utilisées
analyses AROME France - observations conventionnelles et satellites



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An observation influence study : ground-based GPS

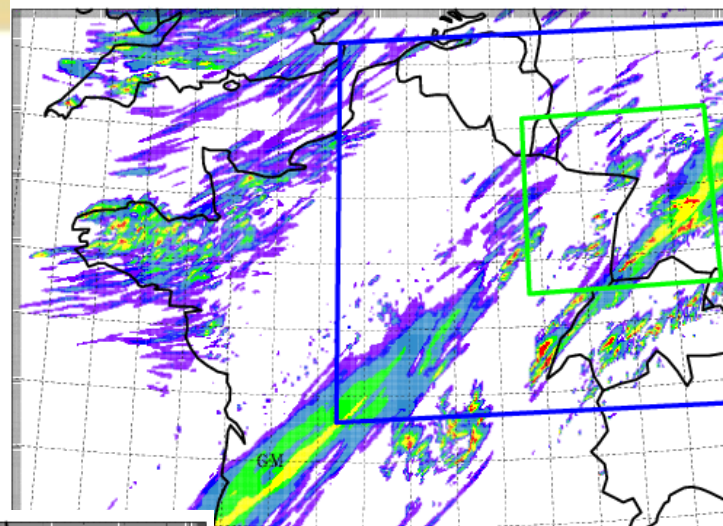
- Experiment in order to evaluate the influence of additional Ground-based GPS observations in AROME data assimilation system.
- Use of 194 stations (blue star) + 84 additional stations (green circle).
- Give information on integrated humidity profile



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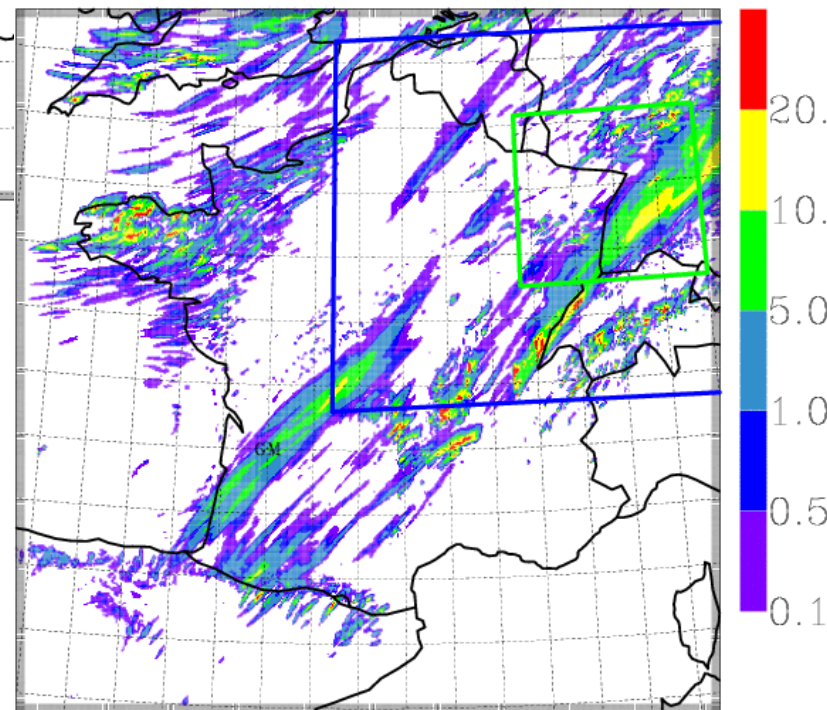
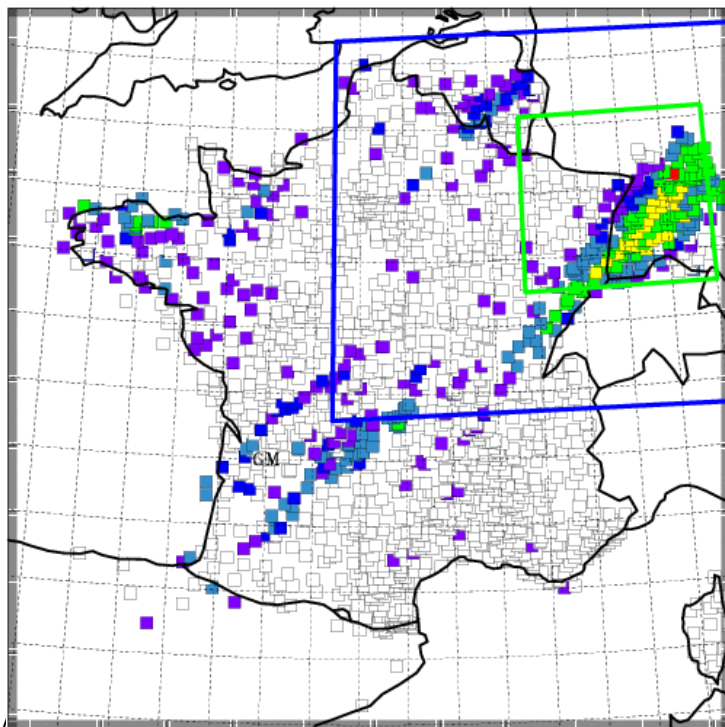
Cumulative rainfall, 18 July 2007 03-15 UTC

Raingauges
measurements



194 stations

194 + 84
stations



20.0
10.0
5.0
1.0
0.5
0.1

5. Current situation and further work



Current situation and further work

- GPS ZTD operational assimilation
 - Started at Météo-France 4 years ago
 - Initially in global and European models, now also in operational mesoscale AROME model
- Previous methodology
 - Chose a « white list » approach to accomodate expanding/improving networks/methods
- Under development :
 - classical black-list method
 - all couples (station, Analysis Center) allowed to be assimilated
 - reduce the interdistance selection according to the mesh size
 - variational bias correction
 - active quality control
- In experimental suite in december 2010, operational in early 2011...



Thank you for your attention

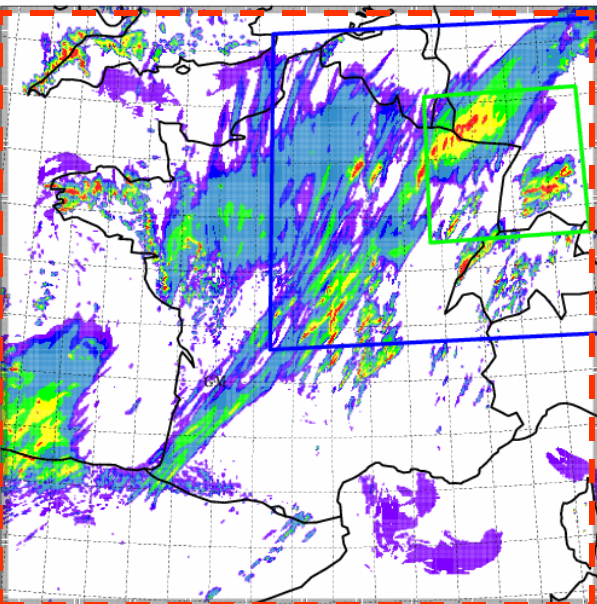
patrick.moll@meteo.fr



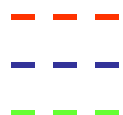
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Impact sur la prévision AROME

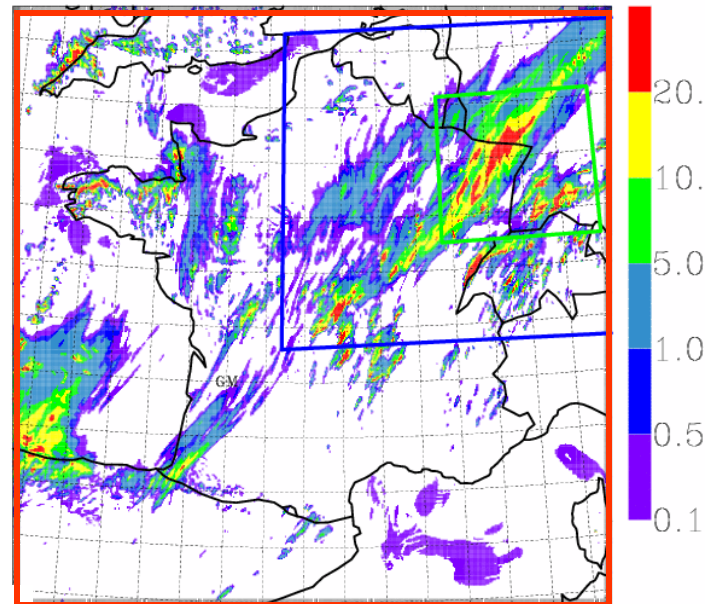
AROME, initialisé à partir de l'analyse 00UTC, 19 juillet 2008



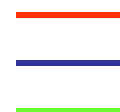
sans assimilation de données de ZTD



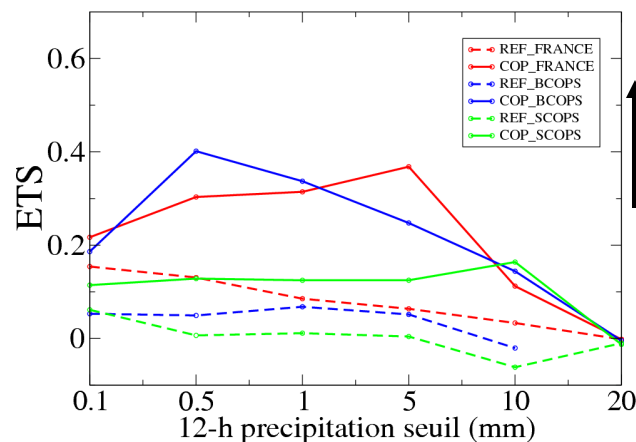
Précipitations cumulées
entre 03UTC et 15UTC,
19 juillet 2008



avec assimilation de données de ZTD



Equitable Threat Score



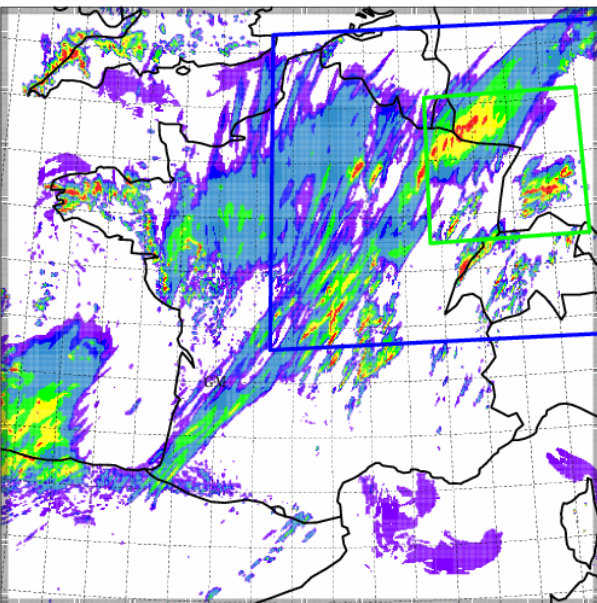
Plus proche des observations



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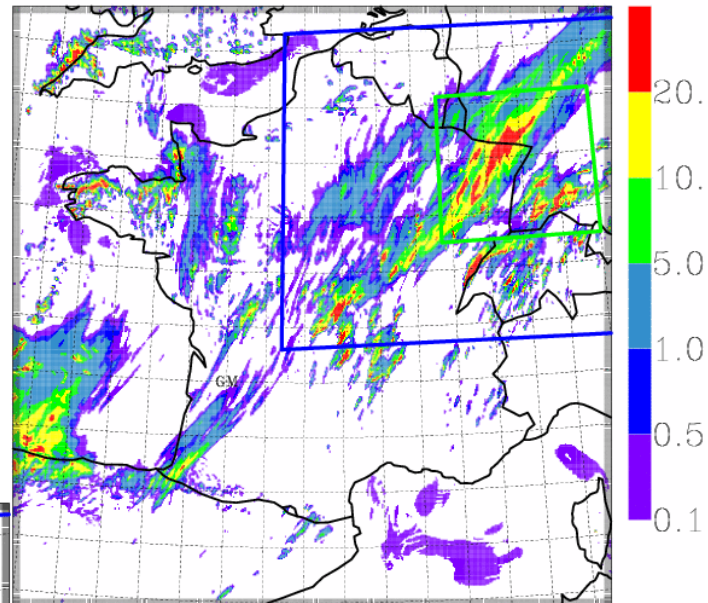
Impact on AROME forecast

AROME, starting from the 00UTC analysis, 19 July 2008

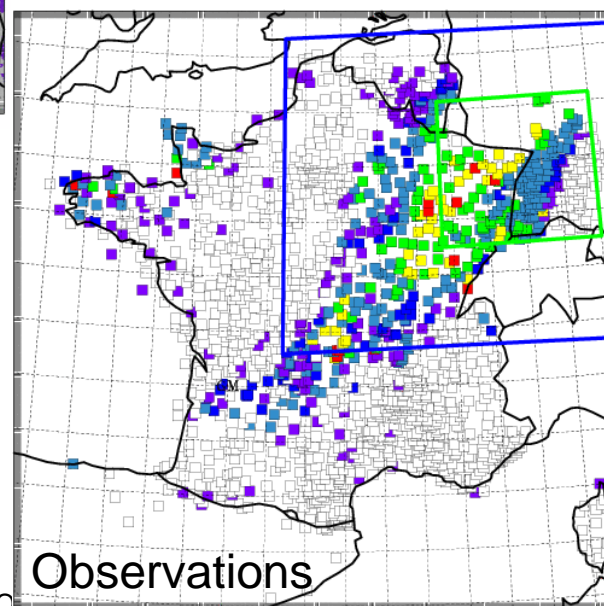


WITHOUT ZTD data
assimilation

Cumulated rain between
03UTC and 15UTC,
19 July 2008



WITH ZTD data
assimilation



Observations



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