

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

Patrick Moll

Centre National de Recherches Météorologiques  
CNRS/GAME, Météo-France, Toulouse, France



**METEO FRANCE**  
Toujours un temps d'avance

# Outline

- The operational models at Météo-France
- Implementation of ground based GNSS ZTD
- Monitoring and use of ground based GNSS ZTD
- Further work at Météo-France
- GNSS at Maroc-Météo



# The operational models at Météo-France

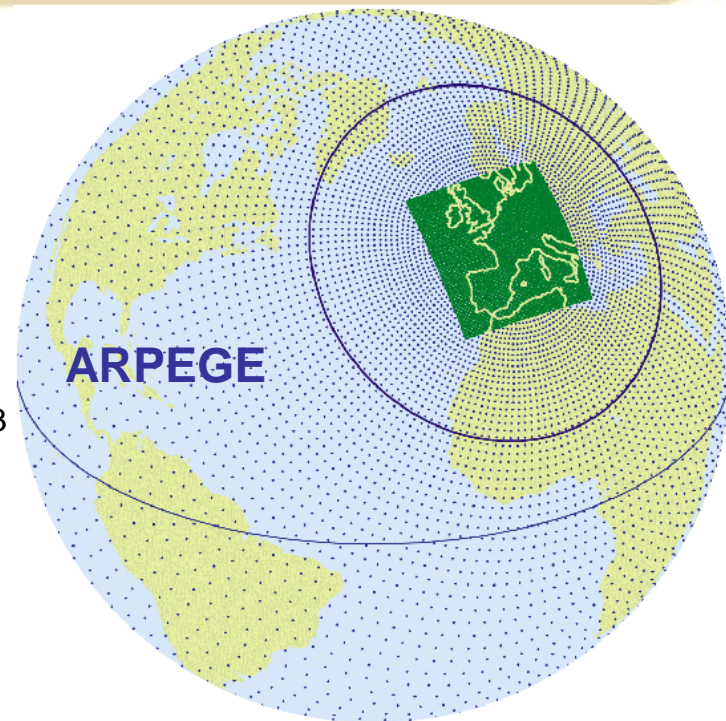


**METEO FRANCE**  
Toujours un temps d'avance

# The operational models at Météo-France

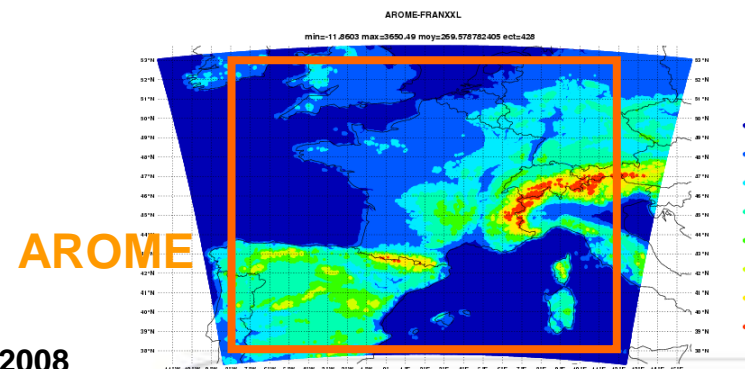
## ■ Global model and 4DVAR assimilation system **ARPEGE**

- 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



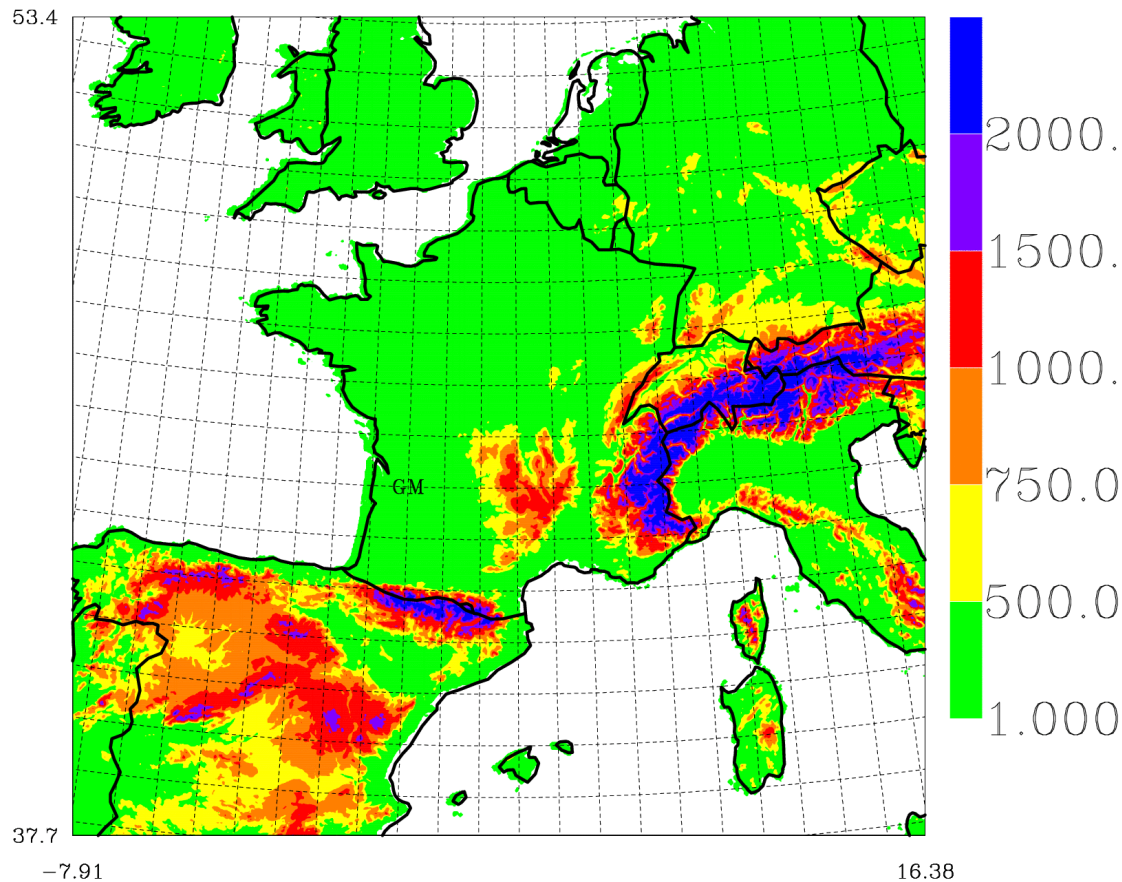
## ■ High-resolution mesoscale non-hydrostatic model and 3DVAR assimilation system **AROME** over France

- 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**

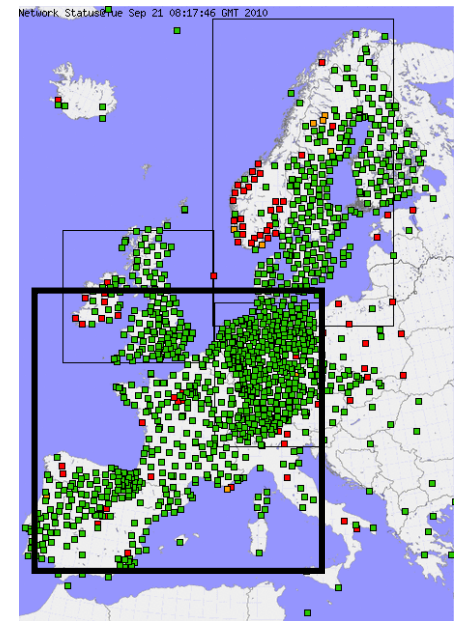


**METEO FRANCE**  
Toujours un temps d'avance

# AROME operational model



Domain 750x720 points  
Boundary conditions : Arpege



**METEO FRANCE**  
Toujours un temps d'avance

# Implementation 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 - 2012**
  - After several experiments, big extension of the white list in the meso-scale model AROME : in operational suite during several months and operational.
  - Operational suite with an extended white list and a direct BUFR decoding in both Arpege and Arome.
- **5th period : 2012 - 2014**
  - Operational suite with an extended white list (including the GOPG data) and a dynamic selection of the observations inside the screening.
  - Pre-operational suite planned early 2014 with a variational bias correction of the GNSS data.



# GPS ZTD Pre-processing : white list

fic\_list\_monitor: Opening file list\_monitor

Finished reading list\_monitor, found : 2702 station/center

number of rejections for bad quality : 371

final number of station/center kept in the white list : 2331

## Summary of the choice by analysis center

IGE_ :	212 over	244
METO:	237 over	246
GOPG:	76 over	124
KNM3:	43 over	65
KNM4:	19 over	33
ROB_ :	181 over	207
SGN1:	322 over	354
SGN_ :	314 over	320
LPT_ :	105 over	121
ASI_ :	41 over	76
GOP1:	71 over	72
LPTR:	12 over	47
GFZ_ :	298 over	316
BKG_ :	99 over	105
ROBH:	301 over	372



**METEO FRANCE**  
Toujours un temps d'avance



# GPS ZTD processing

## Pre-processing input :

- GNSS ZTD data
- White list

## Pre-processing steps :

1. Checking of the observations
  - ❖ 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

## Screening steps :

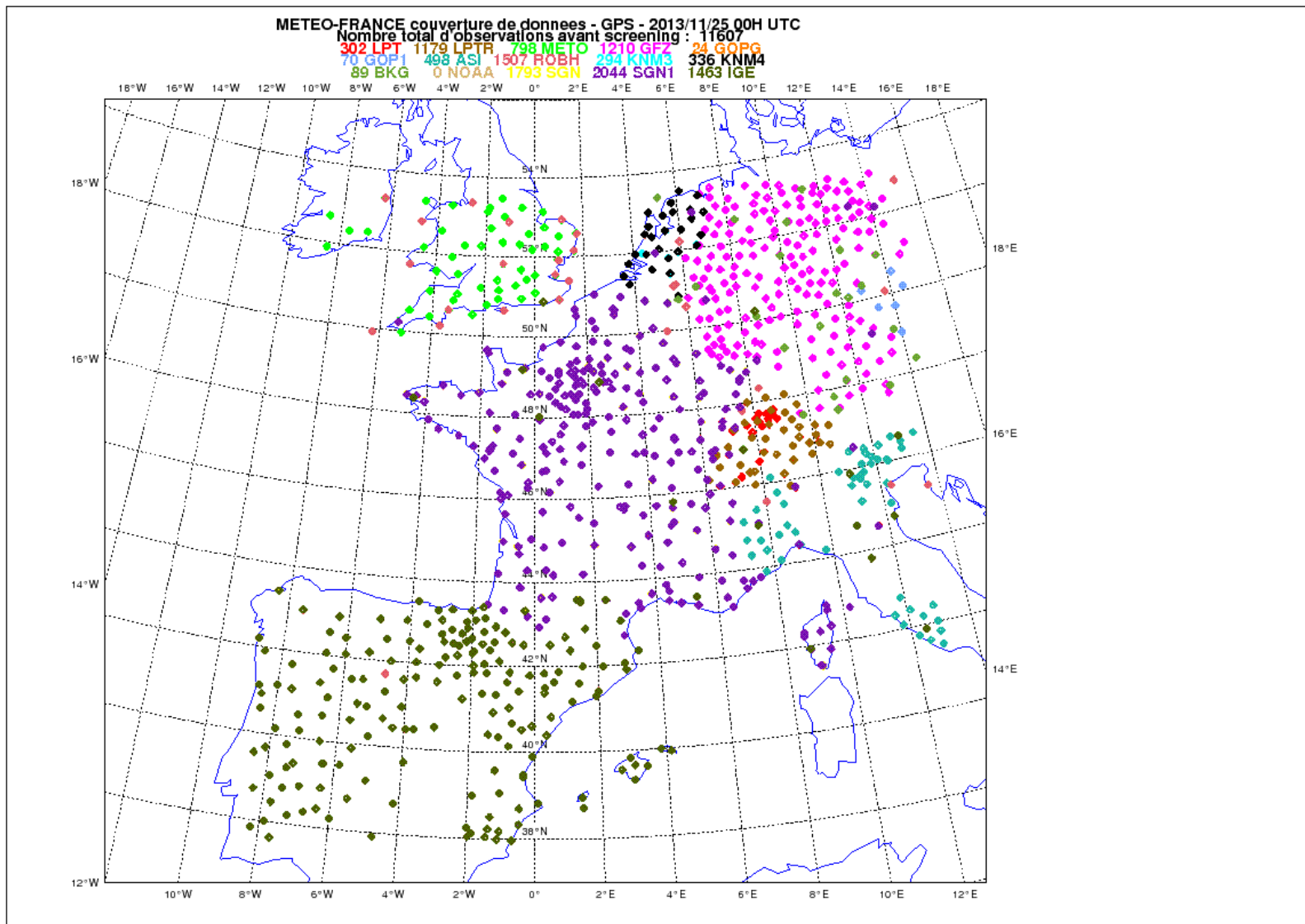
1. First guess check
2. Data selection between all the available « good » observations for each location



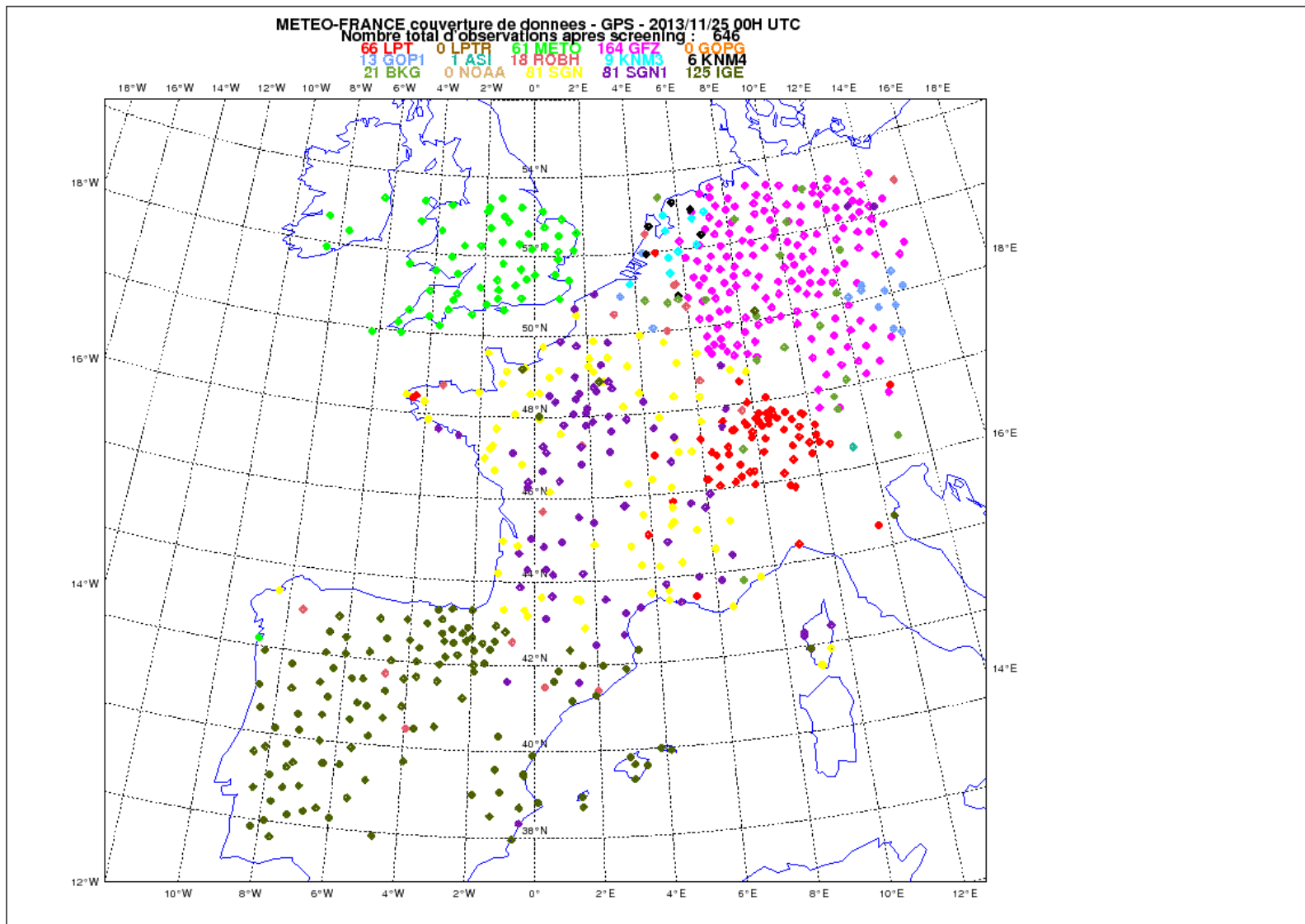
# Monitoring and use of ground-based GNSS ZTD



# 00 UTC long cut-off Arôme (available data)



# 00 UTC long cut-off Arôme (assimilated data)

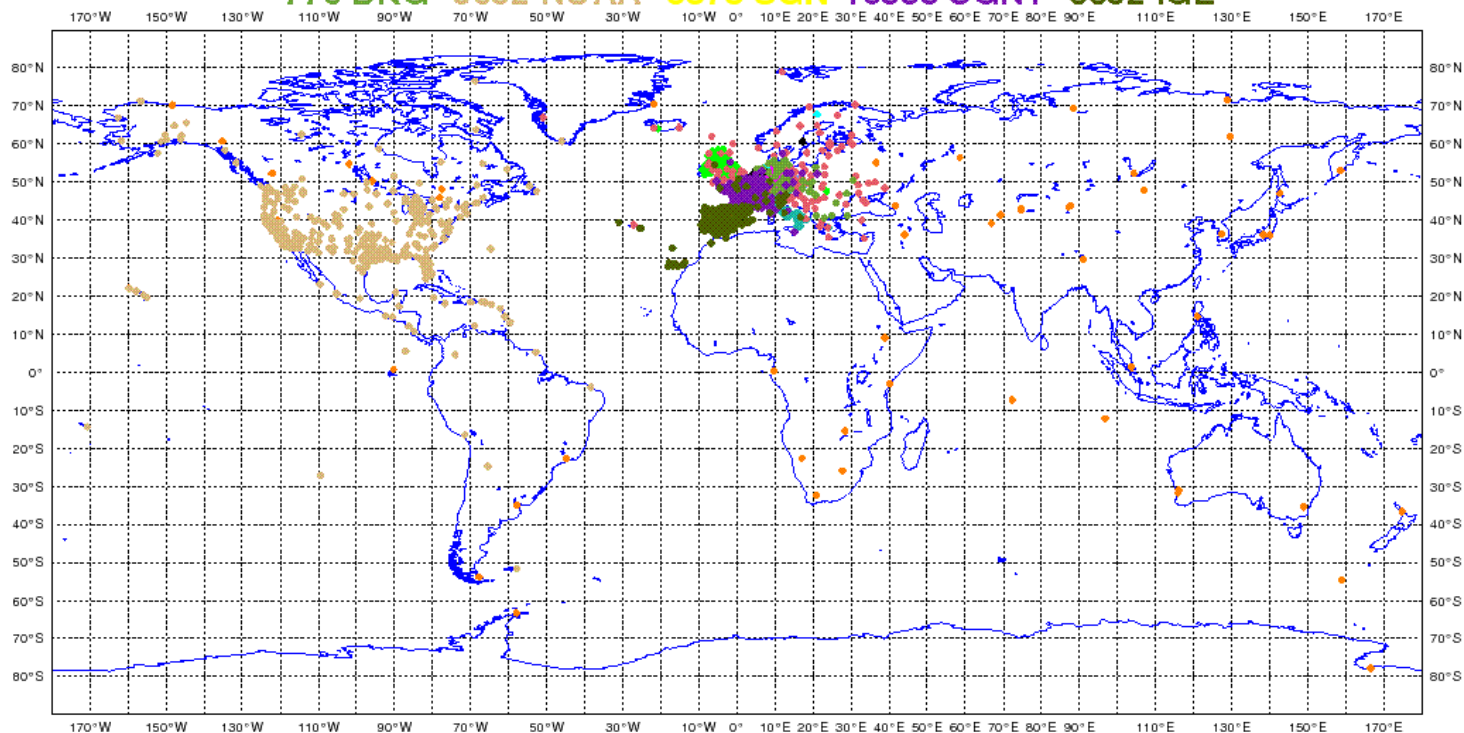


# 00 UTC long cut-off Arpege (available data)

**METEO-FRANCE couverture de donnees - GPS - 2013/11/24 00H UTC cut-off long**

Nombre total d'observations avant screening : 72237

1421 LPT 2956 LPTR 7383 METO 7489 GFZ 1219 GOPG  
631 GOP1 4573 ASI 11228 ROBH 1611 KNM3 1033 KNM4  
776 BKG 3652 NOAA 8878 SGN 10555 SGN1 8832 IGE

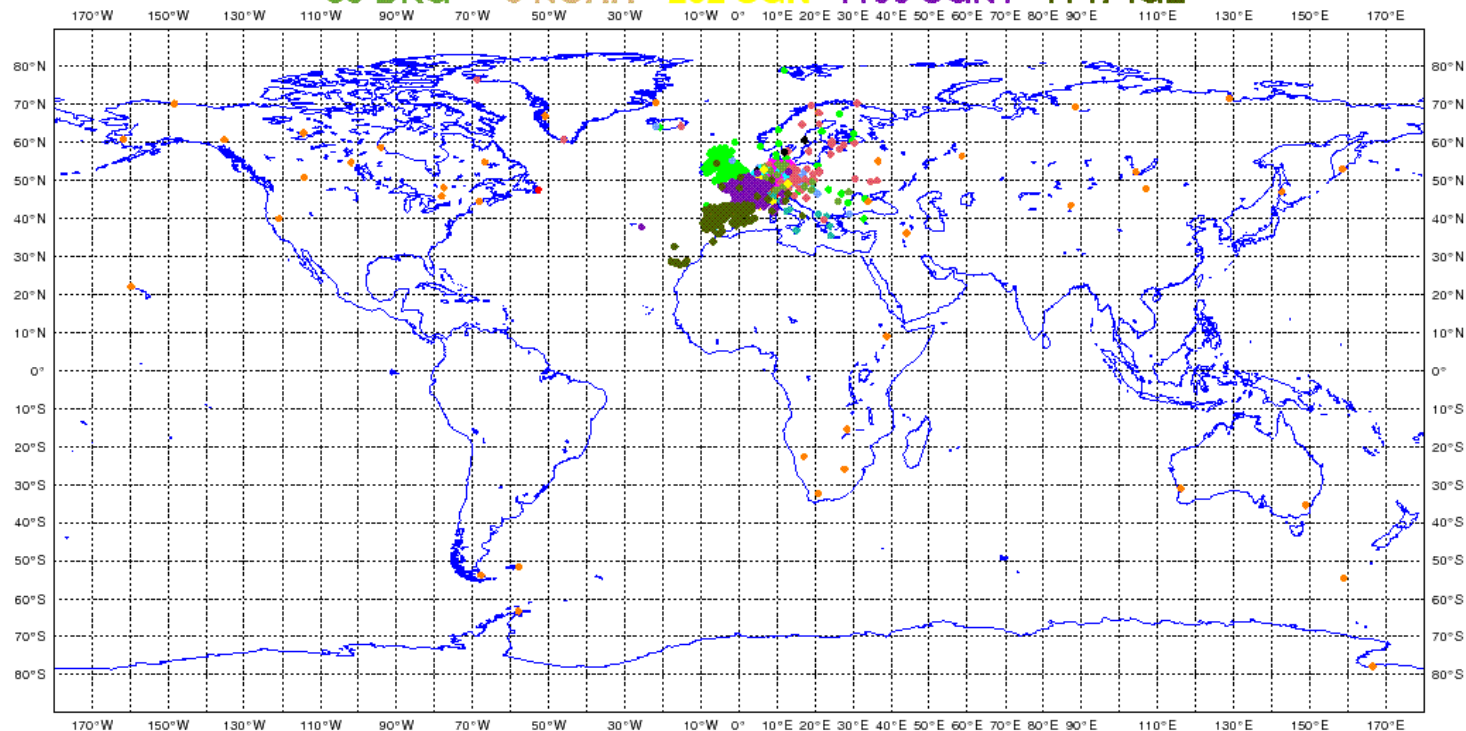


# 00 UTC long cut-off Arpege (assimilated data)

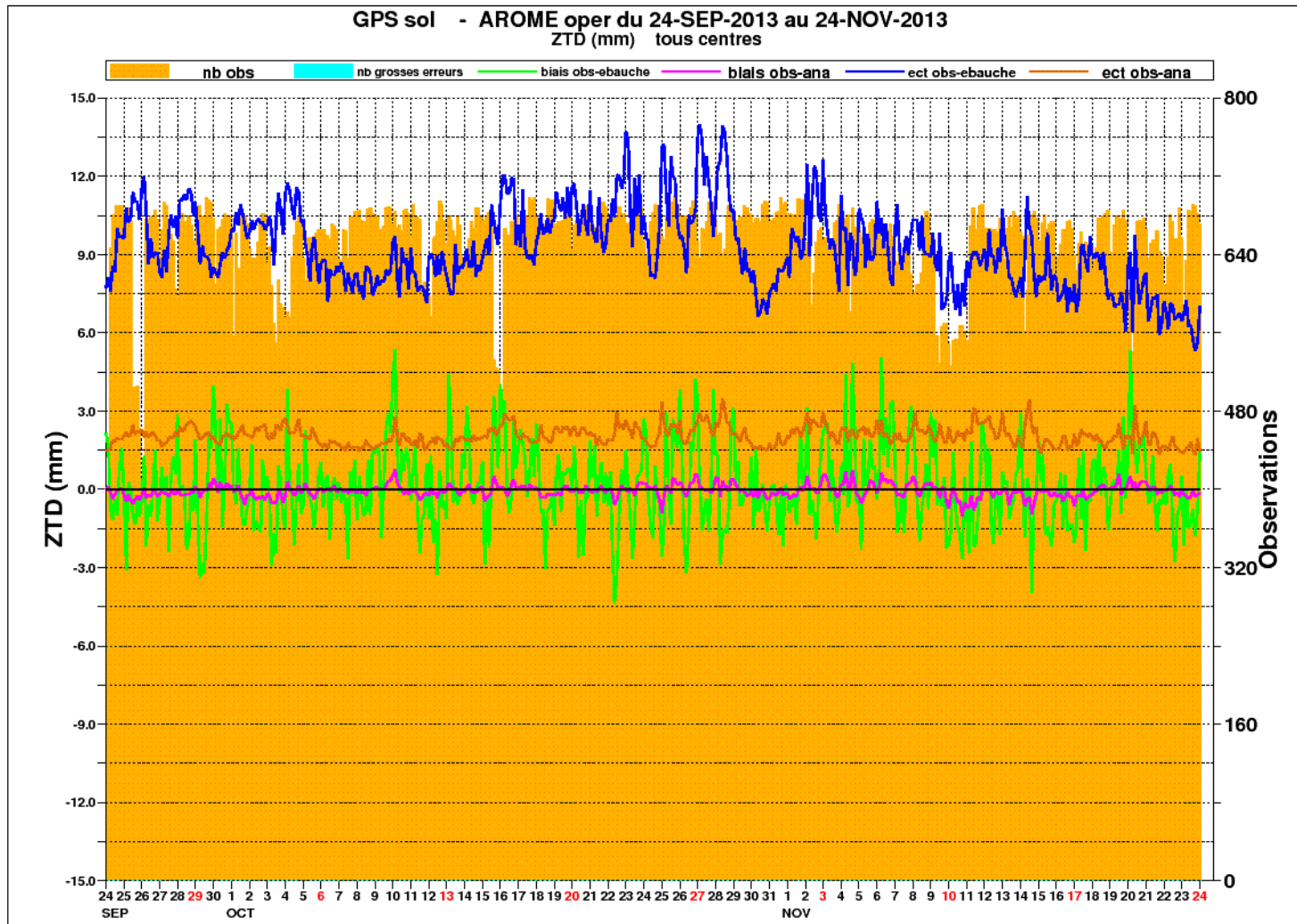
**METEO-FRANCE couverture de donnees - GPS - 2013/11/24 00H UTC cut-off long**

**Nombre total d'observations apres screening : 6557**

395 LPT 7 LPT 978 METO 1330 GFZ 308 GOPG  
245 GOP1 114 ASI 409 ROBH 138 KNM3 29 KNM4  
56 BKG 0 NOAA 202 SGN 1199 SGN1 1147 IGE



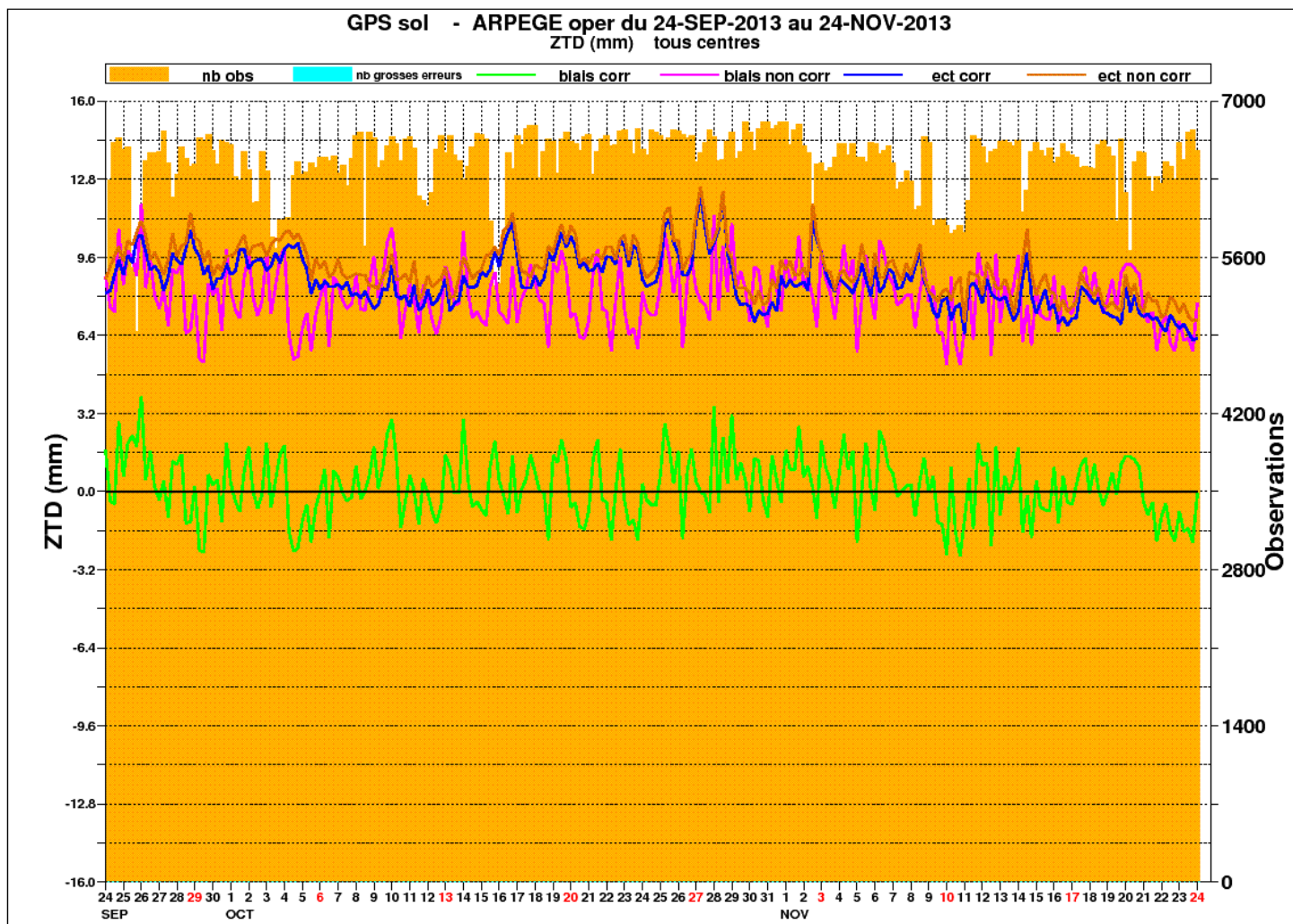
# Monitoring example (time-series)



**METEO FRANCE**  
Toujours un temps d'avance



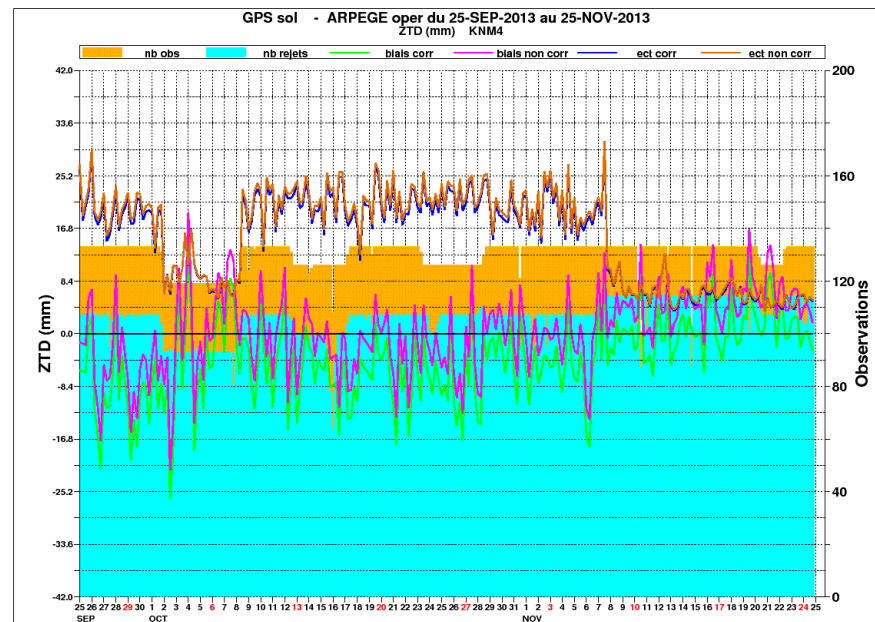
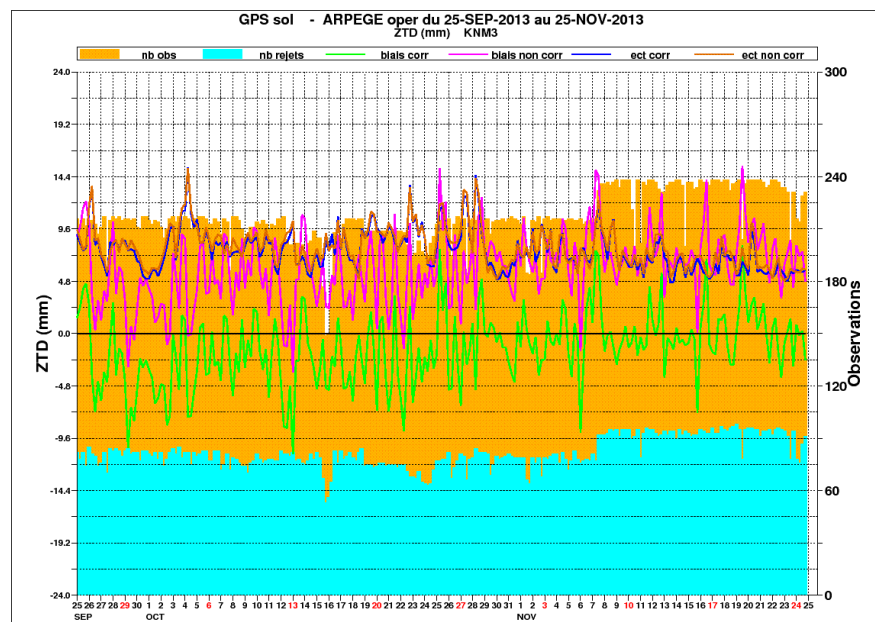
# Monitoring example (time-series)



**METEO FRANCE**  
Toujours un temps d'avance

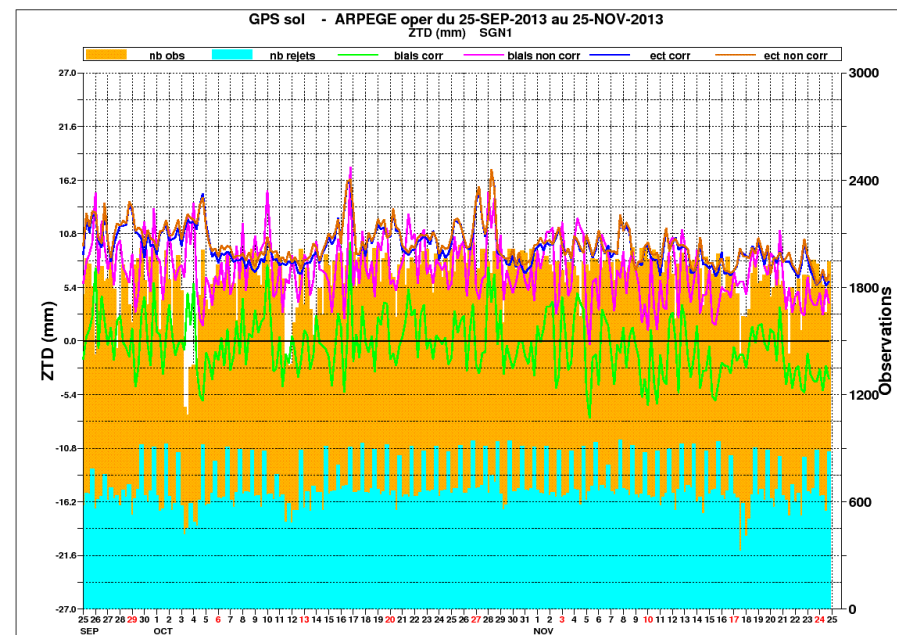
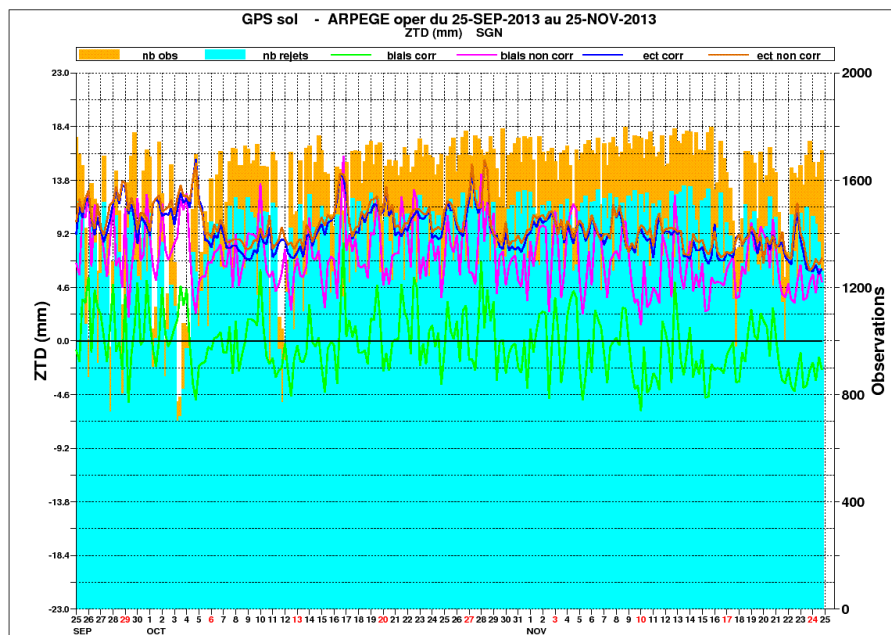


# Monitoring example (time-series)



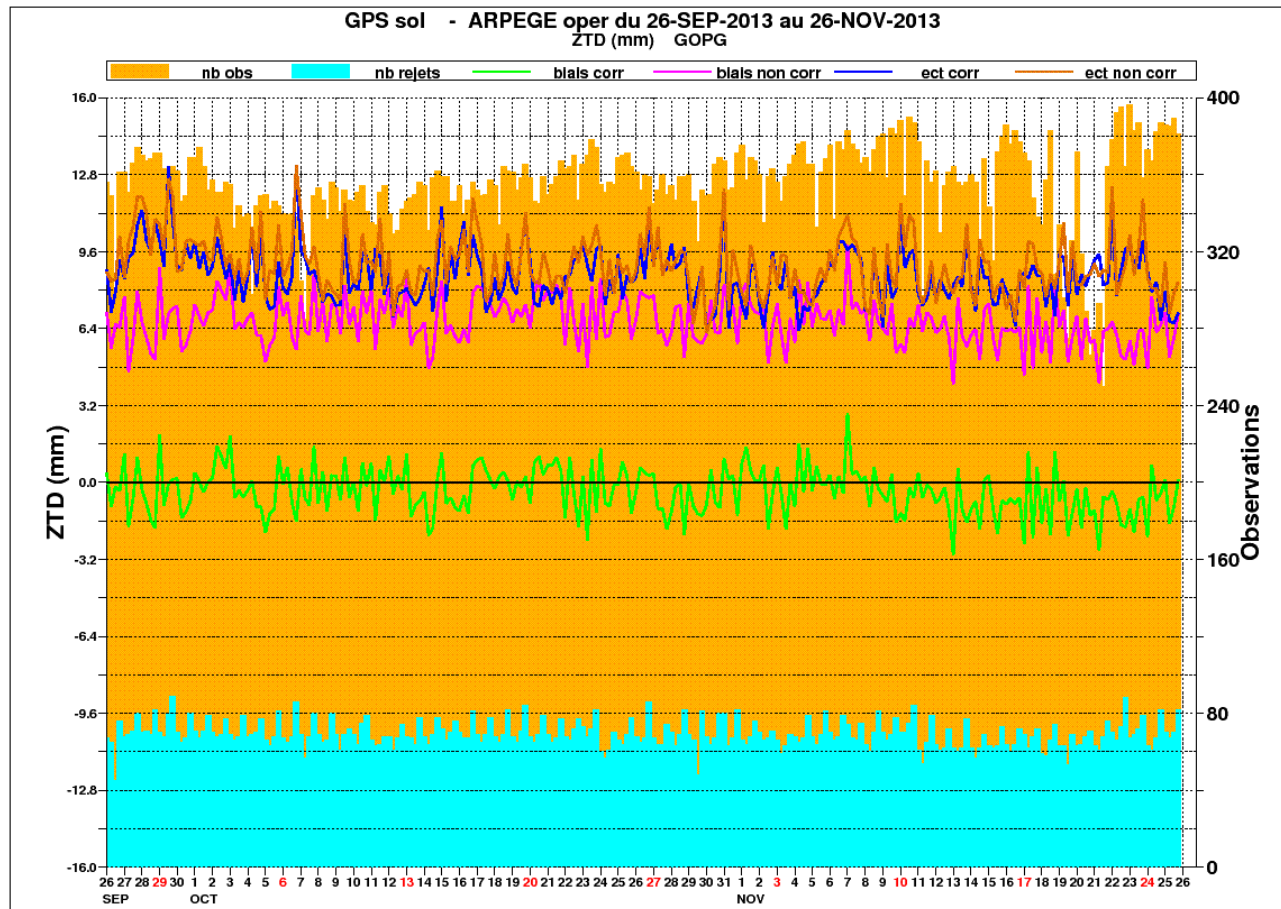
**METEO FRANCE**  
Toujours un temps d'avance

# Monitoring example (time-series)



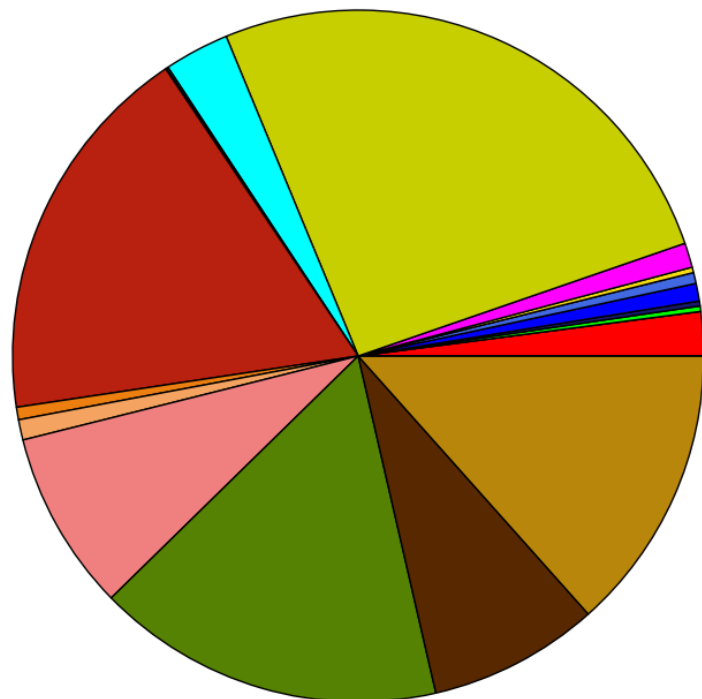
**METEO FRANCE**  
Toujours un temps d'avance

# Monitoring example (time-series)



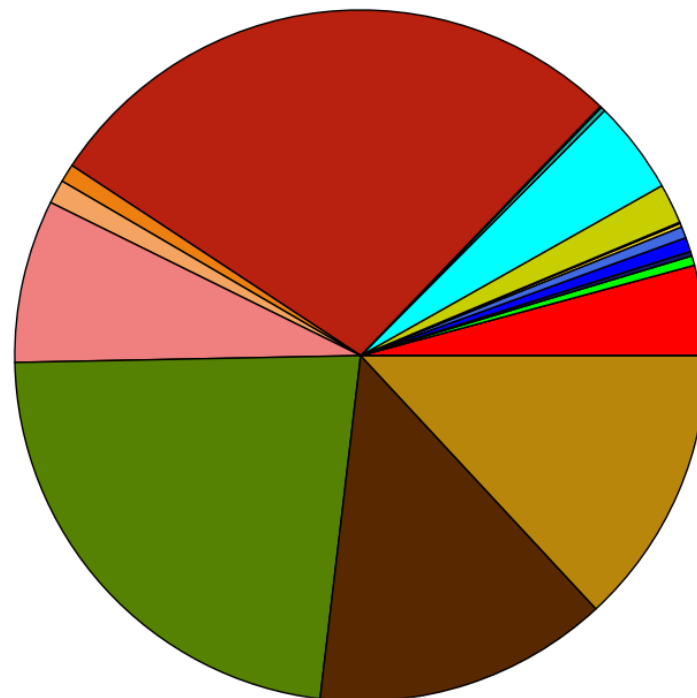
# Arome DFS (rainy days)

Proportions des nombres d'observations utilisées par type d'obs  
analyses cut-off AROME - AROME France oper  
observations conventionnelles et satellites  
cumul du nombre d'observations utilisées sur la période 2012101100 - 2012101121 : 281



GPS ground	2.06%	AIRS	1.15%	PILOT/PRF	0.95%
GPS sat	0.00%	IASI	25.96%	TEMP	8.42%
SATOB	0.25%	SEVIRI	3.04%	AIRCRAFTS	16.28%
ATOVS HIRS	0.23%	SCATT	0.09%	RADAR Vr	7.99%
ATOVS AMSU-A	0.82%	BUOY	0.04%	RADAR Hur	13.40%
ATOVS AMSU-B	0.51%	SYNOP/SEVIRI/RADOME	17.96%	BOGUS	0.00%
SSMIS	0.26%	SHIP	0.58%		

Part des DFS par type d'obs  
analyses cut-off AROME - AROME France oper  
observations conventionnelles et satellites  
cumul du DFS sur la période 2012101100 - 2012101121 : 100548

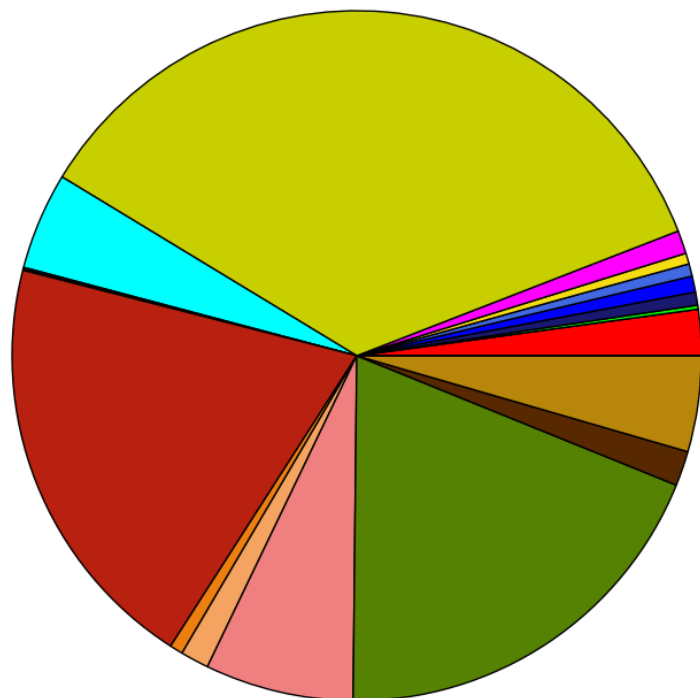


GPS ground	4.21%	AIRS	0.06%	PILOT/PRF	1.12%
GPS sat	0.00%	IASI	1.87%	TEMP	7.62%
SATOB	0.44%	SEVIRI	4.36%	AIRCRAFTS	22.81%
ATOVS HIRS	0.22%	SCATT	0.21%	RADAR Vr	13.78%
ATOVS AMSU-A	0.67%	BUOY	0.07%	RADAR Hur	13.09%
ATOVS AMSU-B	0.54%	SYNOP/SEVIRI/RADOME	27.90%	BOGUS	0.00%
SSMIS	0.17%	SHIP	0.85%		

# Arome DFS (dry days)

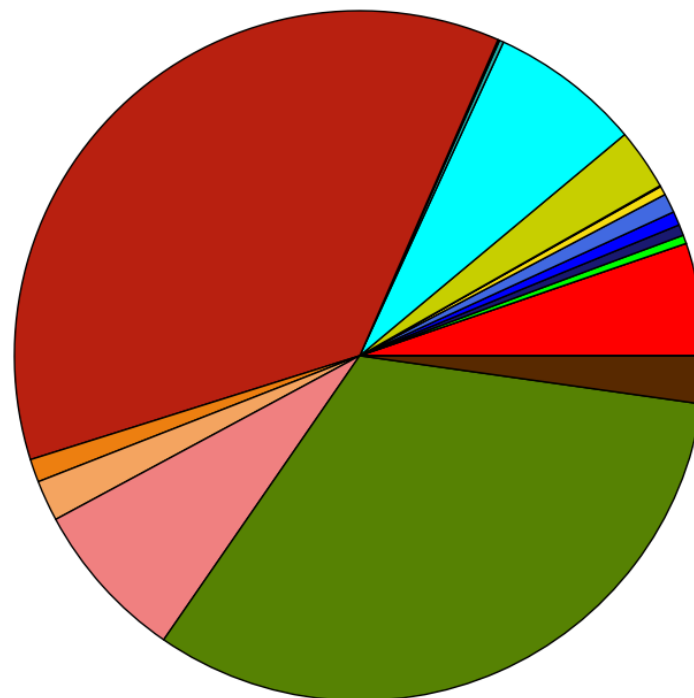
Proportions des nombres d'observations utilisées par type d'obs  
analyses cut-off AROME - AROME France oper  
observations conventionnelles et satellites

cumul du nombre d'observations utilisées sur la période 2012100500 - 2012100521 : 25



Part des DFS par type d'obs  
analyses cut-off AROME - AROME France oper  
observations conventionnelles et satellites

cumul du DFS sur la période 2012100500 - 2012100521 : 76214



GPS ground	2.16%	AIRS	1.08%	PILOT/PRF	1.33%
GPS sat	0.00%	IASI	35.44%	TEMP	6.96%
SATOB	0.19%	SEVIRI	4.55%	AIRCRAFTS	19.05%
ATOVS HIRS	0.62%	SCATT	0.09%	RADAR Vr	1.63%
ATOVS AMSU-A	0.75%	BUOY	0.05%	RADAR Hur	4.49%
ATOVS AMSU-B	0.58%	SYNOP/SYNOR/RADOME	19.91%	BOGUS	0.00%
SSMIS	0.51%	SHIP	0.62%		

GPS ground	5.28%	AIRS	0.05%	PILOT/PRF	1.92%
GPS sat	0.00%	IASI	2.87%	TEMP	7.53%
SATOB	0.40%	SEVIRI	7.09%	AIRCRAFTS	32.37%
ATOVS HIRS	0.52%	SCATT	0.20%	RADAR Vr	2.23%
ATOVS AMSU-A	0.65%	BUOY	0.08%	RADAR Hur	0.00%
ATOVS AMSU-B	0.90%	SYNOP/SYNOR/RADOME	36.42%	BOGUS	0.00%
SSMIS	0.42%	SHIP	1.08%		

# Further work



# Further work

- Operational implementation of a variational bias correction.
- Automatisation of the white-list computation
- Classical black-list method ?
- Experiments currently done or planned (case studies, HyMex, etc.)
- Big interest in the global sets of data for Arpege (GOPG, METG, US network, etc.)



# GNSS at Maroc-Météo

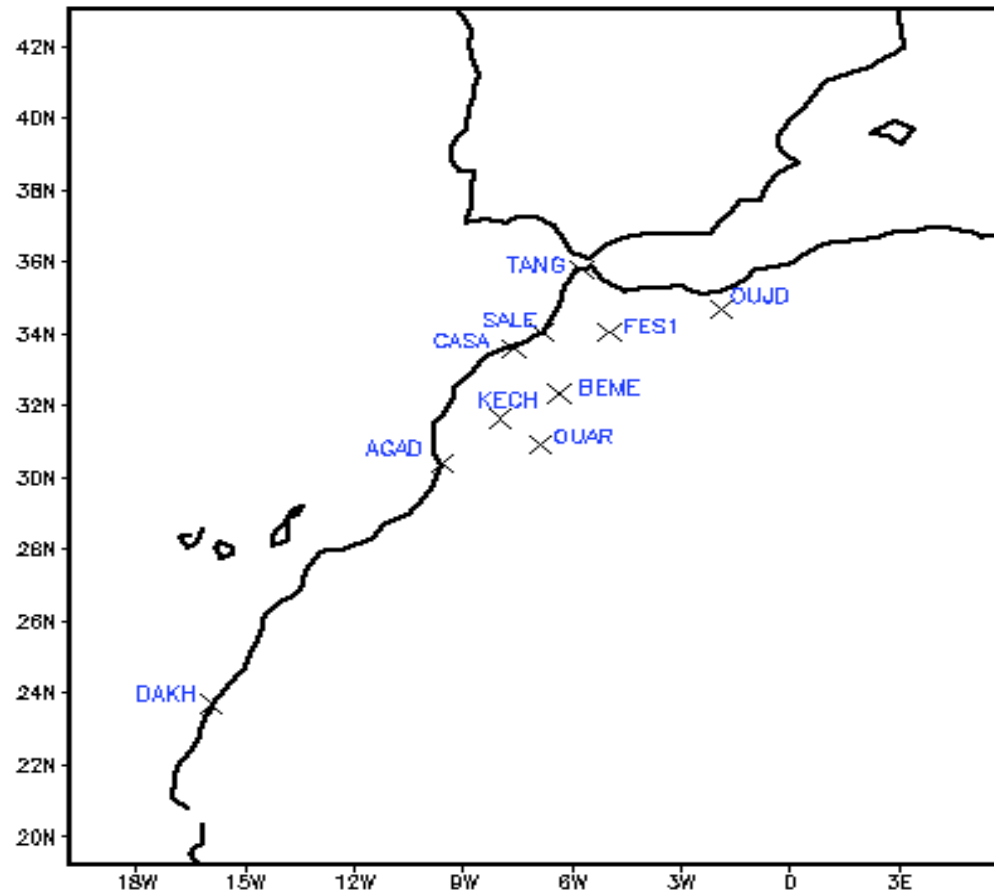


**METEO FRANCE**  
Toujours un temps d'avance



# Moroccan GNSS network

- 10 ASHTECH ProFlex type GPS stations installed in Morocco
- Proflex station with a GPS multi-constellation antenna (GPS, GLONASS, GALILEO) et high-precision multi-signal



**METEO FRANCE**  
Toujours un temps d'avance

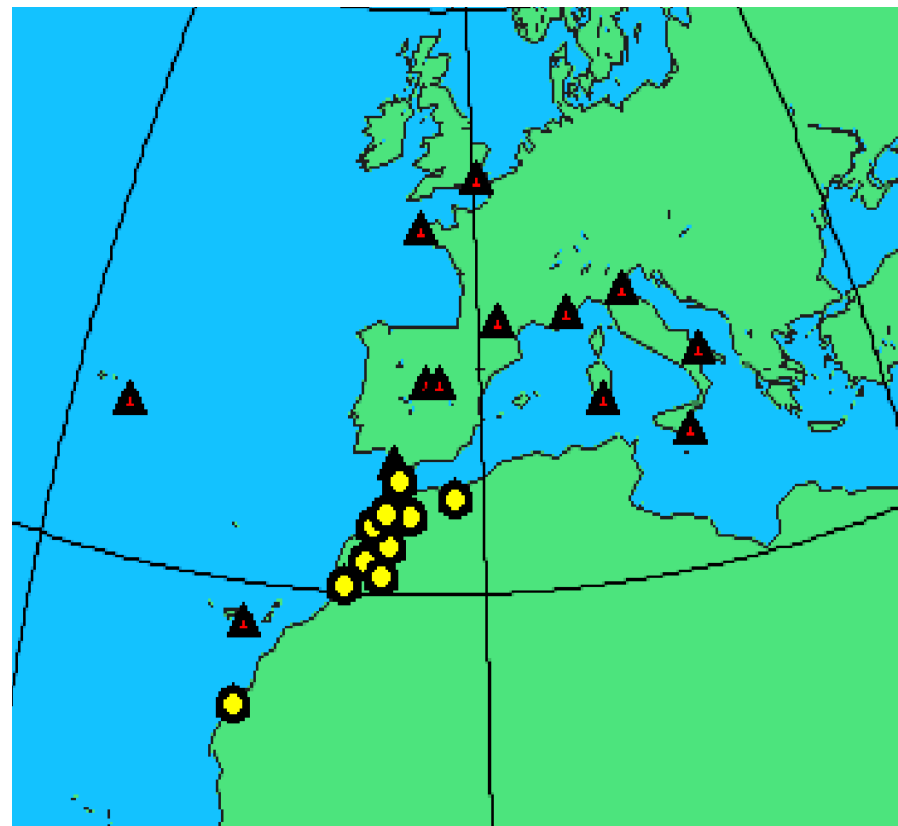
# Computing suite with Bernese software

- GPS data concentration et archiving : RINEX format
- Observation frequency : 30 secondes (1 seconde is possible)
- Use of BERNESE 5.0 software to compute the coordinates and the ZTD
- 15 minutes average



# Validation of the coordinates computation

- To evaluate the quality of the coordinates given by the local BERNESE, use of the results of the Australian centre AUSPOS as a reference.
- AUSPOS treats the same stations : 10 Moroccan network stations + 13 IGS stations).



**METEO FRANCE**  
Toujours un temps d'avance

# Result of the validation for IGS stations

Nom de la station IGS	$\Delta X$ (m)	$\Delta Y$ (m)	$\Delta Z$ (m)
BRST	0.0096	0.0055	0.0130
CAGL	0.0077	0.0017	0.0005
GMAS	0.0139	0.0029	0.0064
HERS	0.0064	0.0060	0.0160
RABT	0.0115	0.0011	0.0035



# Result of the validation for Moroccan stations

Nom de la station	$\Delta X$ (m)	$\Delta Y$ (m)	$\Delta Z$ (m)
AGAD	0.0209	0.0088	0.0029
BEME	0.0141	0.0082	0.0029
CASA	0.0213	0.0075	0.0071
DAKH	0.0186	0.0087	0.0059
FES1	0.0177	0.0081	0.0073
KECH	0.0218	0.0093	0.0047
OUAR	0.0151	0.0093	0.0009
OUJD	0.0159	0.0075	0.0083
SALE	0.0197	0.0083	0.0070
TANG	0.0145	0.0080	0.0056



# Further work

- Automatisatisation of the ZTD computation process
- Assimilation of the ZTD data in the ALADIN-MAROC model
- Computation of the water vapor
- Collaboration with E-GVAP ?



Thank you for your attention

[patrick.moll@meteo.fr](mailto:patrick.moll@meteo.fr)



**METEO FRANCE**  
Toujours un temps d'avance