# Assimilation of European GPS ZTD Data at Météo France

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# GPS ZTD Assimilation at Météo France

Operational since September 19, 2006, in the following forecast and assimilation systems:

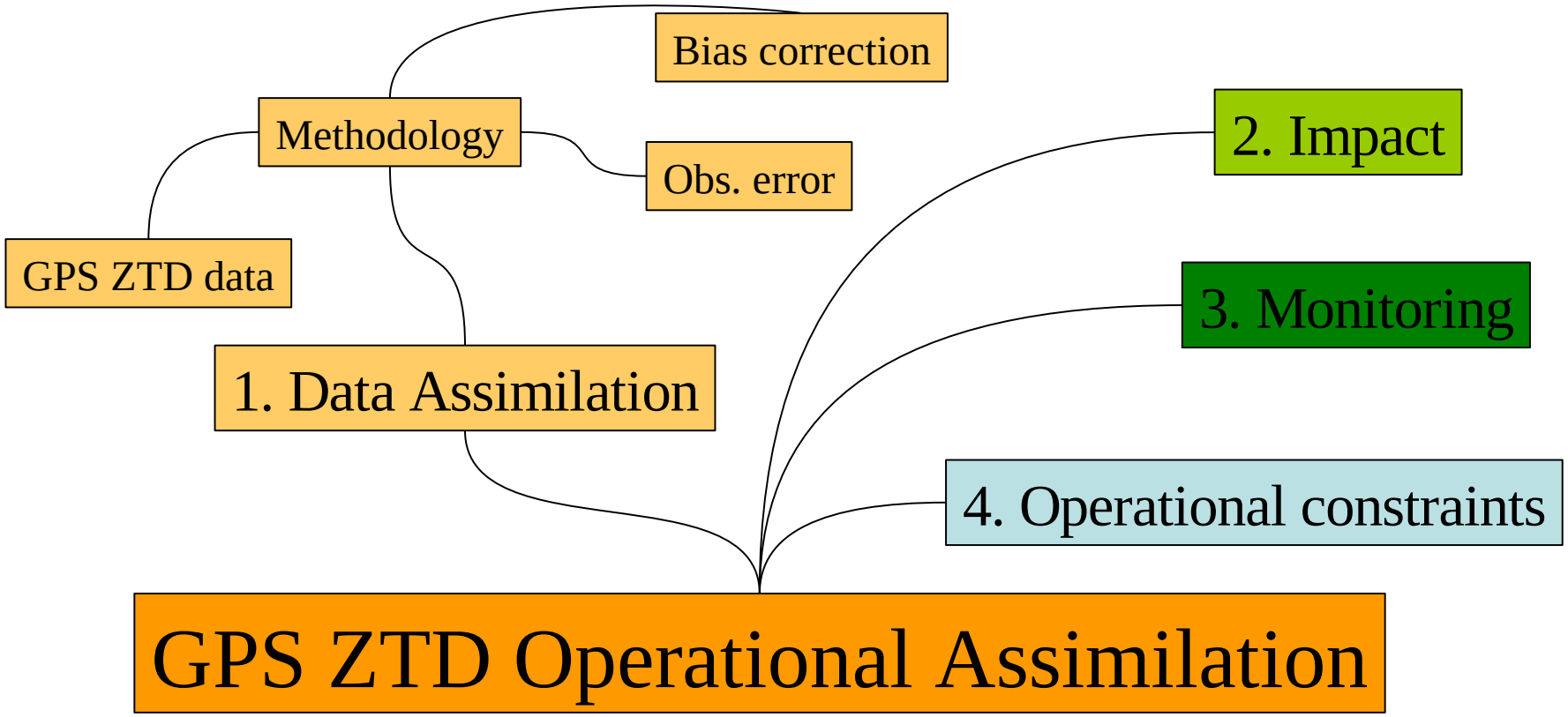
- Global streched 4DVAR ARPEGE
- Global regular grid 4DVAR ARPEGE-TROPIQUES
- European limited-area 3DVAR ALADIN

Thanks to: good quality GPS ZTD data received from several analysis centers and coordination under COST-716, TOUGH, and E-GVAP and to Met Office BUFR dissemination

After several assimilation and forecast trials inside Meteo France system:

- 3 seasons (Spring, Winter, Summer)
- Experimental assimilation and forecast suite ran for the whole summer 2006 in parallel with operational suites

# Presentation Themes




Conclusions and future work

# Data Assimilation

Combine

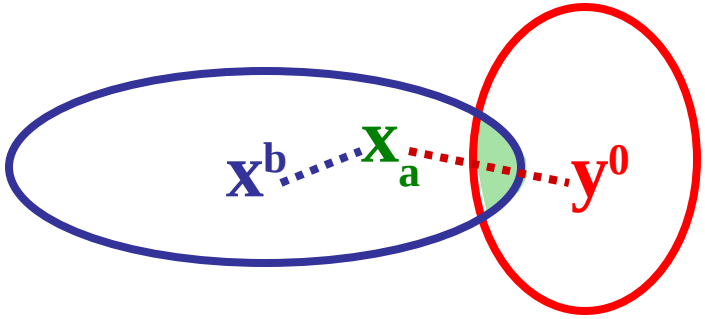
- observations ($y^0$) with
- background estimate ($x_b$) in order to
- determine optimal solution analysis $x_a$

Assuming all sources of error are unbiased

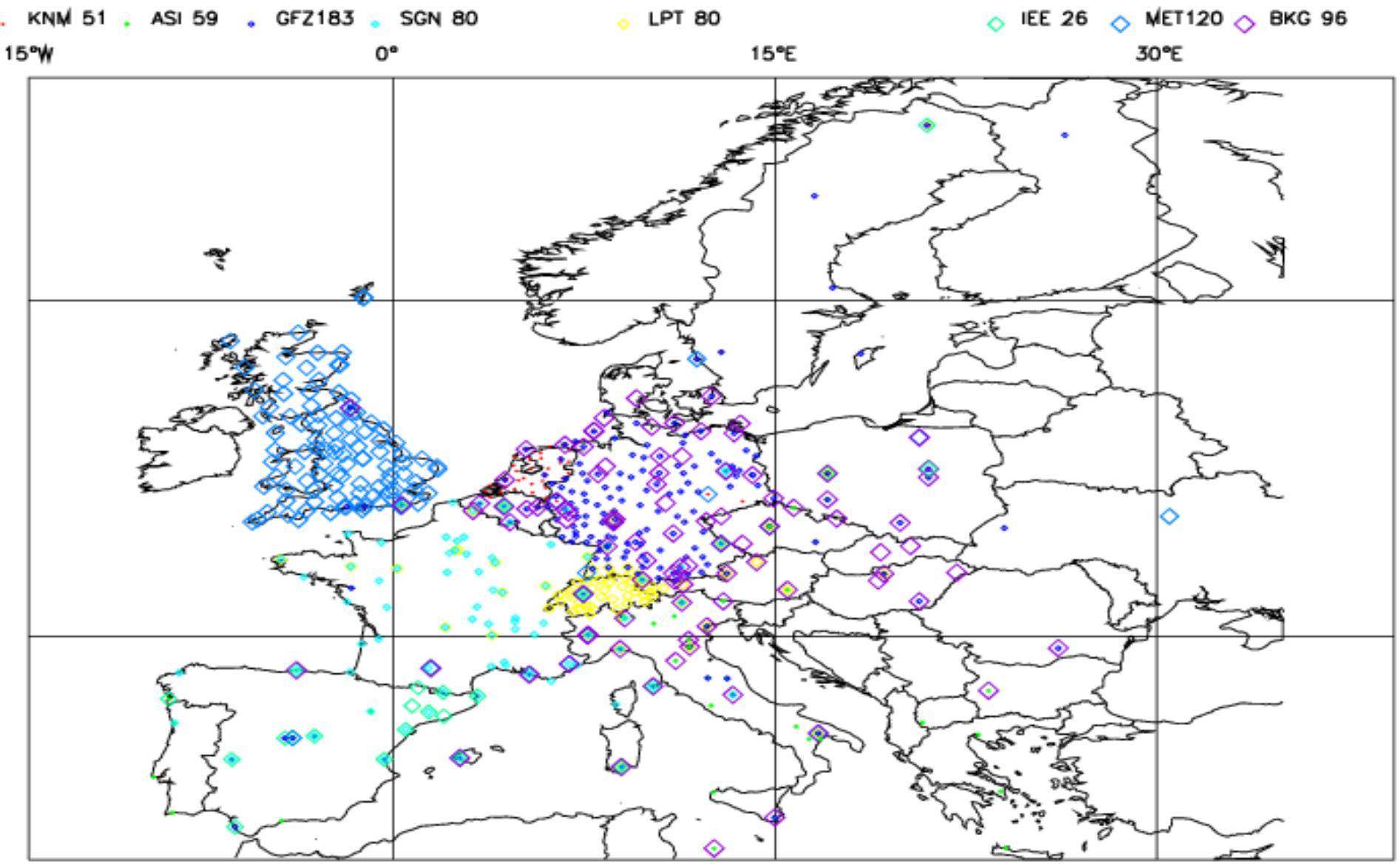
Assuming all errors present Gaussian patterns

Assuming observation errors are uncorrelated with each other

Assuming observation error and background error are uncorrelated



# GPS ZTD Stations: Coverage (1–10 Jan 2007)
# Average ~60 000 obs per day



# GPS ZTD Data Specific Characteristics

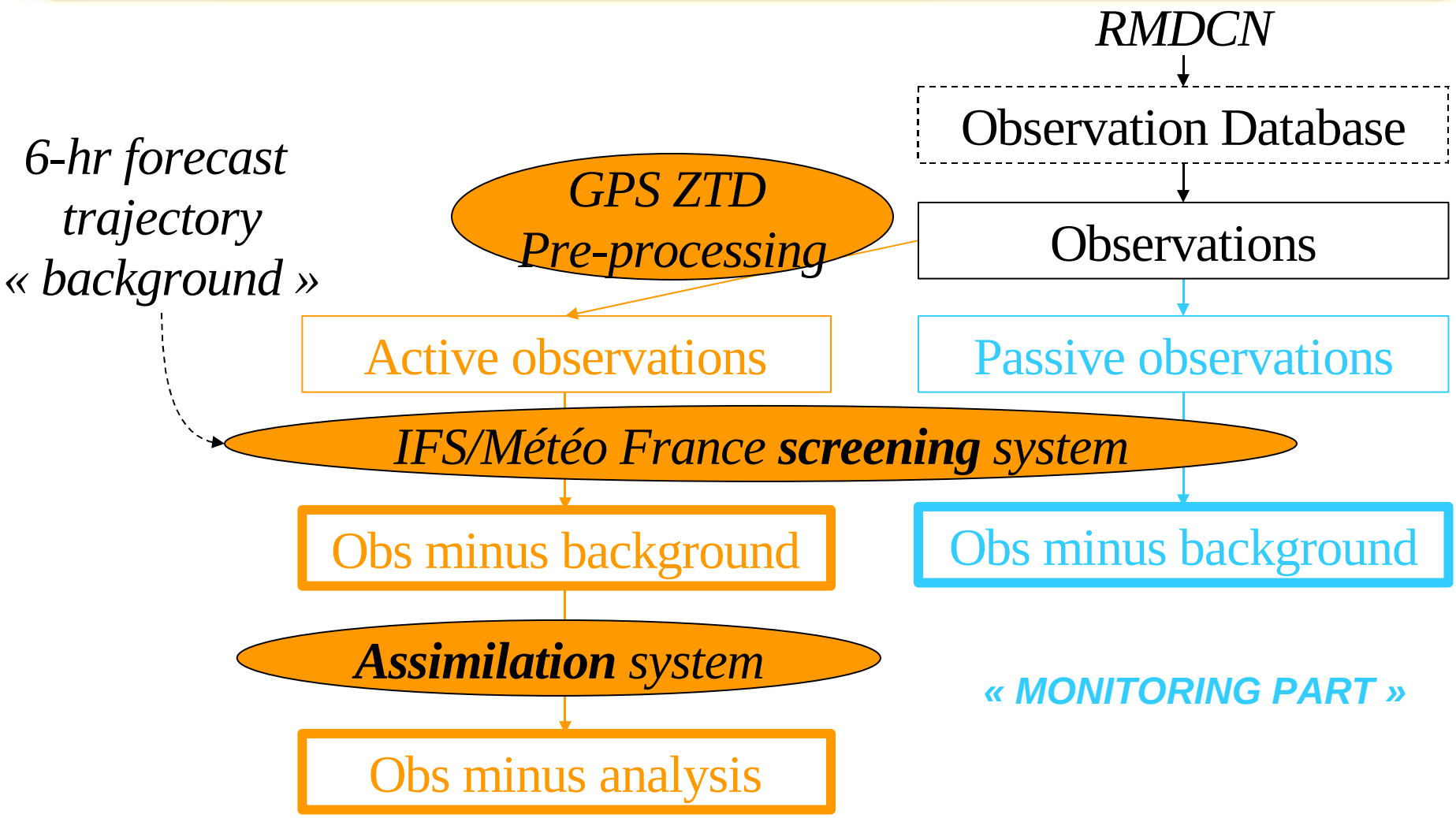
Fact: GPS ZTD data *quantity and quality* seem to evolve all the time

- Example: Analysis centers:
  - Some seem to stop activities
  - Others seem to include more stations to their networks

2. As end users we have tried to keep all options open and develop the capability to monitor ALL the ZTD data we receive
3. But at the same time we also wanted to start using these data in operations so that
   - Their usefulness (demonstrated in various studies) be applied to the benefit of everybody
   - We can learn how to make best use of the information contained therein and share experiences with data producers

So we had to make choices/compromises !

# GPS ZTD Data Assimilation Flow



# GPS ZTD Pre-processing

Input: A set of GPS ZTD observations, and
A station selection map

3. Select only the observations coming from stations in the map
   - Check all values within physical range
   - Verify latitude, longitude, altitude, time significance (*)
4. Apply time thinning:
   - In 4DVAR: average observations by time-slot (‘time super-obing’)
   - In 3DVAR: retain only ‘most central’ obs
5. Remove an observation minus background bias (*)
6. Assign an observation standard deviation error (*)

(*) = means information from the station selection map is used

# How we build the Station Selection Map based on several days' worth of monitoring

A station (e.g. BRUS-ROB) is selected based on the following criteria:

Location
- Station is located in, or close to, Europe (no isolated stations outside Europe)
- Station altitude is below 1000 m altitude
- Station altitude is within 150 m of the model orography
- Next closest station is located more than 50 km away
- 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 (chi2)

If there are several analysis centers meeting all the criteria (e.g. BRUS-ROB and BRUS-GFZ), retain the one for which observation minus background standard deviation is the smallest

# GPS ZTD Station Selection Map Example

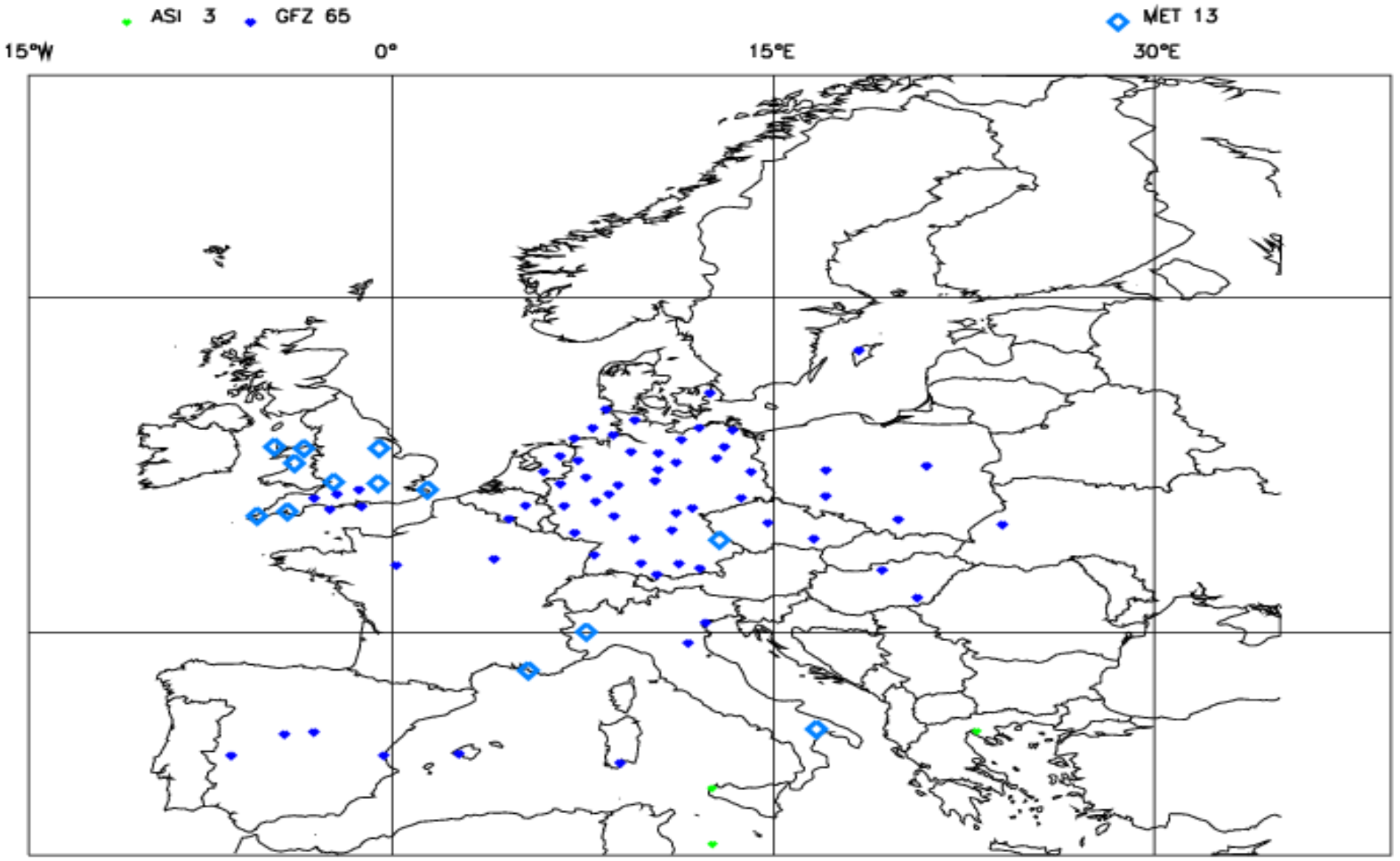
These 4 pieces of information may indicate processing changes at the analysis centers

Used for bias correction

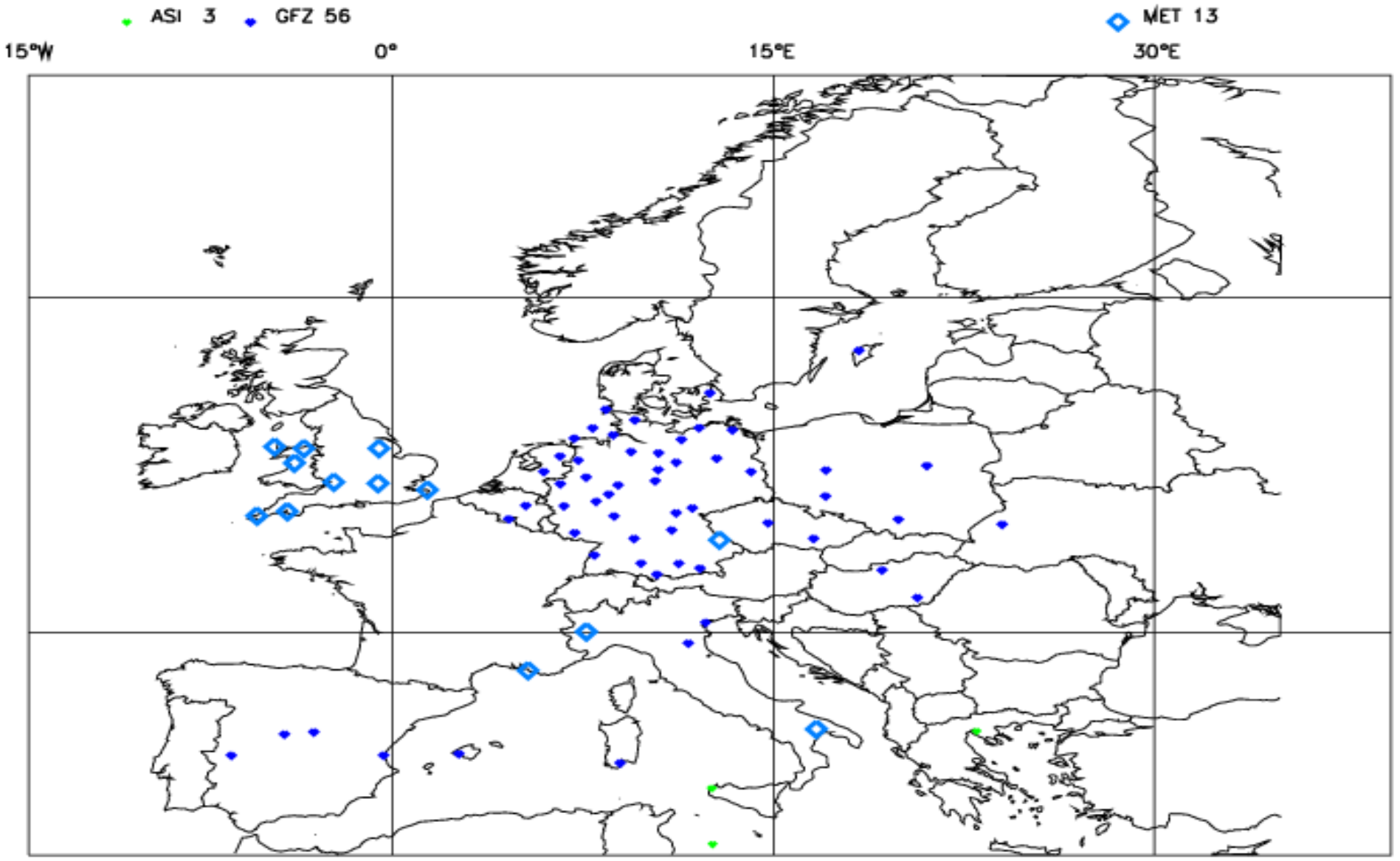
Used in assimilation

| Station name | Lat [deg] | Lon [deg] | Alt [m] | Time period [min] | Bias [mm] | Obs Error Stdev. [mm] |
|---|---|---|---|---|---|---|
| AMER-MET | 51.6772 | -0.5594 | 88. | 15. | 7.3 | 14.8 |
| APEL-GFZ | 52.2119 | 5.9623 | 73. | 30. | 4.9 | 9.9 |
| LAMP-ASI | 35.4998 | 12.6057 | 20. | 15. | 20.1 | 17.6 |

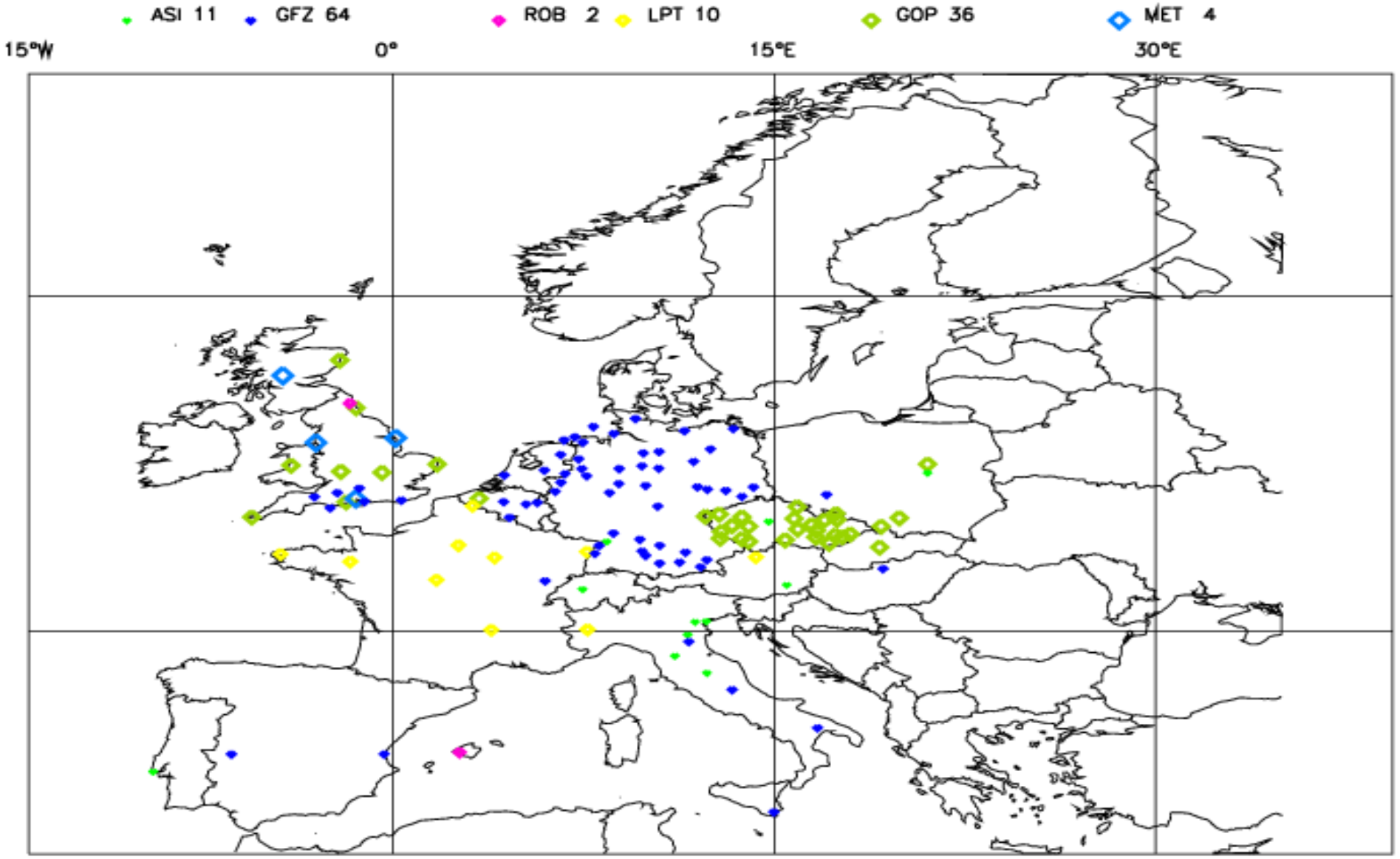
# GPS ZTD Stations:
# Selection Map for global model ARPEGE



# GPS ZTD Stations whose data were assimilated in global model (1–10 Jan 2007)



# GPS ZTD Stations:
# Selection Map for limited-area model ALADIN



# On the Issue of Bias Correction

## Purpose

- To ensure that the mean of (observation minus background) [over several days] is close to zero

## What we do

- Rely on a station-dependent bias computed over 10 days (June 2006)

## Justification

- Assimilation experiments on several seasons showed that 10-day bias presents little annual variation
- There seems to be 2 parts in the bias:
  - Constant over time: model vs. station terrain
  - Flow-dependent: TPW-related (may reflect model biases?)

## Future work

- Assimilation at Meteo France is moving toward a consistent, automatic, variational bias correction for all observation types (VarBC)

# On the Issue of Observation Error Std. Dev.

Purpose

- To indicate the assimilation system how to distribute increments
- Two parts in the obs error: measurement + representativeness

What we do

- Assume station-dependent obs. errors

Methodology and Justification

| **1. Estimate ZTD observation error** | **4. Determine ZTD observation error to use in assimilation =** |
|---|---|
| Using Desroziers' [2005] method : $\mathbf{R} = < [y^0-h(x_a)] \cdot [y^0-h(x_b)]^T >$ About 5 —7 mm year-round | Estimated obs error * (bkg error used / estimated bkg error) |
| **2. Estimate background error in ZTD** | **3. Determine background error used in assimilation in ZTD** |
| Using Desroziers' [2005] method : $\mathbf{HBH^T} = < [h(x_a)-h(x_b)] \cdot [y^0-h(x_b)]^T >$ About 5 mm (9 mm) in winter (summer) | Using randomization method: About 10 mm (20 mm) in winter (summer) |

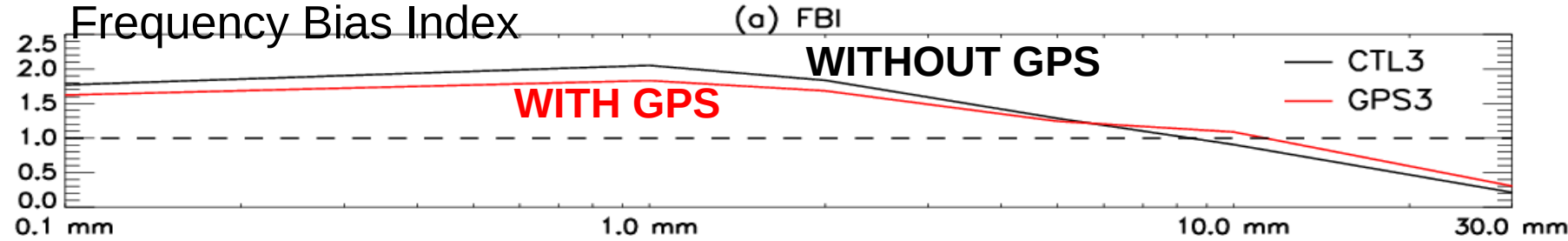
Future work

- Assess the importance of inter-station correlations

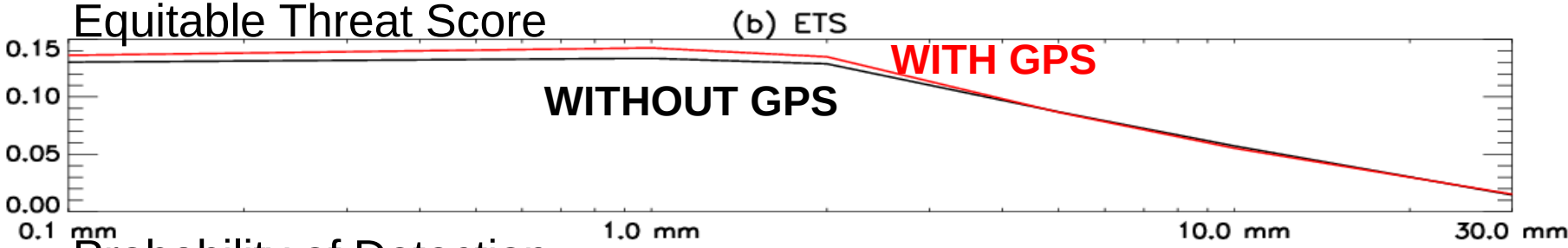
# Impact of GPS ZTD Assimilation on Quantitative Precipitation Forecasts over France

*18 Jun – 11 Jul 2005*

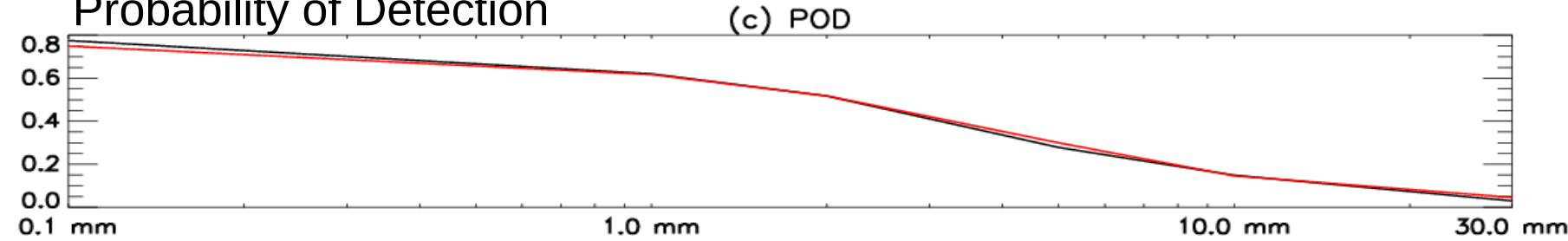
## Frequency Bias Index



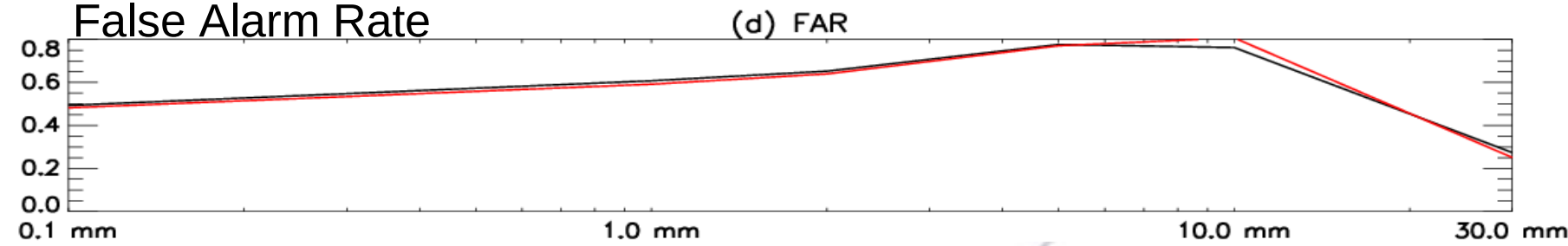

## Equitable Threat Score




## Probability of Detection




## False Alarm Rate



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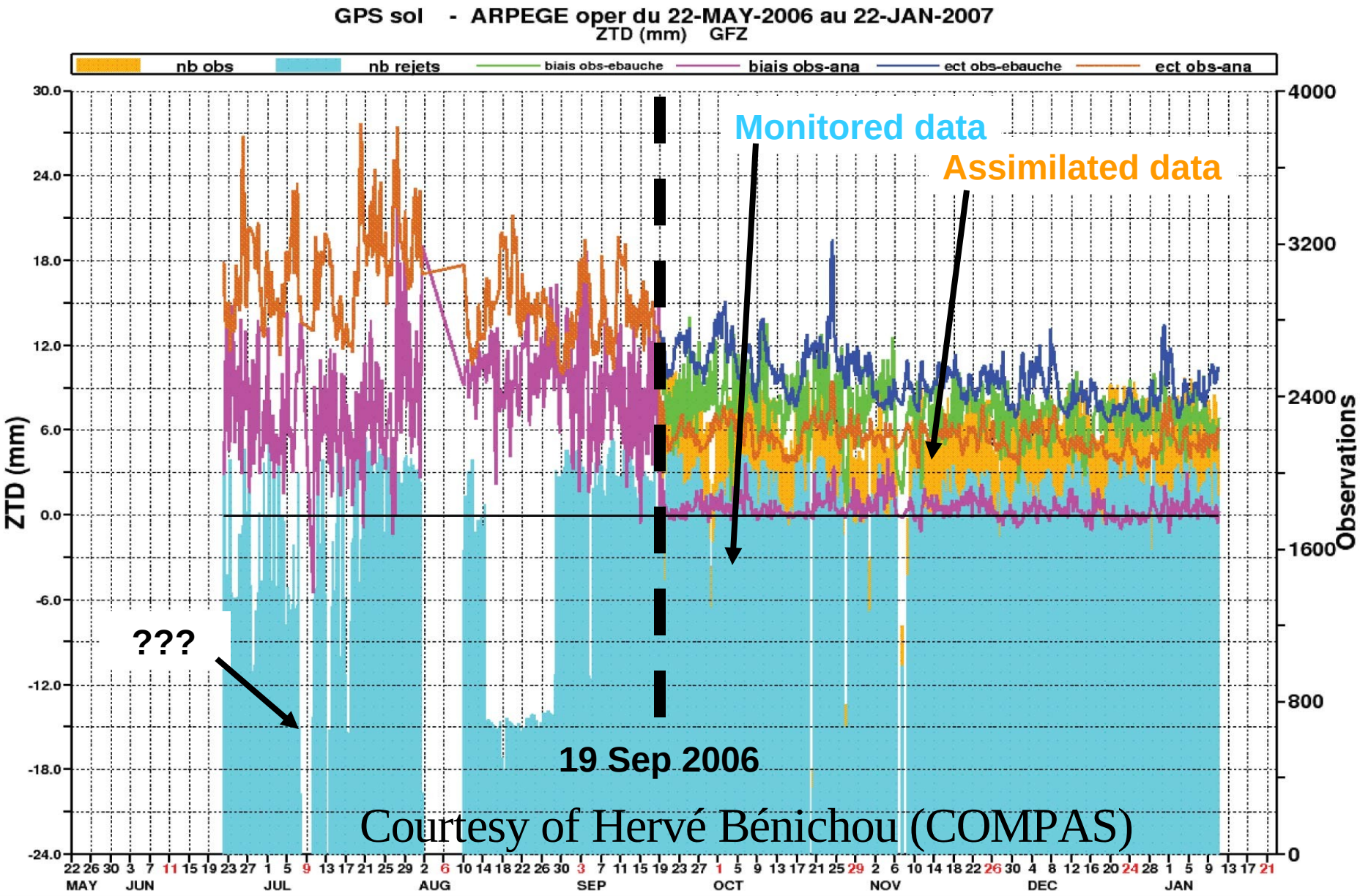
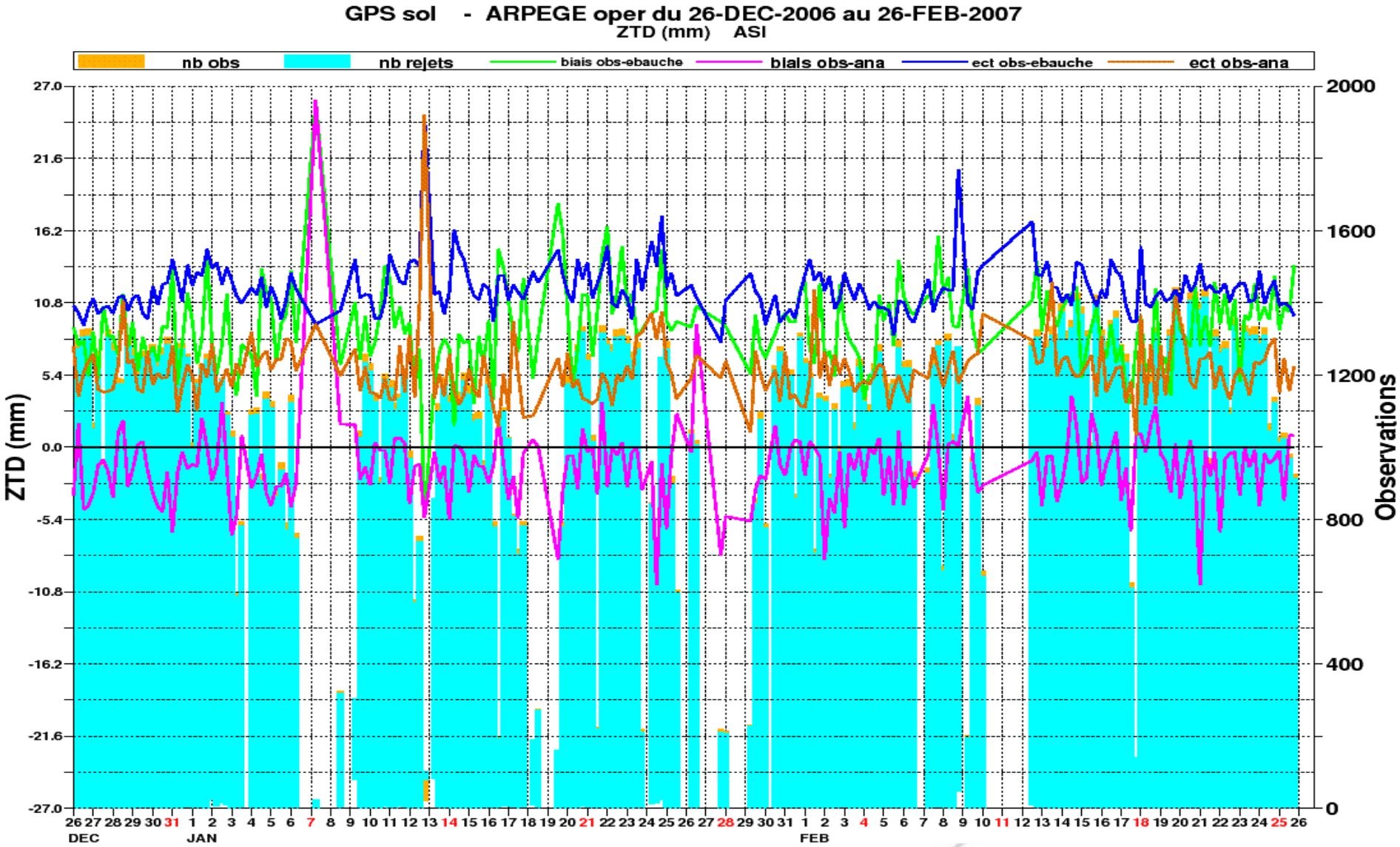
# GPS ZTD Assimilation & Monitoring : Example : GFZ




Courtesy of Hervé Bénichou (COMPAS)

# Monitoring: ASI



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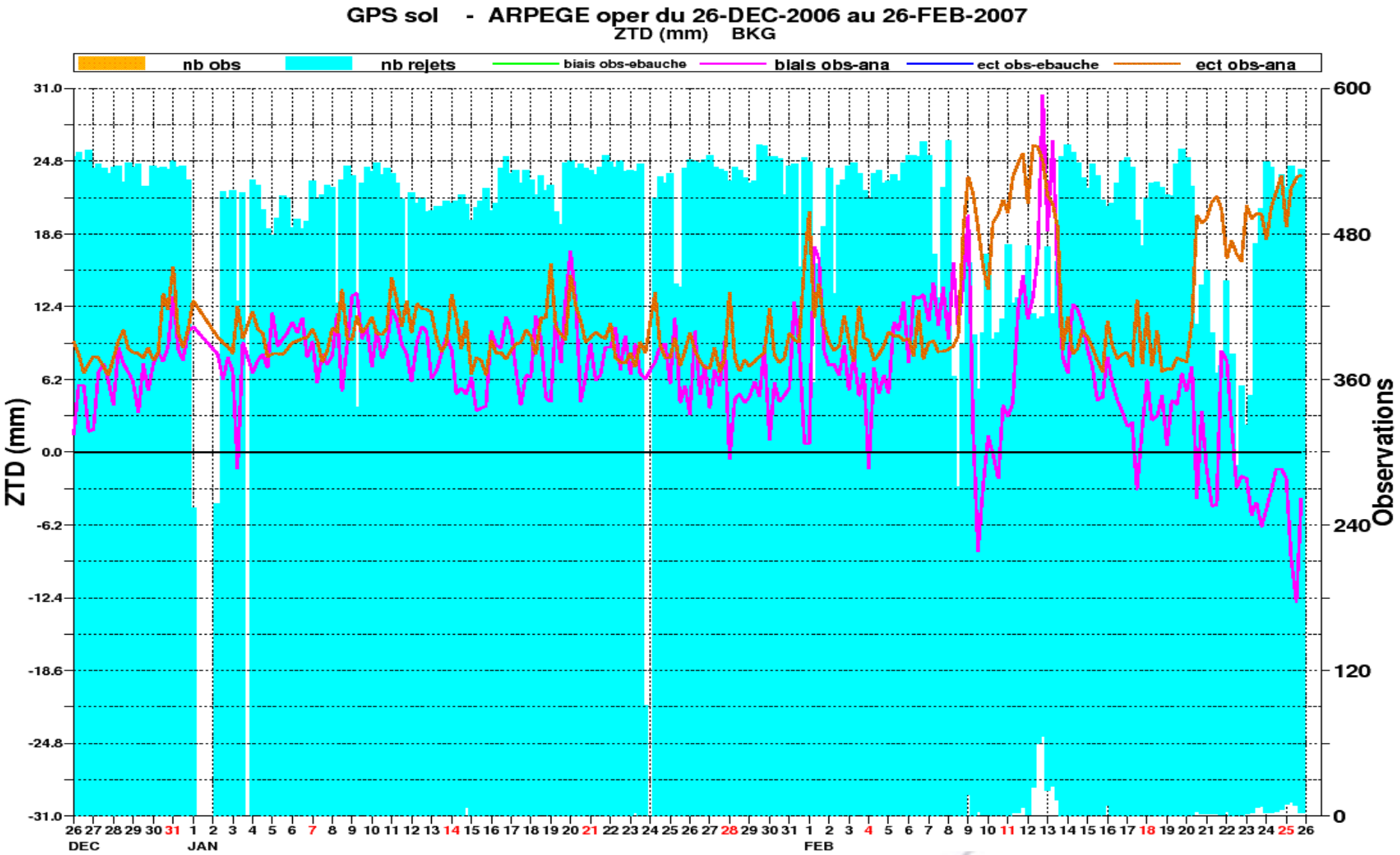
# Monitoring: BKG



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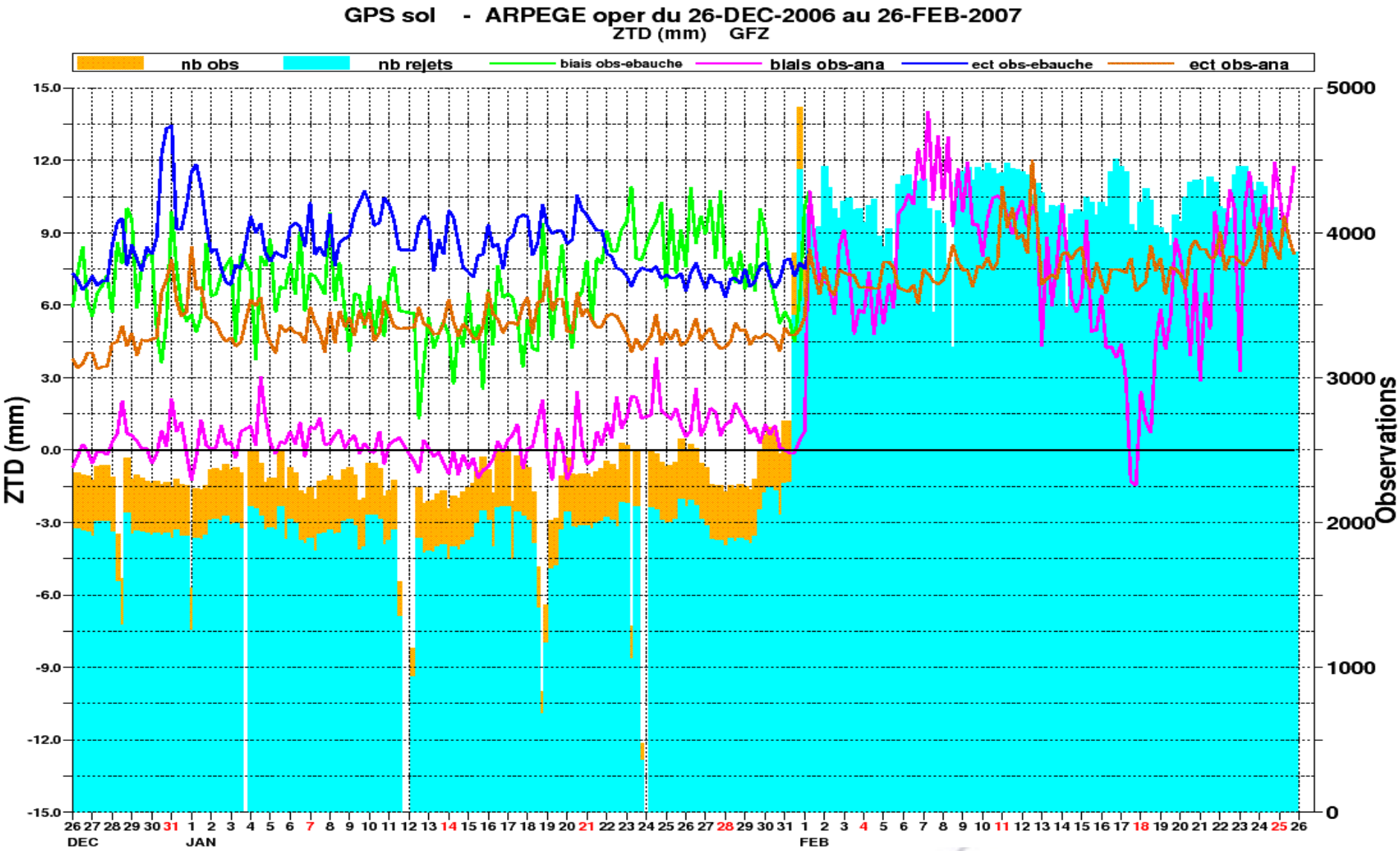
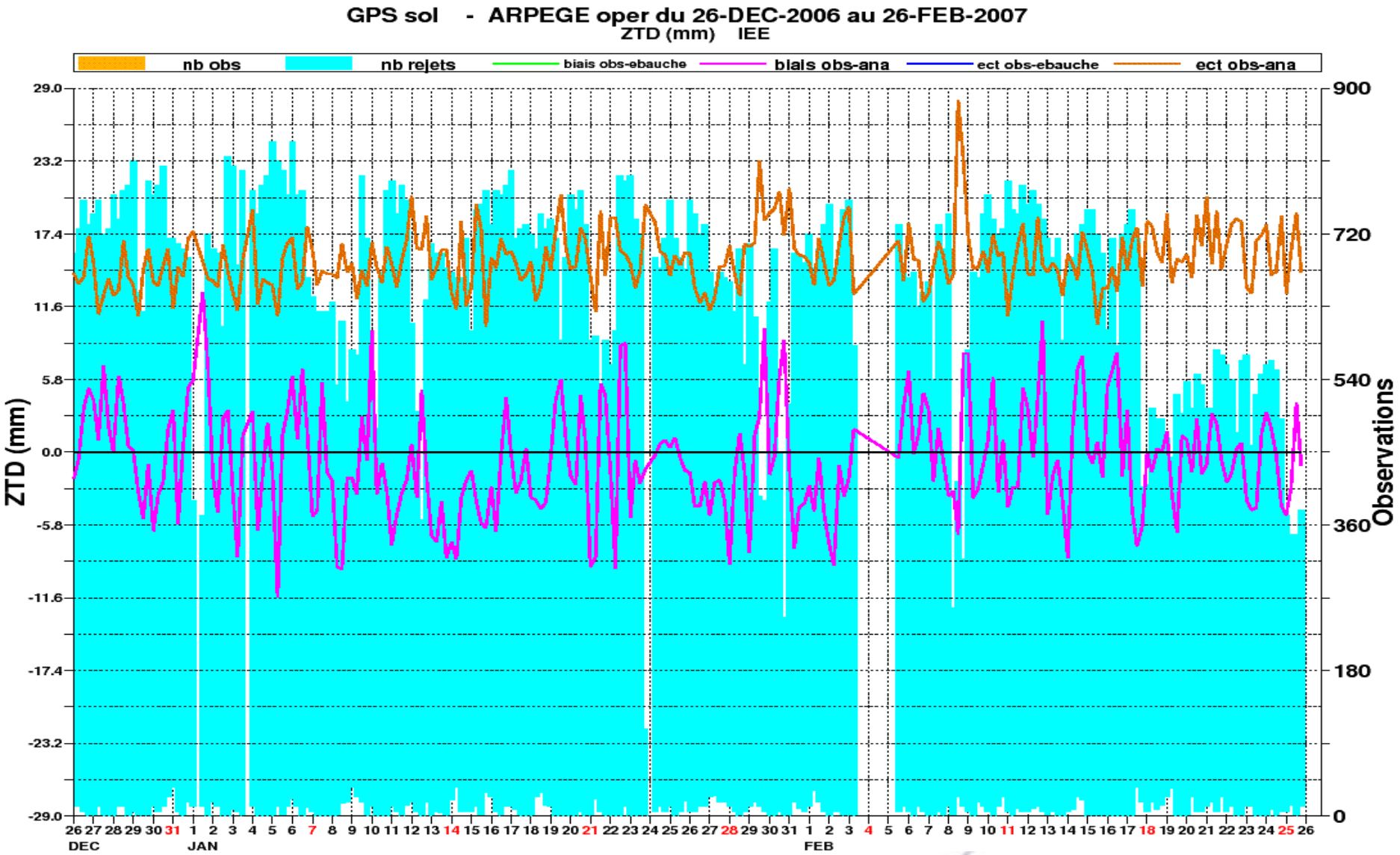
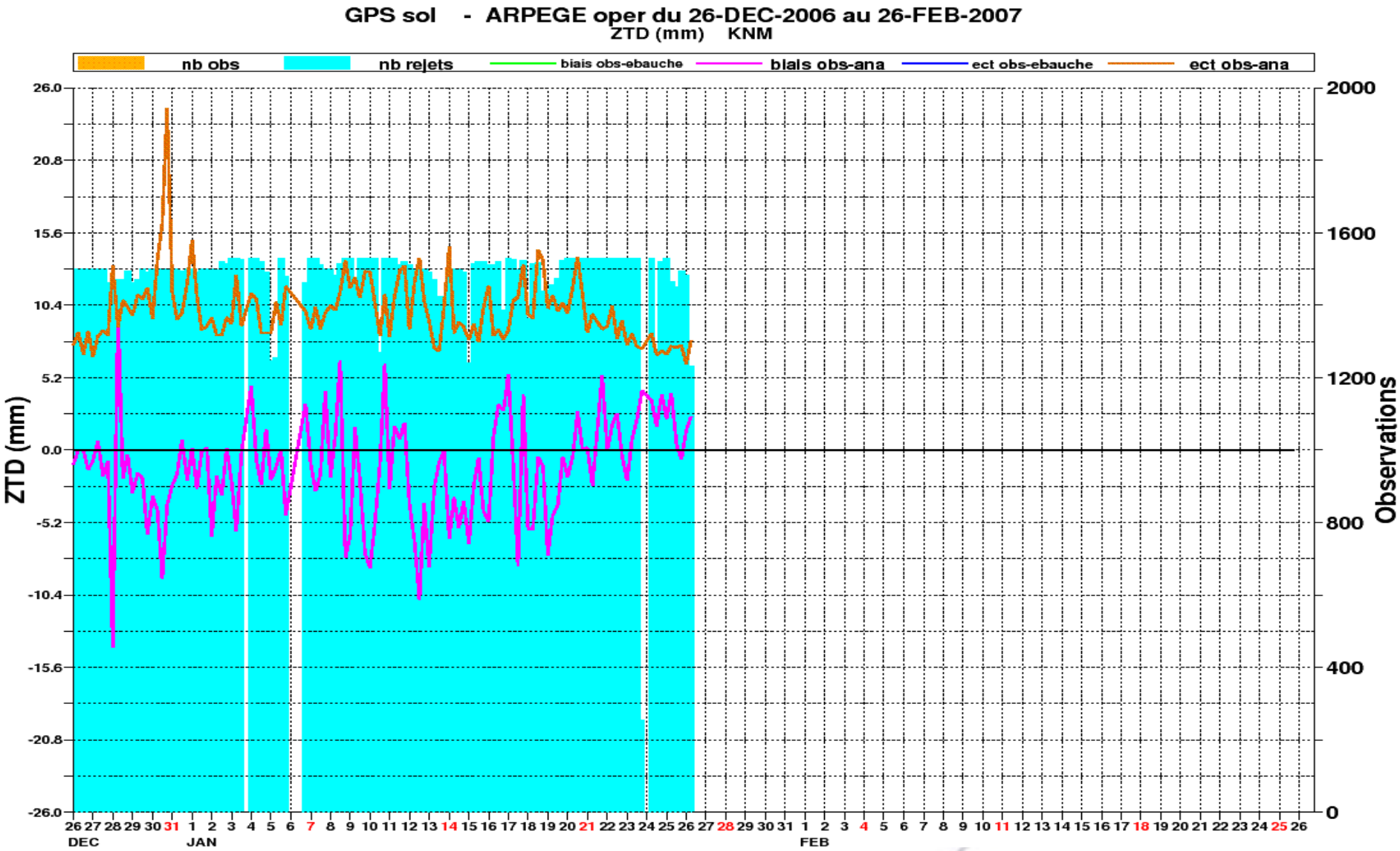
# Monitoring: GFZ



# Monitoring: IEE



# Monitoring: KNM



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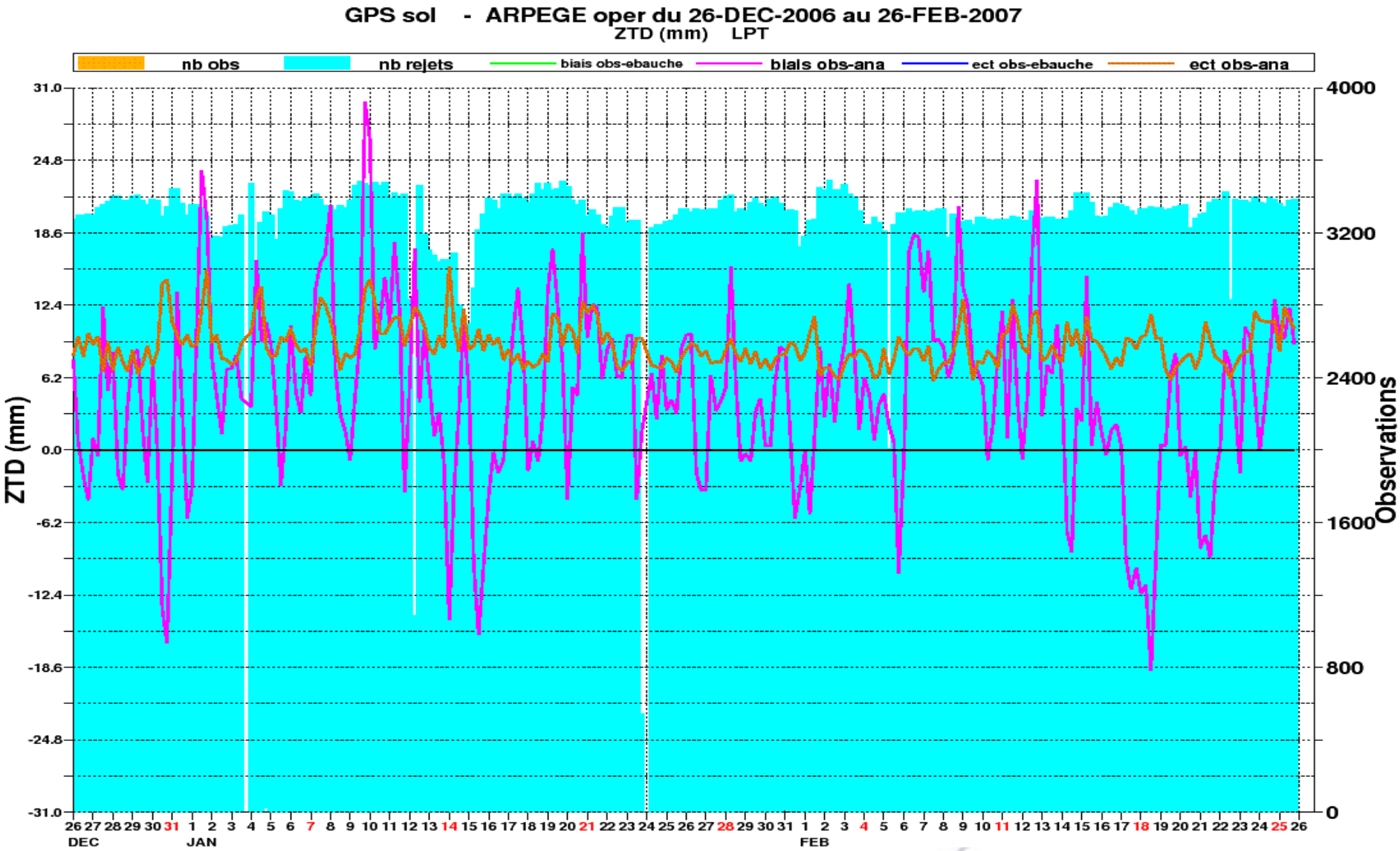
# Monitoring: LPT



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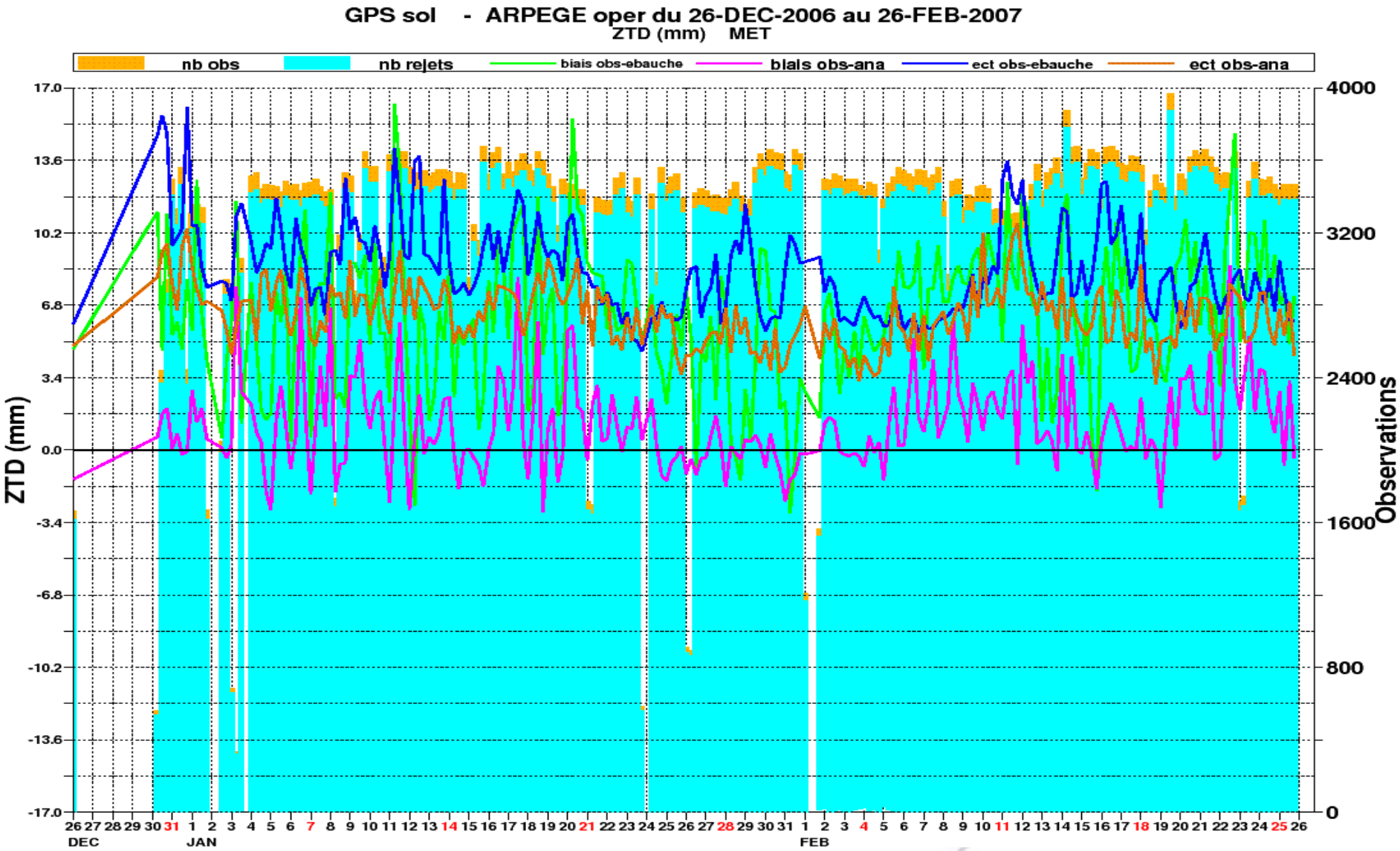
# Monitoring: MET



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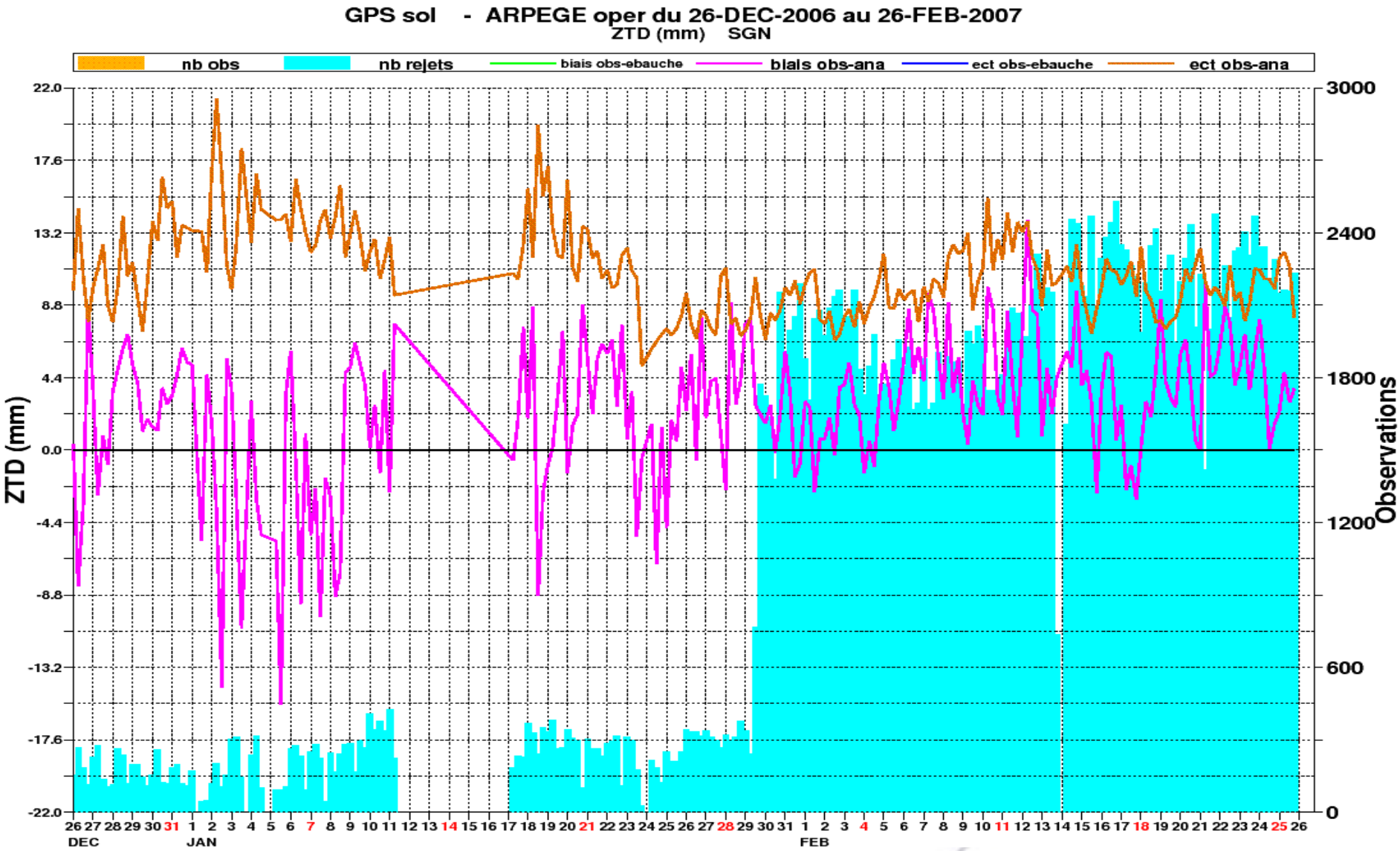
# Monitoring: SGN



# Monitoring

Could we discuss a norm to decide which data present so-called « large errors » and should be left out of model comparison statistics ? [similar rules exist to enable comparison with RAOBs between met centers for example]

- Propose a ZTD observation minus background limit of 50 mm ?
- If so, any ZTD observation that would depart from the background equivalent by more than 50 mm would:
  - Increase the number of « large errors » by 1
  - Not count towards the bias and standard deviation

# Operational constraints

Having a data type assimilated in operations has some implications

- Operators/managers are confused by warnings triggered by a complete absence of ZTD data
  - Issue e-mail messages in the total absence of ZTD data ?

- Changes in data processing may mean that the way we use the data may not be correct any more (example: bias correction)
  - Issue e-mail messages whenever significant changes are done ? (ie. allow a station to change coordinates, or changes in processing period)

Absence of ZTD data for any given station means that

(a) the data from that station cannot be monitored appropriately

(b) the chances of selecting that station for later assimilation are reduced

# Conclusions and Future Work

Good quality GPS ZTD data received at Meteo France via RMDCN and subsequent positive impact in forecasts have enabled operational switch to be turned on in September 2006

Although the assimilation setup is still very preliminary it allows to gain a better understanding of ZTD data variability

- Operational use also means constraints
- Agreement sought on threshold for « large errors »

Future work:

- Refine the station selection map (allow for more than one analysis center per station, in case data from prime provider are missing)
- Investigate the VarBC option for the ZTD bias correction
- Investigate obs. error spatial correlations (important for LAM)