Assimilation at Météo-France

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Data Assimilation basic kit working days

Lisbon, 22-23 March 2017

Outline

- Handling of observations in MF's Meteorological Database (BDM)
- Monitoring and quality control of observational data
- Obs control within the data assimilation system
  - Bator
  - Screening
  - VarBC
- Specific aspects : IAU in Arome
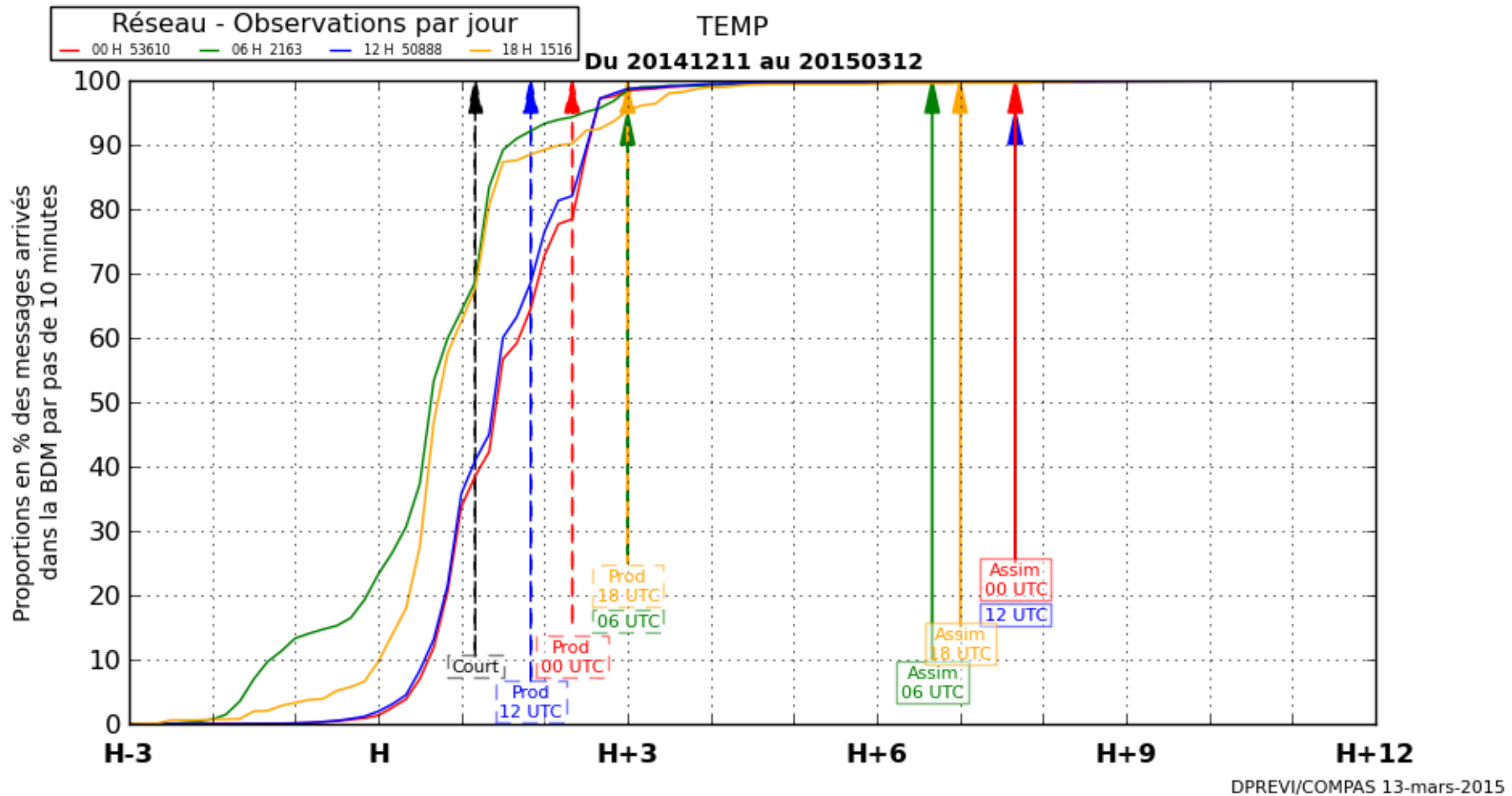
Handling of observations in MF's BDM

- Structure of BDM is generic : it has a database structure but it contains only a « thin layer » of specific information

- 1 file = 1 station ; grouped stations (in 1 BUFR) are split into N BUFR files, one per station

- Input files and fields are stored in a very raw format, so as to store them with a minimum of delay between arrival and availability to downstream applications (eg. Production, NWP suites etc.)

- Only very few specific information is extracted, and only a few actions of QC type are performed directly at BDM level :
  - Specifc metadata are extracted, like lat/lon, date, satellite ID/number, ID of sending or producer station of obs data => simple QC is performed on these metadata
  - Specific fields are extracted and stored in the BDM for Production needs, followed by some raw QC (eg. Temperature, snow cover height, etc.)
  - More « sophisticated » QC is done inside « Bator »

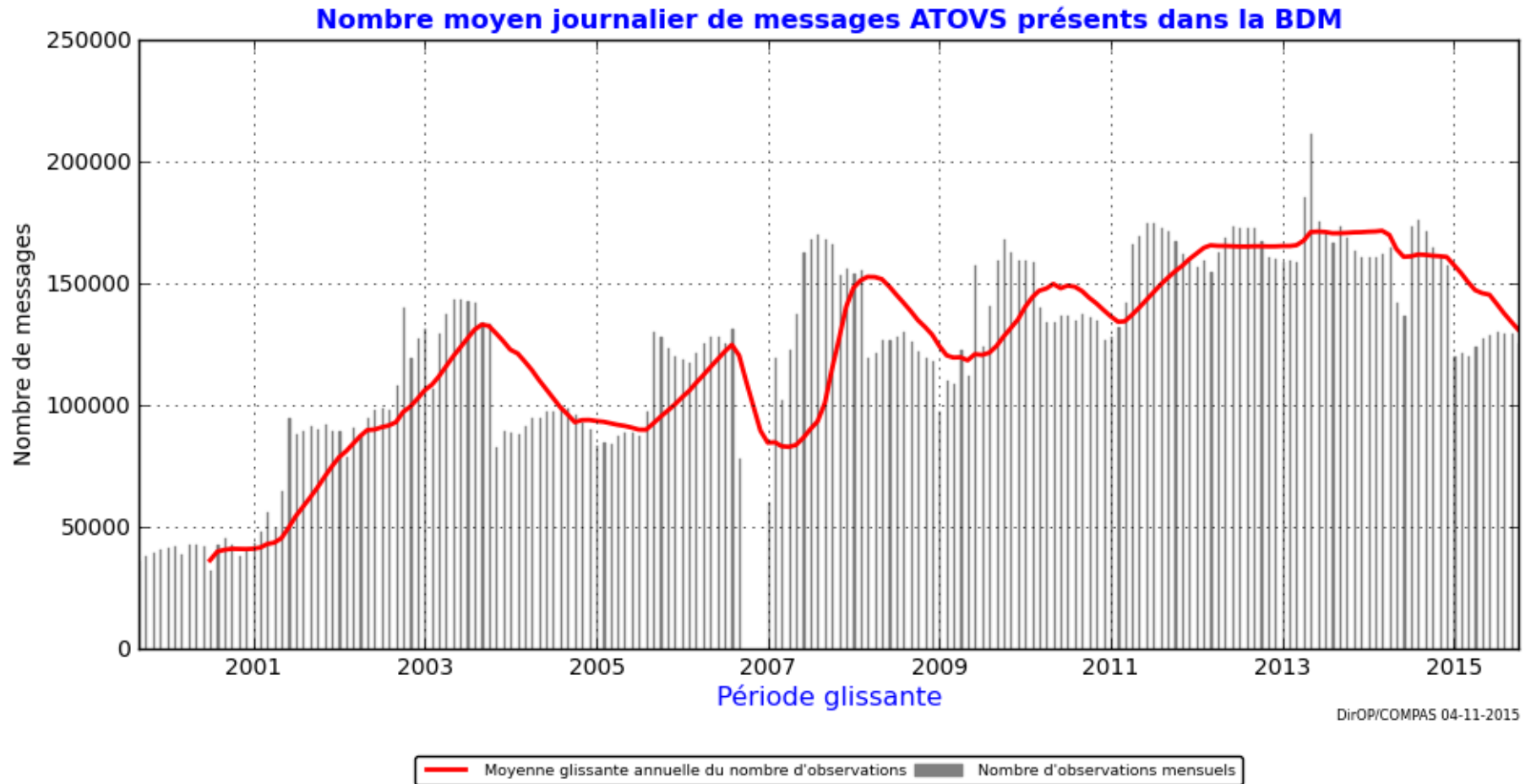# Arrival time of observations in MF's BDM: example of ATOVS
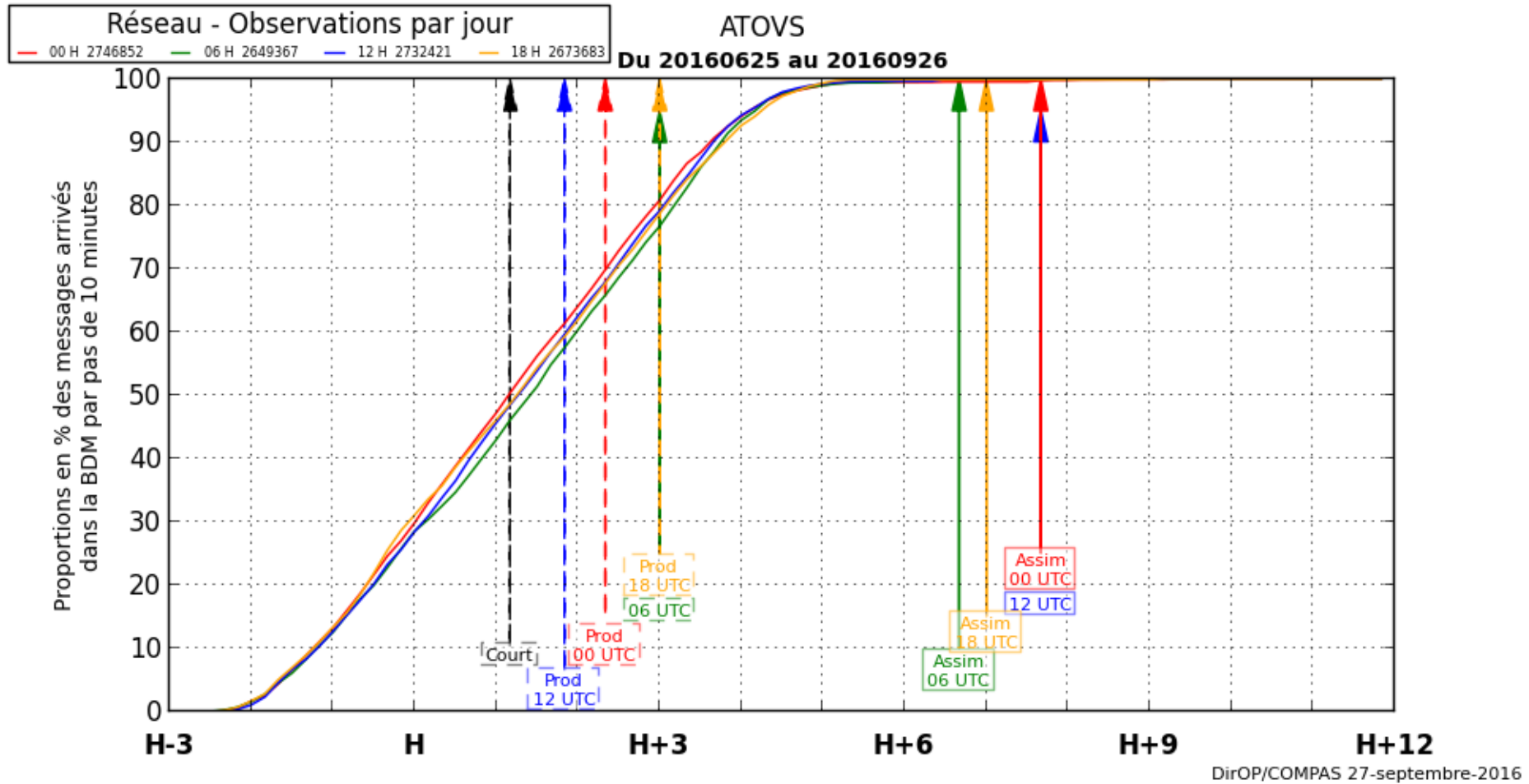
Courtesy by MF/DirOP/COMPAS

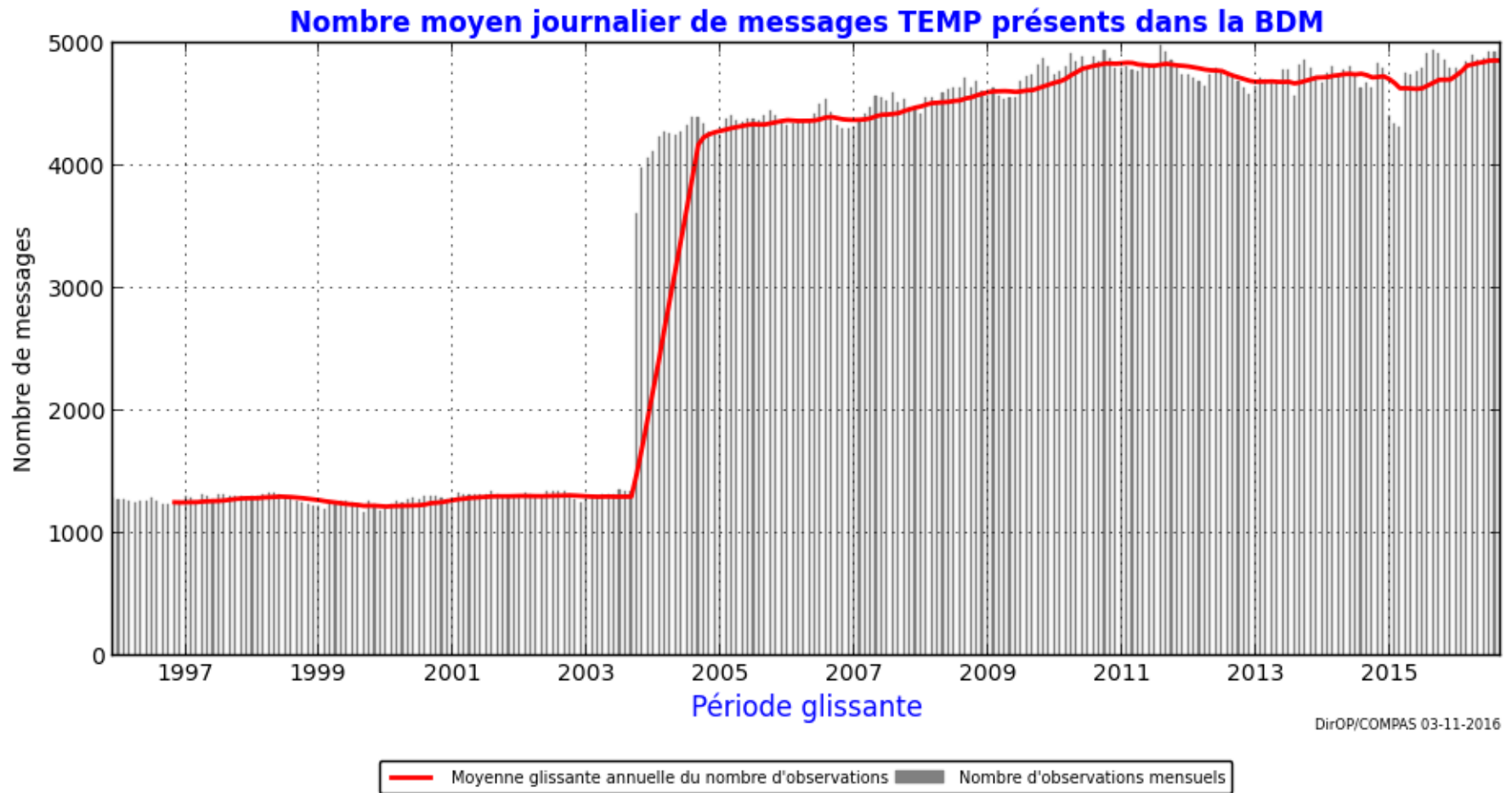# Arrival time of observations in MF's BDM: example of TEMP

DPREVI/COMPAS 13-mars-2015

- Courtesy by MF/DirOP/COMPAS

Mean amount of messages present in MF's BDM per day: example of ATOVS

Nombre moyen journalier de messages ATOVS présents dans la BDM

DirOP/COMPAS 04-11-2015

Legend: Moyenne glissante annuelle du nombre d'observations — Nombre d'observations mensuels

- Courtesy by MF/DirOP/COMPAS

Mean amount of messages present in MF's BDM per day: example of TEMP

Nombre moyen journalier de messages TEMP présents dans la BDM

Axis labels: Nombre de messages (y-axis), Période glissante (x-axis)

DirOP/COMPAS 03-11-2016

Legend: — Moyenne glissante annuelle du nombre d'observations ▮ Nombre d'observations mensuels

- Courtesy by MF/DirOP/COMPAS

Bator : from OBS files to ODB

- Extraction from MF's BDM : *not discussed here (oulan etc.)*
- The OBS files are read by Bator, which can handle several input formats (as stored in the BDM) :
  - BUFR, NetCDF, Oracle or SQL Tables, soon HDF-5 (OPERA)
  - Information treated by Bator is geographical references and observational data (observed values + some meta-data). Basically anything requested by the IFS/Arpège assimilation codes.
- Filtering in Bator :
  - Geographical thinning (eg. Take one pixel out of N, etc.)
  - Blacklists (define rejected OBS, ascii format file « liste_loc » etc.)
  - LAMFLAG : selection of OBS positions precisely in LAM projected model domain
  - Selection of instruments and channels for satellite data
- As a result, Bator will write out an ODB formatted file fit for an IFS/Arpège/Arome Screening step

CONTROL AND SURVEY OF OBSERVATIONS : *MONITORING*

- **GOALS** *:*
  - ✓ Control of observations (in situ+satellite), any parameter assimilated in surface or in altitude : Z, T, T_b, Hu, FF, DD and SST
  - ✓ Construction and updates of blacklists
  - ✓ Control of assimilations

- **MEANS** *:*

  $$O\text{-}E = (O\text{-}O_{vrai})+(E\text{-}E_{vrai})+(E_{vrai}\text{-}O_{vrai})$$

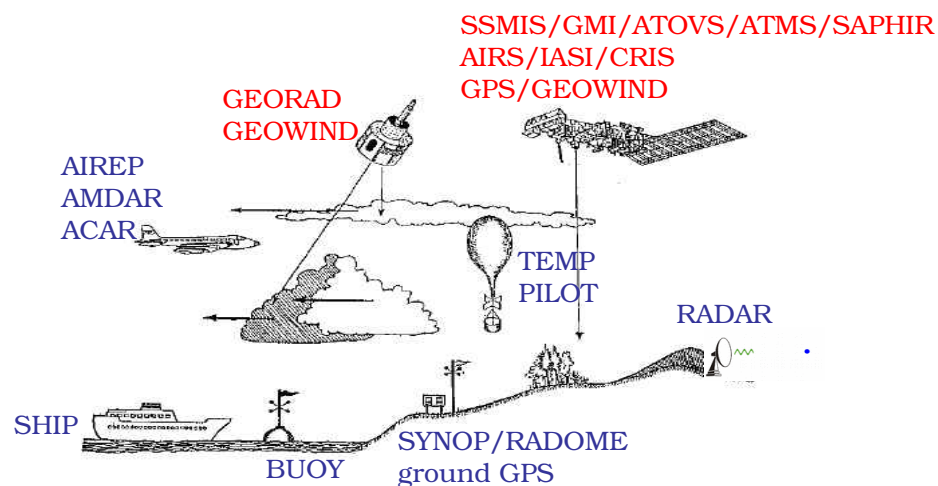 *erreur   observation   ébauche   représentativité*

- **APPLICATIONS** *:*
  - ✓ Monthly statistics : based on WMO standards with « arbitrary » thresholds for bias, stdev, RMS and/or nber of large errors => « unusual » observations
  - ✓ Daily statistics of satellite observations

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Toujours un temps d'avance

Type of controlled data

GLOBAL DATA MONITORING REPORT

SSMIS/GMI/ATOVS/ATMS/SAPHIR
AIRS/IASI/CRIS
GPS/GEOWIND

GEORAD
GEOWIND

AIREP
AMDAR
ACAR

TEMP
PILOT

RADAR

SHIP

SYNOP/RADOME
ground GPS

BUOY

NOVEMBER, 2008

DPrevi/COMPAS

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Monitoring of observations

- Assess presence / absence of data ; time of arrival

- Based on generally monthly statistics, and daily statistics for satellites

- *Note : some monitoring is performed by MF's Observation Dept (DSO) – not shown here -, and the main activity w/r to NWP is done by the Operations Dept (COMPAS)*

- Survey any potential failure of observational data :
  - Temporary change in bias or stdev of man-made observation can be due to human mistake : modified condition of obs, bad reporting
  - Suspicious values for automated in-situ measurements can be due to instrumental problem (drift, misfit w/r to saturation for RH, etc.) or change in environment
  - Action : correction (re-calibrate bias correction) or removal of obs (blacklist)
  - Satellite instruments can undergo a drift (bias) of their measurements (deterioration of instrument, change of satellite positioning etc.), failure of instrument, sudden stop of emission etc.

- Monitoring includes checking obs minus analysis, so there is actually a continuous dialogue between monitoring and assimilation
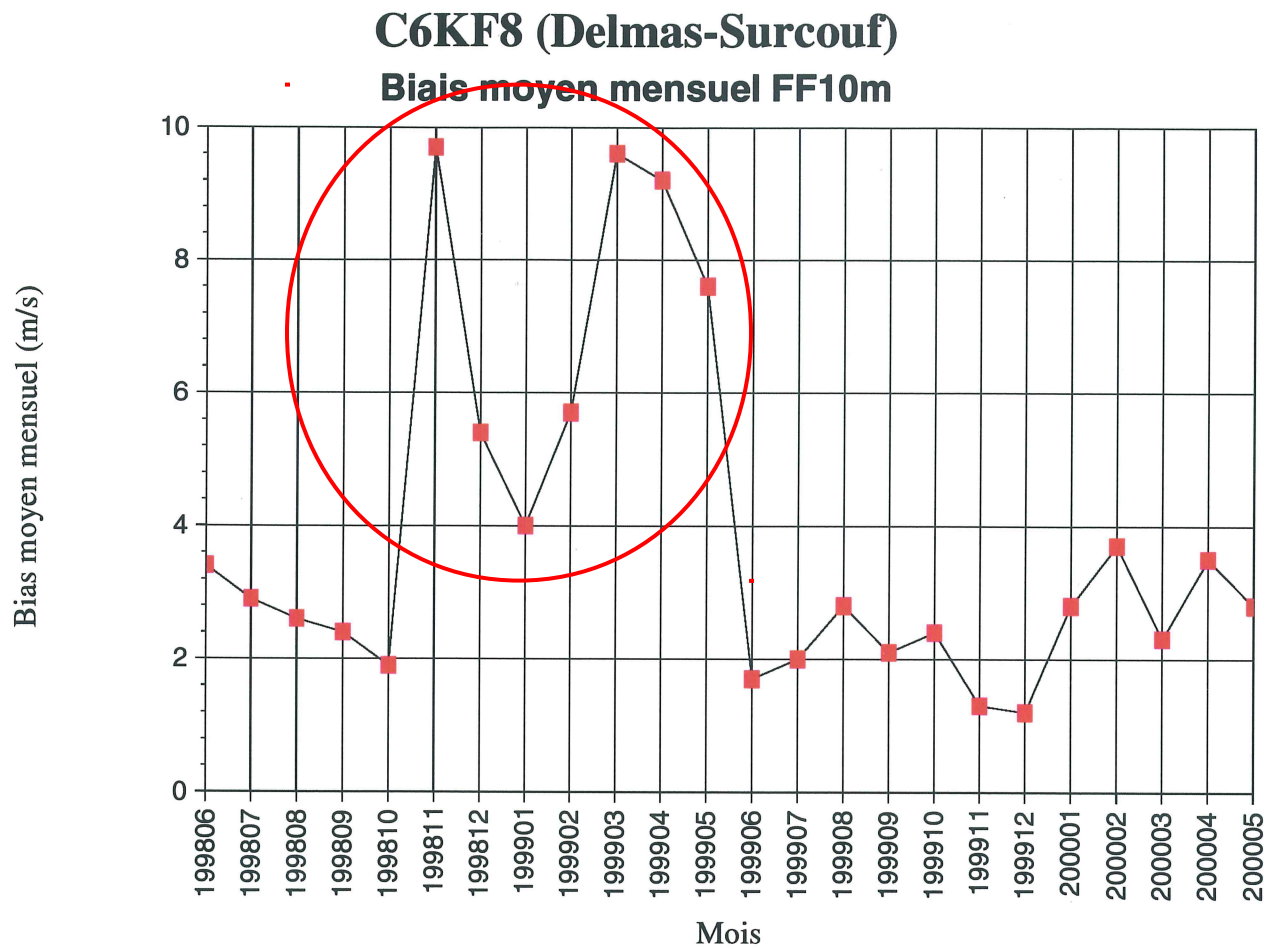
Detection of anomalies : French AWS RADOME

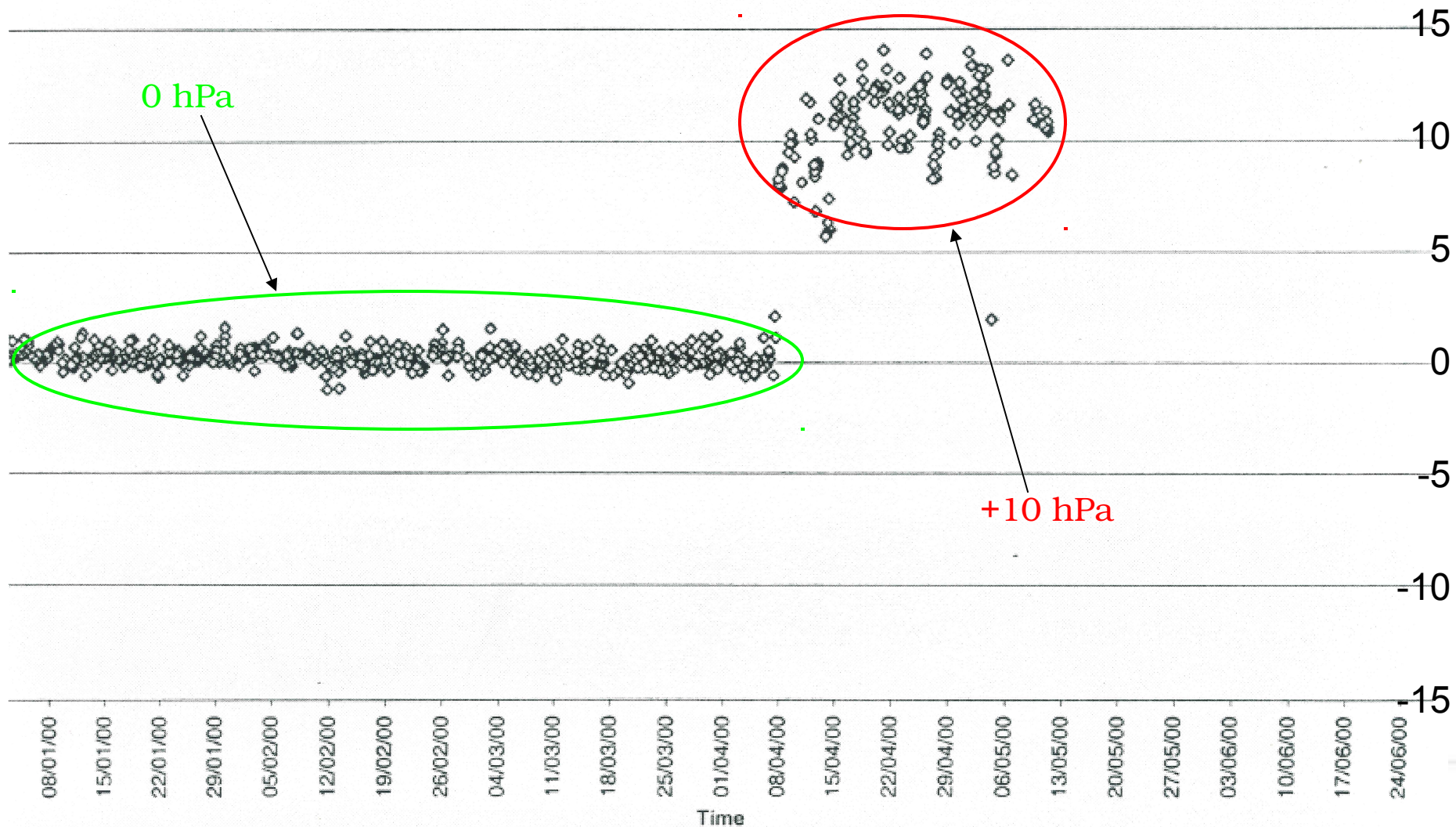STATION / ECART TYPE > 2 * ECART TYPE MOYEN REGION

Valenciennes
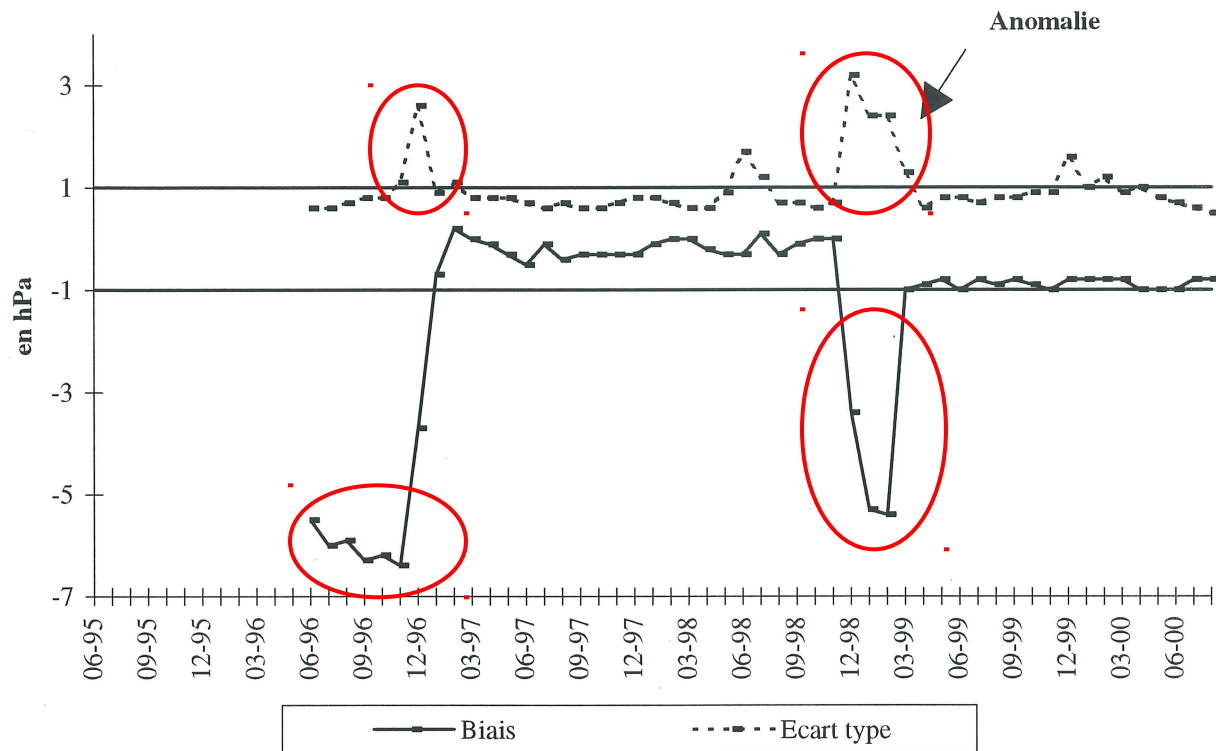
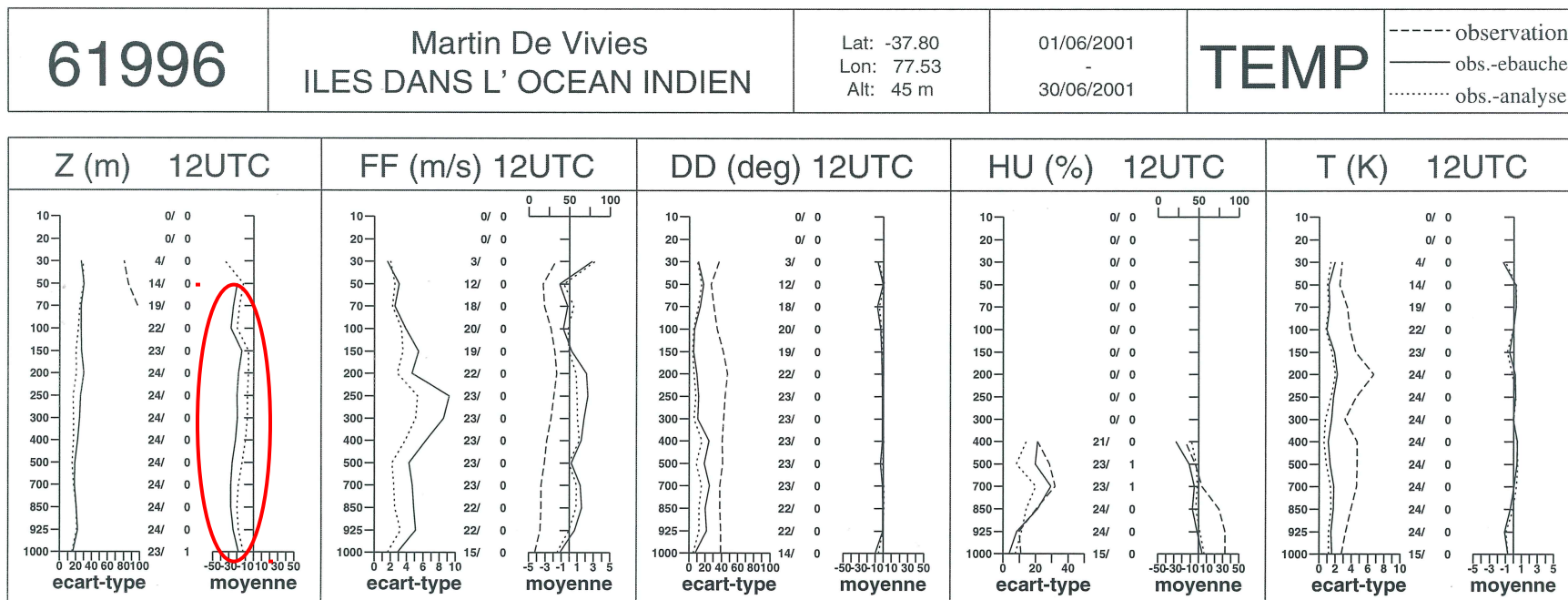# Detection of anomalies : French SHIP

Detection of anomalies : BUOY

O-B pressure (hPa) for identifier 52815
Number of obs. plotted = 696   Number of outliers = 1

Detection of anomalies : Overseas TEMP
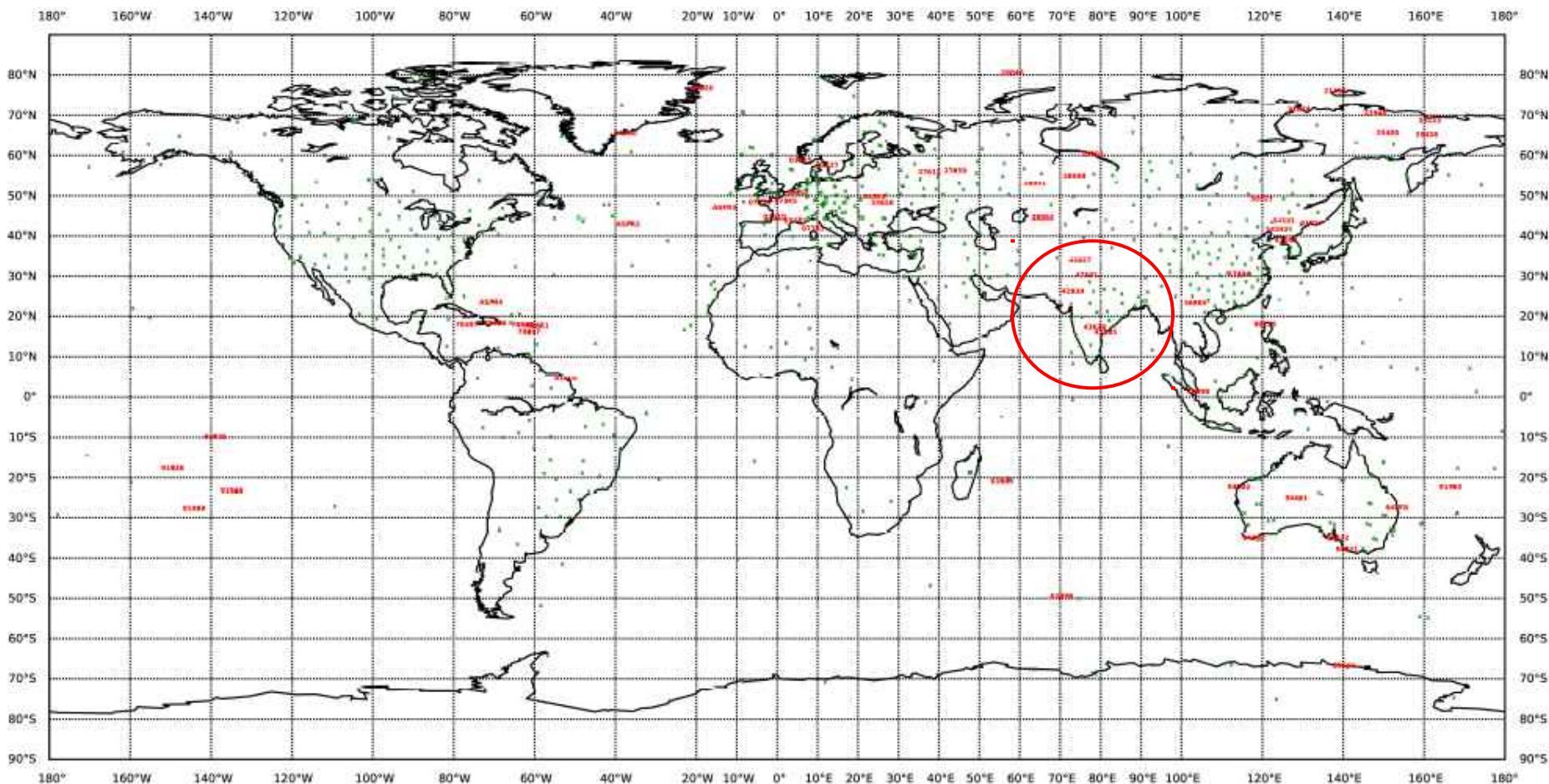
Blacklist : map for TEMP/T

Detection of anomalies : ATOVS AMSU-A from NOAA 16

ATOVS Bracknell NOAA 16 - ARPEGE oper du 15-DEC-2004 au 15-FEB-2005
Tb (K) clair AMSU-A 9 (90 hPa)
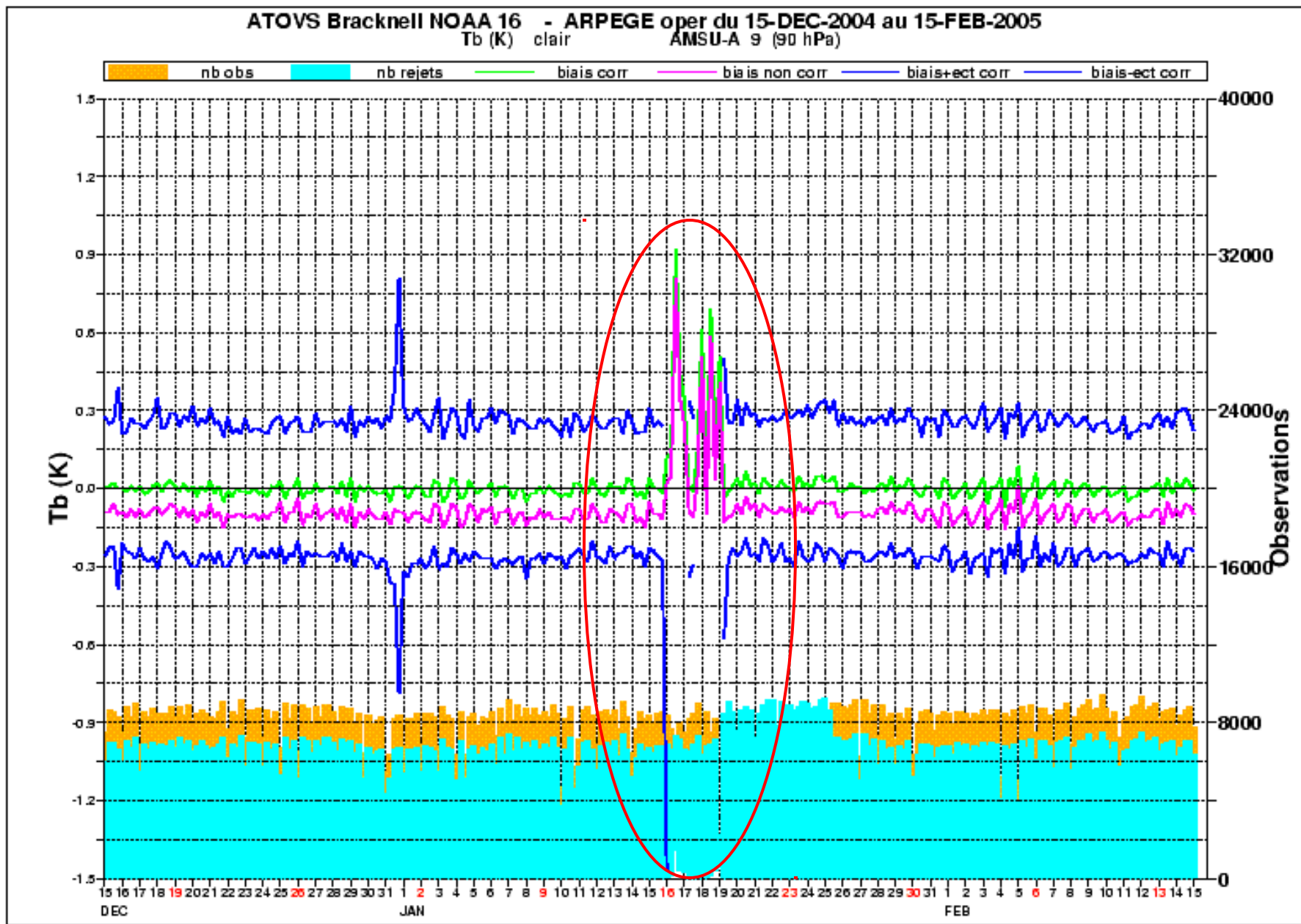
Detection of anomalies : ATOVS AMSU-B from NOAA 17
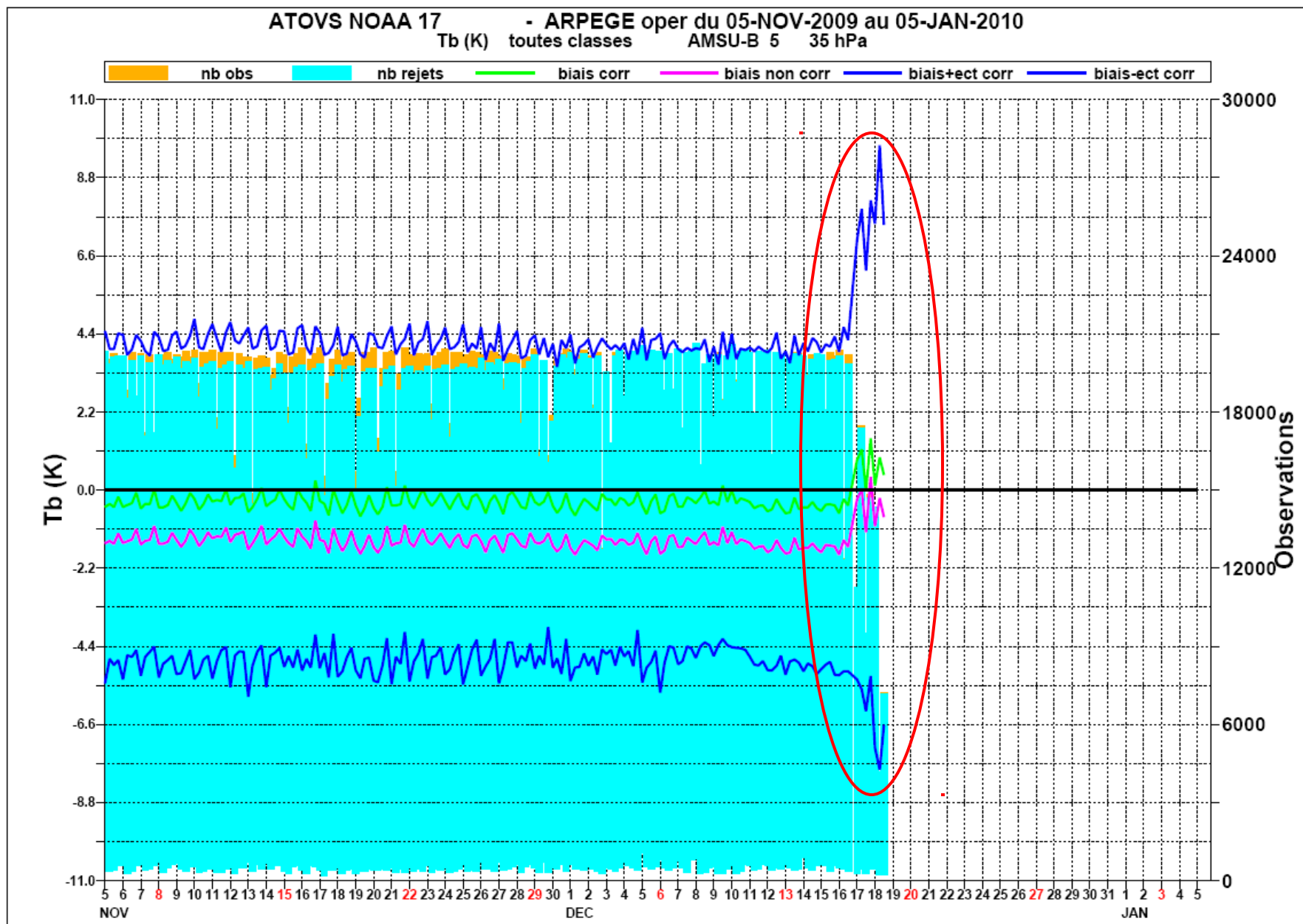
Deterction of anomalies : ATOVS AMSU-A from METOP A

liste noire

dérive lente
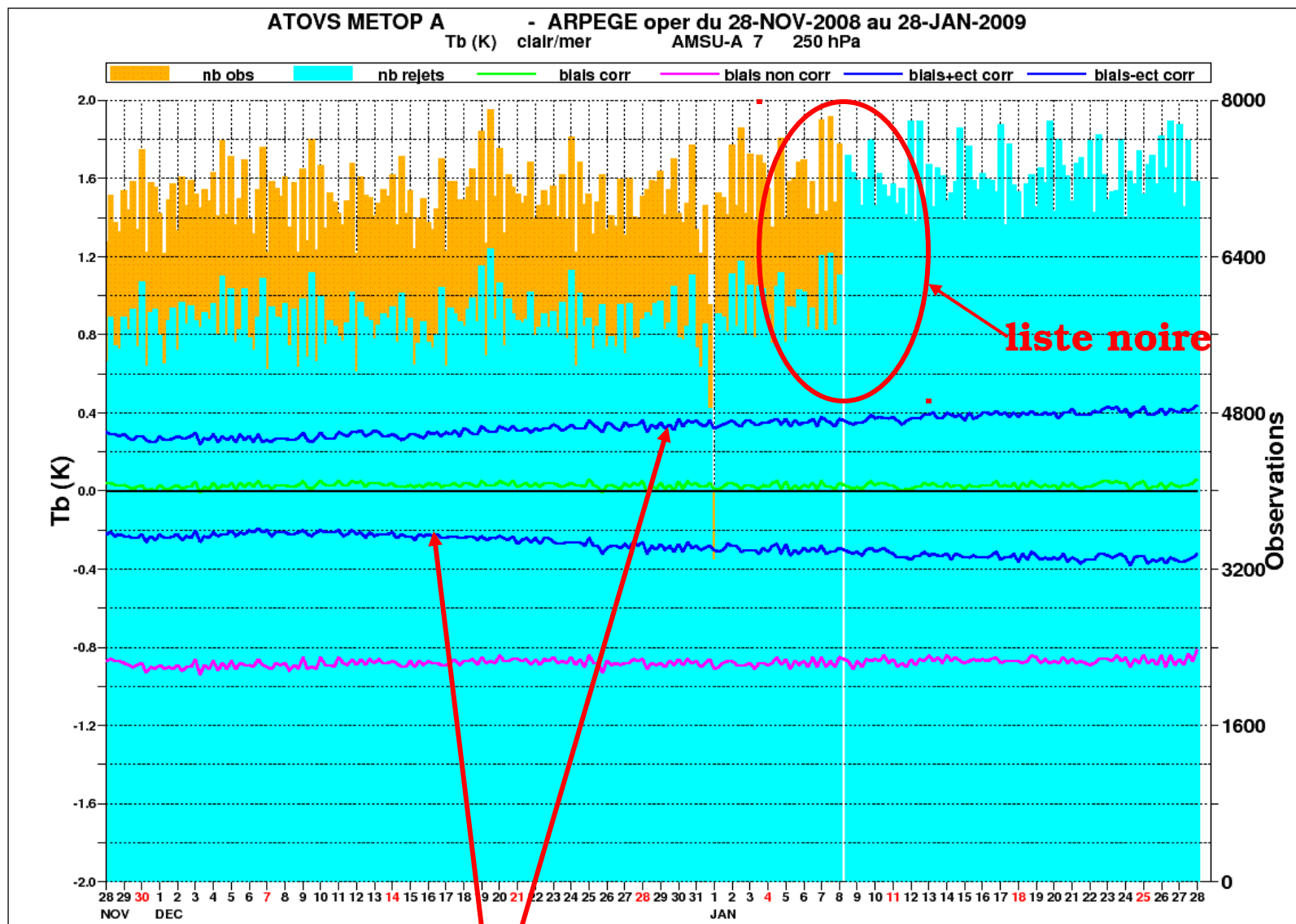
Monitoring acts on the assimilation system

- The results from Monitoring tasks can have an effect on the assimilation system

- Modify/update Blacklist files ; remove OBS types from Whitelist

- Generally, the technical change would be done via an update in Bator

- After we've seen BDM, Monitoring of OBS and the Bator tool for some types of data selection and conversion to ODB, we now enter the core world of the IFS/Arpège/LAM assimilation codes : Screening, Minimization including VarBC, potential Model step updates ...
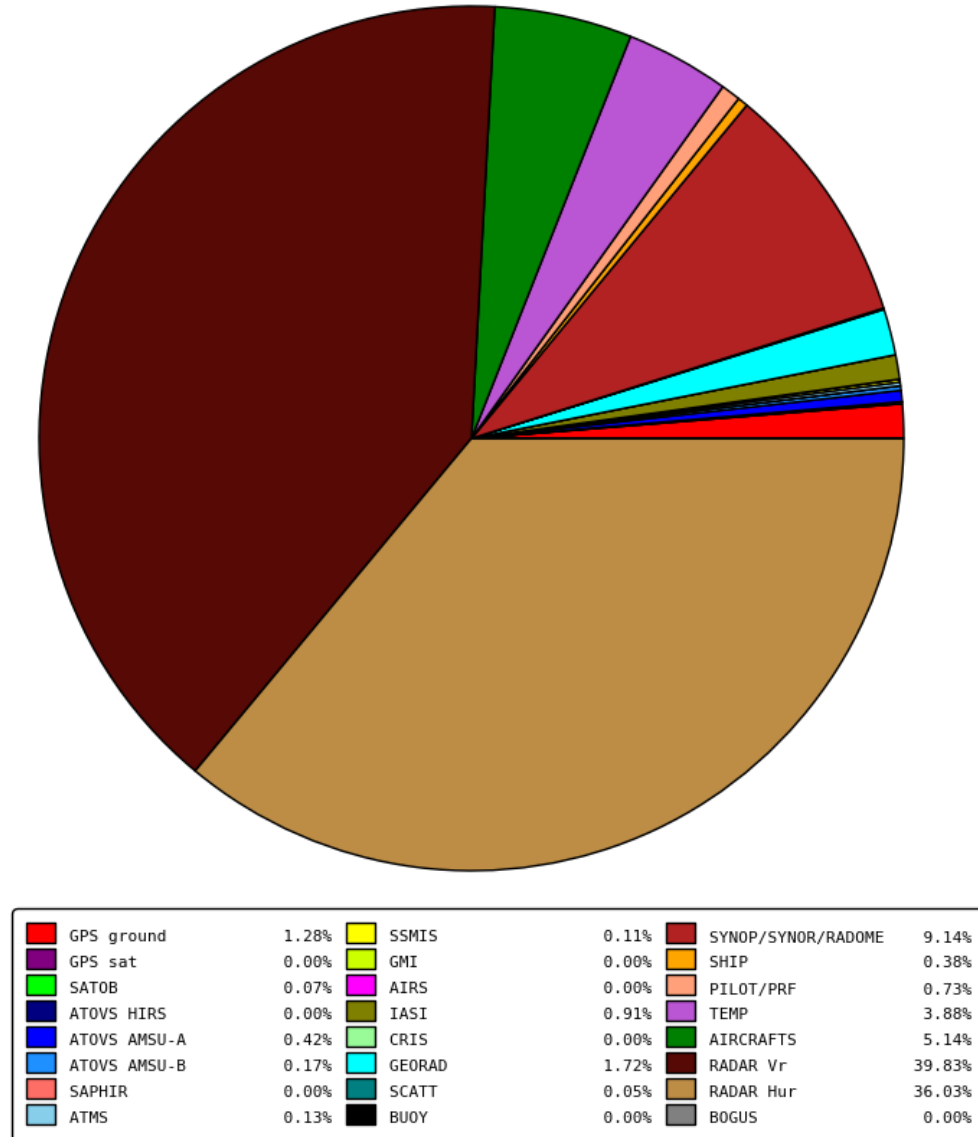
Screening of observations

- Aka « écrêmage » (in French)

- Accept or reject observation according to several criteria

- Screening is part of the IFS/Arpège/LAM codes (thus code is shared among all partners)

- Some criteria are independent of first guess (or model forecast) information : redundancy check, consistency check, completeness check

- Thinning of observations in boxes : only keep a prescribed spatial density of a given type of obs

- Others depend on model (first guess) information, like the « first guess check » :

$$\frac{|y - H(Xb)|}{\sigma} \leqslant \lambda$$

Example of number of observations entering the AROME assimilation

Proportions des nombres d'observations utilisées par type d'obs
analyses cut-off AROME - AROME France dbl
observations conventionnelles et satellites
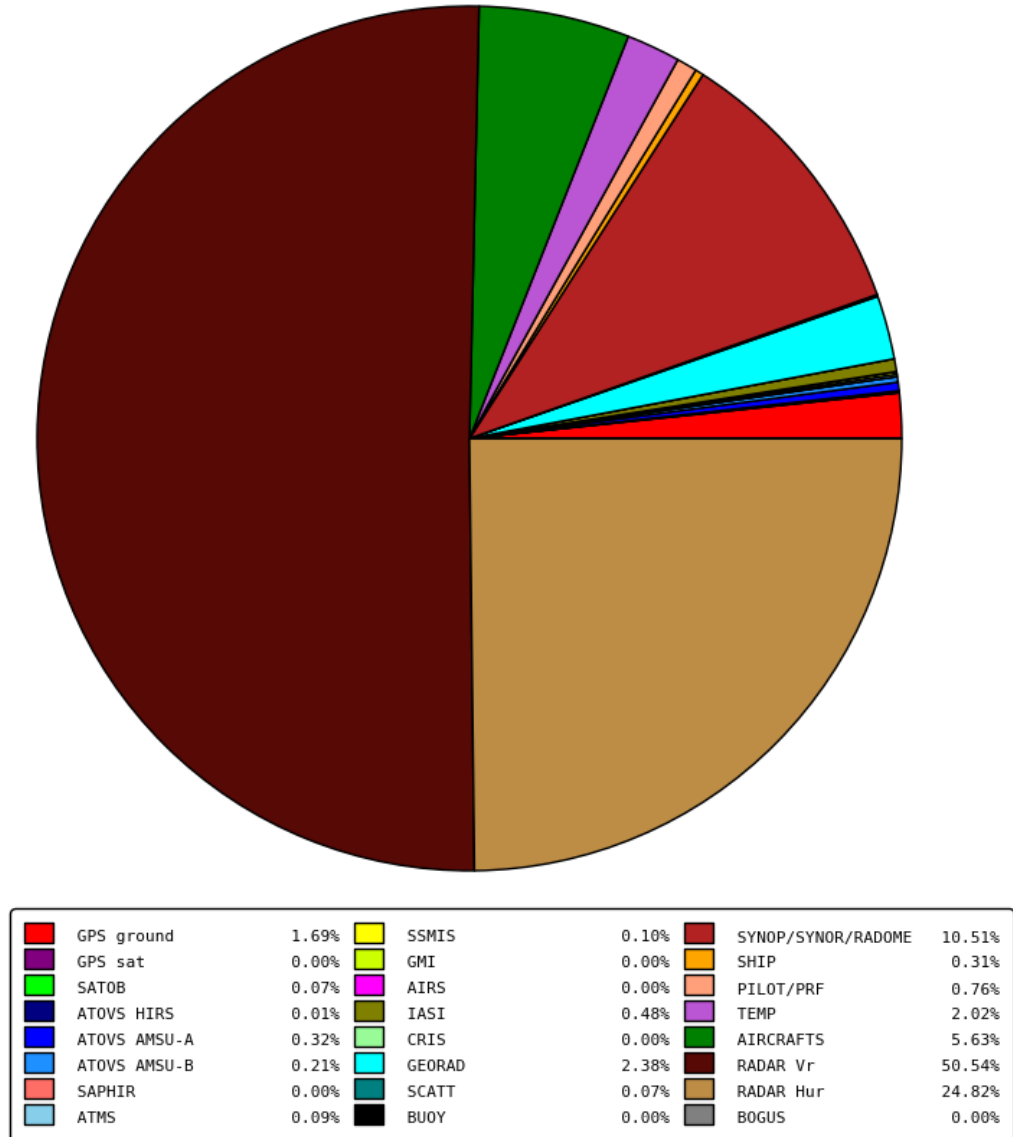cumul du nombre d'observations utilisées sur la période 2015112000 - 2015112023 : 1753089

GPS ground	1.28%	SSMIS	0.11%	SYNOP/SYNOR/RADOME	9.14%
GPS sat	0.00%	GMI	0.00%	SHIP	0.38%
SATOB	0.07%	AIRS	0.00%	PILOT/PRF	0.73%
ATOVS HIRS	0.00%	IASI	0.91%	TEMP	3.88%
ATOVS AMSU-A	0.42%	CRIS	0.00%	AIRCRAFTS	5.14%
ATOVS AMSU-B	0.17%	GEORAD	1.72%	RADAR Vr	39.83%
SAPHIR	0.00%	SCATT	0.05%	RADAR Hur	36.03%
ATMS	0.13%	BUOY	0.00%	BOGUS	0.00%

- Courtesy by MF/DirOP/COMPAS

Degrees of Freedom for Signal of observations entering the AROME assimilation:
how to quantify the ability of an observation type to modify the analysis

$$DFS = N - Tr\left(P^a\right)$$

Part des DFS par type d'obs
analyses cut-off AROME - AROME France dbl
observations conventionnelles et satellites
cumul du DFS sur la période 2015112000 - 2015112023 : 408959

GPS ground	1.69%	SSMIS	0.10%	SYNOP/SYNOR/RADOME	10.51%
GPS sat	0.00%	GMI	0.00%	SHIP	0.31%
SATOB	0.07%	AIRS	0.00%	PILOT/PRF	0.76%
ATOVS HIRS	0.01%	IASI	0.48%	TEMP	2.02%
ATOVS AMSU-A	0.32%	CRIS	0.00%	AIRCRAFTS	5.63%
ATOVS AMSU-B	0.21%	GEORAD	2.38%	RADAR Vr	50.54%
SAPHIR	0.00%	SCATT	0.07%	RADAR Hur	24.82%
ATMS	0.09%	BUOY	0.00%	BOGUS	0.00%

- Courtesy by MF/DirOP/COMPAS

Variational bias correction (VarBC)

- « old fashioned » bias correction was static (eg. Harris-Kelly method)

- « modern » bias correction of assimilated data is done « adaptively », based on the VarBC formulation

- Idea : all obs types collaborate in order to adapt bias correction terms for specific obs types, using the variational (minimization) framework of 3D/4D-VAR

- Formulation : in addition to evaluating the analysis increment (the *Delta X0* of the next slide), an increment for the bias correction coefficients is also evaluated during the minimization (the *Delta Beta* of the next slide). As minimization goes on, the updated bias correction terms are continuously added to the obs minus background term of Jo (the *minus P times Delta Beta* of the next slide)

Incremental strong constraint 4D-VAR with increments w.r.t x_0^g

$$J(\delta x_0, \delta \beta) = \frac{1}{2} \left\| \begin{bmatrix} b \\ c \\ d \end{bmatrix} - \begin{bmatrix} I & 0 \\ 0 & I \\ H & P \end{bmatrix} \begin{bmatrix} \delta x_0 \\ \delta \beta \end{bmatrix} \right\|_{\tilde{B}^{-1}}^2$$

Where

$$b = x_0^b - x_0^g$$

$$c = \beta^b - \beta^g$$

$$d = y - \mathcal{H}(x_0^g) - P(x^g)\beta^g$$

$\tilde{\mathbf{B}}^{-1} = \operatorname{diag}(B_0^{-1}, \mathbf{B}_\beta^{-1}, \mathbf{R}^{-1})$.

Weak constraint 4D-VAR

$$J(\delta x, \delta \beta) = \frac{1}{2} \left\| \begin{bmatrix} b \\ c \\ d \end{bmatrix} - \begin{bmatrix} L & 0 \\ 0 & I \\ H & P \end{bmatrix} \begin{bmatrix} \delta x \\ \delta \beta \end{bmatrix} \right\|_{\tilde{B}^{-1}}^2$$

with $\tilde{\mathbf{B}}^{-1} = \operatorname{diag}(\mathbf{D}^{-1}, \mathbf{B}_\beta^{-1}, \mathbf{R}^{-1})$ and $\mathbf{b} = \mathbf{p}^b - \mathbf{p}^g$
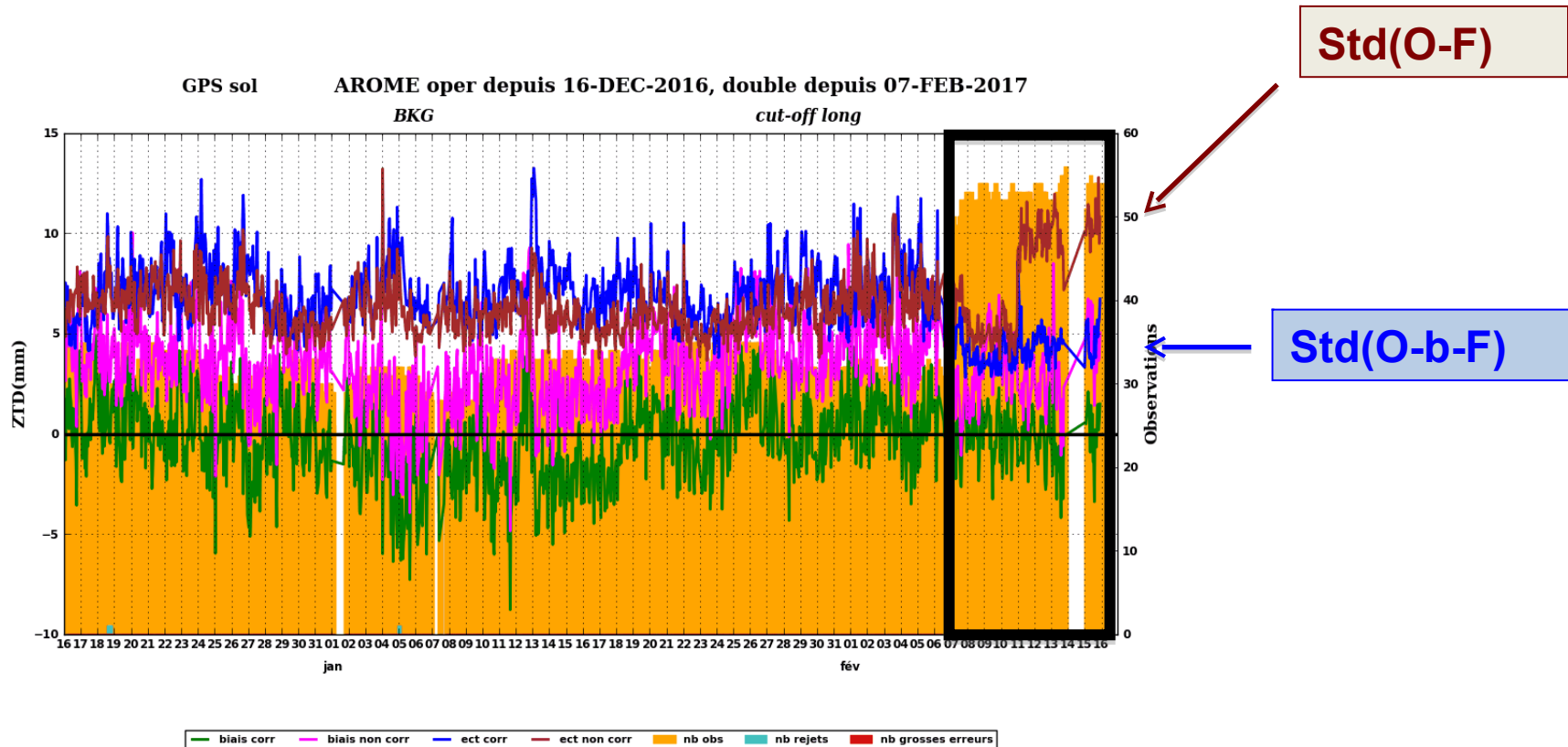
$$J(\delta \mathbf{x}, \delta \beta) = \frac{1}{2} \|\mathbf{b} - \mathbf{L}\delta \mathbf{x}\|_{\mathbf{D}^{-1}}^2 + \frac{1}{2} \|\mathbf{c} - \delta \beta\|_{\mathbf{B}_\beta^{-1}}^2 + \frac{1}{2} \|\mathbf{d} - \mathbf{H}\delta \mathbf{x} - \mathbf{P}\delta \beta\|_{\mathbf{R}^{-1}}^2$$

Oper bias correction for GPS/ZTD in Arome-France
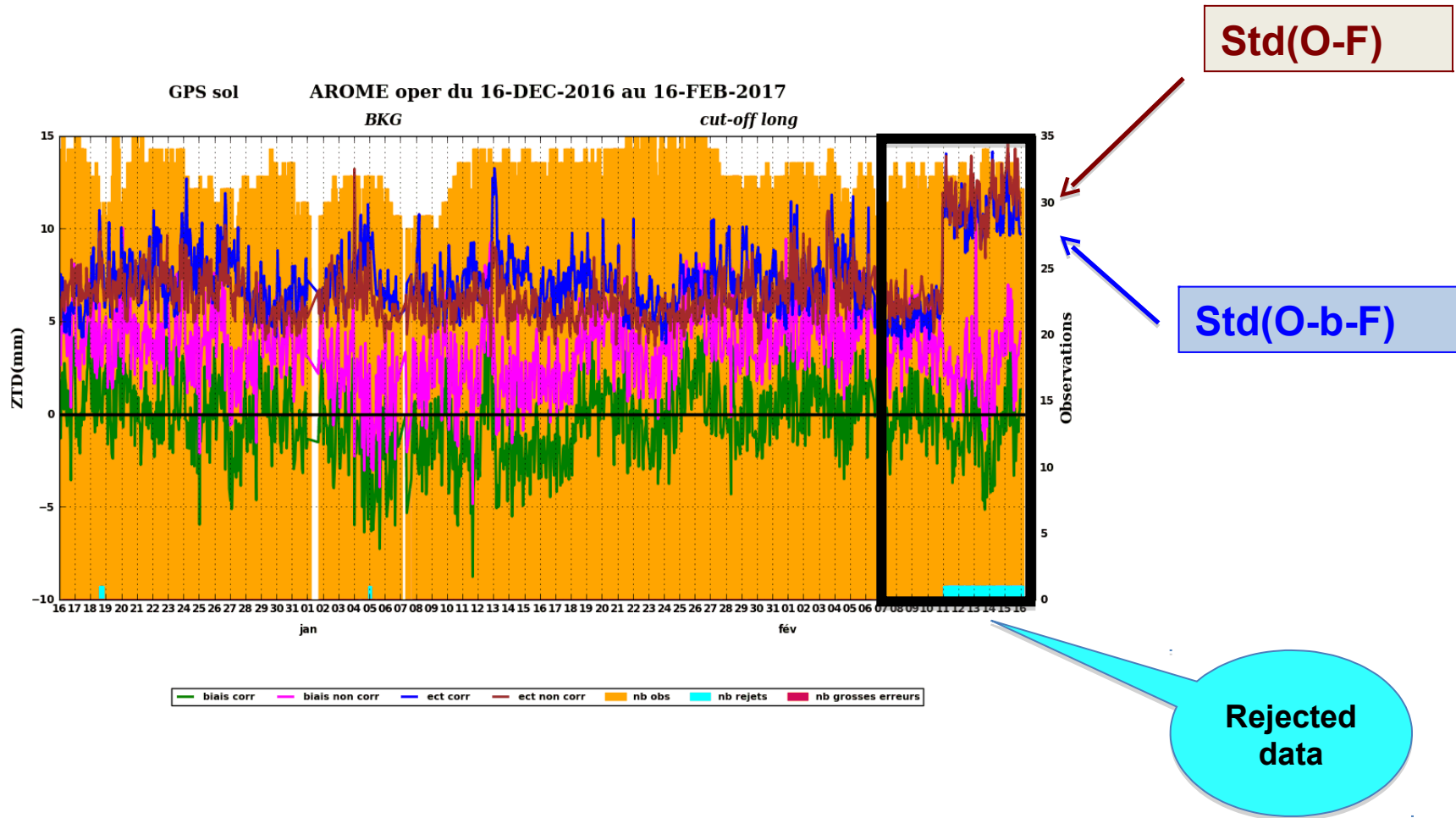
Static bias correction

Present e-suite (CY42_op2) : VarBC for GPS/ZTD in Arome-France


Std(O-F)

Std(O-b-F)

Adaptive bias correction

Data assimilation suite : tools in MF

- Operations have their own scripting system (Unix Shell scripts)

- Research Dept uses experimental interface via OLIVE

- Common underlying toolbox presently being deployed in both Operations and Research (VORTEX)

- Specific parameters regurlarly scrutinized (Oper and Res.) :
  - time critical path,
  - duration of tasks on the critical path,
  - cutoff times for observations and times of start of tasks,
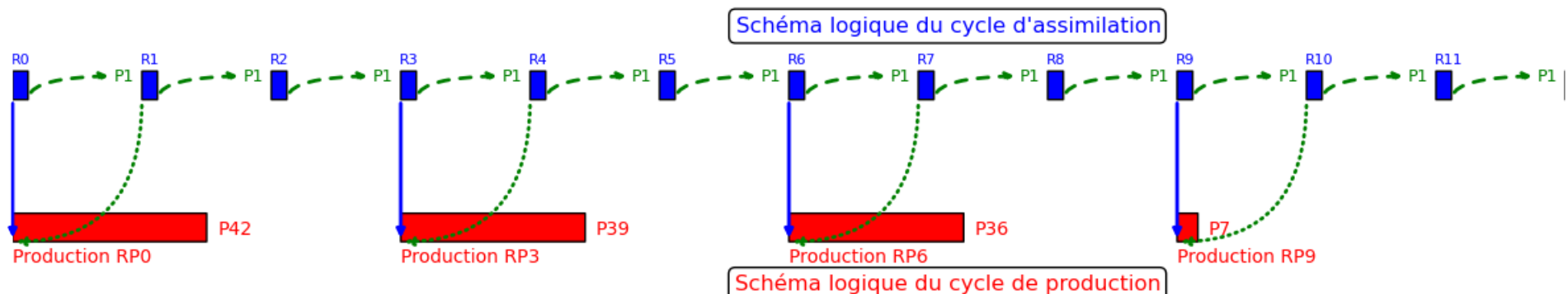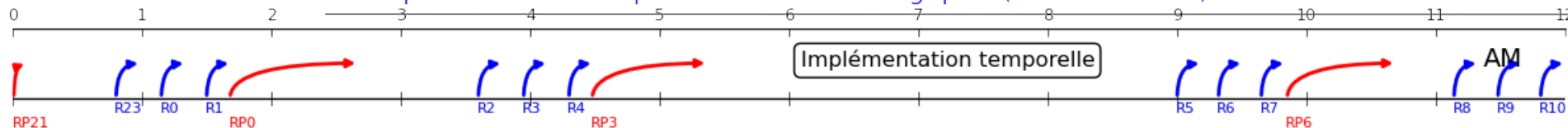 - delivery time of model outputs for the downstream production

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ARPEGE DA and production suite

CHAINE DE PREVISION OPERATIONNELLE POUR ARPEGE
schéma logique (heures en UTC)
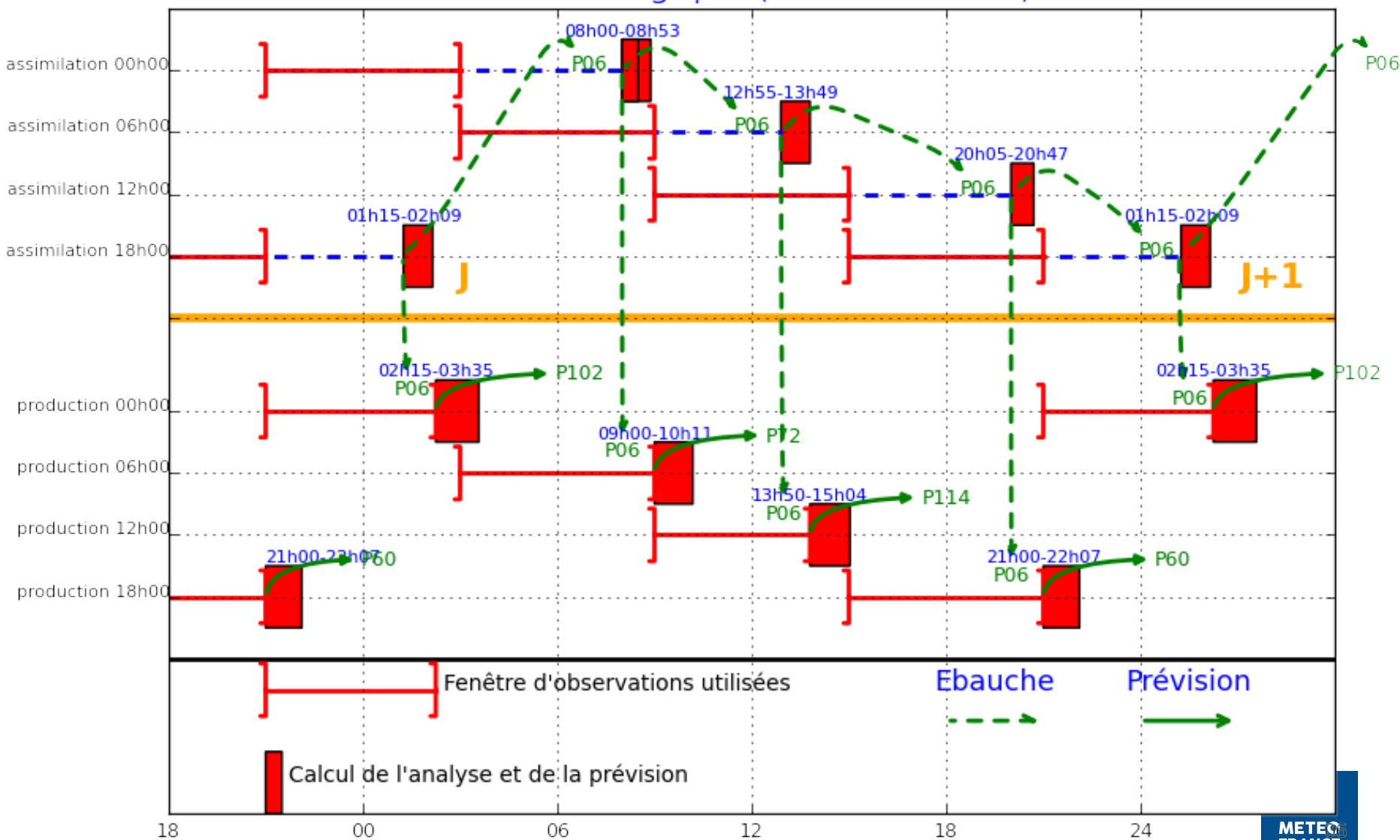
AROME-France DA and production suite

CHAINE DE PREVISION OPERATIONNELLE POUR AROME
Implémentation temporelle et schémas logiques (heures en UTC)
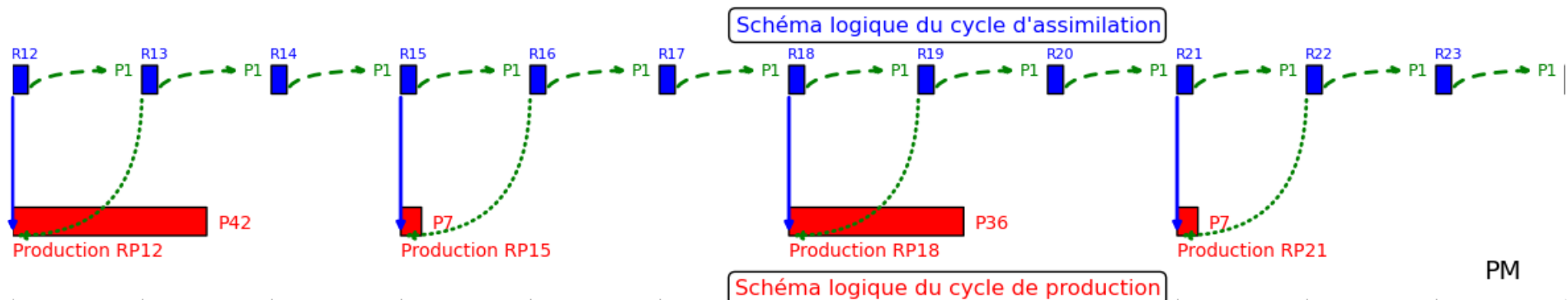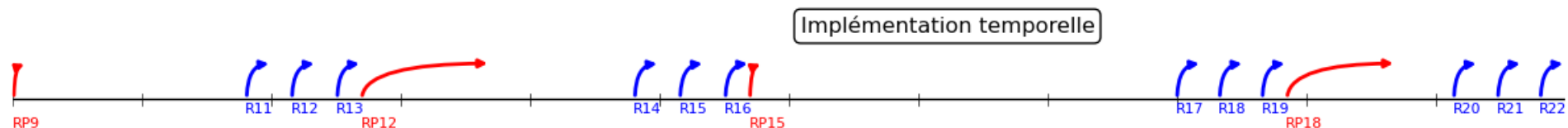
How to update a LAM forecast state with an analysis from Arpège or IFS ?

- In AROME-France : Incremental Analysis Update (IAU) is used to inject the AROME analysis from the follow-on network (H+1h) into the production forecast of the previous network (H). IAU is applied between H+30mn and H+1h in the production run.

- In AROME-Overseas : an IFS analysis increment is computed using the +6h LBC data from the previous IFS network and the +0h LBC data for the current network. IAU is applied between H-1h and H (the actual target network time for the start of the production forecast).

- Can IAU be of interest to some partners, wishing to blend a high resolution forecast (from a previous run) with a « fresh » analysis valid for the current time ? (in dynamical adaptation mode).

- In cycling mode : not tested at MF.

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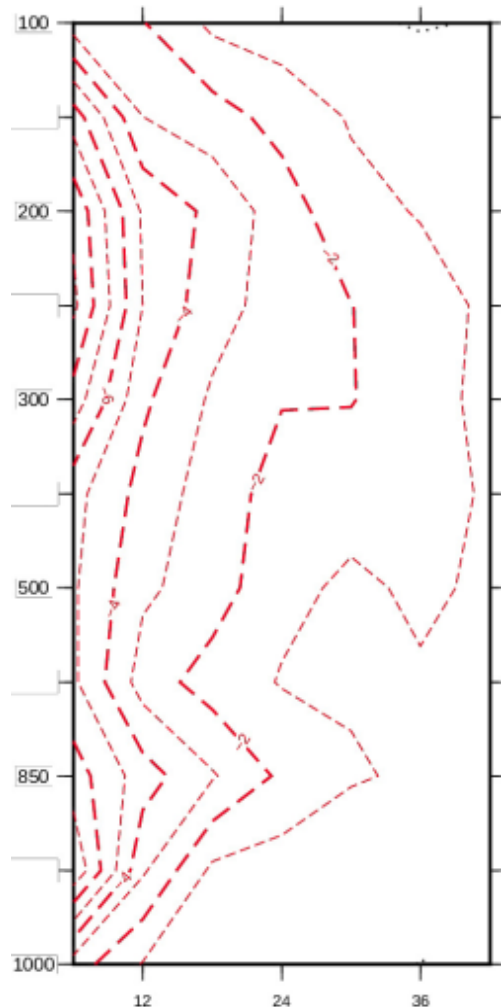# Simulated radar reflectivity field for Tropical Cyclone Fantala

- Courteous by G. Faure
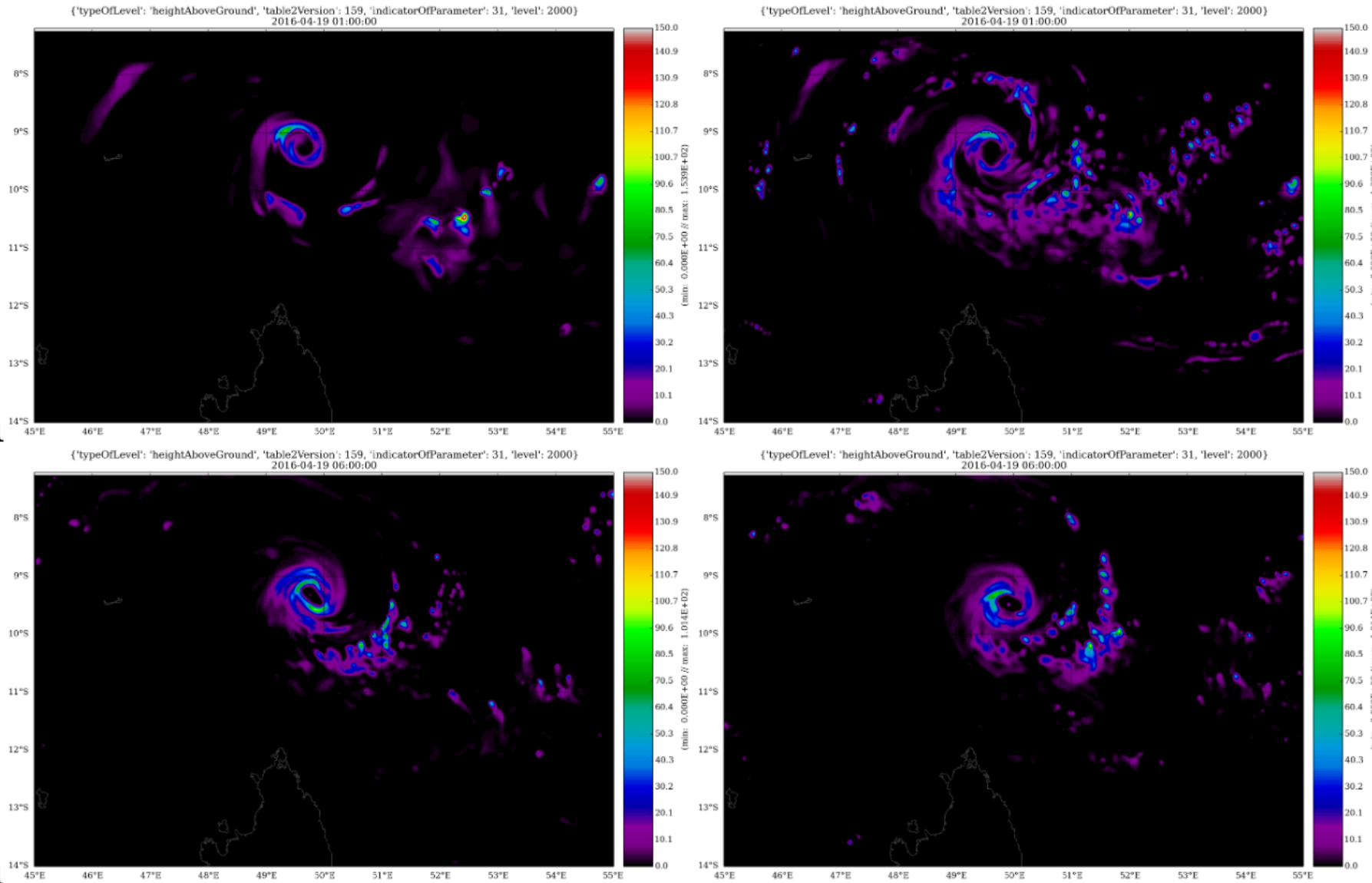
RMS scores for relative humidity, compared between dyn adapt networks and with or without IAU
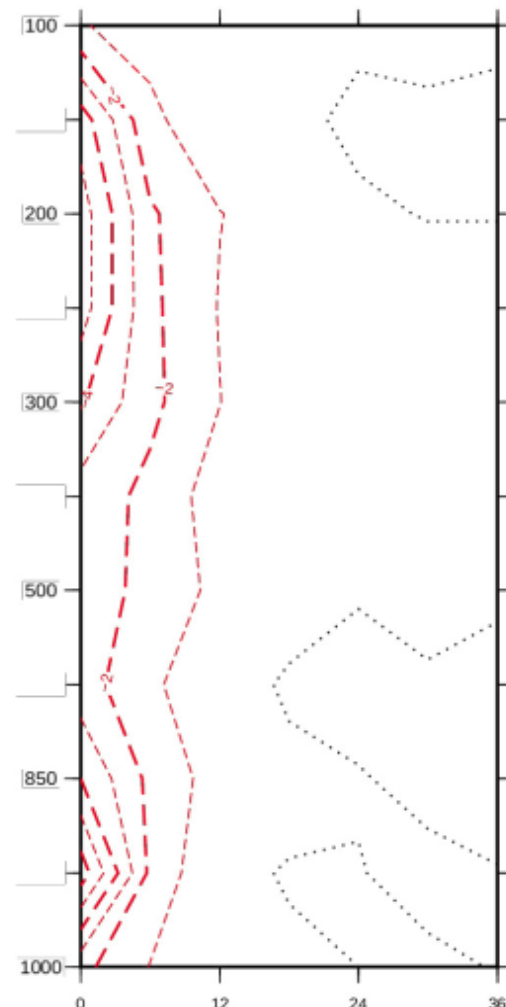
Réseau N-1 vs réseau N

Avec IAU vs Sans IAU

Domaine Antilles

Min=-9.23 Max=0.1 Moy=-2.21

Min=-6.59 Max=0.17 Moy=-0.90

24 simulations (500hPa) de 42 h du 20160602 au 20160627

Courteous by G. Faure

Thank you for your attention !