Handling Biases in Surface Pressure (Ps) Observations in Data Assimilation

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- **Introduction/Motivation**
- **Choice of Ps Bias Correction Methods:**
  - ➔ **OI Method**
  - ➔ **Kalman Method**
- **Practical Implementation**
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- **Ps Bias Correction Monitoring**
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Introduction/Motivation

- It is well known that Ps observations reported by a large number of SYNOP (both land and sea based) and DRIBU stations are biased, by several hPa in many cases
- The biases are mostly related to incorrect assumptions about the station heights, and remain fairly constant in time
- Several hundred stations would normally appear on the ECMWF blacklist due to a significant long-term bias
- A practical scheme is needed to estimate and correct observational Ps bias

Ps Bias Correction Methods: OI and Kalman

- A few years ago, at ECMWF, Anders Persson (AP) and Peter Janssen (PJ) each proposed suitable adaptive methods for bias correction of Ps time series
- They are based on linear estimation theory and are referred to as Kalman (AP) and OI (PJ) methods, respectively
- They are essentially similar in that they provide estimates of the bias and its confidence station by station, based on time series of observation-minus-background departures (O-M)
- Both methods rely on two assumptions:

  ➔ That the observational Ps bias is local for a given station (assuming no spatial correlation), and

  ➔ That the there is no, or small, model bias

OI Method

- The new bias estimate B_n is found as a linear combination between previously estimated bias B_p and new observation departure D_n:

$$B_n = W_p D_n + (1 - W_p)\, B_p$$

- W_p is the interpolation weight calculated at the previous observation departure occurrence D_p
- The new bias interpolation weight $W_{n,}$ to be used for the next departure occurrence, is calculated as:

$$W_n = \sigma^2_{b\_n} / (\sigma^2_{b\_n} + \sigma^2_{o\_n})$$

- $\sigma^2_{b\_n}$ and $\sigma^2_{o\_n}$ are new bias estimate and observation variances, respectively
- They are calculated in a two step procedure

OI Method

- In the first step, intermediate or "guess" variances $\sigma^2_{o\_g}$ and $\sigma^2_{b\_g}$ are found:

$$\sigma^2_{o\_g} = \min\,[D^2_n,(D_n-B_n)^2]$$

$$\sigma^2_{b\_g} = [(D_n-B_n) - (D_p-B_p)]^2 / C$$

- C is a constant(=16)
- In the second step the final variances are calculated:

$$\sigma^2_{o\_n} = W_c\sigma^2_{o\_g} + (1-W_c)\sigma^2_{o\_p}$$

$$\sigma^2_{b\_n} = W_p\sigma^2_{b\_g} + (1-W_p)\sigma^2_{b\_p}$$

- $\sigma^2_{o\_p}$, $\sigma^2_{b\_p}$ are the previous bias estimate and observation variances
- W_c is a constant interpolation weight (=0.010)

Kalman Method

- "First Guess" bias estimate B_g and its variance $\sigma^2_{b\_g}$ are found first:

$$B_g = AB_p$$

- B_p is the previous bias estimate and A(=1.0) is a coefficient
- "System Performance Constant" S is calculated next:

$$S = F(D_n - B_p)^2$$

- F is a "fading" term to simulate memory (=0.001) and D_n is new departure
- "Guess" value of the bias estimate variance $\sigma^2_{b\_g}$ is found next:

$$\sigma^2_{b\_g} = A^2\sigma^2_{b\_p} + S$$

- $\sigma^2_{b\_p}$ is the previous bias estimate variance

Kalman Method

- New bias estimate B_n is found as:

$$B_n = W_n D_n + (1-W_n) B_g$$

- W_n is the new bias interpolation weight:

$$W_n = \sigma^2_{b\_g} / (\sigma^2_{b\_g} + b^2_o)$$

- σ^2_o is the observation variance (kept constant)
- New bias estimate variance $\sigma^2_{b\_n}$ is calculated:

$$\sigma^2_{b\_n} = (1-W_n)^2 \sigma^2_{b\_g} + W^2_n \sigma^2_{b\_p}$$

Practical Implementation

- Based on these two methods a practical scheme was needed for estimating and correcting Ps bias
- Such a scheme has been developed
- Almost all the development work and preliminary testing and tuning was done off-line
- Both the OI and Kalman methods have been included and tested with the scheme
- For the final testing and experimentation and its eventual operational implementation the ECMWF analysis-forecast system had to be modified
- Ps bias correction was introduced operationally in the ECMWF operational analysis-forecasting system earlier this year

Practical Implementation

- **Any practical scheme needs to carry forward (cycle) in time a number of parameters: departures, bias estimates, weights, variances etc.**
- **Except for the departures, all the relevant parameters are internal to the scheme**
- **Departures are provided externally by the analysis**
- **The cycling mechanism is provided by the scheme's database (PSBIAS)**
- **PSBIAS is a type of hierarchical database modelled on the operationally used ODB database used for storing and handling observations in the ECMWF analysis-forecast system**
- **PSBIAS main entry points are stations**
- **Each entry point or station is then further divided into a HEADER and BODY with appropriate links**

Practical Implementation

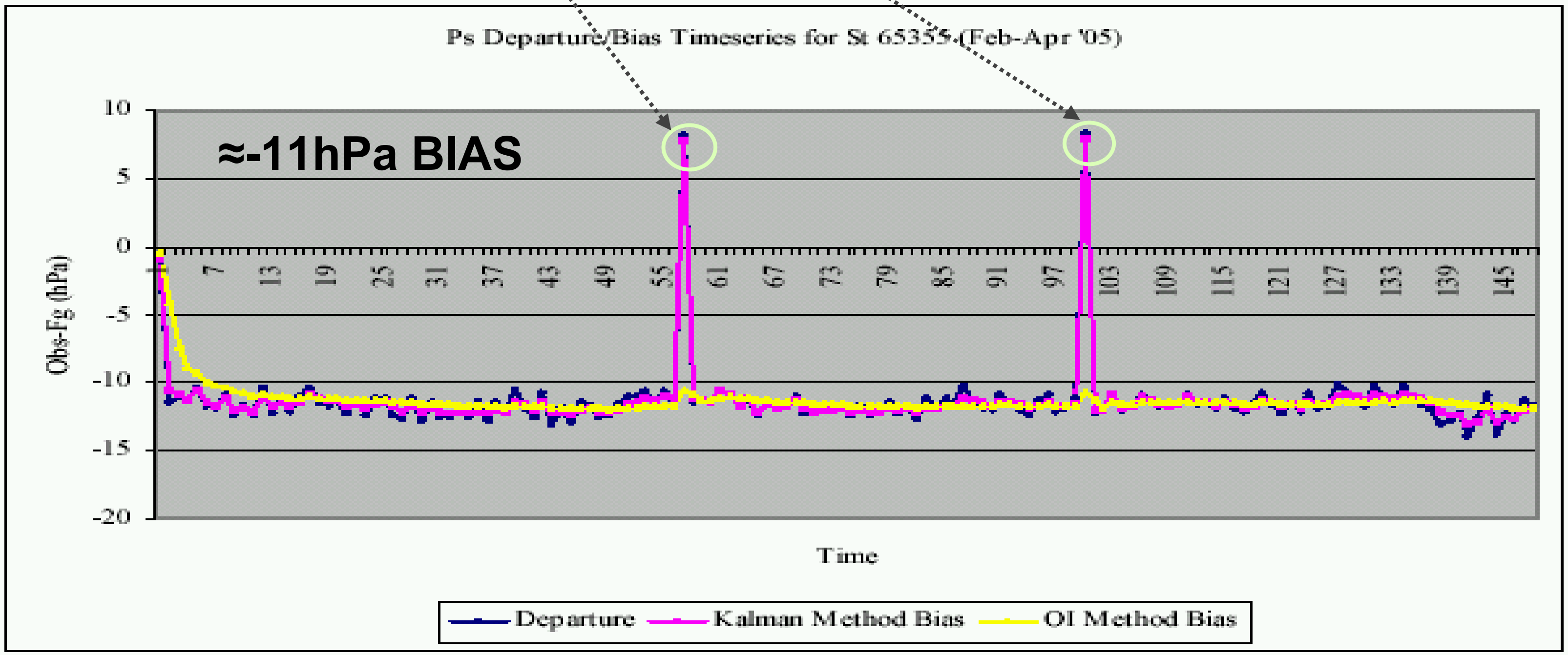
- HEADER has 72 columns holding both the basic station parameters (ID, Lat, Lon, Date, Time etc.) as well as all relevant Ps bias correction parameters needed to be carried forward in time in order to perform the Ps bias correction (Current and Previous Departures, Interpolation Weights, Bias Estimates and Observation variances, etc.)
- Each BODY keeps the station time record which is up to one month long for hourly observations and longer for less frequent observations
- Information kept in the BODY are: Date, Time, Observed Ps, Departure, Bias Estimate etc.
- A single BODY has up to 756 (31*24+12) entries with 15 columns each

Practical Implementation

- PSBIAS database normally contains about 11000+ entries/stations
- Not all stations are considered for Ps bias corrections for example if:
  - ➔ Station height is missing, or
  - ➔ Height difference between station and model is grater then 200m
- Bias is calculated only if station sample size (timeseries length) is big enough; currently sample size limit is set to 30
- Station is assumed to be biased only if its bias estimate is bigger then 1 standard deviation
- Currently bias estimates smaller then 1hPa are discarded in order to avoid correcting for possible small model bias
- Too old bias estimates are not used; bias estimates older then 5 days are considered as old and are recalculated (cold start)
- Both proposed schemes, OI and Kalman, are run in parallel and their bias estimates with other relevant parameters stored in the PSBIAS every analysis cycle

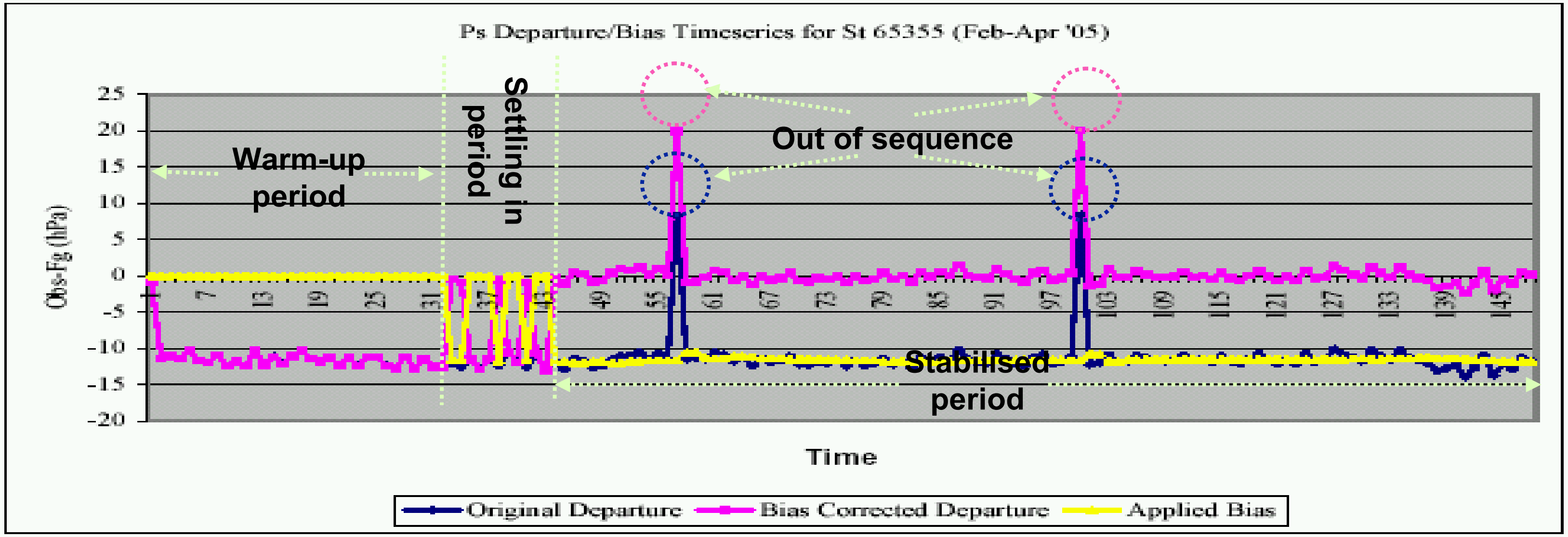
Practical Implementation

- Ps departure, Kalman and OI bias estimates for 65355 station (Feb-Apr '05)
- Ignore TWO spikes for now
- Kalman bias estimates" follow" departures too closely; OI bias estimates are somewhat smoother
- Attempted to make Kalman method broader operator by modifying the "System Performance Constant" (S), but results were still poorer
- OI method was chosen as a preferred method for operational implementation



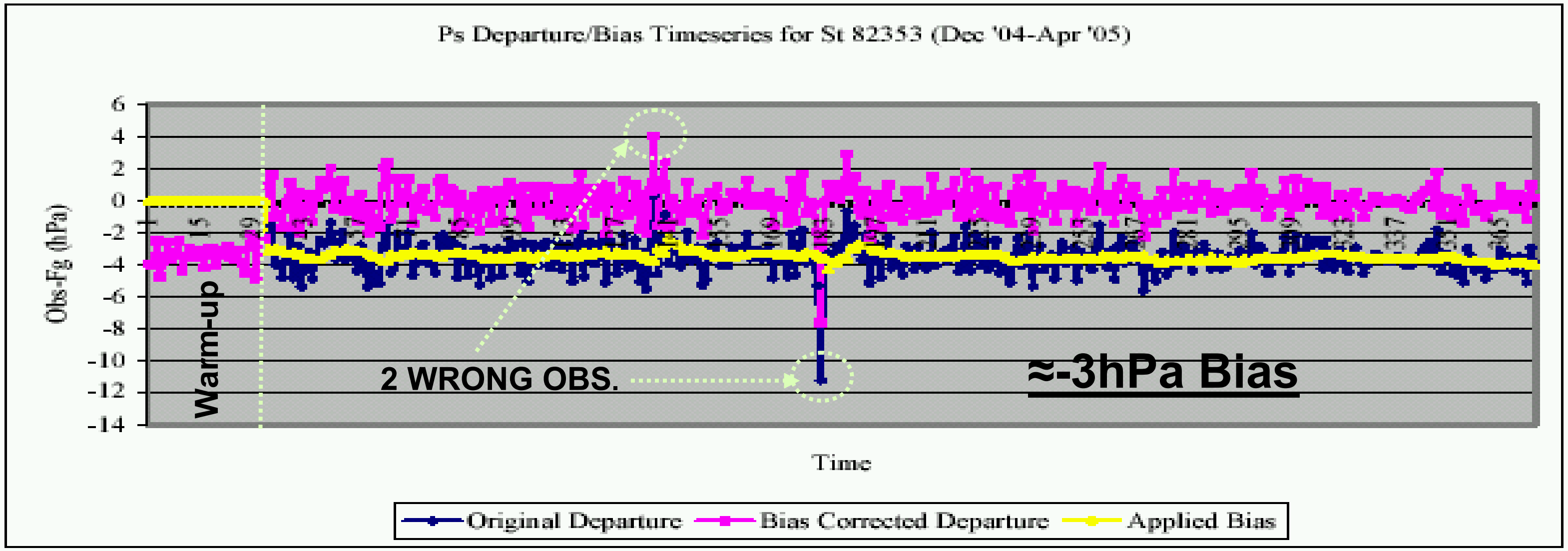
Practical Implementation

- Time series of Original Ps departure, OI Ps bias estimate and Corrected Ps departure for station 65365 (Feb-Apr '05)
- Once the sample size (30) was reached (Warm-up) bias correction kicked in
- To start with the scheme was switching itself on and off before settling in
- Long-term bias (≈-11hPa) was nicely identified and corrected
- Two out of sequence departures; bias correction made it worse but recovered
- Not used station due to the overriding RDB (Report Data Base) flag on the station height
- "First Guess" check also flagged it
- If the station's height was to be corrected, it would have been used in the analysis
- Potential to include more stations by correcting their height and taking them off either the RDB flagging list or blacklist



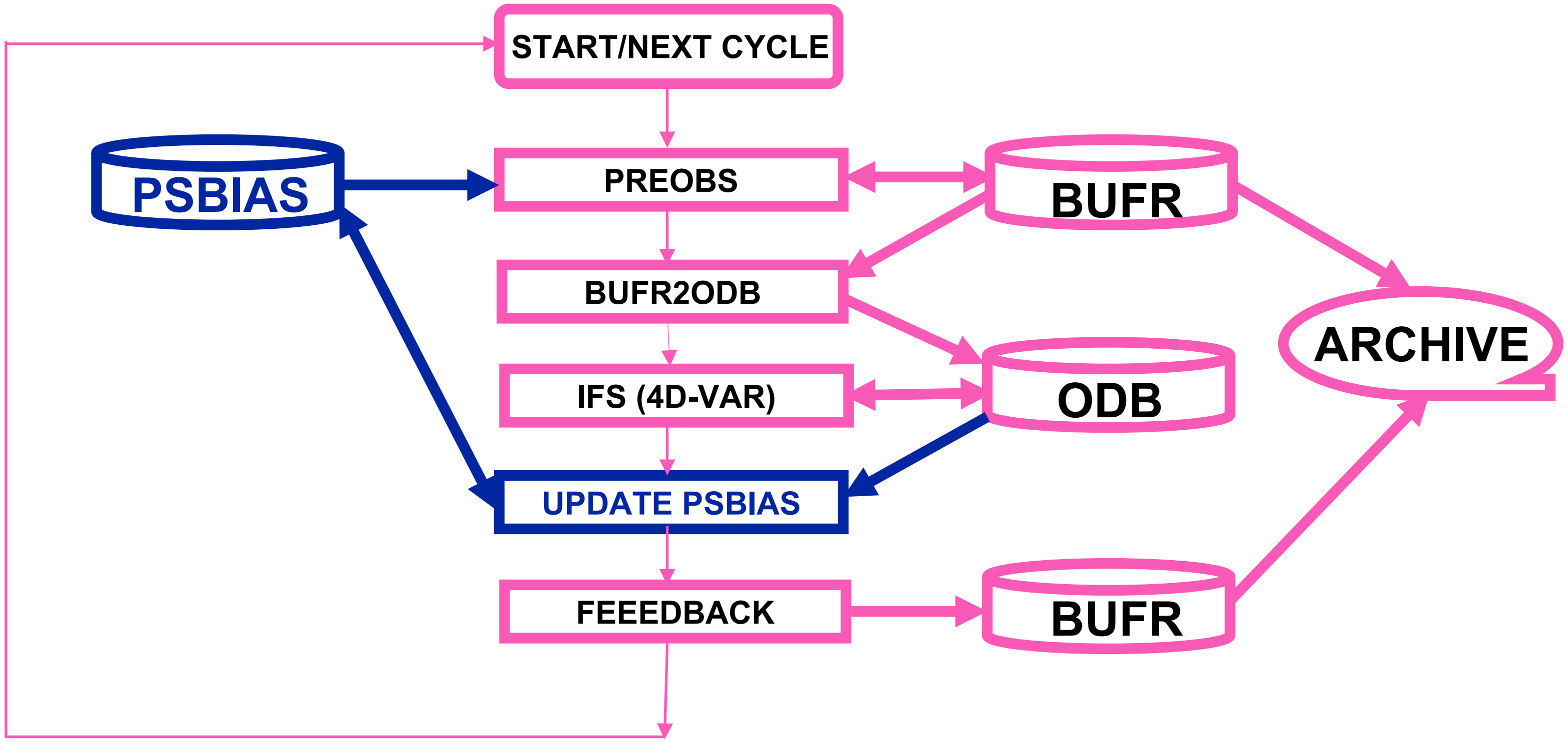
Practical Implementation

- Time series of Original Ps departure, OI Ps bias estimate and Corrected Ps departure for station 82353 (Dec-Apr '05)
- Once the sample size (30) was reached (Warm-up period) bias correction kicked in
- Long-term bias of about -3hPa was recognised and corrected for
- Station height is thought to be correct and real reason for bias is unknown
- Two "wrong observations": (1) positive departure (bias correction made it worse) and (2) negative departure but twice the usual size (bias correction corrected it but still to big)
- If not bias corrected the station was just surviving the "First Guess" check but to be rejected by the analysis check
- When bias corrected, the station survived all the checks and was successfully used in the analysis



Practical Implementation

- Simplified ECMWF operational flow diagram with Ps bias correction scheme included
- Latest Bias is one analysis cycle behind
- Ps bias stored with input BUFR data, hence no need to redo them for experimentation

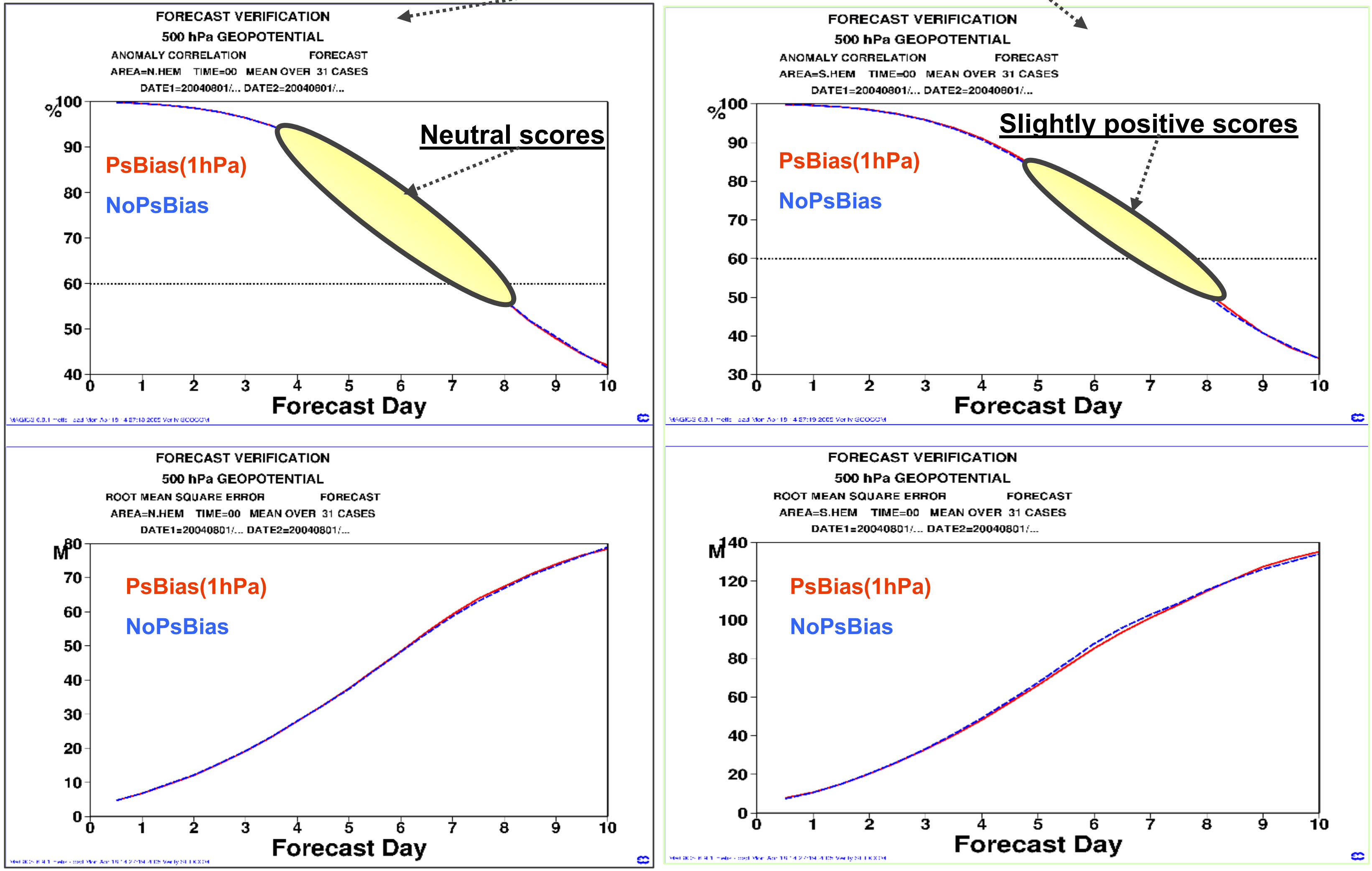


Experiments and Tests

- Prior to the pre operational implementation testing (E-suite) a number of one week long data assimilation experiments WITH and WITHOUT the Ps bias correction were carried out
- In brief they all showed expected results:
  - ➔ A few hundred biased stations
  - ➔ More Ps observation used
  - ➔ Analysis increments somewhat smaller
  - ➔ Neutral forecast scores
- E-suite type experiment (el21) with Ps bias correction ACTIVE was run from 1st August 2004 till 31st December 2004
- E-suite type experiment (el6o) Ps bias correction OFF was run to shadow the el21 during August
- Comparing el21 (Ps bias correction ON) and el6o (Ps bias correction OFF) showed expected results as seen in the shorter runs before:
  - ➔ The scheme performed satisfactorily
  - ➔ 800-1000 bias corrected station
  - ➔ Overall a better fit to Ps observations
  - ➔ Average analysis increments slightly reduced
  - ➔ Forecast scores: neutral in the Northern hemisphere and slightly positive in the Southern hemisphere
- Good confidence to continue with the E-suite type experiment el21

Practical Implementation

- 10-day forecast 500hPa Geopotential anomaly correlation scores and RMS errors for "PsBias(1hPa)" and "NoPsBias" runs for the Northern and Southern hemispheres; August 2004



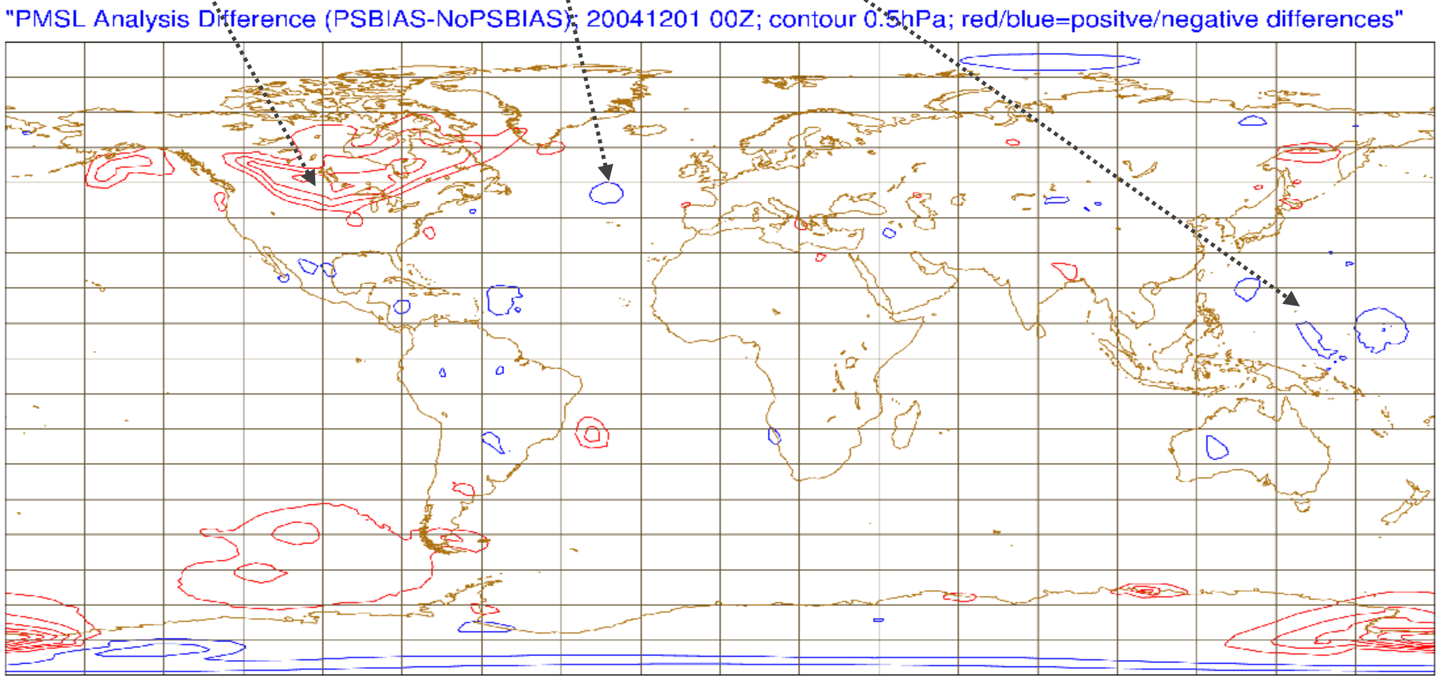
Experiments and Tests

- As already said the E-suite type experiment el21 ("PsBias(1hPa)") went on till the end of December 2004
- E-suite type experiment was compared with Operations
- During September-November 2004 all seemed fine
- However the forecast scores did not look that good for December 2004
  - ➔ Neutral in the Southern hemisphere, and
  - ➔ Rather negative in the Northern hemisphere
- This needed further investigation
- New E-suite type experiment (eltv) for December 2004 was started from el21 with Ps bias correction switched OFF
- PMSL analysis difference between these two runs for the very first analysis cycle (01/12/2004 00Z) are looked at first

Experiments and Tests

- **Ps analysis differences ("PsBias(1hPa)"-"NoPsBias") for 01/12/2004 00Z**

- **Differences are manly SMALL and LOCAL, however there is a rather large scale positive (2hPa) difference ("BLOB") over the North America (USA/Canada)**
- **The "BLOB" stayed there for about two weeks, just moving around slightly**
- **Furthermore, the "BLOB" survived in the ensuing forecasts and propagated downstream with the flow, thus contributing to the bad forecast scores**



Experiments and Tests

- There was no immediate answer to what went wrong
- PSBIAS database for this particular analysis cycle (12 hour) was checked:
  - ➔ Total number of Ps stations in the region was about 135 (1200 reports) of which 60% or 80 stations (950 reports=250 SYNOPs + 700 METARs) were bias corrected
  - ➔ Ps bias size ranged from -1hPa to -3hPa (negative bias)
- It was not expected feature to have the same bias sign for all of them
- The first assumption when designing the Ps bias correction scheme was that:

<u>Observational Ps Bias Is Not Spatially Correlated</u>

- Looking at the time series for the bias corrected stations leading up to this analysis cycle one could not see anything unusual

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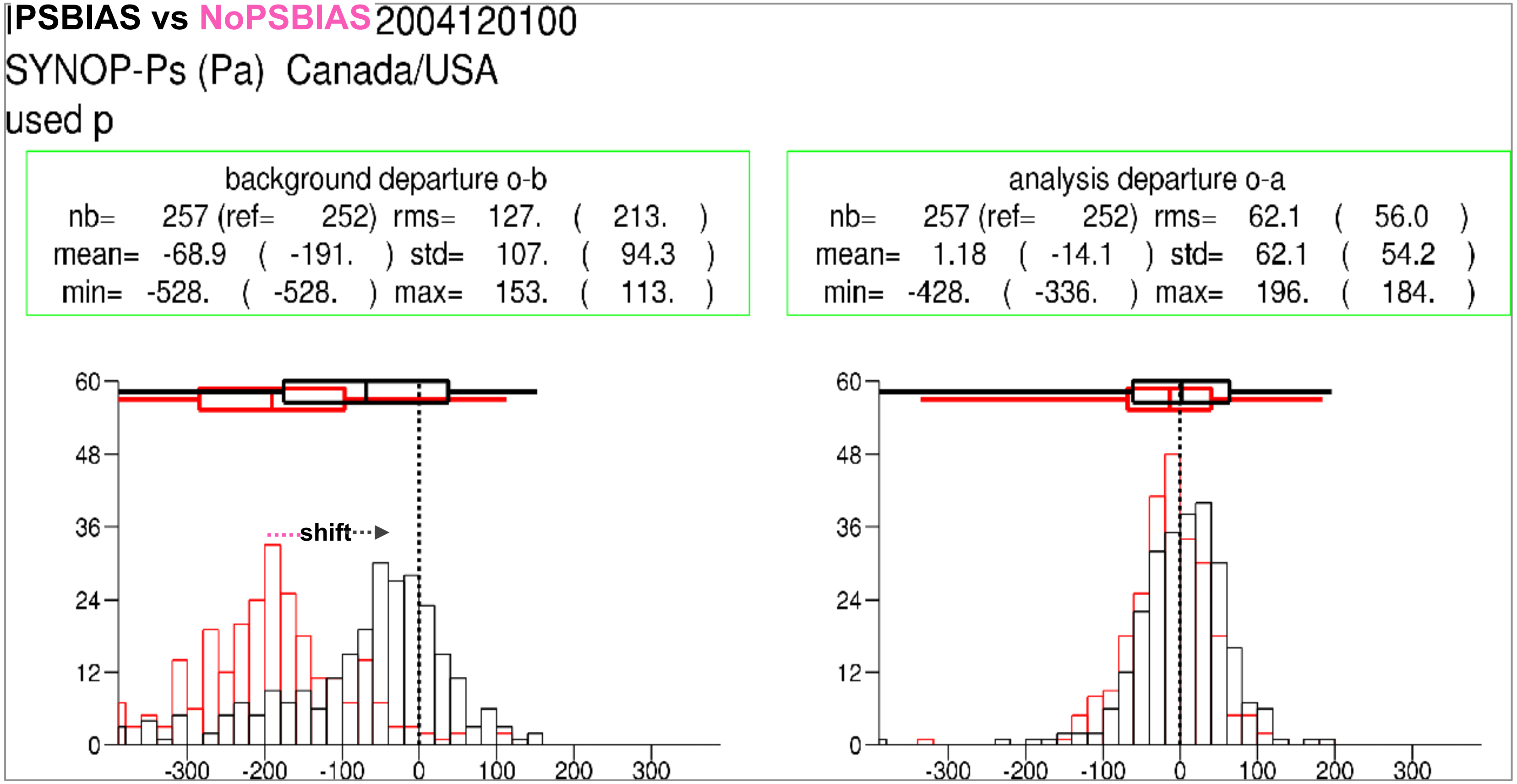
Experiments and Tests

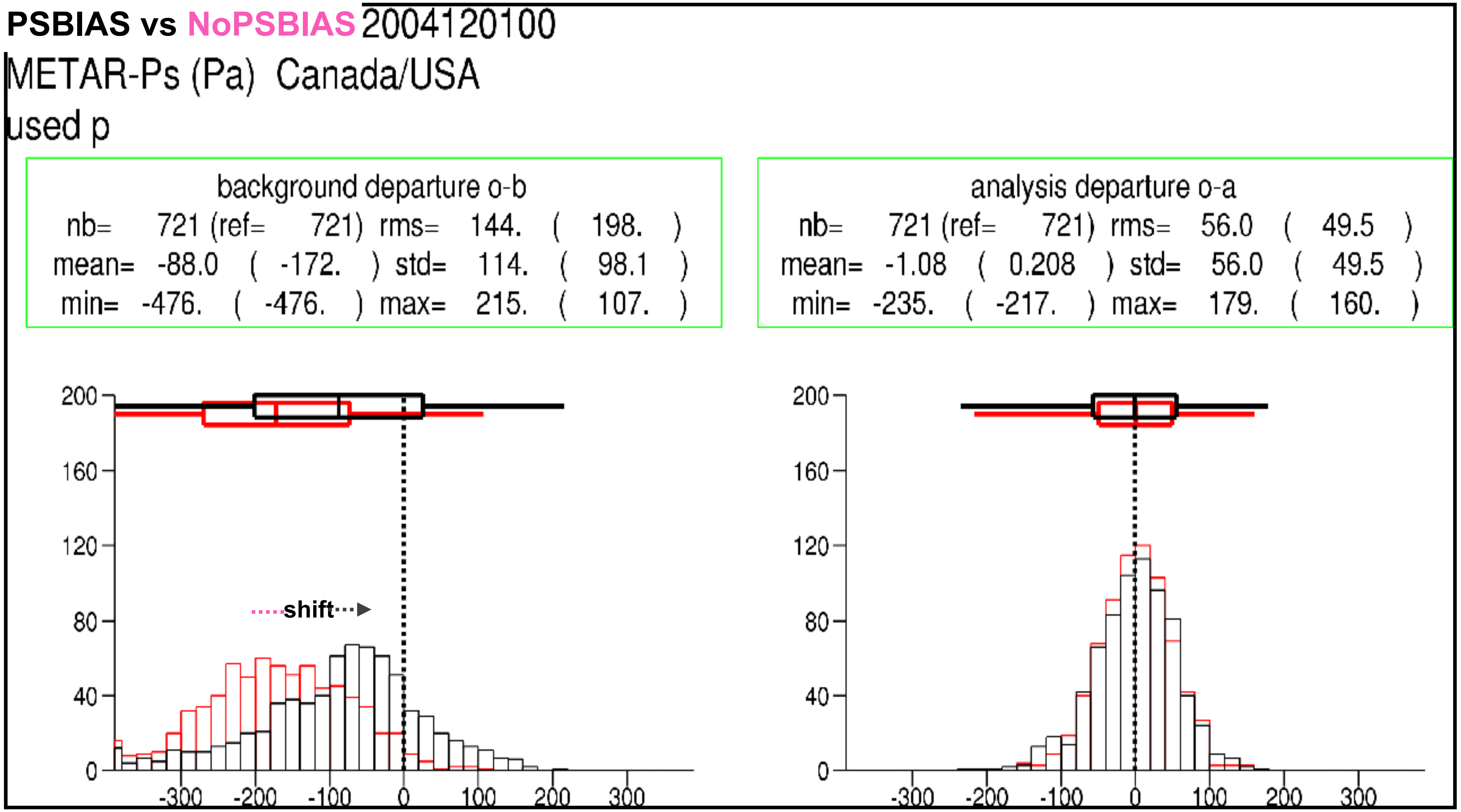
- Background and Analysis fit to SYNOP Ps data for "PSBIAS" (BLACK) and "NoPSBIAS" (RED) runs for 01/12/2004 00Z
- "NoPSBIAS" run shows -2hPa bias, hence the "PSBIAS" run did a rather good job by recognising and removing it
- Both Analyses fit Ps data well, however the "PSBIAS" analysis creates the "BLOB" which in the ensuing forecast propagates downstream and has negative impact on the forecast scores



Experiments and Tests

- **Background and Analysis fit to METAR Ps data for "PSBIAS" (BLACK) and "NoPSBIAS" (RED) runs for 01/12/2004 00Z**
- **"NoPSBIAS" run shows -2hPa bias and "PSBIAS" run, again, did a rather good job by recognising and removing it**
- **Both analyses fit Ps data well, however the "PSBIAS" analysis creates the "BLOB" and has negative impact on forecast scores**

PSBIAS vs NoPSBIAS



Experiments and Tests

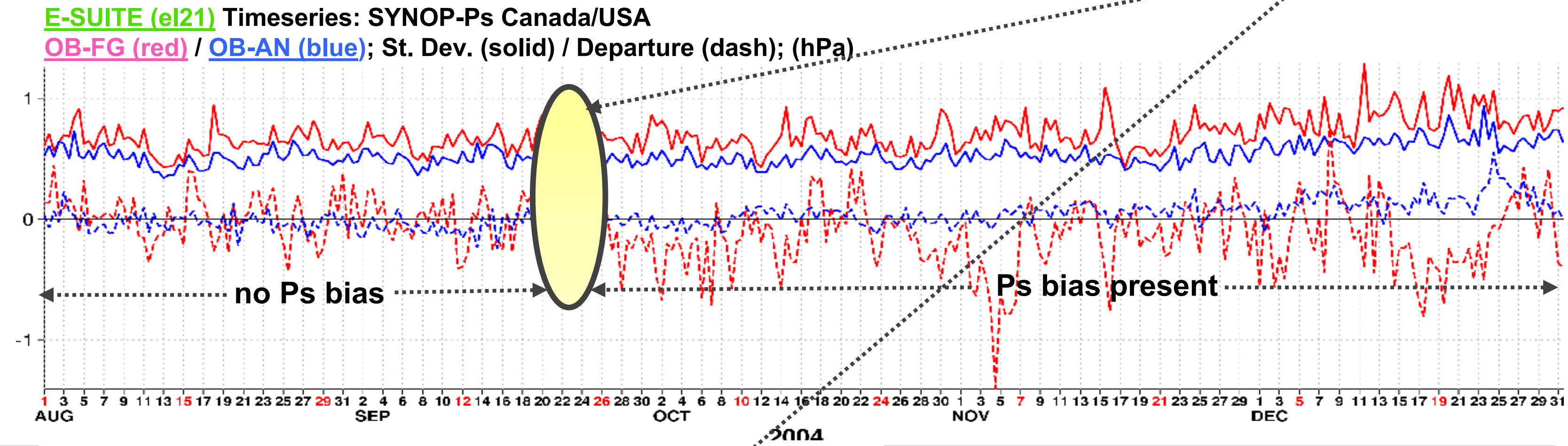
- None of the just described behaviour was noticed during the August runs
- The question was:

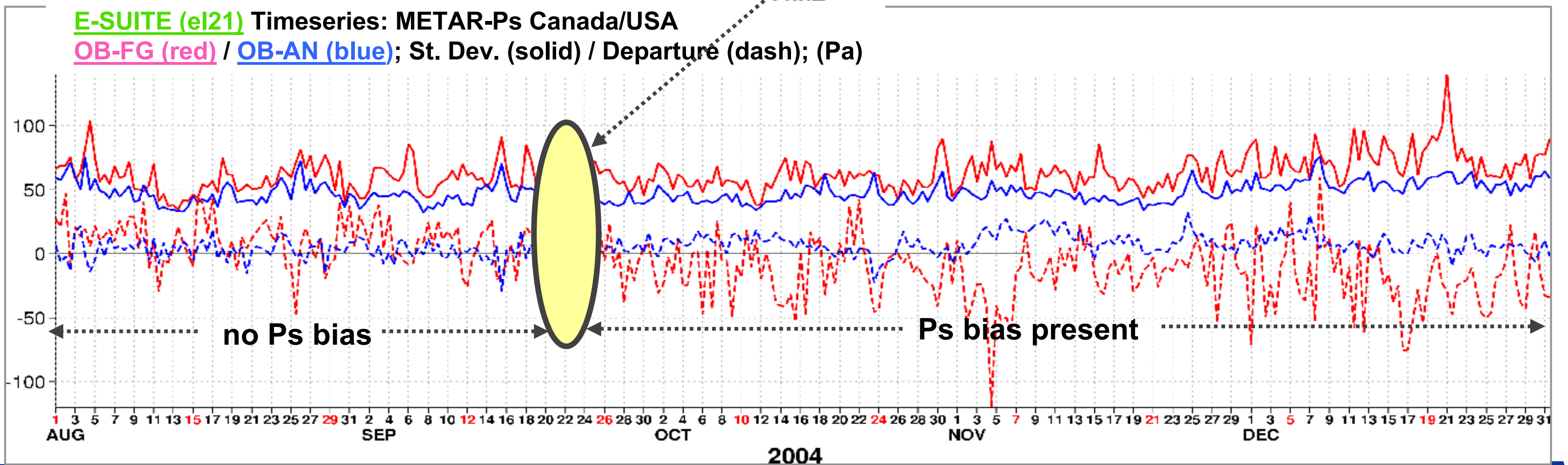
What Happened With Ps Biases From September Till The End December?

- No immediate answer to what went wrong
- In order to try to answer this question maybe a Ps departure time series for the Canada/USA region is a good starting point to look at for further investigation
- Long (August-December) E-suite type experiment el21 ("Ps Bias" run)
- Separate timeseries for SYNOP and METAR
- Operational run, but only for SYNOP

Experiments and Tests

- **Ps departures (dash) and Standard Deviation (solid) timeseries for E-SUITE (el21) for SYNOP (TOP) and METAR (BOTTOM) observations during August-December period for Canada/USA**
- **Very similar picture for both data sets**
- **For both types, at the end of September the bias started creeping in (Ps Bias Onset)**

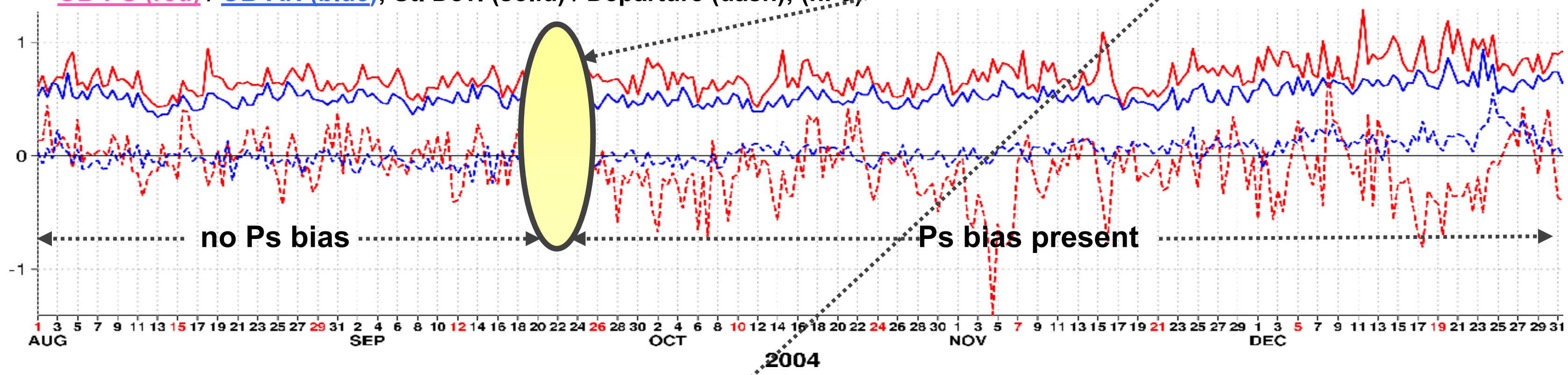




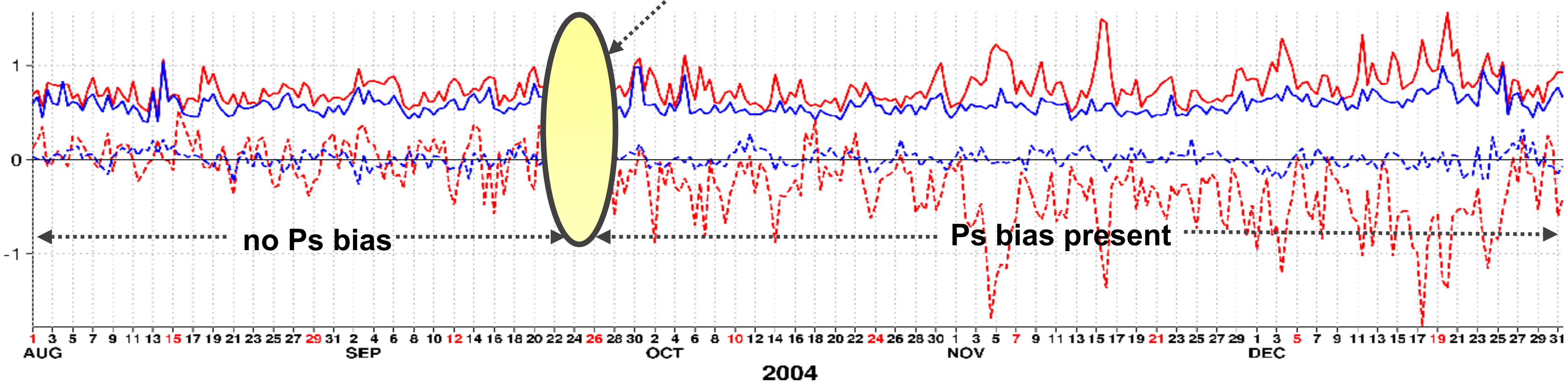
Experiments and Tests

- Ps departures (dash) and Standard deviation (solid) timeseries for E-SUITE (TOP) and OPERATIONS (BOTTOM) for SYNOP during August-December period for Canada/USA
- Slightly bigger bias in the Operational run because there was no bias correction
- In both runs, at the end of September the bias started creeping (Ps Bias Onset)

E-SUITE (el21) Timeseries: SYNOP-Ps Canada/USA
OB-FG (red) / OB-AN (blue); St. Dev. (solid) / Departure (dash); (hPa)



OPERATIONS Timeseries: SYNOP-Ps Canada/USA
OB-FG (red) / OB-AN (blue); St. Dev. (solid) / Departure (dash); (hPa)



Experiments and Tests

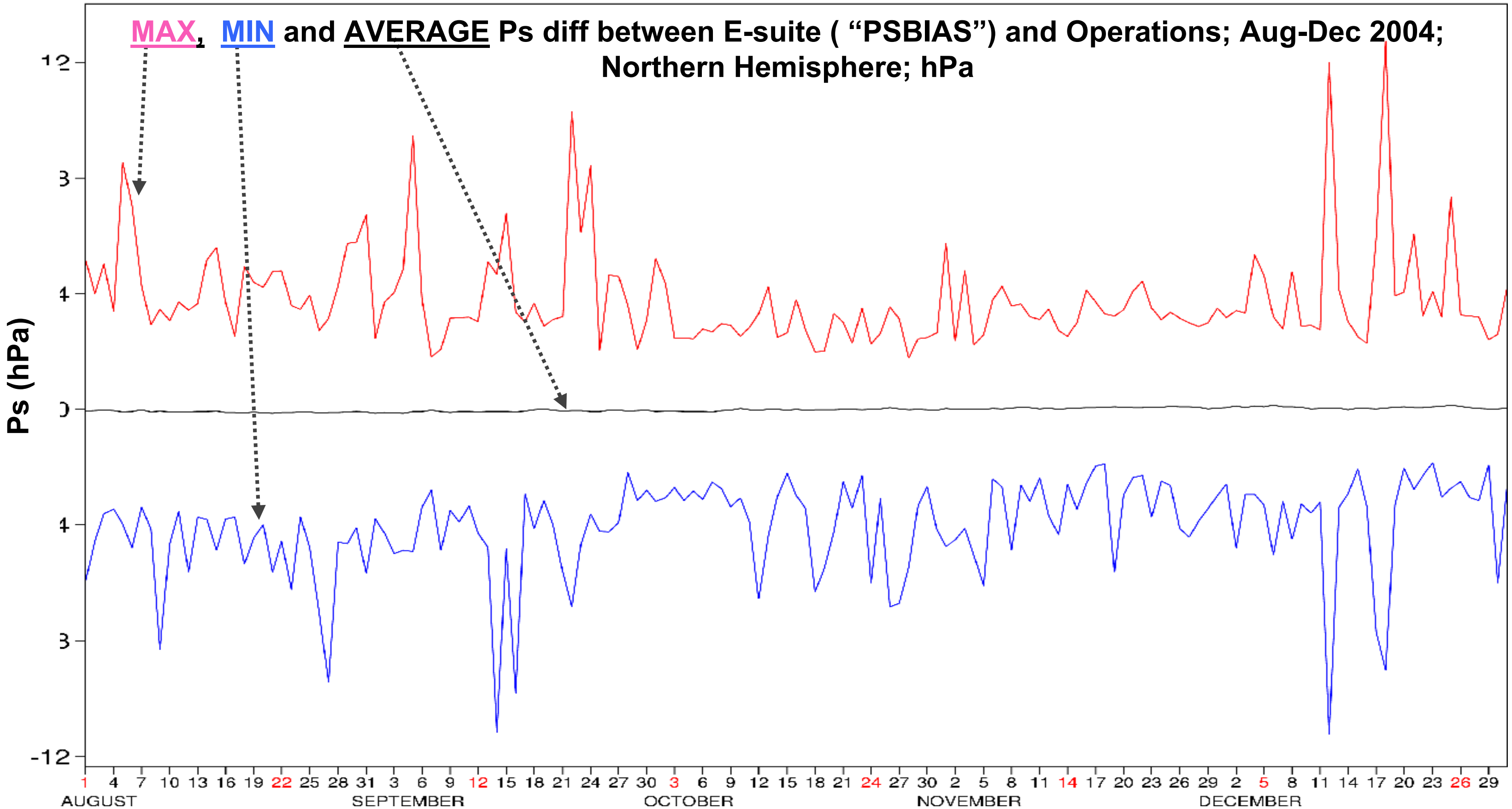
- Now it started looking as we might be dealing with a possible model bias
- If true, the Ps bias correction scheme should not have been applied
- Against the second bias correction scheme assumption, which is that:

<u>There Is NO, Or SMALL, Model Bias</u>

- 1hPa limit when to apply bias correction had been introduced in an attempt to avoid correcting for possible small model biases
- Canada/USA was the only region in which this problem could be observed
- Timeseries of MAX, MIN and AVERAGE PMSL analysis differences to look at
- Both MAX and MIN differences would vary day by day, but the AVERAGE differences should be stable and around 0hPa
- Time series of PMSL analysis differences between E-suite type experiment (el21) and operations for August-December period for various regions are looked at

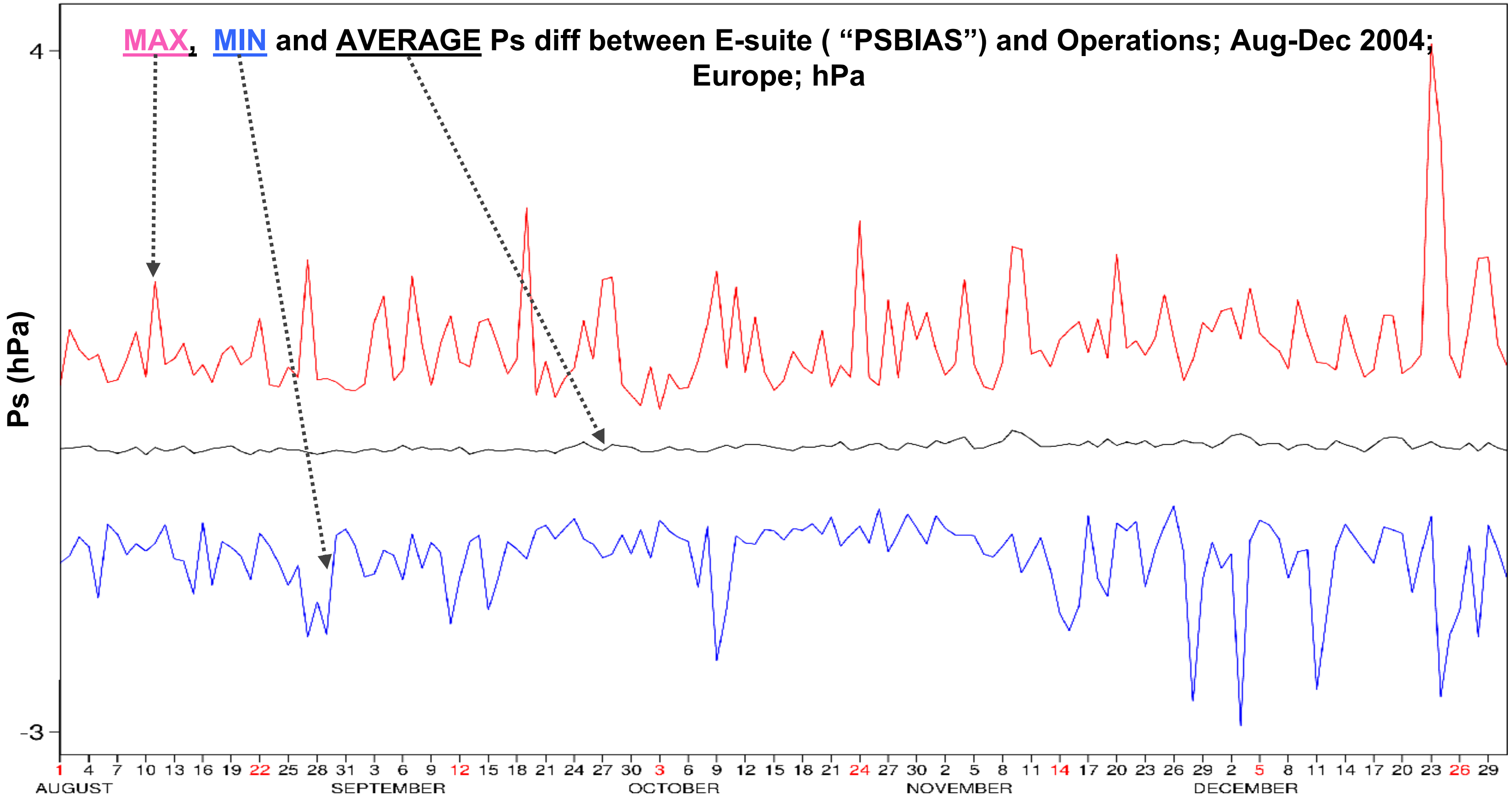
Experiments and Tests

- Northern hemisphere PMSL analysis difference between “PSBIAS” E-suite type exp. (el21) run and Operations for August-December 2004 period
- Similar picture for the Southern hemisphere
- No surprises, MAX and MIN Ps differences vary daily and pretty much flat AVERAGE Ps differences throughout the period



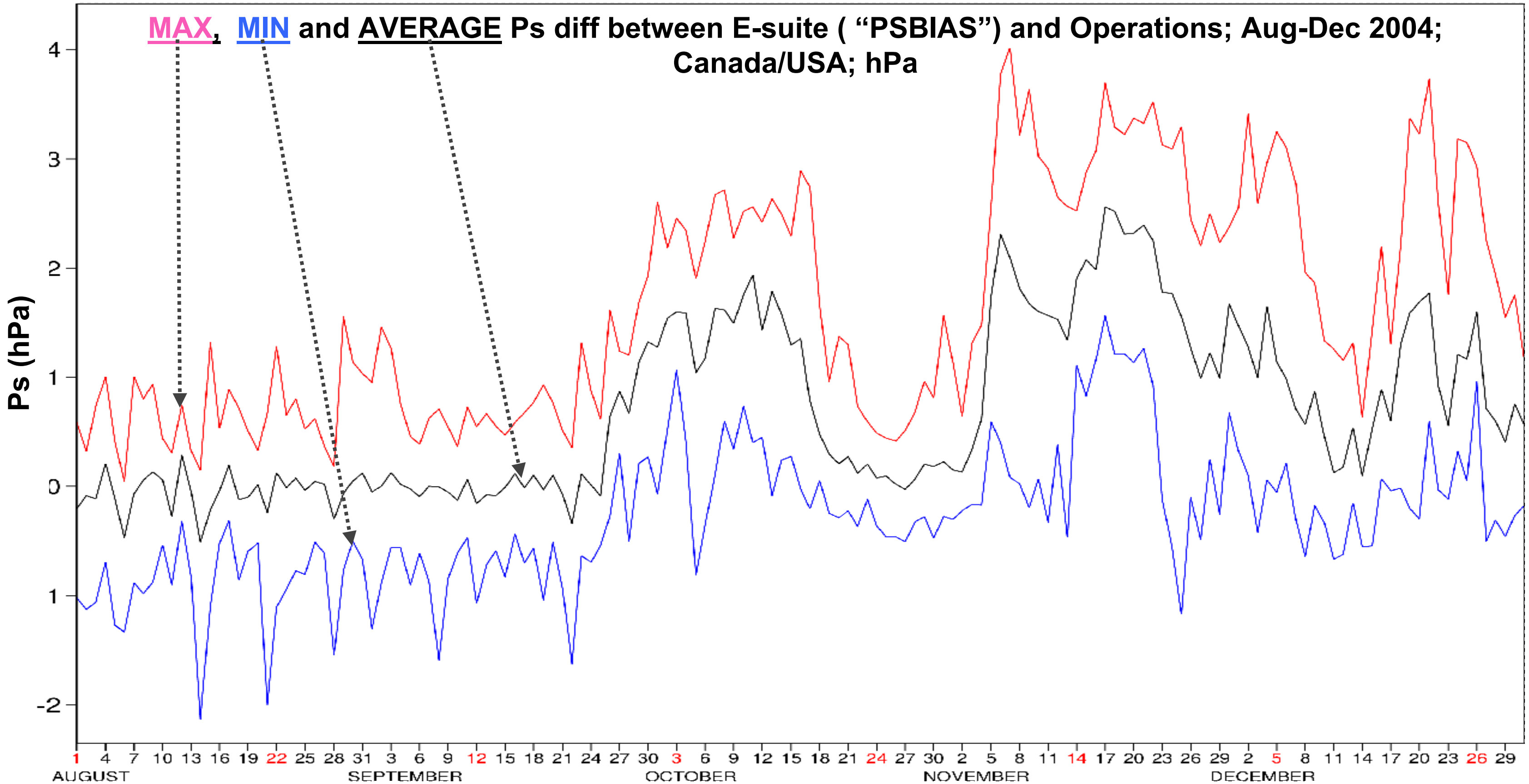
Experiments and Tests

- PMSL analysis difference between “PSBIAS” E-suite type exp. (el21) and Operations for August-December 2004 period for Europe
- Again expected picture of daily variations of MAX and MIN PMSL differences and a rather stable AVERAGE PMSL difference



Experiments and Tests

- PMSL analysis difference between “PSBIAS” E-suite type exp. (el21) and Operations for August-December 2004 period for Canada/USA
- Big surprise, From August till late September, the average differences are reasonably stable but after that till the end of December they are far from stable and are as big as 2hPa, or even bigger
- This seems to coincide with a large scale Ps bias identified earlier



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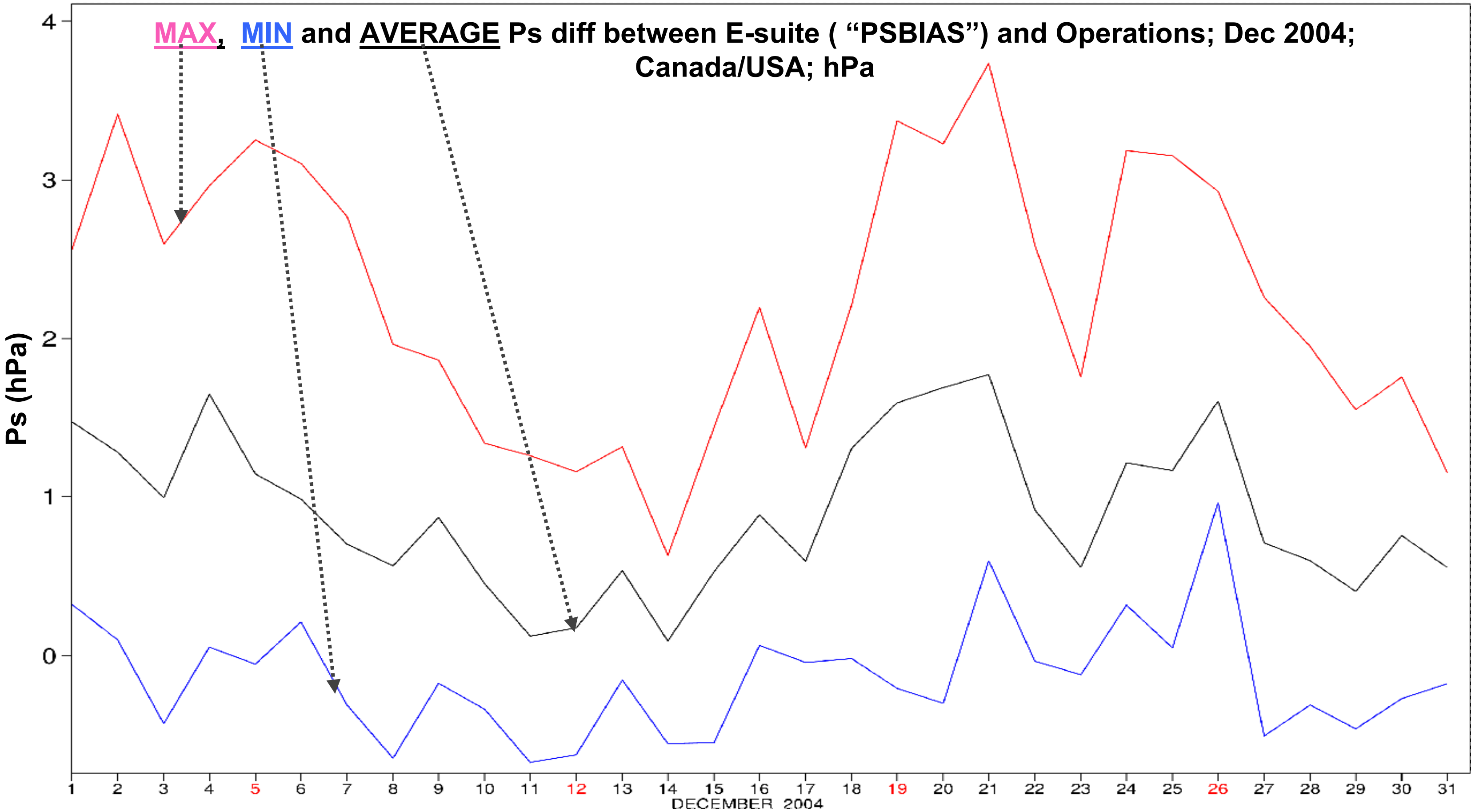
Experiments and Tests

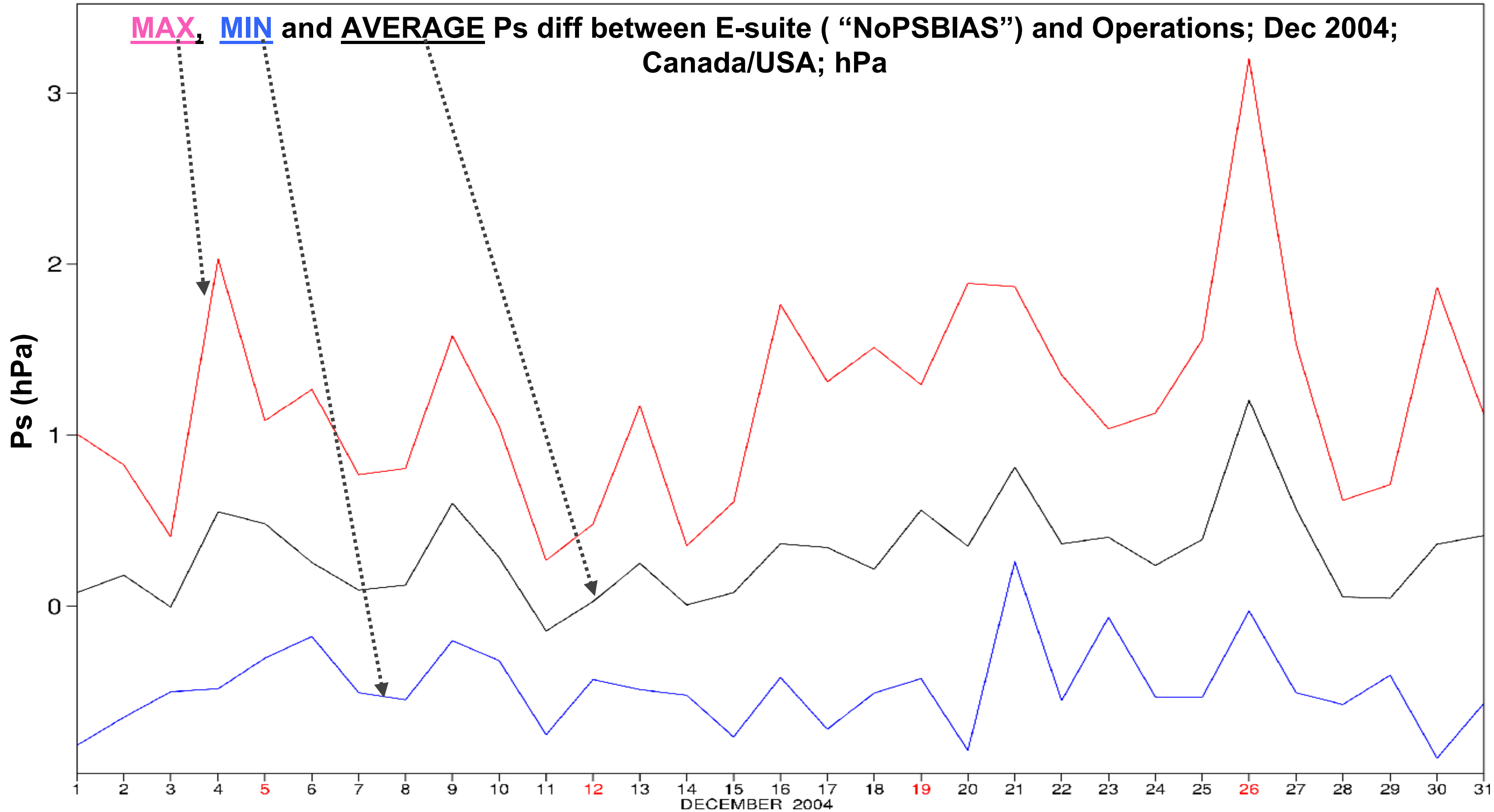
- PMSL analysis difference between “PSBIAS” E-suite exp. (el21) and Operations for December 2004 period for Canada/USA
- As noticed the average differences are not stable, and go as high a 2hPa



ECMWF

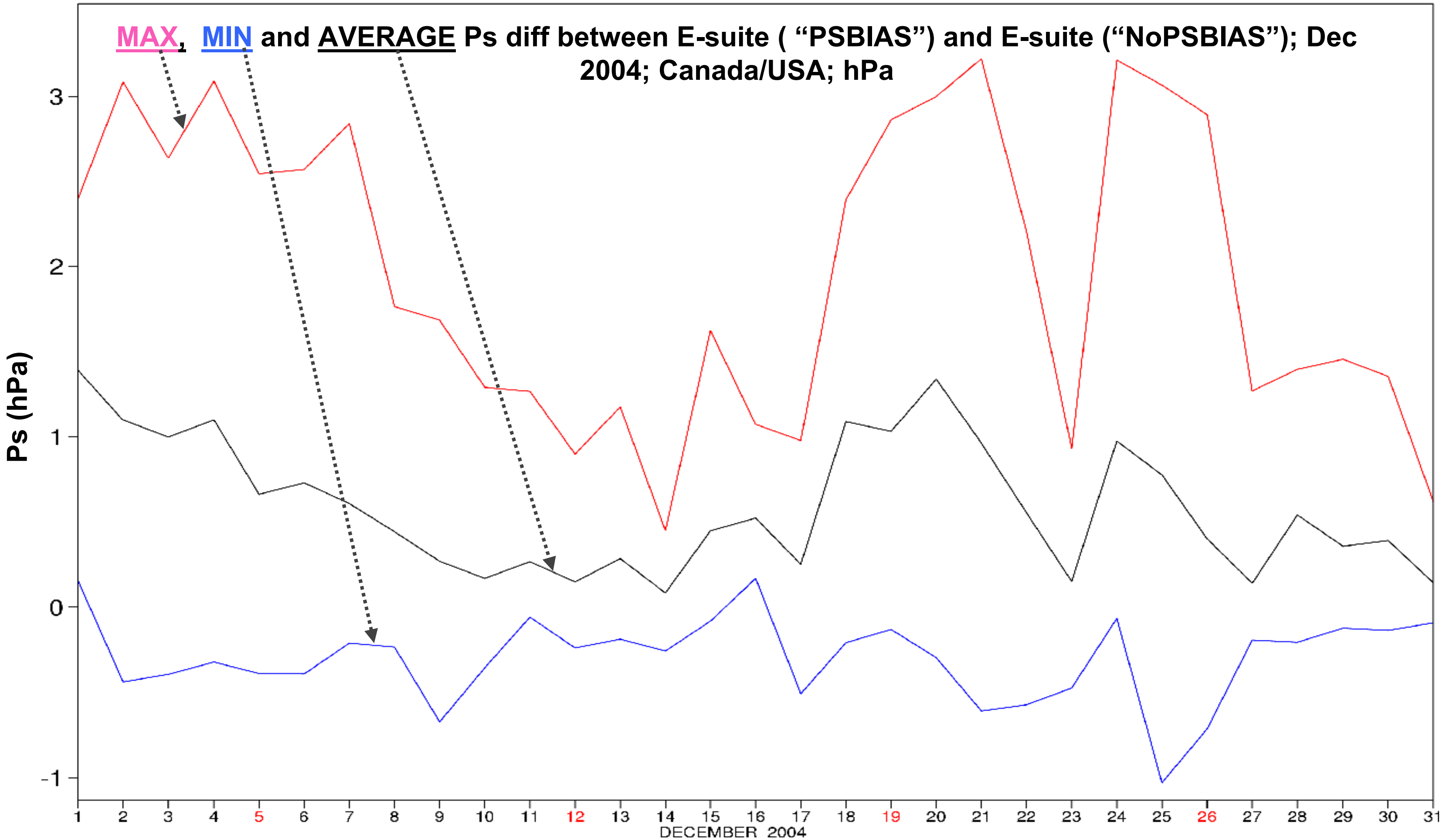
Experiments and Tests

- PMSL analysis difference between "NoPSBIAS" E-suite exp. (eltv) and Operations for December 2004 period for Canada/USA
- The average differences are not stable, and go as high a 1hPa



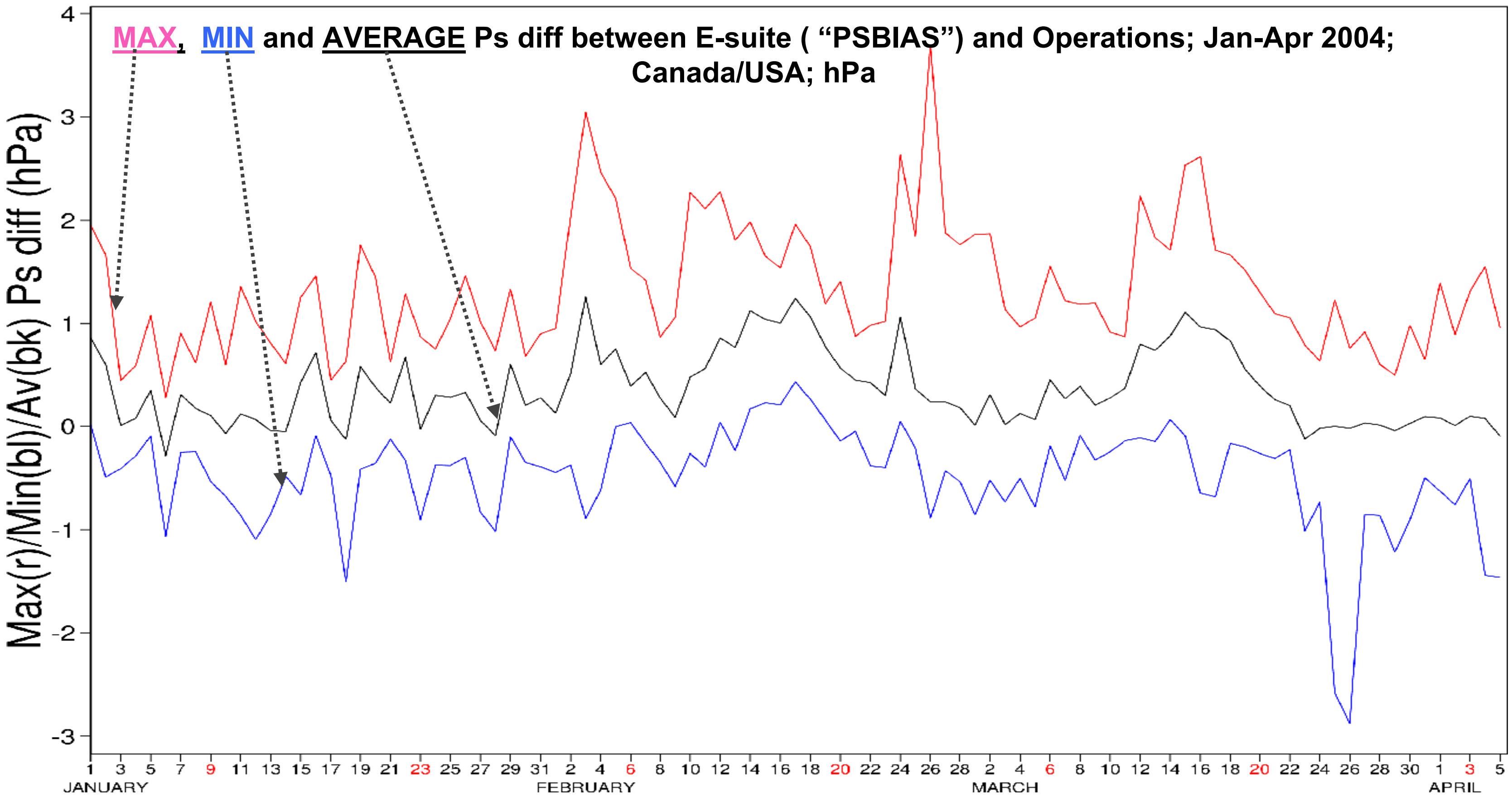
Experiments and Tests

- **PMSL analysis difference between “PSBIAS” E-suite exp. (el21) and “NoPSBIAS” E-suite exp. (eltv) for December 2004 period for Canada/USA**



Experiments and Tests

- E-suite started on 01/01/2005
- PMSL analysis difference between E-suite ("PSBIAS") and Operations for January-April 2005 period for Canada/USA
- AVERAGE differences are not entirely stable but their amplitudes are reduced compared to the October-December ones



Experiments and Tests

- **All this was suggesting that, here, we are dealing with unexpected model bias**
- **Ps bias correction scheme presented and introduced here is supposed to deal with uncorrelated observational bias only and:**

In The Presence Of A Larger Scale Model Bias The Correction Should Not Be Applied

- **As just discussed, by correcting observations for model bias leads to a rather poor result and it should not be done**
- **The difficulty here is:**

How Do We Identify The Model Bias And Subsequently Separate It From The Observational One?

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Model and Observational Ps Bias Separation

- It is worth remembering that we introduced 1hPa limit when to apply the bias correction in order to avoid correcting for small model bias
- This limit could now be increased to, lets say, 2hPa
- This quick fix should hopefully eliminate noticed problem over the North America
- However, since the limit would be applied globally, the increase would unjustly exclude a number of genuinely biased stations from being corrected
- Therefore, the positive effects of the Ps bias correction scheme would be reduced
- We should be seeking a little bit more selective solution to this problem

Model and Observational Ps Bias Separation

- **The presented analysis of the problem was clearly pointing out that when it happens a large number of stations are in agreement in terms of both the bias sign and the bias size**
- **Now if we remember the old OI analysis system where we used to have one quality control procedure, not used in the current analysis system, called the "BUDDY" check**
- **In brief, the idea was that in order to quality control a given observation one could actually do the analysis at that point without the observation itself being used; if analysed and observed values at that point agree within some limits one assumes that the datum is probably correct**
- **If we, now, turn the original "BUDDY" check idea around:**

If For A Given Biased Station Its Bias Value Agrees, Within Limits, With The Analysed Bias From Its Neighbours Without Using the Station's Bias Itself, Then One Should Not Apply Bias Correction At That Station

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Model and Observational Ps Bias Separation

- **The neighbouring stations to be considered should be within a circle of a certain radius**
- **Also, as an agreement limit we could use for example the analysed bias value +/- a multiple of standard deviation**
- **Not to forget, there should be a limit on how many stations ought to be found in the vicinity**
- **Since this type of check is very similar to the original "<u>BUDDY</u>" check but in the opposite sense, naming it the "<u>ANTI-BUDDY</u>" check sounded appropriate**
- **There were at least two possibilities on how to perform the bias analysis from the neighbouring stations:**
  - ➔ **First, one could do a simple statistical analysis, calculate the mean and standard deviation and use the mean as analysed bias value along with the standard deviation to perform the "<u>ANTI-BUDDY</u>" check,**
  - ➔ **Secondly, instead of using the mean as the analysed bias value a type of 2D univariate bias analysis can be done**

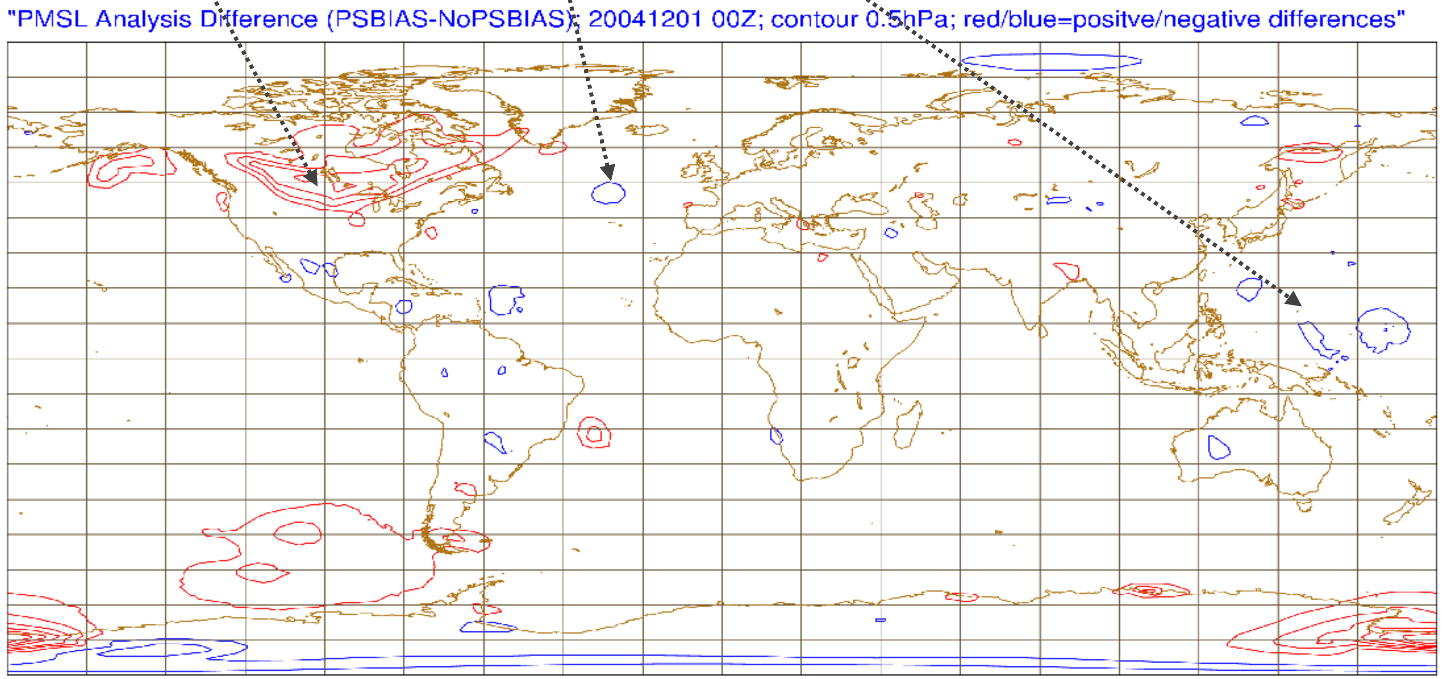
Model and Observational Ps Bias Separation

- "ANTI-BUDDY" check has been added to the Ps bias correction scheme and its main points are:
  - ➔ A list of potentially biased stations is compiled,
  - ➔ For each of station the "ANTI-BUDDY" check is applied
  - ➔ The circle radius around a given station is set to 300km
  - ➔ Number of influencing stations in order to perform the "ANTI-BUDDY" check is set to 10 or more
  - ➔ The analysed bias value is assumed to be the mean bias
  - ➔ The agreement limit is set to be analysed bias value +/- 2.0 standard deviations
  - ➔ Stations which do not have enough neighbours are not subjected to this check
- Now we reran the analysis cycle for which earlier we saw the large-scale positive PMSL analysis difference or the "BLOB"

Model and Observational Ps Bias Separation

- Ps analysis differences ("PsBias(1hPa)"-"NoPsBias") for 01/12/2004 00Z

- Differences are manly SMALL and LOCAL, however there is a Rather Large Scale Positive (2hPa) difference ("BLOB") over the North America (USA/Canada)
- The "BLOB" stayed there for about two weeks, just moving around slightly
- Furthermore, the "BLOB" survived in the ensuing forecasts and propagated downstream with the flow, thus contributing to the bad forecast scores

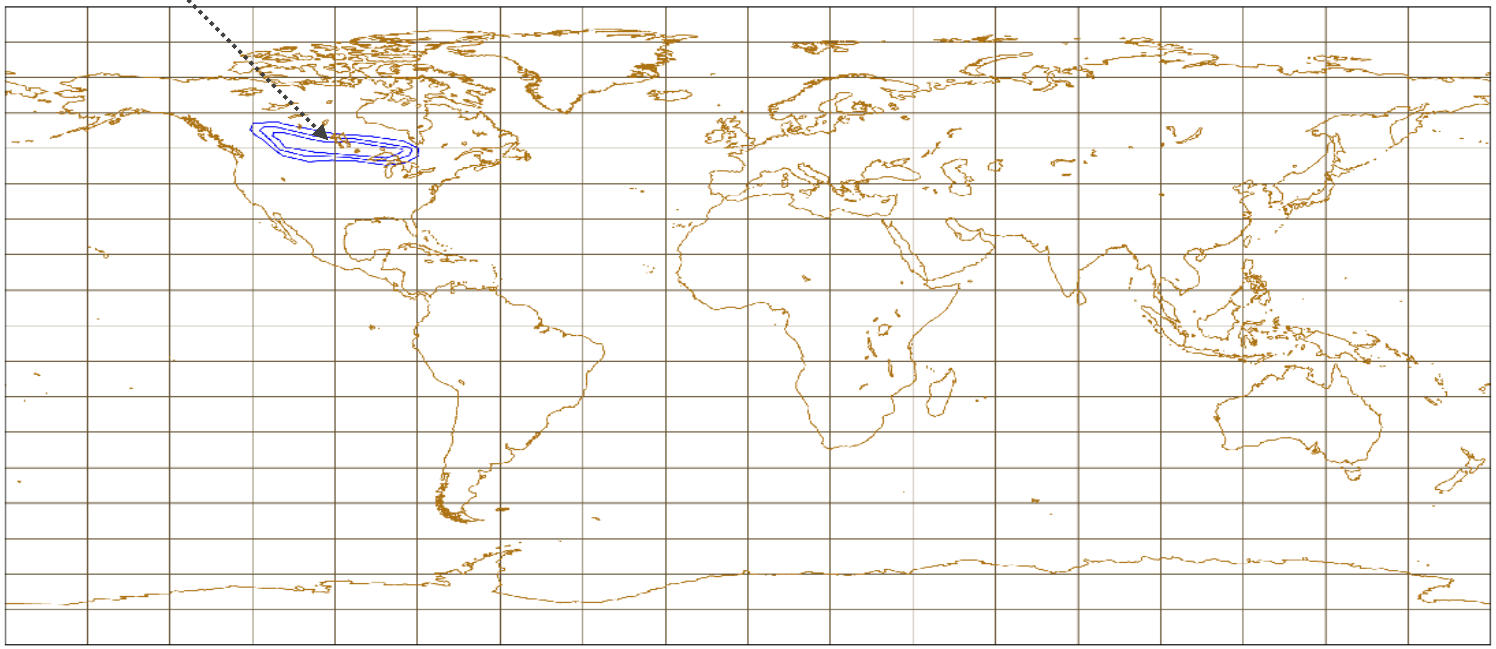


Model and Observational Ps Bias Separation

- Ps analysis differences (“PsBias(1hPa+AB)”-” PsBias(1hPa)”) for 01/12/2004 00Z

- As it can be seen, the map is mainly void except for the Canada/USA region where we experienced the problem before
- This was a very good result
- The “<u>ANTI-BUDDY</u>” check clearly had impact only in the problematic region
- The “<u>BLOB</u>” is undone

"PMSL Analysis Difference (PSBIAS(AntiBuddy)-PSBIAS); 20041201 00Z; contour 0.5hPa; red/blue=positive/negative differences"



Model and Observational Ps Bias Separation

- Background and Analysis fit to SYNOP Ps data for "AntiBuddyPSBIAS" (BLACK) and "NoPSBIAS" (RED) runs for 01/12/2004 00Z
- Not correcting as much of the bias as it used to do
- Fit to SYNOP Ps observation in the area is now similar for two runs; certainly the result we were hoping to see

AntiBuddyPSBIAS vs NoPSBIAS 2004120100

SYNOP-Ps (Pa) Canada/USA

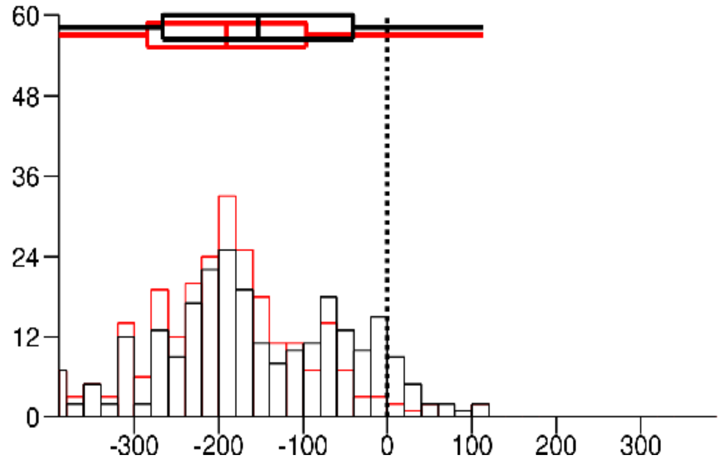
used p

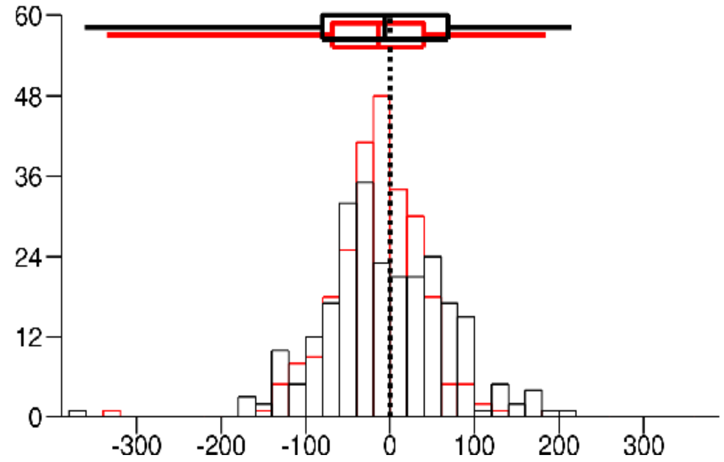
background departure o-b

nb= 252 (ref= 252) rms= 191. (213.)
mean= -154. (-191.) std= 113. (94.3)
min= -528. (-528.) max= 113. (113.)

analysis departure o-a

nb= 252 (ref= 252) rms= 74.7 (56.0)
mean= -5.94 (-14.1) std= 74.5 (54.2)
min= -362. (-336.) max= 215. (184.)





Model and Observational Ps Bias Separation

- **Background and Analysis fit to METAR Ps data for "AntiBuddyPSBIAS" (BLACK) and "NoPSBIAS" (RED) runs for 01/12/2004 00z**
- **Not correcting as much of the bias as it used to do**
- **Fit to METAR Ps observation in the area is now similar for two runs; the result we were hoping for**

AntiBuddyPSBIAS vs NoPSBIAS 2004120100

METAR-Ps (Pa) Canada/USA

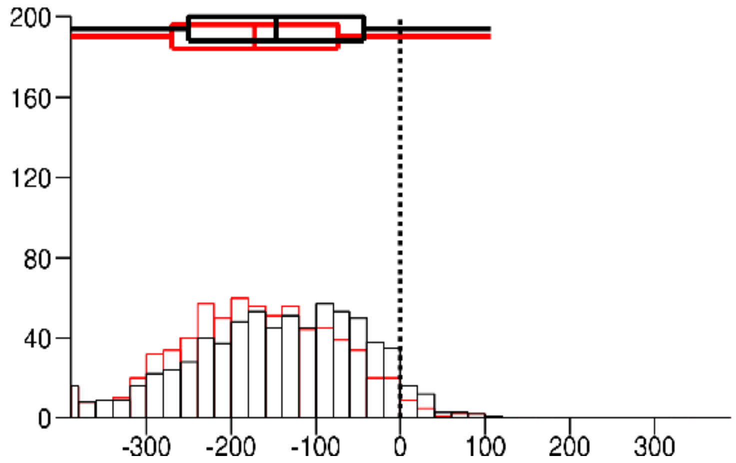
used p

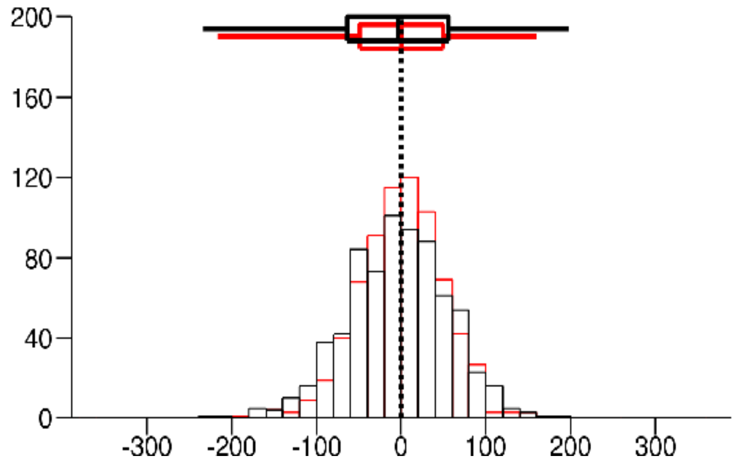
background departure o-b

nb= 721 (ref= 721) rms= 180. (198.)
mean= -147. (-172.) std= 104. (98.1)
min= -476. (-476.) max= 107. (107.)

analysis departure o-a

nb= 721 (ref= 721) rms= 59.9 (49.5)
mean= -4.05 (0.208) std= 59.8 (49.5)
min= -234. (-217.) max= 198. (160.)





Model and Observational Ps Bias Separation

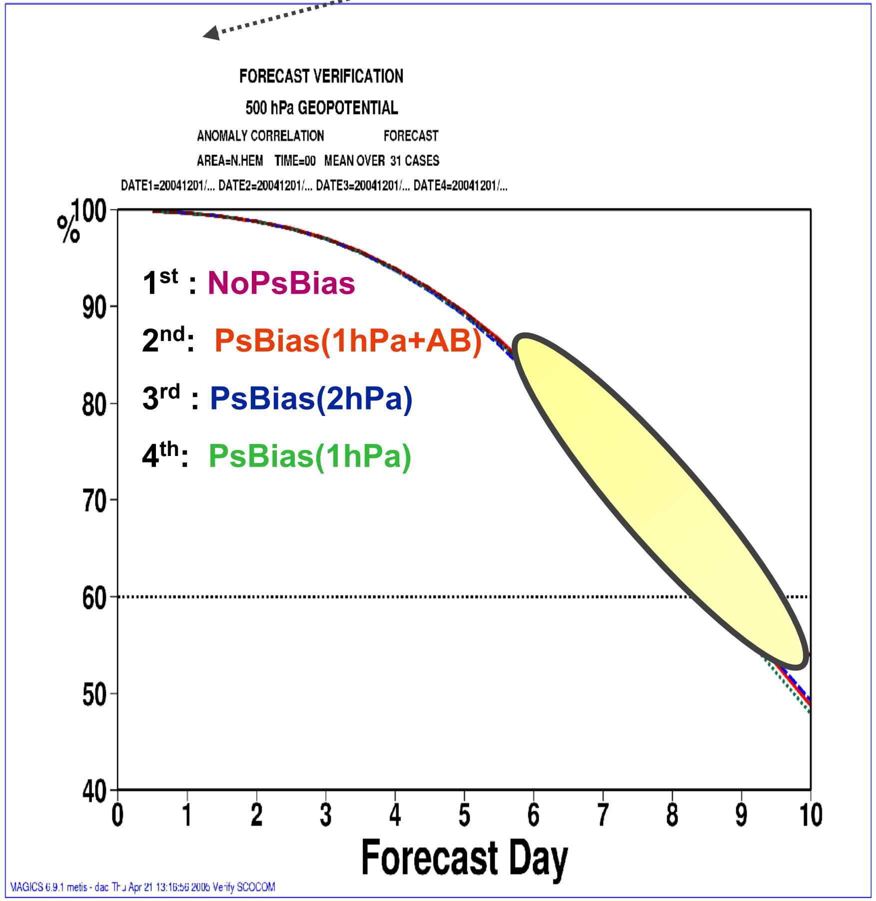
- **Now comes the all important question:**

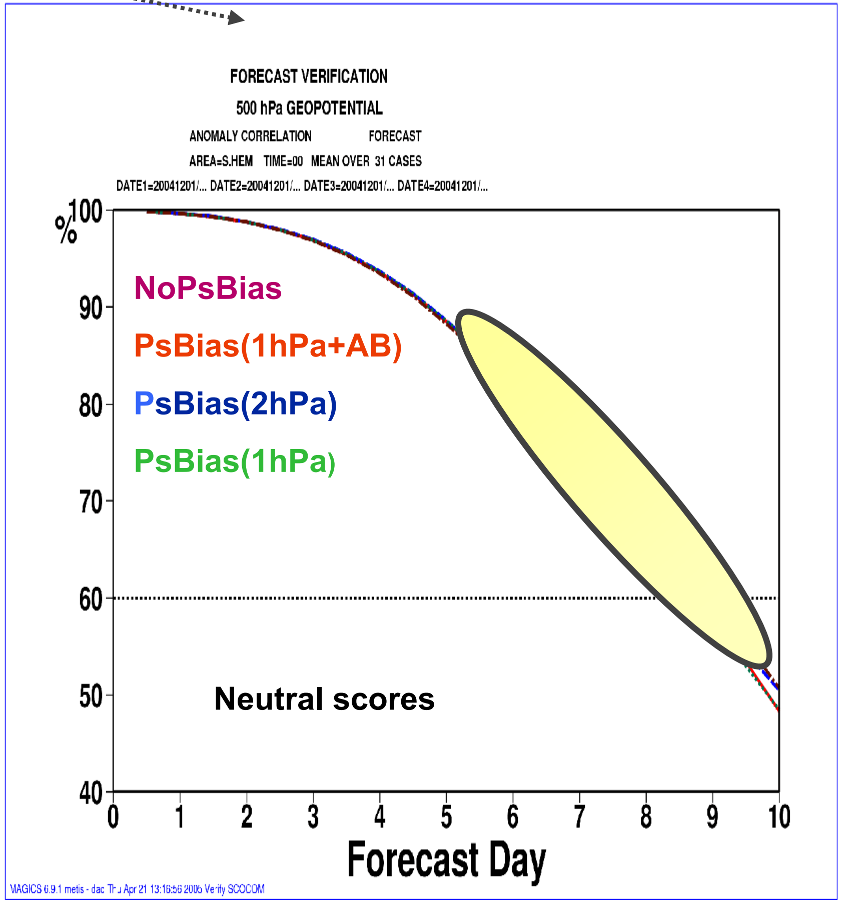
If We Were To Rerun The E-suite Type Experiment With The "ANTI-BUDDY" Check Included For December, Would That Improve The Forecast Scores?

- **Such an experiment was carried out**
- **Furthermore, for the sake of completeness, an experiment where the limit of 1hPa when to apply bias correction was increased to 2hPa was performed, too**
- **A number hemispheric and regional forecast score for various runs for December 2004 to look at**

Model and Observational Ps Bias Separation

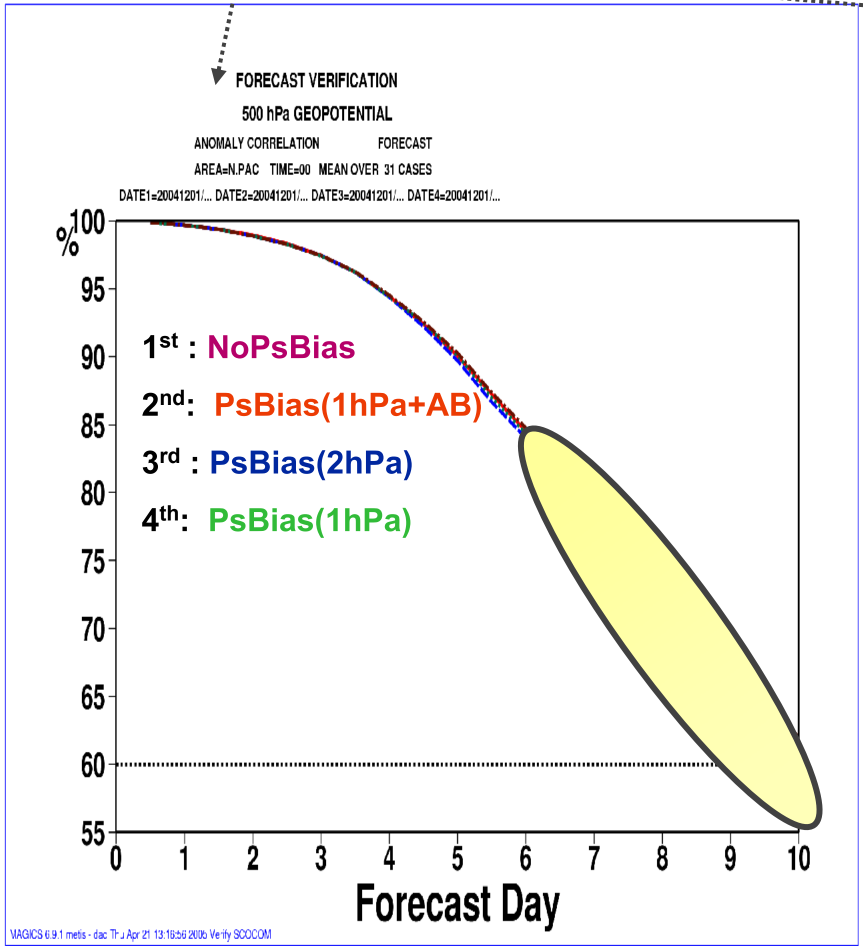
- 10-day forecast 500hPa Geopotential anomaly correlation scores for December 2004 for the Northern and Southern hemispheres
- Both the “PsBias(2hPa)” and “PsBias(1hPa+AB)” improved scores but still under performed the “NoPsBias” in the Northern hemisphere
- Pretty much neutral scores in the Southern hemisphere; there was not much of the problem anyway

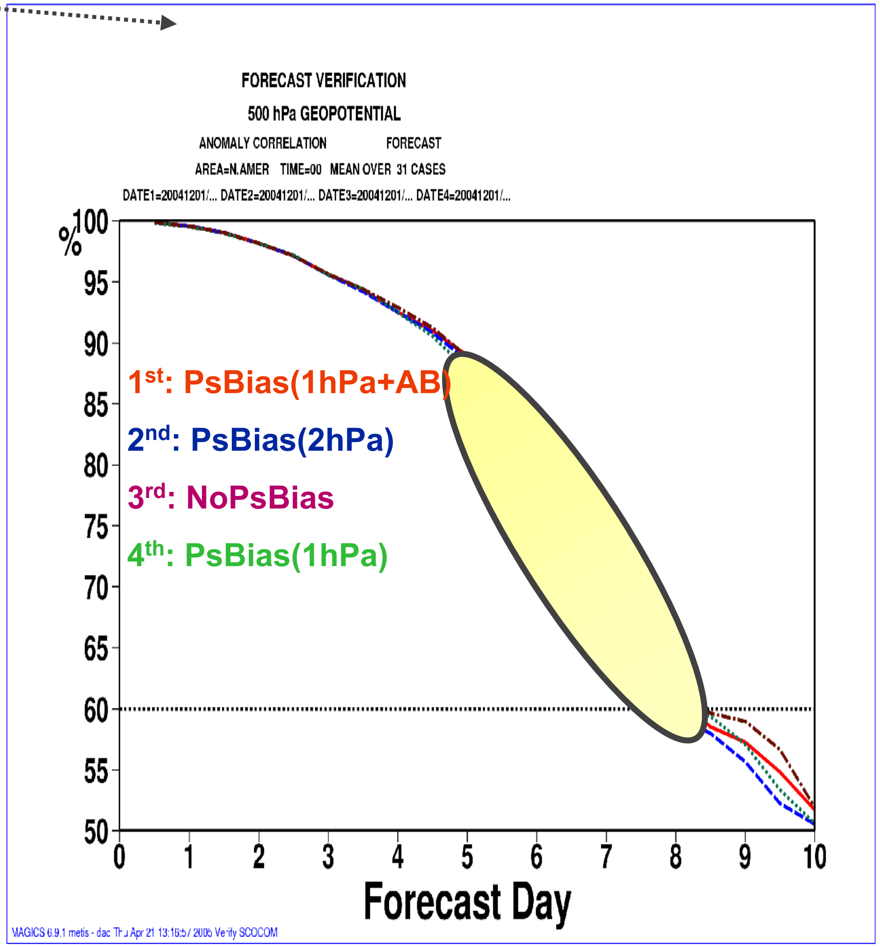




Model and Observational Ps Bias Separation

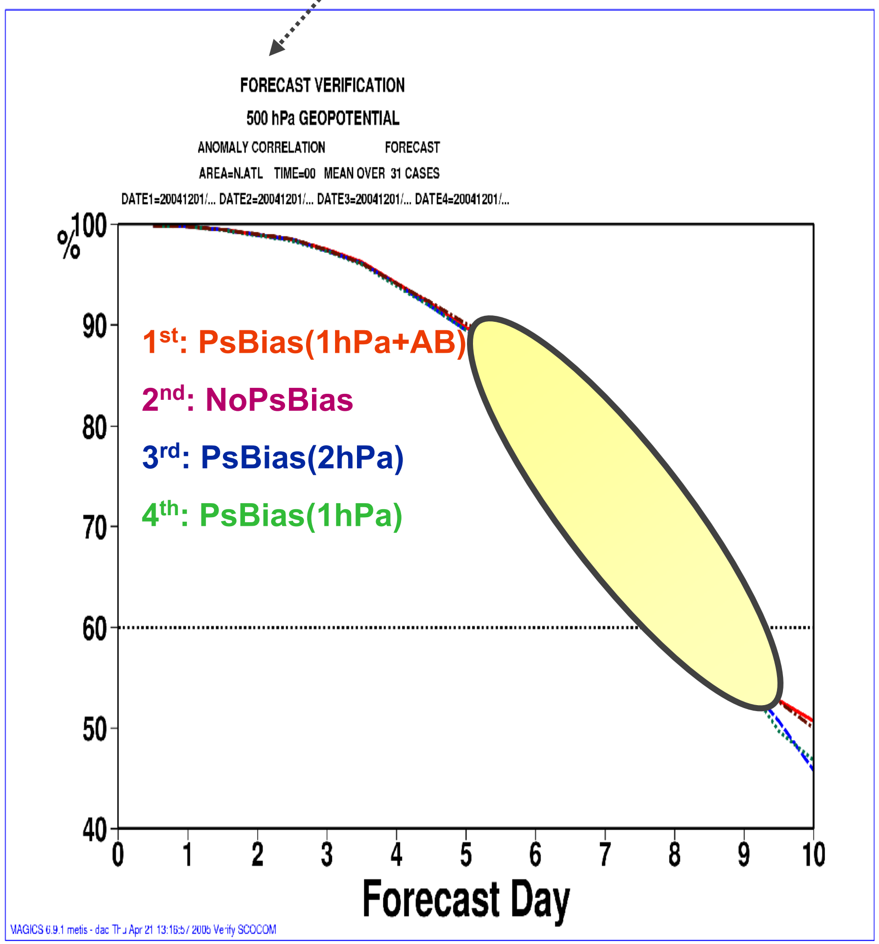
- **10-day forecast 500hPa Geopotential anomaly correlation scores for December 2004 for the North Pacific and North America**
- **"NoPsBias" forecast scores turned to be the best for the North Pacific with the "PsBias(1hPa+AB)" coming clearly the second best**
- **In the North America case the "PsBias(1hPa+AB)" was doing very well**

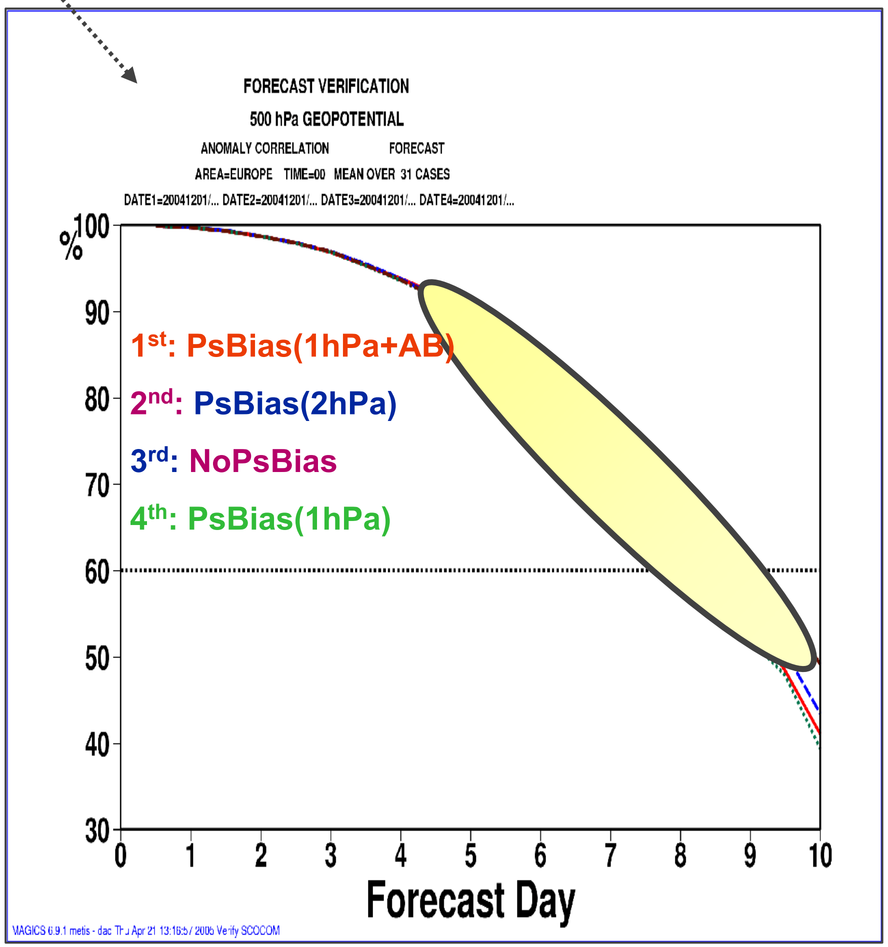




Model and Observational Ps Bias Separation

- **10-day forecast 500hPa Geopotential anomaly correlation scores for December 2004 for the North Atlantic and Europe**
- **"PsBias(1hPa+AB)" improved scores in these two regions and came on the top**





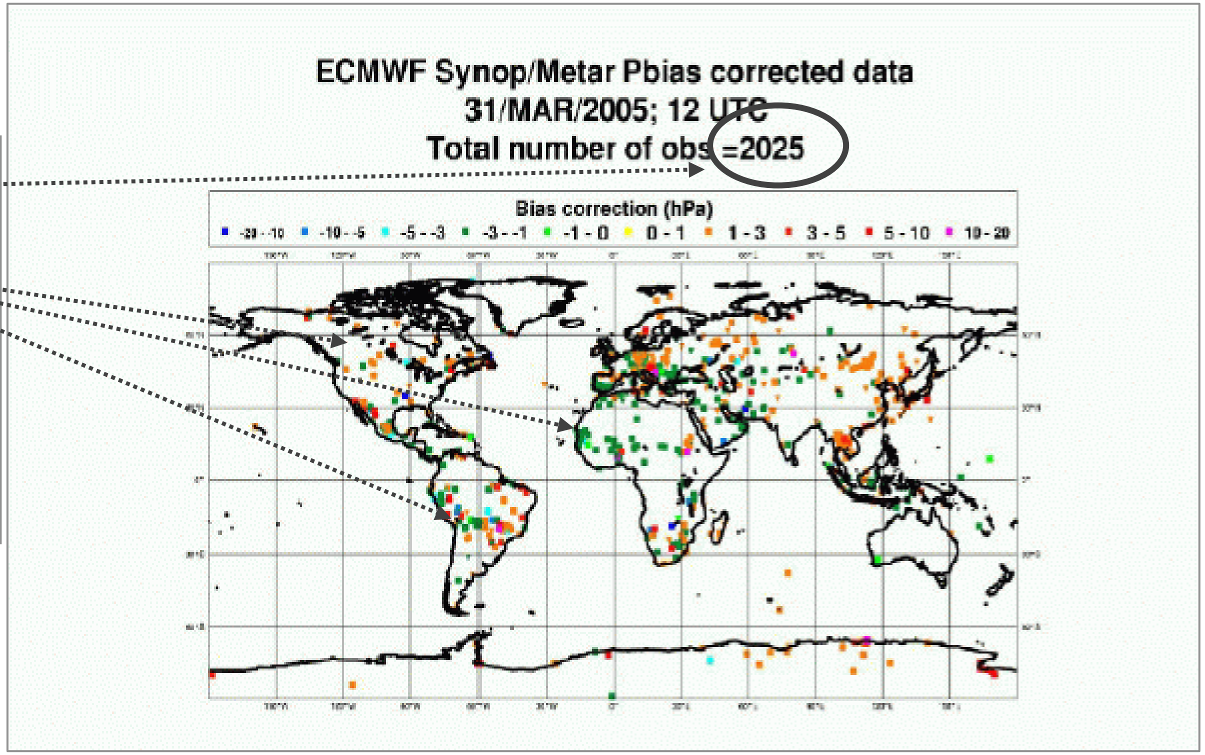
Model and Observational Ps Bias Separation

- Clearly, the "ANTI-BUDDY" check had a positive impact on both the analysis and forecast
- However, it did not go all the way to solving all of the December problems
- It became the integral part of the Ps bias correction scheme which was implemented operationally in April 2005

Ps Bias Monitoring

- Since the operational implementation of the Ps bias correction scheme we started daily monitoring of Ps biases
- There are separate pages for SYNOP/METAR and DRIBU observations

- How many reports are bias corrected
- Geographical position
- Colour coding the bias amounts one can now spot areas of a larger scale bias correction



Conclusion

- The Ps bias correction scheme, based on the OI method, for estimating and correcting Ps bias is now a part of the ECMWF operational system (from the 5th April 2005)
- The scheme identifies between 800 and 1000 biased stations out of about 11000 surface stations
- The biases are mostly related to incorrect station height and remain more or less constant in time
- The scheme is based on two assumptions: (1) Ps bias is local (no spatial correlation) and (2) no model bias, or very small model bias
- When both of these assumptions are satisfied the scheme had a positive impact on both the analysis and forecast
- However, in a presence of a larger model bias (both spatially and size wise) the scheme was not performing as well
- Thus, an adjustment to the original scheme was needed to recognise a possible model bias and separate it for the observational bias
- It has been demonstrated that the proposed "ANTI-BUDDY" check has managed to fulfil this requirement
- Since it was implemented about 100 stations have been taken of the ECMWF blacklist
- A large scale Ps bias pattern seen earlier has not been observed since operational implementation