# Results Using the Current Version 6 Candidate at SRT

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**Sounder Research Team (SRT)**

**NASA Sounder Science Team Meeting**

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# Outline

- Current Version (V5.26) compared to Latest JPL Version (V5.20)
- Comparison of results using V5.26 and V5.26AO with V5.0

  Is this good enough to freeze, with minor tweeks, if necessary?

  Does the level of improvement shown justify reprocessing of the whole data set?
- Plans for future improvements to the extent that time allows

# Improvements in Version 5.26 Compared to Current JPL Version (V5.20)

Version 5.20 improved over Version 5 primarily with regard to surface skin temperature and spectral emissivity

Version 5.26 has further improvements

* AMSU-4 and AMSU-5 (almost) removed from Version 5.26

  Cloudy regression still contains AMSU-4 and AMSU-5

* Almost no (1%) retrievals left behind

  Cloud parameters and OLR are (almost) always derived from final product

* Upgraded OLR RTA

  Removes most of the bias between AIRS and CERES OLR

- Modifications designed to decrease negative trends in yield and T(p)
- Improved Error Estimate and Quality Flag methodology
- Changes in minor details

* Presented at May 2009 Science Team Meeting – called Version 5.24

# Assessment of Results – Version 5.26 vs. Version 5.20

We ran retrievals for 6 days

September 6, 2002, January 25, 2003, September 29, 2004, August 5, 2005, February 24, 2007, and August 10, 2007

Assessments are done based on differences from ECMWF for 6 days

All experiments have their own error estimate (EE) coefficient

Version 5 and 5.20 generate EE using data from September 29, 2004

Version 5.26 generates EE using data from September 29, 2004 and August 10, 2007 – 2 day EE

We look at 1) yields; 2) RMS differences from ECMWF, and 3) bias differences

We compare 6-day means and temporal trends of 1) – 3) for each

To begin with, we use same T(p) thresholds for Version 5.26 as used in Version 5.20

**Merit Criteria**

1) Best RMS temperature differences from ECMWF with highest yield

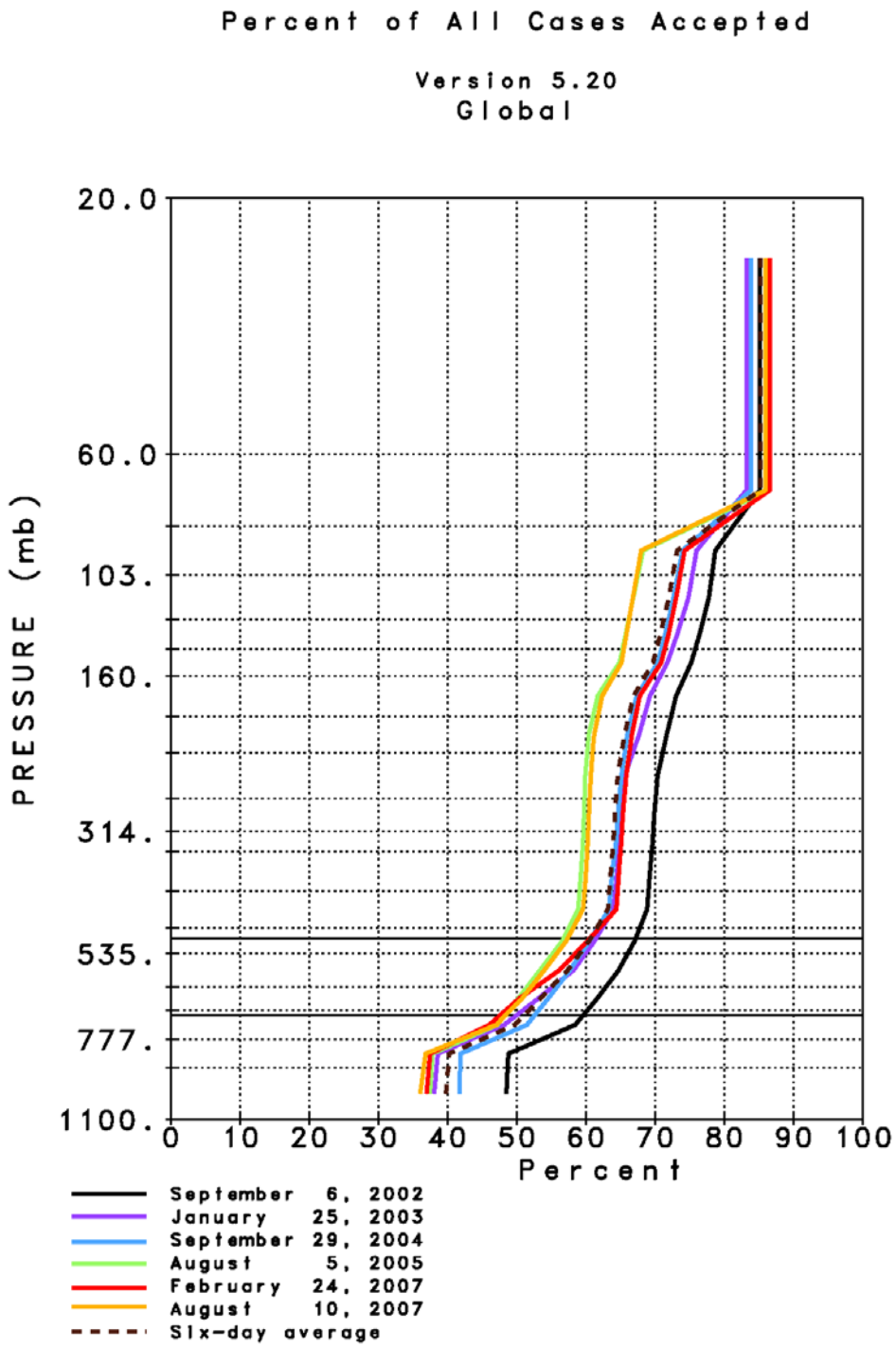
We now are significantly improving forecast skill by assimilating T(p)

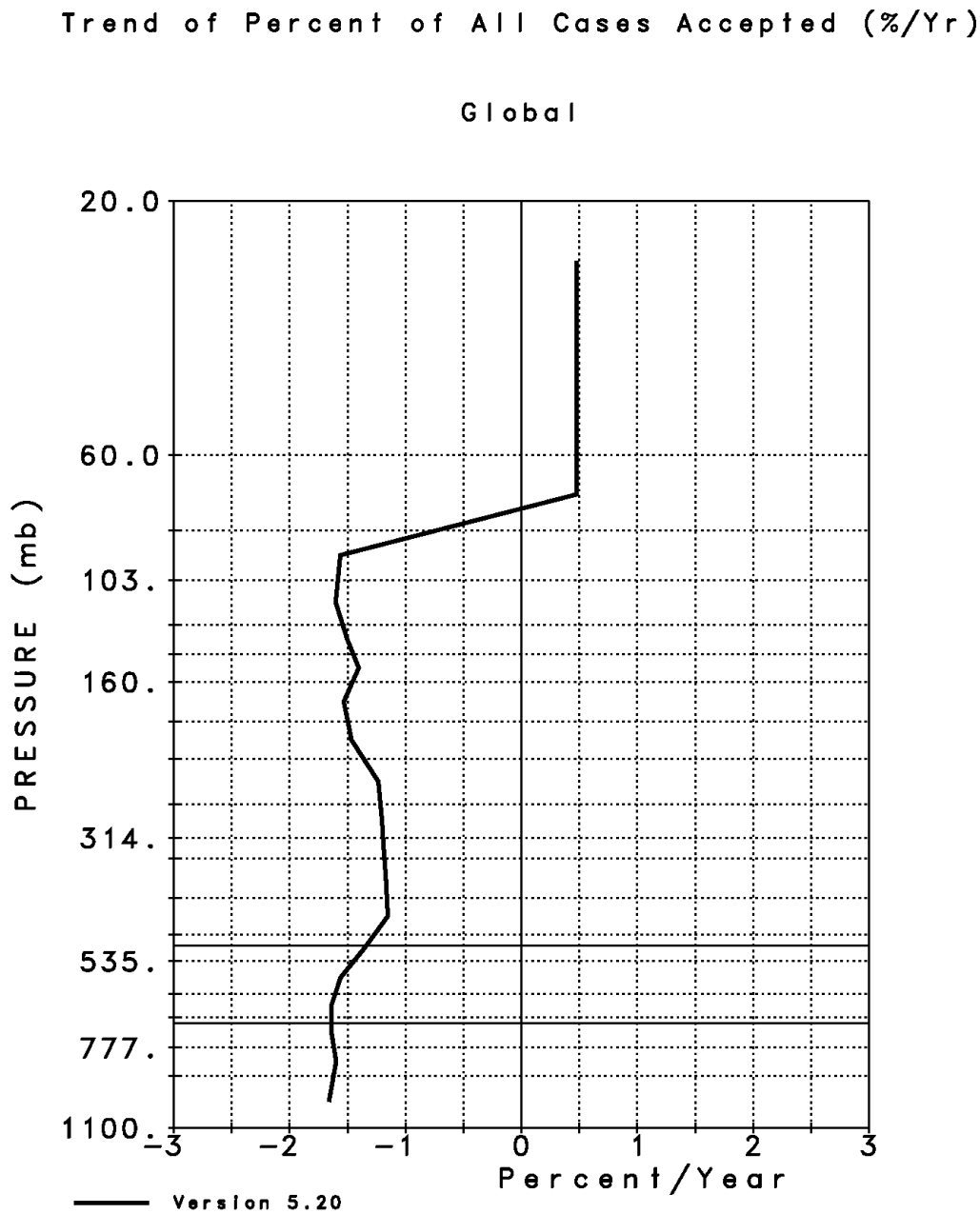
We do not want to lose this

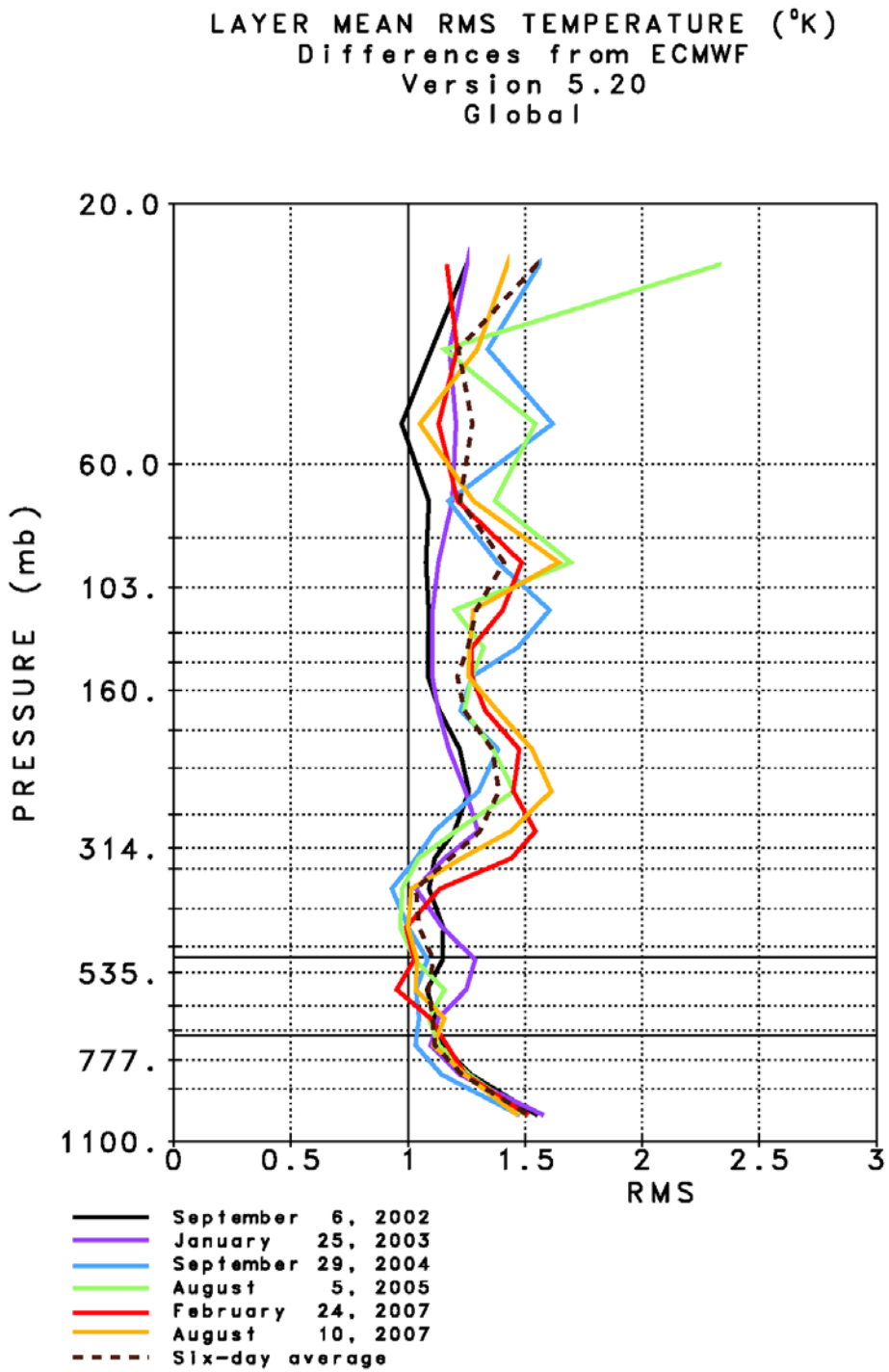
2) Smallest (negative) trends in yield

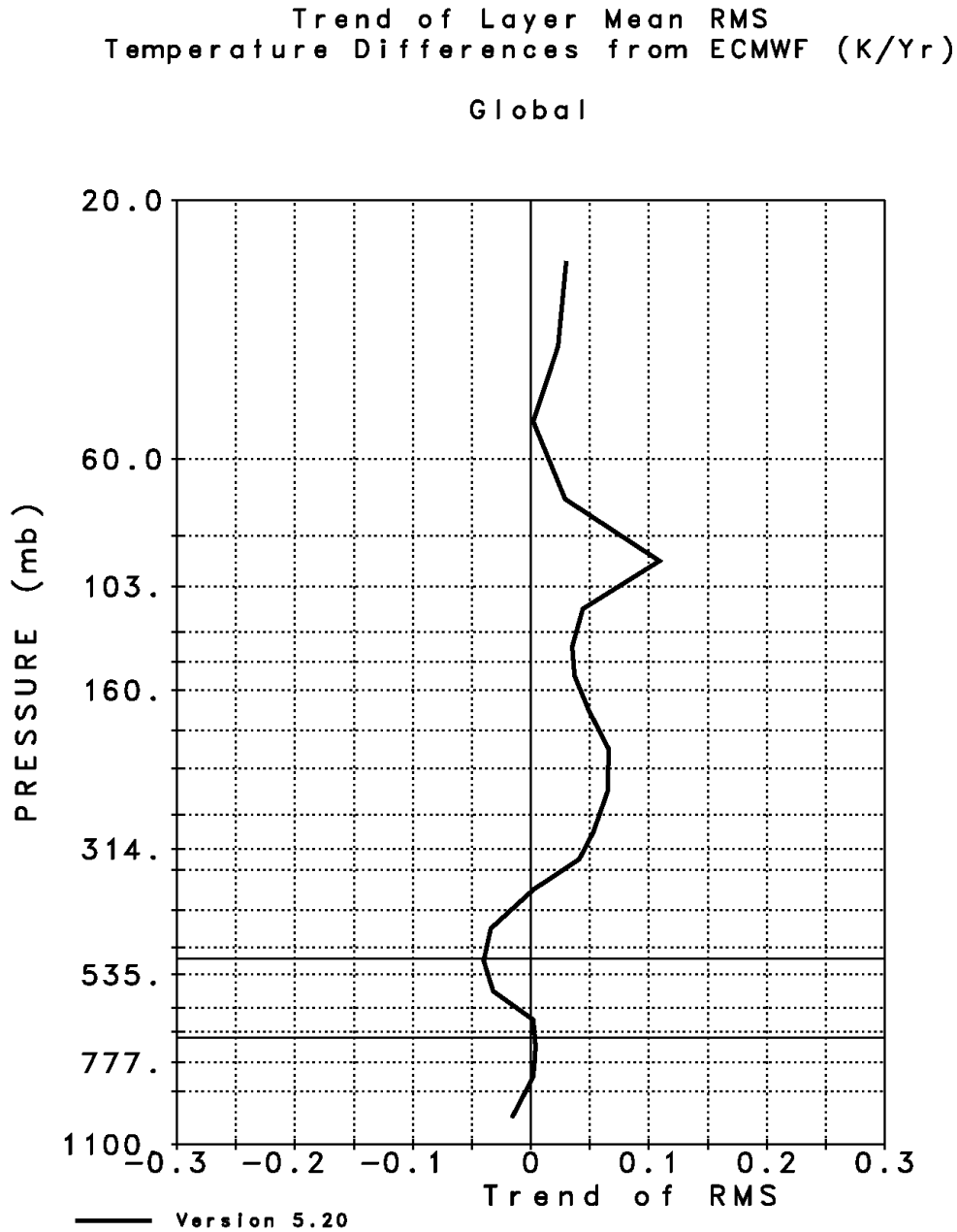
Is the system stable over time?

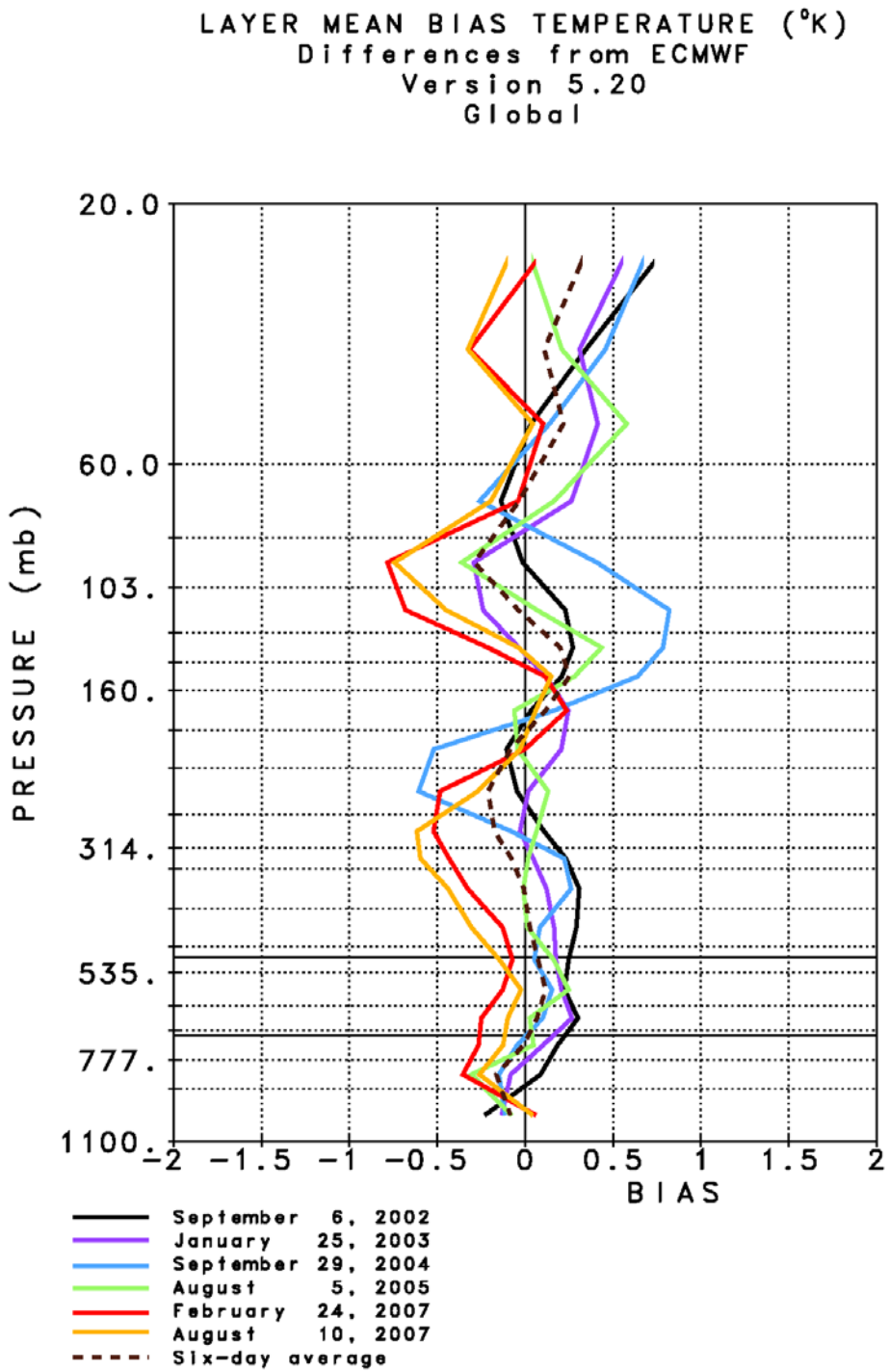
3) Smallest trends in (T(p) – ECMWF)

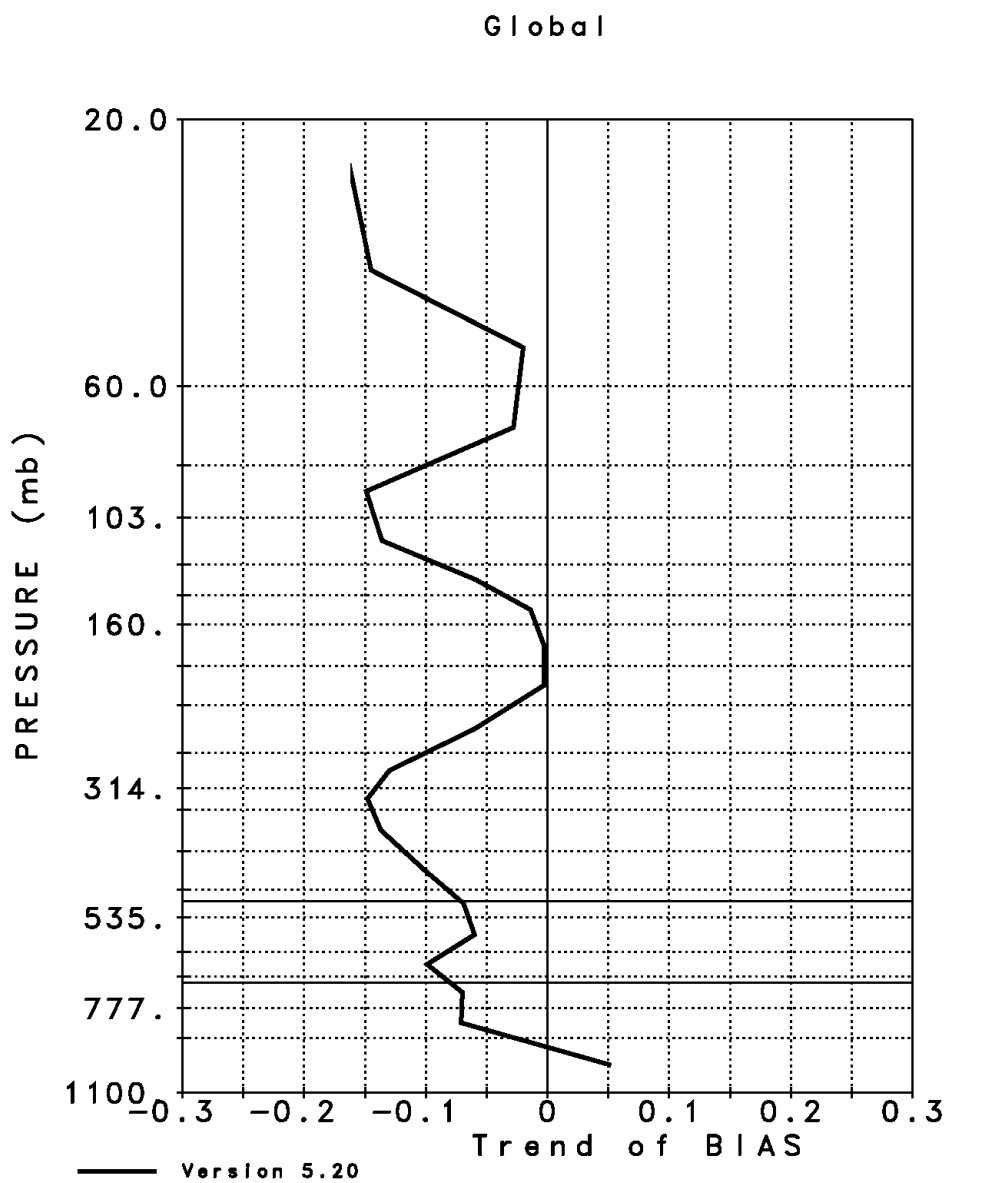

Percent of All Cases Accepted
Version 5.20
Global
PRESSURE (mb)
20.0
60.0
103.
160.
314.
535.
777.
1100.
0 10 20 30 40 50 60 70 80 90 100
Percent
September 6, 2002
January 25, 2003
September 29, 2004
August 5, 2005
February 24, 2007
August 10, 2007
Six-day average

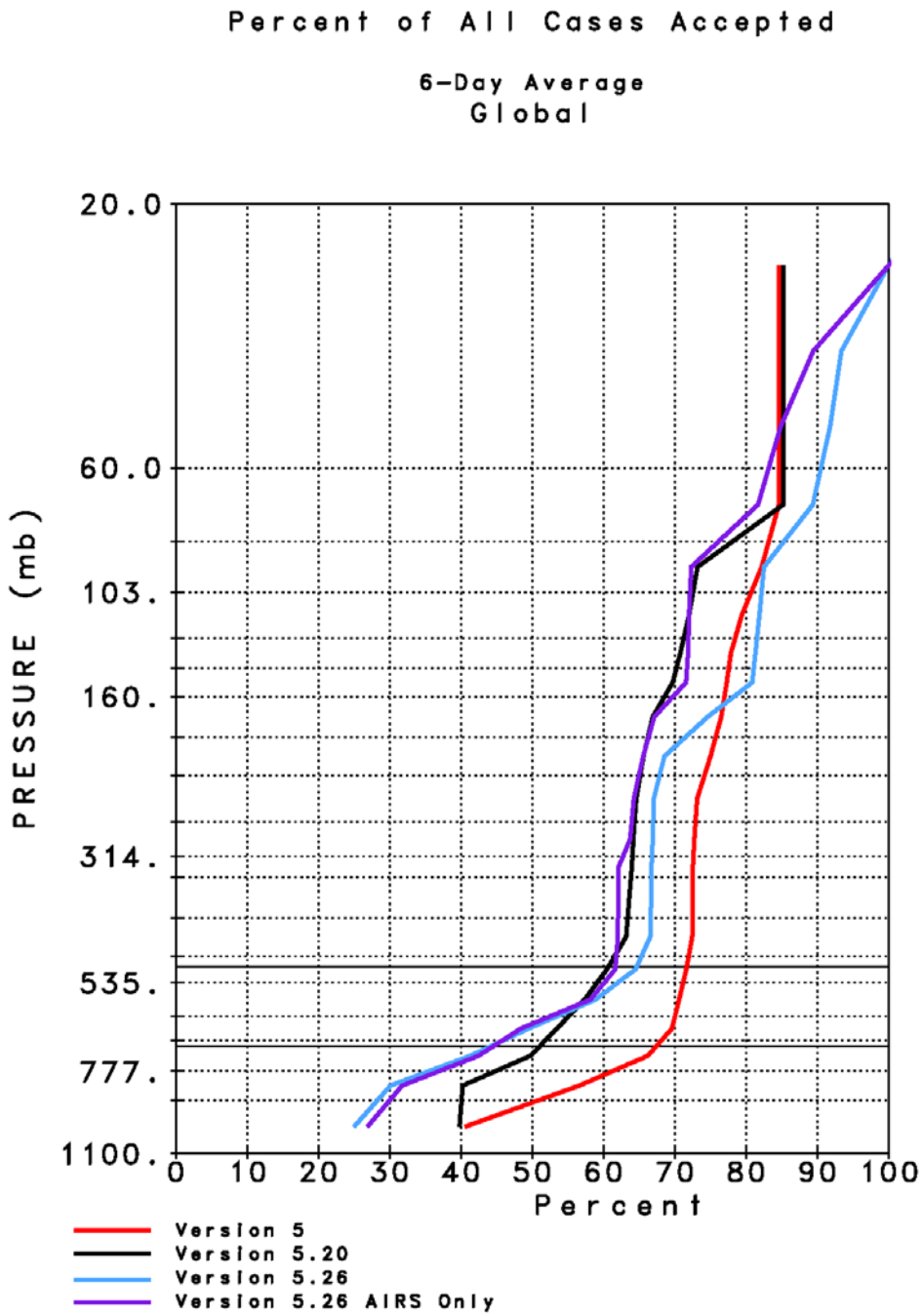

Trend of Percent of All Cases Accepted (%/Yr)
Global
PRESSURE (mb)
20.0
60.0
103.
160.
314.
535.
777.
1100.
−3 −2 −1 0 1 2 3
Percent/Year
Version 5.20

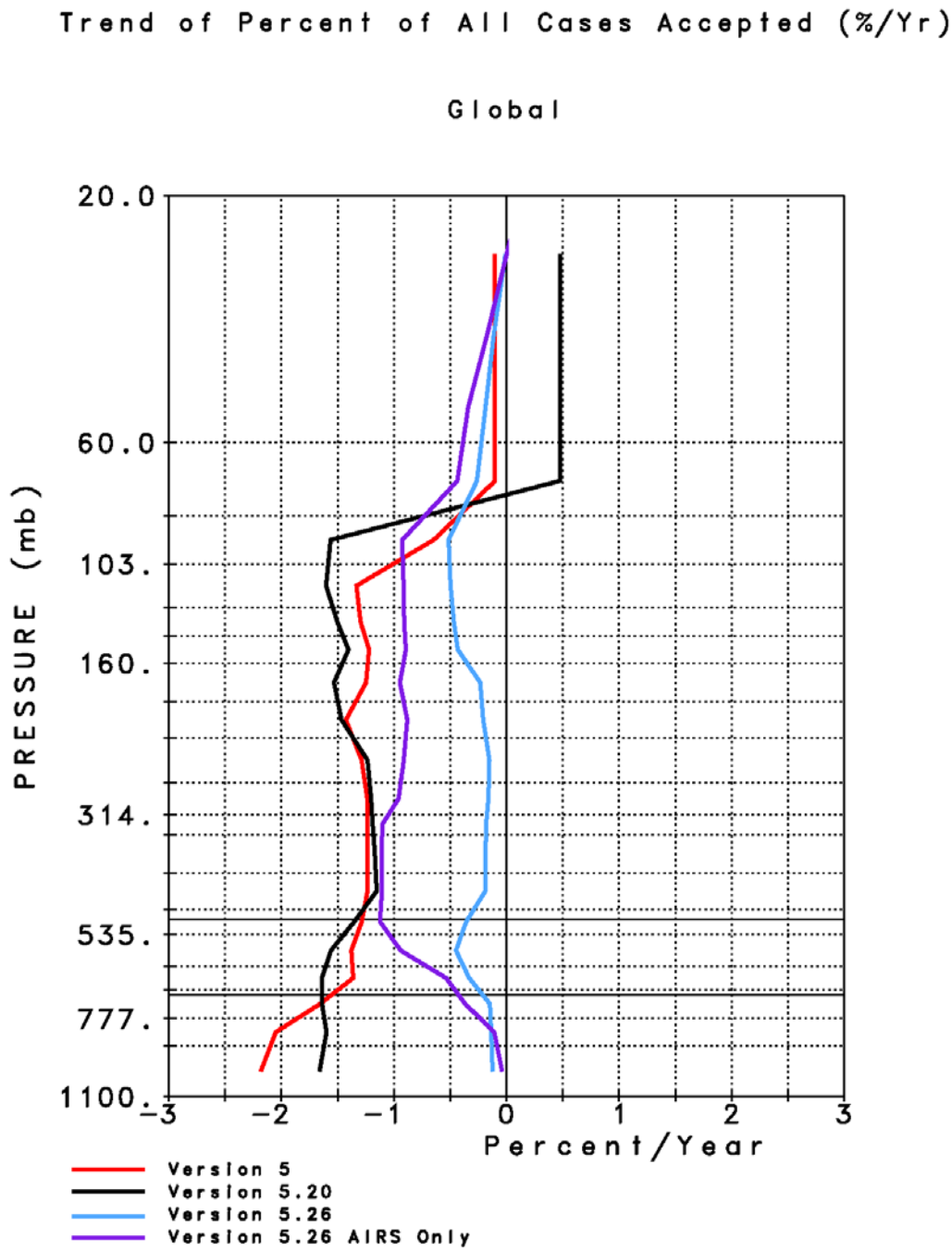

LAYER MEAN RMS TEMPERATURE (°K)
Differences from ECMWF
Version 5.20
Global
PRESSURE (mb)
20.0
60.0
103.
160.
314.
535.
777.
1100.
0
0.5
1
1.5
2
2.5
3
RMS
September 6, 2002
January 25, 2003
September 29, 2004
August 5, 2005
February 24, 2007
August 10, 2007
Six-day average

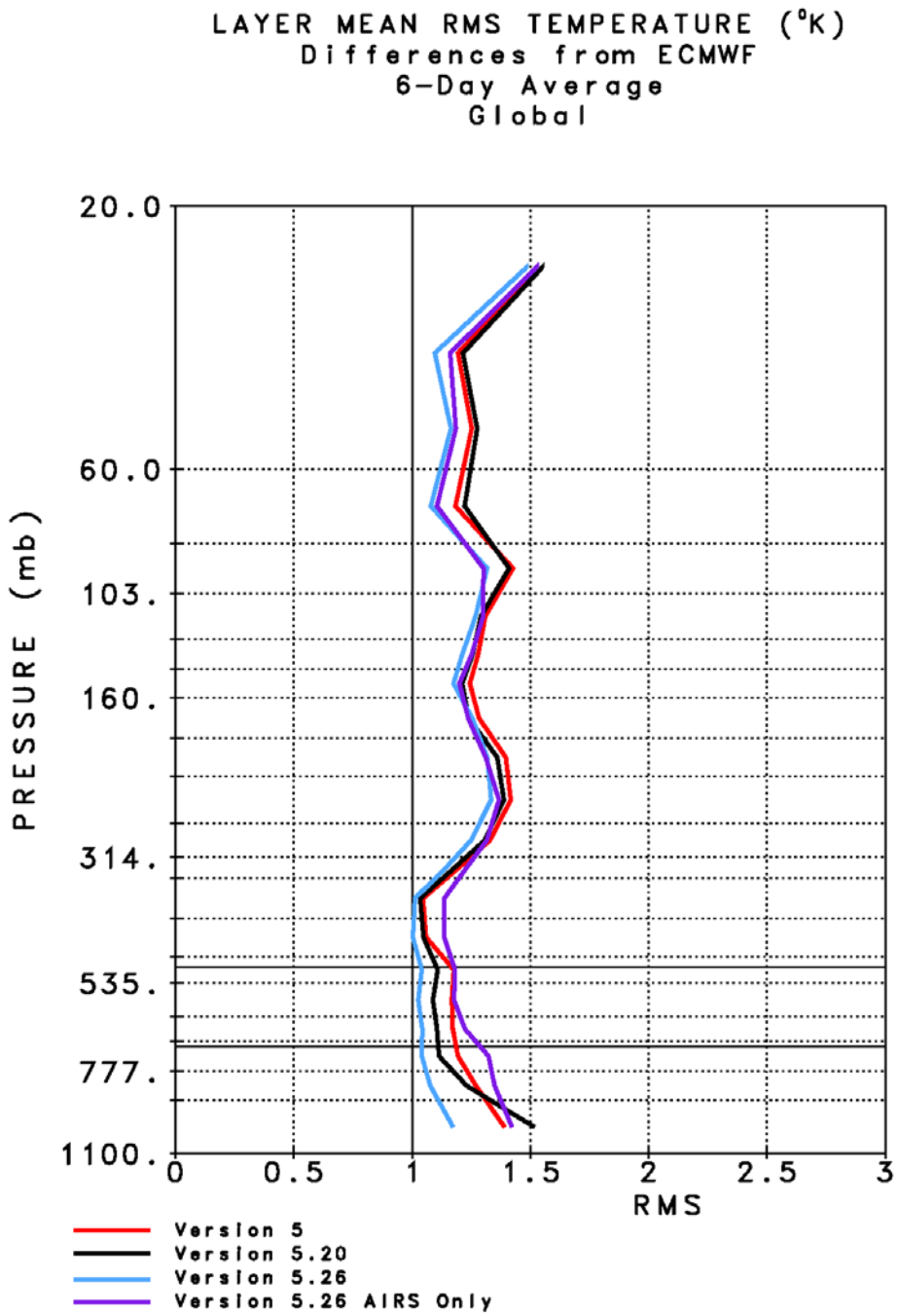

Trend of Layer Mean RMS
Temperature Differences from ECMWF (K/Yr)
Global
PRESSURE (mb)
20.0
60.0
103.
160.
314.
535.
777.
1100
−0.3
−0.2
−0.1
0
0.1
0.2
0.3
Trend of RMS
Version 5.20

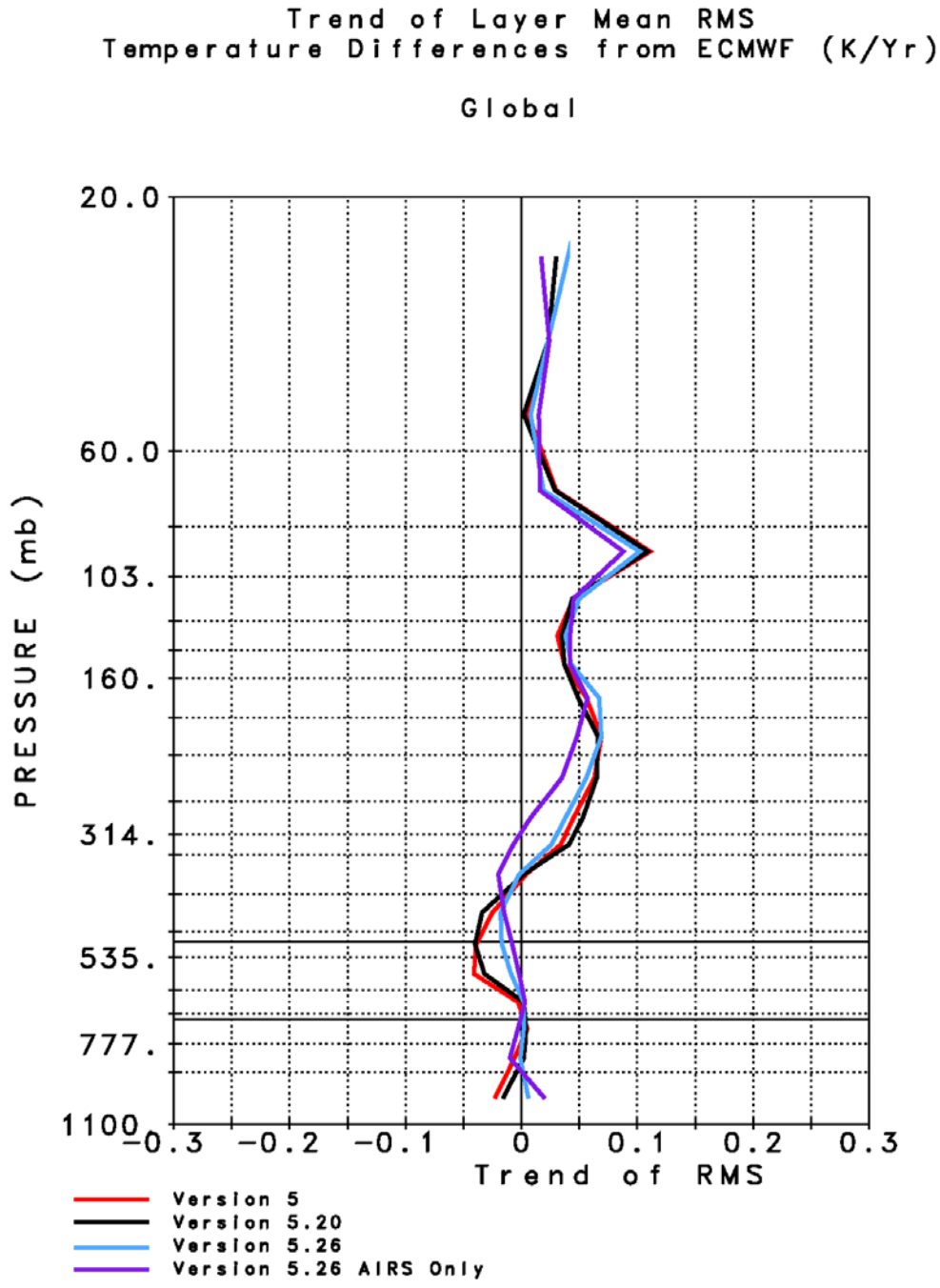

LAYER MEAN BIAS TEMPERATURE (°K)
Differences from ECMWF
Version 5.20
Global
PRESSURE (mb)
20.0
60.0
103.
160.
314.
535.
777.
1100.
−2 −1.5 −1 −0.5 0 0.5 1 1.5 2
BIAS
September 6, 2002
January 25, 2003
September 29, 2004
August 5, 2005
February 24, 2007
August 10, 2007
Six-day average

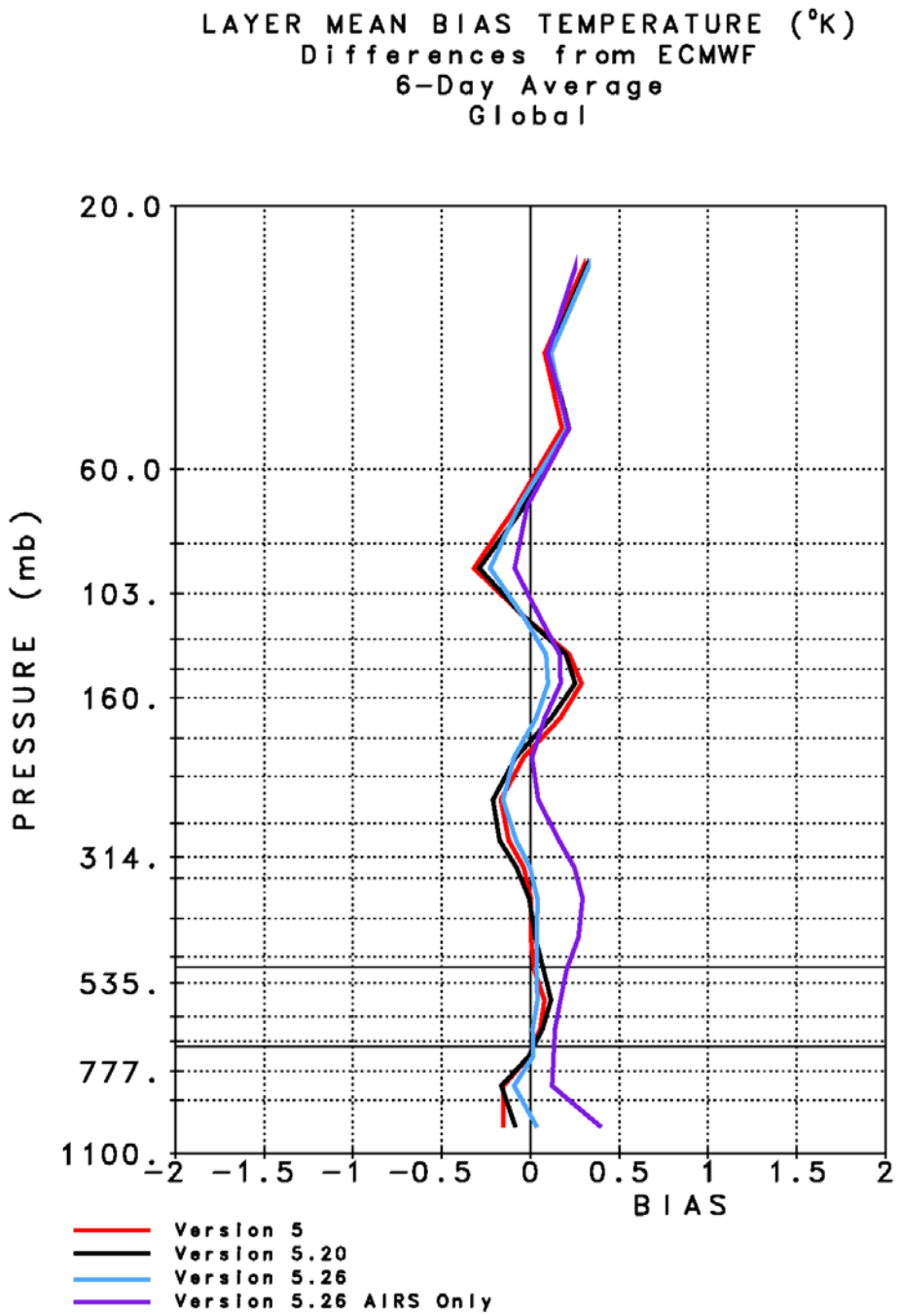

Trend of Layer Mean Bias
Temperature Differences from ECMWF (K/Yr)
Global
PRESSURE (mb)
20.0
60.0
103.
160.
314.
535.
777.
1100
−0.3 −0.2 −0.1 0 0.1 0.2 0.3
Trend of BIAS
Version 5.20

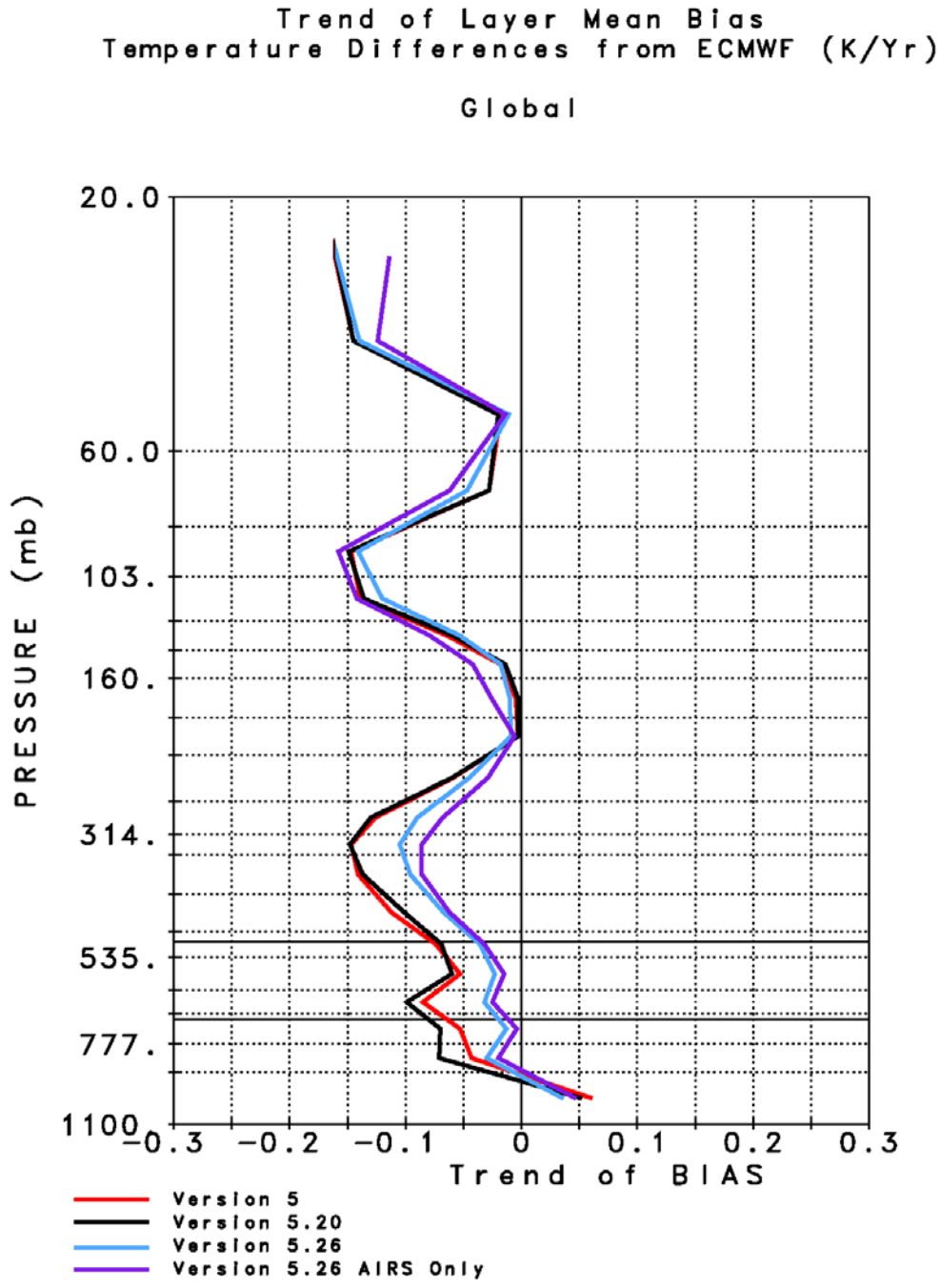

Percent of All Cases Accepted
6-Day Average
Global
PRESSURE (mb)
20.0
60.0
103.
160.
314.
535.
777.
1100.
0 10 20 30 40 50 60 70 80 90 100
Percent
Version 5
Version 5.20
Version 5.26
Version 5.26 AIRS Only


Trend of Percent of All Cases Accepted (%/Yr)
Global
PRESSURE (mb)
20.0
60.0
103.
160.
314.
535.
777.
1100.
−3 −2 −1 0 1 2 3
Percent/Year
Version 5
Version 5.20
Version 5.26
Version 5.26 AIRS Only


LAYER MEAN RMS TEMPERATURE (°K)
Differences from ECMWF
6-Day Average
Global
PRESSURE (mb)
20.0
60.0
103.
160.
314.
535.
777.
1100.
0
0.5
1
1.5
2
2.5
3
RMS
Version 5
Version 5.20
Version 5.26
Version 5.26 AIRS Only


Trend of Layer Mean RMS
Temperature Differences from ECMWF (K/Yr)
Global
PRESSURE (mb)
20.0
60.0
103.
160.
314.
535.
777.
1100.
−0.3
−0.2
−0.1
0
0.1
0.2
0.3
Trend of RMS
Version 5
Version 5.20
Version 5.26
Version 5.26 AIRS Only


LAYER MEAN BIAS TEMPERATURE (°K)
Differences from ECMWF
6-Day Average
Global
PRESSURE (mb)
20.0
60.0
103.
160.
314.
535.
777.
1100.
-2 -1.5 -1 -0.5 0 0.5 1 1.5 2
BIAS
Version 5
Version 5.20
Version 5.26
Version 5.26 AIRS Only


Trend of Layer Mean Bias
Temperature Differences from ECMWF (K/Yr)
Global
PRESSURE (mb)
20.0
60.0
103.
160.
314.
535.
777.
1100.
-0.3 -0.2 -0.1 0 0.1 0.2 0.3
Trend of BIAS
Version 5
Version 5.20
Version 5.26
Version 5.26 AIRS Only

# Changes Made in 5.26 to Reduce Negative Trends

In the September 3, 2009 NetMeeting we showed that

- Negative trends in (T(p) – ECMWF) did not depend much on start up state

  Skipping second (cloud cleared) regression step slightly lessened negative (T(p)-ECMWF) trend

  Cloudy regression followed by MW retrieval was used as first guess for physical retrieval

- Skipping second regression significantly reduced negative yield trend

  Two regression based predictors were also eliminated in generating error estimates

  14 terms vs. 16 terms in V5.0 and V5.20

- Skipping second regression step caused some degradation in SST and $\varepsilon_\nu$

**In Version 5.26 the following modifications were made to reduce trends**

1) We run second regression but only use $T_{skin}^{reg}$ and $\varepsilon_\nu^{reg}$ as first guess for physical retrieval

   Rest of first guess comes from cloudy regression followed by MW retrieval

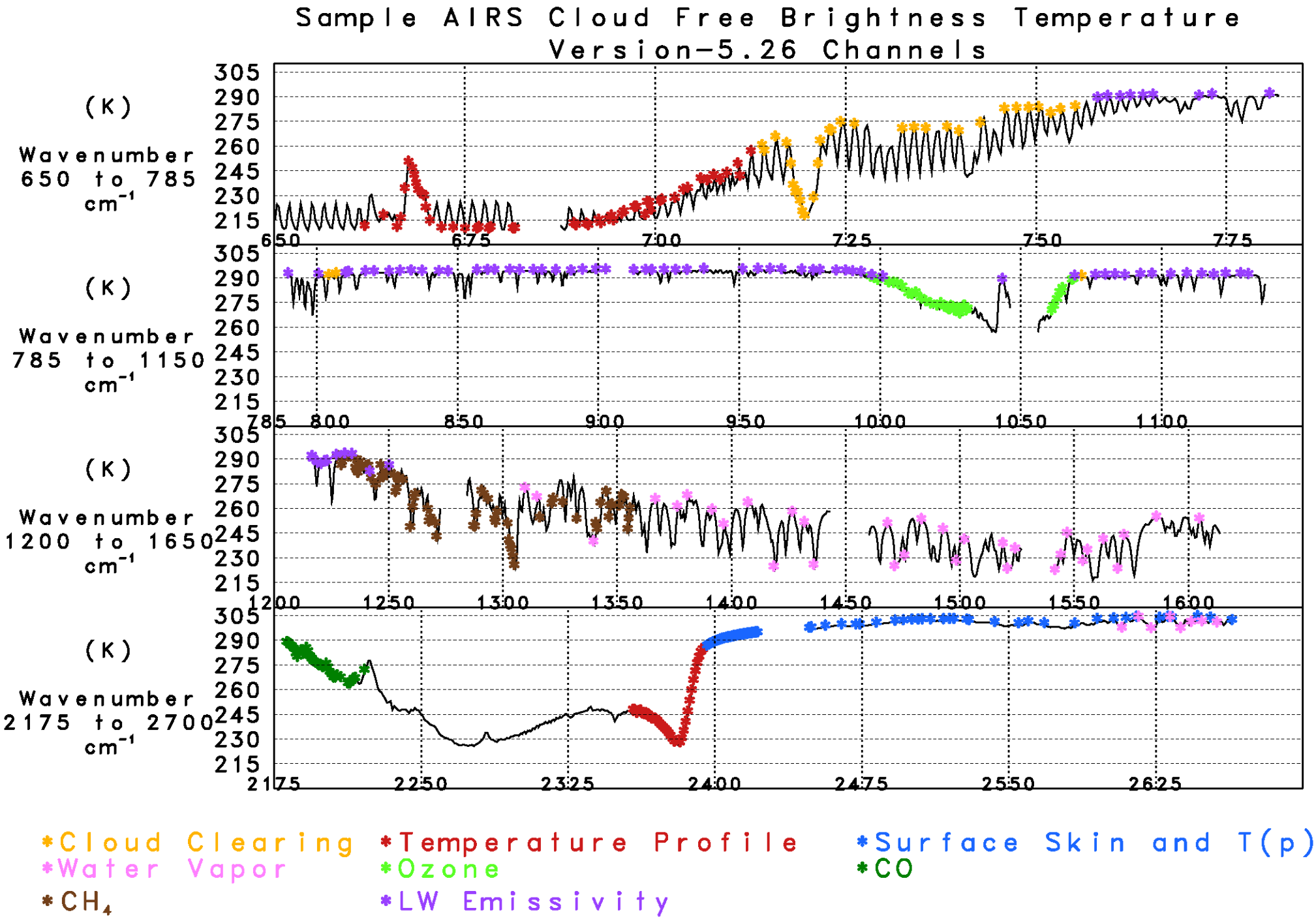
   We still use only 14 predictors to generate error estimates (11 predictors in V5.26AO)

2) As suggested by Eric Maddy and Chris Barnet, we also removed $N_2O$ channels near 2250 $cm^{-1}$ from T(p) retrieval

**Findings**

Version 5.26 almost eliminates negative bias trends in yield of T(p)

Both V5.26 and V5.26AO significantly lessen negative tropospheric bias trends in T(p)


Sample AIRS Cloud Free Brightness Temperature
Version-5.26 Channels
(K)
Wavenumber 650 to 785 cm-1
Wavenumber 785 to 1150 cm-1
Wavenumber 1200 to 1650 cm-1
Wavenumber 2175 to 2700 cm-1
305
290
275
260
245
230
215
650
675
700
725
750
775
785
800
850
900
950
1000
1050
1100
1200
1250
1300
1350
1400
1450
1500
1550
1600
2175
2250
2325
2400
2475
2550
2625
*Cloud Clearing
*Temperature Profile
*Surface Skin and T(p)
*Water Vapor
*Ozone
*CO
*CH4
*LW Emissivity

# Version 5 Temperature Profile Quality Control

Used for all Stratosphere Good cases – otherwise Qual_Temp = 2

Temperature profile error estimates $\delta T(p)$ are used to determine pressure $p_{best}$, down to which Qual_Temp = 0 (shorthand QC = 0)

$p_{best}$ is the pressure down to which $\delta T(p) \leq \Delta T(p)$ where $\Delta T(p)$ is an acceptance threshold

Version 5 $\Delta T(p)$ thresholds were one "size fits all" – called $\Delta T(p)^{standard}$

- Same thresholds were used for weather (data assimilation) and climate purposes
- $\Delta T(p)$ was specified at 3 pressures: 70 mb, $p_s/2$, and $p_s$
- $\Delta T(p)$ linearly interpolated in $\ell n\ p$ between these pressures

Data assimilation needs highest accuracy with good spatial coverage

- Data assimilation experiments showed Version 5 $\Delta T(p)$ was looser than optimal
- Forecasts using $\Delta T(p)^{tight}$ for QC were significantly better $\Delta T(p)^{standard}$

Climate requires best spatial coverage with good (unbiased) accuracy

- Use of Version 5 soundings over land only down to $p_{best}$ in Level 3 produces very poor spatial coverage
- Therefore more soundings are included in Version 5 over land in Level 3 product (QC=1)

For all cases, $p_{good}$ represents the pressure down to which soundings are included in Level 3 (QC=0,1)

- $p_{good}$ over land was set equal to $p_{surf}$ in Version 5 if $p_{best} \geq 300$ mb

# Improved Version 6 Approach to Obtain $p_{good}$

$p_{good}$ was obtained in an ad-hoc manner in Version 5

Over ocean QC = 0 yield was "good enough" when $p_{good}$ equals $p_{best}$ (QC never = 1)

Over land desperate measures were used to get adequate coverage near the surface

Sometimes soundings near surface were not good when $p_{best}$ > 300 mb and QC set = 1

Gaps still existed in Level 3 product over land

**In Version 6, $p_{good}$ will be determined by error estimate thresholds as is $p_{best}$**

We define two sets of thresholds $\Delta_A T(p)$ and $\Delta_C T(p)$ to replace $\Delta T(p)^{standard}$ now used

$\Delta_A T(p)$ and $\Delta_C T(p)$ used for data assimilation and climate purposes respectively

$p_{best}$ is defined as before but using $\Delta_A T(p)$

$\Delta_A T(p)$ is tighter than current $\Delta T(p)^{standard}$ - analogous to Version 5 $\Delta T(p)^{tight}$

$p_{good}$ is defined analogously to $p_{best}$ but using $\Delta_C T(p)$

$\Delta_C T(p)$ is looser than current $\Delta T(p)^{standard}$

Level 2 soundings will be flagged as QC = 0 down to $p_{best}$ as done now

Level 2 soundings will be flagged as QC =1 between $p_{best}$ and $p_{good}$

Proposal by George: Level 2 soundings will not be used in Level 3 product at any level unless

$p_{good} = p_{surf}$

This differs from Version 5 approach

# (Almost) No Levels Left Behind in New Level 3A Product

Level 3A is a new product requested by George Aumann

Level 3A is a gridded product where a value of (almost) all soundings is included at all possible levels

Level 2 product has soundings with Qual_Temp = 0 or 1 down to $p_{good}$

Level 3A product will include soundings with Qual_Temp = 3 (and maybe Qual_Temp = 4)

Qual_Temp = 3 includes T(p) down to $p_{fair}$

$p_{fair}$ determined using a further relaxed threshold $\Delta_R T(p)$

Retrieved T(p) may be adequate for use in Level 3A if $\delta T(p) = 4K$ but not 10K

Qual_Temp = 4 uses fabricated data $T'(p)$ beneath $p_{fair}$

One possibility is given by

$T'(p) = T_{CLIM}(p) + \Delta T_{CLIM}$ between $p_{fair}$ and $p_{surf}$ where

$\Delta T_{CLIM} = T(p_{fair}) - T_{CLIM}(p_{fair})$

Some cases, such as overcast at 100 mb are still best “left behind”

It may also be sufficient to “leave behind” all cases where $p_{fair} < p_{surf}$ if yield is still high enough

# New Statistical Plot

Current plots of % yield, RMS errors and biases include Qual_Temp = 0 cases only

We will also include two more statistics

Include Qual_Temp = 0 or 1 (used for Level 3)

Include Qual_Temp = 0, 1, or 3 (or 4?) (used for Level 3A)

These statistics will be used to test the performance of different options for Level 3 and Level 3A

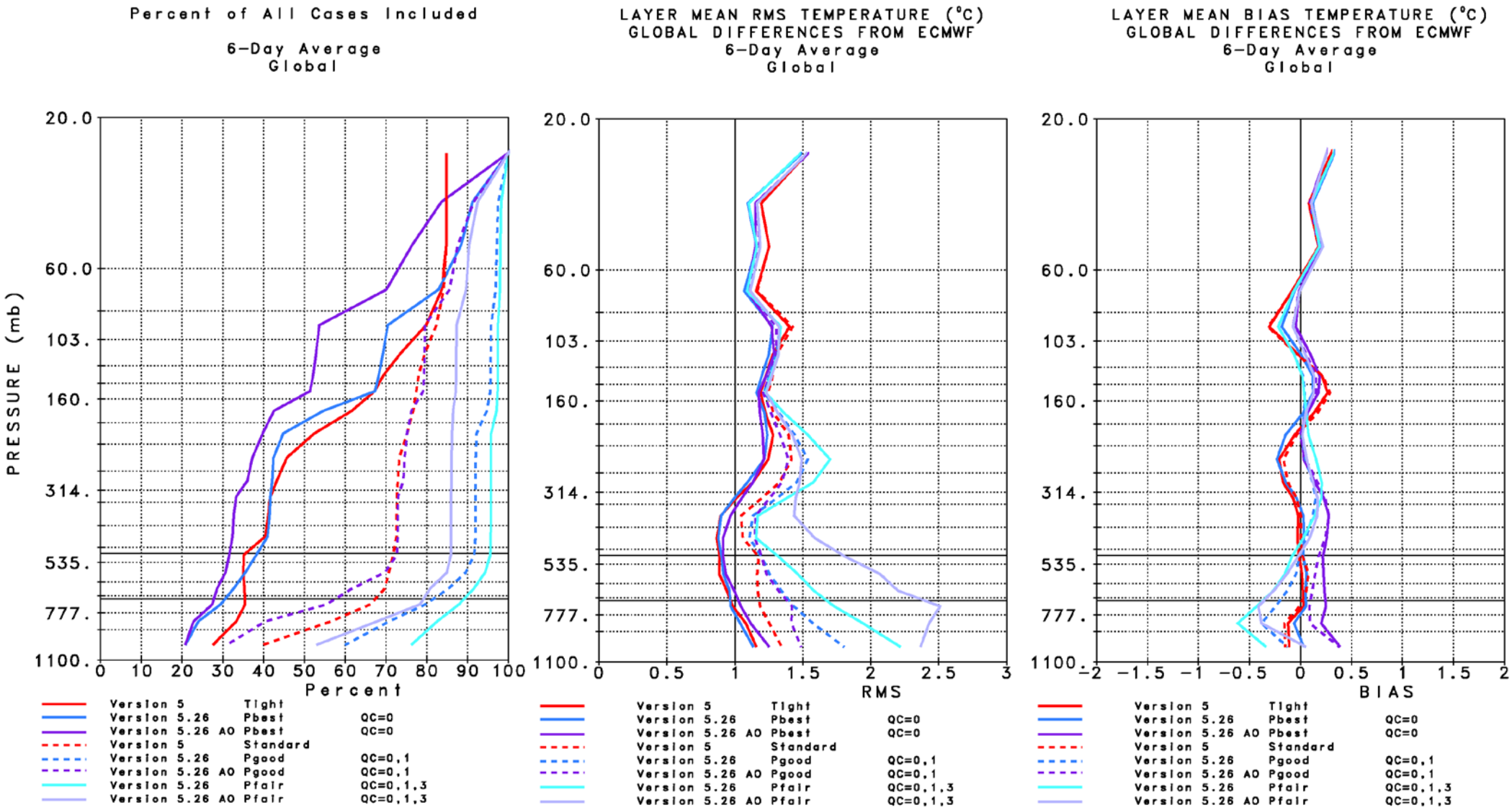
Sample results are shown for “trial balloon” thresholds based on limited testing

Optimization of QC thresholds will be needed for $p_{best}$, $p_{good}$, and $p_{fair}$ for both V5.26 and V5.26AO

# Current Trial Balloon for $\Delta T(p)_A$, $\Delta T(p)_C$, and $\Delta T(p)_R$ – Proof of Concept

| | Ocean | | | Land | | |
|---|---|---|---|---|---|---|
| V5.26 | $\Delta T(30)$ | $\Delta T(p_s/2)$ | $\Delta T(p_s)$ | $\Delta T(30)$ | $\Delta T(p_s/2)$ | $\Delta T(p_s)$ |
| $\Delta T_A\,(p_{best})$ | 1.5 | 0.8 | 1.4 | 1.5 | 0.8 | 1.4 |
| $\Delta T_C\,(p_{good})$ | 2.8 | 2.5 | 2.8 | 3.3 | 2.8 | 3.0 |
| $\Delta T_R\,(p_{fair})$ | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |

| | Ocean | | | Land | | |
|---|---|---|---|---|---|---|
| V5.26AO | $\Delta T(30)$ | $\Delta T(p_s/2)$ | $\Delta T(p_s)$ | $\Delta T(30)$ | $\Delta T(p_s/2)$ | $\Delta T(p_s)$ |
| $\Delta T_A\,(p_{best})$ | 1.5 | 0.8 | 1.4 | 1.5 | 0.8 | 1.4 |
| $\Delta T_C\,(p_{good})$ | 2.0 | 1.5 | 1.5 | 2.0 | 1.5 | 1.5 |
| $\Delta T_R\,(p_{fair})$ | 2.0 | 2.5 | 2.5 | 2.0 | 2.5 | 2.5 |


Percent of All Cases Included
6-Day Average
Global
PRESSURE (mb)
20.0
60.0
103.
160.
314.
535.
777.
1100.
0 10 20 30 40 50 60 70 80 90 100
Percent
Version 5 Tight
Version 5.26 Pbest QC=0
Version 5.26 AO Pbest QC=0
Version 5 Standard
Version 5.26 Pgood QC=0,1
Version 5.26 AO Pgood QC=0,1
Version 5.26 Pfair QC=0,1,3
Version 5.26 AO Pfair QC=0,1,3
LAYER MEAN RMS TEMPERATURE (°C)
GLOBAL DIFFERENCES FROM ECMWF
6-Day Average
Global
0 0.5 1 1.5 2 2.5 3
RMS
Version 5 Tight
Version 5.26 Pbest QC=0
Version 5.26 AO Pbest QC=0
Version 5 Standard
Version 5.26 Pgood QC=0,1
Version 5.26 AO Pgood QC=0,1
Version 5.26 Pfair QC=0,1,3
Version 5.26 AO Pfair QC=0,1,3
LAYER MEAN BIAS TEMPERATURE (°C)
GLOBAL DIFFERENCES FROM ECMWF
6-Day Average
Global
-2 -1.5 -1 -0.5 0 0.5 1 1.5 2
BIAS
Version 5 Tight
Version 5.26 Pbest QC=0
Version 5.26 AO Pbest QC=0
Version 5 Standard
Version 5.26 Pgood QC=0,1
Version 5.26 AO Pgood QC=0,1
Version 5.26 Pfair QC=0,1,3
Version 5.26 AO Pfair QC=0,1,3

## Findings Based on Trial Balloon $\Delta T_A$, $\Delta T_C$, and $\Delta T_R$

**$\Delta T_A$- $p_{best}$**

Global Accuracy and % yields for V5 Tight, V5.26 and V5.26AO are all similar

V5.26AO performs as well as V5.26 for the "easier" cloud cases

Assimilation of QC T(p) from either V5.26 or V5.26AO should continue to improve forecast skill

**$\Delta T_C$- $p_{good}$**

V5.26 has a substantially higher yield than V5.0 Standard, with somewhat degraded results

Perhaps somewhat tighter values of $\Delta T_C$ would be better

V5.26AO has comparable accuracy with V5.26, with lower yield

V5.26 can handle some of the harder cloud cases than V5.26 AO can't

**$\Delta T_R$- $p_{fair}$**

Results of reasonable accuracy can be obtained for almost all cases in V5.26

There is a negative and larger RMS error beneath 500 mb.

It might be better to extrapolate from climatology beneath 500 mb

# Comparison of V5.26 and V5.0 for Other Geophysical Parameters

Comparisons are based on 6 days of data, day and night averaged

Surface emissivity not addressed in this talk

- Surface emissivity over land addressed by Glynn Hulley
- Surface emissivity over ocean addressed previously

Ocean Surface Skin Temperature

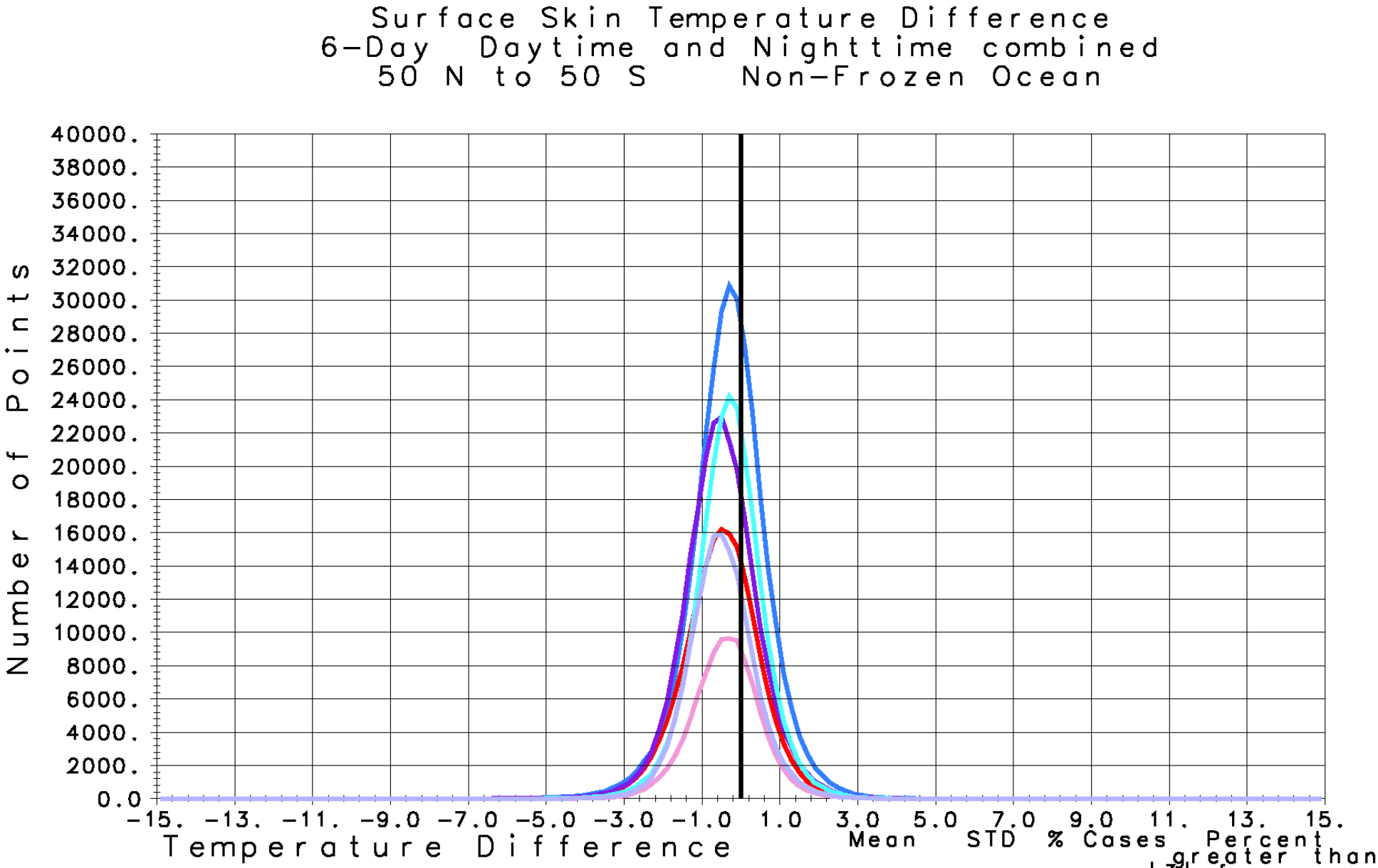
- Histograms of counts versus $T_s$ ECMWF
  - Want smaller biases, lower % outliers with higher yield
- Spatial plots of 6 day averaged differences from ECMWF for Qual_Surf=1
  - Do not want “blue” cold biases – tighter QC
  - Do not want large gaps – looser QC

Cloud fields

- Not shown
  - No difference in cloud retrieval from V5.0, except (almost) no fallback cases

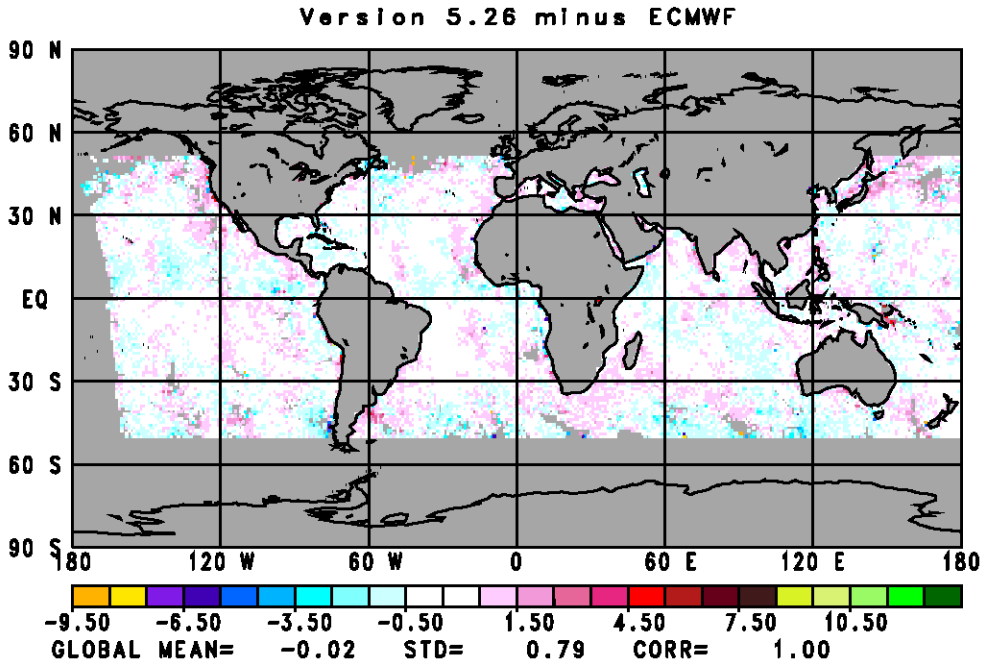
OLR

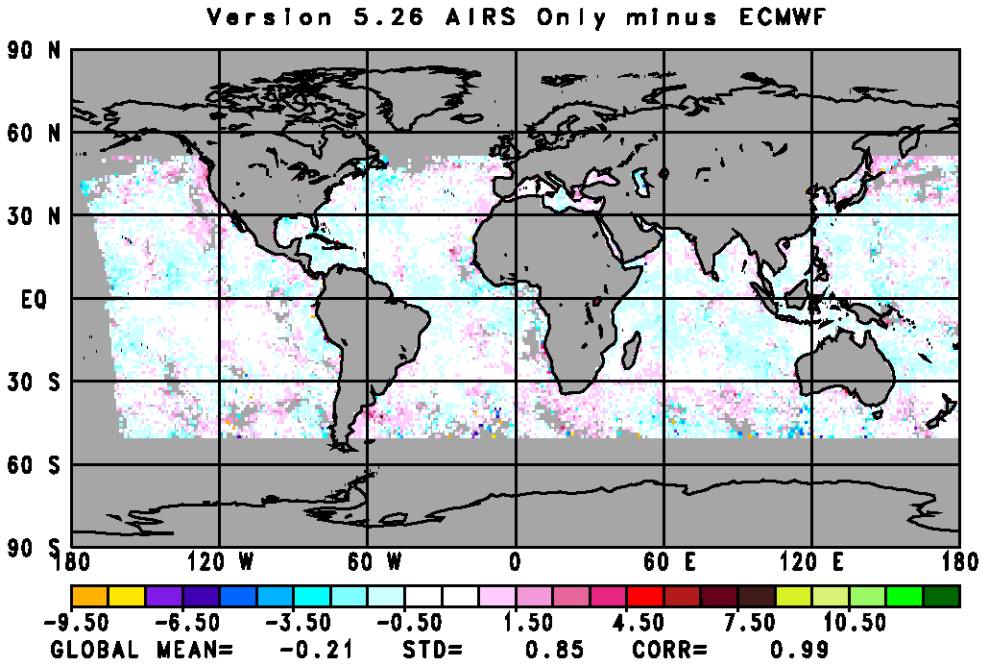
- Affected by changes in OLR RTA and fallback cases

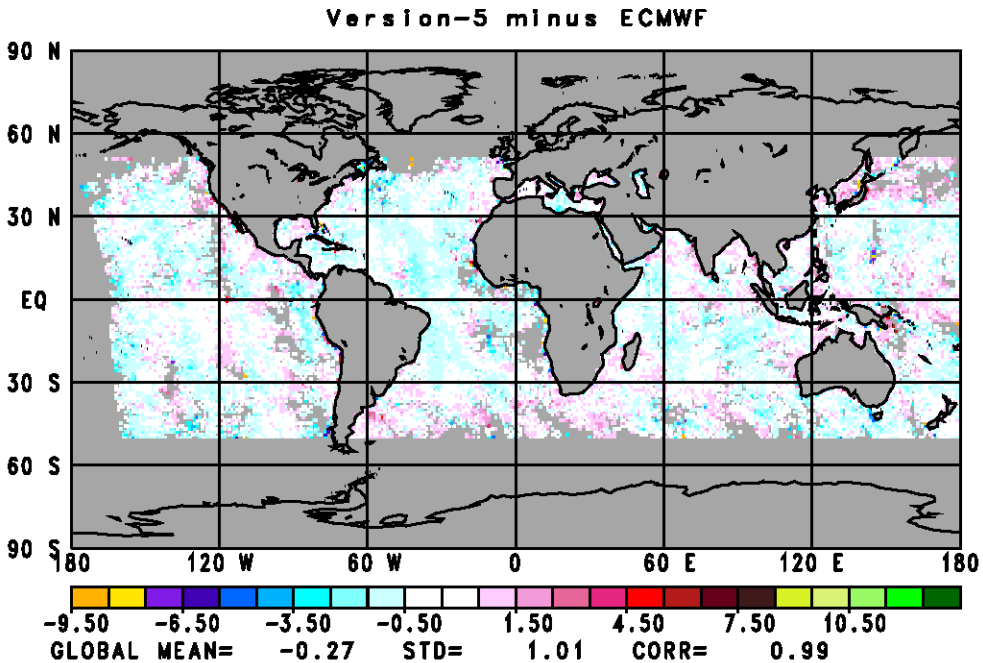



| | | Mean | STD | % Cases | Percent greater than \|3\| from mean |
|---|---|---|---|---|---|
| Version 5.0 | QC=0,1 | -0.31 | 0.98 | 26.00 | 1.21 |
| Version 5.26 | QC=0,1 | -0.12 | 0.99 | 43.87 | 1.26 |
| Version 5.26 AO | QC=0,1 | -0.33 | 0.97 | 36.82 | 1.18 |
| Version 5.0 | QC=0 | -0.20 | 0.87 | 14.02 | 0.49 |
| Version 5.26 | QC=0 | -0.12 | 0.88 | 31.41 | 0.61 |
| Version 5.26 AO | QC=0 | -0.32 | 0.86 | 23.21 | 0.50 |

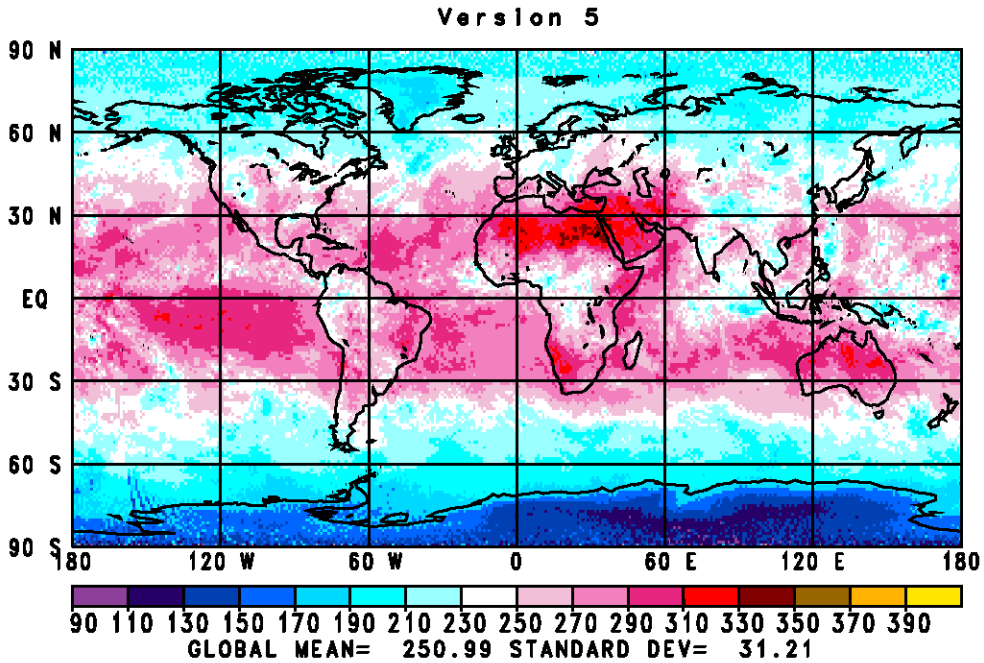
# Surface Skin Temperature (K)
## 6-Day Average
## 50 N to 50S
## QC=0,1

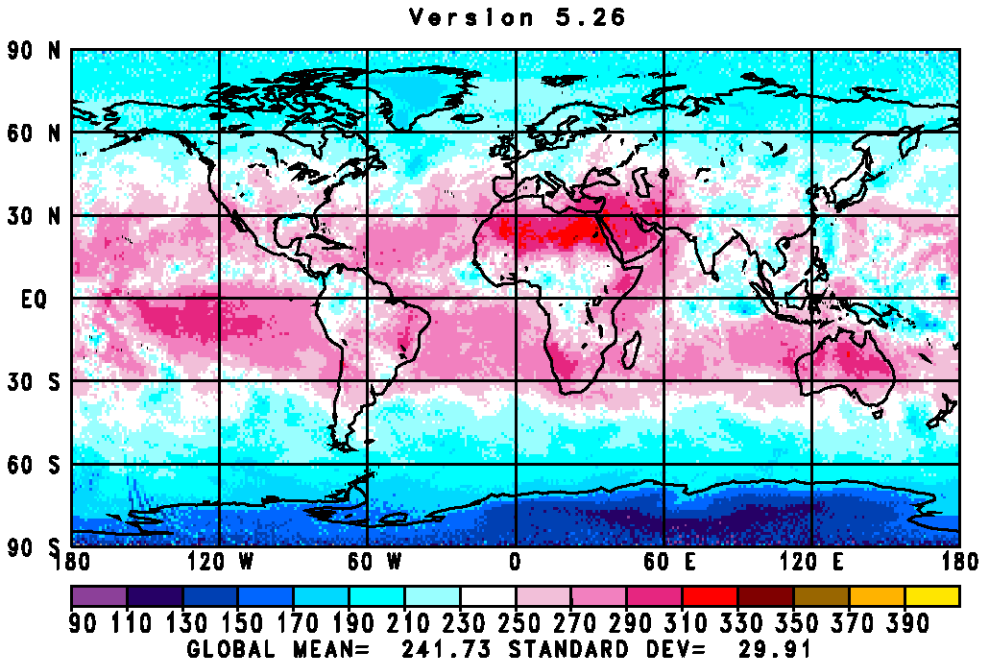


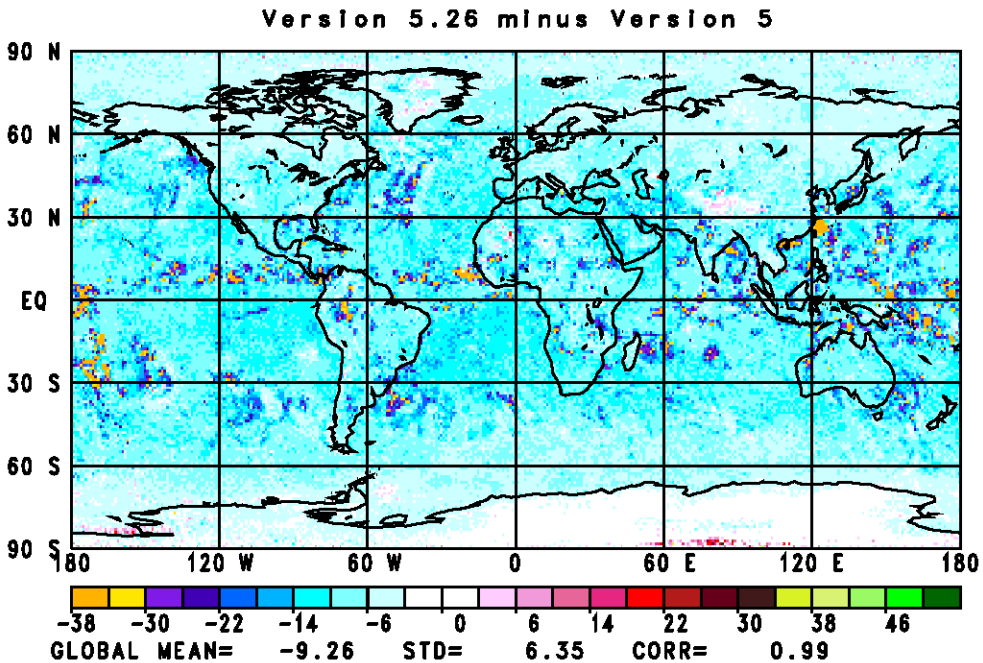



# Outgoing Longwave Radiation (Watts/M²)
## 6-Day average



# Summary

Version 5.26 significantly improves on V.5 in a number of ways

- The negative trend in Version 5.0 T(p) yield is all but eliminated
- The spurious negative trend in Version 5 tropospheric T(p) is substantially reduced
- Version 5.26 has substantially improved land surface emissivity compared to Version 5.0 (see Glynn Hulley's presentation)
- Version 5.26 has a significantly improved Ocean SST product
- Version 5.26 OLR agrees much better with CERES OLR
- Version 5.26 has no retrievals left behind
- Version 5.26 has improved T(p) Quality Flag methodology compared to Version 5.0
- Version 5.26 (almost) does not use AMSU A channels 4 and 5
- Version 5.26 has a viable AIRS Only capability

Further tests and improvements are still necessary before possible release

# Required Work Before Delivery of Version 6

- Installation of current 5.26 at JPL (3 weeks)
- Start-up procedure must not use AMSU-4 and AMSU-5

  Preferred – A new cloudy regression from NOAA without AMSU-4 and 5 (2 weeks to test)

  Second practical option – Evaluate use of cloudy regression without any AMSU (1 week to test)
- Further research optimizing $\Delta T_A$ ($P_{best}$), $\Delta T_C$ ($P_{good}$), and $\Delta T_R$ ($P_{fair}$) (2 weeks)
- Evaluate all fields generated using 5.26 and 5.26AO including QC (3 weeks)

  Water vapor, Trace Gasses, and $\widehat{R}_i$
- Installation of 5.27 – any of the above changes at JPL (3 weeks)
- Resolve level-3 issues (1 week)

  Surface skin temperature level-3 gridding 40S to 60S

  Coastline inclusion in level-3 product

# Desired Work Before Delivery of Version 6

- Further testing to see if spurious negative bias trend at 300 mb can be further mitigated (1 month+)
- Installation of a final cloud parameter retrieval step at end of the retrieval (2 weeks)

  Include cloud spectral emissivity retrieval (6 weeks)
- Install and test new RTA from NOAA which allows for variable frequencies (2 months)

  **This will be our highest priority when it is delivered**
- Include dust score in error estimate coefficients (2 weeks)

  Evaluation of channels used to compute dust score (UMBC)

  Determination of which dust score value to use for error estimate coefficient
- Further minor improvements in retrieval methodology as time permits

# Desirable, But May Not Be Feasible For Version 6

- Install and evaluate neural network start-up (1-2 months)
- Install dust retrieval (needs new RTA installed first) (2 months)
- Assessment of a procedure for Qual_Temp=4 for what to do below $P_{fair}$ (?)

  for level 3A

  Need climatology data set (JPL?) and interface

NASA