Enhanced use of radiance data in NCEP data assimilation systems

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NOAA/NWS/NCEP/EMC

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ITSC-13 Sainte Adèle Canada

Changes in use of radiance data

- Updates to radiative transfer
  - Updated Microwave and IR LBL calculations
  - Separate water vapor continuum
  - VanDelst's surface emissivity (later talk)
- Modifications to data selection and quality control
  - Equal area data selection based on:
    - Likelihood of passing QC
    - Center of box
    - Smallest time difference
  - IR QC based on estimating cloud top and percentage from $\_T_b$

Changes in use of radiance data

- Changes to data assimilation and forecast systems – Implementation by end of year
  - Improved time interpolation – allows use of more frequent output fields – time interpolates surface fields
  - Allows use of guess solution – early analysis can be used for GFS
  - Satellite data monitoring file upgrade
    - http://wwwt.emc.ncep.noaa.gov/gmb/gdas/radiance/prx/index.html (parallel)
    - http://wwwt.emc.ncep.noaa.gov/gmb/gdas/radiance/prq/index.html (AIRS)
  - Streamline code, simplified data handling, and a few bug fixes

Radiance usage

- IR instruments
  - GOES-10/12 sounder
  - HIRS/2 NOAA-14
  - HIRS/3 NOAA-16/17
  - AIRS
  - GOES imager
  - AVHRR
- Microwave instruments
  - MSU NOAA-14
  - AMSU-A NOAA-15/16/17, EOS
  - AMSU-B NOAA-15/16/17
  - SSM/IS

New data types/usages

- AIRS data
- GOES imager data
- SSM/I data
- SST analysis

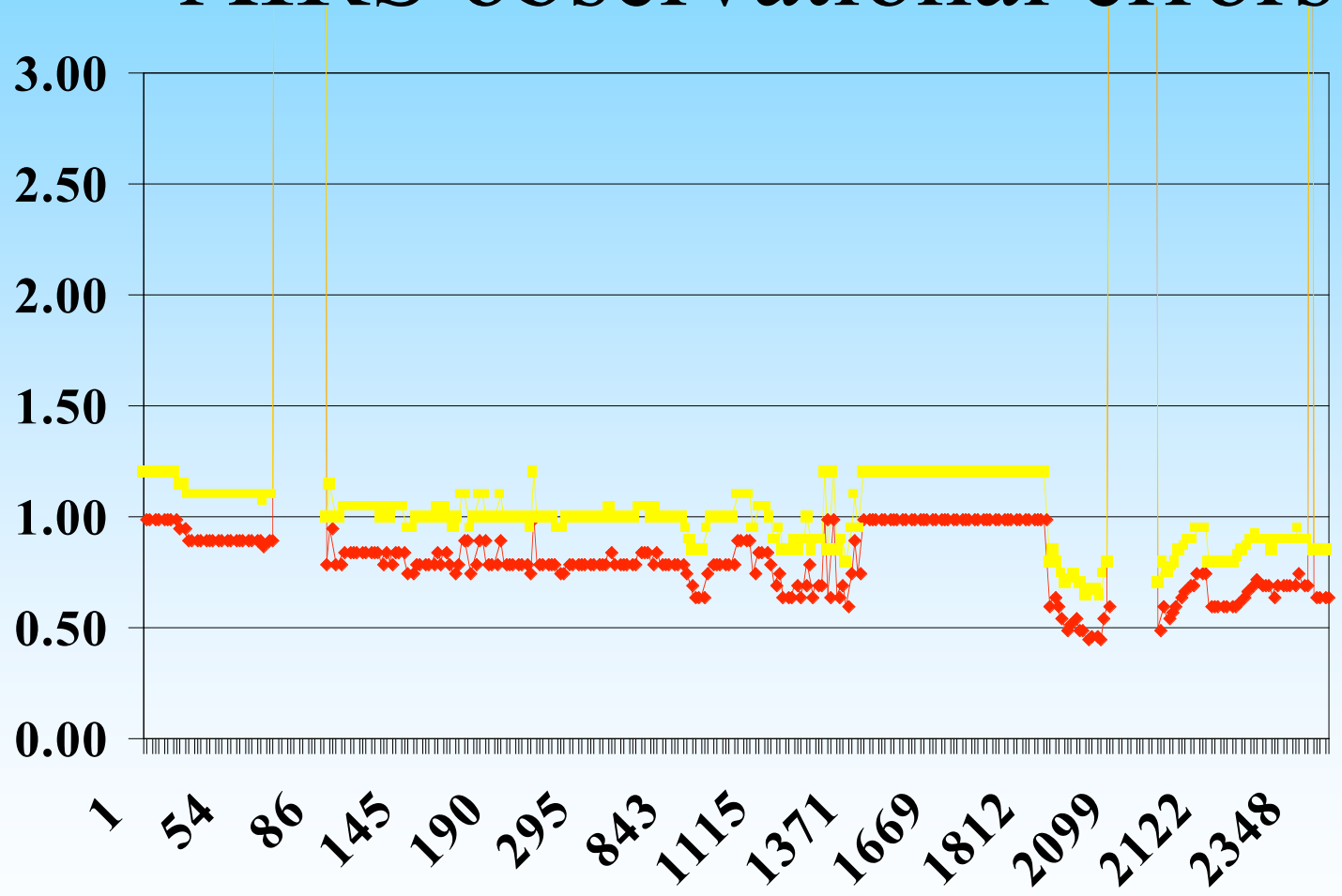
AIRS data

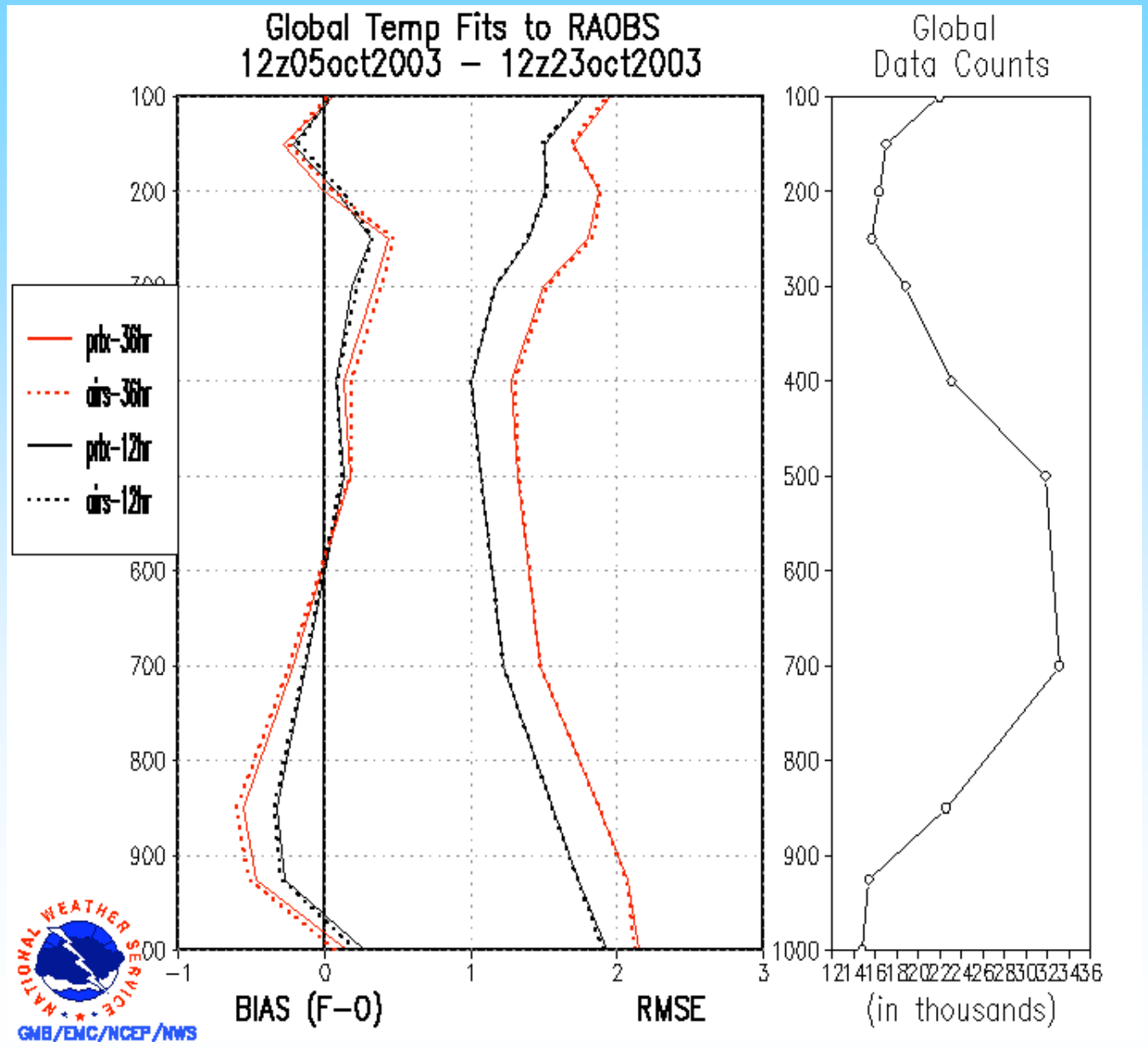
- 254 out of 281 channels used
  - 73-86 removed (Channels peak too high)
  - 1937-2109 removed (non-LTE)
  - 2357 removed (Large obs-background diff.)
- Shortwave channels down weighted (wavenumber > 2000) or removed (wavenumber > 2400) during day

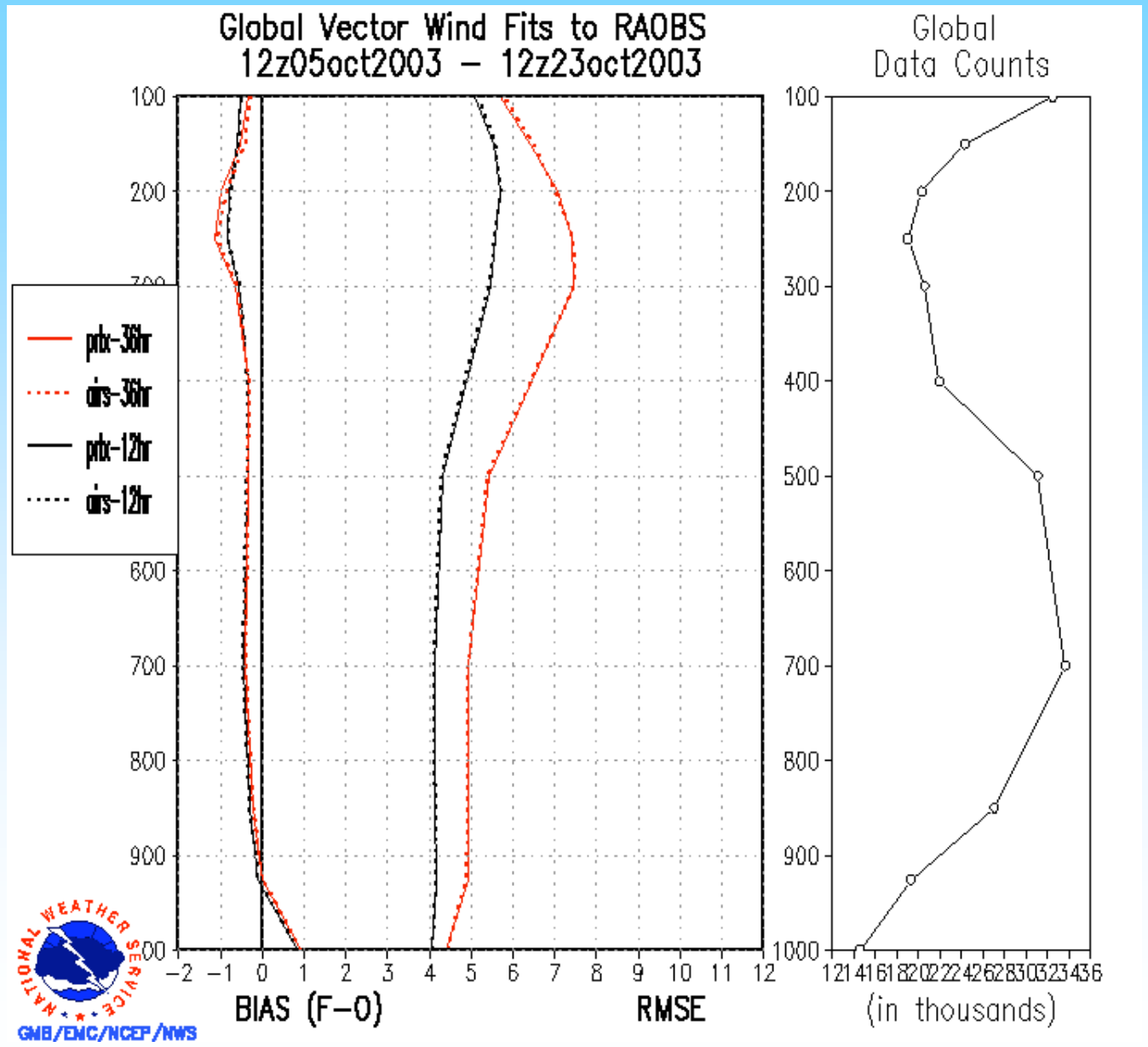
Parallel testing

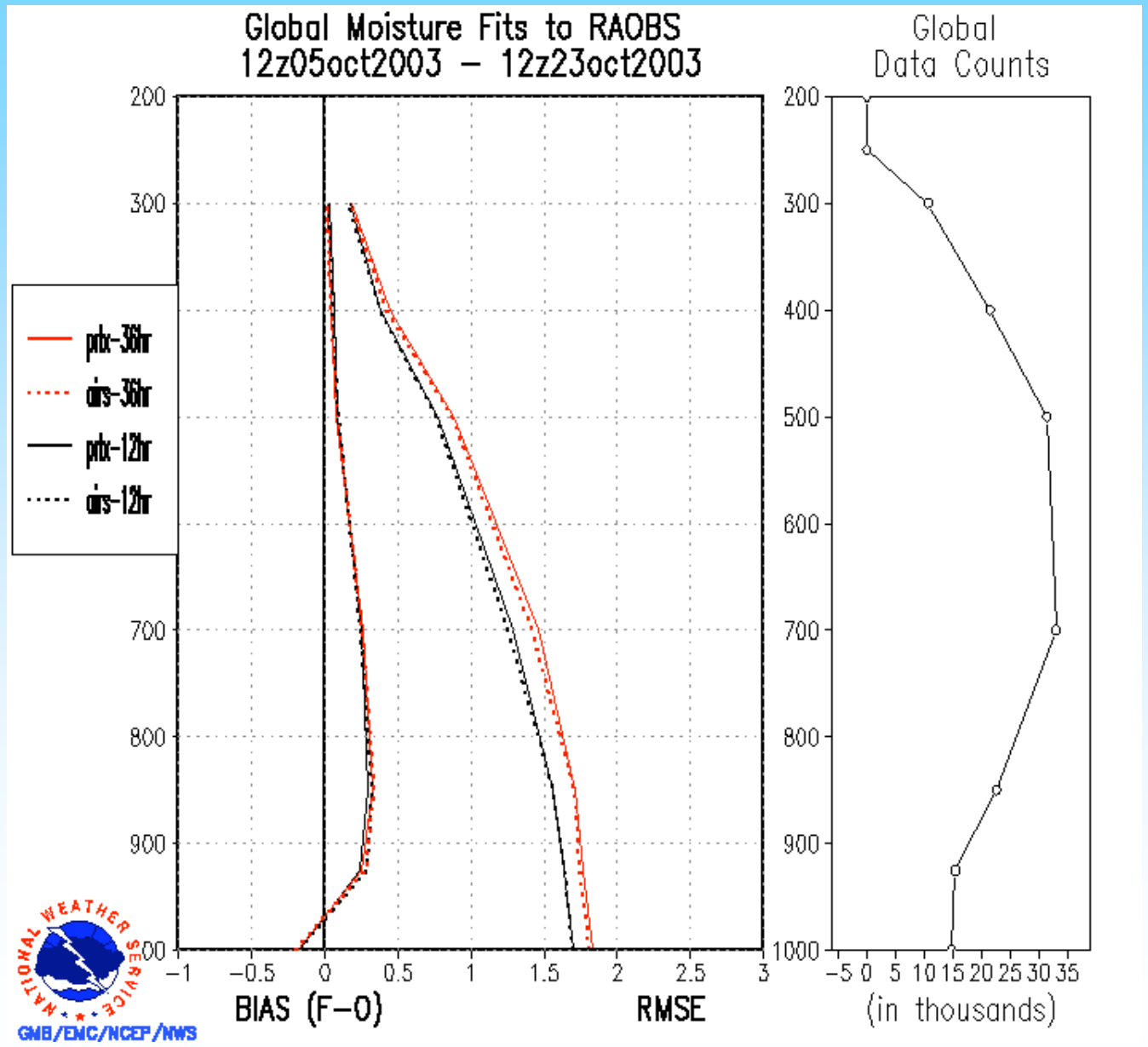
- Testing of system and data impact underway
- System updated as problems uncovered
- Recent changes
  - Removal of channel 2357 – large differences
  - Thinning to 225km vs. 150km – AIRS penalty too large – slow convergence
  - Increase observational error .2 K – AIRS penalty too large – slow convergence

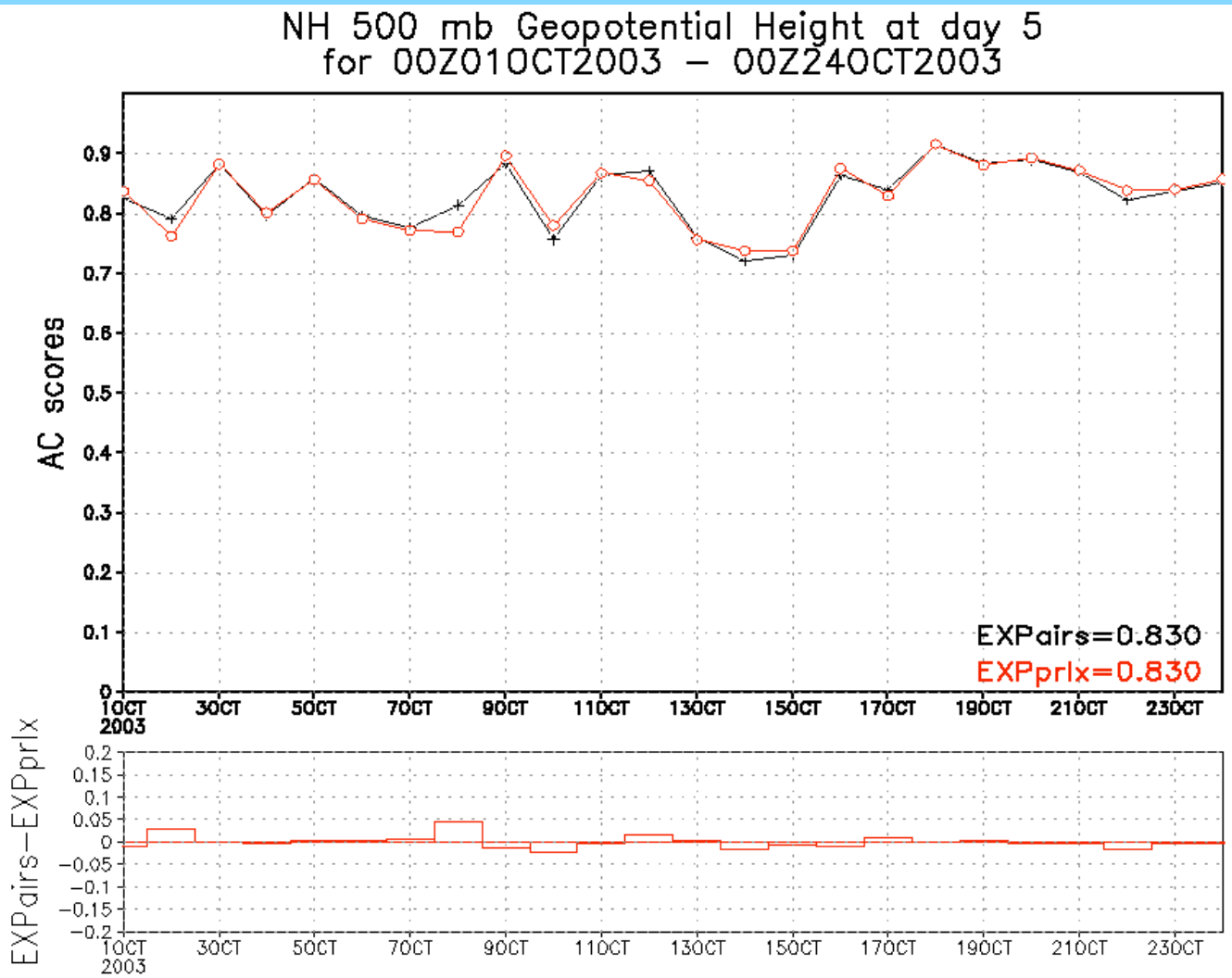
AIRS observational errors

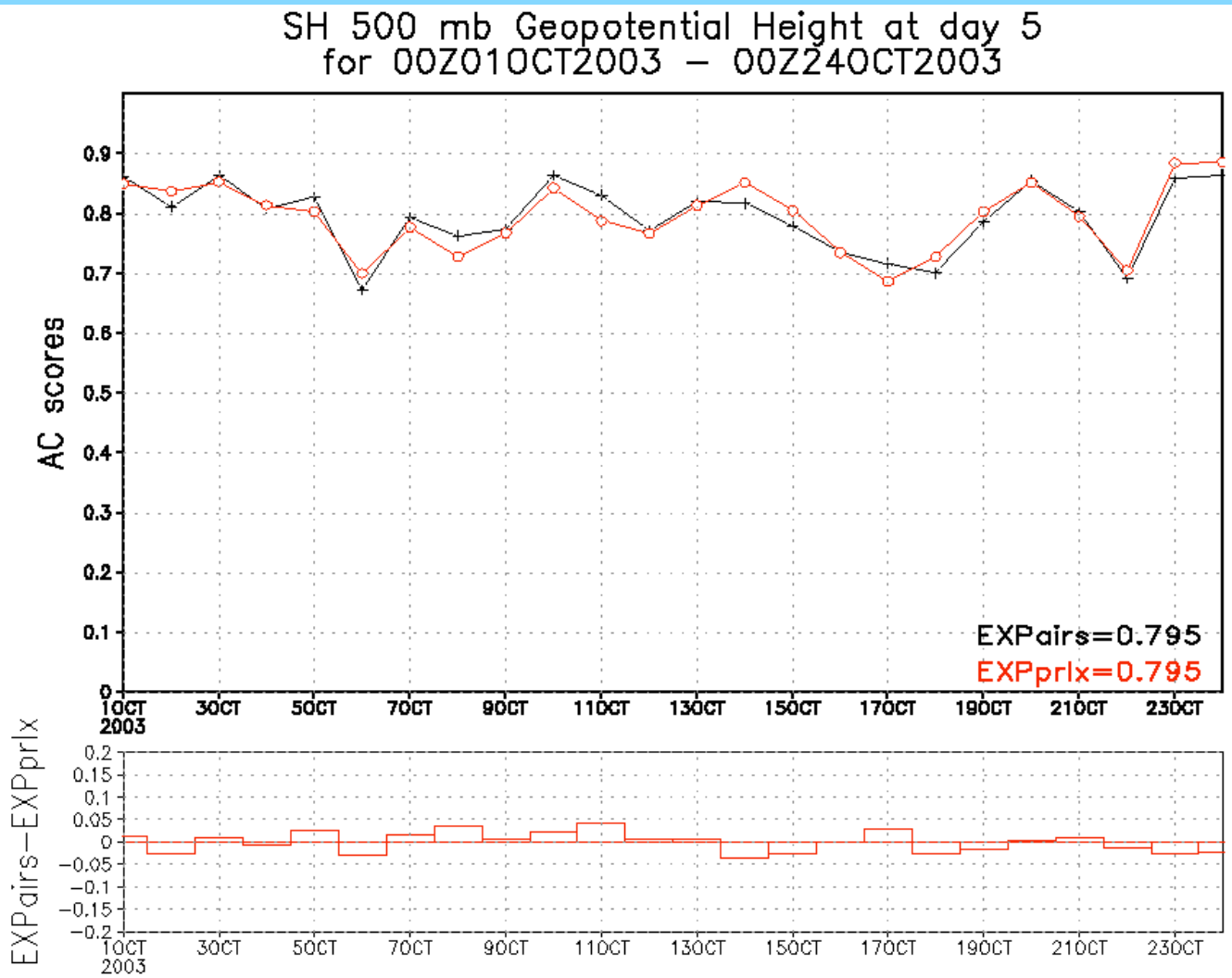


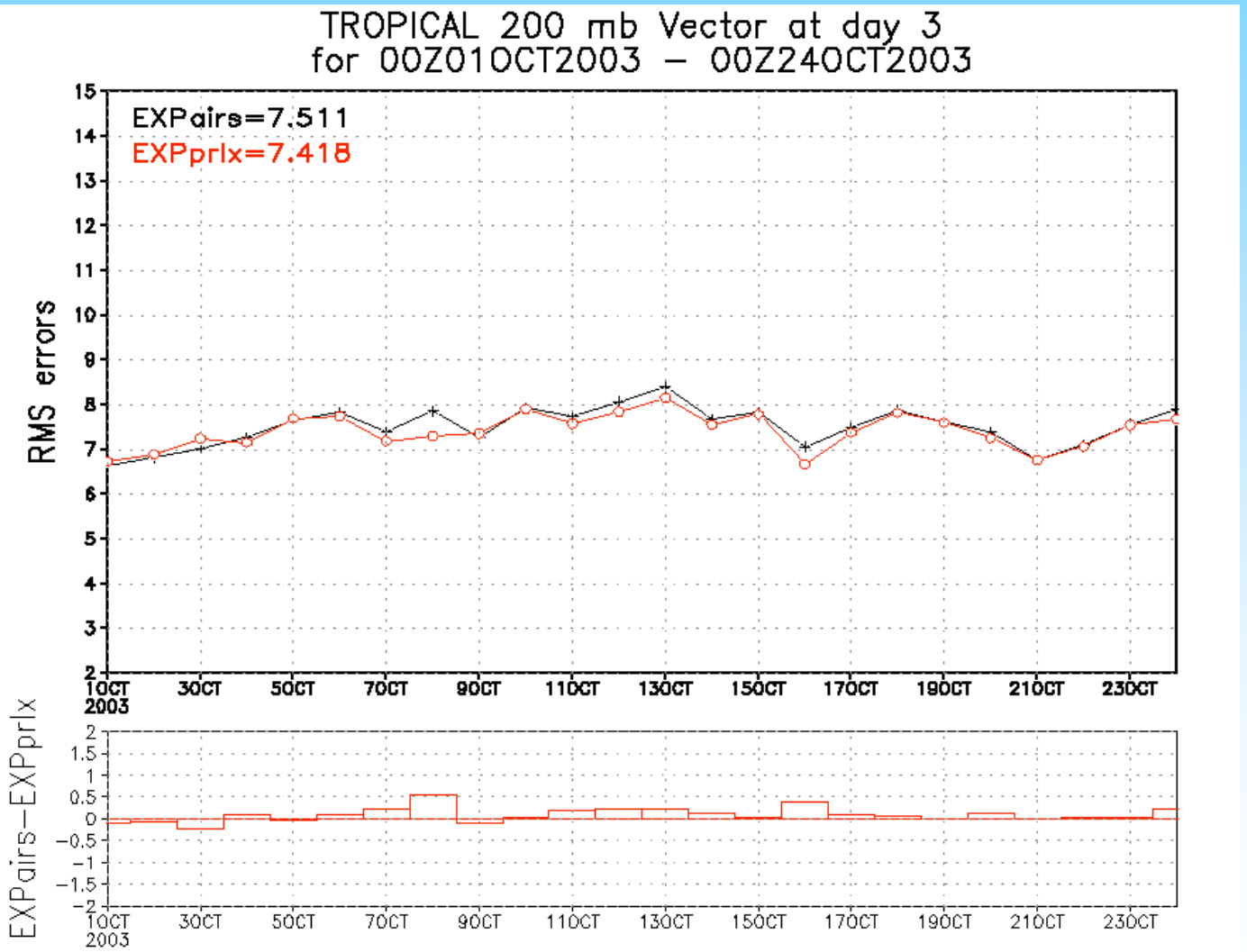

Global Temp Fits to RAOBS
12z05oct2003 – 12z23oct2003
Global
Data Counts
ptkx-36hr
oiss-36hr
ptkx-12hr
oiss-12hr
100
200
300
400
500
600
700
800
900
1000
−1
0
1
2
3
BIAS (F−O)
RMSE
1 2 1 4 1 6 1 8 2 0 2 2 2 4 2 6 2 8 3 0 3 2 3 4 3 6
(in thousands)
NATIONAL WEATHER SERVICE
GMB/EMC/NCEP/NWS

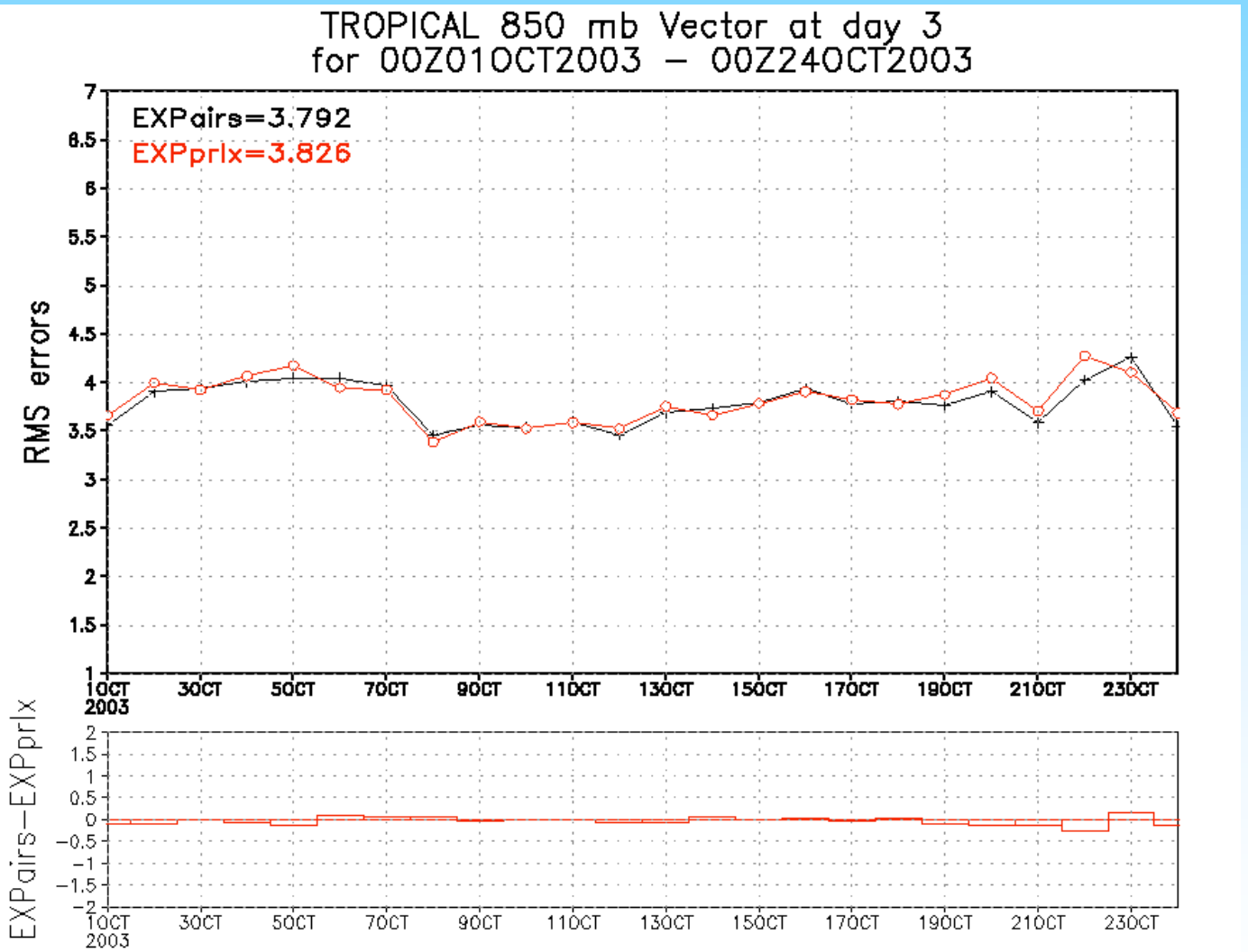

Global Vector Wind Fits to RAOBS
12z05oct2003 – 12z23oct2003
Global
Data Counts
ptx-36hr
ctrs-36hr
ptx-12hr
ctrs-12hr
100
200
300
400
500
600
700
800
900
1000
−2 −1 0 1 2 3 4 5 6 7 8 9 10 11 12
BIAS (F−O)
RMSE
1 2 1 4 1 6 1 8 2 0 2 2 2 4 2 6 2 8 3 0 3 2 3 4 3 6
(in thousands)
NATIONAL WEATHER SERVICE
GMB/EMC/NCEP/NWS


Global Moisture Fits to RAOBS
12z05oct2003 – 12z23oct2003
Global
Data Counts
ptkx-36hr
oiws-36hr
ptkx-12hr
oiws-12hr
200
300
400
500
600
700
800
900
1000
−1
−0.5
0
0.5
1
1.5
2
2.5
3
BIAS (F−O)
RMSE
−5 0 5 10 15 20 25 30 35
(in thousands)
NATIONAL WEATHER SERVICE
GMB/EMC/NCEP/NWS


NH 500 mb Geopotential Height at day 5
for 00Z01OCT2003 – 00Z24OCT2003
AC scores
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
EXPairs=0.830
EXPprlx=0.830
1OCT
2003
3OCT
5OCT
7OCT
9OCT
11OCT
13OCT
15OCT
17OCT
19OCT
21OCT
23OCT
EXPairs–EXPprlx
0.2
0.15
0.1
0.05
0
–0.05
–0.1
–0.15
–0.2


SH 500 mb Geopotential Height at day 5
for 00Z01OCT2003 – 00Z24OCT2003
AC scores
EXPairs=0.795
EXPprlx=0.795
EXPairs–EXPprlx
1OCT
2003
3OCT
5OCT
7OCT
9OCT
11OCT
13OCT
15OCT
17OCT
19OCT
21OCT
23OCT


TROPICAL 200 mb Vector at day 3
for 00Z01OCT2003 – 00Z24OCT2003
EXPairs=7.511
EXPprlx=7.418
RMS errors
15
14
13
12
11
10
9
8
7
6
5
4
3
2
10CT
2003
30CT
50CT
70CT
90CT
110CT
130CT
150CT
170CT
190CT
210CT
230CT
EXPairs–EXPprlx
2
1.5
1
0.5
0
–0.5
–1
–1.5
–2
10CT
2003
30CT
50CT
70CT
90CT
110CT
130CT
150CT
170CT
190CT
210CT
230CT

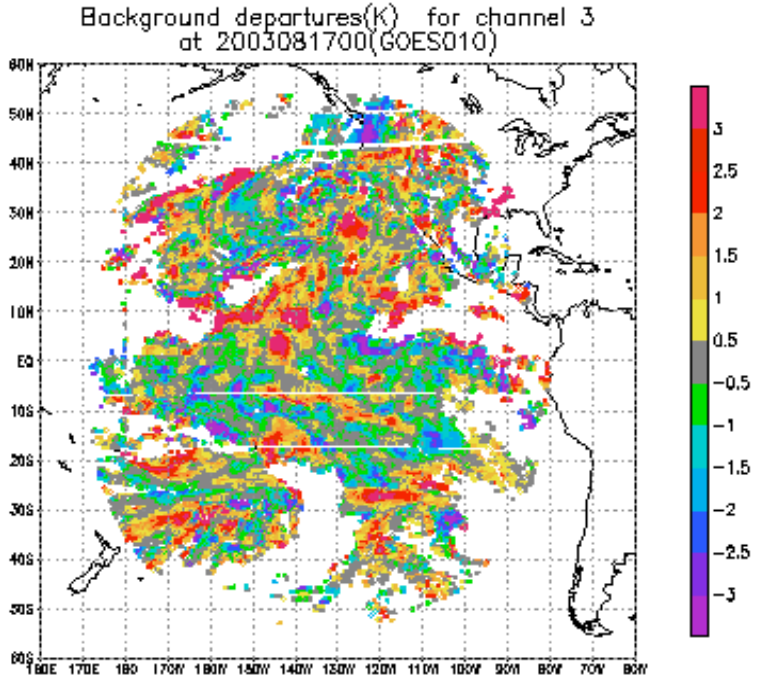

TROPICAL 850 mb Vector at day 3
for 00Z01OCT2003 – 00Z24OCT2003
EXPairs=3.792
EXPprlx=3.826
RMS errors
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
1OCT
2003
3OCT
5OCT
7OCT
9OCT
11OCT
13OCT
15OCT
17OCT
19OCT
21OCT
23OCT
EXPairs–EXPprlx
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
1OCT
2003
3OCT
5OCT
7OCT
9OCT
11OCT
13OCT
15OCT
17OCT
19OCT
21OCT
23OCT

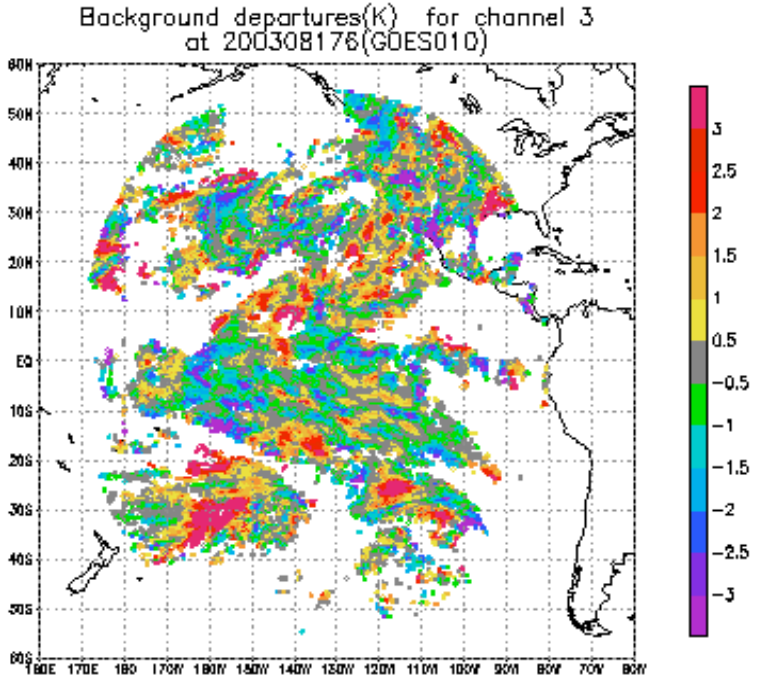
AIRS Comments

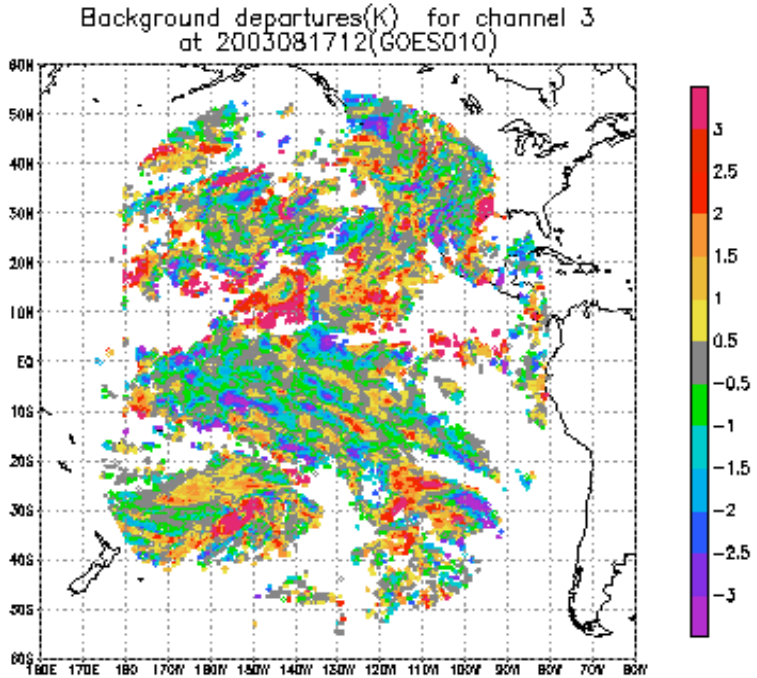
- AIRS data used when radiances clear (above and between clouds) – 38 % of thinned data used
- To date – little impact of AIRS data
- Impact studies continuing

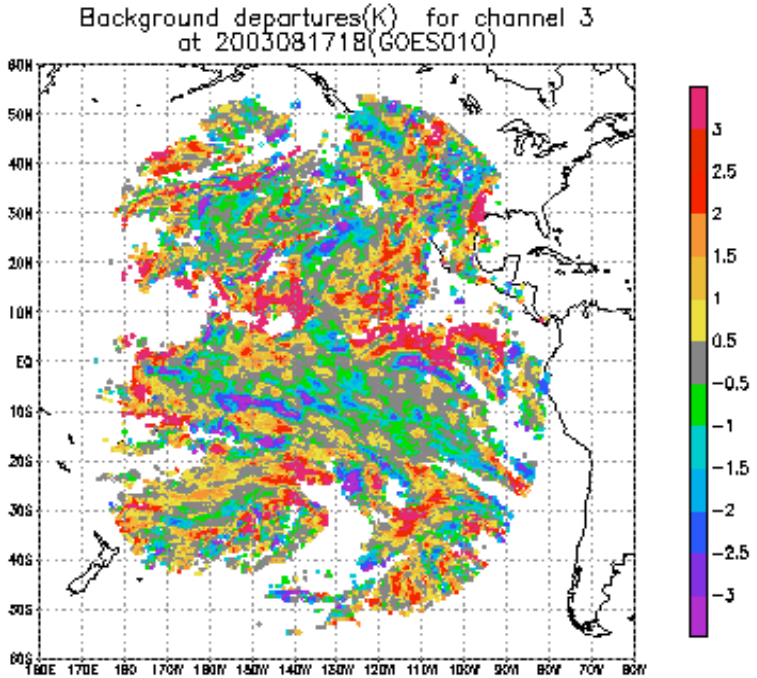
GOES imager data

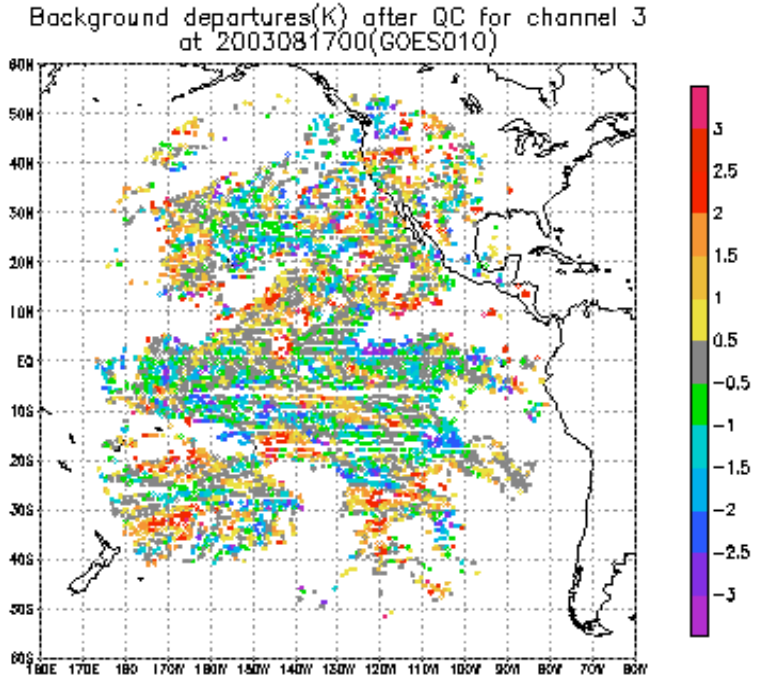
- Using NESDIS box average data
- Data Quality Control
  - Greater than 25% clear sky fraction for GOES-12, 10% for GOES-10
  - Bright Temperature Standard Deviation (BTSD from box averaging) less than 1.5K and background departure less than 3 times error
  - Not using 6z for GOES 12 because of midnight effect
- Thinning the data (110km, 20000 → 4000)
- Observational error varies depending on BTSD

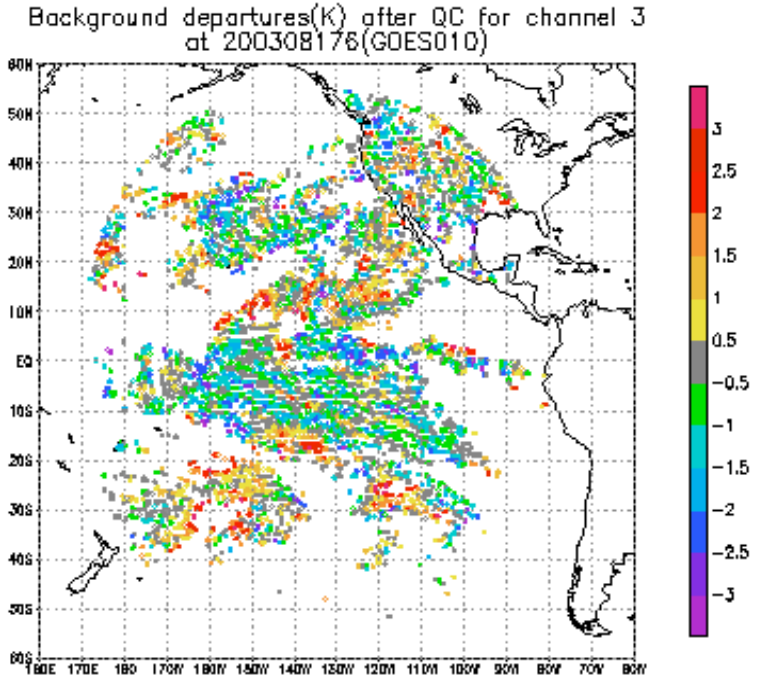

Background departures(K) for channel 3
at 2003081700(GOES010)
3
2.5
2
1.5
1
0.5
−0.5
−1
−1.5
−2
−2.5
−3

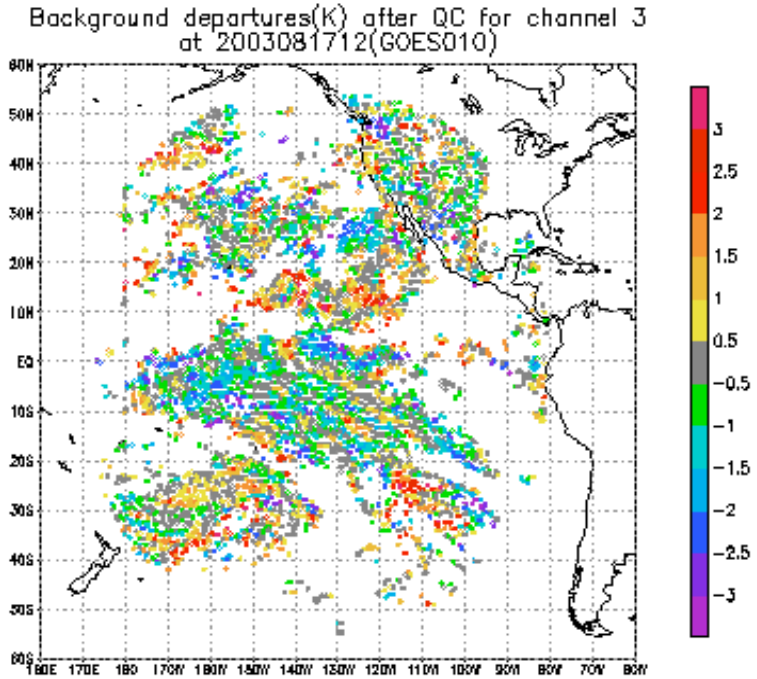

Background departures(K) for channel 3
at 2003081706(GOES010)
3
2.5
2
1.5
1
0.5
−0.5
−1
−1.5
−2
−2.5
−3

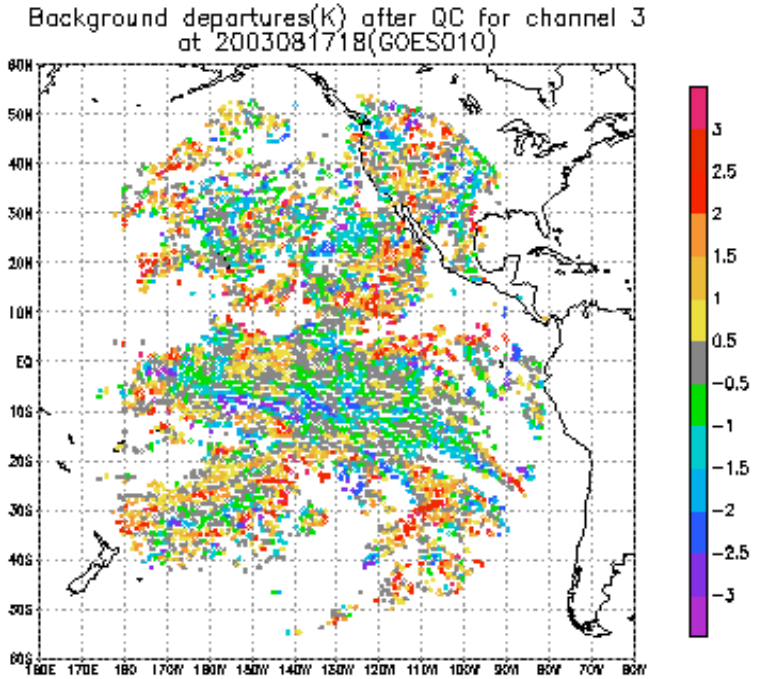

Background departures(K) for channel 3
at 2003081712(GOES010)
3
2.5
2
1.5
1
0.5
−0.5
−1
−1.5
−2
−2.5
−3

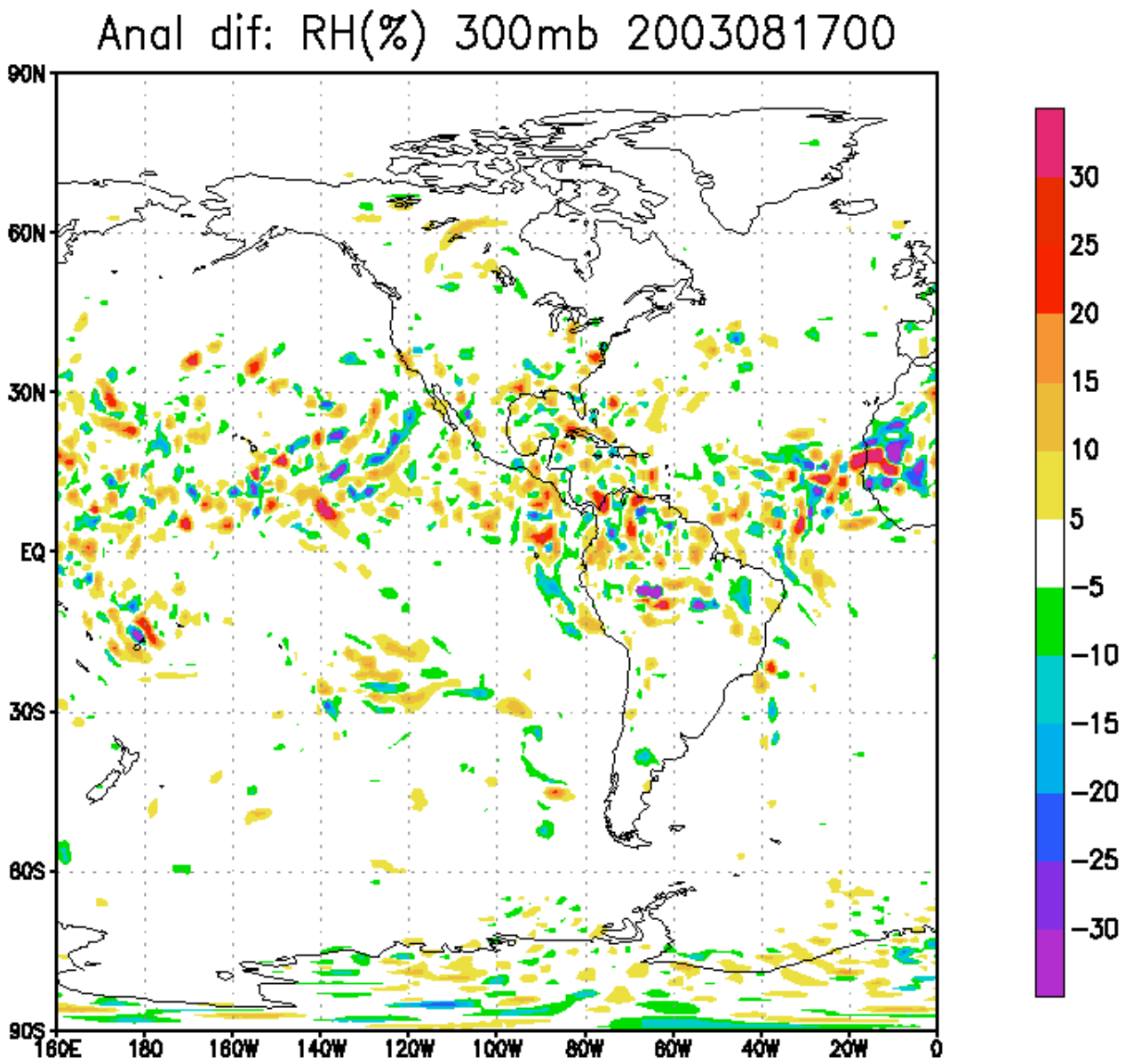

Background departures(K) for channel 3
at 2003081718(GOES010)
3
2.5
2
1.5
1
0.5
−0.5
−1
−1.5
−2
−2.5
−3

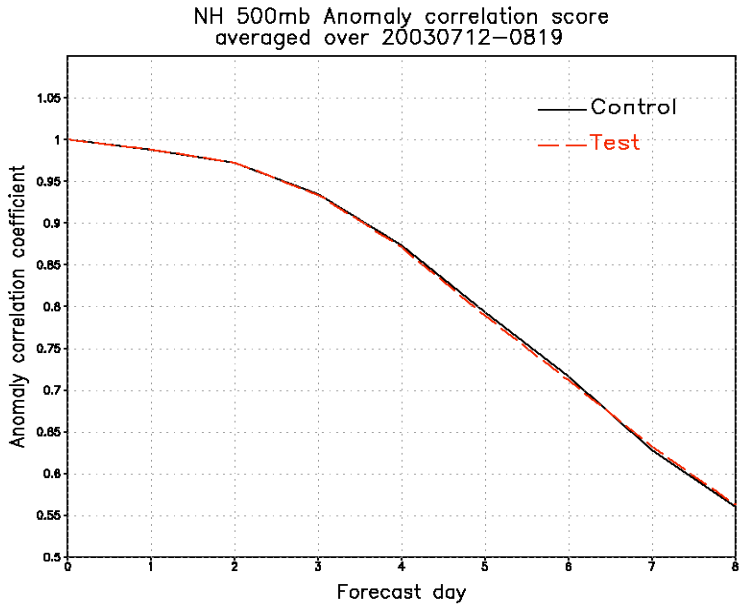

Background departures(K) after QC for channel 3
at 2003081700(GOES010)
3
2.5
2
1.5
1
0.5
−0.5
−1
−1.5
−2
−2.5
−3

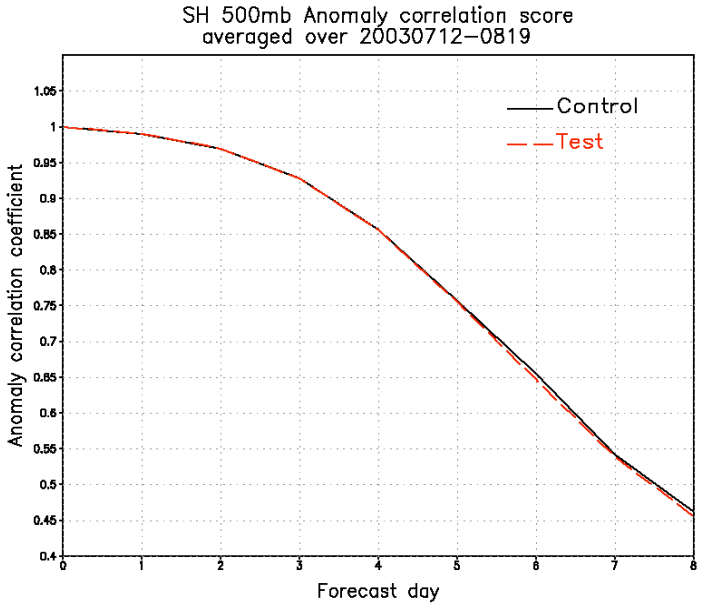

Background departures(K) after QC for channel 3
at 2003081706(GOES010)
3
2.5
2
1.5
1
0.5
−0.5
−1
−1.5
−2
−2.5
−3

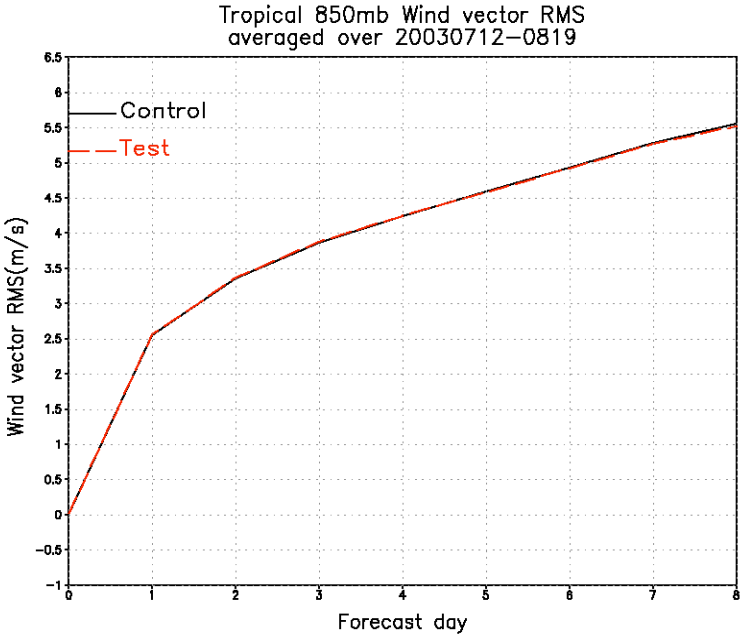

Background departures(K) after QC for channel 3
at 2003081712(GOES010)
3
2.5
2
1.5
1
0.5
−0.5
−1
−1.5
−2
−2.5
−3

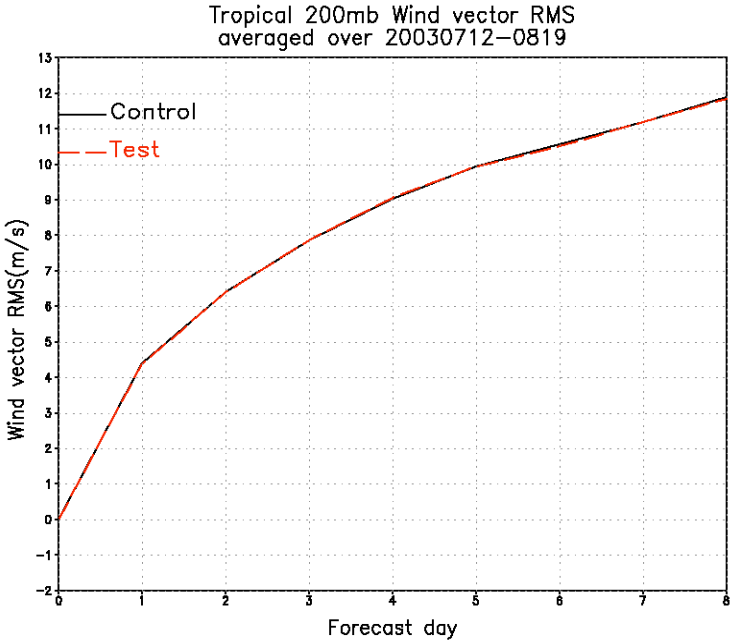

Background departures(K) after QC for channel 3
at 2003081718(GOES010)
3
2.5
2
1.5
1
0.5
−0.5
−1
−1.5
−2
−2.5
−3


Anal dif: RH(%) 300mb 2003081700
90N
60N
30N
EQ
30S
60S
90S
160E
180
160W
140W
120W
100W
80W
60W
40W
20W
0
30
25
20
15
10
5
−5
−10
−15
−20
−25
−30


NH 500mb Anomaly correlation score
averaged over 20030712–0819
Control
Test
Anomaly correlation coefficient
Forecast day


SH 500mb Anomaly correlation score
averaged over 20030712–0819
Control
Test
Anomaly correlation coefficient
Forecast day

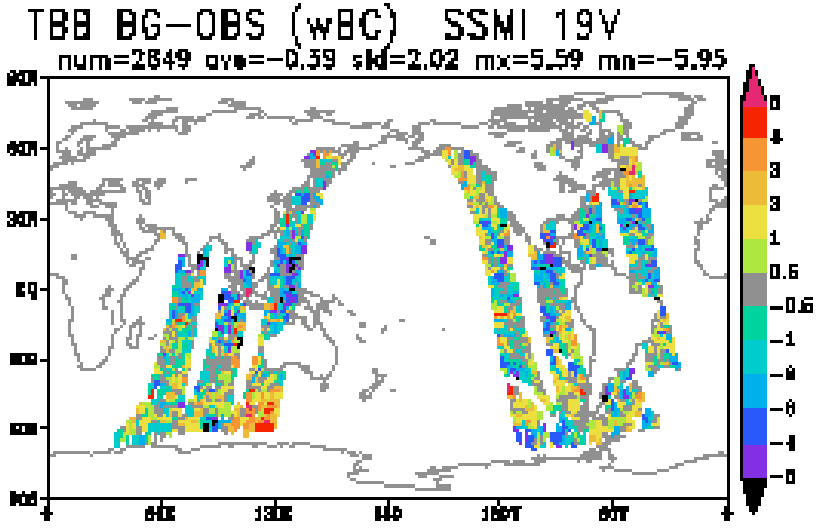

Tropical 850mb Wind vector RMS
averaged over 20030712–0819
Control
Test
Wind vector RMS(m/s)
Forecast day

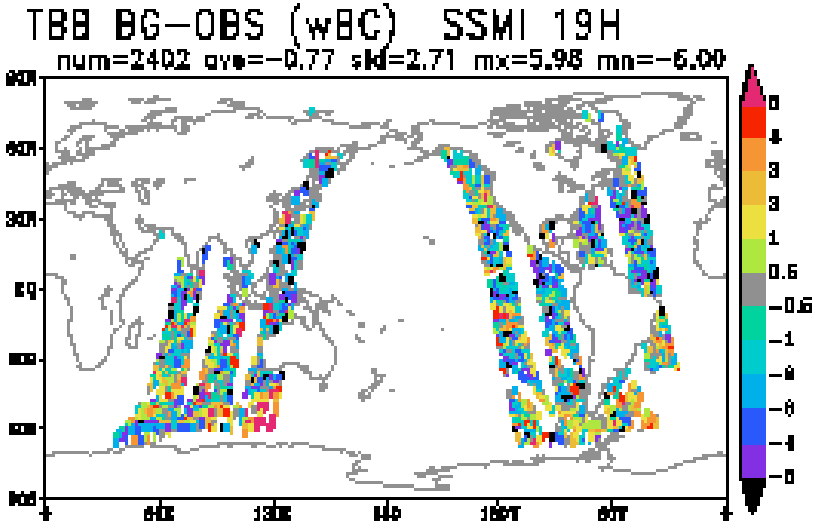

Tropical 200mb Wind vector RMS
averaged over 20030712–0819
Control
Test
Wind vector RMS(m/s)
Forecast day

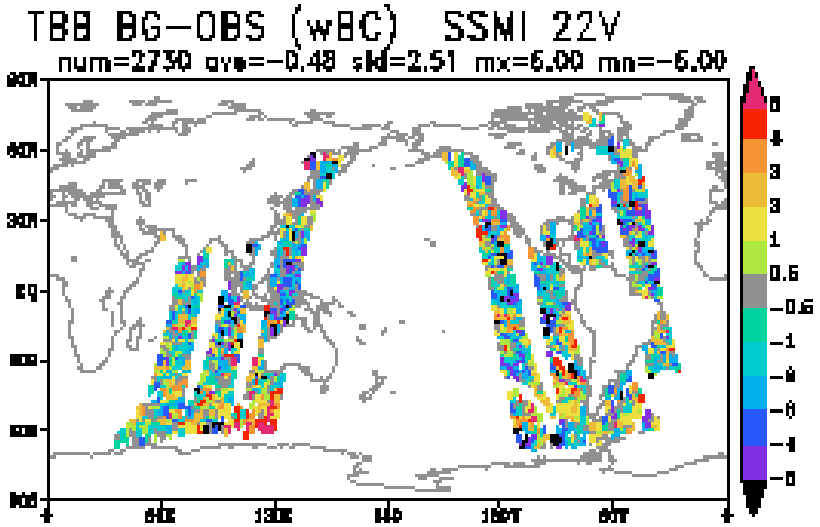
SSM/I Data

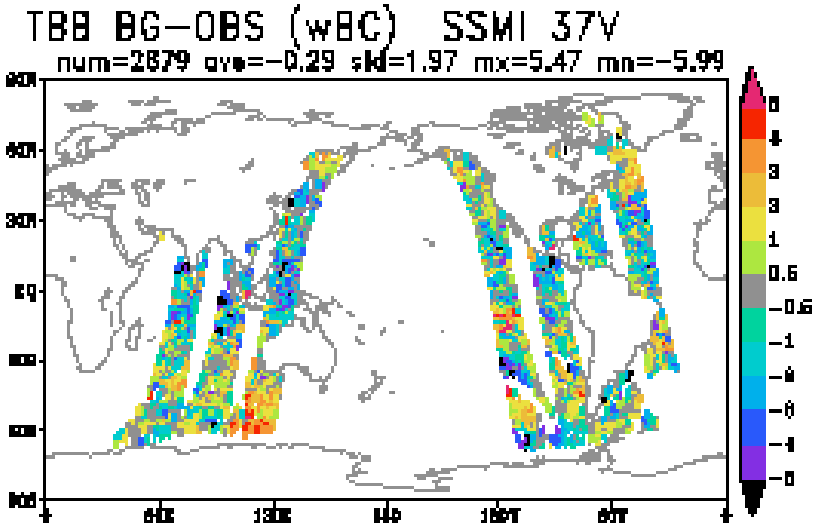
- Developed quality control and bias correction for SSM/I data
- Examining impact of direct use of SSM/I data on analysis system (primarily moisture)
- Eventual extension to use of data over land and ice
- Preparation for SSM/IS and CMIS data

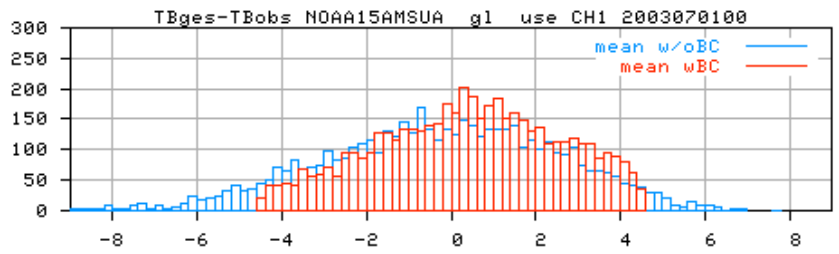
Used DMSP13 SSMI 00Z01JUL2003

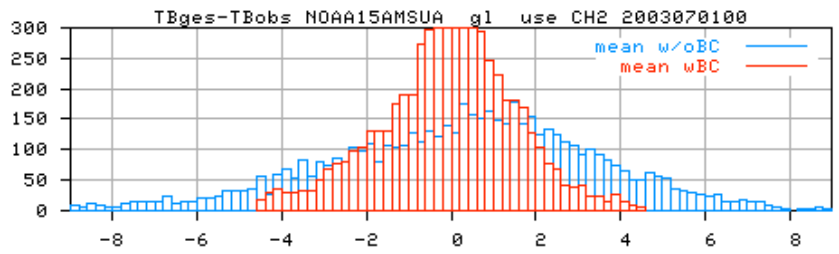


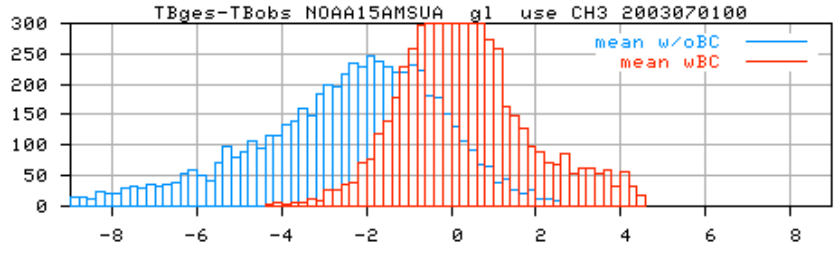


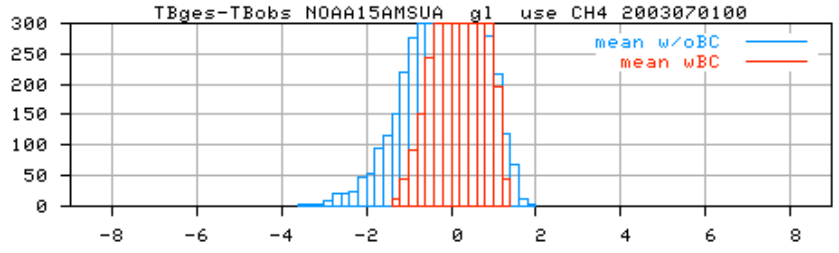


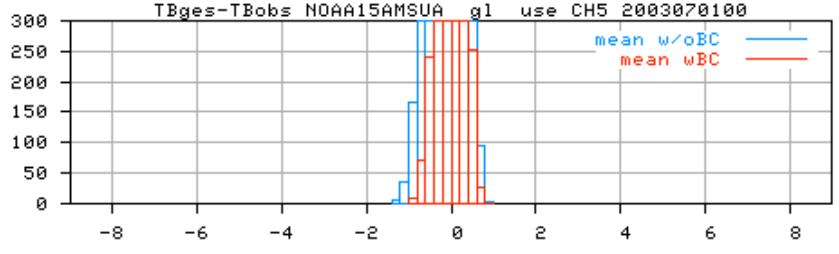


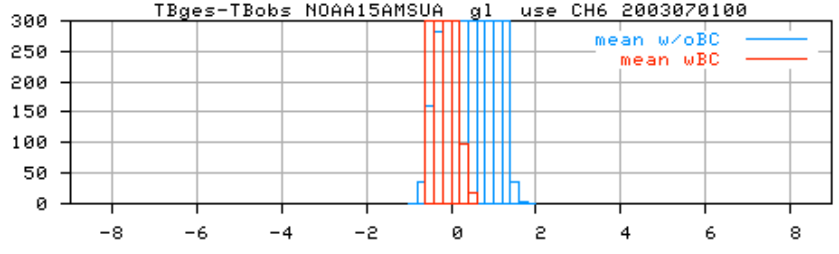

TBges-TBobs NOAA15AMSUA gl use CH1 2003070100
mean w/oBC
mean wBC

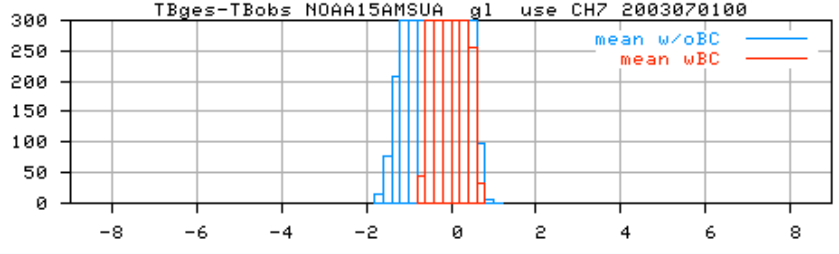

TBges-TBobs NOAA15AMSUA gl use CH2 2003070100
mean w/oBC
mean wBC

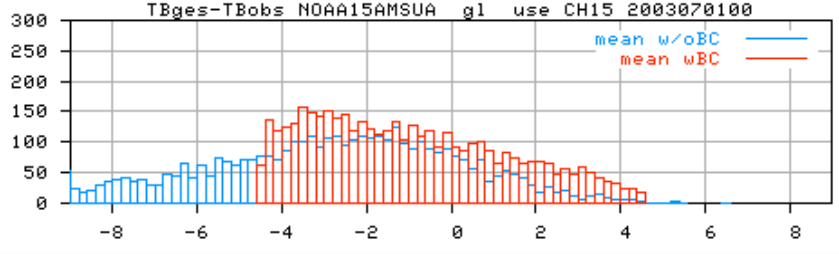

TBges-TBobs NOAA15AMSUA gl use CH3 2003070100
mean w/oBC
mean wBC

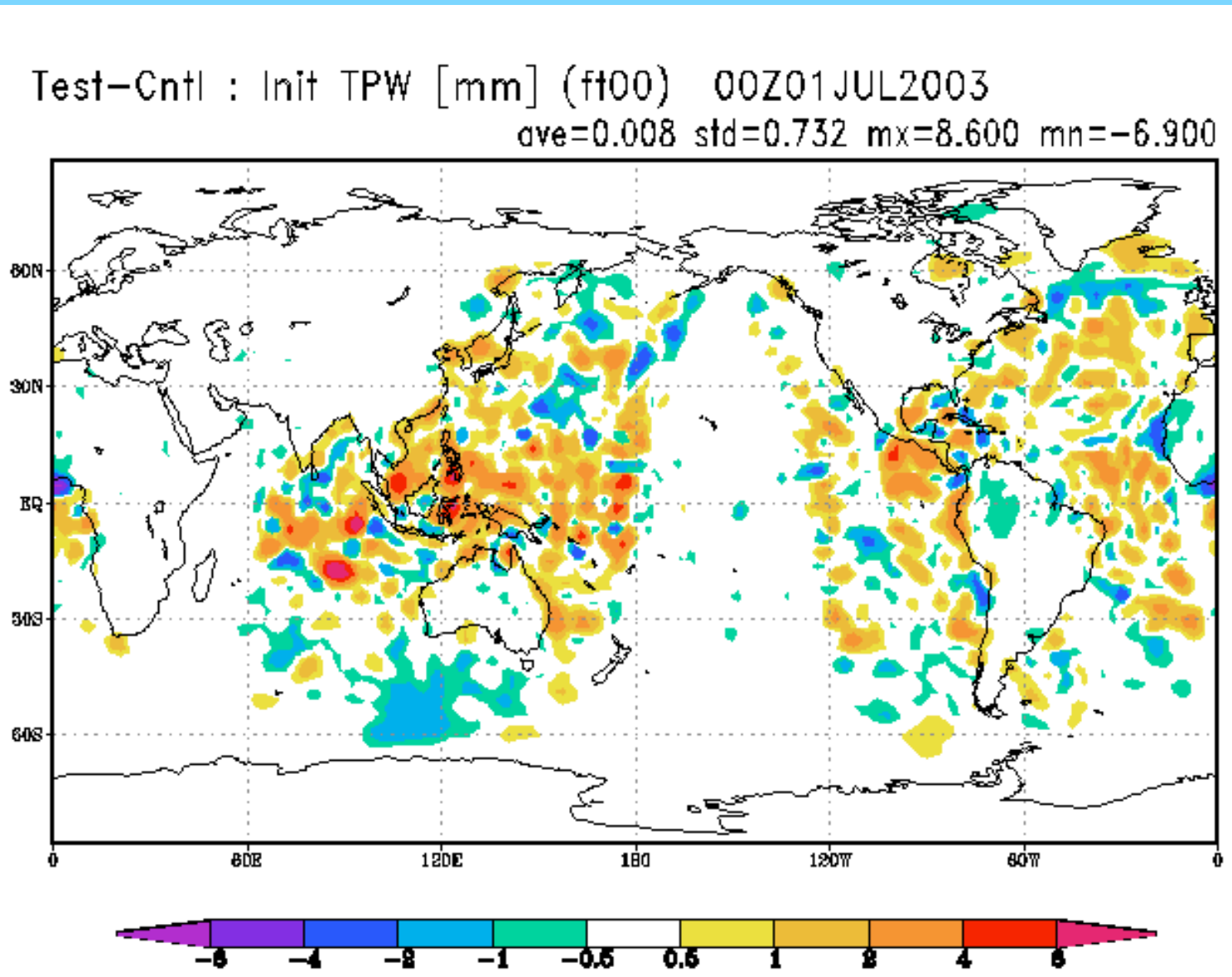

TBges-TBobs NOAA15AMSUA gl use CH4 2003070100
mean w/oBC
mean wBC

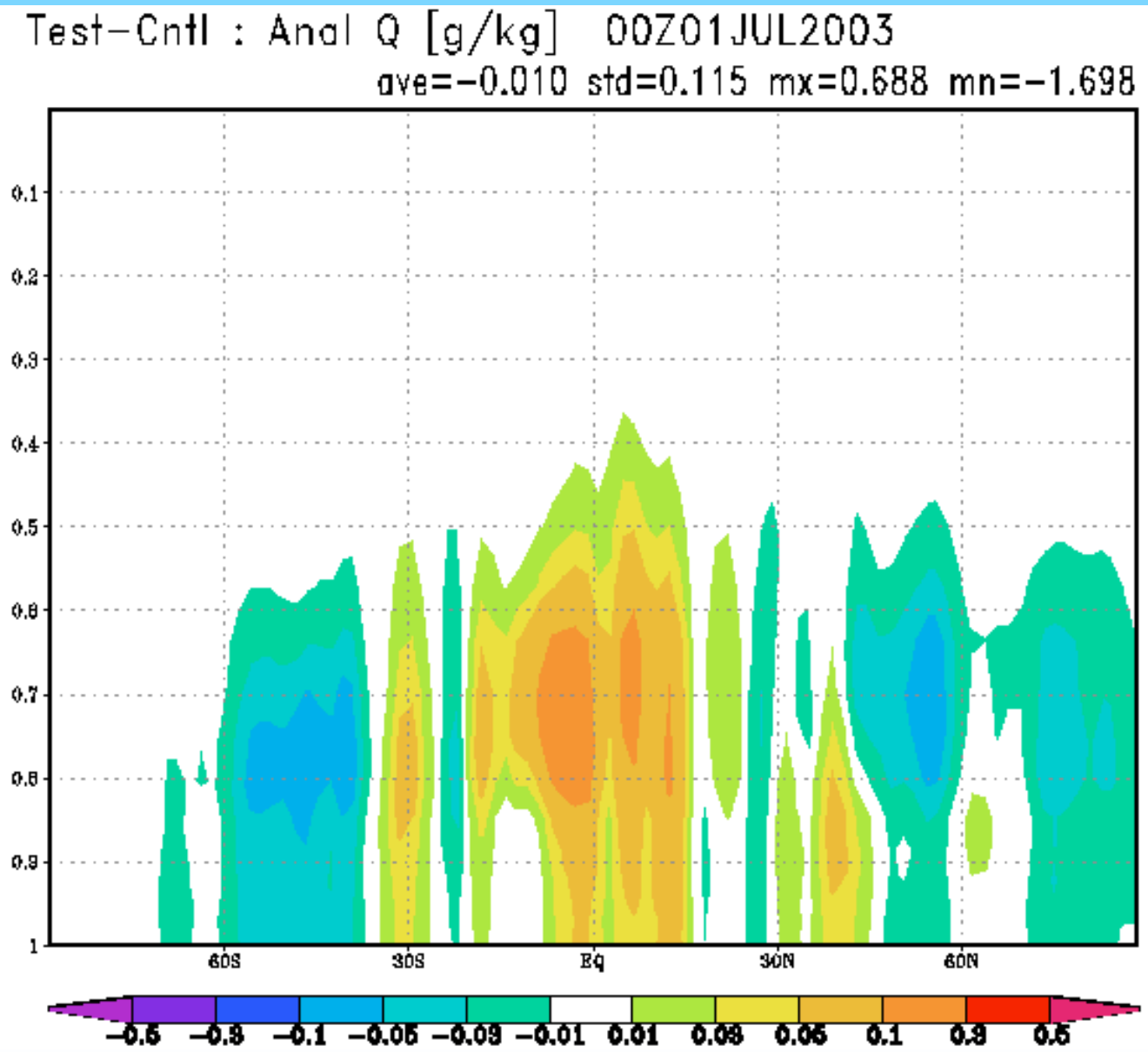

TBges-TBobs NOAA15AMSUA gl use CH5 2003070100
mean w/oBC
mean wBC

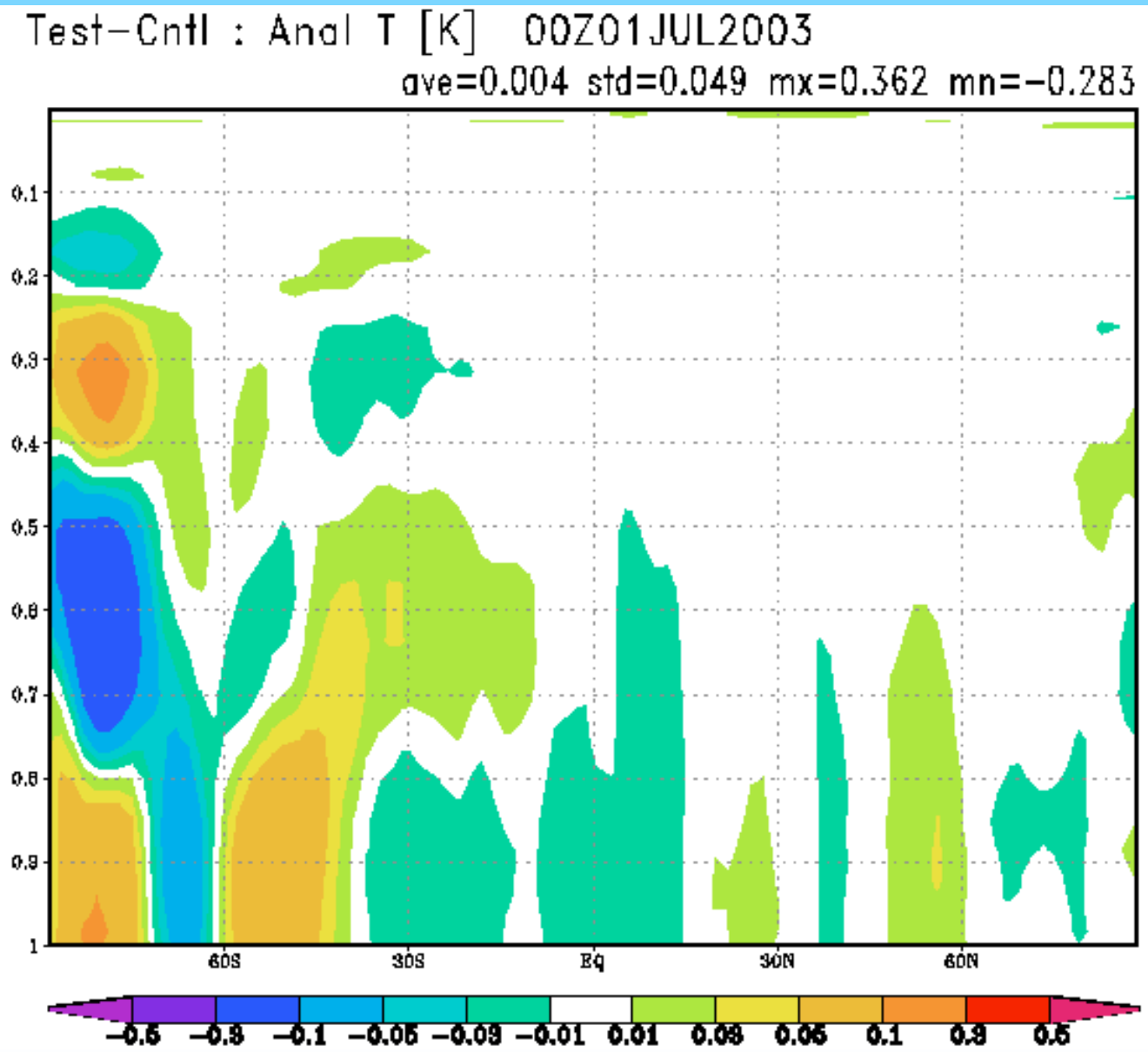

TBges-TBobs NOAA15AMSUA gl use CH6 2003070100
mean w/oBC
mean wBC


TBges-TBobs NOAA15AMSUA gl use CH7 2003070100
mean w/oBC
mean wBC


TBges-TBobs NOAA15AMSUA gl use CH15 2003070100
mean w/oBC
mean wBC


Test−Cntl : Init TPW [mm] (ft00) 00Z01JUL2003
ave=0.008 std=0.732 mx=8.600 mn=−6.900
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
0
−6
−4
−2
−1
−0.5
0.5
1
2
4
6

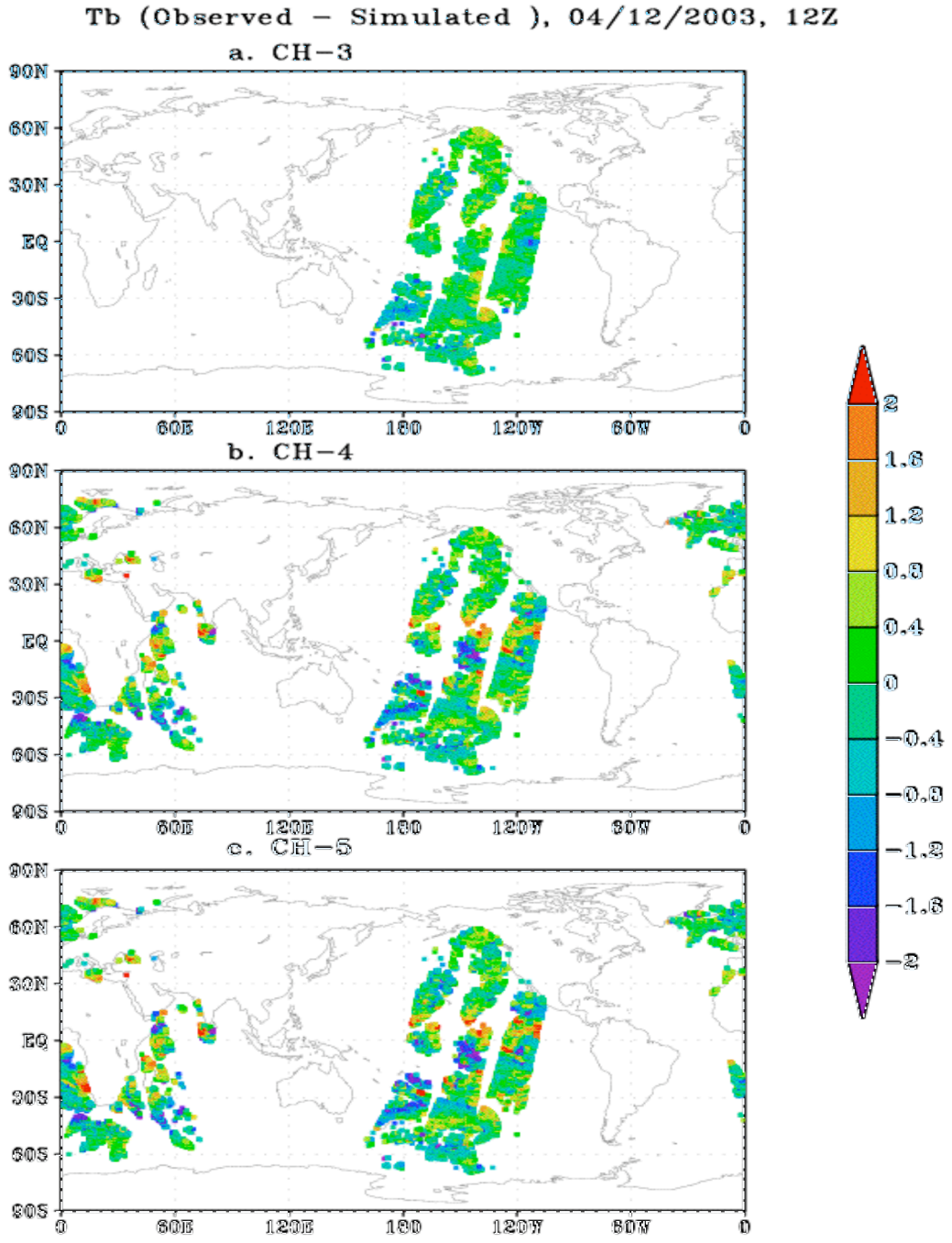

Test−Cntl : Anal Q [g/kg] 00Z01JUL2003
ave=−0.010 std=0.115 mx=0.688 mn=−1.698
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
60S
30S
EQ
30N
60N
−0.5
−0.3
−0.1
−0.05
−0.03
−0.01
0.01
0.03
0.05
0.1
0.3
0.5

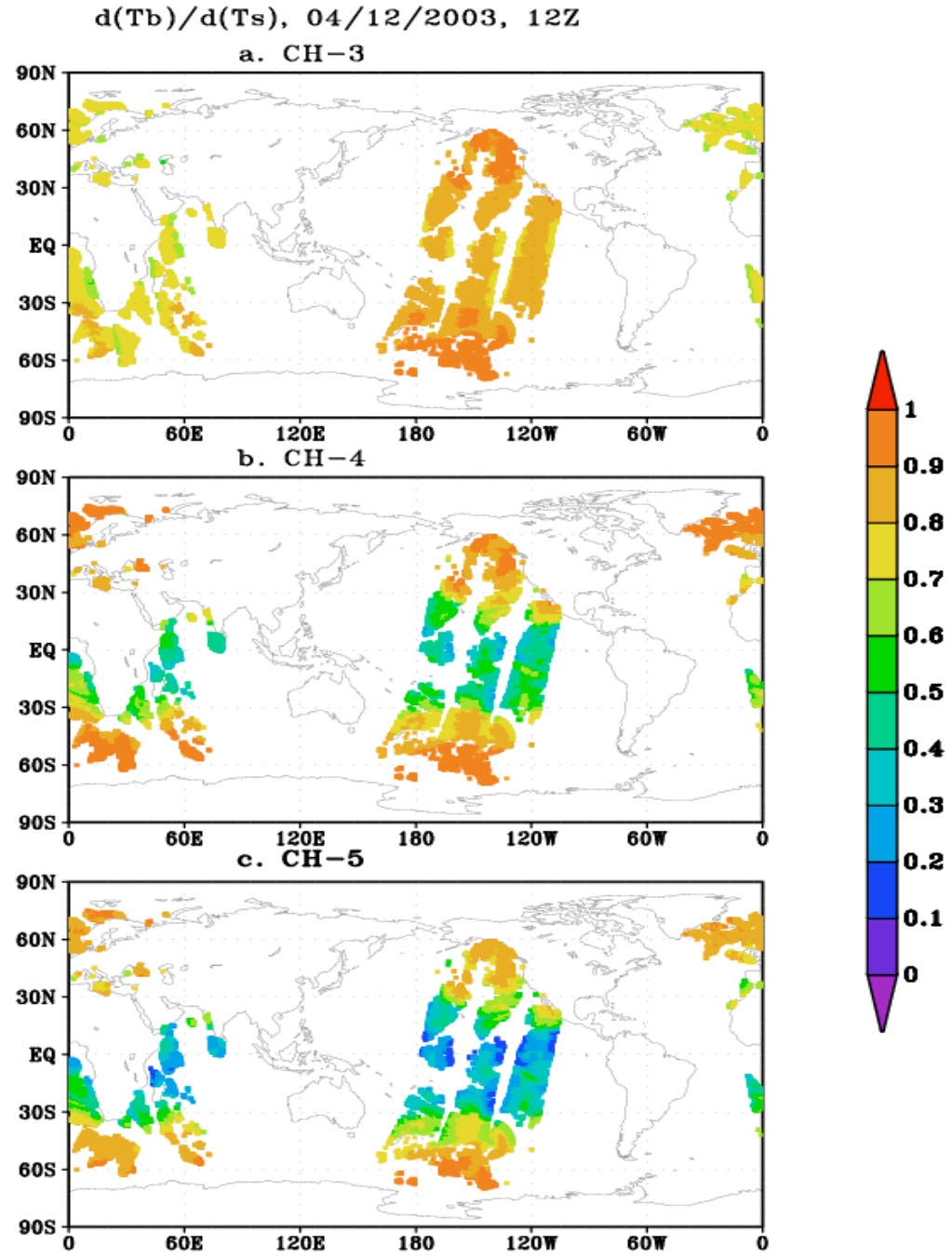

Test−Cntl : Anal T [K] 00Z01JUL2003
ave=0.004 std=0.049 mx=0.362 mn=−0.283
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
60S
30S
EQ
30N
60N
−0.5 −0.3 −0.1 −0.05 −0.03 −0.01 0.01 0.03 0.05 0.1 0.3 0.5

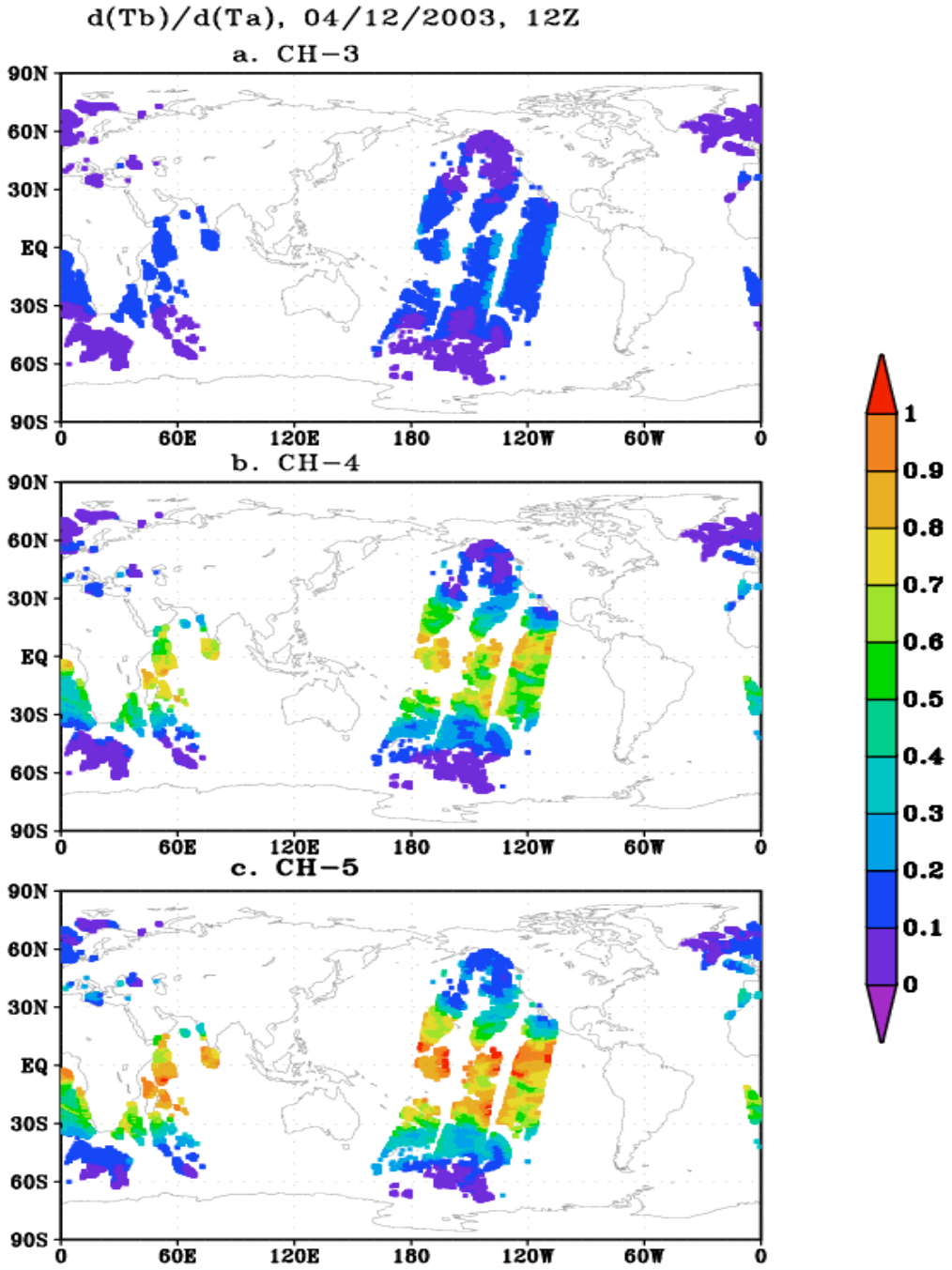
SST analysis using radiances

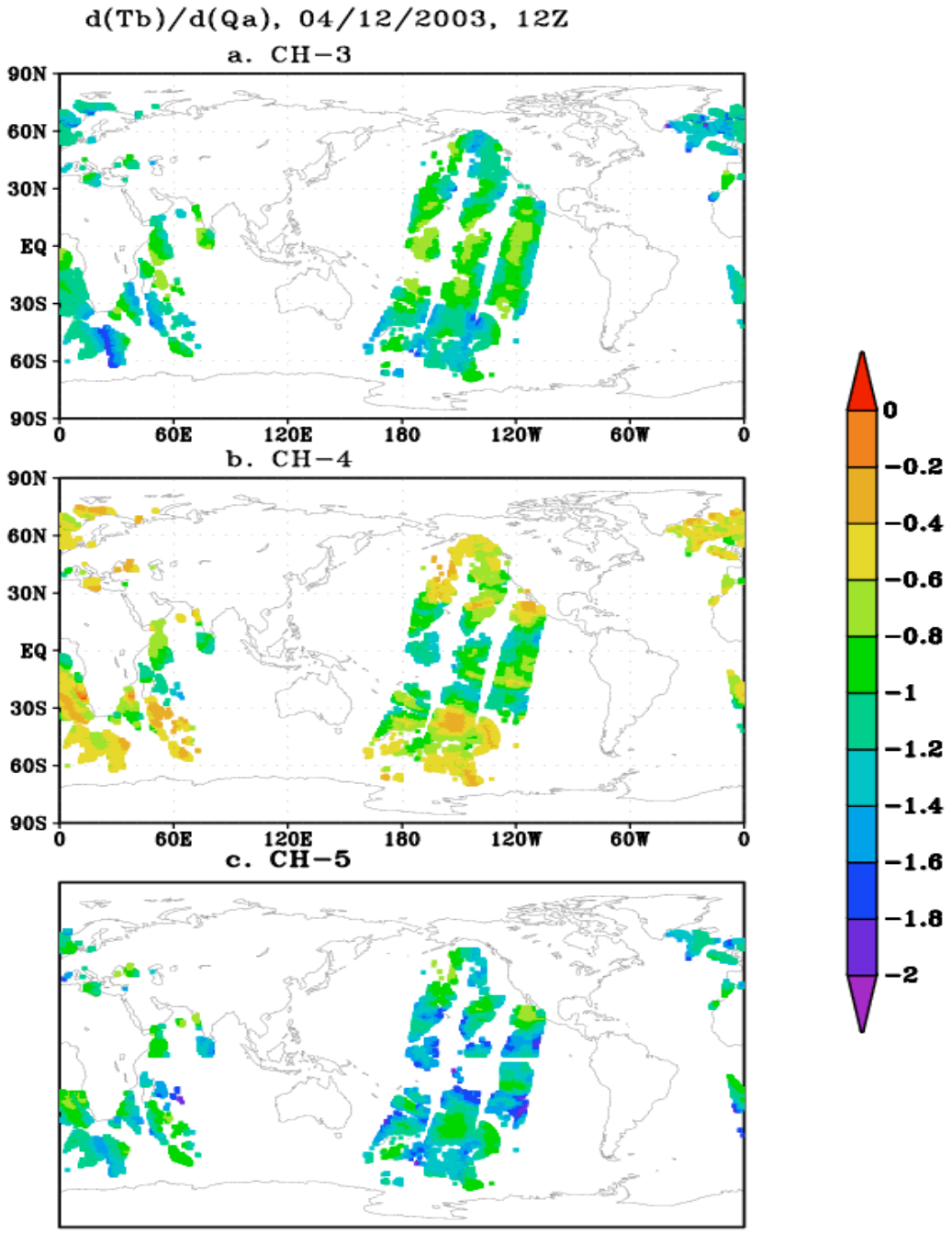
- Physical retrievals as first step in development
  - Community radiative transfer code
  - NCEP's GDAS atmosphere
  - NCEP's SST analysis from previous day
  - U.S. Navy Brightness Temperatures
- Solve for d(Ts), d(Ta), d(Qa) and assume $d(T_a)$ and $d(Q_a)$ do not vary with height
- Minimize:

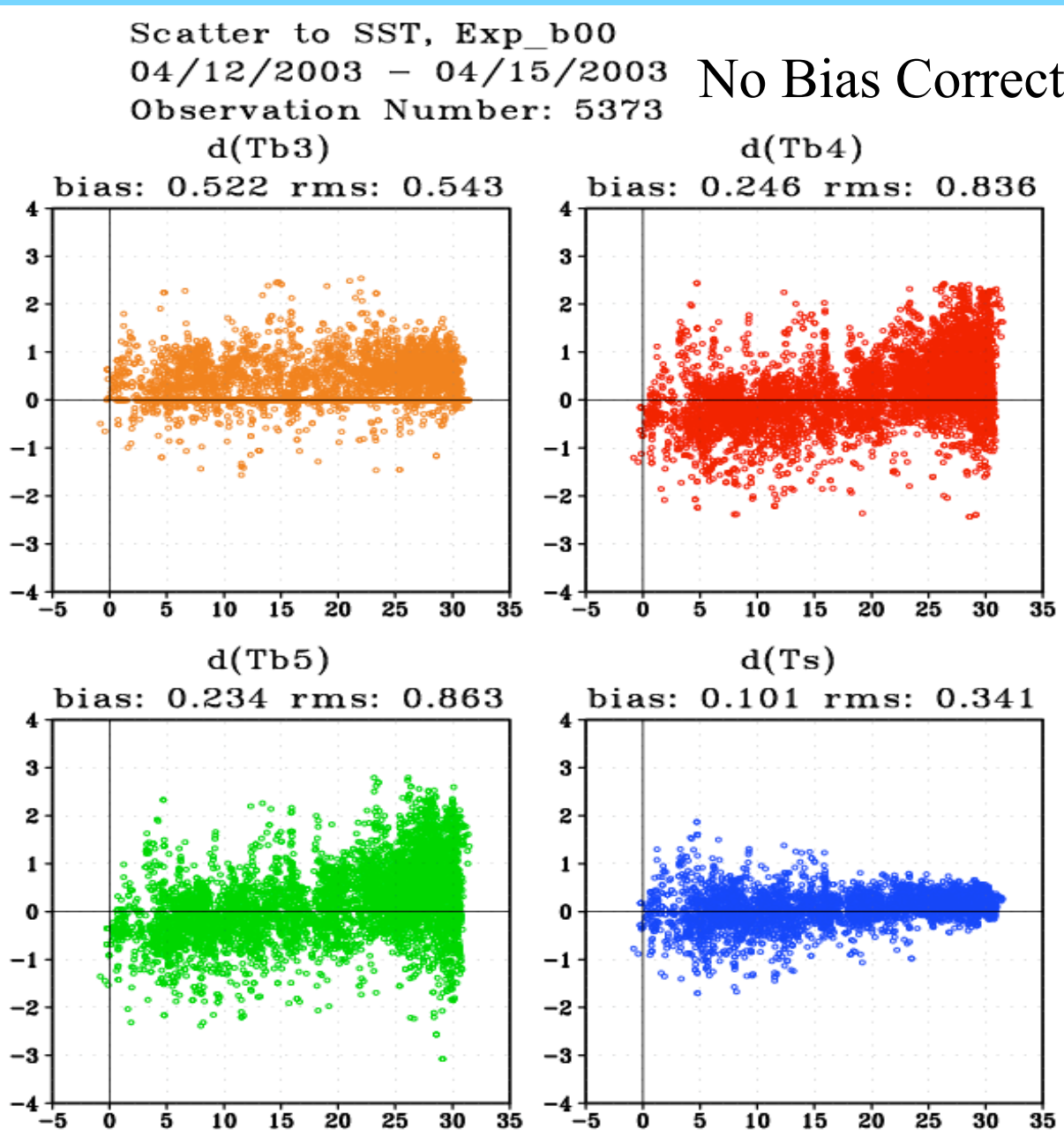
$$J = \sum_i \frac{1}{\sigma_{b,i}^2}[T_{b,i}^o - (T_{b,i}^f + dT_{b,i})]^2 + \frac{1}{\sigma_{T_s}^2}(dT_s)^2 + \frac{1}{\sigma_{T_a}^2}(dT_a)^2 + \frac{1}{\sigma_{Q_a}^2}(dQ_a)^2$$


Tb (Observed − Simulated), 04/12/2003, 12Z
a. CH−3
b. CH−4
c. CH−5
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
2
1.6
1.2
0.8
0.4
0
−0.4
−0.8
−1.2
−1.6
−2


d(Tb)/d(Ts), 04/12/2003, 12Z
a. CH-3
b. CH-4
c. CH-5
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

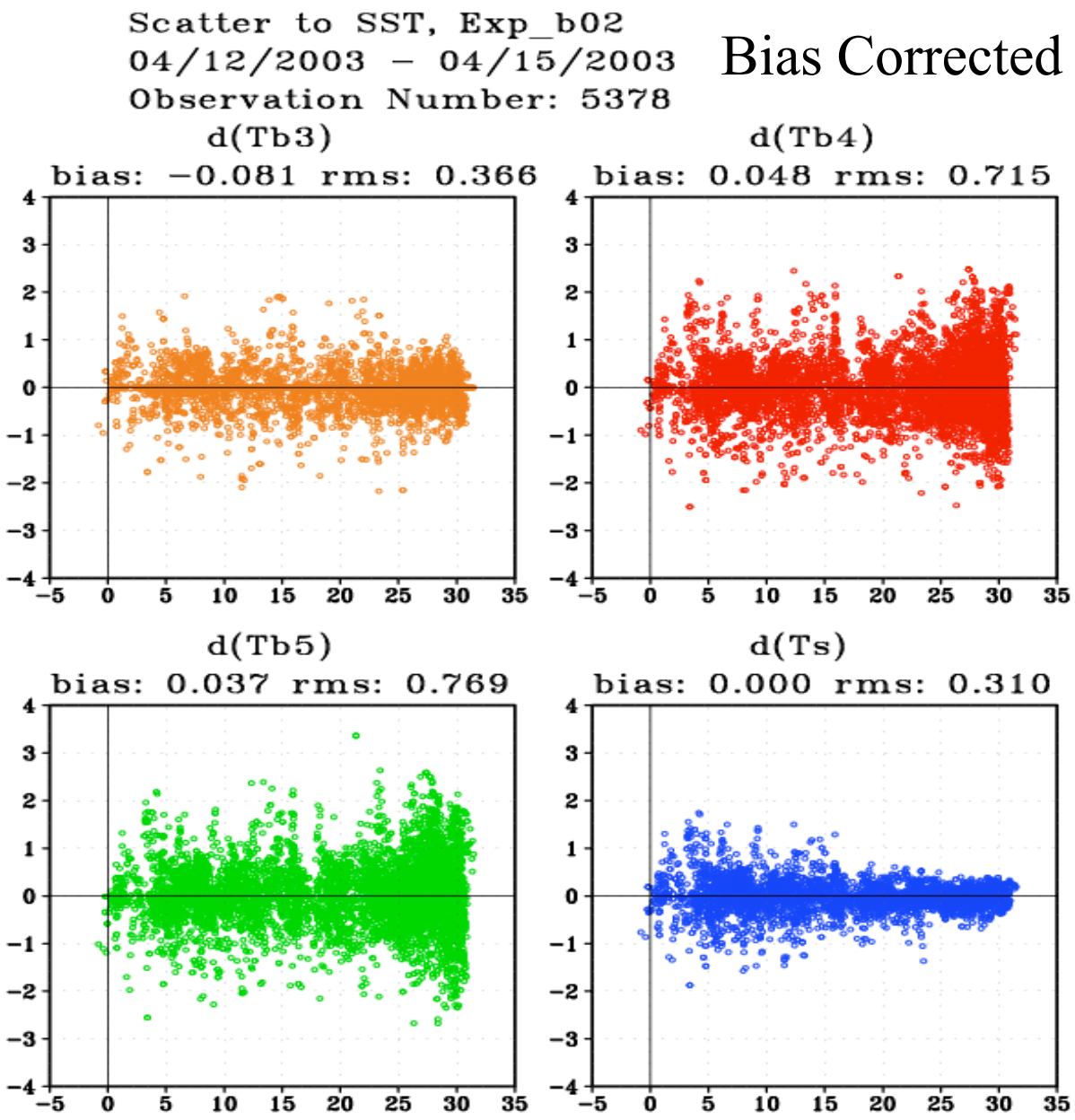

d(Tb)/d(Ta), 04/12/2003, 12Z
a. CH−3
b. CH−4
c. CH−5
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

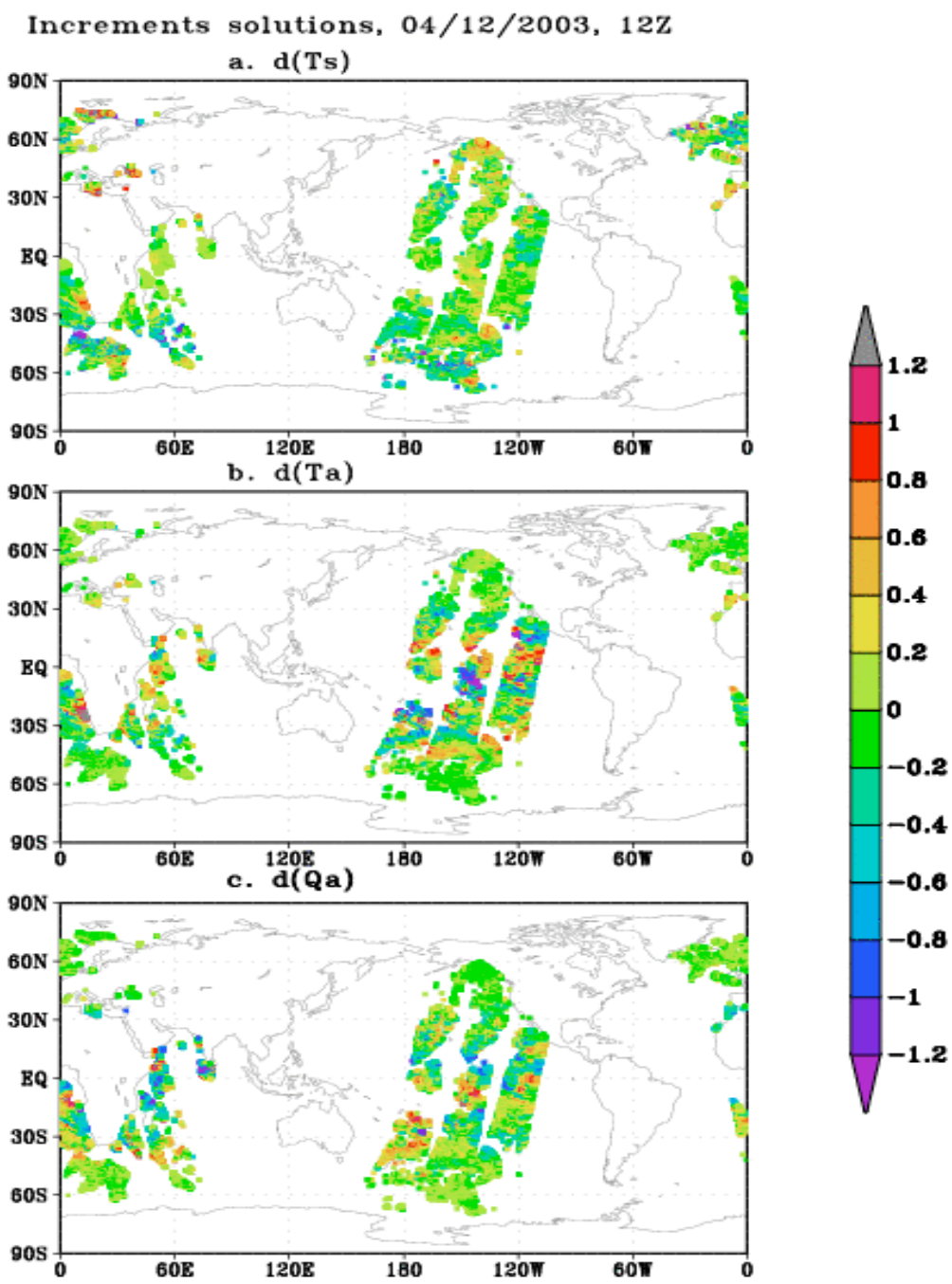

d(Tb)/d(Qa), 04/12/2003, 12Z
a. CH-3
b. CH-4
c. CH-5
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2



No Bias Correction

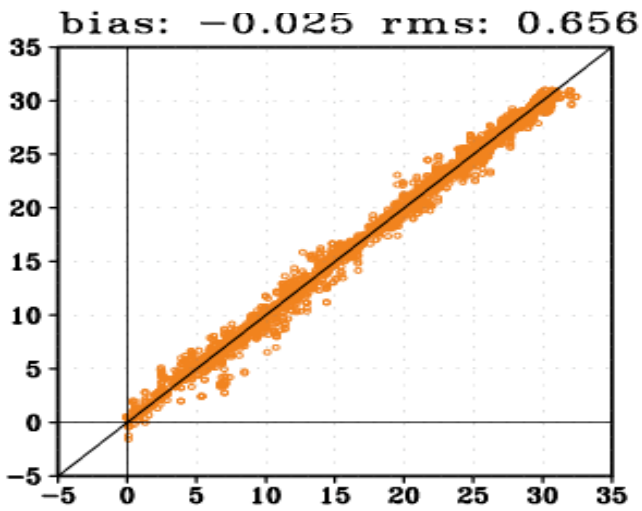
Bias Corrected



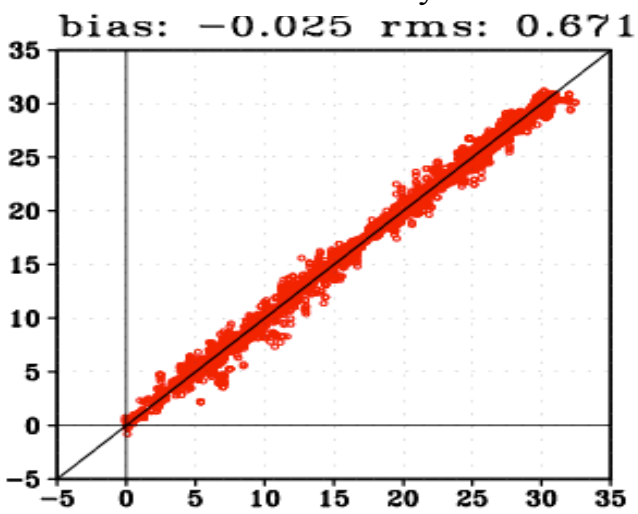

Increments solutions, 04/12/2003, 12Z
a. d(Ts)
b. d(Ta)
c. d(Qa)
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
1.2
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2

Scatter to Buoy data, Exp_b02
04/12/2003 – 04/15/2003
Observation Number: 5378

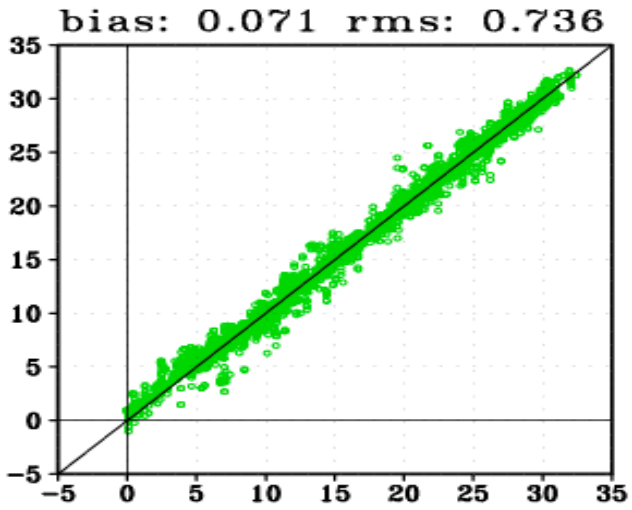
NCEP Retrieval



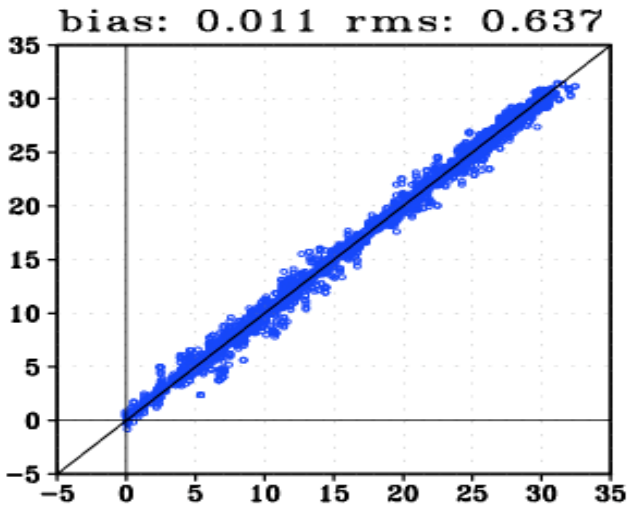
NCEP T-1 Analysis



Navy Retrieval



Current NCEP analysis



Future SST development

- Include additional satellites and instruments
- Supply retrievals to SST analysis and cycle
- Use raw AVHRR level–1c data (GAC)
- Incorporate radiances directly in SST analysis
- Develop SST predictive capability to enhance guess – discriminate between skin temperature and bulk SST

Final Comments

- Use of radiances in NWP has reached a level of maturity with new instruments being added routinely over ocean in non-cloud/precipitation situations
- Improvements to RT, models and assimilation techniques continue to extend/improve use of data
- Extension of direct radiance techniques to other data/applications (e.g., imager/SST) is ongoing

International TOVS Study Conference, 13th, TOVS-13, Sainte Adele, Quebec, Canada, 29 October-4 November 2003. Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center, Cooperative Institute for Meteorological Satellite Studies, 2003.