



Climate Applications of High Resolution Infrared Sounders



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NOAA/NESDIS/STAR

ECMWF/EUMETSAT NWP-SAF Workshop on the assimilation of IASI in NWP



Climate Applications

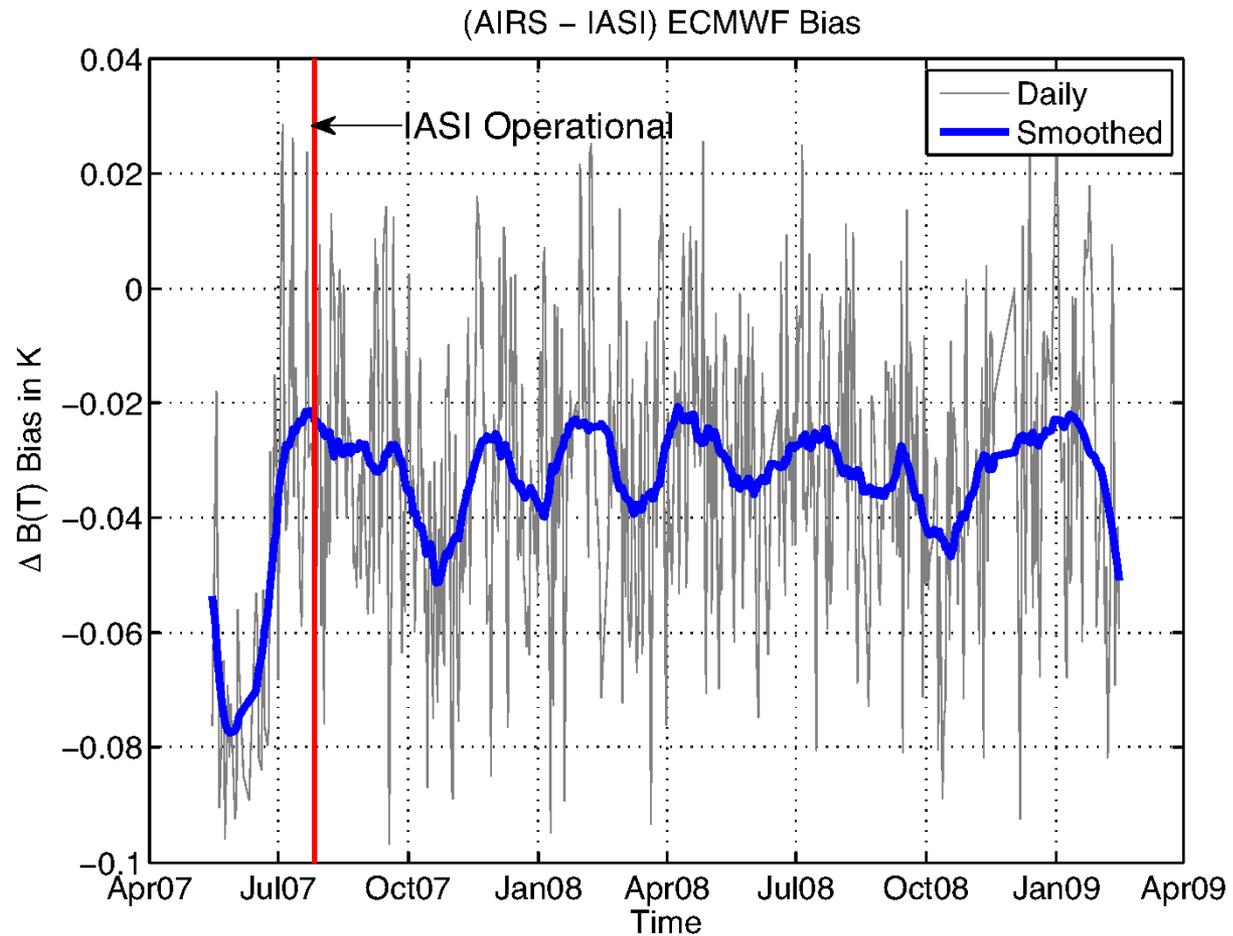
- Climate applications = information with high confidence
- Challenge - long term stability, accuracy, precision of observations.
- AIRS and IASI have exceptional long term stability and remarkable accuracy

AIRS versus IASI Stability

-0.0019K/year \pm 0.008K/year (corrected for lag-1 correlation of 0.45)

IASI/AIRS

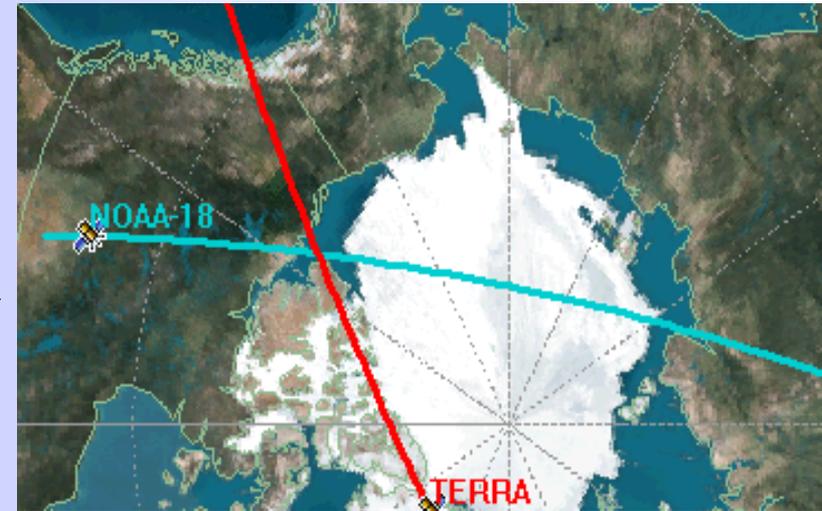
L. Strow
UMBC



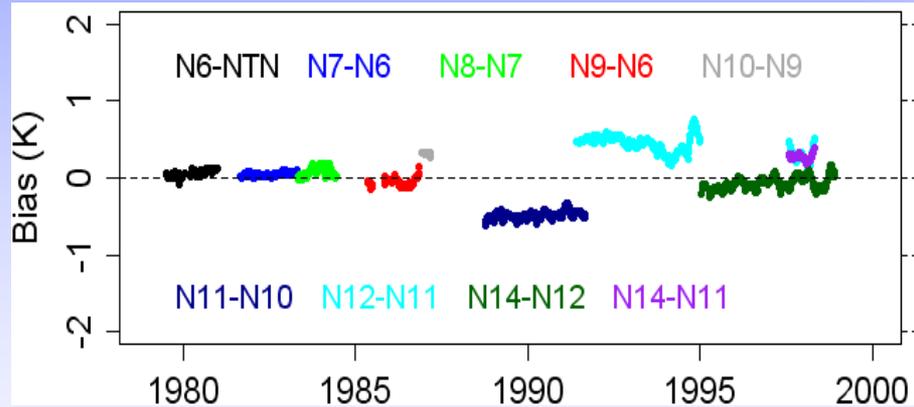


Satellite Intercalibration

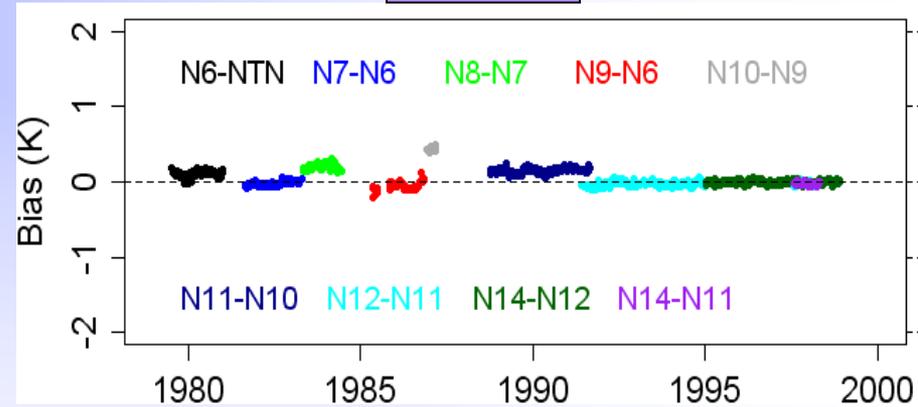
MSU Channel 2 Observations: Before and After Intercalibration



Before

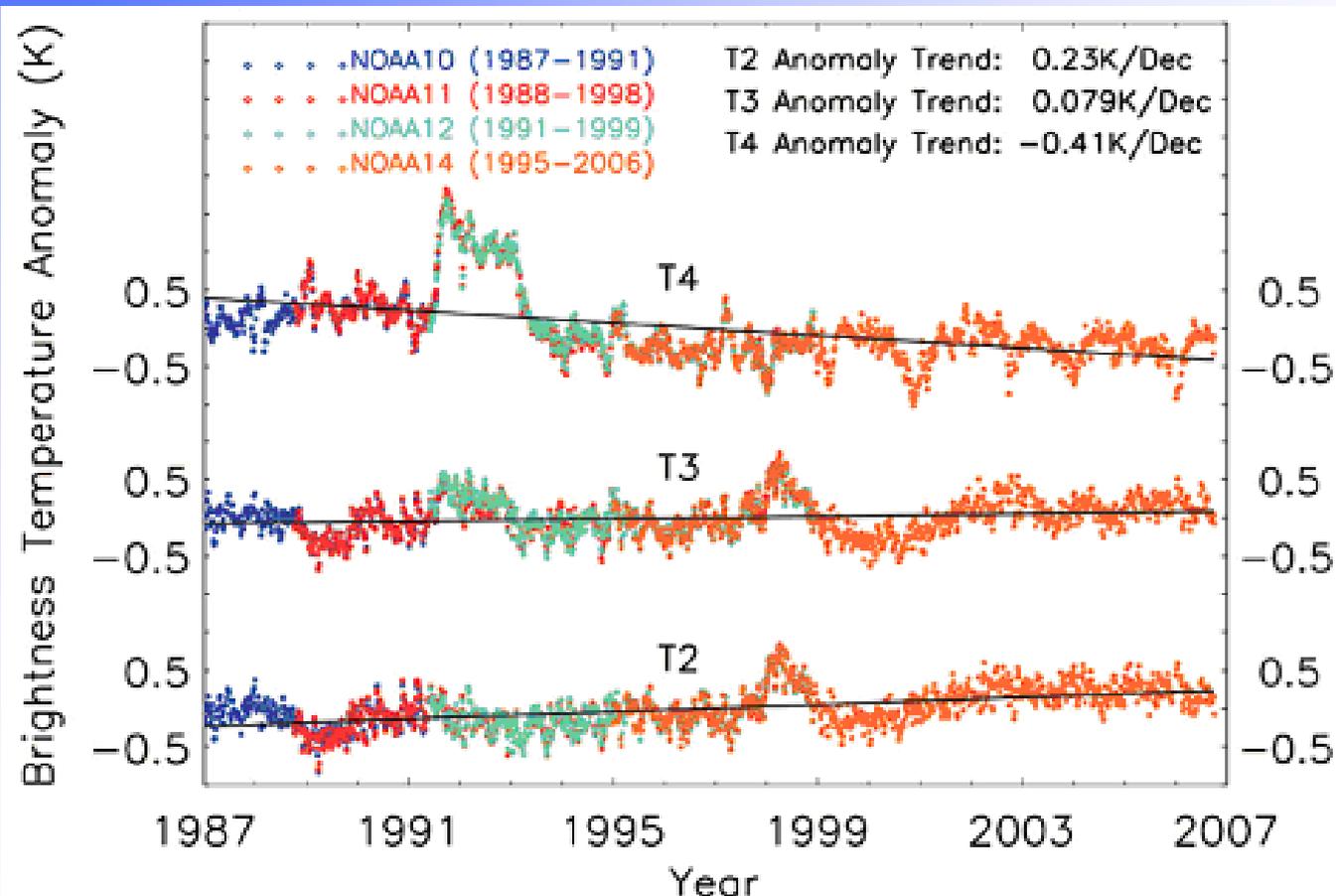


After



GLOBAL BIAS

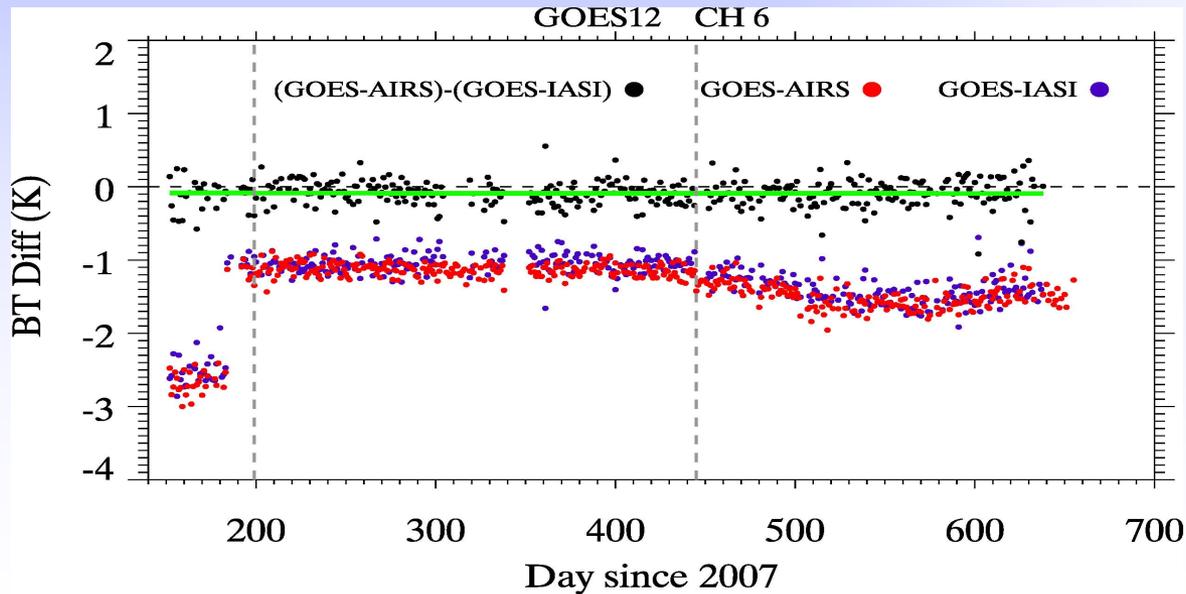
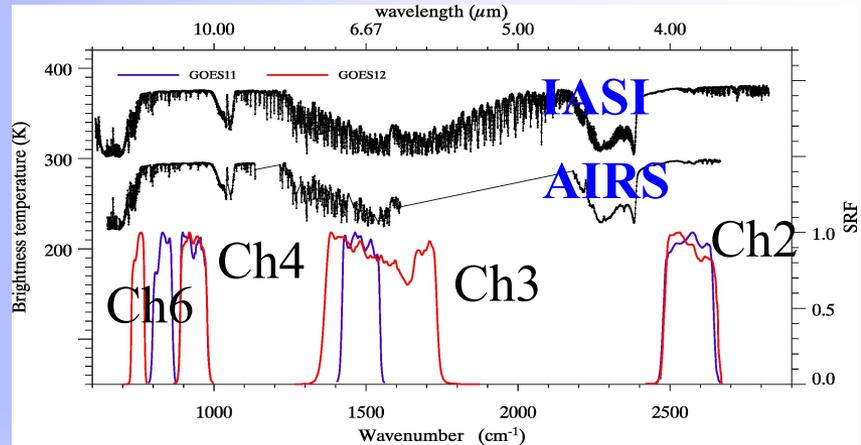
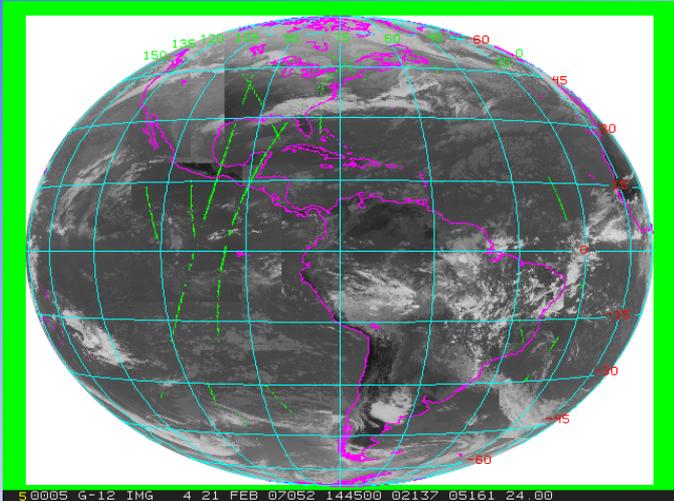
NESDIS recalibrated MSU record is being used in climate reanalysis projects at NCEP and NASA and to derive reliable atmospheric temperature trends

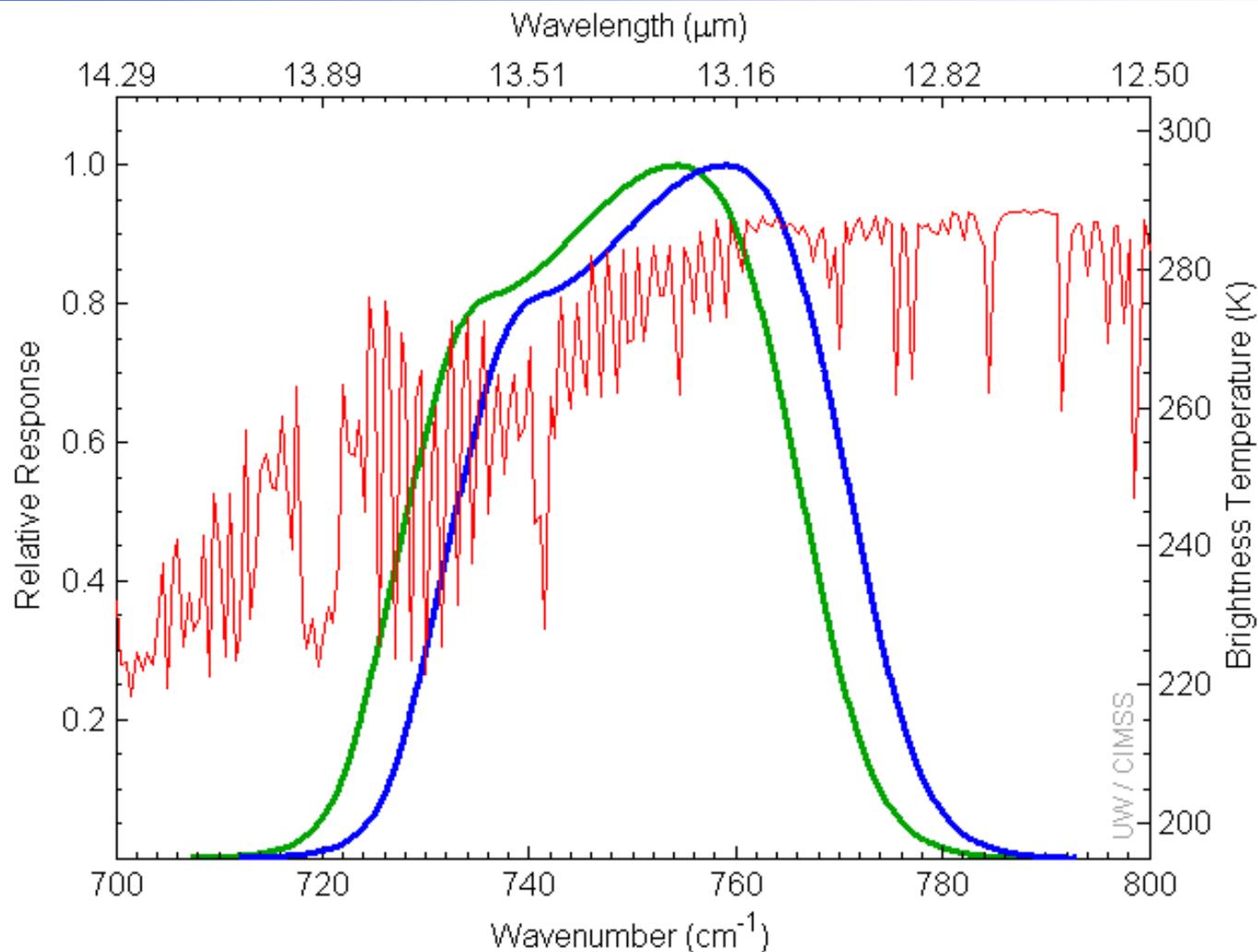


Temperature trends over oceans in the mid-troposphere (T2), tropopause region (T3), and lower stratosphere (T4) from MSU channel 2, 3, and 4 observations (Zhu, Gao, and Goldberg, *J. Clim.*, In Press)

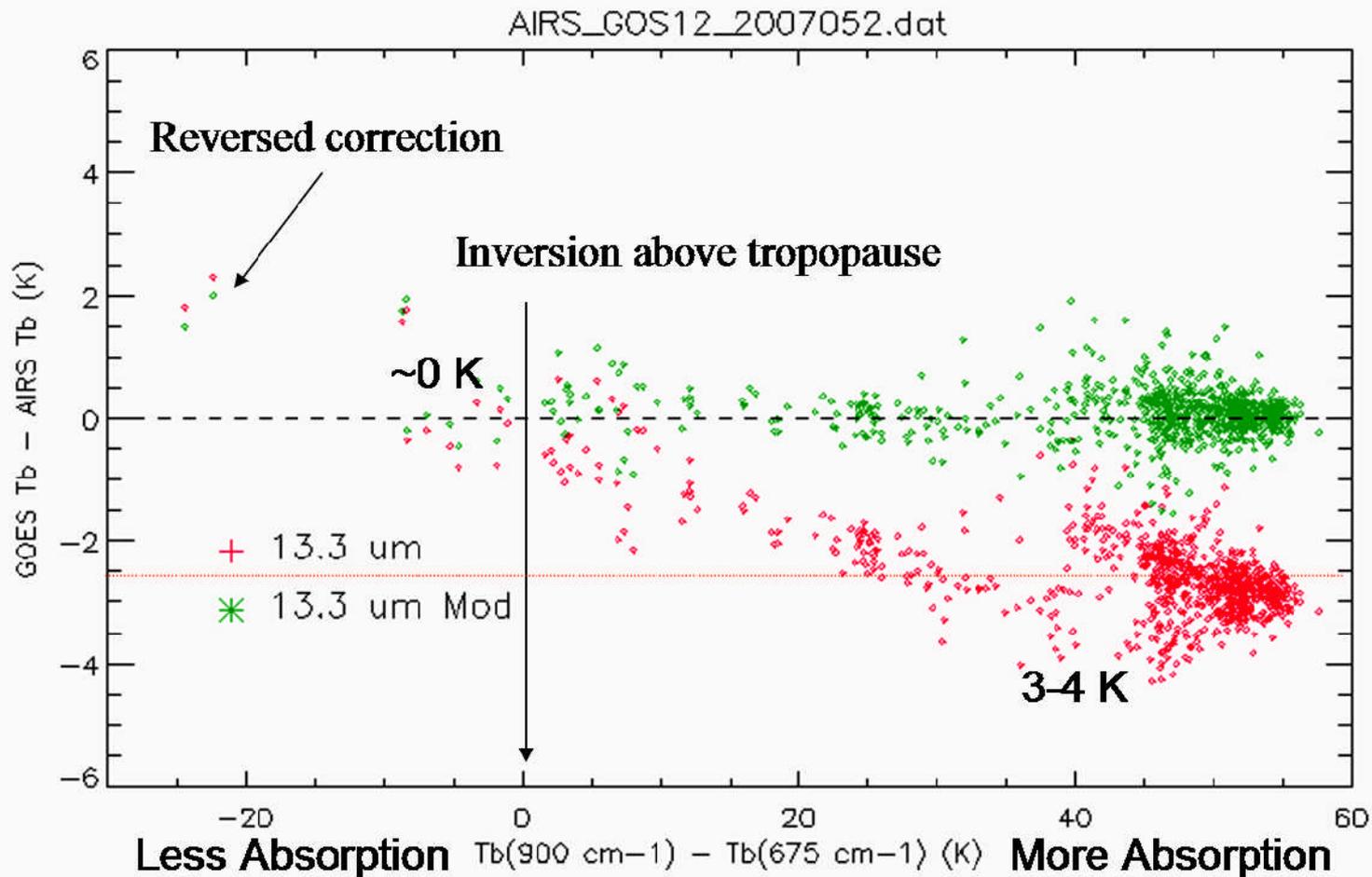
After careful intercalibration there is still disagreement in
with Christy and Mears. The data is not irrefutable

Coordinated international program for sustained operational implementation of satellite intercalibration and characterisation





GOES-13 Imager Band 6 spectral response functions, original (blue) and with a -4.7 cm^{-1} shift (green), superimposed on spectral radiance for the U. S. Standard Atmosphere (red).

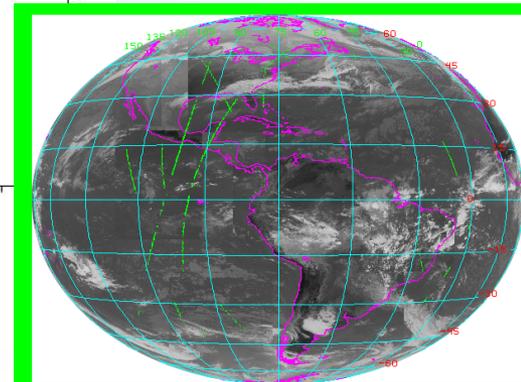
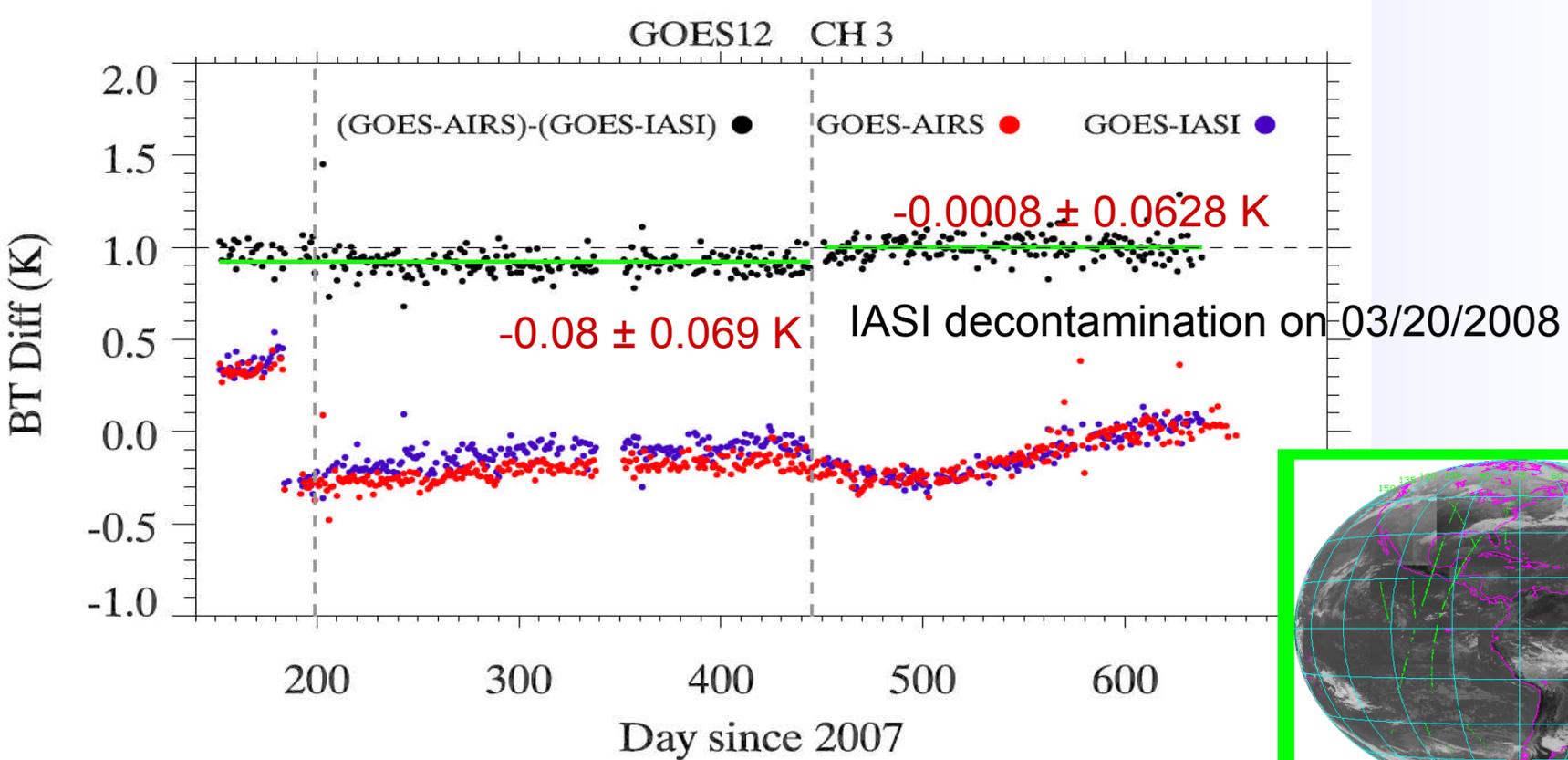
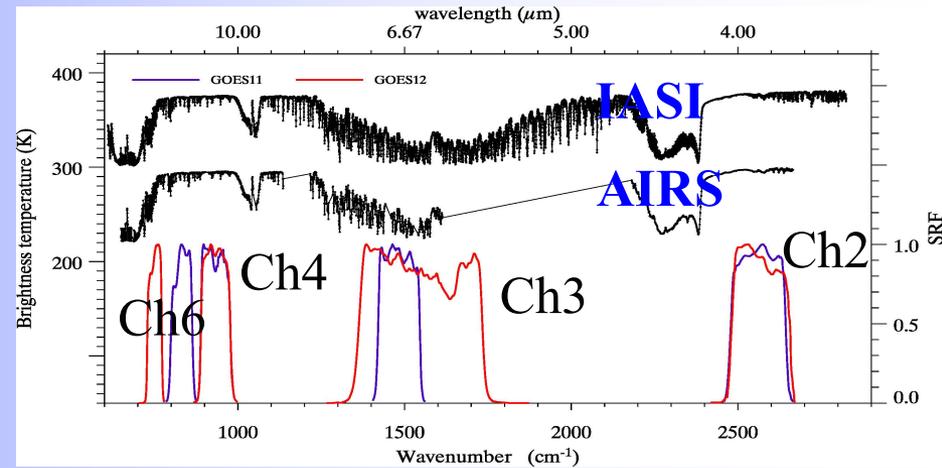


Adding a constant under-corrects warm scenes and over-corrects cold scenes



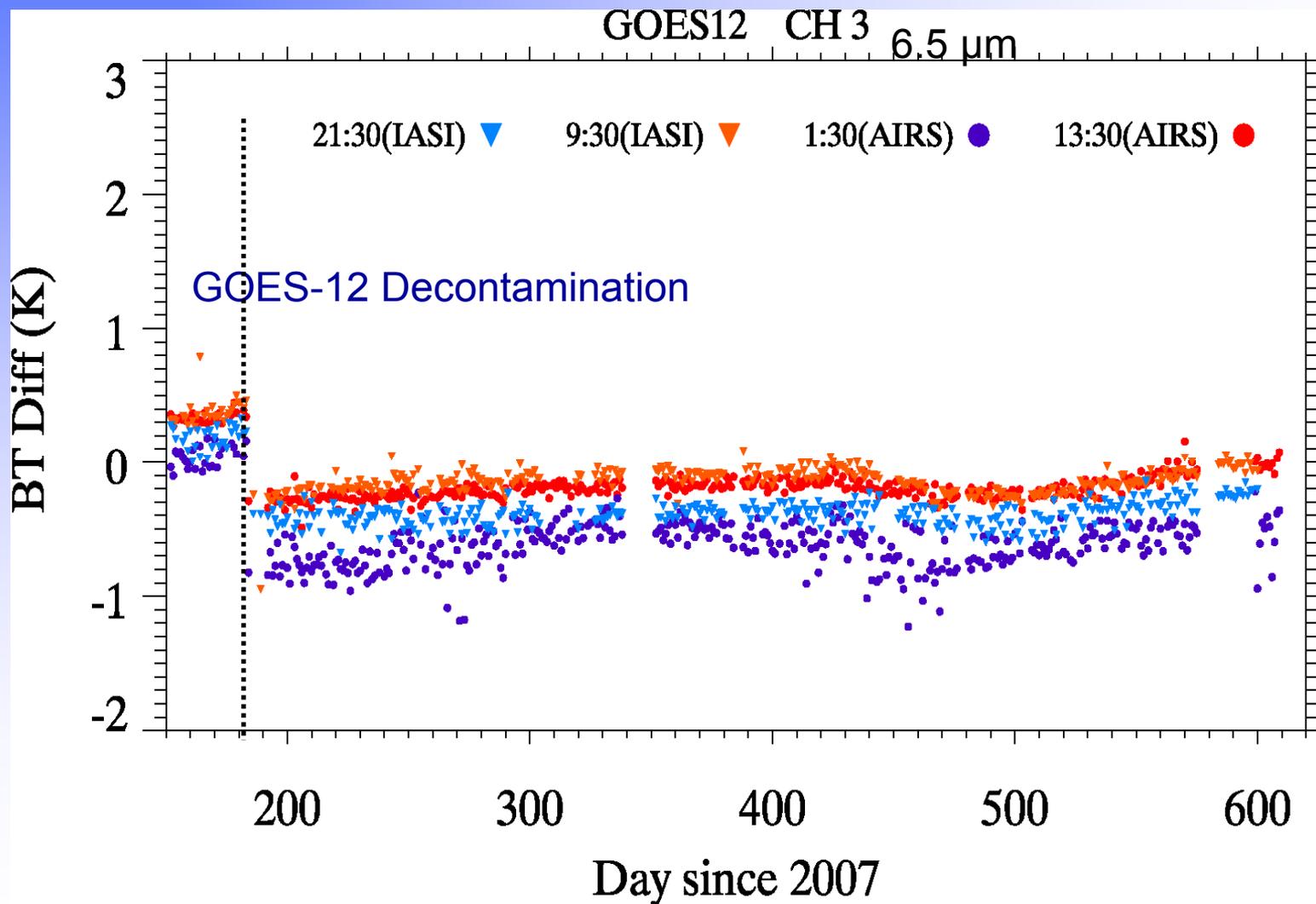
GOES as transfer radiometer

GOES12: 6.5 μm channel





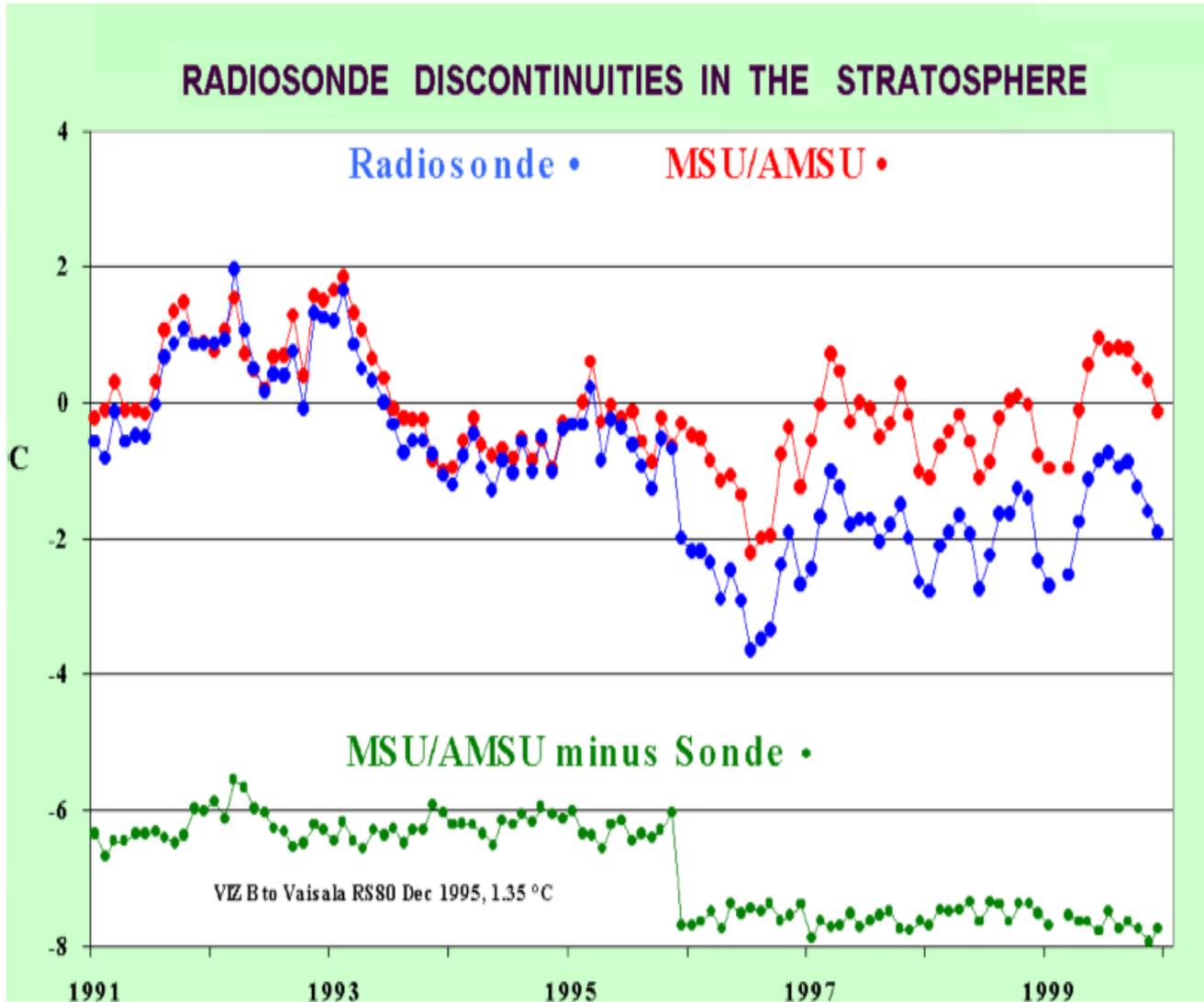
Assess GOES Calibration Accuracy: 1) Diurnal Bias





What do you do with an irrefutable data set??

- Monitor change
- Validate other observing systems
- Validate NWP analyses, forecasts, reanalyses, climate projections
- Derive level 2 products but the retrieval process will result in the products not being irrefutable.

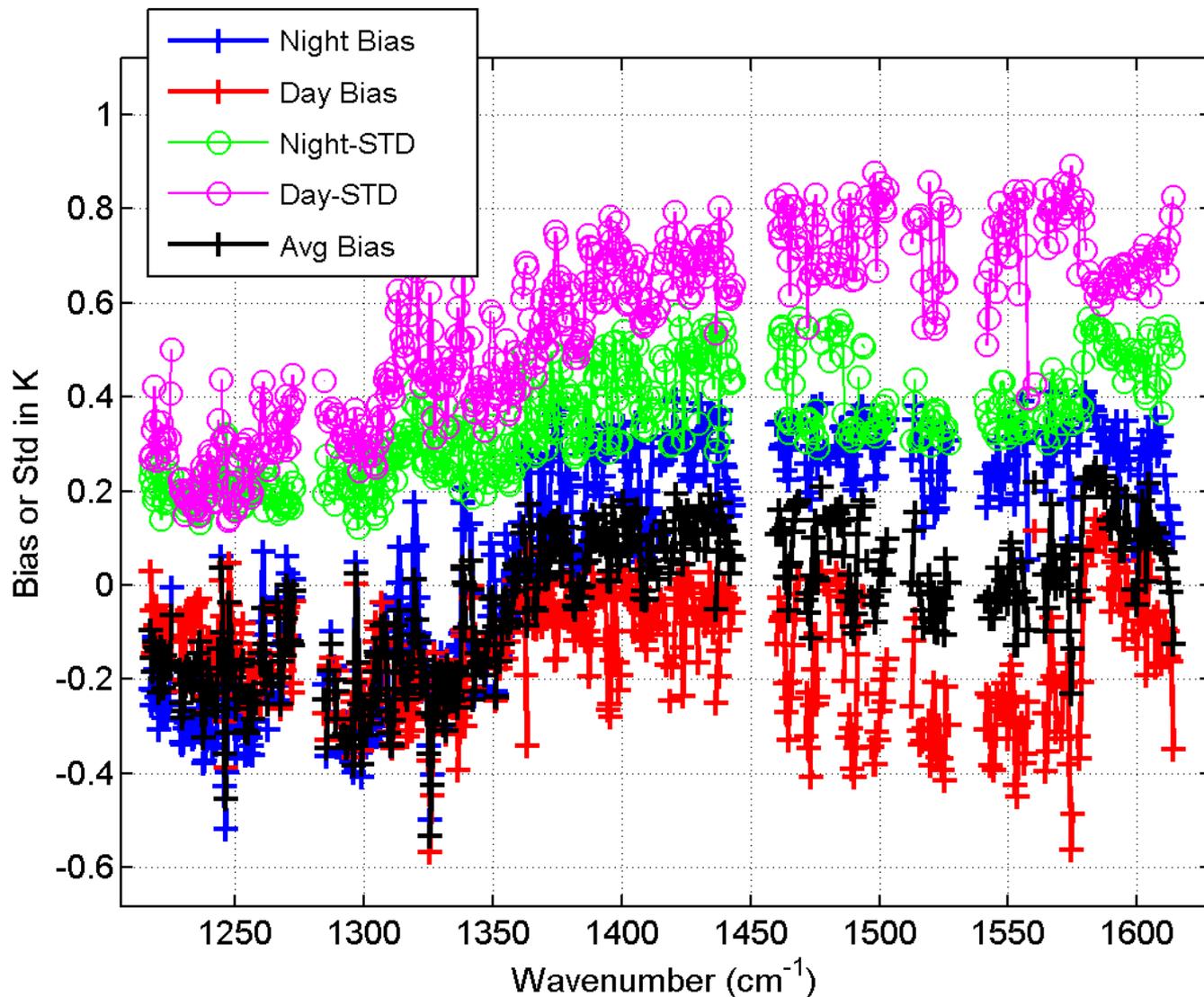


Satellites can serve as transfers standards to monitor radiosondes

VIZ B to Vaisala (RS80) at Chuuck Island



Validation of Mid- to Upper-Trop Water Raobs



Averages over
hundreds of sonde
launches over 3 years,
5+ sites.

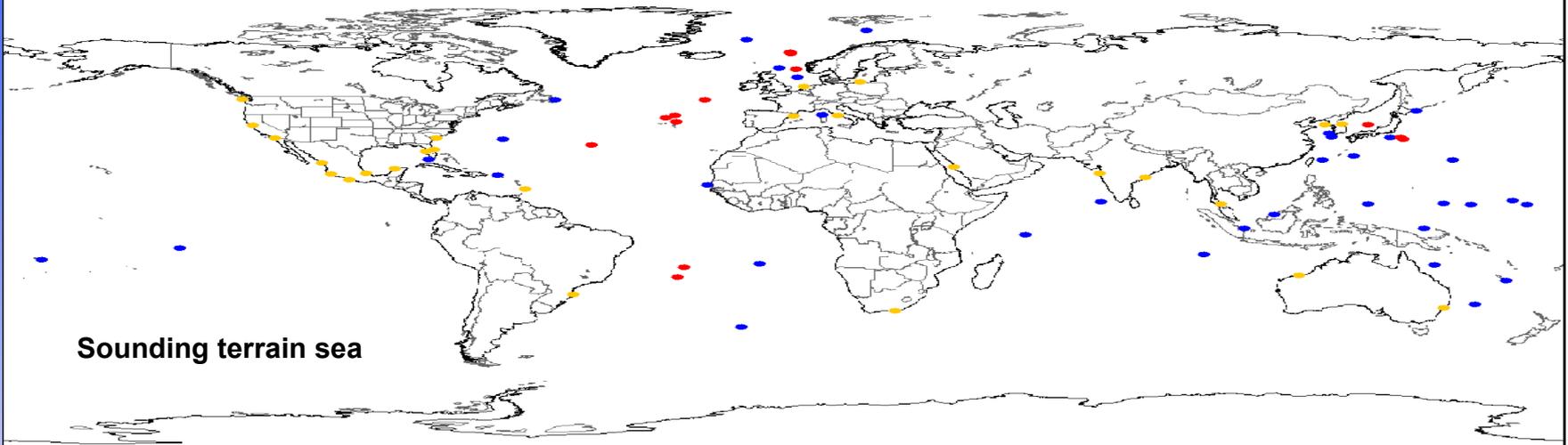
Possible RS-90
day vs night bias

Radiosonde Location

Retrieval/Radiosonde Collocations

116 available out of 7377

Coast Land Island Coast Island Inland Ship



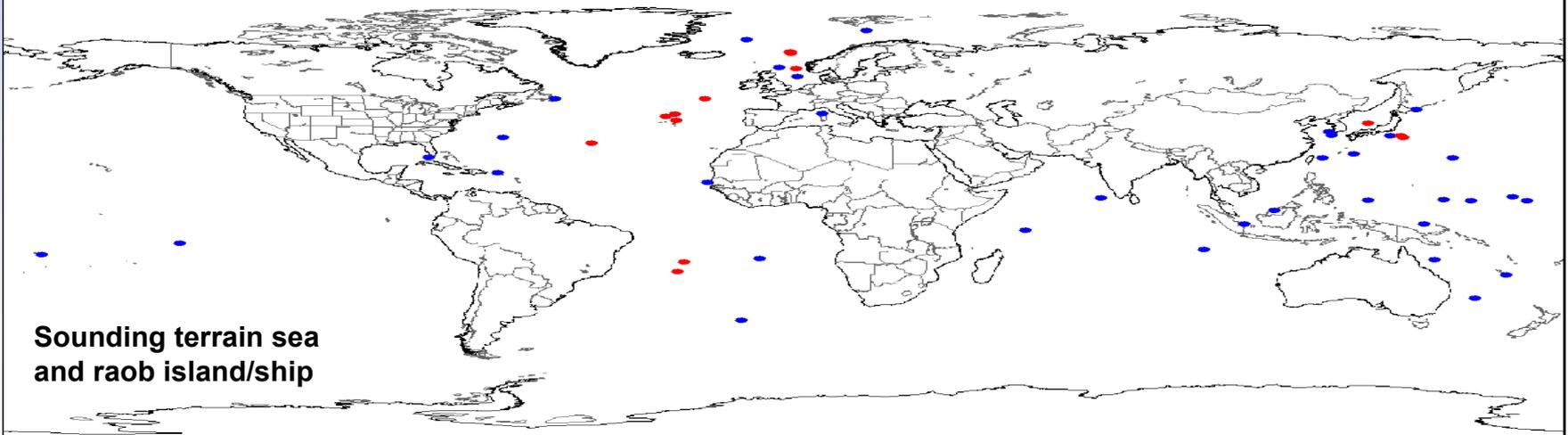
April 25, 2009 (16z) to May 1, 2009 (14z)

Radiosonde Location

Retrieval/Radiosonde Collocations

86 available out of 7377

Coast Land Island Coast Island Inland Ship

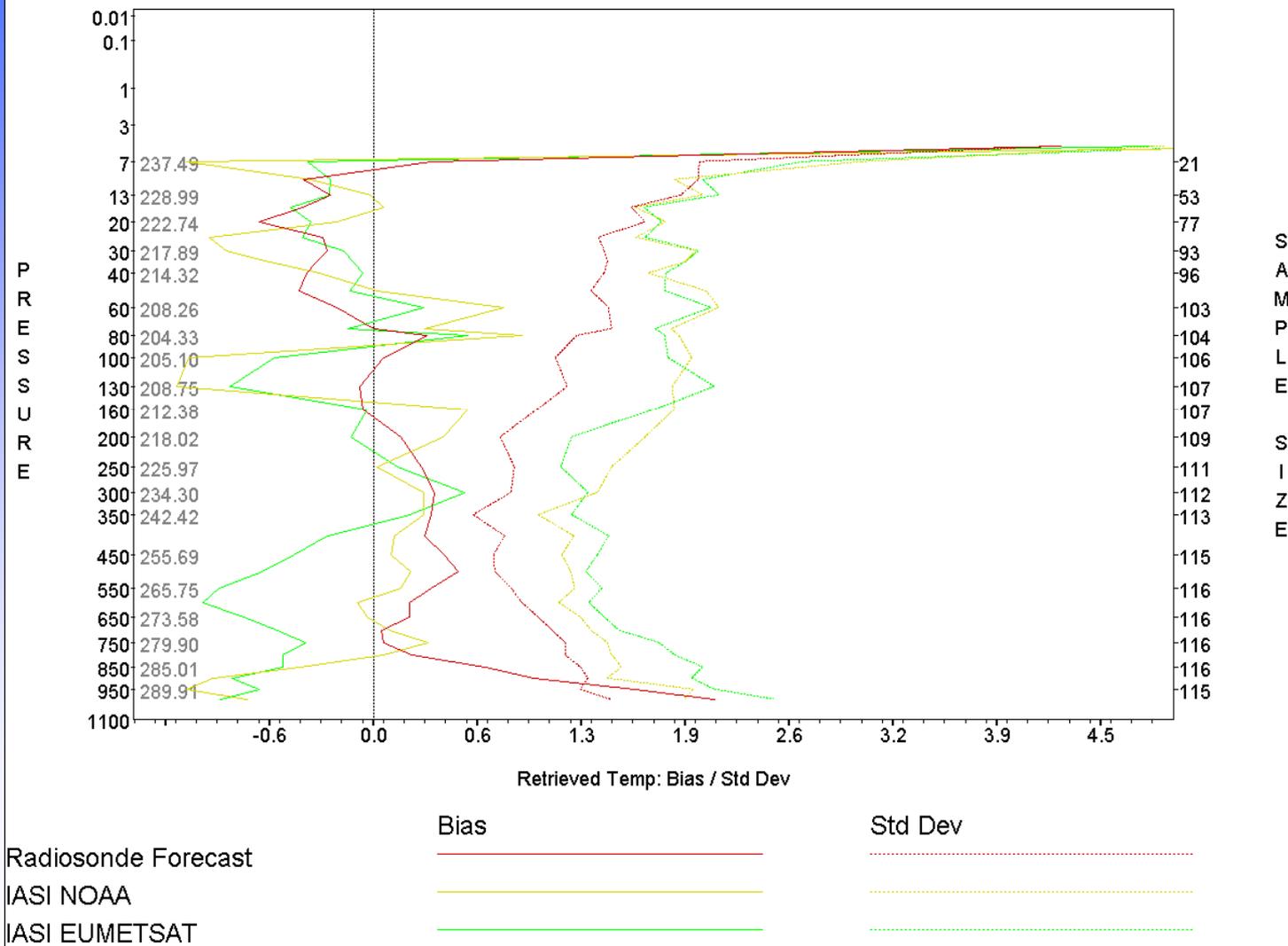


April 25, 2009 (16z) to May 1, 2009 (14z)

IASI EU and IASI NOAA common denominator sample w/QC over sea



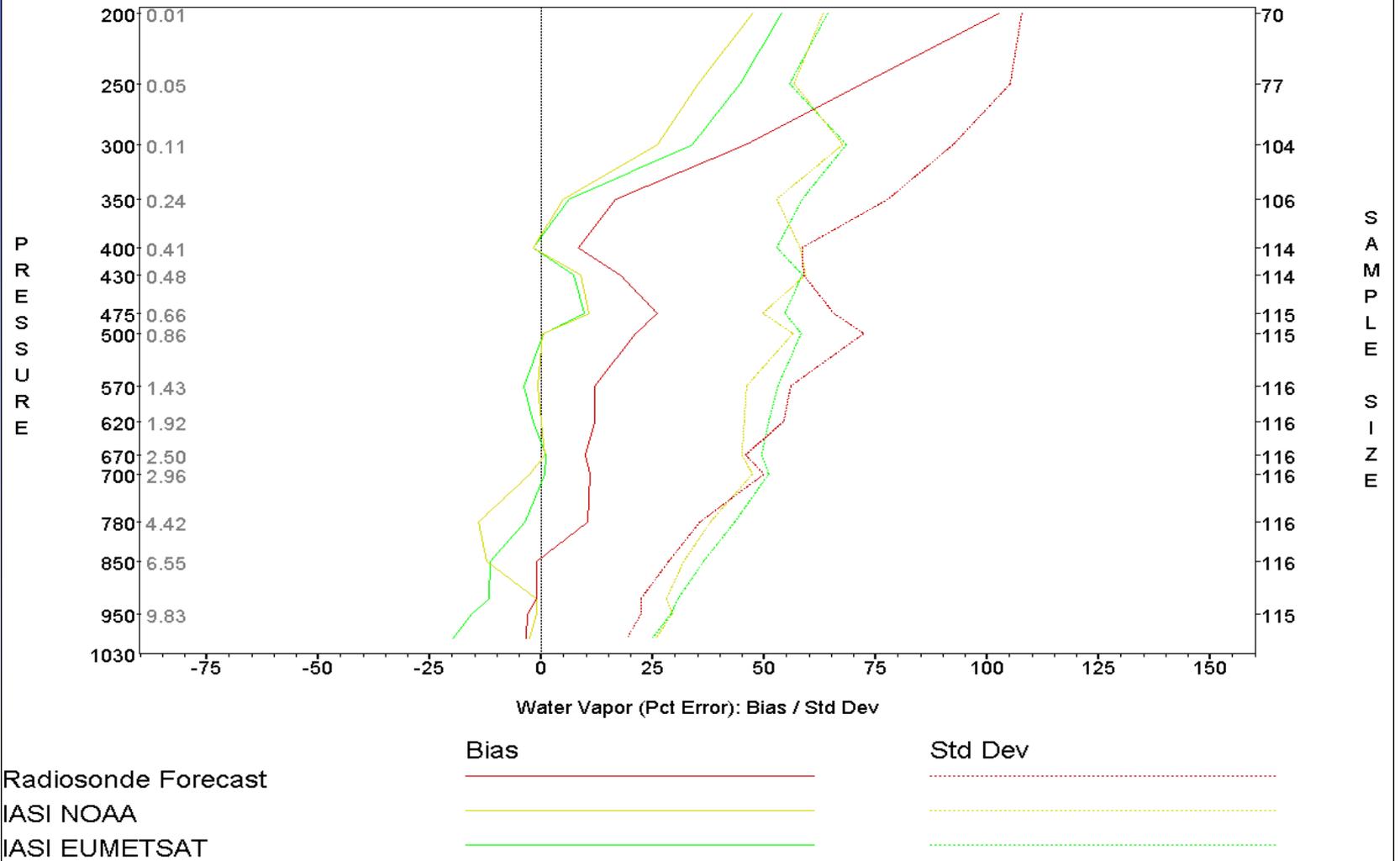
Vertical Statistics Display



IASI EU and IASI NOAA common denominator sample w QC



Vertical Statistics Display



IASI EU and IASI NOAA common denominator sample w QC

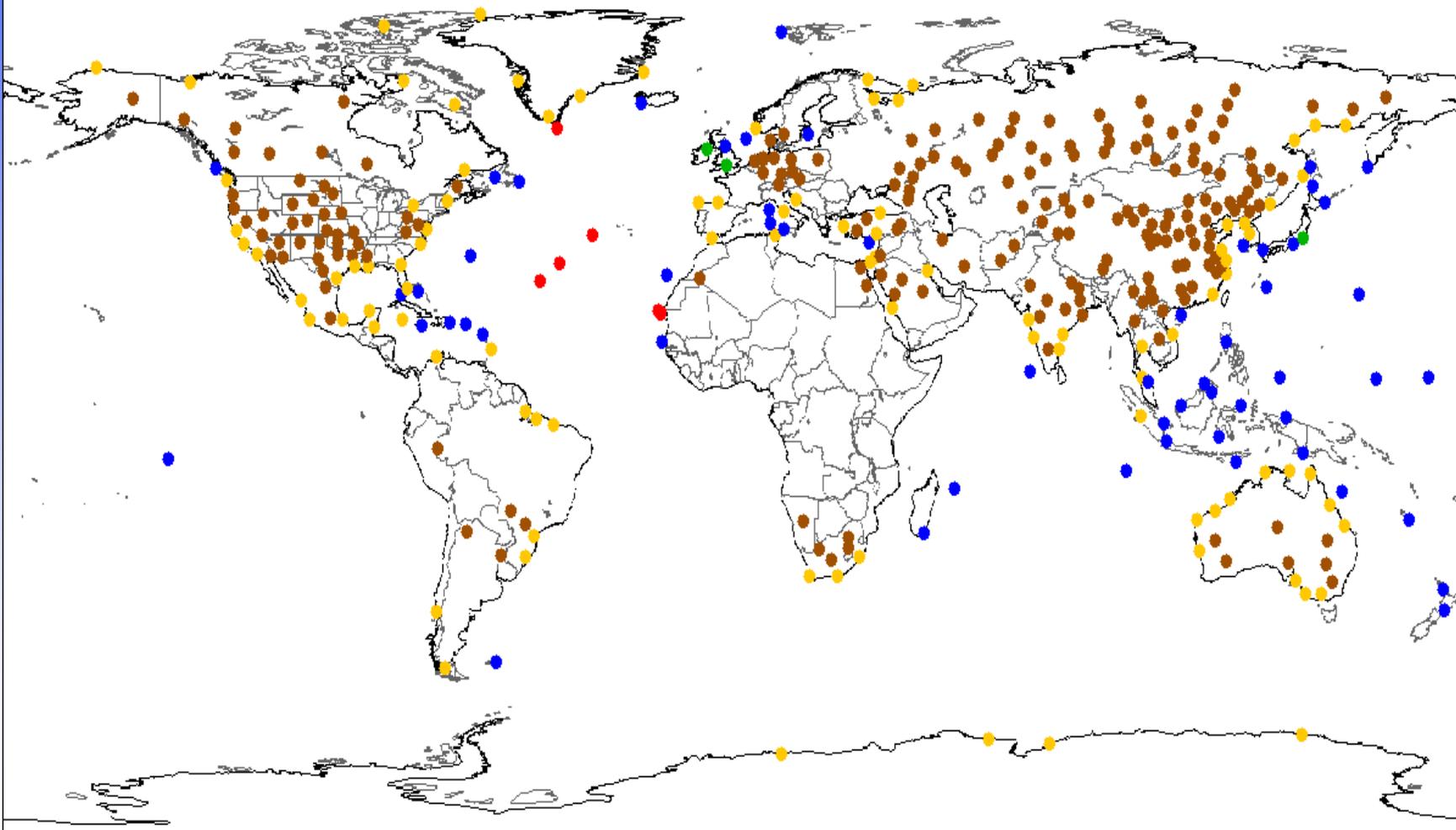


Retrieval/Radiosonde Collocations

Radiosonde Location

575 available out of 3727

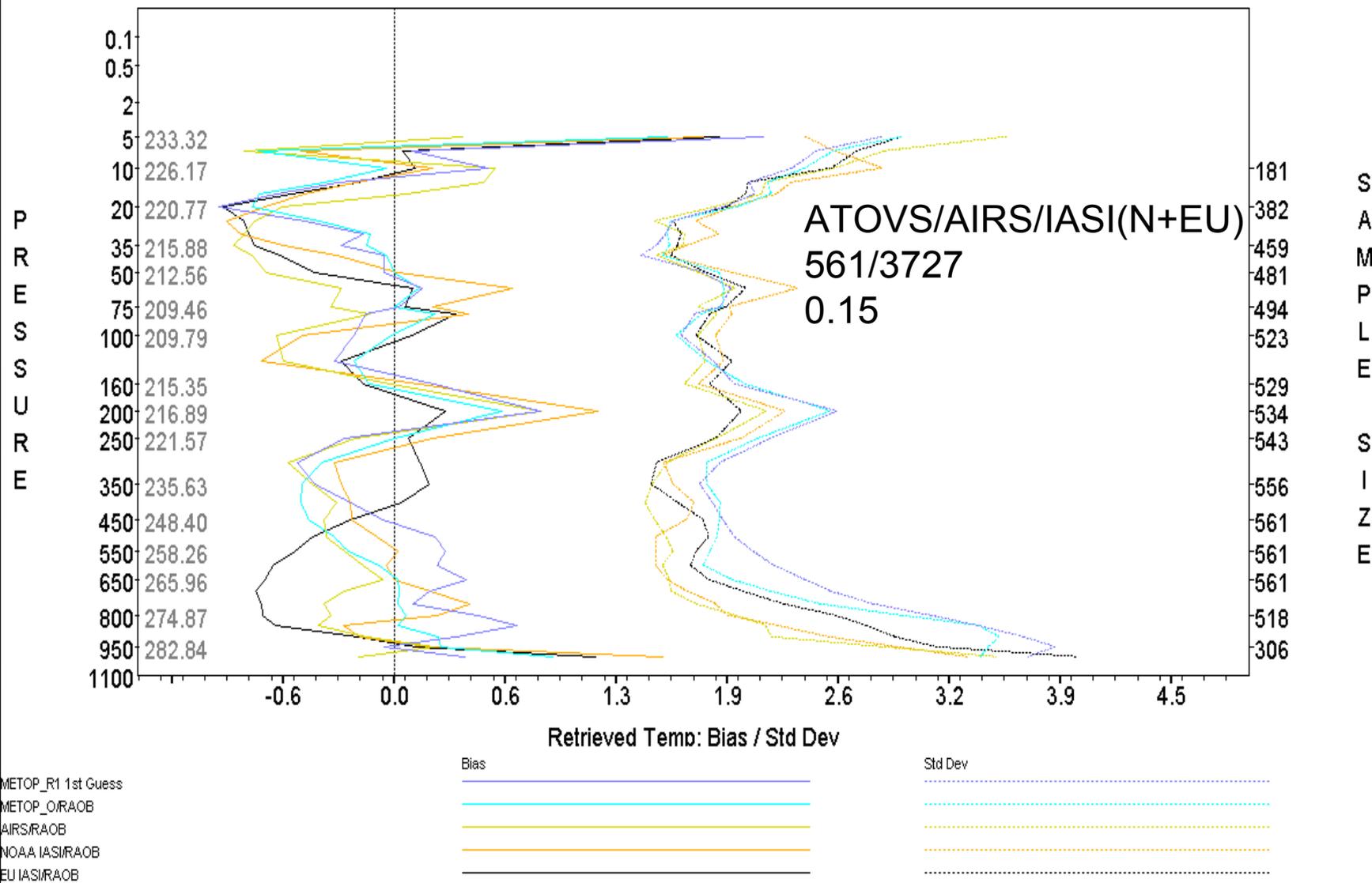
Coast Land Island Coast Island Inland Ship



March 28, 2009 (16z) to March 31, 2009 (14z)

ATOVS, AIRS, IASI-NOAA and IASI-EU ... common denominator sample after respective QC

NOAA/NESDIS Collocated Profile Display
Vertical Statistics Display



ATOVS, AIRS, IASI-NOAA and IASI-EU ... common denominator sample after respective QC



Motivation

- AIRS and IASI spectrally resolved radiances for the first time provides the capability to produce a climate data record of spectrally resolved infrared radiances (SRIR) with excellent spatial coverage, twice per day coverage with unprecedented accuracy and long-term stability
- We have developed a SRIR climate data record



Outline

- Overview of the Spectrally Resolved Infrared Radiances (SRIR)
- Approach to derive the SRIR Climate Data Record (CDR)
- Validation of the SRIR CDR
- Validating ECMWF and NCEP analysis fields using the SRIR CDR
 - (mostly using September months for 2003 through 2008)
- Summary and Conclusion



Spectrally Resolved Infrared Radiances (SRIR) Overview



AIRS Radiances observes the Signature of Climate Change

- High spectral resolution AIRS radiance provides sensitivity to nearly all climate forcing, responses and feedbacks.
- The AIRS radiances are sensitive to changes in
 - Carbon dioxide
 - Methane
 - Carbon monoxide
 - Ozone
 - Water vapor
 - Temperature
 - Clouds
 - Aerosols
 - Surface characteristics
 - Etc..
- Spectral Resolved Infrared Radiance datasets allow us to validate the accuracy of the model by directly comparing simulated with observed data.

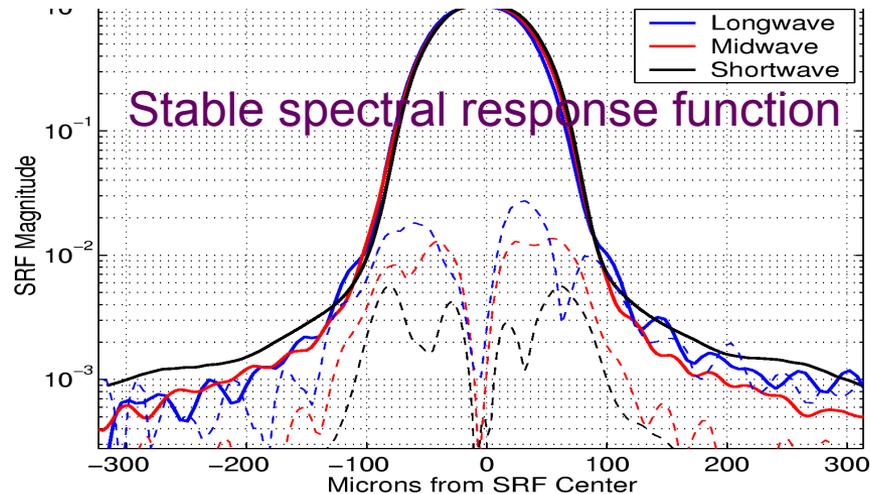
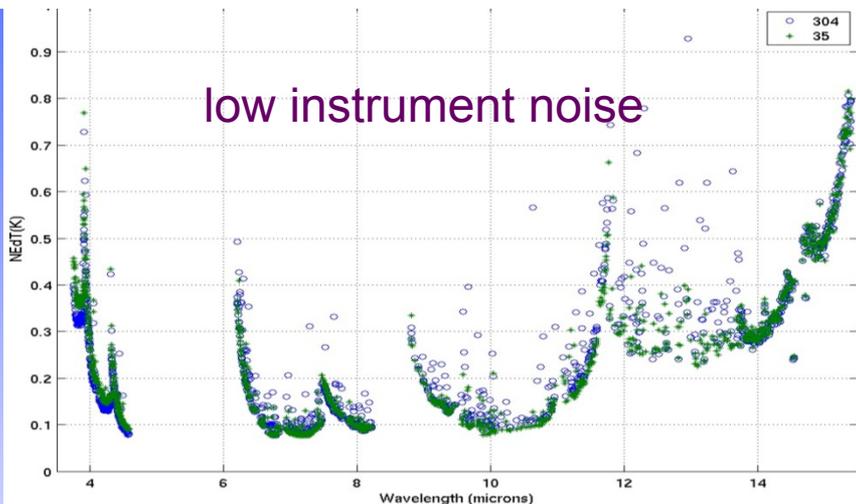


SRIR Objective

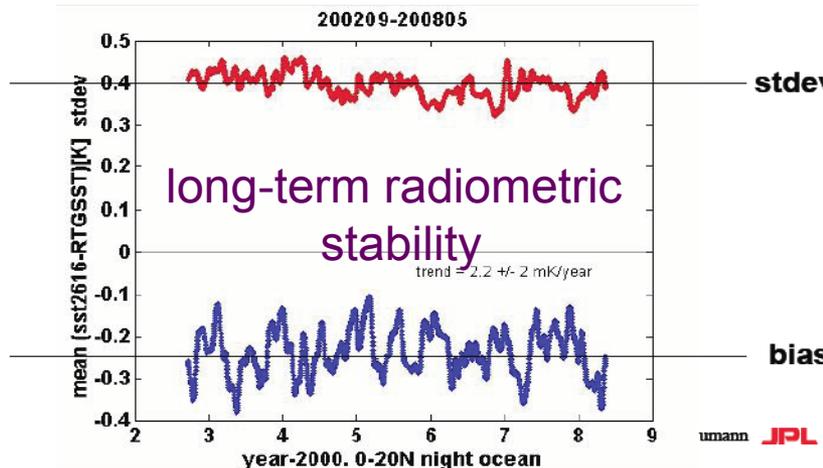
- To develop a very accurate SRIR CDR (with high spatial coverage) from AIRS and demonstrate its utility to:
 - Detect and monitor climate change of temperature, moisture, GHGs and clouds
 - Validate of weather and climate models; to test the realism of the model-derived atmospheric states with very high certainty.
 - Assess changes in model-derived fields due to assimilation of new data or an operational change in processing

Demonstrated in presentation

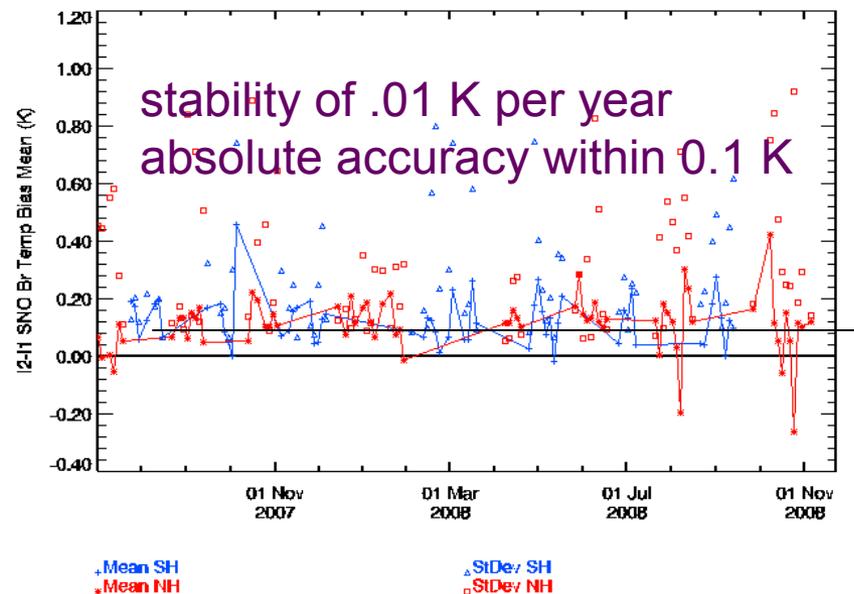
AIRS has been demonstrated by many investigators to have excellent accuracy, precision and stability (critical requirement to produce a CDR without adding uncertainties using adhoc methods to make a dataset stable)



The analysis of the first 6 years of data show that the AIRS trend for the direct difference (sst2616-rtgsst) is <4 mK/year. Absolute accuracy validation is limited by residual cloud contamination.



I2-I1 SNO Br Temp Bias Mean & StDev vs. Date Mean
I1:METOP02/IASI(13.83microns) I2:EOS_AQUA/AIRS_IR(13.83microns)





SRIR Climate Data Records

from the Advanced IR Sounders 2002-2020++

- AIRS (available from 2002) spectrally resolved radiances for the first time demonstrated the capability to produce a climatology of SRIR with excellent spatial coverage, twice per day coverage, unprecedented accuracy and long-term stability.
- Extended SRIR climate data records can be derived from:
 - NASA AIRS - Atmospheric Infrared Sounder (2002 – 2012) (14 km fov)
 - EUMETSAT IASI - Infrared Atmospheric Sounding Interferometer (2006 – 2020's) (12 km)
 - NPP/NPOESS CrIS - Cross-track Infrared Sounder (2011 – 2020's) (15 km)
 - Possible Geostationary Advanced Sounder (2020's) (10 > 5 km)
- Continuous accumulation of the SRIR datasets will enable broad applications of the data set in climate analysis and model verifications.



Steps to derive the SRIR climatology



Steps

- Gridded radiances are converted to Principal Component Scores (PCS) and stored into gridded daily datasets (0.5 long x 2.0 lat, ascending and descending).
- PCS are limb adjusted and stored in angle adjusted gridded daily datasets
- Angle adjusted PCS are converted to brightness temperatures and stored in gridded daily datasets.
- Each gridbox for each dataset has a clear flag.
- Compute daily/monthly clear and all-sky gridded datasets of limb adjusted brightness temperatures.



AIRS Limb Adjustment Methodology:

Step 1) Limb adjust the off-nadir PCS to the nadir PCS.

Use regression to predict the limb adjusted PCS from the first six PCS and the PCS to be limb adjusted

$$\text{Limb-adj PCS}(n,\text{angle}) = \sum_{i=1}^6 C(i,\text{angle}) * \text{PCS}(i,\text{angle}) + C(n,\text{angle}) * \text{PCS}(n,\text{angle})$$

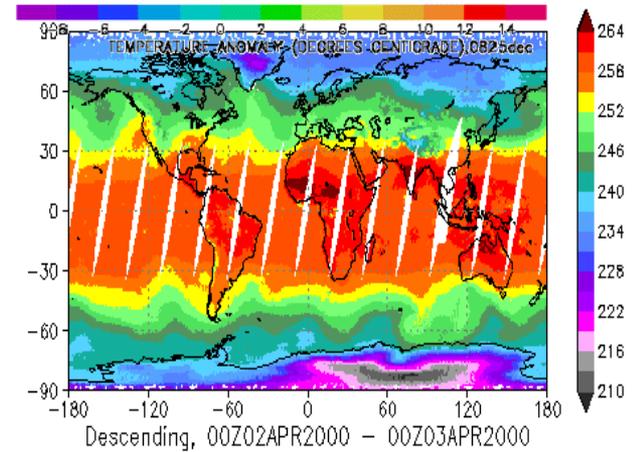
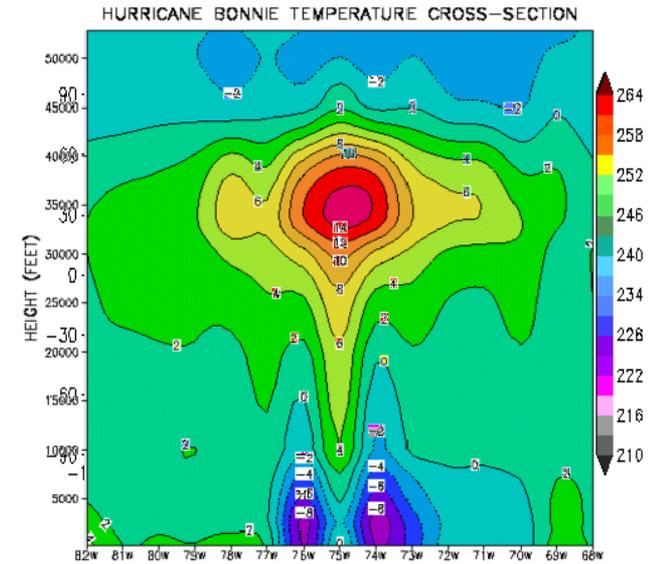
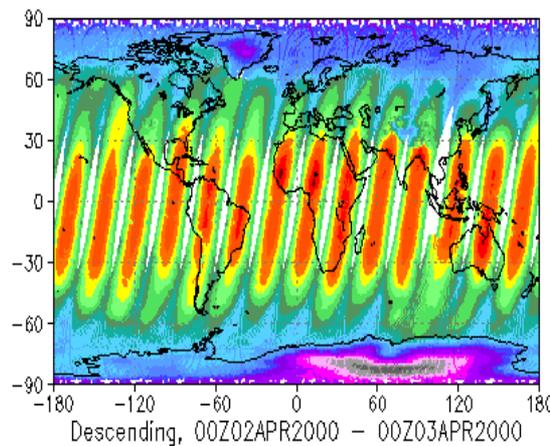
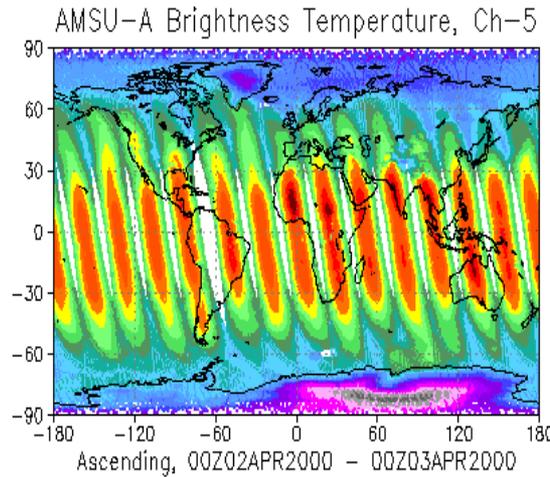
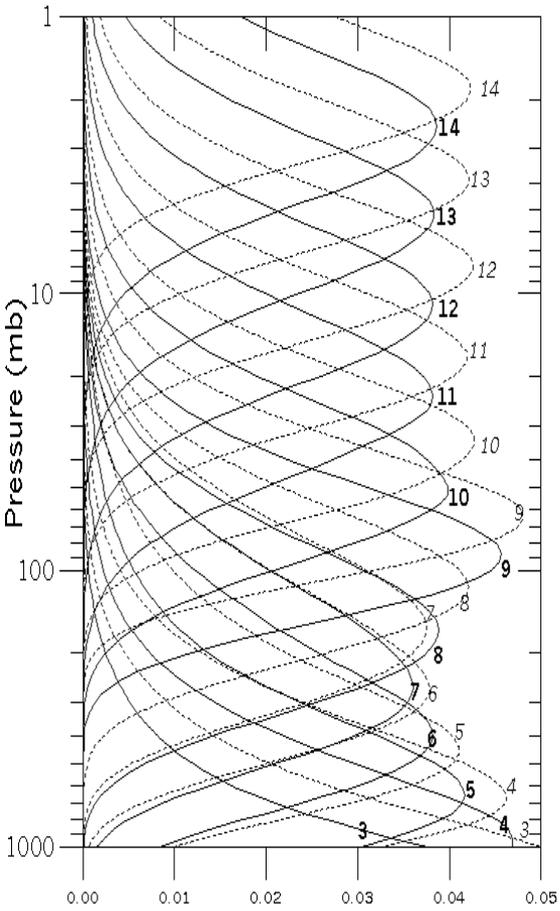
The regression coefficients are generated from six months of data. Averaged PCS as a function of scan angle (90 per scan line) over two degree latitude bands for ocean and non ocean cases.

Step 2) Reconstruct the limb adjusted radiance from the limb-adjusted PCS.

Step 3) Convert the limb adjusted radiances to limb adjusted brightness temperatures

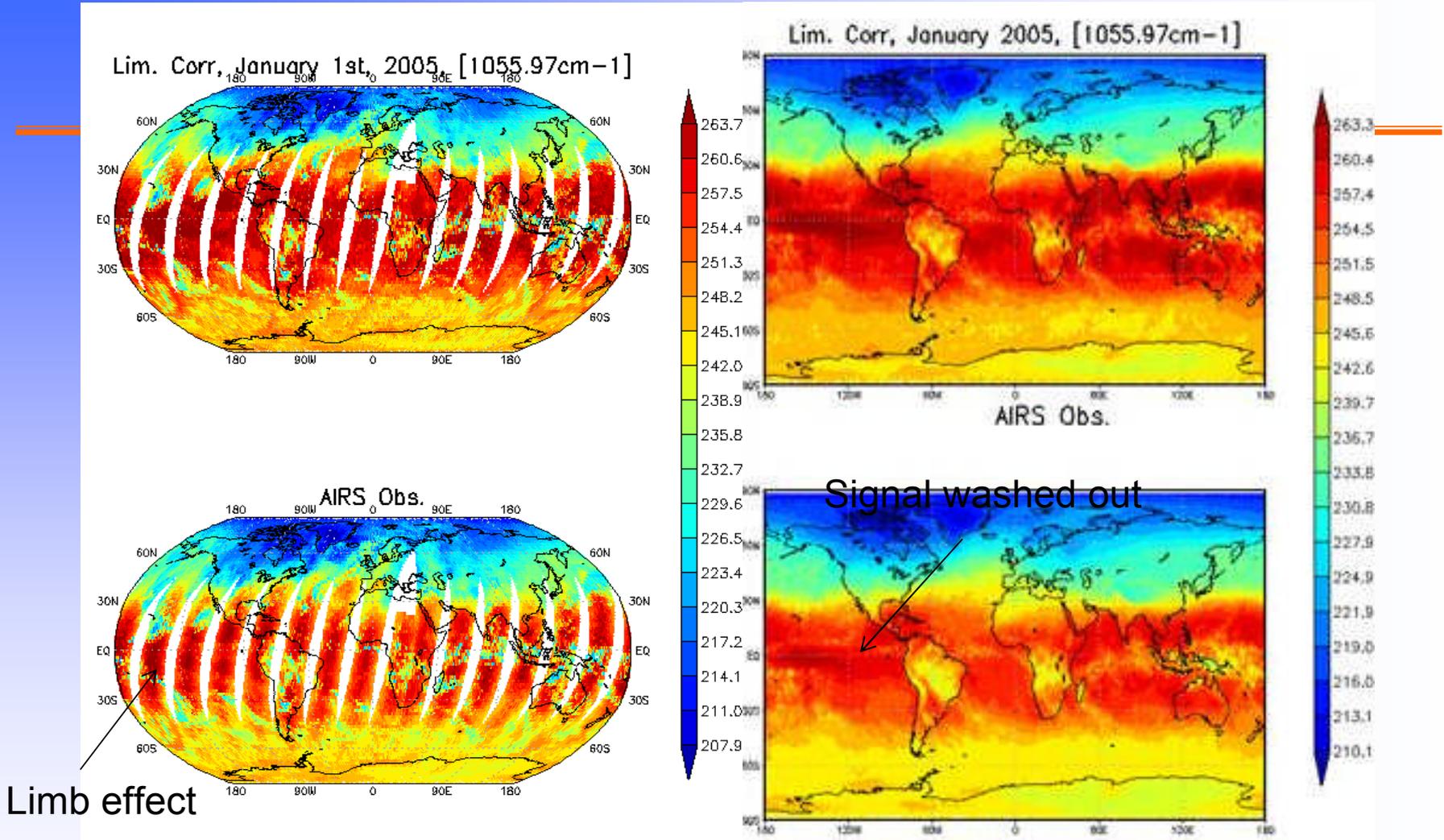


Need to limb adjust radiances to allow for studies related to spatial patterns (AMSU example)





Example of AIRS limb adjusted data



Limb corrected (upper left) and original observed (lower left) AIRS radiance; monthly averaged limb corrected (upper right) and original (lower right) AIRS radiance

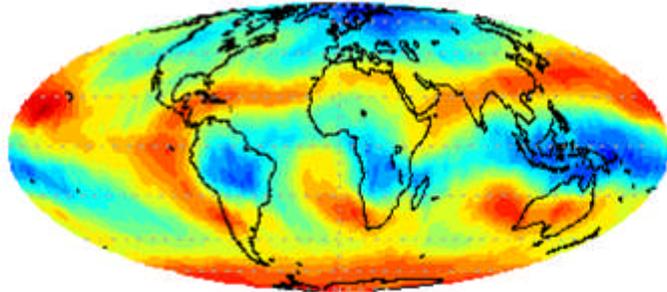
Must limb adjust the data to create meaningful global datasets



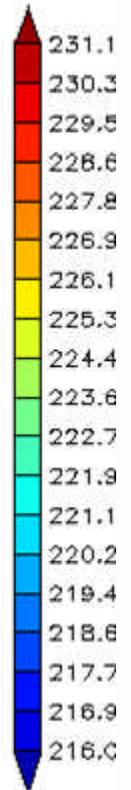
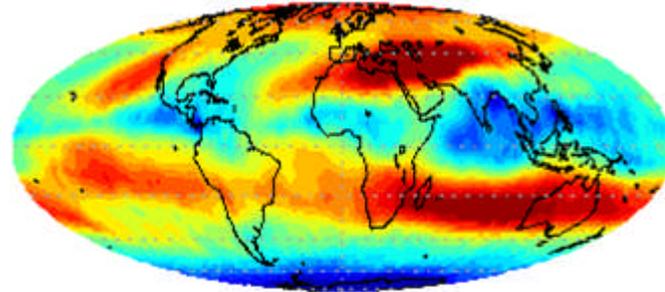
1520.87cm⁻¹

2006 Mid – upper tropospheric water vapor channel

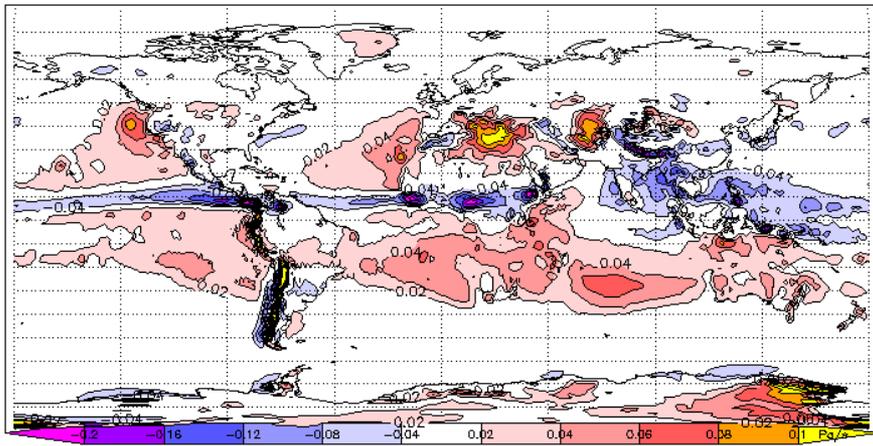
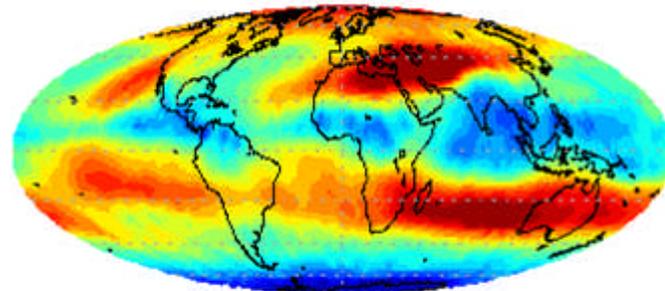
Jan Ascending



Jul Ascending



Jul Descending



ERA40 July 1979-2001 mean

Warmer brightness temperatures correspond to dryer air and matches areas of descending air from ERA40



Clear Flag

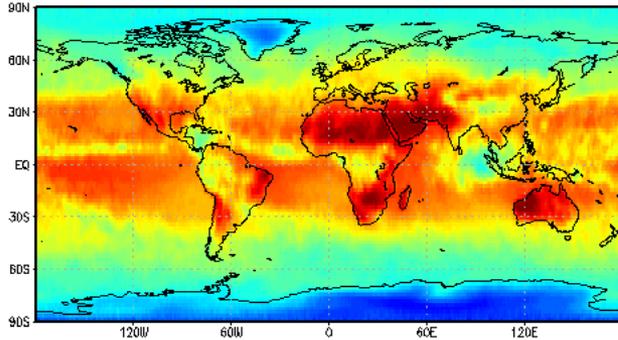
- Clear test is described in detail in [*Goldberg et al.*, 2003].
- Predict clear AIRS (2390 cm^{-1}) from AMSU
- Compare predicted AIRS (2390 cm^{-1}) with actual AIRS.
- Predict surface temperature from AIRS and compare with NCEP forecast surface temperature.
- Compute variability of AIRS (2390 cm^{-1}) for 3x3 array of AIRS footprints within the AMSU footprint.



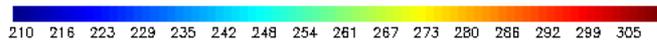
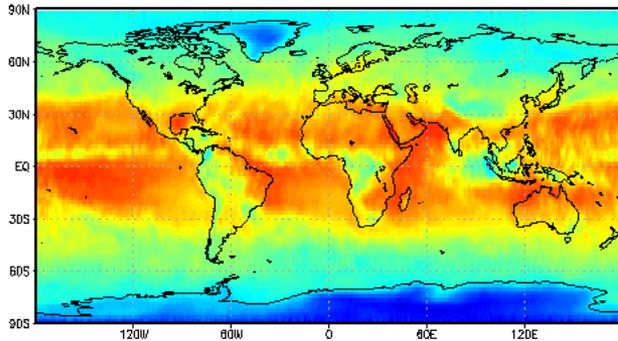
All Sky

Monthly Average Limb Adjusted BT, All Sky, Oct 2005, 1001.38cm-1

Ascending: mean=267.007 std=18.127
count=64386 min=209.532 max=316.106



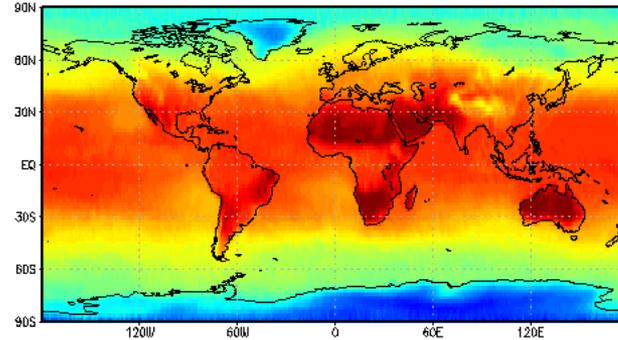
Descending: mean=263.883 std=16.8159
count=64422 min=198.485 max=297.527



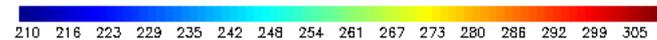
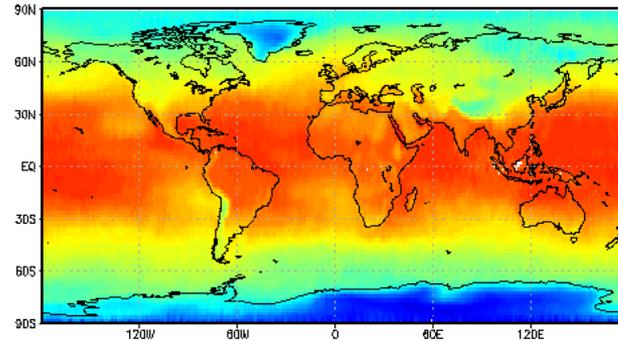
Clear Sky

Monthly Average Limb Adjusted BT, Clear Sky, Oct 2005, 1001.38cm-1

Ascending: mean=274.198 std=19.1584
count=64011 min=209.532 max=317.288



Descending: mean=270.57 std=18.0633
count=63972 min=198.314 max=297.494



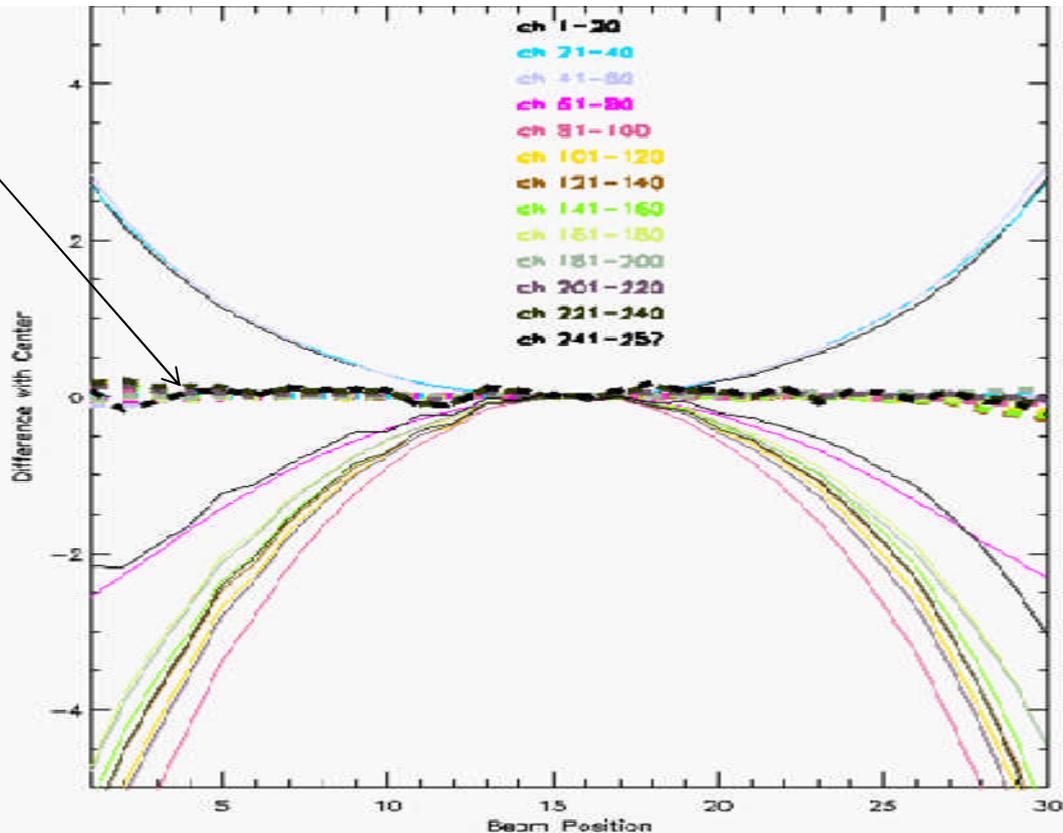


Validation of the SRIR climatology



Validation of Limb Adjustment

Limb adjustment successfully removes the large scanline dependency



Deviations of averaged original (colored curves) for groups of channels and limb adjusted (heavy dashed curve) brightness temperatures from nadir as a function of beam position

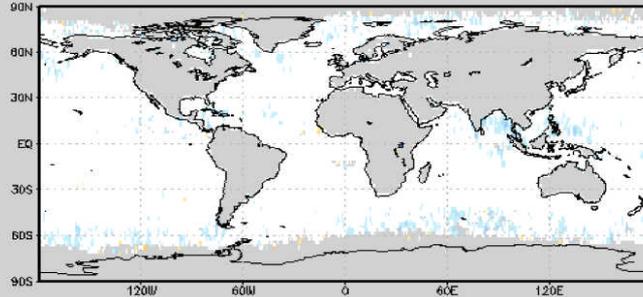


SKIR validation by comparing measured vs simulated brightness temperatures against ECMWF with and without limb adjustment

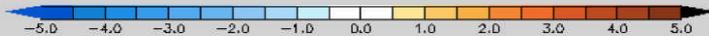
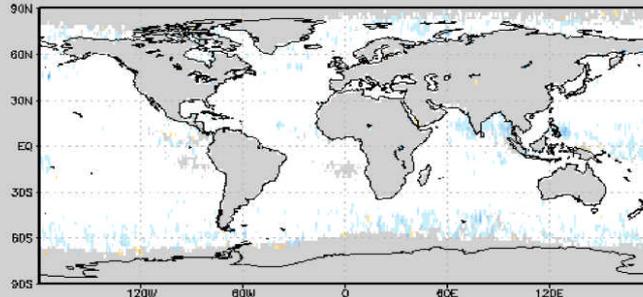
Original - EC(sim, f(angle))

Observation - ECMWF, 723.029cm⁻¹, Clear Sky, No Score, Sep, 2004

Ascending: bias=-0.15108 rms=0.456039
count=35252 min=-8.52405 max=2.38672



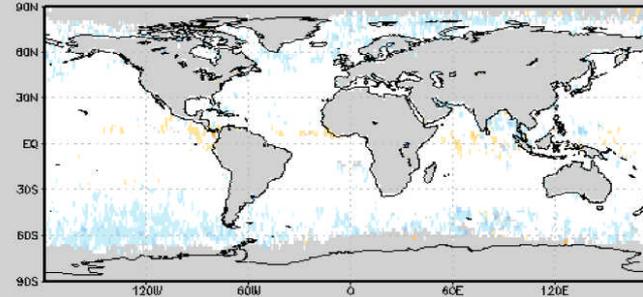
Descending: bias=-0.166967 rms=0.486816
count=33603 min=-10.3709 max=2.37924



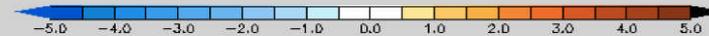
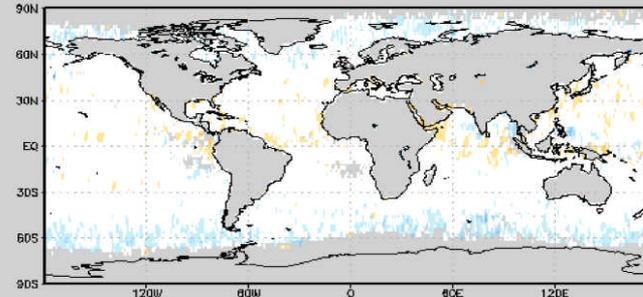
Limb adjusted - EC(sim, f(nadir))

Limb Adjusted BT, 7 PCs - ECMWF (NAD), 723.029cm⁻¹, Clear Sky, No Score, Sep, 2004

Ascending: bias=-0.190429 rms=0.556302
count=35245 min=-8.60046 max=2.74487



Descending: bias=-0.0413993 rms=0.565617
count=33592 min=-10.9084 max=3.48587



Bias and standard deviation nearly the same, channel peaks near 700 mb

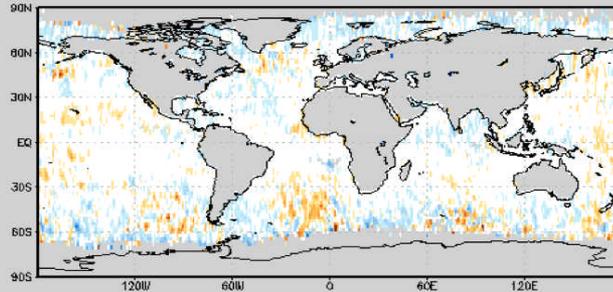


SKIR validation by comparing measured vs simulated brightness temperatures against ECMWF with and without limb adjustment

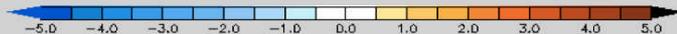
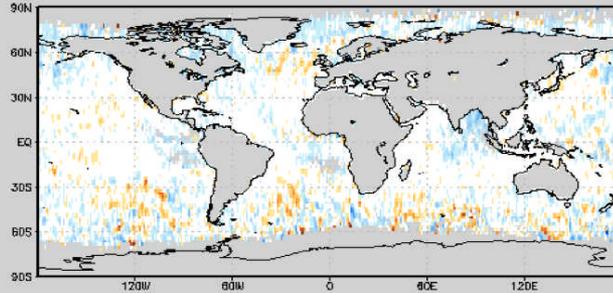
Original - EC(sim, f(angle))

Observation - ECMWF, 1598.49cm-1, Clear Sky, No Score, Sep, 2004

Ascending: bias=-0.0661891 rms=1.11611
count=35252 min=-9.79042 max=16.7093



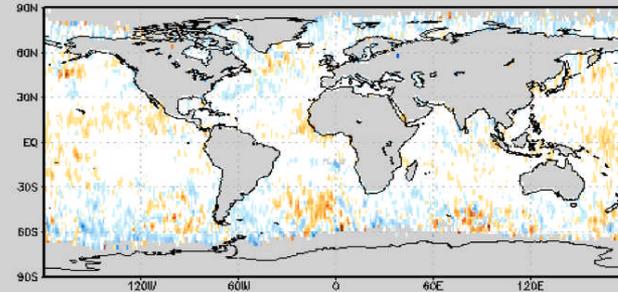
Descending: bias=-0.116707 rms=1.19503
count=33603 min=-11.6857 max=13.0458



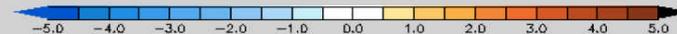
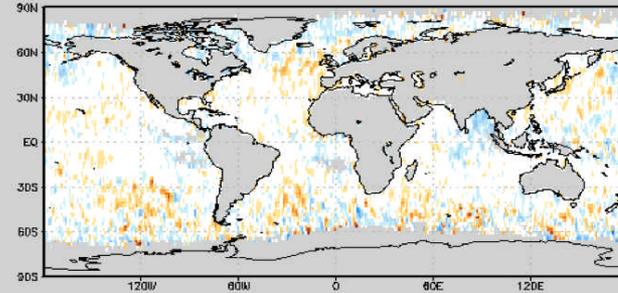
Limb adjusted - EC(sim, f(nadir))

Limb Adjusted BT, 7 PCs - ECMWF (NAD), 1598.49cm-1, Clear Sky, No Score, Sep, 2004

Ascending: bias=-0.00965988 rms=1.12849
count=35245 min=-10.0071 max=16.4171



Descending: bias=0.0265201 rms=1.18533
count=33592 min=-11.5689 max=13.0889



Bias and standard deviation nearly the same, water vapor channel peaking near 500 mb (for mean profile)

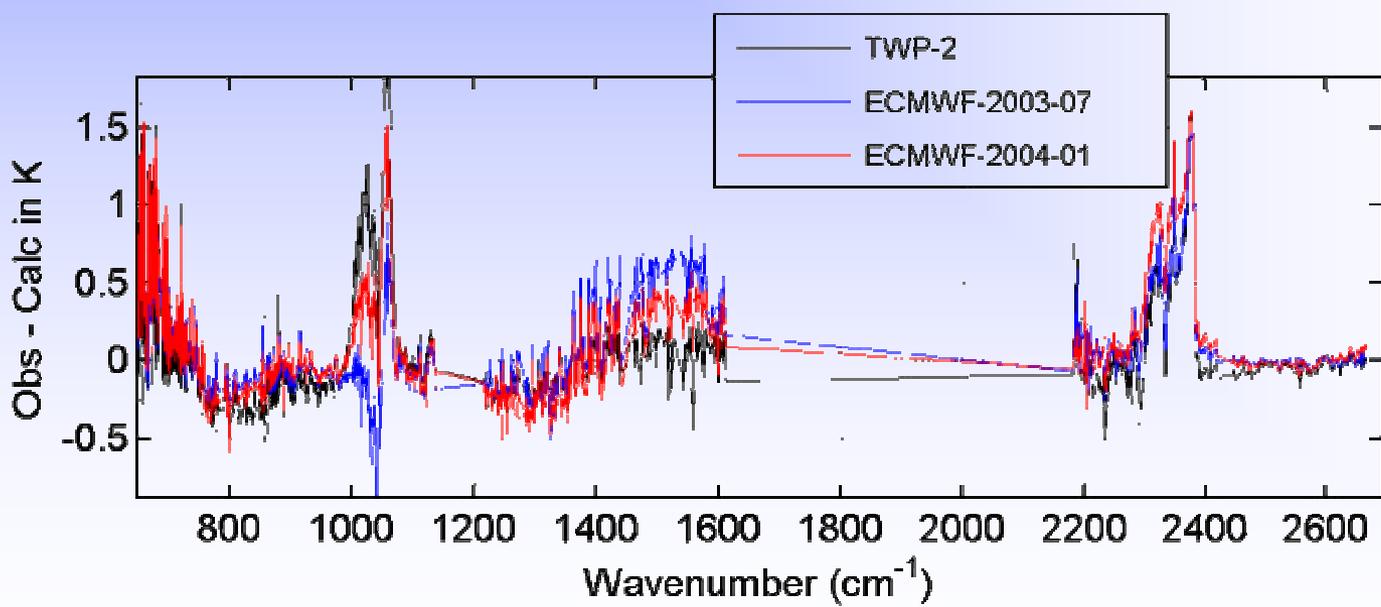
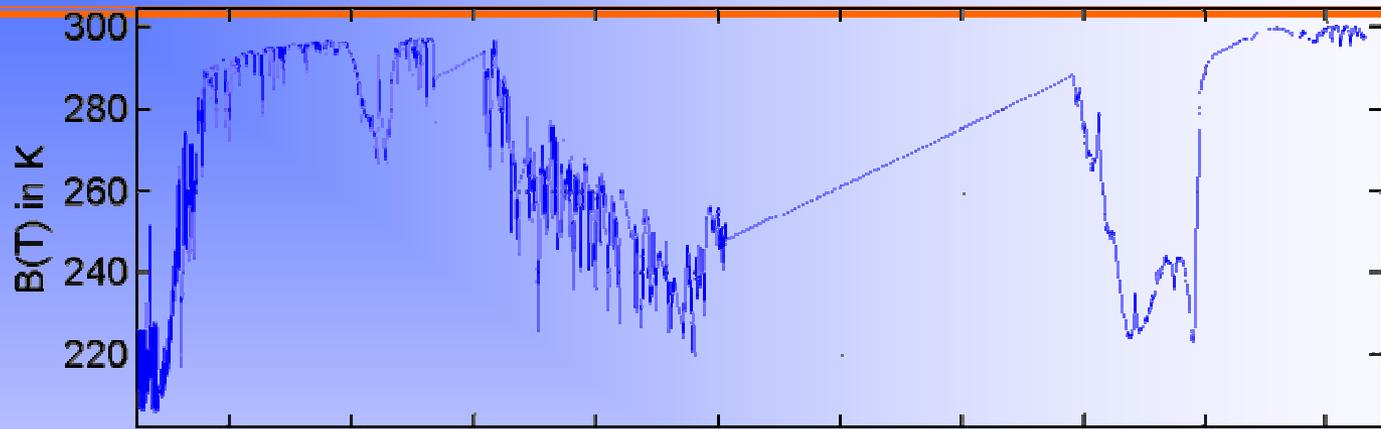


Validation of model fields using AIRS clear-sky SRIR climatology



NCEP vs ECMWF

- There are differences between the NCEP and ECMWF analyses
- Mean bias and standard deviations for temperature are nearly the same, except in upper stratosphere.
- Water vapor differences are very large
- Following few slides shows differences of simulated AIRS (ECMWF) – simulated AIRS(NCEP/GDAS) (no measured data are used)

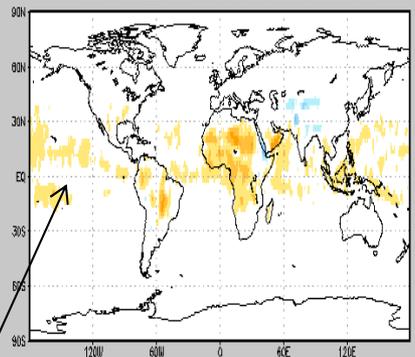




: ECMWF minus GDAS simulated
brightness temperatures for A: 801.09 cm⁻¹
(850 mb), B: 723.029 cm⁻¹ (700 mb), and
C: 704.436 cm⁻¹ (350 mb)

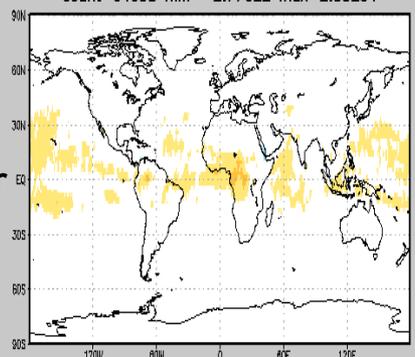
ECMWF (NAD) - GDAS (NAD), 801.099cm⁻¹, All Sky, Sep, 2004

Ascending: bias=0.152822 rms=0.345362
count=64722 min=-3.0799 max=2.88982



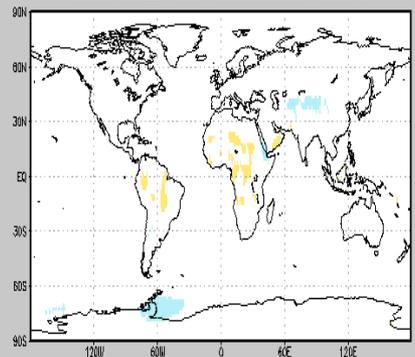
A

Descending: bias=0.149493 rms=0.300216
count=64655 min=-2.77622 max=2.00234



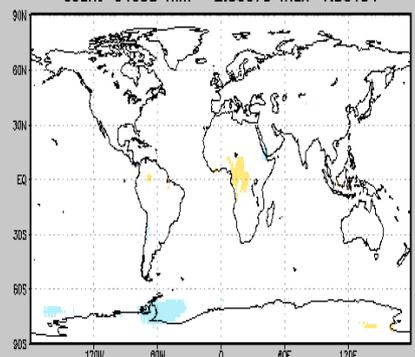
ECMWF (NAD) - GDAS (NAD), 723.029cm⁻¹, All Sky, Sep, 2004

Ascending: bias=0.0034263 rms=0.22101
count=64722 min=-2.0102 max=1.36794



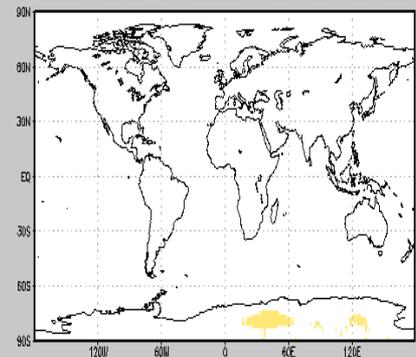
B

Descending: bias=-0.00183653 rms=0.218622
count=64655 min=-2.08679 max=1.38104



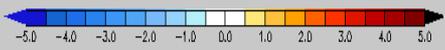
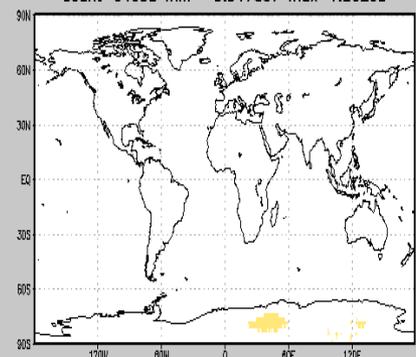
ECMWF (NAD) - GDAS (NAD), 704.436cm⁻¹, All Sky, Sep, 2004

Ascending: bias=-0.12814 rms=0.219024
count=64722 min=-1.16527 max=1.39995



C

Descending: bias=-0.136878 rms=0.224389
count=64655 min=-0.947857 max=1.26265



Water vapor
sensitivity

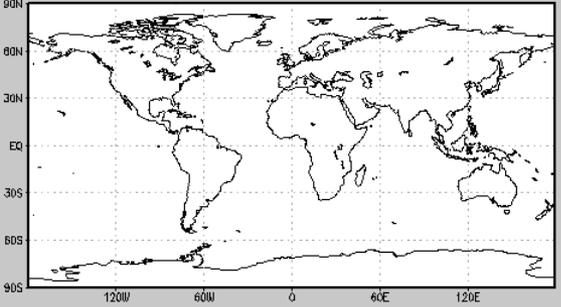
Temperature channel differences are very small



ECMWF minus GDAS simulated brightness temperatures for C: 666.766 cm⁻¹ (40 mb), and D: 667.018 cm⁻¹ (25 mb)

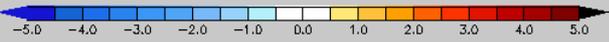
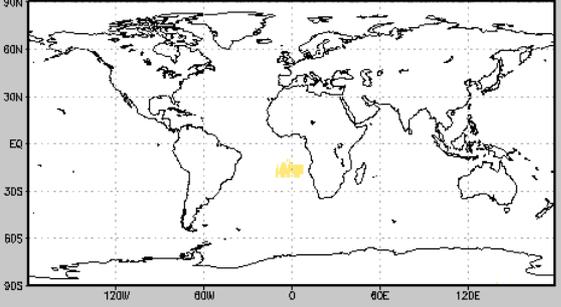
ECMWF (NAD) - GDAS (NAD), 666.766cm⁻¹, All Sky, Sep, 2004

Ascending: bias=0.0177204 rms=0.117121
count=64722 min=-1.57379 max=2.52542



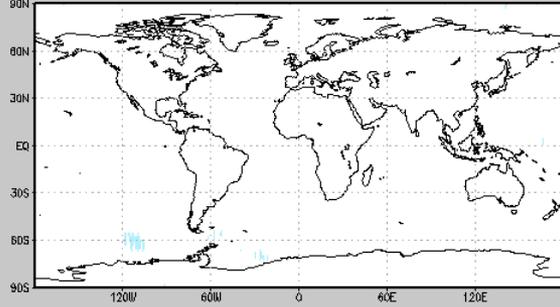
C

Descending: bias=0.0362061 rms=0.149237
count=64655 min=-1.44522 max=3.10333



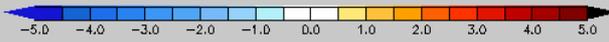
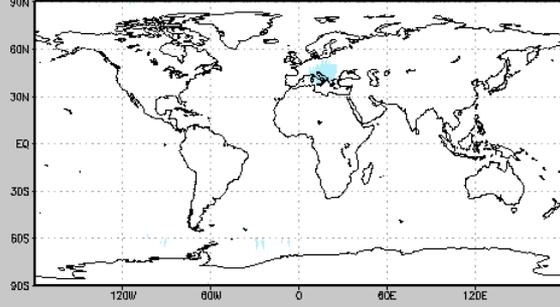
ECMWF (NAD) - GDAS (NAD), 667.018cm⁻¹, All Sky, Sep, 2004

Ascending: bias=-0.22552 rms=0.26192
count=64722 min=-1.75775 max=2.05731



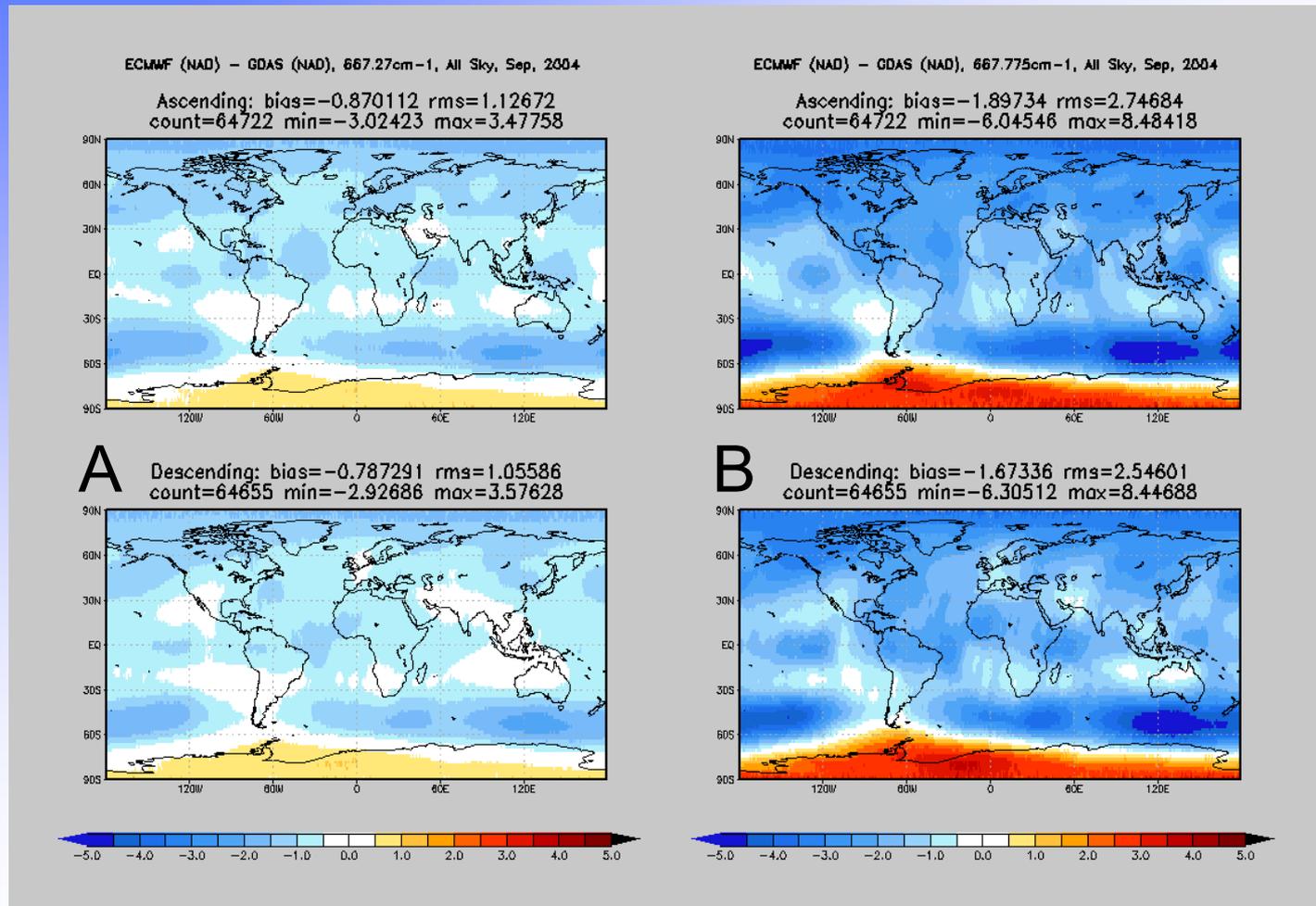
D

Descending: bias=-0.209098 rms=0.256626
count=64655 min=-1.99518 max=1.34569





ECMWF minus GDAS simulated brightness temperatures for A: 667.27 cm⁻¹ (15 mb) and B: 667.775 cm⁻¹ (1.5 mb)



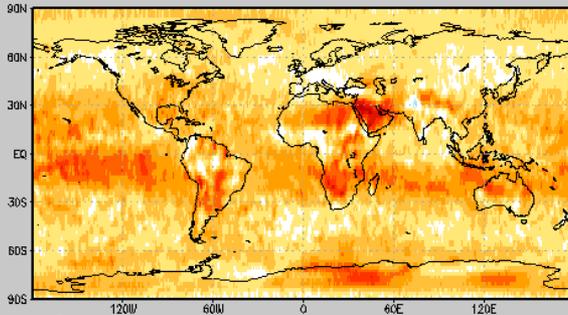
Finally we see large differences at 15 and 1.5 mb



ECMWF minus GDAS simulated brightness temperatures for A: 1519.07 cm⁻¹ (315 mb) and B: 1598.45 cm⁻¹ (490 mb)

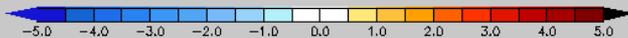
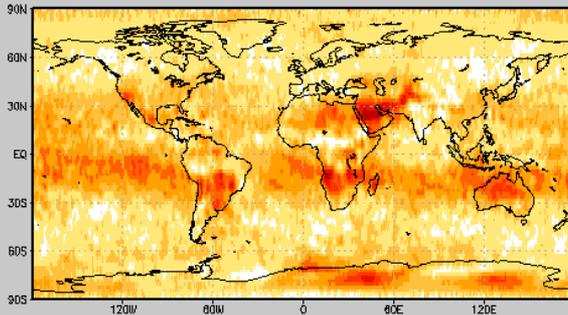
ECMWF (NAD) - GDAS (NAD), 1519.07cm⁻¹, All Sky, Sep, 2004

Ascending: bias=1.2539 rms=1.43501
count=64722 min=-2.85356 max=5.502



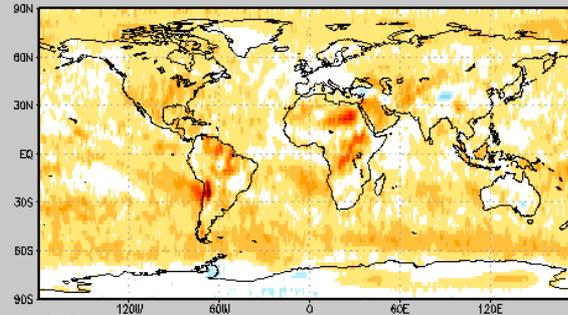
A

Descending: bias=1.20973 rms=1.39601
count=64655 min=-3.51067 max=5.75882



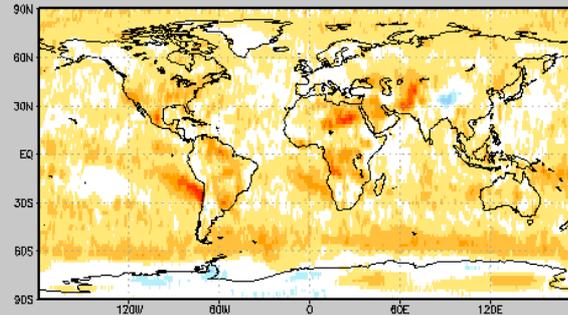
ECMWF (NAD) - GDAS (NAD), 1598.49cm⁻¹, All Sky, Sep, 2004

Ascending: bias=0.76404 rms=0.968526
count=64722 min=-3.15038 max=8.00342



B

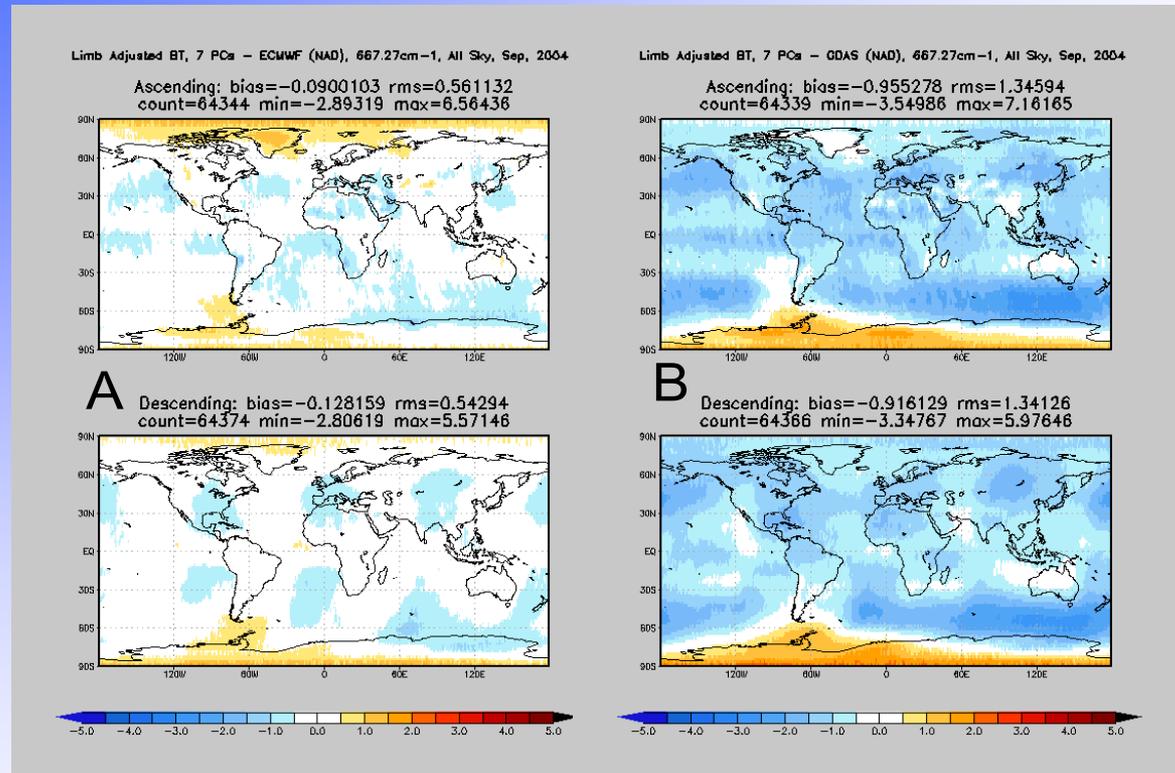
Descending: bias=0.743487 rms=0.949117
count=64655 min=-3.0182 max=4.69273



And large differences in water vapor



We use the SRIR as the Jury



Difference between limb adjusted AIRS
and simulated ECMWF brightness
temperatures (A) and with NCEP (B) for
667.27 cm⁻¹ (15 mb)

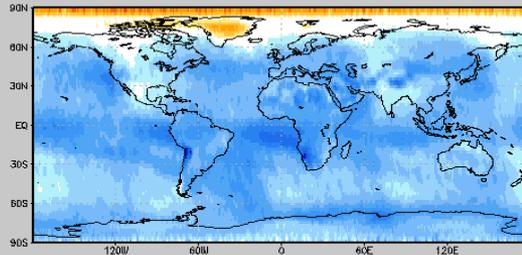
ECMWF agrees with the AIRS SRIR Climate Data Record ,
The difference with ECMWF is nearly zero



We use the SRIR as the Jury

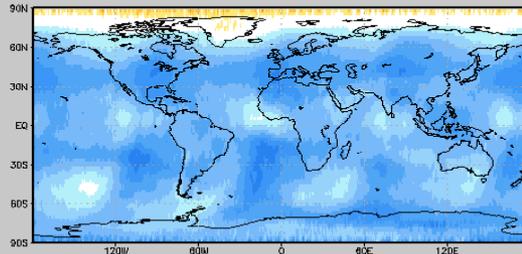
Limb Adjusted BT, 7 PCs - ECMWF (NAD), 667.775cm⁻¹, All Sky, Sep, 2004

Ascending: bias=-1.66927 rms=1.99811
count=64344 min=-8.47488 max=4.86778



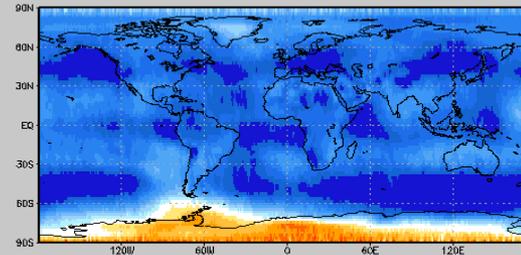
A

Descending: bias=-1.83739 rms=2.0548
count=64374 min=-10.463 max=4.77075



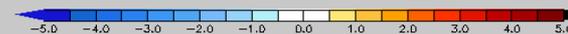
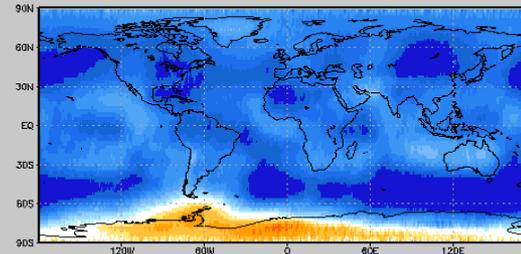
Limb Adjusted BT, 7 PCs - GDAS (NAD), 667.775cm⁻¹, All Sky, Sep, 2004

Ascending: bias=-3.56201 rms=4.06716
count=64339 min=-7.96894 max=7.25009



B

Descending: bias=-3.51311 rms=3.96571
count=64366 min=-7.76561 max=6.00906



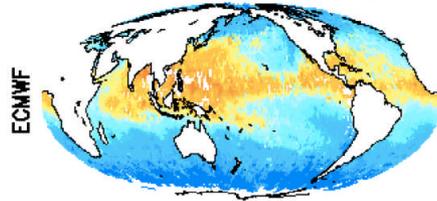
Difference between limb adjusted AIRS
and simulated ECMWF brightness
temperatures (A) and with NCEP (B) for
667.775 cm⁻¹ (1.5 mb)

ECMWF agrees better with the AIRS SRIR Climate Data Record ,
Both model analysis need to improve

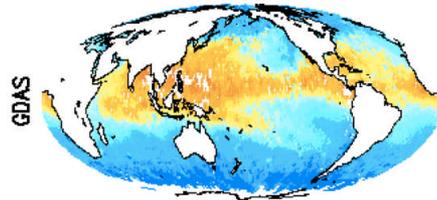


How about water vapor??

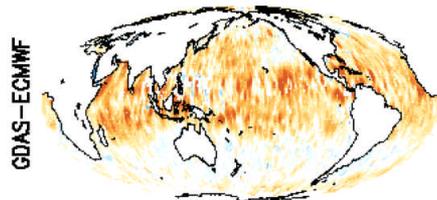
Total Precip Water (mm), Sept. 2003



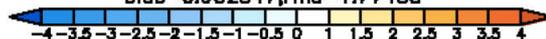
mean=23.2159, stdv=14.4149



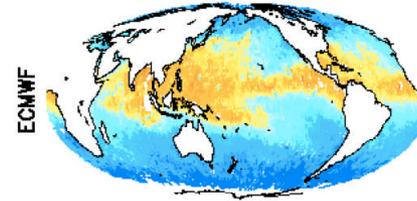
mean=24.1483, stdv=14.8546



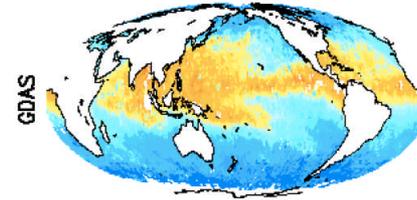
bias=0.932347, rms=1.77488



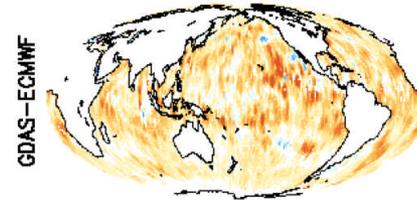
Total Precip Water (mm), Sept. 2004



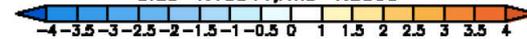
mean=23.2858, stdv=14.1998



mean=24.437, stdv=14.3881



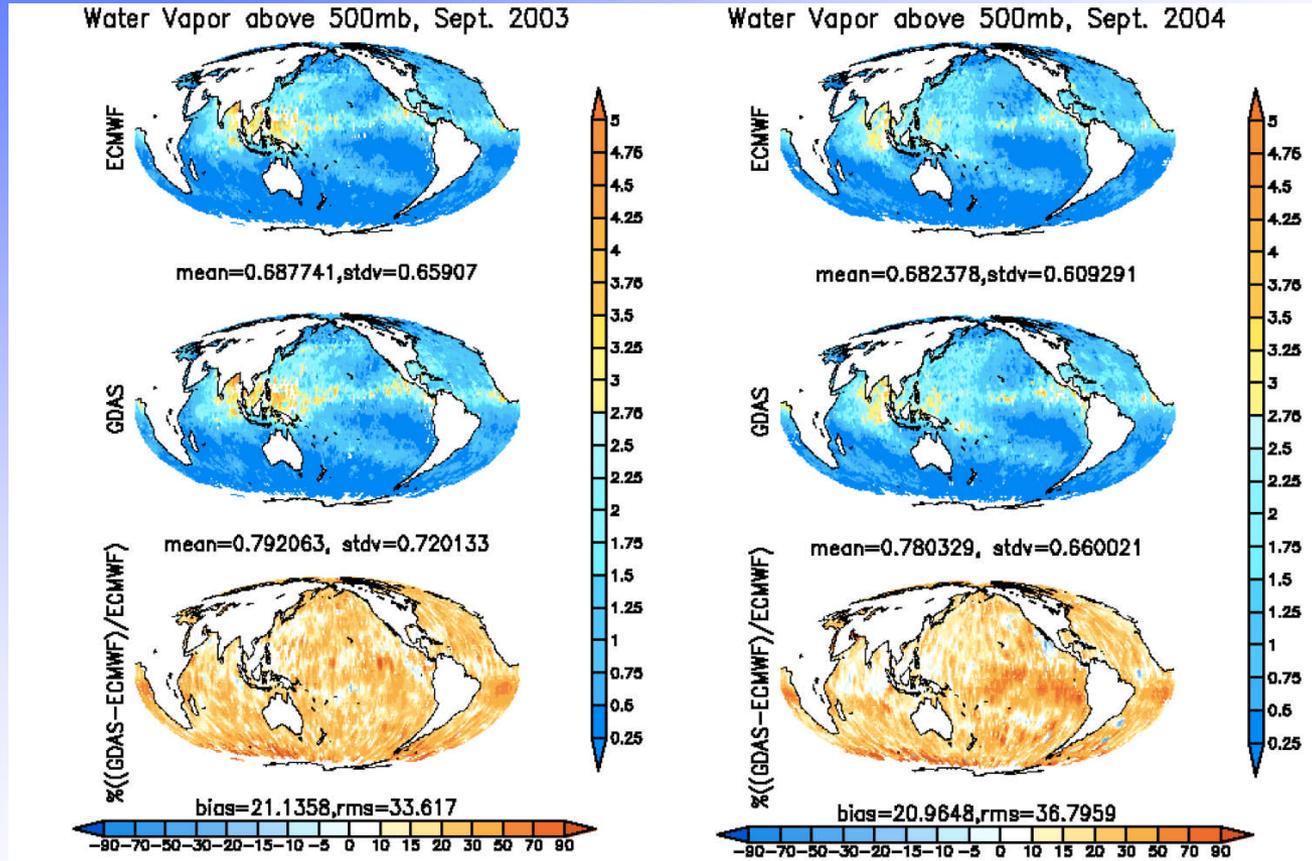
bias=1.13944, rms=1.8063



NCEP water vapor (TPW) is consistently higher



How about water vapor??

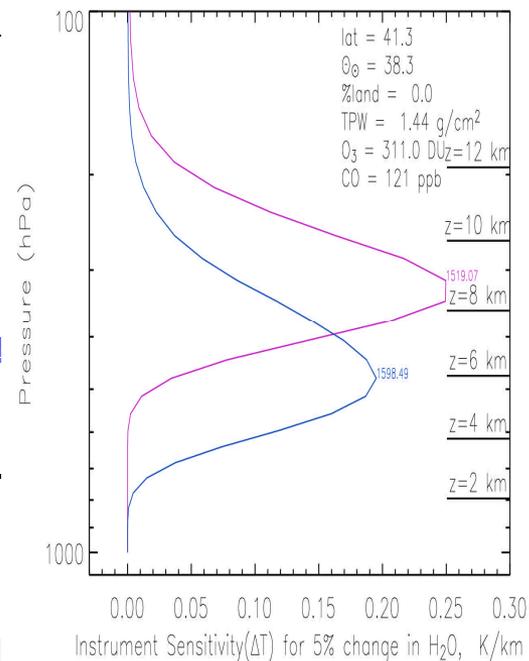
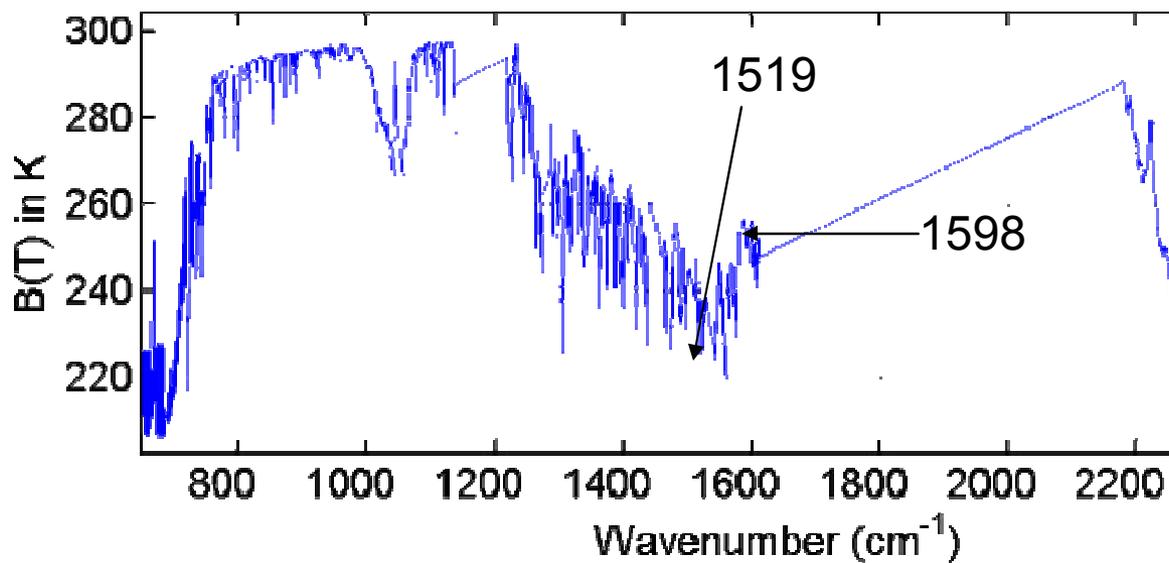


NCEP water vapor above 500 mb (TPW) is consistently higher (20%)



Which water vapor field more accurate?

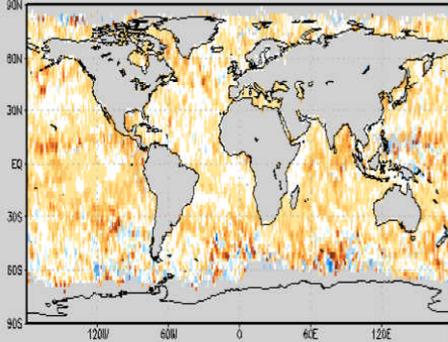
We selected an upper tropospheric water vapor channel (1519 cm^{-1})
and a mid tropospheric water vapor channel (1598 cm^{-1})



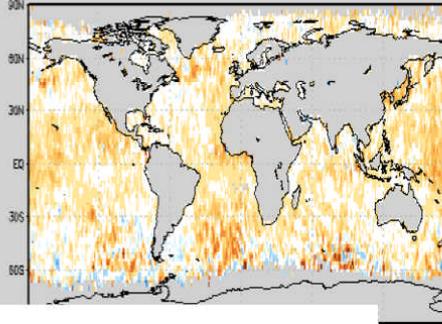


Observed AIRS minus ECMWF Simulated AIRS for Upper Trop. Water Vapor

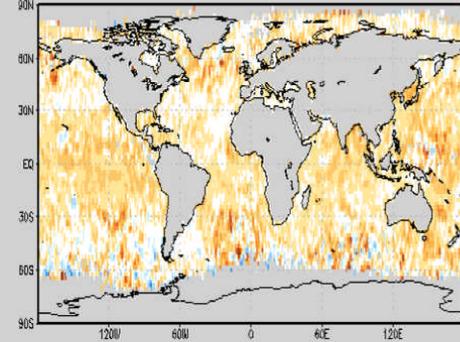
Ascending: bias=0.739526 rms=1.64274
count=33296 min=-16.2292 max=20.2521



Ascending: bias=0.611965 rms=1.39402
count=35245 min=-10.596 max=16.6671

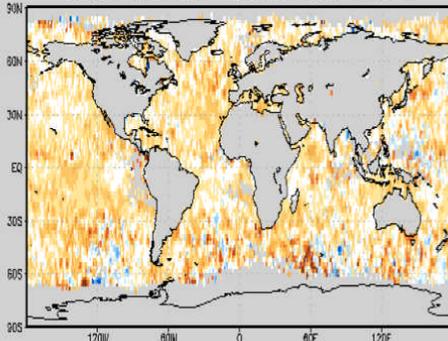


Ascending: bias=0.713495 rms=1.42539
count=34461 min=-14.687 max=15.7027

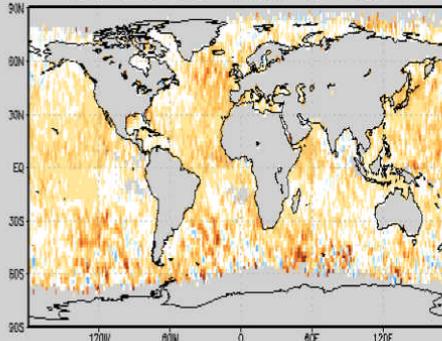


September, 1519.07 cm⁻¹

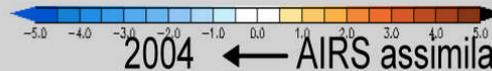
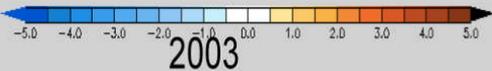
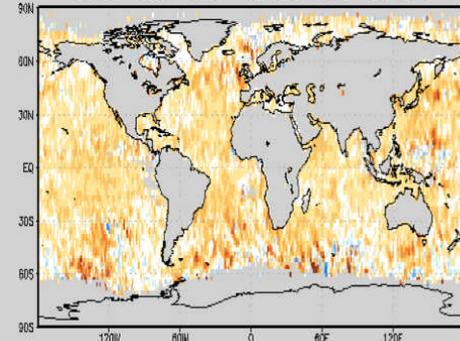
Descending: bias=0.806916 rms=1.68002
count=31107 min=-20.7551 max=17.8908



Descending: bias=0.737426 rms=1.32481
count=33592 min=-12.8482 max=16.5283



Descending: bias=0.816108 rms=1.53891
count=32612 min=-10.2056 max=19.5798



2003

2004

← AIRS assimilated operationally →

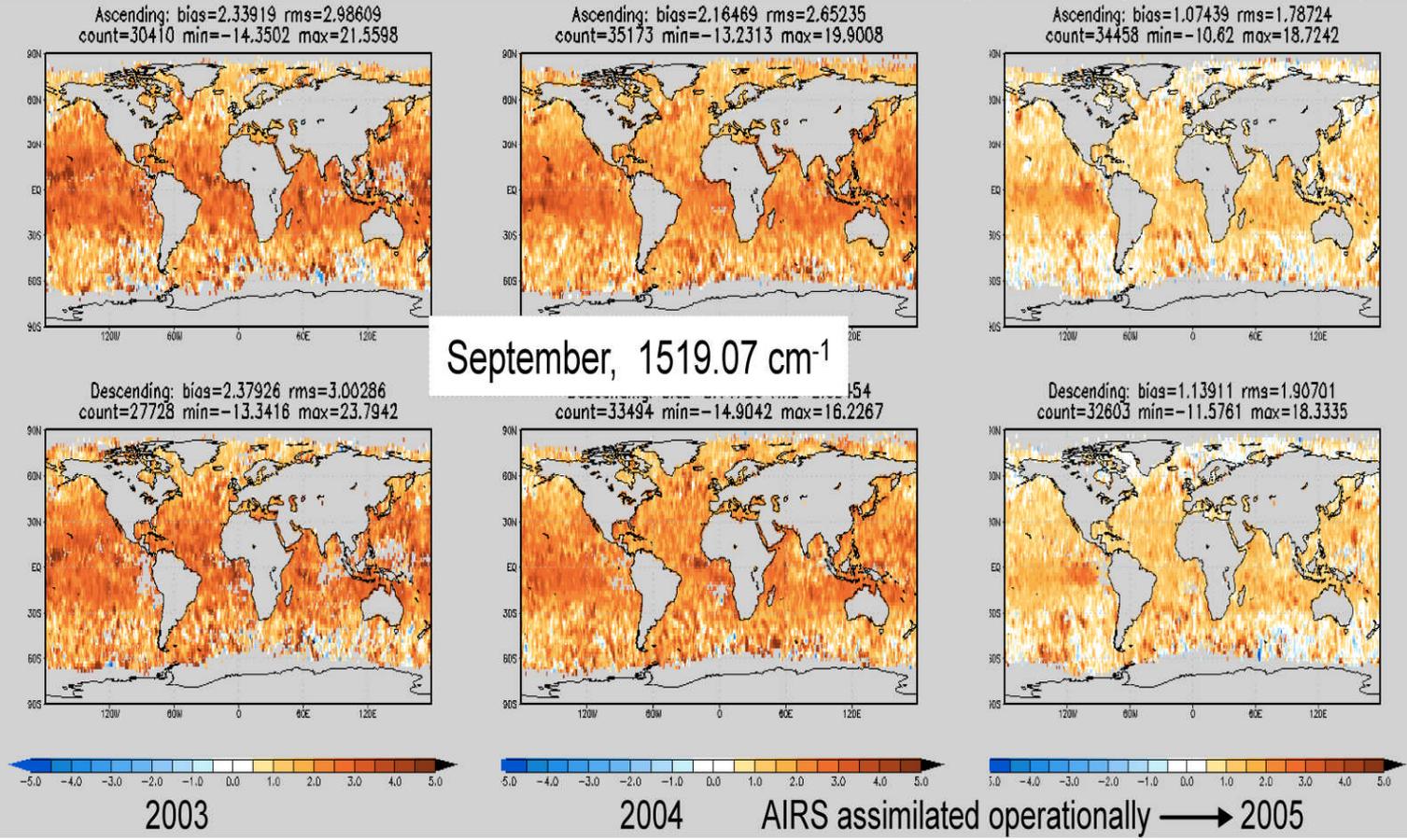
2005

ECMWF bias is about 0.7 K, and seems to be consistent for 2003 – 2005

Note 2004 ECMWF assimilated AIRS



Observed AIRS minus NCEP Simulated AIRS for Upper Trop. Water Vapor

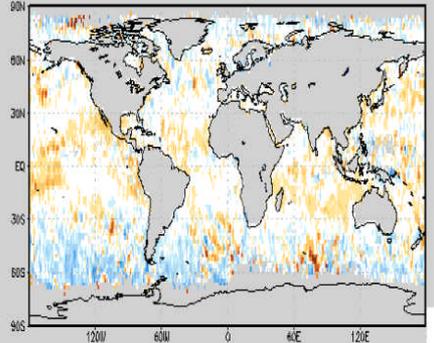


NCEP bias is 3 times larger but reduces by half after AIRS is assimilated.

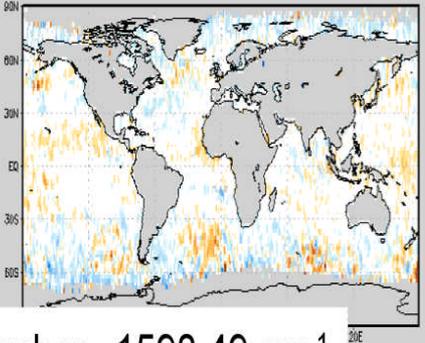


Observed AIRS minus ECMWF Simulated AIRS for Mid. Trop. Water Vapor

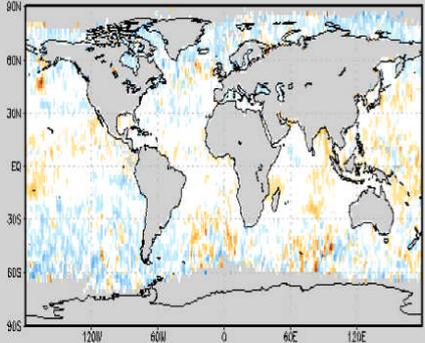
Ascending: bias=0.0775871 rms=1.36024
count=33296 min=-11.4684 max=15.5337



Ascending: bias=-0.00965988 rms=1.12849
count=35245 min=-10.0071 max=16.4171

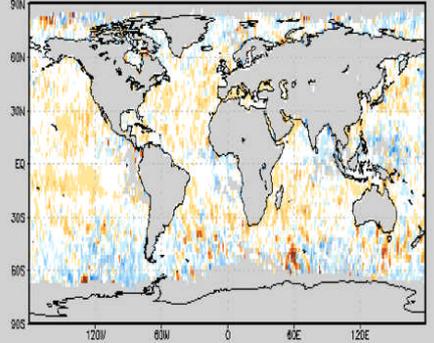


Ascending: bias=-0.0989282 rms=1.14666
count=34461 min=-12.2345 max=14.0103

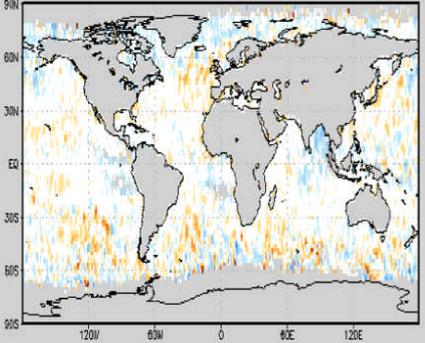


September, 1598.49 cm⁻¹

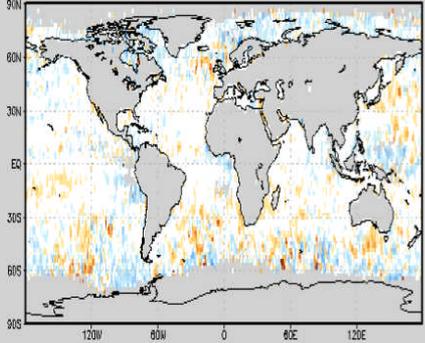
Descending: bias=0.134889 rms=1.37997
count=31107 min=-11.1455 max=12.9063



Descending: bias=0.0262021 rms=1.18533
count=33592 min=-11.5689 max=13.0889



Descending: bias=-0.0133827 rms=1.19657
count=32612 min=-9.85136 max=13.8735

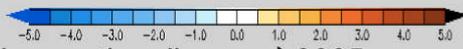


2003



2004

← AIRS assimilated operationally →



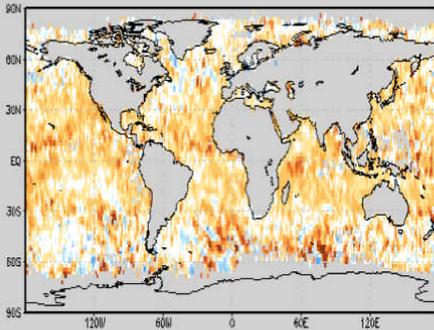
2005

ECMWF bias is nearly zero !!!

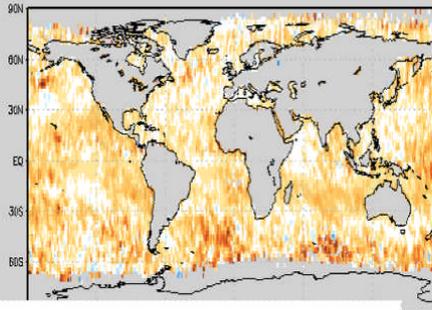


Observed AIRS minus NCEP Simulated AIRS for Mid. Trop. Water Vap or

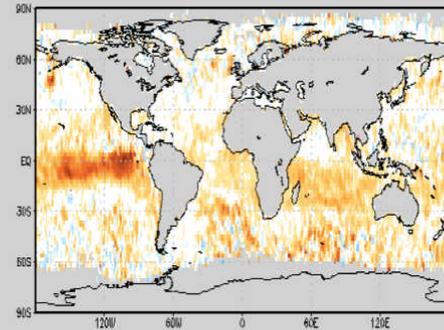
Ascending: bias=0.878548 rms=1.809
count=30410 min=-12.9485 max=18.2543



Ascending: bias=0.89881 rms=1.57801
count=35173 min=-8.46484 max=16.6099

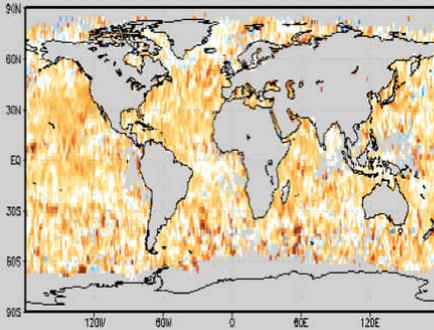


Ascending: bias=0.572103 rms=1.41223
count=34458 min=-9.91933 max=14.0816

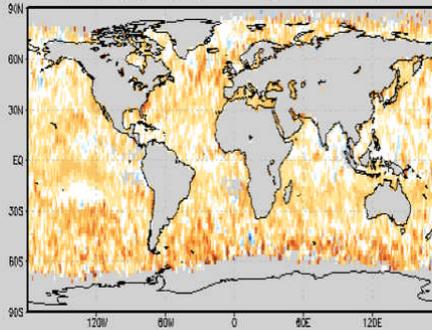


September, 1598.49 cm⁻¹

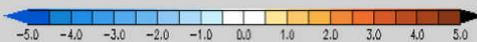
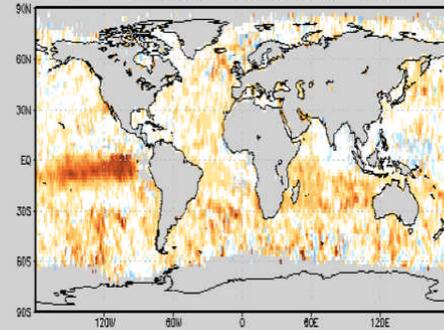
Descending: bias=0.935697 rms=1.8164
count=27728 min=-11.1691 max=16.7782



Descending: bias=0.628501 rms=1.5489
count=32603 min=-8.68994 max=17.4972



Descending: bias=0.628501 rms=1.5489
count=32603 min=-8.68994 max=17.4972

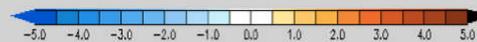


2003



2004

AIRS assimilated operationally → 2005

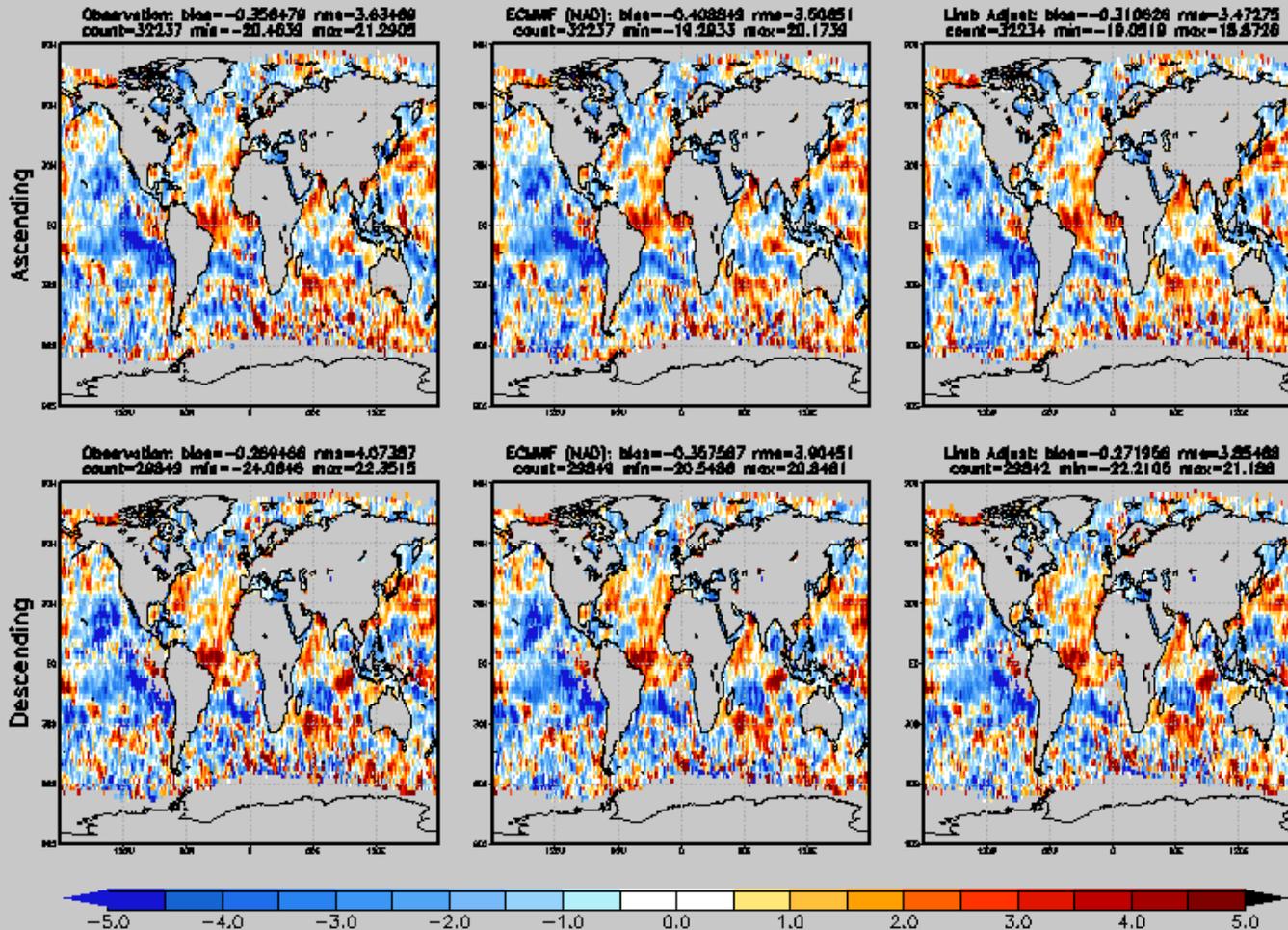


NCEP bias is relatively much larger, reduces after AIRS is assimilated, but large bias over equatorial eastern Pacific



Interannual difference - EC

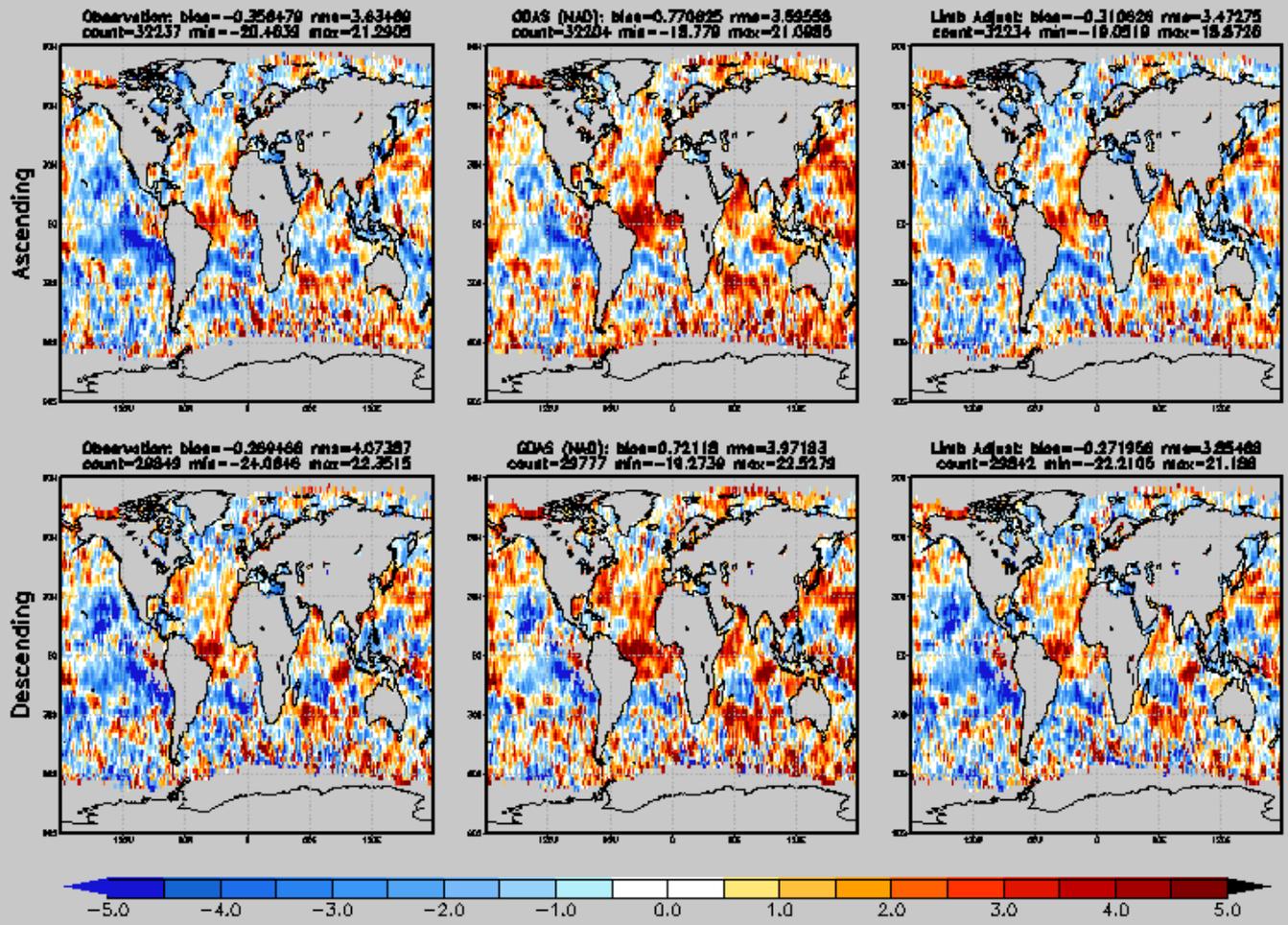
BT Monthly different, 1519.07cm-1, Clear Sky, No Score, 7 PCs, Sep2005-Sep2004





Interannual differences - NCEP

BT Monthly different, 1519.07cm-1, Clear Sky, No Score, 7 PCs, Sep2005-Sep2004





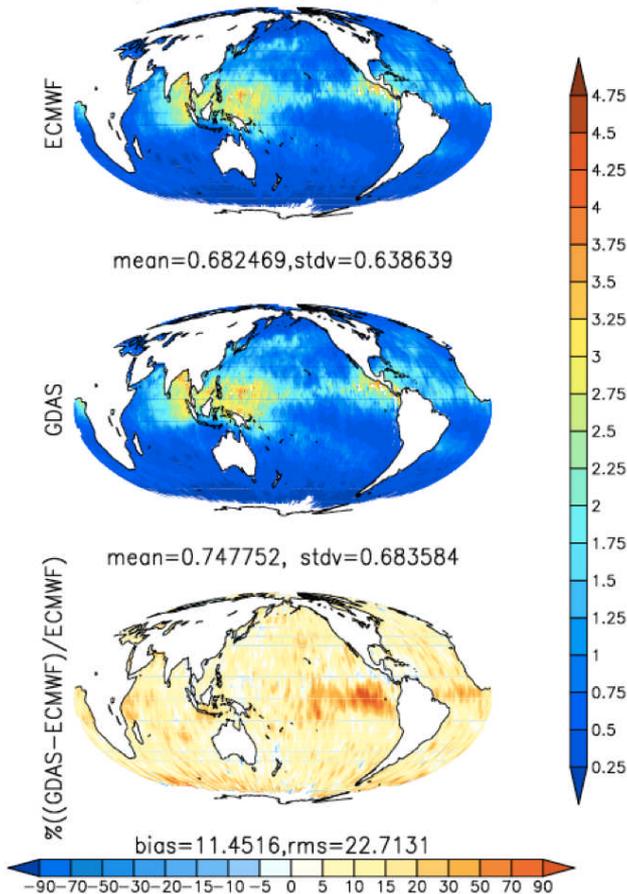
Jury declares ECMWF water vapor more accurate

- But
- Operational change in ECMWF in Sept. 2006 caused an increase in the bias. (e.g. adaptive bias tuning)
- NCEP above 500 mb TPW in 2003 and 2004 was 20% higher, then in 2005 just 11% higher because NCEP assimilated AIRS, and in 2006 the difference is close to 0% because of a change in the ECMWF water vapor field.

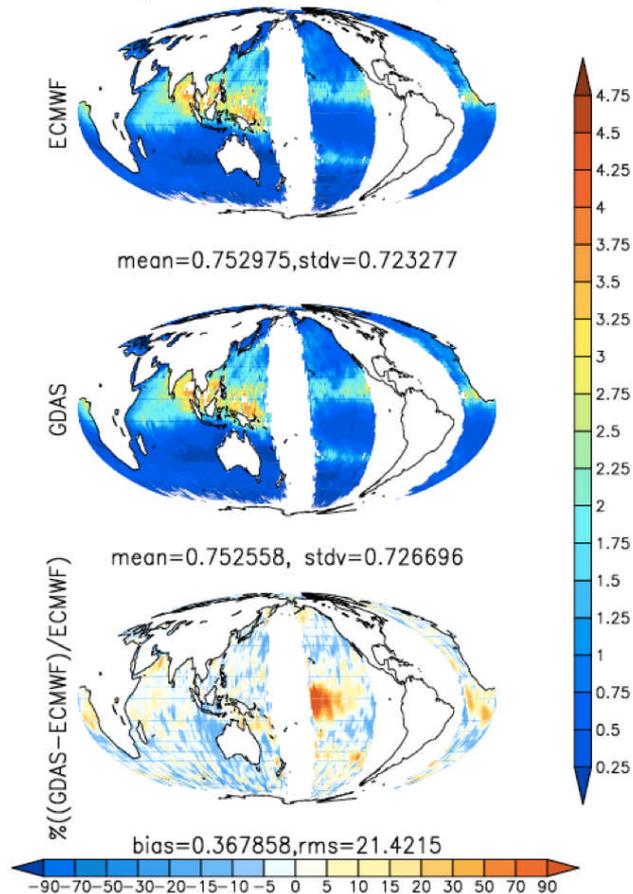


Note ECMWF TPW above 500 mb in 2006 is now similar with NCEP

Water Vapor above 500mb, Sept. 2005

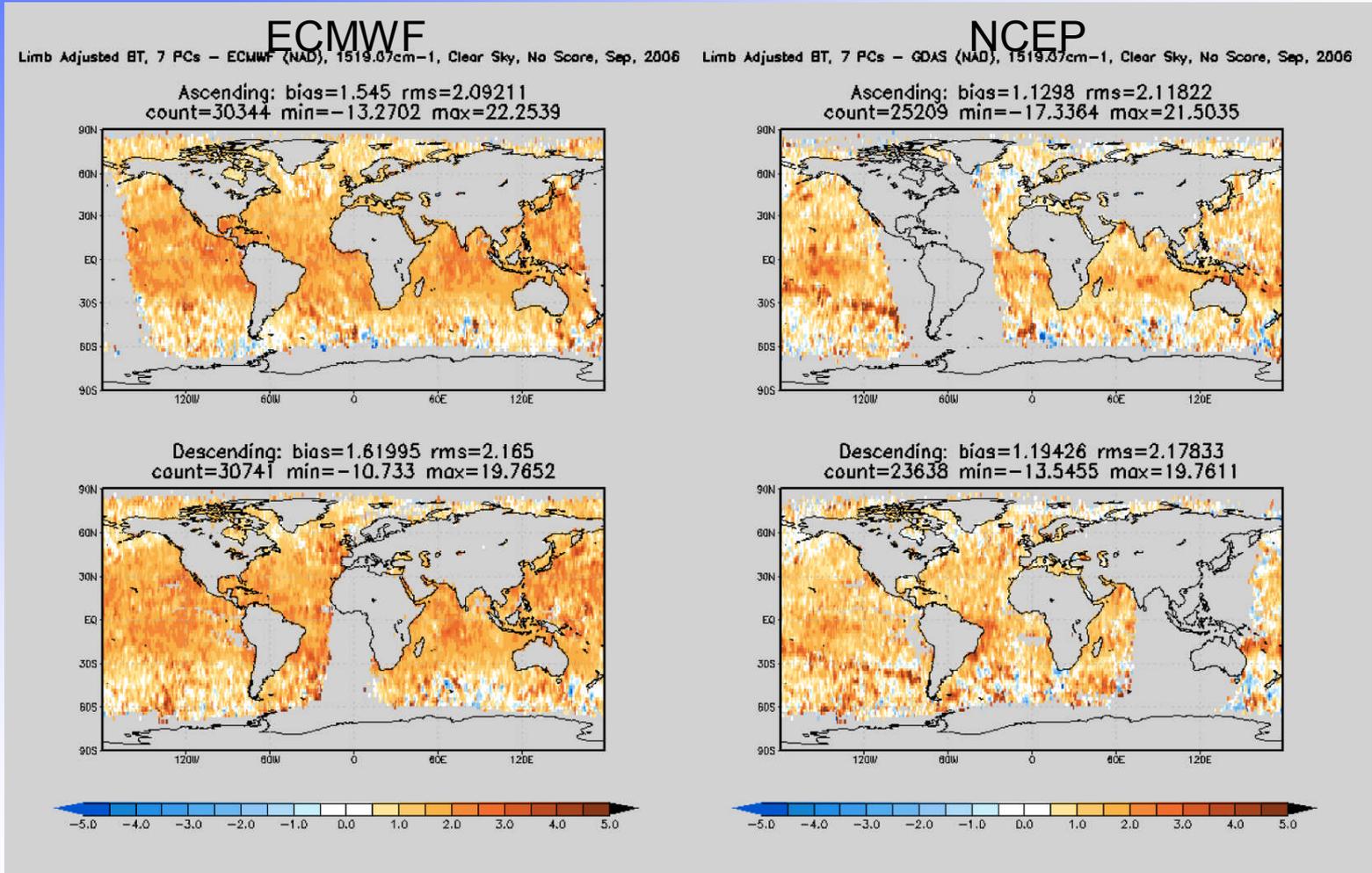


Water Vapor above 500mb, Sept. 2006





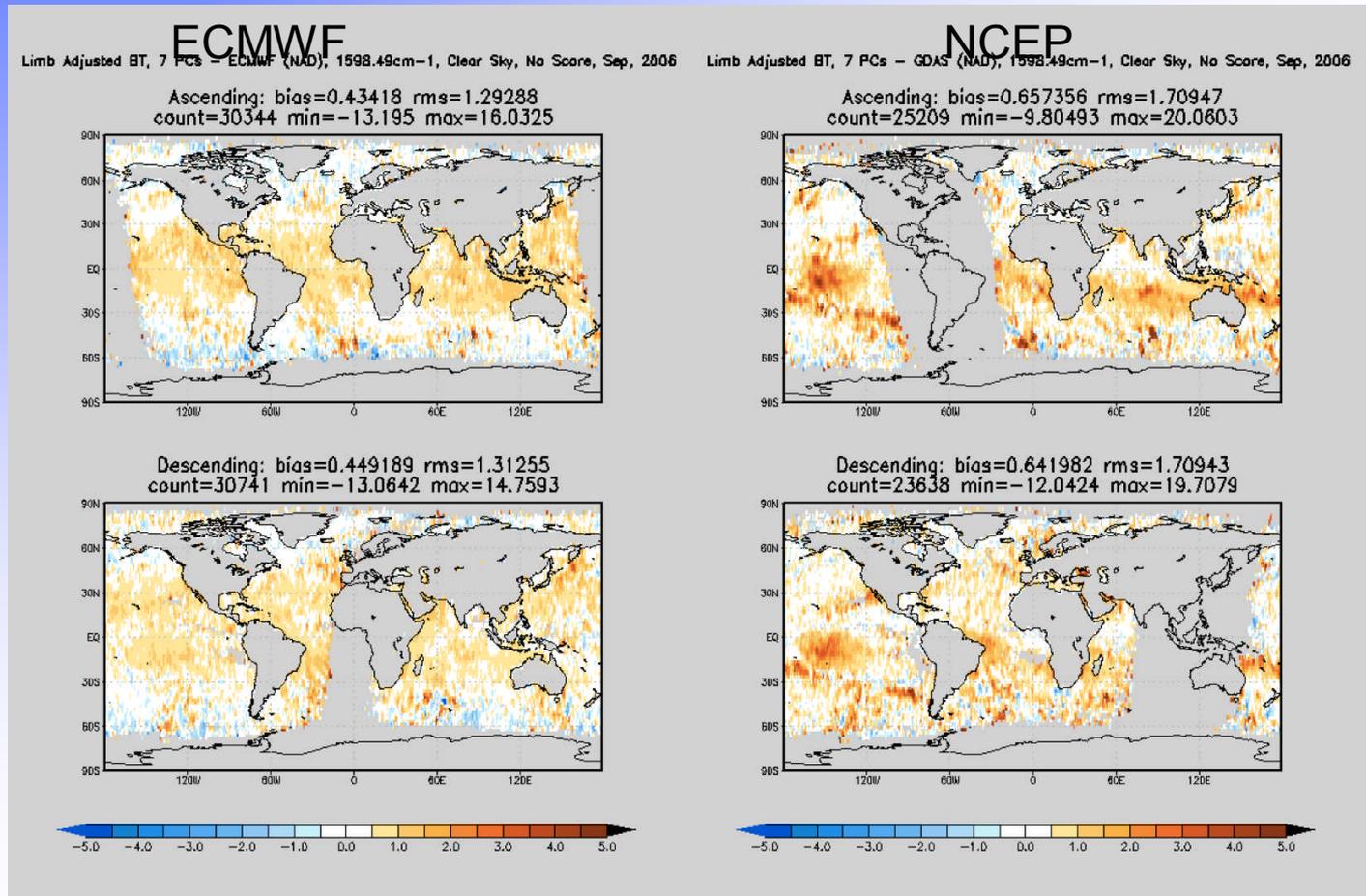
Upper Tropospheric Water Vapor Channel



ECMWF bias is now larger than NCEP!!! (increased by ~0.8 K)



Mid Tropospheric Water Vapor Channel



ECMWF bias is nearing NCEP

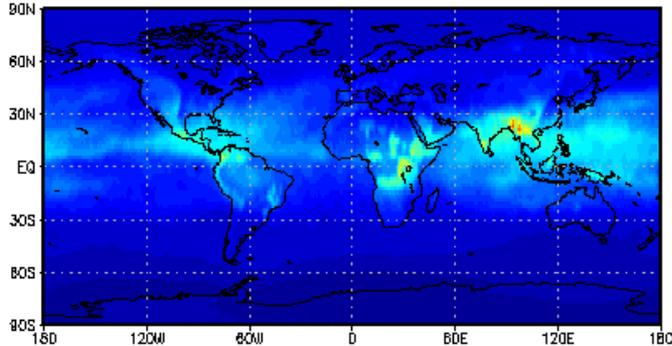


So what is the cause??

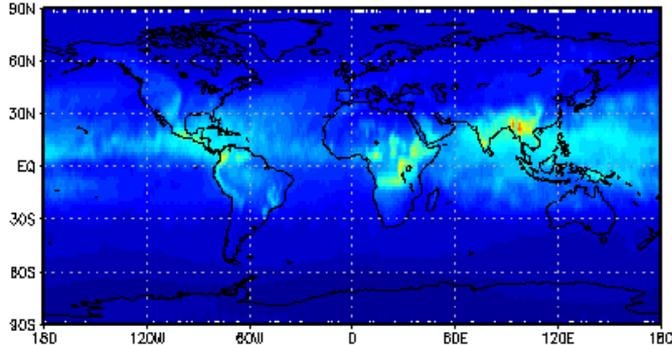
We found the water vapor (TPW) above 200 mb is nearly twice as large
(this is consistent for 2006, 2007, 2008)

Precip Water (above 200MB), ECMWF, Sep. 2005

Ascending: mean=0.00689914 std=0.00409231
count=64812 min=0.00229686 max=0.0422541



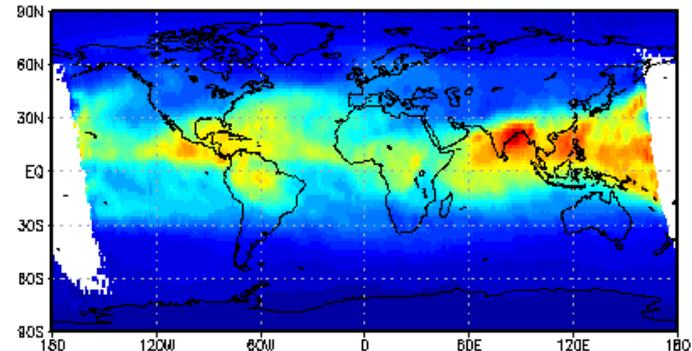
Descending: mean=0.00698395 std=0.00414626
count=63308 min=0.00215838 max=0.0384316



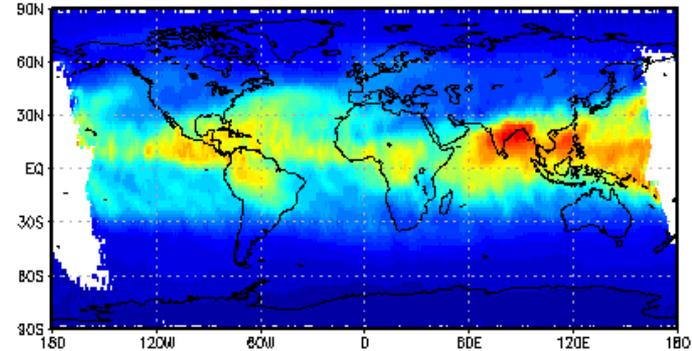
0.002 0.006 0.009 0.013 0.018 0.020 0.024 0.027 0.031 0.034 0.038 0.041

Precip Water (above 200MB), ECMWF, Sep. 2006

Ascending: mean=0.0103912 std=0.00666976
count=60533 min=0.00268439 max=0.0367425



Descending: mean=0.010538 std=0.0067149
count=58623 min=0.00261917 max=0.0359632



0.003 0.006 0.009 0.012 0.015 0.018 0.021 0.024 0.027 0.030 0.033 0.036

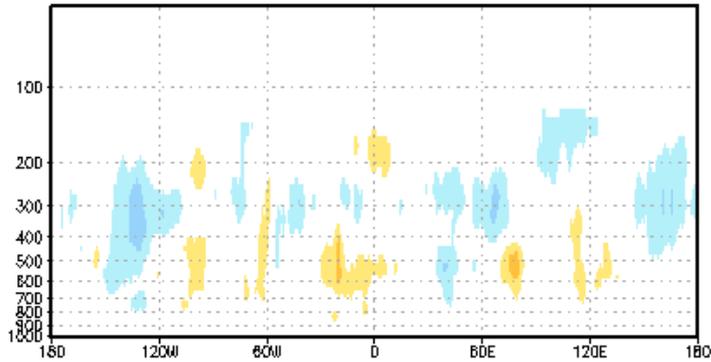


Compare Annual Difference (%) of ECMWF using 2005 as Base Year

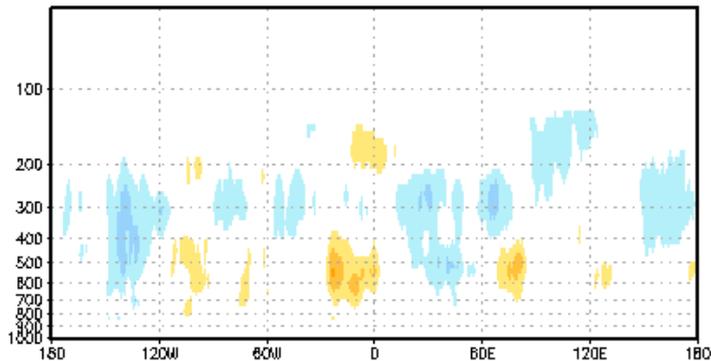
Very small year to year differences (2003 – 2005, 2004 – 2005)

Water Vapor Cross-Section, ECMWF, (2003-2005)/2005 (%)

Ascending: mean=-1.69638 std=6.69409
count=46208 min=-30.6876 max=27.7328



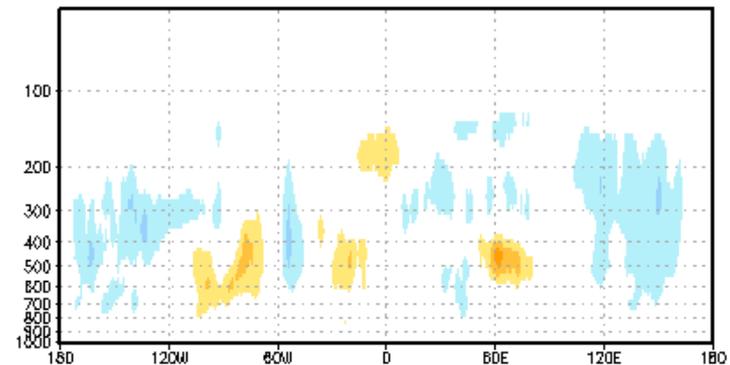
Descending: mean=-1.81166 std=7.04918
count=46208 min=-25.4245 max=33.1656



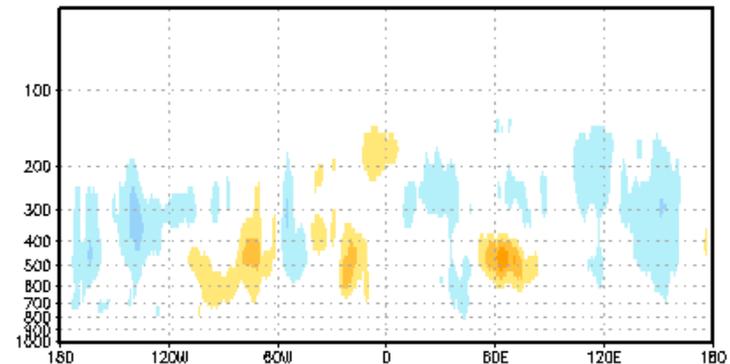
2003

Water Vapor Cross-Section, ECMWF, (2004-2005)/2005 (%)

Ascending: mean=-1.92665 std=7.30636
count=46208 min=-25.3074 max=38.101



Descending: mean=-1.47719 std=7.45873
count=46208 min=-25.0952 max=41.1136



2004

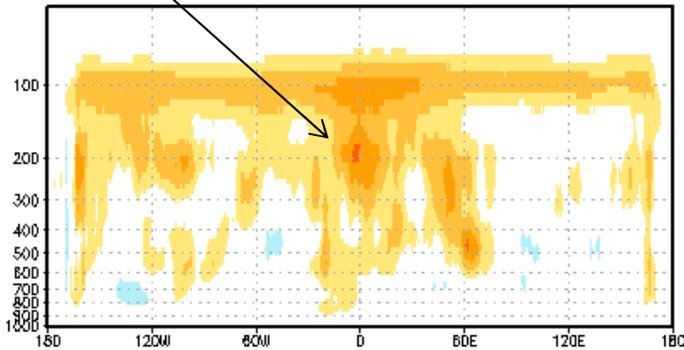


Compare Annual Difference (%) of ECMWF using 2005 as Base Year

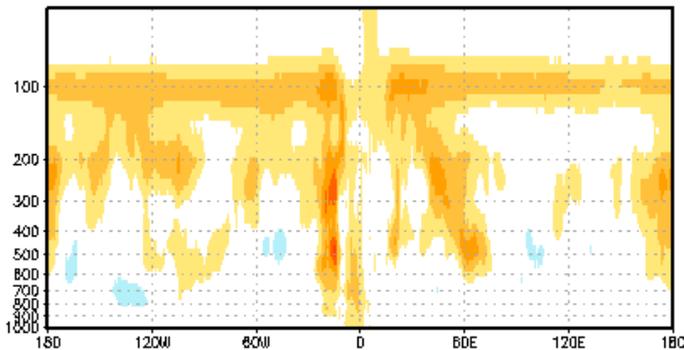
More water from previous years, difference with 2005 is now much larger

Water Vapor Cross-Section, ECMWF, (2006-2005)/2005 (%)

Ascending: mean=7.06542 std=10.6581
count=46208 min=-23.9533 max=44.2831



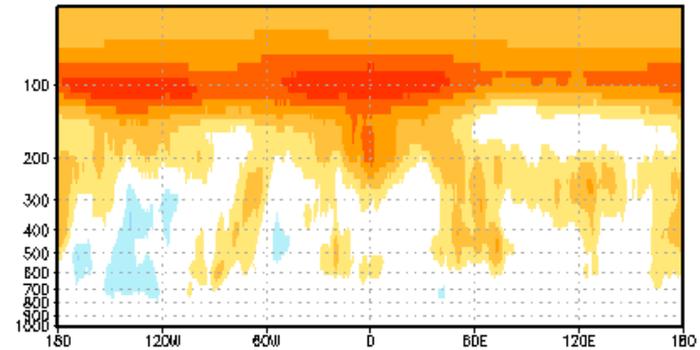
Descending: mean=7.1877 std=10.6747
count=46208 min=-20.3207 max=55.8853



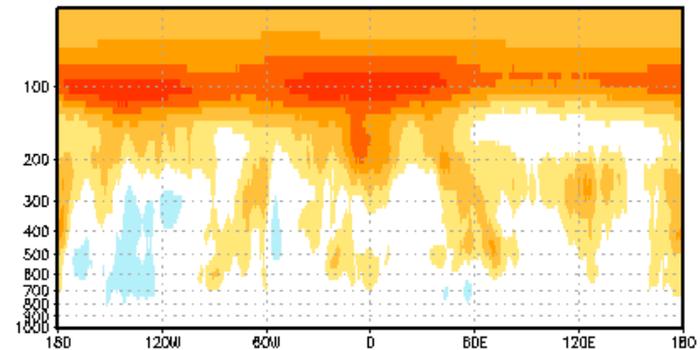
2006

Water Vapor Cross-Section, ECMWF, (2007-2005)/2005 (%)

Ascending: mean=12.7902 std=16.0639
count=46208 min=-21.4512 max=59.8314



Descending: mean=12.5862 std=16.1389
count=46208 min=-19.6088 max=58.9336



2007

(2008 ~ 2007)



		2003	2004	2005	2006
a	ECMWF TPW	23.22 mm	23.29	22.70	22.34
b	NCEP TPW	24.15 mm	24.44	24.02	24.01
c	NCEP - ECMWF	0.93 mm	1.14	1.32	1.67
d	ECMWF PW above 500mb	0.69 mm	0.68	0.68	0.75
e	NCEP PW above 500 mb	0.79 mm	0.78	0.75	0.75
f	NCEP - ECMWF	21.14%	20.96%	11.45%	0.37%
g	ECMWF 1519cm ⁻¹	0.73 K	0.61	0.71	1.55
h	NCEP 1519cm ⁻¹	2.34 K	2.16	1.06	1.13
i	NCEP - ECMWF*	-1.61 K	-1.55	-0.35	0.42
j	ECWMF 1598cm ⁻¹	0.10 K	-0.01	-0.10	0.43
k	NCEP 1598cm ⁻¹	0.86 K	0.90	0.56	0.65
l	NCEP - ECMWF*	-0.76 K	-0.91	-0.66	-0.22
m	SUM OF DIFF*	-2.37 K	-2.46	-1.01	0.20



September 2008 AIRS – EC bias remains consistent with 2006

Upper trop water vapor

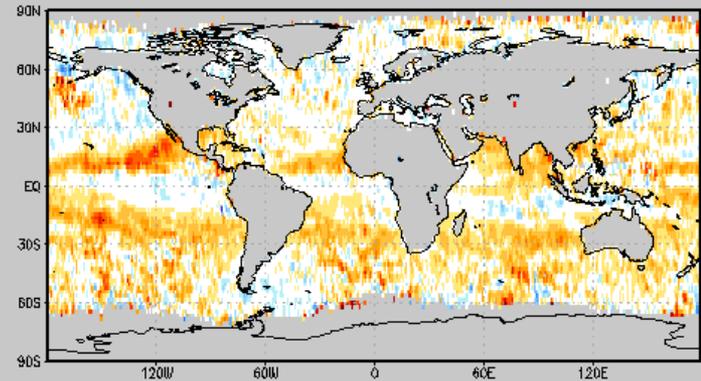
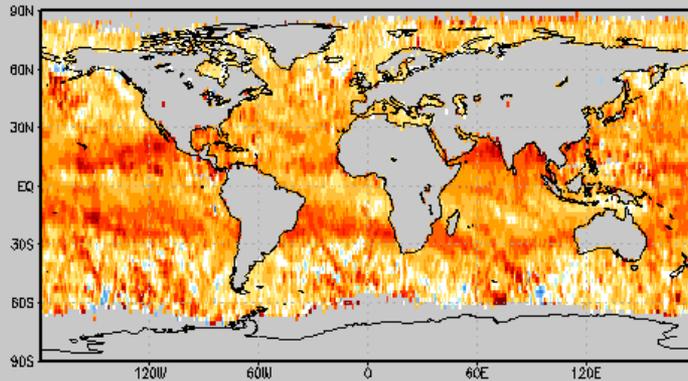
mid trop water vapor channel

Limb Adjusted BT, 7 PCs – ECMWF (NAD), 1519.07cm⁻¹, Clear Sky, SST Only, Sep, 2008

Limb Adjusted BT, 7 PCs – ECMWF (NAD), 1598.49cm⁻¹, Clear Sky, SST Only, Sep, 2008

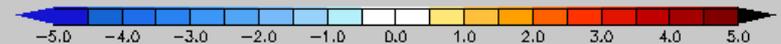
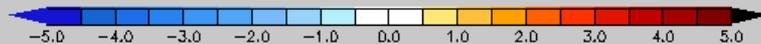
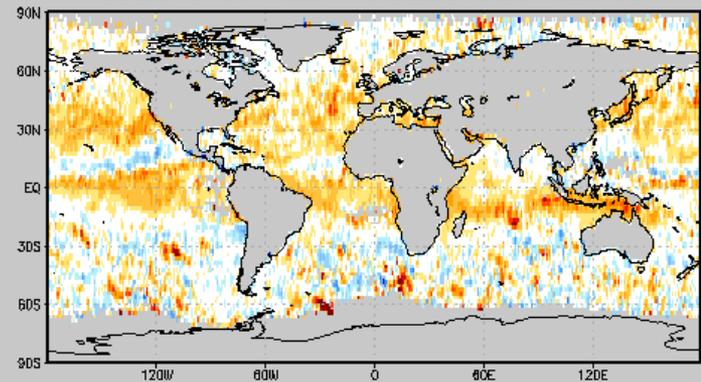
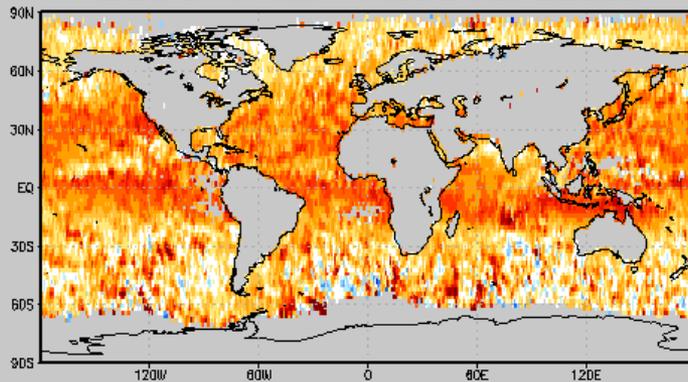
Ascending: bias=1.58327 rms=2.21479
count=38422 min=-17.2329 max=19.0339

Ascending: bias=0.512161 rms=1.51725
count=38422 min=-13.0998 max=13.3609



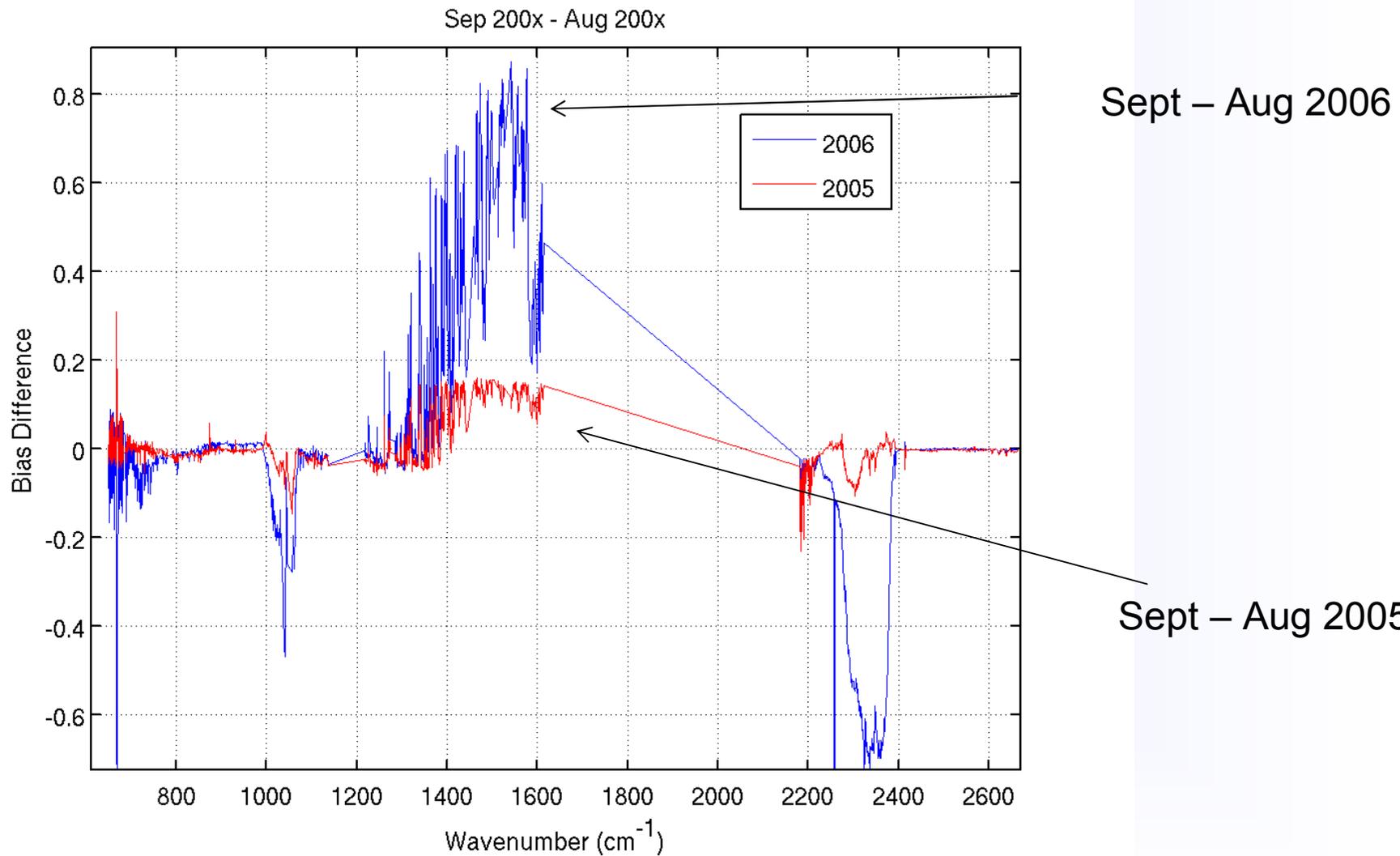
Descending: bias=1.58977 rms=2.39864
count=34417 min=-17.9672 max=20.3508

Descending: bias=0.407457 rms=1.64683
count=34417 min=-14.3076 max=16.5478





Our results agree with findings from Larrabee Strow (UMBC) using small datasets of collocated super clear AIRS and ECMWF data



ECMWF added adaptive bias tuning on Sept 12, 2006



Sept. 2006 Changes

- 12 September 2006 Introduction of Cycle 31r1. This version includes the following changes:
- Revisions to the cloud scheme, including treatment of ice supersaturation and new numerics
- Implicit computation of convective transports
- Introduction of turbulent orographic form drag scheme and revision to sub-grid scale orographic drag scheme
- Gust fix for orography and stochastic physics
- Reduction of ocean surface relative humidity from 100% to 98% (due to salinity effects)
- Revised assimilation of rain-affected radiances
- **Variational bias correction of satellite radiances**
- Thinning of low level AMDAR data (mainly affects Japanese AMDAR network)



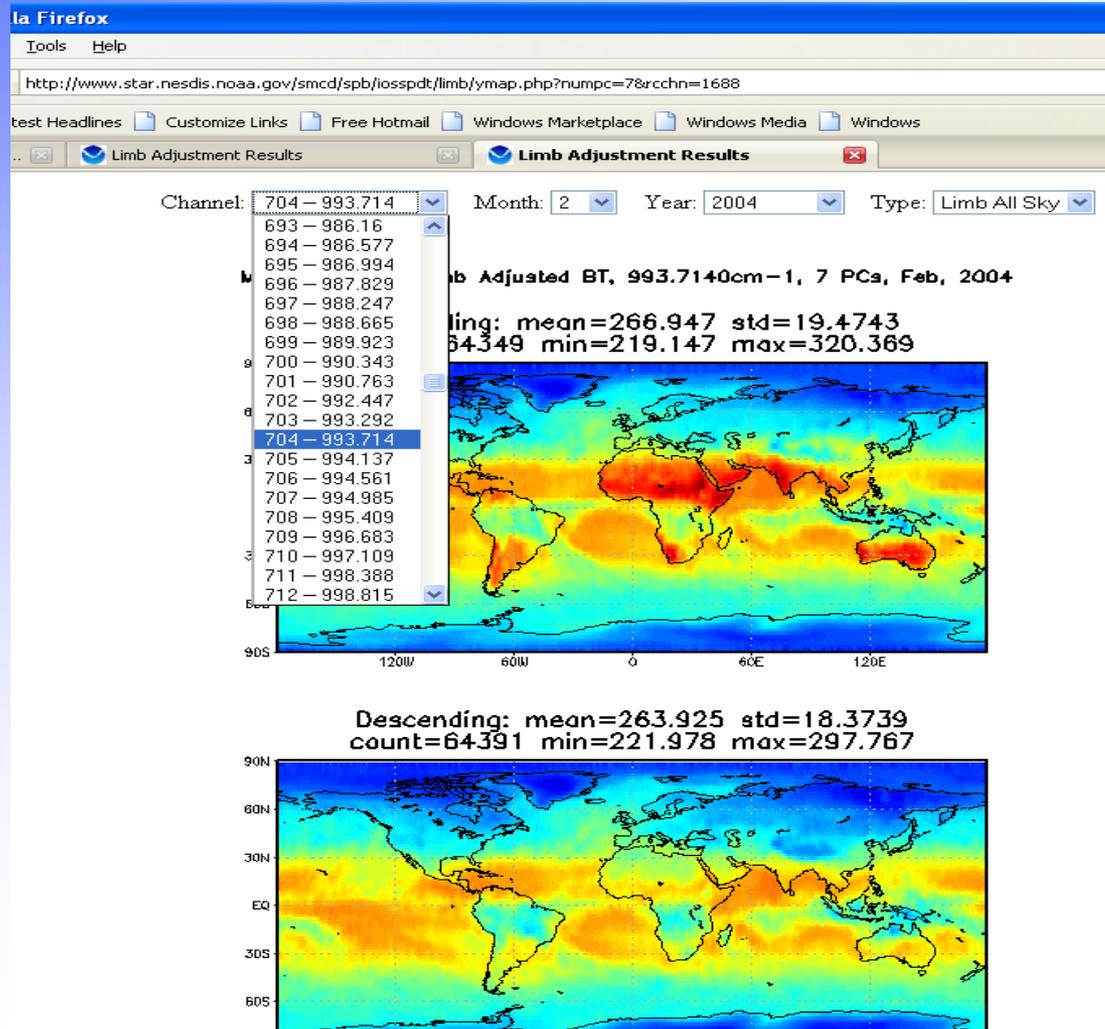
Summary

- Developed a SRIR radiance CDR
- The CDR consists of daily/monthly brightness temperatures for all AIRS channels
 - Ascending (day), clear sky
 - Ascending, all sky
 - Descending (night), clear sky
 - Descending, all sky datasets



Summary

Datasets have been generated for 5 years data from January 2003:





Summary

- First major step towards developing a much longer record of thermal infrared radiances at high spectral resolution and high spatial global coverage to:
 - Monitor climate change
 - Assess the accuracy and realism of weather and climate analyses and forecasts.



Contribution

- Fundamental dataset for independent and very accurate validation of model reanalyses and climate projections, and for monitoring climate change.
- Climatology will be extended to include IASI and CrIS.