Validation of AIRS Spatial Trends of Temperature, OLR, and Cloud Cover

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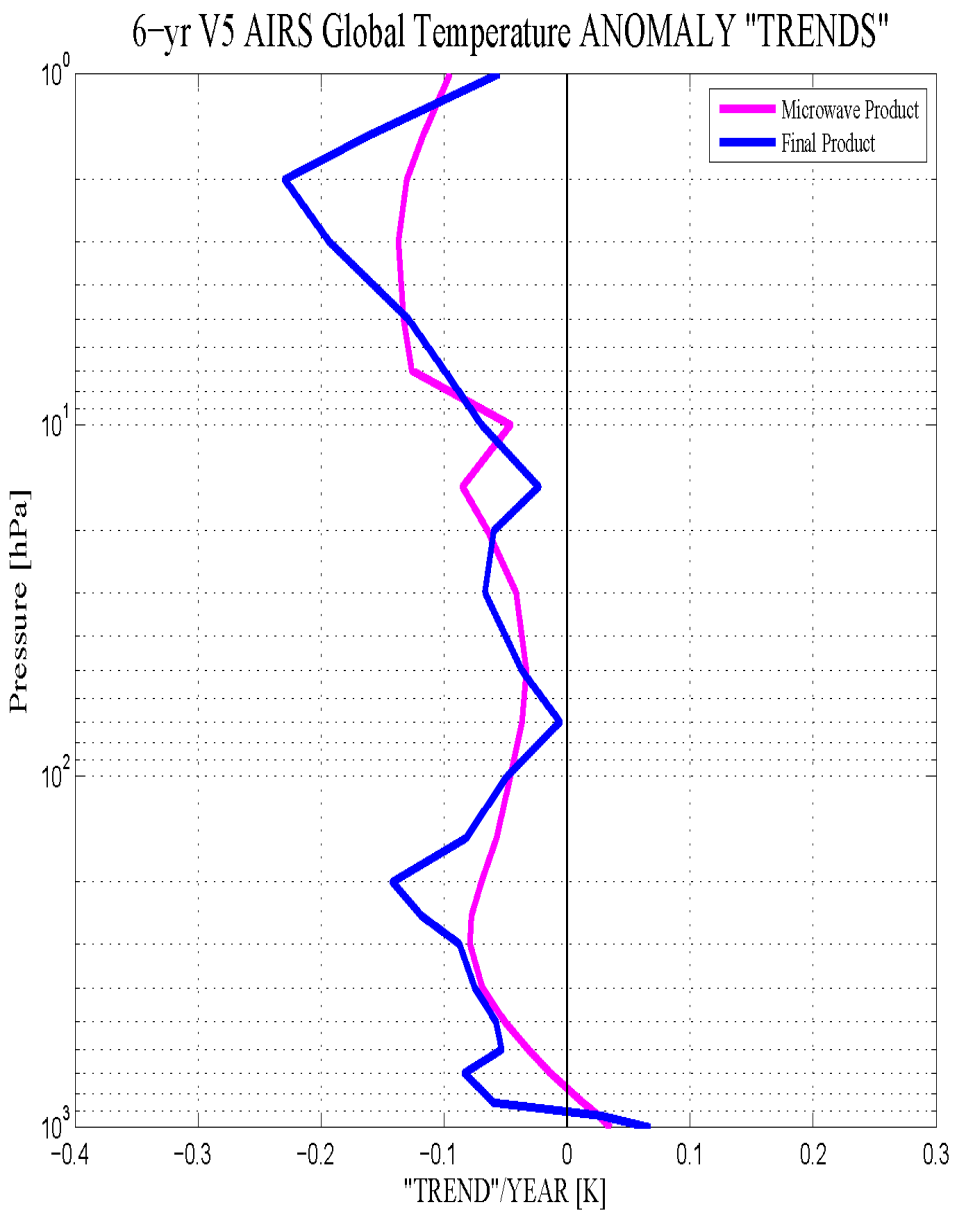
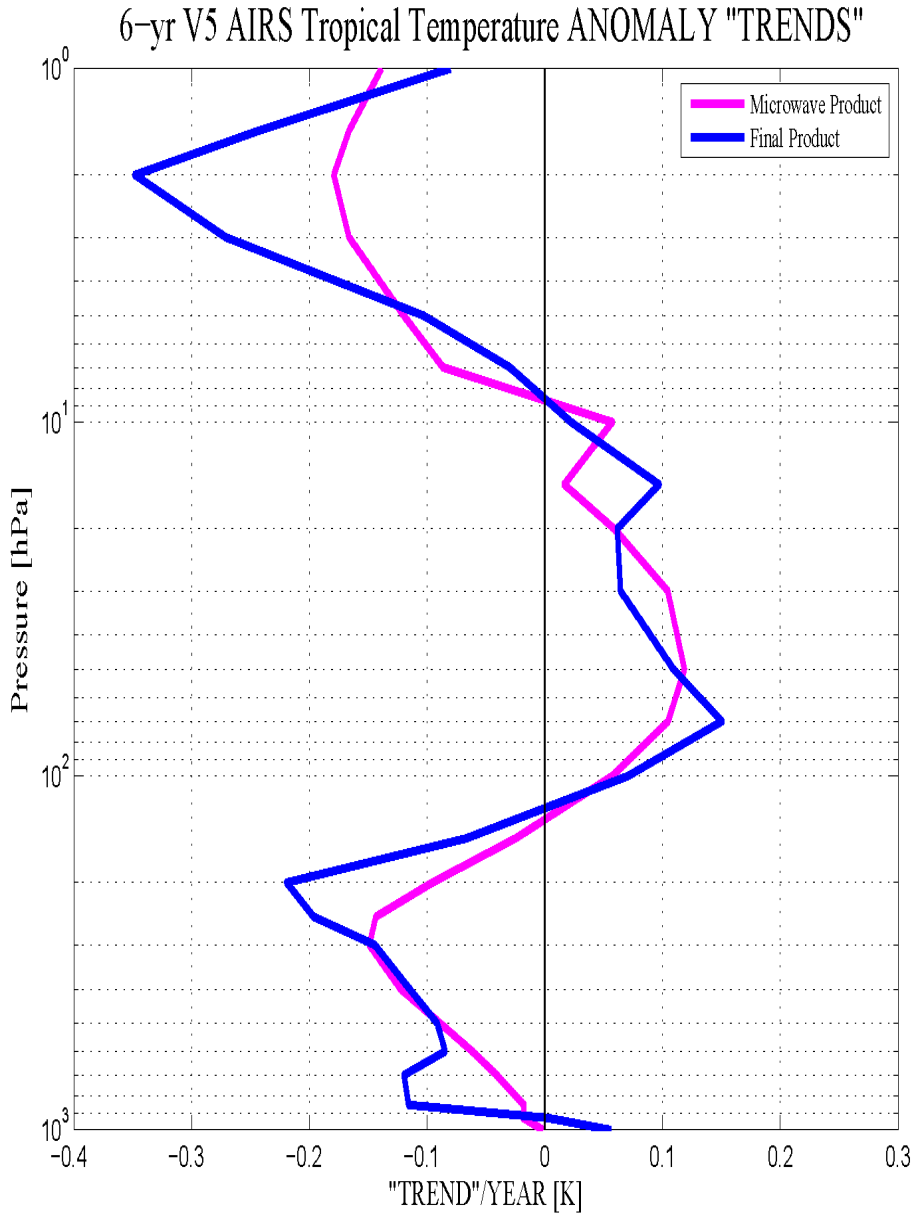
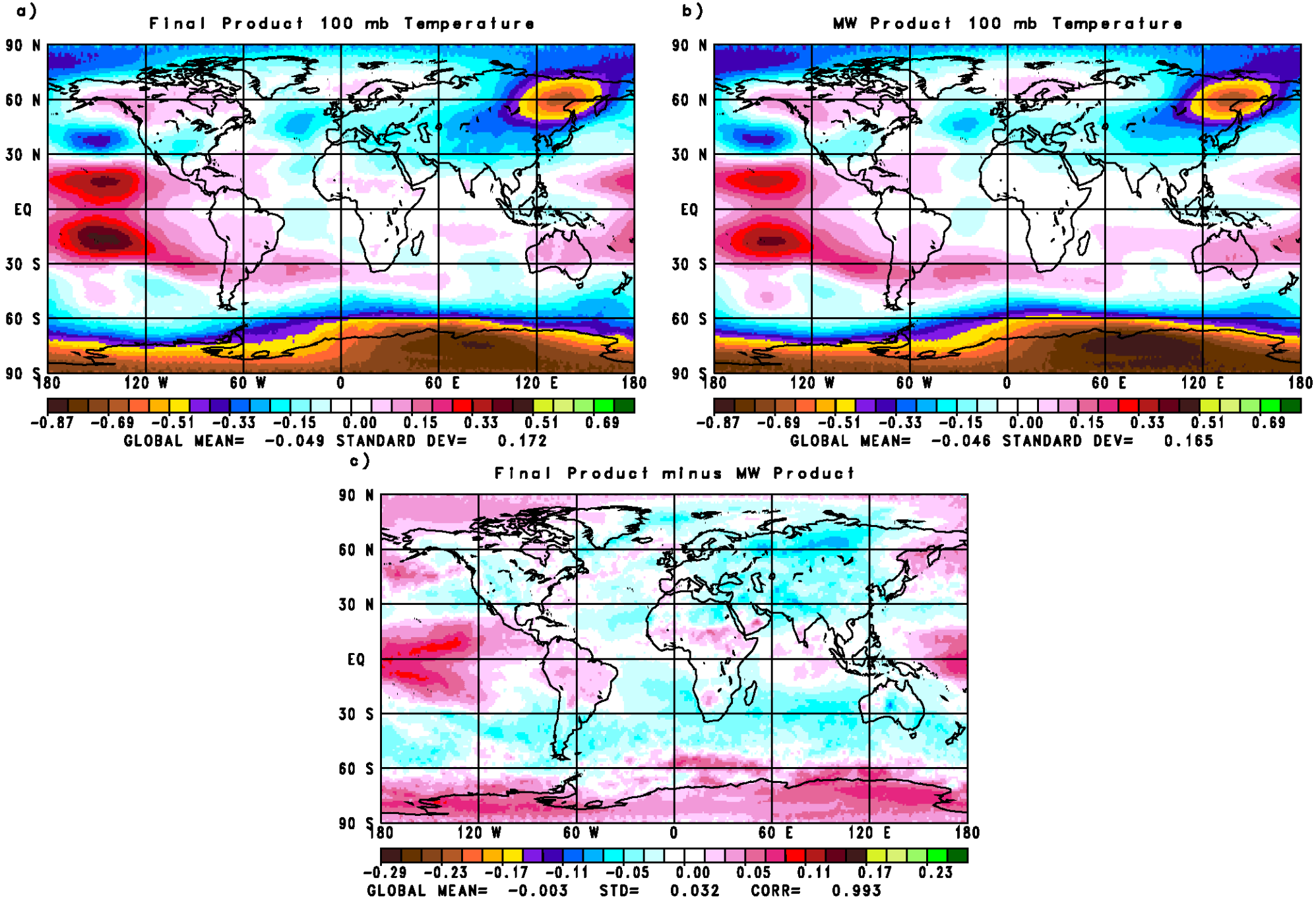
I. Assessment of Accuracy of AIRS V5 T(p) Trends

- **AIRS T(p) trends can be spurious for a number of reasons:**
  - **AIRS radiometric and spectral drifts**
  - **Effects of changing CO_2 on**
    - **Cloud clearing, regression, physical retrieval, quality control**
- **We compare AIRS T(p) trends (final product) with AMSU T(p) trends (MIT microwave product)**
- **We also compare AIRS Coarse Climate Indicator trends with analogous products from Mears and Wentz (which is an *updated/continued Spencer and Christy-type* product)**
- **AIRS T(p) trends are independent of those being compared to**
  - **Neither will be affected by concerns about AIRS listed above**
- **AIRS T(p) retrieval has more vertical resolution than AMSU T(p) retrieval**
  - **Therefore AIRS T(p) trends have more vertical resolution than AMSU T(p) trends**
- **AIRS T(p) trends agree well with AMSU T(p) trends, both in height and in space**
  - **This implies 3D structure of AIRS T(p) trends is reasonable**

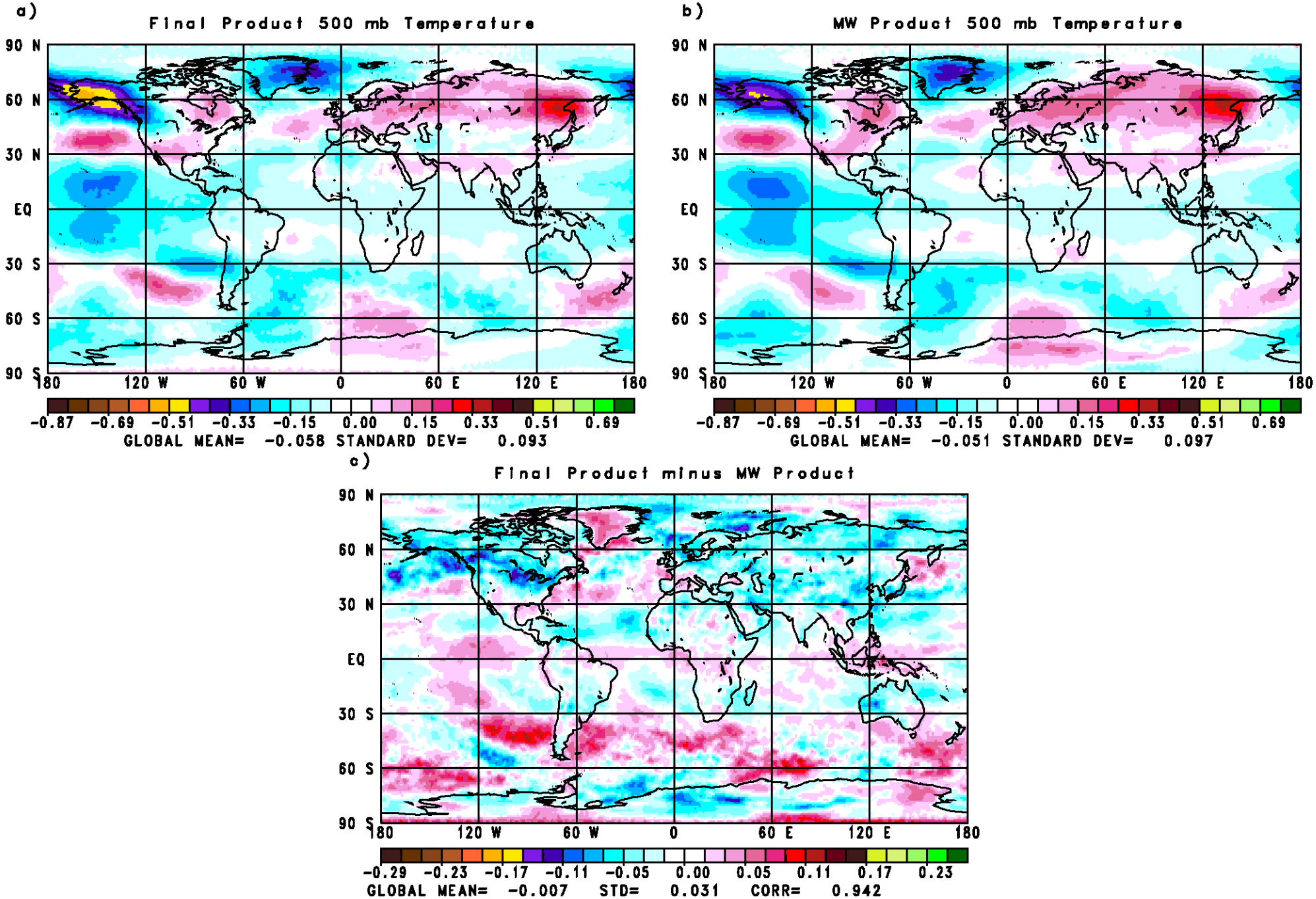

6−yr V5 AIRS Global Temperature ANOMALY "TRENDS"
Microwave Product
Final Product
Pressure [hPa]
"TREND"/YEAR [K]
10^0
10^1
10^2
10^3
−0.4
−0.3
−0.2
−0.1
0
0.1
0.2
0.3


6−yr V5 AIRS Tropical Temperature ANOMALY "TRENDS"
Microwave Product
Final Product
Pressure [hPa]
"TREND"/YEAR [K]
10^0
10^1
10^2
10^3
−0.4
−0.3
−0.2
−0.1
0
0.1
0.2
0.3

100 mb Temperature Anomaly "Trend" (°C/yr)
September 2002 through August 2008



500 mb Temperature Anomaly "Trend" (°C/yr)
September 2002 through August 2008



AIRS Coarse Climate Indicators (CCI's)

- **AIRS CCI's are contained in the Level 3 support products**

- **AIRS Mid Tropospheric CCI is a pressure weighted integral of AIRS T(p) between 300 mb and the surface Pressure weighting is done so to give an analogous product to Mears and Wentz's MSU/ AMSU Temperature Middle Troposphere (TMT) product**

- **AIRS Lower Stratospheric CCI is a pressure weighted integral of AIRS T(p) between 150 mb and 30 mb to give an analogous product to Mears and Wentz's MSU/AMSU Temperature Lower Stratosphere (TLS) product**

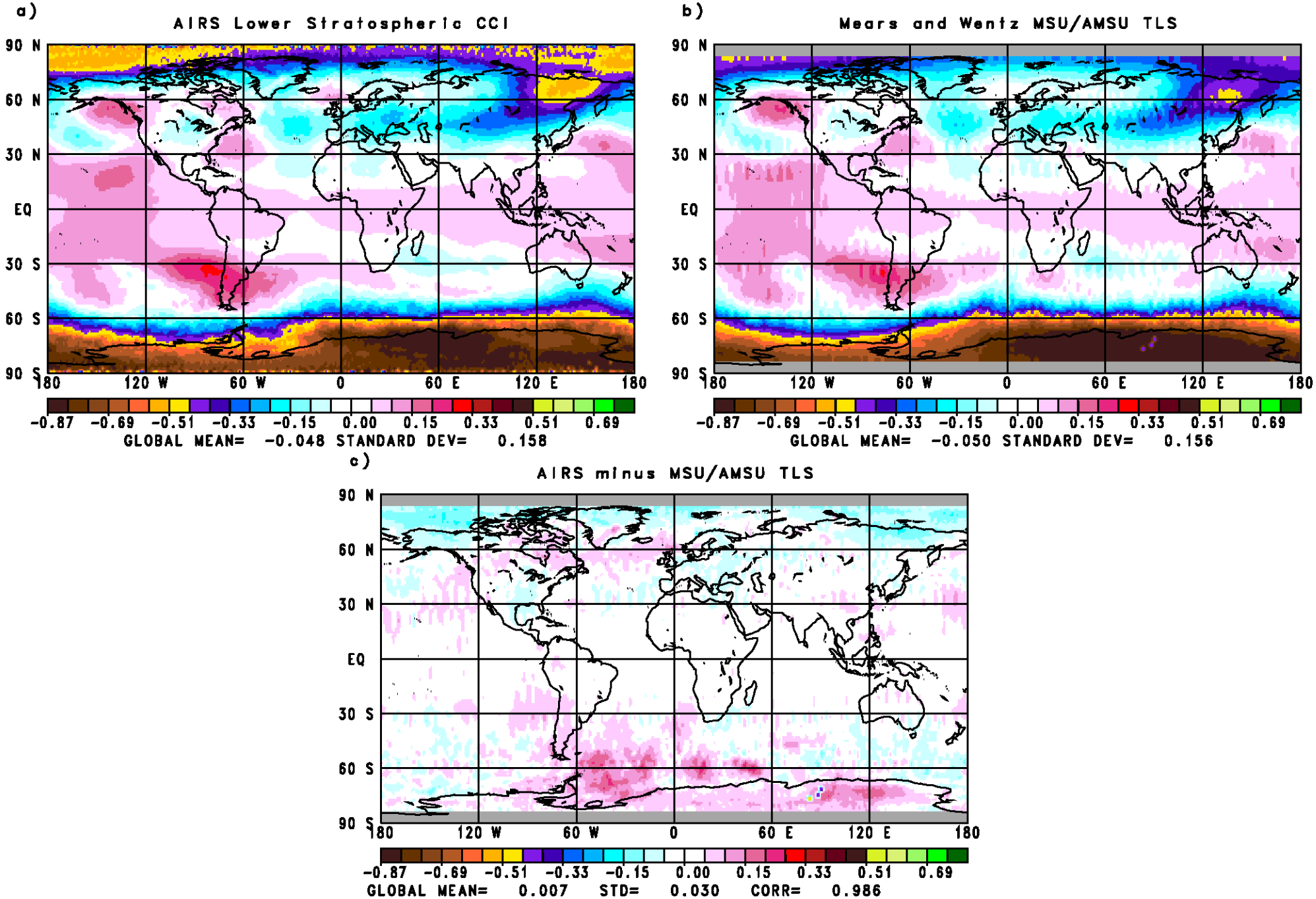
- **Trends of AIRS CCI's are vertically integrated values of trends of AIRS T(p)**

- **Comparison of appropriate AIRS CCI trends with TMT and TLS trends is an *independent check* [Mears and Wentz do not use AMSU on Aqua] on AIRS T(p) trends [Mears and Wentz do not use AMSU on Aqua]**

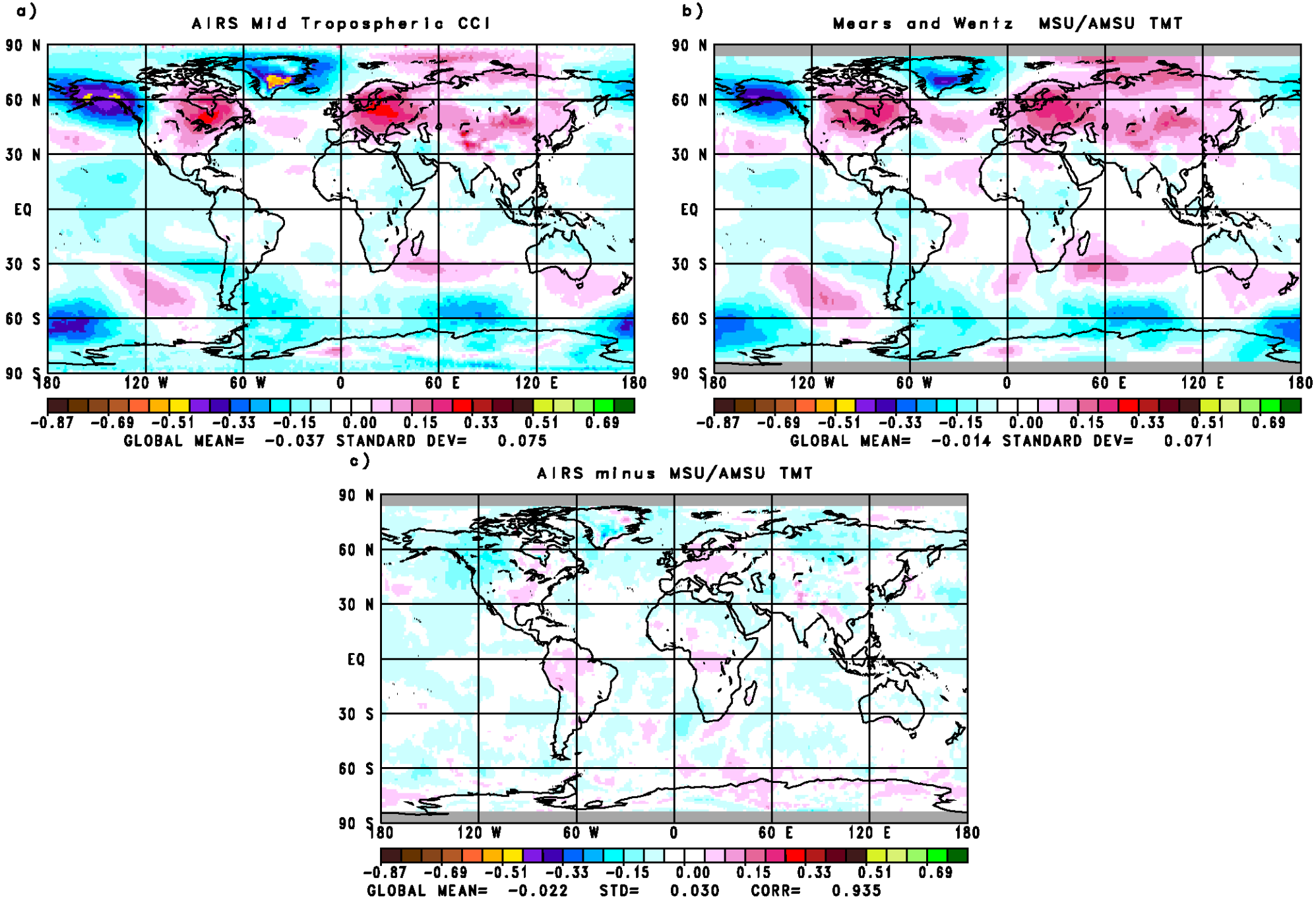
- **Note: The Mears and Wentz TMT and TLS are gridded on a 2.5° x 2.5° lat.-long. grid**

  AIRS CCI's are gridded on a 1° x 1° grid

Lower Stratospheric Temperature Anomaly "Trend" (°C/yr)
September 2002 through August 2007



Mid Tropospheric Temperature Anomaly "Trend" (°C/yr)
September 2002 through August 2007



Findings Comparing AIRS CCI's with Mears and Wentz

- Global mean lower stratospheric trends agree to 0.007K/yr (AIRS less negative)
- Global mean middle tropospheric trends agree to 0.022K/yr (AIRS more negative)

This implies AIRS layer average T(p) trends are accurate to the order of 0.02K/yr

- Accuracy can actually be better because:
  - Mears and Wentz are not measuring exactly the same integral as AIRS CCI's
  - Mears and Wentz results are not perfect truth
  - AIRS Tropospheric CCI trend features appear stronger than Mears and Wentz's

    Therefore Mears and Wentz might be underestimating nature of actual tropospheric cooling

Further significance:

AIRS T(p) and CCI products explain why surface measurements show warming while Mears and Wentz show cooling

II. Assessment of OLR and Cloud Cover Trends

Validation of AIRS OLR Trends by Comparison with CERES OLR

- CERES OLR is measured (2.5° x 2.5° grid)

  CERES OLR_{CLR} is the subset of OLR measured for clear cases
- Current CERES data set ends December 2006 (52 'AIRS-Months')
- Climate model performance is sometimes judged by ability to depict CERES OLR anomalies
- AIRS OLR is computed from products (1° x 1° grid)

  Both for OLR (all cases) and OLR_{CLR} (only cases when water vapor is retrieved)
- AIRS and CERES OLR products and trends are complementary if they agree
- If AIRS and CERES anomalies and trends agree, then

  1) Anomalies and trends in AIRS products explain anomalies and trends in CERES observations

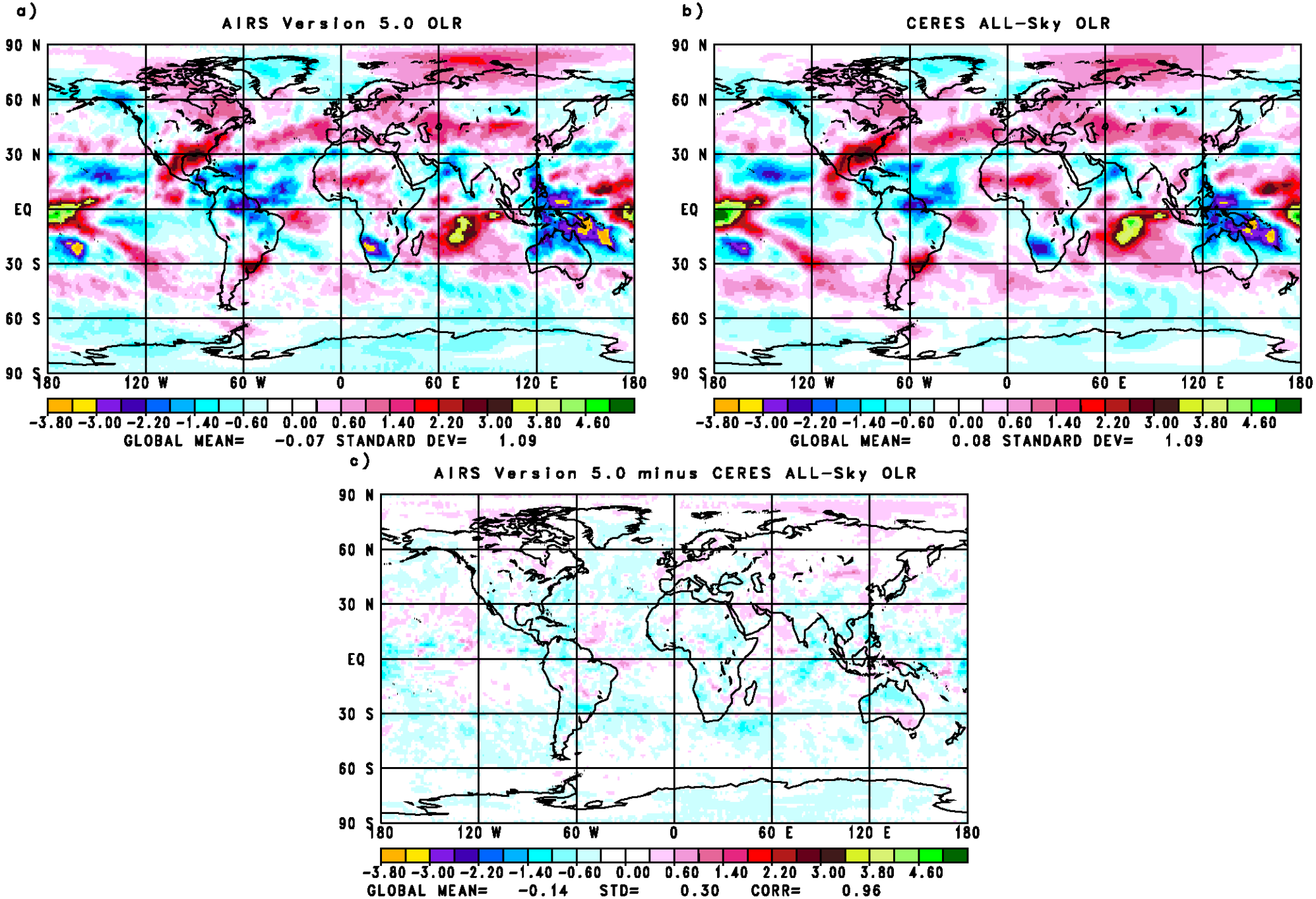
  2) AIRS product anomalies and trends are indirectly validated by CERES observations

Findings:

- Agreement of 52 month AIRS and CERES OLR trends is excellent

  Both show 0 ± 0.08 Wm^{-2} global trend over 4 1/3 year period
- However, the 52-Months AIRS cloud fraction trend may have a small spurious global cloud fraction trend of +0.23%/yr

OLR "Trend" (W/m²/yr)
September 2002 through December 2006



Validation of AIRS *Cloud Fraction* Trends using MODIS

- AIRS determines the radiatively effective cloud fraction $\alpha\varepsilon$ and cloud top pressure p_c

  $\alpha\varepsilon$ and p_c are the two cloud parameters used to compute OLR
- Agreement of AIRS and CERES OLR trends is an indirect validation of AIRS $\alpha\varepsilon$ and p_c trends
- We also compare AIRS $\alpha\varepsilon$ trends with those found in MODIS Aqua Collection 5

  MODIS Aqua Collection 5 contains MODIS cloud fraction α and MODIS cloud emissivity ε

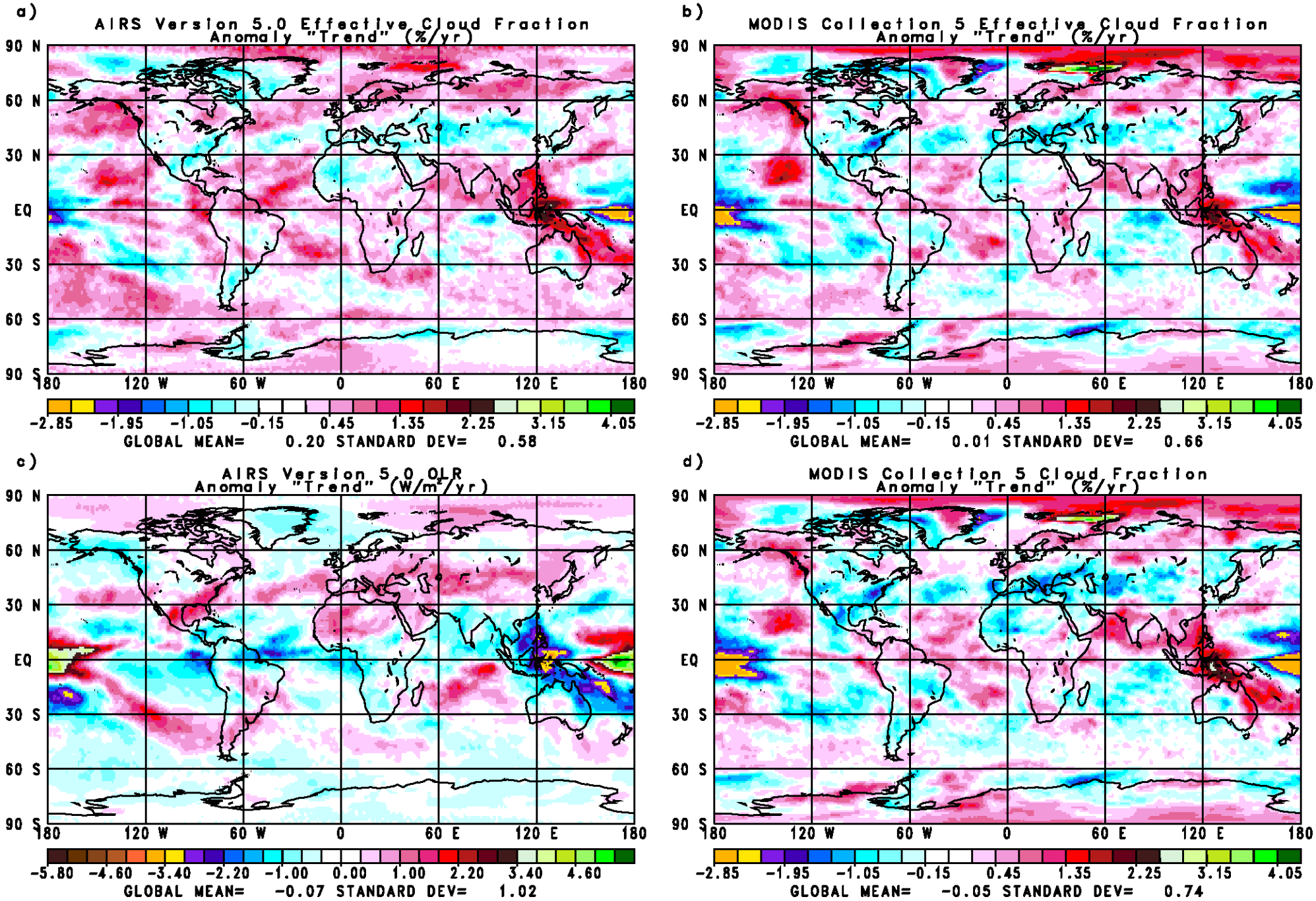
  MODIS α indicates the fraction of MODIS pixels contaminated by some cloud

  MODIS α is much larger than AIRS $\alpha\varepsilon$

  Therefore, expect local trends of MODIS α to be bigger than local trends of AIRS $\alpha\varepsilon$
- We construct MODIS $\alpha\varepsilon$ by multiplying MODIS α with MODIS ε

  This product is more consistent with AIRS $\alpha\varepsilon$

Cloud Parameter "Anomaly Trend"
September 2002 through August 2008



Results

- Agreement of trends of AIRS $\alpha\varepsilon$ and MODIS $\alpha\varepsilon$ is very good

- Both show very small global increase: 0.20%/yr for AIRS; 0.01%/yr for MODIS

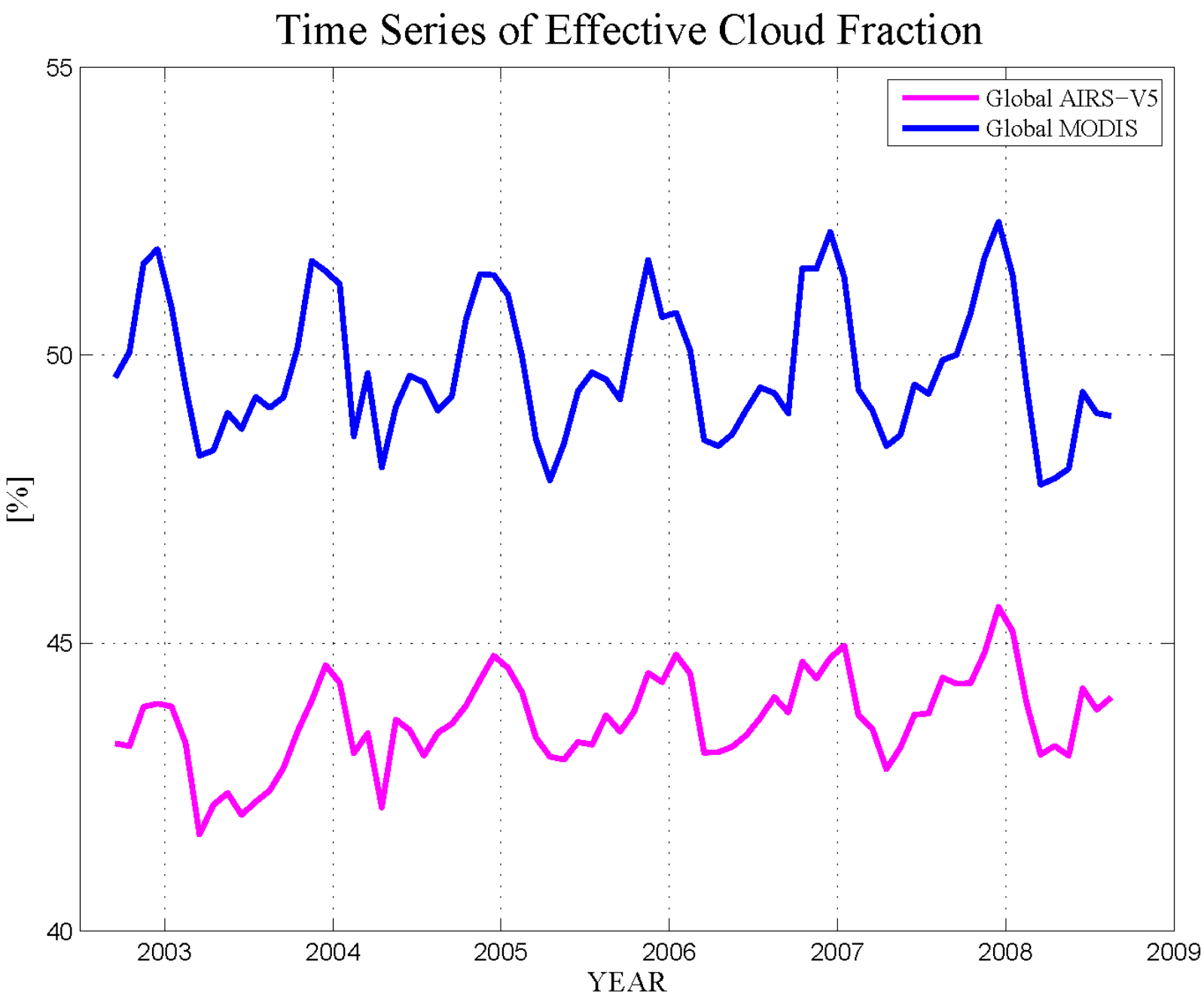
- AIRS and MODIS spatial trends of $\alpha\varepsilon$ agree extremely well with 2 exceptions:

1) The patterns of trends are different off the west coast of South America ≈ 80°W, 20°S

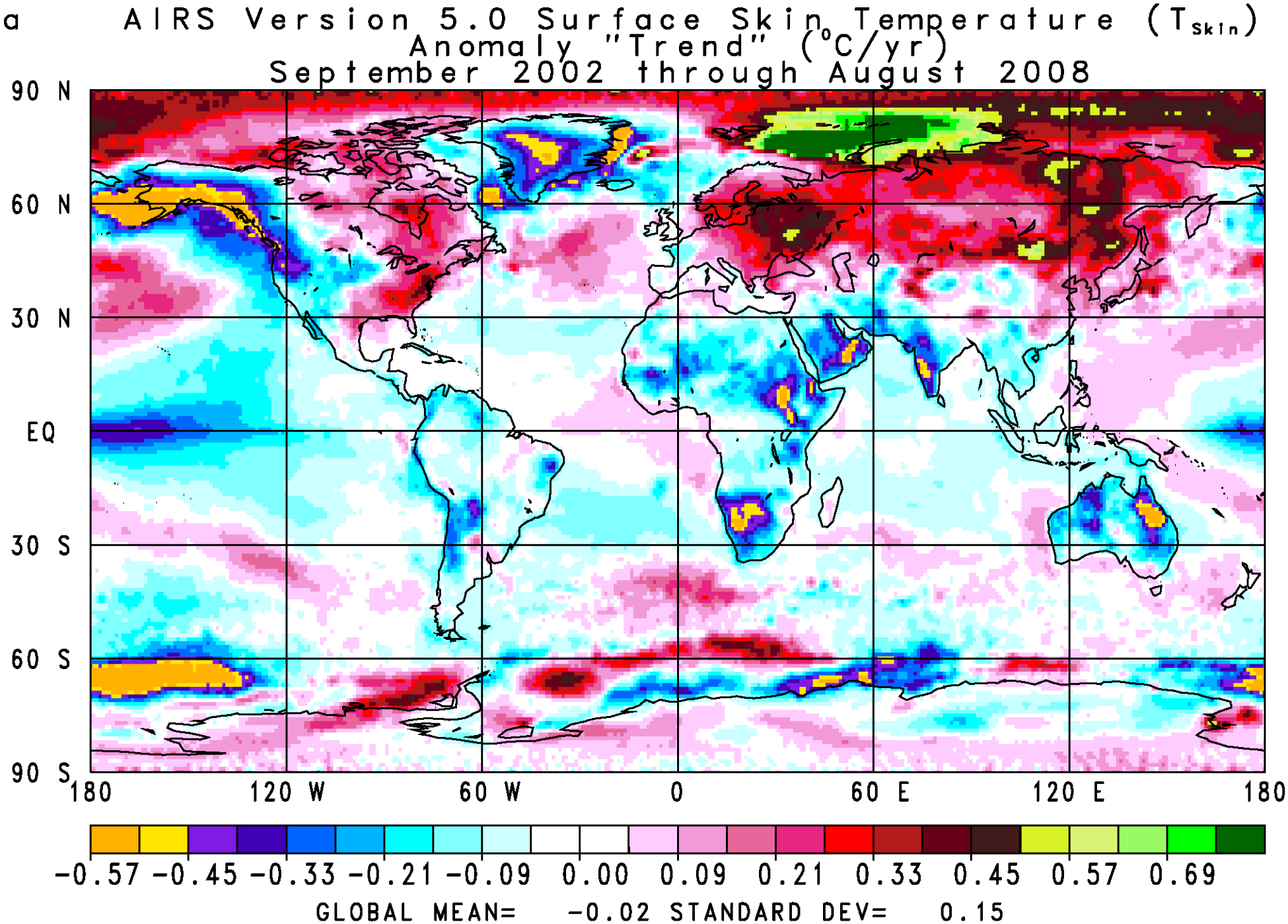
   AIRS OLR trend is more consistent with AIRS $\alpha\varepsilon$ trend than with MODIS $\alpha\varepsilon$

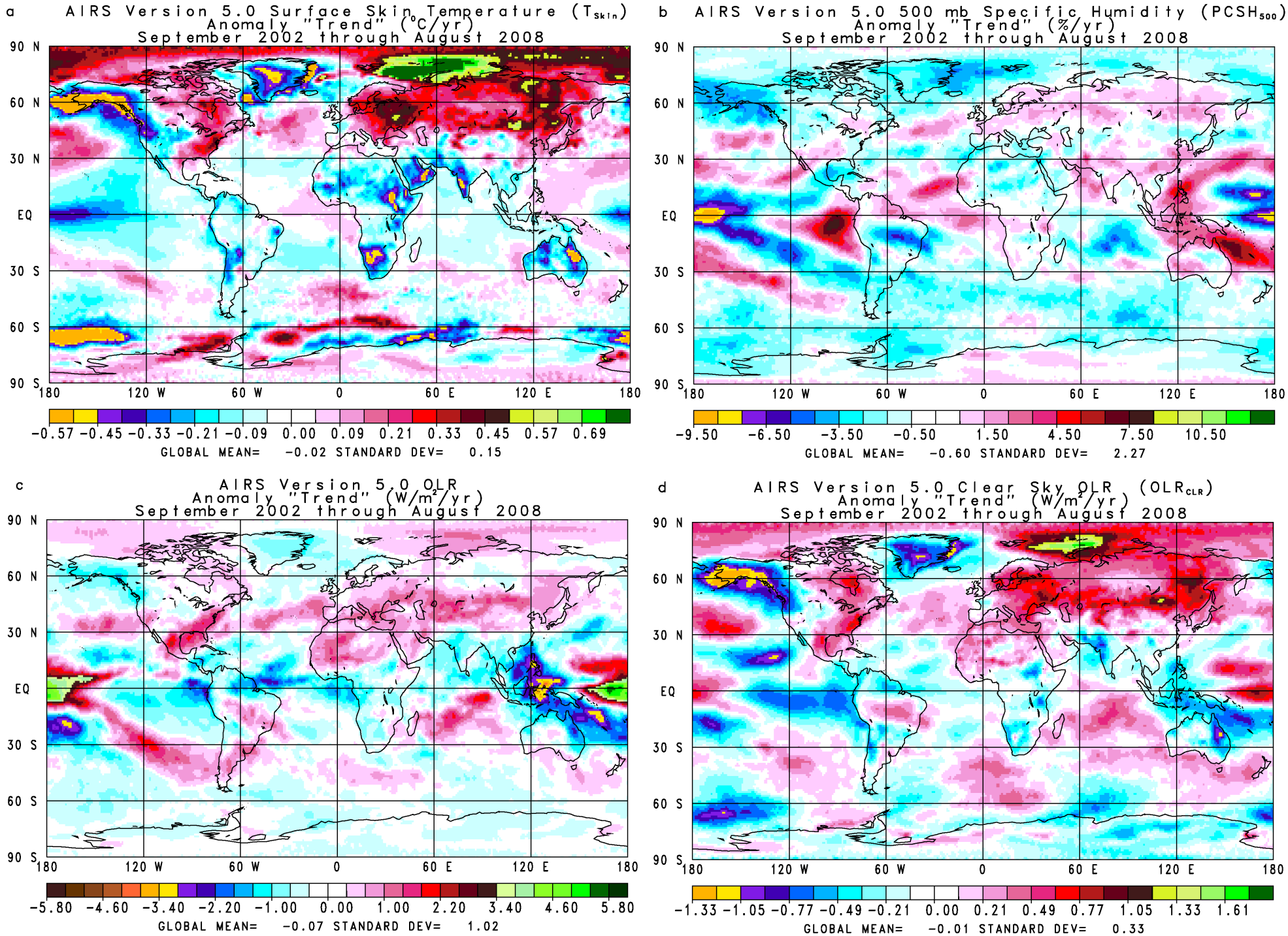
2) A significant difference in trends of $\alpha\varepsilon$ also occurs near the North Pole

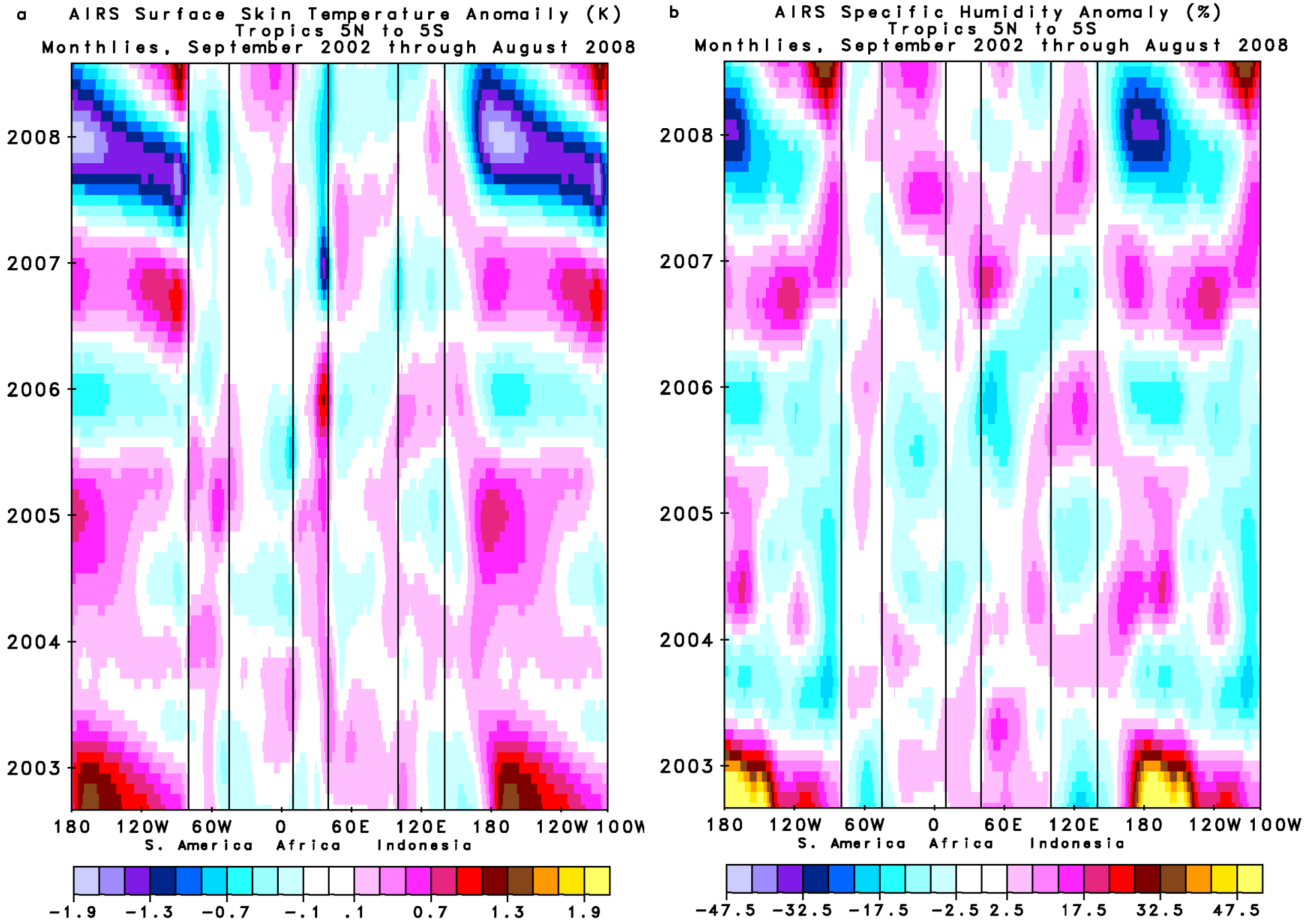
   We have no validation for this area - OLR trends are dominated by T_s trends here

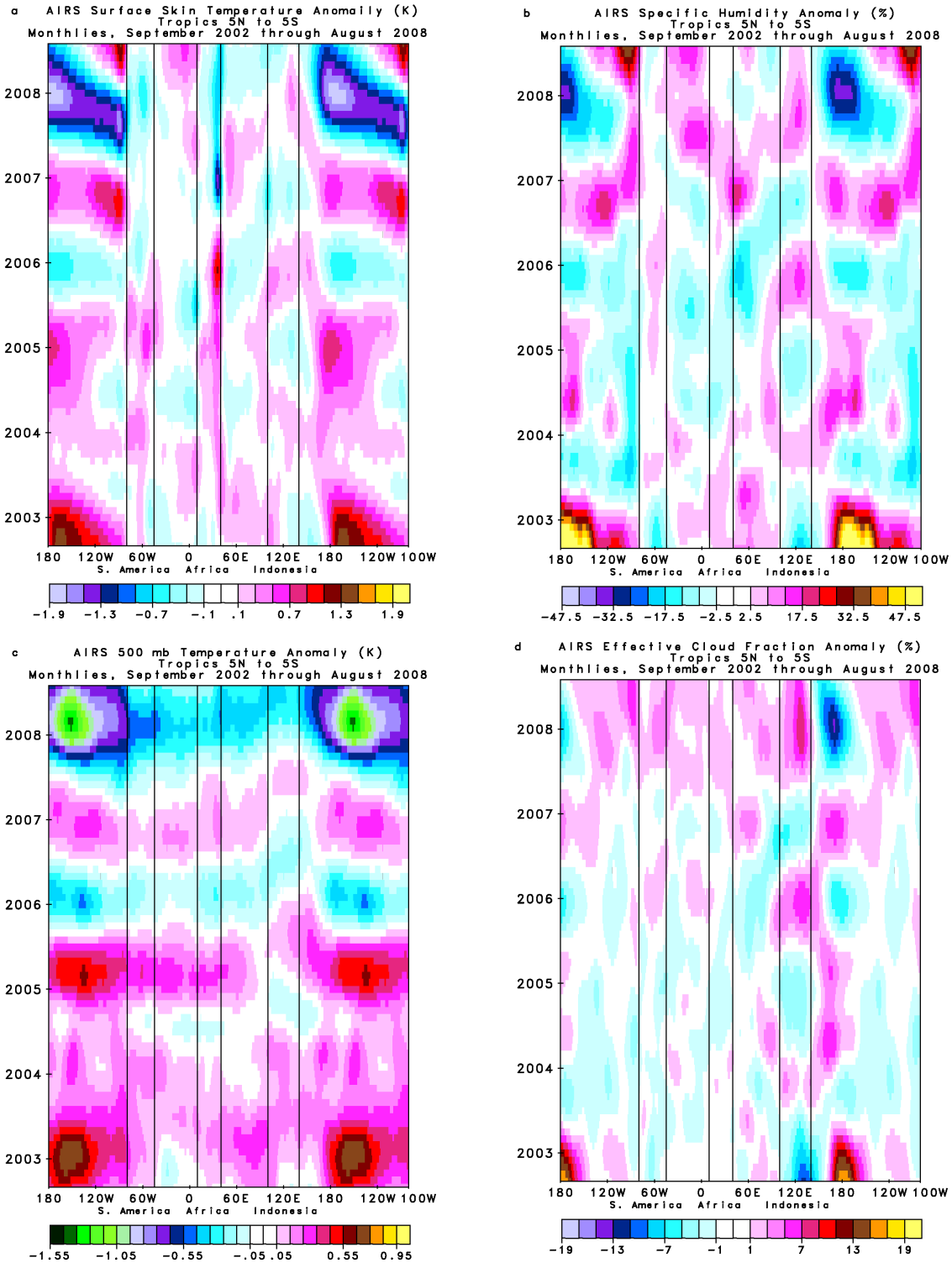

Time Series of Effective Cloud Fraction
Global AIRS−V5
Global MODIS
55
50
45
40
[%]
2003
2004
2005
2006
2007
2008
2009
YEAR

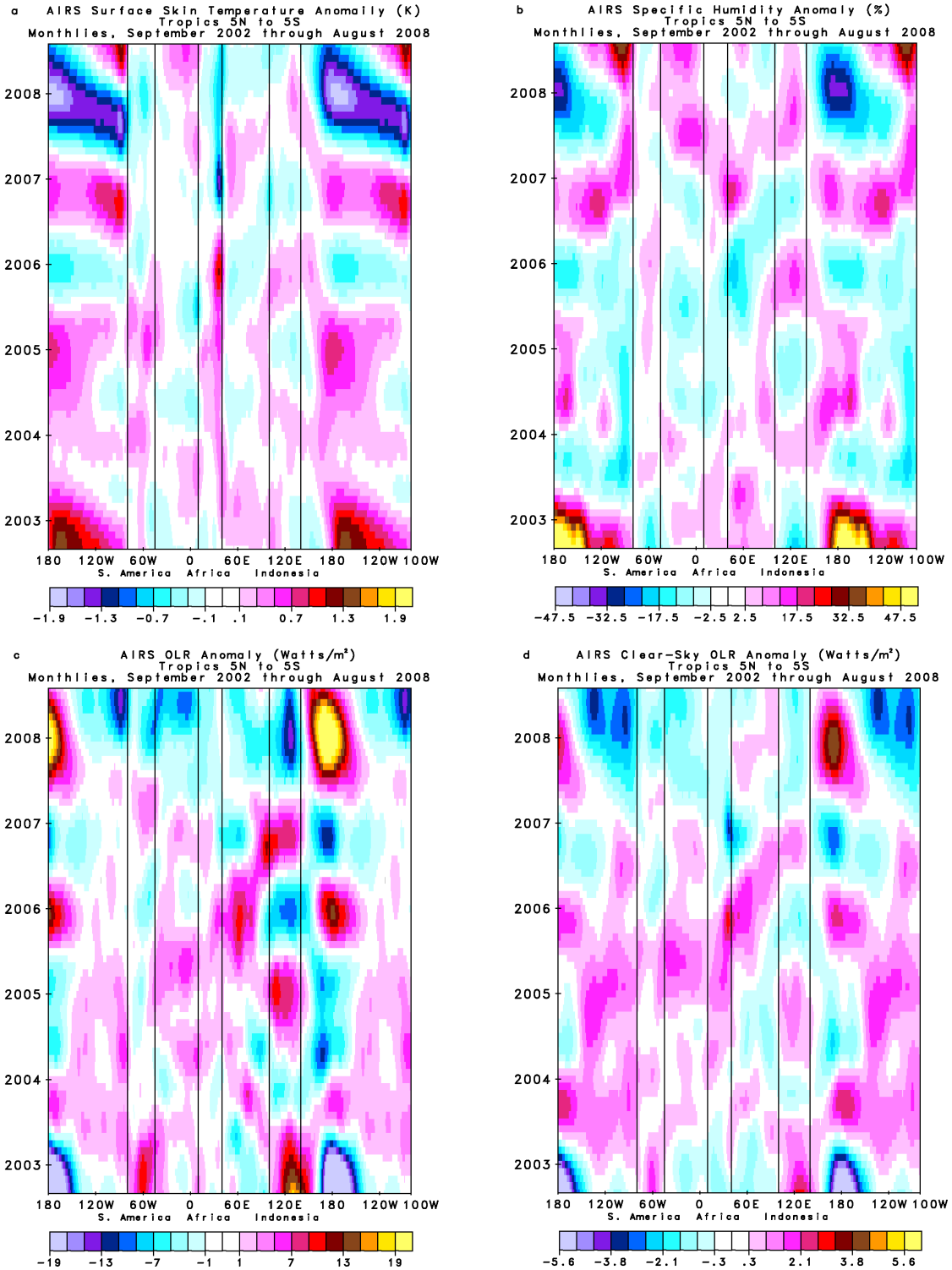
Now, Some Science


a
AIRS Version 5.0 Surface Skin Temperature (T_{Skin})
Anomaly "Trend" (°C/yr)
September 2002 through August 2008
90 N
60 N
30 N
EQ
30 S
60 S
90 S
180
120 W
60 W
0
60 E
120 E
180
-0.57 -0.45 -0.33 -0.21 -0.09 0.00 0.09 0.21 0.33 0.45 0.57 0.69
GLOBAL MEAN= -0.02 STANDARD DEV= 0.15


a
AIRS Version 5.0 Surface Skin Temperature (T_{skin})
Anomaly "Trend" (°C/yr)
September 2002 through August 2008
90 N
60 N
30 N
EQ
30 S
60 S
90 S
180
120 W
60 W
0
60 E
120 E
180
-0.57 -0.45 -0.33 -0.21 -0.09 0.00 0.09 0.21 0.33 0.45 0.57 0.69
GLOBAL MEAN= -0.02 STANDARD DEV= 0.15
b
AIRS Version 5.0 500 mb Specific Humidity ($PCSH_{500}$)
Anomaly "Trend" (%/yr)
September 2002 through August 2008
-9.50 -6.50 -3.50 -0.50 1.50 4.50 7.50 10.50
GLOBAL MEAN= -0.60 STANDARD DEV= 2.27
c
AIRS Version 5.0 OLR
Anomaly "Trend" ($W/m^2/yr$)
September 2002 through August 2008
-5.80 -4.60 -3.40 -2.20 -1.00 0.00 1.00 2.20 3.40 4.60 5.80
GLOBAL MEAN= -0.07 STANDARD DEV= 1.02
d
AIRS Version 5.0 Clear Sky OLR (OLR_{CLR})
Anomaly "Trend" ($W/m^2/yr$)
September 2002 through August 2008
-1.33 -1.05 -0.77 -0.49 -0.21 0.00 0.21 0.49 0.77 1.05 1.33 1.61
GLOBAL MEAN= -0.01 STANDARD DEV= 0.33


a
AIRS Surface Skin Temperature Anomaily (K)
Tropics 5N to 5S
Monthlies, September 2002 through August 2008
2008
2007
2006
2005
2004
2003
180 120W 60W 0 60E 120E 180 120W 100W
S. America Africa Indonesia
-1.9 -1.3 -0.7 -.1 .1 0.7 1.3 1.9
b
AIRS Specific Humidity Anomaly (%)
Tropics 5N to 5S
Monthlies, September 2002 through August 2008
2008
2007
2006
2005
2004
2003
180 120W 60W 0 60E 120E 180 120W 100W
S. America Africa Indonesia
-47.5 -32.5 -17.5 -2.5 2.5 17.5 32.5 47.5


a
AIRS Surface Skin Temperature Anomaly (K)
Tropics 5N to 5S
Monthlies, September 2002 through August 2008
2008
2007
2006
2005
2004
2003
180 120W 60W 0 60E 120E 180 120W 100W
S. America Africa Indonesia
-1.9 -1.3 -0.7 -.1 .1 0.7 1.3 1.9
b
AIRS Specific Humidity Anomaly (%)
Tropics 5N to 5S
Monthlies, September 2002 through August 2008
2008
2007
2006
2005
2004
2003
180 120W 60W 0 60E 120E 180 120W 100W
S. America Africa Indonesia
-47.5 -32.5 -17.5 -2.5 2.5 17.5 32.5 47.5
c
AIRS 500 mb Temperature Anomaly (K)
Tropics 5N to 5S
Monthlies, September 2002 through August 2008
2008
2007
2006
2005
2004
2003
180 120W 60W 0 60E 120E 180 120W 100W
S. America Africa Indonesia
-1.55 -1.05 -0.55 -.05 .05 0.55 0.95
d
AIRS Effective Cloud Fraction Anomaly (%)
Tropics 5N to 5S
Monthlies, September 2002 through August 2008
2008
2007
2006
2005
2004
2003
180 120W 60W 0 60E 120E 180 120W 100W
S. America Africa Indonesia
-19 -13 -7 -1 1 7 13 19


a
AIRS Surface Skin Temperature Anomaly (K)
Tropics 5N to 5S
Monthlies, September 2002 through August 2008
2008
2007
2006
2005
2004
2003
180 120W 60W 0 60E 120E 180 120W 100W
S. America Africa Indonesia
-1.9 -1.3 -0.7 -.1 .1 0.7 1.3 1.9
b
AIRS Specific Humidity Anomaly (%)
Tropics 5N to 5S
Monthlies, September 2002 through August 2008
2008
2007
2006
2005
2004
2003
180 120W 60W 0 60E 120E 180 120W 100W
S. America Africa Indonesia
-47.5 -32.5 -17.5 -2.5 2.5 17.5 32.5 47.5
c
AIRS OLR Anomaly (Watts/m²)
Tropics 5N to 5S
Monthlies, September 2002 through August 2008
2008
2007
2006
2005
2004
2003
180 120W 60W 0 60E 120E 180 120W 100W
S. America Africa Indonesia
-19 -13 -7 -1 1 7 13 19
d
AIRS Clear-Sky OLR Anomaly (Watts/m²)
Tropics 5N to 5S
Monthlies, September 2002 through August 2008
2008
2007
2006
2005
2004
2003
180 120W 60W 0 60E 120E 180 120W 100W
S. America Africa Indonesia
-5.6 -3.8 -2.1 -.3 .3 2.1 3.8 5.6

Summary

- **The 6 year period September 2002 - August 2008 was marked by 2 major sets of events**
  - **Considerable warming of Northern Hemisphere extra tropical land skin temperatures**
  - **A pronounced El Nino/La Nina cycle resulting in cooling of tropical Pacific Ocean skin temperatures**

- **AIRS Version 5 climate products accurately depict the inter-relationship of spatial and temporal anomalies of temperature profiles, moisture profiles, cloud cover, and OLR in response to these events**

- **This data provides a good test of the response of GCM's to surface forcing**

- **Data can be found at NASA GSFC DISC website**

  http://disc.gsfc.nasa.gov/data/datapool/AIRS/index.html

- **AIRS data set will (hopefully) eventually cover a 15 year period to 2017**

NASA