and Summer

The Warmest Boreal Spring as Observed by AIRS

Washington post in Aug.

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Acknowledgment: AIRS team

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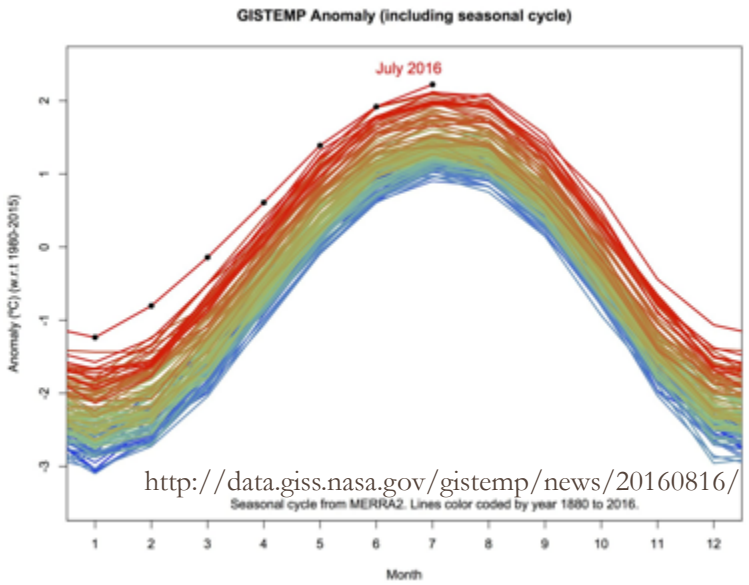
3. Applied Physics Lab/Johns Hopkins University, Laurel, MD

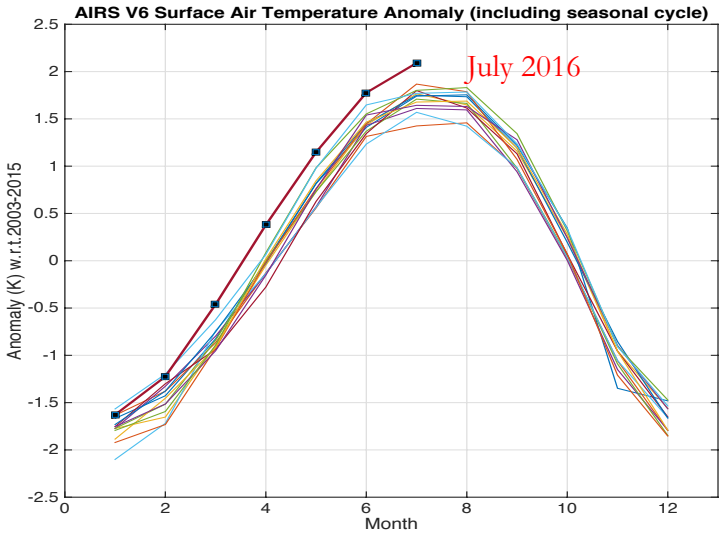
Goddard SPACE FLIGHT CENTER

NASA Analysis Finds July 2016 is Warmest on Record (posted on GISTEMP News on 16, August, 2016).

https://www.washingtonpost.com/news/capital-weather-gang/wp/2016/08/16/july-was-absolutely-earths-hottest-month-ever-recorded/



136 years GISTEMP since 1880



14 years AIRS Tair since 2003

- A warming trend in surface temperature is very likely, with a march of 10 consecutive months since October 2015.
- July is the peak of the seasonal cycle, July 2016 was the warmest month since records began in 1880. Warmest year of 2016 is very likely.

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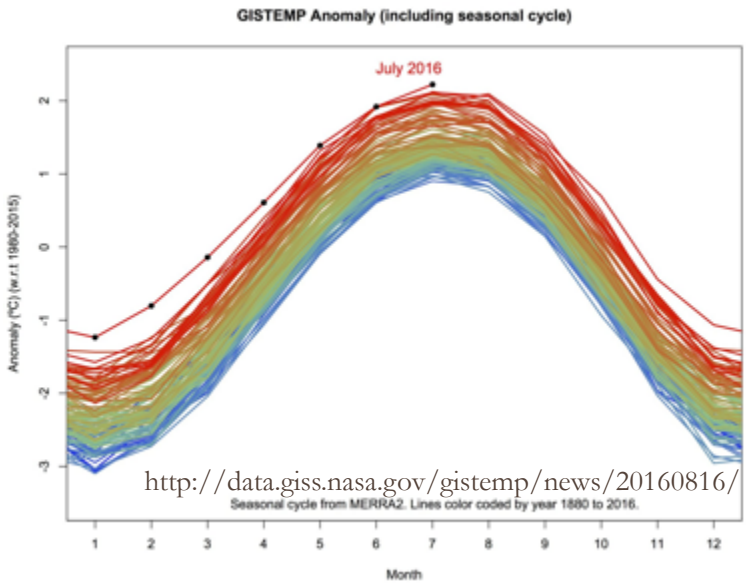

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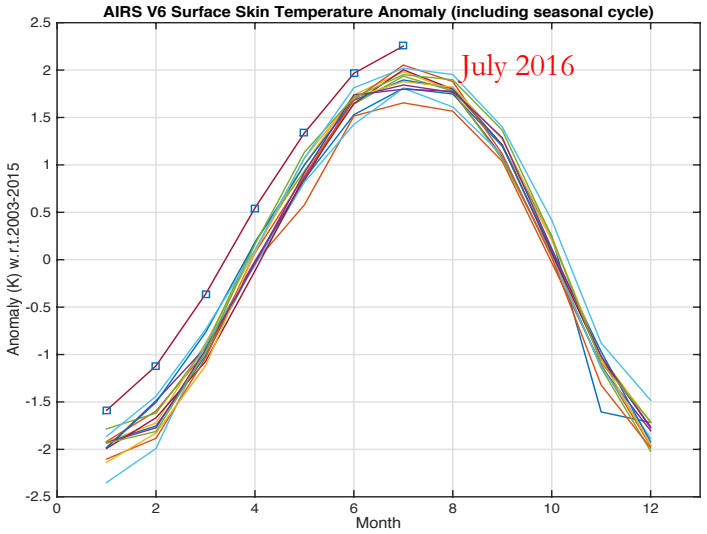

14 years AIRS Tskin since 2003

- A warming trend in surface temperature is very likely, with a march of 10 consecutive months since October 2015.
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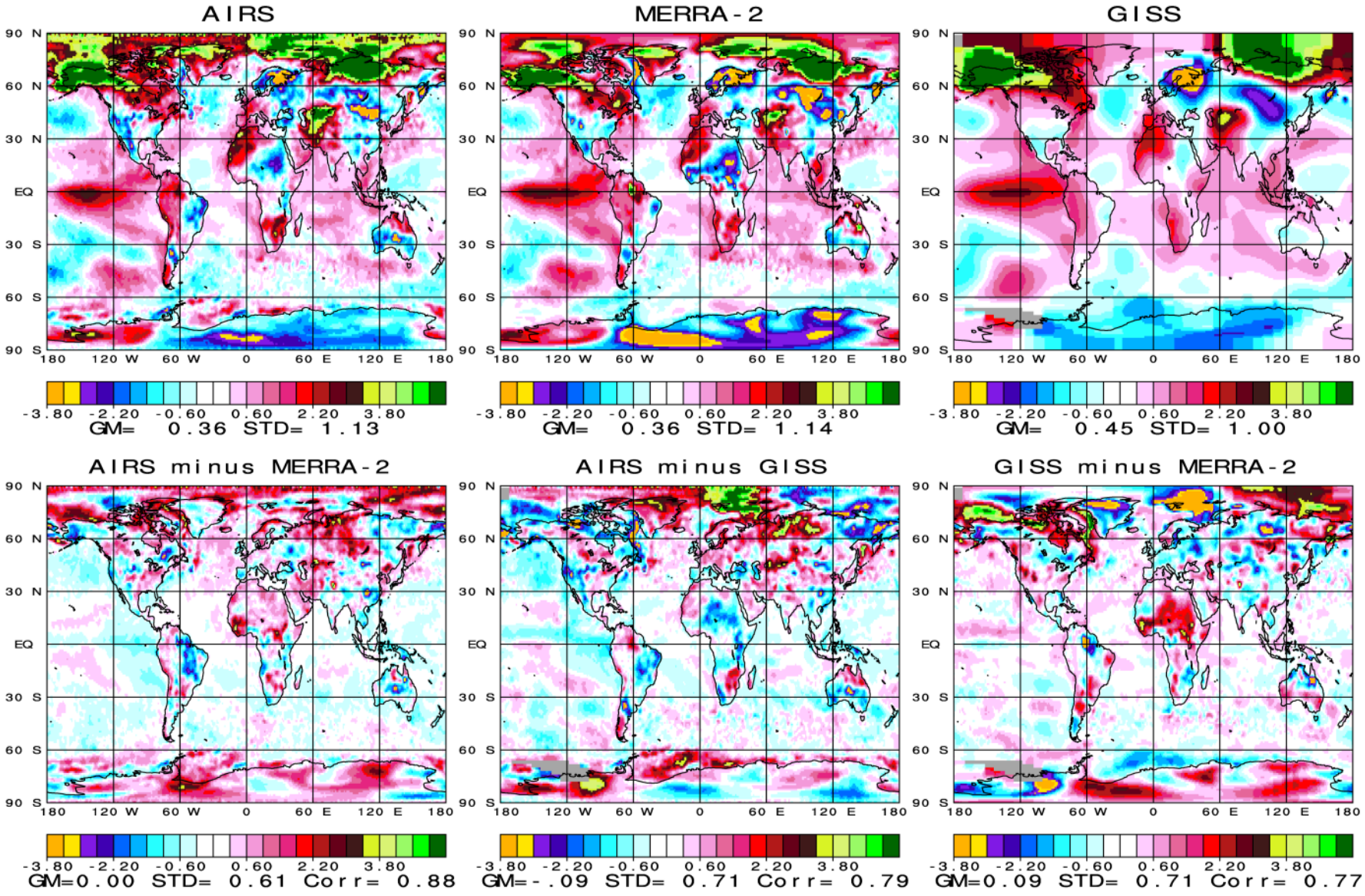
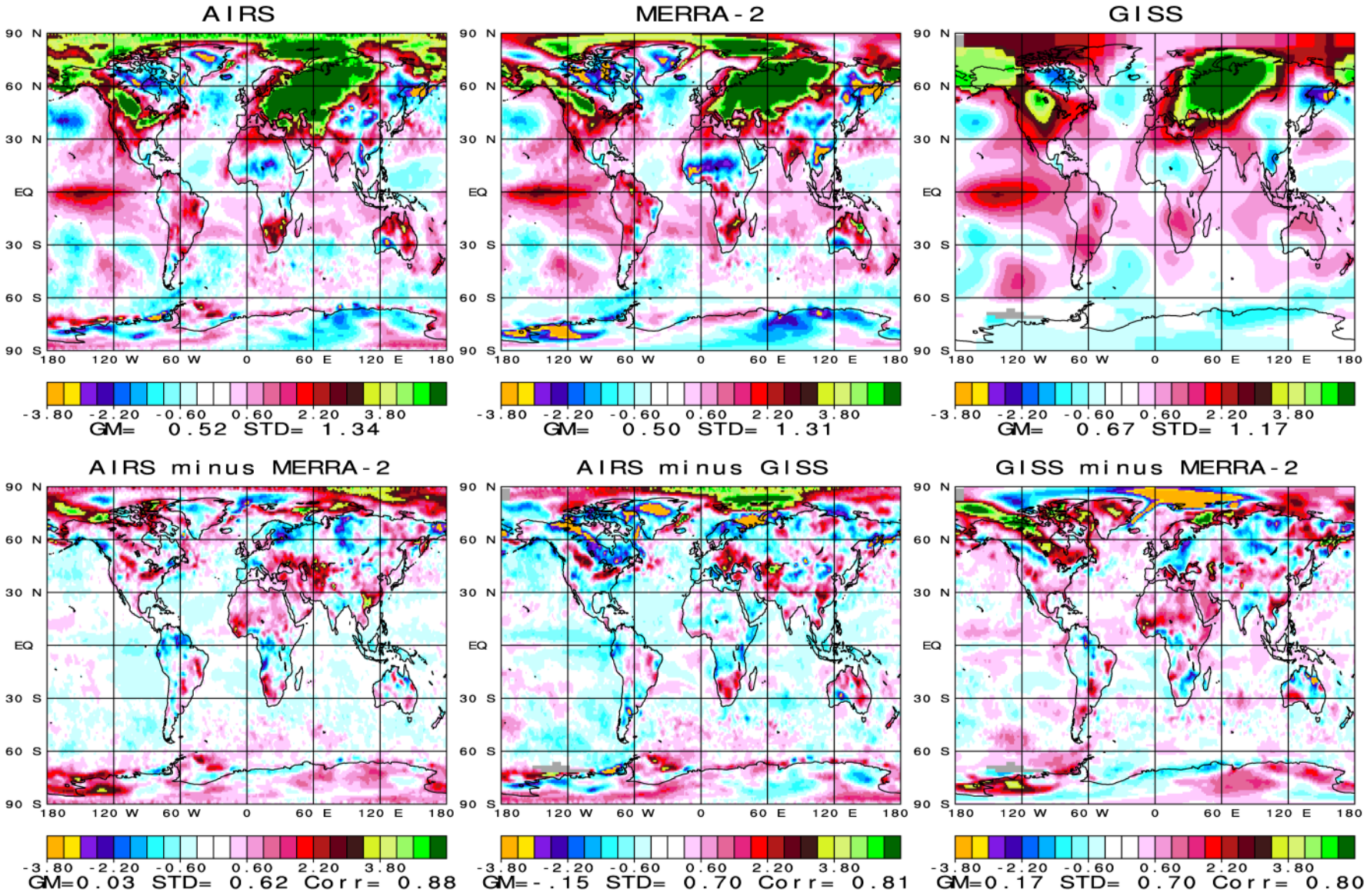
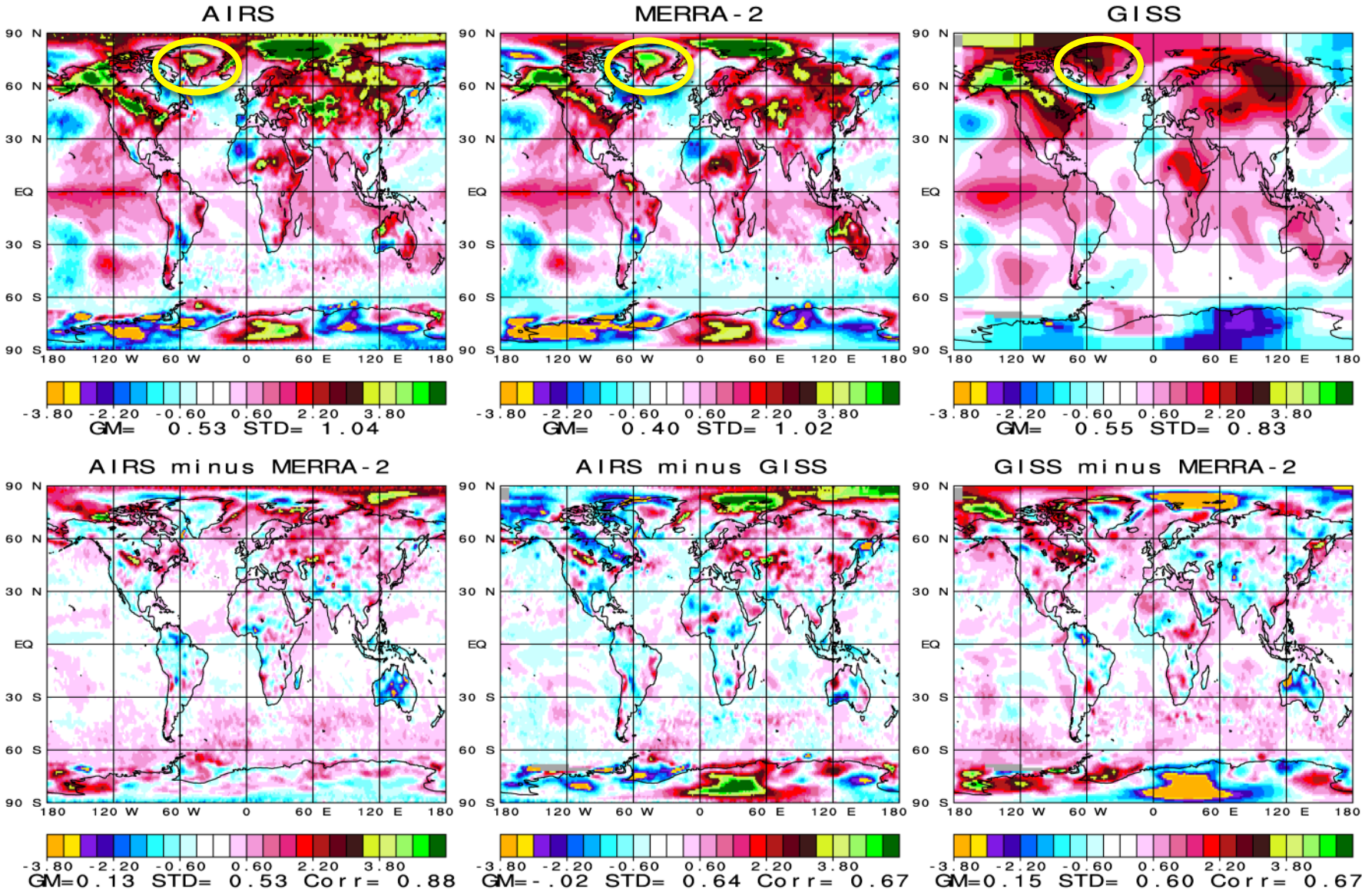
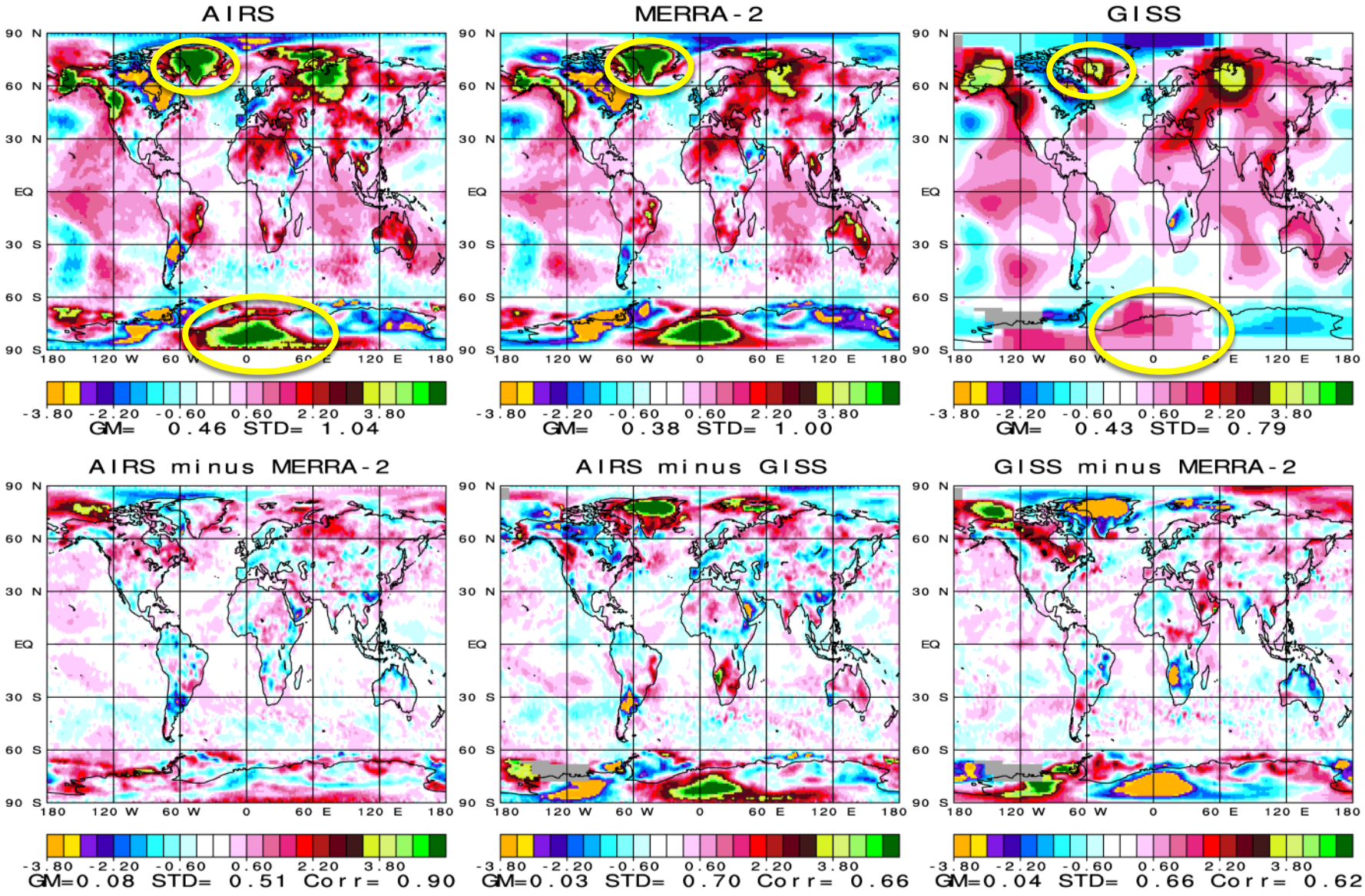
Surface temperature data

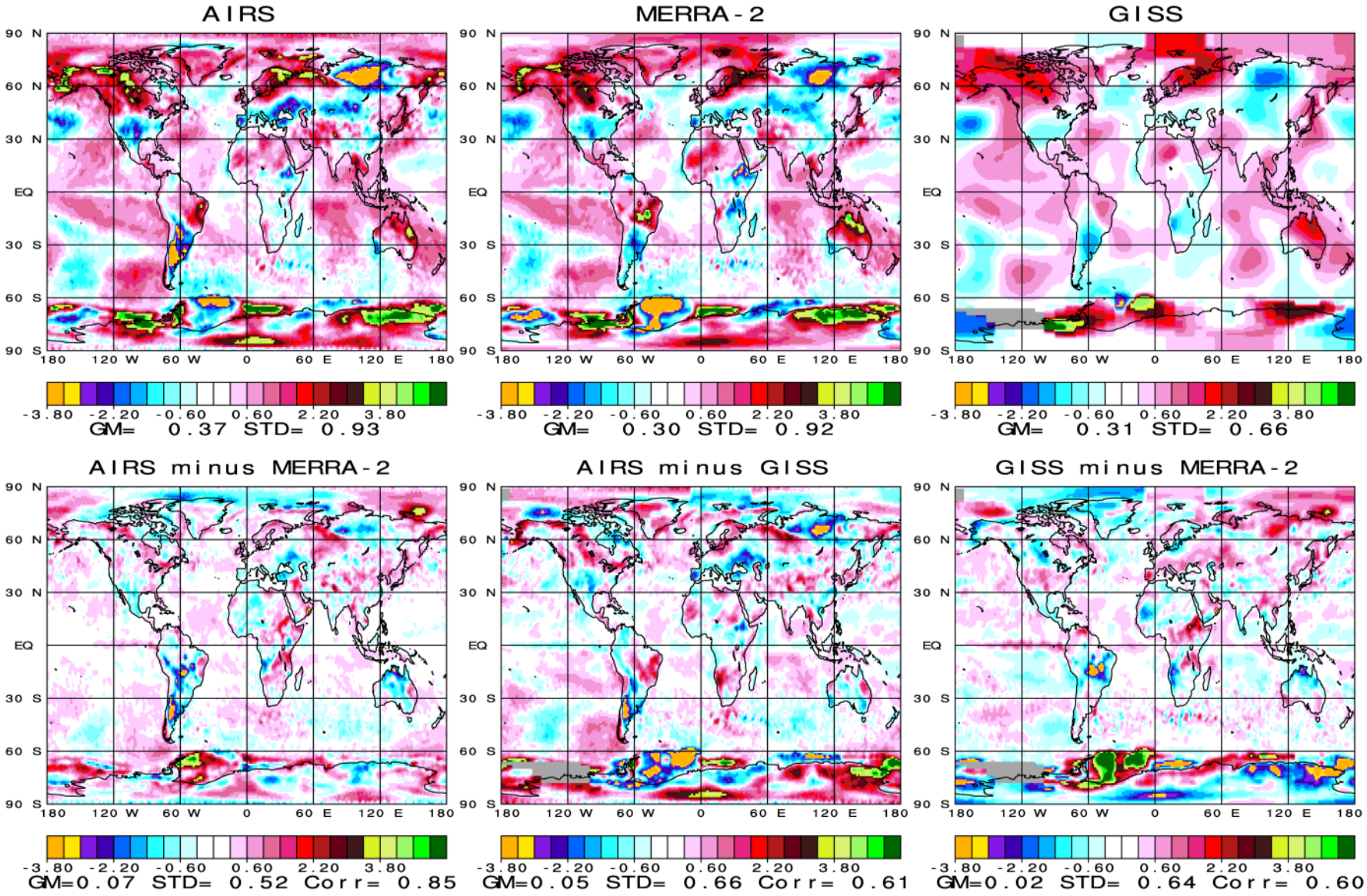
- GISTEMP Monthly Anomalies: ~ 6,300 meteorological stations since 1880.
- MERRA2 Surface temperatures: high spatial resolution data since 1980.
- AIRS V6 Surface Skin and Air Temperatures with
  - -- vertical sounding data +
  - -- global coverage with continuous daily AM and PM observations since Sep. 2002 to present ++
  - -- without major algorithm changes since 2002, independent from models +++
- Each data set can complement each other to assess the surface warming trend, if any.

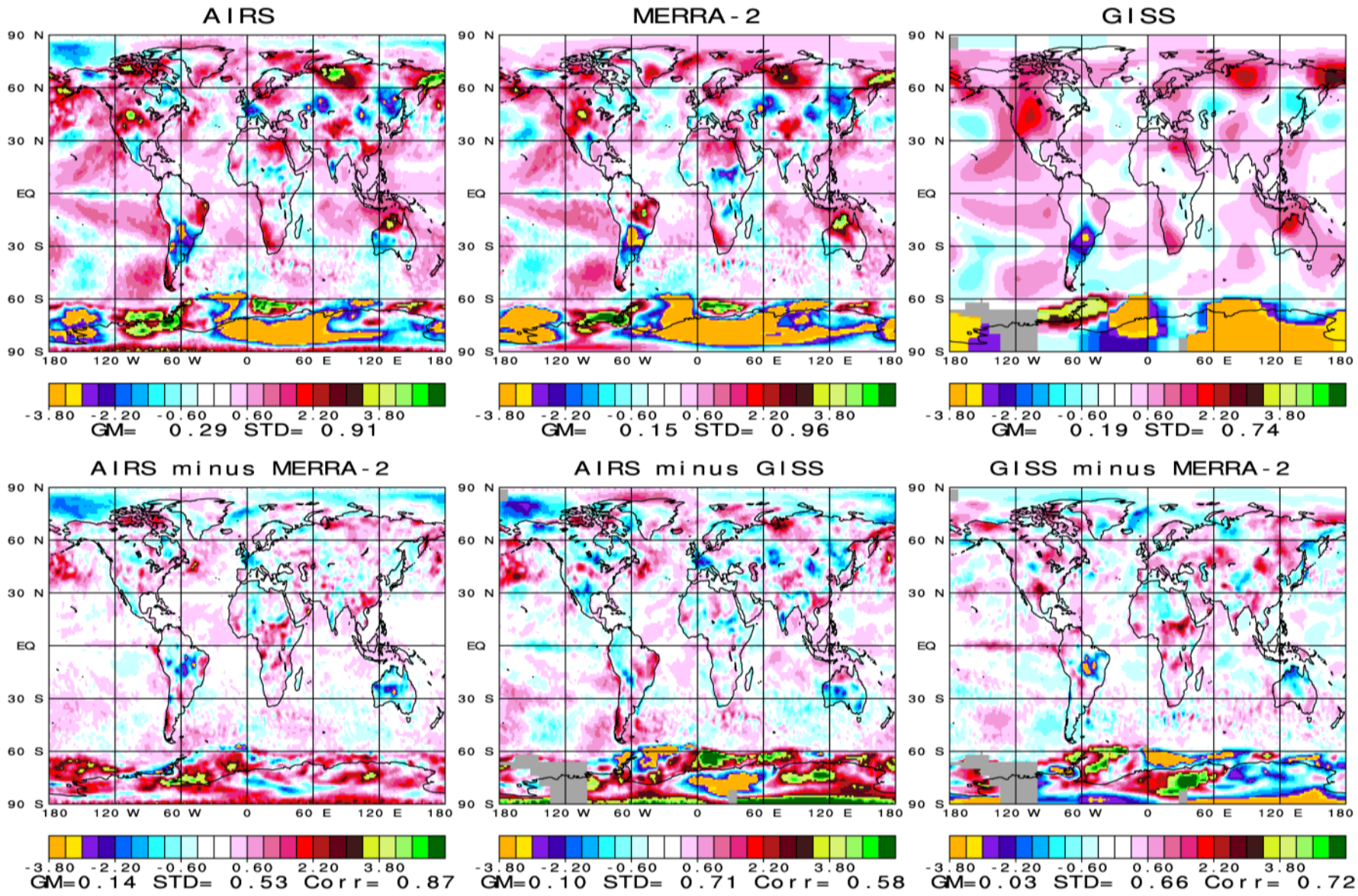

Surface Skin Temperature (K)
January 2016 minus 2003 through 2016 average
AIRS
MERRA-2
GISS
90 N
60 N
30 N
EQ
30 S
60 S
90 S
180 120 W 60 W 0 60 E 120 E 180
-3.80 -2.20 -0.60 0.60 2.20 3.80
GM= 0.36 STD= 1.13
GM= 0.36 STD= 1.14
GM= 0.45 STD= 1.00
AIRS minus MERRA-2
AIRS minus GISS
GISS minus MERRA-2
GM=0.00 STD= 0.61 Corr= 0.88
GM=-.09 STD= 0.71 Corr= 0.79
GM=0.09 STD= 0.71 Corr= 0.77

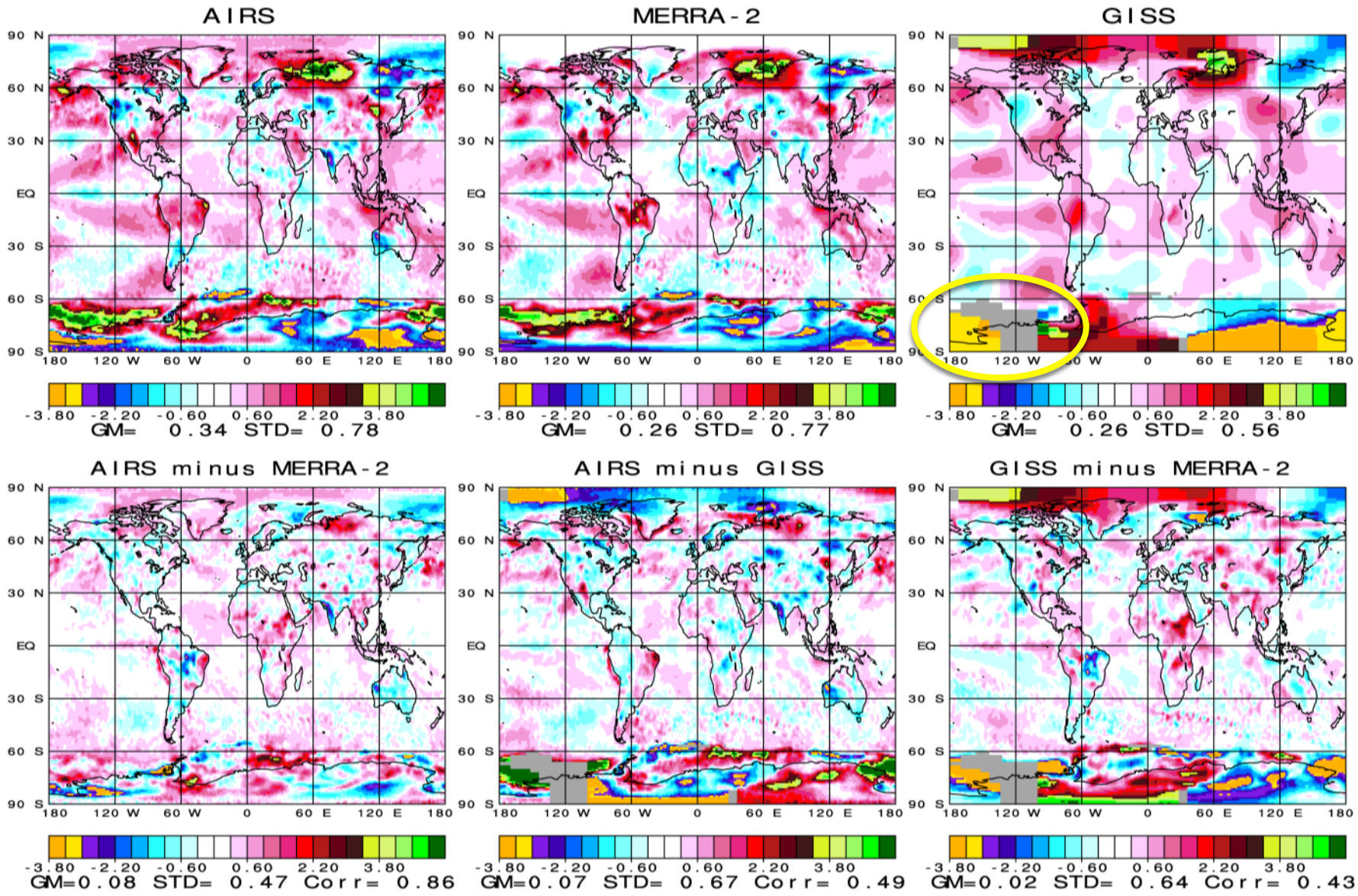

Surface Skin Temperature (K)
February 2016 minus 2003 through 2016 average
AIRS
MERRA-2
GISS
90 N
60 N
30 N
EQ
30 S
60 S
90 S
180 120 W 60 W 0 60 E 120 E 180
-3.80 -2.20 -0.60 0.60 2.20 3.80
GM= 0.52 STD= 1.34
GM= 0.50 STD= 1.31
GM= 0.67 STD= 1.17
AIRS minus MERRA-2
AIRS minus GISS
GISS minus MERRA-2
GM=0.03 STD= 0.62 Corr= 0.88
GM=-.15 STD= 0.70 Corr= 0.81
GM=0.17 STD= 0.70 Corr= 0.80


Surface Skin Temperature (K)
March 2016 minus 2003 through 2016 average
AIRS
MERRA-2
GISS
90 N
60 N
30 N
EQ
30 S
60 S
90 S
180 120 W 60 W 0 60 E 120 E 180
-3.80 -2.20 -0.60 0.60 2.20 3.80
GM= 0.53 STD= 1.04
GM= 0.40 STD= 1.02
GM= 0.55 STD= 0.83
AIRS minus MERRA-2
AIRS minus GISS
GISS minus MERRA-2
GM=0.13 STD= 0.53 Corr= 0.88
GM=-.02 STD= 0.64 Corr= 0.67
GM=0.15 STD= 0.60 Corr= 0.67

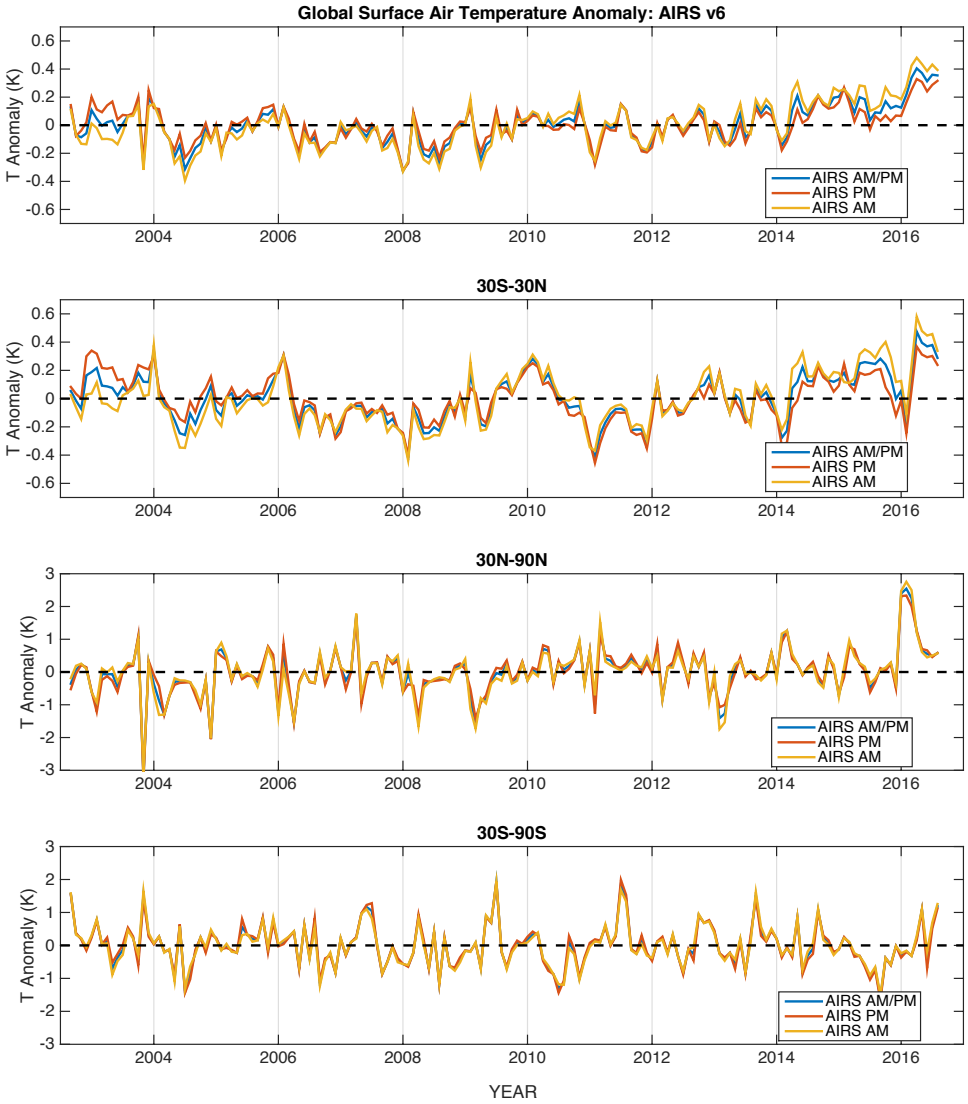

Surface Skin Temperature (K)
April 2016 minus 2003 through 2016 average
AIRS
MERRA-2
GISS
90 N
60 N
30 N
EQ
30 S
60 S
90 S
180 120 W 60 W 0 60 E 120 E 180
-3.80 -2.20 -0.60 0.60 2.20 3.80
GM= 0.46 STD= 1.04
GM= 0.38 STD= 1.00
GM= 0.43 STD= 0.79
AIRS minus MERRA-2
AIRS minus GISS
GISS minus MERRA-2
GM=0.08 STD= 0.51 Corr= 0.90
GM=0.03 STD= 0.70 Corr= 0.66
GM=0.04 STD= 0.66 Corr= 0.62


Surface Skin Temperature (K)
May 2016 minus 2003 through 2016 average
AIRS
MERRA-2
GISS
90 N
60 N
30 N
EQ
30 S
60 S
90 S
180 120 W 60 W 0 60 E 120 E 180
-3.80 -2.20 -0.60 0.60 2.20 3.80
GM= 0.37 STD= 0.93
GM= 0.30 STD= 0.92
GM= 0.31 STD= 0.66
AIRS minus MERRA-2
AIRS minus GISS
GISS minus MERRA-2
GM=0.07 STD= 0.52 Corr= 0.85
GM=0.05 STD= 0.66 Corr= 0.61
GM=0.02 STD= 0.64 Corr= 0.60


Surface Skin Temperature (K)
June 2016 minus 2003 through 2016 average
AIRS
MERRA-2
GISS
90 N
60 N
30 N
EQ
30 S
60 S
90 S
180 120 W 60 W 0 60 E 120 E 180
-3.80 -2.20 -0.60 0.60 2.20 3.80
GM= 0.29 STD= 0.91
GM= 0.15 STD= 0.96
GM= 0.19 STD= 0.74
AIRS minus MERRA-2
AIRS minus GISS
GISS minus MERRA-2
GM=0.14 STD= 0.53 Corr= 0.87
GM=0.10 STD= 0.71 Corr= 0.58
GM=0.03 STD= 0.66 Corr= 0.72


Surface Skin Temperature (K)
July 2016 minus 2003 through 2016 average
AIRS
MERRA-2
GISS
90 N
60 N
30 N
EQ
30 S
60 S
90 S
180 120 W 60 W 0 60 E 120 E 180
-3.80 -2.20 -0.60 0.60 2.20 3.80
GM= 0.34 STD= 0.78
GM= 0.26 STD= 0.77
GM= 0.26 STD= 0.56
AIRS minus MERRA-2
AIRS minus GISS
GISS minus MERRA-2
GM=0.08 STD= 0.47 Corr= 0.86
GM=0.07 STD= 0.67 Corr= 0.49
GM=0.02 STD= 0.64 Corr= 0.43

Area mean Tair Time Series Anomaly (K)

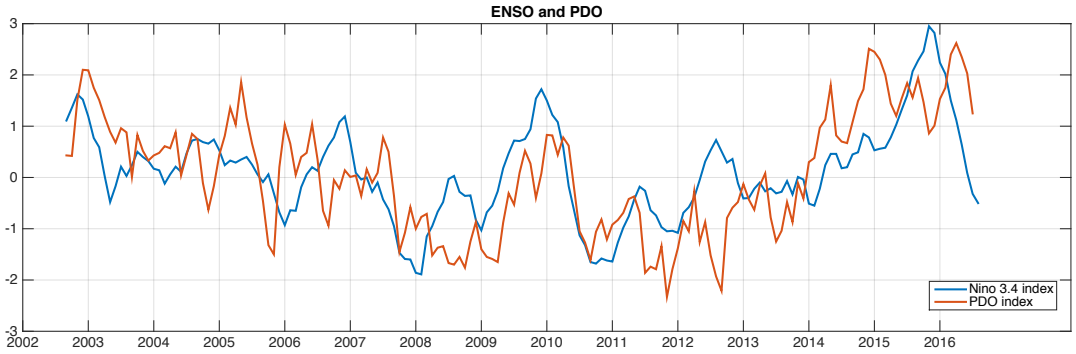


- ~ 0.5K global Ta anomaly during spring and summer 2016
- Nighttime Ta from descending orbit leads the global and tropical warming
- Global surface warming began in 2014

- Arctic winter/spring warming was unprecedented
- Antarctic fall/winter warming contributed

Relationship with spatial teleconnection patterns?

- Warming over southern Alaska and Canada since January could be the extra-tropical response to the El Niño impact [Cullather et al. 2016]. This warming signal is observed until April, when 2015/2016 El Niño significantly has decayed.
- The Pacific North American (PNA) teleconnection was in the positive phase from the last winter through April this year. The impact of the positive phase of the PNA is to act to drive warm condition over the region.

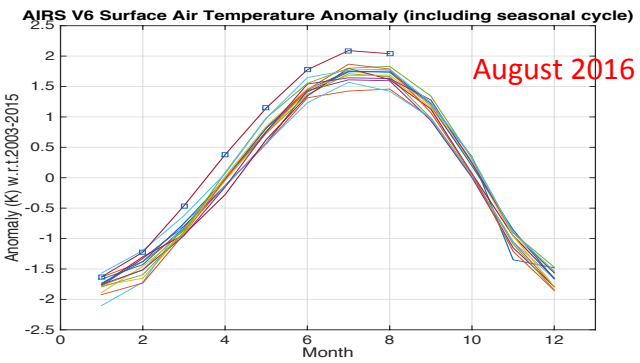


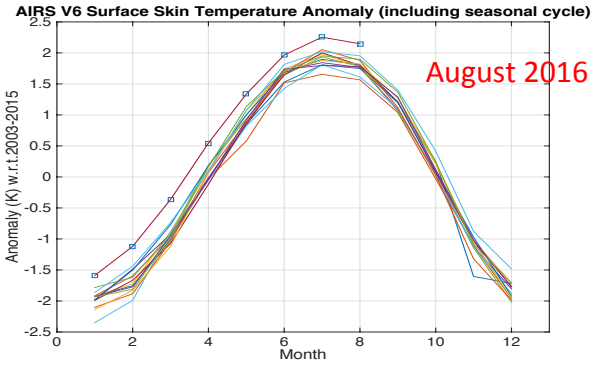
- Strong warming in Greenland in March and April : The NAO tends to drive warming over Greenland when the NAO is in the negative phase. The NAO in those months was, however, in the positive phase. The cause of the Greenland warming should be sought from the other climate impacts. (Needs further investigation)

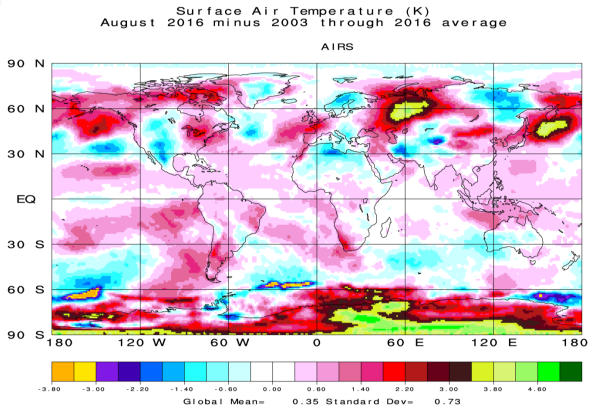
What happened in August 2016?

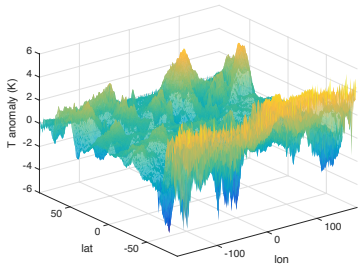
Yes, it was the warmest August as observed by AIRS.

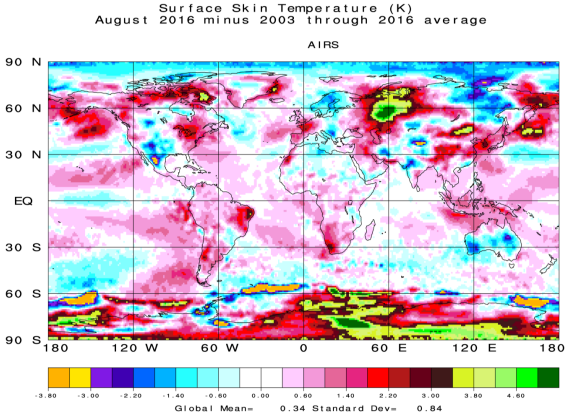
- AIRS processing is faster, surface temperature (Ts and Tair) broke the record of warmest August (summer) ever recorded.
- GES DISC only takes a few days to publish L3 monthly products.











Coolest

Spring (and Summer) as Observed by AIRS/AMSU

GES DISC
Goddard Earth Sciences Data and Information Services Center

NASA GHRC
Global Hydrology Resource Center

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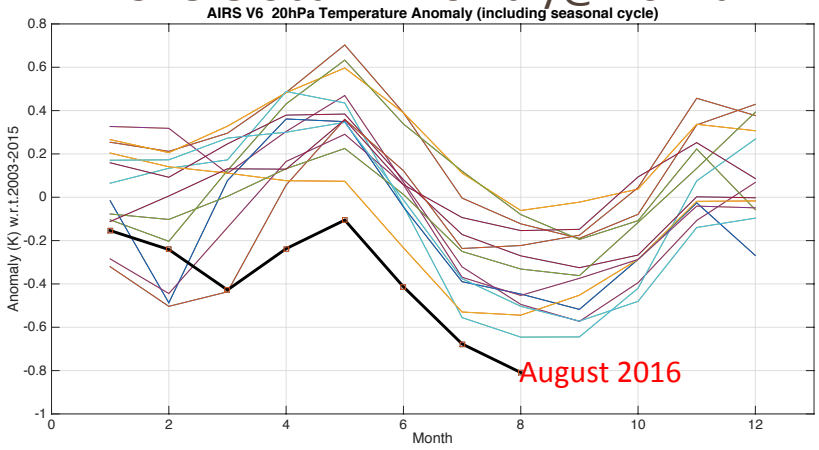
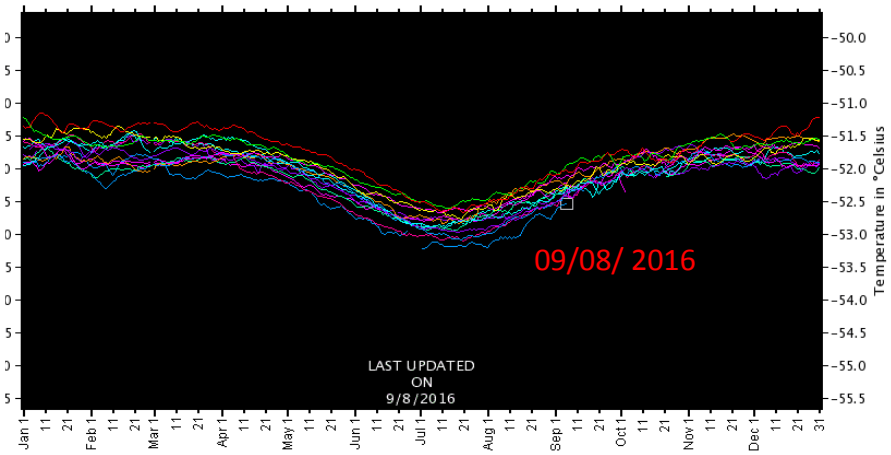
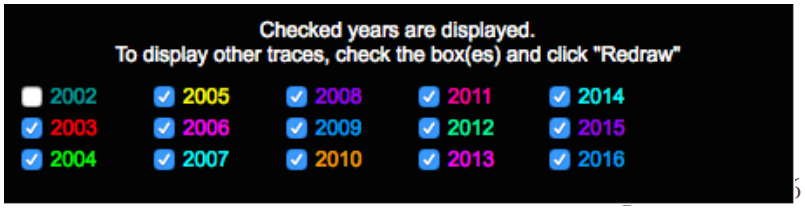
DAILY GLOBAL AVERAGE TEMPERATURE AT: 82,000 FT / 25 KM / 25 MB (AQUA CH11)

AIRS L3 Global T Anomaly@ 20hPa

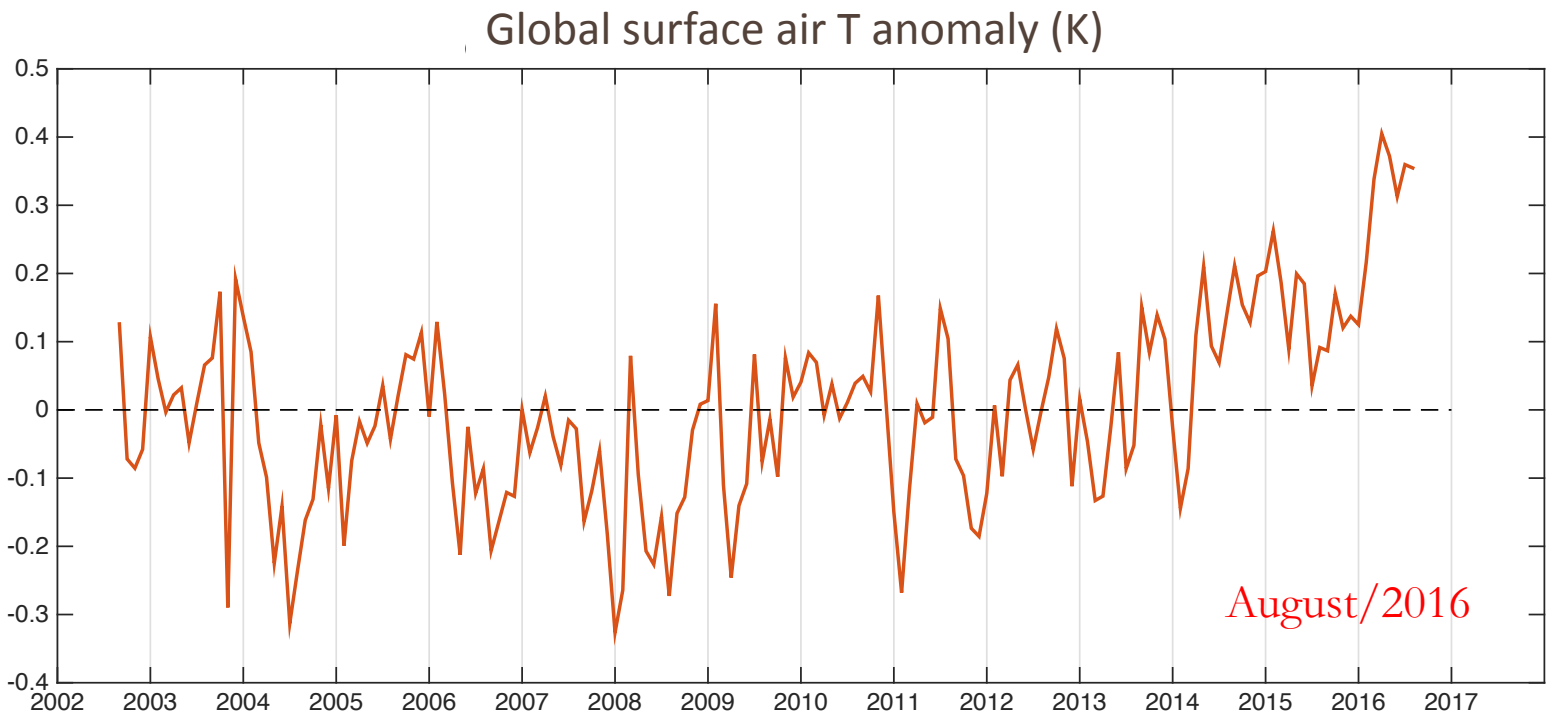


AMSU L1 Tb @ 25hPa

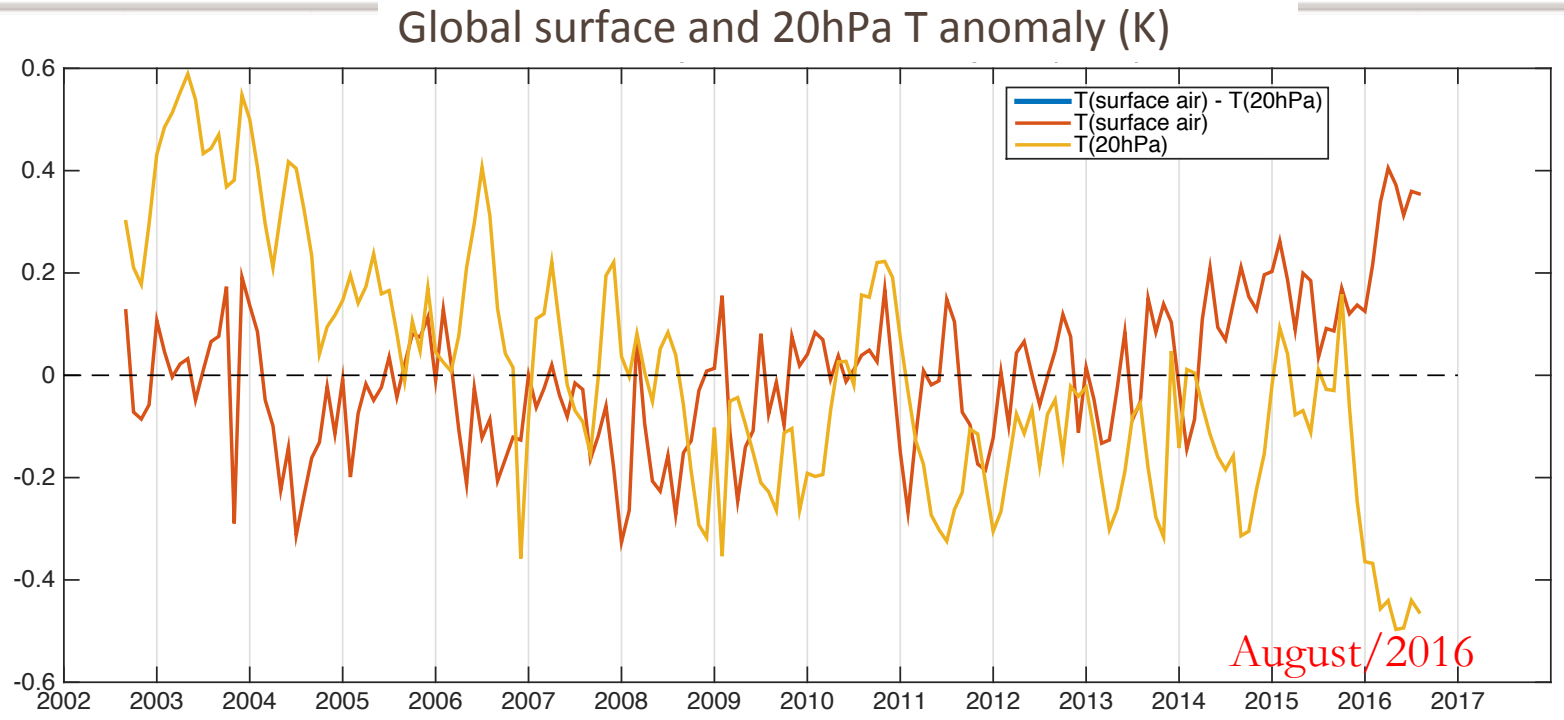




AIRS V6 L3 Global T Anomaly

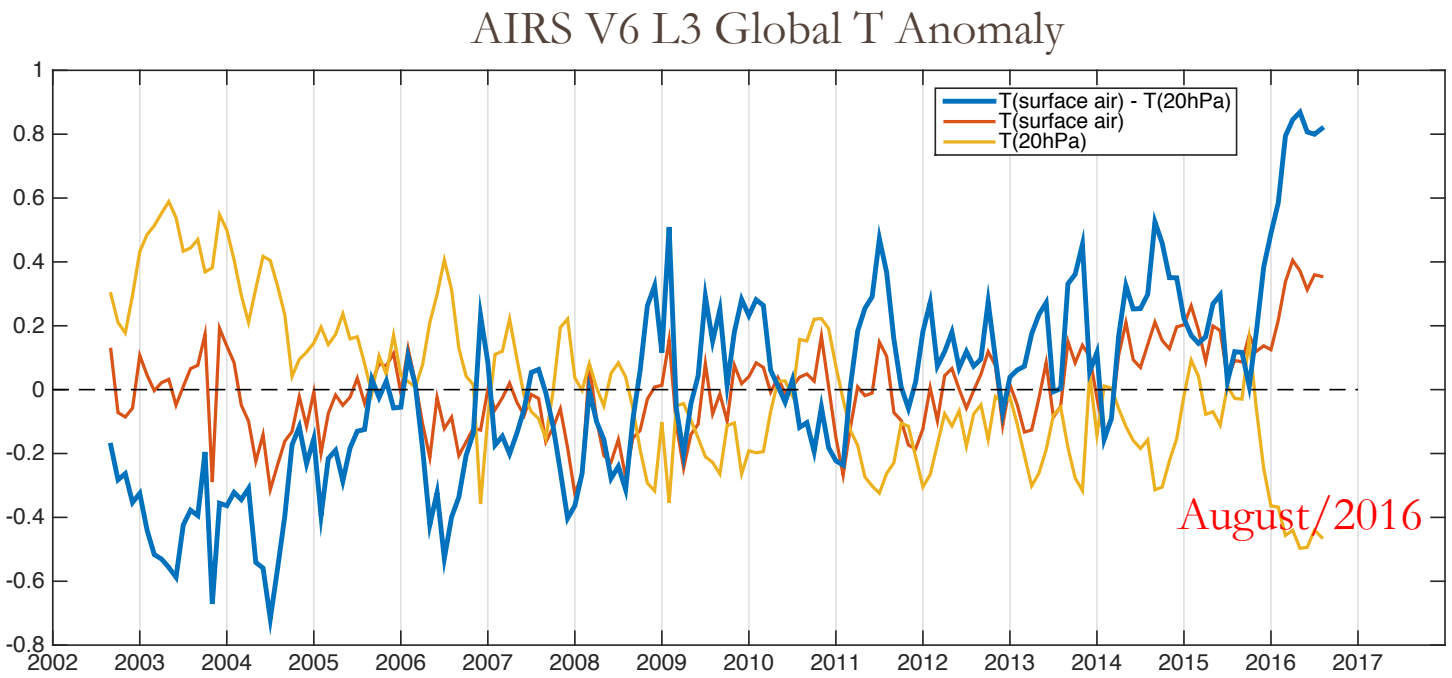


AIRS V6 L3 Global T Anomaly

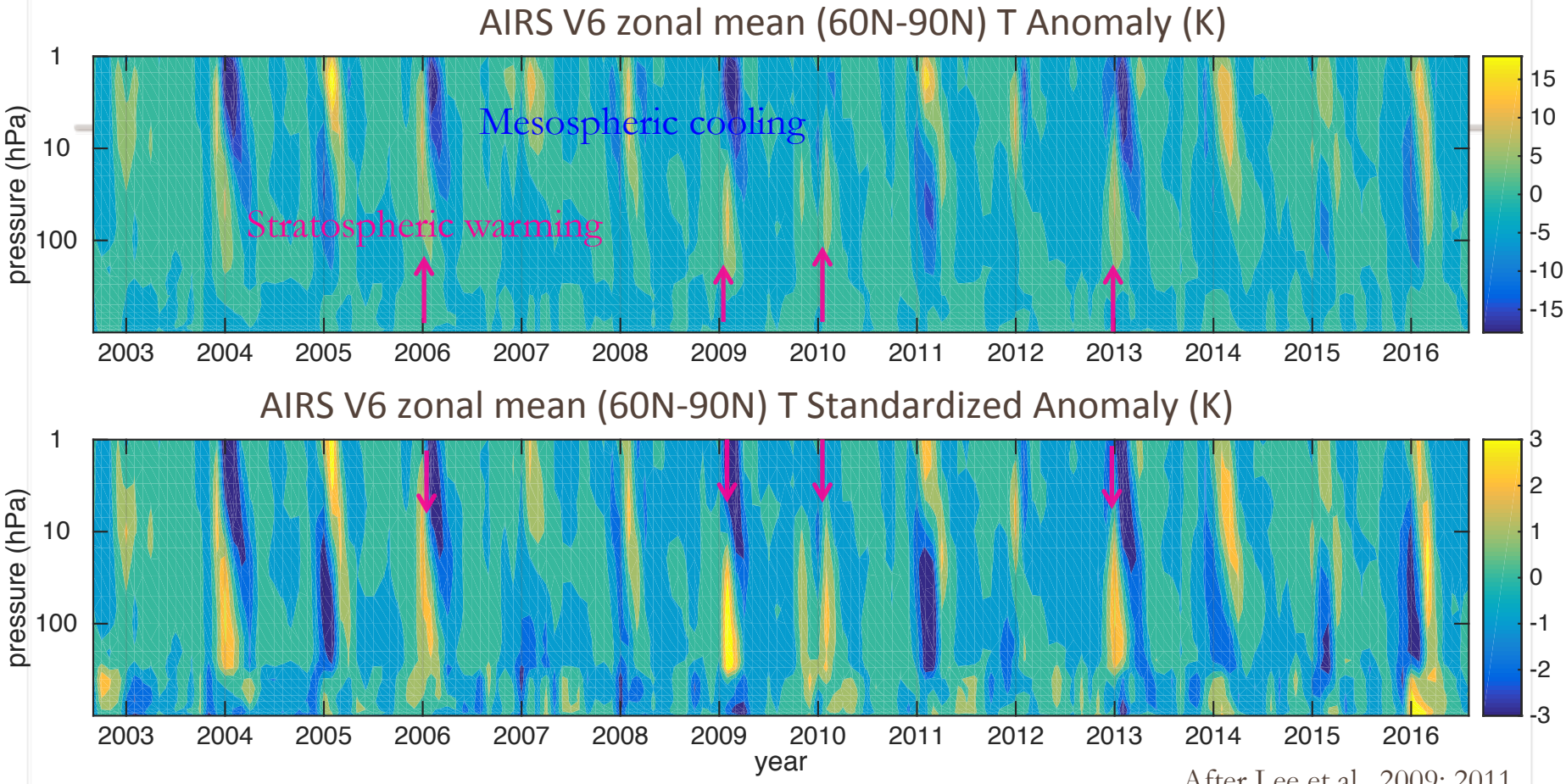


Is This a Vertical Human Fingerprint?

Surface warming with stratospheric cooling caused by CO_2 increase and ozone depletion [Santer et al., 2013; Randel et al. 2016]



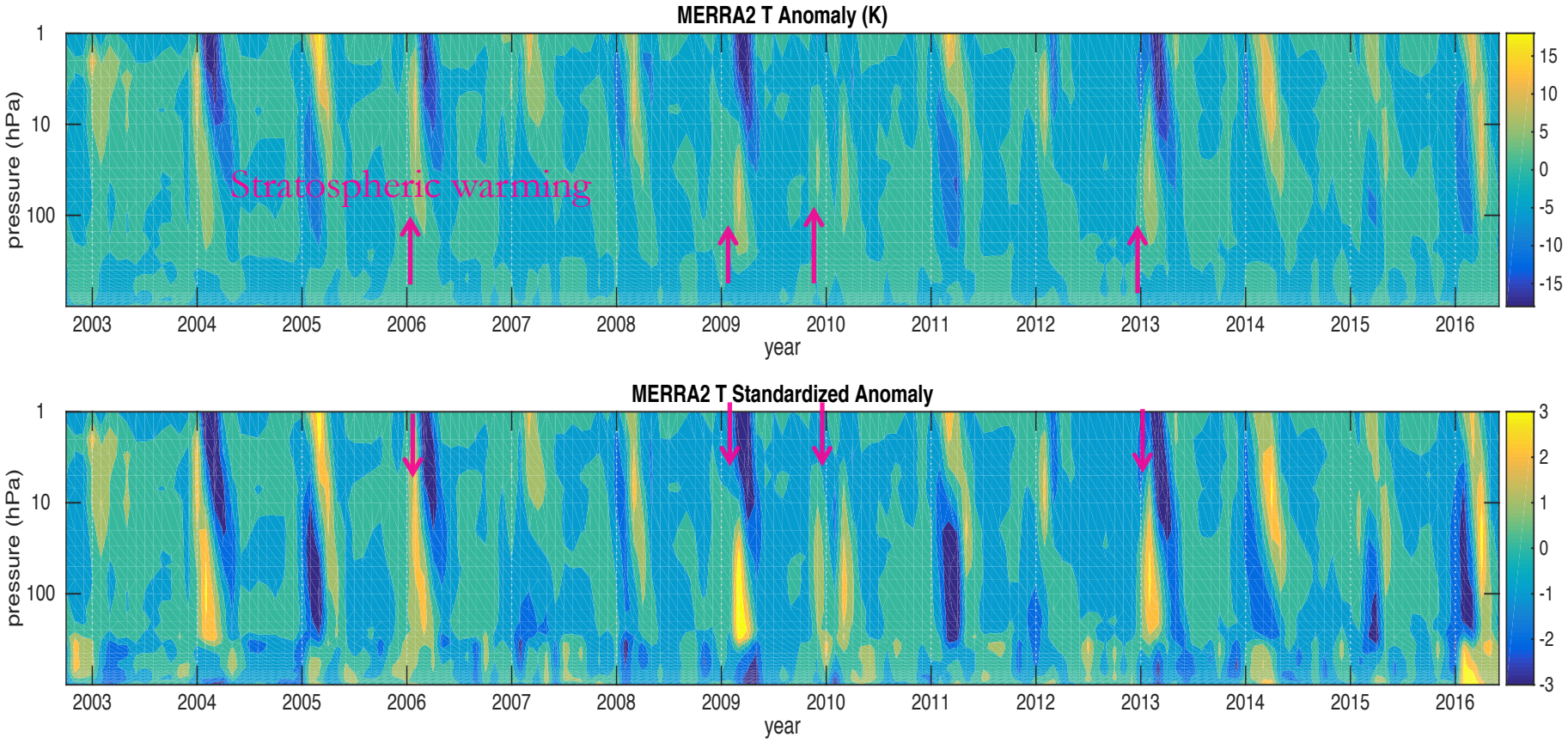
- **Relationship with vertical teleconnection patterns?**



After Lee et al., 2009; 2011

- Surface warming of 2016 spring is extending to 500hPa level, and connected with stratospheric cooling and warming afterwards.
- Temperature variations in stratosphere are large, but relative warming is outstanding at surface.

- **Relationship with vertical teleconnection patterns in MERRA2?**

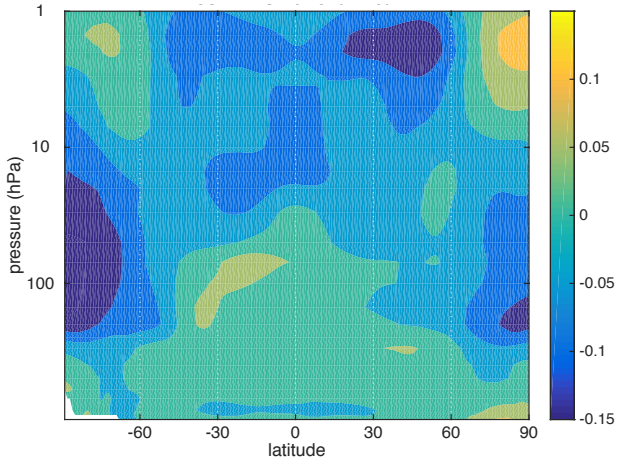


- MERRA2 Temperature also show identical vertical structure.

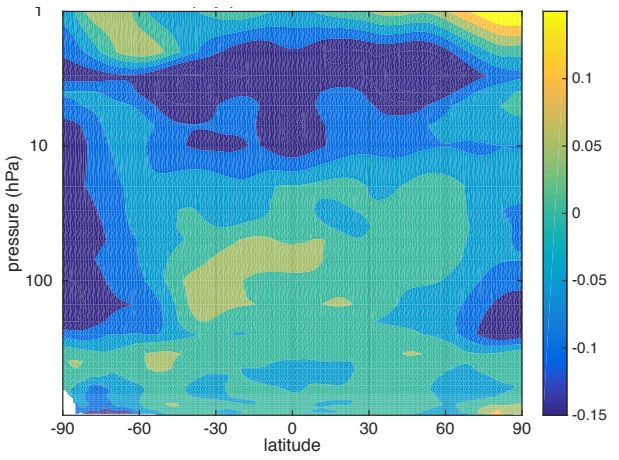
Stratospheric cooling trends?

Average Rates of Change (ARCs)

ARCs (K/yr): AIRS zonal mean T



ARCs (K/yr): MERRA2 zonal mean T



Summary

or probably warmest year

- 2016 is the warmest spring and summer as observed by AIRS. The global surface temperature anomaly patterns are in good agreement among AIRS, MERRA2, and GISTEMP.
- Teleconnections? More study is needed.
- It is also the coolest spring and summer in the stratosphere as observed by AMSU/AIRS. Is this vertical human fingerprint by CO_2 increase and/or ozone depletion? What would be the consequences of this cooling?
- More validation of AIRS data in the stratosphere with MLS, etc. and models.

Acknowledgment

- NASA IDS and Terra-Aqua program
- AIRS, MERRA2, and GISTEMP K. W. Lo and Team
- GES DISC and GHRC Team for data tool