Recent Global Warming as Observed by AIRS and Depicted in GISSTEMP and MERRA-2

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Overview

This paper compares monthly mean anomaly time series of earth surface temperature $T_s$ contained in 4 different data sets:

AIRS/AMSU Version-6
- September 2002 – August 2016
- AMSU A2 died in September 2016

AIRS Only Version-6 (AO)
- September 2002 – September 2017

MERRA-2
- September 2002 – September 2017

*GISS TEMP(GIS)
- September 2002 – July 2017

*GIS is considered the “Gold Standard” of surface temperature data sets. GIS uses only in-situ measurements.
Construction of Monthly $T_s$ Anomalies

We constructed $T_s$ anomalies for each data set on a $1^\circ$ lat by $1^\circ$ lon spatial scale. The $T_s$ anomaly for a given month, in a given year, is the difference of its value for that year from a 14 year $T_s$ climatology we constructed for that month.

Monthly Climatologies

Monthly climatologies are based on 14 consecutive years for that month.

- September–December: 14 consecutive years from September 2002-December 2015.
All data sets show oscillations, but with an onset of significant global warming starting in 2015, with a peak in early 2016.
AIRS/AMSU anomalies match those of AO very closely over their common time period. MERRA-2 anomalies have a discontinuity compared to AO in the 2007-2008 time frame. They are higher than AO through 2006 and lower after 2009.
Tropical mean GIS data is only available through December 2016. The tropics, representing 50% of the globe, has warmed as much as the whole globe did after 2015. Therefore tropical and extratropical warming has been the same after 2015.
Two types of spatial plots related to $T_s$ anomalies are shown:

1) Average rates of change (ARCs) of anomaly time series.
   The ARC of an anomaly time series is the slope of the least squares fit to the anomaly time series ($K/yr$).
   We compare ARCs of AO, GIS, and MERRA-2 $T_s$ values over the time period September 2002 through July 2017, as well as anomalies for July 2017.

2) Spatial plots of recent AO $T_s$ anomalies.
   Monthly mean $T_s$ anomalies have large scale structures. Some areas are warmer than their climatological values, and some are cooler. These locations change from month to month, and year to year, but recent global mean $T_s$ anomalies are all positive, as are tropical mean anomalies.
A discontinuity in MERRA-2 $T_s$ anomalies has resulted in a spurious global trend showing almost no warming. Significant differences between AO and MERRA-2 ARCs exist over Africa and Antarctica.

AIRS and GIS both show the Earth’s surface has warmed globally by about 0.022 K/yr over the period September 2002 through July 2017. GIS is at a $2^\circ \times 2^\circ$ spatial resolution. Its features are smaller and smoother than those of AIRS. The relative GIS and AO patterns agree very well.

ARCs September 2002 through July 2017

**GIS Surface Temperature ARC (K/yr)**

Mean = 0.021  STD = 0.023

**AO Surface Skin Temperature ARC (K/yr)**

Mean = 0.024  STD = 0.032

**MERRA-2 Surface Temperature ARC (K/yr)**

Mean = 0.006  STD = 0.042

A discontinuity in MERRA-2 $T_s$ anomalies has resulted in a spurious global trend showing almost no warming. Significant differences between AO and MERRA-2 ARCs exist over Africa and Antarctica.
Basic patterns of AIRS and GIS July 2017 $T_s$ anomalies are very similar. As with ARCs, GIS anomalies are smoother and weaker. The global mean MERRA-2 $T_s$ anomaly is less positive than those of AO or GIS, but July 2017 anomaly patterns agree reasonably well with those of AO.
February and March 2016 and 2017 all have very large positive global mean $T_s$ anomalies. All anomalies show an El Niño pattern, with values larger in 2016 than in 2017. Corresponding global mean $T_s$ anomalies are also more positive in 2016.
El Niño conditions still exist in all months, but are weaker than they were in February and March. Global mean $T_s$ anomalies are positive, but are less so than in the previous 2 months in both years. The largest $T_s$ anomalies occur poleward of 60°N and 60°S.
El Niño conditions no longer exist, but positive global mean $T_s$ anomalies still exist. $T_s$ anomalies are largest in polar regions, especially in local winter. The tropics remain anomalously warm.
La Niña conditions are beginning in both 2016 and 2017. Global mean $T_s$ anomalies remain positive, but are less in 2017 than in 2016. Part of this reduction is a result of large negative $T_s$ anomalies poleward of 60°S.
Summary

- AIRS Version-6 monthly mean level-3 surface temperature products confirm the reported result, depicted in the GISSTEMP dataset, that the earth's surface temperature has been warming since early 2015. AIRS is at a higher spatial resolution than GISSTEMP, and produces sharper spatial features which are otherwise in excellent agreement with those of GISSTEMP with regard to both ARCs and anomalies.

- Version-6 AO $T_s$ anomalies are consistent with those of Version-6 AIRS/AMSU over their common time period. Version-7 AO anomalies should be even more accurate than Version-6 AO, especially at high latitudes.

- ARCs of MERRA-2 $T_s$ anomalies have spurious features. Part of this is the result of a discontinuity which occurred somewhere between 2007 and 2008, which also resulted in spuriously low global mean trends.