Six-Month (May 1 2011 – Oct 31 2011) Report for

NOAA CDR Project (Award No. NA10NES4400004)

Creating UTH-Related FCDRs from IR and Microwave Sensors Cross Calibrated by In Situ Measurements from Commercial Aircraft

Principal Investigator:

Zhengzhao "Johnny" Luo

Dept. of Earth & Atmospheric Sciences
and NOAA-CREST Center
City College of New York, CUNY
New York NY 10031
Phone: 212-650-8936
Email: luo@sci.ccny.cuny.edu

Co-Investigators:

William B. Rossow

Dept. of Electrical Engineering
and NOAA-CREST Center
City College of New York, CUNY
New York NY 10031

Dieter Kley

Department of Atmospheric Science
Colorado State University
Fort Collins CO 80523
and
ICG-2, Forschungszentrum Juelich (FZJ)
Germany

Recipient's Institute:

Attn: Adam Greenberg

Acting Director of Research Administration
City College of New York, CUNY
212-650-7904
New York NY 10031

1. Introduction & Overview

As described in the original proposal, the objective of this project is to "*bring together all the upper-tropospheric humidity (UTH)-relevant radiance data from multiple satellites and process them to establish a long-term, global radiance record from which a climate data record (CDR) of UTH can be retrieved and UTH research may be conducted*". Emphasis is placed on the *microwave sensors*, in particular those that have not been well archived in the past, such as SSM/T2. IR UTH radiances, in contrast, have been thoroughly studied (e.g., Bates et al. 1996; 2001) and were already turned into an operational CDR by NCDC scientists (see http://www.ncdc.noaa.gov/cdr/operationalcdrs.html). Fig. 1 shows an example of the 183 ±1 GHz brightness temperature (TB) measurements from SSM/T2. One can clearly see the dry and moist regions in the tropics and midlatitude, as represented by high and low TBs, respectively.

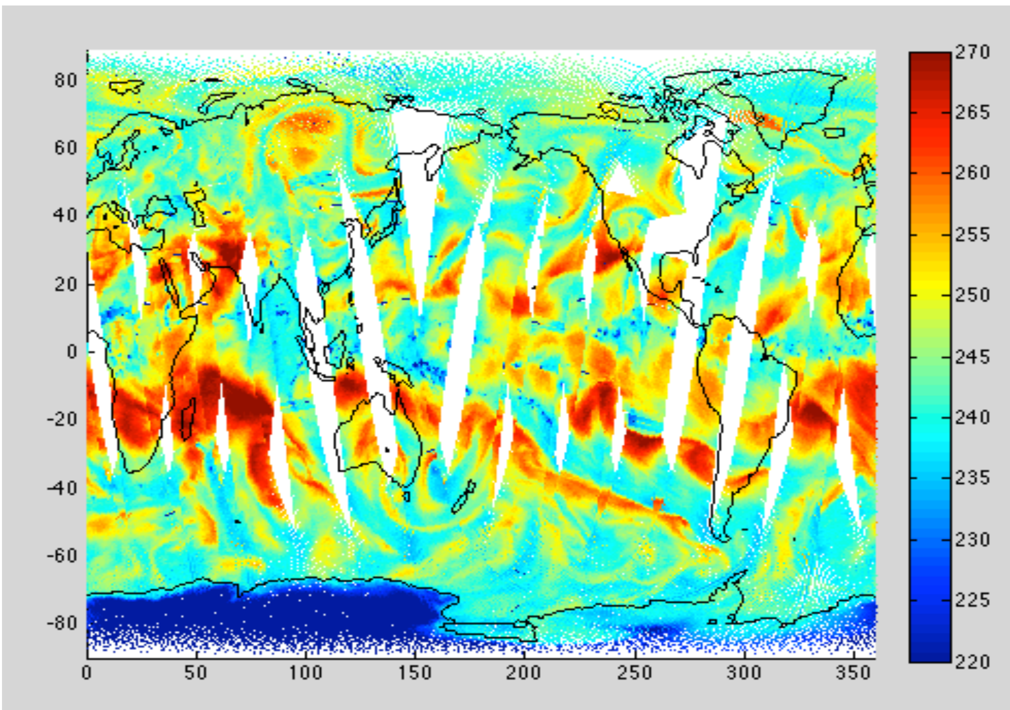

Figure 1. Brightness temperature (TB) at 183 ±1 GHz from SSM/T2 for May 24 1999. This channel is mostly sensitive to upper-tropospheric humidity.

For the past 6 months (May 1 2011 – Oct 31 2011), our research efforts focused on the following areas:

1. Repackaging and cleaning up SSM/T2 data: a continuing effort
2. An attempt for absolute calibration: compare SSM/T2 brightness temperatures with the matched MOZAIC sounding profiles
3. Relative calibration 1: Simultaneous Nadir Overpass (SNO) analysis of SSM/T2 from different satellites

4. Relative calibration 2: Comparison of zonal/monthly mean brightness temperatures among different satellites

2. Research Progress

2.1 Repackaging and cleaning up SSM/T2 data: a continuing effort

An important goal of this CDR project is to create a clean version of the SSM/T2 data. We've been working toward this goal since the beginning of the project. Over the past 6 months, we addressed the following issues:

1) Estimate missing parameters in metadata:

Our current version of the SSM/T2 data is from the NESDIS archive (NSS.SSMT2 files). In this archive, metadata change from time to time. Specifically, the offset parameters that convert the raw count to brightness temperature (TB) changed twice: one in February 1999 (well documented), and another change in September 2001 that was, unfortunately, undocumented, making the whole SSM/T2 data unusable after that. We tried to estimate the missing offset by comparing TB distribution for October 2001 (the month after the change) with that of the previous October. The same analysis was done for other months. Under the assumption that TB distribution stays the same for the same month of different years, the best-fit offset value was selected as our "guesstimate" of the missing offset parameter [*].

2) Incomplete data record

SSM/T2 data from NESDIS archive only cover 1994-2005. With the help of Hilawe Semunegus (NCDC), we are working with NOAA NGDC to obtain data for other years. Just a few days ago, NGDC uploaded the whole data record (from 1992 till now; ~80 GB) unto their server. We are in the process of downloading them. Early in the summer, NGDC sent us two months of their version of the SSM/T2 archive. We've used those data to set up our code already. Some minor inconsistency (e.g., shift of a few scan lines) exists between the NESDIS and NGDC version.

2.2 An attempt for absolute calibration: compare SSM/T2 brightness temperatures with matched MOZAIC sounding profiles:

We compared SSM/T2 brightness temperatures (TB) at 183 GHz with matched temperature/humidity profiles derived from MOZAIC take-off and landing measurements (which we interpret as representing the local sounding). To convert from sounding profiles to TBs, we employed the Community Radiative Transfer Model (ftp://ftp.emc.ncep.noaa.gov/jcsda/CRTM/). So far, we completed the analysis of one satellite (F-14): ~1200 matched cases were found. But to reduce uncertainties, we imposed some extra conditions: 1) the MOZAIC takeoff/landing profiles have to extend to above 250 hPa (because the weighting function for 183 ±1

---

[*] PI's note: a major challenge facing the task of re-archiving SSM/T2 data is lack of experts to consult. We had to "plow" through the data using various trial-and-error methods.

GHz has some significance contribution from above 250 hPa); 2) clear sky during takeoff or landing (we adopted the cloudy/clear index as proposed by Buehler et al. 2007). Eventually, only ~ 200 data points pass all these conditions. Figure 1 shows scatter plot of the observed Vs simulated TB(183±1 GHz) for F-14. The regression line shows that the simulated TBs are colder than the observed by ~ 1-3K, with some scattering ($R^2 \sim 0.8$). Currently, we are working on other satellites (F12, F-15) to see if we have a similar conclusion.

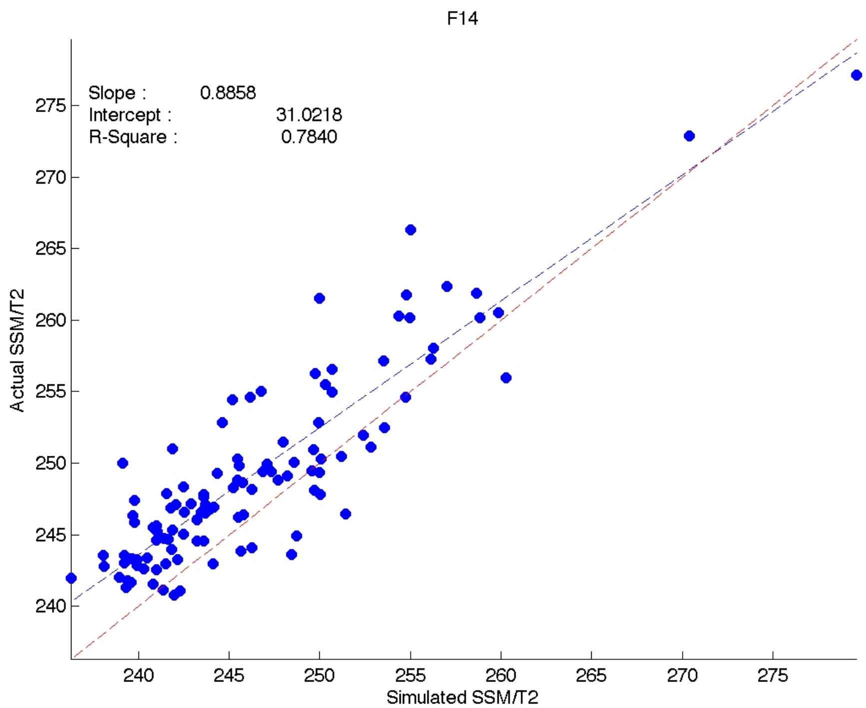

Figure 2. Simulated Vs observed TB (183±1 GHz). Results are shown for F-14 only.

2.3 Relative calibration 1: Simultaneous Nadir Overpass (SNO) analysis of SSM/T2 from different satellites

Simultaneous Nadir Overpass (SNO) has become a standard approach to inter-calibrate two satellites (Cao et al. 2004). Figure 3 shows the Equator Crossing Time for different satellites carrying SSM/T2. The overlapped periods between any two satellites can be exploited for SNO analysis. Considering the spatial resolution of SSM/T2 (~ 48 km at nadir), we impose the spatial and temporal separation thresholds at 100 km and 1 min, respectively. Figure 4 shows one example of the SNO comparison between F-12 and F-14 (red dots). Overall, the two TB records agree very well, with the bias being less than 0.5 K and $R^2 \sim 0.98$. Similar analysis has been performed for other satellite pairs. For the 183 ±1GHz channel, agreement is generally within 1 K, although in some cases, there is fair amount of scattering.

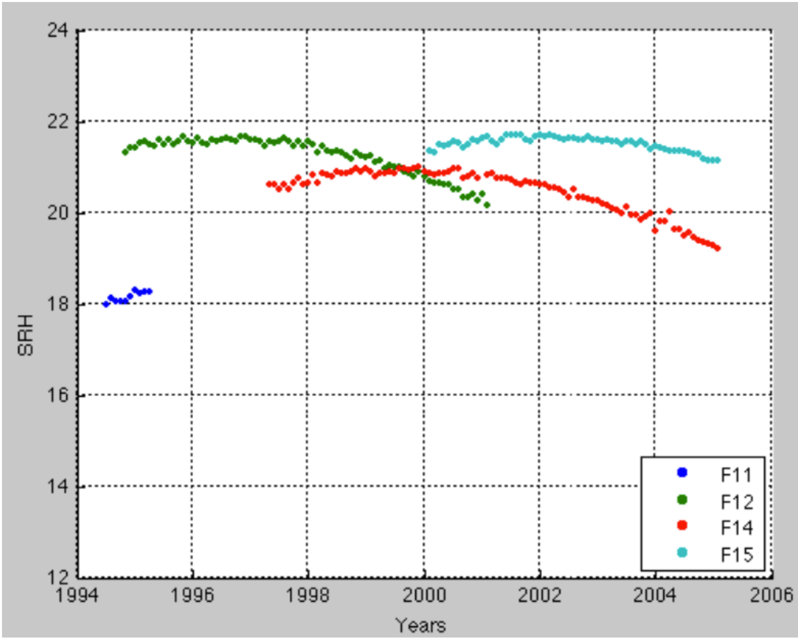

Figure 3. Equator Crossing Time for different satellites carrying SSM/T2. Data before 1994 and beyond 2005 are not available from NESDIS, but NGDC is helping us retrieve them.

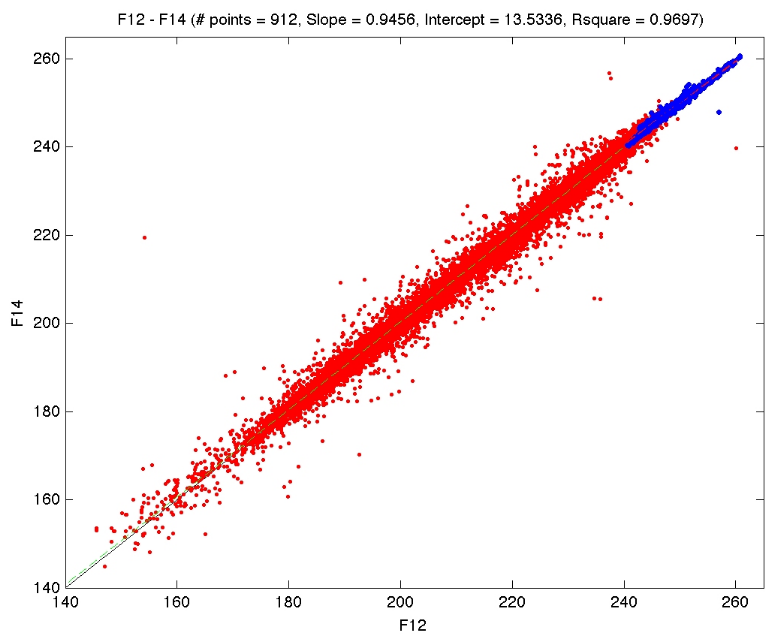

Figure 4. (Red) SNO analysis for TB (183 ±1GHz) from F-12 and F-14. (Blue) Zonal/monthly mean comparison between F-12 and F-14.

<u>2.4 Relative calibration 2: Comparison of zonal/monthly mean brightness temperatures among different satellites</u>

One constraint for the SNO approach is that the comparison can only be done over the high latitudes, where two polar-orbiting satellites meet. To compensate for this limitation, we also compare the monthly/zonal mean TBs for the latitudinal zones between 60S-60N, where SNO does not cover. The blue dots in Fig. 4 show such a comparison between F-12 and F-14 for the same latitude and month. The relative shifts between the two satellites are within 0.6 K. Similar analysis has been done for other satellite pairs.

3. Future plans

This is the 2nd year of the 3-year project. Our immediate future plans for the next 6 months include (Nov 1 2011 – Apr 30 2012):

1) Continue with the SSM/T2 data "clean-up" and repackaging effort.
2) Incorporate AMSU-B water vapor radiances
3) Continue to work on the different calibration methods, looking for consistency among them.

For the final year (May 1 2012 – Apr 30 2013), we will focus on:

1) Package up SSM/T2 and AMSU-B UTH radiances as a FCDR, with all the inter-calibration procedures documented and calibration coefficients provided
2) Append the UTH FCDR with new ISCCP 10-km cloud products
3) Transition code and operation to NCDC

References:

Cao, C., M. Weinreb, and H. Xu, 2004: Predicting simultaneous nadir overpasses among polar-orbiting meteorological satellites for the intersatellite calibration of radiometers, J. Atmos. Oceanic Technol., 21, 537 - 542

Bates, J. J., X. Wu, and D. L. Jackson, 1996: Interannual variability of upper-tropospheric water vapor band brightness temperature, *J. Climate*, 9, 427-438

Bates, J. J., D. L. Jackson, F.-M. Breon, and Z. D. Bergen, 2001: Variability of tropical upper tropospheric humidity 1979 – 1998, *J. Geophys. Res.*, 106, 32,271-32,281.

Buehler, S. A., M. Kuvatov, T. R. Sreerekha, V. O. John, B. Rydberg, P. Eriksson, and J. Notholt, 2007: A cloud filtering method for microwave upper tropospheric humidity measurements, Atmos. Chem. Phys., 7, 5531-5542

Six-Month (Nov 1 2011 – Apr 30 2012) Report for

NOAA CDR Project (Award No. NA10NES4400004)

Creating UTH-Related FCDRs from IR and Microwave Sensors Cross Calibrated by In Situ Measurements from Commercial Aircraft

Principal Investigator:

Zhengzhao "Johnny" Luo

Dept. of Earth & Atmospheric Sciences
and NOAA-CREST Center
City College of New York, CUNY
New York NY 10031
Phone: 212-650-8936
Email: luo@sci.ccny.cuny.edu

Co-Investigators:

William B. Rossow

Dept. of Electrical Engineering
and NOAA-CREST Center
City College of New York, CUNY
New York NY 10031

Dieter Kley

Department of Atmospheric Science
Colorado State University
Fort Collins CO 80523
and
ICG-2, Forschungszentrum Juelich (FZJ)
Germany

Recipient's Institute:

Attn: Adam Greenberg

Acting Director of Research Administration
City College of New York, CUNY
212-650-7904
New York NY 10031

1. Overview

The objective of this project is to "*bring together all the upper-tropospheric humidity (UTH)-relevant radiance data from multiple satellites and process them to establish a long-term, global radiance record from which a climate data record (CDR) of UTH can be retrieved and UTH research may be conducted*". Because the IR UTH radiances (e.g., HIRS Channel 12) have already been made an operational CDR by scientists at NCDC, the emphasis of our project is placed on the microwave sensors. In particular, we focus on the UTH radiances from SSM/T2, a poorly archived and documented dataset. Further, realizing that UTH is closely related to deep convection and high clouds, we append the UTH radiances with cloud information from the ISCCP, making the CDR more research friendly.

From November 2011 – April 2012, our research and data production effort focus on the following two areas:

1. Clean up and calibrate the NGDC version of SSM/T2 data (1992-2008)
2. Merge SSM/T2 with ISCCP cloud product

2. Research Progress

2.1 Clean up and calibrate the NGDC version of SSM/T2 data

At the beginning of the project, we received the first version of SSM/T2 data from NESDIS, which only covers 1994-2001 (data files exist until 2005 but because of a metadata problem, no useful information can be retrieved from 2001 to 2005). Various calibration methods have been tested using these data. Recently, with the help of Hilawe Semunegus (NCDC) and Daniel Kowal (NGDC), we were able to obtain the NGDC archive of the SSM/T2, a more complete version that spans from April 1992 to May 2008. Figure 1 shows the temporal coverage of the NGDC archive using the Equator Crossing Time (at descending node) of the DMSP satellites that carry SSM/T2. Much of the work over the past six months have been put on analyzing this longer data record.

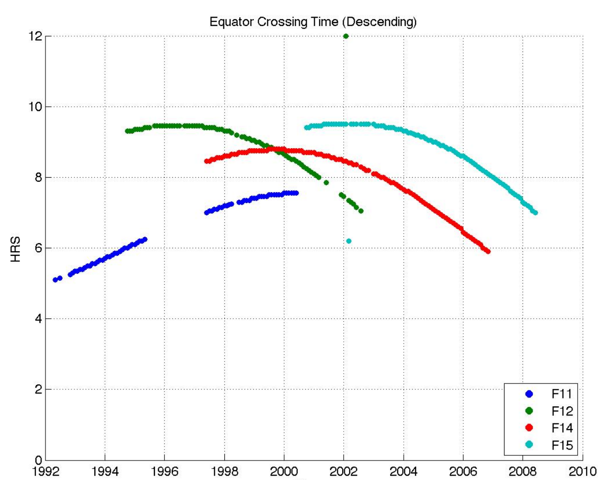

Figure 1. Equator Crossing Time (at descending node) of the DMSP satellites that carry SSM/T2 based on NGDC archive.

Unlike the NESDIS archive, SSM/T2 data from NGDC are not as well documented. It took us some time to figure out data format. Simultaneous nadir overpass (SNO) analysis was conducted to inter-calibrate the data, following Cao et al. (2004). Table 1 summarizes the calibration results for 183 ±1 GHz. We are now in the process of calibrating them against MOZAIC sounding data using CRTM as a bridge. Eventually, we look for consistency among different calibration methods.

Satellite Pairs	Slope	Intercept	R-Square
F11 - F12	0.98	2.63	1.00
F11 - F14	0.99	2.38	0.99
F12 - F14	1.00	1.18	0.99
F12 - F15	0.99	1.45	0.98
F14 - F15	0.98	2.82	0.95

Table 1. Slope and intercepts for SNO comparison between overlapping pairs of satellites.

2.2 Merge SSM/T2 with ISCCP cloud information

SSM/T2 UTH radiances are influenced by high-level clouds, especially those thick high clouds with large ice particles. To better calibrate SSM/T2 radiances, certain cloud clearing is needed. Another motivation for appending collocated cloud information is for future research concerning the influence of deep convection on UTH (e.g., Luo et al. 2012). Programming code has been developed over the past several months to merge ISCCP pixel-level data with SSM/T2. Testing is being performed to assess the merged product.

3. Future Plans

The immediate future plans (May 2012 – Oct 2012) are as follows:

1. Finish different calibration analyses (e.g., SNO, MOZAIC-SSM/T2 comparison) for the NGDC version of SSM/T2 data; look for consistencies.
2. Finish merging SSM/T2 and ISCCP; append cloud information to SSM/T2 radiances.

3. Incorporate AMSU-B UTH radiances (another CDR team, led by Ralph Ferrro and Huan Meng, is also working on AMSU-B data; collaboration will be formed between the two groups).

As we are entering into the 3rd year of the project, our research will gradually shift to finishing up calibration, packaging up software and delivering code and data to NCDC.

References:

Cao, C., M. Weinreb, and H. Xu, 2004: Predicting simultaneous nadir overpasses among polar-orbiting meteorological satellites for the intersatellite calibration of radiometers, J. Atmos. Oceanic Technol., 21, 537 - 542

Bates, J. J., X. Wu, and D. L. Jackson, 1996: Interannual variability of upper-tropospheric water vapor band brightness temperature, *J. Climate*, 9, 427-438

Luo, Z. J. , D. Kley, R. H. Johnson, G. Y. Liu, S. Nawrath, and H. G. J. Smit, 2012: Influence of sea surface temperature on humidity and temperature in the outflow of tropical deep convection, J. Climate, 25,1340-1348