NOAA/SDS Project Status Report

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Title: A Fundamental Climate Data Record of SSM/I, SSMIS, and Future Microwave Imagers
Period: Year 1 (July 1, 2009 – June 30, 2010)

Long-term Research Objectives and Specific Plans to Achieve Them:

To create a Fundamental Climate Data Record (FCDR) of the operational SSM/I and SSMIS sensors starting with F8 in July of 1987 and extending to the present, with the potential for application to future operational microwave imagers such as MIS. Our framework for this effort involves creating both a new Level 1A dataset, which we refer to as BASE files, as well as the final FCDR. The proposed new Level 1A Base file dataset will contain the original counts recorded by the sensor as well as all the available sensor data such as hot and cold loads, thermister temperatures, spacecraft ephemeris and pointing information, etc. Unlike the original data the files will be broken into single orbit granules and written in NetCDF. This will provide a starting point for the creation of the FCDR, and would preserve the most original information from the satellite/sensor available to allow for future refinements of the techniques if necessary. The final FCDR will incorporate our best effort intercalibration as well as quality control of the original data, improved geolocation and Earth incidence angle information, and corrections for any other issues such as cross-track biases etc. Many of the specific objectives for this project are as follows.

Specific Objectives:

- Development and production of a Level 1A BASE file dataset in NetCDF. This will involve orbitized Level 1 data granules containing all of the information in the original Temperature Data Record (TDR) files. In addition, certain value added fields will be added including improved spacecraft ephemeris data calculated from from NORAD Two-Line Element (TLE) files, additional date/time fields in a human readable format, and comprehensive metadata fields.
- Revisit quality control procedures and reconstruction of the most complete possible time series of SSM/I TDR data.
- Characterization of anomalous emission/reflection from targets such as antenna emission, lunar emission, and others. Several known issues include the falloff in brightness temperatures from SSM/I near the edge of the scan as well as an emissive SSMIS antenna.
- Characterization of radio frequency interference for several intensive contamination periods and development of correction algorithms. This is particularly an issue with the activation of the radar calibration (i.e., RADCAL) beacons on board F15 in August of 2006. Corrections have been published for the 22.235-GHz channel, but noise apparent in alternating 85-GHz, H-polarization scans is not as well understood.

- Characterization of warm load instability and solar/stray light contamination and computation of solar angles for analysis of spacecraft heating on calibration.
- Characterization of sensor specific antenna pattern function for accurate antenna to sensor brightness conversion.
- Characterization of errors in the pixel geolocation, and thus the Earth incidence angle, as a function of time resulting from changes in the spacecraft attitude.
- Characterization and resolution of intersensor biases using multiple approaches. This will include investigating the dependence of biases on the scene temperature by using techniques over both land and ocean and developing a best practice for estimating the errors in the SSM/I two-point calibration system.
- Production of an FCDR of microwave imager brightness temperatures from SSM/I and SSMIS along with processing code suitable for transition to NCDC.
- Full documentation of the procedures involved in going from the Level 1A to the FCDR dataset.

Accomplishments/Highlights During Past Year:

Development/Generation of SSM/I Level 1A Base Files: Original SSM/I TDR files have been rewritten to generate a first version of what we call Level 1A BASE Files. These Network Common Data Format (NetCDF) files are a granularized (according to the ascending node) version of the original TDR files with the addition or a new calculated Ephemeris generated from NORAD Two-Line Element (TLE) files. To date such a granularized version of these data does not exist. These uniform and consistent files represent the starting point for scientific work. The BASE Files are to be processed by what we call a stewardship code which will read the files and generate the final Fundamental Climate Data Record (FCDR). The code to generate the FCDR files from the BASE files is presently being written. The Stewardship codes structure is modular allowing the scientist to readily modify or update approaches presently used (e.g., cross track bias, Ta to Tb, QC, etc.). We believe this structure will facilitate ease of use and empower scientists to change techniques to suit their continuing research. A preliminary version of the SSM/I BASE files is expected to be complete in fall 2010.

Intersatellite Calibration of the SSM/I Brightness Temperatures: As noted in the goals for the project, the underlying motivation for creating an FCDR for SSM/I and SSMIS is to produce a long-term record of intercalibrated brightness temperatures for climate applications . Towards this end, a major part of our efforts to date have been on characterizating and attempting to resolve intersensor biases using multiple approaches. The aim of using multiple approaches is not only to establish the most accurate intercalibration, but also to assess the uncertainty of the final intercalibration. Towards this end, we have investigated several different methods for calibration over the ocean:

1. **Calibration using coincident matchups:** This method involves finding matchups between two satellites within a half hour and 50km. For this approach, data from the TRMM Microwave Imager (TMI) are used since the low inclination TRMM orbit regularly crosses the orbit path of the sun-synchronous DMSP spacecraft, thus providing relatively frequent collocated observations. Once matchups are found,

mean TBs are calculated for the one-degree area around the matchup and screening is applied to remove matchups contaminated by precipitation and clouds. Different sensors have different incidence angles and can have different channels in the case of comparisons against TMI. These differences are removed by retrieving state parameters from one satellite and then simulating TBs for each satellite to calculate the difference due to IA/sensor differences. This is then subtracted from the matchups to remove these IA/sensor differences.

2. **Calibration against in situ parameters:** This technique has been initially developed to compare satellite retrieved wind speed over oceans to buoy wind estimates. Satellite overpasses of the buoys are found and wind is retrieved using multiple kinds of algorithms, to investigate/understand the sensitivity of various algorithms to calibration errors. Several retrieval approaches for wind speed retrievals including optimal estimation, empirical regression, and neural networks have been coded so far with several different versions of each type of algorithms being used. The wind speed bias between the retrieved and actual wind can then be used to characterize the calibration error for the satellite against the in situ measurements.
3. **Vicarious Cold Calibration:** This technique works by finding the theoretical minimum value for each channel based on histograms of all available data and using this to estimate intercalibration differences. In practice, moisture in the atmosphere contaminates this minimum so extensive screening is required to remove moist, cloudy or precipitating pixels. This technique works best for the 19, 22 and 37GHz channels as the vicarious cold point is not strictly observed for the 85GHz channels. Despite this, the method is still applicable for the 85GHz channels since the method tends to detect the coldest observed TB, although this is different from the coldest theoretical TB.

We also expect to implement other techniques including Vicarious Warm Calibration and polar matchups. The later involves polar matchups between SSM/I satellites and the former is similar to the Vicarious Cold Calibration, but high-emissivity targets are chosen over land (primarily rainforests). The Vicarious Warm Calibration technique is particularly useful since the other techniques tend to be based on colder TBs, thus the warm calibration allows for the assessment of temperature-dependencies in the calibration over a wide range of observed brightness temperatures.

At present, we have calibration values from the coincident matchup technique and the polar matchup technique with preliminary numbers from the vicarious cold technique. The comparison of wind speed retrievals with in situ buoy data found that the wind alone did not contain enough information to estimate offsets for multiple channels and so it was not possible to converge on a final set of calibration estimates. This approach does however yield significant information on the sensitivity of geophysical retrievals to the calibration and will thus be a useful case study of the impact of the intercalibration on estimates from the climate data record. This is an important finding since understanding how different geophysical retrievals/approaches respond to calibration errors is critical to assessing errors and the resulting capabilities for long-term climate analysis.

One of the issues with the various SSM/I sensors is that the true Incidence Angle (IA) is not known. The nominal IA was 53.1, but subtle changes in mount angle and spacecraft attitude (spacecraft pitch, roll, yaw) lead to important changes in the TBs, which must be accounted for during intercalibration (and when retrieving geophysical variables). Previous estimates of the spacecraft attitude were based on coastline analyses where various spacecraft pitch and roll values are used to perturb the geolocation until the data matches the coastline. We have developed an alternate methodology that involves estimating the spacecraft pitch and roll from the shape of the TBs from either the mean or the vicarious calibration across the scan. A spacecraft pitch causes the scan to have symmetric curvature whilst a roll leads to a slope across the scan that has opposite sign in the vertical and horizontal polarizations. By estimating the degree of these signatures, the pitch and roll can be estimated and accounted for in the IA, which can then be used to obtain a more accurate calibration. We in tend to supplement this analysis with a geolocation/coastline analysis which will be used to validate the pitch and roll offsets and to establish any yaw offset which cannot be detected from analysis of the scan pattern alone. A secondary benefit of this analysis is the ability to produce improved geolocation estimates for the individual pixel locations when used in combination with our improved spacecraft ephemeris calculated from the two-line element files.

Plans for year 2 of the project: Our goal is to create an initial version of the FCDR dataset with basic quality control, error corrections, and initial calibration adjustments during the next year. This will involve creating a full record of the SSM/I and SSMIS BASE files, which is then the starting point for the various corrections to the final brightness temperature data record. We are currently working to finish up the base files for the SSM/I sensors, which involves dealing with numerous data issues, particularly in the earlier data record. We will then adapt the code for SSMIS. In initial version of the stewardship code has been written with work ongoing to specify the output FCDR format and contents. The stewardship code approach will allow us to add new corrections easily as we develop improvements to the calibration, quality control, error correction, and geolocation modules.