The Challenges of Producing Climate Data Records from Satellite Microwave Radiometers

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1. INTRODUCTION

For several decades, satellite microwave (MW) radiometers have been observing a number of key climate variables including tropospheric temperature and sea ice (since 1979), atmospheric moisture (vapor, cloud, rain) and sea-surface wind (since 1987), and sea-surface temperature (since 1998). These sensors have provided the most definitive evidence to date that the arctic sea ice is declining and the troposphere is both warming and moistening.

This poster focuses on the challenge of inter-calibrating these MW radiometers at the sensor level and then producing consistent climate data records (CDR). In total, there are 184 satellite years of observations that need to be consistently processed in order to provide the community with reliable climate information. Sensor related issues such as spacecraft pointing and attitude errors, emissive antennas, sun intrusion into hot loads, and long-term stability will be discussed along with the MW radiative transfer model and the associated retrieval algorithms. We will describe a holistic approach to CDR generation that considers all aspects of the problem, including sensor calibration, geophysical retrievals, and product validation. Climate trends from different satellites will be compared to assess the reliability of the trend estimates.

1. Engineering Climate Data Records: The Problem

Large Volume: Over 200 satellite-years of observations from Microwave Radiometers

Microwave Imagers

SSM/I: F08, F10, F11 F13, F14, F15

SSM/IS: F16, F17, F18

TMI

AMSR-E and AMSR
WindSat

Microwave Sounders

MSU: Tiros-N, NOAA 6, 7, 8, 9, 10, 11, 12, and 14 AMSU: NOAA 15, 16, 17 18, and 19, Aqua, MetOP A

Difficult Calibration: Each sensor has its unique set of problems

Sensor pointing and S/C attitude errors
Antenna pattern knowledge error
Scan-dependent errors
Sun intrusion and thermal gradients in Hot Load
Emissive Antenna

High Precision Required: Climate Variability is typically 1% of the Mean

2. Engineering Climate Data Records: The Method

Maintain a High Level of Consistency

The <u>steadfast adherence</u> to the same principles and methods in data processing all the way from radiometer counts \rightarrow to climate time series, including:

Geolocation
Radiometer calibration
Geophysical retrievals

On-going and Comprehension Validation

Radiosondes GPS vapor

Ocean buoy winds and SST

Scatterometer wind retrievals

SST, Cloud and Rain retrievals from satellites IR sensors

Much of this validation is done by the User community via peer reviewed papers

Sensor Calibration and Geophysical Retrievals Use same Radiative Transfer Model

All MW imagers are calibrated to the same RTM All retrievals come from the inverse of the RTM (RTM⁻¹)

3. The Fundamental, Fundamental Data Record: Radiometer Counts

Consistency in data processing requires the antenna temperatures or brightness temperature obtained from various data providers like TDRs from NOAA, NASA Level 1 dataset, JAXA L1A data be reversed engineered back to the original radiometer counts in the telemetry downlink.

Also satellite position, velocity, and attitude vectors are required

RSS maintains a complete archive of radiometer counts (both earth view and calibration), and associated spacecraft ephemeris and housekeeping data (thermistors).

Dataset is fully q/c and organized into orbital files.

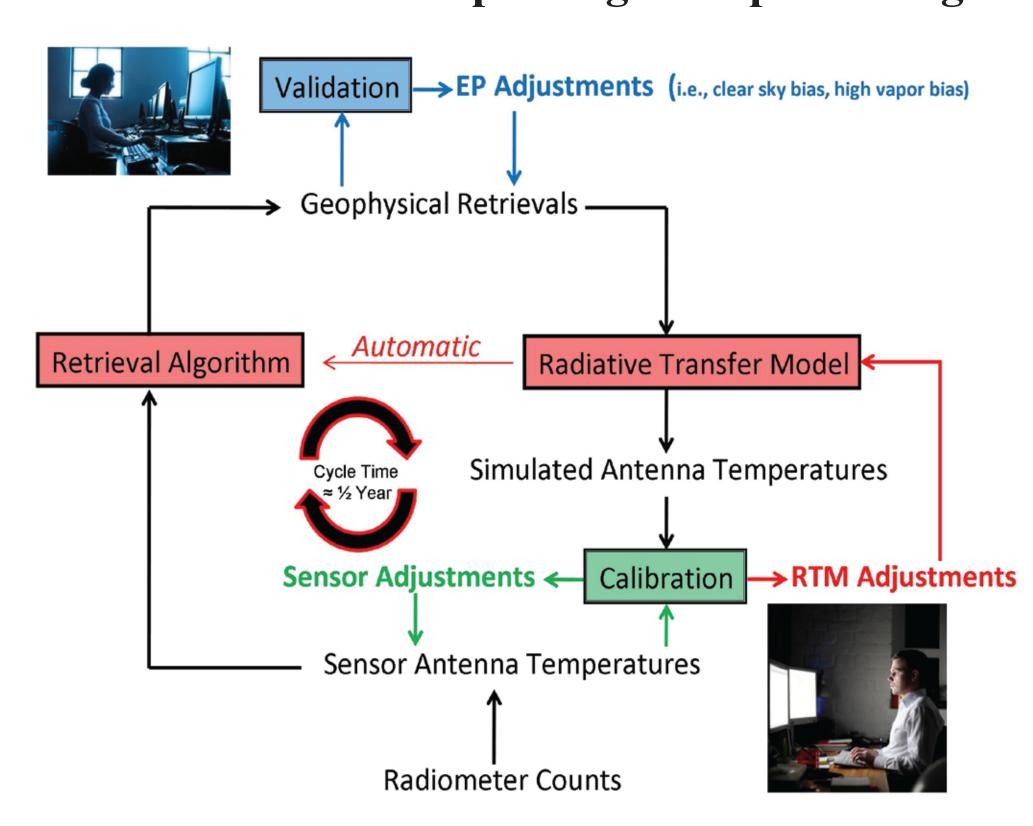
Volume size is relatively small

Basis for all product generation at RSS (Ta, Tb, EDR, CDR).

Non-Controversial

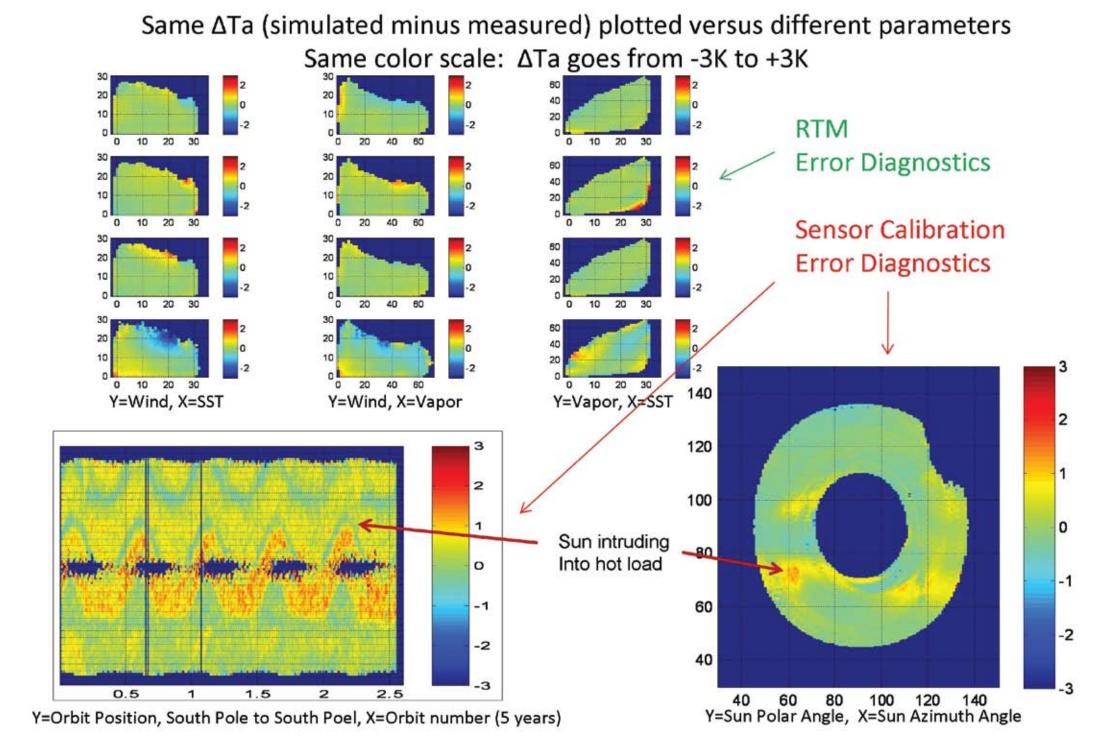
4. Methodology:

Continuous Updating & Reprocessing



This figure shows how sensor calibration is done. It is an iterative process that begins with the launch of a new satellite. The process begins by computing the sensor antenna temperature (TAmea) using pre-launch calibration information and the original sensor counts. TAmea is converted to brightness temperature (TBmea) using the pre-launch antenna pattern correction (APC), which removes spillover and cross-pol coupling. The retrieval algorithm is run to provide set of geophysical parameters. The retrieved geophysical parameters are then subjected to a rigorous validation using in situ observations and retrievals from other satellites. Adjustments are made to the initial set of retrievals so that they agree with the validation data in a statistical sense forming a reference geophysical state for each sensor measurement. The adjusted geophysical parameters along with ancillary data (if necessary) are then input into the radiative transfer model (RTM) and simulated TB are computed for each observation and the inverse APC is applied to generate TArtm. Differences ΔTA = TAmea - TArtm are then found. These differences are then interpreted as either sensor calibration errors or errors in the RTM, as is explained in the next figure.

5. Distinguishing Sensor Errors from RTM Errors



This figure shows an example of this error partitioning method as applied to the F16 SSMIS. The F16 SSMIS is problematic in that its antenna is emissive due to flaws in the aluminum coating and its hot load design allows for sunlight to enter, either directly or via a single reflection, introducing significant thermal gradients that decorrelate the temperature measured by the embedded thermistors from the effective radiating temperature of the load. The figure shows ΔTA for 6-years of observations binned and averaged the three ways listed above. The upper left image shows the v-pol ΔTA binned according to the geophysical parameters. Each row of the upper left plots corresponds to a different frequency: 19, 22, 37, 92 GHz. These statistics are used to correct errors in the RTM. The lower left image in the Figure shows the 37 GHz v-pol Δ TA binned according to intra-orbit position and orbit number. The lower right image shows the $37V \Delta TA$ binned according the sun zenith and azimuth angles as measured in the spacecraft coordinate systems. In these two images, one can see both the effect of the SSMIS emissive antenna and sun intrusion into the hot load. The sun intrusion is a spot in the right image and is the thin sinusoidal blue line in the left image. The emissive antenna is the heavy sinusoidal orange feature in the middle of the image. Other SSMIS calibration and validation activities [Poe, 2005; Bell, 2006] did not detect the emissive antenna problem at these lower frequencies of 19 and 37 GHz. Yet in the ΔTA plots, the effect is very apparent even in the lowest 19.35 GHz channel. The 19H emissivity is about 1% and the 37H emissivity is about 2%. These emissivity values are consistent with those found by other investigators [Brown et al., 2007; Kunkee et al., 2008; Swadley et al., 2010].

6. Version 7 data

100+ Satellite-Years of Earth System Data Records
Consistently Processed with Common Algorithms
Same RTM Used for Calibration and Retrievals for all Sensors

The Products

- > SST (not all sensors)
- ➤ Wind Speed
- Columnar Water Vapor
- Columnar Liquid Water
- ➤ Rain Rate

The Sensors

- > SSM/I: F08, F10, F11, F13, F14, F15
- > SSM/IS: F16, F17, F18
- > AMSR-E
- ➤ WindSat
- > TMI (to be done 2012)

Availability

Products are hosted at www.remss.com

SSM/I V7 Brightness Temperature archived at NCDC early 2012.

