National Aeronautics and Space Administration

Microwave Sounder Scan Bias Analysis from AIRS/AMSU Observations

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Abstract The Atmospheric Infrared Sounder (AIRS) instrument suite, which includes the Advanced Microwave Sounding Unit A (AMSU-A) as well as a near-copy of the AMSU-B - the Humidity Sounder for Brazil (HSB), was launched on the NASA Aqua satellite in May 2002. During the on-orbit checkout it became apparent that the microwave instruments, in particular AMSU-A, exhibit a significant scan angle dependent bias. This phenomenon has also been noticed in the AMSU instruments operated by NOAA on NOAA-15 through NOAA-17 and is expected to also be a feature of the next series of AMSU instruments, on NOAA-N and NOAA-N' as well as on equivalent European satellites. The Advanced Technology Microwave Sounder (ATMS), to be launched first in 2006 on the NASA NPP satellite and thereafter on a number of NPOESS satellites, is also expected to have significant scan bias. This bias is a major hindrance to the effective use of the microwave observations, both operationally and in atmospheric research, and much effort has been devoted by NOAA as well as NASA to analyze it, with a view toward correcting the measurements on an objective basis from first principles. These efforts have not yet been entirely successful, and many data users have resorted to making empirically derived corrections instead. While that may be satisfactory for operational use, it is not desirable for climate research and similar applications. The effort to model the bias therefore continues. In this paper we report on work that has been done at the Jet Propulsion Laboratory in this regard, including some progress in modeling the bias.

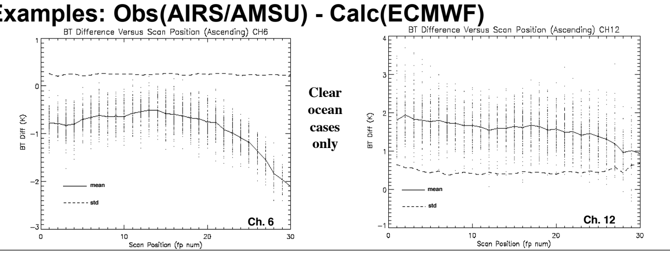
Background

Observations
- Substantial scan bias in the observations; Asymmetric w.r.t. nadir; Magnitude varies along the orbit

Remedial action by AIRS
- Preliminary analysis to characterize the behavior - not yet fully modeled, but results are promising
- In the meantime: empirical "bias tuning" is applied instead as part of the retrieval processing

Ongoing effort
- Fully characterize the scan bias & model the effect from physical principles
- Determine modeled bias corrections, to be applied at the calibration processing stage
- Result is to convert earth scene "antenna temperatures" to "brightness temperatures"

Examples: Obs(AIRS/AMSU) - Calc(ECMWF)



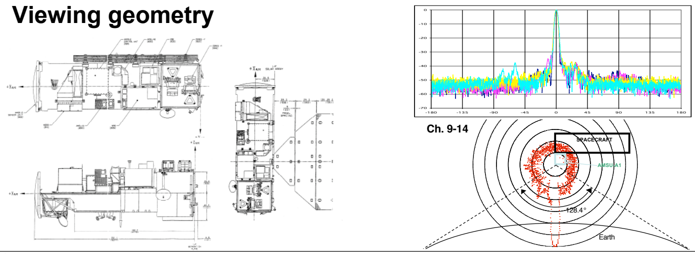
Cause

Zeroth order effect : Imperfect antenna patterns
- Approx. 1% of received energy comes from outside the Earth (space & spacecraft) —> negative bias
- "Sidelobe" energy tapers off with angle relative to boresight —> bias increases with scan angle

First order effect : Spacecraft structures interfere with reception
- S/C blocks space view, reflects space radiation, reflects Earth radiation —> increased or decreased bias
- Asymmetric S/C environment —> left-right asymmetric scan bias; AMSU-A1/A2 differences

Second order effects : Dynamic changes
- Solar panels rotate, causing variable interference —> orbital modulation of scan bias
- Multiple reflections of sunlight from multiple surfaces possible near terminator —> orbital/seasonal

Viewing geometry



Modeling the scan bias

Measured antenna temperature is a composite integrated over all scenes

$T_{obs} \approx f_e \langle T_e \rangle + f_c T_c + \rho f_s \langle T_s \rangle$

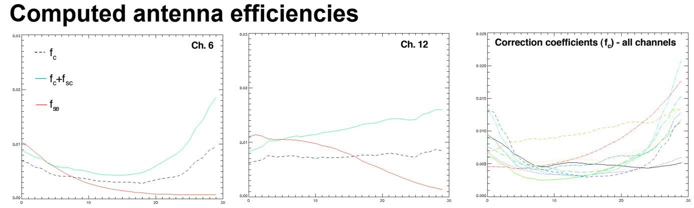
$\langle T_e \rangle$ = mean Earth temp; T_c = space temp; $\langle T_s \rangle$ = mean temp reflected from S/C; ρ=S/C reflectivity
f's are antenna efficiencies integrated over Earth (f_e), space (f_c), spacecraft (f_s), computed from measured antenna patterns

Simplest case: Uniform Earth T_e

Bias = $T_{obs} - T_e \approx -f_e T_{obs} - f_{sc} T_{obs} + \rho f_{sc} T_c$

Ignoring S/C reflections: $T_e \approx T_{obs} + f_e T_{obs}$

Computed antenna efficiencies

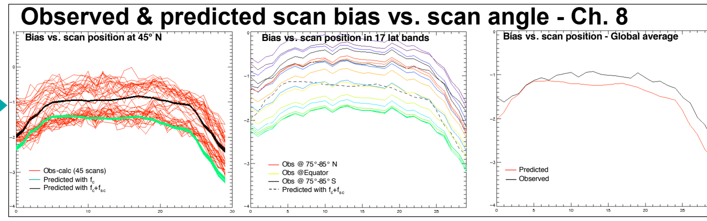


Verification

Use AMSU channel 8
- No surface effects —> avoid highly variable T_e
- Relatively low variability in radiometric field (near tropopause)
- "Truth" is relatively well known **- But see below**

Results
- Shape of predicted bias vs. scan angle agrees well with observations
- Asymmetry in bias is generally explained
- Absolute nadir-referenced bias offset is generally wrong **—> Problems with the "truth"?**

Observed & predicted scan bias vs. scan angle - Ch. 8

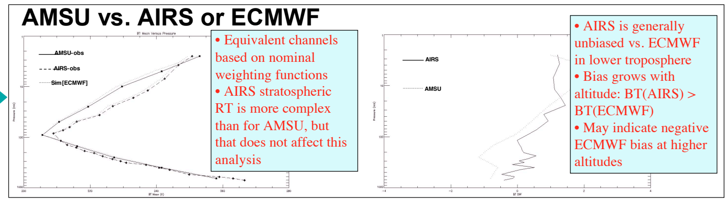


How good is the "Truth"

Bias = Obs(AMSU) - Calc(truth); What is best "truth"?
- Truth #1: Forecast fields (ECMWF etc.) ←
- Truth #2: Radosondes etc. We will look at these here
- Truth #3: AIRS retrievals ←

AIRS vs, AMSU vs. ECMWF
- Step 1: Find AIRS channels with weighting functions matching AMSU's
- Step 2: Compare bias (AIRS-ECMWF) with bias(AMSU-ECMWF)

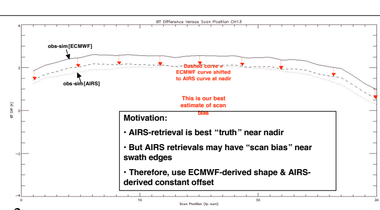
AMSU vs. AIRS or ECMWF



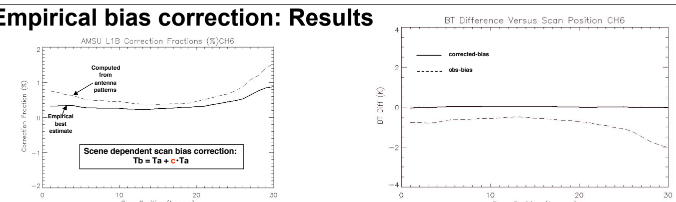
Empirical bias correction

Currently most used approach
- Compute obs-calc(ECMWF) for many cases
- Fit mathematical/regression model
- Determine bias corrections coefficients

Method described here
- Step 1: Compute obs-calc(ECMWF)
- Step 2: Compute obs-calc(AIRS)
- Step 3: Use shape from Step 1; offset from Step 2



Empirical bias correction: Results



Future work

Work continues on AIRS/AMSU, to replace empirical with modeled bias corrections
Model S/C environment more accurately
This is pursued for NPP/ATMS: the "climate" component of mission requires non-empirical corrections
A method to measure antenna efficiencies (f_x) directly on the ground has been proposed

Acknowledgments

This work was carried out at the Jet Propulsion Laboratory, California Institute of Technology under a contract with the National Aeronautics and Space Administration.

The assistance of Zi-Ping (Frank) Sun, who carried out much of the analysis, has been invaluable.