The Development of AMSU FCDR's and TCDR's for Hydrological Applications

Huan Meng, Ralph Ferraro
Satellite Climate Studies Branch
NOAA/NESDIS/STAR/CoRP
301-405-8799, Huan.Meng@noaa.gov
301-405-0893, Ralph.R.Ferraro@noaa.gov

Chabitha Devaraj, Isaac Moradi, Wenze Yang
Corporative Institute for Climate and Satellites
University of Maryland, College Park

CDR Team Meeting
July 31 – Aug 2, 2012

Outline

- Project Description
- Production and QA Approach
- Applications
- Schedule & Issues

Project Description (1/2)

- **Goals**
  - Develop AMSU-A/-B and MHS FCDR's for "window" and "water vapor" channels
    - AMSU-A: 23.8, 31.4, 50.3, 89.0 GHz
    - AMSU-B/MHS: 89, 150/157; 183±1, 183±3, 183±7/190 GHz
  - Develop TCDR's for hydrological products (12 products)
    - Rain rate (and snowfall detection), total precipitable water, cloud liquid water, ice water path, sea ice concentration, snow cover, snow water equivalent, land surface temperature, land surface emissivity 23, 31 and 89 GHz.
- **Input**
  - NOAA-15,16,17,18,19 & MetOp-A L1B data
  - Ancillary data: PATMOS-x, ERA-interim, NORAD TLEs, GDAS
- **Deliverables**
  - FCDR's and TCDR's from 2000 - 2010 for all satellites (depending on launch date)
  - Documents and programs

Project Description (2/2)

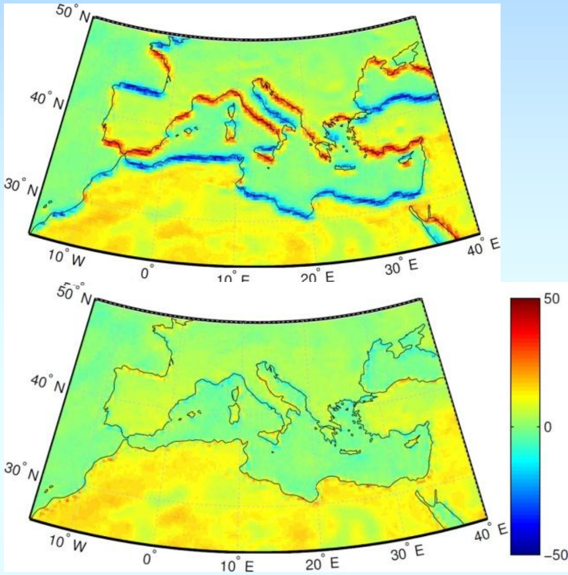
CDR(s) (Validated Outputs)	Period of Record	Spatial Resolution; Projection information	Time Step	Data format	Inputs	Uncertainty Estimates (in percent or error)	Collateral Products (unofficial and/or unvalidated)
AMSU-A window channels Tb's	2000-2010	48 km at nadir; no projection	8 s per scanline (30 FOV's)	NetCDF4	L1B, ancillary data	Not available yet	Geolocation corrected data
AMSU-B all channels Tb's	2000-2010	16 km at nadir; no projection	8/3 s per scanline (90 FOV's)	NetCDF4	L1B, ancillary data	Not available yet	Geolocation corrected data
MHS all channels Tb's	2005-2010	16 km at nadir; no projection	8/3 s per scanline (90 FOV's)	NetCDF4	L1B, ancillary data	Not available yet	Geolocation corrected data
AMSU-A products (TPW, CLW, Ts, □)	2000-2010	48 km at nadir; no projection	8 s per scanline (30 FOV's)	NetCDF4	AMSU-A FCDR Tb's, ancillary data	Not available yet	None
AMSU-B products (all others)	2000-2010	16 km at nadir; no projection	8/3 s per scanline (90 FOV's)	NetCDF4	AMSU-A & -B FCDR Tb's, ancillary data	Not available yet	None
MHS products (all others)	2005-2010	16 km at nadir; no projection	8/3 s per scanline (90 FOV's)	NetCDF4	AMSU-A & MHA FCDR Tb's, ancillary data	Not available yet	None

Production Approach

- **FCDR single satellite calibration**
  - QC
  - Antenna pattern correction
  - Onboard RFI: NOAA-15 and -17 AMSU-B
  - Geolocation correction
  - Cross-scan bias correction: vicarious calibration (CRTM simulation), separate ocean and land calibration
- **FCDR inter–satellite calibration**
  - SNO: polar and global
  - Vicarious: Antarctic and tropical oceans
  - Global comparison with diurnal adjustment
- **TCDR development**
  - Generated from the finalized FCDR
  - Assures the robustness of FCDR

Precision and Uncertainty

- **Antenna pattern and RFI corrections**
  - Existing approaches – no error estimates
  - Lack of truth on Tb
- **Geolocation correction**
  - Precision (accuracy): ascending and descending Tb difference along coastlines
  - Uncertainty: STD of the calculated attitude and the resulting geolocation errors



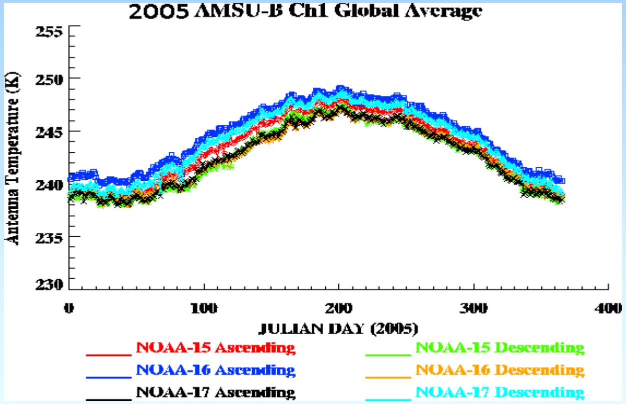
- **Cross-scan bias correction**
  - Precision (accuracy)
    - Asymmetry index: from Tb differences between left and right of nadir
    - Tb accuracy highly dependent on the cross-scan accuracy of CRTM
  - Uncertainty: Derive from correction results using multiple RTM simulations
- **Inter-satellite calibration**
  - TBD

Special Issues

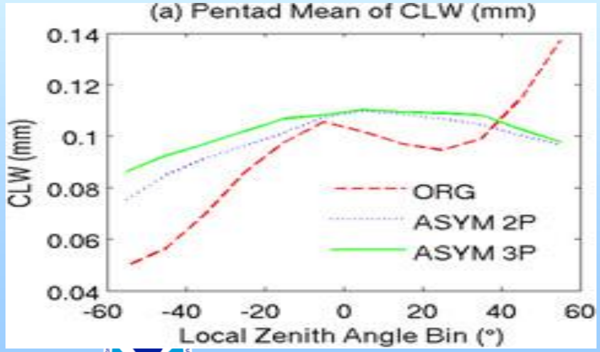
- **Geolocation correction**
  - Current correction method is not very effective for detecting yaw error
- **Cross-scan bias correction**
  - Exceptions to the current AMSU-A cross-scan bias correction approach which is Tb dependent: desert, precipitation with strong convection, etc.
  - Severe sensor degradation in NOAA-15, -16, and -17 AMSU-B water vapor channels in later years. Will be a major challenge to perform cross-scan bias correction.
- **Inter-satellite calibration**
  - Only three pairs of satellites overlap, each pair for a short period of time
  - Inter-satellite bias is latitude and scene temperature dependent

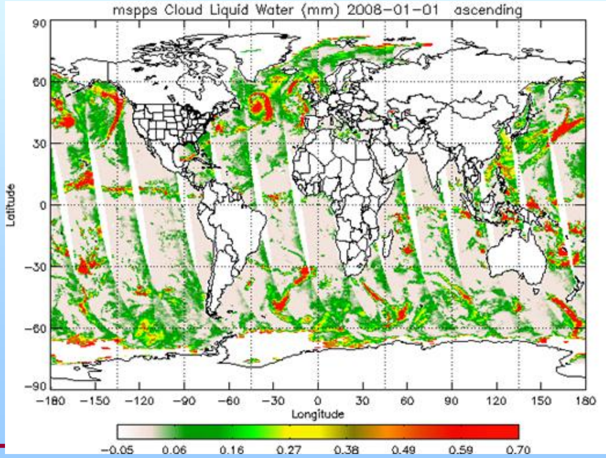
Quality Assurance Approach

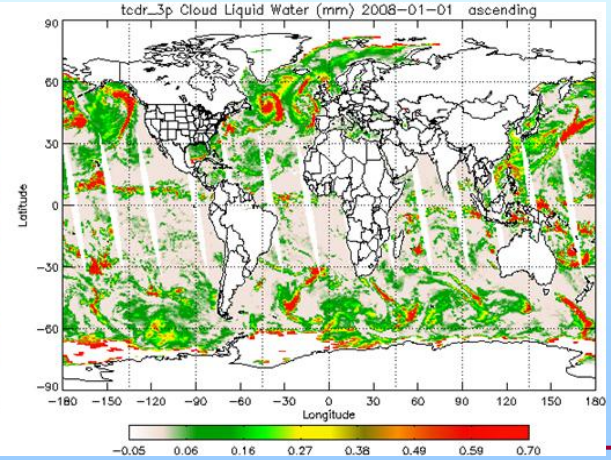
- **Quality assurance for FCDR's**
  - Inter-satellite calibration ensures the consistency of Tb's across satellites for the entire period
  - Cross-scan bias correction is based on CRTM for all satellites
  - Time series to verify long-term consistency and continuity



- **Quality assurance for TCDR's**
  - Daily/pentad/monthly/yearly asymmetry plots
  - Long-term time series of all satellites to verify long-term continuity







Applications (1/2)

- AMSU-B/MHS measurements possess unique remote sensing capability at 89 GHz and higher, i.e:
  - Sensitivity to lighter precipitation rates, including snowfall
  - Freshly fallen snow
  - Depth of convection
- Time period with 2 or more satellites offers better depiction of diurnal cycle of hydrological variables
  - Reduction in sampling error allows for greater confidence in climate signals
- AMSU CDR’s are geared for use with other similar data sets
  - Because time series is only 11 years in length at present, the stand alone TCDR’s do not offer information of long term trends
  - The CDR’s are best suited when they are combined with similar CDR’s from other sensors (e.g., SSM/I, AMSR-E, TMI)

Applications (2/2)

- Primary "scientific" user would be "blended" product developers and organizations, e.g., for precipitation:
  - GEWEX/GPCP
  - NASA/TRMM and GPM programs
  - NOAA/CMORPH precipitation product

- Users of the blended products include:
  - Climate community
    - Government, research, planning/mitigation
  - Insurance industry
    - Areas of vulnerability for hazards such as floods (and in areas where conventional data does not exist) (See detailed statement from Jeff McCollum, FM Global)
  - Commodity Market
    - Agricultural monitoring and changes and potential crop losses (See detailed statement from Alan Basist, WeatherPredict Consulting)
  - Water Resource Managers
    - Seasonal to interannual changes

Schedule & Issues (1/2)

- **Project status**
  - Completed geolocation correction for all satellites and all sensors
  - Completed AMSU-A cross-scan asymmetry characterization and correction
  - Completed AMSU-B/MHS cross-scan asymmetry characterization
  - Performed preliminary inter-satellite calibration for AMSU-A/AMSU-B/MHS
  - Beta data (NetCDF4 w/ metadata) are available including geolocation correction and cross-scan bias correction (AMSU-A) for 2008 NOAA-18.
  - Project website: **http://cics.umd.edu/AMSU-CDR/home.html**
  - Two papers from the project: one in print, one accepted
- **Plans for next phase**
  - Complete inter-satellite calibration for all satellites and sensors
  - Complete AMSU-B/MHS cross-scan asymmetry correction for the channels that require correction
  - [Expand into NPP/ATMS data record if funding could be sustained somehow…]

Schedule & Issues (2/2)

- **Risks or concerns**
  - Sustained funding (1 FTE?) beyond initial three-year project is likely required to complete delivery package (programs, documentation, etc.) and transition
  - Can the initial operating capability be done on CICS-MD machines in conjunction with NCDC focal point?
  - Outside dependencies: PATMOS-x data (2006/2007 for some satellites, 2010)
- **How can the CDR Program better assist you?**
  - Ensure completion of third year funding in early 2013

Acknowledgements

Cheng-Zhi Zou, Tsan Mo, Andy Heidinger, Matt Sapiano, Stephen Bilanow, Ben Ho, Jonny Luo, Hai-Tien Lee, Wesley Berg, Brian Nelson, Hilawe Semunegus, Mark Liu, Yong Han, Fuzhong Weng, Jim Shiue, William Blackwell, Darren McKague, Peter Bauer, Viju John

Project Papers:

- Yang, W., H. Meng, R. Ferraro, I. Moradi, C. Devaraj, D. McKague, 2012: Cross-Scan Asymmetry of AMSU-A Window Channels: Characterization, Correction and Verification. *IEEE Transactions on Geoscience and Remote Sensing*. In print.
- Moradi, I., H. Meng, R. Ferraro, S. Bilanow, 2012: Correcting geolocation errors for microwave instruments aboard NOAA satellites. *IEEE Transactions on Geoscience and Remote Sensing*. Accepted.

Backups

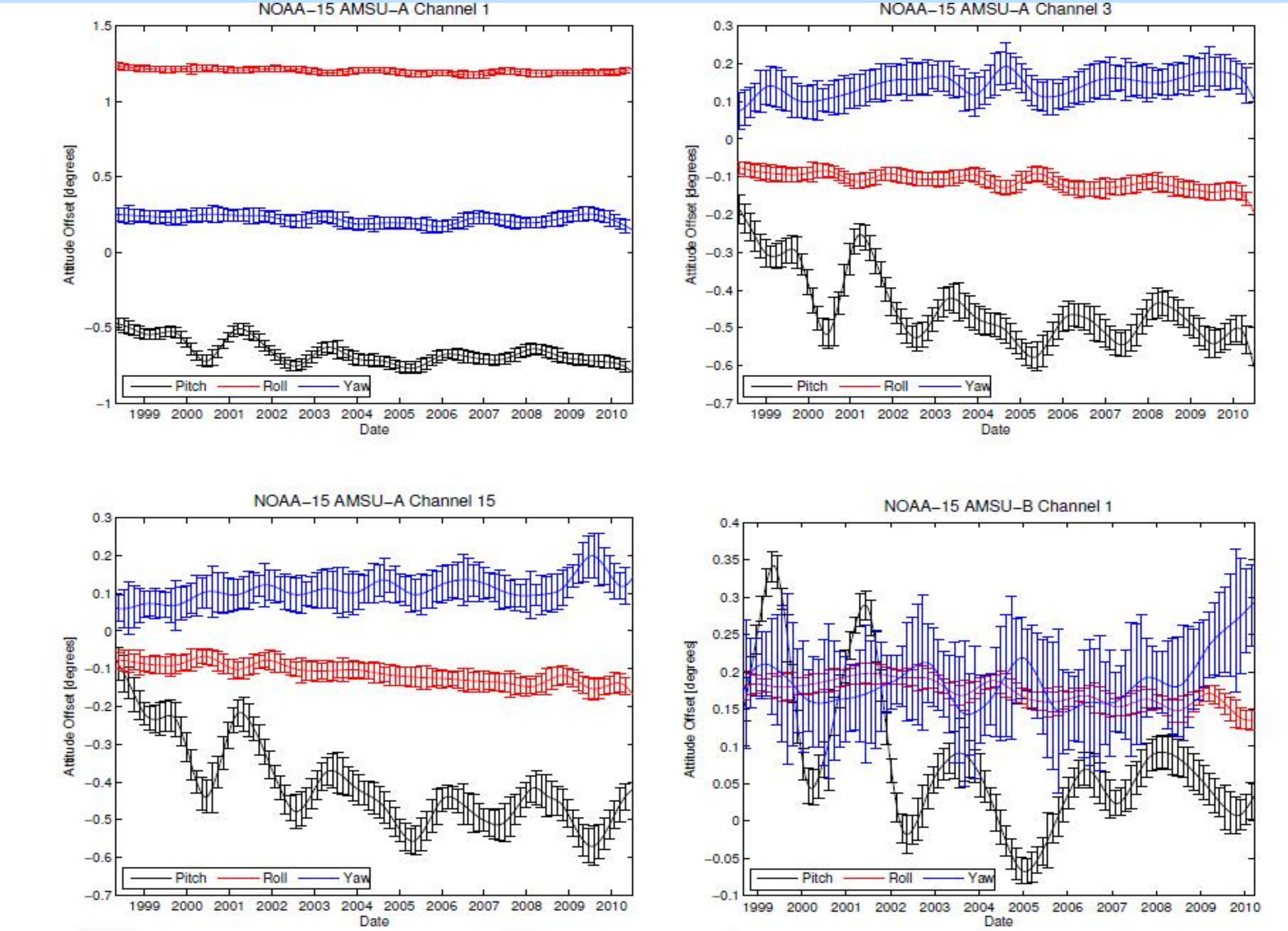
Geolocation Error

AMSU/MHS Sensor Geolocation Error (km)/LZA error (deg)

	AMSU-A2 channel-1 & -2	AMSU-A1-2 channel-3	AMSU-A1-1 channel-15	AMSU-B/MHS all channels
NOAA-15	20/1.2*	10/0.15	10/0.15	small/0.15-0.2
NOAA-16	10/0.25	10/0.4	10/0.2	small/small
NOAA-17	5-10/small	-**	-	5-10/0.25
NOAA-18	20/0.2	5-10/small	5-10/0.4	5-10/0.15
NOAA-19	5-10/0.2	5-10/0.35	5-10/0.2	5-10/0.1

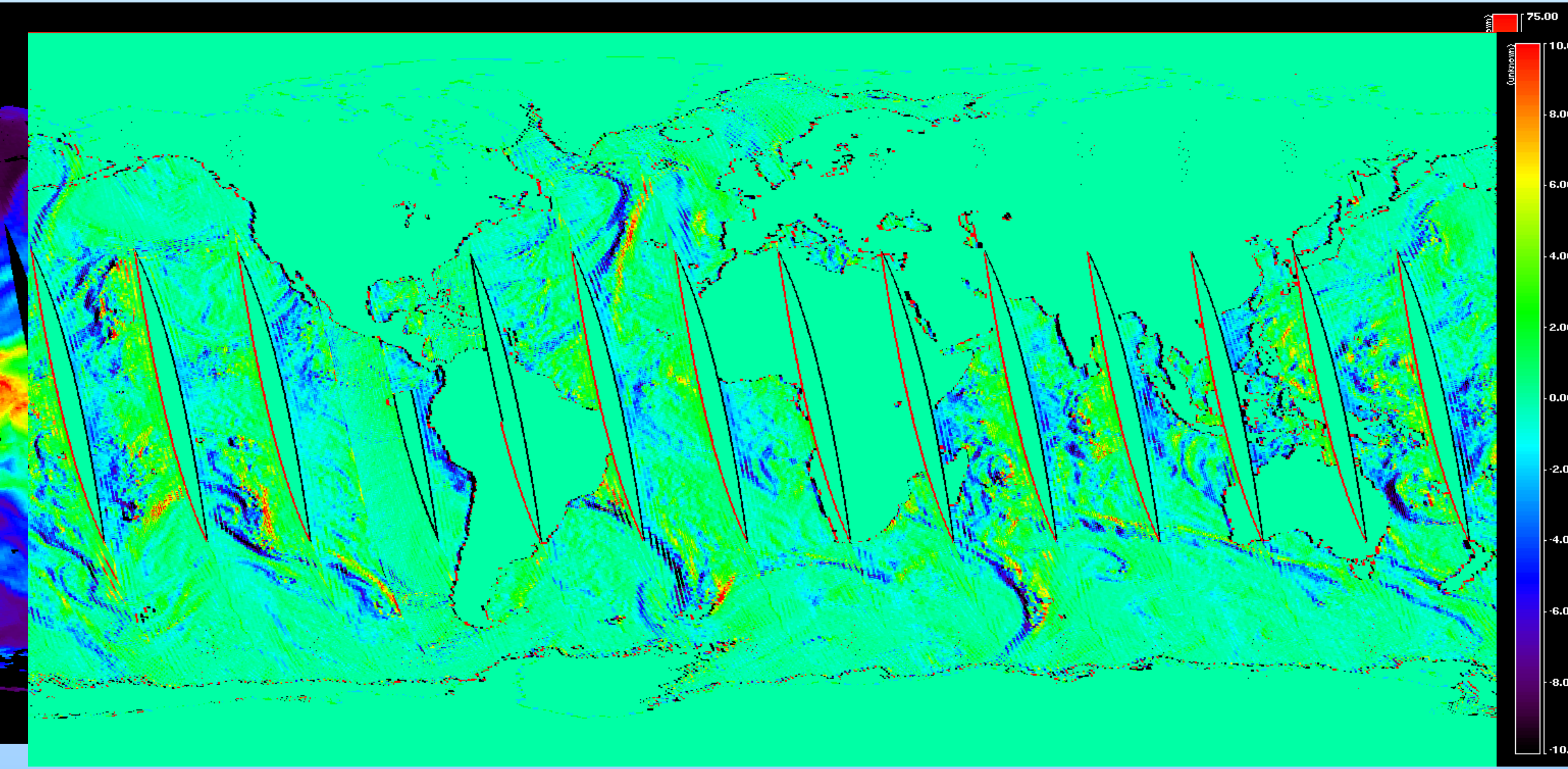
** Geolocation and LZA errors vary in time. The values shown are estimated averages.*
*** NOAA-17 AMSU-A1 has a short record due to instrument failure.*

Geolocation Correction – Attitude (Pitch/Roll/Yaw) Determination



Impact of Geolocation Correction on Products – TPW

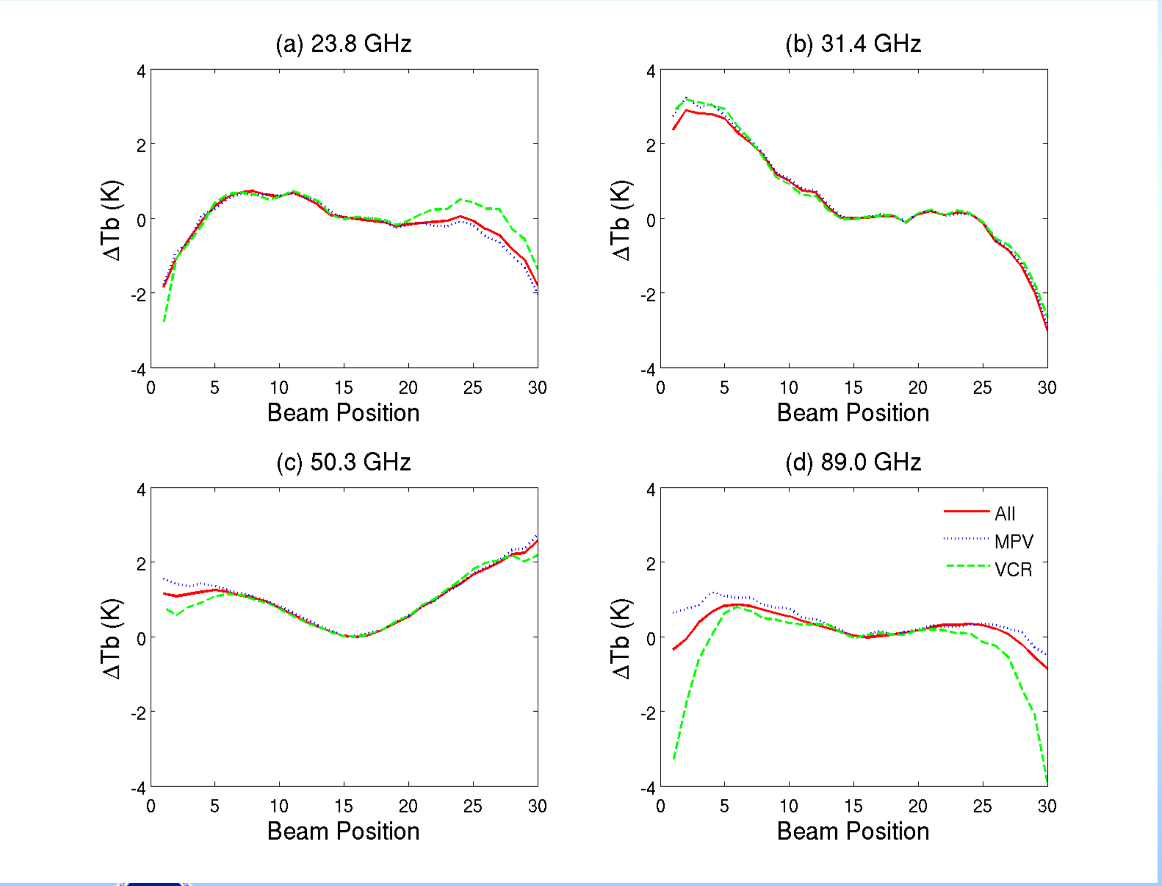
TPW Difference



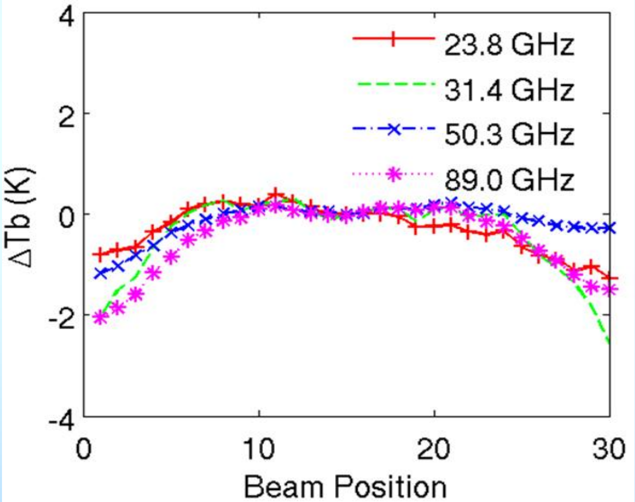
Cross-Scan Bias Characterization – AMSU-A

Vicarious Cold Reference (VCR) over ocean; Vicarious Hot Reference (VHR) in Amazon

Ocean

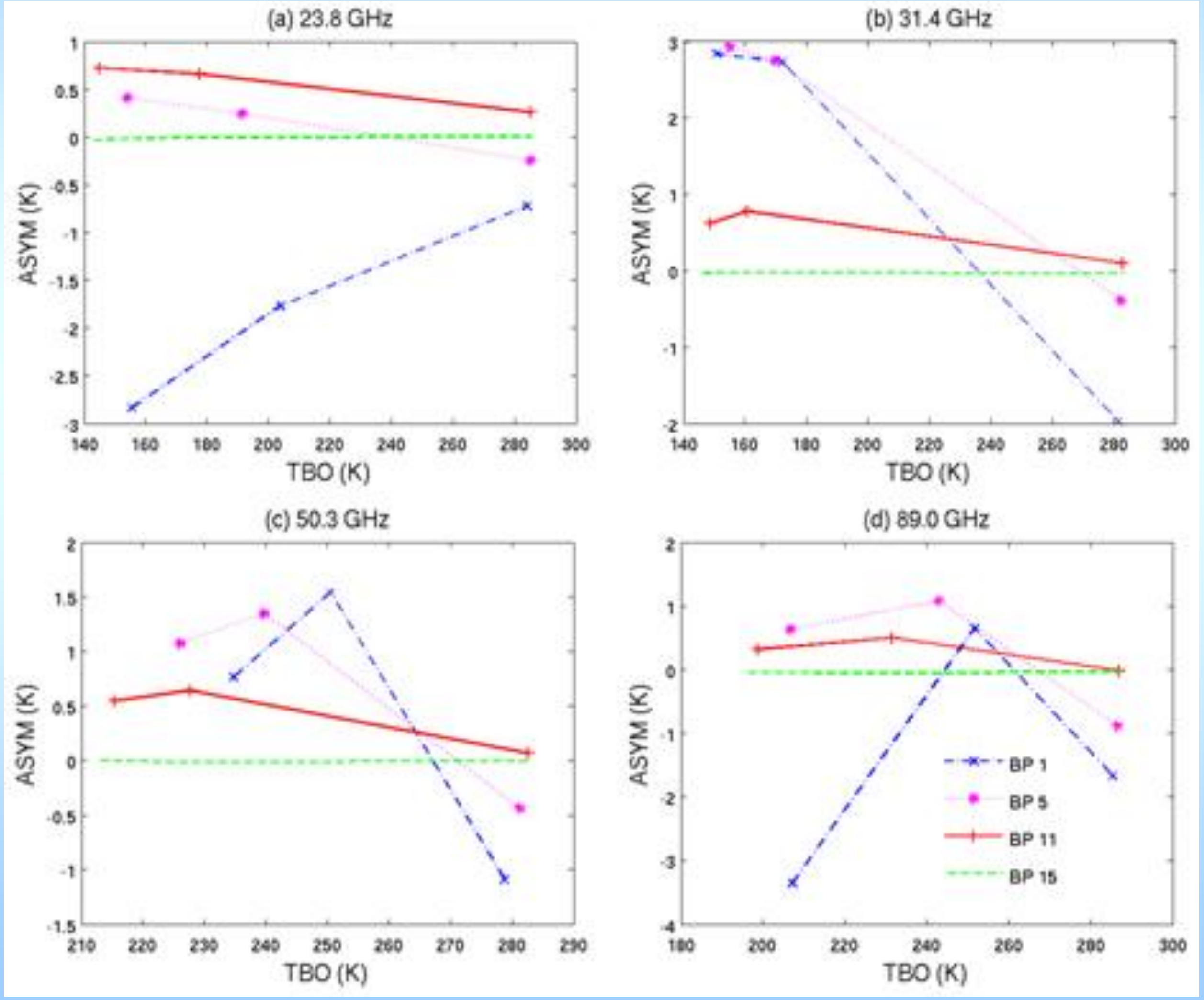


Land/Amazon

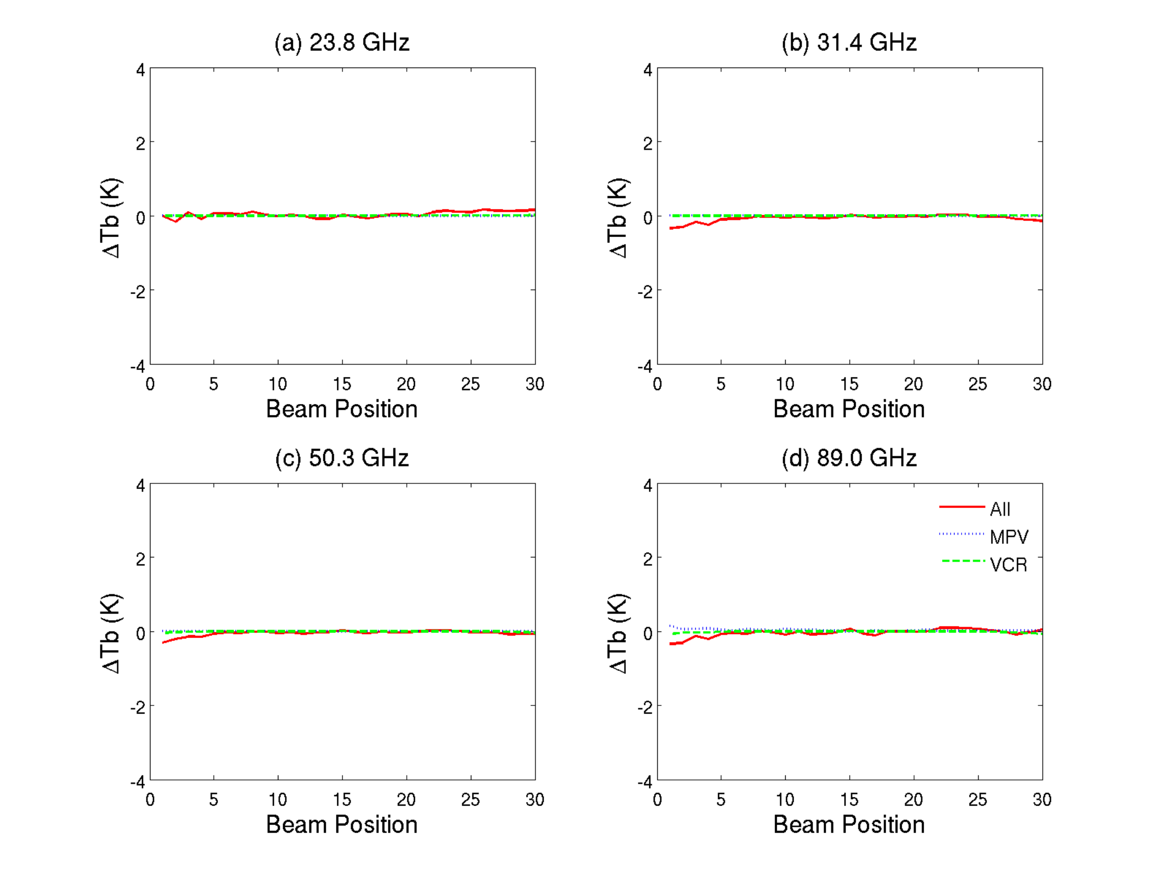


AMSU-A Cross-Scan Bias Correction

Three-point bias correction:

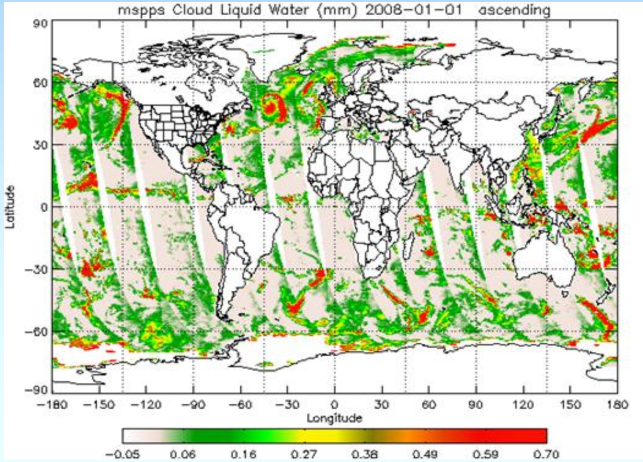


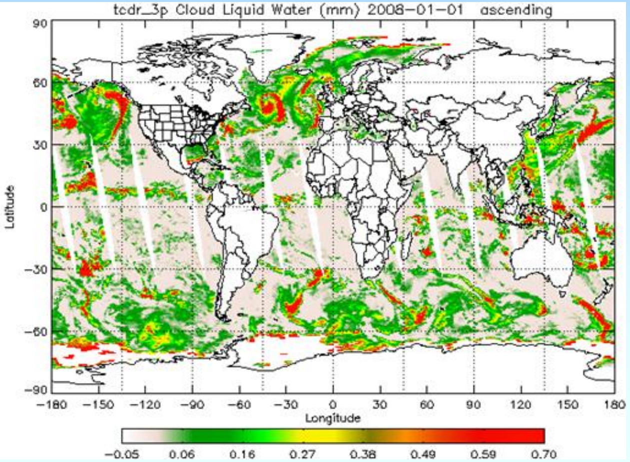
Cross-Scan Bias Correction – AMSU-A Result



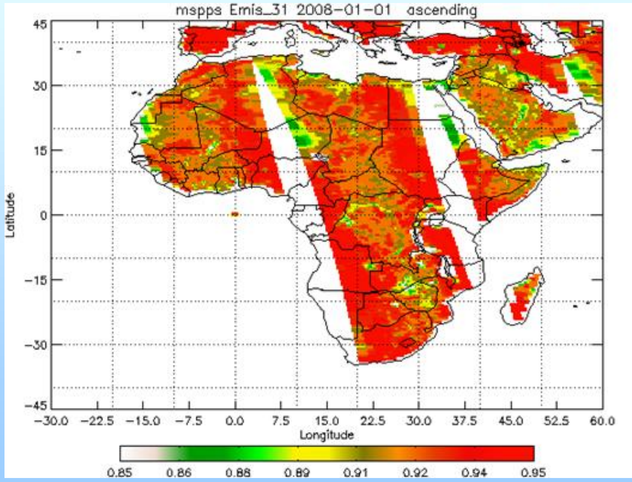
Impact of Cross-Scan Bias

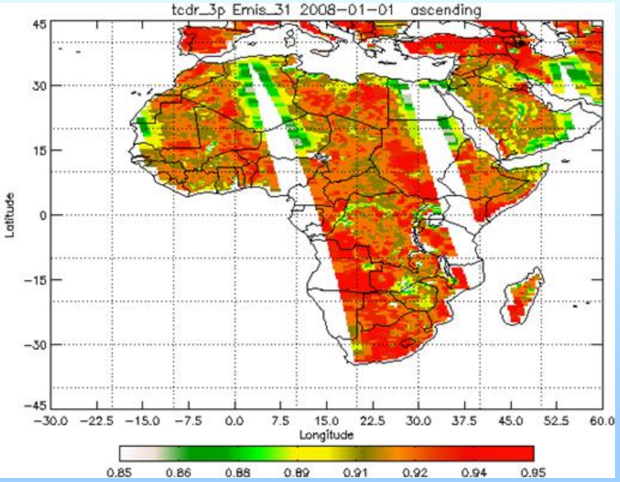
Cloud Liquid Water – before and after cross-scan bias correction



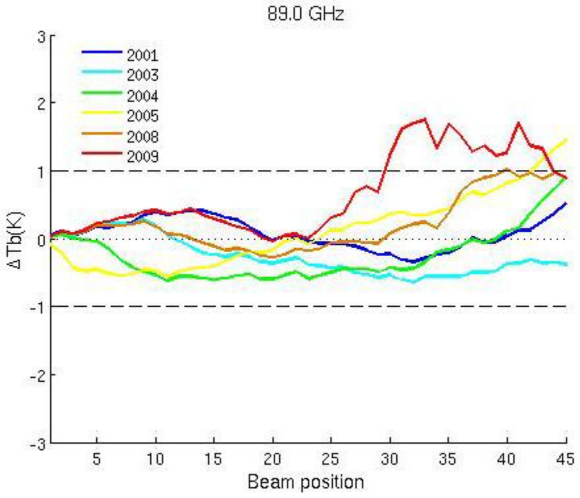


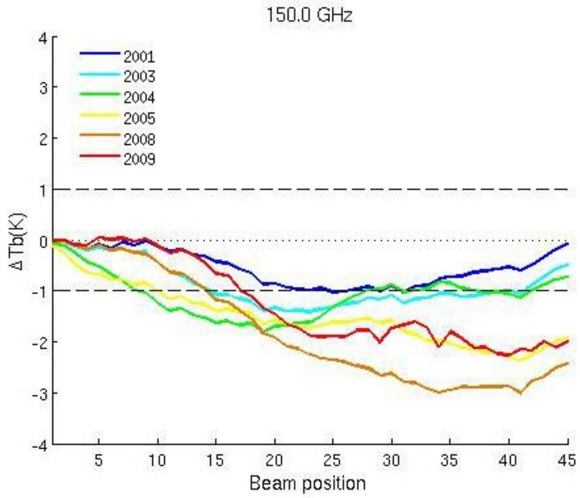
Surface emissivity at 31.4 GHz – before and after cross-scan bias correction



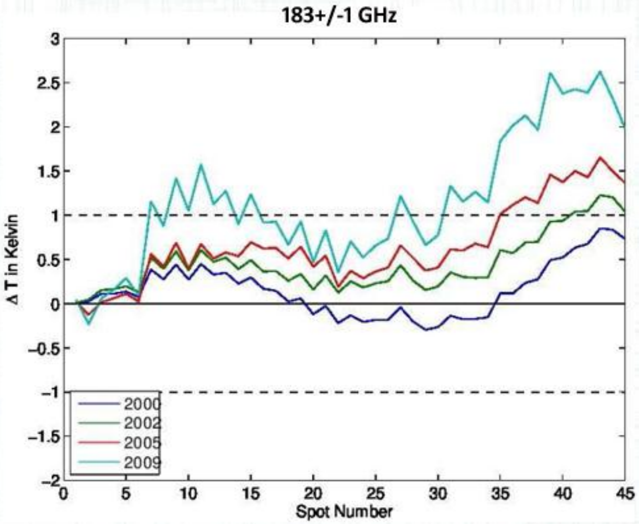


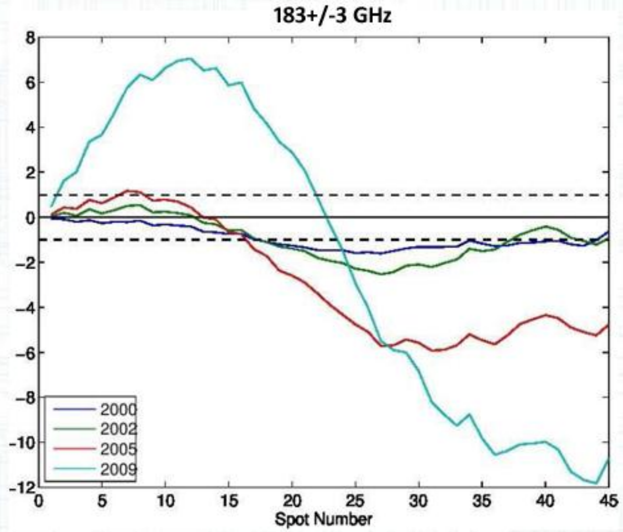
Cross-Scan Bias Characterization – NOAA-15 AMSU-B

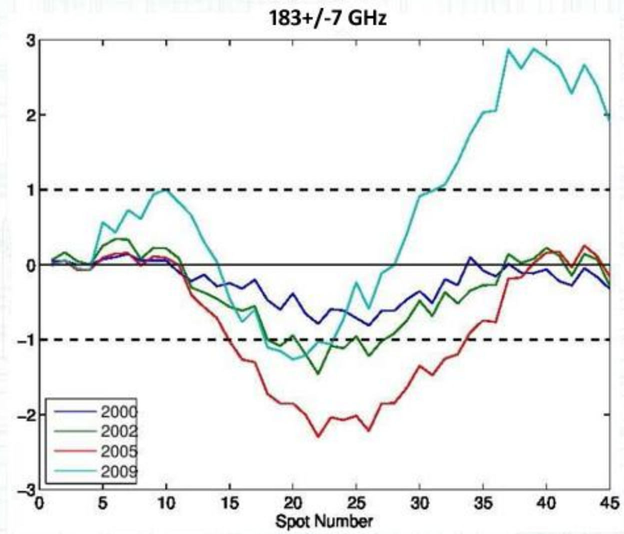




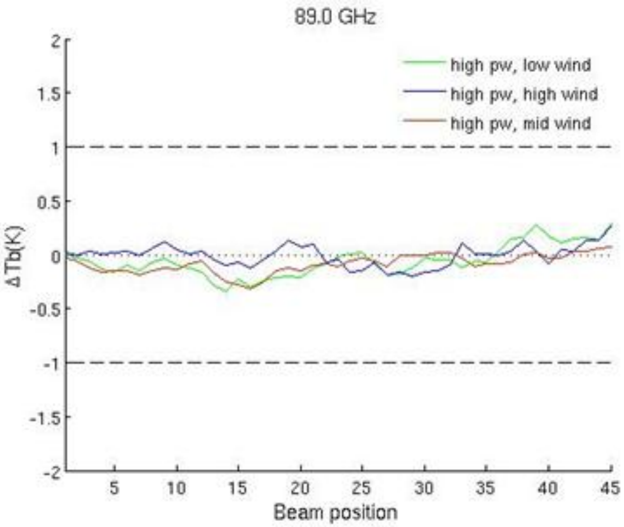
- NOAA-15 AMSU-B Tb differences between corresponding left and right beam positions relative to nadir
- Sensor degradation over the years

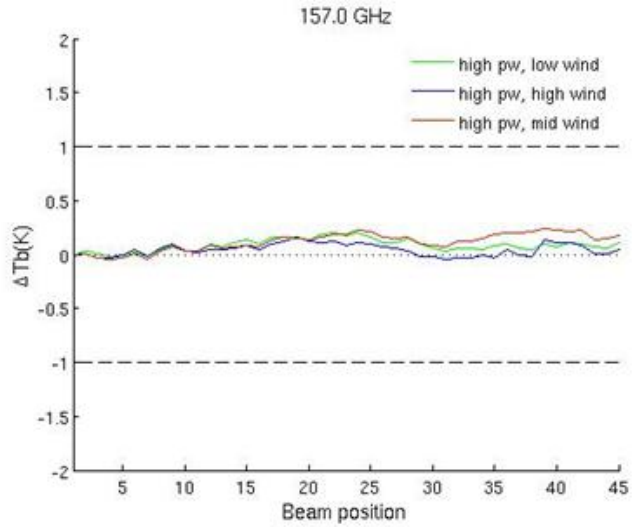




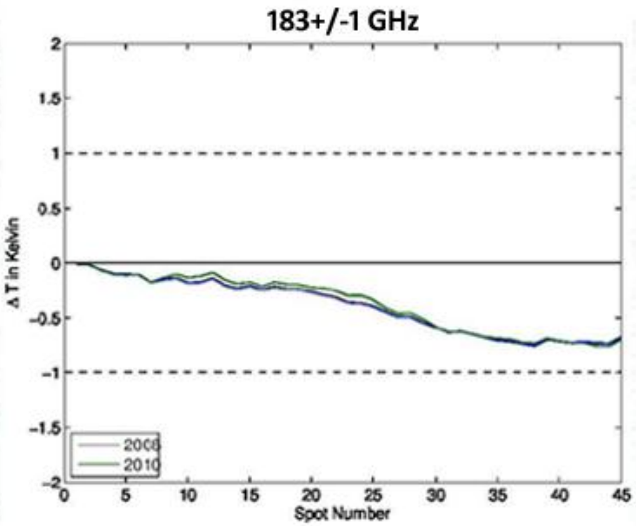


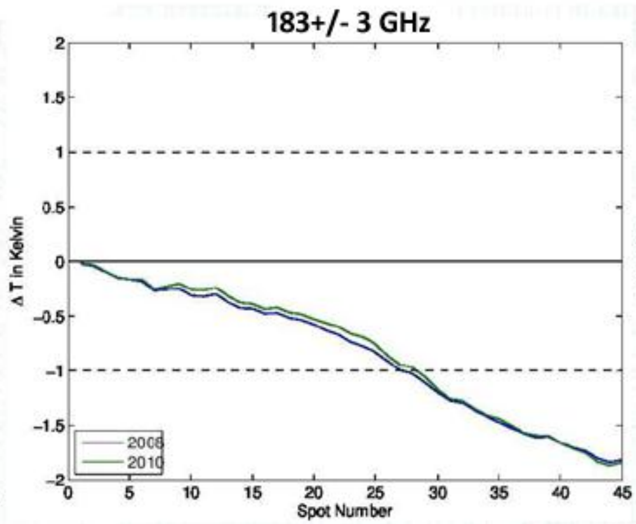
Cross-Scan Bias Characterization – Metop-A MHS

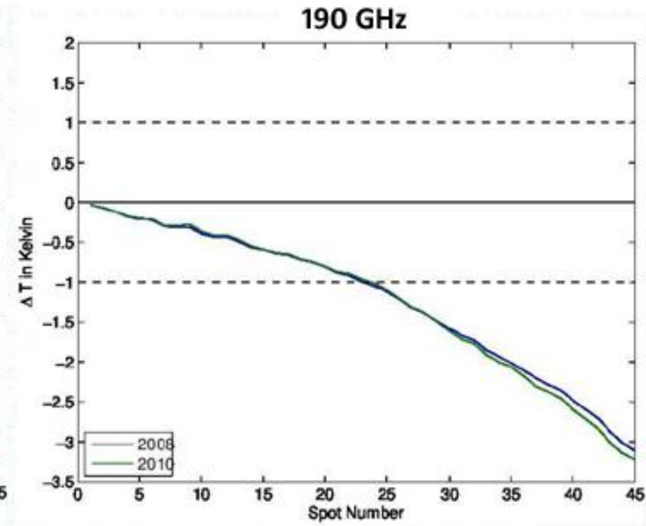




- Metop-A MHS Tb differences between corresponding left and right beam positions relative to nadir
- Large asymmetry in channels-3, 4 & 5

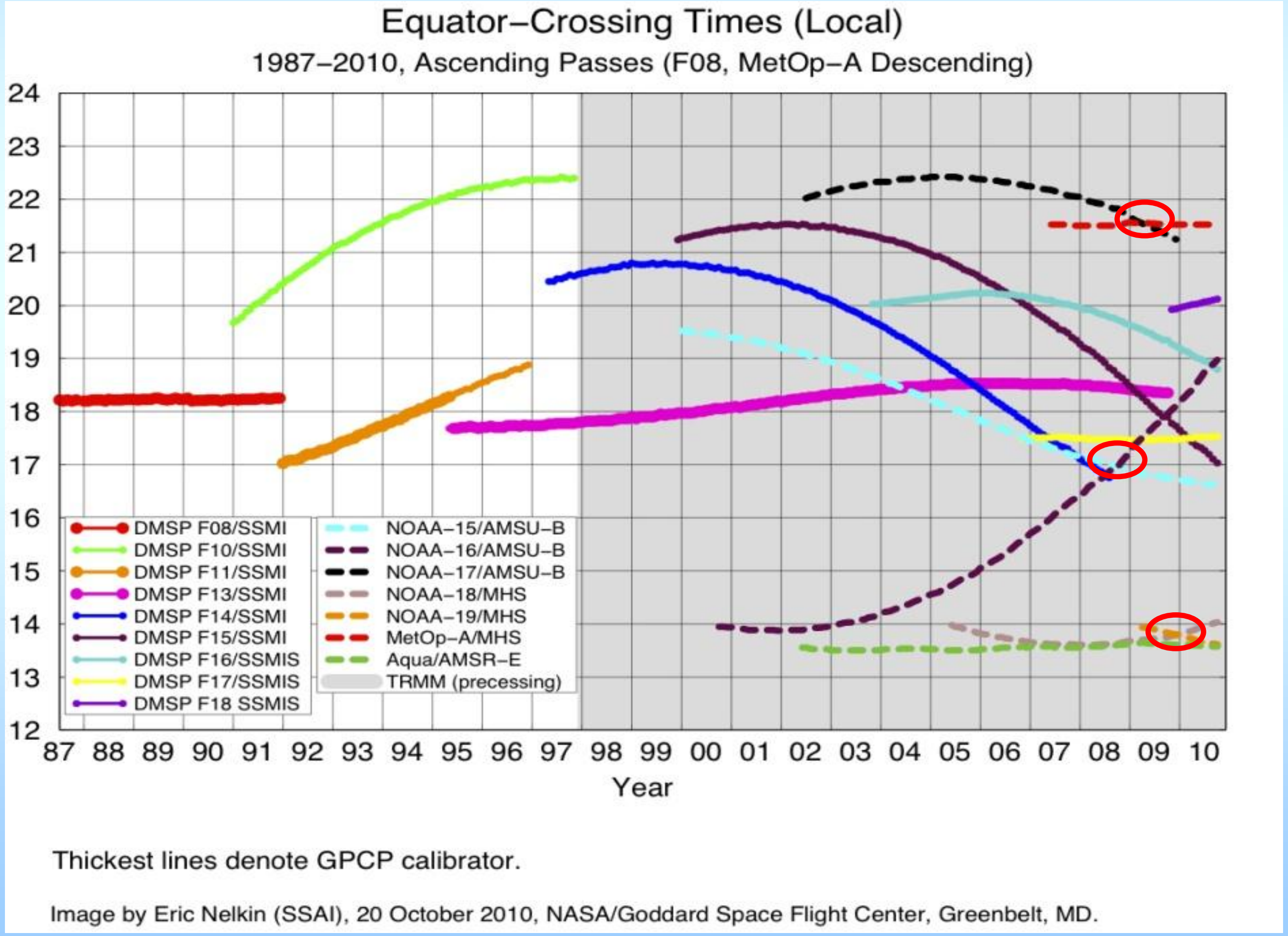




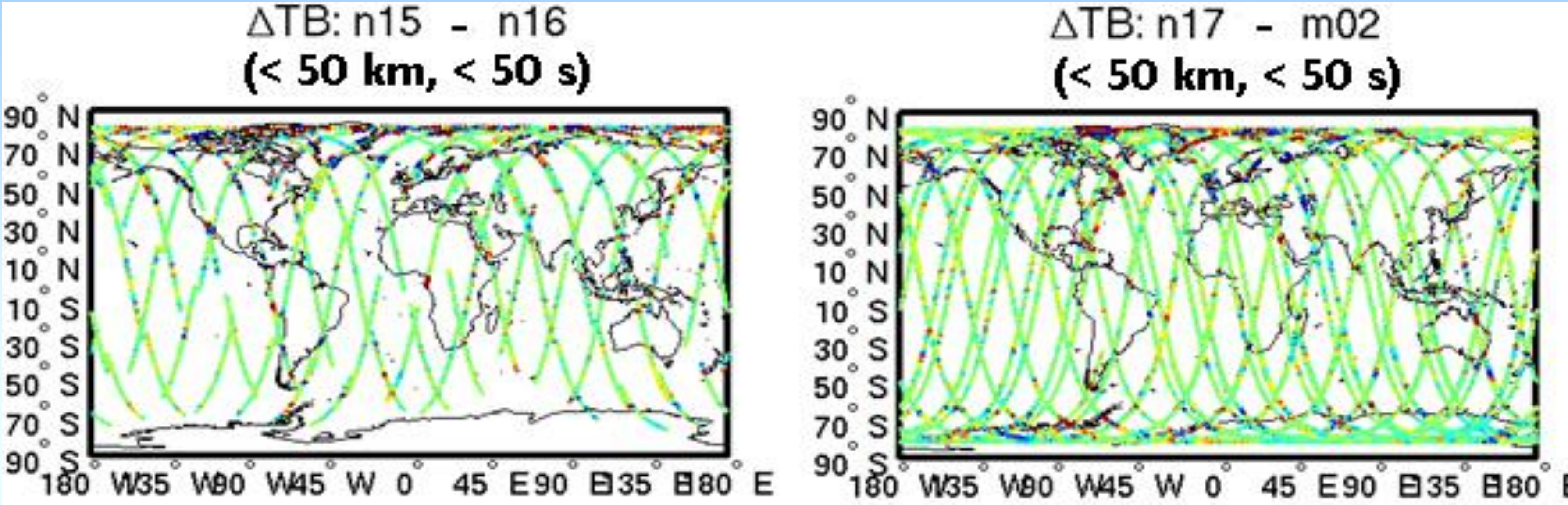


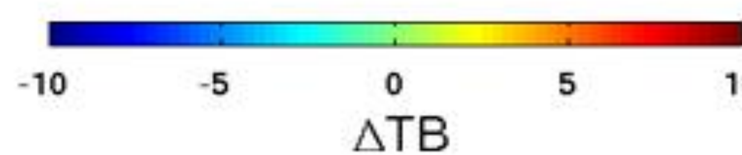
Inter-satellite Calibration – Satellite Overlap

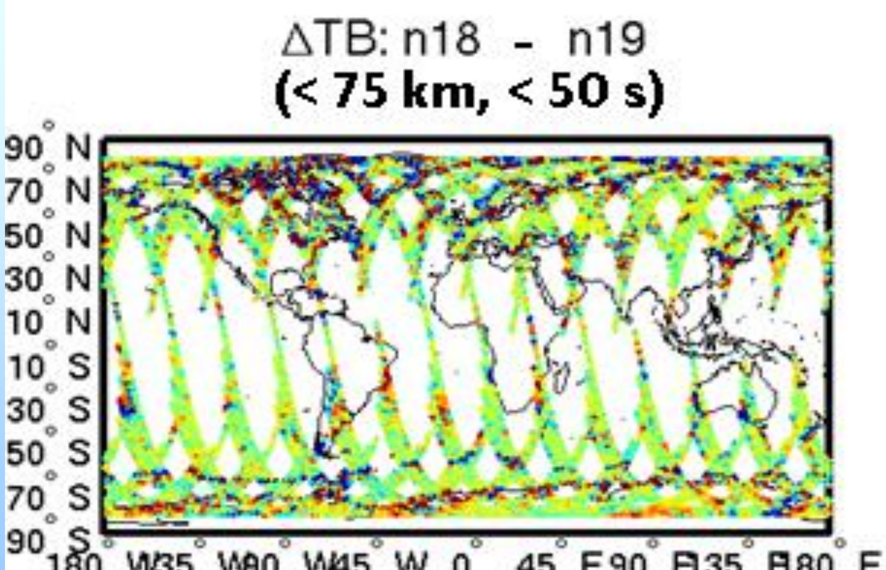
- Three pairs of POES satellites overlaped briefly due to orbital drift: NOAA-15 and -16, NOAA-17 and Metop-A, NOAA-18 and -19



Inter-satellite Calibration – Global SNO (1/2)



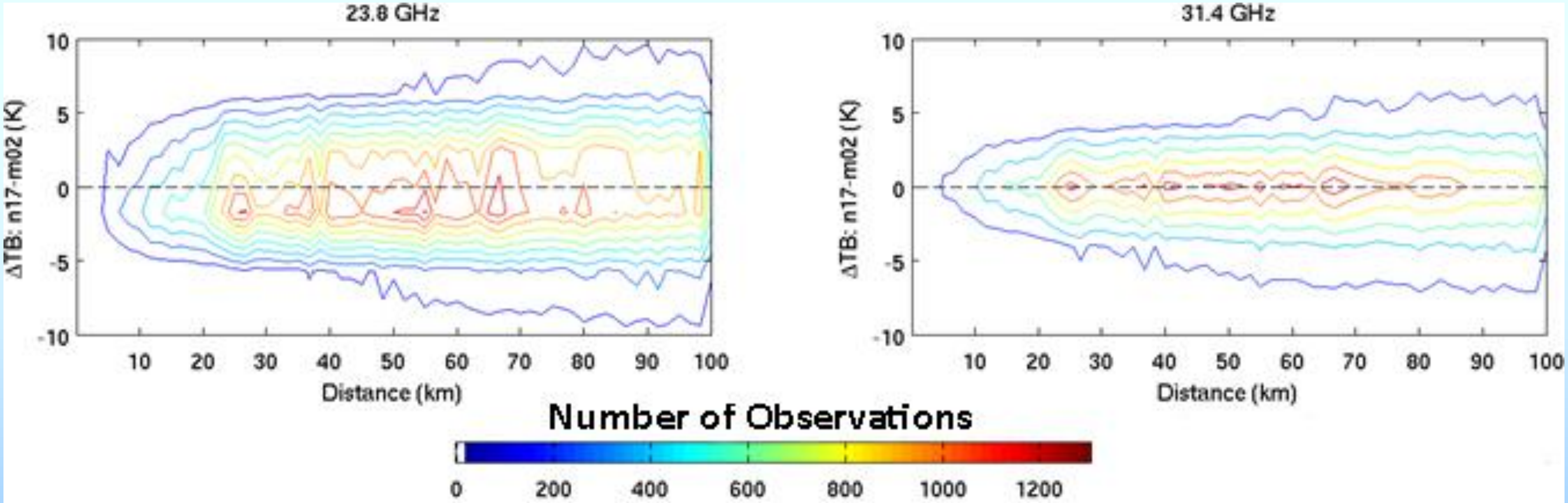




- 23.8 GHz global SNO
- Matching criteria:
  - Distance ≤ 50/75 km depending on satellite pairs
  - Time ≤ 50 s

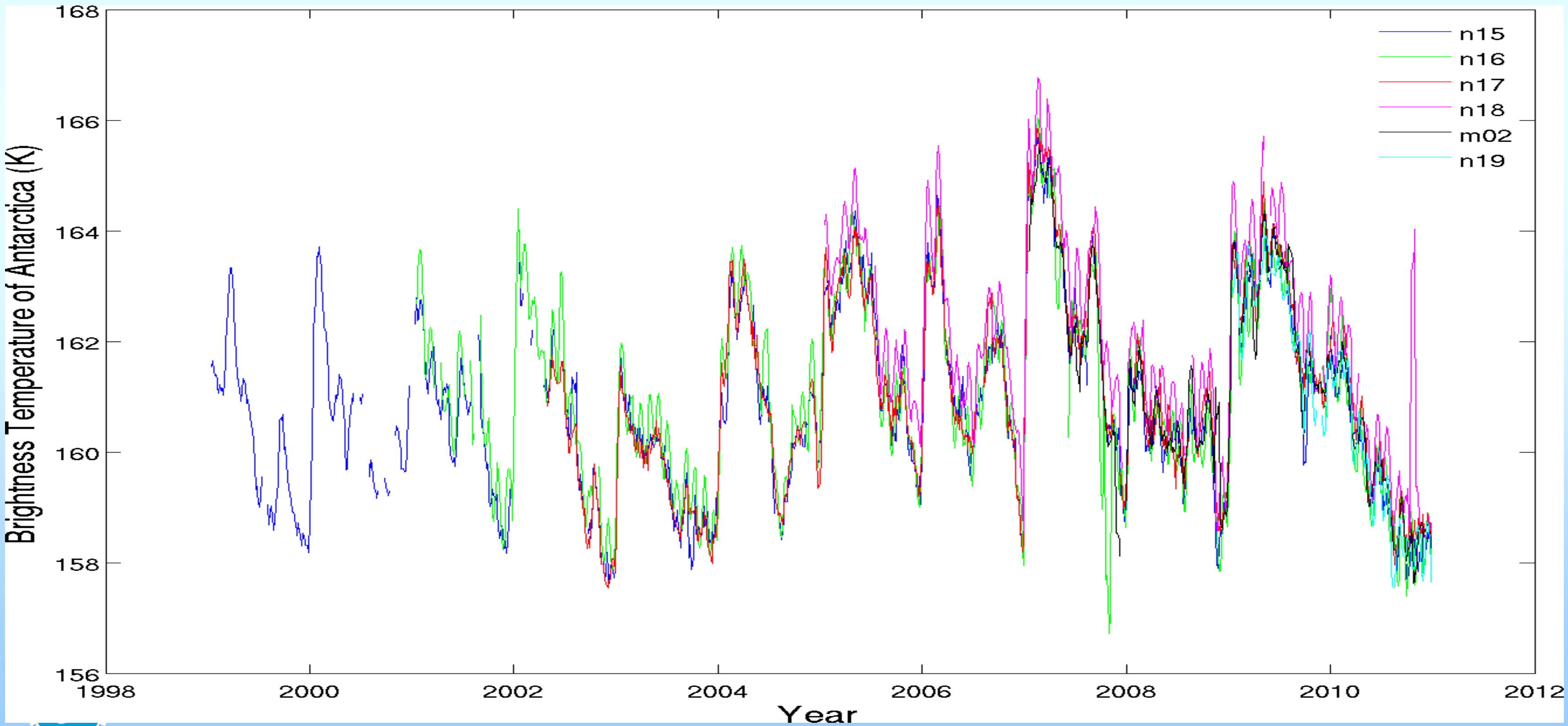
Inter-satellite Calibration – Global SNO (2/2)

- 2D histogram of ΔTb vs. distance between matching pixels
- Metop-A 23.8 tends to be ‘warmer’ than NOAA-17 regardless of the distance criterion used, but 31.4 GHz is comparable.



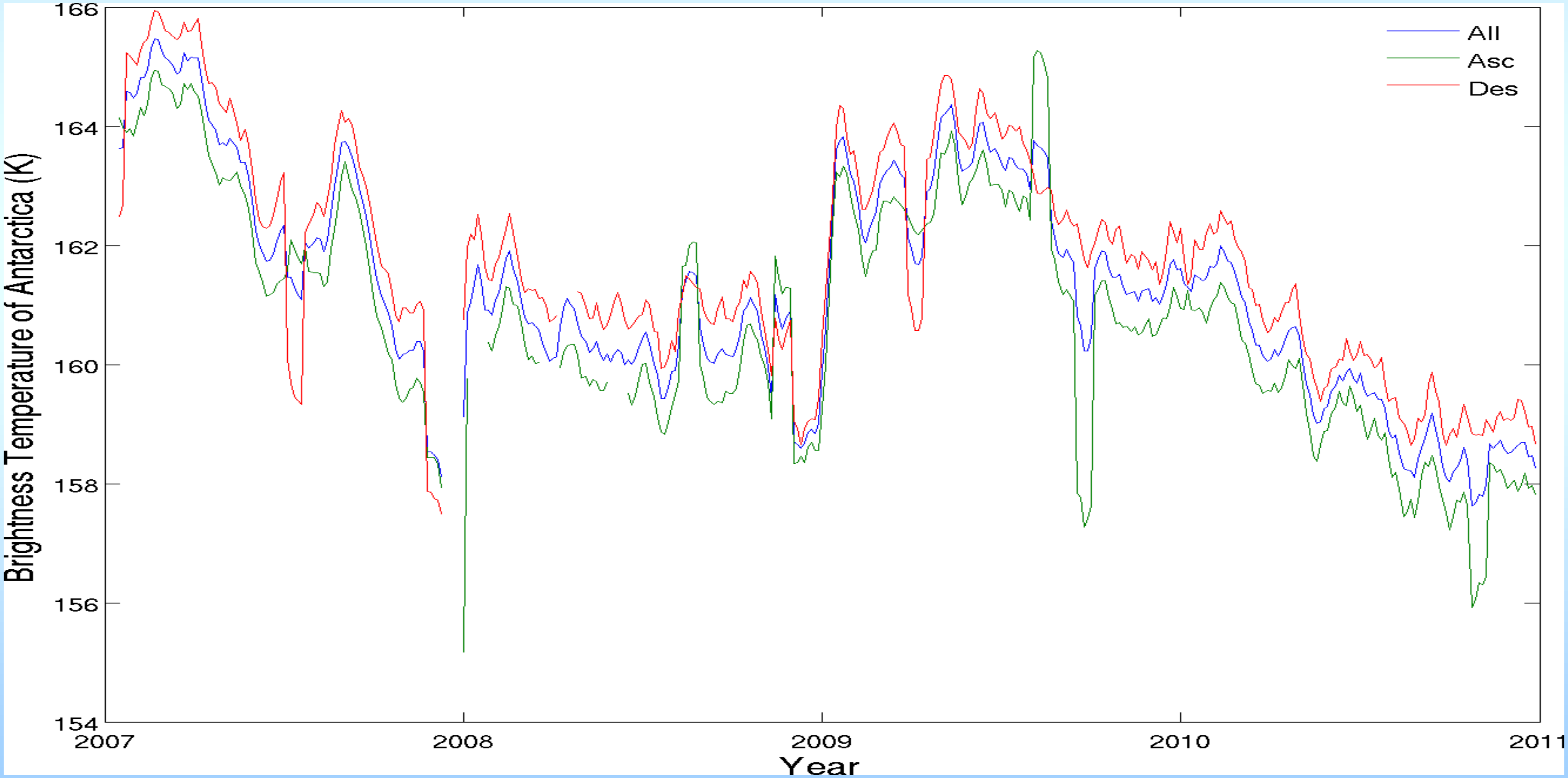
Inter-satellite Calibration – Antarctic (1/2)

- Use Jun-Aug Antarctic winter data from each year to reduce the impact of diurnal cycle due to the almost 24-hr polar night
- Use data from Dome C and the vicinity area to minimize surface heterogeneity
- Satellite measurements (here 23.8 GHz) generally follow the same variation pattern. However, systematic difference is noticeable among satellites



Inter-satellite Calibration – Antarctic (2/2)

- Metop-A ascending and descending 23.8 GHz differ from each other consistently. While the difference is small (~ 1K), it indicates that diurnal cycle impact is still present in the data set



User Application Statements

- From Jeff McCollum, FM Global Insurance:
  - "We've recently started flood mapping outside the U.S. where flood maps aren't readily available. We've started where stream gage and rain gauge data are available, so that we can get by without satellite data (although they can be helpful for hydrologic model calibration). But as we expand into other locations with limited ground-based data, remote sensing and reanalyses/land surface models may be our main data source. We need climate data records that are as long as possible so we can estimate magnitudes for extreme events, e.g. 100-yr rainfall. Then we can use hydrologic modeling to estimate x-yr discharges used for flood mapping. Since the reanalyses/land surface model data outputs are usually longer but less accurate than satellite precip, we can also use satellite precip to somehow make the longer but less accurate model precip data more useful."
- From Alan Basist, WeatherPredict Consulting:
  - "Weather Predict Consulting consistently uses the microwave satellite data provided by NESDIS to run operational products for Renaissance Reinsurance. These services are essential to the planning and monitoring activities, in order to assess risk profiles for return period of natural disasters, as well as their associated loss profiles. This helps us to assign the appropriate level of premium, and/or determine if an offer from a reinsurance program is properly priced. The data allows us to also assess hazards (such as flood, drought, and crop yields) as they develop. We use these data to determine the probability of various level of loss, which allows us to calculate the loss/cost ratio as an event unfolds. This is beneficial to monitoring our potential payout, and maintaining a up-to-date calculation of the cost of an impending event. Any additional data we could use from the AMSU instrument would be an useful contribution to the expanding utility of the services and products provided by NESDIS."