Overview of AMSU-A Inter-satellite Calibration Bias Analysis Using the SNO Method

March 2, 2011

NOAA CDR Workshop, 2011   College Park, MD

Robert Iacovazzi, Jr. **(ERT, Inc.), Changyong Cao (NESDIS/StAR) and Sid-Ahmed Boukabara (NESDIS/StAR)**

Outline

- AMSU-A instrument characteristics and AMSU-A intersatellite bias detection utilizing the SNO method
- SNO-ensemble avg. biases between AMSU-A instruments at sounding channels (Chs 3-14)
- The impact of data collocation method on SNO bias uncertainty estimates
- SNO-ensemble biases inferred for NOAA-14 MSU and NOAA-15 AMSU-A
- Summary

National Environmental Satellite, Data, and Information Service

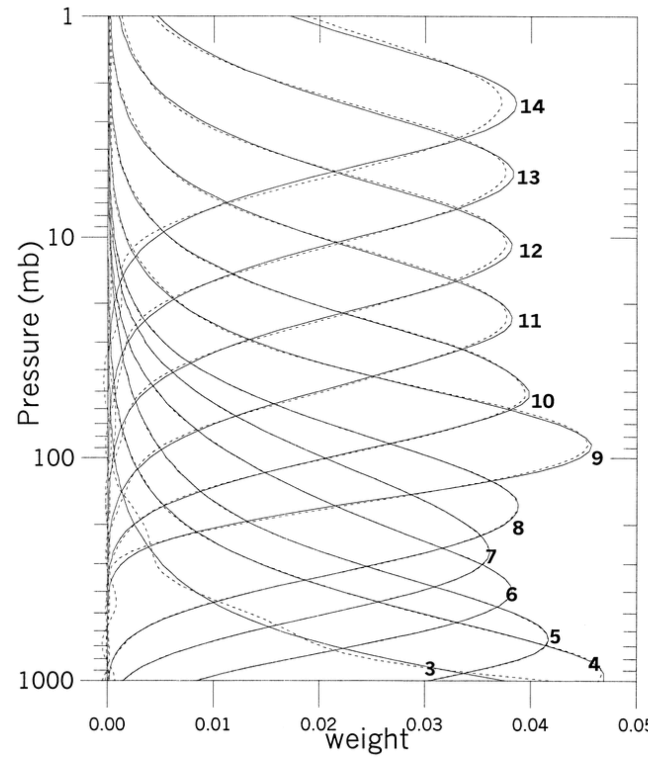
Earth Resources Technology

Outline

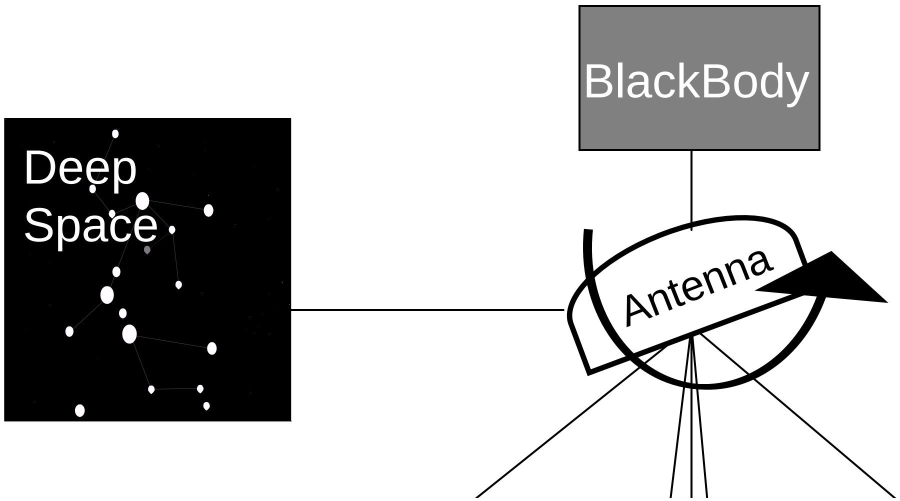
- **AMSU-A instrument characteristics and AMSU-A intersatellite bias detection utilizing the SNO method**
- **SNO-ensemble avg. biases between AMSU-A instruments at sounding channels (Chs 3-14)**
- **The impact of data collocation method on SNO bias uncertainty estimates**
- **SNO-ensemble biases inferred for NOAA-14 MSU and NOAA-15 AMSU-A**
- **Summary**

Advanced Microwave Sounding Unit-A Instrument Characteristics

Frequencies: 15 Channels @ 24, 31, 50-57, and 89 GHz

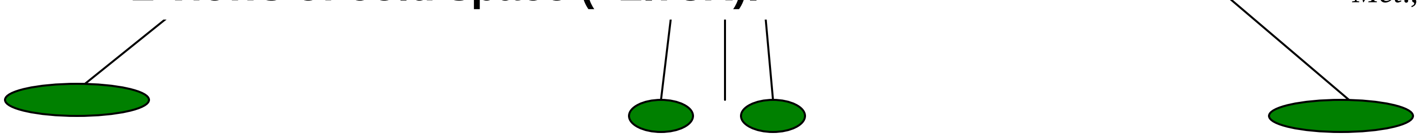


Goldberg et al., 2000: *J. Applied Met.*, **40**, 70-83.



During each eight second in-orbit scan line, the AMSU-A views three different types of targets:

- **30 Earth view (EV) positions,**
- **2 views of the internal warm target (~300K), and**
- **2 views of cold space (~2.73K).**



EV-1 (~-48.3 Deg)

EV-30 (~+48.3 Deg)

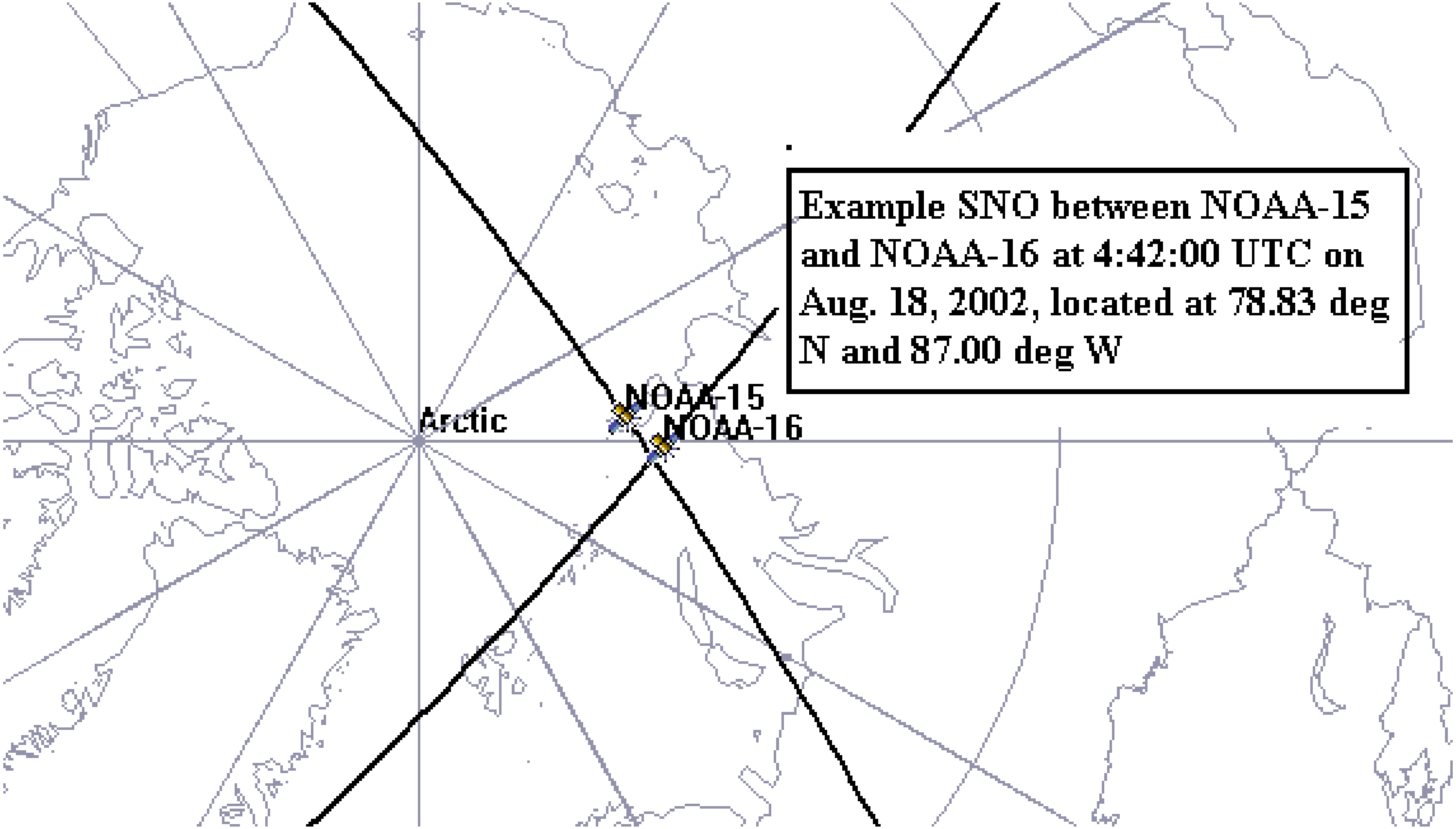
~ 50 km Footprint Near-Nadir

~ 150 km Limb Footprint @ Limb

National Environmental Satellite, Data, and Information Service

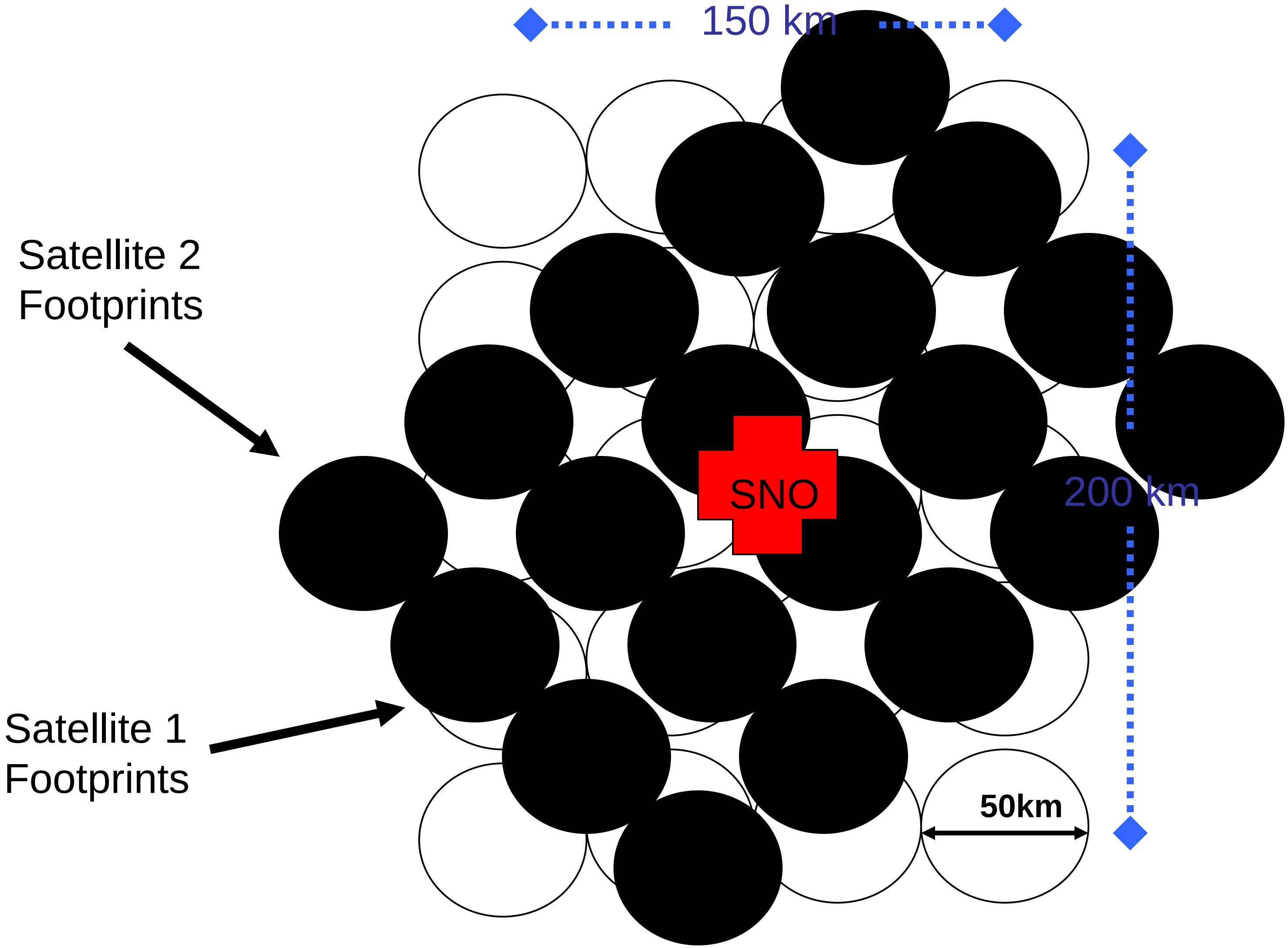
Earth Resources Technology

Typical Simultaneous Nadir Overpass (SNO)



Cao *et. al.*, J. Atmos. Ocn. Tech., 2004

AMSU-A SNO Dataset Collocation



Outline

- AMSU-A instrument characteristics and AMSU-A intersatellite bias detection utilizing the SNO method
- **SNO-ensemble avg. biases between AMSU-A instruments at sounding channels (Chs 3-14)**
- The impact of data collocation in SNO bias estimation uncertainty
- SNO-ensemble biases inferred for NOAA-14 MSU and NOAA-15 AMSU-A
- Summary

Operational AMSU-A SNO Ensemble Dataset

Time Period: *May 21, 2005* to *July 31, 2006*

Locations: *Typically Around 80⁰ North and South*

SNO Time Threshold: *30 Seconds*

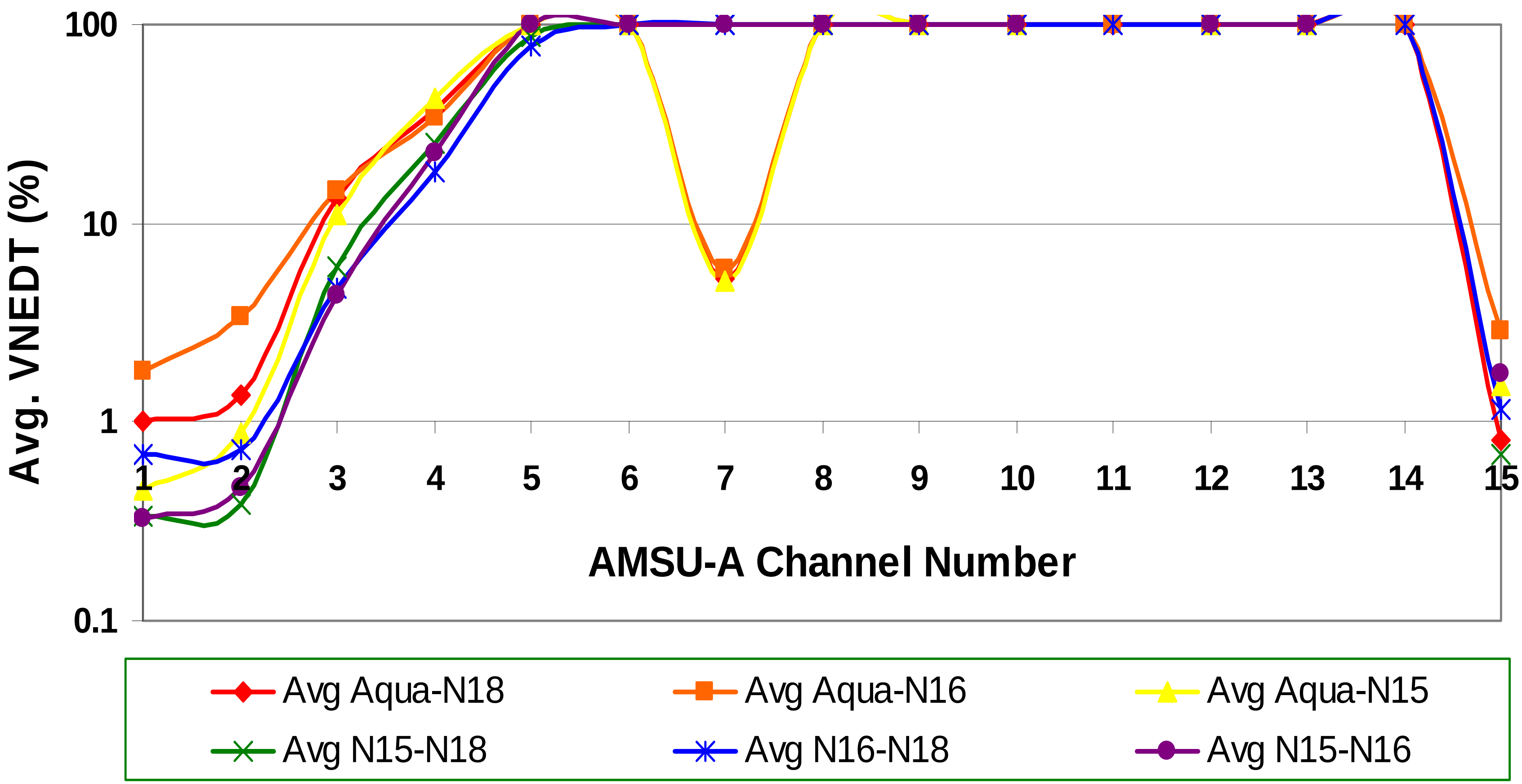
Number of SNOs:

	Aqua / N15	Aqua/ N16	Aqua/ N18	N15/ N16	N15/ N18	N16/ N18
Northern Hemisphere (NH)	63	57	58	57	60	54
Southern Hemisphere (SH)	65	53	55	55	57	54
Globe	128	110	113	112	117	108

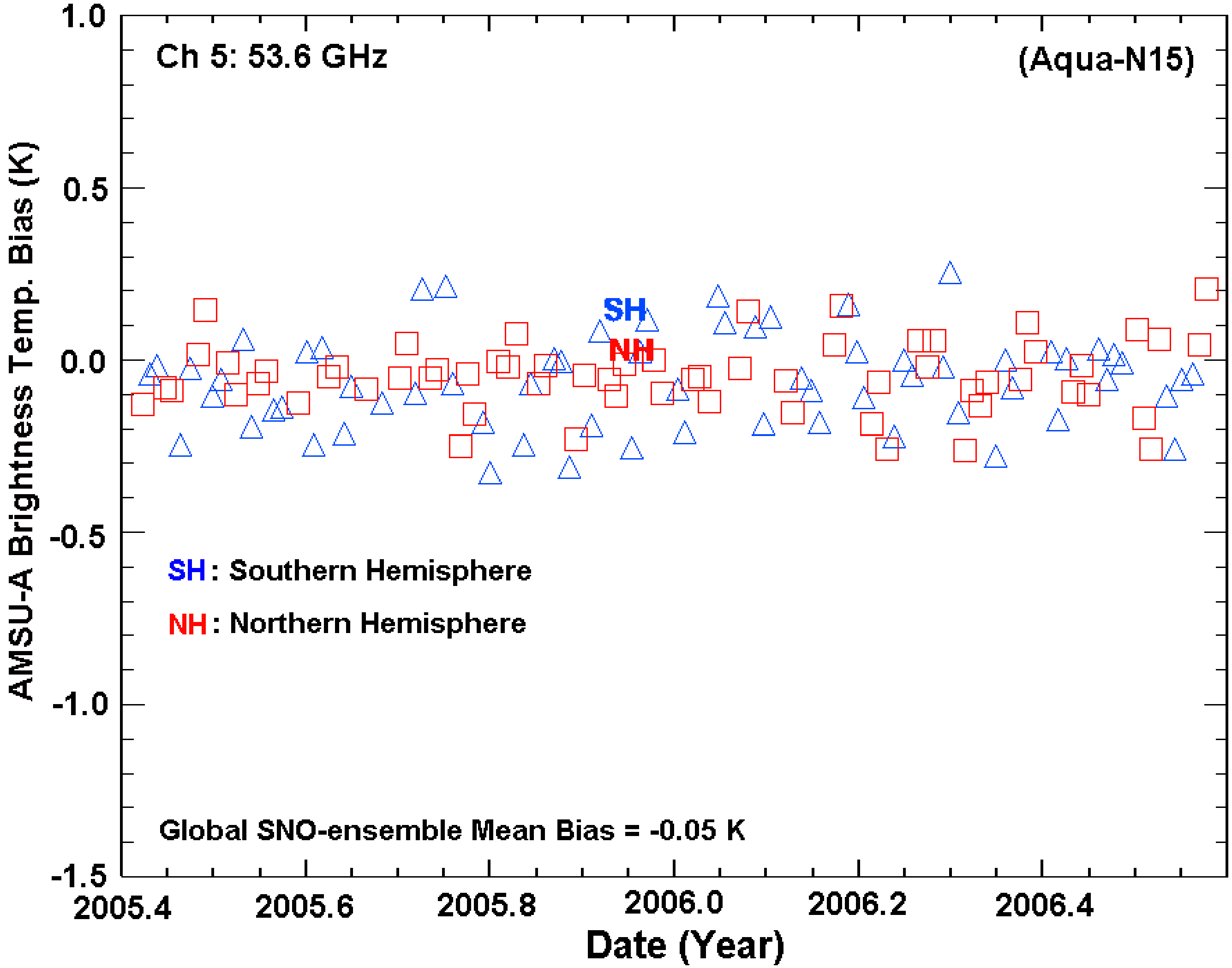
AMSU-A SNO Uncertainty Relative to NEDT

Avg. Percentage of SNO Bias Variance due to NEDT

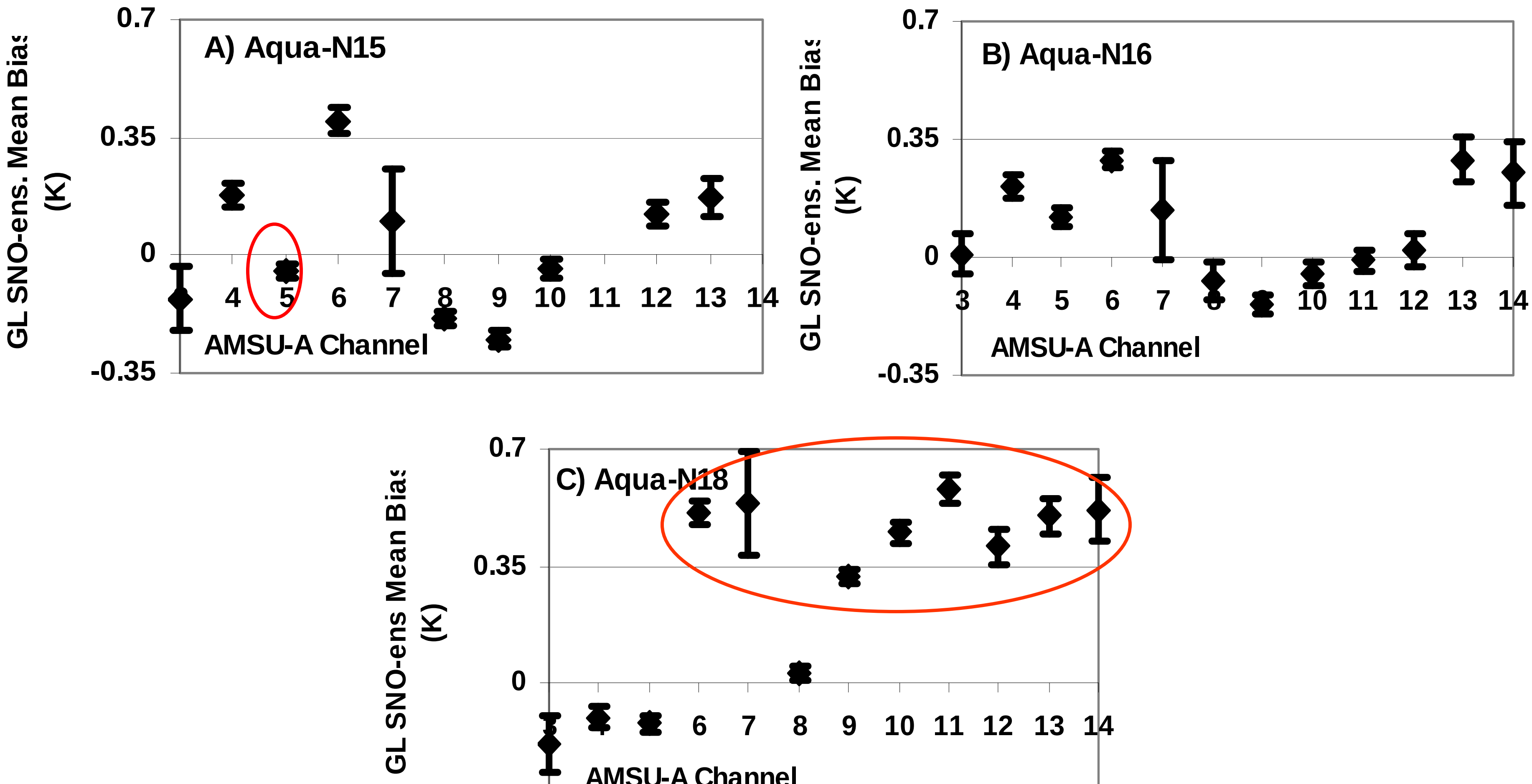
$$V_{NEDT} = 100 \times \sum_{N=1}^{N_{sno}} \left(\frac{\sigma^2_{NEDT}(Sat1) + \sigma^2_{NEDT}(Sat2)}{\sigma^2_N (Sat1 - Sat2)} \right) \Big/ N_{sno}$$



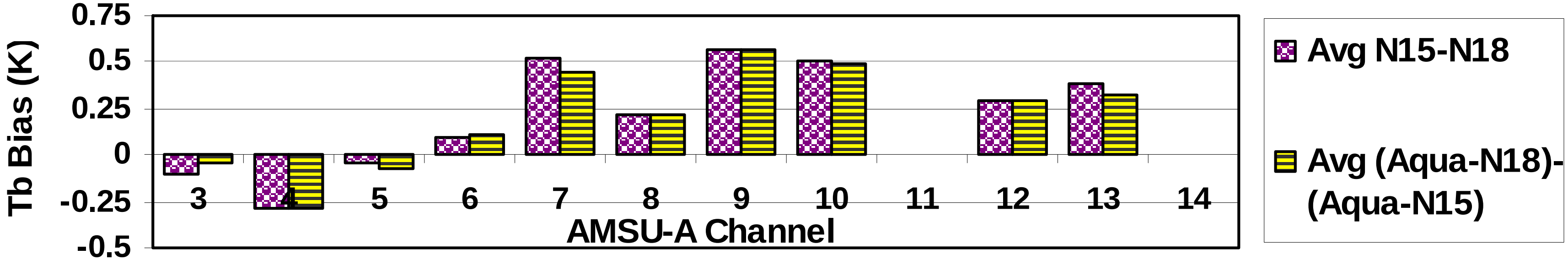
Aqua and N15 AMSU-A Individual SNO Mean Bias Time Series

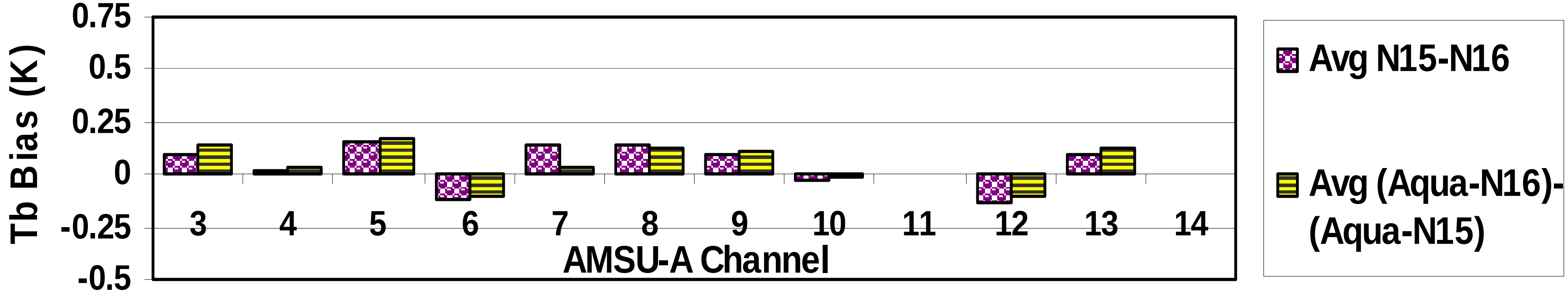


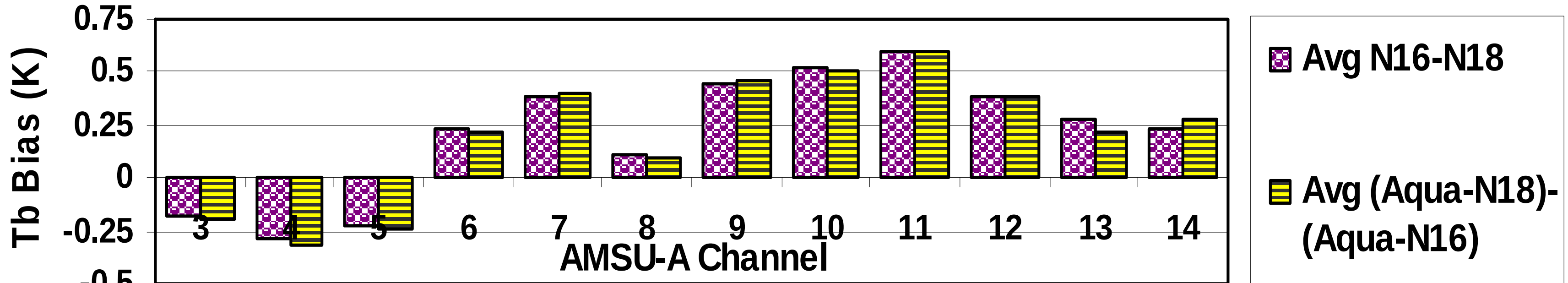
POES and Aqua AMSU-A SNO-ensemble Mean Biases and 99% Confidence Intervals



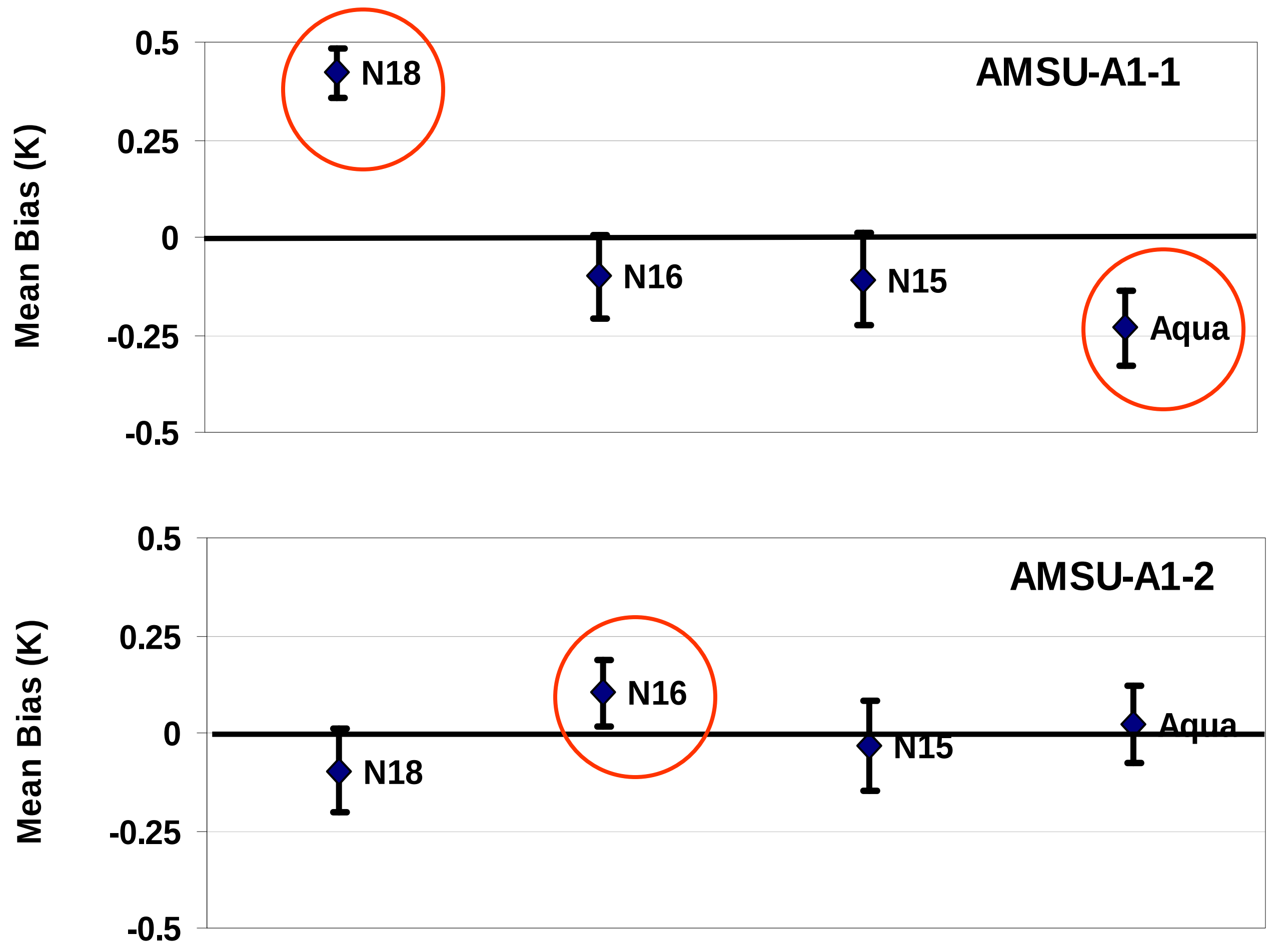
Estimated and Observed and AMSU-A SNO biases using Aqua/AMSU-A as a Calibration Transfer Radiometer



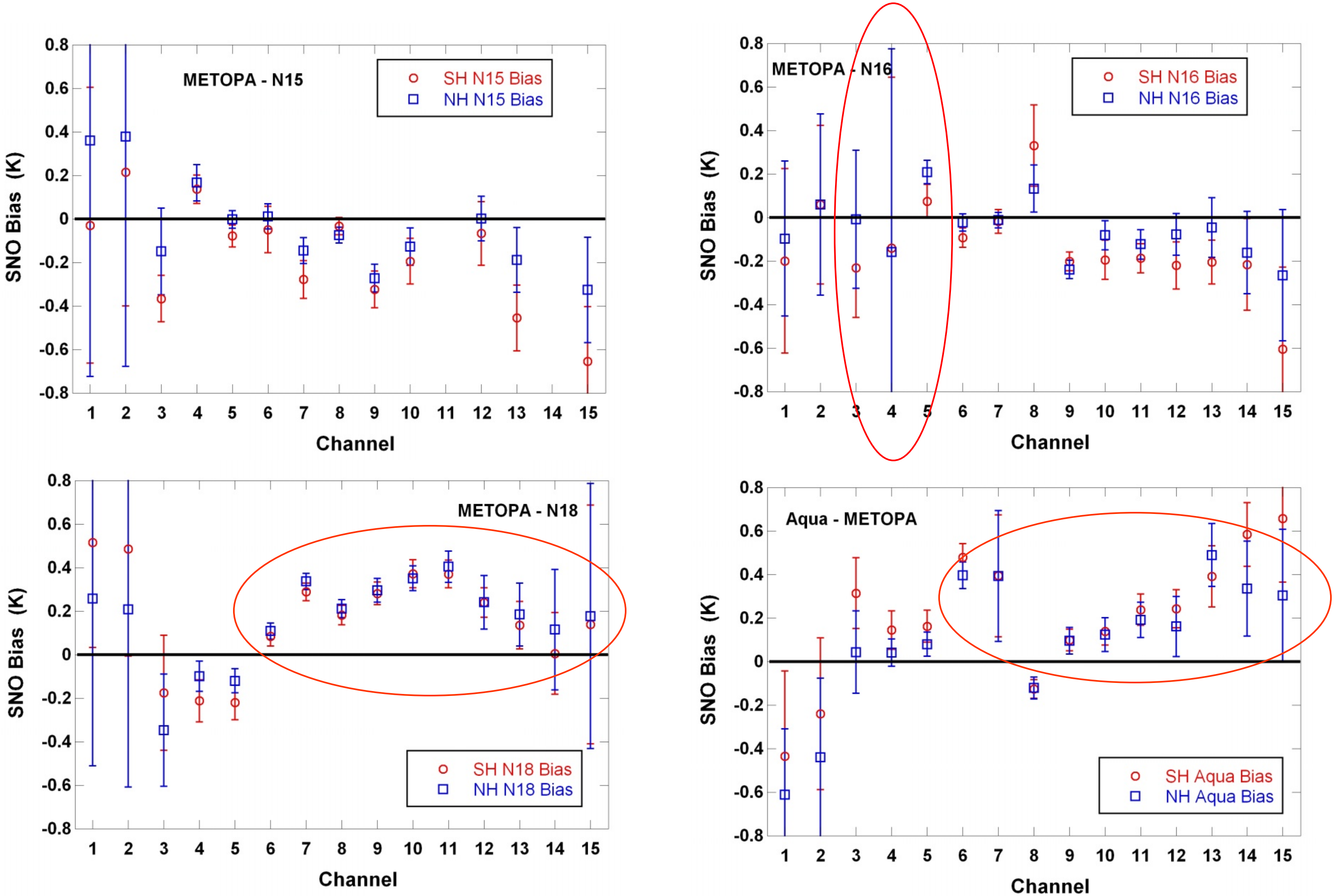




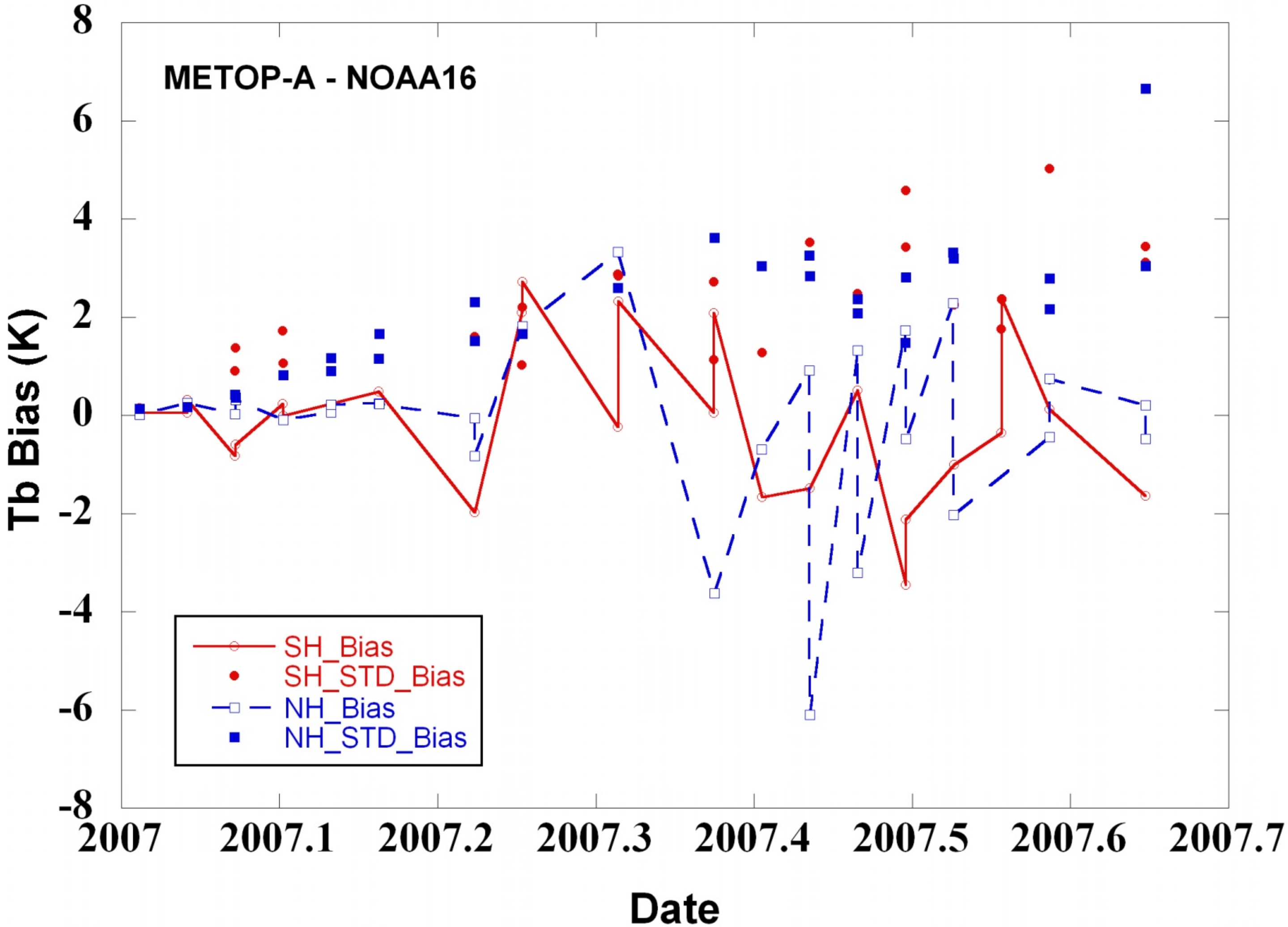
Channel aggregated SNO biases for AMSU-A1-1 and AMSU-A1-2 subunits



MetOP-A AMSU-A SNO-ensemble Mean Biases and 99% Confidence Intervals



AMSU-A SNO Mean Biases and STD MetOP-A/NOAA16 Ch 4



National Environmental Satellite, Data, and Information Service

Earth Resources Technology

Outline

- AMSU-A instrument characteristics and AMSU-A intersatellite bias detection utilizing the SNO method
- SNO-ensemble avg. biases between AMSU-A instruments at sounding channels (Chs 3-14)
- **The impact of data collocation method on SNO bias uncertainty estimates**
- SNO-ensemble biases inferred for NOAA-14 MSU and NOAA-15 AMSU-A
- Summary

Operational AMSU-A SNO Ensemble Dataset

Satellites: NOAA18 and EOS-Aqua

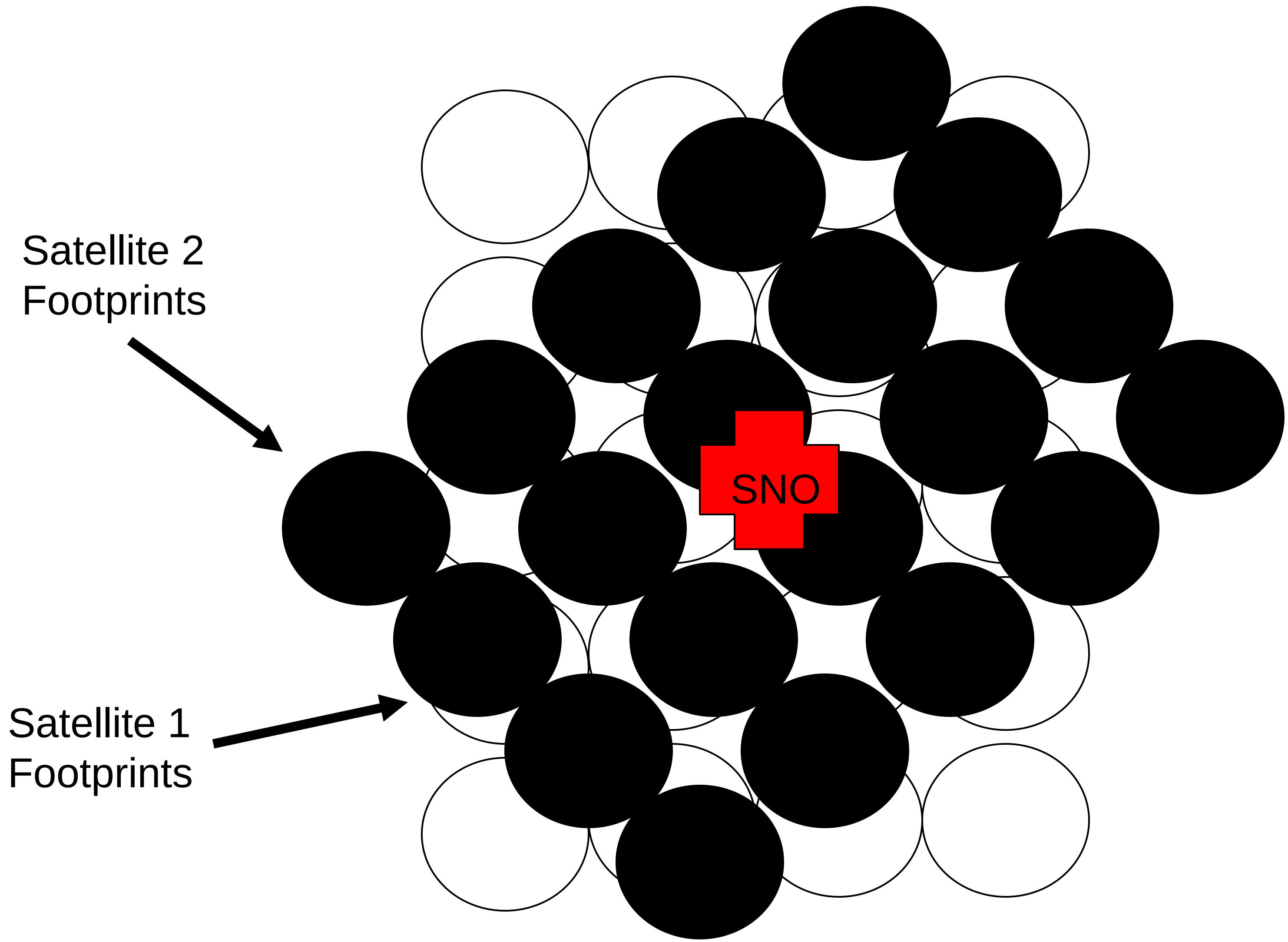
Time Period: *21 May 2005* - 31 *January 2007*

Locations: *Typically Around 80^0 North and South*

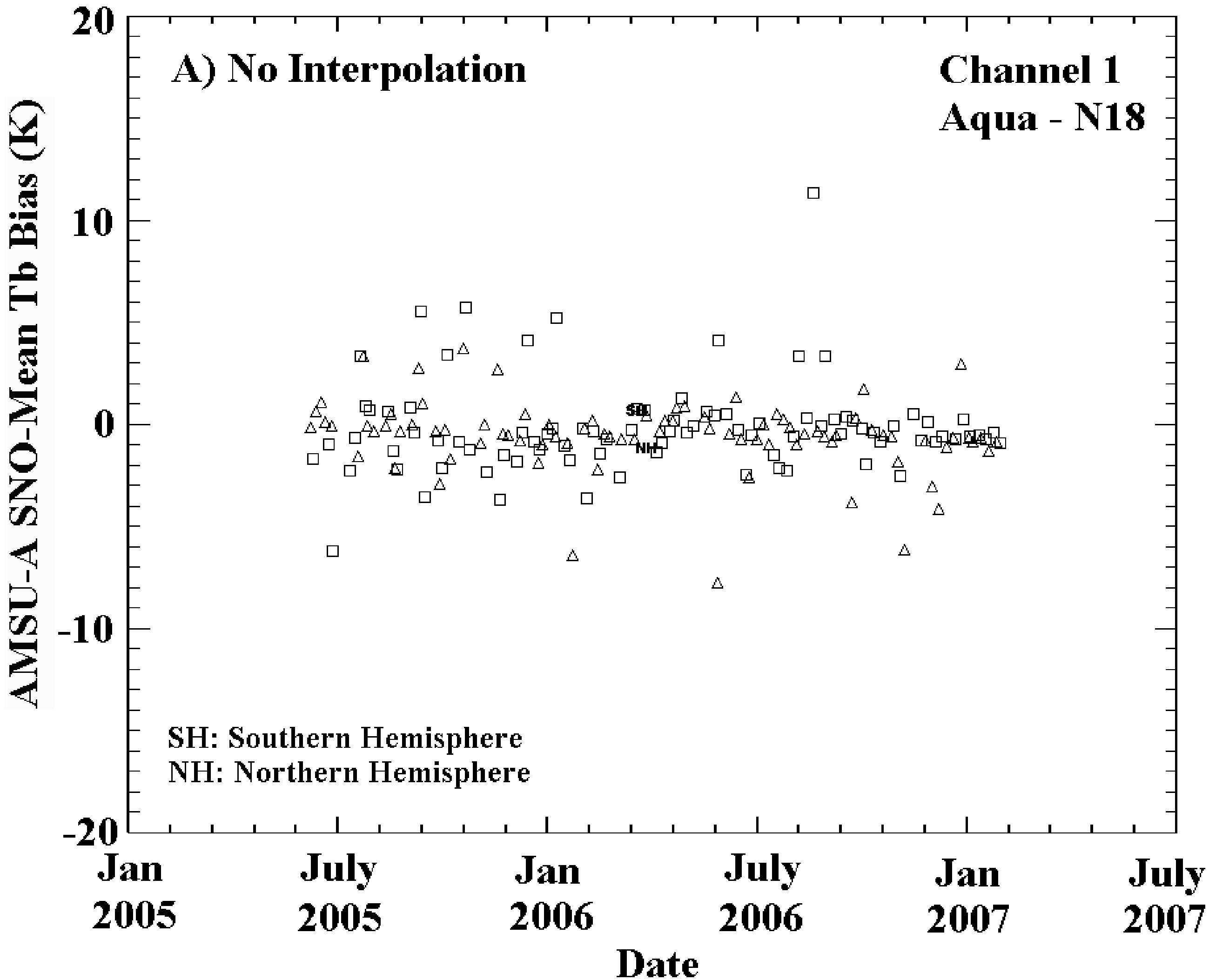
SNO Time Threshold: *30 Seconds*

Number of SNOs:
89 *Northern Hemisphere*
85 *Southern Hemisphere*

Nearest-Neighbor Data Collocation



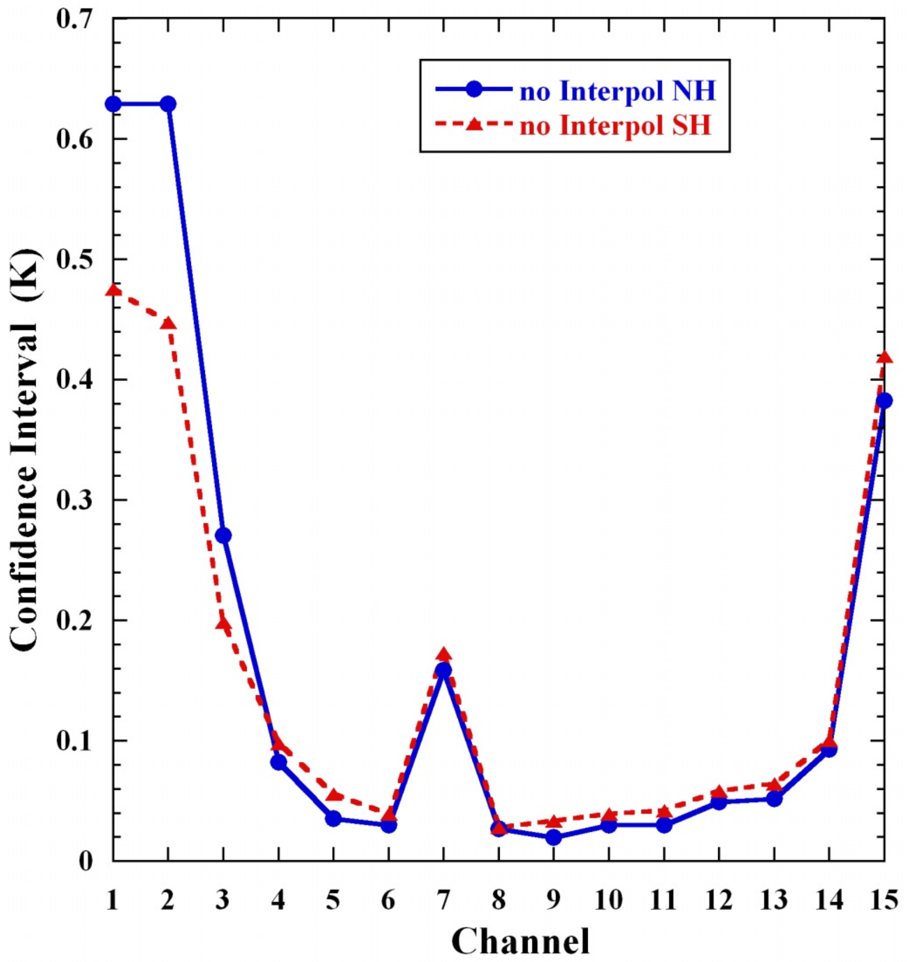
AMSU-A Ch 1 SNO Mean Bias Time Series Using Nearest-neighbor Collocation



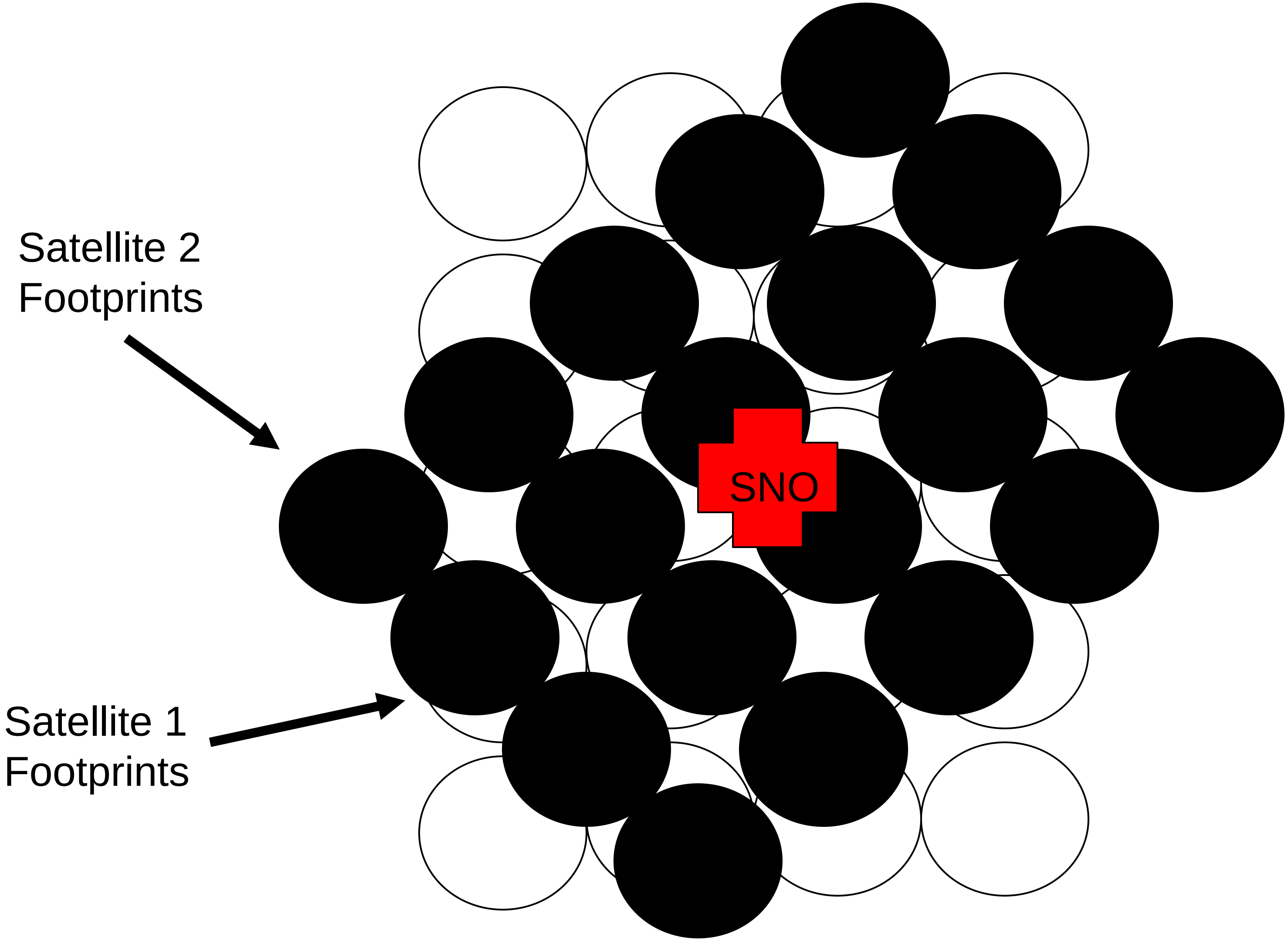
National Environmental Satellite, Data, and Information Service

Earth Resources Technology

AMSU-A SNO Mean Bias Uncertainties Using Nearest-neighbor Collocation



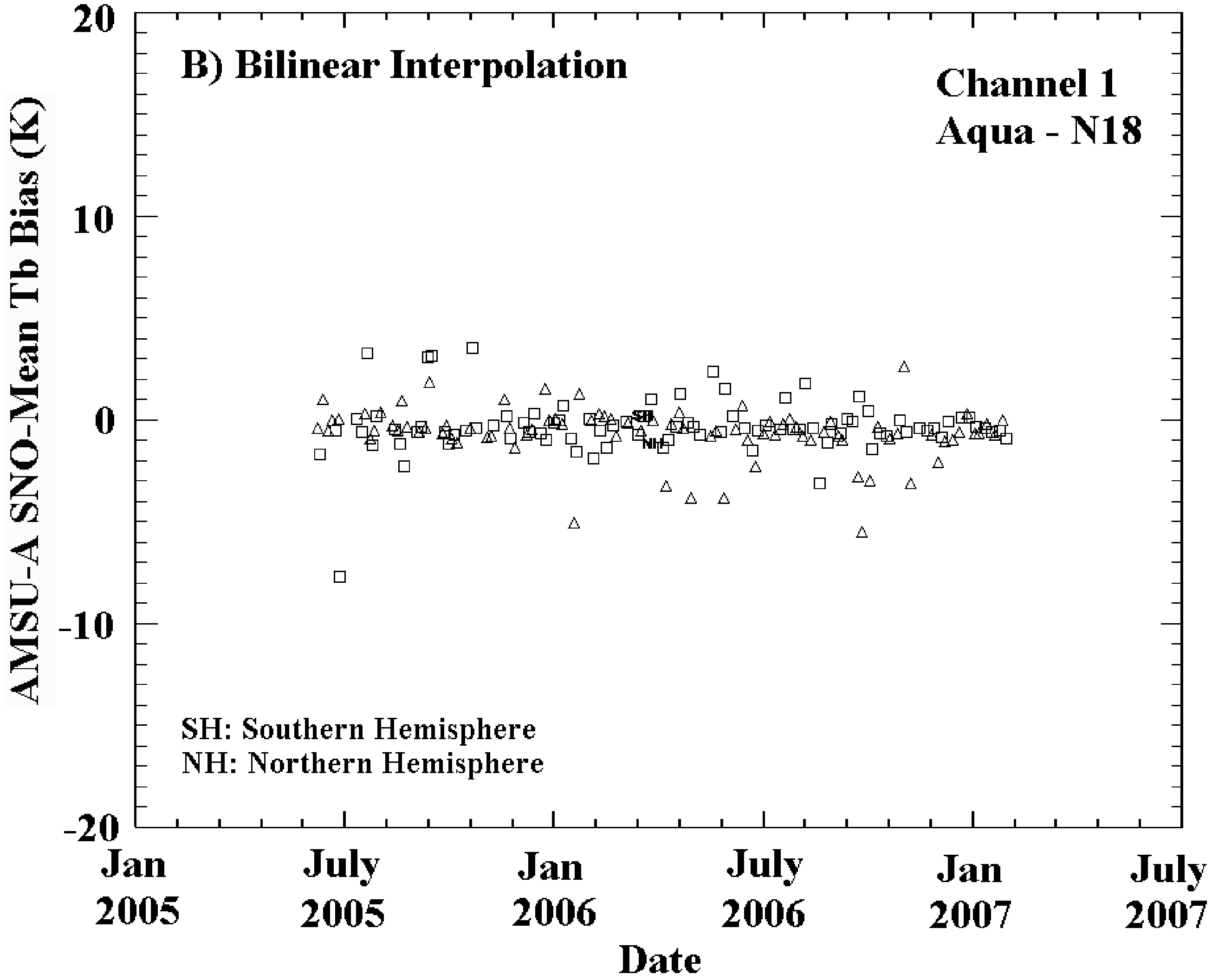
Bilinear Interpolation Data Collocation



National Environmental Satellite, Data, and Information Service

Earth Resources Technology

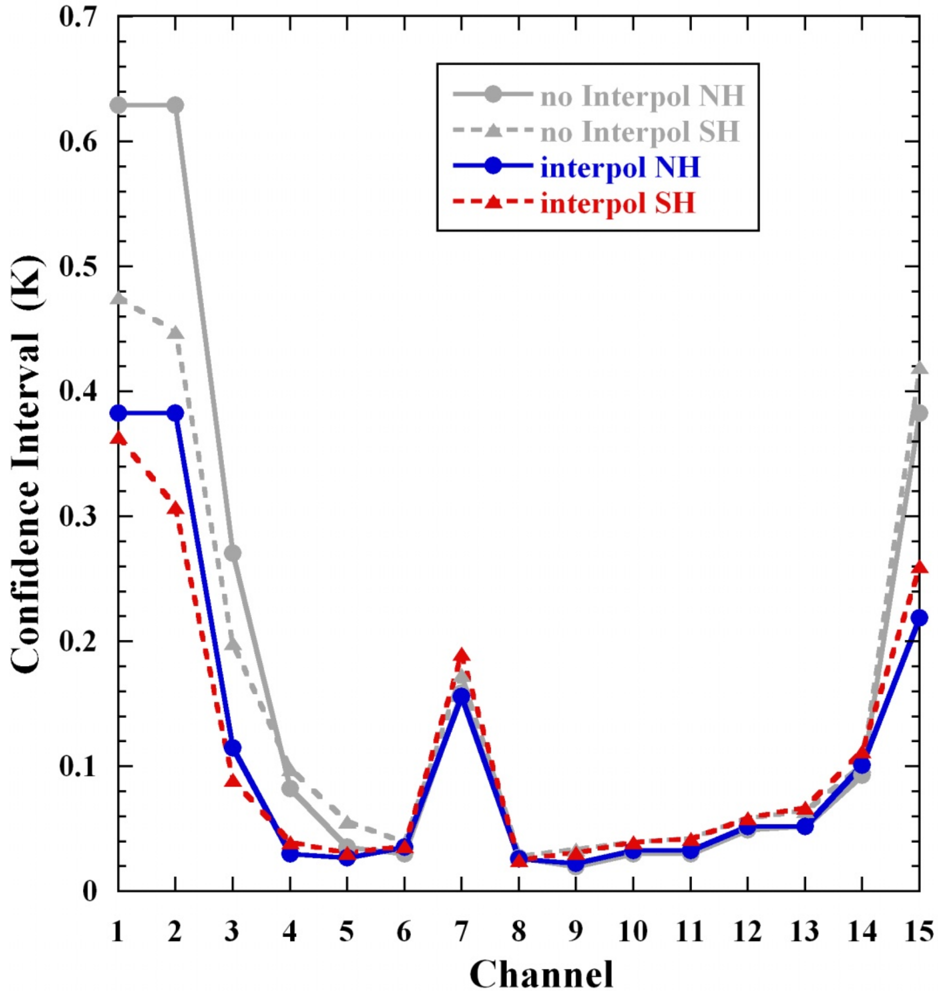
AMSU-A Ch 1 SNO Mean Bias Time Series Using Bilinear Interpolation Collocation



National Environmental Satellite, Data, and Information Service

Earth Resources Technology

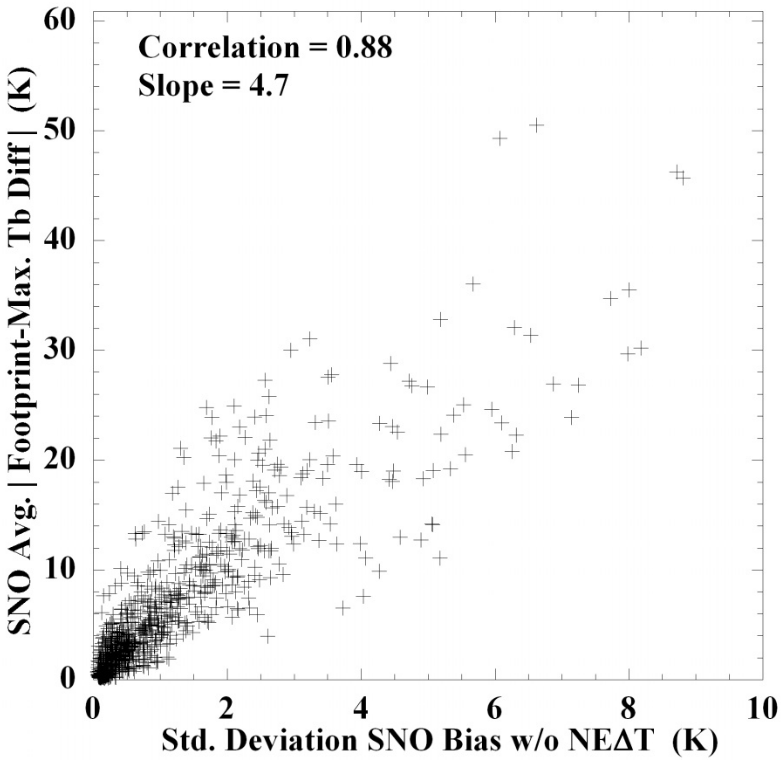
AMSU-A SNO Mean Bias Uncertainties Using Bilinear Interpolation Collocation



National Environmental Satellite, Data, and Information Service

Earth Resources Technology

Screening SNO Events for Anomalous Scene Inhomogeneity



Establish a maximum brightness temperature (Tb) difference threshold around a given observation using

1) **Assume a target SNO Bias STD (without NEΔT) at a given channel**

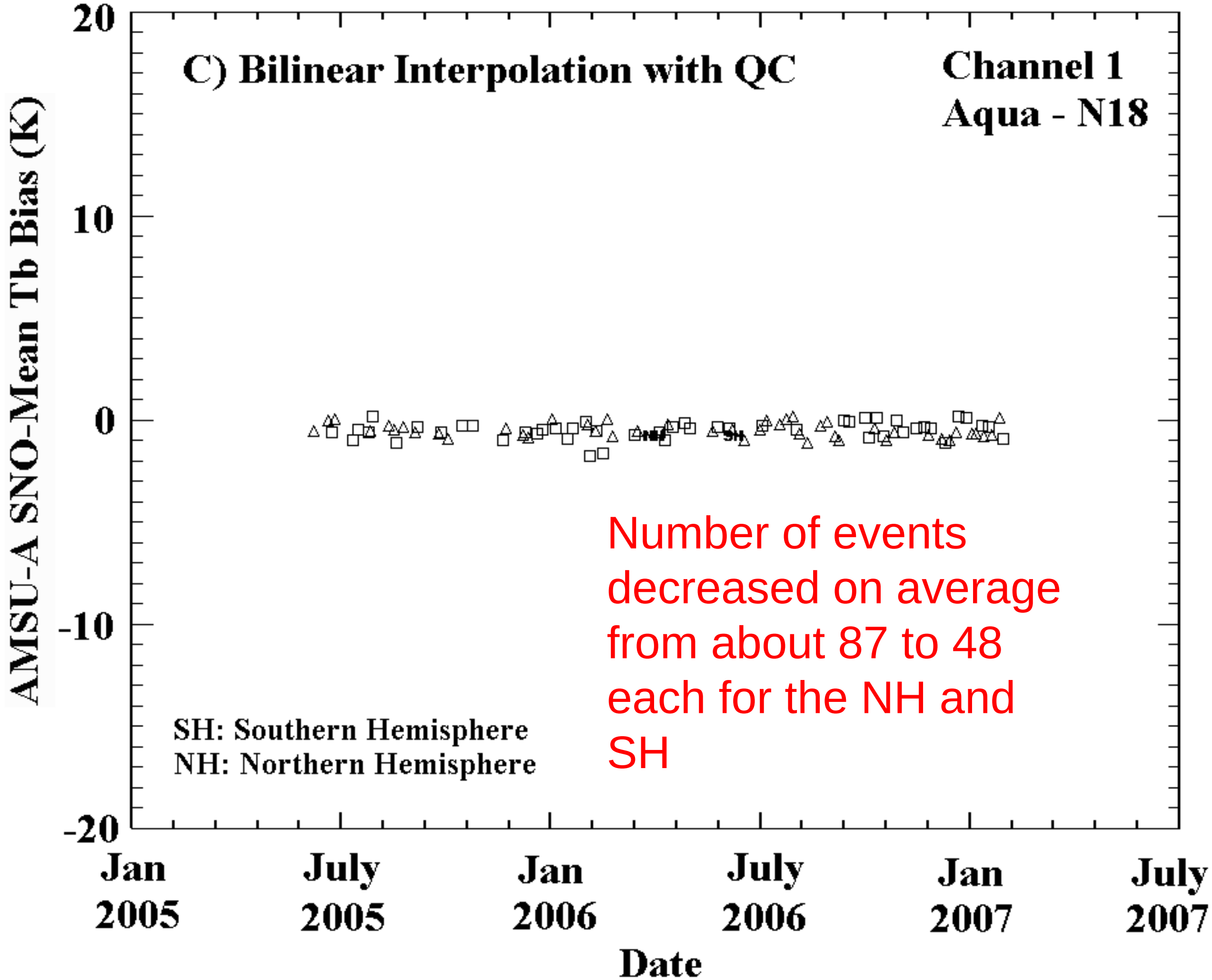
2) **Relate target SNO Bias STD to scene-average maximum difference**

$$\overline{\left|\delta Tb_{\max}\right|} = \underbrace{slope}_{Relating\ Factor} \times \underbrace{\left[3\times\sqrt{NE\Delta T_{instr1}^{2} + NE\Delta T_{instr2}^{2}}\right]}_{Target\ SNO\ Bias\ STD}$$

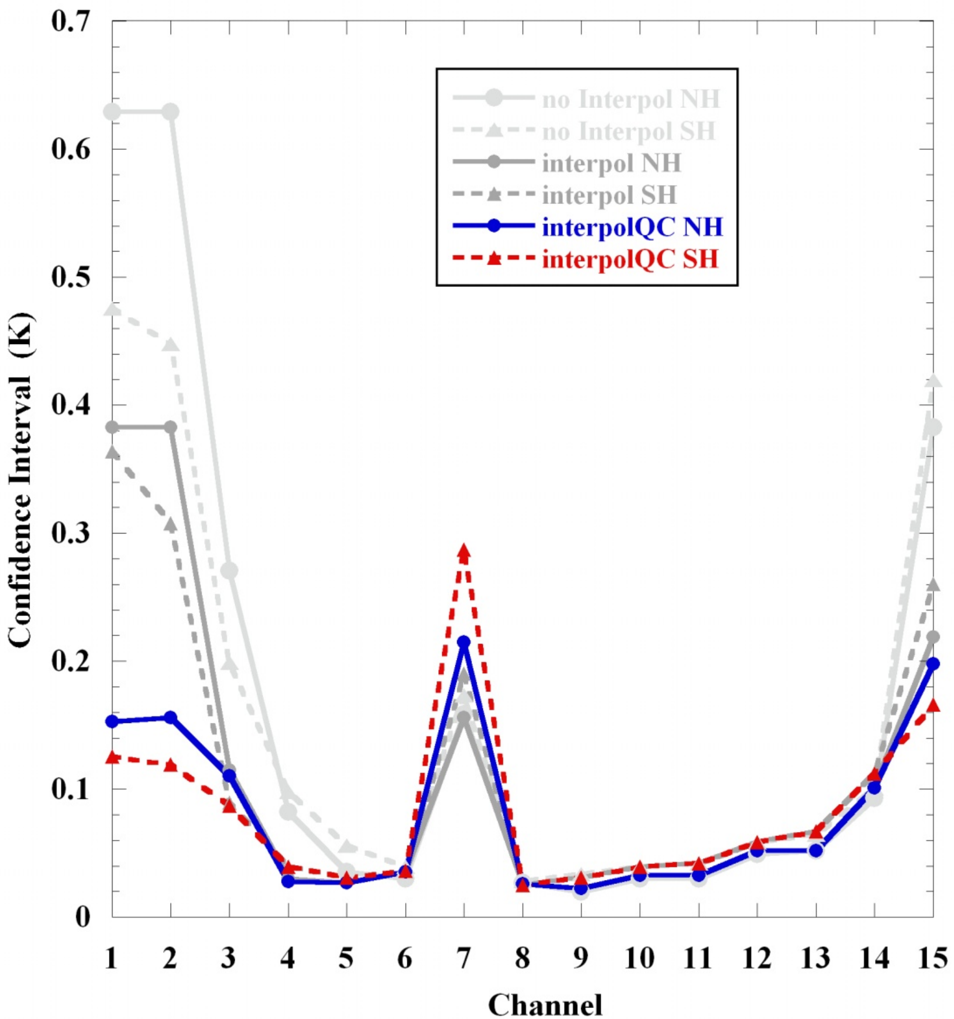
National Environmental Satellite, Data, and Information Service

Earth Resources Technology

AMSU-A Ch 1 SNO Mean Bias Time Series After Data Quality Control



AMSU-A SNO Mean Bias Uncertainties After Data Quality Control



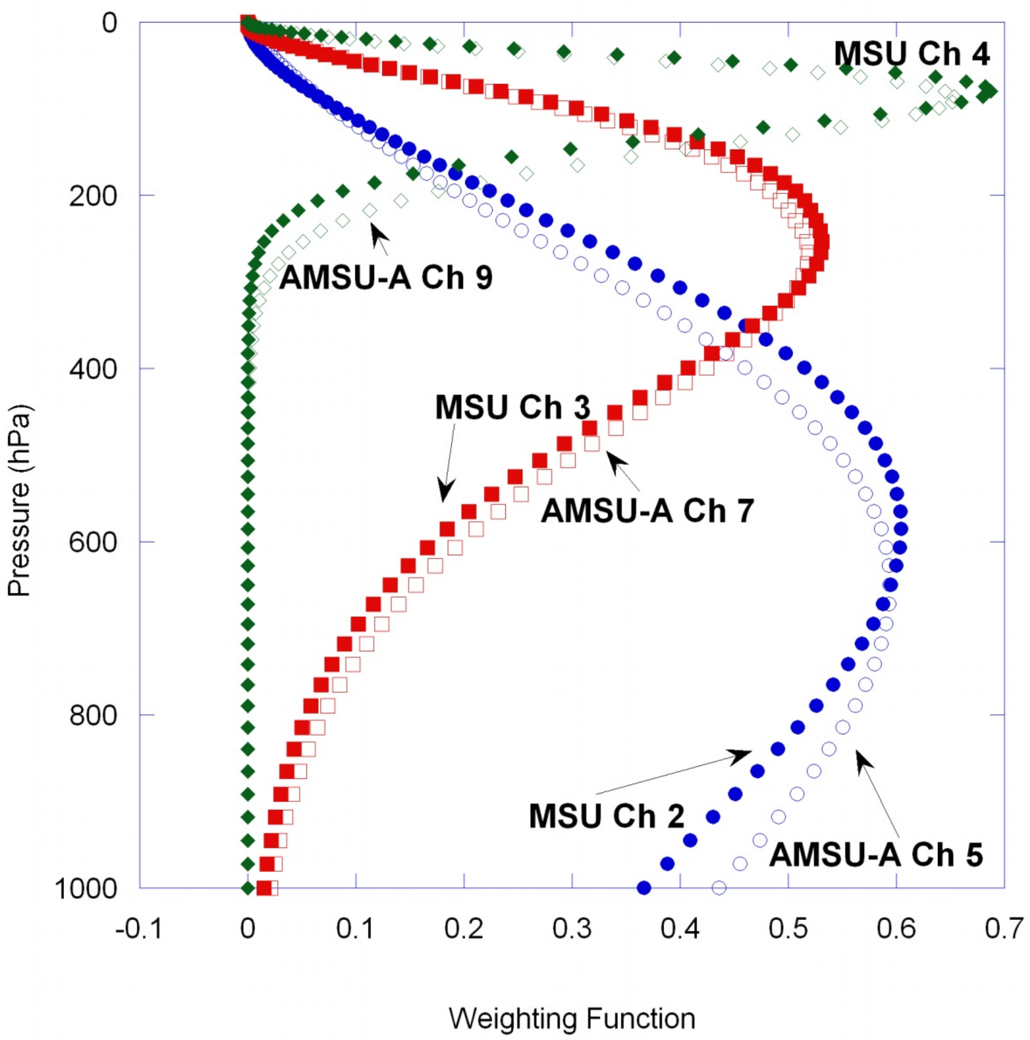
Outline

- AMSU-A instrument characteristics and AMSU-A intersatellite bias detection utilizing the SNO method
- SNO-ensemble avg. biases between AMSU-A instruments at sounding channels (Chs 3-14)
- The impact of data collocation method on SNO bias uncertainty estimates
- **SNO-ensemble biases inferred for NOAA-14 MSU and NOAA-15 AMSU-A**
- Summary

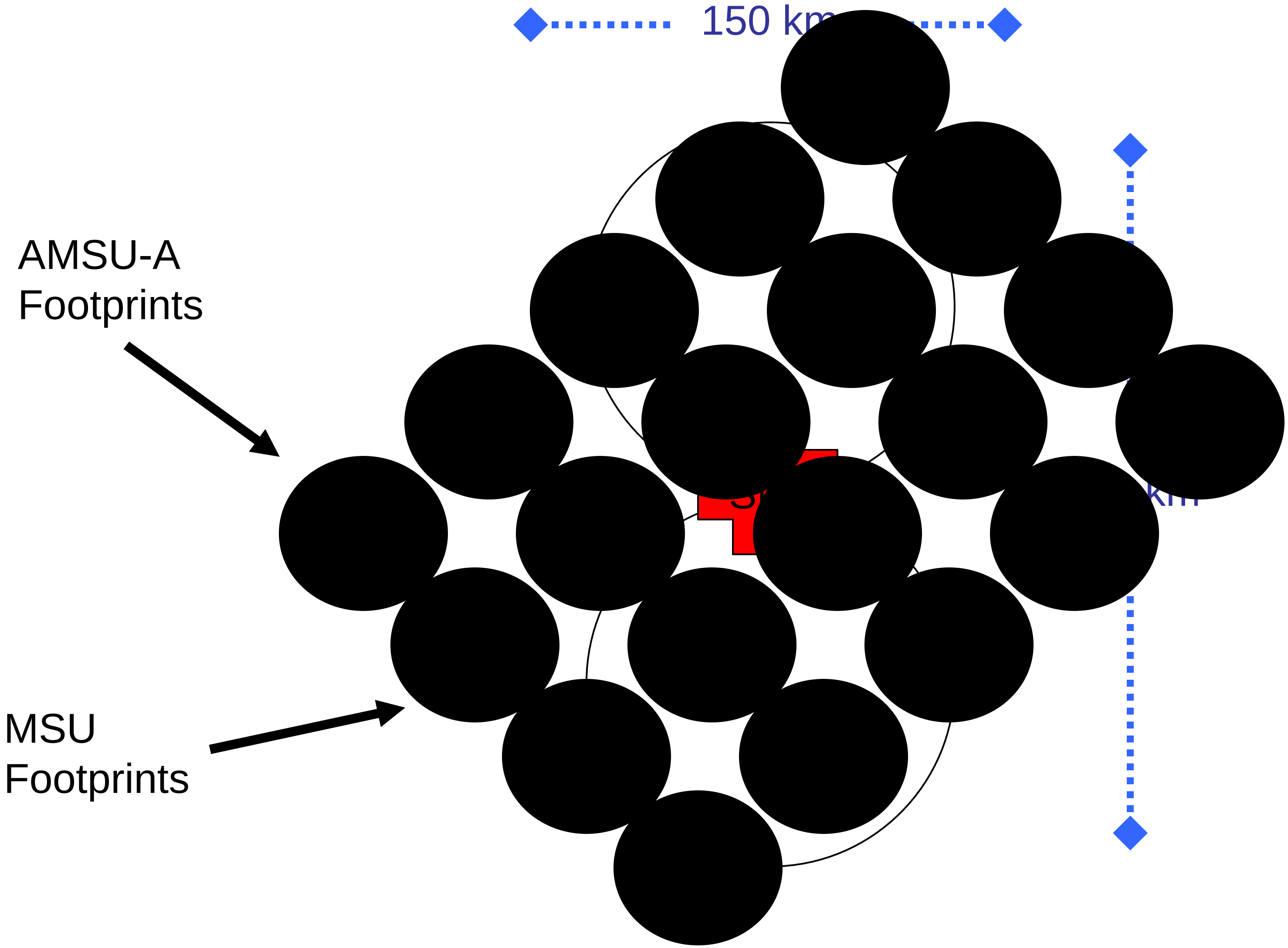
Microwave Sounding Unit (MSU) and Advanced MSU Series-A (AMSU-A) Comparison

Ch #	Ch *f* (GHz)	# Bands	Nominal Bandwidth (GHz)	Nominal Beamwidth (degrees)	NEΔT (K) (Spec.)	Nadir Polar-ization	Subunit
MSU 1	50.30	1	0.20	7.5	0.30	V	N/A
AMSU 3	50.30	1	0.18	3.3	0.40	V	A1-2
MSU 2	53.74	1	0.20	7.5	0.30	H	N/A
AMSU 5	53.596 ±0.115	2	0.17	3.3	0.25	H	A1-2
MSU 3	54.96	1	0.20	7.5	0.30	V	N/A
AMSU 7	54.94	1	0.40	3.3	0.25	V	A1-1
MSU 4	57.95	1	0.20	7.5	0.30	H	N/A
AMSU 9	57.29	1	0.33	3.3	0.25	H	A1-1
Note: H indicates horizontal and V indicate vertical polarization							

Microwave Sounding Unit (MSU) and Advanced MSU Series-A (AMSU-A) Comparison



MSU/AMSU-A SNO Dataset Collocation



National Environmental Satellite, Data, and Information Service

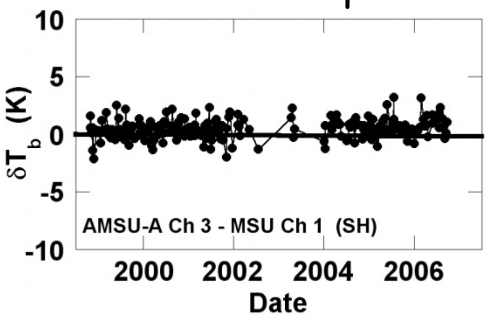
Earth Resources Technology

NOAA-14 MSU and NOAA-15 AMSU-A Tb Biases

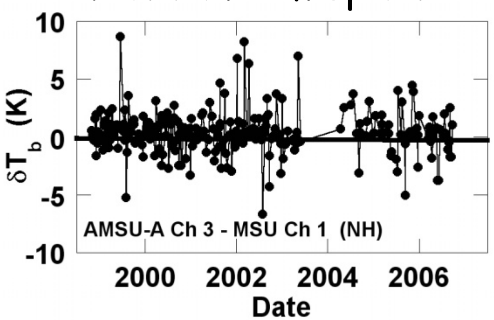
Estimated from Raw Data (Oct. 1998 – Sept. 2006)

AMSU-A 3 - MSU 1

South Hemisphere

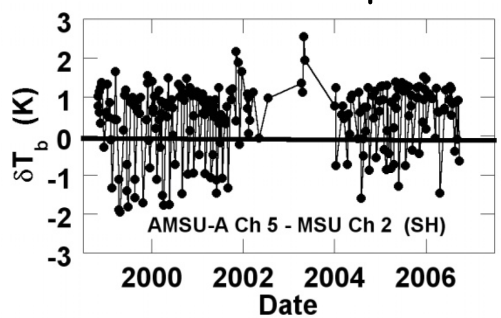


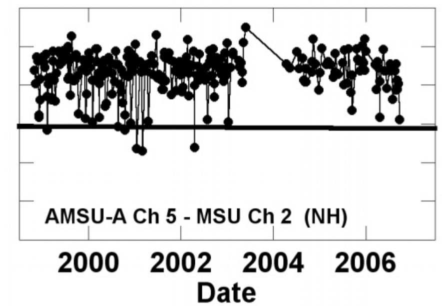
North Hemisphere



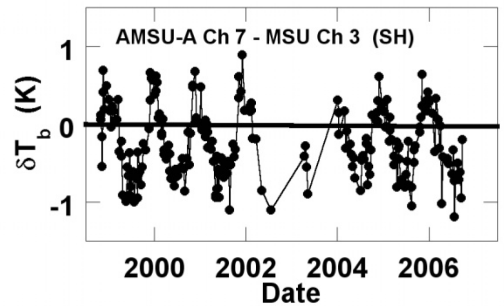
South Hemisphere | North Hemisphere

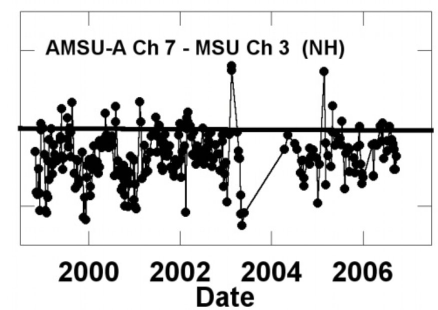
AMSU-A 5 - MSU 2



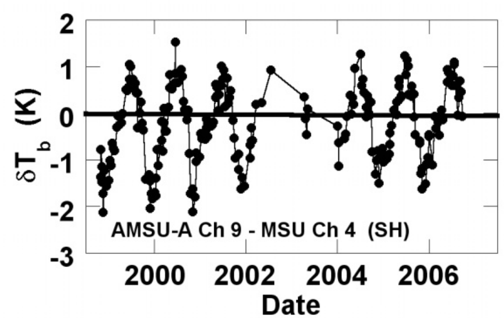


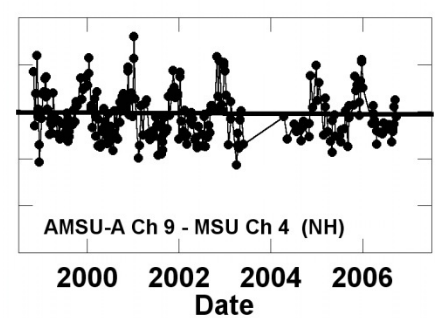
AMSU-A 7 - MSU 3





AMSU-A 9 - MSU 4





NOAA Microwave Integrated Retrieval System (MIRS) and Community Radiative Transfer Model (CRTM)

- NOAA MIRS (Boukabara et al. 2006) is a microwave instrument retrieval software engineered around the CRTM (Han et al. 2006)

- CRTM utilizes atmospheric soundings and surface parameters from the National Centers for Environmental Prediction (NCEP) Global Data Assimilation System (GDAS).

MIRS/CRTM Analysis for MSU/AMSU-A

- For the 14th or 15th day of each month of 2007, GDAS soundings and surface parameters interpolated in time and space to AMSU-A footprint geolocations

- CRTM used in the forward model mode to simulate both N14 MSU and N15 AMSU-A measurements

- Simulations for four nearest-nadir AMSU-A scan positions give about 3,400 (3,000) simulated MSU and AMSU-A data values for the Northern (Southern) Hemisphere region poleward of 75 deg N (75 deg S) in a given month

- Differences between simulated MSU and AMSU-A measurements for similar channel pairs is only due to their frequency and band width differences

National Environmental Satellite, Data, and Information Service

Earth Resources Technology

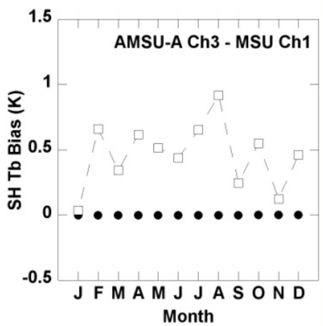
NOAA-14 MSU and NOAA-15 AMSU-A Tb Biases

Projected from MIRS/CRTM for 2007 (MSU/AMSU-A center frequency and band width differences only) and Raw Data for 1998-2006

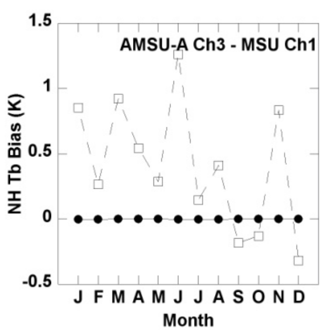
South Hemisphere North Hemisphere

AMSU-A 3 - MSU 1

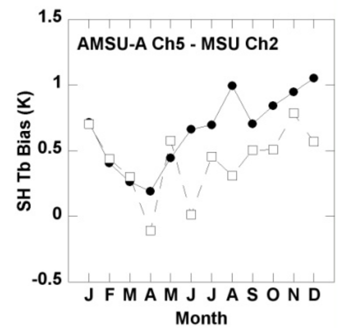
South Hemisphere

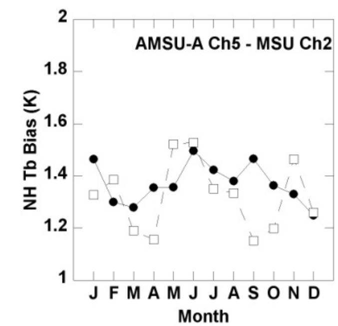


North Hemisphere

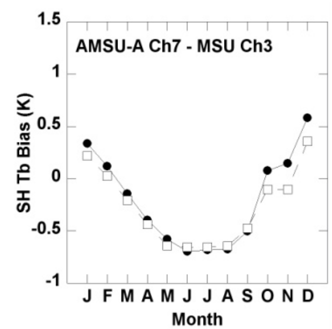


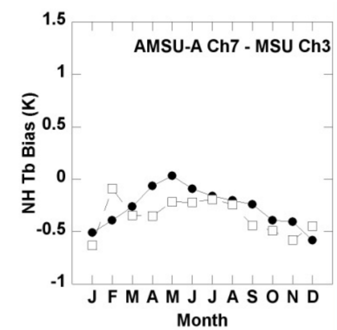
AMSU-A 5 - MSU 2



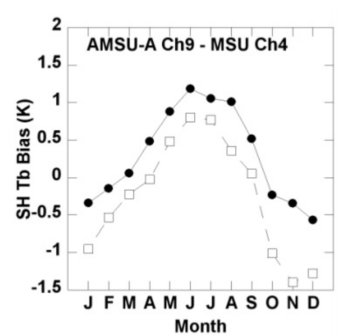


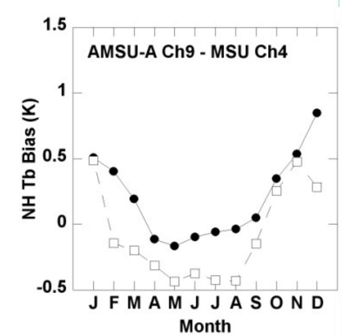
AMSU-A 7 - MSU 3





AMSU-A 9 - MSU 4



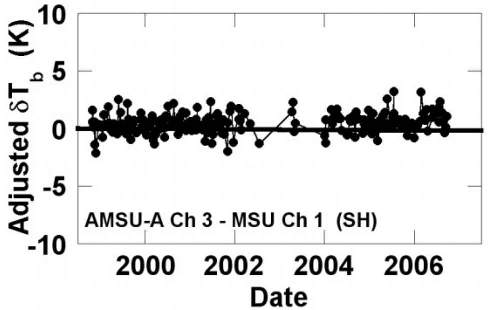


NOAA-14 MSU and NOAA-15 AMSU-A Tb Biases

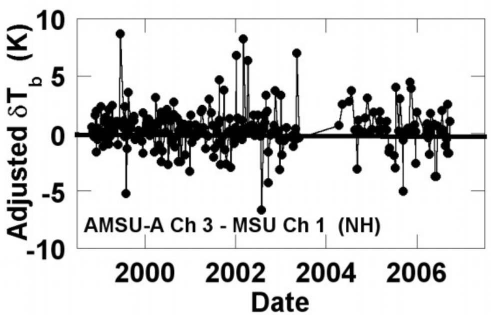
Estimated after MIRS/CRTM Adjustments to Raw Data

AMSU-A 3 - MSU 1

South Hemisphere

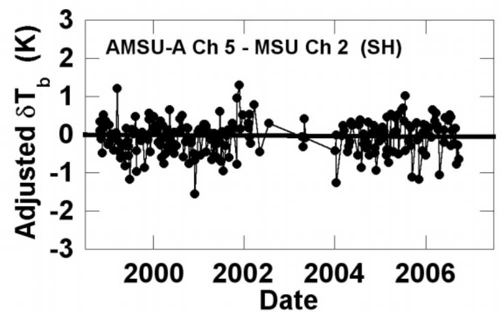


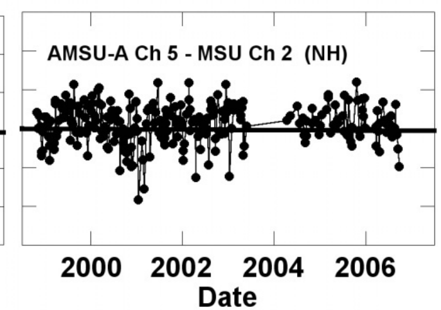
North Hemisphere



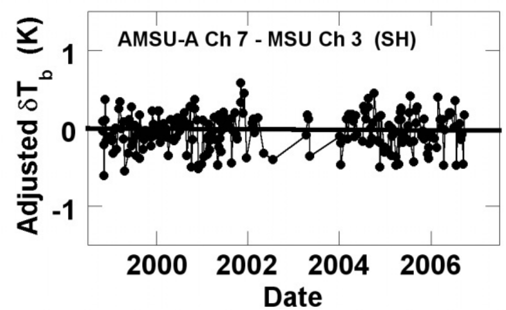
South Hemisphere | North Hemisphere

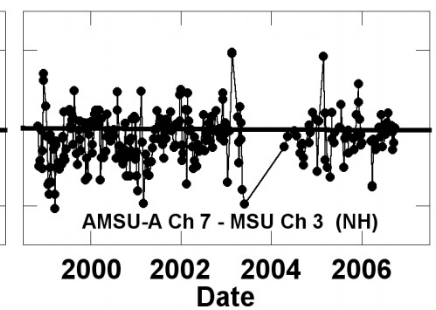
AMSU-A 5 - MSU 2



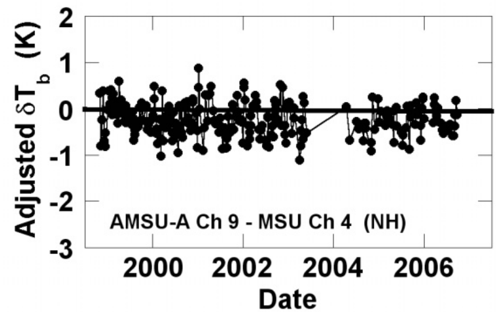


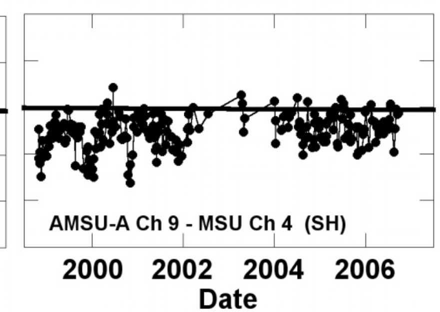
AMSU-A 7 - MSU 3





AMSU-A 9 - MSU 4





NOAA-14 MSU and NOAA-15 AMSU-A Tb Biases

Estimated after MIRS/CRTM Adjustments to Raw Data

Channel Pair	Northern Hemisphere			Southern Hemisphere		
	$\overline{\delta T_b}$ (K)	$\overline{\delta T_b}$ *Conf. Int. (K)	δT_b vs. time Slope (Kdecade^{-1}) / *Significant	$\overline{\delta T_b}$ (K)	$\overline{\delta T_b}$ *Conf. Int. (K)	δT_b vs. time Slope (Kdecade^{-1}) / *Significant
MSU Ch 1 / AMSU-A Ch 3	0.38	0.36	-0.32 / No	0.46	0.18	0.69 / Yes
MSU Ch 2 / AMSU-A Ch 5	**0.11**	0.08	0.08 / No	**-0.07**	0.09	0.10 / No
MSU Ch 3 / AMSU-A Ch 7	-0.13	0.06	0.17 / No	-0.05	0.05	0.03 / No
MSU Ch 4 / AMSU-A Ch 9	**-0.24**	0.07	-0.15 / No	**-0.52**	0.08	0.41 / Yes

*All confidence levels are defined at the 0.01 significance level.

Examination of Residual Biases

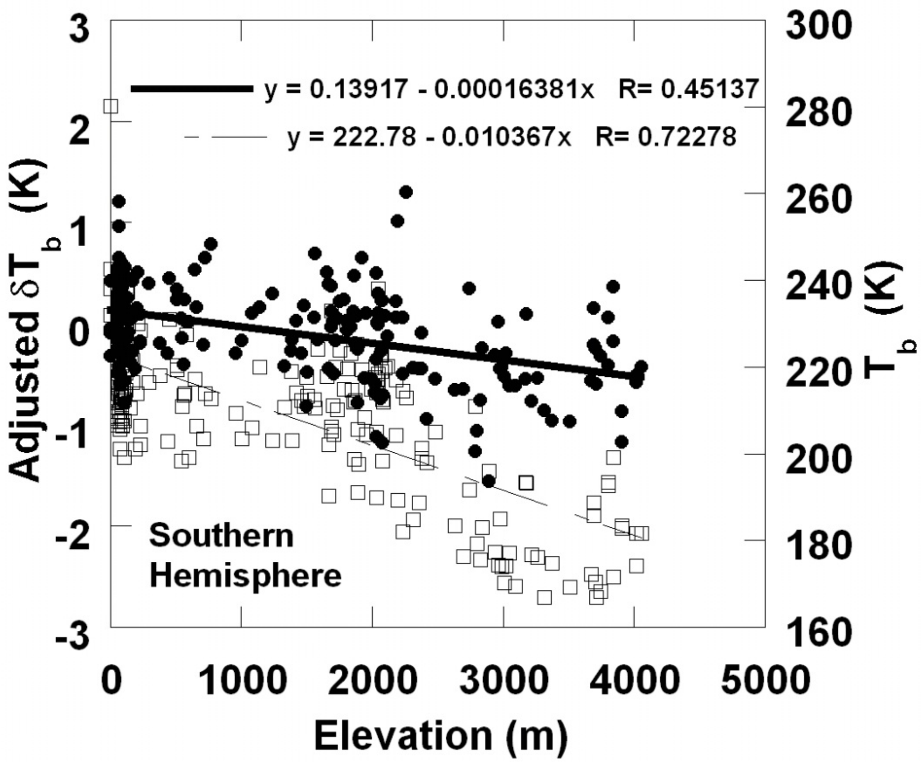
Regressions of Adjusted Tb Biases with respect to Calibration-related parameters:

- Tb
- Solar zenith angle
- Instrument space view and blackbody target counts
- Temperatures of the blackbody, antenna, scan motor, RF shelf, local oscillator, MSU dicke load, etc

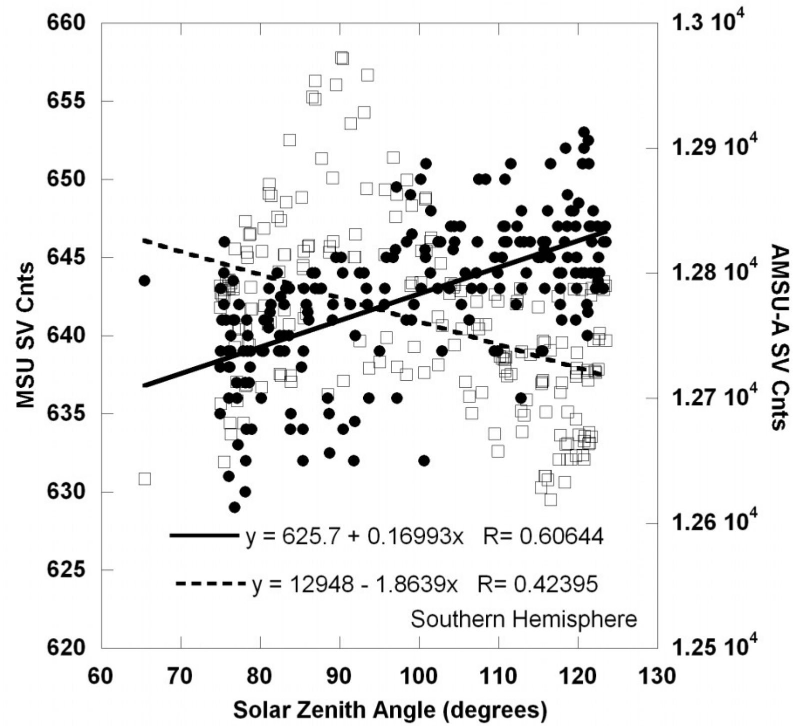
Largest regressions coefficients were: Tb Bias versus

- Solar Zenith Angle (0.35 in Southern Hemisphere for MSU4/AMSU-A9)
- Tb (0.32 in Southern Hemisphere for MSU2/AMSU-A5)
- MSU Space View Counts (0.31 in Southern Hemisphere for MSU4/AMSU-A9)

Examination of Residual Biases



Adjusted AMSU-A5-MSU2 δTb (Dots)
MSU2 Tb (Squares)



MSU4 (Dots)
AMSU-A9 (Squares)

National Environmental Satellite, Data, and Information Service

Earth Resources Technology

Outline

- AMSU-A instrument characteristics and AMSU-A intersatellite bias detection utilizing the SNO method
- SNO-ensemble avg. biases between AMSU-A instruments at sounding channels (Chs 3-14)
- The impact of data collocation method on SNO bias uncertainty estimates
- SNO-ensemble biases inferred for NOAA-14 MSU and NOAA-15 AMSU-A
- **Summary**

National Environmental Satellite, Data, and Information Service

Earth Resources Technology

Summary

- High radiometric consistency exists between concurrently operating AMSU-A instruments, with biases ~0.5 K or less.
- AMSU-A1-1 on N18 and Aqua, and AMSU-A1-2 on N16, show significant biases across all platforms. Large noise anomaly found in N16 Ch. 4.
- Main source of uncertainty of SNO-inferred biases in surface-influenced channels is surface emissivity and temperature inhomogeneities, and in other channels it is NEDT.
- Bilinear interpolation with QC reduces N18/Aqua SNO-ensemble mean Tb bias confidence intervals (STD) at AMSU-A surface-influenced channels by nearly 68 % (76 %) on average over nearest-neighbor collocation.
- Need a sufficient population (> 50 – 60 SNO events)
- Calibration and diurnal-cycle related Tb biases must be estimated for all pairs of MSU and/or AMSU-A instruments used to make a time series
- Frequency and band width differences between similar MSU and AMSU-A instrument channels must be carefully evaluated as a function of season and earth location.
- Further analysis of Tb bias residuals with respect to sensor data must be done to isolate Tb bias related to radiative transfer model and initial condition errors, as well as instrument affects.

Backup Slides

Development of MSU/AMSU-A Fundamental Climate Data Records

➢ What was done

- Isolated calibration-related biases for NOAA-14 MSU and NOAA-15 AMSU-A

➢ What needs to be done

- Using MIRS/CRTM, create a LUT of MSU/AMSU-A center frequency and band width difference Tb biases as a function of earth coordinates and season
- Estimate diurnal cycle related MSU/AMSU-A Tb biases resulting from intersatellite orbit differences and drifts. Can be estimated using a climate model (Mears, 2003) or could use ocean-only data where the diurnal cycle is very small (Zou et al., 2006)
- Cumulatively remove net frequency and band width difference, calibration and diurnal time-dependent Tb biases between each successive co-orbiting MSU, MSU/AMSU-A, or AMSU-A instrument pair from the first satellite in the time series to the last
- Perform a residual analysis