Recalibration and Reprocessing of MSU/AMSU Observations for Climate Studies

Cheng-Zhi Zou

NOAA/NESDIS/Office of Research and Applications

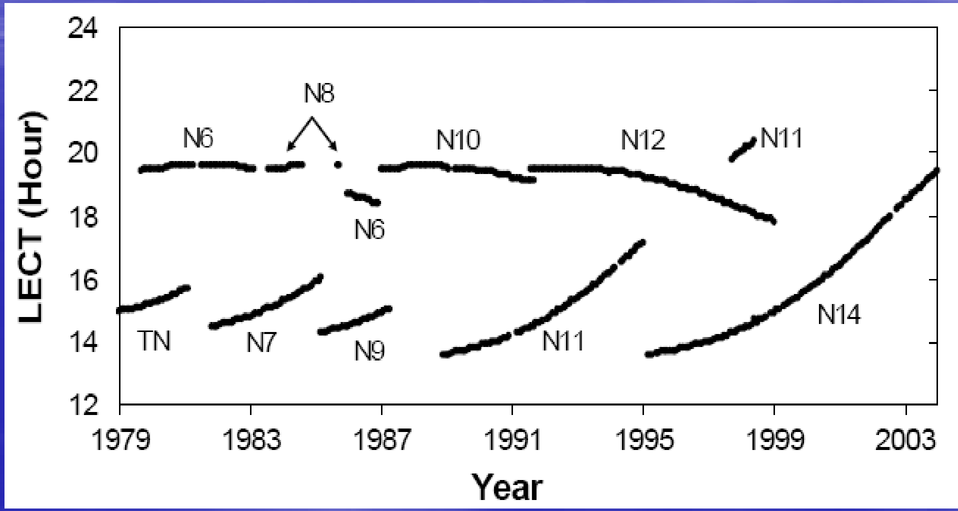
15th International TOVS Study Conference, Maratea, Italy, October 4-10, 2006

Acknowledgment

Mitch Goldberg	NESDIS/ORA
Zhaohui Cheng	QSS Group, Inc.
Jerry Sullivan	NESDIS/ORA
Changyong Cao	NESDIS/ORA
Mei Gao	CAMS/CMA
Dan Tarpley	NESDIS/ORA

NOAA MSU/AMSU Satellites

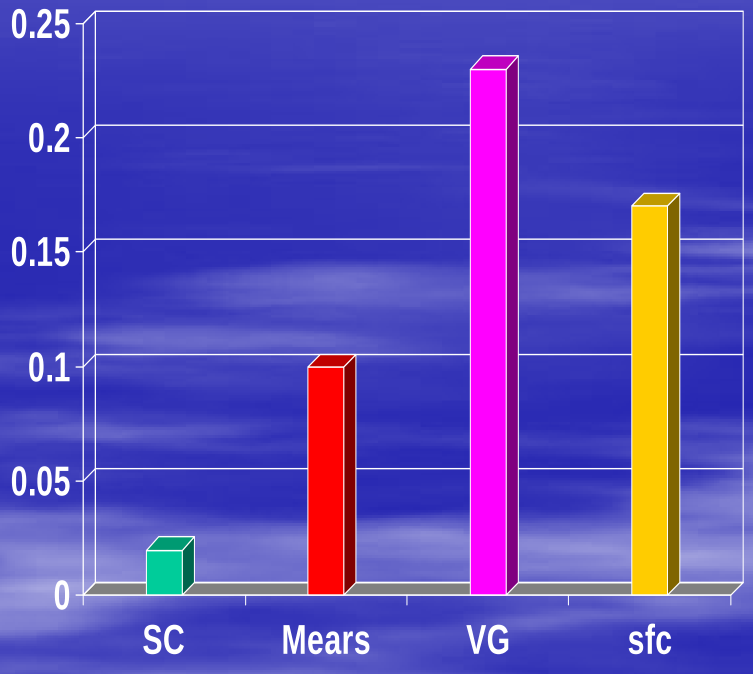
- Each satellite has
  a life cycle of a few years
- Each satellite overlaps
  With other satellites
- LECT gradually changes
  With time–
  orbital drift phenomenon
- Merging these satellites
  is a non-trivial task



Satellite Local Equator Crossing Time (LECT) vs time

Past MSU CH 2 Trend Studies

- Spencer and Christy (1992): 0.02 K Dec^{-1}, 1979-1988
- Christy et al. (2003): 0.02 K Dec^{-1}, 1979-2002
- Prabhakara et al. (2000): 0.13 K Dec^{-1}, 1980-1999
- Mears et al. (2003, 2005): 0.10 K Dec^{-1}, 1979-2001
- Vinnikov and Grody (2003): 0.22-0.26 K Dec^{-1}, 1979-2002
- Grody et al. (2004) 0.17 K Dec^{-1}, 1979-2002
- Vinnikov et al. (2006): 0.20 K Dec^{-1}, 1978-2004



Fake Trend Problems

- **Intersatellite Biases:**

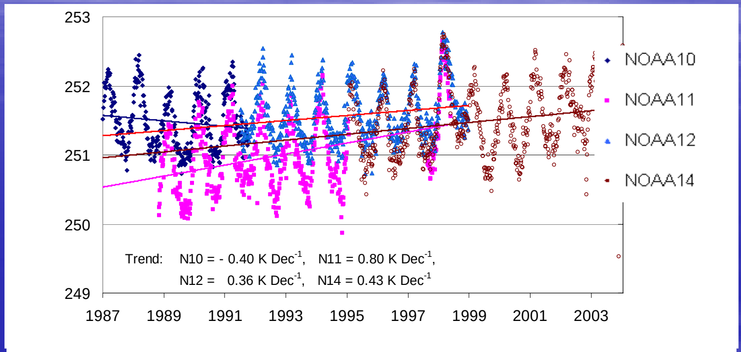
  -- 0.1K biases enough to lead different conclusion

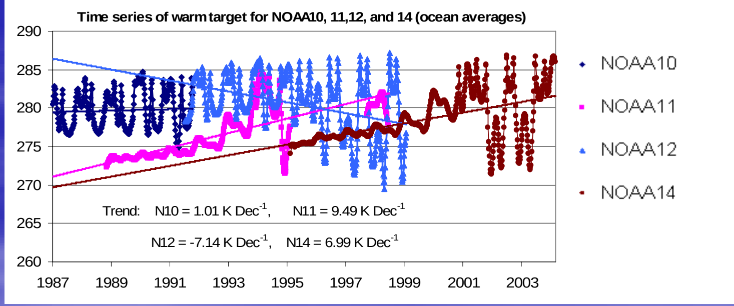
- **Warm target temperature Contamination**

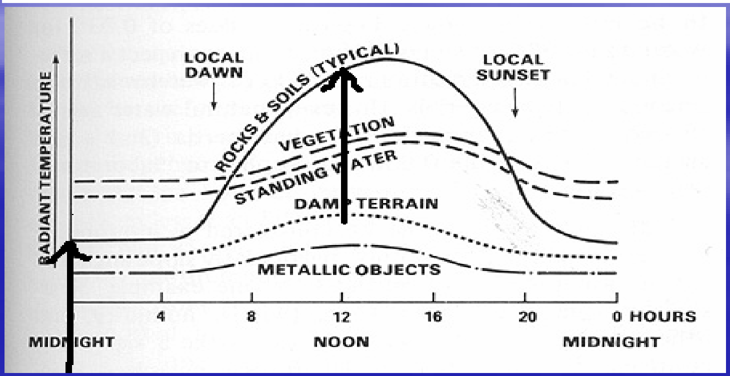
  --Require brightness temperature not a function of warm target temperature

- **Diurnal cycle effect**

  -- Convert observations of different local time to a common time to remove diurnal cycle effect





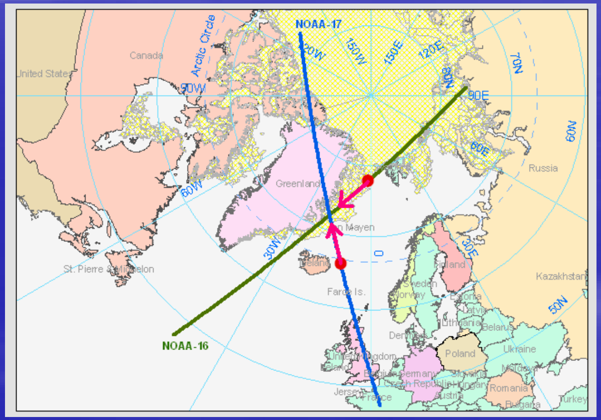


SNO Definition

Method to find SNO matchups:

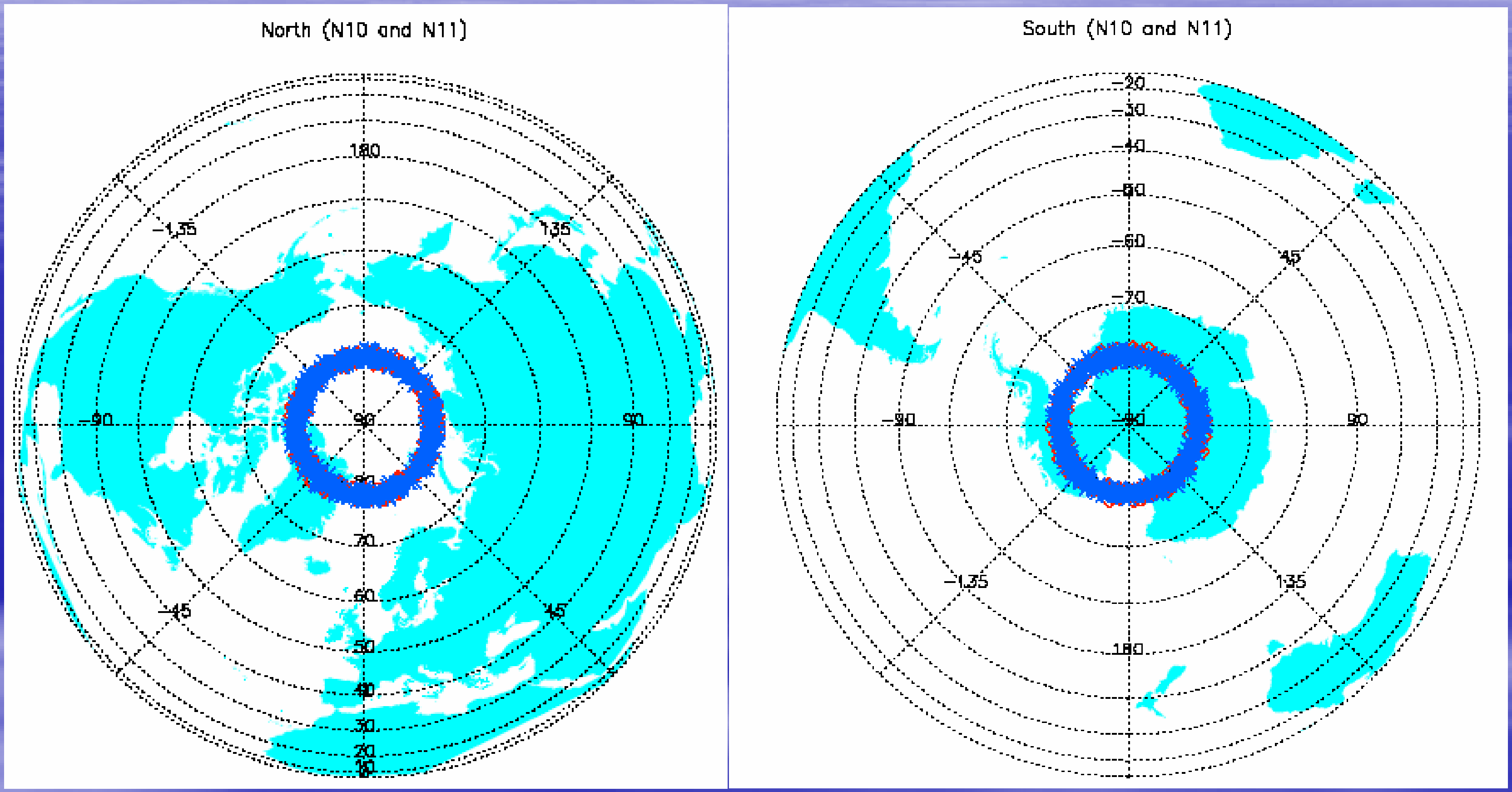
- **Use Cao's (2004) method to find the orbits that have intersections**

- **Use time and location information in the 1B file to determine simultaneity between two pixels**



Schematic viewing the overpasses between two NOAA satellites

SNO Locations

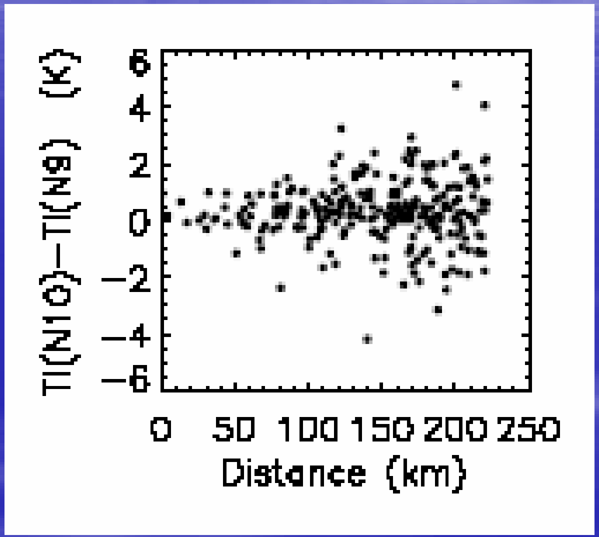


SNO Temperature range for CH. 2: 200-250 K
Global temperature range for CH. 2: 200-260 K

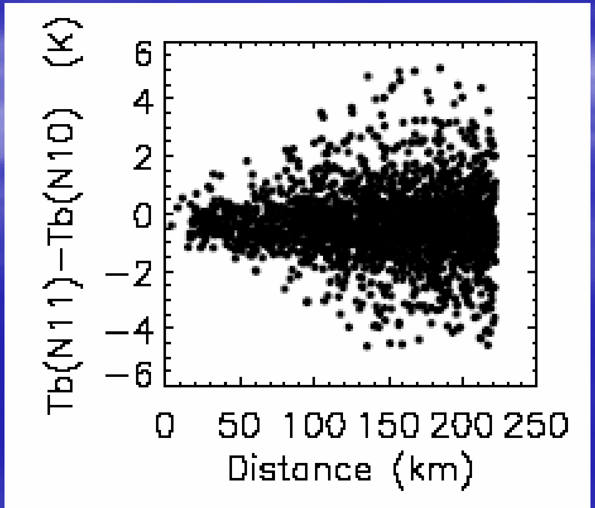
SNO Bias Characteristics

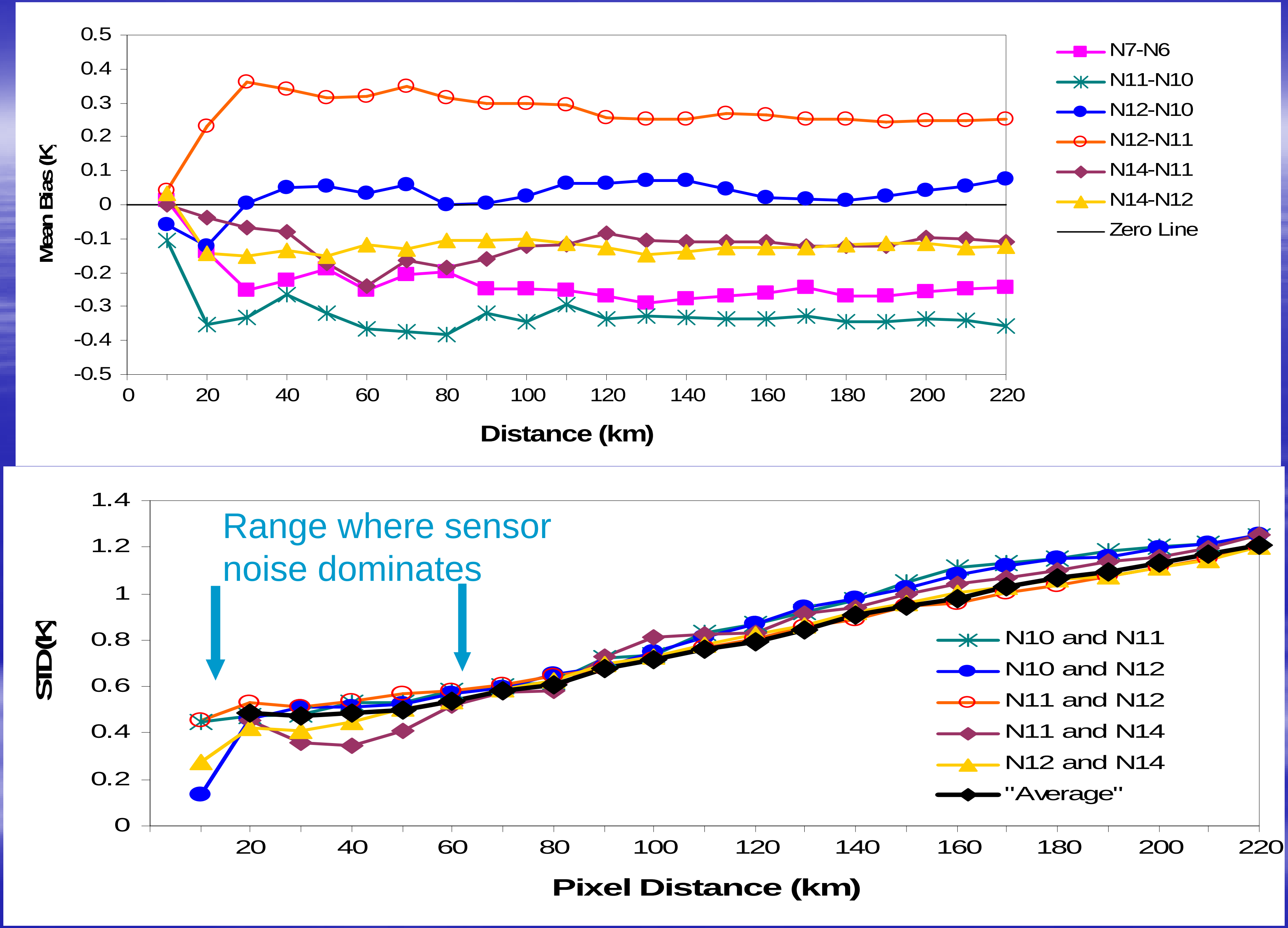
- T_b difference gets larger when the SNO pixel distance gets larger
- SNO numbers increase with the distance
- Different satellite pairs have different SNO numbers because of different overlap period

NOAA 9 and NOAA 10



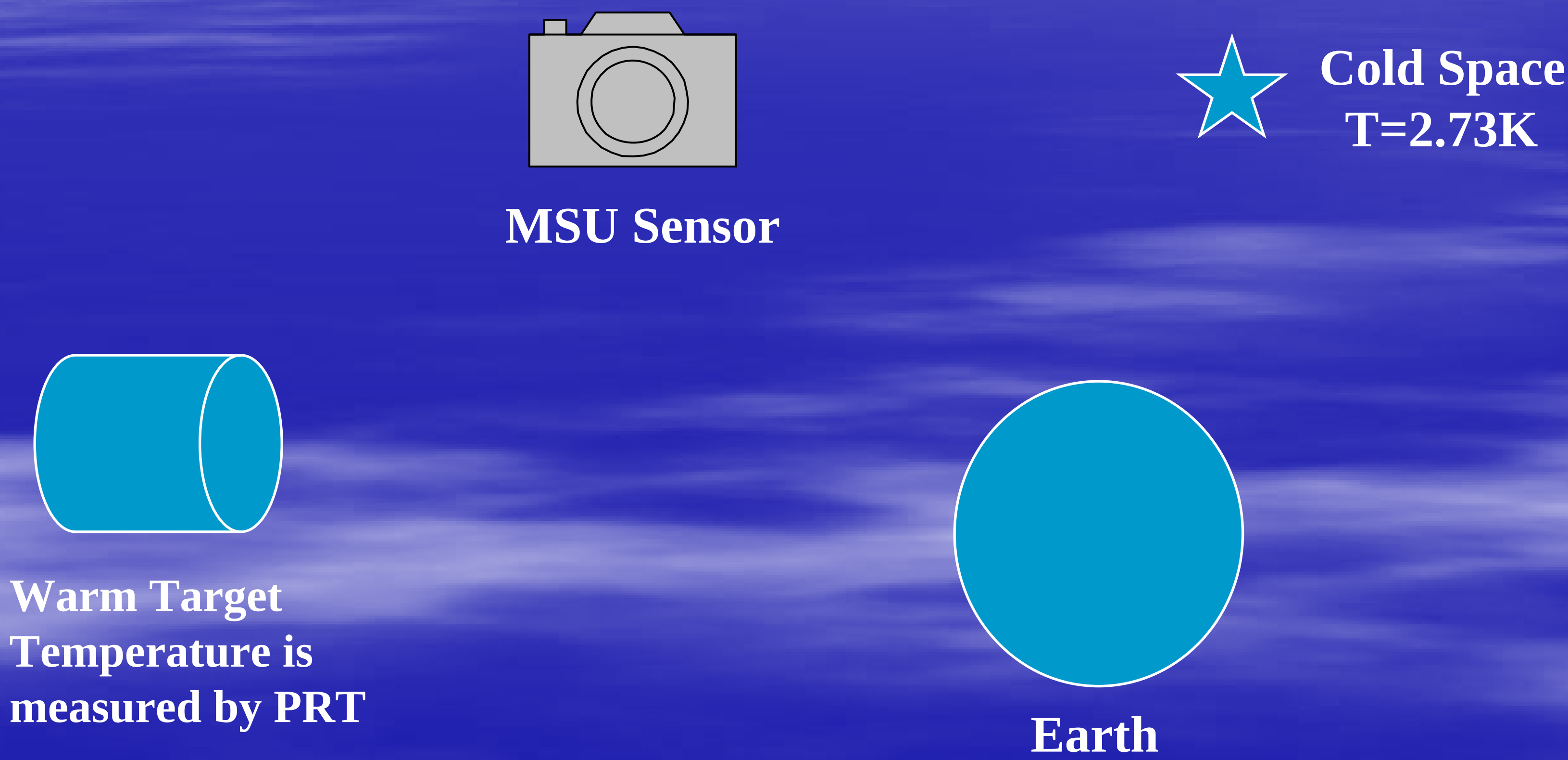
NOAA 10 and NOAA 11





STD and biases of channel 2 brightness temperature differences between satellite pairs versus center distance of the nadir overpass pixels. (a) Biases (b) STD . Linear calibration algorithm at level 0 is used.

MSU In-Orbit Calibration Process



Conceptual diagram of MSU observational procedure

Level 0 Calibration Equation

Linear Calibration

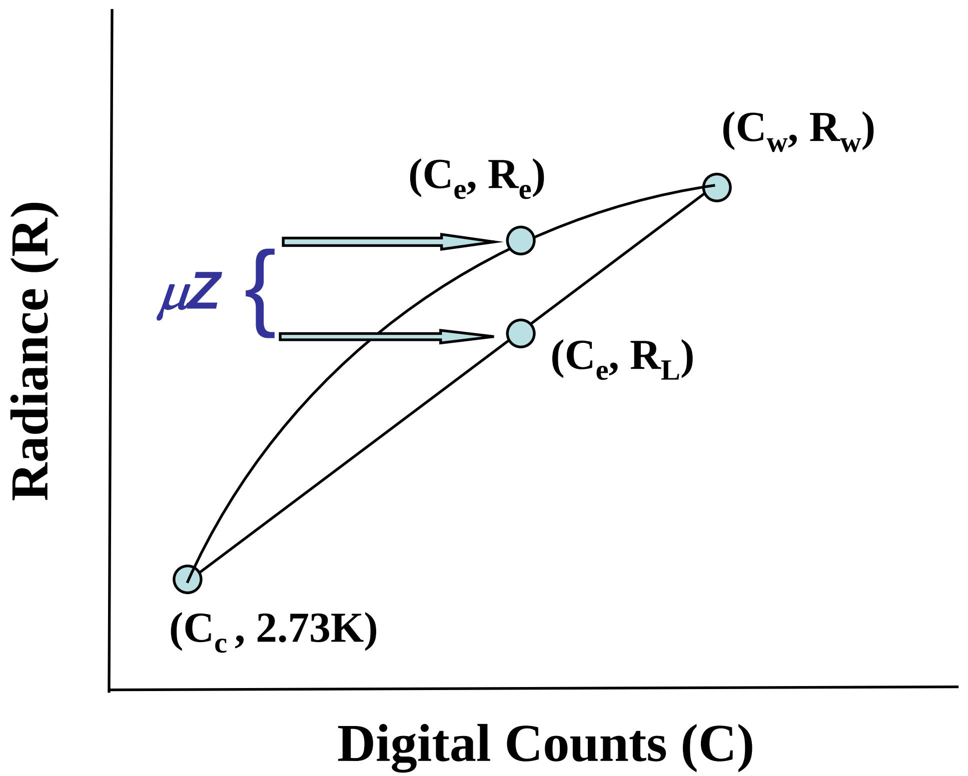
$$R_L = R_c + S(C_e - C_c)$$

S ⟶ Slope

Nonlinear Calibration (Mo 1995)

$$R = R_L - \delta R + \mu Z$$

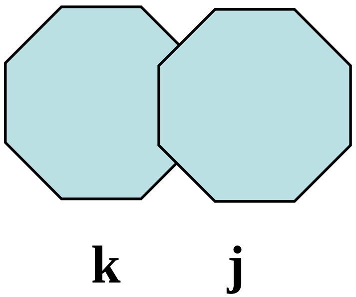
$$Z = S^2 (C_e - C_c)(C_e - C_w)$$



SNO Radiance Error Model

$$R_k = R_{L,k} - \delta R_k + \mu_k Z_k$$

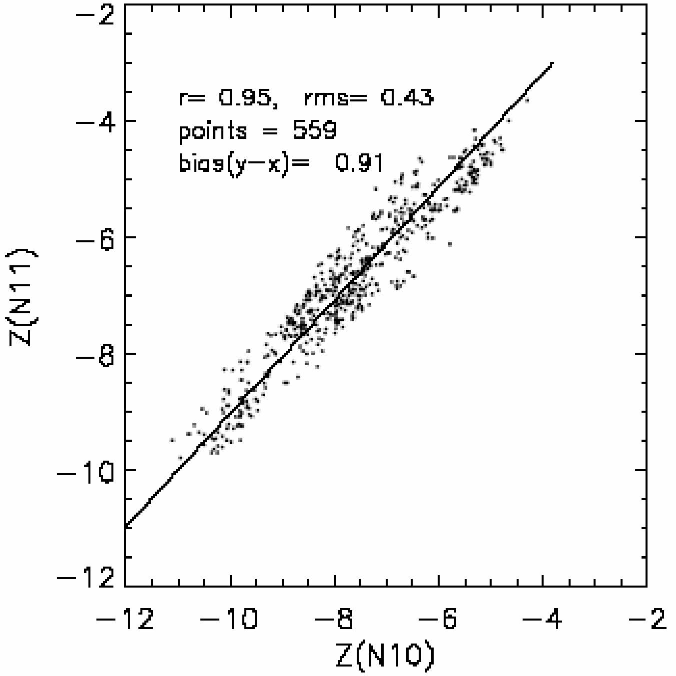
$$R_j = R_{L,j} - \delta R_j + \mu_j Z_j$$



Radiance Error Model for SNO Matchup K and J :

$$\Delta R = \Delta R_L - \Delta \delta R + \mu_k Z_k - \mu_j Z_j$$

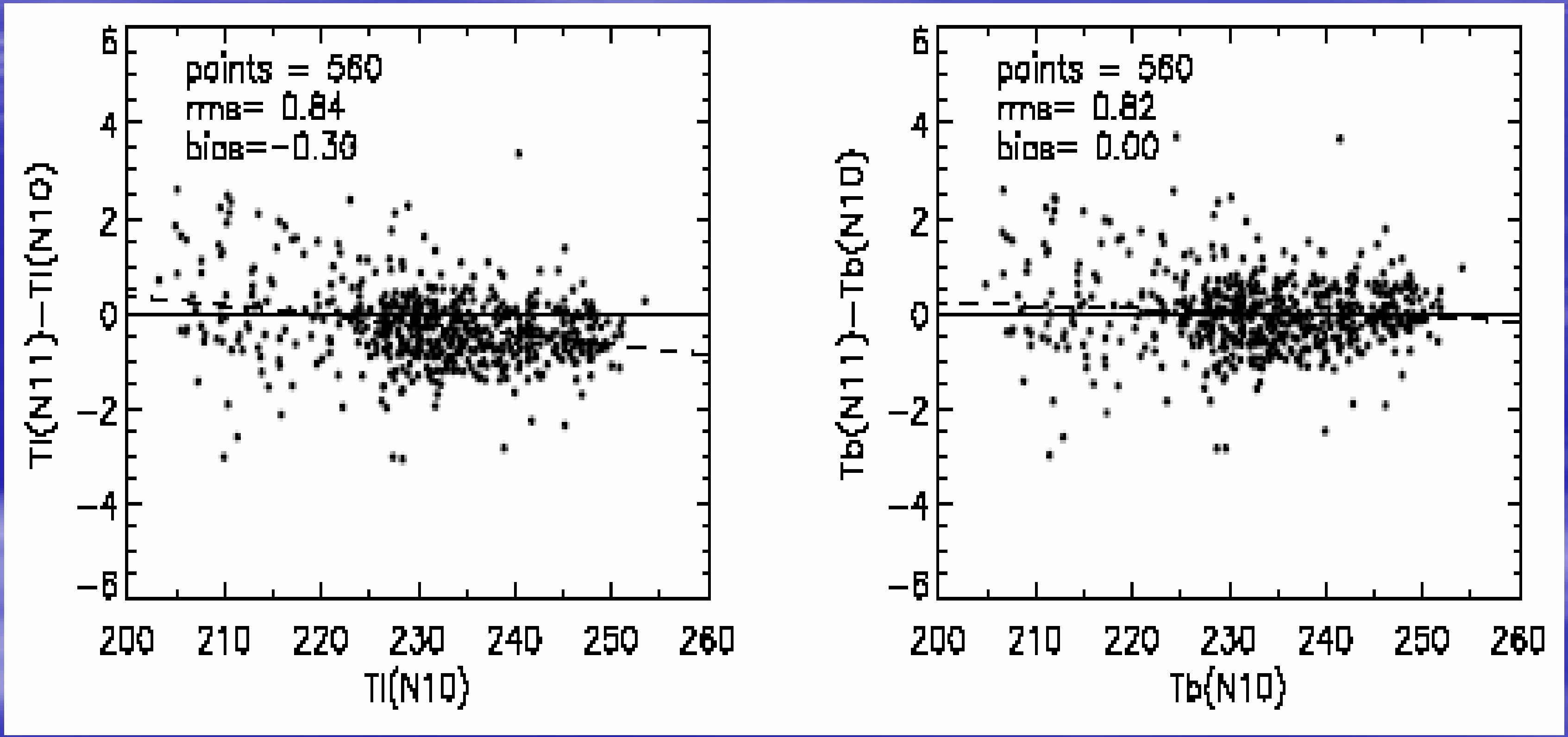
$$Z_j = \beta Z_k + \alpha$$



SNO Nonlinear Calibration—Bias Removal

Linear Calibration

Nonlinear calibration using SNO



Scatter plots showing effects of the nonlinear calibration on the error statistics and distribution of the brightness temperature differences between NOAA 10 and NOAA 11.

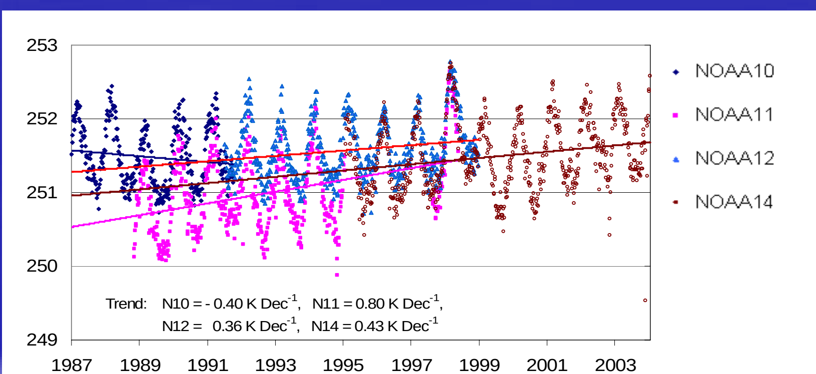
SNO Sequential Calibration Procedure

- Assuming NOAA 10 as the reference satellite and using its pre-launch coefficient for reference
- Obtain calibrated radiance (1b) for NOAA 10
- Compute NOAA 11 coefficients from regressions of N11-N10 SNO
- Obtain calibrated radiance (1b) for NOAA 11
- Repeat above procedure for NOAA 12 with calibrated NOAA 11 as references

…………

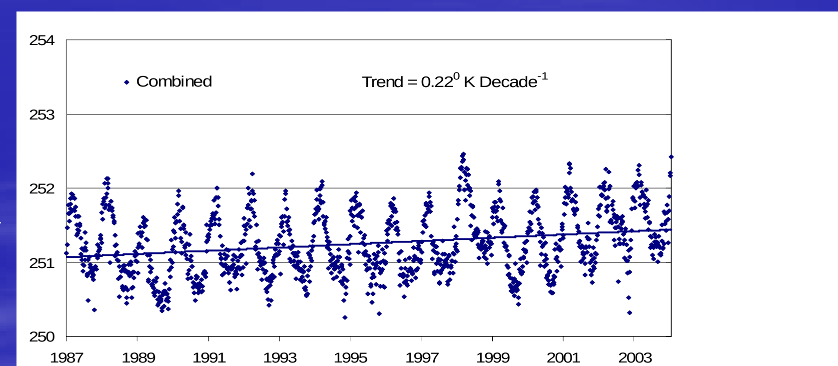
Effect on time series and trend

- Intersatellite biases largely reduced
- Trend values are more reliable

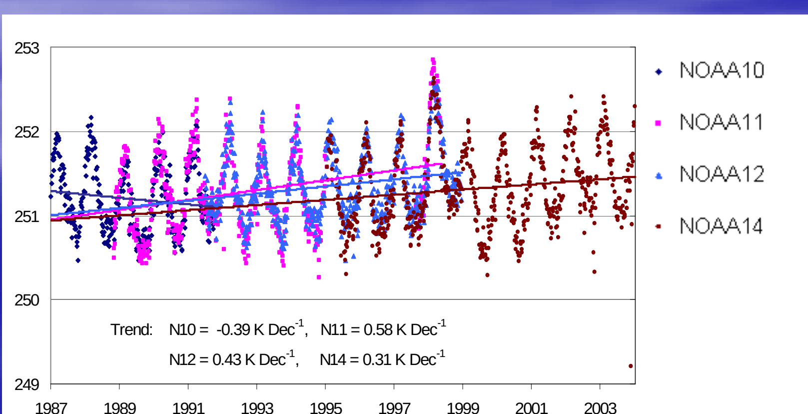


NESDIS Operational Calibration

0.22 K Dec^{-1}

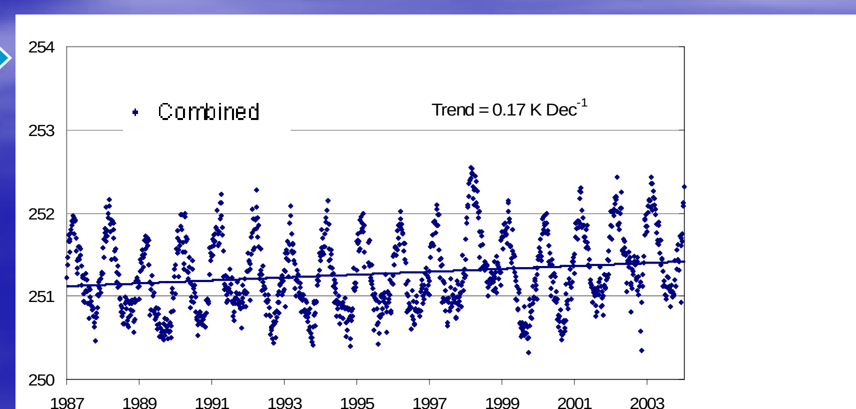


(Vinnikov and Grody, 2003)



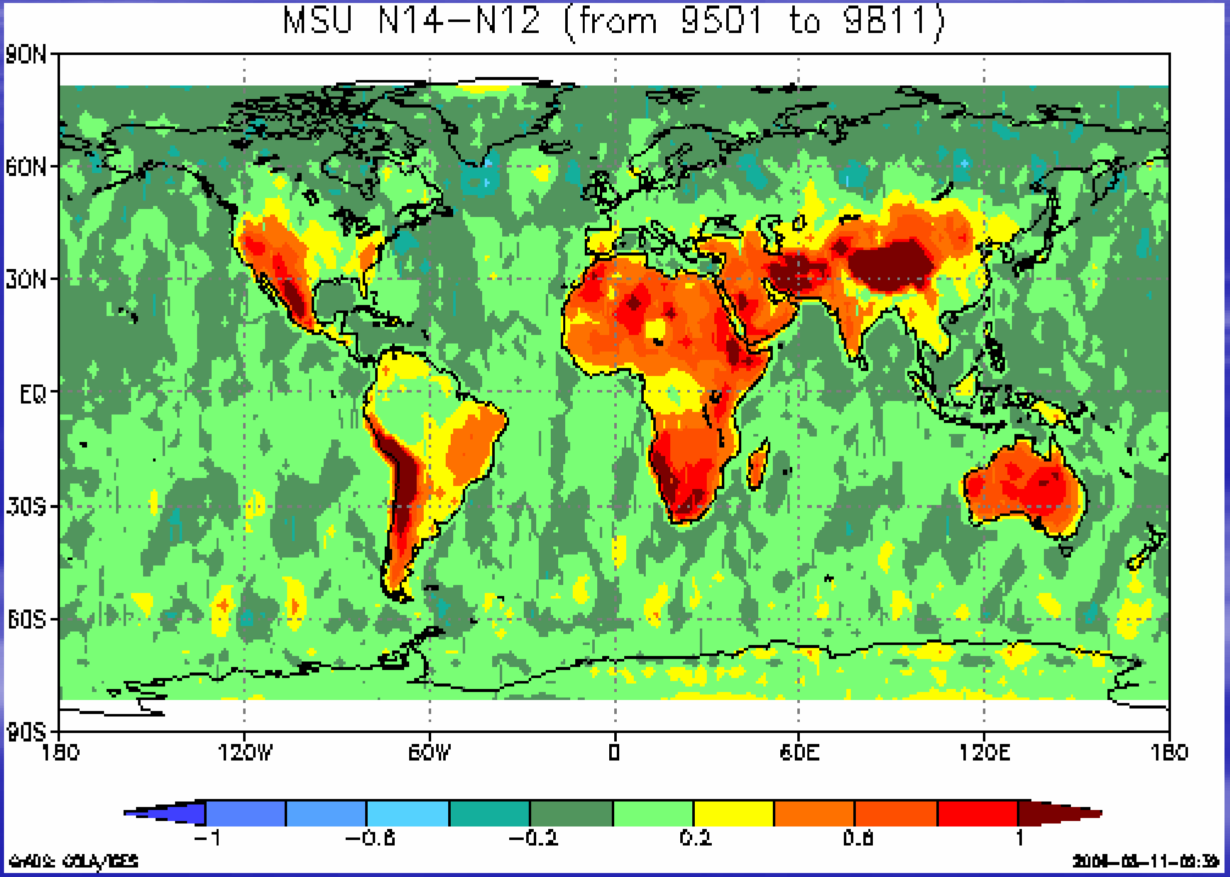
SNO calibration

0.17 K Dec^{-1}

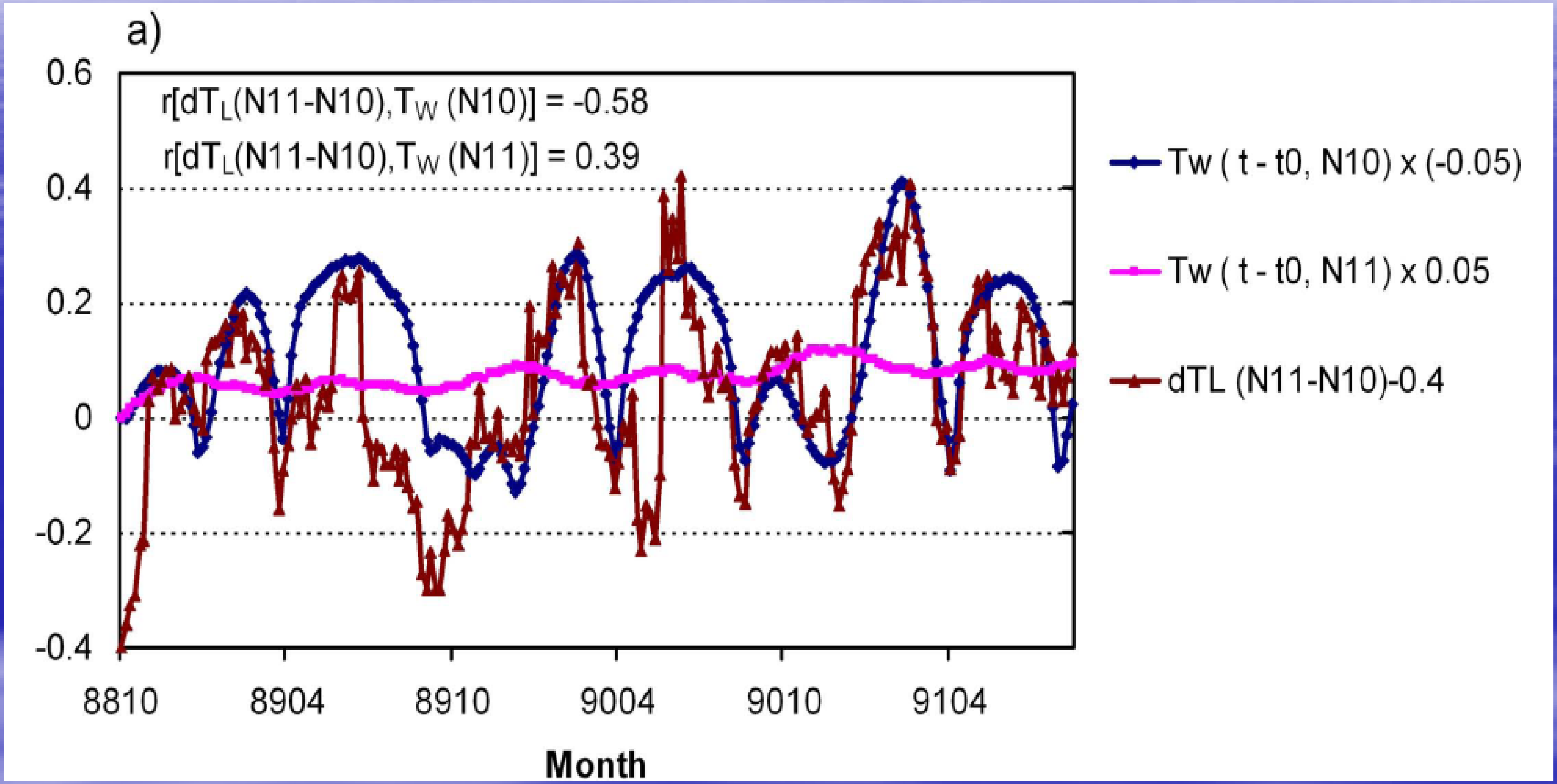


Spatial Distribution of Biases

- Ocean OK
- Land needs diurnal cycle corrections



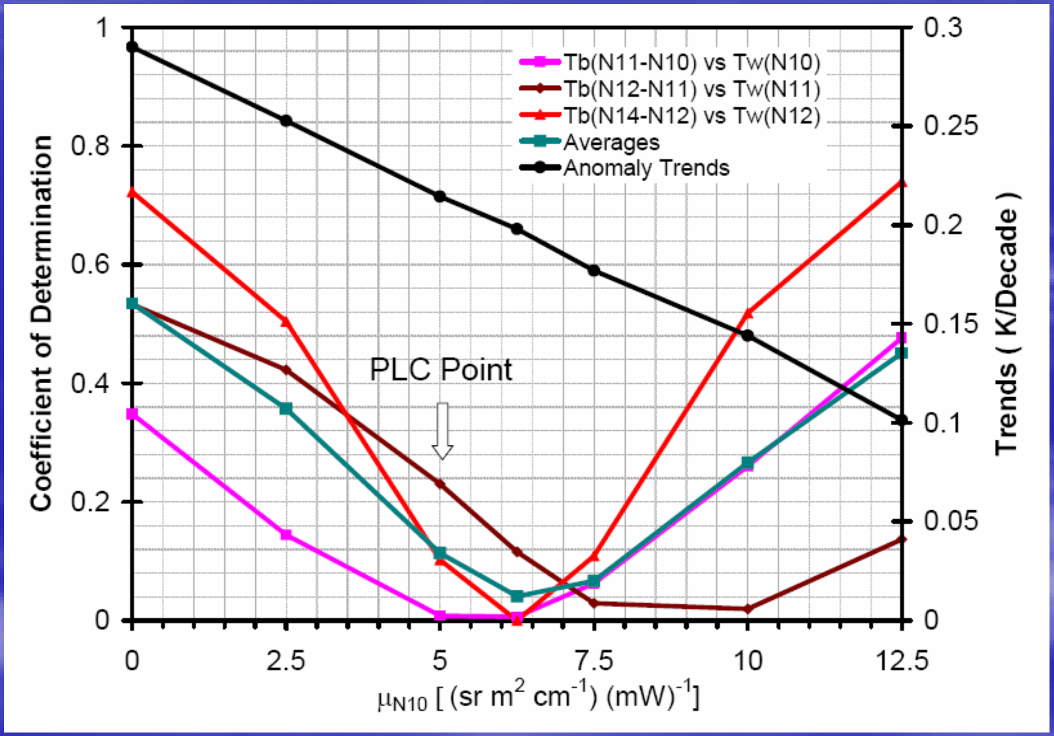
Warm Target Contamination



Brown Line: T_b differences between NOAA 10 and 11
Blue Line: T_w of NOAA 10
Pink Line: T_w of NOAA 11

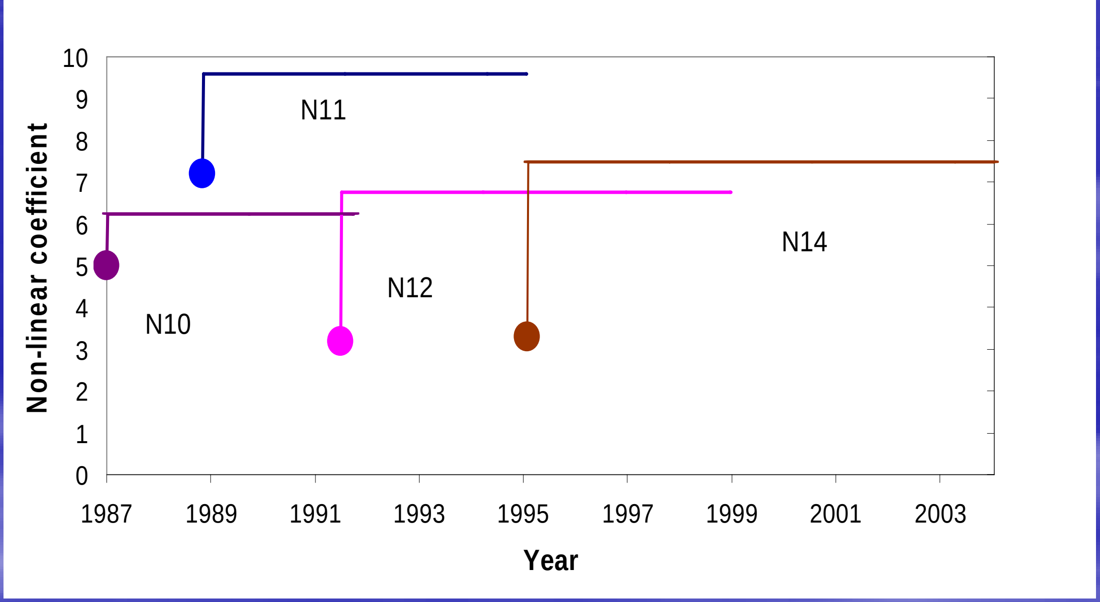
Determine Absolute Calibration by Removing T_w Contamination

- μ_{N10} small or large, large warm target temperature contamination
- When μ_{N10} is 25% larger than its pre-launch value, averaged warm target temperature contamination reaches a minimum (4%)
- Corresponding trend is 0.198 ± 0.02 K Dec^{-1}
- Degree of freedom about 30, correlation is significant at 95% when r^2>13%



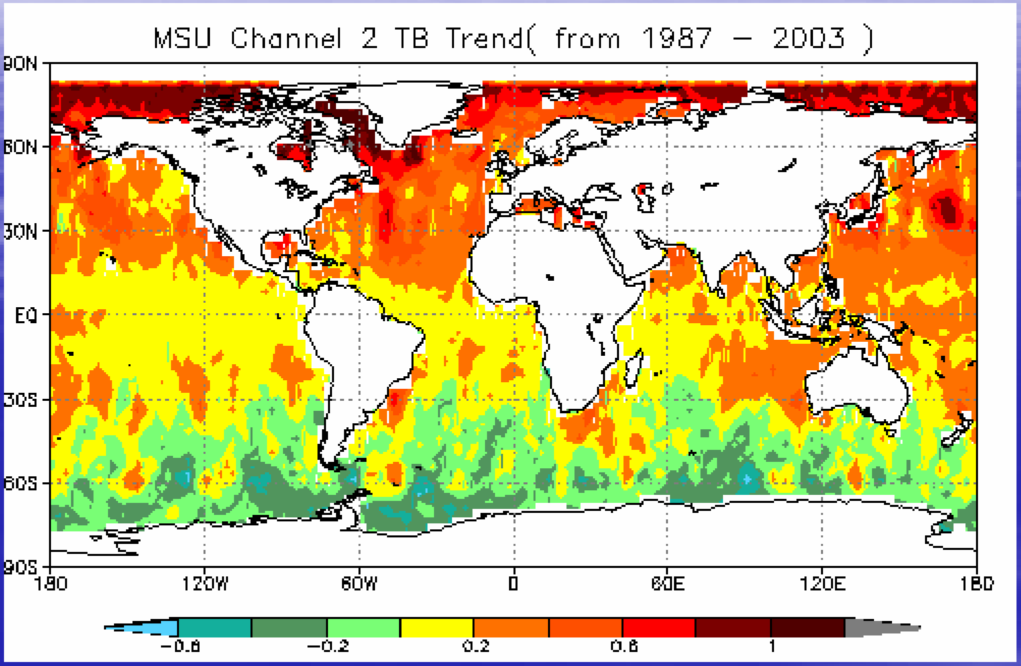
Summary on SNO Calibration

- Post-launch coefficients larger than Pre-launch values

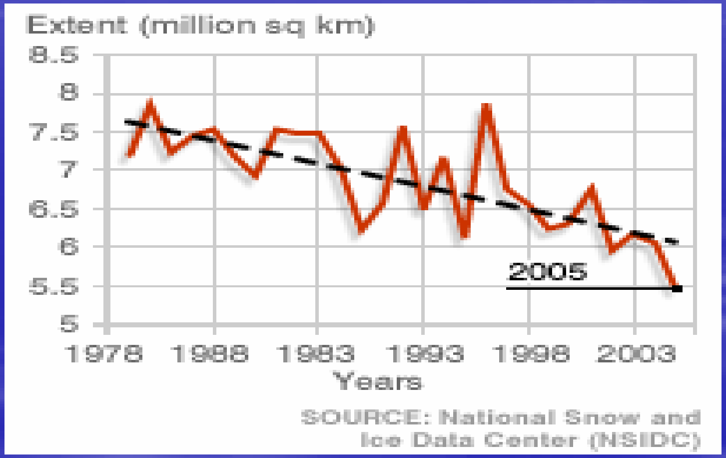


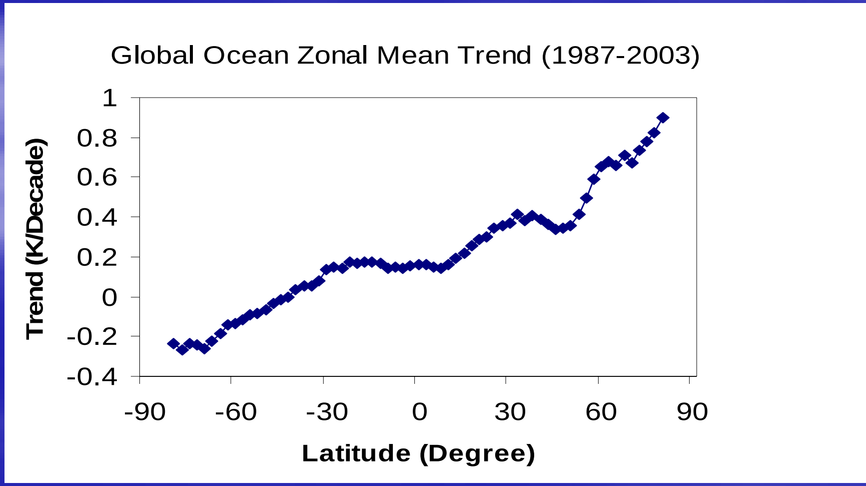
Dots: Pre-launch values
Line: SNO calibration values.

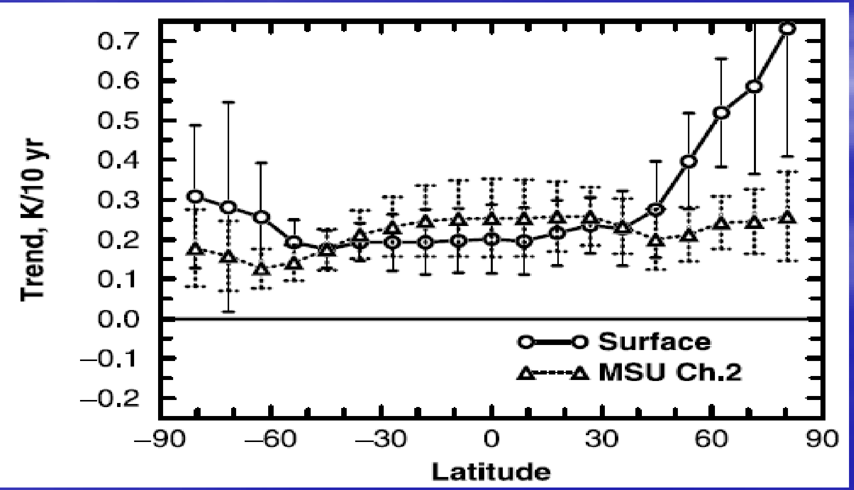
Spatial Distribution of Trend



ARCTIC SEA ICE EXTENT - SEPTEMBER TREND, 1978-2005 (http://nsidc.org/news/press/20050928_trends_fig1.html)







On-going Work and Future Plans

- Diurnal cycle corrections

  --land problems
- Recalibrate and Reprocess all MSU satellites

  --TIROS-N to NOAA 14, for all channels 2,3,4
- Connect MSU with AMSU

  -- Consider different pixel resolutions and frequencies
- Impact on Reanalyses

  -- Assimilate SNO calibrated MSU/AMSU 1b to next generation reanalyses

  -- affect trend of all reanalysis variables

  -- diurnal cycle problem resolved
- Compare with other data

-- Radiosonde (Tony Reale)

  -- GPS Radio Occultation (Ben Ho, Bill Kuo)
- Other instruments

  -- SSM/I and SSMIS (Weng)

Reference and Website

- **Zou, C.,** M. Goldberg, Z. Cheng, N. Grody, J. Sullivan, C. Cao, and D. Tarpley (2006): Recalibration of Microwave Sounding Unit for climate studies using simultaneous nadir overpasses, *J. Geophys. Res*, 111, doi: 10.1029/2005JD006798

- http://www.orbit.nesdis.noaa.gov/smcd/emb/mscat/mscatmain.htm