

# MSU channel 2 brightness temperature trend when calibrated using simultaneous nadir overpasses

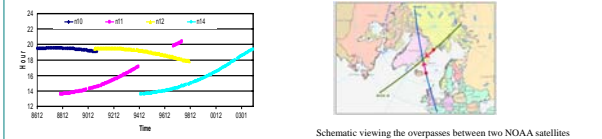
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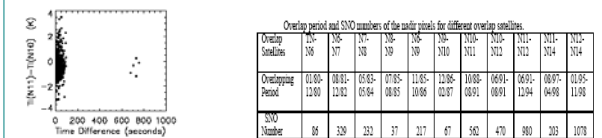
## 1. Purpose

- To re-calibrate MSU observations at level 0 using simultaneous nadir overpasses
- To generate well-calibrated and well-merged multi-satellite MSU 1B data for use by the climate community
- To investigate the MSU trend derived from the well-merged 1B dataset
- To compare with previous trend studies and identify problems with previous use of the MSU data
- To provide a guidance on the future use of MSU data
- To provide the climate community an observed reference on the tropospheric temperature trend

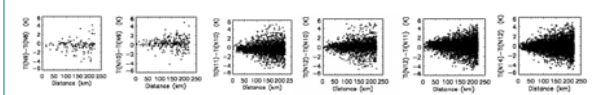
## 2. SNO dataset



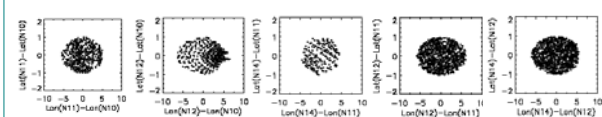
The local equator crossing time (LECT) of the ascending orbit of NOAA satellites



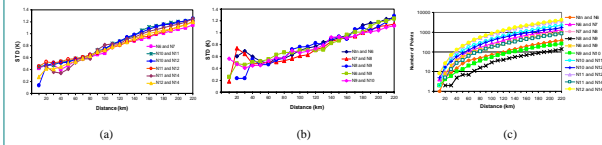
Relationship of the Channel 2 brightness differences between NOAA 10 and 11 of the nadir pixels versus time window for the SNO dataset. The maximum spatial distance for the SNOs is set to be 111 km. Note that when the time difference is larger than about 100 seconds, many SNO data pairs can be found.



Scatter plot of the brightness temperature difference versus the center distance between two nadir pixels for some selected overlaps. The pixel center distance has been extended to 222 km from 111 km and the time window is still set to be 100 sec. The brightness temperature is computed using the linear calibration equation.



Latitudinal difference vs longitudinal difference for the SNO pairs for some satellite overlaps. Unit is in degree



STD of channel 2 brightness temperature differences between satellite pairs versus center distance of the nadir overpass pixels. (a) Satellite pairs that have a well defined relationship, (b) satellite pairs that do not show well defined SDT-distance relationship for smaller distance due to sampling size problems, and (c) SNO numbers used in the STD computation for a corresponding distance.

## 3. Calibration algorithm

$$R_i = R_e + S(C_e - C_w) \quad (1) \rightarrow \text{Linear calibration equation;}$$

$R_i \rightarrow$  Earth-view radiance by linear calibration  
 $R_e \rightarrow$  Cold Space Radiance, fixed value;  $C_e \rightarrow$  cold space raw counts;  $C_w \rightarrow$  Earth-view raw counts;

$$S = \frac{R_w - R_e}{C_w - C_e} \quad (2) \rightarrow \text{slope;}$$

$R_w \rightarrow$  Blackbody target radiance;  $C_w \rightarrow$  Blackbody target raw counts

$$R_e = R_i - \delta R + u S^2 (C_e - C_w)(C_e - C_w) = R_i - \delta R + u Z \quad (3) \rightarrow \text{nonlinear calibration equation;}$$

$R_i \rightarrow$  Earth-view radiance by nonlinear calibration;  
 $\delta R \rightarrow$  constant offset;  $u \rightarrow$  nonlinear calibration coefficient

## 4. Calibration with SNO dataset

$$R_j(t_j, X_j) = R_j'(t_j, X_j) + \epsilon_j \rightarrow \text{observed radiance R by satellite j at time and location } (t_j, X_j)$$

$$R_k(t_k, X_k) = R_k'(t_k, X_k) + \epsilon_k \rightarrow \text{observed radiance R by satellite k at time and location } (t_k, X_k)$$

$R' \rightarrow$  error free measurement;  $\epsilon \rightarrow$  noise;

Taking differences  $\downarrow$

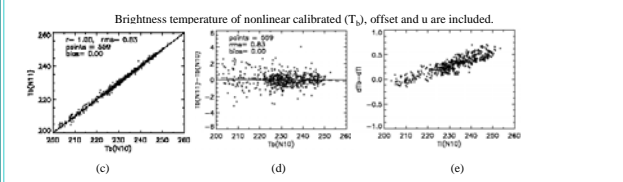
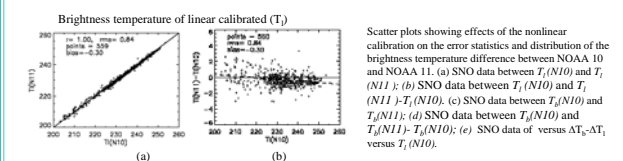
$$\Delta R = R_k'(t_j, X_j) - R_j'(t_j, X_j) + \epsilon_k - \epsilon_j + \Delta R(\Delta t, \Delta X)$$

Using (3)  $\downarrow$

$$\Delta R_j - \Delta \delta R + u_k Z_k - u_j Z_j = \epsilon_k - \epsilon_j + \Delta R(\Delta X) \quad (4) \rightarrow \text{Error equation for any SNO data pairs}$$

We solve  $\Delta \delta R = \delta R_k - \delta R_j, u_k$  and  $u_j$  using regression method; however, colinearity between  $Z_k$  and  $Z_j$  has to be considered (see figure). With colinearity, only  $\Delta \delta R$  and  $\Delta u = u_k - u_j$  can be reliably obtained from regression method. Therefore,  $\delta R$  and  $u$  for reference satellite have to be determined *a priori* from pre-launch calibration.

Here  $\delta R = 0$  and  $u = 5$  for reference satellite NOAA 10.

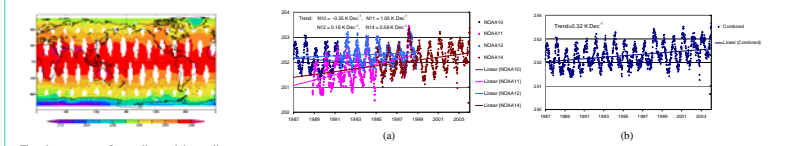


Calibration coefficients for different satellite channels for the regression adjusting process using the SNO dataset when NOAA 10 is assigned to be the reference satellite. Unit for  $\delta R$  and  $u$  is  $10^{-6}$  (mW<sup>2</sup>) (sr m<sup>2</sup> cm<sup>-2</sup>) and (sr m<sup>2</sup> cm<sup>-2</sup>)<sup>2</sup>, respectively.

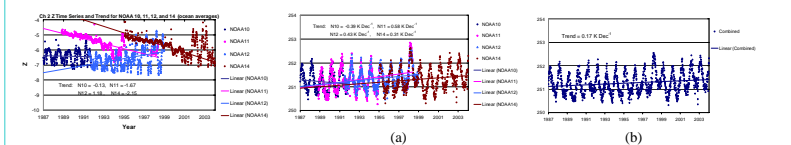
Non-constant quantities ( $\delta R_k + u_k Z_k$ ) and ( $u_k - u_j Z_j$ ) obtained from regression of SNO using Eq. (3). Units for  $\delta R$  and  $u$  are  $10^{-6}$  (mW<sup>2</sup>) (sr m<sup>2</sup> cm<sup>-2</sup>) and (sr m<sup>2</sup> cm<sup>-2</sup>)<sup>2</sup>, respectively.

Satellite Pairs	$\delta R_k + u_k Z_k$	$u_k - u_j Z_j$
N10 - N11	0.000	0.000
N10 - N12	0.000	0.000
N10 - N14	0.000	0.000
N10 - N11	0.000	0.000
N10 - N12	0.000	0.000
N10 - N14	0.000	0.000

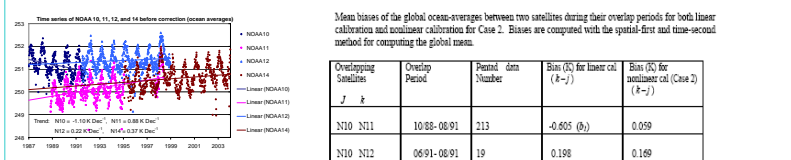
## 5. Results



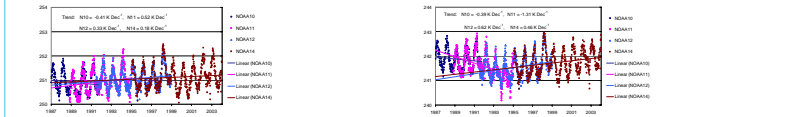
Five-day averages of ascending and descending orbits for NOAA 11 for the period of October 1-5, 1998. Pixels 5, 6, and 7 are used in generating the pentad data.



Global ocean-averaged pentad time series and trend of the nonlinear Z term for NOAA 10, 11, 12, and 14. Unit for Z is  $10^{-6}$  (mW<sup>2</sup>) (sr m<sup>2</sup> cm<sup>-2</sup>)<sup>2</sup>.



Time series and trend for the pentad dataset of the global ocean-averaged MSU channel 2 brightness temperature for NOAA 10, 11, 12 and 14 with NESDIS operational calibration algorithm.



Pentad time series and trend for the global ocean-averaged MSU channel 2 brightness temperature for NOAA 10, 11, 12 and 14 calibrated by Grody et al. (2004) calibration algorithm. The adjustment is directly on the global ocean-averaged pentad time series with linear calibration at level 0. Combined trend is 0.19 K/Decade.

## 6. Summary and Future work

- Use new nonlinear calibration equation to convert raw counts to radiance. Coefficients for reference satellite are determined by pre-launch calibration but non-reference satellites are determined by post-launch SNO data.
- Very-well calibrated and merged MSU channel 2 data are generated. Biases for pentad global ocean-averages are on the order of 0.05 to 0.1 K between satellite pairs, compared to 0.5 to 1 K with NESDIS operational algorithm.
- Global ocean trend with this merged dataset is 0.17-0.20 K/Decade, consistent with surface temperature trend.

Reference: Zou, C.-Z., M. Goldberg, Z. Cheng, N. Grody, J. Sullivan, C. Cao, and D. Tarpley, 2005: MSU channel 2 brightness temperature trend when calibrated using simultaneous nadir overpasses, to be submitted as NOAA Technical Report. Email: Cheng-Zhi.Zou@noaa.gov