# Study of MSU Channel-3 Brightness Temperature Time Series Using SNO calibration method


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## 1. Introduction

- MSU observations have been extensively used to investigate the temperature trends of the atmosphere. This paper focuses on the channel 3 trend analyses.
- There are biases among different satellites. To merge the multi-satellite time series, different inter-satellite calibration algorithms are compared.
- MSU channel 3 trends are obtained with different algorithms.
- Based on Zou et al. (2005) and Goldberg (2004) research, MSU channel 2 and channel 3 trends are combined to minimize the influence of the stratosphere.

## 2. Calibration algorithms used in this study

- Linear Calibration $R_l = R_c + S(C_e - C_c)$
- SNO calibration (see Zou et al. 2005)

$$R_e = R_l - \delta R + u S^2 (C_e - C_c)(C_e - C_w) = R_l - \delta R + uZ$$

- SNO calibration to original orbit data and Grody calibration to global ocean average pentad data

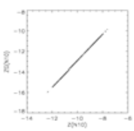
Grody et al. (2004) calibration algorithm:

$$T_b^{'} = T_b - \delta T + U_G Z_G$$

$U_G$ is a constant; $Z_G=(Tb-Tc)(Tb-Tw)$, here $Tc$ is the cold space temperature which is fixed to be 4.2 K, and $Tw$ is the warm target temperature

- linear calibration to original orbit data and Grody calibration to global ocean average pentad data

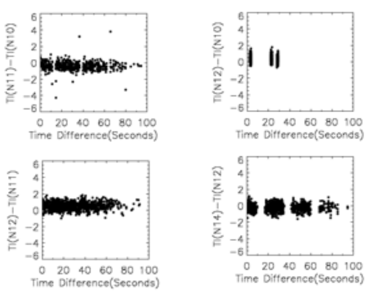
In this case, $U_G$ is computed by the equation from Zou, which is: $U_G = \kappa UZ/Z_G$ where $\kappa \approx 5\times10^4$ K (mW) $^{-1}$ (sr m$^2$ cm$^{-1}$) is the conversion factor between the radiance and the brightness temperature. Therefore $Z/Z_G$ can be obtained from their linear relation as shown below.



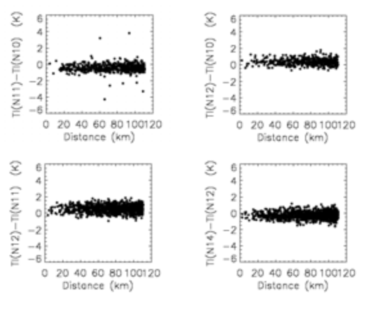
Scatter relationship between Z and $Z_G$ factors for NOAA 10 for the SNO data pairs between NOAA 10 and 11. Unite for Z and $Z_G$ are $10^{-6}$ (mW)$^2$ (sr m$^2$ cm$^{-1}$) $^{-2}$ and $10^3$ K$^2$, respectively.

## 3. Channel 3 SNO dataset

When two satellites meet each other and view the same location on earth at nadir at the same time, a SNO data pair is generated.

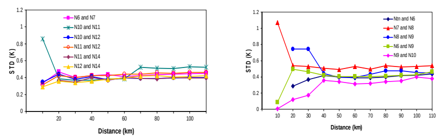


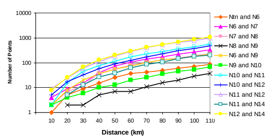
Scatter plot of the brightness temperature difference versus time difference between two nadir pixels of the overpass satellites for some selected overlaps. The brightness temperature is computed using the linear calibration equation.



Scatter plot of the brightness temperature difference versus the center distance between two nadir pixels of the overpass satellites for some selected overlaps. The brightness temperature is computed using the linear calibration equation.

## 3. Channel 3 SNO dataset (continued)

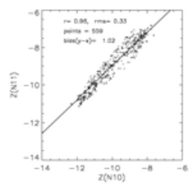




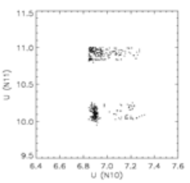
STD of channel 3 brightness temperature differences between satellite pairs versus center distance of the nadir overpass pixels. (a) Satellite pairs that have a well defined relationship, (b) satellite pairs that do not show well defined SDT-distance relationship for smaller distance due to sampling size problems, and (c) SNO numbers used in the STD computation for a corresponding distance.

## 4. Apply SNO calibration on channel3 observations

Scatterplot of Z factor between NOAA 10 and NOAA 11 for their SNO data pairs. Same as channel 2, the figure shows high colinearity between two satellites for channel3

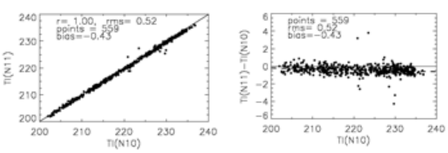


To apply non-linear adjustment, we have same assumption as ch2 $\delta R = 0$ for reference satellite NOAA10. Based on the U values for three given reference Dicke temperature provided by Mo et al. (2001) from the pre-launch calibration, the U is computed using interpolations. The figure below shows the scatter plot of U between N10 and N11. We choose U=7.2 for N10



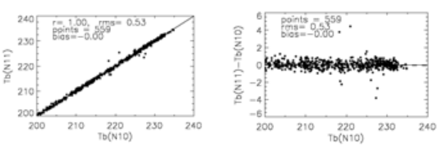
## 5. Bias comparison between linear and SNO calibration

Brightness temperature of linear calibrated (Tl)

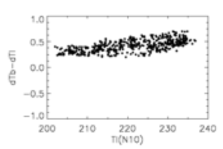


(a) (b)

Brightness temperature of nonlinear calibrated (Tb), offset and u are included.



(c) (d)



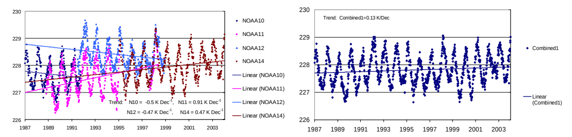
(e)

Scatter plots showing effects of the nonlinear calibration on the error statistics and distribution of the brightness temperature difference between NOAA 10 and NOAA 11. (a) SNO data between *Tl (N10)* and *Tl (N11 ); (b)* SNO data between *Tl (N10)* and *Tl (N11 )-Tl (N10).* (c) SNO data between *Tb(N10)* and *Tb(N11); (d)* SNO data between *Tb(N10)* and *Tb(N11)- Tb(N10); (e)* SNO data of versus $\Delta T_b$-$\Delta T_l$ versus $T_l$ *(N10).*

Mean biases of the global ocean-averages between two satellites during their overlap periods for both linear calibration and nonlinear calibration.

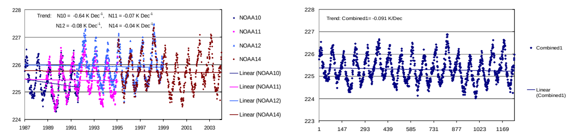
| Overlapping Satellites J k | Overlap Period | Pentad data Number | Bias (K) for linear cal ($k-j$) | Bias (K) for nonlinear cal ($k-j$) |
|---|---|---|---|---|
| N10 N11 | 10/88- 08/91 | 213 | -0.37412 | 0.106188 |
| N10 N12 | 06/91- 08/91 | 19 | 0.704 | 0.645842 |
| N11 N12 | 06/91- 12/94 | 261 | 0.921954 | 0.465912 |
| N12 N14 | 04/95- 11/98 | 267 | -0.41306 | -0.1166 |

## 6. Channel 3 trend comparison for different algorithms



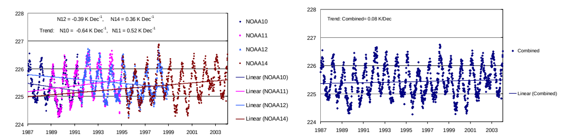
(a) (b)

Time series and trend for the pentad dataset of the global ocean-averaged MSU channel 3 brightness temperature for NOAA 10, 11, 12 and 14 with linear calibration algorithm. (a) Individual time series and trend for NOAA 10, 11, 12 and 14. (b) Combined time series and trend for NOAA 10, 11, 12 and 14. The mean biases between different satellites has been removed with NOAA 10 as the reference satellite.



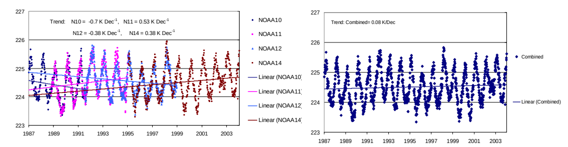
(a) (b)

Time series and trend for the pentad dataset of the global ocean-averaged MSU channel 3 brightness temperature for NOAA 10, 11, 12 and 14 with SNO calibration algorithm. (a) Individual time series and trends for NOAA 10, 11, 12 and 14. (b) Combined time series and trend for NOAA 10, 11, 12 and 14. The mean biases between different satellites as shown in Table 6 have been removed with NOAA 10 as the reference satellite



(a) (b)

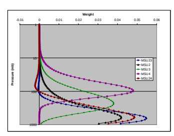
Pentad time series and trend for the global ocean-averaged MSU channel 2 brightness temperature for NOAA 10, 11, 12 and 14 calibrated by Grody et al. (2004) calibration algorithm. The Grody nonlinear adjustment is directly on the global ocean-averaged pentad time series with SNO calibration ( $\delta R = 0$ and $U_G$=0 for N10)



(a) (b)

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 Grody non-linear adjustment is directly on the global ocean-averaged pentad time series with linear calibration at level 0 ( $\delta R = 0$ , $U_G$ =2.7856*$10^{-4}$ for N10 and $U_G$ is computed by the method introduced from section 2)

## 7. Adjust channel 2 trend



**Influence of the stratosphere on MSU2, MSU23 and MSU24 – sensitivity study**

Assume constant stratospheric cooling of -0.4 C, and tropospheric /surface warming of 0.2 C per decade. The resultant trend would be:

Tropopause @ 500 MB: -0.10, 0.25, -0.05
Tropopause @ 400 MB: -0.03, 0.22, 0.02
Tropopause @ 300 MB: 0.02, 0.20, 0.09
Tropopause @ 200 MB: 0.11, 0.19, 0.18
Tropopause @ 100 MB: 0.17, 0.19, 0.22

weighting function shows that the channel 2 observations contain contributions of atmospheric radiation from not only the lower troposphere , but also the upper troposphere and lower stratosphere

To remove the effect of upper-troposphere and stratospheric effect on channel2 :
Goldberg: 1.43*channel2 -0.43*channel3
Fu (2004): 1.15*channel2-0.15*channel4

Stratospheric effect is better removed by Goldberg.

## 8. Summary and Future work

- The inter-satellite biases are largely removed after using the SNO calibration and Grody calibration on MSU channel 3 observations.
- The biases resulting from the non-linear SNO calibration is 50% ~ 75% less than that of the linear calibration.
- Applying Grody's calibration on pentad data after the original orbit data calibration results in a MSU channel 3 trend 0.08K/Decade.
- Using the above MSU channel 3 trend, Zou et al's MSU channel 2 trend (0.17K/Decade) and Goldberg's channel 2 and channel 3 combination algorithm, the MSU channel 2/3 trend is 0.21K/Decade
- Future work will investigate the combination algorithm of trend analyses on MSU channels 2, 3, and 4. Compare Fu's combine algorithm (channel 2 and channel 4) with that of Goldberg's.


**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 to JGR.



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