MSU channel 2 brightness temperature trend when calibrated using the simultaneous nadir overpass method

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The MSU channel 2 on board nine different NOAA polar-orbiting satellites has been measuring the deep-layer tropospheric temperature for more than 25 years. Due to its continuity as well as its channel characteristics, the MSU measurement represents a unique opportunity for providing possible answers to the question of whether the troposphere is warming or cooling over the last several decades. However, the temperature trends derived from these measurements are under significant debate. In particular, different calibration algorithms, different merging methods for the multi-satellite time series, different treatments of the satellite orbital drift, and different modeling efforts for the diurnal cycle in the time series may all affect the MSU trend analyses. Current results range from nearly no trend (Christy et al. 2003) to a relatively large trend of 0.260C /decade (Vinnikov and Grody 2004) for the MSU channel 2 dataset. More recently, Grody et al., (2004) found that the trend decreased from 0.260C /decade to 0.170C using more accurate calibration adjustments. It is desirable that more efforts be devoted to investigate the problems.

As part of the NOAA/NESDIS/ORA effort, this study intends to construct a well-merged MSU channel 2 time series at the 1B level using the simultaneous nadir overpass (SNO) method. We use the new nonlinear calibration algorithm suggested by Mo et al. (2001) to convert the MSU raw counts to the Earth-view radiance. The algorithm consists of the dominant linear responses of the MSU radiometer raw counts to the Earth-view radiance plus a weak quadratic term caused by an 'imperfect' square-law detector. The cold space view and an on board warm target view are used as two reference calibration points. Uncertainties in the calibration algorithm are represented by a constant offset and errors in the coefficient for the nonlinear quadratic term. To merge the multiple NOAA satellites together, a reference satellite has to be specified a prior. In this study, NOAA 10 is taken as the reference satellite. The offset value for the reference satellite is assumed to be zero and its nonlinear coefficient is determined by the pre-launch calibration with the chamber test data plus information on the radiometer body temperature.

A unique feature of this study is that the offset values and nonlinear coefficients for the other satellites are determined by the SNO method. The SNO dataset, generated using the SNO method developed by Cao et al. (2004), contains simultaneous nadir observations of less than 2 minute apart of the Earth over the polar region for the nadir pixels from any two NOAA satellites, including both morning and afternoon satellites. Thus, it provides a unique opportunity for an accurate post-launch calibration and merger of different satellites. In this study, different satellites are merged together sequentially starting from the reference satellite. An ordinary linear regression method is used to derive the offset and nonlinear coefficients using the SNO dataset in this sequential adjustment procedure. The coefficients obtained with this method are 'optimal' in a least-squares sense and, by definition, they automatically remove the biases between any two satellite measurements in the SNO datasets and a temperature-dependent non-uniformity in the biases caused by orbital drift.

Applying these offset and nonlinear coefficients to the entire MSU observations, we obtain a merged MSU 1B dataset. A 5-day averaged (pentad) dataset is then derived from the 1B data and used to investigate the trend of the MSU channel 2 observations. A great advantage of the current calibration is that the biases for the global ocean between two satellites in the pentad dataset are only on the order of 0.05 to 0.1 K for their overlap periods. This is an order of magnitude smaller than previous investigations using NESDIS operational MSU 1B data. After these small biases are removed in the pentad dataset, we obtain a MSU channel 2 trend of 0.17 K decade-1 for the global ocean for a 15-year merged time series containing NOAA 10, 11, 12, and 14.