Results from the NOAA-14 Microwave Sounding Unit Pitch Test

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Abstract

A pitch over maneuver was performed on NOAA-14 to evaluate the Microwave Sounding Unit for asymmetry. This paper presents the results of this test, as well as previously unpublished results from a similar maneuver performed on NOAA-6 in 1984.

Introduction

The Microwave Sounding Unit (MSU) was first launched on the Television-InfraRed Observational Satellite-N (TIROS-N) in October of 1978. It has subsequently flown on a series of NOAA polar orbiting spacecraft up to and including NOAA-14, and has provided a continuous record of observations for almost twenty-eight years. A number of temperature time series analyses have been derived from these observations, notably those of Christy et al. (2000), Mears and Wentz (2006), Vinnikov and Grody (2003), and Fu et al. (2006). Considering the ongoing debate on global warming, it is imperative that the MSU be characterized to the fullest extent. This paper will describe a pitch over maneuver (POM) that was performed on NOAA-14 in order to characterize the earth scene cross-track symmetry and validate the space calibration view. In addition, this paper will present for the first time results from a similar maneuver performed on NOAA-6.

History

Pitch maneuvers have been performed on NOAA spacecraft before. They were conducted on NOAA 2 and 3 to characterize the Improved Temperature Profile Radiometer, NOAA-10 to characterize the Earth Radiation Budget, and most notably on NOAA66 to examine the MSU for asymmetry. Unfortunately the original data from the NOAA66 maneuver has been lost, and the most of the scientists and engineers who worked on it have retired or passed on. The results of this study were published only as internal memoranda (Crone (1984), McMillin (1984), Reinhardt (1984), and references therein). Moreover, some of these memos disagreed on the interpretation of the observations. The conclusion of Reinhardt (1984) is that there was a systematic scan dependence and that it was due to "…out-of-field coupling to on-board sources…". It is notable that the sense of the asymmetry is opposite for the vertical and horizontally polarized channels.

Methodology

The term "pitch maneuver" is a misnomer, since during normal orbital operations, POES spacecraft pitch forward 360^{o} each orbit so that the instruments on the nadir side continuously faces the earth (Figure 1). For the maneuver, the pitch motion is stopped, and the spacecraft maintains inertial pointing in the pitch direction. With time, the horizon comes down (from the instrument point of

view) and the instruments view space. Eventually the horizon comes up from the other side, and the instruments re-acquire the earth view. After exactly one orbit, the normal pitch motion is resumed.

Considerable commanding is done to the spacecraft in conjunction with the maneuver. For example, since the spacecraft is in an inertial drift, the solar array must stop rotating in order for the panels to maintain sun orientation. The earth sensor array is disabled in order to put the spacecraft into the inertial drift. Thrusters are enabled in case the spacecraft tumbles and thruster firing is required to assist magnetic torque recovery or to dump momentum. Normal spacecraft redundancy actions are overridden. Thruster firings did occur at the end of the NOAA-14 maneuver as the spacecraft recovered and returned to a nominal mode.

Results

One hundred and thirty nine scans were selected while the instrument was viewing deep space, on 10 August 2006, from time 59315.934 to 62848.734. Since the instrument counts vary with instrument temperature, the calibration space view was subtracted from the nominal earth scene counts for each scan. The mean difference of counts as a function of scan position is shown in Figure 2. The sub-figures are grouped by polarization, channels 1 and 3 (V) and 2 and 4 (H). Also shown in Figure 2 are the corresponding statistics extracted from a figure in Crone (1984) describing the NOAA-6 POM, which was performed on 15 March 1984. There are 160 consecutive scans in the NOAA-6 data.

The first point to note is that the nominal earth scene viewing space registers different values than the space calibration view. This difference is greatest in channel 1 with about four counts for NOAA-14 and five counts for NOAA-6. At the nominal gain of 0.12 K/count this corresponds to about 0.5 and 0.6 K respectively.

The second point is that there is a marked asymmetry in the nominal earth scene, and the characteristics of the asymmetry differ for the different polarizations. The vertically polarized channels display maximum difference from the space look near the nominal nadir position. The horizontal polarized channels on NOAA-14 tend to have a maximum in the lower scan positions, and a minimum in the higher scan positions. The same channels on NOAA-6 show almost no deviation from the space look for channel 4, and a similar behavior as the vertical polarization but in the opposite sense for channel 2.

The third point is that position 1 reads higher values than position 2. Position 1 is in the direction of the bulk of the spacecraft body, and position 11 is in the opposite direction, away from the spacecraft and closest to the space calibration view. In spite of the conclusion of Reinhardt (1984) quoted above, it is likely that the MSU side lobe is viewing the spacecraft in position 1.

Summary

The National Oceanographic and Atmospheric Administration has successfully performed a POM on NOAA-14. The test showed that earth scene viewing space reads different values than the space calibration view, that there is an asymmetry in the observations, and that scene 1 is warmer than scene 2. These conclusions are true for NOAA-14 and NOAA-6, with the exception of NOAA-6 channel 4.

It is not known if the asymmetry is constant or variable. If it is constant, it should have little or no effect on the temperature trends. If it is variable, there is nothing that can be done about it since it is

unlikely any more such maneuvers will be performed on NOAA-14. However, since the space calibration view has different readings from the nominal earth scene viewing space, some adjustment of the calibration algorithm should be possible in order to fine tune the long term temperature time series.

There is additional information to be gleaned from this maneuver. As the MSU cleared the earth limb, the outermost scan positions cleared first, subsequently followed by inner scan positions, with the nadir position clearing last. By co-locating the imagery from the Advanced Very High Resolution Radiometer with the MSU, it is possible to ascertain exactly when the MSU is clear of the earth. With this information is should be possible to partially assess the side-lobe characteristics. This assessment is the subject of continuing work.

The data from the POM are available from the Comprehensive Large Array-data Stewardship System (http://www.class.noaa.gov). The data set name is NSS.MSUS.NJ.D06222.S1611.E1752.B5987677.GC .

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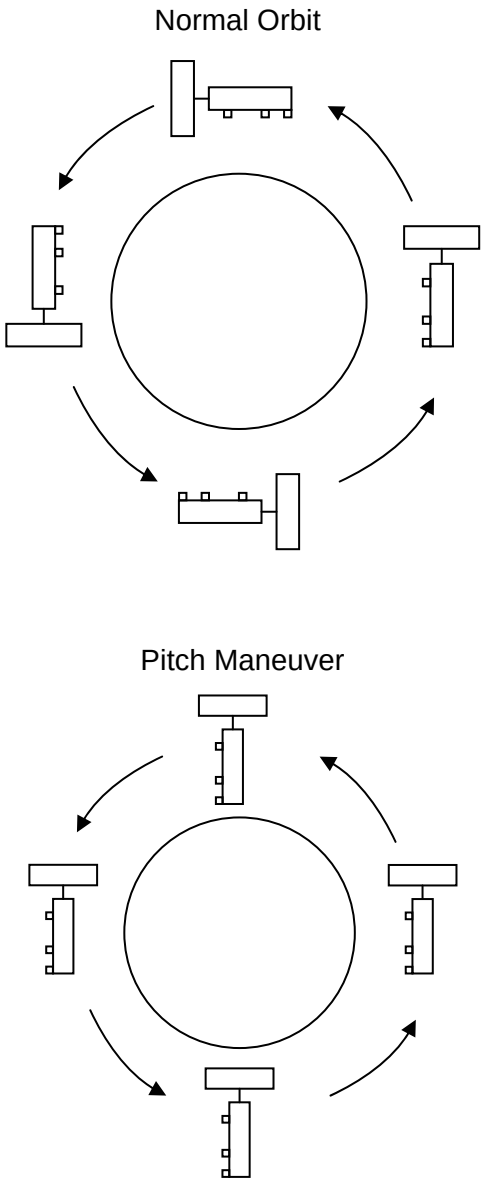

Figure 1: Schematic of spacecraft attitude in normal orbit and during the pitch maneuver.

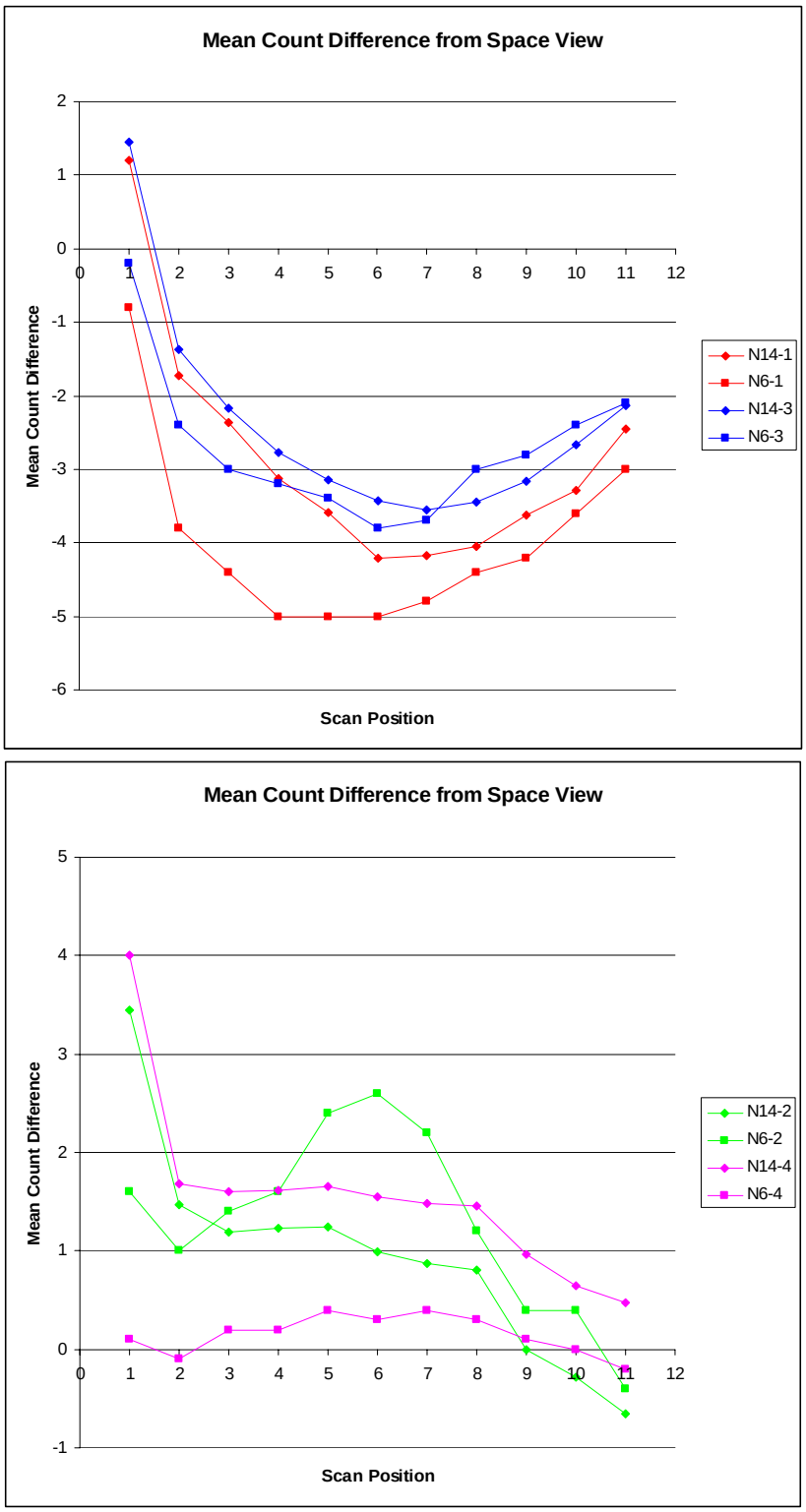

Figure 2. Mean count difference of nominal earth scene viewing space as a function of scan position. Top: Channels 1 (red) and 3 (blue). Bottom: Channels 2 (green) and 4 (magenta). N14 refers to the NOAA-14 Pitch Over Maneuver. N6 refers to the NOAA-6 Pitch Over Maneuver.