# 2015 STAR ICVS Instrument Performance Review

# ATMS/AMSU/MHS Anomaly Report

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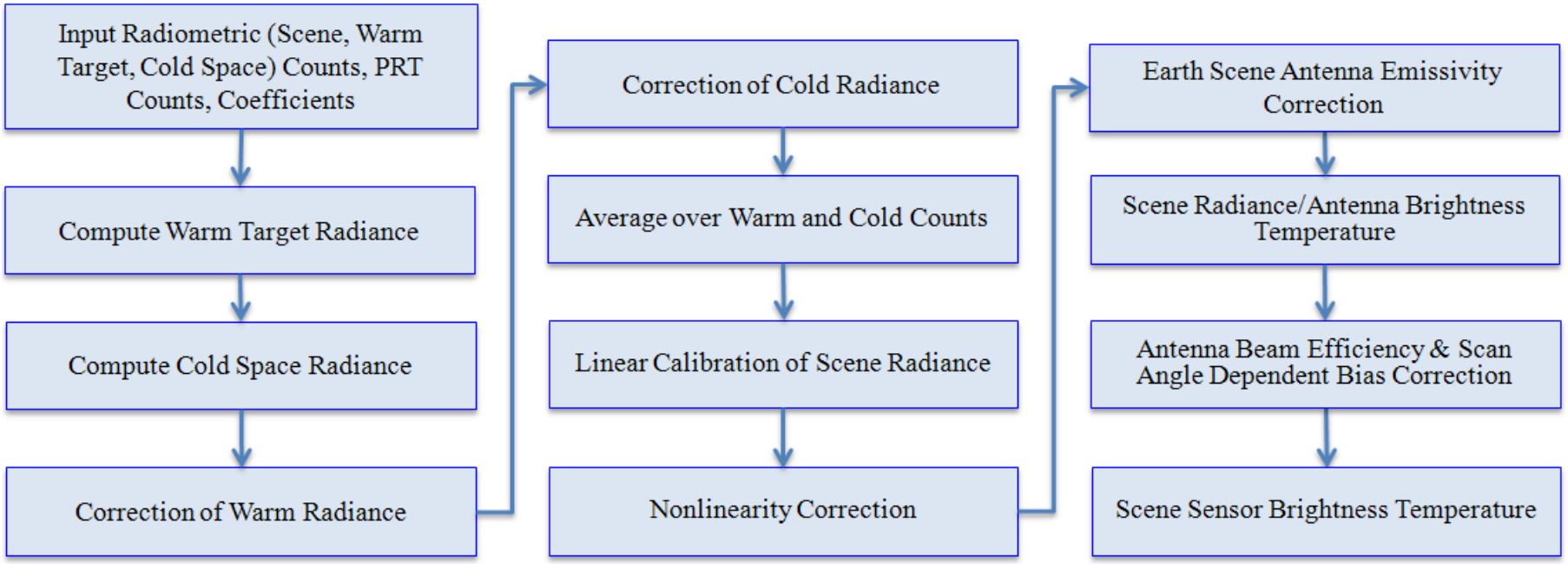
NOAA/NESDIS/STAR

# Microwave Instrument Calibration Procedure

Microwave Remote Sensing Two-Point Calibration Equation

$$T_b = T_b^w + \frac{C^s - \overline{C^w}}{\overline{C^w} - \overline{C^c}}(T_b^w - T_b^c) + Q$$

- $T_b^w$ Hot Load PRT Temperature
- $T_b^c$ Cosmic Background Temperature
- $C^s$ Earth Scene Count
- $\overline{C^w}$ Averaged Hot Load Count
- $\overline{C^c}$ Average Cold Space View Count
- $Q$ Non-linearity Correction Term



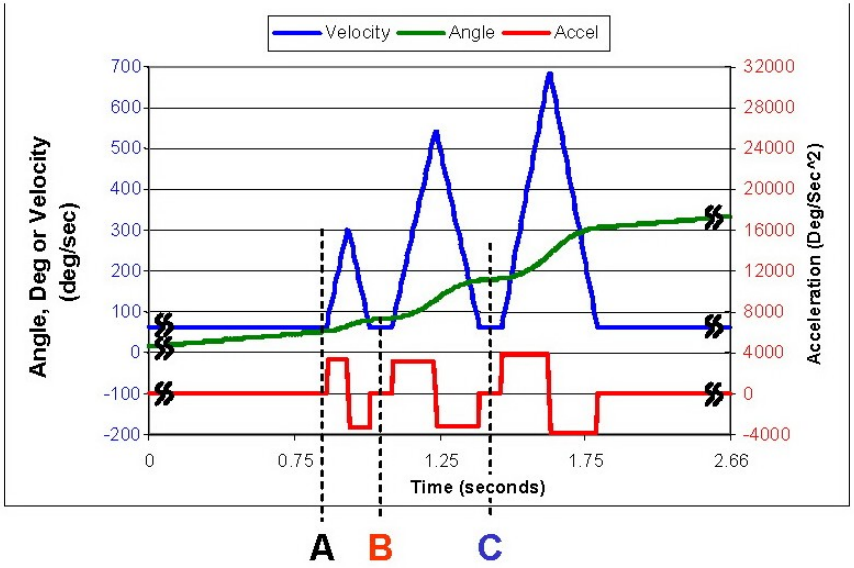
# Microwave Instrument LTM Parameters

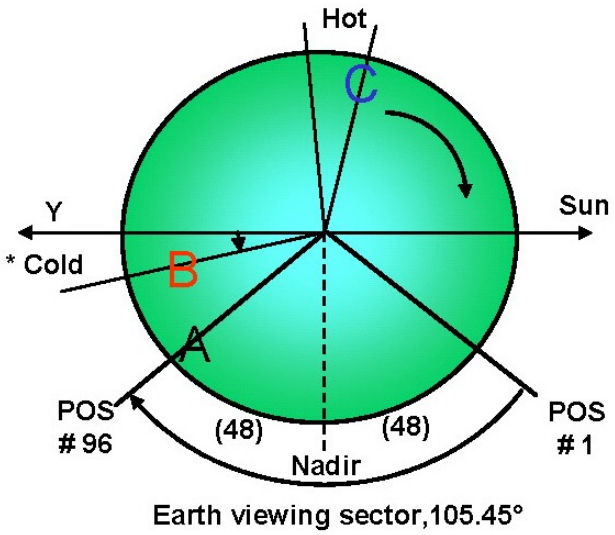
| Parameters | Descriptions | Dimensions | Usage |
|---|---|---|---|
| **Channel NEΔT** | Noise equivalent differential temperature | by channels | sensitivity trending |
| **Warm Count** | Blackbody warm target count | by channels | Onboard calibration target trending |
| **Space view Count** | Space view cold target count | by channels | Onboard calibration target trending |
| **Channel Gain** | Calibration gains for each channel | by channels | Calibration trending |
| **Warm load PRT Temperature** | Blackbody platinum resistance thermometer (PRT) temperature | by readings | Stability trending |
| **Instrument Temperatures** | Mixer/IF Amplifier, Local oscillator, RF MUX, RF shelf, Scan motor, Feedhorn temperature, etc. | as provided | Instrument health status |
| **Instrument Health Status Telemetry** | Antenna drive motor current, Signal processing voltage, Phase lock loop voltage, LO voltage, PLLO voltage, etc. | as provided | Instrument health status |
| **Data Product Quality Flags** | Granule level, scan level, pixel level quality flags | as provided | Data health status |
| **Bias Characterization** | Observations v.s. RTM simulations | by channels | Data quality status |

# Introduction to ATMS Instrument

**Advanced Technology Microwave Sounder (ATMS)**

- Multi-channel microwave radiometer
- For temperature profiling, water vapor profiling, snow and ice coverage, cloud liquid water, rain rate, and other surface product retrieval
- Scan rate: 8/3 Seconds
- Scan type: Continuous
- Sample pixel size per scan: 96
- Integration time: 18 msec
- Instantaneous FOV beamwidth: 5.2 °(K/Ka), 2.2°(V), 1.1°(W/G)
- Footprint size at nadir: 74.8 km (K/Ka), 31.6 km (V), 15.8 km (W/G)
- Max scan angle: ±52.7°
- Swath: 2503 km



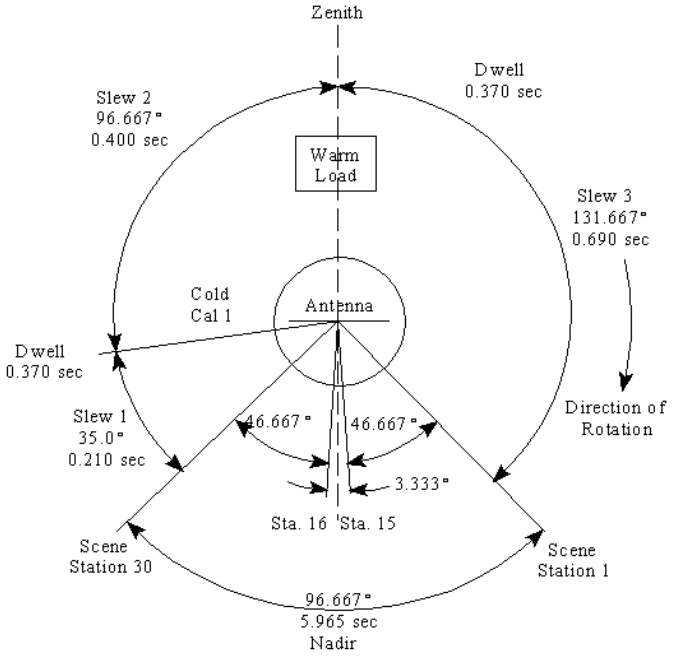
# Introduction to ATMS Instrument

| Channel | Channel Center Freq.(MHz) | Polarization | Bandwidth Max. (MHz) | Frequency Stability (MHz) | Calibration Accuracy (K) | Nonlinearity Max. (K) | NEΔT (K) | 3-dB Bandwidth (deg) | Channel | Channel Center Freq.(MHz) | Polarization | Bandwidth Max. (MHz) | Frequency Stability (MHz) | Calibration Accuracy (K) | Nonlinearity Max. (K) | NEΔT (K) | 3-dB Bandwidth (deg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 23800 | QV | 270 | 10 | 1.0 | 0.3 | 0.5 | 5.2 | 12 | $f_o$±322.2±48 | QH | 36 | 1.2 | 0.75 | 0.4 | 1.0 | 2.2 |
| 2 | 31400 | QV | 180 | 10 | 1.0 | 0.4 | 0.6 | 5.2 | 13 | $f_o$±322.2±22 | QH | 16 | 1.6 | 0.75 | 0.4 | 1.5 | 2.2 |
| 3 | 50300 | QH | 180 | 10 | 0.75 | 0.4 | 0.7 | 2.2 | 14 | $f_o$±322.2±10 | QH | 8 | 0.5 | 0.75 | 0.4 | 2.2 | 2.2 |
| 4 | 51760 | QH | 400 | 5 | 0.75 | 0.4 | 0.5 | 2.2 | 15 | $f_o$±322.2±4.5 | QH | 3 | 0.5 | 0.75 | 0.4 | 3.6 | 2.2 |
| 5 | 52800 | QH | 400 | 5 | 0.75 | 0.4 | 0.5 | 2.2 | 16 | 88200 | QV | 2000 | 200 | 1.0 | 0.4 | 0.3 | 2.2 |
| 6 | 53596±115 | QH | 170 | 5 | 0.75 | 0.4 | 0.5 | 2.2 | 17 | 165500 | QH | 3000 | 200 | 1.0 | 0.4 | 0.6 | 1.1 |
| 7 | 54400 | QH | 400 | 5 | 0.75 | 0.4 | 0.5 | 2.2 | 18 | 183310±7000 | QH | 2000 | 30 | 1.0 | 0.4 | 0.8 | 1.1 |
| 8 | 54940 | QH | 400 | 10 | 0.75 | 0.4 | 0.5 | 2.2 | 19 | 183310±4500 | QH | 2000 | 30 | 1.0 | 0.4 | 0.8 | 1.1 |
| 9 | 55500 | QH | 330 | 10 | 0.75 | 0.4 | 0.5 | 2.2 | 20 | 183310±3000 | QH | 1000 | 30 | 1.0 | 0.4 | 0.8 | 1.1 |
| 10 | 57290.344($f_o$) | QH | 330 | 0.5 | 0.75 | 0.4 | 0.75 | 2.2 | 21 | 183310±1800 | QH | 1000 | 30 | 1.0 | 0.4 | 0.8 | 1.1 |
| 11 | $f_o$± 217 | QH | 78 | 0.5 | 0.75 | 0.4 | 1.0 | 2.2 | 22 | 183310±1000 | QH | 500 | 30 | 1.0 | 0.4 | 0.9 | 1.1 |

# Introduction to AMSU-A Instrument

**Advanced Microwave Sounding Unit (AMSU)**

- Multi-channel microwave radiometer
- For temperature profiling, water vapor profiling, snow and ice coverage, cloud liquid water, rain rate, and other surface product retrieval
- Scan rate: 8 Seconds
- Scan type: Stop and stare
- Sample pixel size per scan: 30
- Integration time: 165 msec (A1) and 158 msec (A2)
- Instantaneous FOV beamwidth: 3.3°
- Footprint size: 48 km at nadir
- Max scan angle: ±48.33°
- Swath: 2072 km




| Spacecraft | Launch Date | Current Operational Status |
|---|---|---|
| NOAA-19 | 02/06/2009 | PM Primary |
| NOAA-18 | 05/20/2005 | PM Secondary |
| NOAA-15 | 05/13/1998 | AM Secondary |
| METOP-B | 04/24/2013 | AM Primary |
| METOP-A | 05/21/2007 | AM Backup |

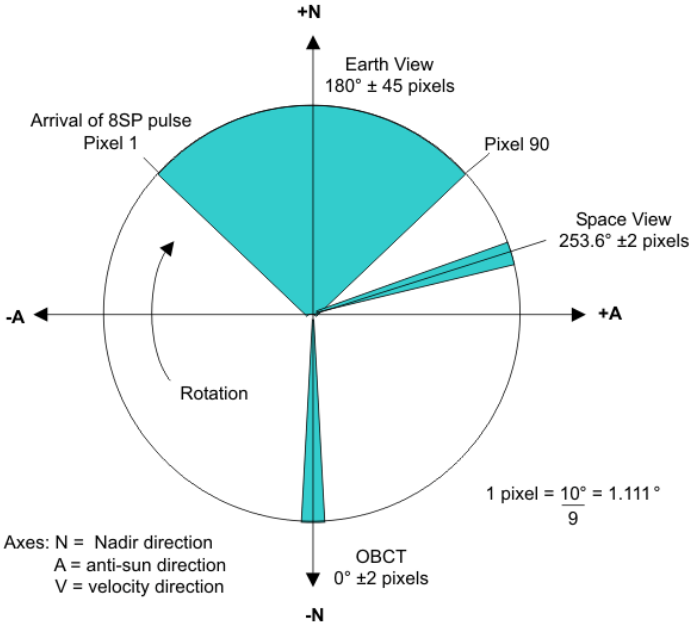
# Introduction to AMSU-A Instrument

| Ch. | Central Freq. (MHz) | # Bands | Nominal Bandwidth (MHz) | Nominal Beamwidth (degree) | Central Frequency Stability (MHz) | Temperature Sensivity (K) NEΔT | Calibration Accuracy (K) | Polarization at nadir | Component |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 23800 | 1 | 270 | 3.3 | 10 | 0.3 | 2.0 | V | A2 |
| 2 | 31400 | 1 | 180 | 3.3 | 10 | 0.3 | 2.0 | V | A2 |
| 3 | 50300 | 1 | 180 | 3.3 | 10 | 0.4 | 1.5 | V | A1-2 |
| 4 | 52800 | 1 | 400 | 3.3 | 5 | 0.25 | 1.5 | V | A1-2 |
| 5 | 53596±115 | 2 | 170 | 3.3 | 5 | 0.25 | 1.5 | H | A1-2 |
| 6 | 54400 | 1 | 400 | 3.3 | 5 | 0.25 | 1.5 | H | A1-1 |
| 7 | 54940 | 1 | 400 | 3.3 | 5 | 0.25 | 1.5 | V | A1-1 |
| 8 | 55500 | 1 | 330 | 3.3 | 10 | 0.25 | 1.5 | H | A1-2 |
| 9 | 57290.344 | 1 | 330 | 3.3 | 0.5 | 0.25 | 1.5 | H | A1-1 |
| 10 | 57290.344±217 | 2 | 78 | 3.3 | 0.5 | 0.4 | 1.5 | H | A1-1 |
| 11 | 57290.344±322.2±48 | 4 | 36 | 3.3 | 1.2 | 0.4 | 1.5 | H | A1-1 |
| 12 | 57290.344±322.2±22 | 4 | 16 | 3.3 | 1.2 | 0.6 | 1.5 | H | A1-1 |
| 13 | 57290.344±322.2±10 | 4 | 8 | 3.3 | 0.5 | 0.80 | 1.5 | H | A1-1 |
| 14 | 57290.344±322.2±4.5 | 4 | 3 | 3.3 | 0.5 | 1.20 | 1.5 | H | A1-1 |
| 15 | 89000 | 1 | <6000 | 3.3 | 50 | 0.5 | 2.0 | V | A1-1 |

# Introduction to MHS Instrument

**Microwave Humidity Sounder (MHS)**

- Multi-channel microwave radiometer
- Scan rate: 8/3 Seconds
- Scan type: Continuous
- Sample pixel size per scan: 90
- Integration time: 18 msec
- Instantaneous FOV beamwidth: 1.1°
- Footprint size: 16 km at nadir
- Max scan angle: ±48.44°
- Swath: 2198 km




| Ch. | Central Freq. (MHz) | # Bands | Nominal Bandwidth (MHz) | Nominal Beamwidth (degree) | Temperature Sensivity (K) NEΔT | Polarization at nadir |
|---|---|---|---|---|---|---|
| 1 | 89000 | 1 | 2800 | 1.1 | 1.0 | V |
| 2 | 157000 | 1 | 2800 | 1.1 | 1.0 | V |
| 3 | 183311±1000 | 2 | 2 x 500 | 1.1 | 1.0 | H |
| 4 | 183311±3000 | 2 | 2 x 1000 | 1.1 | 1.0 | H |
| 5 | 190311 | 1 | 2200 | 1.1 | 1.0 | V |

# Microwave Instrument NEΔT Algorithm

Current operational NEΔT calculation method,

$$NE\Delta T_{ch} = \sqrt{\frac{1}{NM}\sum_{i=1}^{N}\sum_{j=1}^{M}\left(\frac{C_{ch}^{w}(i,j)-\overline{C_{ch}^{w}}(i)}{\overline{G_{ch}}(i)}\right)}$$

**where $C_{ch}^{w}$ represents the warm count readings at each scan, $\overline{G_{ch}}$ is the averaged calibration gain.**

**By using overlapping Allan deviation, NEΔT can be calculated via**

$$NE\Delta T_{ch}^{Allan}(M,m) = \sqrt{\frac{1}{2m^{2}(M-2m+1)}\sum_{i=1}^{M-2m+1}\sum_{k=i}^{i+m-1}\left[\frac{C_{ch}^{w}(k+m)-C_{ch}^{w}(k)}{\overline{G_{ch}}}\right]^{2}}$$

**when $m = 1$ , NEΔT can be calculated using neighborhood Allan deviation**

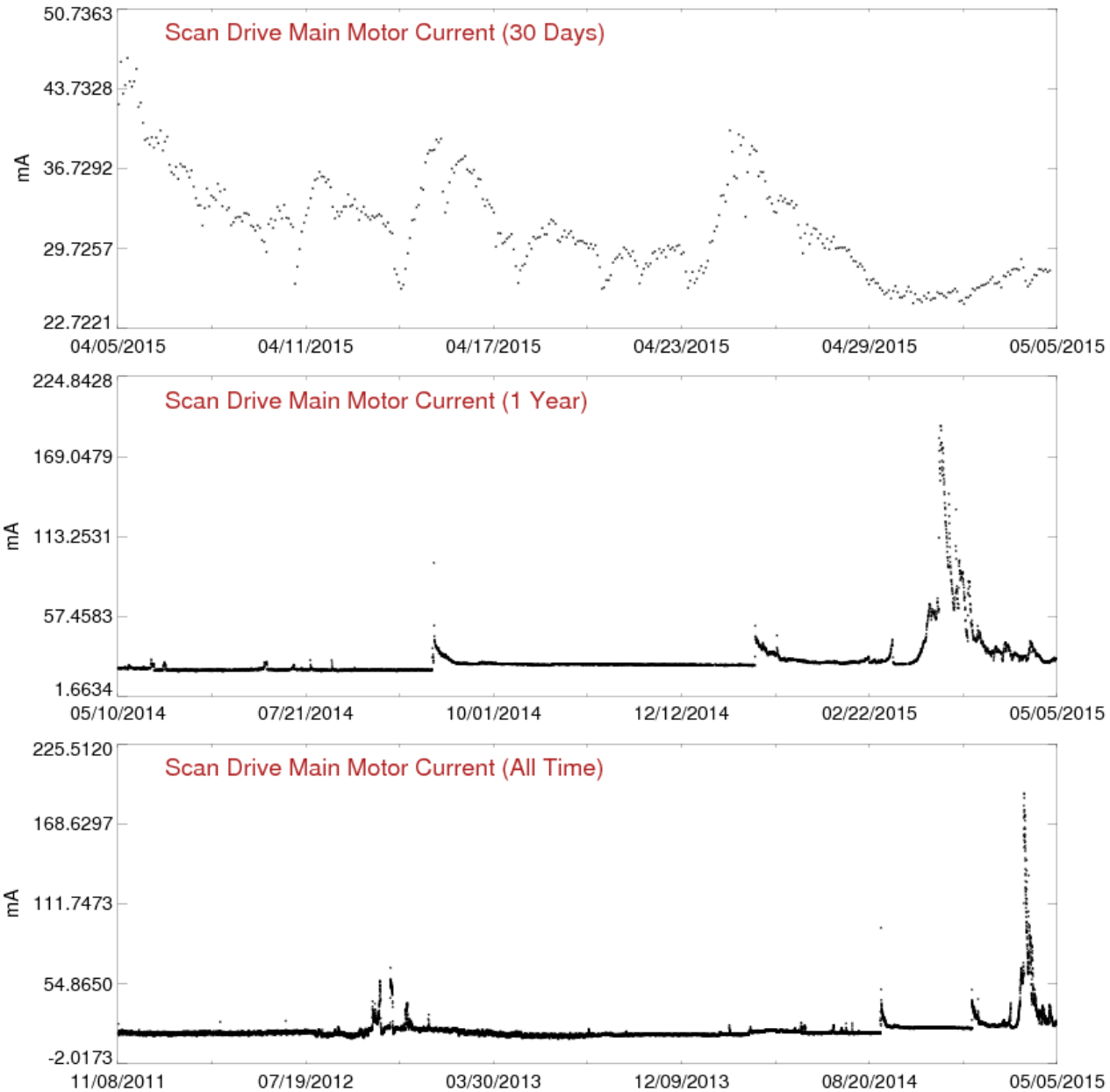
$$NE\Delta T_{ch}^{Allan} = \sqrt{\frac{1}{2(M-1)}\sum_{i=1}^{M-1}\left[\frac{C_{ch}^{w}(i+1)-C_{ch}^{w}(i)}{\overline{G_{ch}}}\right]^{2}}$$

# On-orbit ATMS NEΔT

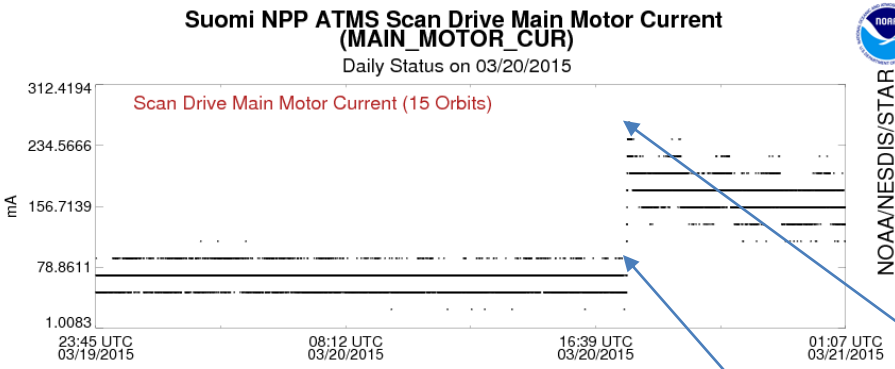
| Channel | Channel Center Freq.(MHz) | NEΔT Spec. (K) | On-orbit NEΔT (K) | Channel | Channel Center Freq.(MHz) | NEΔT Spec. (K) | On-orbit NEΔT (K) |
|---|---|---|---|---|---|---|---|
| 1 | 23800 | 0.5 | 0.13 | 12 | $f_o$±322.2±48 | 1.0 | 0.29 |
| 2 | 31400 | 0.6 | 0.18 | 13 | $f_o$±322.2±22 | 1.5 | 0.43 |
| 3 | 50300 | 0.7 | 0.20 | 14 | $f_o$±322.2±10 | 2.2 | 0.58 |
| 4 | 51760 | 0.5 | 0.19 | 15 | $f_o$±322.2±4.5 | 3.6 | 0.92 |
| 5 | 52800 | 0.5 | 0.16 | 16 | 88200 | 0.3 | 0.20 |
| 6 | 53596±115 | 0.5 | 0.17 | 17 | 165500 | 0.6 | 0.26 |
| 7 | 54400 | 0.5 | 0.15 | 18 | 183310±7000 | 0.8 | 0.23 |
| 8 | 54940 | 0.5 | 0.16 | 19 | 183310±4500 | 0.8 | 0.29 |
| 9 | 55500 | 0.5 | 0.17 | 20 | 183310±3000 | 0.8 | 0.33 |
| 10 | 57290.344($f_o$) | 0.75 | 0.23 | 21 | 183310±1800 | 0.8 | 0.37 |
| 11 | $f_o$± 217 | 1.0 | 0.29 | 22 | 183310±1000 | 0.9 | 0.45 |

❖ **As of April 6, 2015**

# S-NPP ATMS SD Main Motor Current Anomaly



# S-NPP ATMS SD Main Motor Current Anomaly

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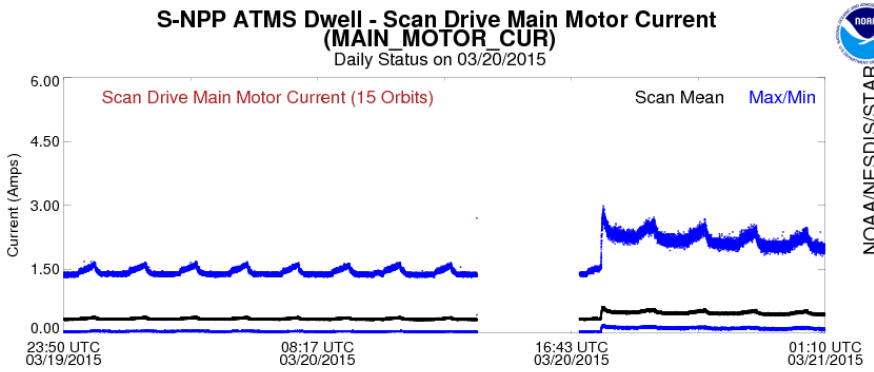
#17573 (2015-03-20), Orbital Mean = 66.90 mA, Orbital Max = 90.29 mA
#17574 (2015-03-20), Orbital Mean = 67.51 mA, Orbital Max = 90.29 mA
#17575 (2015-03-20), Orbital Mean = 70.09 mA, Orbital Max = 112.07 mA
#17576 (2015-03-20), Orbital Mean = 67.44 mA, Orbital Max = 112.07 mA
#17577 (2015-03-20), Orbital Mean = 64.61 mA, Orbital Max = 90.29 mA
#17578 (2015-03-20), Orbital Mean = 63.07 mA, Orbital Max = 90.29 mA
#17579 (2015-03-20), Orbital Mean = 62.31 mA, Orbital Max = 90.29 mA
#17580 (2015-03-20), Orbital Mean = 60.49 mA, Orbital Max = 90.29 mA
#17581 (2015-03-20), Orbital Mean = 62.53 mA, Orbital Max = 90.29 mA
#17582 (2015-03-20), Orbital Mean = 62.36 mA, Orbital Max = 90.29 mA
#17583 (2015-03-20), Orbital Mean = 112.39 mA, Orbital Max = 264.51 mA
#17584 (2015-03-20), Orbital Mean = 181.91 mA, Orbital Max = 242.73 mA
#17585 (2015-03-20), Orbital Mean = 173.13 mA, Orbital Max = 220.96 mA
#17586 (2015-03-20), Orbital Mean = 165.28 mA, Orbital Max = 220.96 mA
#17587 (2015-03-21), Orbital Mean = 160.82 mA, Orbital Max = 220.96 mA

**Maximum at Orbit #17583, 17:47:32**

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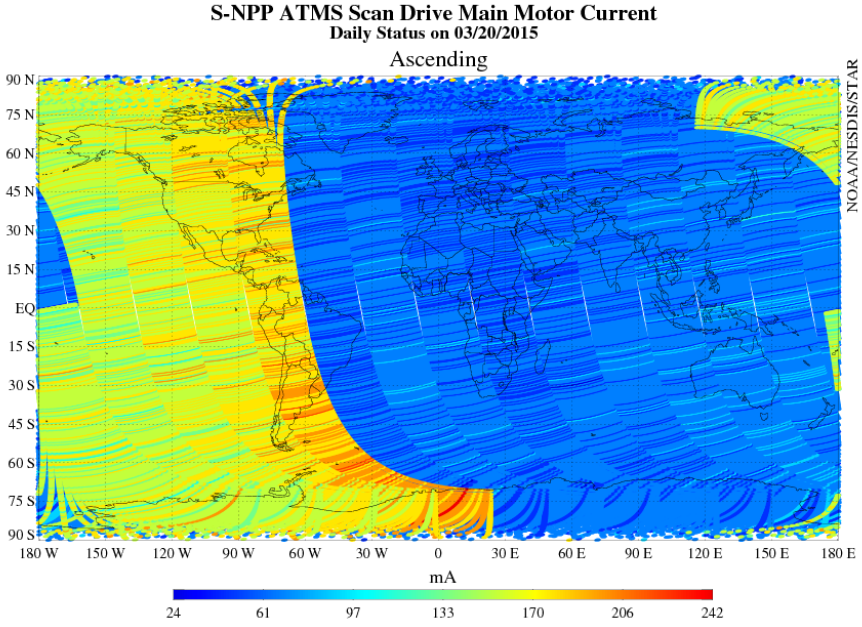
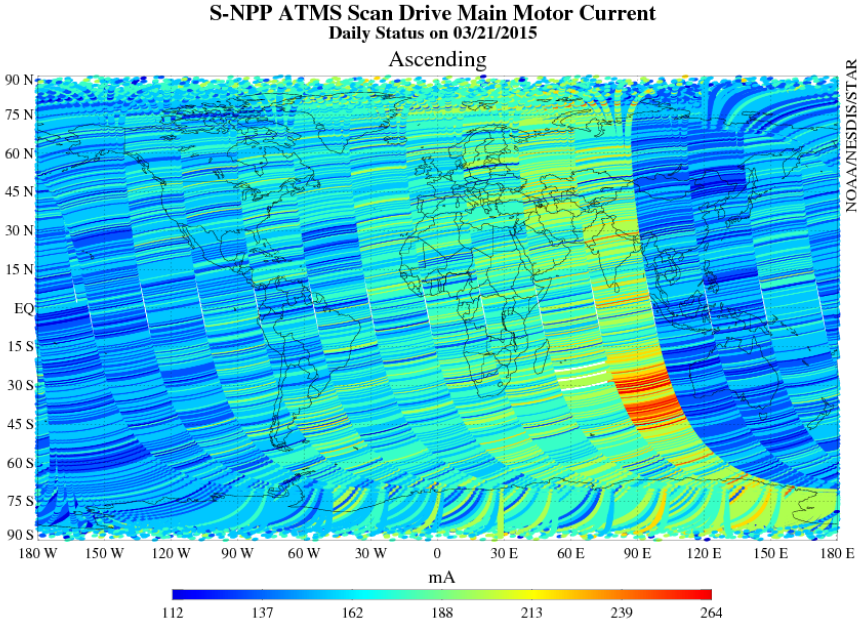
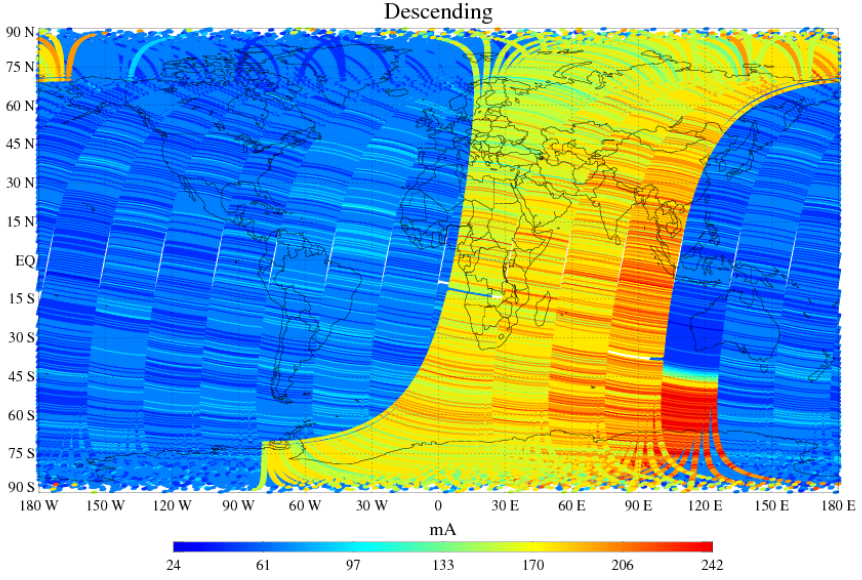
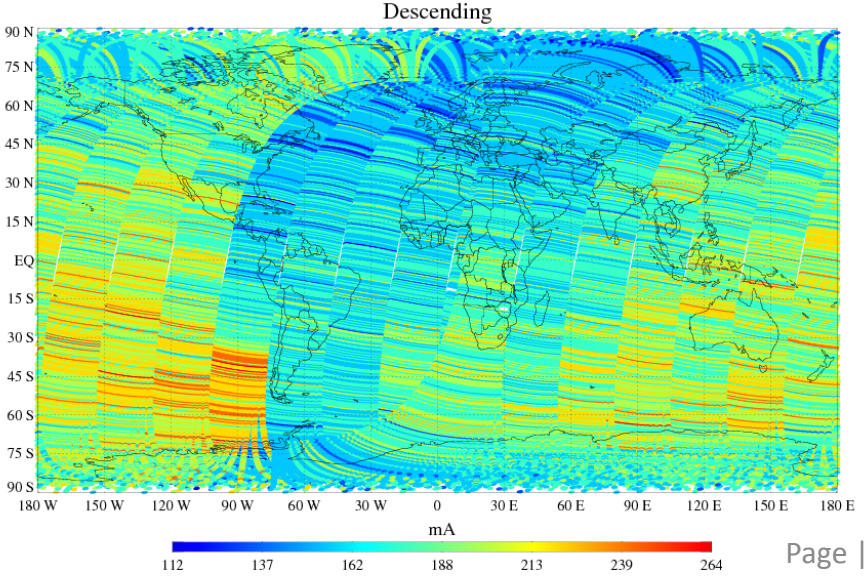
**Starting from Orbit #17583, 17:42:51**

# S-NPP ATMS SD Main Motor Current Global Distribution



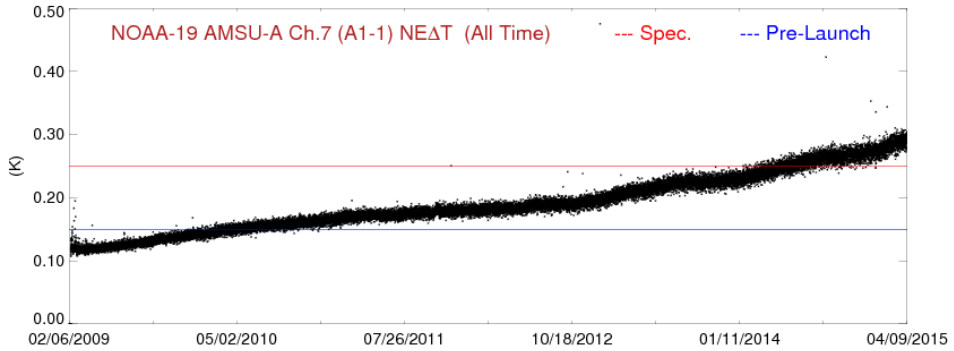



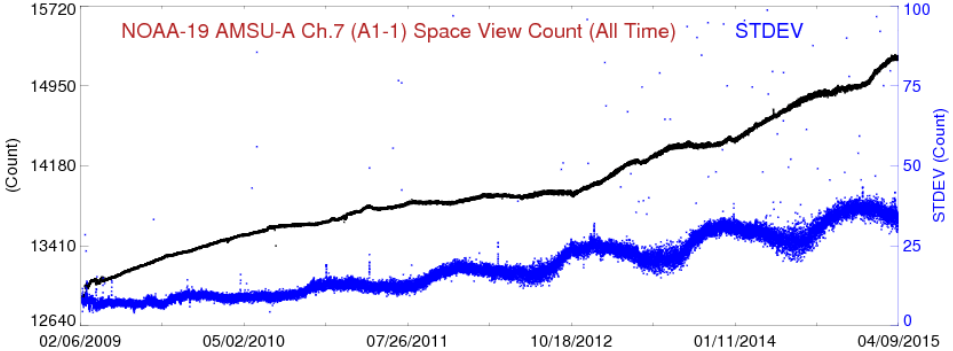
# On-orbit AMSU-A NEΔT

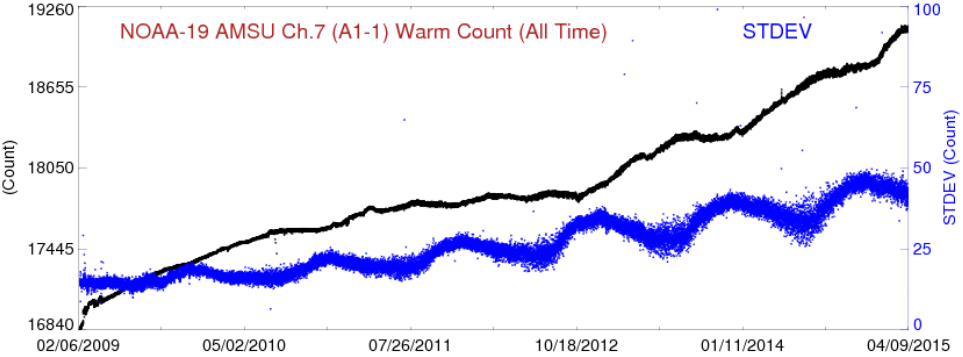
| Ch. | Central Freq. (MHz) | Temperature Sensivity (K) NEΔT Spec. | NOAA-19 On-orbit NEΔT (K) | NOAA-18 On-orbit NEΔT (K) | NOAA-15 On-orbit NEΔT (K) | METOP-B On-orbit NEΔT (K) | METOP-A On-orbit NEΔT (K) |
|---|---|---|---|---|---|---|---|
| 1 | 23800 | 0.30 | 0.13 | 0.15 | 0.13 | 0.13 | 0.12 |
| 2 | 31400 | 0.30 | 0.11 | 0.14 | 0.17 | 0.15 | 0.16 |
| 3 | 50300 | 0.40 | 0.16 | 0.16 | 0.13 | 0.20 | 0.48 |
| 4 | 52800 | 0.25 | 0.09 | 0.13 | 0.09 | 0.12 | 0.11 |
| 5 | 53596±115 | 0.25 | 0.10 | 0.15 | 0.10 | 0.10 | 0.13 |
| 6 | 54400 | 0.25 | 0.09 | 0.09 | 0.08 | 0.10 | 0.09 |
| 7 | 54940 | 0.25 | 0.30 | 0.13 | 0.09 | 0.10 | 200.5 |
| 8 | 55500 | 0.25 | 0.65 | 0.20 | 0.09 | 0.12 | 1.27 |
| 9 | 57290.344 | 0.25 | 0.10 | 0.11 | 0.10 | 0.11 | 0.12 |
| 10 | 57290.344±217 | 0.40 | 0.14 | 0.14 | 0.14 | 0.14 | 0.15 |
| 11 | 57290.344±322.2±48 | 0.40 | 0.15 | 0.16 | 77.8 | 0.17 | 0.18 |
| 12 | 57290.344±322.2±22 | 0.60 | 0.24 | 0.23 | 0.22 | 0.23 | 0.26 |
| 13 | 57290.344±322.2±10 | 0.80 | 0.32 | 0.29 | 0.30 | 0.31 | 0.34 |
| 14 | 57290.344±322.2±4.5 | 1.20 | 0.51 | 0.53 | 75.8 | 0.51 | 0.57 |
| 15 | 89000 | 0.50 | 0.10 | 0.09 | 0.08 | 0.10 | 0.07 |

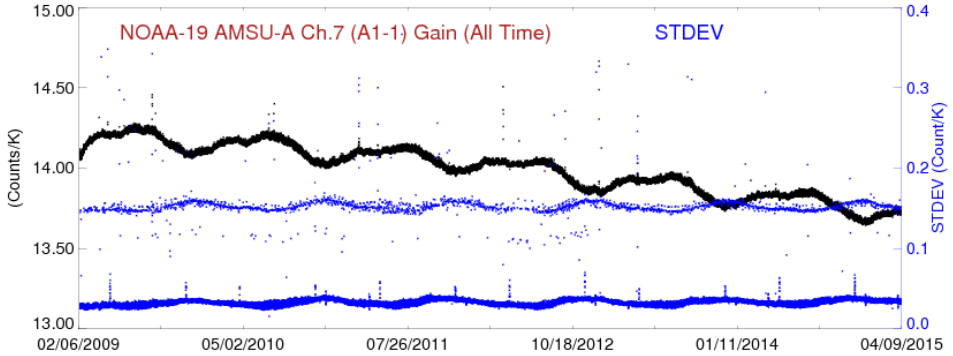
❖ **As of April 6, 2015**

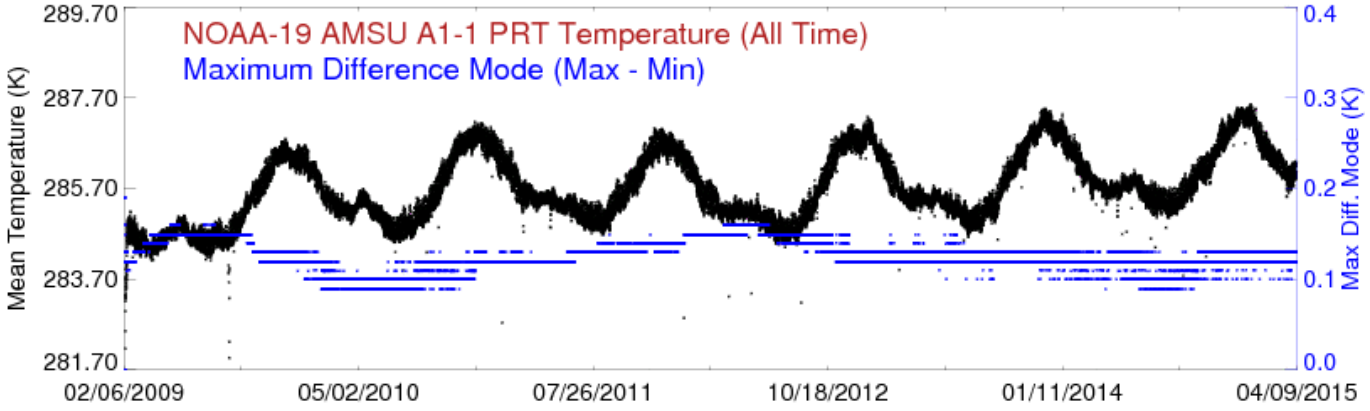
# NOAA-19 AMSU-A Ch. 7 Anomaly Trending



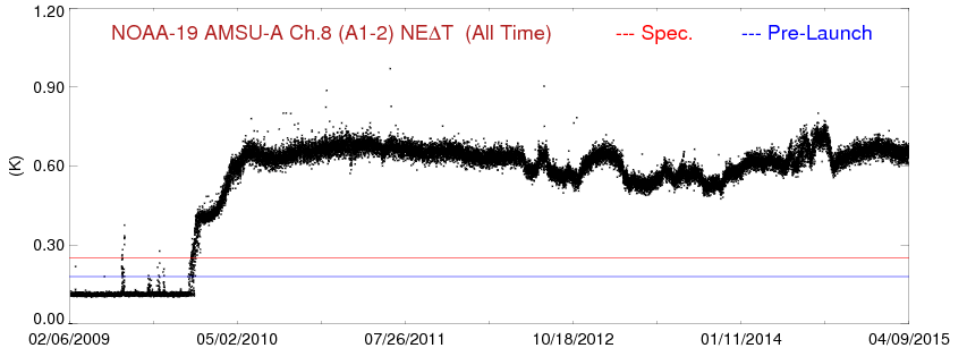



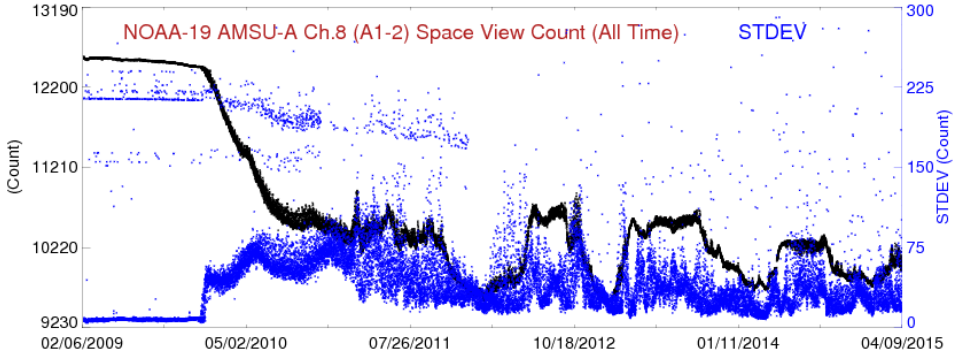



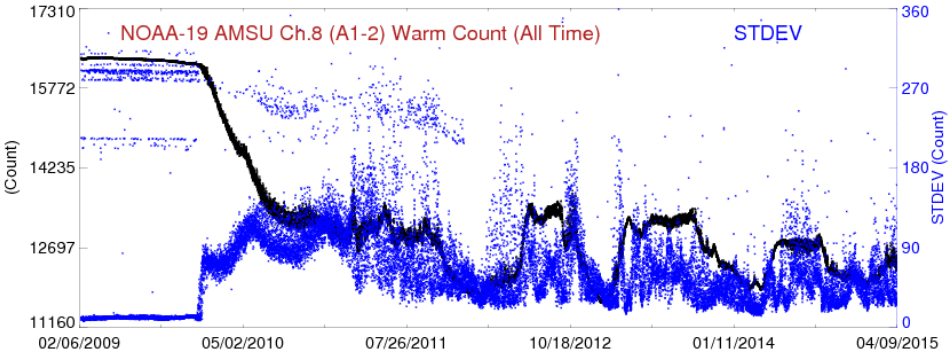



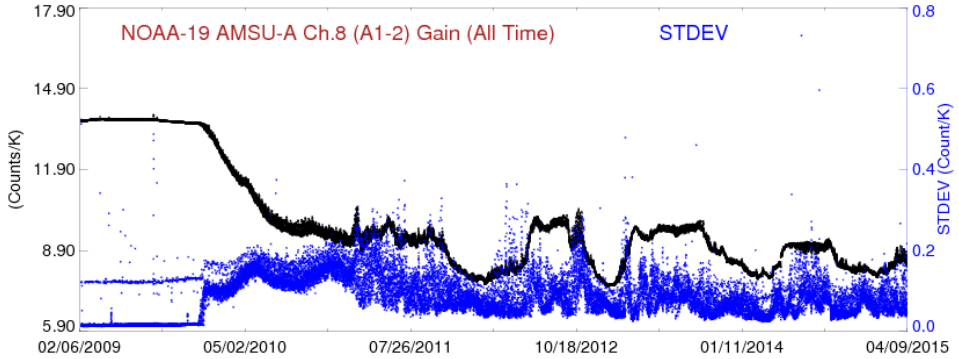



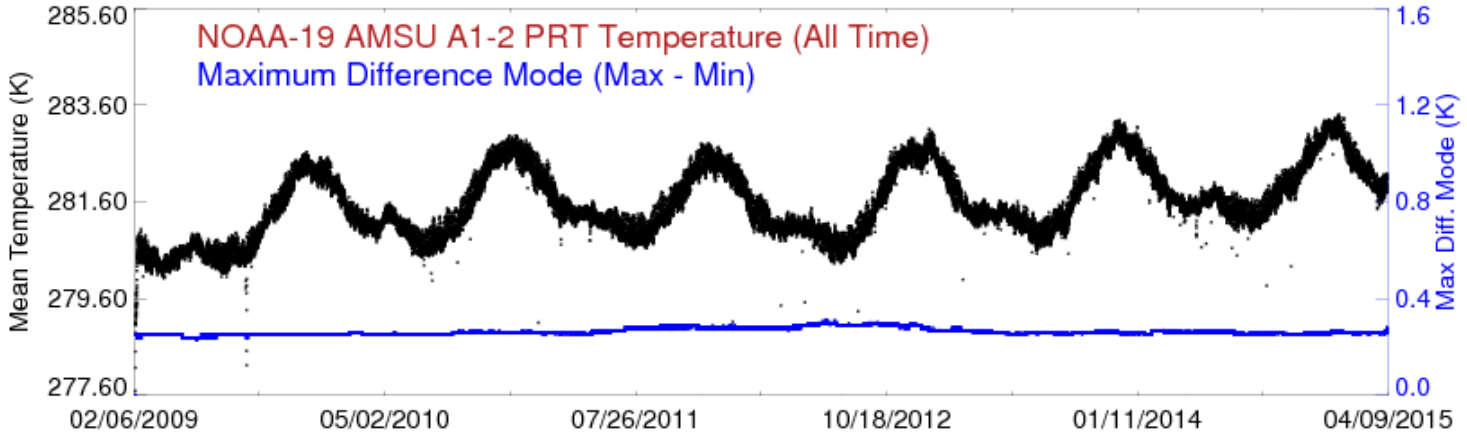
# NOAA-19 AMSU-A Ch. 8 Anomaly Trending



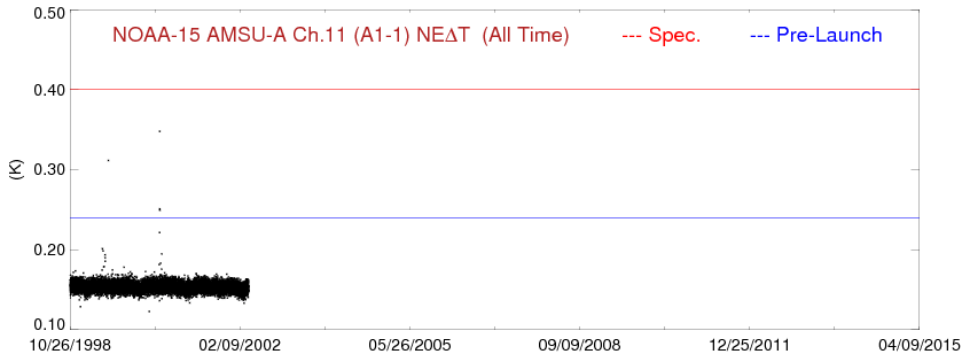



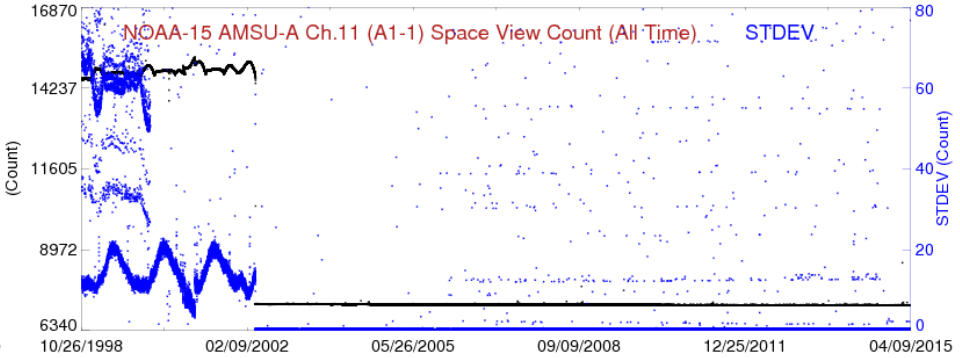



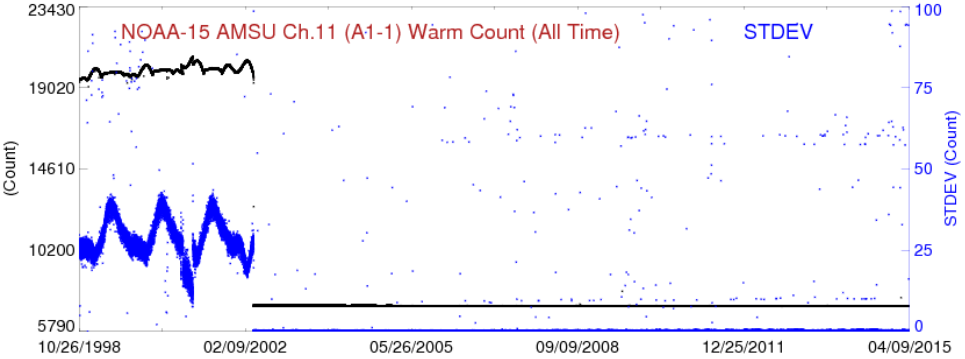



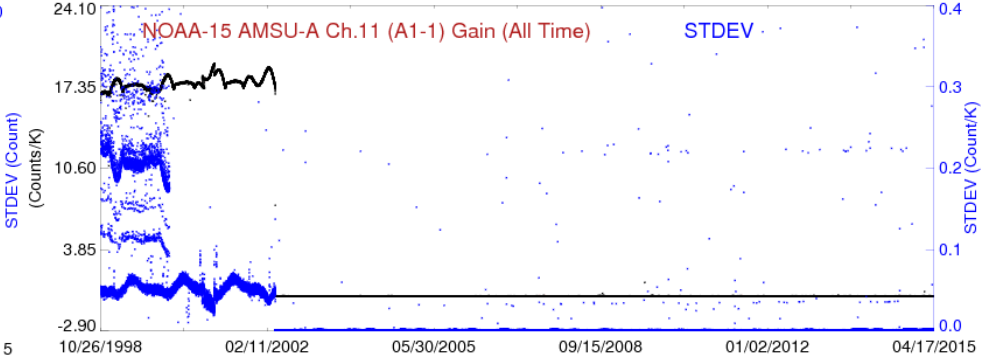



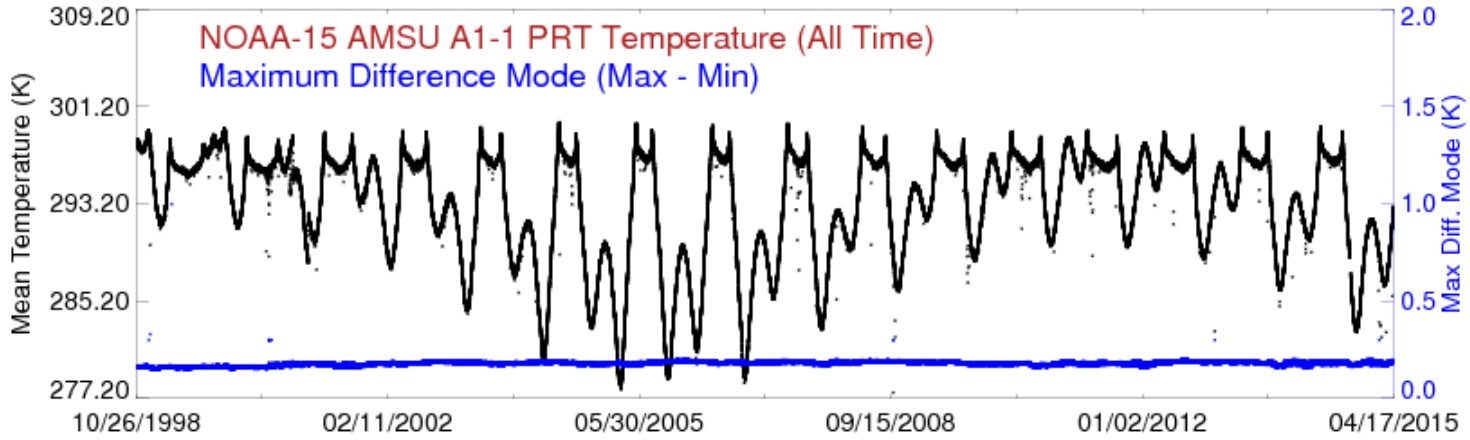
# NOAA-15 AMSU-A Ch. 11 Anomaly Trending



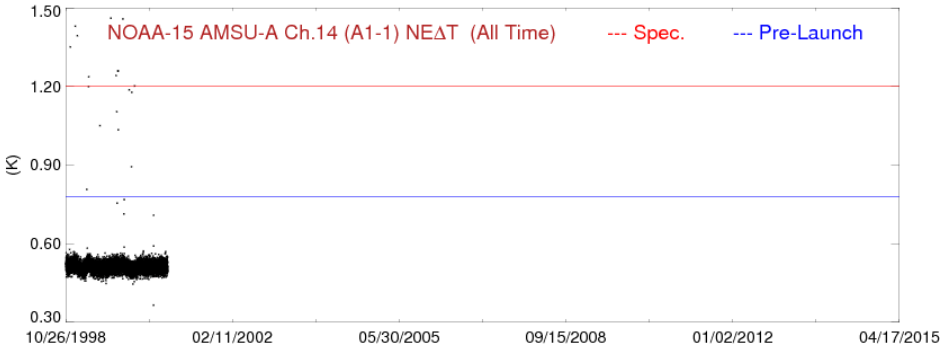



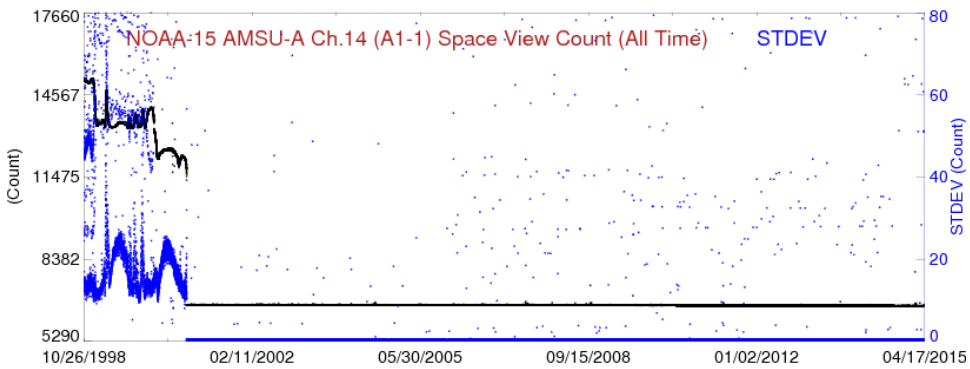



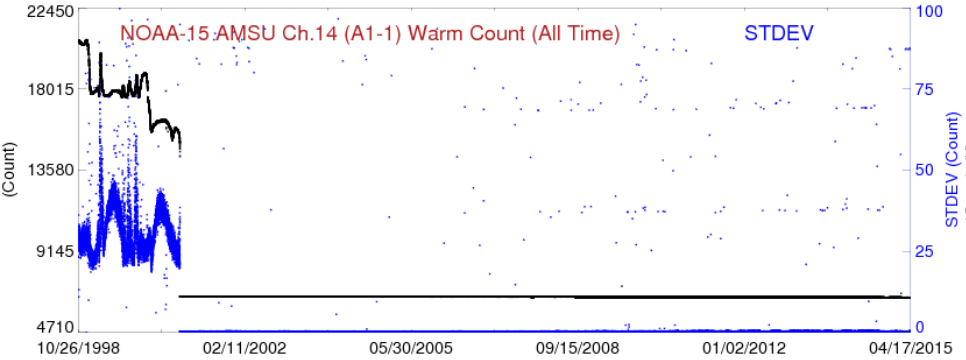



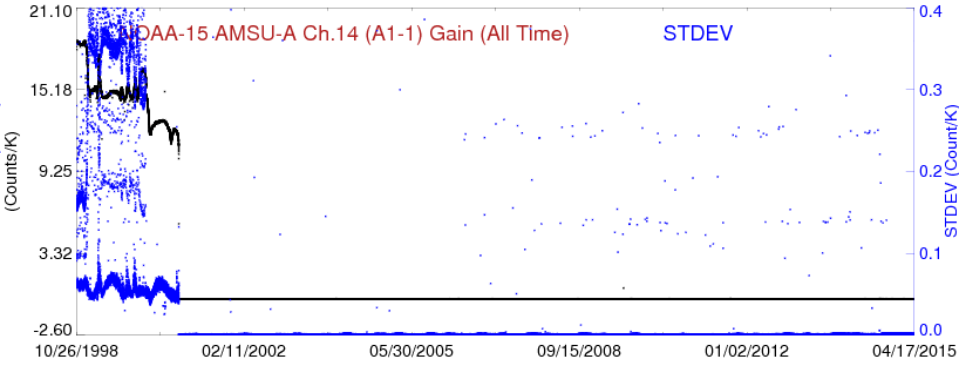



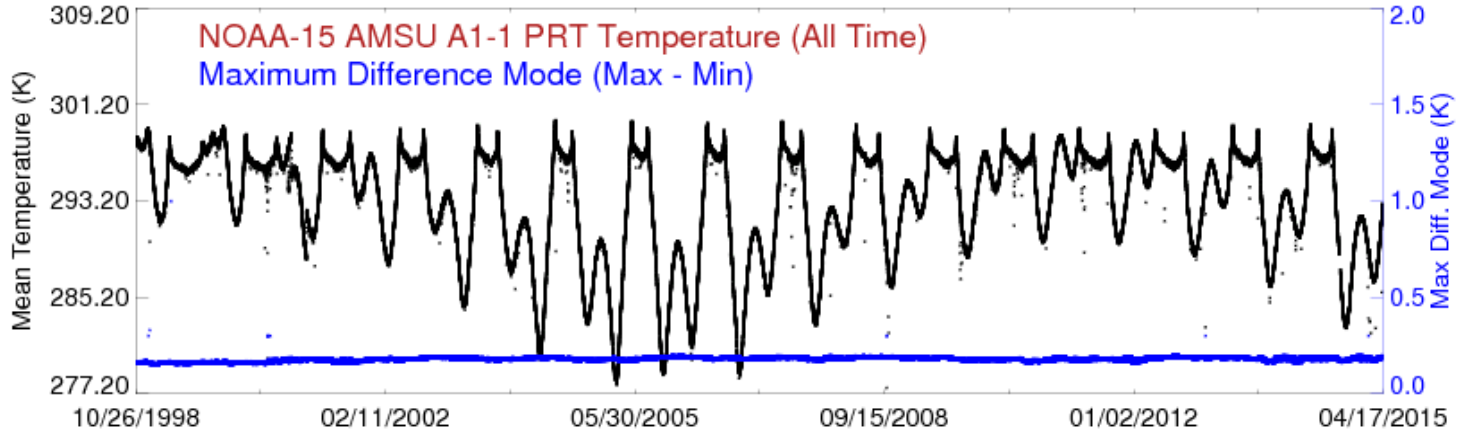
# NOAA-15 AMSU-A Ch. 14 Anomaly Trending



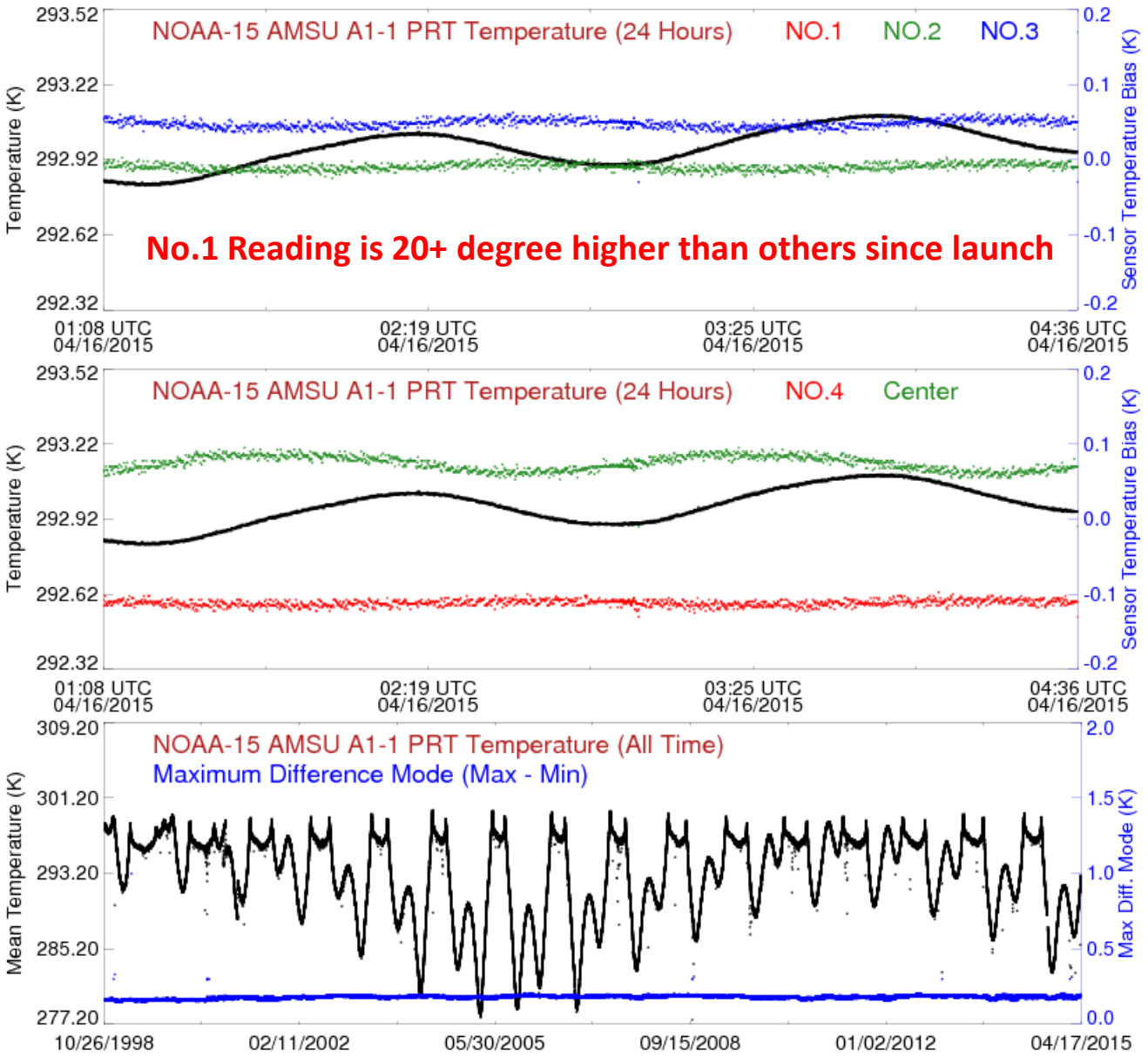



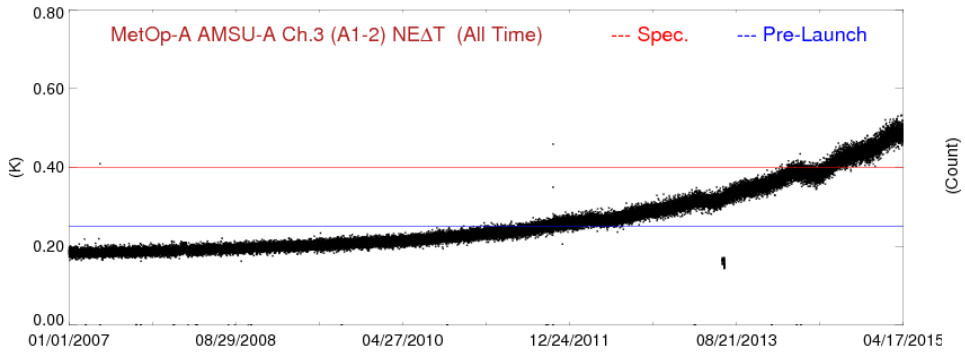



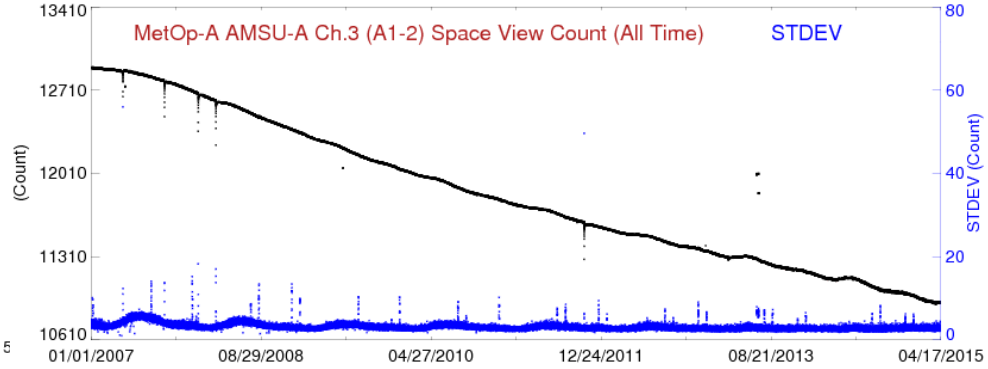



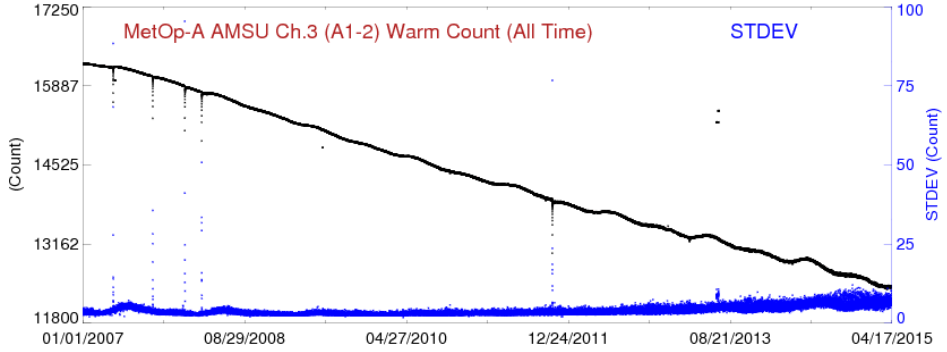
# NOAA-15 AMSU-A A1-1 PRT Temperature

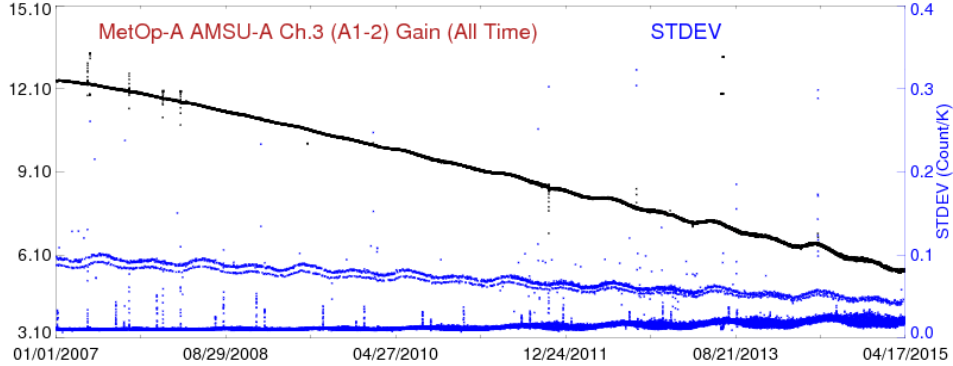


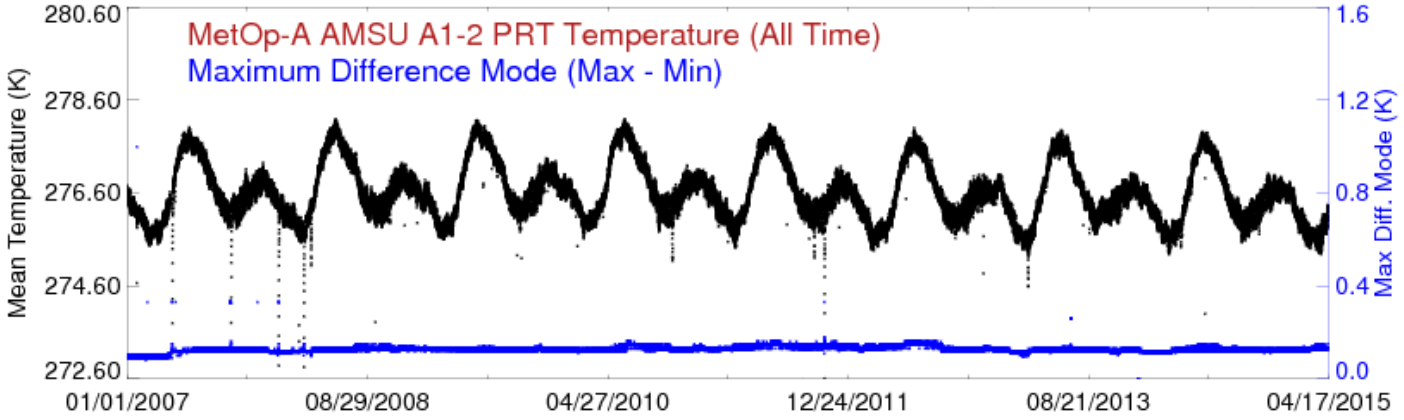
# Metop-A AMSU-A Ch.3 Anomaly Trending



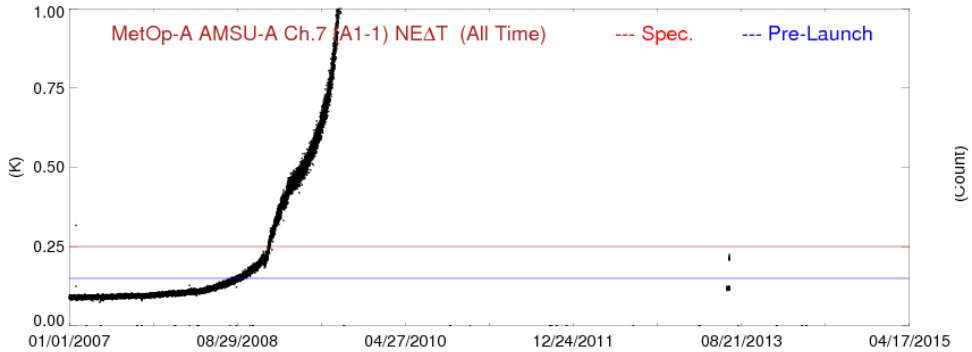



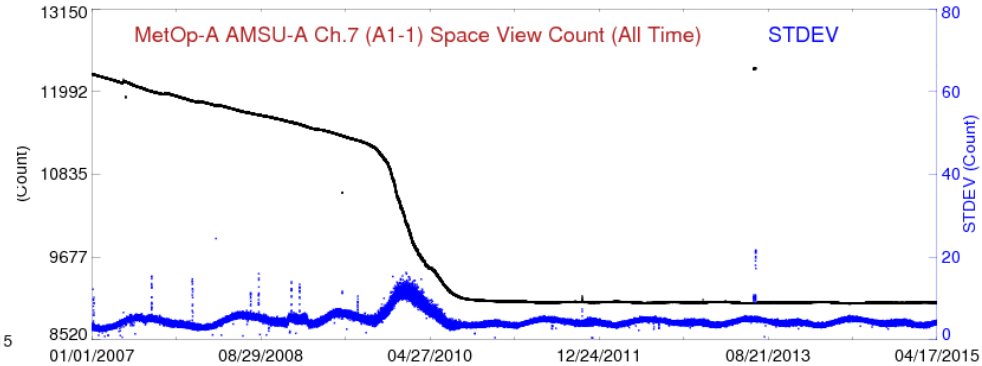



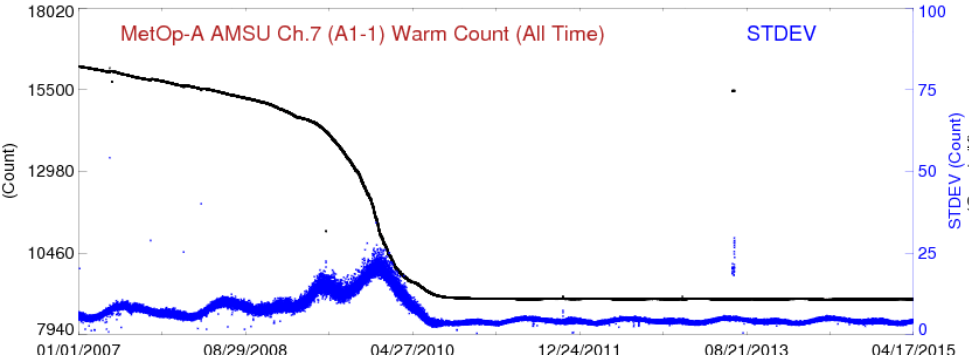



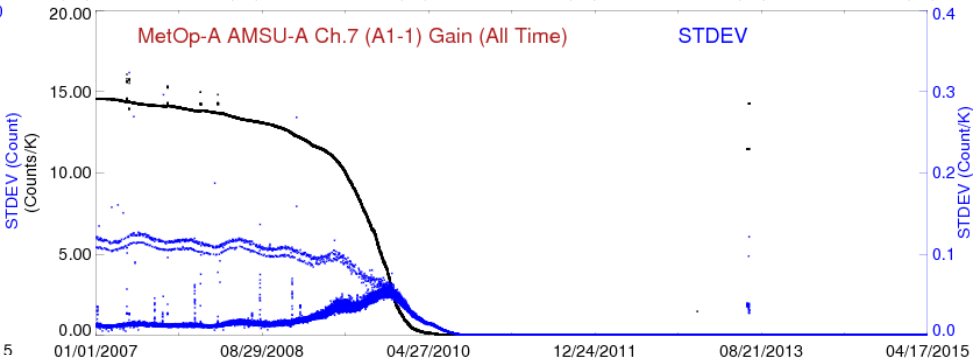



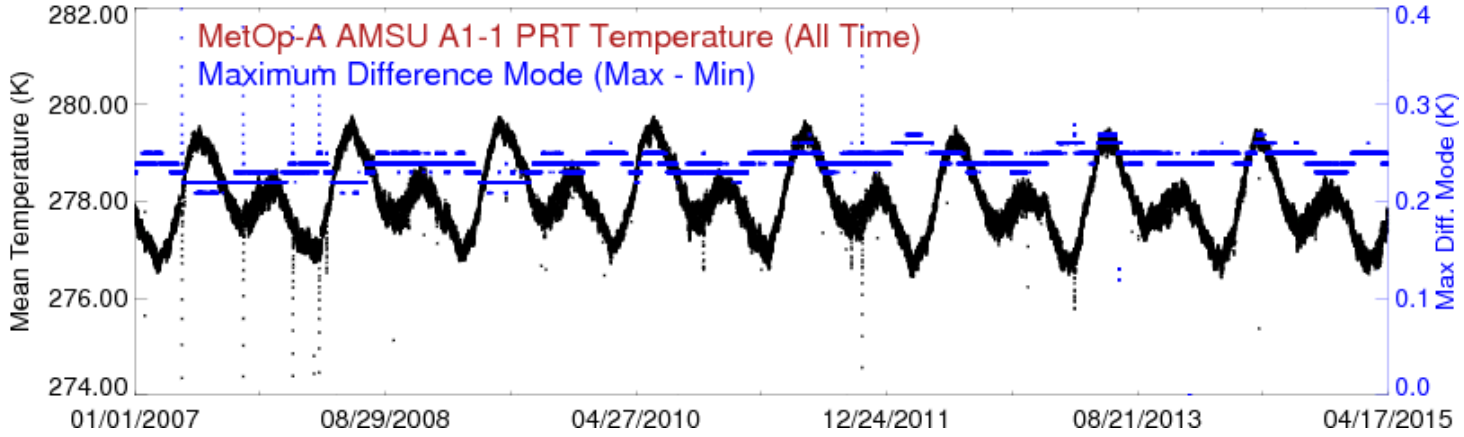
# Metop-A AMSU-A Ch.7 Anomaly Trending



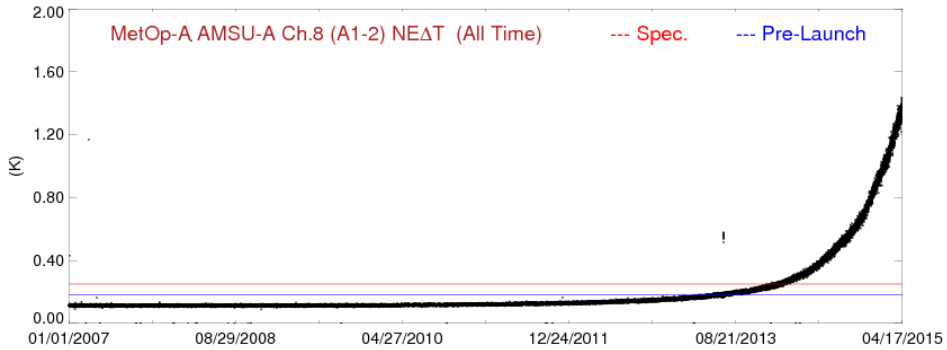



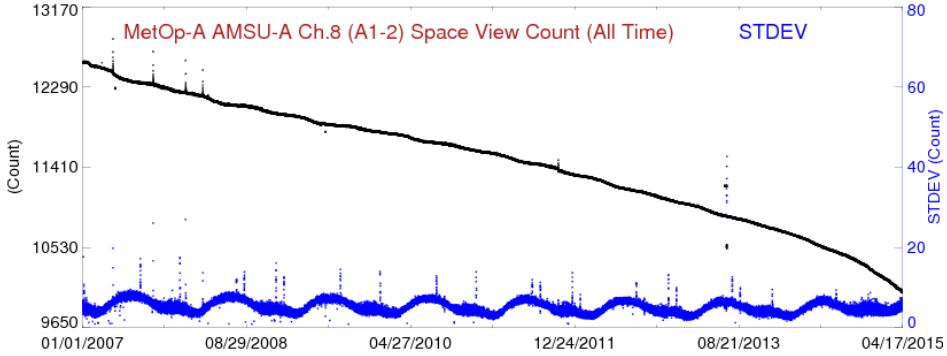



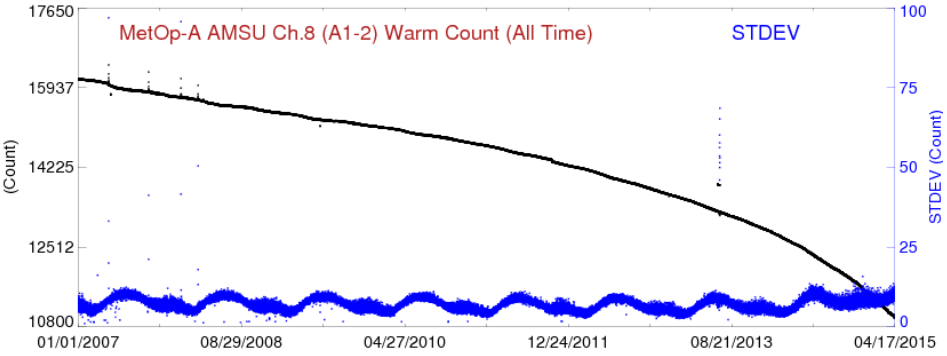



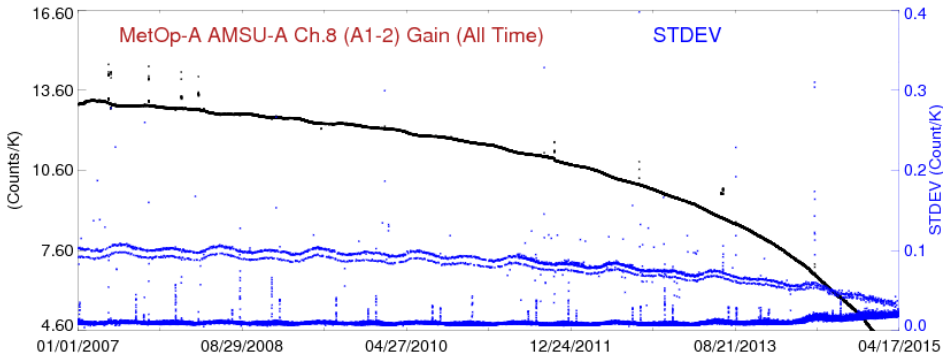



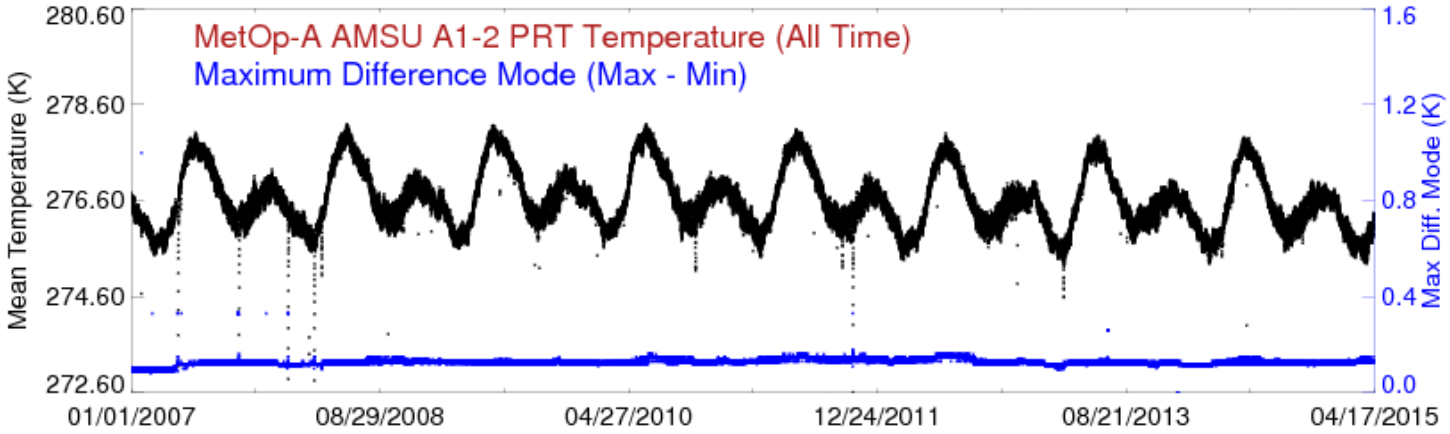
# Metop-A AMSU-A Ch.8 Anomaly Trending



# On-orbit MHS NEΔT

| Ch. | Central Freq. (MHz) | Temperature Sensivity (K) NEΔT Spec. | NOAA-19 On-orbit NEΔT (K) | NOAA-18 On-orbit NEΔT (K) | METOP-B On-orbit NEΔT (K) | METOP-A On-orbit NEΔT (K) |
|---|---|---|---|---|---|---|
| 1 | 89000 | 1.0 | 0.11 | 0.12 | 0.15 | 0.11 |
| 2 | 157000 | 1.0 | 0.27 | 0.27 | 0.29 | 0.24 |
| 3 | 183311±1000 | 1.0 | 2.02 | 0.39 | 0.27 | 0.35 |
| 4 | 183311±3000 | 1.0 | 0.33 | 0.27 | 0.17 | 0.24 |
| 5 | 190311 | 1.0 | 0.17 | 0.25 | 0.19 | 0.25 |

❖ **As of April 6, 2015**

# NOAA-19 MHS Ch.3 Anomaly Trending