



Inrtoduction of STAR Integrated CalVal System (ICVS)

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NOAA Center for Satellite Applications and Research

2015 STAR ICVS Annual Instrument Performance Review, May 8, 2015


NOAA Integrated CalVal System (ICVS)

Monitor on-orbit performance of NOAA satellite instruments

- Monitors over 400 parameters for 28 instruments onboard NOAA/METOP/SNPP satellites
- Monitors and trends the SNPP spacecraft parameters , supporting NASA flight team
- Monitors the instrument performance through trending the instrument house-keeping and telemetry parameters
- Detects the anomaly events and automatically sends the warning messages to NOAA satellite operators, NASA instrument scientists, and senior program managers
- Characterizes the sounder SDR data quality with respect to the numerical weather prediction model (NWP) simulations
- Integrates the state-of-the art CalVal sciences into operations to serve the broad applications

NOAA Integrated CalVal System (ICVS) Online

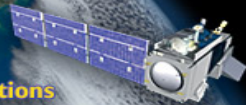
Access: <http://www.star.nesdis.noaa.gov/icvs>



STAR ICVS

Integrated Calibration / Validation System
Long-Term Monitoring

Monitoring and characterizing satellite instrument performance in orbit for weather, climate and environmental applications



STAR ICVS Long-Term Monitoring

Displaying the last 24 hours of instrument status, updated every three hours.

03/31/2015
18:33 UTC

[About the Suomi NPP VIIRS instrument](#)
Instrument Status > NPP > VIIRS

[Slide Show of All Charts for Selected Date](#)

Instrument Performance Monitoring

- Suomi NPP
 - Spacecraft
 - ATMS
 - CrIS
 - CrIS FSR
 - VIIRS >>**
 - OMPS Nadir Mapper
 - OMPS Nadir Profiler
 - OMPS Limb Profiler
- MetOp-B
 - AMSU-A
 - MHS
 - AVHRR
 - HIRS
- NOAA-19
 - AMSU-A
 - MHS
 - AVHRR
 - HIRS
- MetOp-A
 - AMSU-A
 - MHS
 - AVHRR
 - HIRS
- NOAA-18
 - AMSU-A
 - MHS
 - AVHRR
 - HIRS
- NOAA-15
 - AMSU-A

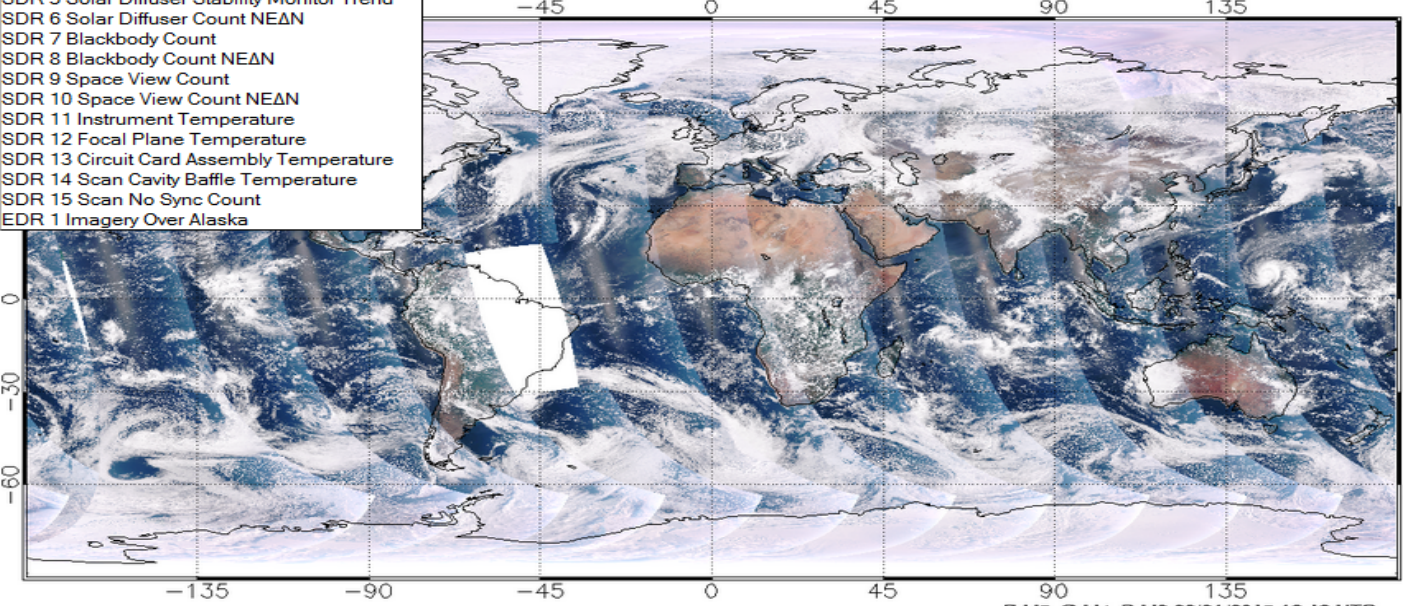
Select a parameter:

- VIIRS Global Image
- VIIRS Global Image
- VIIRS Single Band Image
- VIIRS Overall SDR Quality
- SDR 1 F or H Factor
- SDR 2 Health and Status
- SDR 3 Solar Diffuser Count by Band**
- SDR 4 Solar Diffuser Count by Detector
- SDR 5 Solar Diffuser Stability Monitor Trend
- SDR 6 Solar Diffuser Count NEΔN
- SDR 7 Blackbody Count
- SDR 8 Blackbody Count NEΔN
- SDR 9 Space View Count
- SDR 10 Space View Count NEΔN
- SDR 11 Instrument Temperature
- SDR 12 Focal Plane Temperature
- SDR 13 Circuit Card Assembly Temperature
- SDR 14 Scan Cavity Baffle Temperature
- SDR 15 Scan No Sync Count
- EDR 1 Imagery Over Alaska

VIIRS Global Image

Global True Color Image

Select a Date: 03-31-2015

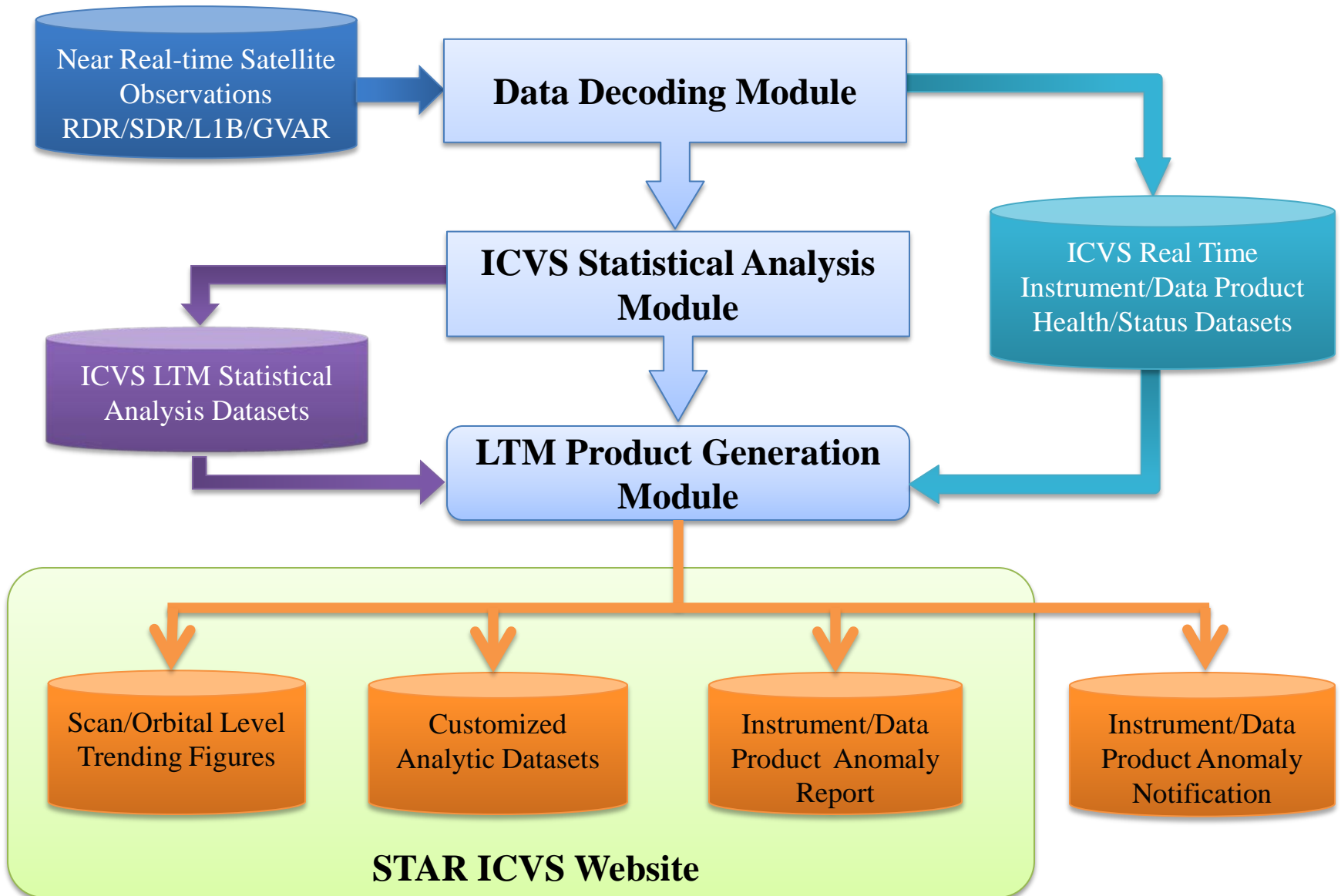


NPP VIIRS - Global True Color Image

R:M5, G:M4, B:M3 03/31/2015-13:18 UTC

3

NOAA ICVS Data Processing Flowchart



Impacts of ICVS NEDT on NWP Users

Weights Assigned to AMSU-A Observations

$$J(\mathbf{x}) = \frac{1}{2}(\mathbf{x} - \mathbf{x}_b)^T \mathbf{B}^{-1}(\mathbf{x} - \mathbf{x}_b) + \frac{1}{2}(H(\mathbf{x}) - \mathbf{y}^{obs})^T (\mathbf{O} + \mathbf{F})^{-1}(H(\mathbf{x}) - \mathbf{y}^{obs})$$

$$J(\mathbf{x}_a) = \min_{\mathbf{x}} J(\mathbf{x}) \quad \forall \mathbf{x} \text{ near } \mathbf{x}_b$$

\mathbf{x} – analysis variable

\mathbf{x}_a – final analysis

\mathbf{x}_b – background

\mathbf{B} – background error covariance

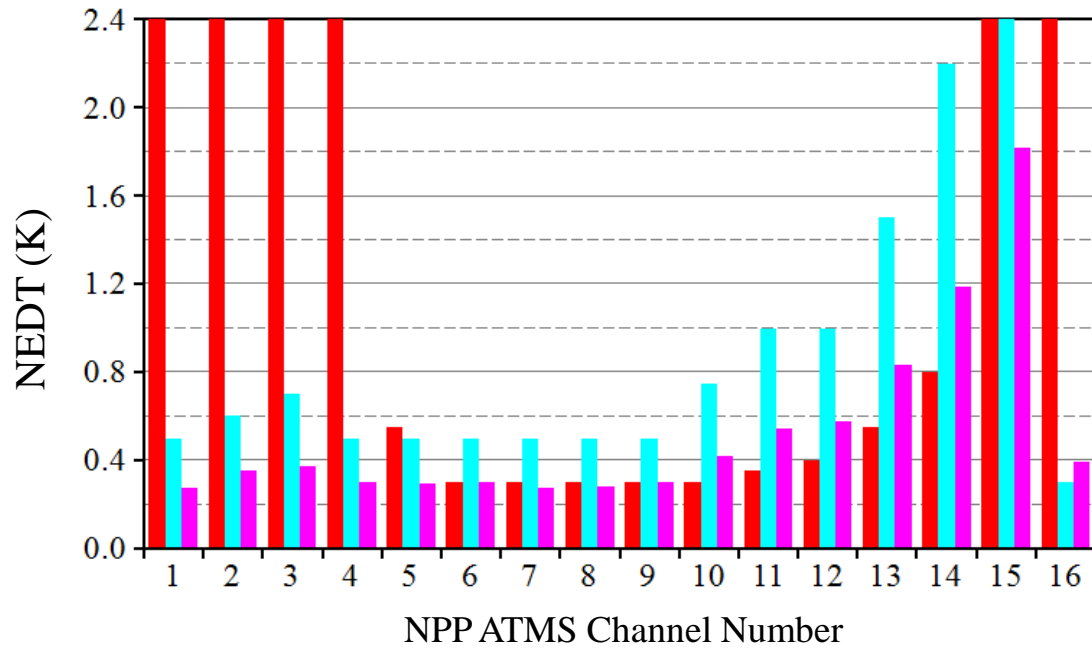
\mathbf{y}^{obs} – observations

\mathbf{O} – observation error covariance

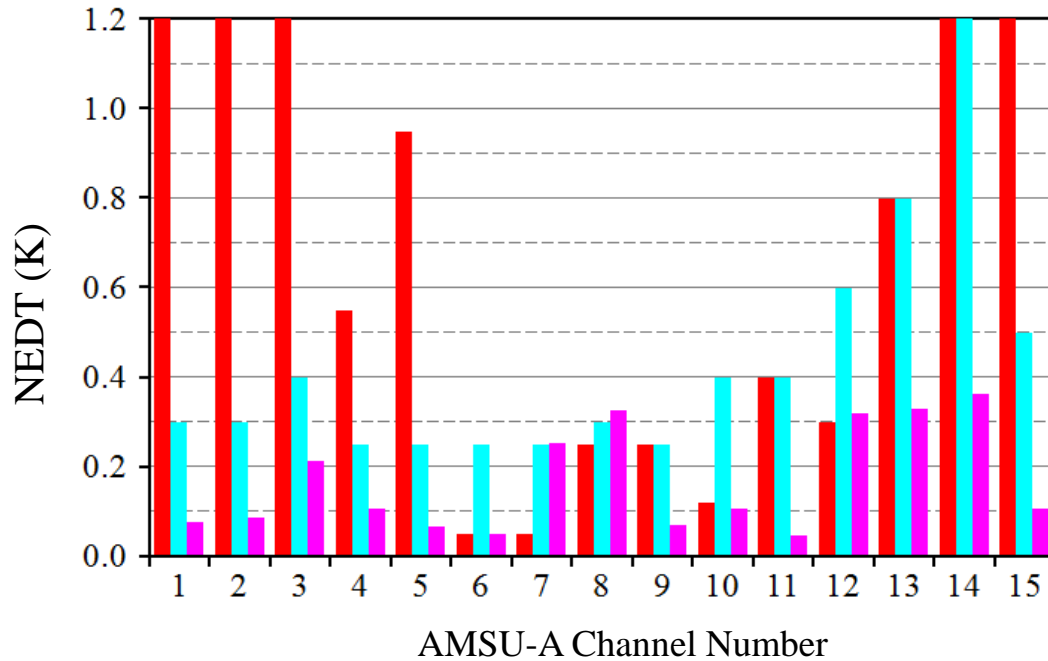
H – observation operator

\mathbf{F} – forward model error covariance

ATMS and AMSU-A Observation Errors



- GSI input
- NEDT
- Spec



Impacts of ICVS NEDT on Climate Analysis

The uncertainty of the trend is

$$\sigma_a^2 = \frac{12(\sigma_o^2 + \sigma_n^2)}{M^3 - M}$$

where:

- M ————— Data length
- σ_o^2 ————— Observation error
- σ_n^2 ————— Natural variability

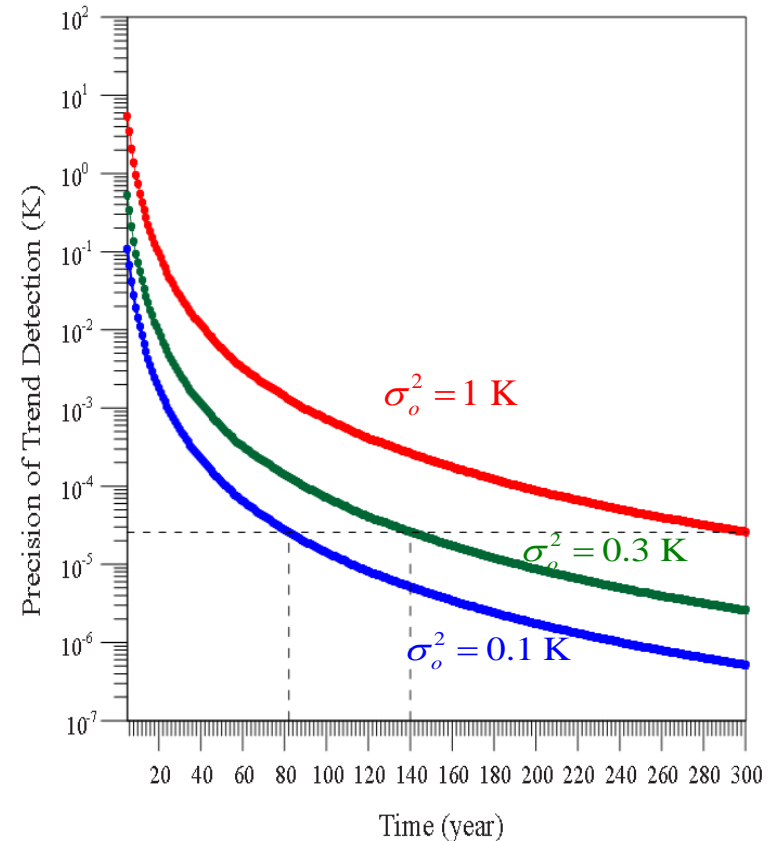


Fig. 2 Variations of σ_{trend} with respect to data length for the trends shown in Fig. 1

ICVS Noise Trending is Now SI Traceable Though Using Allan Deviation

- Allan Deviation was proposed by NIST for characterizing the random noise from a time series which has a variable mean
- It was never implemented for meteorological satellite instruments . Currently, all the NOAA instrument noises are computed by the standard deviation which is only valid for the stationary mean.
- With Allan deviation, all the NEDT and NEDN are SI traceable

D. W. Allan, Should the classical variance be used as a basic measure in standards metrology Instrumentation and Measurement, IEEE Trans. on, IM-36, pp.646-654, 1987

Summary

- NOAA ICVS is critical for earlier detection of instrument anomalies and provides the critical information for the root-cause analysis
- NOAA ICVS monitors the instrument noises and biases that are being used by broader users including NWP communities
- NOAA ICVS is designed with the modern software architecture and meets the enterprise standard
- NOAA ICVS is becoming a gold standard for all the space agencies and is recommended as part of the NOAA common ground system

Backup slides

ICVS Instruments Status Summary

JPSS	S-NPP PM Primary 10-28-2011 ~ 3 yr	POES	MetOp-B AM Primary 09-17-2012 ~ 2 yr	NOAA-19 PM Primary 06-02-2009 ~ 5 yr	MetOp-A AM Backup 10-19-2006 ~ 8 yr	NOAA-18 PM Backup 05-20-2005 ~ 9 yr
ATMS	SD Main Motor Current	AMSU-A1	A1-2 PRT Dispersion	Ch. 7, 8 NEΔT	Ch. 3, 7, 8 NEΔT	
CrIS		AMSU-A2				Ch1, 2 NEΔT
VIIRS		MHS		H3 NEΔT		
OMPS		AVHRR				Ch. 1 SNR
		HIRS		Ch. 1, 2, 4, 5, 6, 7, 10, 14 NEΔN Ch.20 NEΔa		Ch. 2, 4, 5, 6, 7, 9, 10, 19 NEΔN

■ Nominal Condition
 ■ Performance Degraded
 ■ Anomaly Detected/Investigation On-going

ICVS Summary of SNPP Instruments

- **SNPP Spacecraft status**
 - Health and status – **Nominal condition**
 - Instrument health and status – **Nominal**
- **SNPP ATMS status**
 - Instrument sensitivity (NE Δ T) – **Nominal**
 - Instrument health and status – **SD Main Motor Current Anomaly Detected**
 - TDR data product quality – **Nominal**
- **SNPP VIIRS status**
 - Instrument performance (F-/H-factor) – **Major update applied**
 - Instrument health and status – **Nominal**
 - SDR data product quality – **Nominal**
- **SNPP CrIS status**
 - Instrument performance (NE Δ N) – **Nominal**
 - Instrument sensor health and status – **Nominal**
 - SDR data product quality – **Nominal**
- **SNPP OMPS status**
 - Instrument performance – **Nominal**
 - Nadir Mapper (NM) health and status – **Nominal**
 - Nadir Profiler (NP) health and status – **Nominal**
 - Limb Profiler (LP) health and status – **Nominal**

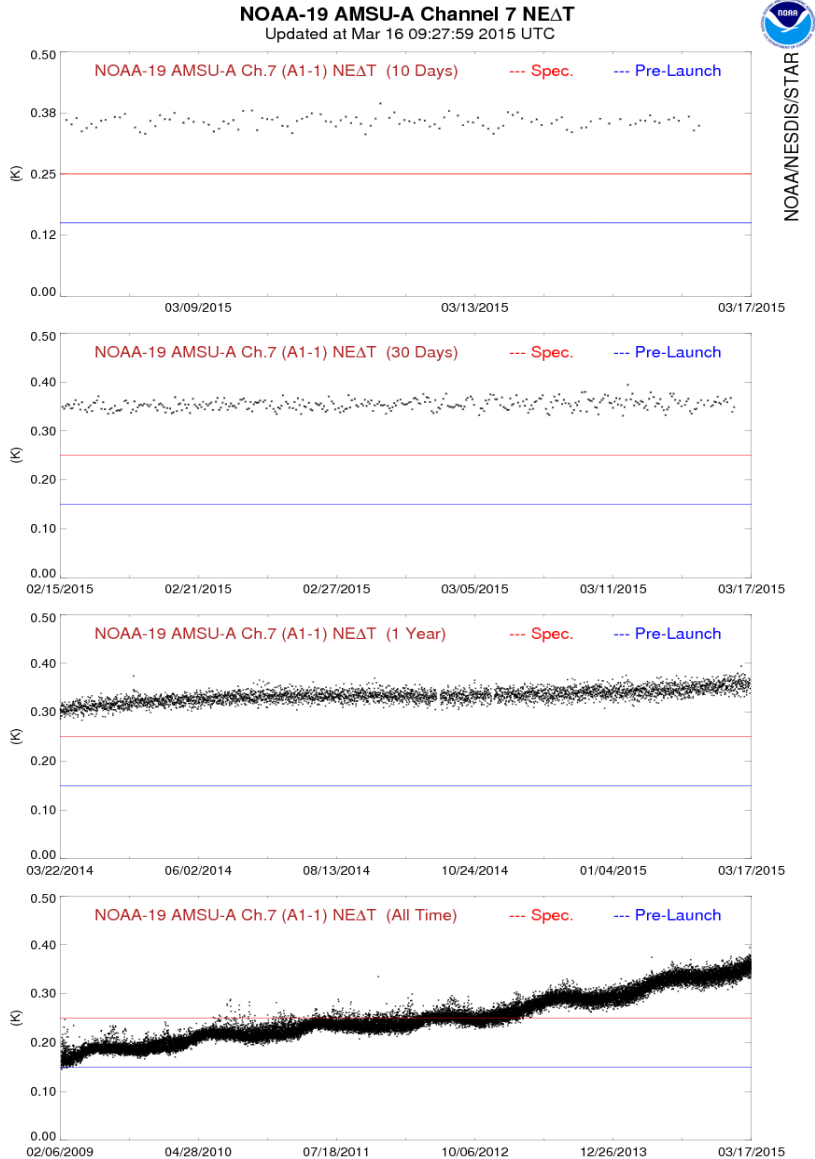
ICVS Summary of NOAA/METOP Instruments

- **POES AMSU/MHS status**
 - MetOp-B AMSU/MHS
 - AMSU NE Δ T within specification
 - AMSU PRT maximum dispersion is higher than specification – ongoing investigation
 - MHS NE Δ T within specification
 - NOAA-19 AMSU/MHS
 - AMSU Ch.7 and Ch.8 NE Δ T out of specification, Ch.8 Gain jump
 - MHS H3 NE Δ T out of specification
 - MetOp-A AMSU/MHS
 - AMSU Ch.3 and Ch. 8 NE Δ T out of specification, Ch.7 is fail
 - NOAA-18 AMSU/MHS
 - AMSU-A Channel 1 and 2 NE Δ T out of specification
 - MHS NE Δ T within specification
- **POES AVHRR status**
 - MetOP-B AVHRR in normal condition
 - NOAA-19 AVHRR in normal condition
 - MetOP-A AVHRR in normal condition
 - NOAA-18 AVHRR
 - Ch. 1 SNR slightly out of specification
- **POES HIRS status**
 - MetOP-B HIRS
 - NE Δ N within specification
 - NOAA-19 HIRS
 - Ch. 1, 2, 4, 5, 6, 7, 10, and 14 calibration target out of limits
 - MetOp-A HIRS
 - NE Δ N within specification
 - NOAA-18 HIRS
 - Ch. 2, 4, 5, 6, 7, 9, and 10 NE Δ N out of specification

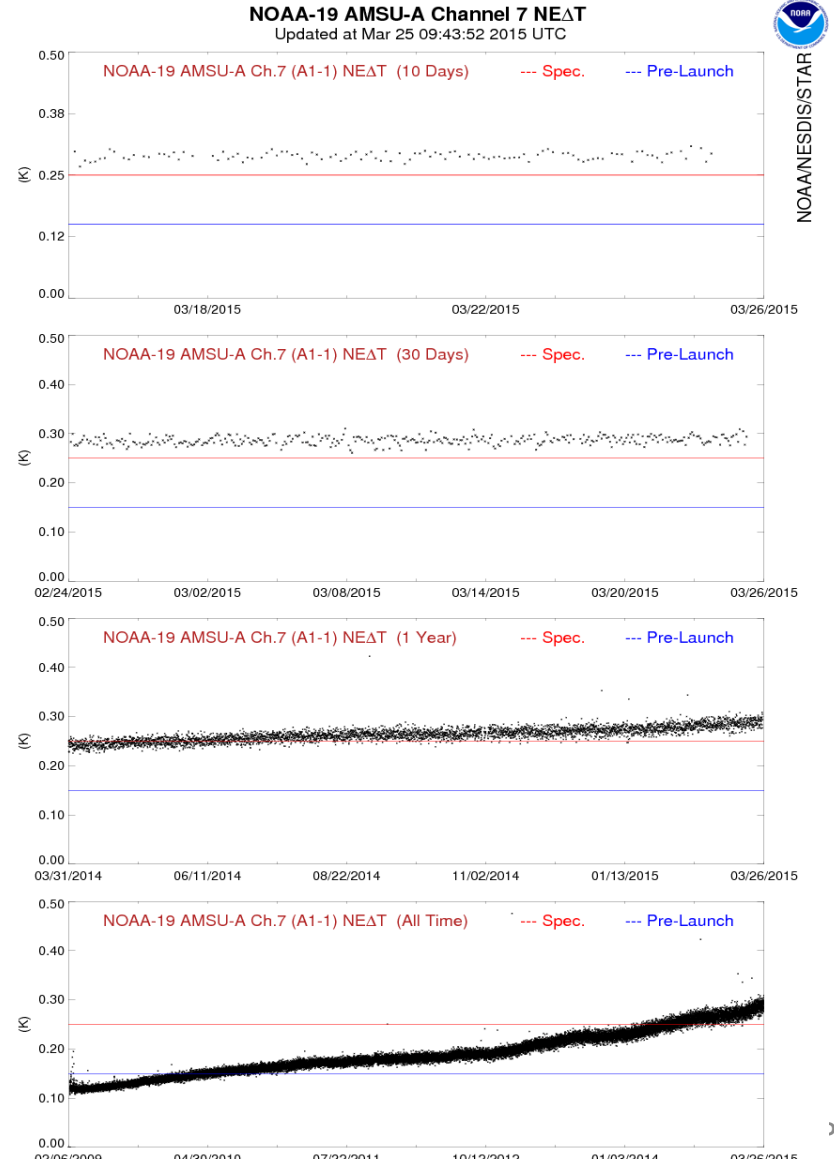
Comparison of Traditional NEDT vs Allan Deviation

NOAA-19 AMSU-A Ch.7 (54.9 GHz)

Standard Deviation



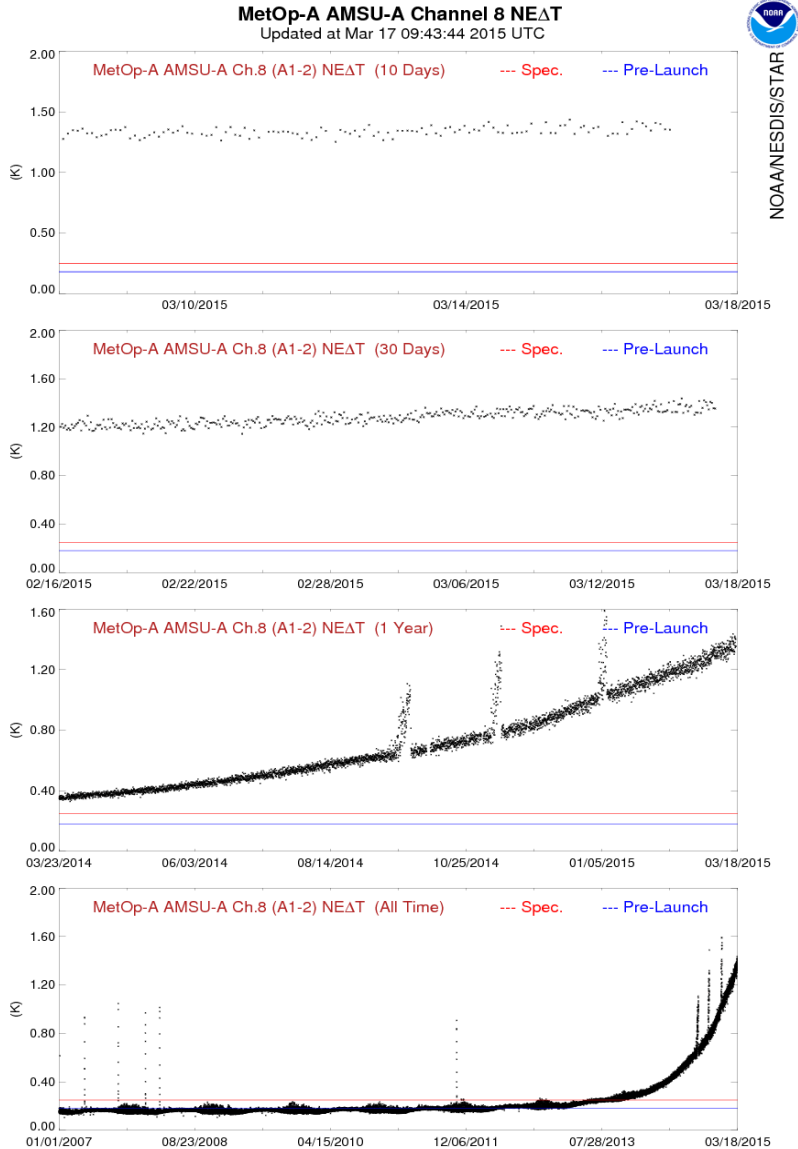
Allan Deviation



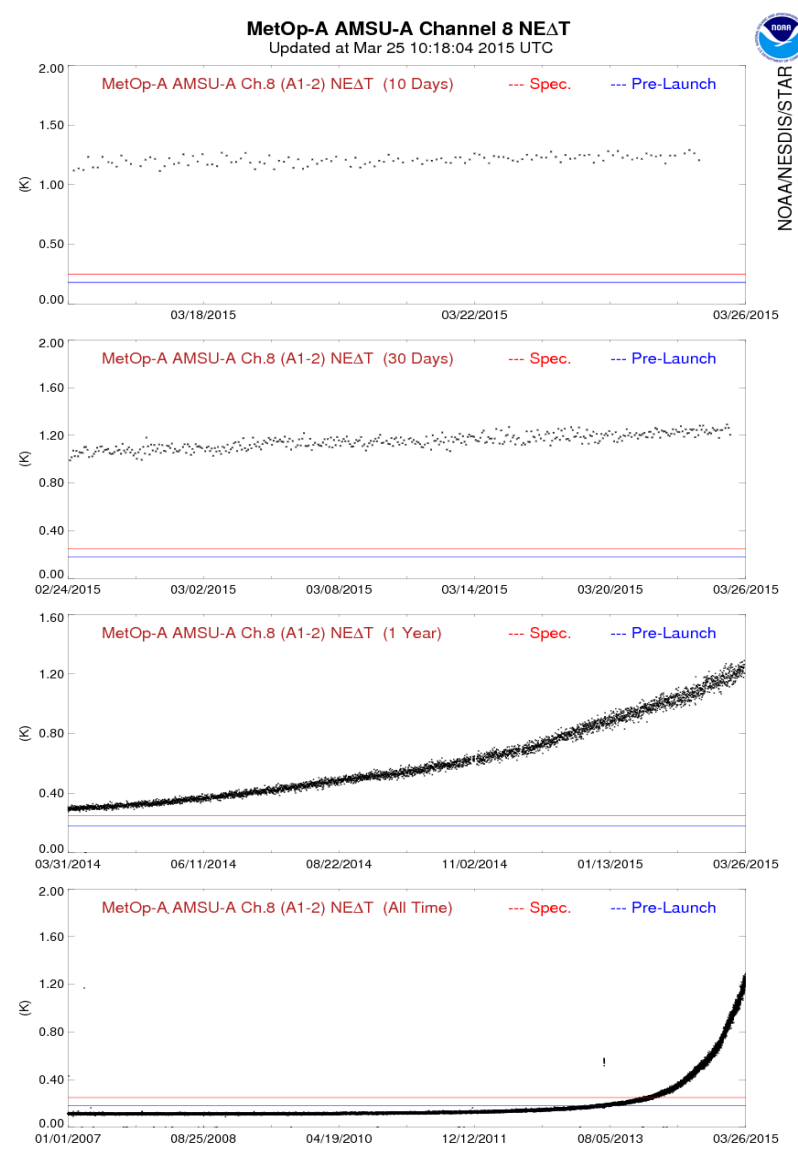
Comparison of Traditional NEDT vs Allan Deviation

MetOp-A AMSU-A Ch.8 (55.5 GHz)

Standard Deviation



Allan Deviation



Monitor NOAA-15 AMSU-A NEDT

A Long-Lived Microwave Sounder still Used in NOAA operation

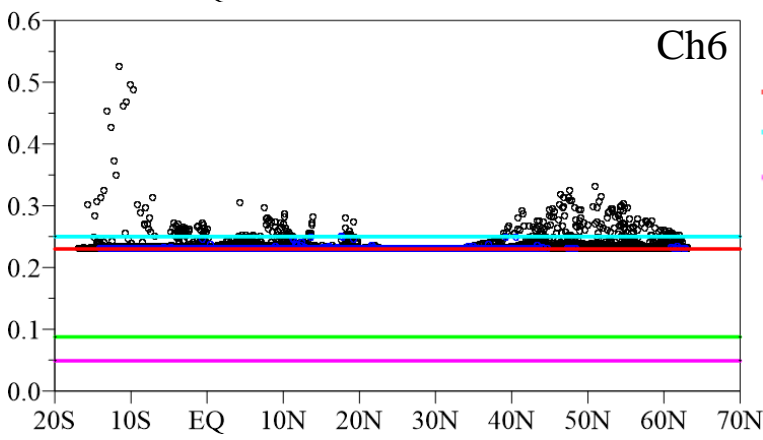
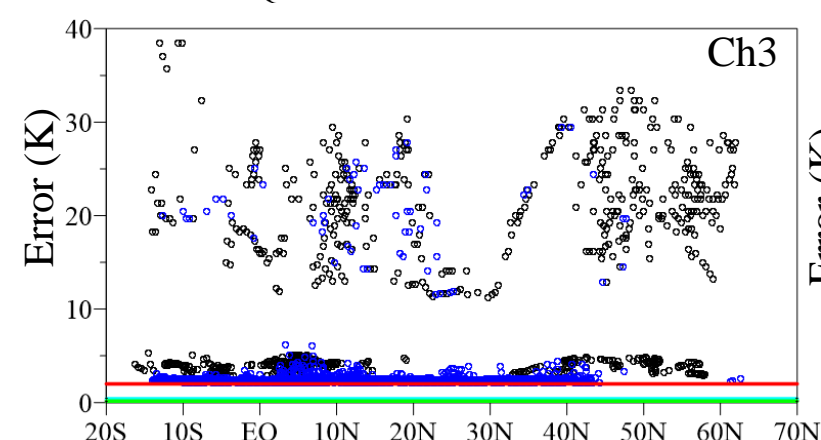
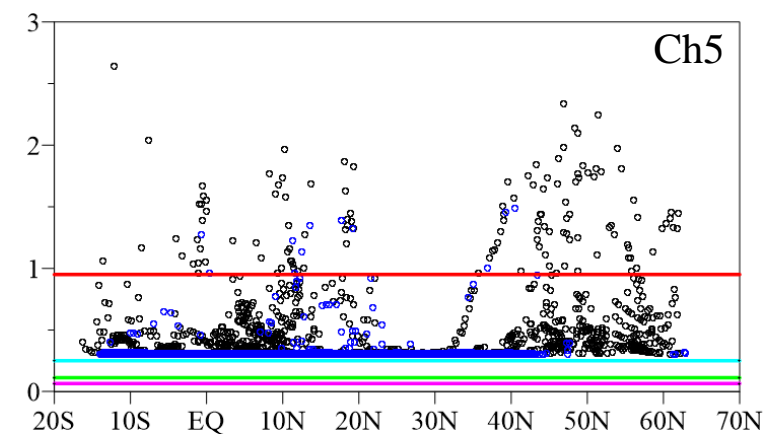
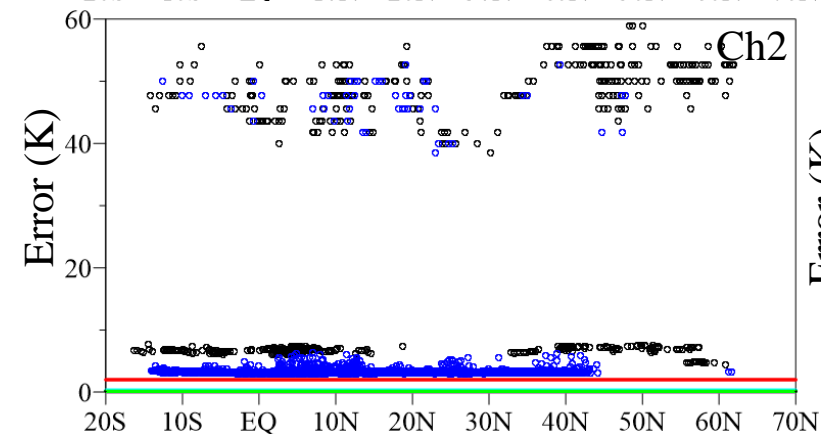
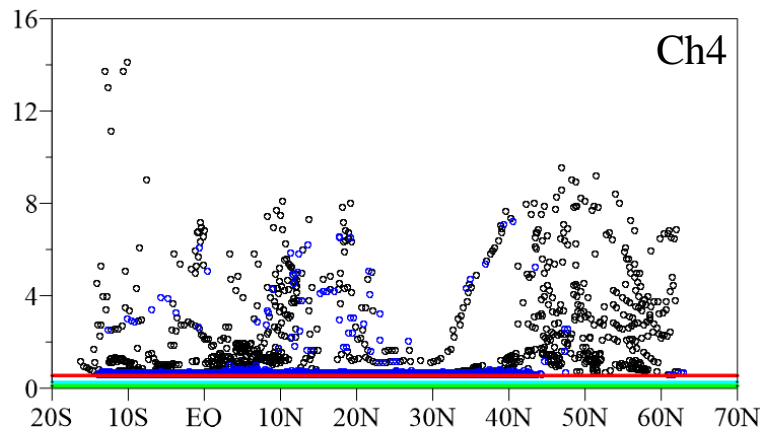
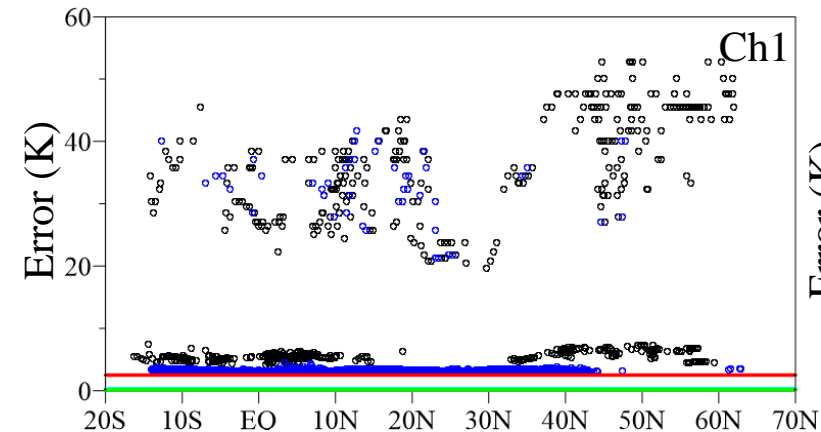


NOAA-15 AMSU-A Channel 5 NEDT
Updated at Mar 31 17:10:02 2015 UTC



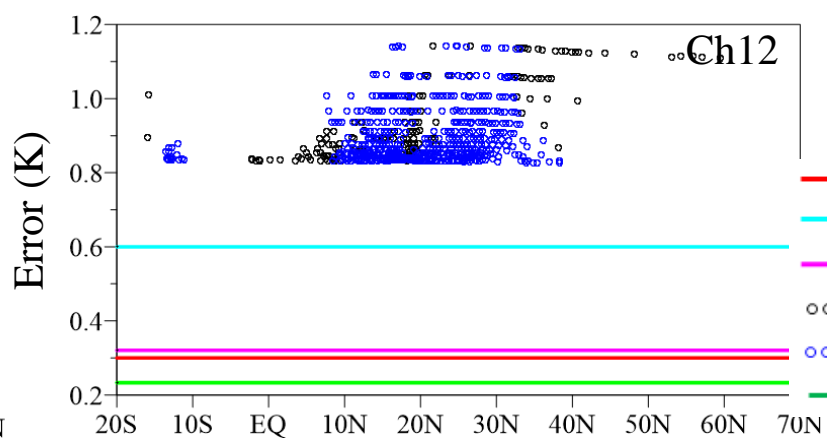
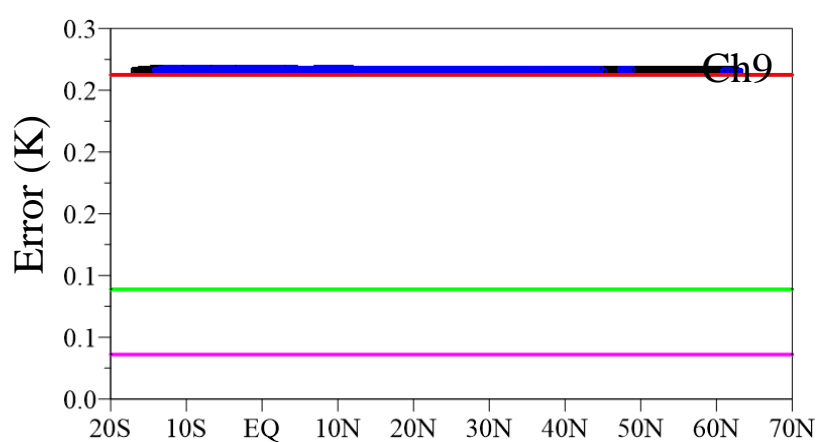
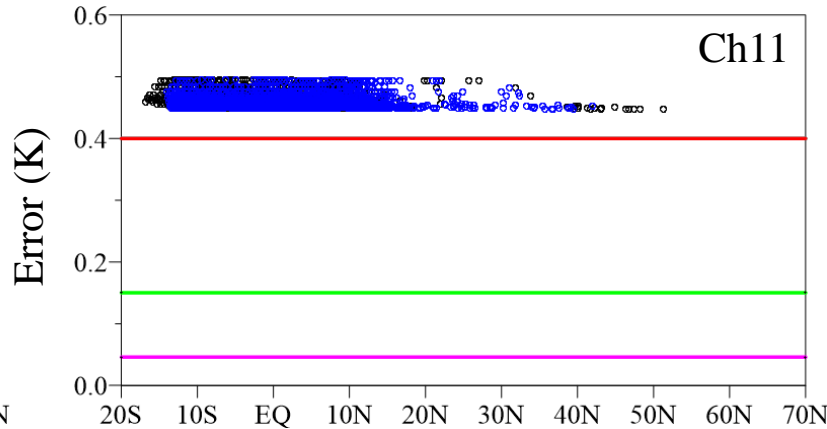
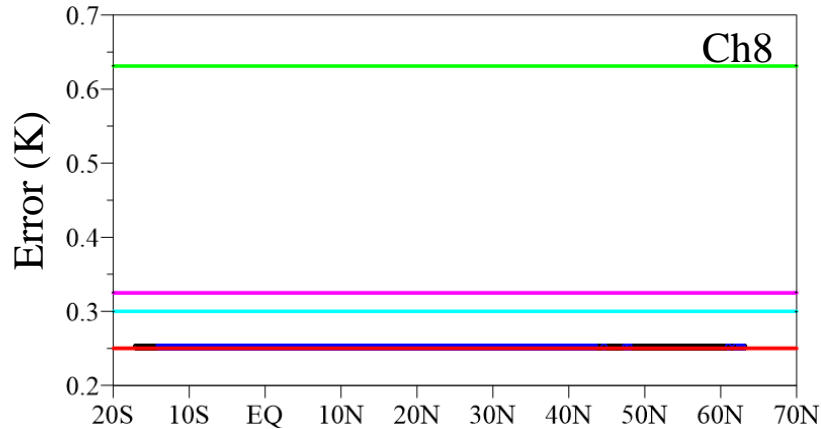
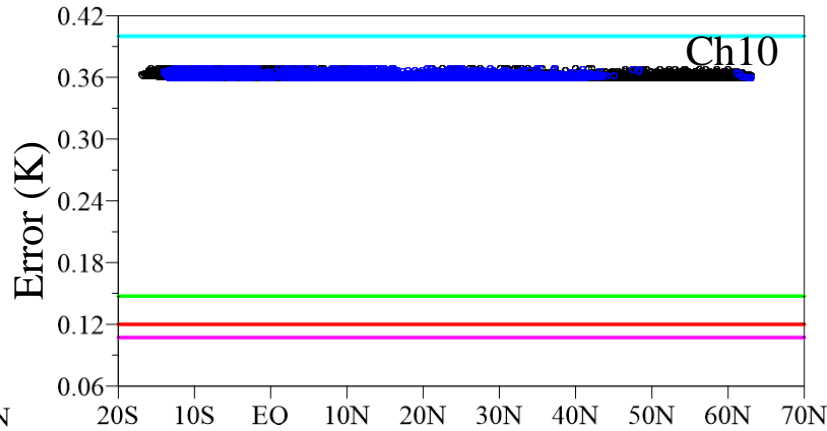
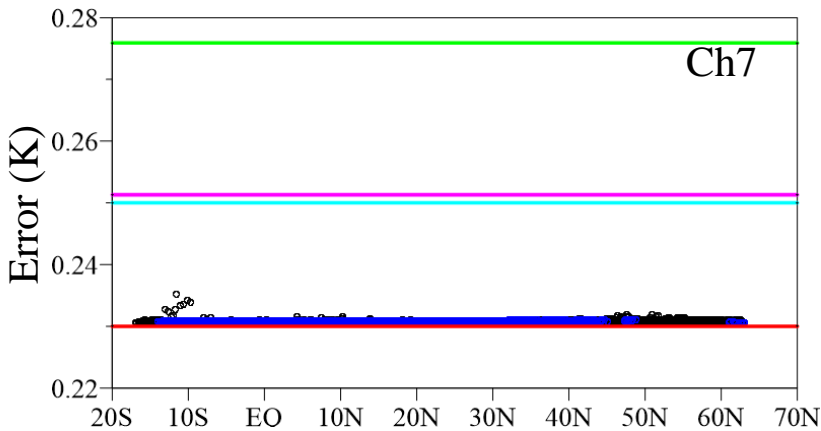
Inflated Errors of NOAA-19 AMSU-A Channels 1-6

1800 UTC
June 23, 2012



- GSI input
- Spec
- NEDT
- Inflated, land
- Inflated, ocean
- Allan Dev.

Inflated Errors of NOAA-19 AMSU-A Channels 7-12



- GSI input
- Spec
- NEDT
- Inflated, land
- Inflated, ocean
- Allan Dev.

Detection of Climate Trend and Its Sensitivity to Measurement Precision and Data Length

Given an observed time series: $\{x_i^o, i = 1, 2, \dots, M\}$

Using a linear-regression model: $x^n = a(t - \bar{t})$

True value of variable x at any time: $x^t = x^n + \varepsilon^n \equiv a(t - \bar{t}) + \varepsilon^n$

The observed time series: $x^o = x^t + \varepsilon^o \equiv a(t - \bar{t}) + \varepsilon^n + \varepsilon^o$

which can be expressed in a matrix form : $\mathbf{x}^o = \mathbf{A}a + \boldsymbol{\varepsilon}$

where:

$$\mathbf{x}^o = \begin{pmatrix} x_1^o \\ x_2^o \\ \dots \\ x_M^o \end{pmatrix} \quad \mathbf{A} = \begin{pmatrix} t_1 - \bar{t} \\ t_2 - \bar{t} \\ \dots \\ t_M - \bar{t} \end{pmatrix} \quad \boldsymbol{\varepsilon} = \begin{pmatrix} \varepsilon_1^n + \varepsilon_1^o \\ \varepsilon_2^n + \varepsilon_2^o \\ \dots \\ \varepsilon_M^n + \varepsilon_M^o \end{pmatrix}$$

Detection of Climate Trend and Its Sensitivity to Measurement Precision and Data Length

The linear regression coefficient (a) is obtained by a least-square fit which minimizes the difference between observations and linear regression model:

$$J = (\mathbf{x}^o - \mathbf{A}a)^T (\mathbf{x}^o - \mathbf{A}a)$$

For a twelve month/year time series, we can obtain the trend as

$$a = \frac{12 \sum_{i=1}^M x_i^o (t_i - \bar{t})}{(M^3 - M)}$$

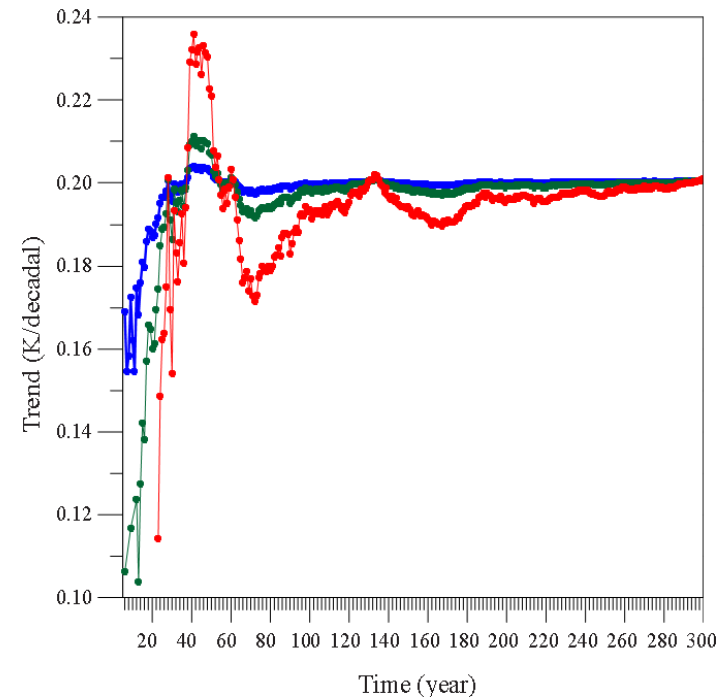


Fig. 1 Climate trend calculated from different lengths of time series with three different observation error variances: 0.1K (blue line), 0.3K (green line) and 1K (red line)