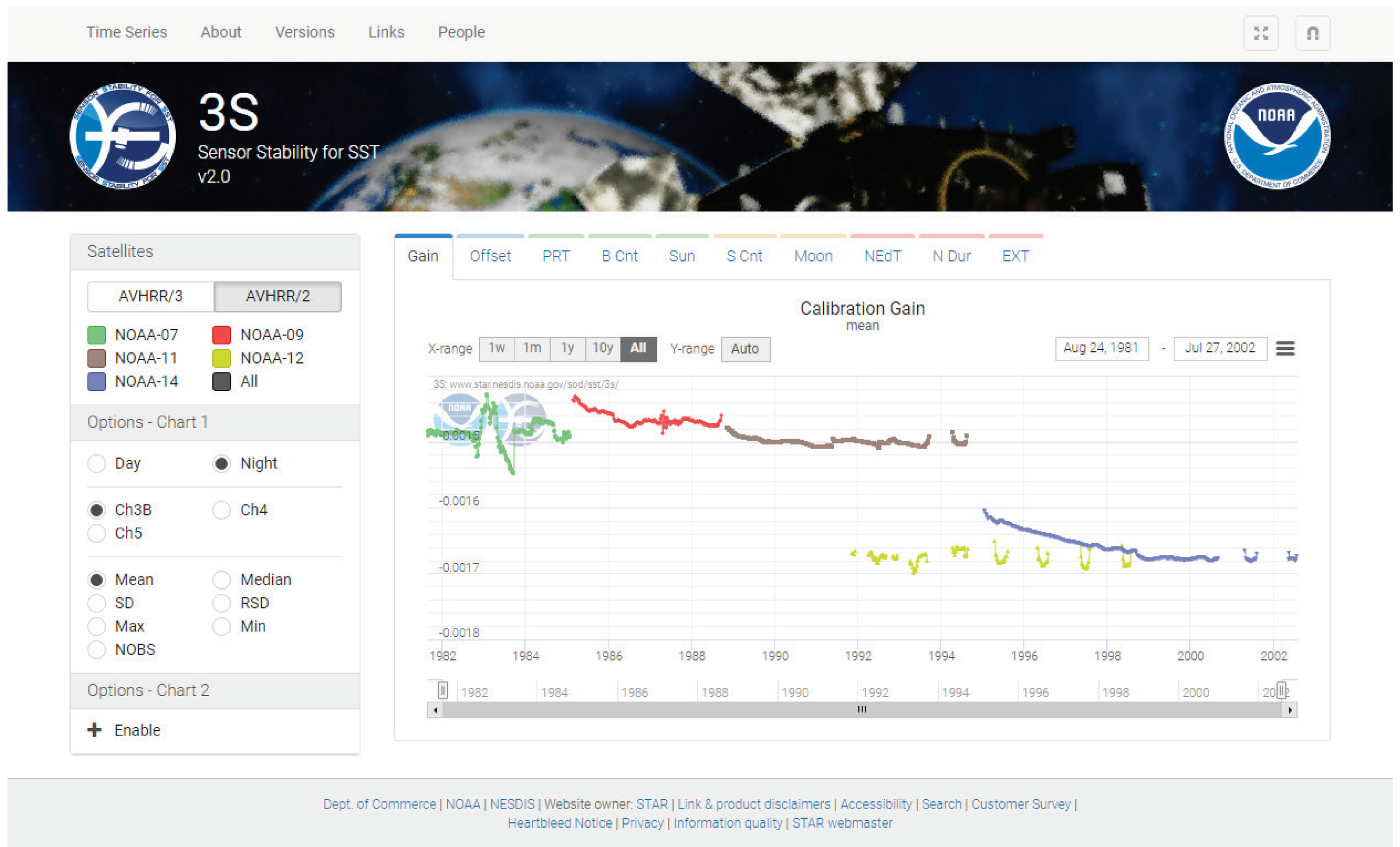
Monitoring AVHRR/2 L1b data in the NOAA Sensor Stability for SST (3S) Version 2

Kai He[1,2], Sasha Ignatov[1]

1. NOAA STAR; 2. Global Science and Technology, Inc.



3S Website: *https://www.star.nesdis.noaa.gov/sod/sst/3s/*

Background

- 3S v1* was developed to support ACSPO GAC SST Reanalysis v1 (RAN1) performed at NOAA from AVHRR/3s onboard NOAA-15 to -19, Metop-A and B (2002 – pr)
  - Artifacts in AVHRR SSTs and in Clear-sky Ocean Brightness Temperatures (BTs) are highly correlated, suggesting that the unstable SSTs are caused by the unstable BTs
  - In turn, artifacts in BTs are caused by the unstable CAL gain/offset (calculated from blackbody view count, BC; space view count, SC; and blackbody temperature, BBT)
  - NOAA has established the Sensor Stability for SST (3S) online system, to monitor AVHRR/3 L1B data (CAL gain/offset, BC/SC/BBT) and corresponding observational context (Sun and Moon positions, Equator crossing time, etc)
- In preparation for RAN2 which will include AVHRR/2 sensors, 3S has been updated to version 2, with two major additions:
  - Include data from AVHRR/2 sensors onboard NOAA-7, 9, 11, 12, 14 (Aug 1981 – Oct 2002)
  - Add monitoring of the NEdT for all AVHRR/2s and AVHRR/3s
- The data availability & well-being of AVHRR/2s, and the NEdTs for all sensors are critically important for the selection of candidate sensors in AVHRR GAC RAN2

* **He, K., Ignatov, A., Kihai, Y., Cao, C. and Stroup, J., 2016. Sensor Stability for SST (3S): Toward improved long-term characterization of AVHRR thermal bands. *Remote Sensing*, 8(4), p.346.**

The 3S System (new in v2)

AVHRR L1b data analyzed in 3S

- AVHRR/3s (NOAA-15, 16, 17, 18, 19, Metop-A, -B) from 1998 – pr
- **AVHRR/2s (NOAA-7, 9, 11, 12, 14) from 1981 – 2002**

Orbital statistics (stratified by day/night)

- L1b in SST bands only (ch3b, 4, 5)
  - Gain/Offset; BC/SC/PRT
- Ancillary variables
  - Sun Angle (in blackbody view)
  - Moon Angle/Phase (in space view)
  - Equator Crossing Time (EXT)
  - **NEdT for AVHRR/3s and AVHRR/2s**
  - Night Duration (length of satellite night)
- Statistics
  - Mean/Median, SD/RSD, Min/Max, NOBS
- Day/Night
  - Defined at satellite (Outside/Inside the Earth shadow, respectively)

AVHRR/2 Data Availability and Stability

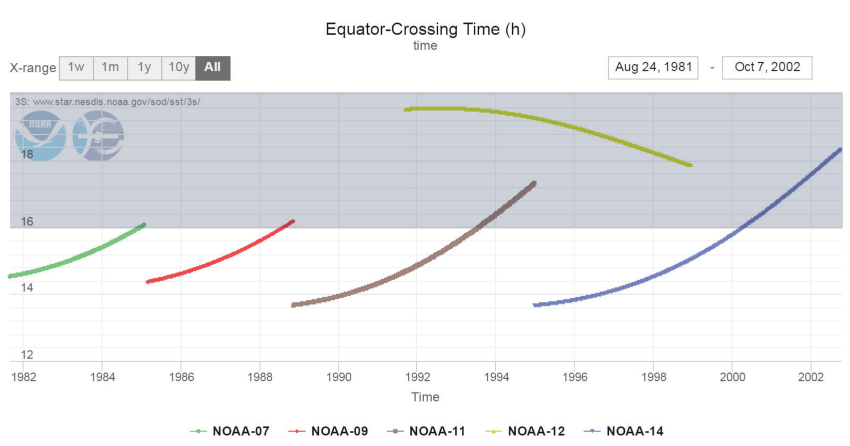
AVHRR/2 data coverage

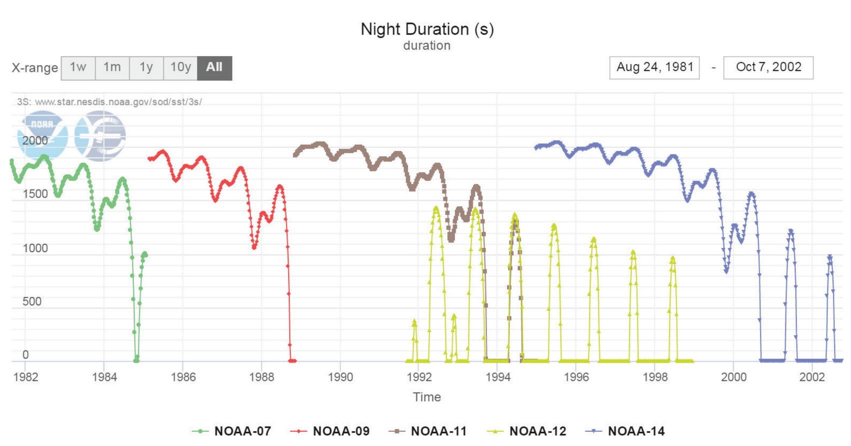
- Minimal to no overlaps in time

	Type	Launch date	L1b start	L1b end	EXT at launch
NOAA-14	PM	12/30/1994	01/01/95	10/07/02	1:30 am/pm
NOAA-12	AM	05/14/1991	09/16/91	12/14/98	7:30 am/pm
NOAA-11	PM	09/24/1988	11/08/88	12/31/94	1:30 am/pm
NOAA-9	PM	12/12/1984	02/25/85	11/07/88	2:30 am/pm
NOAA-7	PM	06/23/1981	08/24/81	02/01/85	2:30 am/pm

Orbital drift

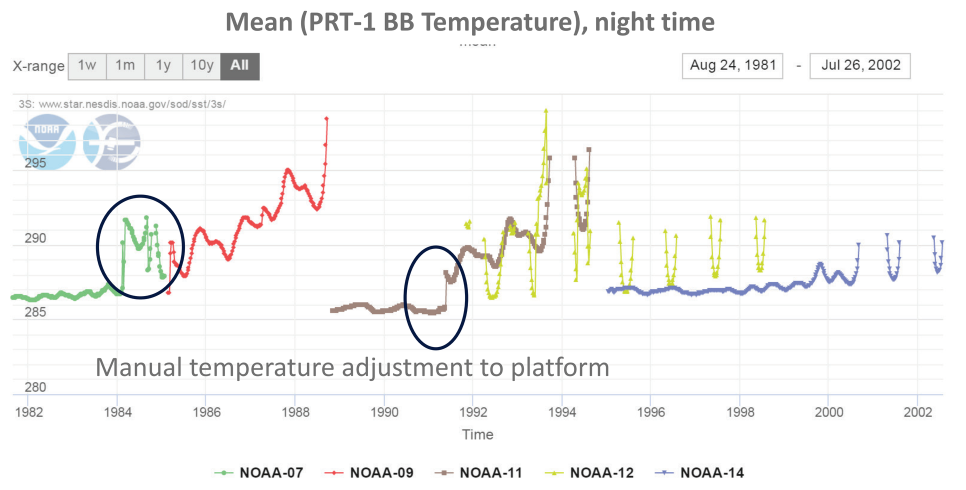
- NOAA satellites are known to drift in orbit over time
  - NOAA-7, 9, 11, 14 (PM) drifted into terminator zone within 4-6 years after launch
  - NOAA-12 (AM) flew a terminator orbit for full mission (similarly to NOAA-15)
- Extensive exposure to sunlight in terminator orbits causes instability of AVHRR thermal CAL





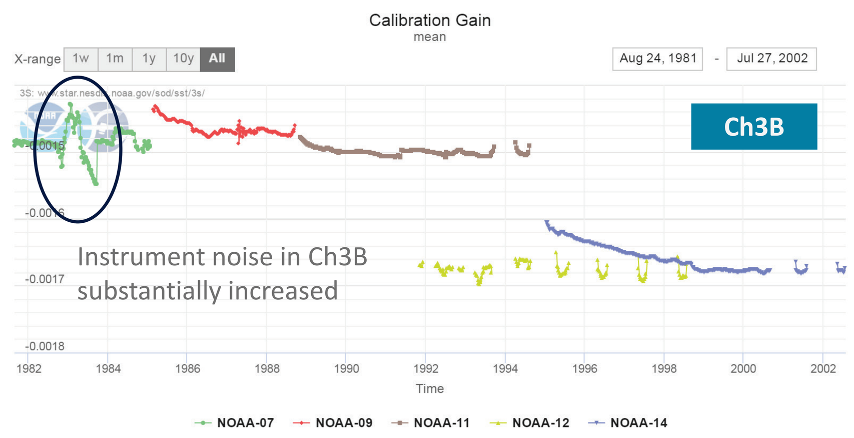
AVHRR/2s' Thermal Stability

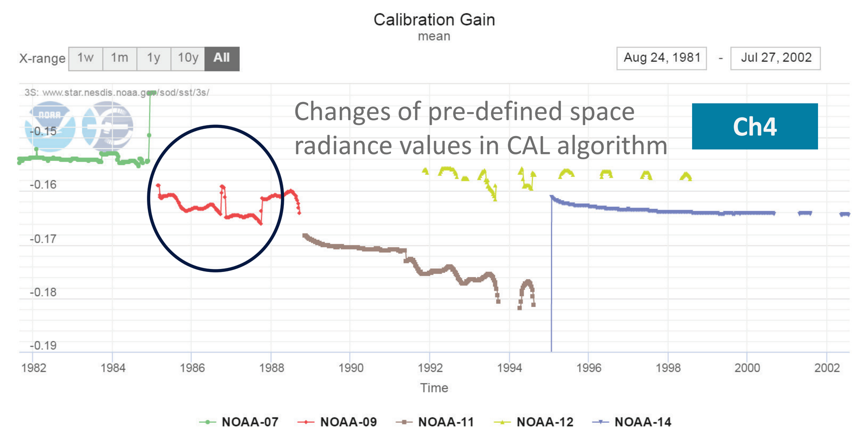
- AVHRRs become thermally unstable when entering terminator orbits
- Manual warm-ups/cool-downs on some instruments/platforms
  - ~5K jumps/drops for NOAA-7 in Feb 1984
  - ~2.5K increase for NOAA-11 in May 1991



AVHRR/2s' calibration gain

- Thermal instability leads to instability in calibration (CAL) coefficients
- Other instances of anomalous behavior
  - Anomalous noise in some bands on some sensors (e.g. Ch3B on NOAA-7 around 1983)
  - Manual changes to CAL algorithm may result in gain discontinuity (e.g., @Ch4 for NOAA-9)





Noise Equivalent Differential Temperature (NEdT)

- NEdT: Random error in the brightness temperature due to instrument noise
- To calculate NEdT, NEdN (radiance noise) is first evaluated
  - Assumption: noise levels are similar for SP, ICT, and Earth view, according to Trishchenko *et al.*
  - Error in detector measurement (δC) is estimated as SD of space counts
  - G is gain for each channel (not corrected for nonlinearity for Ch4 & 5)

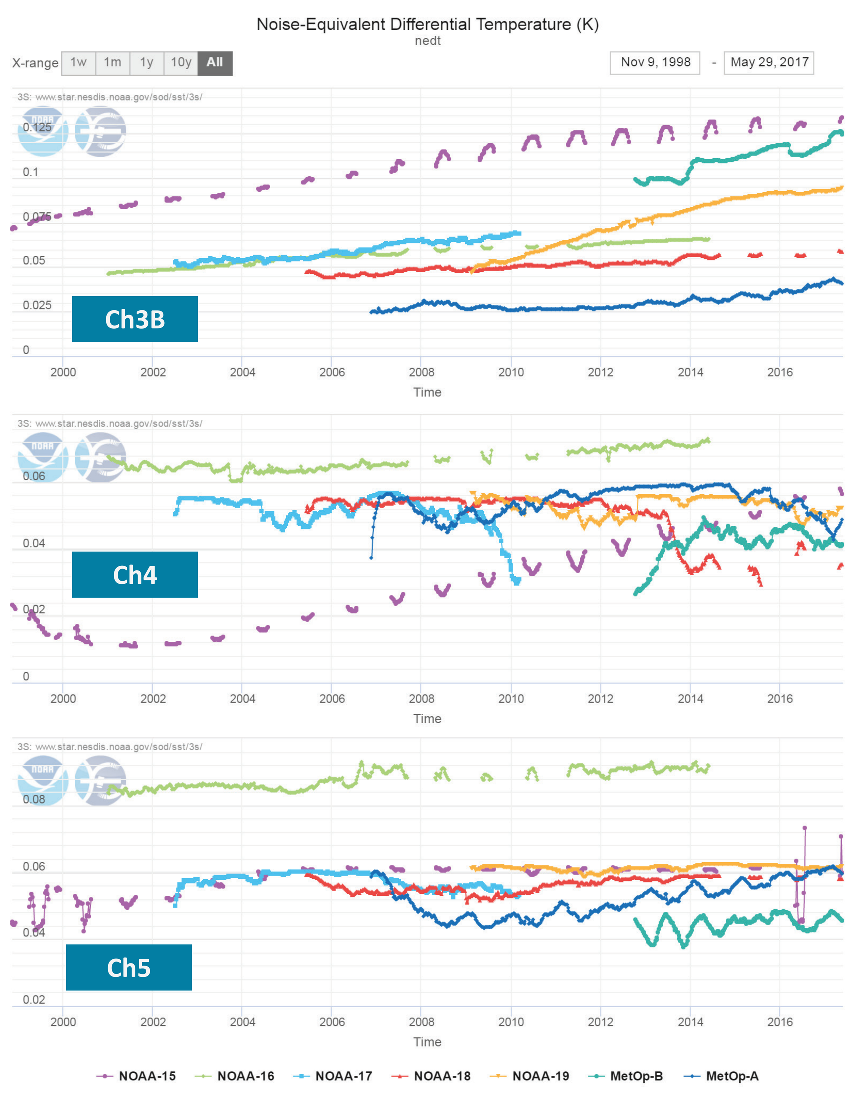
$$\mathrm{NE}dN = G \cdot \delta C$$

- NEdT is converted from NEdN at a typical scene temperature (e.g. 300K)
  - Conversion coefficient (K) is evaluated by differentiating the plank's function

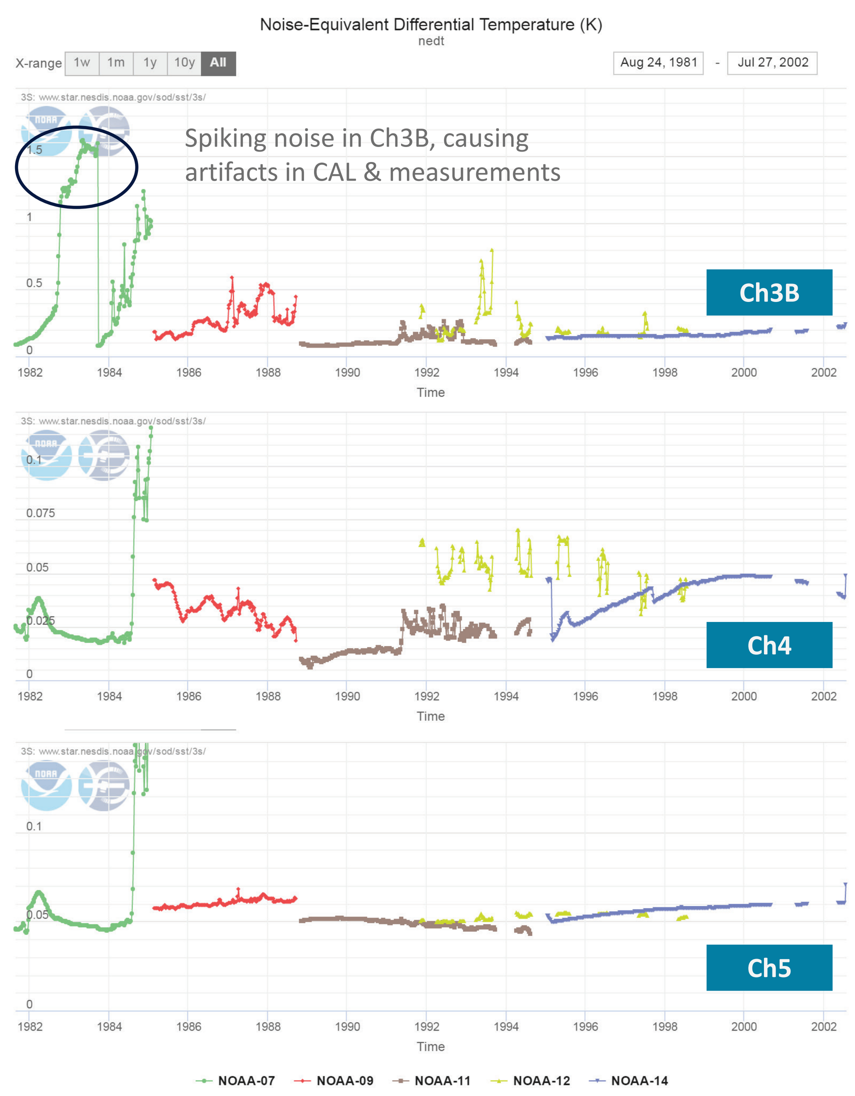
$$\mathrm{NE}dT = K_{T=300\mathrm{K}} \cdot \mathrm{NE}dN$$

- AVHRR NEdT specs: 0.12K @300K

AVHRR/3 NEdT



AVHRR/2 NEdT



Summary & Future Work

- 3S has been upgraded to v2 to add:
  - AVHRR/2 onboard NOAA-7, 9, 11, 12, and 14, from Aug 1981 to Oct 2002
  - Noise equivalent differential temperature (NEdT) for all AVHRR/2s and AVHRR/3s
- Some AVHRR/2s have been thermally unstable, due to terminator orbits (NOAA-12, NOAA-14 in later years) and manual adjustment (NOAA-7, 11).
- High NEdTs (e.g. NOAA-7 Ch3B) may render Ch3B useless for SST
- Future work:
  - compute BTs for AVHRR/2s and analyze the linkage between artifacts in BT and thermal CAL
  - Reprocess L1B to stabilize BTs

Acknowledgments

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- The views, opinions, and findings in this report are those of the authors and should not be construed as an official NOAA or U.S. government position or policy

 Kai.He@noaa.gov