NOAA Sensor Stability for SST (3S) for Improved Characterization of AVHRR Thermal Bands

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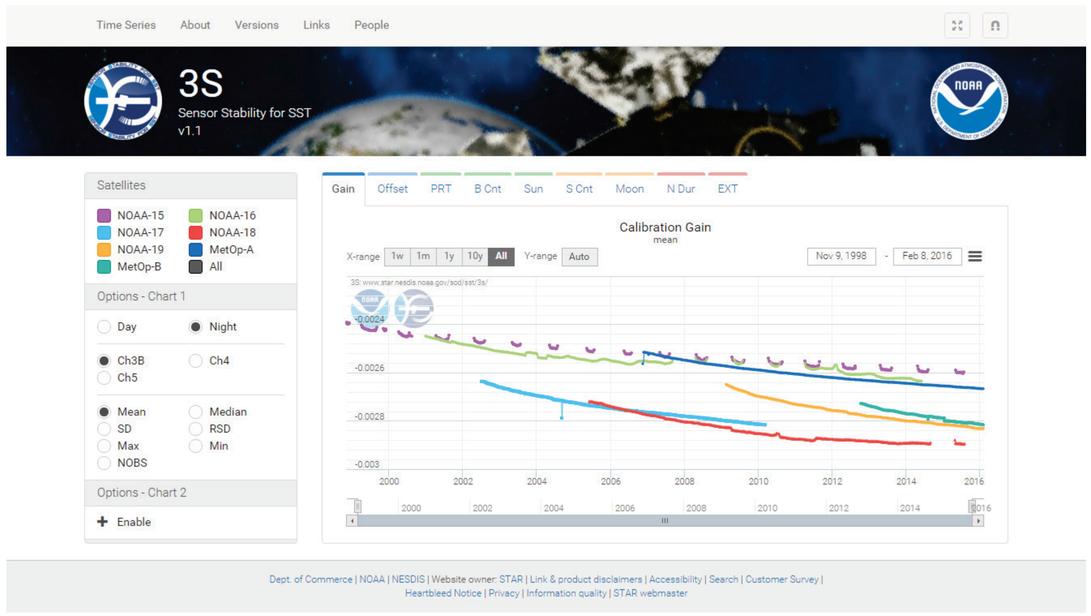


3S Website: http://www.star.nesdis.noaa.gov/sod/sst/3s/

Motivation

- ACSPO SST Reanalysis v1 (RAN1) performed at NOAA (NOAA-15 to -19, Metop-A and B, from 2002 – pr)
- AVHRR SSTs and Clear-sky Ocean Brightness Temperatures (BTs) in bands 3B, 4, 5
  - Time series of ΔSSTs (SST minus Ref SST) and ΔBTs (BT minus Ref BT) are highly correlated → suggest that artifacts in SST are mainly caused by artifacts in AVHRR BTs
  - SSTs were empirically stabilized using variable regression coefficients (using a ±45-day moving window) but the BTs are left intact, in RAN1
- Stable BTs are also needed in the next AVHRR reprocessing
  - Some ACSPO users are interested in direct radiance assimilation
  - Reducing BT artifacts will improve the efficiency of the empirical SST stabilization
- BT artifacts are due to the unstable CAL Gain/Offset [calculated from blackbody view count (BC), space view count (SC), and blackbody temperature (BBT)]
- NOAA has established a Sensor Stability for SST (3S) online system, to monitor AVHRR L1B data (CAL gain/offset, BC/SC/BBT) and ancillary variables

The 3S System

AVHRR L1b data analyzed in 3S

- Currently, AVHRR/3s (NOAA-15, -16, 17, 18, 19, Metop-A, -B) from 1998 – pr
- The plan is to include AVHRR/2s (initially extend back to 1994, and then to 1981)

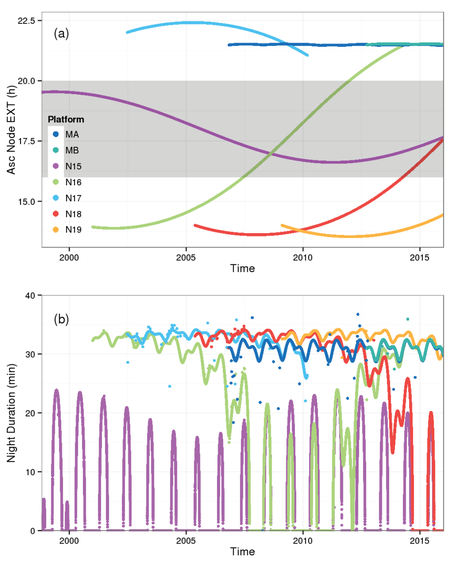
Orbital statistics (stratified by day/night)

- 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)
  - Night Duration (length of satellite night)
- Type of statistics
  - Mean/Median, SD/RSD, Min/Max, NOBS
- Satellite day/night
  - Defined as outside/inside the Earth shadow

Observations in the 3S

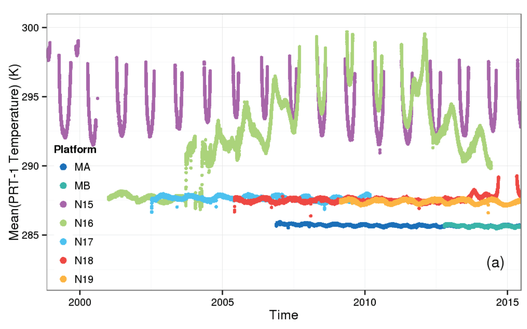
Orbital Stability

- Metop orbits are corrected in-flight
- NOAA orbits are not controlled and "drift"
- Terminator orbits (N15, recently N16 & N18)



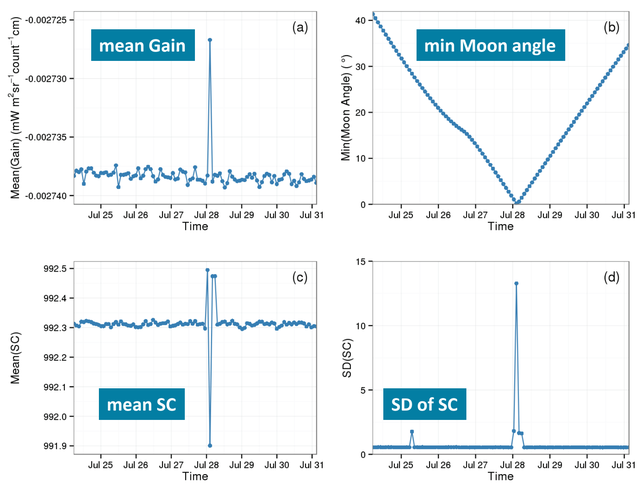
Thermal stability

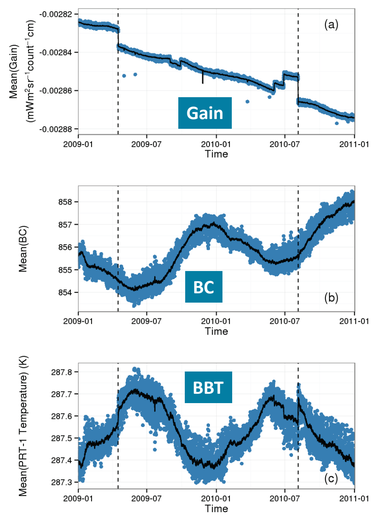
- AVHRRs are designed to operate at 286 – 288K
- More stable on Metop-A, and -B, N17 – N19 (except N18 recently)
- Most unstable on N15, and late N16 due to terminator orbits (extensive exposure to sunlight)



Discontinuities in NOAA-18 gain

- April 16, 2009 and Aug 4, 2010 (dashed lines)
- BC is smooth and continuous
- PRT shows ~0.1K jumps (but not corresponding response in BC!)
- Likely due to non-documented CPIDS changes (CPIDS: control file to L1b processing)





Moon in space view

- Moon may transverse the space view, and affect the SC and thereby CAL
- An example of NOAA-17
- L1b QC did not capture this event

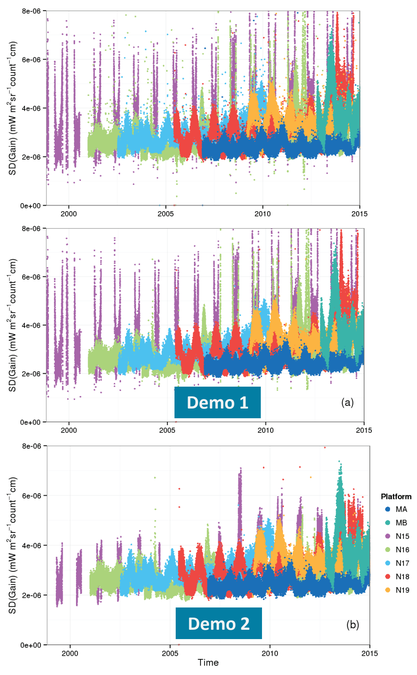
L1b Quality Control and CAL Algorithm

SDs of the nighttime gain @Ch3b

- Expected to be close to 0 (sensor sensitivity does not change dramatically on short time scales)
- Large outliers and spikes due to
  (1) Moon events
  (2) near-full Sun orbits (terminator orbits)
- More stringent QC is needed (and feasible)

2 Case Studies showing effect of improved QC

- Demo 1: Removing data with Moon effects
  - Moon angle < 2° and |SC –orbital median SC| > 1
  - Affected orbit ratio < 0.8%; about 0.9%-1.5% of nighttime scan lines in an affected orbit
- Demo 2: Additionally excluding orbits with short nights
  - Number of scan lines < 2000
  - 45%, 11%, 2% of data points for N15, N16, N18, respectively.



Current AVHRR calibration

- On line-by-line basis
- Occasional substitution for "gain anomaly" due to solar contamination
- Controlled by CPIDS (L1b control file)

Potential new AVHRR calibration

- Best part of an orbit and/or best parts of satellite lifetime
- For stable platforms (e.g. Metops), derive CAL from the nighttime portion of an orbit
- For unstable platforms (e.g. N15, N16), fill in gaps (full-Sun periods) by interpolating from other orbits
- Empirical fit to CAL trend

Conclusions & Future Work

- The 3S system is fully functional at NOAA for AVHRR/3s from 1998 – pr
- 3S analyses suggest improvements to AVHRR L1b are needed & feasible
  - Need more stringent QC
  - Fill in non-calibratable scan lines/orbits from context (by extra/interpolation)
- Future Work 1: Reprocess L1b
  - Improve L1b (a) QC and (b) CAL algorithms; Generate a "cleaner" AVHRR L1B
  - Generate stable BTs/SSTs from improved L1b; Quantify improvements in 3S (CAL), MICROS (BT), SQUAM (SST)
- Future Work 2: Process AVHRR/2s from 1981 – 2002
  - Add in the 3S, Analyze, Generate/Validate improved L1b

References

- 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.

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