Satellite and *in situ* SSTs Reprocessing and Harmonization at NOAA

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NOAA Center for Satellite Applications and Research (STAR)

Supported by NOAA ORS Program

NOAA satellite fleet is being upgraded with new climate quality SST sensors

STAR is responsible for Satellite SST Products, Algorithms, Cal/Val

Joint Polar Satellite System (JPSS) Replaces Polar Operational Environmental Satellites (POES) System

- ✓ S-NPP launched in Oct 2011
- ✓ J1 will be launched in 2017
- ✓ J2 (2021), J3 (2026, J4 (2031) are planned
- ✓ "Climate quality" Visible Infrared Imager Radiometer Suite (VIIRS) replaces "weather quality" AVHRR flown onboard NOAA and Metops since 1981

Launch of S-NPP
October 28, 2011

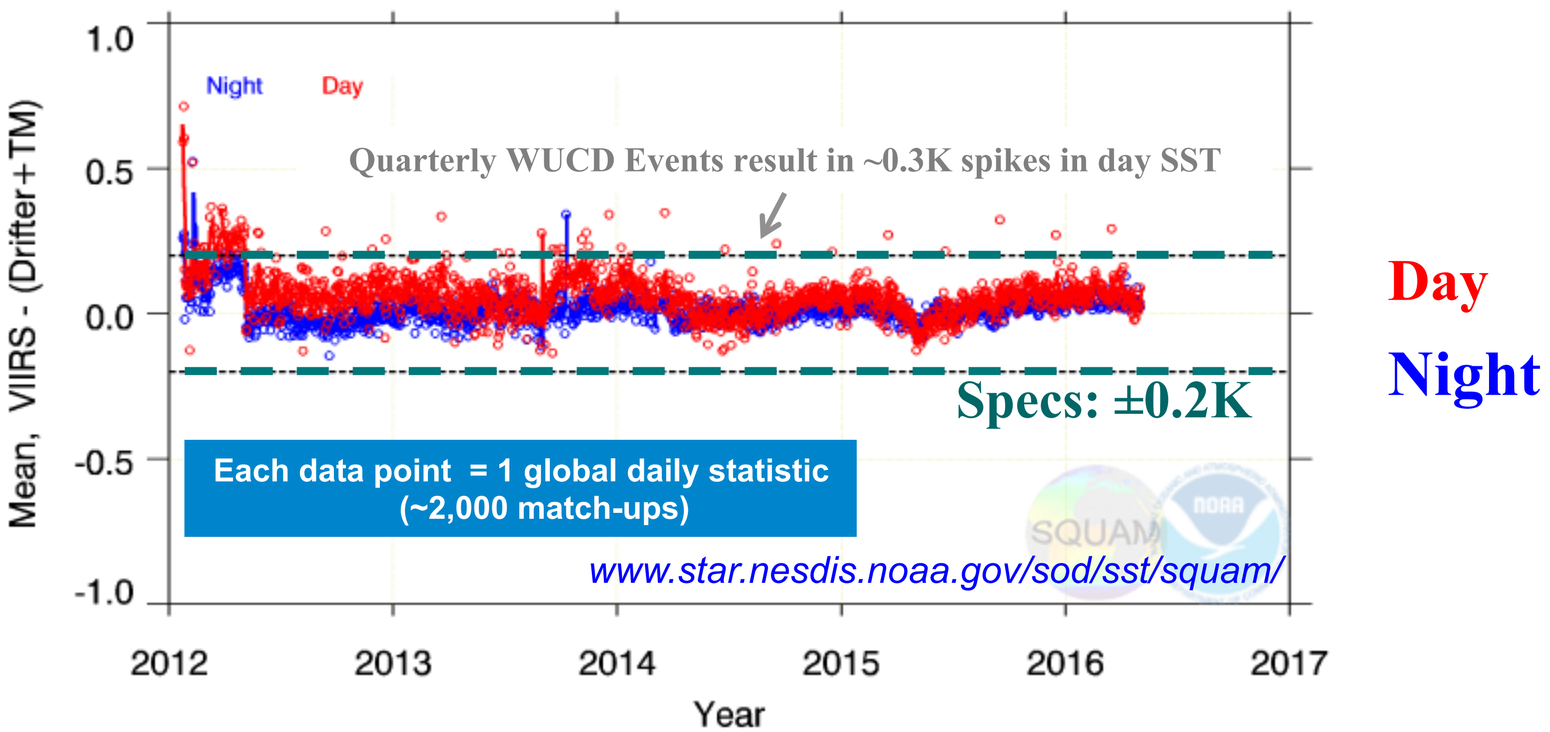
Launch of Himawari-8
October 7, 2014

GOES R series Replaces Heritage GOES

- ✓ GOES-R ABI will be launched in Nov 2016. It will be followed by GOES-S/T/U through ~2035
- ✓ Himawari-8 AHI was launched in Oct 2014 (Himawari-9: Nov 2016). NOAA produces SST from the AHI (sister to ABI) radiometer, too.
- ✓ "Climate quality" Advanced Baseline Imager / Advanced Himawari Imager (ABI/AHI) replace "whether quality" geo imagers onboard GOES, Himawari-7 and Meteosat satellites from 1994-pr

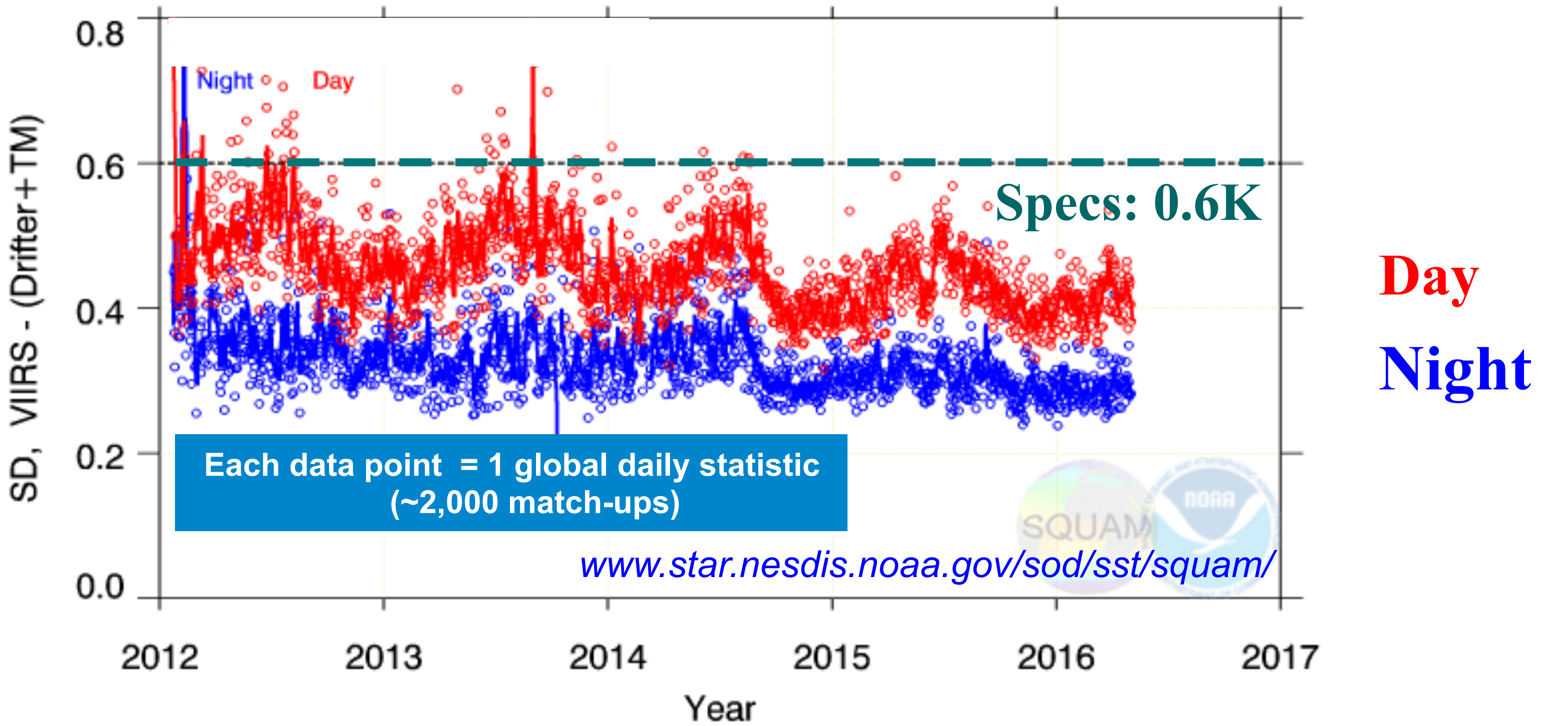
NOAA satellite SST products are produced using Advanced Clear-Sky Processor for Ocean (ACSPO) Enterprise System

VIIRS SST Validation Bias Vs. Drifters + Trop. Moor.



- Product meets specs and users' requirements
- Biases gradually improve in time as ACSPO algorithms mature
- **Reprocessing underway to produce uniform & complete time series**

VIIRS SST Validation Std. Dev. Vs. Drifters + Trop. Moor.



- Current SDs ~0.35K (Night) and ~0.45K (Day) meet specs and users' requirements
- SD smaller at night (skin VIIRS SST is closer to buoy bulk SST)
- SDs improve as ACSPO SST algorithms mature – **Reproprocessing underway**

It will take awhile to accumulate climate records from VIIRS/ABI/AHI

In the meantime, users requested AVHRR SSTs reprocessed with NOAA ACSPO system

AVHRR SST Reanalysis (RAN) Using NOAA ACSPO System

Advanced Very High Resolution Radiometer (AVHRR)

- ✓ AVHRRs have been flown onboard US NOAA satellites since 1981 and onboard European Metop satellites since 2006
- ✓ NOAA Coral Reef Watch Team requested long-term consistent ACSPO AVHRR SST record for assimilation in the geo-polar blended SST
- ✓ UMD, NASA GMAO, NASA JPL and NOAA NCEI/Asheville requested sample RAN1 data

ACSPO AVHRR RAN

- ✓ RAN1 (Jul 2002 – Dec 2015): 3 afternoon (N-16, 18, 19) and 2 mid-morning (N-17, Metop-A) satellites
- ✓ RAN2 will extend data record back to 1994, and RAN3 to 1981

Ignatov, et al., 2016: AVHRR GAC SST Reanalysis version 1 (RAN1), Remote Sens., 8(4), 315.

3 long-term AVHRR SST Products

Pathfinder V5.2 (PFV5.2) L3C (collated) – tied to *in situ* SSTs (drifters)

- ✓ Data available from Sep 1981 – Dec 2012 (one satellite at a time)
- ✓ Satellite SSTs regressed against buoys & -0.17K subtracted for "skin"
- ✓ *Kilpatrick et al, JGR, 2001; Casey et al, 2010; Kilpatrick, CATBD, 2013*

CCI L2P v1.0 – fully independent of *in situ* SSTs

- ✓ Data available from Sep 1991 – Dec 2010 (up to 3 satellites at a time)
- ✓ Satellite SSTs derived using physical retrievals & independently from *in situ*
- ✓ Retrieved SST is "skin" → -0.17K bias is expected
- ✓ *Merchant et al, Geosci Data J., 2014*

AVHRR RAN1 L2P – heavily anchored to *in situ* SSTs (drifters + TMs)

- ✓ Data available from Jul 2002 – Dec 2015 (two best satellites at a time)
- ✓ Satellite SST regressed against (drifters + TM) using a 3-month moving window (no bias wrt *in situ* expected)
- ✓ New single scanner error statistics (SSES) trained against drifters + TM → bias corrected SST is a better proxy for "depth" (*Petrenko et al, JTECH 2016*)
- ✓ *Ignatov et al, Remote Sens., 2016*

Analyzed below are night SSTs w/QL=5, from Jul 2002 – Dec 2015

In situ SSTs used for satellite Cal/ Val at NOAA

NOAA *in situ* SST Quality Monitor (*i*Quam)

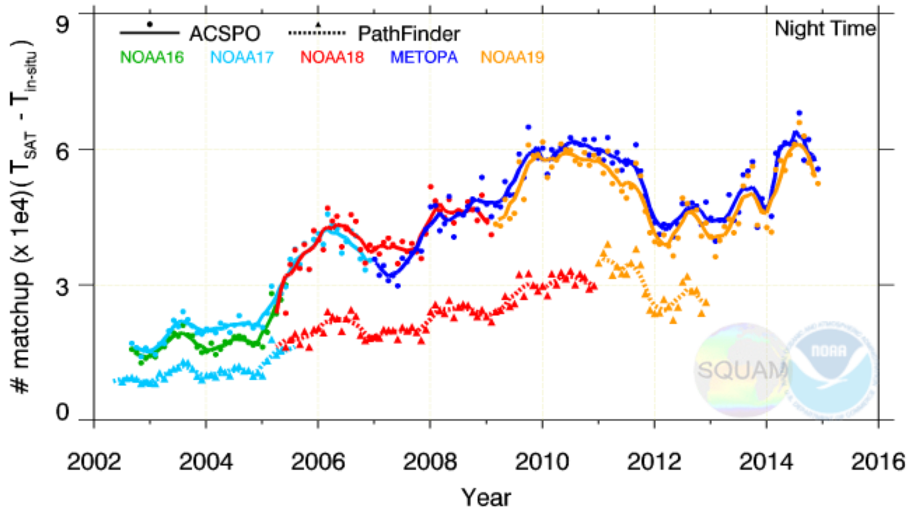
- **In 2008, conducted inventory of available *in situ* SSTs for the use in Cal/Val**
  - ICOADS r2.40 (Sep 1981 – Jul 2007; not available in NRT; suboptimal QC for satellite Cal/Val)
  - FNMOC (Sep 1998 – pr; available in NRT; suboptimal QC for satellite Cal/Val)
  - NCEP GTS (Jan 1991 – pr; available in NRT; no QC)
  - *Xu, Ignatov, 2010: Evaluation of in situ SSTs for use in Cal/Val, JGR, 115, C09022.*
- **In 2009, launched *in situ* SST Quality Monitor version 1 (*i*Quam1)**
  www.star.nesdis.noaa.gov/sod/sst/iquam/ (google "iquam")
  - Uses NCEP GTS data as feed (1991-pr)
  - Included drifters, tropical and coastal moorings, ships
  - State of the art UK MO Bayesian QC
  - *Xu, Ignatov, 2014: In situ SST Quality Monitor (iQuam), JTECH, 31, 164.*
- **In 2015, reprocessed *i*Quam1 and upgraded to version 2 (*i*Quam2)**
  - Extended period to 1981 using ICOADS v2.5
  - Improved QC (added 2nd reference field in the reference check, and performance history check)
  - Added 4 new data types (Argo Floats, High-Resolution GHRSST Drifters, IMOS Ships, CRW buoys)
  - Improved web interface; Changed data format to GHRSST NetCDF4 (from hdf4 in *i*Quam1)
  - *Ignatov, et al., 2016: iQuam2, JTECH, in prep.*

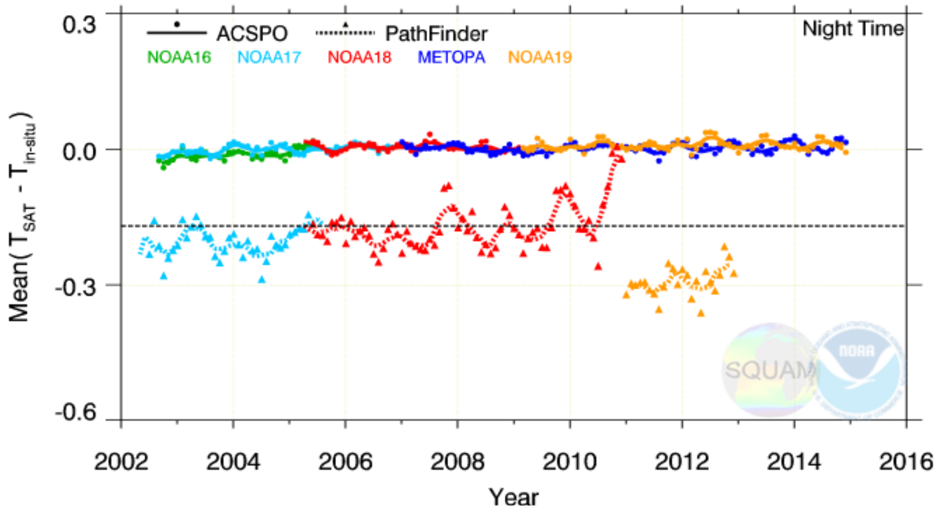
Online validation in the NOAA SST Quality Monitor (SQUAM)

www.star.nesdis.noaa.gov/sod/sst/squam/

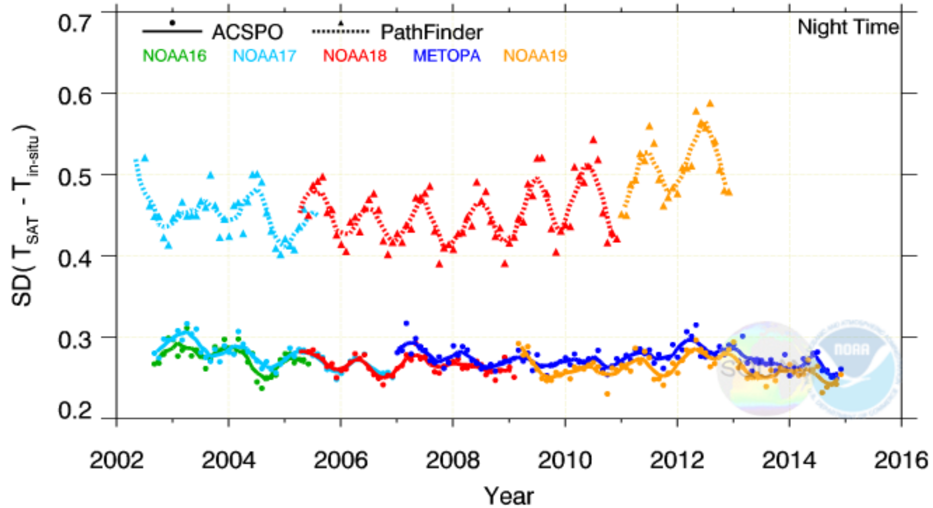
1. RAN1 vs. PFV5.2

Validation of Nighttime AVHRR RAN1 and PFV5.2 Vs. Drifters + Trop. Moor.

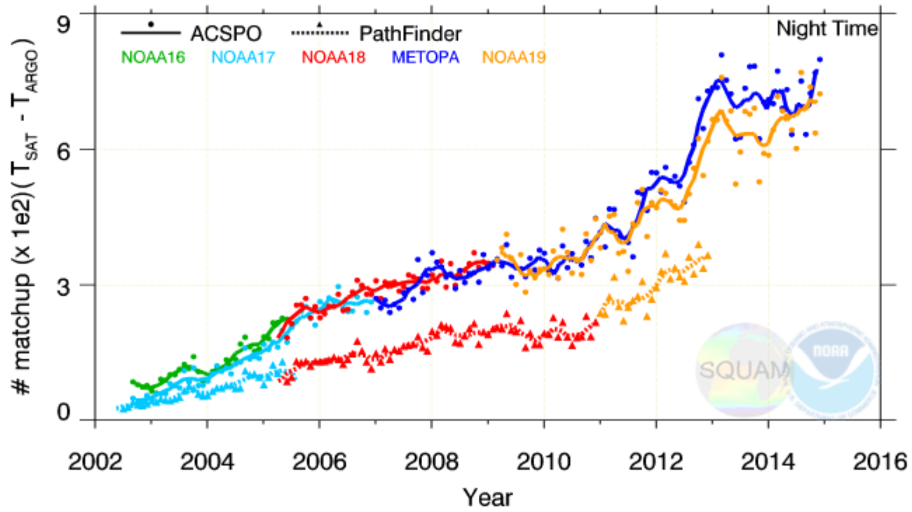


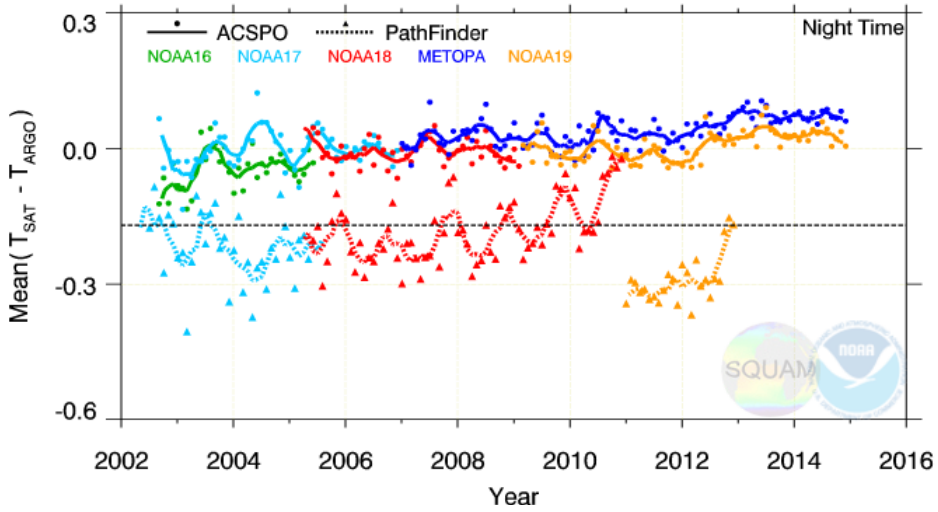


- RAN1 reports 2 satellites at a time (PFV5.2: one satellite)
- Each satellite in RAN1 reports ×2 more retrievals than in PFV5.2
- In 2016, number of RAN1 match-ups ~60K/month
- RAN1 bias vs. drifters + TMs is ±0.05K.
- PFV5.2: “skin product” resulting in a -0.17K bias
- RAN1 SD~0.3K are smaller than PFV5.2 SD~0.5K

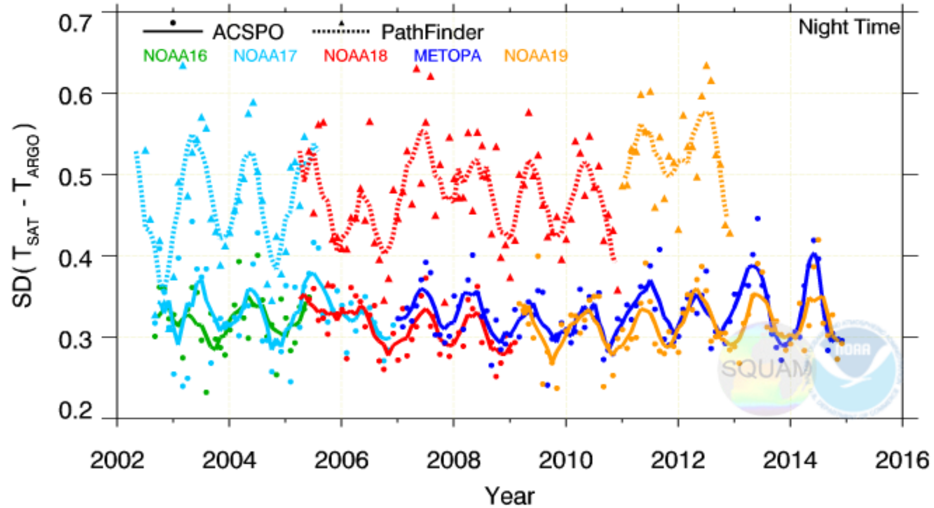


Validation of Nighttime AVHRR RAN1 and PFV5.2 Vs. Argo Floats

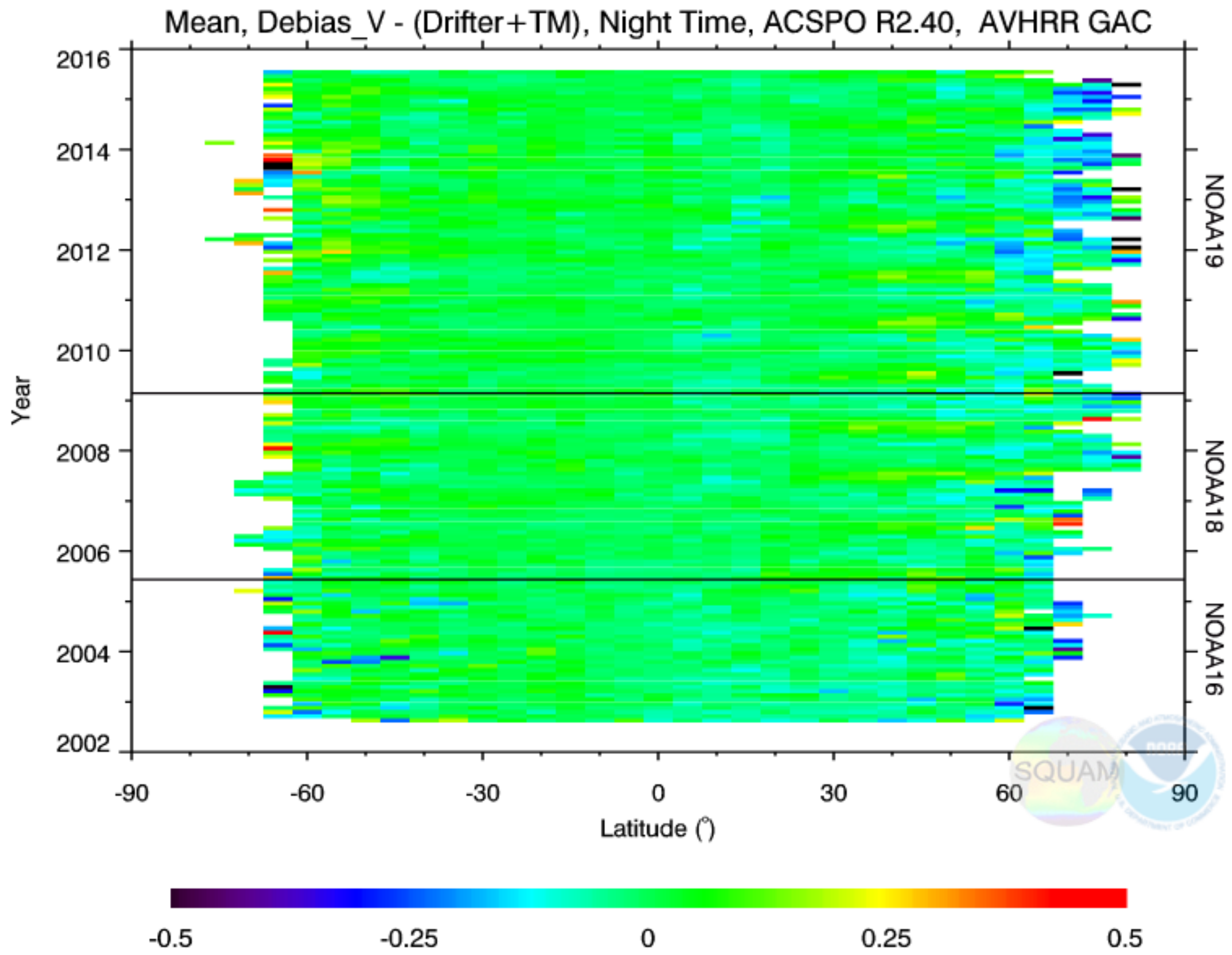




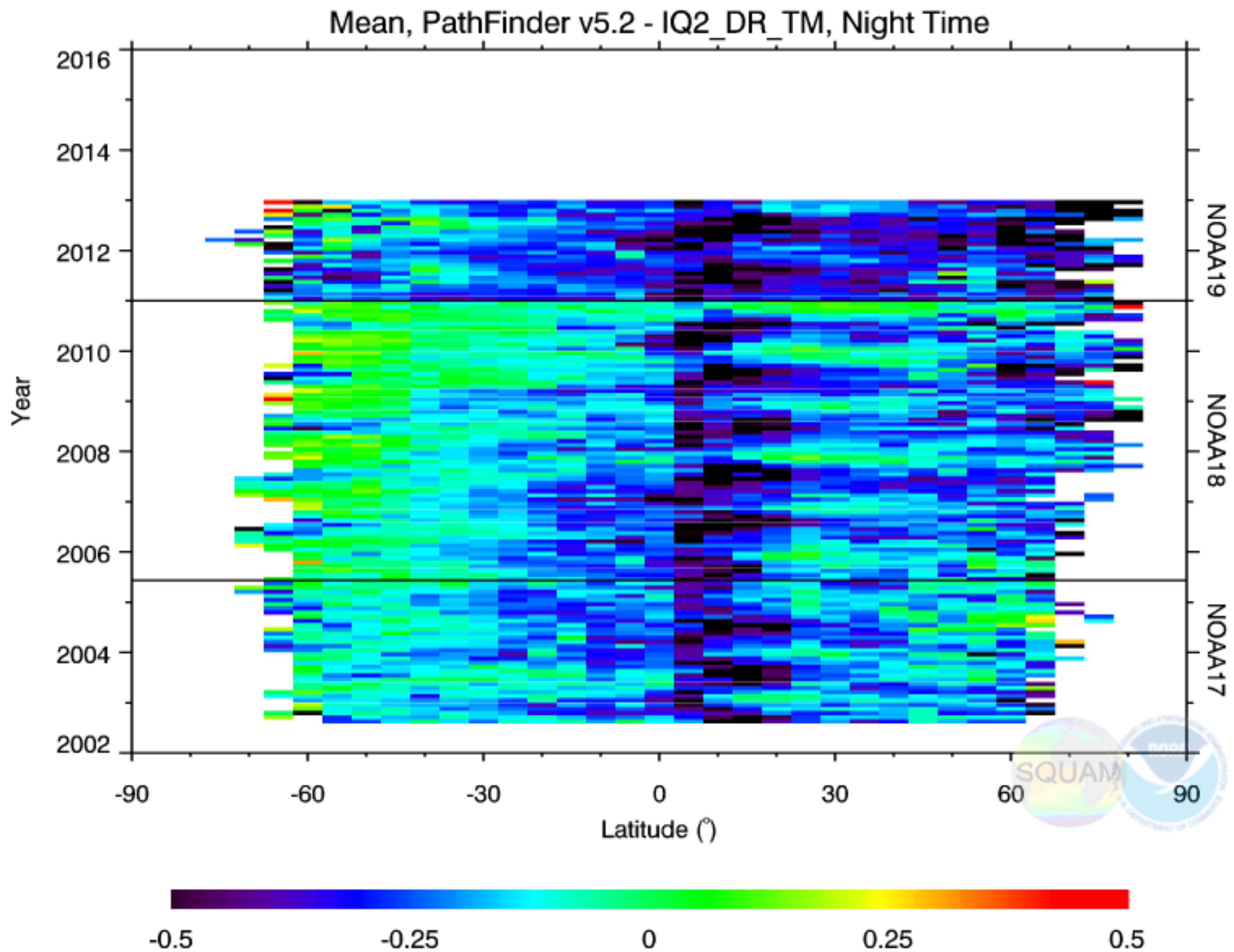
- In Argo matchups, all major trends & relationships are consistent with (Drifters + Tropical Moorings) but are more noisy
- This is because number of Argo matchups is ~2 orders smaller compared to (Drifters + Tropical Moorings)



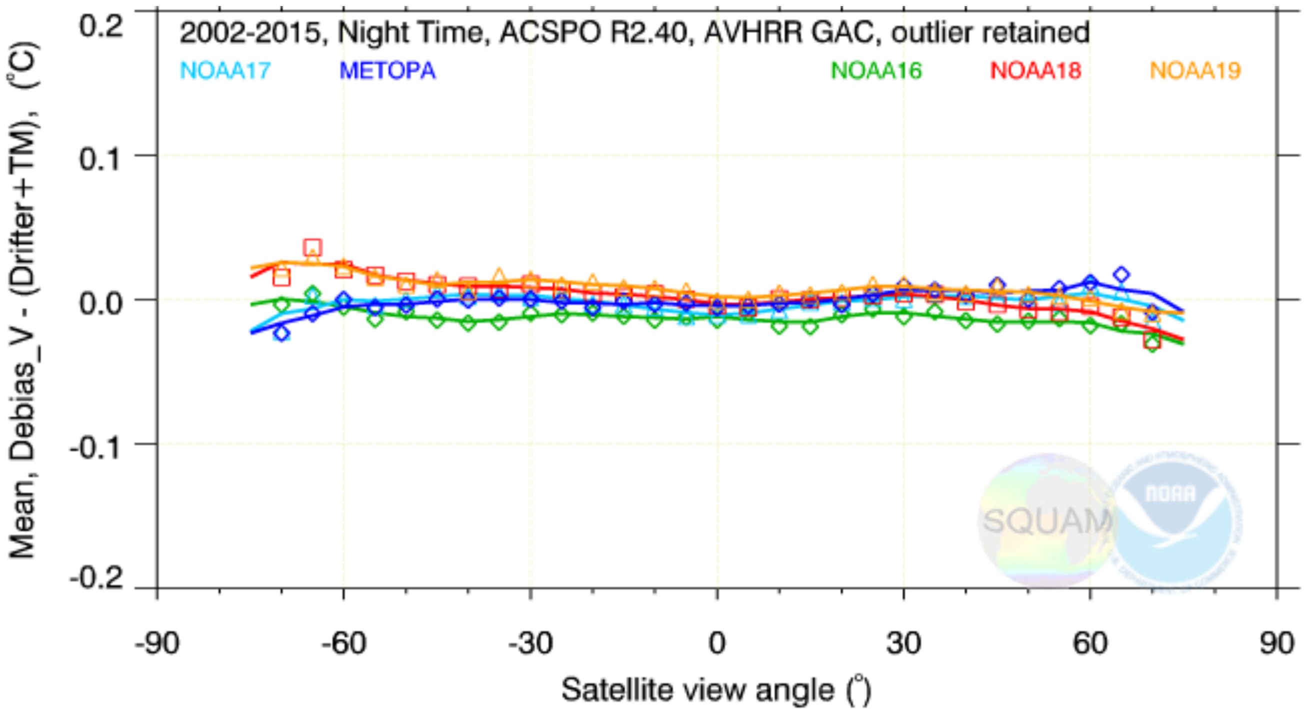
Hovmoller Diagram of Biases (RAN1 – *in situ*)



Hovmoller Diagram of Biases (PFV5.2 – *in situ*)

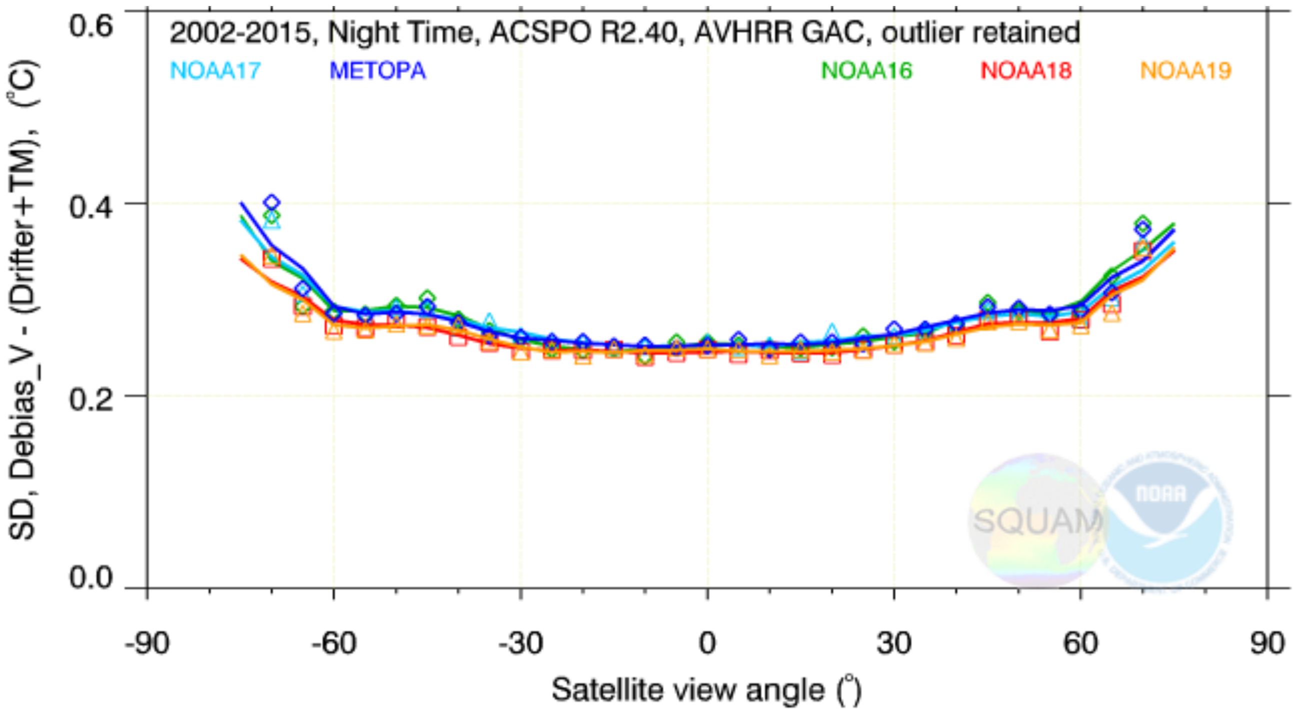


Angular Dependencies of Biases (RAN1 – *in situ*)



- RAN1 makes retrievals in the full AVHRR swath ±68º
- AVHRR SST is near-flat in the full swath, to within several hundredth of deg C

Angular Dependencies of SDs (RAN1 – *in situ*)



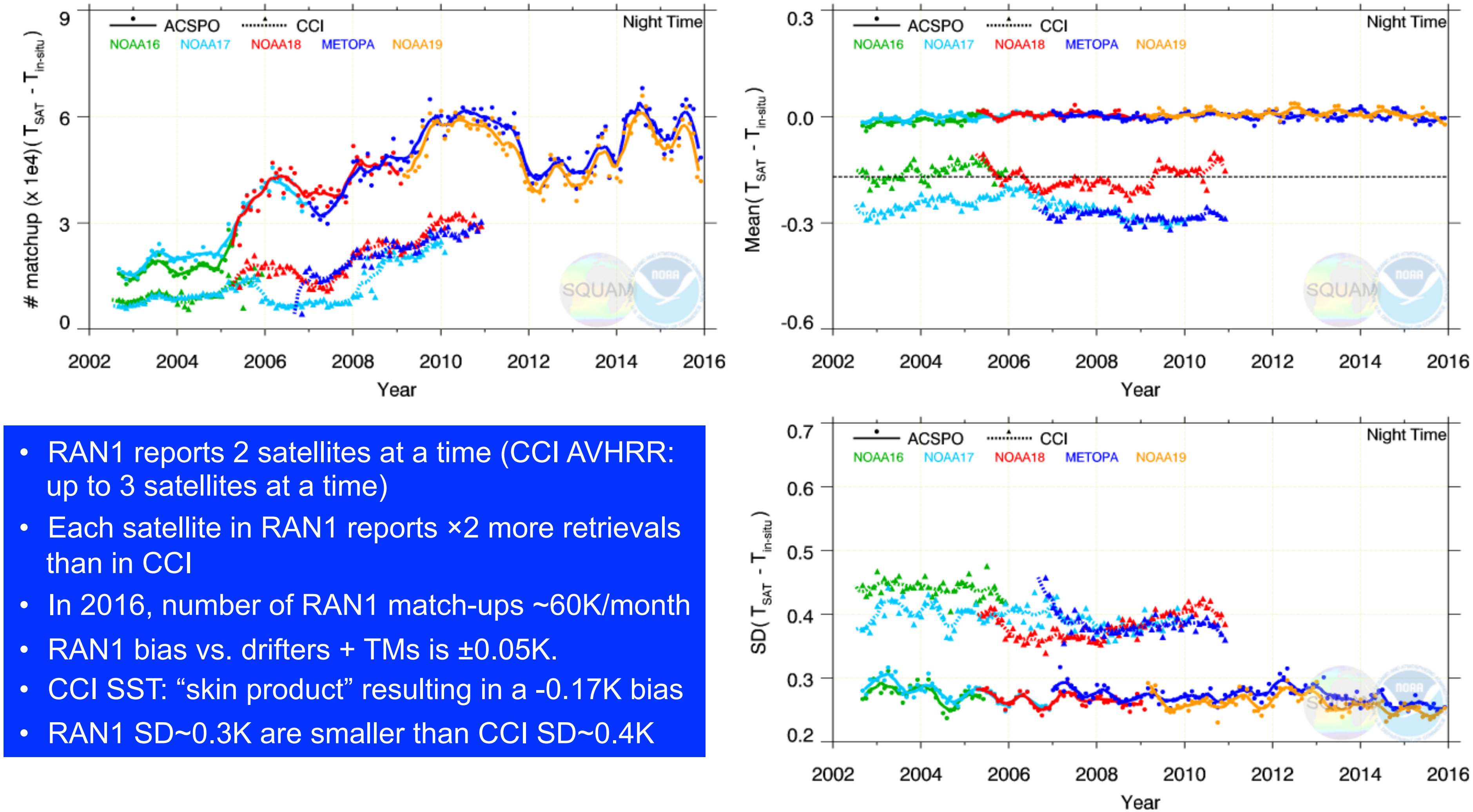
- RAN1 makes retrievals in full AVHRR swath ±68º
- Random errors in retrieved SST increase towards swath edges

Online validation in the NOAA SST Quality Monitor (SQUAM)

www.star.nesdis.noaa.gov/sod/sst/squam/

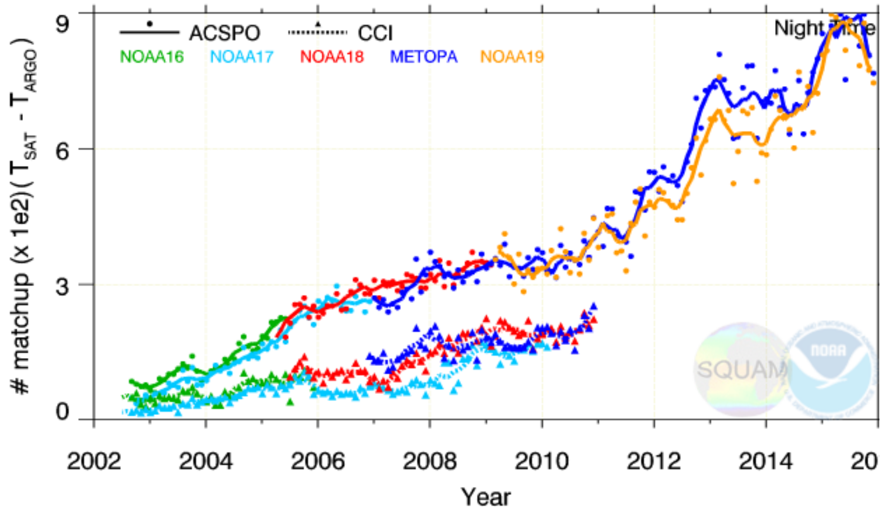
2. RAN1 vs. CCI v1.0

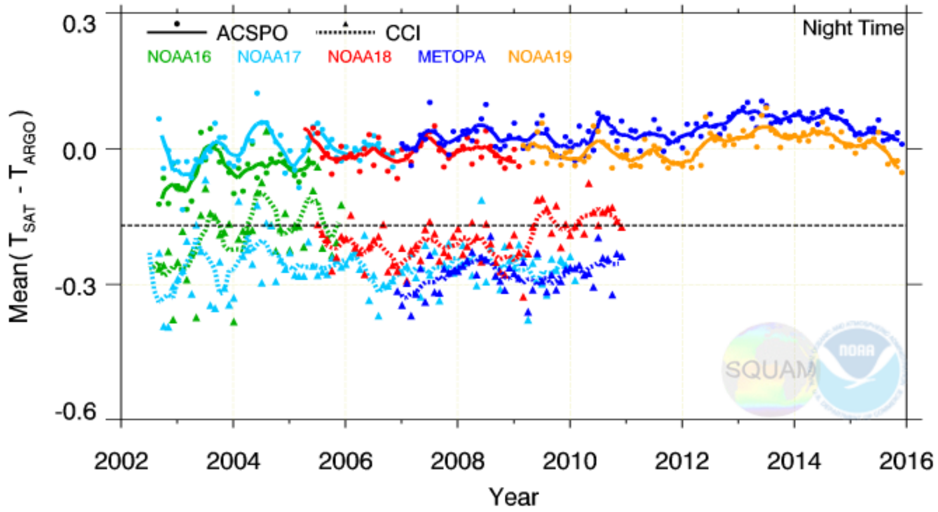
Validation of Nighttime AVHRR RAN1 and CCI v1.0 Vs. Drifters + Trop. Moor.



- RAN1 reports 2 satellites at a time (CCI AVHRR: up to 3 satellites at a time)
- Each satellite in RAN1 reports ×2 more retrievals than in CCI
- In 2016, number of RAN1 match-ups ~60K/month
- RAN1 bias vs. drifters + TMs is ±0.05K.
- CCI SST: "skin product" resulting in a -0.17K bias
- RAN1 SD~0.3K are smaller than CCI SD~0.4K

Validation of Nighttime AVHRR RAN1 and CCI v1.0 Vs. Argo Floats





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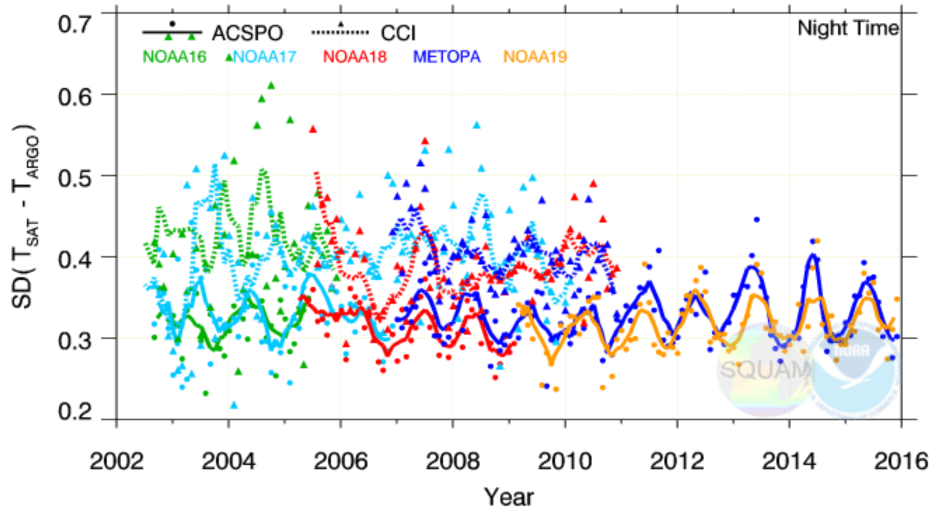

AVHRR RAN Summary and Future Work

AVHRR RAN1

- ✓ Data available from Jul 2002 – Dec 2015, two best satellites at a time
- ✓ Comparisons with two other AVHRR reprocessed datasets, PFV5.2 and CCI v1.0, show that RAN1 is better harmonized with *in situ* (drifter + TM) SSTs
  - Global biases are near-zero because of 3-month moving regression
  - Regional biases minimized using the new single scanner error statistics (SSES) trained against (drifters + TM)
  - Bias-corrected SST: good proxy for "depth" SST (*Petrenko et al, JTECH 2016*)
- ✓ RAN1 also agrees better with independent Argo floats than PFV5.2 and CCI

Future work: AVHRR RAN2 and RAN3

- ✓ AVHRR recalibration effort underway – improved L1b will be used in future RANs
- ✓ Initial plan is go back to 1994 (users' requested to cover GOES era)
- ✓ Then cover full AVHRR era from 1981 – pr

Challenges

- ✓ The need to use AVHRR/2 (inferior to AVHRR/3s)
- ✓ CRTM is used in ACSPO, in conjunction with first guess SST (CMC) and atmospheric profiles (GFS). Our GFS archive only goes back to 2002. CMC SST is only available from 1991–pr (ATSR era). Need use ERA/MERRA & Reynolds L4
- ✓ Non-uniform *in situ* data (ships must be used for Cal/Val in the 1980s)


Thank You!