NOAA-20 VIIRS SST Provisional Maturity

April 18, 2018

JPSS SST Lead

Alexander Ignatov (STAR)

Outline

- SST Cal/Val Team Members
- VIIRS Regression SST Algorithms & Bands Employed
- Status of N20 SST Products, Monitoring/Validation, Distribution, Archival, Users
- JPSS SST Requirements
- Findings/Issues for Provisional Maturity
- Documentation (Science Maturity Check List)
- Conclusion
- Path Forward

STAR SST Cal/Val Team

Name	Organization	Tasks
Ignatov, Sasha	STAR	JPSS Algorithm & Cal/Val Lead
DiGiacomo, Paul	STAR	JPSS Ocean Lead/CoastWatch
Lance, Veronica	STAR – GST	Coast Watch / JPSS Ocean Coordinator
Sapper, John	OSPO	NDE and OSPO Operations, Data distribution & Archival
Kihai, Yury	STAR – GST	ACSPO SW/HW; Preprocessor; L2P Code; In situ match-ups
Pennybacker, Matthew	STAR – GST	L3U/C/S Code/Algorithms (U=Uncollated; C=Collated; S=Super-Collated); Resampling; Pattern Recognition; Ocean Fronts
Jonasson, Olafur	STAR – GST	VIIRS SST Reanalysis (RAN); RDR-to-SDR; SST Quality Monitor (SQUAM)/Monitoring IR Clear-sky Radiances for SST (MICROS) – back end
Petrenko, Boris	STAR – GST	ACSPO Algorithms: Clear-Sky Mask/SST/Error Characterization
Zhou, Xinjia	STAR – CIRA	SST Quality Monitor (SQUAM)/Monitoring IR Clear-sky Radiances Oceans for SST (MICROS)/In Situ Quality Monitor (*i*Quam) – back end
Ding	STAR – CIRA	ACSPO Regional Monitor for SST (ARMS) – back end; L3U product
He, Kai	STAR – GST	SQUAM/MICROS/iQuam/ARMS – front ends
Kramar, Maxim	STAR – GST	ACSPO Beta testing in STAR; Routine scripts/cron jobs
Xi, Xin	STAR – CIRA	Monitoring VIIRS Radiances (Stability/Consistency); SST/Aerosol correction
Gladkova, Irina	STAR–CCNY CREST/GST	L3U/C/S Code/Algorithms (U=Uncollated; C=Collated; S=Super-Collated); Resampling; Pattern Recognition; Ocean Fronts; ARMS
Arnone, Bob	U. Mississippi	SST Cal/Val in coastal areas and from overlapping passes

VIIRS ACSPO SST System & Bands

- VIIRS SST product is produced using the NOAA enterprise Advanced Clear-Sky Processor for Ocean (ACSPO) system
- ACSPO is also employed to process data of polar (AVHRR GAC/FRAC & MODIS) and geostationary (GOES-R ABI, Himawari-8/9 AHI) sensors

Sensor	SST Bands
Night: VIIRS & MODIS	3.7 / 8.6 / 10.8 / 12 µm 3.7 / 8.5 / 11.0 / 12 µm
Day: VIIRS & MODIS	10.8 / 8.6 / 12 µm 11.0 / 8.5 / 12 µm
ABI & AHI (Day & Night)	8.5 / 10.3 / 11.2 / 12.3 µm

- VIIRS/MODIS and ABI/AHI have new band(s) suitable for SST. In particular, M14 @8.6µm is now included in day and night retrievals (in addition to daytime split-window M15/16 centered at 11/12µm, and nighttime shortwave M12 @3.7µm)
- Two reflectance bands centered at 0.68/0.86 µm (VIIRS M5/7) are also employed in ACSPO for SST QC

VIIRS Regression SST Algorithms

Night:

$$T_S = a_0 + a_1T_{11} + a_2(T_{11}-T_{3.7}) + a_3(T_{11}-T_{8.6}) + a_4(T_{11}-T_{12}) + [a_5 + a_6T_{11} + a_7(T_{11}-T_{3.7}) + a_8(T_{11}-T_{8.6}) + a_9(T_{11}-T_{12})]S_\theta + [a_{10}(T_{11}-T_{3.7}) + a_{11}(T_{11}-T_{8.6}) + a_{12}(T_{11}-T_{12})]T_S^0$$

Day:

$$T_S = a_0 + a_1T_{11} + a_3(T_{11}-T_{8.6}) + a_4(T_{11}-T_{12}) + [a_5 + a_6T_{11} + a_8(T_{11}-T_{8.6}) + a_9(T_{11}-T_{12})]S_\theta + [a_{11}(T_{11}-T_{8.6}) + a_{12}(T_{11}-T_{12})]T_S^0$$

$T_{3.7}$, $T_{8.6}$, T_{11}, T_{12}	BTs at 3.7, 8.6, 11 and 12 µm
$S_\theta = 1/\cos(\theta) - 1$	θ is VZA
T_S^0	L4 SST in °C (currently by Canadian Meteorological Center – CMC)
a's	regression coefficients, trained against drifters and mooring buoys

- Regressors are constructed from 3 (day) or 4 (night) radiometric bands, and VZA
- Potential instabilities of the regression coefficients are mitigated by taking special steps to keep only significant number of eigenvectors/values of the covariance matrix

Status of N20 SST Products, Monitoring, Validation, Distribution, Archival

Product	SNPP	N20
L2P (26GB/day)	STAR routine production: Jan’2012	STAR routine production: Jan’2018
	Match-ups w/in situ, Monitoring & Validation in SQUAM/ARMS: Jan’2012	Match-ups w/in situ, Monitoring & Validation in SQUAM/ARMS: Jan’2018
	NDE Operational Production & Distribution via PDA & EUMETCast: Mar’2014	NDE Operational Production and Distribution via PDA & EUMETCast: TBD
	Archived PO.DAAC & NCEI: May’2014	Archived PO.DAAC & NCEI: TBD (Preliminary agreement to archive N20)
	Distributed via Coast Watch: 2017	Distributed via Coast Watch: 2018
0.02º L3U (0.5GB/day)	STAR routine production: May’2014	STAR routine production: Jan’2018
	Match-ups w/in situ, Monitoring & Validation in SQUAM/ARMS: May’2014	Match-ups w/in situ, Monitoring & Validation in SQUAM/ARMS: Jan’2018
	NDE Operational Production & Distribution via PDA & EUMETCast: May’2015	NDE Operational Production and Distribution via PDA & EUMETCast: TBD
	Archived PO.DAAC & NCEI: May’2015	Archived PO.DAAC & NCEI: TBD (Preliminary agreement to archive N20)
	Distributed via Coast Watch: 2017	Distributed via Coast Watch: 2018

ACSPO VIIRS SST Users

Established

- ✓ CMC (D. Surcel-Colan)
- ✓ Met Office OSTIA (S. Good)
- ✓ NOAA CoastWatch (P. DiGiacomo/V. Lance) – N20 test data distributed via CW
- ✓ NOAA Geo-Polar Blended (E. Maturi/A. Harris) – shared N20 test data
- ✓ Australian Bureau of Meteorology (H. Beggs/C. Griffin/P. Govekar) – shared N20 test data
- ✓ NOAA NOS West Coast Ocean Forecast Systems /WCOFS (A. Kurapov)
- ✓ CRW (M. Eakin /W. Skirving / E. Geier)
- ✓ U. Melbourne (A. Babanin/H. Zhang/I. Yang)
- ✓ Danish Meteorological Institute (Jacob Høyer)
- ✓ Digital Globe, Inc. – supports US Fisheries (USA)
- ✓ NOAA NOS Chesapeake Bay Ocean Forecast System/CBOFS (C. Brown)

Emerging

- ✓ NOAA NMFS (C. Wilson /K. Hyde/K. Shotwell)
- ✓ NCEP NCODA (J. Cummings/I. Rivin/A. Mehra)
- ✓ NASA Global Model Assimilation Office (R. Todling/S. Akella)
- ✓ Japan Met Agency/MGDSST (T. Sakurai)
- ✓ Monterey Bay Aquarium Research Institute (MBARI) (M. Messie)
- ✓ NOAA OISST (T. Smith/V. Banzon)
- ✓ NCEP RTG (B. Grumbine)

JPSS SST Requirements

EDR Attribute	Threshold	Objective
a. Horizontal Cell Size (Res)	1.6km[1]	0.25km
b. Mapping Uncertainty, 3σ	2km[1]	0.1km
c. Measurement Range	271 K to 313 K	271 K to 318 K
d. Measurement Accuracy[2]	0.2K	0.05K
e. Measurement Precision[2]	0.6K	0.2K (<55° VZA)
f. Refresh Rate	12 hrs	3 hrs
g. Latency	90 min	15 min
h. Geographic coverage	Global cloud and ice-free ocean; excluding lakes and rivers	Global cloud and ice-free ocean, plus large lakes and wide rivers

[1]Worst case scenario (corresponding to swath edge); both numbers are ~1km at nadir

[2]Represent global mean bias and standard deviation validation statistics against quality-controlled drifting buoys (for day and night, in full VIIRS swath, in full range of atmospheric conditions). Uncertainty is defined as square root of accuracy squared plus precision squared. Better performance is expected against ship radiometers.

JPSS Data Products Maturity Definition

JPSS/GOES-R Data Product Validation Maturity Stages –
COMMON DEFINITIONS (Nominal Mission)

1. Beta

- Product is minimally validated, and may still contain significant identified and unidentified errors.
- Information/data from validation efforts can be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose.
- Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists.

2. Provisional – Currently, N20 SST Meets Provisional Maturity Requirements

- ✓ Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts.
- ✓ Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose.
- ✓ Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists.
- ✓ Product is recommended for potential operational use (user decision) and in scientific publications after consulting product status documents.

3. Validated

- Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).
- Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.
- Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.
- Product is ready for operational use based on documented validation findings and user feedback.
- Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument.

Evaluation in the NOAA SST Monitoring System (Comprising Five Major Sub-systems)

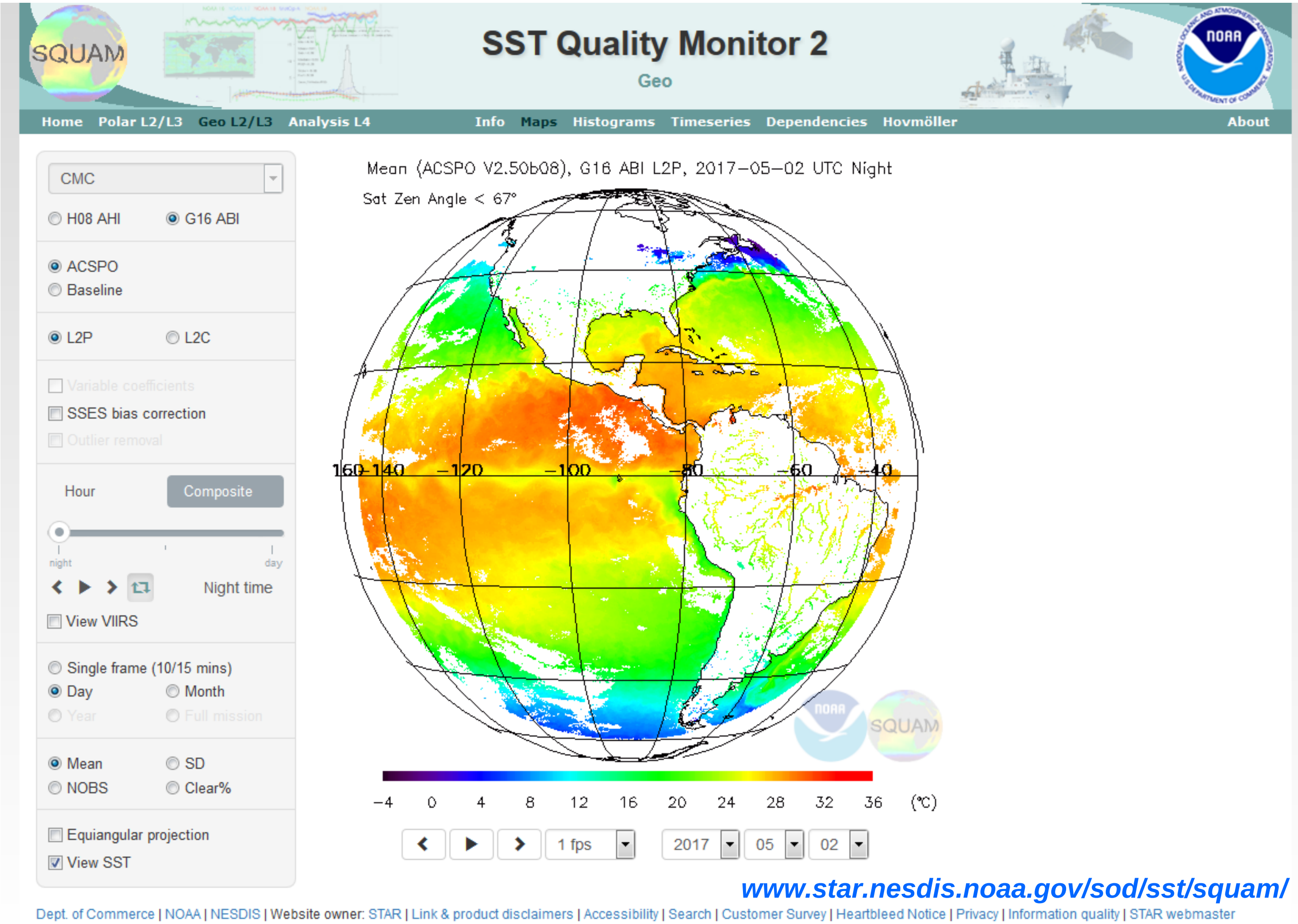
- Visualization of validation using match-ups with global Level 4 (L4) fields, Canadian Meteorological Center (CMC) in the NOAA SST Quality Monitor (**SQUAM**; *www.star.nesdis.noaa.gov/sod/sst/squam/; Dash et al., 2014*)
- Validation against QC'ed *in situ* SSTs from NOAA *In situ* SST Quality Monitor (***i*Quam**; *www.star.nesdis.noaa.gov/sod/sst/iquam/; Xu, Ignatov, 2014*)
- **Match-up** code of satellite SSTs with in situ iQuam SSTs and global L4 analyses
- Visualization of regional imagery in the ACSPO Regional Monitor for SST (**ARMS**; *www.star.nesdis.noaa.gov/sod/sst/arms/; Ding et al, 2016*)
- Monitoring of IR Clear-sky SST Radiances over Ocean for stability/consistency (**MICROS**; *www.star.nesdis.noaa.gov/sod/sst/micros/; Liang et al, 2011*)

All five SST validation subsystems have been fully established, documented & well utilized by the SST community (e.g., Group for High Resolution SST, GHRSST)

Consistent QC/Val/Evaluation methodologies applied to various *in situ/*satellite SSTs and radiances, produced from JPSS, POES, H8, GOES-R etc, to facilitate selection of best fit-for-purpose product to meet users' needs

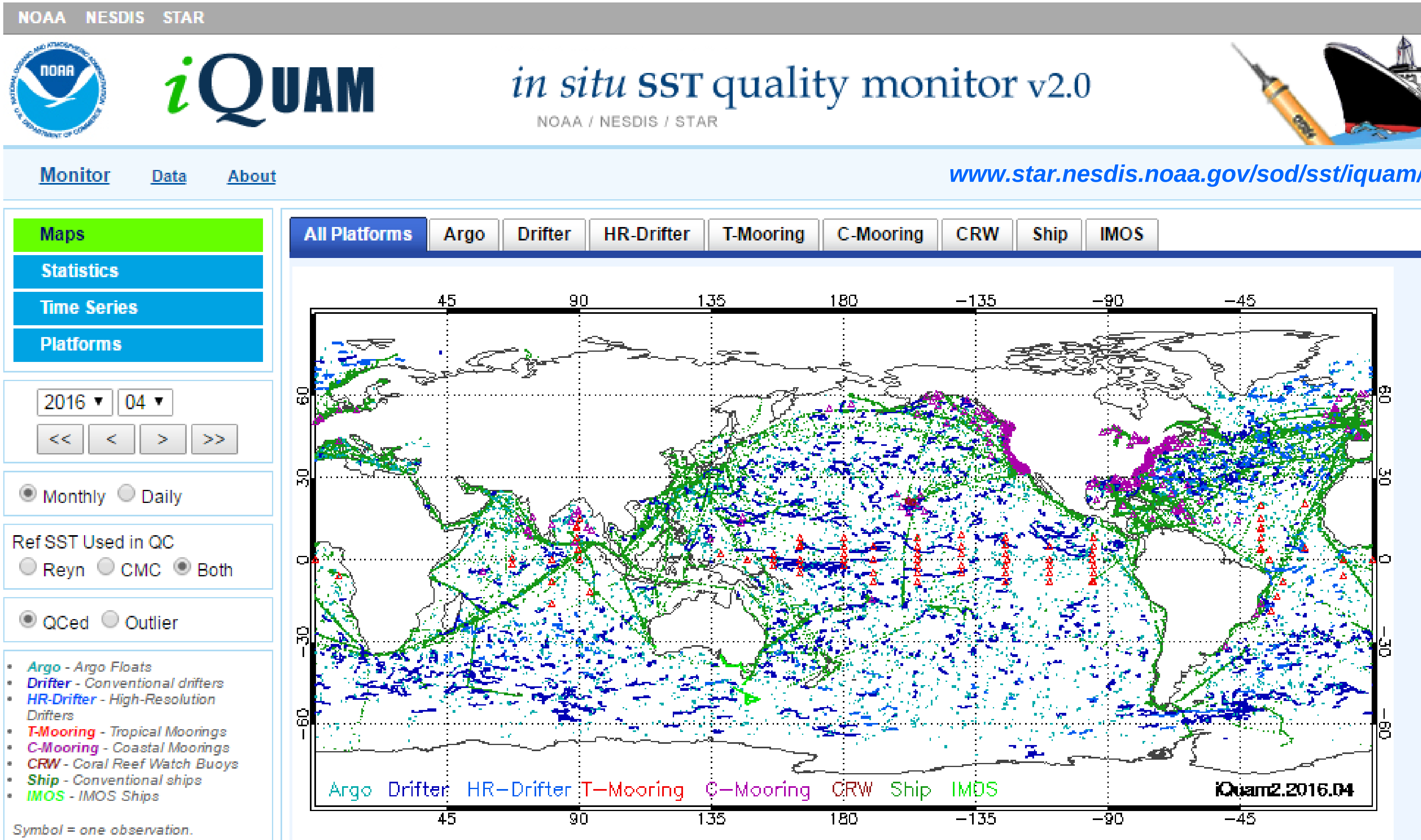
NOAA SST Monitoring allows easy comparisons of N20 SST with SNPP SST

SST Quality Monitor (SQUAM)



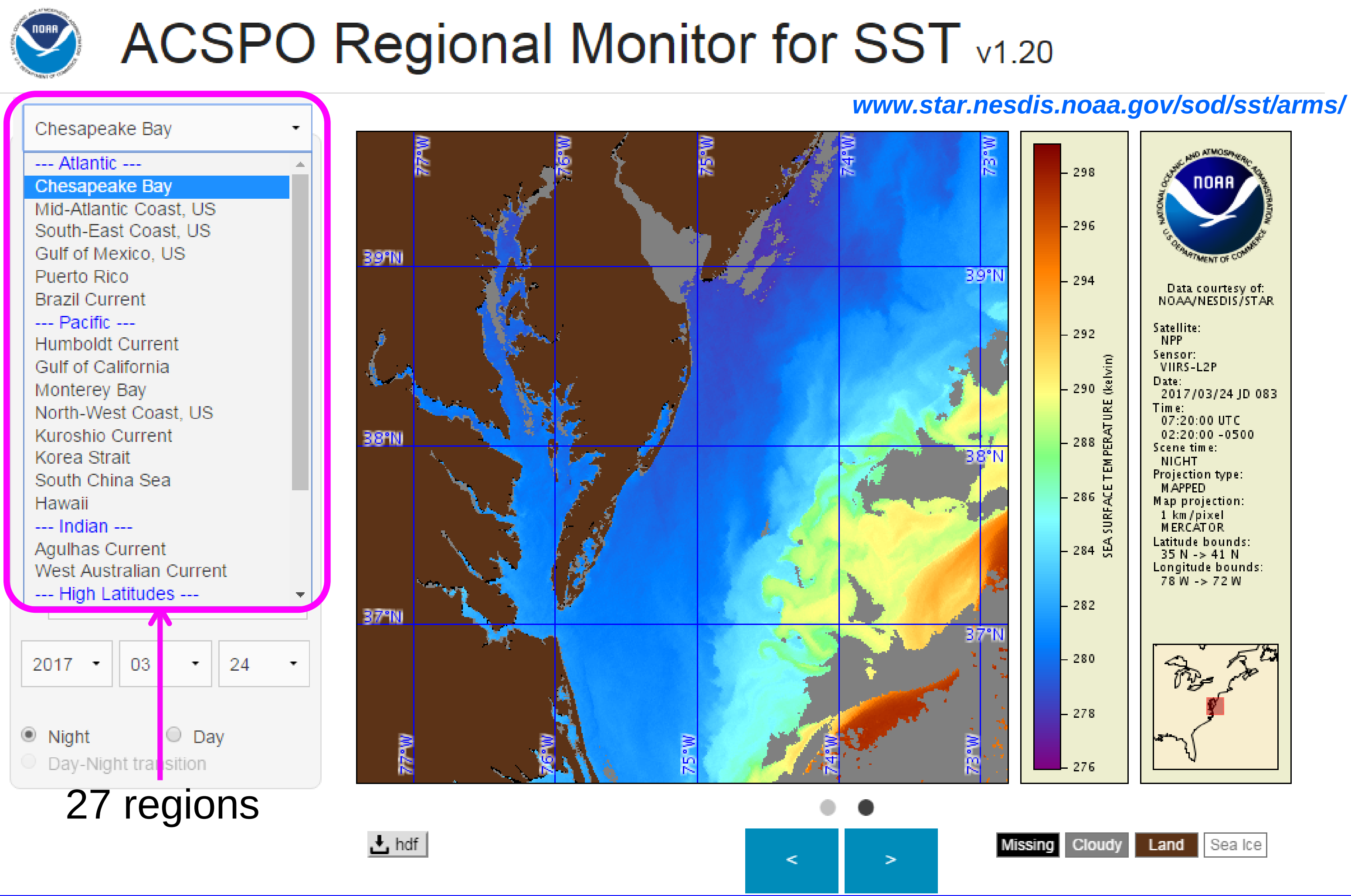
SQUAM monitors NOAA & partners SSTs globally, against *in situ* and L4 analyses

In situ SST Quality Monitor (iQuam)



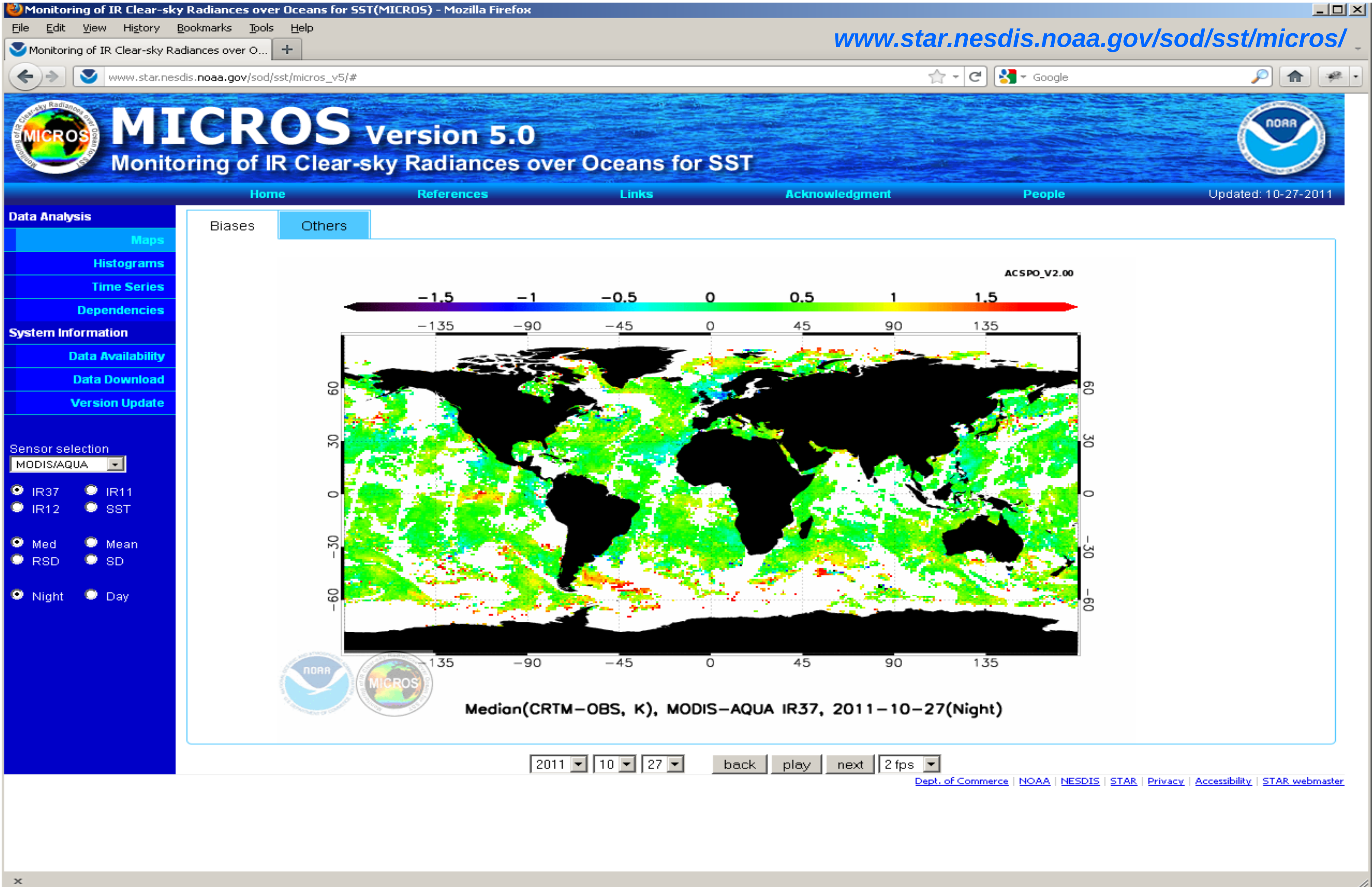
***i*Quam applies uniform QC to *in situ* SSTs (drifters, moorings, Argo, ships) & serves to users**

ACSPO Regional Monitor for SST (ARMS)



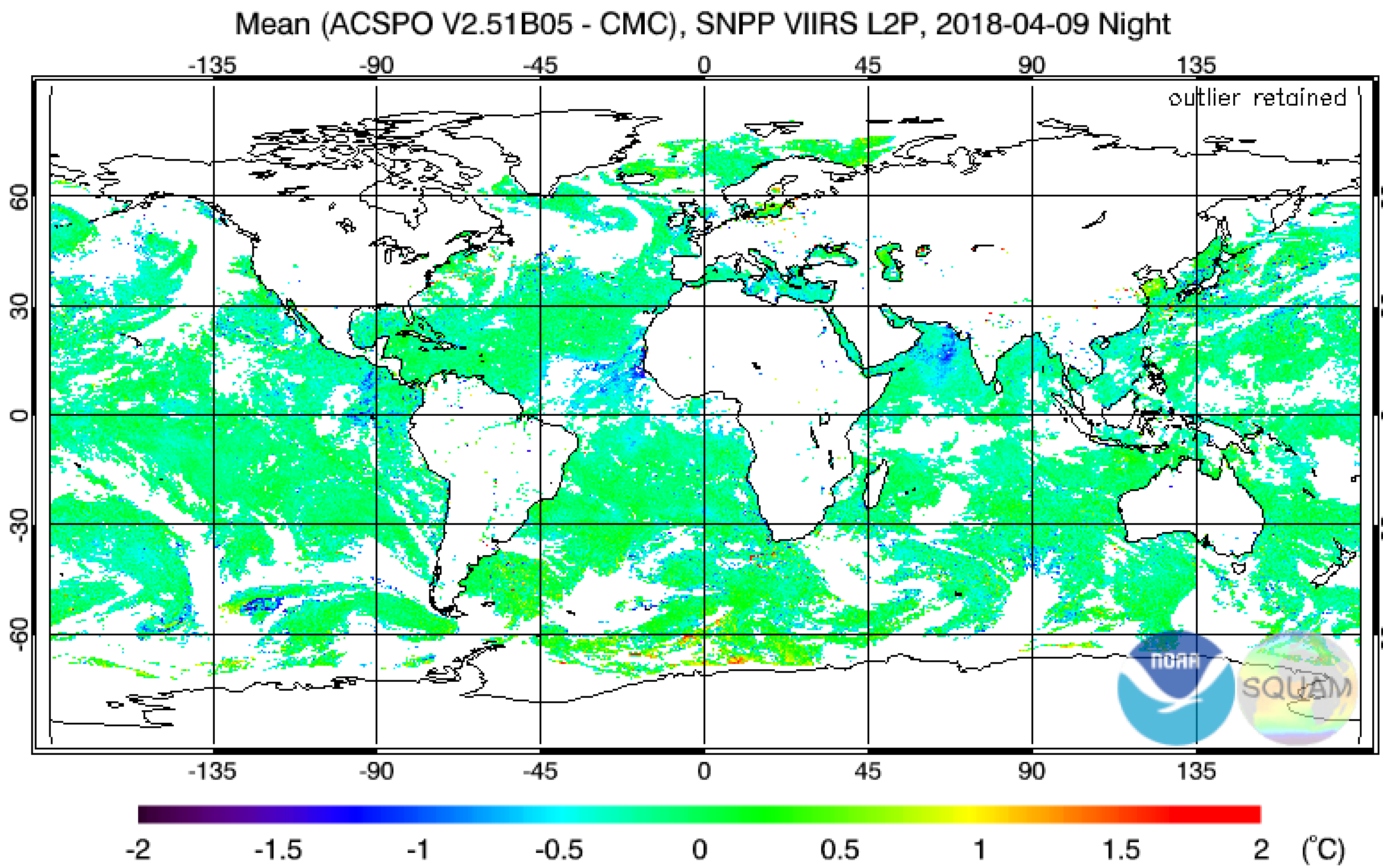
ARMS monitors several L2/3/4 SST products regionally & checks them for consistency

Monitoring of IR Clear-sky Radiances over Ocean for SST (MICROS)



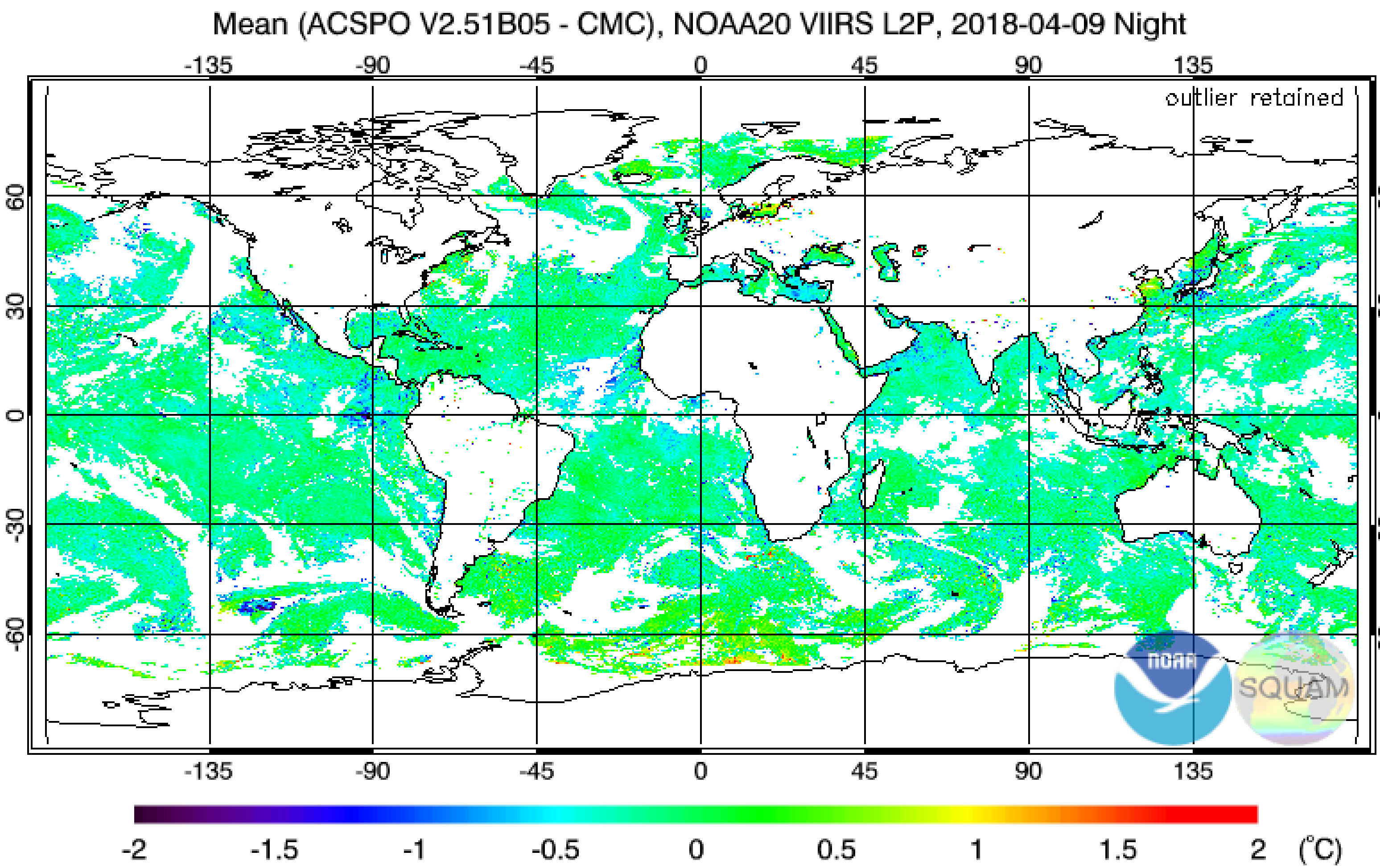
MICROS monitors radiances in SST bands against CRTM for stability & cross-platform consistency

NPP L2P – CMC L4 SST: 9 April 2018 (Night)



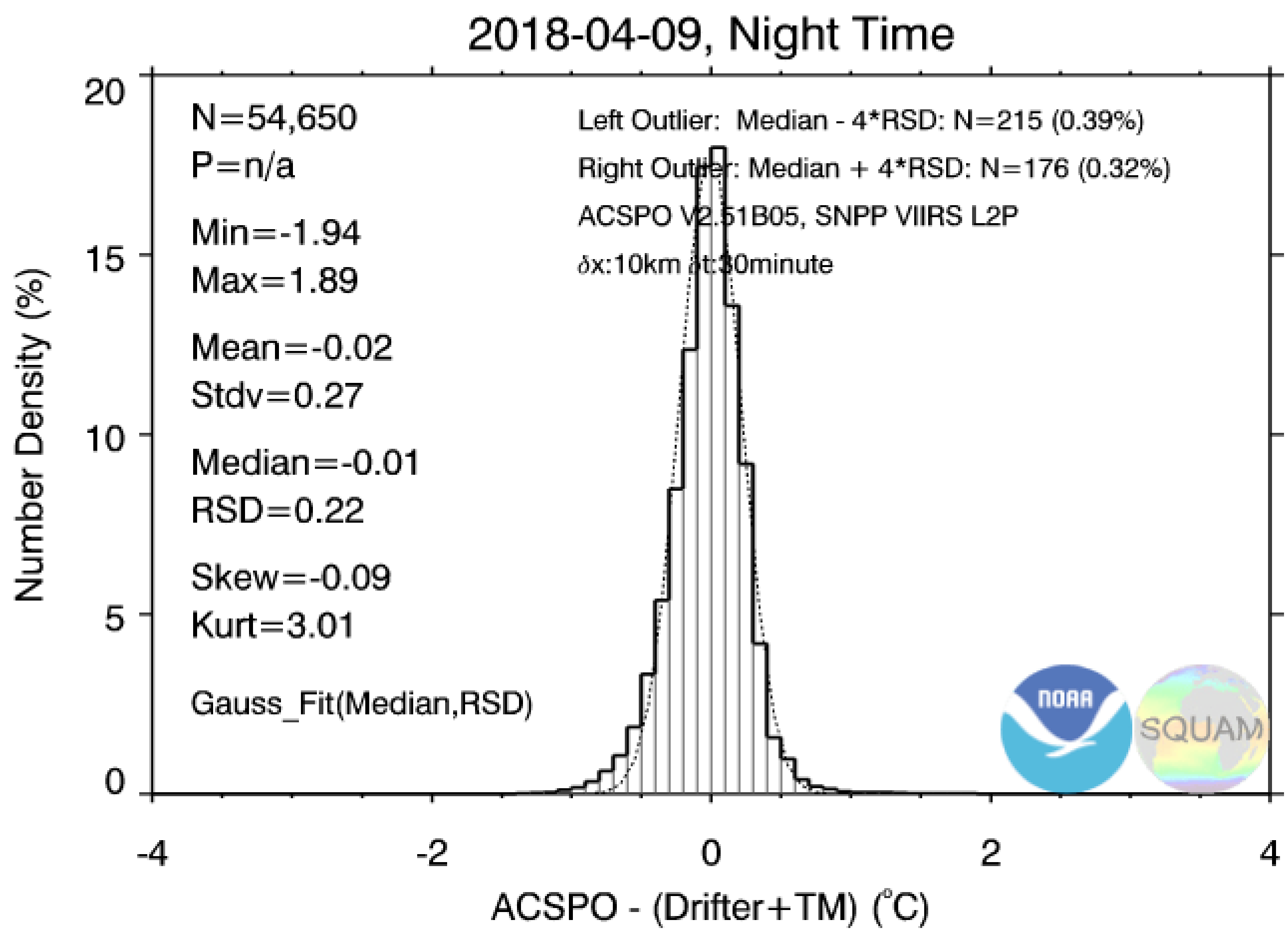
Coldish spots suggest residual cloud/aerosol contamination in SNPP SST

N20 L2P – CMC L4 SST: 9 April 2018 (Night)



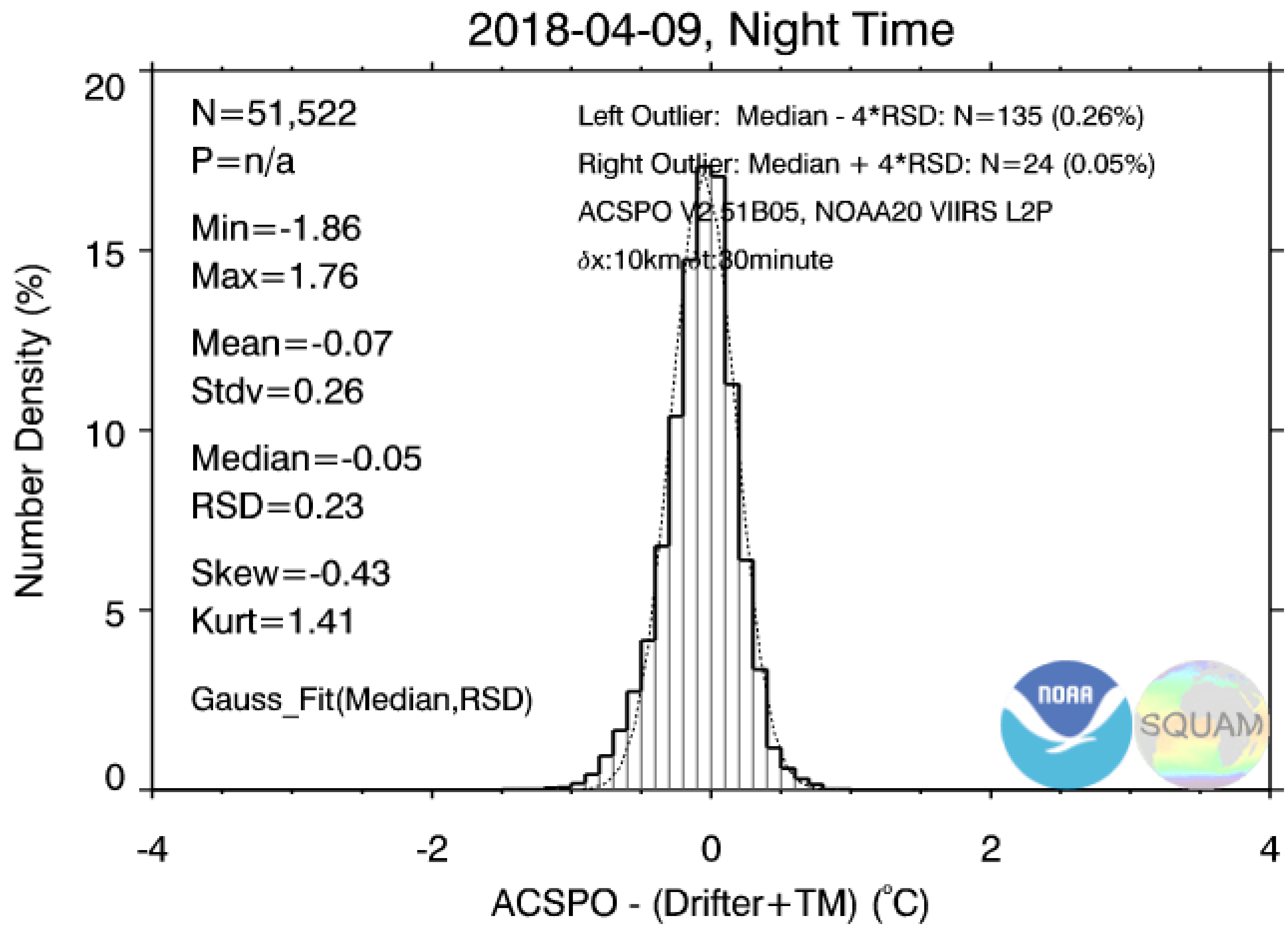
Coverage & Residual cloud comparable to SNPP – data fusion is being explored

NPP L2P – in situ SST: 9 April 2018 (Night)



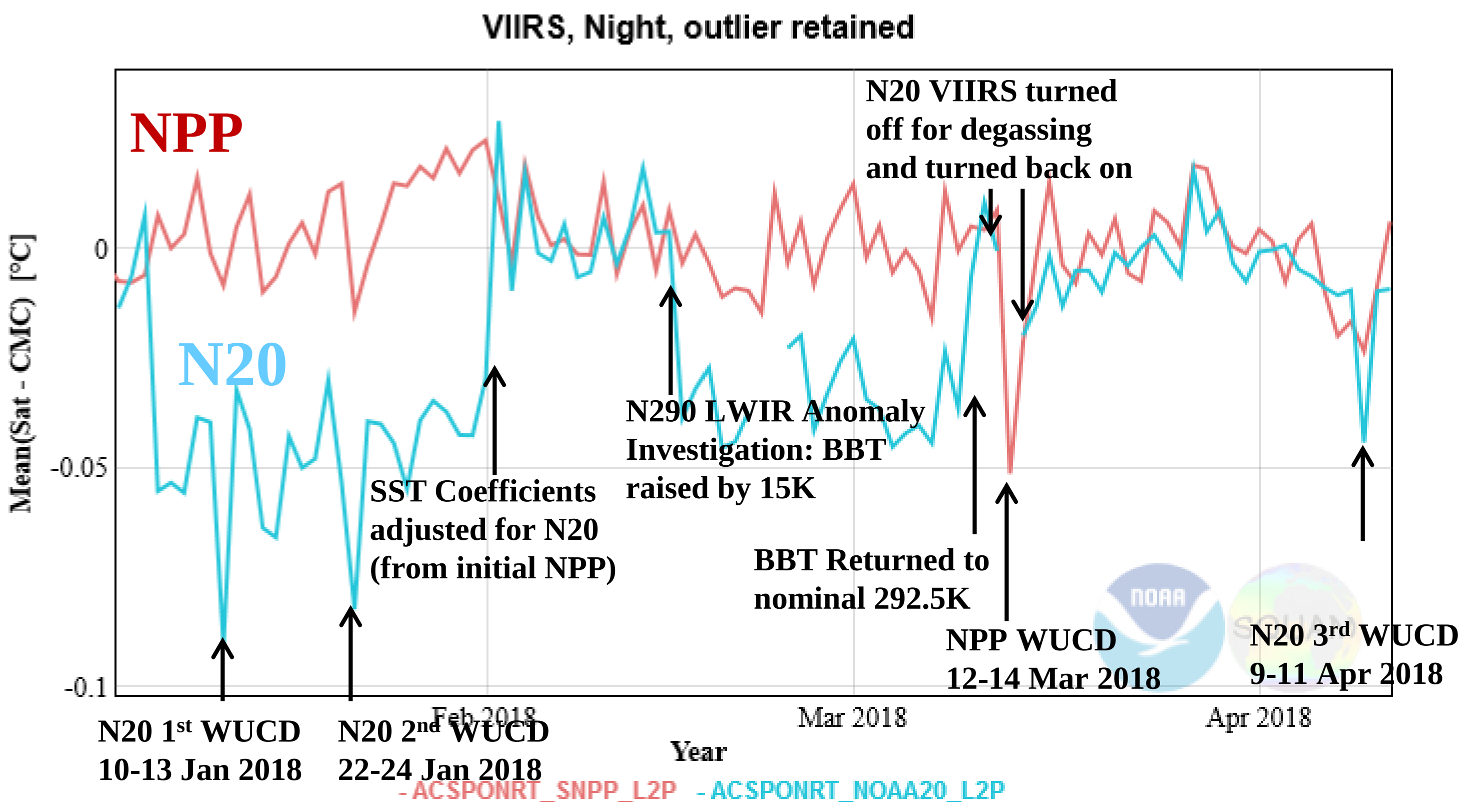
Histogram close to Gaussian shape, Mean Bias close to zero, SD~0.3K

N20 L2P – in situ SST: 9 April 2018 (Night)



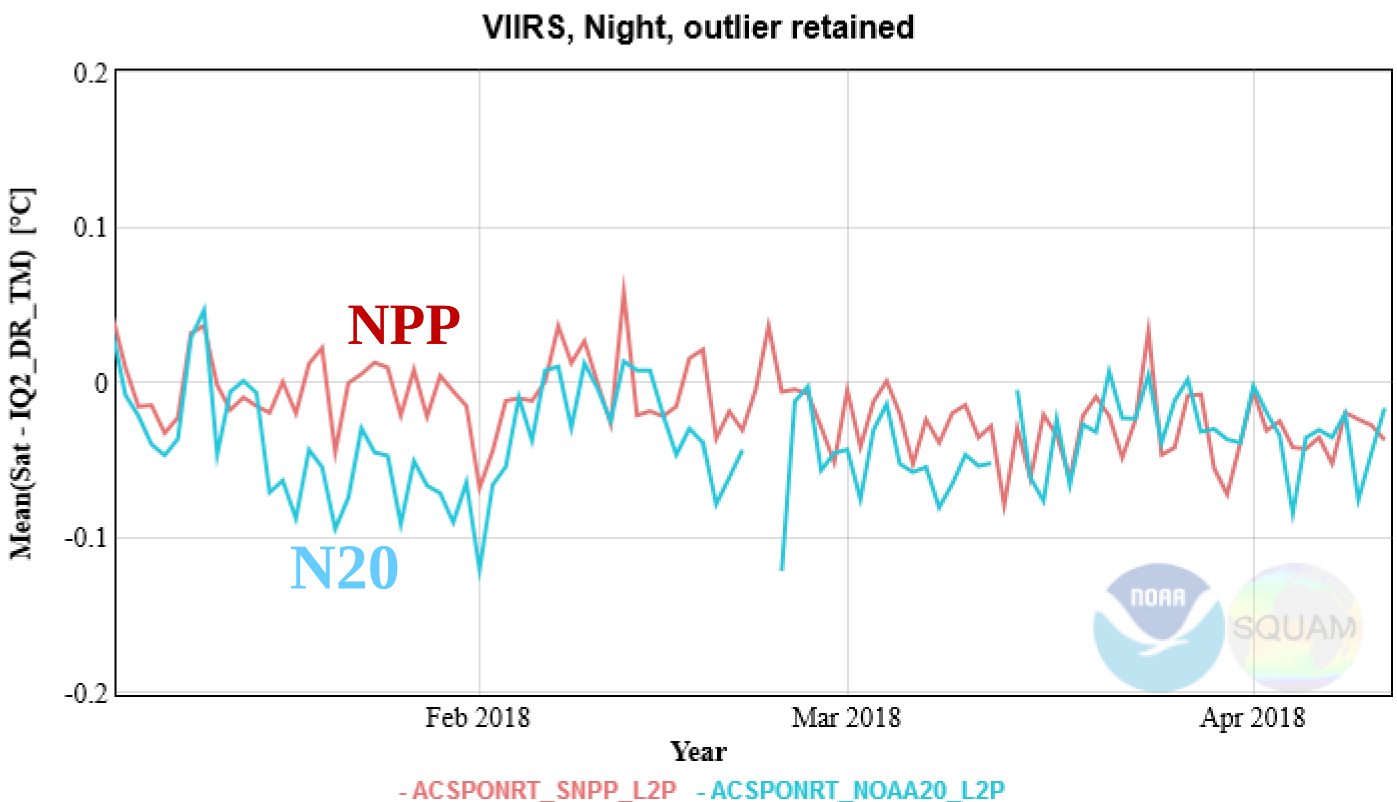
Histogram close to Gaussian shape, Mean Bias -0.05K colder, SD~0.3K

Mean Bias “NPP/N20 L2P – CMC L4” SST (Night)



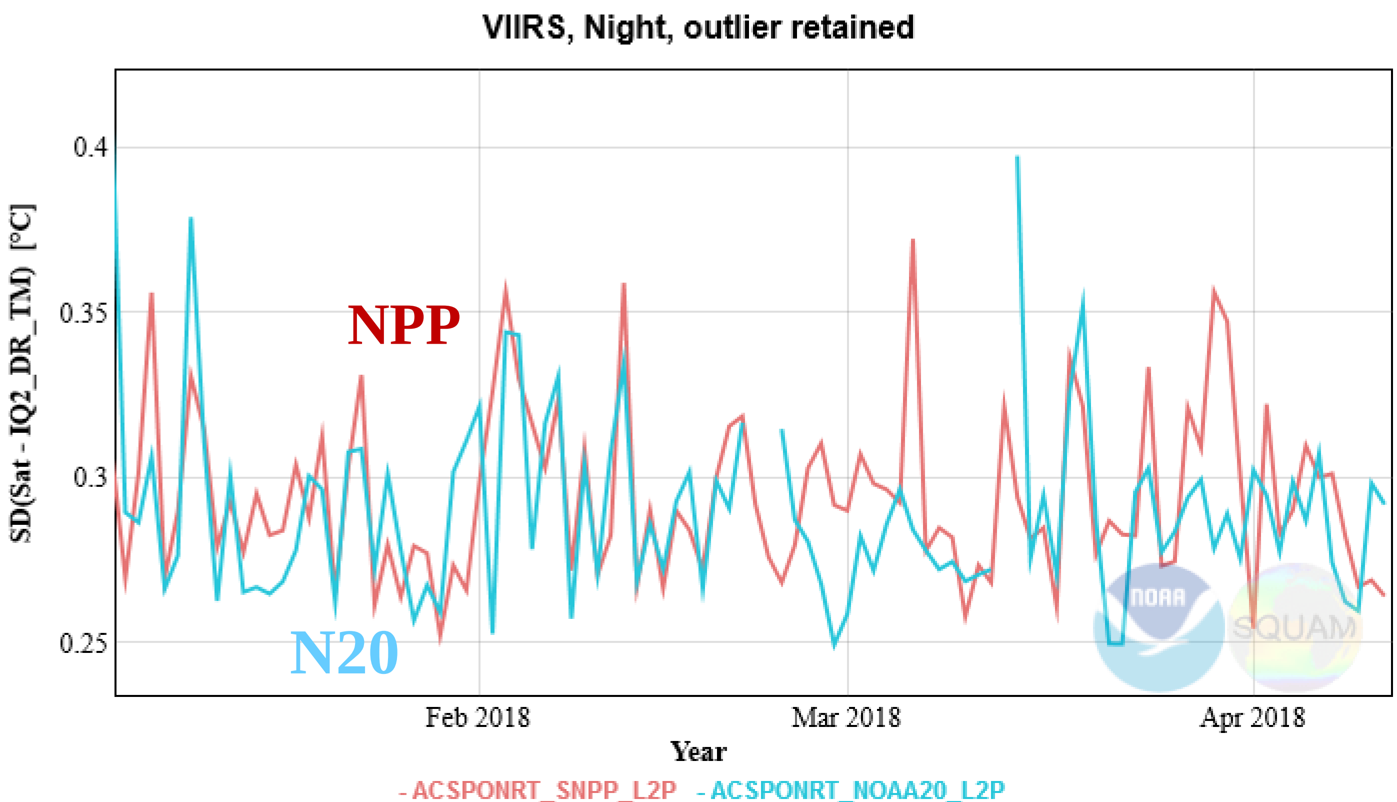
Histogram close to Gaussian shape, Mean Bias -0.05K colder, SD~0.3K

Mean Bias "NPP/N20 L2P – in situ" SST (Night)



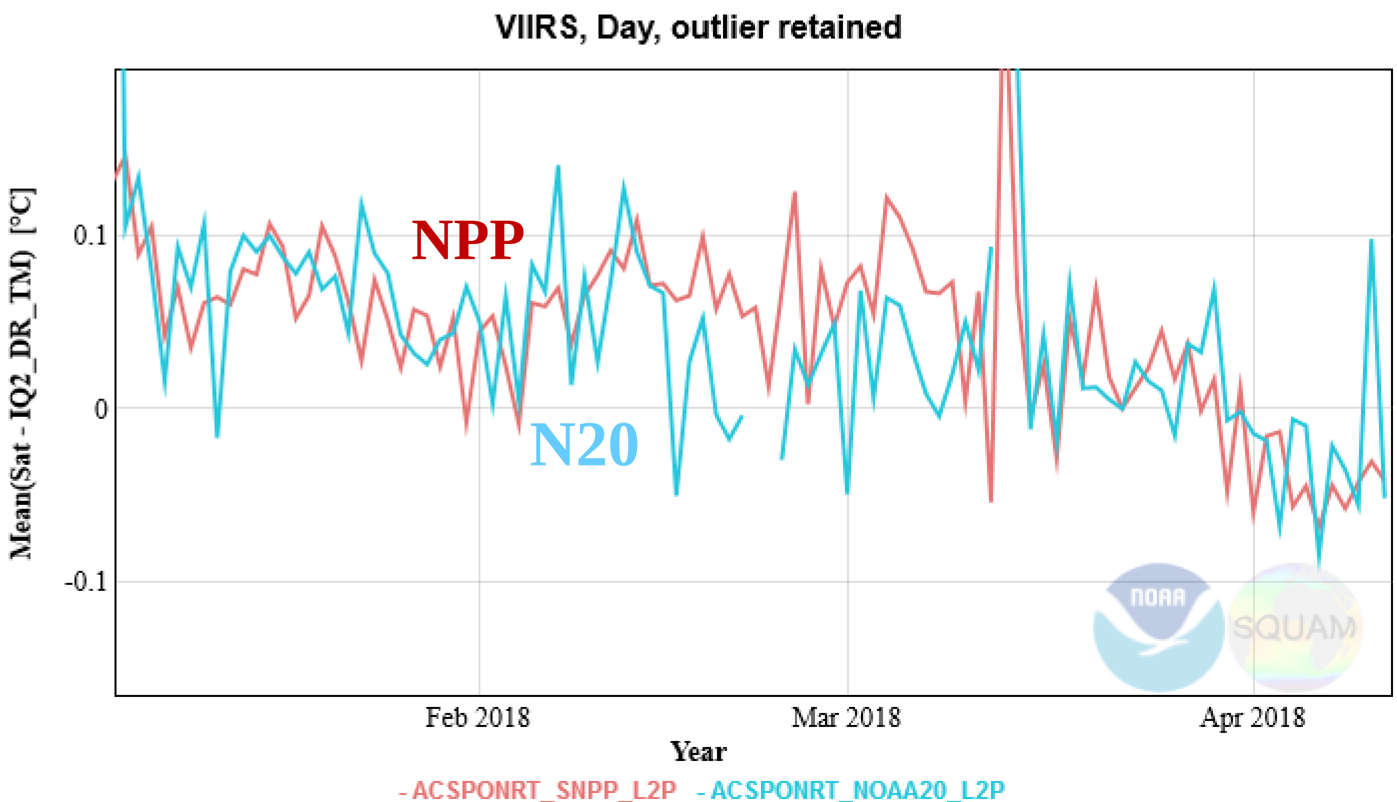
Non-uniformities vs in situ similar to vs L4, but noisier. NPP & N20 SSTs both meet ±0.2K specs

Std. Dev. “NPP/N20 L2P – in situ” SST (Night)



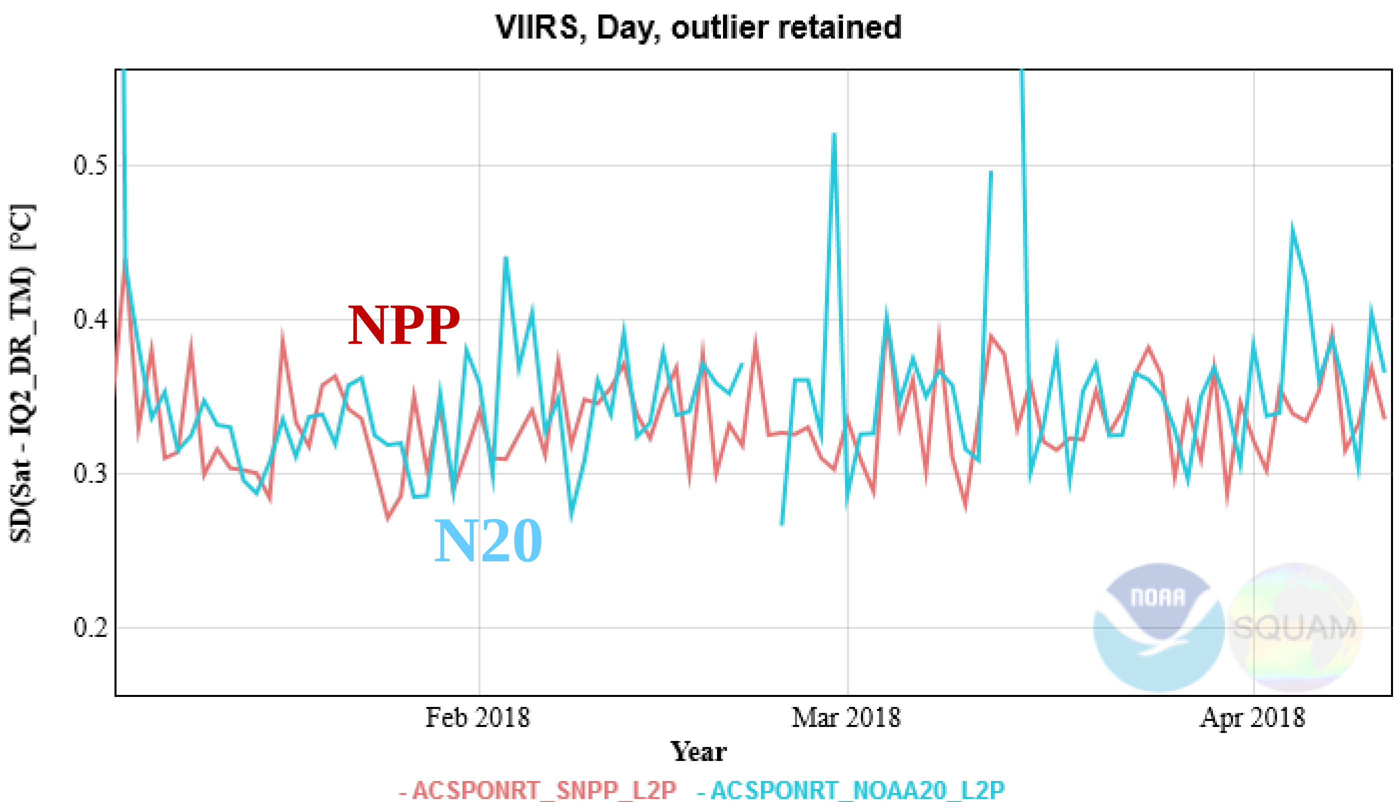
Std. Dev’s wrt in situ SST are comparable and well within 0.6K specs, for both NPP & N20

Mean Bias “NPP/N20 L2P – in situ” SST (Day)



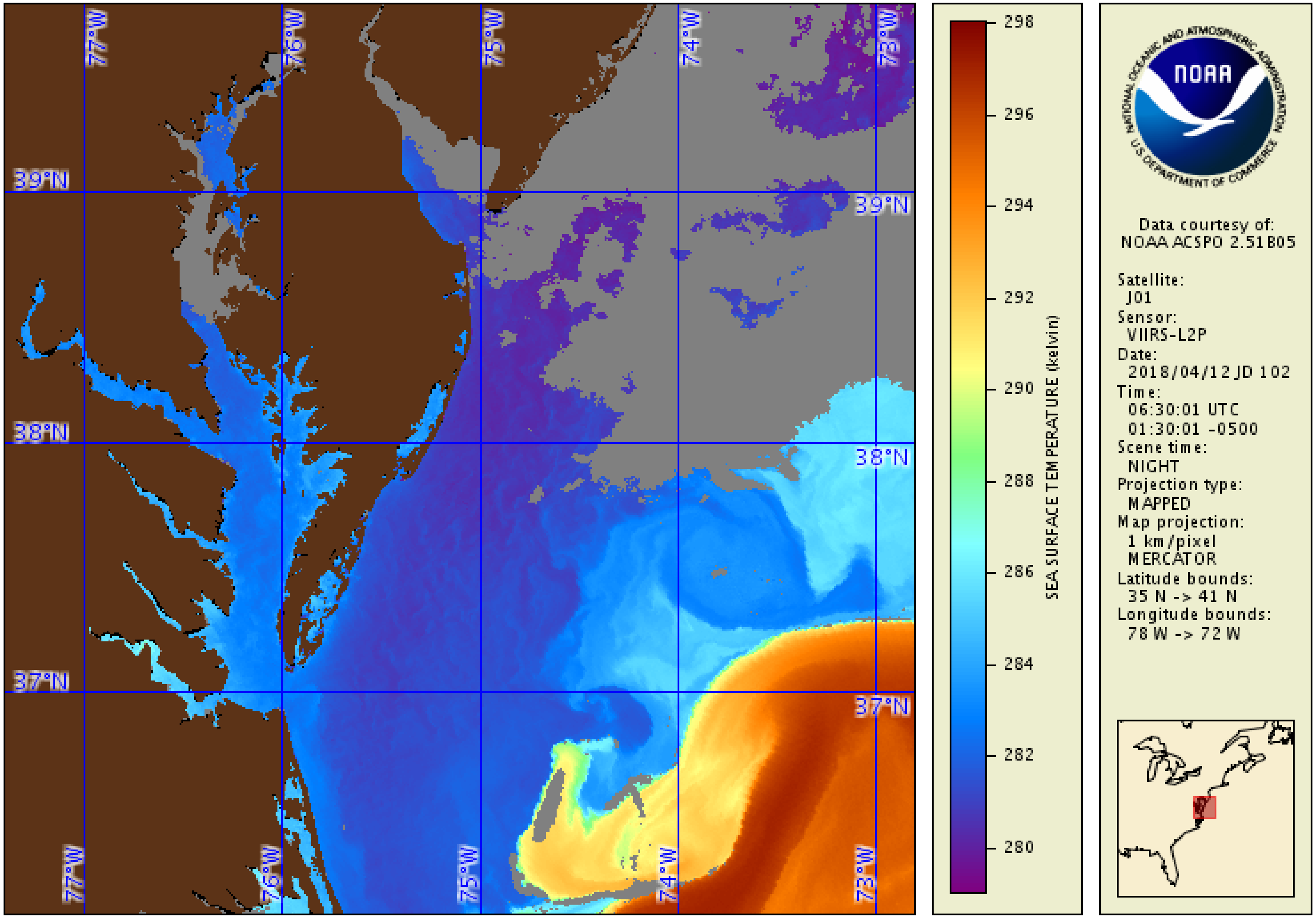
Biases vs. in situ data are consistent between the NPP & N20 SSTs. Both are within ±0.2K specs

Std. Dev. “NPP/N20 L2P – in situ” SST (Day)



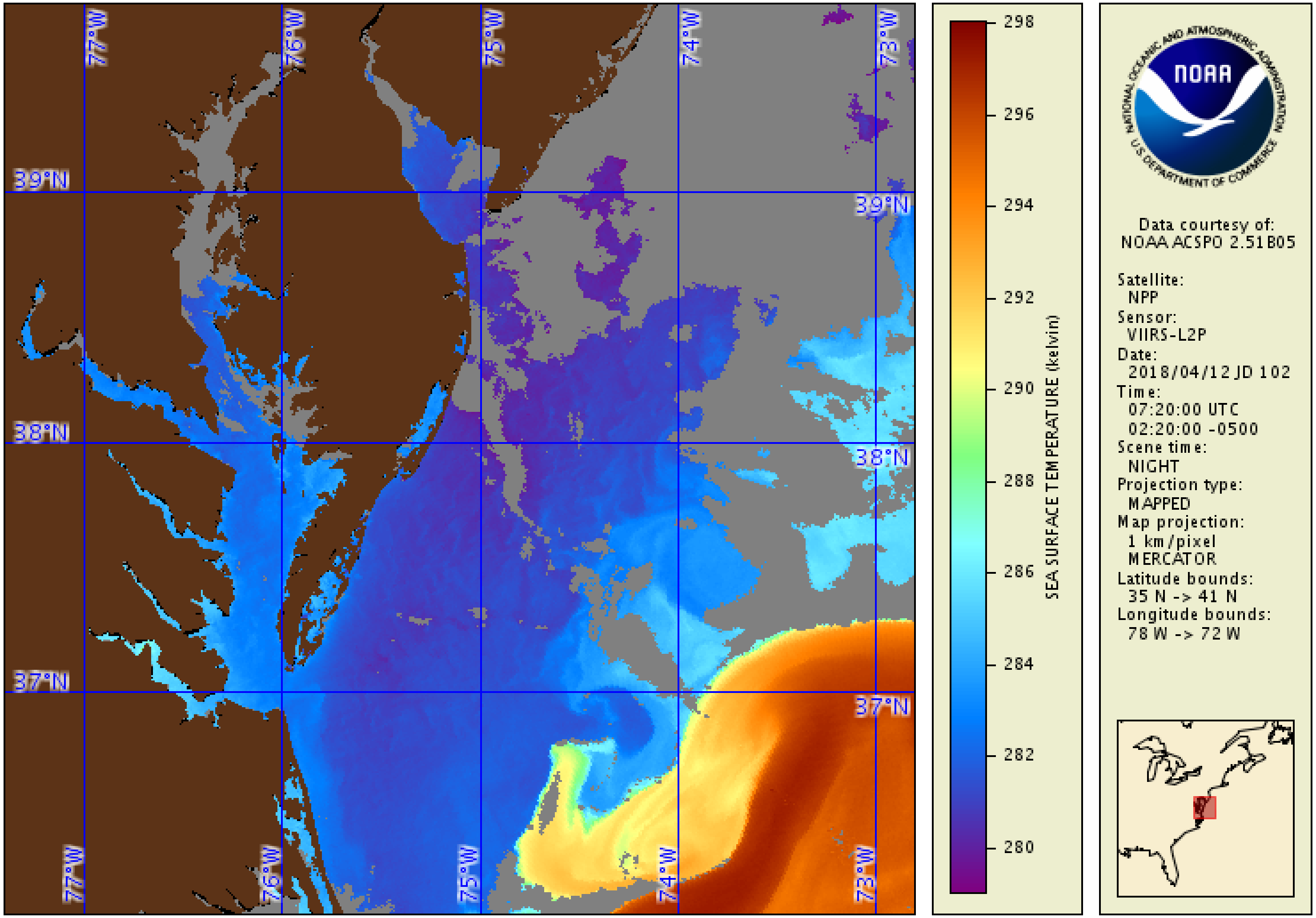
Std. Dev’s wrt in situ SST for NPP/N20 comparable & within specs. Spikes due to sensor outages

N20 SST Imagery: 12 April 2018 (Night)



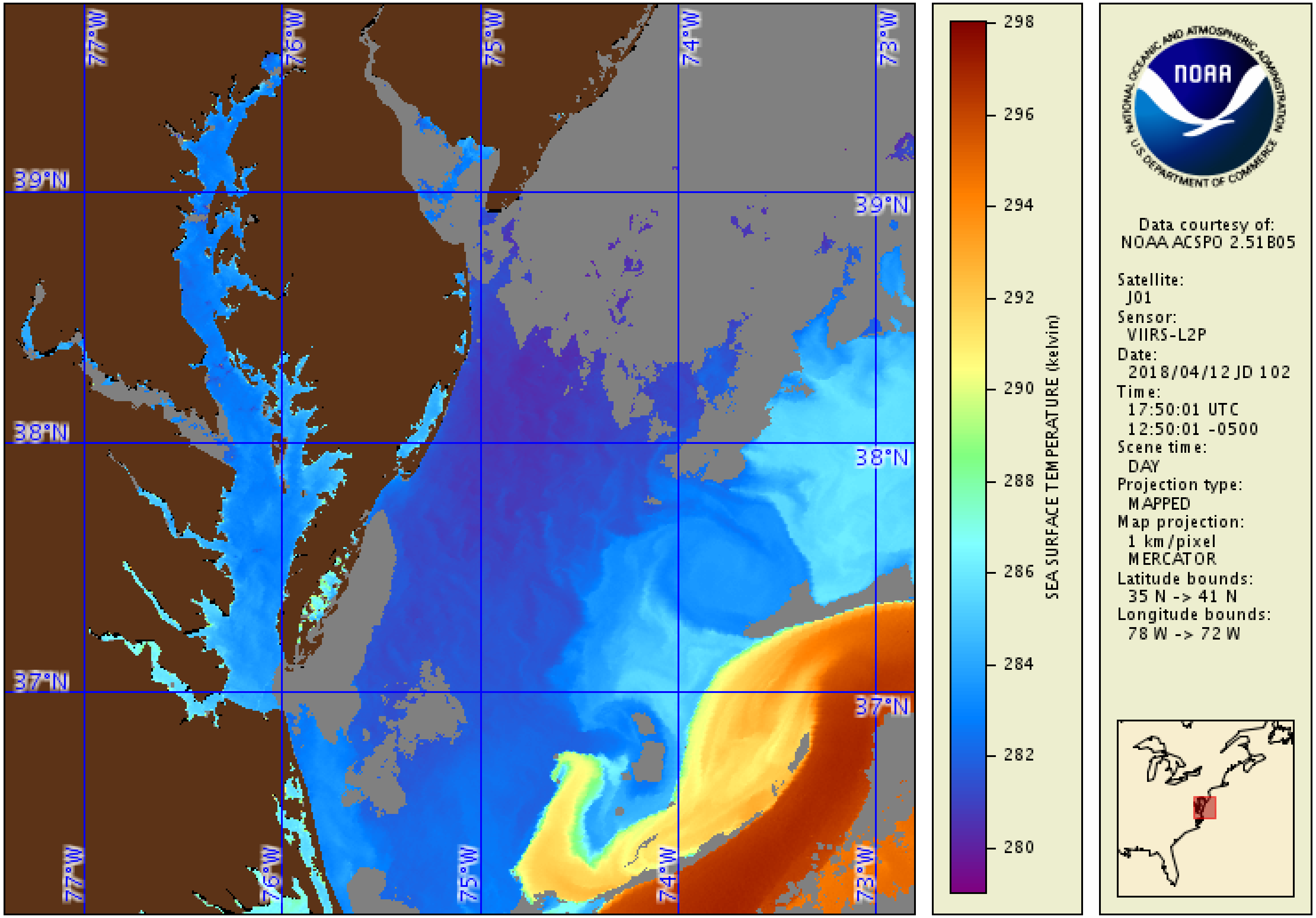
N20 BTs are resampled & destriped. N20 SST Imagery is of high quality and comparable with NPP

NPP SST Imagery: 12 April 2018 (Night)



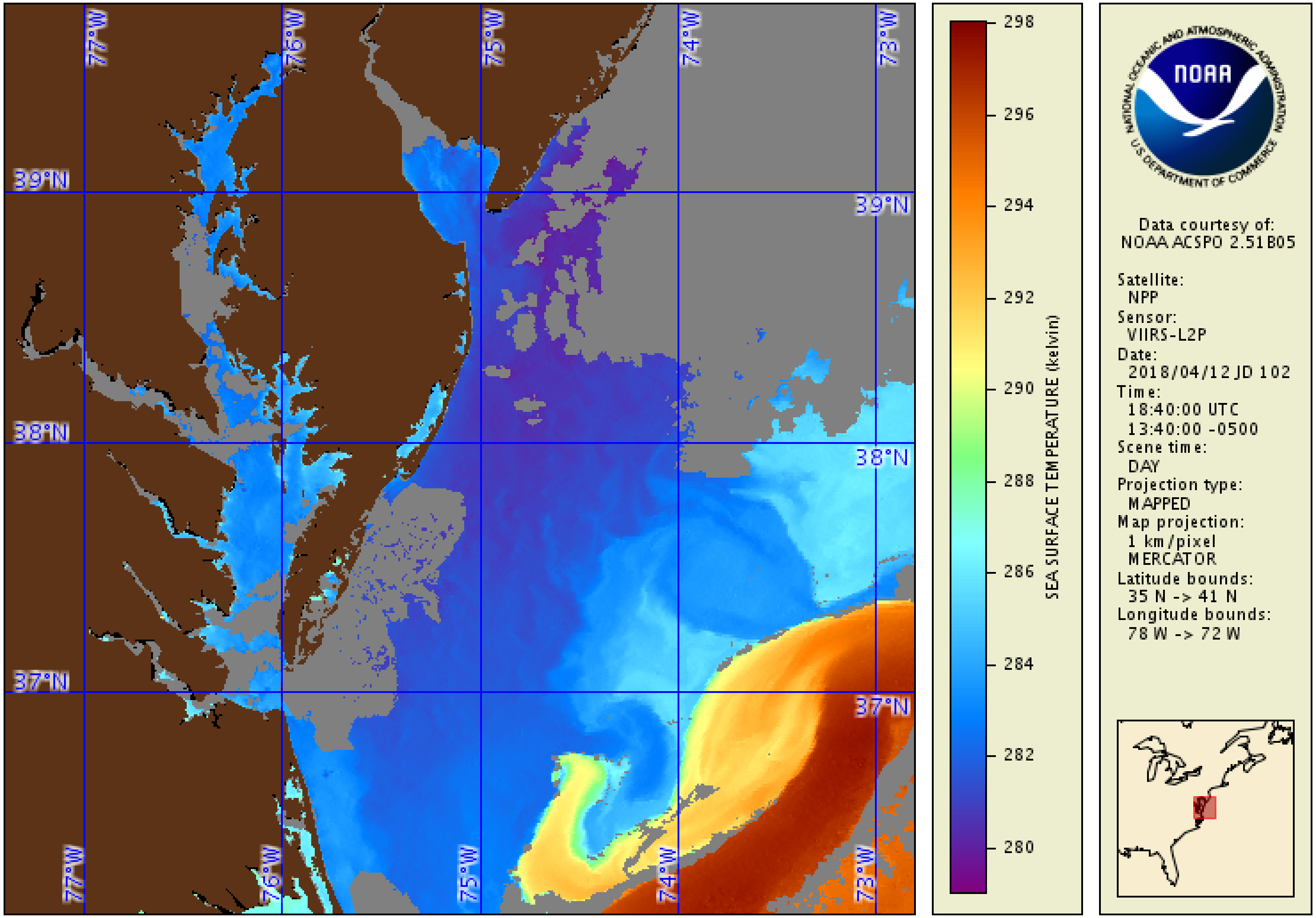
N20 and NPP have complementary coverage and show that features move over 50min time

N20 SST Imagery: 12 April 2018 (Day)



N20 SST Imagery is of high quality and comparable with NPP

NPP SST Imagery: 12 April 2018 (Day)



N20 and NPP have complementary coverage. SST features move over 50min time

Documents (Check List)

Science Maturity Check List	Yes ?
ReadMe for Data Product Users	Yes (N20)
Algorithm Theoretical Basis Document (ATBD)	Yes (SNPP)
Algorithm Calibration/Validation Plan	Yes (N20)
(External/Internal) Users Manual	Yes (SNPP)
System Maintenance Manual (for ESPC products)	Yes (SNPP)
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Yes (SNPP)
Regular Validation Reports (at least annually) (Demonstrates long-term performance of the algorithm)	JPSS Annual Meeting presentations

Summary and Path Forward

- **N20 SST has reached provisional maturity, w/performance comparable to NPP**
  - ✓ Product performance demonstrated through analysis of a large, but still seasonally limited number of independent global in situ matchups
  - ✓ Product analyses are sufficient for qualitative and limited quantitative, determination of product fitness-for-purpose
  - ✓ Necessary documentation exists
  - ✓ Product is recommended for potential operational use (user decision) and in scientific publications. Consulting with SST Team recommended

- **Path Forward**
  - 1) Complete ACSPO v2.60. 2) Deliver to NDE. 3) Reprocess available stable N20 time series. 4) Distribute via Coast Watch. 5) Work with PO.DAAC/NCEI to archive NDE & reprocessed N20 data.
  - Continue creating in situ matchups, product Val/Monitoring, NPP comparisons for representative seasonal domain. Tweak algorithms

- **Recommendation to the Program**
  - Minimize sensor instabilities to the maximum extent possible. Ensure stable thermal regime of the N20 /NPP sensors (WUCD etc.)