NOAA ACSPO Himawari-8 SST Product

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NOAA SST Algorithms and Products

NOAA pioneered SST regression algorithms..

- 1970/80s: Multi-Channel SST (MCSST)
- 1990s: Non-Linear SST (NLSST)

.. and operational SST products

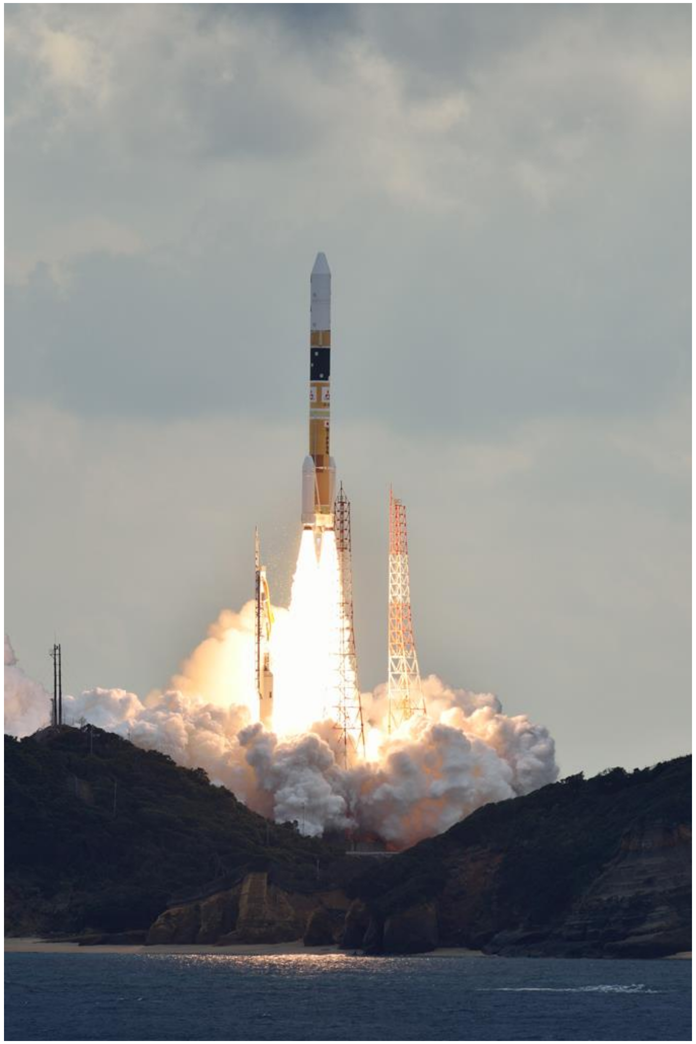
- 1981: Polar (from NOAA-7/AVHRR2)
- 1999: Geo (from GOES-8/Imager)

Historically, the polar and geo SST systems at NOAA have evolved independently and diverged over time

Currently, NOAA is consolidating SST processing under the ACSPO (Advanced Clear-Sky Processor for Ocean) Enterprise System

The objective is to facilitate data production (Management / Research & Development / Operations/ Maintenance/ Cost), monitoring and use (unified formats/ performance/ archives/..)

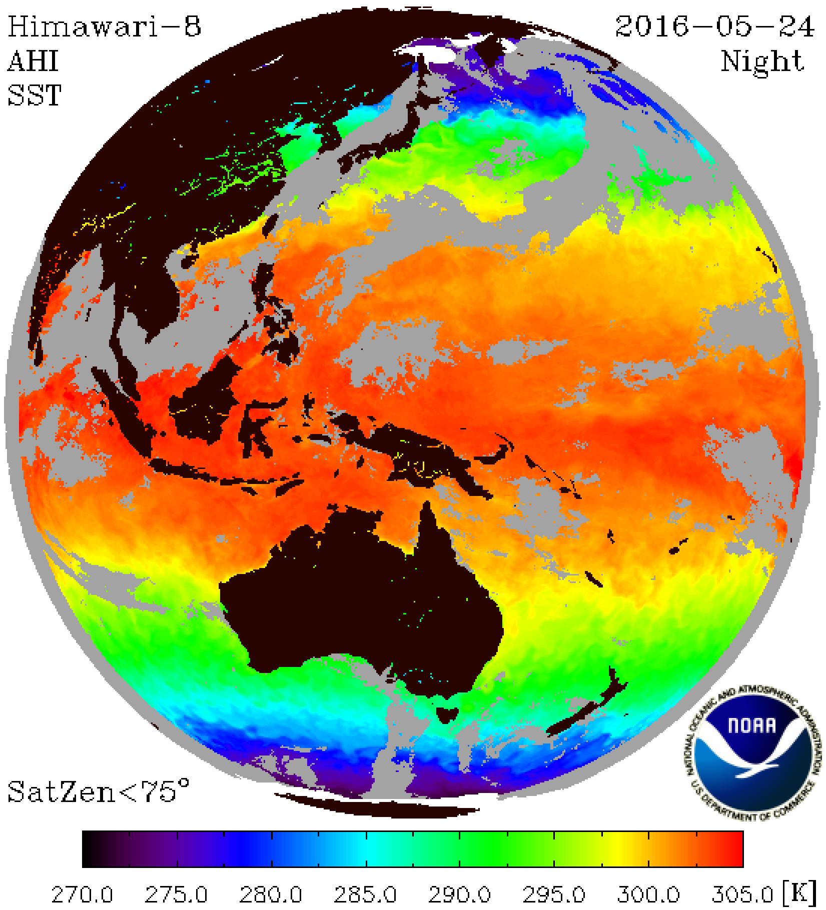
ACSPO SST from Himawari-8 (H8) AHI



- Himawari-7 (MTSAT2) SST was produced by the NOAA heritage geo system
- At the same time, ACSPO Team worked on GOES-R SST Algorithm (will launch in Oct 2016)
- H8 launched in Oct 2014 with AHI sensor onboard (AHI is a sister sensor to GOES-R ABI)
- NOAA management asked us to produce AHI SST using ACSPO system
  - to replace the H7 SST in the NOAA geo-polar blended
  - H8 SST was also viewed as GOES-R risk reduction

ACSPO H8 SST

- **Current Status**
  - 1 Jul 2015: Experimental ACSPO L2P SST (10min, swath projection) produced, 46 GB/day
  - L2P files and AHI vs. VIIRS images available online ftp://ftp.star.nesdis.noaa.gov/pub/sod/sst/acspo_data/l2/ahi/
  - Data from 1 Apr 2015 monitored in SQUAM www.star.nesdis.noaa.gov/sod/sst/squam/GEO/ along with NOAA H7 and JAXA H8 SSTs
  - 4 Dec 2015: AACSPO SST assimilated into geo-polar blended (hourly; 5/6 granules not used)



- **Ongoing Work**
  - Generate 1hr H8 L2C/L3C (4-6GB/day) and archive
  - Improve clear-sky mask based on pattern recognition and generate thermal fronts product
  - Revisit SST algorithm, ensure sensitivity = 1
  - Support GOES-R Algorithm & Cal/Val (Oct'2016)

AHI/ABI Bands

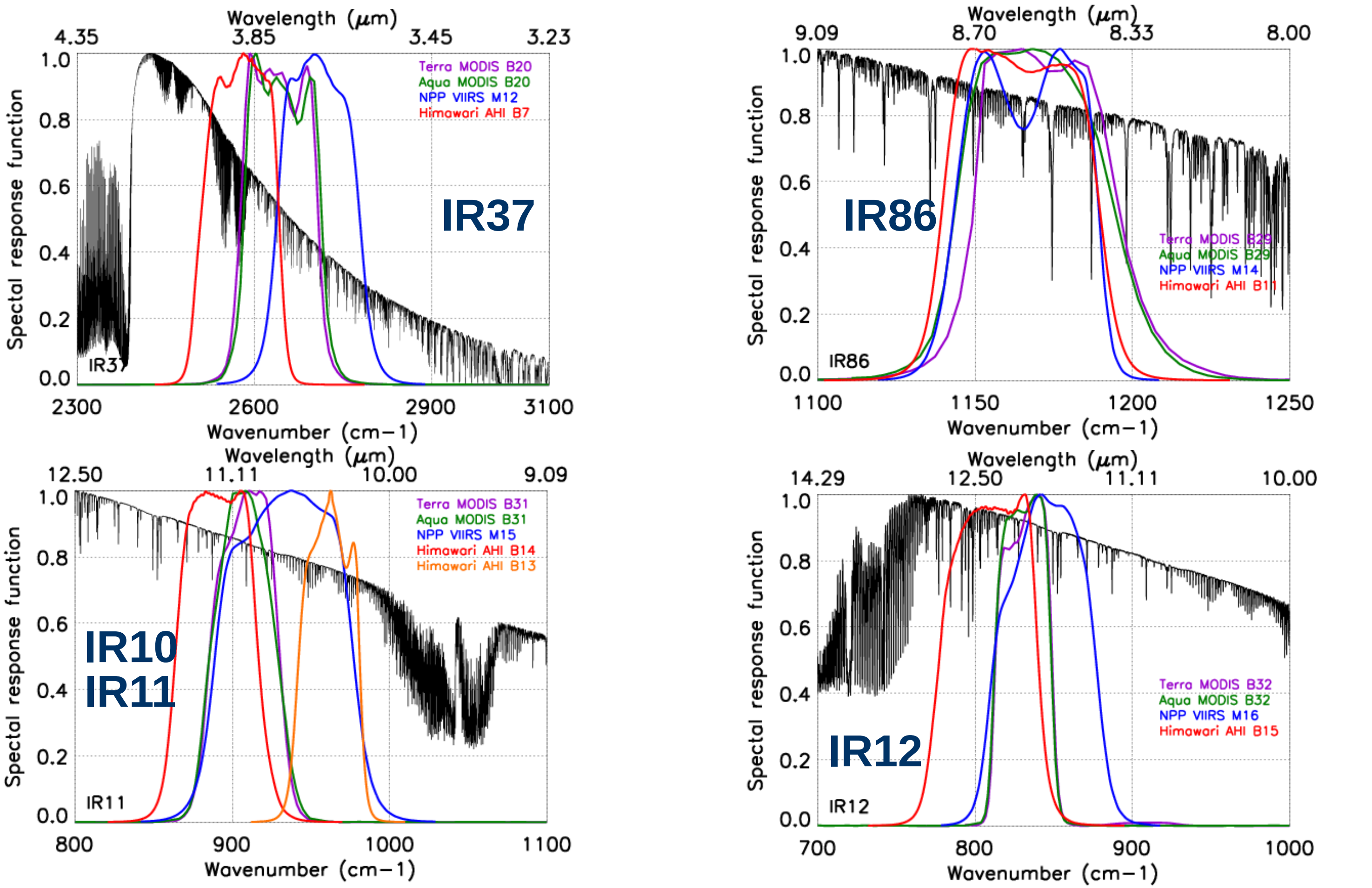
GOES-R/ABI Himawari/AHI SST Bands

Band	AHI/ABI			VIIRS			MODIS		
	B	CW (μm)	SR (μm)	B	CW (μm)	SR (μm)	B	CW (μm)	SR (μm)
IR37	7	3.85	3.59-4.11	M12	3.70	3.66-3.84	20	3.75	3.66-3.84
IR86	11	8.60	8.12-9.07	M14	8.58	8.40-8.70	29	8.55	8.40-8.70
IR10	13	10.45	9.90-10.96						
IR11	14	11.20	10.31-12.18	M15	10.73	10.26-11.26	31	11.03	10.78-11.28
IR12	15	12.35	11.17-13.66	M16	11.85	11.54-12.49	32	12.02	11.77-12.27

Temporal AHI Sampling: 10min

Spatial resolution in IR bands (at nadir): 2 km

ABI/AHI SST Bands



- Three bands in the longwave IR (vs. 2 on polar sensors) + 8.6 µm band
- The 3.9 band is shifted to longwave and covers two N2O absorption lines

ACSPO Algorithms

ACSPO AHI Algorithms

ACSPO Clear-Sky Mask (Petrenko et al., JTECH, 2010)

- ✓ Current ACSM is “in-pixel” (with the exception of spatial uniformity test)
- ✓ Somewhat overly conservative (especially in dynamic and coastal areas)
- ✓ Analyses of spatial / temporal context underway to improve coverage

ACSPO Single-Sensor Error Statistics (SSES; Petrenko et al, JTECH, 2016)

- ✓ SSES derived against *in situ* data with piece-wise regressions as a function of Fisher distance
- ✓ Correction for SSES biases improves consistency with *in situ* data (NB: monitored in SQUAM and shown here are non-SSES bias corrected)
- ✓ We recommend to SSES-bias correct for the use in L4s blending with *in situ* and aiming at foundation SST (e.g., CMC, OSTIA, GAMSSA, Reynolds)

SST algorithm: Regression vs. Drifters/Trop. Moorings (Petrenko et al, JGR 2014)

- ✓ OSI-SAF-like algorithms (which focus on VZA dependencies) are employed in ACSPO, as opposed to MODIS/PF-like (which focus on water-vapor correction)
- ✓ Unlike polar algorithms (stratified by day/night), one H8 algorithm is used
- ✓ The shortwave 3.9 μm band is not used in the regression

AHI SST Algorithm

$$T_S = a_0 + a_1 T_{10.4} + a_2(T_{10.4} - T_{12}) + [a_3(T_{10.4} - T_{8.6}) + a_4(T_{10.4} - T_{11.2})]S_\theta +$$
$$+ [a_5(T_{10.4} - T_{8.6}) + a_6(T_{10.4} - T_{11.2}) + a_7(T_{10.4} - T_{12.4})]T_S^0$$

$T_{8.6}, T_{10.4}, T_{11.2}, T_{12.4}$	observed BTs at 8.6, 10.4, 11, and 12.4 µm
$S_\theta = 1/cos(\theta)$	where θ is the satellite view zenith angle
T_S^0	first guess SST (in °C) (CMC L4)
a	regression coefficients (estimated from matchups)

The ACSPO SST is anchored to buoys → it is sub-skin (not biased -0.17K)

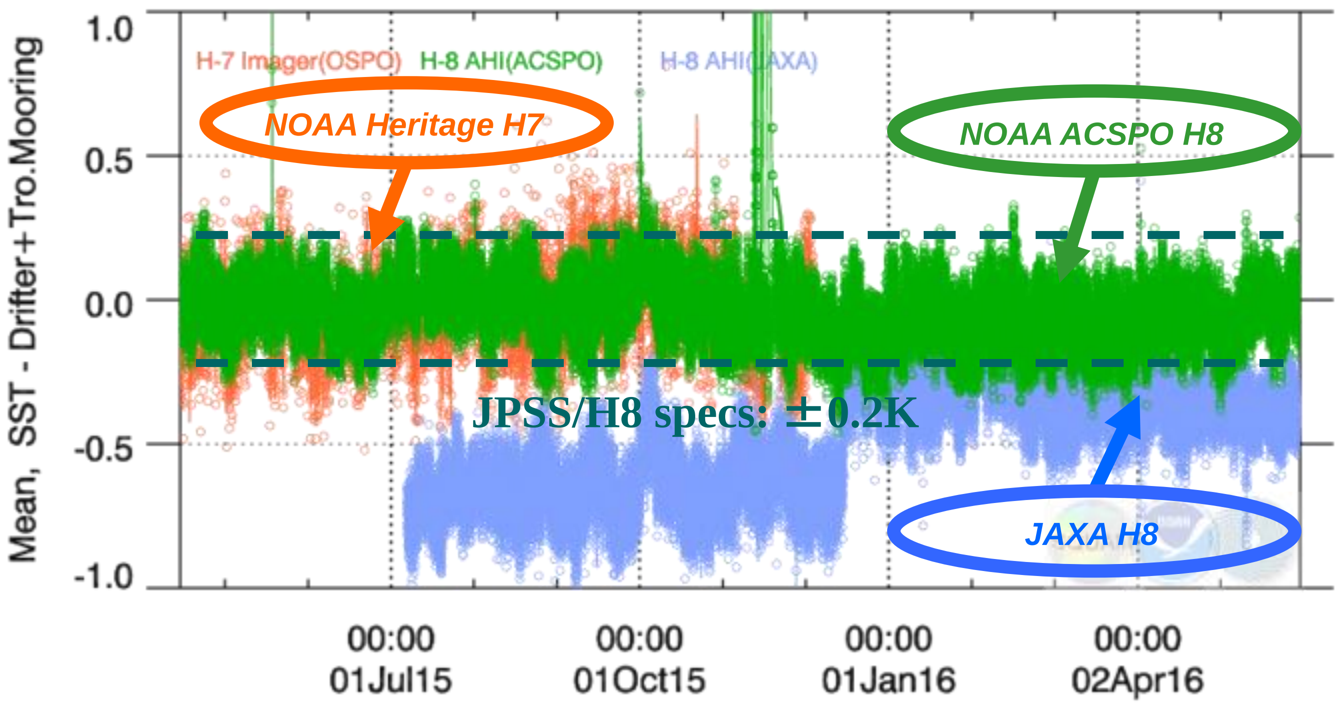
Currently, only SSTs with QL=5 are recommended to users and used in SQUAM.
(Per G16 recommendation, work is underway to revisit – see Petrenko et al. poster)

- Single SST equation is used for AHI (unlike polar algorithms, which use different equations at night and during the daytime)
- This minimizes SST and clear-sky mask discontinuities in the terminator zone and facilitates analysis of the diurnal cycle
- The AHI 3.9 µm band proved inefficient for SST retrievals and is not used in the SST algorithm (apparently, it was shifted back to 3.7 µm on ABI – need to verify)

Evaluation of H8 SSTs in SQUAM

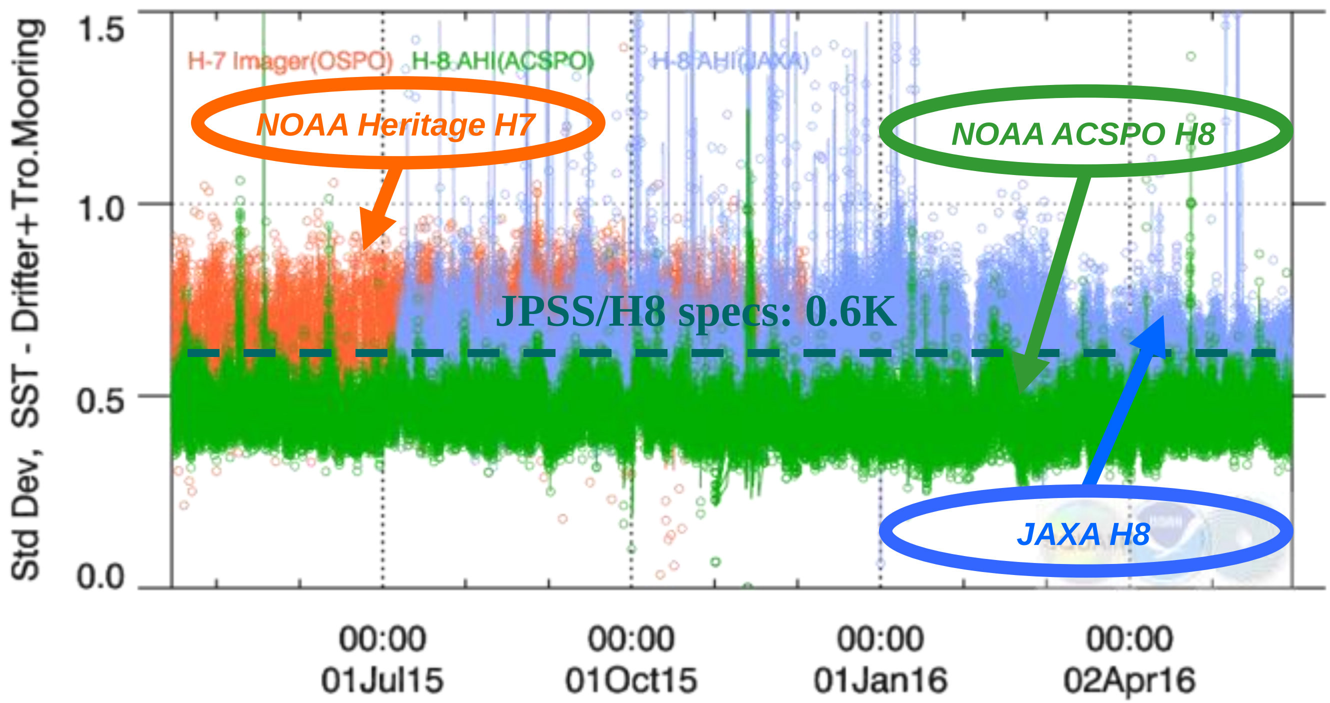
www.star.nesdis.noaa.gov/sod/sst/squam/GEO/

VAL BIAS wrt. *i*Quam Drifters + Tropical Moorings



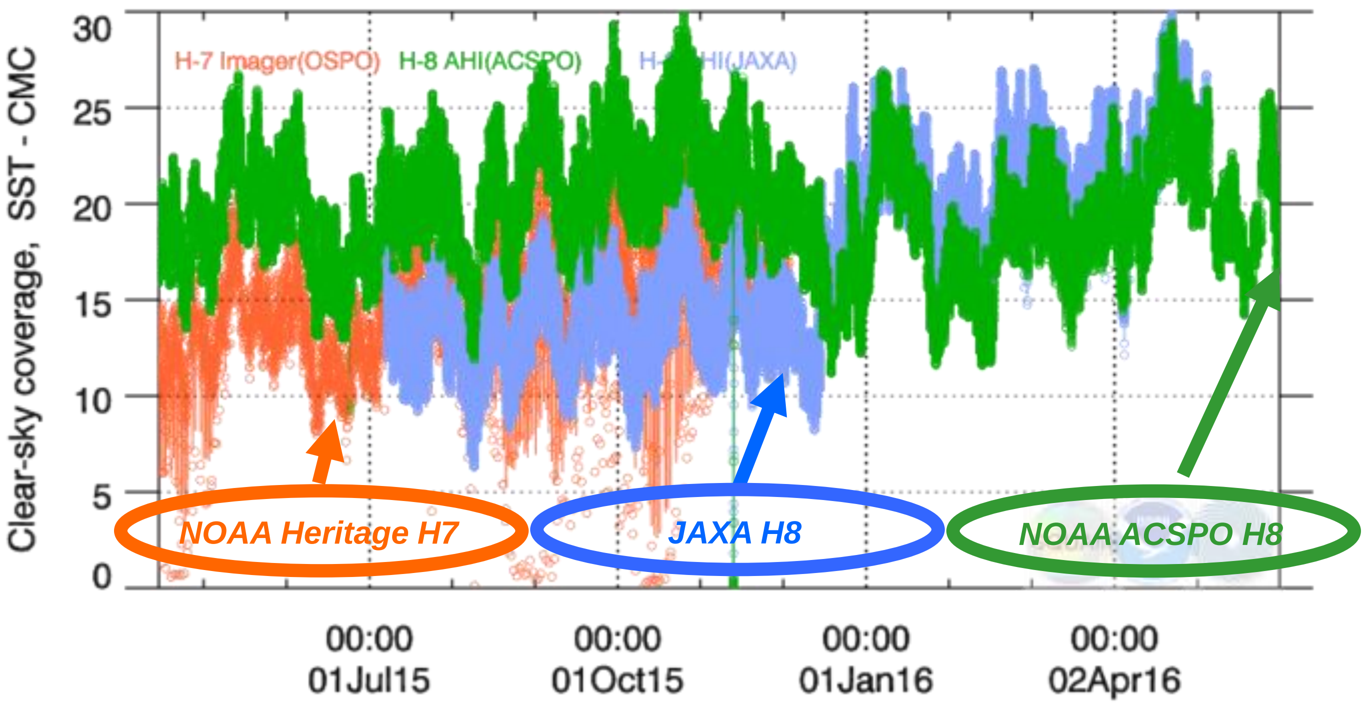
- Each data point: H8 = 10min L2P granule; H7 (ended 4 Dec 2015) = 1 hr
- ACSPO H8 SST is close to meeting JPSS and H8 specs. Tighter than H7 SST
- JAXA H8 SST is a skin product. -0.17K bias is expected. JAXA changed algorithm in Dec 2015. Remains biased ~-0.15K cold (on the top of the expected -0.17K bias)

VAL SD wrt. *i*Quam Drifters + Tropical Moorings



- SD smaller at night when skin SST closer to bulk buoy, and larger during daytime
- H8 ACSPO SDs range from ~0.4K (Night) to ~0.6K (Day). Close to JPSS/H8 specs
- SDs for H8 ACSPO are smaller than for the NOAA heritage H7 and H8 JAXA SSTs. Outliers in JAXA SSTs reduced in 2016

Clear-Sky Coverage in the H7/H8 SST Products

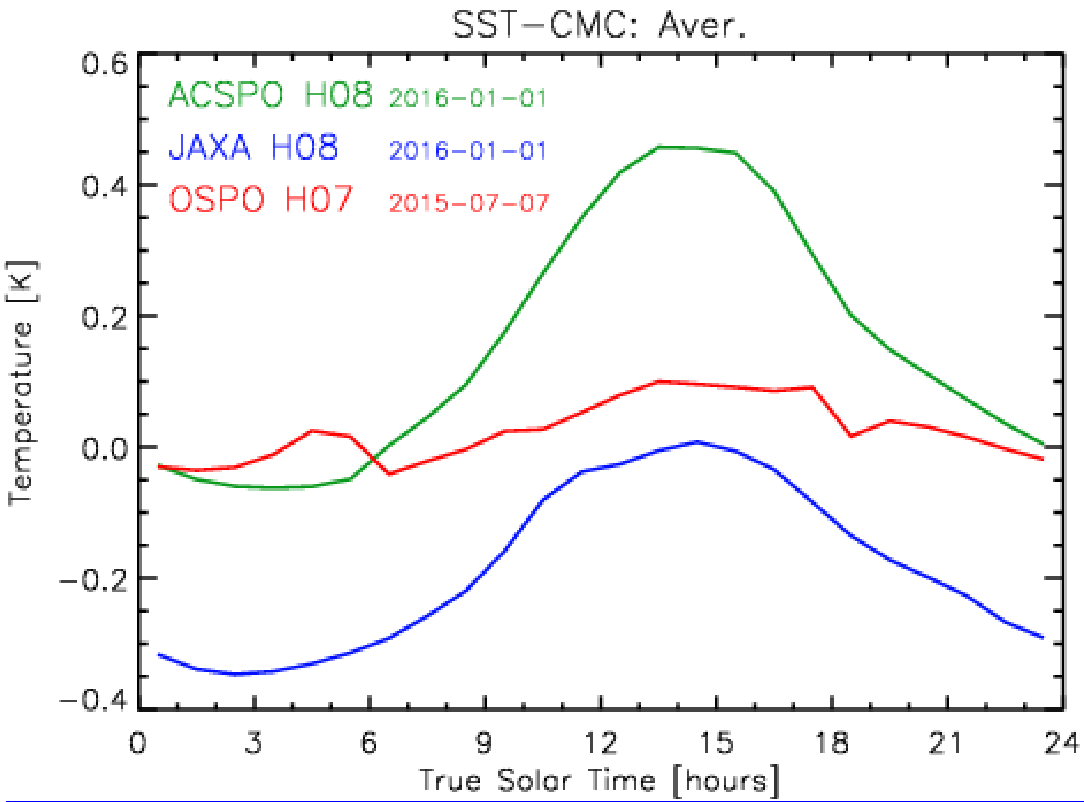


- H8 ACSPO Clear-Sky Coverage exceeds NOAA H7 and initial JAXA H8
- After fixes in Dec 2015, JAXA coverage is comparable to ACSPO
- Large-scale variations in clear-sky fraction occur in sync in the three products, and are likely due to real changes in cloud coverage over the Himawari domain

Ongoing Work – 1:

Ensure Sensitivity to true SST = 1; Accurately Resolve Diurnal Cycle & Spatial Gradients

Diurnal Cycle in Retrieved SST Averaged over FD



- Sensitivity to true SST (Merchant et al., GRL 2009) matters!
- Should we output sensitivity in GDS2?
- The ACSPO, JAXA, and H7 systems all run RTM, so the "sensitivity infrastructure" is there

- The shape of the diurnal cycle: Similar between H8 ACSPO and JAXA, noisy in H7
- ACSPO (& H7) SSTs agree with CMC at night as expected, and deviate during daytime
- At night, JAXA SST is biased -0.3K cold (-0.17K expected, -0.15K unexplained).
- During daytime, JAXA and ACSPO are offset by -0.45K
- Diurnal amplitudes are ~0.55K in ACSPO H8; ~0.35K in JAXA; 0.15K in H7

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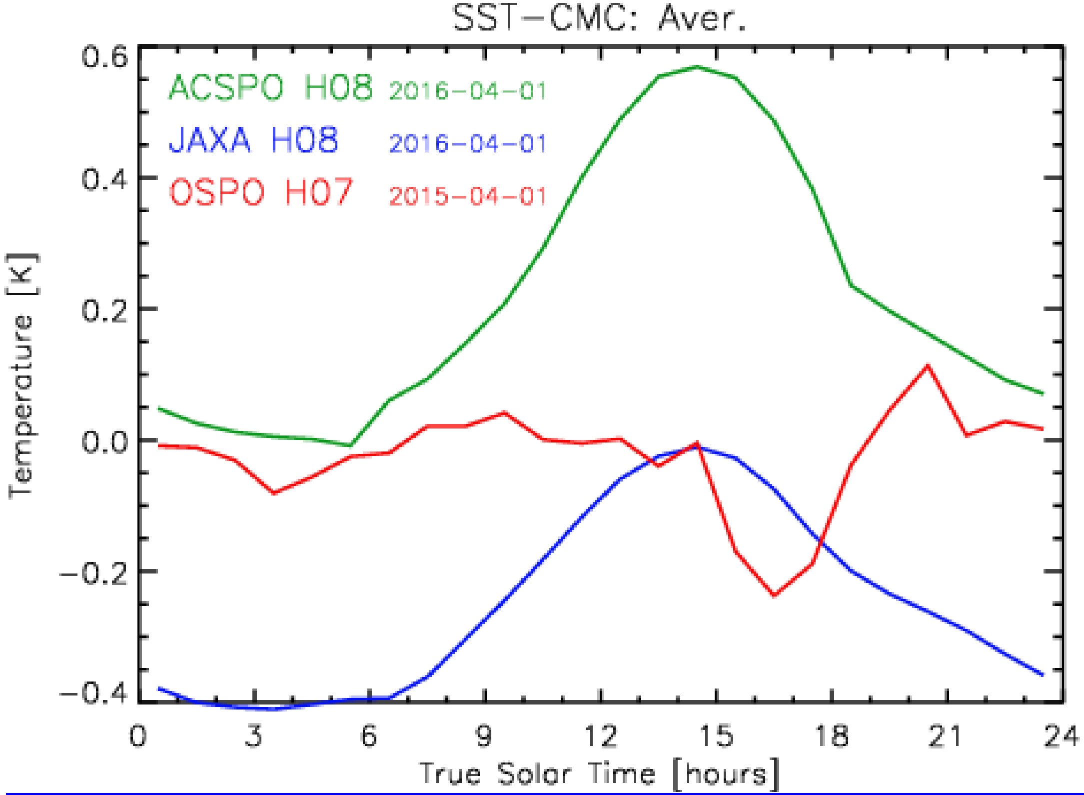

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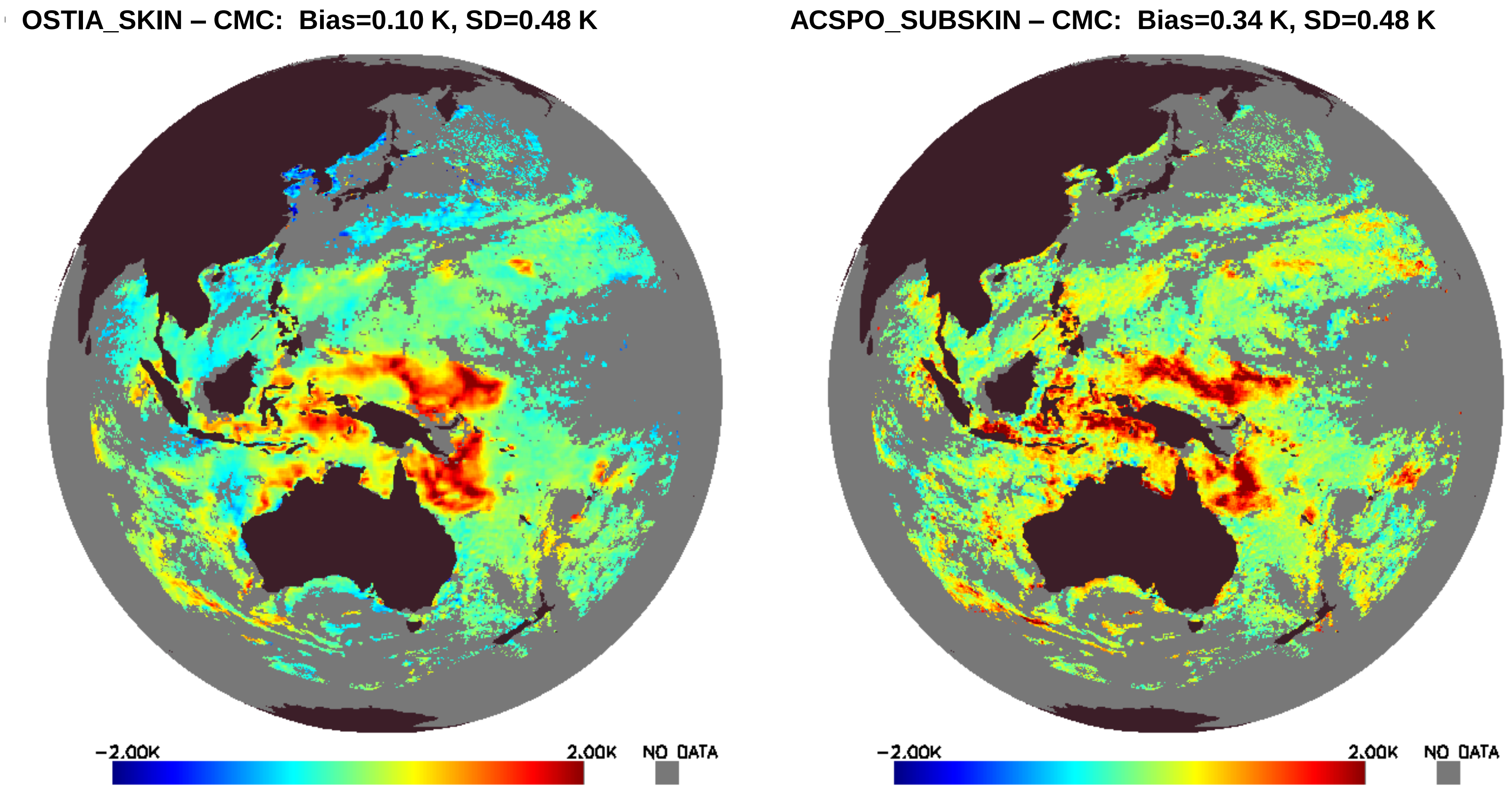
OSTIA Diurnal and ACSPO wrt CMC, Himawari-8 AHI, 8 January 2016, 5:00 UTC (Day)

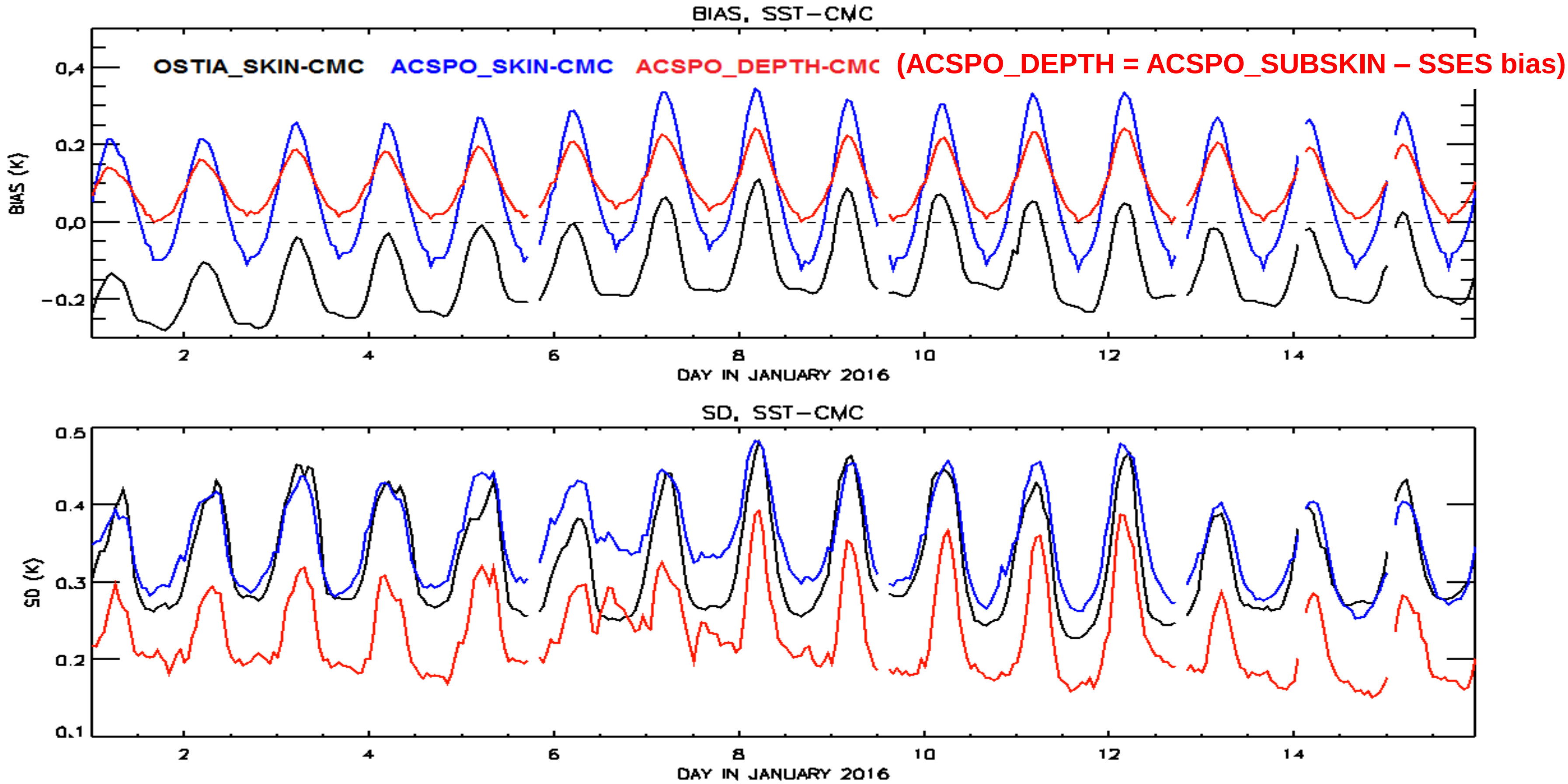


OSTIA_SKIN and ACSPO_SUBSKIN show different yet similar global biases with respect to CMC

OSTIA_SKIN is -0.24K colder (-0.17K comes from "skin"). Two products show close global SDs

Thanks to UKMO James While, Matt Martin, Chongyuan Mao

Bias & SD in OSTIA and ACSPO – CMC SST Himawari-8 AHI, 1-15 January 2016



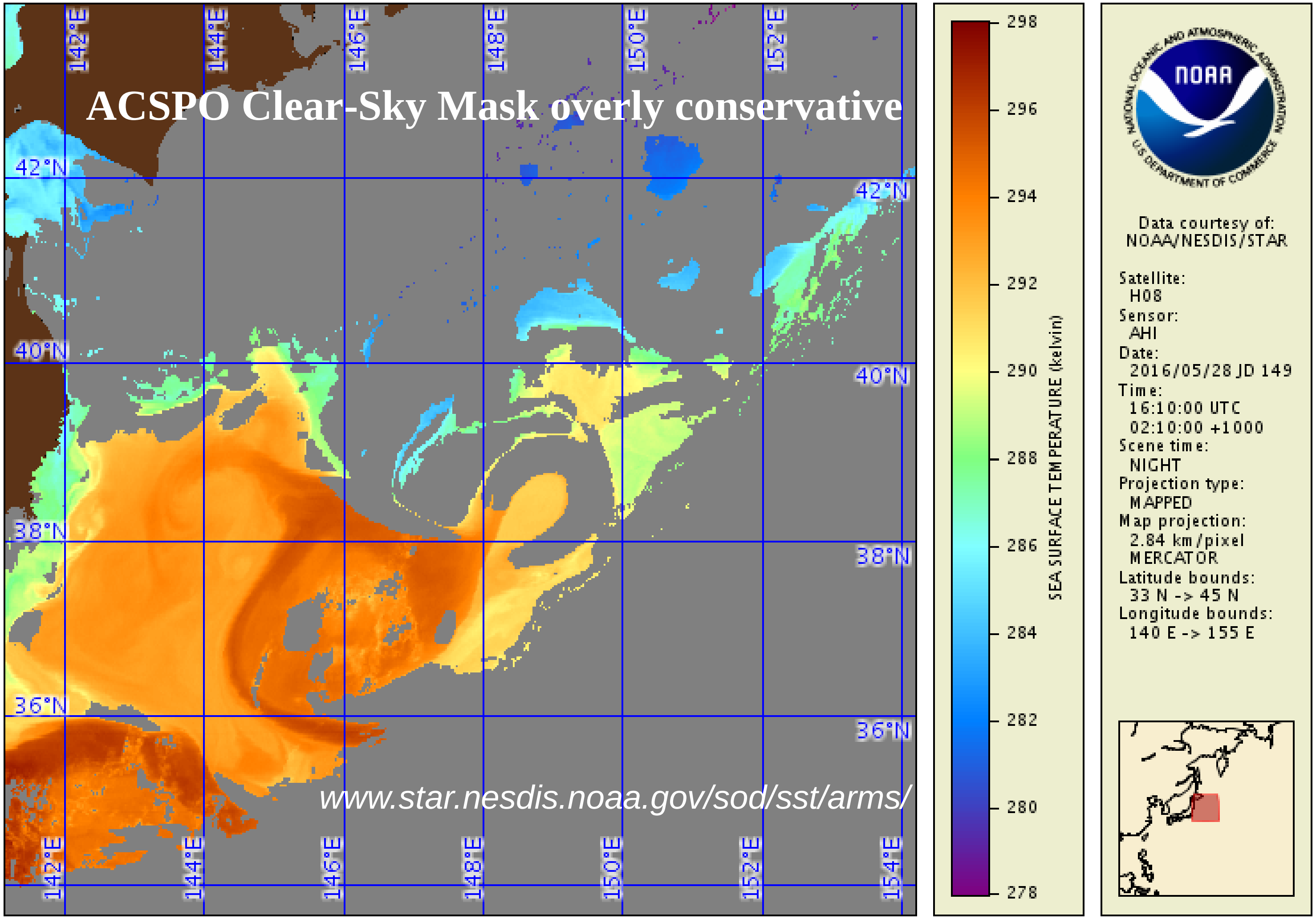
- Diurnal cycle in all products suppressed (function of UTC rather than local time). OSTIA_SKIN: Biased ~-0.17K cold wrt CMC, as expected. ACSPO_subsin: ~50% more diurnal warming than OSTIA_SKIN
- ACSPO_DEPTH is closest to CMC at night and least affected by diurnal warming

Thanks to UKMO James While, Matt Martin, Chongyuan Mao

Ongoing Work – 2:

Use Pattern Recognition to Improve Coverage in Dynamic Areas and Derive Thermal Fronts

H8 AHI SST, 28 May 2016 @16:10UTC

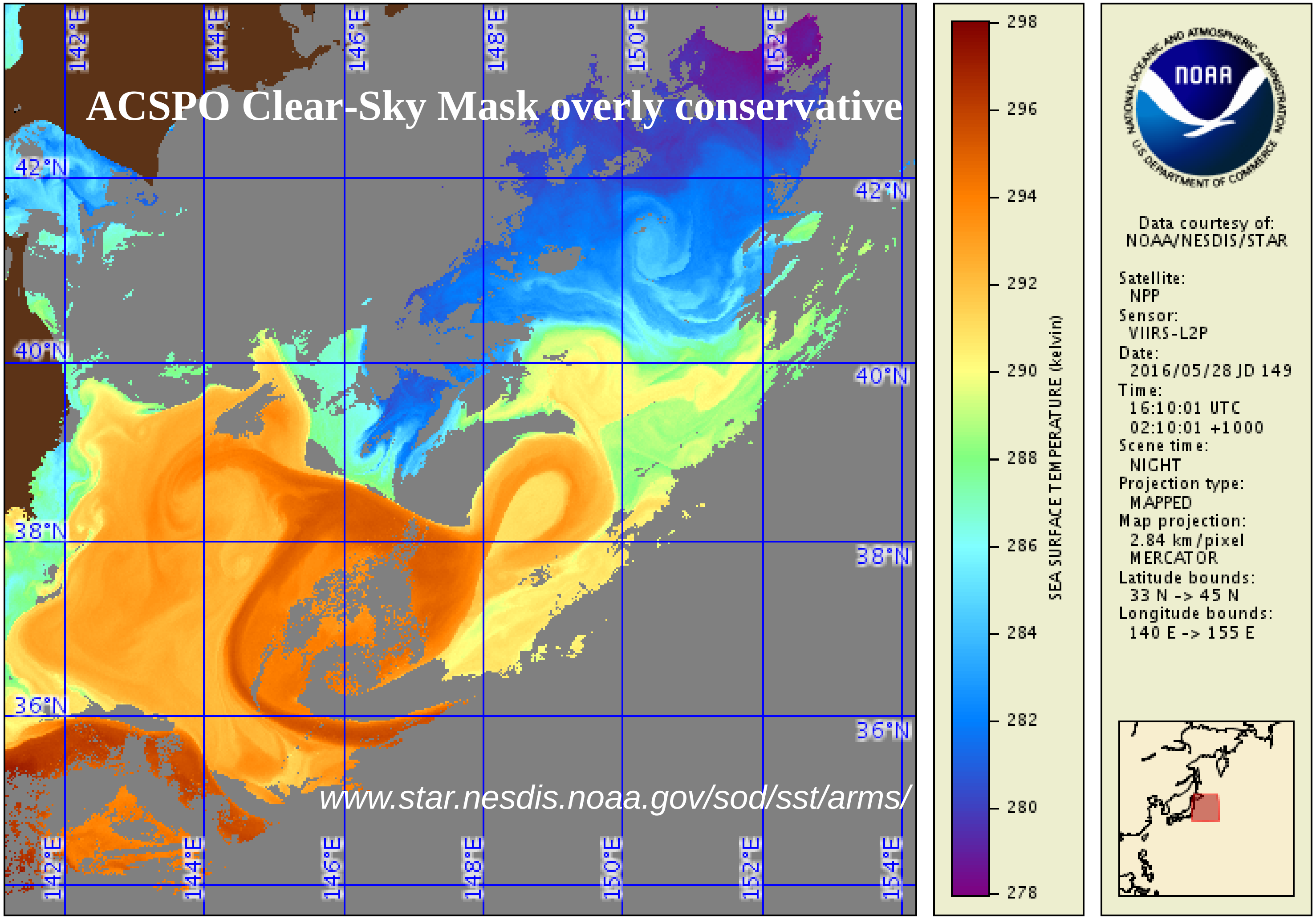


ACSPO Clear-Sky Mask is overly conservative

Future version of ACSPO will utilize pattern recognition to fix this for VIIRS

Next step will be implementation of pattern recognition to H8 SST

S-NPP VIIRS SST, 28 May 2016 @16:10UTC



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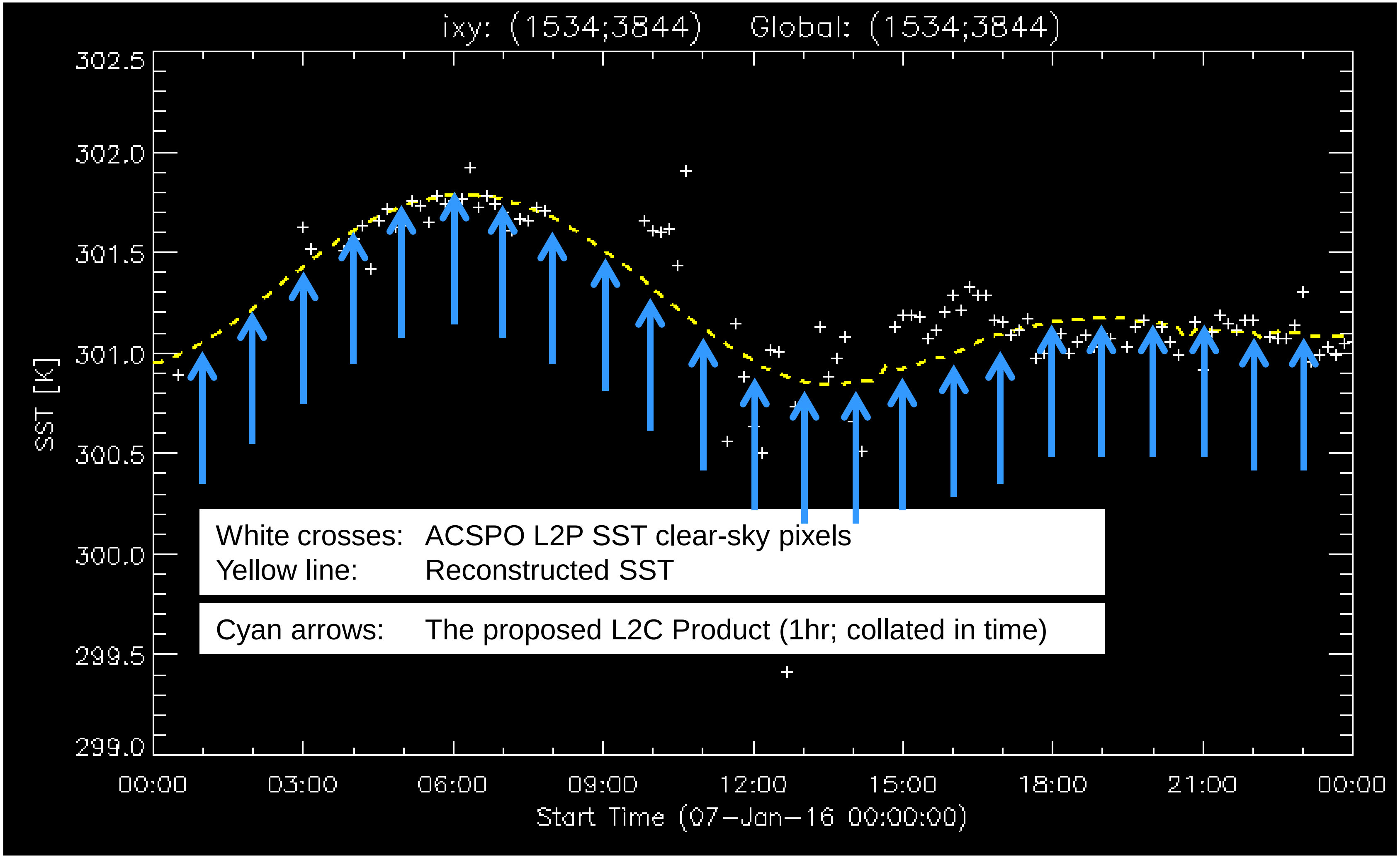
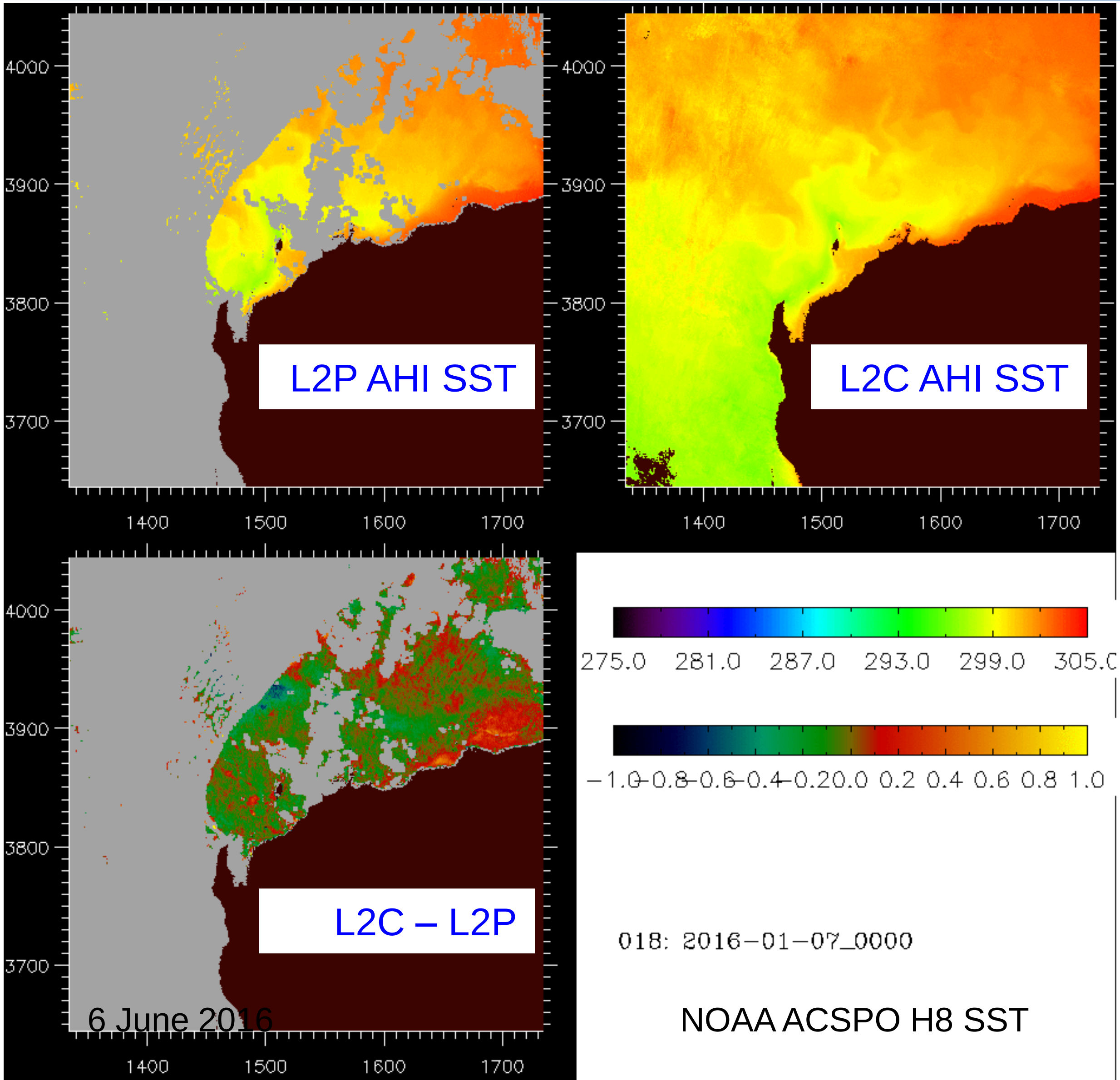
Ongoing Work – 3:

Use Temporal Context to Increase SST Domain, Reduce Noise, and Generate L2C/L3C Product

L2C ("Collated in Time") AHI SST Product: 1 hr



L2C "Collated" AHI SST Product



- The users cannot use 10min data and the archives cannot archive, due to large size
- The L2C product will reduce the data volume to ~6GB/day (from 45 GB/day in L2P)
- L2C: in original swath projection but collated in time (reported @1hr not 10min)
- The "temporal noise" will be reduced by fitting a smooth curve through cloud free data
- Many cloud gaps will be filled "from temporal context" (but areas with persistent cloud will still remain data void)

Summary

NOAA ACSPO H8 SST Product

- ✓ Successfully replaced the H7 SST as input in geo-polar blended
- ✓ Risk reduction exercise for GOES-R

Product performance

- ✓ Meets formal NOAA requirements for accuracy (±0.2K) and precision (0.6K)
- ✓ Realistically resolves SST diurnal cycle
- ✓ Improves upon NOAA heritage H7 SST (improved sensor, algorithms)
- ✓ Compares favorably with JAXA H8 product

Work ahead

- ✓ Derive L2C/L3C of reduced size & archive
- ✓ Revisit SST algorithm, ensure sensitivity to true SST = 1
- ✓ Implement pattern recognition algorithms, derive thermal fronts

Support launch of GOES-R in October 2016