ACSPO L3U SST Products from SNPP VIIRS and Metop-A and -B AVHRR FRAC

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Acknowledgement: JPSS and NOAA ORS Programs

Thanks to Helen Beggs, Chris Griffin (BoM), Boris Petrenko (NOAA)

NOAA JPSS VIIRS and Metop SSTs

- SNPP (Suomi National Polar-orbiting Partnership) satellite was launched in Oct 2011. J1 will be launched in Sep 2017 and J2-4 will follow
- SNPP/JPSS satellites carry VIIRS (Visible Infrared Imager Radiometer Suite)
- NOAA and EUMETSAT signed Joint Polar System (JPS) agreement. SNPP/JPSS VIIRS covers afternoon orbit (1:30am/pm) while Metop AVHRR covers mid-morning orbit (9:30am/pm)
- NOAA produces GDS2 L2P and L3U SST products from VIIRS & AVHRR using Advanced Clear Sky Processor for Ocean (ACSPO) system

This presentation discusses ACSPO L3U algorithms & products

Current ACSPO (v2.40) VIIRS Data

L2P: GDS2 Swath Projection

- Organized in 10min granules (27 GB/day)
- Operational data (May 2014 – on): PO.DAAC & NOAA NCEI
- Reprocessed VIIRS L2P “Reanalysis1 RAN1” (Mar’12 – Dec’15): ftp://ftp.star.nesdis.noaa.gov/pub/socd2/coastwatch/sst/ran/viirs/
- Assimilated into NOAA Geo-Polar Blended and CMC L4 analyses
- EUMETCast initially pulled L2P data but requested reduced volume data
- BoM, Met Office, JMA also requested reduced volume VIIRS files

L3U: GDS2 Gridded Equiangular (0.02º) Uncollated

- Organized in 10min granules (~0.7 GB/day)
- Initial implementation based on the BoM L3U code (C. Griffin, H. Beggs)
- Distributed via EUMETCast. This is how Met Office accesses the data
- Operational Data (19 May 2015 – on): PO.DAAC & NOAA NCEI
  This is how BoM, CMC and JMA access the data
- VIIRS L3U RAN1: ftp://ftp.star.nesdis.noaa.gov/pub/socd2/coastwatch/sst/ran/viirs/

New ACSPO v2.41 VIIRS L3U

- **NOAA revisited the L3U code in ACSPO v2.41 to**
  1. Customize for ACSPO, gain full control of the products quality & consistency
  2. Produce consistent L3Us, initially from VIIRS and AVHRR FRAC
  3. Prepare for consistent L3Us from ABI/AHI, AVHRR GAC, and MODIS
  4. Prepare for future ACSPO L3C ("collated") and L3S ("super-collated") products
- **New L3U code delivered to NOAA operations & now under testing**
  - Aims to achieve maximal consistency with L2P
  - Preserves spatial gradients, while reducing imagery noise elsewhere
  - Preserves complete set of L2P flags
  - Provides comparable to L2P global coverage & performance statistics
  - Minimizes ACSPO residual clear-sky mask artifacts

N.B. L2P data continue being archived at PO.DAAC and NOAA NCEI, for those users interested in full-resolution swath data (e.g., MUR)

Users Requested Equiangular Projection

Equiangular projection is defined as $x = \lambda$ (longitude), $y = \varphi$ (latitude)

Simple binning (quantization) can be used to map the geo-locations of the centers of the swath L2P pixels onto the L3U grid cells:

$$Q_{\Delta\lambda}\colon \lambda_{L2} \rightarrow \lambda_{L3}$$

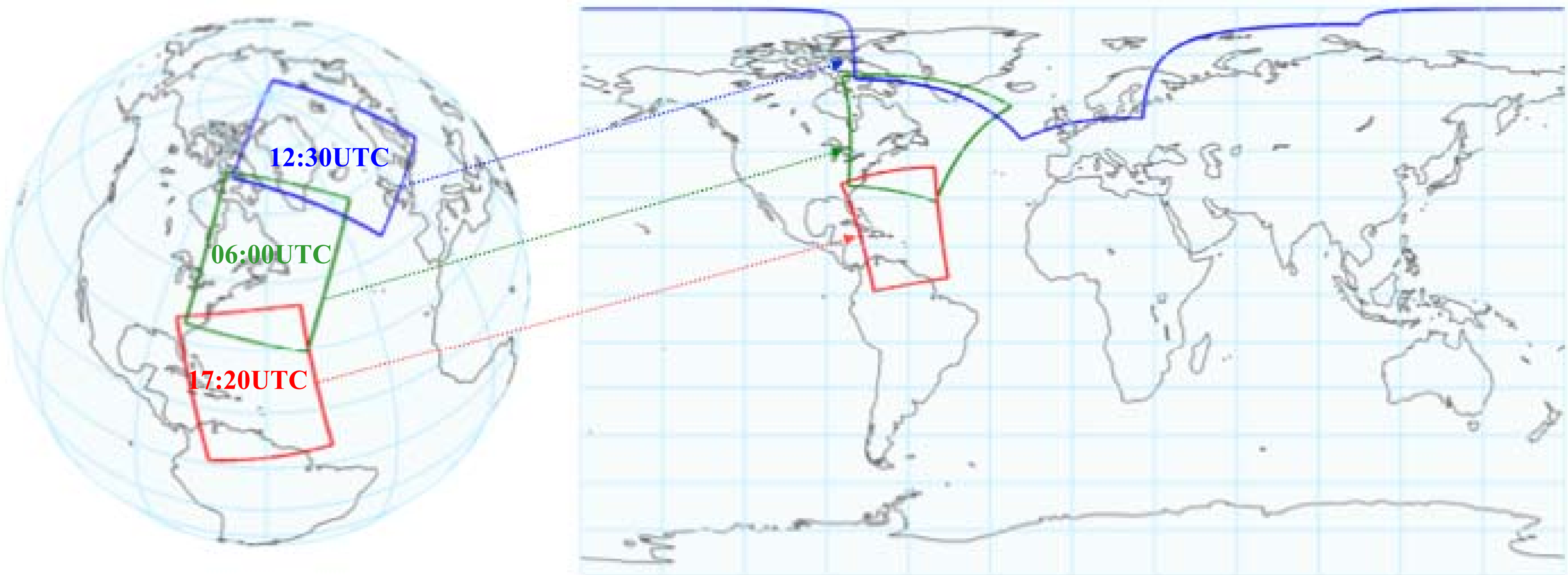
$$Q_{\Delta\varphi}\colon \varphi_{L2} \rightarrow \varphi_{L3}$$

Using rounding procedure:

$$Q_{\Delta z}(z) = \left\lfloor \frac{z}{\Delta z} \right\rceil \Delta z$$

Several L2P values within an L3U grid, or in its neighborhood, should be aggregated into one representative SST value

Extended Search Neighborhood



ACSPO granules on the globe

ACSPO granules on the L3U grid

At high latitudes (and view zenith angles), there are more data "gaps". Search domain may/should be extended to include L3U neighborhood

Approaches to Remapping

1. Nearest neighbor (NN)
2. Arithmetic averaging
3. Median
4. Spatial weighting: Weights inversely proportional to geo-distance *
5. Bilateral weighting: In addition to distance, weights also depend on the deviation from the "typical" values of the "grid ensemble" *

The contributing L2P pixels may be limited to the L3U grid.
Or, they may belong to an extended L3U neighborhood

Spatial vs. Bilateral Weighting: 1/2

Spatial Weighting: $G(I)_p = \sum_{q \in L2} w_{p,q} I_q, \; w_{p,q} = G_\sigma(d(p,q))$

$$G_\sigma(d) = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{d^2}{2\sigma^2}\right).$$

- Pixels contribute in inverse proportion to square-distance from grid center

Bilateral Weighting: $B(I)_p = \frac{1}{W_p} \sum_{q \in \mathcal{S}} w_{p,q} I_q,$

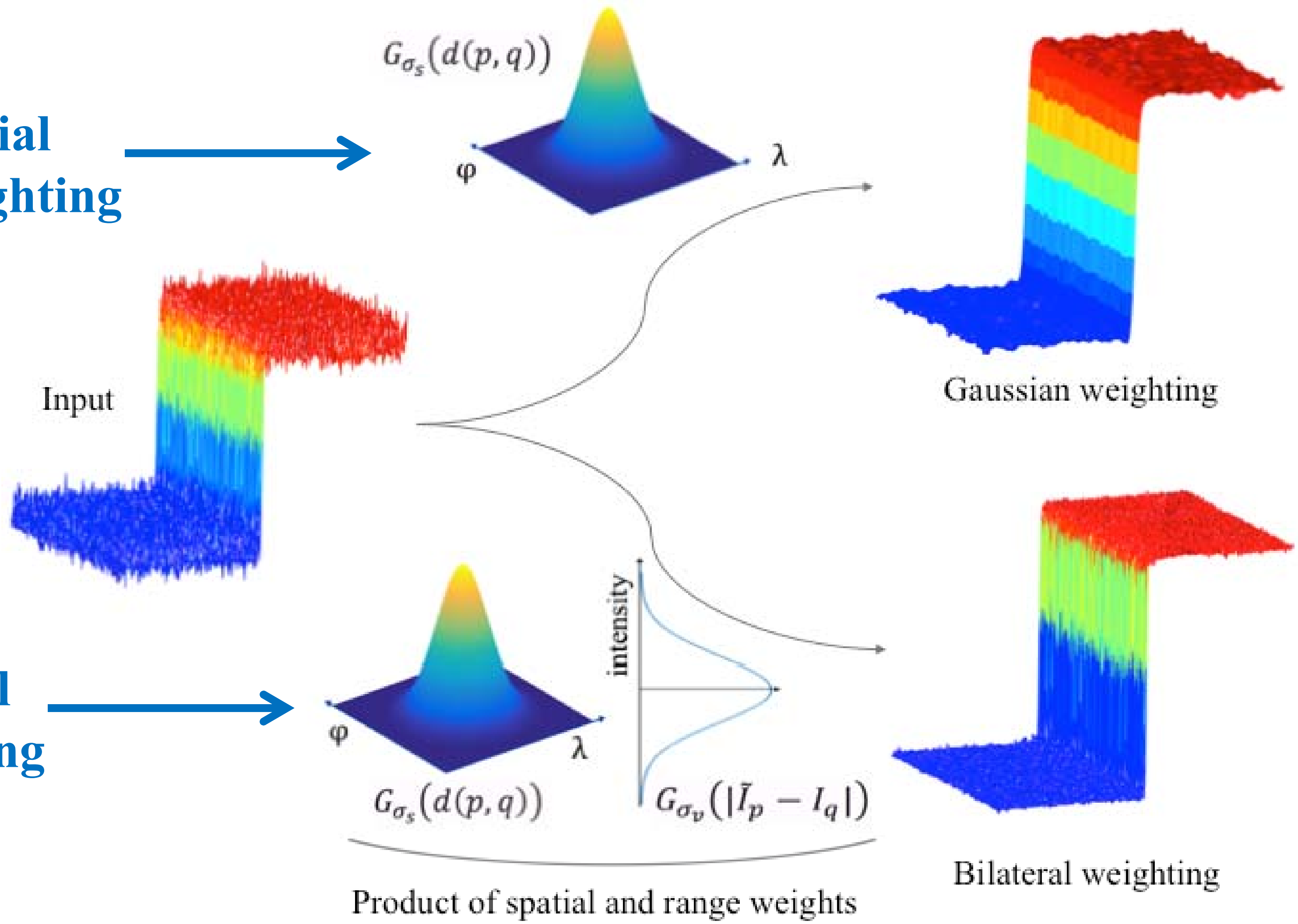
$$w_{p,q} = G_{\sigma_s}(d(p,q)) \cdot G_{\sigma_v}(|\tilde{I}_p - I_q|)$$

- Pixel's contribution to the grid value depends on two factors
  1. distance from L3U center, and ("spatial weighting")
  2. Deviation of pixel SST from the median SST ("range weighting")

Spatial vs. Bilateral Weighting: 2/2

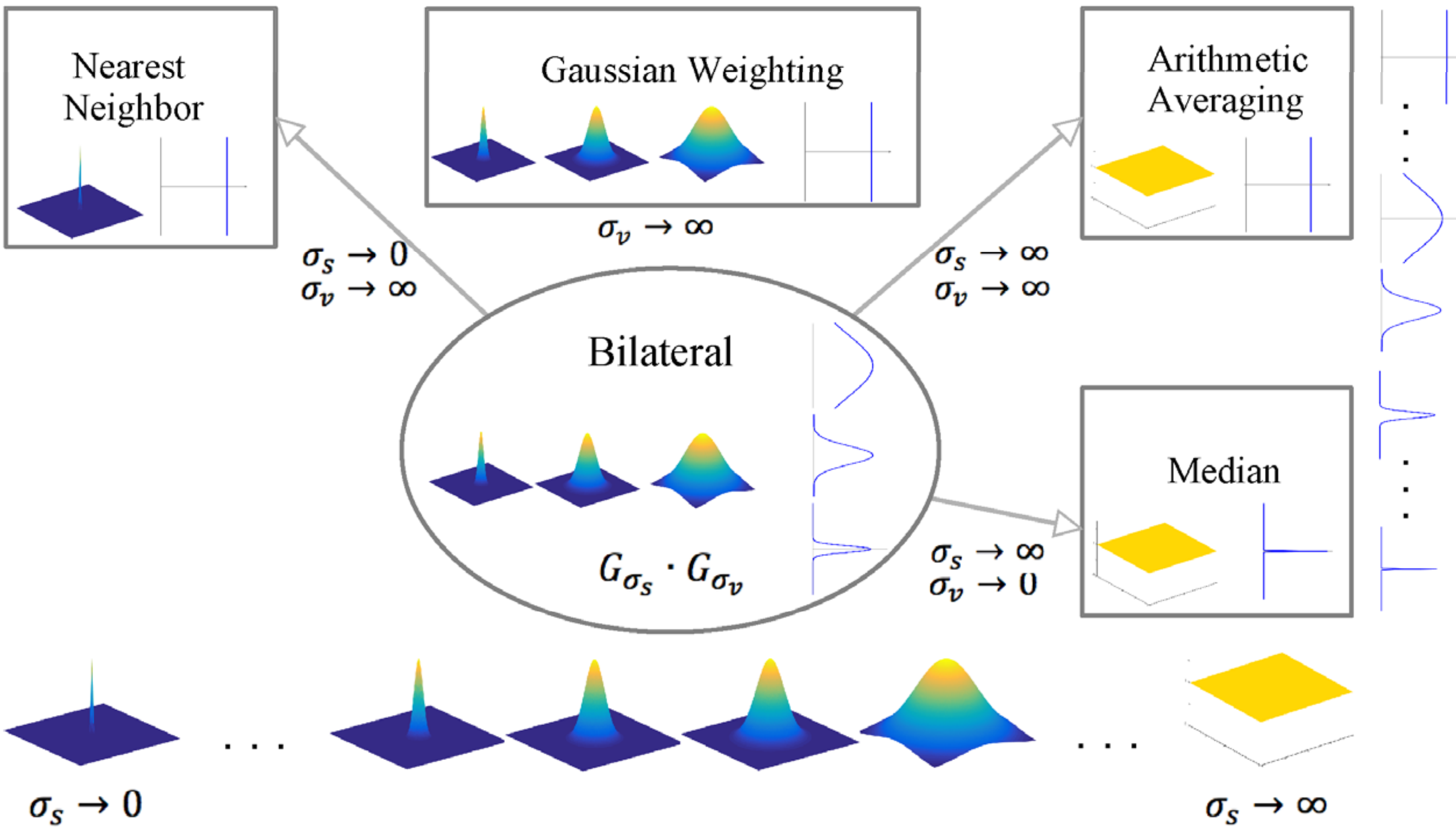
Spatial Weighting

Bilateral Weighting



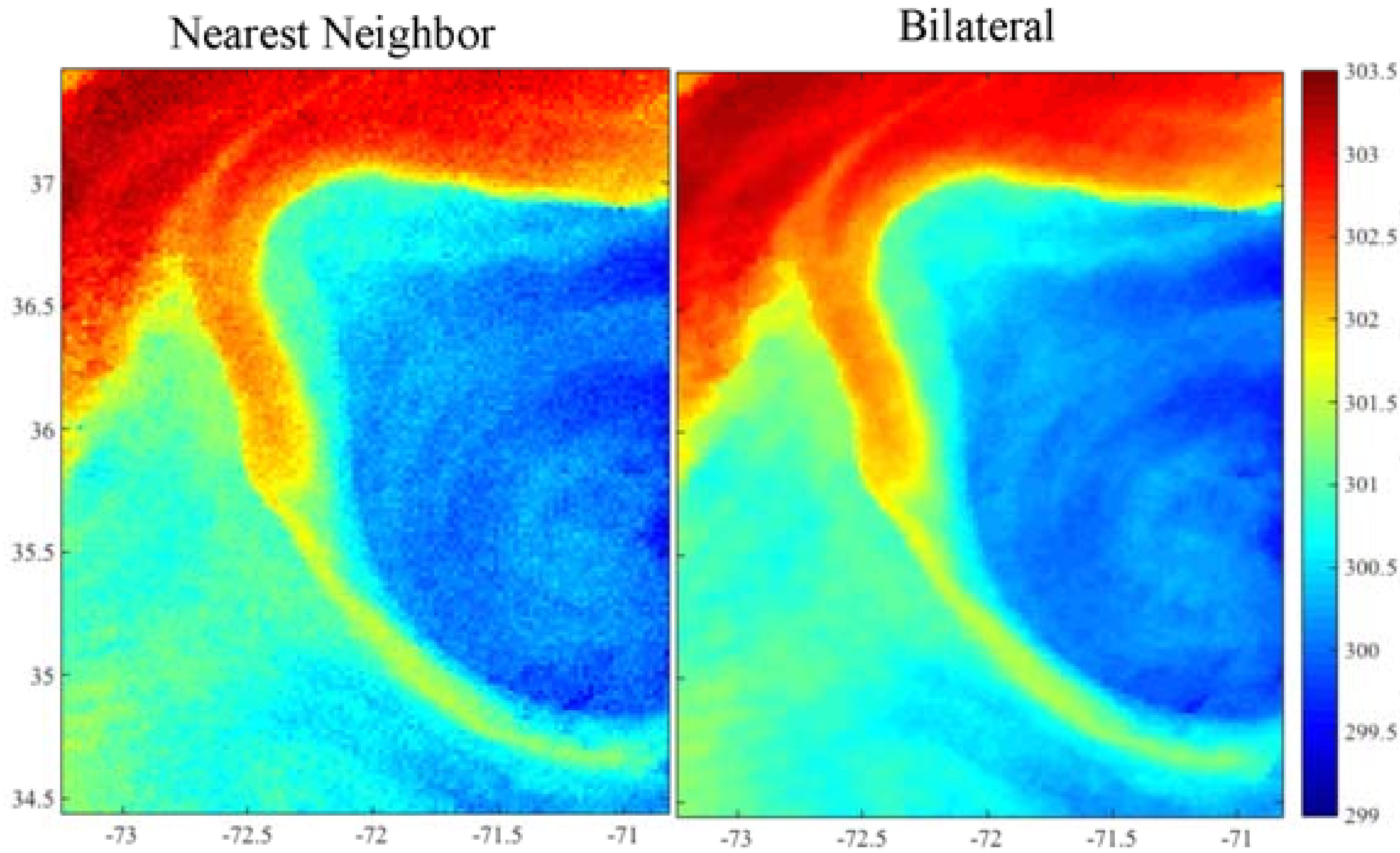
The "Range Weighting" preserves edges. The "Spatial Weighting" suppresses noise elsewhere

Relationship Between Approaches



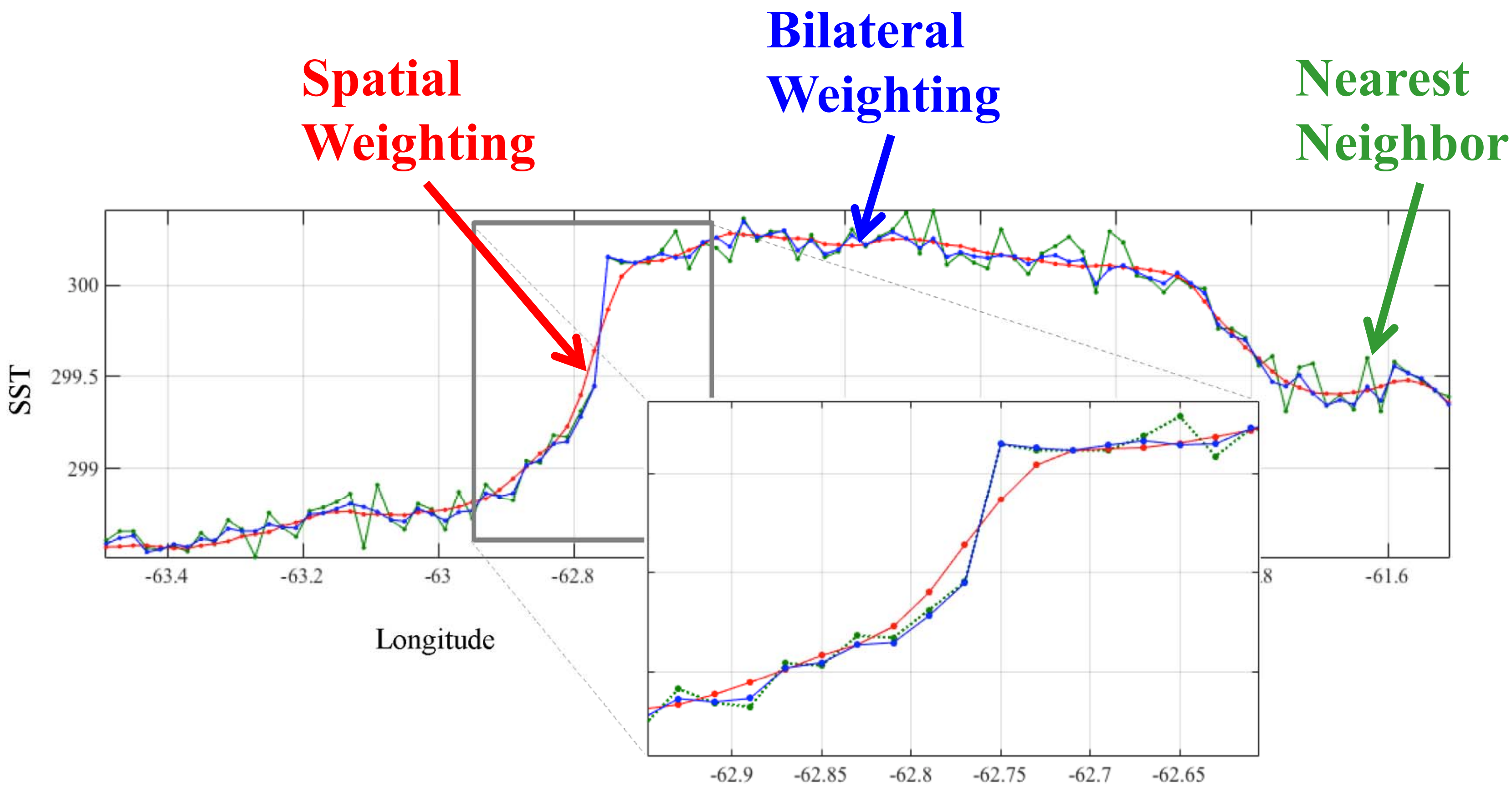
The bilateral algorithm is most generic. The NN, Arithmetic, Media, and Spatial Weighting are all its degenerate cases, with various combinations of (σs → 0 or ∞) and (σv → 0 or ∞)

Remapped VIIRS Image 15 July 2016



Both algorithms preserve edges. The bilateral additionally suppresses noise away from fronts

Preserving Front Profile



The NN preserves edges but does not suppress noise away from fronts.

The Spatial Weighting does suppress all variability in data, including noise and fronts.

The Bilateral combines the advantages of the two while minimizing their deficiencies.

Current Parameters of Bilateral Algorithm

	σs, km (0.02° grid)	σv, K	ΔT, K
SNPP VIIRS	0.75 km	0.100 K	0.30 K
Metop-A AVHRR FRAC	0.75 km	0.215 K	0.50 K
Metop-B AVHRR FRAC	0.75 km	0.175K	0.45 K

Defined by the size of the grid (~2km)

Defined by NEdT in SST (sensor-specific)

ACSPO-specific (ensures that front is not displaced)

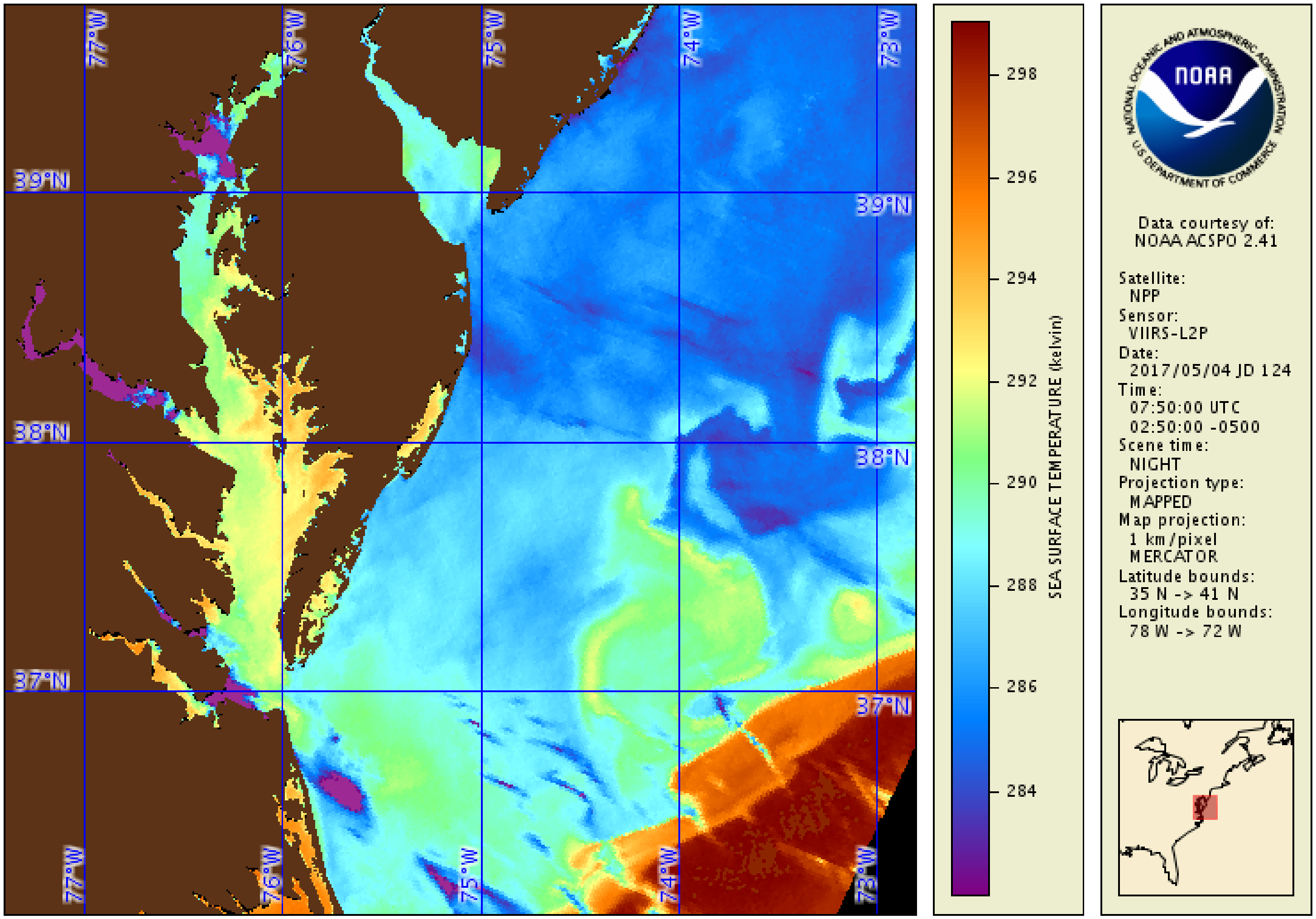
Numerical implementation considerations: To minimize CPU/RAM usage, the search window is limited to (5 L3U × 5 L3U grids) and to ≤11 L2P pixels closest to the grid center

QLs/QFs in L3U

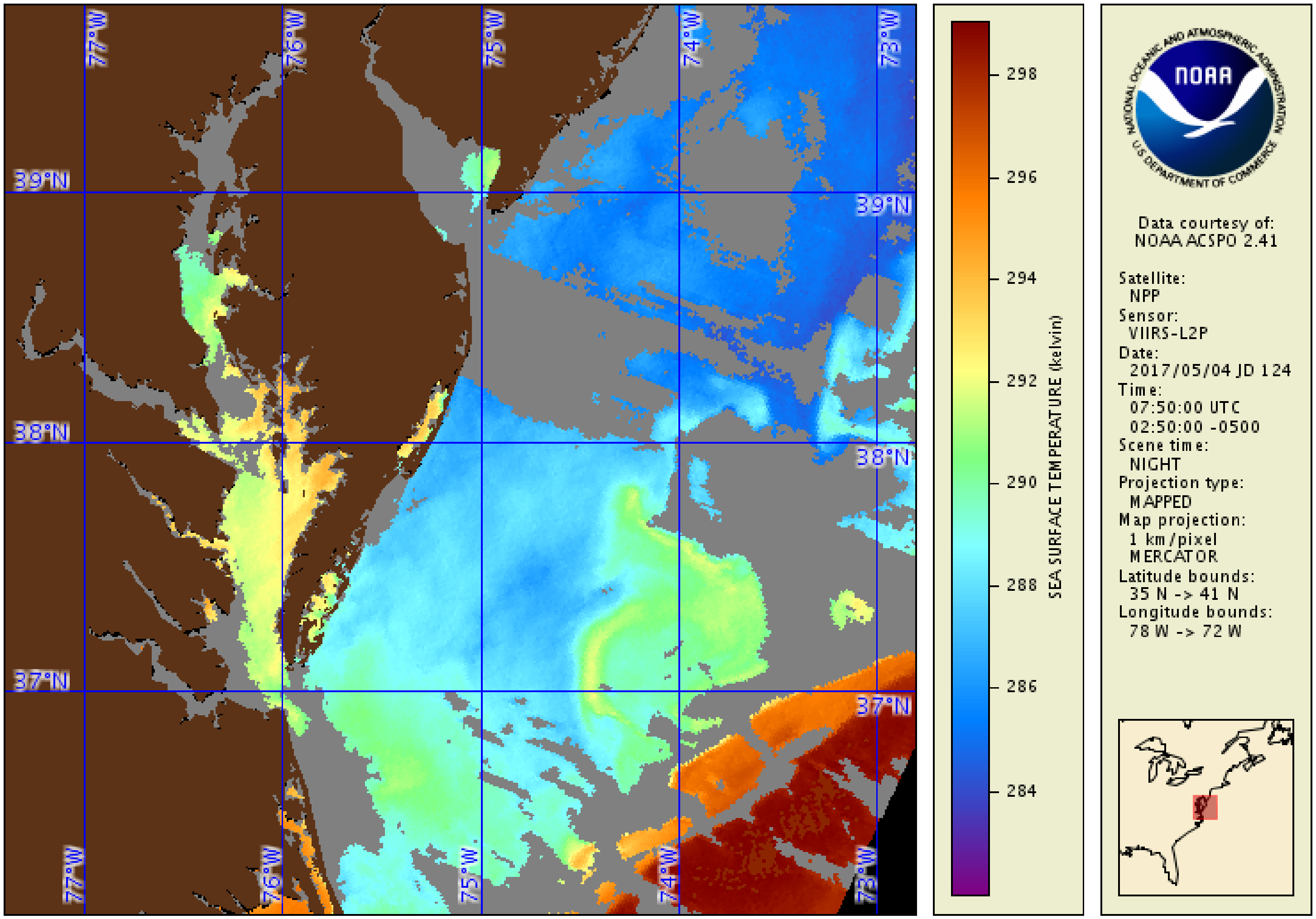
- The L2P QFs/QLs are preserved on L3U using "majority voting rule"
- If majority of L2P pixels (>50%) within the "search domain" have QL=5, then the L3U grid is assigned a QL=5, and 0 otherwise
- Other L3U quality bits (land/ice/water, glint. Twilight, day/night, etc) are also calculated from the L2P using the same majority voting rule

VIIRS on 4 May 2017
(Nighttime)

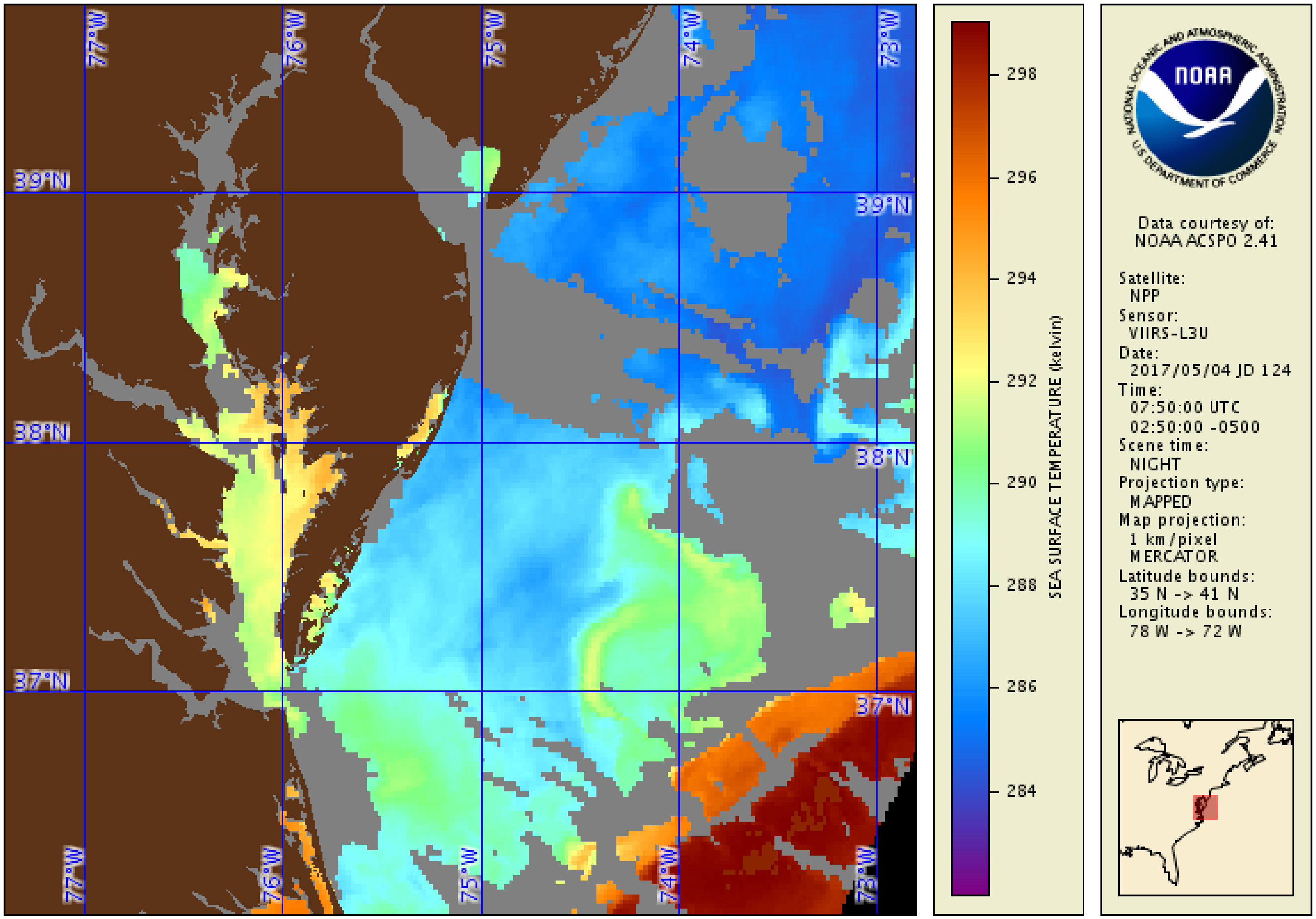
SNPP VIIRS L2P All-Sky



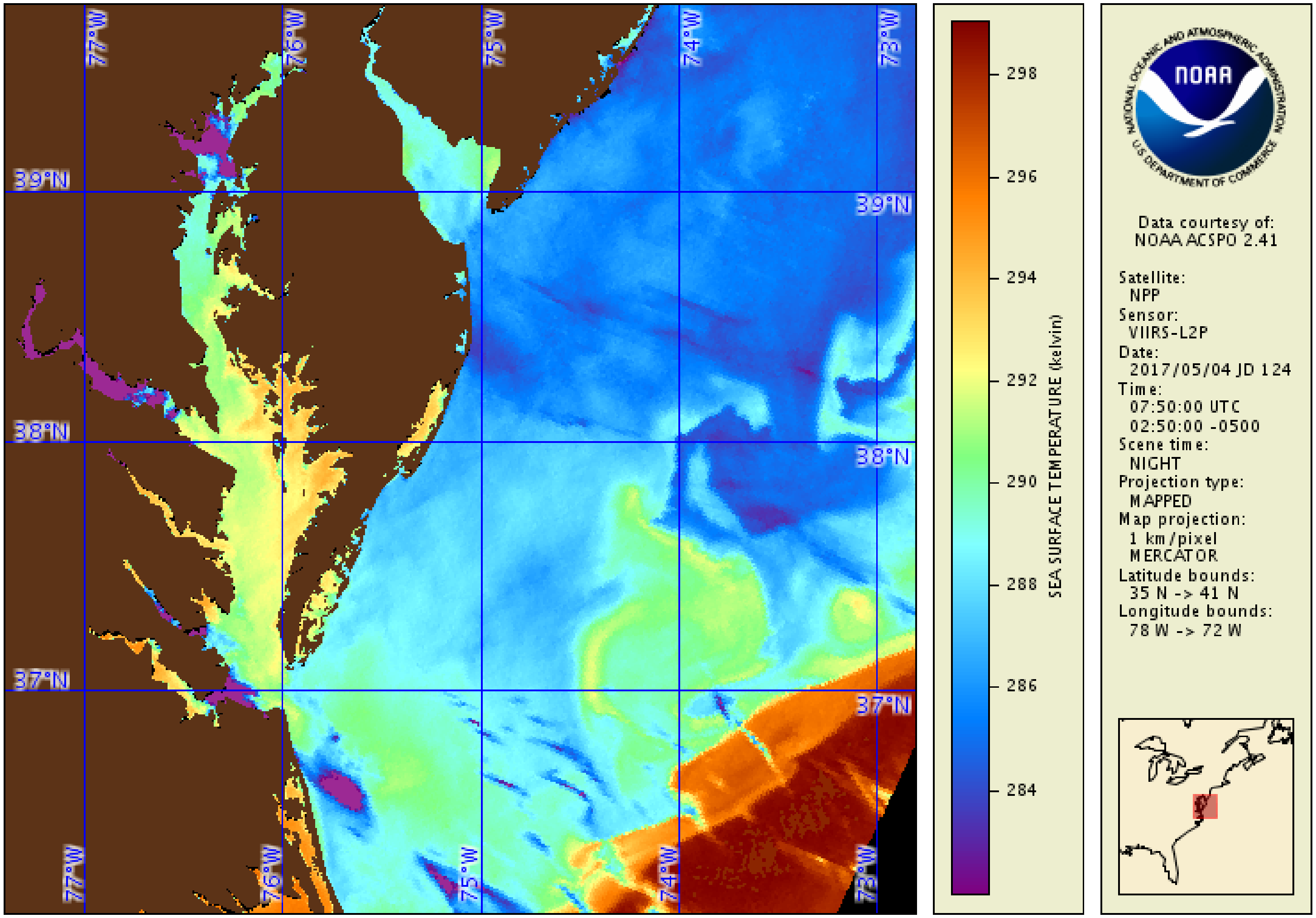
SNPP VIIRS L2P Clear-Sky



SNPP VIIRS L3U Clear-Sky



SNPP VIIRS L2P All-Sky



Front Preservation in ACSPO L3U

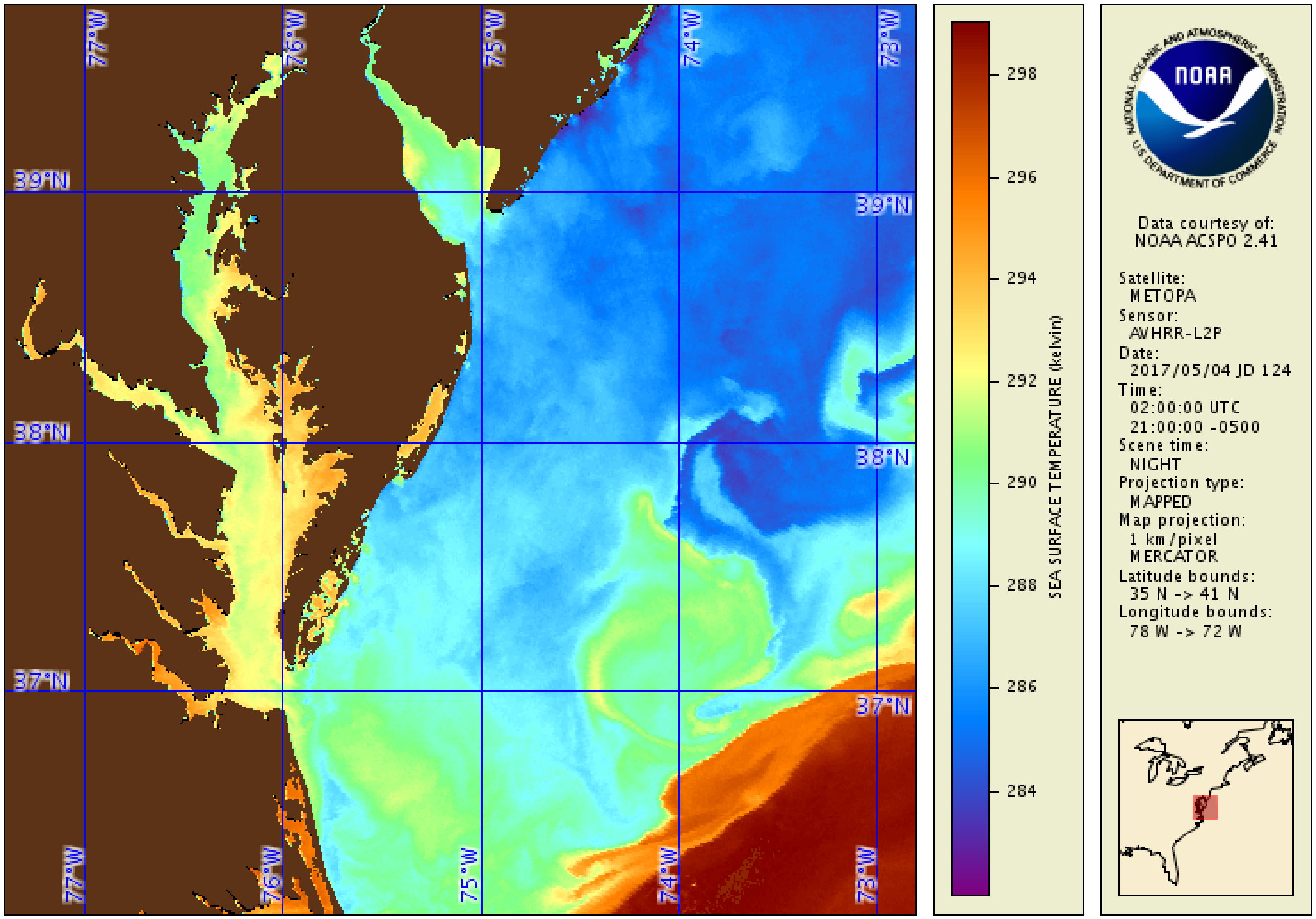
- L3U domain is slightly larger than in L2P, due to a 5×5 L3U grids search window

- The current ACSPO L2P clear-sky mask tends to exclude colder side of the thermal fronts as “cloud”. *(This problem occurs relatively infrequently and does not appear to affect the global performance of the L2P SST, but it should be accounted for in L3U processing)*

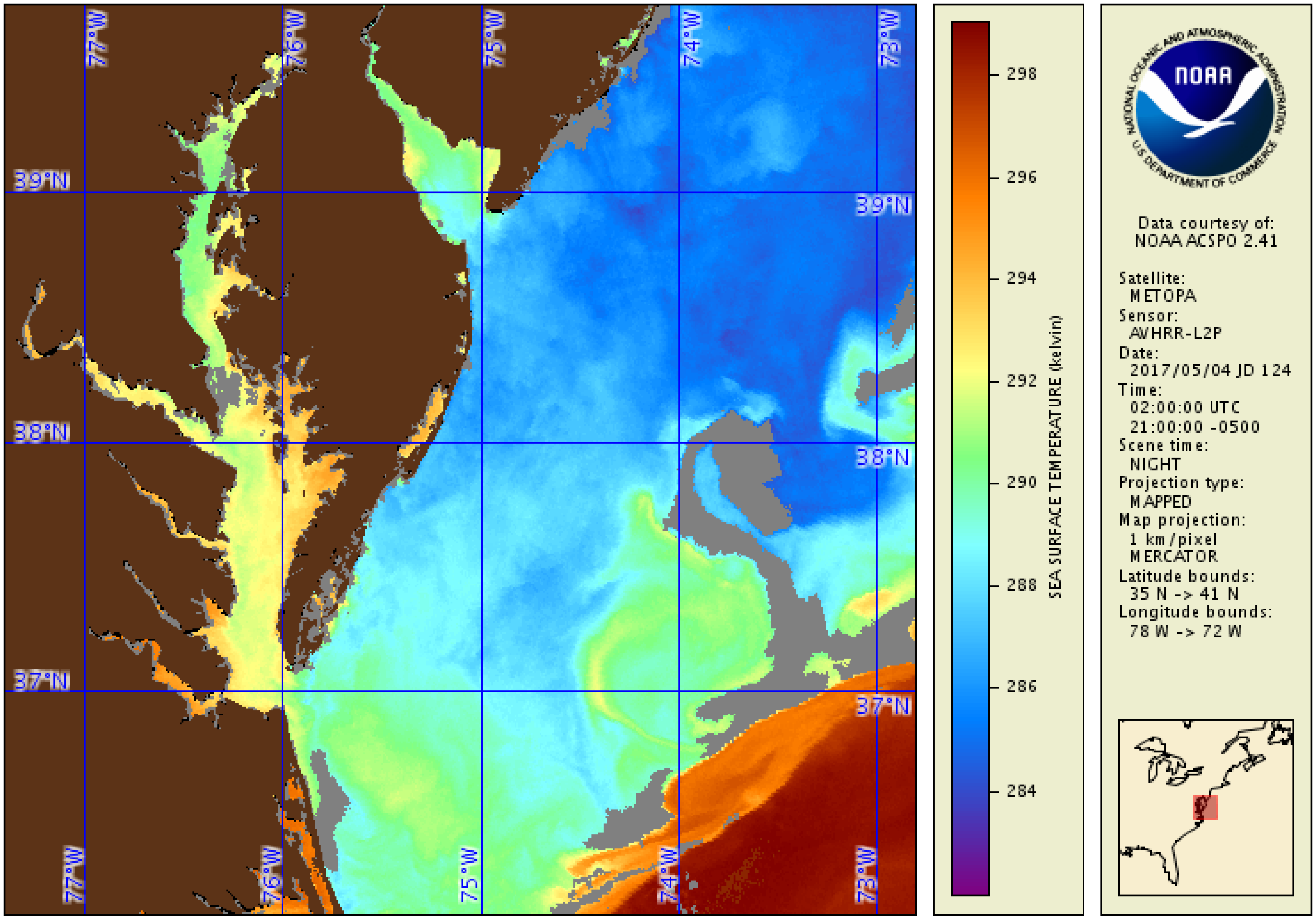
- A special step was taken in the L3U code to avoid extending the warm SSTs to the cold side of the fronts: Calculate NN (for all-sky pixels) & compare its result with that of the Bilateral (for clear-sky only). If the two are within the tolerance ΔT, the grid is preserved in c L3U

Metop-A on 4 May 2017 (Nighttime)

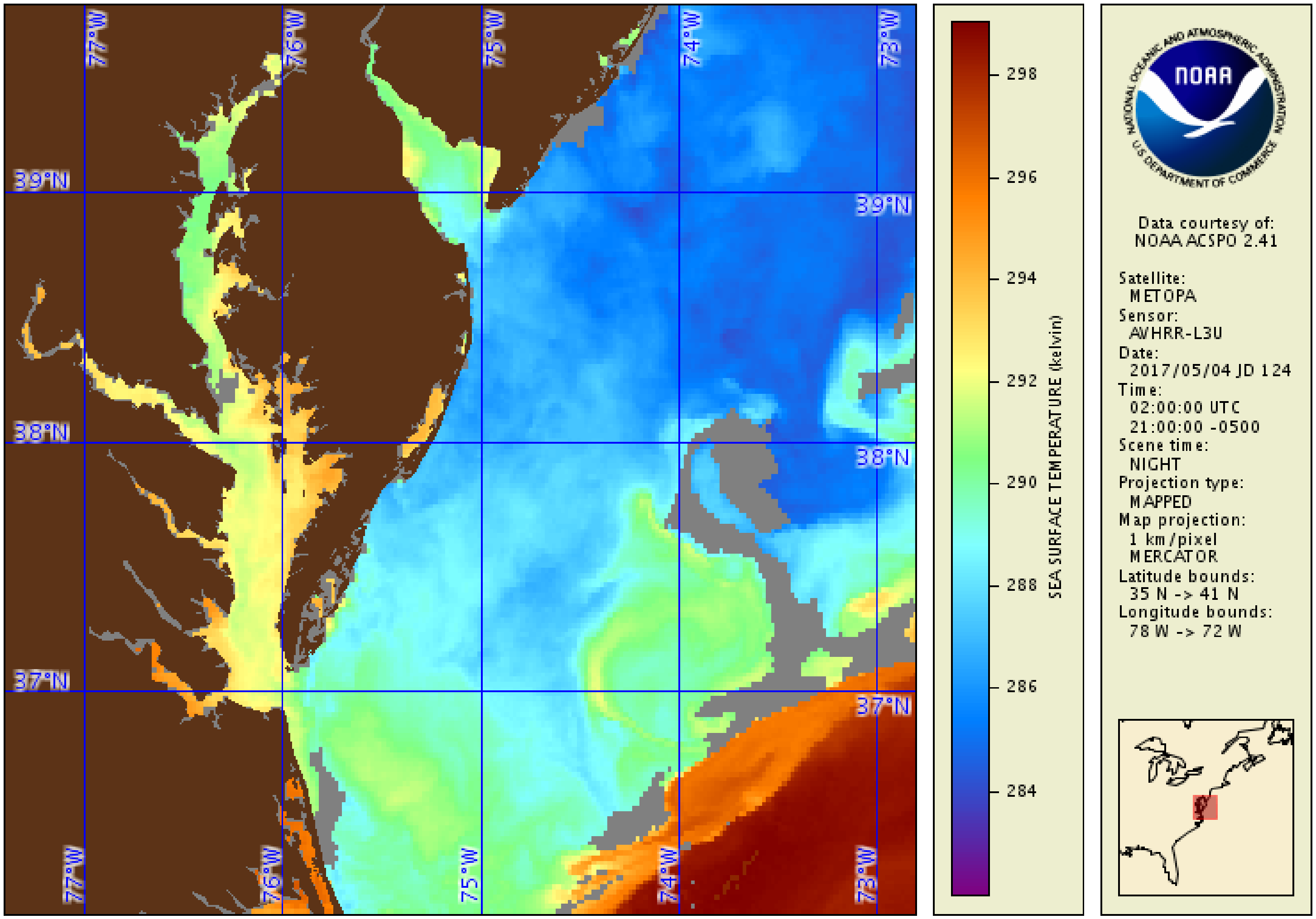
Metop-A AVHRR FRAC L2P All-Sky



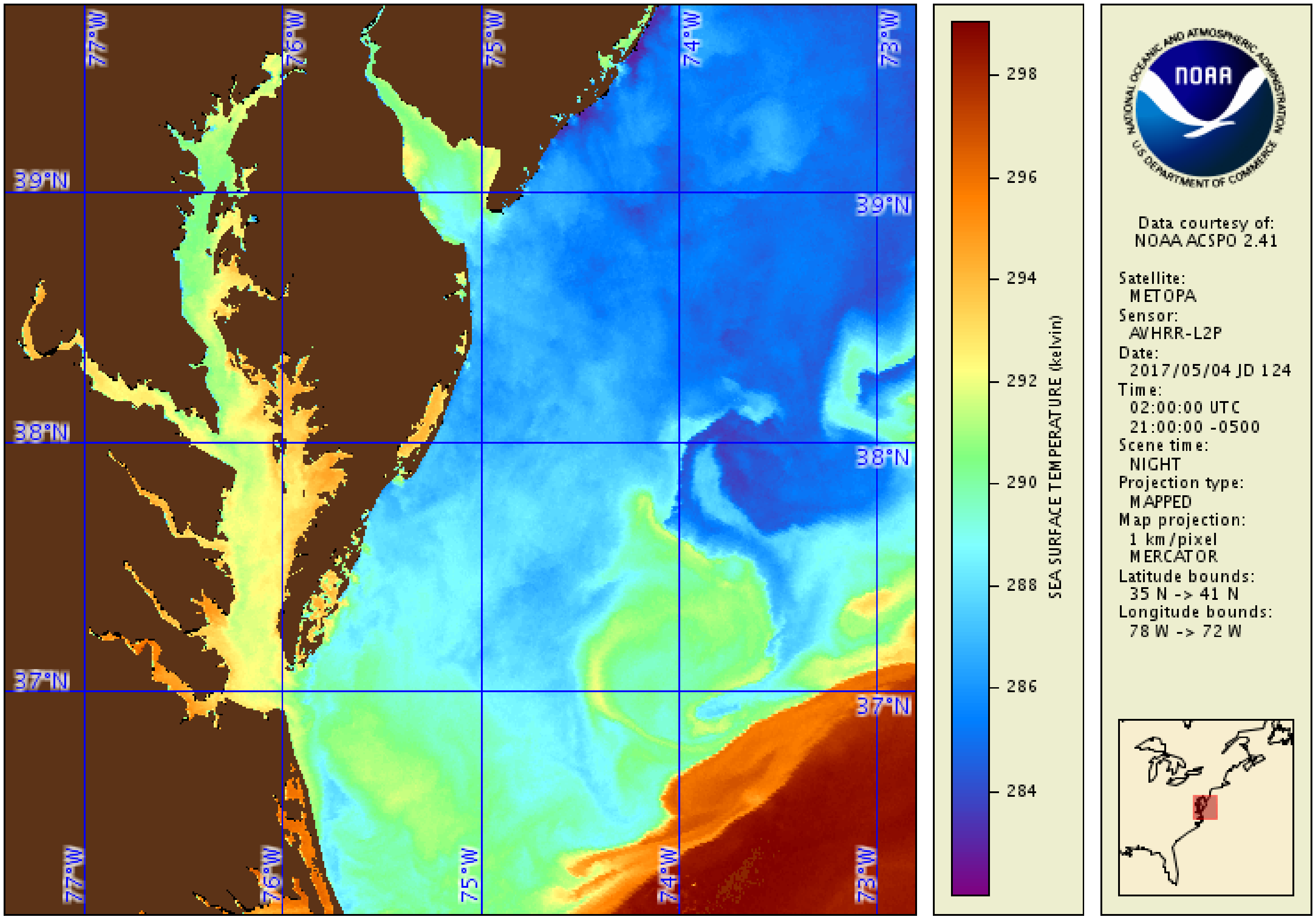
Metop-A AVHRR FRAC L2P Clear-Sky



Metop-A AVHRR FRAC L3U Clear-Sky

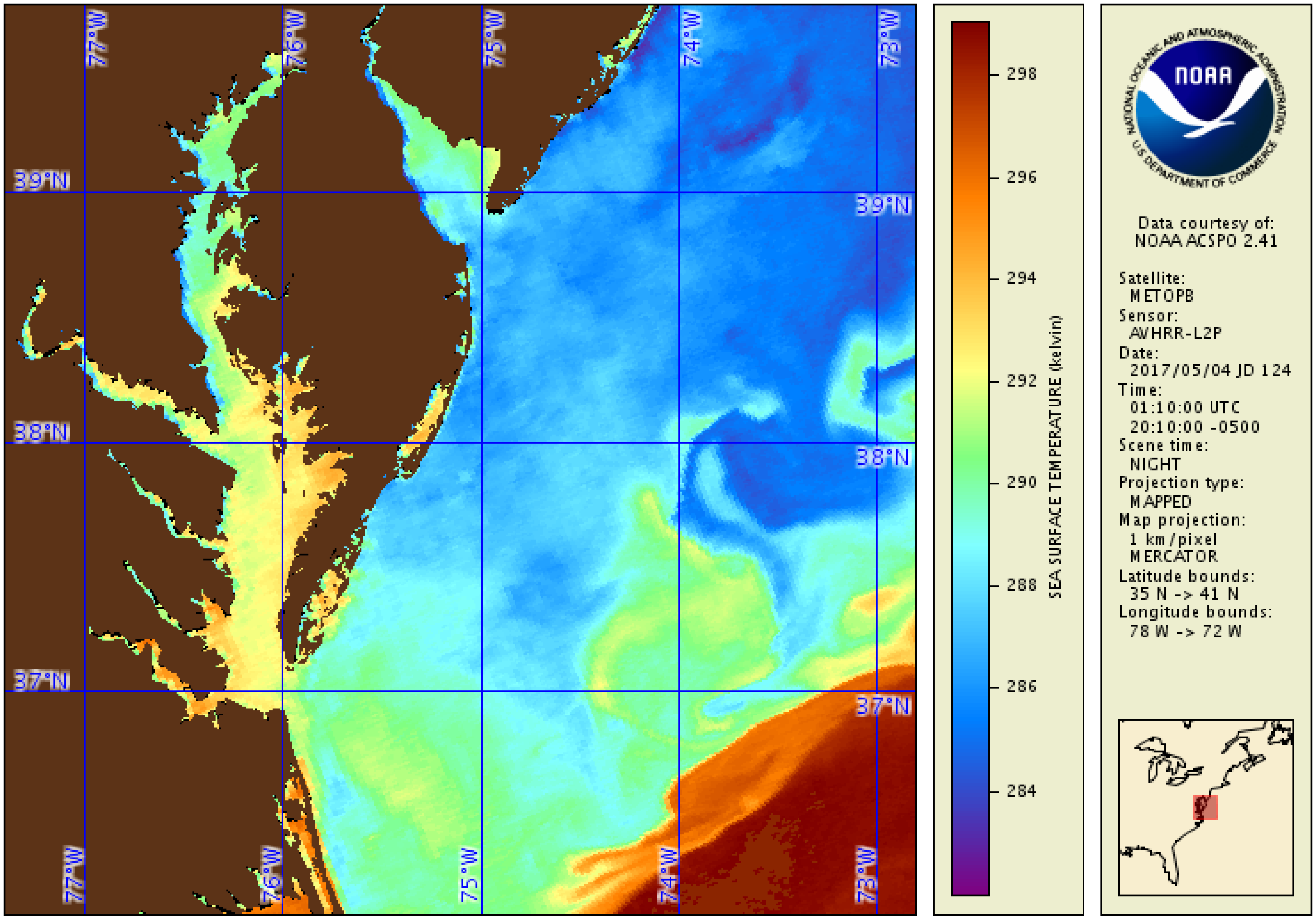


Metop-A AVHRR FRAC L2P All-Sky

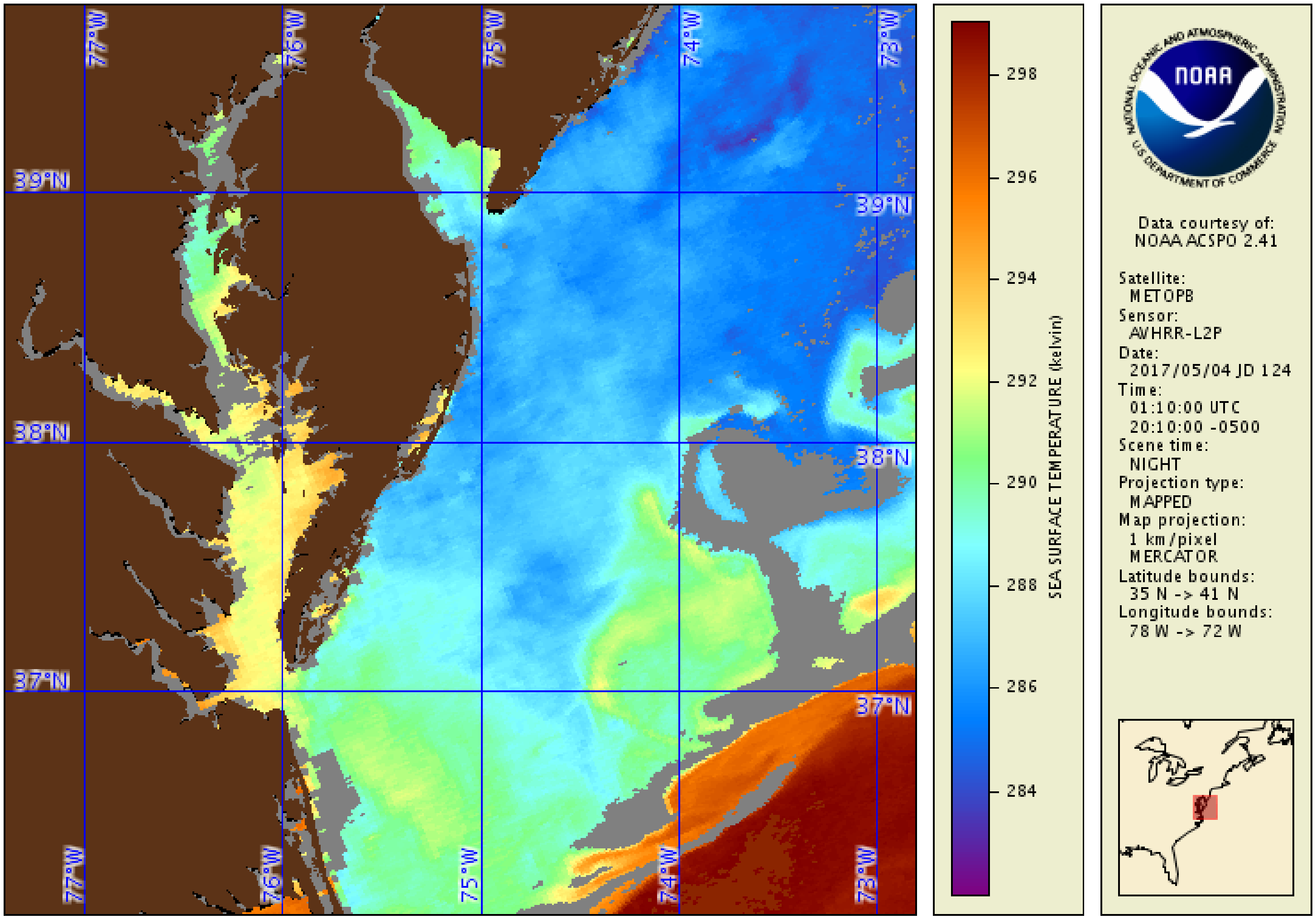


Metop-B on 4 May 2017 (Nighttime)

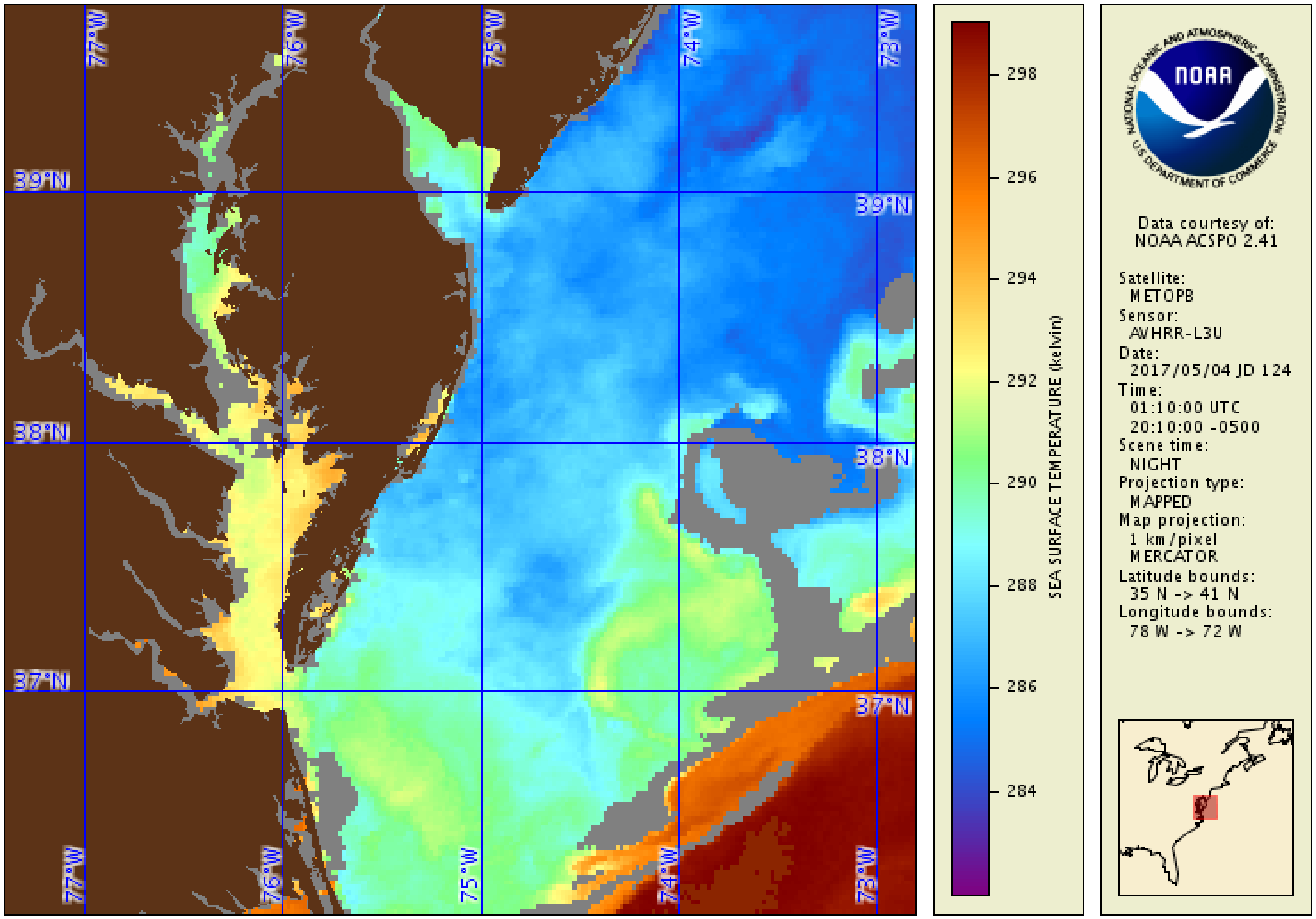
Metop-B AVHRR FRAC L2P All-Sky



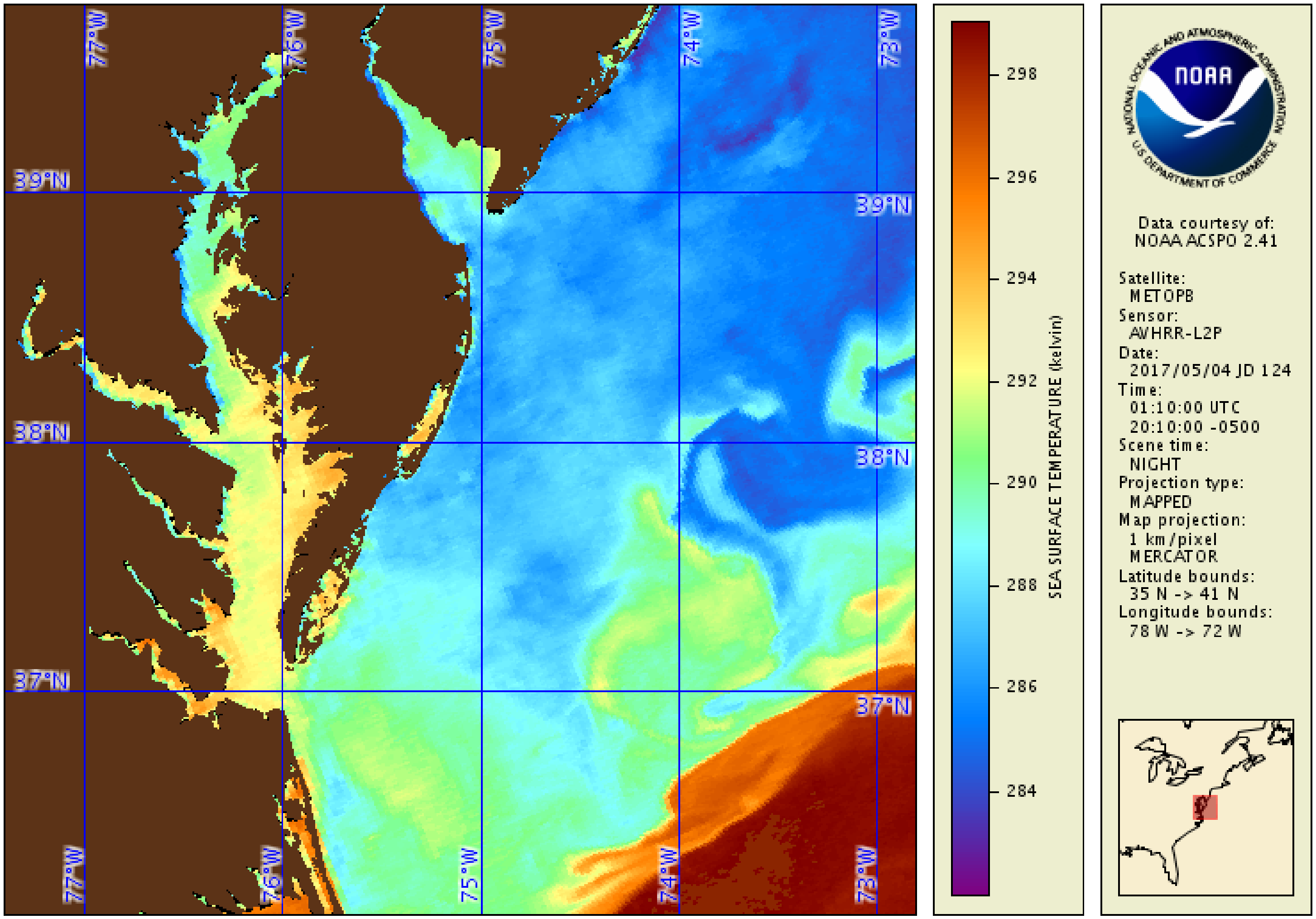
Metop-B AVHRR FRAC L2P Clear-Sky



Metop-B AVHRR FRAC L3U Clear-Sky



Metop-B AVHRR FRAC L2P All-Sky

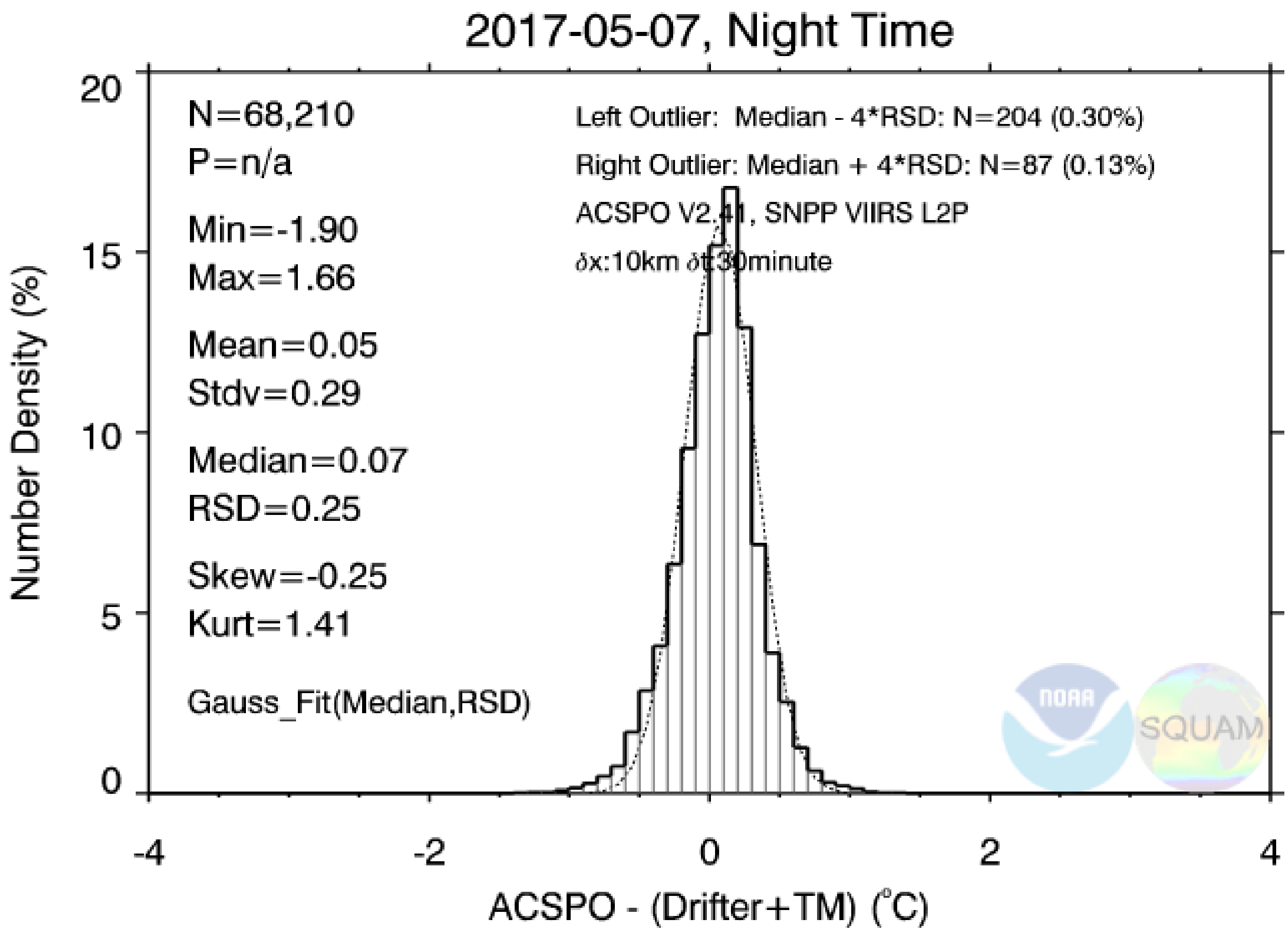


VAL against (Drifters + Trop. Moorings)
L2P – (D+TM) vs. L3U – (D+TM)

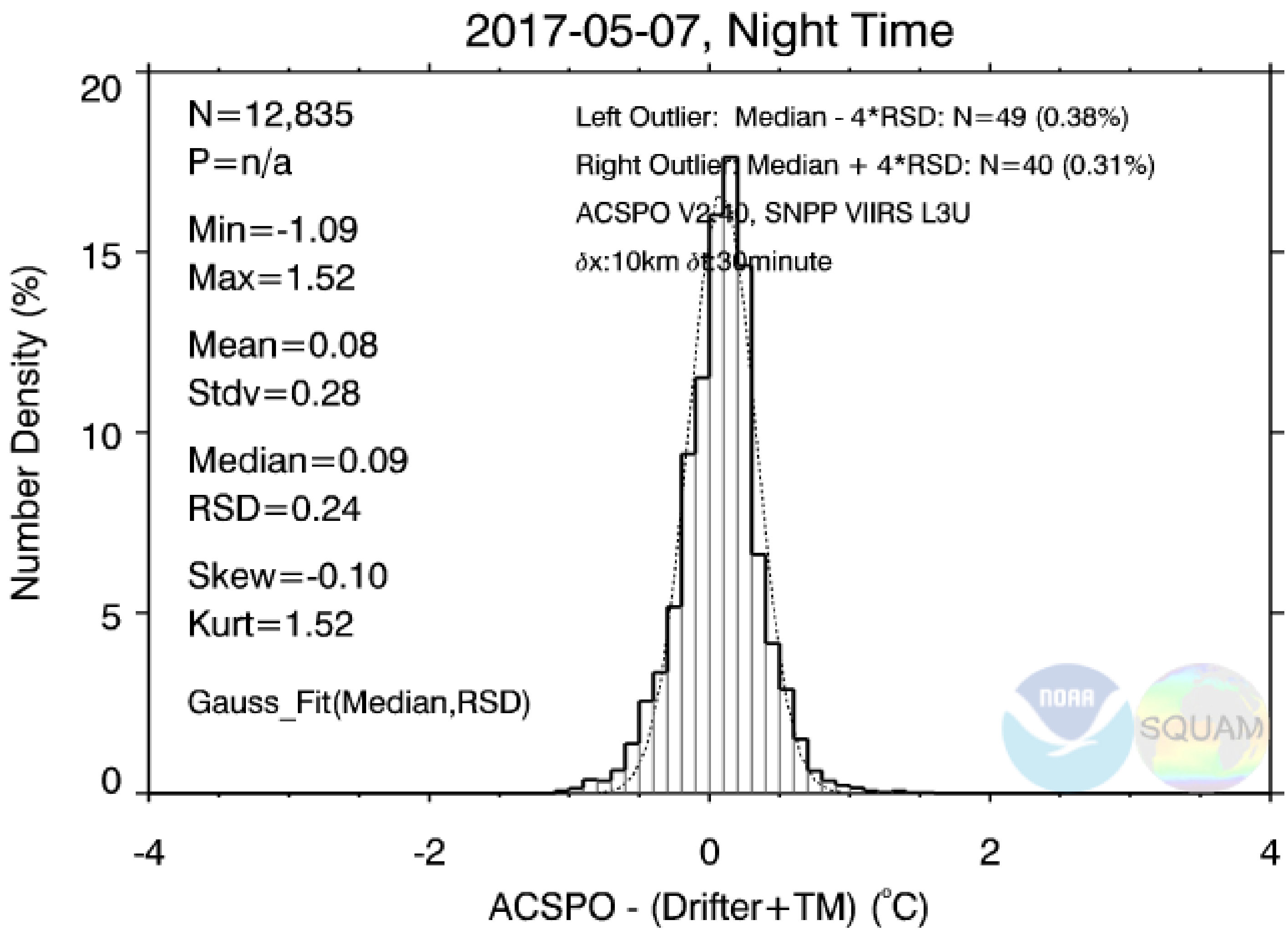
Example for May 7, 2017 (Nighttime)

Results are representative of relative L2P/L3U performance for other days, and for daytime SST

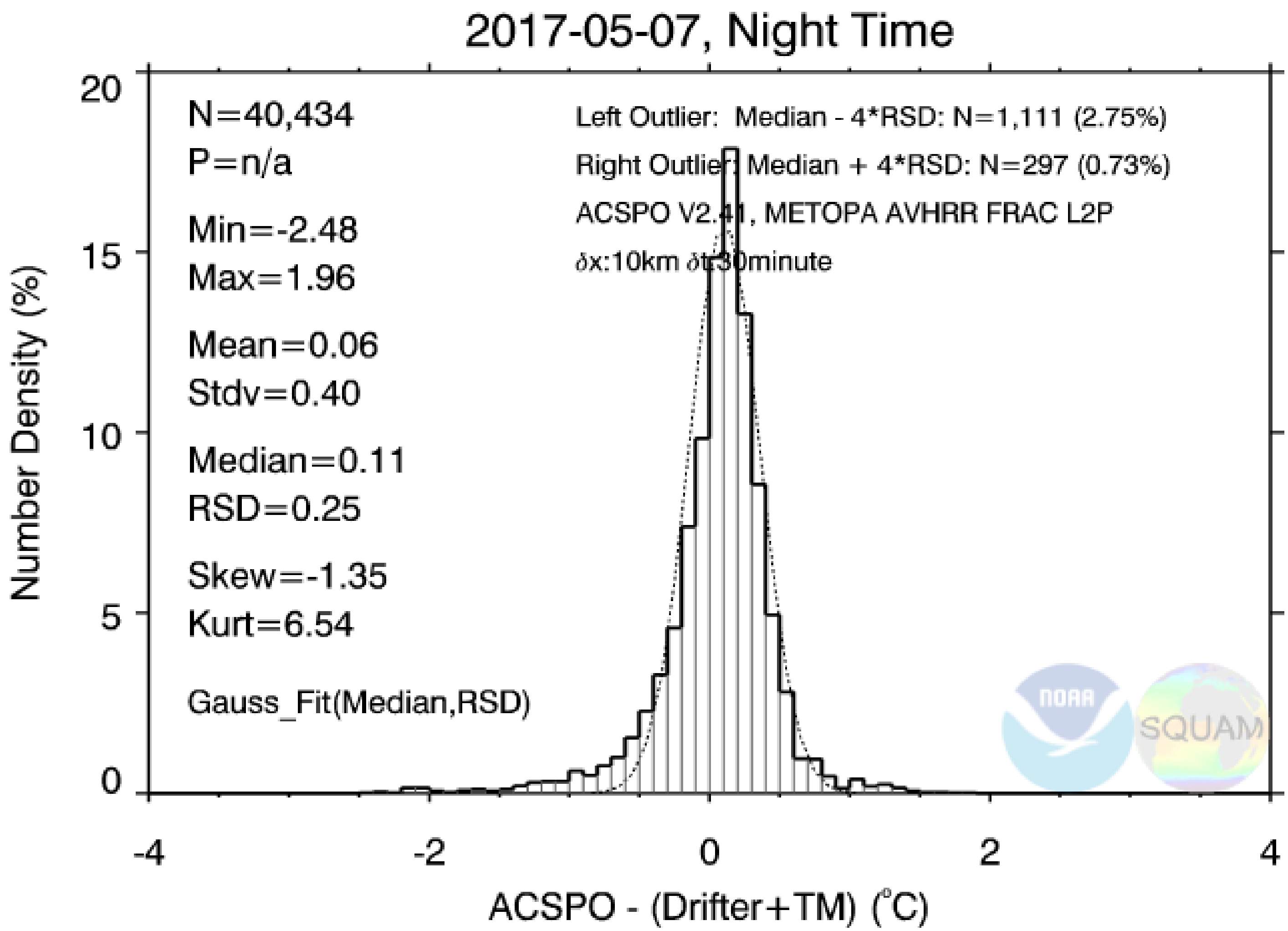
SNPP VIIRS L2P: Night



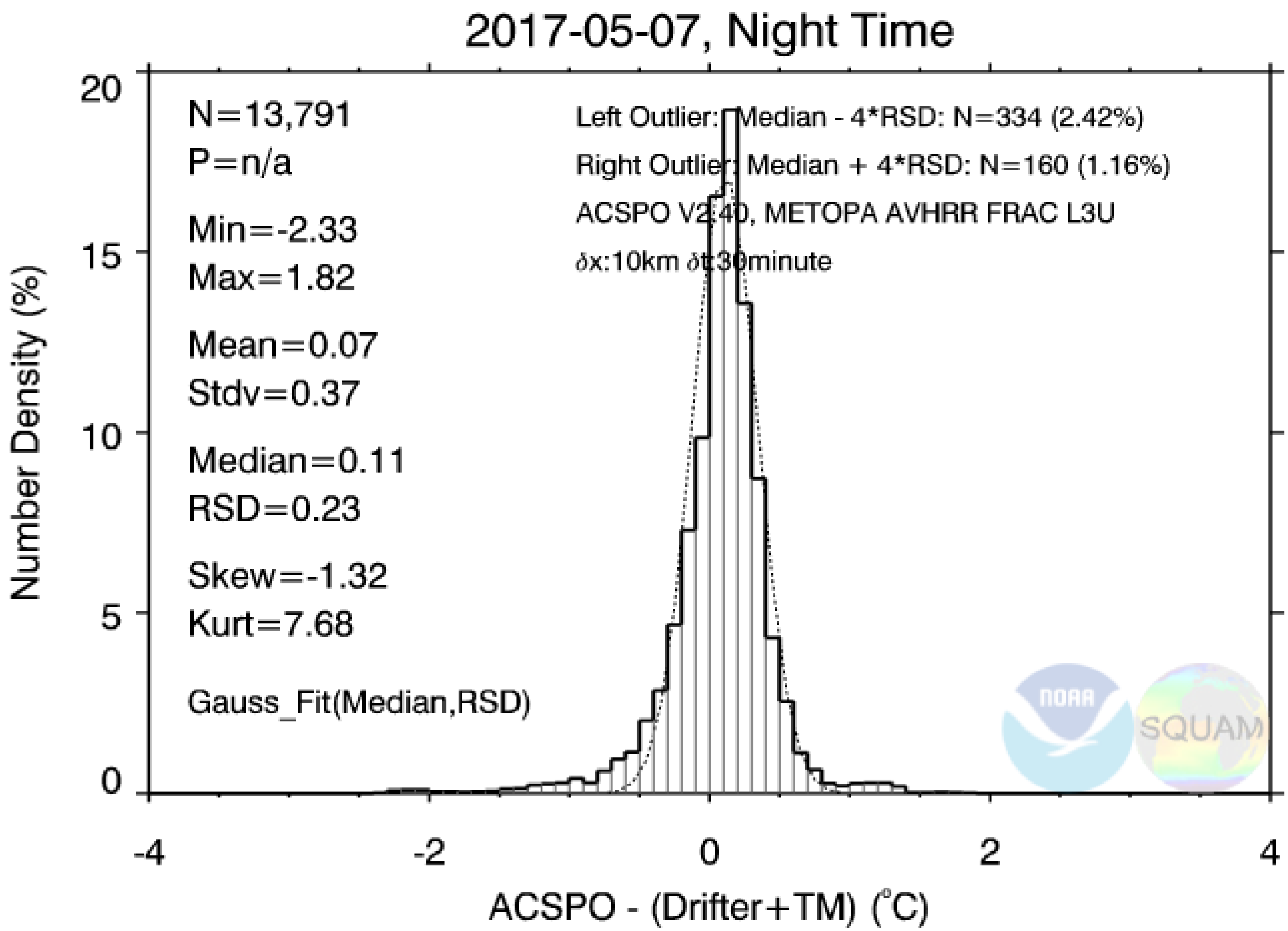
SNPP VIIRS L3U: Night



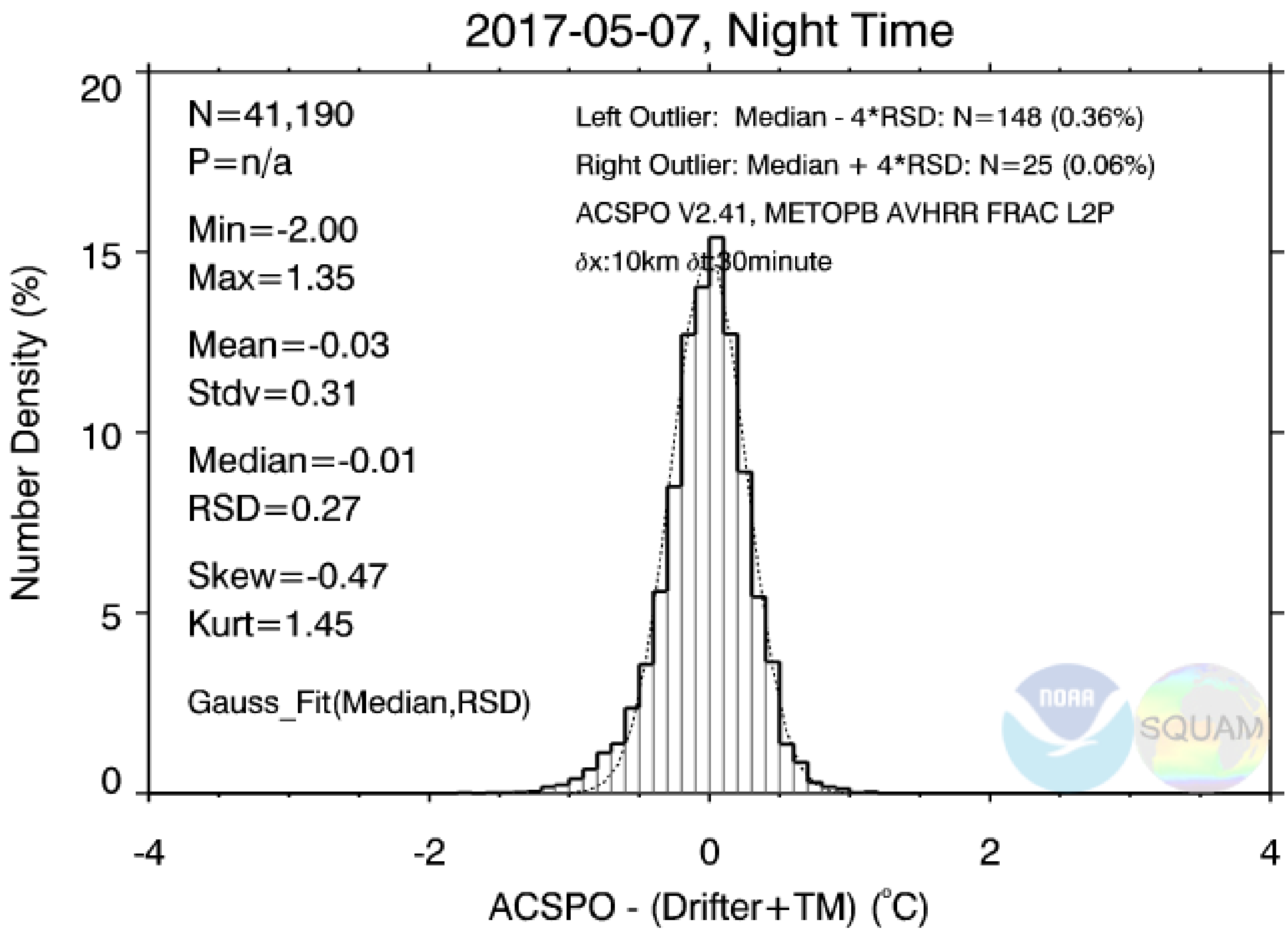
Metop-A AVHRR FRAC L2P: Night



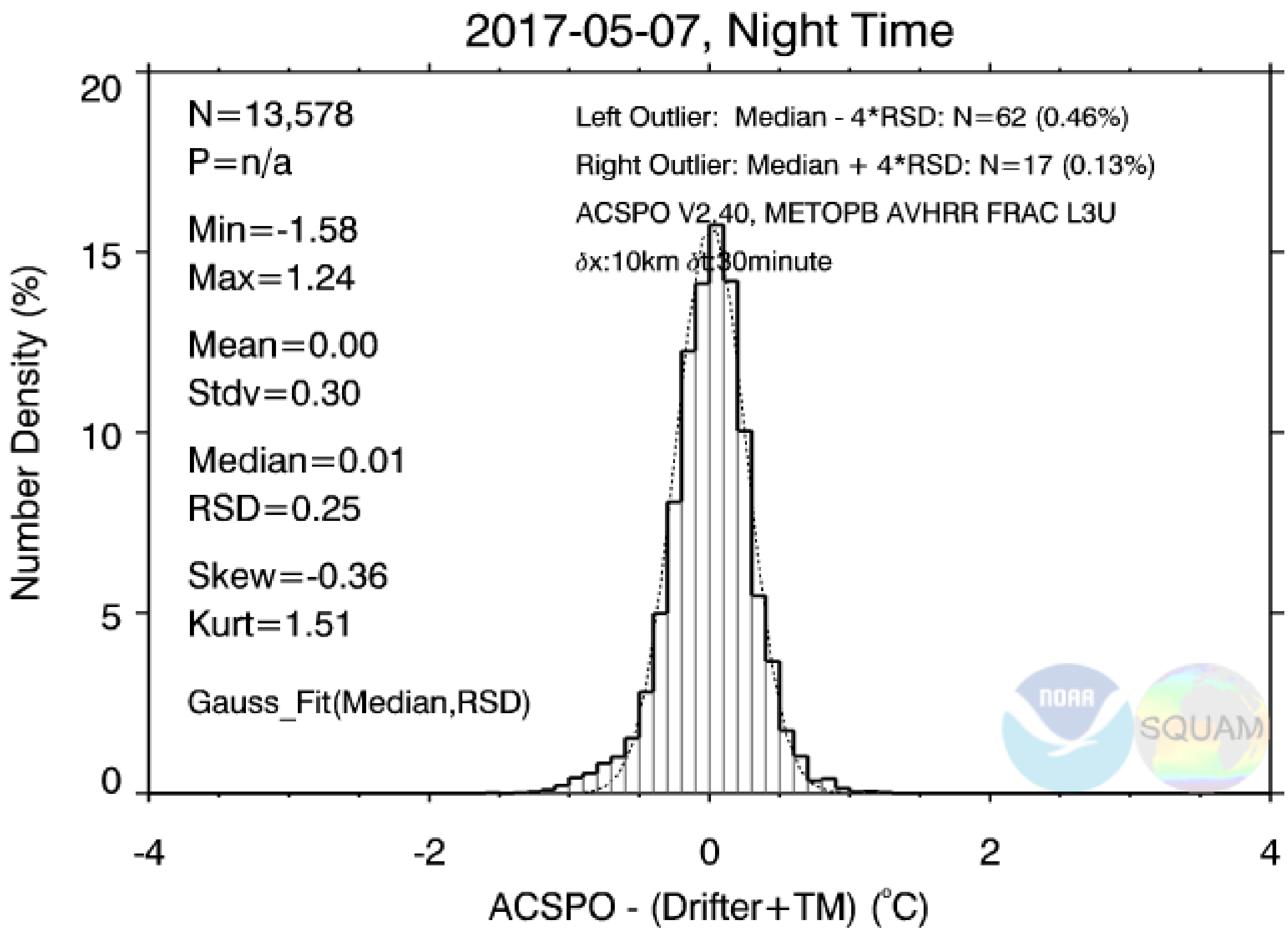
Metop-A AVHRR FRAC L3U: Night



Metop-B AVHRR FRAC L2P: Night



Metop-B AVHRR FRAC L3U: Night



Conclusion

- ACSPO v2.41 L3U better accounts for the specifics of the ACSPO SST product
- The algorithm employs bi-lateral weighting to produce L3U close to L2P. In particular, is preserves the edges while reducing image noise
- ACSPO v2.41 L3U includes a complete set of L2P QLs/QFs
- The VIIRS and AVHRR FRAC L3U products are routinely monitored and validated against *i*Quam in the NOAA SST Quality Monitor (SQUAM) and ACSPO Regional Monitor for SST (ARMS) systems
- All global and regional analyses so far suggest that the VIIRS and Metop-A and -B FRAC L3U product is comparable with the L2P, in feature resolution & preservation, and global performance statistics

A consistent line of L3U products will be soon available from Metop-A and -B AVHHR FRAC, and from Metop-C (after Oct'2018). Contact Alex.Ignatov@noaa.gov for data

Future Work

Near-future

- Generate L3Us from other polar (AVHRR GAC, MODIS) and geo (H8/AHI and G16/ABI) sensors

More distant future

- Test Level 3C ("collated") from L3Us
- Test Level 3S products ("super-collated") from L3U
- May explore improvements to the gridding algorithm/its parameters (in particular, latitude and view zenith angle dependent parameters)

For more information

- Ignatov, A., I. Gladkova, Y. Ding, F. Shahriar, Y. Kihai, X. Zhou, 2017. JPSS VIIRS Level 3 uncollated SST Product at NOAA. *J. Appl. Remote Sens.*, **11**(*3*), 032405, doi:10.1117/1.JRS.11.032405.

Thank You!