Consistent Line of ACSPO L3U SST Products

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Irina Gladkova[2,3], Alexander Ignatov[1], Yury Kihai[1,2]

(1) NOAA/STAR (2) GST, Inc. (3) CCNY

Acknowledgements: Xinjia Zhou (CSU CIRA); Yanni Ding (formerly CSU CIRA); Kai He (formerly GST, Inc.)

Previous ACSPO (v2.41) VIIRS L3U

L2P: GDS2 Swath Projection

- Organized in 10 minute granules (26 GB/day)
- Assimilated into NOAA Geo-Polar Blended and CMC L4 products
- EUMETCast initially pulled L2P data but asked for reduced volume data
- BoM, Met Office, JMA also asked for reduced volume VIIRS files

L3U: GDS2 Gridded Equiangular (0.02°) Uncollated

- Organized in 10 minute granules (0.45 GB/day)
- Initial implementation based on the BoM L3U code (C. Griffin, H. Beggs)
- Preserves spatial gradients, while reducing imagery noise elsewhere
- Preserves complete set of L2P flags
- Provides global coverage & performance statistics comparable to L2P
- Minimizes ACSPO residual clear-sky mask artifacts

New ACSPO (v2.60) L3U for Multiple Sensors

L3U: GDS2 Gridded Equiangular (0.02°) Uncollated

- Generated operationally for VIIRS (SNPP), ABI (G16), and AHI (H08)
- Also generated in near-real-time for VIIRS (N20), AVHRR FRAC (MetOp-A/B), AVHRR GAC (MetOp-A/B/N18/N19), MODIS (Terra/Aqua)
- Consistently organized in
  - 10 minute uncollated granules (L3U) for all polar platforms; and
  - Hourly collated granules (L3C) for all geostationary platforms
- Uniform algorithm across all sensors with parameters specific to each sensor
- Continues to provide global coverage & performance statistics comparable to L2P/C
- Feature-preserving upsampling for sensors with a native resolution lower than the 0.02° equiangular grid (AVHRR GAC/ABI/AHI)
- All products are available in a two-week rotating buffer from NOAA CoastWatch: **coastwatch.noaa.gov/cw_html/sst.html**

L2P vs. L3U Data Volume

	GDS2 L2P (GB/day)	GDS2 L3U (GB/day)	Factor
VIIRS (S-NPP/N20)	26	0.45	~58x
MODIS (Aqua/Terra)	7.1	0.45	~16x
AVHRR FRAC (MetOp-A/B)	7.5	0.4	~19x
AVHRR GAC (MetOp-A/B/N18/N19)	0.7	0.3	~2.5x
ABI (G16/G17, Hourly)	6.2	0.6	~10x
AHI (H08/09, Hourly)	6.5	0.6	~11x

(Average of 1-7 March 2018, ACSPO V2.60 beta04)

Bilateral Algorithm Parameters

The ACSPO L3U algorithm uses **bilateral filtering**:

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

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

- The parameter σ_s determines the spatial weighting and roughly corresponds to the sensor resolution.
- The parameter σ_v determines the intensity weighting and roughly corresponds to the sensor noise level.
- An additional parameter ΔT helps preserve the positions of fronts: If the nearest neighbor is less than ΔT from the result of bilateral filtering, then the nearest neighbor value is used

Current Parameter Values

	σ_s, km	σ_v, K	ΔT, K
VIIRS (S-NPP/N20)	1.0	0.100	0.350
MODIS Aqua	1.5	0.200	0.475
MODIS Terra	1.5	0.250	0.500
AVHRR FRAC MetOp-A	2.0	0.215	0.575
AVHRR FRAC MetOp-B	2.0	0.175	0.550
AVHRR GAC (MetOp-A/B & N18/19)	5.0	0.200	0.0
ABI (G16/17)	1.0 *	0.100	0.350
AHI (H08/09)	1.0 *	0.100	0.350

* VZA dependent, nadir value listed

Determined by the sensor resolution

Determined by the sensor NEdT

Empirically minimizes front displacement

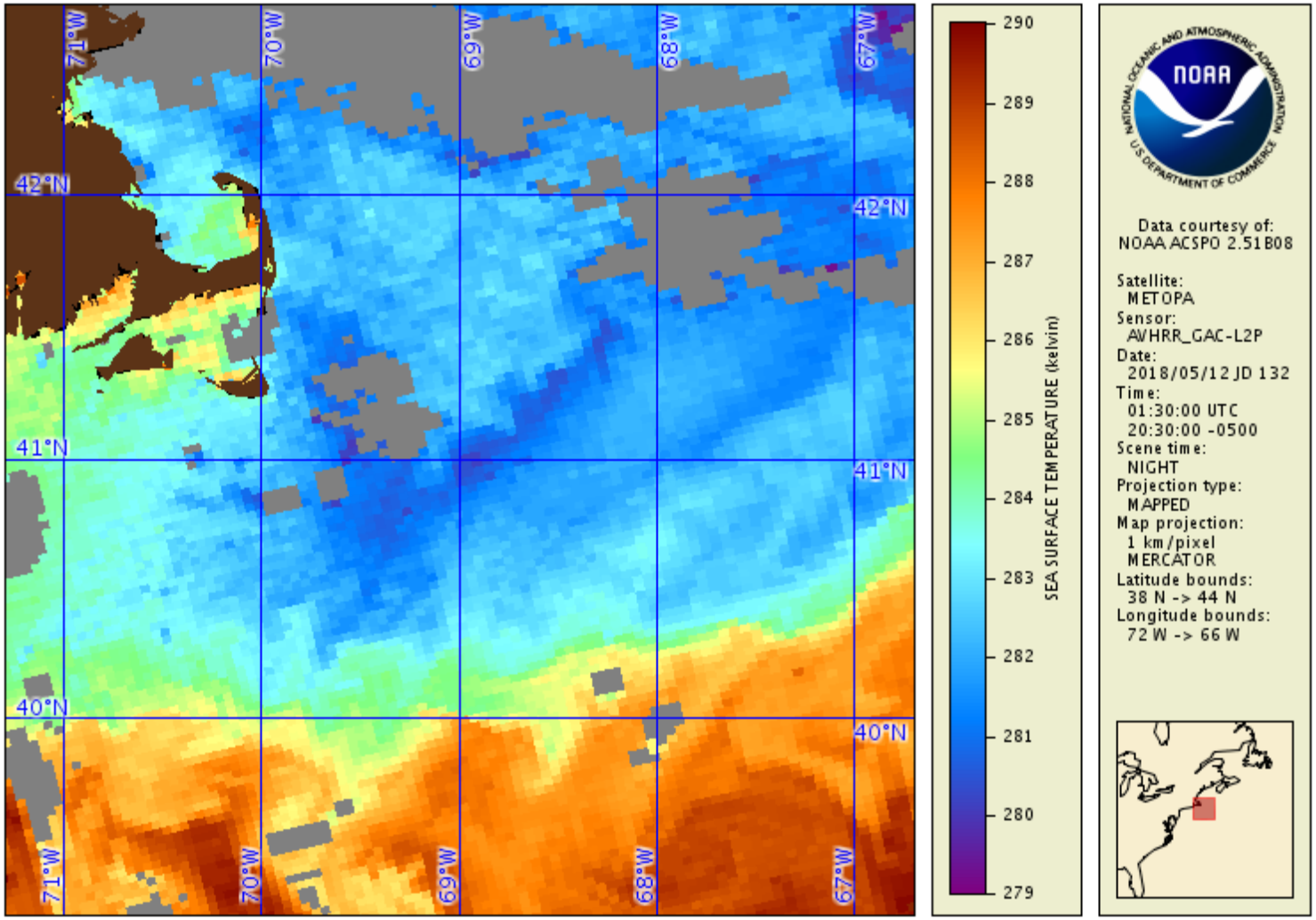
Quality Levels, Flags, and SSES

- The L2P quality level (QL) and flags are preserved in L3U using a “majority voting rule”
- If majority of L2P pixels (> 50%) in the “neighborhood” of an L3U grid have QL = 5, then the L3U pixel is assigned QL = 5, otherwise it is assigned QL = 0
- Other L3U flags (land/water, ice, glint, twilight, day/night, etc.) are calculated from the L2P using the same majority voting rule
- SSES bias and standard deviation are re-gridded using the same bilateral algorithm as the SST.

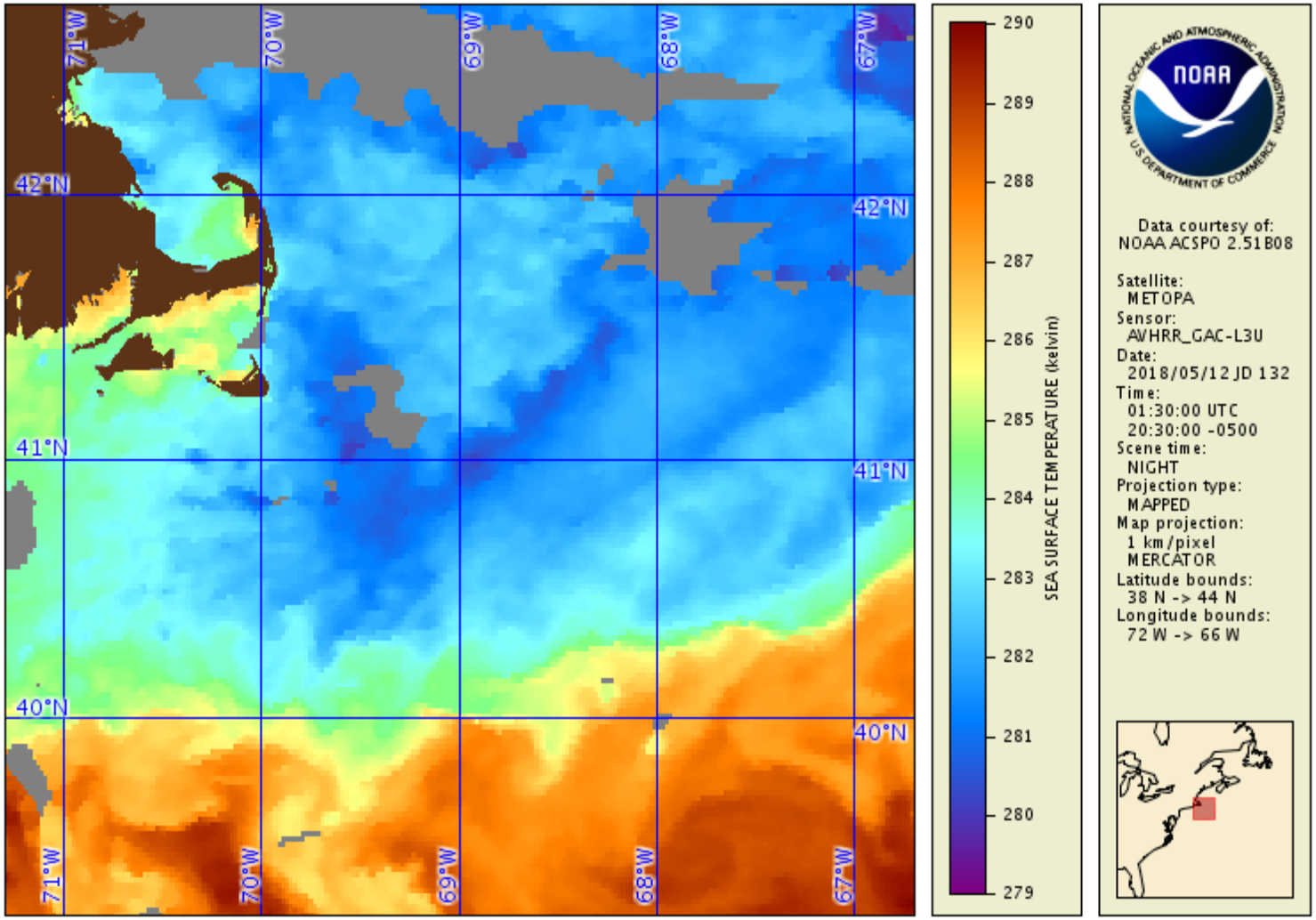
Upsampling Low-Resolution Sensors

- The bilateral algorithm is well suited for sensors which are at least as well resolved as the 0.02° L3U grid (VIIRS full swath; ABI/AHI, AVHRR/FRAC and MODIS at nadir)
- For lower-resolution sensors, we use the same bilateral algorithm but on L2P data which were upsampled using only spatial weighting. (Currently, only implemented for AVHRR GAC; plan to eventually extend to ABI/AHI, AVHRR/FRAC, and MODIS)
- The upsampling is performed in the swath projection so that the view-angle-dependent footprint of the pixels is automatically accounted for
- Only data which are marked QL = 5 are included in the spatial weighting, and QLs/flags are assigned by nearest neighbor
- The result is a consistent algorithm across all sensors, which **preserves features** for high-resolution sensors and **reveals features** for low-resolution sensors

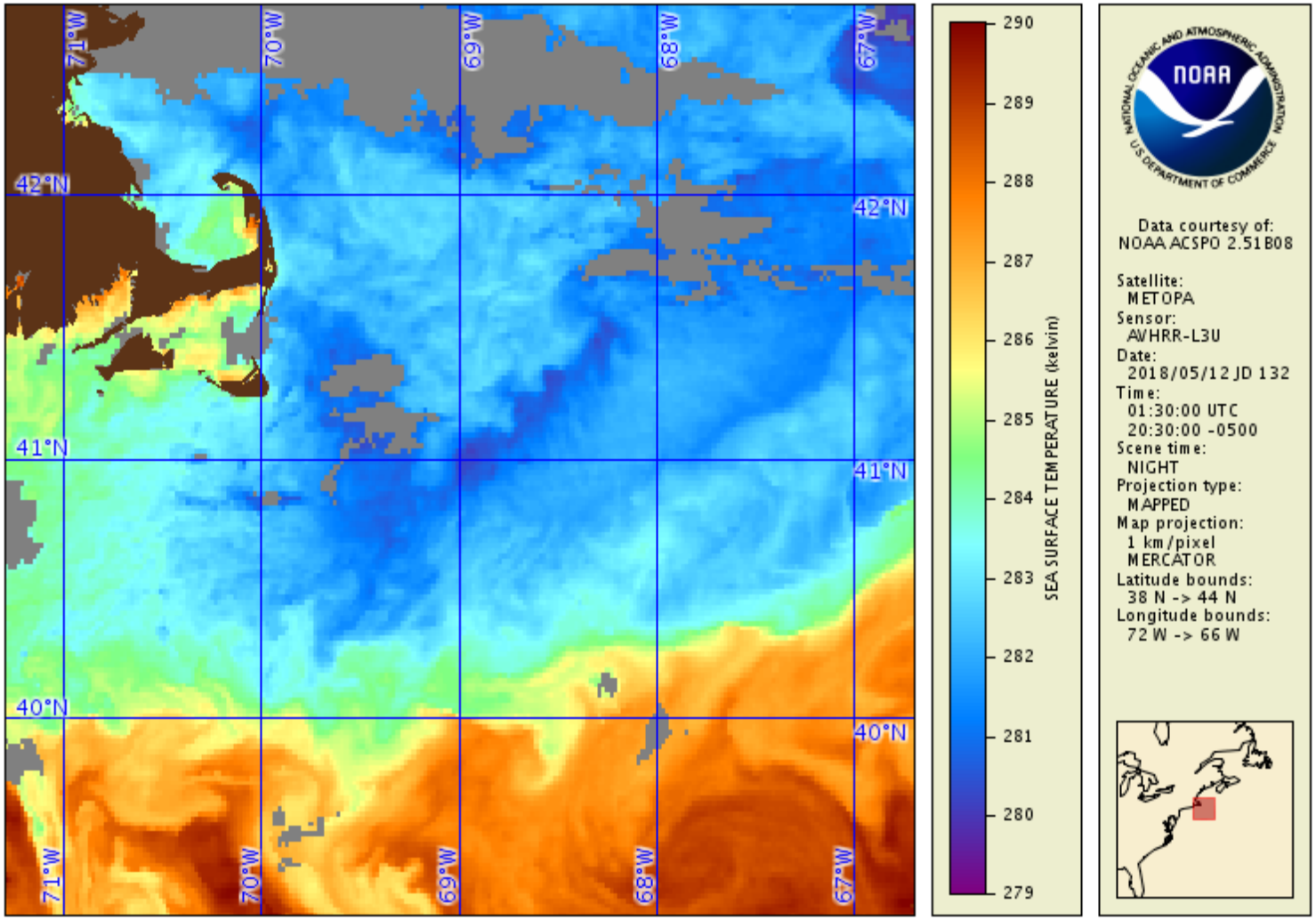
Metop-A GAC L2P (Near Nadir)



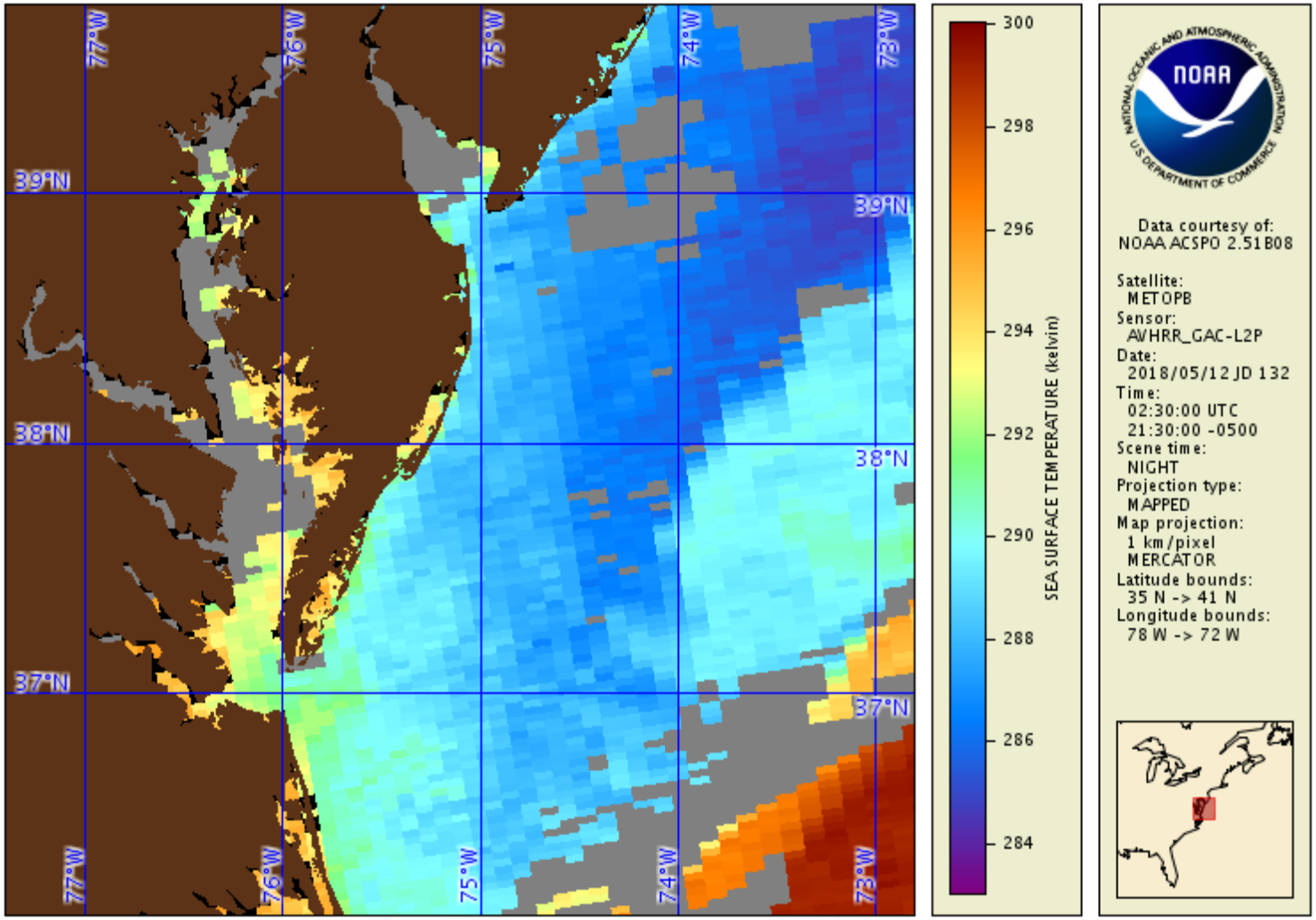
Metop-A GAC L3U (Near Nadir)



Metop-A FRAC L3U (Near Nadir)



Metop-B GAC L2P (Swath-Edge)



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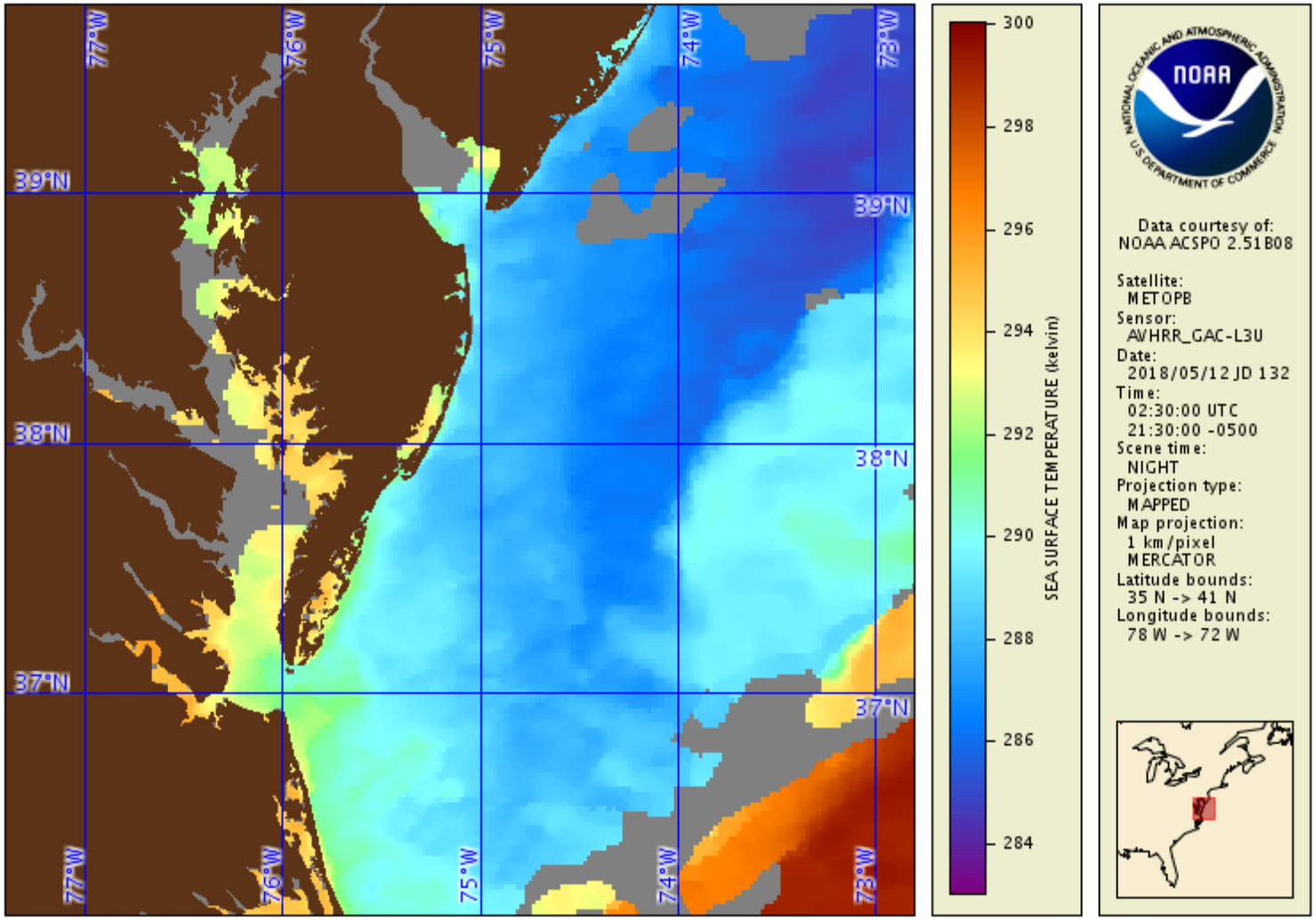
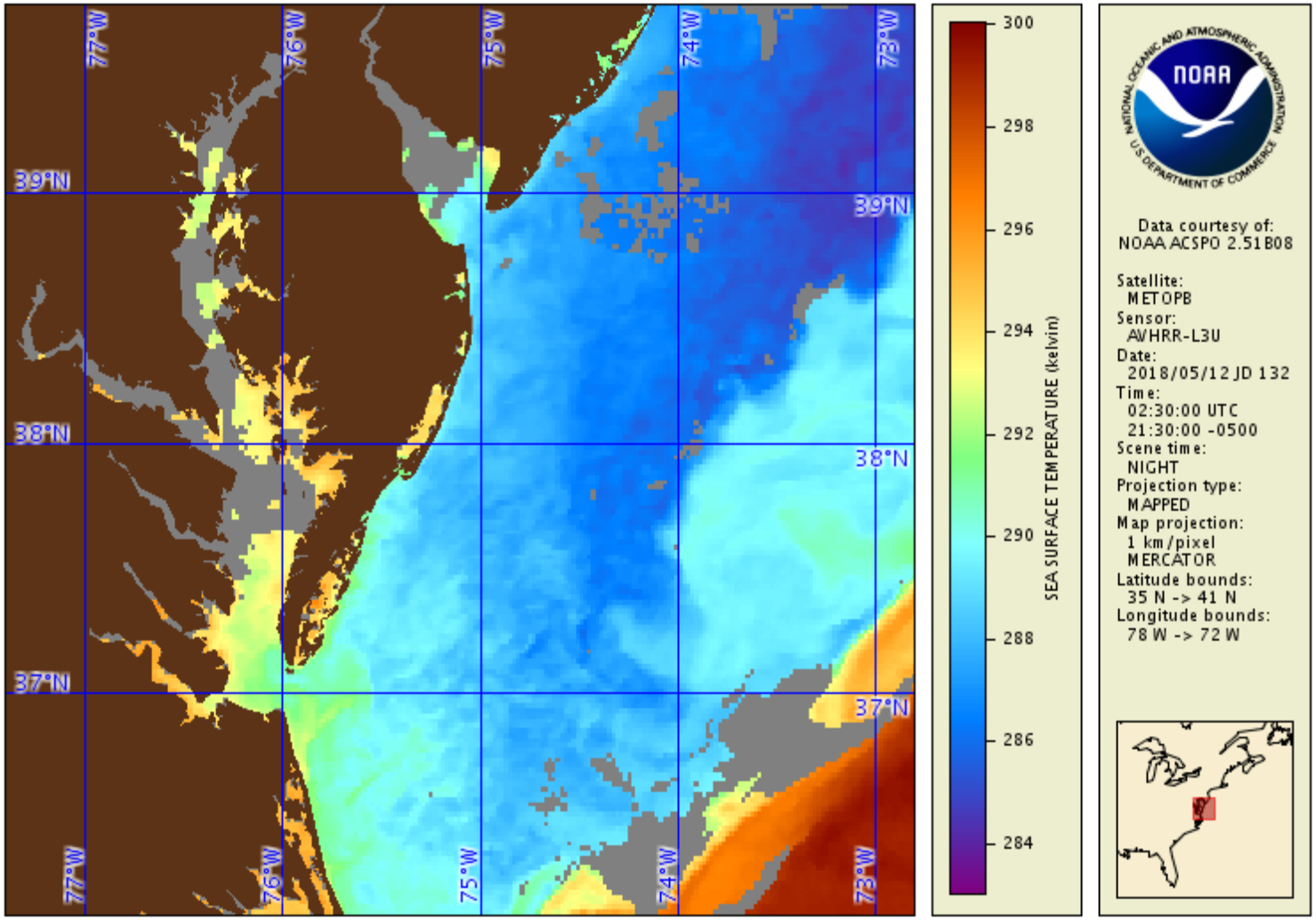


Metop-B FRAC L3U (Swath-Edge)



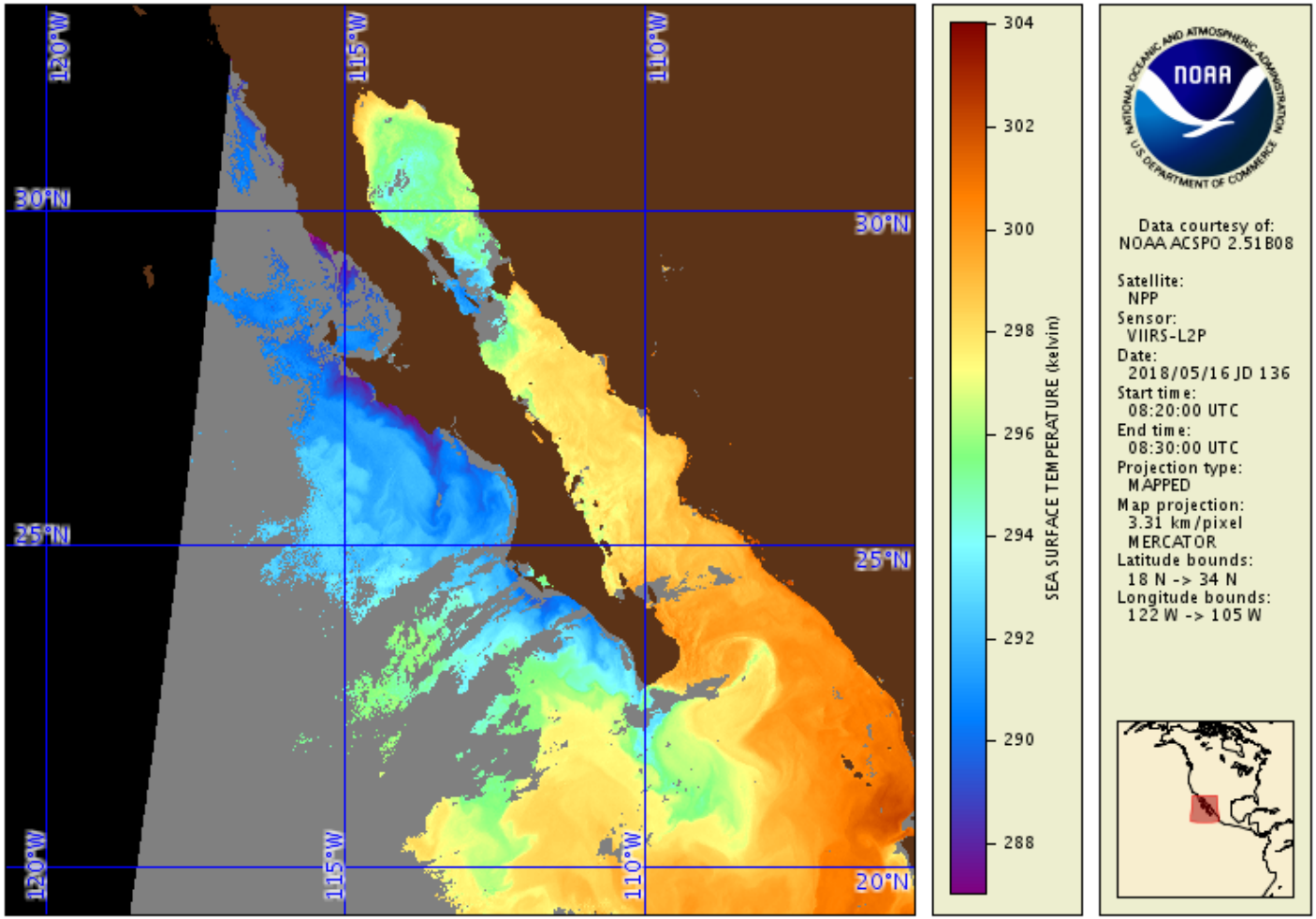
Sample Imagery

16 May 2018 (Night)

Results are representative of relative L2P/L3U performance for other dates and for daytime

For more imagery, visit ARMS: https://www.star.nesdis.noaa.gov/sod/sst/arms/

S-NPP VIIRS L2P



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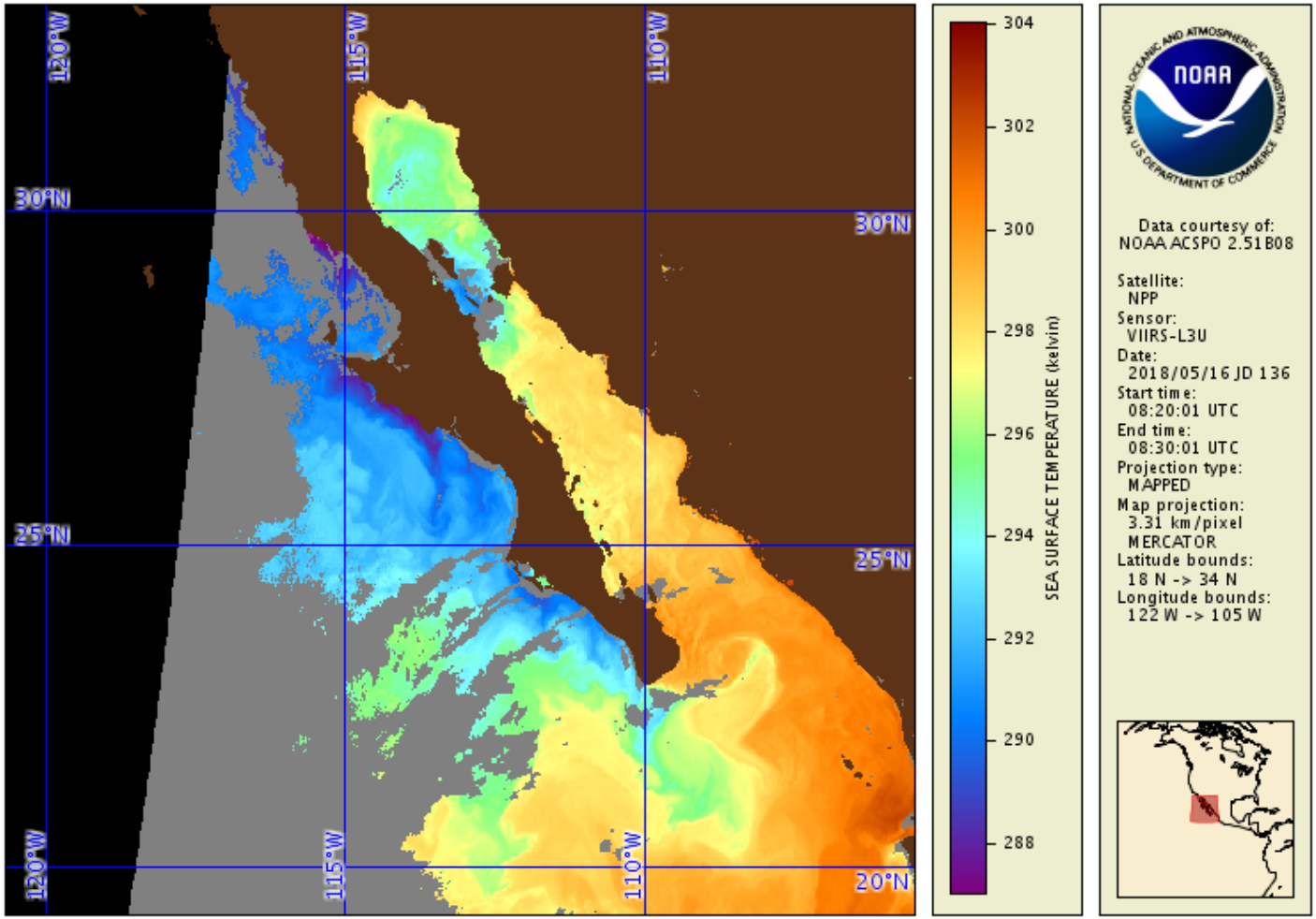
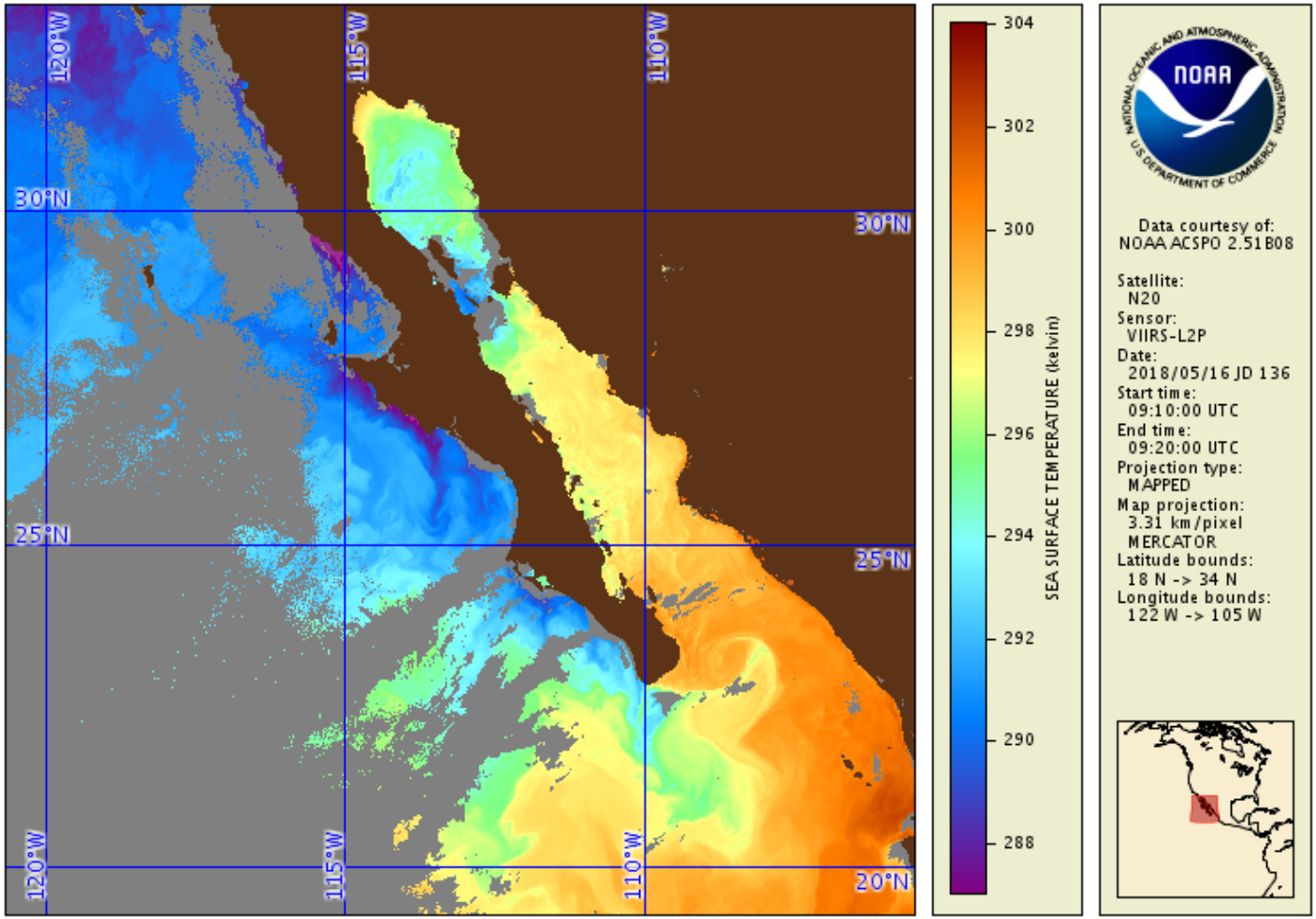
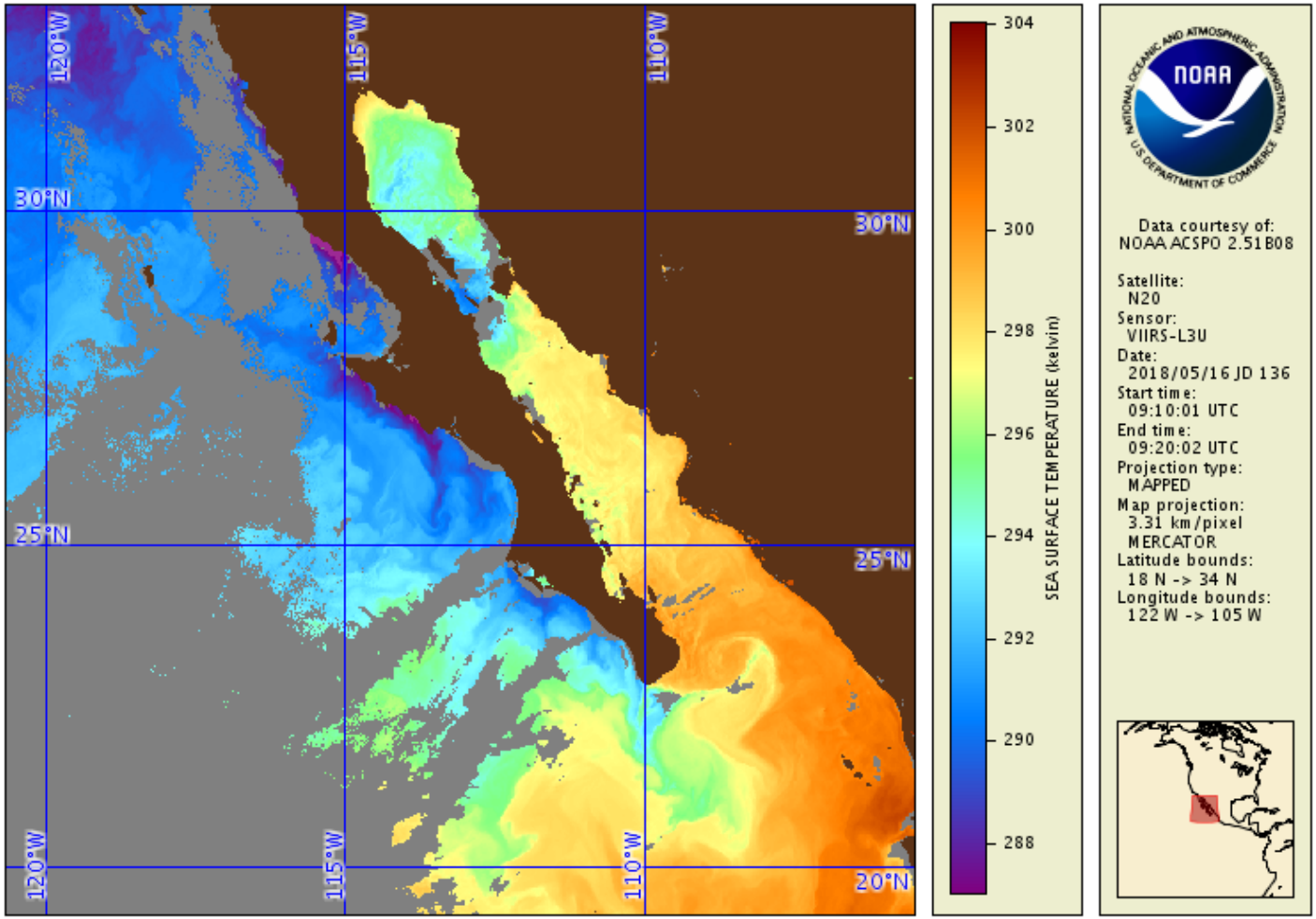


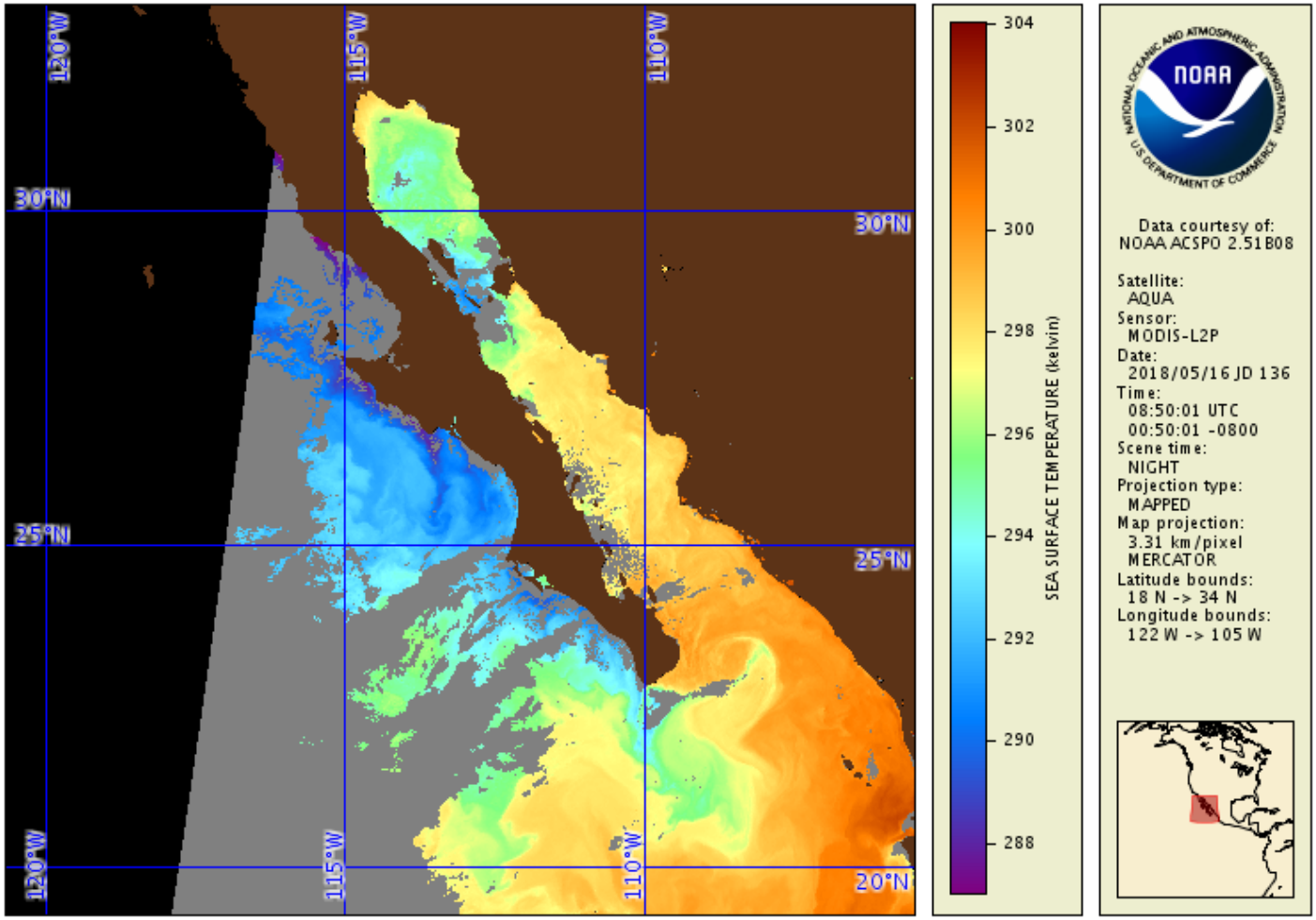
N20 VIIRS L2P



N20 VIIRS L3U



Aqua MODIS L2P



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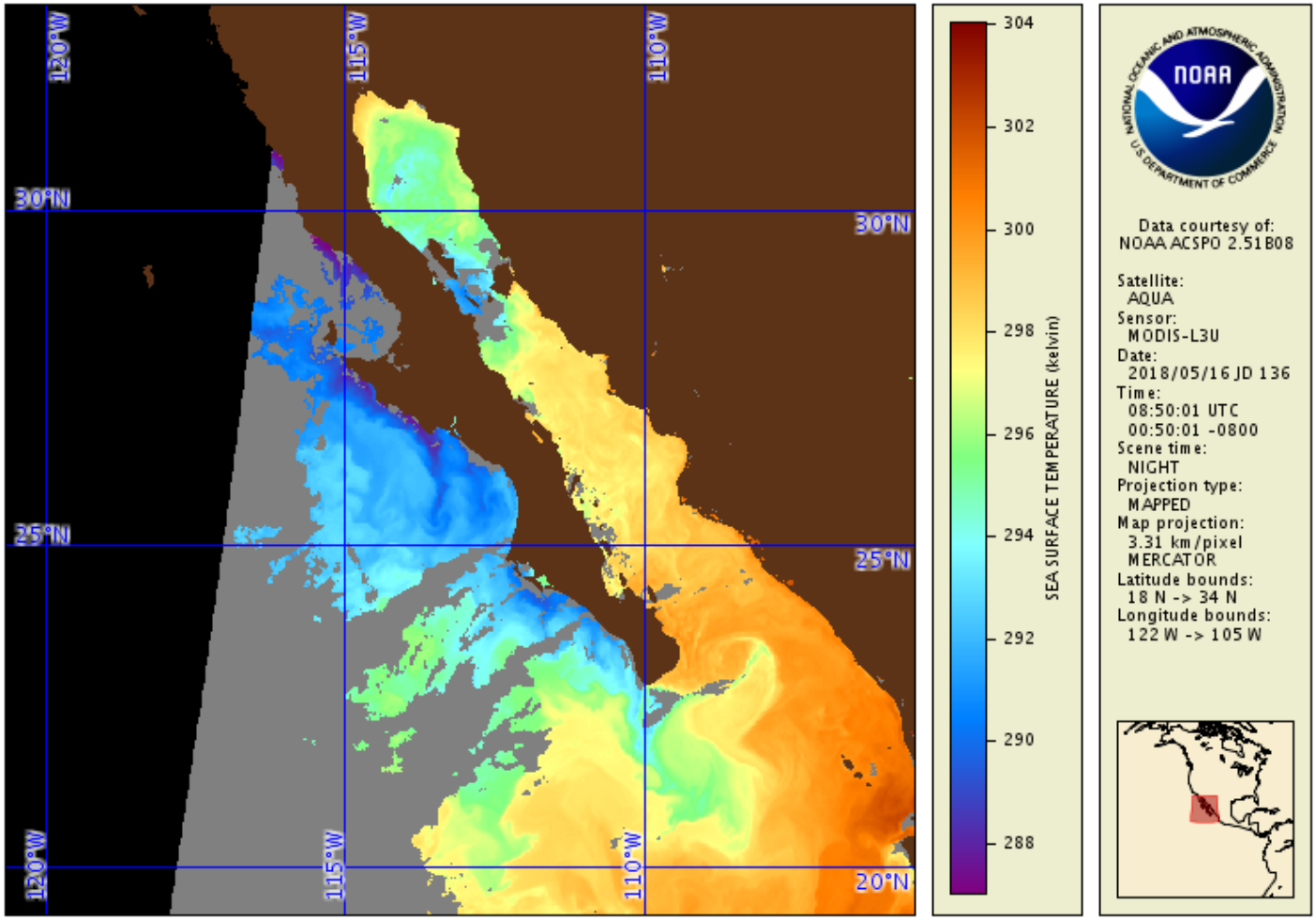
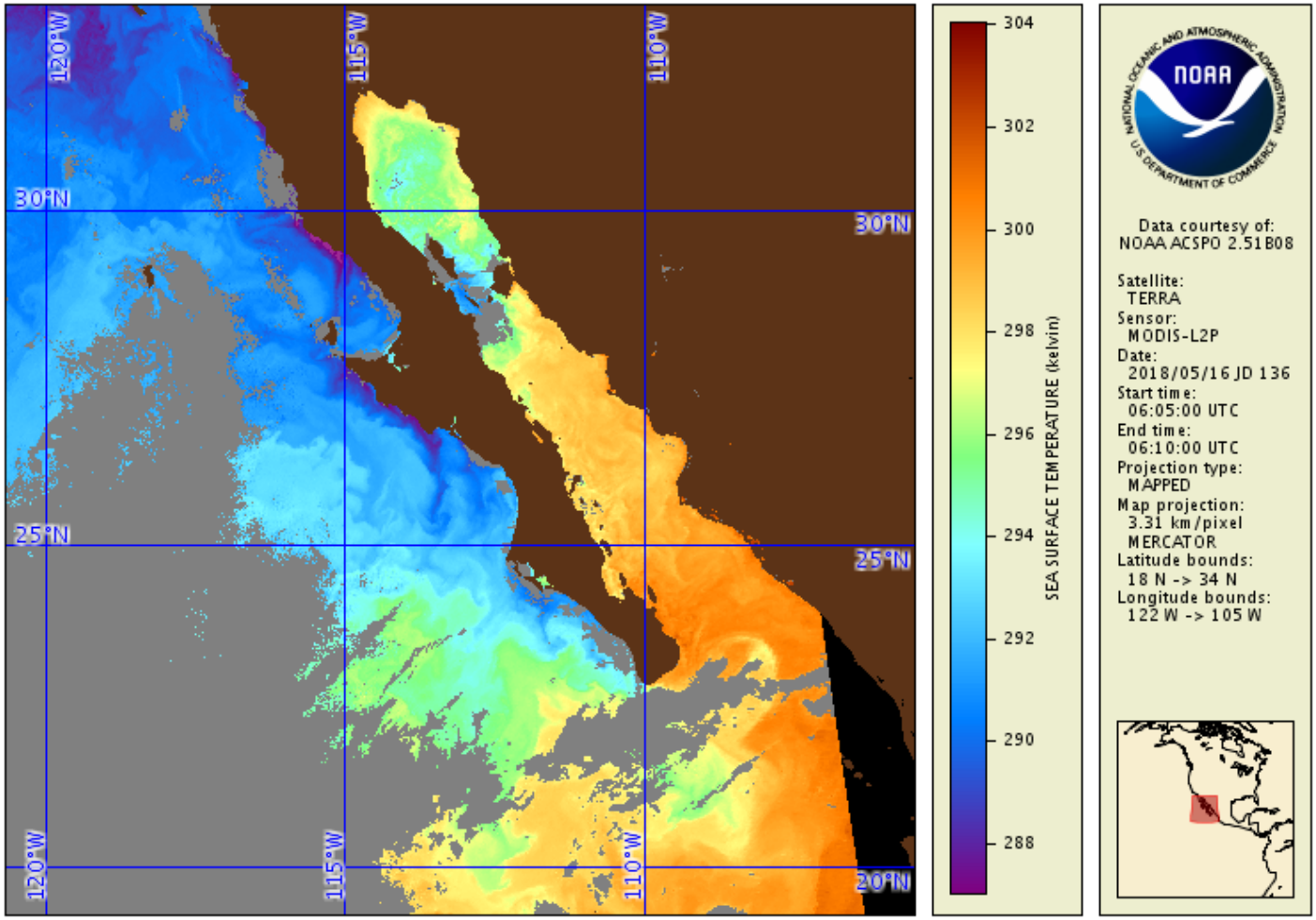
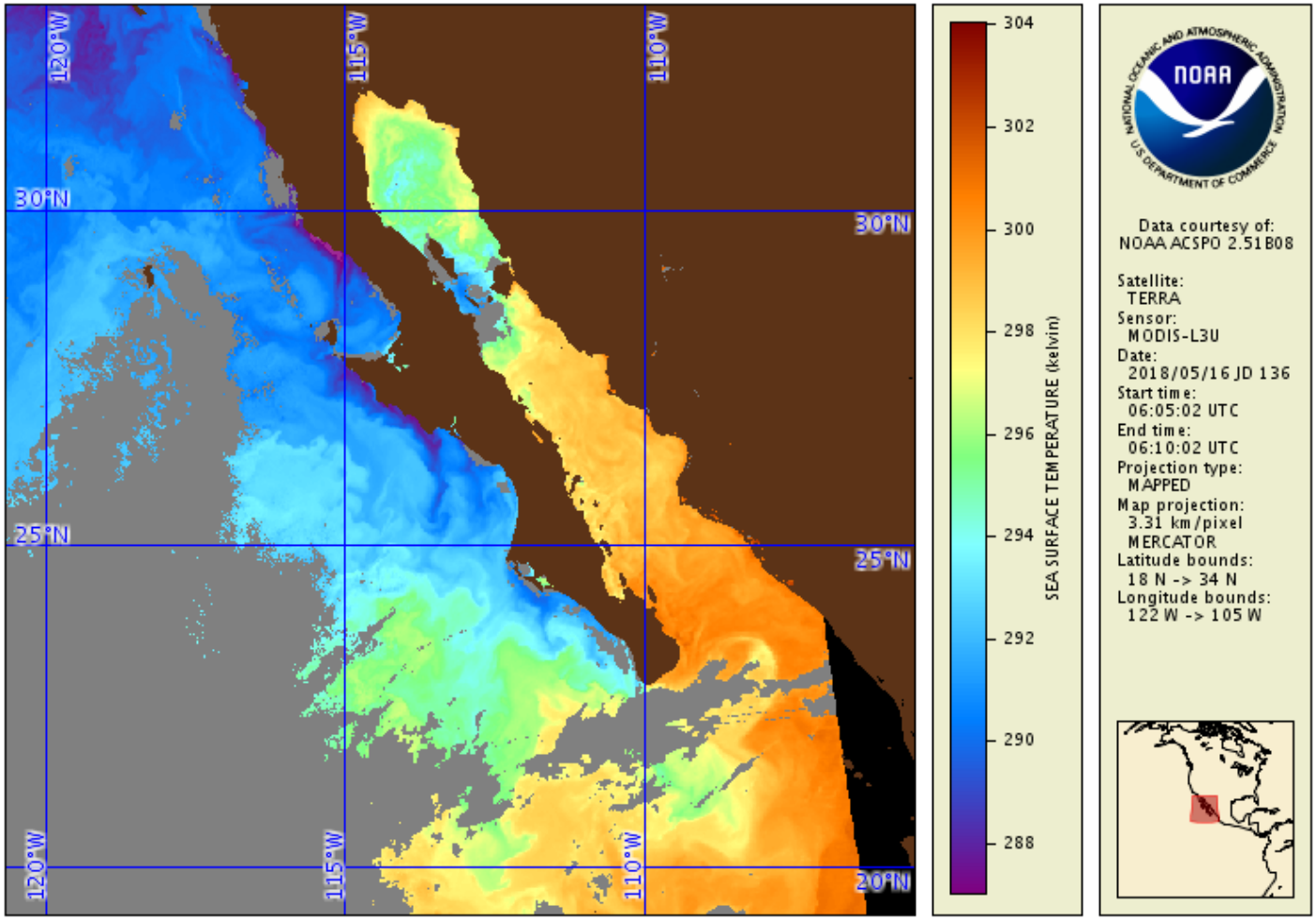


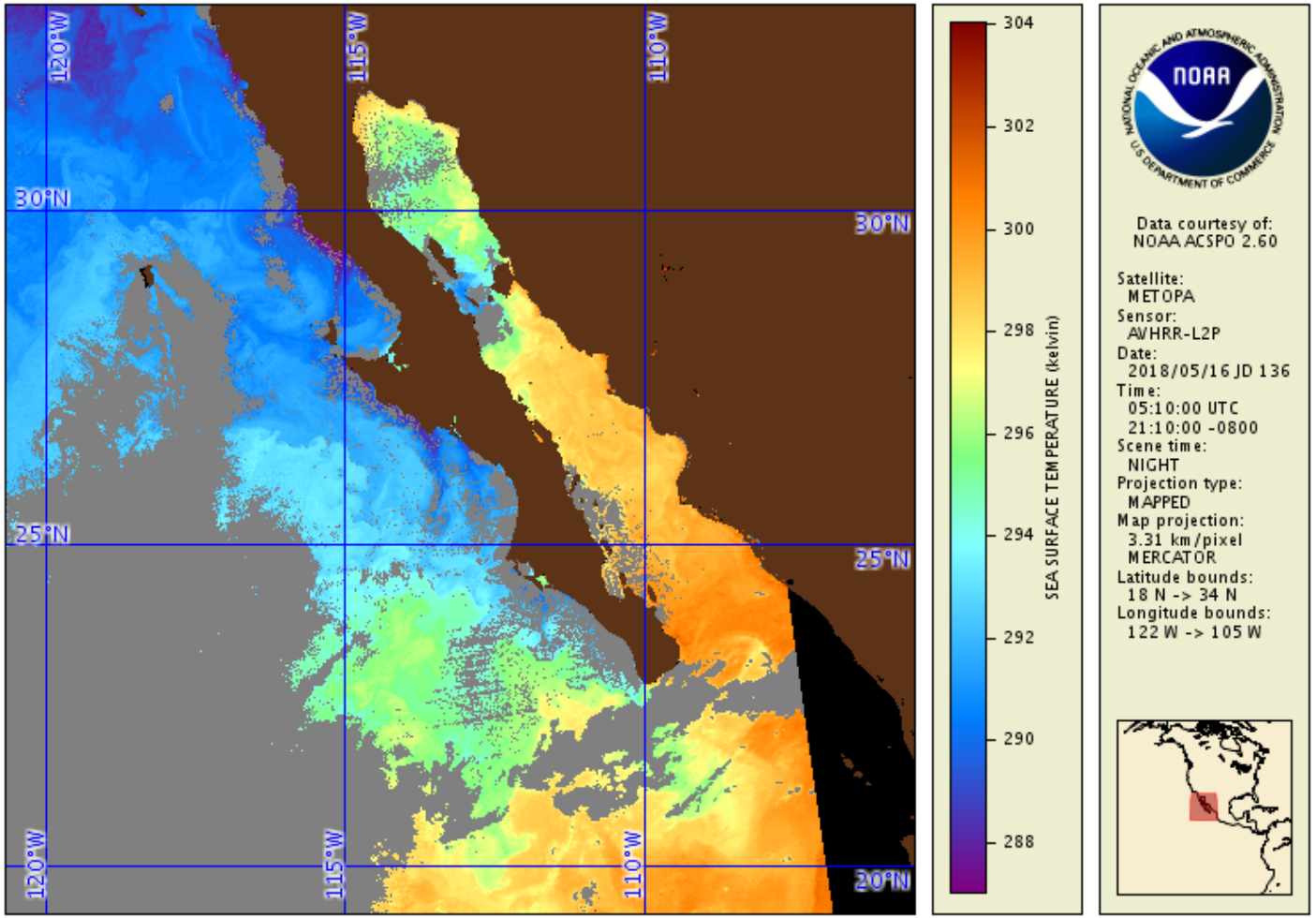
Terra MODIS L2P



Terra MODIS L3U



Metop-A FRAC L2P



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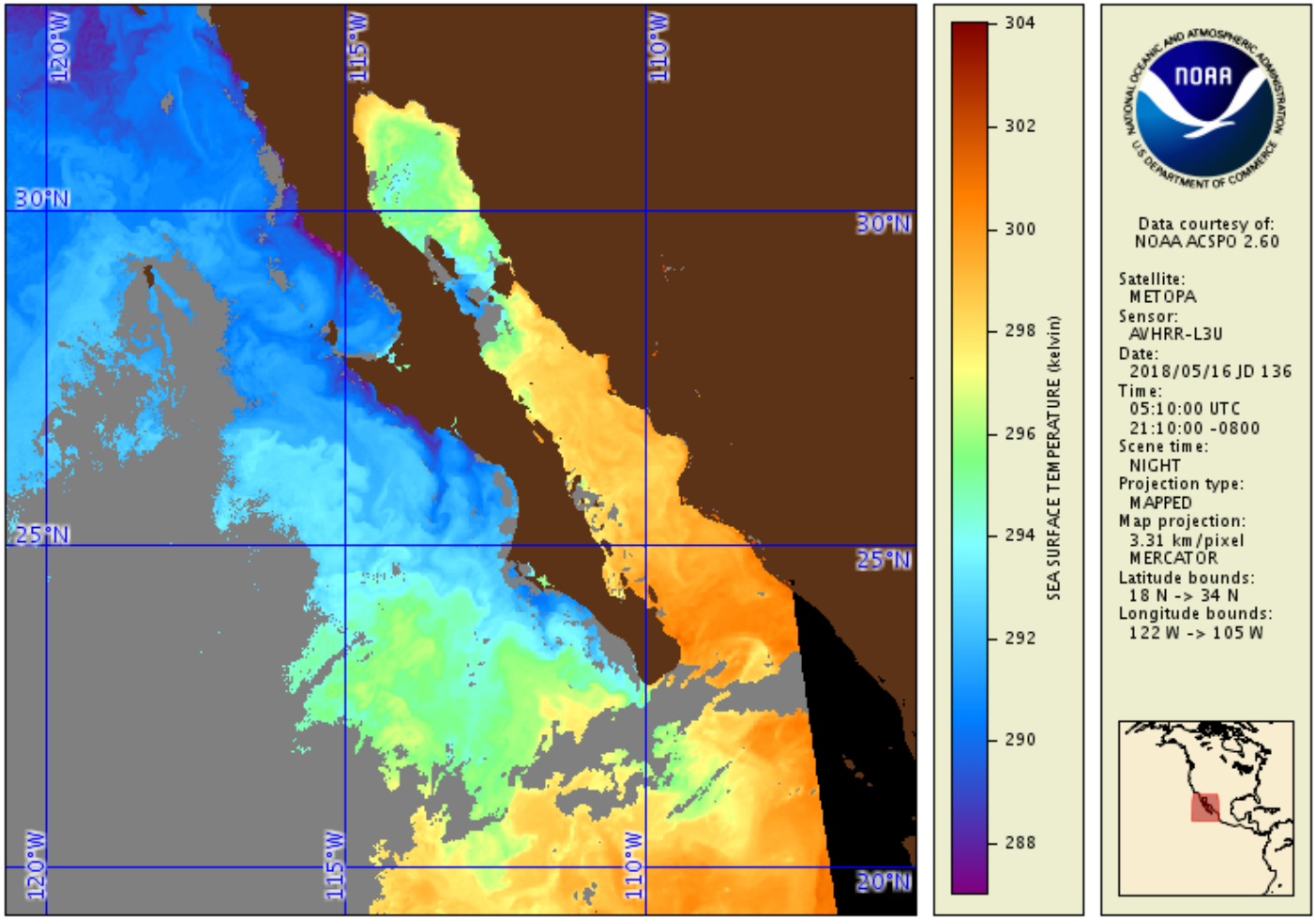
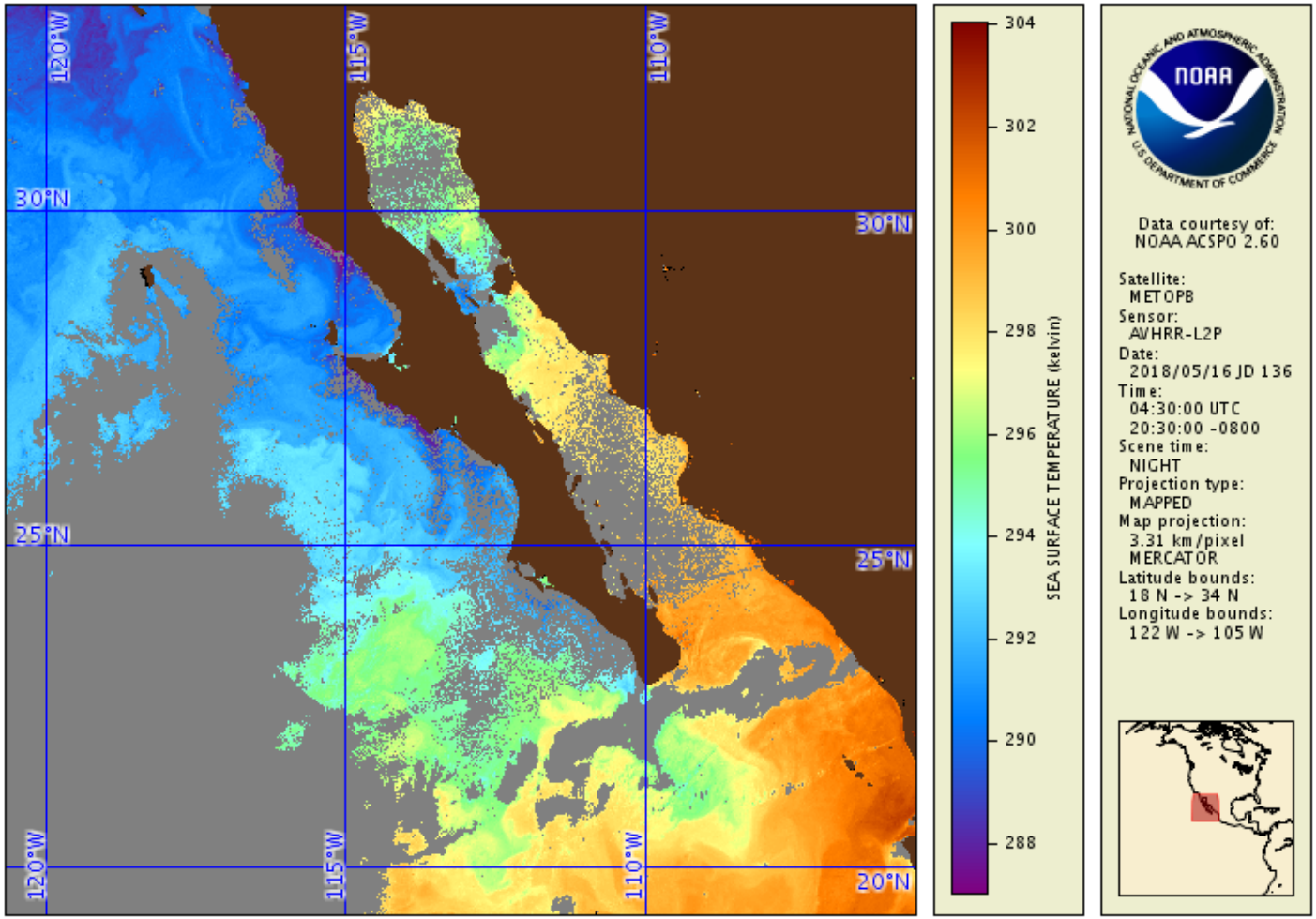
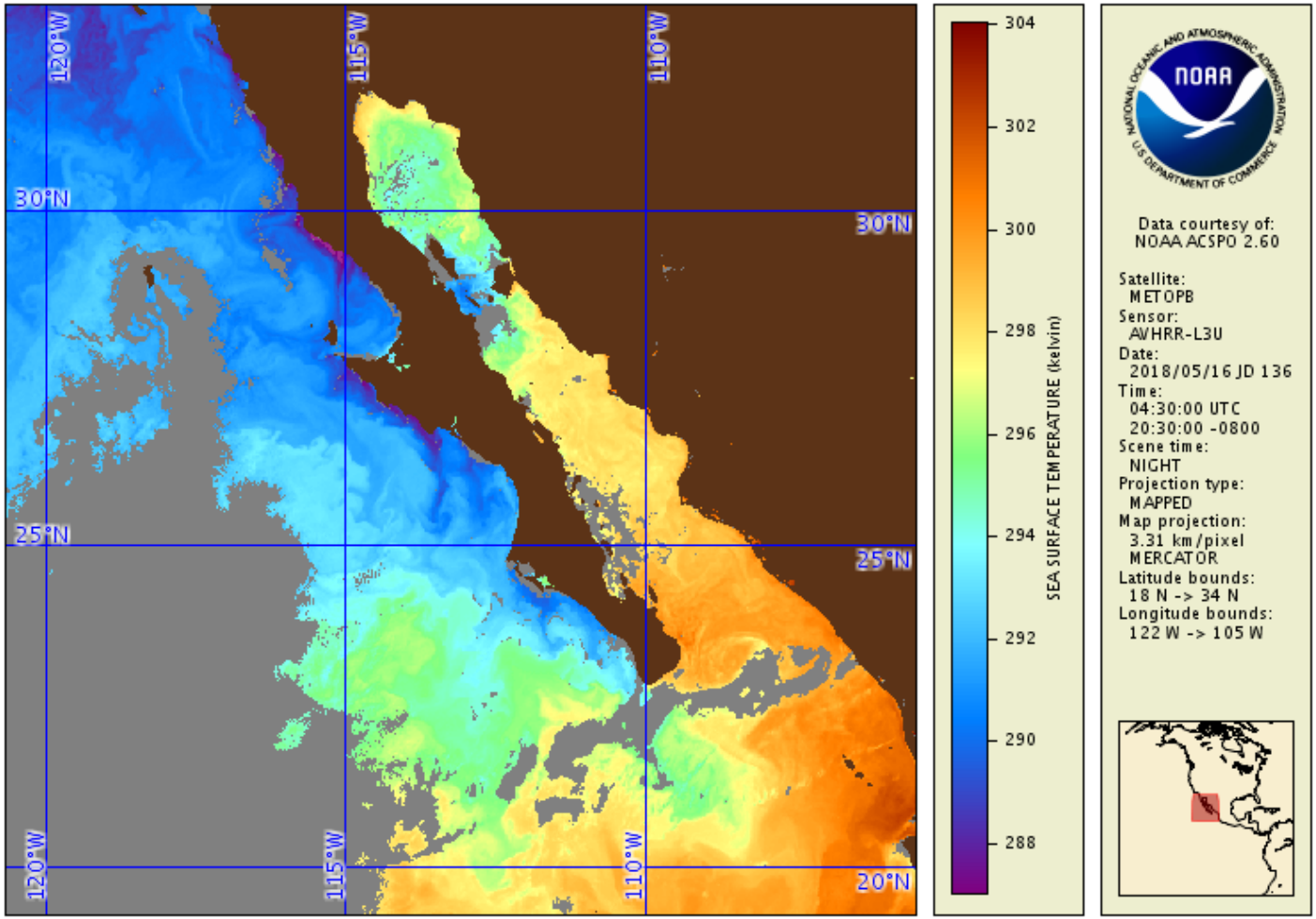


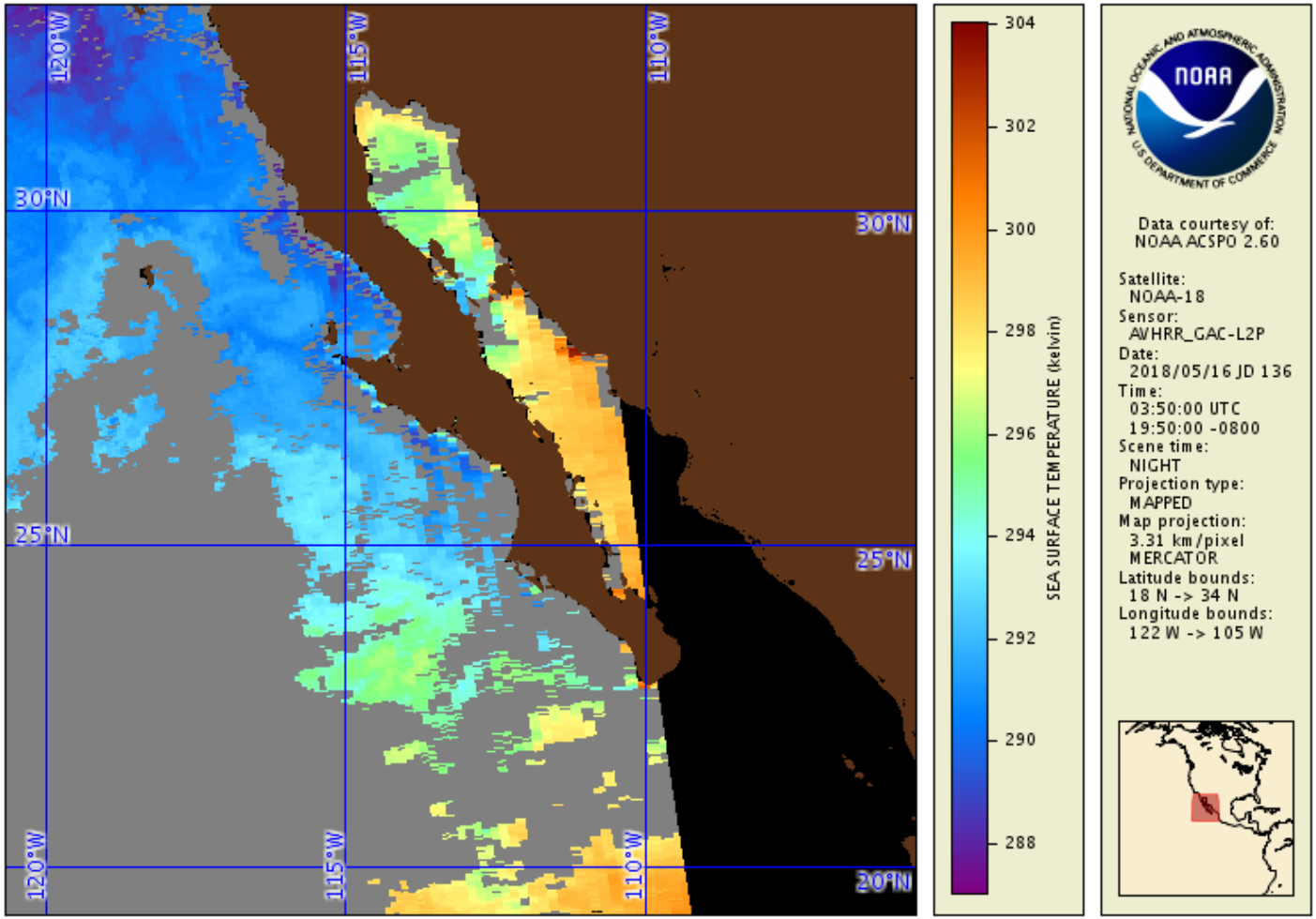
Metop-B FRAC L2P



Metop-B FRAC L3U



N18 GAC L2P


120°W
115°W
110°W
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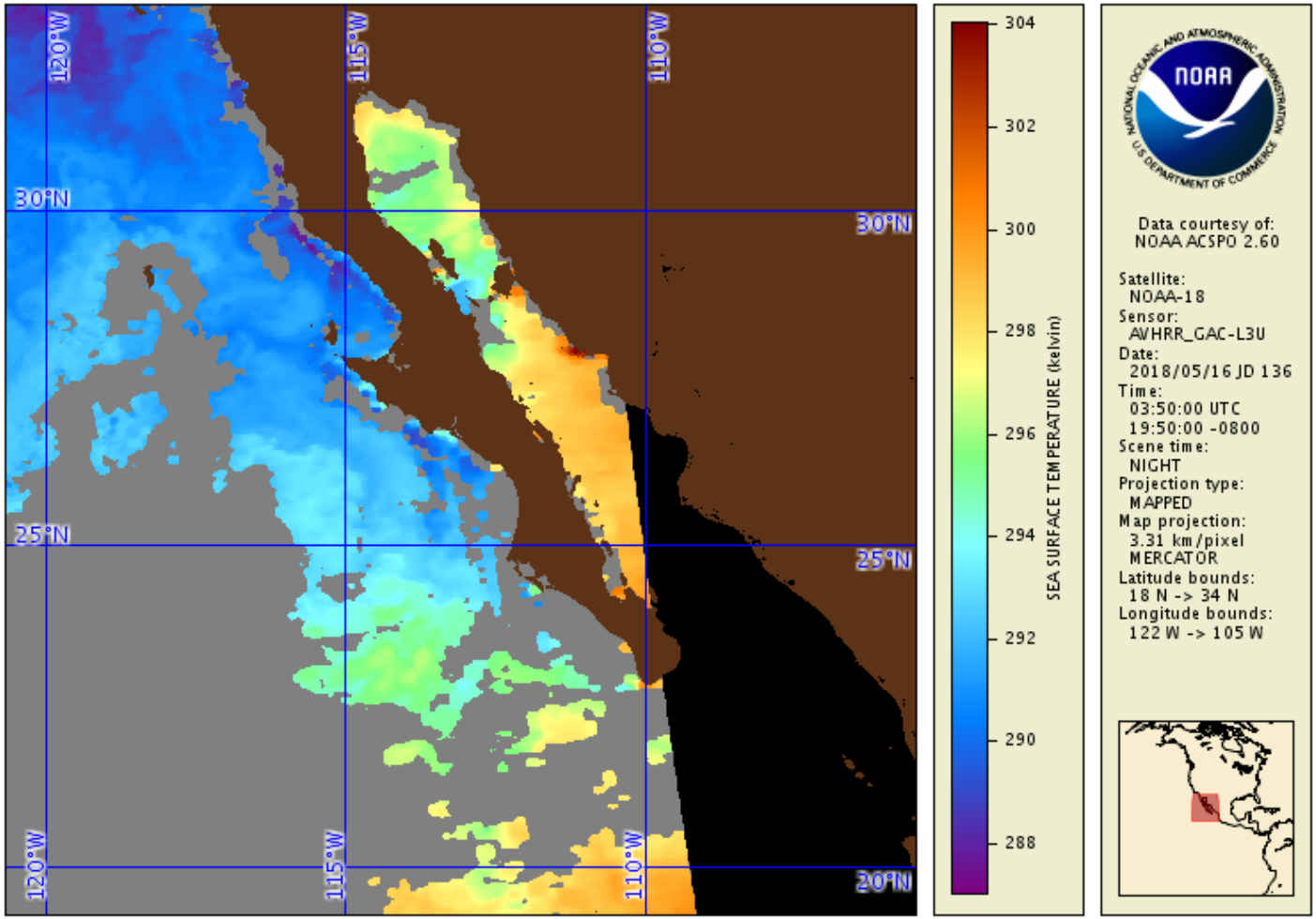
SEA SURFACE TEMPERATURE (kelvin)
Data courtesy of:
NOAA ACSPO 2.60
Satellite:
NOAA-18
Sensor:
AVHRR_GAC-L2P
Date:
2018/05/16 JD 136
Time:
03:50:00 UTC
19:50:00 -0800
Scene time:
NIGHT
Projection type:
MAPPED
Map projection:
3.31 km/pixel
MERCATOR
Latitude bounds:
18 N -> 34 N
Longitude bounds:
122 W -> 105 W

N18 GAC L3U


120°W
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20°N
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SEA SURFACE TEMPERATURE (kelvin)
Data courtesy of:
NOAA ACSPO 2.60
Satellite:
NOAA-18
Sensor:
AVHRR_GAC-L3U
Date:
2018/05/16 JD 136
Time:
03:50:00 UTC
19:50:00 -0800
Scene time:
NIGHT
Projection type:
MAPPED
Map projection:
3.31 km/pixel
MERCATOR
Latitude bounds:
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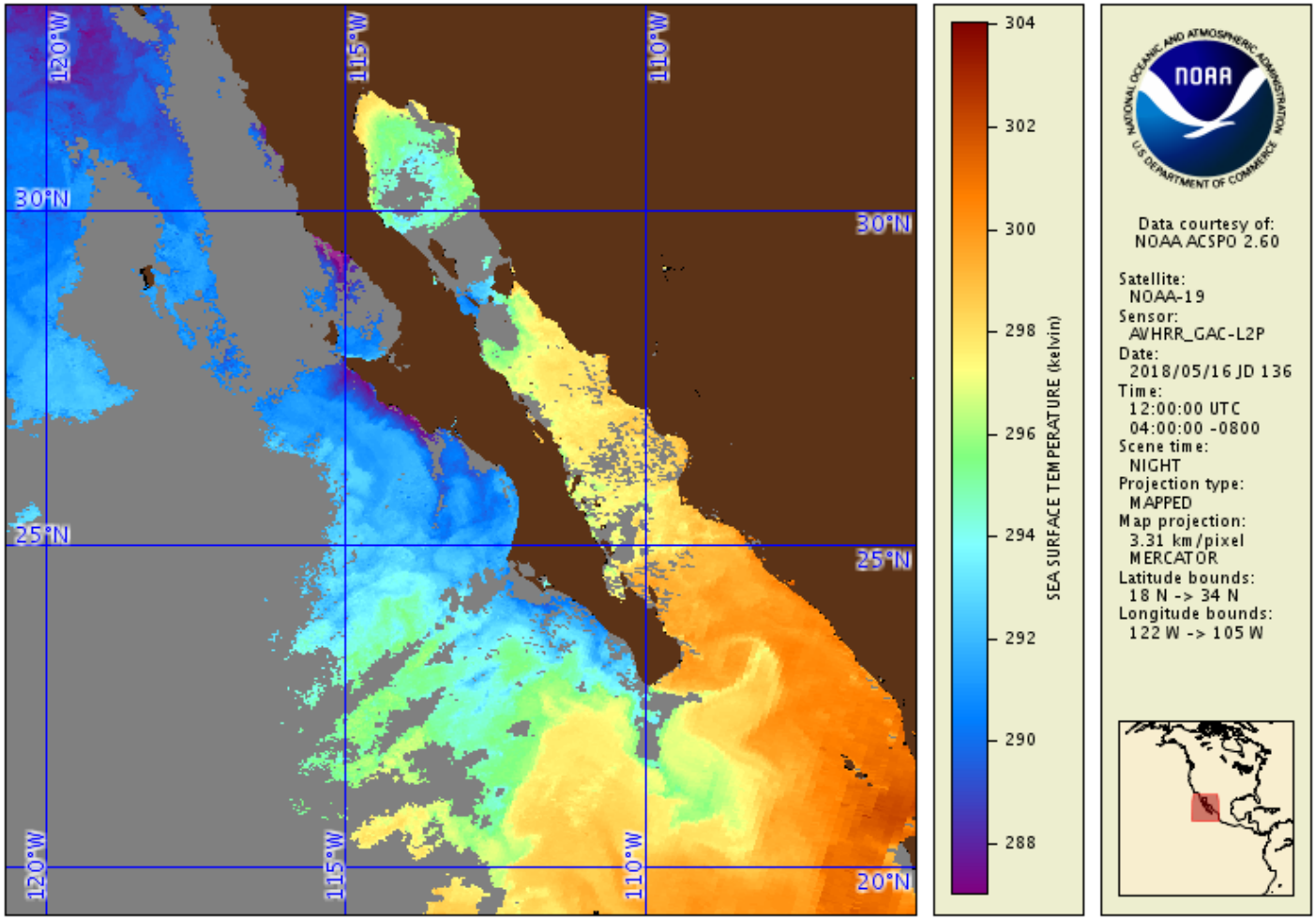
Longitude bounds:
122 W -> 105 W

N19 GAC L2P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SEA SURFACE TEMPERATURE (kelvin)
Data courtesy of:
NOAA ACSPO 2.60
Satellite:
NOAA-19
Sensor:
AVHRR_GAC-L2P
Date:
2018/05/16 JD 136
Time:
12:00:00 UTC
04:00:00 -0800
Scene time:
NIGHT
Projection type:
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Map projection:
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MERCATOR
Latitude bounds:
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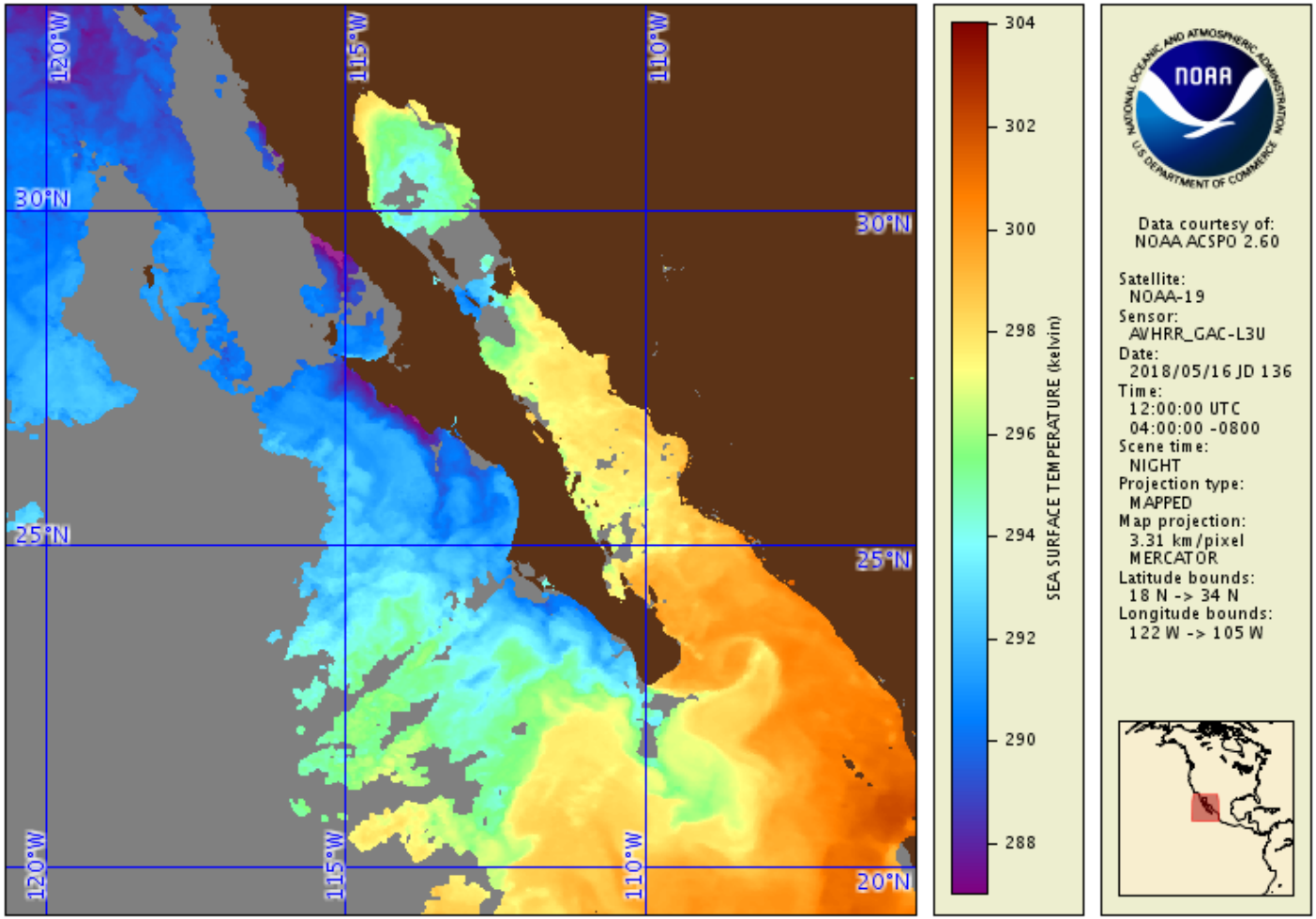
Longitude bounds:
122 W -> 105 W

N19 GAC L3U


120°W
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SEA SURFACE TEMPERATURE (kelvin)
Data courtesy of:
NOAA ACSPO 2.60
Satellite:
NOAA-19
Sensor:
AVHRR_GAC-L3U
Date:
2018/05/16 JD 136
Time:
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04:00:00 -0800
Scene time:
NIGHT
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Map projection:
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MERCATOR
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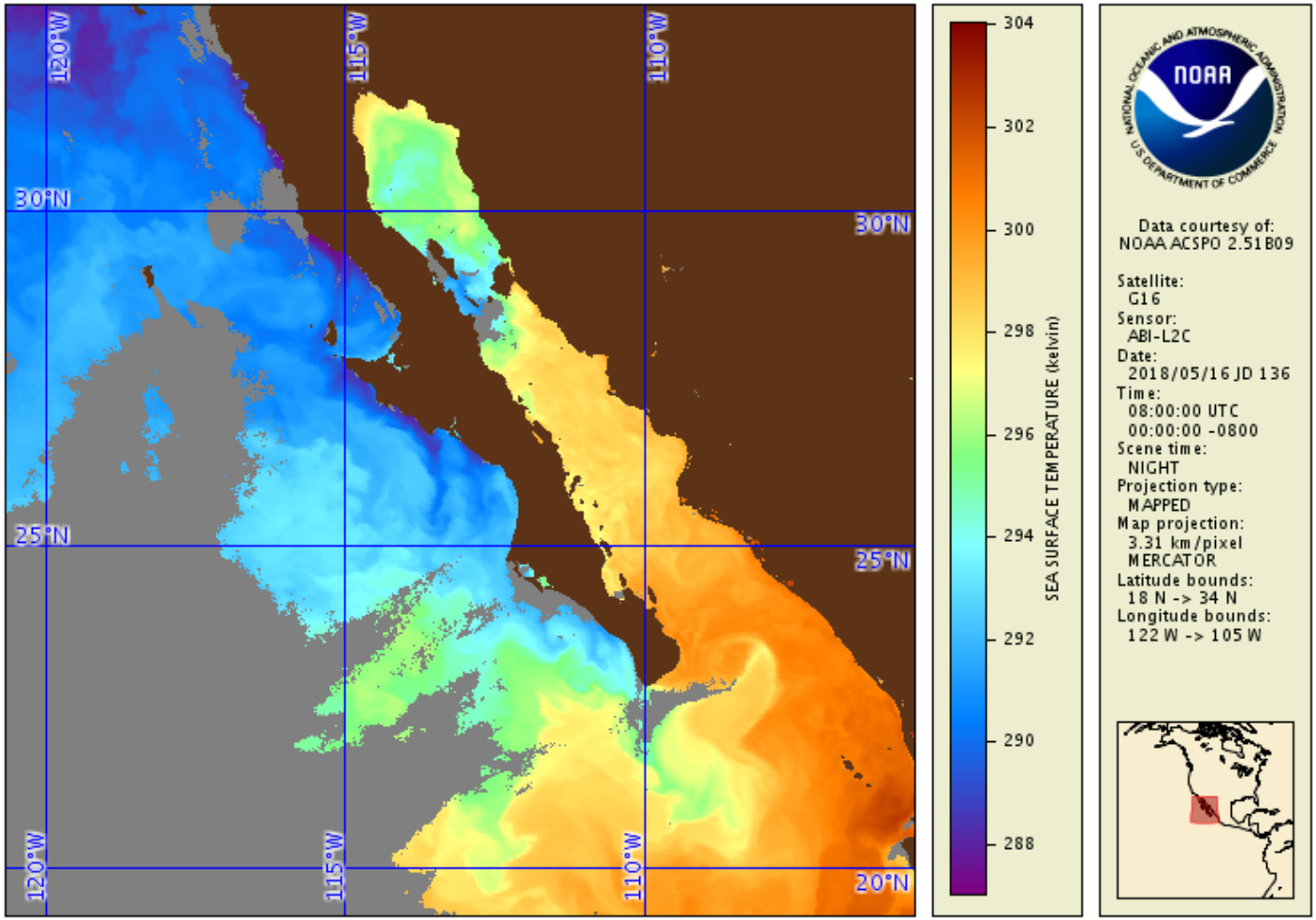
Longitude bounds:
122 W -> 105 W

G16 ABI L2C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SEA SURFACE TEMPERATURE (kelvin)
Data courtesy of:
NOAA ACSPO 2.51B09
Satellite:
G16
Sensor:
ABI-L2C
Date:
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Time:
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Scene time:
NIGHT
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Map projection:
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MERCATOR
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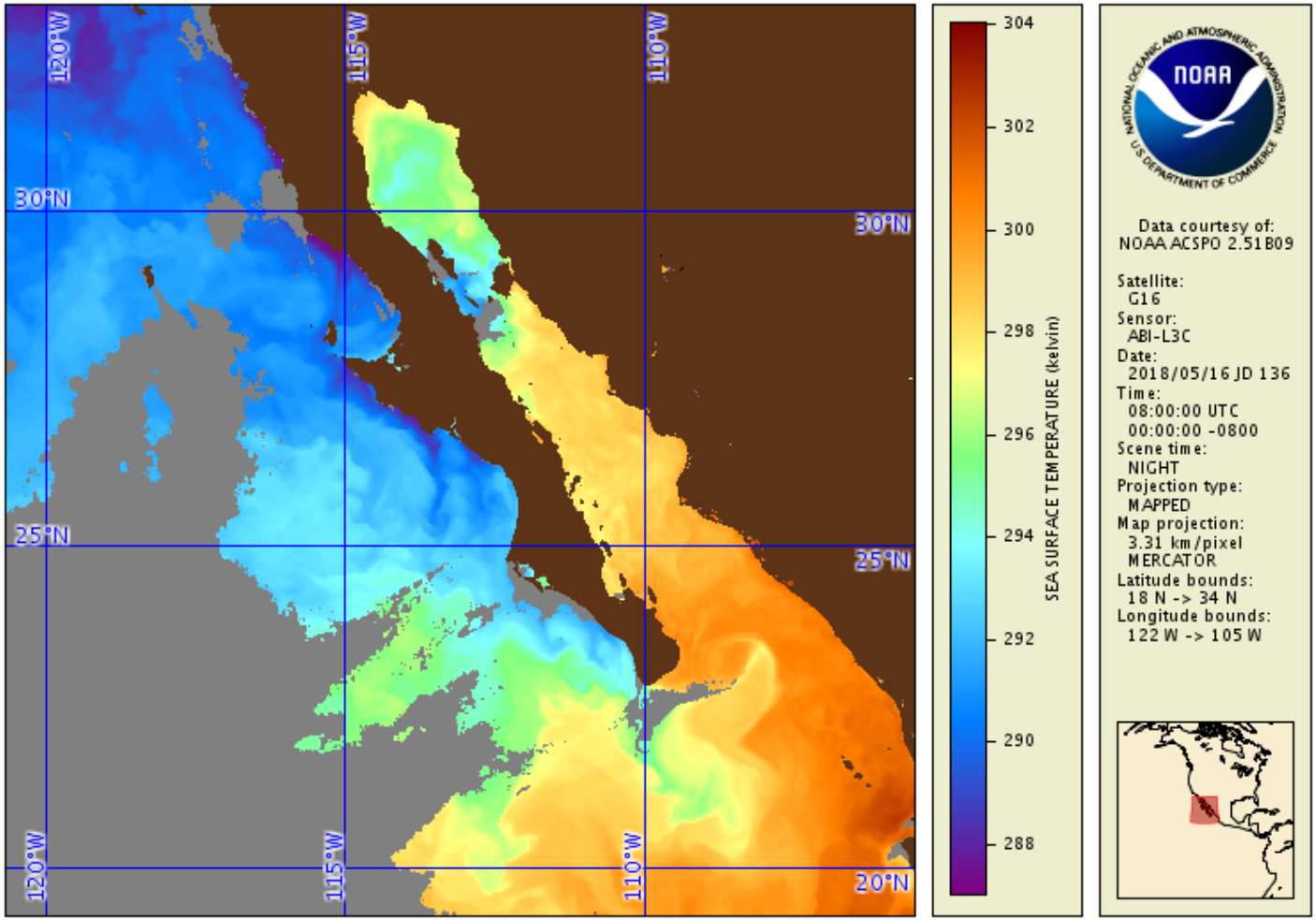
Longitude bounds:
122 W -> 105 W

G16 ABI L3C


120°W
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SEA SURFACE TEMPERATURE (kelvin)
Data courtesy of:
NOAA ACSPO 2.51B09
Satellite:
G16
Sensor:
ABI-L3C
Date:
2018/05/16 JD 136
Time:
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00:00:00 -0800
Scene time:
NIGHT
Projection type:
MAPPED
Map projection:
3.31 km/pixel
MERCATOR
Latitude bounds:
18 N -> 34 N
Longitude bounds:
122 W -> 105 W

Sample Validation

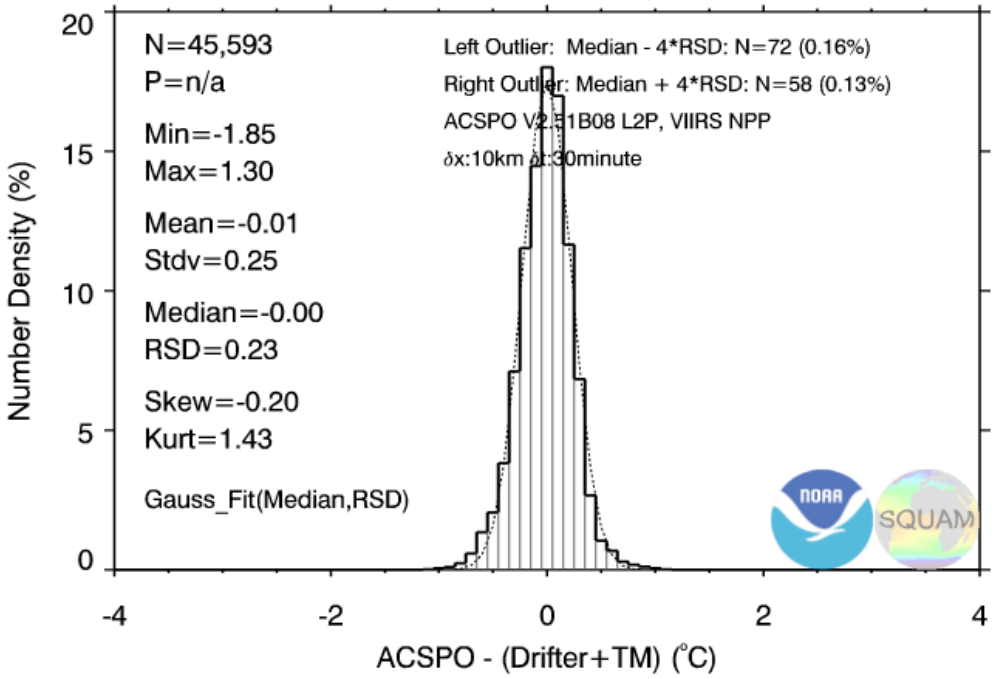
16 May 2018 (Night)

Comparison with Drifters + Trop. Moorings, *i.e.* L2P SST - (D+TM) vs. L3U SST - (D+TM)

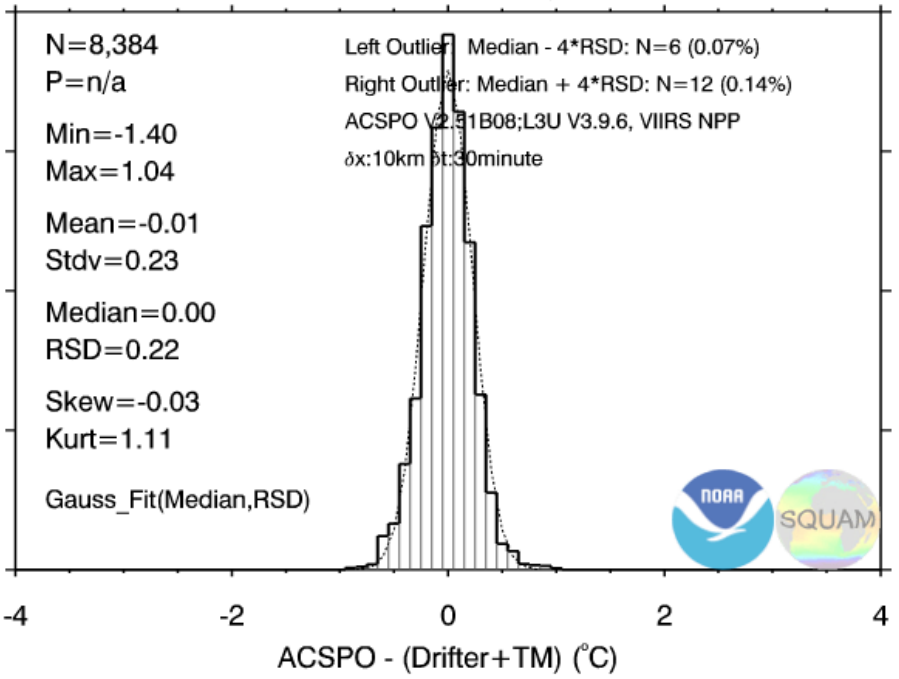
Results are representative of relative L2P/L3U performance for other dates and for daytime

S-NPP VIIRS

L2P

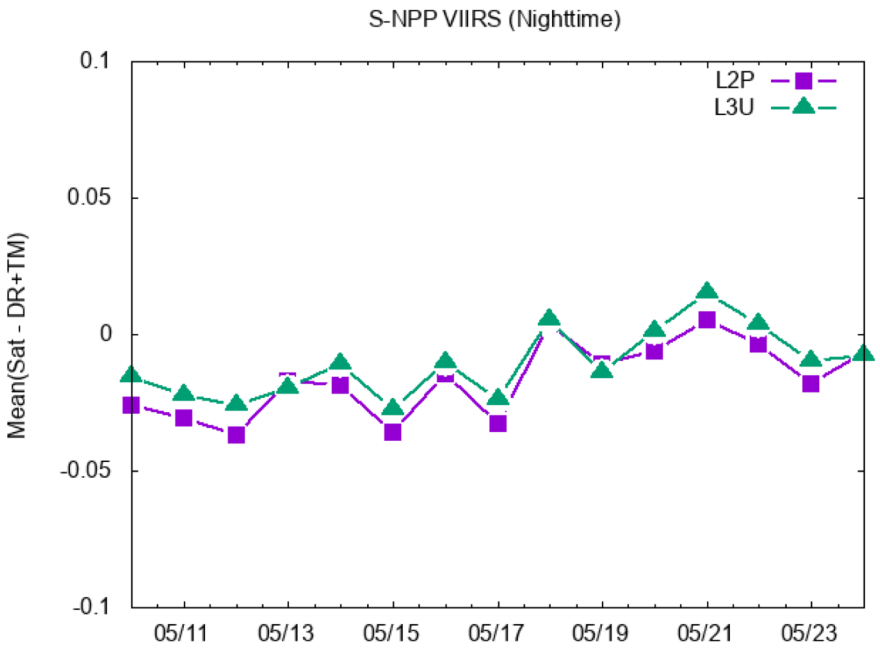


L3U

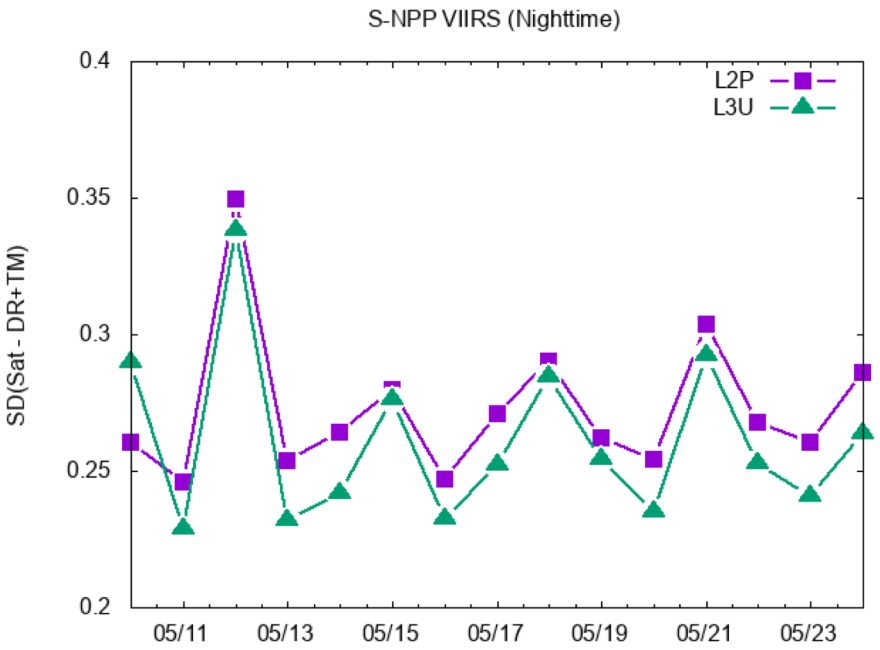


S-NPP VIIRS Timeseries

Mean

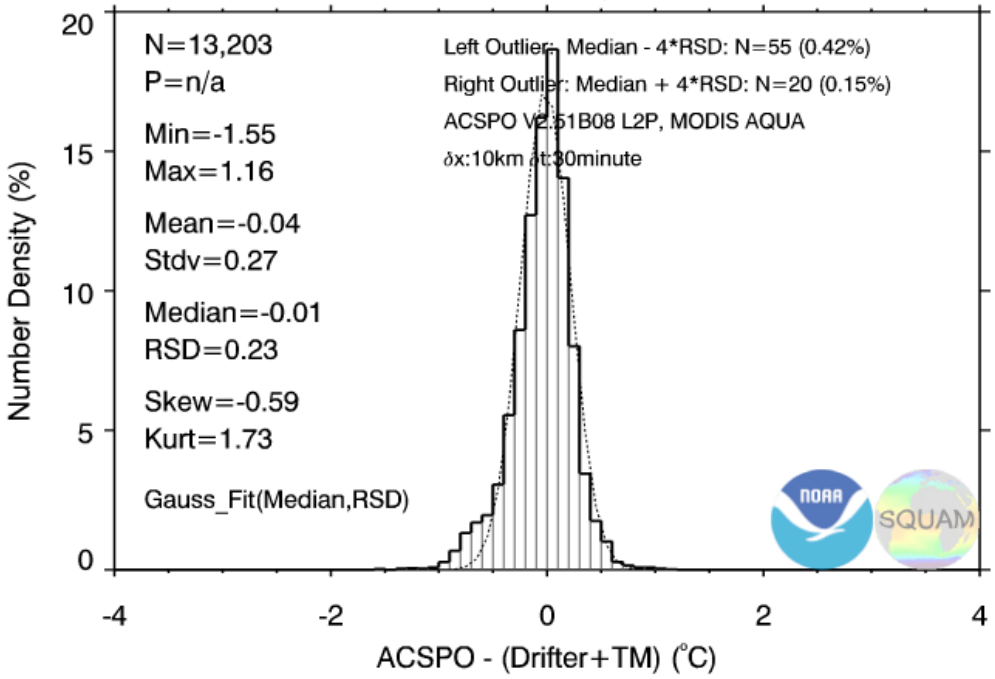


Std. Dev.

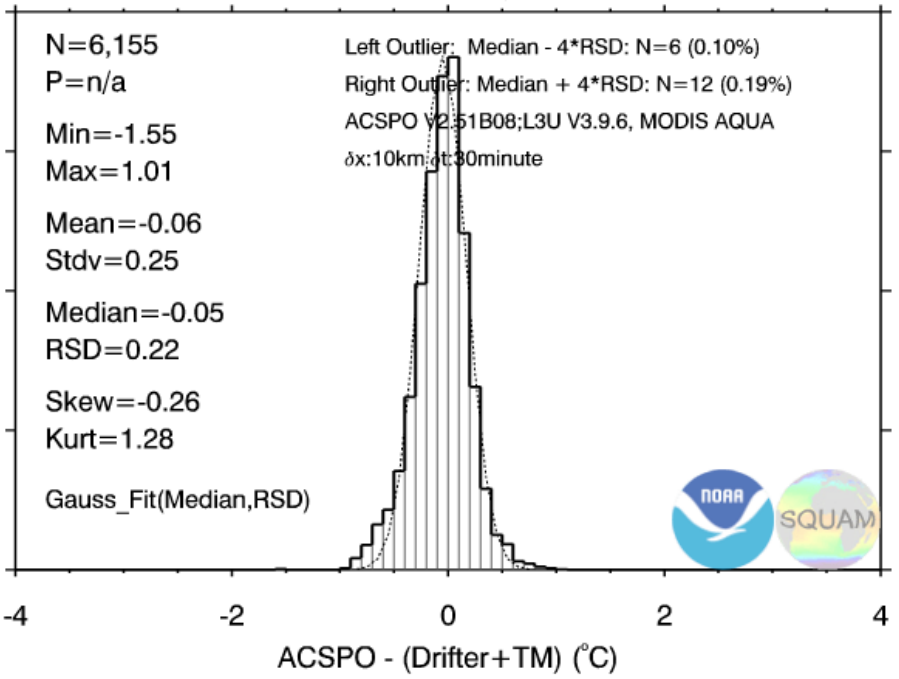


Aqua MODIS

L2P

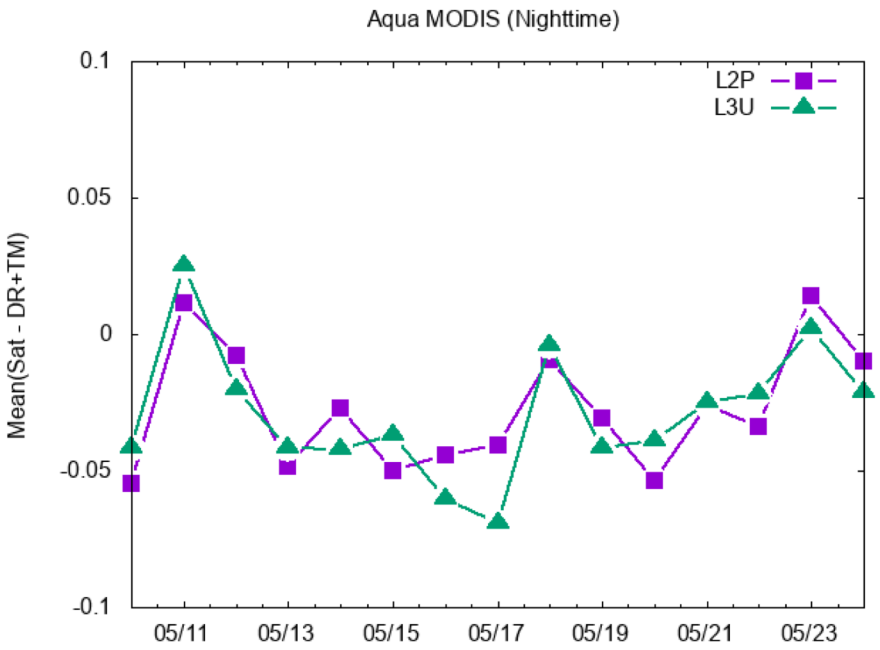


L3U

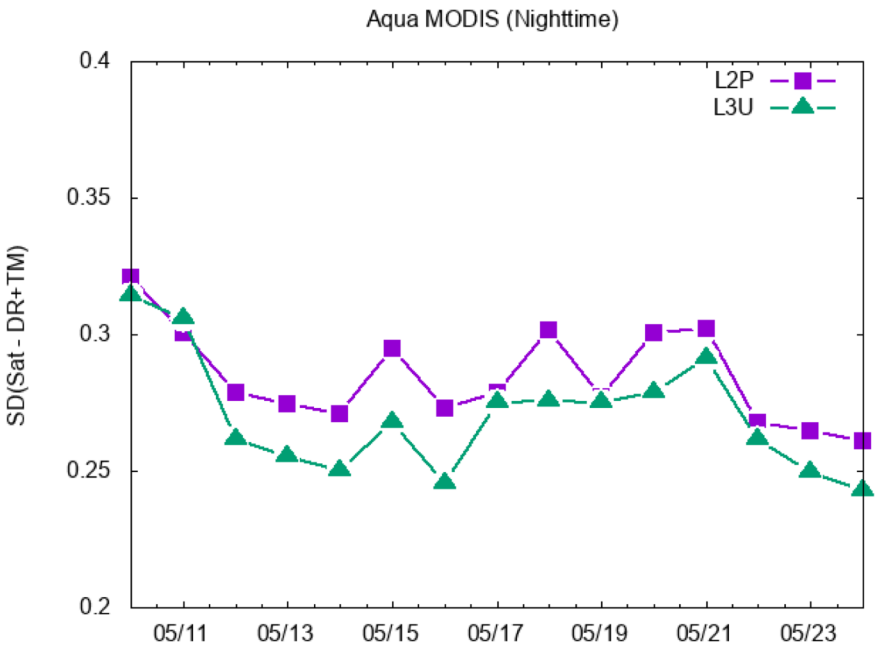


Aqua MODIS Timeseries

Mean

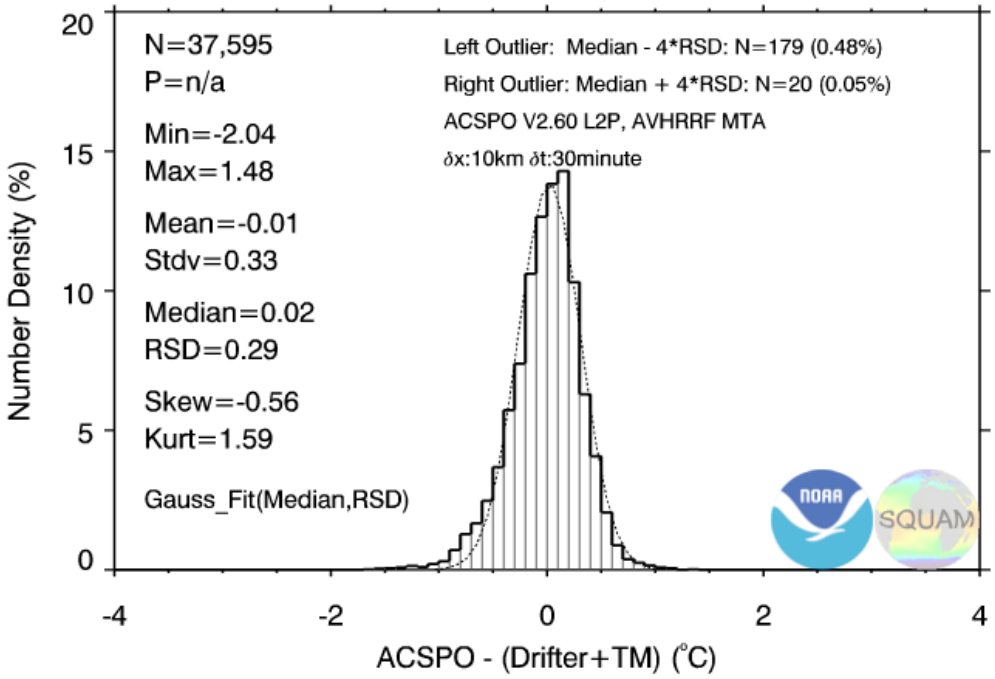


Std. Dev.

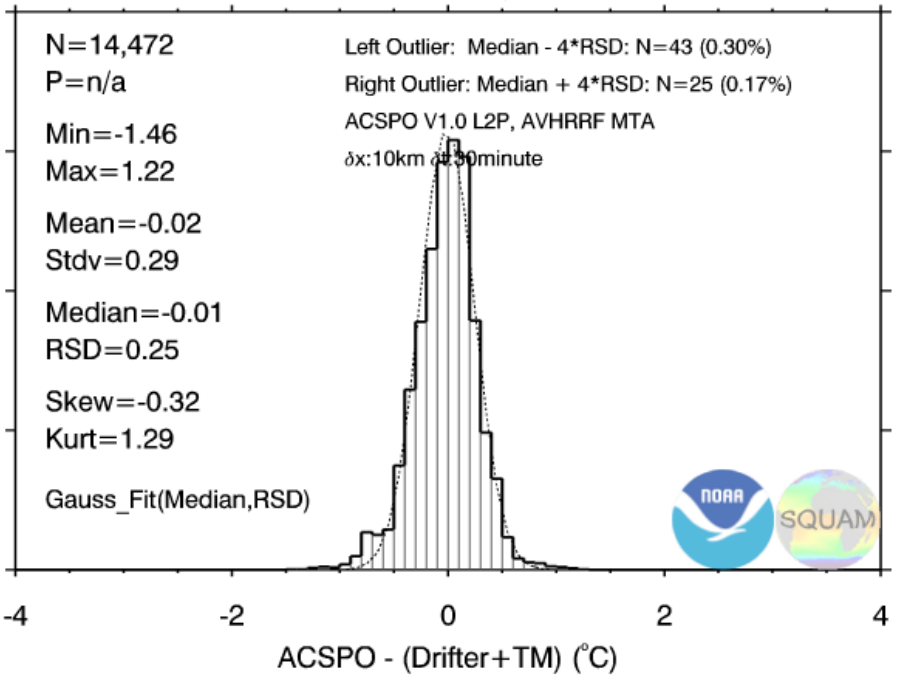


Metop-A FRAC

L2P

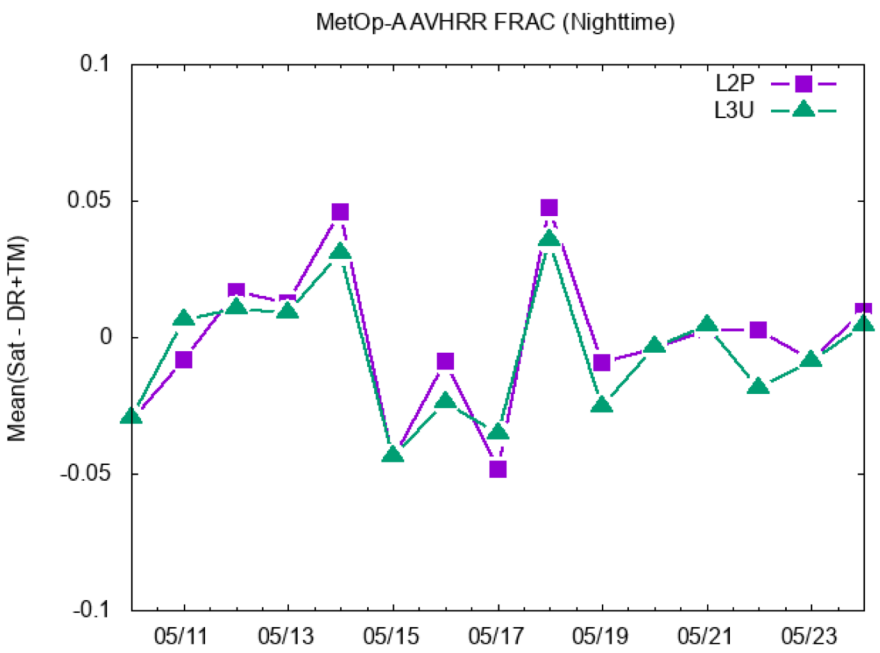


L3U

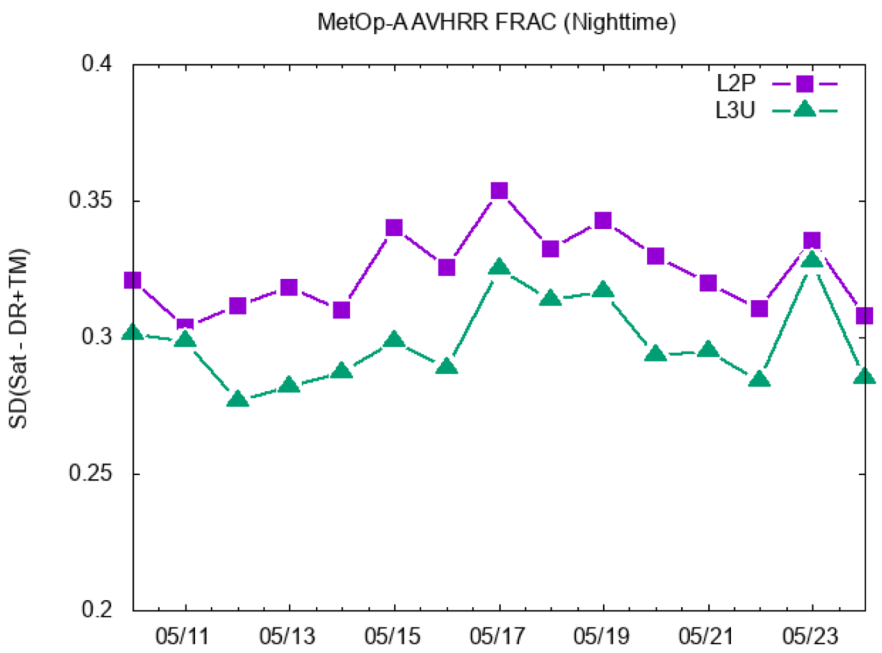


Metop-A FRAC Timeseries

Mean

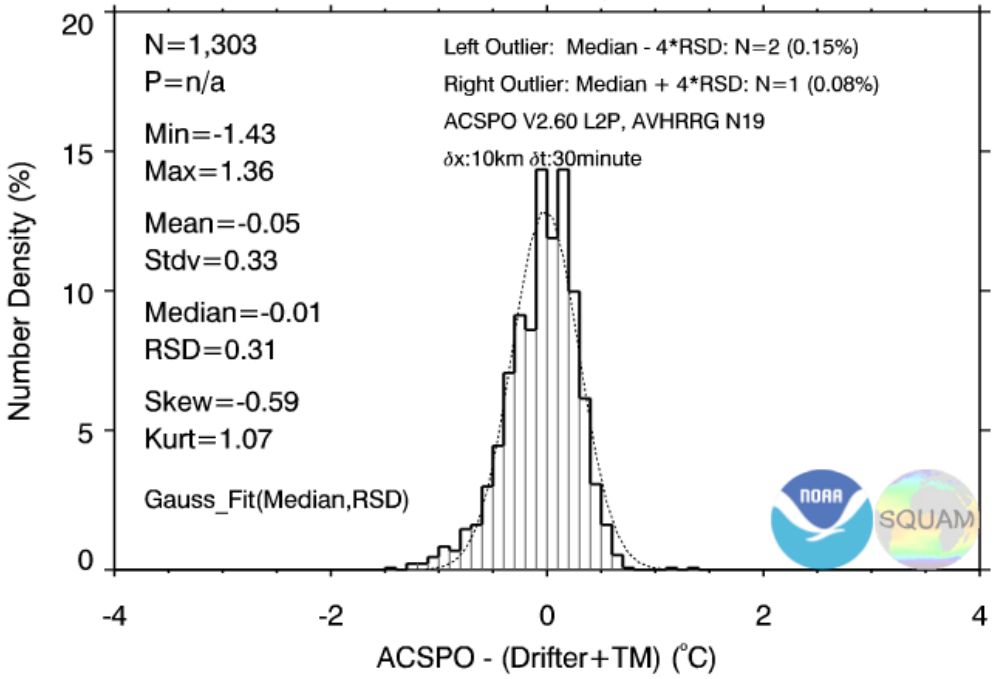


Std. Dev.

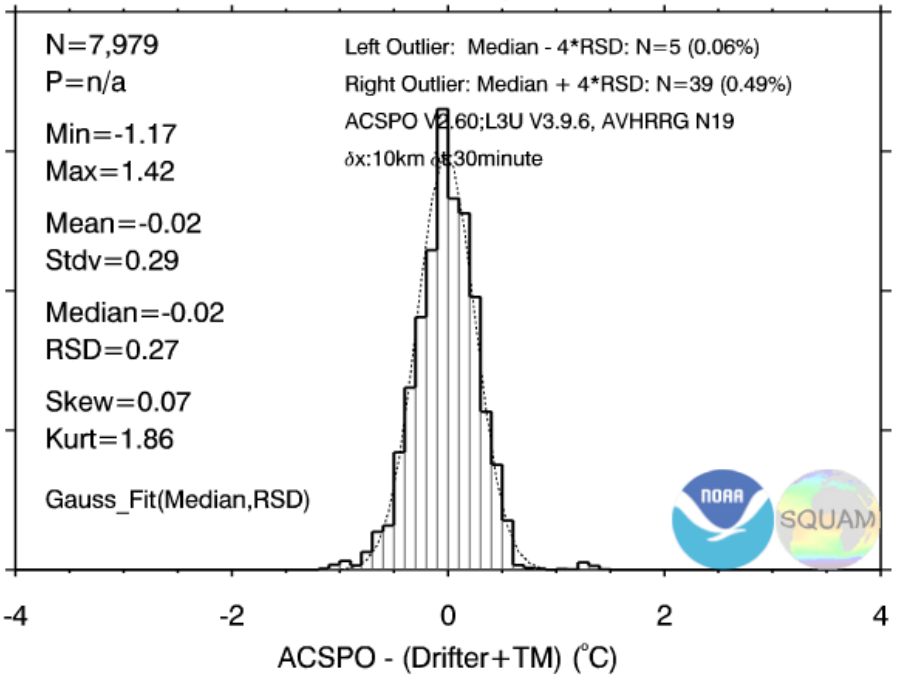


N19 GAC

L2P

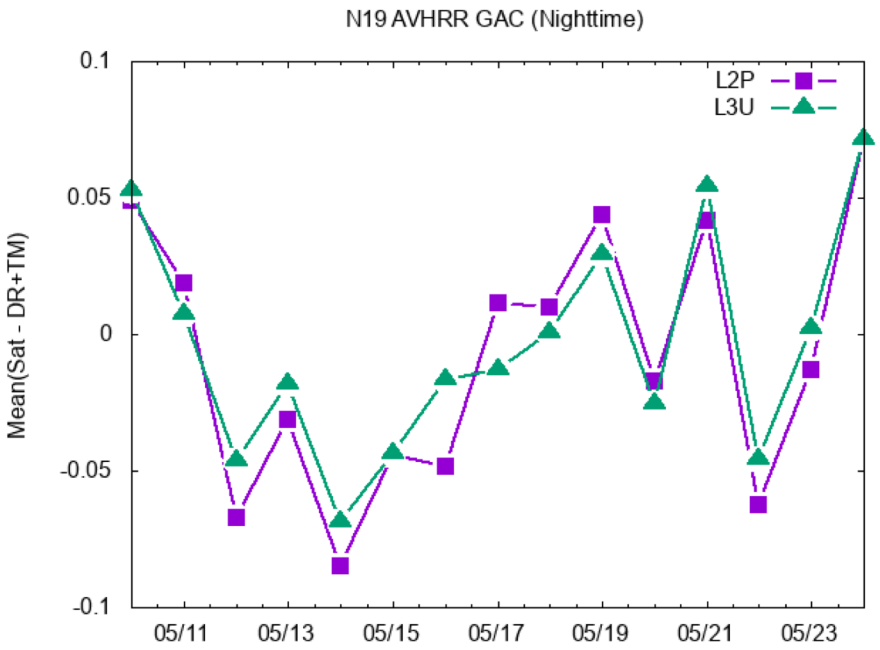


L3U

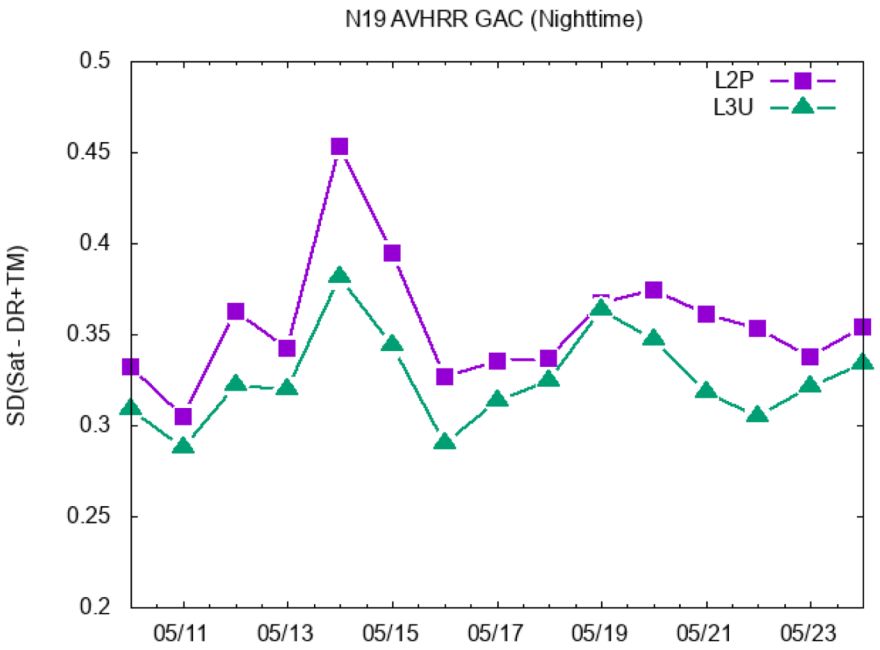


N19 GAC Timeseries

Mean

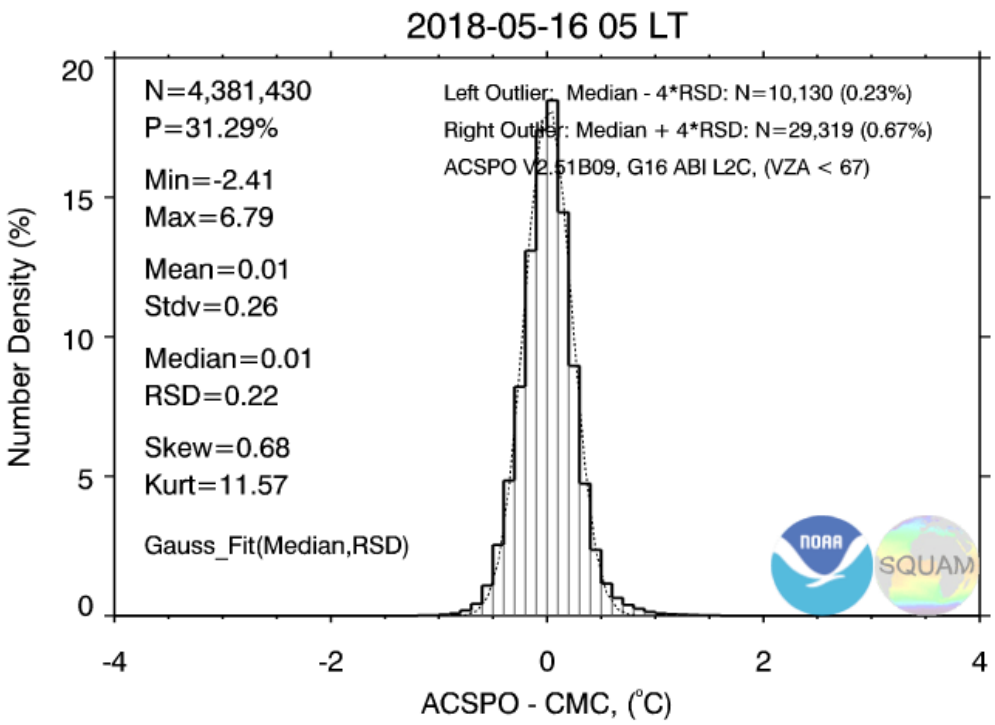


Std. Dev.

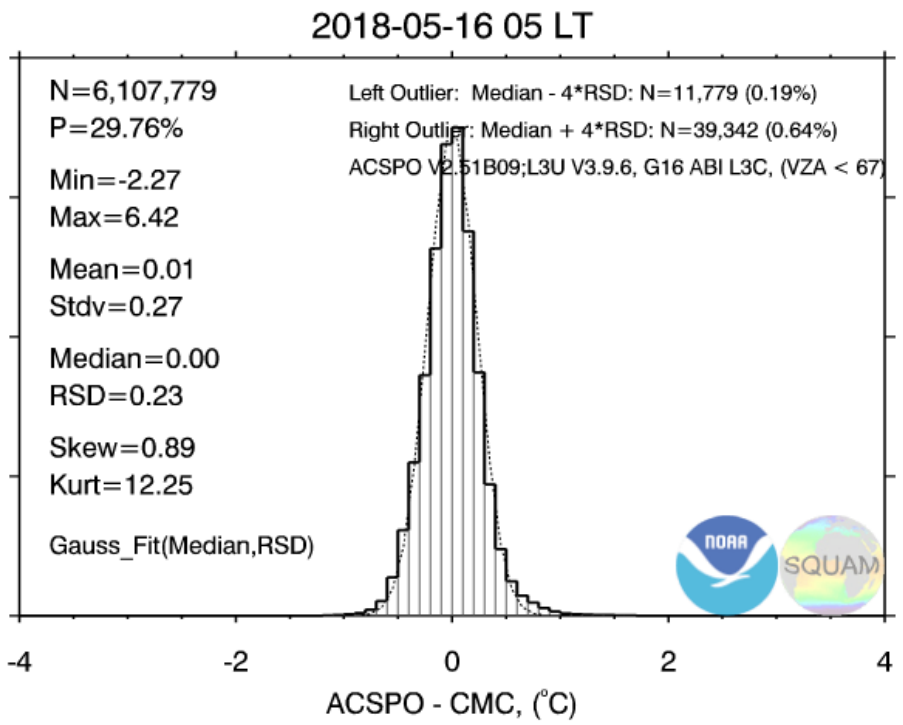


G16 ABI

L2C

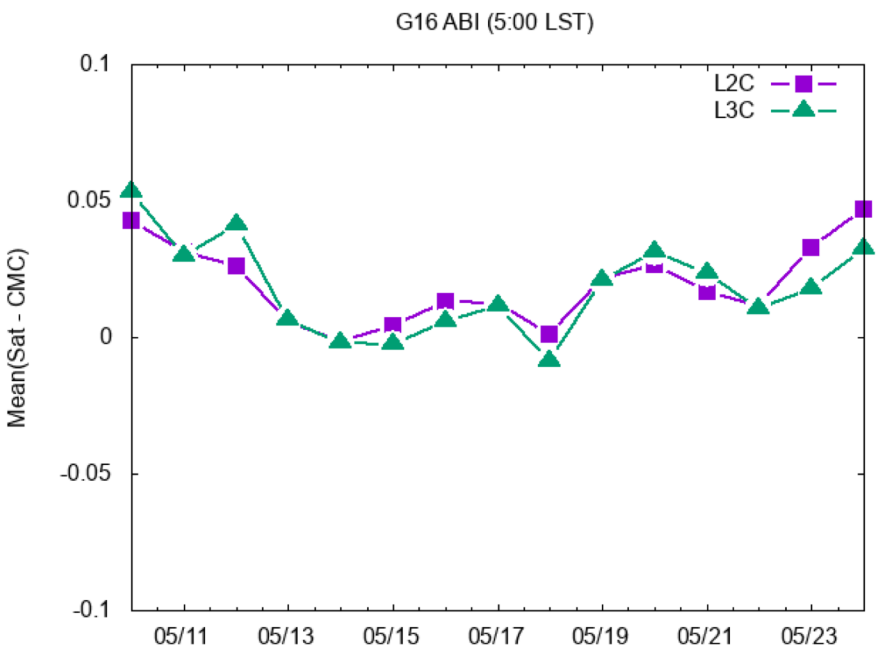


L3C

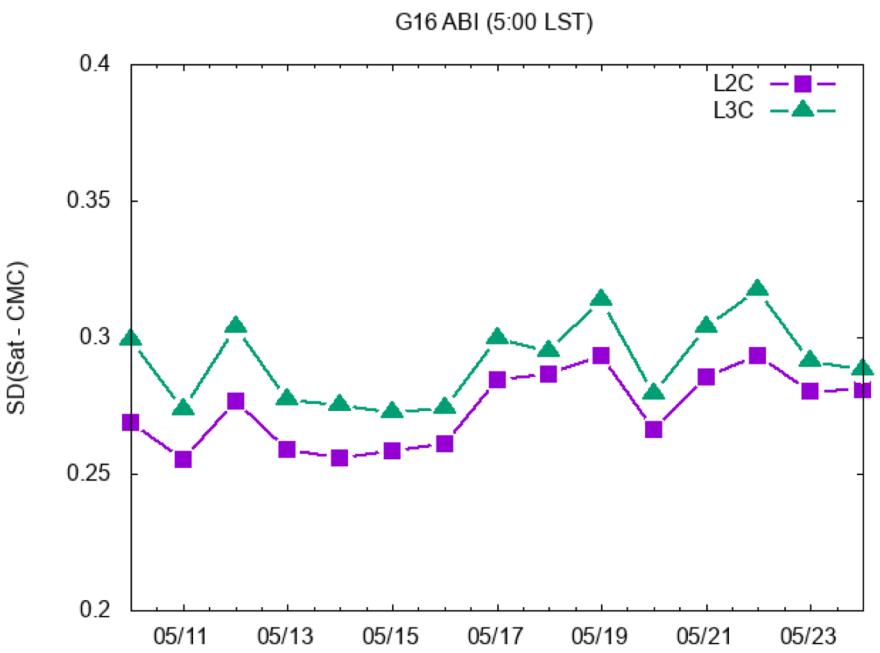


G16 ABI Timeseries

Mean



Std. Dev.



Reanalysis

- Upsampled 0.02º L3U for AVHRR GAC RAN1 (MetOp-A, N16/17/18/19; 2002-present) is now available from NOAA CoastWatch: **coastwatch.noaa.gov/cw_html/sst.html**
- We plan to extend RAN1 using AVHRR/2 instruments back to 1996 and eventually to 1981.
- We are also in the process of generating VIIRS RAN2 for S-NPP and ABI/AHI RAN1 for G16/H08 using ACSPO v2.60.
- Upon completion, data will be posted at NOAA CoastWatch and analysis posted in the NOAA SST Quality Monitor (SQUAM).

Summary

- ACSPO v2.60 generates a consistent line of L3U products across all available sensors and platforms
- The algorithm employs bilateral weighting to produce L3U close to L2P. In particular, it preserves features while reducing image noise
- Low-resolution sensors are upsampled using spatial weighting, before being passed to the bilateral algorithm
- ACSPO v2.60 L3U includes a complete set of L2P QLs/Flags
- All ACSPO L3U products are routinely monitored and validated against *i*Quam drifters and tropical moorings in the NOAA SST Quality Monitor (SQUAM)
- Quality of L2P and L3U imagery is routinely monitored in the ACSPO Regional Monitor for SST (ARMS)
- All global and regional analyses so far suggest that every ACSPO L3U product is comparable with the L2P in feature resolution and preservation, and in global monitoring w.r.t. *in situ* SSTs

Future Work

Document ACSPO v2.60 L3U algorithm

Path towards (super-)collated products

- Generate and test US regional Level 3C ("collated") and 3S ("super-collated") products from L3U
- Eventually generalize these products to global coverage

L3U improvements

- Explore improvements to the gridding algorithm in order to enable 0.01º regional L3U/C/S products and alternative geolocation grids (*e.g.* polar stereographic projection)

For more information about the original ACSPO L3U algorithm

- Ignatov, Gladkova, Ding, Shahriar, Kihai, 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!