Motivation for Super-Collocated (L3S) SST Product at NOAA
- NOAA provides high resolution SST products from multiple satellites/sensors using its Advanced Clear Sky Processor for Oceans (ACSP) system. 
  - LEO (low earth orbiters): Hi-Res ~1km nadir: NPP/N20 VIIRS, Metop-A/B/C AVHRR FRAC, Terra/Aqua MODIS. In 2022, J2/VIIRS & Metop-SG/VIIRI will be launched. Lo-Res (~4km): NOAA-07 to -19 AVHRR GAC. 
  - GEO (geostationary orbit): Hi-Res (~2300 km) GT16/17 ABI & H18/19 ABI. In 2021, GOES-T/ABI & MTG/F/FCI will be launched. 
- Users are faced with an overwhelming data volumes and number of files. Moreover, they are left to deal with regular, regional and cross-sensor biases in SST retrievals. 
- Often, they don’t know the specifics of the products they are trying to fuse. 
- As a result, they often resort to using gap-free level 4 (L4) analyses (MUR, OSTIA, GPB, Reynolds OI SST), despite their degraded feature resolution.
- **Our answer is data fusion** – ACSPO L3S: Global Gridded Super-Collocated (multi-sensor) Products.

Overview of Current and Future ACSPO L3S Products
- Experimental L3S data available on NOAA CoastalWatch site [1].
- Two lines of L3S products are under development: L3S-LEO & L3S-GEO.
- L3-S-LEO includes PM (afternoon orbits) and AM (mid-orbiting) SST products.
- Figure 1 shows histograms of normalized number of observations as a function of local solar time for both PM and AM products (day and night), demonstrating their potential to cover a large portion of the diurnal cycle.
- L3S-GEO will be organized into 24 hourly files, capable of resolving the diurnal cycle.
- Table 1 shows overview of current/future products and estimated data volumes.

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<thead>
<tr>
<th>L3S</th>
<th>Satellites</th>
<th>Number of day/night</th>
<th>Volume (Gb/day)</th>
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<td>GEO</td>
<td>GS16, GS17, H08, MTG</td>
<td>24 (hourly)</td>
<td>~2</td>
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Figure 1: Normalized histograms of number of observations as a function of local solar time. (Based on aggregated data from January 2020.)

**Example:** L3S-PM SST Imagery
- Mid-Atlantic Coast, US (figure 2).
- Four VIIRS overpasses available: Improved coverage in L3S compared to L3U.
- Feature resolution preserved/improved but gaps due to clouds are not filled.
- Images shown here are taken from the ARMS online system [2].

Overview of the ACSPO Collation Algorithm
The ACSPO collation algorithm comprises two steps (see further info in Refs. [3] and [4]):
1. **Angular Debiasing/Normalization**
   - Satellite SST data are subject to residual intra-inter-sensor biases between consecutive overpasses that depend strongly on view zenith angle (VZA).
   - The ACSPO collation algorithm mitigates these by creating a low-resolution, satellite-based lowest VZA (LVZA) “SST reference” produced by combining near-nadir data from multiple overpasses.
   - SST reference is used to debias input L3U data while maintaining feature resolution.
   - Figure 3 demonstrates improved NPP/N20 consistency after LVZA debiasing.

**References**
[1] https://www.star.nesdis.noaa.gov/socd/sst/arms

2. Adaptive SST Weighting
- Each L3U pixel (from step 1) is weighted, using an iterative adaptive weighting procedure, which preserves features, suppresses noise and minimized spatial discontinuities.
- SST values more consistent with surrounding are weighted higher (reduces impact of cloud contaminated data). Figure 4 demonstrates improvement in imagery (a) with adaptive weighting compared to (b) simple average weighting.
- Measurements made at lower VZAs are weighted higher. This preference is greater in dynamic regions, to minimize smoothing of SST contrasts such as thermal fronts. Figure 5 demonstrates improvement in imagery due to (a) VZA weighting compared to (b) simple average weighting.

**Global Validation**
- We evaluated the L3S-PM SST product and compared to individual-sensor L3Us.
  - Validation is performed using the SQUAM online system [5] using match-up statistics (drifters and tropical moorings) from the iQuam online system [6].
  - Evaluation period between Nov 1 2020 and Apr 9 2021
- Table 2 below summarizes validation statistics for sub-skin and deep SST.

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Figure 3. Panels (a) and (b) show difference in night-time sub-skin SST between consecutives overpasses between N20 (11:00 UTC) and NPP (10:10 UTC) (a) with and (b) without the LVZA debiasing. The NPP overlap was over cloudy water, and the N20 overlap over a cooler biased area. After debiasing, (b), the agreement is greatly improved. Panel (c) shows histograms of differences with and without debiasing demonstrating improved agreement in terms of shape of the histogram, show Gaussian, and comparisons statistics (mean, standard deviation). Imagery location is off the coast of California on 4 Feb 2020.

Figure 4. L3S-PM SST imagery from the South Atlantic Ocean (Brazil Current). (a) Using adaptive weighting. (b) Using simple average weighting. Panel (c) shows a slice of (a) and (b) at a constant longitude marked by black vertical lines. Black arrows denote cloud contaminations that are mitigated by adaptive weighting.

Figure 5. L3S-AM SST imagery from the Indian Ocean (Agulhas Current). (a) Using adaptive weighting. (b) Using simple average weighting. Panel (c) shows a slice of (a) and (b) at a constant longitude marked by black vertical lines. Black arrows denote sharp thermal fronts that are degraded in magnitude with simple average weighting.