Current status and upcoming changes in ACSPO VIIRS SST

Boris Petrenko(1,2), Alexander Ignatov(1), Yury Kihai(1,2), Xinjia Zhou(3), Kai He(3), Maxim Kramar(1,2)

(1) NOAA STAR, USA; (2) GST, Inc., USA; (3) CSU CIRA, Inc., USA
## Current ACSPO 2.41 VIIRS SST products

<table>
<thead>
<tr>
<th>Product</th>
<th>Global Regression (GR) SST</th>
<th>Piecewise Regression (PWR) SST (aka De-biased SST)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Representation in ACSPO GDS2 file</strong></td>
<td>“sea_surface_temperature”</td>
<td>“sea_surface_temperature” - “SSES_bias”</td>
</tr>
<tr>
<td><strong>Algorithm</strong></td>
<td>Two regression equations, (one for day and one for night)</td>
<td>Piecewise regression with multiple sets of coefficients for separate segments of the SST domain</td>
</tr>
</tbody>
</table>
| **Bands used** | Night: M12 (3.7 μm), M15 (10.76 μm) and M16 (12.01 μm)  
Day: M15 and M16 | |
| **Coefficients training** | Least-squares method: best fit of in situ SST | |
| **Precision wrt in situ SST** | Night: ~0.3 K  
Day: ~0.4 K | Night: ~0.25 K  
Day: ~0.3 K |
| **Mean sensitivity to SSTskin** | Night: ~0.97  
Day: ~0.9 | Not controlled |

- GR SST is sensitive to “skin” SST – “subskin” SST
- PWR SST precisely fits in situ SST - proxy for “depth” SST

8/17/2017

ACSPO SST algorithms
### Changes in VIIRS SST algorithms in ACSPO v.2.50

<table>
<thead>
<tr>
<th>Change</th>
<th>Expected improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. VIIRS band M14 (8.55 μm) is involved in SST retrieval, along with</td>
<td>✓ Improved precision with respect to <em>in situ</em> SST</td>
</tr>
<tr>
<td>bands M12, M15 and M16</td>
<td></td>
</tr>
<tr>
<td>2. The PWR SST equation accounts for GFS wind speed and Local Solar</td>
<td>✓ Improved precision of PWR SST with respect to <em>in situ</em> SST</td>
</tr>
<tr>
<td>Time</td>
<td>✓ Improved reproduction of diurnal cycle in “depth” SST</td>
</tr>
<tr>
<td>3. The definition of SSES SD changes from SD of GR SST-<em>in situ</em> SST</td>
<td>✓ Improved assimilation of PWR SST in L4 analyses (potentially)</td>
</tr>
<tr>
<td>to SD of PWR SST – <em>in situ</em> SST</td>
<td></td>
</tr>
<tr>
<td>4. PWR “skin” SST is implemented for internal testing</td>
<td>✓ Improved “skin” SST retrieval (compared with GR SST)</td>
</tr>
</tbody>
</table>
VIIRS GR SST equations in ACSPO v.2.50

Night:

\[ T_S = a_0 + a_1 T_{11} + a_2 (T_{11} - T_{3.7}) + a_3 (T_{11} - T_{8.6}) + a_4 (T_{11} - T_{12}) + \\ + [a_5 + a_6 T_{11} + a_7 (T_{11} - T_{3.7}) + a_8 (T_{11} - T_{8.6}) + a_9 (T_{11} - T_{12})] S_\theta + \\ + [a_{10} (T_{11} - T_{3.7}) + a_{11} (T_{11} - T_{8.6}) + a_{12} (T_{11} - T_{12})] T_S^0 \]

Day:

\[ T_S = a_0 + a_1 T_{11} + a_3 (T_{11} - T_{8.6}) + a_4 (T_{11} - T_{12}) + \\ + [a_5 + a_6 T_{11} + a_8 (T_{11} - T_{8.6}) + a_9 (T_{11} - T_{12})] S_\theta + \\ + [a_{11} (T_{11} - T_{8.6}) + a_{12} (T_{11} - T_{12})] T_S^0 \]

- \( T_{3.7}, T_{8.6}, T_{11}, T_{12} \) observed BTs
- \( S_\theta = 1/\cos(\theta) - 1 \) \( \theta \) 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

- New equations include regressors of the conventional types, which can be constructed from 3 or 4 radiometric bands
- The coefficients are stabilized by cutting off the least informative dimensions in the space of regressors instead of dropping some regressors (Petrenko et al., SPIE, 2016)
- The SST noise is reduced by smoothing the differential regressors without the loss of sensitivity (Petrenko et al., SPIE, 2015)
Expected improvement of SST precision because of using VIIRS band M14

<table>
<thead>
<tr>
<th>SST</th>
<th>SD wrt in situ SST</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without M14</td>
</tr>
<tr>
<td><strong>Day</strong></td>
<td></td>
</tr>
<tr>
<td>Global Regression</td>
<td>0.41</td>
</tr>
<tr>
<td>Piecewise Regression</td>
<td>0.28</td>
</tr>
<tr>
<td><strong>Night</strong></td>
<td></td>
</tr>
<tr>
<td>Global Regression</td>
<td>0.34</td>
</tr>
<tr>
<td>Piecewise Regression</td>
<td>0.26</td>
</tr>
</tbody>
</table>

• Band M14 (8.55 \(\mu\)m) improves precision, especially for PWR SST
Modification of PWR SST equation

• The current ACSPO PWR SST fits in situ SST with SD≈0.25 K
• The further improvement of precision requires accounting for new sources of errors
• One of such error sources is the bias between in situ SST and “skin” SST.
• Two of the variables driving the skin/depth bias, available during the SST retrieval wind speed (V) and Local Solar Time (LST)

Day:

\[ T_s = a_0(LST) + a_1 T_{11} + a_3 (T_{11} - T_{8.6}) + a_4 (T_{11} - T_{12}) +\]
\[ + [a_5 a_6 T_{11} + a_8 (T_{11} - T_{8.6}) + a_9 (T_{11} - T_{12})] S_\theta +\]
\[ + [a_{11} (T_{11} - T_{8.6}) + a_{12} (T_{11} - T_{12})] T_s^0 + a_{13} V \]

• LST is accounted for by correcting the offsets in the SST equations for every LST hour. During L2 processing, the offsets are interpolated to actual LST
• GFS Wind speed is added to the equation as an additional regressor
Expected improvement of daytime PWR SST precision wrt *in situ* SST due to accounting for $V$ and LST

<table>
<thead>
<tr>
<th>Dataset of matchups</th>
<th>$V$ and LST are not accounted for</th>
<th>$V$ and LST are accounted for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training (January – December 2016)</td>
<td>0.25</td>
<td>0.24</td>
</tr>
<tr>
<td>Validation (January-June 2017)</td>
<td>0.26</td>
<td>0.25</td>
</tr>
</tbody>
</table>

- Accounting for wind speed and LST reduces daytime SD wrt *in situ* SST
Daytime PWR SST bias wrt CMC as function of wind speed and local time

- Accounting for $V$ and LST in the PWR SST equations:
  - Improves the reproduction of dependencies of in situ SST-CMC bias from $V$ and LST
  - Shifts the maximum of the diurnal warming signal from $\sim12:30$ to $\sim14:30$, consistently with in situ SST
Experimental Piecewise Regression “skin” SST

- The goals of the **Piecewise Regression “skin” SST (PWRskin SST)** are:
  - ✓ To reduce regional SST biases (compared with the GR SST);
  - ✓ To bring the sensitivity closer to 1 and to make it more uniform

- The **PWR skin SST** uses the segmentation of the SST domain in the space of regressors, like it is done in the current PWR SST

- **PWRskin SST** coefficients are trained under the constraint “mean sensitivity =1”
### SD wrt in situ SST and sensitivity for GR SST and PWR skin SST

<table>
<thead>
<tr>
<th>SST</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SD wrt <em>in situ</em> SST</td>
<td>Sensitivity</td>
</tr>
<tr>
<td>GR SST</td>
<td>0.37</td>
<td>0.85±0.08</td>
</tr>
<tr>
<td>PWR skin</td>
<td>0.38</td>
<td>1.00±0.05</td>
</tr>
</tbody>
</table>

- PWR skin brings the mean sensitivity to 1 and reduces its variations.
Daytime biases and SDs of SST- *in situ* SST and sensitivities as function of latitude

- GR SST produces large biases at high latitudes in the South
- PWRskin SST biases and SDs are maximum at low latitudes (expected)
- The biases and SDs for PWR are the smallest and the most uniform
- Sensitivity of GR SST is minimum at low latitudes, whereas the sensitivity of PWRskin SST is more uniform and closer to 1
Daytime maps of GR SST-CMC, PWR “skin” SST-CMC and GR SST-PWR “skin” SST (5 July 2017)

GR SST – CMC: Bias=0.46K, SD=0.50 K

PWRs SST – CMC: Bias=0.32K, SD=0.50 K

- PWRskin SST reduces warm biases in high latitudes
Nighttime maps of GR SST-CMC, PWR “skin” SST-CMC and GR SST-PWR “skin” SST (5 July 2017)

GR SST – CMC: Bias=0.11K, SD=0.32 K

PWRS SST – CMC: Bias=0.06K, SD=0.33 K

At night, the PWRskin SST reduces warm biases in high latitudes in the South
PWR SST minus CMC (5 July 2017)

PWR SST – CMC, **DAY**: Bias=0.18K, SD=0.27 K

PWR SST – CMC, **NIGHT**: Bias=0.02K, SD=0.17 K

PWR SST is highly precise with respect to CMC
Sensitivities for GR SST and PWR skin SST

GR SST, DAY: mean=0.85, SD=0.08

GR SST, NIGHT: mean=0.91, SD=0.03

PWR skin SST, DAY: mean=0.99, SD=0.05

PWR SST, NIGHT: mean=0.99, SD=0.02

• Sensitivities for PWR skin SST are closer to 1 and more uniform
In ACSPO v. 2.50, SSES SD represents SD of PWR SST - *in situ* SST and may be used for optimal weighting of PWR SST with other products during L4 analyses.
Summary of improvements

• Using the VIIRS band M14 (8.55 µm) for SST, in addition to the previously used bands will improve the precision of ACSPO SST products wrt *in situ* SST

• The precision of the PWR SST will be further improved by accounting for GFS wind speed and local solar time in the regression equations

• The new experimental product, Piecewise Regression “skin” SST will be tested and is expected to become a better proxy for SSTskin than the current Global Regression SST

• SSES SD will represent SD of PWRdepth SST wrt *in situ* SST to facilitate the assimilation in L4 analyses.
THANK YOU