ACSP PO SST algorithm improvements

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Current SST algorithms in ACSPO: 1. Baseline SST (BSST)

- Two “global” regression equations for day and night
- Trained on global data sets of matchups (MDS)

Day: \[ T_S = a_0 + a_1 T_{11} + a_2 S_\theta T_{11} + a_3 \Delta T_{11-12} + a_4 \Delta T_{11-12} T_S^0 + a_5 \Delta T_{11-12} S_\theta + a_6 S_\theta \]

Night: \[ T_S = b_0 + b_1 T_{3.7} + b_2 S_\theta T_{3.7} + b_3 \Delta T_{11-12} + b_4 S_\theta \Delta T_{11-12} + b_5 S_\theta \]

- For further information see Petrenko et all, JGR, 2014

- BSST provides a tradeoff between precision of fitting in situ SST (“bulk”) and sensitivity to “skin” SST
- Referred to as “sub-skin” rather than “skin” SST because:
  - It is trained against in situ data
  - The sensitivity to “skin” SST is non-uniform and, in general, less than 1
Current SST algorithms in ACSPO:
2. Piecewise Regression (PWR) SST

Produced with multiple regression equations for specific segments of the SST domain

- Segments are defined in the space of regressors rather than in the space of physical variables
- Segmentation parameter (Fisher distance) is derived from statistics of regressors within the global MDS:
- Regression coefficients are trained separately for each segment using the Least-Squares (LS) method
- PWR SST may be obtained from the ACSPO GDS2 files as BSST-SSES bias
- For further information see Petrenko et al., JTECH, 2016

- Precisely fits in situ SST, sensitivity to “skin” SST may be low
- May be soundly referred to as “bulk” SST
Night, BSST – CMC: Bias=0.07 K, SD=0.35 K
Night, PWR SST – CMC: Bias=0.05 K, SD=0.27 K

Day, BSST – CMC: Bias=0.27 K, SD=0.57 K
Day, PWR SST – CMC: Bias=0.27 K, SD=0.40 K

• BSST provides reasonable global precision wrt L4 CMC, PWR SST further improves the precision
• Now that we have “bulk” SST, can “sub-skin” BSST be brought closer to “skin”?  
  • We cannot do it in full unless we get a reliable set of matchups with “skin” SST  
  • However we can adjust the sensitivity to “skin” SST (make it more uniform and closer to 1)
Involving new VIIRS bands in SST retrieval

<table>
<thead>
<tr>
<th>VIIRS Band</th>
<th>Wavelength (µm)</th>
<th>Current usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>M12</td>
<td>3.7</td>
<td>Night only</td>
</tr>
<tr>
<td>M13</td>
<td>4.05</td>
<td>Not used</td>
</tr>
<tr>
<td>M14</td>
<td>8.55</td>
<td>Not used</td>
</tr>
<tr>
<td>M15</td>
<td>10.76</td>
<td>Day, night</td>
</tr>
<tr>
<td>M16</td>
<td>12.01</td>
<td>Day, night</td>
</tr>
</tbody>
</table>

- Currently, only the VIIRS bands, similar to AVHRR are used
- Two more VIIRS bands, 4.95 and 8.55 µm, also may be used for SST

• This requires adding new regressors to the SST equations
Constructing “Extended” SST equation

In general, SST equation for N bands may include up to 3×N regressors:

\[ T_S = a_0 + a_1 T_{\lambda 1} + \ldots + a_N T_{\lambda N} + \]
\[ + a_{N+1} T_{\lambda 1} S_\theta + \ldots + a_{2N} T_{\lambda N} S_\theta + \]
\[ + a_{2N+1} \Delta T_{\lambda 1-\lambda 2} T_S^0 + \ldots + a_{3N-1} \Delta T_{\lambda 1-\lambda N} T_S^0 + a_{3N} S_\theta \]

In the case of extended SST equation, the conventional Least Squares (LS) method may be suboptimal for coefficients calculation:

- The sensitivity of regression SST to “skin” SST may be low;
- The LS estimates of regression coefficients may be instable

A new approach to calculation of regression coefficients is required
Modified Method for Calculation of Regression Coefficients

• A constraint on mean sensitivity over the MDS is posed on the LS solution (Constrained Least-Squares (CLS) method):
  \[
  \text{mean sensitivity} = 1
  \]

• Stability of coefficients is controlled by rejecting the least informative dimensions in the space of regressors (rather than by limiting the number of regressors).

• For further information, see Petrenko et al., Proc. SPIE, 2016

The resulting “extended” regression equation may include many regressors while producing stable SST estimates with predefined mean sensitivity
Initial Himawari-8 AHI BSST – CMC and sensitivity
(8 January 2016, 5:00 UTC)

- AHI bands 8.6, 10.4, 11.2 and 12.3 μm are used
- BSST is retrieved for VZA < 67°

Initial coefficients calculated in June 2015 with the LS method using a limited (~1 month) MDS

BSST-CMC: Bias=0.56 K, SD=0.65 K
Sensitivity: Mean=0.76
Himawari-8 AHI BSST with CLS coefficients
(8 January 2016, 5:00 UTC)

The equation with CLS coefficients was implemented in May 2016 using ~ 1 year of matchups

- The mean sensitivity increased from 0.76 to 0.95
- The diurnal warming effect in SST also increased
- However, the sensitivity remains spatially non-uniform
Next step: Combining the PWR and the CLS Methods

- In ACSPO, PWR SST is produced using multiple regression equations for different segments of the SST domain. The coefficients are calculated with the LS method.
- This provides precise approximation of *in situ* SST but suppresses the sensitivity to “skin” SST.
- Now that we can control the mean sensitivity, we can recalculate the PWR coefficients with the CLS method.
- This approach was tested within the experimental version of ACSPO VIIRS.
Global Daytime Statistics of the BSST Algorithms wrt in situ SST

Statistics are derived from dataset of VIIRS matchups from May 2014 – June 2016

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>VIIRS Bands</th>
<th>SD, SST-in situ</th>
<th>Mean Sensitivity</th>
<th>SD sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Global + Least Squares (current)</td>
<td>11.2 and 12.3 μm</td>
<td>0.42</td>
<td>0.90</td>
<td>0.091</td>
</tr>
<tr>
<td>2. Global + Constrained Least Squares</td>
<td>8.6, 11.2 and 12.3 μm</td>
<td>0.47</td>
<td>1.00</td>
<td>0.091</td>
</tr>
<tr>
<td>3. PWR + Constrained Least Squares</td>
<td>8.6, 11.2 and 12.3 μm</td>
<td>0.39</td>
<td>1.00</td>
<td>0.043</td>
</tr>
</tbody>
</table>

• Since the largest effect was found for day, here we compare three daytime SST algorithms

• The Global + LS (2 bands) algorithm provides usual SST precision and low mean sensitivity

• The Global + CLS (3 bands) algorithm brings the mean sensitivity to 1, increases SD of fitting matchups

• The PWR + CLS (3 bands) algorithm keeps the mean sensitivity =1, reduces SD of fitting matchups
Daytime maps of VIIRS BSST-CMC and Sensitivity with the Current and PWR+CLS algorithm (17 July 2016)

2-band BSST-CMC: Bias=0.27K, SD=0.57K

3-bands PWR/CLS SST-CMC: Bias=0.36K, SD=0.51K

2-band Sensitivity: Mean=0.90K, SD=0.09K

3-bands PWR/CLS Sensitivity: Mean=1.00, SD=0.05K

The 3-band PWR/CLS SST:
  • Increases daytime bias wrt CMC but reduces SD
  • Optimizes mean sensitivity and improves its spatial uniformity
Summary

• The current ACSPO Baseline SST may be brought closer to “skin” SST by
  • Using VIIRS bands 4.05 and 8.55 μm for SST retrieval along with the currently used bands 3.7, 11 and 12 μm
  • Bringing the mean sensitivity to the optimal value of 1 by using the Constrained Least-Squares method for coefficients calculation
  • Reducing spatial non-uniformity of sensitivity by Using the Piecewise Regression approach along with the CLS coefficients
• The “global” BSST algorithm with CLS coefficients has already been implemented for Himawari-8 AHI.
• Testing and implementation of the PWR algorithms with CLS coefficients is underway.

THANK YOU