MODIS SEA-SURFACE TEMPERATURES

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MODIS Science Team Meeting, April 2014.
SUMMARY

• MODIS SSTs are stable and of good accuracy
• New algorithmic enhancements to improve accuracy, especially towards edges of swaths
• New V6 code delivered to OBPG and tested for next reprocessing cycle
• New M-AERIIs being deployed for skin SST validation
• SI-calibration traceability leads to rigorous CDR generation
  • But desired CDR accuracies not yet met
SST ACCURACY REQUIREMENTS

- SST is an Essential Climate Variable (CEOS)
- Required Errors and Uncertainties in SST for CDRs:
  - Accuracy: better than 0.1K
  - Stability: better than 0.04 K/decade
- SST CDRs require traceability to SI-Standards
- Difficulties are not only to achieve these, but to demonstrate whether they have been achieved
- “Reference satellite sensor” – AATSR – terminated in April 2012 with failure of Envisat – focus on MODIS
ATMOSPHERIC CORRECTION ALGORITHMS

Collection 5: 6:

• $$SST = a_0 + a_1 T_{31} + a_2 (T_{31} - T_{32}) T_{sfc} + a_3 (\sec(\theta) - 1)(T_{31} - T_{32})$$
  $$+ a_4(fn(\text{mirror.side})) + a_5(\theta)$$
  $$+ a_6(\theta)^2$$

• $$SST4 = a_0 + a_1 T_{22} + a_2 (T_{22} - T_{23}) + a_3 (\sec(\theta) - 1)$$
  $$+ a_4(fn(\text{mirror.side})) + a_5(\theta) + a_6(\theta)^2$$

• Quality flagging improved
Matchups between Aqua MODIS and drifters, after QA, for 2012. 79986 for day & night, but spatial distribution is uneven.

Buoy measurements are of a subsurface temperature.
### MODIS TERRA – SST residual statistics for each quality level (day + night)

<table>
<thead>
<tr>
<th>Quality</th>
<th>Min</th>
<th>Q1</th>
<th>Median</th>
<th>Mean</th>
<th>Q3</th>
<th>Max</th>
<th>RMS</th>
<th>SD</th>
<th>MAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-4.461</td>
<td>-0.359</td>
<td>-0.109</td>
<td>-0.110</td>
<td>0.137</td>
<td>6.080</td>
<td>0.453</td>
<td>0.439</td>
<td>0.368</td>
</tr>
<tr>
<td>1</td>
<td>-5.170</td>
<td>-0.574</td>
<td>-0.209</td>
<td>-0.244</td>
<td>0.114</td>
<td>10.851</td>
<td>0.715</td>
<td>0.672</td>
<td>0.507</td>
</tr>
<tr>
<td>2</td>
<td>-7.573</td>
<td>-1.457</td>
<td>-0.779</td>
<td>-1.040</td>
<td>-0.283</td>
<td>5.525</td>
<td>1.598</td>
<td>1.214</td>
<td>0.833</td>
</tr>
</tbody>
</table>

### MODIS TERRA – SST4 residual statistics for each quality level (night only)

<table>
<thead>
<tr>
<th>Quality</th>
<th>Min</th>
<th>Q1</th>
<th>Median</th>
<th>Mean</th>
<th>Q3</th>
<th>Max</th>
<th>RMS</th>
<th>SD</th>
<th>MAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-4.475</td>
<td>-0.292</td>
<td>-0.140</td>
<td>-0.163</td>
<td>-0.007</td>
<td>4.664</td>
<td>0.359</td>
<td>0.320</td>
<td>0.210</td>
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<tr>
<td>1</td>
<td>-4.756</td>
<td>-0.474</td>
<td>-0.223</td>
<td>-0.283</td>
<td>-0.027</td>
<td>4.703</td>
<td>0.529</td>
<td>0.447</td>
<td>0.324</td>
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<tr>
<td>2</td>
<td>-6.673</td>
<td>-1.071</td>
<td>-0.411</td>
<td>-0.641</td>
<td>-0.057</td>
<td>3.765</td>
<td>1.102</td>
<td>0.896</td>
<td>0.660</td>
</tr>
</tbody>
</table>

Expect mean error of -0.17K from skin effect
### AQUA MODIS SST RESIDUALS

#### MODIS AQUA – SST residual statistics for each quality level (day + night)

<table>
<thead>
<tr>
<th>Quality</th>
<th>Min</th>
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<th>MAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-4.546</td>
<td>-0.362</td>
<td>-0.131</td>
<td>-0.139</td>
<td>0.093</td>
<td>13.024</td>
<td>0.460</td>
<td>0.438</td>
<td>0.338</td>
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<tr>
<td>1</td>
<td>-5.882</td>
<td>-0.565</td>
<td>-0.208</td>
<td>-0.255</td>
<td>0.087</td>
<td>10.948</td>
<td>0.701</td>
<td>0.652</td>
<td>0.477</td>
</tr>
<tr>
<td>2</td>
<td>-7.231</td>
<td>-1.584</td>
<td>-0.851</td>
<td>-1.111</td>
<td>-0.323</td>
<td>8.764</td>
<td>1.639</td>
<td>1.202</td>
<td>0.885</td>
</tr>
</tbody>
</table>

#### MODIS AQUA – SST4 residual statistics for each quality level (night only)

<table>
<thead>
<tr>
<th>Quality</th>
<th>Min</th>
<th>Q1</th>
<th>Median</th>
<th>Mean</th>
<th>Q3</th>
<th>Max</th>
<th>RMS</th>
<th>SD</th>
<th>MAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-4.394</td>
<td>-0.312</td>
<td>-0.152</td>
<td>-0.183</td>
<td>-0.013</td>
<td>3.961</td>
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<td>0.219</td>
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<tr>
<td>1</td>
<td>-5.178</td>
<td>-0.597</td>
<td>-0.292</td>
<td>-0.381</td>
<td>-0.074</td>
<td>3.473</td>
<td>0.640</td>
<td>0.514</td>
<td>0.372</td>
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<tr>
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<td>-7.684</td>
<td>-1.871</td>
<td>-1.041</td>
<td>-1.235</td>
<td>-0.348</td>
<td>4.111</td>
<td>1.703</td>
<td>1.172</td>
<td>1.101</td>
</tr>
</tbody>
</table>

Expect mean error of -0.17K from skin effect
MEDIAN OF SST ERRORS

Collection 5 – red. Collection 6 - blue

MODIS Science Team Meeting, April 2014.
MEAN ABS DIFFS OF SST ERRORS

Terra - MAD of SST residuals

Aqua - MAD of SST residuals

Collection 5 – red. Collection 6 - blue
COMPARISON WITH OTHER SSTS

Aqua MODIS SST vs Reynolds OI

Aqua MODIS SST vs WindSat SST

Temperature difference, K
Mean difference between M-AERI SSTs = 0.064K

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M-AERI CALIBRATION
M-AERI DEPLOYMENTS

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ISAR DEPLOYMENTS
MODIS – M-AERI SKIN SSTs

TERRA version 6 SST – MAERI SST, quality=0, night

AQUA version 6 SST – MAERI SST, quality=0, night

MODIS Science Team Meeting, April 2014.
# GLOBAL STATS vs RADIOMETERS

<table>
<thead>
<tr>
<th>MAERI</th>
<th>SST4 V6</th>
<th>mean</th>
<th>median</th>
<th>sd</th>
<th>mad</th>
<th>IQR</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>TERRA</td>
<td></td>
<td>0.047</td>
<td>0.082</td>
<td>0.297</td>
<td>0.227</td>
<td>0.291</td>
<td>84</td>
</tr>
<tr>
<td>AQUA</td>
<td></td>
<td>-0.056</td>
<td>-0.024</td>
<td>0.304</td>
<td>0.242</td>
<td>0.308</td>
<td>135</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MAERI</th>
<th>SST night V6</th>
<th>mean</th>
<th>median</th>
<th>sd</th>
<th>mad</th>
<th>IQR</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>TERRA</td>
<td></td>
<td>-0.076</td>
<td>-0.073</td>
<td>0.444</td>
<td>0.492</td>
<td>0.627</td>
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<tr>
<td>AQUA</td>
<td></td>
<td>-0.087</td>
<td>-0.023</td>
<td>0.428</td>
<td>0.305</td>
<td>0.418</td>
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</table>

<table>
<thead>
<tr>
<th>ISAR</th>
<th>SST4 V6</th>
<th>mean</th>
<th>median</th>
<th>sd</th>
<th>mad</th>
<th>IQR</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>TERRA</td>
<td></td>
<td>0.110</td>
<td>0.085</td>
<td>0.618</td>
<td>0.289</td>
<td>0.388</td>
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<tr>
<td>AQUA</td>
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<td>-0.017</td>
<td>0.016</td>
<td>0.373</td>
<td>0.270</td>
<td>0.414</td>
<td>369</td>
</tr>
</tbody>
</table>

<table>
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<th>SST night V6</th>
<th>mean</th>
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<th>mad</th>
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</tr>
</thead>
<tbody>
<tr>
<td>TERRA</td>
<td></td>
<td>0.003</td>
<td>0.044</td>
<td>0.716</td>
<td>0.525</td>
<td>0.727</td>
<td>798</td>
</tr>
<tr>
<td>AQUA</td>
<td></td>
<td>0.059</td>
<td>0.066</td>
<td>0.495</td>
<td>0.384</td>
<td>0.521</td>
<td>355</td>
</tr>
</tbody>
</table>
M-AERI Mk2

Three M-AERI Mk2s being deployed on RCCL cruise liners….
M-AERI Mk3

M-AERI Mk 3 small enough to be helicopter mounted....
CDR GENERATION

Satellite radiometers

1. Transfer radiometers onboard TXR.
2. SI-standard blackbody calibrator (ITS-90) at an NML.
3. SI-calibrated blackbody calibrator in laboratory.
4. SI-calibrated thermometers.
6. Thermometers calibrated to SI standards prior to launch.
7. Every scan meter rotation.
8. Calibrated top of atmosphere radiances in radiometer passbands.

Ship-borne radiometers

1. Transfer radiometers onboard TXR.
2. SI-standard blackbody calibrator (ITS-90) at an NML.
3. SI-calibrated thermometers.
4. Well-calibrated thermometers ideally to SI.
5. Well-calibrated internal blackbodies in ship radiometers.
6. SI-traceable blackbody calibrator (ITS-90) at an NML.
7. SI-calibrated thermometers.
8. Every few minutes.
9. Every few months.
10. Every few years.
11. SI-traceable SST measurements.
12. SST-derived SST data EDRs.
15. Validation agreement.
17. Purple: non-SI traceable links.

Basis for SST CDR

1. SI-traceable SST measurements.
2. Radiometric, inter/intrastandard (TXR, AMBER,...).
4. Radiometric inter/intrastandard (TXR, AMBER,...).
5. SI-traceable radiance measurements (ITS-90).
6. SI-traceable SST measurements.
7. SI-traceable validation of SST and accuracy.
8. Validation agreement.
LOOKING FORWARD

• Minor improvements to algorithms
• Forward solution – optimum estimation of skin SST
• Evaluate sampling errors resulting from clouds
• Better partitioning of sources of uncertainties to derive improved estimate of MODIS SST accuracies
• Continue at-sea deployments……
• Continue to grow MUDBs to demonstrate stability of MODIS SSTs……
• Ensure MODIS and VIIRS SSTs are compatible and can contribute to the SST CDR
• Not seek the 8th significant figure in SST
RSMAS SST TEAM

• Kay Kilpatrick
• Gui Podesta
• Miguel Izaguirre
• Goshka Szczodrak
• Liz Williams
• Sue Walsh
• Warner Baringer
• Mike Reynolds – RMR Co, Seattle
SUMMARY

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• New algorithmic enhancements to improve accuracy, especially towards edges of swaths
• New V6 code delivered to OBPG and tested for next reprocessing cycle
• New M-AERIs being deployed for skin SST validation
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