Inter-Calibration of AATSR and MERIS Reflectances

Dr Dave Smith,
Space Science and Technology Department
CCLRC
Rutherford Appleton Laboratory
Chilton, Didcot
Oxfordshire OX11 0QX
United Kingdom
Outline

• Introduction
• Calibration sites
• Long Term Drift
• Comparisons
• Conclusions
Why?

• AATSR and MERIS are two of the latest in a series of large scale optical sensors designed for quantitative remote sensing.
  – Both sensors have on-board calibration.
  – Early remote sensing instruments rely almost entirely on vicarious calibration

• To allow products to be developed from combined AATSR and MERIS datasets we need to compare the basic top-of-atmosphere measurements produced by the two instruments

• Stable, remote desert and ice sites can be used to compare the calibrations of AATSR and MERIS and also with other sensors (in particular ATSR-2).

• Long-term stability of sites will enable temporal calibration drifts to be determined.
### AATSR + MERIS

<table>
<thead>
<tr>
<th>AATSR Channels (µm)</th>
<th>MERIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.413</td>
<td>0.560</td>
</tr>
<tr>
<td>0.442</td>
<td>0.620</td>
</tr>
<tr>
<td>0.510</td>
<td>0.665</td>
</tr>
<tr>
<td>0.560</td>
<td>0.665</td>
</tr>
<tr>
<td>0.560</td>
<td>0.665</td>
</tr>
<tr>
<td>0.560</td>
<td>0.665</td>
</tr>
<tr>
<td>0.620</td>
<td></td>
</tr>
<tr>
<td>0.665</td>
<td></td>
</tr>
<tr>
<td>0.665</td>
<td></td>
</tr>
<tr>
<td>0.681</td>
<td></td>
</tr>
<tr>
<td>0.708</td>
<td></td>
</tr>
<tr>
<td>0.753</td>
<td></td>
</tr>
<tr>
<td>0.778</td>
<td></td>
</tr>
<tr>
<td>0.865</td>
<td>1.020</td>
</tr>
<tr>
<td>0.865</td>
<td>1.020</td>
</tr>
<tr>
<td>0.885</td>
<td>1.020</td>
</tr>
<tr>
<td>0.900</td>
<td>1.020</td>
</tr>
</tbody>
</table>

+ ATSR-2 = 10 year data set

555km Swath  
Dual View  
1 Diffuser  
1020km Swath  
Single View  
3 Diffusers
## Site Locations

<table>
<thead>
<tr>
<th>Site</th>
<th>Lat center (°)</th>
<th>Long center (°)</th>
<th>lat-min</th>
<th>lat_max</th>
<th>long_min</th>
<th>long_max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria3</td>
<td>30.32</td>
<td>7.66</td>
<td>29.82</td>
<td>30.82</td>
<td>7.16</td>
<td>8.16</td>
</tr>
<tr>
<td>Algeria5</td>
<td>31.02</td>
<td>2.23</td>
<td>30.52</td>
<td>31.52</td>
<td>1.73</td>
<td>2.73</td>
</tr>
<tr>
<td>Arabia1</td>
<td>18.88</td>
<td>46.76</td>
<td>18.38</td>
<td>19.38</td>
<td>46.26</td>
<td>47.26</td>
</tr>
<tr>
<td>Libya1</td>
<td>24.42</td>
<td>13.35</td>
<td>23.92</td>
<td>24.92</td>
<td>12.85</td>
<td>13.85</td>
</tr>
<tr>
<td>Libya2</td>
<td>25.05</td>
<td>20.48</td>
<td>24.55</td>
<td>25.55</td>
<td>19.98</td>
<td>20.98</td>
</tr>
<tr>
<td>Sudan</td>
<td>21.74</td>
<td>28.22</td>
<td>21.24</td>
<td>22.24</td>
<td>27.72</td>
<td>28.72</td>
</tr>
<tr>
<td>Sonora</td>
<td>31.8</td>
<td>-113.86</td>
<td>31.54</td>
<td>32.06</td>
<td>-114.18</td>
<td>-113.54</td>
</tr>
<tr>
<td>Greenland</td>
<td>73.75</td>
<td>-40</td>
<td>70</td>
<td>77.5</td>
<td>-45</td>
<td>-35</td>
</tr>
</tbody>
</table>
Desert Calibration Targets

Sudan - Egypt

Sonora - Mexico
Ice Targets

Ice - Greenland

AATSR GBTR image for 1st June 2004 superimposed on coincident MERIS Reduced Resolution Image
Atmospheric Effects

Transmission vs. Wavelength (μm) for different atmospheric effects:
- Total
- Raleigh
- H₂O
- O₃

Transmission and Normalised Response graphs are overlaid for:
- AATSR (red)
- MERIS (blue)
Image Processing

• Check that calibration site is in image?

• Screen image for clouds/dust in site
  – For Deserts
    • Spatial uniformity test (0.87µm and 1.6 µm)
    • Brightness temperature test (low BT = clouds)
  – For Ice
    • Spatial Uniformity (0.87µm and 12µm)
    • 1.6µm threshold test (refl > 20% = water cloud)

• Only scenes that are cloud free over whole region are used

• Reflectances averaged over test site
  – For ice averages over 16km x 16km regions

• Correct ice TOA reflectances for Ozone absorption

• Compare TOA reflectances, plot trends …
Example ‘cloud’ test result

Sonora, Mexico

- No clouds
- 1.6um reflectances out of range
- 12um variance threshold exceeded
- 11um variance threshold exceeded
- 11 and 12um variance threshold exceeded
- 1.6um threshold exceeded
- 1.6um + 12um threshold exceeded
- 1.6um + 11um threshold exceeded
- 1.6um + 11um +12um threshold exceeded
- BT distribution Test failed
METRIC Extractions

• METRIC tar files downloaded from FENICE Site (8751 files)

• No METRIC outputs for SONORA, Dunhuang, Hay, Amburla and Thangoo

• HDF Files extracted from tar files and read by IDL routine

• TOA reflectances extracted and stored in file for each site – note only products containing full site are used in study

• Coincident MERIS and AATSR observations compared (928 match-ups to date over selected sites)
Long term stability determination

• Extract cloud free top of atmosphere reflectances for each site

• Fit BRDF to reflectance as a function of scattering angle.

• Normalise reflectance to BRDF and plot time series

• Fit drift function $D = \exp(rate*ndays)$ to time series

• Reiterate as necessary
Reflectance vs Scattering Angle (ATSR-2)

Use archive of ATSR-2 TOA Reflectances from 1995 to 2000

Coefficients for ATSR-2 BRDF for site SUDAN1 (R = a₀ + a₁γ + a₂γ²)

<table>
<thead>
<tr>
<th></th>
<th>Nadir</th>
<th>Along Track</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a₀</td>
<td>a₁</td>
</tr>
<tr>
<td>1.6µm</td>
<td>78.2736053</td>
<td>-0.2023685</td>
</tr>
<tr>
<td>0.87µm</td>
<td>65.2568512</td>
<td>-0.2483396</td>
</tr>
<tr>
<td>0.67µm</td>
<td>56.3275871</td>
<td>-0.2425693</td>
</tr>
<tr>
<td>0.56µm</td>
<td>34.4137306</td>
<td>-0.1228843</td>
</tr>
</tbody>
</table>
Results from Long-Term Monitoring of ATSR-2

- **0.87μm Drift**
  - Drift = 0.0003 Year⁻¹
  - October 2002 Data

- **0.66μm Drift**
  - Drift = 0.0000 Year⁻¹
Long Term Stability - AATSR

AATSR Reflectances normalised to BDRF for Arabian Desert Site

Intercalibration of AATSR and MERIS

MERIS/AATSR Workshop – ESRIN Sep 2005
AATSR Drift Rates

AATSR visible calibration drift rates for desert & ice targets

<table>
<thead>
<tr>
<th>Location</th>
<th>1.6μm</th>
<th>0.87μm</th>
<th>0.67μm</th>
<th>0.56μm</th>
<th>Date Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria3</td>
<td>0.7</td>
<td>1.6</td>
<td>1.8</td>
<td>3.3</td>
<td>Oct-02 Dec-04</td>
</tr>
<tr>
<td>Algeria5</td>
<td>0.3</td>
<td>1.6</td>
<td>3</td>
<td>3.2</td>
<td>Oct-02 Dec-04</td>
</tr>
<tr>
<td>Libya1</td>
<td>-0.1</td>
<td>0.9</td>
<td>2.2</td>
<td>4.5</td>
<td>Oct-02 Dec-04</td>
</tr>
<tr>
<td>Libya2</td>
<td>0.1</td>
<td>0.5</td>
<td>1.2</td>
<td>3.6</td>
<td>Oct-02 Dec-04</td>
</tr>
<tr>
<td>Sudan1</td>
<td>0.4</td>
<td>1.4</td>
<td>1.9</td>
<td>2.6</td>
<td>Oct-02 Dec-04</td>
</tr>
<tr>
<td>Arabia1</td>
<td>-0.2</td>
<td>1.1</td>
<td>1.9</td>
<td>2.7</td>
<td>Oct-02 Dec-04</td>
</tr>
<tr>
<td>Sonora</td>
<td>-0.1</td>
<td>1.6</td>
<td>2.3</td>
<td>4.0</td>
<td>Oct-02 Dec-04</td>
</tr>
<tr>
<td>Greenland</td>
<td>-</td>
<td>2.3</td>
<td>3.1</td>
<td>6.3</td>
<td>May-03 Jun-04</td>
</tr>
<tr>
<td>Average</td>
<td>0.2</td>
<td>1.3</td>
<td>2.1</td>
<td>3.4</td>
<td></td>
</tr>
<tr>
<td>Std Dev.</td>
<td>0.3</td>
<td>0.4</td>
<td>0.6</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>ATSR-2</td>
<td>0.3</td>
<td>1.1</td>
<td>1.1</td>
<td>1.6</td>
<td>May-95 Jan-00</td>
</tr>
<tr>
<td>Std Dev.</td>
<td>0.1</td>
<td>0.3</td>
<td>0.2</td>
<td>0.2</td>
<td></td>
</tr>
</tbody>
</table>

Drift = exp(-rate*time)

NOTE: Greenland data not included in average
Long-Term Stability – MERIS

Arabia

0.87μm Drift

Drift = -0.0006 Year⁻¹


0.66μm Drift

Drift = -0.0007 Year⁻¹


0.56μm Drift

Drift = 0.0032 Year⁻¹

## MERIS Drift Rates

<table>
<thead>
<tr>
<th>Location</th>
<th>0.87um</th>
<th>0.67um</th>
<th>0.56um</th>
<th>Date Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria3</td>
<td>1.0</td>
<td>0.8</td>
<td>1.6</td>
<td>Oct-02 Feb-05</td>
</tr>
<tr>
<td>Algeria5</td>
<td>-0.1</td>
<td>-0.2</td>
<td>0.1</td>
<td>Oct-02 Feb-05</td>
</tr>
<tr>
<td>Libya1</td>
<td>0.4</td>
<td>0.4</td>
<td>1.1</td>
<td>Oct-02 Feb-05</td>
</tr>
<tr>
<td>Libya2</td>
<td>-0.2</td>
<td>-0.4</td>
<td>-0.7</td>
<td>Oct-02 Feb-05</td>
</tr>
<tr>
<td>Sudan1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
<td>Oct-02 Feb-05</td>
</tr>
<tr>
<td>Arabia1</td>
<td>-0.1</td>
<td>-0.1</td>
<td>0.3</td>
<td>Oct-02 Feb-05</td>
</tr>
<tr>
<td>Greenland</td>
<td></td>
<td></td>
<td></td>
<td>May-03 Jun-04</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>0.2</td>
<td>0.1</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td><strong>Std Dev.</strong></td>
<td>0.5</td>
<td>0.4</td>
<td>0.8</td>
<td></td>
</tr>
</tbody>
</table>
ATSR-2 Visible Calibration Status

0.56\mu m = 0.965\%
0.67\mu m = 0.969\%
0.87\mu m = 0.978\%
1.6\mu m = 0.991\%

Intercalibration of AATSR and MERIS
Summary of Comparisons with ATSR-2

Drift correction and 1.6µm nonlinearity correction applied

Coeffs $R_{\text{AATSR}}$ vs. $R_{\text{ATSR2}}$

Slope  Offset
1.6µm  1.008  0.98%
0.87µm  1.030  2.23%
0.66µm  1.009  2.41%
0.56µm  1.034  1.60%
Comparisons with MERIS over Deserts

- Comparisons made at corresponding wavelengths only

- Ratio $R_{\text{AATSR}}/R_{\text{MERIS}}$
  - 0.87µm = 1.063
  - 0.66µm = 1.048
  - 0.56µm = 1.111

No drift correction
AATSR/MERIS – Time Series

AATSR Drift Corrected
AATSR vs. MERIS After Drift Correction

- Applying drift correction to AATSR reflectances yields better agreement between AATSR and MERIS

- Ratio $R_{\text{AATSR}} / R_{\text{MERIS}}$
  
  - $0.87 \mu m = 1.034$
  - $0.66 \mu m = 1.002$
  - $0.56 \mu m = 1.034$
Comparisons with MERIS over ICE

![Graphs showing comparisons with MERIS over ICE](image-url)
Greenland Comparisons after Drift Correction

- Ratio using desert drift rate

\[ \frac{R_{\text{AATSR}}}{R_{\text{MERIS}}} \]

0.87\(\mu\)m = 1.034
0.66\(\mu\)m = 1.006
0.56\(\mu\)m = 1.023
Summary of AATSR reflectance comparisons

Wavelength (µm)

RAATSR/REF

ATSR-2
Clouds
MERIS
GOME
SADE (Cabot et al)
NDVI Trends

Intercalibration of AATSR and MERIS

Out-gassings
AATSR/MERIS NDVI Comparisons

AATSR 0.87µm scaled by 0.967
Summary of Results

• AATSR and MERIS long term drifts have been measured using desert and ice targets

• Comparisons of AATSR and MERIS TOA reflectances show excellent agreement
  – Consistent with results from GOME and cloud measurements

• Comparisons with ATSR-2 show some bias or offset at 0.87µm, 0.67µm and 0.56µm
  – Work is in progress to understand bias
  – 1.6µm channels show good agreement

• AATSR and MERIS NDVI show excellent agreement after applying drift + bias corrections
  – AATSR data are affected by periodic outgassing – this can be compensated by use of same orbit VC1 files
AATSR + MERIS Synergy
Conclusions

• AATSR and MERIS provide well calibrated and corresponding datasets for cloud, land and ocean monitoring

• Combining AATSR + MERIS data can give enhanced L2-L3 products

• With 10+ years of ATSR-2 data coming on-line – we can start to build a record of the impact of Man’s activity on the climate