AATSR 1st Year Calibration Results

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AATSR Calibration 1st Year Results

• AATSR Visible Calibration System
• ATSR-2 Calibration Results
• Calibration Targets
  – Deserts, Ice
• Comparisons with MERIS
• Comparisons with AATSR
• Mission Trends
• Summary of Results
• Conclusion
Calibration Studies

- Smith – Comparisons with MERIS and ATSR-2 using Desert and Ice targets (Relative)

- Latter, Kerridge and Siddans – Comparisons with GOME, ATSR-2 and SCIA (Relative)

- Hagolle et al – Comparisons with CNES database (Absolute and Relative)

- Poulsen et al – Cirrus and Deep Convection Clouds (Absolute and Relative)
MODTRAN 3.5 - Mid Summer

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\[ r_{\text{VISCAL}} = A_{M2}/A_{\text{AATSR}} \cos(\pi/4)r_{M1}r_{M2}r_{\text{UV}}RI(0,\pi/4) \]
Calibration Algorithms

• Radiance detected by AATSR from scene of reflectance $R_{\text{Scene}}$ is
  \[ L_{\text{scene}} = R_{\text{scene}} I_0 d\lambda \cos(sza)/\pi = \alpha \frac{(C_{\text{scene}} - C_{\text{dark}})}{\text{SCP\_Gain}} \]

• Similarly the VISCAL unit produces a radiance $L_{\text{VISCAL}}$ corresponding to a reflectance $R_{\text{VISCAL}}$
  \[ L_{\text{VISCAL}} = R_{\text{VISCAL}} I_0 d\lambda/\pi = \alpha \frac{(C_{\text{VISCAL}} - C_{\text{DARK}})}{\text{SCP\_Gain}} \]

• Using this we can calibrate the AATSR raw counts to give a normalised top-of-atmosphere radiance such that
  \[ \text{VIS\_GBTR} = R_{\text{scene}} \cos(sza) = R_{\text{VISCAL}} (C_{\text{scene}} - C_{\text{dark}})/(C_{\text{VISCAL}} - C_{\text{DARK}}) \]

• In this work the difference between two measurements made by AATSR and a reference instrument is expressed as a ratio
  \[ R_{\text{AATSR}}/R_{\text{INST}} \]
Visible Channel Signal Trend

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Corresponds to behaviour at start of ATSR-2 mission
• Photodiode monitor on M2 gives indication of Opal stability
Results from intercomparisons between ATSR-2 and Other Sensors/Methods

Average Ratio (Ignoring Desert Model Results)

- 0.56µm = 0.986
- 0.67µm = 0.983
- 0.87µm = 0.989

Note variation in results!

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ATSR-2 Long Term Monitoring – After Drift Correction

Data from Libyan Desert

Drift = 0.0003 Year^{-1}

Drift = 0.0000 Year^{-1}

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Calibration Targets

Desert - Sudan - Egypt

Ice - Greenland

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

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Calibration Targets for Calibration

- Desert and Ice Targets used extensively for calibration and monitoring of AVHRR, ATSR-2, GOES, POLDER, Vegetation, MISR…
- Uniform reflectance over large area
- Long term-radiometric stability of the calibration sites
  - ensures long-term stability of the top-of-the atmosphere (TOA) albedo (and of seasonal variations, if any) or reflectance over large spatially uniform areas.
- High surface reflectance to maximise the signal-to-noise and minimise atmospheric effects on the radiation measured by the satellite
- Bi-directional reflectance factor (BRDF) due to surface anisotropy and other angular effects, and must be accounted for when determining long-term calibration trends.
ATSR-2 Desert BRDF measurements

ATSR-2
TOA reflectance archive from 1995 to 2000

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

<table>
<thead>
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<th>Nadir</th>
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<th>Along Track</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>a₀</td>
<td>a₁</td>
<td>a₂</td>
<td>a₀</td>
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<td>0.56μm</td>
<td>34.4137306</td>
<td>-0.1228843</td>
<td>0.0005610</td>
<td>60.6836205</td>
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</tbody>
</table>

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0.87μm Corrected for Ozone Absorption

0.66μm Corrected for Ozone Absorption

0.56μm Corrected for Ozone Absorption

AATSR-2 Greenland Data 1995-1999

+ 1995
◊ 1996
☆ 1997
△ 1998
□ 1999

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MERIS/AATSR Comparison Over Deserts

Results from 370 METRIC Extractions

- 560nm
  \[ R_{\text{AATSR}} / R_{\text{MERIS}} = 1.041 \]

- 660nm
  \[ R_{\text{AATSR}} / R_{\text{MERIS}} = 1.001 \]

- 870nm
  \[ R_{\text{AATSR}} / R_{\text{MERIS}} = 1.037 \]

AATSR Vs. MERIS Comparisons

\[ y = 1.0417x \]

\[ y = 1.0051x \]

\[ y = 1.0371x \]

MERIS 560nm Reflectance (%) vs. AATSR 555nm Reflectance (%)

MERIS 665nm Reflectance (%) vs. AATSR 670nm Reflectance (%)

MERIS 865nm Reflectance (%) vs. AATSR 865nm Reflectance (%)
AATSR vs. MERIS Greenland

560nm
\[ \frac{R_{\text{AATSR}}}{R_{\text{MERIS}}} = 1.034 \]

660nm
\[ \frac{R_{\text{AATSR}}}{R_{\text{MERIS}}} = 1.012 \]

870nm
\[ \frac{R_{\text{AATSR}}}{R_{\text{MERIS}}} = 1.037 \]
AATSR Calibration 1st Year Results

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### AATSR vs. MERIS Summary

<table>
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<tr>
<th></th>
<th>0.87</th>
<th>0.67</th>
<th>0.56</th>
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<tr>
<td>Smith</td>
<td>1.037</td>
<td>1.001</td>
<td>1.041</td>
</tr>
<tr>
<td>Poulsen et al</td>
<td>1.037</td>
<td>1.012</td>
<td>1.034</td>
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<td>Hagolle, Cabot et al</td>
<td>1.054</td>
<td>1.026</td>
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<tr>
<td><strong>Average</strong></td>
<td>1.039</td>
<td>1.011</td>
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<tr>
<td><strong>Stdev</strong></td>
<td>0.011</td>
<td>0.011</td>
<td>0.009</td>
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<tr>
<td><strong>Meris Relative to ATSR-2</strong></td>
<td>1.053</td>
<td>1.060</td>
<td>1.047</td>
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</tbody>
</table>

- Deserts
- Greenland
- Deep Convection Clouds
- SADE
• Inter-comparison requires
  • *Spectral* averaging of SCIA/GOME
  • *Spatial* averaging of AATSR/ATSR-2

• GOME & SCIA pixels not same size or coincident, therefore
  • Perform comparison for accurately co-located GOME/ATSR-2
  • Average SCIA to give scene comparable to GOME; compare to properly averaged AATSR
  • Associate nearest GOME/SCIA pixels to allow cross platform comparison; accept “noise” due to scene variation (time difference).
Comparisons for 15th Dec 2002

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Comparison of AATSR, ATSR-2 and GOME
Reflectance : 0.56µm

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Comparison of AATSR, ATSR-2 and GOME
Reflectance : 0.67µm

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Summary of Orbit Comparisons

- AATSR is high relative to ATSR-2
- AATSR agrees well with GOME
- ATSR-2 is low relative to GOME
- Better agreement with AATSR and GOME if ATSR-2 data not corrected for long-term drift
AATSR vs. ATSR-2 Direct Comparisons over Desert Targets

- Obtained 5 match-ups over cloud free scenes in Oct 2002

![Graphs showing comparisons between AATSR and ATSR-2 at different wavelengths: 1.6µm, 0.87µm, 0.67µm, and 0.56µm.](image)
AATSR Calibration 1st Year Results

Data for Sep 2002 to Aug 2003

0.87µm

ATSR-2 Normalised Radiance %
ATSR Normalised Radiance %

Desert Data
Y = X
Fit

0.67µm

ATSR-2 Normalised Radiance %
ATSR Normalised Radiance %

Desert Data
Y = X
Fit

0.56µm

ATSR-2 Normalised Radiance %
ATSR Normalised Radiance %

Desert Data
Y = X
Fit
Greenland Ice Comparisons

AATSR GBTR for 1st-May 2003

ATSR-2 GBT for 1st-May 2003

AATSR Cloud Mask for 1st-May 2003

ATSR-2 Cloud Mask for 1st-May 2003

AATSR Calibration 1st Year Results

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Current Data vs. Archive

Greenland Ice Reflectance Measurements at 01-MAY-2003 14:10

0.87µm

AATSR Data

0.66µm

0.56µm

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Combined AATSR vs. ATSR-2 Results

AATSR Calibration 1st Year Results

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### AATSR vs. ATSR-2 Summary

<table>
<thead>
<tr>
<th>Ratio $R_{AATSR}/R_{ref}$</th>
<th>1.6</th>
<th>0.87</th>
<th>0.66</th>
<th>0.56</th>
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<tbody>
<tr>
<td>Smith</td>
<td>0.932</td>
<td>1.079</td>
<td>1.078</td>
<td>1.126</td>
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<td></td>
<td>0.947</td>
<td>1.090</td>
<td>1.093</td>
<td>1.144</td>
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<tr>
<td></td>
<td>-</td>
<td>1.108</td>
<td>1.050</td>
<td>1.033</td>
</tr>
<tr>
<td></td>
<td>0.986</td>
<td>1.157</td>
<td>1.108</td>
<td>1.108</td>
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<tr>
<td>Latter et al</td>
<td>1.101</td>
<td>1.124</td>
<td>1.079</td>
<td>1.076</td>
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<tr>
<td>Poulsen et al</td>
<td>1.023</td>
<td>1.023</td>
<td>1.020</td>
<td>1.056</td>
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<tr>
<td>Hagolle, Cabot et al</td>
<td>0.935</td>
<td>1.078</td>
<td>1.069</td>
<td>1.054</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>0.987</td>
<td>1.094</td>
<td>1.071</td>
<td>1.085</td>
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<tr>
<td><strong>Standard Deviation</strong></td>
<td>0.066</td>
<td>0.042</td>
<td>0.029</td>
<td>0.041</td>
</tr>
</tbody>
</table>

- Desert BRDF
- Desert - Coincidence
- Ice - BRDF
- Ice - Coincidence
- Stratus Clouds (Poulsen et al)
- SADE Database (Cabot et al)
- Orbit Differences (Latter et al)

AATSR Calibration 1st Year Results

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AATSR Calibration 1st Year Results

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0.87µm AATSR/ATSR-2

0.67µm AATSR/ATSR-2

0.56µm AATSR/ATSR-2

Data for Desert Targets Only

AATSR Calibration 1\textsuperscript{st} Year Results

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Conclusions

• Results from a range of calibration targets show that AATSR visible channel radiances are higher than those measured by ATSR-2

• AATSR agrees well with MERIS

• Significant differences observed between AATSR/MERIS and ATSR-2

• Results consistent with other investigations

• If differences are real then possibly due to:
  – Degradation/Contamination of VISCAL optics since calibration – most likely during launch
  – Pre-launch calibration error
  – Out-of-band leakage
    • Available data suggests that this is insignificant
  – Incorrect assumptions about ATSR-2?
  – Other?
Future Activities

• Include 1.6\textmu m channel in analysis
  - Data has been processed but non-linearity effect needs to be included

• Download further METRIC files and perform additional comparisons

• Investigate possible seasonal effects

• Investigate differences between ATSR-2 and GOME

• Long Term analysis
  - Requires data for early mission phase March 2002 – End September 2002 (excluding some commissioning phase activities)
  - Requires data products delivered on a regular (monthly) basis – preferably on CD-ROM rather than FTP site
AATSR Calibration over desert sites

- Comparison of ToA reflectances under matching geometries.
- Study sites have been selected and monitored over extensive periods.
- Spectral and directional behavior assessed through ground campaign.
- Dedicated database and interface, operational context as used for VEGETATION and SPOT5-HRG sensors.
Desertic sites

- Spatial uniformity
- Temporal stability atmosphere surface
- Directional and spectral behavior faint or accessible to modelisation
- Low cloudiness
The SADE Database

280 AATSR views over 10 sites, 9 months
SADE Architecture

- Main goal is to concentrate all necessary data sets for relative and multitemporal calibration.
- Continuous monitoring and archiving helps the consistency of calibration studies and improves our knowledge of the sites.
Methods

• Data processing and selection
  – Calibration using pre-launch coefficients to allow comparison to a common reference.
  – Results are always presented as the ratio of in-flight to pre-launch calibration.
  – Cloud or high optical thickness filtering
  – Extraction of 100x100km2 areas and averaging

• Comparison
  – Need to account for
    • Directional effects
    • Atmospheric effects
    • Spectral discrepancies
Methods

• Directional effects
  – Closest geometry
    For each data point of instrument to compare, look into the reference data set to find matching geometry (same $\theta_s$, $\theta_v$, $\Delta\phi$)
  – One result per data point matched to reference.

• Atmospheric effects
  – For others: Ozone from TOMS/Earth Probe
  – Water vapor from NCEP
  – Correction for Rayleigh scattering and gaseous transmission.
Methods

- POLDER Data
  - Atmospheric correction to surface reflectances
    - Spectral model fit
  - Simulation of surface reflectances for sensor 2
  - Atmospheric simulation to TOA reflectances
- Sensor 2 Data
  - Comparison

AATSR Calibration Team Meeting, 11/07/2003
Spectral and directional variations

- Differences in spectral sensitivities can lead to systematic differences in reflectance measurements up to a few %.

- Orbit and field of view
Atmospheric variations

- Large variations can give significant errors in absorption affected bands.
- Scattering affected bands sensitive to pressure but,
- Largest unknown aerosol optical depth.
Direct comparison of reflectances

- Direct comparison show discrepancies in the 5 to 10% range.
- High scattering, despite near nadir selection.
- VEGETATION NIR band is more sensitive to water vapor.

AATSR Calibration Team Meeting, 11/07/2003
Accuracy issues

• Sensitivity study
• Based on complete simulation of satellite measurements:
  – Spectral and bidirectional model for surface reflectance
  – True geometric and atmospheric conditions
  – Randomly generated aerosol optical thickness
• End to end test of the calibration methods using:
  – Erroneous atmospheric variables (6% errors)
  – Constant optical thickness
• Overall accuracy ranging from 2% to 3.2% for various spectral bands
• Accuracy of trend estimates is better than 0.15%/month.
• No spectral noise or bias considered.
Results

Comparisons with MERIS

Few data because of simultaneity criterion

No significant variation with time except maybe for 550 nm

AATSR reflectances even higher than MERIS

AATSR/MODIS
Results

Comparison with POLDER 2

- bias between 5% to 10%
- no significant trend with time
Results - 870 nm

- Correlation coefficients are all above 80% with best for MERIS, thanks to simultaneous acquisitions.

- Rmse with respect to the linear regression are all below 3%.

<table>
<thead>
<tr>
<th>AATSR 870 nm</th>
<th>Linear fit A</th>
<th>Linear fit B</th>
<th>rmse</th>
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<tr>
<td>MERIS</td>
<td>0.912</td>
<td>0.068</td>
<td>0.011</td>
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<tr>
<td>MODIS</td>
<td>0.967</td>
<td>0.049</td>
<td>0.015</td>
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<tr>
<td>POLDER</td>
<td>0.952</td>
<td>0.102</td>
<td>0.024</td>
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<tr>
<td>POLDER2</td>
<td>1.178</td>
<td>-0.055</td>
<td>0.019</td>
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<tr>
<td>VGT2</td>
<td>0.983</td>
<td>0.059</td>
<td>0.018</td>
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<tr>
<td>ATSR2</td>
<td>0.964</td>
<td>0.070</td>
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Synthesis

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<th>AATSR</th>
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<td>A0</td>
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<td>A0</td>
<td>σ</td>
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<tr>
<td>560</td>
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</table>

• MERIS comparison shows consistency between the two sensors at the 3% level
• All other results show a consistent overestimation of reflectances by AATSR from 560 to 870 and under estimation at 1600.
• Inconsistency with ATSR2 instrument calibrated in the same way as AATSR is not normal
Perspectives

- Ingest and process additional data as they become available (which is quite rare).
- Estimate loss rate more accurately. Needs at least one complete year of data.

- MERIS calibration over the La Crau site is ongoing, making use of simultaneous surface reflectance and atmospheric condition measurements, and can be transferred to AATSR.
Outline

– Method
  • Absolute calibration of AATSR(ATSR-2) using Arctic stratus clouds
  • Inter channel calibration of AATSR and MERIS using tropical clouds.

– Results
– Conclusions