OCEANSAT-2
Ocean Colour Monitor (OCM-2)

Pre-launch calibration & Post-launch performance

presented by

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International Ocean Colour Science (IOCS-IOCCG) Meet May 6-8, 2013 Darmstadt, Germany
Oceansat-2

Launched: 23 Sept 2009
Orbit: 720 Km
Inclination: 98.28 deg
Revisit cycle: 2-days
Swath/Resolution: 1420 Km/
360 m X 236m
Time of Pass: 12 noon
Along track Steering: ± 20 deg

Instruments on Oceansat-2
• OCM-2: Ocean Colour Monitor
• OSCAT: Ku-band Scatterometer
• ROSA: ASI’s Radio Occultation Sounder for Atmosphere

(OCM-2 Optics side) (detector head side)

OCM-2 Design

(8 VNIR spectral bands)

• 8-element telecentric lens assembly per band
• f-length: 20 mm ; f/no. = 4.3
• FOV: ± 43 deg
• 2-element bandpass filter + 1 thermal filter
• 3730 of 6k element linear array CCD device
• 12 – bit quantisation
• Exposure (gains) : 16 levels
• Band-to-band registration : ± 0.25 pixel
• MTF > 0.26
• 4 LED’s as onboard cal source per band
OCM-2 Data Products

LEVEL-1 Product: Basic Data Products
- L1A RAW Products
- L1B Radiance Product
- L1C Radiometrically and Geometrically corrected

LEVEL-2 Product: Geo-Physical Parameters
- Chlorophyll-a concentration
- Total Suspended Matter (TSM)
- Diffused Attenuation Coefficients ($K_d$ at 490 nm)
- Aerosol Optical Depth (AOD) at 865 nm

LEVEL-3 Product: Binned Products (4 km)
- Weekly
- Monthly
- Yearly

Scene Layout

1420 km s⁻¹
6020 lines

Path n
Row m
1420 km (3730 pixels)
Row m
Path n+1

Overlap 73 km
Sidelap 38 km

GAC Coverage
1 Km/ 4 Km Spatial resolution
Onboard recording and Playback

LAC Coverage
360 m Spatial Resolution
Real time transmission

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Sensor Characterisation

- Pre-launch Spatial & Radiometric
- Onboard calibration using LEDs
- Vicarious calibration using Ocean Buoy
- Lunar Calibration
- Spatial & Radiometric Image based characterization

System Performance

A) Geometric/ Spatial Parameters
   - MTF / SWR
   - Band-to-Band Registration
   - Payload cube alignment
   - IGFOV as a fn of look angle

A) Radiometric Parameters
   - Relative Spectral Response
   - Saturation Radiance
   - Signal-to-Noise Ratio
   - Temperature Response at 5 deg to 25 deg C
Uncertainty in radiometric calibration:

- Veiling Glare of Lens Assembly: < 1.6 %
- Polarization of lens assembly: < 2.3 %
- Absolute calibration of standard source: < 2.4 % @ 655 nm
- Transfer radiometer uncertainty: < 2.0 %
- Non uniformity of integrating sphere: < 4.0 %

Overall Absolute Radiometric Uncertainty (1σ) < 6 %

MTF Performance @ nadir (360m X 360 m)

- Lens MTF: 0.55
- Device MTF:
  - Along Track: 0.75
  - Across track: 0.57
- Due to alignment & Envir.: 0.84
- System MTF:
  - Along Track: 0.34
  - Across Track: 0.26

Mis-registration (Band-to-Band) in pixel

- BBR @ Ambient: ± 0.16
- Format matching (+test set up): ± 0.15
- Distortion: ± 0.05
- BBR Stability (environment) rss: ± 0.16
- Collinearity: ± 0.10
- Format Change: ± 0.10
- Structural stability: ± 0.05
- Distortion change due to environment: ± 0.05

Overall mis-registration (band-to-band): ± 0.23
## OCM-2 System Noise performance

### OCM-2 Noise Equivalent Spectral Radiance ($mW/cm^2/sr/\mu$)

<table>
<thead>
<tr>
<th>Band</th>
<th>Ocean Ref Rad.</th>
<th>NEΔL&lt;sub&gt;noise&lt;/sub&gt;</th>
<th>SNR (noise)</th>
<th>NEΔL&lt;sub&gt;norm&lt;/sub&gt;</th>
<th>NEΔL&lt;sub&gt;quant&lt;/sub&gt;</th>
<th>NEΔL&lt;sub&gt;prod&lt;/sub&gt;</th>
<th>SNR (prod)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>9.1</td>
<td>0.033</td>
<td>274</td>
<td>0.013</td>
<td>0.005</td>
<td>0.036</td>
<td>254</td>
</tr>
<tr>
<td>C2</td>
<td>8.4</td>
<td>0.025</td>
<td>334</td>
<td>0.027</td>
<td>0.003</td>
<td>0.037</td>
<td>228</td>
</tr>
<tr>
<td>C3</td>
<td>6.6</td>
<td>0.017</td>
<td>397</td>
<td>0.015</td>
<td>0.002</td>
<td>0.023</td>
<td>290</td>
</tr>
<tr>
<td>C4</td>
<td>5.6</td>
<td>0.015</td>
<td>379</td>
<td>0.016</td>
<td>0.002</td>
<td>0.022</td>
<td>254</td>
</tr>
<tr>
<td>C5</td>
<td>4.6</td>
<td>0.013</td>
<td>357</td>
<td>0.014</td>
<td>0.001</td>
<td>0.019</td>
<td>239</td>
</tr>
<tr>
<td>C6</td>
<td>2.5</td>
<td>0.007</td>
<td>357</td>
<td>0.006</td>
<td>0.001</td>
<td>0.009</td>
<td>270</td>
</tr>
<tr>
<td>C7</td>
<td>1.6</td>
<td>0.005</td>
<td>345</td>
<td>0.005</td>
<td>0.001</td>
<td>0.007</td>
<td>224</td>
</tr>
<tr>
<td>C8</td>
<td>1.1</td>
<td>0.004</td>
<td>256</td>
<td>0.007</td>
<td>0.001</td>
<td>0.008</td>
<td>135</td>
</tr>
</tbody>
</table>

### Graph

**OCM2 Photon Noise Performance B5**

- Equation: $y = 0.4855x - 2.497$
- $R^2 = 0.9998$

- Log Photon Signal vs. Log Photon Noise
- Data points show a linear relationship with high correlation.
Transfer of radiance scale (Vis-NIR-SWIR)

(from Reference source to the sensor under test)

Reference source
Calibration traceable to NIST scale

Check relative spectral profile

calibrate

Filter radiometer with flat response and different spectral filters

Transfer scale to

Integrating Sphere
(850mm dia port)

Transfer scale to

Payload under test

International Ocean Colour Science (IOCS-IOCCG) Meet May 6-8, 2013 Darmstadt, Germany
Laboratory Radiometer & NMI Traceable Reference Sources

The calibration factor of the radiometer is given by:

\[
\text{Cal. Factor} = \left( \frac{\text{Band avg sp. rad}_{\text{Reference}}}{\text{Radiometer output}} \right), \text{ mW/cm}^2\text{-sr} \mu \text{per mA}
\]

VNIR Radiometer Head – UDT Inc. make

12” Integrating Sphere
Labsphere Inc. USA

6” Integrating Sphere
Calibrated at FASCAL Facility NIST

FEL lamp + diffuser
(EG&G Gamma Scientific, USA)

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Post-launch Performance

In-flight Calibration:

- Monitors system degradation; optics not covered
- Four LEDs in each band mounted at 71 deg to detector array plane
- Generates 16 intensity levels through exposure control mechanism of CCD
- 128 lines used to compute statistical parameter of individual pixel on the detector
- Criteria applied for detector flagging is based in Chi-squared fit statistics

<table>
<thead>
<tr>
<th>Band No</th>
<th>% Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>-0.3</td>
</tr>
<tr>
<td>B2</td>
<td>-0.7</td>
</tr>
<tr>
<td>B3</td>
<td>-0.2</td>
</tr>
<tr>
<td>B4</td>
<td>-0.6</td>
</tr>
<tr>
<td>B5</td>
<td>-0.6</td>
</tr>
<tr>
<td>B6</td>
<td>2.3</td>
</tr>
<tr>
<td>B7</td>
<td>0.4</td>
</tr>
<tr>
<td>B8</td>
<td>-2.3</td>
</tr>
</tbody>
</table>
OCM-2 detector Temp varying through diff orbit

- Shows diurnal variation in CCD temperature
- Last data on 17-April-2013
**Geometric & Radiometric Performance:** (monitored on regular basis)

- **Geometric parameters (specs)**
  - a) Location accuracy ($< \pm 3.8$ km)
  - b) Scale variation ($< 0.05\%$)
  - c) Internal Distortion ($< \pm 3$ pixel)
  - d) Residual attitude bias
  - e) Band-to-band Registration (BBR)
    - i) Rad product (± 0.5 pixel)
    - ii) Geometric product (+ 0.25 pixel)

- **Radiometric parameters**
  - a) Scene Dynamic Range
  - b) Signal-to-Noise Ratio
  - c) Relative band behaviour
  - d) Inter-sensor comparison
    - i) OCM-2 with OCM-1
    - ii) OCM-2 with Aqua MODIS

**Results**

- Location accuracy for L1C product: Within 2-3 pixels
- Internal Distortion: Within 1.5 pixel
- Side lap (gives info on orbit drift): 9% to 17.3% (for 90% of products) (2009-2011)

- Algorithms for band-to-band registration (a) Sequential Similarity Detection (b) Mean bias correlation
- BBR quantifies per pixel classification based on along and across track computation
- Features like desert, barren land, lake water used to check linearity, dynamic range, SNR
- Along the pixel array direction BBR is within specs L1C ±0.5 pixel; along track it is about 0.8 pixel

**Platform is stable and Products are found to meet specs**

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Comparison of instrument scaled irradiance for three dates covering a period of 2010-2012

Y-error bar shows 5% limits

- 26-Jul-10
- 11-Nov-11
- 01-Aug-12
- Average

OCM2 Central Wavelength (nm)
### Vicarious calibration results of OCM2

#### Gain coefficients measured at Kavaratty site

![Graph showing TOA radiance with 95% confidence](image)

<table>
<thead>
<tr>
<th>Band No.</th>
<th>Total points</th>
<th>CC (R²)</th>
<th>Mean TOA radiance (µW/cm²/sr/nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>KVT</td>
</tr>
<tr>
<td>1</td>
<td>20</td>
<td>0.978</td>
<td>8.865</td>
</tr>
<tr>
<td>2</td>
<td>19</td>
<td>0.977</td>
<td>7.530</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
<td>0.976</td>
<td>5.684</td>
</tr>
<tr>
<td>4</td>
<td>21</td>
<td>0.936</td>
<td>4.402</td>
</tr>
<tr>
<td>5</td>
<td>19</td>
<td>0.876</td>
<td>3.094</td>
</tr>
<tr>
<td>6</td>
<td>20</td>
<td>0.873</td>
<td>1.873</td>
</tr>
<tr>
<td>7</td>
<td>21</td>
<td>0.929</td>
<td>0.817</td>
</tr>
<tr>
<td>8</td>
<td>15</td>
<td>0.910</td>
<td>0.392</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Band</th>
<th>Year 2009-10 Gain ± SD</th>
<th>Year 2011 Gain ± SD</th>
<th>Year 2012 Gain ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.93 ± 0.04</td>
<td>0.97 ± 0.03</td>
<td>0.95 ± 0.03</td>
</tr>
<tr>
<td>2</td>
<td>1.03 ± 0.04</td>
<td>1.06 ± 0.04</td>
<td>1.06 ± 0.02</td>
</tr>
<tr>
<td>3</td>
<td>0.96 ± 0.04</td>
<td>0.97 ± 0.04</td>
<td>0.92 ± 0.04</td>
</tr>
<tr>
<td>4</td>
<td>1.00 ± 0.07</td>
<td>0.97 ± 0.05</td>
<td>0.97 ± 0.04</td>
</tr>
<tr>
<td>5</td>
<td>1.00 ± 0.09</td>
<td>0.93 ± 0.07</td>
<td>0.91 ± 0.05</td>
</tr>
<tr>
<td>6</td>
<td>0.95 ± 0.08</td>
<td>0.86 ± 0.07</td>
<td>0.87 ± 0.06</td>
</tr>
<tr>
<td>7</td>
<td>0.88 ± 0.07</td>
<td>0.88 ± 0.06</td>
<td>0.92 ± 0.07</td>
</tr>
<tr>
<td>8</td>
<td>0.88 ± 0.05</td>
<td>0.71 ± 0.05</td>
<td>0.81 ± 0.02</td>
</tr>
</tbody>
</table>
Data dissemination and web portal

Calibration & Validation Program

ISRO has taken multi pronged initiatives for understanding key issues concerning global changes. This activity requires validation for all the products generated thereby.

A high-tech site is developed at Kavaratti with sensors installed in the ocean for measuring various parameters. Similarly, Principal Investigators and Collaborating Agencies also collect data at field level. Other sites and sub sites are being developed at Kolkata, Gadanki and so on for collecting in-situ data and supporting CALVAL activity for all ISRO Science Missions.

This web site facilitates the archival, visualisation and dissemination of the in-situ data for scientific interpretation and analysis of data from these and future missions.

- OCEANSAT-2
- INSAT-3D
- MEGHA TROPIQUES
- SARAL/ALTAKA

OCEANSAT-II is India's second satellite launched for the study of the oceans as well as the interaction of oceans and the atmosphere to facilitate climatic studies. It carries two major payloads viz. Scatterometer (Ku band) and ROSA (GPS receiver).

View More..
Lessons Learnt

• Interoperability of Ocean Colour sensors is a necessity
• Validation of pre- and post-launch calibration
• Contingency plan to guard against test instrument failure
• Follow set processes and guidelines in laboratory practices
• Detector based traceability chain to be implemented
• Image evaluation as part of pre-launch calibration prior to launch
• Specify ‘quality’ indicators
Contributions from

National Remote Sensing Centre - Hyderabad

• A Senthilkumar   Time Series data with onboard LEDs
• B Santhisree

Space Applications Centre - Ahmedabad

• B Kartikeyan   In-orbit Spatial & Radiometric charact. & Lunar Cal (used ROLO model)
• Yogdeep Desai
• Bankim Shah

• A K Shukla   CalVal (Ocean buoy – Kavaratty Islands)
• K N Babu

• Nitant Dubey   Data Products software & Lunar observation

• Prakash Chauhan   Estimate of ocean parameters & Intercomparison OCM-2 with Aqua MODIS

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