Compact High Resolution Imaging Spectrometer (CHRIS): the future of hyperspectral satellite sensors

Imagery of Oostende coastal and inland waters

Barbara Van Mol
Kevin Ruddick
OVERVIEW

- Introduction
- CHRIS/PROBA
- Traditional Ocean Colour satellite sensor vs. airborne imaging spectroscopy
- CHRIS potential
- CHRIS images from test site Oostende
  - Image processing
  - Sea
    - Comparison with other data sources
    - SPM & CHL
  - Inland: Spuikom
- Conclusion
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INTRODUCTION

- BELCOLOUR: creation of Suspended Particulate Matter (SPM) and chlorophyll maps
  - Airborne imagery: VITO
  - Satellite imagery: MUMM
    - SeaWiFS: Sea-viewing Wide Field of view Sensor
    - MERIS: MEedium Resolution Imaging Spectrometer Instrument
    - MODIS: Moderate Resolution Imaging Spectroradiometer
    - CHRIS: Compact High Resolution Imaging Spectrometer

- Why here?
  - Satellite sensor (CHRIS) has similar characteristics with airborne imaging spectroscopy
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CHRIS

- Compact → < 15 kg
- High Resolution → 18 m
- Imaging Spectroscopy → “class of instruments which preserve the image field while also determining the spectrum”

62 spectral bands
410nm-1050nm
1.3nm at 410nm
12nm at 1050nm

- developed by Sira Electro-Optics Ltd.
PROBA

- Project for on board autonomy
- Advanced small satellite
- Pointable
- High level of autonomy
- Created by Verhaert
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<table>
<thead>
<tr>
<th>Evaluation Area</th>
<th>Satellite based IS</th>
<th>CHRIS/PROBA</th>
<th>Airborne IS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homogeneous data quality over a long time-frame</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Level of support</td>
<td>+</td>
<td>+/-</td>
<td>-</td>
</tr>
<tr>
<td>Entire earth is viewed with regular repetition</td>
<td>+</td>
<td>+/-</td>
<td>-</td>
</tr>
<tr>
<td>Pointable</td>
<td>+/-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Geographical flexibility</td>
<td>-</td>
<td>+/-</td>
<td>+</td>
</tr>
<tr>
<td>Spectral resolution</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Programmable spectral bands and pixel sizes</td>
<td>-</td>
<td>+/-</td>
<td>+</td>
</tr>
</tbody>
</table>
Traditional Ocean Colour satellite sensor vs. airborne imaging spectroscopy (2)

- Unprocessed CASI image Oostende (16 June 2003) (R=643nm, G=551nm, B=461nm)
- Unprocessed CHRIS image (21 September 2003) (R=691nm, G=561nm, B=442nm)
- Unprocessed SeaWiFS image (5 August 2003) (670nm)
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CHRIS potential

- Small low-cost
- > spectral resolution than current ocean colour sensors
- Pointability Atmospheric effects
  - → same area, different angles
    - Air-sea interface effects
    - Special event
- Mapping small features
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CHRIS images from test site Oostende

- 13 image sets, 4 cloud free
- 9 with sea borne measurements...BUT only 2 cloud free image sets with sea borne measurements
- Mode 1: 62 spectral bands (411-997nm), 36 m² resolution
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Image processing (1)

- Some problems: destriping, atmospheric correction and georeferencing
- Destriping
  - Correction factor based on a 5 column moving average
- Atmospheric correction
  - Darkest pixel approach

- Georeferencing
  - GCP’s on land
  - Problem: uncertainty is amplified considerably far from land
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Comparison with other data sources of 2 points at sea Images of 5 August 2003(1)

- TriOS, MERIS, SeaWiFS
Comparison with other data sources of 2 points at sea
Images of 5 August 2003 (2)

- All sensors show higher reflectance at station 130
- Differences in values: → Time
  → Darkest pixel assumption
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SPM maps (1)

<table>
<thead>
<tr>
<th>Station</th>
<th>SPM (mg/l) FBZ = -36°</th>
<th>SPM (mg/l) FBZ = 0°</th>
<th>Measured SPM (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>130</td>
<td>11.41</td>
<td>11.35</td>
<td>8.20</td>
</tr>
<tr>
<td>230</td>
<td>7.98</td>
<td>7.16</td>
<td>7.27</td>
</tr>
</tbody>
</table>
SPM maps (2)

MERIS (5 August 2003, 10:25)

SeaWiFS (5 August 2003, 13:02)
chlorophyll maps

<table>
<thead>
<tr>
<th>Station</th>
<th>Satellite value (mg/m³)</th>
<th>Measured value (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>130</td>
<td>39.27</td>
<td>11.37</td>
</tr>
<tr>
<td>230</td>
<td>32.25</td>
<td>11.49</td>
</tr>
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Inland waters: adjacency effects?
Images of 6 July 2004

- Only image with FBZ = 0°
Inland waters: adjacency effects?
Images of the Spuikom on 6 July 2004

Reflectance image D: FBZ=0°
Inland waters: adjacency effects?
Some spectra

Spectral Profiles 06/07/2004

0 0.005 0.01 0.015 0.02 0.025 0.03 0.035 0.04 0.045 0.05
400 500 600 700 800 900
reflectance

Spectral 06/07/2004

1 (450,519)
2 (450,524)
3 (450,534)
4 (428,536)
5 (380,460)

Clear and near land

offshore

Clear/turbid

turbid

Airborne Imaging Spectroscopy Workshop
Brugge, 8 October 2004
http://www.mumm.ac.be/BELCOLOUR
Inland waters: adjacency effects?
North-South transect Spuikom

- NIR North shore (vegetation) > NIR South shore (urban)
- North: NIR reflectance > red reflectance
Inland waters: adjacency effects?

- Bottom reflection?
  - Northern and Eastern parts: bottom visible
  - BUT bottom reflectance become rapidly absorbed for red and NIR wavelengths
  - e.g. clear water, 1m → surface signal of bottom reflectance attenuated to factor 0.45 and 0.015 or smaller at 709nm and 850nm respectively

- Adjacency (environmental straylight)?
  - Rapid decrease by going away from the North shore is consistent with atm. forward scattering
  - Higher reflectance at 777nm is consistent with a similar difference for the nearby vegetation
  - Turbid water in the South tends to hide the adjacency effect
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Conclusions

- Some problems in image quality
- Simple dark pixel atmospheric correction gives reasonable results
good enough for suspended particulate matter
BUT better atmospheric correction by radiative transfer modeling
- CHL detection ???
- CHRIS data for inland water body are contaminated in the NIR, especially for clear water pixels → adjacency effect
Bottom reflection ?
- Great potential
  - Hyperspectral → more info for CHL detection
  - Spatial resolution → smaller features visible
- CHRIS/PROBA provides proof of the concept and advance warning of expected problems in future systems
Acknowledgement

- Tuimelaar crew
- BMM Chemistry lab
- Vera De Cauwer
- ESA & SIRA
- Peter Fletcher
- You......
....FOR YOUR ATTENTION