RESORT – remote sensing for seasonal and overseas retrieval of TSM
Els Knaeps, Sindy Sterckx, Mark Bollen, Koen trouw
Overview

» Scheldt - Seasonal robustness
  » Available datasets
  » Pre-processing
  » Regression analysis and sensitivity analysis
  » results
» Doha – feasibility study
Why a seasonally robust SPM algorithm for the Scheldt?

» The calibration of empirical algorithms requires a large amount of in-situ sampled data.

» Scheldt river = dynamic environment
  » Water samples only representative taken within a close time span of the overpass of the satellite or airplane.
  » restriction to the acquisition of a sufficient number of training samples
  » need for multiple vessels, equipment and personnel making
  » very expensive and operationally complex.

» A seasonally robust SPM algorithm would therefore be of great interest to the users community since extensive field campaigns are no longer required and one could save upon cost and time.
Datasets available

- Airborne AHS data and field campaign 2005
- Airborne AHS data and field campaign 2007
- Monthly measurements 2007
  - SIOPS
  - SPM concentration
  - CHL concentration
  - Water-leaving reflectance

-> Large dataset gathered under different circumstances
-> Large variety in the dataset
Airborne data and field campaign 2005

- 15 June 2005
- 15 flight lines in +/- 2.5 h
- Spatial resolution: +/- 4m
- 2 vessels!
Airborne and field campaign 2007

- 6 October 2007
- 8 flight lines
- Spatial resolution: +/- 7 m
- 1 vessel

Water level on 6 October in Antwerp

![Graph showing water level in Antwerp on 6 October 2007 with image acquisitions and highest water level marked.](image-url)
Objectives:

» to have an idea of the full range of seasonal variability in optical properties and water quality

What is measured?

» TSM and Chl concentration
» Optical properties (absorption and scattering)
» Water-leaving reflectance
Pre-processing

- Atmospheric and geometric corrections of airborne imagery in CDPC
  - Includes air-water interface correction
  - Visibility and water vapor estimated from the image, aerosol type from sunphotometer readings
- Additional correction of in-situ water-leaving reflectance spectra based on residual corrections using NIR wavelengths (Ruddick et al., 2005)
Regression analysis

R(0-) spectra and corresponding SPM concentrations from
- in situ measurements using ASD spectrometer during airborne campaigns
- in situ measurements using ASD spectrometer – monthly measurements

Tested:
- Single bands
- Difference of two bands
- Sum of two bands
- First derivative
- Ratio of two bands
- Linear and exponential relationships
## Regression analysis - Results

### How to decide which algorithm is most robust through the seasons?

<table>
<thead>
<tr>
<th>Relationship type</th>
<th>Spectral bands</th>
<th>R²</th>
<th>RMSE (mg/l)</th>
<th>RMSE (%)</th>
<th>band nr.</th>
<th>central wavelength</th>
<th>FWHM</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{Ln}(SPM) = a \frac{R_0^-(\lambda_1)}{R_0^-(\lambda_2)} + b )</td>
<td>6/10</td>
<td>0.78</td>
<td>15.72</td>
<td>25.33</td>
<td>1</td>
<td>0.456</td>
<td>0.030</td>
</tr>
<tr>
<td></td>
<td>11/12</td>
<td>0.75</td>
<td>18.27</td>
<td>23.96</td>
<td>2</td>
<td>0.482</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td>10/4</td>
<td>0.85</td>
<td>12.3</td>
<td>21.21</td>
<td>3</td>
<td>0.510</td>
<td>0.033</td>
</tr>
<tr>
<td></td>
<td>6/8</td>
<td>0.81</td>
<td>14.89</td>
<td>23.15</td>
<td>4</td>
<td>0.539</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td>6/9</td>
<td>0.85</td>
<td>11.54</td>
<td>20.63</td>
<td>5</td>
<td>0.568</td>
<td>0.031</td>
</tr>
<tr>
<td></td>
<td>12/11</td>
<td>0.74</td>
<td>18.53</td>
<td>24.42</td>
<td>6</td>
<td>0.596</td>
<td>0.032</td>
</tr>
<tr>
<td>( \text{Ln}(SPM) = a \frac{(R_0^-(\lambda_1) - R_0^-(\lambda_2))}{b} + b )</td>
<td>12-20</td>
<td>0.77</td>
<td>18.68</td>
<td>26.09</td>
<td>7</td>
<td>0.624</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td>13-20</td>
<td>0.77</td>
<td>20.26</td>
<td>30.59</td>
<td>8</td>
<td>0.653</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td>14-20</td>
<td>0.78</td>
<td>18.84</td>
<td>25.84</td>
<td>9</td>
<td>0.681</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td>15-20</td>
<td>0.79</td>
<td>20.74</td>
<td>30.49</td>
<td>10</td>
<td>0.710</td>
<td>0.033</td>
</tr>
<tr>
<td></td>
<td>12-19</td>
<td>0.77</td>
<td>18.72</td>
<td>26.03</td>
<td>11</td>
<td>0.738</td>
<td>0.031</td>
</tr>
<tr>
<td></td>
<td>12-18</td>
<td>0.77</td>
<td>18</td>
<td>25.50</td>
<td>12</td>
<td>0.767</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td>16-18</td>
<td>0.80</td>
<td>16.53</td>
<td>24.24</td>
<td>13</td>
<td>0.795</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td>17-19</td>
<td>0.77</td>
<td>17.98</td>
<td>26.06</td>
<td>14</td>
<td>0.825</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td>15-17</td>
<td>0.79</td>
<td>18.66</td>
<td>25.03</td>
<td>15</td>
<td>0.855</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td>14-17</td>
<td>0.77</td>
<td>20.34</td>
<td>26.26</td>
<td>16</td>
<td>0.884</td>
<td>0.032</td>
</tr>
</tbody>
</table>

How to decide which algorithm is most robust through the seasons?
Sensitivity analysis using an analytical model

» Generate synthetic spectra for different SIOPS and SPM/CHL concentrations using an analytical model. Use as input SIOPS from Scheldt.

» Apply empirical algorithm.

INPUT
- Monthly SIOPS
- 5 different CHL concentrations
- 12 different SPM concentrations

Estimated SPM concentration

Empirical model

RANGE

Initial SPM concentration

Compare initial and estimated SPM concentration

Estimated SPM concentration
Results of sensitivity analysis

<table>
<thead>
<tr>
<th>Relationship type</th>
<th>Spectral bands</th>
<th>$R^2$ average range (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>b</td>
<td>Ra SPMLn</td>
<td>+−(0)(0* )21λλ</td>
</tr>
<tr>
<td>0.78</td>
<td>0.85</td>
<td>0.81 0.74</td>
</tr>
<tr>
<td>22.52</td>
<td>47.45</td>
<td>114.86 28.67</td>
</tr>
<tr>
<td>Lillo - March</td>
<td>13-20</td>
<td>12-19 16-18</td>
</tr>
<tr>
<td>B12/B11</td>
<td>0 B6/B10</td>
<td>0 2 04 06 08 0 1 0 1 4 0 1 6 0</td>
</tr>
<tr>
<td>Anna - End of December</td>
<td>Anna - End of December</td>
<td>Anna - July</td>
</tr>
<tr>
<td>Anna - July</td>
<td>Anna - June</td>
<td>Anna - June</td>
</tr>
<tr>
<td>Anna - May</td>
<td>Anna - May</td>
<td>Anna - October</td>
</tr>
<tr>
<td>Anna - October</td>
<td>Lillo - Beginning of December</td>
<td>Lillo - Beginning of December</td>
</tr>
<tr>
<td>Lillo - End of December</td>
<td>Lillo - End of December</td>
<td>Lillo - July</td>
</tr>
<tr>
<td>Lillo - July</td>
<td>Lillo - June</td>
<td>Lillo - June</td>
</tr>
<tr>
<td>Lillo - March</td>
<td>Lillo - March</td>
<td>Lillo - March</td>
</tr>
<tr>
<td>Series21</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Initial SPM concentration

Estimated SPM concentration

Anna - End of December
Anna - July
Anna - June
Anna - May
Anna - October
Lillo - Beginning of December
Lillo - End of December
Lillo - July
Lillo - June
Lillo - March
Validation of algorithm with airborne data
Feasibility study: Doha

Problem:
High concentrations of suspended matter -> dredging operations are stopped -> enormous costs involved
-> Can we locate the SPM plume and quantify the SPM concentration?

Available:
Database of historic field measurements from Dredging International
-> Search databases of available satellites with appropriate spatial and spectral resolution
-> 5 coincident SPOT scenes (2005-2006)
Doha – raw imagery
Doha – available in –situ data

ORB=5 fixed monitoring positions(2,4,7,9,11)
WBM=water box monitoring (N, E, S1, S2)
PWR=power station
Plumetracking (metingen achter baggerschepen)
Best relationship after regression analysis

Low concentrations observed -> NIR band contains no information on SPM concentration

B2 has good overall relationship

Overall relationship

\[ y = 2.3575x - 5.5874 \]

\[ R^2 = 0.9093 \]
Doha1 – 12/07/2005 – enhanced imagery
Doha1 – 12/07/2005 – SPM concentration map
Doha 4 – 09/03/2006 – SPM concentration map
Conclusions

» We have found a seasonally robust algorithm for the Scheldt, the algorithm uses a band ratio of two NIR bands. Exponential relationships provided the best results

» The type of algorithm depends on the user requirements: Accurate vs. temporally robust

» Doha: SPM concentrations maps with only a limited number of water samples!

» To be useful: Users need Quality indication -> implement error propagation in processing chain and provide user with quality layers.