MAVT meeting 20-24 March 2006

MERIS Case 1 Validation ->

Performance of the NN case 2 water algorithm for case 1 water

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Case 2 Water Algorithm

COASTLOOC  COLORS  MAPP

Bio-optical measurements
\( a(\lambda), b(\lambda), \text{Pig}, \text{TSM}, C, Y \)
Lu/Ed(\(\lambda, z\)), RLw

Bio-optical Model
Incl. variability

Set up radiance transfer model
Monte Carlo, Hydrolight

Simulation of RLw(\(\lambda, \theta_v, \theta_s, \phi_{vs}\), > 20 000 Spectra

Training and Test of aNN

faNN, baNN
MERIS Processor

3 angles  8 RLw

aNN

TSM  Pig  Gelb  Conf. Flag

MERIS Product
Comparison between algal_1 and algal_2 algorithm

• algal_1 algorithm based on reflectance ratios using 4 bands: 442, 490, 510, 560 nm

• Algal_1 takes absorption and scattering of phytoplankton into account

• Based on a large worldwide data base of mainly case 1 water attenuation and reflectance measurements

• Algal_2 neural network uses bands 1-7, 9 range 412-708 nm

• Trained to determine IOPs (absorption of pigments, yellow substance + bleached particles, scattering of all particles)

• NN is trained with simulated bi-directional water leaving radiance reflectances

• Bio-optical model for reflectance simulations is mainly based on North Sea measurements
The water leaving reflectances are fully normalised for the 4 following wavelengths: 442, 490, 510, 590 (bands 2-5):

\[ bb_{over\_a}(\lambda) = \frac{\rho'_w(\lambda, j, f)}{f_{over\_q1\_value}(\lambda)} \]

3 ratios are derived:

\[ r1 = \frac{bb_{over\_a}(442)}{bb_{over\_a}(560)} \]
\[ r2 = \frac{bb_{over\_a}(490)}{bb_{over\_a}(560)} \]
\[ r3 = \frac{bb_{over\_a}(510)}{bb_{over\_a}(560)} \]

and the max taken:

\[ r_{\text{max}} = \text{MAX}(r1, r2, r3) \]

and finally:

\[ LChl1 = \sum_{p=0}^{N_{\text{Chl1}}} \log_{10} \text{coeff\_LUT}(p, b442) \left[ \log_{10} \left( r_{\text{max}} \right) \right]^p \]

with Coeffs=\{0.4245, -3.4479, 5.2272, -5.857, 2.2136\} and \( N_{\text{Chl1}} = 4 \)

Chl1=10^{LChl1}

If Chl1 < min_chl1 then Chl1= min_chl1 // do not raise PCD! //
If Chl1 > max_chl1 then Chl1= max_chl1 // do not raise PCD! //
The MERIS case II water NN algorithm

- $r, r'$ – log of reflectances
- $c$ – log of concentrations
- $g$ – geometry information
- $q$ – quality indicator

If $RL_w < 0.0009$, $RL_w = 0.0009$ ($\rho \approx 0.003$)

Flag PCD1_16,17 $q$ true if sum $(r(i) / r'(i)) > 4.0$

C:
- $\log(b_{tot})$
- $\log(a_{ys}+a_{btsm})$
- $\log(a_{pig})$

All at 443 nm
Scheme of a bio-optical model: optical components for MERIS

Water sample

- In situ AC-9 BB-4
- Particle total absorption
- Absorption of bleached fraction = SPM absorption
- Gelbstoff absorption spectrum
- Spectral exponent
- Absorption of bleached fraction + gelbstoff = total gelbstoff

Particle scattering backscattering
- Absorption of Total - bleached fraction = phytoplankton absorption
- Total - bleached fraction = phytoplankton absorption

Optical properties at 442 nm

- TSM
- Algal_2
- a_ys
Changes in MEGS 7.4 compared to IPF 4.10

- Training of NN based on larger data set (GKSS MAVT cruises, data of Kai Sorensen, Marcel Babin, Herbert Siegel)
- Conversion for algal_2 now: $algal_2 = 21 \times a_{pig_{442}}^{1.04}$
- Algal_2, tsm, ys flag threshold set to 4.0
- Cut-off reflectance $\rho = 0.003$
- NN net based on log reflectances
- $a_{ys}$ on log scale in product

**Why cut-off?**
- To avoid that neg. or uncertainly low reflectances (log!) go into the NN
- NN is trained with the cut-off
- Problem when this happens for band1 and band2: chlorophyll and ys is unreliable
- These conditions are presently not flagged!!
Bio-optical model

- Based on: MAVT North Sea / German Bight (GKSS), Norwegian waters (NIVA, Uni Oslo, NERSC), Baltic Sea (IOW), recommendations by M. Babin

- Gelbstoff absorption exponent: 0.014 \pm 0.002
- Bleached particle absorption exponent: 0.008 \pm 0.005
- Particle scattering exponent: 0.4 \pm 0.2
- White particles scattering exponent: 0.0
- Phytoplankton pigment absorption: > 221 spectra from different areas and seasons

- Gelbstoff absorption $a_{ys}(443)$: 0.005 – 5.0 m⁻¹
- Particle scattering $b_p(443)$: 0.005 – 30.0 m⁻¹
- White particle scattering: 0.005 – 30.0 m⁻¹
- Phytoplankton pigment absor. $a_{pig}(443)$: 0.001 – 2.0 m⁻¹
- Minimum particle scattering $b_p(443)$: 0.25*$a_{pig}(443)$
- Bleached particle absorption $a_{bp}(443)$: 0.1*$b_p(443)$+ran_gauss*0.03*$b_p(443)$
Pigment absorption spectra H187, Norway different locations
Pigment absorption – Chl. a, H187

Conversions:
Chl. a [mg m\(^{-3}\)] = 21 \* a\_pig\_442 \(^{1.04}\)
Validation of scaling factor for Chl2.hplc versus Chl2-apig(442)

Chl2.hplc = 26.212 x apig(442)^0.77135

Chl2.hplc = 21.848 x apig(442)^1.044
Conversions:
TSM \([\text{g m}^{-3}]\) = 1.72 * \(b_{\text{tsm} 442}\)
Relationship between yellow substance (ays 442) and bleached particle absorption (bpa 442)
Relationship between TSM scattering ($b\ 440$) and bleached particle absorption ($abp\ 440$)

$y = 0.1245x + 0.0013$

$R^2 = 0.9546$
MEGS 7.2 algal_1 / algal_2=21*a_pig^1.04

Red dots indicate pixels localized in the map (next pages), these dots have been selected by hand, because they form a second cloud in the scatter plot. As seen in the map they belong mainly to case 2 water.

The regression line was also determined by hand only for the upper data cloud (case 1 water)

Algal_2=21*a_pig^1.04
World map of MERIS data of MEGS 7.2 processing, red dots indicate data which form a second cloud in the scatter plot.
Comparison Case 1 / Case 2 Water Algorithm for Pigment

Adriatic Sea,
May 3, 2002

Algal_1

Algal_2
Transect chlorophyll

The graph shows the distribution of chlorophyll a (µg/l) across a transect. The x-axis represents the pixel coordinate, ranging from 240 to 310, while the y-axis represents the chlorophyll a concentration, ranging from 0 to 5 µg/l. Two different algal samples, labeled as algal_1 and algal_2, are plotted on the graph. The algal_1 data points are shown in black, and the algal_2 data points are shown in pink.
West Canda_ferry 20020814 algal_1 with non-confidential algal_1 flag
Rio de la Plata Algal_1 20030924
Algal Transect 1

Algal transect plata 1

Concentration mg m$^{-3}$

Longitude deg

MAPT, ESRIN 20.-24. March 2006
algal_2 vs algal_1 Plata transect

MAVT, ESRIN 20.-24. March 2006
Amazone 20030914 Spectra
Algal_2, TSM. YS a442 Amazone transect 1

case2 conc transect 1

MÄVT, ESRIN 20.-24. March 2006
Hawai 20030705

Algal_1

Algal_2

MAVT, ESRIN 20.-24. March 2006
Hawai 20030705, unflagged area

- **Algal_1**: 0.014 - 0.13, mean: 0.06 ± 0.011
- **Algal_2**: 0.049 – 0.47, mean: 0.08 ± 0.013
- **Yellow s**: 0.0044 – 0.021, mean: 0.0055 ± 0.00061
- **TSM**: 0.061 – 0.67, mean: 0.27±0.054
MERS Case 2 algorithm test against IOCCG simulated data set

Total absorption at 442 nm

Total scattering at 442 nm
How to compute total scattering and absorption from case 2 products

- **Algal_2**
  - Conversion from \( a_{\text{pig\_443}} \) (NN output) to chlorophyll concentration
  - \( \text{algal\_2} = 21 \times a_{\text{pig\_443}}^{1.04} \)
  - Inverse to compute absorption again:
    - \( a_{\text{pig\_443}} = \exp(\log(\text{algal\_2}/21)/1.04) \)

- **TSM**
  - Total_susp = 1.73 \( \times b_{\text{tot\_443}} \)
  - Inverse to compute total scattering again:
    - \( b_{\text{tot\_443}} = \text{total\_susp}/1.73 \)

- **Total absorption**:
  - \( a_{\text{tot\_443}} = a_{\text{pig\_443}} + \text{yellow\_subs} \)
Med 20030601 TSM and YS
Med 20030601 b_tot and a_tot at 443 nm
After improvements in MEGS 7.4 compared to IPF 4.0:

• NN based case 2 products can be used also in case 1 conditions
• Algal_1 and algal_2 similar values
• Algal_2 larger range compared to algal_1
• Algal_1 more robust against errors in atmospheric correction
• Algal_2 and YS fail when reflectances are below cut-off threshold
• YS and TSM can be used also for case 1 conditions
• Values look reasonable, but are not validated
• From NN b_tot and a_tot at 443 nm can be easily computed
• Robust products according to experience of IOCCG working group
MEGS 7.2 relationship, log ref. input

Red line: \( \text{alg1}=21\cdot\text{apig}^{1.04} \)
MEGS 7.3 coefficients