A hyperspectral view of the North Sea

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BELCOLOUR project partners :

MUMM

esa ULB

Vlaamse Instelling voor Technologisch Onderzoek

MOL

CASI airborne campaign

Image acquisition details

Spatial resolution : 4m x 4m

96 spectral bands

FWHM : 6 nm

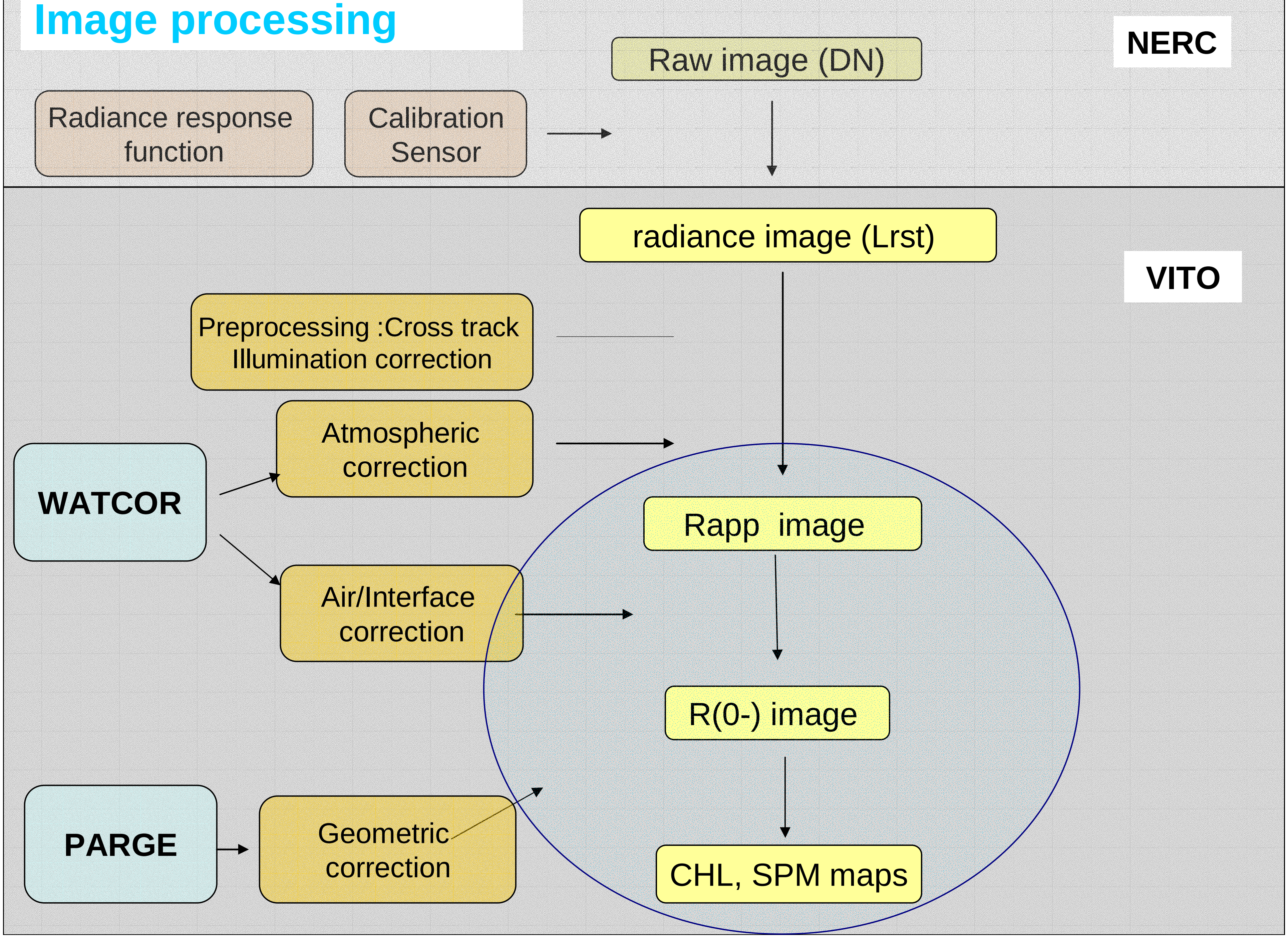
Spectral range : 405 nm – 947 nm

Swath : 303 pixels (=>+/- 1200 m)

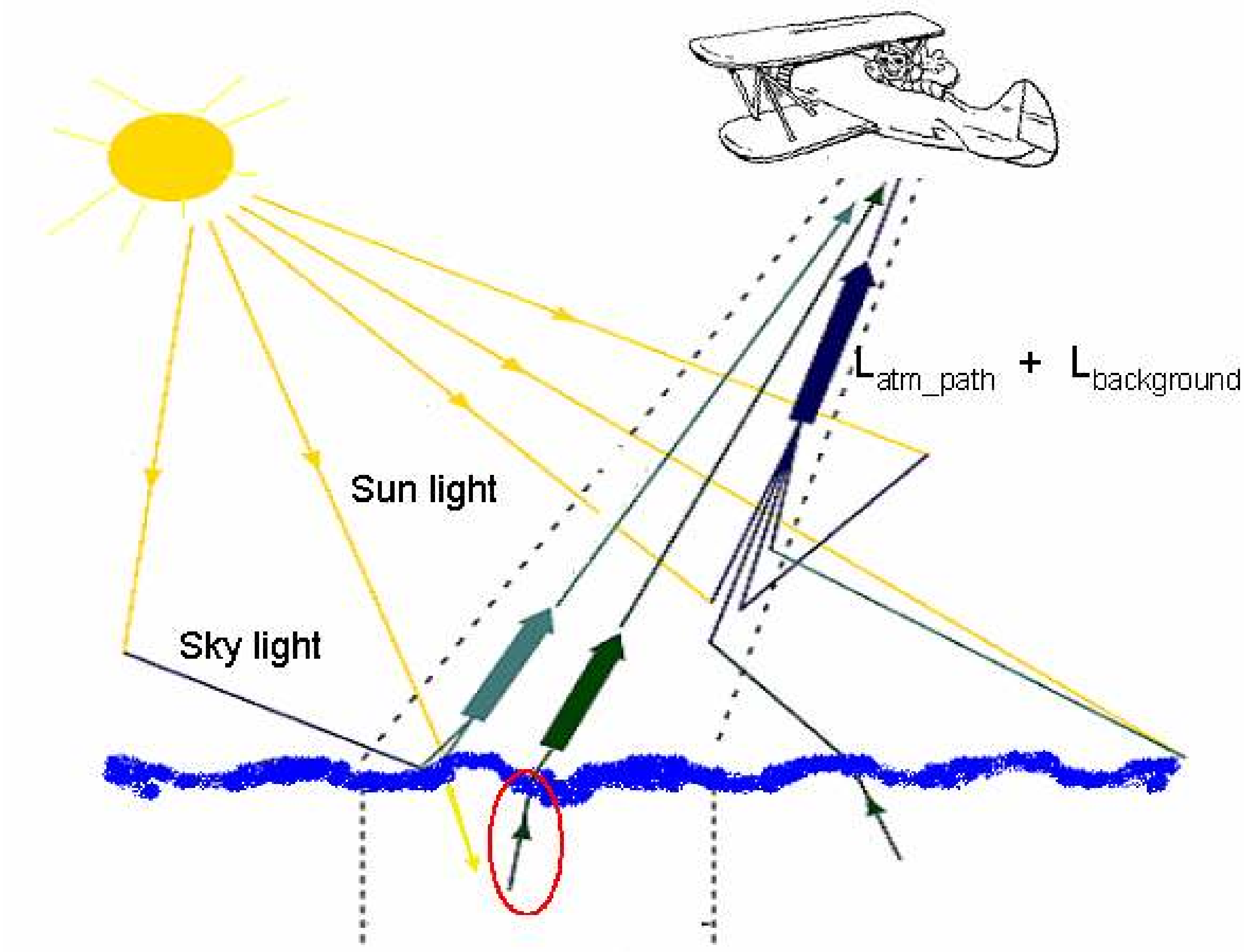
Date : 16/6/2003

GMT: between 11:57 and 13:39

Image processing



Atmospheric & Air/interface correction



Absorption of light by
particles and water

Rad. Cal.

Preprocessing

Atm. cor.

- Theory
- WATCOR
- Atm. Info
- Results

Geom. cor

CHL & SPM maps

ALGORITHMS (De Haan and Kokke, 1996)

At-sensor radiance = Path radiance + target radiance + background

$$L_{rs} = L_{atm-path} + \frac{d^*_{direct} R_{app} E_d}{\pi} + \frac{d^*_{diffuse} A_{app} E_d}{\pi}$$

Apparent Reflectance :

$$R_{app} = \frac{c_1 + c_2 L_{rs} + c_3 L_{rs,b}}{c_4 + c_5 L_{rs,b}}$$

$c_1 \ldots c_5$: 3 MODTRAN runs

+

Subsurface irradiance reflectance :

$$R(0^-) = \frac{-d_1 + R_{app}}{d_2 + s^*_{\text{int}} R_{app}}$$

d_1, d_2 : 2 MODTRAN runs

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Required input parameters to run MODTRAN :

- Flight/sensor parameters: altitude, heading, view angle,…..
- Sun zenith and azimuth angle
- Atmospheric parameters: Visibility, aerosol type/profile, H20,

Problem : A lot of Modtran runs !

- Viewing directions vary within 1 image
- Sun angles, flight geometry … vary between images

⇩

LOOK UP TABLES

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WATCOR FUNCTIONALITY

LOOK_UP_TABLES

- Large LUT :

  Variable parameters:

  flight altitude and heading, sun zenith/azimuth angles, water vapour, visibility

  Fixed parameters :

  aerosol type and profile

- Ad hoc LUT :

  All parameters fixed ,

  except: Visibility and Viewing nadir angle

AEROSOL

- Standard Modtran aerosol types
- User defined Aerosol (**OPAC**) in function of concentration of different components : insoluble, water-soluble, soot

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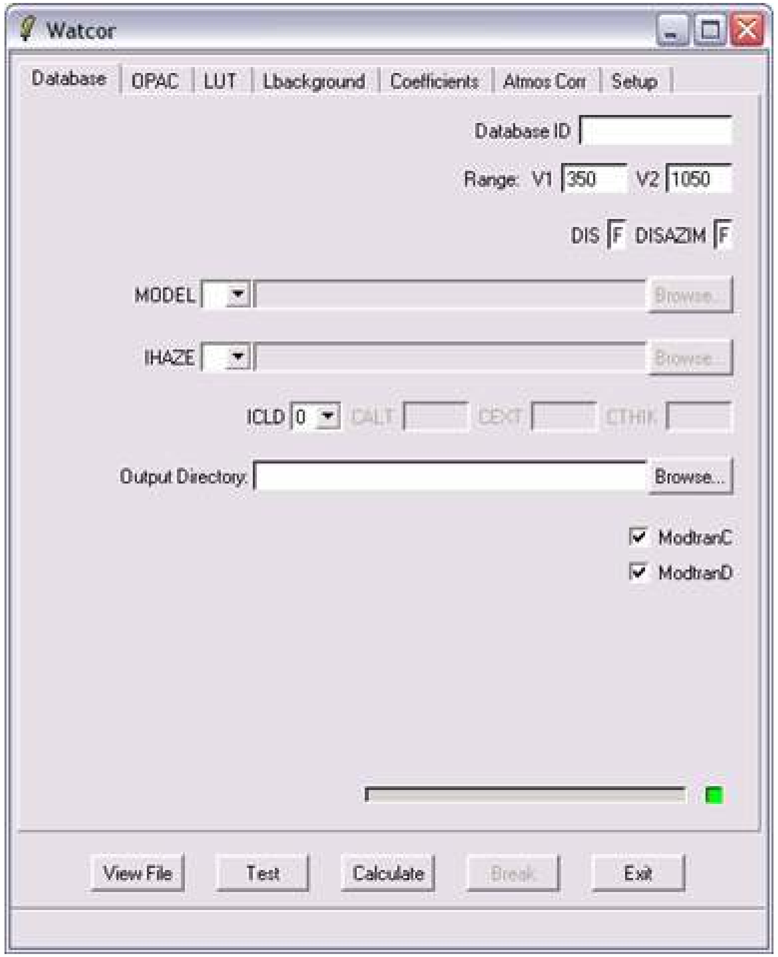
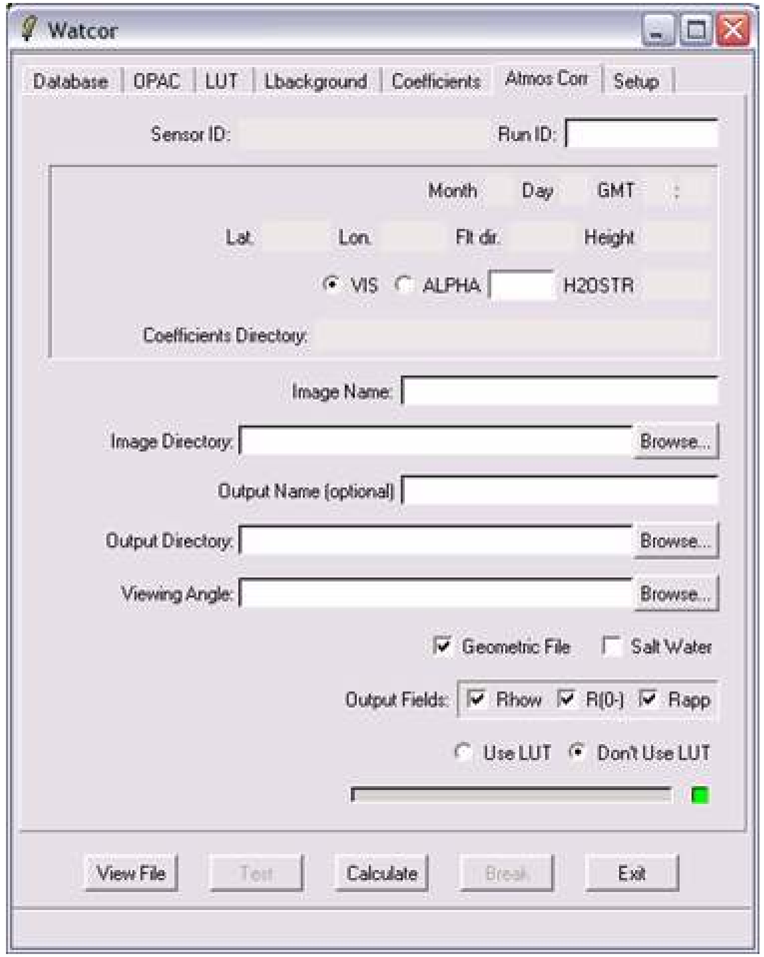
WATCOR INTERFACE





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1. Sun photometer data + Modtran

CIMEL

(OOSTENDE AERONET SITE)

SIMBADA

Belgica vessel

2. Image derived visibility : Adapted dark target approach (Keller, 2001)

Radiom. Cal.

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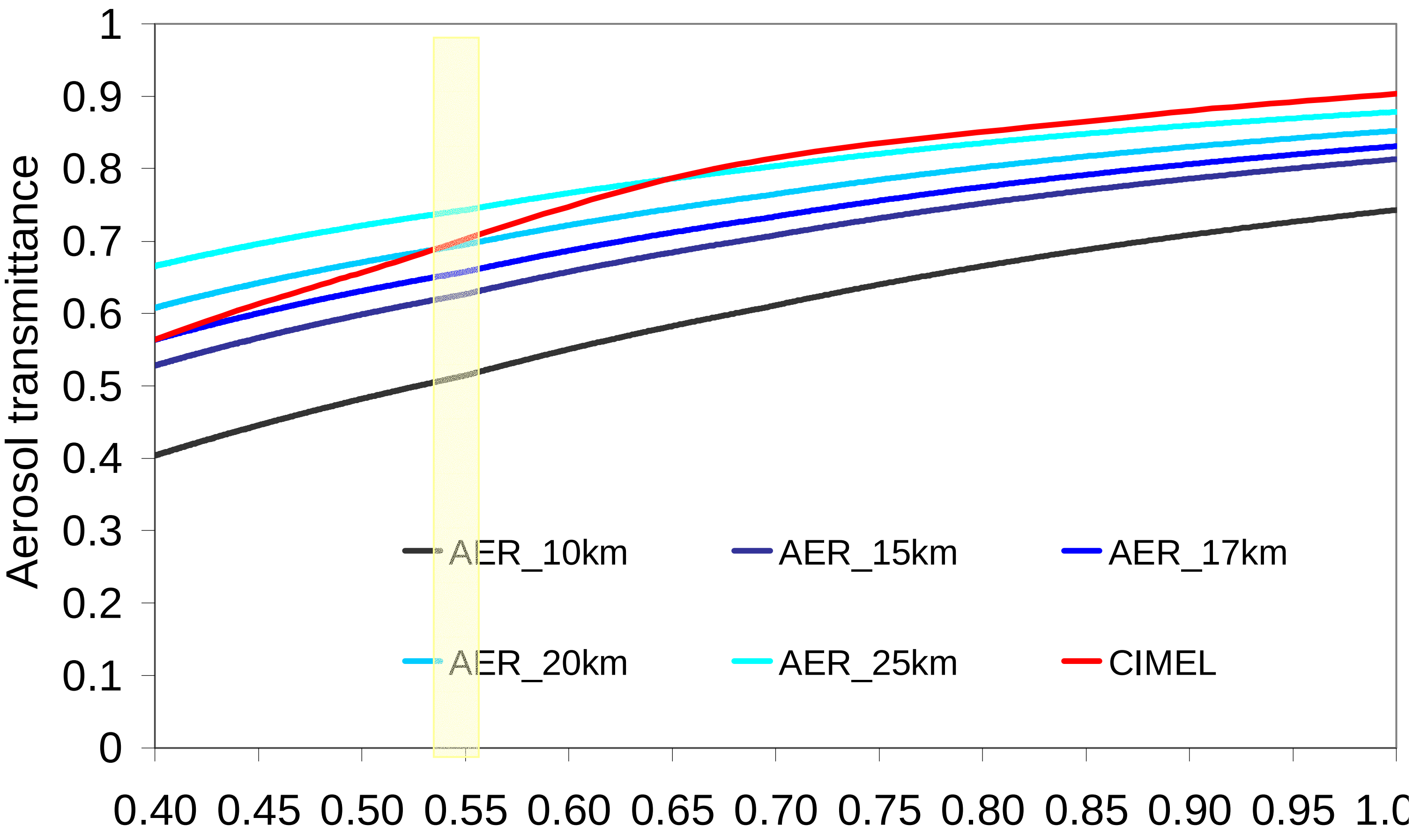
1. Modtran aerosol transm vs Cimel aerosol transm



- Radiom. Cal.
- Preprocessing
- **Atmos. cor.**
  - Algorithms
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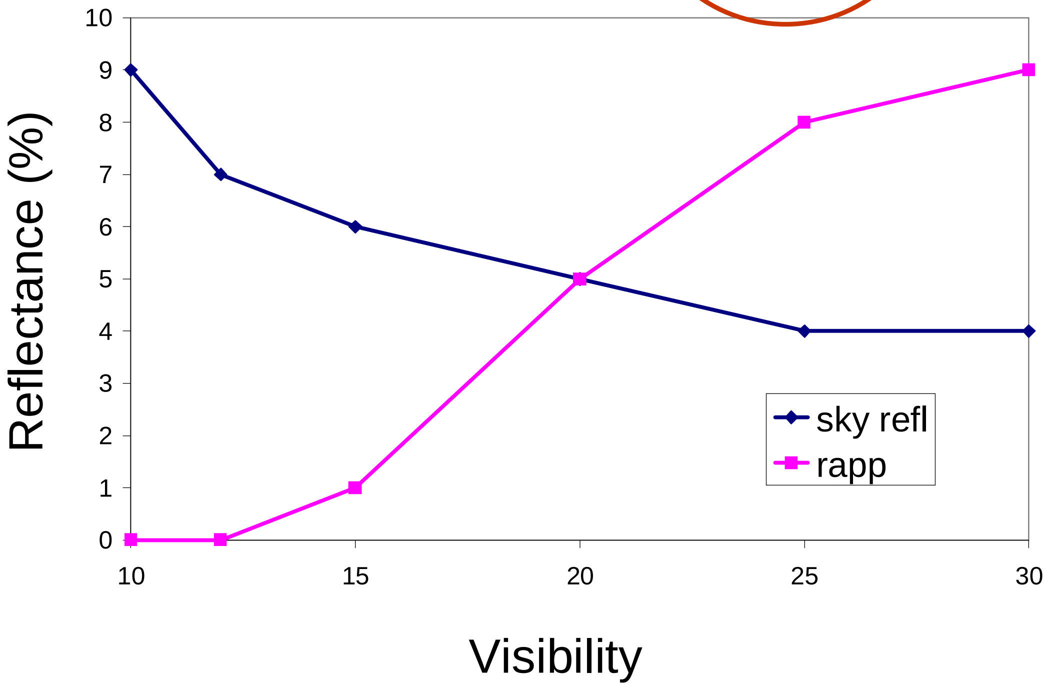
2. Image derived visibility : Dark target approach

Find darkest pixel at 860 nm in each image

Determine visibility for which :

$$\rho_w(860) = Rapp(860) - \frac{\pi r(\theta_v) L_d}{E_d} = 0$$

Surface reflection of skylight



Radiom. Cal.

Preprocessing

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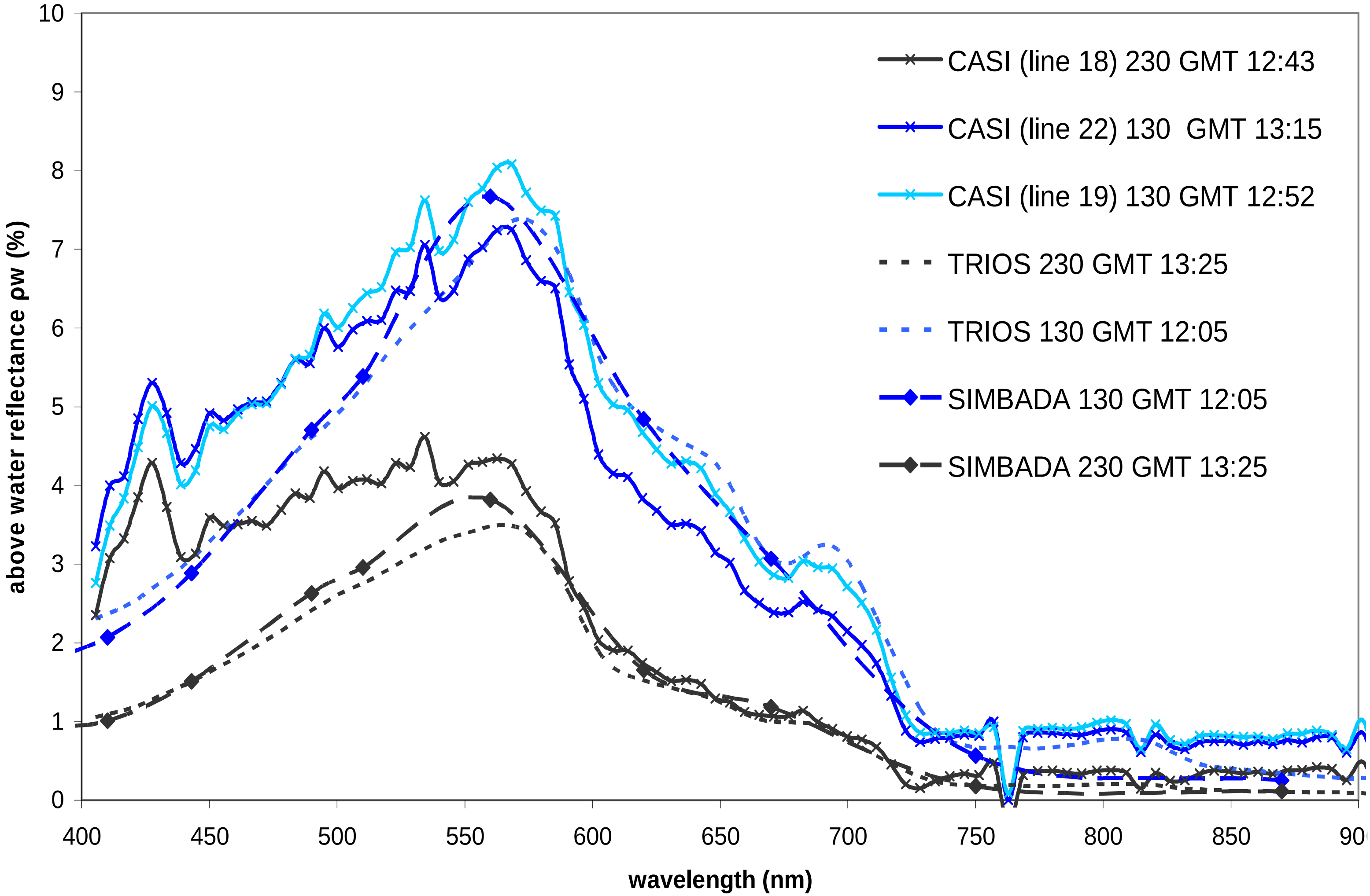
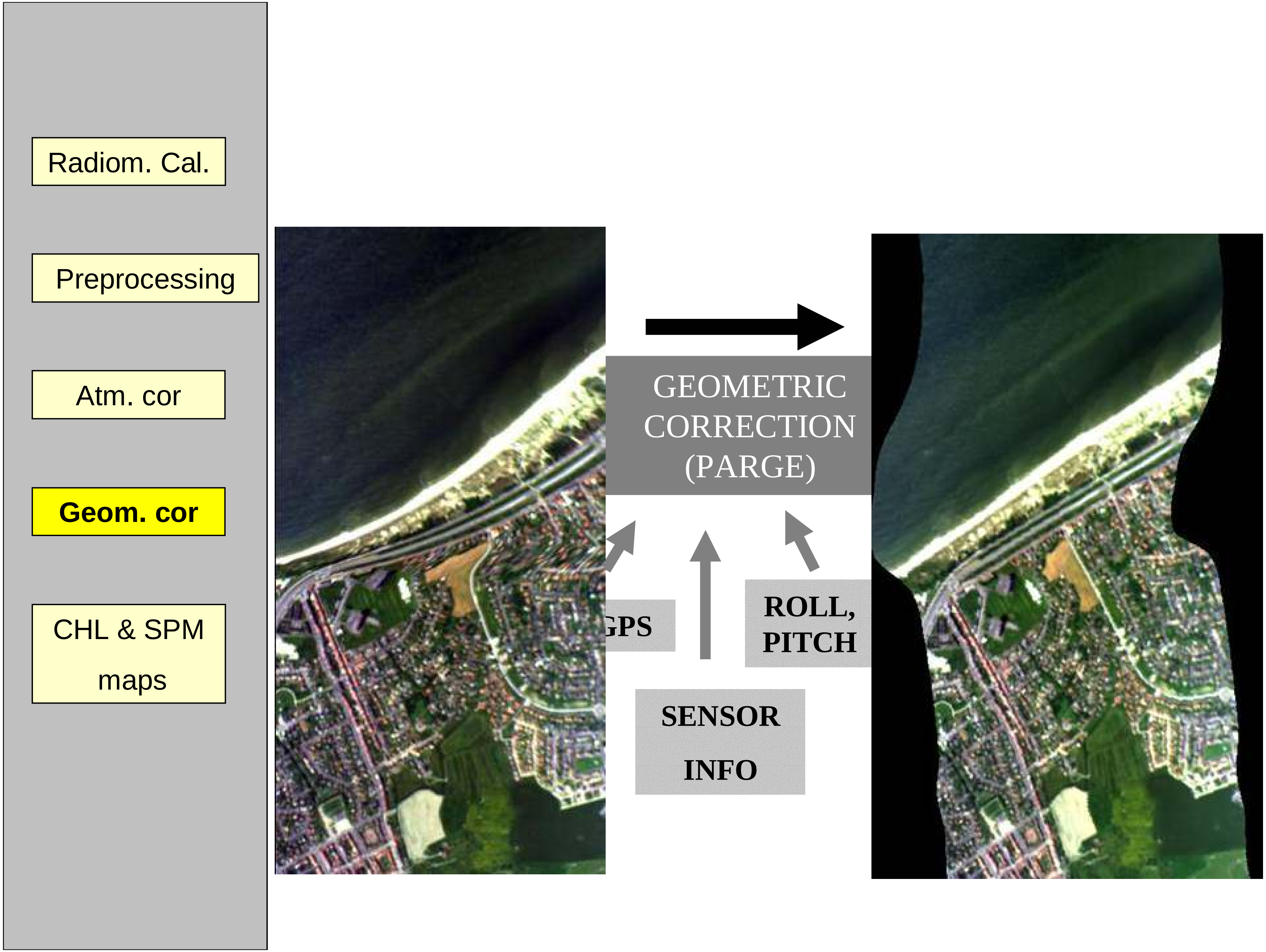
Geom. cor

CHL & SPM maps




Radiom. Cal.
Preprocessing
Atm. cor
Geom. cor
CHL & SPM
maps
GEOMETRIC
CORRECTION
(PARGE)
GPS
ROLL,
PITCH
SENSOR
INFO

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SEMI-ANALYTICAL ALGORITHMS

- CHLOROPHYLL : NIR/red band ratio algorithm (Gons, 1999)

$$CHL = \frac{\left(\frac{R(0-,705) * (a_w(705) + b_b)}{R(0-,671)} - a_w(671) - b_b \right)}{a^*_{ph}(671)}$$

- SUSPENDED MATTER : one-band algorithm (Nechad et al.,2003)

$$MUMM - SPM = 111.21 \cdot \frac{\rho_w(708)}{0.187 - \rho_w(708)} + 4.46$$

=> calibrated for the Belgian Coastal waters and for the MERIS sensor

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ANALYTICAL ALGORITHMS : MATRIX INVERSION

$$R(0-,\lambda) = f \cdot \frac{b_b(\lambda)}{a(\lambda) + b_b(\lambda)}$$

Gordon et al., 1975

Absorption — Backscattering

a(λ) and b_b(λ) are lineair functions of the consistuents' concentrations :

$$R(0-) = f \cdot \frac{b_{bw} + SPM \cdot b^*_{b,P}}{a_w + CDOM \cdot \tilde{a}_{CDOM} + CHL \cdot a^*_{ph} + (SPM - 0.07CHL) \cdot a^*_{NAP} + b_{bw} + SPM \cdot b^*_{b,P}}$$

can be written for *m* wavelength

=> set of *m* linear equations

=> with 3 unknowns SPM, CHL, CDOM

=> can be solved with least-square approach

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CHL & SPM

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$$R(0-) = f \cdot \frac{b_{bw} + SPM \cdot b^*_{b,P}}{a_w + CDOM \cdot \tilde{a}_{CDOM} + CHL \cdot a^*_{ph} + (SPM - 0.07CHL) \cdot a^*_{NAP} + b_{bw} + SPM \cdot b^*_{b,P}}$$

Specific absorption/backscattering spectra of CHL, SPM, CDOM

Should ideally be measured at same location and time period as the CASI data

In this case both literature values and field measurements (2003, 2004)

parameter	source
a^*_{NAP} , a^*_{ph}	Field measurements station 230 17 June 2003
a_w	Buiteveld et al.,1994
$\tilde{a}_{CDOM}$, $g440$	Field measurements (station 130, 230) April - May 2004
b_{bw}	Morel,1974
$b^*_{b,p}$	$b^*_p(550) = 0.54$ and $b^*_p(\lambda) = b^*_p(550) \cdot \left(\lambda / 550\right)^{-4}$ from Babin et al.,2003

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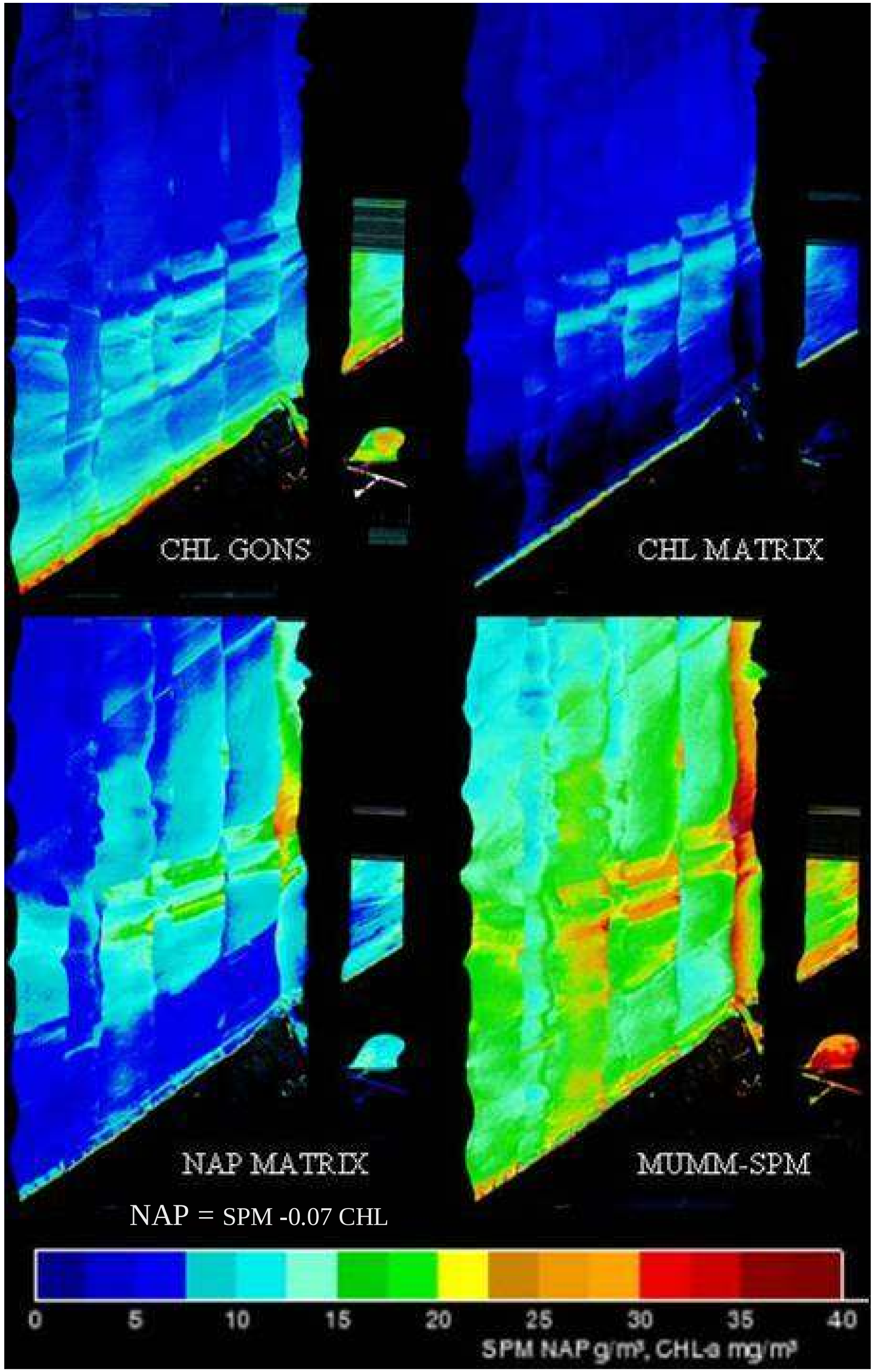

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Water quality from AIRBORNE, *SEABORNE* AND **IN-SITU** MEASUREMENTS

STATION 130

source	GMT	concentrations
in-situ SPM (GF/F PA)[1] (g/m³)	**12:05**	**22.27**
in-situ SPM (GF/C)[2] (g/m³)	**12:05**	**36.40**
MUMM SPM (TRIOS) (g/m³)	*12:05*	*21.53*
MUMM SPM (line 22) (g/m³)	13:15	16.26
MUMM SPM (line 19) (g/m³)	12:52	19.97
in-situ CHL a (GF/C) (mg/m³)	**12:05**	**16.60**
in-situ CHL a (GF/F) (mg/m³)	**12:05**	**13.76**
Gons Chl (TRIOS) (mg/m³)	*12:05*	*7.80*
Gons Chl (line 22) (mg/m³)	13:15	4.85
Gons Chl (line 19) (mg/m³)	12:52	6.95
Matrix Chl (TRIOS) (mg/m³)	*12:05*	*10.48*
Matrix Chl (line 22) (mg/m³)	13:15	6.35
Matrix Chl (line 19) (mg/m³)	12:52	7.86
in-situ NAP[3] (GF/F) (g/m³)	**12:05**	**21.31**
Matrix NAP (TRIOS) (g/m³)	*12:05*	*14.76*
Matrix NAP (line 22) (g/m³)	13:15	9.99
Matrix NAP (line 19) (g/m³)	12:52	13.77

[1] Samples taken at 1 m depth on GF/F filters -PA: Pre Ashed

[2] Samples taken at 3 m depth on GF/C filters

[3] NAP = SPM (GF/F) - 0.07 CHL a (GF/F)

conclusions

- Visibility information retrieved from (1) sun photometer and (2) image inherent information was comparable (20 km vs 18.3 km)
- Difficult to determine the accuracy of CHL/SPM maps with only 2 in-situ stations
- Matrix inversion technique should be optimized with more accurate SIOPs, …

Acknowledgements

- MUMM : Seaborne reflectance data, CIMEL data
- ULB : SIOP laboratory measurements
- Belgian Science Policy

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