# Water quality of lakes over Europe using Sentinel-2; Atmospheric Correction and Validation

*Antoine Mangin[1,2], Romain Serra[1], Chloé Chauvin[1], Odile Hembise Fanton d'Andon[2]*
*(1) ACRI-HE, France; (2) ACRI-ST, France*

# Plan

- Rationale and motivation
- Atmospheric Correction (AC) – final algorithms
- Secchi disk depths, turbidity and Chlorophyll-a derivation
- Impact of AC on Chl-a retrieval
- Conclusions/perspectives

**Main targets for continental waters monitoring**

- Environmental regulations (National, Water Framework Directive, MFSD, BW..)
- Fresh water management / Water energy management

Sentinel-2 opens the door to « ocean colour » at suitable spatial scale (water surfaces less or equal 0,5 km2)

**Challenges**

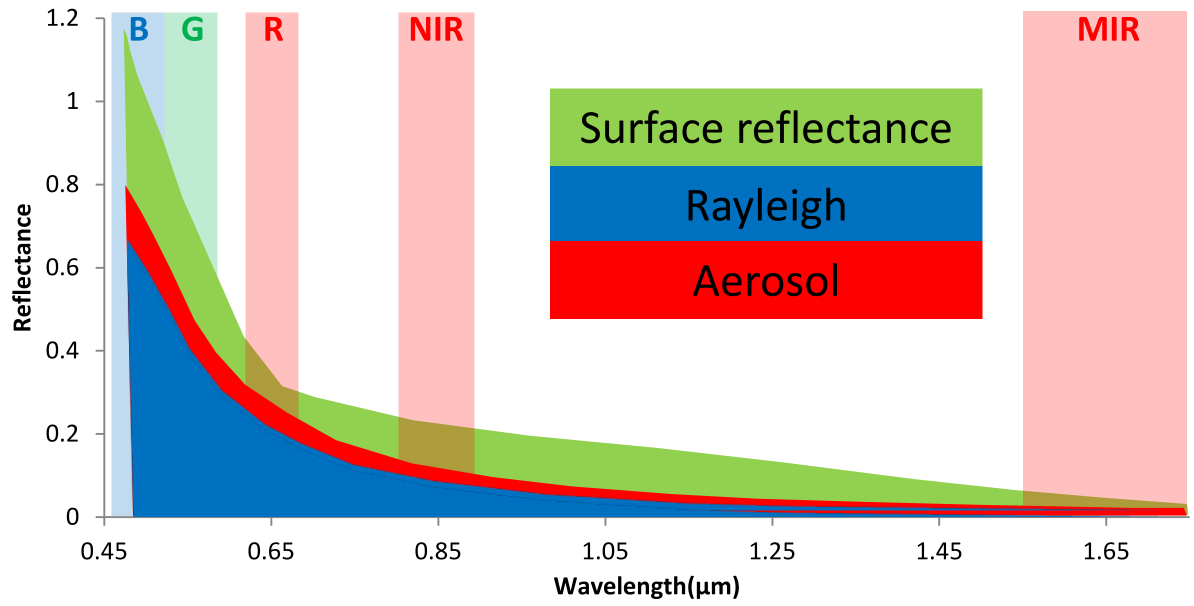
Atmospheric corrections, optical properties retrieval in very different waters, land/water optical contamination, …

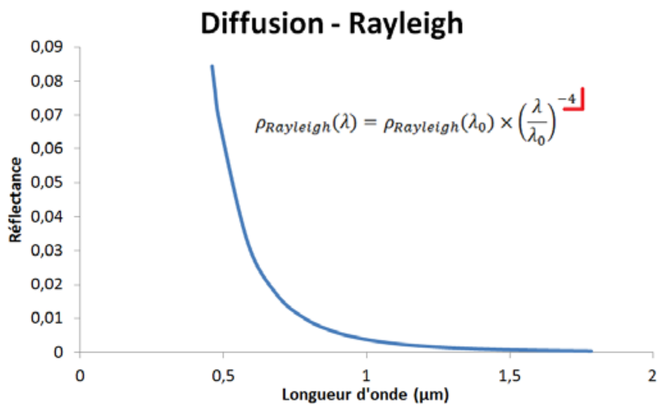
In preparation to S2, ACRI-ST (and partners; Veolia, EDF, NA countries…) is working with Landsat 7/8 for *Coastal Zones* and ***Inland Waters***

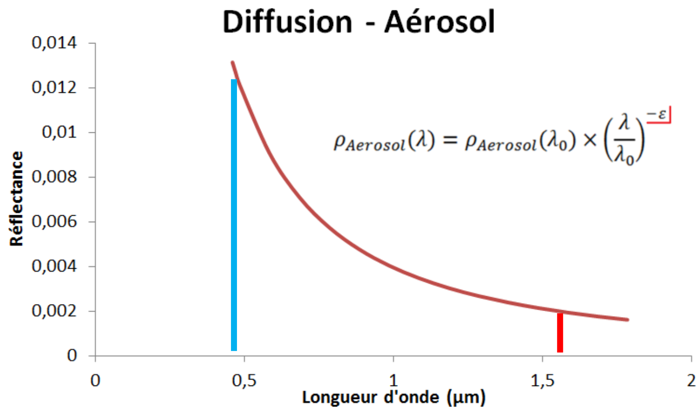
Thematic works are done within

- **SIRHYUS** project led by Veolia (support :French Industry Ministry) - IW
- **FP7-MEDINA** project – CW

IT works are done within **FP7-SenSyf** project


1.2
1
0.8
0.6
0.4
0.2
0
Reflectance
B
G
R
NIR
MIR
Surface reflectance
Rayleigh
Aerosol
0.45
0.65
0.85
1.05
1.25
1.45
1.65
Wavelength(µm)


Diffusion - Rayleigh
$\rho_{Rayleigh}(\lambda) = \rho_{Rayleigh}(\lambda_0) \times \left(\frac{\lambda}{\lambda_0}\right)^{-4}$
Réflectance
Longueur d'onde (µm)

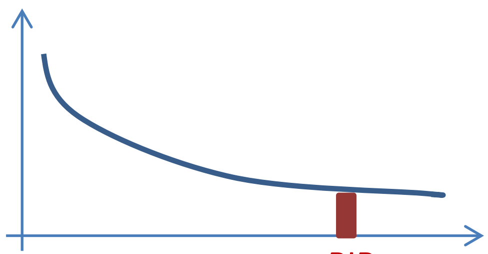

Diffusion - Aérosol
$\rho_{Aerosol}(\lambda) = \rho_{Aerosol}(\lambda_0) \times \left(\frac{\lambda}{\lambda_0}\right)^{-\varepsilon}$
Réflectance
Longueur d'onde (µm)

# Atmospheric Correction (AC) – final algorithms

$$\rho_{abs\_corr}-\rho_{Ray}=\rho_{aero}+t_d\cdot\rho_{surf}$$

## Sea Side

- No (surface) marine signal in the PIR



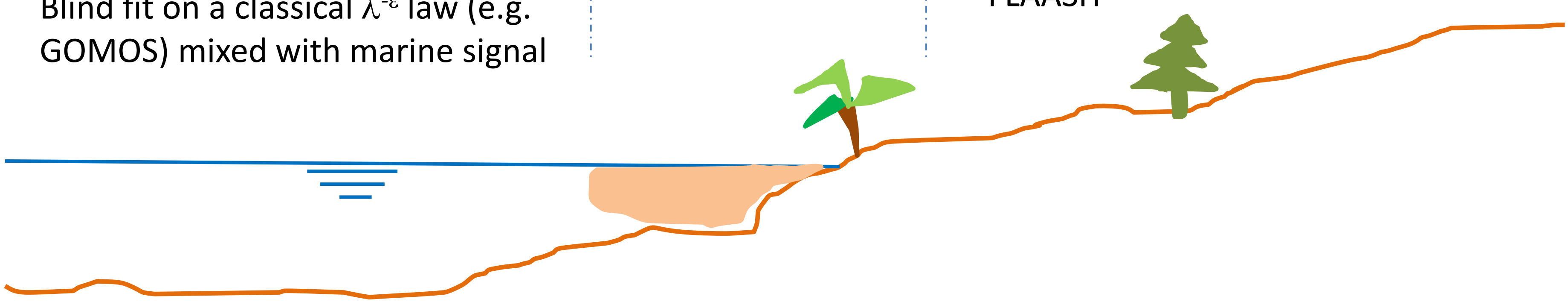

$$\rho_{abs\_corr}-\rho_{Ray}=\rho_{aero}(PIR)$$

$\rho_{aero}(\lambda)$ estimated from 2 bands

- Blind fit on a classical $\lambda^{-\varepsilon}$ law (e.g. GOMOS) mixed with marine signal

## Land Side

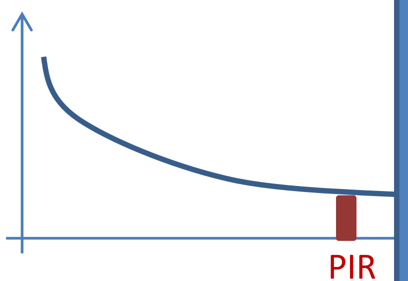
- Dark pixel in the blue and
- guess-estimate of $\rho_{aero}(\lambda)$ law (Chavez 88)
- Dark Dense Vegetation + knowledge of $\rho_{aero}(\lambda)$ dependency for 2 wavelengths (Remer, SMAC, MACCS..)
- Spatial consistency (QUAC)
- Temporal variability over stable targets (Hagolle)
- Radiative Transfer Computations FLAASH



$$\rho_{abs\_corr} - \rho_{Ray} = \rho_{aero} + t_d \cdot \rho_{surf}$$

**Sea Side**

- No (surface) marine s




$\rho_{abs\_corr} - \rho_{Ray} = \rho_{aer}$

$\rho_{aero}(\lambda)$ estimated fr

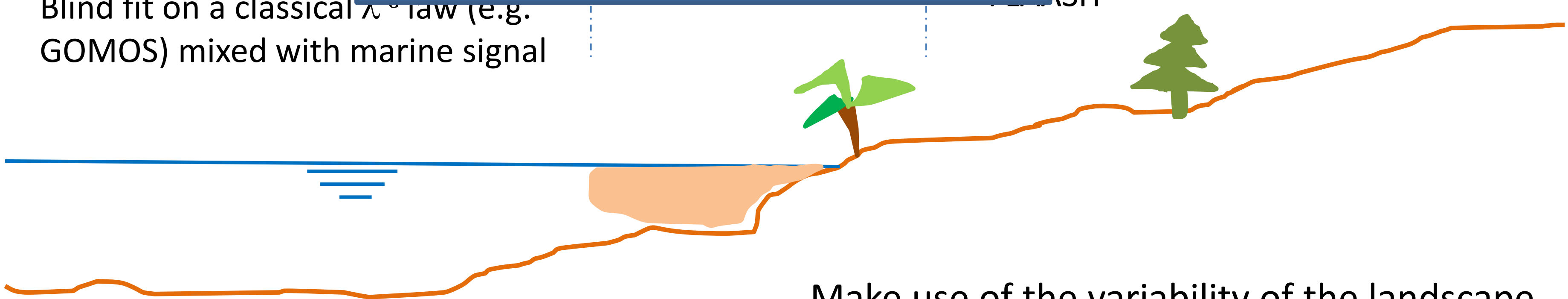
- Blind fit on a classical $\lambda^{-\alpha}$ law (e.g. GOMOS) mixed with marine signal

**Coastal/inland waters**

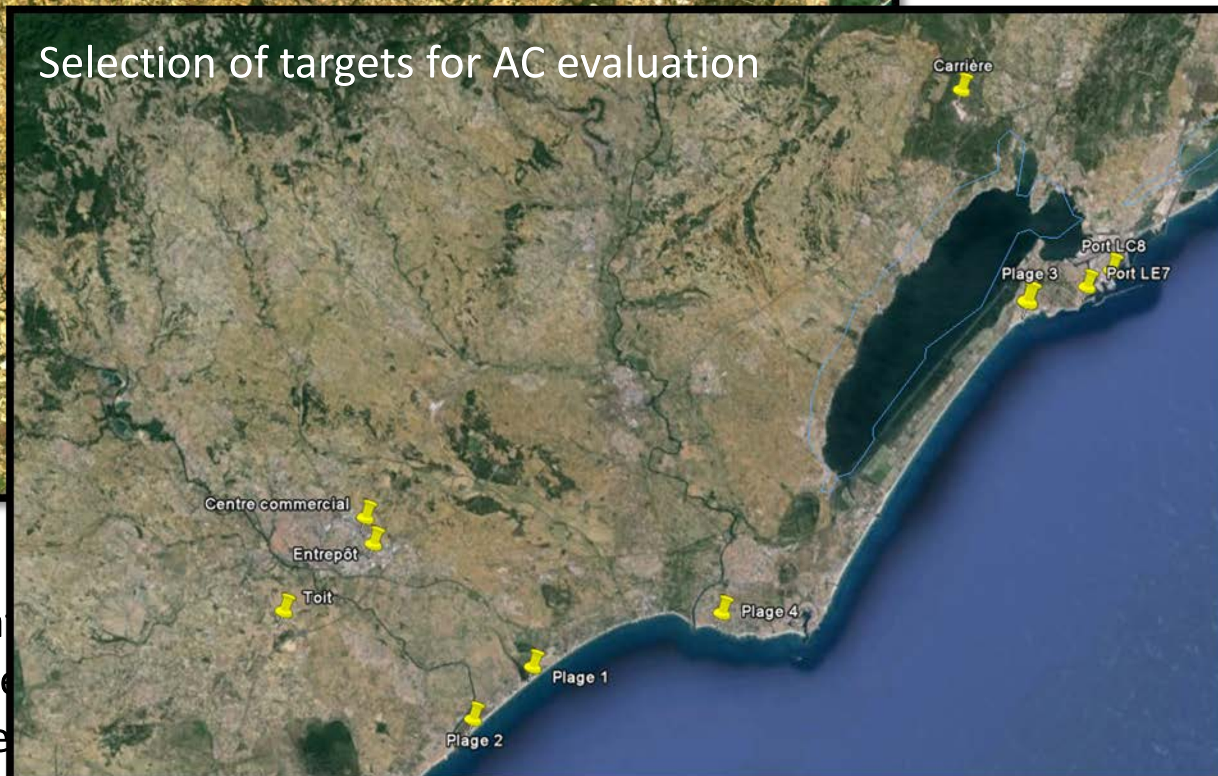
1. Screening of the whole scene to find out the darkest MIR pixel (Percentile 1)
2. Building of each ε-power law spectrum with the reference MIR pixel and the darkest pixel of each band
3. Selection of the minimum spectrum (no band is overcorrected)

**Land Side**

k pixel in the blue and
s-estimate of $\rho_{aero}(\lambda)$ law
vez 88)
k Dense Vegetation + knowledge
$_{aero}(\lambda)$ dependency for 2
elengths (Remer, SMAC,
CS..)
ial consistency (QUAC)
poral variability over stable
ets (Hagolle)
ative Transfer Computations
ASH



Make use of the variability of the landscape

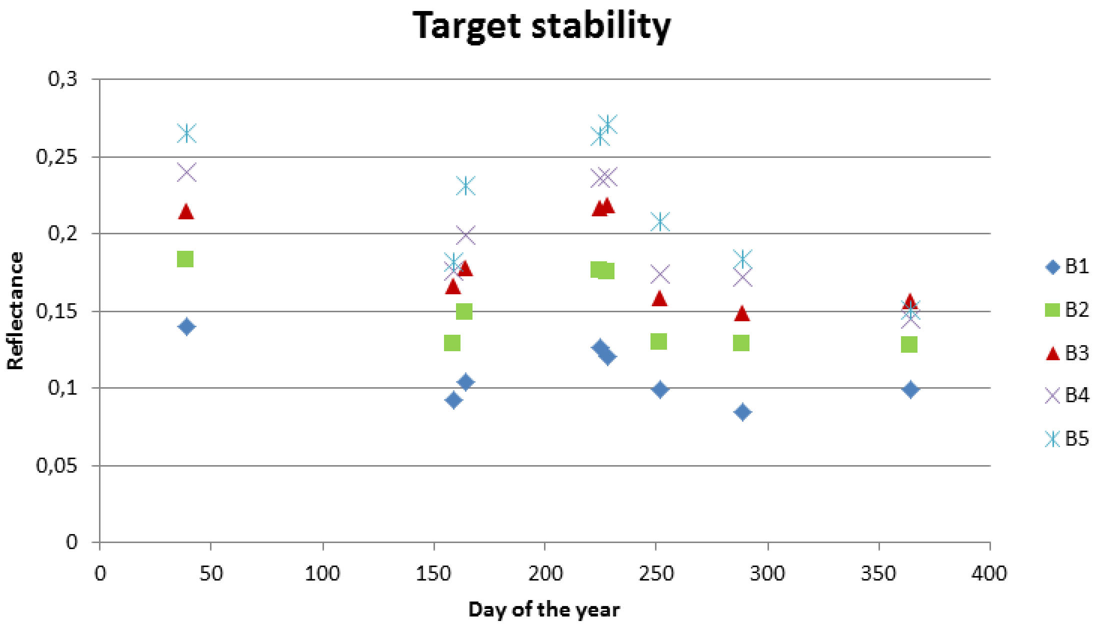



s been done on
au » area that
y of landscape

Identifica
targ
atmosphe

Red : stable
Blue : unstable

# Atmospheric Correction (AC) – final algorithms evaluation

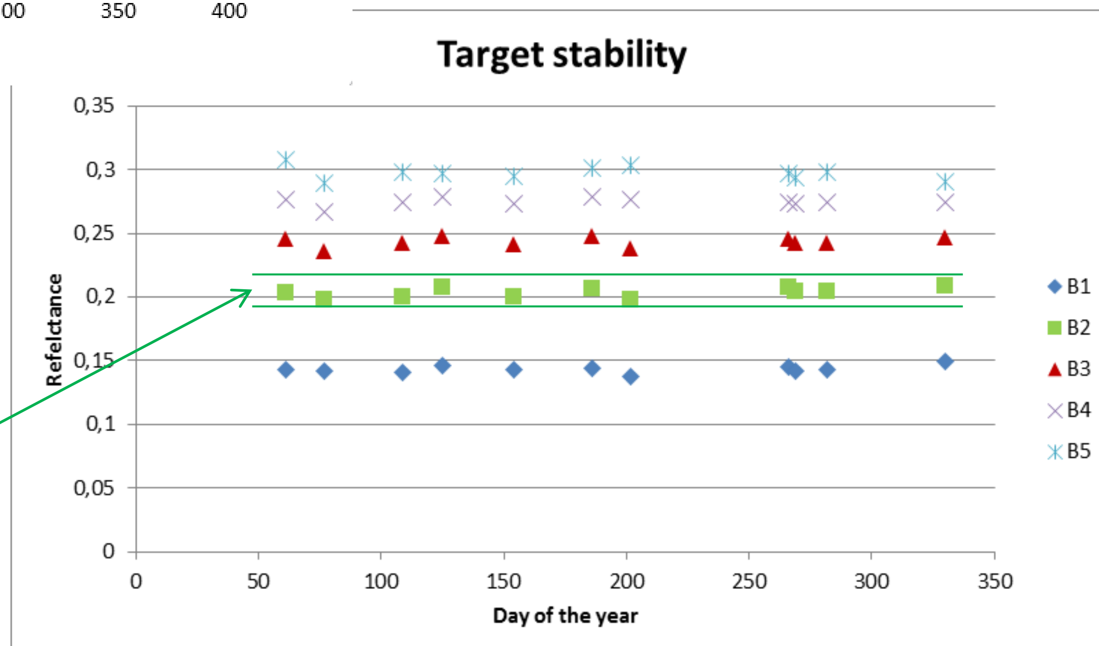



One target with AC applied to Landsat 7

Same target with AC applied to Landsat 8

*Very good stability*

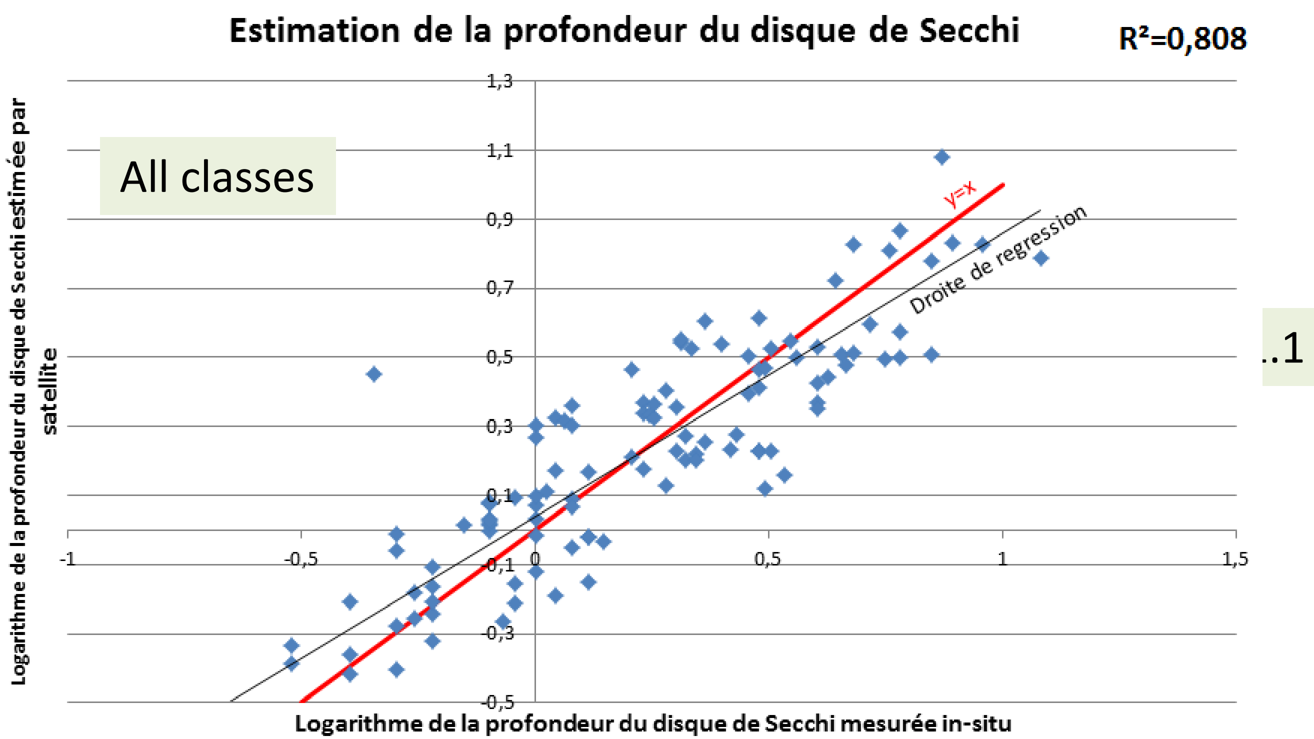
Low level of « unstability » (here for instance with B2)



Algorithm for Chlorophyll-a has been derived after a complete data analysis (data has been provided by EDF and ONEMA – some from Veolia in the frame of Sirhyus project) :

First, 110 matchups of Secchi disk depths have allowed to derive formulae for three classes:

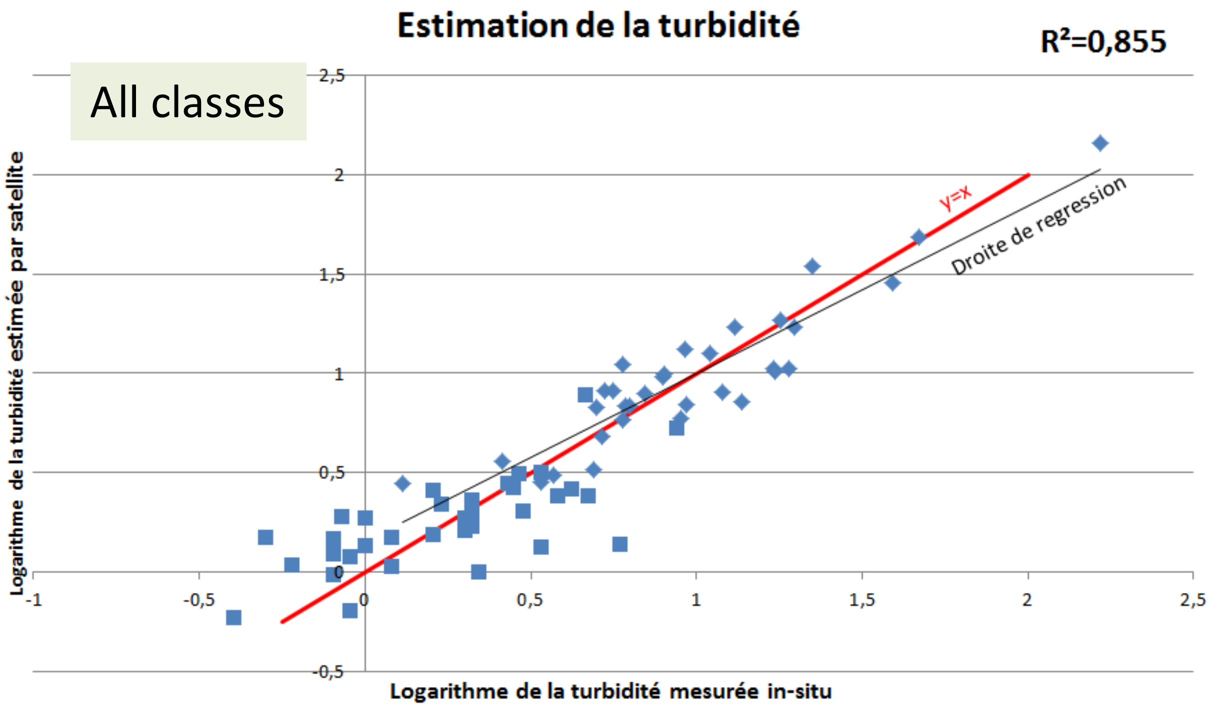
Secchi_disk




Secchi disk depth

Second, 68 matchups of turbidity (NTU) have allowed to derive formulae for two classes:

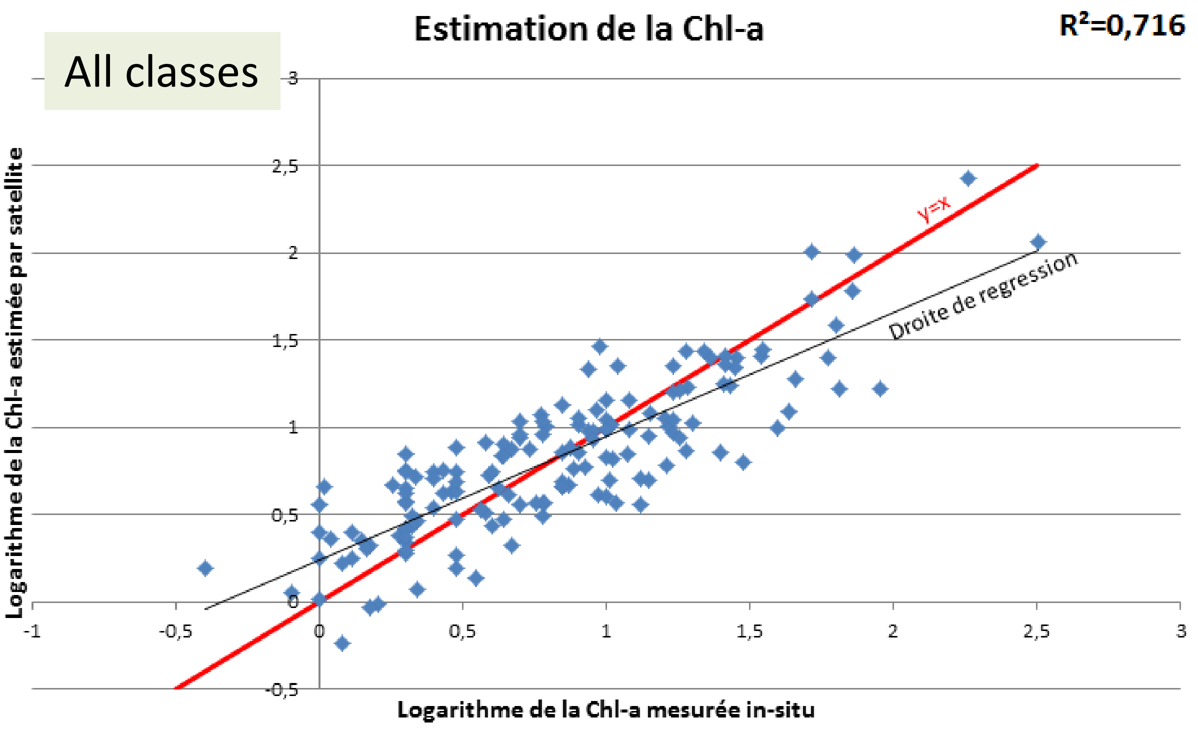
turbidity=f(classe, visible bands (B,V,R,NIR), lake depth, Secchi disk depth)



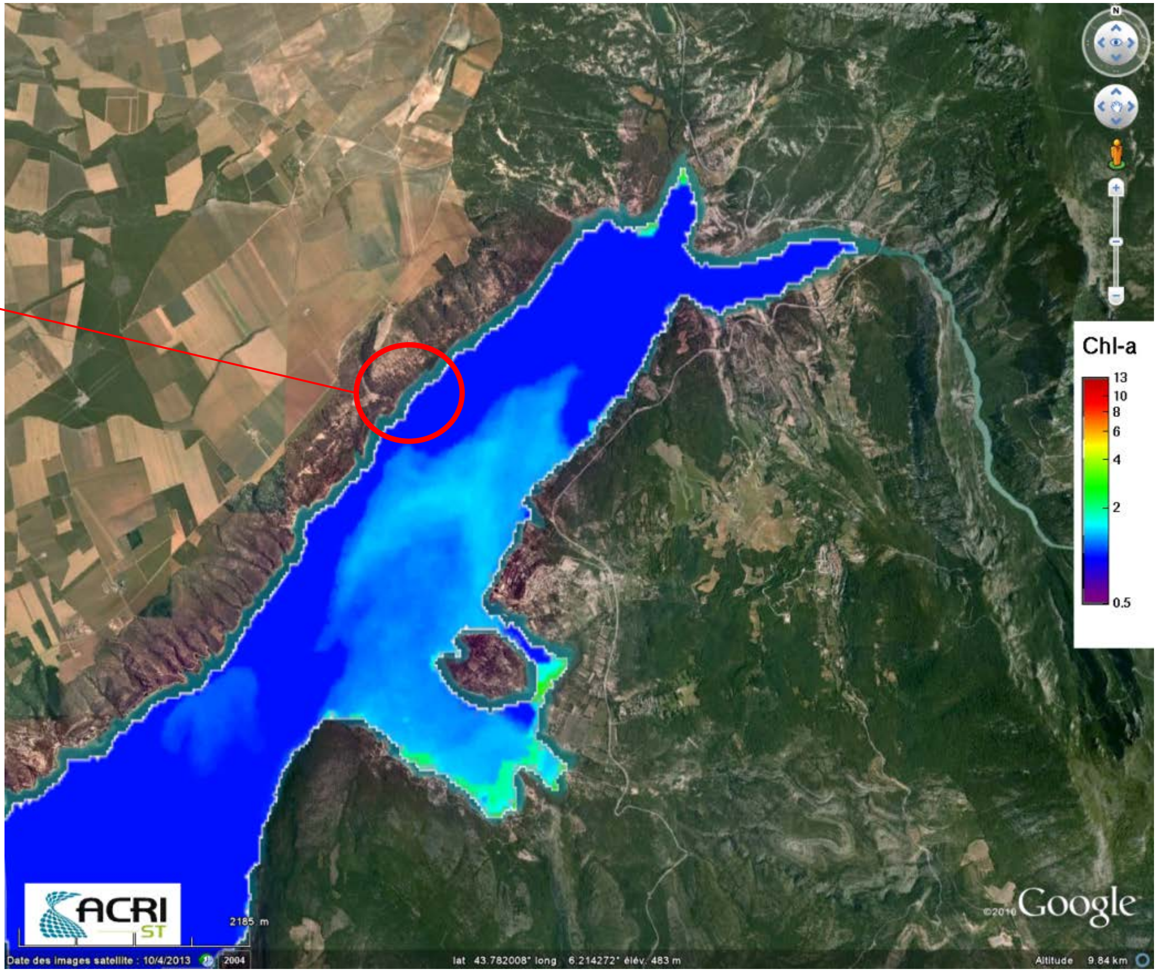
Lastly, 156 matchups of Chlorophyll concentrations have allowed to derive formulae for three classes:

Chla=f(classe, visible bands (B,V,R,PIR), turbidity)

All classes

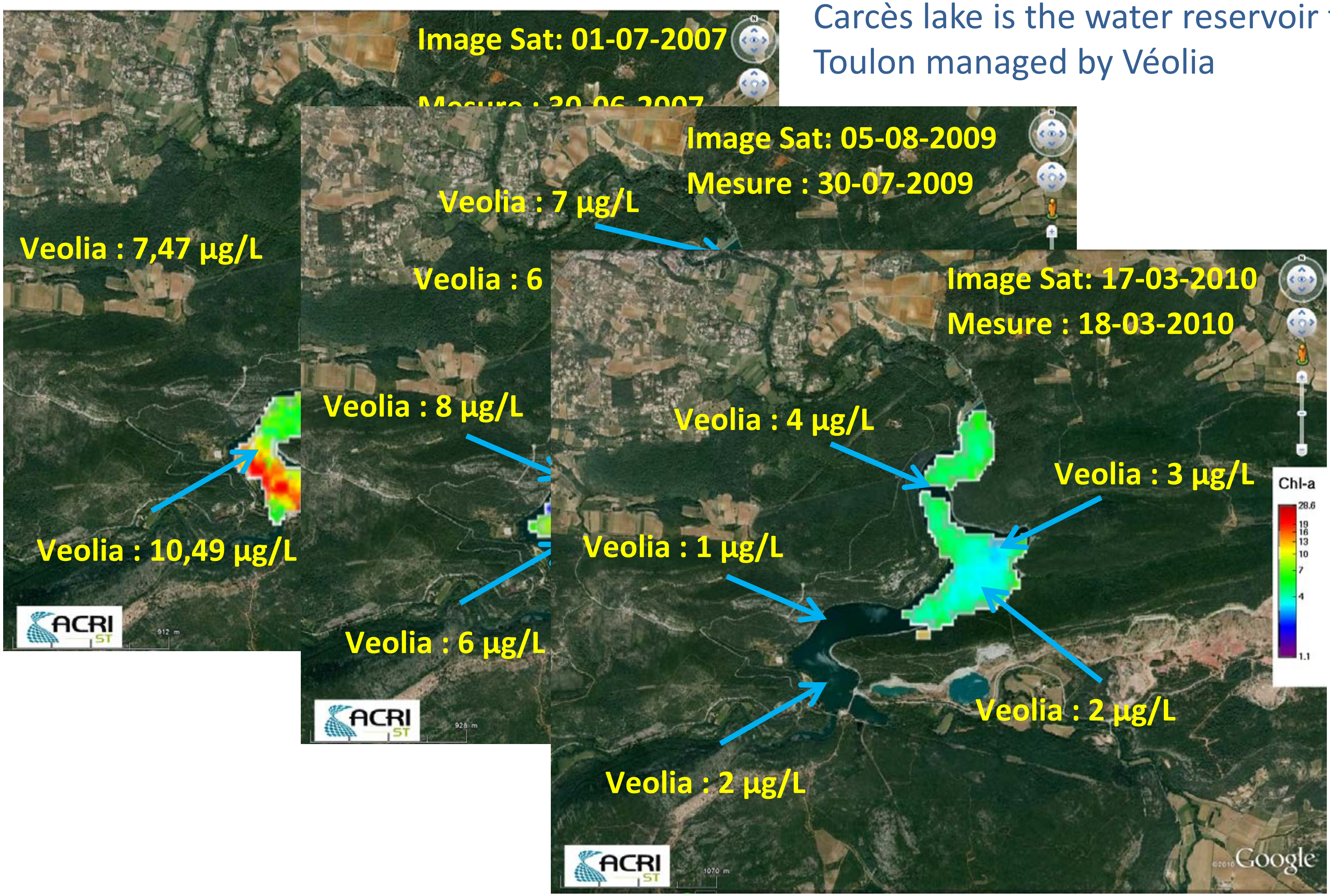


No visible adjacency effects

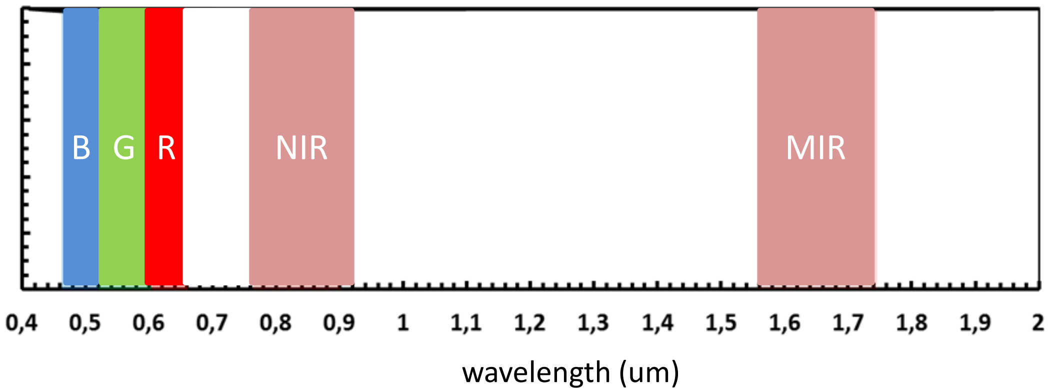


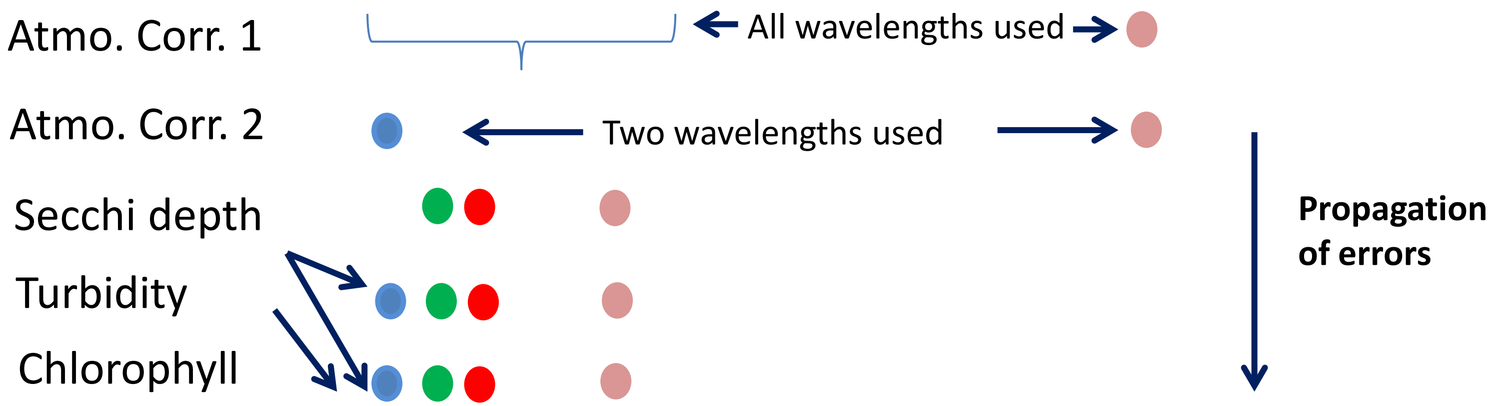

Lac de Sainte-Croix

Carcès lake is the water reservoir for Toulon managed by Véolia

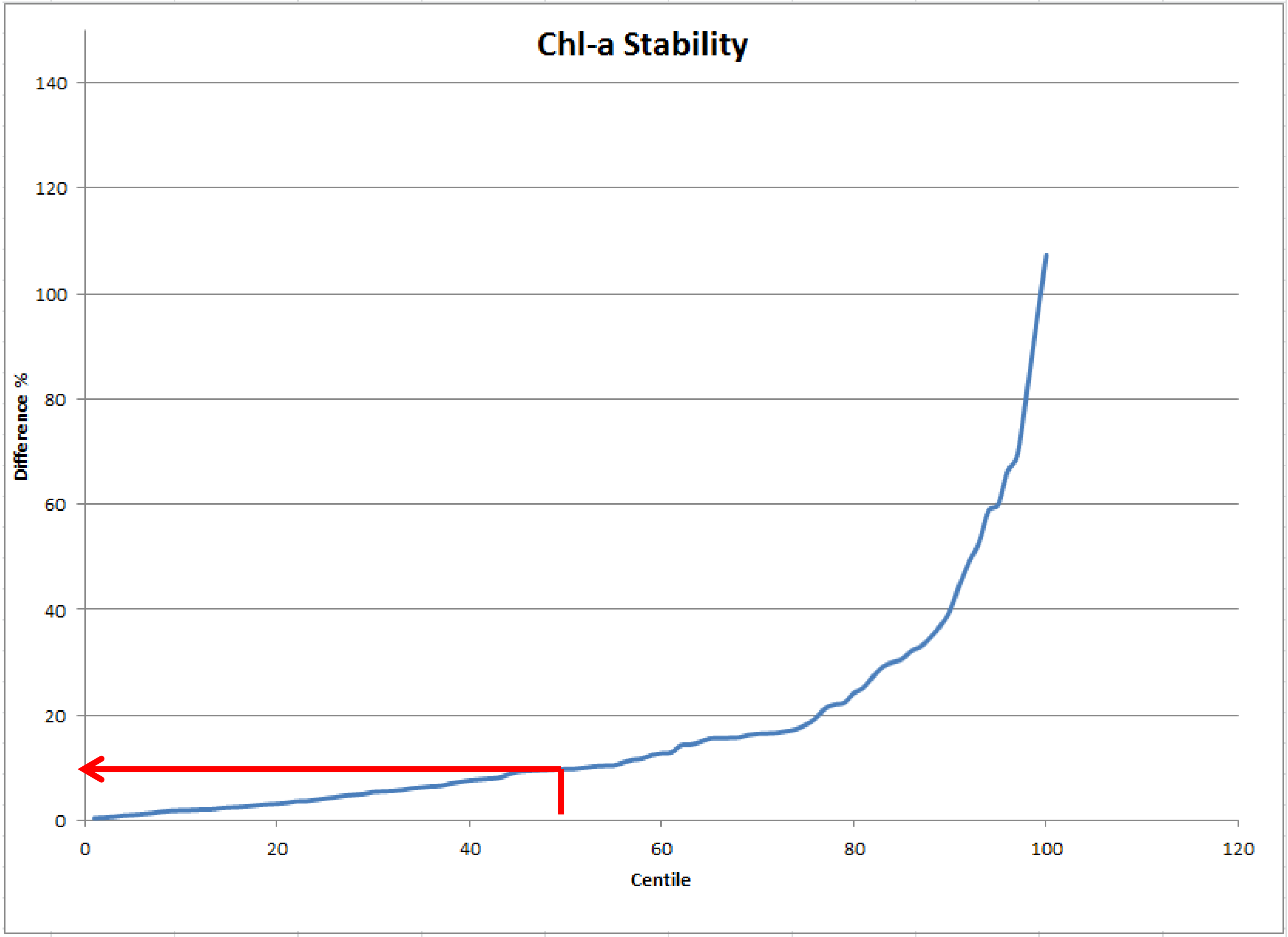


# Summary


B
G
R
NIR
MIR
0,4
0,5
0,6
0,7
0,8
0,9
1
1,1
1,2
1,3
1,4
1,5
1,6
1,7
1,8
1,9
2
wavelength (um)

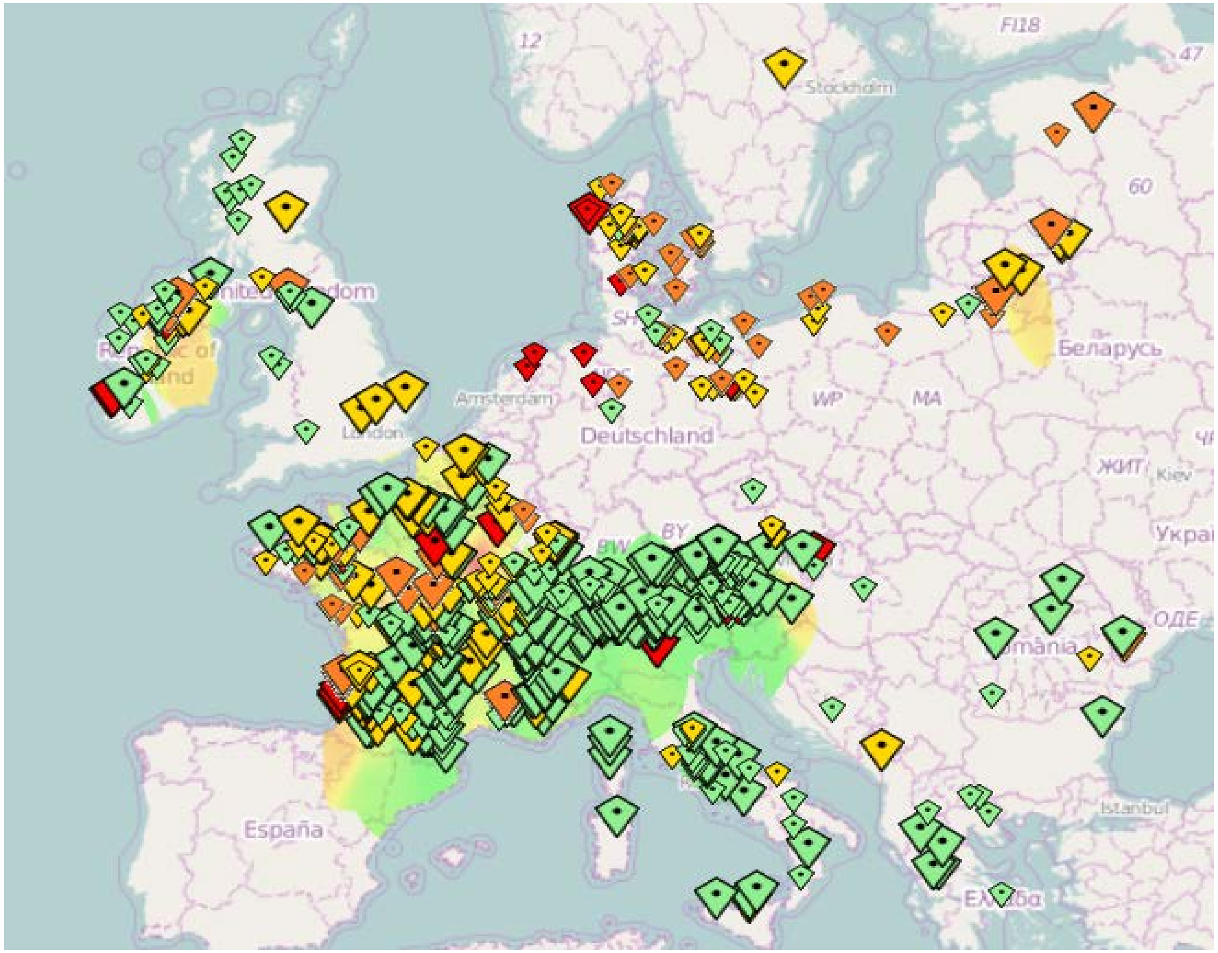

Atmo. Corr. 1
All wavelengths used
Atmo. Corr. 2
Two wavelengths used
Secchi depth
Turbidity
Chlorophyll
Propagation of errors

The fluctuations in AC has been propagated into the algorithm of Chlorophyll determination




The fluctuations in AC impacts by about 10% the chlorophyll retrieval

## Eye_On_Water : http://eyeonwater.eu




**Availability**
from May 2013 – updated every day

**Spatial coverage**
presently limited to 650 lakes/reservoirs for testing purpose

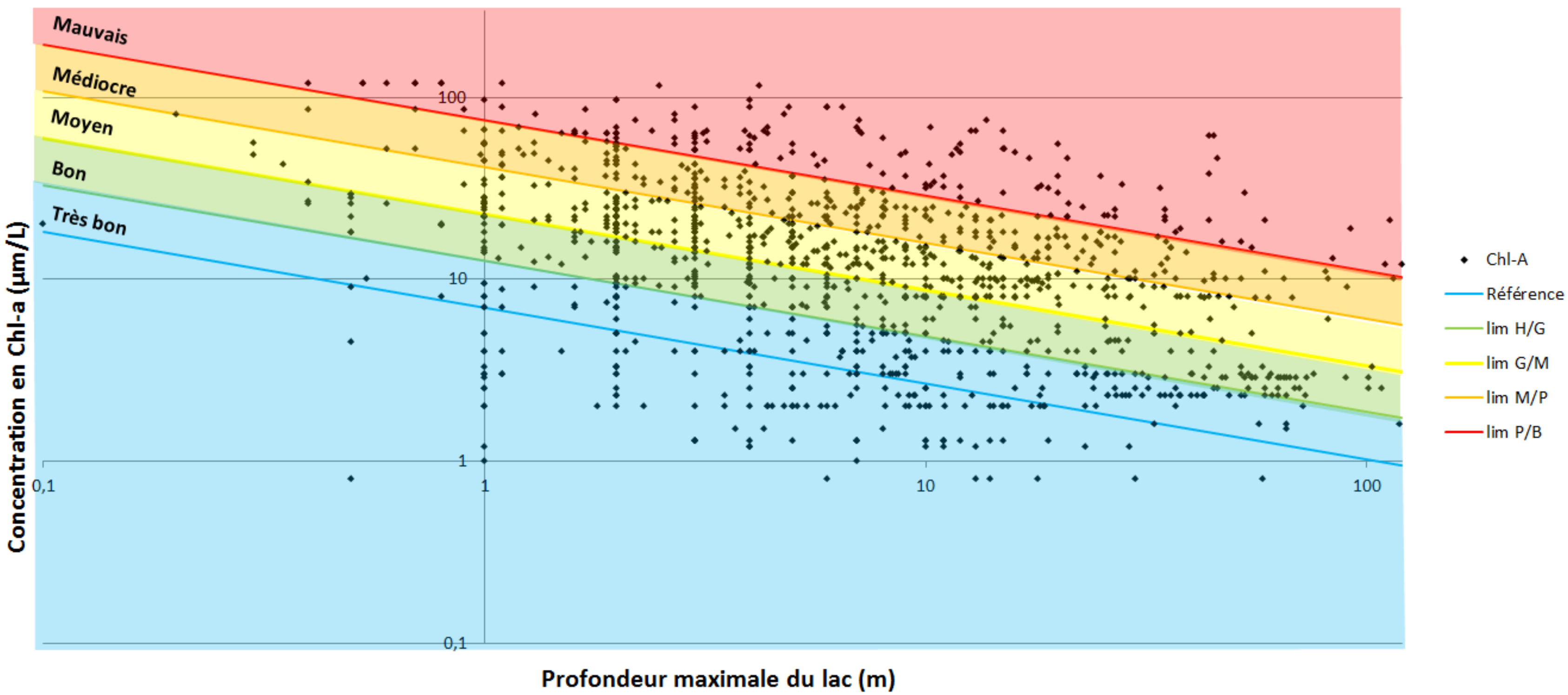
**Data used**
Landsat 7/8 (in preparation to Sentinel-2)

**Algorithms**
Atmospheric correction
Surface Chlorophyll concentration (4 types of waters) – ACRI-ST

- Display and navigation are supported by Open Street Map
- Largest symbols point toward a more recent information (from which iso-value contours are computed)

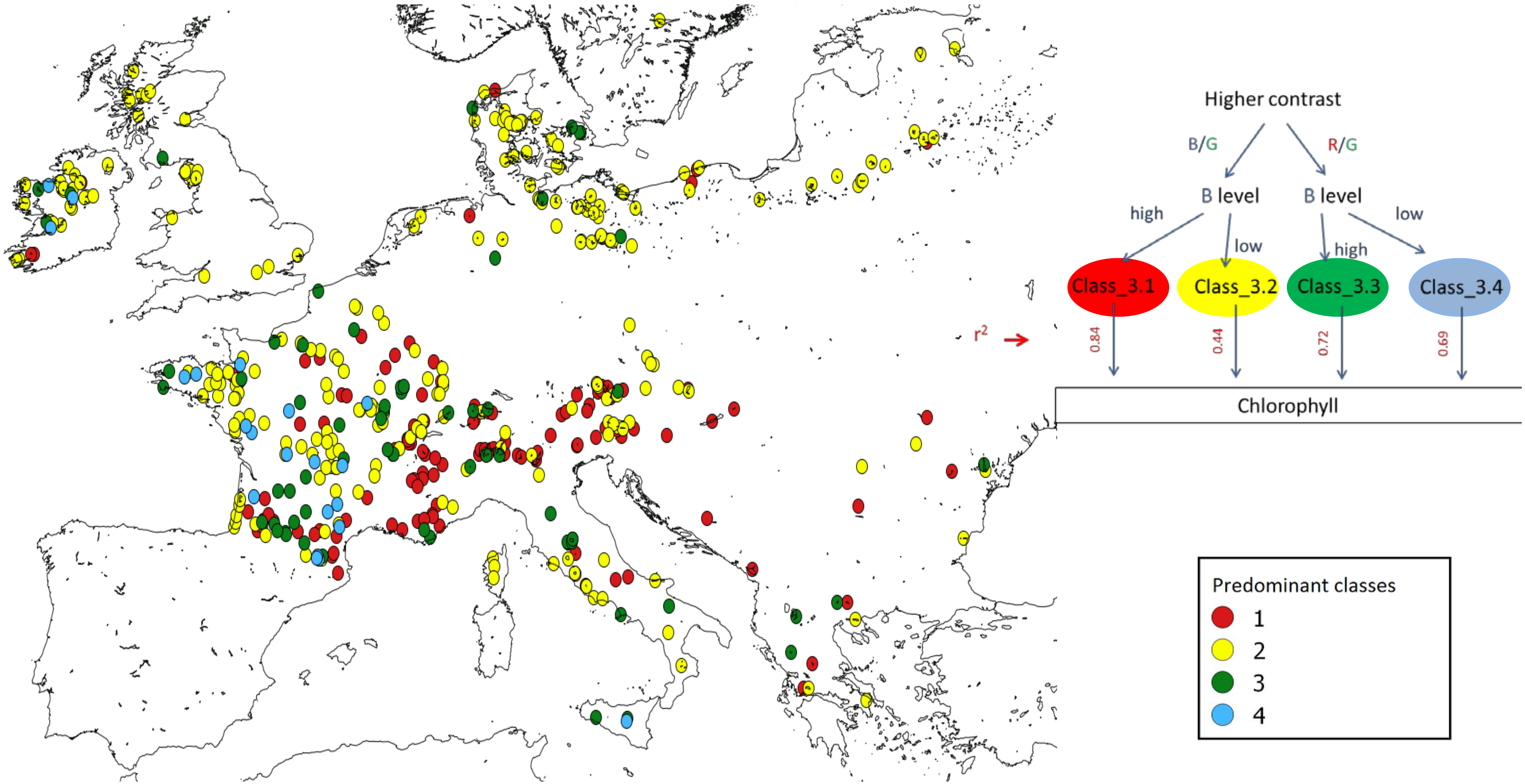
Color codes are following the standards state/pressure from De Bortoli et Argillier (2008)

Quality levels are depending on surface chlorophyll concentrations and lakes depths

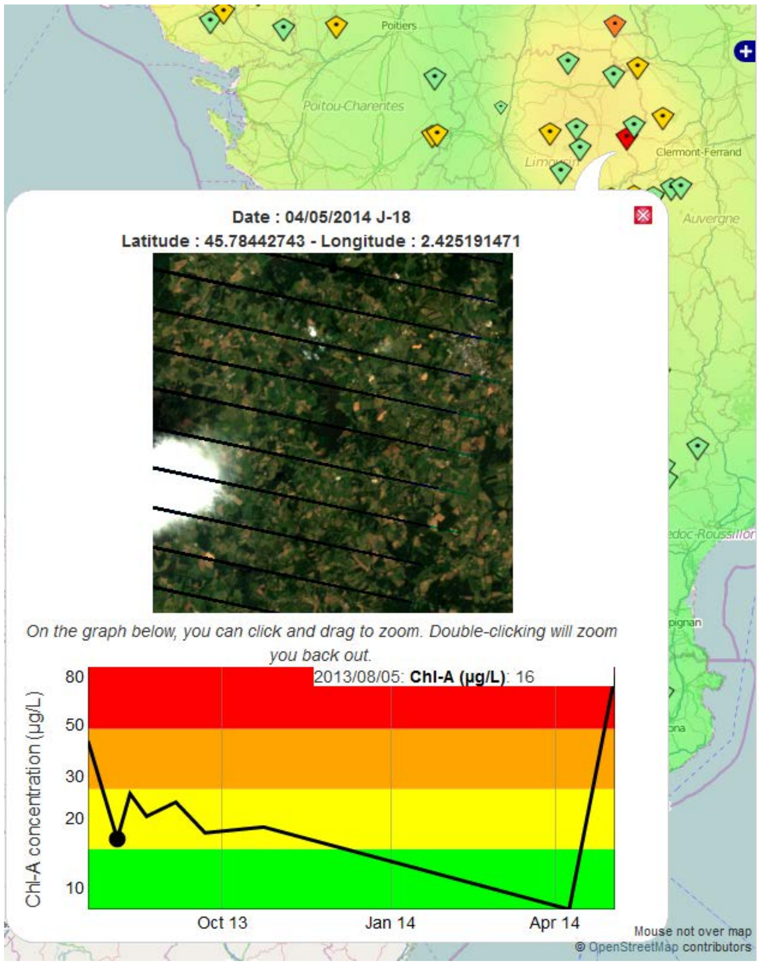


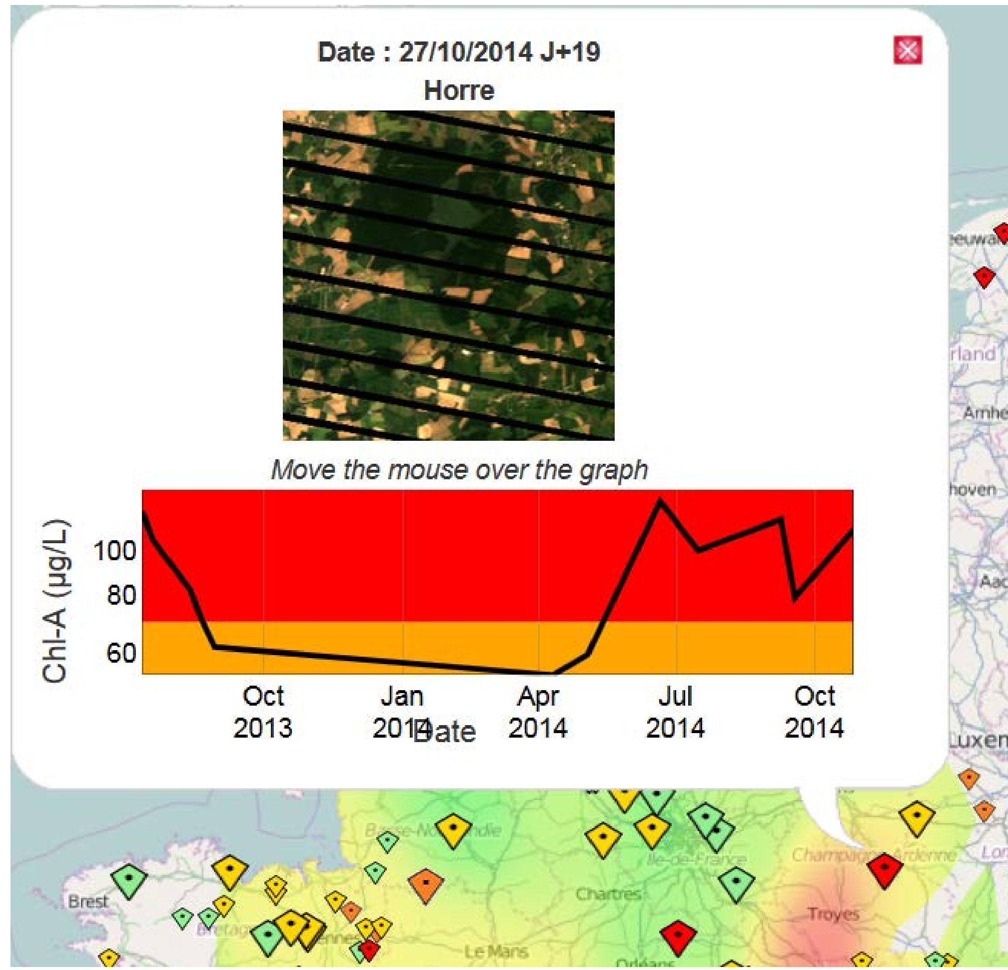
The tool is presently used for validation to detect temporal and/or spatial artifact

## Stability of lake classification



The tool is presently used for validation to detect temporal and/or spatial artifact



## Atmospheric correction

- Use of the mixed landscape (water + land) to derive (robust) atmospheric correction
- Reasonable assumption is stability of aerosols over one scene
- Aerosols absorption not considered
- Adjacency effects not considered (has to be evaluated and considered in a quality indicator)

## Chlorophyll derivation

- Already operational and under large scale evaluation
- Adaptation to Landsat-8 done
- Quality of in situ data needs to be better described

## Operational system

- Fully (and easily) adaptable to Sentinel-2

## Validation

We are in a process of setting up a validation “club” for the **eyeonwater.eu** open to

- Scientists
- Institutions in charge of WQ monitoring
- Large public

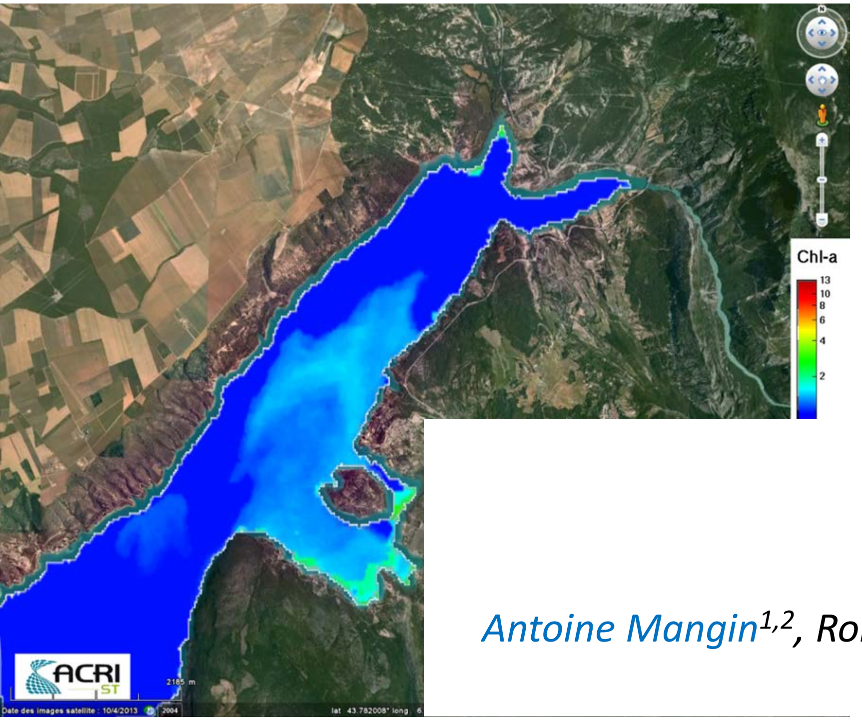
To get feedback on the site, validation material, in situ truth

If you are interested you are welcome ! (send a mail from the site)

## Operational system

We are fully open to implement and run other algorithms (AC and WQ) for cross-evaluation and improvements of the system.

For both aspects, if you are interested you are welcome !
(send a mail from the site)




**Water quality of lakes over Europe using Sentinel-2;**
**Atmospheric Correction and Validation**

*Antoine Mangin[1,2], Romain Serra[1], Chloé Chauvin[1], Odile Hembise Fanton d'Andon[2]*
*(1) ACRI-HE, France; (2) ACRI-ST, France*

# Thank you for attention

antoine.mangin@acri-st.fr

**Eyeonwater.eu**