SPPA
Sensor Performance, Products and Algorithms

# Atmospheric Correction and Vicarious Calibration of MERIS/OLCI

Constant Mazeran, sol√o, France

In collaboration with Jean-Paul Huot (ESA/ESTEC)
& Gerald Moore (Bio-Optika)

# Content

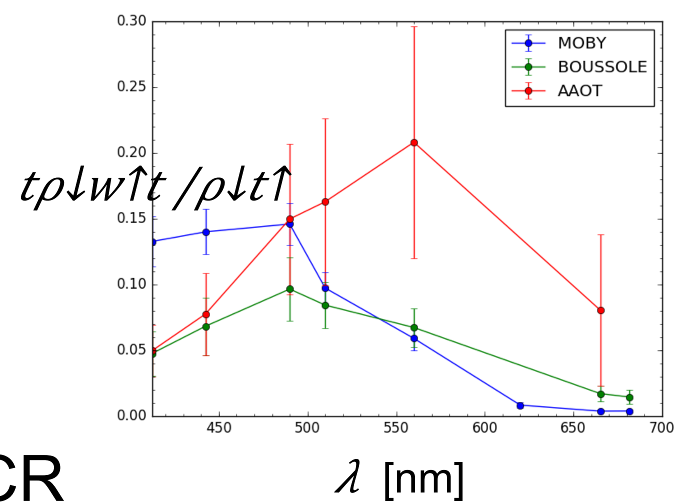
- Atmospheric correction: principle, Black Pixel vs Bright Pixel
- Bright Pixel Atmospheric Correction (BPAC): model, issues, algorithm, validation
- System Vicarious calibration (SVC): MERIS, uncertainties, OLCI

# Ocean Colour Radiometry (OCR)

- Colour of the ocean with the atmosphere above

$$\rho_{t}(\lambda)=t_{g}(\lambda)(\rho_{R}(\lambda)+\rho_{a}(\lambda)+\rho_{aR}(\lambda)+T\rho_{G}(\lambda)+t\rho_{w}(\lambda))$$

Marine reflectance $\rho_{w}$ is only a small part of the TOA signal (~ 10%)

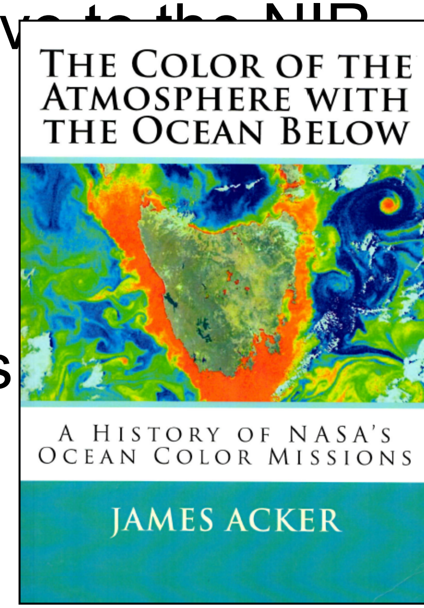



- The sources of uncertainty for OCR
  - Atmospheric scattering functions
  - Calibration, including SVC

$$\rho_{w}(\lambda)=g(\lambda)*\rho_{gc}(\lambda)-\rho_{path}(\lambda)/t(\lambda$$

# Atmospheric correction

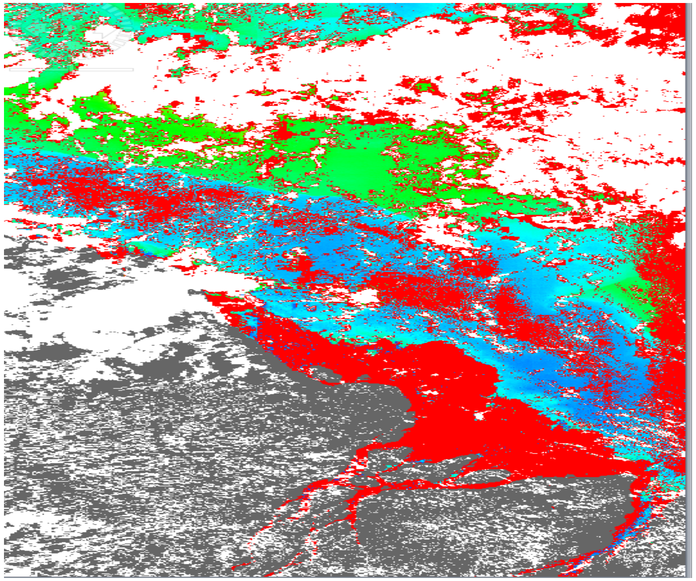
- *Standard* AC used in MERIS/OLCI (Antoine & Morel 1999)
  - Black pixel assumption: aerosol detection in the NIR
  - Pros: no assumption on marine modelling in the VIS
  - Cons: aerosol detection is highly sensitiv




- The case of Bright pixel
  - Marine signal in the NIR
  - Need to decouple atm. & marine signals

# 3RP BPAC issues

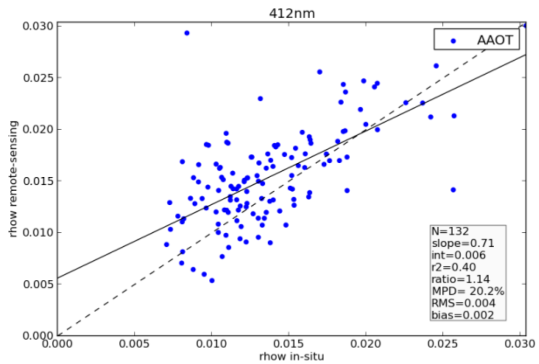
- Negative reflectance for (very) turbid waters



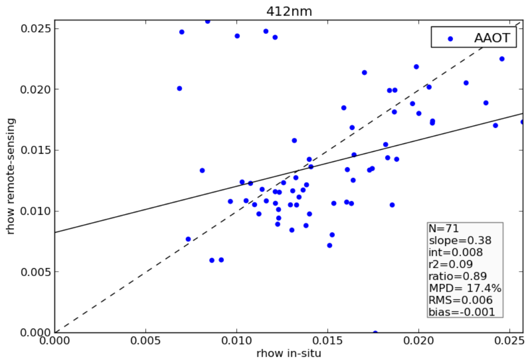
$\rho_w$ (412)

PCD_1_13

- Too strong sensitivity to NIR calibration




Applying NIR vicarious gains



# The BPAC model (Moore 2011)

1) Marine IOPs + Petzold phase function

$$b_{bp}(\lambda) = b_{bp}(\lambda_0)\left(\frac{\lambda}{\lambda_0}\right)^{-S_b}$$

$$a_p(\lambda) = a_p(\lambda_0)e^{-S_a(\lambda-\lambda_0)}$$

2) Marine AOP through radiative transfer

$$\omega(\lambda) = \frac{b_{bw}(\lambda) + b_{bp}(\lambda)}{a_w(\lambda) + a_p(\lambda) + b_{bw}(\lambda) + b_{bp}(\lambda)}$$

$$\eta(\lambda) = \frac{b_{bw}(\lambda)}{b_{bw}(\lambda) + b_{bp}(\lambda)}$$

$$F'(\lambda,\eta,\omega) = A_0(\lambda) + A_1(\lambda)\eta + a_0(\lambda) + a_1(\lambda)\omega + a_2(\lambda)\omega^2 + a_3(\lambda)\omega^3 + a_4(\lambda)\omega^4$$

$$\rho_w(\lambda) = F'(\lambda,\eta,\omega) * \omega(\lambda)$$

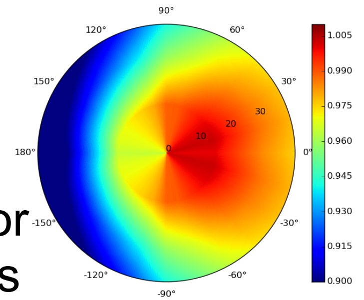
3) Atmospheric & TOA model

$$t(\lambda) = e^{-\left(0.5\tau_R(\lambda) + (1-f\omega_a)\tau_a(\lambda_0)\left(\frac{\lambda}{\lambda_0}\right)^{\alpha}\right)M}$$

$$\rho_a(\lambda) = \rho_a(\lambda_0)\left(\frac{\lambda}{\lambda_0}\right)^{\alpha}$$

$$\rho_{RC}(\lambda) = t(\lambda)\rho_w(\lambda) + \rho_a(\lambda)$$

4) Free variables, justified by a sensitivity analysis: $b_{bp}(\lambda_0)$, $\rho_a(\lambda_0)$, $\alpha$

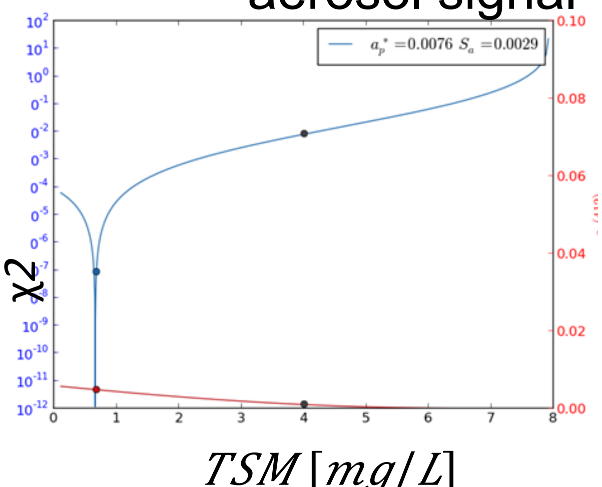



Remark: this model can be used for BRDF correction over turbid waters

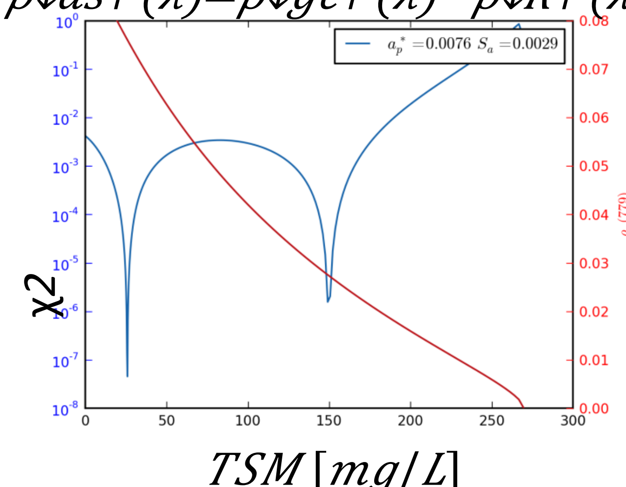
# Understanding the BPAC issues

## 1. Ambiguity in the BPAC model

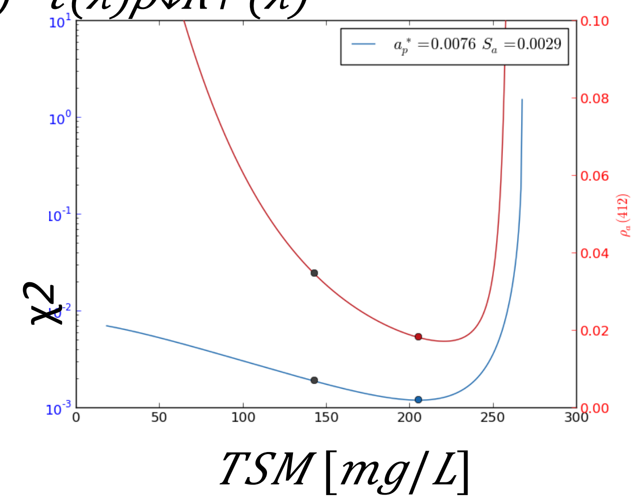
- Several solutions may be possible depending on TSM and bands
- For any TSM, compute the $\chi^2$ of the log-log fit of the remaining aerosol signal $\rho_{as}(\lambda)=\rho_{gc}(\lambda)-\rho_{R}(\lambda)-t(\lambda)\rho_{R}(\lambda)$




Clear water: unique solution when considering 709+779+865




Very turbid water: two solutions when considering 709+779+865

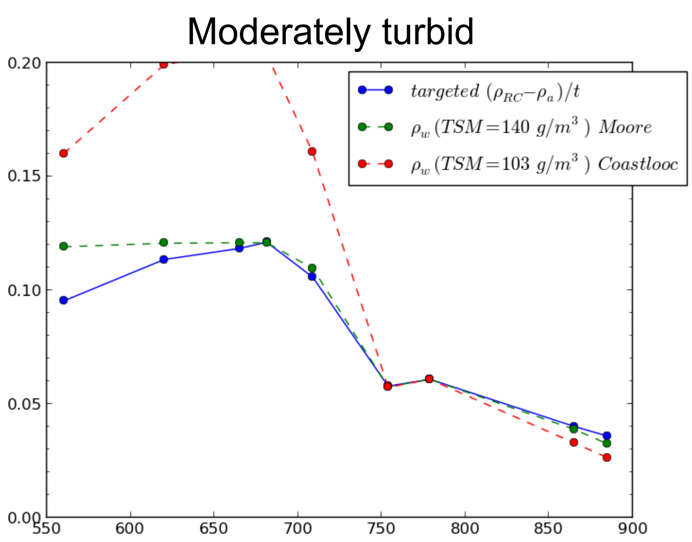


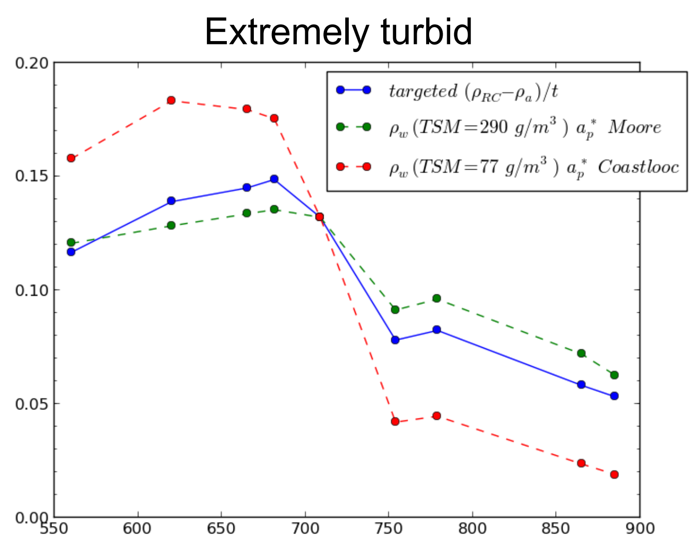

Very turbid water: unique solution when considering the five NIR bands

# Understanding the BPAC issues

## 2. Suitability of the marine model with respect to $a_p$

- Particulate absorption is the most important fixed parameter over very turbid water
- Various ap exist in the literature

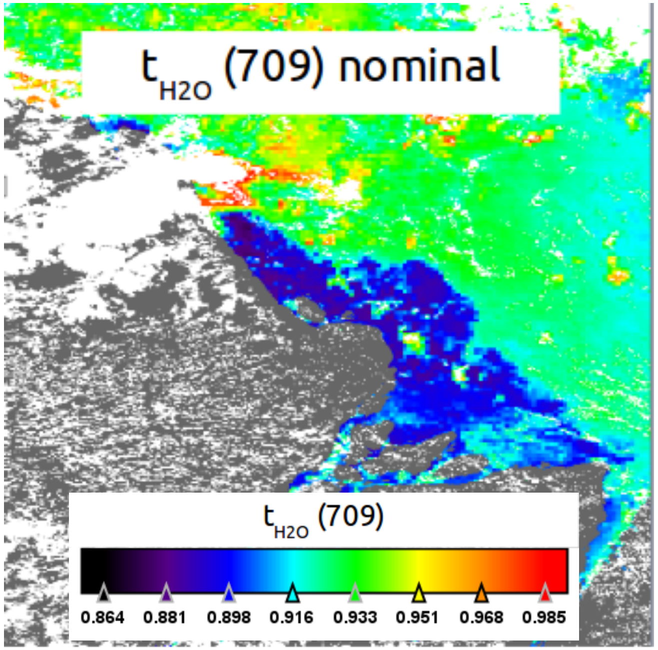


# Understanding the BPAC issues

## 3. Water vapour issue

- MERIS band 709 nm is theoretically very useful for remote-sensing of coastal waters, but:
  - It is impacted by H2O absorption (885 nm as well)
  - H2O correction is based on the 900/885 ratio using the "black pixel" assumption

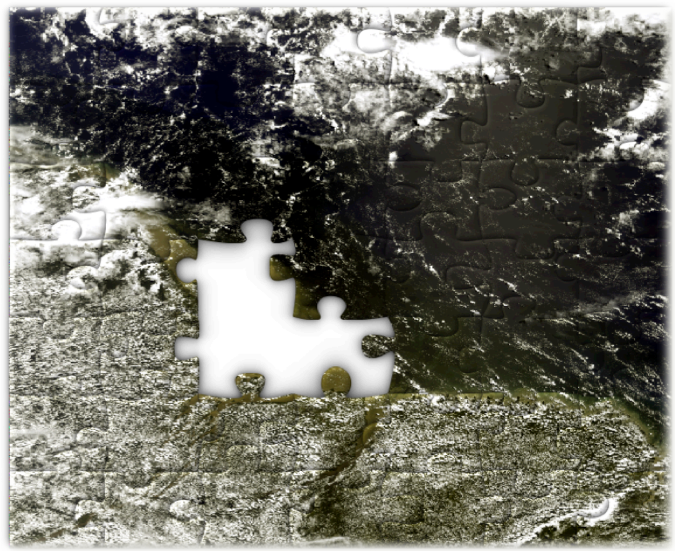



TOA errors over the Amazon:

510 nm: ~ 0.6%
681 nm: ~ 0.1%
753 nm: ~ 0.1%
**709 nm: ~ 3.5%**
779 nm: ~ 0.1%
865 nm: ~ 0.2%
**885 nm: ~ 1.5%**

# Understanding the BPAC issues

1. **Ambiguity in the BPAC model**



2. **Suitability of the marine model with respect to $a_p$**

3. **Water vapour issue**

# Algorithm for MERIS 4th reproc. and OLCI (ATBD 2.6)

1. **Ambiguity in the BPAC model**
   → Removed when $\chi^2$ mainly constructed by 753, 779, 865 nm

$$\chi^2 = \sum_{\lambda} \left(\frac{r(\lambda)}{\sigma(\lambda)}\right)^2$$

$$r(\lambda) = t(\lambda)\rho_w(\lambda) + \rho_a(\lambda_0)\left(\frac{}{\lambda_0}\right)^{\alpha} - \rho_{RC}(\lambda)$$

$\sigma^2(709)$ and $\sigma^2(885)$ growing with TSM

No more iterative first guess with TSM=0

2. **Suitability of the marine model with respect to $a_p$**
   → Sediment absorption weakly impacts $\chi^2$ at high turbidity

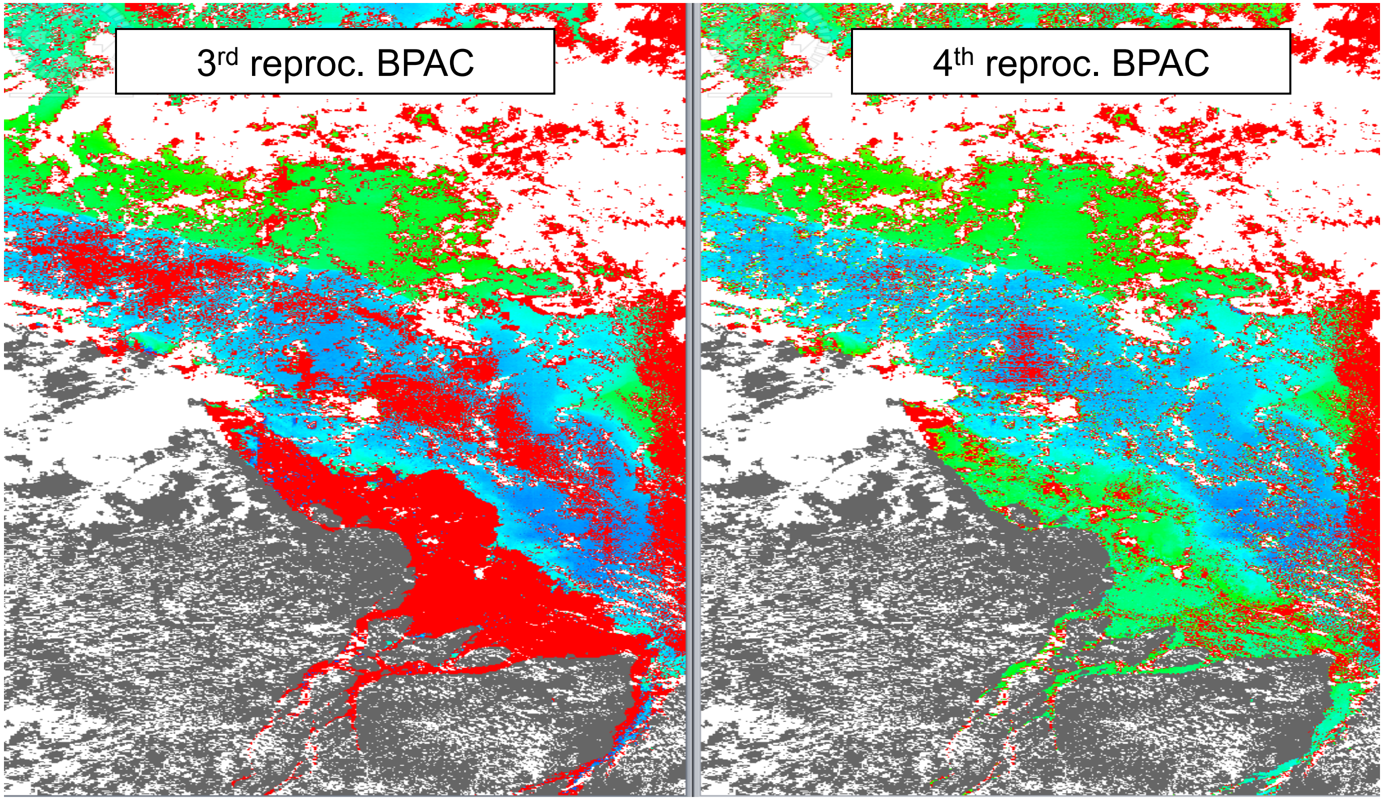
3. **Water vapour issue**
   → Does not impact $\chi^2$

Other conclusion for MERIS: NIR vicarious calibration (inter band) is no more strictly required

# Results: the Amazone plume

$\rho_w$ (412)

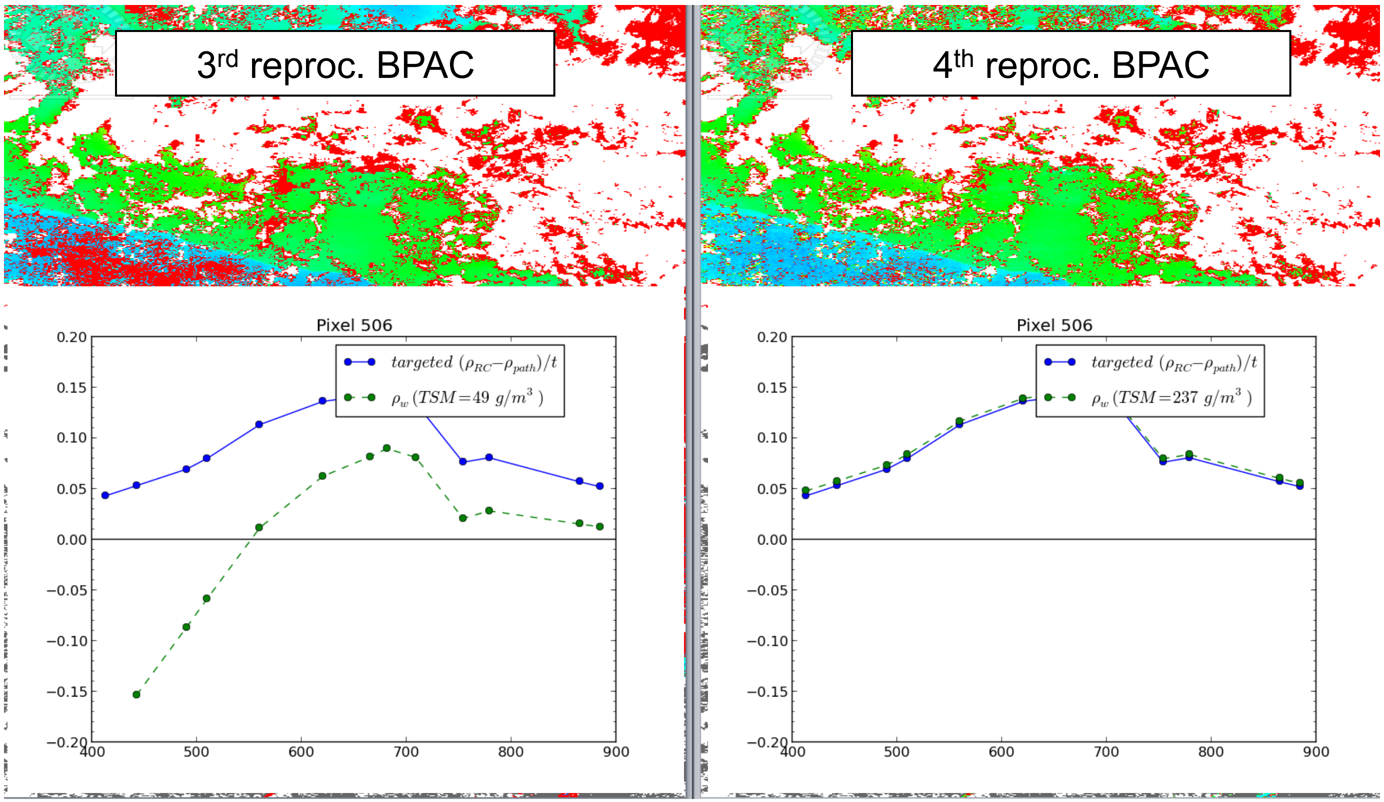
PCD_1_13



# Results: the Amazone plume

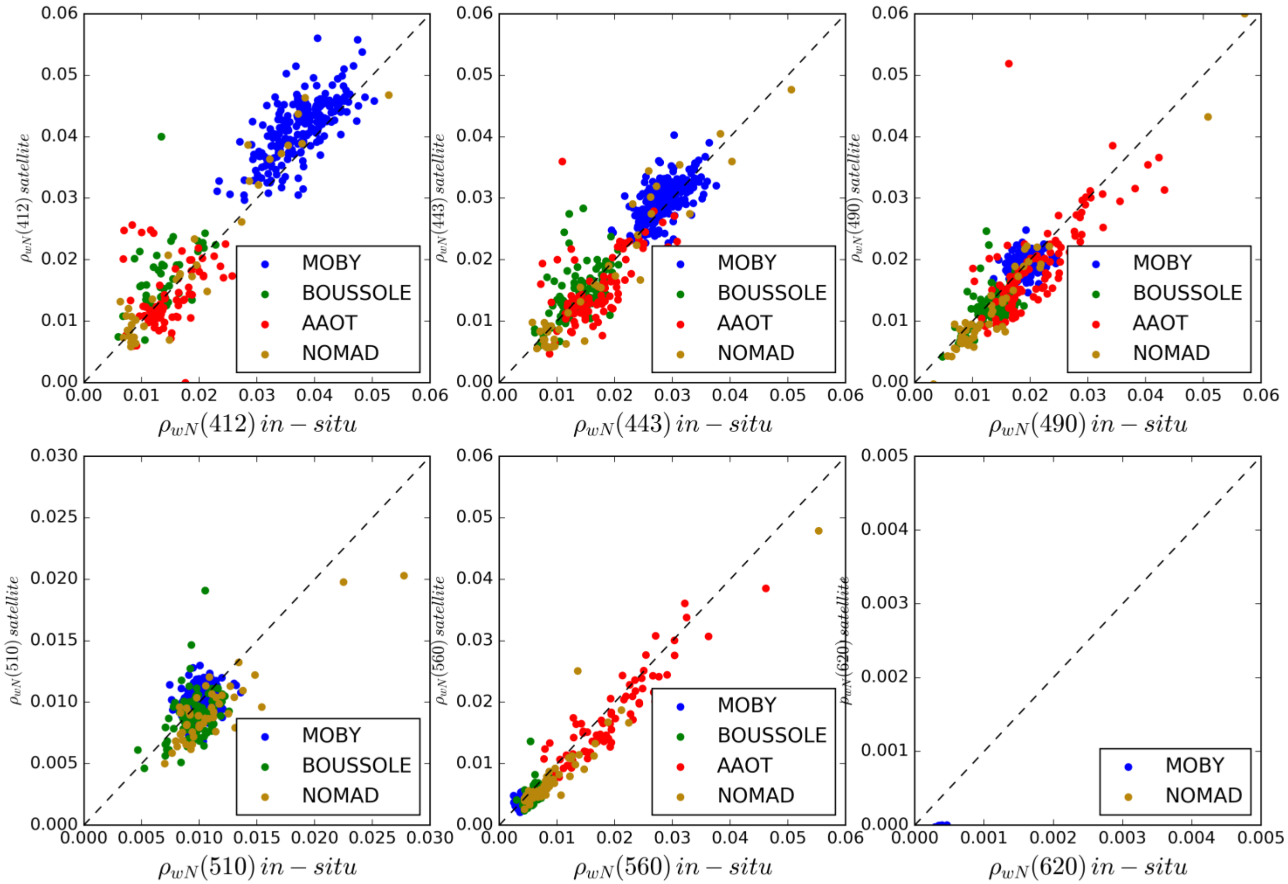
$\rho_w$ (412)

PCD_1_13



# Validation: MERMAID match-ups

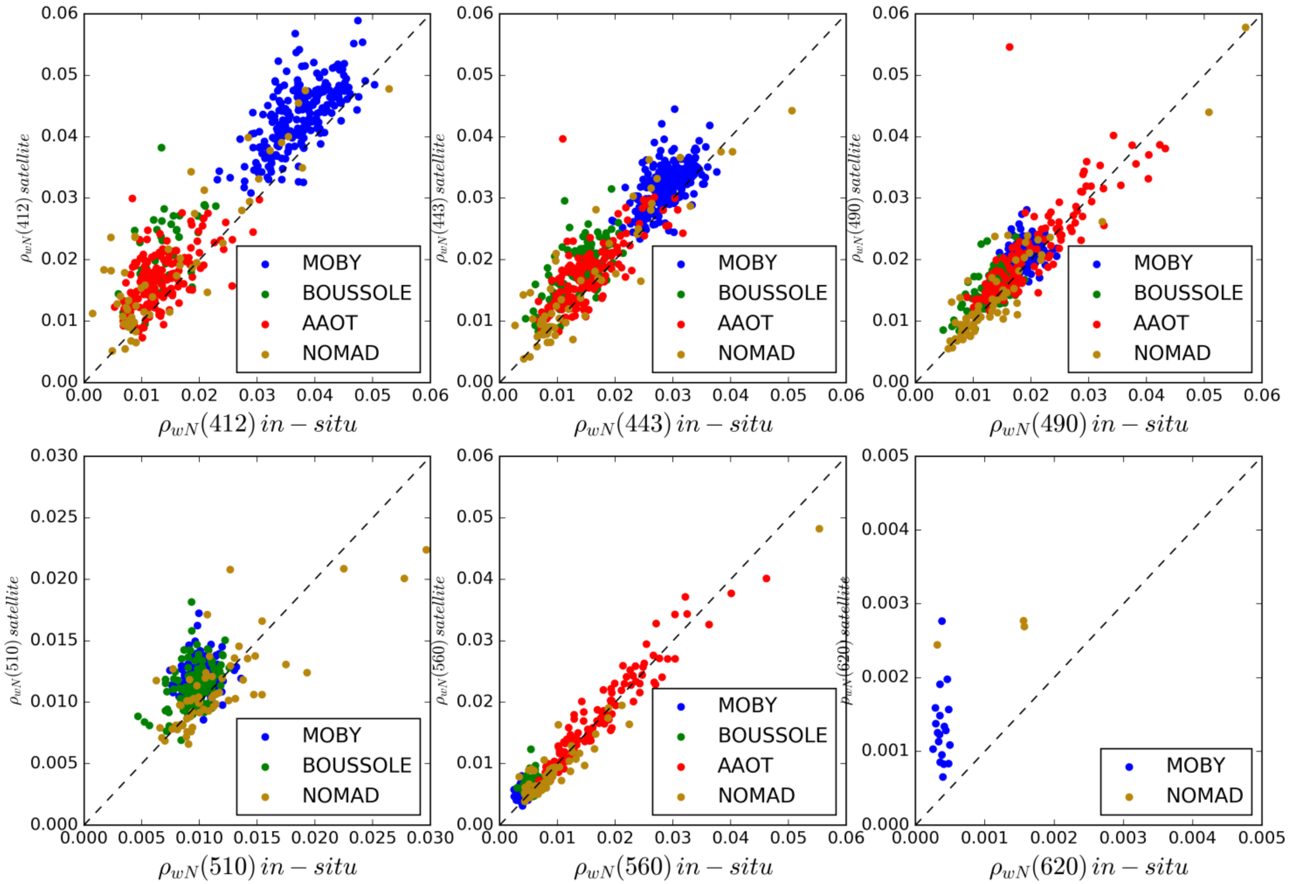
3RP BPAC (before VIS vicarious cal.)




Acknowledgements to ACRI & ESA for MERMAID and to PIs: G. Zibordi, JRC (AAOT), D. Antoine, LOV (BOUSSOLE) , K. Voss, Univ. Miami (MOBY), Werdell and Bailey 2005(NOMAD)

# Validation: MERMAID match-ups

## 4RP BPAC (before VIS vicarious cal.)




More consistent biases between different water types → there is a chance to have a <u>global</u> positive impact of VIS vicarious cal.

Acknowledgements to ACRI & ESA for MERMAID and to PIs: G. Zibordi, JRC (AAOT), D. Antoine, LOV (BOUSSOLE) , K. Voss, Univ. Miami (MOBY), Werdell and Bailey 2005(NOMAD)

# Validation: very turbid waters

## In collaboration with Pierre Gernez, Univ. Nantes

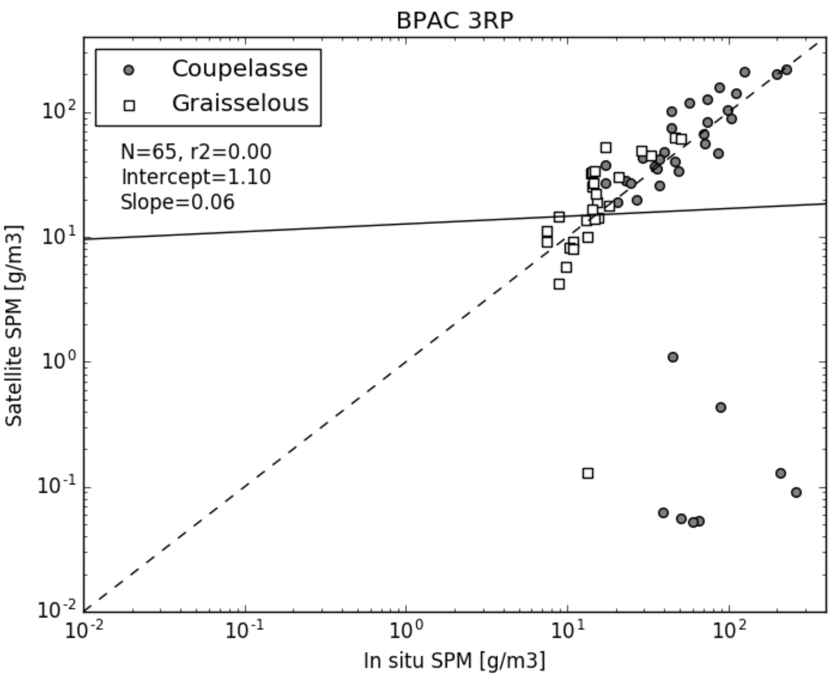
- Bourgneuf Bay
- In situ TSM from Dutertre et al 2009


- Data & method:
  - MERIS Full Resolution data (MERCI)
  - Match-up extraction (BEAM)
  - Pixel selection (closest underwater pixel to the station)
  - Time interpolation of in situ TSM to MERIS time
  - Processing (ODEAS)
  - Regional TSM model from marine reflectance (Gernel et al. 2014)

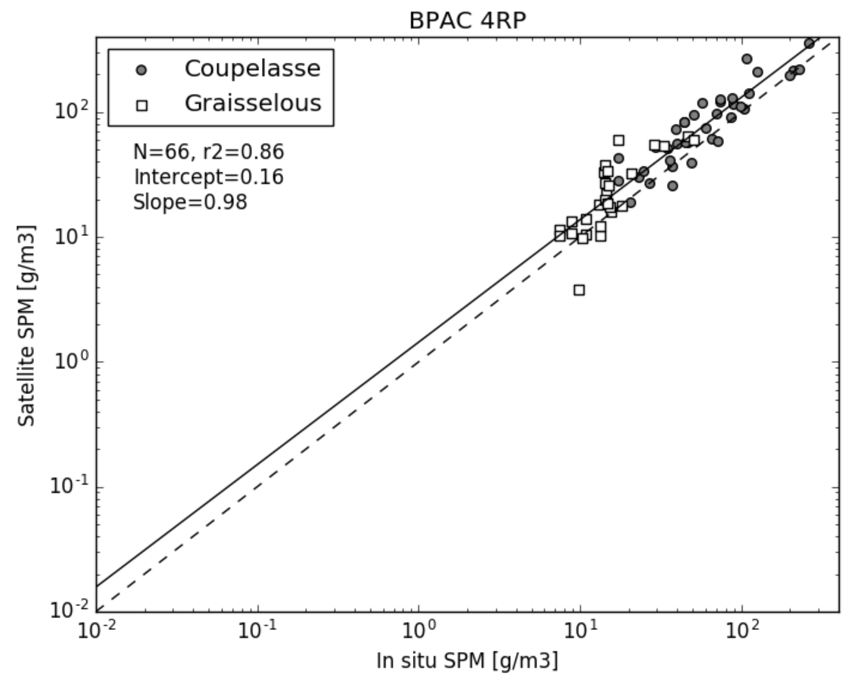
# Validation: very turbid waters

## In collaboration with Pierre Gernez, Univ. Nantes

3RP BPAC

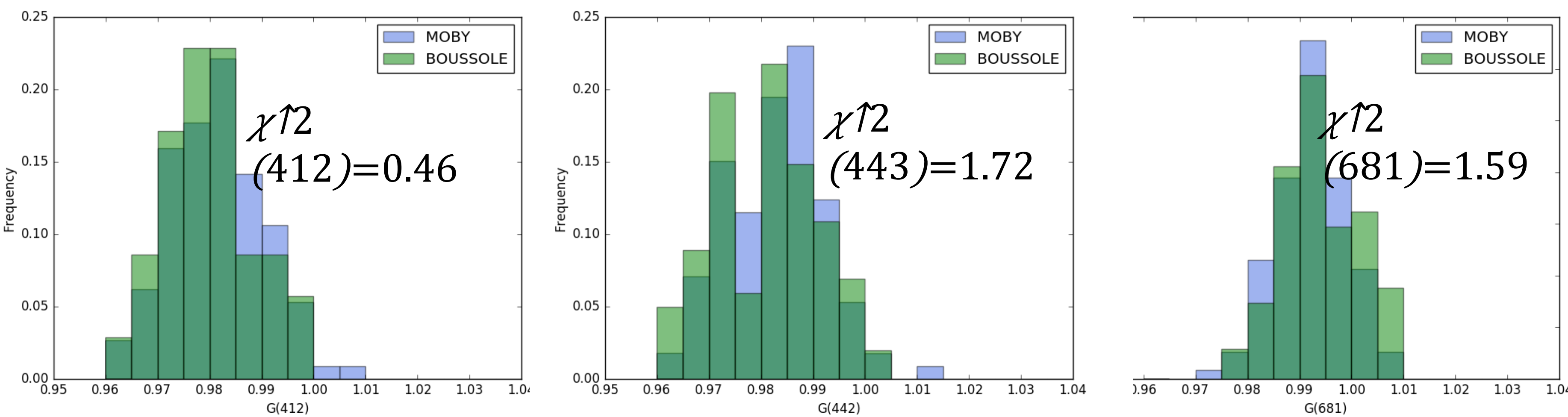



4RP BPAC



# MERIS SVC for 4RP

- SVC gain definition: $g(\lambda)=(t(\lambda)\rho_w^t(\lambda)+\rho_{path}^t(\lambda))/\rho_{gc}^t(\lambda)$
- Questions: uncertainties, choice of site(s) and consistency
- MOBY and BOUSSOLE gains agreement: Chi2 test of homogeneity: if $|g_M - g_B|/\sqrt{\sigma_M^2/N_M + \sigma_B^2/N_B} < 1.96$, there is 95% probability that both sets of gains belong to the same distribution



# SVC for OLCI

- Only few matchups: can we use a L3 climatology for $\rho_w^t$?
  - Limiting factor is satellite, not in-situ (daily measurements exist at MOBY): several sites must be considered → consistency
  - Uncertainty due to using past $\rho$ data):

$$u(g)=t\rho_w^t/\rho_{ac}^t * u(\rho_w^t)/\rho_w^t$$

$$u(\rho_w^t) \approx std(\rho_w^t(past))$$

→ Stability of $\rho_w^t$ per L3 temporal bin needs to be within 5% for each site

G. Zibordi, F. Mélin / Remote Sensing of Environment 190 (2017) 122–136

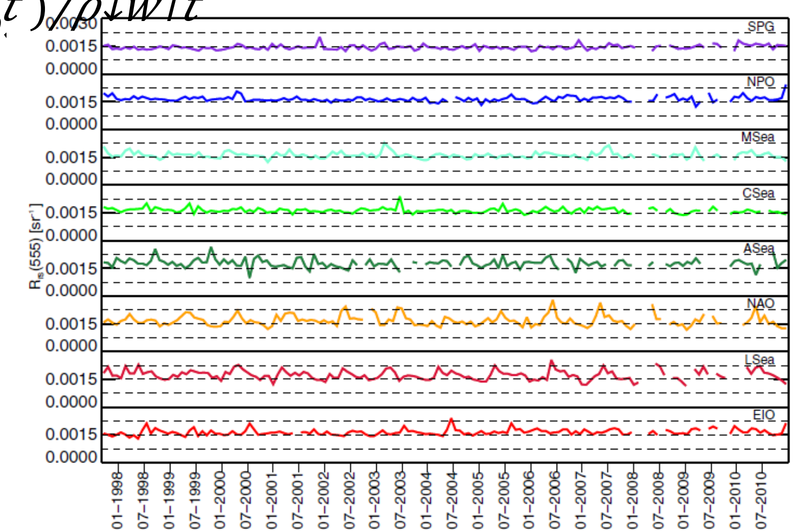



**Fig. 3.** Time-series of monthly values of $R_{rs}(555)$ for the various regions of interest.

# Conclusion: messages for SSPA

1. **OCR needs an integrated algorithmic approach**
   - Vicarious calibration depends on AC
   - AC depends on BPAC – even over clear waters
   - BPAC depends on upstream steps (glint, gas, NIR cal.)

2. **BPAC has been improved by working on the numerical inversion, while keeping same model**

3. **Check consistency of AC with AERONET data (for SVC)**

   → See Francis Zagolski's presentation

4. **Validation requires more match-ups and tools (data extraction). Plan for OLCI?**