ESA/MERIS vicarious calibration

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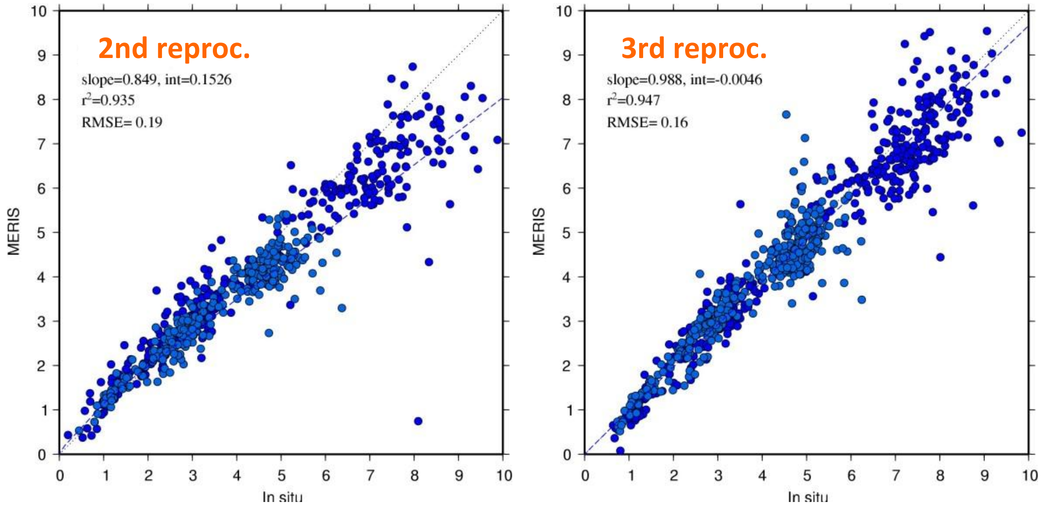
Context of the MERIS vicarious calibration

- **From 2002 to 2011: no vicarious calibration in MERIS 1st and 2nd reprocessing**
  - Significant bias in marine reflectance in the blue/green (Zibordi et al Geophys. Res. Lett 2006, Antoine et al JGR 2008)
- **2008: MERIS Quality Working Group advocated to implement a vicarious cal. in 3rd reproc.**
  - Start from the existing method of SeaWiFS and MODIS (Franz et al AO 2007, Bailey et al AO 2008)
  - 2009-2010: tests and development by ACRI-ST, under QWG and ESA supervision..many discussions…
  - January-February 2011: archive reprocessed at ACRI-ST
  - July 2011: public delivery of 3rd data reprocessing by ESA (past archive + rolling-archive)

$\rho_w(443)/\rho_w(560)$ (dark blue)

$\rho_w(490)/\rho_w(560)$ (light blue)

Dataset: MOBY+BOUSSOLE+NOMAD+SIMBADA



- **Documentation: https://earth.esa.int/instruments/meris/atbd/atbd_2.24_v1.0.pdf**
  - Lerebourg, C., Mazeran, C., Huot, J-P, Antoine, D., Vicarious adjustment of the MERIS Ocean Colour Radiometry, MERIS ATBD 2.24, Issue 1.0, 2011

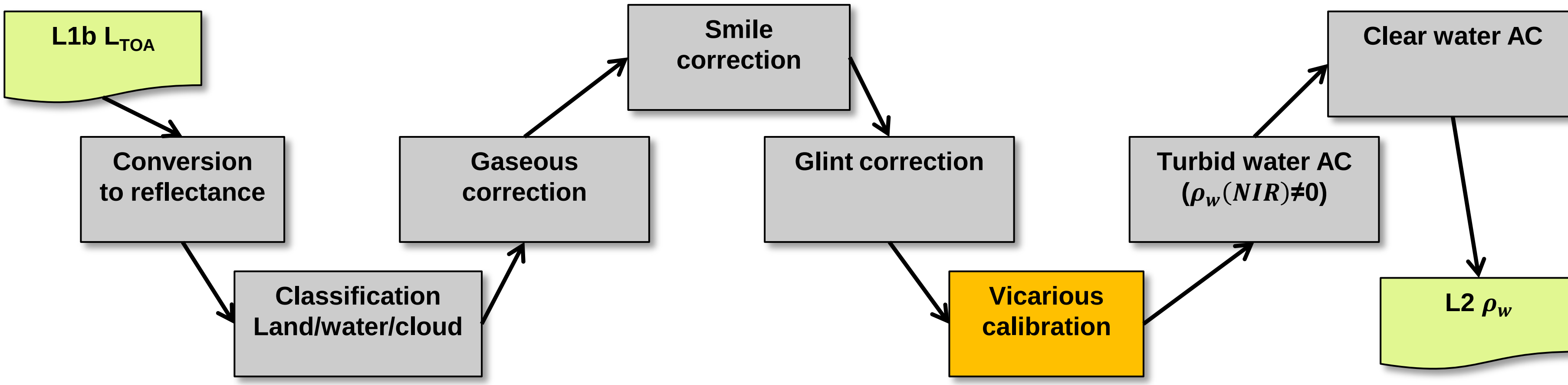
Comparison with SeaWiFS/MODIS approach

- **MERIS vicarious calibration follows the overall NASA/OBPG two-step approach**
  - Computation of gain factor in the NIR, over oligotrophic sites SPG & SIO
  - Computation of gains in the VIS $g(\lambda)$, based on in-situ $\rho_w(\lambda)$ to construct a targeted TOA signal
  - Analogous protocols to select the matchups (size of macro-pixel windows, data screening), average, median, etc.

- **But there are 3 main differences**
  1. Vicarious calibration is applied in the Level2 after some corrections (gaseous, smile correction, glint)
  2. NIR calibration is done:
     1. Without assuming as reference the farthest band of atmospheric correction (865 nm)
     2. Without assumption on aerosol model
  3. VIS gains are built on combined MOBY and BOUSSOLE measurements

#1 - Vicarious calibration within the Level 2 chain

- **Location of the vicarious cal. after some corrections**



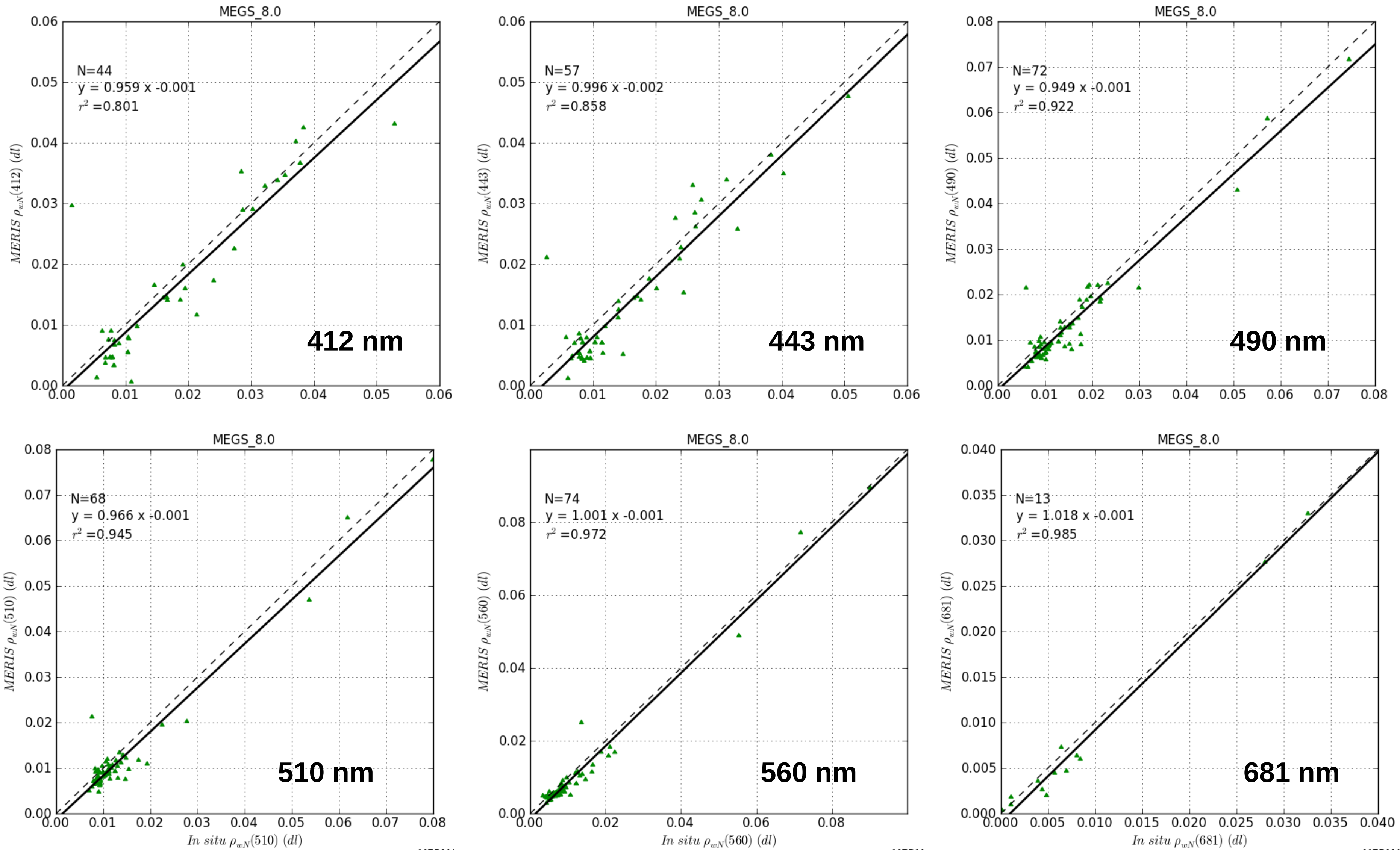
- **Reasons**
  - Non invertible processes in the Level2 chain (water vapour absorption, smile correction for λ CCD)
  - Calibration of the whole system {sensor+processing} (in particular AC, atmospheric LUT, etc.)

- **Issue with respect to glint correction - before versus after: $t\rho_G(\lambda) * (1 - g(\lambda))$**
  - Unsignificant differences were found between applying vicarious before/after glint correction, based on matchup analysis

- **Issue with respect to Bright pixel atmospheric correction (removal of $\rho_w(NIR) \neq 0$)**
  - Contrary to NASA processing, there is no iteration between BPAC and Clear Water AC
  - Gains are computed for clear waters (i.e. $\rho_w(NIR) \approx 0$), in part. SPG & SIO where BPAC has no impact
  - It was discovered that vicarious calibration in the NIR can make BPAC fail over turbid waters
  - The historical NIR vicarious cal. is mainly justified for clear water; more attention should be paid on impact on turbid water for future processing

#1 - Vicarious calibration within the Level 2 chain

Validation on NOMAD dataset (Werdell & Bailey, 2005; matchups from MERMAID)



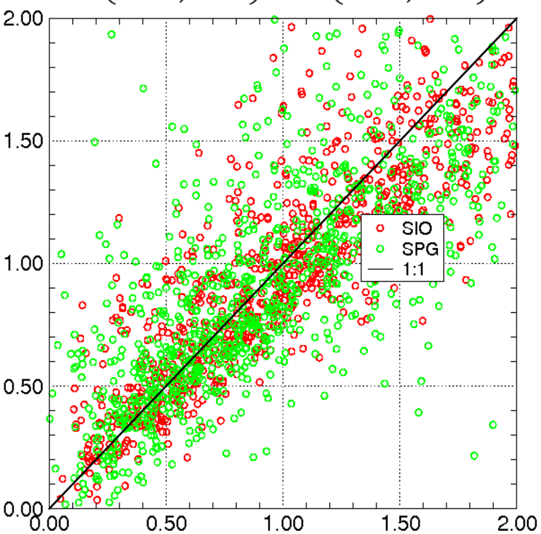
#2 -NIR calibration without assumption on aerosol

❖ Need for a NIR calibration

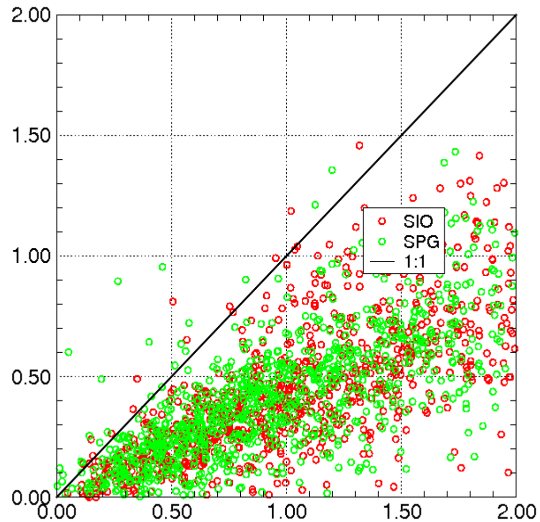
- A problem in the NIR spectral shape was identified at SPG & SIO, for band 865 (and 885 nm)
- Theoretical shape should be

$$\rho_{gc}^{t}(\lambda) = \rho_R(\lambda) + \rho_{aer}(\lambda_{ref})\left(\frac{\lambda}{\lambda_{ref}}\right)^{\varepsilon} + \overbrace{t\rho_w^{pw}(\lambda)}^{\text{pure seawater}}$$

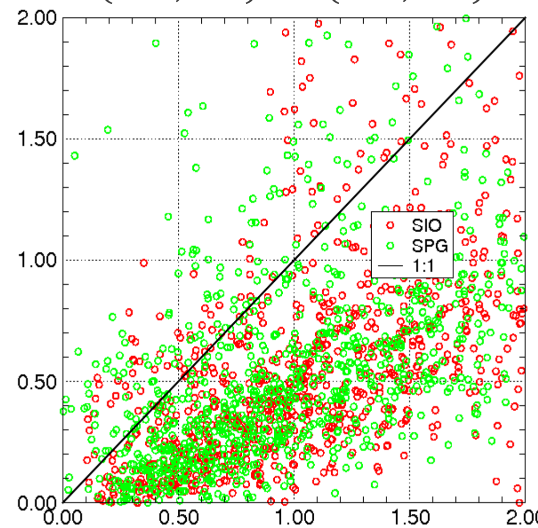
ε(709,753) vs ε(665,753)



ε(709,753) vs ε(778,865)



ε(709,753) vs ε(753,865)



- Problem may come from Level1 issue (straylight), but the NIR vic. was asked to solve it in 3rd reproc.

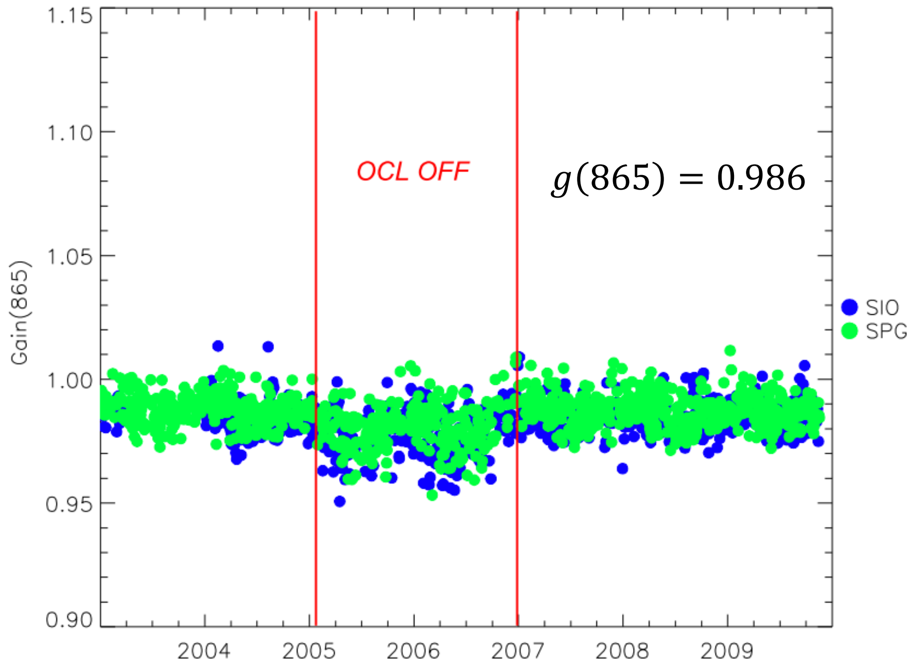
❖ Method

- Consider 709 and 779 nm bands as baseline
- Calibrate 865 nm on the spectral shape, with $\rho_{aer}(\lambda_{ref})$ and ε as free parameters
- Sensitivity analysis on RTM data (F. Zagolski, MEROS simulation): accuracy of 0.1% and precision better than 1%

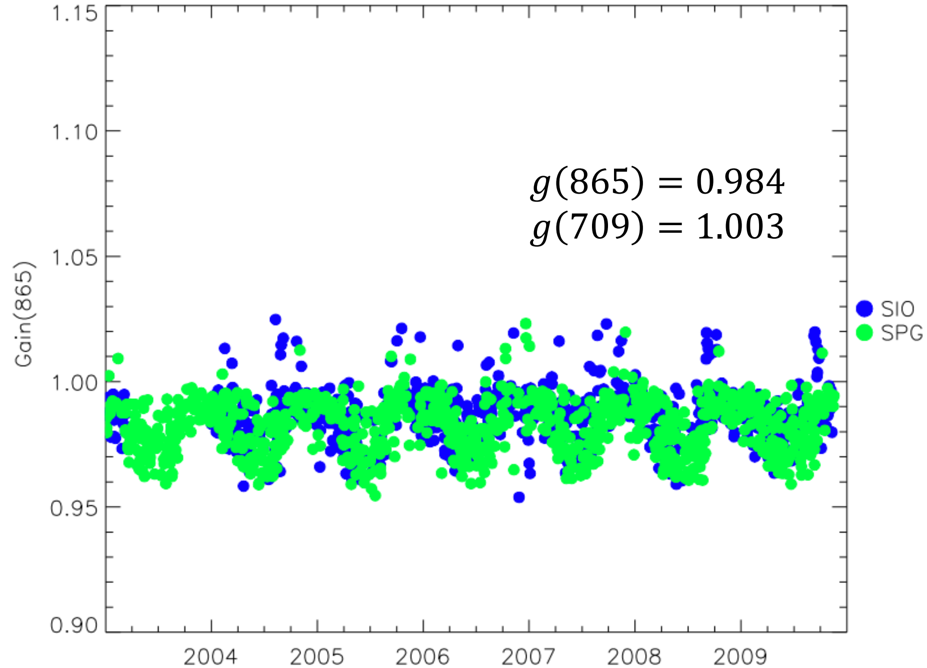
#2 -NIR calibration without assumption on aerosol

❖ **NIR gains time-series and averaged value**

Spectral shape method



If fixed aerosol model (MAR90)



- **Very good consistency between SPG and SIO**
- **Uncertainties similar to NASA's computation σ(865)=0.006 and σ(885)=0.01 (SeaWiFS: σ(765)=0.010)**
- **The spectral shape approach is much robust to seasonal effects; less dependence on scattering angle**

- **A distinctive period appears (13/12/2004-09/10/2006): de-activation of the Offset Control Loop (dark current correction) - not included in our statistics**

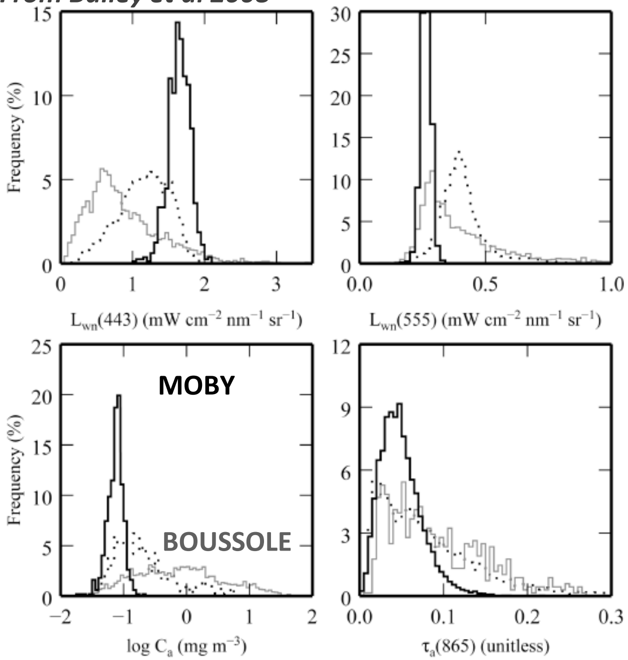
#3 - VIS gains on MOBY and BOUSSOLE

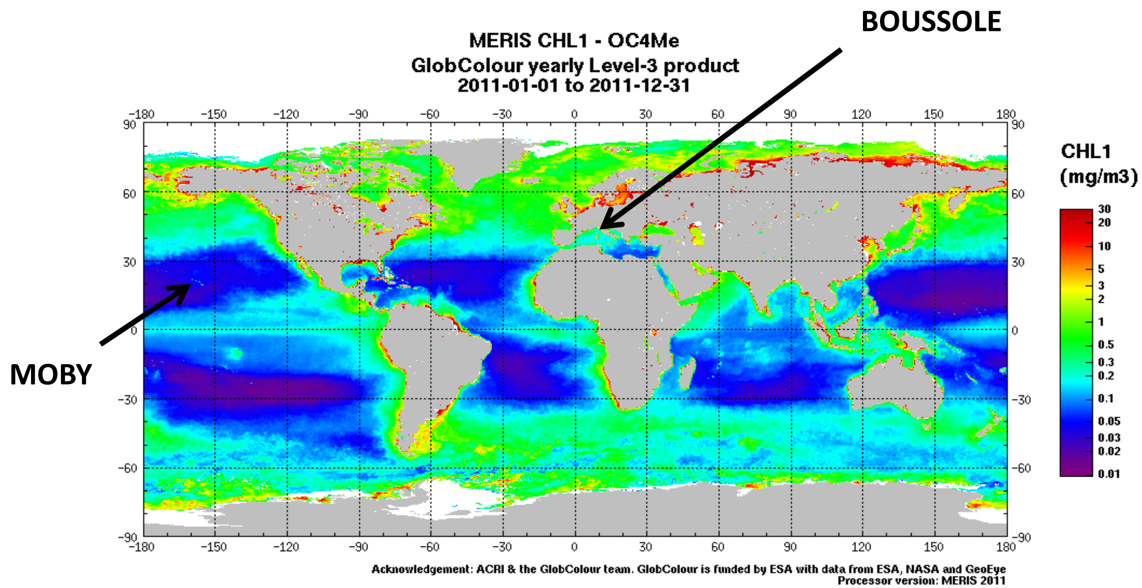
- A unique VIS gain cannot correct for different biases of several datasets

$$g(\lambda) = \frac{\rho_{gc}^{t}(\lambda)}{\rho_{gc}(\lambda)} = 1 - \underbrace{\left(\frac{t_d(\lambda)\,\rho_w^{in\ situ}(\lambda)}{\rho_{gc}(\lambda)}\right)}_{\%\text{ of marine signal}} \underbrace{\left(\frac{\rho_w(\lambda) - \rho_w^{in\ situ}(\lambda)}{\rho_w^{in\ situ}(\lambda)}\right)}_{\text{relative error}}$$

- Choice of the dataset for a global calibration
  - Representative of a « global state »…
  - Long-term time-series, sound protocols and quality checks
  - Statistically signifiant number of points
  - → MOBY (Clark et al. 2003) and BOUSSOLE (Antoine et al. 2006, Antoine et al. 2008) buoys

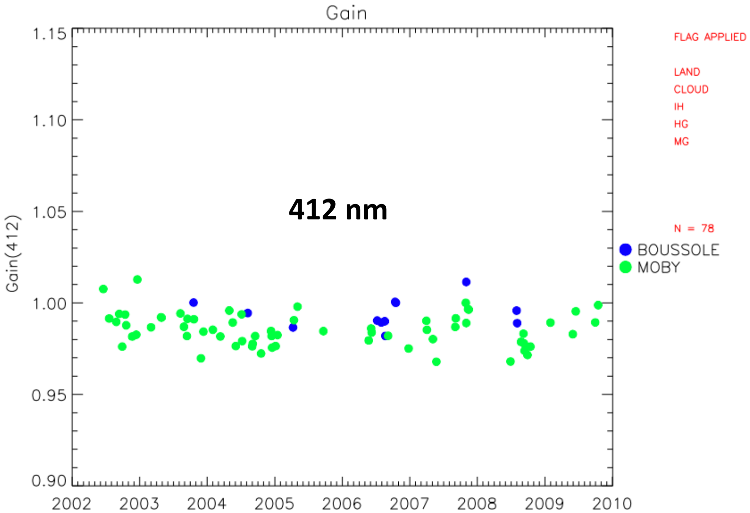
From Bailey et al 2008

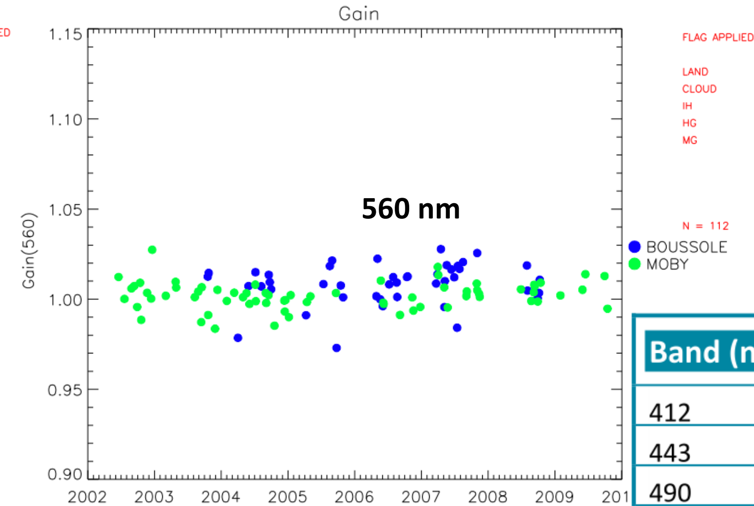




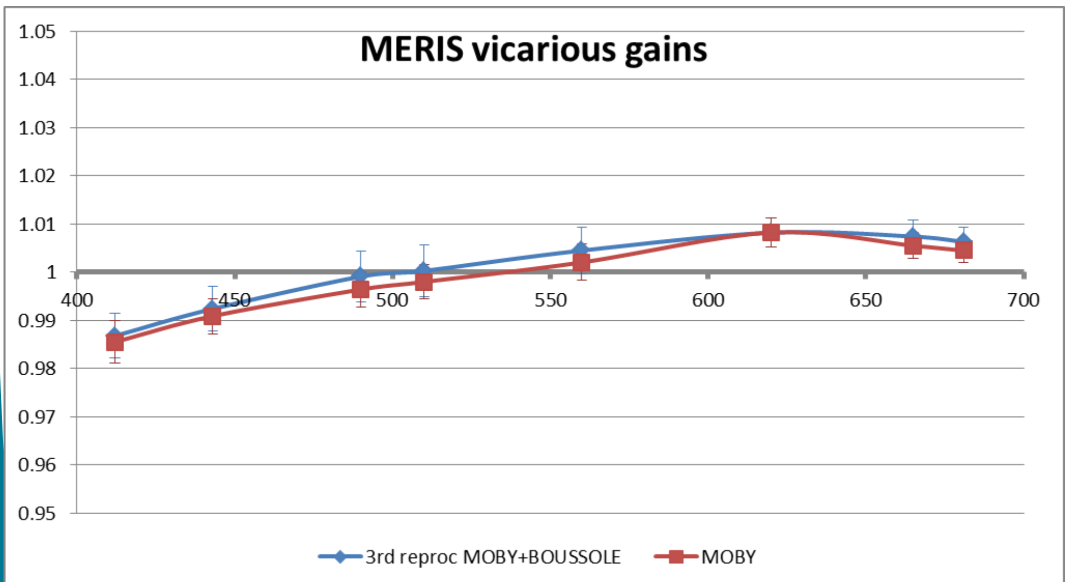
#3 - VIS gains on MOBY and BOUSSOLE

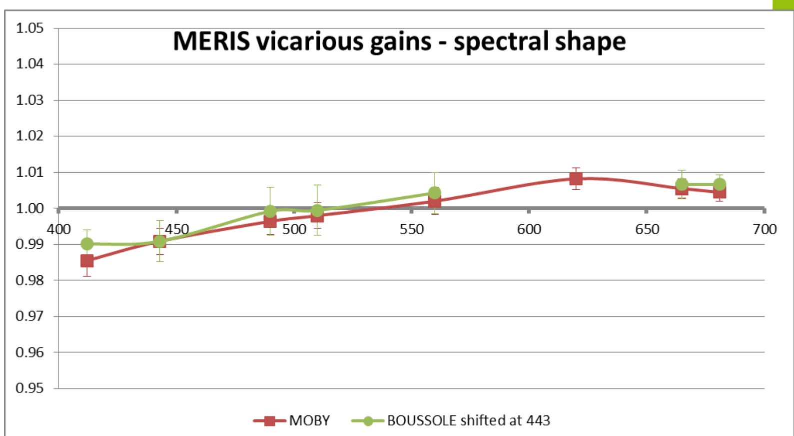
❖ VIS gains time-series and averaged values





Band (nm)	Gain	Std-dev	N
412	0.9868	0.0093	78
443	0.9924	0.0092	105
490	0.9991	0.0105	108
510	1.0003	0.0107	113
560	1.0045	0.0097	112
620	1.0082	0.0060	67
665	1.0074	0.0069	106
681	1.0063	0.0059	94

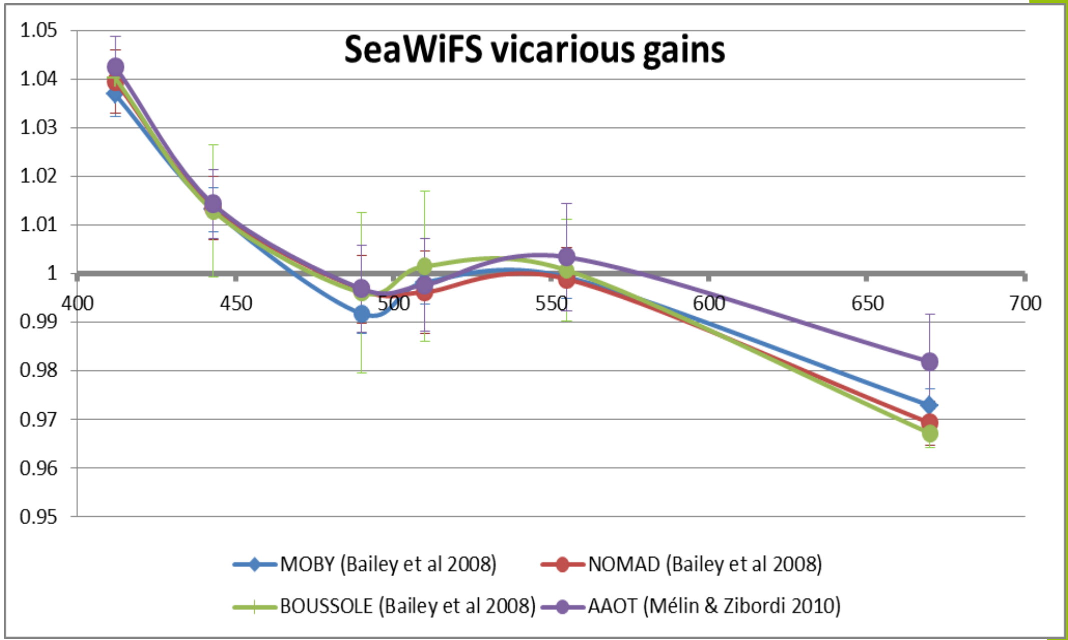


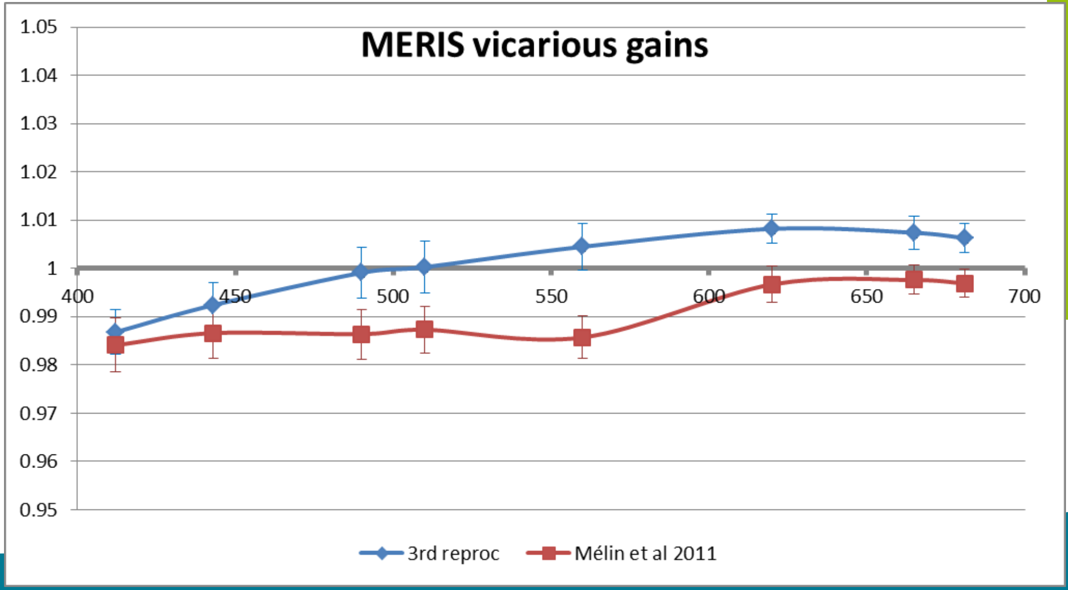


#3 - VIS gains on MOBY and BOUSSOLE

- **Comparison with other approaches**
  - SeaWiFS - Bailey et al 2008: "Vicarious calibration coefficients derived from both the NOMAD and BOUSSOLE data sets are quite comparable to the standard MOBY-derived coefficients"
  - SeaWiFS - Mélin & Zibordi 2010: Factors considered for <u>regional</u> and not <u>global</u> applications : "In general, the coefficients obtained at the coastal sites are fairly consistent with the NASA coefficients, and the difference between two sets is lower than one standard deviation " [with NASA NIR gains]
  - MERIS - Mélin et al 2011: no NIR calibration, SeaDAS processing, MOBY data only

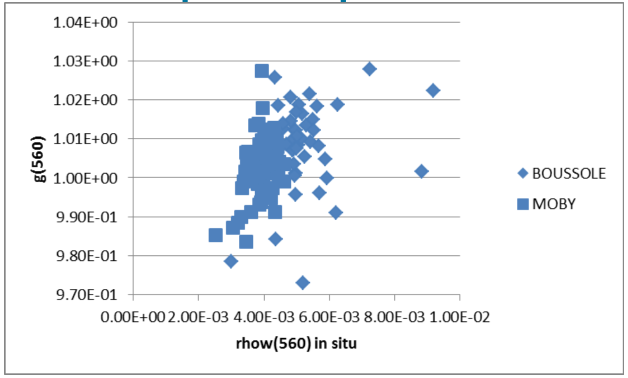
→ clearly the major driver is the atmospheric correction





Summary and concluding remarks

- **NIR spectral shape calibration is simple and robust**
  - Do we need to consider another target in the Northern Hemisphere?
  - Impact on the Bright Pixel Atmospheric Correction must be considered carefuly
- **Joint use of BOUSSOLE + MOBY for vicarious**
  - Help to add more points
  - Very consistent spectral shape in the gain
  - Need better inter-calibration of both sites
  - Need a 3rd (or more) independent site for validation
- **Limitation of the approach based on a unique multiplicative factor**
  - Non-linearity ?
  - More evolved techniques?



- **How to apply a vicarious calibration at the end of the 6 month commissioning phase?**
  - Little number of matchups
  - Ocean radiometry model?
  - Combination of different sources in-situ measurements?

Acknowledgment

- MERIS Quality Working Group members for their interest and support on this topic
- Mickael Ondrusek (NOAA) for MOBY data (now Ken Voss)
- David Antoine (LOV) for BOUSSOLE data

- Contributing PIs to MERMAID (ESA, ACRI-ST, Argans, http://hermes.acri.fr/mermaid) for validation:
  - AERONET- OC sites AAOT, Abu Al Bukhoosh, Gustav Dalen Tower and Helsinki Lighthouse: **Giuseppe Zibordi (JRC)**
  - Sagres: **John Icely (University of Algarve)**
  - Bristol Channel and Irish Sea: **David McKee (University of Strathclyde)**
  - California Current: **Mati Kahru (University of California, San Diego)**
  - East English Channel and French Guiana: **Hubert Loisel (LOG)**
  - MUMMTriOS: **Kevin Ruddick (MUMM)**
  - AERONET-OC MVCO: **Doug Vandemark & Hui Feng (University of New Hampshire)**
  - NOMAD: **Jeremy Werdell (NASA), Larry Harding (University of Maryland), Antonio Mannino (NASA), Ajit Subramaniam (University of Maryland), Dariusz Stramski (University of California, San Diego), Greg Mitchell (University of California, San Diego), William Balch (Bigelow Laboratory for Ocean Sciences), Frank Muller-Karger (University South Florida), Ru Morrison (Woods Hole Oceanographic Institution), Zhongping Lee (University of Massachusetts), Ken Carder (Professor Emeritus University South Florida), Norman Nelson (University of CaliforniaS), Richard Gould (NRL), Robert Arnone (NRL) and Stan Hooker (NASA)**
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  - SIMBADA: **Pierre-Yves Deschamps (Laboratoire d'Optique Appliquée)**
  - Wadden Sea: **Annelies Hommersom (IVM)**

Extra slides

Validation on clear waters

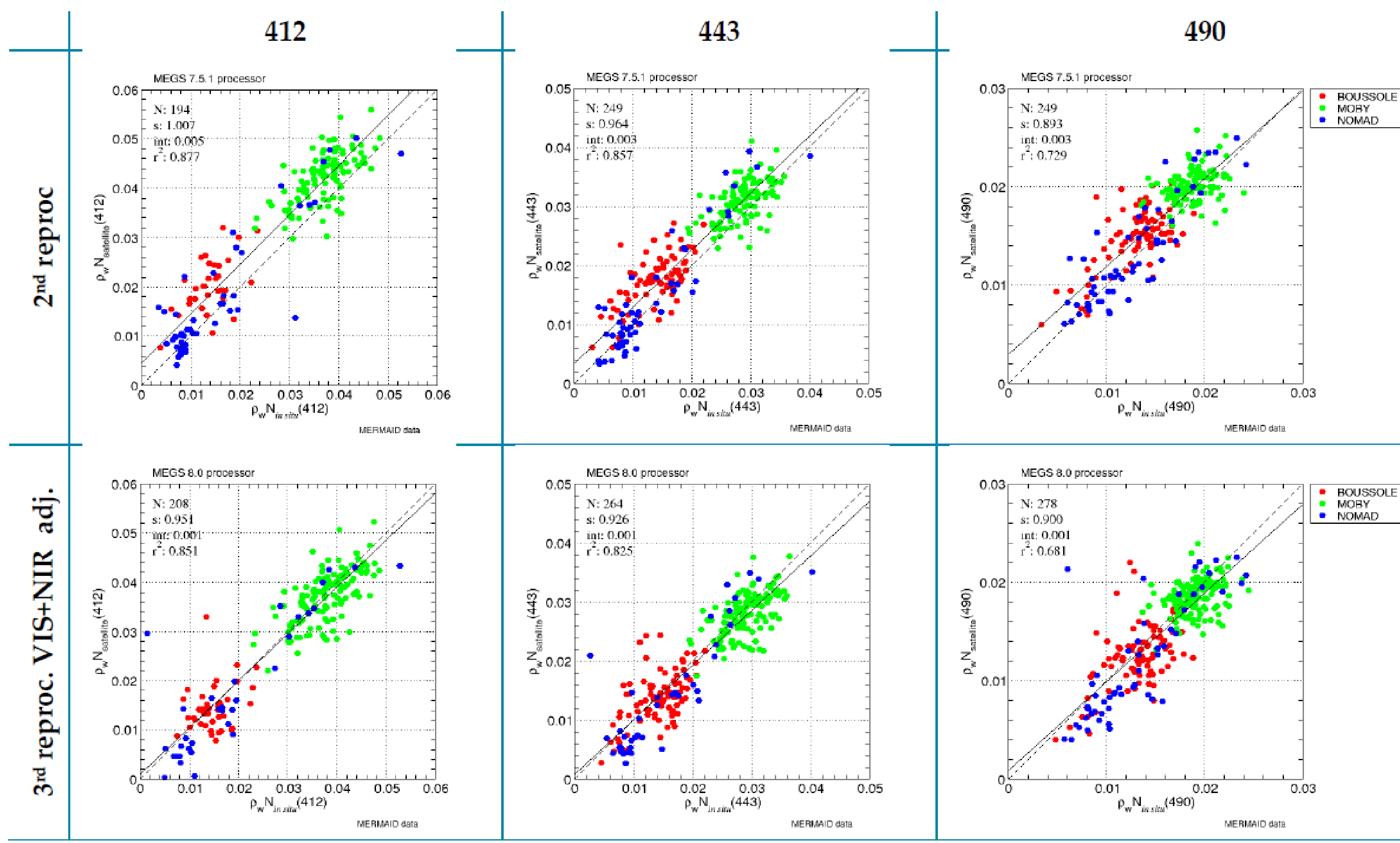

Figure 18: 2nd and 3rd reprocessing regression versus in situ data (MERMAID clear water dataset - bands 412, 443, 490)

From Lerebourg et al 2011

Data points used in the calibration removed in the validation

Validation on clear +complex waters

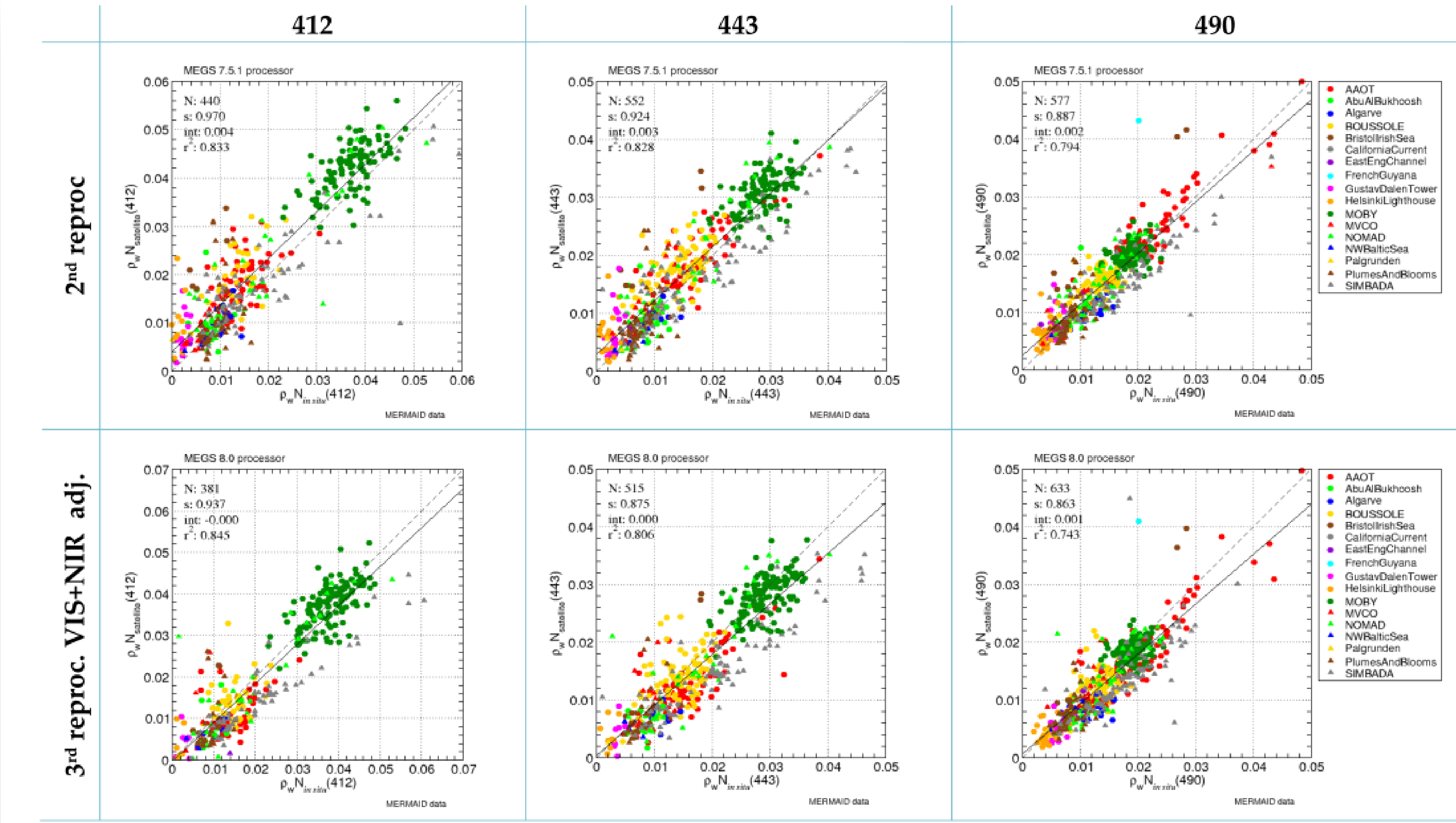

Figure 22: 2nd and 3rd reprocessing regression versus in situ data (MERMAID all dataset - bands 412, 443, 490)

From Lerebourg et al 2011

Data points used in the calibration removed in the validation