ESA/MERIS vicarious adjustment

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Ocean Colour System Vicarious Calibration for Science and Operational missions Workshop

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Outline

- **Session 1 – Current Status**
  - **MERIS vicarious adjustment**
    - **Status overview, approach and differences with SeaWiFS/MODIS**
    - **NIR methodology and results**
    - **VIS methodology, results, discussion**

- Session 3 – VIS methodology and recommendations towards standardization
  - Implementation issues for MERIS & OLCI
  - Uncertainties
  - Other methods for early phase mission? Rayleigh results

Status overview

- **From 2002 to 2011: no vicarious calibration in MERIS 1st and 2nd reprocessing**
  - Significant bias in marine reflectance in the VIS (Zibordi et al GRL 2006, Antoine et al JGR 2008)

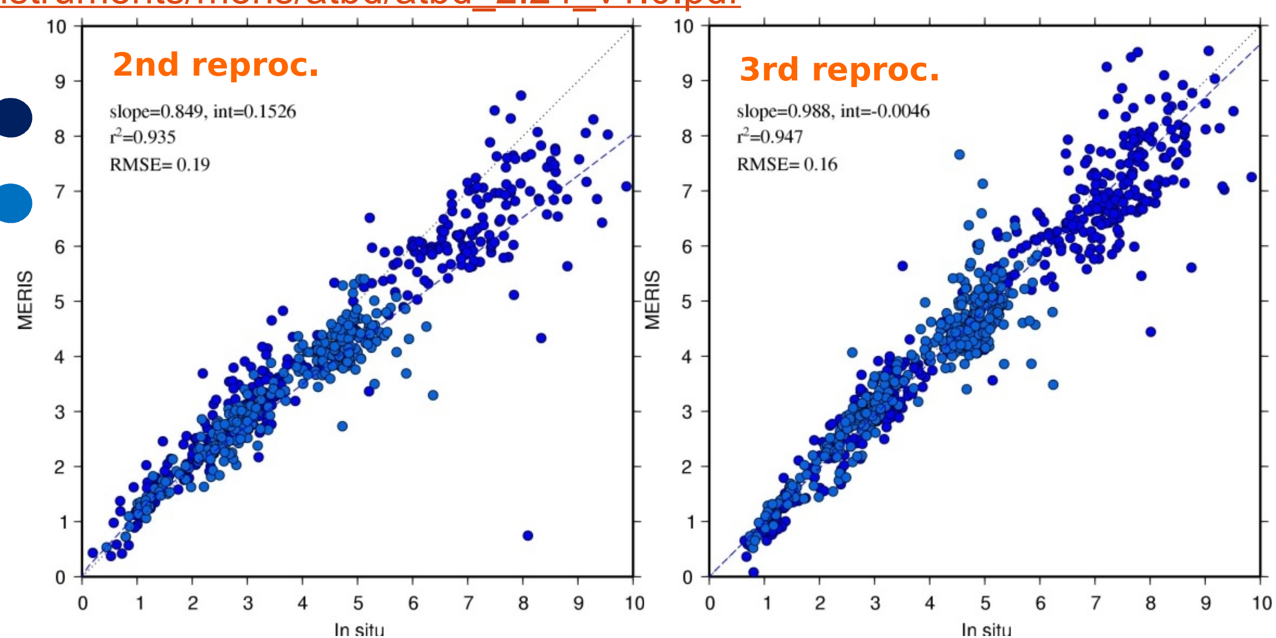
- **2008: MERIS QWG advocated to implement a vicarious calibration in 3rd reprocessing**
  - Start from existing method of SeaWiFS and MODIS (Franz et al AO 2007, Bailey et al AO 2008)
  - 2009-2010: tests and development by ACRI-ST under QWG and ESA supervision

- **July 2011: public delivery of 3rd data reprocessing by ESA + documentation**
  - 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 https://earth.esa.int/instruments/meris/atbd/atbd_2.24_v1.0.pdf

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

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

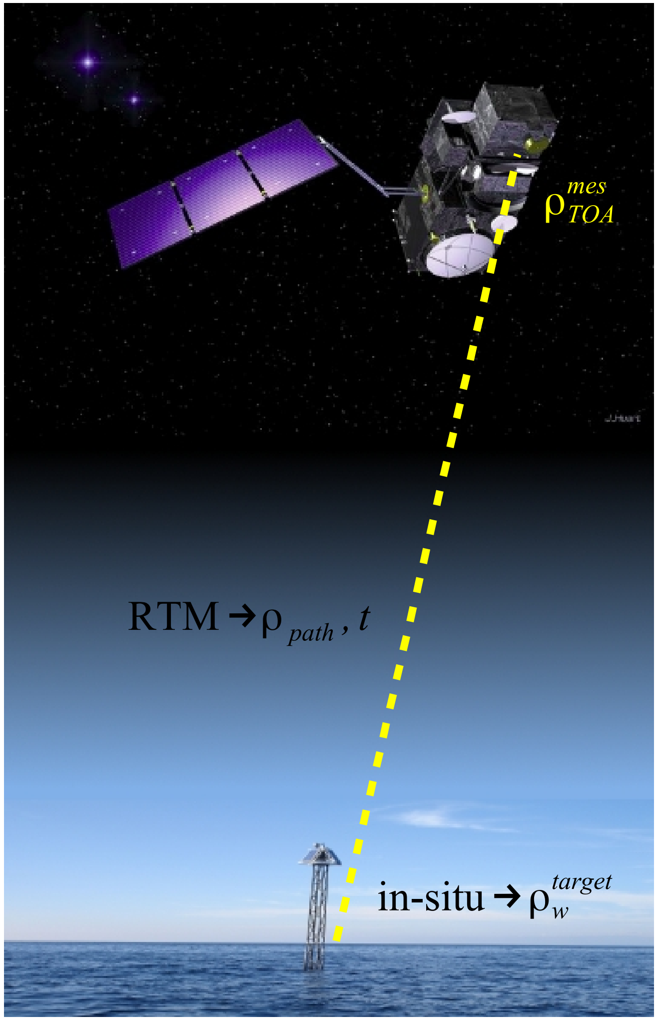
MOBY + BOUSSOLE
+ NOMAD + SIMBADA



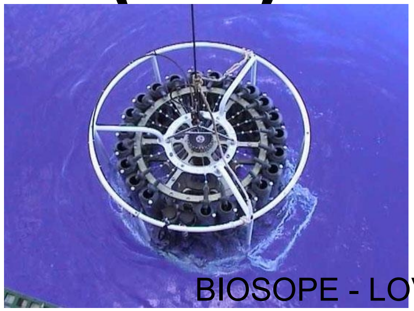
Comparison with SeaWiFS/MODIS approach

- **Implementation follows the overall OBPG two-steps approach**
  - Computation of gain factor in the NIR, over SPG & SIO
  - Computation of gain in the VIS based on in-situ ρ_w to construct targeted TOA signal
  - Analogous protocols for matchups (size of macro-pixel, data screening, average, median...)

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

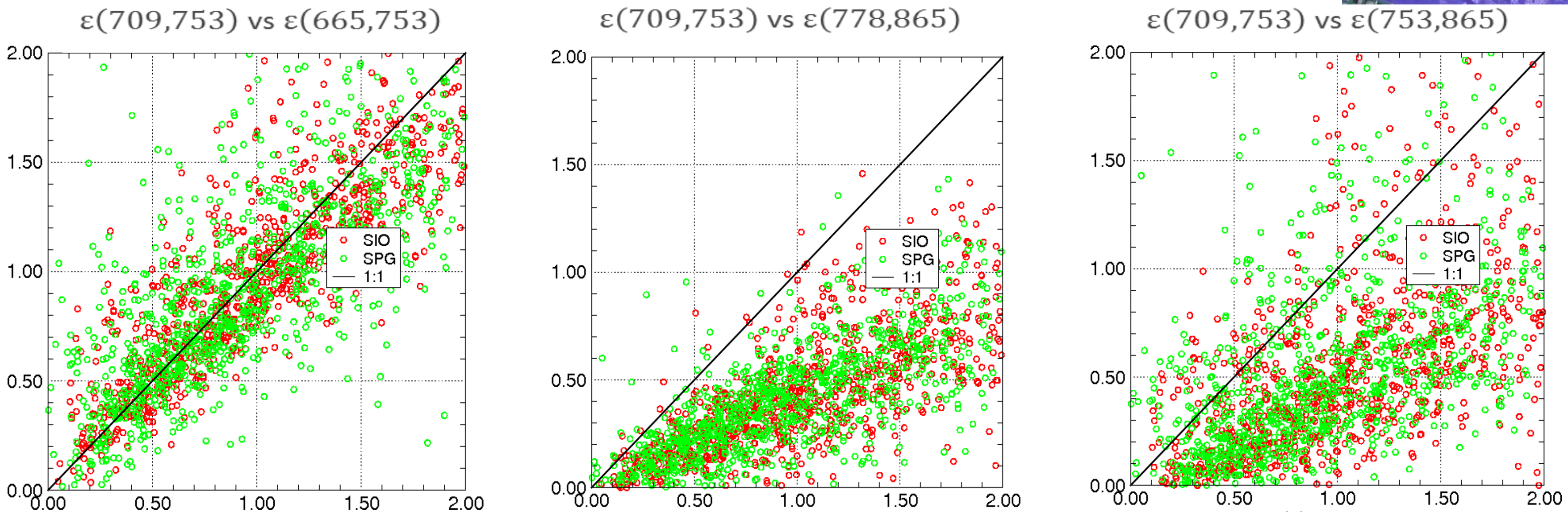


MERIS vicarious adjustment in the NIR (1/4)



- **A problem in the NIR spectral shape was identified at SPG & SIO at 865 nm**

$$\rho_{TOA}^{theo}(\lambda)=\rho_R(\lambda)+\rho_a(\lambda_{ref})\left(\frac{\lambda}{\lambda_{ref}}\right)^{\epsilon}$$

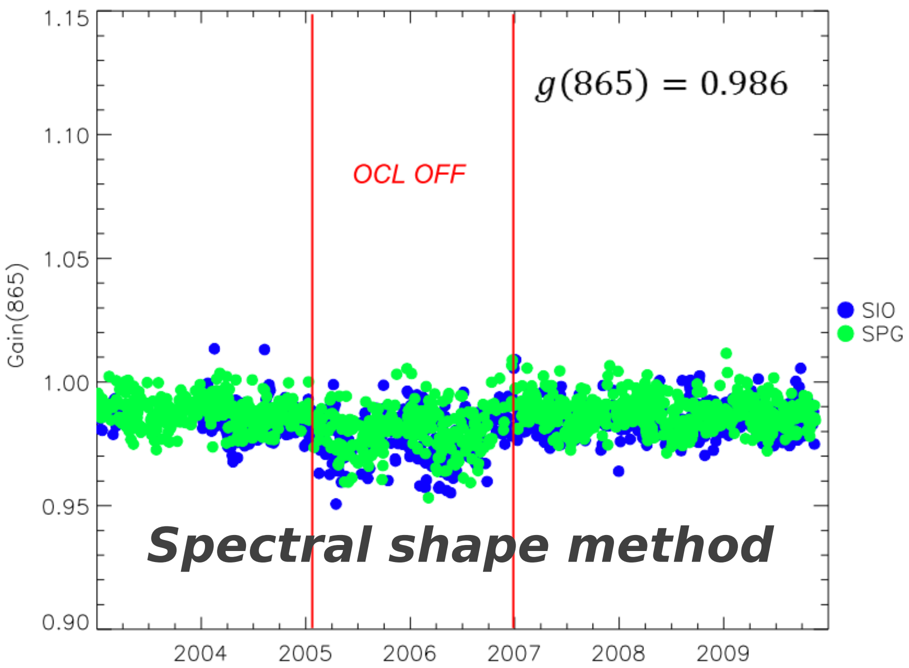


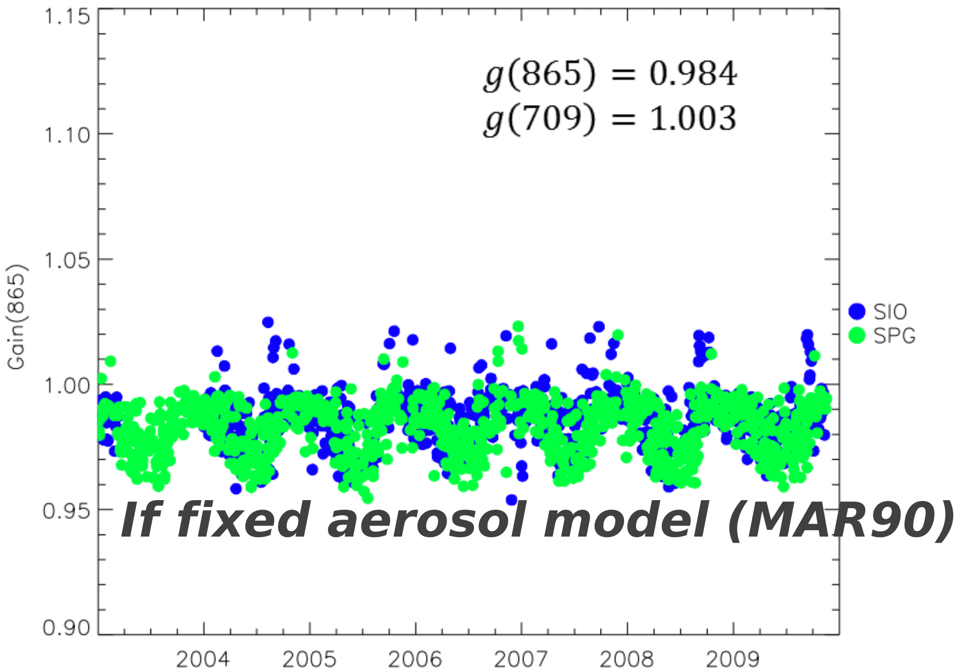
- **Problem may come from Level1 issue (straylight), but the NIR vic. was asked to solve it in 3rd reproc.**

- **Method:**
  - Identify two bands as baseline709 and 779 nm
  - Adjust 865 nm on theoretical shape with free ε

MERIS vicarious adjustment in the NIR (2/4)

- **Results**
  - A distinctive period appears (13/12/2004-09/10/2006): de-activation of the Offset Control Loop (dark current correction) → possible capability for real-time monitoring
  - Very good consistency between both sites
  - Sensitivity analysis on RTM data: accuracy of 0.1% and precision better than 1%
  - Uncertainties similar to other OC missions: σ(865)=0.006 and σ(885)=0.01
  - The spectral shape approach is much more robust to seasonal effects than when fixing an aerosol model; less dependence on scattering angle

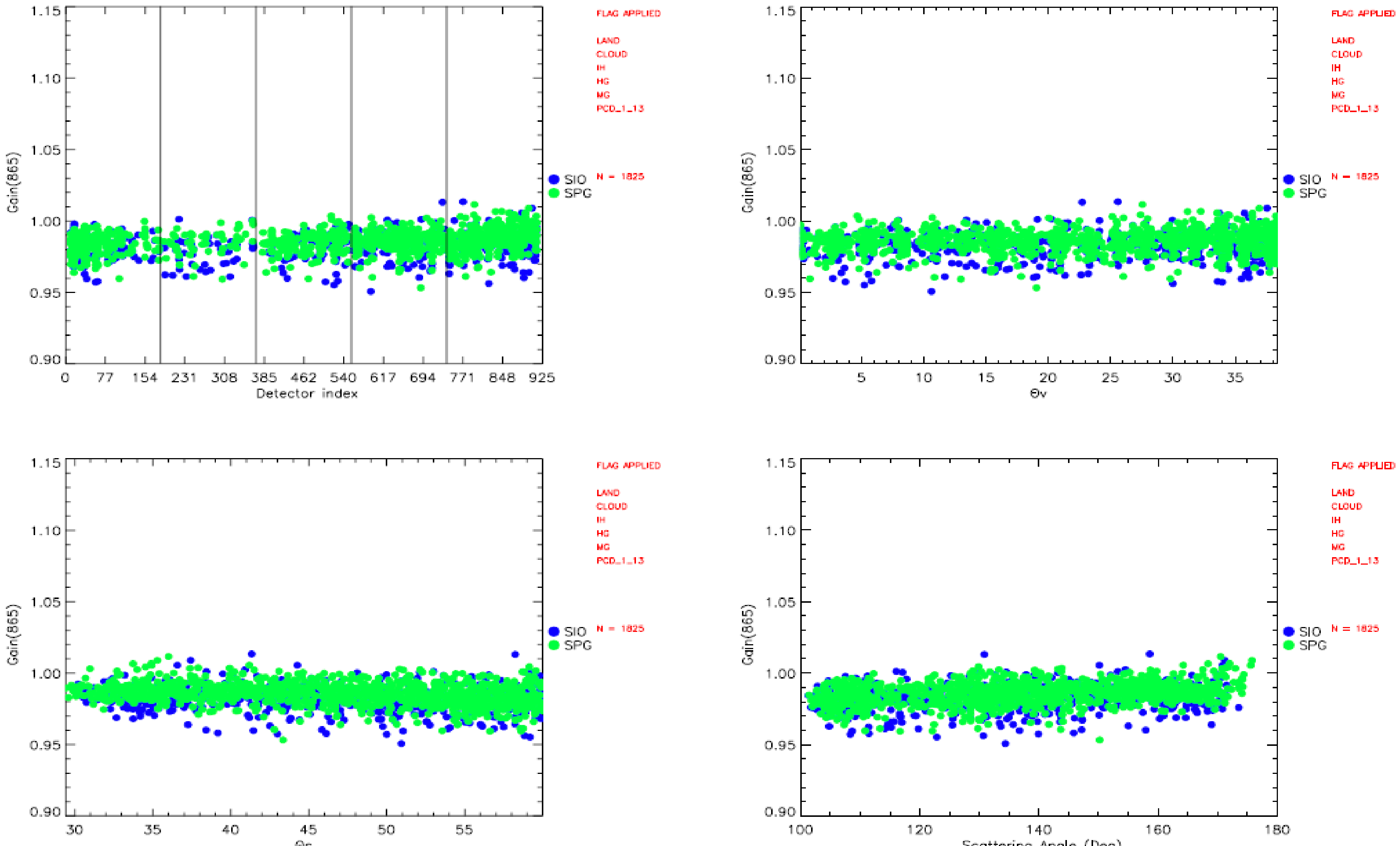




From Lerebourg et al. 2011

MERIS vicarious adjustment in the NIR (3/4)

- **NIR gains dependency**



From Lerebourg et al. 2011

MERIS vicarious adjustment in the NIR (4/4)

- **Impact of the NIR adjustment alone in the VIS**

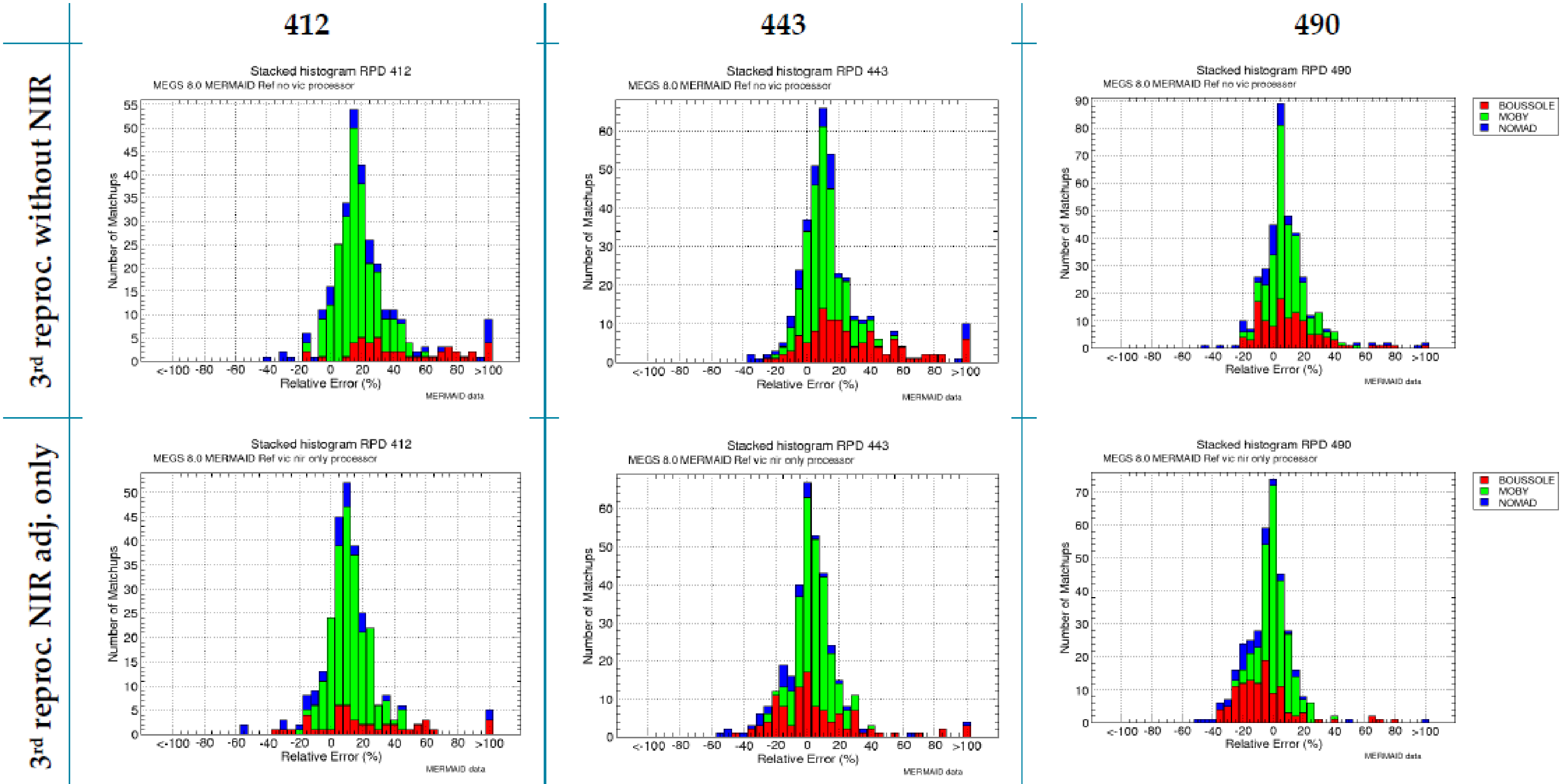


Figure 14: Histograms of 3[rd] reprocessing ρ_w relative errors without NIR adj. (top) and with NIR adjustment (bottom)

From Lerebourg et al. 2011

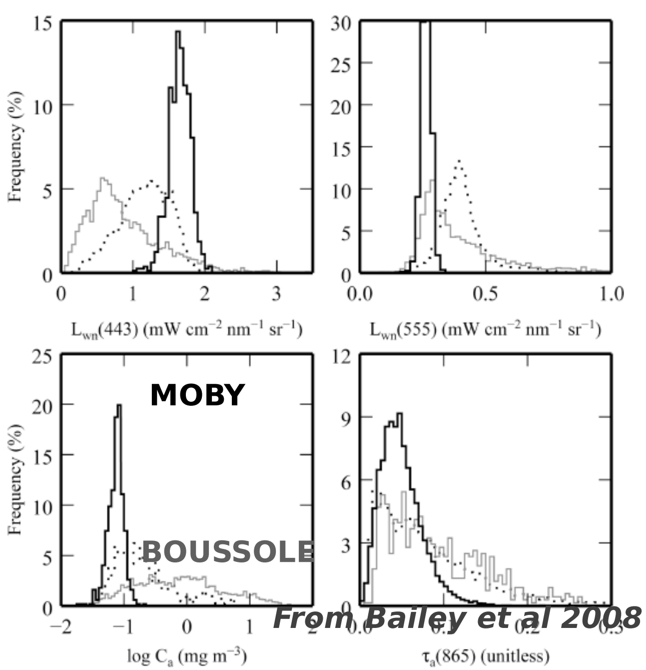
MERIS vicarious adjustment in the VIS (1/4)

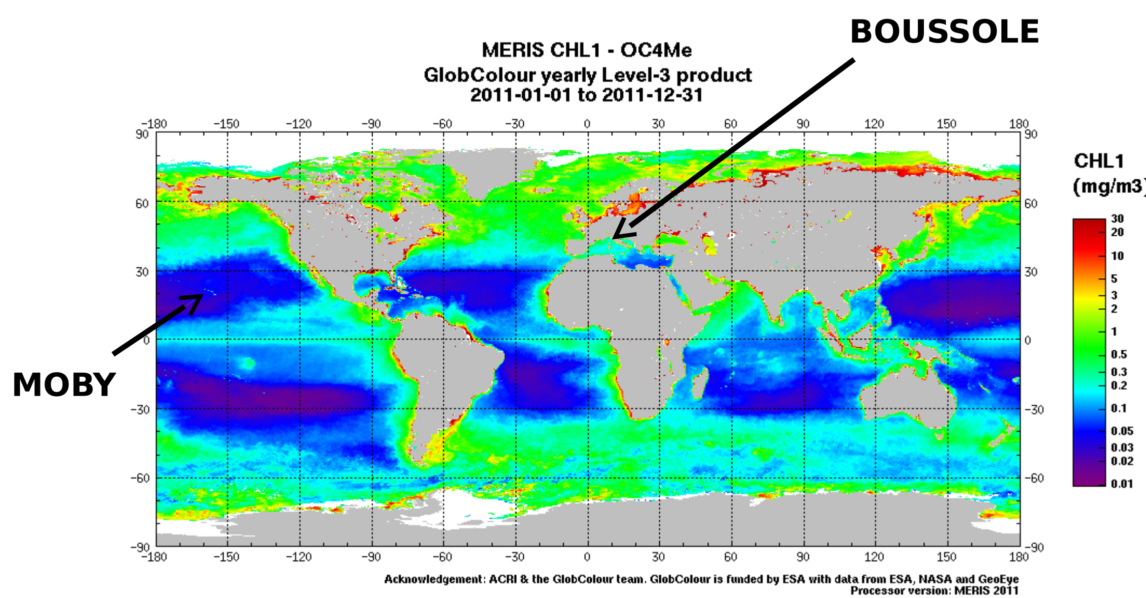
- **A unique VIS gain cannot correct for different biases of different datasets**

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

- **Choice of the dataset for a global calibration**
  - Representative of a “global state”
  - Long-term time-series, sound protocol and QC
  - Statistically significant number of points

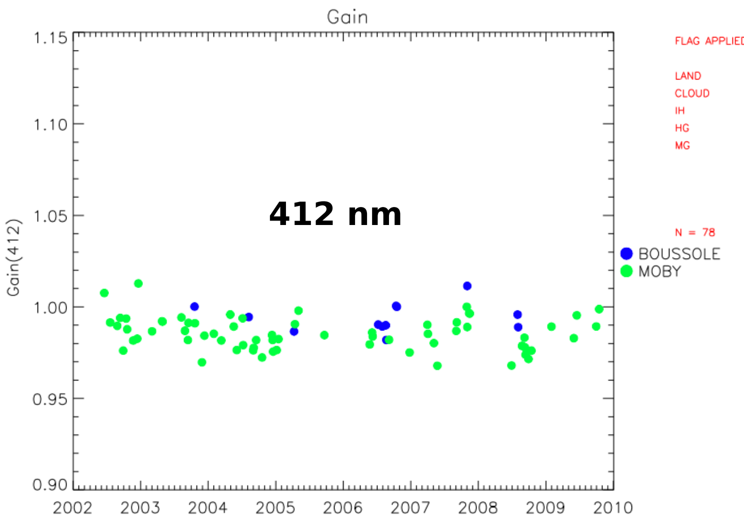
  → MOBY (Clark et al 2003) and BOUSSOLE (Antoine et al 2006, Antoine et al 2008)

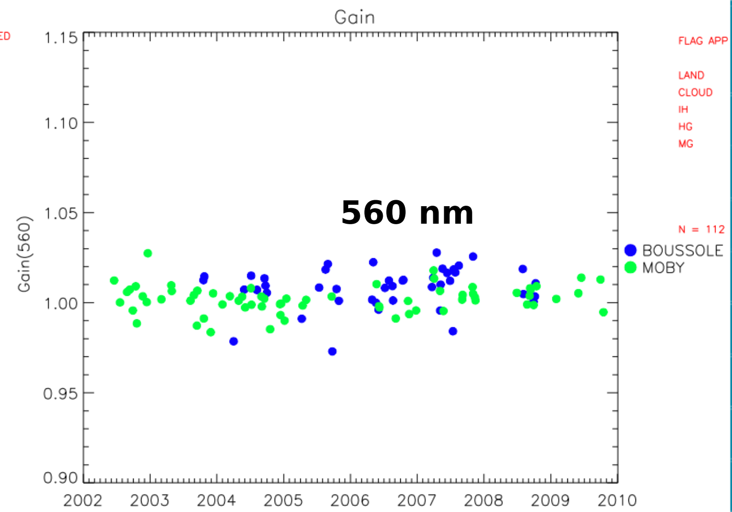




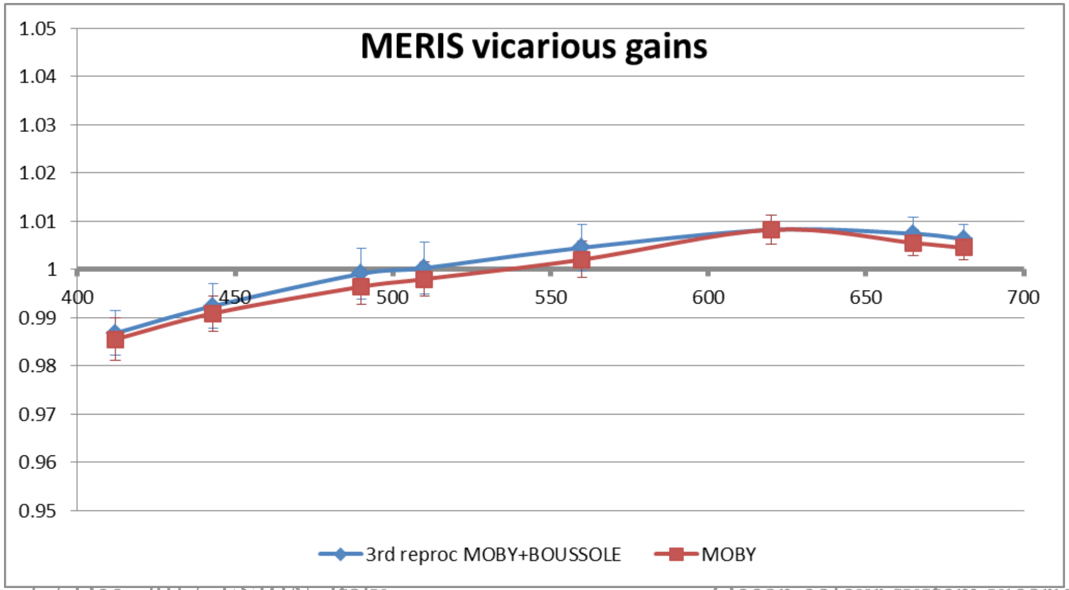
MERIS vicarious adjustment in the VIS (2/4)

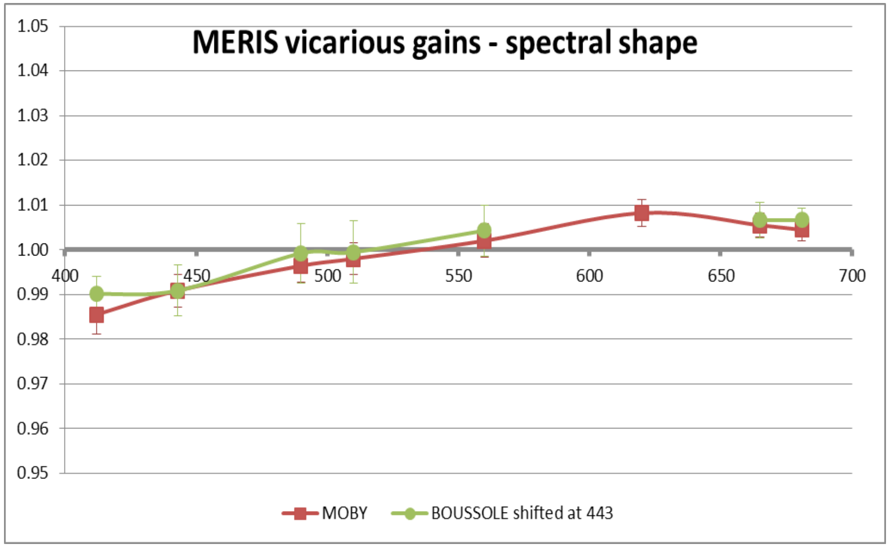
- **VIS gains time-series and averaged values**
  - Within 2%. Analogous standard-deviation as SeaWiFS (0.01 or better) but less calibration points





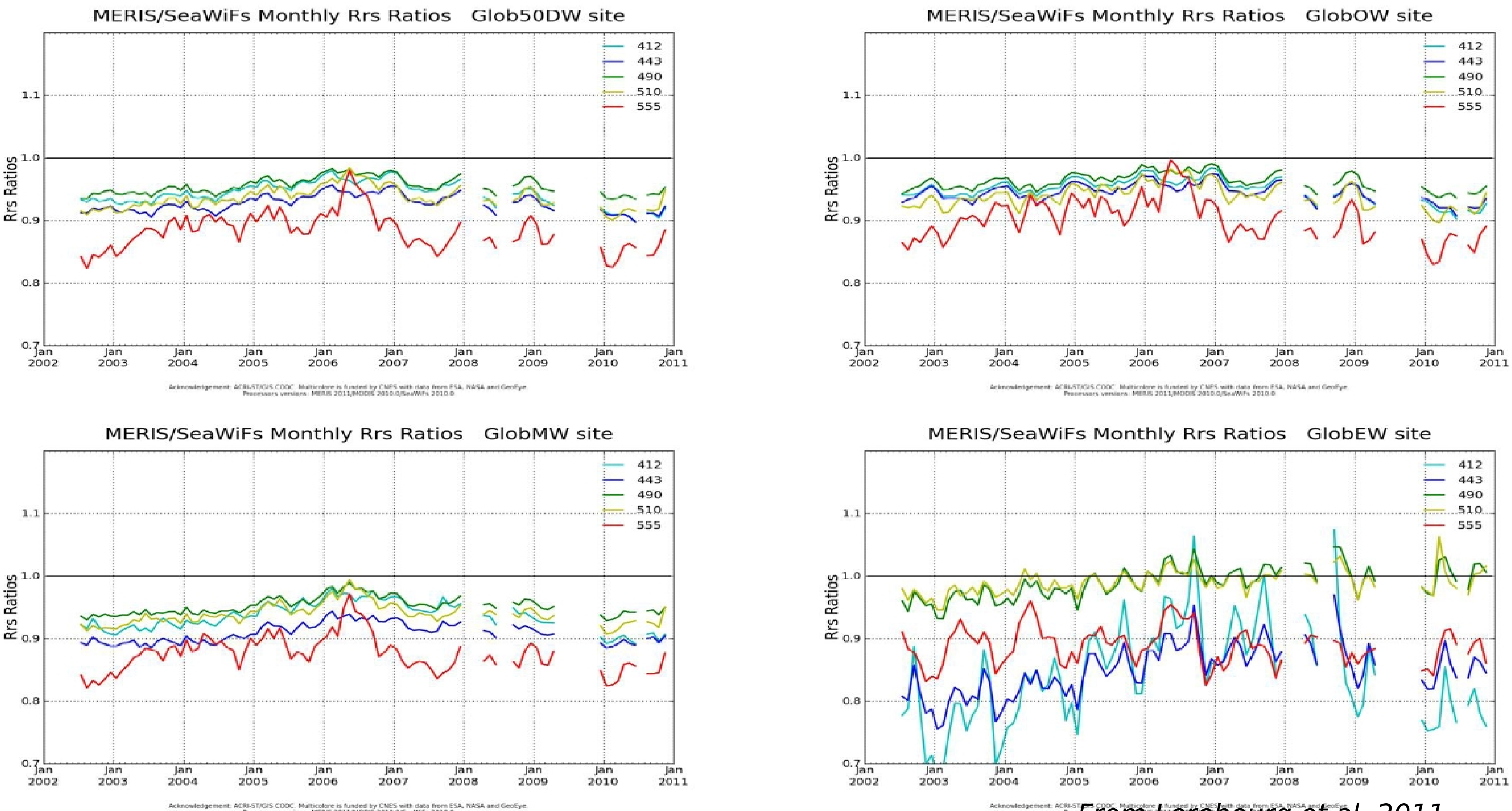
Band (nm)	Gain	Std-dev	N
412	0.9868	0.0093	78
443	0.9924	0.0092	105
490	0.9991	0.0105	108
510	1.0003	0.0107	113
560	1.0045	0.0097	112
620	1.0082	0.0060	67
665	1.0074	0.0069	106
681	1.0063	0.0059	94





MERIS vicarious adjustment in the VIS (3/4)

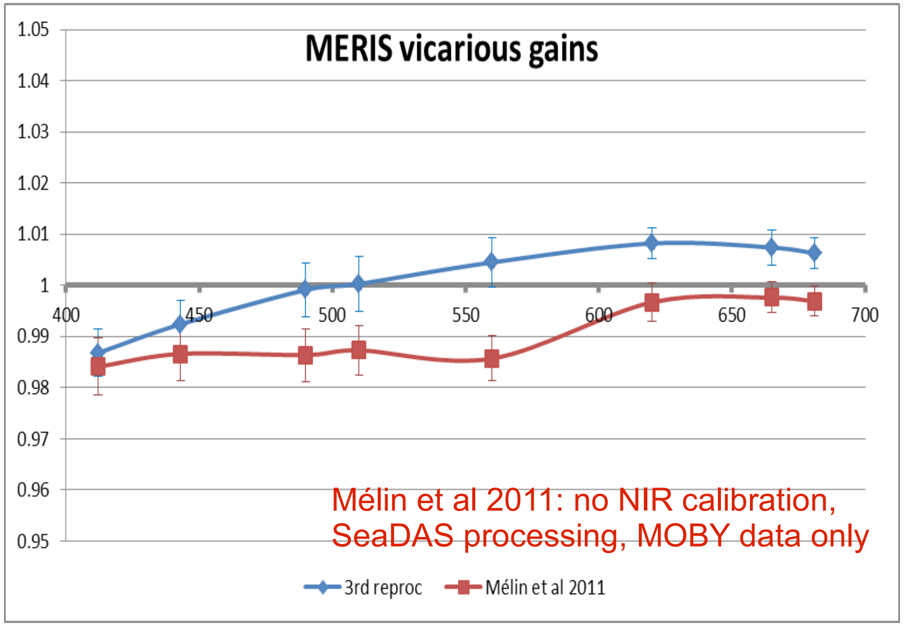
- **About the observed differences between MERIS and SeaWiFS ρ_w time-series ...**



From Lerebourg et al. 2011

MERIS vicarious adjustment in the VIS (4/4)

- **<u>Observed differences between MERIS and SeaWiFS ρ_w time-series do not come from the combined use of MOBY and BOUSSOLE (whatever the pros/cons of this approach)</u>**
  - Gains difference between MOBY and {MOBY+BOUSSOLE} is less than 0.3%:
    0.1% at 412 and 443nm, 0.3% at 490 nm, 0.2% at 510 nm and <0.01% at 560 nm
  - This can lead only to a max 3% difference on ρ_w
  - Furthermore spectral shape is identical, hence no impact on Chl-a computation



- **Possible sources of difference on ρ_w**
  - Atmospheric correction
    - ρ_{path} is still 80-90% of the signal!
    - Using a common atmospheric correction would probably align results of all missions but this is not an absolute validation
  - MOBY in-situ data handling?
    - The MOBY data file provided by NOAA to MERIS QWG is not exactly the same as the one used by OBPG: spectral integration on sensor response, solar illumination, further post-processing....

Conclusion on MERIS vicarious adjustment

- **NIR spectral shape calibration is simple and robust**
  - Good accuracy and statistically relevant
  - Method could still be revised and improved (e.g. assumption on 2 bands alignment)
  - Do we need to consider supplementary oligotrophic targets? e.g. in the Northern Hemisphere ?

- **Use of two calibration sites for the VIS**
  - Helped to have more points.
  - Minor difference in the spectral shape
  - Drawback: no independent clear water site for validation. Need inter-calibration of both sites
  - This does not explain the difference in ρ_w with other OC missions
    - Atmospheric correction and RTM is surely the main driver

- **It could be worth inspecting in details the OBPG & ESA computations on few common points (e.g. MOBY on MERIS) to eventually make straight the exact source of difference between missions**

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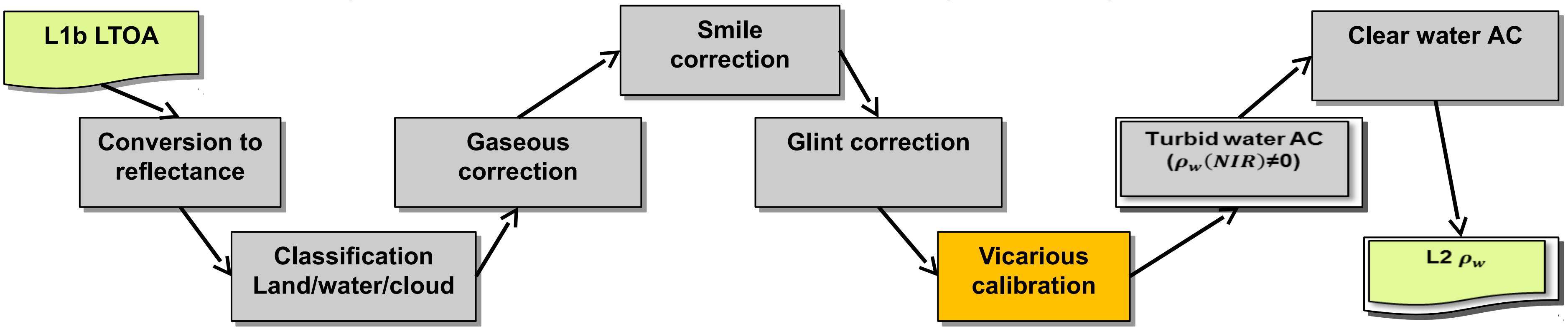
  - **Implementation issues for MERIS & OLCI**
  - **Uncertainties**
  - **Other methods for early phase mission? Rayleigh results**

Implementation issues for MERIS & OLCI

- **Vicarious adjustment is implemented after some corrections, in the water branch**
  - Non-invertible processes in the Level 2 chain: water vapour absorption, smile correction for CCD



- **Issue with respect to glint (before/after vicarious):** TOA difference is tdir*ρ_G*(1-g)
  - Unsignificant differences were found between applying vicarious after/before glint correction, based on matchups analysis

- **BPAC**
  - Contrary to NASA processing, there is no iteration between BPAC and Clear Water AC
  - NIR gains are computed at SPG & SIO where BPAC has no impact
  - It was discovered that vicarious calibration in the NIR can make BPAC fail over turbid water
    - Reasons still not clear.... and alternative BPAC may be more robust

Uncertainties on vicarious gains due to in-situ

- **We need a 0.5% max uncertainty in VIS gains (TOA) + consistency in the spectral shape**
  - This required ~ 5% max uncertainty in reference ρ_w + spectral consistency
- **Total uncertainty in gain comes independently from in-situ and AC:** $\sigma_g^2 = \left(\sigma_g^{IS}\right)^2 + \left(\sigma_g^{AC}\right)^2$
- **We can check a posteriori the in-situ uncertainty contribution in total gain uncertainty**
  - Consider σ_g^{IS} the uncertainty in g due to in-situ ρ_w: can be simulated by random variation of ρ_w *with known uncertainty (e.g. ~ 5%)*
  - Assess the total gain uncertainty σ_g through real gains dispersion
  - Compute the contribution of in-situ data uncertainty with ratio $\left(\sigma_g^{IS}\right)^2 / \left(\sigma_g\right)^2$

MOBY

Band	σ^{IS} (%)	σ_g^{IS}	$\left(\sigma_g^{IS}/\sigma_g\right)^2$ (%)
412	5.00	0.0066	64.41
443	5.00	0.0069	94.88
490	5.00	0.0073	104.41
510	5.00	0.0049	52.54
560	5.00	0.0030	22.08
620	5.00	0.0004	0.60
665	12.50	0.0005	1.07
681	?	?	?

BOUSSOLE

Band	σ^{IS} (%)	σ_g^{IS}	$\left(\sigma_g^{IS}/\sigma_g\right)^2$ (%)
412	6.00	0.0032	15.87
443	6.00	0.0039	12.06
490	6.00	0.0058	24.90
510	6.00	0.0049	18.74
560	6.00	0.0041	17.06
620	∅	∅	∅
665	6.00	0.0007	1.29
681	6.00	0.0009	3.90

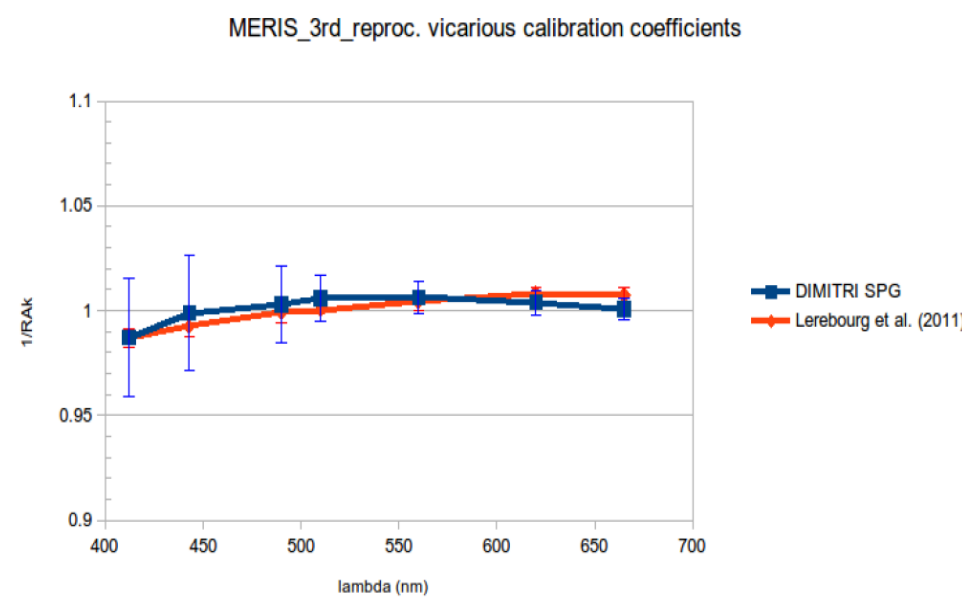
→ Uncertainty on MOBY gains is well explaind by 5% uncertainty on MOBY data until 510 nm
→ Uncertainty on BOUSSOLE gains is not explained by 6% uncertainty on BOUSSOLE data:
More complex atmosphere at BOUSSOLE. MERIS maritime models never selected

Which method for early phase of OC mission?

- **Issue with in-situ data**
  - About 7% of “good” MERIS matchups among all available (same ratio at MOBY and BOUSSOLE)
  - Franz et al 2007: need ~ 40 points at 555nm for stable gains

    → Need ~ 570 in-situ observations, i.e. 1.5 year assuming daily in-situ measurement & concurrent OLCI data (realistic time estimated for SeaWiFS: 2 years)

- **Alternatives? Rayleigh scattering vicarious method (Hagolle et al 1999 and CNES)**
  - Atmospheric contribution identical to standard vicarious approach (RTM, AC...)--> same uncertainty
  - Water reflectance given by a marine model + Chl climatology → is uncertainty acceptable?
    - Uncertainty of the model
    - Uncertainty of the input Chlorophyll
  - Preliminary results of Rayleigh vicarious calibration from the MOSAEC project & DIMITRI tool (ESA/ARGANS) ------------------>
  - See also Werdell et al 2007, but on BATS and HOT, not SPG/SIO



Summary for OLCI

- Specific constraints of the Level2 chain mus be taken into account
- Care must be taken to the BPAC after NIR adjustment
- Consistency between in-situ uncertainties and vicarious gain consistency could be used as a QC
- Need to find a method in early phase of the mission when only few in-situ data will be available