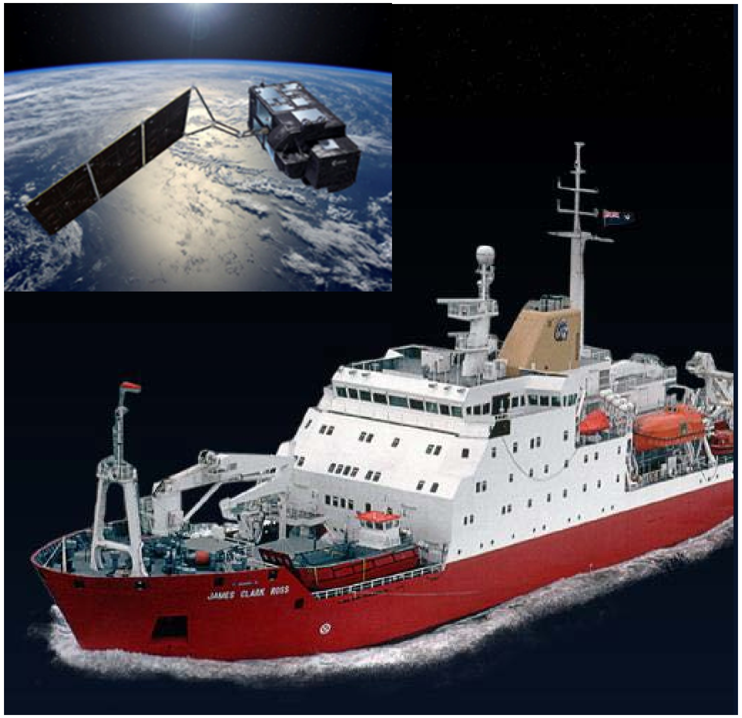
PML | Plymouth Marine Laboratory

amt4sentinelfrm

Listen to the ocean

# Validation of Sentinel-3A OLCI ocean colour products in the Atlantic Ocean.

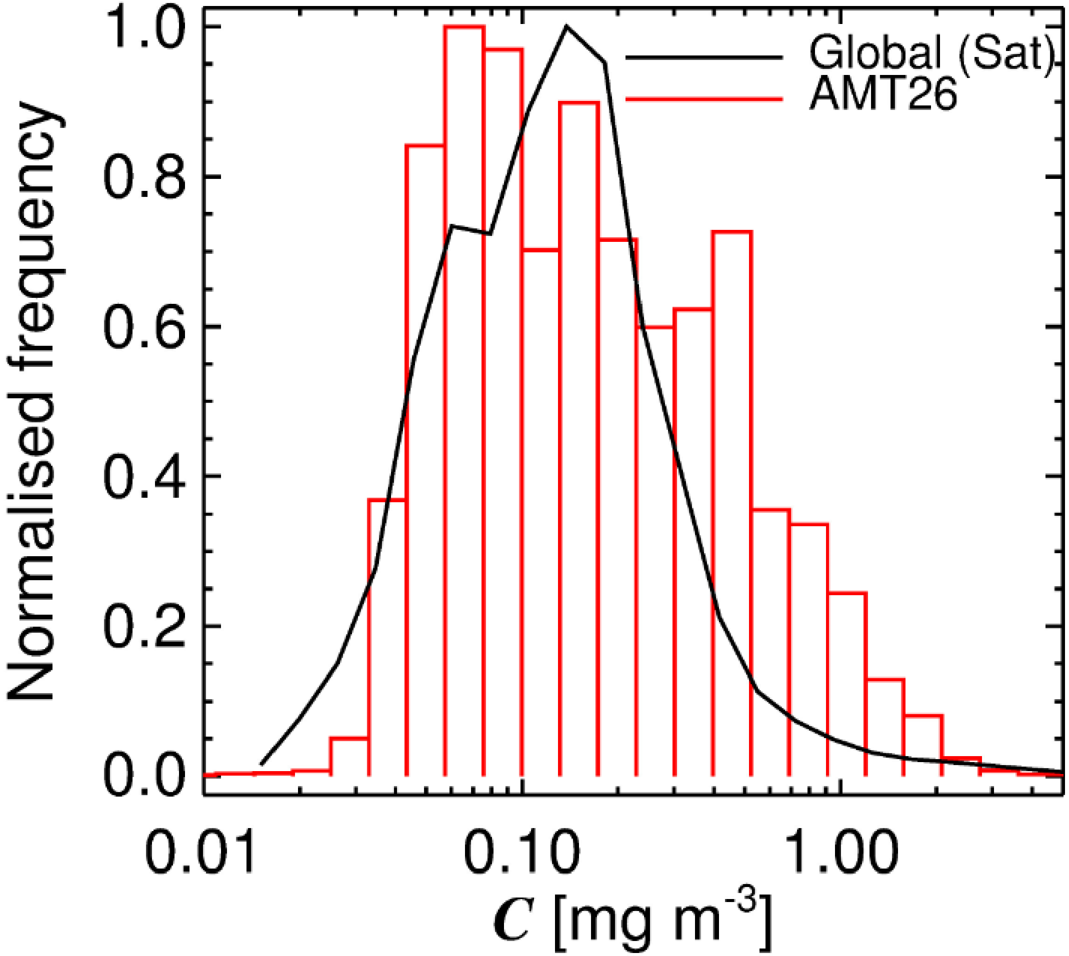


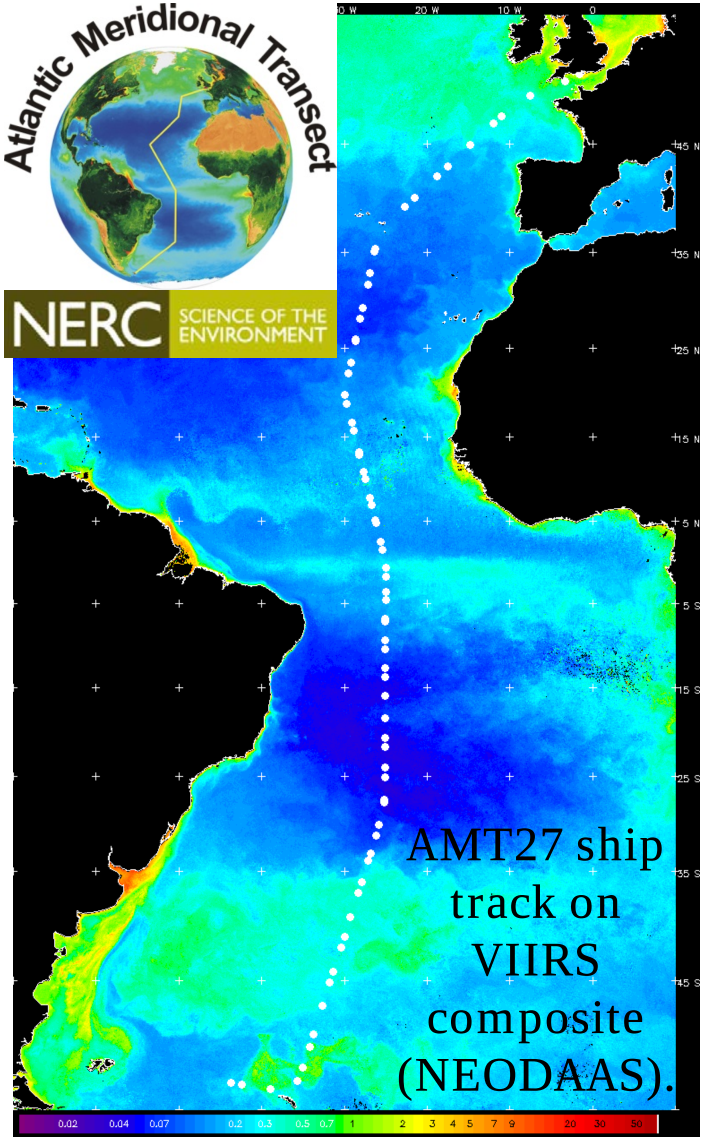

**Gavin Tilstone, Silvia Pardo, Hayley Evers-King, Thomas Jackson, Giorgio Dall'Olmo, Bob Brewin.**

**Plymouth Marine Laboratory, UK.**

# Motivation

Open-ocean oligotrophic waters are under-sampled in the global ocean.

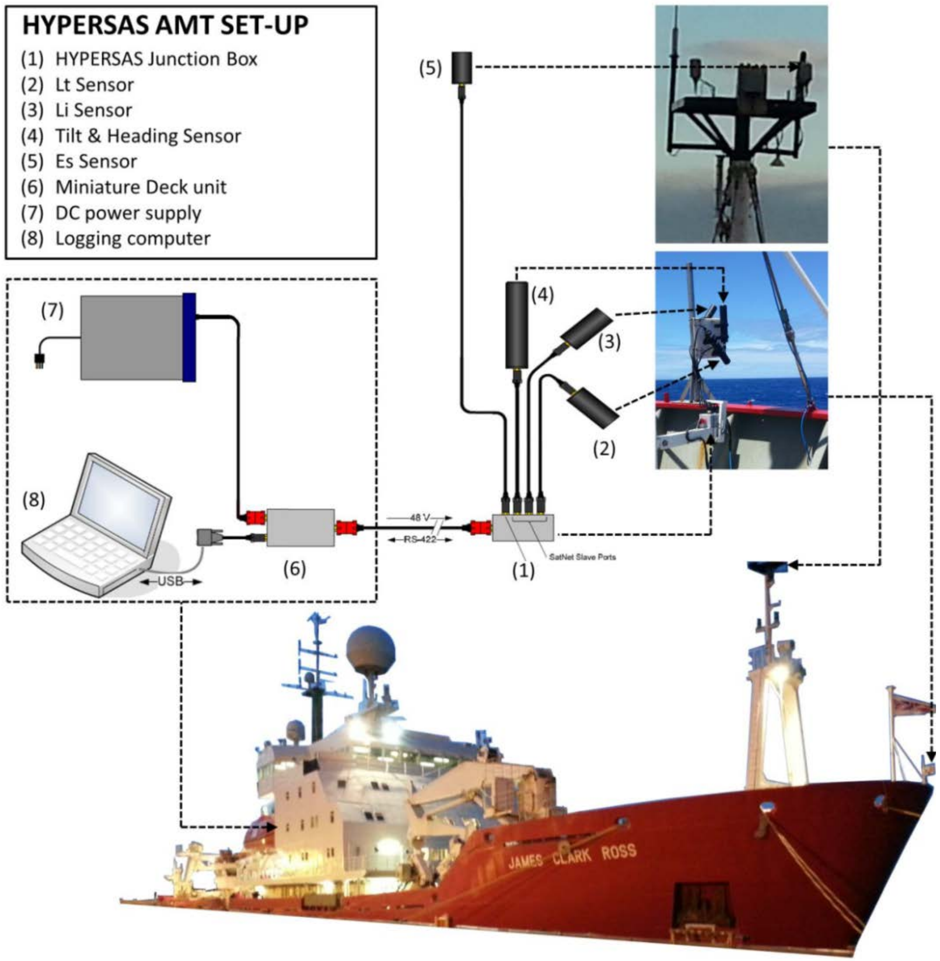


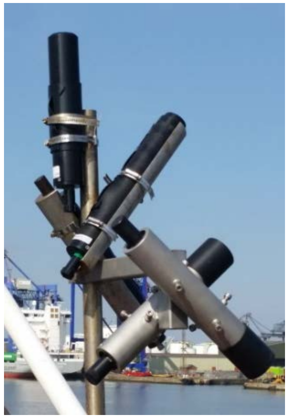

**FRMs required in low Chl-a waters to properly test case 1 Ocean Colour algorithms.**

# Atlantic platform for OLCI validation.

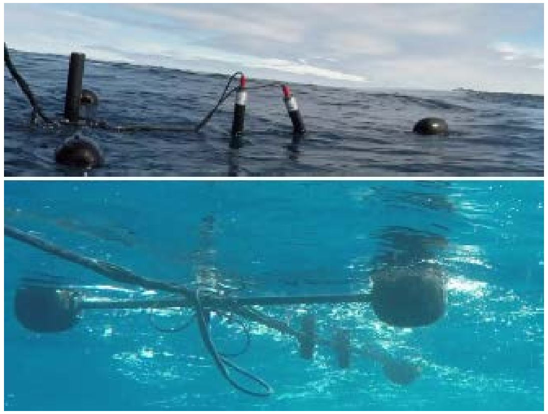
## Semi-autonomous optical radiometers.



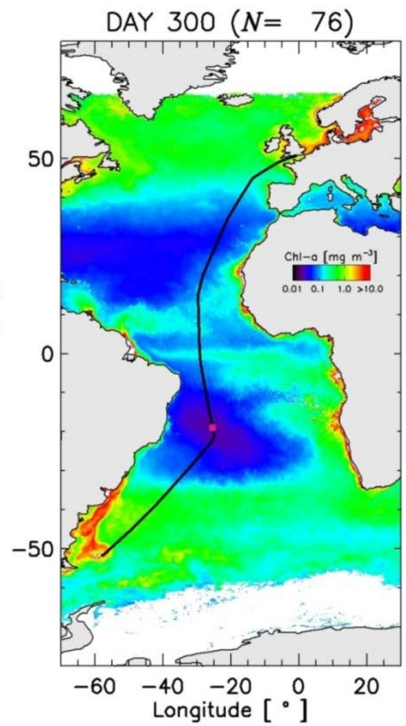

Schematic of PML Radiometer set-up on NERC/BAS ships.

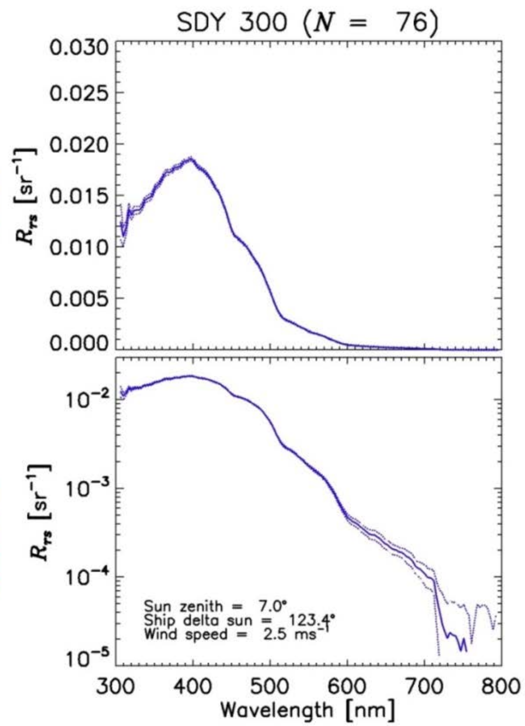


Bow mounted sensors.



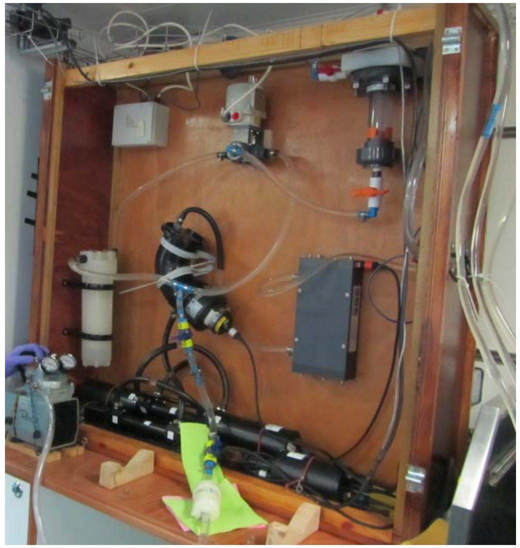
Coincident in water TRIOS courtesy G. Zibordi.

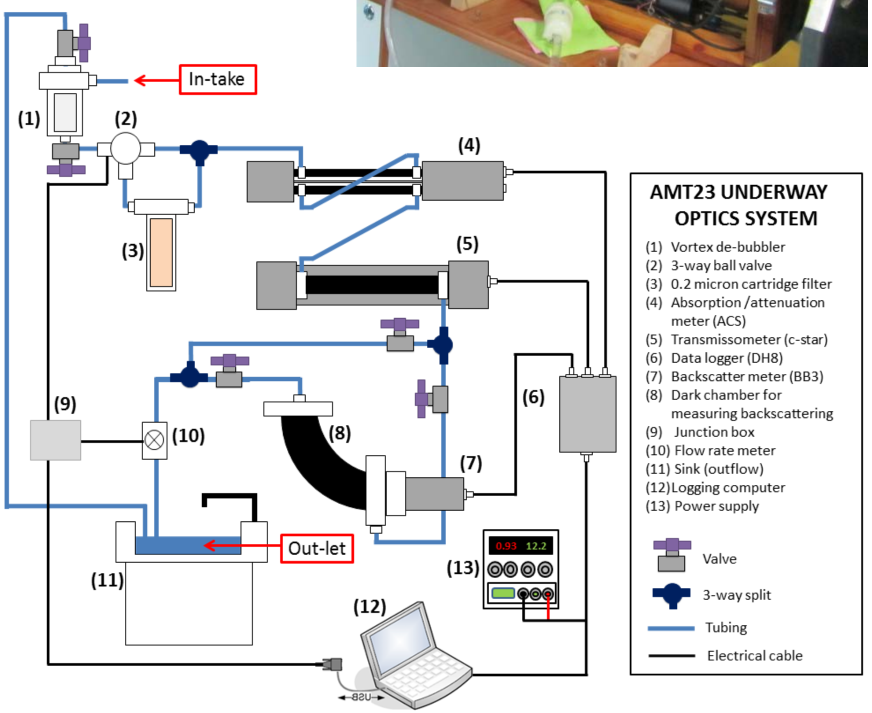


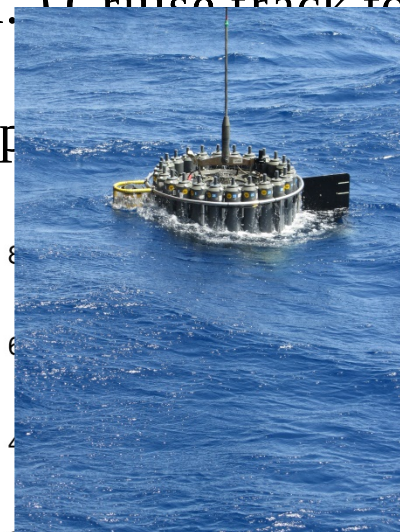
# Semi-autonomous IOP system.

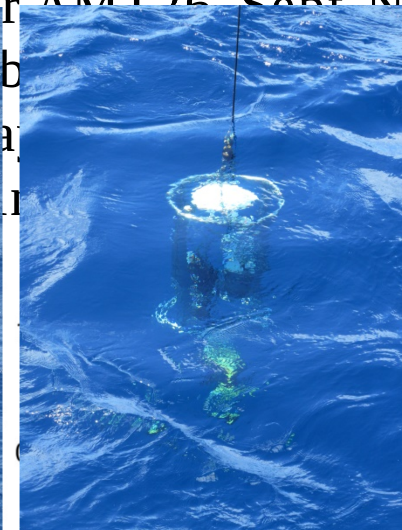
**IOP along track system:** ac-S calibrated with HPLC Chl-a.

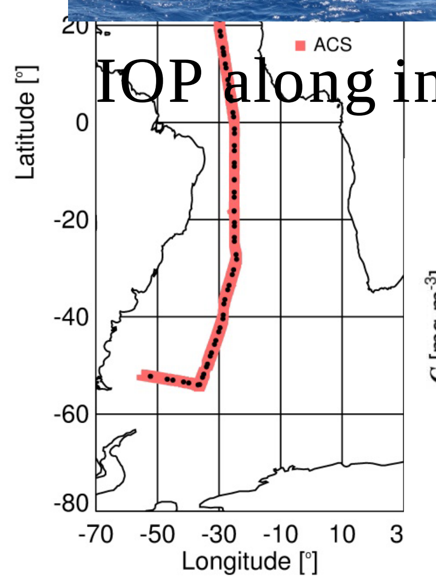




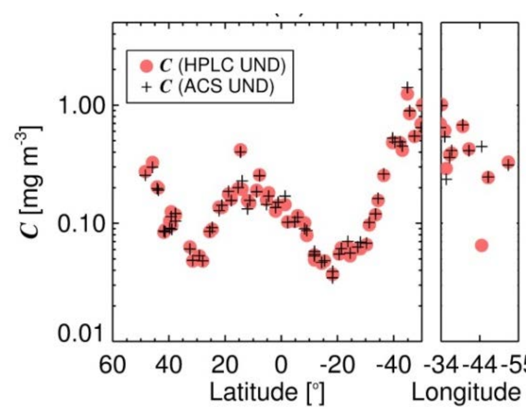

(a.) Cruise track for AMT26, Sept-Nov








**IOP along in water profiles.**

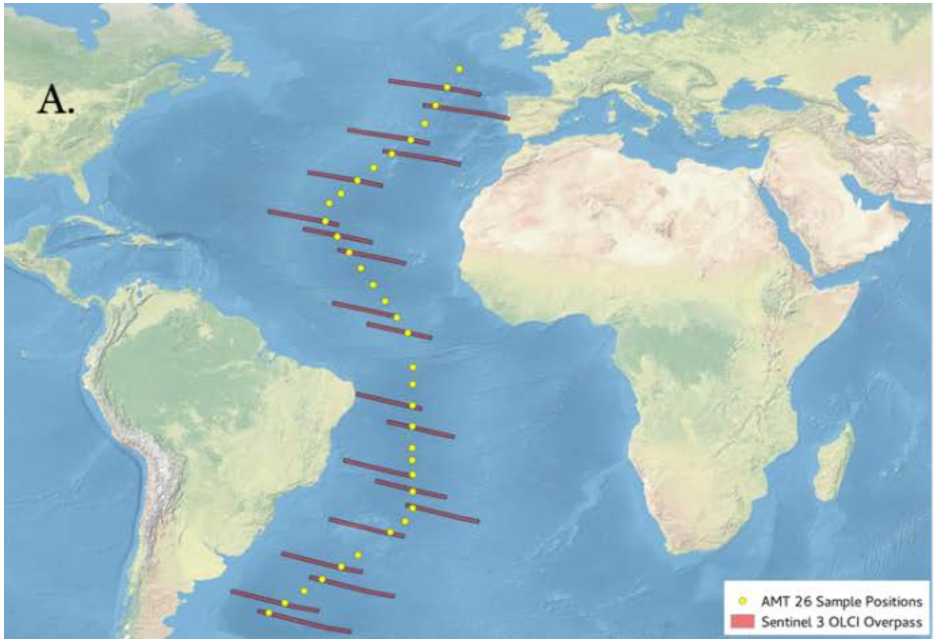


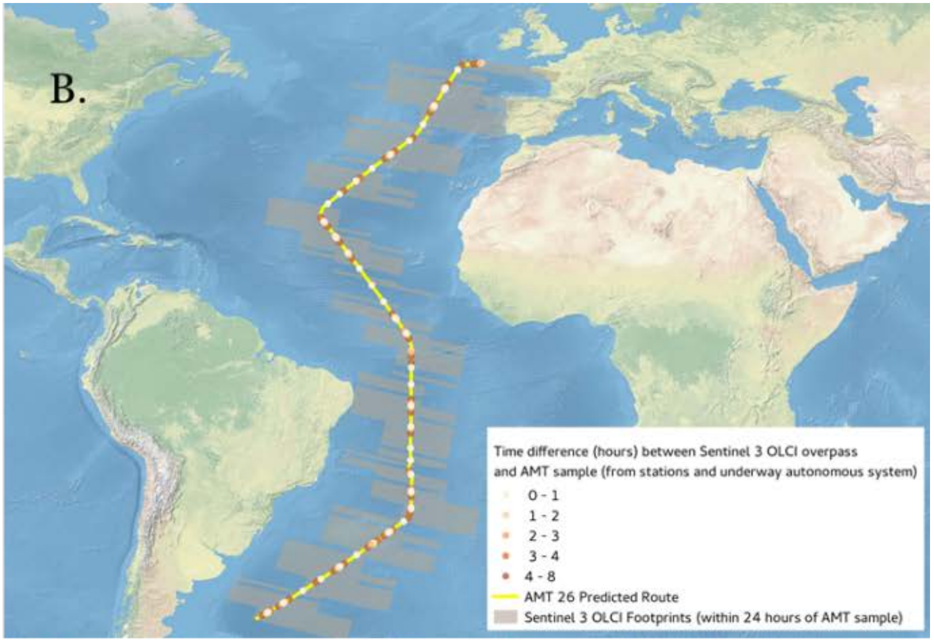

**N Chl-a = 40,000**

*Brewin et al. (2016) RSE, 183: 82-97.*

# Enhancing the number of match-ups

S-3A overpasses at AMT stations. S-3A overpasses on AMT track.



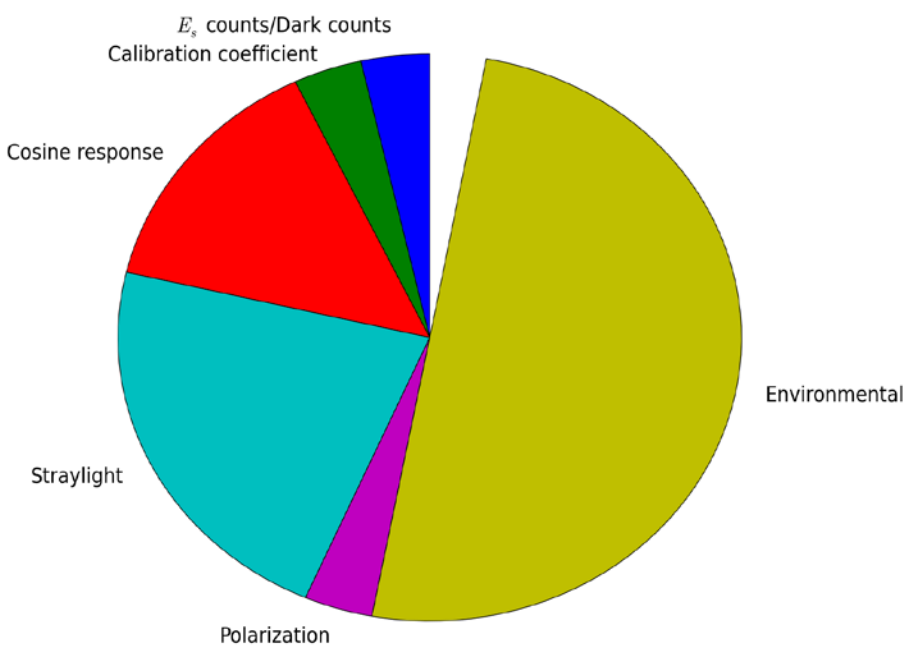



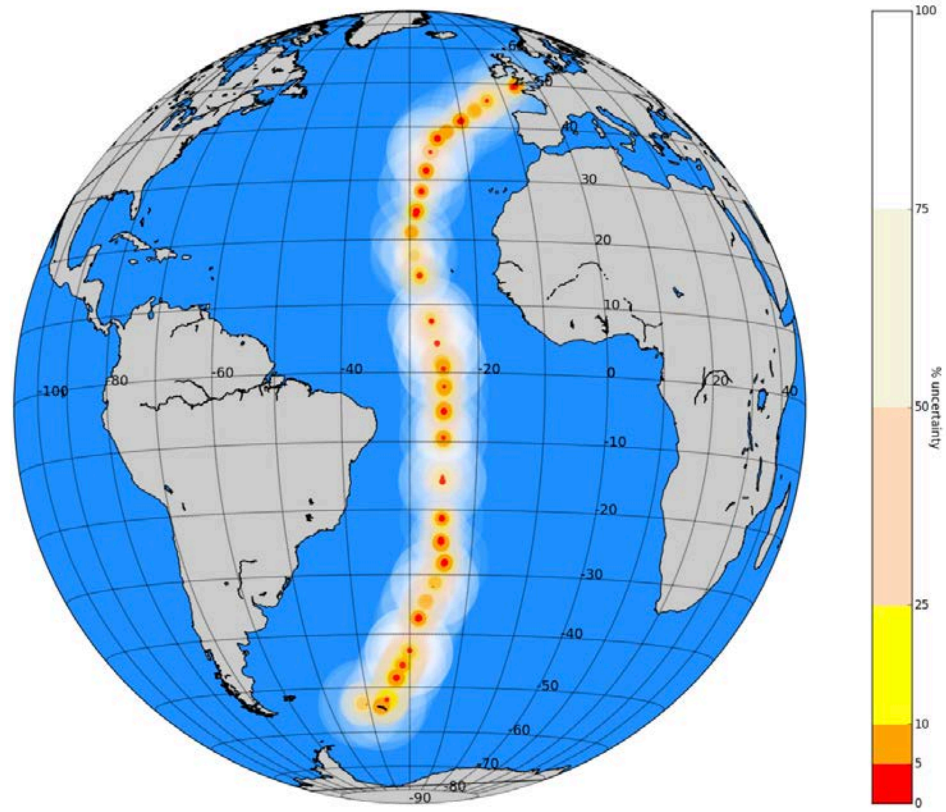

Use of semi-**autonomous systems**, **significantly increases** the number of **match-ups** with Sentinel-3A. On AMT26, from 40 CTD stations sampled ~6 match-ups; using the semi-autonomous systems on a single AMT, >460 match-ups.

# Uncertainty budget for in situ Rrs.

**Fiducial Reference Measurements (FRM)** are distinct from in situ measurements**:** *"The suite of* ***independent ground measurements using accepted satellite protocols*** *, traceable to metrology standards , referenced to inter-comparison exercises, with a full* ***uncertainty budget*** *to provide* ***independent, high quality , satellite validation measurements*** *for the duration of a satellite mission."* ***ESA S-3 Validation Team.***

## Characterising uncertainties in Rrs for Fiducial Reference Measurements




**Satellite Match-up Criteria:**

- Within a +/-1 hour window.
- 3x3 pixel centred on in situ data.
- median coefficient of variation (CV) <0.15
- Std QC satellite flags applied.

# Validation of S-3A OLCI Rrs – pb2.23.

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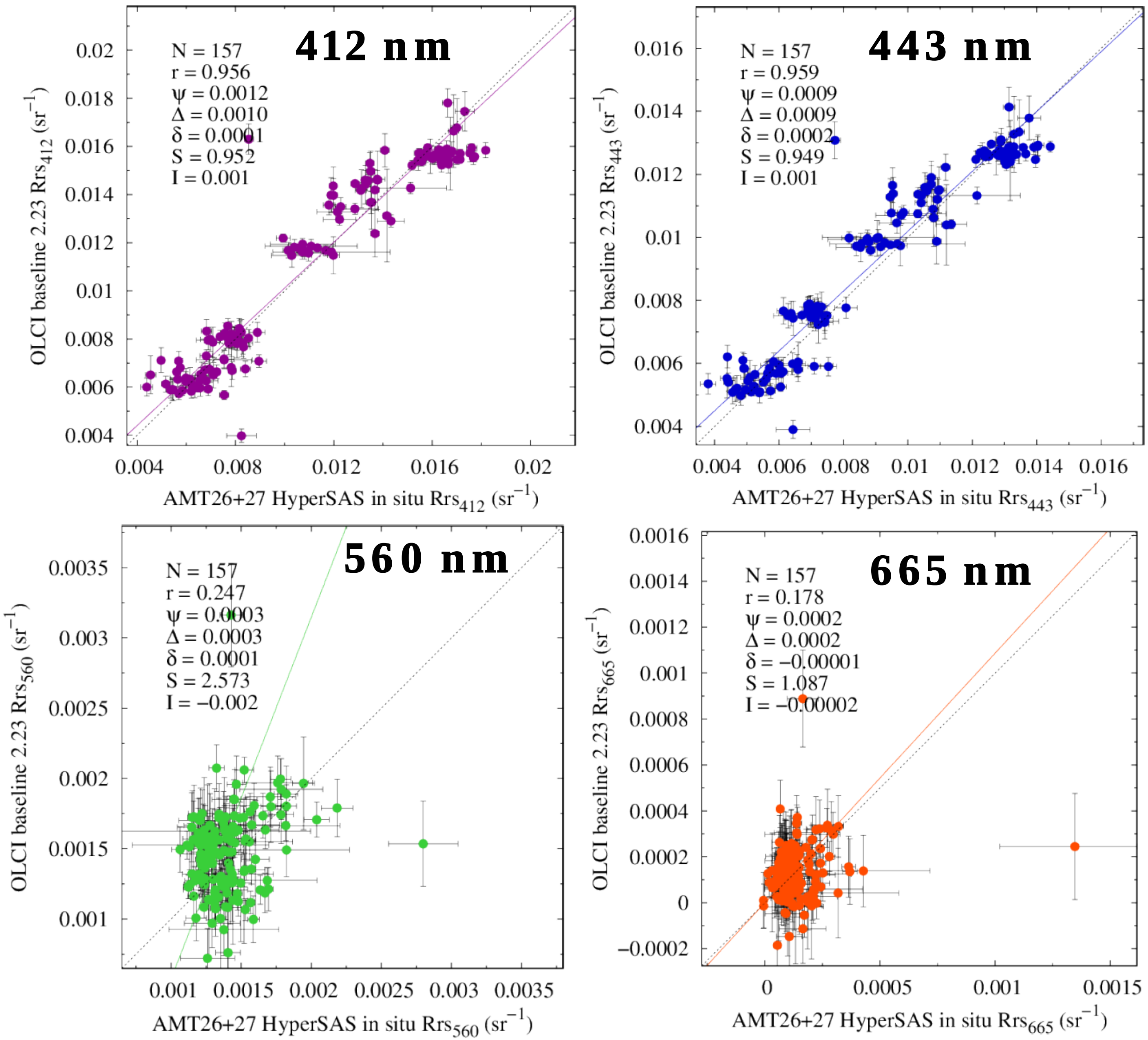
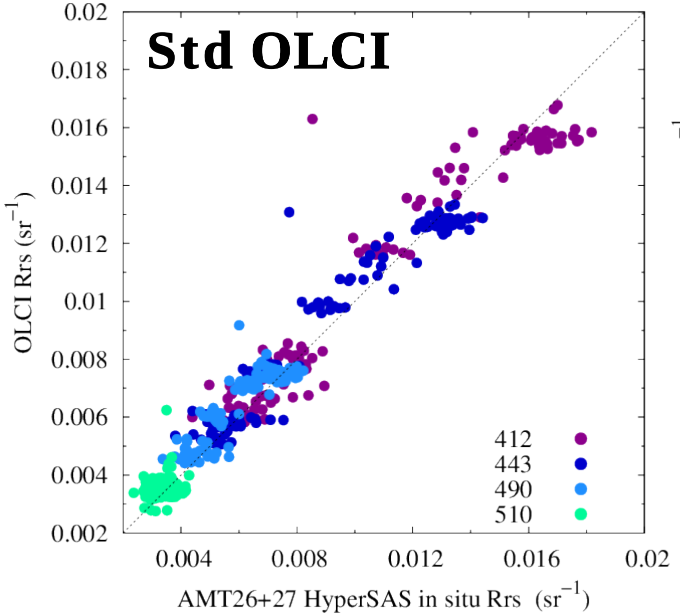


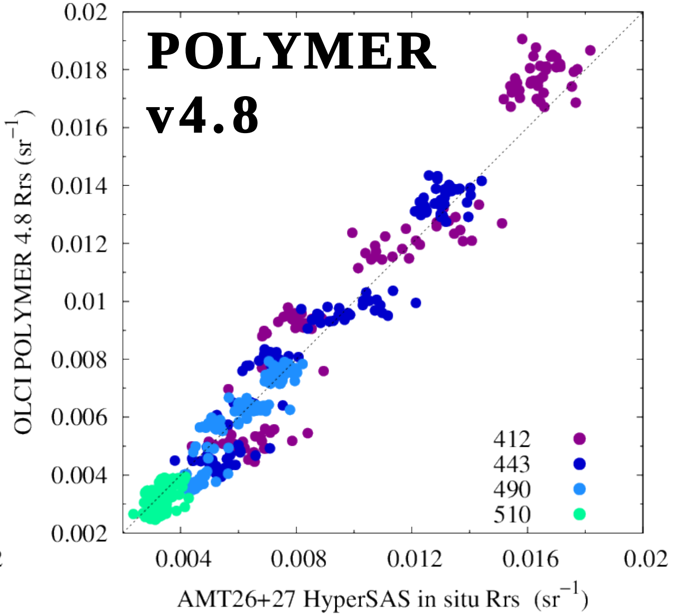

Number of points (N)
coefficient of determination (*R*),
absolute root mean square error (*ψ*),
Centre pattern RMSE (*Δ*),
bias (*δ*),
slope (*S*)
intercept (*I*)
type-2 linear regression

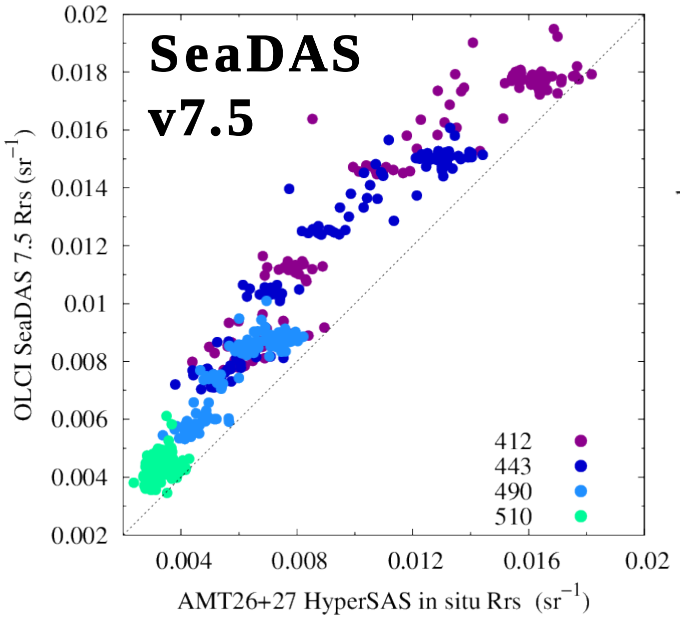
**Performance of OLCI Rrs pb2.23 (RPD):**
Blue bands 8 %
Green – 18 %,
over-estimate in red 88 %.

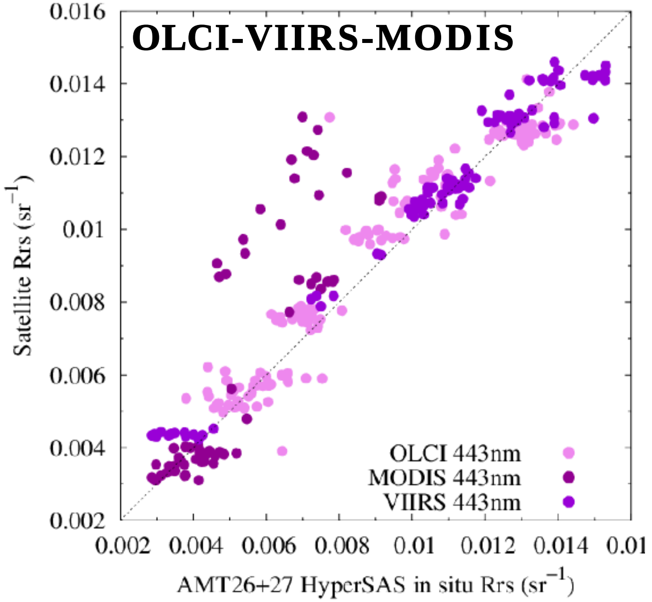
# Comparison of AC processors.

Which is the most accurate atmospheric correction model?



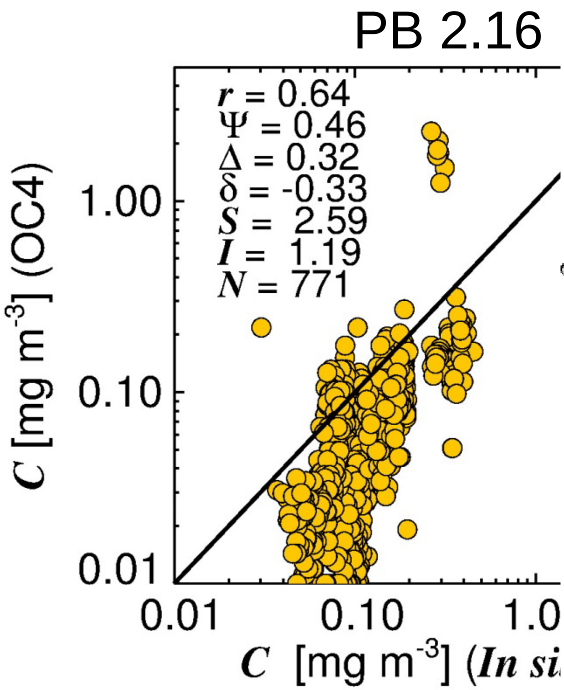



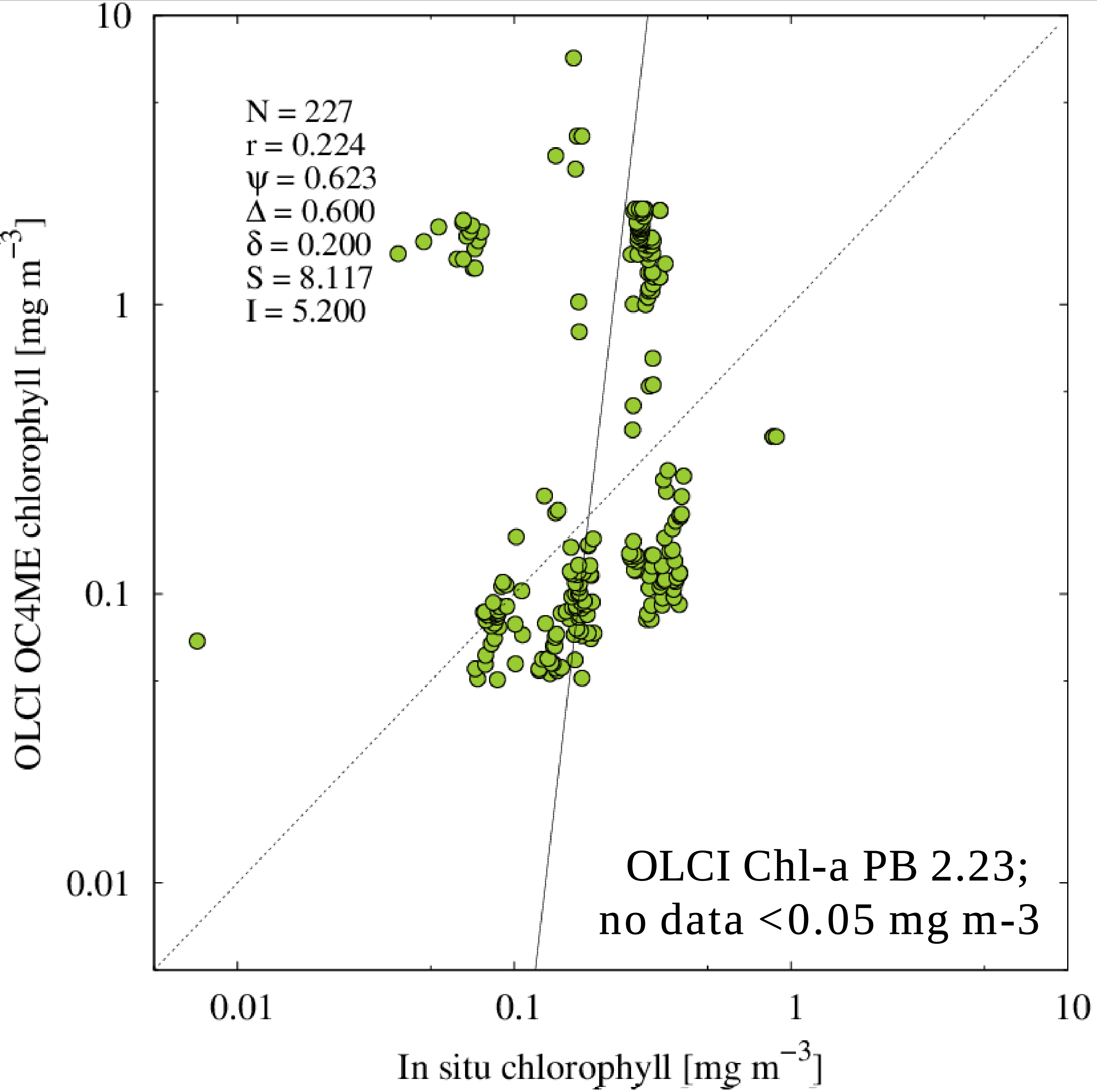




**Relative Percentage Difference of AC processors (443 nm):**
OLCI 4 %;
VIIRS 3%;
MODIS-A 48%.

**Conclusion:**
The most accurate AC is Std OLCI, which is similar to VIIRS. Systematic bias in MODIS-Aqua.

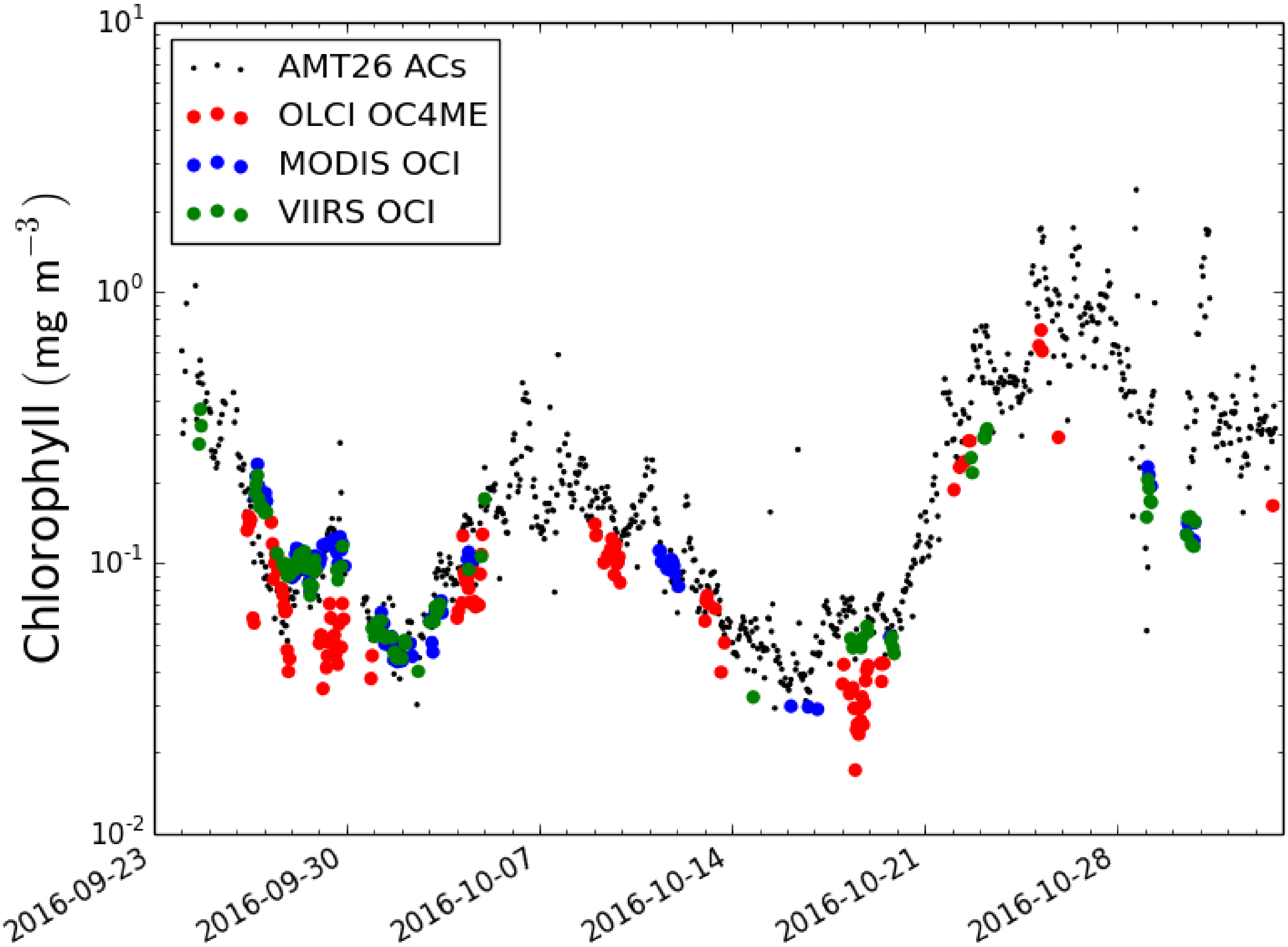
# Validation of S-3A OLCI Chl-a – PB 2.23.



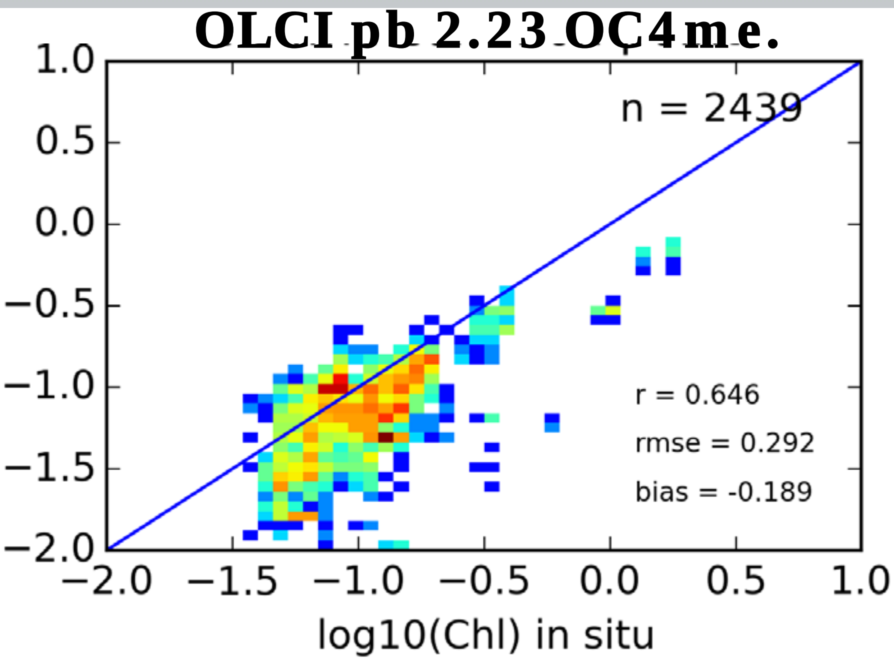

**PB 2.16: 47 %,**
**PB 2.23 >100%**
under-estimate
in OLCI Chl-a in
open ocean
areas.

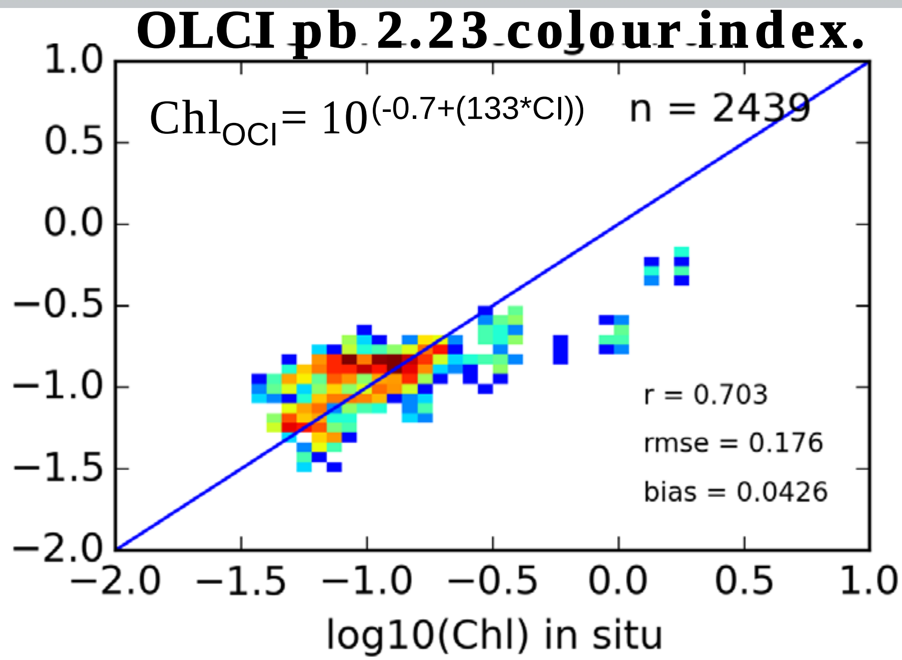
# S-3A OLCI, MODIS-A, VIIRS Chl-a.

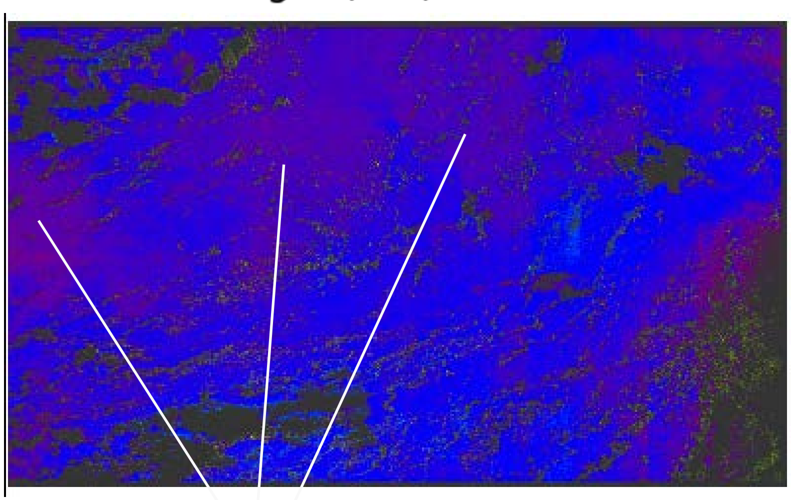



**Consistent under-estimate** in **OLCI Chl-a** compared to VIIRS and MODIS-A.

# Atlantic Gyres: S-3A OC4Me & OCI Chl-a.

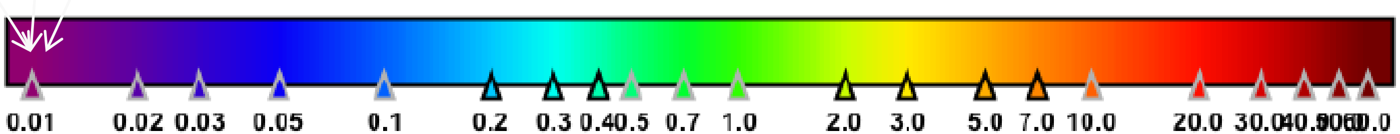


3A O
d by
ndex


Chl-a
0.01 $mgm^{-3}$



# Conclusions.

- AMT4SentinelFRM has supplied FRMs in **open-ocean blue waters, which represent 60% of the global ocean**.
- **Maximising Sentinel Match-ups:** through deployment of semi-autonomous optical systems, 10 fold increase in S-3A match-ups.
- **OLCI PB 2.23**, the FRMs showed that there was an **over-estimate in $R_{rs}$** ranging from 8 % in blue, 18 % in green & 88 % in red bands. However std OLCI $R_{rs}$ is more accurate than other AC models & consistent with VIIRS.
- This produced a **large under-estimate in OLCI PB 2.23 Chl-a in open ocean areas** & over-estimate at higher Chl-a, relative to MODIS-A & VIIRS.
- **Under-estimate in OLCI Chl-a** can be **improved** using **Colour Index algorithm**.

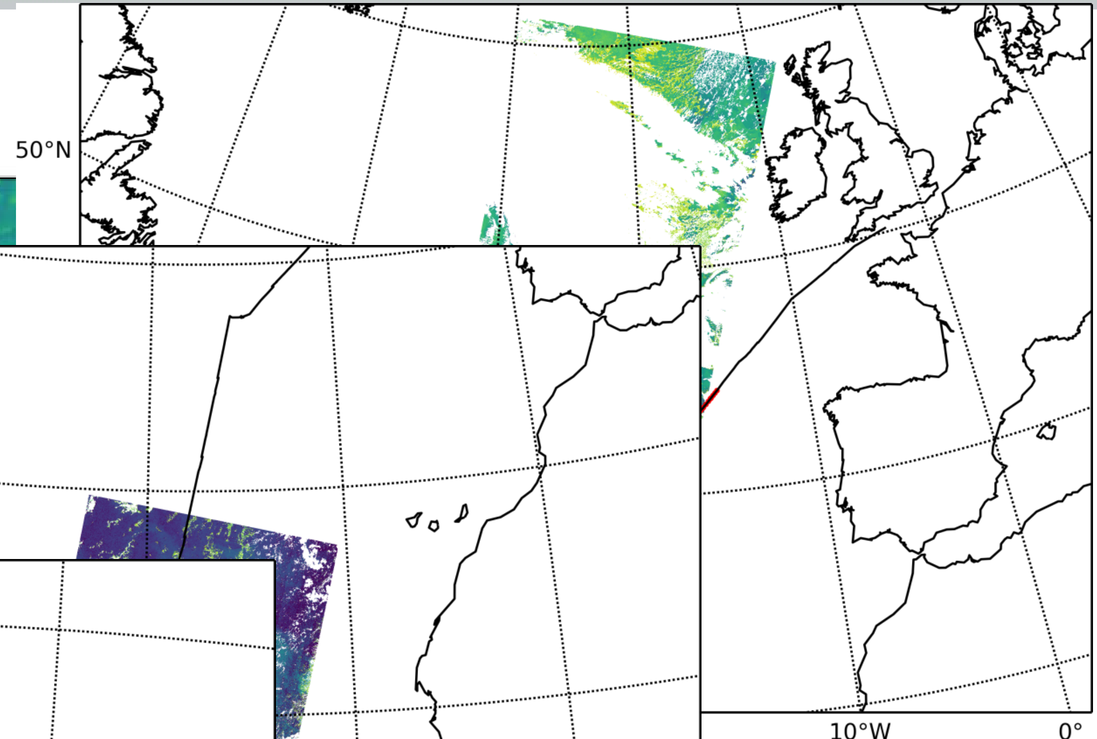
# Recommendations.

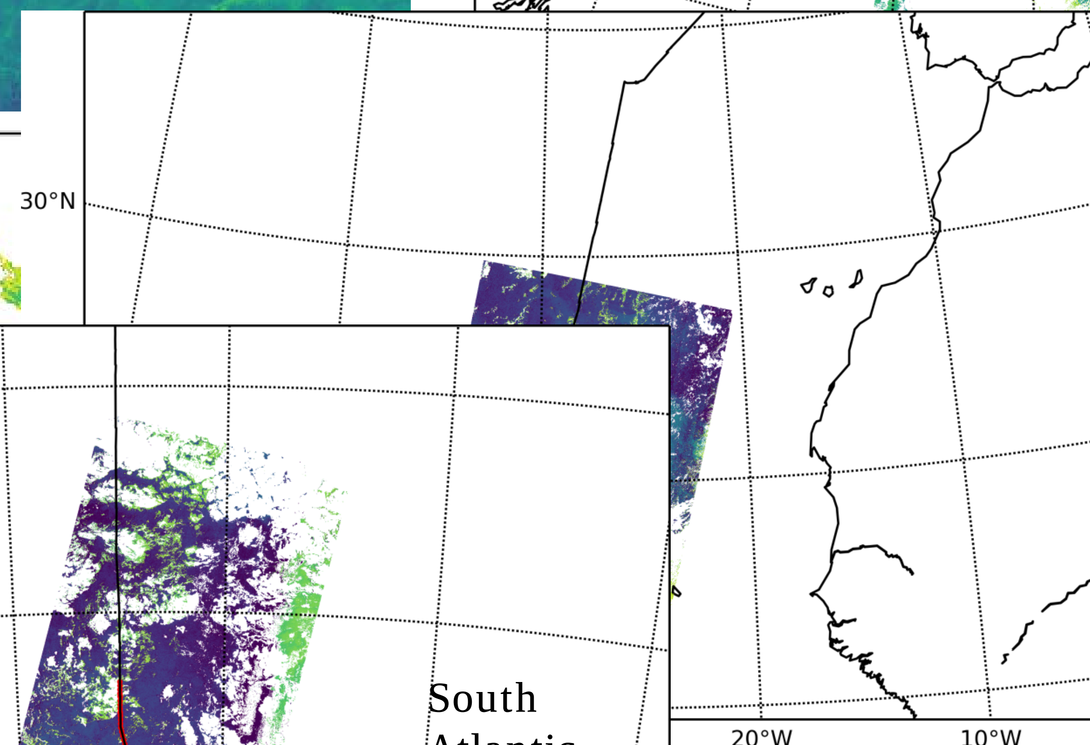
- The NERC UK **Atlantic Meridional Transect** is an ideal platform to validate **multiple Satellite products** across a range of oceanographic conditions and **especially** in the **oligotrophic** blue **waters, of the Atlantic Ocean**.
- Specific funding to facilitate collection of high quality FRMs for continued validation of satellite products.
- **For accurate Sentinel-3 remote sensing reflectance ($R_{rs}$)** in the Atlantic Ocean, use **std OLCI** processor or **POLYMER**.
- **Under-estimate in OLCI Chl-a** in oligotrophic waters can be **improved** using **Colour Index algorithm**.
- **Integration** of the **most accurate Sentinel products** into Global Earth Observation Systems (**GEOS**) for societal benefit for the Atlantic Ocean; for estimating carbon / $CO_2$ flux budgets, maintaining healthy seas & sustainable food provision.

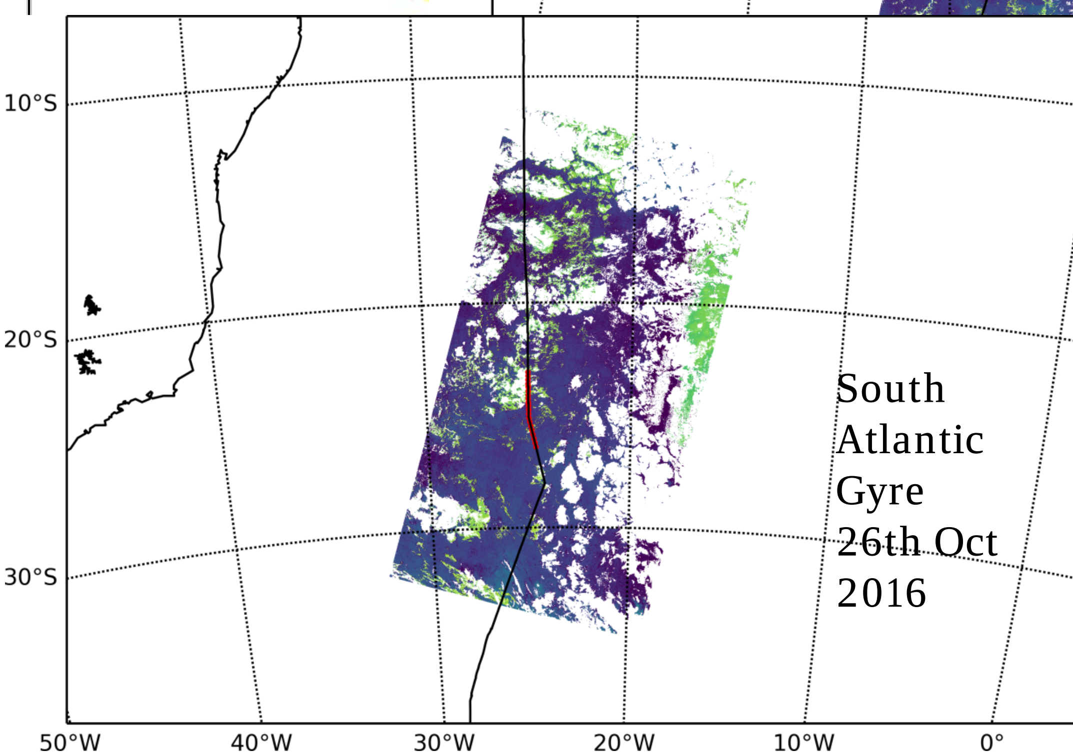
# Thank you

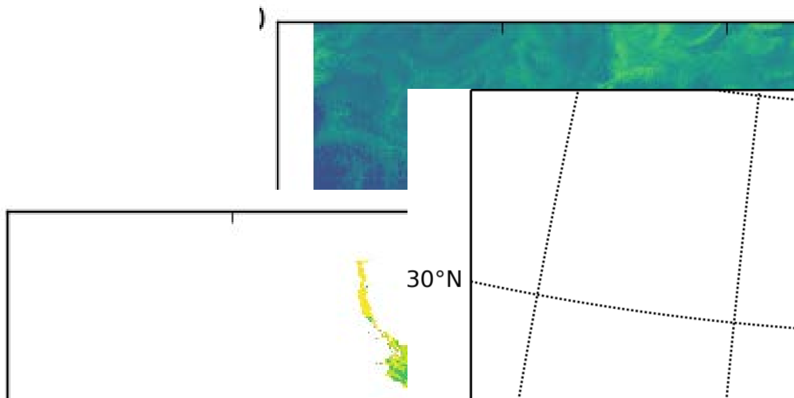
# AMT4SentinelFRM: OLCI validation.

**TWO AMT4SentinelFRM Campaigns:**
**AMT26:** UK to Falkland Islands , **20 Sept - 5 Nov 16.**




**AMT27:**
UK to Falkland Islands,
**23 Sept – 5 Nov 2017.**

# Calculation of uncertainty – HyperSAS $R_{rs}$ example

$$R_{rs} = \frac{L_t - \rho L_i}{E_s}$$

**Calculation equation for $R_{rs}$**

$$\sigma^2_{R_{rs}} = \left(\frac{\delta R_{rs}}{\delta L_t}\sigma_{L_t}\right)^2 + \left(\frac{\delta R_{rs}}{\delta L_i}\sigma_{L_i}\right)^2 + \left(\frac{\delta R_{rs}}{\delta E_s}\sigma_{E_s}\right)^2 + \left(\frac{\delta R_{rs}}{\delta \rho}\sigma_{\rho}\right)^2$$

**Measurement equation and sensitivity coefficients**

$$+2\frac{\delta R_{rs}}{\delta L_t}\frac{\delta R_{rs}}{\delta L_i}\sigma_{L_t}\sigma_{L_i}\Re(L_t, L_i) + 2\frac{\delta R_{rs}}{\delta L_t}\frac{\delta R_{rs}}{\delta E_s}\sigma_{L_t}\sigma_{E_s}\Re(L_t, E_s) + 2\frac{\delta R_{rs}}{\delta L_i}\frac{\delta R_{rs}}{\delta E_s}\sigma_{L_{it}}\sigma_{E_s}\Re(Li, E_s)$$

$$+\sigma^2_{others}$$

**Further uncertainty terms to be added**

**Correlation terms**

# Calculation of uncertainty – HyperSAS $L_t$ example

$$L_t = \left(C_{L_t} - D_{L_t}\right) S_{L_t}$$

**Calculation equation for $L_t$**

$$\sigma_{L_t}^2 = \left(\frac{\delta L_t}{\delta C_{L_t}}\sigma_{C_{L_t}}\right)^2 + \left(\frac{\delta L_t}{\delta D_{L_t}}\sigma_{D_{L_t}}\right)^2 + \left(\frac{\delta L_t}{\delta S_{Lt}}\sigma_{S_{L_t}}\right)^2 + \sigma_{others}^2$$

**Measurement equation and sensitivity coefficients**

Type B estimates of straylight, polarization, environmental etc

$$S_{L_t} = \frac{S_{2016} + S_{2017}}{2}$$

**Calculation equation for $L_t$ calibration coefficient (S)**

$$\sigma_{S_{L_t}}^2 = \left(\frac{\delta S_{L_t}}{\delta S_{2016}}\sigma_{S_{2016}}\right)^2 + \left(\frac{\delta S_{L_t}}{\delta S_{2017}}\sigma_{S_{2017}}\right)^2$$

**Measurement equation and sensitivity coefficients**

2% uncertainty in calibration process

# AMT26: OLCI validation criteria.

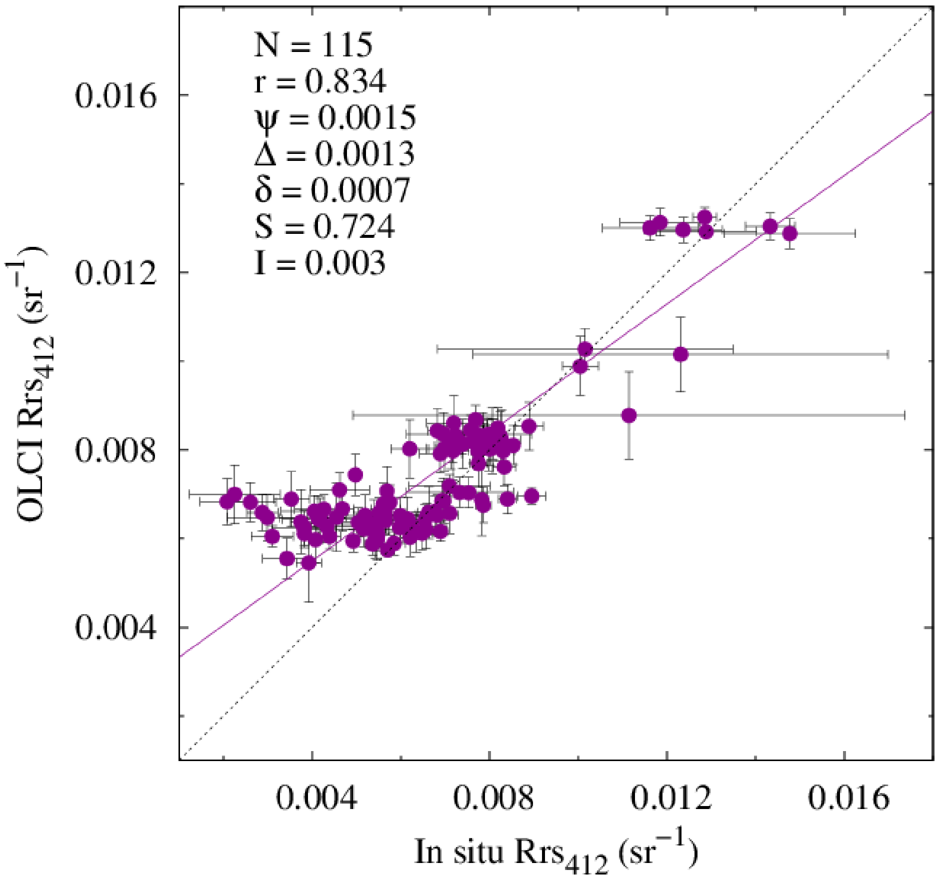
**Match-up selection:**

- Within a +/-1 hour window (though played with this window)
- 3x3 pixel box centred in the coordinates of the in situ observation.
- When multiple in situ data in pixel, the average value used.
- Match-ups were excluded if the median coefficient of variation (CV) of Rrs was higher than 0.15
- Standard deviation of the satellite derived Rrs over the 3x3 pixels extraction used as index of variation.
- QC flag used:

INVALID, LAND, CLOUD, CLOUD_AMBIGUOUS, CLOUD_MARGIN, SNOW_ICE, SUSPECT, HISOLZEN, SATURATED, HIGHGLINT, WHITECAPS, AC_FAIL, OC4ME_FAIL, ANNOT_TAU06, RWNEG_O2, RWNEG_O3, RWNEG_O4, RWNEG_O5, RWNEG_O6, RWNEG_O7 and RWNEG_O8.

# OLCI Validation: Impact of Uncertainty.

**HyperSAS 412 nm ±1 hour window, CV < 0.15, no unc. QC**




**HyperSAS 412 nm ±1 hour window, CV < 0.15, unc. < 5%**