

# *Three years of Aerosol Measurements Using an Automated Photometer on the First long-term AERONET Ship Site*

B. Torres, L. Blarel, P. Goloub, G. Dubois, M.F. Sanchez-Barrero, E. Lind, A. Smirnov  
I. Slutsker, J.C. Antuña, R. González, M. Sicard, J.M. Metzger and P. Tulet



## Work highlight:

**3-year data on-board R.V. Marion Dufresne (MAP-IO project - Tulet et al., 2024)**

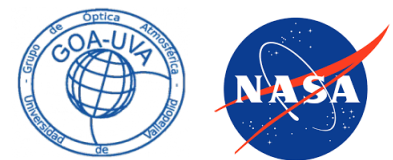
*A milestone in bringing AERONET's automated measurements and protocols to research vessels, using a ship-adapted version of the CIMEL 318-T.*



From land (ex. Dakar site)



to ocean (ex. North sea tests)



# Ship Photometer Integration in Mobile Development at LOA



Developments within Agora-lab  
between LOA and CIMEL.  
Financed by  
ESA & ACTRIS



## A. Mobile platforms with *slow movements*

- Speed < 40 km/h
- Platform: Ships
- Small oscillations < 5°
- Completely automatic
- Adapted version CIMEL 318T (1)
  - Extinction (sun/moon) + Rad.
  - Scenarios/measurements same as in AERONET.



## B. Mobile platforms with *fast movements*

- 40 km/h < Sp < 1000 km/h
- Platform: Plane, train & car
- Allows full oscillations
- Only optics from CIMEL
- Semi-automatic (on board)
- Modulable AERONET measurements
- Specific design (3 versions)
  - PLASMA 1 (Extinction) (2)
  - PLASMA 2 (Extinction) (3)
  - PLASMA 3 (Ext. Moon/Sun + Rad.) (4)



# A bit of history of ship adapted version...

2004-2024

2017

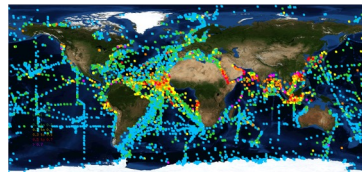
2018

2019

2020

2021

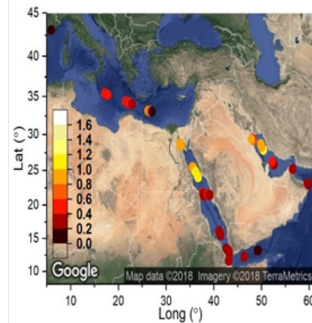
**MAN Network  
(AERONET)  
Microtops II  
(manual measurements)**



**1st ship-borne AOD automatic  
CIMEL CE318-T measurements  
(France- Kuwait, Unga et al. 2019)**

- Boat's attitude taken with magnetic compass (like PLASMA in planes)
- Several issues since the system required frequent calibration to account for the magnetic environment.
- Revealed need of an Airshield
- Revealed need of a new rain sensor

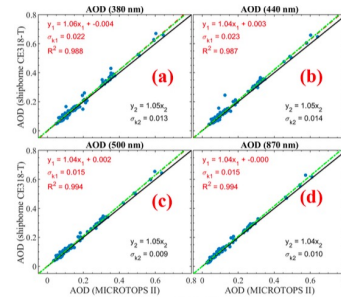
**RV Kommandor Iona  
First automatic CIMEL CE318T  
AQABA campaign**



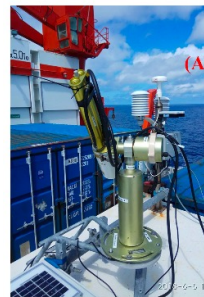
**PS113 PS116  
RV POLARSTERN  
CE318-T**



**MOSAIC/Arctic**



**A lot of quality AOD compared to the 1st campaign.  
Yin 2019 et al. presented a comparison of AOD  
measurements with a MAN Microtops-II instrument.  
Good results: RMSE between 0.009 and 0.015**

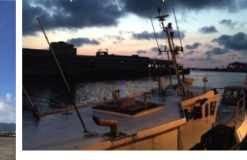


- Boat's attitude from CIMEL CE318T GPS and SIMRAD-H60 Compass
- Errors up to 5°-10° complicating sun tracking on some occasions
- First Airshield system (air from cabin)
- New optical rain sensor.

**TANGORA  
CE318-T  
Sea2Cloud**



**Phishing boat  
CE318-T (GPS imp.)  
North Sea**

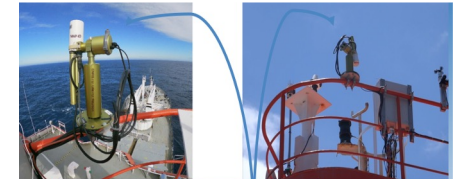


**Last steps before operational.**

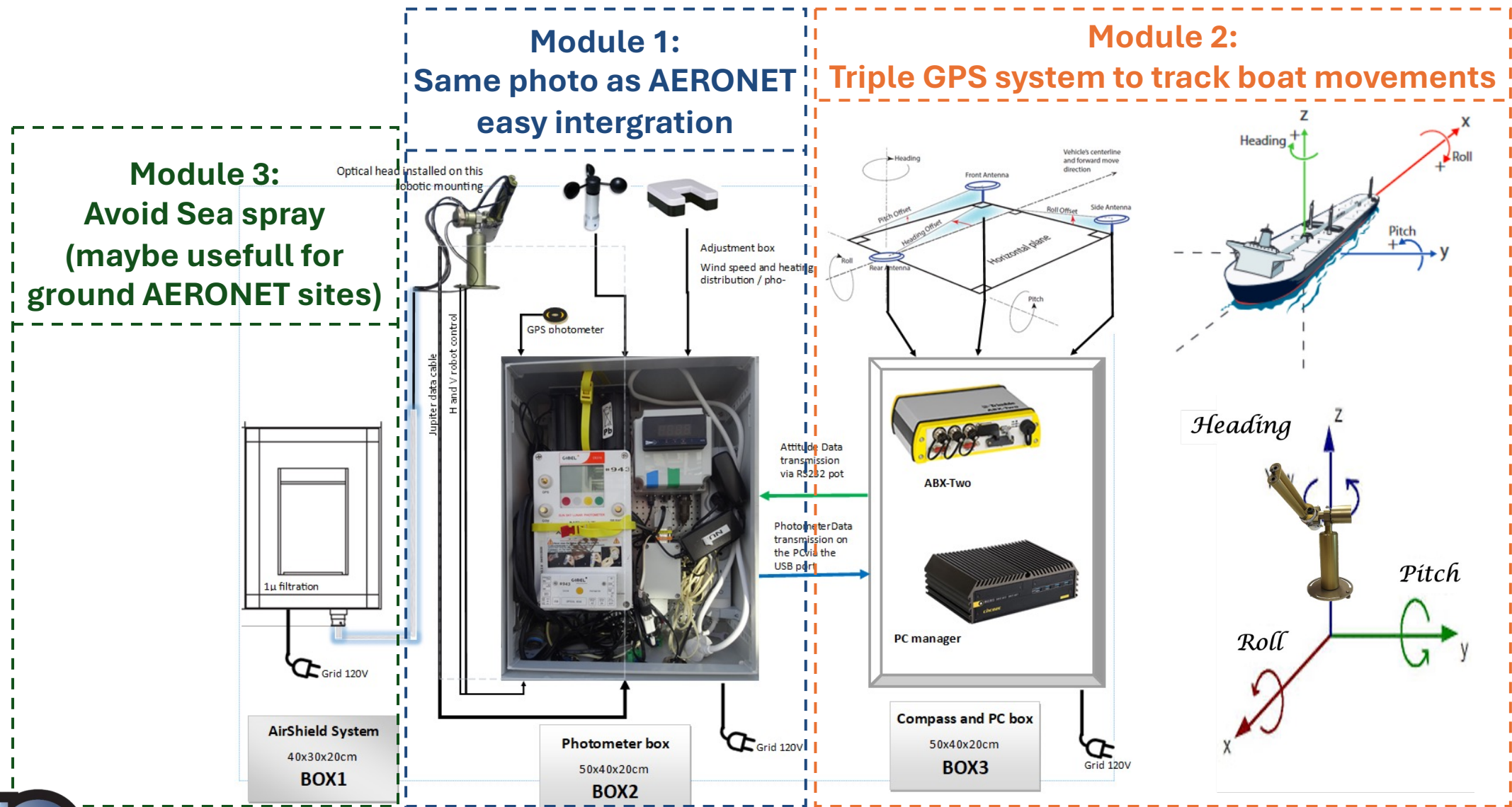
- New inertial GPS unit ABX-Two.
- Uncertainty less than 0.5°
- New Airshield (air from outside)
- New firmware for sky measurements



**Marion Dufresne  
CE318-T  
Permanent  
operational since 2021**



# Ship Photometer: strategy based on a modular concept

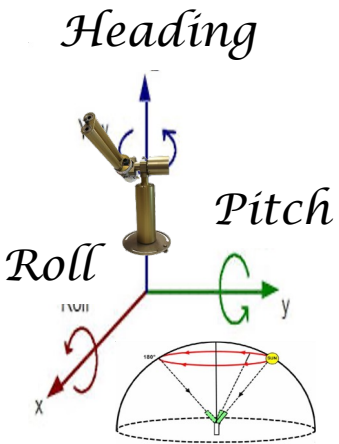


# R.V. Marion Dufresne: 1<sup>st</sup> “long-term” automated Ship Site

## 1. 100% AERONET compatible: Thanks to the use of CIMEL 318-T photometer

- Same wavelengths: 340, 380, 440, 500, 675, 870, 940 (IWV), 1020 and 1640nm.
- Fulfilling AERONET protocols/standard requirements.
- Same control and automation standards of ground-based AERONET photometer.

## 2. Control of ship movements (1 Hz frequency)



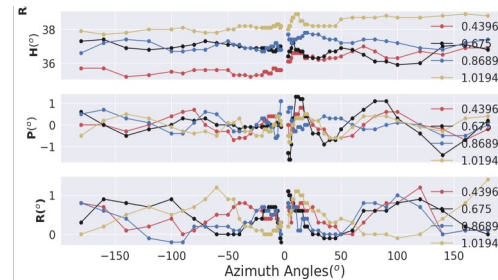
A. Information considered for direct sun

*Go sun corrected: Software adapted thanks to our close collaboration with CIMEL (AGORA-lab)*

B. Monitoring the movements during radiance

measurements:

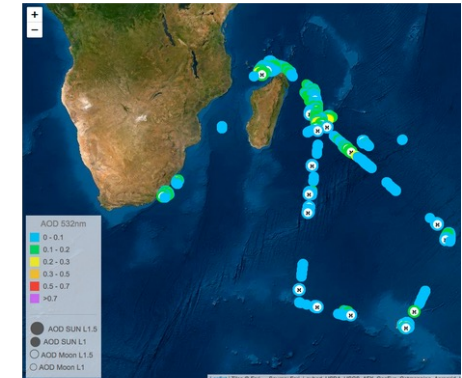
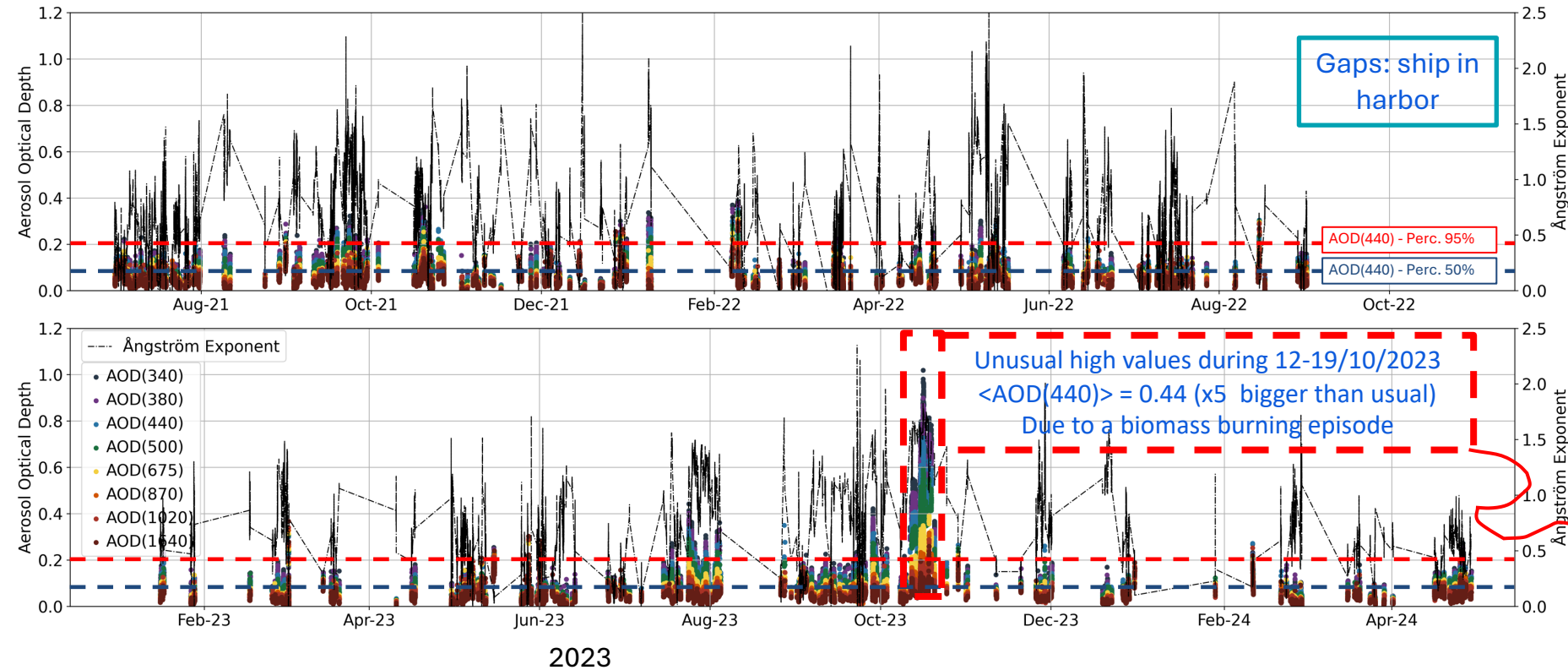
*Quality control*



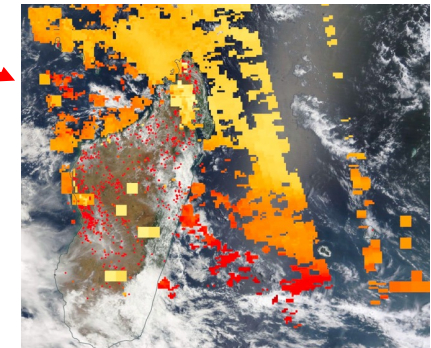
# R.V. Marion Dufresne: 1<sup>st</sup> “long-term” automated Ship Site

## 3. Quality assured AOD data for 3 years - Time series

Data available at AERES/ACTRIS and <https://mobile.photons.univ-lille.fr/>



Spatial distribution of Version 3 level 1.5 AOD data from MD during 2021 and 2022. Mostly at West/Indian Austral Region



$\langle \text{AOD}(440) \rangle = 0.096$   
 $\langle \text{Ångström Exponent} \rangle = 0.74$

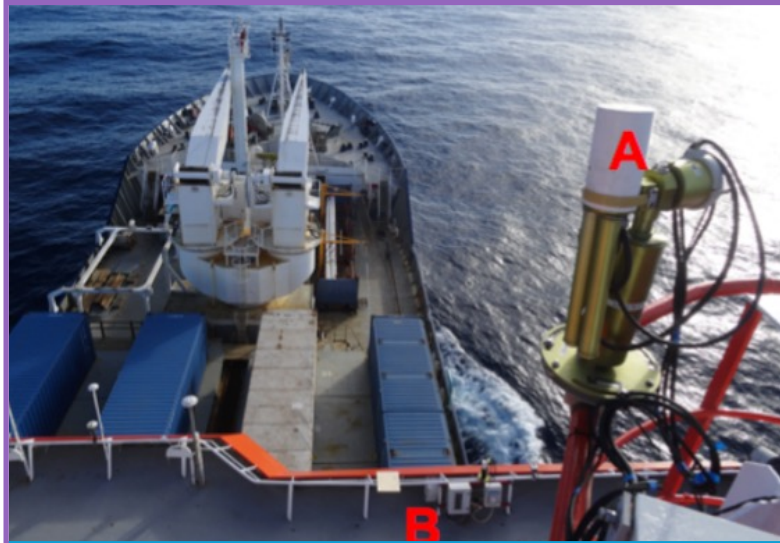
Normally pristine conditions. Averages consistent with other studies in the area (Smirnov et al. 2002, Mallet et al. 2018 ...)

AOD(440) typically under the limit of 0.20 (percentile 95%)

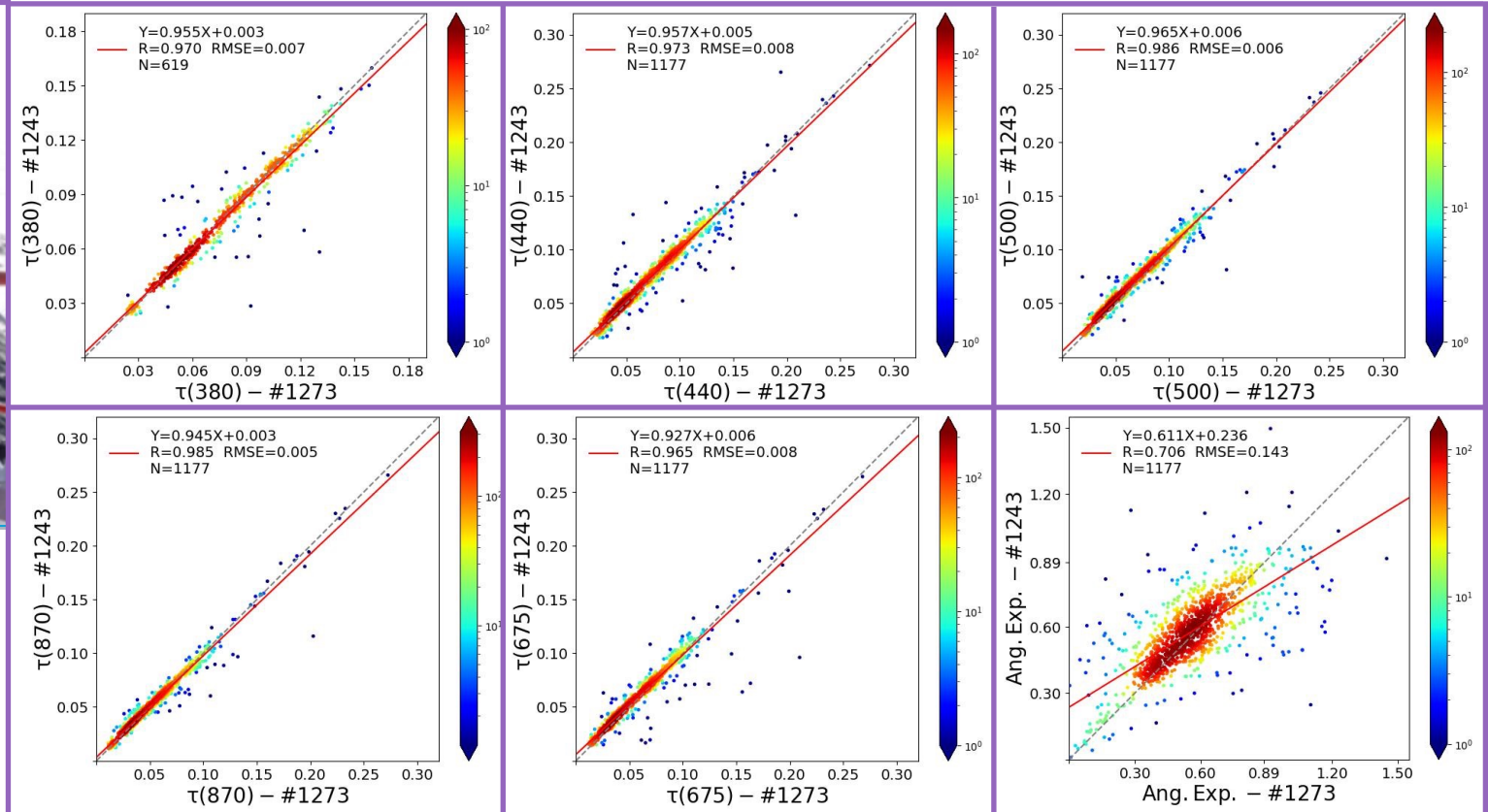


# R.V. Marion Dufresne: 1<sup>st</sup> “long-term” automated Ship Site

## 3. Quality assured AOD data for 3 years : Validation I – 2 photo. in Transama



- Around 1 month of collocated data:
  - A) #1273 official photometer
  - B) #1243 testing photometer
- Data in Level 1.5 (maximum on ships), it includes moon data



*More about TRANSAMA in Sanchez Barrero's Poster*

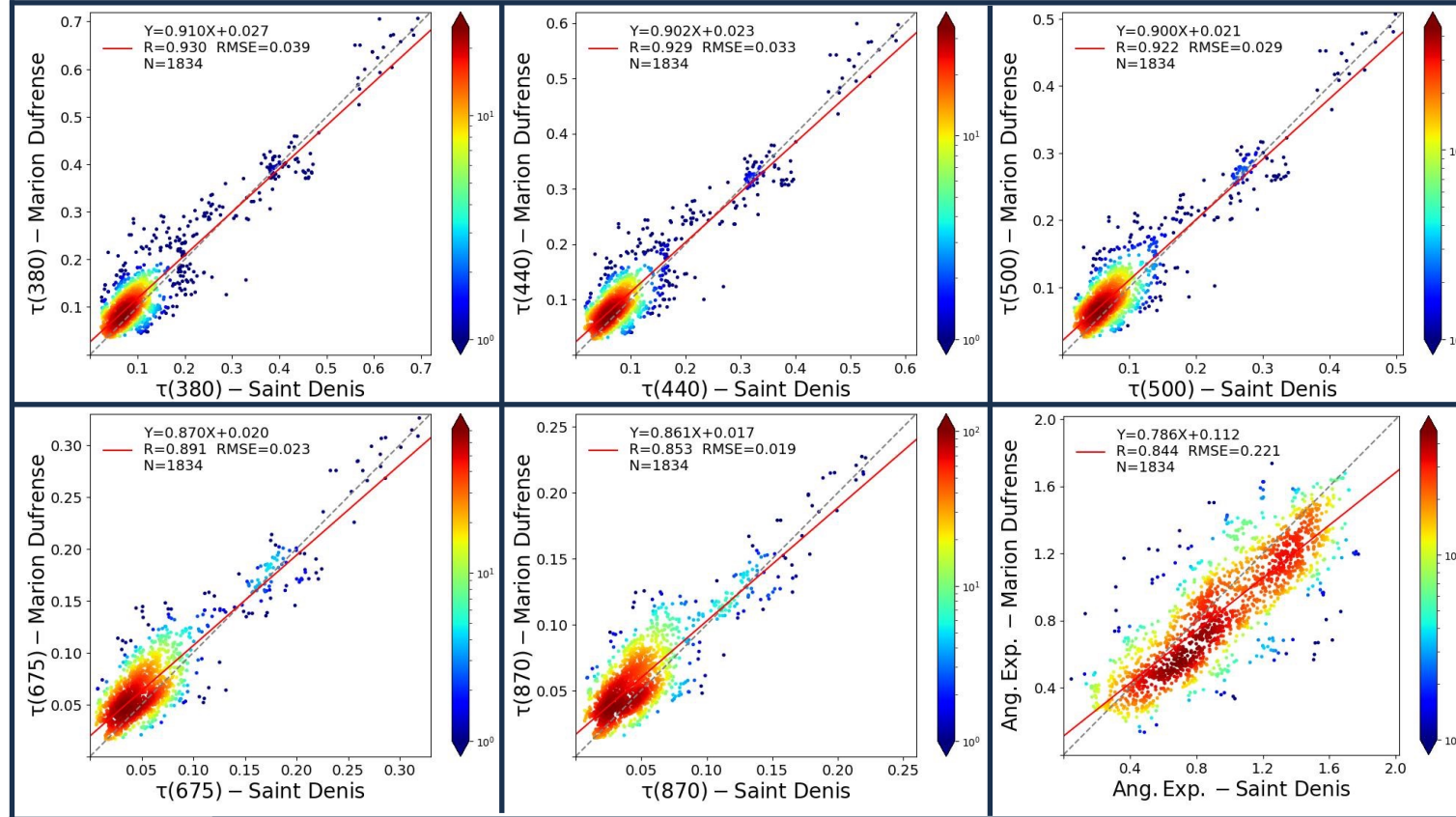
- Overall, there is good correlation for all AOD channels with  $R > 0.96$  and slopes close to 1. There is almost no BIAS (maximum value at 500 nm  $\sim 0.002$ , not shown).  $RMSE < 0.01$  (lower than AERONET AOD error estimation).
- Correlation for the Angstr. Exponent is more discrete, likely due to small AOD values.



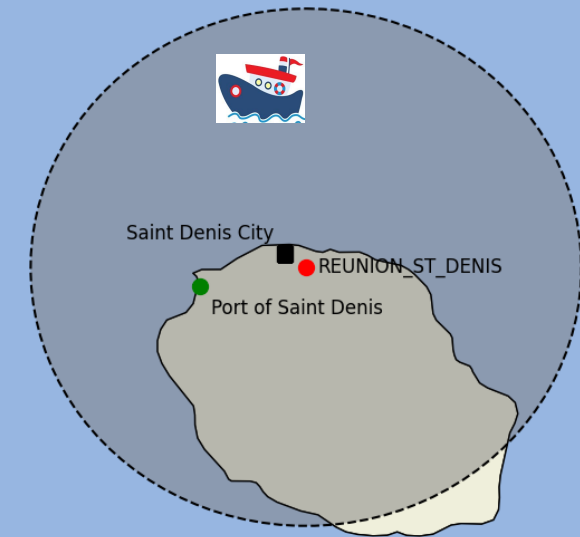


# R.V. Marion Dufresne: 1<sup>st</sup> “long-term” automated Ship Site

## 3. Quality assured AOD data for 3 years – Validation II : Comparison with St Denis site



- Measurements within a distance of 50km
  - ... and a time difference of 3 minutes
  - Level 2.0 for St Denis data (no moon)



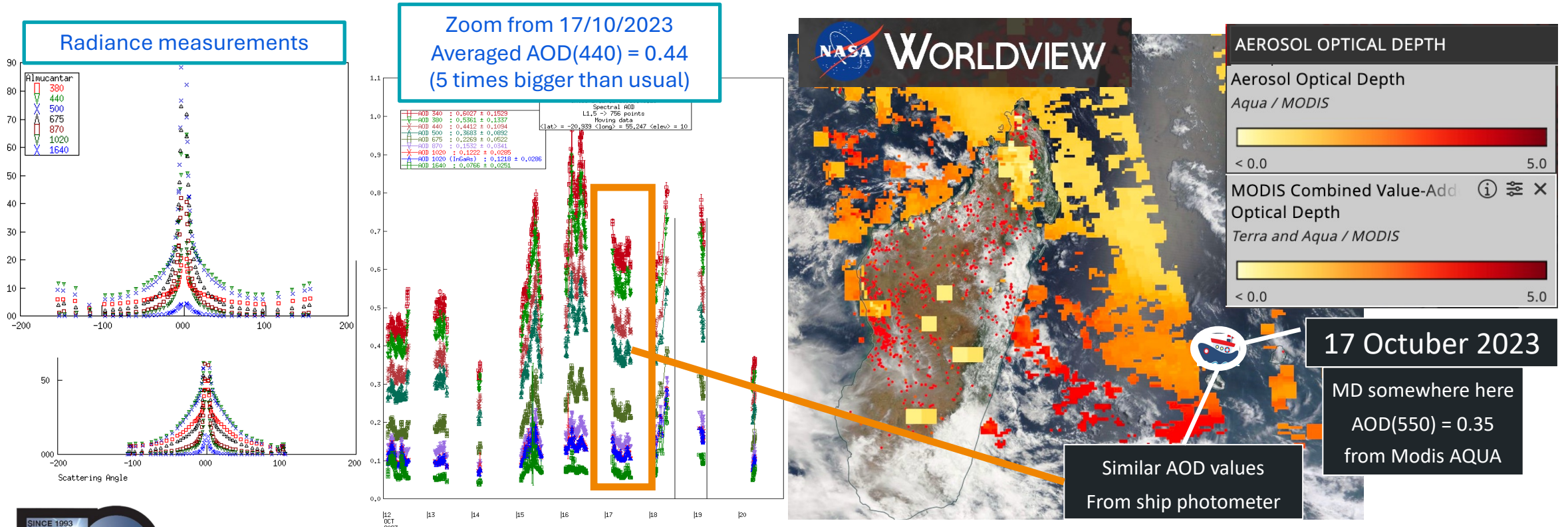
- Overall, good correlation for all channels and for the Angstrom Exponent (with  $R \sim 0.9$ )
- Positive and significant BIAS for all AOD channels (ex. +0.018 for 380nm, +0.011 for 870nm) likely due to the elevation of the REUNION\_ST\_DENIS site at 93 m.a.s.l. Angstrom Exponent present a small negative BIAS (-0.09) larger influence of urban aerosol



# R.V. Marion Dufresne: 1<sup>st</sup> “long-term” automated Ship Site

## 4. We also measure radiance following AERONET protocols. Possibility to perform AERONET standard retrievals from a boat: aerosol microphysical and optical properties

- Example: Fires in Madagascar caused  $\tau(440) > 0.4$  for almost week (potential L2 AERONET retrievals) ➤ *Specially useful for aerosol optical properties from new performant satellite sensor validations (PACE, 3MI, etc.)*

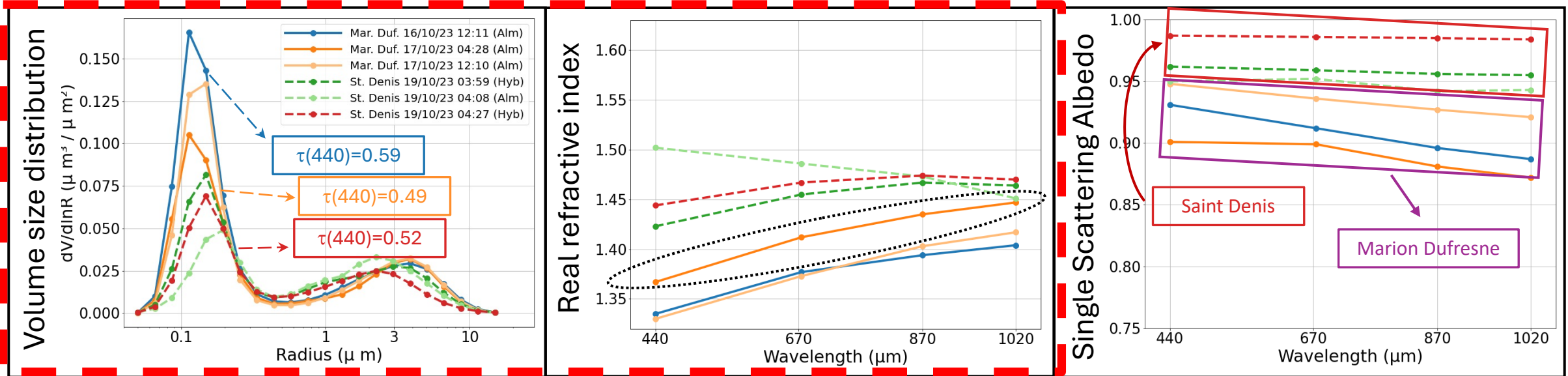


# R.V. Marion Dufresne: 1<sup>st</sup> “long-term” automated Ship Site

## 4. We also measure radiance following AERONET protocols. Possibility to perform AERONET standard retrievals from a boat: aerosol microphysical and optical properties

3 first AERONET retrievals (potentially L2) from a boat (16th-17th Oct.)  
Presented together with the closest L2 retrievals at St Denis (19th Oct.)

Only few retrievals due to clouds



Some words about this “validation” (not the same day & around 40 km distance) :  
Maybe too large fine mode (artifact) due to (anti-) correlation with real ref. index or  
maybe partially true: hygroscopicity since it is in the middle of the ocean ? (under discussion)

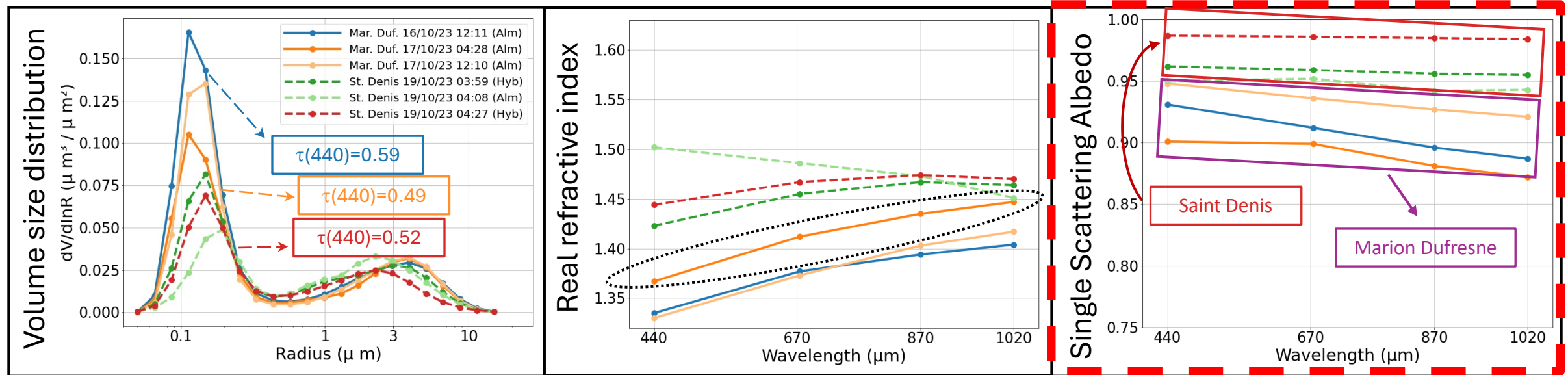


# R.V. Marion Dufresne: 1<sup>st</sup> “long-term” automated Ship Site

## 4. We also measure radiance following AERONET protocols. Possibility to perform AERONET standard retrievals from a boat: aerosol microphysical and optical properties

3 first AERONET retrievals (potentially L2) from a boat (16th-17th Oct.)  
Presented together with the closest L2 retrievals at St Denis (19th Oct.)

Only few retrievals due to clouds



Concerning absorption : The values of SSA for the three Level 2.0 retrievals are between 0.9 and 0.95 which seems quite reasonable (very first check) for a BB event, though St Denis presents much higher SSA values on 19<sup>th</sup> (Level 2)

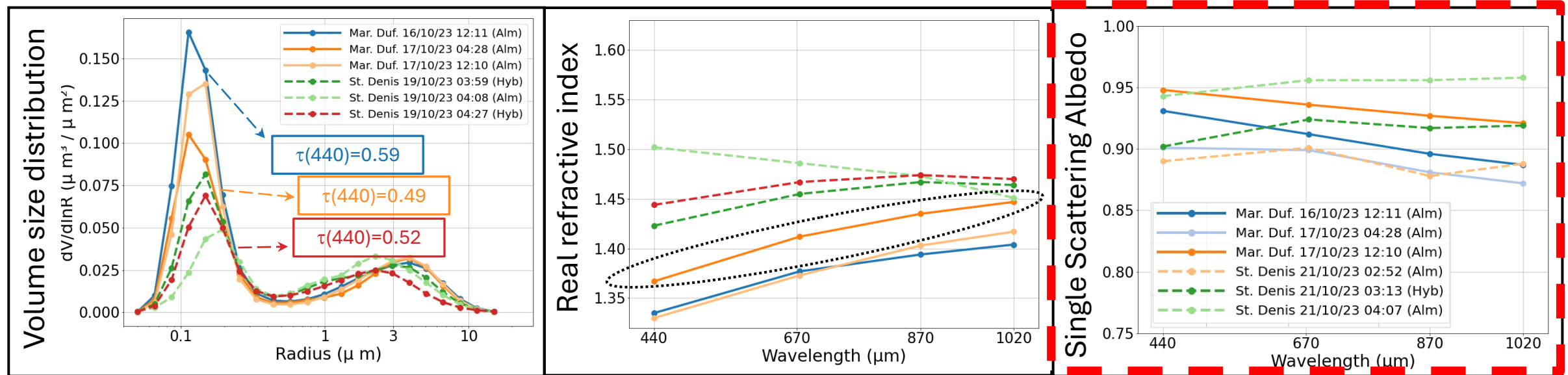


# R.V. Marion Dufresne: 1<sup>st</sup> “long-term” automated Ship Site

## 4. We also measure radiance following AERONET protocols. Possibility to perform AERONET standard retrievals from a boat: aerosol microphysical and optical properties

3 first AERONET retrievals (potentially L2) from a boat (16th-17th Oct.)  
Presented together with the closest L2 retrievals at St Denis (19th Oct.)

Only few retrievals due to clouds



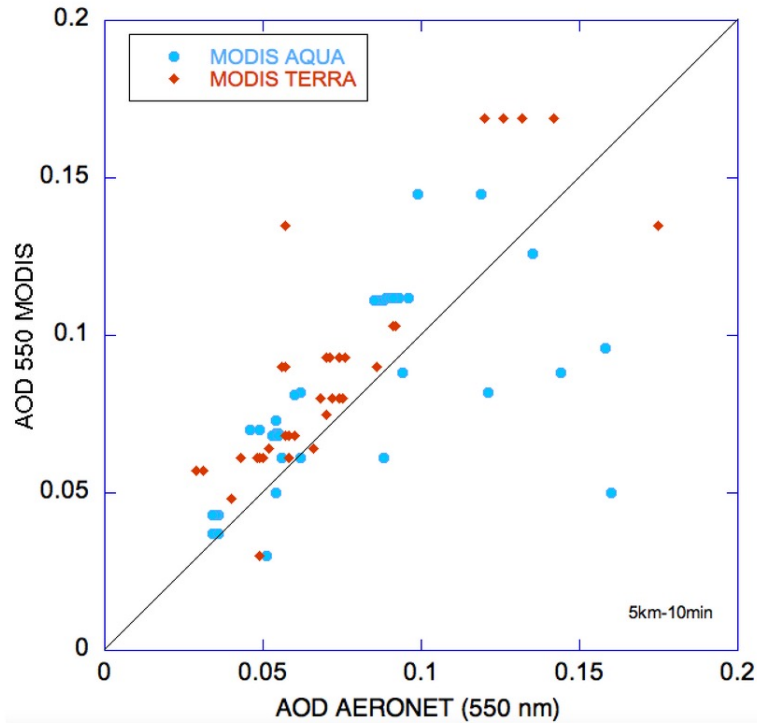
When we looked at the retrievals at St Denis from the following days (shown retrievals on 21<sup>st</sup> thought not in level 2.0 -  $\tau(440)=0.26$ ) or previous days (for instance 12<sup>th</sup> not in level 2.0  $\tau(440)=0.35$ , not shown) present much lower values of SSA matching the values obtained at Marion Dufresne



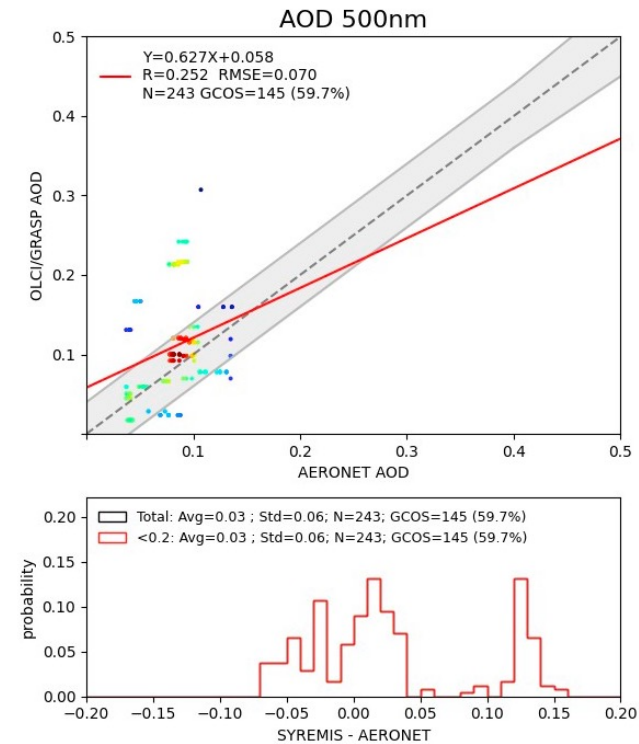
# R.V. Marion Dufresne: First long-term automated Ship Site

## 5. Three-year series of valuable data for satellite cal/val activities

Examples of first comparisons of AOD values



Comparison of AOD(550) from MD ship-photometer and MODIS TERRA/AQUA official product during Jul 2021 and Aug 2022. (Credit to AERES)



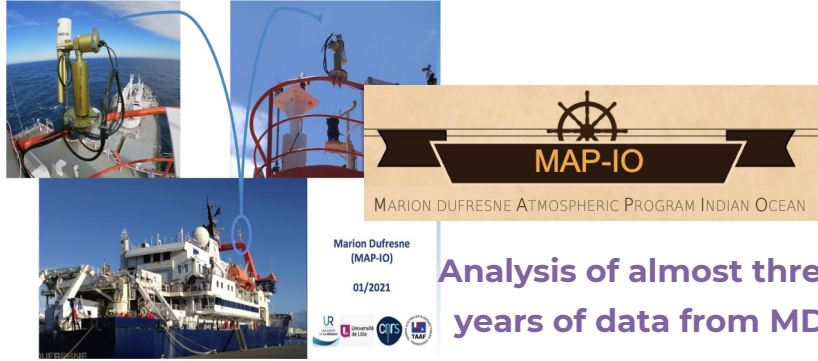
Comparison of AOD(500) from MD ship-photometer and S3/OLCI official product during Jul-Sept 2021. (Credit to GRASP-SAS - [J.C. Antuña](#))  
*The whole 3 years validations for S3-OLCI and S5P-TROPOMI coming soon*



# After 2021 – The future question: Towards an automatic sea-network?

Permanent

Campaigns



**MAP-IO**  
MARION DUFRESNE ATMOSPHERIC PROGRAM INDIAN OCEAN

Marion Dufresne (MAP-IO)  
01/2021

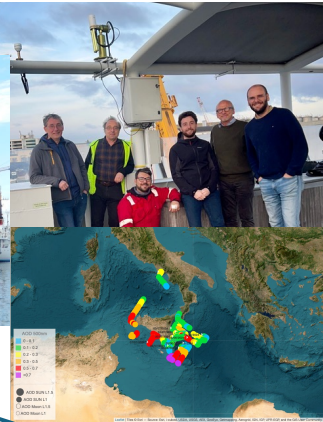
Analysis of almost three years of data from MD

**RV Marion Dufresne**  
CNRS (FRANCE)  
Permanent – operational since 2021

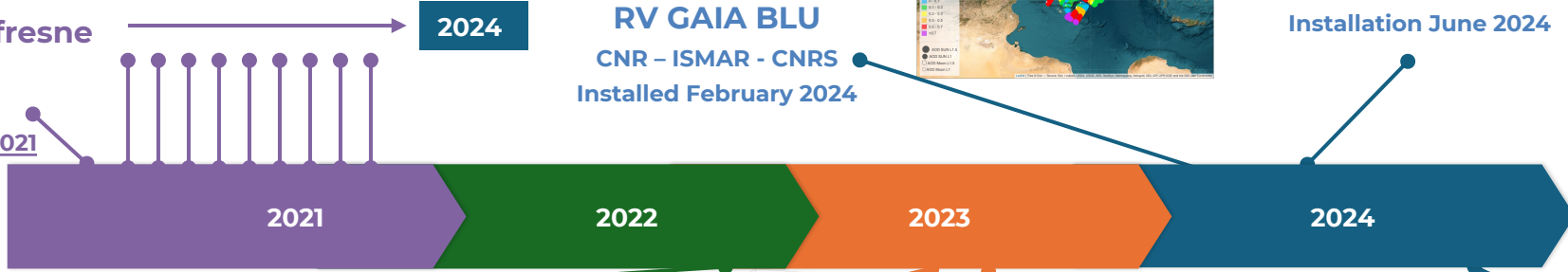
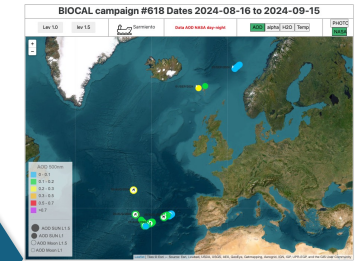
2024



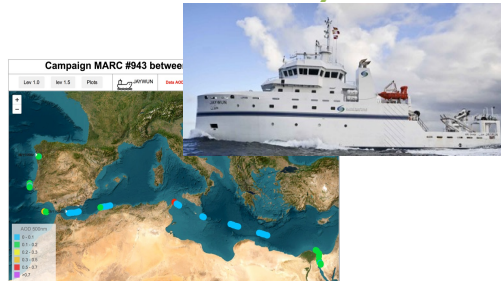
**RV GAIA BLU**  
CNR – ISMAR – CNRS  
Installed February 2024




**RV Sarmiento de Gamboa**  
CSIC – GOA – CNRS  
Installation June 2024

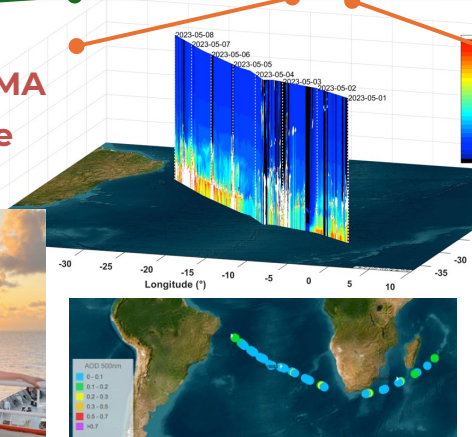


**AREAD campaign**  
RV Jaywun  
(Dec 2022-Jan. 2023)



Campaign MARC #943 between

**AMARYLLIS-TRANSAMA**  
RV Marion Dufresne  
APR-MAY 2023



See poster of Sanchez-Barrero et al.

**AEROHDF**  
Côte d'albâtre (Ferry)  
JULY 2023



**RV SHEARWATER**  
NASA – NOAA – CNRS  
PACE-PAX campaign  
SEPT 2024



## Next steps

1. **Scientific publication describing the whole system and the first 3 years of data on the R.V. Marion Dufresne (MAPIO project):** on going...
2. **Analysis of the first data coming from new vessels:** R.V. Gaia Blu and R.V. Sarmiento.
3. **Establishing new ship sites:** already in contact with the R.V. Mario Ruivo from Portugal (Maria Joao, Univ. Evora) and some North American vessels (through NASA-GODDARD).
4. **Some technical improvements:** change the GPS system (stock issues), develop a new 'variable airshield' system, and create a new enhanced weather control box.
5. **Management of a new ship photometer network (5-7 instrument).** Support from ESA, EUMETSAT, AERONET-NASA-GODDARD and CIMEL & GRASP companies.
6. **Further future – Big Network:** After proof of concept, a bigger network will need a new robust system made by a company (CIMEL in collaboration with LOA within AGORA-lab)





# Thanks



Etna from Gaia Blu. Credit to the crew of the Gaia Blu