Validation of the ocean products from the space-borne ATLAS, ALADIN and CALIOP and air-borne LNG lidars

Cédric Jamet[1], Cyrille Flamant[2], Eric Lécuyer[2], Julien Delanoë[2], Xavier Mériaux[1], Quitterie Cazenave[2], Sayoob Vadakke Chanat[1]

[1] *LOG/ULCO, Wimereux, France*

[2] *LATMOS, Paris, France*

10- Measurement techniques and observations of Ocean properties

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Purpose of the study

Remote sensing of ocean color has changed our vision of the distribution of phytoplankton and ocean carbon for the past forty years → Synoptic view at high spatial (hundreds to thousand meters) and temporal (~2 days) resolutions

BUT observation limited to clear-sky, day-light, over clouds, high Sun elevation angles and are exponentially weighted toward the ocean surface

→ **LIDAR can help to overcome some of these issues**

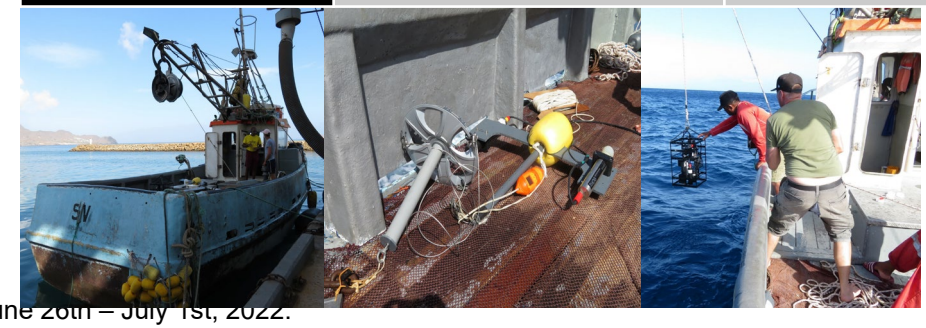
→ No existing oceanic profiling lidar but space-borne lidars exist: CALIOP on CALIPSO and ATLAS on IceSat-2

→ **Need to validate the oceanic products from those space-borne lidars**

DATASET

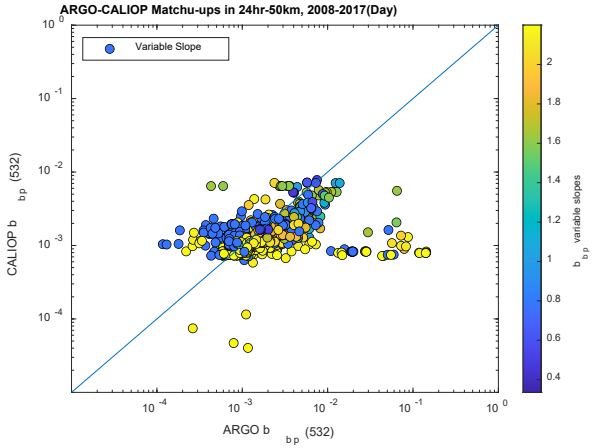
- AEOLUS DATA
  - ALADIN UV HSRL
  - Monitoring of wind profiles
- CALIOP DATA
  - (http://orca.science.oregonstate.edu/lidar_nature_2019.php)
  - 2010-2017
  - Globally
  - Day- and nighttime
- IN-SITU MEASUREMENTS
  - In-situ measurements in Cabo Verde
  - BGC-Argo (Claustre et al., 2020)
    - Globally
    - 2010-2017

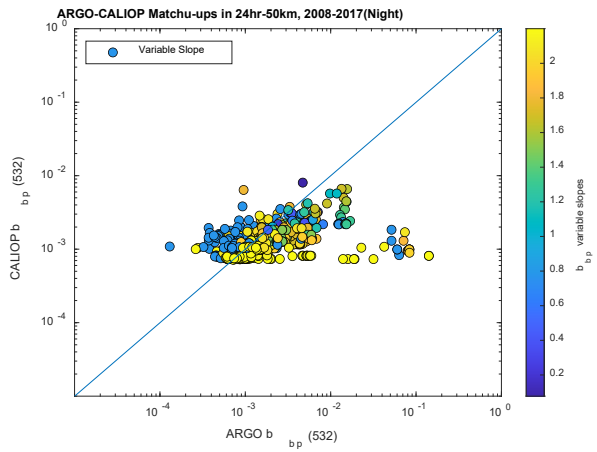
Sensor	Dates	# stations
ADM/AEOLUS	10-15-17-22 Sept. 2021	9
CALIOP	09 Sept. 2021	2
LNG	10-17-18 Sept. 2021	11



VALIDATION OF CALIOP OCEANIC PRODUCTS

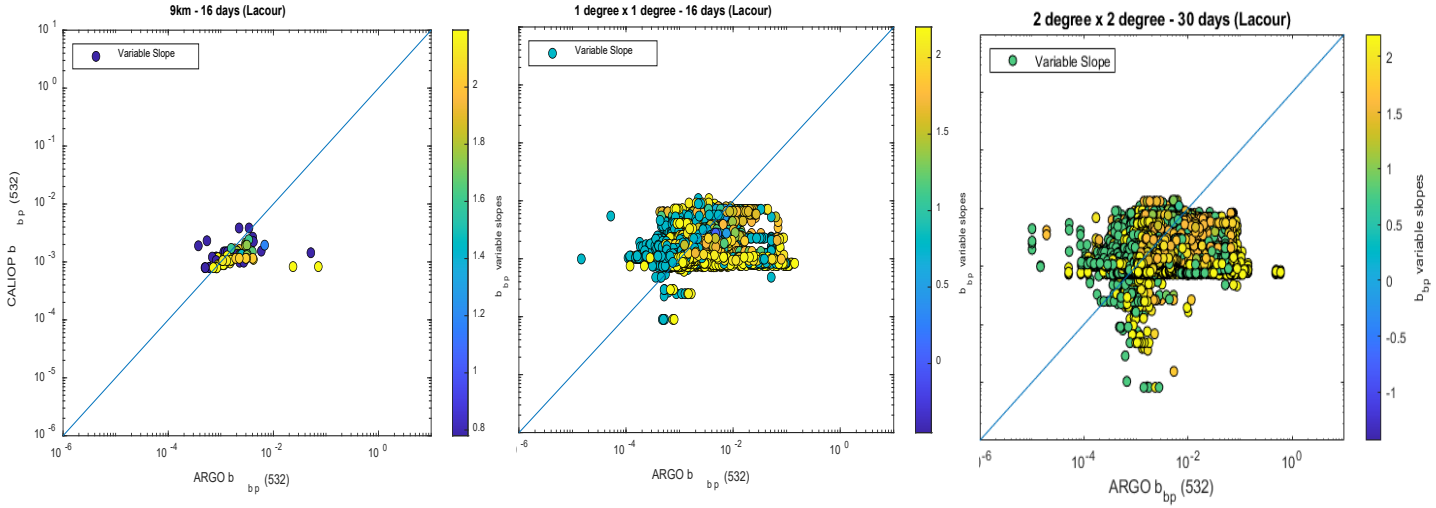
MATCHUPS RESULTS FOLLOWING BISSON MATCHUP PROTOCOL FOR CALIOP





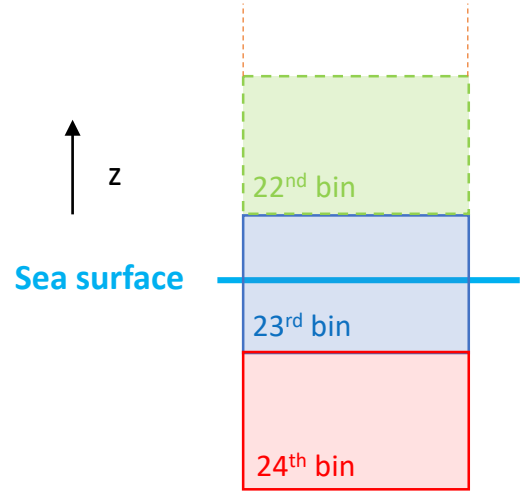
	DAY	DAY	NIGHT	NIGHT
Statistical parameters	Fixed slope	Variable slope	Fixed slope	Variable slope
N	1007	1007	788	788
RMSE (m^{-1})	0.00983	0.01385	0.00927	0.01232
Bias (m^{-1})	-0.00170	-0.00265	-0.00173	-0.00257
Relative Error (%)	56	49	48	43

MATCHUPS RESULTS FOLLOWING LACOUR



	CONFIG 1 ALL	CONFIG 1 ALL	CONFIG 2 ALL	CONFIG 2 ALL	CONFI G 3 ALL	CONFIG 3 ALL
Statistical parameters	Fixed slope	Variable slope	Fixed slope	Variable slope	Fixed slope	Variable slope
N	102	102	15103	15103	146263	146263
RMSE (m^{-1})	0.00707	0.00896	0.00738	0.019493	0.009973	0.01343
Bias (m^{-1})	-0.00138	-0.00204	-0.001139	-0.001744	-0.001474	-0.002184
Relative Error (%)	44	44	61	54	61	53

- Estimation approach for the **LiDAR derived optical parameters**
  - › ADM-AEOLUS HSRL algorithm
    - Taking into account the **altitude of the bins** to get signal from the **ocean**
    - SNR of bin #24 may be too low -> **choice of bin #23**
    - Decomposition of the Lidar signal in bin #23 (Li et al., 2007; Josset et al., 2010)



$$S(23) = S_{atm} + S_s + S_{wc} + S_o$$

Corrected by using the 22nd bin considering the lower atmosphere homogeneous

≈ 0 as the off-nadir angle of ADM-AEOLUS is 35°

≈ 0 for low surface wind (<3 m.s^{-1})

Signal of interest for this study

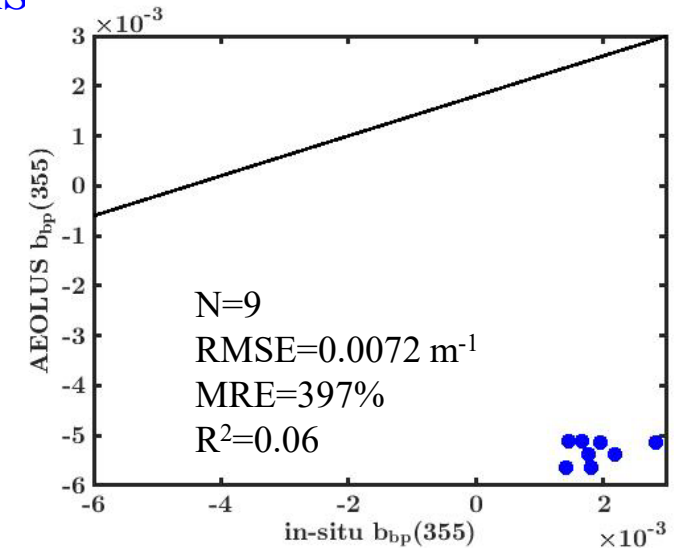
- S_{atm} is the **contribution of the atmosphere** in the 23rd bin
- The **specular reflection of the LiDAR signal on the sea surface S_s** is a function of the wind speed
- The **whitecaps signal S_{wc}** is a function of the effective reflectance and the surface wind
- S_0 is the ocean attenuated backscatter signal, i.e. the **signal of interest**

VALIDATION OF AEOLUS OCEANIC PRODUCTS

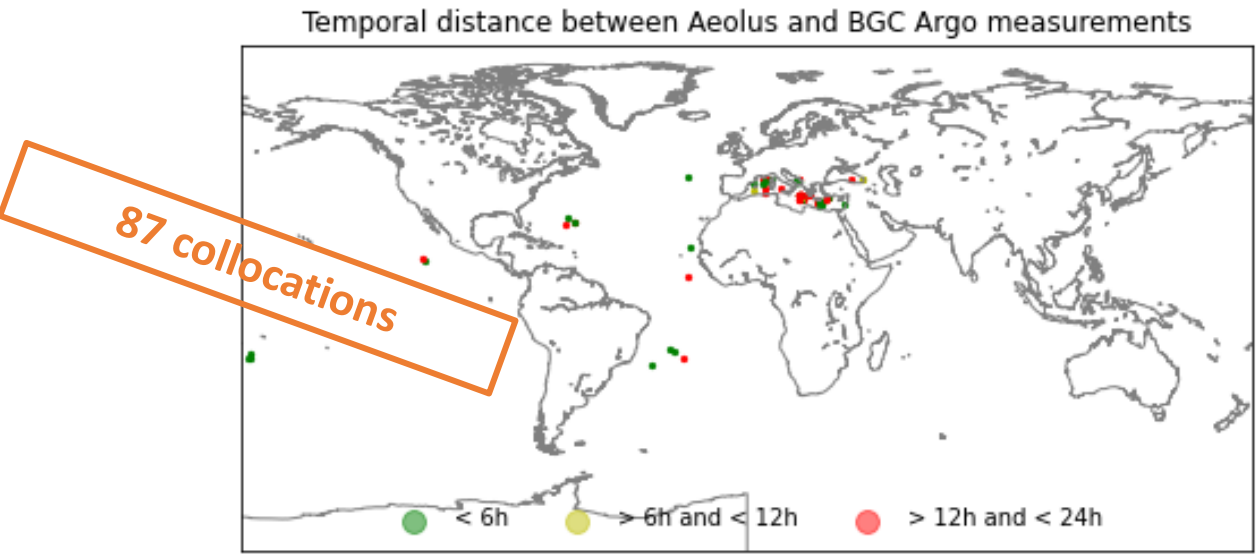
COMPARISON OF AEOLUS DERIVED-b_{bp} AGAINST IN-SITU MEASUREMENTS IN CABO VERDE

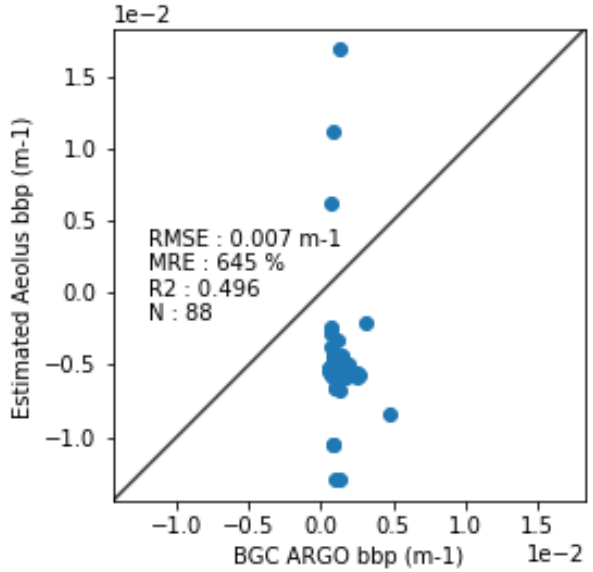
- $\beta_P = \beta_M \frac{(K_{Ray}C_1 - S_R K_{Mie} C_4)}{(S_R K_{Mie} C_3 - K_{Ray}C_2)}, with\ S_R = {}^{S_M}/_{S_P}$
- $b_{bp} = 2\pi.\chi(180°).\beta_p$
- $S_{atm}(23) = S_{atm}(22)\frac{altitude\_bin(23)}{height\_bin(23)}$
- Cross-talk (for **water spectra**,

$C_1 = 1.14,\ C_2 = 1.64,\ C_3 = 1.30,\ C_4 = 1.00$)



COMPARISON OF AEOLUS DERIVED-b_{bp} AGAINST IN-SITU MEASUREMENTS GLOBALLY





CONCLUSIONS

- Use of space-borne lidar to estimate bio-optical and biogeochemical properties of the seawater → No dedicated oceanic lidar → Use of CALIOP, ATLAS and ALADIN → Need to validate estimates

- **Validation of CALIOP oceanic products using BGC-Argo and two different validation schemes**
  - Comparison of two validation protocols for the day- and nighttime CALIOP b_{bp} data using BGC-Argo worldwide between 2010 and 2017
  - **Slight differences between day- and nighttime**
  - **Increased errors when increasing the temporal and distance windows**
  - **Impact of the b_{bp} spectral slope**
  - **Impact of the calculation of BGC-Argo $b_{bp}(532)$ from $b_{bp}(700)$**

→ Need to mix between config 1 of Lacour and Bisson's scheme

→ Need to validate against other datasets such as in Cabo Verde

→ **Need to develop a validation protocol adopted by the community**

- **Algorithm's development to use ALADIN UV HSRL signals to estimate the particulate back-scattering coefficient at 355 nm**
  - **High error on b_{bp} retrievals**
  - Impact on the wway to correct the atmosphere
  - Negative values when including Cx coefficients
  - No relevant to derive *POC* and C_{phyto} at this stage

→Need to better understand the ALADIN signal (threshold on the SNR, binning on more observations)

→Sensitivity study on the Cx values

→Need to consider the surface as a function of the wind speed

→Need to understand the content of the ground signal → May be useful to correct the contribution of the atmosphere

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