Particulate optical properties in the Mediterranean and Black seas through CALIPSO spaceborne lidar measurements

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The Rationale

Ocean subsurface particle distributions have been successfully derived using **CALIOP** (Cloud-Aerosol Lidar with orthogonal Polarization) lidar measurements on the **CALIPSO** (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations) satellite. Assessing the oceanic surface layer's **optical properties** through **CALIOP** is one of the reasons of the **extension** of the **CALIOP** mission for another **3 years** (2018-2020).

The Objective

is the **evaluation** of the potential **CALIOP** ocean products at **regional scale**. **Mediterranean** and **Black seas** have been considered as study cases. Multi-sensor L3 **Ocean Color** (OC) product (MODIS-AQUA and NPP-VIIRS data) provided by the **Copernicus Marine Environment Monitoring Systems** (CMEMS) were used as reference.

Methods

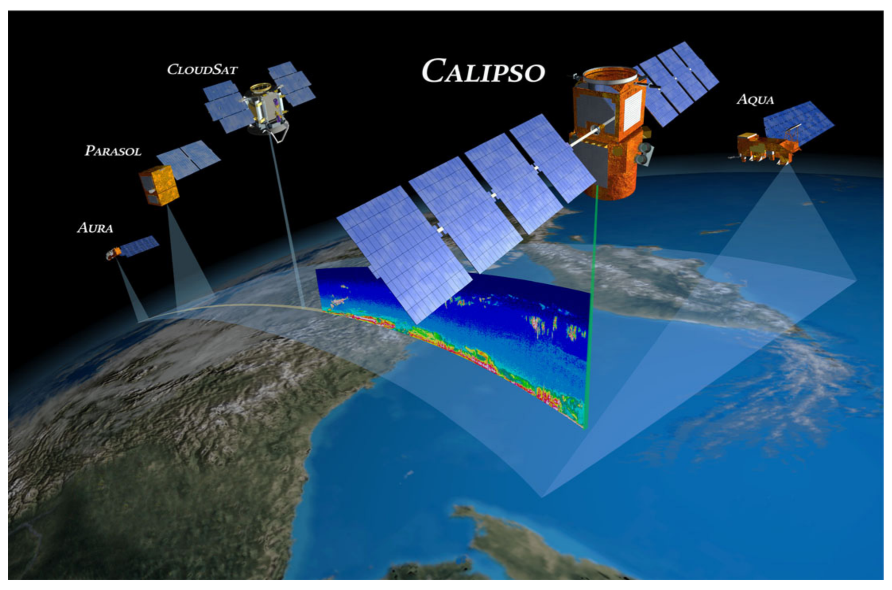
CALIOP

Co-polarized and cross polarized components of the attenuated backscatter coefficient at 532 nm retrieved by **CALIOP** are used, on the basis of [1] and [2], to estimate the column-integrated total (δ_T) and ocean subsurface depolarization ratio (δ_w).

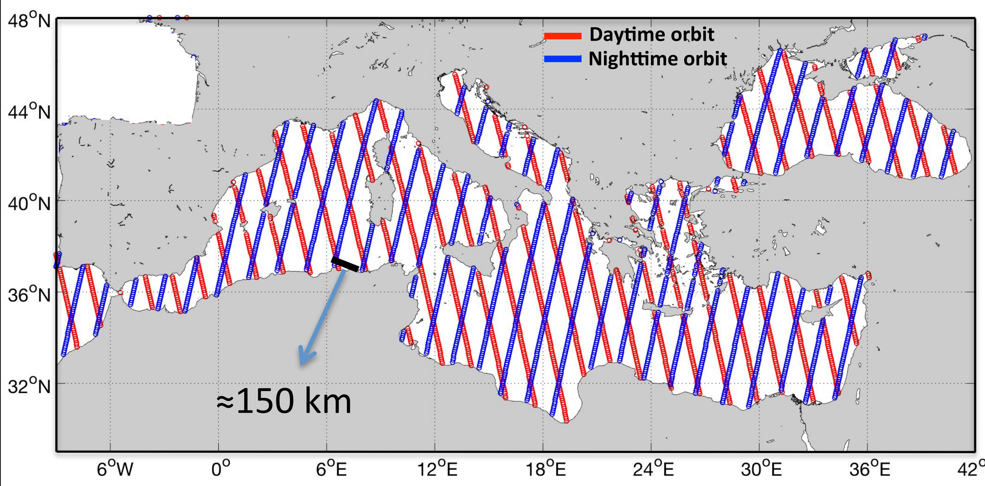
$$\delta_T = \frac{\sum_{i=p}^{i=p+5} \beta_{\perp}^{corr}(z_i)}{\sum_{i=p}^{i=p+5} \beta_{\parallel}^{corr}(z_i)} \quad (1) \qquad \delta_w = \frac{\sum_{i=p+1}^{i=p+5} \beta_{\perp}^{corr}(z_i)}{\sum_{i=p+1}^{i=p+5} \beta_{\parallel}^{corr}(z_i)} \quad (2)$$

The column-integrated ocean subsurface lidar backscatter (γ) is obtained combining (1), (2) and the ocean surface mean squares wave slopes (σ^2, estimated using the wind speed from scatterometer ASCAT and OSCAT and from ECMWF analysis).

$$\gamma = \frac{0.0209}{4\pi\sigma^2 cos^4\theta} exp\left[-\frac{tan^2\theta}{2\sigma^2}\right]\frac{\delta_T}{1-\delta_T/\delta_w} \quad (3) \qquad \frac{\Delta\gamma}{\gamma} \approx 0.15 \quad (4)$$



Dataset used: CALIOP version 4.1 L1 data product ((horizontal resolution of 1/3 km and vertical resolution of 30 m, 22.5 m in water)

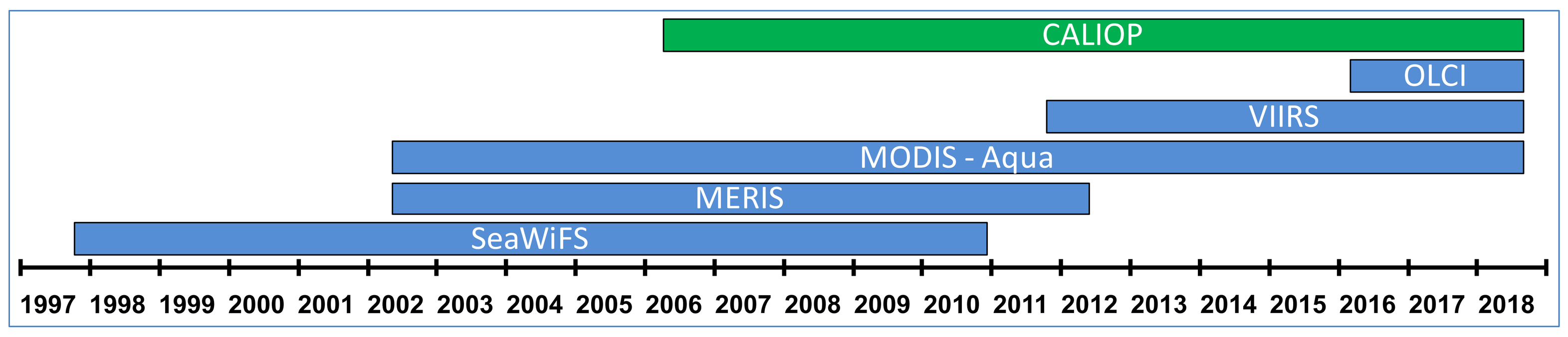


Data sample

Filtering procedure	N° of profiles per year
-Starting data (integration of 30 profiles)	123000
-Filtering for surface height and saturation	92000
-Clear air condition	42000
-Transient response correction and filtering	25000
- Filtering on δ_T and γ and rebinning at 0.25°	6000

Multi-sensor CMEMS OC product

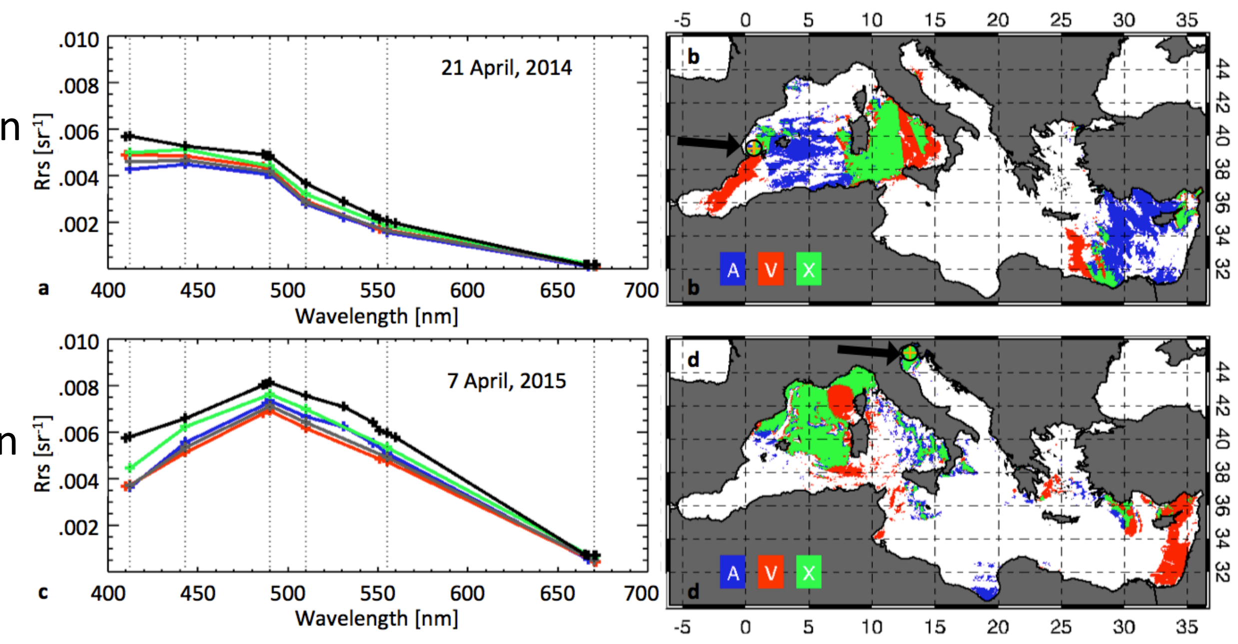
Combination of all available **OC** sensors at any given time



Sensor-Merging: Band-shifting + Inter-Sensor Bias Correction

Application of regional algorithms

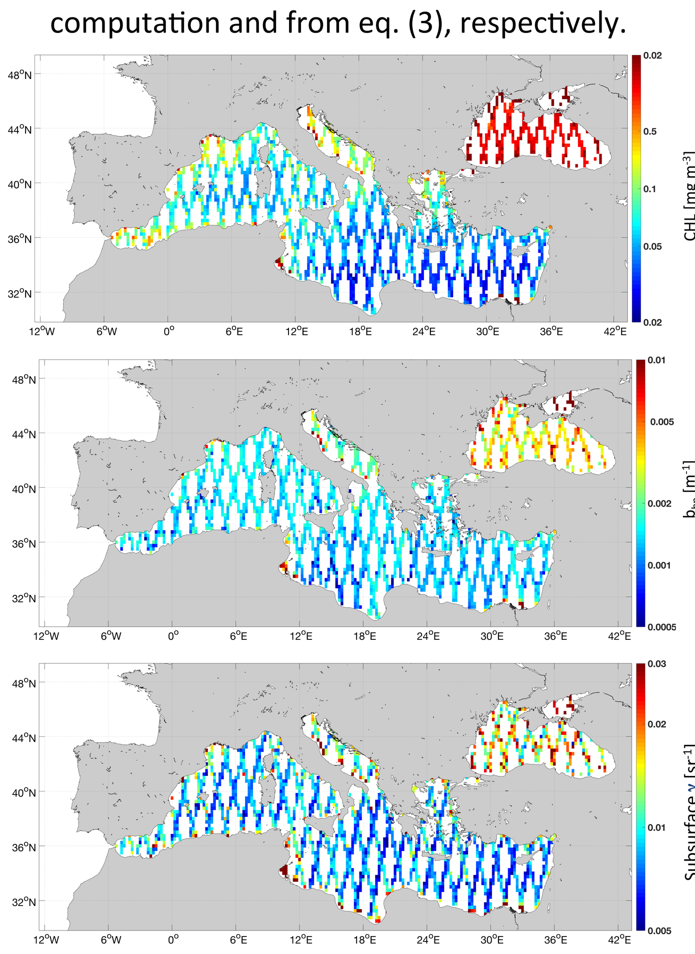
- QAA for IOP computation
- MedOC4.2018 for Chl as in [3]
- BS Algorithm for Chl as in [4]



CHL, BBP and γ comparison

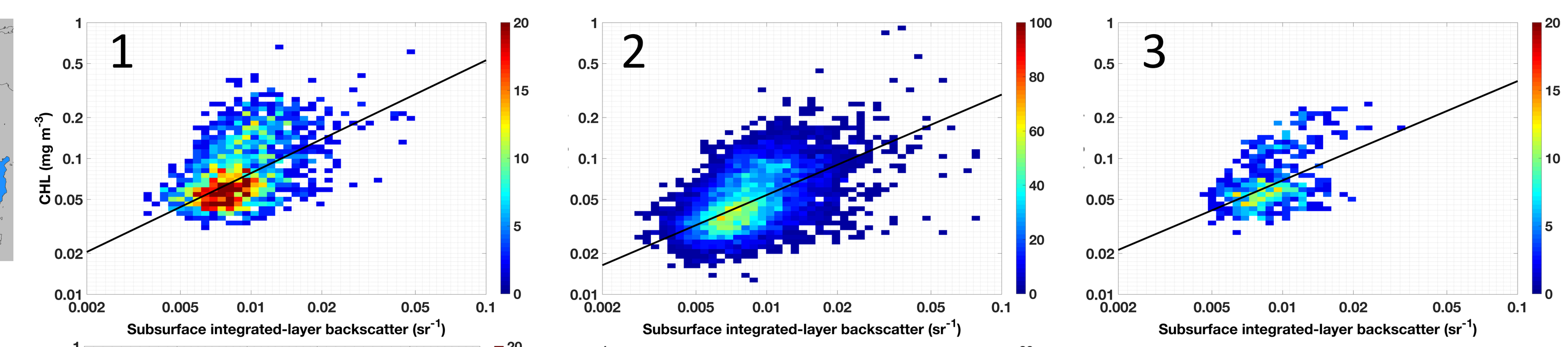
According to different 'trophic regimes' [5], MED is divided in four bioregions: West Med (1), East Med (2), Tyrrhenian Sea (3), Adriatic Sea (4).

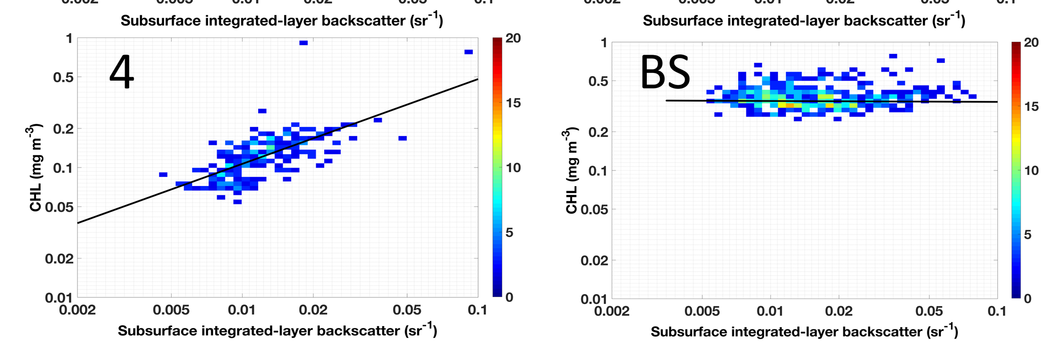
Distribution of CHL, b_{bp} and γ along the CALIOP groundtracks (a, b and c panels, respectively) obtained from CMEMS computation and from eq. (3), respectively.



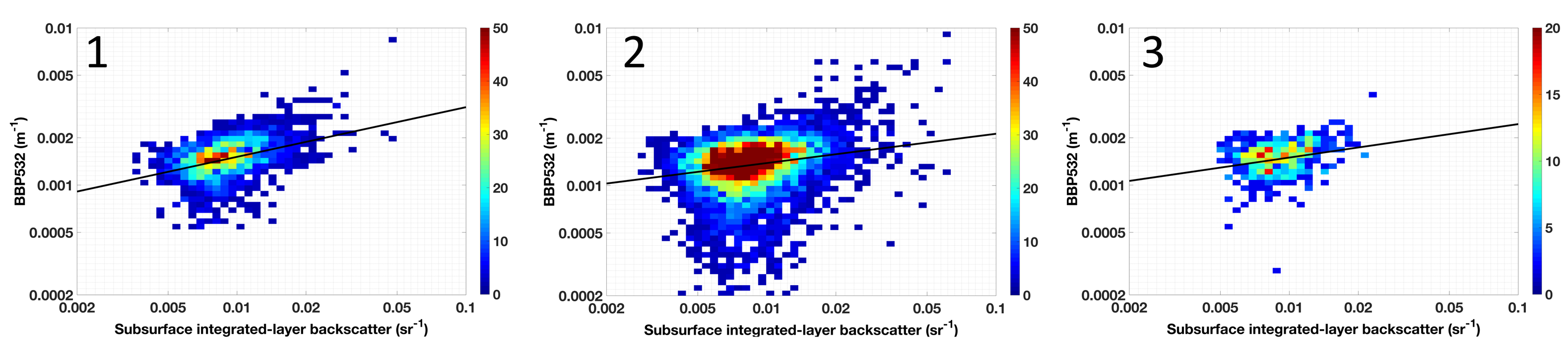
- γ and CHL: significant correlation for Adriatic Sea, low correlation for the other bioregions

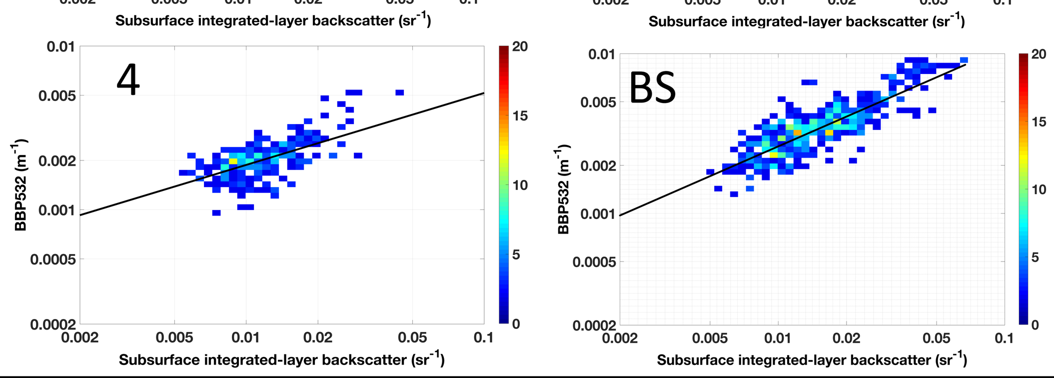
– γ and b_{bp}: high correlation for BS and Adriatic Sea ($R\geq0.80$), significant correlation for West Med, low signal and correlation in no bloom regions (2 and 3)





γ vs CHL	1	2	3	4	MED	BS
N° of points	2678	7920	955	520	10905	1105
R	0.35	0.35	0.50	**0.57**	0.32	0.09
a, b [logy=alogx +b]	0.83 0.55	0.73 0.20	0.73 0.30	0.65 0.33	0.77 0.34	-0.00 7 -0.47





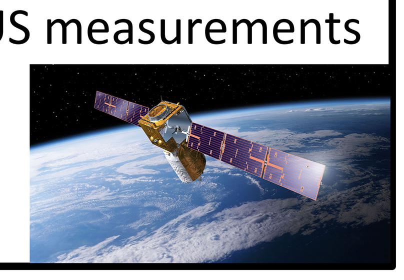
γ vs BBP	1	2	3	4	MED	BS
N° of points	2678	7920	955	520	10905	1105
R	**0.58**	0.48	0.41	**0.80**	0.54	**0.85**
a, b [logy=alogx +b]	0.31 2.18	0.18 -2.48	0.21 -2.39	0.43 -1.84	0.25 -2.33	0. 61 1.34

Conclusions

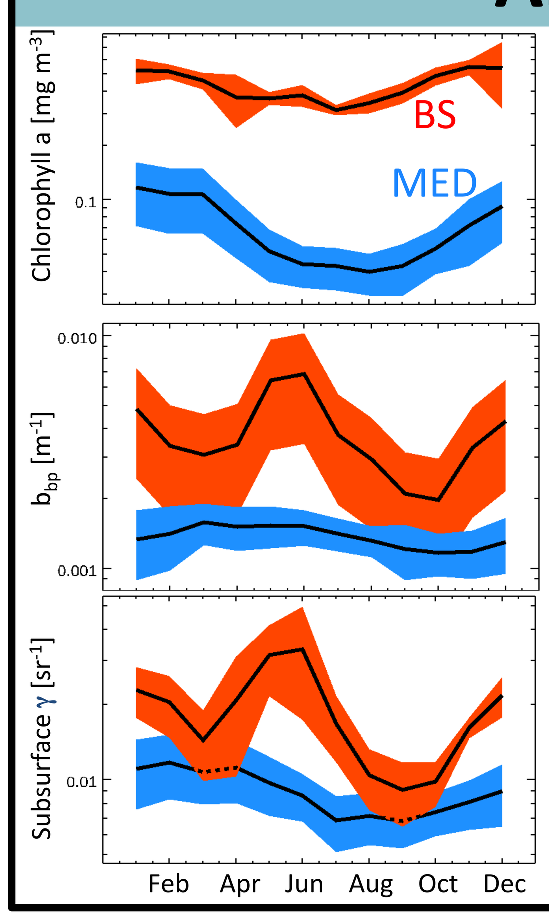
- Particulate optical properties in the Mediterranean and Black seas were estimated through CALIPSO spaceborne lidar measurements
- Depolarization ratio δ well compares with the sub-surface backscatter γ observations
- Sub-surface backscatter γ presents good correlation with the backscattering as derived by **OC** in optically complex waters (coastal and/or dominated by terrigenous load)
- Sub-surface integrated backscatter γ demonstrated to be as efficient as **OC** parameters for the phytoplankton dynamics at seasonal and basin scales

What's next

- Full mission (2006 - 2017) analysis of CALIOP depolarization ratio δ and sub-surface integrated backscatter γ in MED and BS
- Analysis of ADM-AEOLUS measurements to estimate the sub-surface signal contribution



Annual Cycles



Different trophic and optical regimes in **MED** and **BS**

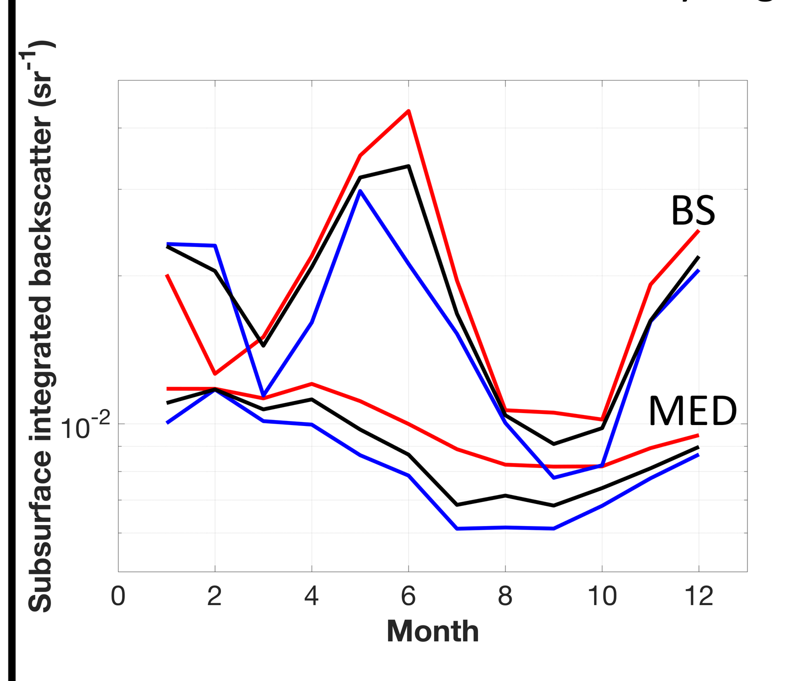
Similar phytoplankton biomass annual cycle
- summertime minima
- wintertime maxima

Different particulate (b_{bp}) annual cycle
- **BS:** semi-annual cycle
- **MED** summertime maxima

Sub-surface γ annual cycle
- **BS:** semi-annual cycle
  - good agreement with b_{bp}
- **MED:** summer min+ winter max
  - agreement with Chl

Day vs Night

Day and night data provide similar coverage and correlation consistent with day+night analysis.



Annual cycle:

BS: day-night difference is due to spatial sampling

MED: day-night difference ≈ 30% between may and september (real signal?)

References

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[5] D'Ortenzio, F. and Ribera d'Alcalà, M.: On the trophic regimes of the Mediterranean Sea: a satellite analysis, Biogeosciences, 6, 139-148, https://doi.org/10.5194/bg-6-139-2009, 2009.