Enhancing Chla fluorescence measurement's quality of southern elephant seals bio-logging data in the Southern Ocean with concomittant irradiance: improvements in accuracy and spatial resolution

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1. Motivations

Recent missions like the Surface Water and Ocean Topography (**SWOT**) mission enable to access to spatial scales down to 15-30 km but lack of an in-situ equivalent in the SO.
Bio-logging devices mounted on Southern Elephant Seals (SES) have the potential to address the in-situ (sub)mesoscale sampling gap (~60 profiles / day, 2-3 km between profiles, mean depth ~500 m).

Chla concentration ([Chla], the best proxy for **phytoplankton biomass**), can be estimated with the in vivo fluorescence. Two major issues with SRDLs' **Chla fluorescence sensors**:
- no pre-deployment calibration
- switch on only every ~15 profiles (save battery power)

Objectives: Improve the **accuracy** and **horizontal resolution** of SRDLs' [Chla] estimates by retrieving
(1) a calibrated measurement of in-situ [Chla]
(2) at submesoscale (O(10 km)).

2. Data & Methods

SRDL data
- developed by the Sea Mammal Research Unit (UK)
- parameters: Conductivity, Temperature, Depth (CTD), photosynthetically available radiation (PAR) and Chla fluorescence (FChla).
- 18 SRDL tags, 89 197 vertical profiles
- sampled between Oct-2018 and Jan-2021
- Kerguelen Islands
- GPS/ARGOS positioning
- CTD and PAR (~60 profiles / day), FChla (~4 profiles / day)

Satellite data
- Copernicus Marine Service's GlobColour
- Multi-sensor daily Level-3, 4 km resolution
- Matchups with in-situ data: 3 x 3 pixel box / 1-day time window

Development of a Linear Functional Model (LFM) to infer [Chla] from K_d
The vertical diffuse attenuation coefficient for PAR (K_d) used as a predictor for [Chla] enables to
(1) ensure the interoperability of the fluorescence sensors
(2) Increase the spatial resolution of the [Chla] measurements
1387 training profiles ([$Chla^{Fluo}$], K_d) / 14 686 predicted profiles ([$Chla^{LFM}$])

3. Two-step calibration of FChla data

Step 1 - The **data homogenization** step exploits the predictive capabilities of the LFM to adjust the (uncalibrated) FChla data provided by multiple tags and to make the data interoperable

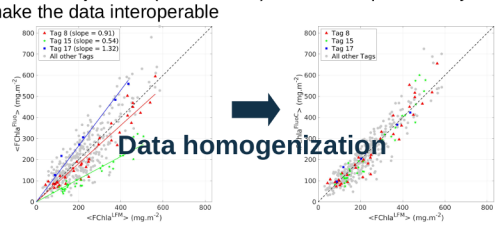

Figure 1. Fluo data homogenization with the LFM

Step 2 - The **satellite calibration** step aligns the FChla data of the merged inter-calibrated tags with a common benchmark for [Chla], estimated by ocean color radiometry (Copernicus Marine Service's GlobColour ocean-color data).

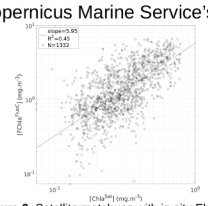

Figure 2. Satellite matchups with in situ Fluo data

4. Model performance

Two subsets
Model training:
970 profiles (70%)
Performance assessment:
417 profiles (30%)

Assessment metrics:
<Chla>,<Chla>$_{\%ML}$,
$[Chla]_{surf}$, $[Chla]_{max}$,
Z_{max}

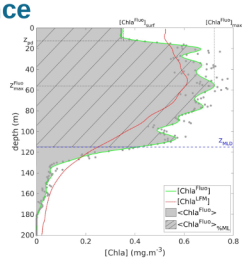

Figure 3. Vertical profile of [Chla] as measured (green) and predicted with the LFM (red), and associated metrics

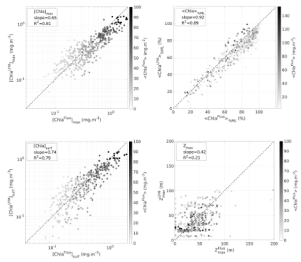

Figure 4. LFM Model performance assessment

Results
Good retrieval of
- <Chla> amounts (<Chla>,<Chla>$_{\%ML}$) and [Chla] metrics ($[Chla]_{surf}$, $[Chla]_{max}$)
Insufficient performance on the vertical (Z_{max})

5. Application on a SES transect

LFM prediction the transect of a southern elephant seal
- 5 746 km, 70 days at sea (25-Oct-2019 - 02-Jan-2020)
- 234 [$Chla^{Fluo}$] profiles
- 879 K_d profiles
- noticeable fact: malfunctioning of the fluorescence sensor from 09-Nov-2019 to 02-Dec-2019

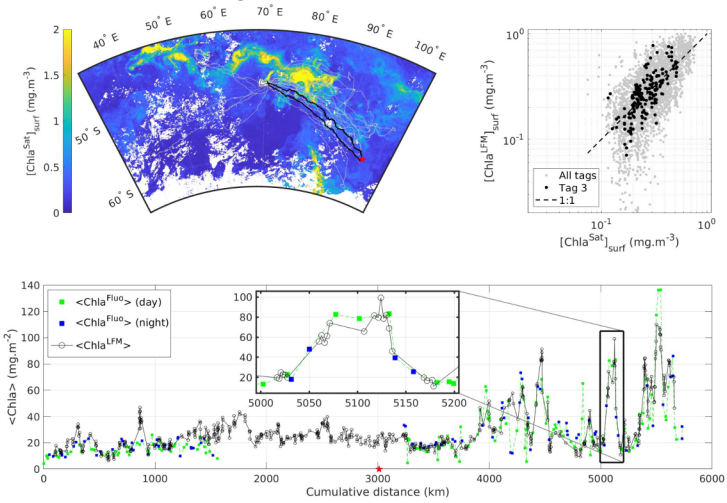

Figure 5. Transect of a southern elephant seal equipped in Kerguelen in October 2019 with a SRDL (recovered on January 2020)

Analysis of the variance spectrum
Objective: assess the improvement brought by the LFM in terms of spatial resolution

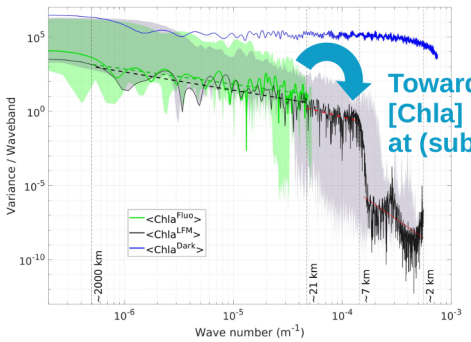

Figure 6. Variance spectrum of <Chla> from observations and model predictions

Other applications
The calibration procedure applied to the FChla data opens the way to the interoperability of SRDLs with other autonomous platforms (floats, gliders).
The use of K_d as a predictor for [Chla] can be extended to a larger range of bio-logging tags deployed in the past measuring PAR but no Fluo.

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