Toward the Synergistic Use of Ocean Colour products to Improve the Description of Phytoplankton Productivity within the Global Ocean

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Ocean Carbon From Space Workshop

2nd Workshop in the CLEO (Colour and Light in the ocean from Earth Observation)

Uncertainty in marine primary production estimates

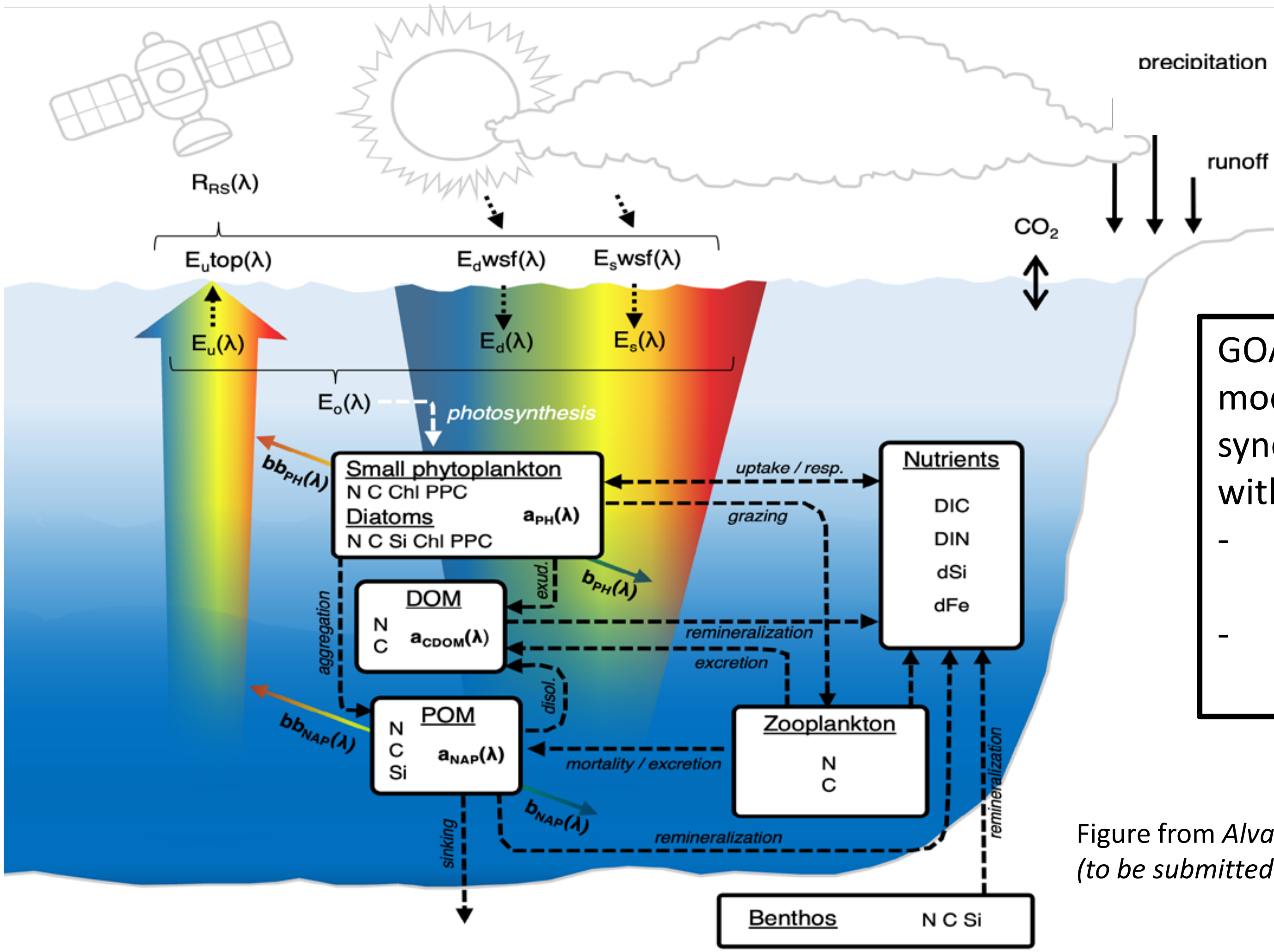


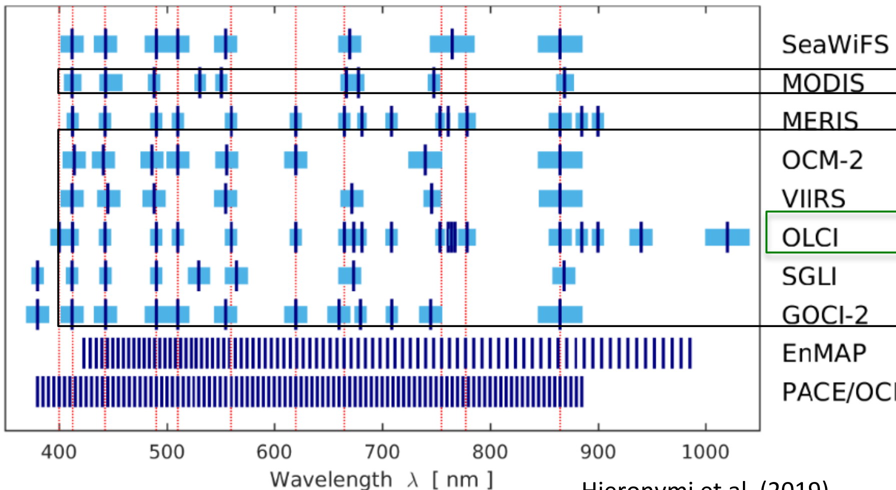
Figure from *Alvarez et al.*
(to be submitted to JAMES)

GOAL: Improve data sets for model development via synergy across sensors and within the euphotic zone:

- Phytoplankton composition
- Spectral composition of underwater light field

Diagram of coupling biogeochemical model REcoM2 (Hohn 2009; Schartau et al. 2007, Alvarez et al. 2019) and RTM following Dutkiewicz et al. (2015, 2018). Figure from Alvarez et al. (to be submiited to JAMS)

Ocean Colour beyond multispectral satellite data



Hieronymi et al. (2019)

-2

Current multispectral

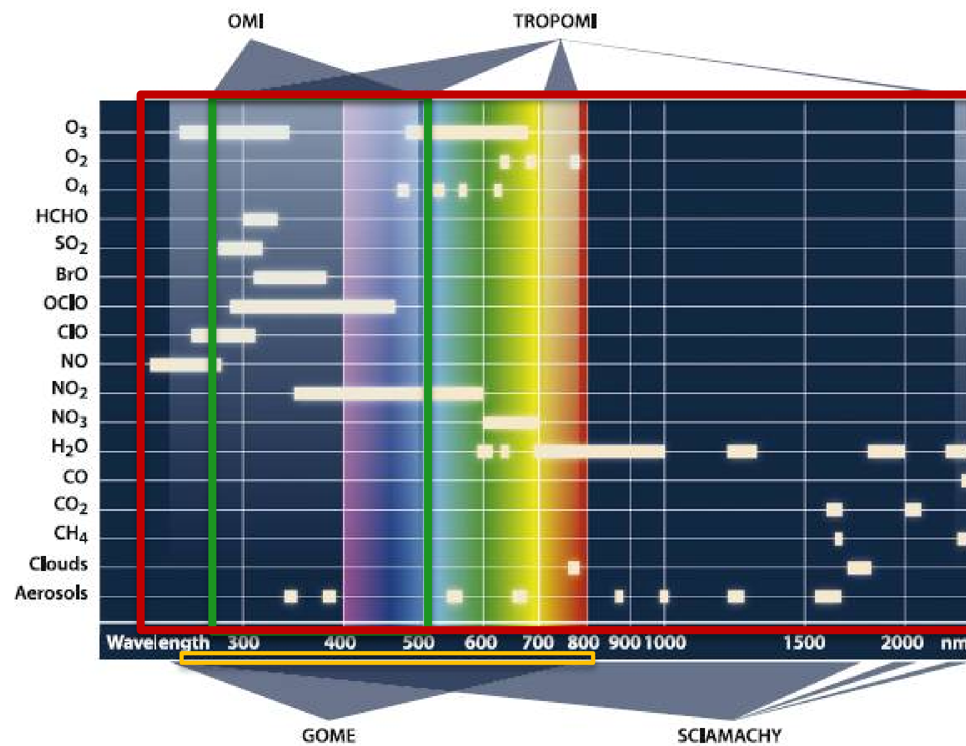
<1 km pixel

1.5-3 days global coverage

2022-, 30m pixel, 5000km/orbit*

2024-, 1km pixel, 2 days

*similar to DESIS 2018-, PRISMA 2019-



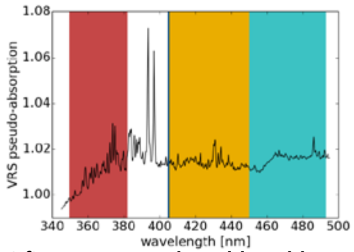
SCIAMACHY/ENVISAT:2002-2012, 30 x 60 km pixel
6 days global coverage

GOME-2/METOP: 2007 - , 40 x 80 km pixel
3 days global coverage

TROPOMI/S5P: 5/2018 -, 5.5 x 3.5 km pixel
daily global coverage

Diffuse attenuation (Kd) in three spectral bands from S5P (TROPOMI) Vibrational Raman Scattering (VRS): UV to short blue

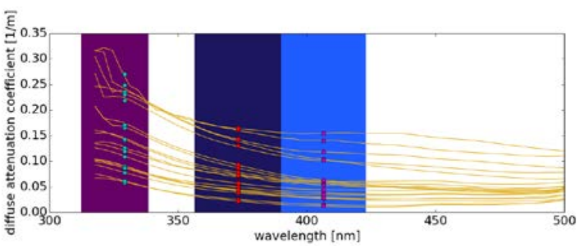
PhytoDOAS* Kd-retrieval (basis Vountas et al. 2007, Dinter et al. 2015, Oelker et al. 2019)



VRS fit: UV short-blue blue

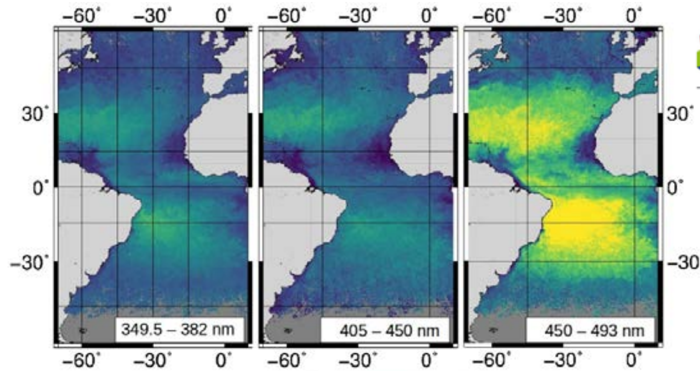
LUT (RTM)

Kd [m^{-1}]: UVAB UVA (short)-blue



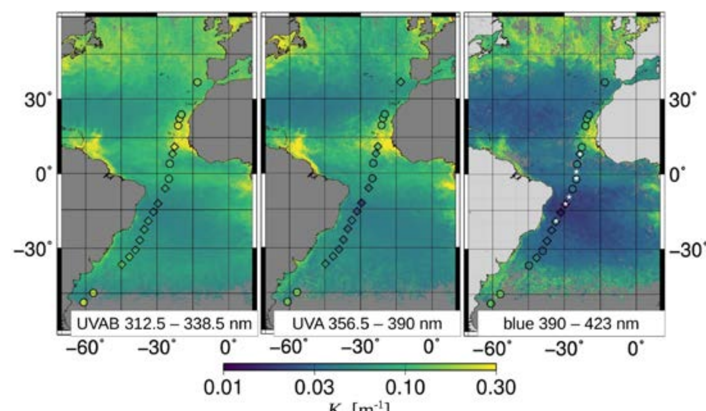
*PhytoDOAS: Differential Optical Absorption Spectroscopy to derive OC products

S5P Inelastic Scattering (VRS) in Ocean Water



LUT (RTM)

S5P Diffuse Attenuation in Ocean Water



frontiers

In press

TROPOMI-retrieved underwater light attenuation in three spectral regions: ultraviolet to blue

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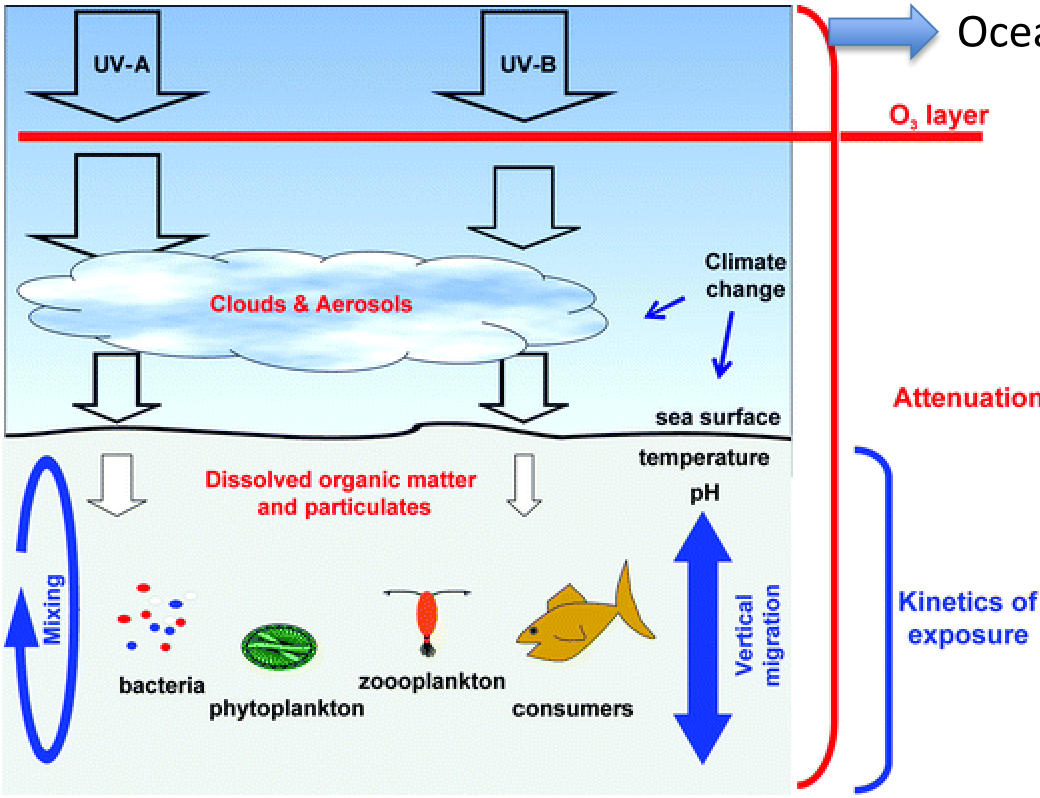
- Close to in-situ matchups
- Agreement to OCCCI- and OLCI-Kd within OCCCCI-Kd uncergtainties.
- Low VRS fit errors (<15%)
- Low model (VRS cross section, LUT) errors for atmospheric and oceanic parameters

First time Kd retrievals in UV-AB & UV-A from satellite UV measurements via inversion!

Perspective: Application of global data sets of S5P Kd(UVAB), Kd(UVA) and Kd(short-blue)

Higher accuracy of ocean SW radiation



Häder et al. 2011

Ocean – atmosphere radiation feedback

Ocean photochemistry (some UV spec.):

Primary production (50% of global produced in the ocean!)

Photodegradation (phyto, CDOM, …)

Trace gas (e.g. halocarbons) & aerosol precursors

Global biogeochemical cycles
e.g. carbon pool
Marine Food Web

Standard ocean color remote sensing product only Kd490 – extend to spectral Kd (e.g. use Lee et al 2005 / Jamet et al. 2012) and then combine S5P UV-blue & S3/MODIS/… to obtain Kd at **325 373 406 412 443 510 560 620** (665? 674? 682?)

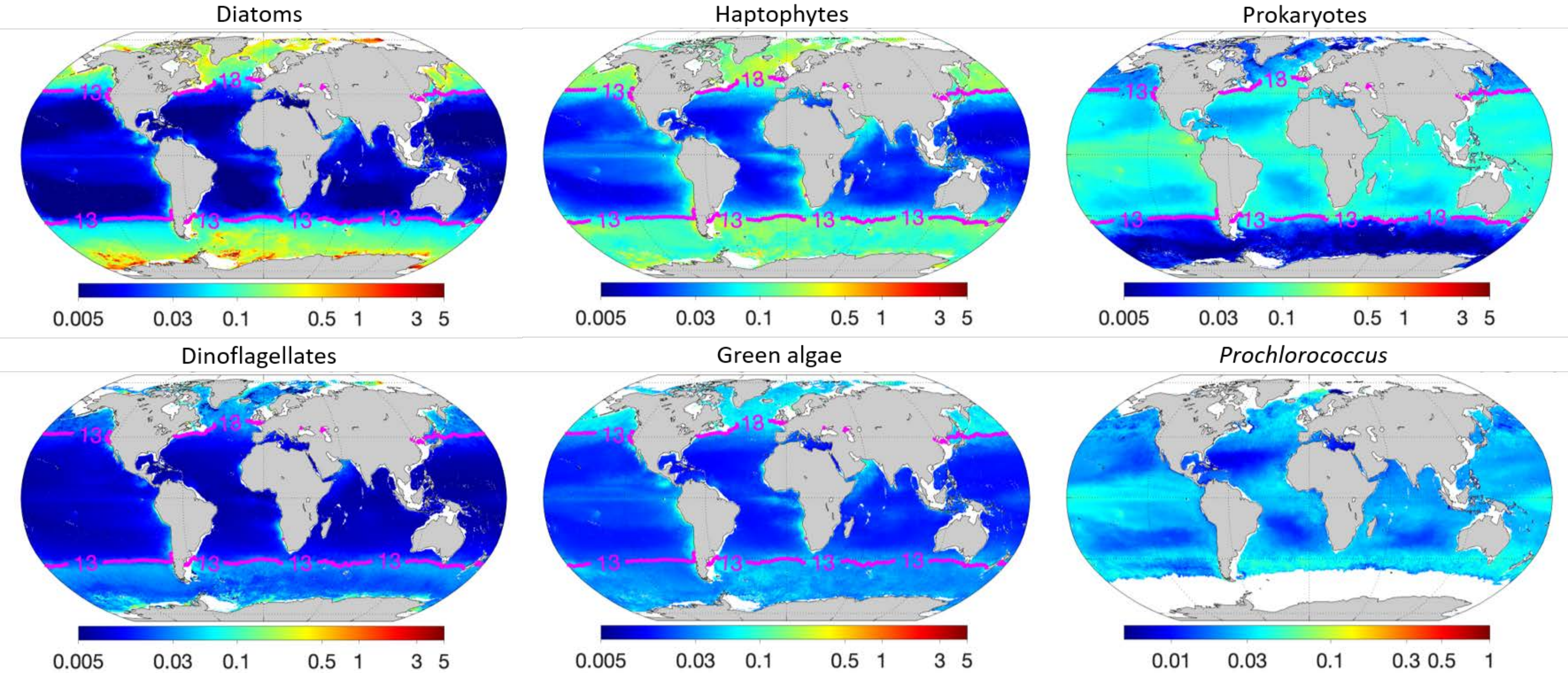
See posters: Wang et al. #147 (in situ & VIRRS); Dionisi et al. #188 (Aeolus Kd & bioARGO UV Kd)

EOF-PFT: Global approach for PFT chlorophyll retrieval using ocean color reflectance data and SST

Xi et al. RSE 2020: Xi et al. JGR 2021

- A set of empirical orthogonal function based algorithms applied to RRS at 9-11 bands
- Capability of retrieving Chla of 6 phytoplankton groups

Global incl. pixel uncertainty at 4km globally from 2002 until today at https://marine.copernicus.eu/



- *See also Poster Xi et al. #175*

chl-a [mg/m³]

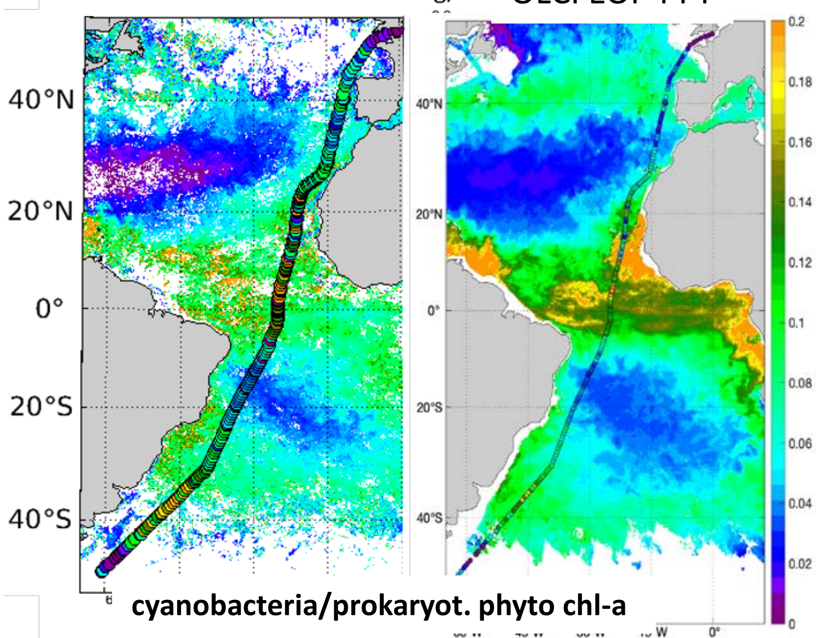
Note different color scales

S5P-PhytoDOAS PFT vs. OLCI EOF-PFT

mod. Bracher et al. 2009 | Xi et al. 2021

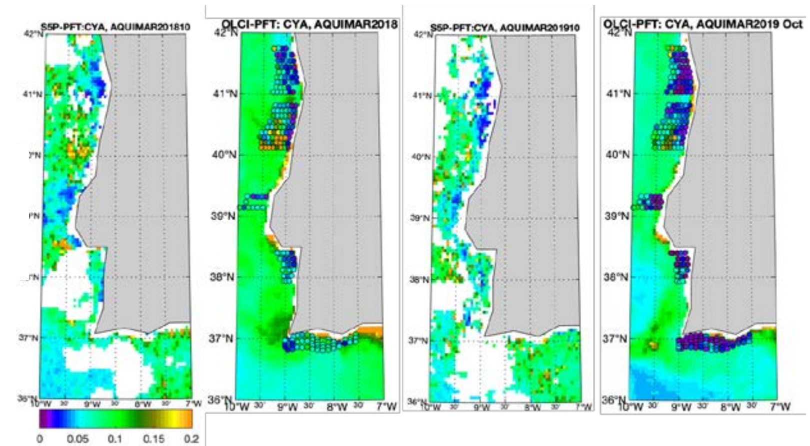
Mean 11 May-9 Jun 2018 (in situ PS113 HPLC)

S5P-PFT | OLCI EOF-PFT

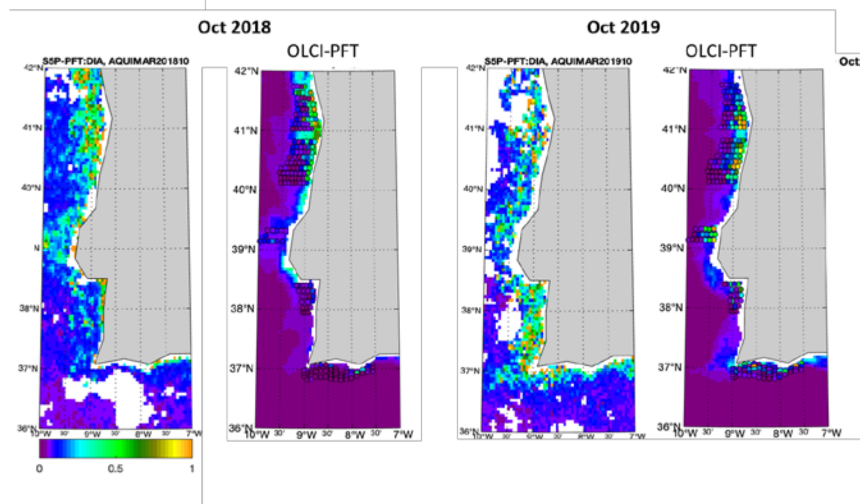


Oct 2018 | Oct 2019

S5P-PFT | OLCI EOF-PFT | S5POC | OLCI-EOF-PFT



cyanobacteria / prokaryotic phyto chl-a



diatom chl-a

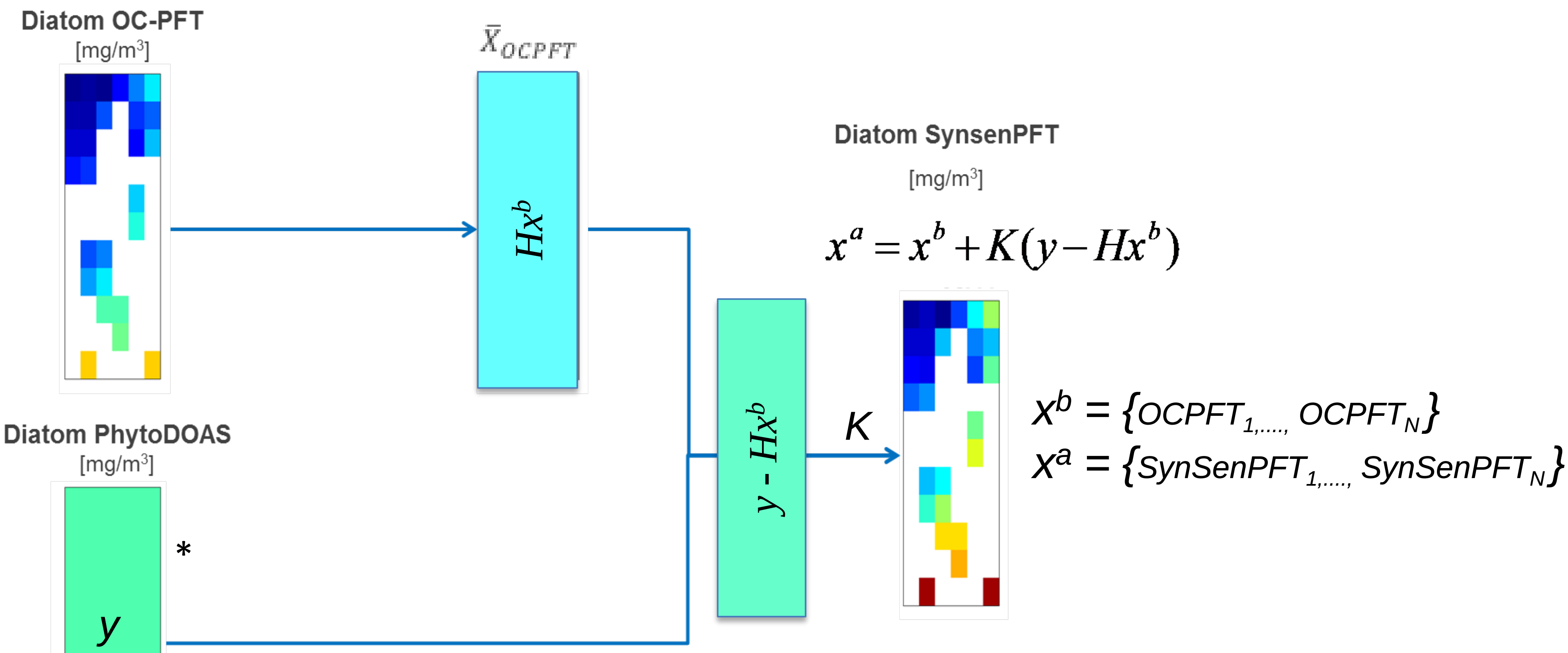
Comparison to in-situ (3x3, same day)

	cyanobacteria		diatoms	
	S5P	OLCI	S5P	OLCI
N	34	164	18	57
R	0.51	0.24	0.85	0.78
MAE	0.020	0.050	0.035	0.084
Bias	0.007	0.026	0.035	-0.040

In situ matchups to S5P sparse, but S5POC agrees better (coastal areas) than OLCI-PFT to in-situ.

Synergy of hyper- and multispectral satellite products: three major PFT In the global ocean at 4km pixel resolution

Physical value is given by the hyperspectral product (SCIAMACHY-PhytoDOAS)
Spatial variability is given by the multispectral product (OCCCI-OCPFT, adapted Hirata et al. 2011)



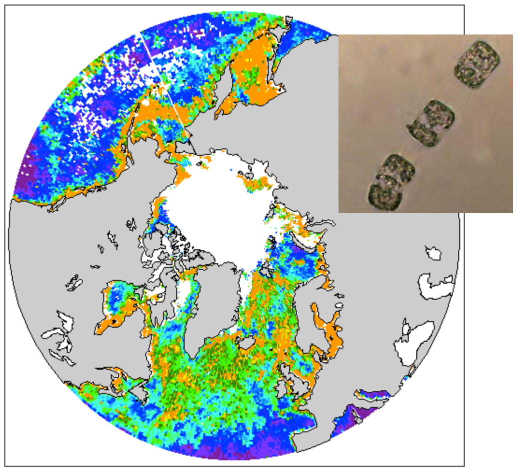
GOAL: PFT satellite product with better spatial, temporal and group-specific information

Losa et al. Frontiers in Marine Sciences 2017

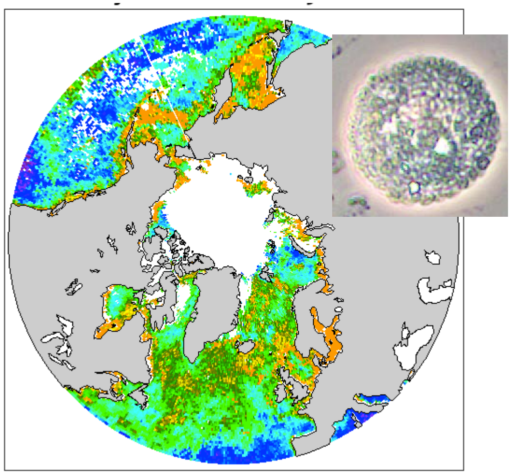
Synergy of hyper- and multispectral satellite products: three major PFT In the global ocean at 4km pixel resolution

Losa et al. Frontiers in Marine Sciences 2017

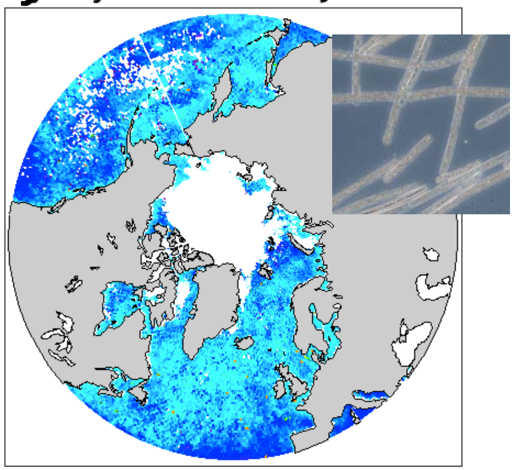
diatom chl-a



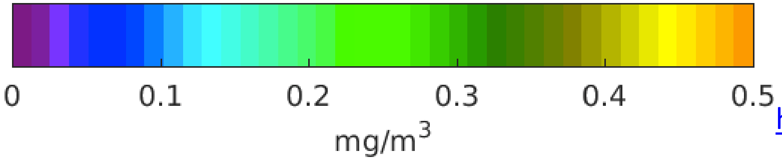
coccolithophore chl-a



cyanobacteria chl-a



Mean June 2010 Mean June 2010



available 2002-2012 daily

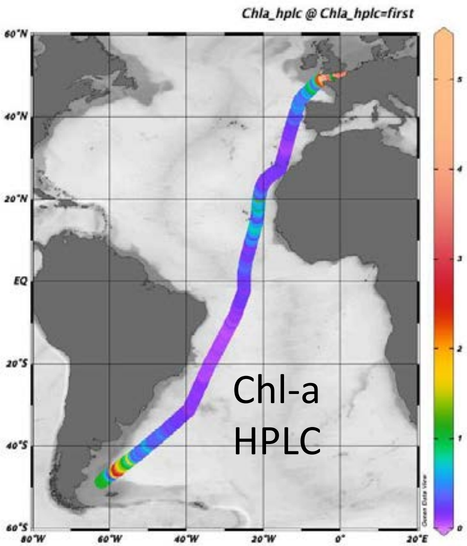
https://doi.org/10.1594/PANGAEA.873210

Benefits of synergistic (SCIAMACY-PhytoDOAS+OCCCI-OCPFT) PFT product over TCHL or just OCPFT or PhytoDOAS data assimilation has been shown in global coupled biogeochemical ocean model (REcoM2-MITgcm) by Pradhan et al. JGR-Oceans 2020.

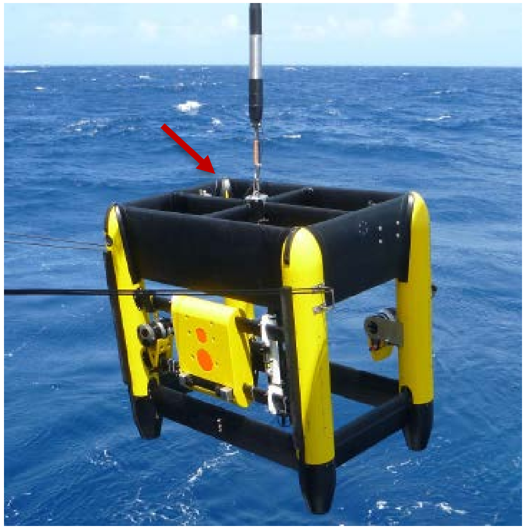
High resolution of PFTs below satellite view from ship-towed undulating radiometry

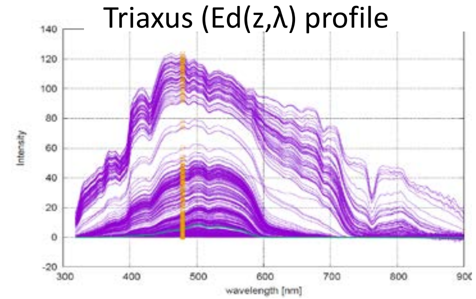
Using EOF based PFT retrieval on derived from Kd(λ, z) with HPLC-PFT

Bracher et al. FMARS 2020



RAMSES radiometer on ship-towed undulator TRIAXUS during Polarstern cruise PS113





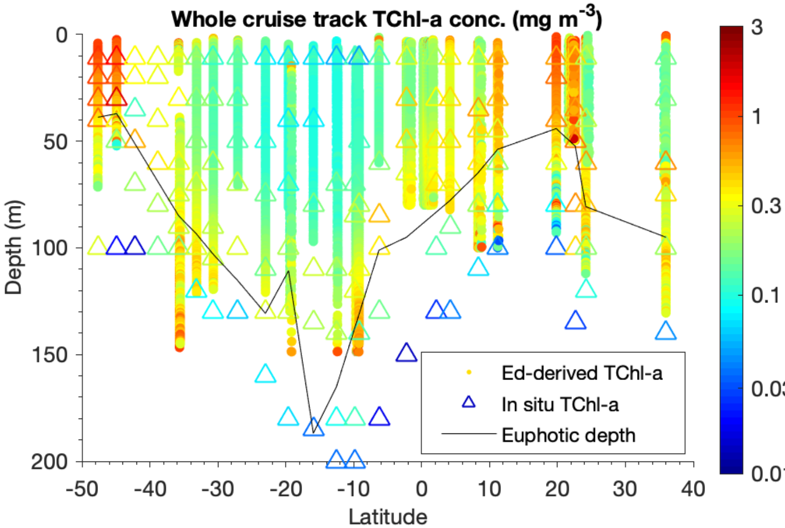
Potential of BioARGO:

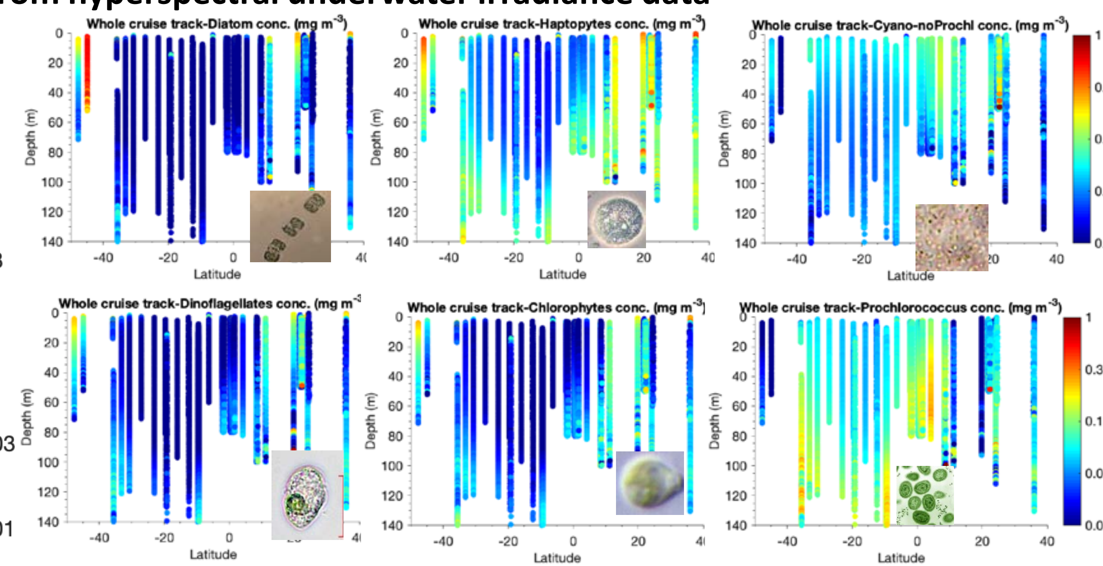
CHL via NN for PSC (Sauzede et al. 2015)

Hyperspectral (Organelli et al. 2021)

Explore hyperspectral ACS data for PFT

TChl-a & PFT-CHL retrieved from hyperspectral underwater irradiance data





PFT data: https://doi.pangaea.de/10.1594/PANGAEA.913536

Priorities for closing knowledge gaps

1-2 years:

Global (2018-) S5P Kd & PFT-Chl incl. uncertainties (fit error, model error, validation)

Combine S5P-OC retrievals with S3 (and similar data for long time series) to obtain

- **Kd(λ) at $\geq$9-bands** from 325-700 nm (325, 373, 405 , 412, 443, 490, 510, 560, 665)
- **higher quality** cyanobacteria and diatom **PFT-Chl** from satellite (models)

Multiplatform (bioARGO, towed, satellite) AOP & IOP **data fusion** for 4D-PFT-Chl, Kd, …

5 years:

Protocols for multiplatform approaches additional data incl. uncertainties

Synergy/hybrid/data fusion across satellite + multiplatform sensors

New products from S5P (S5): UV in water: MAAs, CDOM sources, photodegradation; Chla fluor., DOC

Transfer S5P-OC know-how to **future high spectrally resolved** OC retrievals: S4 (GEO, also GEMS), but also PACE, EnMAP (DESIS, PRISMA)

10 years:

Kd(λ), PFTs, PB, DOC,… long term climate data sets at best spatial & temporal coverage incl. uncertainty from synergy of historic, current and upcoming sensors
4D OC products as basis for reanalysis of ocean state regarding BCP and beyond

Improve match of models and observations to enable reliable assessment/predictions of BCP (ocean C)!

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