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TAKING THE PULSE OF OUR PLANET FROM SPACE

EUMETSAT ECMWF EUSPA

Novel ocean color information from Sentinel-5P's high spectral resolution

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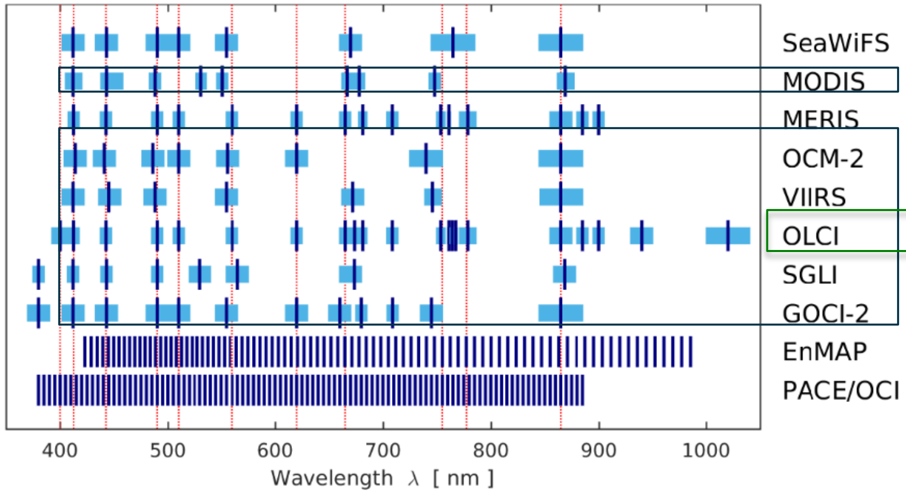
24 May 2022

Ocean Colour beyond multispectral satellite data



Hieronymi et al. (2019)

-2

Current multispectral

<1 km pixel

1.5-3 days global coverage

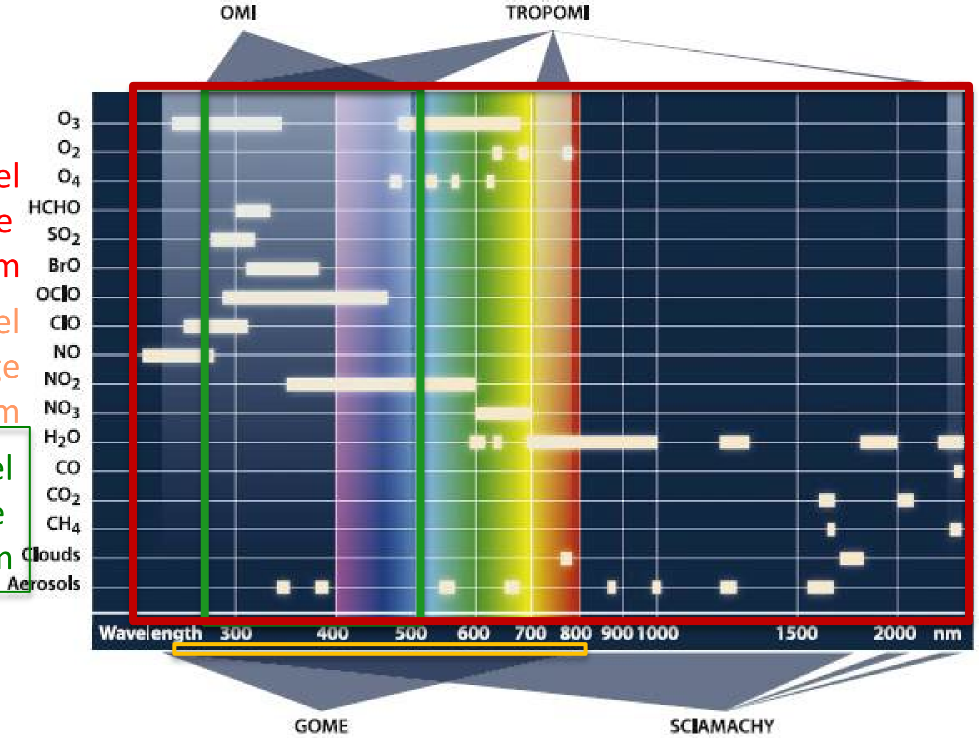
2022-, 30m pixel, 5000km/orbit, as DESIS 2018-, PRISMA 2019-

2024-, 1km pixel, 2 days

SCIAMACHY/ENVISAT: 2002-2012, 30 x 60 km pixel
6 days global coverage
240-2400 nm

GOME-2/METOP: 2007 - , 40 x 80 km pixel
3 days global coverage
240 – 800 nm

TROPOMI/S5P: 5/2018 -, 5.5 x 3.5 km pixel
daily global coverage
280 – 500 nm, 675-775 nm



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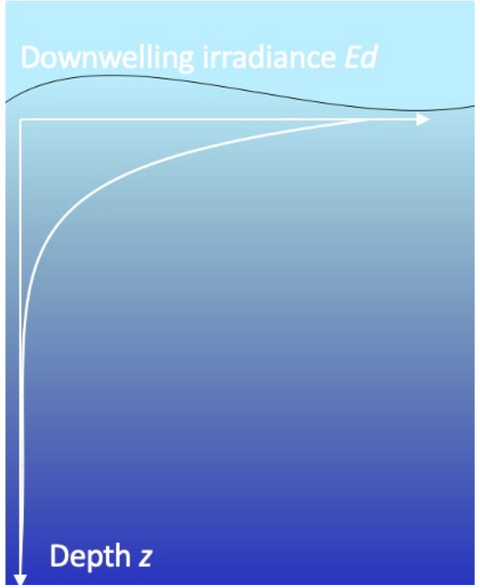
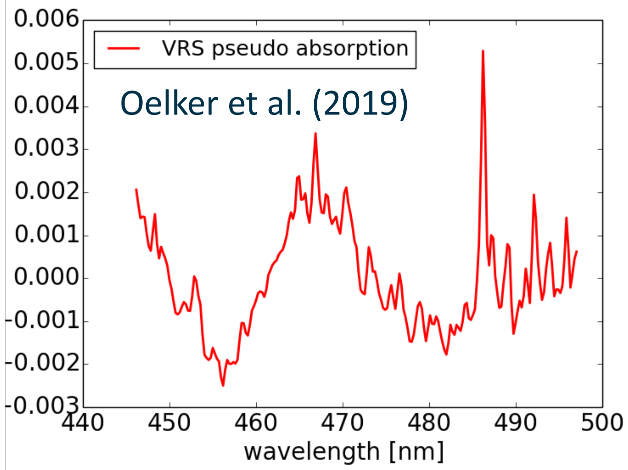
Novel (missing) Ocean Color Products with TROPOMI

Diffuse attenuation Kd



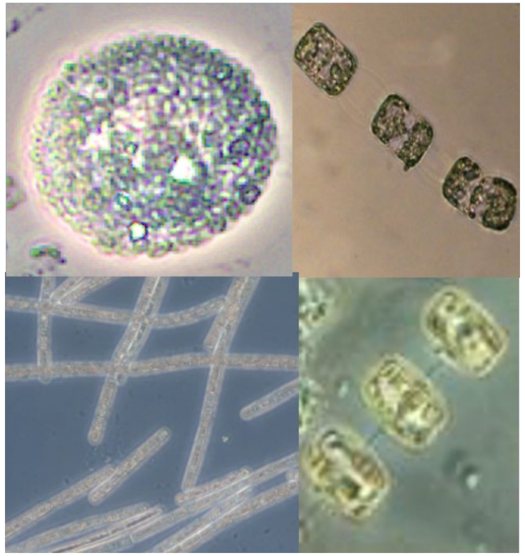


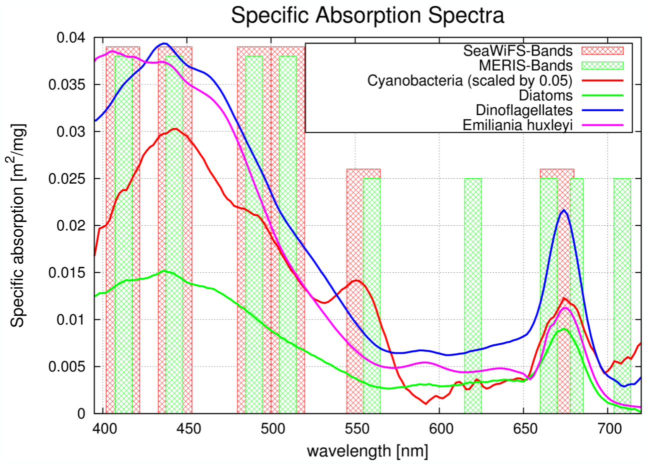
Vibrational Raman scattering VRS) of H2O molecules - causes filling-in in high spectrally resolved backscattered radiation

- ➢ related to the light availability (diffuse attenuation – see for SCIAMACHY (Dinter et al. 2015), for OMI and GOME-2 (Oelker et al. 2019).

PFTs: phytoplankton functional types

Photos by Sonja Wiegmann - AWI





PFT specific absorption can be identified in high spectrally resolved SCIAMACHY data (Bracher et al. 2009, Sadeghi et al. 2012).

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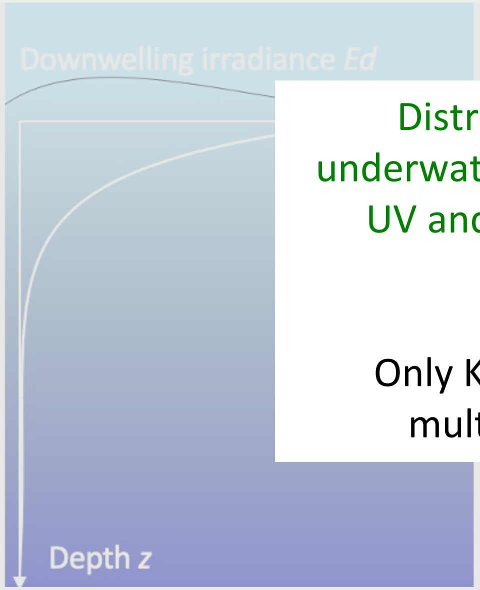
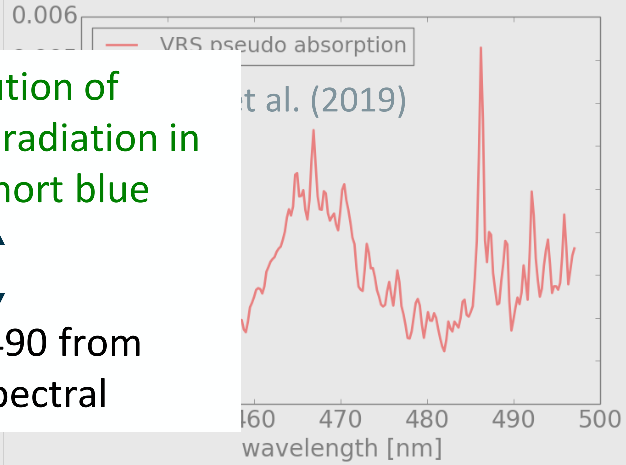
Novel (missing) Ocean Color Products with TROPOMI

Diffuse attenuation Kd



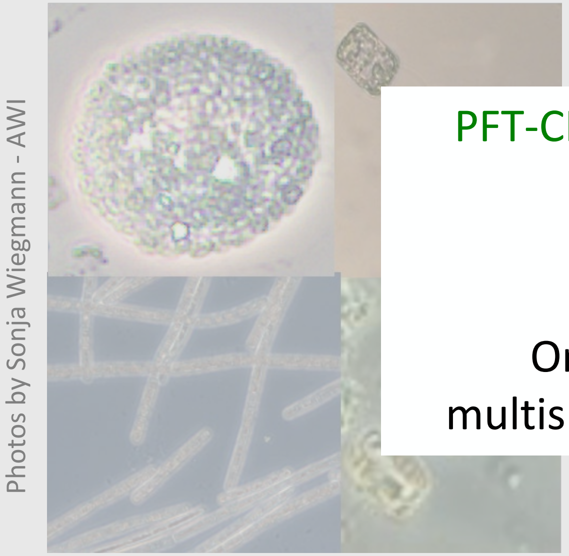


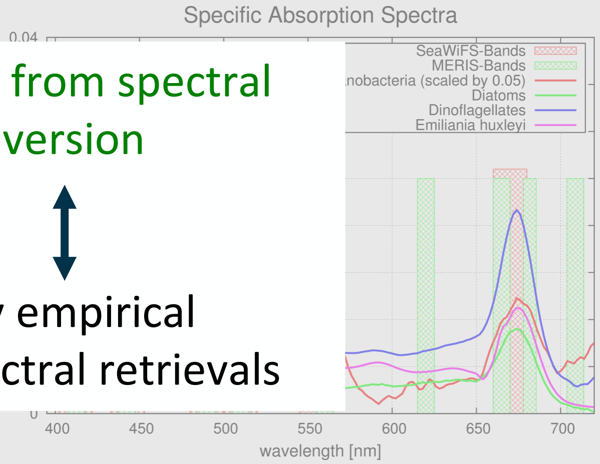
Distribution of underwater radiation in UV and short blue

↕

Only KD490 from multispectral

PFTs: phytoplankton functional types





PFT-CHL from spectral inversion

↕

Only empirical multispectral retrievals

- ✓ KD: Sources of CDOM, UV-absorbing compounds
- ✓ KD: Shortwave radiation budget in the ocean (PP, photodamage, -degradation processes)

Effects of Climate Change

- ✓ PFTs: Indices of biodiversity & more precise descriptors of primary production (PP) ocean carbon pool

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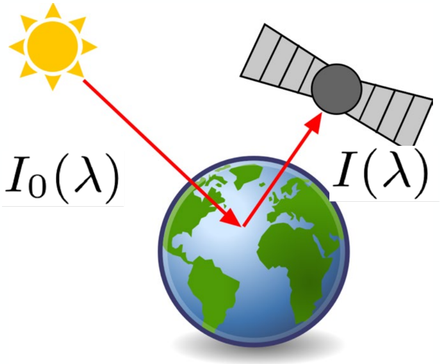
TROPOMI Retrievals: PhytoDOAS

DOAS applied to retrieve ocean products: Vountas et al. 2007, Bracher et al. 2009, Sadeghi et al. 2012, Dinter et al. 2015, Losa et al. 2017, Oelker et al. 2019, Oelker et al. 2022



Based on Beer-Lamberts law

$$\mathrm{I}(\lambda) = I_0(\lambda) \cdot \exp(-\tau(\lambda)) \Rightarrow \tau(\lambda) = \ln \frac{I_0(\lambda)}{I(\lambda)}$$

DOAS equation

$$\tau(\lambda) = \underbrace{\boxed{\sum_{i=0}^{I} S_{a,i}\sigma_{a,i}}}_{\text{Atmospheric absorbers}} + \underbrace{\boxed{\sum_{j=0}^{J} S_{o,j}\sigma_{o,j}}}_{\text{Oceanic absorbers (phytoplankton, liquid water)}} + \underbrace{\boxed{\sum_{k=0}^{K} \overset{\ln(I^+/I^-)}{\uparrow}\, S_{p,k}\sigma_{p,k}}}_{\text{Pseudoabsorption (inelastic scattering: VRS, RRS)}} + \underbrace{\sum_{l=0}^{L} S_{e,l}\sigma_{e,l}}_{\text{instrumental effects}} + \underbrace{\boxed{\sum_{m=0}^{M} x_m \lambda^m}}_{\text{Polynomial (elastic scatt., CDOM+NAP absorption)}}$$

$I^{+,-}$ = modeled radiance with,without inelastic scattering
S = fit factor, σ –= reference spectrum
VRS/RRS=vibrational/rotational Raman scattering

Solved for fit factors and polynomial coefficients via Levenberg Marquard LSM.

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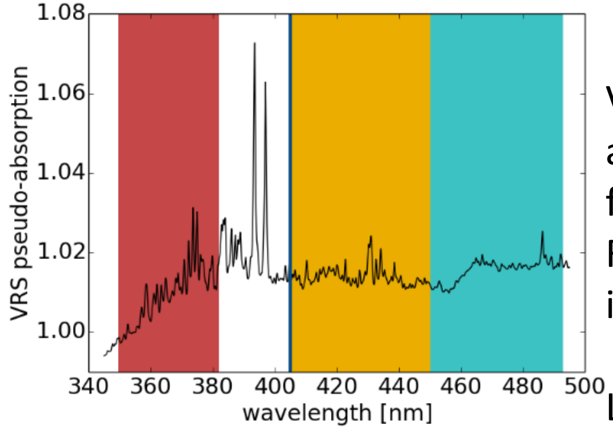
Diffuse attenuation (Kd) in three spectral bands from S5P's instrument TROPOMI (Oelker et al. 2022)

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



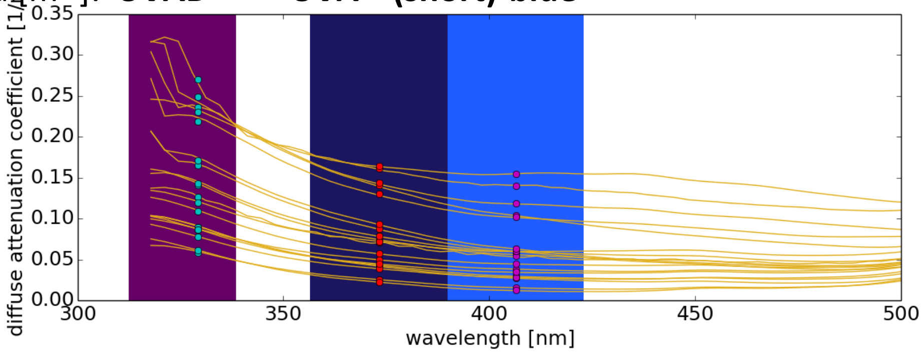
VRS pseudo-absorption derived from coupled O-A RTM SCIATRAN used in PhytoDOAS.

LUT: Look-Up Table links VRS-Fit factor + SZA + VZA to Kd.

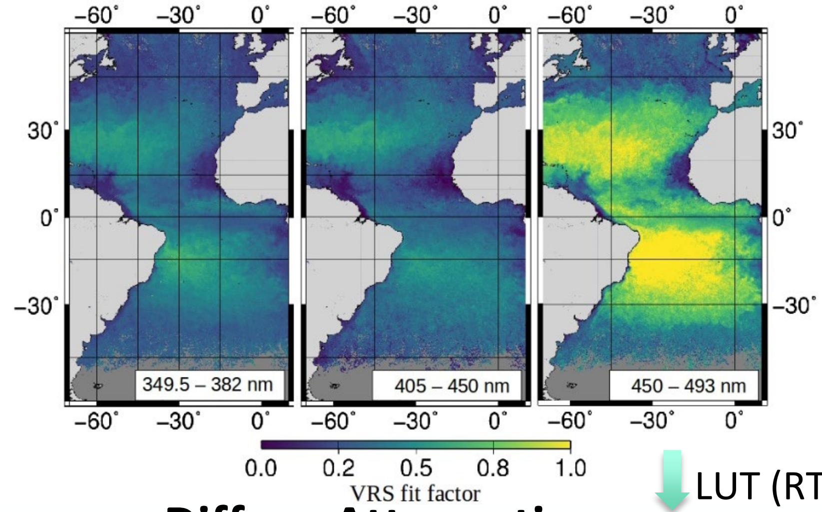
VRS fit: **UV** **short-blue** **blue**

LUT (RTM)

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

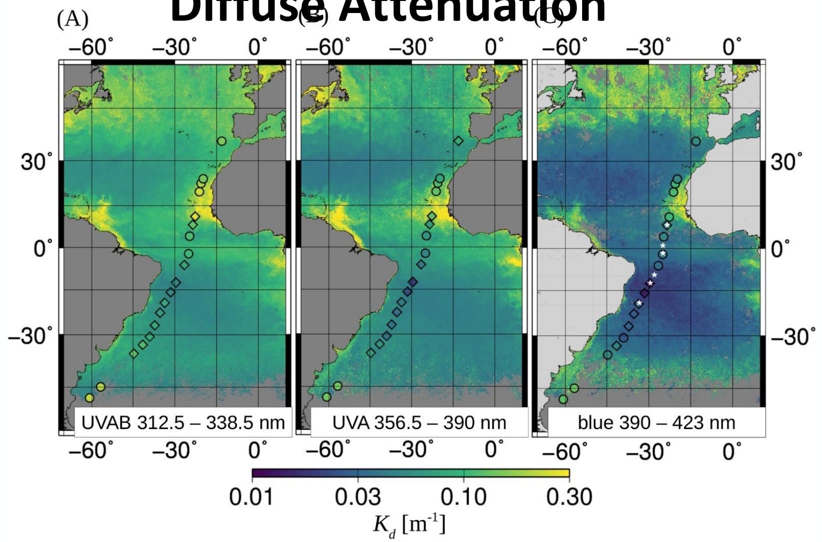


TROPOMI Inelastic Scattering (VRS)



LUT (RTM)

Diffuse Attenuation



frontiers

https://doi.org/10.1594/PANGAEA.940352

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

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First time Kd retrievals in UV-AB & UV-A from satellite UV data (globally, via inversion).

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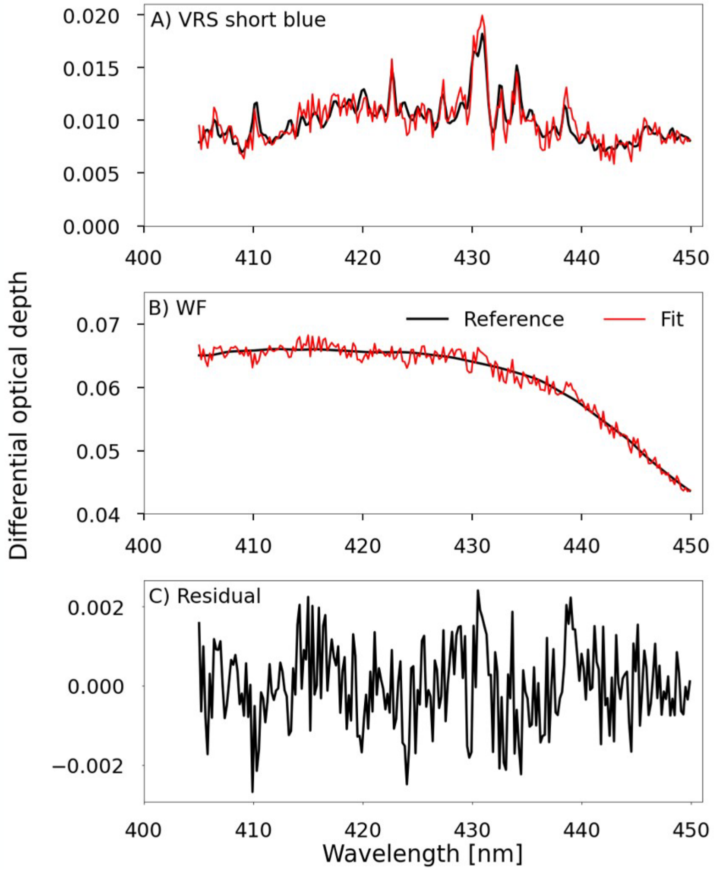
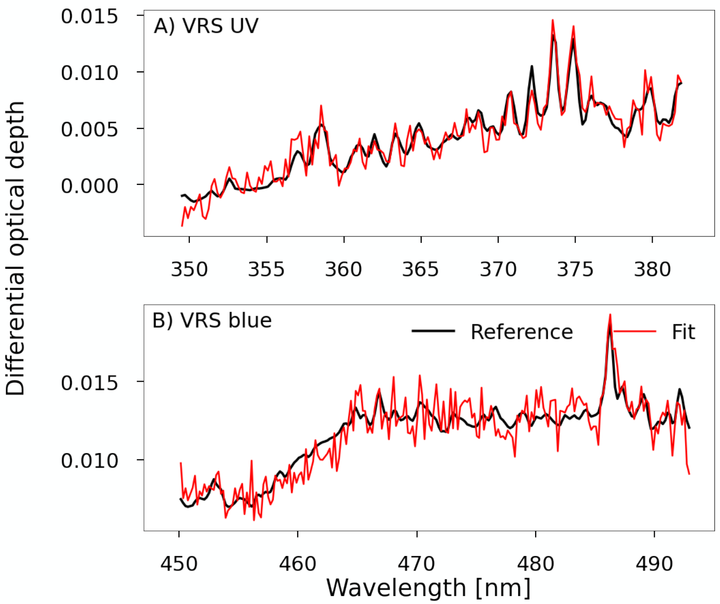
TROPOMI diffuse attenuation (Kd) in UV and short blue: VRS (inelastic scattering) fit sensitivity & error (Oelker et al. 2022)

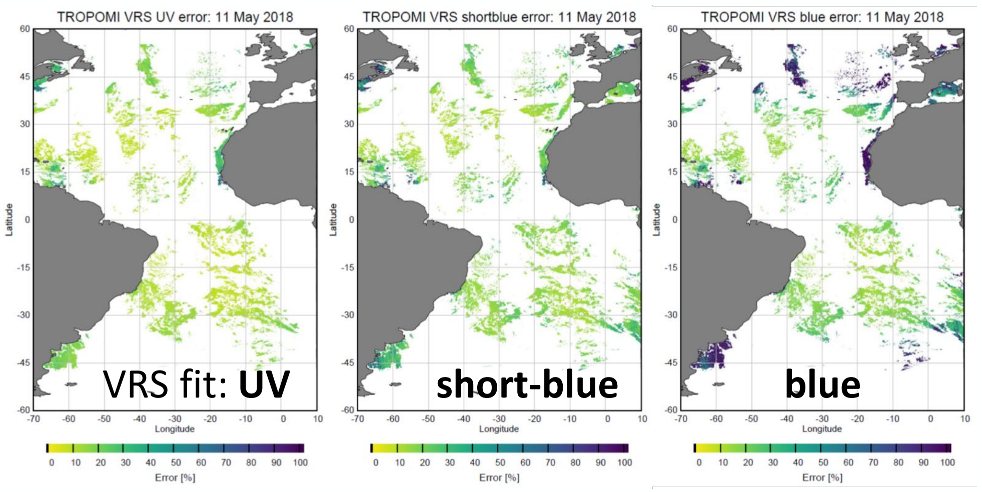
esa

VRS fit with high fit factor





Specific fit factor error [%]



TROPOMI VRS fits:

High sensitivity (10* more than SCIA)

Low errors: < 5% UVA, <10% short-blue, <15% blue

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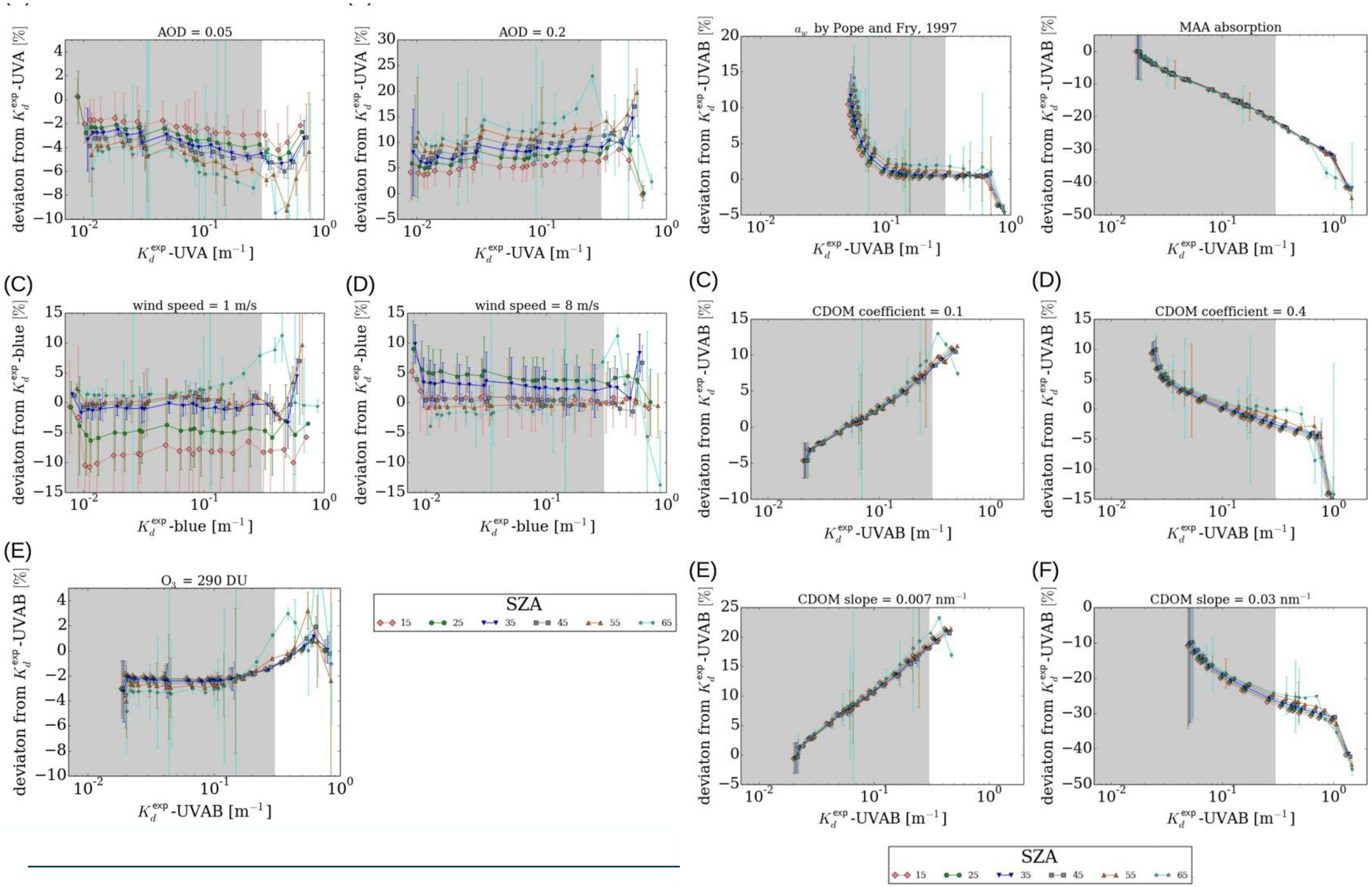
TROPOMI diffuse attenuation (Kd) in UV and short blue: Kd retrieval sensitivity & error budget (Oelker et al. 2022)

Retrieval sensitivity [%] to atmospheric (left) & oceanic (right) parametrizations using O-A RTM



Fit and model error of TROPOMI KD ($<0.3\ m^{-1}$)

Kd	Fit	a_{CDOM}	CDOM-S	a_{ph}*	AOD	WS	O_3
UVAB	10	10	30	20	5	3	3
UVA	15	10	25	20	15	5	0
blue	20	20	25	10	20	10	0

Error contributions as input for pixel-by-pixel uncertainty.

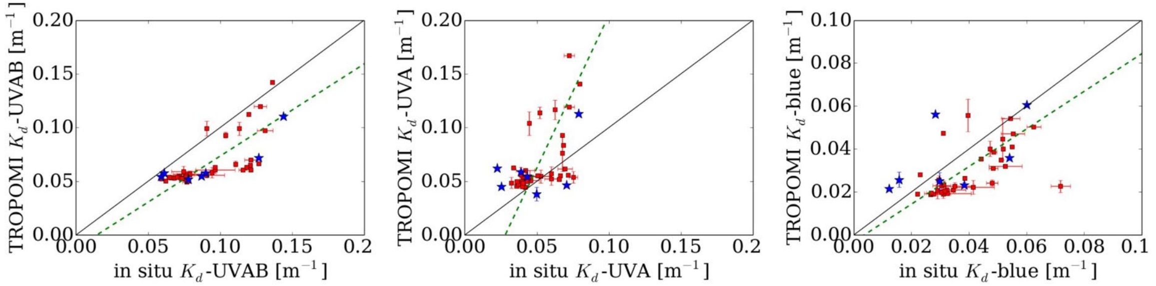
Overall reasonable uncertainty (max. 35%-45%)

~ multispectral Kd490 & CHL retrieval errors.

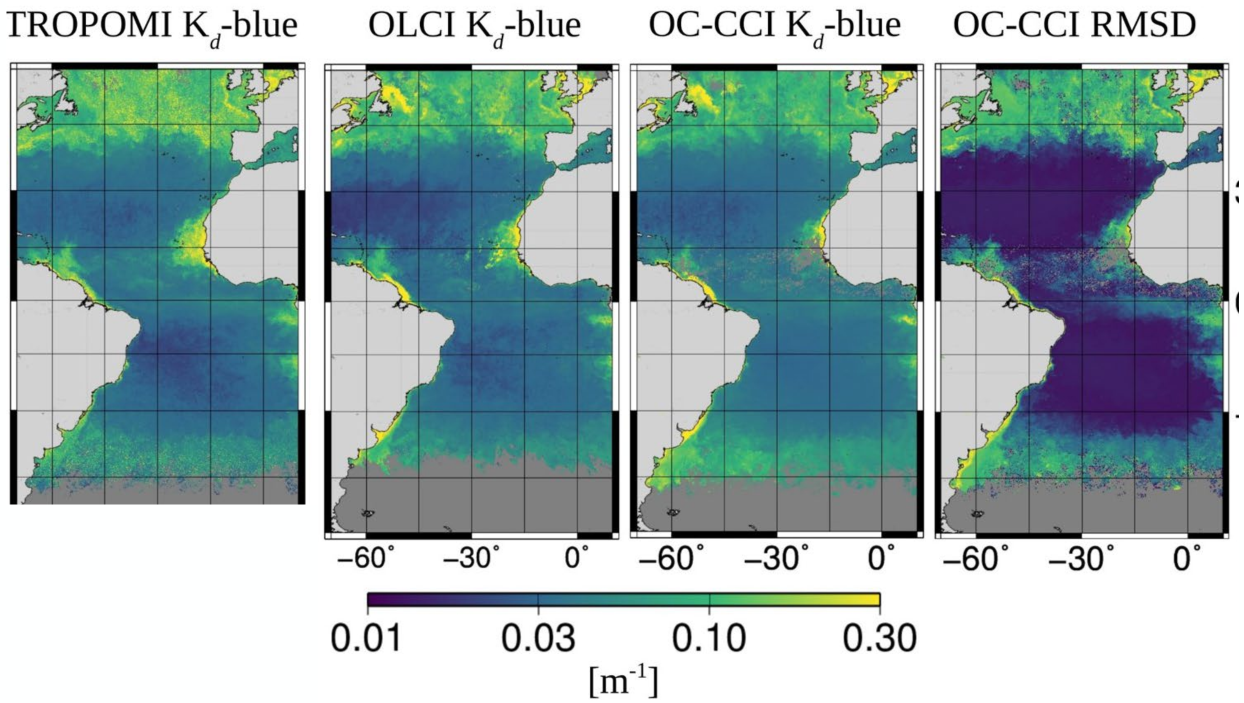
TROPOMI Kd comparison to in-situ and OLCI & OC-CCI KD490

(Oelker et al. 2022)

TROPOMI Kd against in situ



Criteria	Kd-UVAB	Kd-UVA	Kd-blue
r	0.72	0.54	0.54
Bias (m^{-1})	-0.026	0.015	-0.008
MAE (m^{-1})	0.026	0.026	0.012
RMSD (m^{-1})	0.031	0.029	0.015
Unb.RMSE (m^{-1})	0.017	0.025	0.013



TROPOMI Kd-UVAB, -UVA and –blue agree well with in-situ (low # of matchups) and also Kd-blue within OCCCCI Kd.

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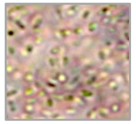
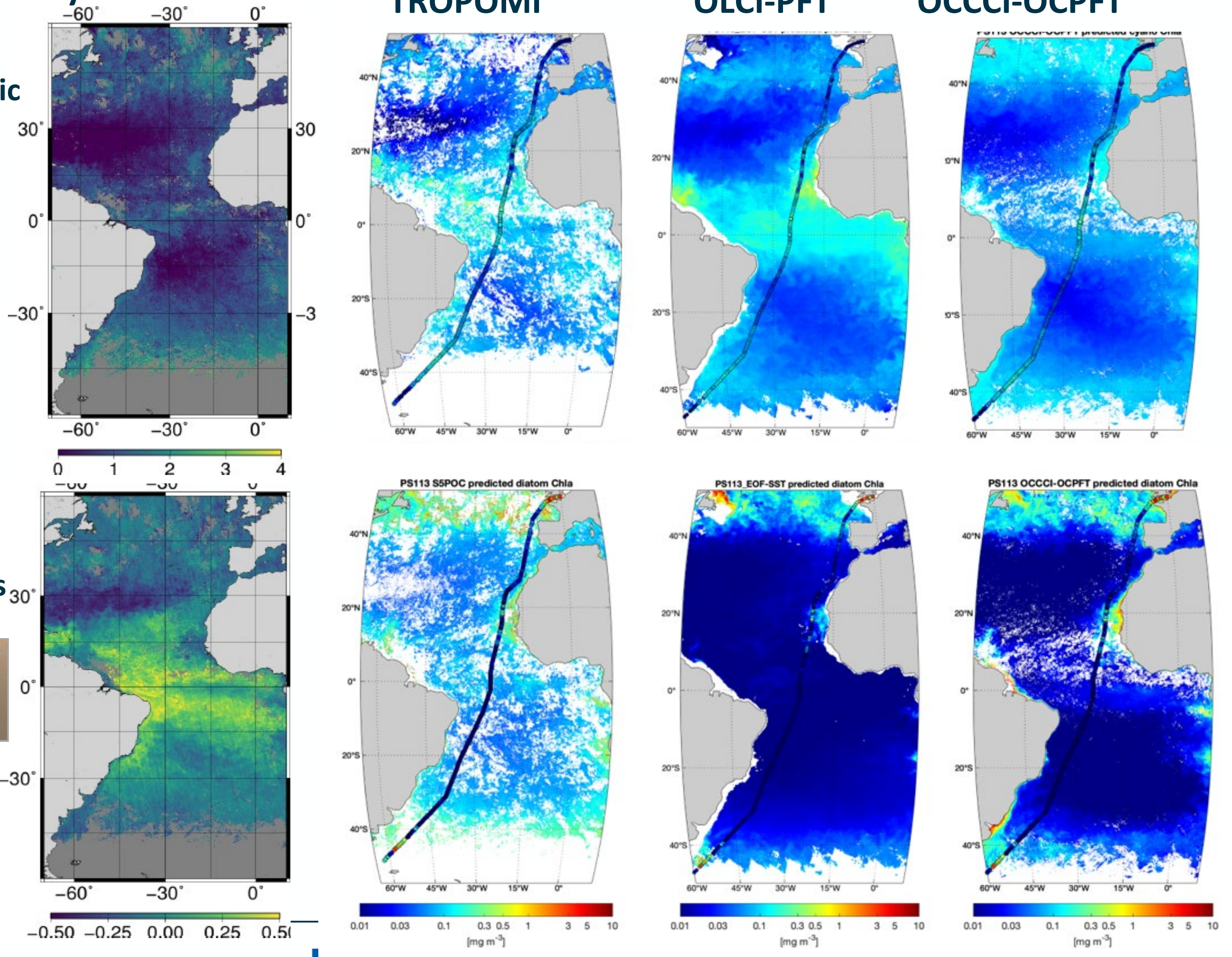
TROPOMI PFT vs. OLCI-PFT vs. OCCCI-OCPFT

TROPOMI PhytoDOAS fit factor	analytical TROPOMI	spectral decomp. OLCI-PFT	abundance-based OCCCI-OCPFT

prokaryotic phyto.



diatoms



11 May- 9 Jun 2018

Circles: PFT from HPLC samples of RV Polarstern expedition PS113

Preliminary results indicate feasible retrievals of diatom and prokaryotic phytoplankton CHL.

OLCI-PFT: Xi et al. 2021 https://marine.copernicus.eu/

OCCCI-OCPFT: CHL from OCCCI, PFT as in Losa et al. (2017)

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Conclusions & next steps for TROPOMI analytical OC products

Now:

- First time Kd in UVAB & in UV-A from satellite UV via inversion with reasonable uncertainty.
- Potential of PFT-CHL to improve empirical / statistical satellite PFT globally.

2-3 years:

Global processing (2018-) S5P Kd & (finalize retrieval) PFT-Chl incl. pixel uncertainty

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

- Kd(λ) at ≥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)

Demonstration of multiplatform (bioARGO, towed, satellite) AOP & IOP data fusion for spectral KD & 4D-PFT-Chl

TROPOMI-OC know-how to new high spectral resolved S4 (GEO), S5 - also PACE, EnMAP, DESIS, PRISMA

5 years:

New TROPOMI products: UV in water: MAAs, CDOM sources, photodegradation (PB), Chla fluorescence, DOC

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