Additive varying coefficient model for estimating diffuse attenuation coefficient from satellite-derived water reflectance

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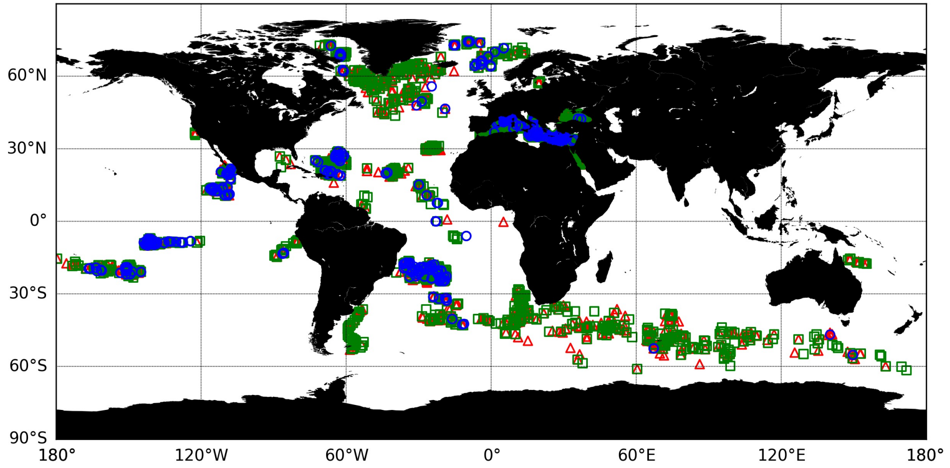
-K_{dPAR} obtained from Biogeochemical-Argo vertical light profiles was matched with R_{rs} derived from MODIS, VIIRS, and OLCI data.

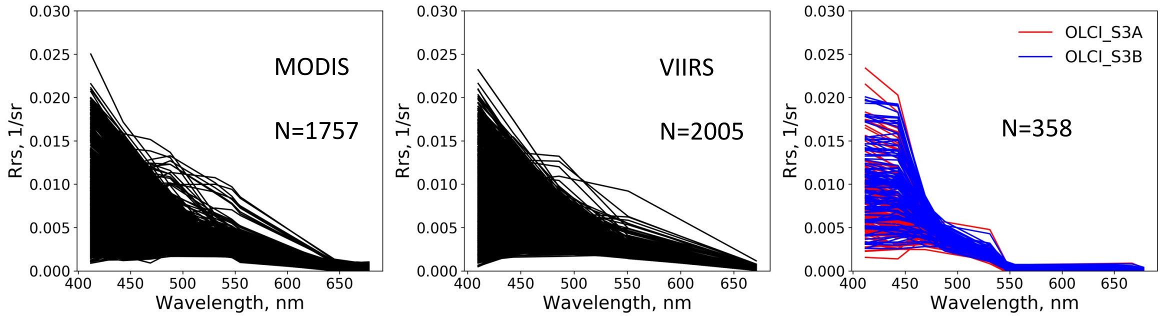
-Matchup data set was used to develop a semi-parametric AVCM to estimate K_{dPAR} from R_{rs} at 410, 443, 486, 551, and 671 nm.

-Model coefficients are function of informative (modifying) variables such as Sun zenith angle, geographic location, sea surface temperature, and day length.

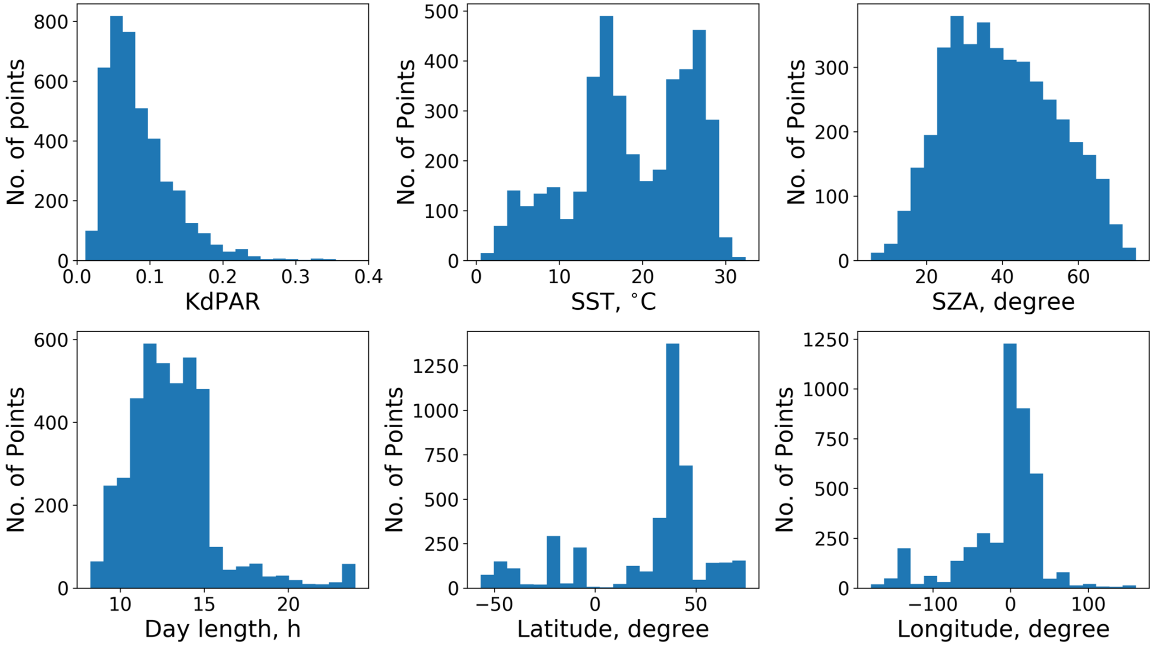
Data sets



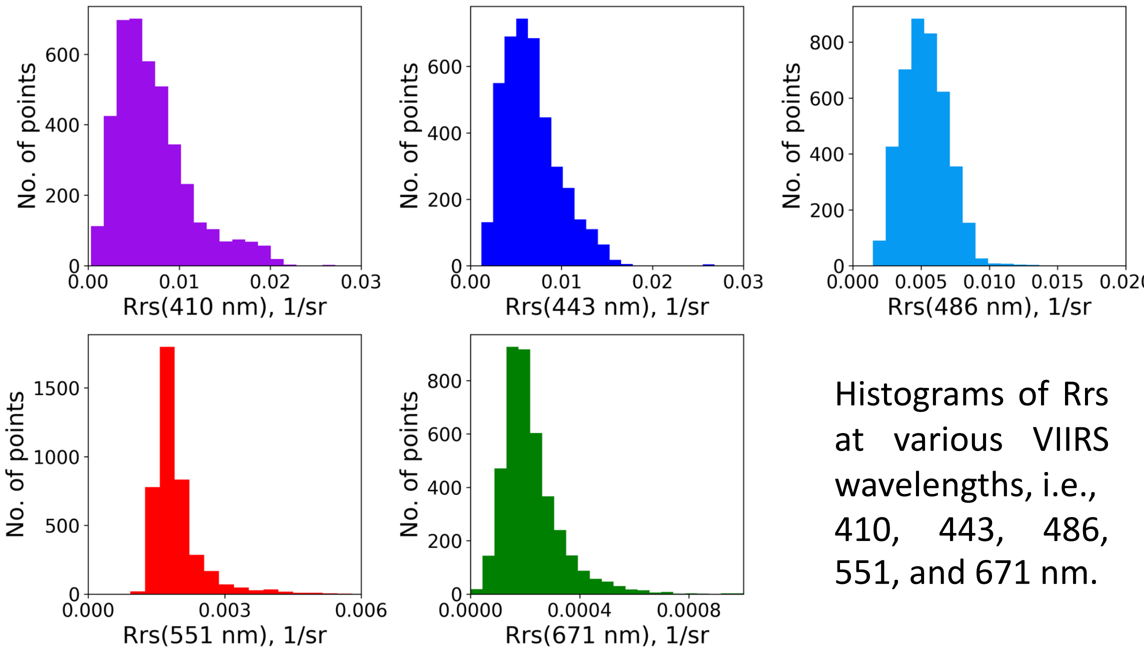
Global map of Argo float locations with MODIS (Red), VIIRS (green), and OLCI (blue) match-ups.



Retrieved Rrs from different sensors in the match-up dataset.



Histograms of K_{dPAR} and various parameters, i.e., SST, SZA, day length, latitude, and longitude.



Histograms of Rrs at various VIIRS wavelengths, i.e., 410, 443, 486, 551, and 671 nm.

AVCM retrieval of K_{dPAR}

-Rrs of various sensors are spectrally interpolated/extrapolated to VIIRS wavelengths, i.e., 410. 443, 486, 551, and 671 nm.

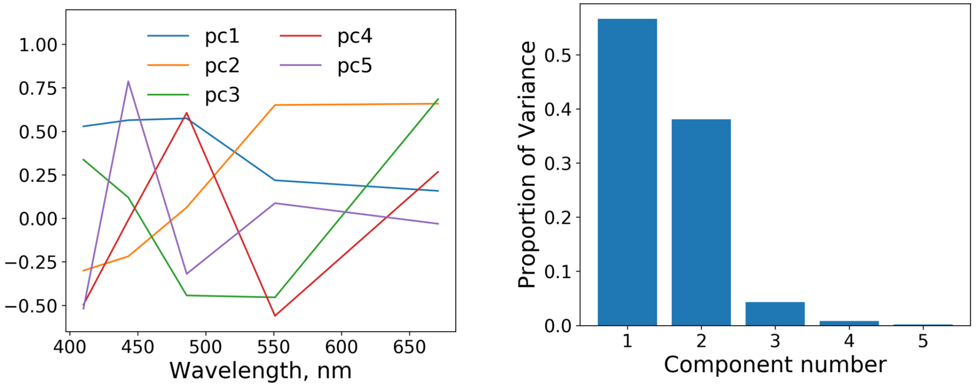
-Rrs(λ) or log(Rrs(λ)/Rrs(551) are decomposed in principal components (PCs) and correlation between PCs and K_{dPAR} is examined. PCs most correlated to K_{dPAR} are eventually selected.

-2 models:

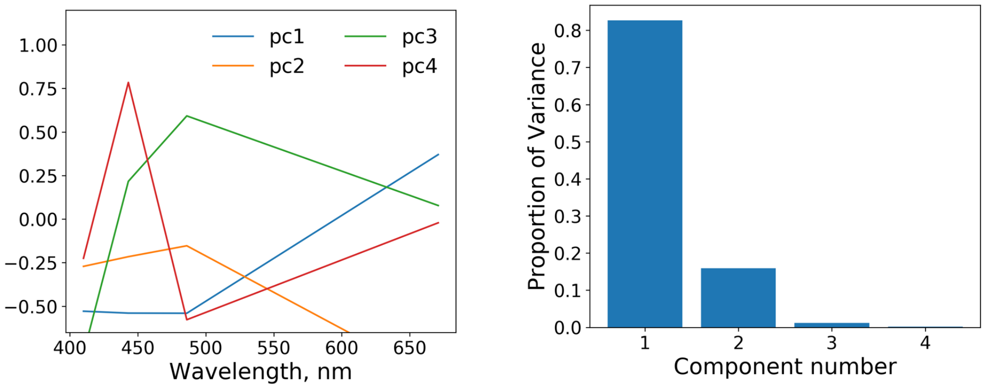
1) $K_{dPAR} = f_0(SZ, SST, Daylength, Lat., Lon.) + \sum_i[f_i(SZ, SST, Daylength, Lat., Lon.)PC_i]$ with Rrs PCs
2) $Log(K_{dPAR}) = f_0(SZ, SST, Daylength, Lat., Lon.) + \sum_i[f_i\ SZ, SST, Daylength, Lat., Lon.)PC_i]$ with log(Rrs(l)/Rrs(551) PCs

-Functions f_0 and f_i constitute the free parameters of the models and are estimated from the data. This is achieved by penalized smoothing splines.

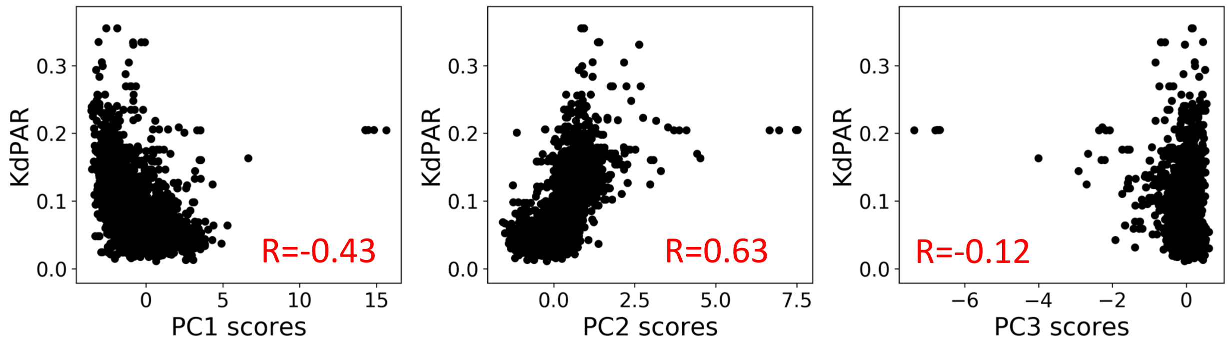
PC analysis

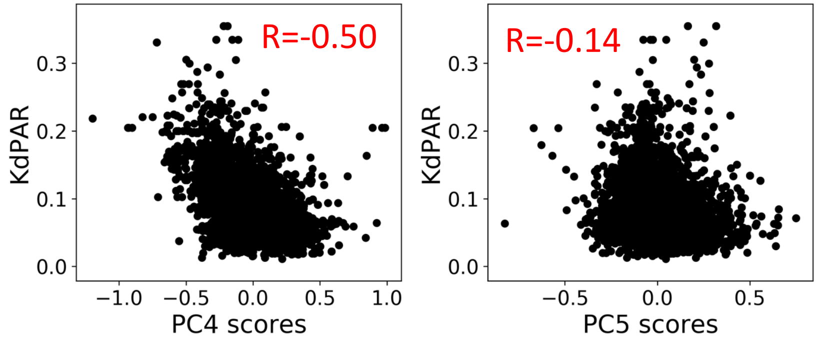


5 Rrs PCs and variance explained for each PC.

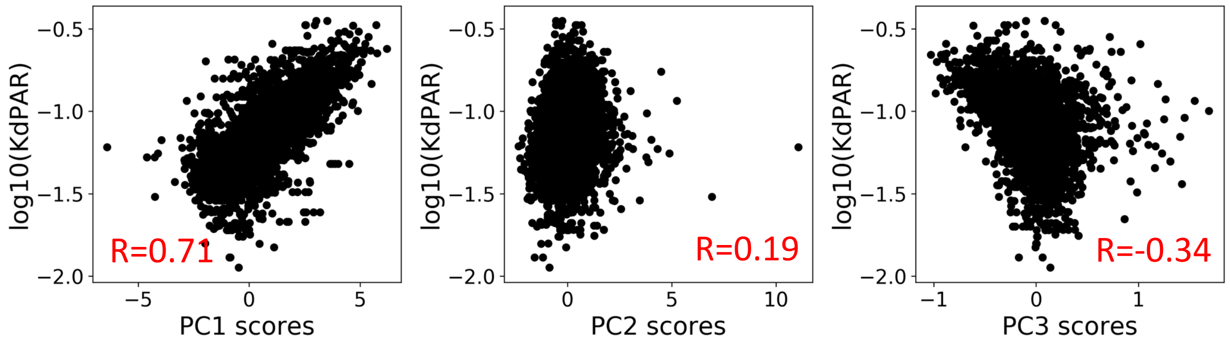


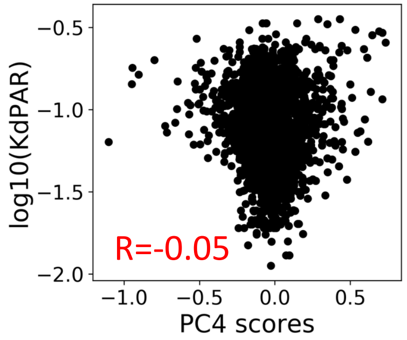
4 Rrs ratio PCs and variance explained for each PC.





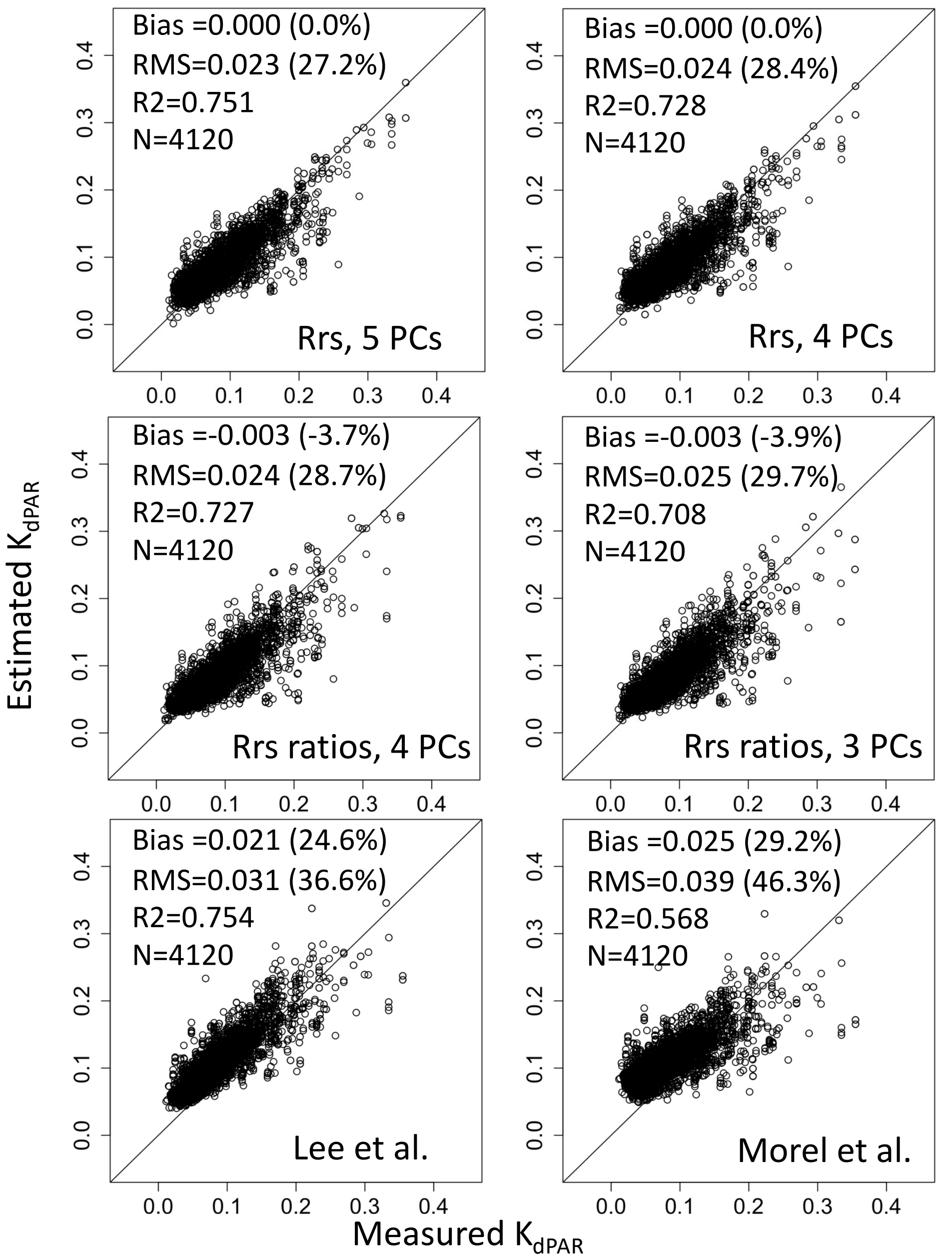
Pearson's correlation coefficients (R) of K_{dPAR} with 5 Rrs PC scores.

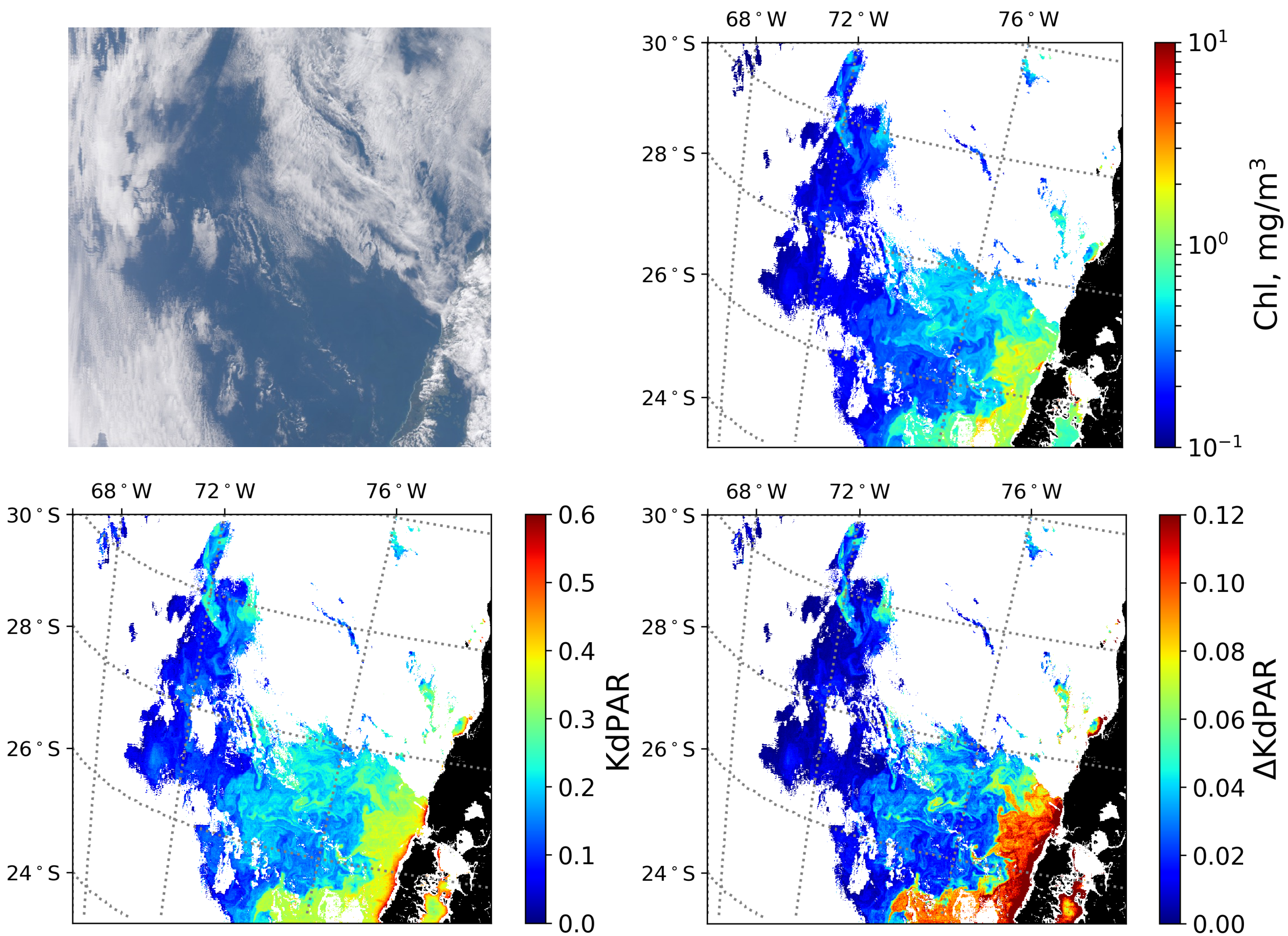




Pearson's correlation coefficients (R) of log10(K_{dPAR}) with 4 Rrs ratio PC scores.

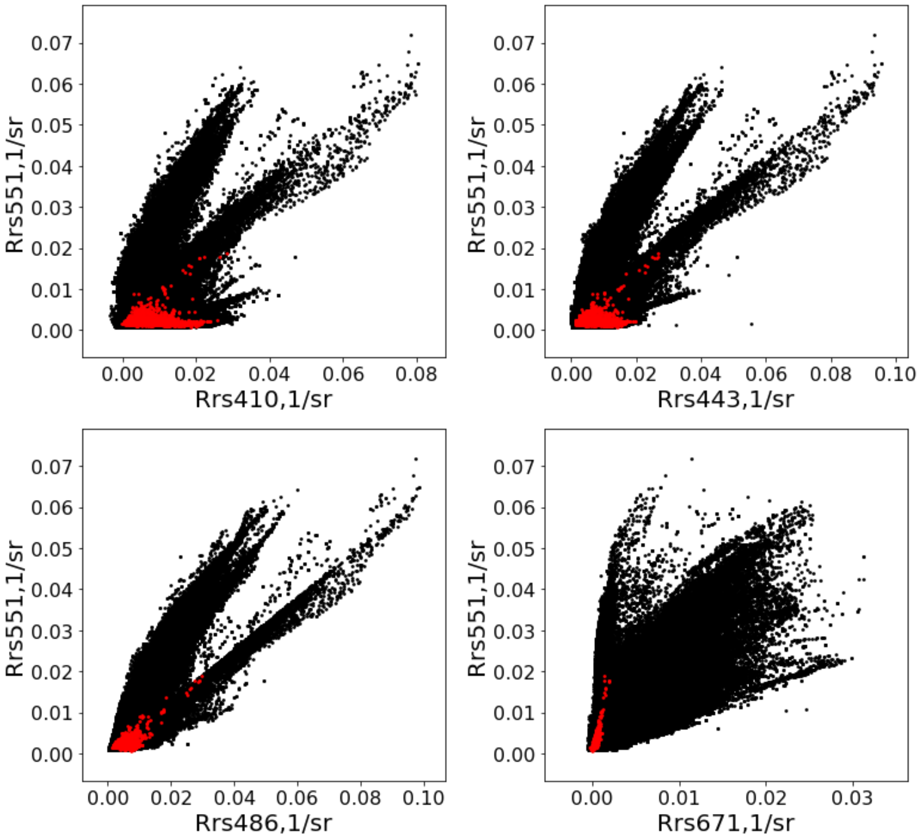
Results





Application to the MODIS-A image on September 30, 2022, near Santiago, Chile: (top) RGB and Chl; (bottom) estimated K_{dPAR} using the best AVCM and uncertainty map. Outliers in MODIS-A Rrs have been removed using the QWIP method (Dierssen et al. 2022).

Conclusions and perspective



Scatter plots of satellite-derived (black) and in-situ measured (red) Rrs(410) vs Rrs(551), Rrs(443) vs Rrs(551), Rrs(486) vs Rrs(551), and Rrs(667) vs Rrs(551). A total of 12 daily global VIIRS images, i.e., images on every 15th from January to December in 2018, were used.

-ACVMs performs better than Lee and Morel models, i.e., they are not or little biased, but variance explained is slightly less than Lee's.

-Using auxiliary variables related to the physical environment improves retrieval accuracy.

-Generalization is difficult, because match-ups do not represent expected situations (e.g., K_{dPAR} values are < 0.4 in the data set).

-Ongoing bio-Argo program will increase the number of available matchups in diverse conditions and regions, allowing more accurate K_{dPAR} estimates at the global scale.