Overview of Bio-optical Algorithms for Open Ocean, Coastal and Inland Water Transitions

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with material from
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Damien Bouffard, Eawag, Kastanienbaum
(and many others)

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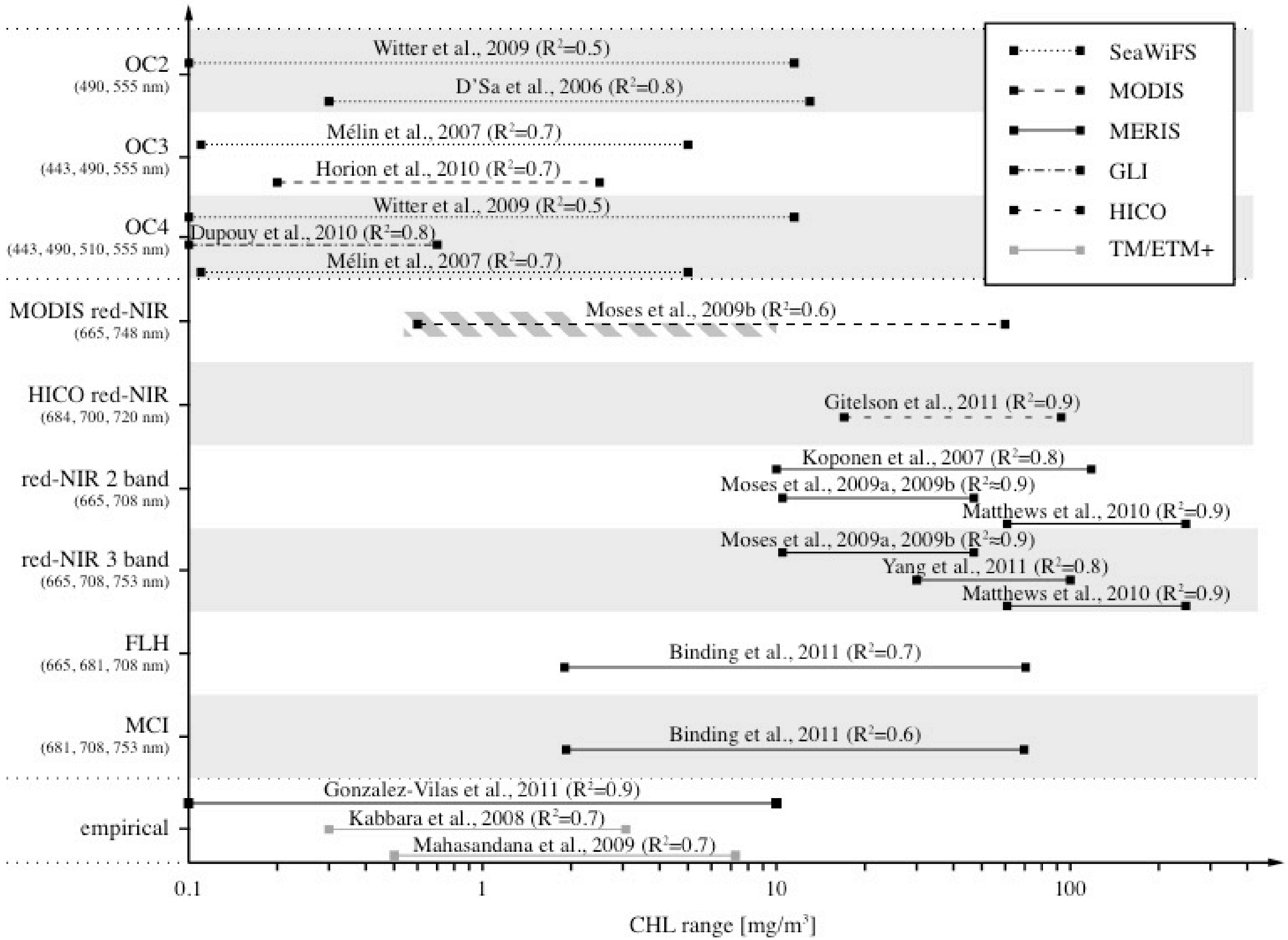
Content

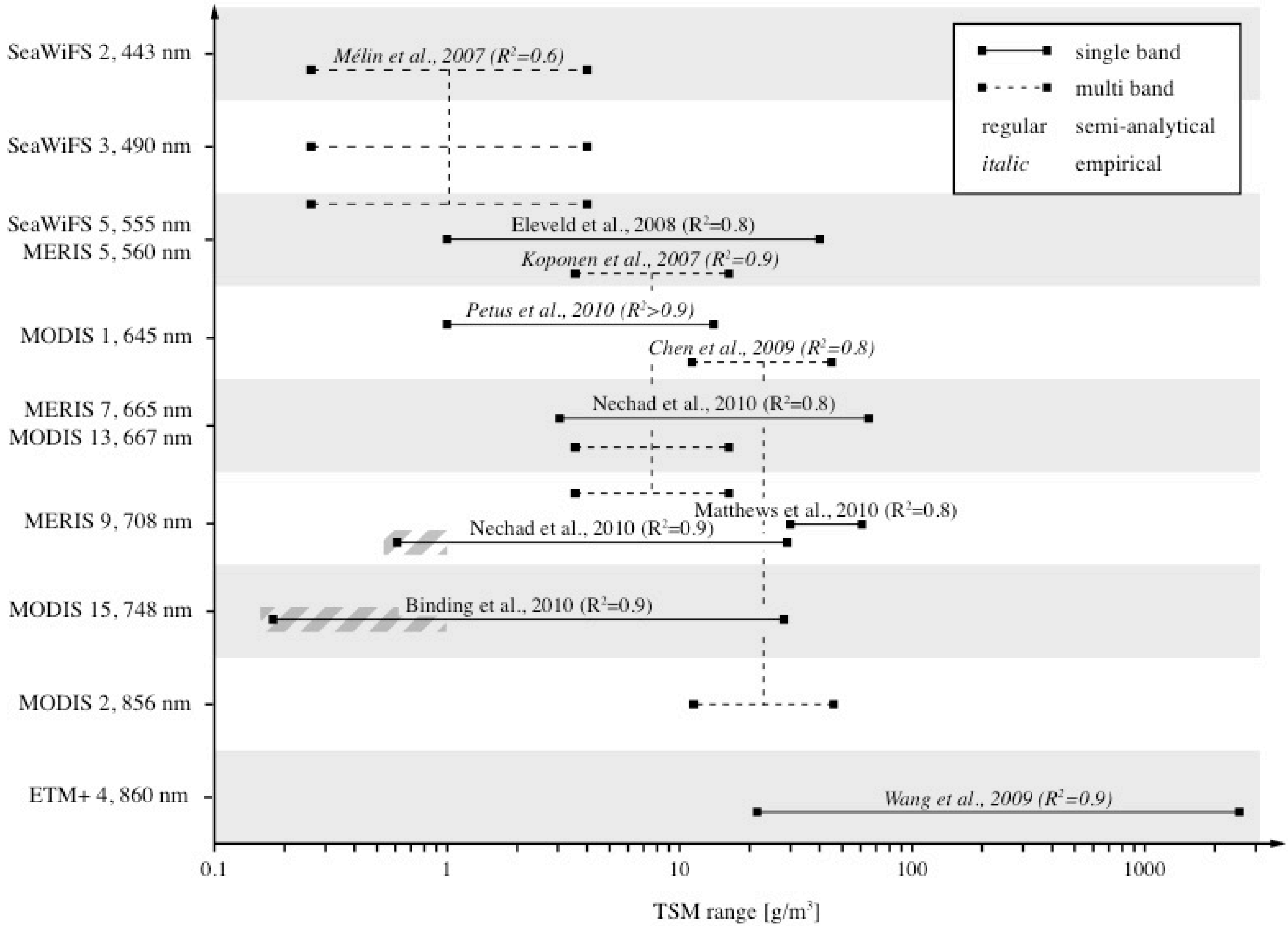
- Band ratio algorithms
- Neural Network algorithms
- Algorithm blending
- Vertical non-uniformities
- Conclusions and suggestions

Review of 2006-2011 *CHL* Band Ratios



Odermatt, D., Gitelson, A., Brando, V.E., and Schaepman, M.E. (2012). Review of constituent retrieval in optically deep and complex waters from satellite imagery. Remote Sens. Environ. 118, 116–126.

Review of 2006-2011 *TSM* Monoband Algorithms

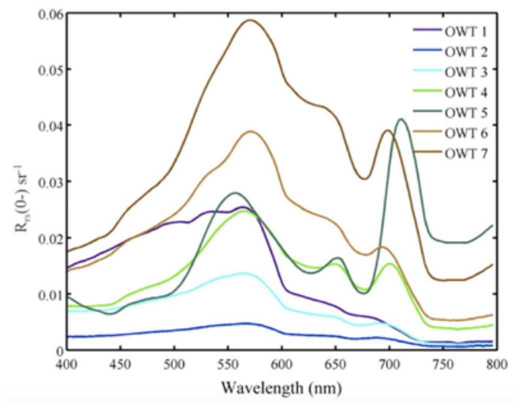


Odermatt, D., Gitelson, A., Brando, V.E., and Schaepman, M.E. (2012). Review of constituent retrieval in optically deep and complex waters from satellite imagery. Remote Sens. Environ. 118, 116–126.

The OWT Framework

Moore et al. (2014):

- Fuzzy *c*-means clustering

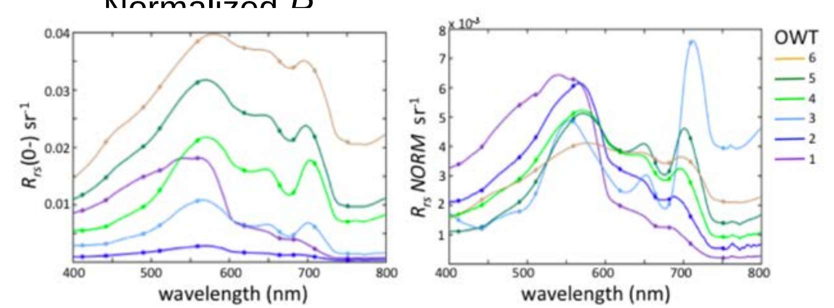


- AC: SeaDAS 6.4 default
- Weighting
  - OC4 * sum of memberships type 1,2,3,6
  - M3B * sum of memberships type 4,5,7

Eleveld et al. (2017):

- Fuzzy *c*-means clustering

R_{rs}



- AC: C2R, C2RCC, MIP
- Weighting
  - N.a.

Moore, T.S., Dowell, M.D., Bradt, S., and Ruiz Verdu, A. (2014). An optical water type framework for selecting and blending retrievals from bio-optical algorithms in lakes and coastal waters. Remote Sens. Environ. 143, 97–111.
Eleveld, M.A., Ruescas, A.B., Hommersom, A., Moore, T.S., Peters, S.W.M., and Brockmann, C. (2017). An Optical Classification Tool for Global Lake Waters. Remote Sens. 9.

Matsushita et al. (2015): *CHL* in Asian Lakes

MCI thresholds rather than classification:

if MCI ≤ 0.0001: OC4E

elif MCI ≤ 0.0016: Gilerson 2-band

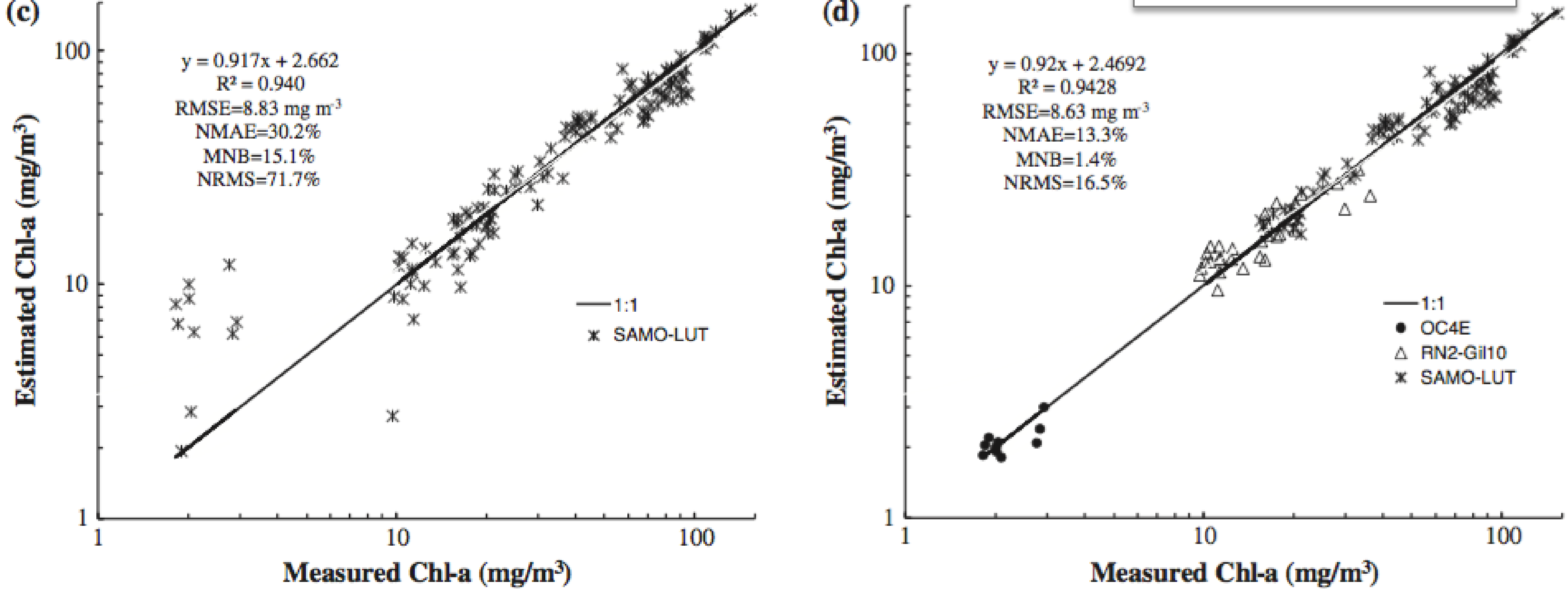
Else: SAMO-LUT

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{N}\left(X_{\mathrm{esti},i} - X_{\mathrm{meas},i}\right)^2}{N-1}}$$

$$\mathrm{NRMS} = \mathrm{stdev}(\varepsilon_i)\%$$

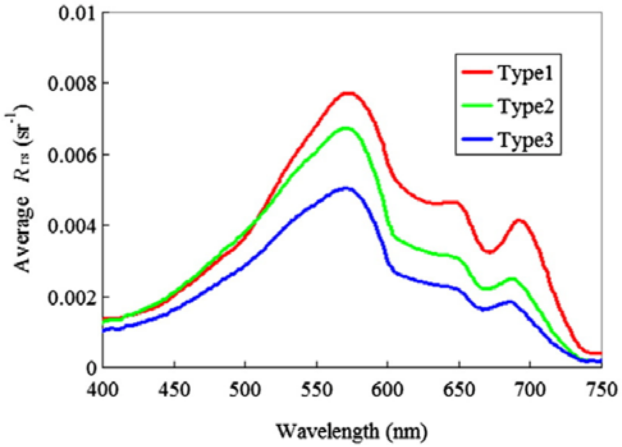
$$\mathrm{MNB} = \mathrm{mean}(\varepsilon_i)\%$$

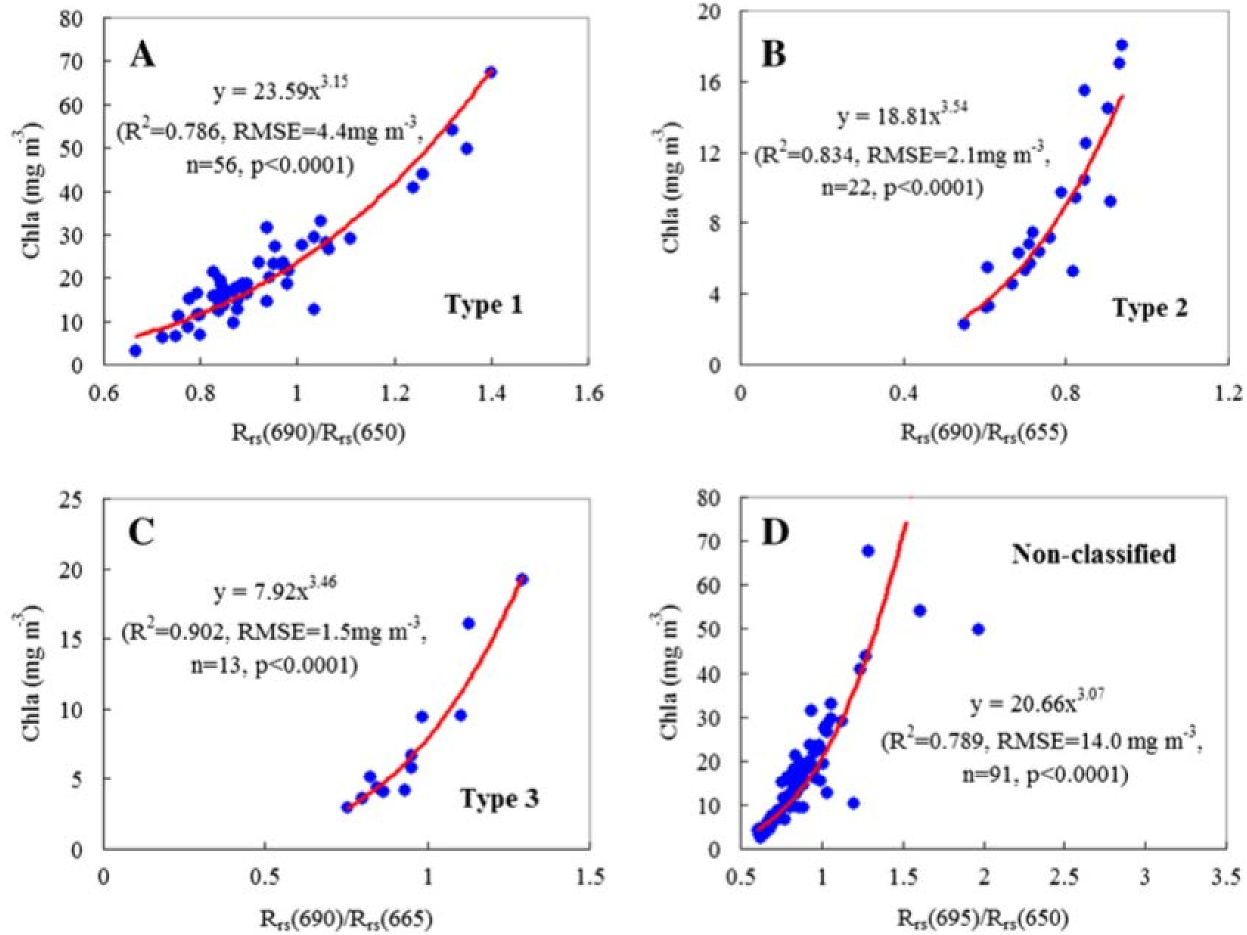
$$\mathrm{NMAE} = \mathrm{mean}(|\varepsilon_i|\%)$$



Matsushita, B., Yang, W., Yu, G., Oyama, Y., Yoshimura, K., and Fukushima, T. (2015). A hybrid algorithm for estimating the chlorophyll-a concentration across different trophic states in Asian inland waters. ISPRS J. Photogramm. Remote Sens. 102, 28–37.

Sun et al. (2014): *CHL* in Chesapeake & Tampa Bay





650/655/665 nm
‚Feature-shift' blending

Sun, D., Hu, C., Qiu, Z., Cannizzaro, J.P., and Barnes, B.B. (2014). Influence of a red band-based water classification approach on chlorophyll algorithms for optically complex estuaries. Remote Sens. Environ. 155, 289–302.

Neural Network Training Ranges

[redacted]

Doerffer, R., and Schiller, H. (2008). Lake Water Algorithm for BEAM ATBD (Geesthacht, Germany: GKSS).

Schroeder, T., Schaale, M., and Fischer, J. (2007). Retrieval of atmospheric and oceanic properties from MERIS measurements: A new Case-2 water processor for BEAM. Int. J. Remote Sens. 28, 5627 – 5632.

${}_{PART}+3.1\ b_{WIT}\quad TSM = 1.73\ b_{PART}+3.1\ b_{WIT}$

Brockmann, C., Doerffer, R., Peters, M., Stelzer, K., Embacher, S., and Ruescas, A.B. (2016). Evolution of the C2RCC Neural Network for Sentinel 2 and 3 for the Retrieval of Ocean Colour Products in Normal and Extreme Optically Complex Waters. In Proc. ESA Living Planet Symposium, (Prague, Czech Republic: ESA/ESRIN), p. 6.

Hieronymi, M., Müller, D., and Doerffer, R. (2017). The OLCI Neural Network Swarm (ONNS): A Bio-Geo-Optical Algorithm for Open Ocean and Coastal Waters. Front. Mar. Sci. 4, 140.

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Hieronymi et al. (2017): OLCI NN Swarm

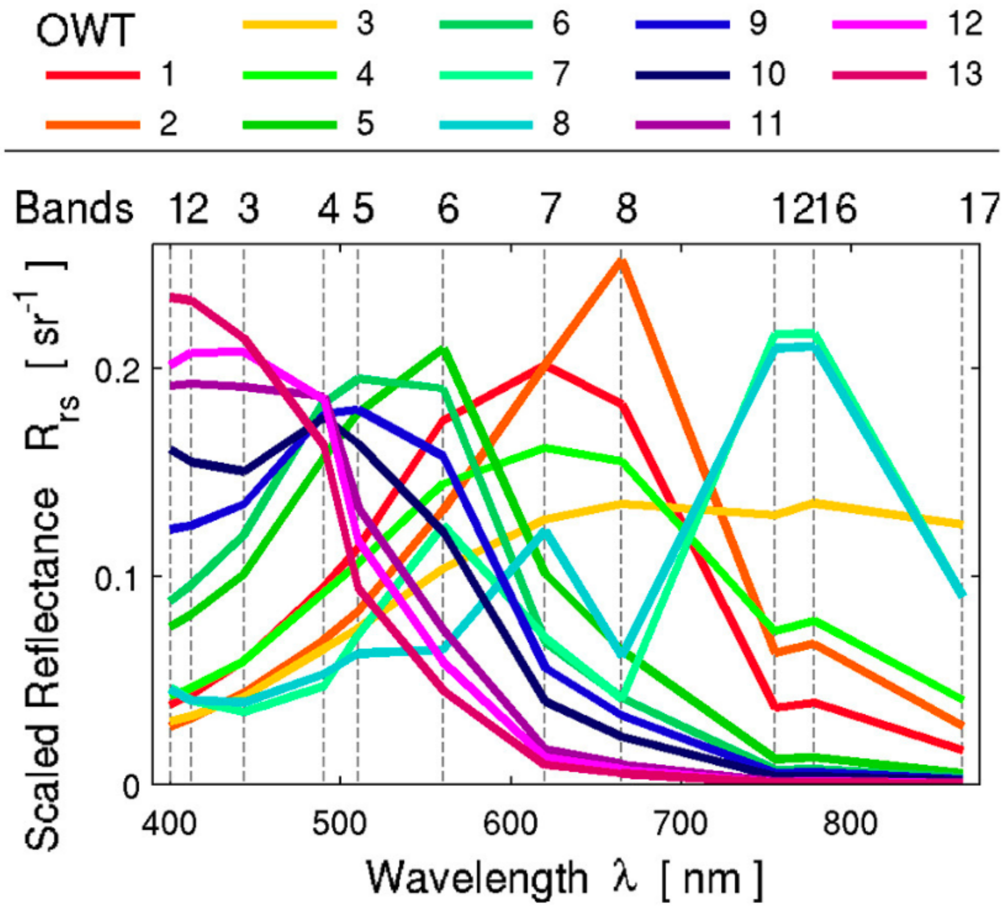
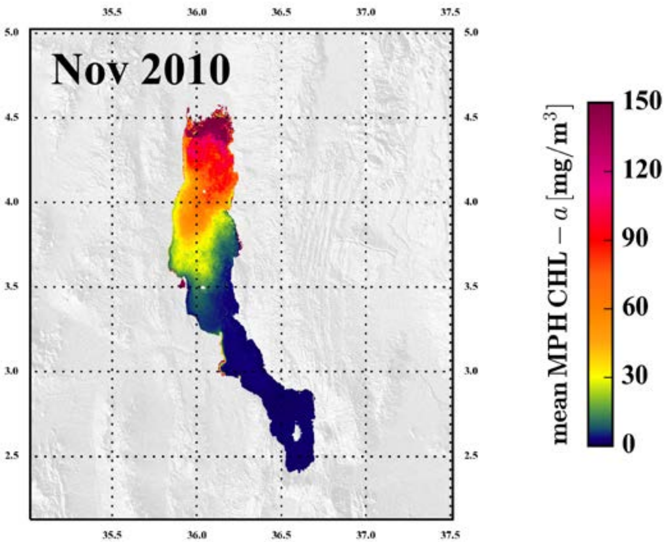
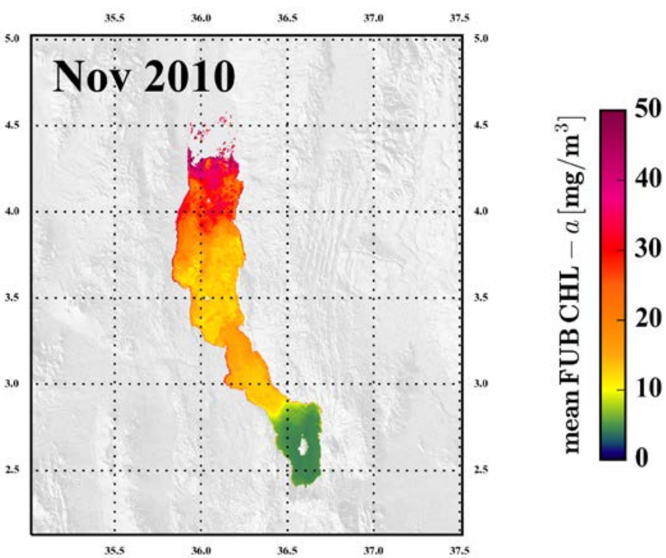


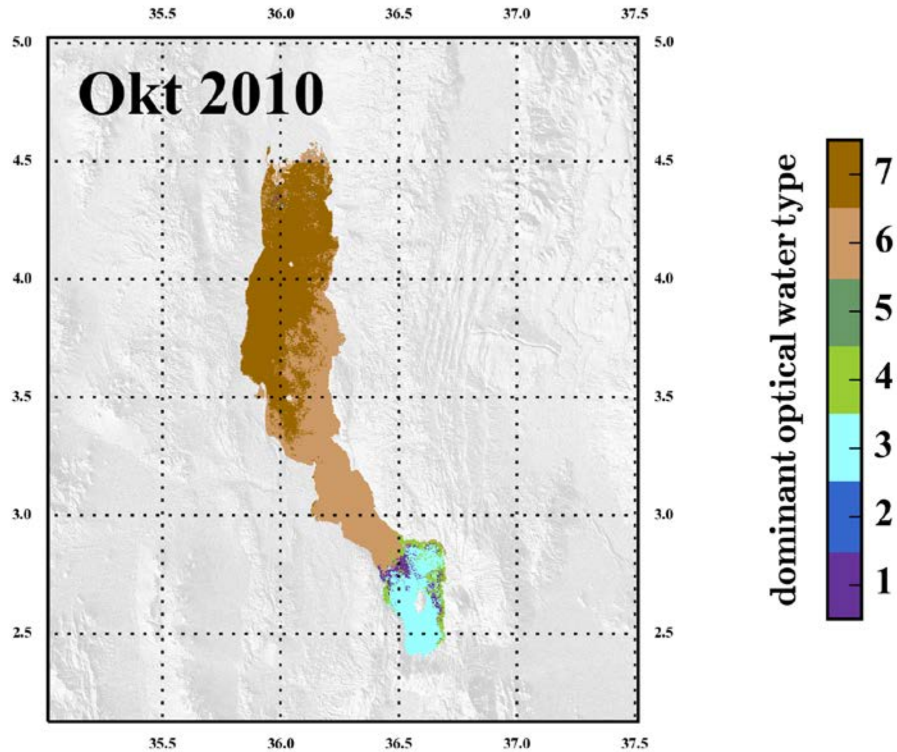
FIGURE 3 | Brightness-scaled remote sensing reflectances for 13 classes of optical water types. Utilized OLCI bands are marked.

Hieronymi, M., Müller, D., and Doerffer, R. (2017). The OLCI Neural Network Swarm (ONNS): A Bio-Geo-Optical Algorithm for Open Ocean and Coastal Waters. Front. Mar. Sci. 4, 140.

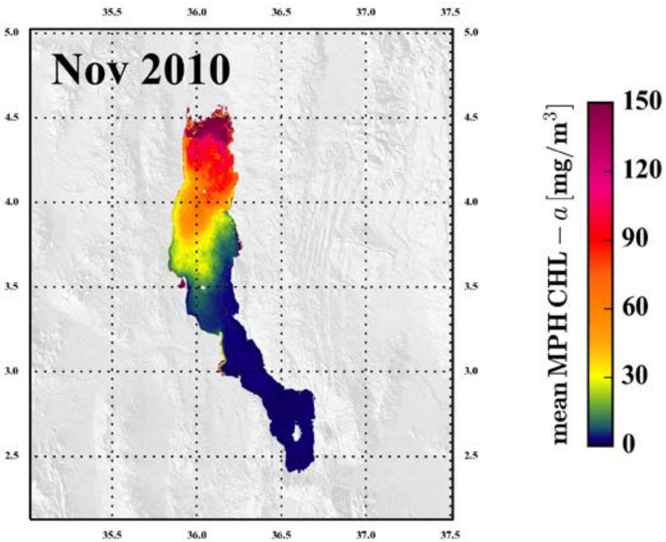
FUB/MPH Divergence around 10 mg/m³ CHL

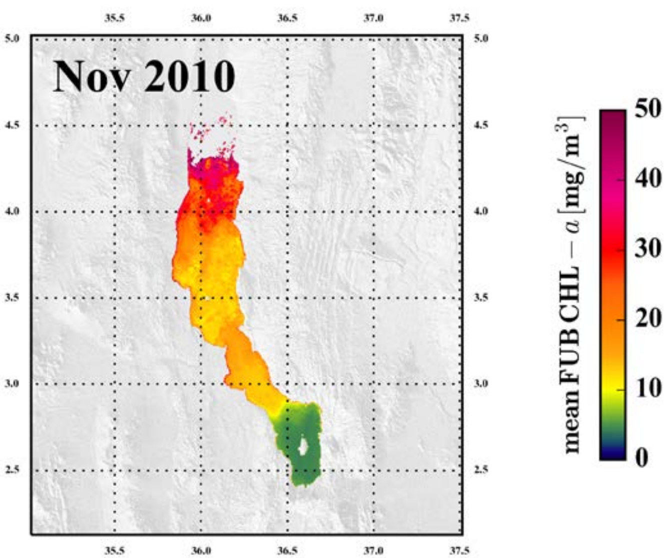


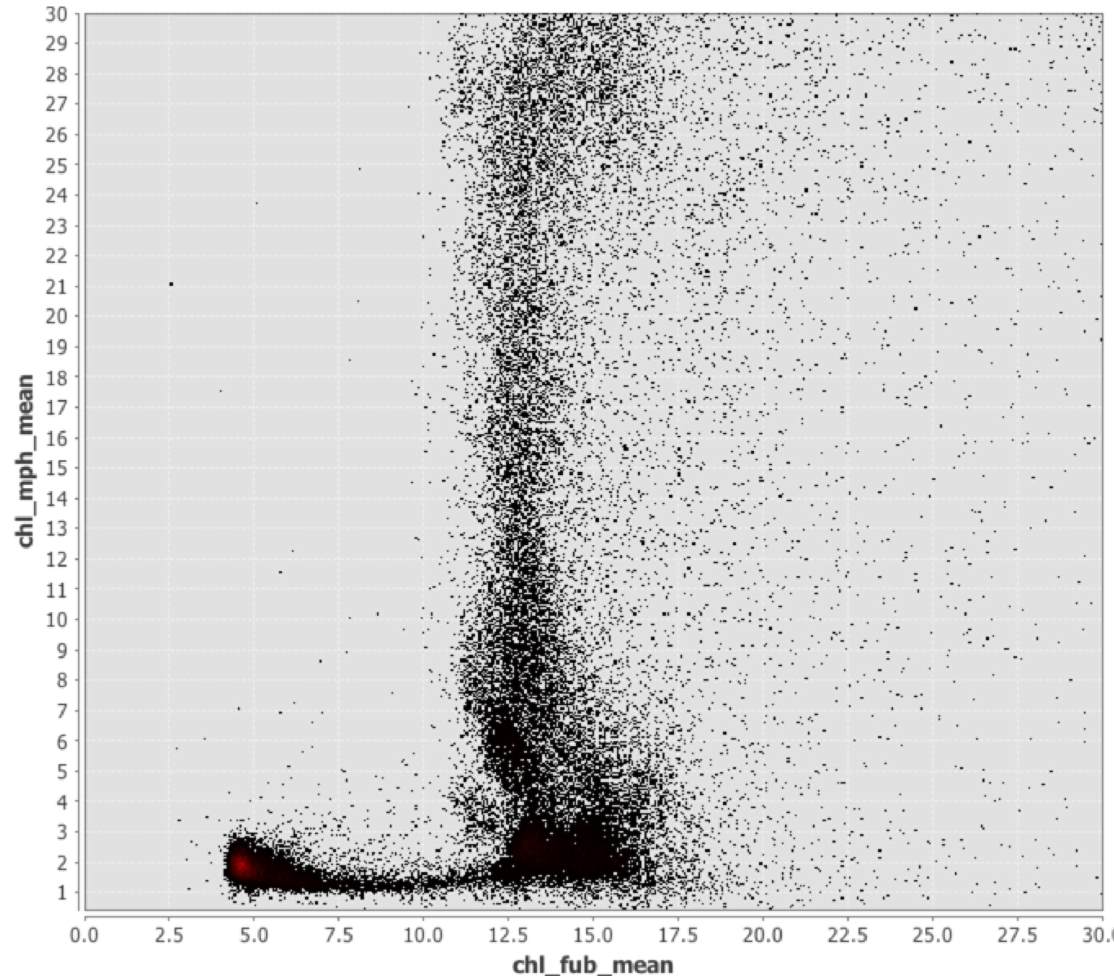




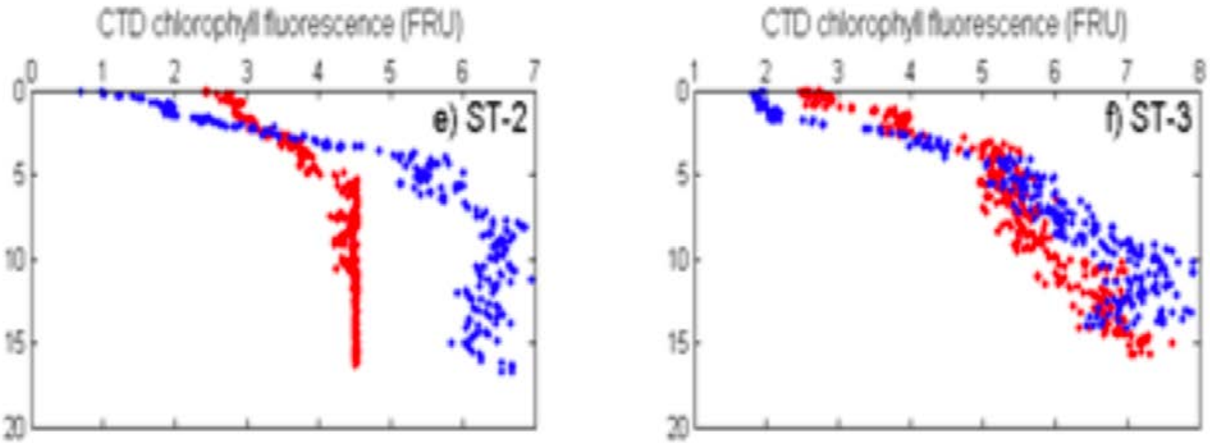
FUB/MPH Divergence around 10 mg/m^3 CHL



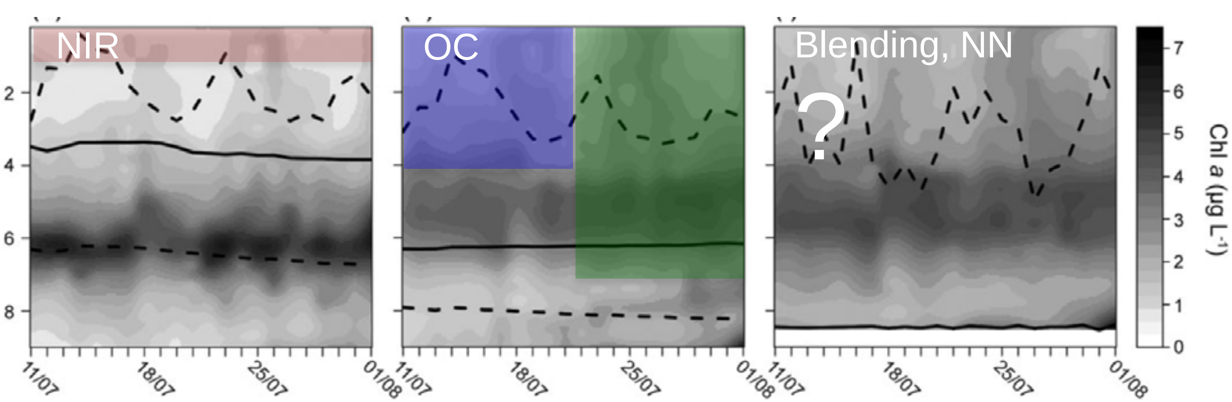




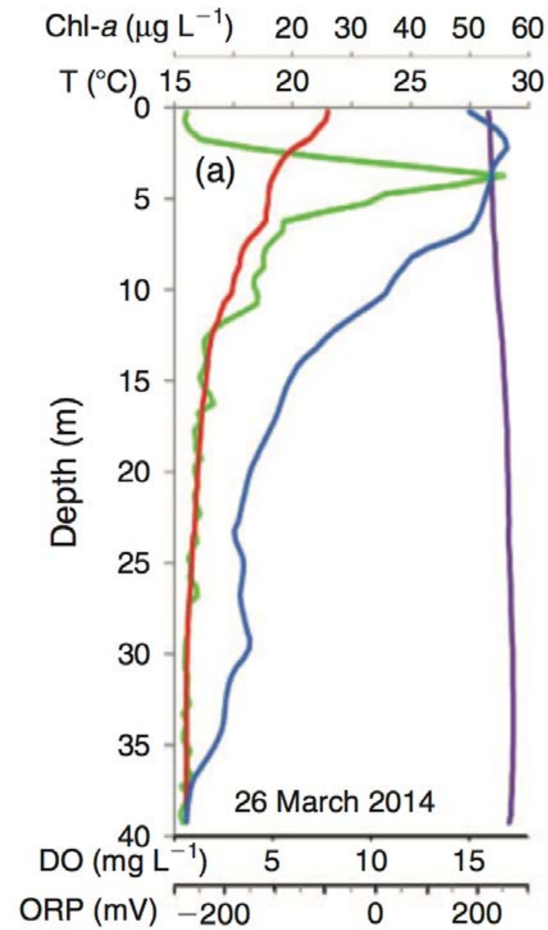
Vertical Non-uniformities and Signal Depths



Lake Malawi (Makuiane et al., 2016)

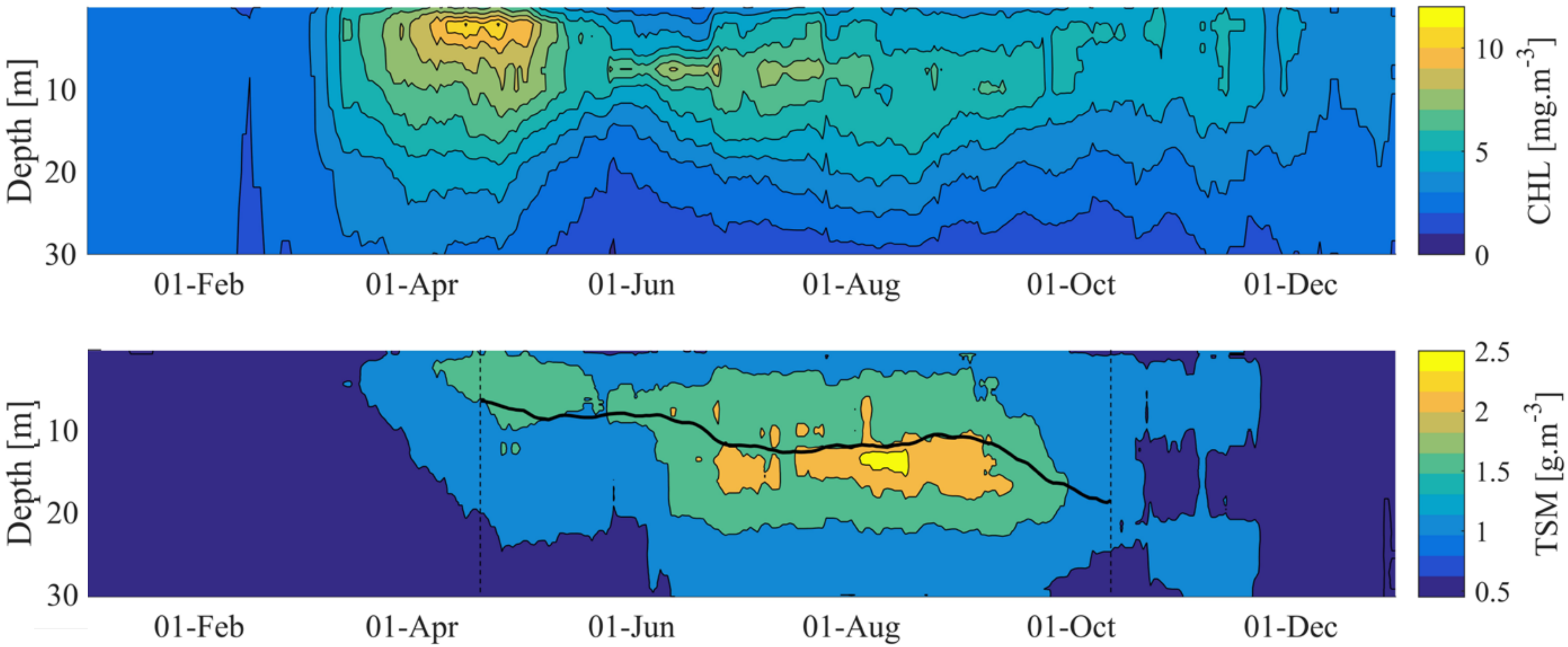


Lake Croche (Ouellet Jobin & Beisner., 2014)



Lake Kinneret
(Sela-Adler et al., 2015)

Lake Geneva 2002-2015 Averaged Profiles



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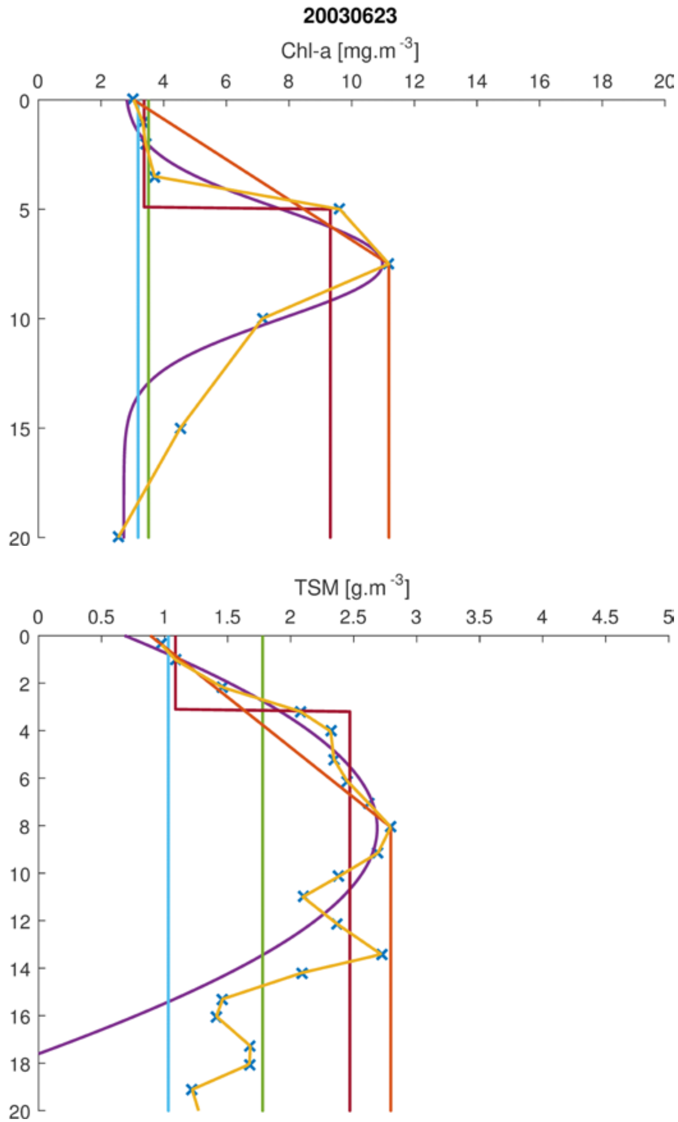
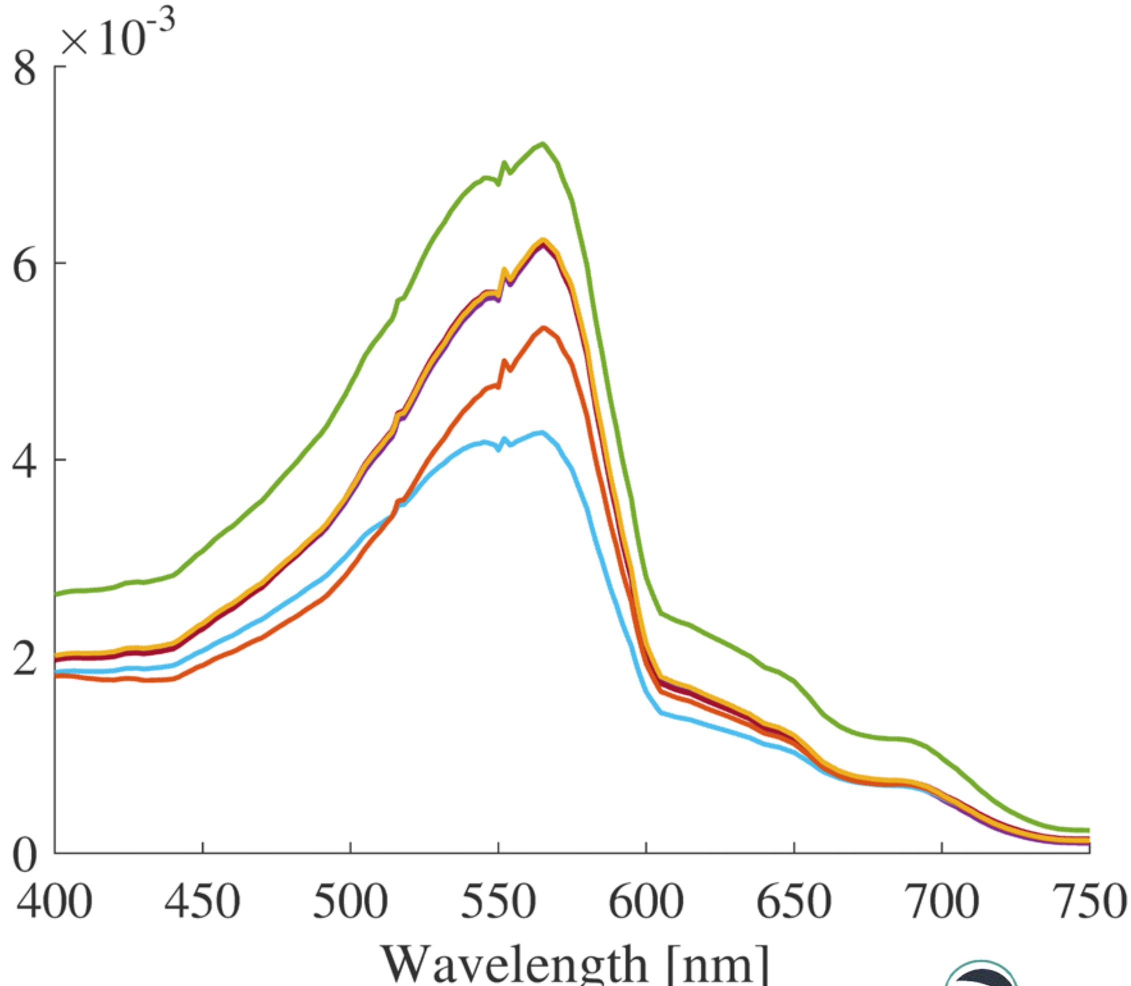
coresim

Simulated Effects on Reflectance





Conclusions and Suggestions

- Blending conventional algorithms improves constituent retrieval performance measures, but classification and blending approaches vary widely, and AC selection remains critical
- Invert the dependency between water types and algorithms:
  - Turn “water-type specific algorithms” into “algorithm specific water-types”
  - Yield adequate validity flags in addition to blended products
- Red-NIR feature-shift blending preserves a consistent signal depth, ‘trans-spectral’ blending (and other spectral inversion algorithms) are affected by vertical nonuniformities
- Turn varying signal depths into an asset using ancillary measurements or models

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Appendix

Overview of Bio-optical Algorithms for Open Ocean, Coastal and Inland Water Transitions

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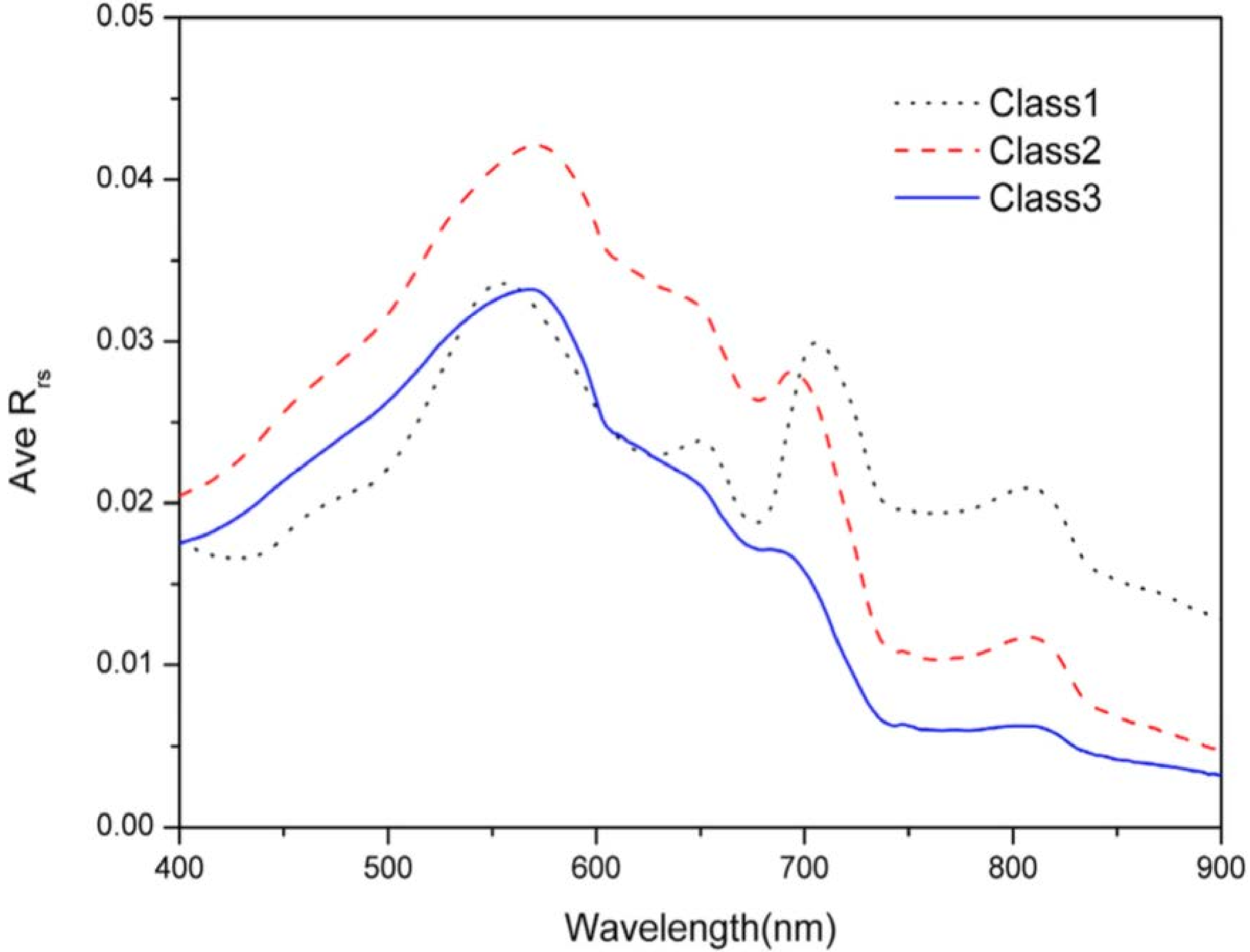
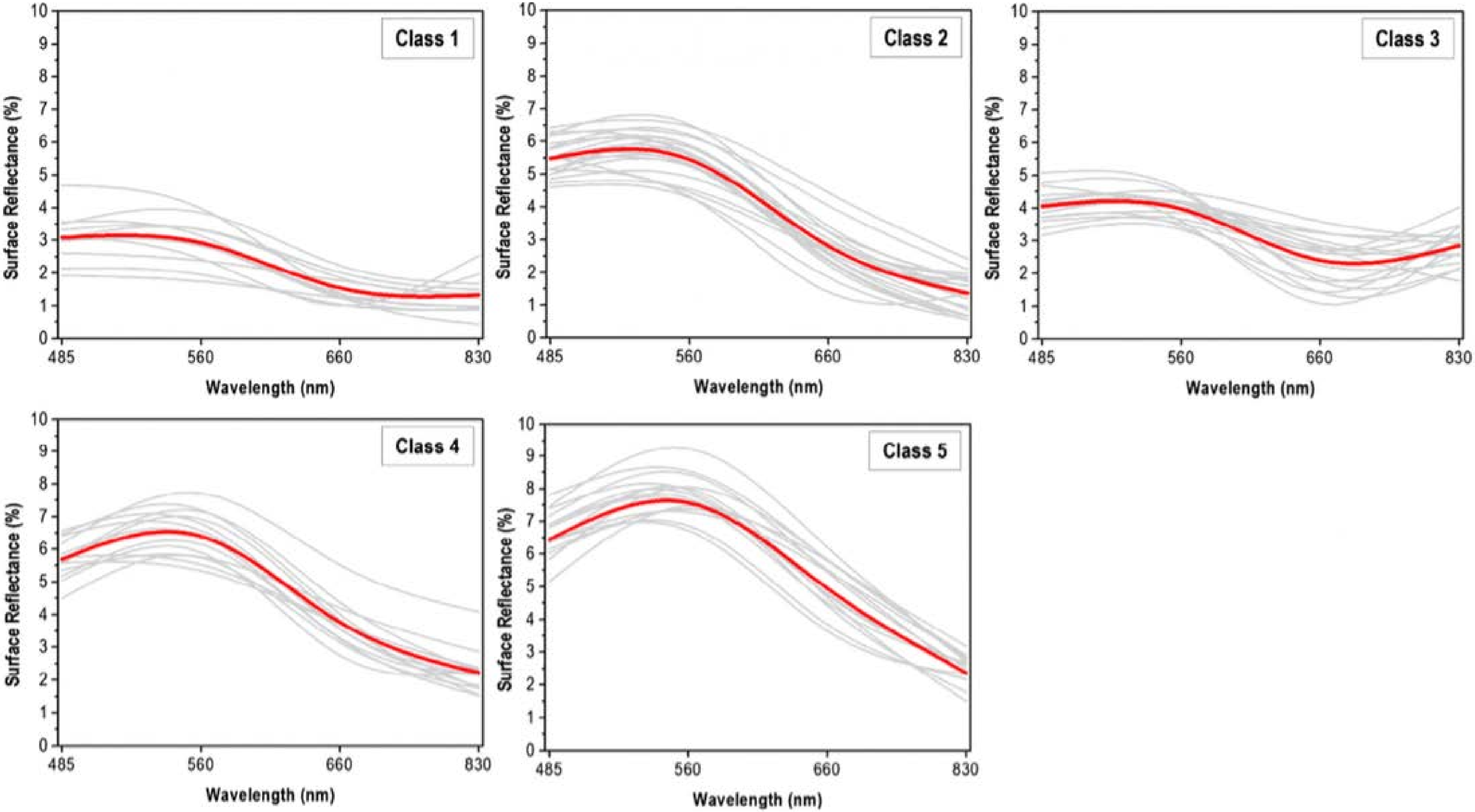
Bao et al. (2015): chl-*a* in Lake Taihu from GOCI



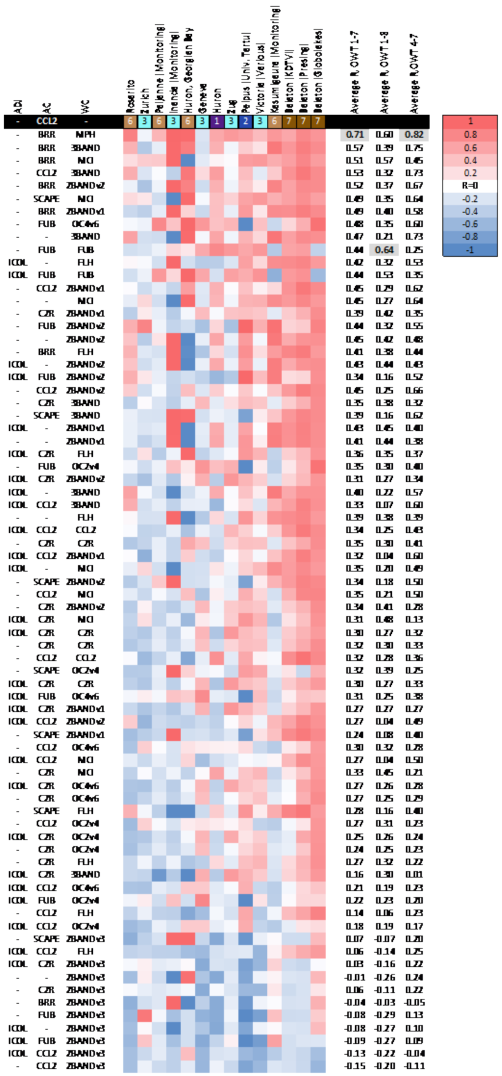
Bao, Y., Tian, Q., and Chen, M. (2015). A Weighted Algorithm Based on Normalized Mutual Information for Estimating the Chlorophyll-a Concentration in Inland Waters Using Geostationary Ocean Color Imager (GOCI) Data. Remote Sens. 7, 11731–11752.

Nazeer & Nichol (2016): chl-*a* and ss around Hongkong with Landsat TM



Nazeer, M., and Nichol, J.E. (2016). Improved water quality retrieval by identifying optically unique water classes. J. Hydrol. 541, Part B, 1119–1132.

Diversity II Global OWT Application



Approach:

- 74 AC/ADJ/WC algorithm combinations
- CHL reference data for 42 lakes
- OWT-7 derived from matchup R_{rs} using CoastColour NN

Outcome:

- FUB performed best for OWT 1-3
- MPH performed best for OWT 4-7
- OWT4, 5 underestimated due to AC
- FUB/MPH do not converge around 10-20 mg/m^3 CHL

Odermatt, D., Gangkofner, U., Ratzmann, G., Ruescas, A.B., Stelzer, K., Philipson, P., and Brockmann, C. (2015). Algorithm Theoretic Baseline Document v2.4 (ESA DUE Project Diversity II).