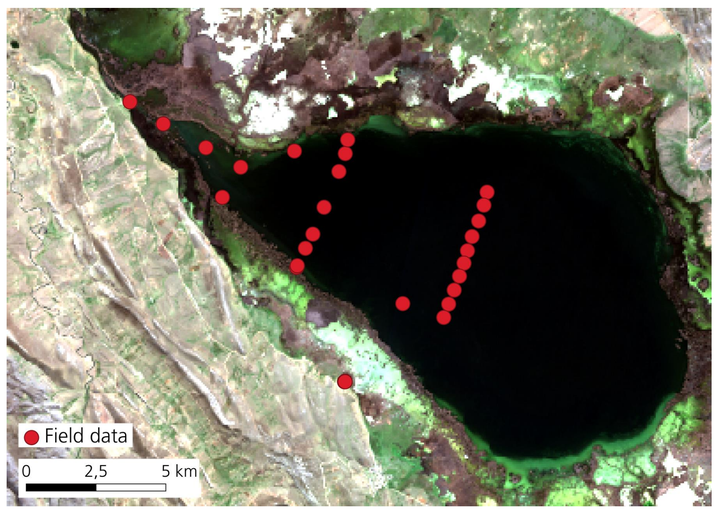
Suitability of multispectral satellites for deriving water constituents in high-altitude lakes: A case study from Peru

I. Somlai-Schweiger*[1], S. Plattner[1], S. Schmid[1], P. Klotz[2], P. Gege[1]

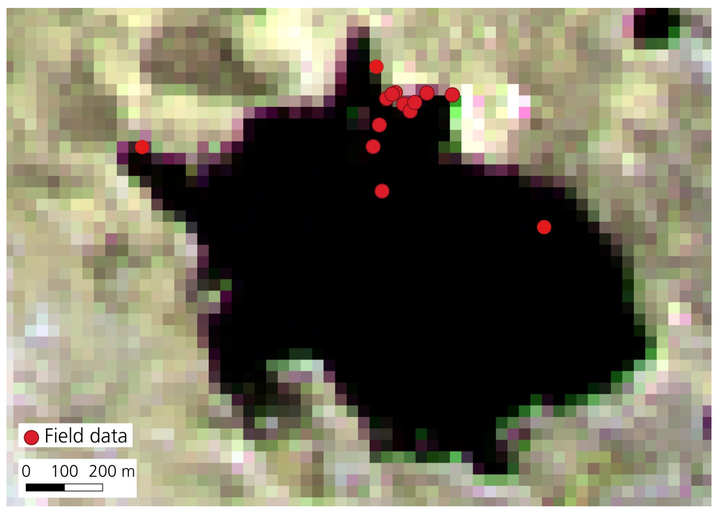
[1]German Aerospace Center (DLR), Earth Observation Center, Remote Sensing Technology Institute, Experimental Methods Department
[2]German Aerospace Center (DLR), Earth Observation Center, Remote Sensing Data Center, Land Surface Dynamics Department
*ian.somlai@dlr.de

This study examined the feasibility to derive water constituents using multispectral data from Sentinel-2, Landsat-8/9 and PlanetScope SuperDoves of three high-altitude lakes in the Peruvian Andes. Field spectrometer measurements and water sample analysis for chlorophyll-a were carried out for validation. Atmospheric correction was performed with ACOLITE. WASI was used to derive concentrations of Chl-a, TSM and CDOM from both satellite and in-situ spectral data in deep water areas.

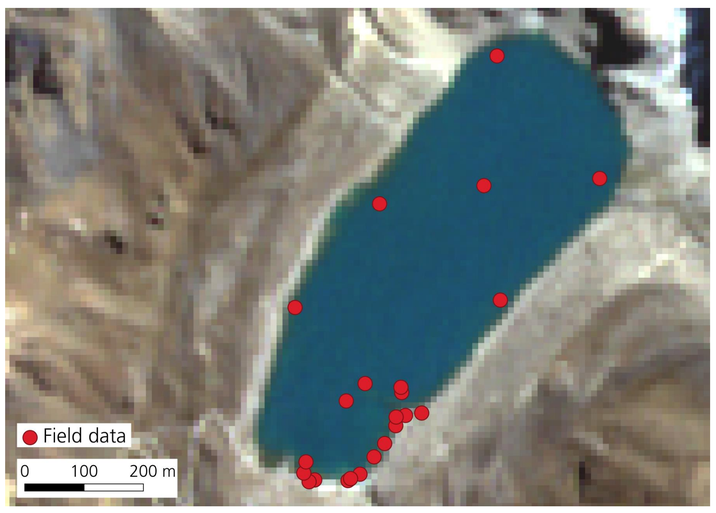
Junín - 4085 m.a.s.l., mesotrophic
Sentinel-2B, 24.06.2023



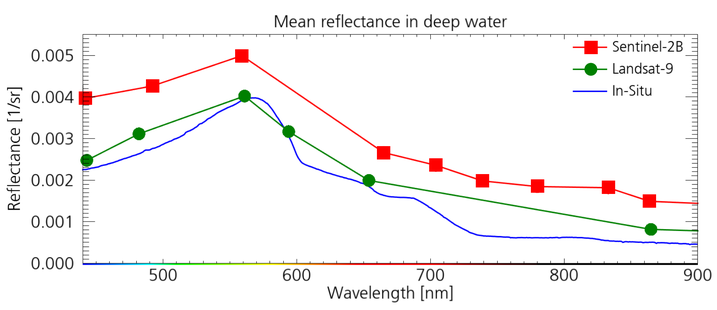
Huacracocha - 4460 m.a.s.l., eutrophic
Landsat-8, 21.06.2023

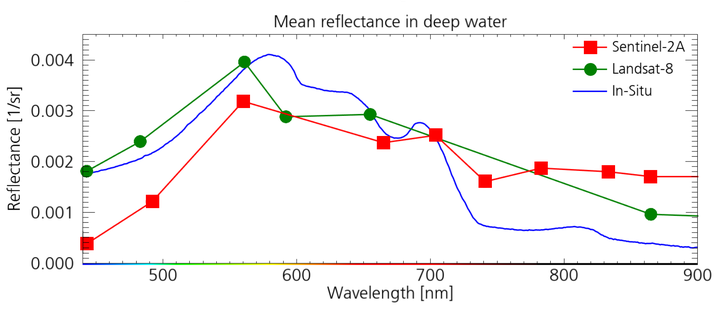


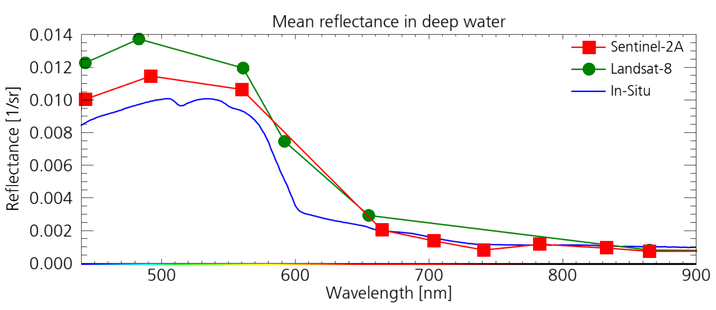
Lasuntay - 4650 m.a.s.l., oligotrophic
Sentinel-2A, 19.06.2023



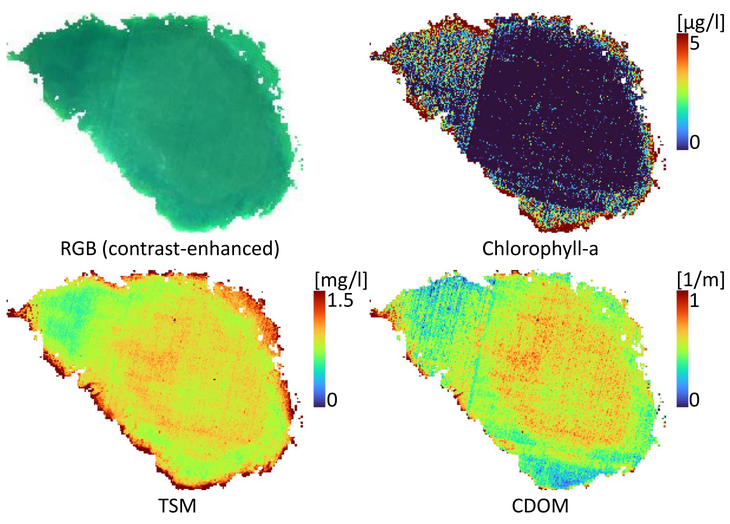
Reflectance spectra in deep water areas (not corrected for sun and sky glint)





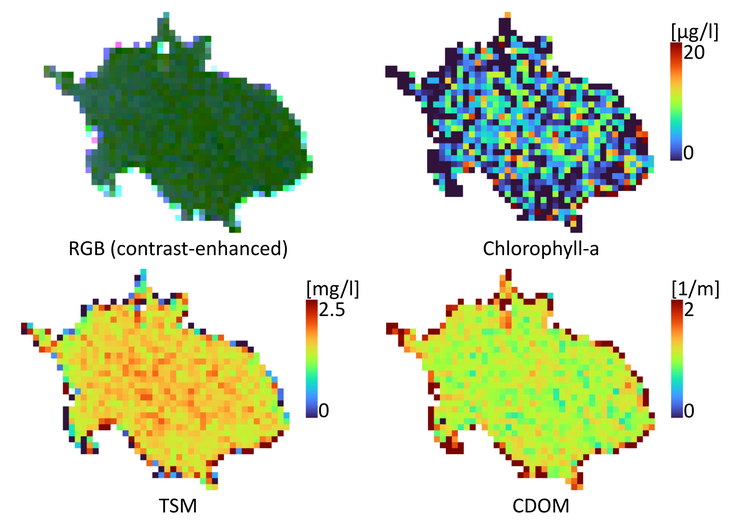


Water constituents



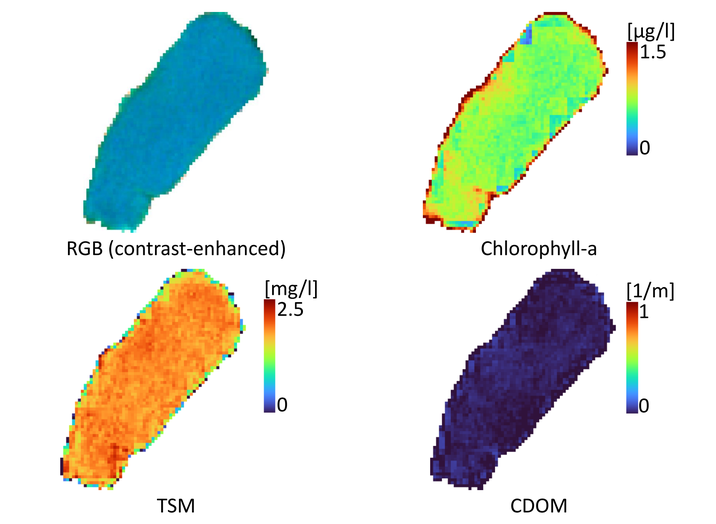
Mean values		Sentinel-2B 24.06.23	Landsat-9 20.06.23	Field spectrometer	Water samples
	Chl-a [µg/l]	1.2 ± 1.7	0.6 ± 2.3	2.1 ± 0.9	1.3 ± 0.6
	TSM [mg/l]	0.9 ± 0.1	1.3 ± 0.7	1.3 ± 0.2	--
	CDOM [1/m]	0.5 ± 0.1	0.9 ± 0.1	0.5 ± 0.1	--

Lake-specific observations:
- Influence of heterogeneous underground in shallow areas yields unreliable results.
- Need to consider water depth: reliable results in areas deeper than 2 m (82% of main lake).
- Sensor artifacts increase result uncertainty.



Mean values		Landsat-8 21.06.23	Sentinel-2A 19.06.23	Field spectrometer	Water samples
	Chl-a [µg/l]	5 ± 4.7	55.7 ± 20.1	16.2 ± 1.3	10 ± 1.3
	TSM [mg/l]	1.6 ± 0.1	3.5 ± 0.6	4.5 ± 0.6	--
	CDOM [1/m]	1.1 ± 0.1	4.5 ± 5.2	1.2 ± 0.1	--

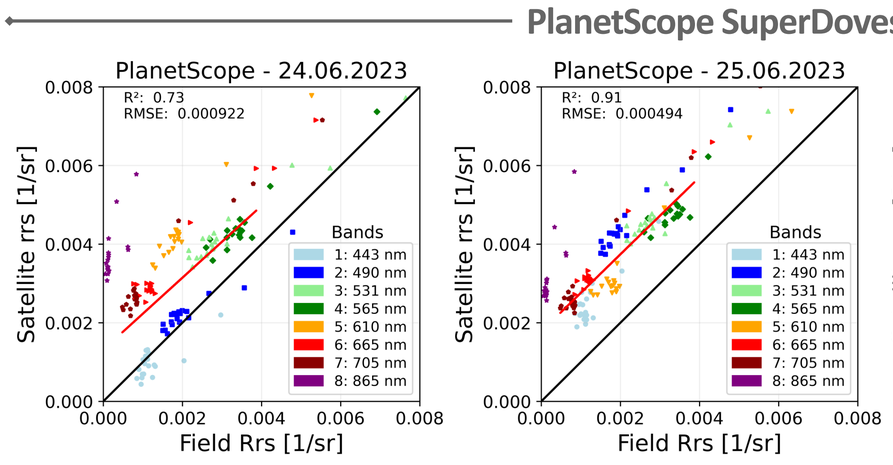
Lake-specific observations:
- Turbid and dark lake, high contrast with surrounding area challenging for the AC.
- Landsat-8/9 yield plausible results in spite of having fewer red and NIR bands than Sentinel-2, which largely overestimates the Chl-a concentration.



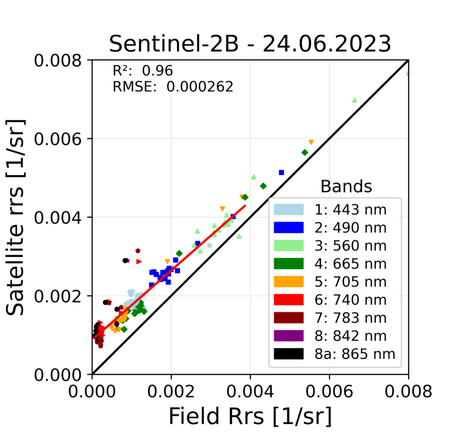
Mean values		Sentinel-2A 19.06.23	Landsat-8 21.06.23	Field spectrometer	Water samples
	Chl-a [µg/l]	0.7 ± 0.1	0.6 ± 0.3	1.8 ± 0.6	0.8 ± 0.1
	TSM [mg/l]	1.8 ± 0.1	2.3 ± 0.5	1.4 ± 0.4	--
	CDOM [1/m]	0.02 ± 0.01	0.002	0.06 ± 0.03	--

Lake-specific observations:
- CDOM very low from both field and satellite data.
- Landsat-8/9 show similar results, with slightly higher TSM concentrations than Sentinel-2.
- Small lake in complex topography: profit from higher Sentinel-2 spatial resolution (10 m against 30 m).

PlanetScope SuperDoves: comparison against field spectrometer data at Lake Junín



- Satellite data not corrected for sun and sky glint.
- Regression lines excluding NIR-band 8.
- Large differences for bands 1 to 7.
- Relevant radiometric differences between sensors from the same constellation.
- Right plot: for reference, same comparison with all Sentinel-2B bands.



Both Sentinel-2 and Landsat-8/9 are suitable to derive water constituents from the studied lakes. CDOM results show the best agreement between satellite and field data, followed by TSM. Chl-a can be obtained reliably for low/middle concentrations (Lasuntay/Junín, respectively), with sensor artifacts increasing result uncertainty. Dark waters (e.g. Huacracocha) remain challenging, specially to retrieve valid Chl-a concentration values. PlanetScope data not suitable for the presented application.

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