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EOM
Earth Observation and Modelling

Mapping indicators of lake ecology at Lake Starnberg

First results of Sentinel-2A

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Introduction

Sentinel-2A offers unprecedented opportunities to map and monitor indicators of lake ecology, such as suspended particulate matter (SPM), chlorophyll-a (chl-a), coloured dissolved organic matter (CDOM), water depths and bottom coverage by remote sensing (Dörnhöfer & Oppelt, 2016). To test this potential, we analysed a Sentinel-2A scene acquired on 13th August 2015 over Lake Starnberg (Germany), a deep, oligotrophic, peri-alpine lake (Fig. 1). We corrected atmospheric influences using the freely available Sen2Cor (Müller-Wilm, 2016). To retrieve indicators of lake ecology we applied WASI-2D (Gege, 2014a). WASI-2D is a freely available tool which inversely models reflectance by solving the water radiative transfer equation. In situ data enabled an evaluation of results.

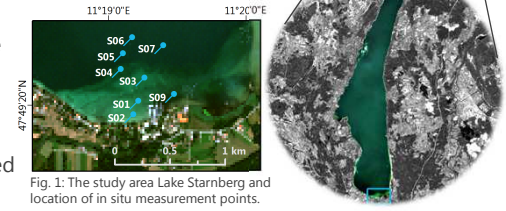

Fig. 1: The study area Lake Starnberg and location of in situ measurement points.

Methodology

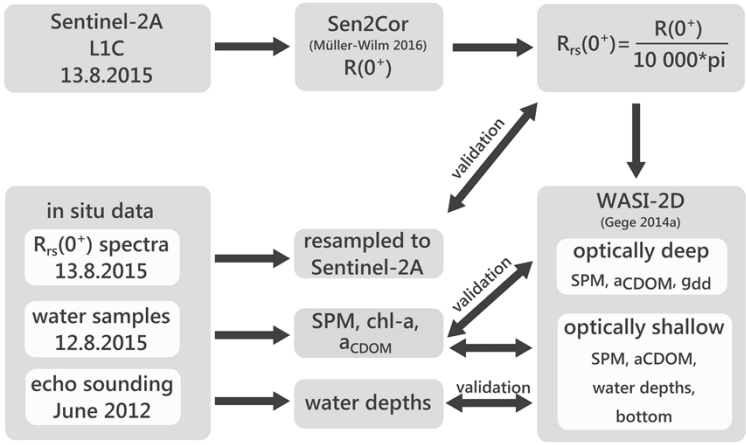

Fig. 2: Methodological flowchart showing processing of data and validation of results. We measured reflectance concurrently to the Sentinel-2A overpass. Water samples were taken the day before, stable weather conditions did not indicate changing water constituents. Echo sounding data originated from June 2012 (Gege, 2014b).

Results - Sen2Cor atmospheric correction

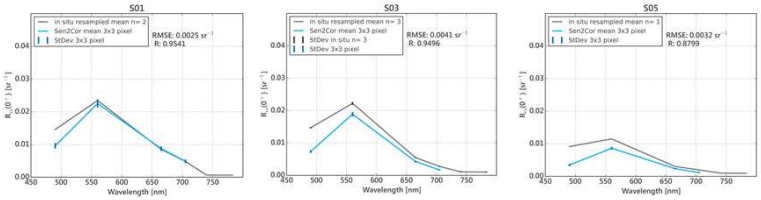

Fig. 3: Comparison between resampled in situ measured $R_{rs}(0^+)$ spectra (gray curve, measured with an Ibsen spectro-radiometer) and atmospheric corrected Sentinel-2A spectra (blue curve). S01 and S03 are located in optically shallow water, S05 is located in optically deep water. The conference paper includes plots of other measure points.

- ✓ High coefficients of determination indicated a very good match in shape.
- ✓ Low RMSE indicated a good correction of atmospheric effects.
- ✗ Bands B2 and B3 showed a small overcorrection, probably due to an erroneous aerosol parameterisation.
- ✗ Bands B6 and B7 often contained no data values.

Results - WASI-2D deep water

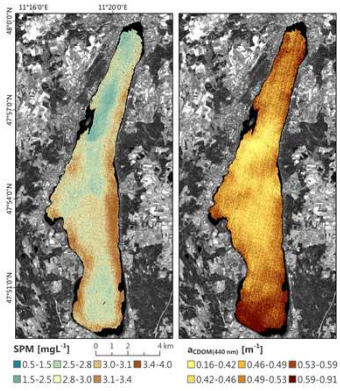

Fig. 4: Results of optically deep water model inversion. The conference paper also includes the map of sun glint factor g_{dd}.

Tab 1: Comparison between in situ and Sentinel-2A (WASI-2D) results in optically deep water.

	S05	S06	S07
SPM [mgL^{-1}] in situ	1.9	1.0	0.4
SPM [mgL^{-1}] WASI	3.2	3.4	3.1
$a_{CDOM(440)}$ [m^{-1}] in situ	0.69	0.66	0.62
$a_{CDOM(440)}$ [m^{-1}] WASI	0.63	0.73	0.65

- ✓ Spatial patterns and low variations of SPM and $a_{CDOM(440)}$ were reasonable.
- ✗ Compared to water samples WASI-2D overestimated SPM.
- ✓ Measured and modelled $a_{CDOM(440)}$ agreed very well.

Results - WASI-2D shallow water

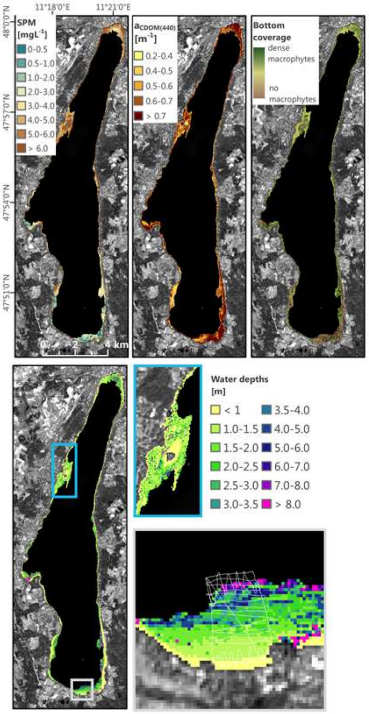

Fig. 5: Results of optically shallow water inversion.

Tab. 2: Comparison between in situ and Sentinel-2A (WASI-2D) results in optically shallow water.

	S01	S02	S03	S04	S10
SPM [mgL^{-1}] in situ	0.7	0.6	0.1	0.1	-
SPM [mgL^{-1}] WASI	0.0	0.0	1.4	1.3	4.0
$a_{CDOM(440)}$ [m^{-1}] in situ	0.83	0.65	0.59	0.59	1.03
$a_{CDOM(440)}$ [m^{-1}] WASI	0.81	1.17	0.55	0.66	0.65
Water depth [m] in situ	1.65	0.86	2.75	3.85	-
Water depth [m] WASI	1.32	0.65	2.63	2.50	-

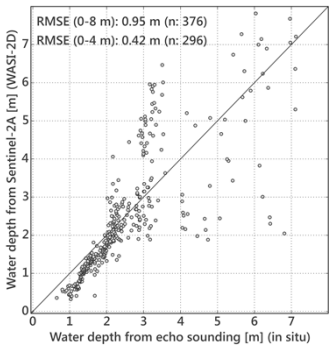

Fig. 6: Comparison between echo sounding data and Sentinel-2A (WASI-2D) derived water depths.

- ✓ All retrieved parameters in shallow water showed reasonable patterns: high $a_{CDOM(440)}$ close to small surface inflows, high SPM concentration in the northern part where more intense ship traffic occurs.
- ✓ WASI-2D modelled $a_{CDOM(440)}$ matched with analysed water samples.
- ✗ WASI-2D overestimated SPM concentrations.
- ✓ Water depths retrieval worked very well until Secchi depth (4.2 ±0.3 m)
- ✗ Difficult parameterisation of bottom types leads to very low water depths in the northern part of the lake (< 2 m).

Sentinel-2A turned out to have a great potential for analysing water constituents, water depths and bottom characteristics of water bodies. First results of Lake Starnberg encourage to test its suitability for lakes with differing optical properties and trophic characteristics.

References:
Dörnhöfer, K. & Oppelt, N. (2016): Remote sensing for lake research and monitoring-Recent advances. *Ecological Indicators*, 64, 105-122.
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Müller-Wilm, U. (2016). S2PAD SEN2COR 2.2.0 – Readme, S2PAD-VEGA-SRN-0001.

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