Validation of EOMAP Water Quality products

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www.eomap.com

Version: 20210223

This report is updated when new validation data becomes available

For further information, please visit http://eoApp.eomap.com and download the actual whitepaper from the help section

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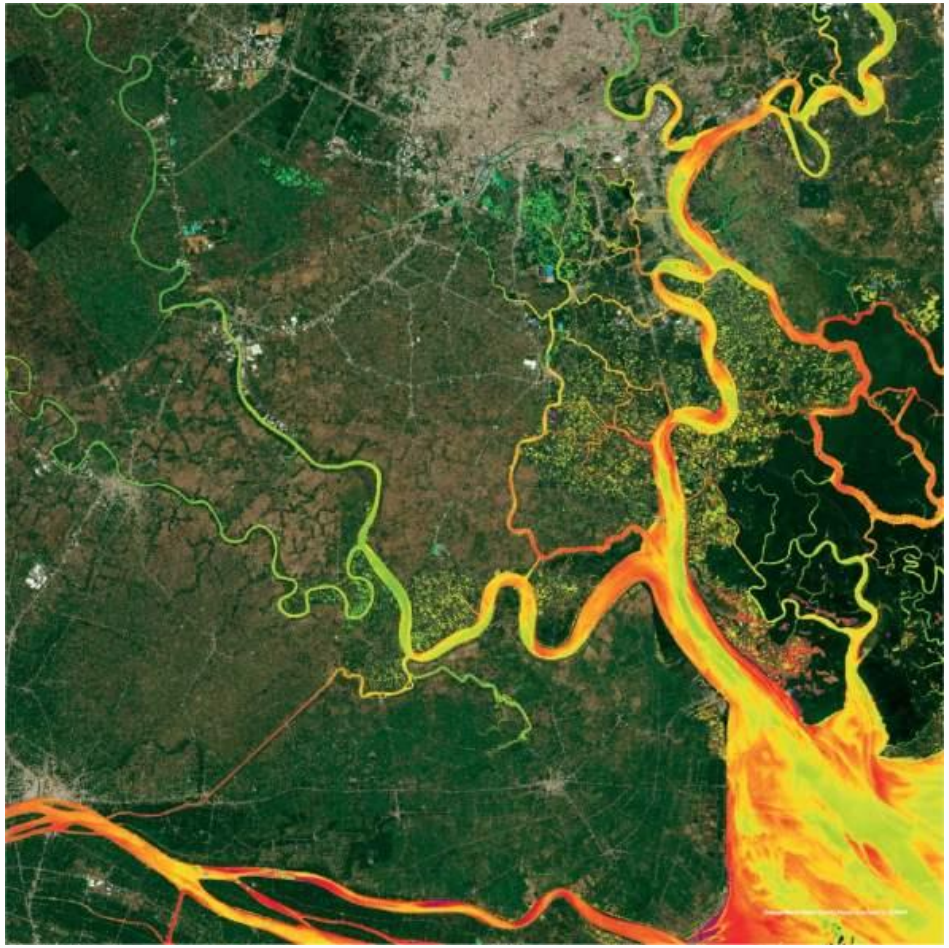
Content



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Summary

Assessable uncertainties of the satellite approach	| **Harmonization level and long-term consistency: Comparable** to in-situ methodologies | **Uncertainties in magnitudes: approx. 10 – 50 %** worse in relation to in-situ methologies (reflecting the in-situ-related inconsistencies on multi-agency level) | **Exceptions:** Chlorophyll in CDOM rich lakes partly overestimated by factor 2-3. Unknown validity: Chlorophyll and absorption in turbid rivers, iron- and calcareous dominated waters
Methodological differences	| **Methodology: In situ <> satellite (MIP-EOMAP)** | Sampling location: point <> area integrated measurement | Sampling depth: various depth <> z90 light penetration depth | Intrinsic measures: various <> Absorption and scattering spectra | Uncertainty impact factors: various <> Recording conditions, inversion methodology
Sampling methodology MIP satellite	| Turbidity: Backscattering [1/m] at 500nm, calibrated to [NTU] (1 NTU = 0.0118 1/m) | Suspended Matter: Backscattering calibrated to [mg/l] (default: **log10(TSM) = 1.02log10(TUR) -0.04**) | Chlorophyll: Pigment absorption [1/m] at 440nm, calibrated to [µg/l] 1 µg/l=0.035 1/m | CDOM: Absorption of dissolved organic materials in [1/m] at 440nm | Other: Total organic absorption, total anorganic absorption in [1/m] at 440nm
Sampling methodology In-situ	| Turbidity: Side-scattering, calibrated to units of [NTU] or [FTU] | Suspended Matter: Gravimetric [mg/l], or turbidity calibrated to [mg/l] | Chlorophyll: HPLC, photometric, fluorometric, unit [µg/l] | CDOM: unit absorption [1/m]

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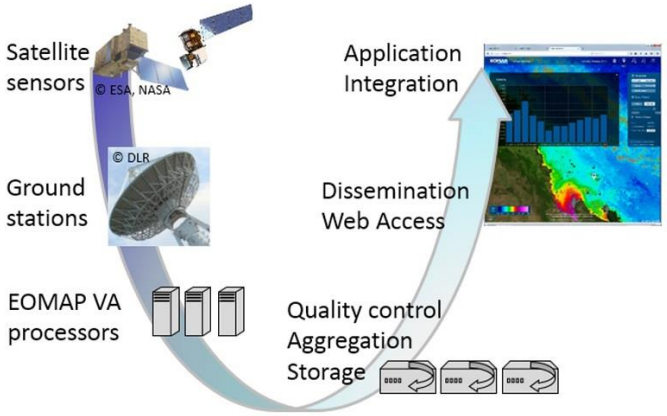
Methodology for satellite derived water quality MIP-EOMAP

Coverage	| Global
Sampling rate & spatial resolution	| Daily: 500 - 250 m | Weekly: 30 - 10 m | Up to daily on request: 5 - 1 m
Satellite sensors	| ASTER (1999), Landsat 5 (1984-2013), Landsat 7 (1999), Landsat 8 (2013), | MERIS, MODIS Aqua/Terra (2002/1999), RapidEye (2009-2020), | Sentinel-2A/*B* (2015/*2017*), Sentinel-3A/B (2016/2018), SPOT & | Worldview 2/3 (2009/2014)
Product examples	| Turbidity, Chlorophyll-a, Secchi Depth, Signal Depth, Total Suspended Matter, | Subsurface Reflectance, Remote Sensing Reflectance,
Data processing components	| Standardized, physics based, automized sensor independent processing. Accounting for the adjacency and terrain altitude impact, fully | coupled and bidirectional atmospheric & in-water retrieval of harmonized water quality properties, reflecting for the full range of | scattering and absorption in natural waters. detection of water, land, cloud, cloud shadows.
Data workflow components	| Fast delivery: Between few hours and 2 days after acquisition, depending on sensor and continent. EOMAP processors are installed in | satellite data ground segments and cloud computing environments. A dedicated IT infrastructure ensures automated product archiving, | aggregation, quality control, web access and dissemination



Remark:

Actual sampling rate depends on regional conditions such as cloud over statistics

Product validity is restricted to optical deep water bodies at minimum extend of 3-5 times the spatial resolution

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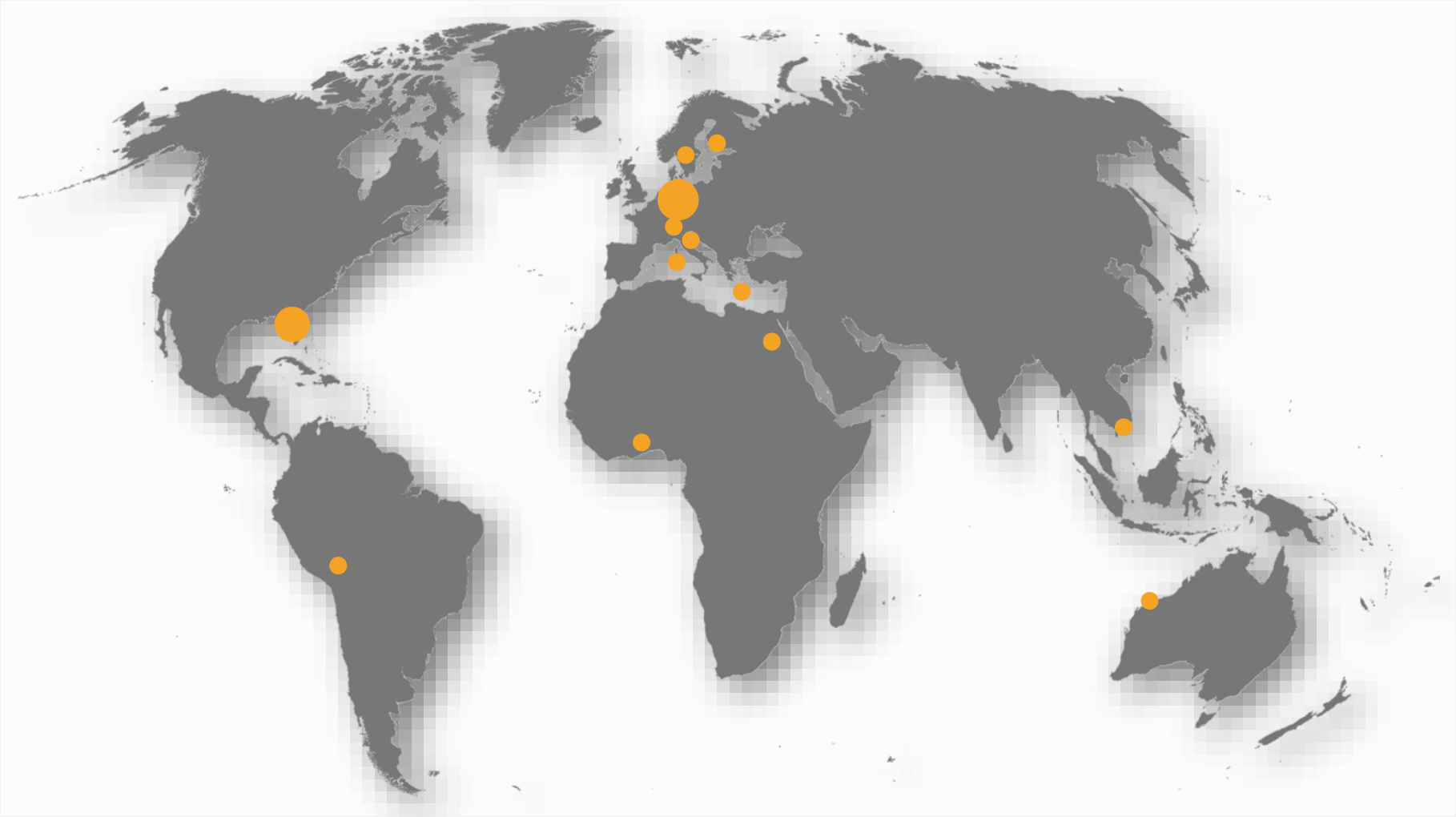
Global Examples

Global Examples



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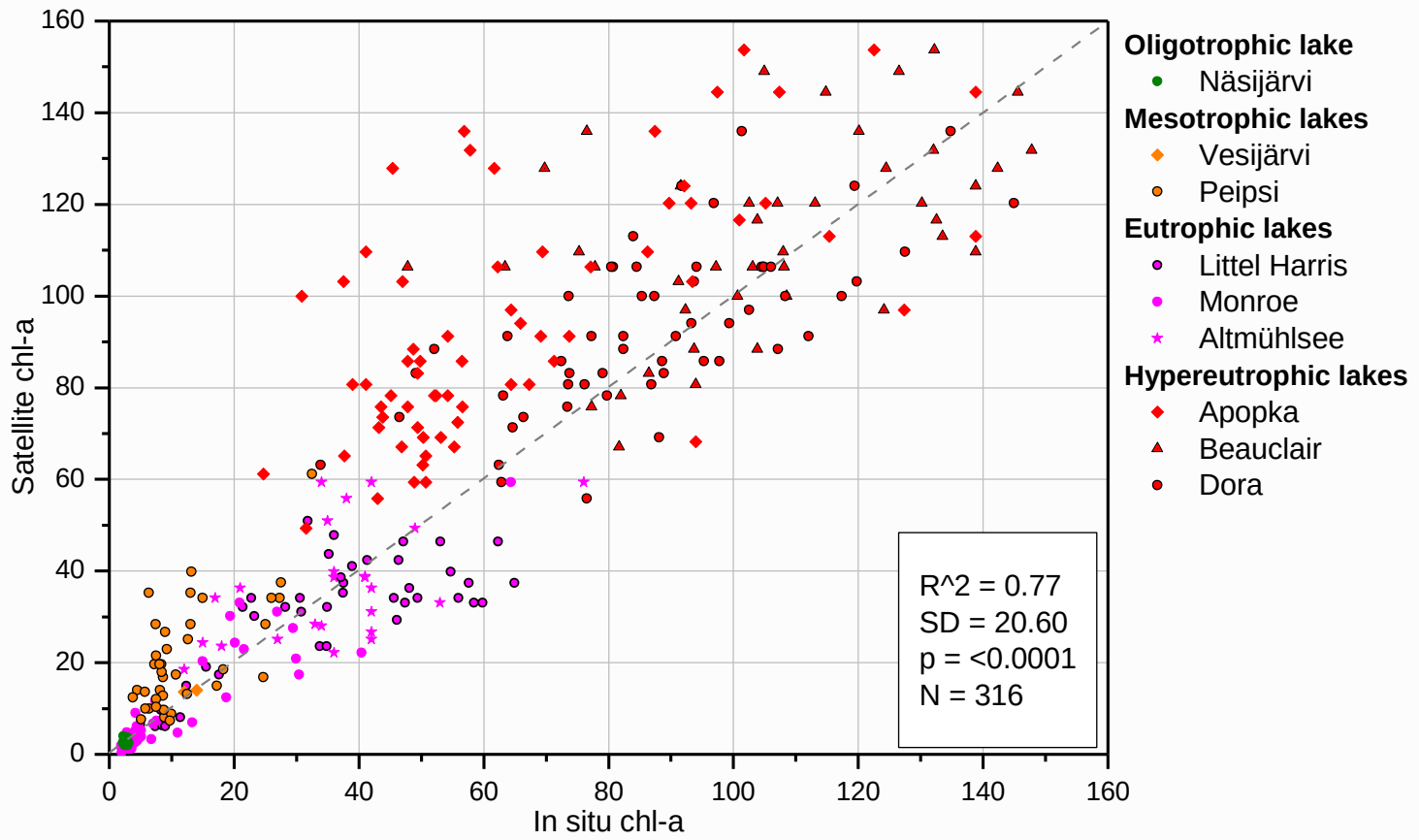
Validation of different lake types and countries

Chlorophyll-a: Time consistency +/- 2 weeks



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In-situ data kindly provided by: Syke Finnish Environment Institute, Lake County Water Authority US/Florida,
Water Supply Zürich, BOWIS / IGKB by LUBW, Bavarian Environment Agency (LfU)., Tartu Observatory Estland

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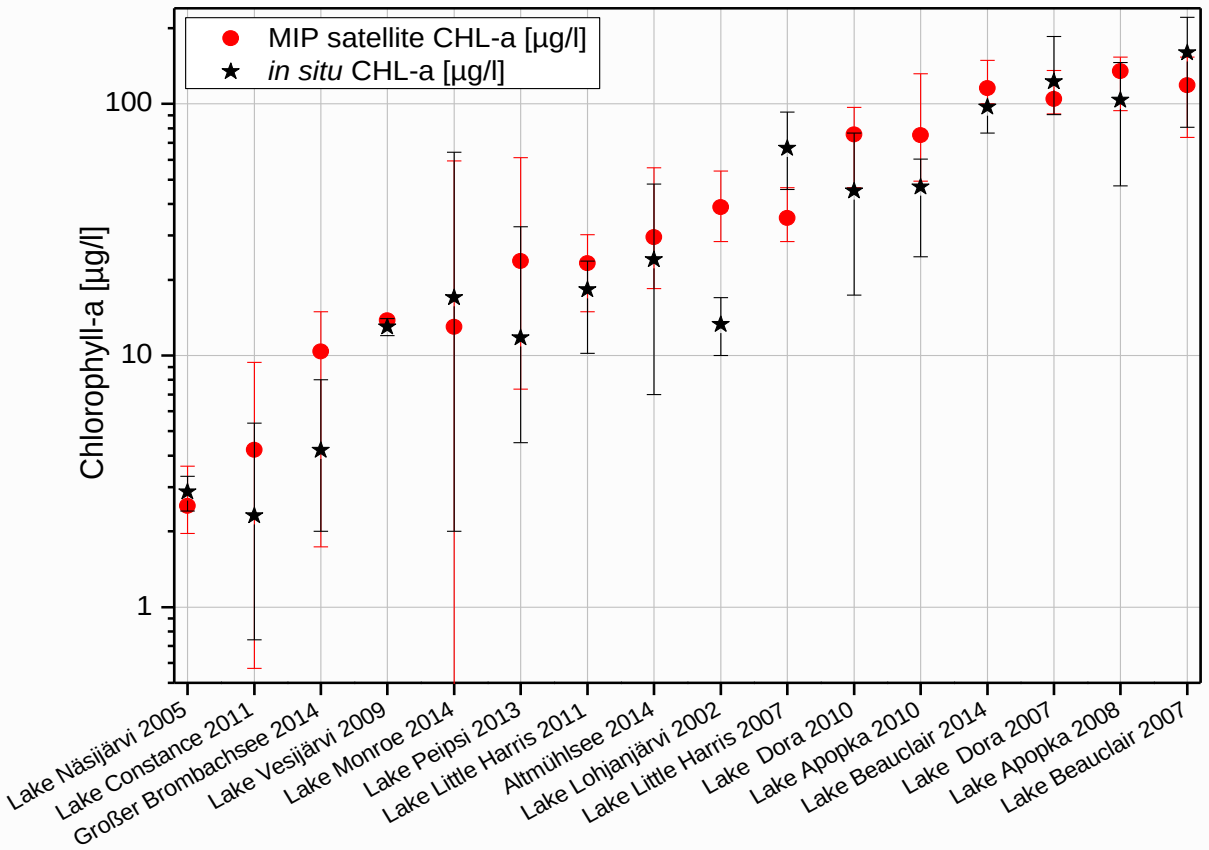
Validation of different lake types and countries
Chlorophyll-a



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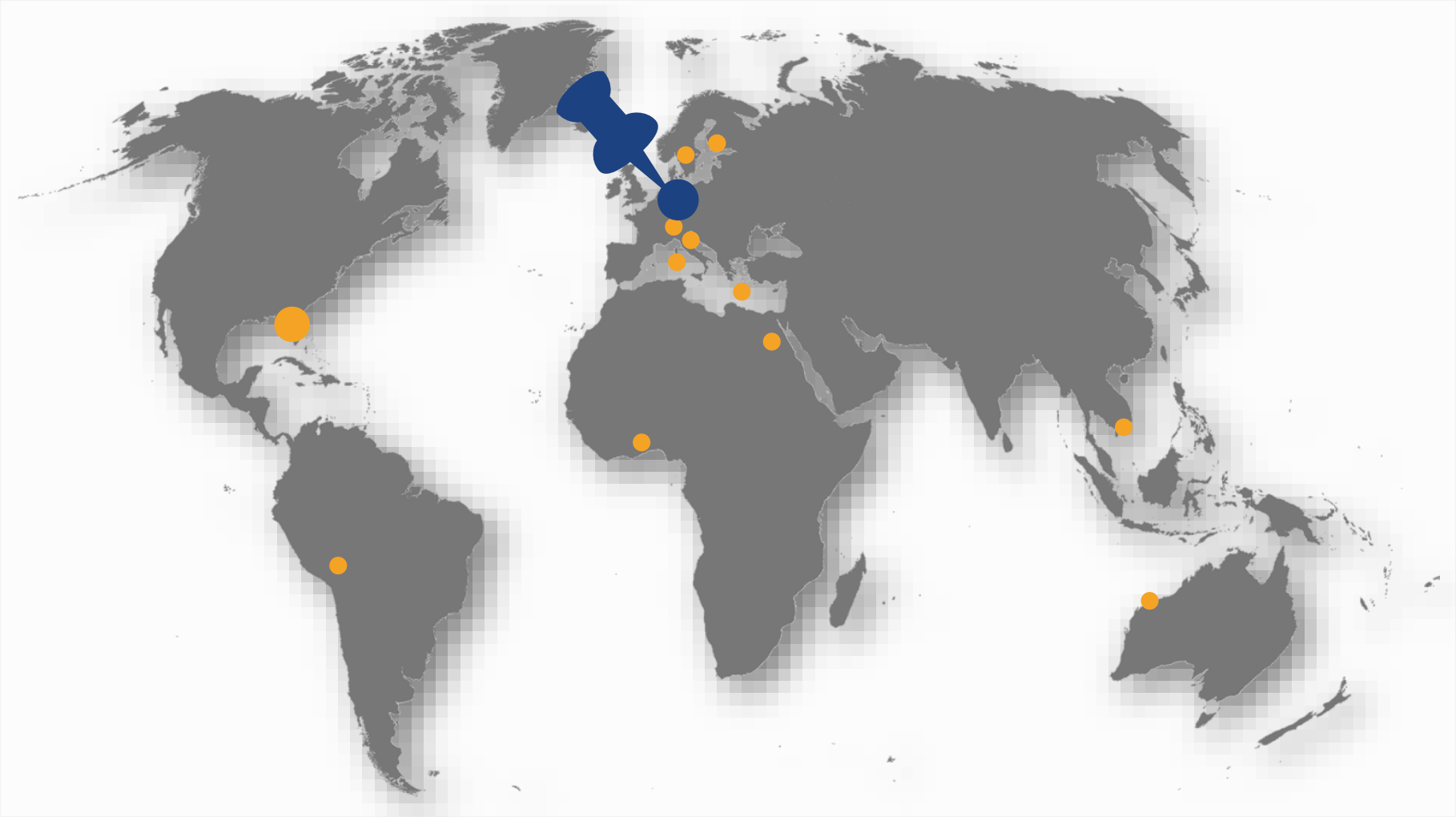
GERMANY



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Validation River Elbe, Germany

Location	River Elbe, Germany
Lake/river size	1.900 km²
Time Period	2010
Parameter	Turbidity
Sensor	Landsat 5 and 7 ETM+
Spatial Resolution	30m
Validation data provided by	Portal Tideelbe www.portal-tideelbe.de

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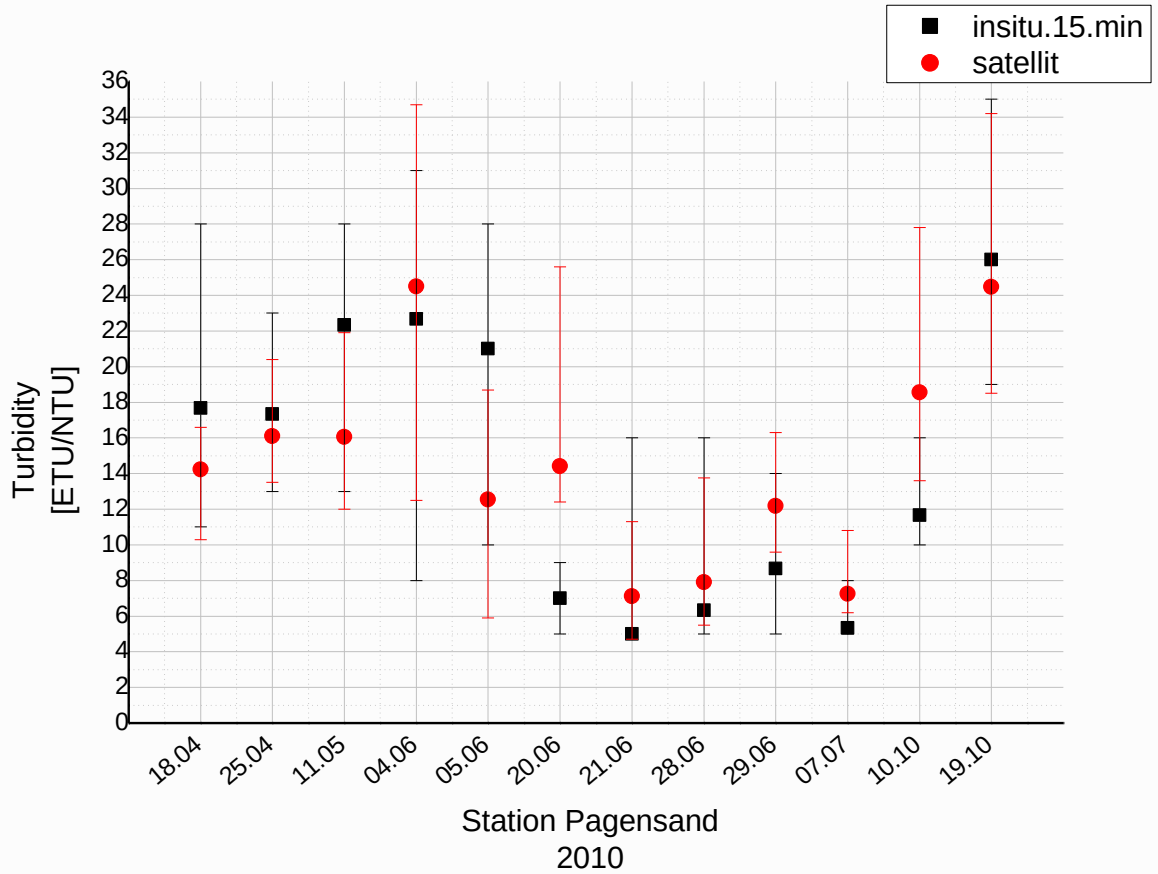
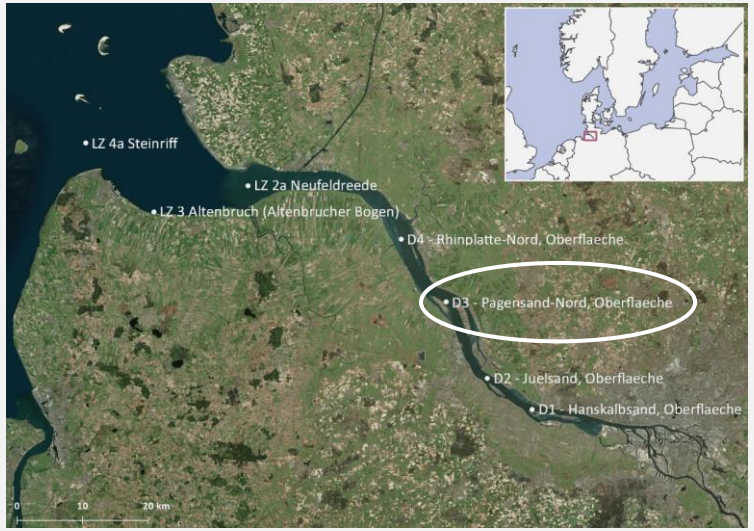
Validation River Elbe, Germany

Landsat vs. in situ turbidity: Station Pagensand - several days



Satellite data: processing MIP © EOMAP, source data: USGS for Landsat 5 and 7 ETM+
In situ data source: www.portal-tideelbe.de



Processor MIP version: 2014
In-situ data kindly provided by: Portal Tideelbe, www.portal-tideelbe.de
Reference: BAW contract

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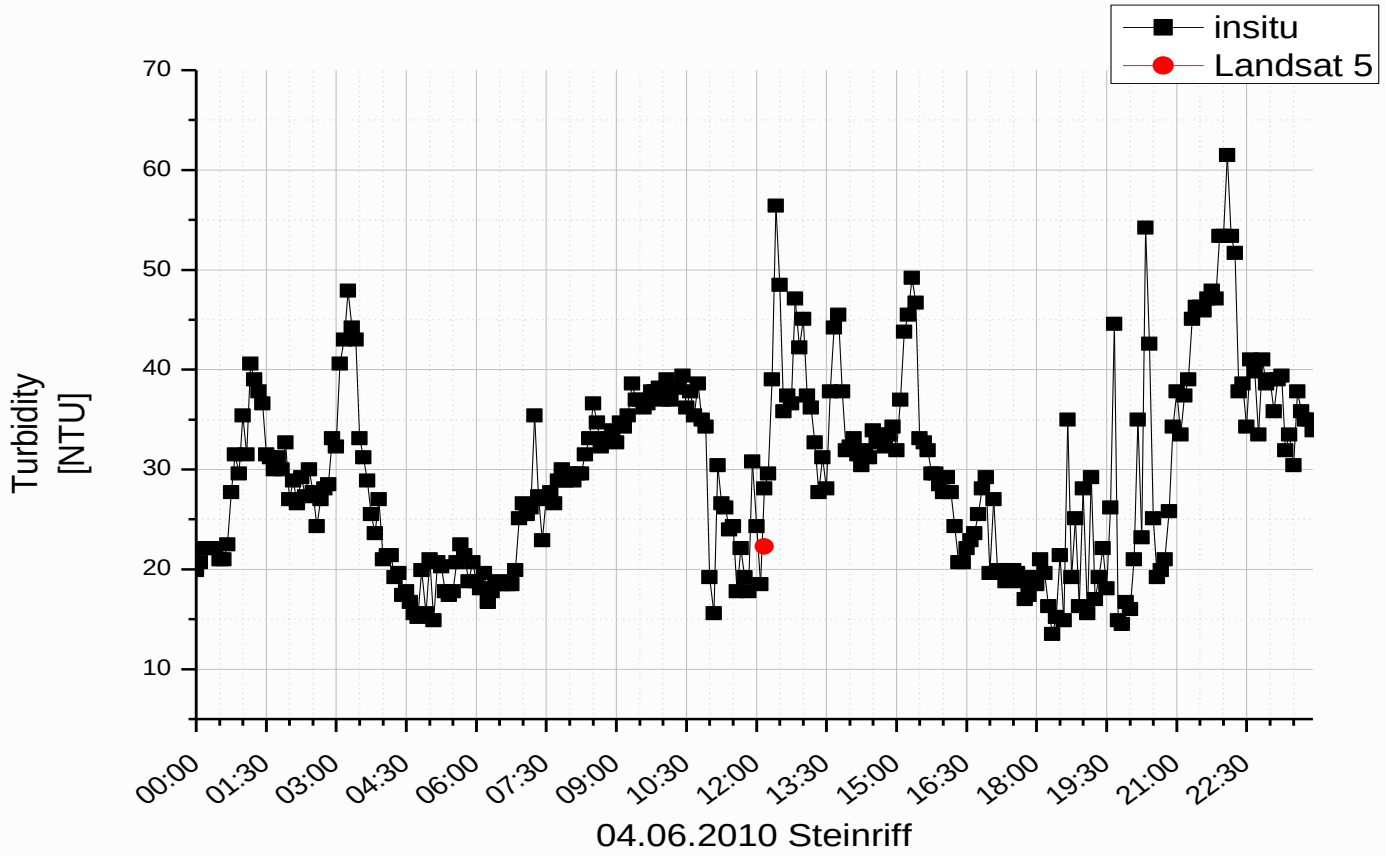
Validation River Elbe, Germany

Landsat vs. in situ turbidity: Station Steinriff - one day



Satellite data: processing MIP © EOMAP, source data: USGS for Landsat 5
In situ data source: www.portal-tideelbe.de

Processor MIP version: 2014
In-situ data kindly provided by: Portal Tideelbe, www.portal-tideelbe.de
Reference: BAW contract

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Validation Lake Constance, Germany

Location	Lake Constance, Germany
Lake/river size	Approx. 530 km²
Time Period	2003 - 2018
Parameter	Chlorophyll-a, Total Suspended Matter
Sensor	MERIS, MODIS, Landsat 7 ETM+, Landsat 8, ASTER, SPOT
Spatial Resolution	500m, 300m, 250m, 30m, 20m, 15m
Stations	FU, field campaign stations
Validation data provided by	IGKB – Bodensee-Wasserinformationssystem BOWIS, EAWAG, ISF
Mean signal depth	~3-5 m
In situ depth	0-20 m
Reference	Karle N., Wolf T., Heege T., Schenk K., Klinger P., Schulz, K. (2019): Satellite remote sensing of chlorophyll and Secchi depth for monitoring lake water quality: a validation study. doi: 10.1117/12.2533233. FRESHMON project (2010-2013): D54.3 Report on FRESHMON data quality and data comparability (available upon request) D54.3_2 Update Report on FRESHMON data quality and data comparability (available upon request)

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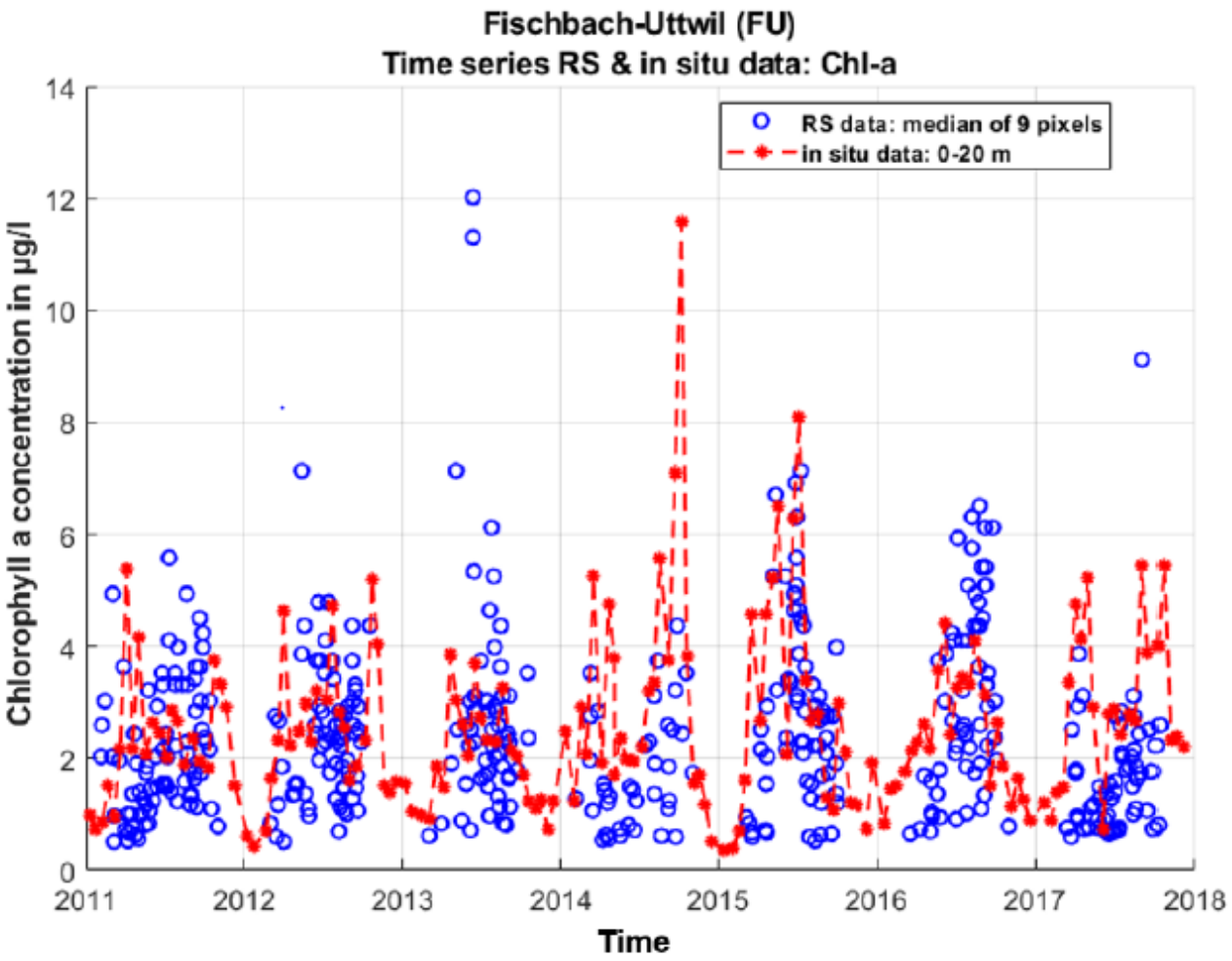
Validation Lake Constance, Germany

Total Suspended Matter: Remote Sensing data & In-Situ data



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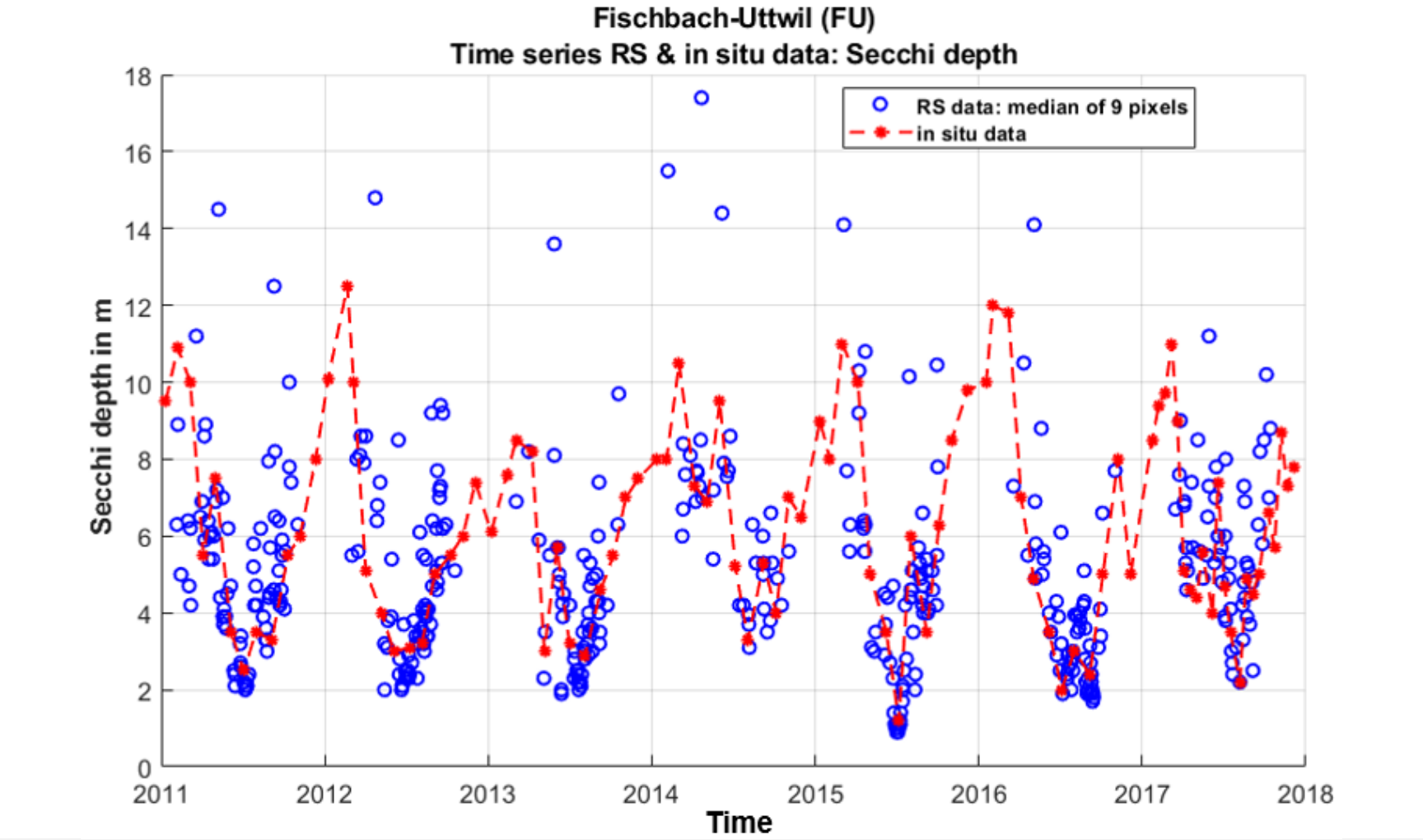
Validation Lake Constance, Germany

Total Suspended Matter: Remote Sensing data & In-Situ data



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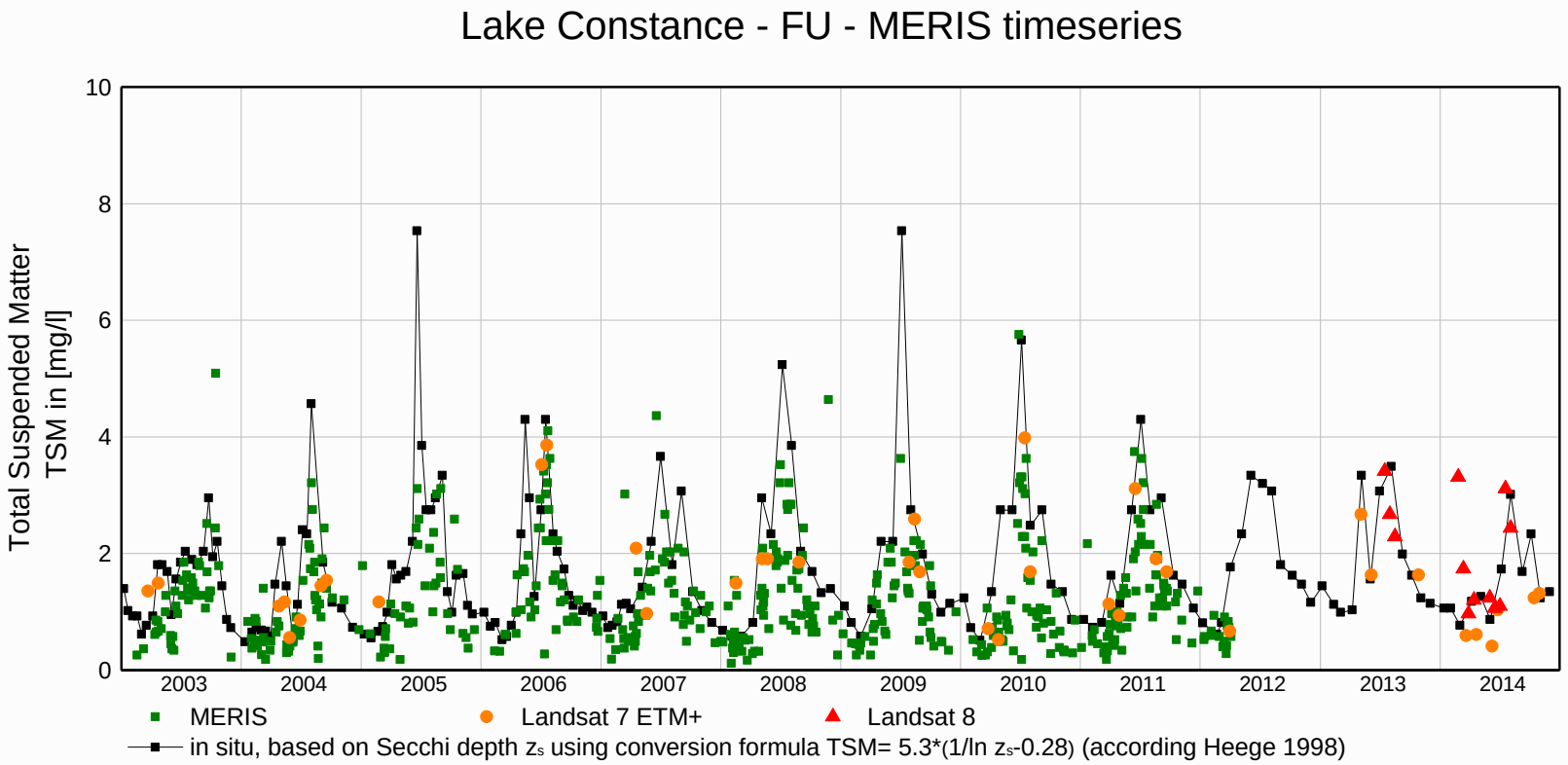
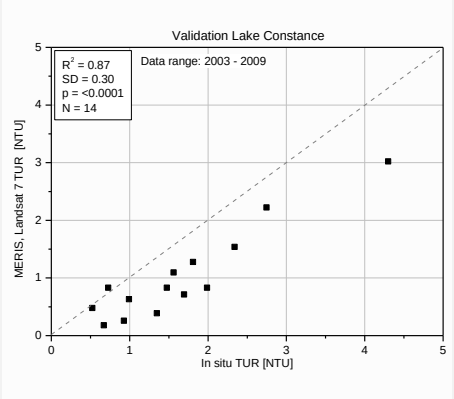
Validation Lake Constance, Germany

Total Suspended Matter: Time Series MERIS 300m Station FU 2003-2014



in situ data © Lake Constance water information system BOWIS of the International Commission for the Protection of Lake Constance (IGKB) provided in context of FRESHMON and GLaSS project; processing: MIP © EOMAP; Satellite data: ESA for MERIS and USGS for Landsat 7 ETM+/ 8



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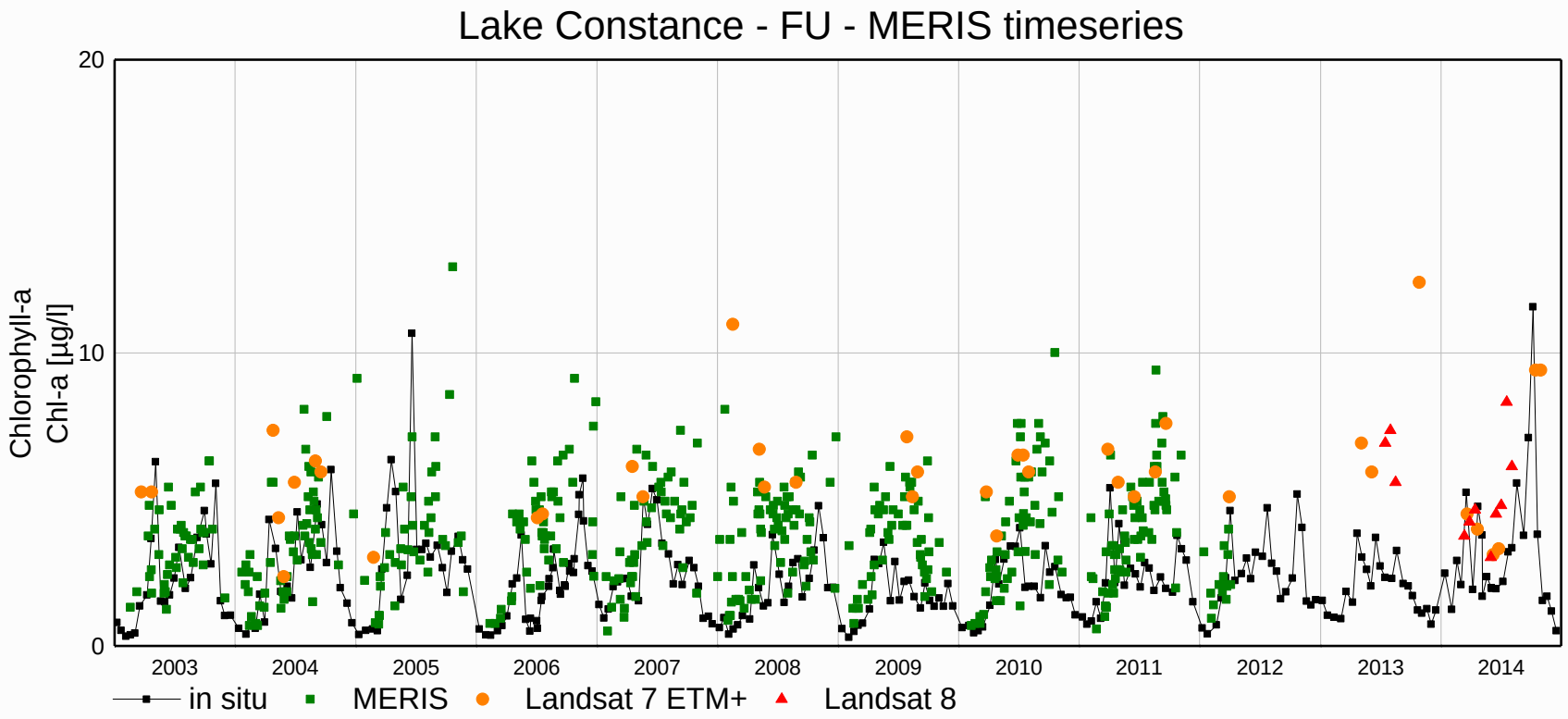
Validation Lake Constance, Germany

Chlorophyll-a: Time Series MERIS 300m Station FU 2003-2014



in situ data © Lake Constance water information system BOWIS of the International Commission for the Protection of Lake Constance (IGKB) provided in context of FRESHMON and GLaSS project; processing: MIP © EOMAP; Satellite data: ESA for MERIS and USGS for Landsat 7 ETM+/ 8

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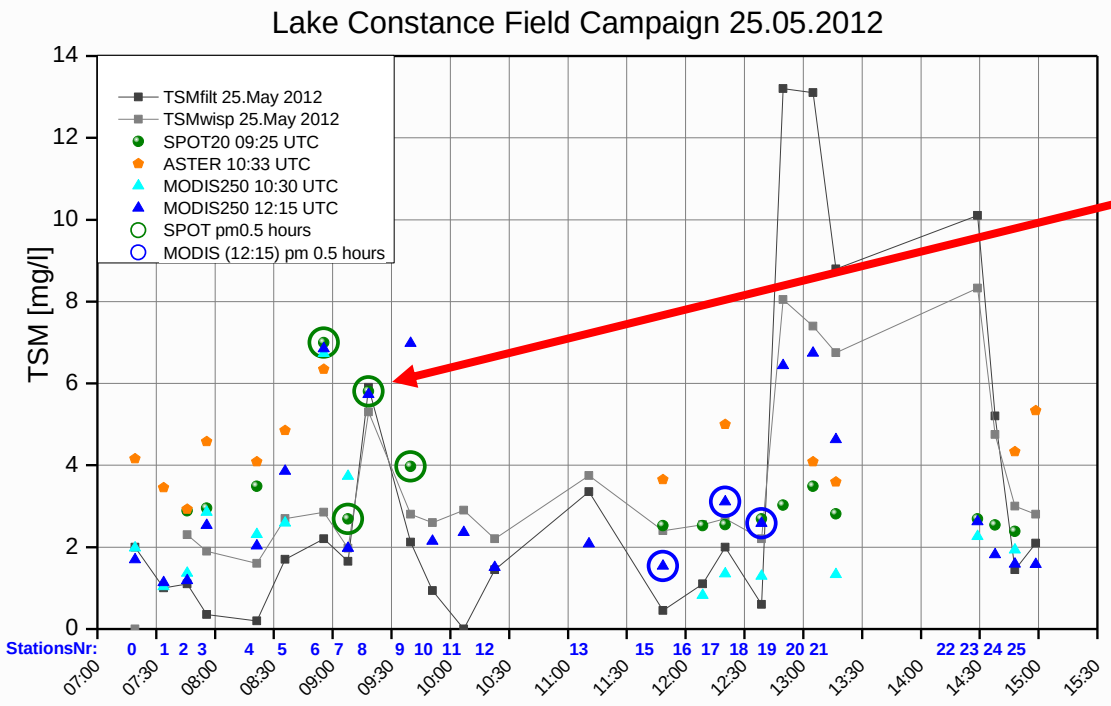
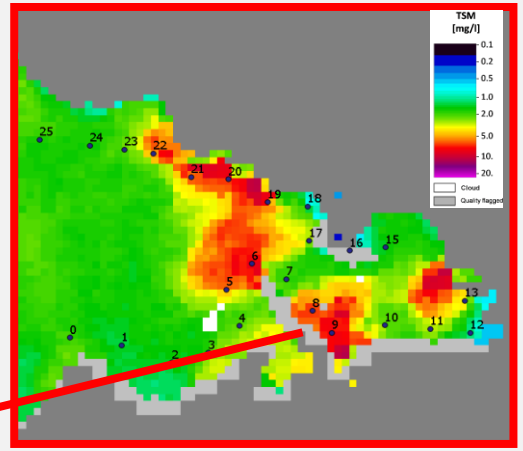
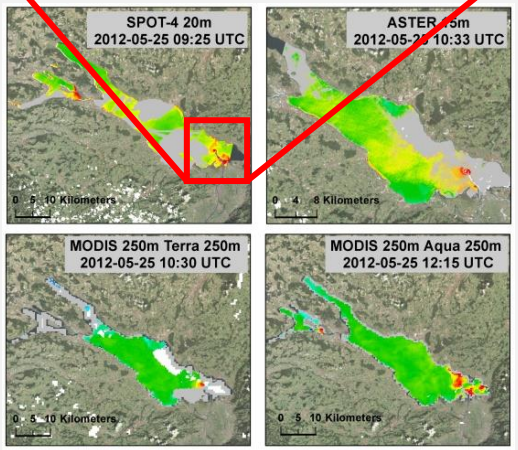
Validation Lake Constance, Germany

2 in-situ measures, 4 satellite sensors - Record date: 25.5.2012

Atmospheric conditions: Varying haze and clouds
In-water conditions: Fast changing turbidity near river mouth Rhine
=> Time-consistency important







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Validation for lakes <1ha Baden-Württemberg, Germany

Location	Several lakes in Baden-Württemberg, Germany
Time Period	2004 - 2012
Parameter	Chlorophyll-a
Sensor	Landsat 7
Spatial Resolution	30m
References	Karle N., Wolf T., Heege T., Schenk K., Klinger P., Schulz, K. (2019): Satellite remote sensing of chlorophyll and Secchi depth for monitoring lake water quality: a validation study. doi: 10.1117/12.2533233. FRESHMON project (2010-2013): D54.3 Report on FRESHMON data quality and data comparability (available upon request) D54.3_2 Update Report on FRESHMON data quality and data comparability (available upon request)

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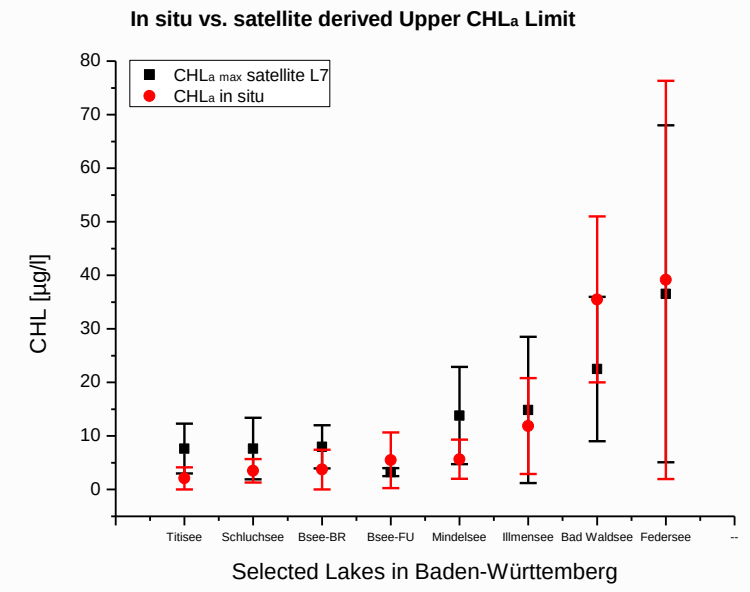
Validation for lakes <1ha Baden-Württemberg, Germany

Chlorophyll-a

	Mindelsee	Federsee	Bad Waldsee	BR (Lake Constance)	FU (Lake Constance)	Illmensee	Schluchsee	Titisee
No. Satellite	30	14	11	10	10	23	8	10
Years Satellite	2004-2012	2004-2012	2004-2012	2004-2012	2004-2010	2005-2012	2004-2012	2004-2012
No. in situ	32	53	8	202	220	18	7	10
Years in situ	2002,2009,2010	2006-2010	1987-2010	2003-2011	2003-2011	2006,2012	2010	2007
Source	ISF	ISF	seenprogramm.de	ISF	ISF	ISF	ISF	ISF



Source: in situ ISF/LUBW, Seenprogramm.de, satellite data: processing EOMAP, raw data USGS Lansat 7

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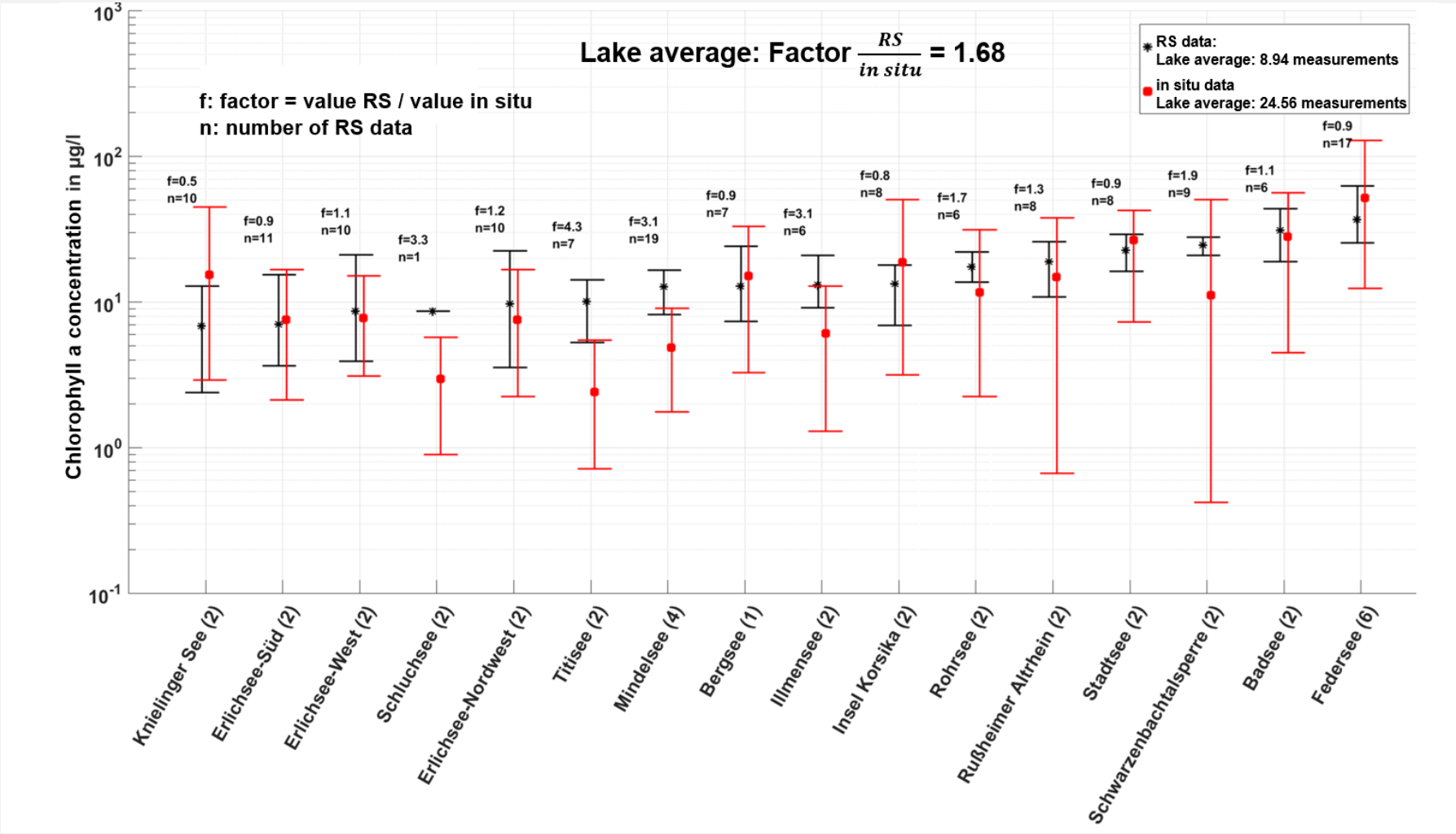
Validation for lakes <1ha Baden-Württemberg, Germany

Chlorophyll-a



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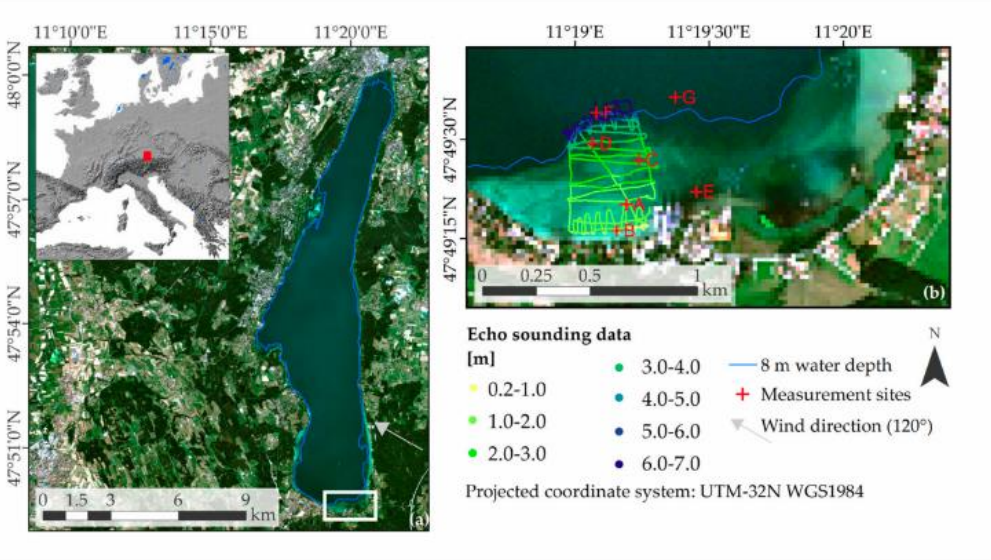
Validation Lake Starnberg, Germany
Atmospheric correction

Location	Lake Starnberg, Germany
Lake/river size	Approx. 56.4 km²
Time Period	2015
Parameter	Remote Sensing Reflectance
Sensor	Sentinel-2A
Spatial Resolution	10m
Stations	7 Field campaign stations
Validation data provided by/ Reference	Dörnhöfer, K. et al. (2016): [Water Constituents and Water Depth retrieval from Sentinel-2A – A first evaluation in an Oligotrophic lake]



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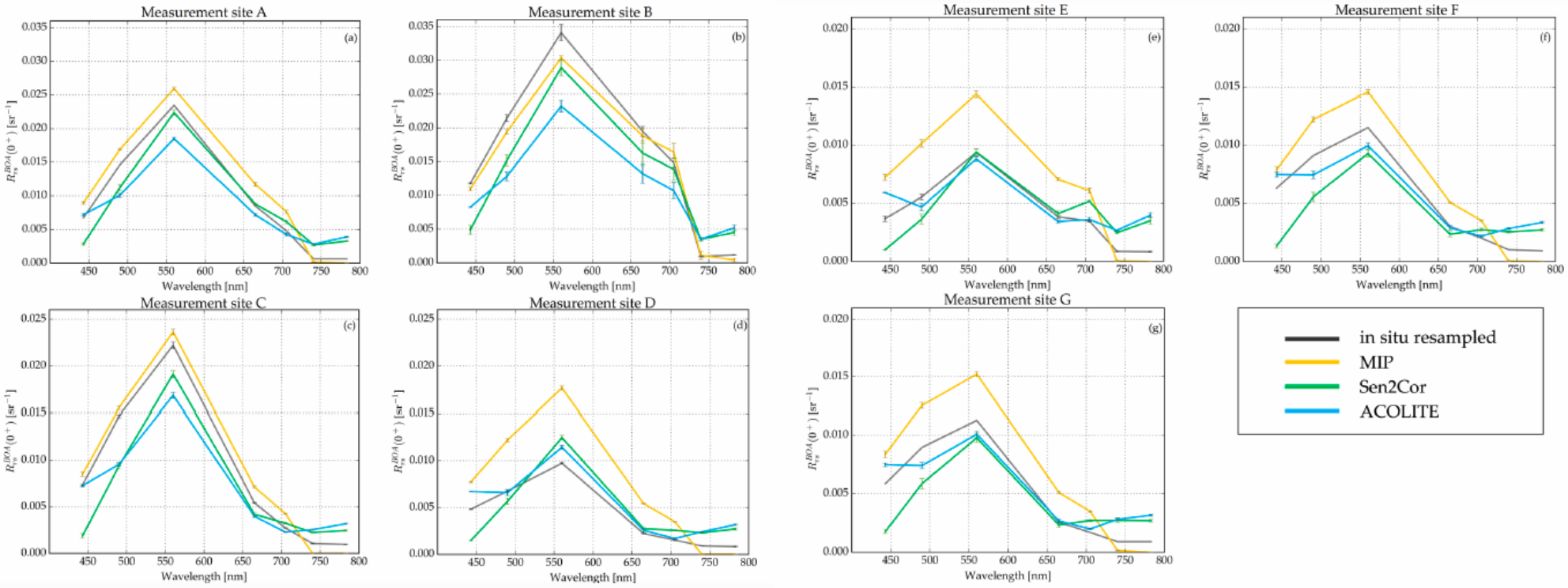
Validation Lake Starnberg, Germany
Atmospheric correction



Comparison of three different atmospheric corrections:
Sen2Cor, ACOLITE and MIP, whereof MIP performed best (r = 0.987, RMSE = 0.002 sr^{-1})

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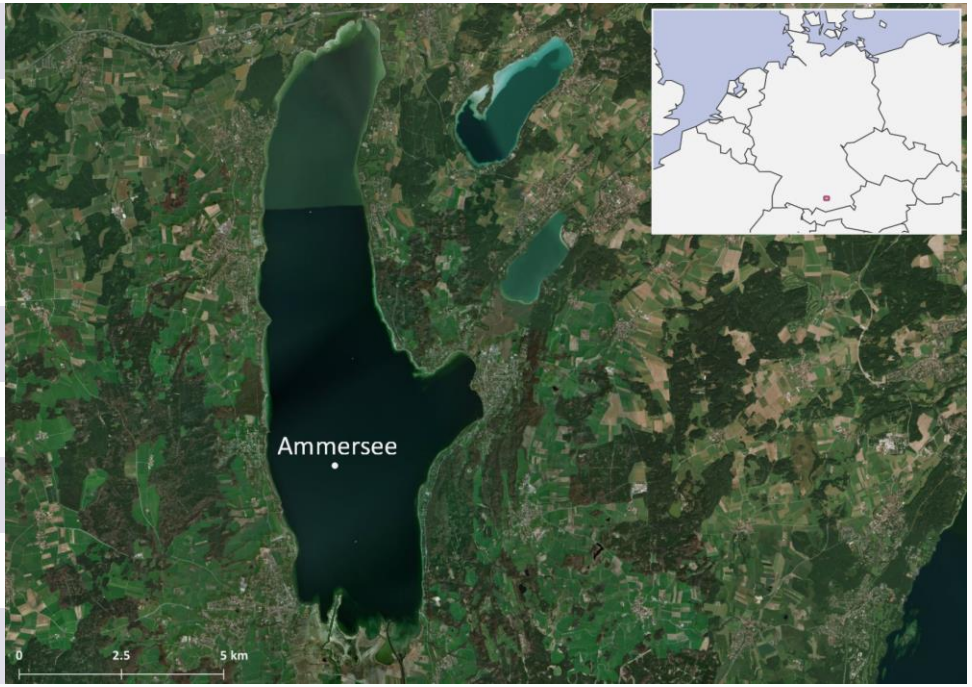
Validation Ammersee, Germany
Time Series MERIS 300m 2008

Location	Ammersee, Germany
Lake/river size	46,6 km²
Time Period	2008
Parameter	Chlorophyll-a, Total Suspended Matter
Sensor	MERIS
Spatial Resolution	300m
Stations	Deepest point
Validation data provided by	Bavarian Environment Agency (LfU)
Mean signal depth	~1-3 m
In situ depth	0-20 m, single steps see graph
Reference	FRESHMON project (2010-2013): D54.3 Report on FRESHMON data quality and data comparability (available upon request) D54.3_2 Update Report on FRESHMON data quality and data comparability (available upon request)



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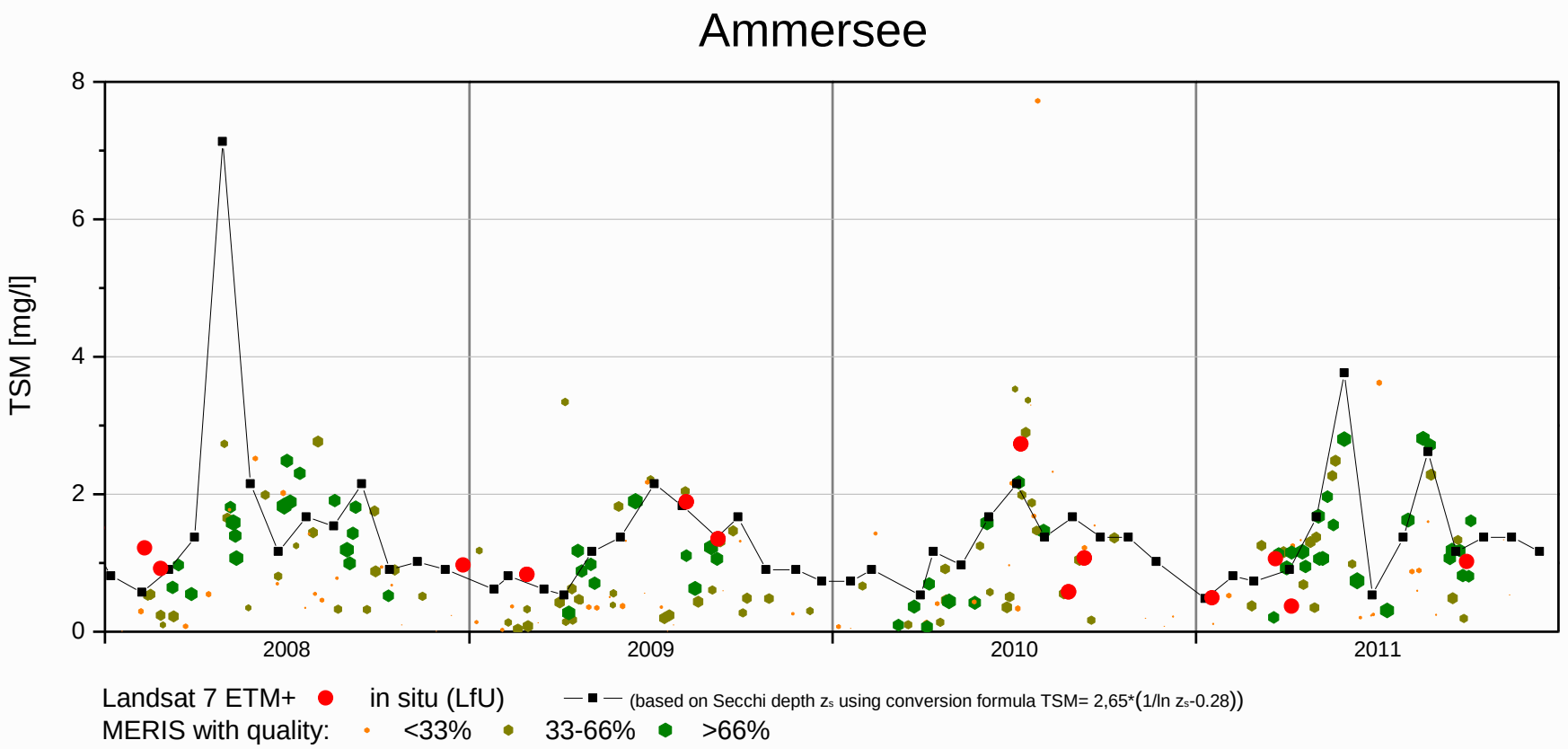
Validation Ammersee, Germany
Time Series 2008-2011



Satellite data: processing EOMAP, source data: USGS for Landsat 7ETM+, ESA for MERIS
In situ data by the Bavarian Environment Agency (LfU) provided in context of FRESHMON project

Processor MIP version: 2013
In-situ data kindly provided by:
Bavarian Environment Agency (LfU).
Reference: EU FRESHMON Project

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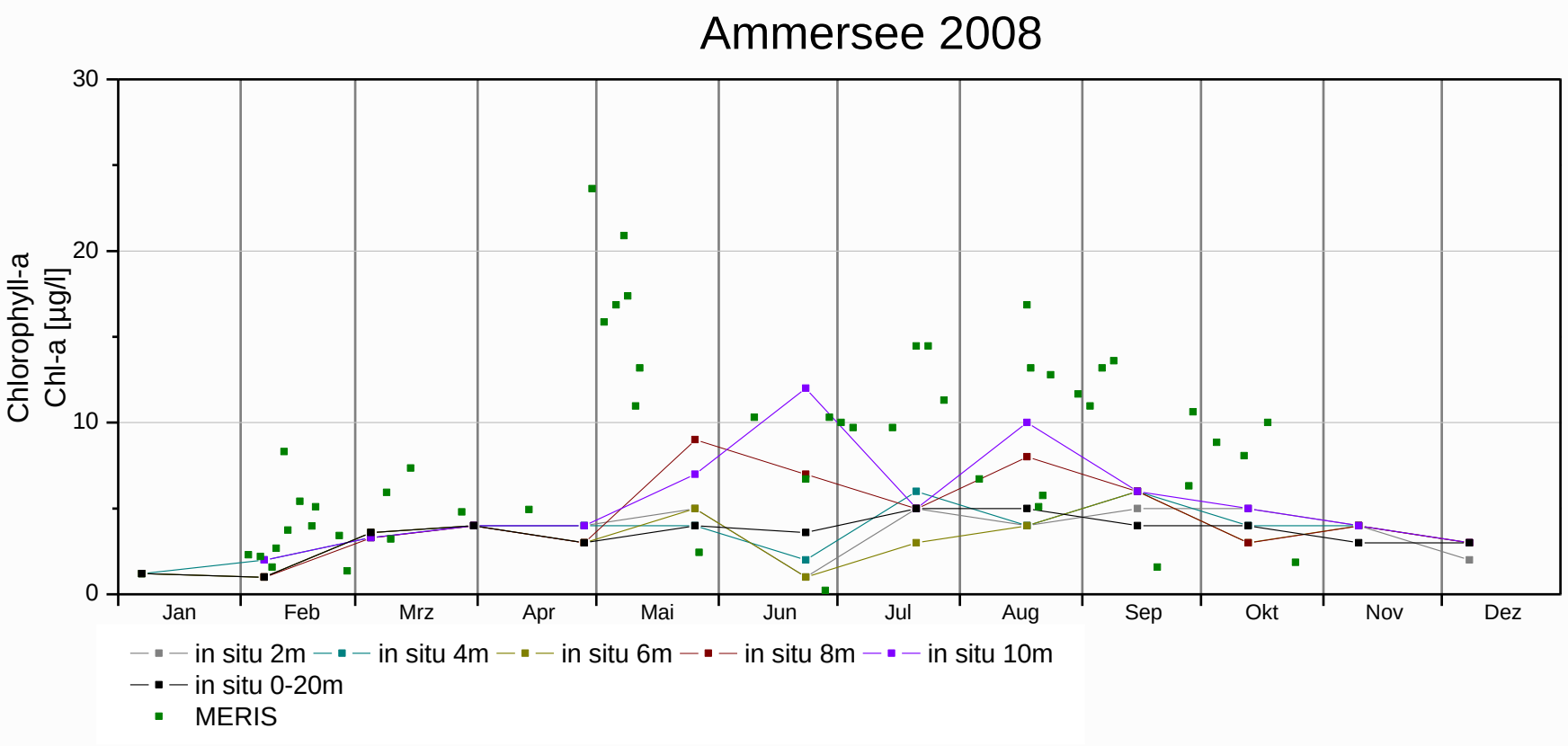
Validation Ammersee, Germany
Time Series 2008



Satellite data: processing MIP © EOMAP, source data: ESA for MERIS
In situ data by the Bavarian Environment Agency (LfU) provided in context of FRESHMON project

Processor MIP version: 2013
In-situ data kindly provided by:
Bavarian Environment Agency (LfU).
Reference: EU FRESHMON Project

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Validation Walchensee, Germany

Location	Walchensee, Germany
Lake/river size	16.27 km²
Time Period	2008
Parameter	Chlorophyll-a, Total Suspended Matter
Sensor	MERIS, Landsat 7 ETM+
Spatial Resolution	300m, 30m
Stations	Deepest point
Validation data provided by	Bavarian Environment Agency (LfU)
Reference	FRESHMON project (2010-2013): D54.3 Report on FRESHMON data quality and data comparability (available upon request) D54.3_2 Update Report on FRESHMON data quality and data comparability (available upon request)

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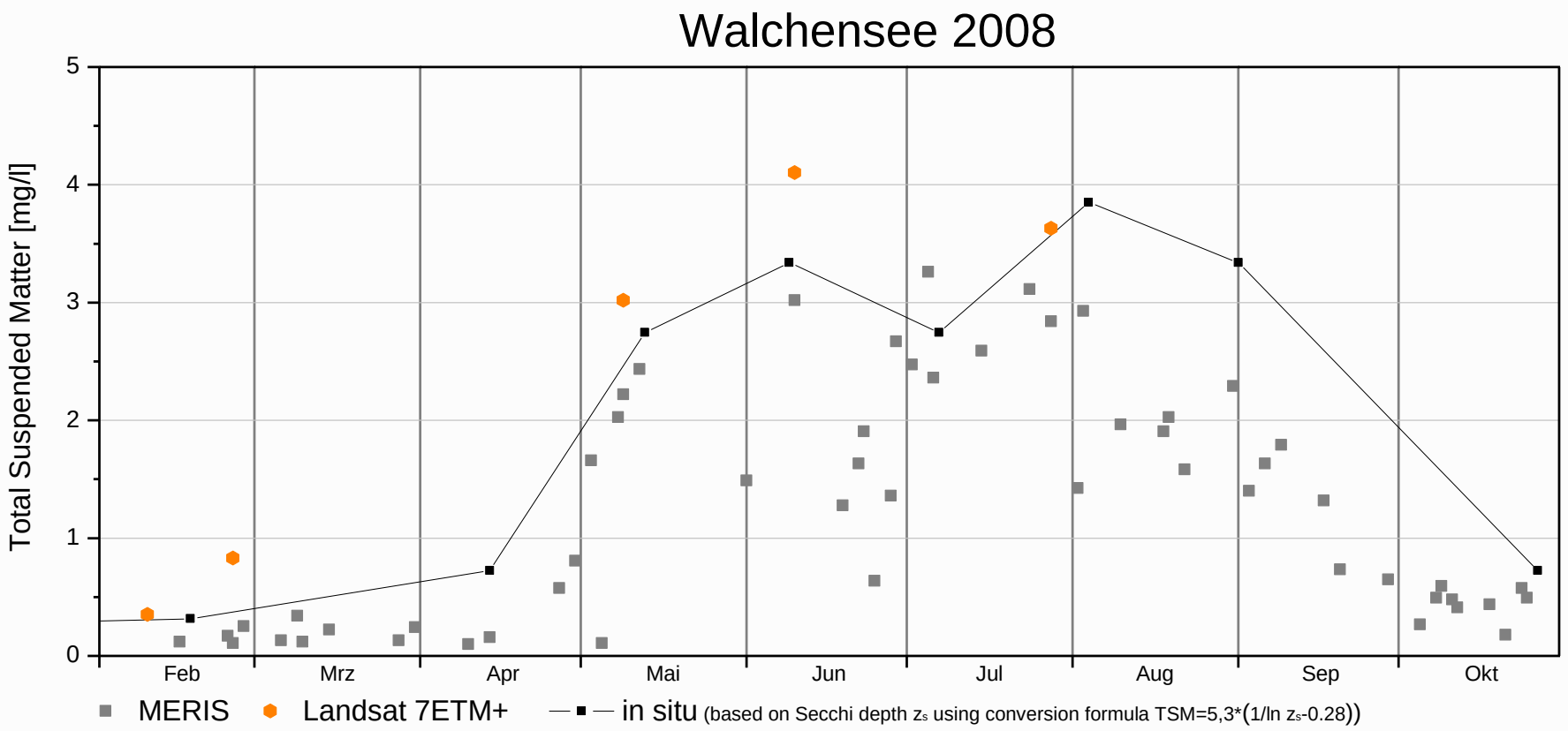
Validation Walchensee, Germany
Total Suspended Matter: Time Series 2008

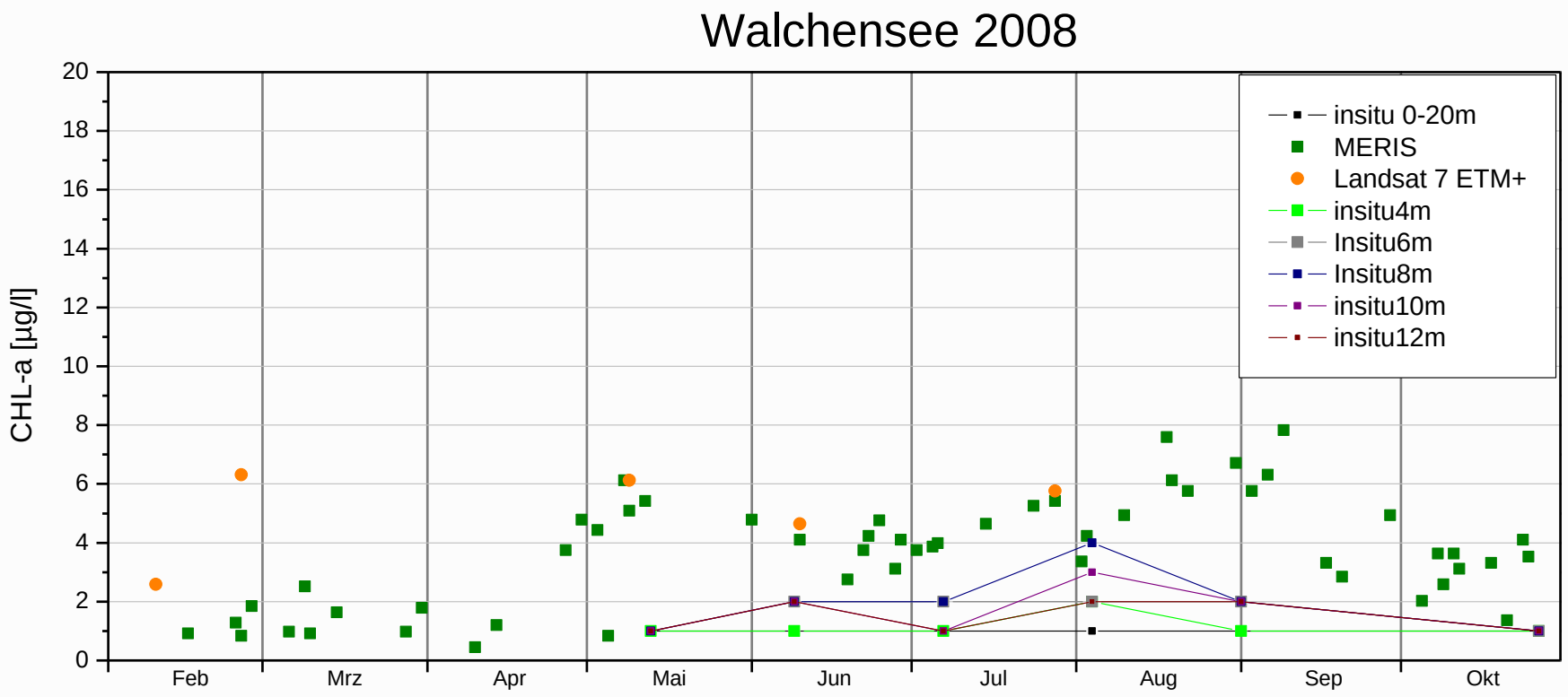


Satellite data: processing MIP © EOMAP, source data: USGS for Landsat 7ETM+, ESA for MERIS
In situ data by the Bavarian Environment Agency (LfU) provided in context of FRESHMON project

Processor MIP version: 2013
In-situ data kindly provided by:
Bavarian Environment Agency (LfU).
Reference: EU FRESHMON Project

EOMAP
detect more.

Validation Walchensee, Germany
Chlorophyll-a: Time Series 2008



Satellite data: processing MIP © EOMAP, source data: USGS for Landsat 7ETM+, ESA for MERIS
In situ data by the Bavarian Environment Agency (LfU) provided in context of FRESHMON project

Processor MIP version: 2013
In-situ data kindly provided by:
Bavarian Environment Agency (LfU).
Reference: EU FRESHMON Project

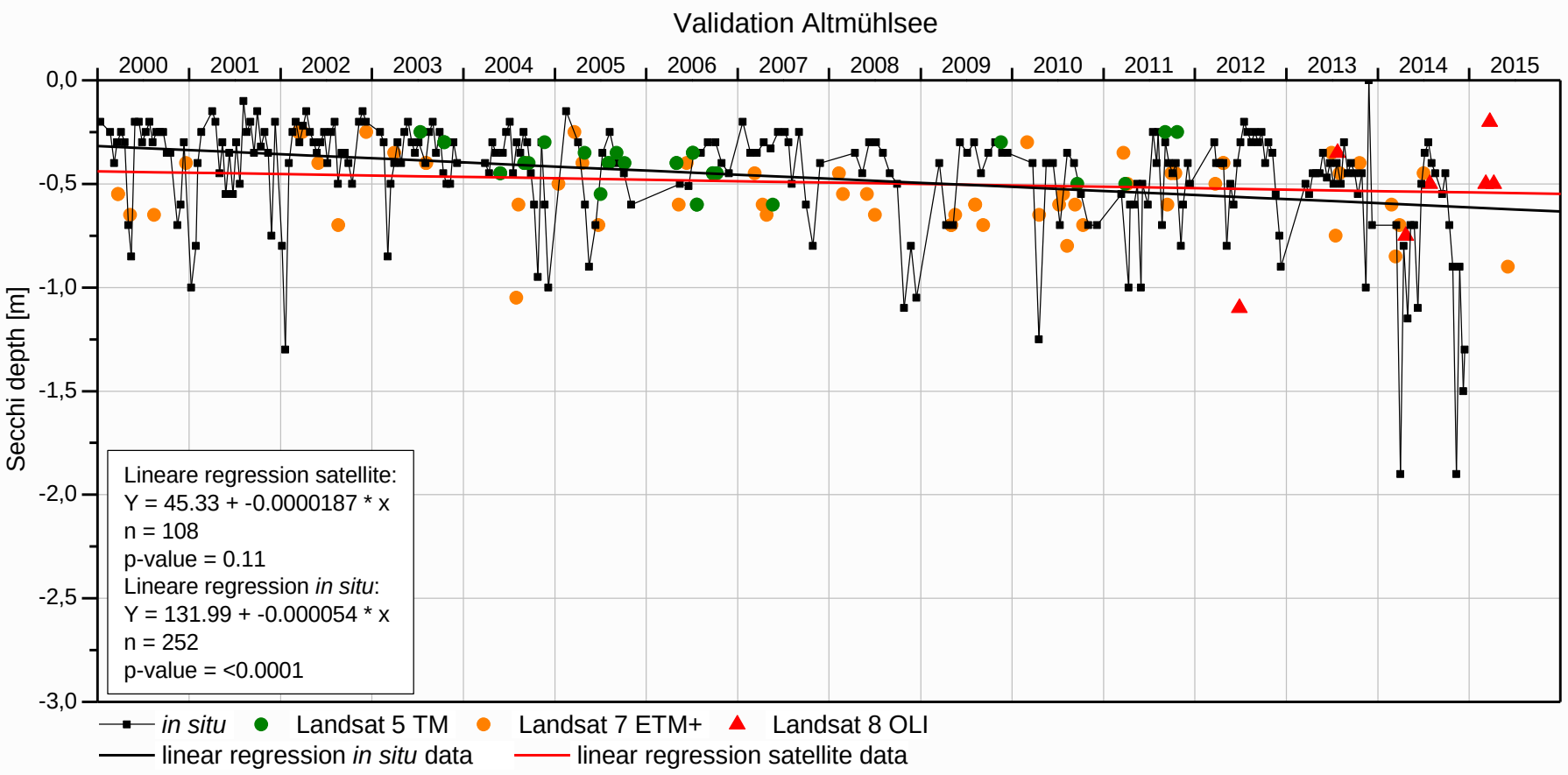
detect more.

Validation Altmühlsee/Brombachsee, Germany

Location	Altmühlsee & Brombachsee, Germany
Time Period	2000-2015
Parameter	Chlorophyll-a, Secchi Depth, Signal Depth
Sensor	Landsat
Spatial Resolution	30m
Validation data provided by	Bavarian Environment Agency (LfU)

EOMAP
detect more.

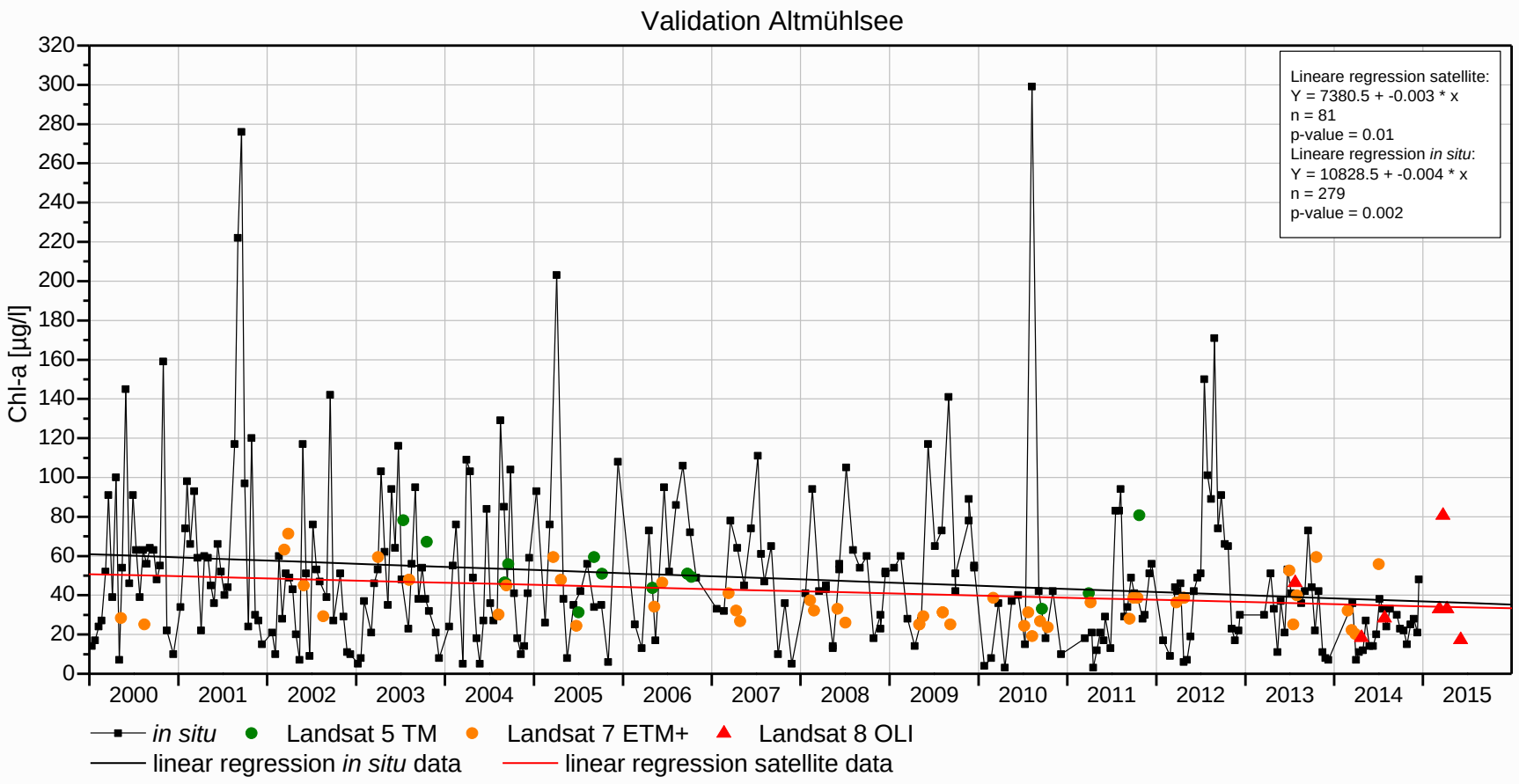
Validation Altmühlsee, Germany
Secchi depth: 2000-2015



Processor MIP version: 2015 Q3
In-situ data kindly provided by:
Bavarian Environment Agency (LfU)
Reference: Broszeit 2015

EOMAP
detect more.

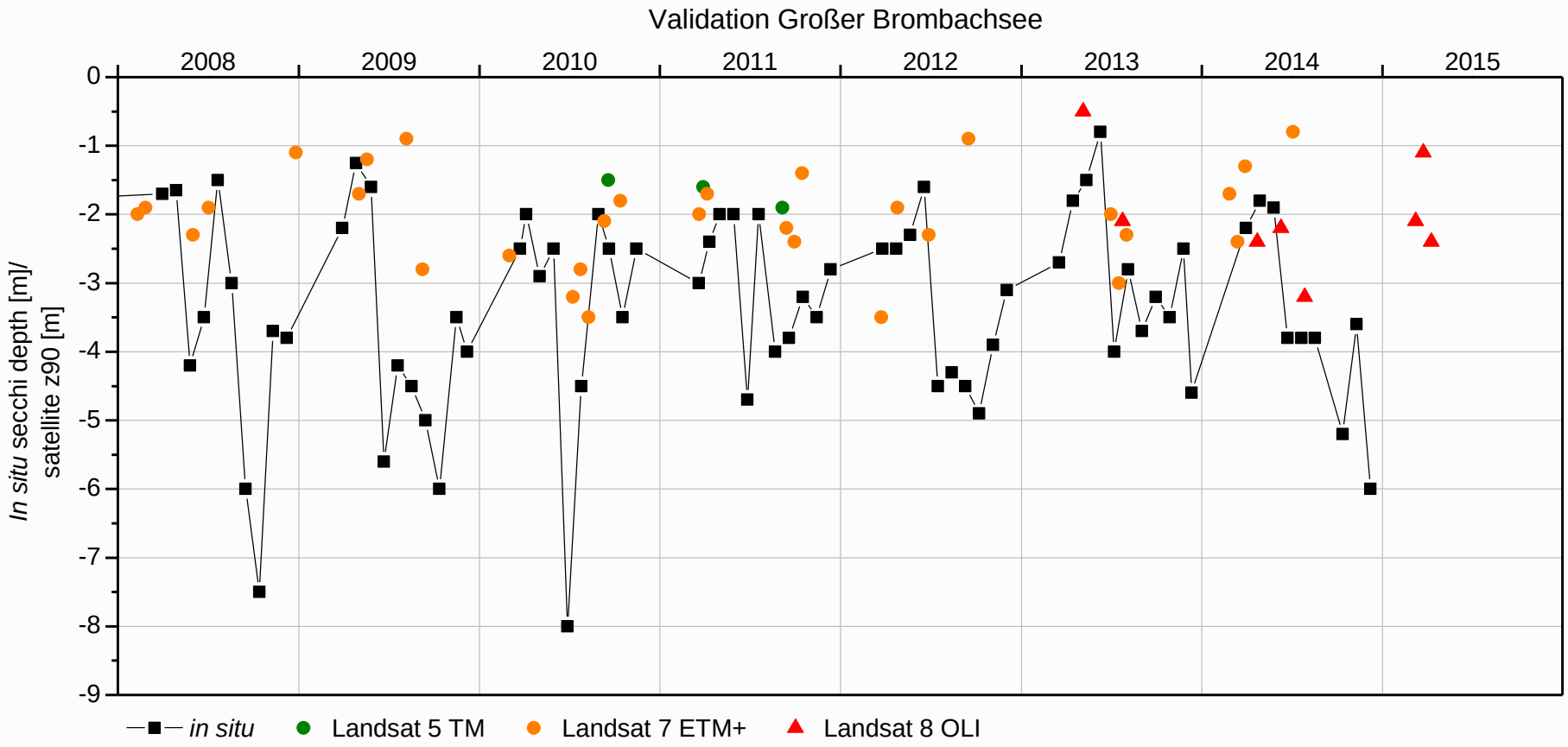
Validation Altmühlsee, Germany
Chlorophyll-a: 2000-2015



Processor MIP version: 2015 Q3
In-situ data kindly provided by:
Bavarian Environment Agency (LfU)
Reference: Broszeit 2015

detect more.

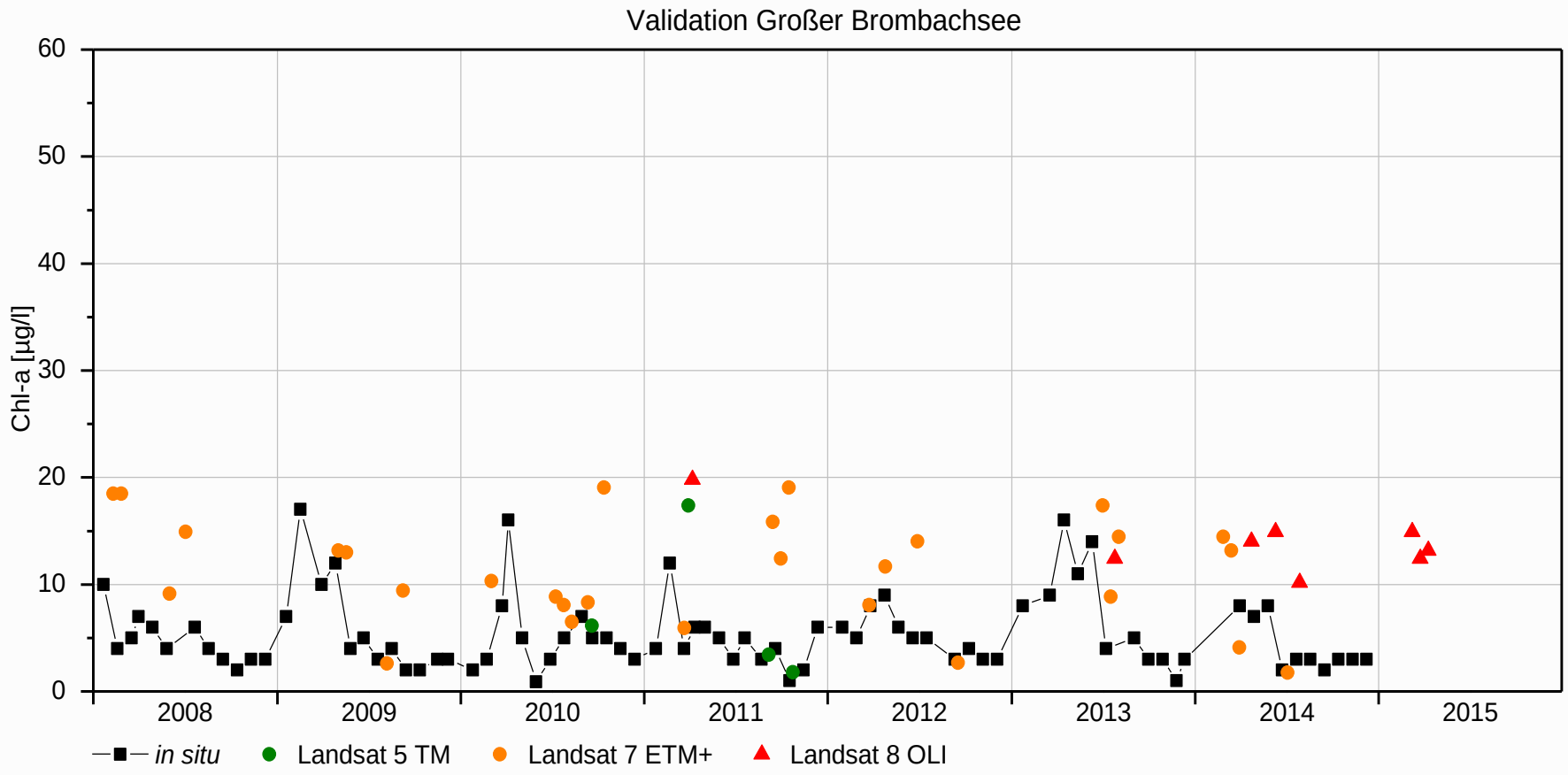
Validation Großer Brombachsee, Germany
Secchi depth: 2008-2015



Processor MIP version: 2015 Q3
In-situ data kindly provided by:
Bavarian Environment Agency (LfU)
Reference: Broszeit 2015

EOMAP
detect more.

Validation Großer Brombachsee, Germany
Chlorophyll-a: 2008-2015

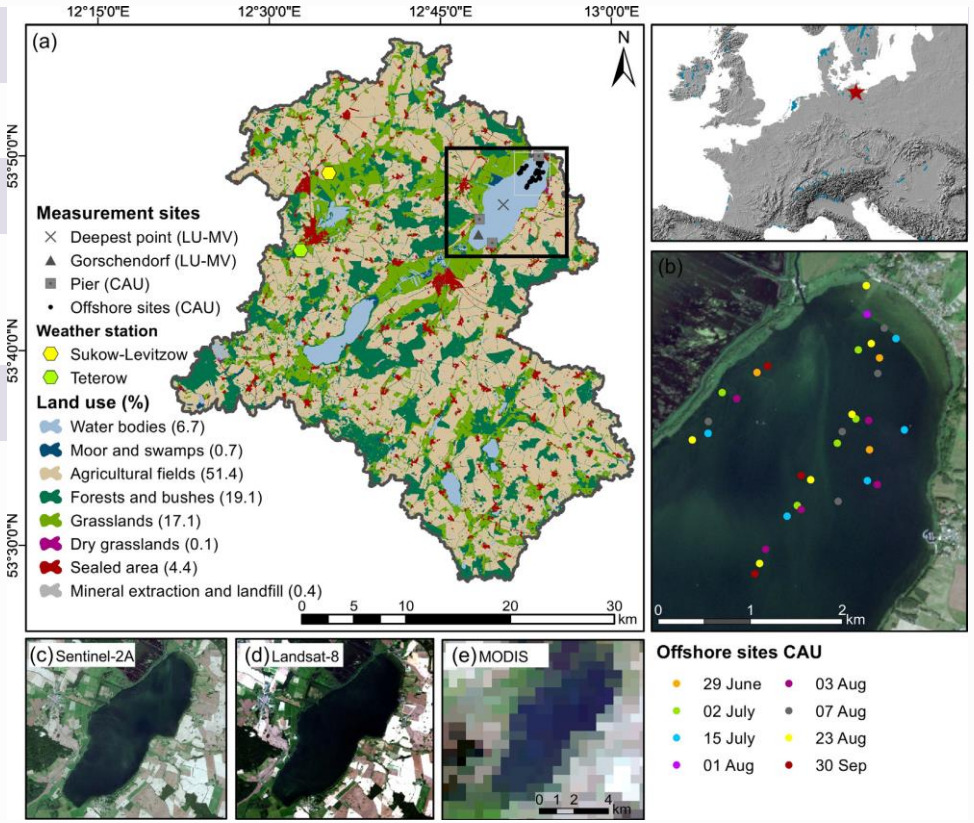


Processor MIP version: 2015 Q3
In-situ data kindly provided by:
Bavarian Environment Agency (LfU)
Reference: Broszeit 2015

detect more.

Validation Kummerower See, Germany

Location	Kummerower See, Germany
Time Period	2015
Parameter	Chlorophyll-a
Sensor	MODIS, Landsat 7, Landsat 8, Sentinel-2a
Spatial Resolution	10-500m
Reference	Dornhöfer K. et al. 2017



Reference: Dörnhöfer K., Klinger P., Heege T., Oppelt N.: Multi-sensor satellite and in situ monitoring of phytoplankton development in a eutrophic-mesotrophic lake. Sci Total Environ. 2018 Jan 15;612:1200-1214. doi: 10.1016/j.scitotenv.2017.08.219. Epub 2017 Sep 8. PMID: 28892864.

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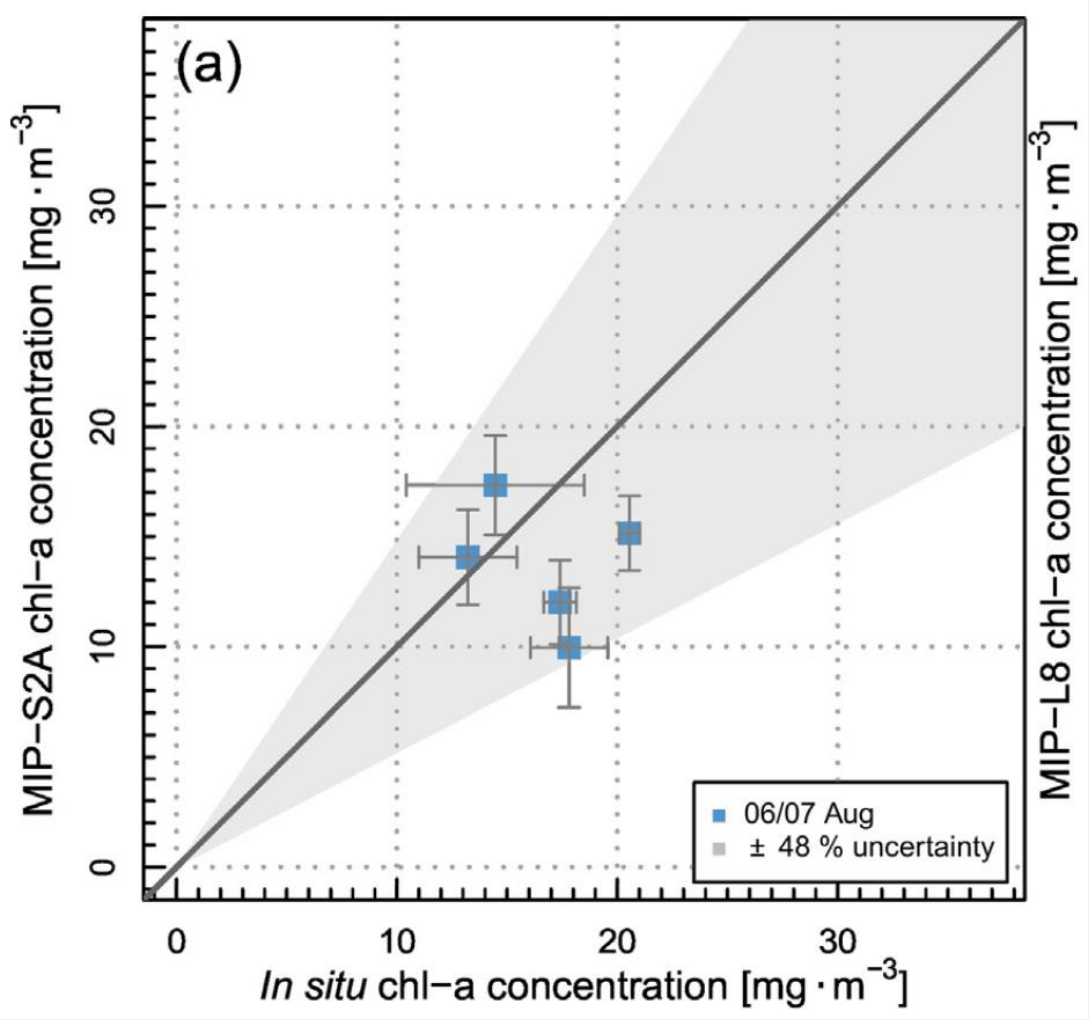
Validation Kummerower See, Germany
Chlorophyll-a



Comparison of Chlorophyll-a retrieved from in situ measurements and Sentinel-2A acquisitions.
Vertical error bars indicate the standard deviation of a 5 × 5 pixel environment. Horizontal error bars represent standard deviation of in situ measurements at the sampling sites, the grey shaded area indicates the 48% uncertainty of in situ measurements.

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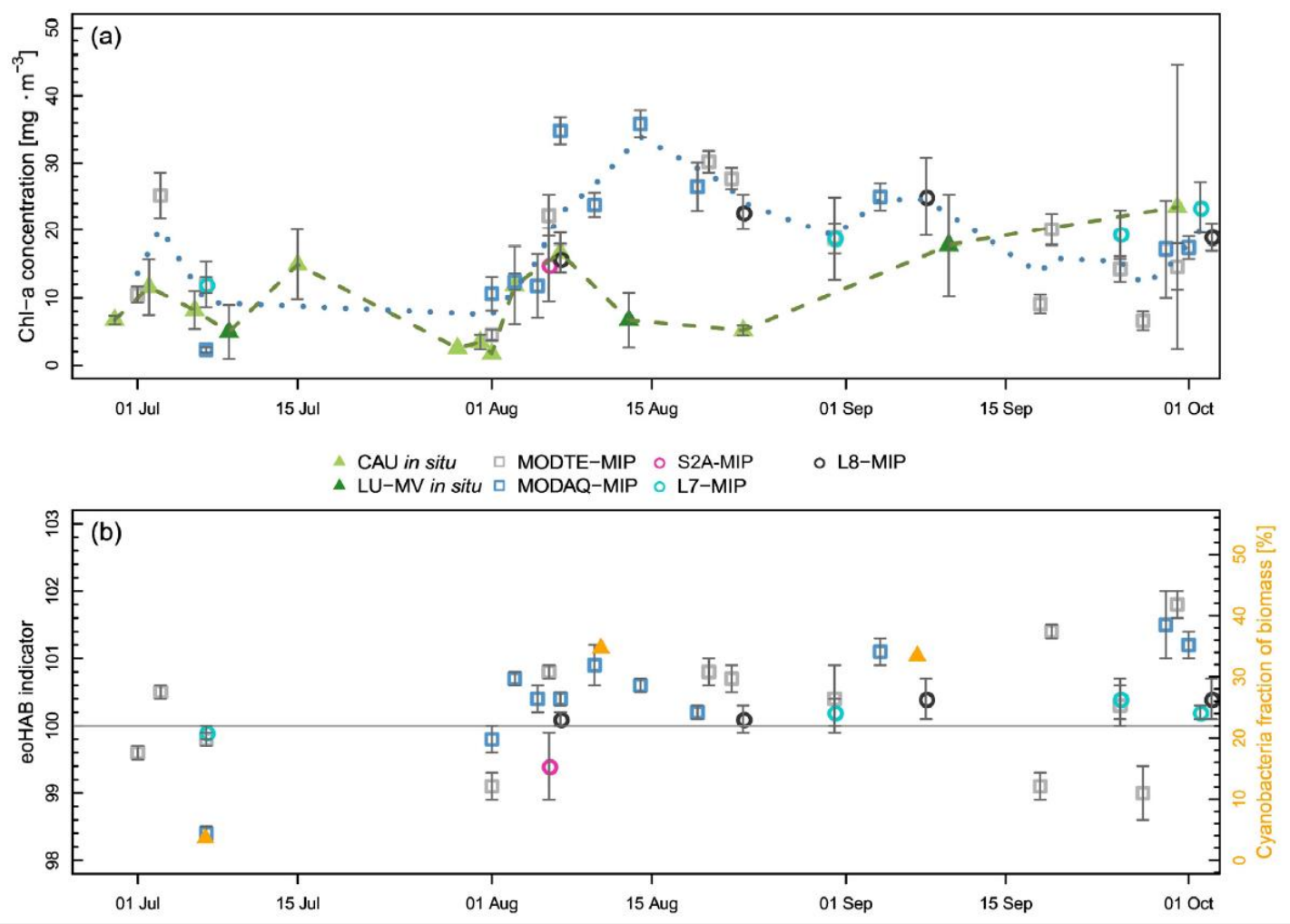
Validation Kummerower See, Germany
Chlorophyll-a & eoHAB



Lake average satellite Chlorophyll-a and in-situ Chlorophyll-a between 1 July and 3 October 2015. Vertical bars indicate standard deviation (a).

Lake average eoHAB and cyanobacteria fraction of biomass (LU-MV, 2015a) (b).

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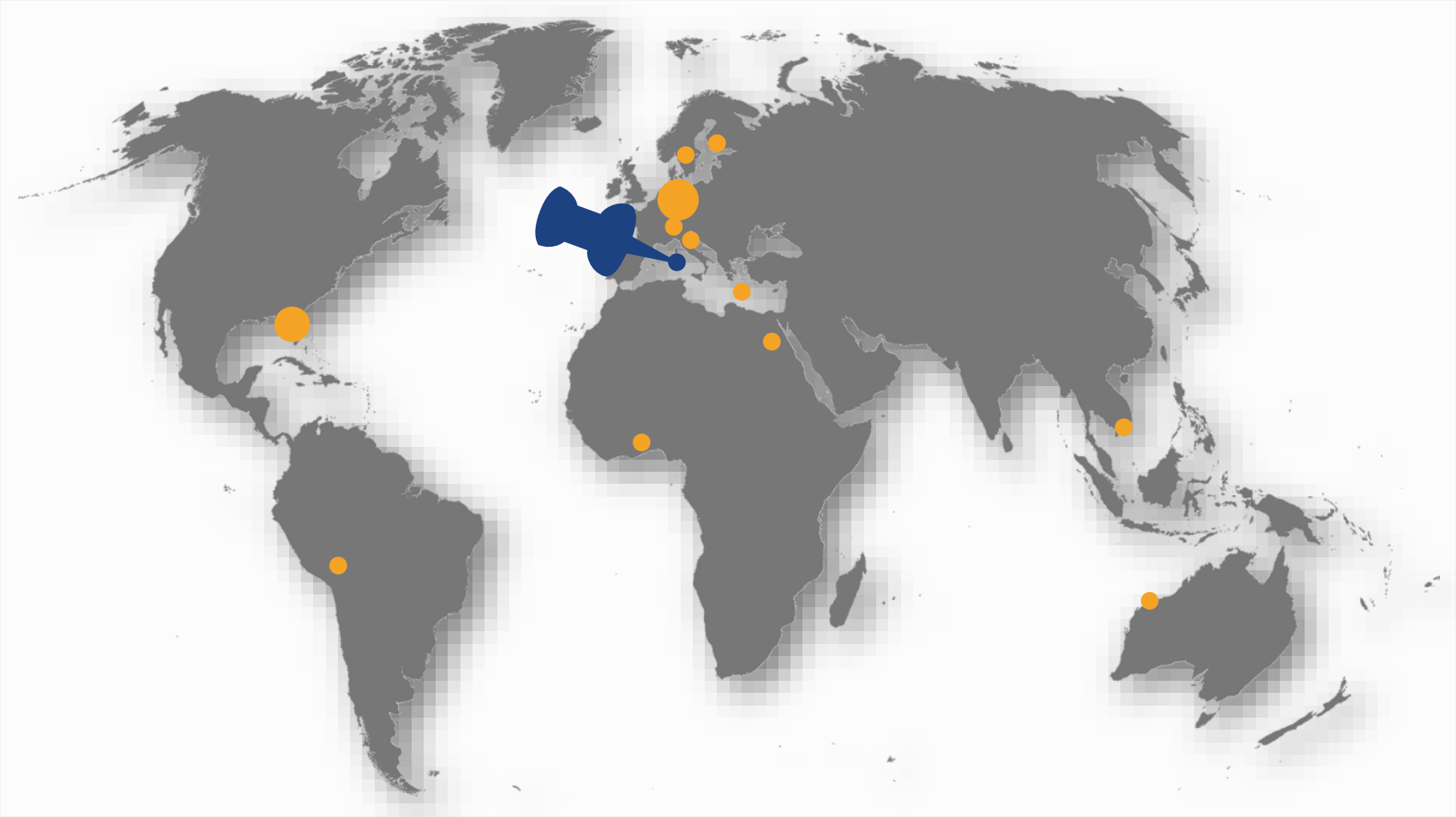
Lake Mulargia, Italy



EOMAP
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Validation Lake Mulargia, Italy

Location	Lake Mulargia, Italy
Lake/river size	Approx. 12.5 km²
Time Period	2013-2018
Parameter	Chlorophyll-a, Turbidity, SST
Sensor	Sentinel-2A, Landsat 7, Landsat 8, WorldView-2
Spatial Resolution	10-30m
Stations	1 Field campaign station (39° 36' 27,1395'', 9° 15' 12,1778'')
Validation data provided by	CNR (Claudia Giardino, Mariano Bresciani), ENAS (Ente Acque della Sardegna)
Reference	SPACE-O project http://www.space-o.eu/

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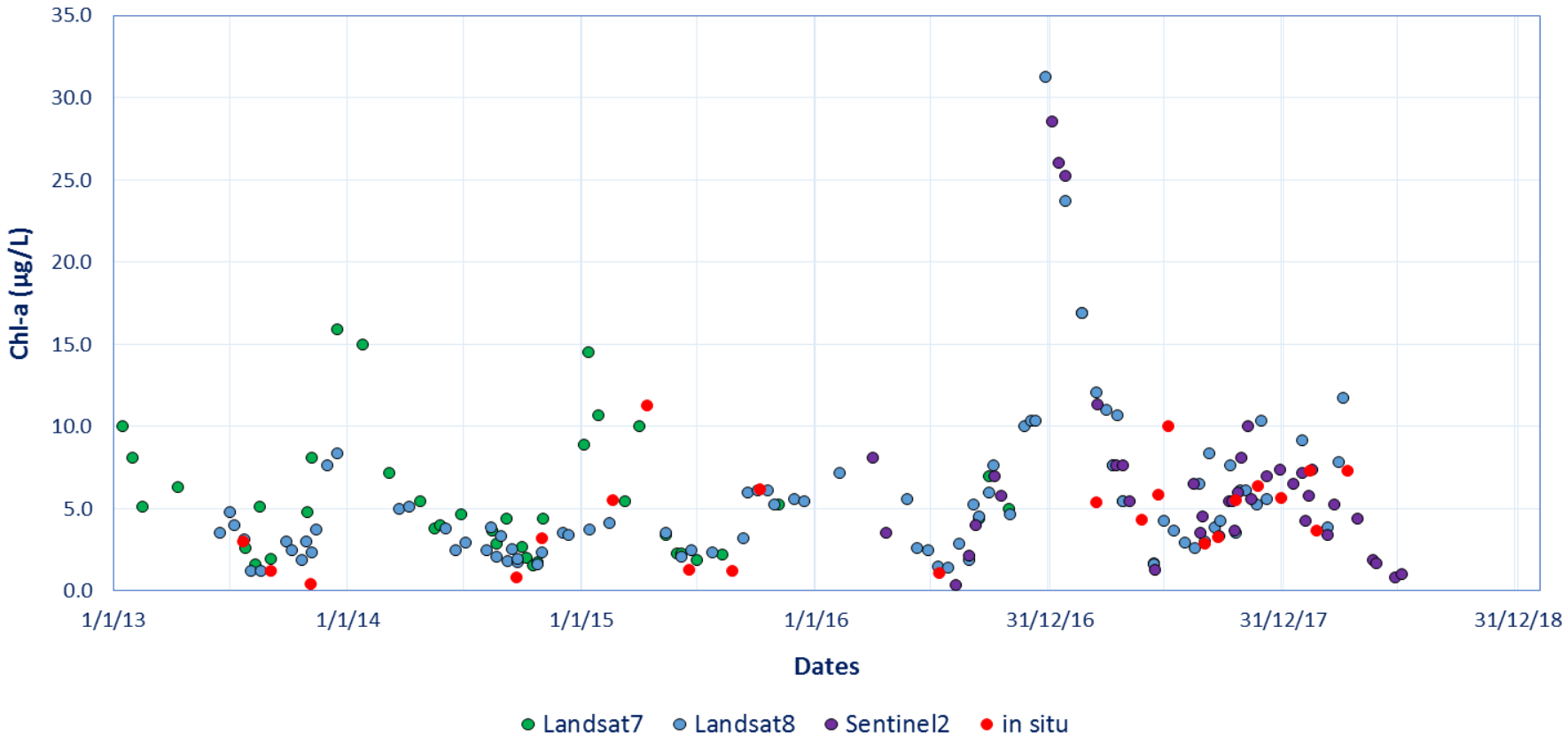
Validation Lake Mulargia, Italy
Chlorophyll-a: 2013-2018



Variations of Chlorophyll-a concentrations from satellite data (Landsat 7, Landsat 8 and Sentinel 2) and in situ data for Lake Mulargia, in correspondence of the ENAS station.

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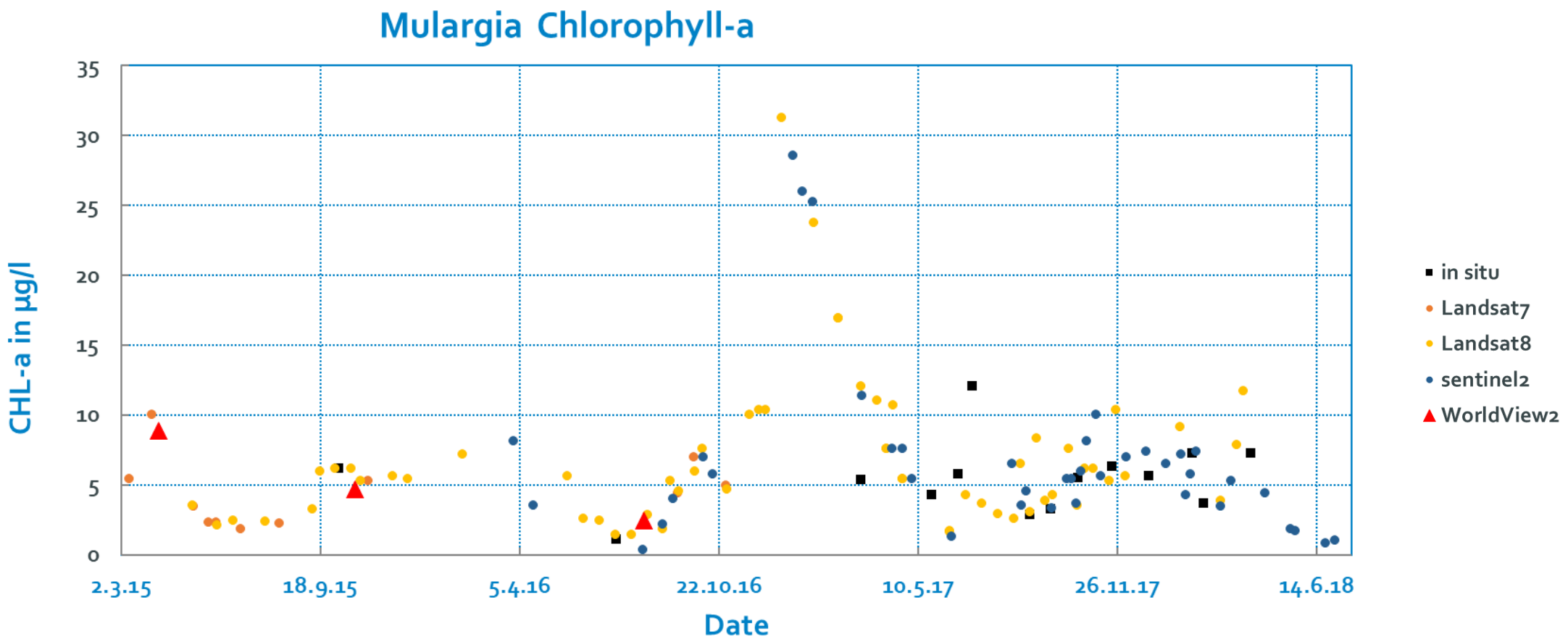
Validation Lake Mulargia, Italy
Chlorophyll-a: 2015-2018



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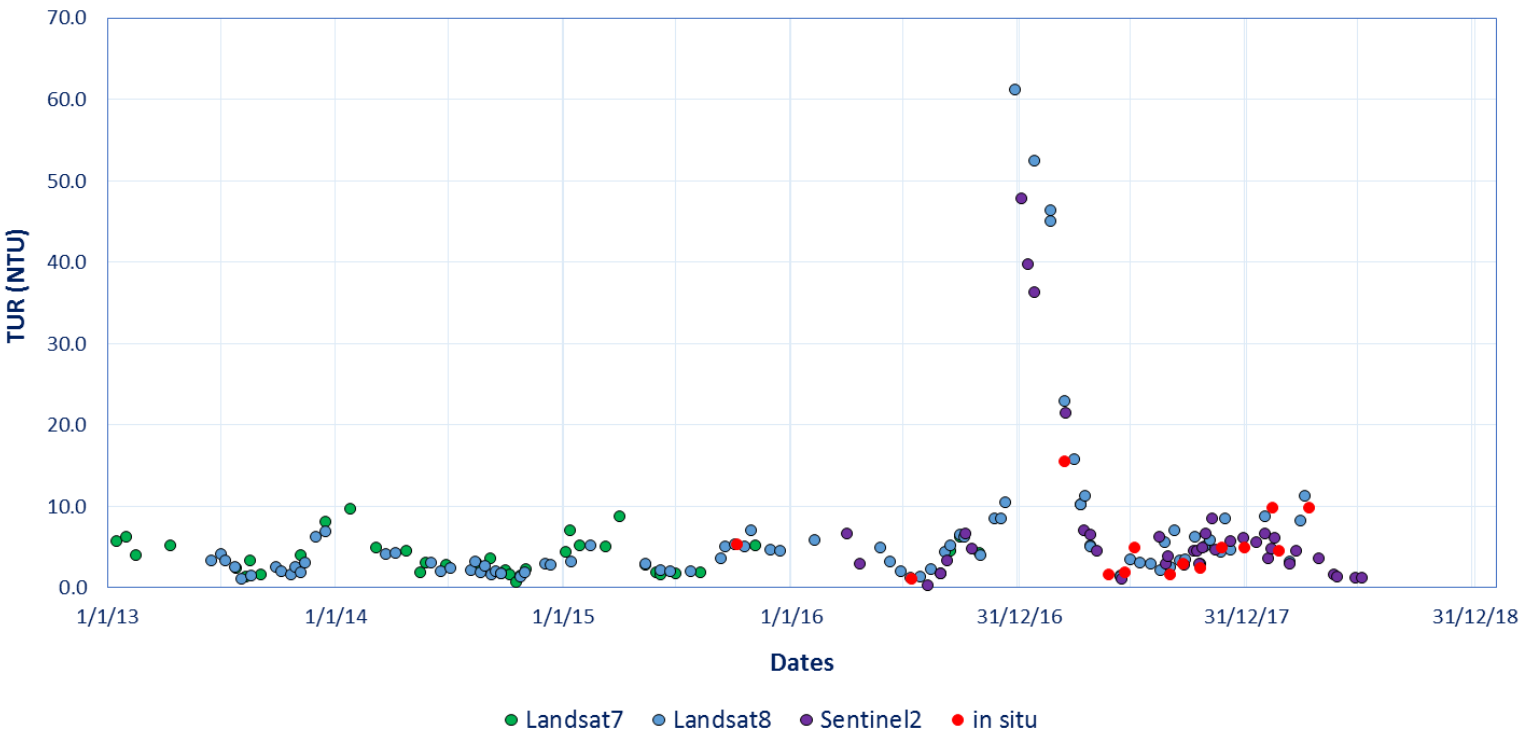
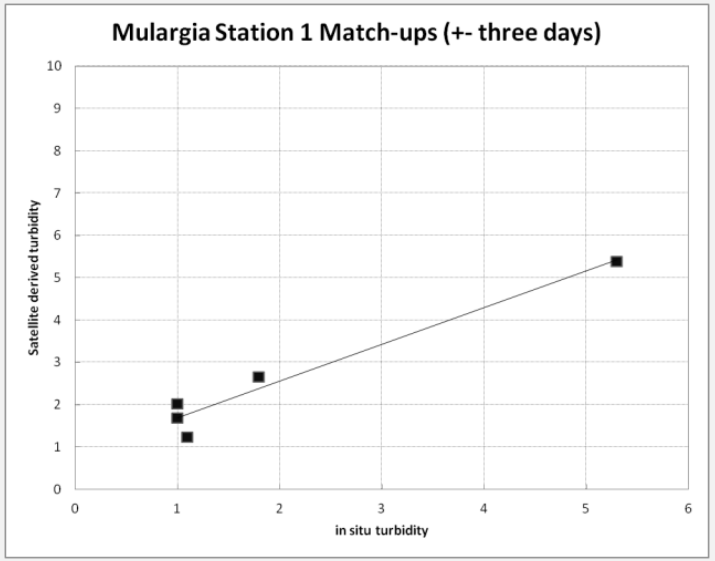
Validation Lake Mulargia, Italy
Turbidity: 2013-2018

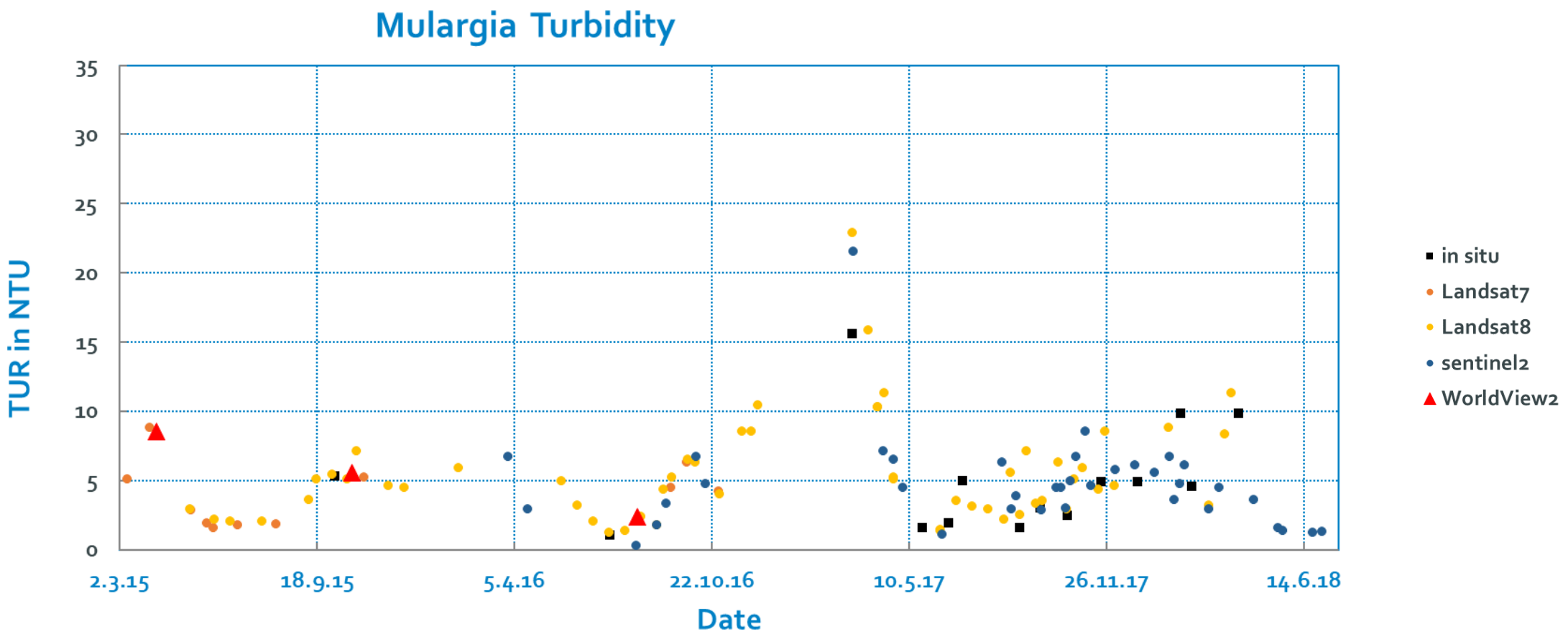




Variations of Turbidity from satellite data (Landsat 7, Landsat 8 and Sentinel 2 platforms) and in situ data for Lake Mulargia, in correspondence of the ENAS station.

EOMAP
detect more.

Validation Lake Mulargia, Italy
Turbidity: 2015-2018



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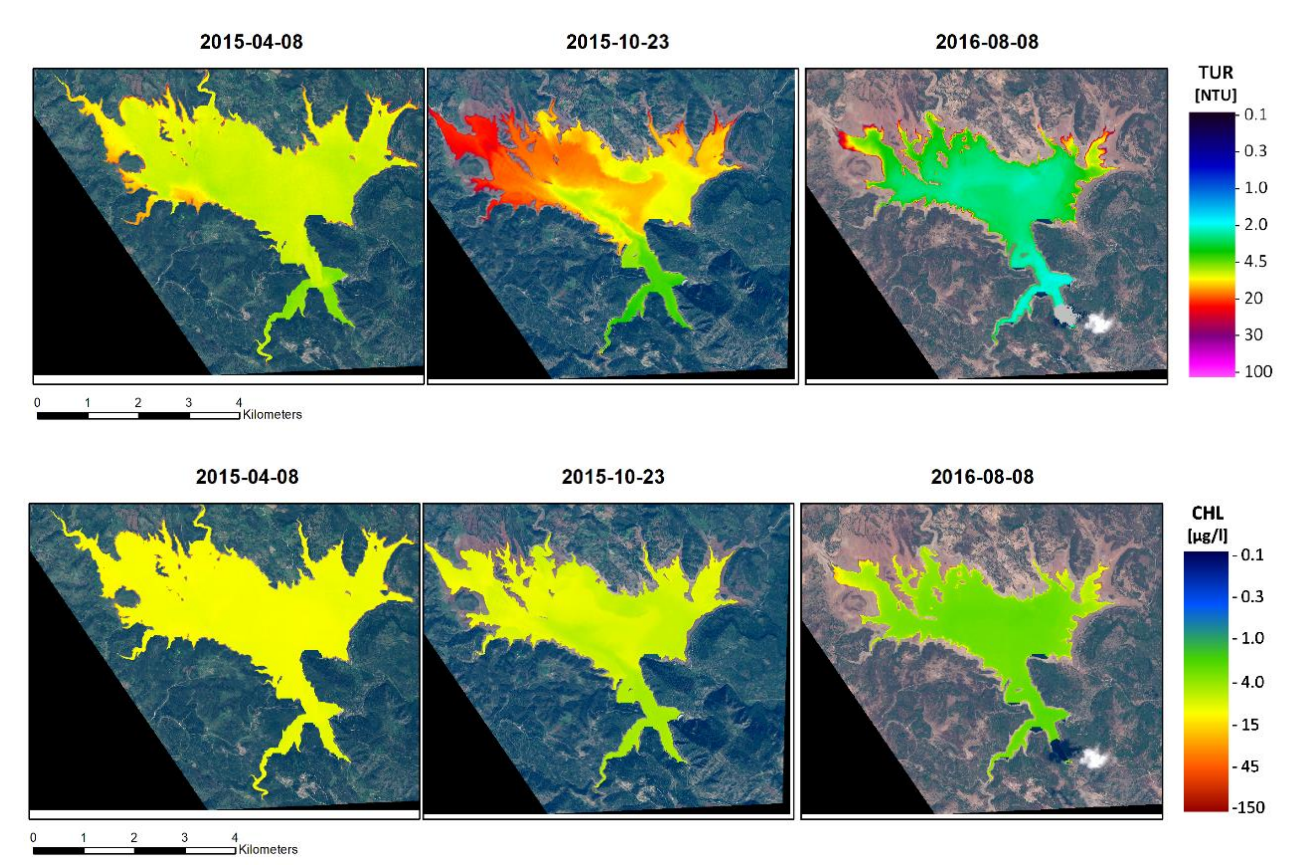
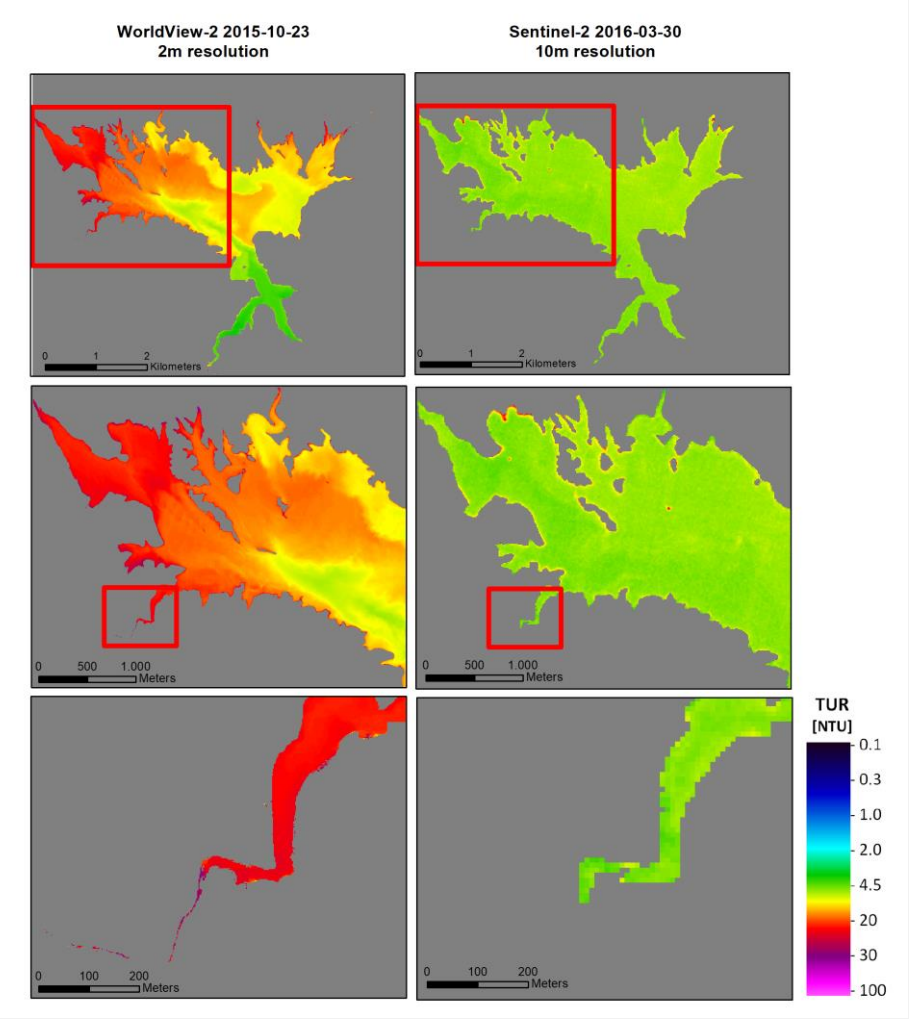
Validation Lake Mulargia, Italy
Chlorophyll-a & turbidity time series





top images contain: WorldView-2 data © 2015,2016 MAXAR
right images contain WorldView-2 data © 2015 MAXAR and Copernicus data (2016)

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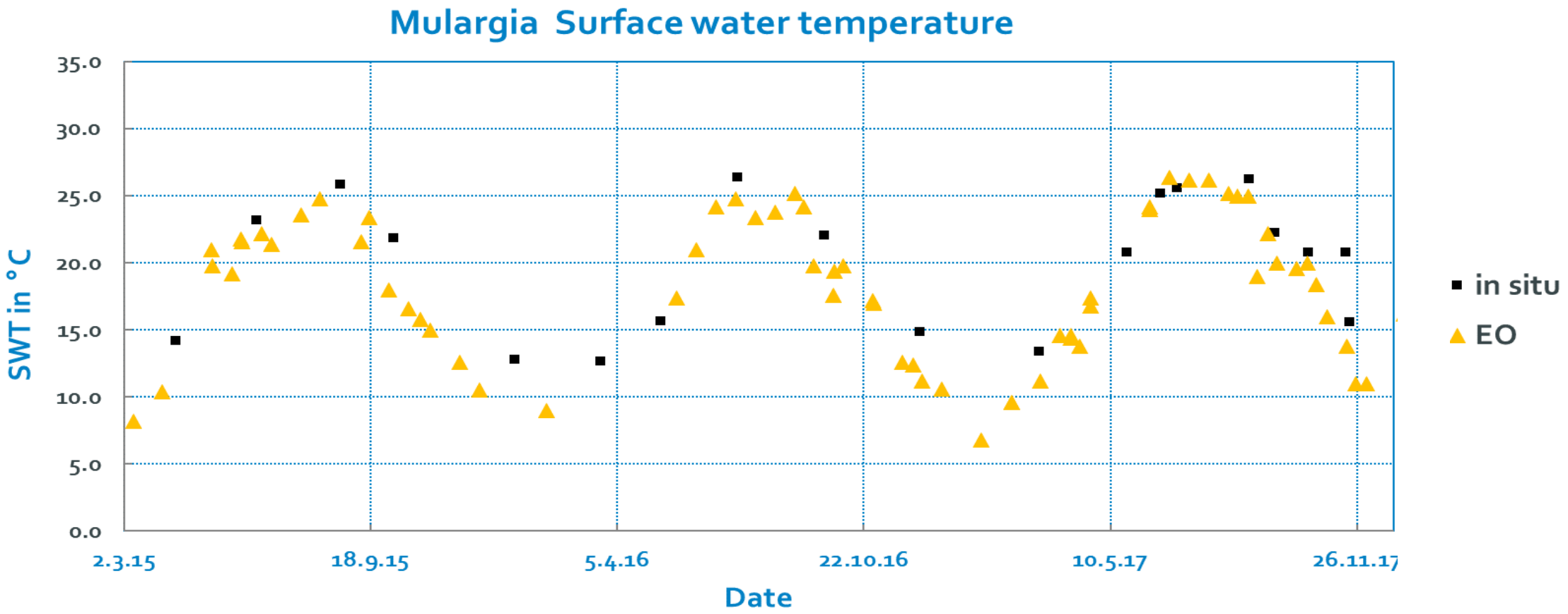
Validation Lake Mulargia, Italy

Surface water temperature: 2015-2017



EOMAP
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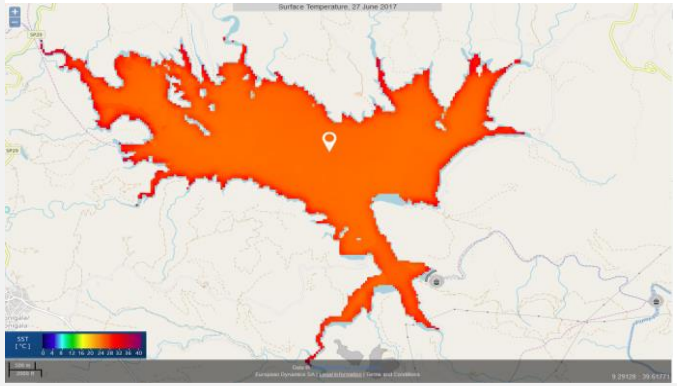
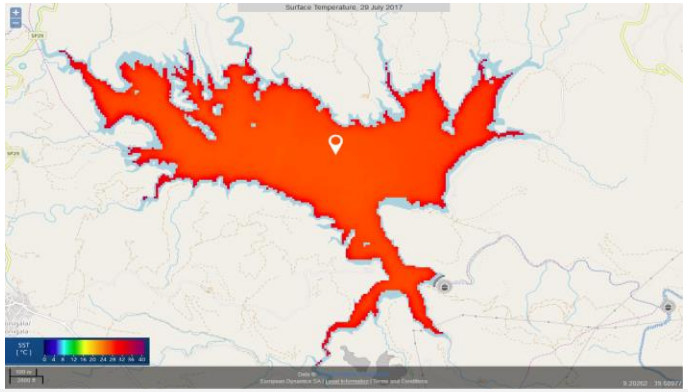
Validation Lake Mulargia, Italy
Water Surface Temperature time series, 2017

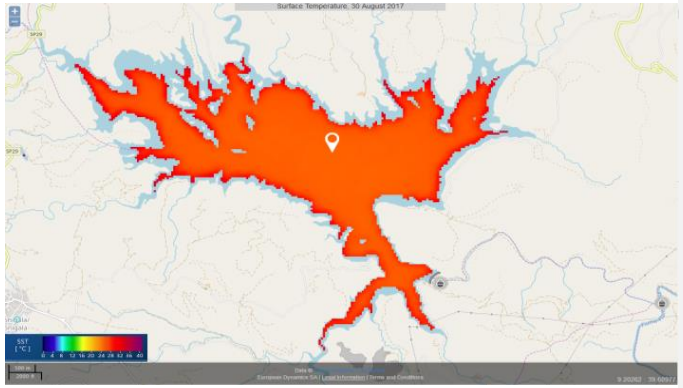
June 2017



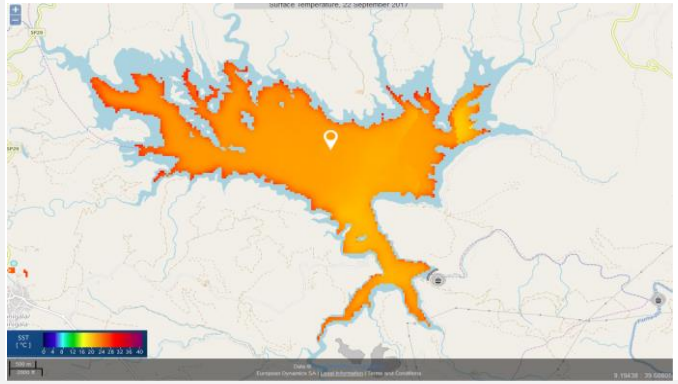
July 2017



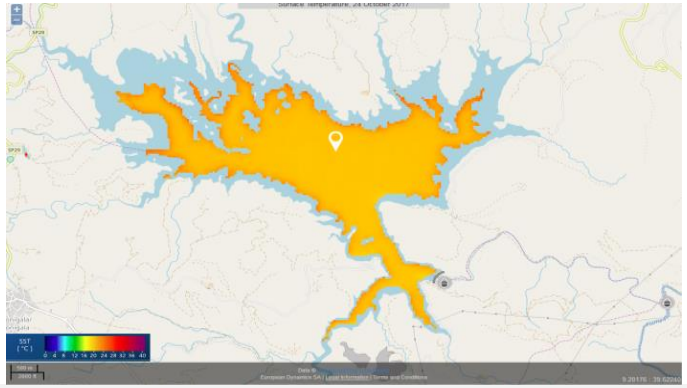
August 2017



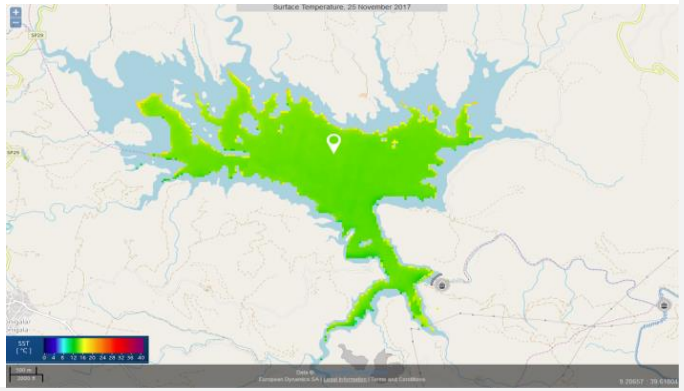
September 2017



October 2017



November 2017



EOMAP
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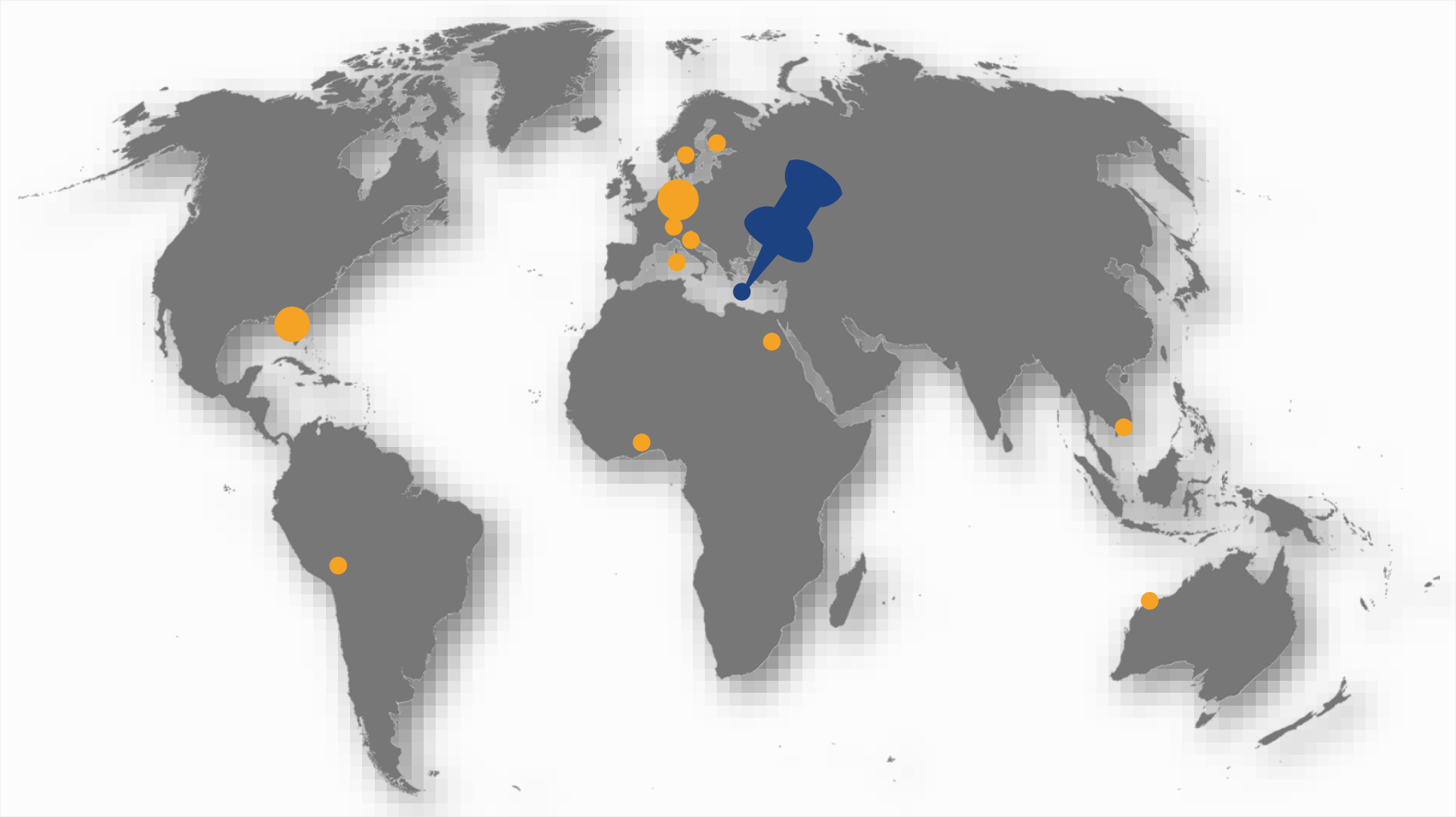
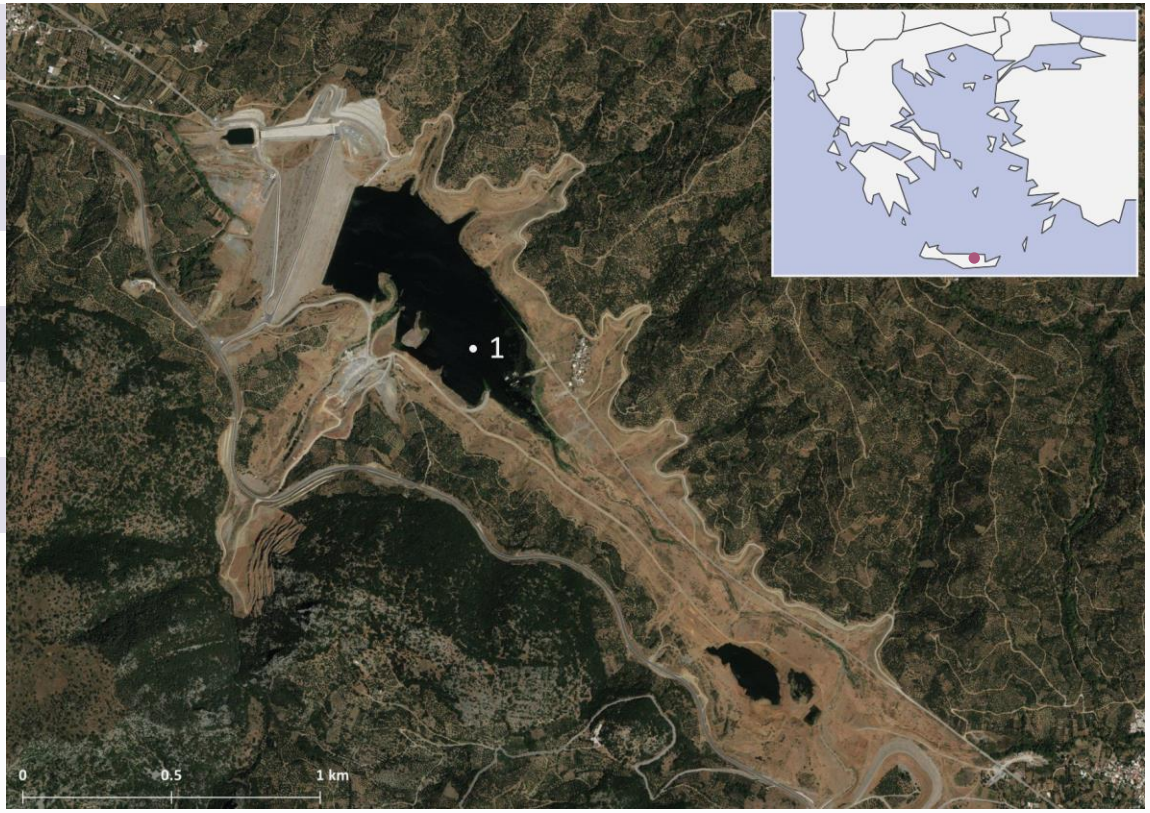
Aposelemis dam in Crete, Greece



EOMAP
detect more.

Consistency Check Aposelemis dam in Crete, Greece

Location	Aposelemis dam in Crete, Greece
Lake/river size	Approx. 2 km²
Time Period	2013-2018
Parameter	Chlorophyll-a, Turbidity, SST
Sensor	Sentinel-2A, Landsat 7, Landsat 8
Spatial Resolution	10-30m
Stations	Station 1
Reference	SPACE-O project (not yet published) http://www.space-o.eu/



EOMAP
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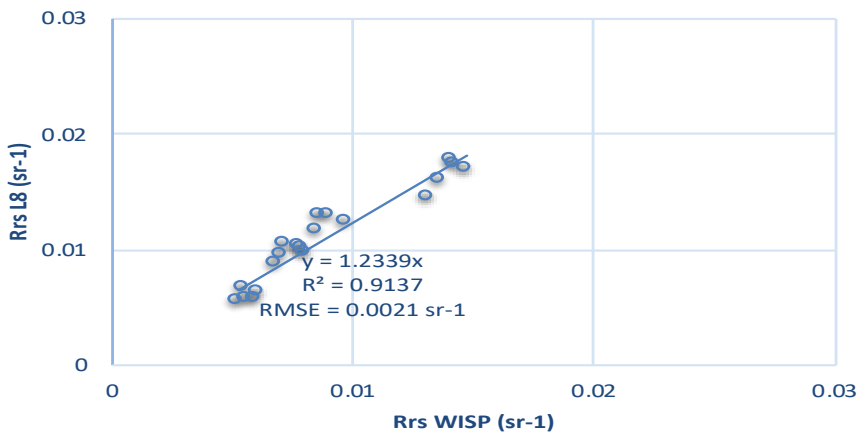
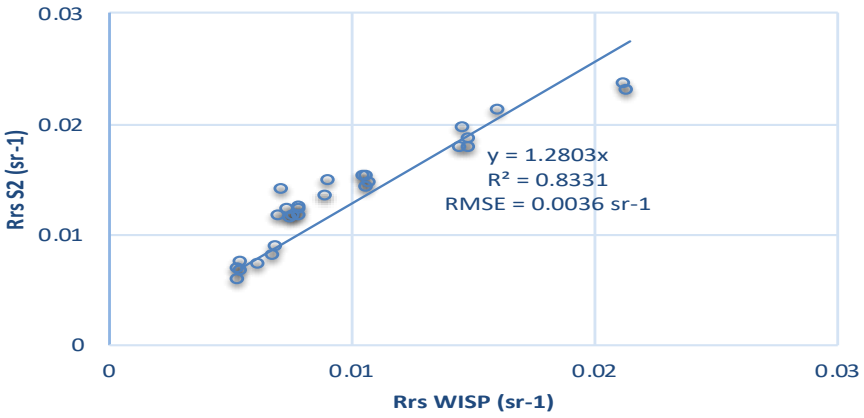
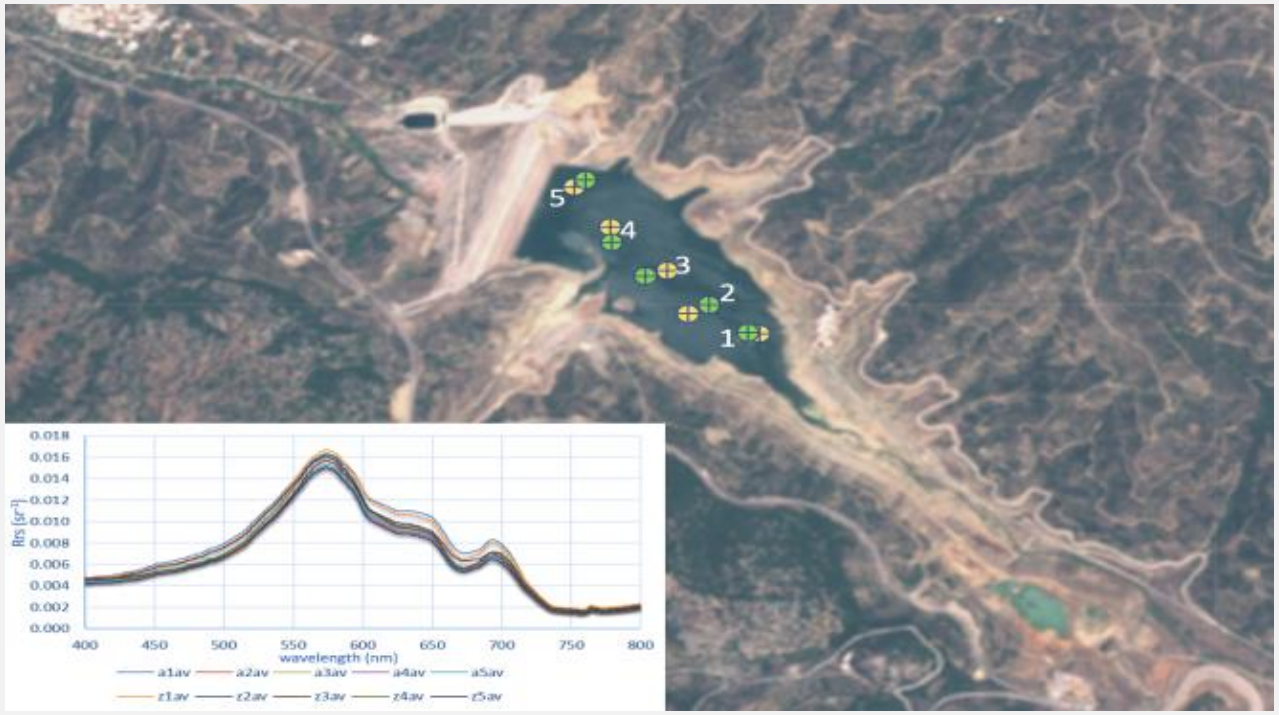
Validation Aposelemis dam in Crete, Greece

Field Measurements



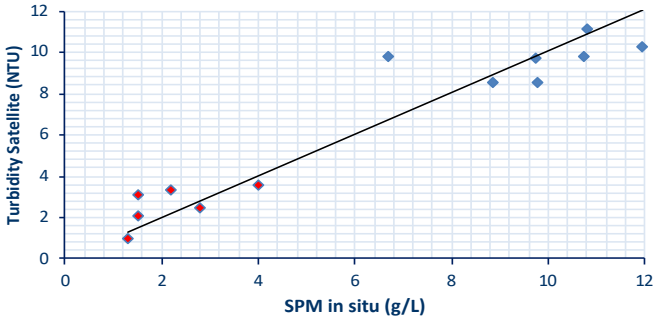


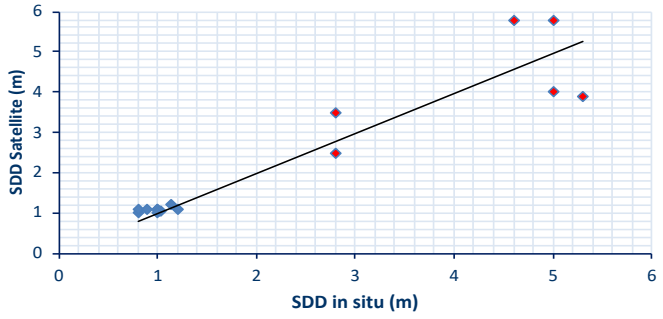


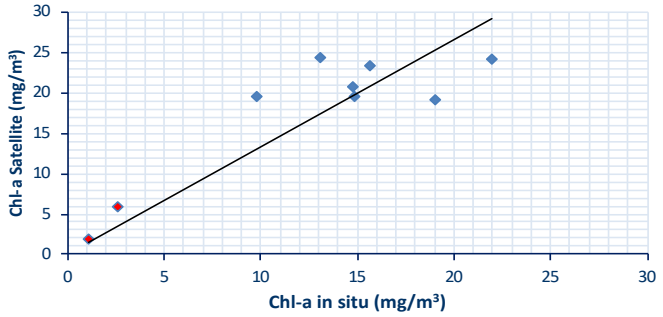
Figures left:
Scatterplot across common bands of Rrs values from WISP and from satellite observations (on the bottom figure: S2 for 2nd and 7th July, on top : L8 for data measured on 03/07/18).

EOMAP
detect more.

Validation Aposelemis dam in Crete, Greece







Parameter	RMSE	Slope	Intercept	R2	Av. In situ	Av. Sat
SPM (gL^{-1})/TUR	1.05	0.92	0.81	0.89	6.90	6.62
SDD (m)	0.41	0.94	0.20	0.88	2.27	2.21
Chl-a (mgm^{-3})	5.11	1.02	4.87	0.77	17.66	12.54

Table on top:
Results of the statistical analysis for evaluation the accuracy of satellite derived products (Lake Mulargia and Aposelemis dam).

Figure left:
Scatterplot of water quality parameters from in situ measurements and from satellite observations; red diamonds are for Lake Mulargia, blue for Aposelemis dam.

EOMAP
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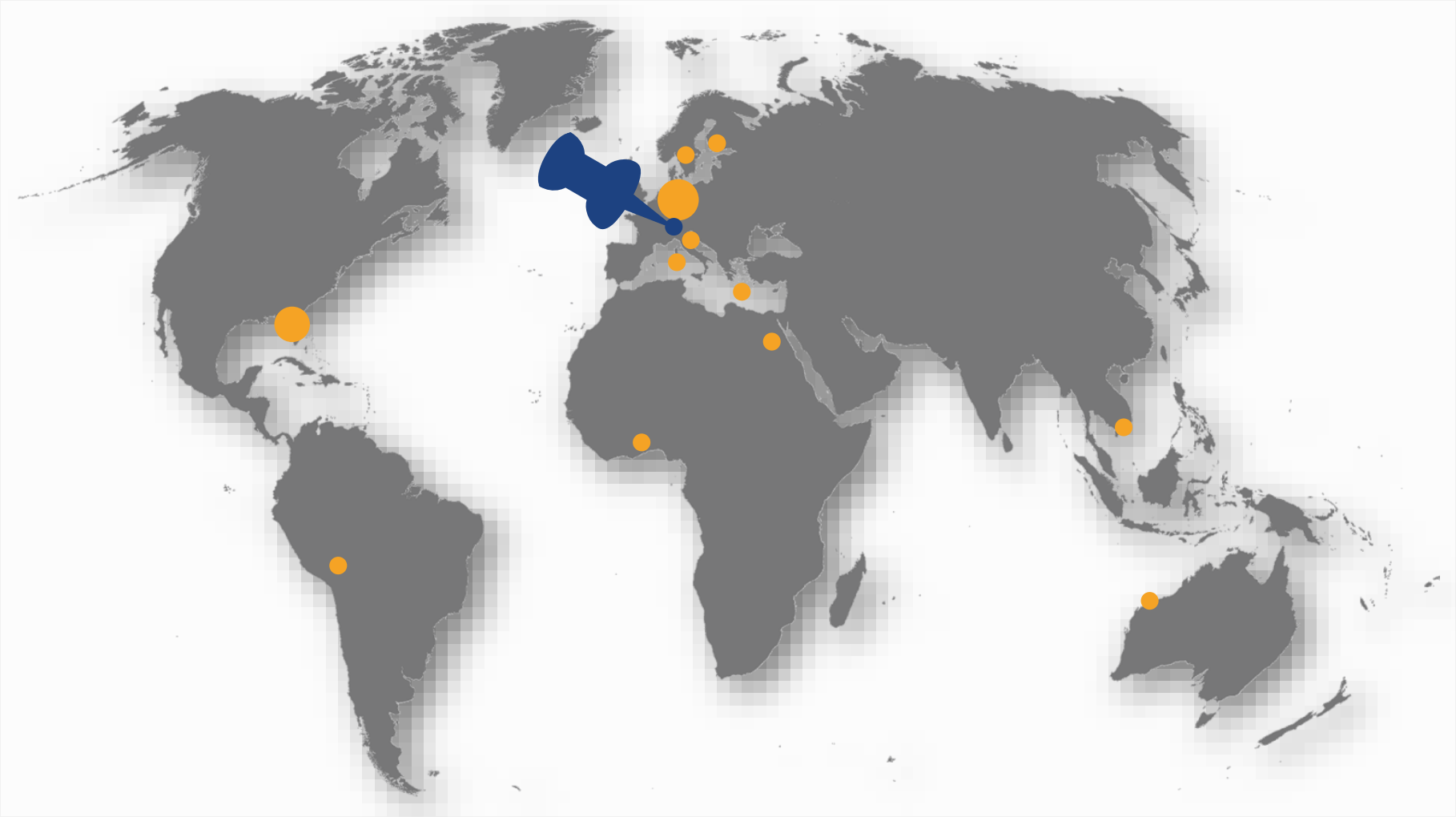
SWITZERLAND



EOMAP
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Validation Lake Zurich, Switzerland

Location	Lake Zurich, Switzerland
Lake/river size	Approx. 88,66 km²
Time Period	2006 - 2011
Parameter	Chlorophyll-a
Sensor	MERIS
Spatial Resolution	300m
Stations	SZHTH
Validation data provided by	Water Supply Zurich
Reference	FRESHMON project (2010-2013): D54.3 Report on FRESHMON data quality and data comparability (available upon request) D54.3_2 Update Report on FRESHMON data quality and data comparability (available upon request)

EOMAP
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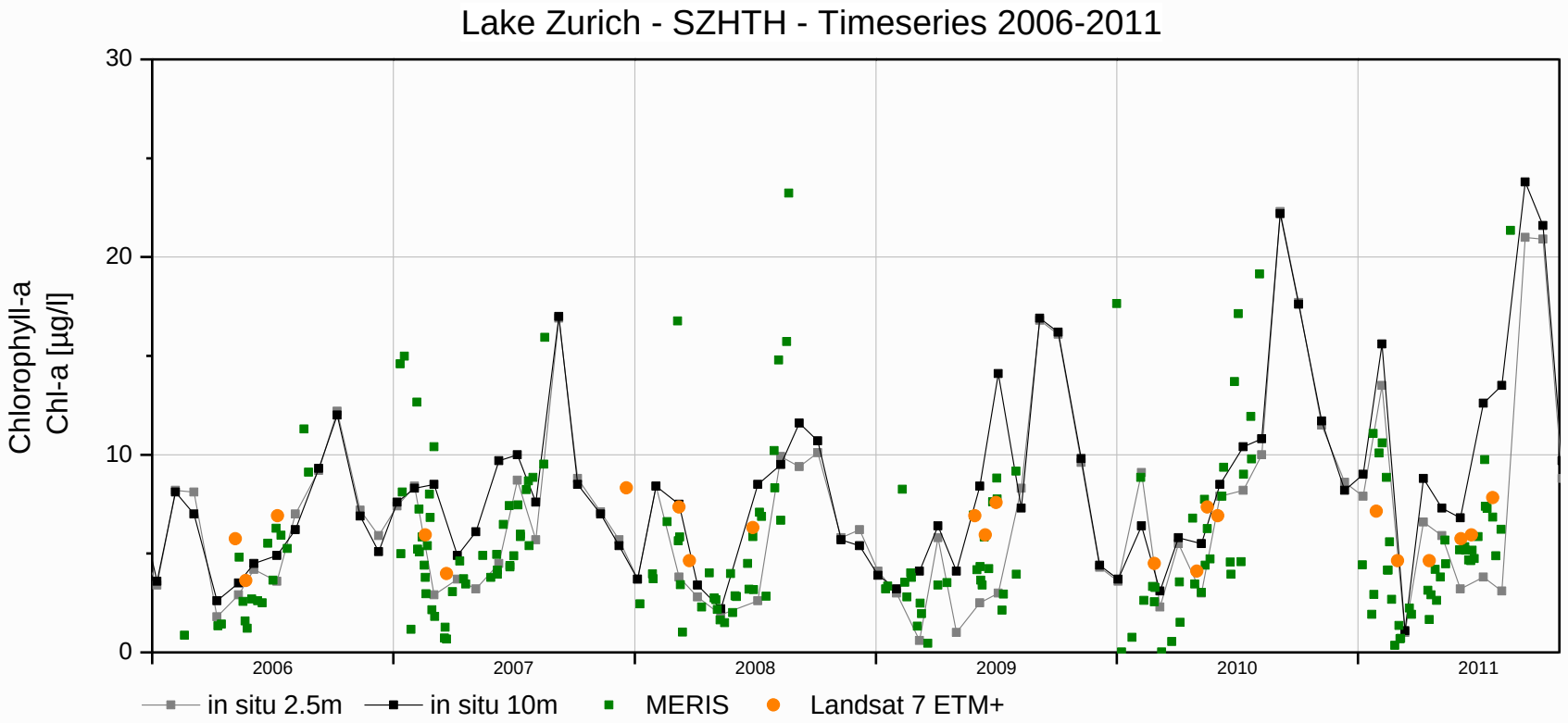
Validation Lake Zurich, Switzerland
Chlorophyll-a: Time Series Station SZHTH 2006-2011



Satellite data: processing MIP © EOMAP, source data: USGS for Landsat 7ETM+, ESA for MERIS
In situ data © Wasserversorgung Zürich 2012 provided in context of FRESHMON project

Processor MIP version: 2013
In-situ data kindly provided by: Water Supply Zürich
Reference: EU FRESHMON Project

EOMAP
detect more.

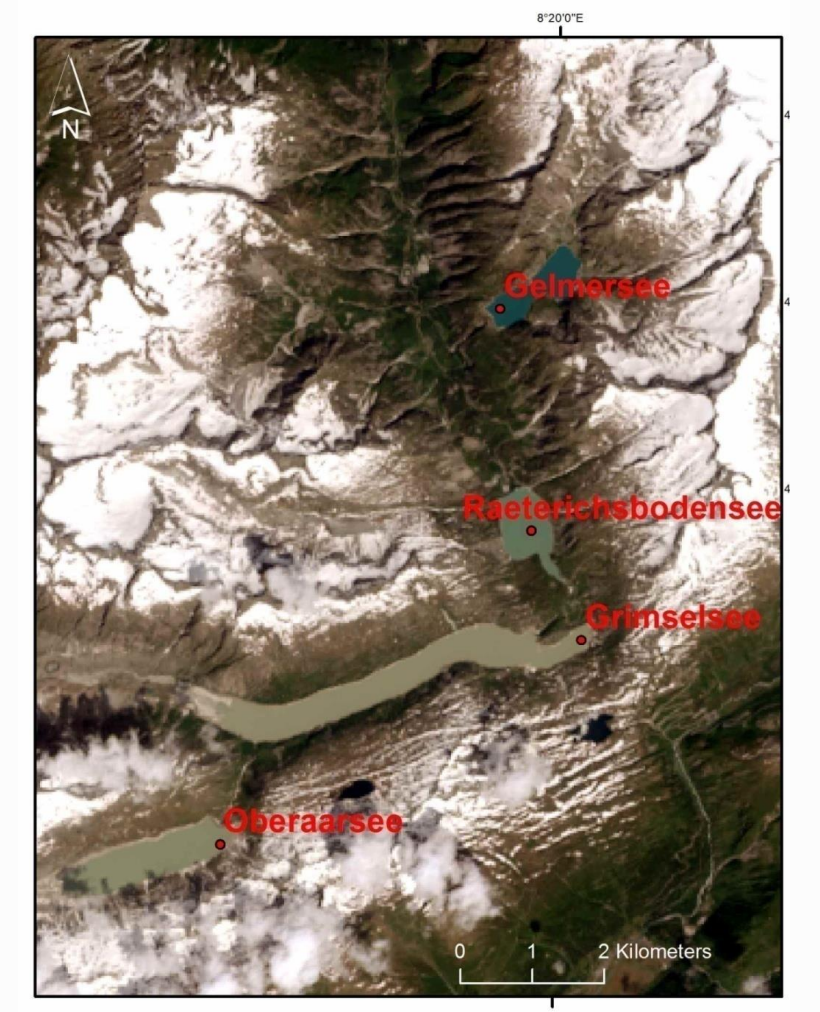
Physical Validation Räterichsbodensee & Gelmersee, Switzerland

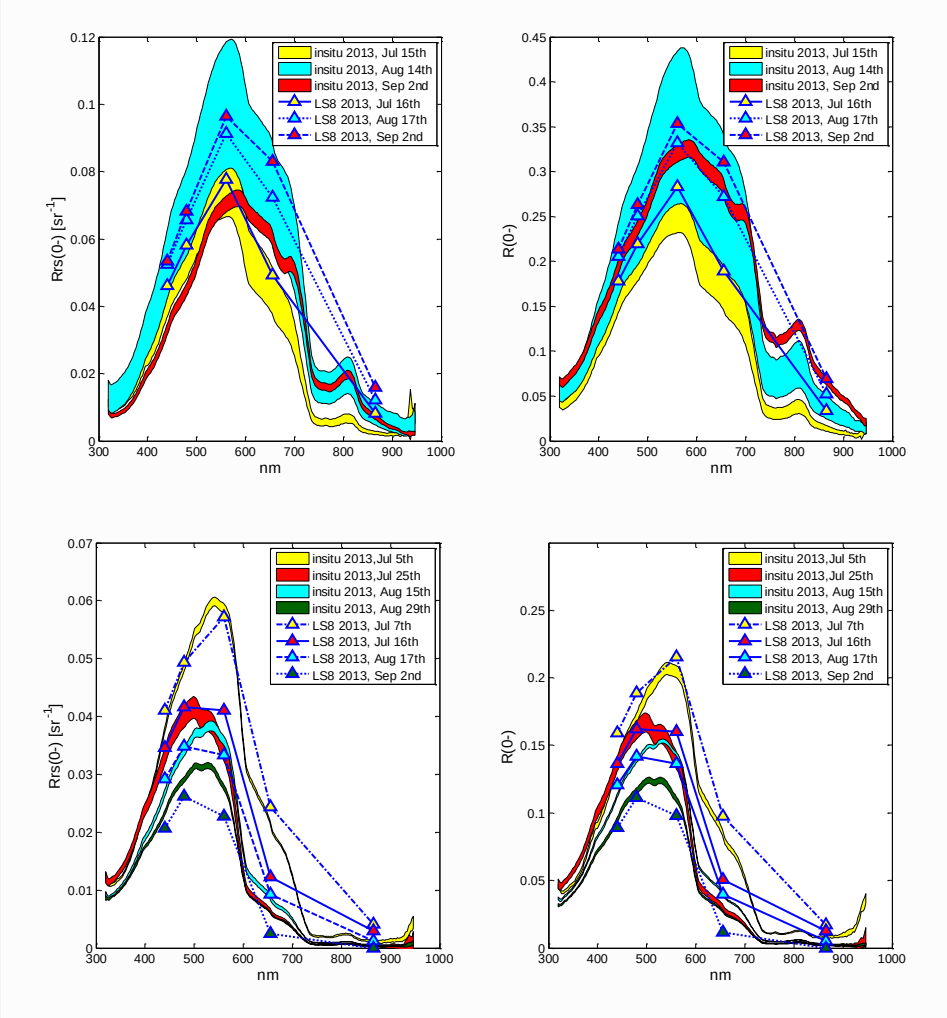
Location	Räterichsbodensee & Gelmersee, Switzerland
Lake/river size	Approx. 0.67 km² & 0.645 km²
Time Period	2013
Parameter	Remote Sensing Reflectance, Subsurface Reflectance
Sensor	Landsat 8
Spatial Resolution	30m
Reference	Eder E., Roettgers R., Damm A., Schenk K., Odermatt D & Wuest A. (2014): Remote sensing of particle mass concentration in Alpine reservoirs. In: Ocean Optics XXII conference. Portland, Maine, USA, 26-31 October 2014.

EOMAP
detect more.

Physical Validation of the Subsurface Reflectance

Examples for adjacency & atmospheric correction for lakes at 1800m altitude



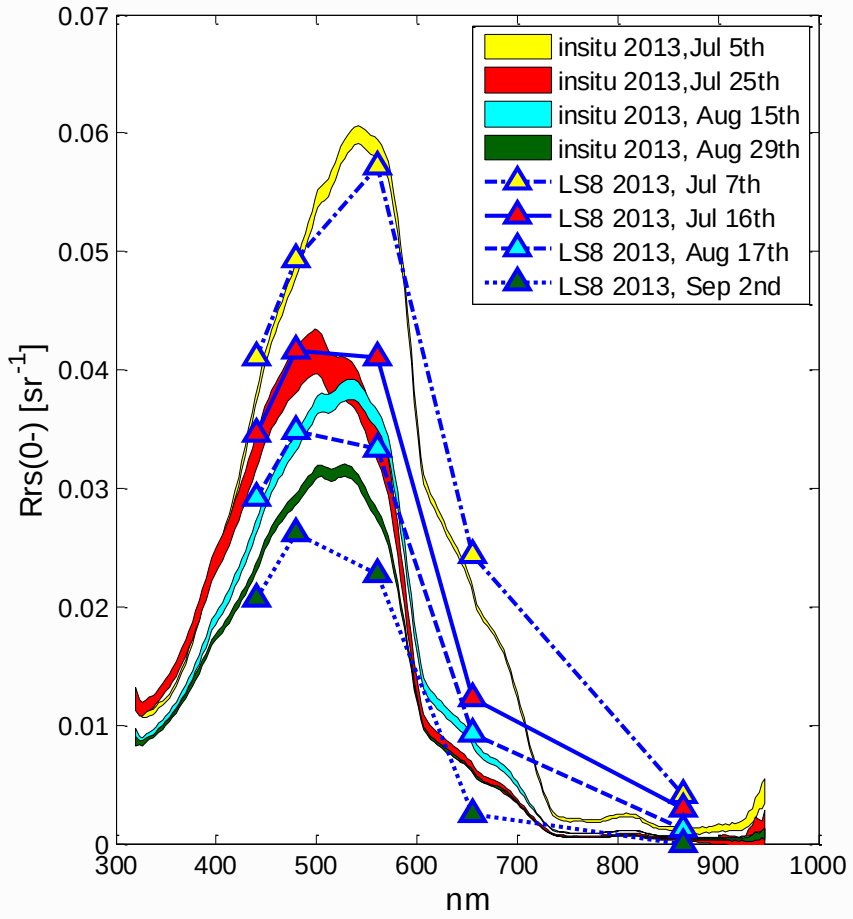


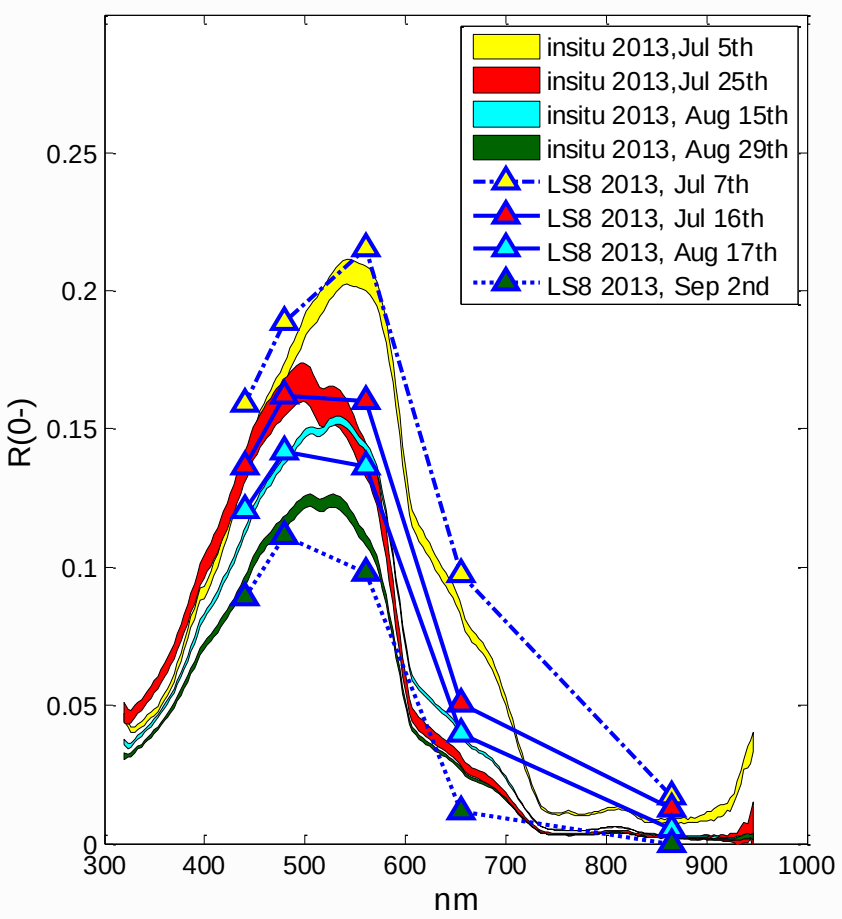
in-situ measured data vs. satellite retrieved values (2013):
top: Räterichsbodensee, bottom: Gelmersee,
in situ provided by Elisabeth Eder presented at Ocean Optics 2014

EOMAP
detect more.

Physical Validation of the Subsurface Reflectance

Examples for adjacency & atmospheric correction for lakes at 1800m altitude



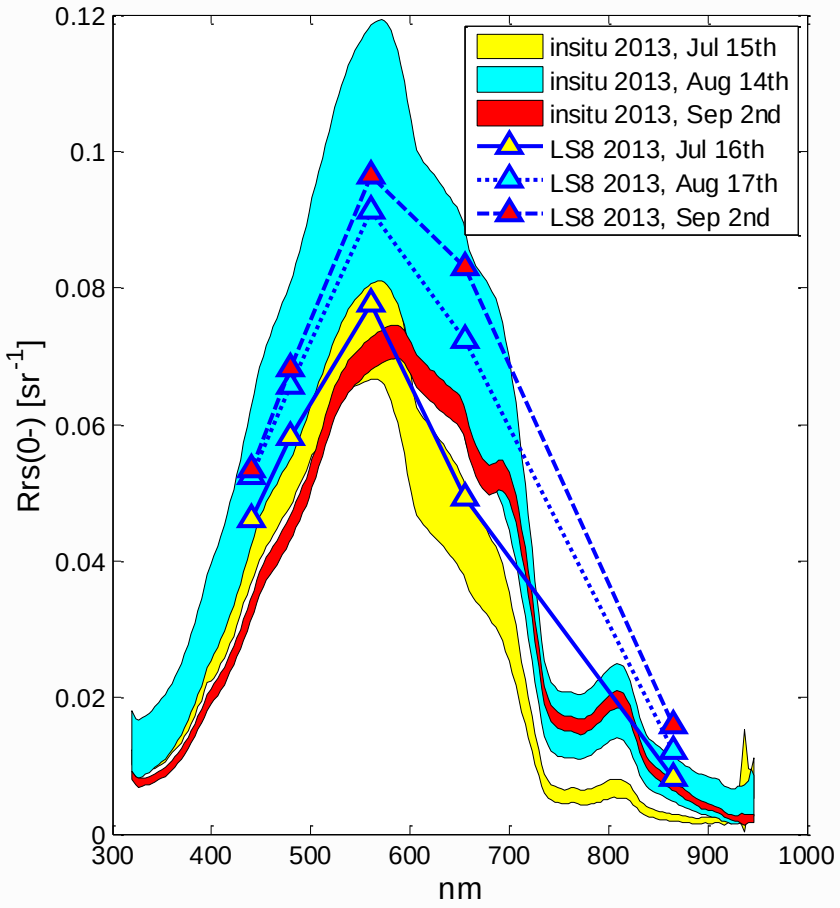


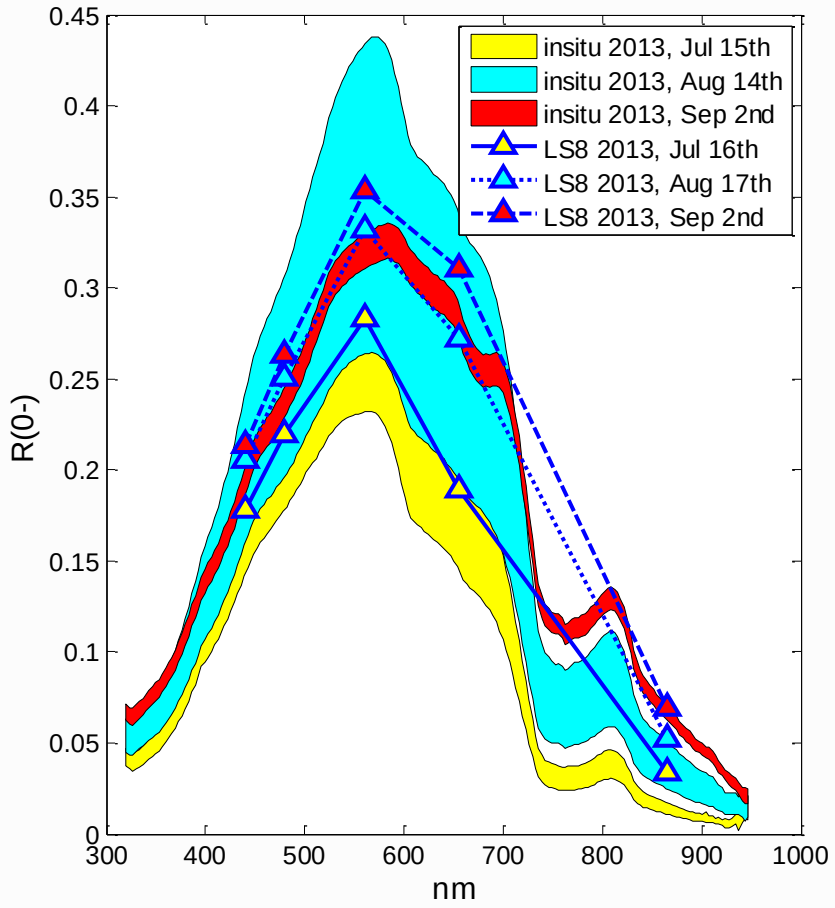
Gelmersee
in-situ measured data vs. satellite retrieved values (2013):
in situ provided by Elisabeth Eder, presented at Ocean Optics 2014

EOMAP
detect more.

Physical Validation of the Subsurface Reflectance

Examples for adjacency & atmospheric correction for lakes at 1800m altitude

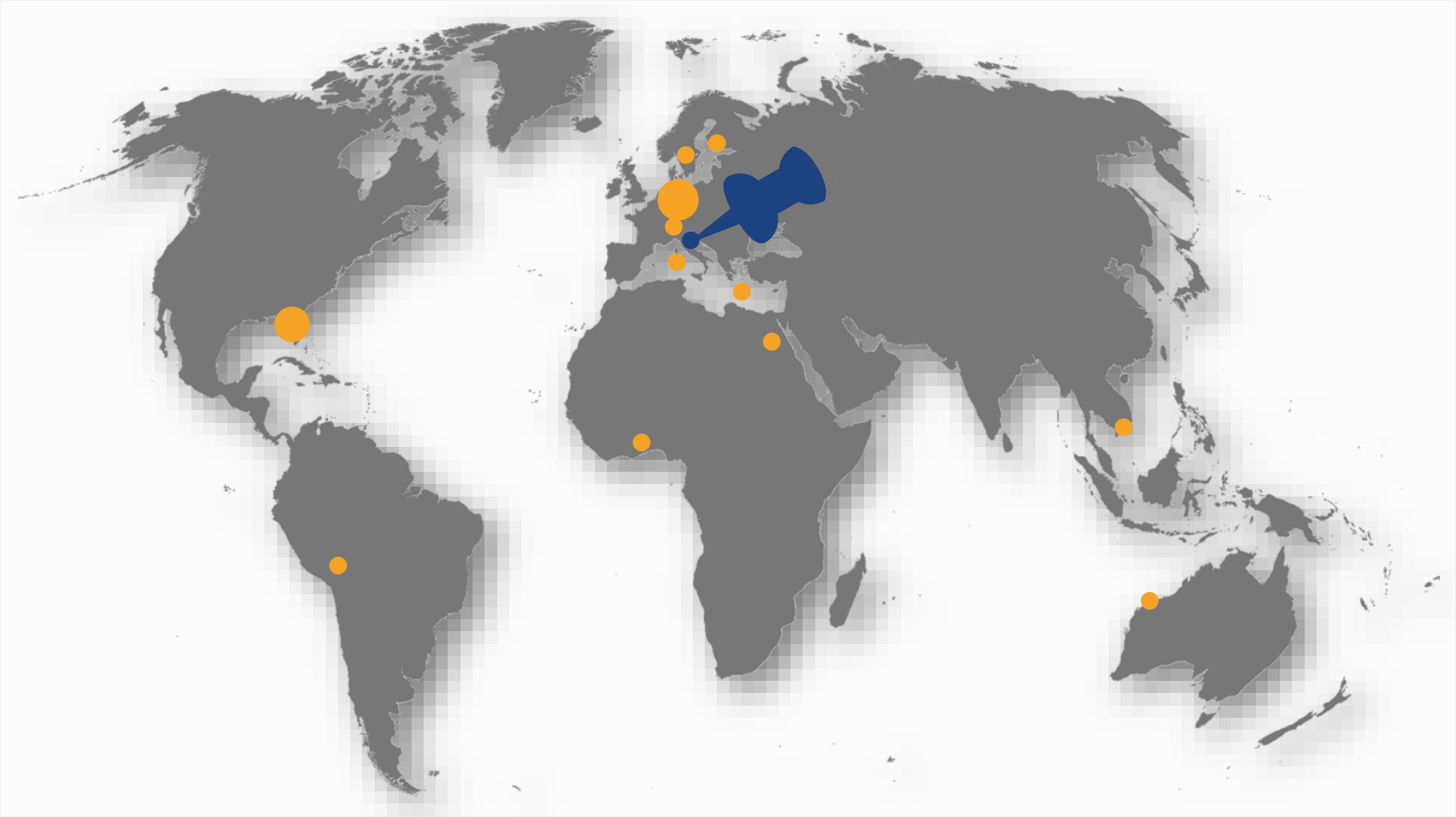




Räterichsbodensee
in-situ measured data vs. satellite retrieved values (2013):
in situ provided by Elisabeth Eder, presented at Ocean Optics 2014

EOMAP
detect more.

Po-Delta, Italy



EOMAP
detect more.

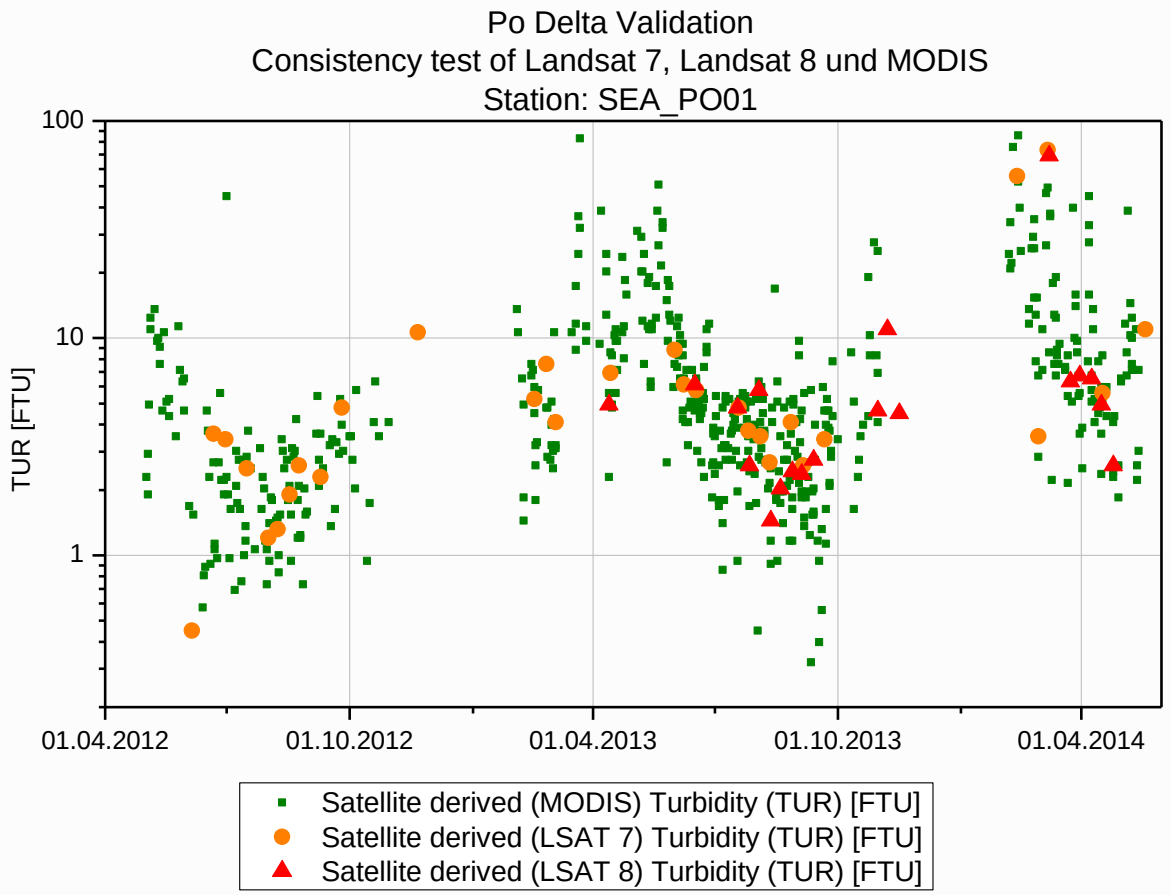
Validation Po-Delta, Italy

Location	Po river delta, Italy
Time Period	2012-2014
Parameter	Turbidity
Sensor	MERIS, Landsat 7 ETM+, Landsat 8
Spatial Resolution	500m, 30m
Stations	PO_SEA01
Mean signal depth	~2-5 m

EOMAP
detect more.

Validation Po-Delta, Italy

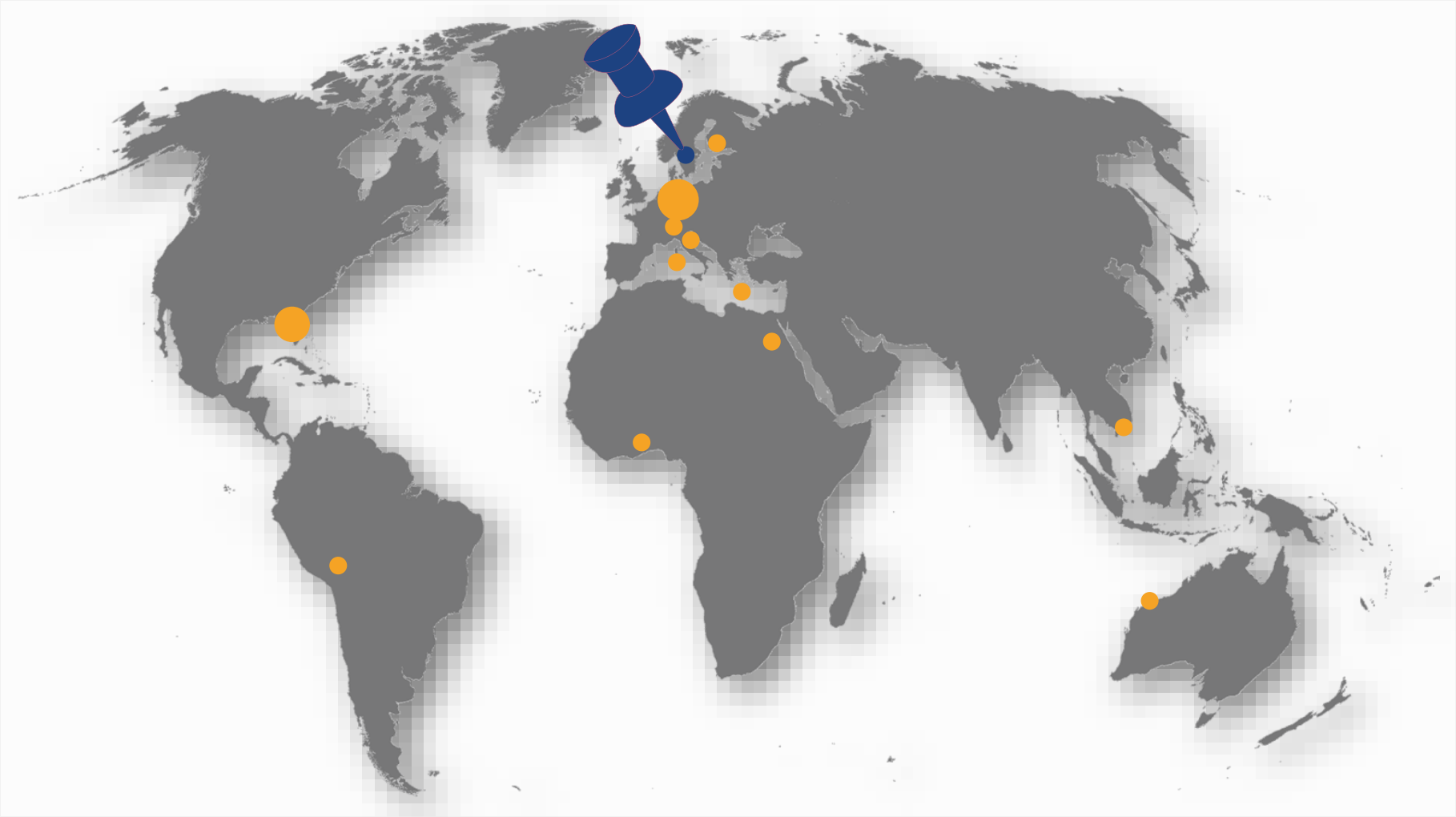
Turbidity: Consistency Analysis MODIS-Landsat 2012-2014



Satellite data processing: MIP © EOMAP
satellite data source: NASA for MODIS (Aqua and Terra) and USGS for Landsat 7 ETM+/8
Processor MIP version: 2015 Q3
Reference: Commercial contract ISPRA

detect more.

Lake Vänern, Sweden



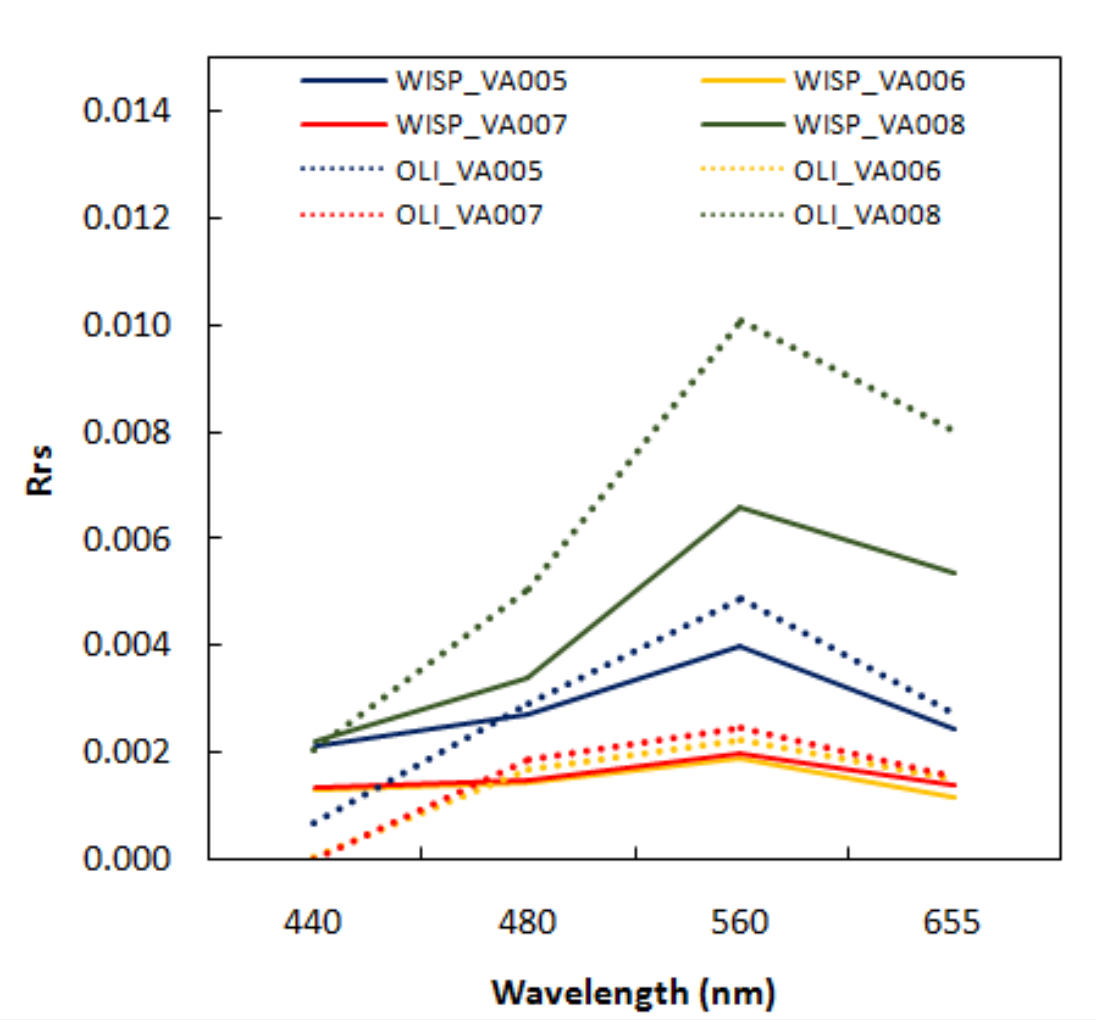
EOMAP
detect more.

Validation Lake Vänern, Sweden
Atmospheric correction

Location	Lake Vänern, Sweden
Lake/river size	Approx. 5600 km²
Time Period	2015
Parameter	Remote Sensing Reflectance
Sensor	Sentinel-2A, Landsat 8
Spatial Resolution	10m, 30m
Stations	Field campaign stations
Validation data provided by	GLaSS consortium partners (Water Insight, Brockmann Consult. Brockmann Geomatics, Tartu Observatory, SYKE, CNR, EOMAP, STICHTING VU-VUMC)
Reference	GLaSS Project (2013-2016): D4.2 Validation report for Nearby Lakes (available upon request)

EOMAP
detect more.

Validation Lake Vänern, Sweden
Atmospheric correction

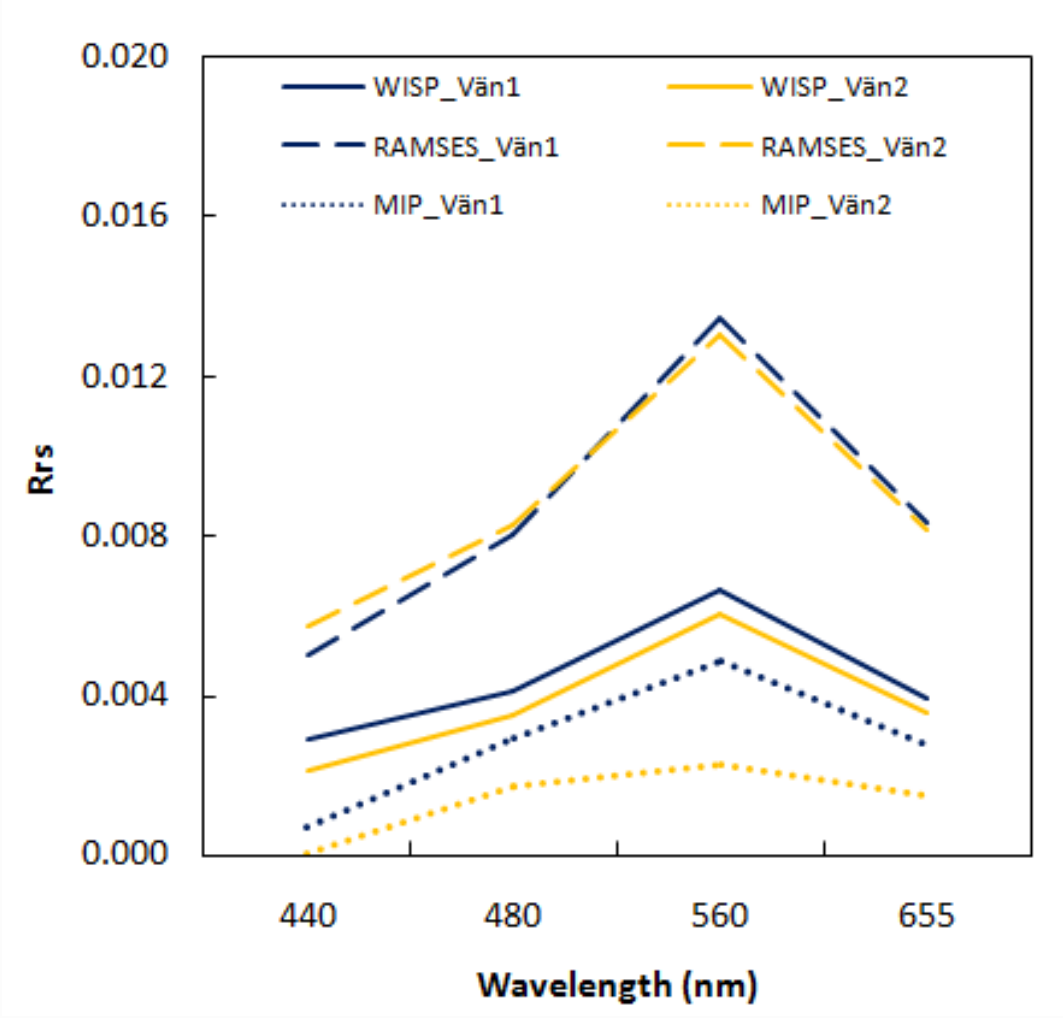


Reflectance spectra of WISP-3 and Landsat 8 (OLI) using MIP in-situ and satellite (both 30th of August 2015)

Good spectral shape and reasonable intensity between satellite and in situ

EOMAP
detect more.

Validation Lake Vänern, Sweden
Atmospheric correction



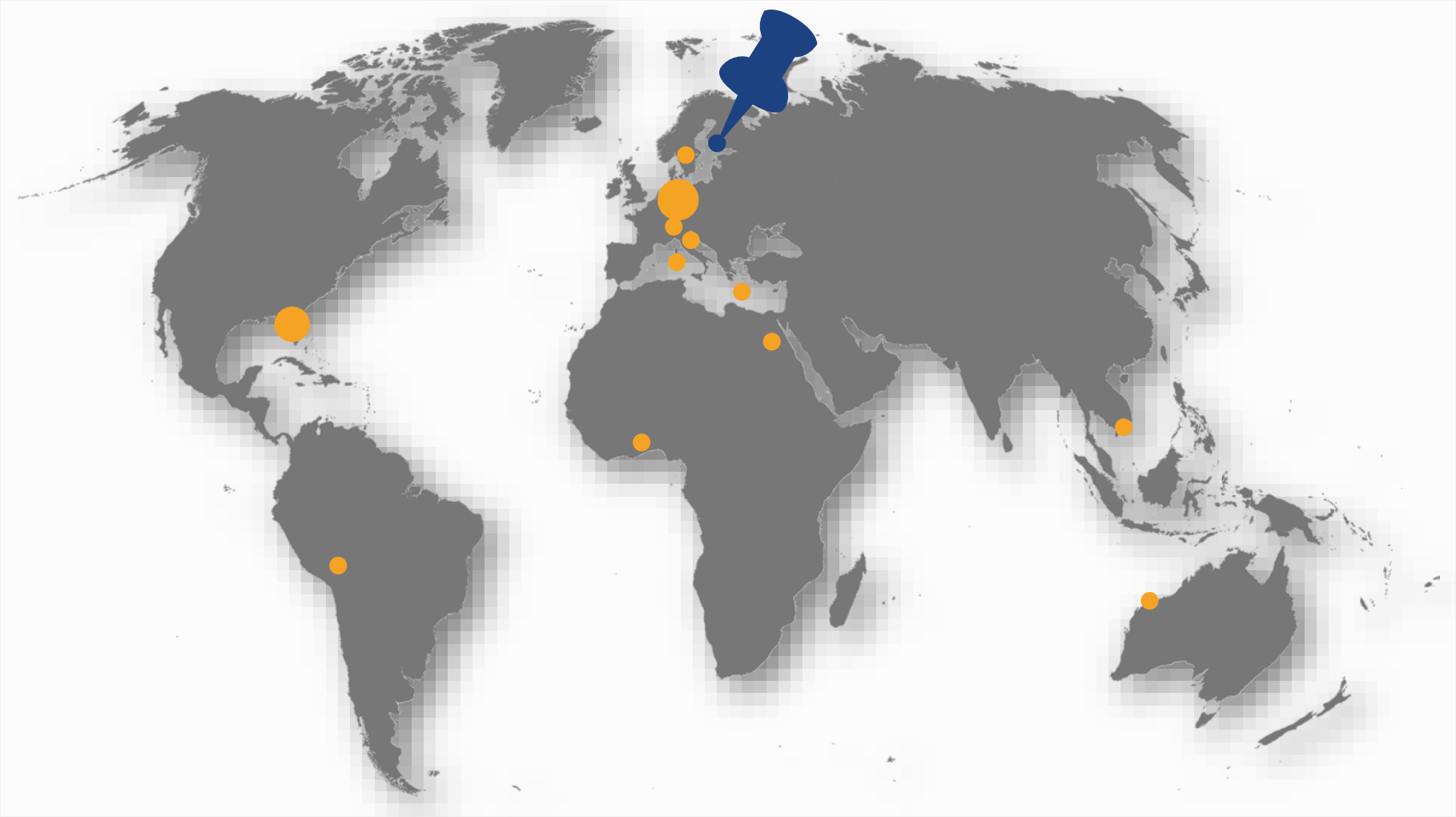
Sentinel 2

Reflectance spectra of WISP-3, RAMSES and Sentinel 2-A MSI for Lake Vänern in-situ (30th of August 2015) and satellite (29th of August 2015)

→ Large differences between in situ measurements

EOMAP
detect more.

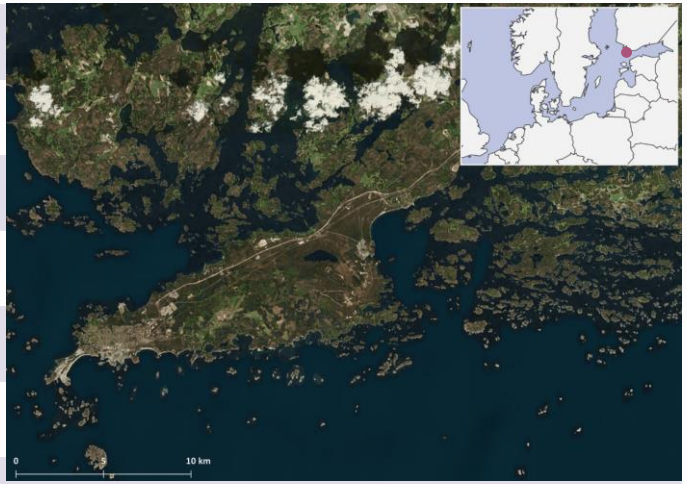
Bay Tvärminne, Finland



EOMAP
detect more.

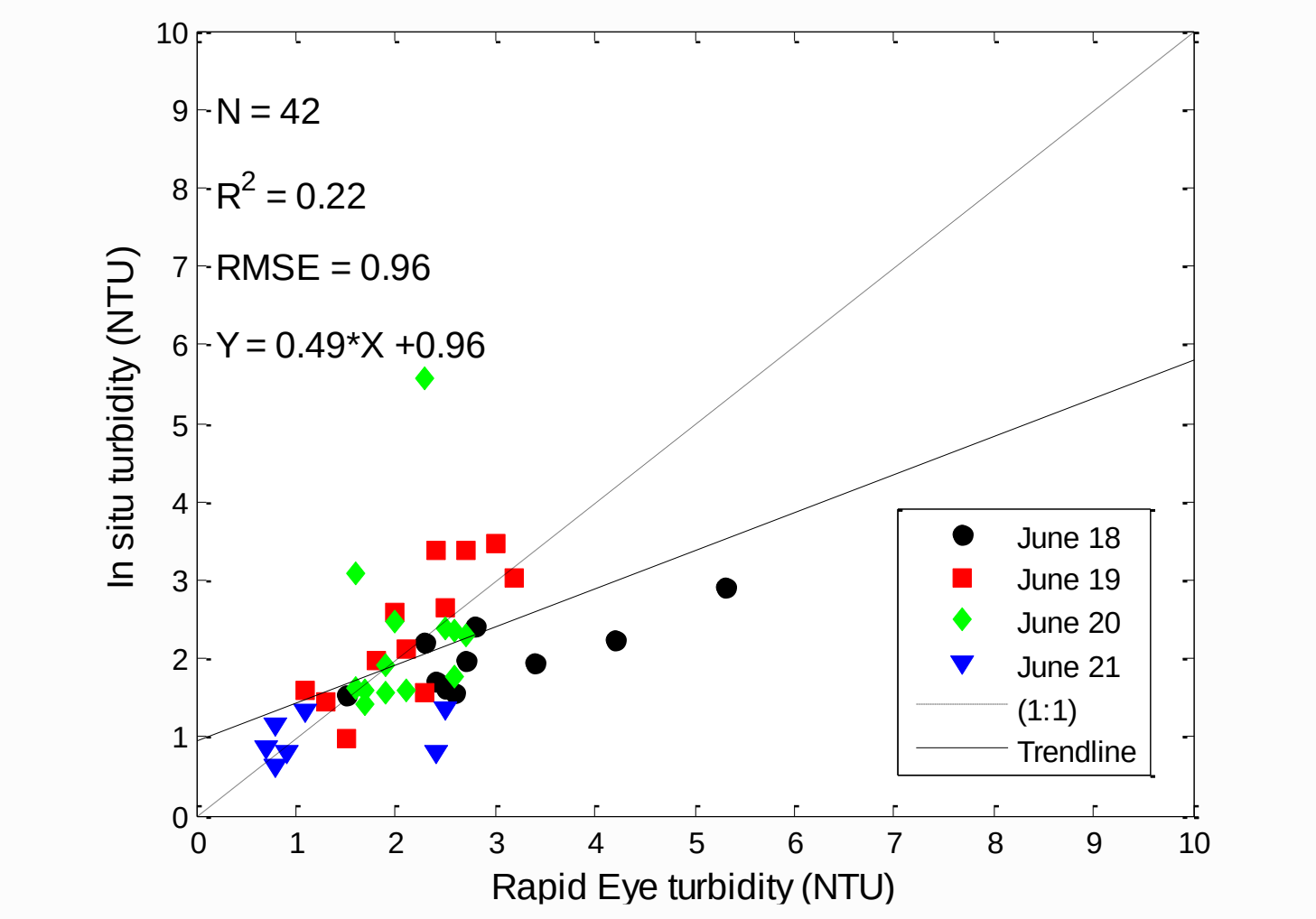
Validation Tvärminne, Finland

Location	Bay Tvärminne, Finland
Time Period	June 2012
Parameter	Signal Depth Z90, Total Suspended Matter, Turbidity
Sensor	RapidEye
Spatial Resolution	5m
Validation data provided by	Finnish Game and Fisheries Research Institute
Reference	FRESHMON project (2010-2013): D54.3 Report on FRESHMON data quality and data comparability (available upon request) D54.3_2 Update Report on FRESHMON data quality and data comparability (available upon request)



EOMAP
detect more.

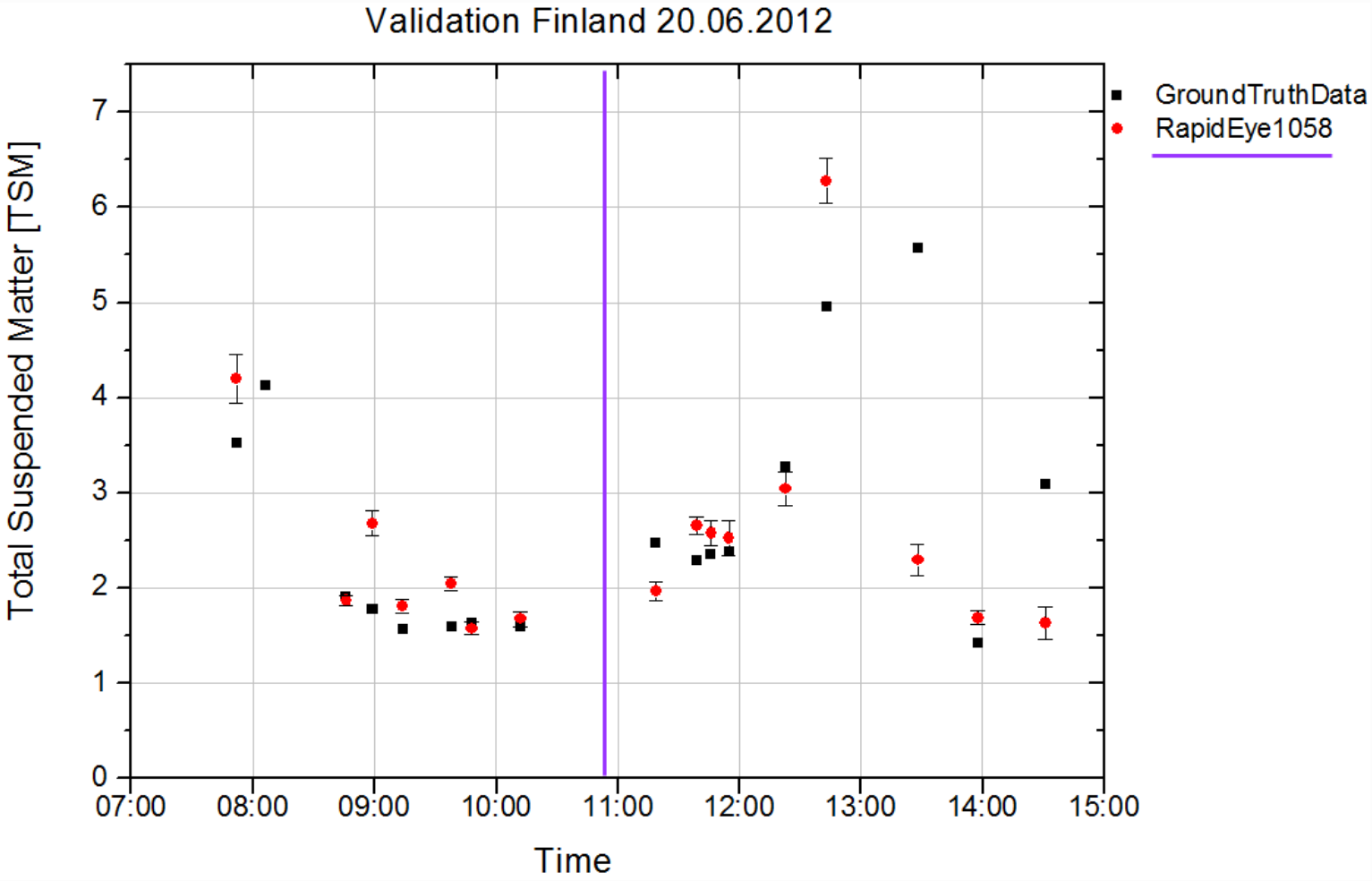
Validation Tvärminne, Finland



Processor MIP version: 2013
In-situ data kindly provided by: Syke Finnish Environment Institute
Reference: EU FRESHMON Project

detect more.

Validation Tvärminne, Finland

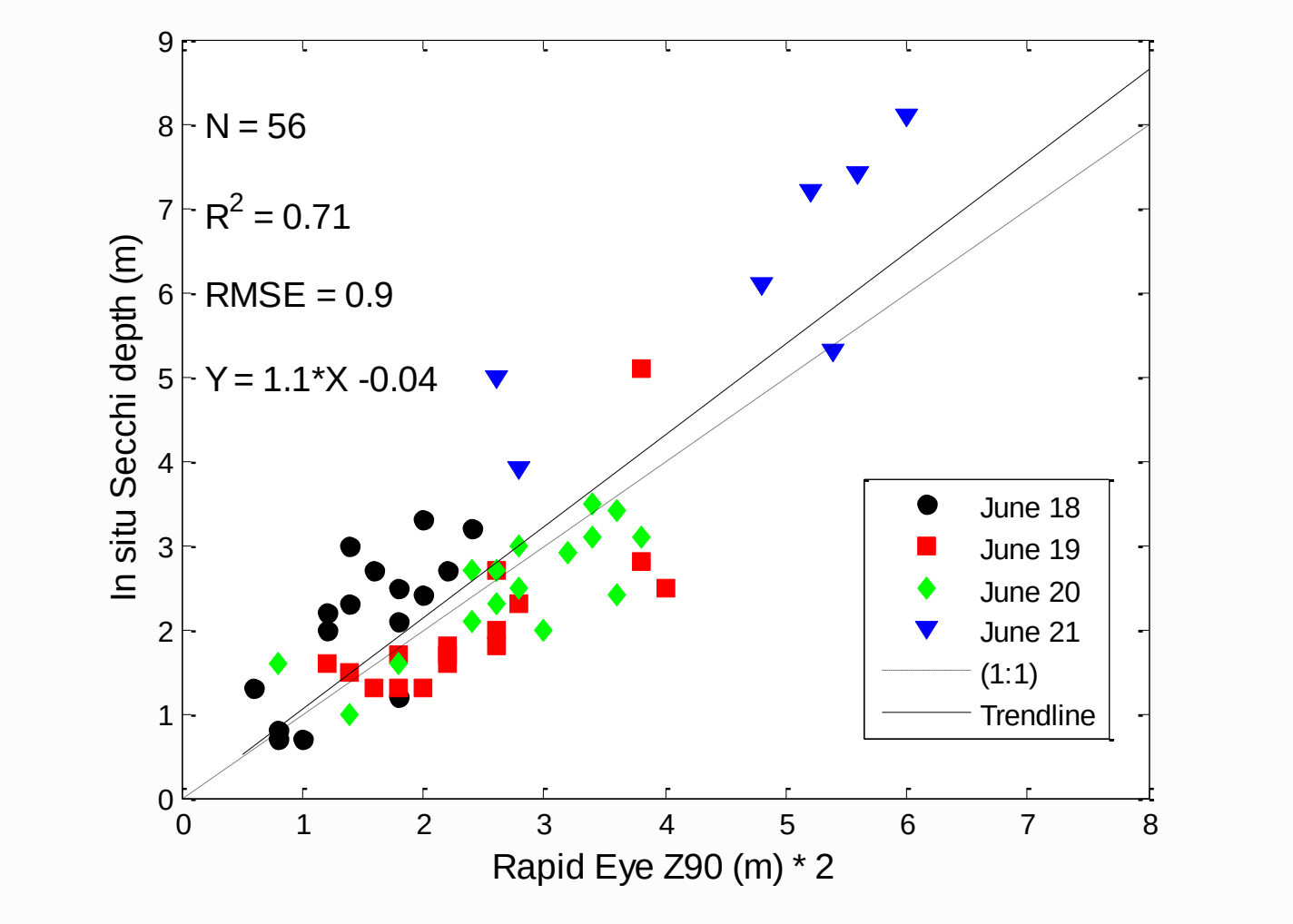


Processor MIP version: 2013
In-situ data kindly provided by: Syke Finnish Environment Institute
Reference: EU FRESHMON Project

detect more.

Validation Tvärminne, Finland

RapidEye water transparency validation 20 June 2012



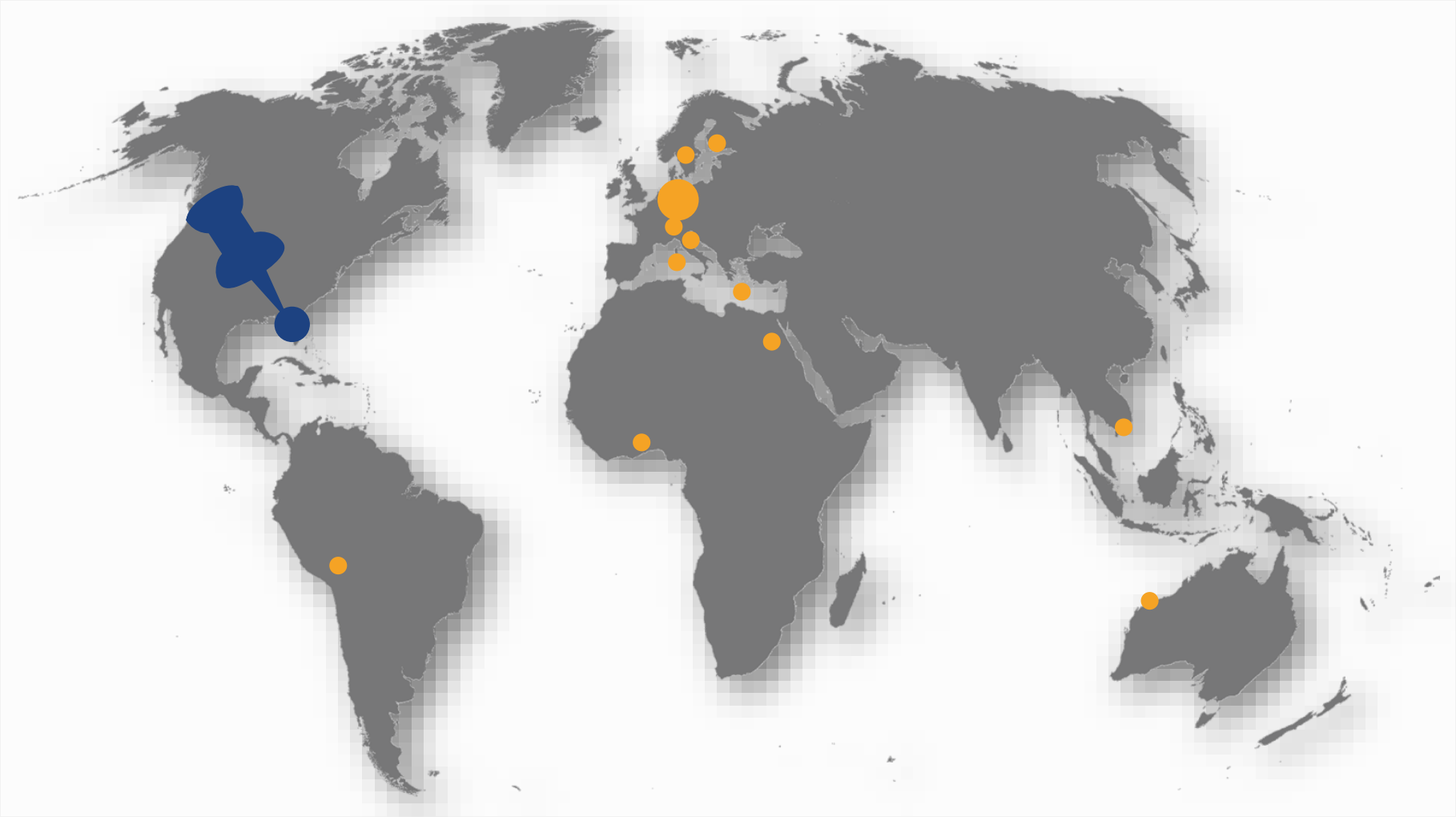
Processor MIP version: 2013
In-situ data kindly provided by: Syke Finnish Environment Institute
Reference: EU FRESHMON Project

detect more.

North and South America

detect more.

Florida, USA



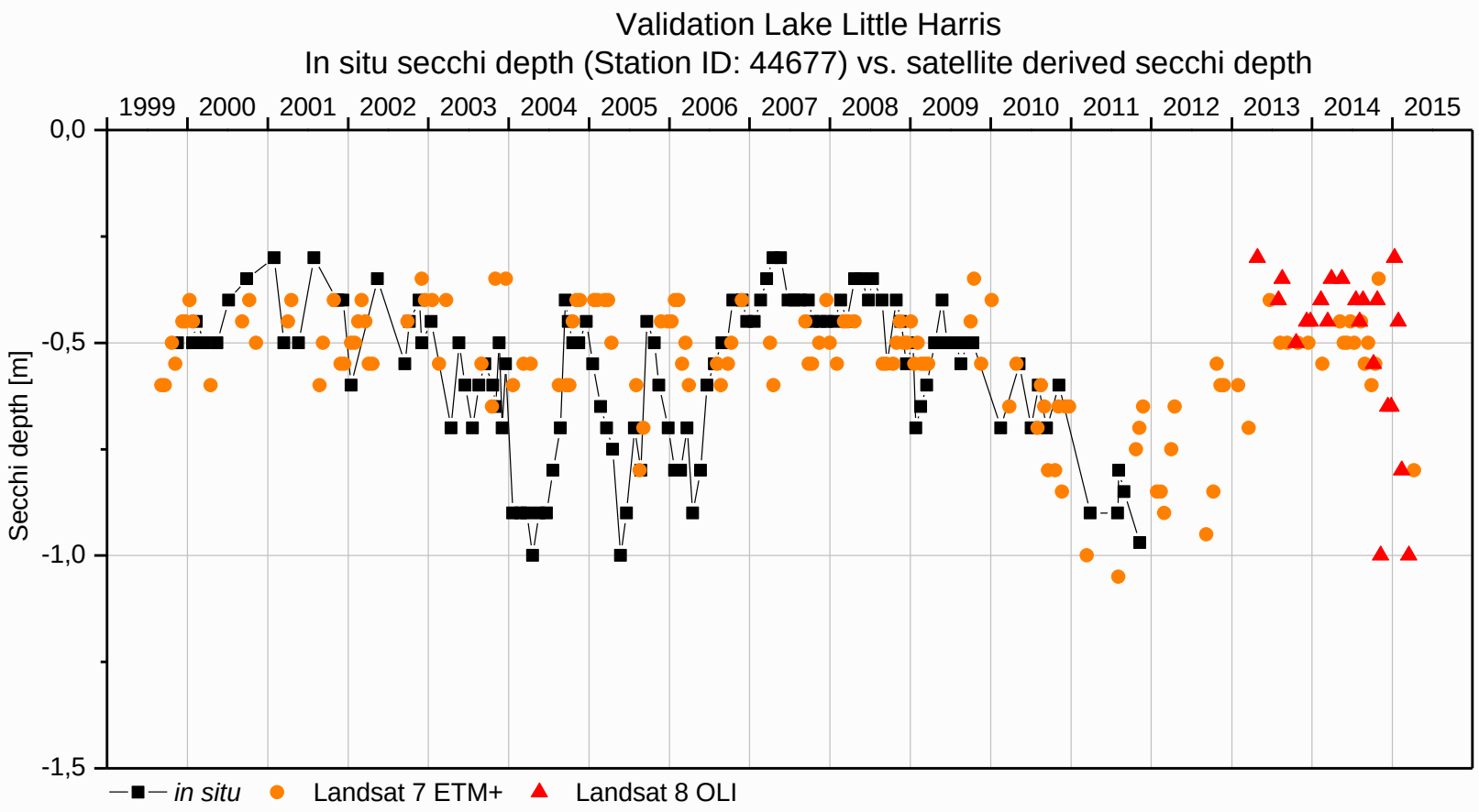
detect more.

Validation Lake Little Harris, Florida/US

Location	Little Harris, Florida/US
Time Period	1999-2015
Parameter	Chlorophyll-a, Secchi Depth, Turbidity,
Sensor	Landsat
Spatial Resolution	30m
Validation data provided by	http://www.wateratlas.usf.edu/

EOMAP
detect more.

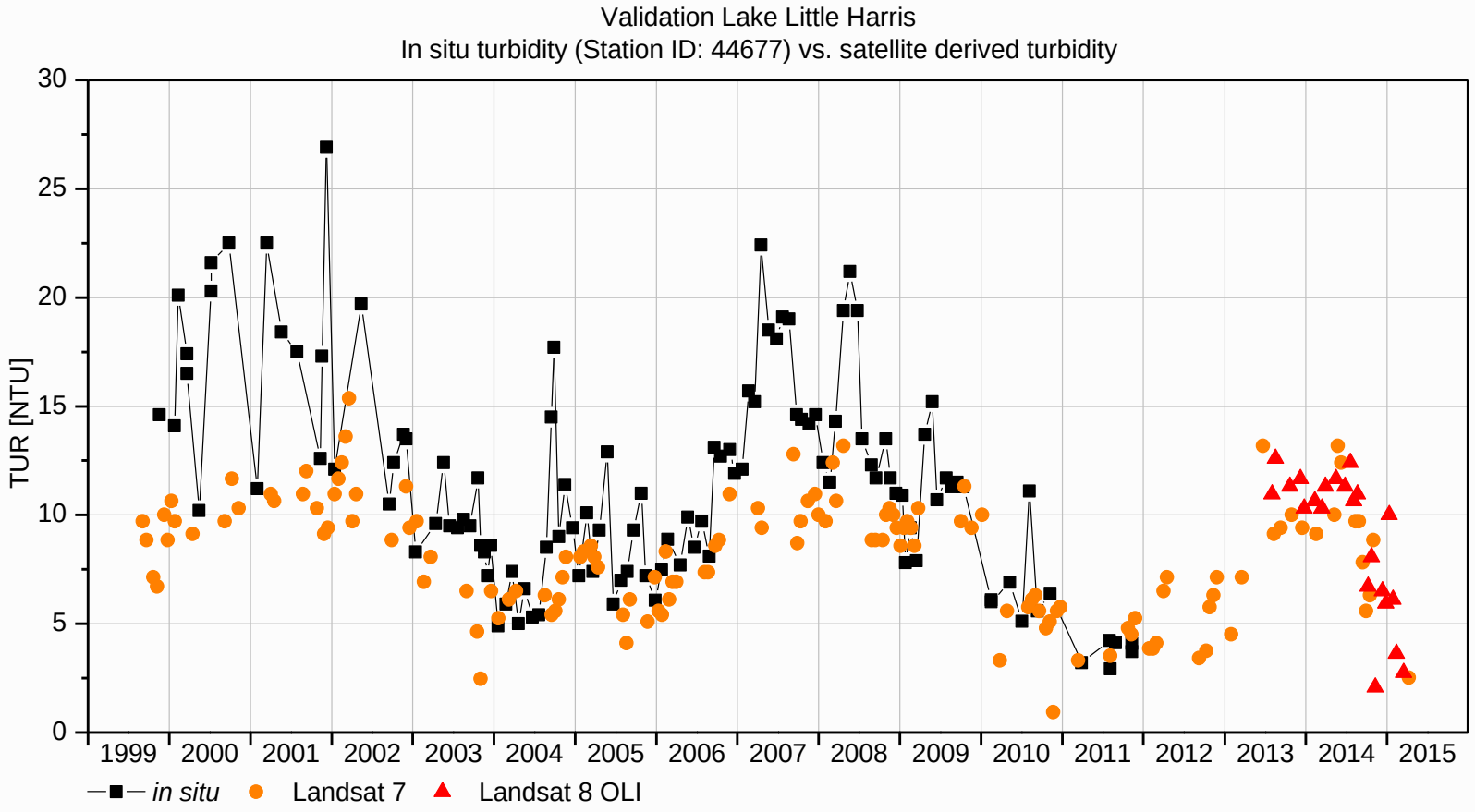
Validation Lake Little Harris, Florida/US
Secchi Depth 1999-2015



Processor MIP version: 2015 Q3
In-situ data kindly provided by: Lake County Water Authority, USF Water Institute (2015)
Reference: Broszeit 2015, http://www.seminole.wateratlas.usf.edu/waterresourcesearch.aspx, 30.9.2015

detect more.

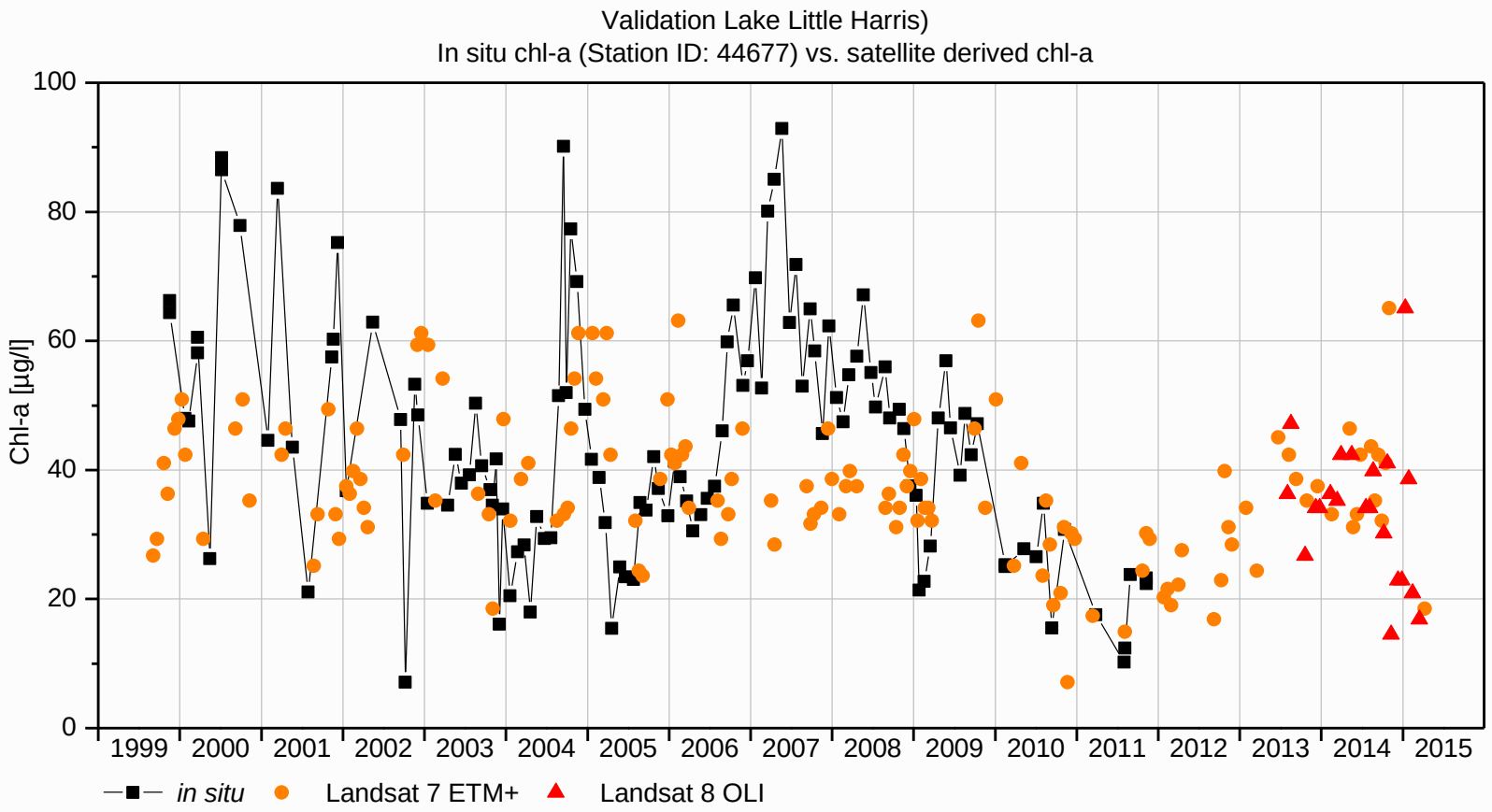
Validation Lake Little Harris, Florida/US
Turbidity 1999-2015



Processor MIP version: 2015 Q3
In-situ data kindly provided by: Lake County Water Authority, USF Water Institute (2015)
Reference: Broszeit 2015, http://www.seminole.wateratlas.usf.edu/waterresourcesearch.aspx, 30.9.2015

EOMAP
detect more.

Validation Lake Little Harris, Florida/US
Chlorophyll-a 1999-2015



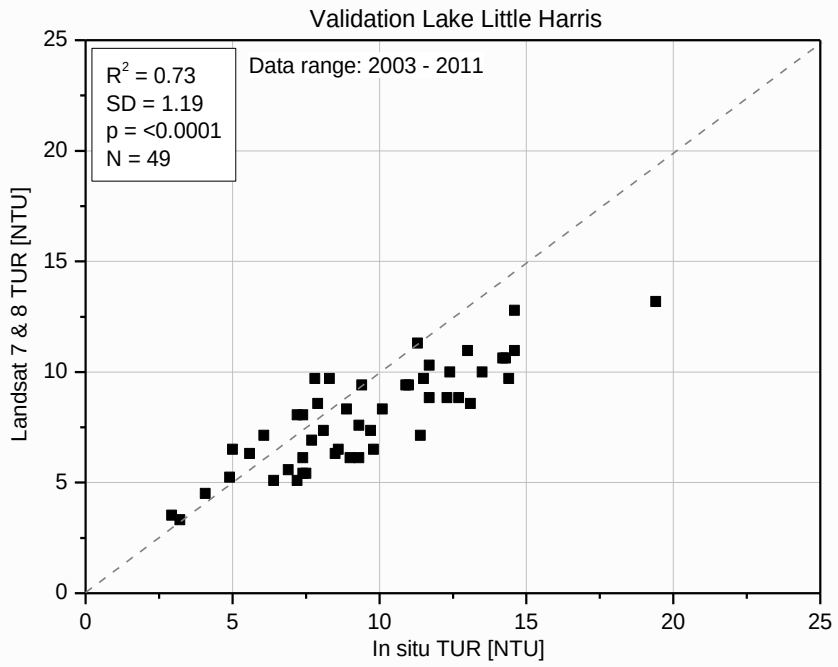
Processor MIP version: 2015 Q3
In-situ data kindly provided by: Lake County Water Authority, USF Water Institute (2015)
Reference: Broszeit 2015, http://www.seminole.wateratlas.usf.edu/waterresourcesearch.aspx, 30.9.2015

EOMAP
detect more.

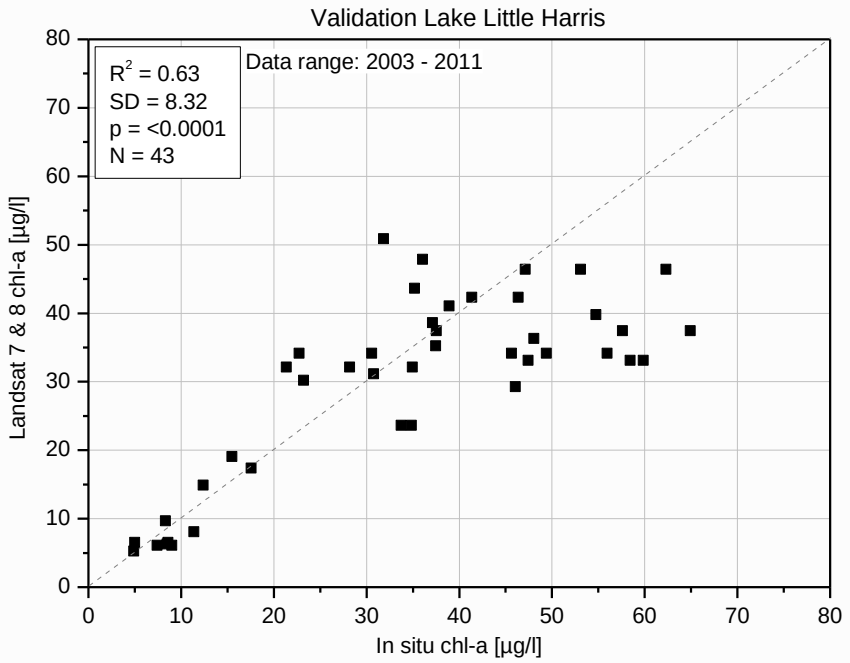
Validation Lake Little Harris, Florida/US

Up to 10 days time difference between in-situ and satellite

Turbidity



Chlorophyll-a

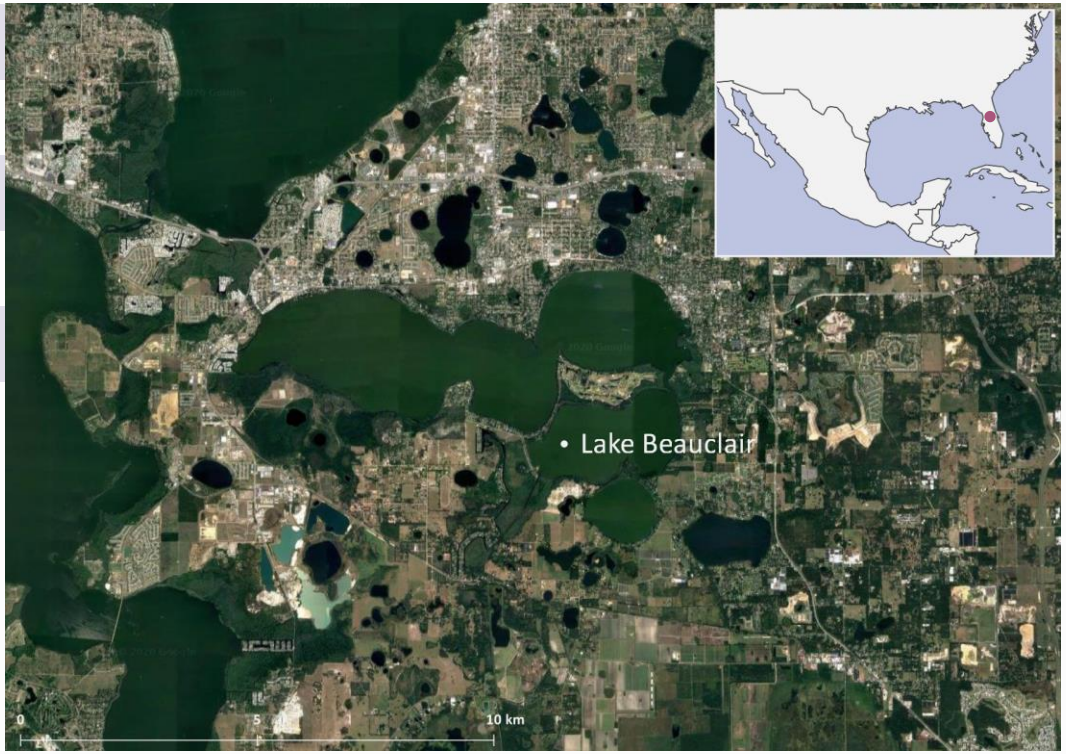


Processor MIP version: 2015 Q3
In-situ data kindly provided by: Lake County Water Authority, USF Water Institute (2015)
Reference: Broszeit 2015, http://www.seminole.wateratlas.usf.edu/waterresourcesearch.aspx, 30.9.2015

EOMAP
detect more.

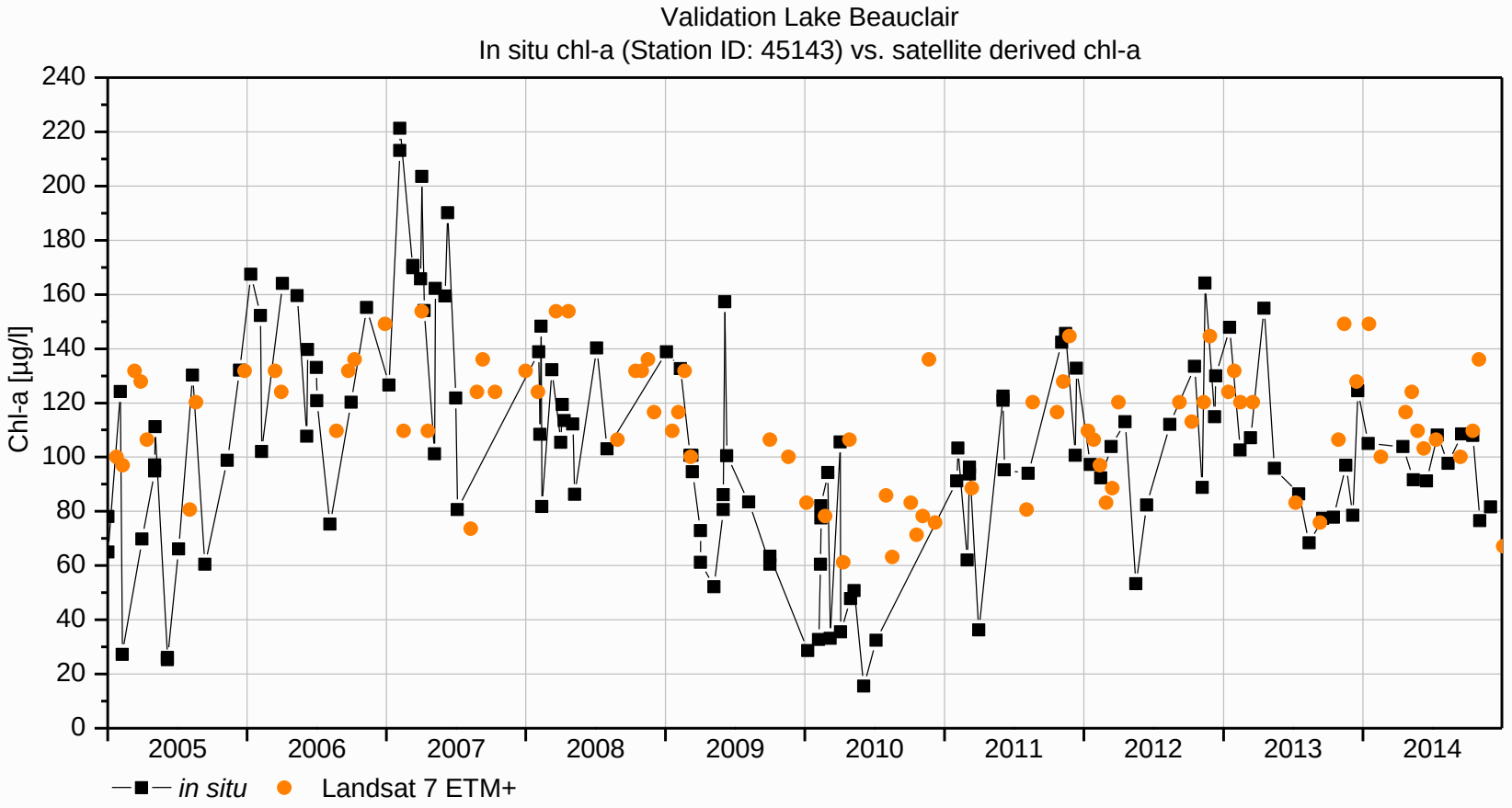
Validation Lake Beauclair, Florida/US

Location	Beauclair, Florida/US
Time Period	2005-2014
Parameter	Chlorophyll-a
Sensor	Landsat
Spatial Resolution	30m
Validation data provided by	http://www.wateratlas.usf.edu/



EOMAP
detect more.

Validation Lake Beauclair, Florida/US
Chlorophyll-a 2005-2014



Processor MIP version: 2015 Q3
In-situ data kindly provided by: Lake County Water Authority, USF Water Institute (2015)
Reference: Broszeit 2015, http://www.seminole.wateratlas.usf.edu/waterresourcesearch.aspx, 30.9.2015

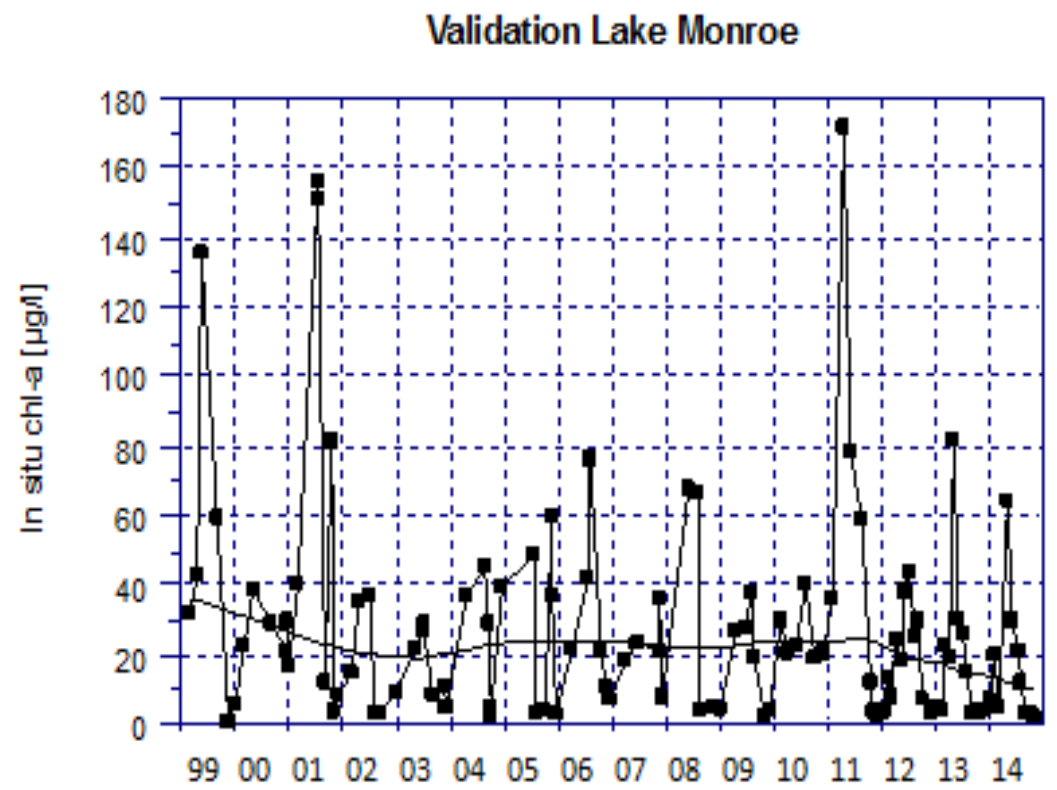
EOMAP
detect more.

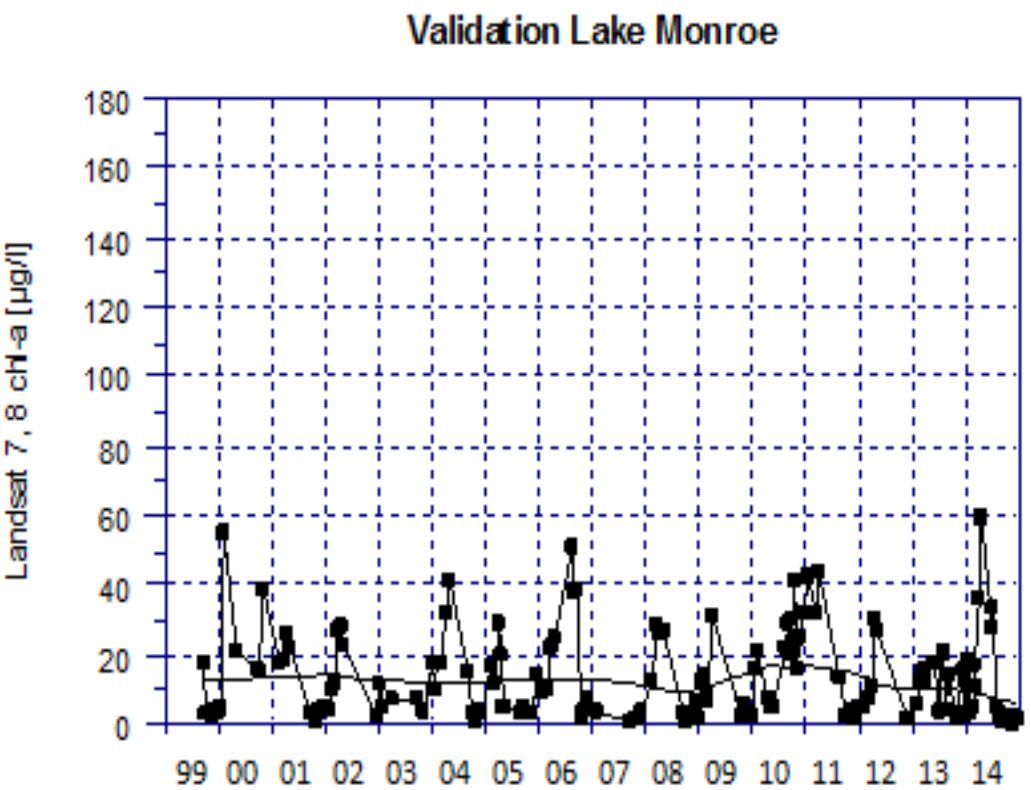
Validation Lake Monroe, Florida/US

Location	Lake Monroe, Florida/US
Time Period	1999-2014
Parameter	Chlorophyll-a, Turbidity
Sensor	Landsat
Spatial Resolution	30m
Validation data provided by	http://www.wateratlas.usf.edu/

EOMAP
detect more.

Validation Lake Monroe, Florida/US
Chlorophyll, 1999-2014





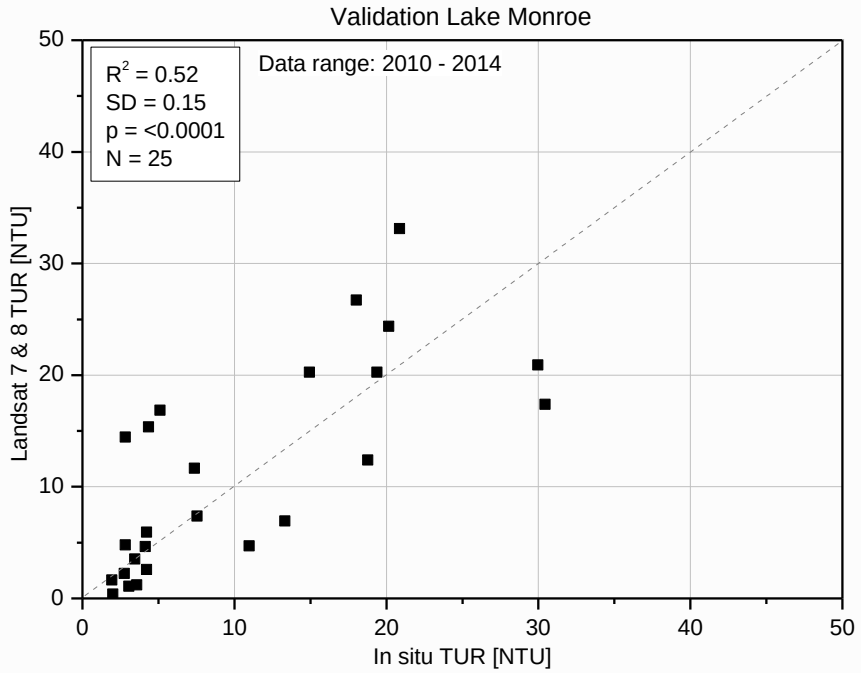
Processor MIP version: 2015 Q3
In-situ data kindly provided by: Lake County Water Authority, USF Water Institute (2015)
Reference: Broszeit 2015, http://www.seminole.wateratlas.usf.edu/waterresourcesearch.aspx, 30.9.2015

EOMAP
detect more.

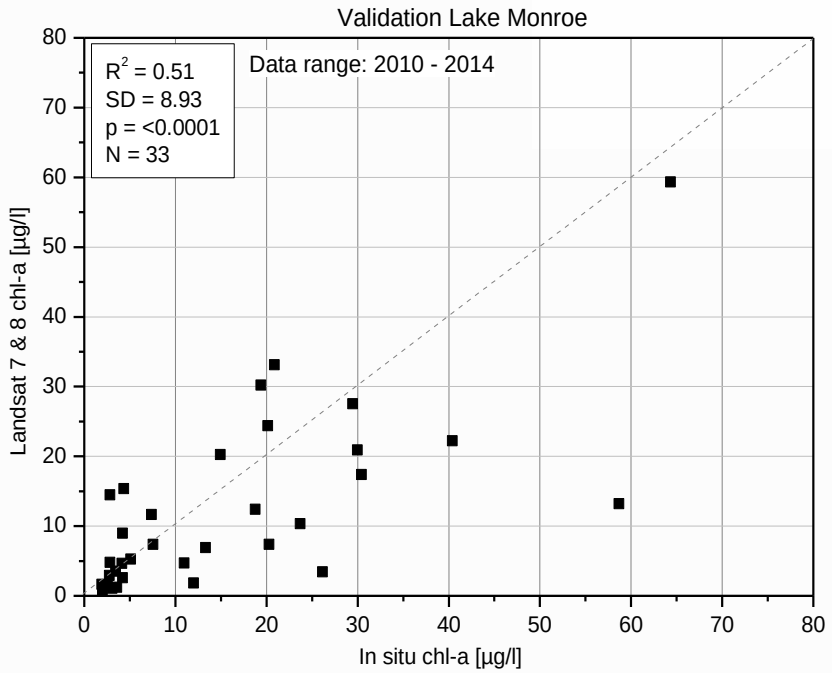
Validation Lake Monroe, Florida/US

Up to 10 days time difference between in-situ and satellite

Turbidity



Chlorophyll-a

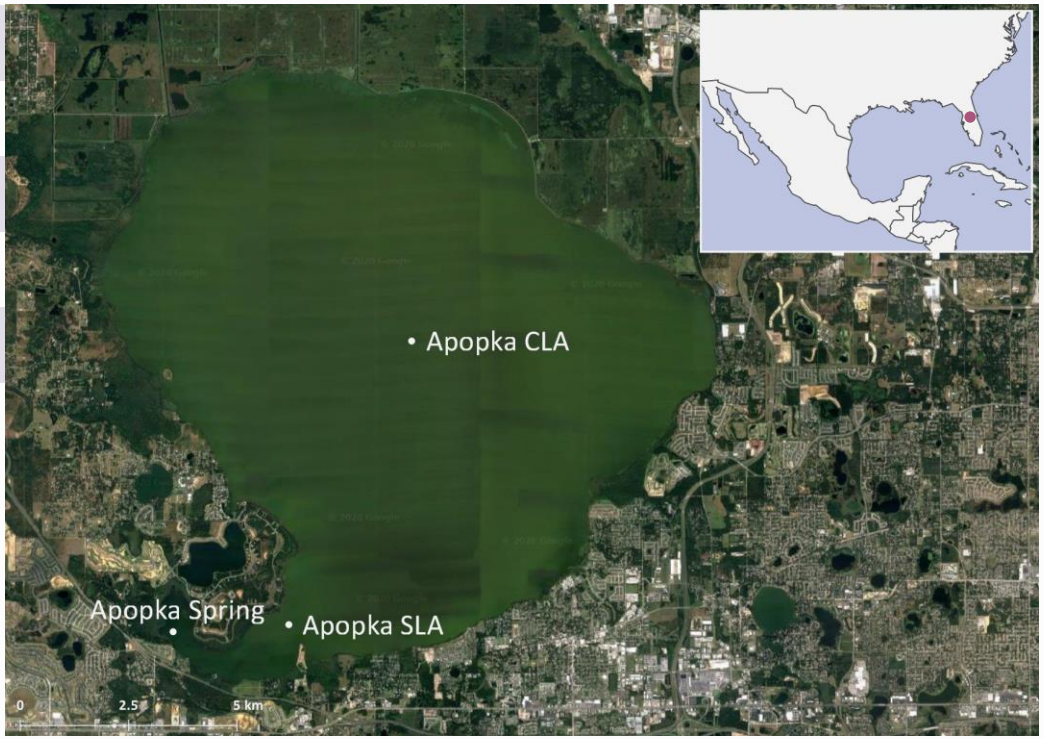


Processor MIP version: 2015 Q3
In-situ data kindly provided by: Lake County Water Authority, USF Water Institute (2015)
Reference: Broszeit 2015, http://www.seminole.wateratlas.usf.edu/waterresourcesearch.aspx, 30.9.2015

EOMAP
detect more.

Validation Lake Apopka, Florida/US

Location	Apopka Lake, Florida/US
Time Period	2000-2015
Parameter	Chlorophyll-a, Turbidity
Sensor	Landsat
Spatial Resolution	30m
Validation data provided by	http://www.wateratlas.usf.edu/

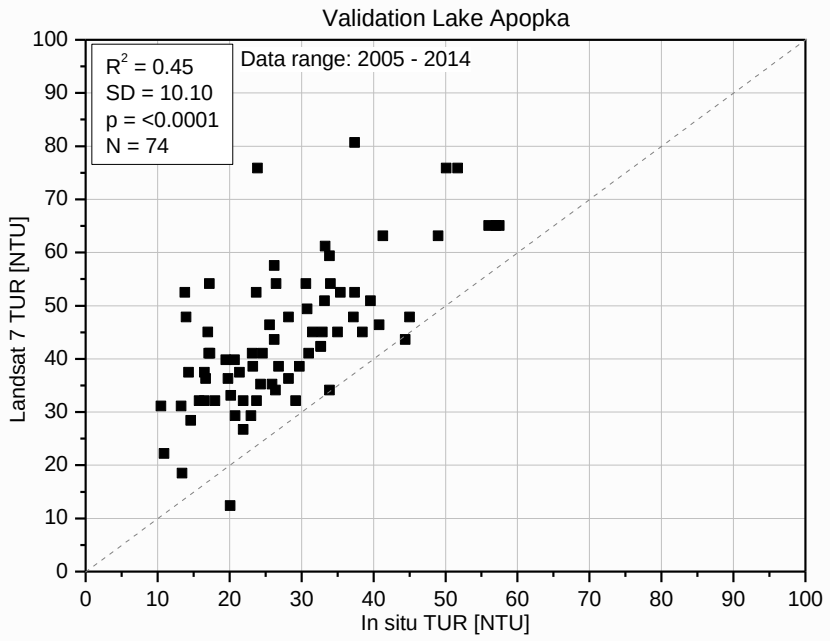


EOMAP
detect more.

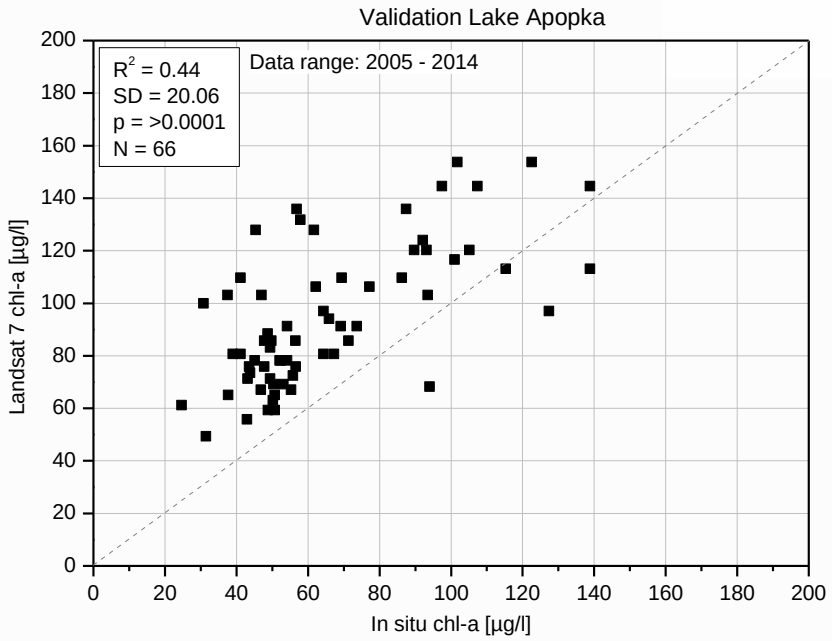
Validation Lake Apopka, Florida/US

Up to 10 days time difference between in-situ and satellite

Turbidity



Chlorophyll-a



Processor MIP version: 2015 Q3
In-situ data kindly provided by: Lake County Water Authority, USF Water Institute (2015)
Reference: Broszeit 2015, http://www.seminole.wateratlas.usf.edu/waterresourcesearch.aspx, 30.9.2015

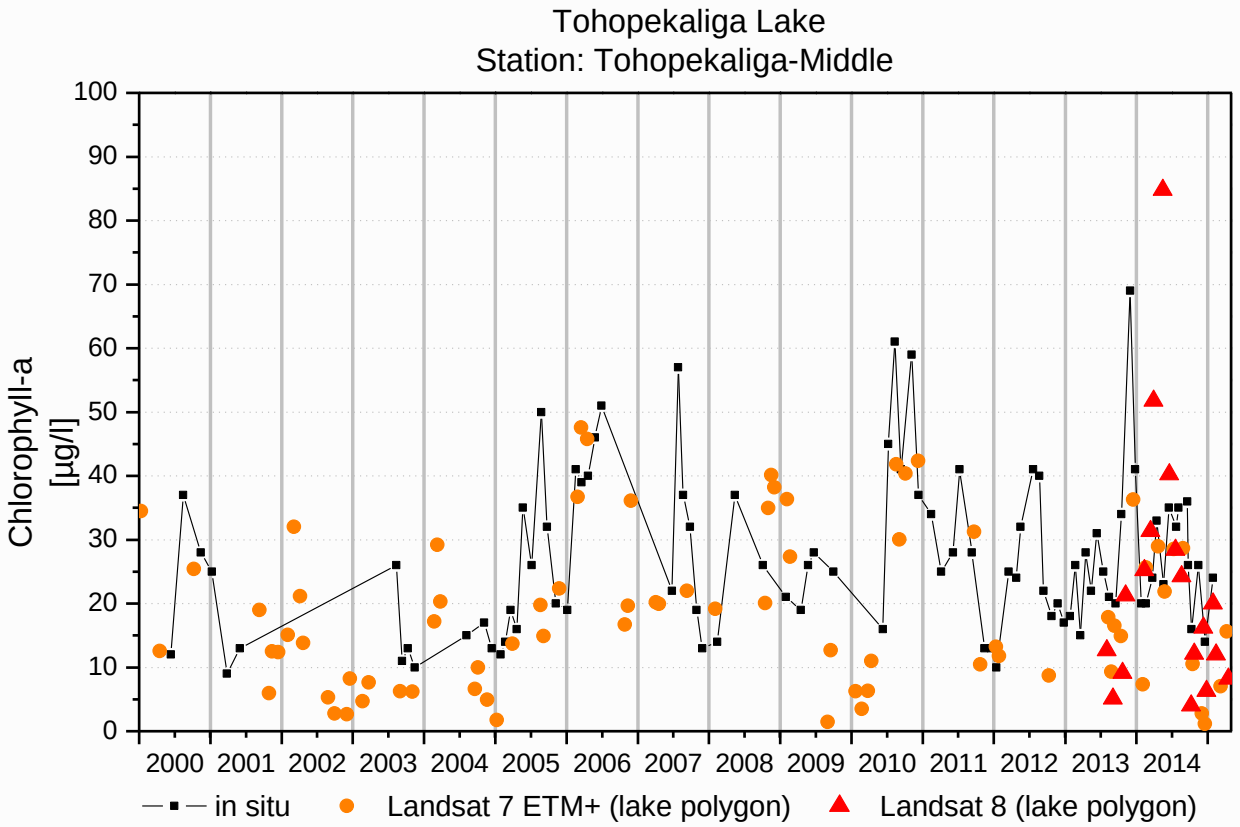
EOMAP
detect more.

Validation Lake Tohopekaliga, Florida/US

Location	Tohopekaliga Lake, Florida/US
Time Period	2008-2014
Parameter	Chlorophyll-a
Sensor	Landsat
Spatial Resolution	30m
Validation data provided by	https://lakewatch.ifas.ufl.edu/

EOMAP
detect more.

Validation Lake Tohopekaliga, Florida/US
Chlorophyll

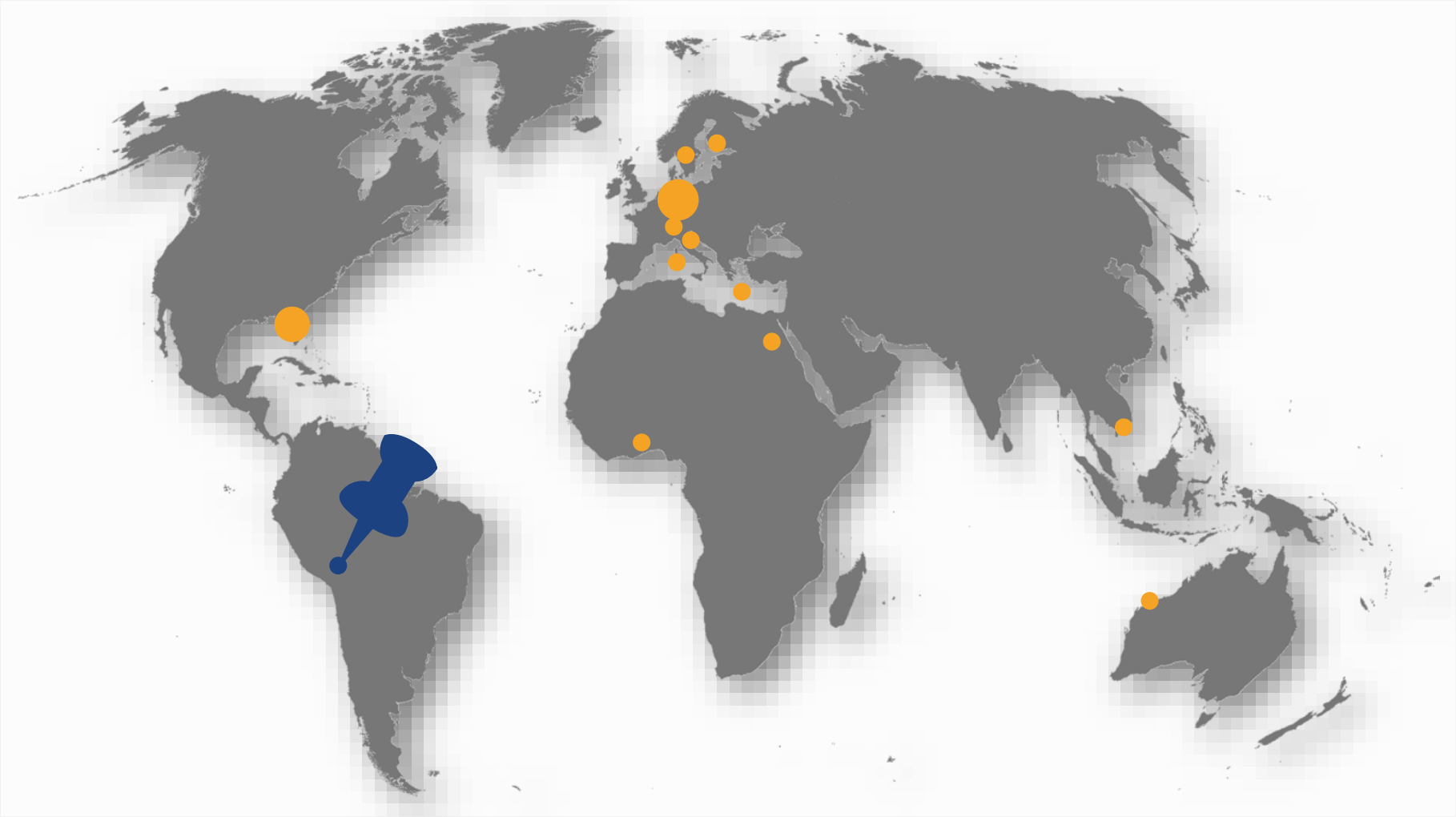


Satellite data: processing MIP © EOMAP, source data: USGS for Landsat 7ETM+ and Landsat 8
In situ data © Florida Lakewatch (http://lakewatch.ifas.ufl.edu/)

Processor MIP version: 2015 Q3
In-situ data kindly provided by: Lake County Water Authority, USF Water Institute (2015)
Reference: Broszeit 2015, http://www.seminole.wateratlas.usf.edu/waterresourcesearch.aspx, 30.9.2015

detect more.

Lake Titicaca, Bolivia/Peru



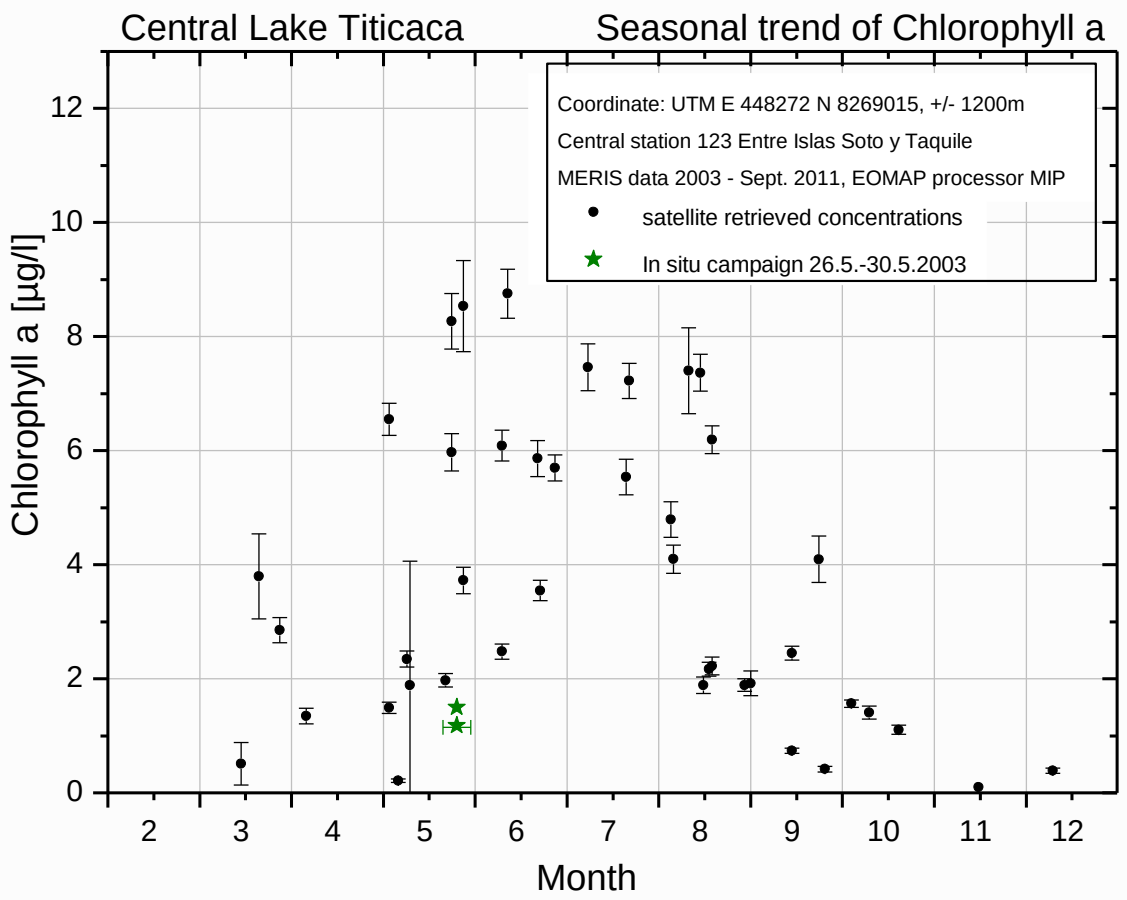
EOMAP
detect more.

Validation Bolivia/Peru

Location	Lake Titicaca, Bolivia/Peru
Lake/river size	~ 1000 km²
Time Period	2007-2010
Parameter	Chlorophyll-a, Total Suspended Matter / Turbidity
Sensor	MODIS
Spatial Resolution	250m
Station	Central station 123 Entre Islas Soto y Taquile
Reference	Eoworld project ESA – Worldbank Partnership Report: 80-85

EOMAP
detect more.

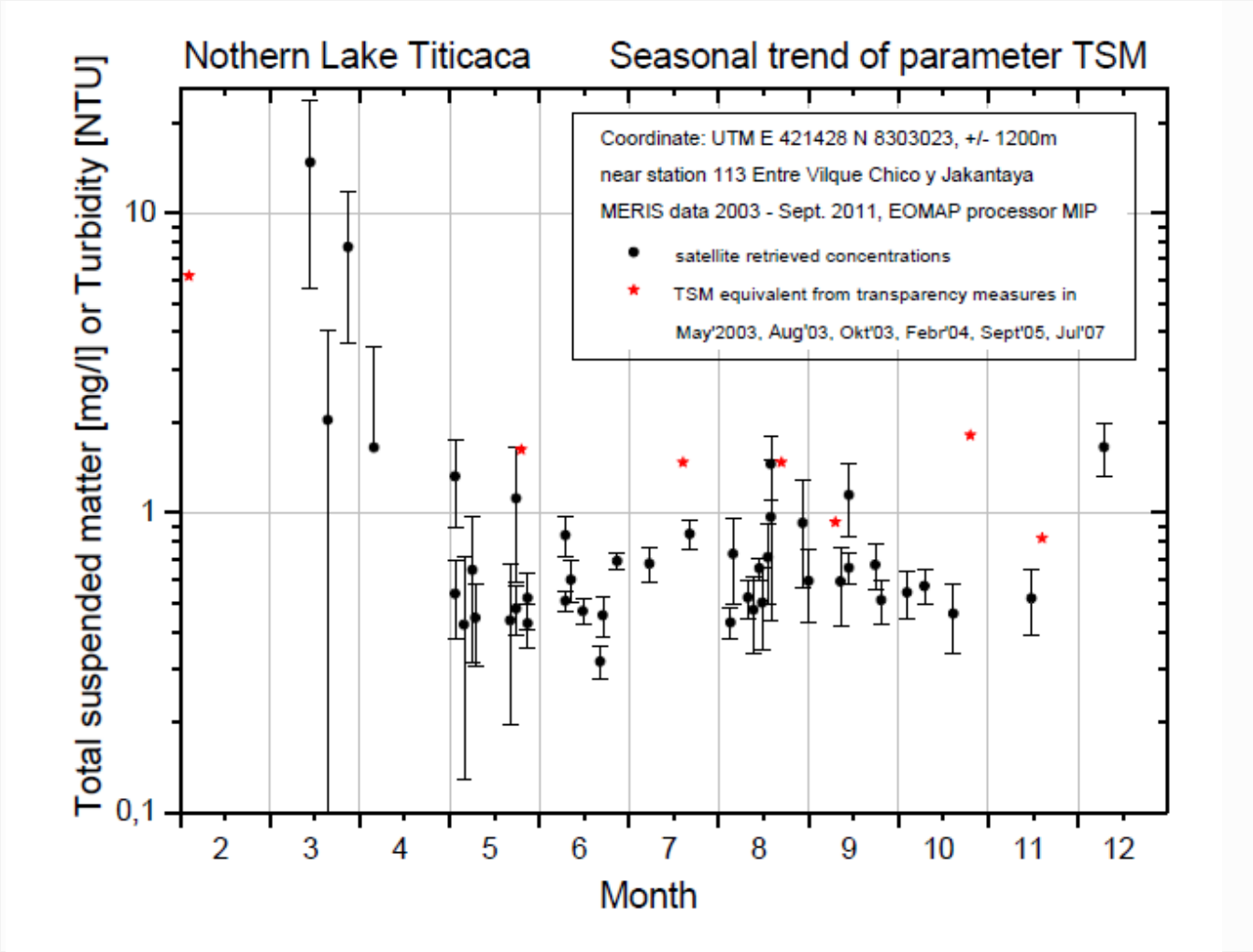
Validation Bolivia/Peru
Chlorophyll-a MODIS 250m



Processor MIP version: 2011
Reference: Commercial contract Woodside Energy. http://www.eomap.com/exchange/pdf/Hausknecht.pdf

EOMAP
detect more.

Validation Bolivia/Peru
Total Suspended Matter MERIS 300 m

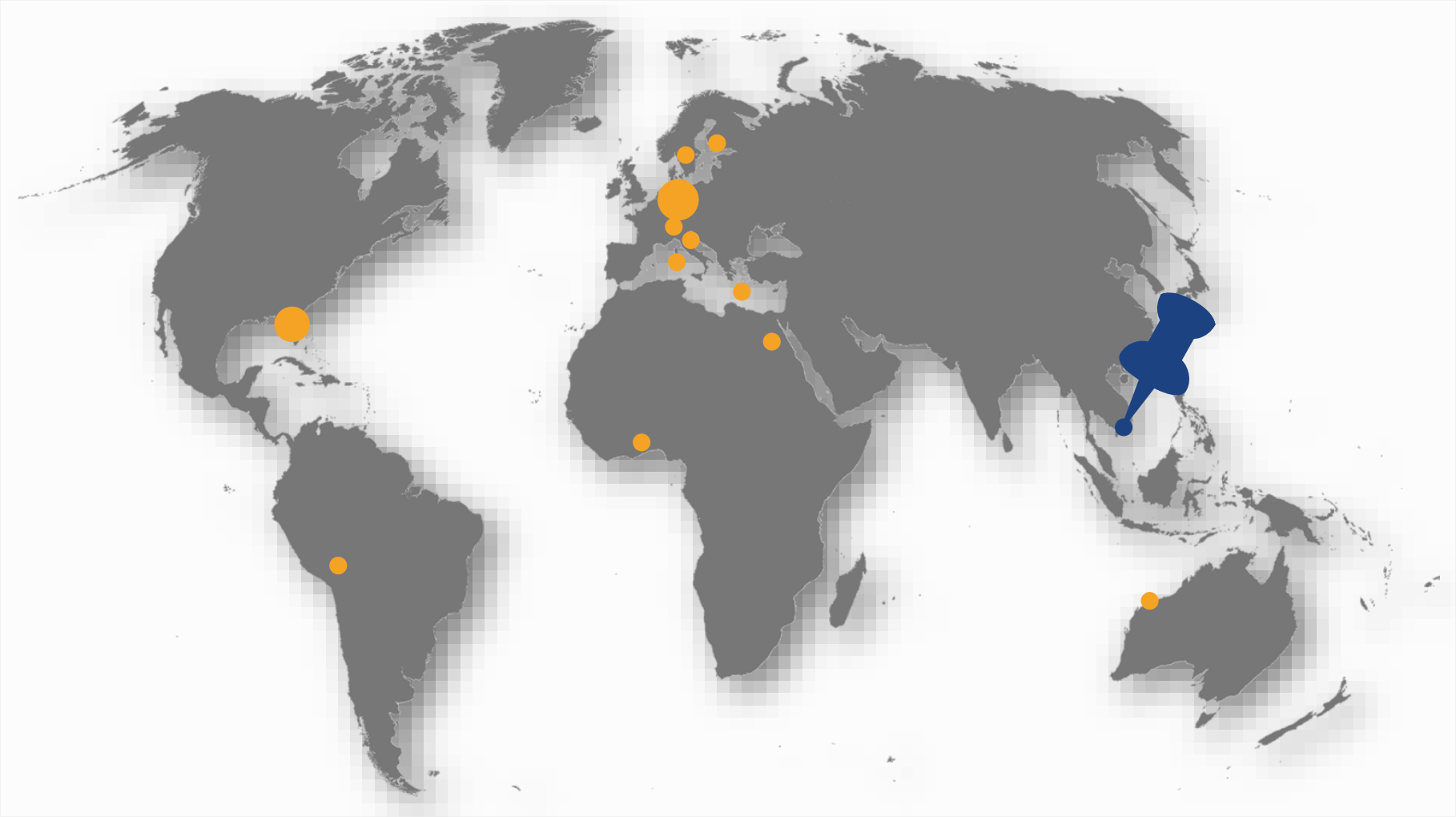


EOMAP
detect more.

Asia

detect more.

Mekong, Vietnam



EOMAP
detect more.

Validation Mekong, Vietnam

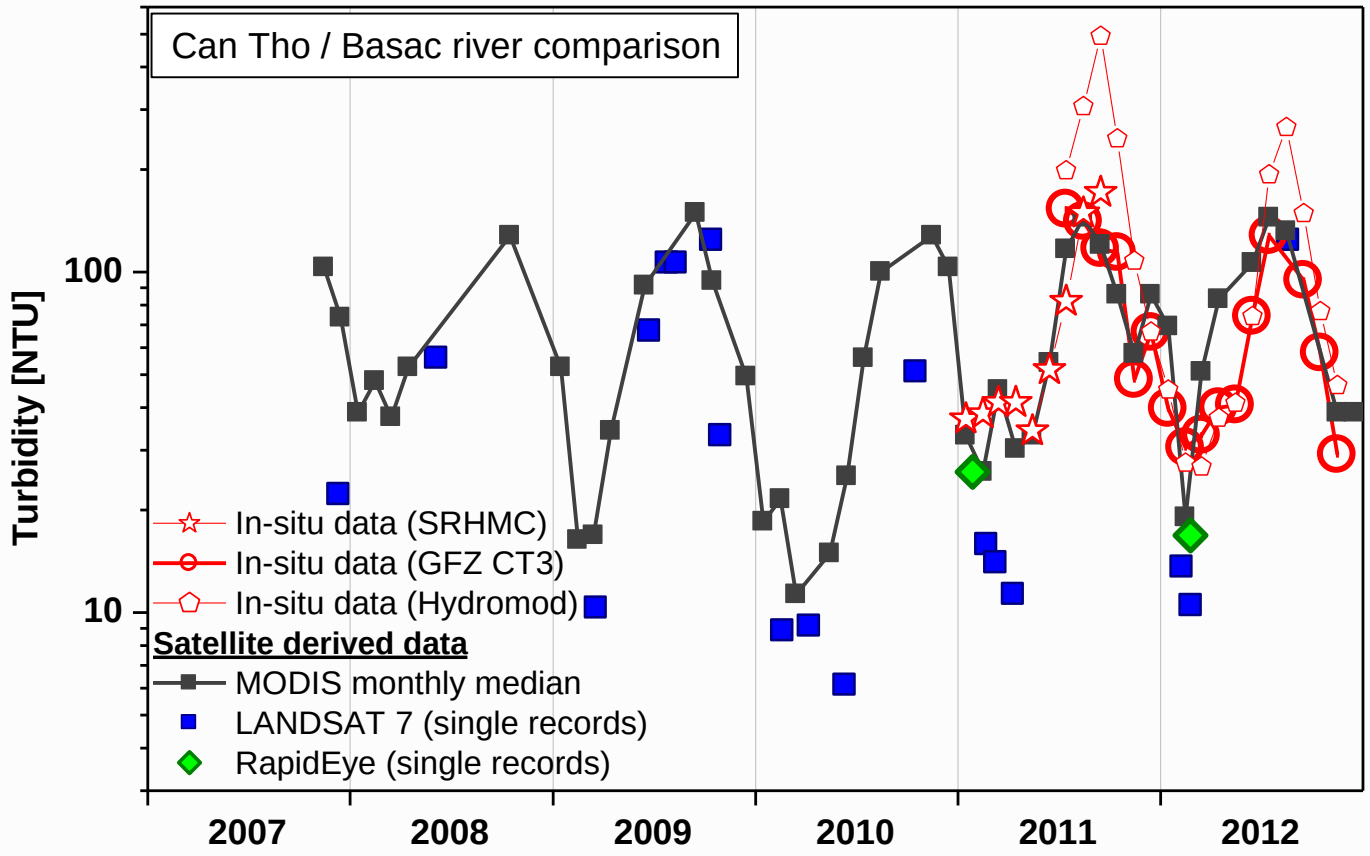
Location	Mekong, Vietnam
Time Period	June 2012
Parameter	Turbidity
Sensor	MODIS, Landsat, RapidEye
Spatial Resolution	250 m, 30 m, 5 m
Validation data provided by	SiWRR and SRHMC Vietnam Hydromod and GFZ Germany
Reference	Heege et al. 2014

Reference: Heege, T., Kiselev, V., Wettle, M., Hung N.N. (2014): Operational multi-sensor monitoring of turbidity for the entire Mekong Delta.
Int. J. Remote Sensing, Special Issues Remote Sensing of the Mekong, Vol. 35 (8), pp. 2910-2926

EOMAP
detect more.

Validation Mekong, Vietnam

Multi-sensor water quality monitoring: Landsat 7, RapidEye, MODIS A&T



Processing: © EOMAP, satellite data: USGS for Landsat 7, NASA for MODIS, Blackbridge for RapidEye
in situ data provided by SRHMC, GFZ, Hydromod
MIP version 2012

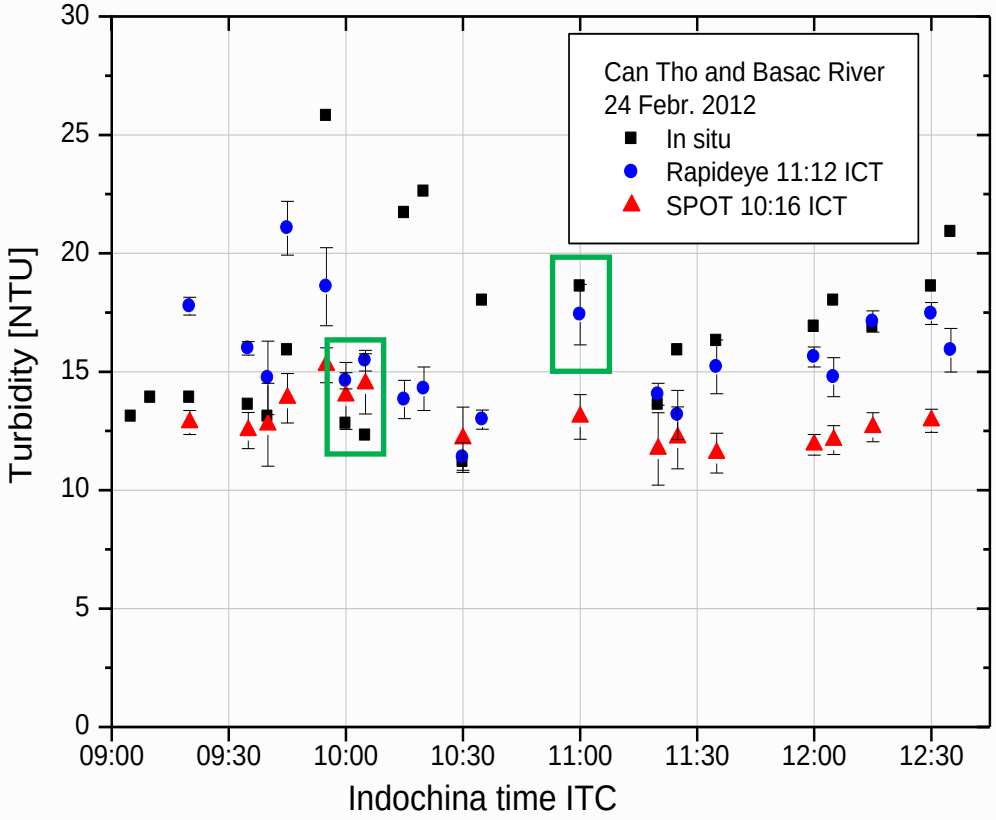
Reference: Heege, T., Kiselev, V., Wettle, M., Hung N.N. (2014): Operational multi-sensor monitoring of turbidity for the entire Mekong Delta . Int. J. Remote Sensing, Special Issues Remote Sensing of the Mekong, Vol. 35 (8), pp. 2910-2926

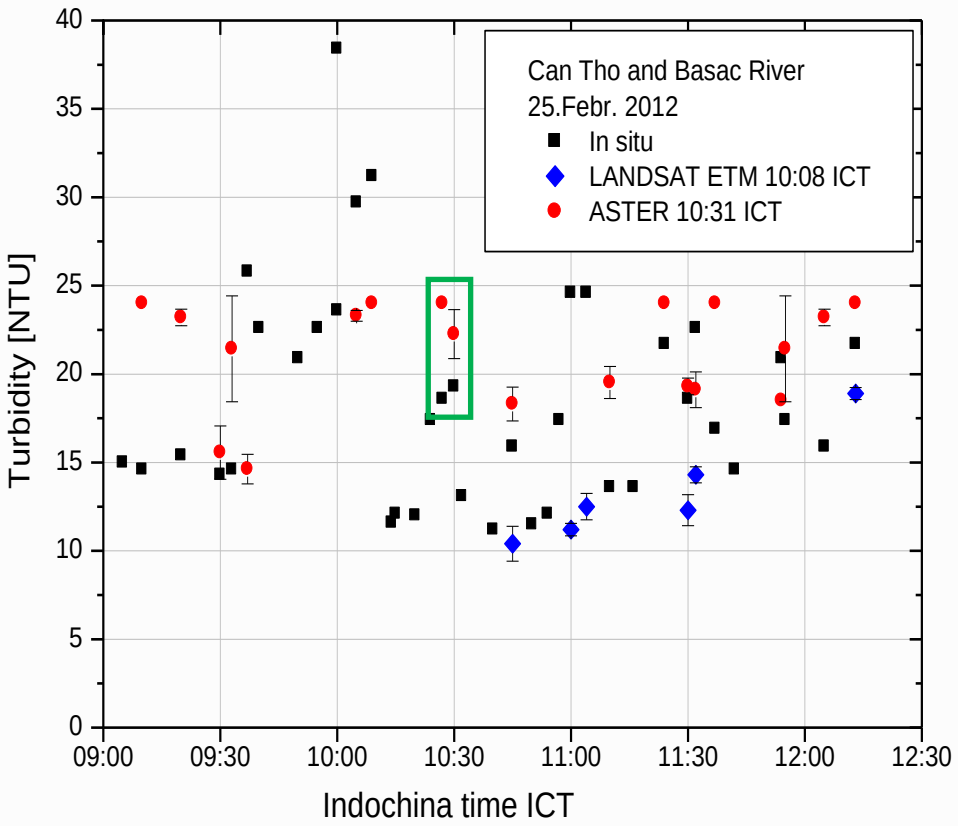
EOMAP
detect more.

Validation Mekong, Vietnam

Multi-sensor water quality monitoring: Landsat 7, RapidEye, SPOT, ASTER

MIP version 2012





Time coincidence of in-situ and satellite

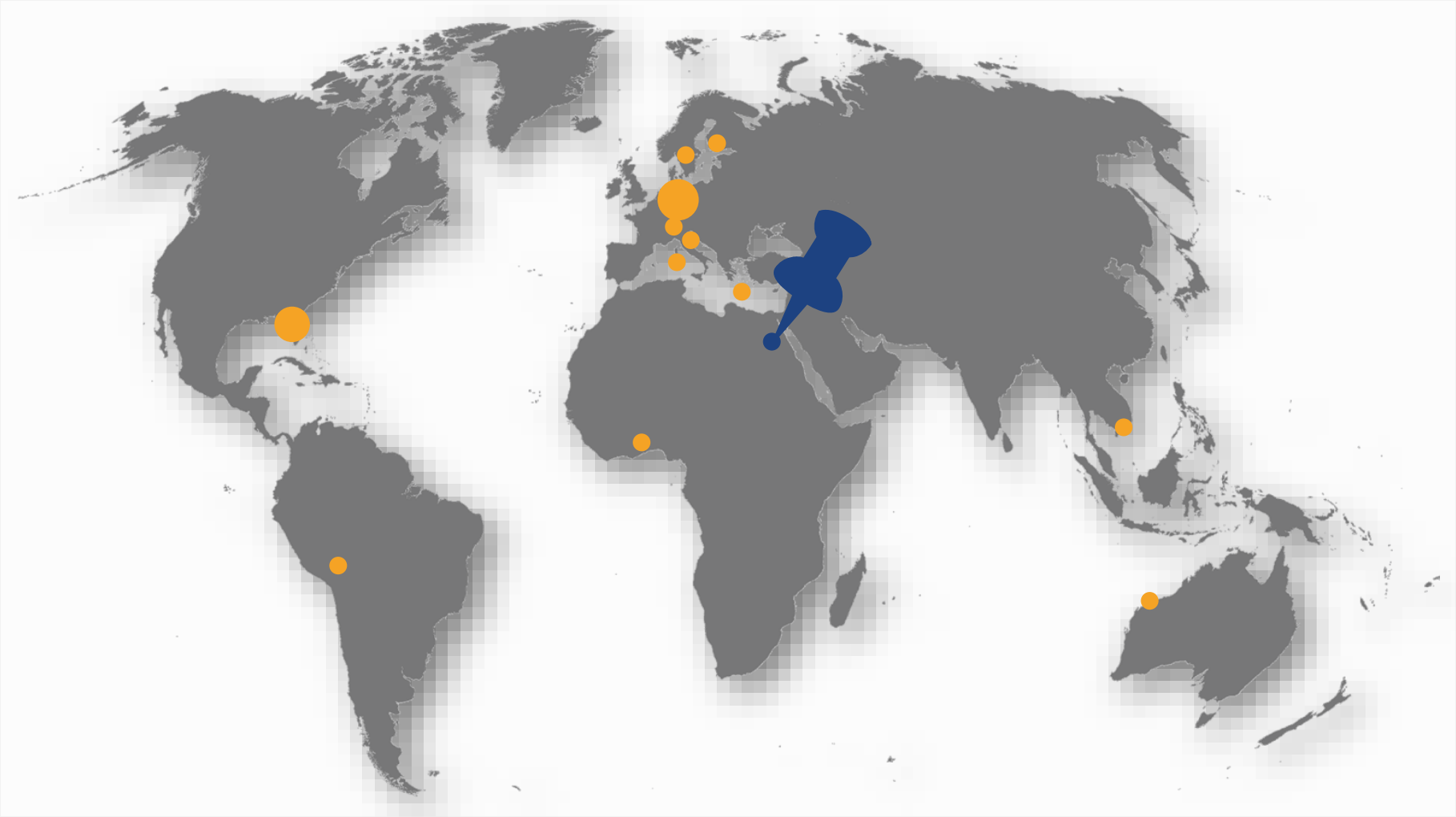
Reference: Heege, T., Kiselev, V., Wettle, M., Hung N.N. (2014): Operational multi-sensor monitoring of turbidity for the entire Mekong Delta . Int. J. Remote Sensing, Special Issues Remote Sensing of the Mekong, Vol. 35 (8), pp. 2910-2926

EOMAP
detect more.

AFRICA

detect more.

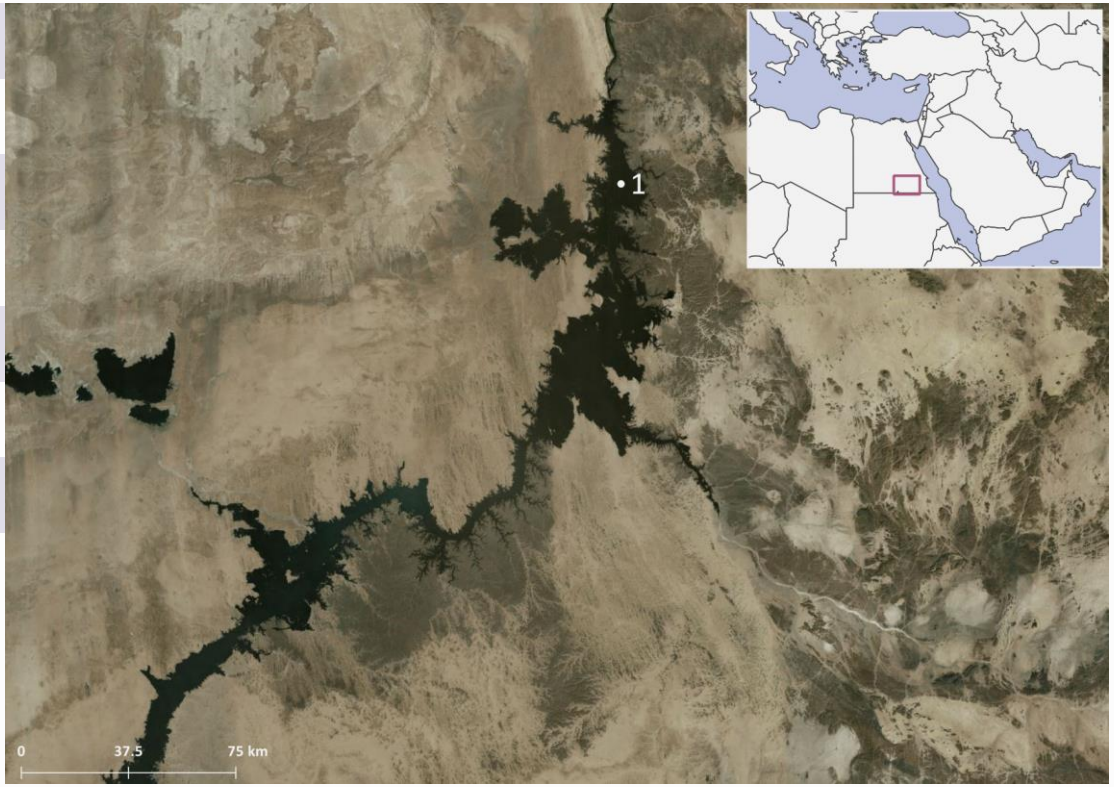
Assuan dam, Egypt



EOMAP
detect more.

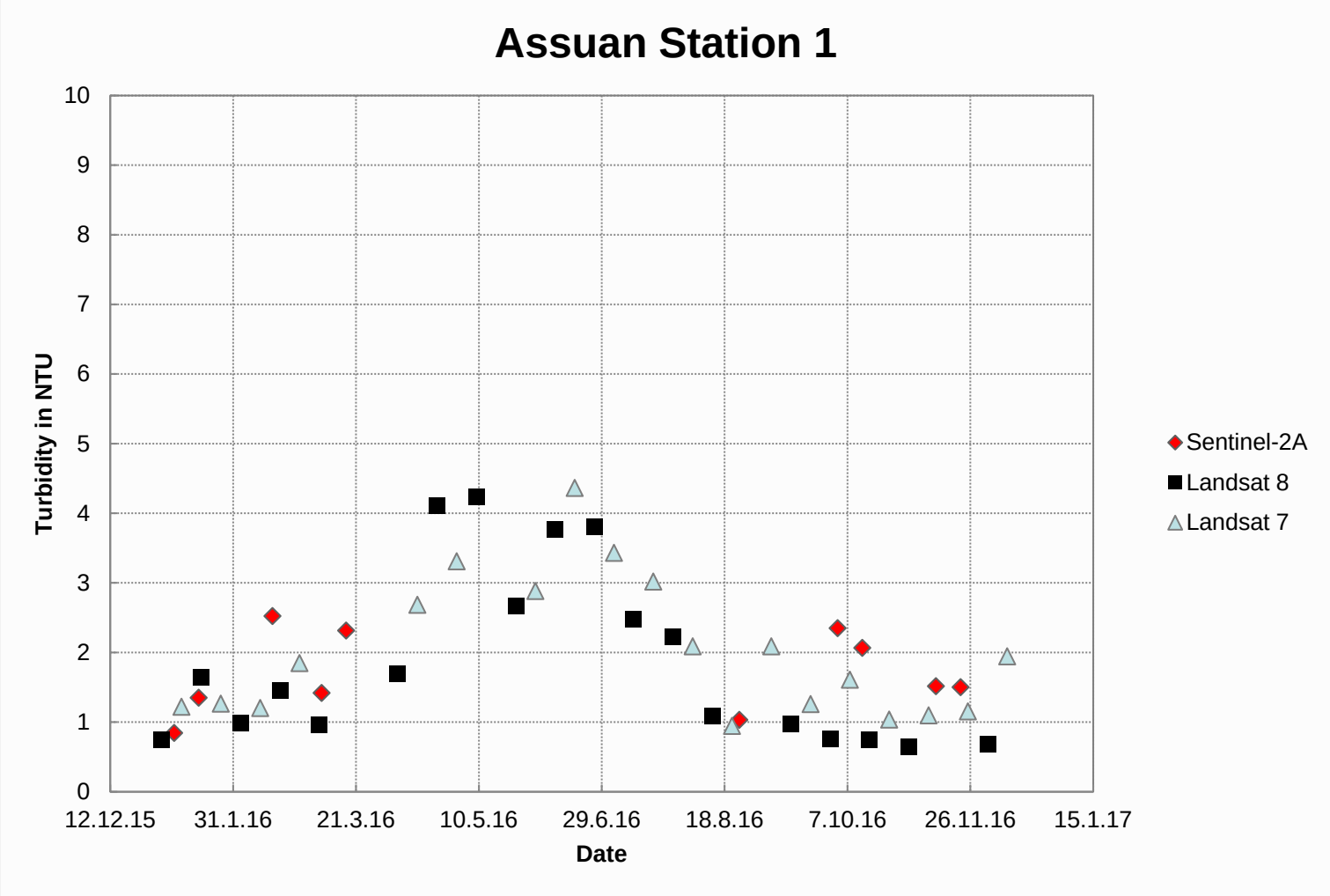
Validation Assuan

Location	Assuan dam, Egypt
Lake/river size	Approx. 5248 km²
Time Period	2016
Parameter	Chlorophyll-a, Turbidity
Sensor	Sentinel-2A, Landsat 7, Landsat 8
Spatial Resolution	10-30m
Stations	1 stations
Reference	UNESCO project (not published yet)



EOMAP
detect more.

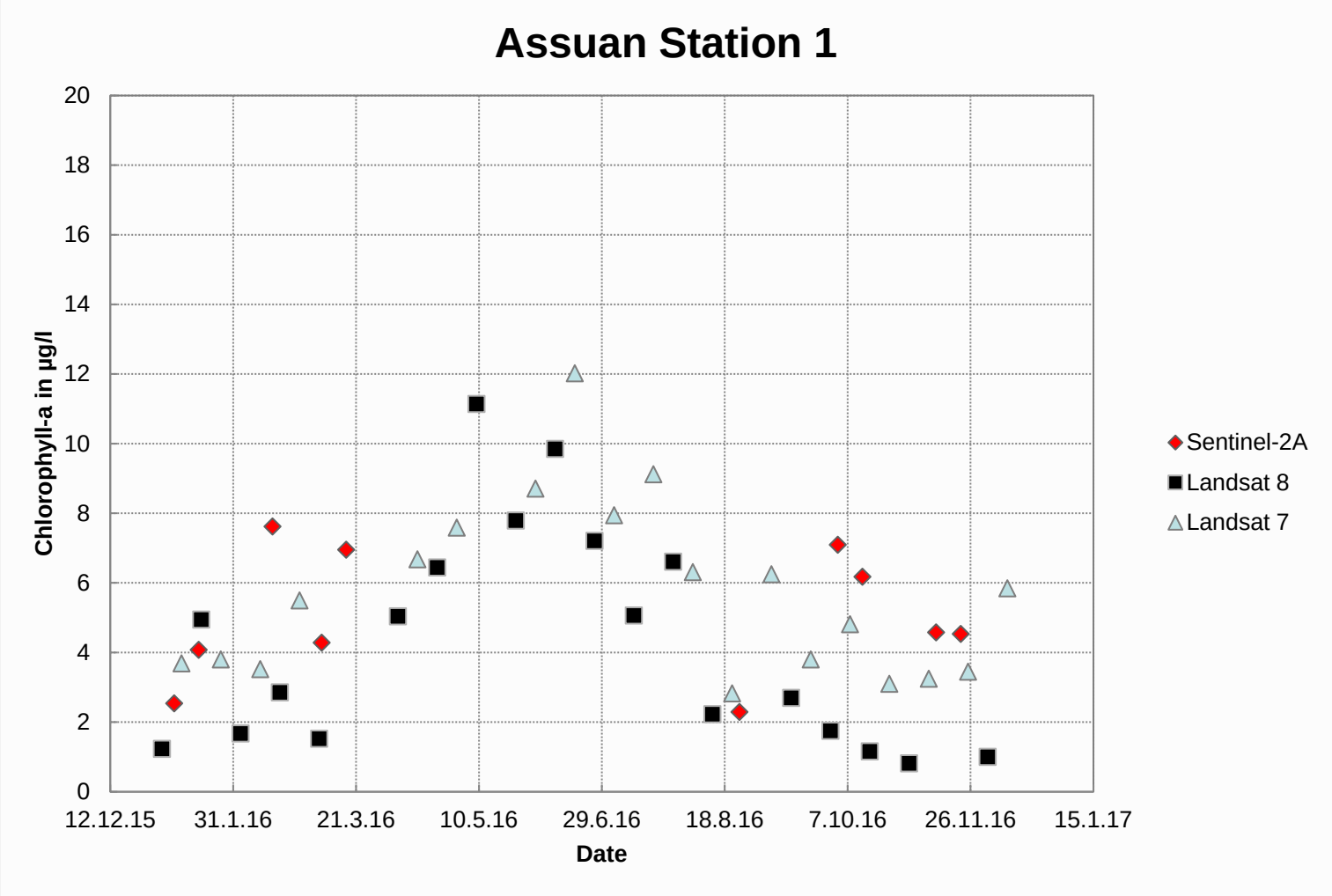
Validation Assuan



Sentinel-2A sunglint in summer months

EOMAP
detect more.

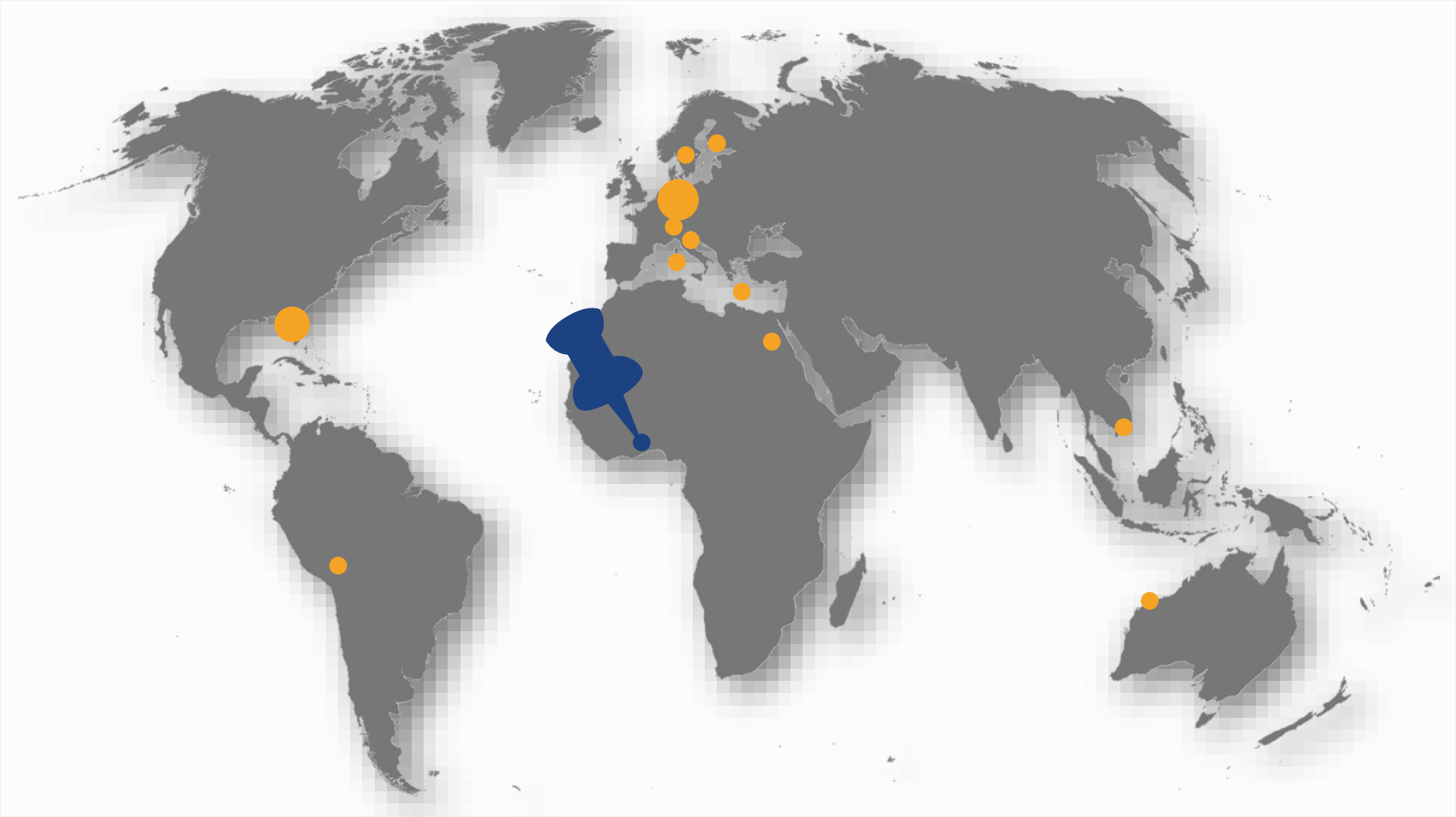
Validation Assuan



Sentinel-2A sunglint in summer months

EOMAP
detect more.

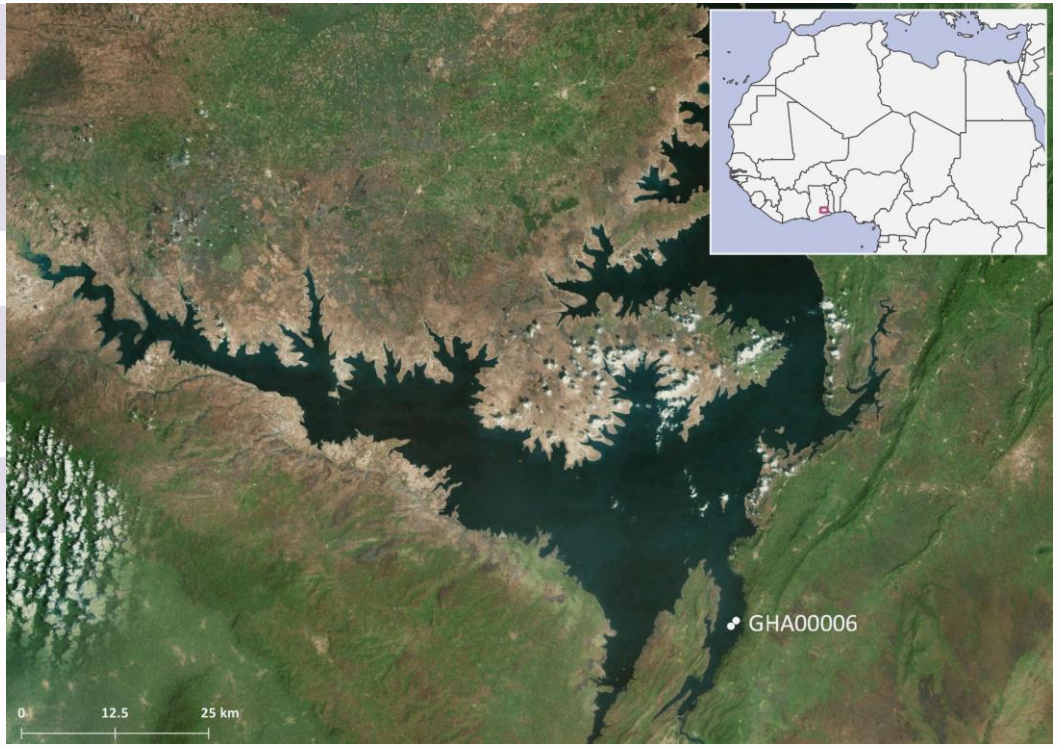
Lake Volta, Ghana



EOMAP
detect more.

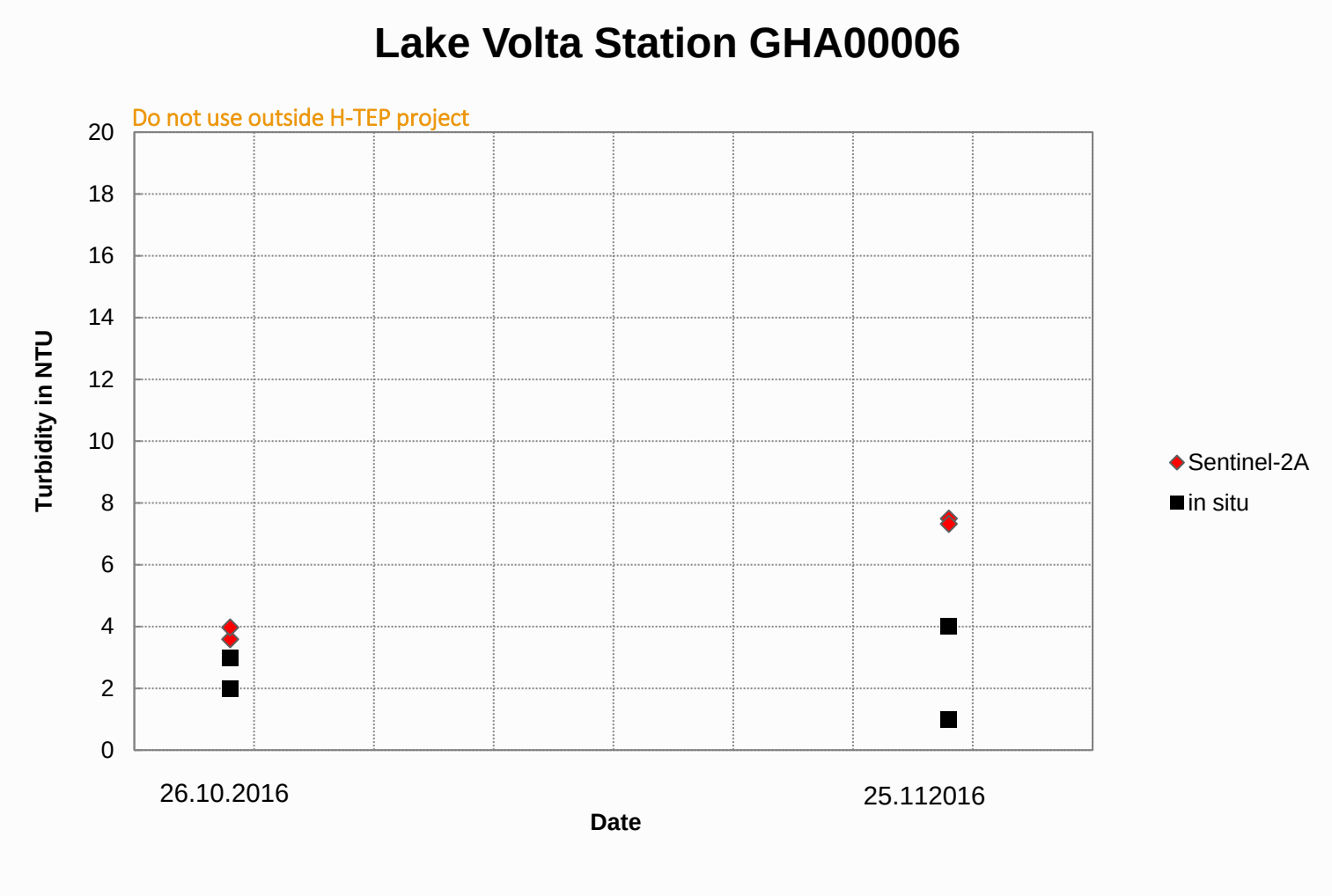
Validation Lake Volta, Ghana

Location	Lake Volta, Ghana
Lake/river size	Approx. km²
Time Period	2016
Parameter	Chlorophyll-a, Turbidity
Sensor	Sentinel-2A
Spatial Resolution	10m
Stations	Station GHA00006
Reference	Hydrology TEP



EOMAP
detect more.

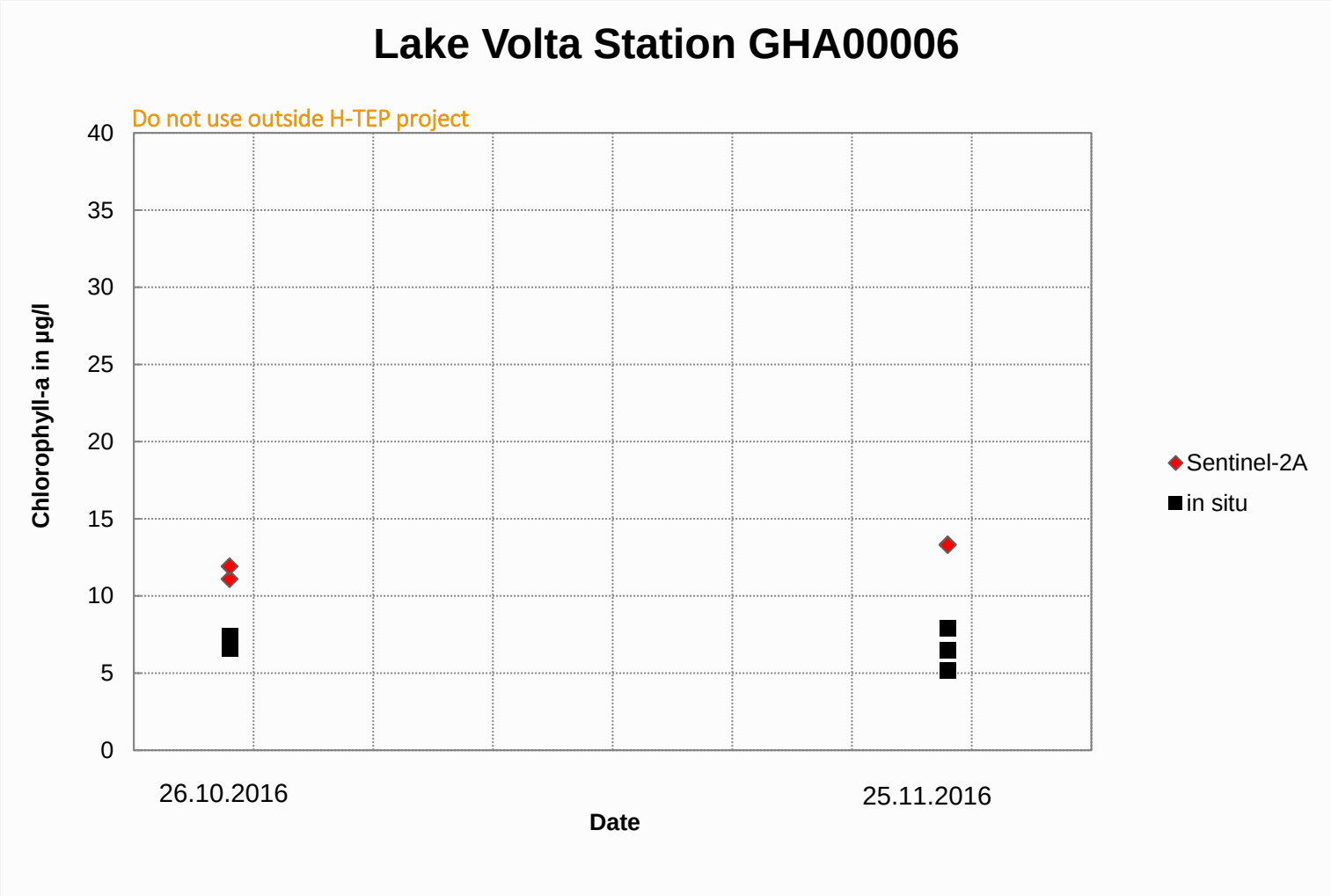
Validation Lake Volta, Ghana

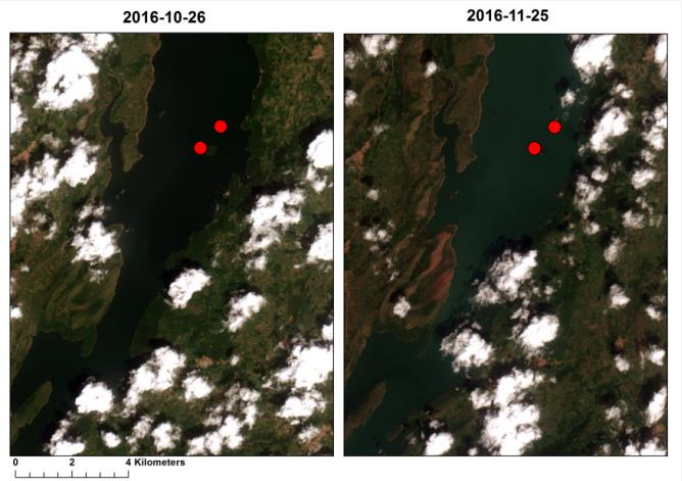


Only two suitable scences, others haze, sunglint or clouds over stations

EOMAP
detect more.

Validation Lake Volta, Ghana





Only two suitable scences, others haze, sunglint or clouds over stations

EOMAP
detect more.

AUSTRALIA

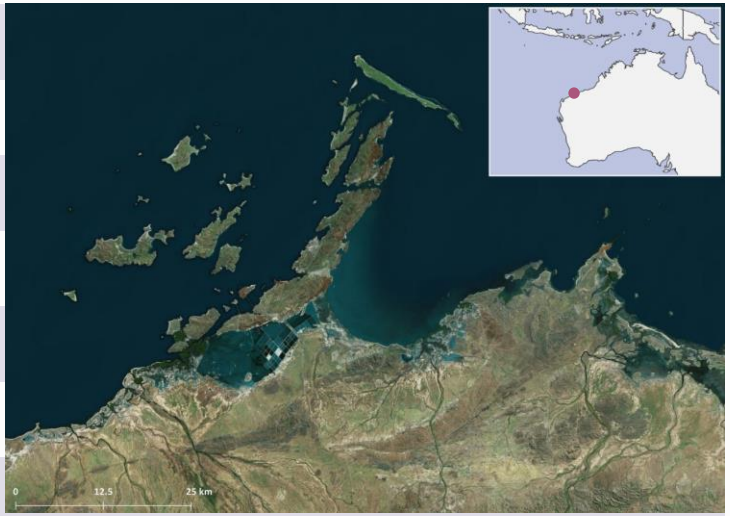
detect more.

Northwest Australia

EOMAP
detect more.

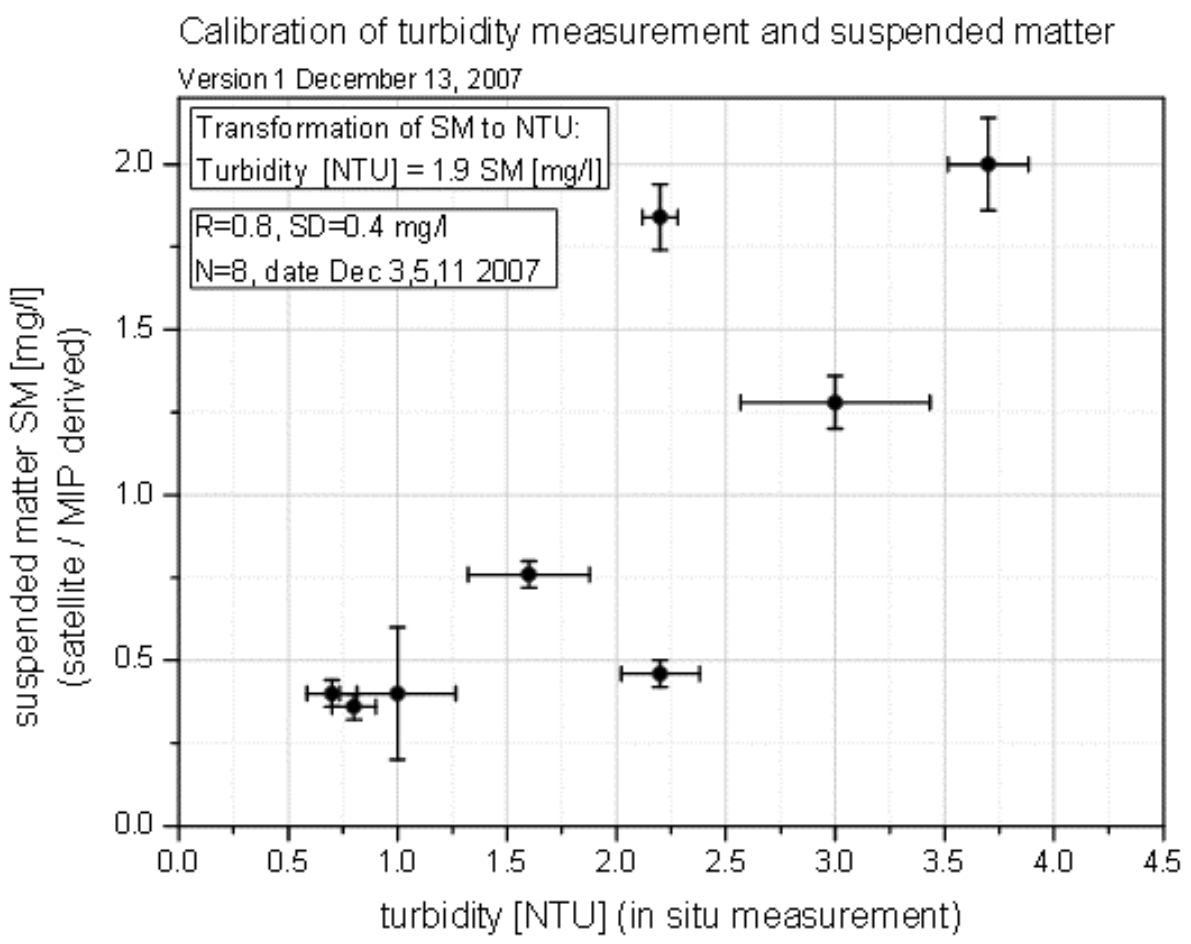
Validation West-Australia

Location	Northwest-Australia
Lake/river size	~ 1000 km²
Time Period	2007-2010
Parameter	Suspended Matter, Turbidity
Sensor	MODIS
Spatial Resolution	250m
Reference	Woodside Energy presentation: http://www.eomap.com/exchange/pdf/Hausknecht.pdf



EOMAP
detect more.

Validation West-Australia



Operational satellite based water quality monitoring service:
EWS and MIP system
400 + data sets since Oct. 2007, Validation for: MODIS 250m turbidity service

Hausknecht, P. (2010): Operational MODIS Satellite based water turbidity monitoring for dredging operations in Woodside. OGP Remote Sensing workshop at ESA, DRIMS 5526810.

Processor MIP version: 2007
In-situ data kindly provided by: Woodside Energy
Reference: Commercial contract Woodside Energy

EOMAP
detect more.