MULTITEMP 2015

Exploiting satellite image time series for monitoring ecological quality parameters of French reservoirs

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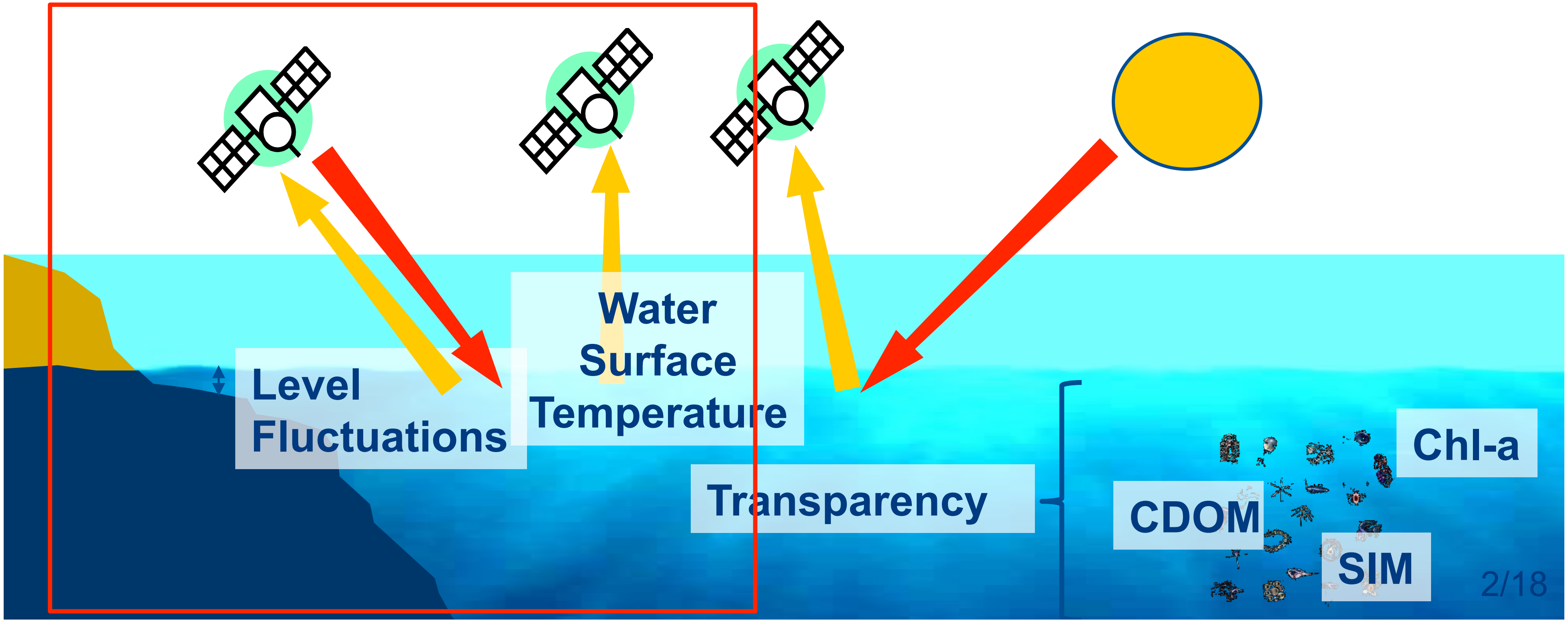
BACKGROUND: The collected information from field observations on 480 French lakes is punctual and discontinuous in time (four dates per year every 6 years in the case of the application of the Water Framework Directive).

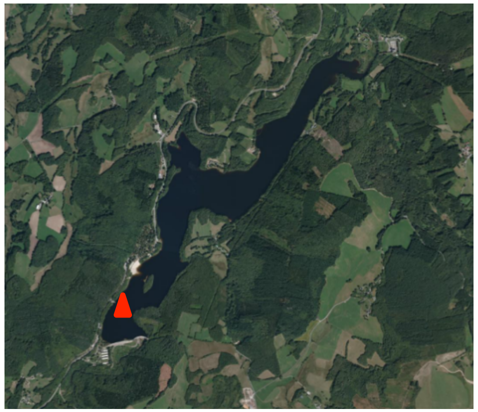
MAIN OBJECTIVE : To what extent the satellite image time series are able to enrich/complete the knowledge on these ecological parameters ?

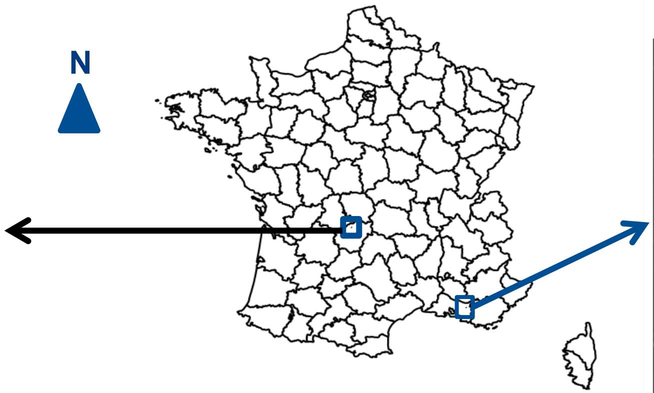


OBJECTIVE : To develop an operational methodology for the retrieval of water surface temperature from single-channel LANDSAT Thermal-infrared archive data (60 m and 100 m)

STUDY SITES

Lake Barioussés (0.857 km²)





Lake Bimont (0.606 km²)

METHOD

The operationality of the method depends strongly of the image correction algorithm for the atmospheric effects. This algorithm have to be efficient , not time-consuming and applicable on large territories.

=> the mono-channel atmospheric correction algorithm
Jimenez et al., 2003 & 2009

depending on sensor characteristics

$$T_s = \gamma \left[\frac{1}{\varepsilon} \left(\psi_1 L_{\text{sen}} + \psi_2 \right) + \psi_3 \right] + \delta$$

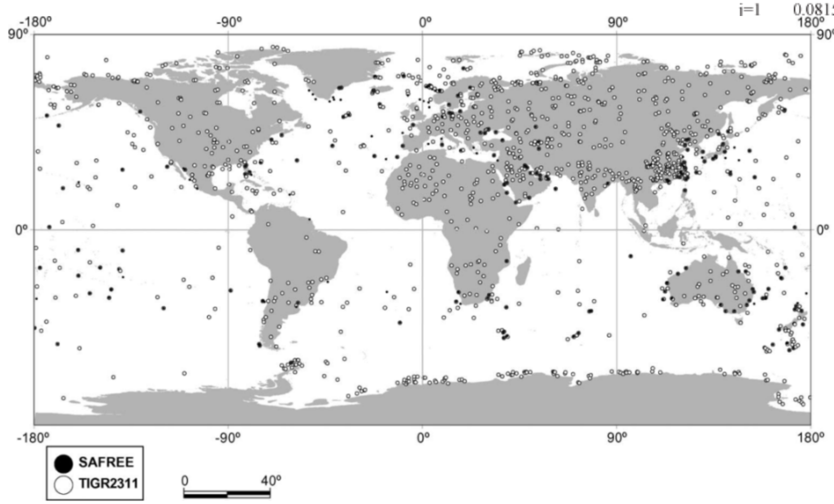
fitted versus only the atmospheric water vapor content using MODTRAN 4 radiative transfer code and basing on 5 different atmospheric sounding databases

$$\psi_1 = \frac{1}{\tau} \quad \psi_2 = -L^{\downarrow} - \frac{L^{\uparrow}}{\tau} \quad \psi_3 = L^{\downarrow}$$

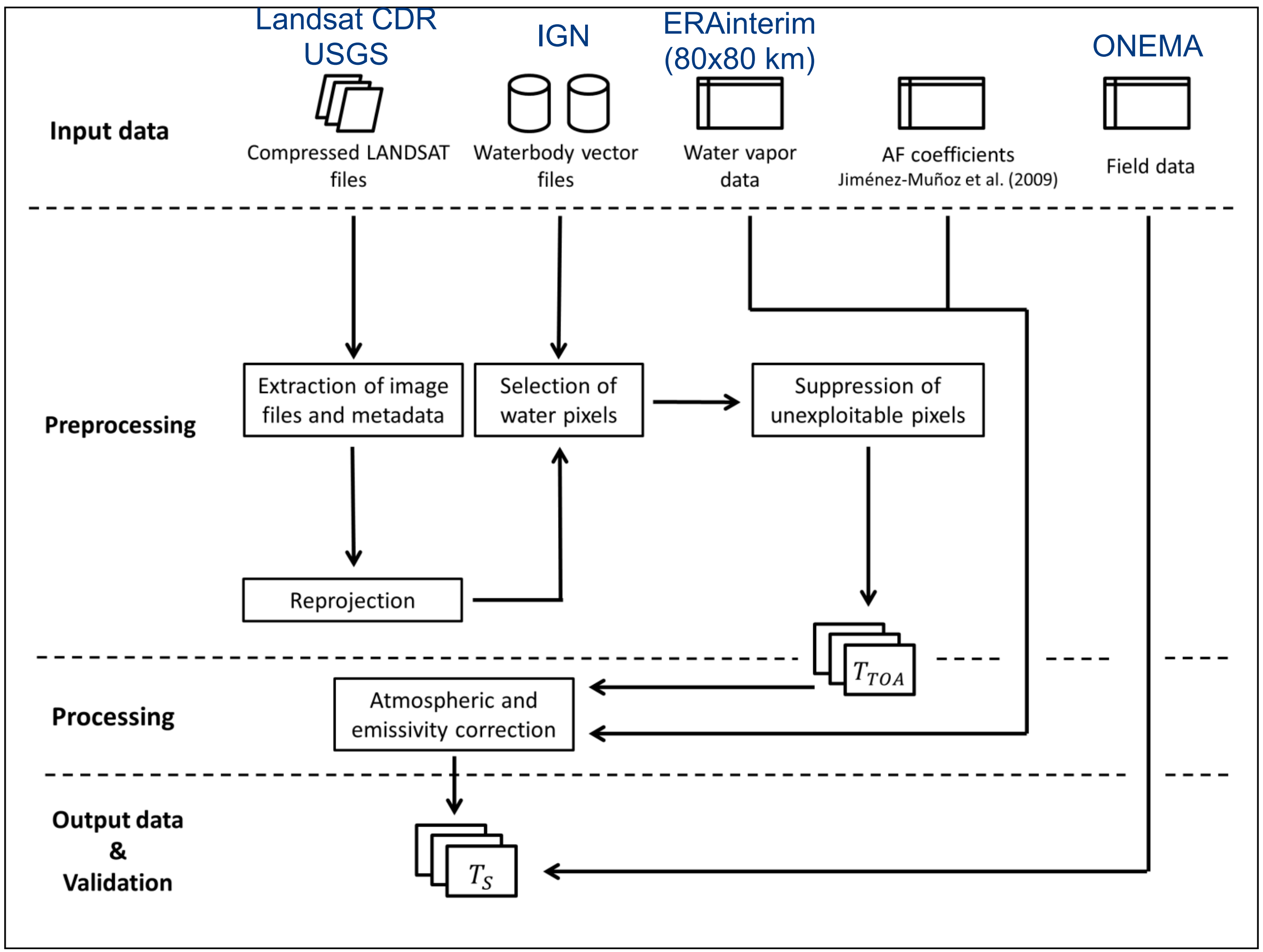
$$\begin{bmatrix} \psi_1 \\ \psi_2 \\ \psi_3 \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} & c_{13} \\ c_{21} & c_{22} & c_{23} \\ c_{31} & c_{32} & c_{33} \end{bmatrix} \begin{bmatrix} w^2 \\ w \\ 1 \end{bmatrix}$$

TABLE II
COEFFICIENTS FOR THE AFS FOLLOWING MATRIX NOTATION EXPRESSED IN (7). VALUES HAVE BEEN OBTAINED USING DIFFERENT ATMOSPHERIC SOUNDING DATABASES FOR BAND 6 OF LANDSAT-4, LANDSAT-5, AND LANDSAT-7 PLATFORMS

Database	Sensor	Cij	i=1	i=2	i=3
STD66	L4B6	j=1	0.08767	-0.09665	1.09023
		j=2	-0.70317	-0.61239	-0.12239
		j=3	-0.02518	1.51142	-0.48763
TIGR61	L4B6	j=1	0.07247	-0.06968	1.0788
		j=2	-0.60283	-0.68176	-0.13311
		j=3	-0.01999	1.43469	-0.46157
TIGR1761	L4B6	j=1	0.06240	0.00373	1.02425
		j=2	-0.52383	-1.19361	0.12908
		j=3	-0.00960	1.33393	-0.25891
TIGR2311	L4B6	j=1	0.06674	-0.03447	1.04483
		j=2	-0.50095	-1.15652	0.09812
		j=3	-0.04732	1.50453	-0.34405
SAFREE402	L4B6	j=1	0.04399	0.05765	1.00499
		j=2	-0.32119	-2.09785	0.59914
		j=3	-0.0554	1.67195	-0.49334
STD66	L5B6	j=1	0.1062	-0.13016	1.11576
		j=2	-0.81365	-0.47596	-0.29139
		j=3	-0.04421	1.61507	-0.48656
TIGR61	L5B6	j=1	0.08735	-0.09553	1.10188
		j=2	-0.69188	-0.58185	-0.29887
		j=3	-0.03724	1.53065	-0.45476
TIGR1761	L5B6	j=1	0.07518	-0.00492	1.03189
		j=2	-0.59600	-1.22554	0.08104
		j=3	-0.02767	1.43740	-0.25844
[illegible]	[illegible]	j=1	0.08158	-0.05707	1.05991
		[illegible]	[illegible]	-1.08536	-0.00448
		[illegible]	[illegible]	1.59086	-0.33513
[illegible]	[illegible]	[illegible]	[illegible]	0.05933	1.01123
		[illegible]	[illegible]	-2.20569	0.55116
		[illegible]	[illegible]	1.76355	-0.47457
[illegible]	[illegible]	[illegible]	[illegible]	-0.09894	1.09659
		[illegible]	[illegible]	-0.64218	-0.17183
		[illegible]	[illegible]	1.54063	-0.46434
[illegible]	[illegible]	[illegible]	[illegible]	-0.07132	1.08565
		[illegible]	[illegible]	-0.70916	-0.19379
		[illegible]	[illegible]	1.46051	-0.43199
[illegible]	[illegible]	[illegible]	[illegible]	0.00683	1.02717
		[illegible]	[illegible]	-1.25866	0.10490
		[illegible]	[illegible]	1.36947	-0.24310
[illegible]	[illegible]	[illegible]	[illegible]	-0.03366	1.04896
		[illegible]	[illegible]	-1.20026	0.06297
		[illegible]	[illegible]	1.52631	-0.32136
[illegible]	[illegible]	[illegible]	[illegible]	0.06269	1.00818
		[illegible]	[illegible]	-2.16801	0.55698
		[illegible]	[illegible]	1.69324	-0.45747



PROCESSING

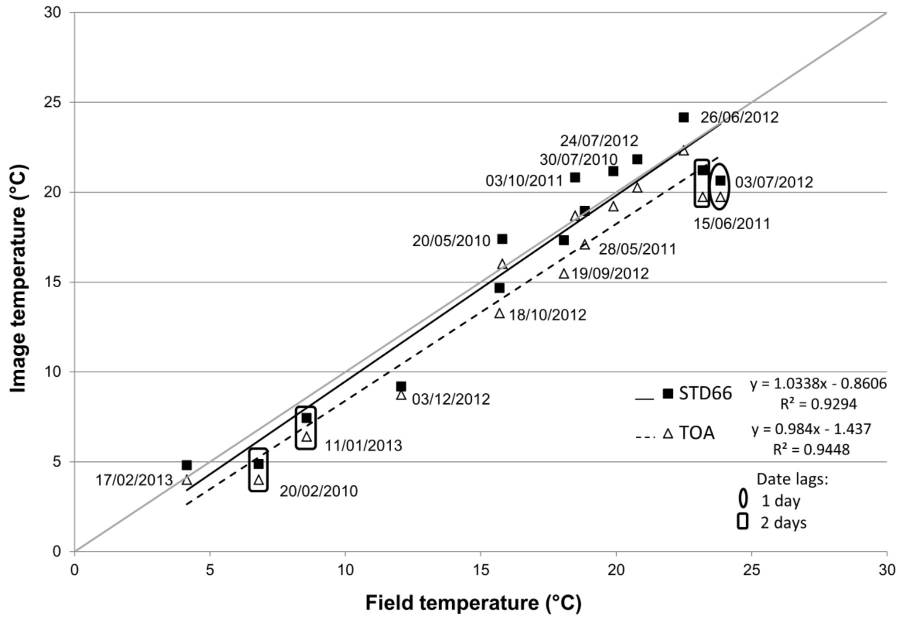

Landsat CDR
USGS
IGN
ERAinterim
(80x80 km)
ONEMA
Input data
Compressed LANDSAT files
Waterbody vector files
Water vapor data
AF coefficients
Jiménez-Muñoz et al. (2009)
Field data
Preprocessing
Extraction of image files and metadata
Selection of water pixels
Suppression of unexploitable pixels
Reprojection
T_{TOA}
Processing
Atmospheric and emissivity correction
Output data
&
Validation
T_S

RESULTS:

- 14 statistical points were available for validation

- whatever the atmospheric sounding database used to fit atmospheric functions r² values are above 0.90 and RMSE are comprised between 1 and 2 °C

- The paired Wilcoxon signed rank test showed a highly significant difference ($p<0.01$) between field and uncorrected image data (TOA), a very highly significant difference between uncorrected and corrected (STD66) image data ($p<0.001$), no significant difference between field and corrected image data ($p>0.5$)



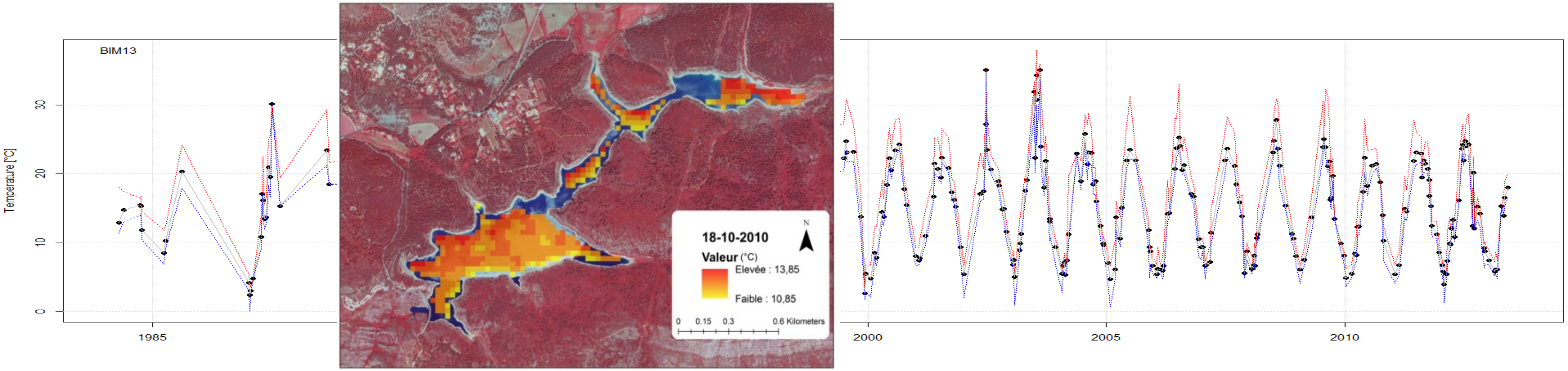
- Similar results were obtained when setting aside the 4 points presenting date lags between field and image data acquisition (i.e. n = 10)

MAIN CONCLUSION

We can complete efficiently water surface temperature information with Landsat archive data for all French lakes (if atmospheric water vapor is between 0.5 g/cm² and 3 g/cm², according to Jimenez et al., 2003 & 2009).

AND NOW

- We are implementing this method on all French lakes and testing water surface temperature data derived from Landsat to fit model of water column temperature.



- We are questioning about the use of the two thermal bands of Landsat 8.

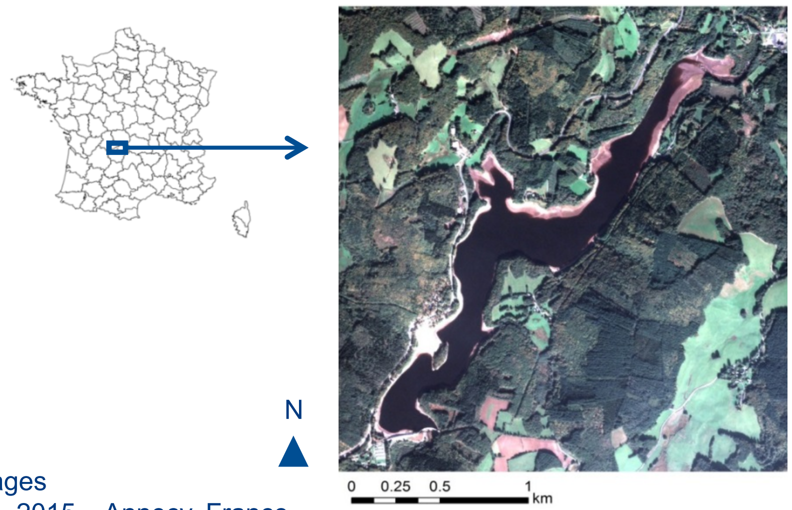
PROBLEMATIC: the footprints of current radar altimeters are too coarse to tracking level fluctuations over the most of French lakes

HYPOTHESIS: water surface altitude fluctuations (i.e. the vertical dimension, acquired in the field) are correlated to water surface area fluctuations (i.e. the horizontal dimensions, extracted from the imagery).

OBJECTIVES : (1) assess the suitability of very high spatial and temporal resolution satellite imagery in tracking this process, and (2) assess the spatial resolution required.

STUDY SITE :

Lake Bariousses



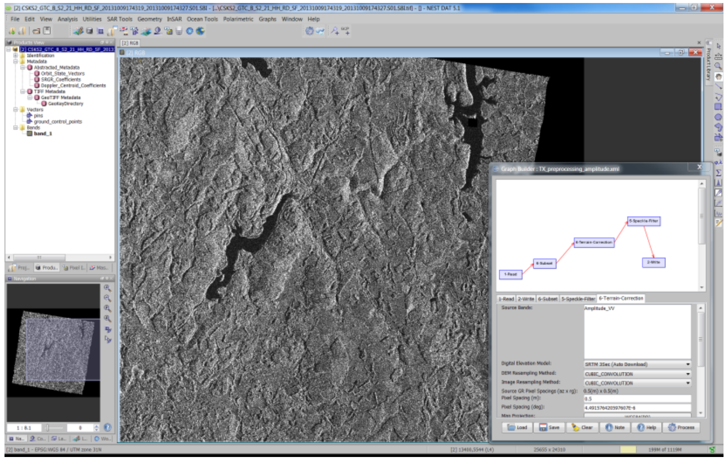
IMAGERY AND FIELD DATA

Imagery	Level	Bands (wavelength/frequency)	Spatial resolution	Quantity
Pléiades	Ortho processing level: georeferenced and corrected for radiometric, sensor and terrain distortions.	Multispectral (4): blue (430-550 nm), green (490-610 nm), red (600-720 nm) and Near Infrared (750-950 nm)	2 m	4 (18th Oct 11th, 14th and 27th Nov 2013)
		1 panchromatic (480-830 nm)	0.5 m	
COSMO-SkyMed	GeoCoded Terrain Corrected Spotlight 2 mode.	1 HH X-band (9.65 GHz)	0.5 m	5 (9th and 17th Oct, 2nd, 11th and 14th Nov 2013)
TerraSAR-X	Multi Look Ground Range Detected, Spatially Enhanced High Resolution Spotlight mode. No terrain correction.	1 VV X-band (9.65 GHz)	0.5 m	5 (6th and 27th (ascending), 15th, 20th and 31st (descending) Oct 2013)

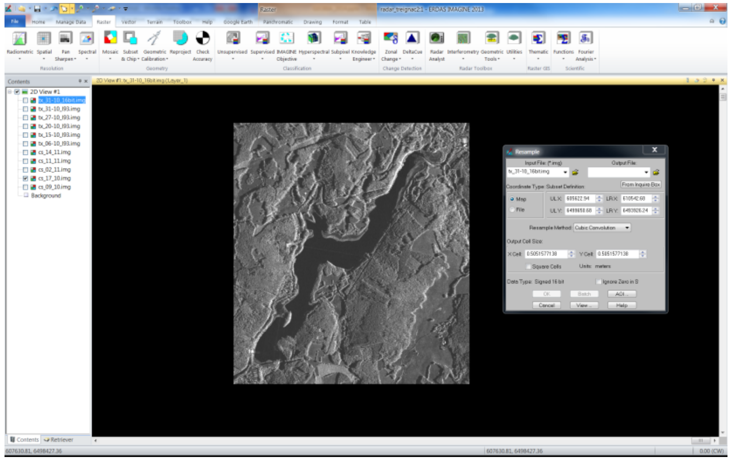
Field data: punctual water surface altitude (m) for all image dates plus a few others to a total of 24 dates.

PREPROCESSING

- All images were clipped around the study site and reprojected.
- **COSMO-SkyMed**: speckle correction (Gamma MAP filter with 7x7 kernel size).
- **TerraSAR-X**: speckle (same as above) and terrain correction (SRTM 3Sec DEM and cubic convolution for both DEM and image resampling).
- Cubic convolution spatial resampling to create 2, 10, 15, 30 and 60 m versions of all images.



NEXT ESA SAR Toolbox



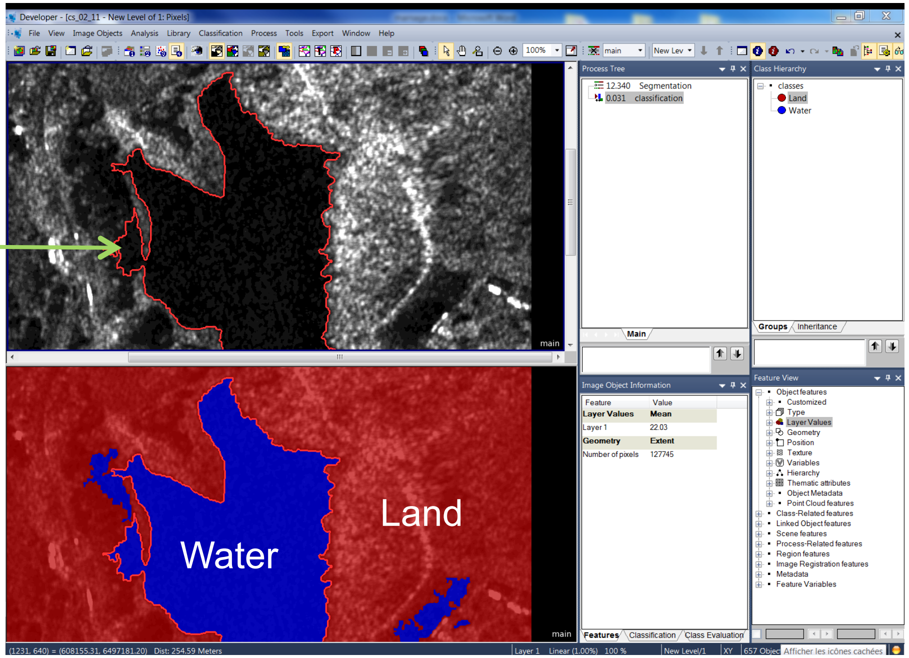
ERDAS Imagine

PROCESSING

- **GEOBIA** adopted given its ability to account for textural and contextual information.
- However, **difficulties** in extracting **total water surface area** from **radar images** due to:

Presence of radar "shadows" which prevent accurate land and water discrimination

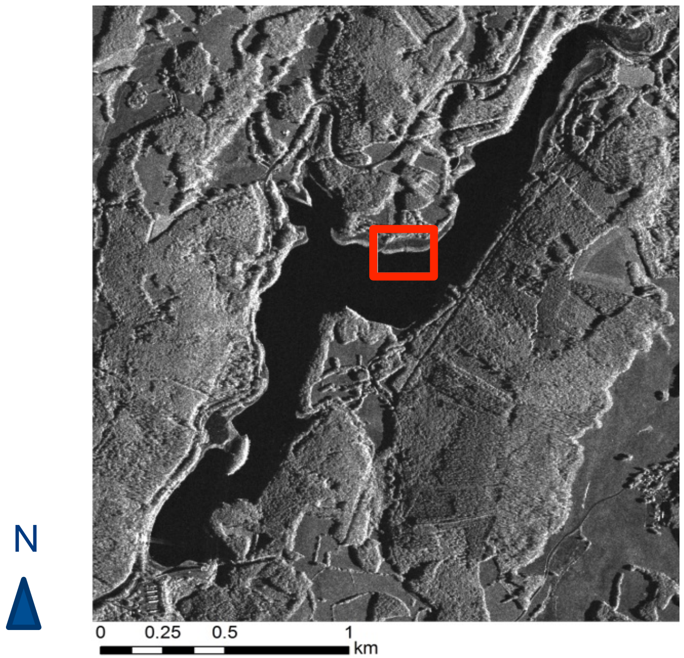
Object affected by radar "shadow"



eCognition Developer

PROCESSING

- **Solution:** bypass the problem by focusing the analysis on a spatial subset of mildly sloping and unencumbered littoral zone.

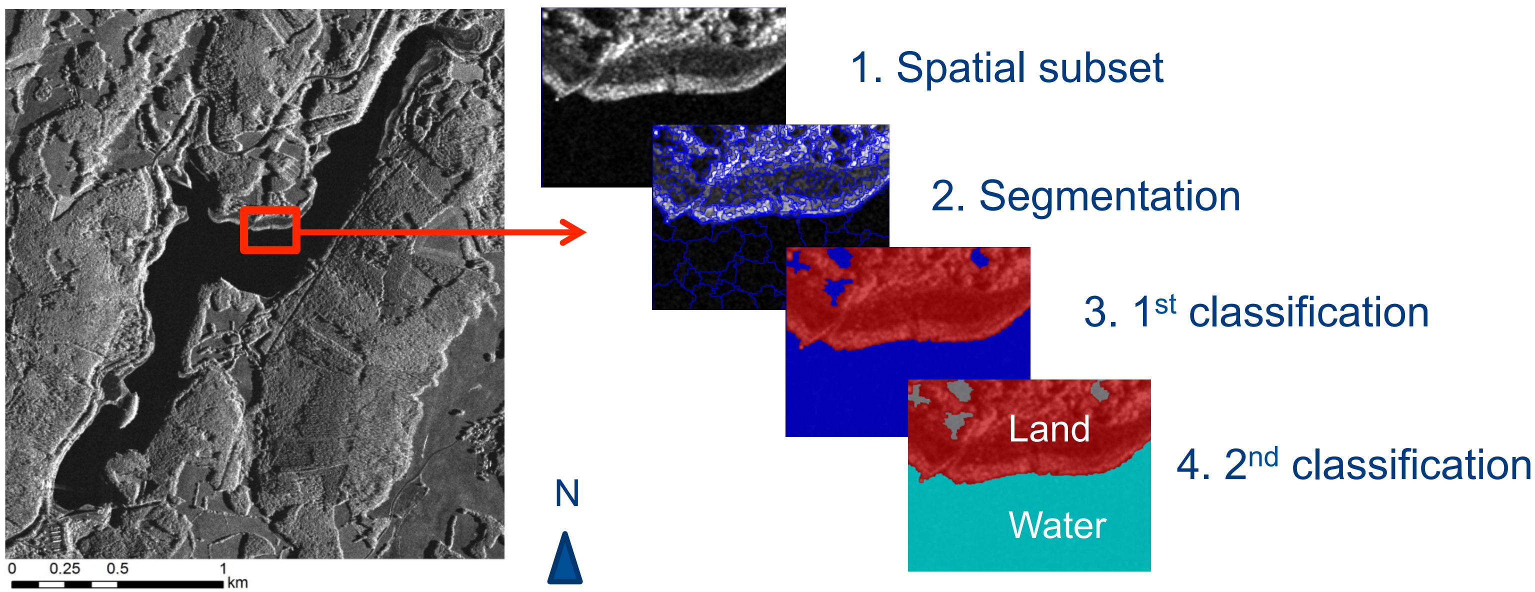


Spatial subset: 190m x 240m
Surface area: 4.56 ha

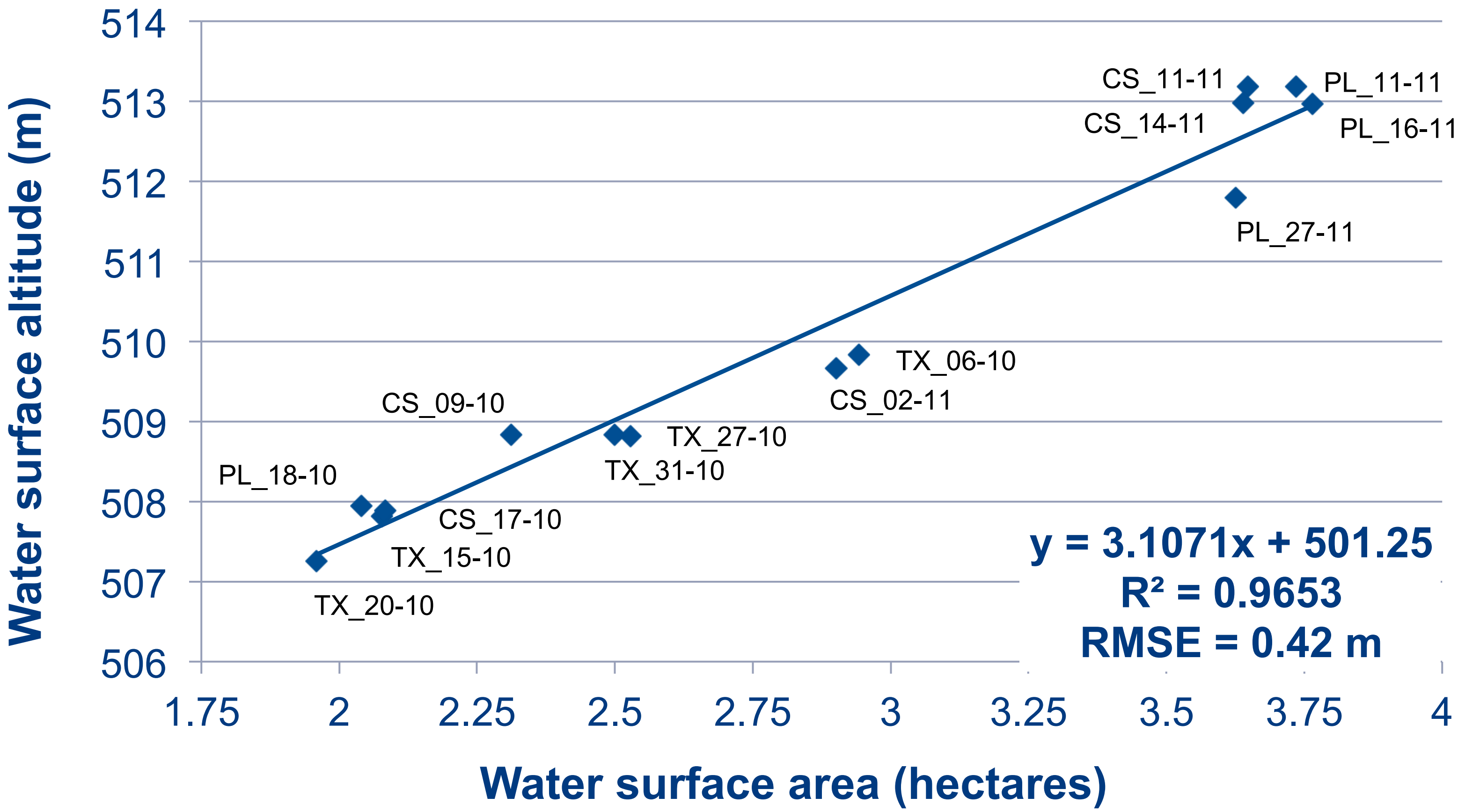
ERSI ArcGIS

PROCESSING

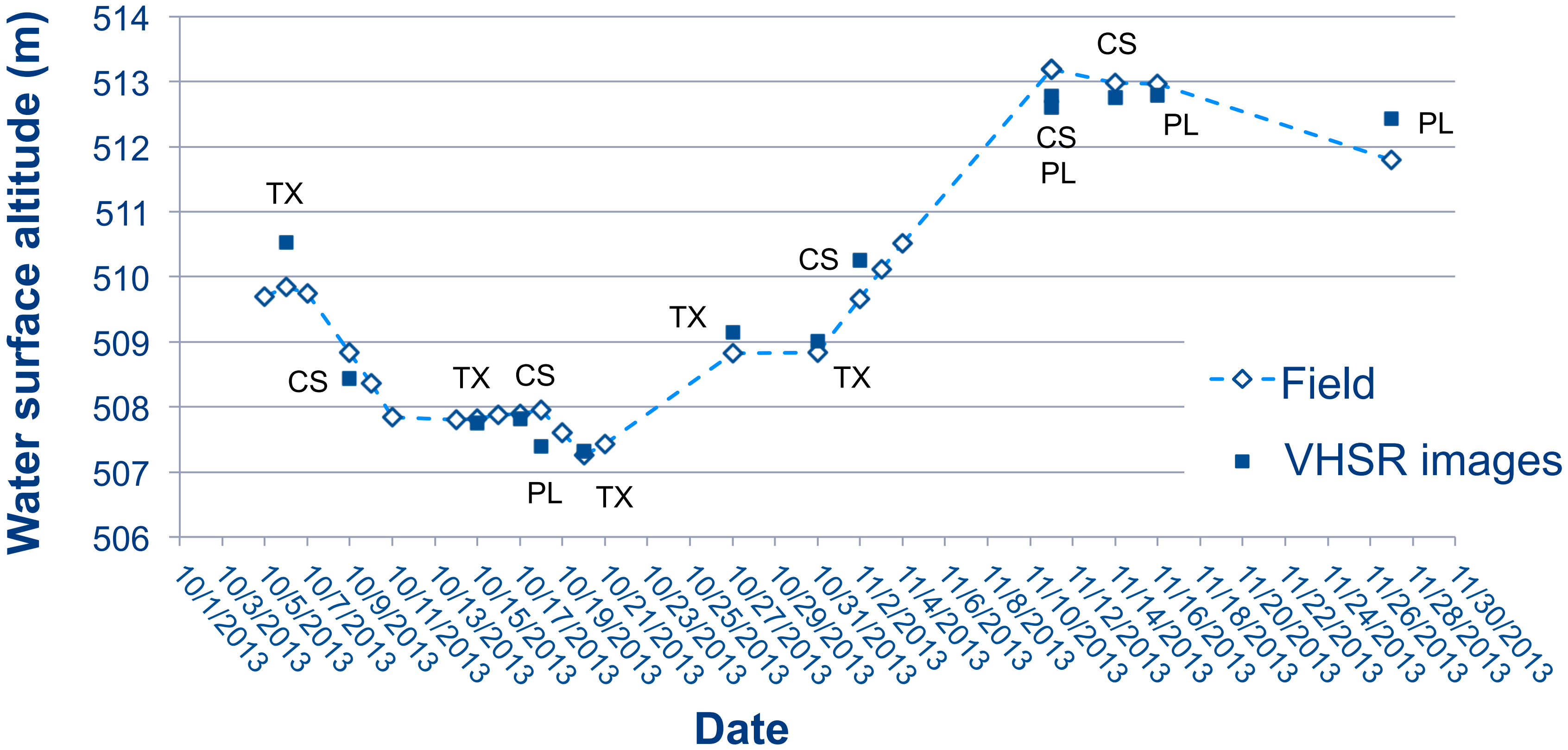
- **Optical images:** single classification based on NDWI threshold values.
- **Radar images:** first classification based on thresholding signal mean followed by a second classification based on thresholding relative border area (a contextual feature).



RESULTS : Regression

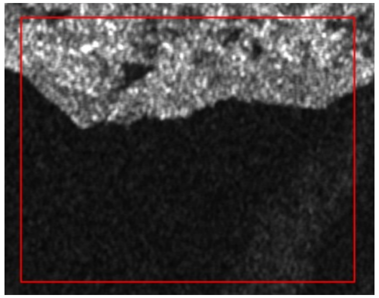


RESULTS : Field vs. Imagery

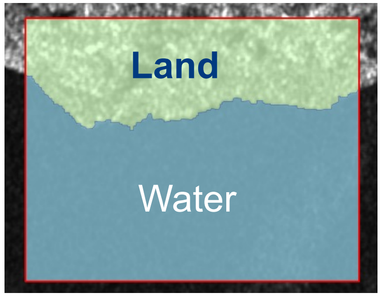


RESULTS : Spatial Resolution Sensitivity Analysis

Image:
TerraSAR-X
06th Oct 2013

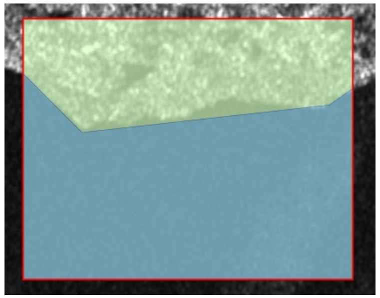


Original image

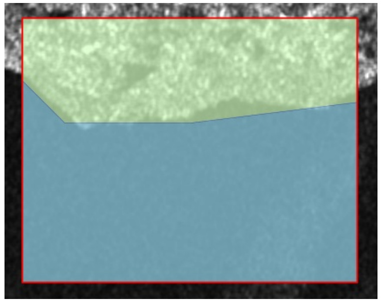


s.r. = 0.5 m
R^2 = 0.963
RMSE = 0.42 m

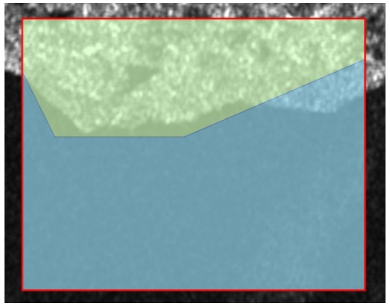
s.r. = 2 m
R^2 = 0.962
RMSE = 0.42 m



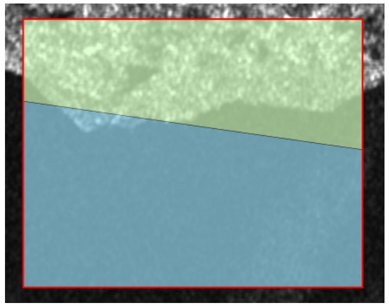
s.r. = 10 m
R^2 = 0.961
RMSE = 0.43 m



s.r. = 15 m
R^2 = 0.891
RMSE = 0.89 m



s.r. = 30 m
R^2 = 0.834
RMSE = 0.72 m



s.r. = 60 m
R^2 = 0.642
RMSE = 1.30 m

MAIN CONCLUSIONS

Simple and easy GEOBIA methodology that bypasses difficulties while also providing good results.

VHSR data not necessarily required to track water level fluctuations. LANDSAT and SENTINEL data might just as well do the job depending on the slope of the littoral zone observed.

PERSPECTIVE

Deploying this method on littoral zones with different topography in order to know what spatial resolution is required according to the slope of littoral zone observed.

CONCLUSION

High interest of satellite image time series for completing field data on ecological parameters for French lakes (increase the knowledge in space and time)

PERSPECTIVES

cnes Project (TELQUEL)

ONEMA Office national de l'eau et des milieux aquatiques

1) A specific atmospheric correction algorithm

2) measure in situ of optical properties of lakes

Transparency

CDOM

Chl-a

SIM

THANK YOU FOR YOUR ATTENTION

For further information :

Simon, R-N., Tormos, T., Danis, P-A. (2014) Retrieving water surface temperature from archive LANDSAT thermal infrared data: Application of the mono-channel atmospheric correction algorithm over two freshwater reservoirs. *International Journal of Applied Earth Observations and Geoinformation*, 30, 247–250

Simon, R.N., Tormos, T. & Danis, P.A. (2015) Very high spatial resolution optical and radar imagery in tracking water level fluctuations of a small inland reservoir. *International Journal of Applied Earth Observation and Geoinformation,* **38,** 36-39.

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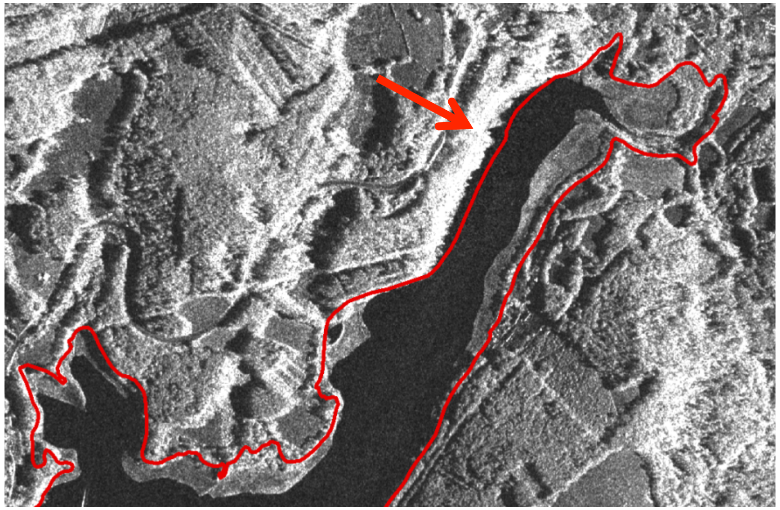
PROCESSING

- **GEOBIA** adopted given its ability to account for textural and contextual information.
- However, **difficulties** in extracting **total water surface area** from **radar images** due to:

1. Lingering **geometric inaccuracies** in the 3 descending pass TerraSAR-X images:

Accurate: ascending path



Inaccurate: descending path

STATISTICS

Field surface water altitude range: 507.25 to 513.19 m (**5.94 m difference**).

GEOBIA	R^2	RMSE	Error range	p
Unsupervised classification	0.963	0.42 m	- 0.69 to 0.58 m	<0.001***
Supervised classification	0.965	0.41 m	- 0.72 to 0.61 m	<0.001***

SPATIAL RESOLUTION ANALYSIS

Spatial resolution	R^2	RMSE	Error range	p
2 m	0.962	0.42 m	-0.66 to 0.60 m	<0.001***
10 m	0.961	0.43 m	-0.74 to 0.69 m	<0.001***
15 m	0.891	0.72 m	-1.05 to 1.21 m	<0.001***
30 m	0.834	0.89 m	-1.96 to 1.45 m	<0.001***
60 m	0.642	1.30 m	-1.98 to 3.09 m	<0.001***

*** Very highly significant.