Assessment of performance of the Lake Ice Extent (LIE) Optical Satellite Data Product and description of the evaluation methodology

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Processing Lines And Operational Services Combining Sentinel And In-Situ Data For Terrestrial Cryosphere And Boreal Forest Zone

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Introduction

The extent of lake ice during spring break-up can be monitored using optical satellite data. Terra/MODIS satellite offers two channels (red and near-infrared) in 250 m spatial resolution. From these channels the NIR -band is utilized here for lake ice monitoring. A simple method of applying a threshold reflectance to the NIR-band is used for identifying the between lake ice stages. Thresholds are given for 3 classes, namely: fully snow covered ice, partially snow covered ice and open water. NIR-band was selected for interpretation as it is less sensitive to changes in the water properties e.g. turbidity.

The LIE product can have several important applications from climate change monitoring and numerical weather prediction and hydrological forecasting to winter transport and recreational activity on lakes.

In order to apply this satellite derived data product the user needs information on the uncertainty related to the interpretation and understanding how the uncertainty information was derived. The purpose of this document is to provide information for the user to evaluate the suitability of the product (in the view of performance characteristics) to the purpose in hand.

1. Document Identifier

SEN3APP_SYKE_LIE_VR_V0.9

2. Title

Assessment of performance of the Lake Ice Extent (LIE) Optical Satellite Data Product and description of the evaluation methodology.

3. Authority and Contact Information

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4. Abstract

The uncertainty information related to the Lake Ice Extent (LIE) product is presented. The derivation of the quantitative measures of uncertainty is presented in detail, so the user can evaluate the suitability of the product for purpose or to track back the procedure and repeat the analysis or use the same procedure to other similar satellite data products.

The validation was conducted under EU FP7 development project SEN3APP, aiming to build satellite data product services for dedicated customers. One of the products in the SEN3APP portfolio was Lake Ice Extent from optical data, developed at the Finnish Environment Institute (SYKE). In order to use the satellite data products, the user needs an estimate on the uncertainty of the product. The uncertainty information is presented here in the QA4EO framework provided and endorsed by Group on Earth Observation (GEO).

The LIE product was previously validated against small dataset of SPOT-satellite images. The SPOT images were interpreted by an operator and compared to data derived from automated image processing for Terra/MODIS data. This provided results that encouraged further development of the product. Here validation scheme and results are presented to cover Finland where regular in-situ observations of ice disappearance date are available from several lakes and spanning across the satellite era. Therefore validation in larger spatial and temporal scales is possible. The variable for validation is the date when the ice disappears from the observation site field of view. The in-situ variable for ice disappearance is determined as the date when ice has disappeared from the observation point (field of view) entirely.

Validation was carried out for four years, namely 2010-2013. The validation shows an average error of +3 days between in-situ observation date of ice disappearance and satellite derived ice disappearance date, with standard deviation of 5.2 days.

5. Keywords

#lake ice, #optical satellite, #MODIS, #ice break-up, #validation, #in-situ

6. Key terminology

Lake ice extent	The area covered by ice on a lake
Field of view of the in-situ observer	For extracting the relevant pixels from the satellite data, this is estimated to be a 2 km radius area seen over the lake from the observation point
Fully snow covered ice	Lake ice cover, where the entire area of the lake ice covered by snow

7. Background, Context and Scope

The Lake Ice Extent (LIE) satellite data product has been developed in SEN3APP EU-FP7 project. The project aim was to develop existing or new satellite data products in collaboration with potential service users and to establish data processing and delivery services for these products. In the beginning of the project a comprehensive list of satellite data products generated by the project partners. Then key users were identified and focus was given to the data products that met their needs.

This is the first version of the validation documentation that should be made easily available where the LIE data is also made accessible and delivered together with the data.

The documentation is based on the QA4EO framework endorsed by Group on Earth Observation (GEO).

8. Product performance and uncertainty

Here the validation has been done in the context of comparing in-situ observation of disappearance of lake ice to the same parameter derived from satellite data (see. Section 11). Considering the simple implementation and adaptation of the method for different optical satellite sensors, the performance of the method is good. Table 8.1. shows the average difference between in-situ and satellite observations and the standard deviation of the difference for the four years, 2010-2013, used for validation. This shows that on average the difference is around +3 days and median of the dataset being +2 days. The standard deviation being 5.2 days.

Table 8.1. Statistics of the difference between in-situ and satellite derived ice disappearance date. The unit used is days.

Difference between in-situ observation of date of ice disappearance and satellite derived date for ice disappearance [days]

	2010	2011	2012	2013	All
Average	3.4	5.4	2.5	1.8	3.3
Median	2	5	2	1	2
STD	5.8	5.5	4.4	4.1	5.2

9. Inputs

The data used in the analysis are described in Table 9.1.

Table 9.1. Dataset used for validation analysis

Input	Description	Link
SYKE Lake Ice Extent satellite data products (based on Terra/MODIS satellite data)	The LIE data is derived from optical satellite data using NIR- channel for interpretation of three classes: 1) fully snow covered ice; 2) partially snow covered ice; 3) open water. The dataset covers Baltic Sea Drainage area (71°N/5°E; 45°N/45°E) daily.	Available on request from SYKE (see contact details)
Lake ice break-up observations (date)	The ice-off observations are performed by SYKE on daily basis during the ice season (VHJ, 1984). Temporally the dataset covers the satellite era. The spatial domain is Finland with distribution covering the whole country.	Available request (specific conditions may apply)

10. Standards and Traceability

The main datasets (satellite and in-situ) can be traced to previous project documentation and the measurement protocol followed for the in-situ observations by SYKE (Table 10.1).

Table 10.1. Documentation describing the derivation of main datasets.

Standard/ Documentation	Description	Link
SYKE Lake Ice Extent Product	The LIE data is derived with the methodology described in the technical reports from Cryoland and SEN3APP-projects	Available on request from SYKE (see contact details)
SYKE Lake ice measurement standard	The lake ice is measured with well-defined protocol for the observations.	VHJ, 1984

11. Methodology, Processing

The product performance is evaluated by comparing the date of disappearance of ice cover from the field of view from the observation point to the satellite date of ice disappearance derived from optical satellite data, in this case Terra/MODIS- satellite data.

1) Determine in-situ site locations used for validation
2) Extract a time-series of sub-regions of LIE- data product from radius of 2.0 km around the in-situ observation site
3) Extract the days when the observation areas are not totally covered by clouds. [this omits the possibility of ice underneath the clouds]
4) Compare the in-situ observation date and the satellite observation date (calculate statistical measures; average, STD and median)

12. Evaluation of Performance

The four year dataset shows good performance of the methodology considering its simplicity. The histogram in Figure 12.1 also shows that in year 2011 the difference to the other years was fairly significant. This is due to long period of cloud cover in late April - early May, where most in-situ observations of ice disappearance fall. This can be seen in the scatterplot in Figure 12.2., where the difference in days is plotted against the number of days after the in-situ ice disappearance observation before the next satellite observation.

The satellite method has tendency to produce later ice disappearance date than in-situ observation. This should be the case as in many cases there is some gap between the in-situ observation day and the next day when satellite data is available from the observation area. The analysis here does not take into account the fact that the water mask covers only part of the field of view from the observation point, meaning, that there can be ice close to the shore, but out of the interpretation area of the satellite, producing too early ice clearance for the site from satellite data. Here the interpretation also takes into account only the cloud free area. Therefore there is possibility of ice underneath the cloud cover, again producing too early day for ice disappearance.

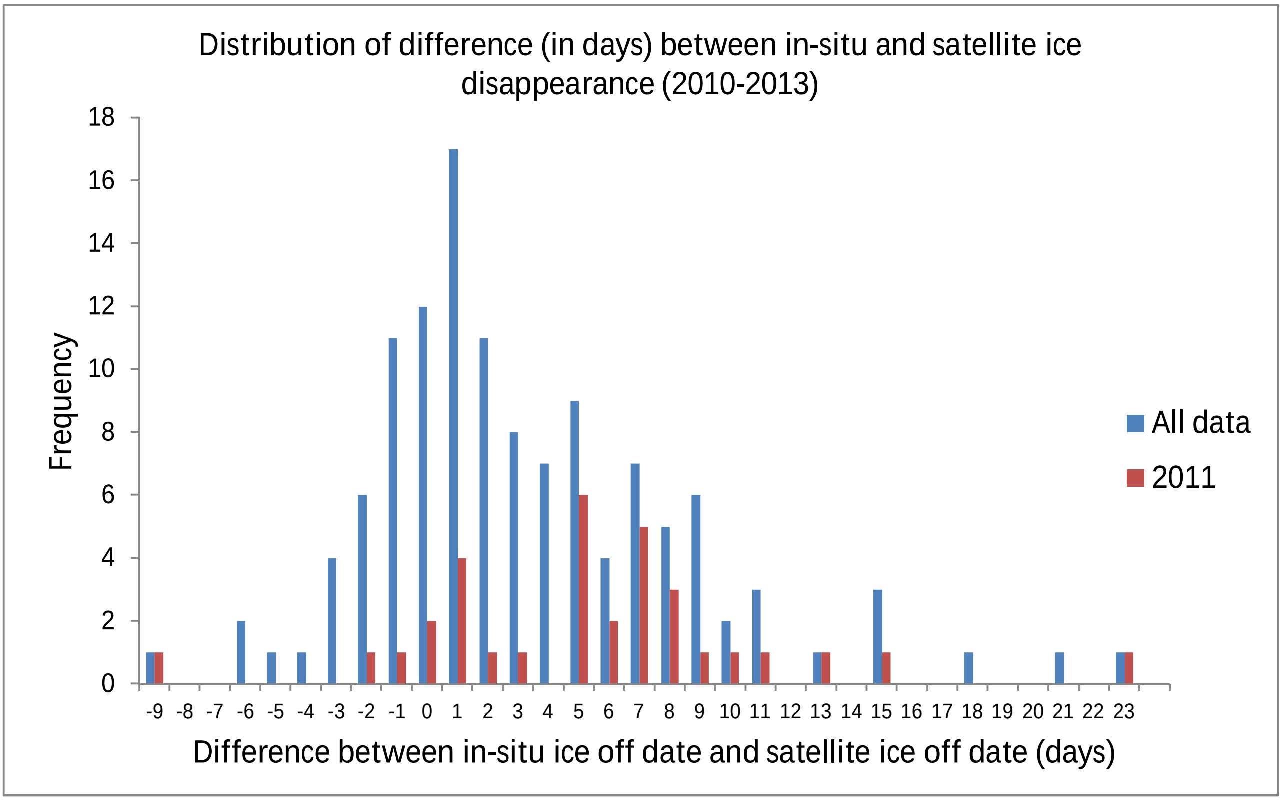

Figure 12.1. Histogram of difference in days between in-situ and satellite ice disappearance date.

Undetected cloud cover, changing water properties (in heavily turbid waters) and changes in reflectance due to sun glint effects are the main causes of over estimation in the ice cover, producing later disappearance of ice cover from satellite data.

To further evaluate the performance of the product, especially in the case of positive difference between satellite and in-situ derived data (i.e. satellite interpretation being later than in-situ), the next available satellite observation from in-situ ice disappearance was interpreted for the percentage of open water pixels from the visible pixels (not cloud covered) for the observation site. The data shows that over 50% from the cases during 2010-2013 the next satellite interpretation was showing that the ice had disappeared.

Table 12.1. Percentages of open water pixels (from all visible observation area pixels) from the first satellite interpretation after the in-situ observation.

Open water percentage [%]	Frequency	Percentage of cases (124) [%]
$0 \leq x \leq 33$	31	25.0
$33 \leq x < 67$	11	8.8
$67 \leq x < 100$	17	13.7
$x = 100$	65	53.4

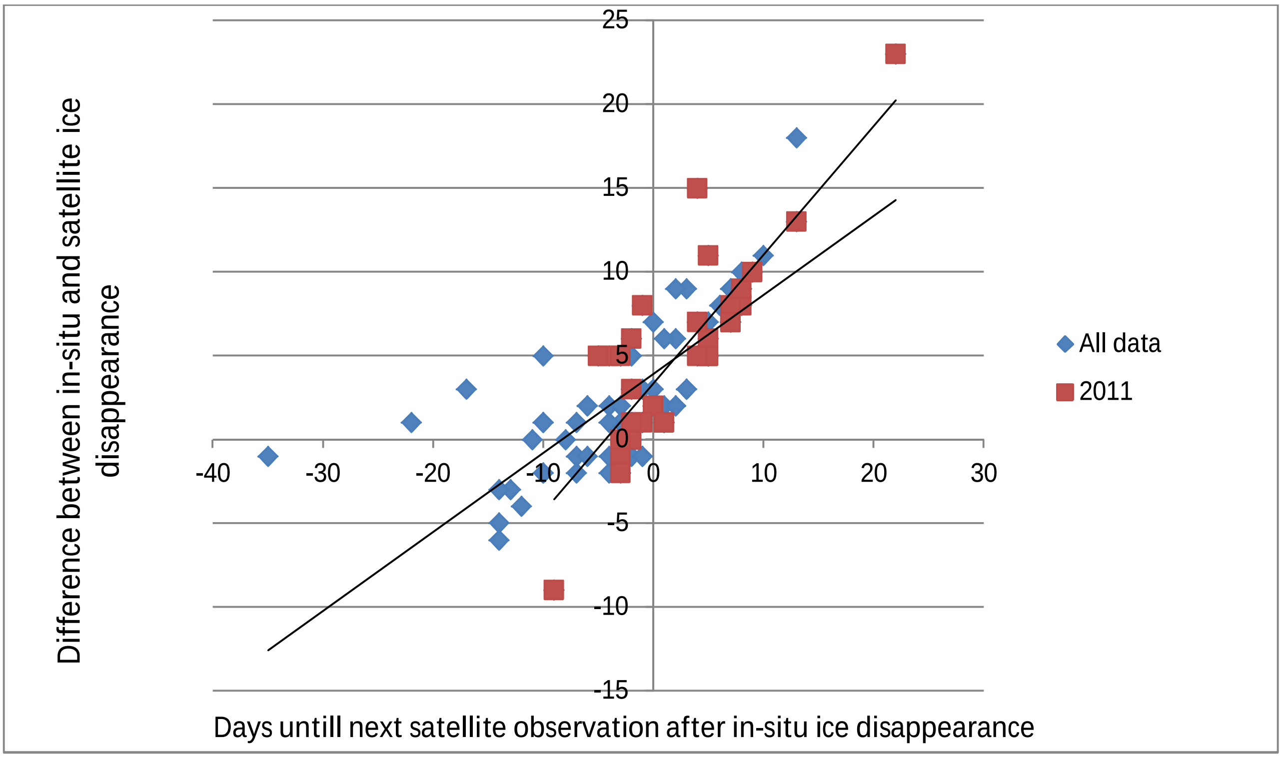

Figure 12.2. Comparison between the Difference in days and number of days from in-situ ice disappearance observation to the date when satellite interpretation could be made.

13. (Evidence to Support Performance Indicator)

Previously, in FP7 Cryoland- project, a comparison was made against operator interpreted lake ice classification from SPOT4 images. The dataset consisted only of 3 SPOT- scenes, and at this point there were four classes. Additional class to the present LIE product was clear ice. With this data the overall classification accuracy was 86%. In Table 13.1 the data is presented with the additional class removed from the analysis. The overall classification accuracy is then 91.6 %. Although, very limited reference data of few high-resolution images, the method proved to be feasible and worth further developing.

Table 13.1. Results of the validation of LIE product (previously conducted inFP7 Cryoland project) against SPOT-4 high resolution satellite data, interpreted by an operator.

	SYKE Ice Extent		
SPOT – Operator Classification	Lake Ice	Open Water	Total Possible
Lake ice	34909	1565	36474
Water	2085	4809	6894
Total	36994	6374	43368

	Omission Error (%)	Commission Error (%)	Mapping Accuracy (%)	
Lake ice	4.3	5.7	90.5	
Water	69.8	22.7	56.9	
Overall Classification Accuracy (%):	91.6			

Recently similar methodology was used for AVHRR data in Weber et al. (2016).

14. References

VHJ, (1984). Hydrologiset havainto- ja mittausmenetelmät. Publications of the National Board of Waters, Finland.

Weber, H., Riffler, M., Nõges, T., & Wunderle, S. (2016). Lake ice phenology from AVHRR data for European lakes: An automated two-step extraction method. Remote Sensing of Environment, 174, 329-340.