

The Lake Ice Extent Information On Hemispherical Scale

Lake ice extent is a sensitive climate change indicator, with a positive feedback to global warming due to the increased absorption of solar radiation into the open water. Beside the climate change aspect, lake ice data are important for transport, safety issues and hydro power, as well as for numerical weather prediction. In addition, ice cover affects the lacustrine ecosystem and water quality.

A novel **ICEmod** method to assess Lake Ice Extent using optical satellite data was developed at SYKE (Heinilä et al. 2021). The method is based on multidimensional Gaussian distributions of several reflectance / thermal bands and indices. The **ICEmod** is exploited in provision of 500m Northern Hemisphere Lake Ice Extent (LIE-NH) as one of the cryosphere products in the Copernicus Global Land Service. The LIE-NH product, relying on Sentinel-3 Land Surface Temperature Radiometer (S3 SLSTR), was validated against over 1700 high-resolution Sentinel-2 Multispectral Instrument (S2 MSI) images including more than 10 million cloud-free LIE-NH product pixels for pixel-by-pixel intercomparison.

LIE-NH will be utilized in the newly released Lake Ice Service, developed under the EU funded Arctic PASSION project (<https://arcticpassion.eu>). Lake Ice Service collects lake ice information from multiple sources and visualizes the information in a format that is easy to access and understand.

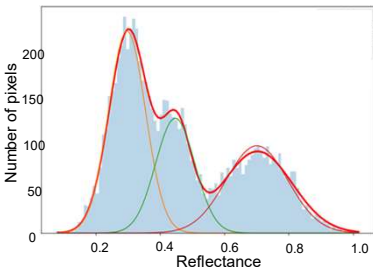


Fig.1. Simulated example of the principle of using Gaussian Mixture Model fitting (in one dimension). For clarity only three components are illustrated. In LIE-NH, the initial number of classes (fitted distributions) is 21 and the number of dimensions is 8: SLSTR bands 1, 2, 5, 6, 8 and 9 and NDSI and NDWI.

The main advantages of the ICEmod method

- ❖ Utilization of several spectral bands and indices
- ❖ Inclusion of simultaneous cloud detection
- ❖ Definition of statistical probability for each pixel
- ❖ Simplicity of processing
- ❖ Easy transition between different satellite sensors

➤ LIE-NH based on **ICEmod** provides lake ice data for more than 13 000 lakes

Validation for the LIE-NH retrieval

- ❖ Reference: cloud-free S2 MSI images from 45 lakes
 - ❖ All seasons from January 2020 to May 2022 were covered
 - ❖ 20 m resolution S2 MSI pixel were classified as water/ice with a simple tree-decision model
 - ❖ Training data included over 38 million classified ice or water pixel

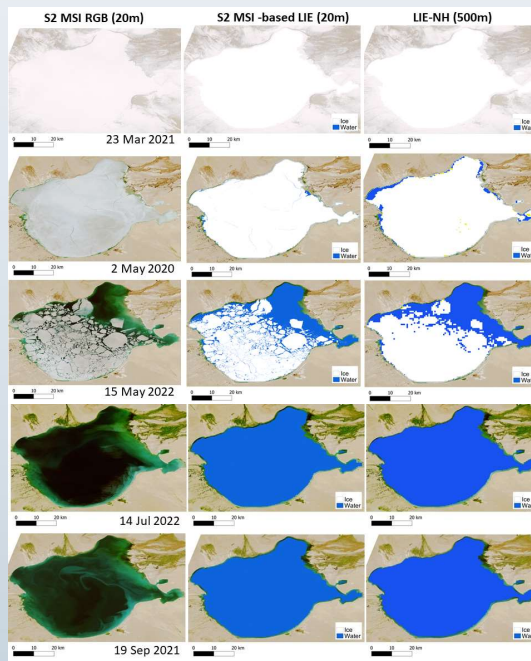


Fig. 2. Validation cases in different seasons in Uvs Lake, Asia (50°18'N 92°42'E). Left pane: S2 MSI-RGB images. Middle pane: 20 m resolution S2 MSI-based LIE product. Right pane: 500 m resolution S3 SLSTR-based LIE-NH product.

Table 1. Contingency matrix for all validated LIE-NH pixels. S2 MSI-based 0.005° reference data is generated using the following threshold: pixel is classified as ice if it contains more than 50% of high-resolution ice pixels

S2 MSI-based 0.005° reference LIE	S3 SLSTR-based 0.005° LIE-NH		
	No ice	Ice	Number of cases
No ice	383144 (TN)	23488 (FP)	3854928
Ice	75697 (FN)	665115 (TP)	6726850
Number of cases	3907137	6674641	10581778

Table 2. The binary metrics derived from Table 1

Metrics	
Recall	98.9%
Overall accuracy	99.1%
Omission error	1.1%
Commission error, FAR	0.6%
Precision	99.7%
F-score	99.3%

Almost all the inaccuracies were found during the low light conditions in late autumn and mid-winter (Nov, Dec, Jan) and for the complex case lakes i.e. including both open and ice-covered pixels

- ❖ Recognizes even dark ice well
- ❖ Very dark ice with water on it, is not identified
- ❖ The commission error is affected by the applied threshold for reference data (50%)

Lake Ice Service for Arctic Climate and Safety

- ❖ Collects lake ice information from multiple sources:
 - ❖ Earth observation data: Copernicus Lake Ice Extent products, true color images
 - ❖ In situ data: Citizen observations, Government lake ice observation network
 - ❖ Visualization for user friendly and easy access
 - ❖ Integrated to TARKKA+ webmap service
- <https://testbed.ymparisto.fi/eo-tarkka/mapandwaterareas/>

