


Lake ice has a notable effect on earth energy balance and local weather by regulating the energy exchange between water and the atmosphere.

# A new method for Lake Ice Extent retrieval for Northern Hemisphere

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 and safety issues as well as for numerical weather prediction. In addition, changes in ice cover affect the ecology of the lake and water quality.

A new **ICEmod** method was developed at SYKE to assess Lake Ice Extent using optical and thermal data by Sentinel-3 Land Surface Temperature Radiometer (SLSTR). The algorithm is based on multidimensional Gaussian distributions of several reflectance / thermal bands and indices. The classification is provided in three categories: i) open water, ii) ice cover and iii) cloud. Each pixel is also given statistical probabilities for all classes.

This novel method is exploited in provision of 500m Lake Ice Extent Northern Hemisphere (LIE-NH) as one of the cryosphere products in the Copernicus Global Land Service. LIE-NH will also be utilized in Arctic Passion (<https://arcticpassion.eu>).

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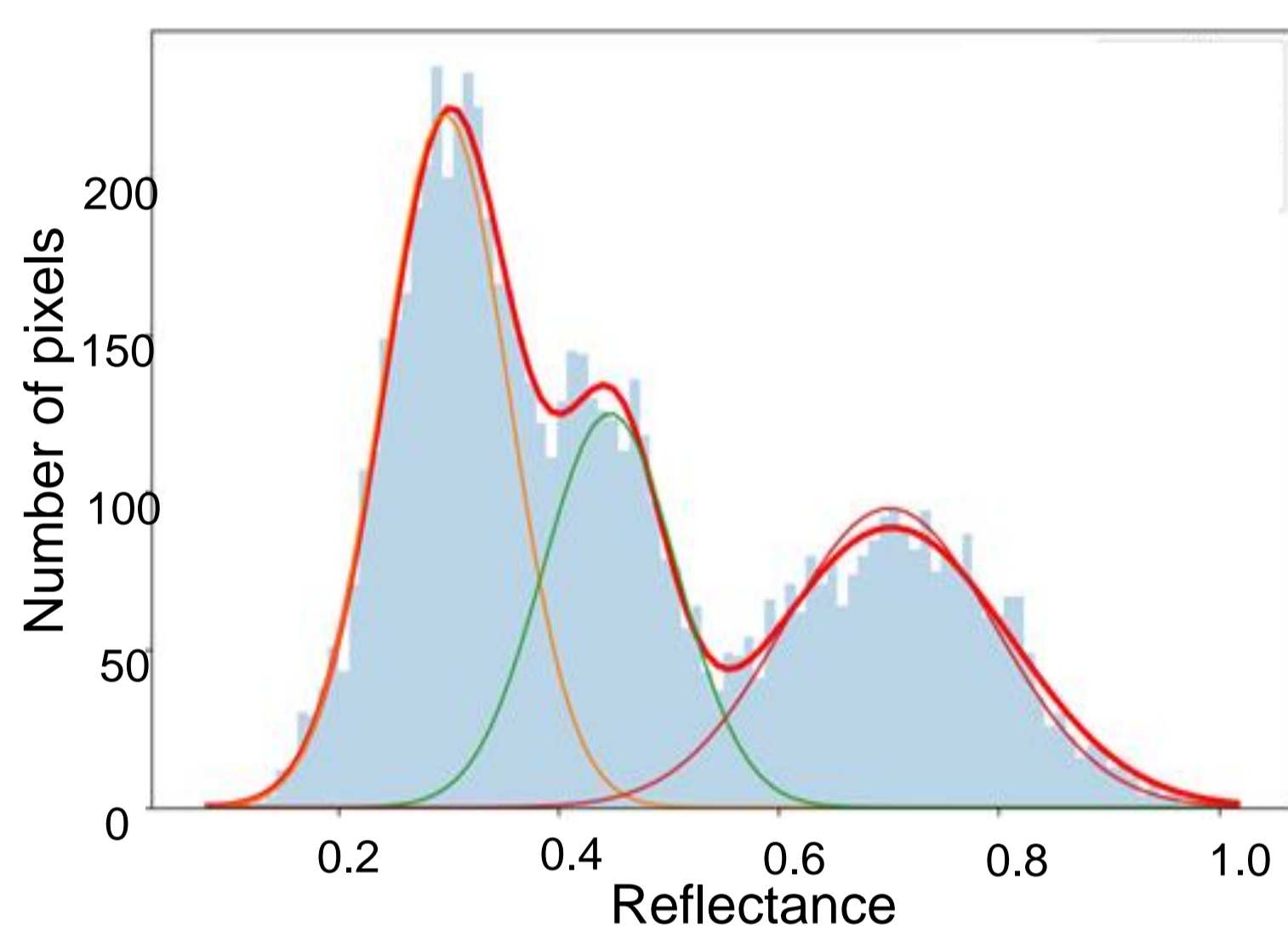


Fig.1. Simulated example of the principle of using Gaussian Mixture Model fitting (in one dimension). For clarity only three components are illustrated. In LIE-NH algorithm the initial number of classes (fitted distributions) is 21 and the number of dimensions is 8: SLSTR bands 1, 2, 5, 6, 8 and 9 and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

## The main advantages of the algorithm

- ❖ 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 retrieval

- ❖ Validated against 118 predominantly cloud-free Sentinel-2 (S2) MSI images
- ❖ Covers ~100 lakes in the different parts of the Northern Hemisphere
- ❖ Focused mostly on complex cases i.e. partially ice-covered, dark ice and/or turbid water

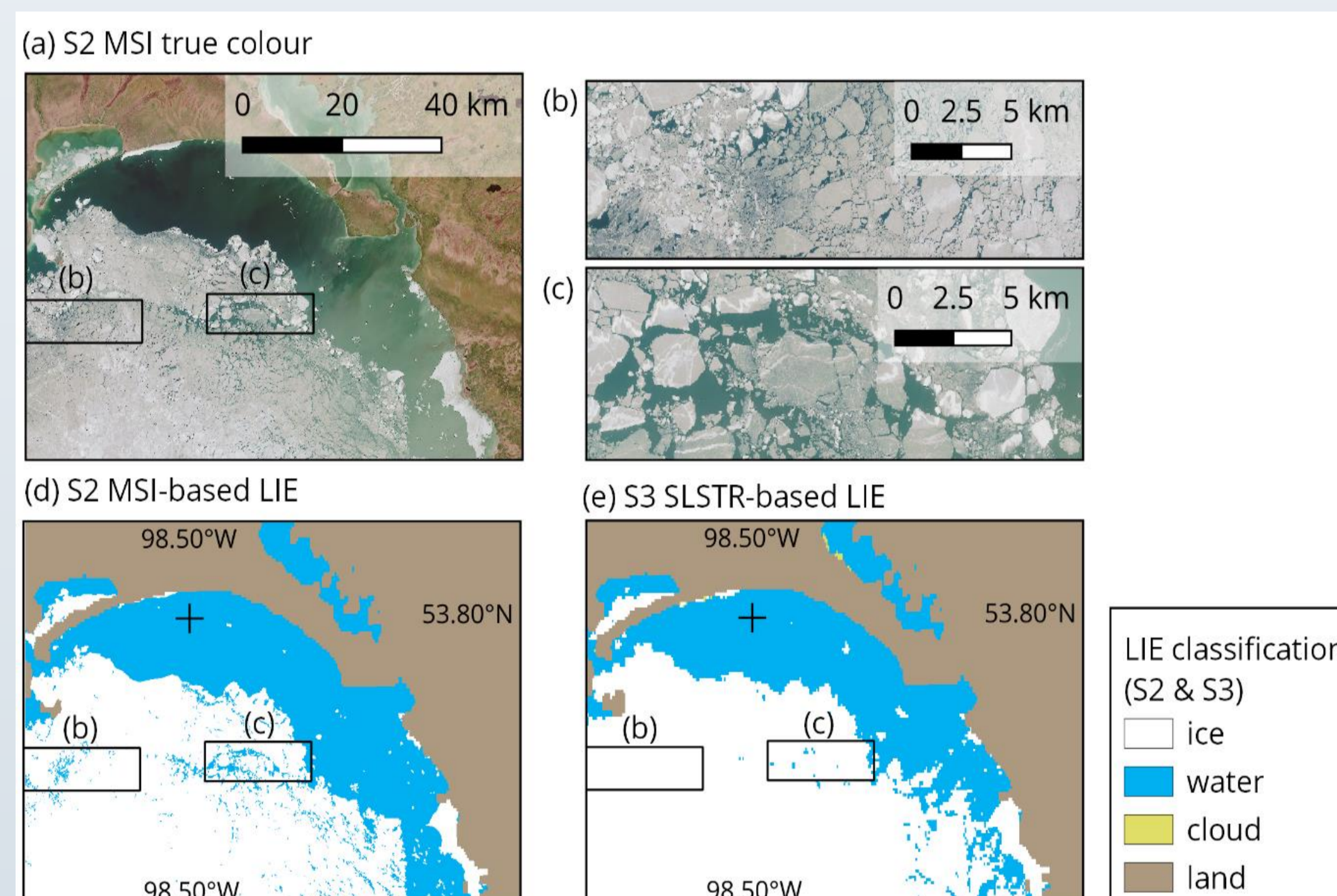


Fig. 2. Lake Winnipeg in Manitoba, Canada on 19 May 2019, as an example of classification when compared to high-resolution S2 MSI data. (a) S2 MSI-RGB image, (b) closeup of the ice cover in S2 MSI-RGB imagery, (c) closeup of broken ice cover in S2 MSI-RGB imagery, (d) S2 MSI-based high-resolution LIE product (e) S3 SLSTR-based 0.005° LIE-NH product.

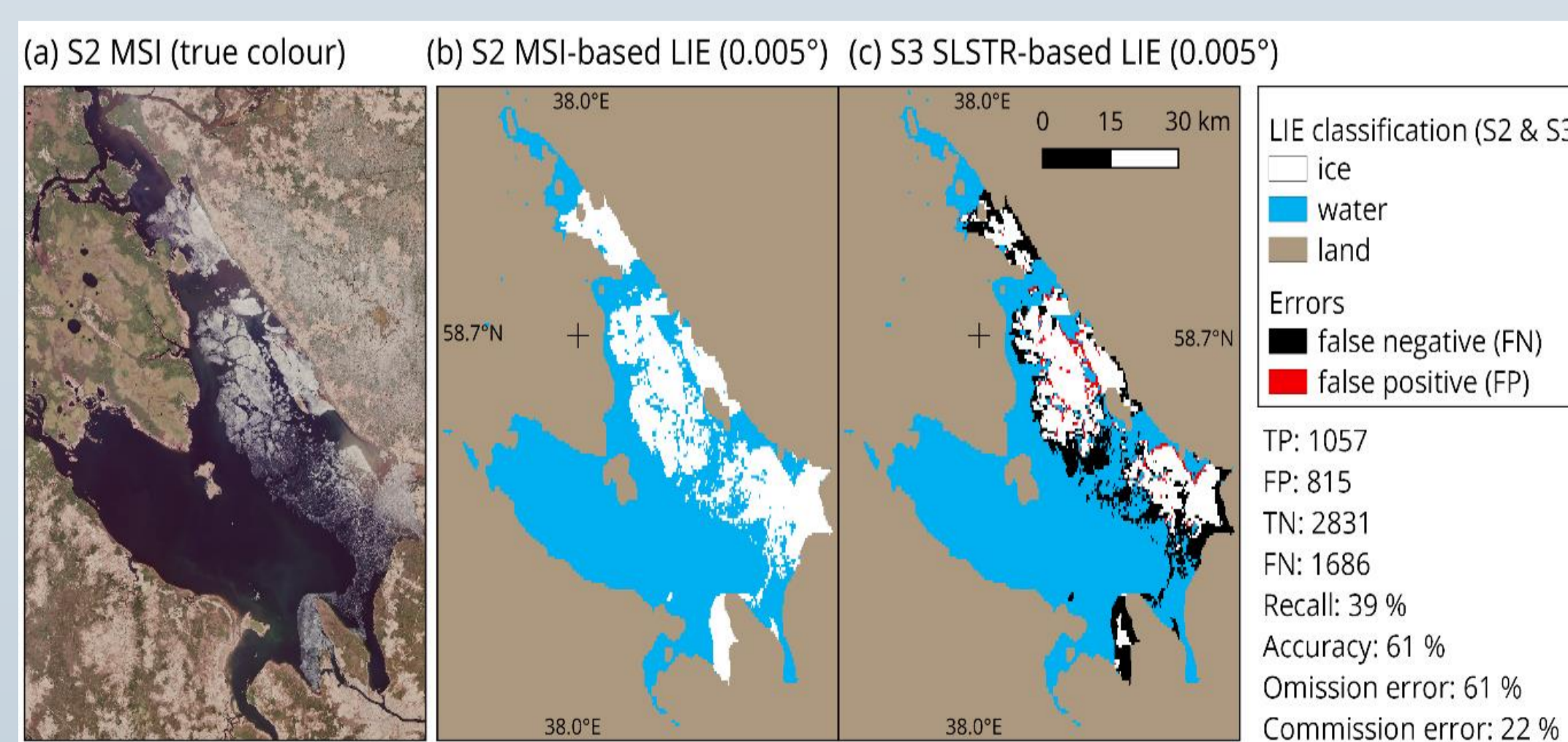


Fig. 3. Rybinsk Reservoir in the Russian Federation on 25 April 2019. (a) S2 MSI-RGB image, (b) S2 MSI-based LIE aggregated to 0.005° reference LIE, (c) S3 SLSTR-based 0.005° LIE-NH, with FN and FP highlighted.

Table 1. Contingency matrix for all validated LIE-NH pixels. S2 MSI-based 0.005° reference data is generated using two different thresholds: pixel is classified as ice if it contains either 1) more than 50% (non-bold numbers) or 2) more than 70% (bold numbers) 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	308278	7982	316260
	<b>306001</b> (TN)	<b>5692</b> (FP)	<b>311693</b>
ice	15342	237798	253140
	<b>17619</b> (FN)	<b>240088</b> (TP)	<b>257707</b>
number of cases	323620	245780	569400
	<b>323620</b>	<b>245780</b>	

Table 2. The binary metrics derived from Table 1 (the better ones in bold).

Metrics	50% threshold	70% threshold
Recall	<b>93.9%</b>	93.2
Overall accuracy	<b>95.9%</b>	<b>95.9%</b>
Omission error	<b>6.0%</b>	6.8%
Commission error, FAR	<b>2.5%</b>	1.8%
Precision	96.8%	<b>97.7%</b>
F-score	95.3%	<b>95.4%</b>

