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NORWEGIAN COMPUTING CENTER

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Automatic estimation of lake ice cover and lake surface temperature using ENVISAT MERIS and AATSR

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Products and sensors

- Lake Ice Cover (LIC): Estimate of ice coverage (concentration) on lakes. Provides fractional ice coverage within each pixel
- Lake Surface Temperature (LST): Estimate of temperature of water, ice or snow surface of lakes

- ENVISAT «Environmental satellite»
- MERIS: Moderate resolution imaging spectrometer, 15 bands (VIS + NIR), 300 m resolution
- AATSR: Advanced Along-track scanning radiometer, 7 bands (VIS + IR), 1 km resolution, dual-view

Lake ice cover (LIC)

- Linear spectral unmixing is used to estimate the relative contribution of endmembers (water, ice, snow) in each pixel.
- Each pixel is represented by a vector, x, describing its spectrum.This is assumed to be a sum of endmember spectra, s_i, (+ noise, w)

$$\boldsymbol{x} = \sum_{i=1}^{M} a_i \, \boldsymbol{s}_i + \boldsymbol{w} = \boldsymbol{S}\boldsymbol{a} + w$$

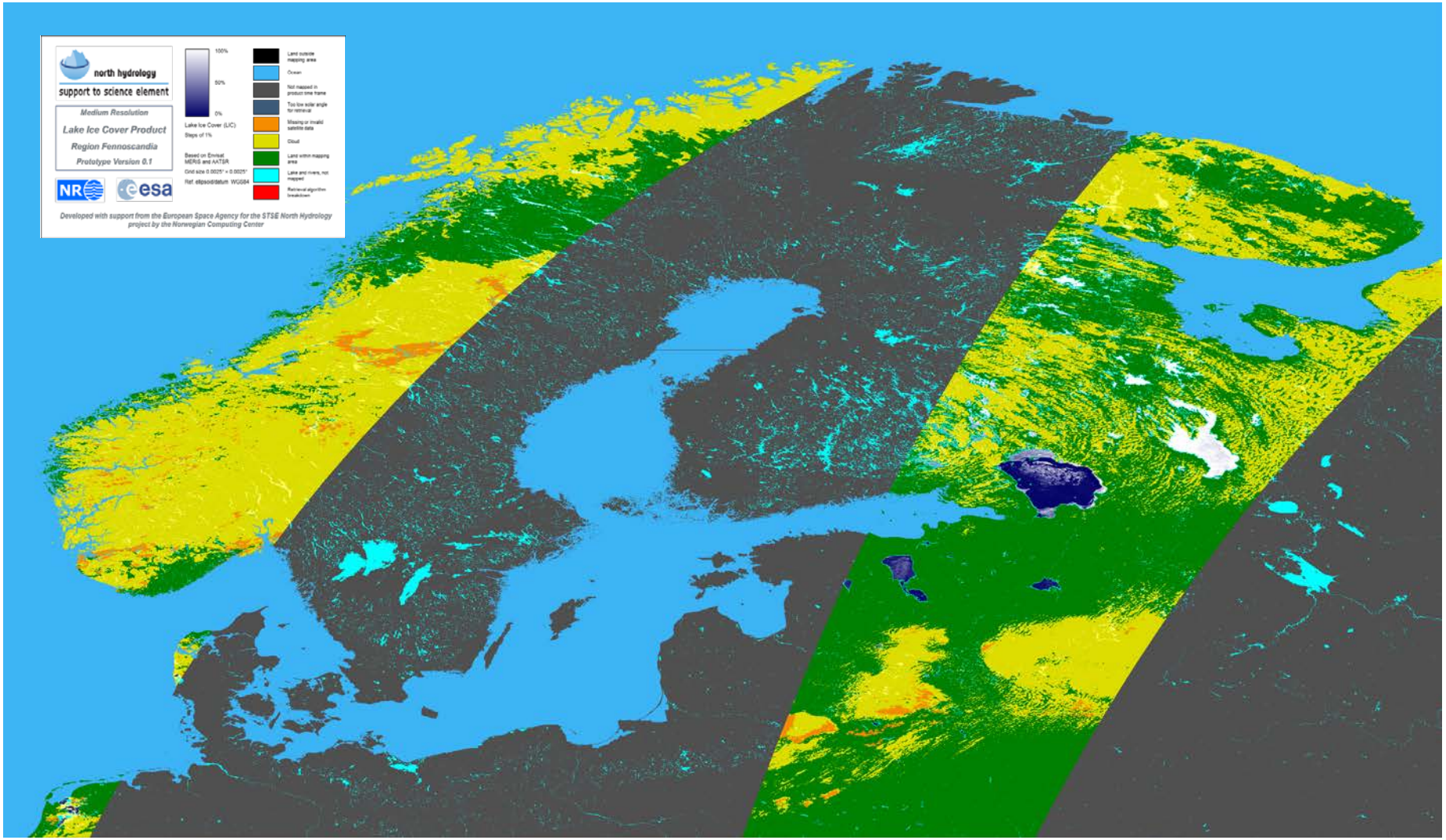
- Solving for each pixel yields an estimate of the relative contribution, a_i, from each endmember.

Lake surface temperature (LST)

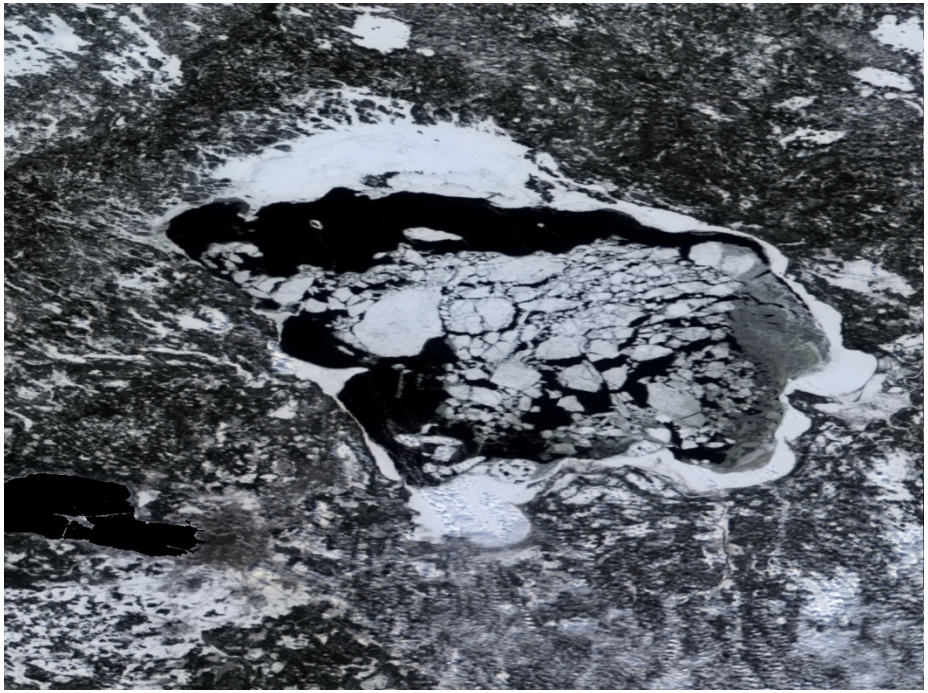
- Estimate of surface skin temperature using thermal AATSR bands
- Planck's law for blackbodies gives a relation between emitted radiation and surface temperature
- Algorithm developed by Key et al. (1997) utilizes split-window (two frequencies) and extended with dual-view properties of AATSR

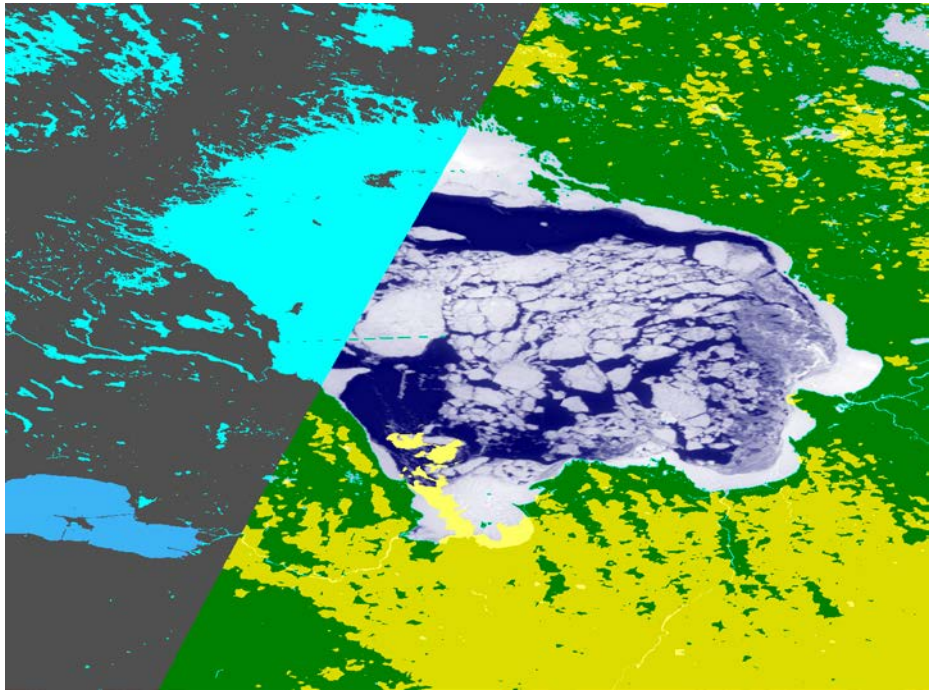
$$T_s = a + bT_{11,nadir} + cT_{11,forward} + dT_{12,nadir} + eT_{12,forward}$$

LIC product example 16.04.2009



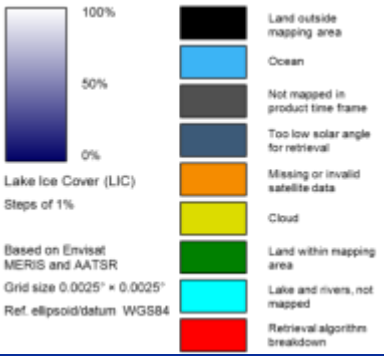
LIC example: Lake Ladoga



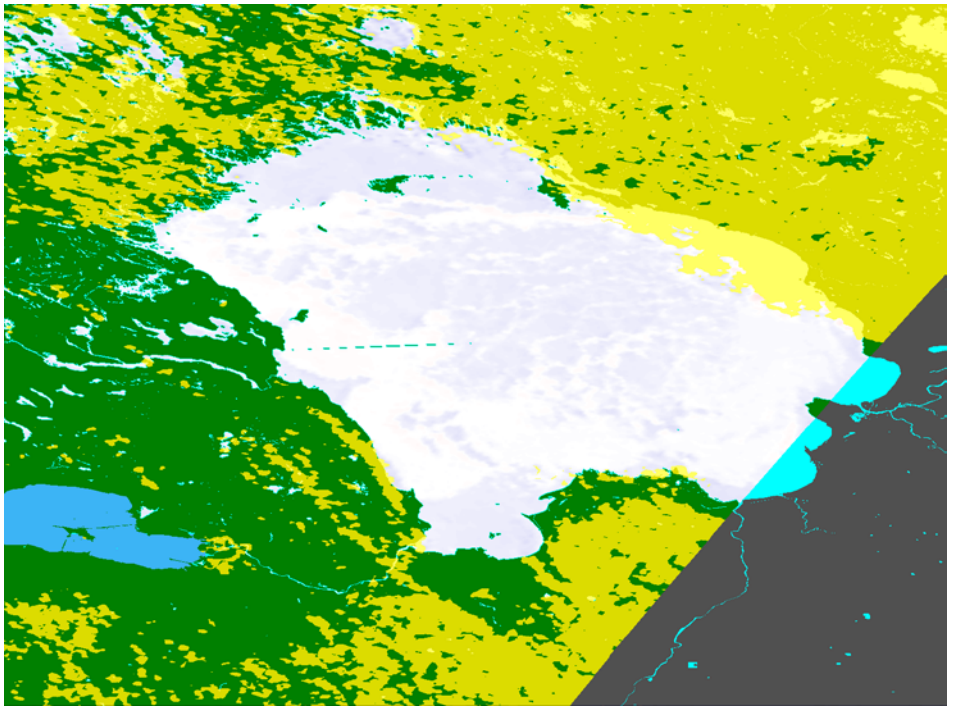


MERIS LIC product

22.03.2009

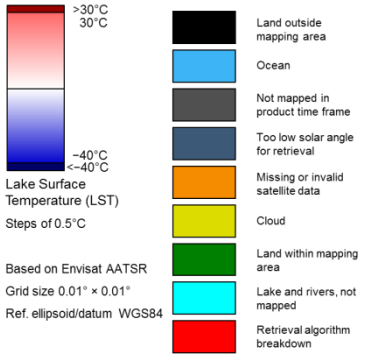


LST example: Lake Ladoga

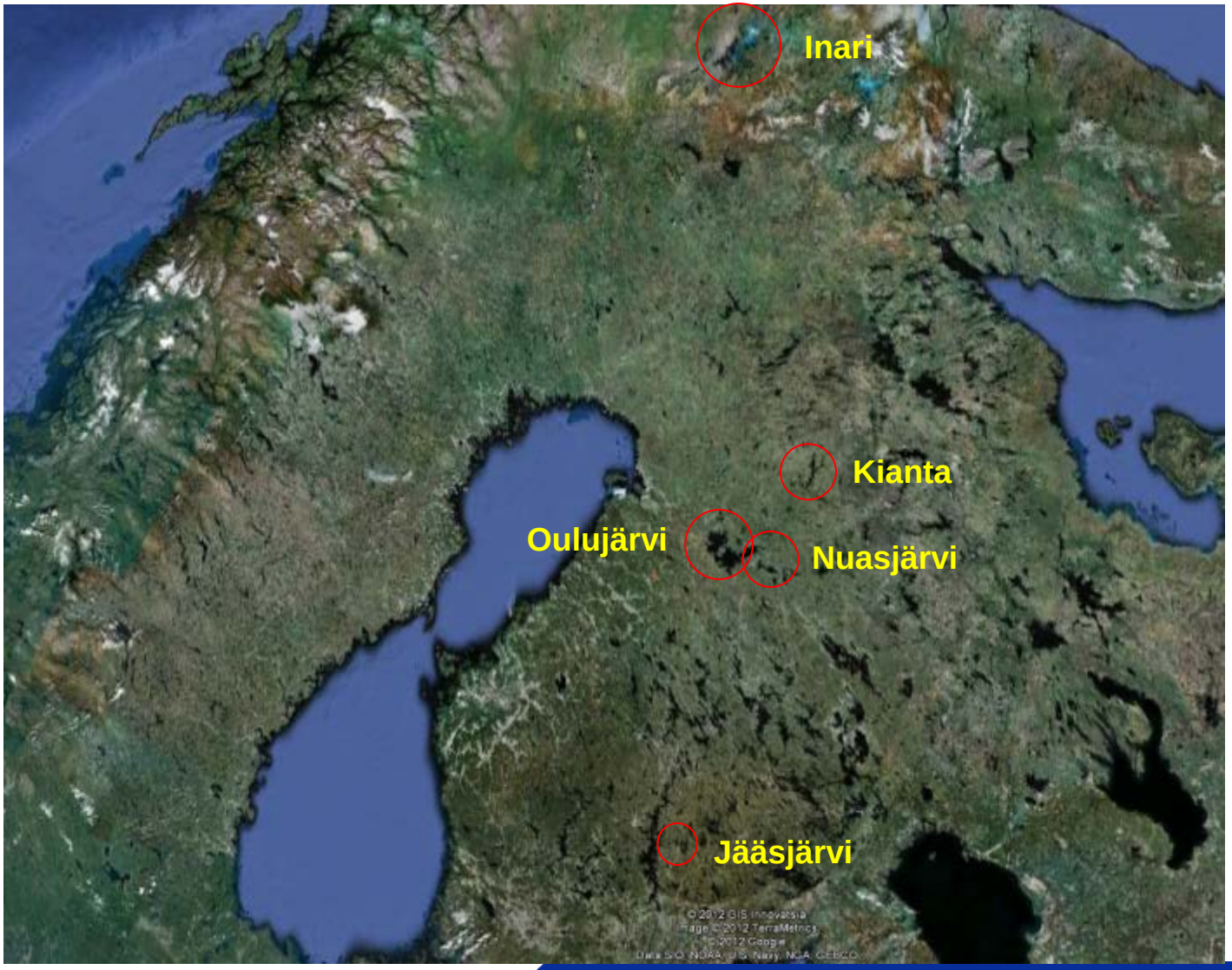


MERIS LST product

21.03.2009



Validation



In situ «Ice off» observations and almost daily temperature measurements by SYKE for a number of Finnish lakes.

Validation: Nuasjärvi

In situ temperature measurements are made at 08:00 in the morning, at 20 cm depth, 1-2m from the observer.

Satellite measurements are performed around noon, estimating *surface skin temperature*.

Ice off: First day of the season with no ice within sight of the observer.

Some distance between measurement points.

Validation of LIC

Date	LIC Inari	LIC Nuasjärvi	LIC Kianta	LIC Oulujärvi, Melalahti	LIC Oulujärvi, Vaala
22.04.2009		79	93	94	44
01.05.2009		43	82	64	9
07.05.2009		10, Ice off			16
11.05.2009		9	10		
14.05.2009		5	5, Ice off	6, Ice off	15, Ice off
16.05.2009	59				
17.05.2009	58				
20.05.2009		8	5	6	
23.05.2009	45				
24.05.2009		49	6		
25.05.2009	55				
26.05.2009				11	
01.06.2009					15
07.06.2009	Ice off				
08.06.2009	0				
10.06.2009	9				

Comparison of Lake Ice Cover estimates and «ice off» dates from in situ observations.

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24.05.2009		49	6		
25.05.2009	55				
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«noise floor»

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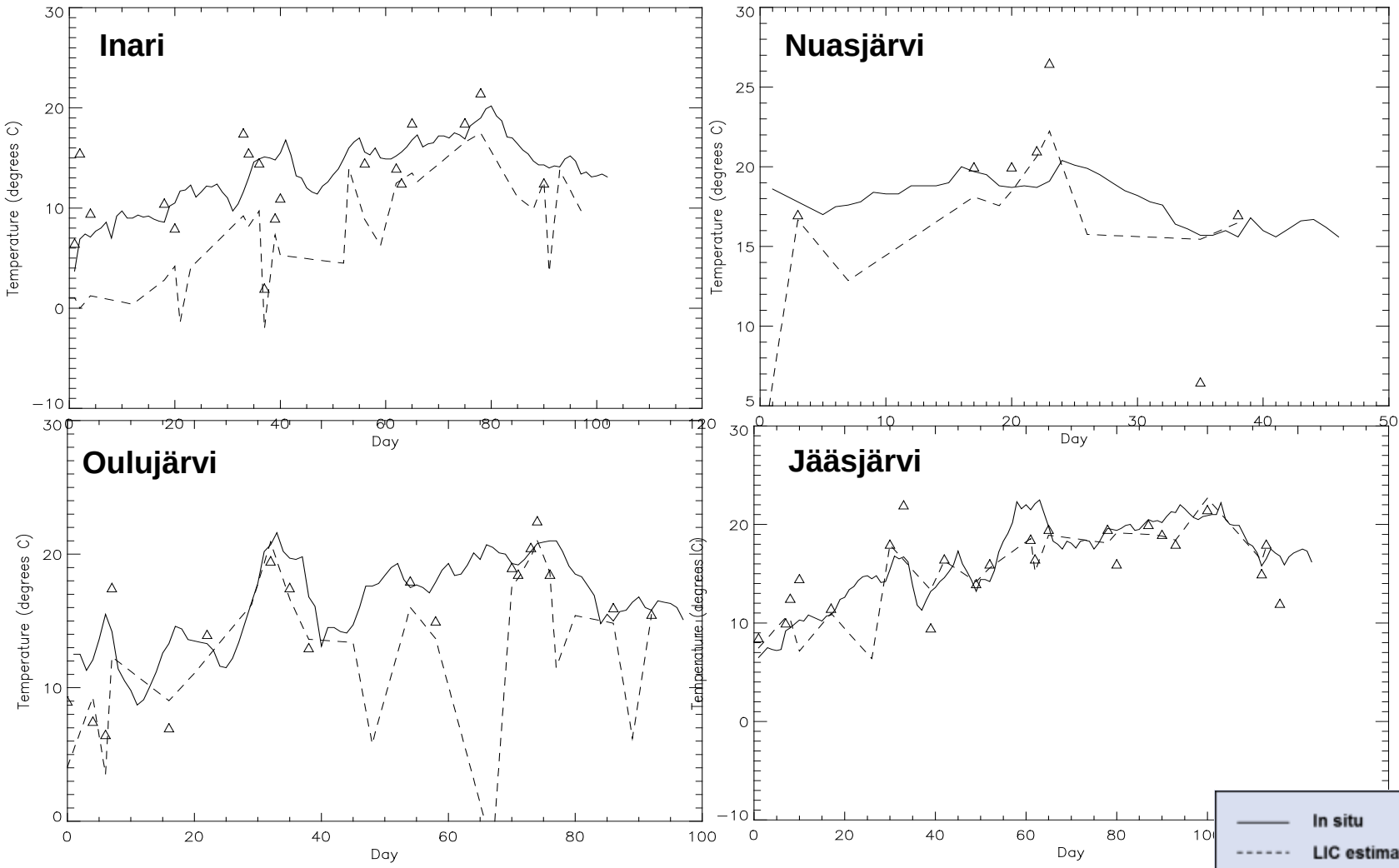
Cloud contamination

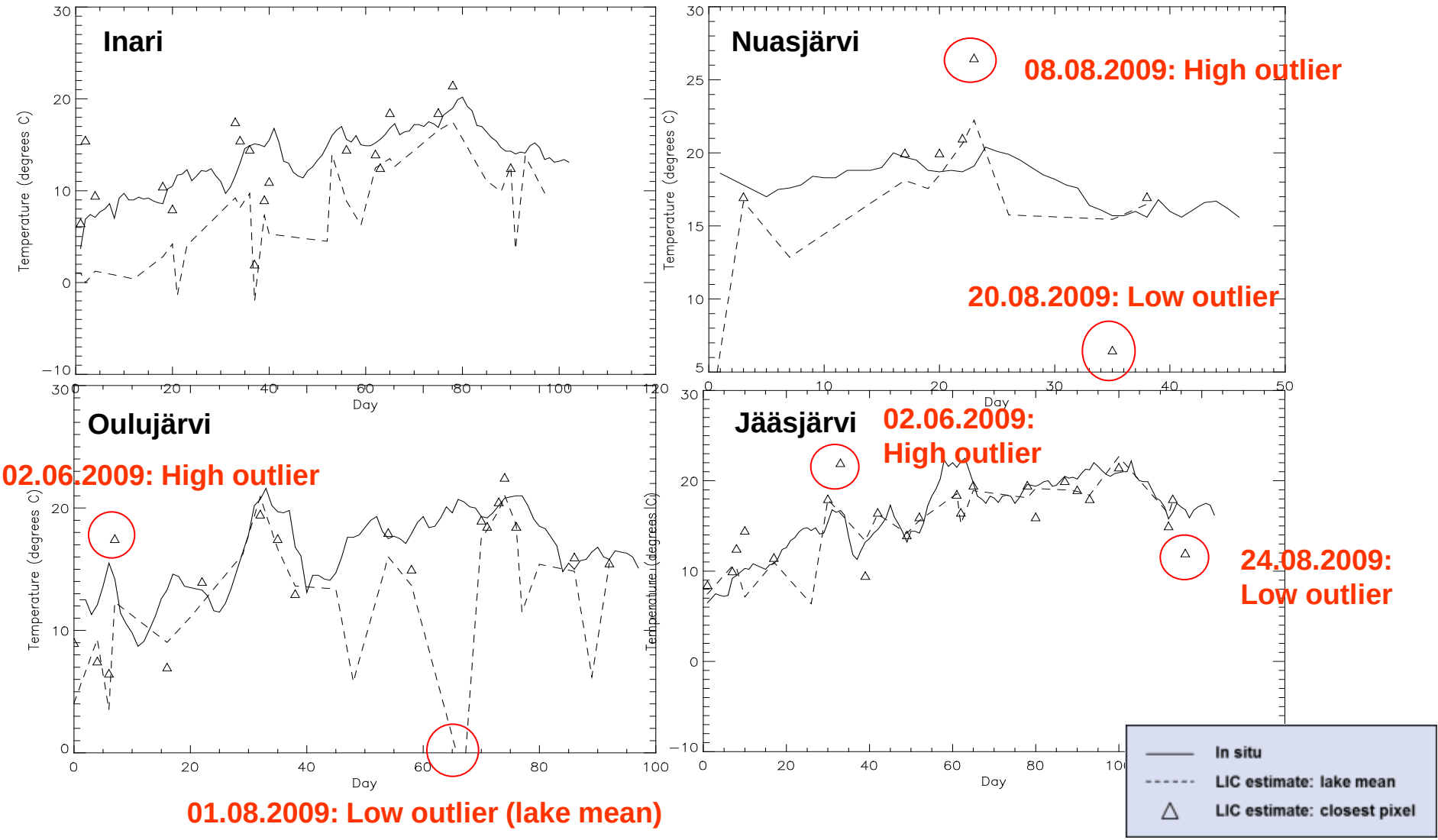
«noise floor»

Comparison of Lake Ice Cover estimates and «ice off» dates from in situ observations.

Validation of LST



Validation of LST



Conclusions

Lake Ice Cover (LIC):

►Good correspondence between LIC estimates and in situ data

►«noise floor» of 10-15%

►Some contamination from unmasked clouds

►Still some problems with thin ice, or ice with water on top

Lake Surface Temperature (LST):

►Most satellite observations are well correlated with in situ measurements

►Some outliers, both high and low

►Contamination from unmasked clouds causes low outliers

►Some differences may be attributed to different time and depth for measurements

Main conclusion: These algorithms are suitable for operational LIC and LST products – if the cloud masking can be improved