Simultaneous Envisat ASAR and MERIS monitoring of lake ice on lake Ladoga

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Outline

- Motivation for lake ice cover monitoring
- Presentation of sensors and study site
- Classification based on ASAR
- Lake Ice Concentration from MERIS
- Fusion of classification results
  - ASAR-based classification
  - MERIS Lake Ice Concentration
  - Combined with priority to MERIS
- Multi-sensor feature-level fusion
- Conclusions

Why monitor lake ice

Interesting for different fields:

- Climate change research - ice mapping can improve parameterization
- Regional climate modelling
- Numerical weather prediction
- Hydrological forecasting

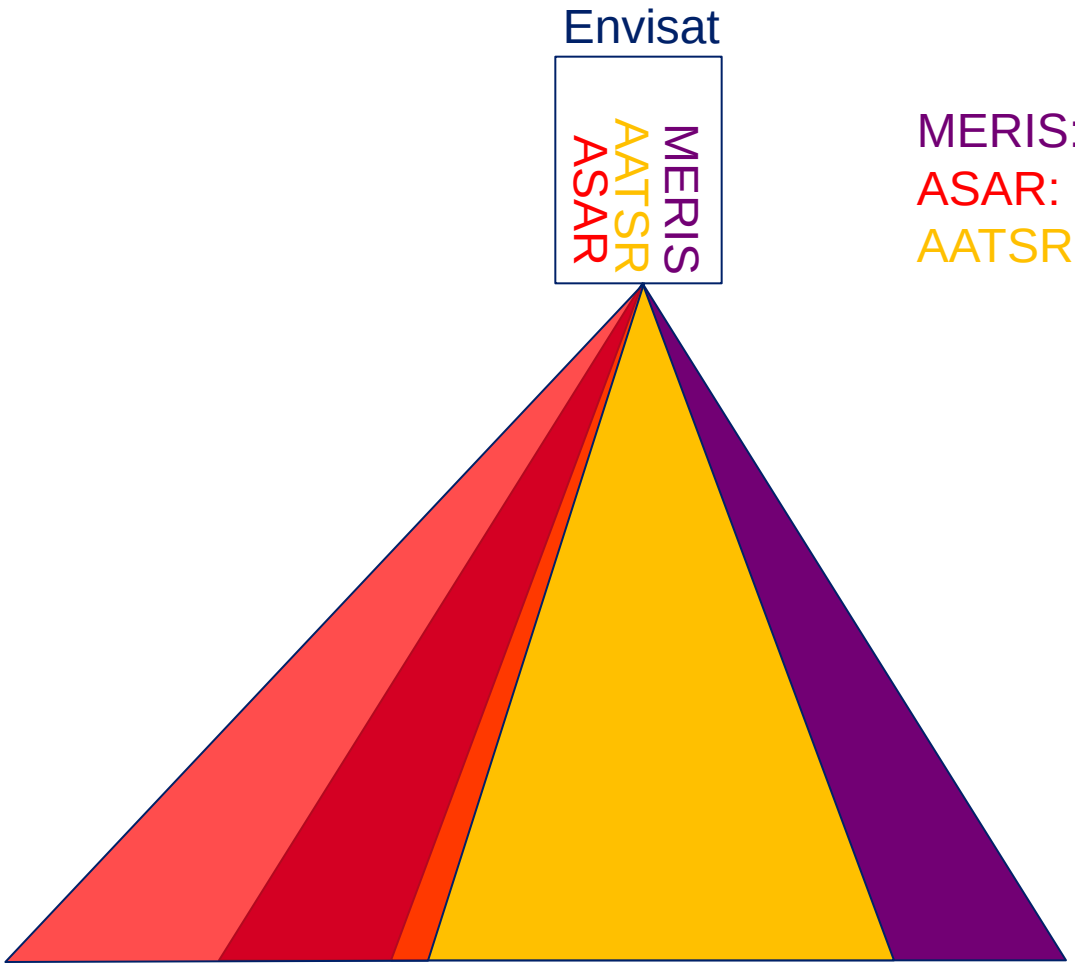
- Data from optical sensors are well suited for segmenting water from ice on lakes, but suffers from lack of observations due to clouds or, in the high north, due to lack of daylight
- SAR data is available regardless of clouds or lack of light, but it is very sensitive to variations of surface roughness and incidence angle

Combining three Envisat sensors

ENVISAT: ”Environmental Satelite”, launched by ESA in 2002, ceased data transmission April 8th 2012.

- MERIS:
  - Optical sensor, 15 spectral bands in visible and NIR
  - Swath width 1150 km and spatial resolution 300 m
- AATSR:
  - Optical sensor, 7 visible and IR bands
  - Swath width 500 km and spatial resolution 1 km
  - Purpose: Cloud detection (not possible over snow and ice with MERIS)
- ASAR:
  - C-band SAR
  - We use wide-swath medium-resolution HH images of about 100 × 100m

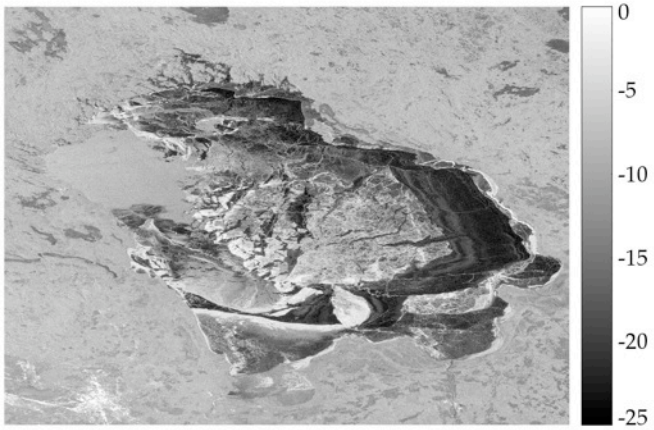
Field of view



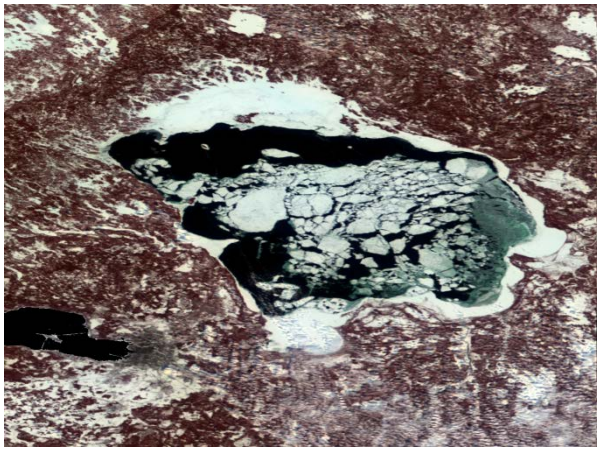
Study site: Lake Ladoga, Russia

From Google Earth

Lake Ladoga



ASAR , Feb 2nd 2006



MERIS , Mar 22nd 2009

Classification based on ASAR

Each pixel (i,j) in the SAR scene is represented by a 2D feature vector

$$x(i,j) = \log\left(\left[E\{n(i,j)\}, \mathrm{var}\{n(i,j)\}\right]\right)$$

- E is mean value, var is variance in a 7-by-7 pixel area around(i,j).
- Model features by Gaussian Mixture Model
- Fit model with Expectation-Maximization, Bayes classifier
- Segment each image into three classes, where one should represent water and two represent different ice areas.
- Backscatter σ^0 corrected for incidence angle θ effects by $\sigma^1=\sigma^0 +1.4(\theta -32\ ^o)$
- Assigning which class is water is done by using a interpolated result from the MODIS snow cover product.

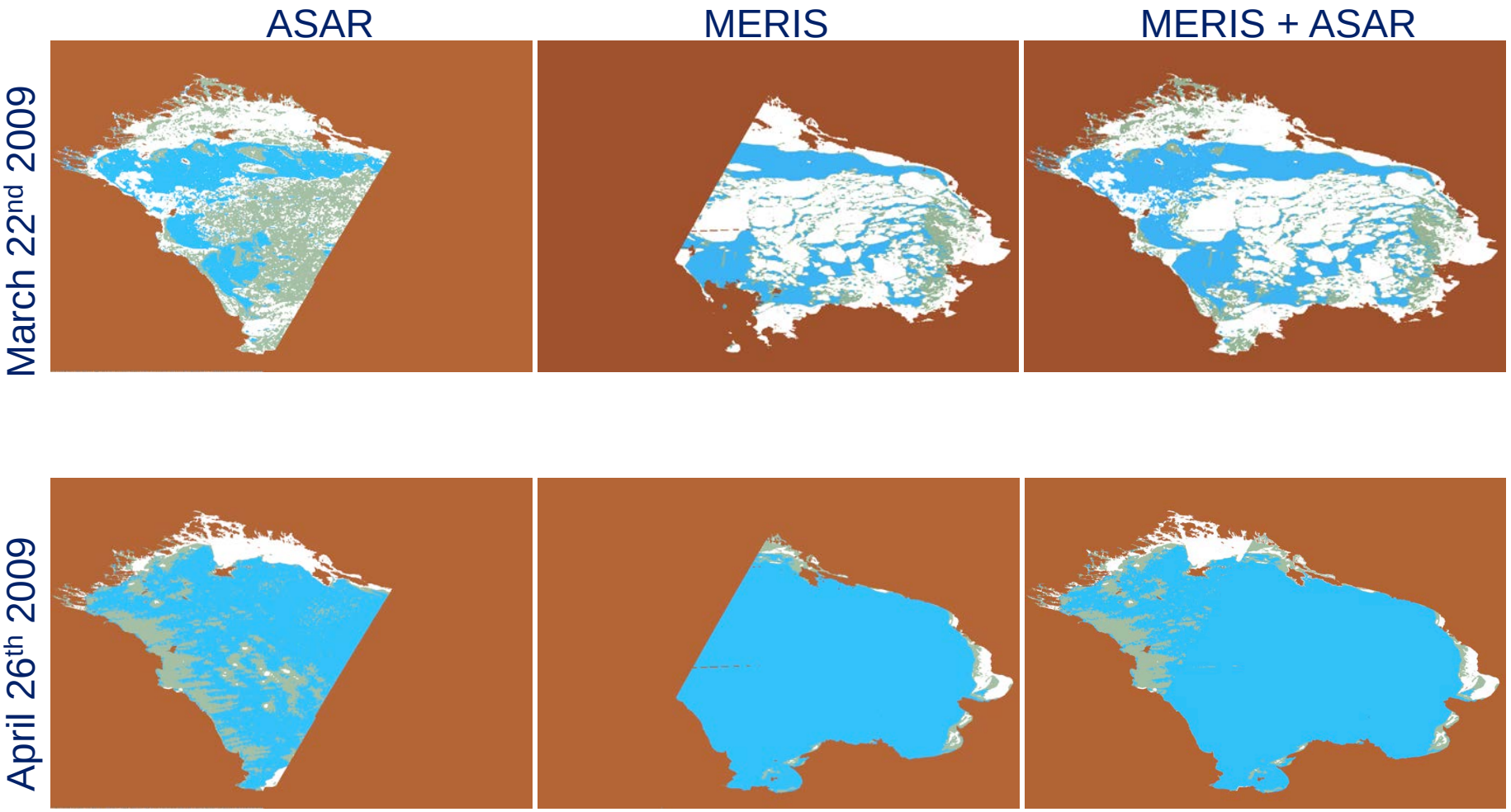
Lake Ice Cover from MERIS

- 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.
- This is used to produce a lake ice cover product.
- Clouds are masked out using AATSR data.

Fusion of classification results



Multi-sensor feature level fusion

- Combine MERIS and ASAR data: Adding two ASAR features to the MERIS data vector as extra bands and normalize:

$$x(i,j) = \begin{bmatrix} \text{MERIS band 1} \\ \text{MERIS band 2} \\ \vdots \\ \text{MERIS band 15} \\ E\{n(i,j)\} \\ \text{var}\{n(i,j)\} \end{bmatrix}$$

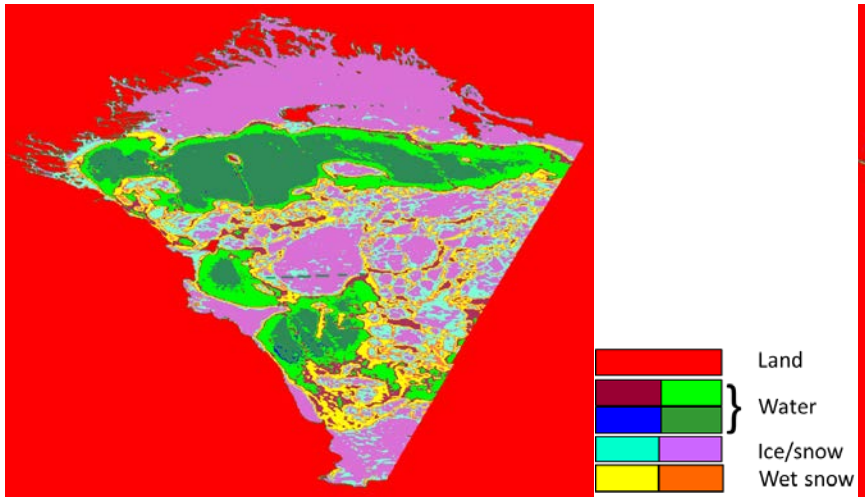
- Perform K-means classification with 12 classes

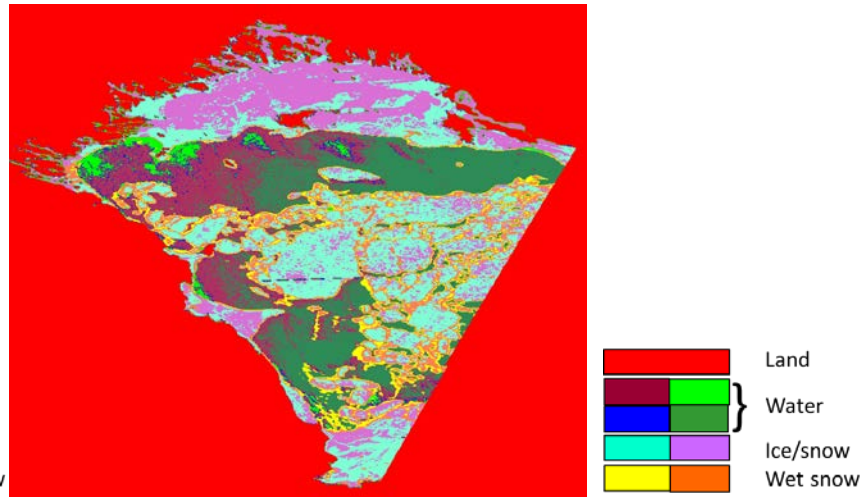
Combined classification

MERIS

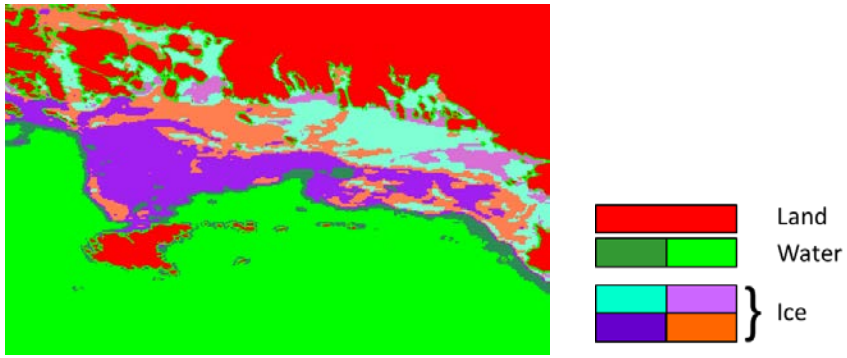
MERIS and ASAR

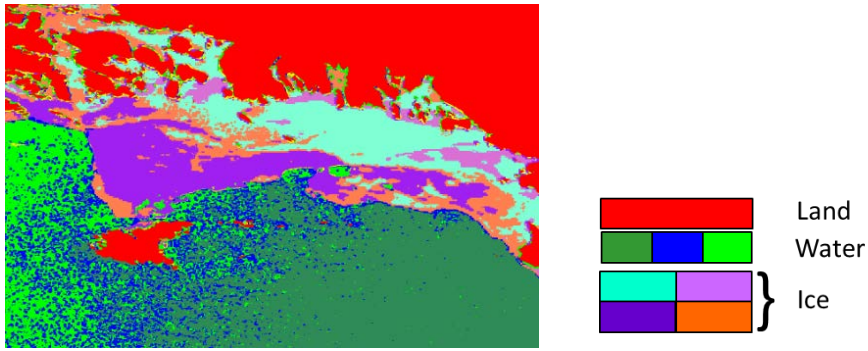
March 22nd 2009





April 26th 2009





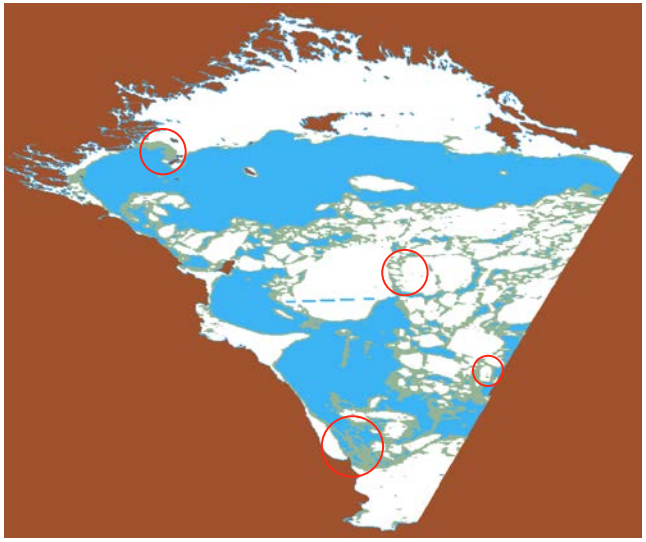
Combined classification

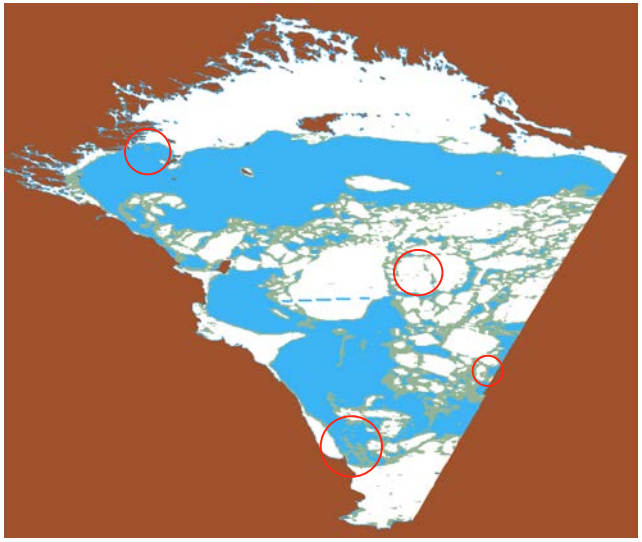
MERIS

MERIS and ASAR

March 22nd 2009

April 26th 2009





Conclusions

- A fusion of SAR and optical sensors for lake ice cover determination shows some promise
- The sensors considered here have very little overlap, has proven difficult to find common data
- Fusion at segmentation level can improve spatial coverage of the lake ice cover product
- Fusion at feature level can be done, but has not been shown to improve the segmentation
- More overlapping data needed to conclude
- Coverage will improve with Sentinel 1 & 3