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SEASAR 2012
The 4th International Workshop on Advances in SAR Oceanography

SAR Measurements of Sea Ice Drift in the Fram Strait and Bay of Bothnia

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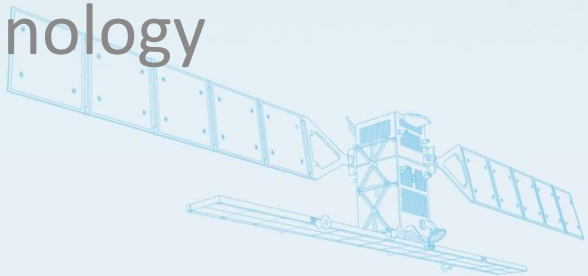
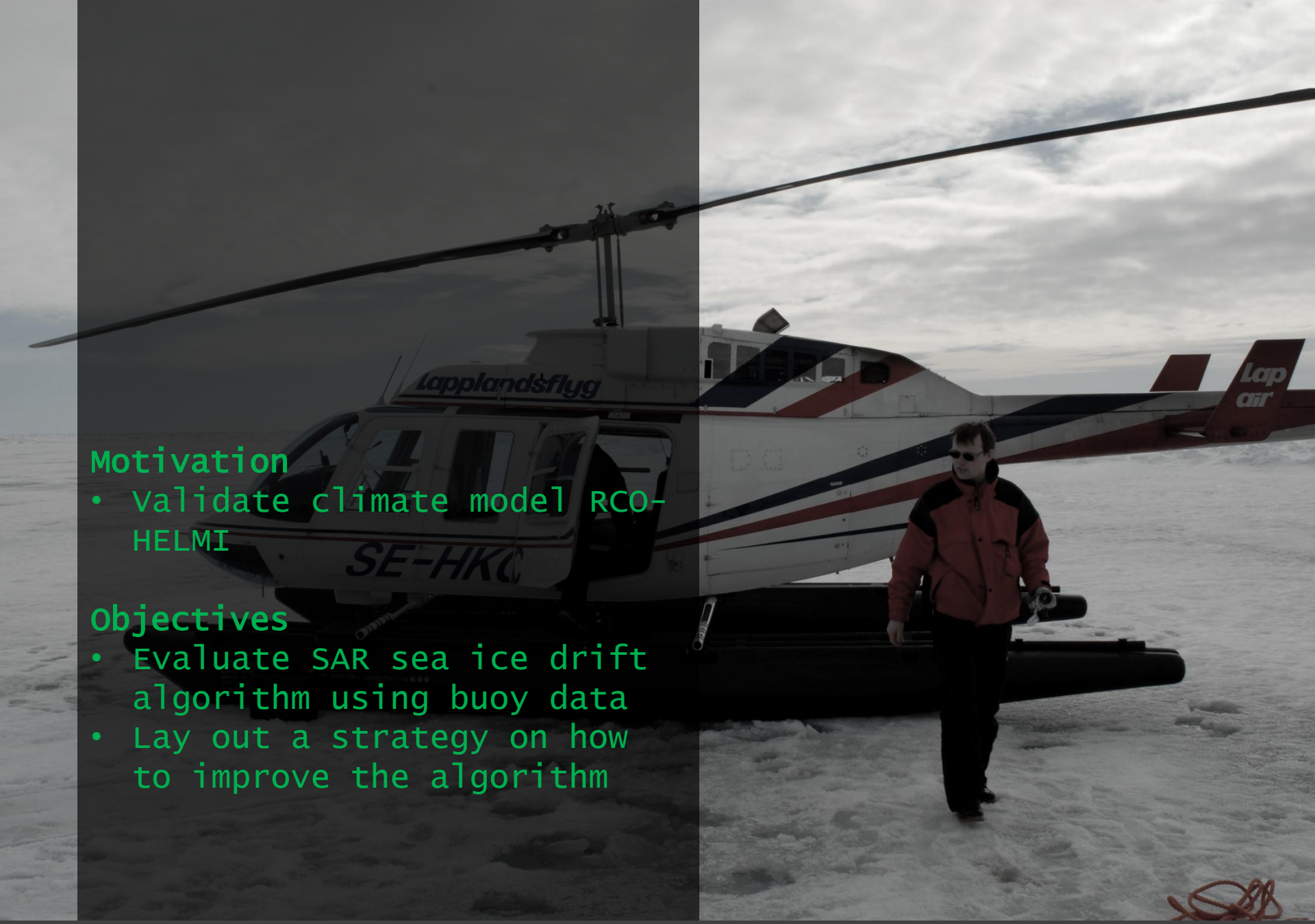


18-22 June 2012 | Tromsø, Norway

Outline

- Background
- SAR algorithm for sea ice drift
- Evaluation using buoy data
- Future work – Feature tracking



Motivation

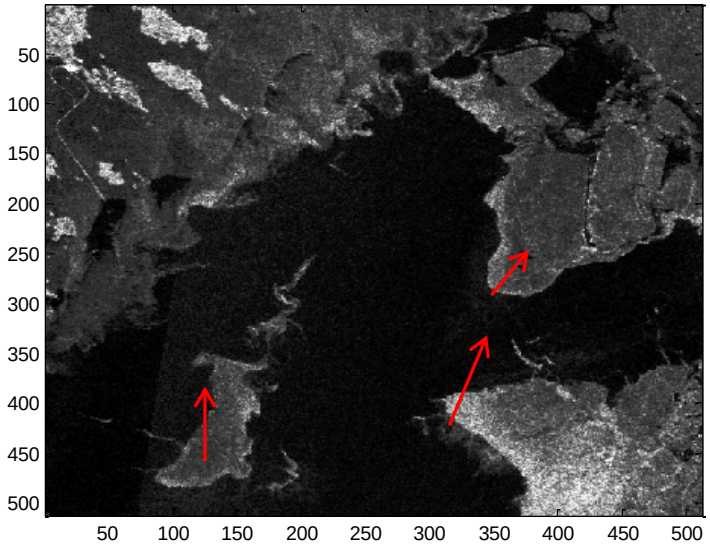
- Validate climate model RCO-HELMI

Objectives

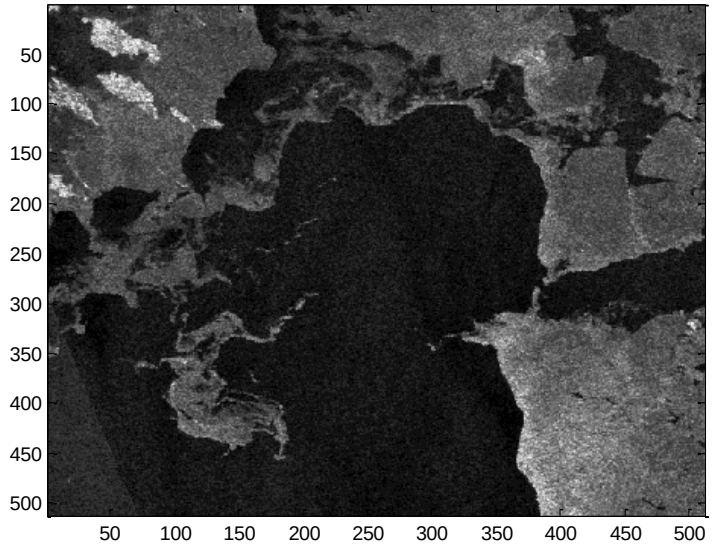
- Evaluate SAR sea ice drift algorithm using buoy data
- Lay out a strategy on how to improve the algorithm

Synthetic Aperture Radar data

- **ENVISAT ASAR Wide Swath Mode images**
  - **Spatial resolution 150 meters**
  - **Swath width 400 km**



2009-04-22
ENVISAT ASAR



2009-04-23
ENVISAT ASAR

Phase correlation

- Image f_2 is a shifted version of f_1:

$$f_2(x) = f_1(x - d)$$

- Fourier transform

$$F_2(\xi) = F_1(\xi)\exp(-2\pi i \xi d)$$

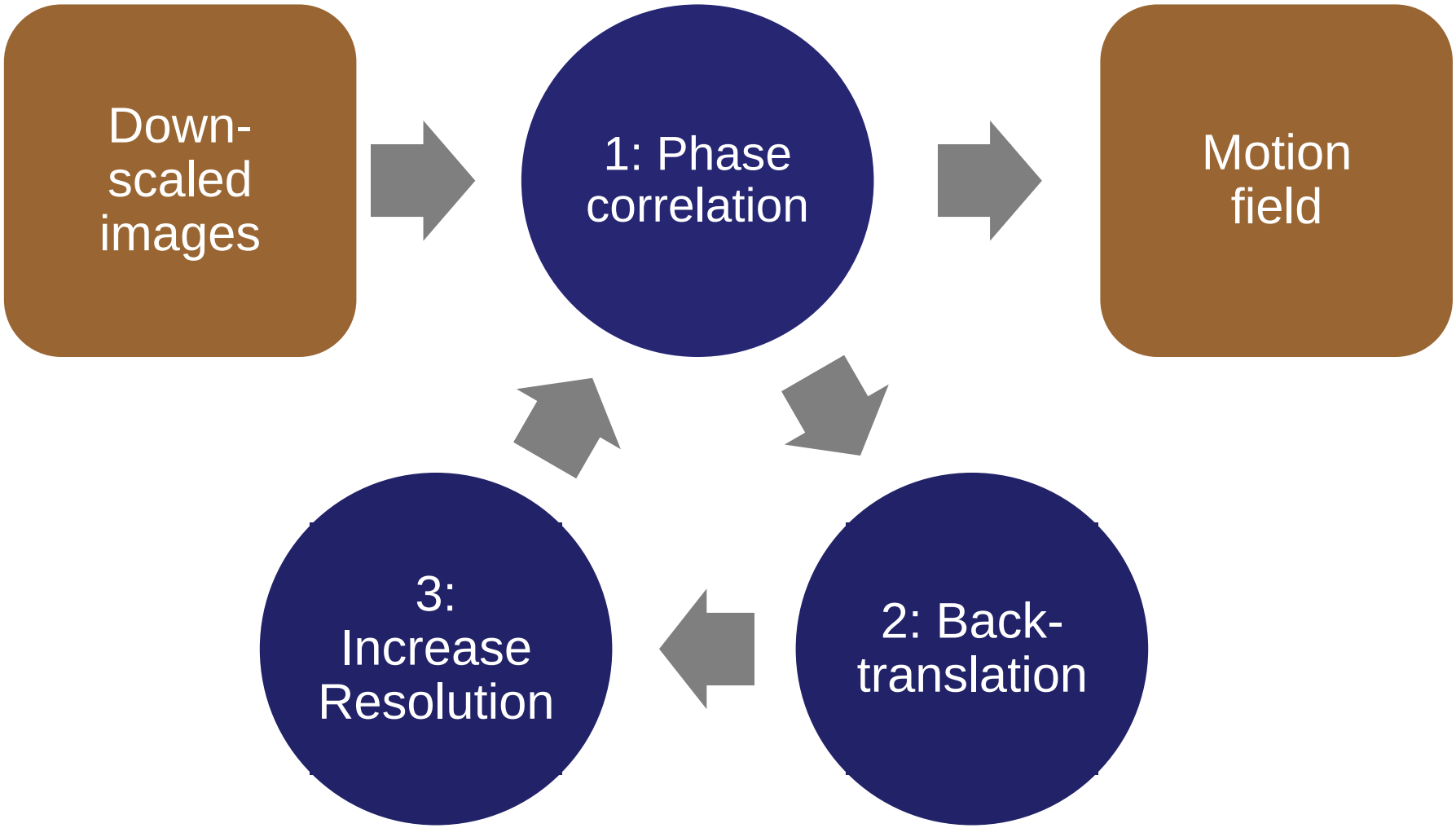
- Multiply with $\overline{F_1(\xi)}$ to cancel out phase from F_1

$$\frac{\overline{F_1(\xi)}F_2(\xi)}{|\overline{F_1(\xi)}F_1(\xi)|} = \exp(-2\pi i \xi d)$$

- Inverse Fourier transform to $\delta(x - d)$

Multi-resolution processing system

M. Thomas *et al.* 2008



Additions to Thomas algorithm

- Rotation determination using Fourier Mellin Log-Polar Transform

$$\begin{cases} \rho = \log(\sqrt{u^2 + v^2}) \\ \theta = \operatorname{atan}(\frac{u}{v}) \end{cases}$$

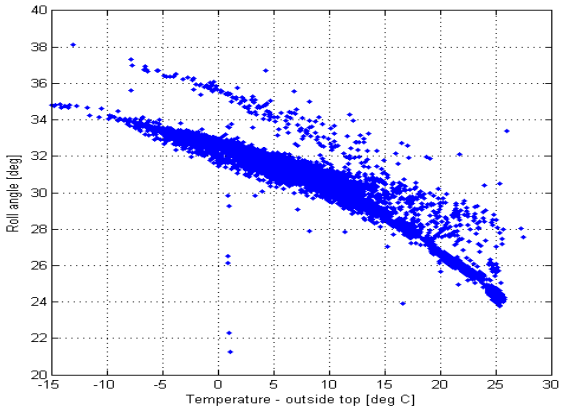
- Weighted median filtering applied to final motion field, using the values of the phase correlation as weights

$$d_{wm}(x_0, y_0) = \underset{d(x,y)}{\operatorname{argmin}} \sum_{(x-x_0)^2+(y-y_0)^2<R^2} w(x,y)|d(x,y) - d(x_0, y_0)|$$

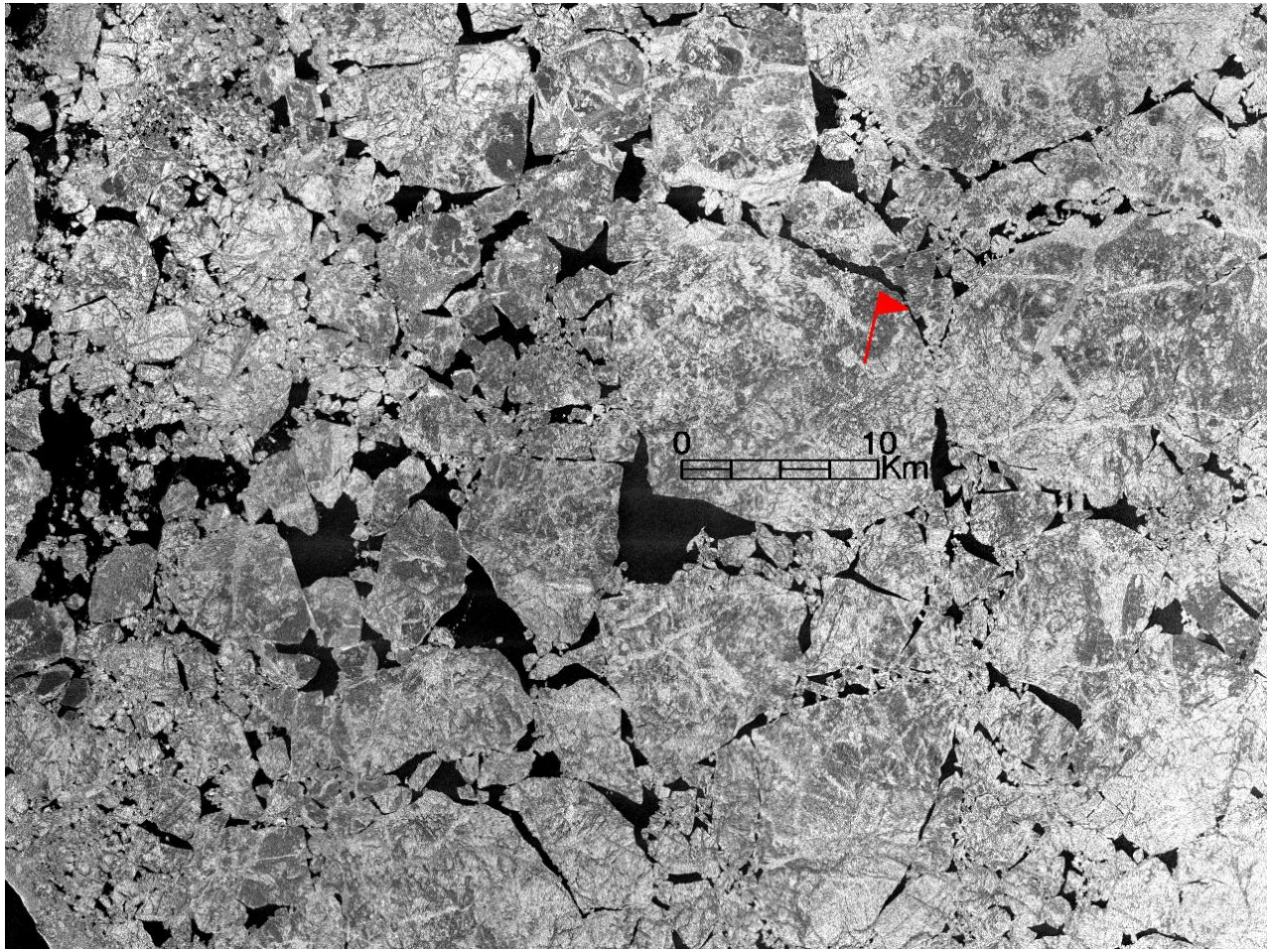
The ice buoy DRIVA

Measures:

- GPS Position
- Temperatures (Air, surface, inside)
- ~~Pitch, Roll, Yaw~~

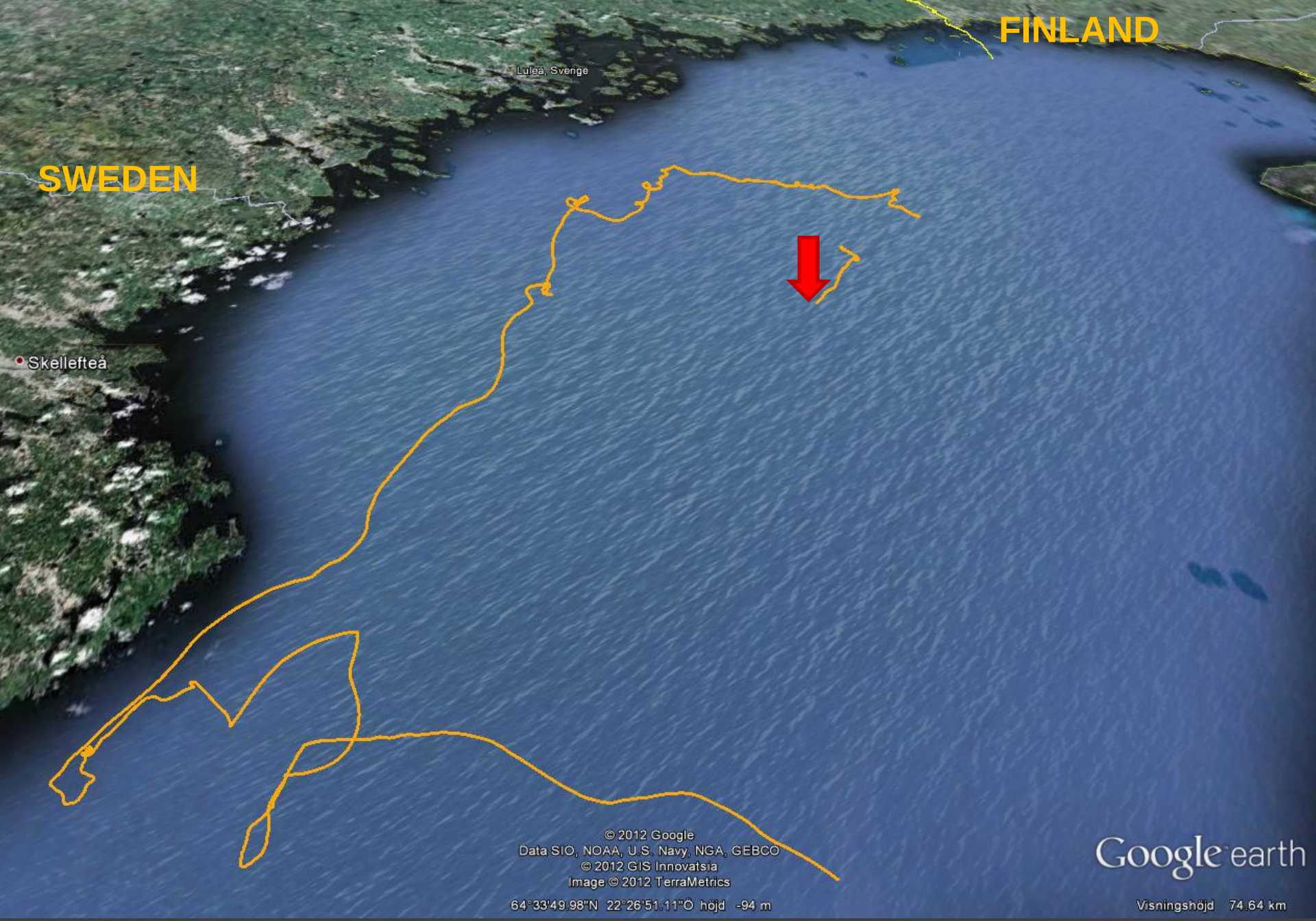


Deployment



TerraSAR-X
ScanSAR
Apr 15, 2010


Bay of Bothnia
64°47’N, 22°57’E


FINLAND
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SWEDEN
Skellefteå
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Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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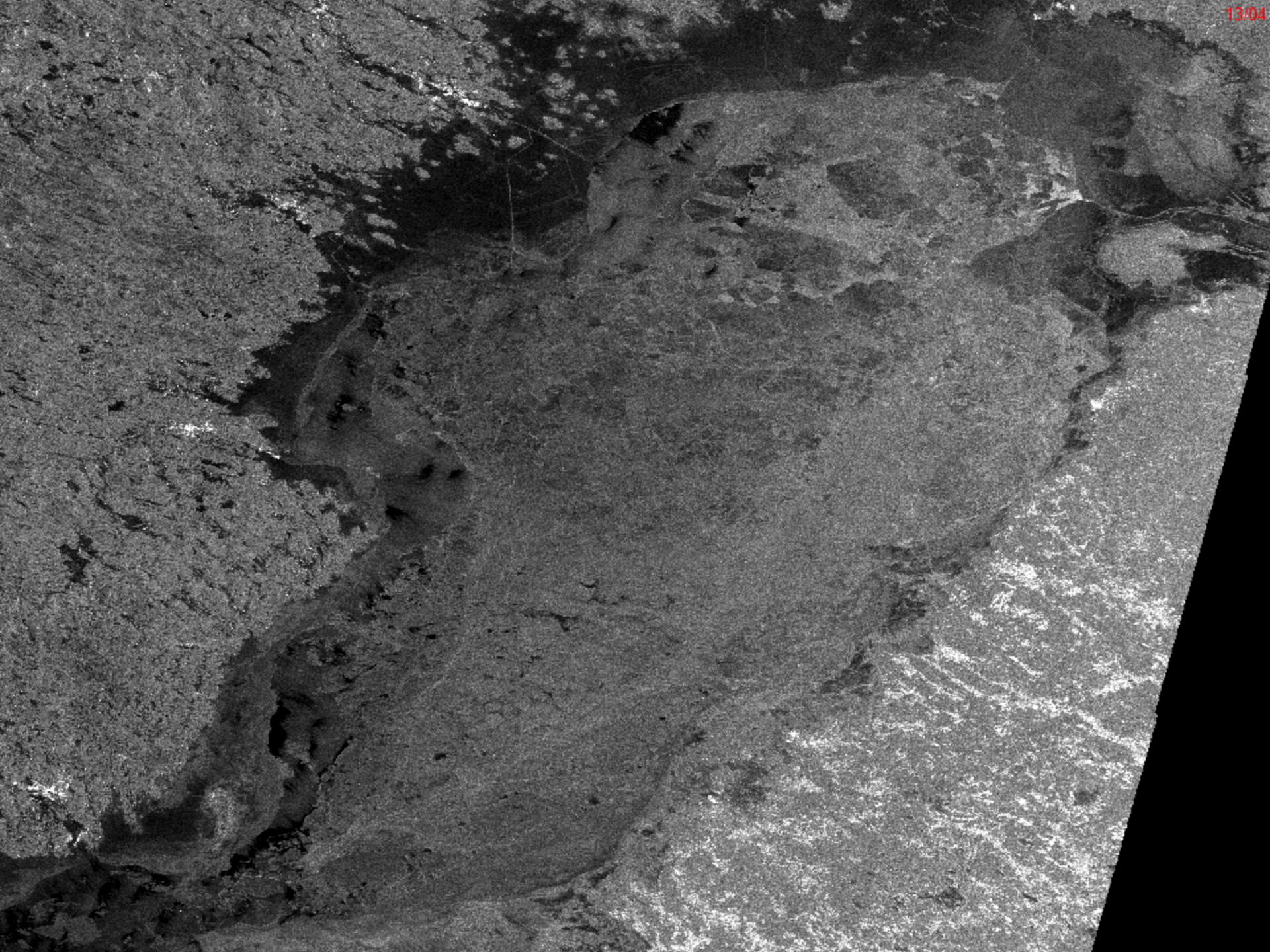
Image © 2012 TerraMetrics
64°33'49.98"N 22°26'51.11"Ö höjd -94 m
Google earth
Visningshöjd 74.64 km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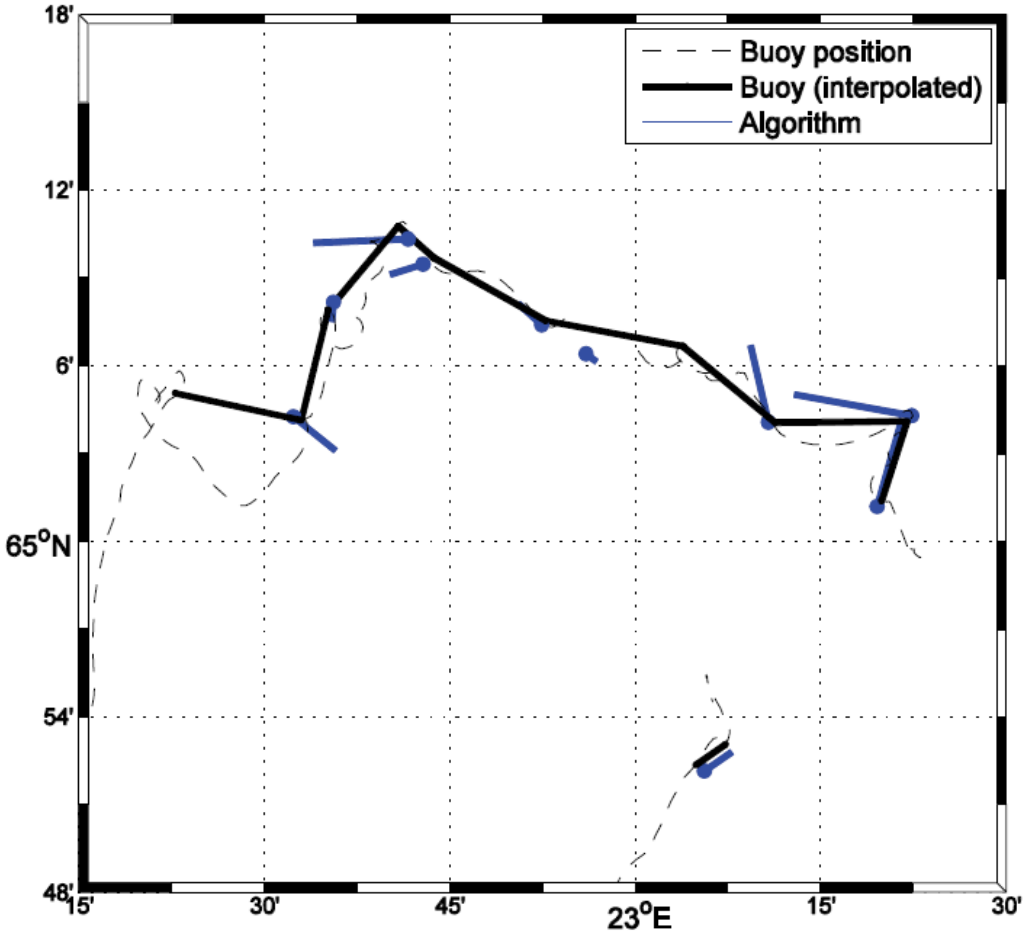
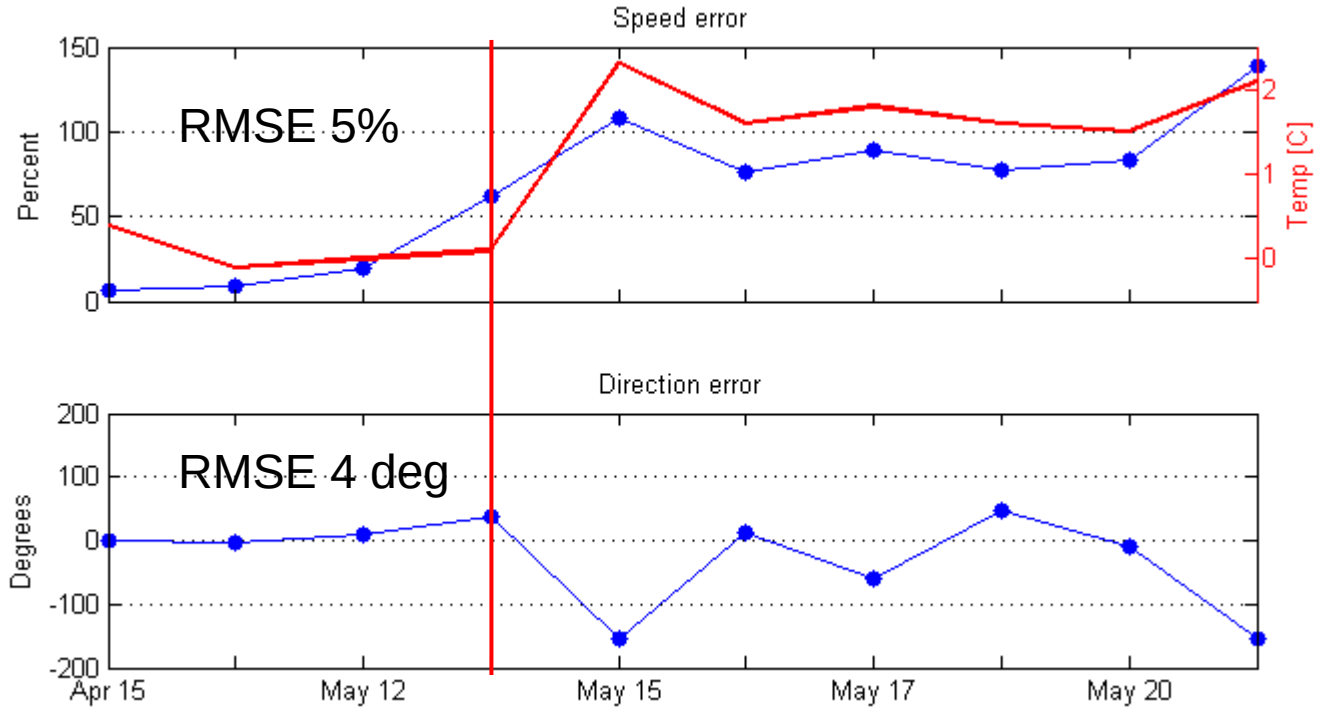
Comparison to buoy data

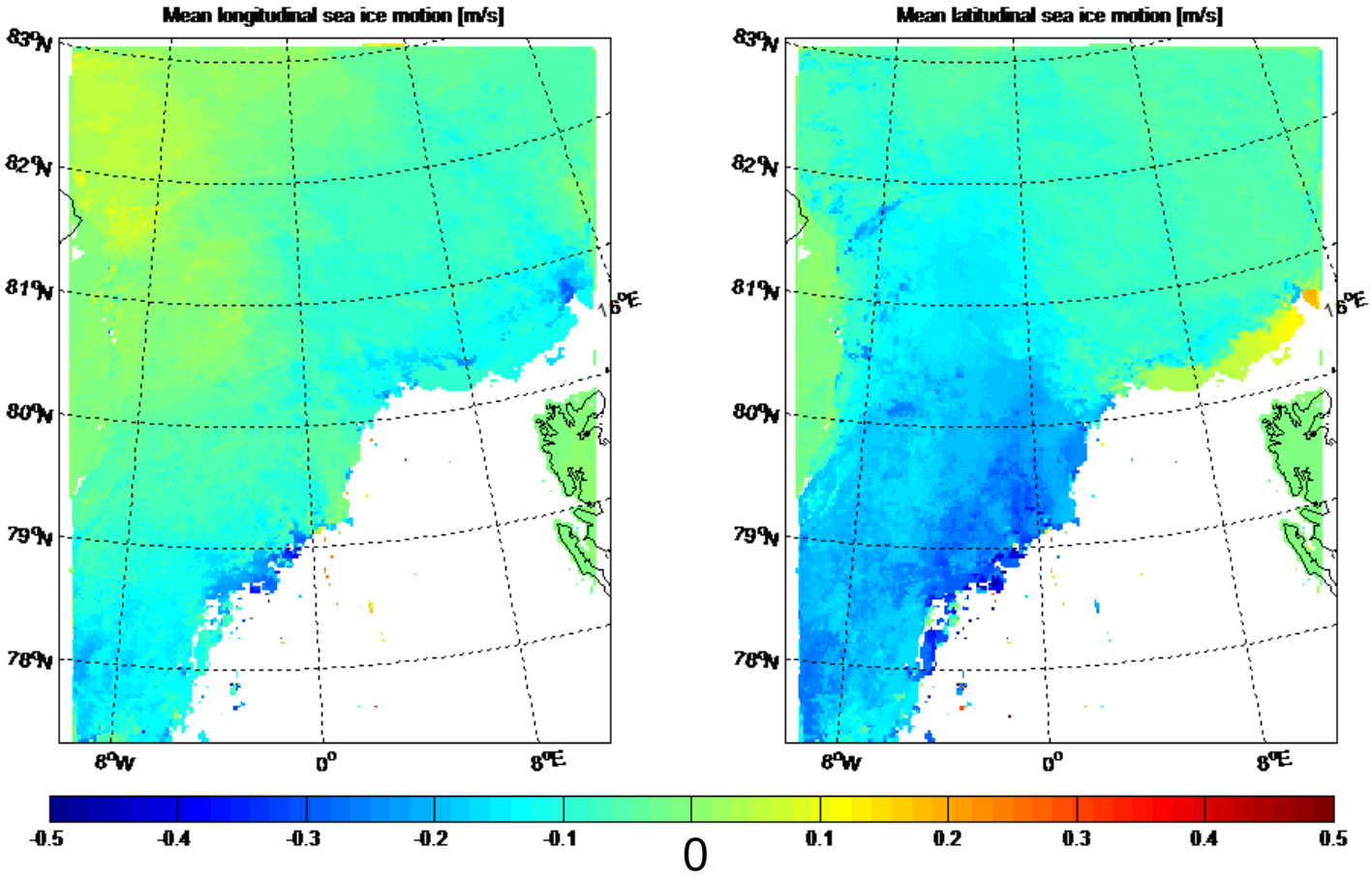


Speed and direction accuracy



Mean ice drift in Fram Strait

April 2011

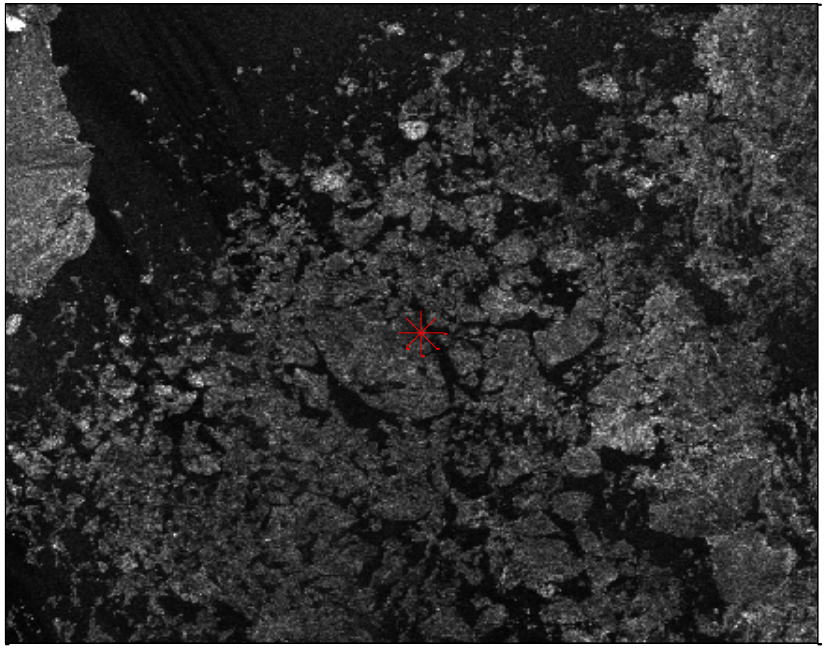


Feature tracking necessary for marginal ice

Requires

1) Image segmentation

2) Feature tracking – Peddada & McDevitt 1996



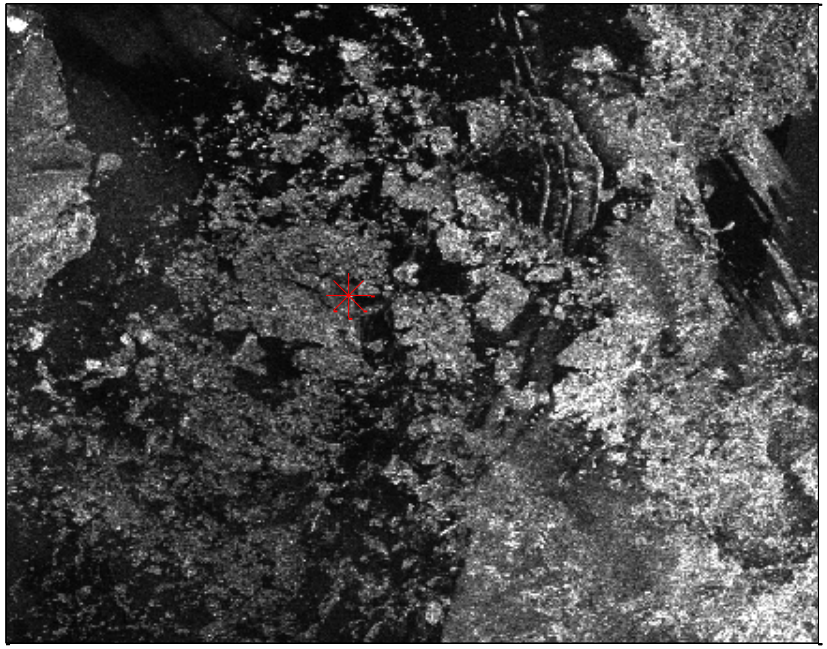
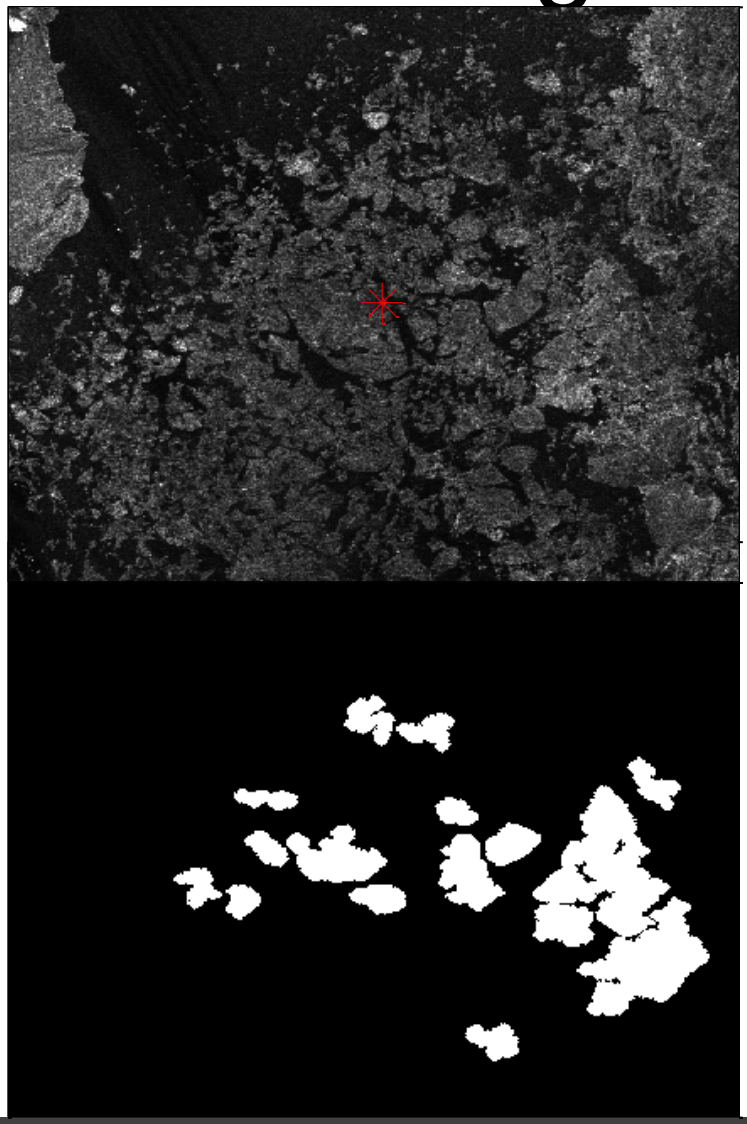
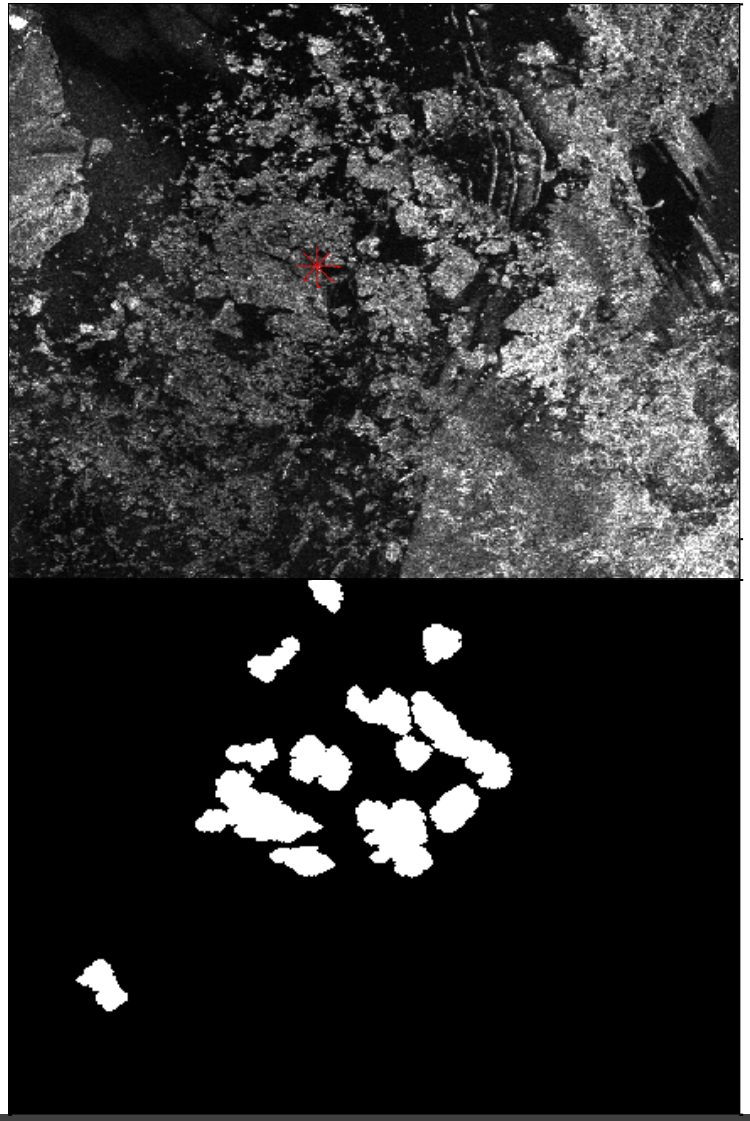
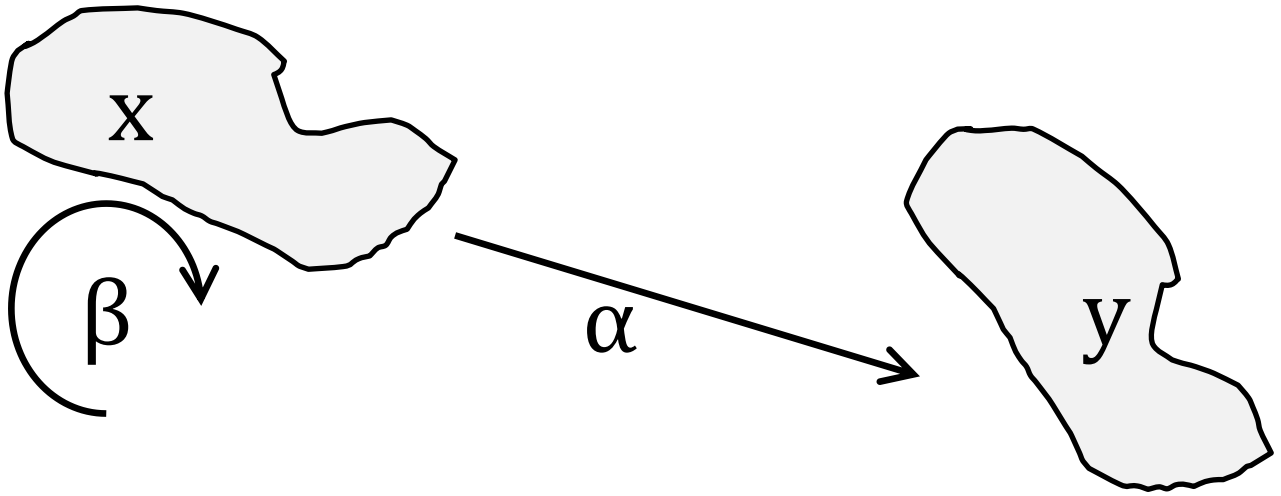


Image segmentation





Feature tracking

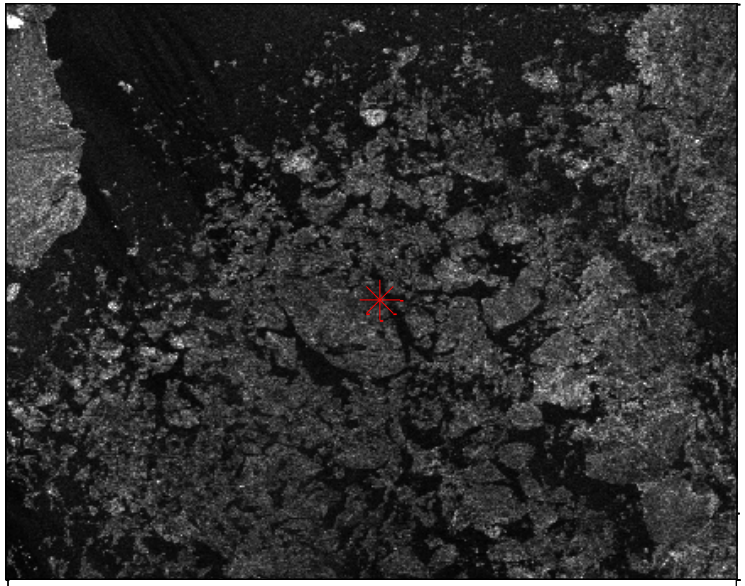


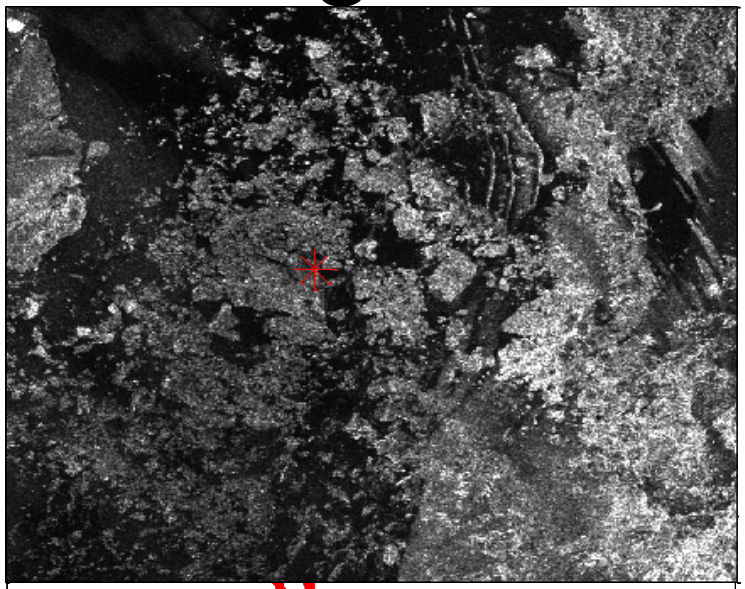
1) $$\min_{\alpha,\beta} S(\alpha,\beta) = \min_{\alpha,\beta} \sum_{i=1}^{n} \left\| \boldsymbol{y}_i - \alpha - \beta \boldsymbol{x}_{j(i)} \right\|$$

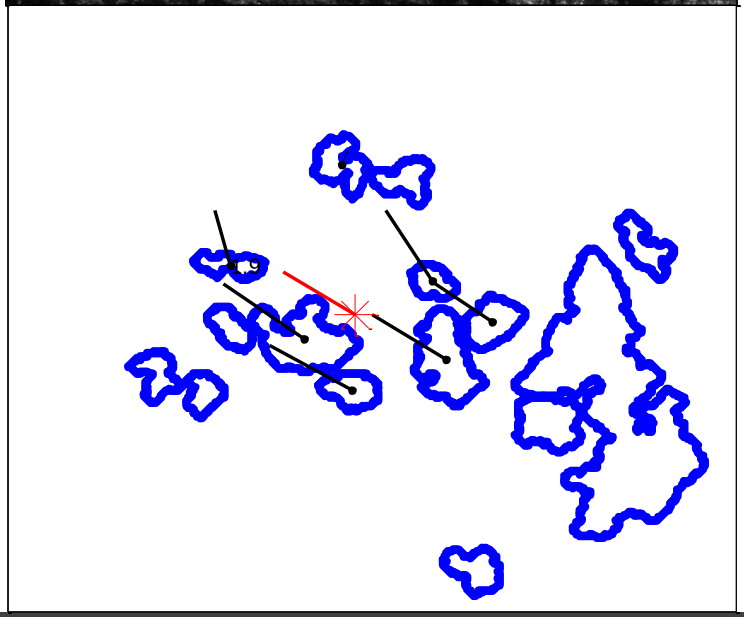
2) $$\left\| \boldsymbol{y}_i - \alpha - \beta \boldsymbol{x}_{j(i)} \right\| = \min_{1 \le r \le m} \left\| \boldsymbol{y}_i - \alpha - \beta \boldsymbol{x}_r \right\|$$

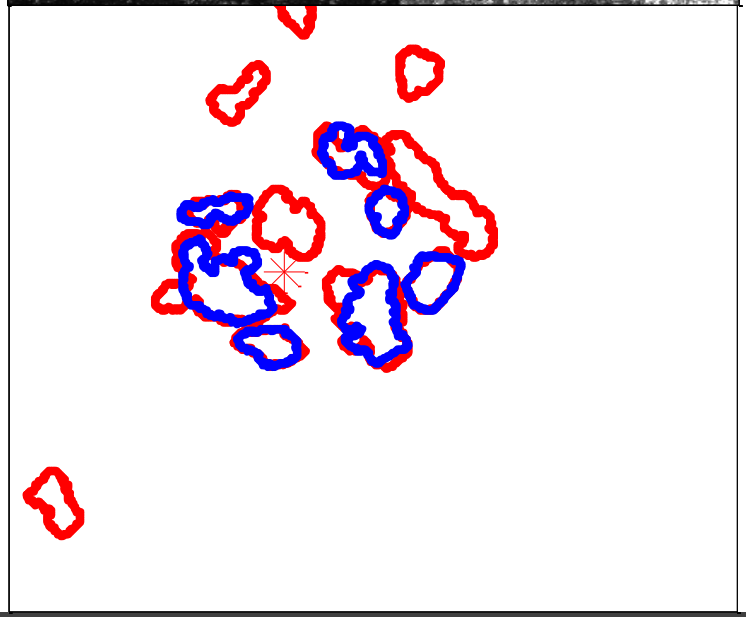
Peddada & McDevitt 1996

Feature tracking









Future work

- Combine feature tracking and area tracking
- Select method based on quality measures

Conclusions

Thank you!

- Phase correlation must be complemented by feature tracking for marginal ice
- The phase correlation algorithm is accurate to 5% (or ~1 cm/s) for the speed and 4 degrees for the direction within the pack ice.
- The ice buoy DRIVA was tested operationally for the first time and successfully measured the ice drift.