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Radar remote sensing of ocean and sea ice in the polar regions

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Photo: Anders Berg, Chalmers

Outline

- Introduction
- Sea ice
  - Ice concentration
  - Ice drift
  - Ice thickness
- Ocean
  - Sea surface wind
  - Ocean currents
- Shipping and oil spill

CLIMATICE

Spaceborne radar measurements of sea-ice parameters for climate models

Area: Seas around Greenland and Gulf of Bothnia

Years: 2010 to 2013

Cooperation: Swedish Meteorological and Hydrological Inst. (SMHI)

Funding: Swedish National Space Board

Data: SAR data from ALOS, Envisat and COSMO-SkyMed

Altimeter data from Cryosat-2

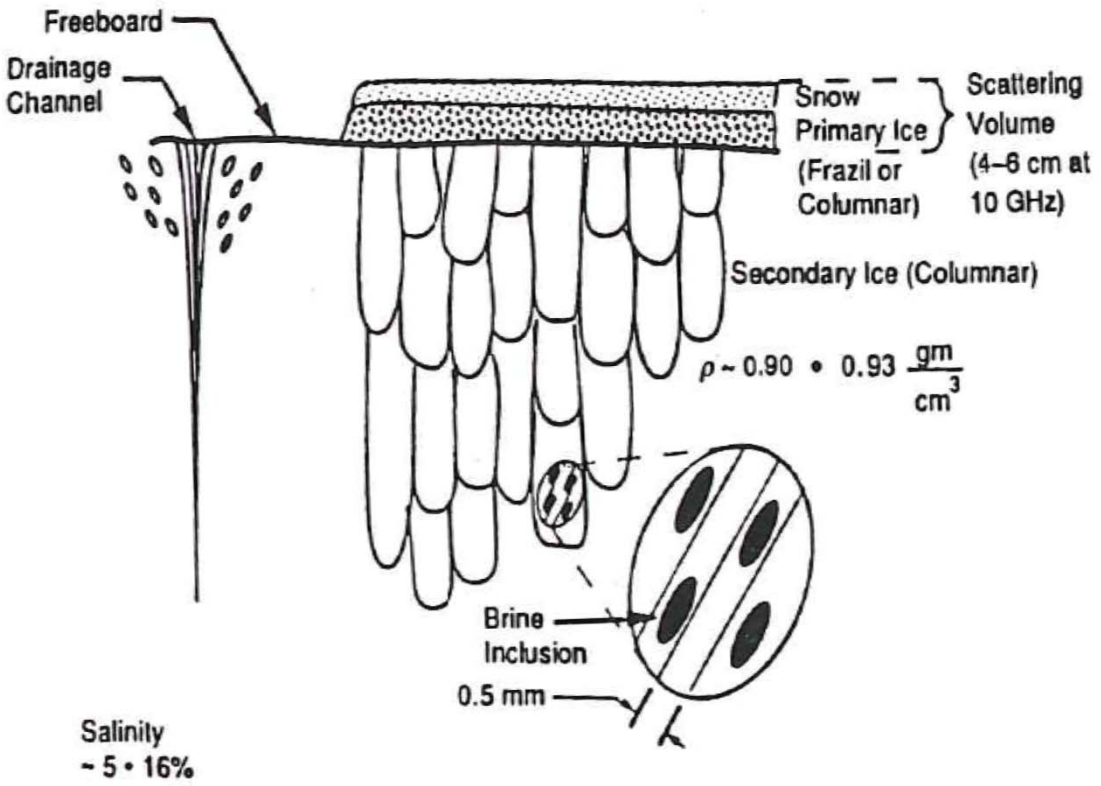
Expected outcome

- New or improved algorithms for retrieval of ice concentration and ice drift.
- New or improved algorithms for retrieval of ice thickness. These algorithms can be based on a combination of altimeter and SAR data.
- Development of satellite based sea-ice products that can be used for validation of climate models.
- Validation that can lead to improved parameterization and/or initialization of the climate model.

Sea ice and radar

Radar backscatter depends on

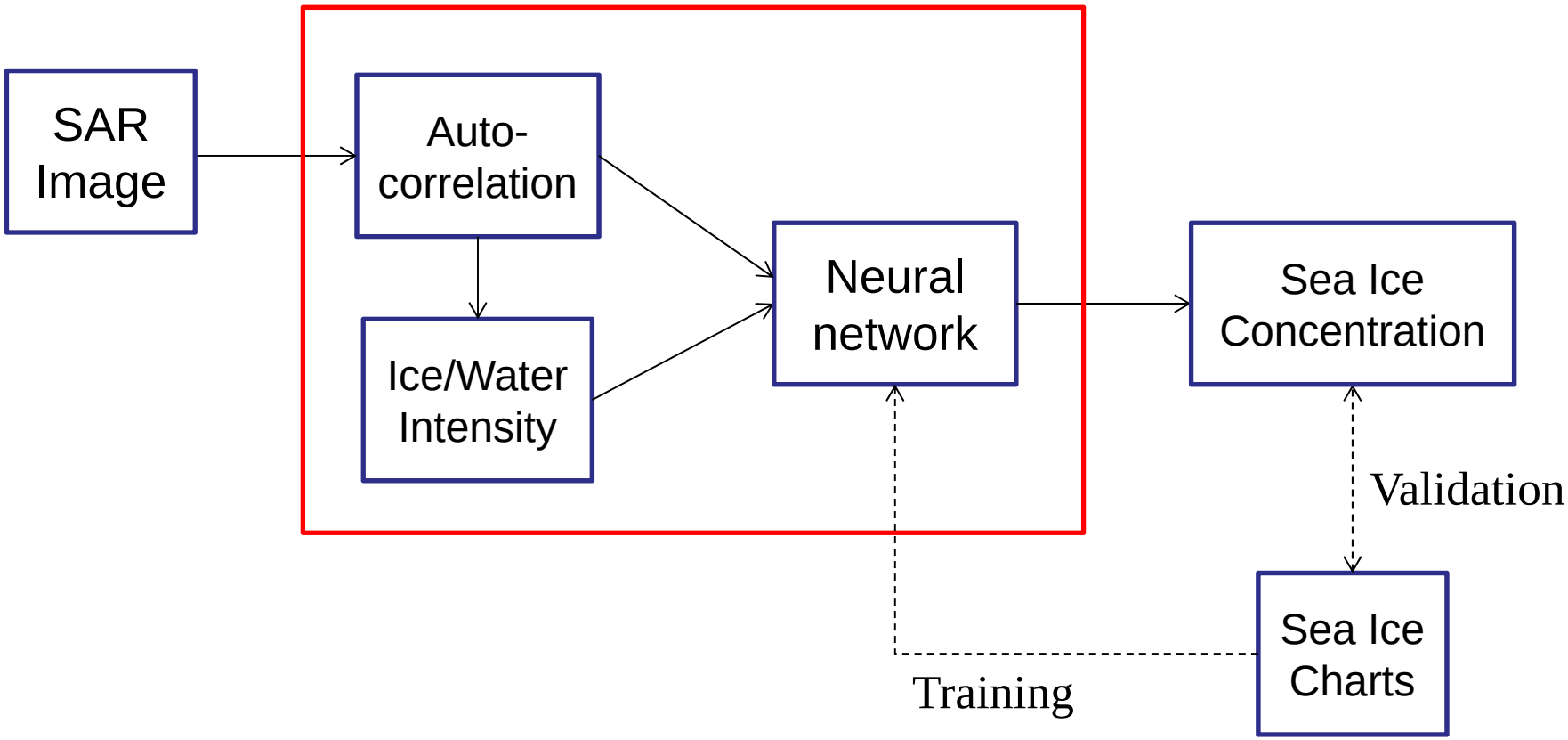
- Surface roughness
- Crystal structure
- Brine content
- Air content
- Snow cover



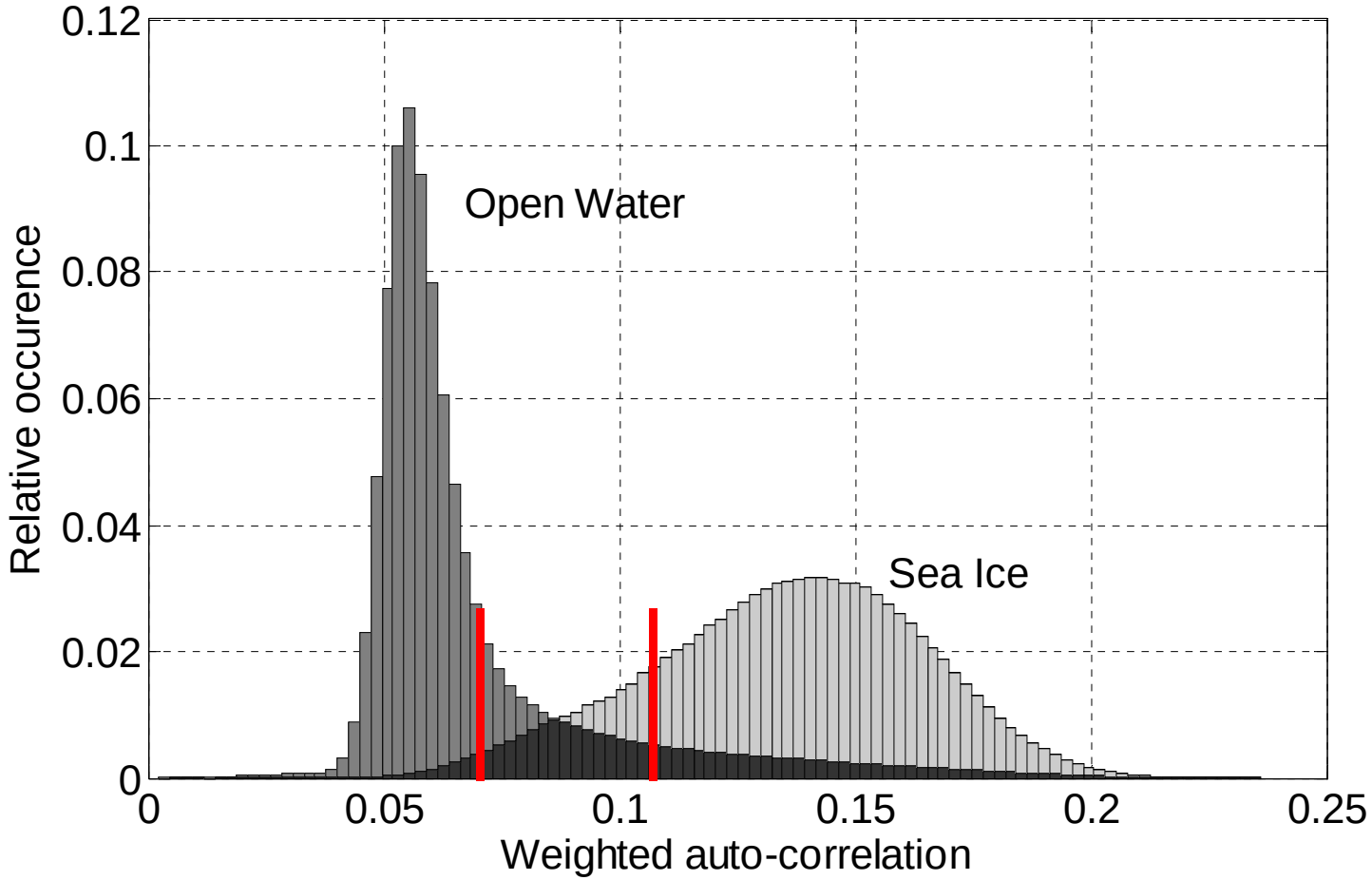
SEA ICE CONCENTRATION ALGORITHM

Berg, A. and Eriksson, L. E. B. ”SAR Algorithm for Sea Ice Concentration – Evaluation for the Baltic Sea”, *IEEE Trans. on Geoscience and Remote Sensing Letters, Vol.* 9 (5), 2012

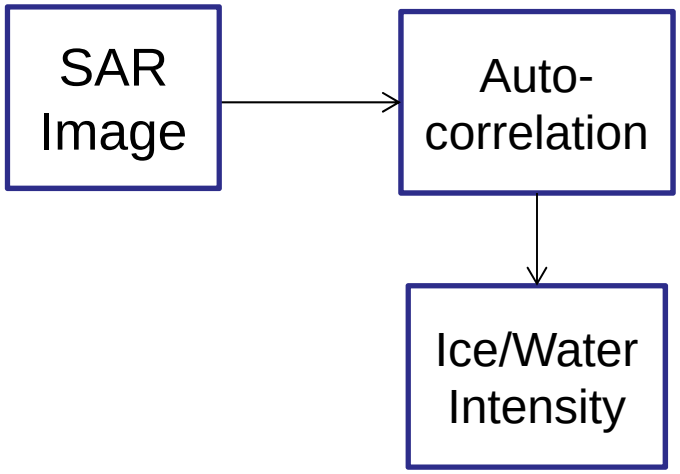
Sea ice concentration algorithm



Rough classification into sea ice/open water

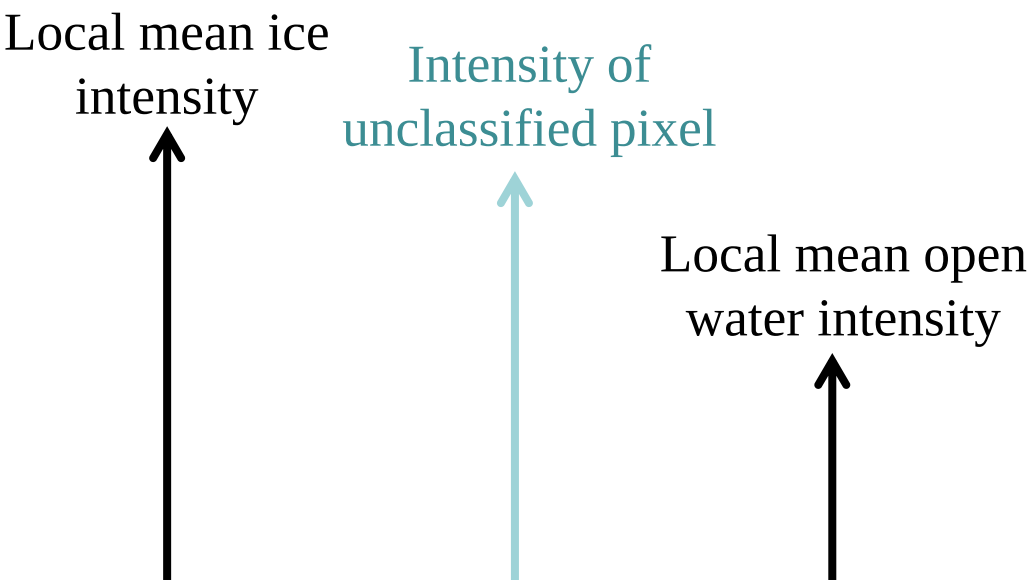


Algorithm description

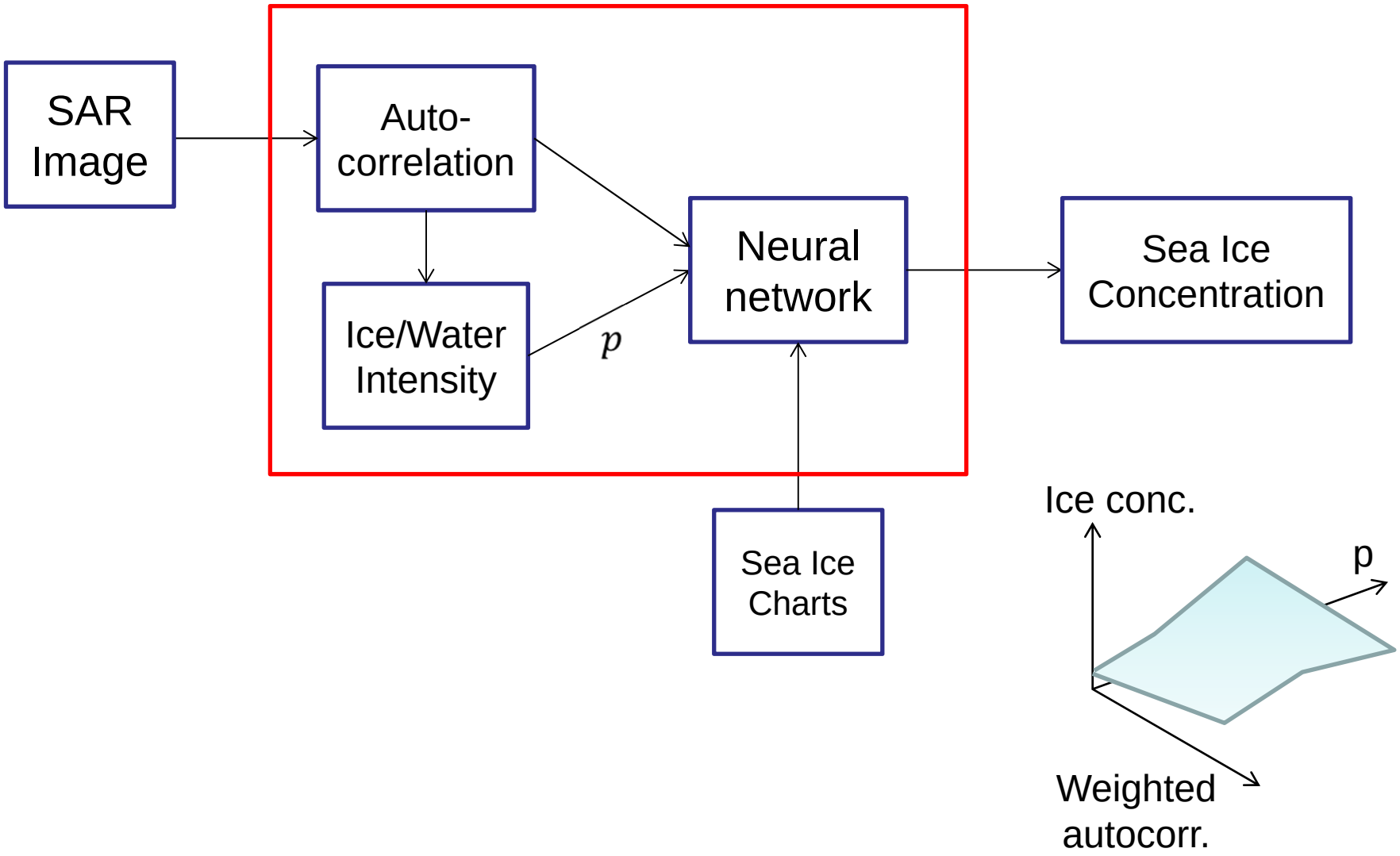


- ”Ice Pixels” => local mean ice intensity
- ”Open water pixels” => local mean open water intensity

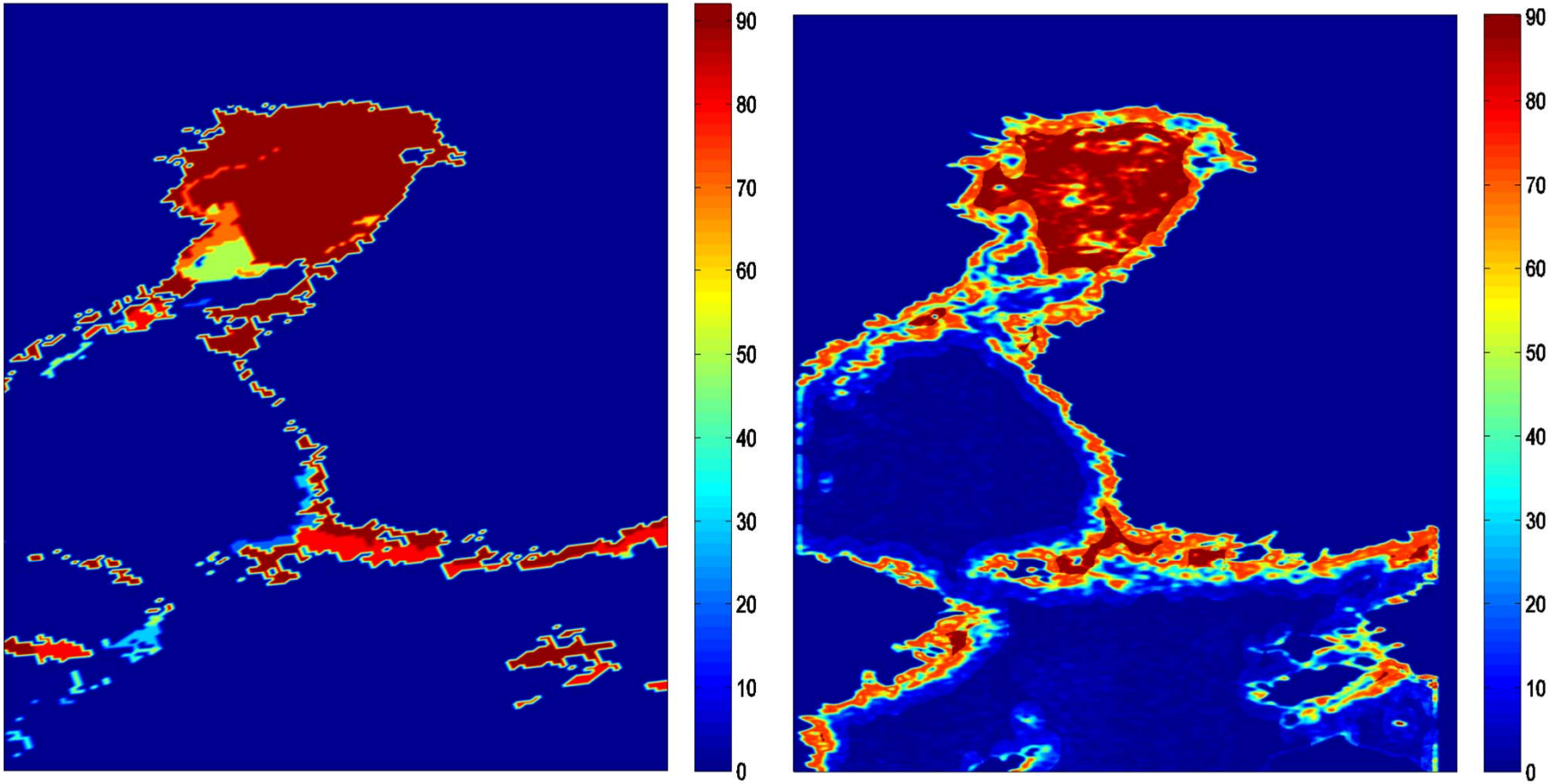
$$p = \frac{I - I_{ow}}{I_{ice} - I_{ow}}$$



Algorithm description



Results and validation



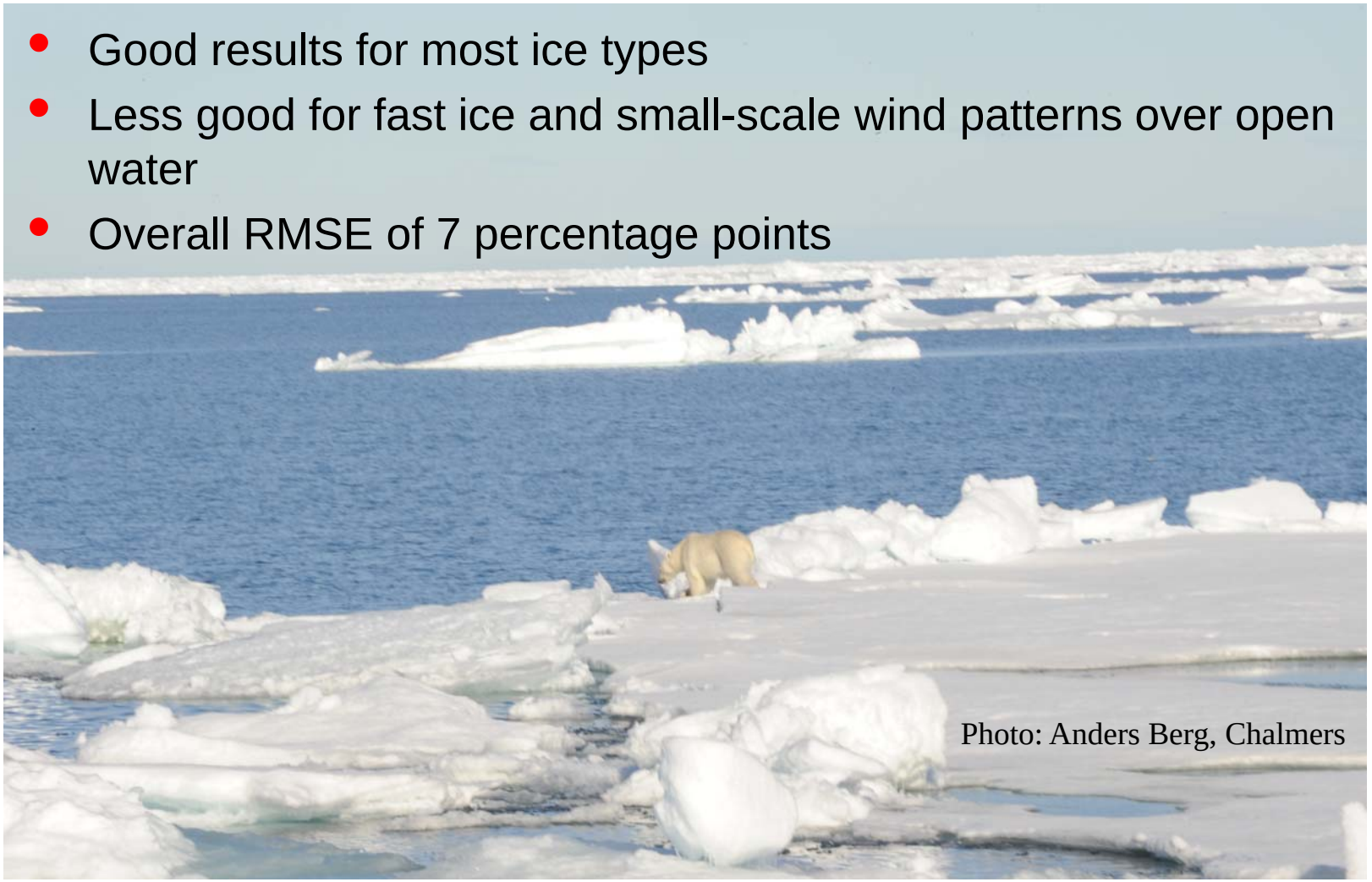
Ice chart (SMHI)

Satellite algorithm

Bay of Bothnia 2009-03-21

Sea ice concentration algorithm

- Good results for most ice types
- Less good for fast ice and small-scale wind patterns over open water
- Overall RMSE of 7 percentage points

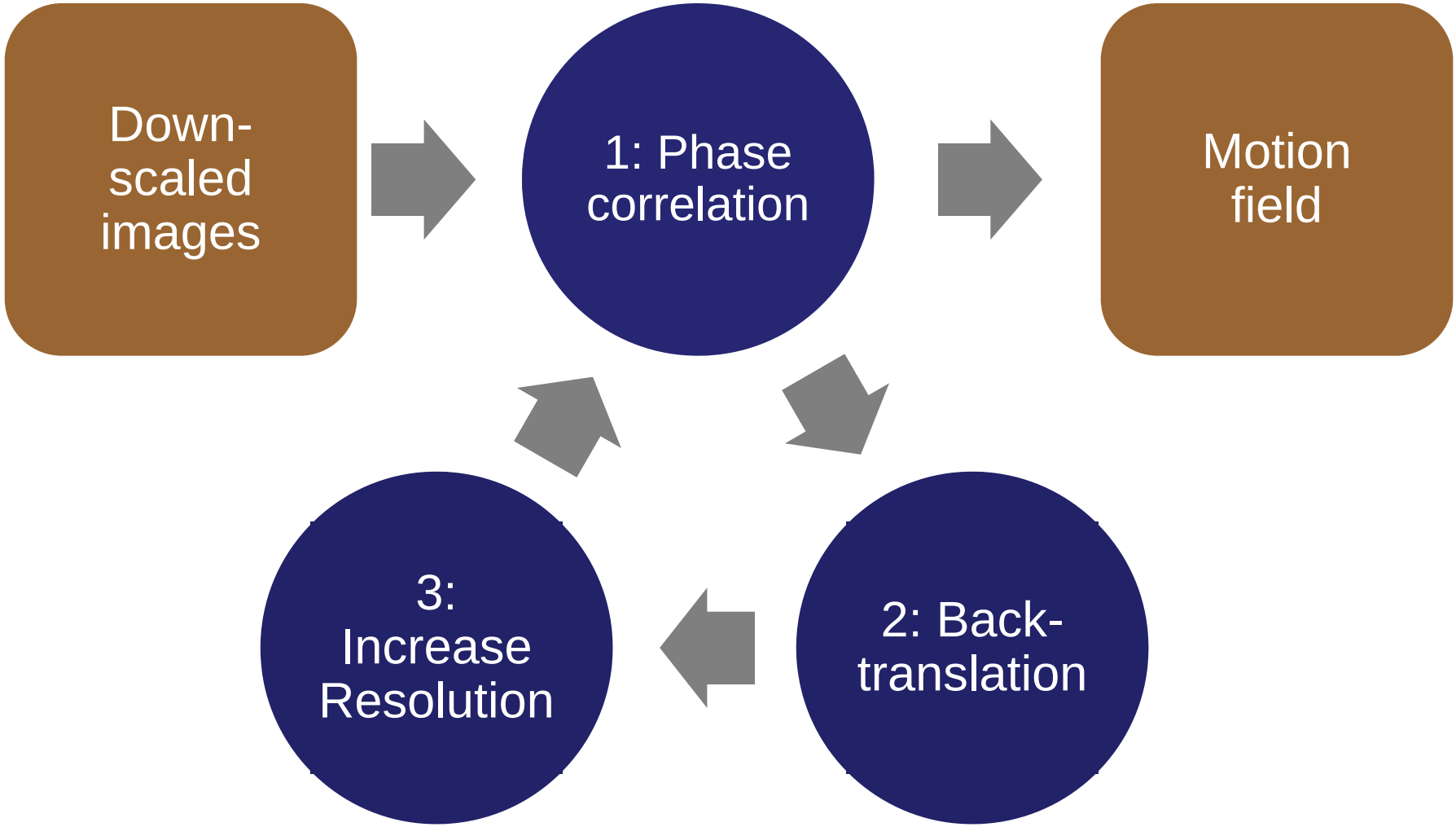


SEA ICE DRIFT ALGORITHM

Berg, A., Eriksson, L. E. B., Borenäs, K., Lindh, H.
“Observations and analysis of sea ice motion with the ice buoy DRIVA during the 2010 spring field campaign in the Bay of Bothnia”, Technical report No. 7, Department of Earth and Space Sciences, Chalmers University of Technology, 2011.

Multi-resolution processing system

M. Thomas *et al.* 2008



Additions to Thomas algorithm

- Rotation determination using
  Fourier Mellin Log-Polar Transform

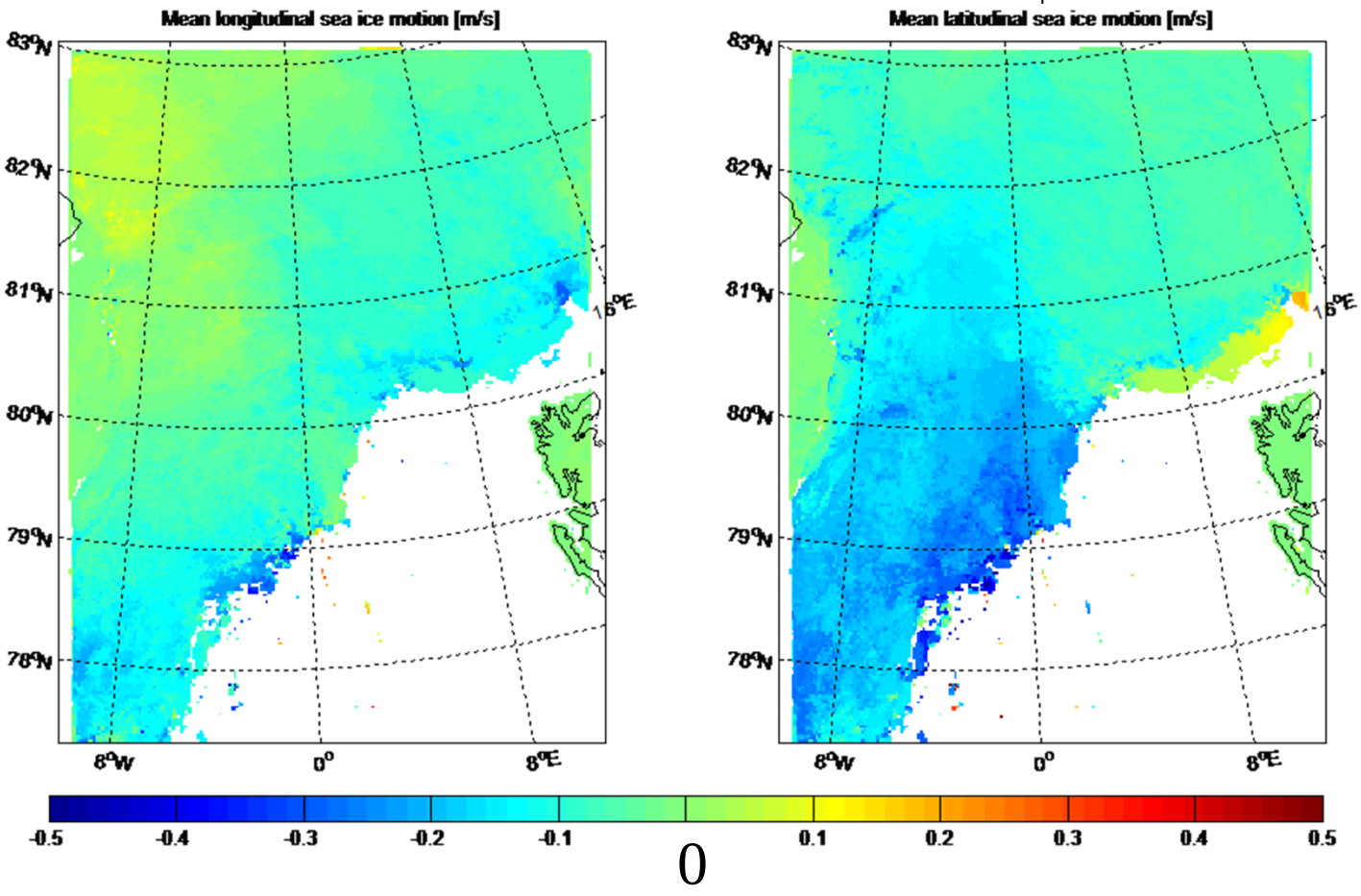
$$\begin{cases} \rho = \log(\sqrt{u^2 + v^2}) \\ \theta = \operatorname{atan}(\frac{u}{v}) \end{cases}$$

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

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

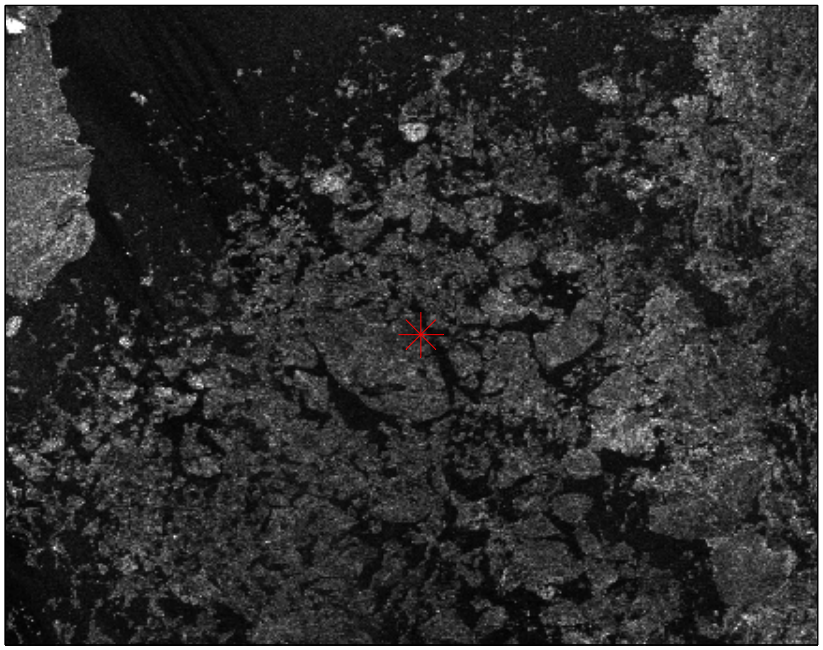
Mean ice drift in Fram Strait

April 2011



Feature tracking necessary for marginal ice

Requires
1) Image segmentation
2) Feature tracking – Peddada & McDevitt 1996



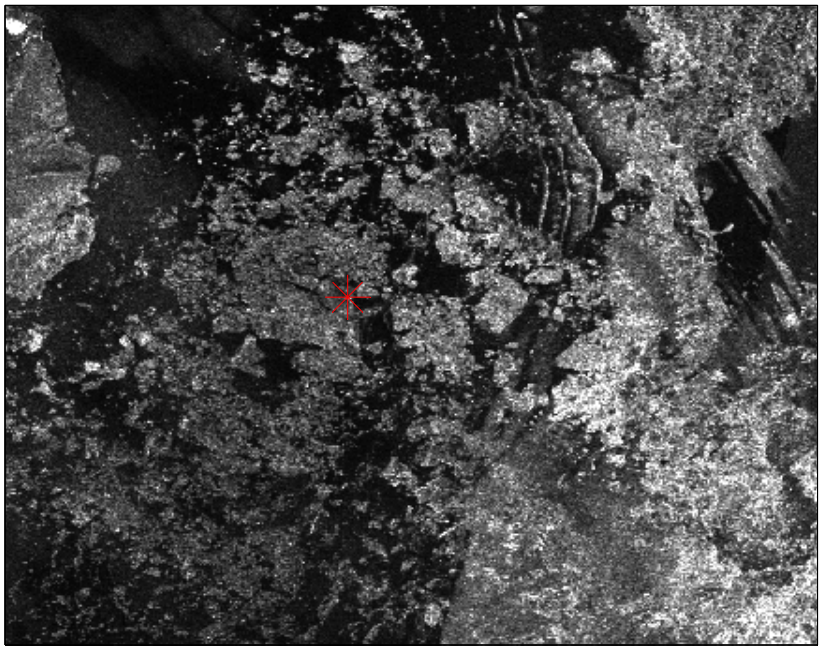
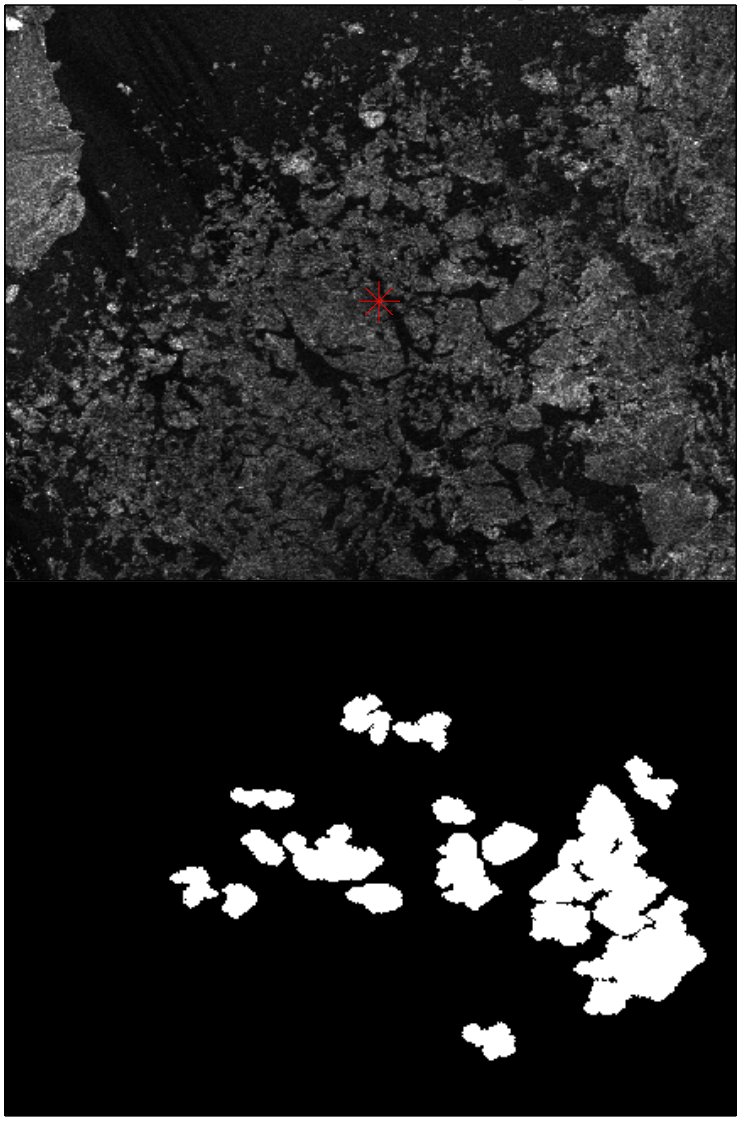
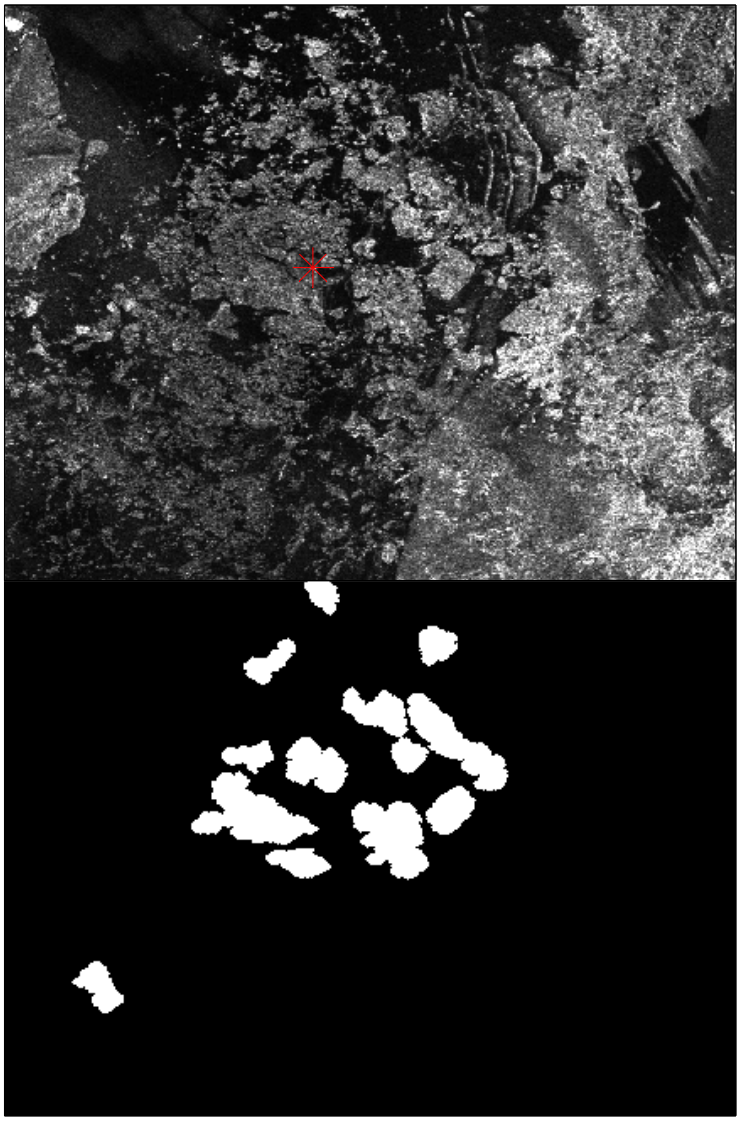


Image segmentation





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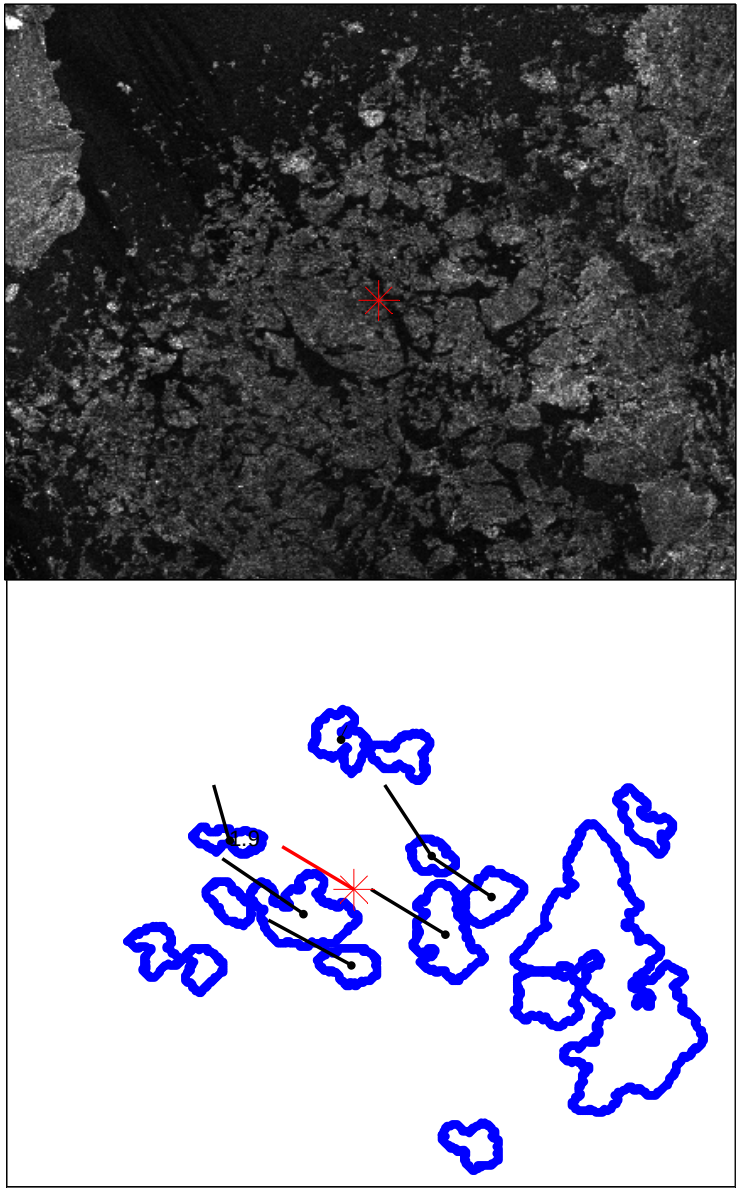
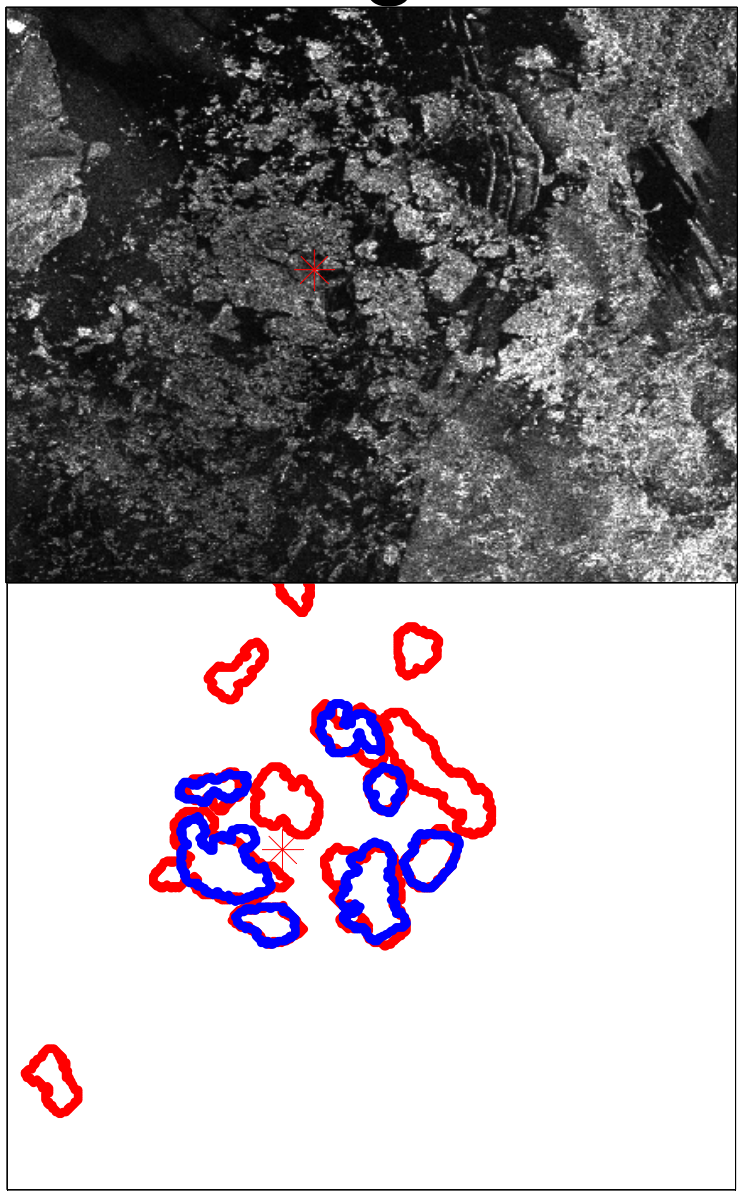
Feature tracking





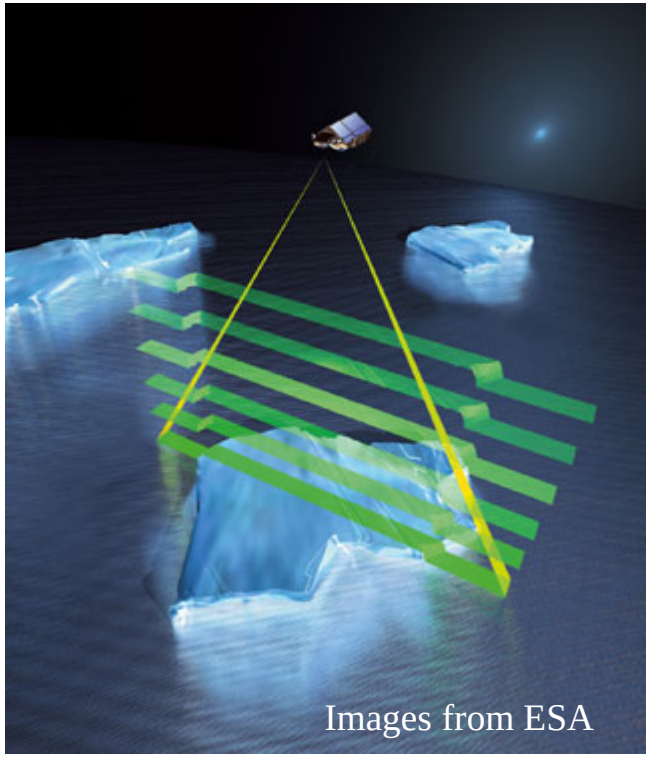
Sea ice drift algorithm

- A **sea ice drift** algorithm has been evaluated and is accurate to 5% (or ~1 cm/s) for the speed and 4 degrees for the direction.
- Phase correlation must be complemented by feature tracking for marginal ice

SEA ICE THICKNESS ALGORITHM

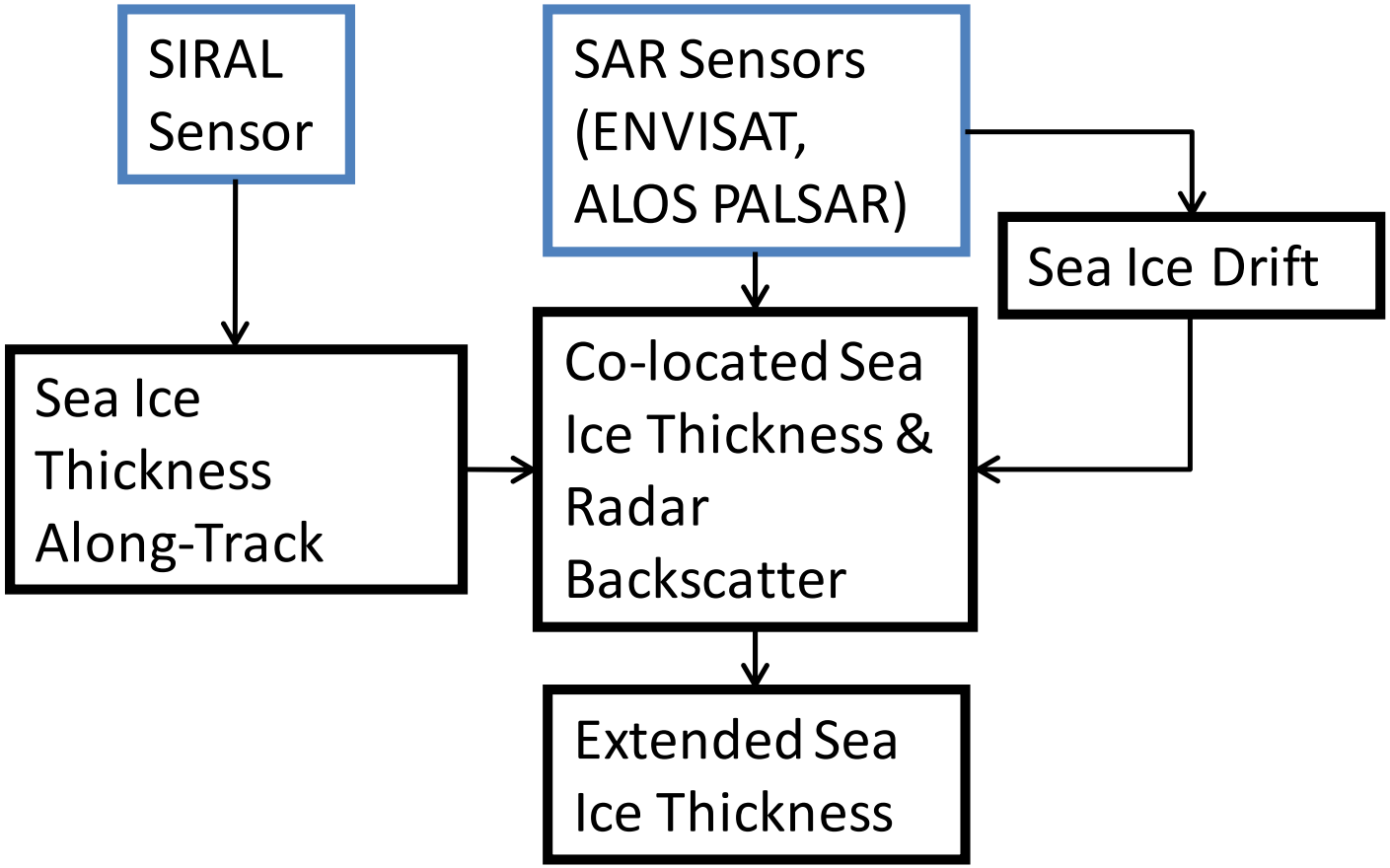
Berg, A., Eriksson, L. E. B., Ulander, L. M. H., Borenäs, K.
“Sea Ice Measurements with Cryosat-2 and SAR”, Poster at the ESA Cryosat Validation Workshop 2011, http://www.cryosat2011.org/.

Cryosat-2

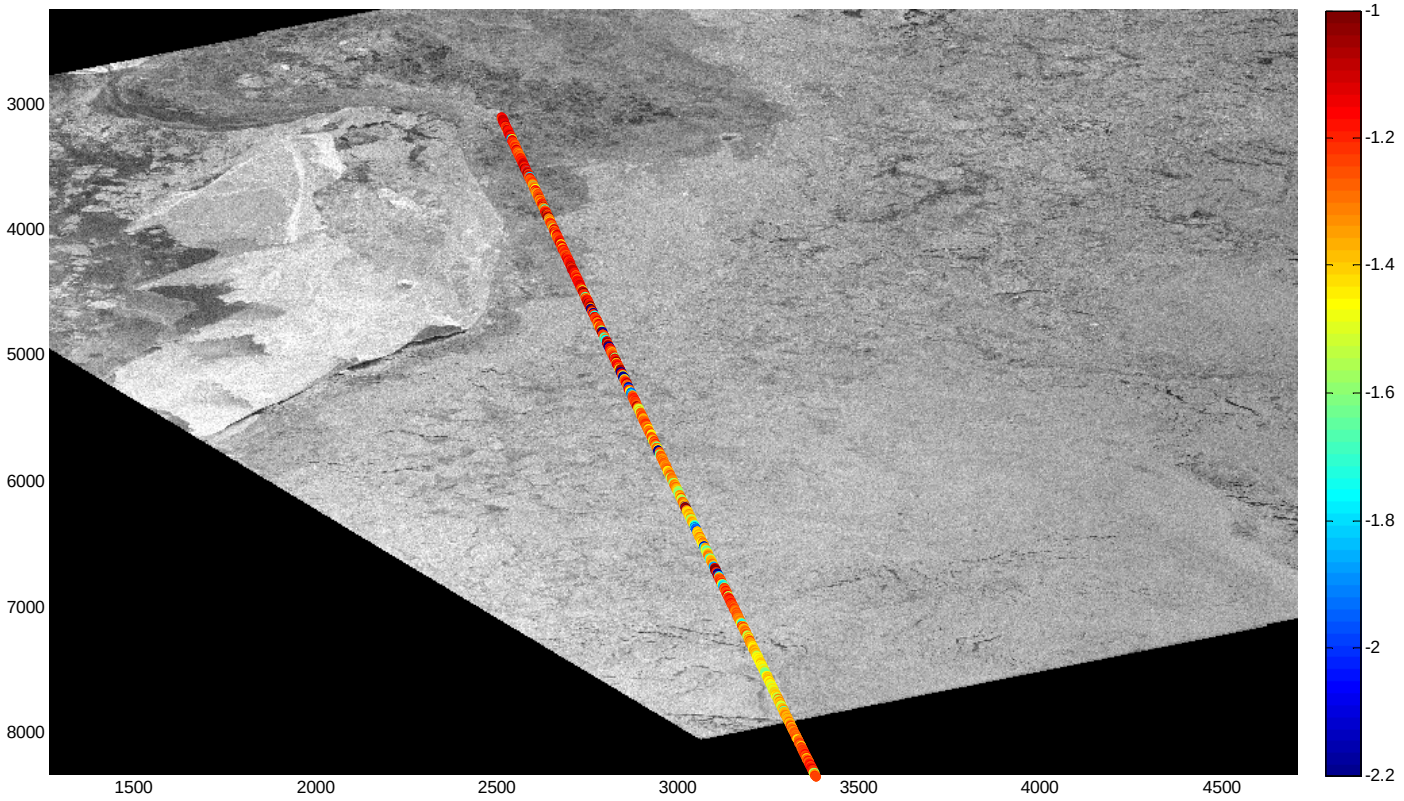


Deriving sea-ice thickness from measured freeboard (difference between ice and water). Use an altimeter with SAR mode to increase the spatial resolution.

SEA ICE THICKNESS ALGORITHM



Combining radar data



Cryosat-2 data points on top of Envisat ASAR image

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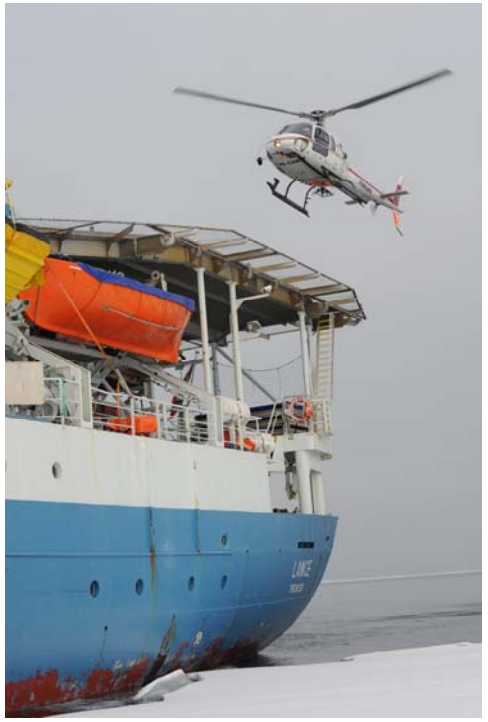
In situ measurments of ice thickness in the Fram Strait

R/V Lance Aug.-Sept. 2012



Three types of thickness measurements:

- Upward looking sonar
- EM measurements from helicopter
- Drill holes

Photos: Anders Berg, Chalmers

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Retrieval of wind with spaceborne SAR for polar oceans and coastal regions

Area: Fram Strait in the Arctic, Amundsen Sea in Antarctica and the Swedish coast

Years: 2013

Cooperation: Swedish Meteorological and Hydrological Inst. (SMHI)

Dept. of Earth Sciences, University of Gothenburg

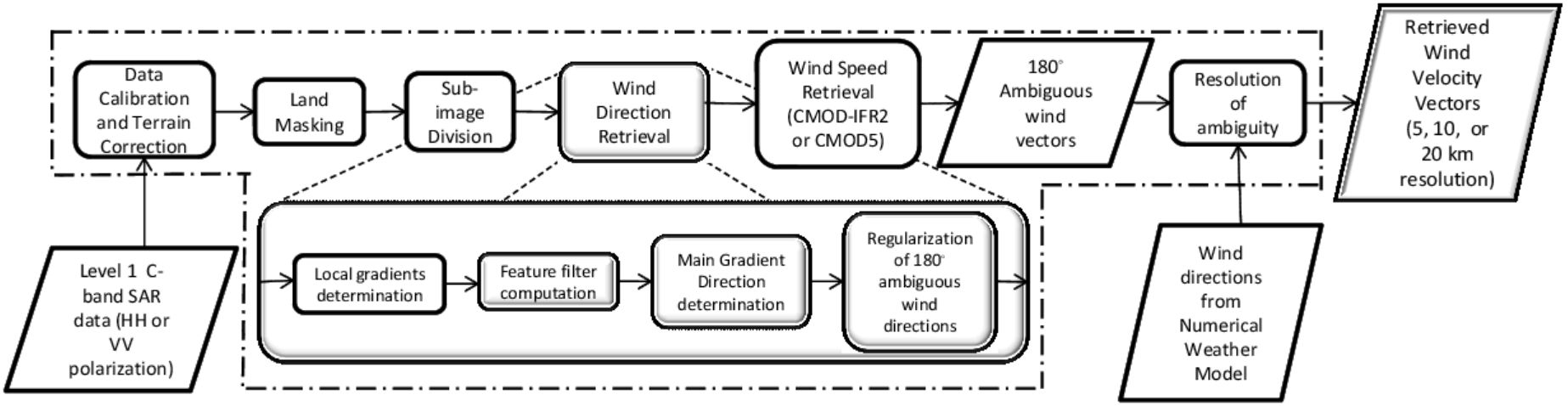
Funding: Swedish National Space Board

Data: Archived SAR data from Envisat and TerraSAR-X

Project objectives

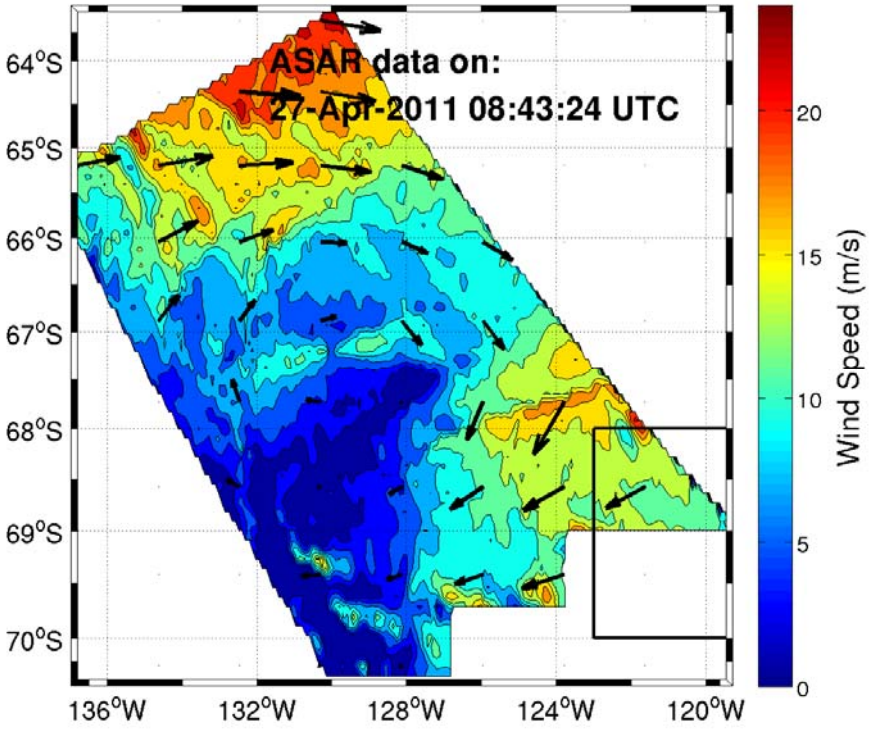
- Radar backscatter from the ocean surface can be used to estimate wind speed and wind direction.
- Radar scatterometers are used operationally, but SAR give higher spatial resolution.
- Higher resolution will potentially give wind information closer to the coast, but has not been validated.
- Wind retrieval close to sea ice is expected to be similar to wind retrieval close to land.
- This project should evaluate the possibility to retrieve high resolution wind fields close to the coast and close to sea ice.

SEA SURFACE WIND ALGORITHM

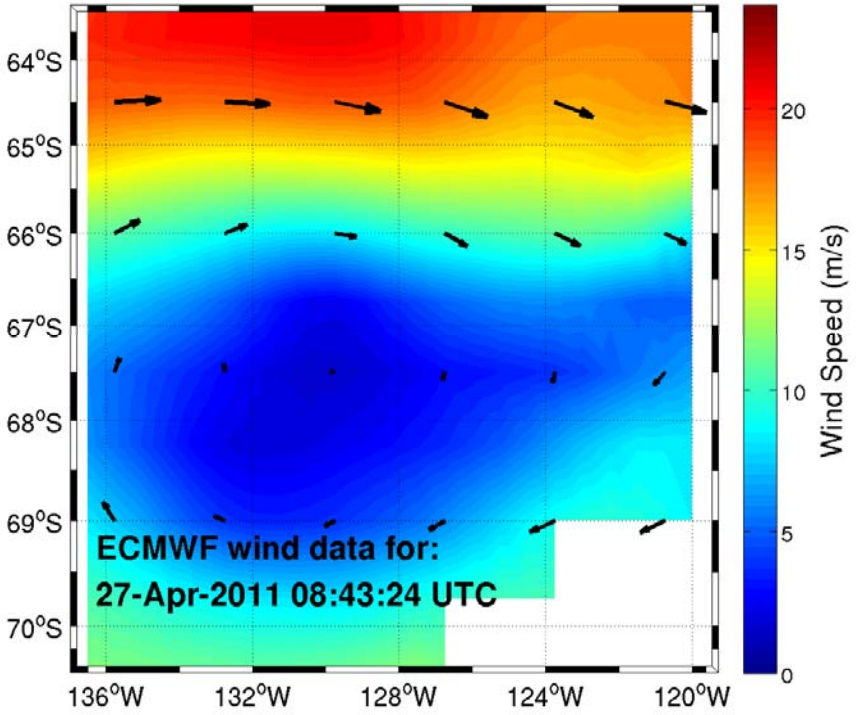


Wind retrieval in Amundsen Sea

Satellite data



Numerical weather model



Ocean currents

- Sea surface winds affect the ocean currents.
- Mainly ocean surface currents, but indirectly also deep water currents.
- The Department of Earth Sciences at Gothenburg University study the influence of ocean currents on the motion and melting of ice shelfs.
- A buoy for measurements of ocean currents has been placed on the ocean floor in the Amundsen Sea in Antarctica.
- In a new study we are analysing the correlation between surface winds and deep water currents in the Amundsen Sea.

SuSArc – Sustainable Shipping in the Arctic

Area: Arctic Ocean

Years: 2013-2014

Cooperation: Dept. of Shipping and Marine Technology, Chalmers

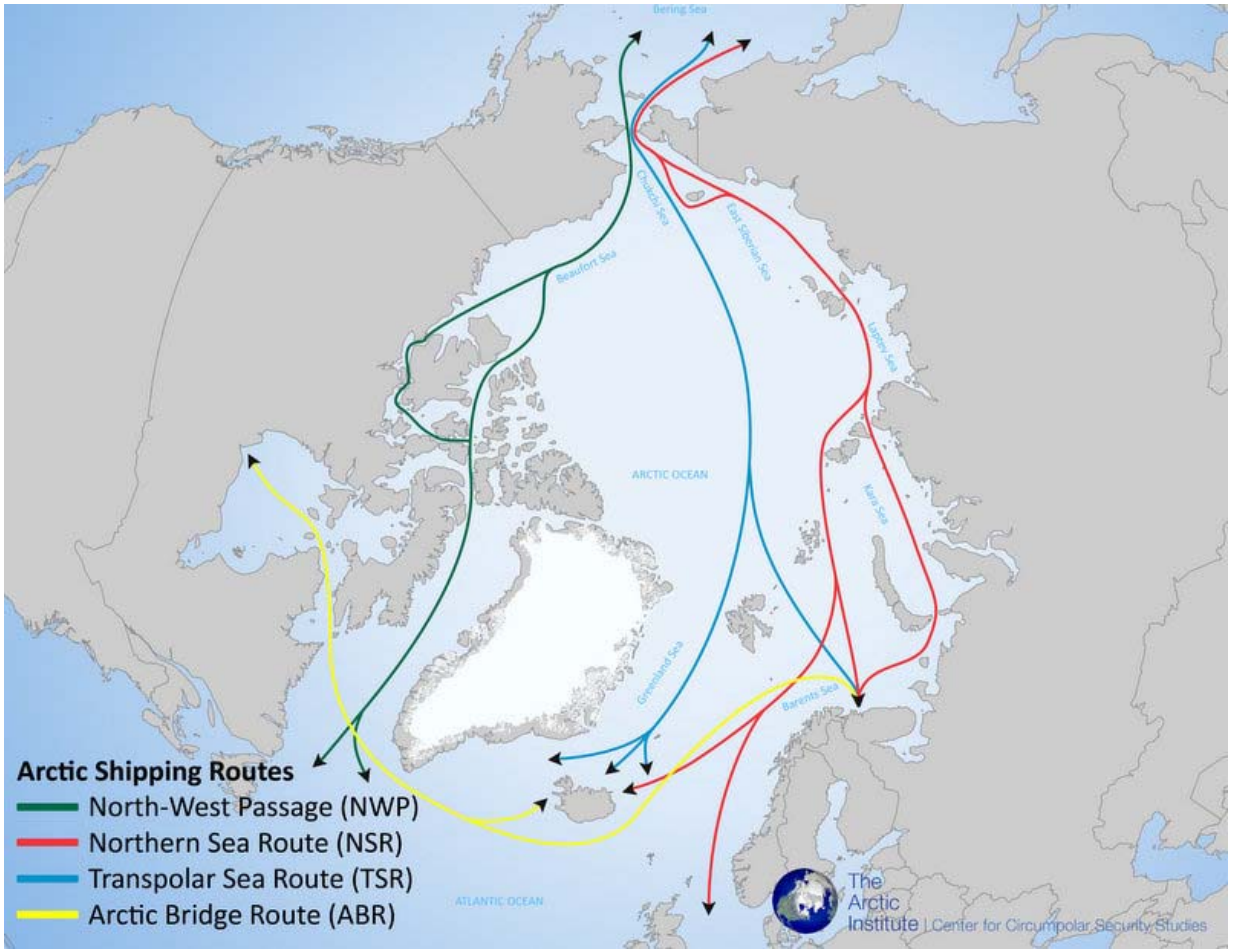
Funding: Chalmers Area of Advance Transport

Data: Archived SAR data from Envisat and TerraSAR-X
New SAR data from Sentinel-1 if available
Radar altimeter data from Cryosat-2

Project objective

- A reduced sea ice cover in the Arctic will open up for an increase in the shipping traffic. This will lead to increased risks for oil spill along the shipping routes.
- The aim of the project is to develop a risk assessment model for environmental risks with oil spill in the sensitive Arctic Ocean.
- Remote sensing data will be used to estimate where the oil would go if an oil spill would occur.
- Parameters that affect the spreading of the oil spill is wind and current at the ocean surface, sea ice extent, sea ice concentration and sea ice drift.

Shipping routes



Shipping in the Arctic

- Thousands of ships move in the Arctic region.
- Most ships has a goal in the Arctic region and are not traveling the entire distance between the Atlantic and the Pacific Oceans
- 1991 was the first year that the northern sea route was open to non-russian ships.
- Predicted ice-free regions in 2040 if not before.

Why use Northern Sea Route?

- Shorter routes
  - The NSR (northern sea route) give 35-60% saving in distance from Europe to Far East and Alaska compared to Suez and Panama.
  - Save fuel
  - Save time
- Can drive slower (save fuel), 40% reduction in speed implies the same time to complete the journey.
- Avoid areas with pirates

Risk analysis

1. Probability of spill
2. The size of the spill
3. Distribution and receiver
4. Consequences
5. Risk analysis

Remote sensing data will be used for point 3, but could potentially be used also for point 2 and 4.

Thank you!

Photo: Anders Berg, Chalmers