

# Monitoring Sea Ice with Space-borne Synthetic Aperture Radar

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CIRFA – A Centre for Research-based Innovation

[cirfa.uit.no](http://cirfa.uit.no)

# Sea ice & climate

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## Some basic facts

- Sea ice covers the polar oceans in the Arctic and the Antarctic
- The area covered by ice varies seasonally; the Arctic sea ice extent in winter is about 3 x larger than in summer (in 2012: factor 4...)
- Sea ice is from a few cm to several meters thick
- Ridging and rafting due to dynamics can lead to very thick ice
- Two main classes: *First-year ice* and *multiyear ice*
- The ice gets covered by snow, which when melting forms melt ponds

# Sea Ice Types

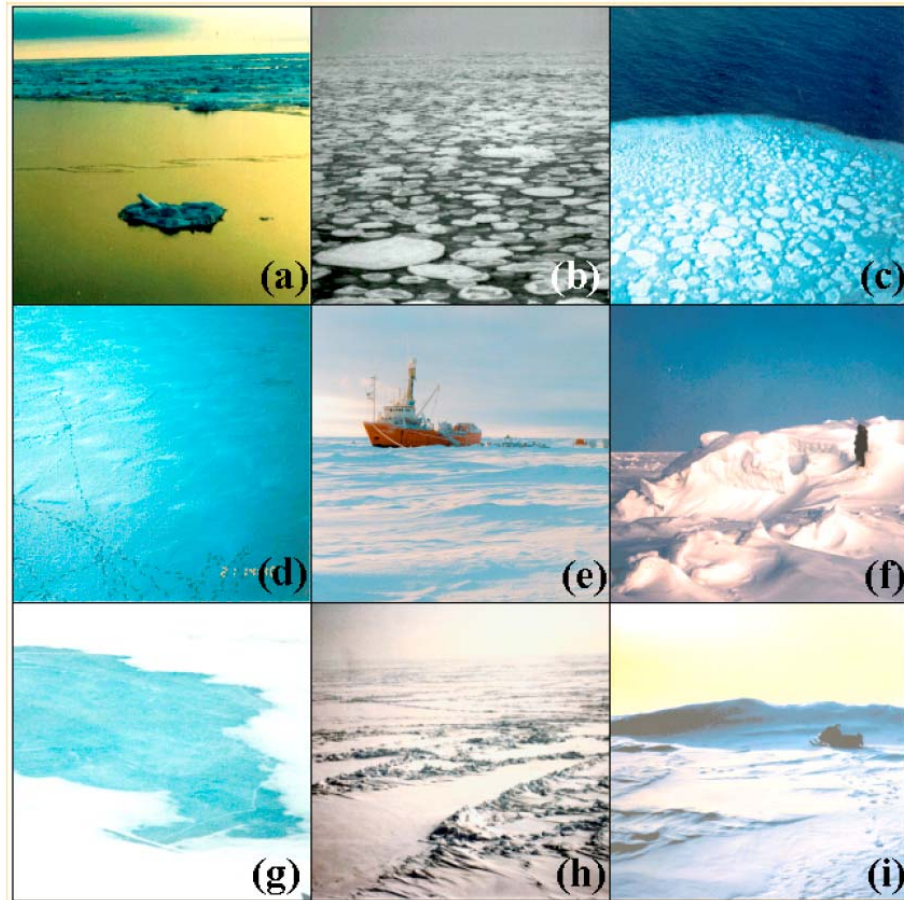
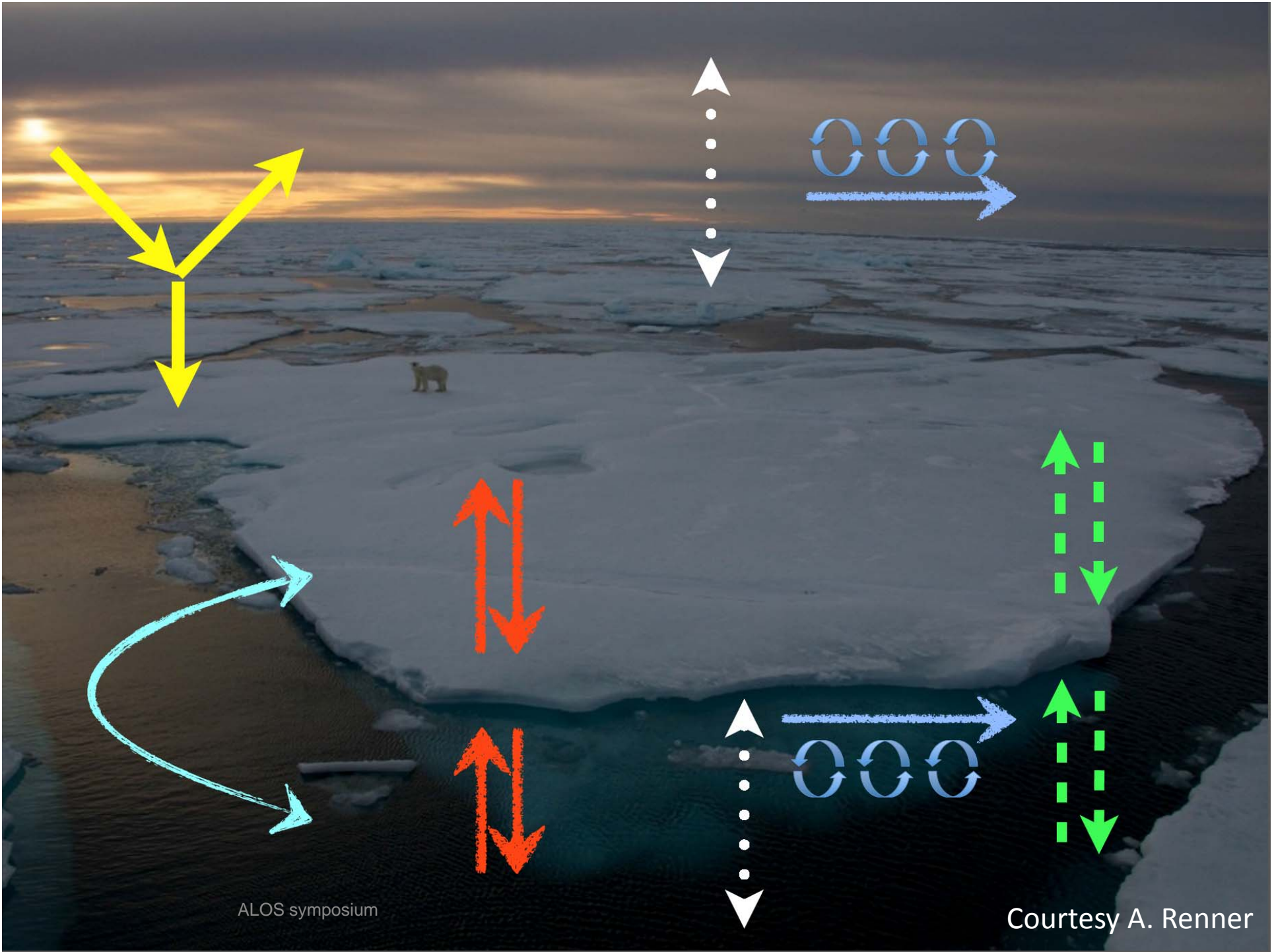


Figure 3.1. Photographs of a variety of sea ice types and forms: (a) new, (b) pancake, (c) marginal ice zone, (d) first year, (e) multiyear, (f) multiyear hummock, (g) multiyear meltpool, (h) first year pressure ridges, and (i) old multiyear pressure ridge ice.

(R.G.Onsott & R. Schuchman)

ALOS symposium



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Courtesy A. Renner

# What do we want to know about sea ice

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- ❑ - Sea ice segmentation
- ❑ - Sea ice type classification
- ❑ - Physical characterization of sea ice
- ❑ - Retrieval of geophysical parameters
  - Concentration, thickness
  - Roughness
  - Ice floe size distribution
  - Lead & ridge fraction
  - Melt pond fraction
  - Sea ice drift estimation

# Sea Ice and Arctic Operations

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- Oil & gas



- Shipping

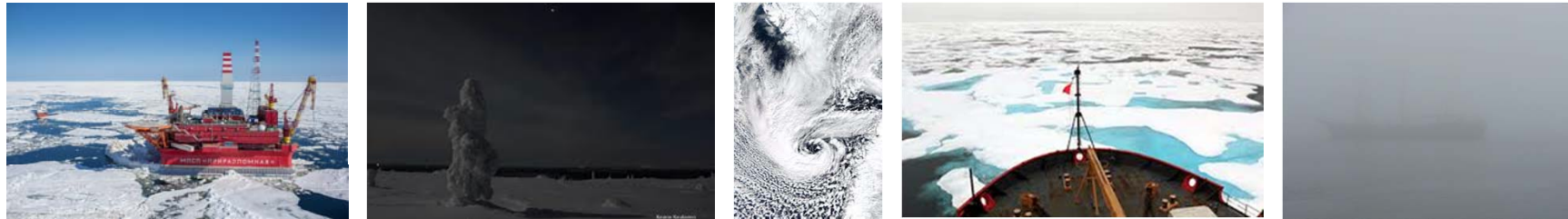


- Tourism



# Challenges related to Arctic industrial activities

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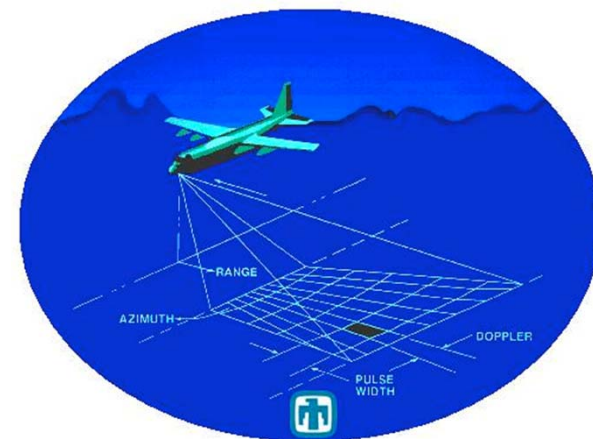
- **Low temperatures**
- **Icing**
- **Remoteness**
- **Sea Ice**
- **Darkness**
- **Low visibility**
- **Polar lows and arctic storms**

# Arctic surveillance: Requirements

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- Independent of weather and light conditions
- Image at multiple scales
- High spatial resolution
- Frequent imaging of "Areas of Interest"
- Provide large information contents

**Combine sensors !**  
**Combine platforms !**  
**'Synthetic Aperture Radar' !**





# Some current & future radar Satellites

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Current



Radarsat 2



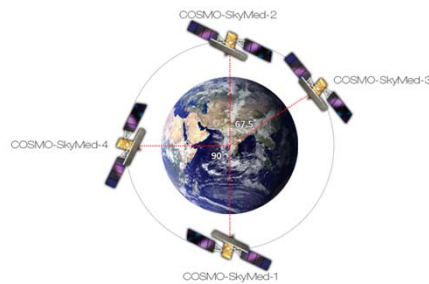
TerraSAR-X



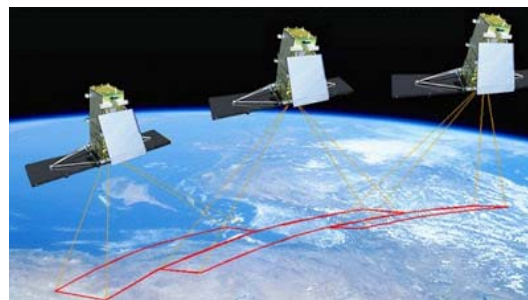
ALOS Palsar 2



Sentinel 1



COSMO-SkyMed



Radarsat Constellation

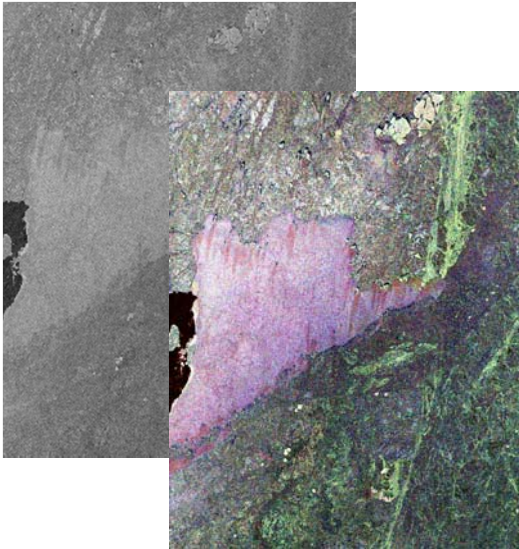


Sentinel family

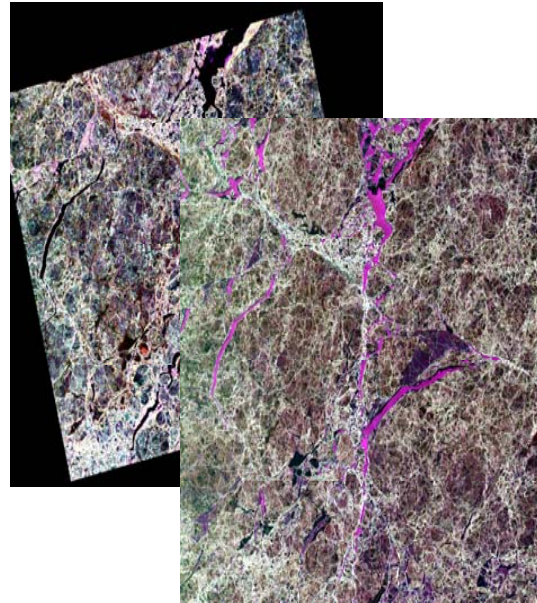
# New opportunities

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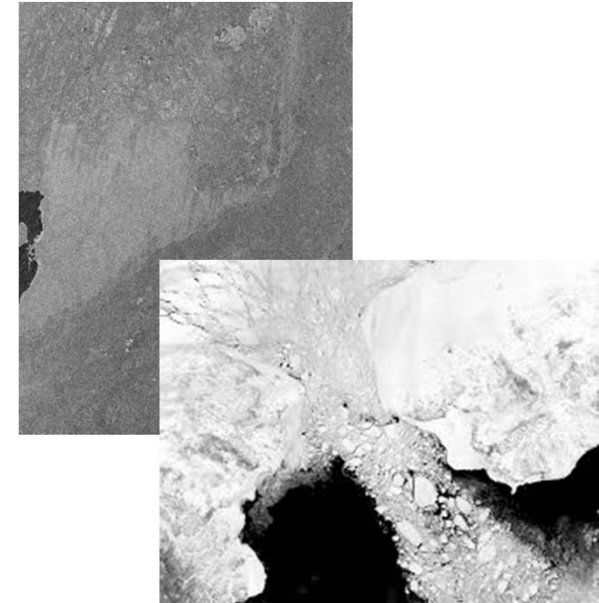
Multiple polarizations



Multiple frequencies

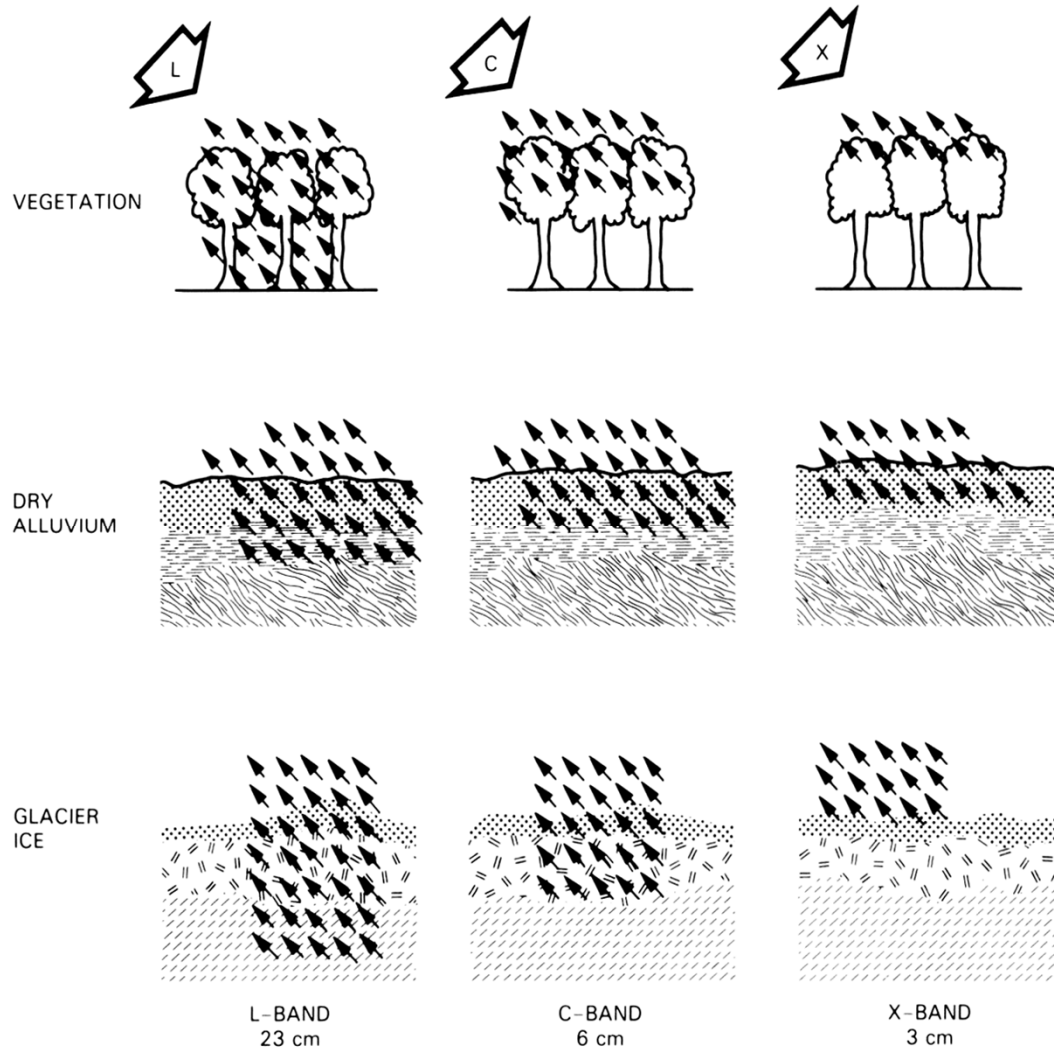


Combined Radar/optical



# Penetration of microwave signals in vegetation, soils and ice

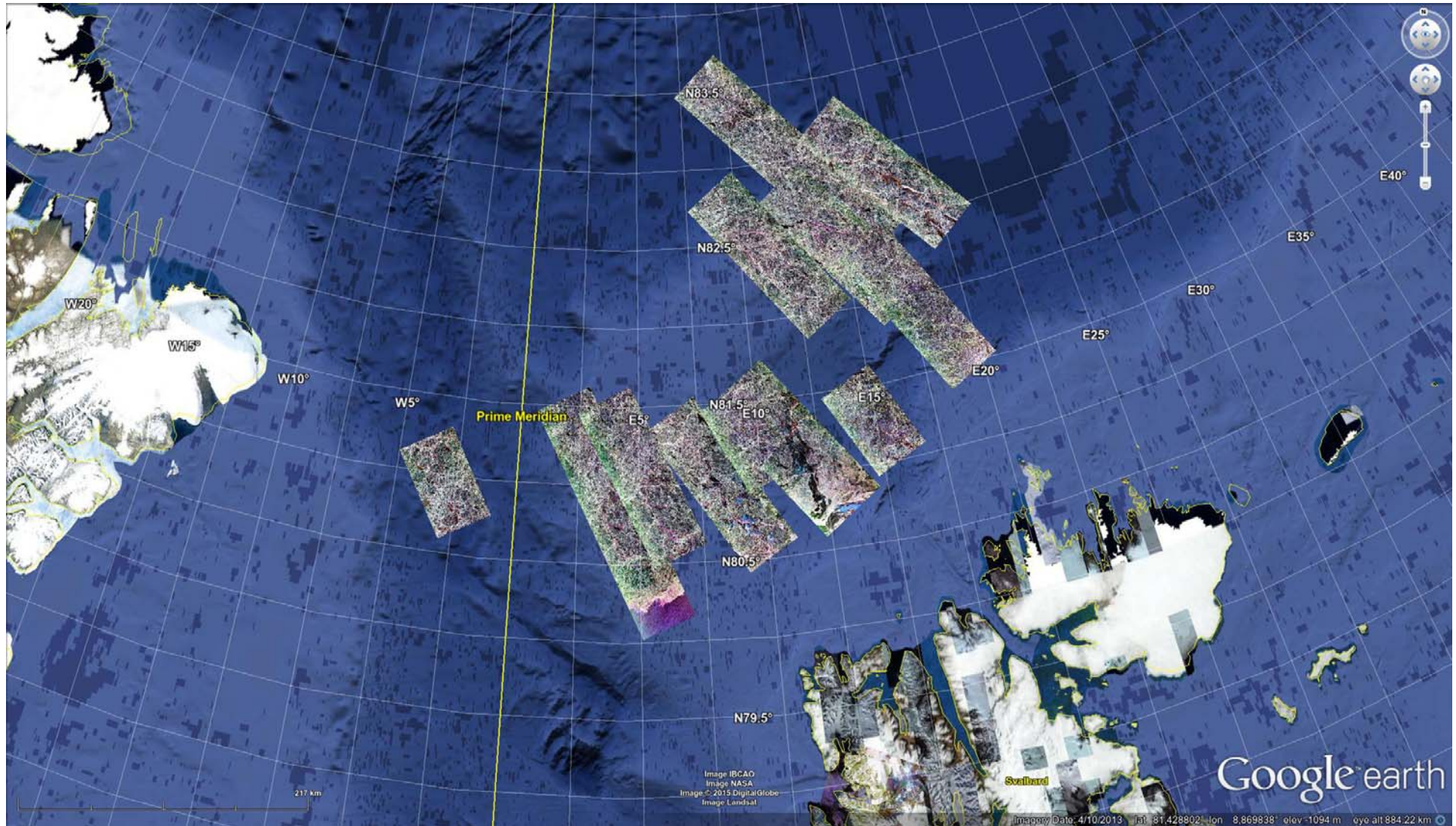
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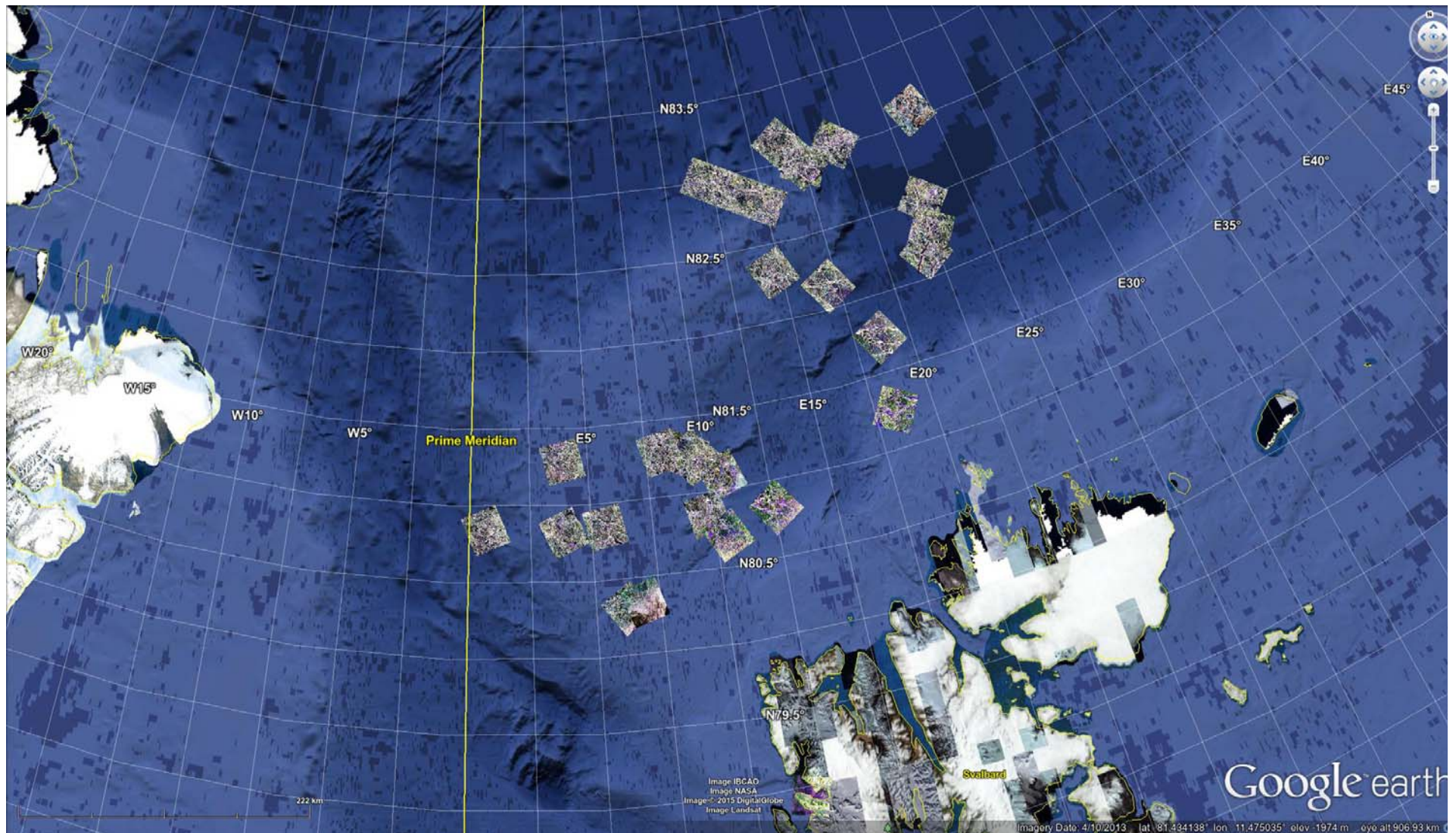
(after NASA, 1987)

ALOS symposium

# ALOS 2 Scenes from the N-ICE campaign

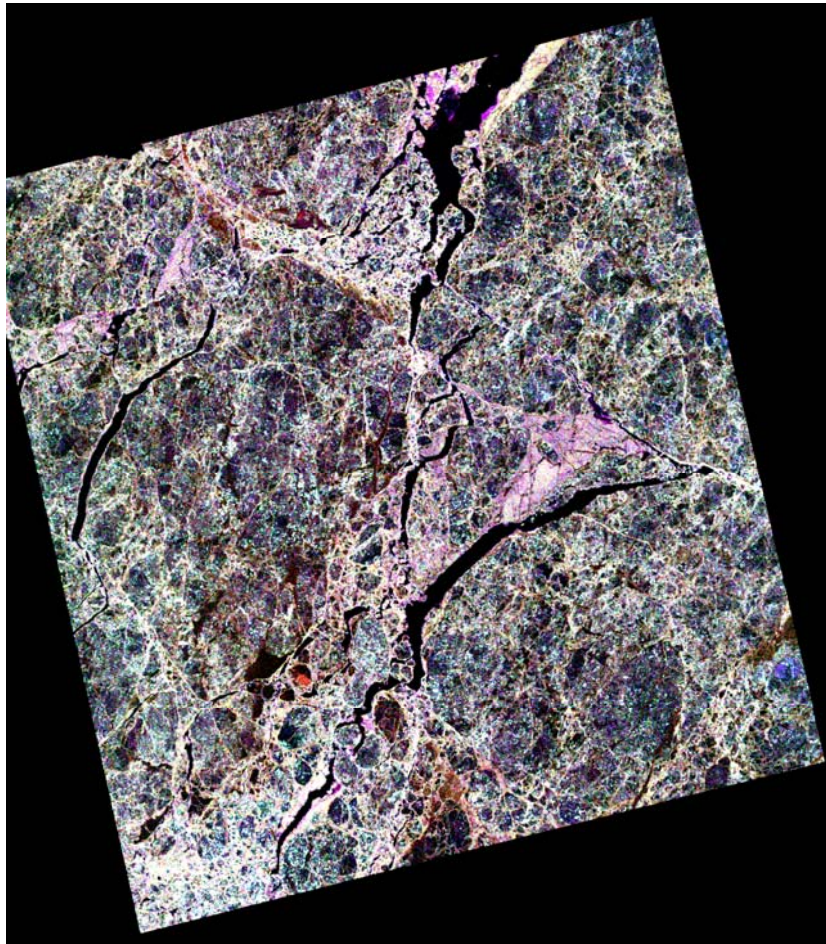


# Radarsat 2 Scenes from the N-ICE campaign



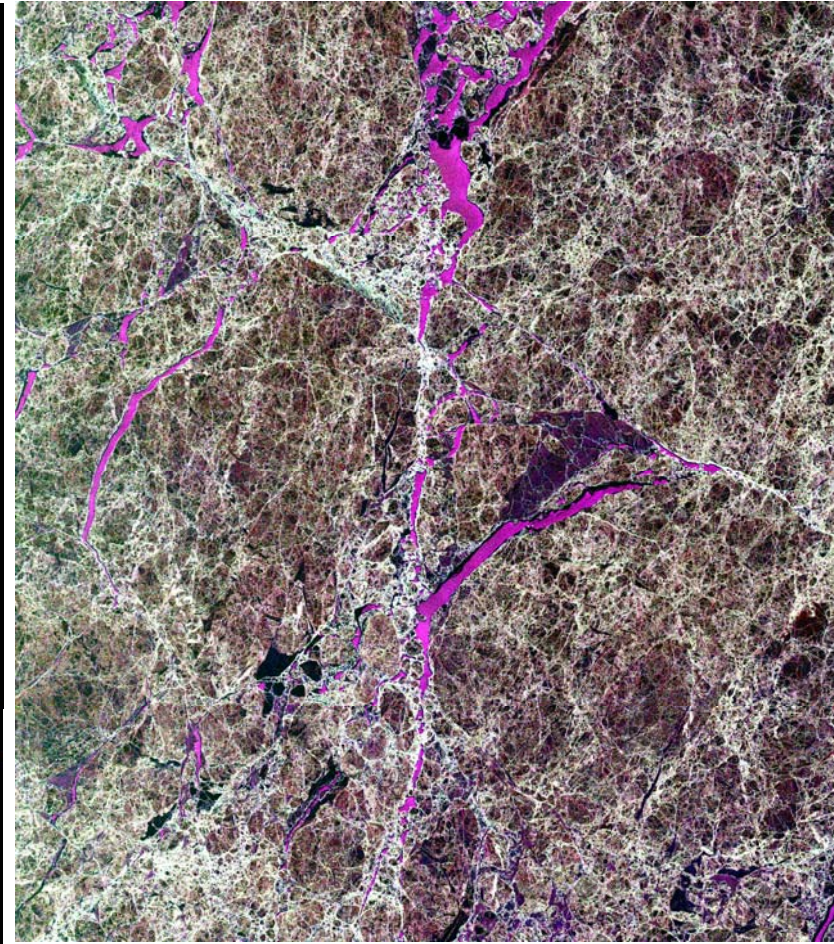
# Pauli-decomposition

RS2: C-band -26. mai, 2015



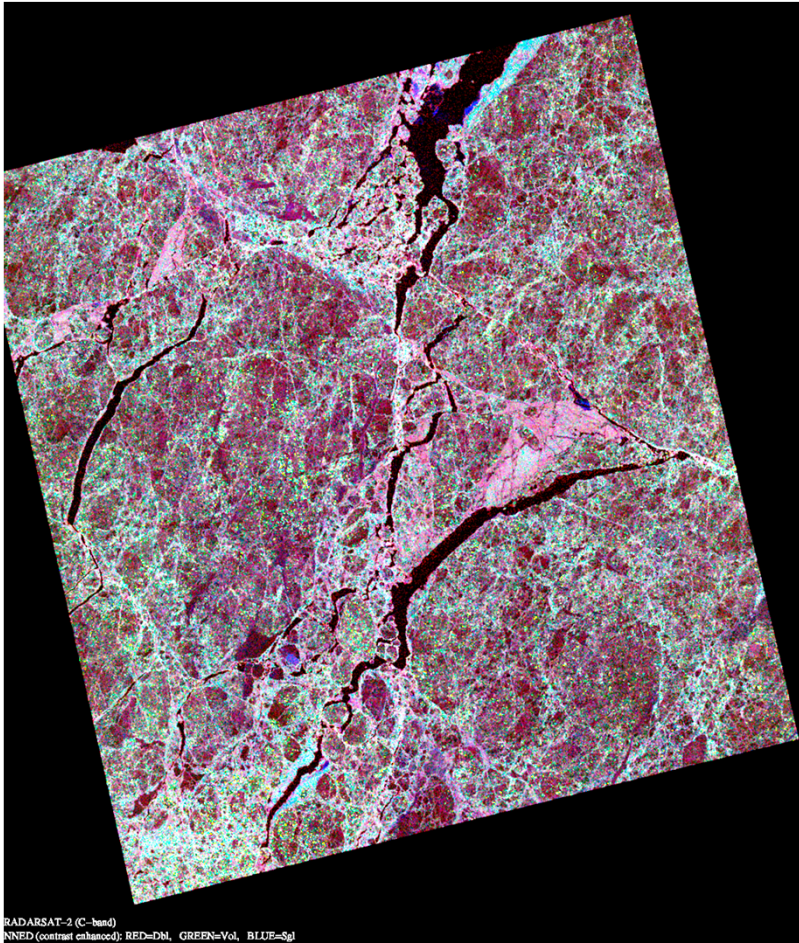
Copyright raw data MDA, 2015. Processed by KSAT

ALOS 2: L-band -26. mai, 2015

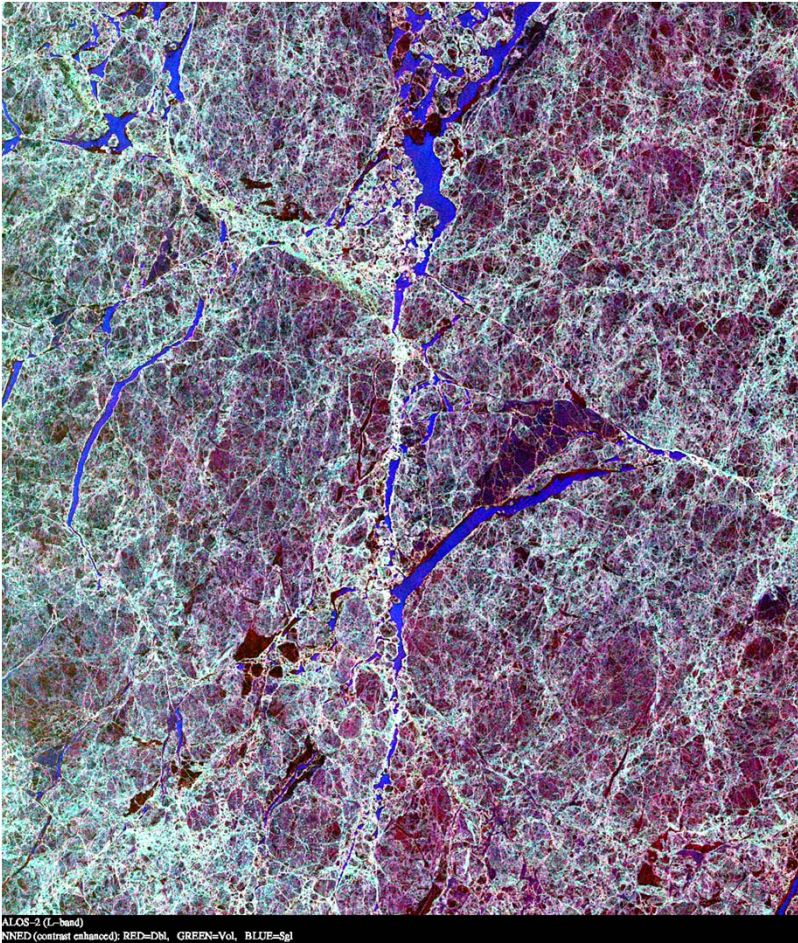


Copyright raw data JAXA, 2015

# NNED decomposition



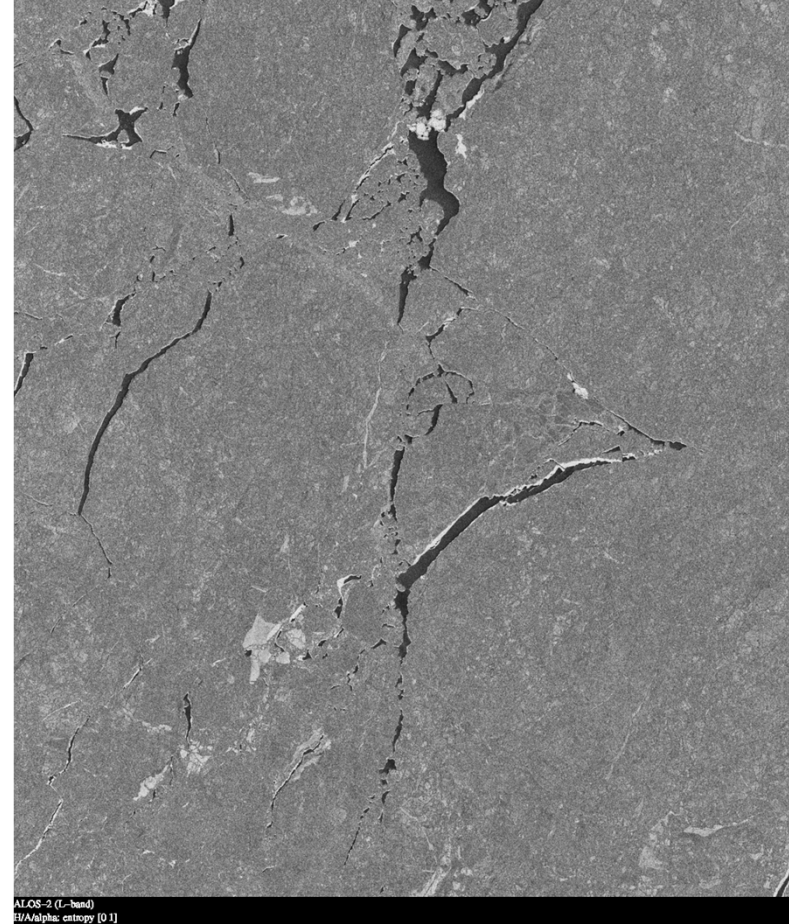
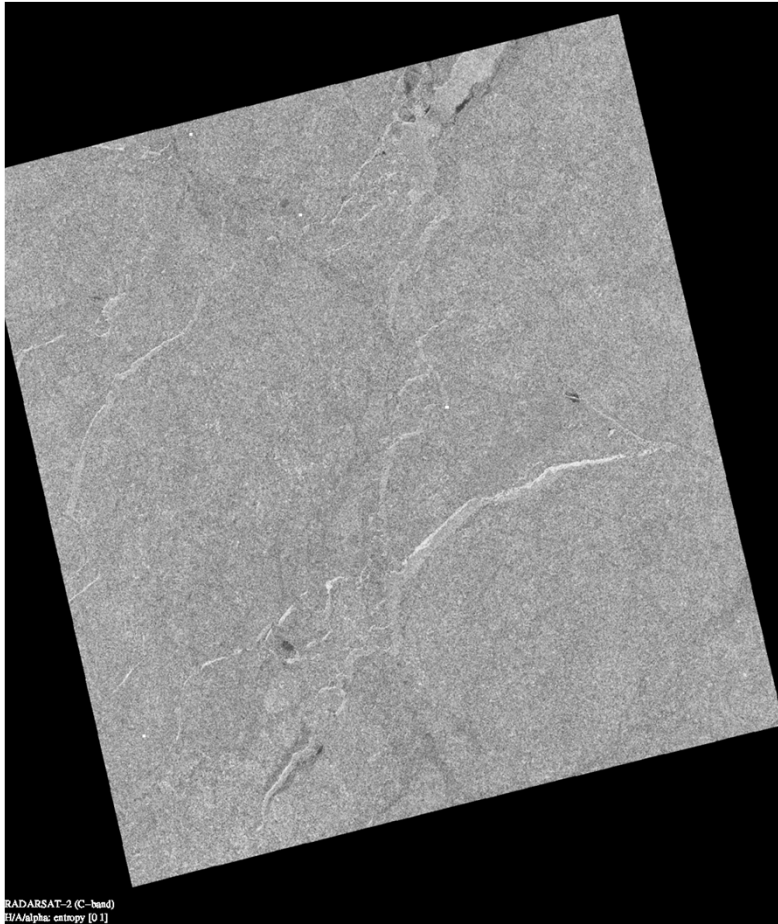
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# Polarimetric Entropy

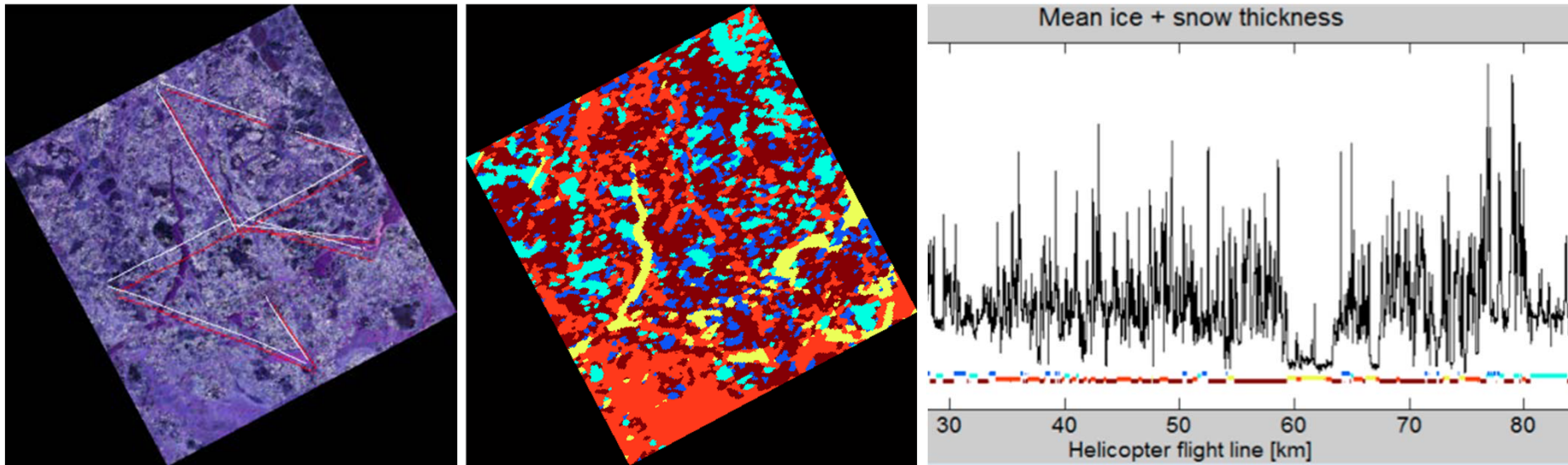
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# Sea ice classification

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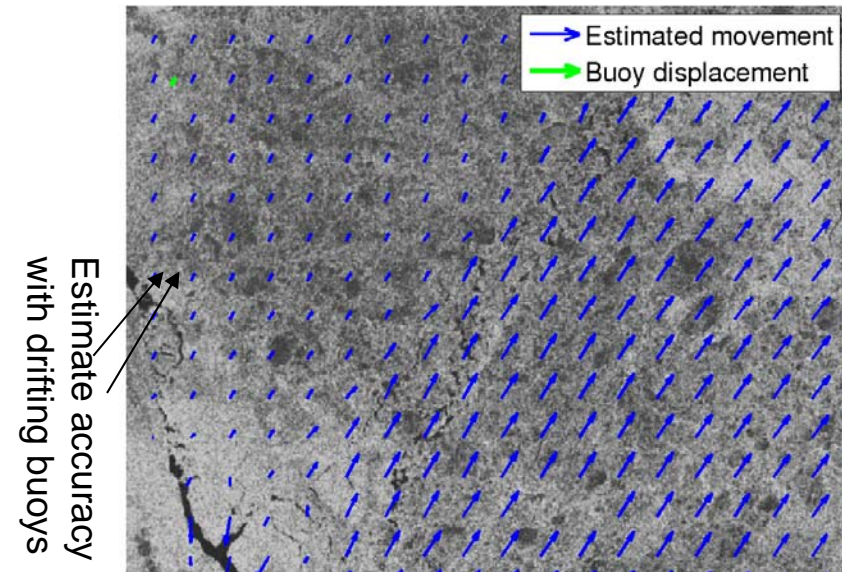
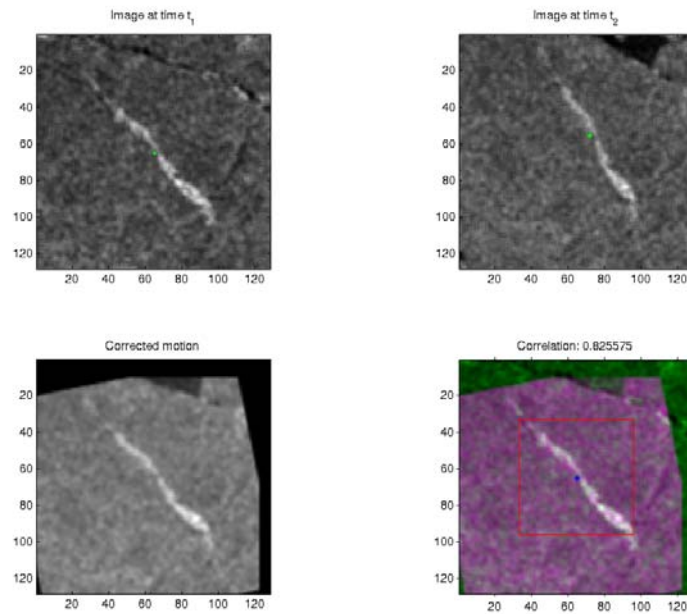


Copyright raw data MDA, 2011. Processed by KSAT

Moen, M.-A.N., A.P. Doulgeris, S.N. Anfinsen, A.H.H. Renner, N. Hughes, S. Gerland and T. Eltoft: "Comparison of automatic segmentation of full polarimetric SAR sea ice images with manually drawn ice charts", *The Cryosphere*, vol. 7, no. 6, pp. 1693-1705, November, 2013.

# Sea ice velocity estimation from image time series

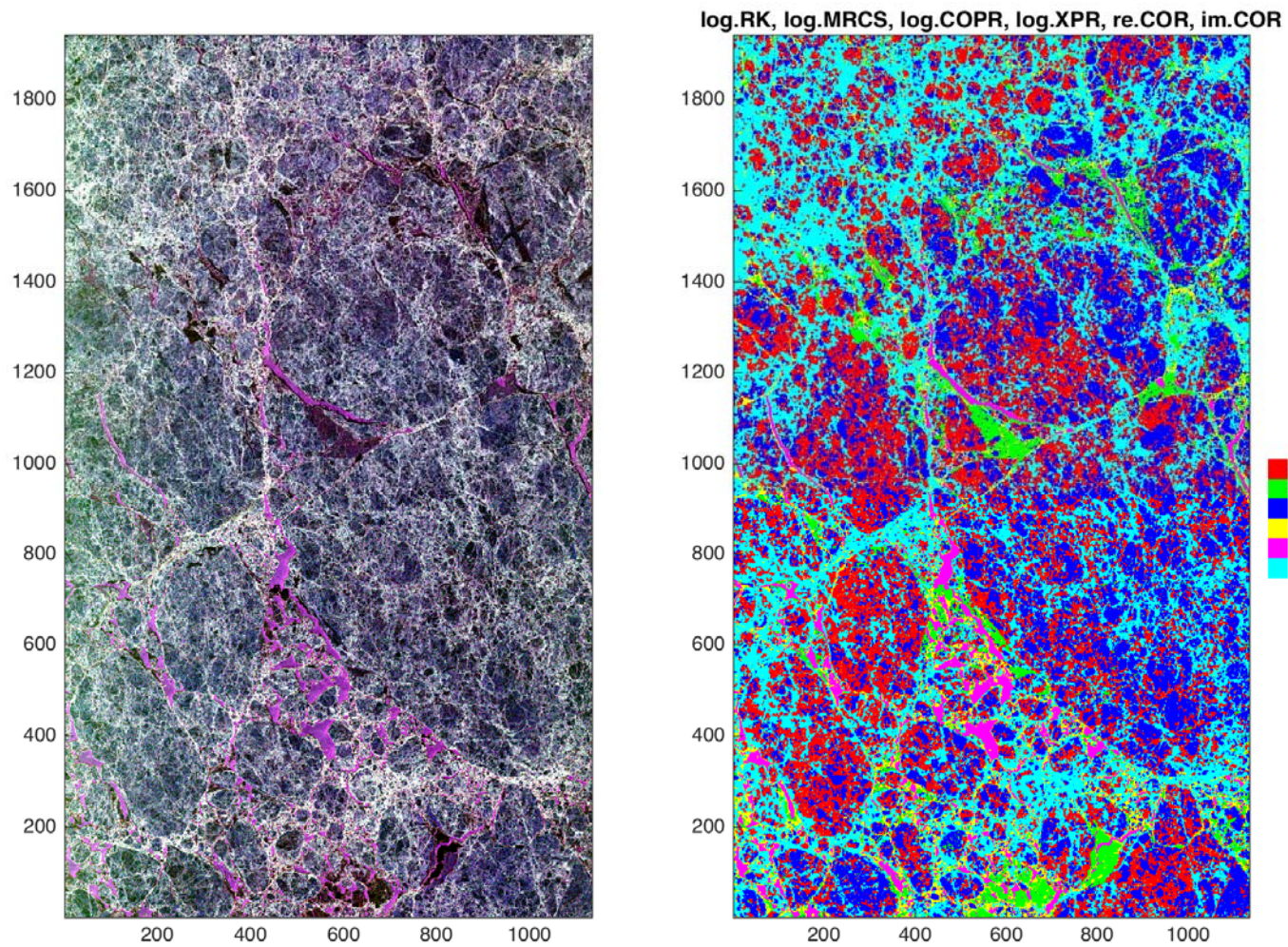
Correlation methods:



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# ALOS-2: Example of sea ice segmentation

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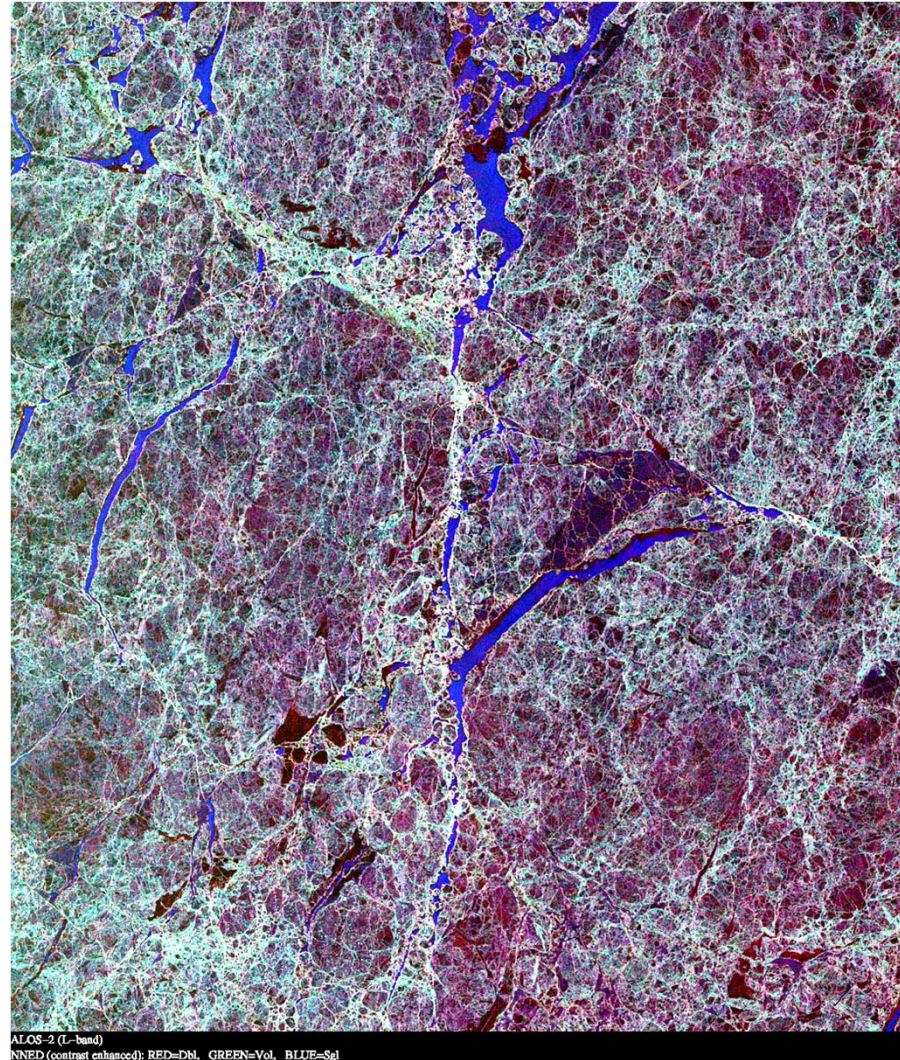


Copyright raw data JAXA, 2015

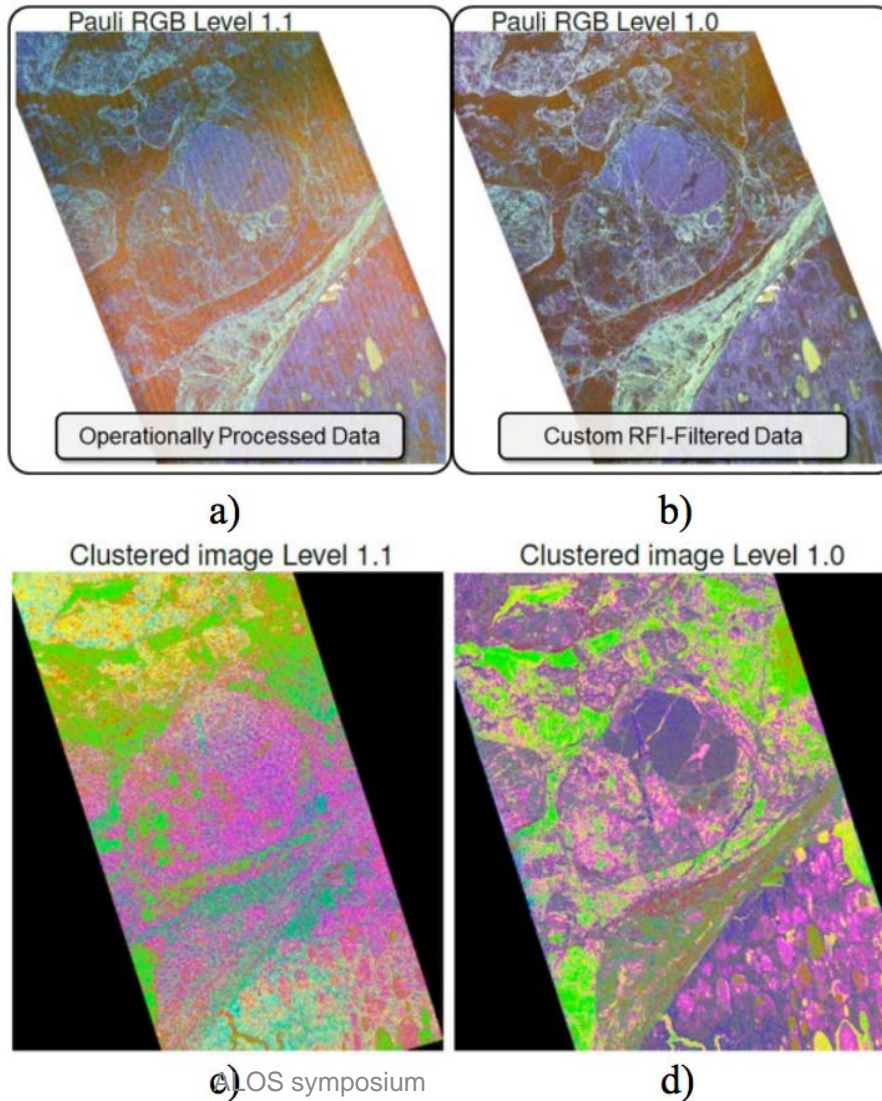
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# ALOS problems?

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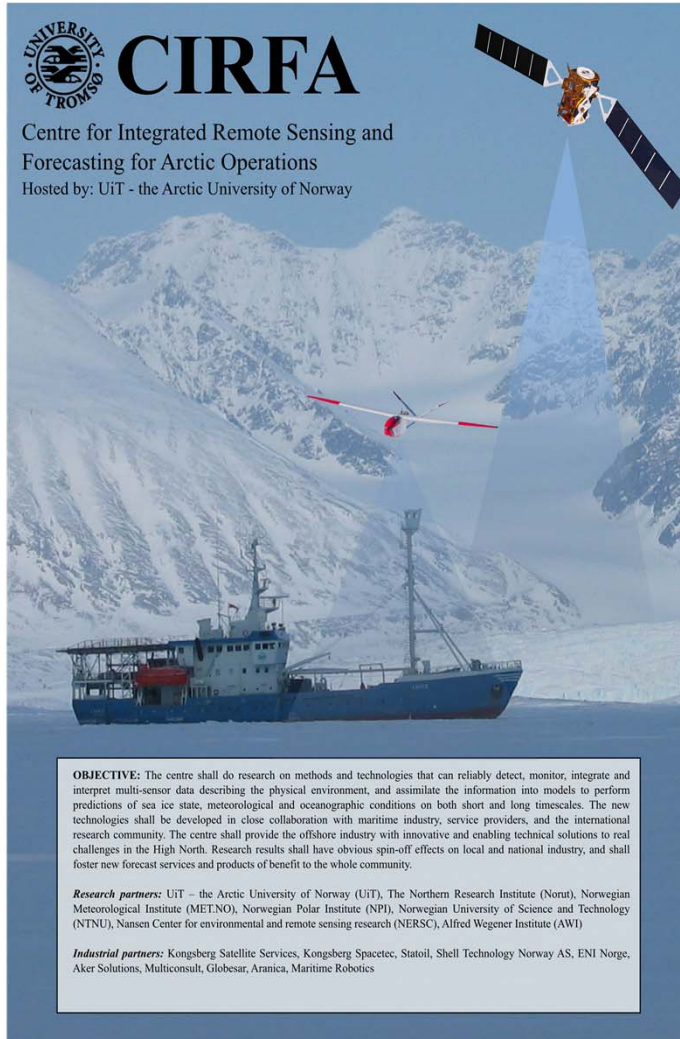
# ALOS problems?



**Figure 7** Improvement of polarimetric signature exemplified by a polarimetric clustering example: a) and b) before-and-after Pauli RGB images; c) and d) before-and-after segmented class images. The proposed filtering algorithm results in flatter response, sharper detail and better defined clusters.

Meyer, F.J., J. Nicoll and A.P. Doulgeris:  
*"Characterization and correction of residual RFI signatures in operationally processed ALOS PALSAR imagery"*,  
Proc. EUSAR 2012, Nuremberg, Germany,  
pp. 84-86, 23-26 April, 2012 (Best Paper Award).

# Centre for Integrated Remote Sensing and Forecasting for Arctic Operations (CIRFA)



**UNIVERSITY OF TROMSØ**  
**CIRFA**  
Centre for Integrated Remote Sensing and Forecasting for Arctic Operations  
Hosted by: UiT - the Arctic University of Norway

**OBJECTIVE:** The centre shall do research on methods and technologies that can reliably detect, monitor, integrate and interpret multi-sensor data describing the physical environment, and assimilate the information into models to perform predictions of sea ice state, meteorological and oceanographic conditions on both short and long timescales. The new technologies shall be developed in close collaboration with maritime industry, service providers, and the international research community. The centre shall provide the offshore industry with innovative and enabling technical solutions to real challenges in the High North. Research results shall have obvious spin-off effects on local and national industry, and shall foster new forecast services and products of benefit to the whole community.

**Research partners:** UiT – the Arctic University of Norway (UiT), The Northern Research Institute (Norut), Norwegian Meteorological Institute (MET.NO), Norwegian Polar Institute (NPI), Norwegian University of Science and Technology (NTNU), Nansen Center for environmental and remote sensing research (NERSC), Alfred Wegener Institute (AWI)

**Industrial partners:** Kongsberg Satellite Services, Kongsberg Spacetec, Statoil, Shell Technology Norway AS, ENI Norge, Aker Solutions, Multiconsult, Globesar, Aranica, Maritime Robotics

## Objectives:

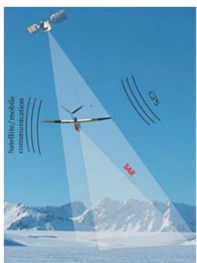
Long term research on integrated remote sensing from satellites and airborne platforms for Arctic operations

## Requests for ALOS data:

Satellite data is needed in algorithm development and in dedicated validation campaigns related to the various work packages

# Work packages

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## WP1: Ocean Remote Sensing

PI: Norut

- 1.1 Retrieval of ocean winds
- 1.2 Retrieval of ocean surface currents
- 1.3 Detection and tracking of polar lows

$$\text{Navier-Stokes equations (general)} \\ \rho \left( \frac{\partial \mathbf{v}}{\partial t} + \mathbf{v} \cdot \nabla \mathbf{v} \right) = -\nabla p + \nabla \cdot \mathbf{T} + \mathbf{f},$$

## WP5: Drift Modelling and Prediction

PI: Met.no

- 5.1: Data assimilation
- 5.2 Sea ice drift modelling and prediction
- 5.3: Oils spill drift modelling and prediction
- 5.4 Iceberg drift and deterioration



## WP2: Sea Ice, Iceberg and Growler Remote Sensing

PI: UiT

- 2.1 Classification & characterization of sea ice
- 2.2 Estimation of sea ice drift velocity field
- 2.3 Iceberg detection & characterization in open waters
- 2.4 Iceberg detection & characterization in sea ice
- 2.5 Tracking methodologies



## WP6: Field Work

PI: NPI

- 6.1 Yearly cruises to collect in-situ data
- 6.2 Yearly helicopter flights with EM sounder
- 6.3 Freeze-in of "Lance" winter 2015



## WP3: Oil Spill Remote Sensing

PI: UiT

- 3.1: Detection & characterization in open water
- 3.2: Detection & characterization in sea ice



## WP7: Pilot Service Demonstration

PI: KSAT & Met.no

- 7.1 Arctic surveillance services design
- 7.2: System and data integration
- 7.3: Pilot service demonstration
  - 7.3.1 Iceberg services
  - 7.3.2 Sea ice services
  - 7.3.3 Oil spill services
  - 7.3.4 Polar Lows services



## WP4: RPAS Technology

PI: Norut

- 4.1: Technology for RPAS operation
- 4.2: Sensors for sea ice and iceberg mapping
- 4.3: Sensors for oil spill mapping
- 4.3: Technology for geo-tagging of icebergs  
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*Thank you for your  
attention*

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