

# The Importance of Microwave Remote Sensing for Operational Sea Ice Services – And Challenges

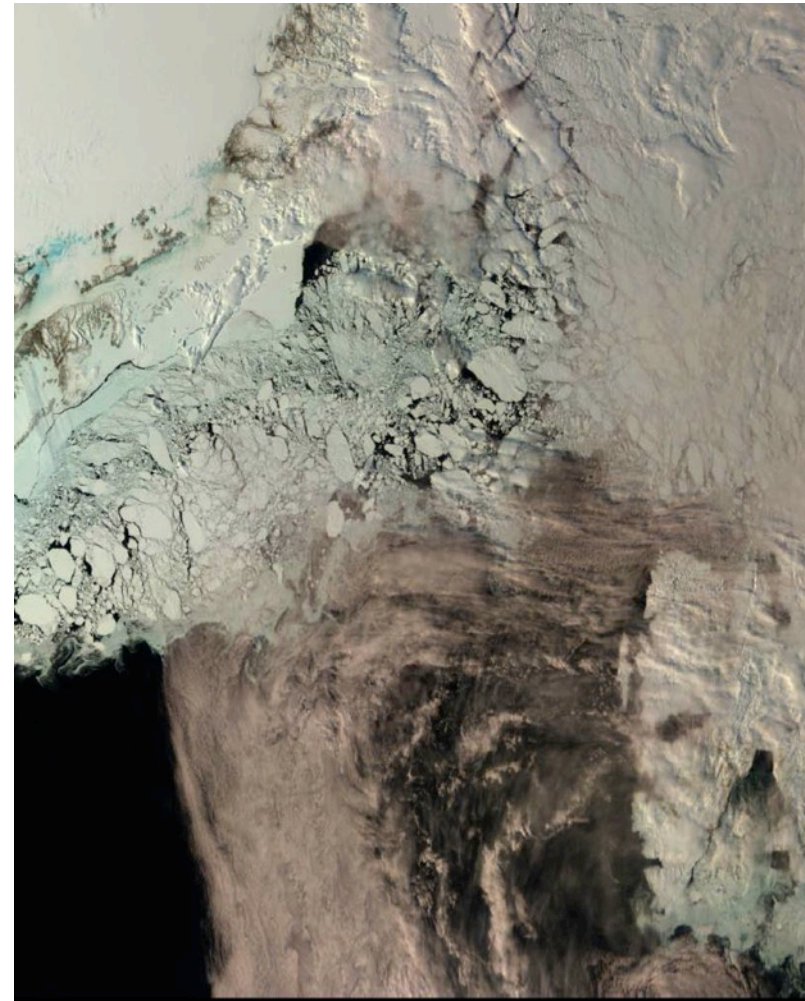
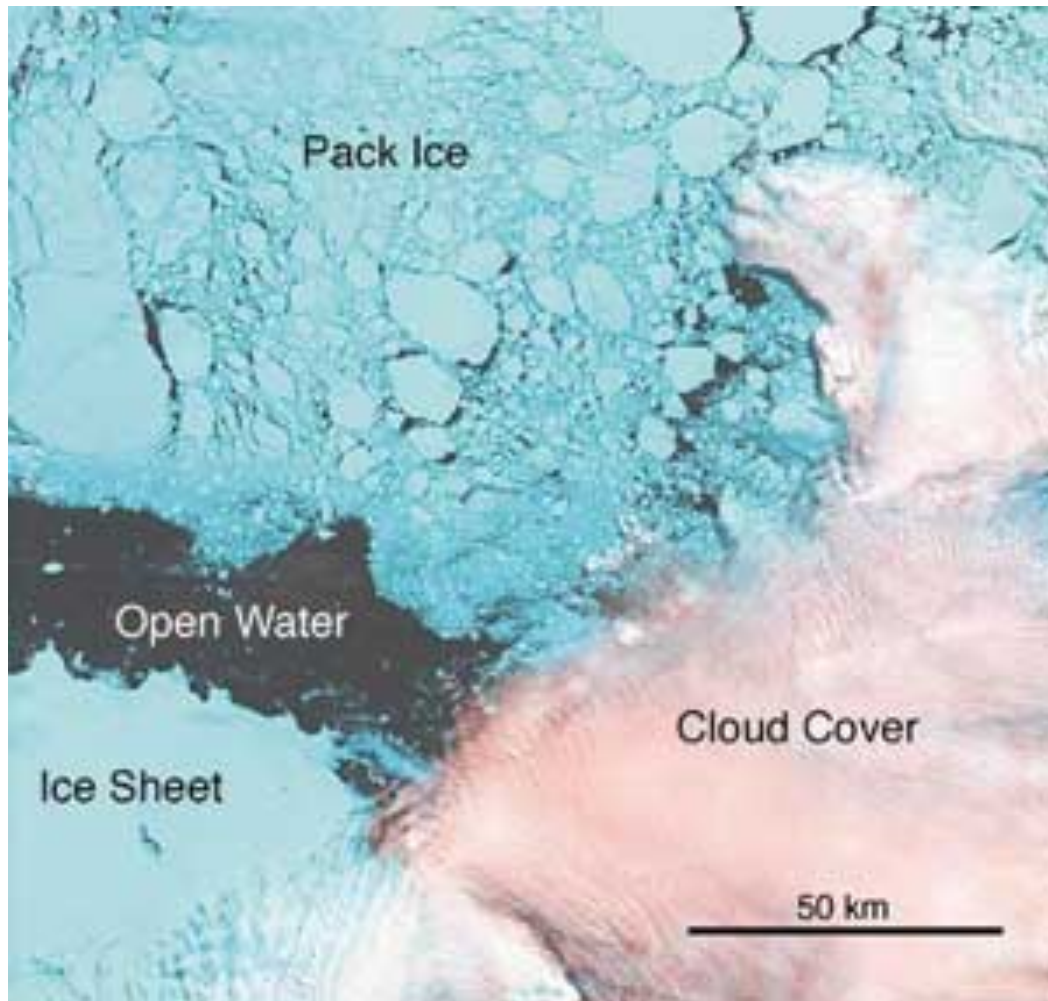
Wolfgang Dierking



**January 2015**

(1) Why is microwave remote sensing important (=useful) for sea ice mapping?

# Problems When Using Optical and IR-Images



*Clouds (and lack of daylight)*

# Problems When Using Optical and IR-Images



**not with microwave (radar) data!**

*...clouds (and lack of daylight)*

# Radars (Microwaves) Look Through Dry Snow



AWI/Optimare  
Airborne  
Color Line-Scanner



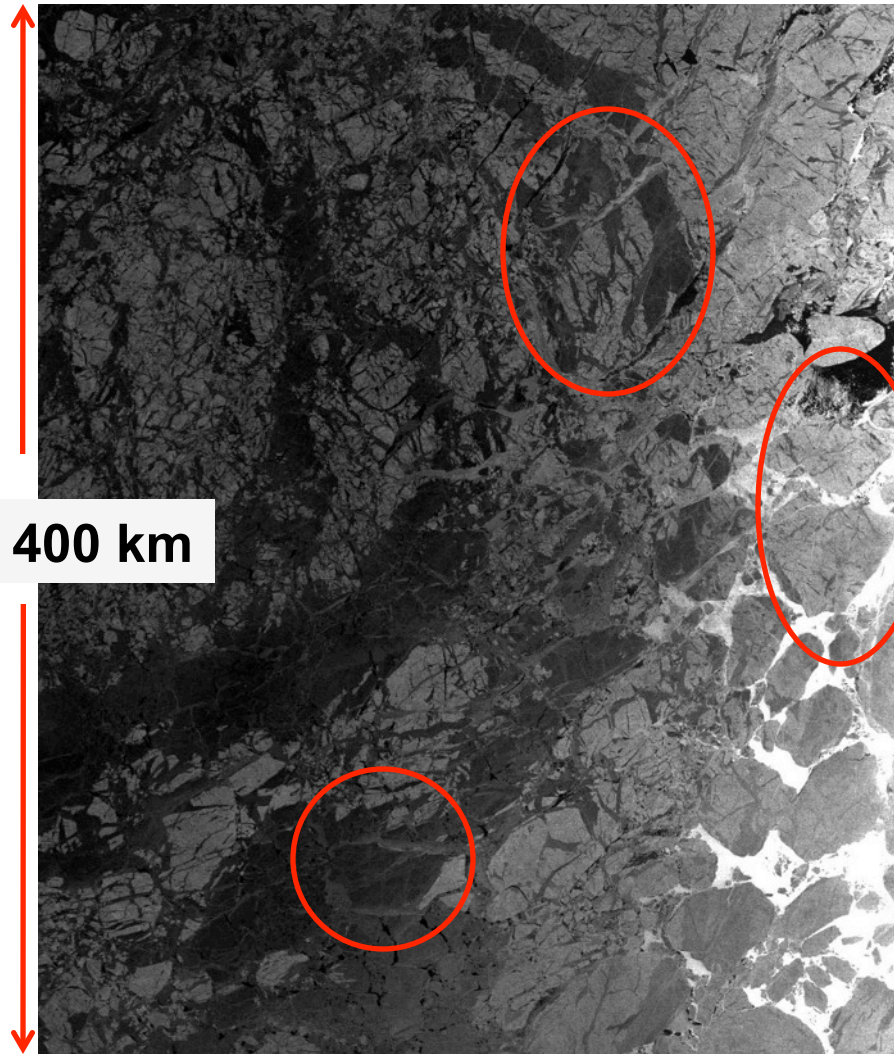
DLR ESAR:  
L-Band  
R: X-Pol.  
G: H-Pol.  
B: V-Pol.

3 km

*Radars (at X to L-band) “looks through” the dry snow, volume and deformation structures are partly visible.*

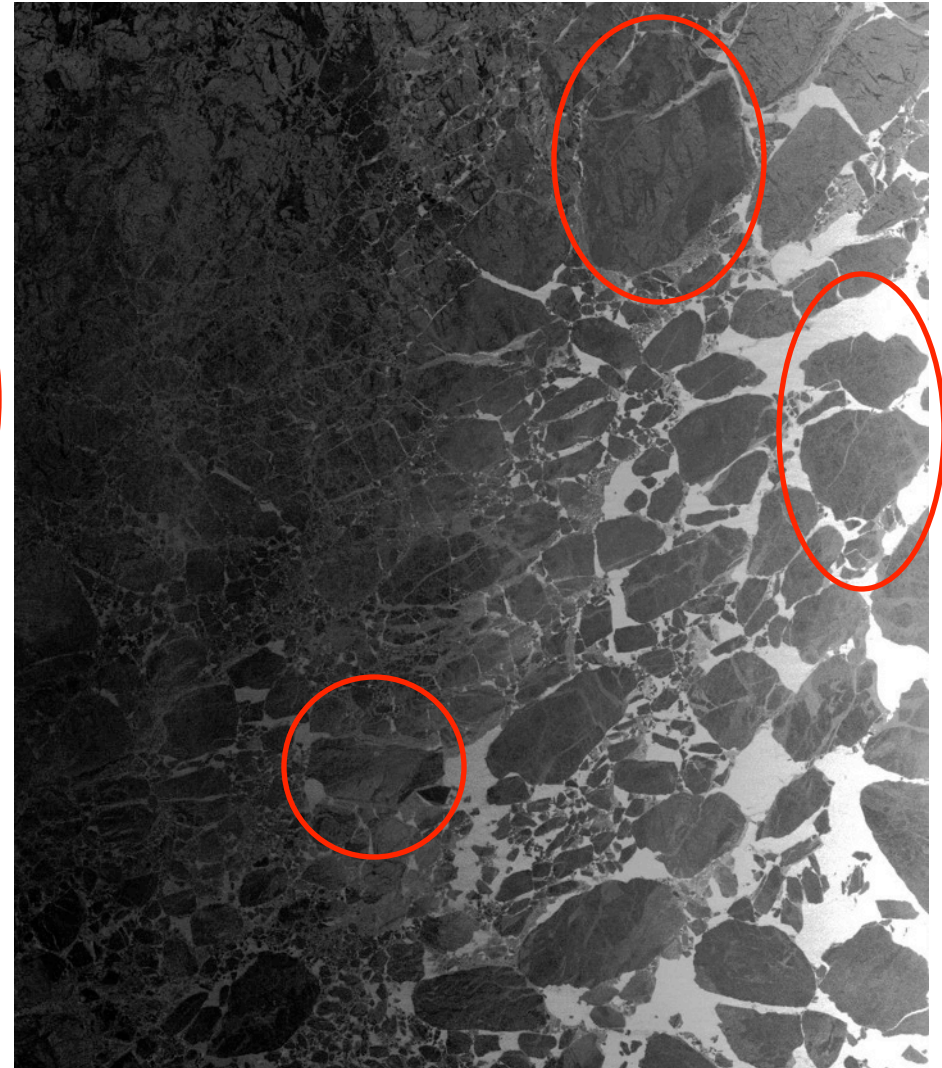
**Fram Strait**

# Radar Doesn't Look Through Wet Snow



ASAR WSM HH-Pol., 02-06-2008

ASAR WSM HH-Pol., 0506-2008



# Radar Doesn't Look Through Wet Snow



400 km

ASAR WSM HH-Pol., 0506-2008



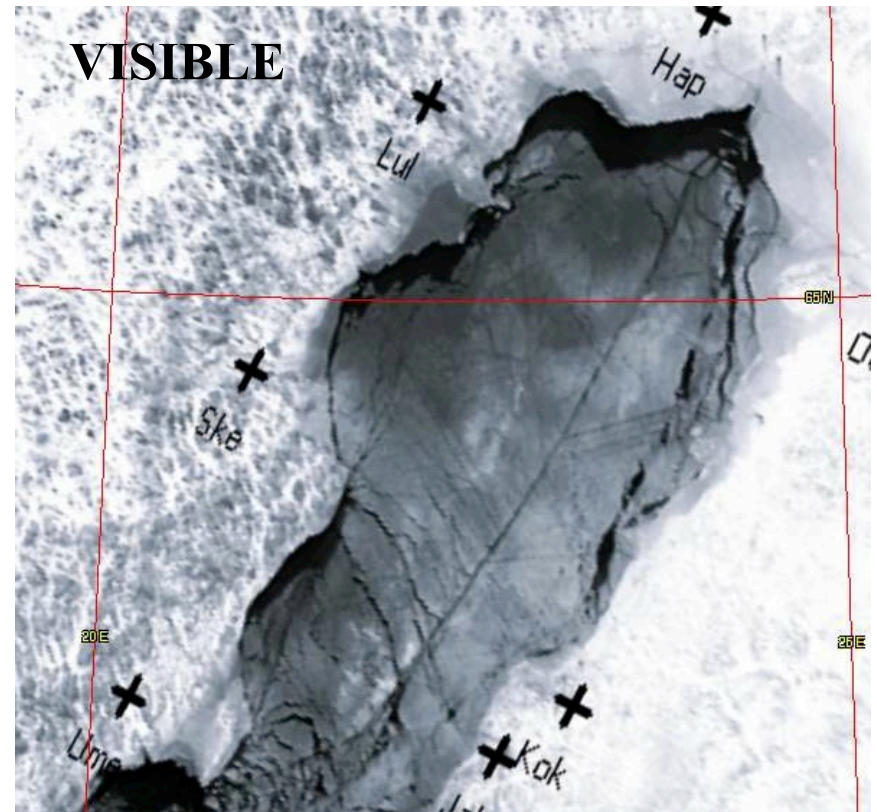
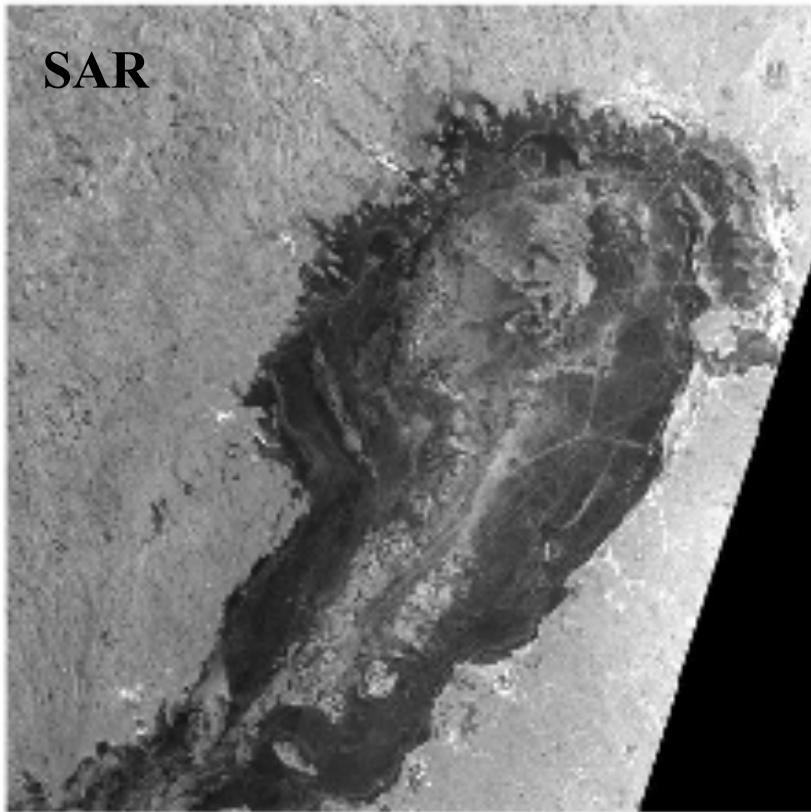
ASAR WSM HH-Pol., 02-06-2008

**but still through the clouds!**

(2) Ice chart production

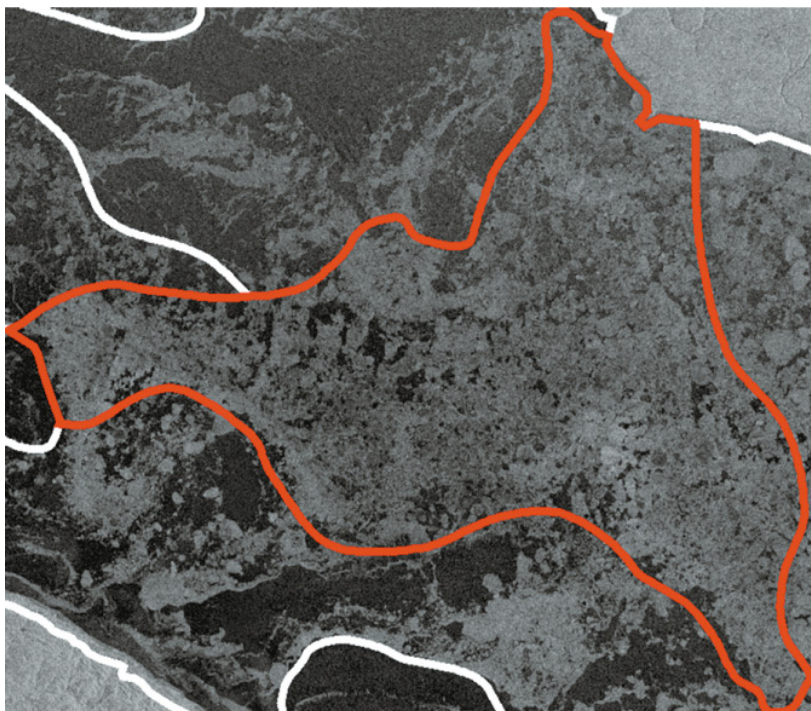


# Operational Approach: Using Sequences of C-Band SAR Imagery

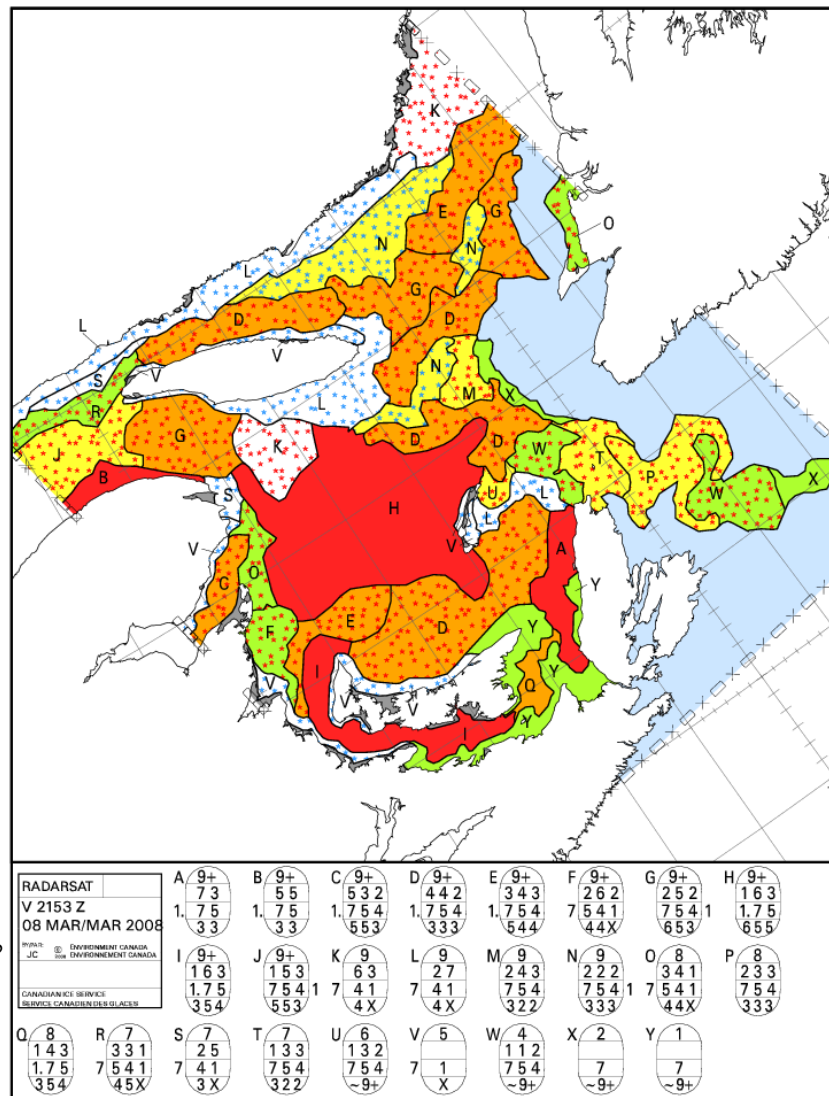


*...complemented by optical/IR images, aircraft reconnaissance, ship reports, weather data etc.*

# Outline of Visually Homogeneous Ice Conditions



Clausi et al., CJRS, 2010



L. Weir, CIS,  
WMO  
June 2009

*Ice characteristics described by “egg-code”*

# Egg-Code

region label

A

6

total ice concentration

concentration  
of ice types

2 3 1

5 4 1



















ice type code

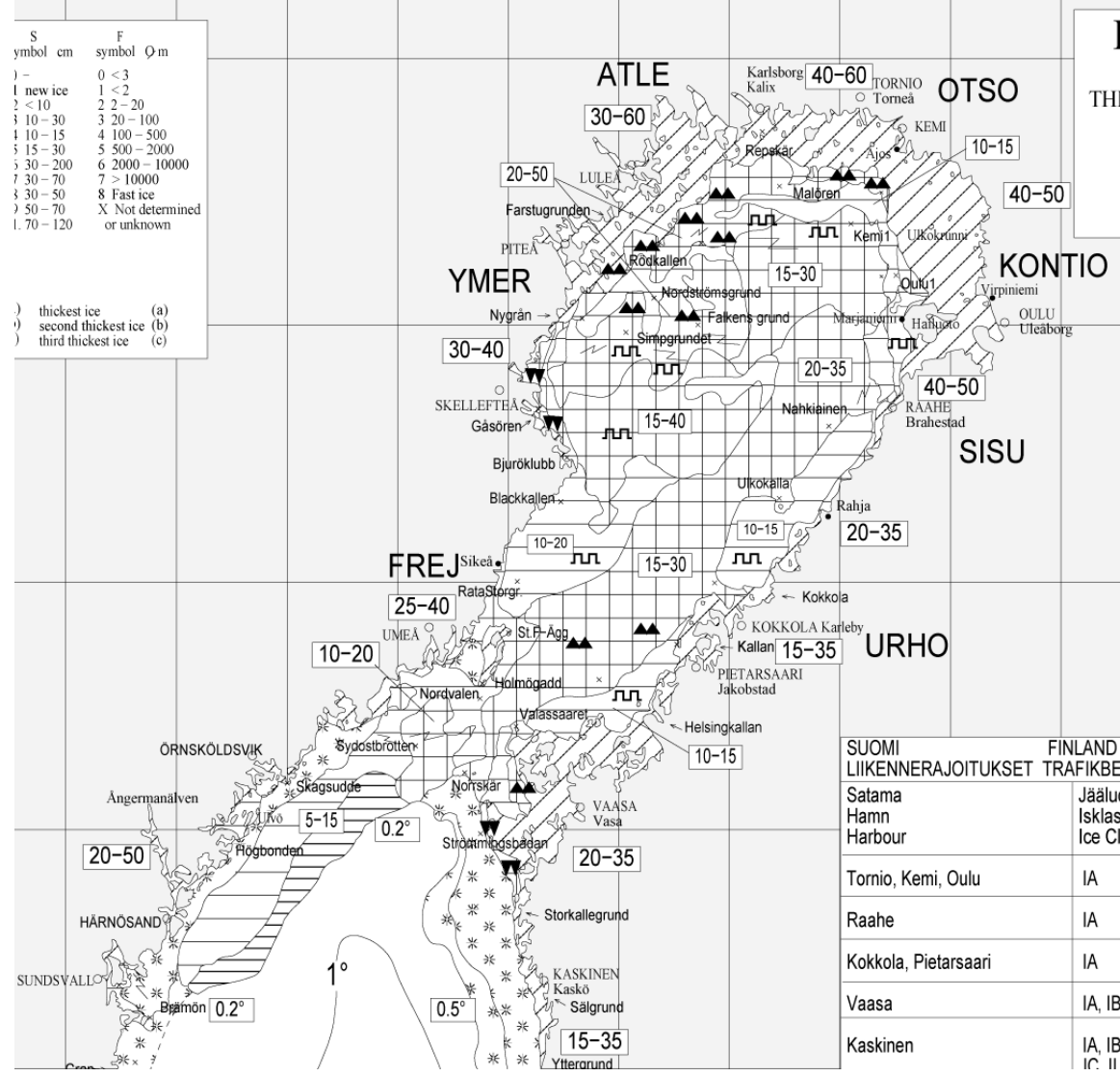
floe size

4 4 x

ice type  
thick -> thin

# Sea Ice Chart Baltic Sea (FIMR, now FMI)

	Yhteenjäätynyt, yhteenajautunut tai hyvin tiheä ajojää Consolidated, compact or very close ice (9–10/10) Sammanfrusen, kompakt eller mycket tät drivis		
	Ahtaunut tai röykkiöitynyt jää (f=ahtaumia/mpk) Ridged or hummocked ice (f=number of ridges/naut.m.) Vallar och upptornad is (f=vallar/naut.m.)		
	Päällekkäin ajautunut jää Rafted ice (C=concentr.) Hopskjutens is		Avovesi <1/10 Open water Öppet vatten
	Tiheä ajojää Close ice (7–8/10) Tät drivis		Uusi jää New ice Nyis
	Harva ajojää Open ice (4–6/10) Spridd drivis		Tasainen jää Level ice Jämn is
	Hyvin harva ajojää Very open ice (1–3/10) Mycket spridd drivis		Kiintojää Fast ice Fastis
	Jään reuna tai jään raja Ice edge or ice boundary Iskant eller isgräns		Sohjovyö Windrow Stampvall
	Arvioitu jään reuna tai jään raja Estimated ice edge or -boundary Uppskattad isgräns eller iskant		Halkeama Fracture Spricka
	Veden lämpötilan tasa-arvokäyrä Watertemperature isotherm, °C Vattentemperatur isotherm, °C		Railo Lead Räk
	Mitattu jään paksuus Thickness measured in cm Uppmätt istjocklek i cm		Haurasta jäätä = Rutten is = Rotten ice



# Sea Ice Chart Svalbard (Met. No.)



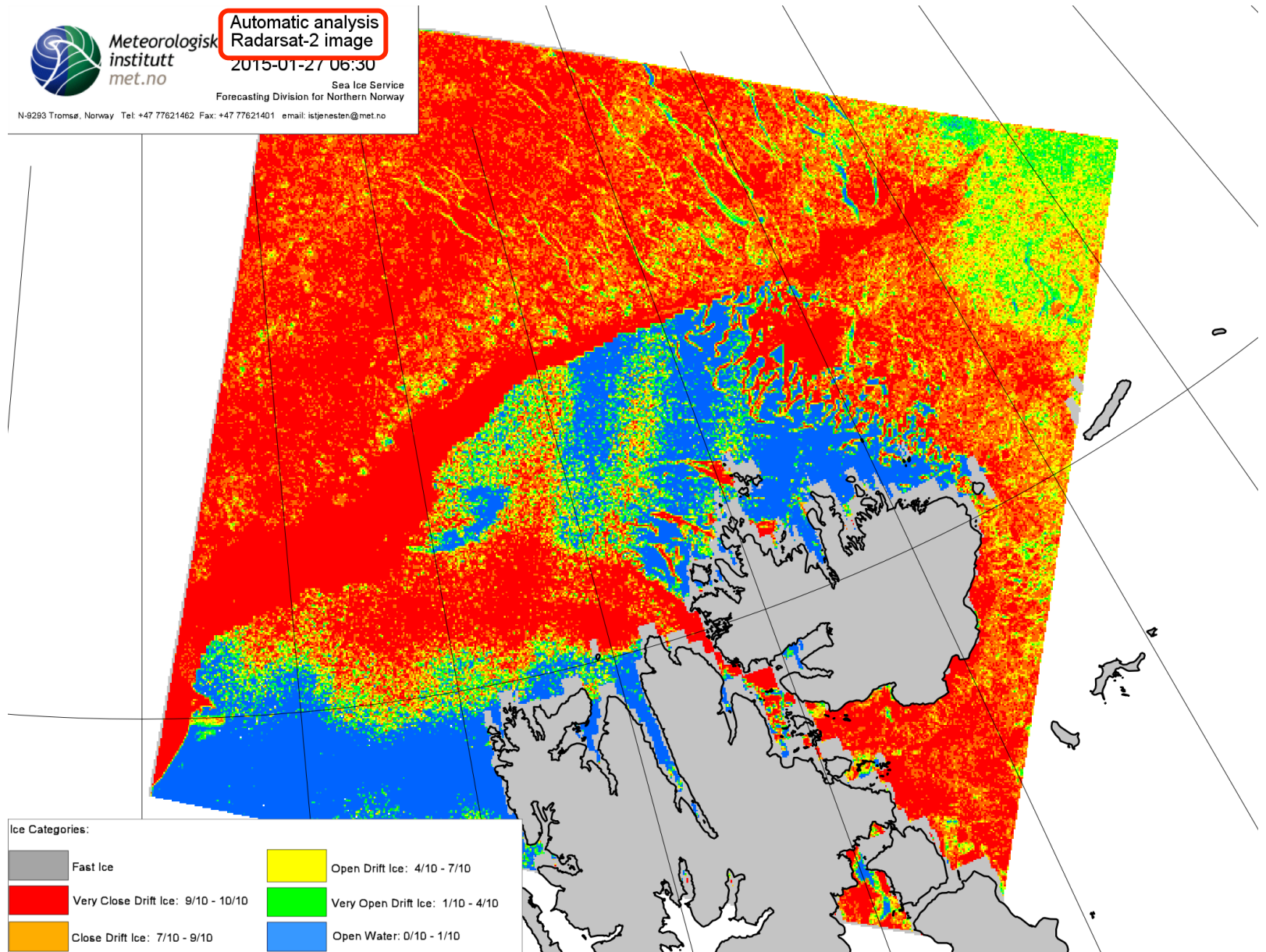
Meteorologisk  
institutt  
met.no

Automatic analysis  
Radarsat-2 image







2015-01-27 06:30

Sea Ice Service  
Forecasting Division for Northern Norway

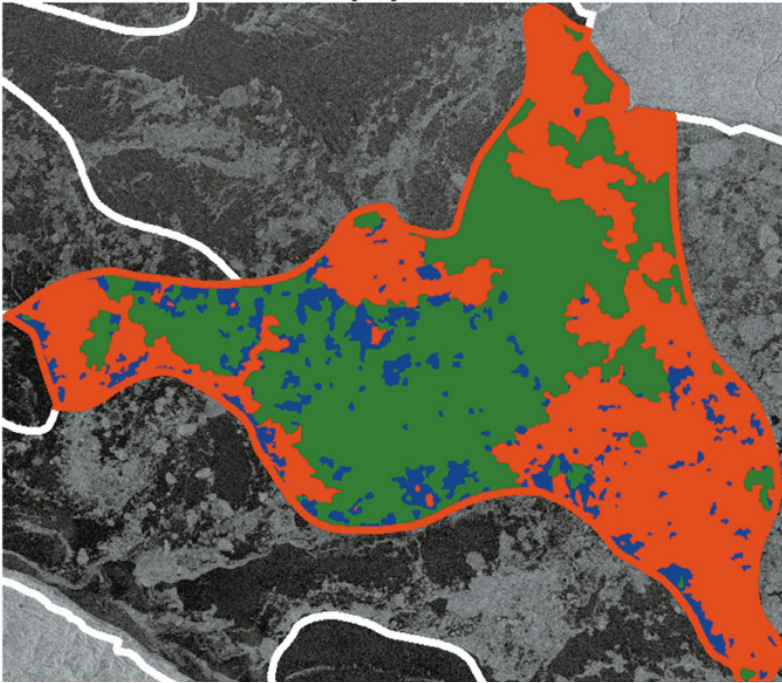
N-9293 Tromsø, Norway Tel: +47 77621462 Fax: +47 77621401 email: isjtenesten@met.no



Ice Categories:

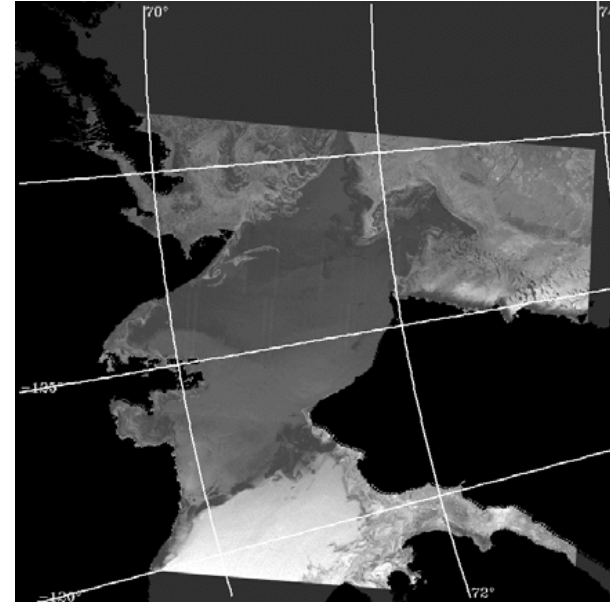
	Fast Ice		Open Drift Ice: 4/10 - 7/10
	Very Close Drift Ice: 9/10 - 10/10		Very Open Drift Ice: 1/10 - 4/10
	Close Drift Ice: 7/10 - 9/10		Open Water: 0/10 - 1/10

# Automated Segmentation And Classification



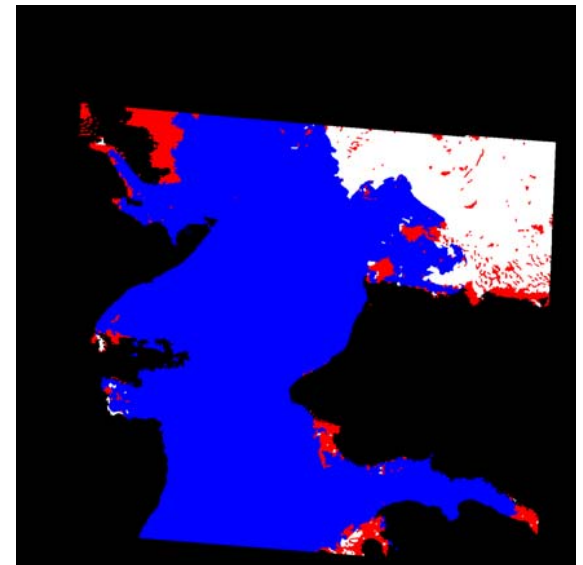
**“MAGIC”**

Clausi et al., CJRS, 2010



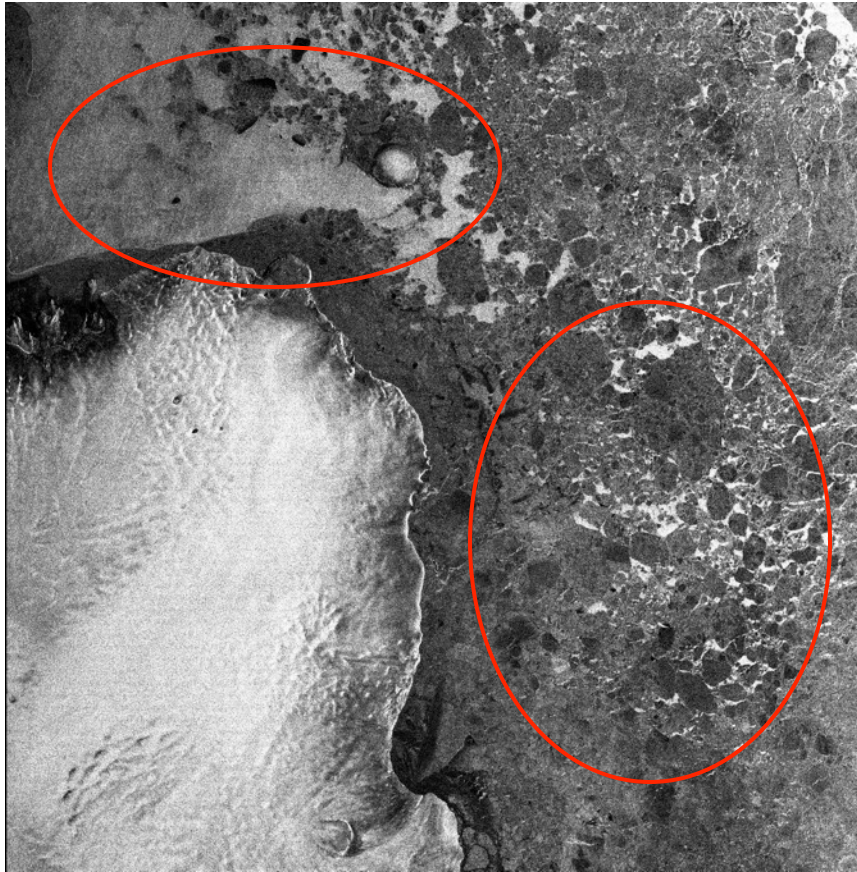
**“ARKTOS”**

Gineris et al., CSE Conf, 2000



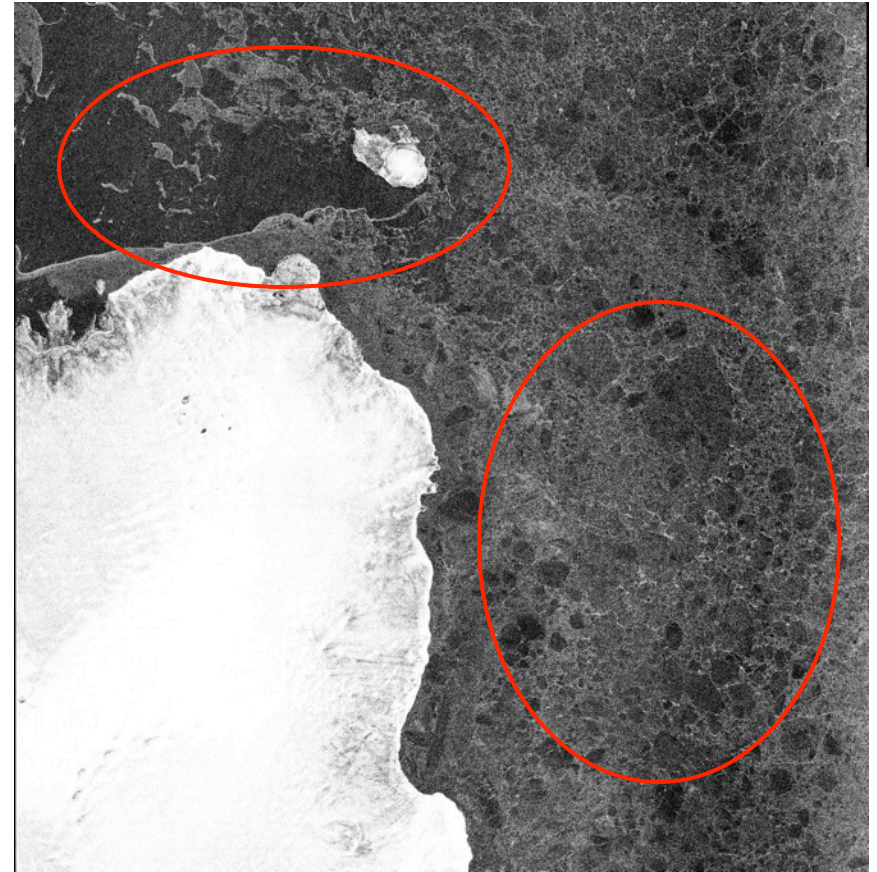
# Recent Improvements: Use of Dual-Polarization...

← 100 km →



**HH-Polarization**

near-  
range



**HV-Polarization**

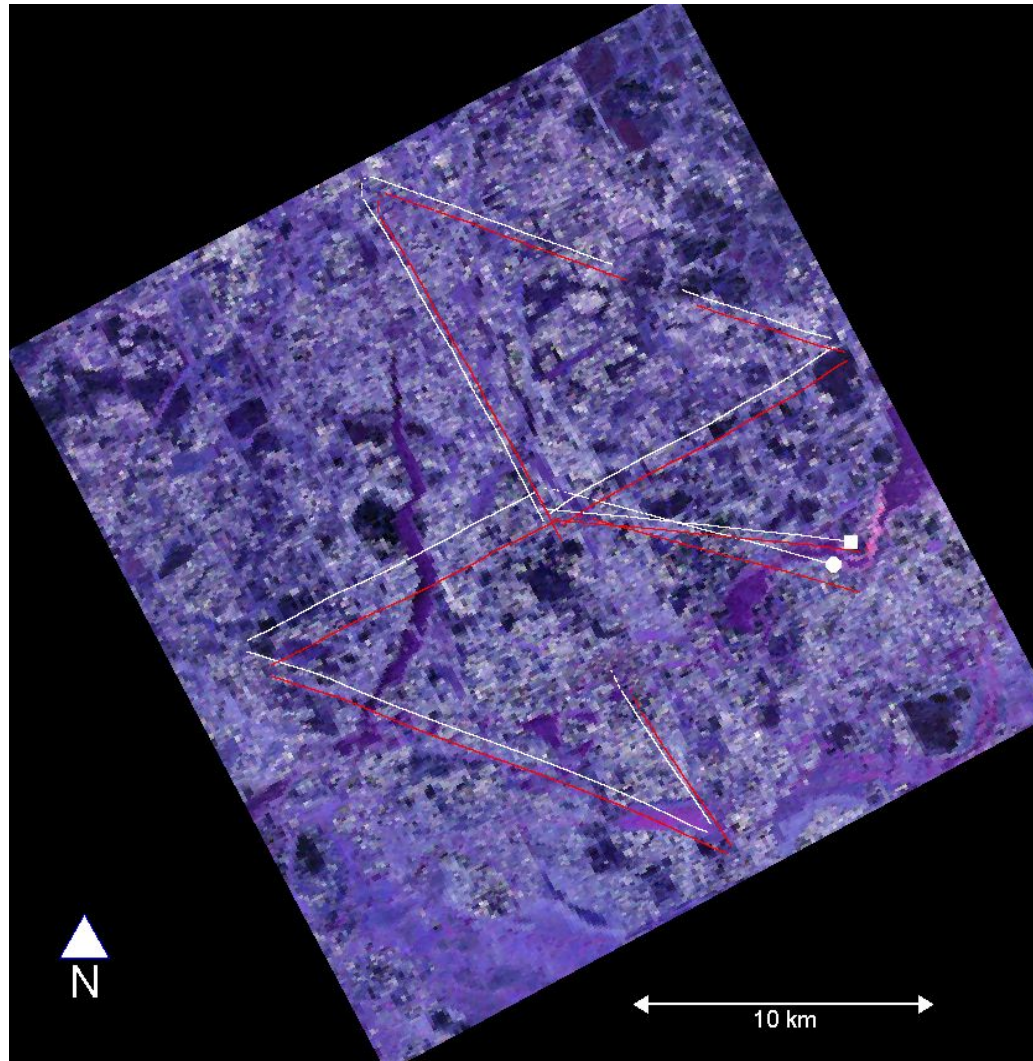
*e. g. MET Norway and CIS use Radarsat-2 ScanSAR Wide (resolution 50-100m, coverage 500 x 500km, HH+HV)*

## (3) Challenges



# Starting Point: Radar Image...

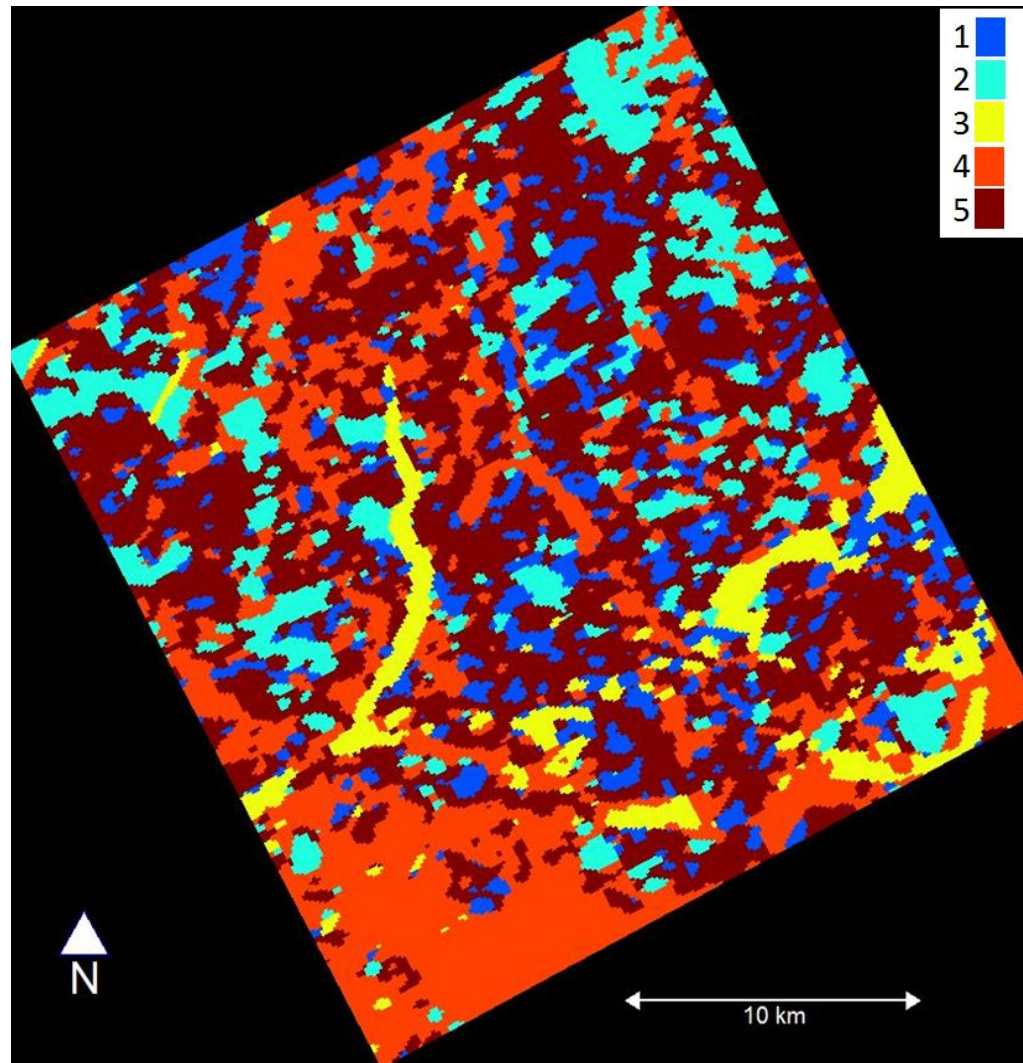
1204 2011  
R-IHH-VVI  
G-VV  
B-IHH+VVI



Moen et al.,  
TC 2013

*(if possible from a combination of different channels)*

## ... Segmentation ... (Clustering)...



Moen et al.,  
TC 2013

*Various algorithms available, tested for special conditions*

# ...Classification

## WMO-“Stage of development scheme”


### *Ice Stage of Development (SoD)*

 Ice of undefined SoD [X]

 Open water [0]

 New ice [1]

 Nilas [2]

 Nilas (with frost flowers) [2]

 Young ice [3]

 Grey ice [4]


 Grey-white [5]

 First year [6]

 Thin first year ice [7]

 First stage first year [8]

 Second stage first year [9]

 Medium first year [1·]

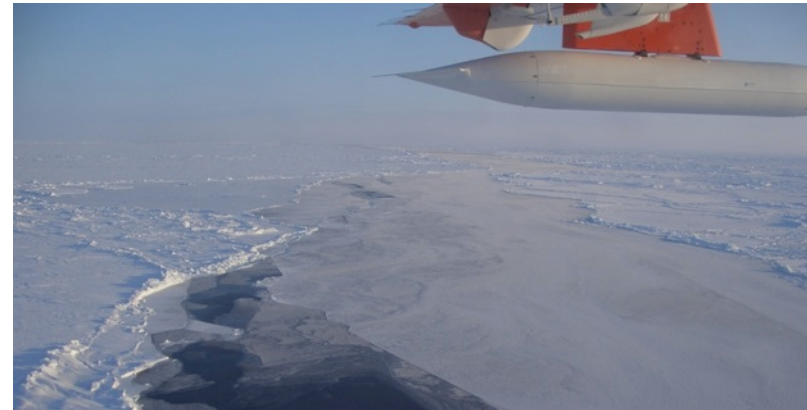
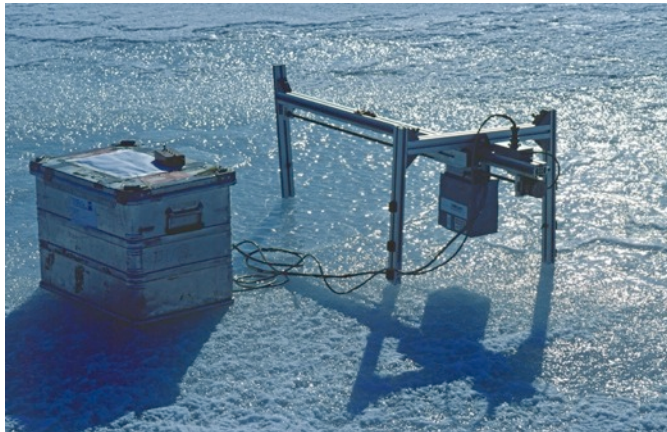
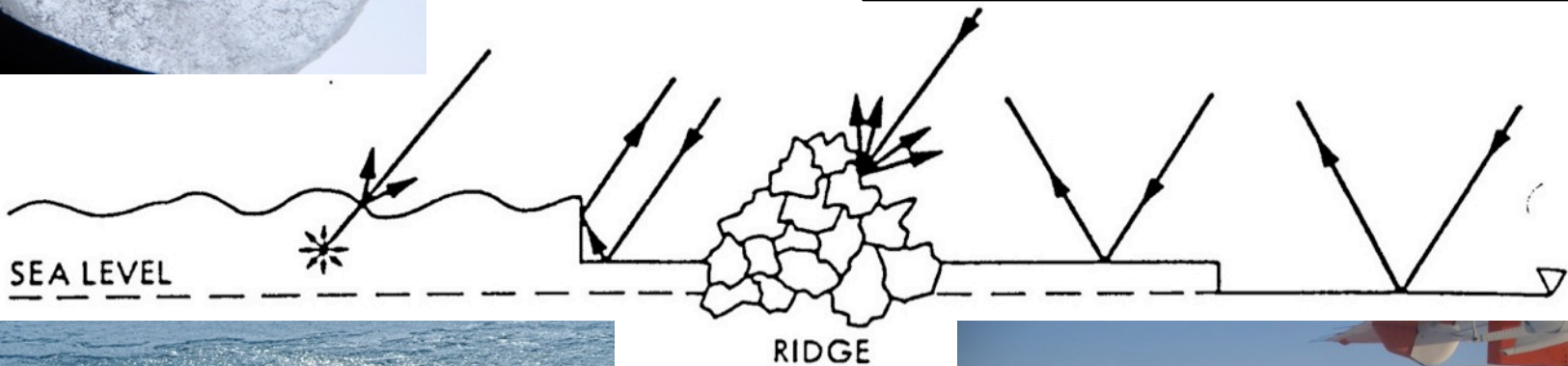
*...WMO scheme suitable for radar classification?*

# Microwave Interaction With Small-Scale Features



## Sources of backscattering:

- surface roughness (ripples, scratches, cracks...)
- volume inhomogeneities (air bubbles, brine cells)



# What Influences the Radar Signal?

## *Sea Ice Parameters:*

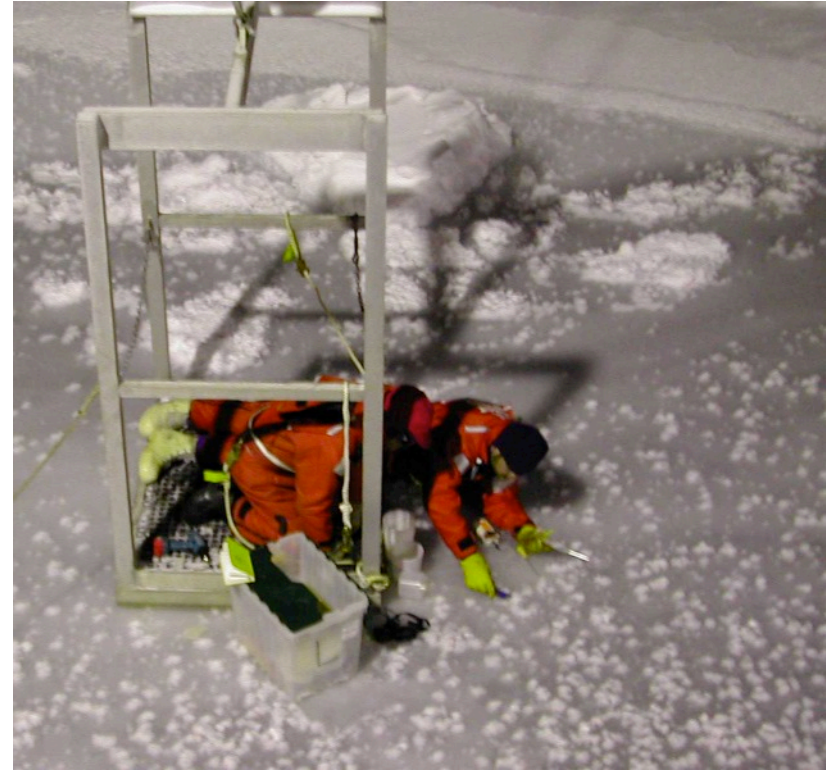
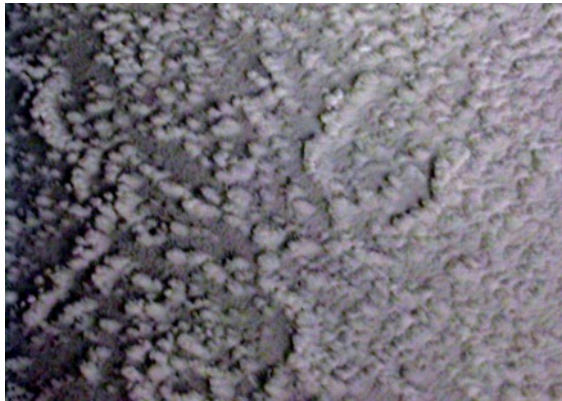
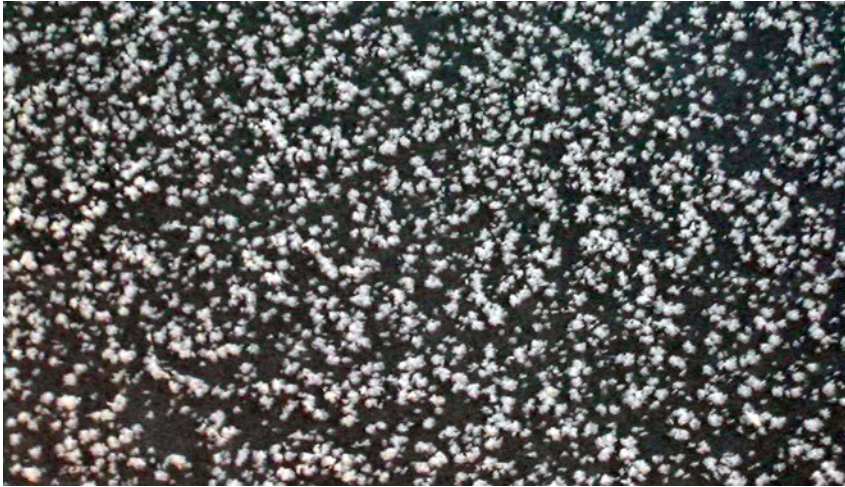
- small-scale surface roughness (mm-dm)
- volume structure (layers, brine inclusions, air bubbles)
- salinity, temperature (dielectric constant, penetration depth)
- snow cover (density, grain size, moisture)
- ice conditions: deformation (brash, ridges), leads, frost flowers

## *Radar Parameters:*

- frequency, polarization, incidence angle
- spatial resolution

*determine  
the  
appearance  
of sea ice  
in the  
radar  
image*

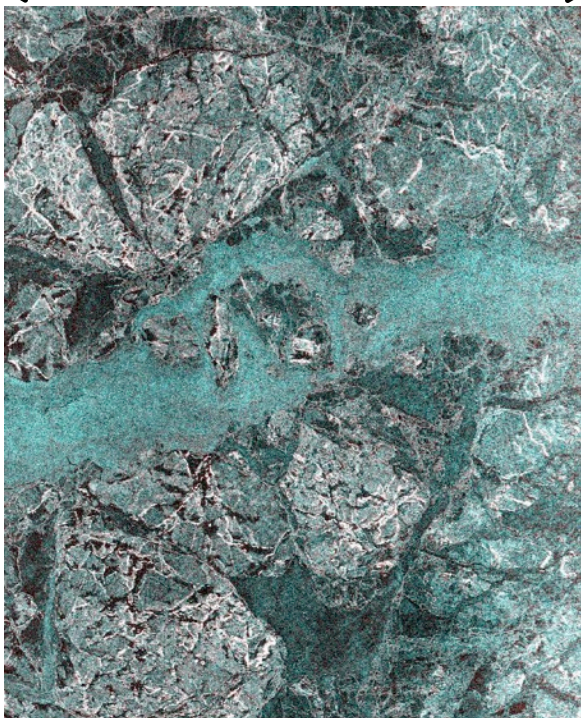
# Frost Flowers



*...hiding the ice beneath*

# Frost Flowers on Lead Ice

3 km

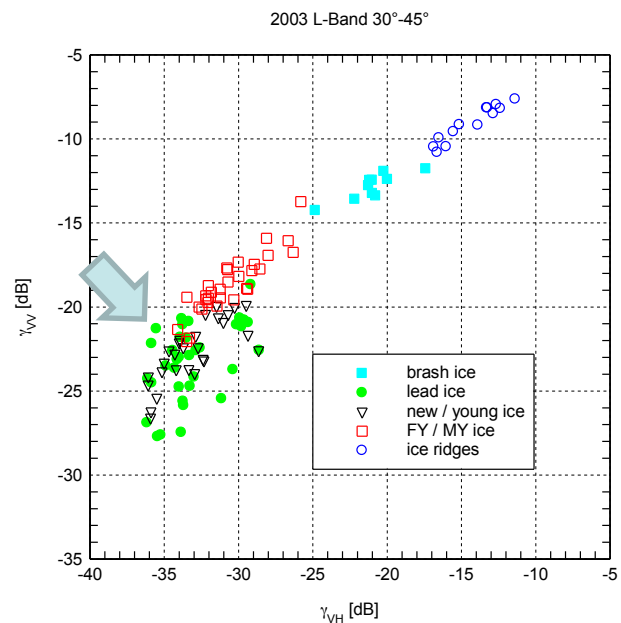
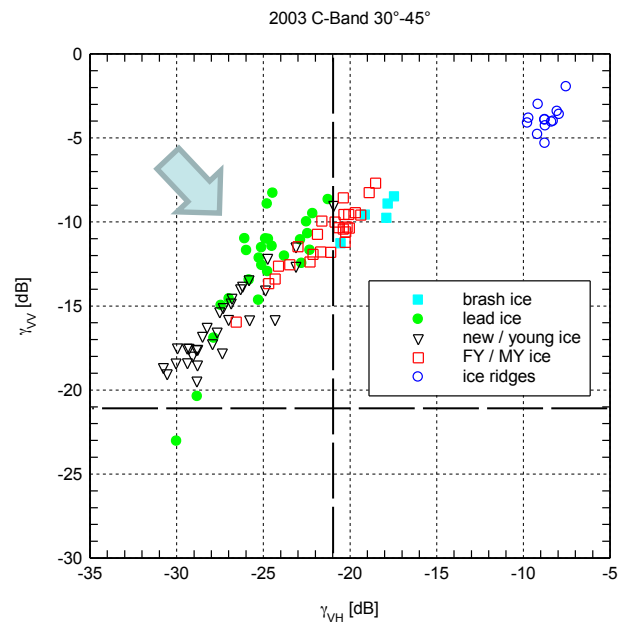


C-Band

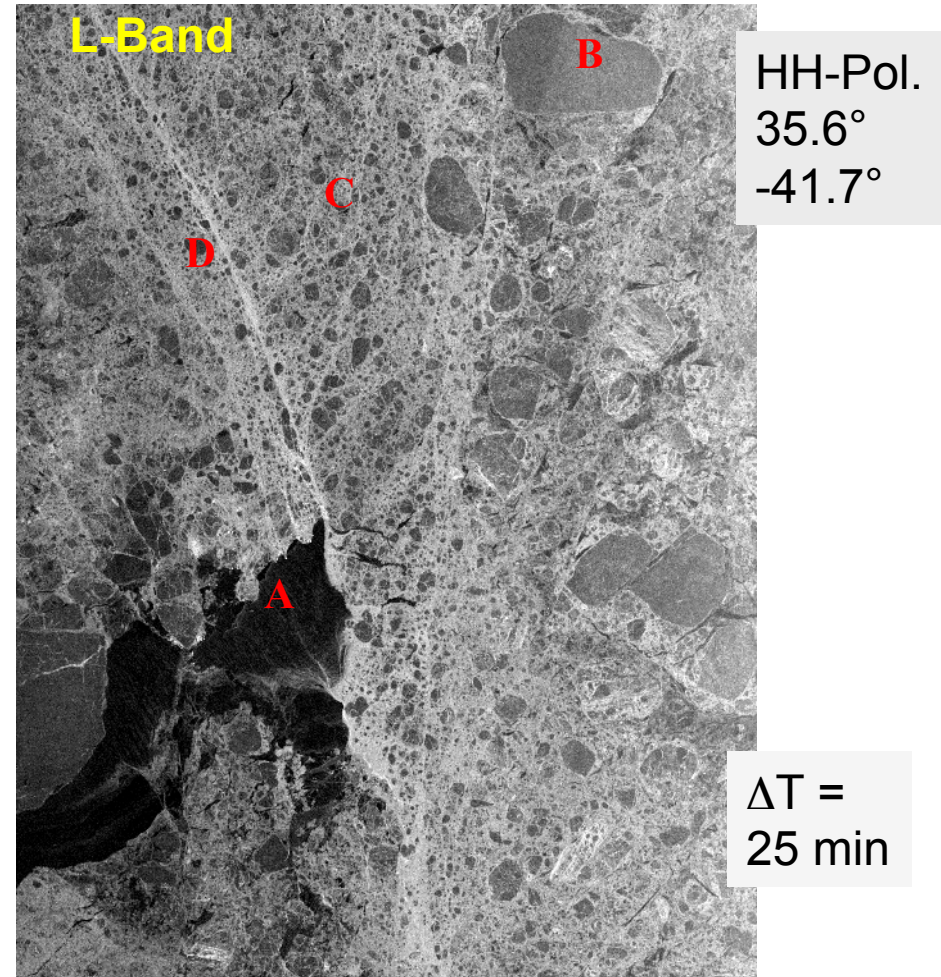
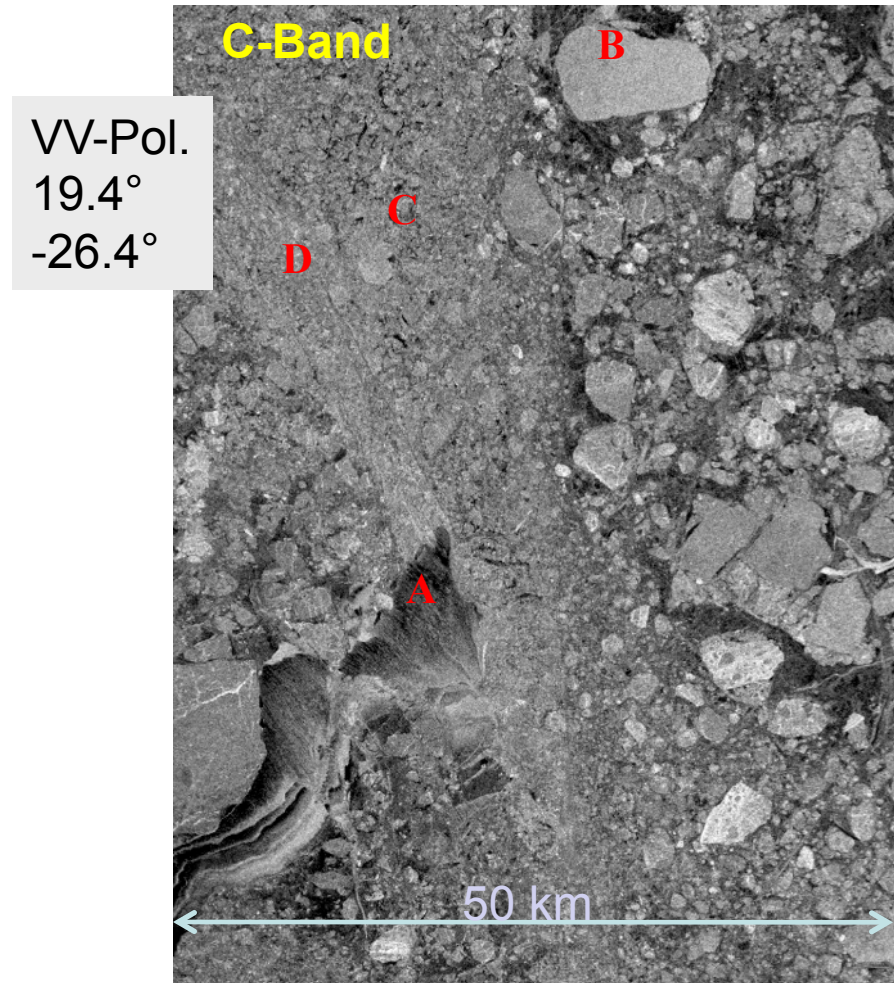
Resolution 2m



L-Band



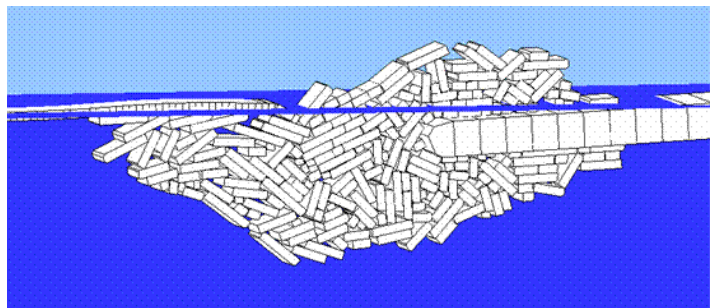
# Testing the Potential of Other Frequencies



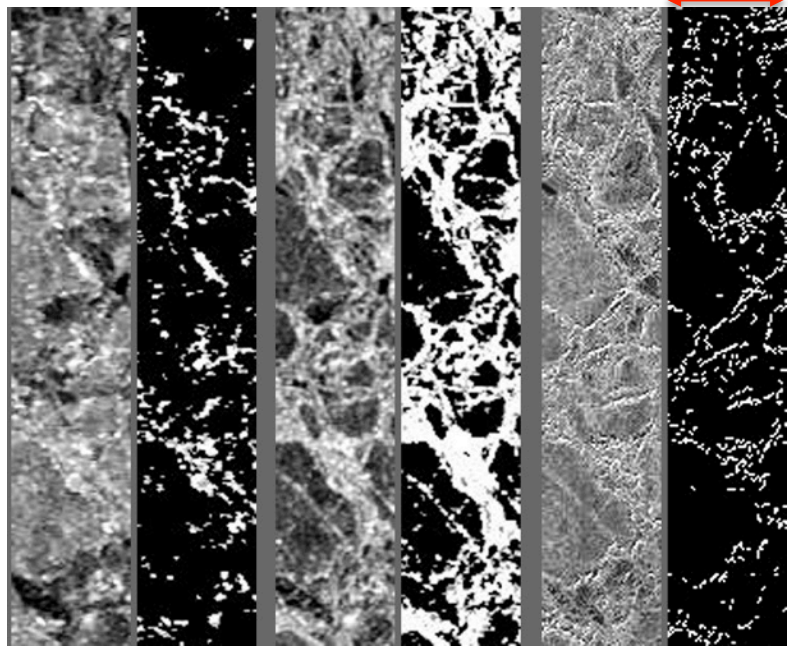
*ERS-1 and JERS-1 Sea Ice Images  
Coast of East Greenland*



# L-Band for Detection of Ice Deformation



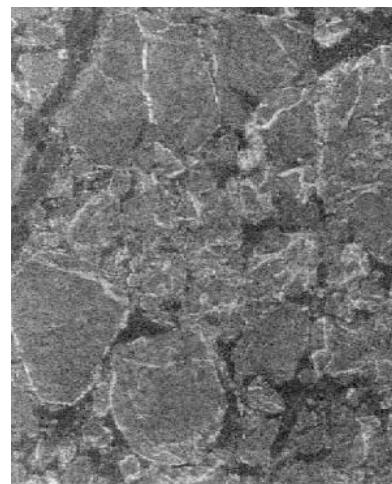
280 m



C-Band

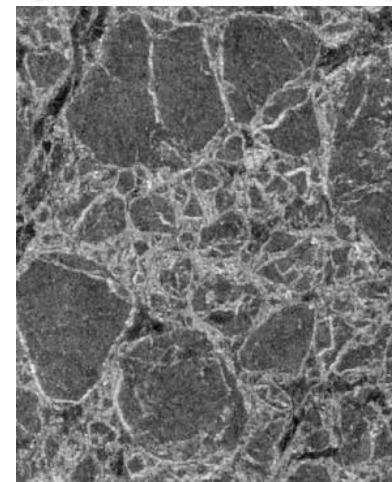
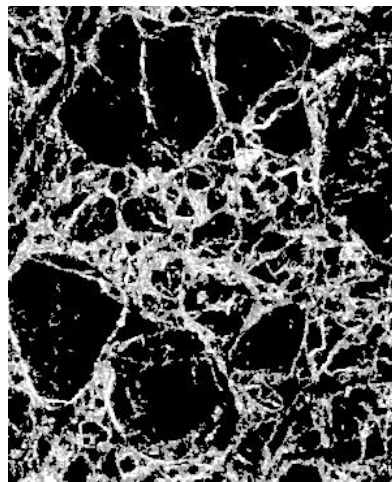
L-Band

Visible



C-Band, VV-Polarization

1.5 km



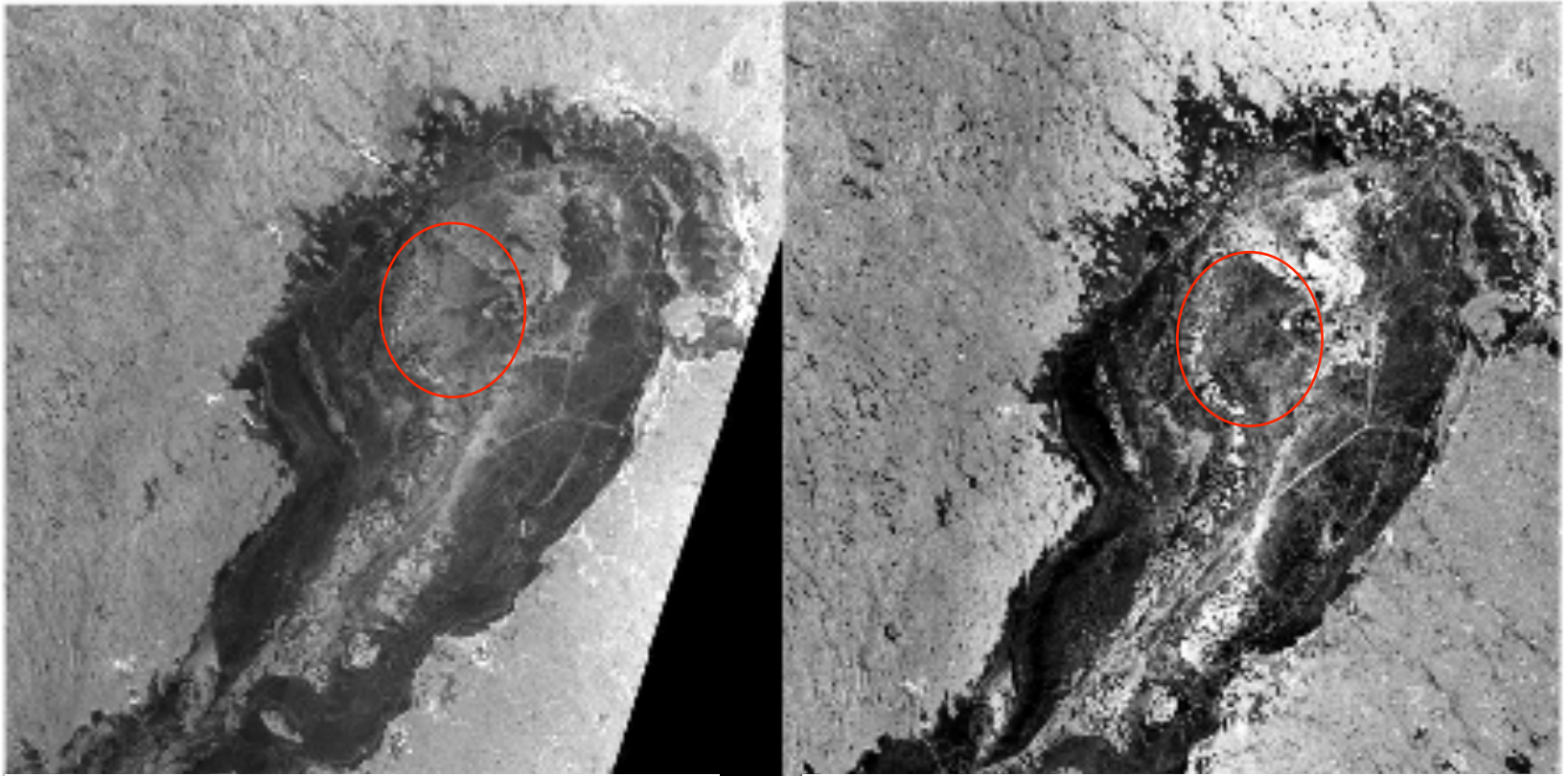
L-Band, VV-Polarization

*...works only at high spatial resolution!*

# Sea Ice Deformation And Roughness



# Different Ice Deformation And Roughness Types



**C-Band (Envisat ASAR WSM)**

**L-Band (ALOS PALSAR ScanSAR)**

*...may cause classification ambiguities*

# Coarser Spatial Resolution: Ice Drift From Image Sequence

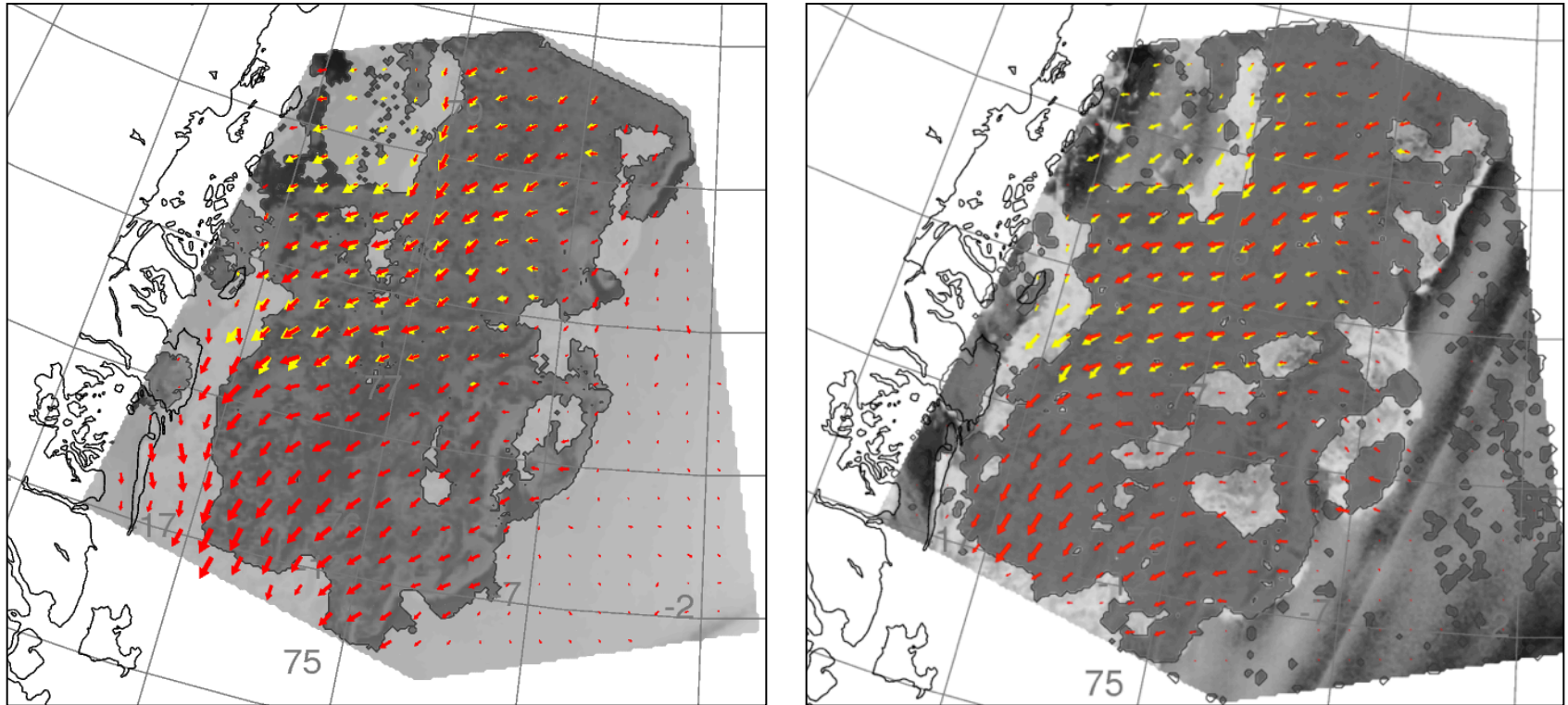
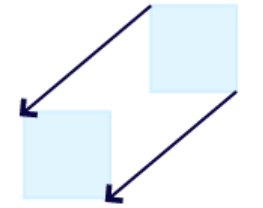
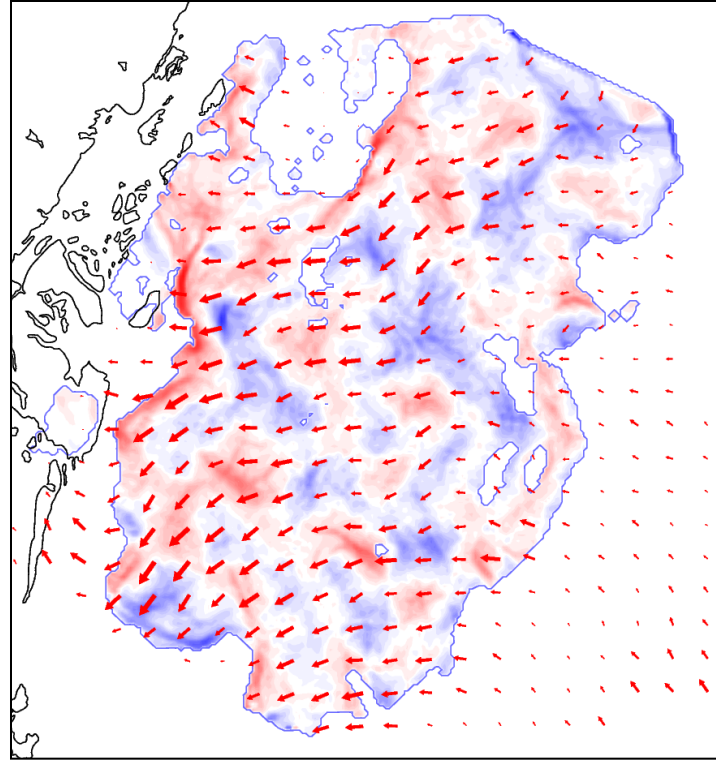
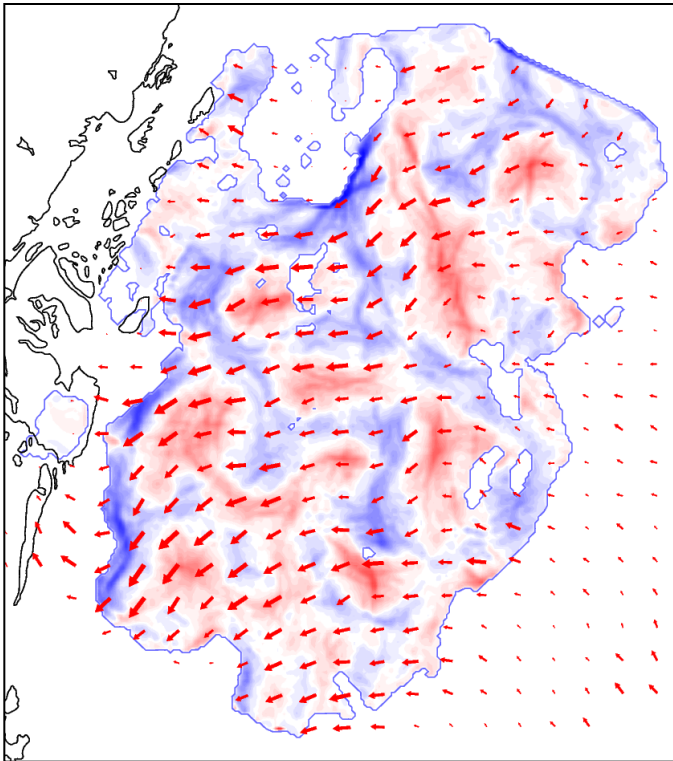


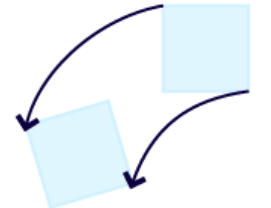
Image pair 16.09.2012. (a) HH-polarization, (b) HV-polarization  
Vectors – red: automatically derived; yellow: reference

*Ice services use image sequences for mapping!*

# Ice Drift -> Ice Deformation



vorticity=0



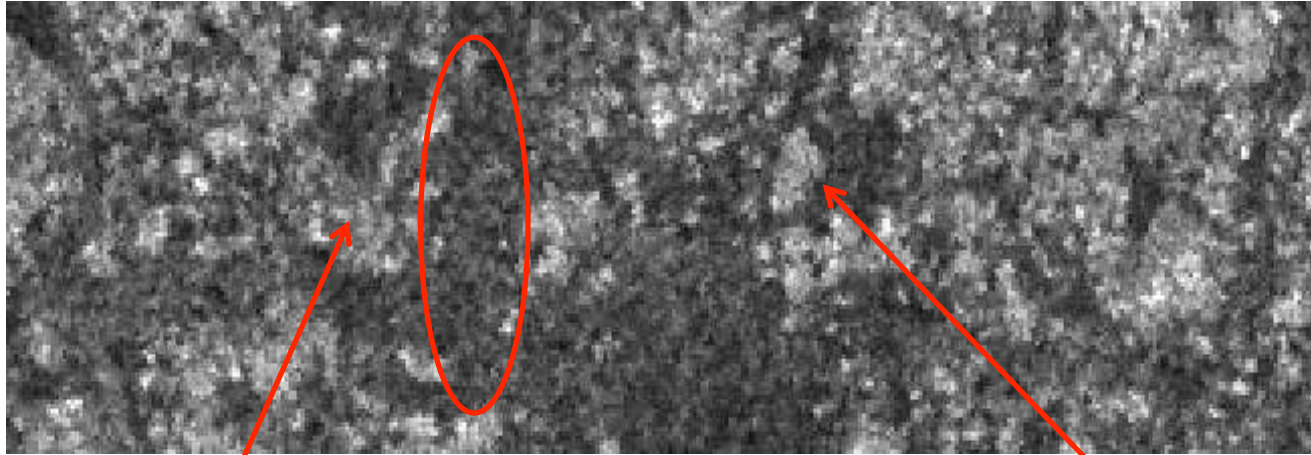
vorticity≠0

Image pair 16.09.2012. (left) divergence, (right) vorticity

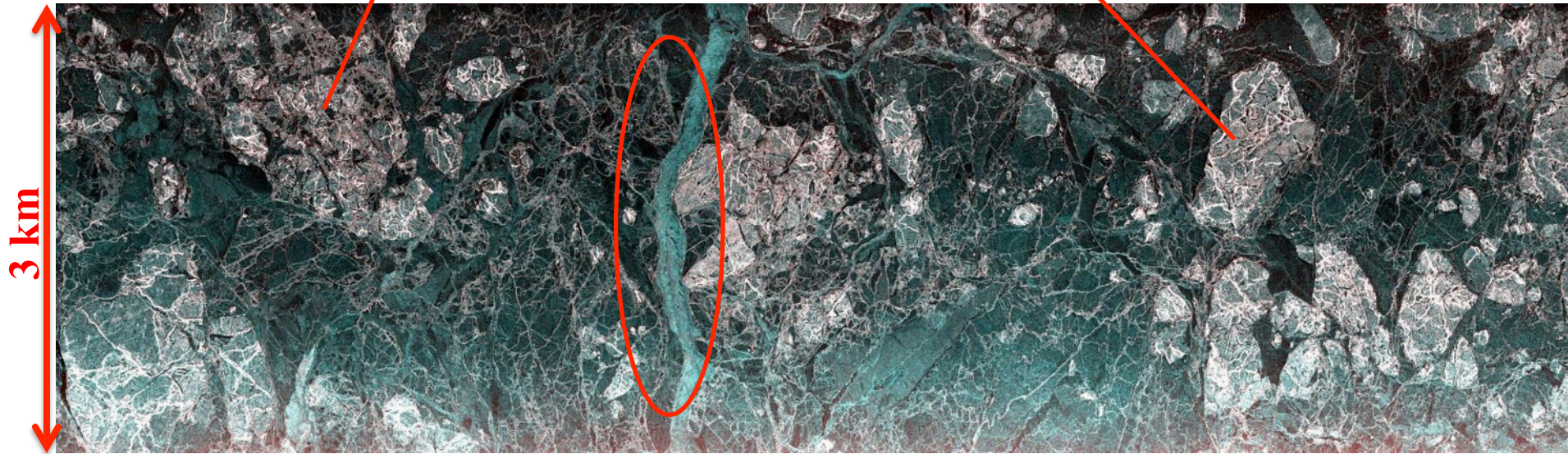
*Deformation zones formed earlier than start of drift analysis are not detected!*

# Effect of Spatial Resolution

ICESAR  
2007  
Fram  
Strait



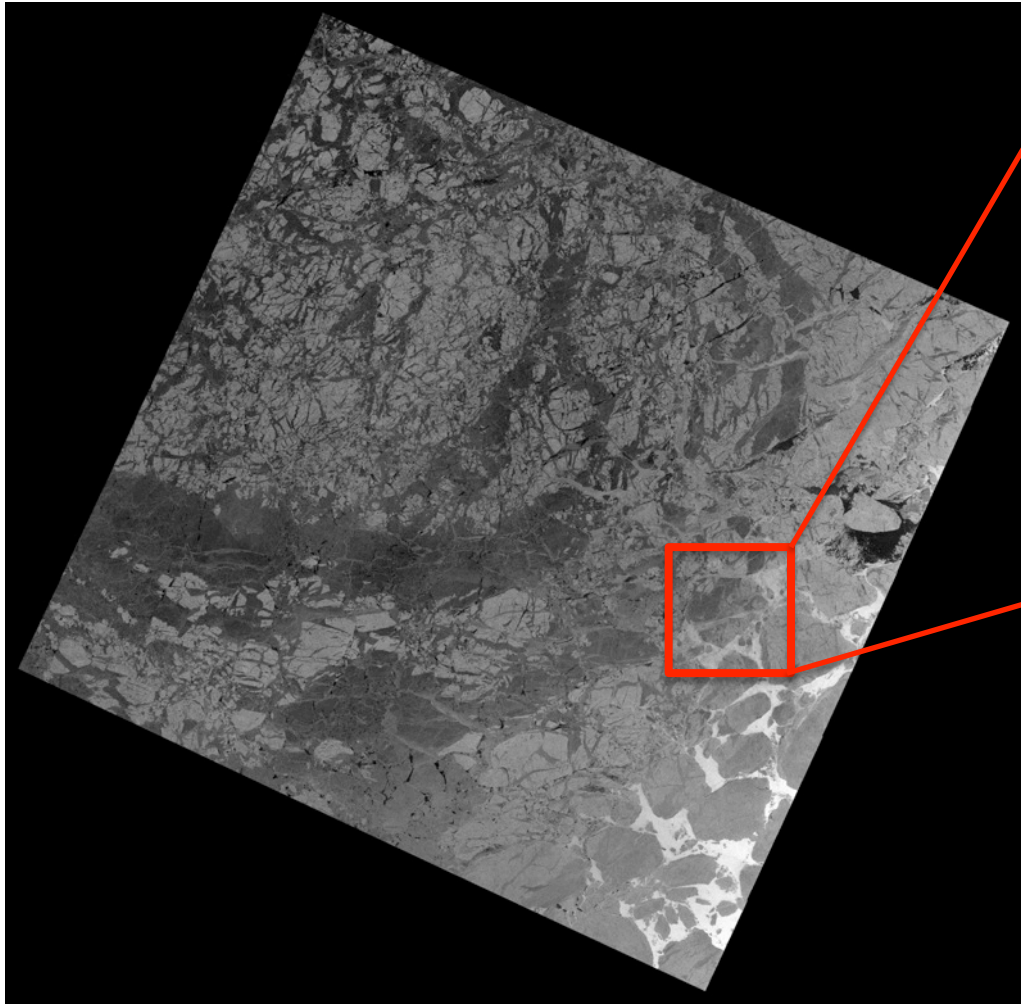
ASAR WSM  
19/03/2007  
11:22UTC  
HH-Pol., 26°



ESAR (R-VH, G-VV, B-VV, 12:26UTC)

*...important details may be lost*

# Combine Different Spatial Resolutions



ASAR WSM, 02/06/2008, 20:27:40UTC, HH-Pol.



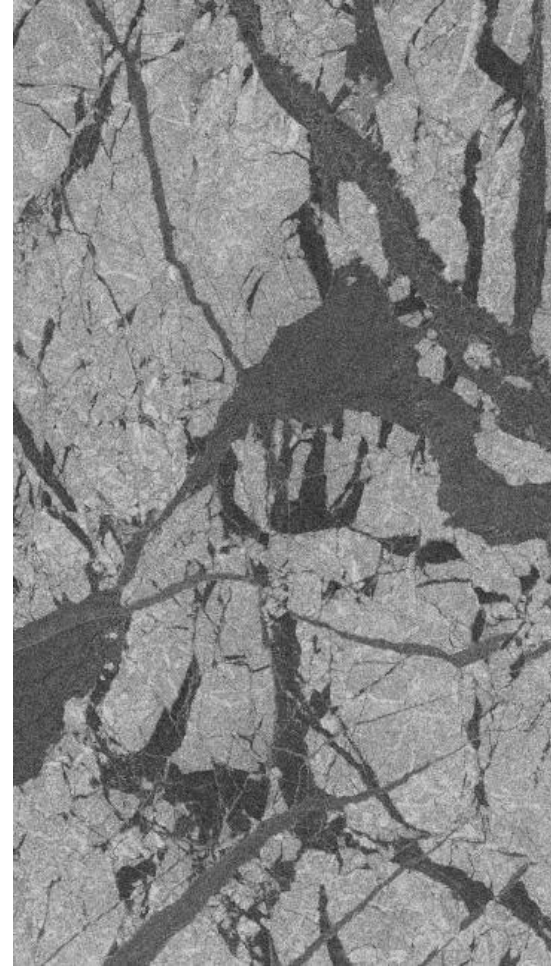
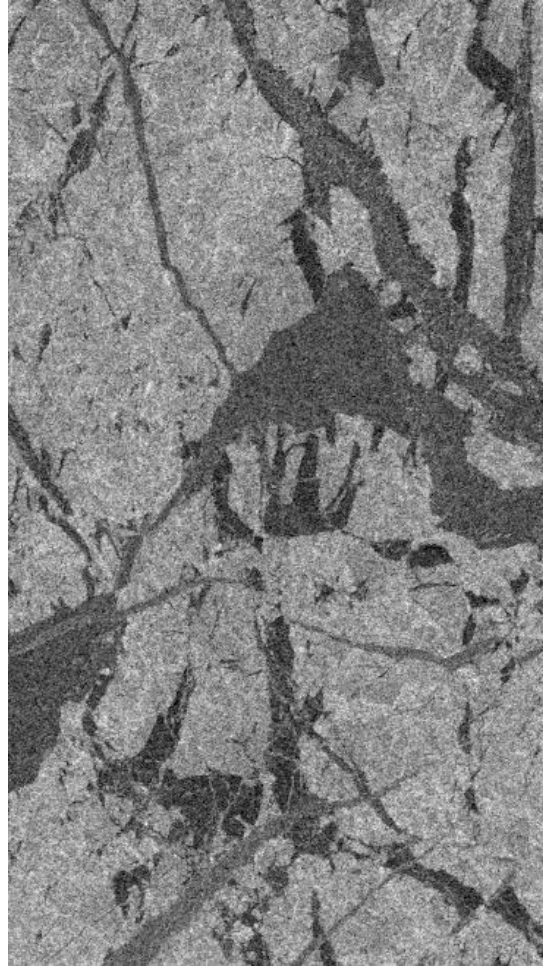
TSX SM  
02/06/2008  
16:06:09UTC  
HH-Pol.

*Possible only for key areas.  
Problem: ice dynamics.*

# Equivalence of C- and X-Band

← 9 km →

RS-2 QUAD  
0306\_154243,  
VV-Pol., 20m,  
40.1-40.7°,  
ENL  $\approx$  20



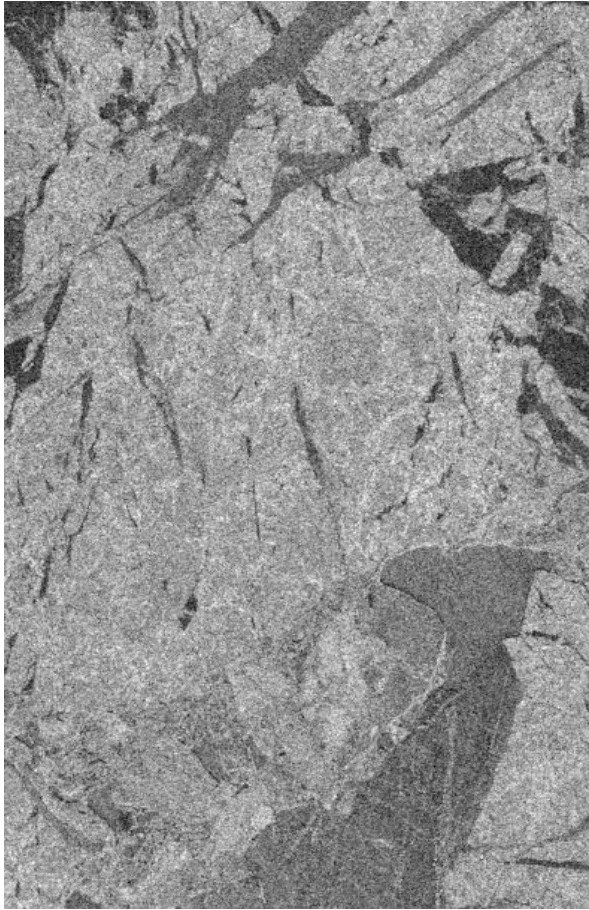
TSX SM  
0306\_154858,  
VV-Pol., 20m,  
41.1-42.1°,  
ENL  $>$  50

*...may be useful for “downscaling”*

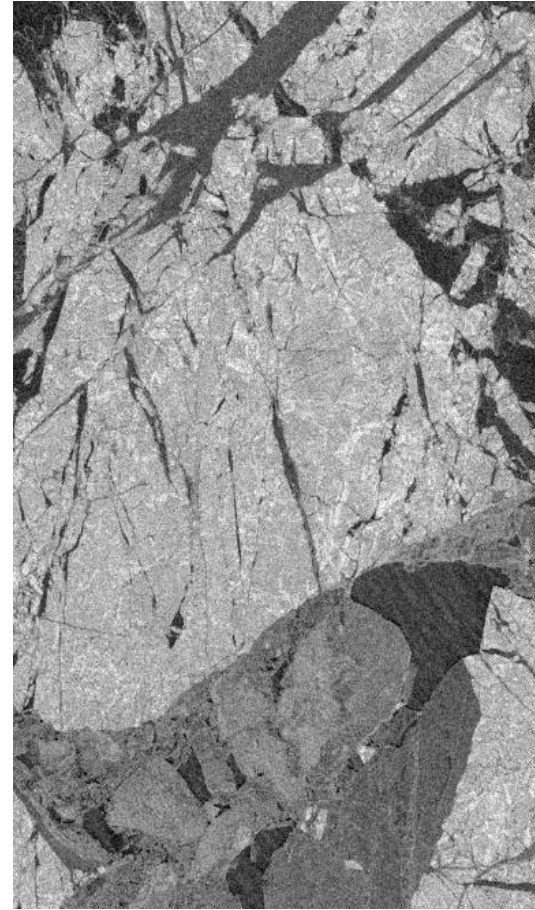


# *Equivalence C- and X-Band?*

RS-2 QUAD  
0306\_154243,  
VV-Pol., 20m,  
40.1-40.7°,  
ENL  $\approx$  20



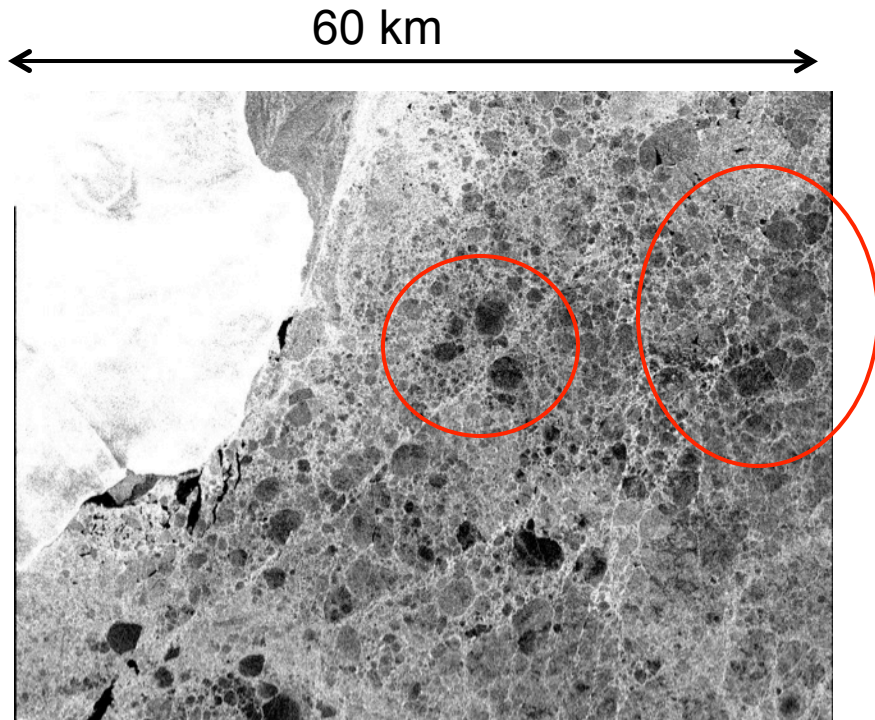
9 km



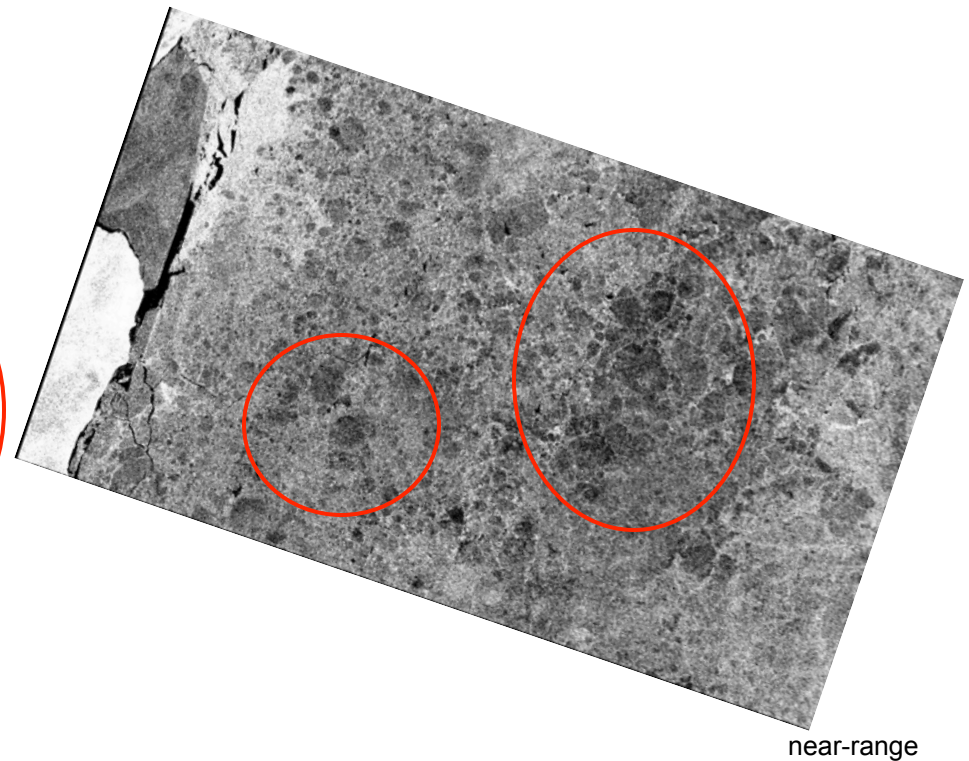
TSX SM  
0306\_154858,  
VV-Pol., 20m,  
41.1-42.1°,  
ENL  $>$  50

*...not always 1:1 correspondence (especially thin ice)*

# Effect of Incidence Angle



ASAR HH-polarization  
20. March 2007, 9:11 UTC  
Incidence angle 42 – 45°



ASAR HH-polarization  
21. March 2007, 10:20 UTC  
Incidence angle 19 – 22°

*...hampers (automatic) segmentation/classification*

# Challenges (1)

## *Automatic segmentation and classification:*

- *Choice of optimal algorithm?*
- *Prior adjustment of acceptable percentage of wrong classification?*
- *How to assess reliability?*
- *Influence of small-scale ice properties?*
- *WMO versus “radar” classification?*

## *Incidence angle correction prior to segmentation*

- *Prior “raw” separation of ice types?*
- *Consider small-scale roughness? (How?)*

## Challenges (2)

### *Identifying deformation areas using drift fields*

- *Link between ice kinematics and deformation features?*
- *Computational speed?*
- *Reliability check?*

### *Combination of different frequencies and spatial resolutions:*

- *Where useful?*
- *Suitable for production workflow?*



**Thank you for your attention !**