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

Wolfgang Dierking

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

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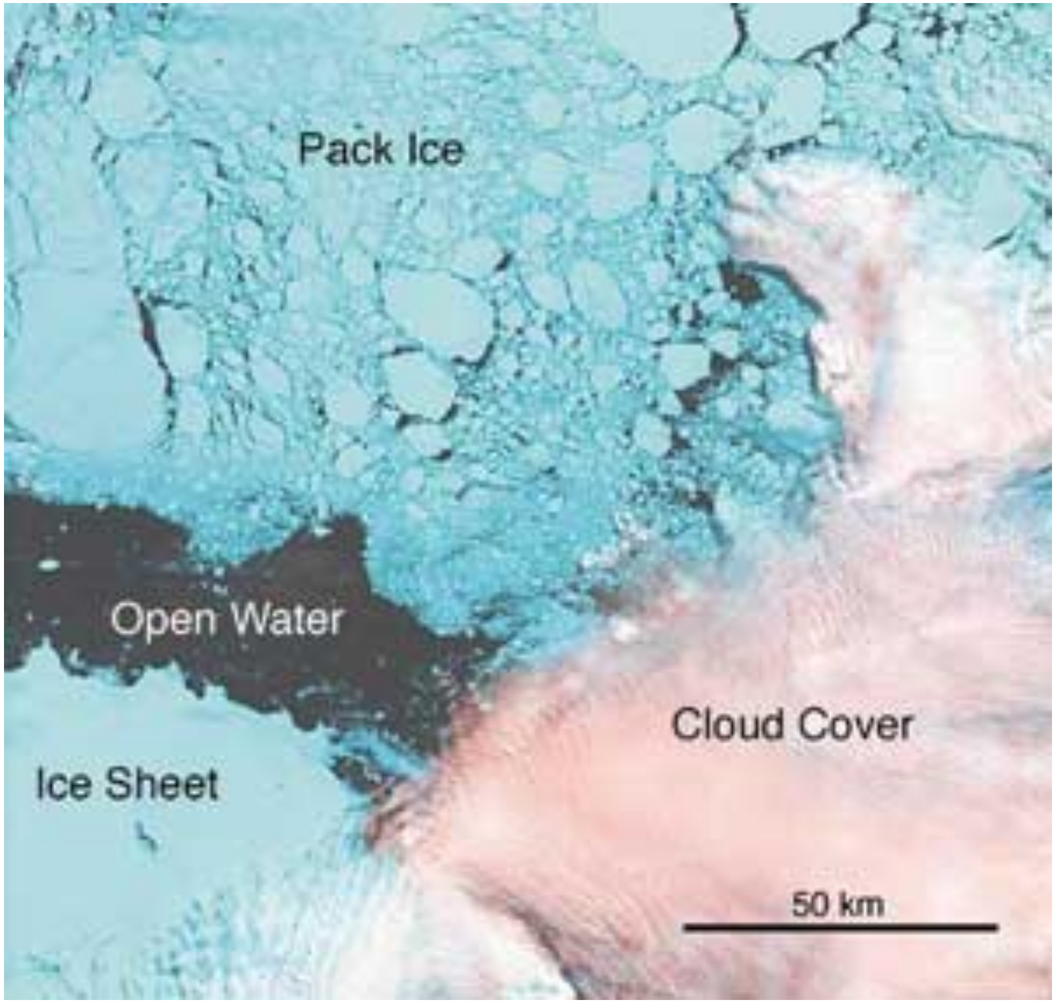
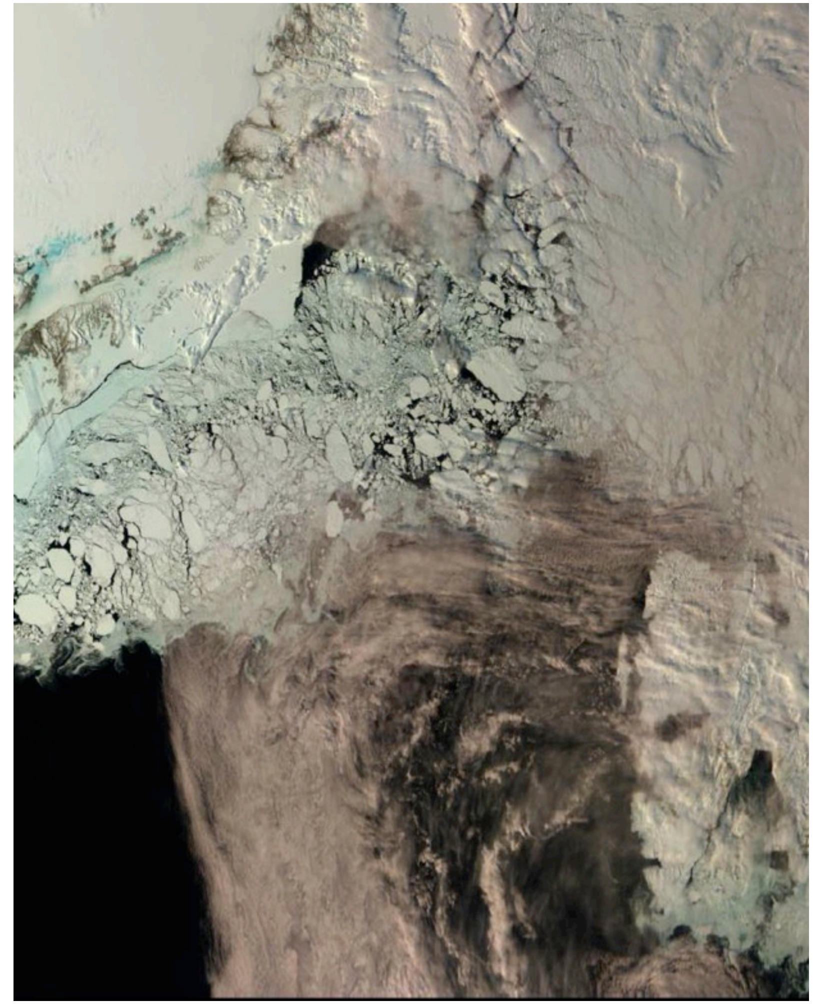
(1) Why is microwave remote sensing important (=useful) for sea ice mapping?

Problems When Using Optical and IR-Images





Clouds (and lack of daylight)

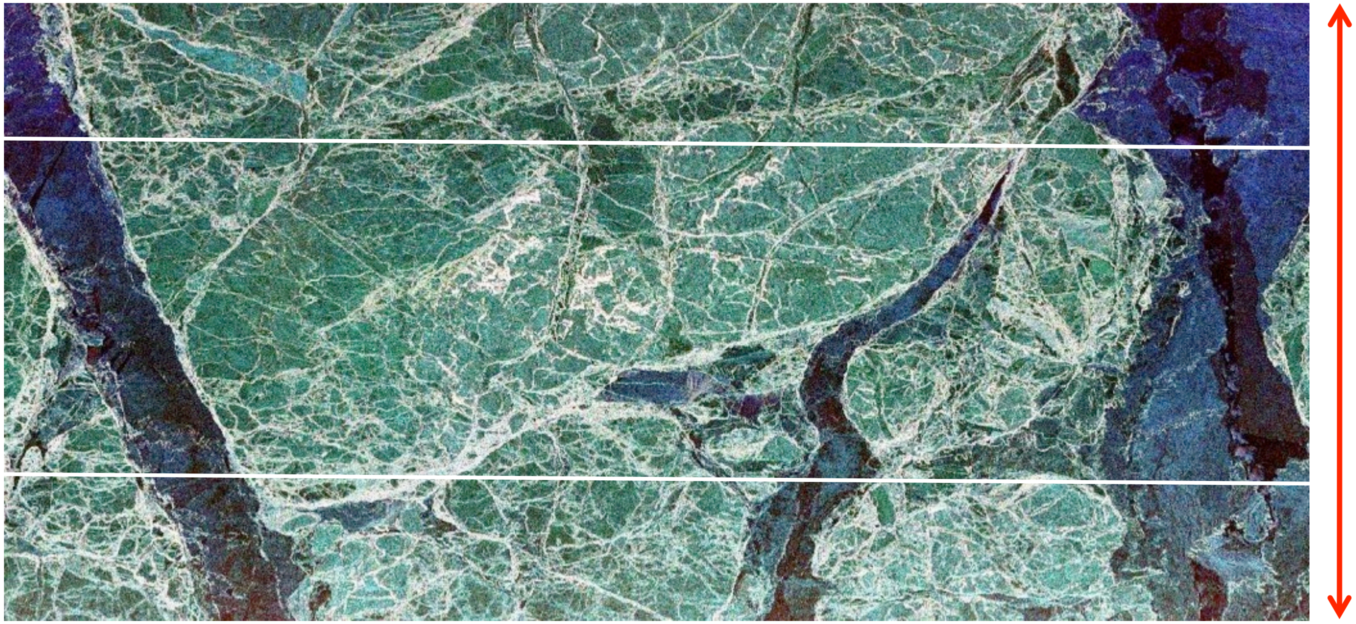
Problems When Using Optical and IR-Images

not with microwave (radar) data!

...clouds (and lack of daylight)

Radars (Microwaves) Look Through Dry Snow

AWI/Optimare
Airborne
Color Line-Scanner



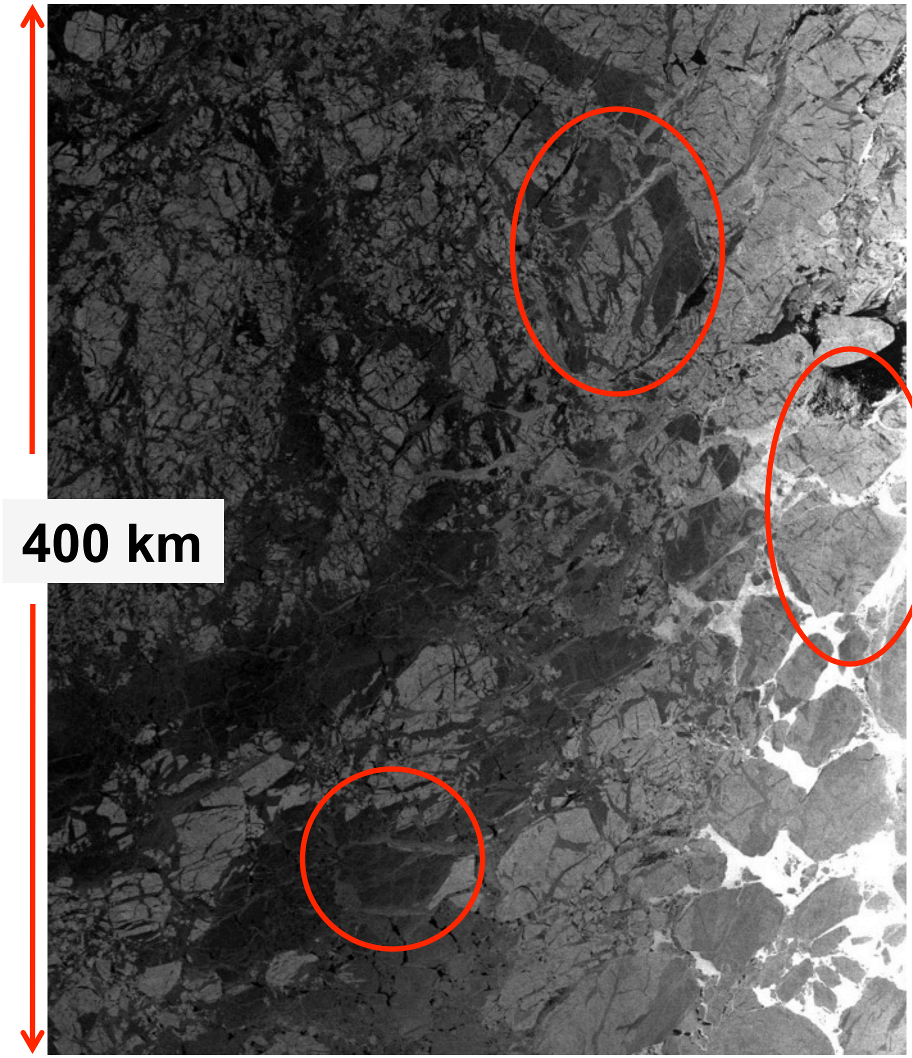
DLR ESAR:
L-Band
R: X-Pol.
G: H-Pol.
B: V-Pol.

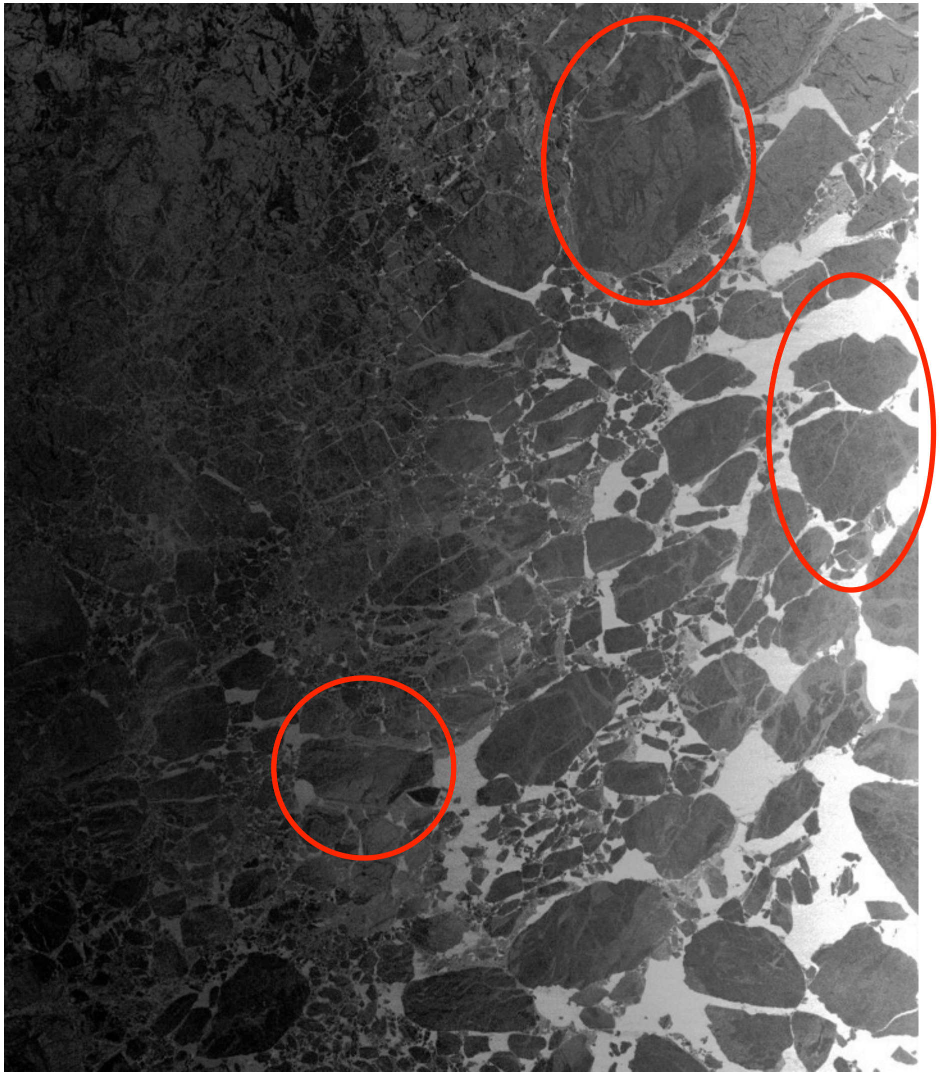
3 km

Radar (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

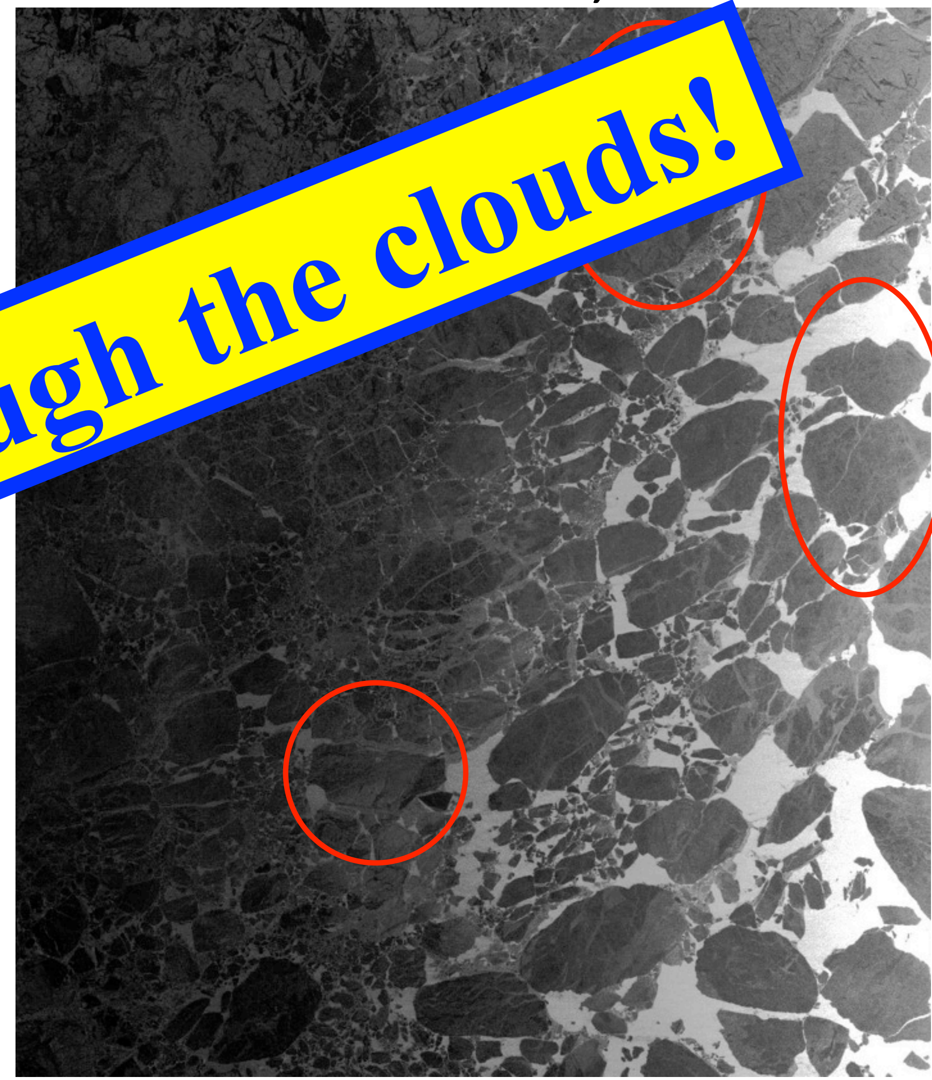




Radar Doesn‘t Look Through Wet Snow

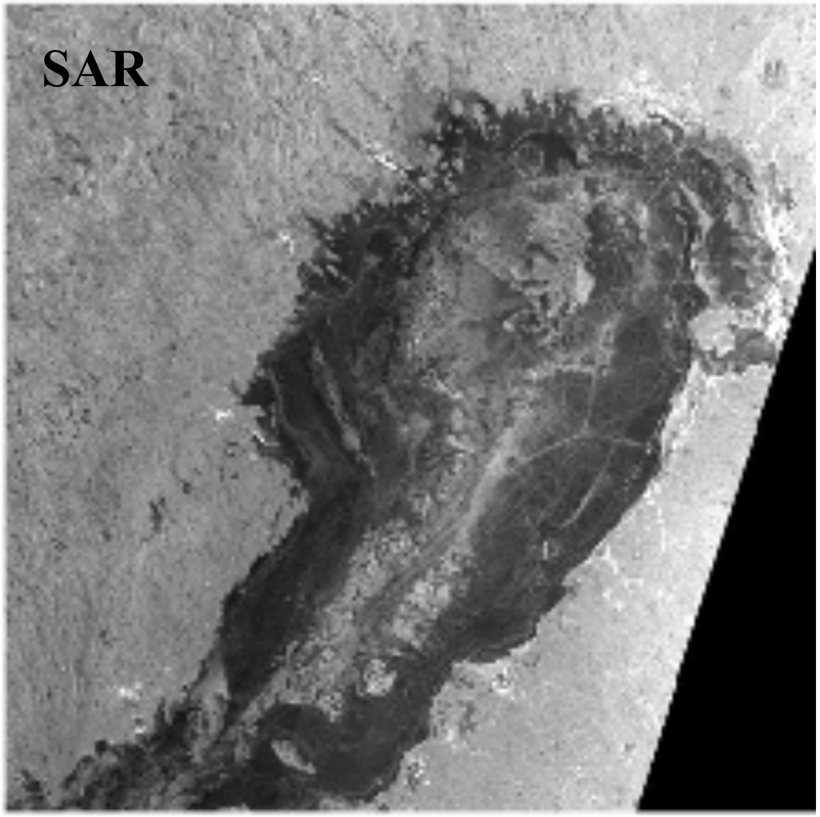
ASAR WSM HH-Pol., 02-06-2008

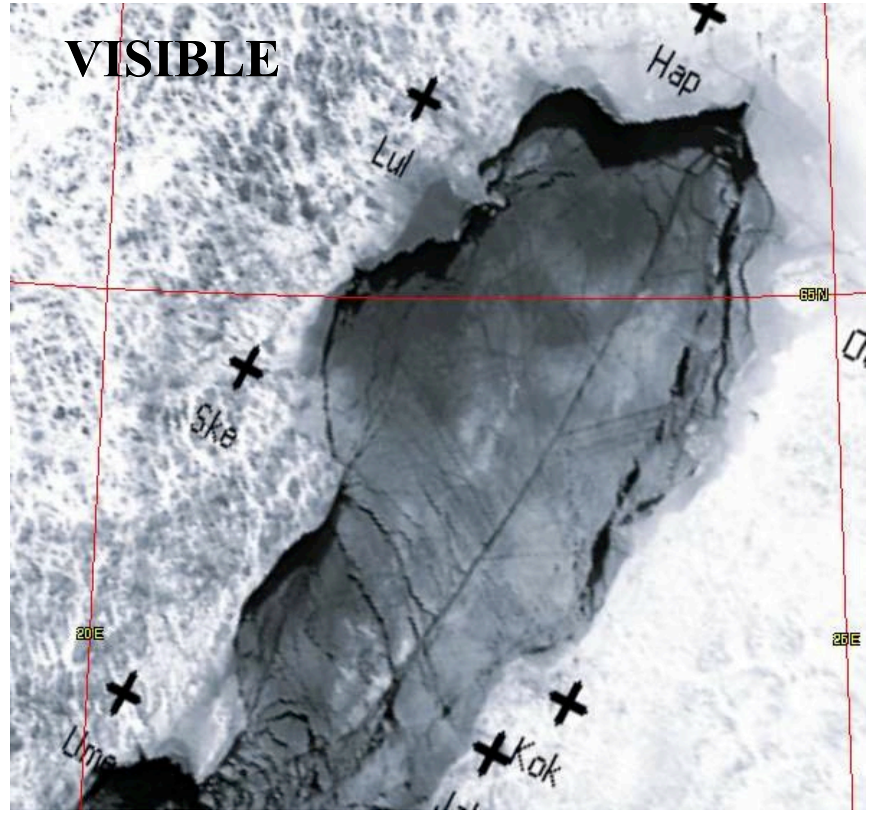
ASAR WSM HH-Pol., 0506-2008



(2) Ice chart production

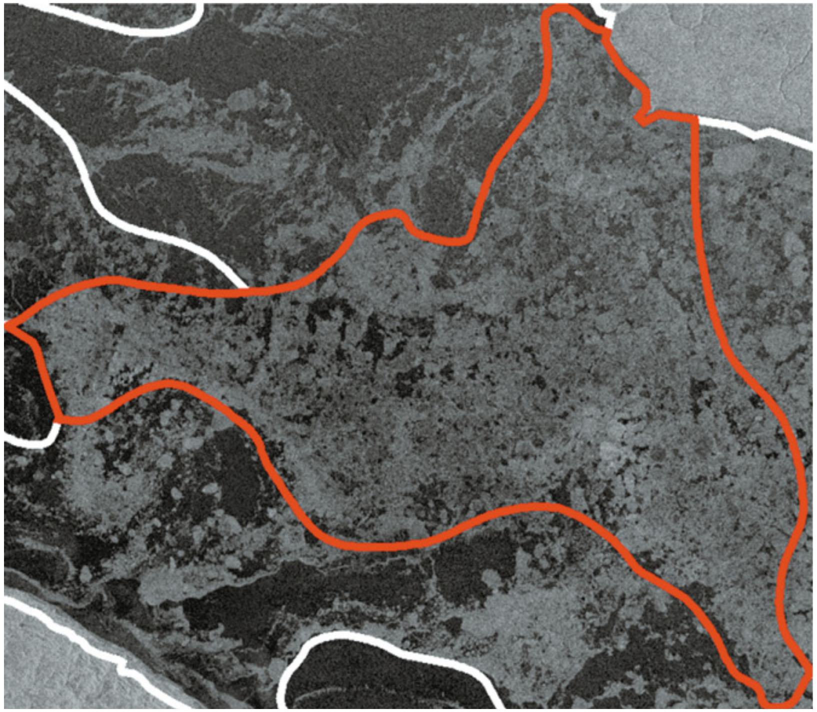
Operational Approach: Using Sequences of C-Band SAR Imagery



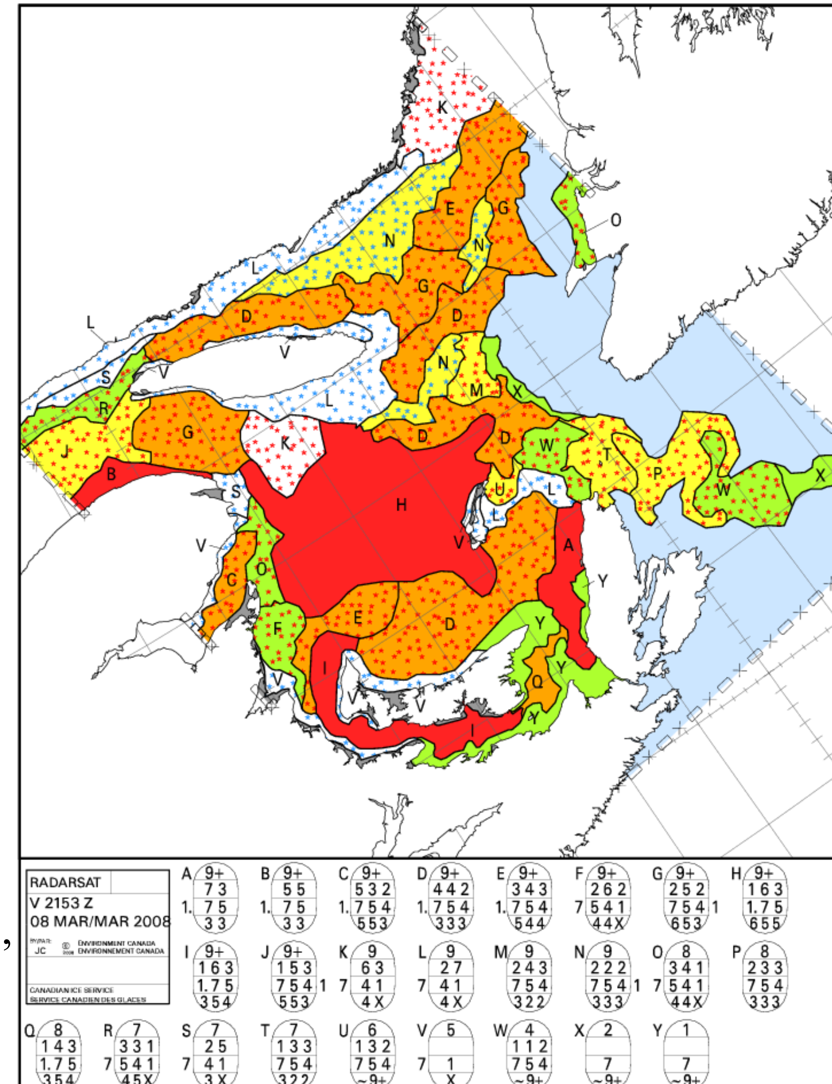


…complemented by optical/IR images, aircraft reconnaissance, ship reports, weather data etc.

Outline of Visually Homogeneous Ice Conditions



Clausi et al., CJRS, 2010

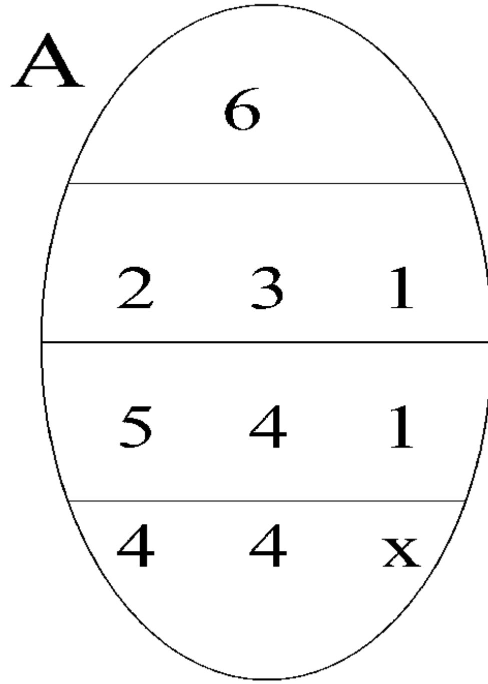


L. Weir, CIS, WMO June 2009

Ice characteristics described by "egg-code"

Egg-Code

region label



total ice concentration

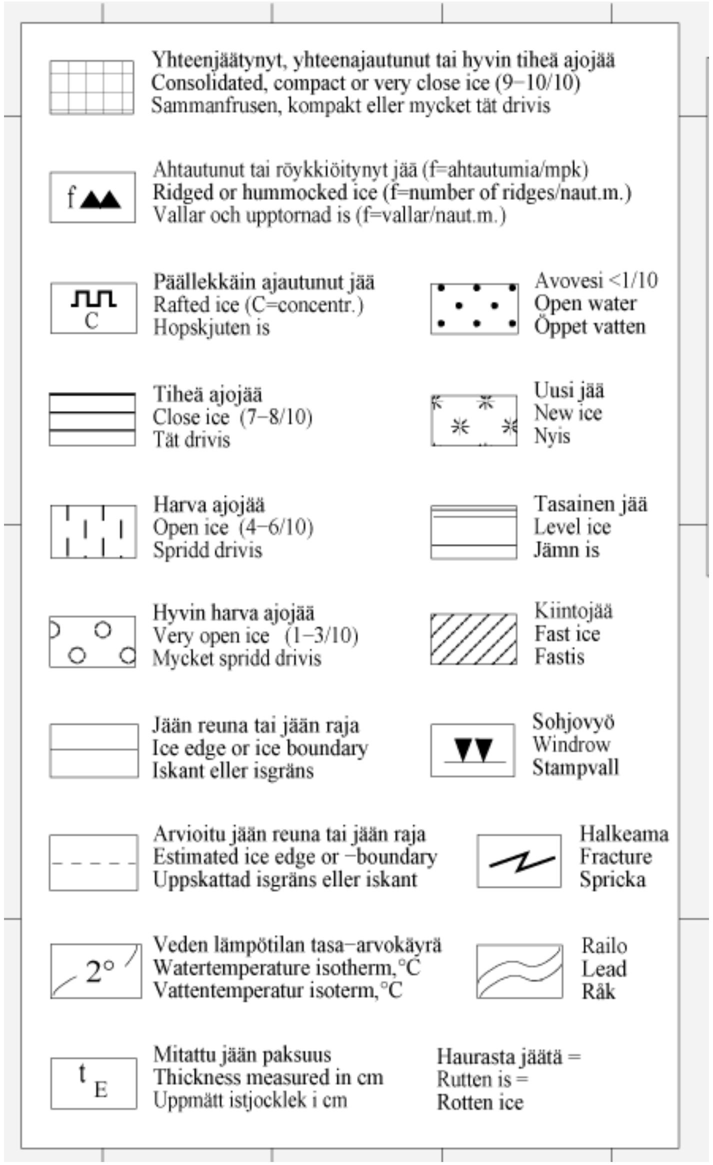
concentration
of ice types

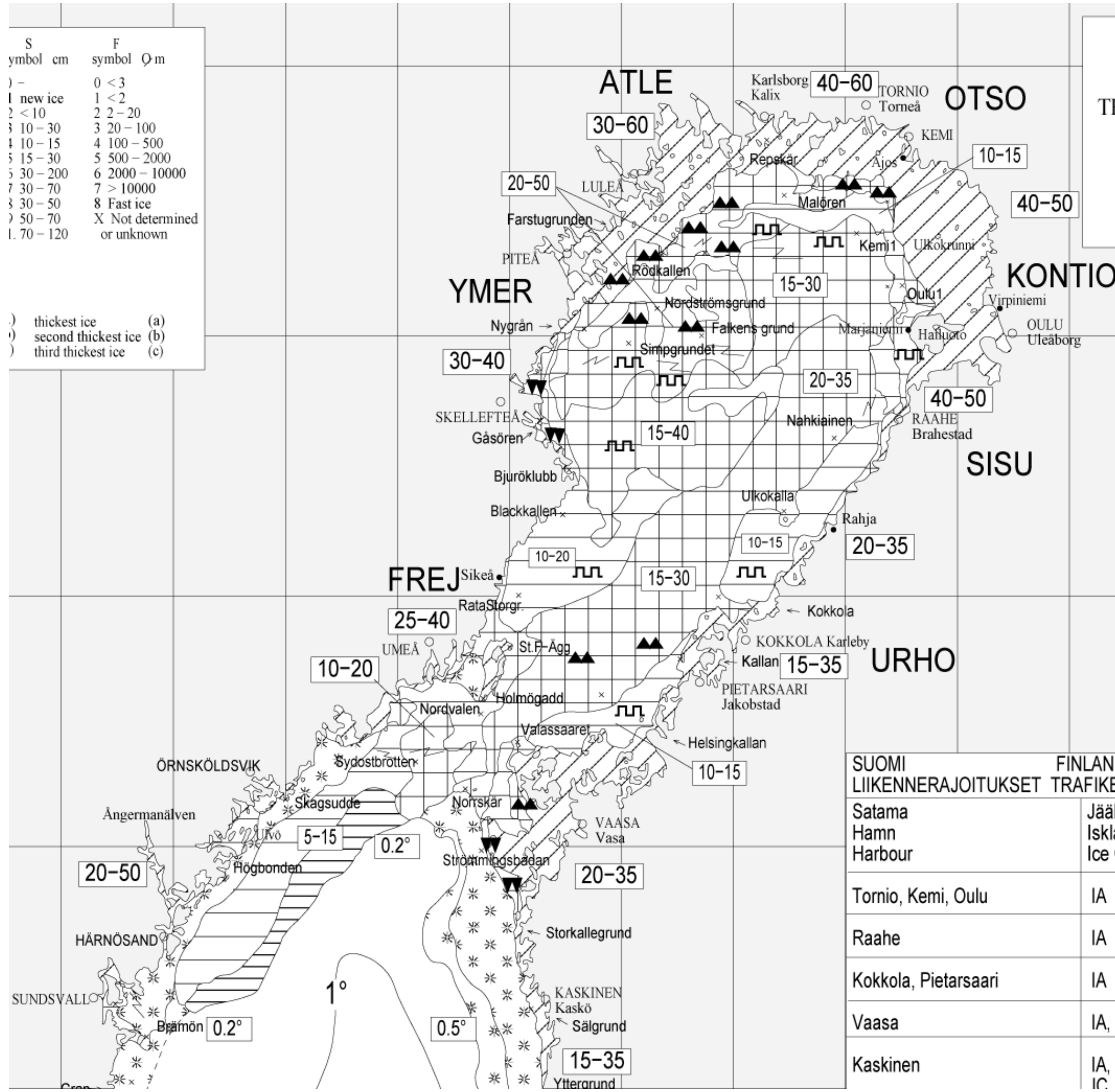
ice type code

floe size

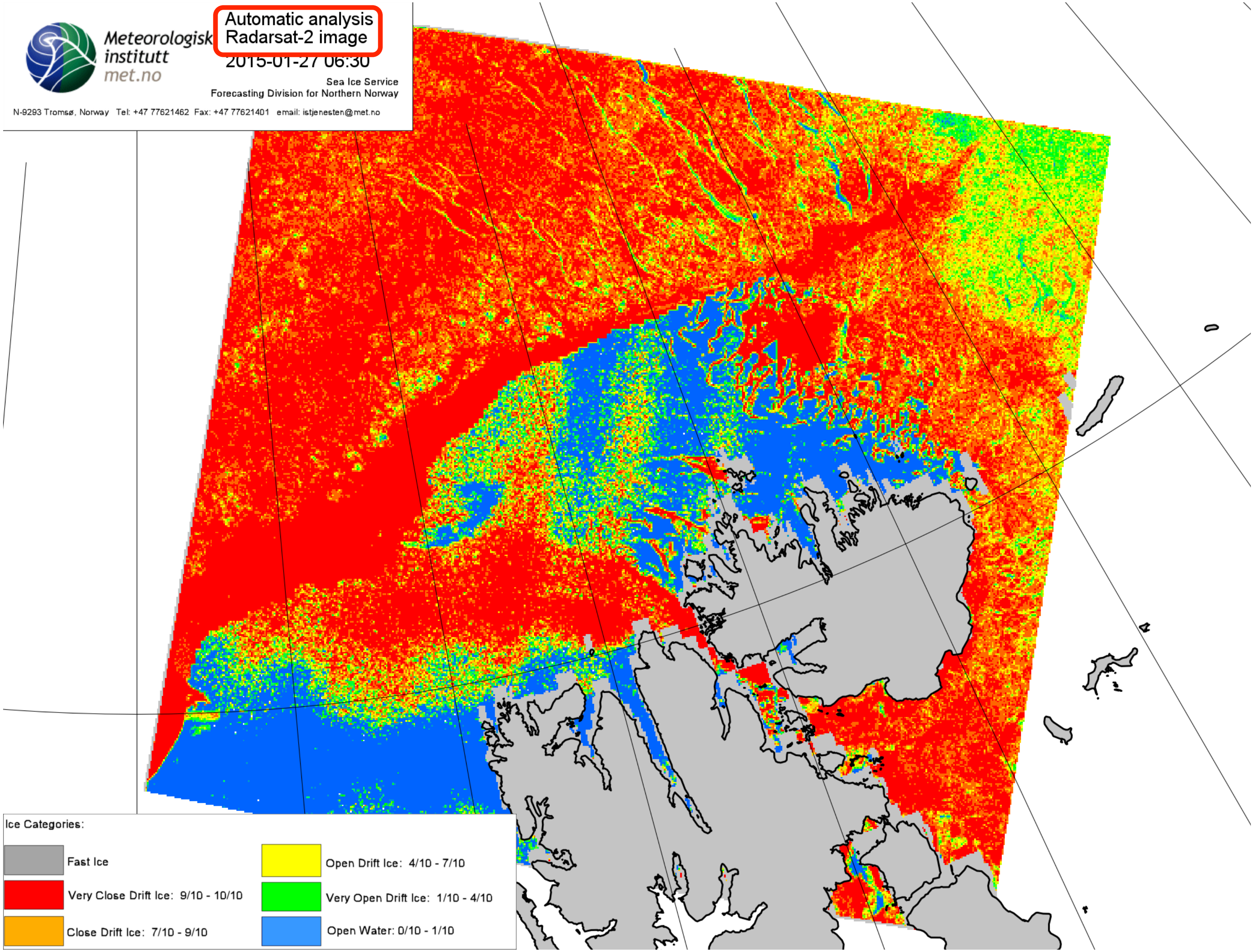
ice type
thick -> thin

Sea Ice Chart Baltic Sea (FIMR, now FMI)

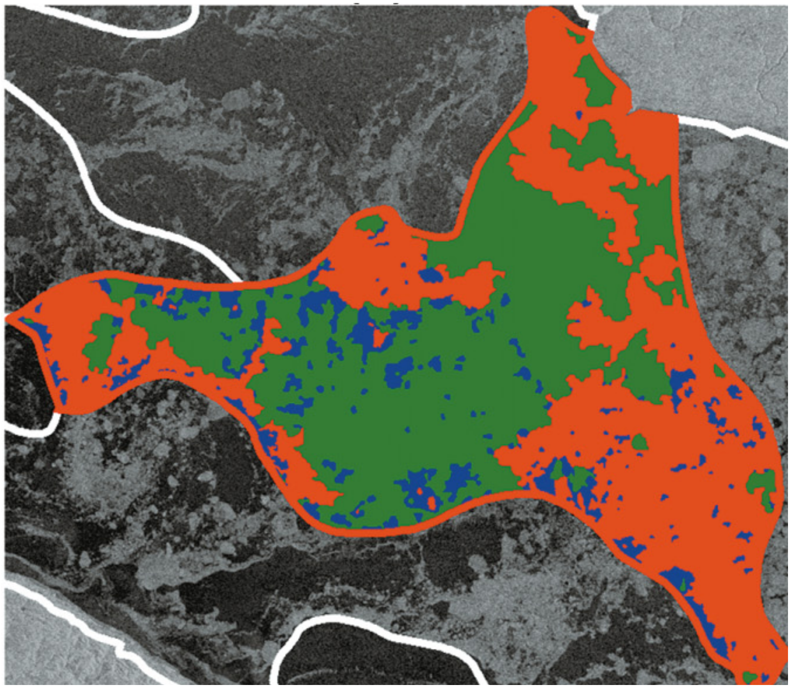


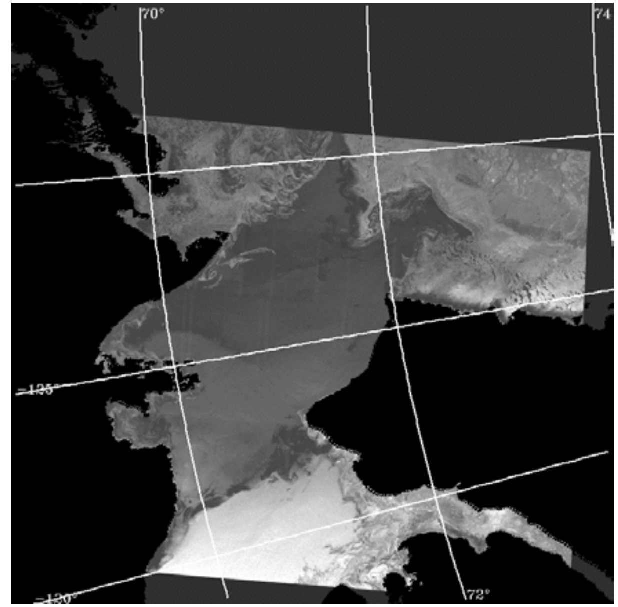


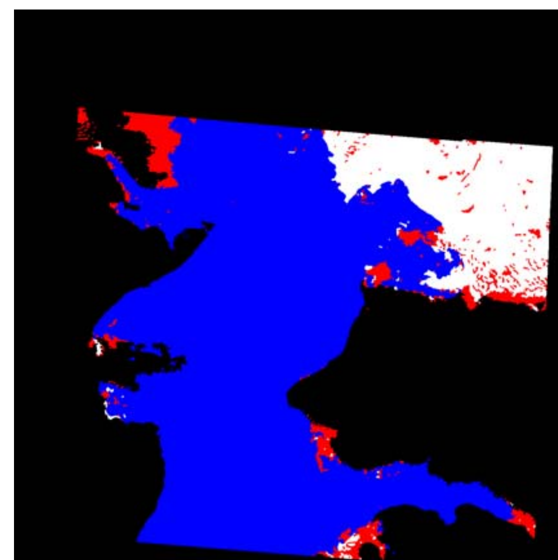
Sea Ice Chart Svalbard (Met. No.)



Automated Segmentation And Classification







“MAGIC”

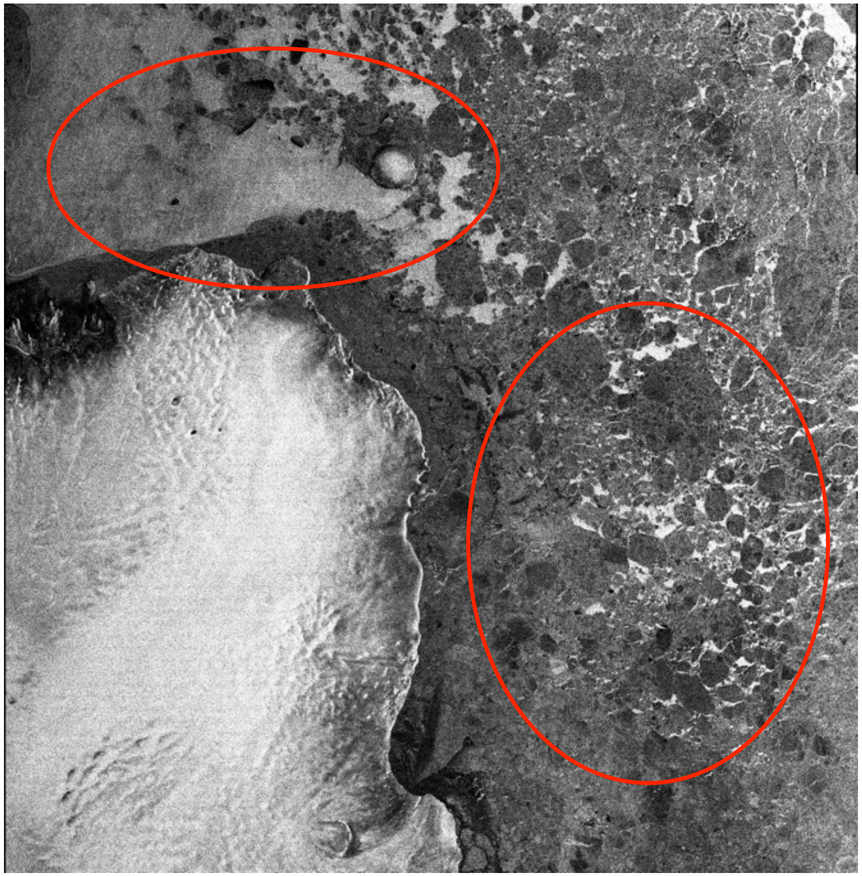
Clausi et al., CJRS, 2010

“ARKTOS”

Gineris et al., CSE Conf, 2000

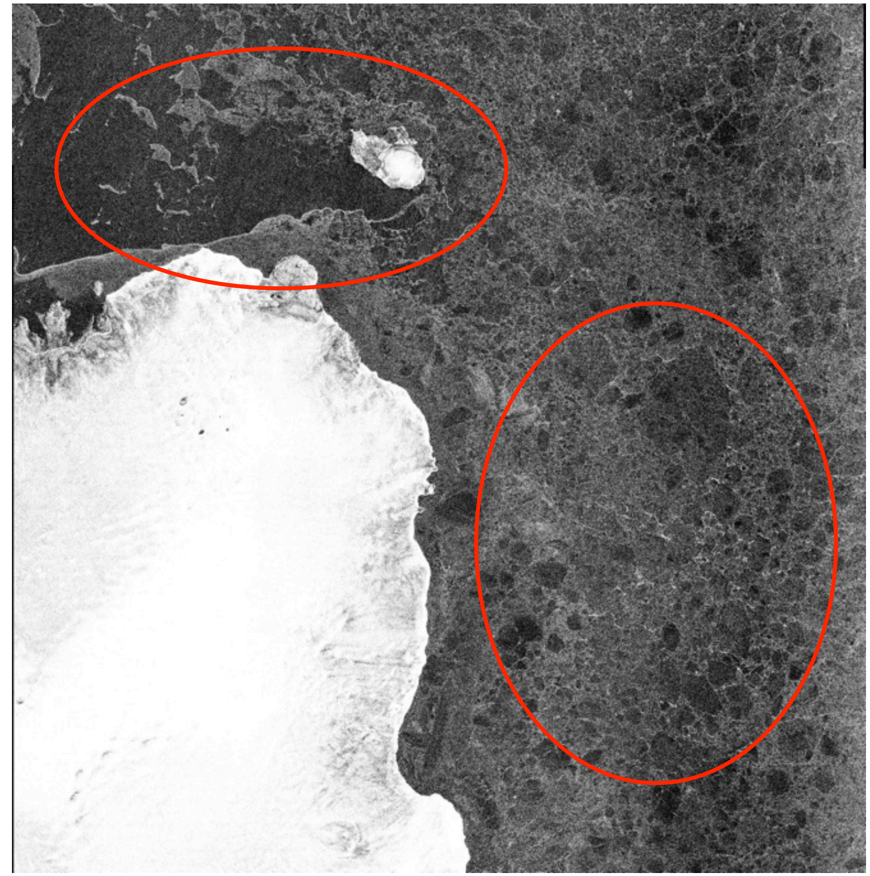
Recent Improvements: Use of Dual-Polarization...

100 km



HH-Polarization

near-range



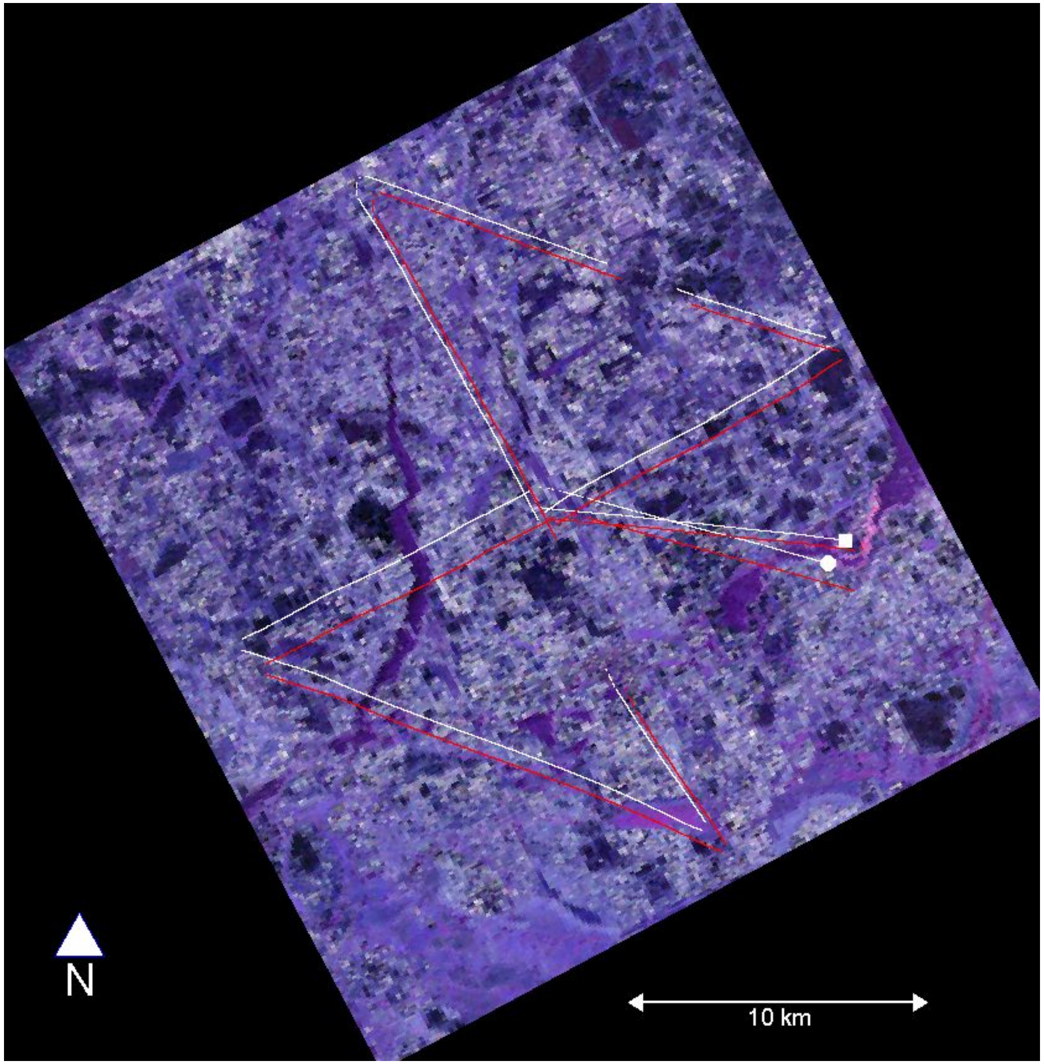
HV-Polarization

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...

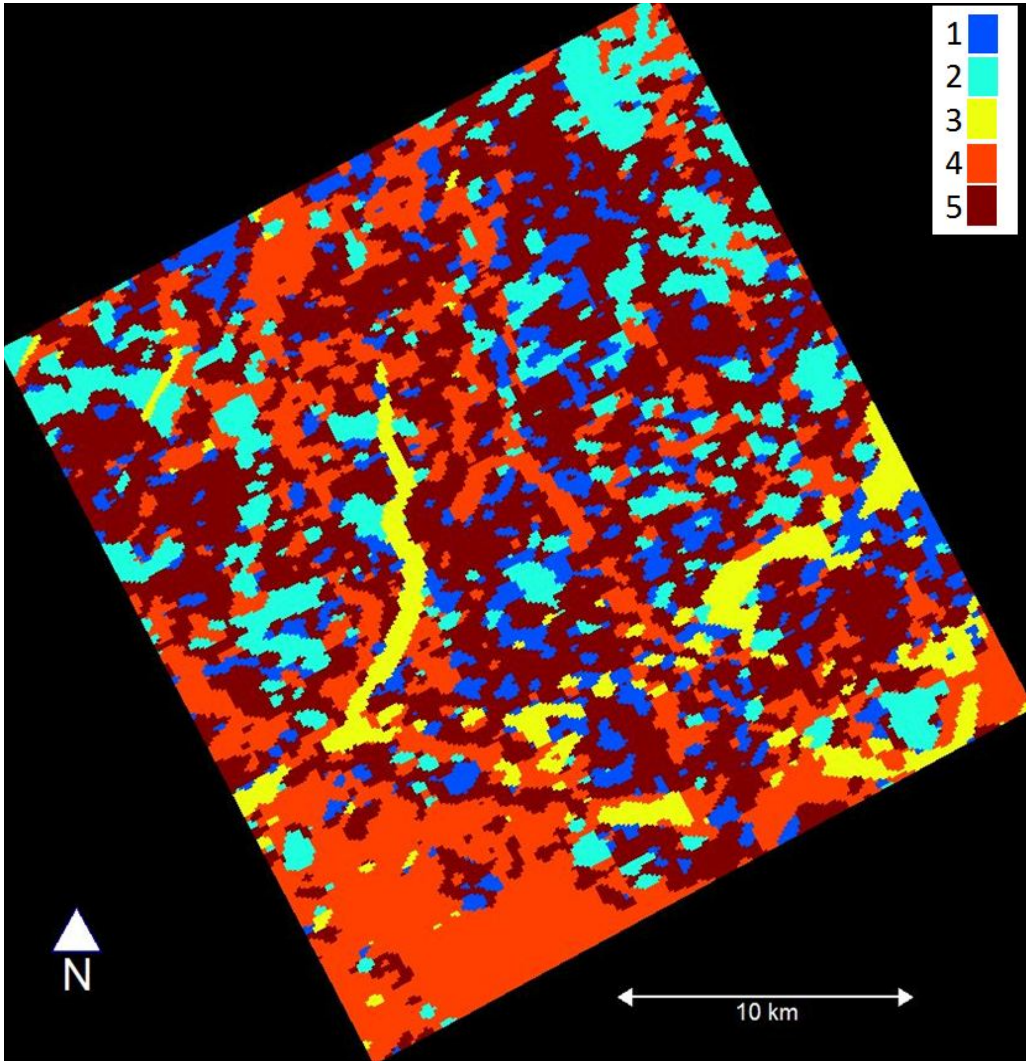
1204 2011
R-IHH-VVI
G-VV
B-IHH+VVI



Moen et al.,
TC 2013

(if possible from a combination of different channels)

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

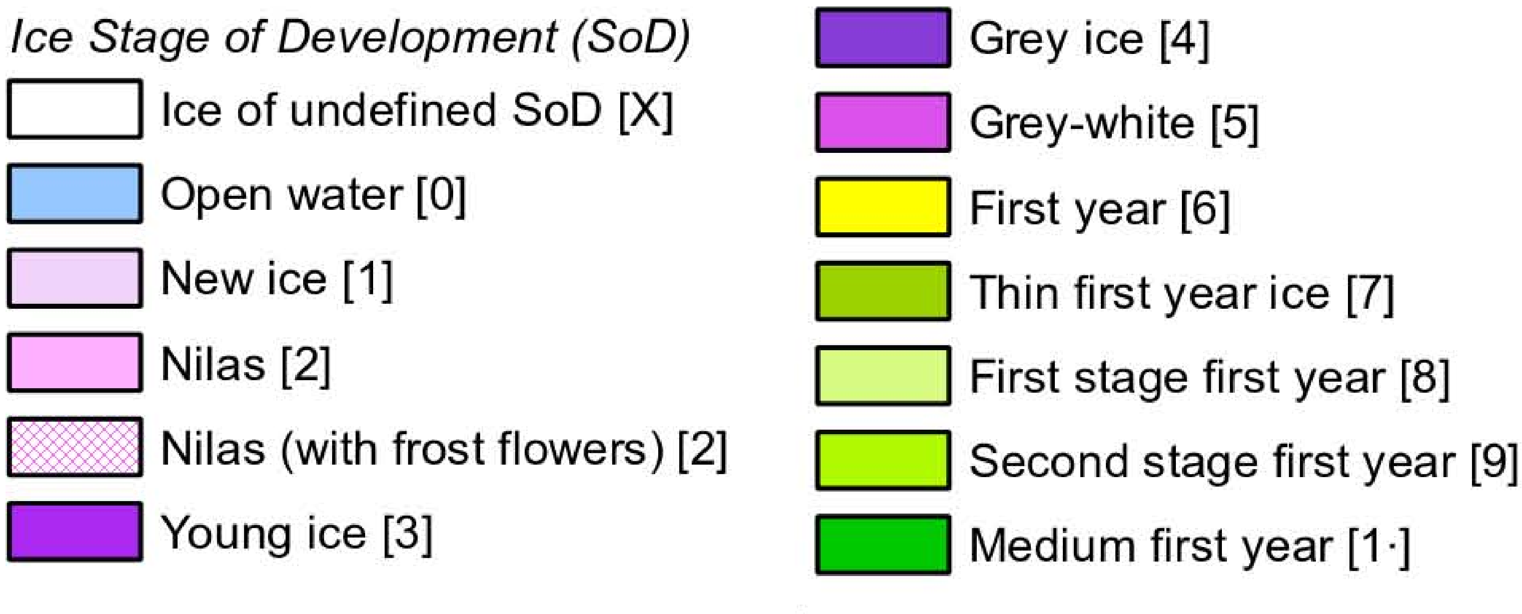


Moen et al.,
TC 2013

Various algorithms available, tested for special conditions

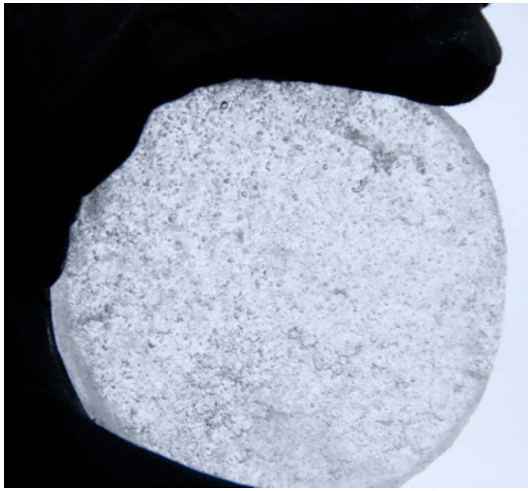
...Classification

WMO-"Stage of development scheme"



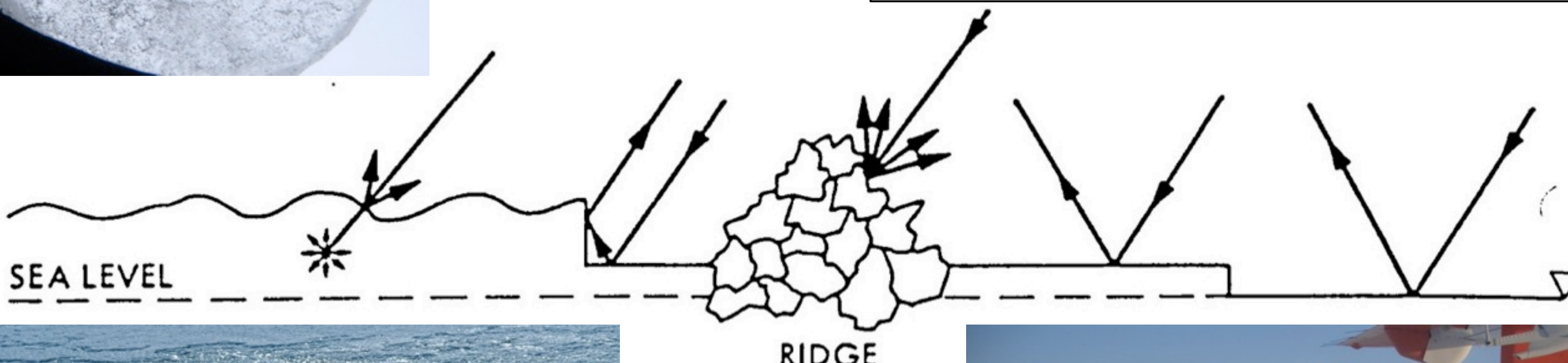
…WMO scheme suitable for radar classification?

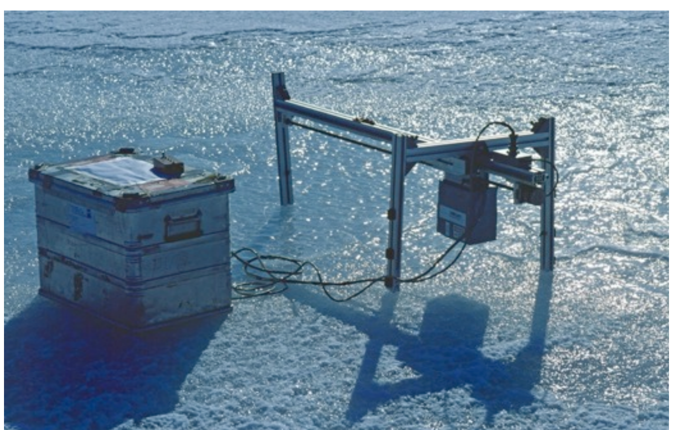
Microwave Interaction With Small-Scale Features

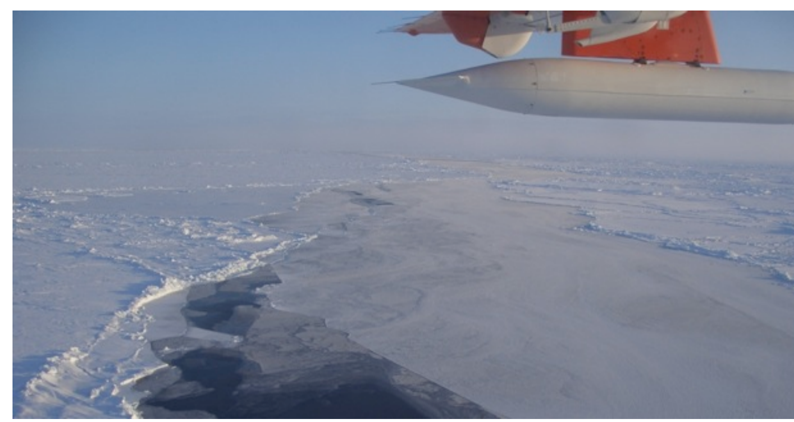


Sources of backscattering:

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







What Influences the Radar Signal?

Sea Ice Parameters:

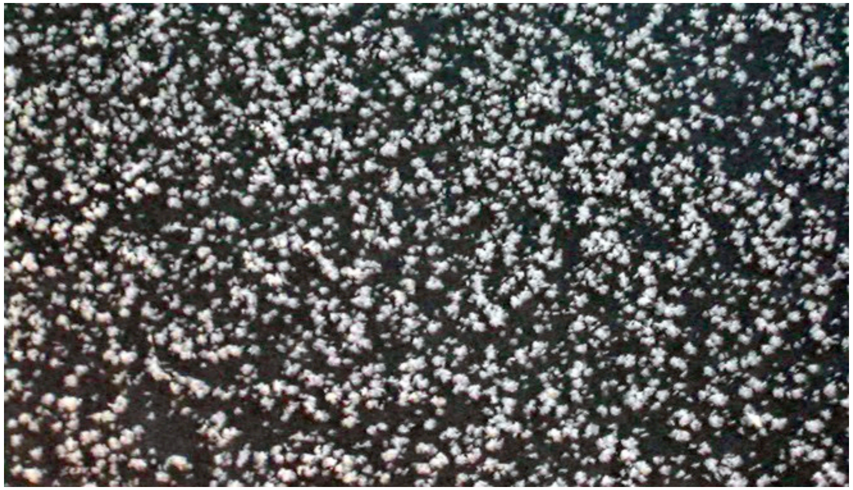
- small-scale surface roughness (mm-dm)
- volume structure (layers, brine inclusions, air bubbles)
- salinity, temperature (dielectric constant, penetration depth)
- snow cover (density, grain size, moisture)
- ice conditions: deformation (brash, ridges), leads, frost flowers

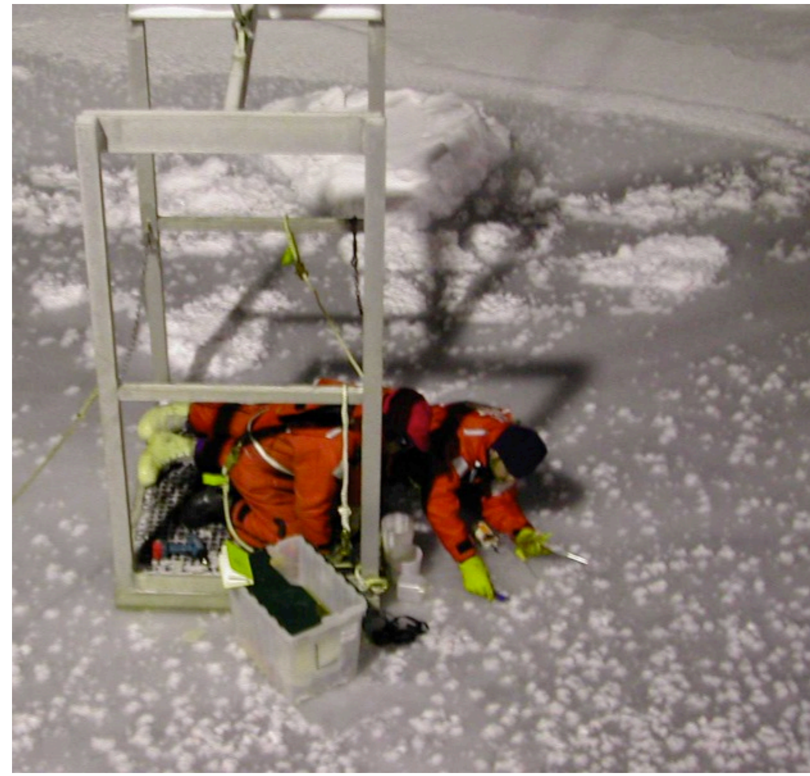
Radar Parameters:

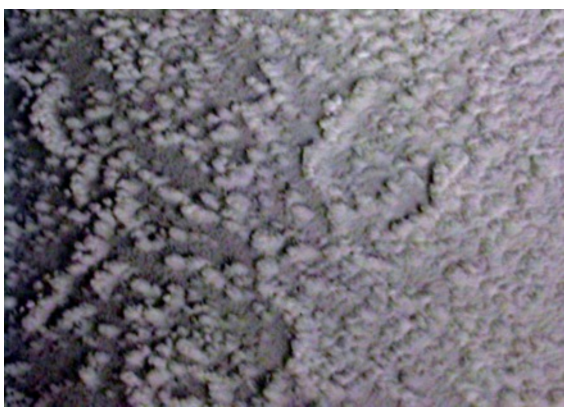
- frequency, polarization, incidence angle
- spatial resolution

determine the appearance of sea ice in the radar image

Frost Flowers





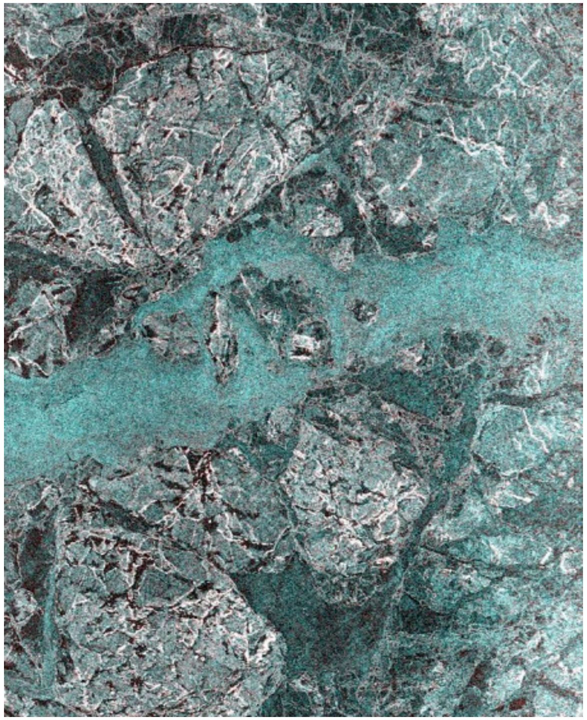


…hiding the ice beneath

Frost Flowers on Lead Ice

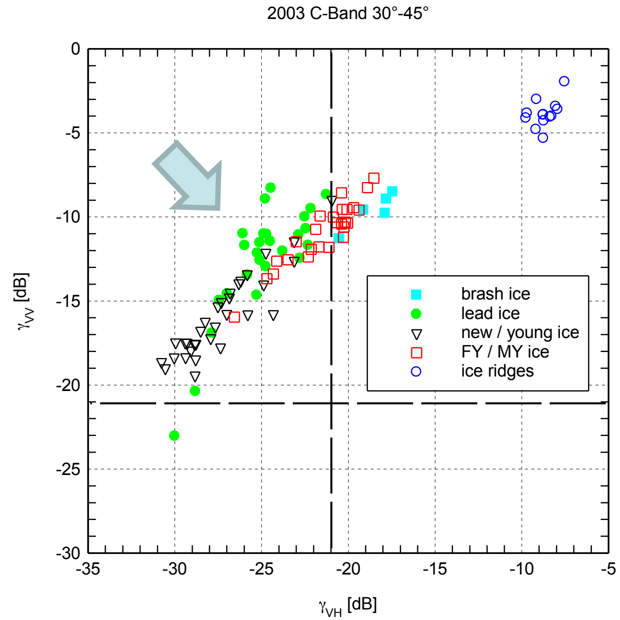
3 km

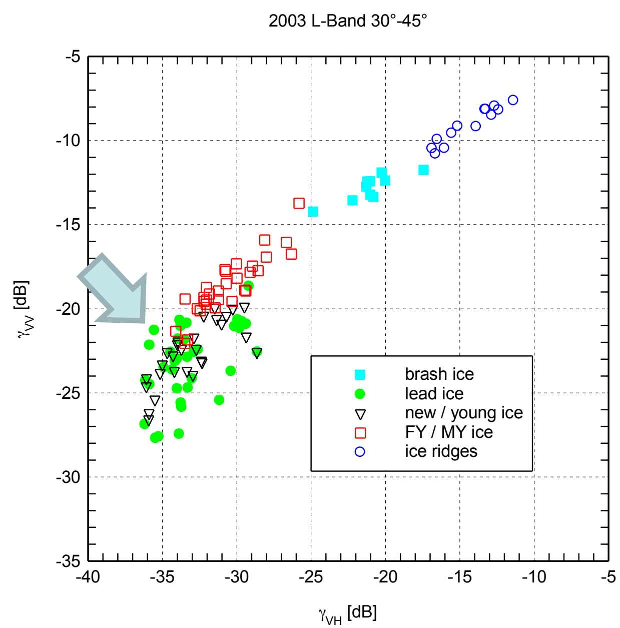
Resolution 2m



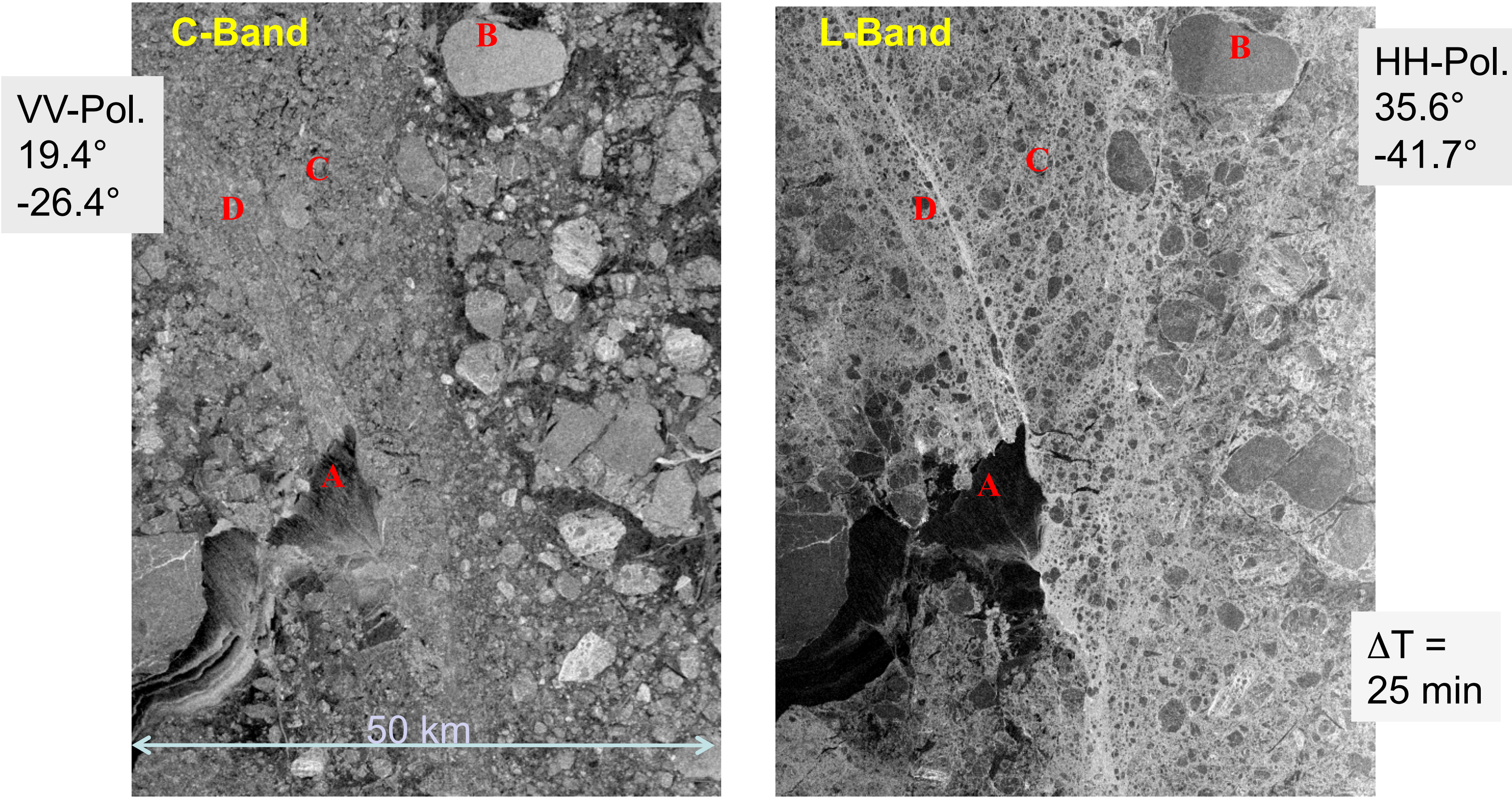
C-Band

L-Band



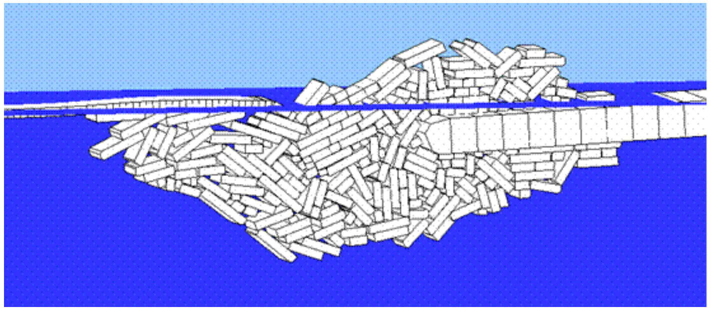


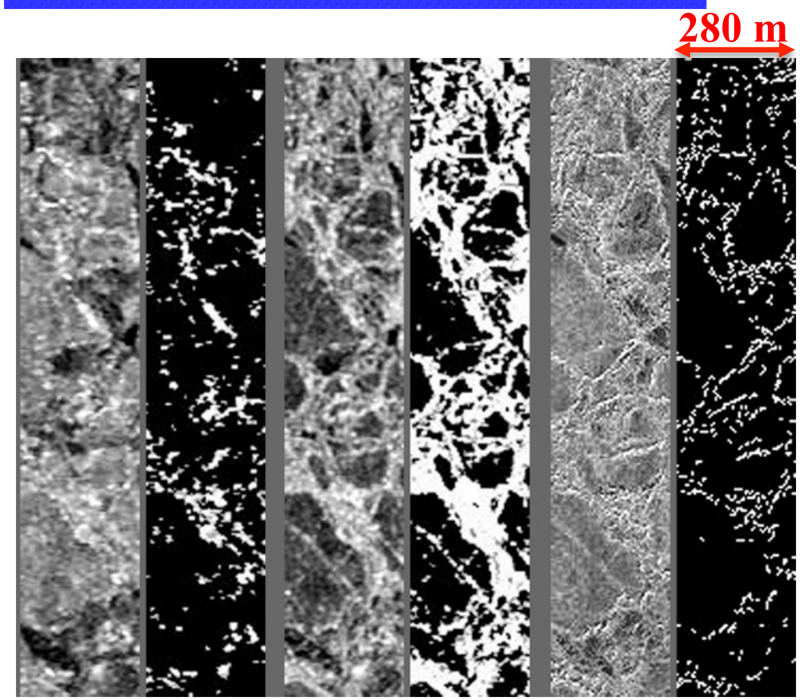
Testing the Potential of Other Frequencies



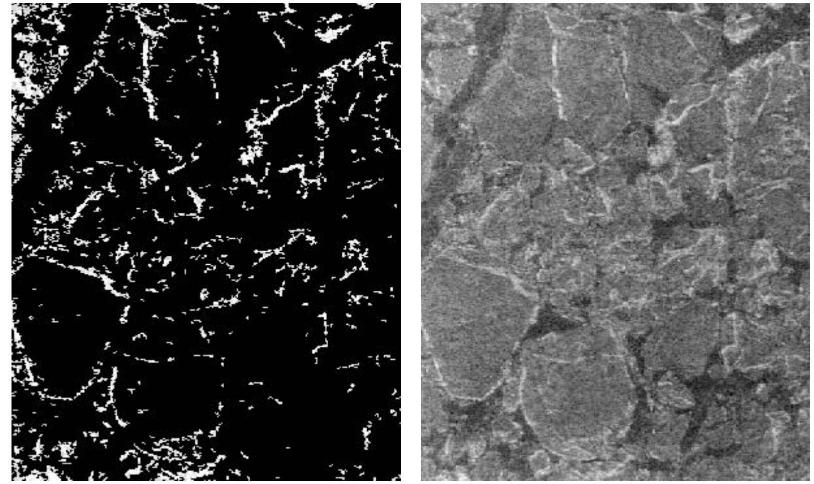
ERS-1 and JERS-1 Sea Ice Images
Coast of East Greenland

L-Band for Detection of Ice Deformation

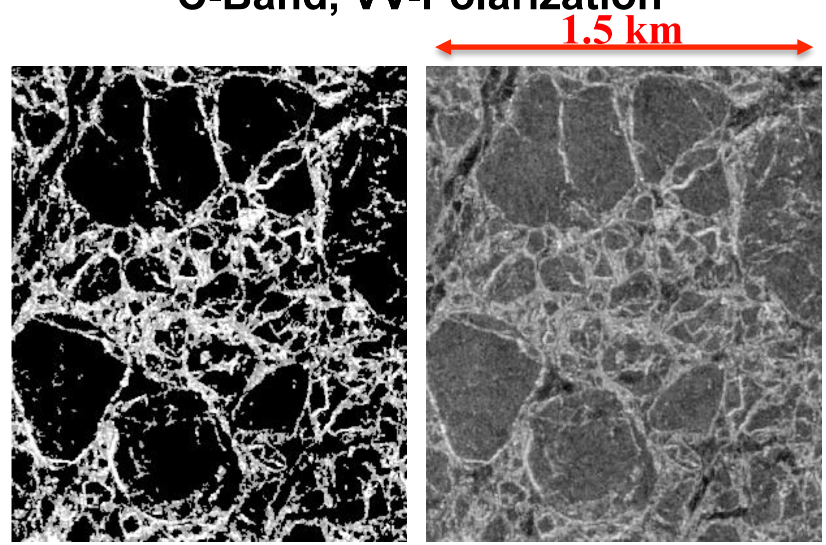




C-Band **L-Band** **Visible**



C-Band, VV-Polarization

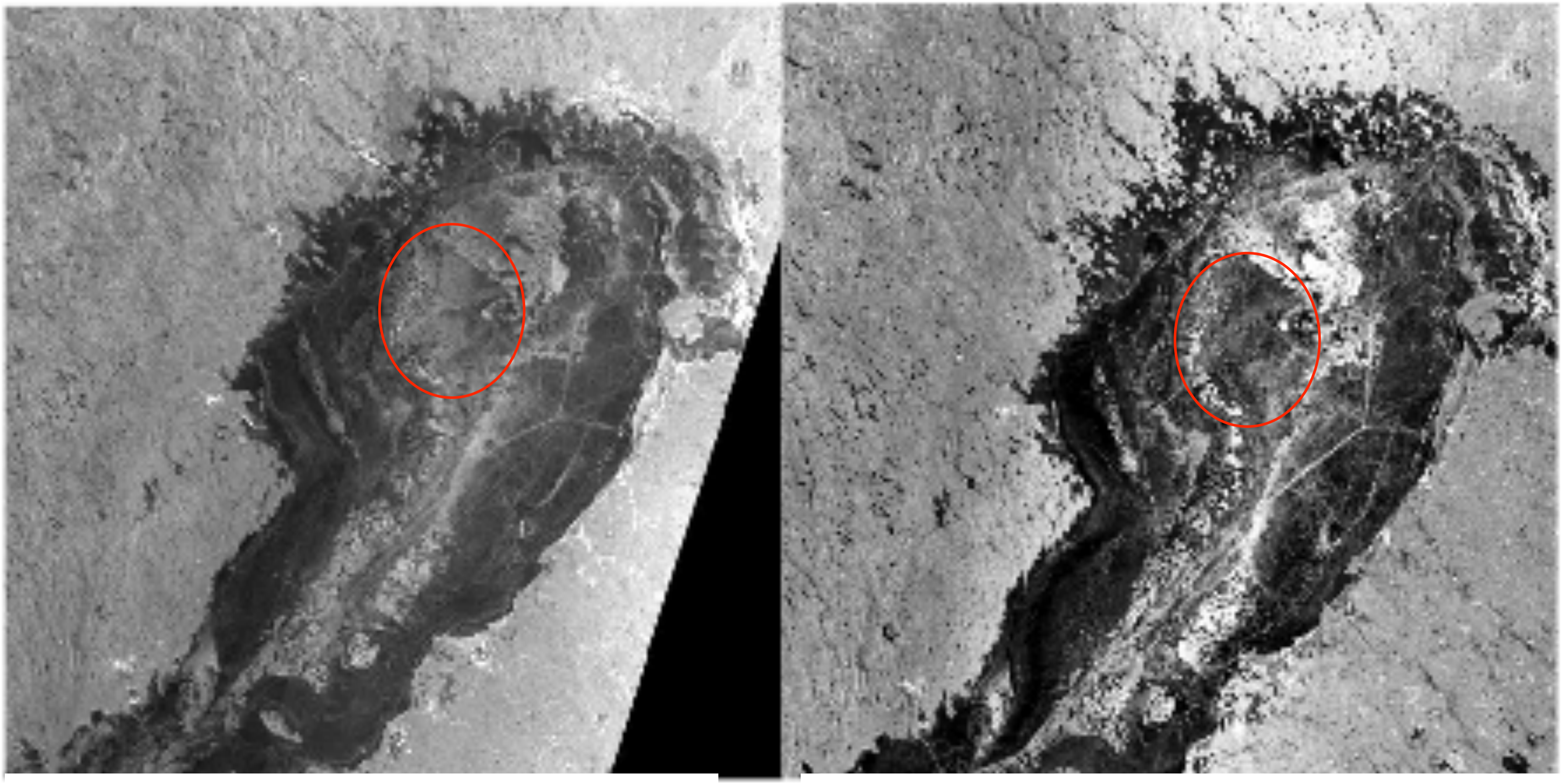


L-Band, VV-Polarization

...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

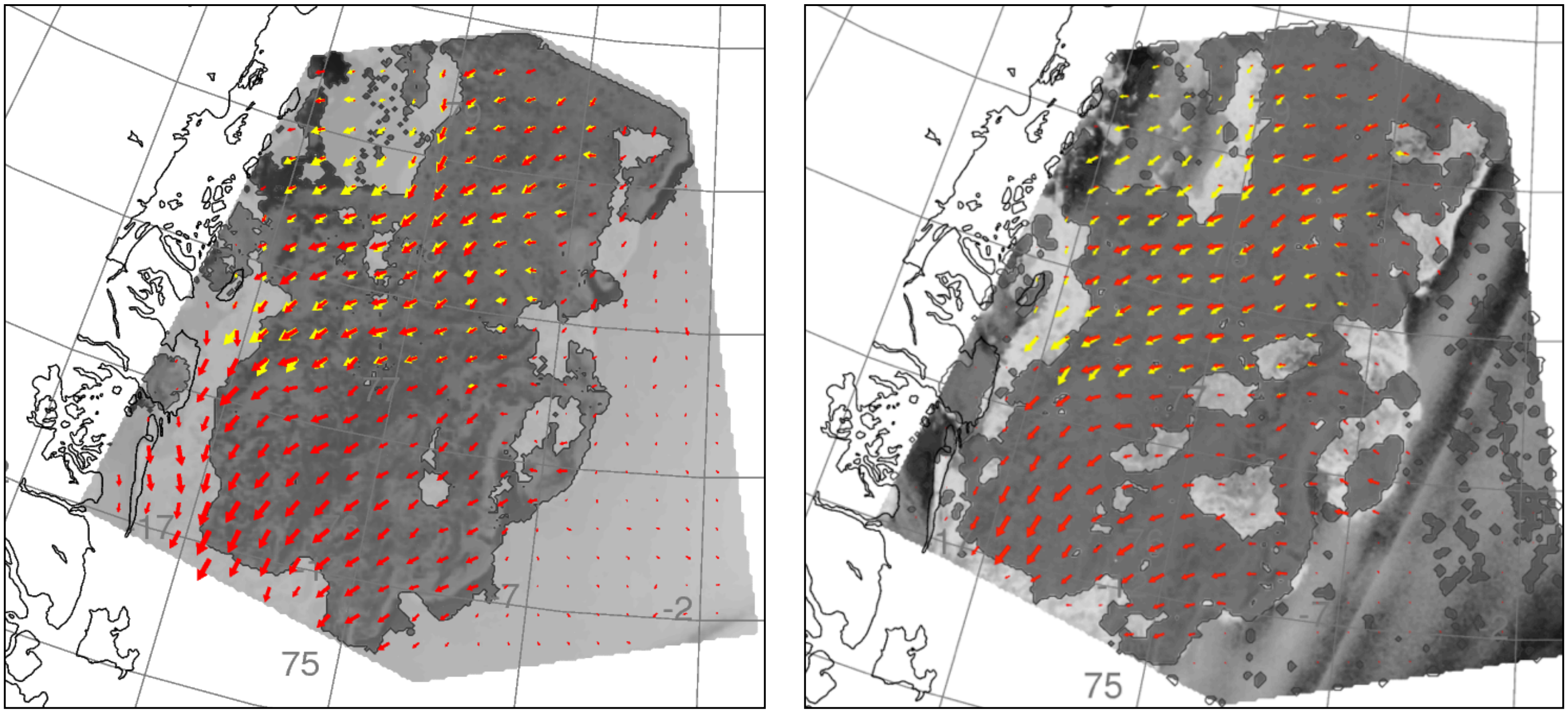
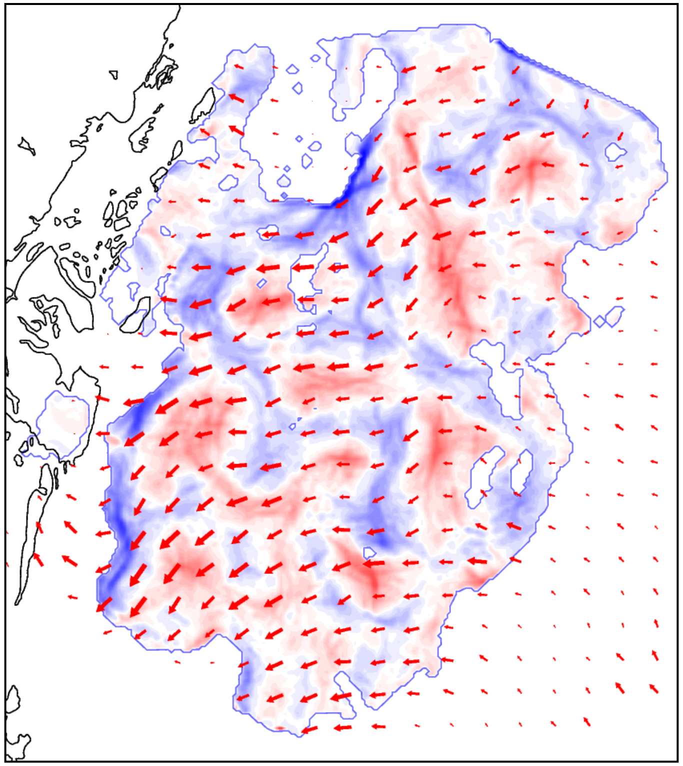
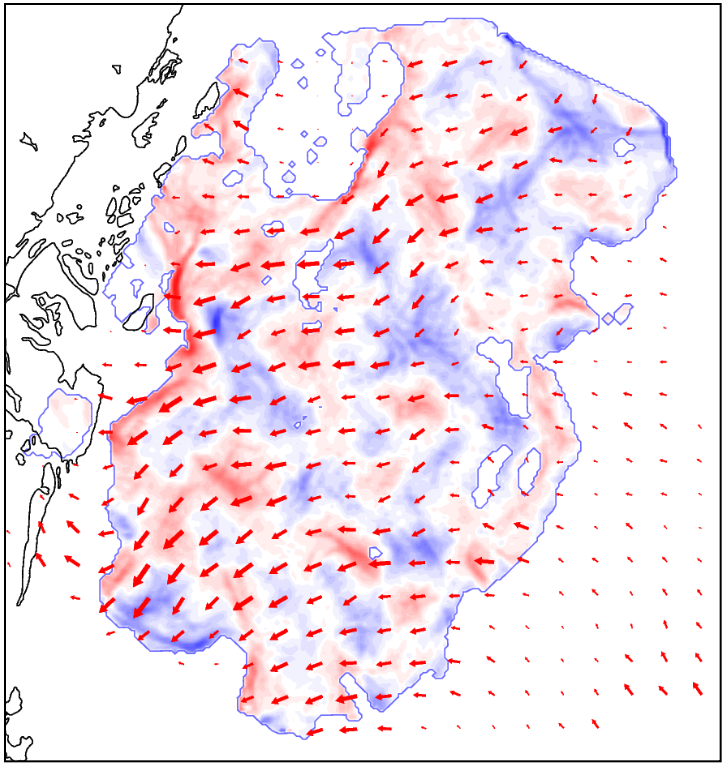


Image pair 16.09.2012. (a) HH-polarization, (b) HV-polarization
Vectors – red: automatically derived; yellow: reference

Ice services use image sequences for mapping!

Ice Drift -> Ice Deformation





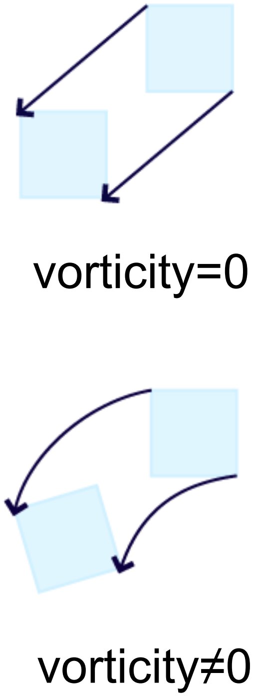
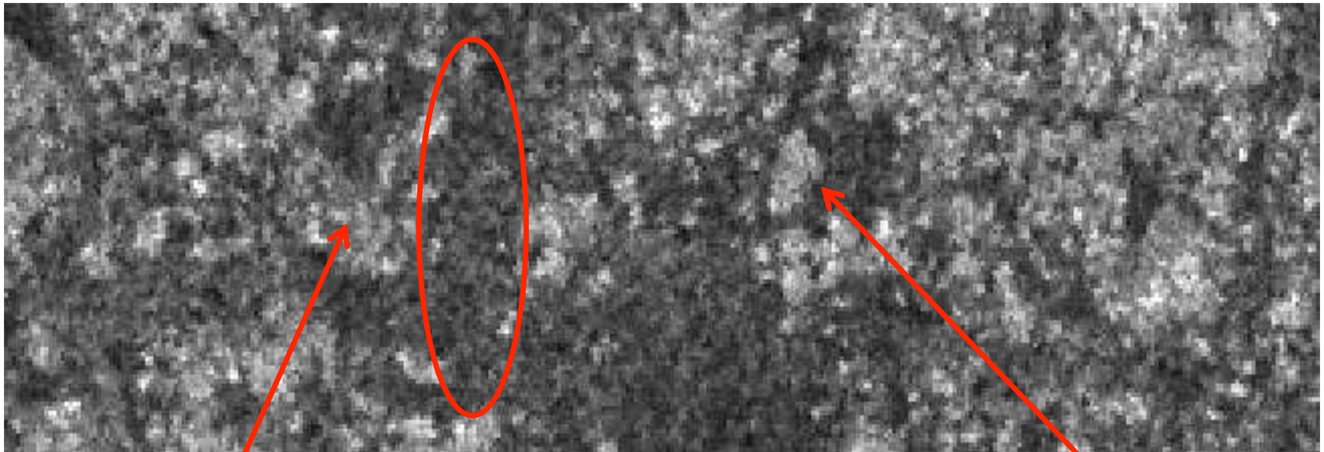


Image pair 16.09.2012. (left) divergence, (right) vorticity

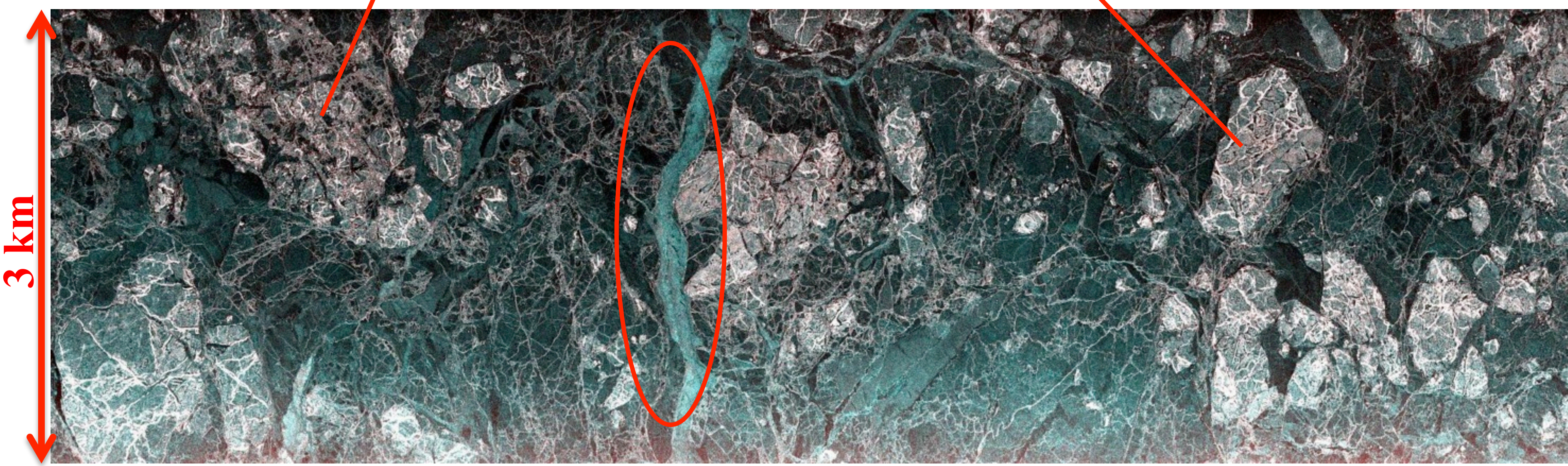
Deformation zones formed earlier than start of drift analysis are not detected!

Effect of Spatial Resolution

ICESAR
2007
Fram
Strait



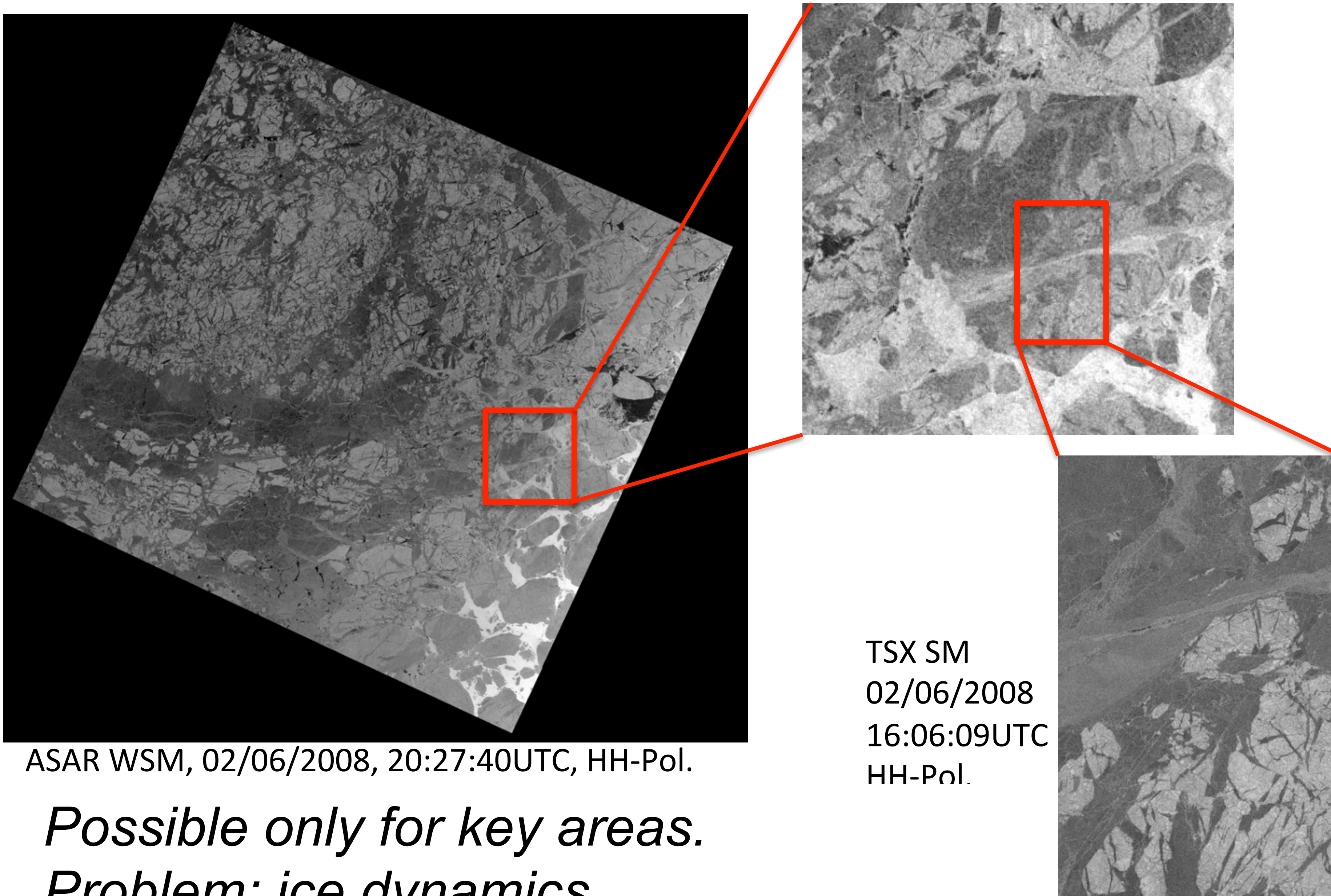
ASAR WSM
19/03/2007
11:22UTC
HH-Pol., 26°



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

…important details may be lost

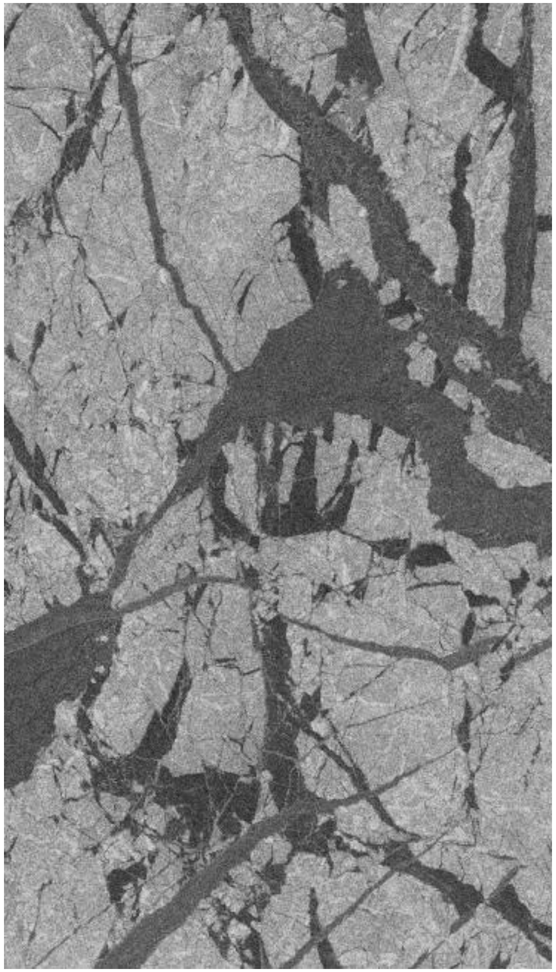
Combine Different Spatial Resolutions



Possible only for key areas.
Problem: ice dynamics.

Equivalence of C- and X-Band

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

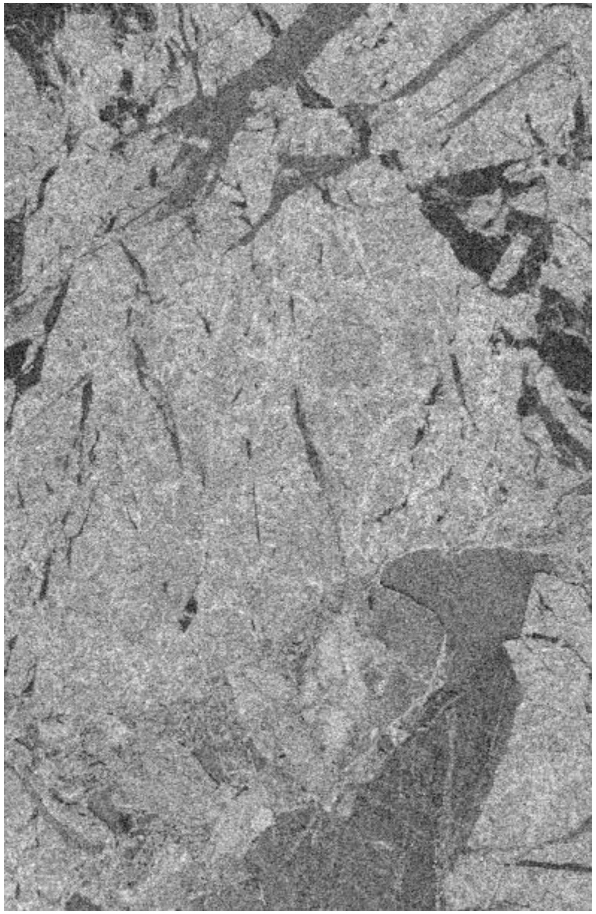


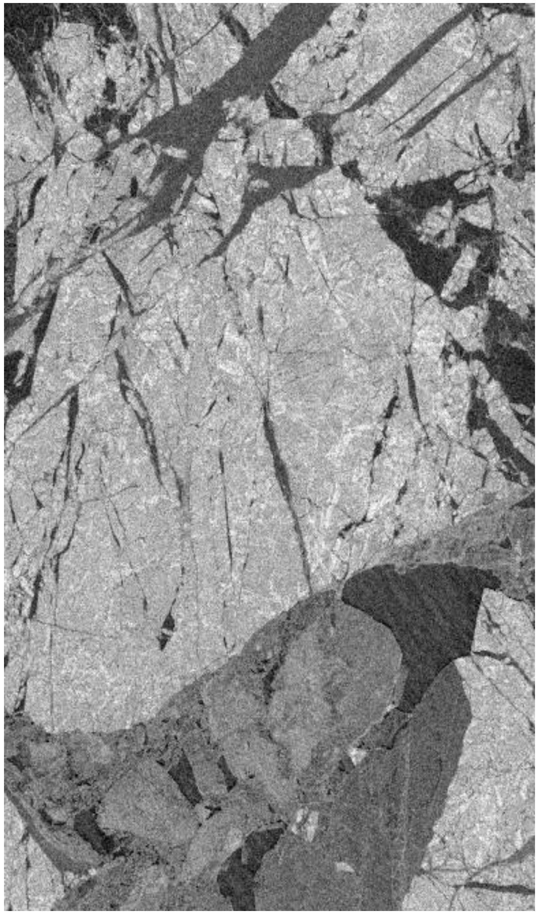
TSX SM
0306_154858,
VV-Pol., 20m,
41.1-42.1°,
ENL > 50

…may be useful for "downscaling"

Equivalence C- and X-Band?

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



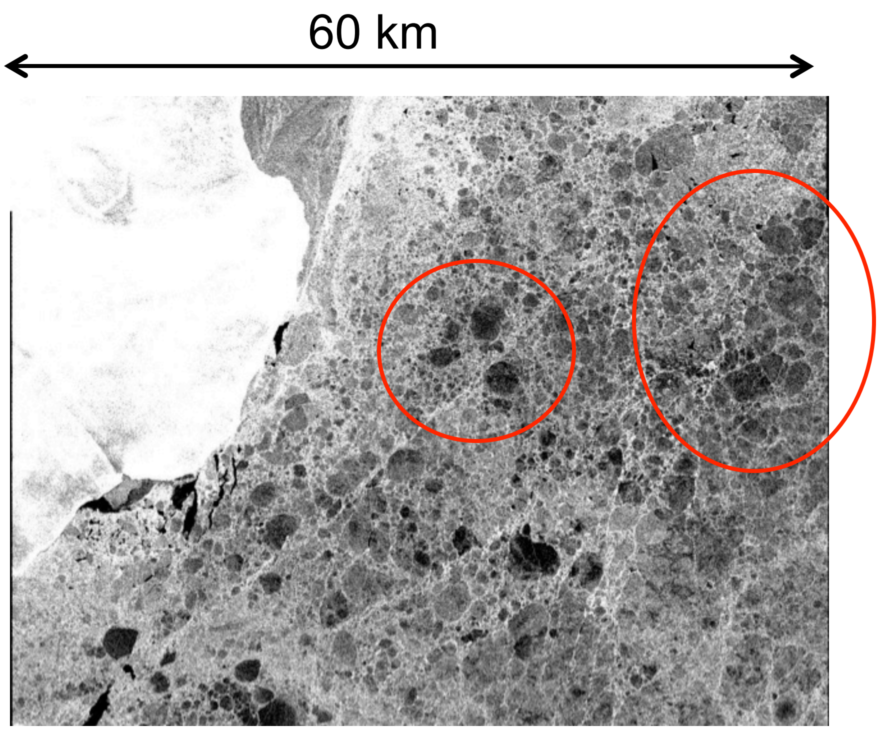


TSX SM
0306_154858,
VV-Pol., 20m,
41.1-42.1°,
ENL > 50

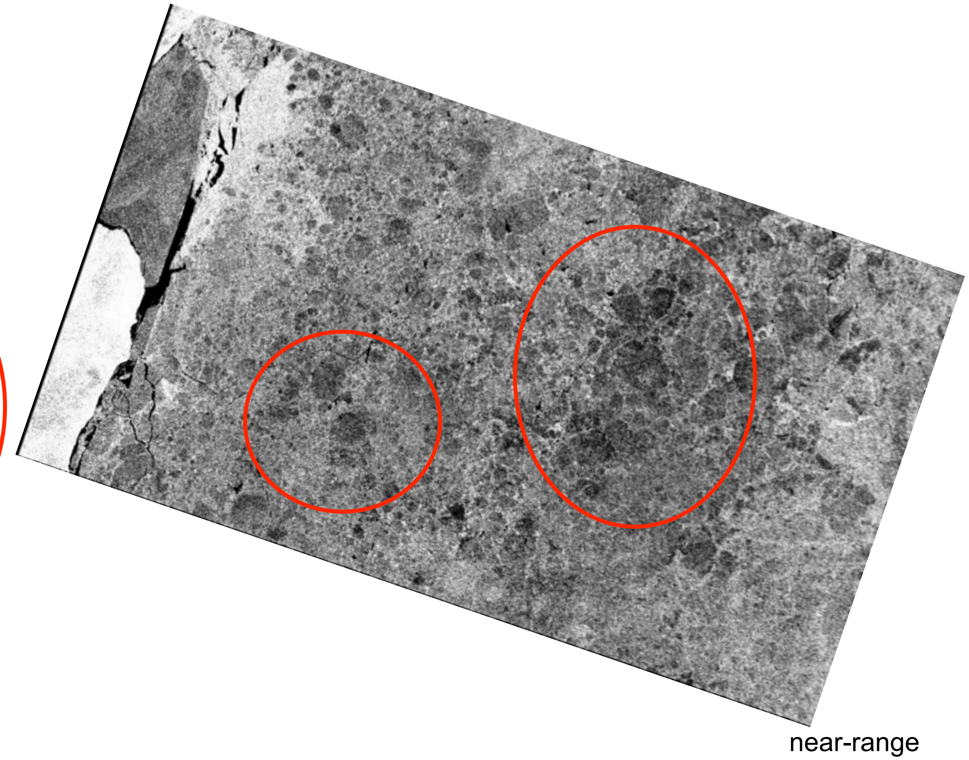
9 km

…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 !