Linking Different Spatial Scales For Retrieval Of Sea Ice Conditions From SAR Images

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Scale
- spatial resolution and coverage of a satellite image (here: SAR)

Choice of appropriate scale?
- desired output information
- method for retrieving the information
- spatial structure of scene

Information Content of a SAR scene

- depends on relationship between the geophysical parameter to be retrieved and the directly measured quantity
- is carried as spatial variation of intensity and phase
- determined by ratio between structures to be identified and spatial resolution / spatial coverage
- depends on frequency, polarization, incidence and azimuth angle
- is affected by noise level, speckle
1. Sea Ice Classification on Different Spatial Scales for Operational and Scientific Use

Wolfgang Dierking, Matt Arkett, Xi Zhang
Combining Different Scales
- Scenario for Sea Ice Monitoring

Sequence of images acquired at different spatial scales and with sufficiently small temporal gaps available?

- in many situations:
  combining different frequencies, polarizations, incidence angles (e.g. ASAR WSM + TSX Scan or SM, ...)

Combination of Different Frequencies And Scales (CIS)
Canadian Waters, Jan 17 2008

RSAT

PALSAR

TSX
L- and C-Band: Complementary information at similar spatial resolution (scale)
Jan 17, ALOS PALSAR (18 hours later)
Jan 17, ALOS PALSAR (18 hours later)

Combination of Images:
=> Increase of information content

Problem:
=> Sea ice drift and deformation
Coverage -> „Large-Scale“ Situation

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

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

Meltex 2008, Beaufort Sea
Coverage -> „Large-Scale“ Situation

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

ASAR WSM, 02/06/2008,
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Meltex 2008, Beaufort Sea
Coverage -> „Large-Scale“ Situation

Meltex 2008, Beaufort Sea
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
Equivalence C- and X-Band?

RS-2 QUAD 0306_154245, VV-Pol., 20m, 40.1-40.7°, ENL ≈ 20

TSX SM 0306_154858, VV-Pol., 20m, 40.9-41.7°, ENL > 50

9 km
Equivalence C- and X-Band?

- one possibility to check: discrete conditional 2-D PDF

- approach as described by Aiazzi et al., Information-theoretic heterogeneity measurement for SAR imagery
  TGRS, Vol. 43, No. 3, 2004
Equivalence C- and X-Band?

No one-to-one correspondence, but in many cases sufficiently similar...
Combining Wide-Swath and High-Resolution: Example from Meltex 2008, June 2

15 km

TSX SM 160609, HH-Pol.
20m, 34.6-35.1°, ENL ≈ 20

ASAR WSM 202740, HH-Pol.,
150m, 22-22.4°, ENL > 100
Combining Wide-Swath and High-Resolution:

TSX, 53pix. window ↔ ASAR, 7pix window

- Differences: consider effect of frequency, temporal gap of 4.5 hours

- Scaling: same “coarse-scale” information content after averaging to same pixel size
Classification of Averaged and Original Images
Classification of Averaged and Original Images

ASAR averaged

ASAR original

TSX averaged

TSX original
Thresholds of Averaged Images -> Original Images

ASAR WSM 202740

TSX SM 160609
Thresholds of Averaged Images -> Original Images

General observation: “In many cases, the use of successively higher spatial resolution data resulted in lower overall classification accuracy“.
Reason: within class intensity (or spectral) variability

→ Averaged image better for separation of major ice classes
   – with subsequent application to the original high-resolution image!
   („coarse resolution“-thresholding does not work in every case...)

Recommendations for Classification of SAR-Data:

- high-resolution imagery: cross-check for classification at coarser resolution (sea ice: small temporal gaps)

- “equivalent“ combination: C+X-band; check of equivalence using conditional 2-D PDF

- use of coarse-resolution (averages of high-resolution) images for fixing thresholds between classes (zonal classification)

- use of high-resolution images for identification of small and narrow ice structures (structural classification)
2. Multi-Sensor And Multi-Scale Observations Of Processes In And Around Coastal Polynias

Thomas Hollands and Wolfgang Dierking
Polynias: increased exchange of heat and matter, ice formation, triggering ocean convection

\[ R = \frac{h_c U_l}{F_F} \]

- **R**: width of polynia
- **h_c**: thickness of accumulated frazil ice
- **U_l**: drift velocity at the polynia edge
- **F_F**: heat loss

"Pease Model" for coastal polynias:
Coastal Polynya

Increased Evaporation and latent heat exchange

Katabatic winds

Ice formation

Ice drift

Brine release

Bottom water formation
The “Perfect” Polynja

⇒ frequent and significant changes, smaller polynja (length scale 100-300 km)

Terra Nova Bay

MacKenzie Bay
Example: Terra Nova Polynia

NASA Earth Observatory
Aqua MODIS 250 m resolution

http://cires.colorado.edu/science/
Here: slightly different! X-Band more sensitive to surface conditions (snow, snow crusts, superimposed ice, slush layers...
Combining Different Sensors

Envisat ASAR (ESA, 2009) 30 m

Terra Nova Bay

Drygalski Ice tongue

25 km
Combining Different Sensors

Envisat ASAR (ESA, 2009) 30m
EO-1 ALI (NASA, 2009) 10m
Earth Observing-1 Satellite
Advanced Land Imager
Combining Different Sensors

AATSR (ESA, 2009)
1000m

25 km
Combining Different Sensors

Envisat ASAR 30m
+ AATSR (ESA, 2009) 1000m

-1.82 to -5°C
-10 to -15°C
-15 to -25°C
< -25°C

25 km

clouds
3. *Sea Ice Drift And Deformation on Different Spatial Scales*

Jakob Griebel, Wolfgang Dierking, Stefanie Linow, Thomas Hollands
1. Spatial Scaling Effect

Total strain rate derived from a high resolution SAR image pair

**Image 1:** Gridspacing ~ 675 m

**Image 2:** Gridspacing ~ 2250 m

Location: Weddell-Sea
Date: 14.02.2014
Dimension: ~ 100 x 90 km
2. Spatial Scaling Law

For the total strain rate from four high resolution SAR image pairs

**Mean Total Strain Rate**

**Standard Deviation**
3. Applying the Scaling Law

Total strain rate derived from a high resolution SAR image pair

**Image 1:** Gridspacing ~ 675 m

**Image 2:** Gridspacing ~ 2250 m

Location: Weddell-Sea
Date: 14.02.2014
Dimension: ~ 100 x 90 km
3. Applying the Scaling Law

Total strain rate derived from a high resolution SAR image pair

Image 1: Gridspacing ~ 675 m
Image 2: Gridspacing ~ 2250 m

Location: Weddell-Sea
Date: 14.02.2014
Dimension: ~ 100 x 90 km
4. Power Density Function

Applying scaling law and comparing power density function obtained at different spatial resolutions

**Image 1**: Gridspacing ~ 675 m

**Image 2**: Gridspacing ~ 2250 m
4. Power Density Function

Applying scaling law and comparing power density function obtained at different spatial resolutions

Image 1: Gridspacing ~ 675 m

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CryoSat-2 based sea ice typing

Eero Rinne and Markku Similä
Finnish Meteorological Institute
Sea ice typing using CryoSat-2 data

- We have studied if it is possible to retrieve sea ice types (hence, also indirect ice thickness information in a large scale) over the whole Arctic using the waveform of CryoSat-2 altimeter data. The results are promising.

- Four sea ice categories used: open water, thin ice (<70 cm), thick FY (>70 cm), MYI.

- As a reference data we have used the AARI ice charts for the Barents and Kara Seas up to the North Pole.

- Next we will examine the relationship between SAR signatures and CS-2 waveform parameters (i.e. combine information from different types of sensors resulting in products of different spatial scales)
Open water/sea ice discrimination using just one parameter (PP)

PP = Pulse peakiness
Classification: OW=blue, thin FYI = green, yellow= thick FYI, brown=MYI

16-31 March 2015

Resolution of the product = 18 km
The classification error rates for Fig. 2. Thin ice strongly underestimated, other classes well identified.
Stay curious about work progress!

Thank you for your attention!