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POLSAR/Multi-frequency Theme 3: Sea ice & Ocean

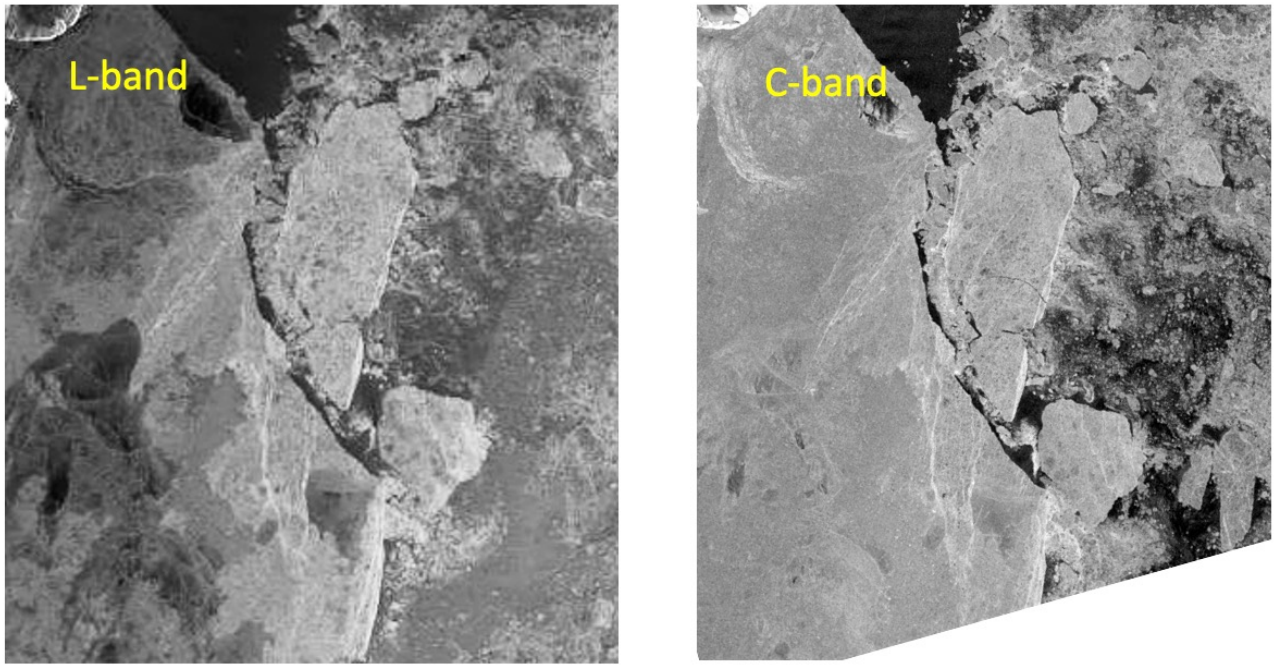
Malin Johansson & Wolfgang Dierking
UiT The Arctic University of Norway

Malin.Johansson@uit.no
Wolfgang.Dierking@awi.de

cirfa.uit.no

Sea Ice : Status SAR monitoring and satellite mission coordination

- **Operational ice services**
  - produce ice charts using C-band dual-pol (HH+HV) SAR imagery
  - start to consider inclusion of L-band data provided their acquisition requirements (e.g. latency, long-term availability) can be met.
- **Benefits of polarimetry / multifrequency data**
  - have been broadly investigated using airborne data and combinations of satellite images acquired at different frequencies (different SAR missions!)
- **Science applications**
  - diverse with respect to the choice of SAR data
  - tendency to investigate images combined from different SAR and non-SAR satellite missions and relating their information content to in-situ ice measurements.



PALSAR-2 WB HH-Pol. 20190708 14:27

S1 EW HH-Pol. 20190708 08:10

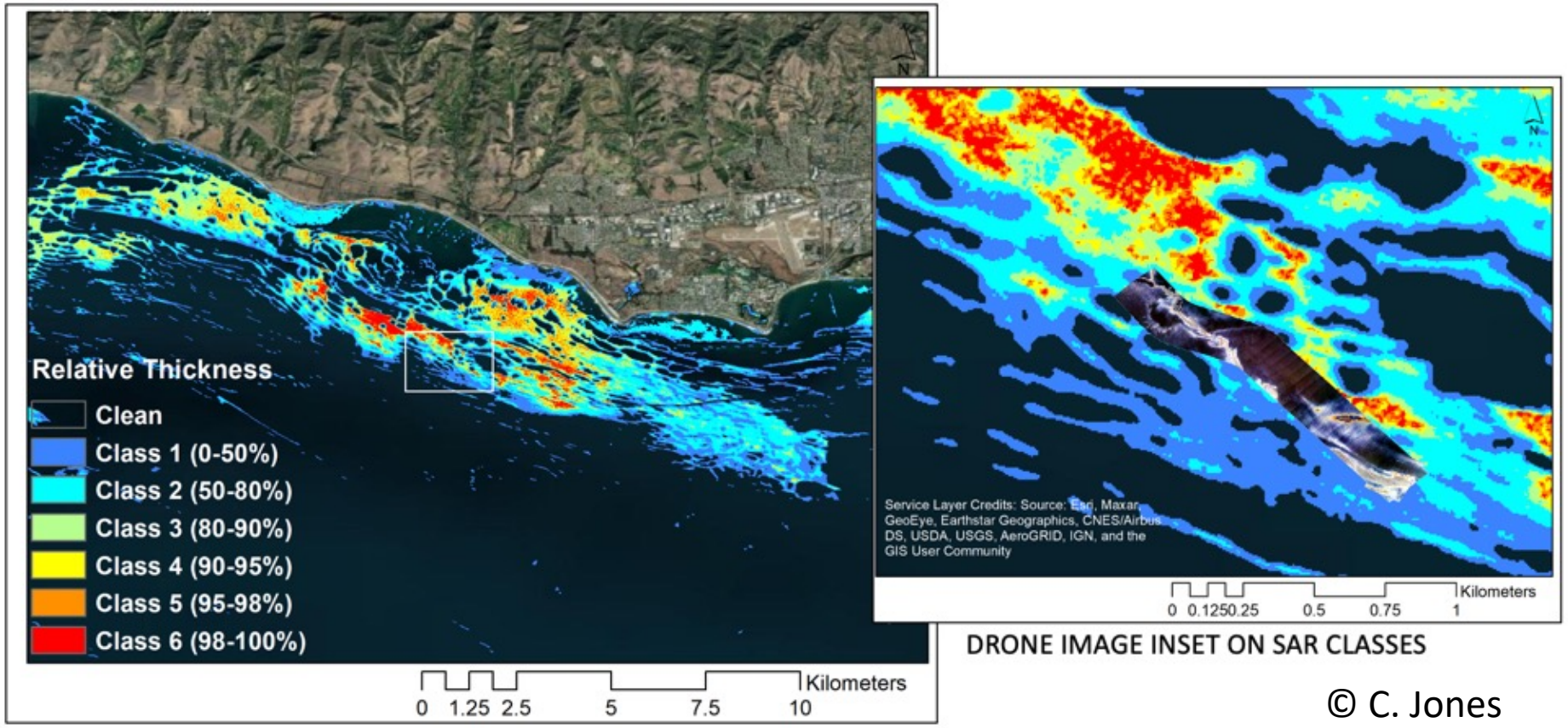
Example of multi-frequency SAR image combination
Belgica Bank (NE Greenland), melting phase: first-year ice (darker signature) easier to distinguish from multi-year ice (brighter areas) at L-band

Courtesy: Nick Hughes and Frank Amdal, Norwegian Ice Service

State of the art – ocean / marine applications

- **High SNR high resolution Co-polarization ratio** – mineral oil thickness
  - Individual studies not operational

- Current situation for spills
  Reduction in accidental and illegal mineral oil spills
  Increase in **new types of fuel** whose **satellite signatures are largely unknown**



DRONE IMAGE INSET ON SAR CLASSES

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Well served areas, gaps highlighted

- *What science communities/application areas in your field are presently well served? How/why?*

- **Operational ice charting services**
  - C-band image acquisitions mostly meet requirements of areal coverage, latency and continuity
  - BUT: spatial and temporal coverage of Antarctic insufficient, ice type separation sometimes ambiguous
- **Science: single process studies, examples:**
  - Fast ice mapping, detection of melt onset and freeze-up
  - Retrieval of average regional ice drift and deformation patterns, determination of long-term changes
- **Combination of in-situ measurements and SAR image analysis**
  - For studying interactions between radar waves and ice and their impacts on ice classification and parameter retrieval, validation of SAR-derived data products
  - BUT: open access to in-situ data needs to be improved
- **SAR as validation tool** – improvement of scatterometer, passive µ-wave radiometer, and altimeter sea ice parameter retrievals
- **Ship detection** – preferably using images at higher spatial resolution

Missing critical elements - Sea Ice

What science communities/application areas are not well served?

- *What are the missing critical elements?*

- **Science - insufficient temporal frequency of SAR image acquisitions for:**
  - more detailed ice drift analysis (e.g. 1-2 hours for recognizing tidal effects)
  - retrieval of fast changing deformation patterns

  => needed for validating model simulation of sea ice movements and ice mass transport, and determination of ice pressure

- **Still missing for increasing accuracy and semi-automation of ice charting**
  - continuous simultaneous multi-frequency SAR acquisitions over Arctic / Antarctic including L-band
    - higher priority for multi-frequency data than for full polarimetry (phase differences)
  - availability of co-pol ratio => advantage for separation of thin ice types

- **Iceberg monitoring**
  - needed: wide swath coverage AND high spatial resolution (smallest bergs < 5 m, “small” bergs 15-60 m)

Missing critical elements - Sea Ice and ocean

What science communities/application areas are not well served?

- *What are the missing critical elements?*

- **Heat budget for the Arctic -> identification of new ice zones**
  - The Arctic sea ice is thinning and more new ice forming
  - Thin ice retrieval requires the two co-pol channels, no need for coherent measurements
  - Lower NESZ

- **Marine surface slick characterization**
  - Frequent passes over areas with a high degree of marine surface slicks
  - High SNR
  - New fuel characterization
  - Ocean winds used operationally to assess possibility of marine surface slicks (well covered)

Near/mid-term SAR coordination - Sea Ice

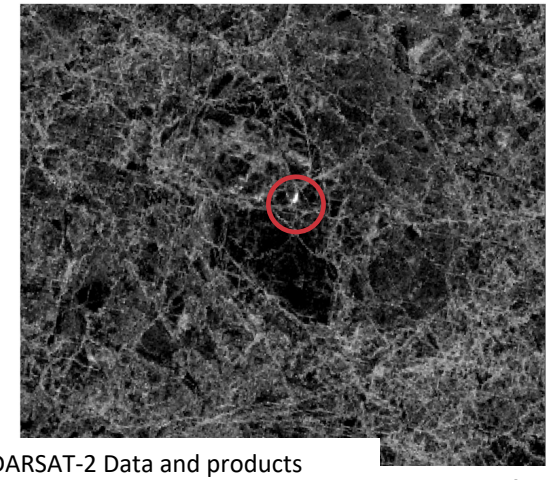
Identify one to three SAR coordination actions that could be taken in the near/mid-term (using current and near future SAR missions) that would improve science/applications of your field overall.

1) Preparation of multi-frequency SAR acquisitions over Arctic and Antarctic

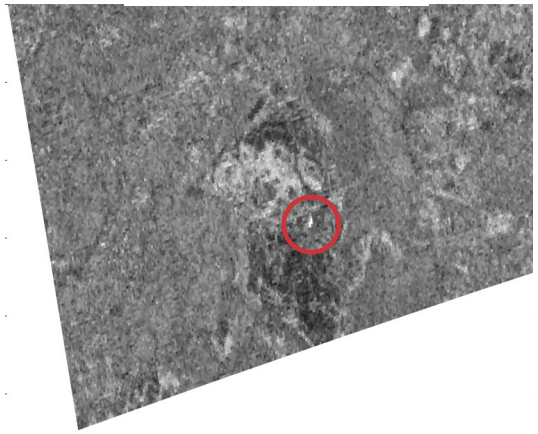
- Publish satellite acquisition plans in advance –> data merging, planning of in-situ data campaigns
- Minimize temporal differences for different frequencies
- Continued coordination for spatial overlap at study sites

Example: 2019 to 2022 cooperation project between ESA and JAXA on Using SAR Satellites In Earth Science and Applications). MOSAiC 2019/2020, CIRFA cruise to Belgica Bank 2022

PALSAR-2

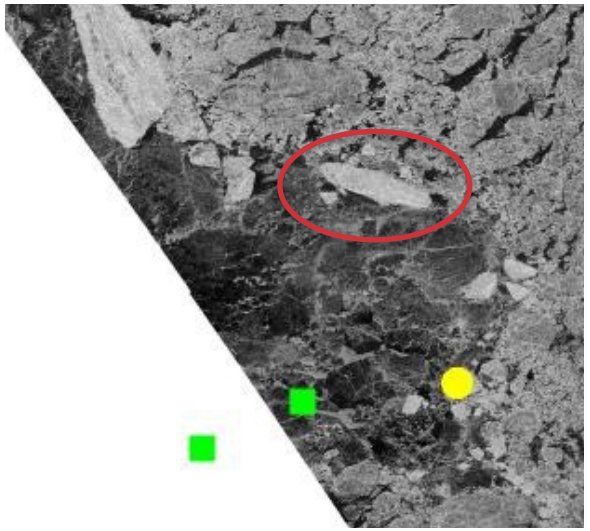


Radarsat-2

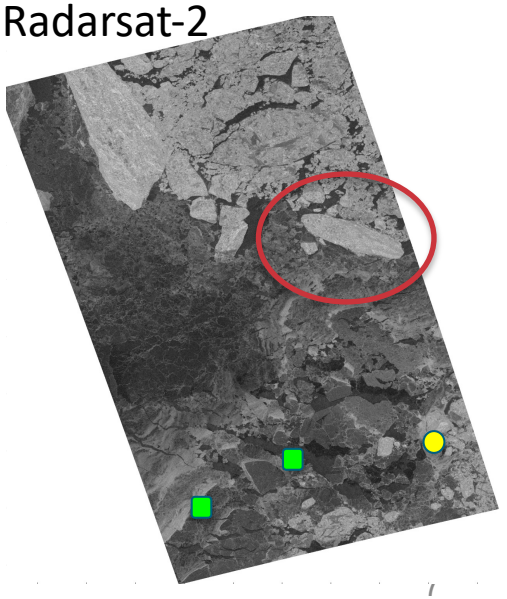


8 h time separation

PALSAR-2



Radarsat-2



5 h time separation

ALOS-2 Palsar-2 scene provided by JAXA under the 2nd Research Announcement on Earth Observations (PI: Torbjørn Eltoft PER2A2N013).

Near/mid-term SAR coordination - Sea Ice

Identify one to three SAR coordination actions that could be taken in the near/mid-term (using current and near future SAR missions) that would improve science/applications of your field overall.

2) Aim for a "**sea ice year"** -> Pan-Arctic/Antarctic coverage

- Multi-mission coordination, e.g.
  - ALOS-4 and Sentinel-1 for Arctic
  - NISAR L- and S-band / SAOCOM and COSMO SkyMed for Antarctic
- Global baseline – to be used in future studies

3) Improved noise compensation algorithms applied to archived products

Near/mid-term SAR coordination – Ocean / marine applications

Identify one to three SAR coordination actions that could be taken in the near/mid-term (using current and near future SAR missions) that would improve science/applications of your field overall.

1) Marine pollution
   - For response/responders to a existing marine pollution -> Frequent imaging, best < 1 h
   - For monitoring frequent imaging -> every 6-12h beneficial
   - Any frequency

2) Coordination with optical and near-IR beneficial
   - From optical and IR the oil thickness can be estimated -> if we have overlaps we can possibly learn the SAR signatures for different oil types, thicknesses better
   - New types of oil -> we need to learn their signatures

Long-term goals - Sea ice and ocean

2. Identify and prioritize the long-term (2030+) goals and objectives for SAR coordination that would vastly improve your science discipline.

- *Mission parameters*
- *Data / products*

Mission parameters

- Continuous multi-frequency SAR coverage of Arctic (e.g. S1/S1N + ROSE-L) and Antarctic (e.g. NISAR, SAOCOM, COSMO SkyMed)
- Increased downlink capacity
- Wide swath + increased spatial resolution (< 10 m) at the same time (e.g. iceberg and oil spill detection)
- SNR as high as feasible – essential for identification of thin sea ice and for marine pollution
- Coordinated combination of SAR and non-SAR data (altimeter, optical, IR)

Long-term goals - Sea ice and ocean

2. Identify and prioritize the long-term (2030+) goals and objectives for SAR coordination that would vastly improve your science discipline.

- *Mission parameters*
- *Data / products*

Data / products

- Data delivery within 15 minutes – operational sea ice and marine applications
- Free sharing of different (SAR-) Sensor data
- Archive(s) combining different SAR and non-SAR sensors and in-situ data with efficient search tool(s)
- Easy-to-handle planning tool for combining data acquisitions of different satellite sensors / missions
- Integration of commercial (SAR) satellite data providers in acquisition strategies

Long-term goals - Sea ice and ocean – priority list

2. Identify and prioritize the long-term (2030+) goals and objectives for SAR coordination that would vastly improve your science discipline.

- *Mission parameters*
- *Data / products*

1. Multi-frequency
2. High temporal resolution (<6h was discussed at the meeting) – this resolution means that we can track hurricanes also in polar regions, as well as marine pollution drift and sea ice
   - Ocean winds and currents as they are incorporated into drift modelling and weather forecasting
3. Seasonal coverage
4. Fully-polarimetric and high spatial resolution
   - High spatial resolution most important for:
     - ice bergs
     - Marine pollution
   - Fully-polarimetric data most important for:
     - Sea ice