GLOBAL SATELLITE OBSERVATION

REQUIREMENTS FOR FLOATING ICE

FOCUSING ON SYNTHETIC APERTURE RADAR

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Objective

• To identify the required set of satellite measurements to address key science questions relevant to the assessment of the impacts of climate change in the polar regions
  – Focusing on Synthetic Aperture Radar
  – Identify the properties of sea ice, icebergs and freshwater ice that are of greatest scientific interest with respect to the impacts of climate change
  – Recommend strategies to monitor and measure these properties with SAR from space.
• Study was conducted between December 2013 and March 2014
Methodology

- Over 150 scientists were contacted by e-mail individually or in small groups to seek input on the observational needs of science and on the type of satellite SAR observations of floating ice that would be most useful
  - Open-ended questions on the relative importance of floating ice characteristics
  - Comment on the SAR parameters that would be most useful to advance the scientific study of sea ice, lake ice, river ice and icebergs
  - Responses received from 60 individuals from 43 different agencies and institutions
- Draft document was circulated broadly in the scientific community and comments incorporated
Results

• Sea Ice
• Icebergs
  – In Open Water
  – In Sea Ice
• Freshwater Ice
  – Lake Ice
  – River Ice
Most Important Sea Ice Questions

1. Thickness and thickness distribution
2. Snow cover on sea ice
3. Ice deformation
4. Other characteristics:
   - Ice Concentration
   - Ice Classification / Type
   - Ice Drift / Motion
   - Melt and Freeze Onset
   - Melt Pond Formation and Evolution
   - Leads and Polynyas
   - Floe Size Distribution
   - Landfast Ice
Most Important Iceberg Questions

• Are iceberg distribution patterns changing and, if so, what are the causes and likely future changes?
  – Automated iceberg detection
    • Small icebergs, bergy bits and growlers
    • Icebergs in sea ice
    • Icebergs in differing sea states
    • Differentiating icebergs from small vessels

• Better understanding of the behaviour of icebergs, particularly their drift and deterioration
  – Individual Iceberg Characteristics
    • Dimensions and mass
    • Calving / melt rate
Most Important Freshwater Ice Questions

- **Lake Ice**
  - The timing of freeze-up and break-up (ice phenology)
  - Ice classification
  - Ice concentration
  - Ice and snow thickness

- **River Ice**
  - The timing of freeze-up and break-up (ice phenology)
  - Ice classification
  - Ice and snow thickness
Summary of Observational Requirements

• Multi-Frequency Observations
  – L-band with either C- or X-band.
  – Little demand for C- and X-band together except to increase temporal resolution.
  – All SAR frequencies available, ideally simultaneously.

• Keep differences in time and incidence angles as small as possible between different satellites providing multi-frequency observation

• Finer temporal resolution
  – Diurnal and tidal effects have an impact on both SAR observation and floating ice properties
  – Approximately 6-hourly intervals are needed to resolve these effects

• Spatial resolution for scientific investigation is typically an order of magnitude finer than for operational use
  – 50-100 metres is common for operational ice charting and NWP
  – 5-10 metres is a more typical requirement for research
Summary of Observational Requirements (cont)

- Minimum polarization requirement is HH+HV and HH+VV
  - Quad-polarization and full polarimetry needed to advance understanding and algorithm and model development
  - Further research is required with compact polarimetry to validate its information content
- Broad range of incidence angles is required
  - Increased interest in assessing steeper angles than have historically been used (<20°)
- Swath width should be as large as possible while meeting the requirements for resolution, polarization and interferometry
- Keep effective noise floor as low as possible (<-35dB) particularly at steep incidence angles and with cross-polarization
Geographic Areas of Importance

- Arctic Ocean, from the Beaufort Sea to Fram Strait
- Canadian Arctic Archipelago
- Entire marine area around Antarctica and extending to the limit of iceberg drift
- Comprehensive coverage of fast ice around the Antarctic ice sheet margins
- Marginal ice zones globally
- The Great Lakes–St Lawrence River system
- Lakes and large rivers of northern North America and Eurasia
- Barents Sea, Baffin Bay, Labrador Sea and around the Antarctic bases (icebergs)

*Particular need for improved sea ice and iceberg information all around Antarctica during the shipping season (including real-/near real-time availability) to aid navigation and logistical resupply of the Antarctic bases*
Satellite SAR Acquisition Strategy for Science Applications

- Aim for a complete coverage of the Northern and Southern Hemisphere ice regions on a daily basis, year-round, at C-band by integrating the baseline acquisition plans of the primary C-band satellites (RADARSAT-2, Sentinel-1, and RADARSAT Constellation Mission)
- Use additional acquisitions by the primaries to provide higher temporal resolution at C-band over particular target areas
- Use acquisitions by other missions, especially X-band, to complement the primaries to increase spatial and temporal resolution
- Overlap acquisitions by non-C-band missions with the primaries to provide multi-frequency observations
- Take advantage of the high revisit time afforded by some satellite constellations (such as Cosmo-SkyMed and TerraSAR-X) to provide specific datasets for individual science projects requiring high temporal resolution
Satellite SAR Acquisition Strategy for Science Applications (cont)

- Acquire SAR data in several frequencies and polarizations for the purpose of comparing with PMR and AMS for cross-assessment and validation to improve our understanding of PMR data
- Undertake specific experiments to investigate the utility of SAR interferometry for measuring floating ice variables
- Design acquisition campaigns over targeted areas to investigate the potential of high-resolution quad-pol, compact polarimetry and fully polarimetric data
- Coordinate acquisitions with known field campaigns - surface and/or aircraft - where possible
- Target geographic areas that not only feature the ice characteristics of interest but are also synergistic with surface and airborne research campaigns and commercial activity (assuming that information-sharing agreements can be reached).
Conflict and Collaboration: Opportunities for Data Sharing

• Significant concern of the scientific community is that the need to acquire data for commercial activities will reduce the quantity and variety of data available for research.
• Data providers have legitimate concerns that making commitments to supply data for science will hurt their business cases.
  – known and repeatable data, processing and analysis techniques
• SAR data providers should recognize the benefits of working together and seek ways to maximize the collaboration between the commercial and scientific communities.
  – identify opportunities, bring parties together, facilitate agreements for data sharing and data release
General Recommendations

- Near-simultaneous observation by different sensor types (passive and active, operating in the optical, thermal, and microwave parts of the electromagnetic spectrum) is necessary to characterize many important sea ice processes.

- It is at the regional modeling level with high spatial and temporal resolution that SAR products provide their greatest support to human infrastructure.

- Scientific advancement in the use of SAR data could benefit from closer collaboration between operational ice services and research institutes dealing with floating ice.

- A vast quantity of satellite SAR data has been collected and saved but much of it remains inaccessible to the research community. Government and private holders of SAR data should be encouraged to make their data accessible to the scientific community.

- Field data, while challenging to acquire, are an essential component of remote sensing research. International collaboration is of great benefit in these efforts but needs continuing support.

- Closer coordination of data acquisition and distribution among satellite operators and data providers would be highly beneficial to the scientific community (central portal for access to data?)
Thankyou