Future Mission Requirements for Ice and Land Applications

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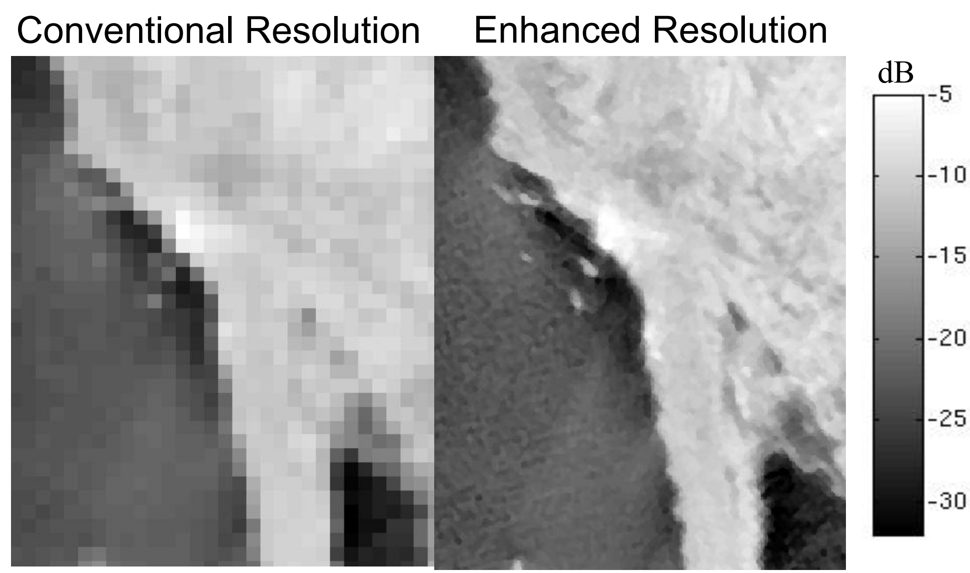
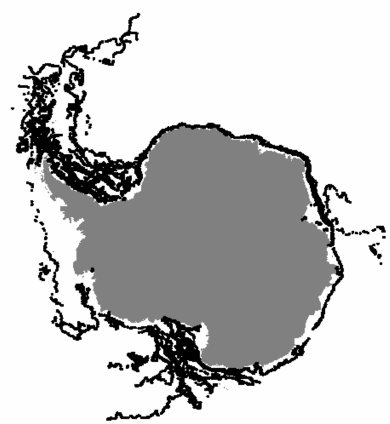
Scatterometers as Land & Ice Observation Instruments

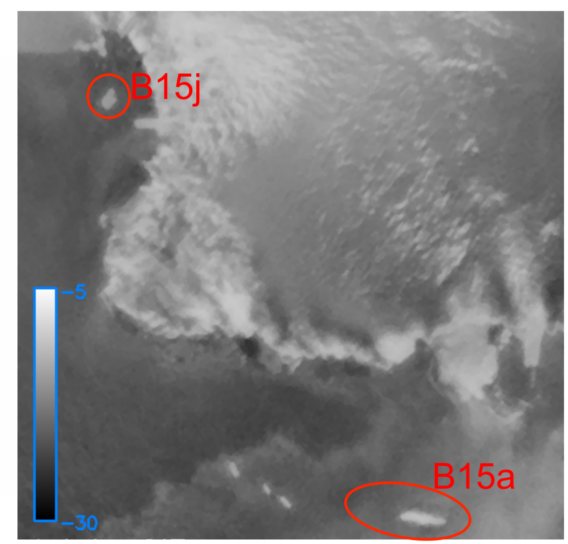
- Scatterometers are designed to measure *vector winds* to support long-term climate and air-sea interaction studies
- Also collect radar backscatter measurements over land/ ice with frequent, all-weather global coverage
  - Backscatter is very sensitive to **liquid water**, **vegetation** characteristics & **scattering mechanisms** (**roughness**)
- Scatterometer backscatter data uniquely supports studies of land and ice
  - Frequent, global coverage help place high resolutions in larger context

“Other” Scatterometer Applications

- **σ^0 imaging**
  - Conventional resolution
  - Enhanced resolution
  - Scattering mechanism
    - Oil spills
    - Volume & surface scattering
- **Ice**
  - Sea ice extent/motion
  - Freeze/thaw state
  - Iceberg tracking
  - Ice “winds”
- **Land**
  - Vegetation
  - Urbanization
  - Flooding
  - Sand dunes

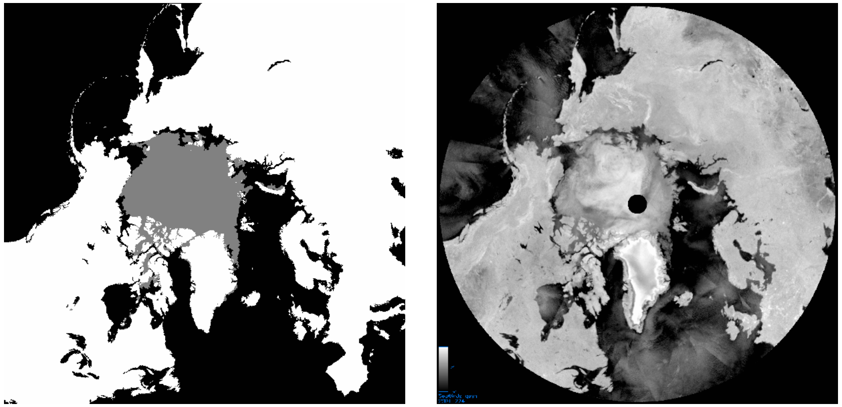




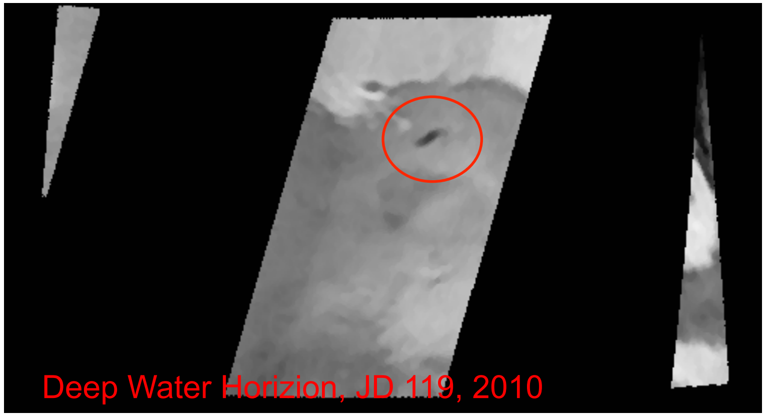


Some Land/Ice Scatterometer Products

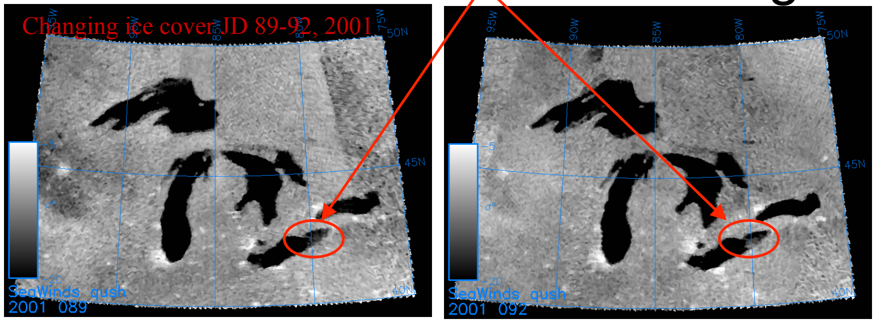
- Sea ice extent & motion



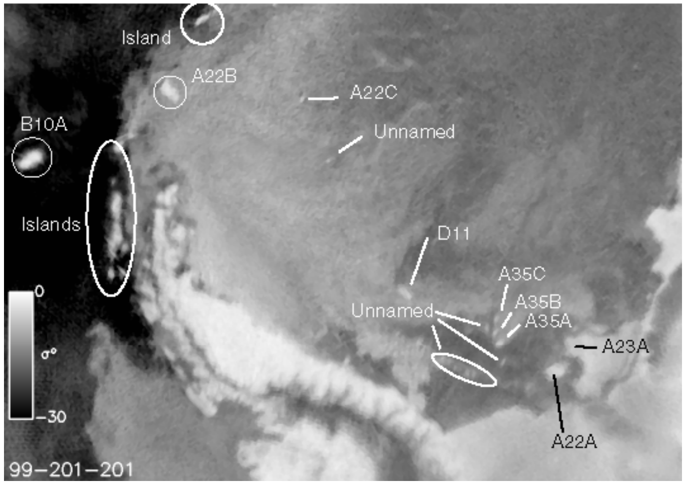
- Oil spill monitoring



- Great Lakes ice monitoring

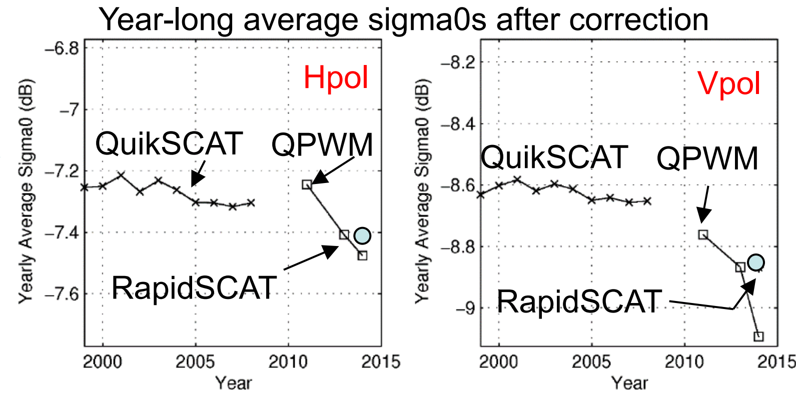


- Iceberg tracking

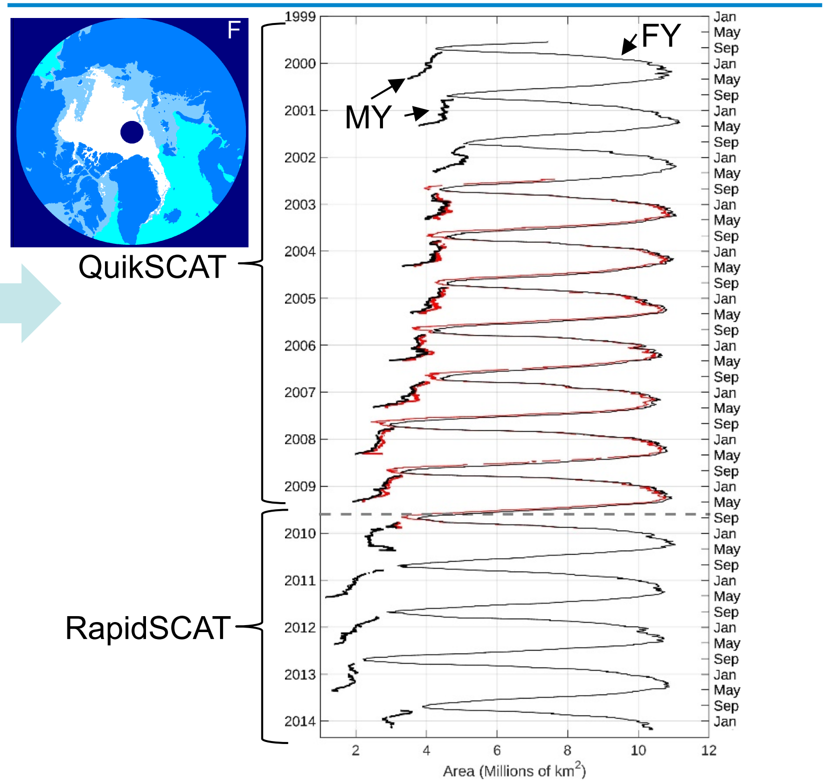


Scatterometers as Land & Ice Climate Observation Sensors

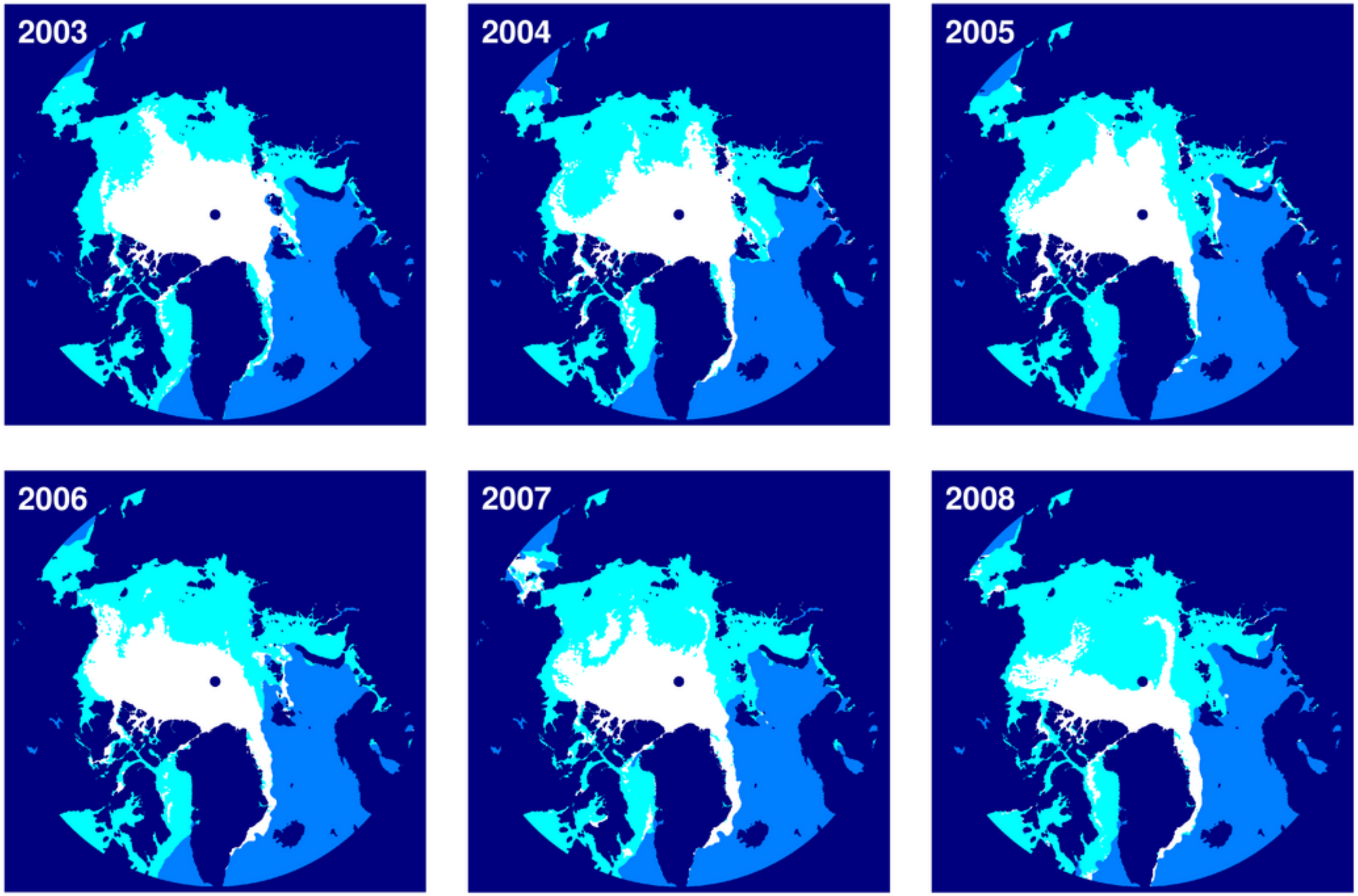
- Long time series of Ku- and C-band surface backscatter
  - Scatterometer Climate Record Pathfinder (SCP) has generated high resolution backscatter maps on consistent grids for all sensors



- Ku-band scatterometer measurements useful for **discriminating First-year (FY) and Multi-year (MY) ice**
  - Together QuikSCAT and OSCAT yield a 2 decade long time series of FY/MY sea ice maps

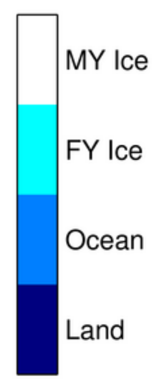


- **Long climate series**



Sea ice Thickness (FY/MY) Mapping

From QuikSCAT

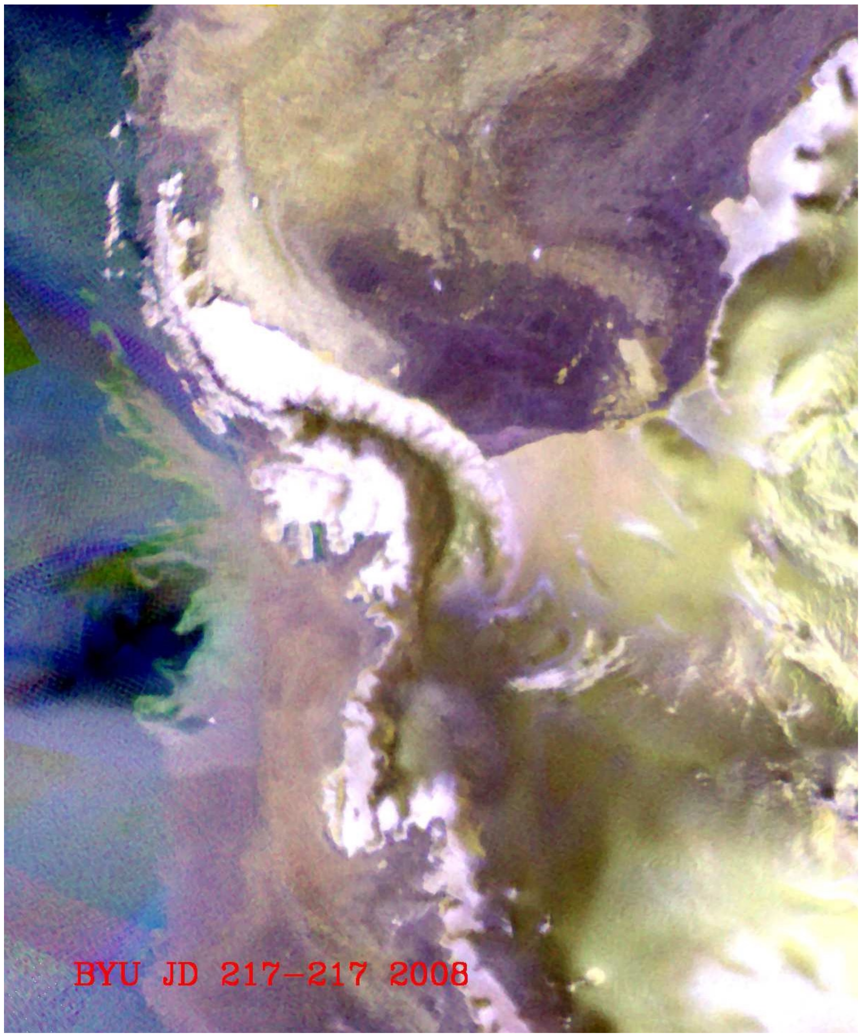


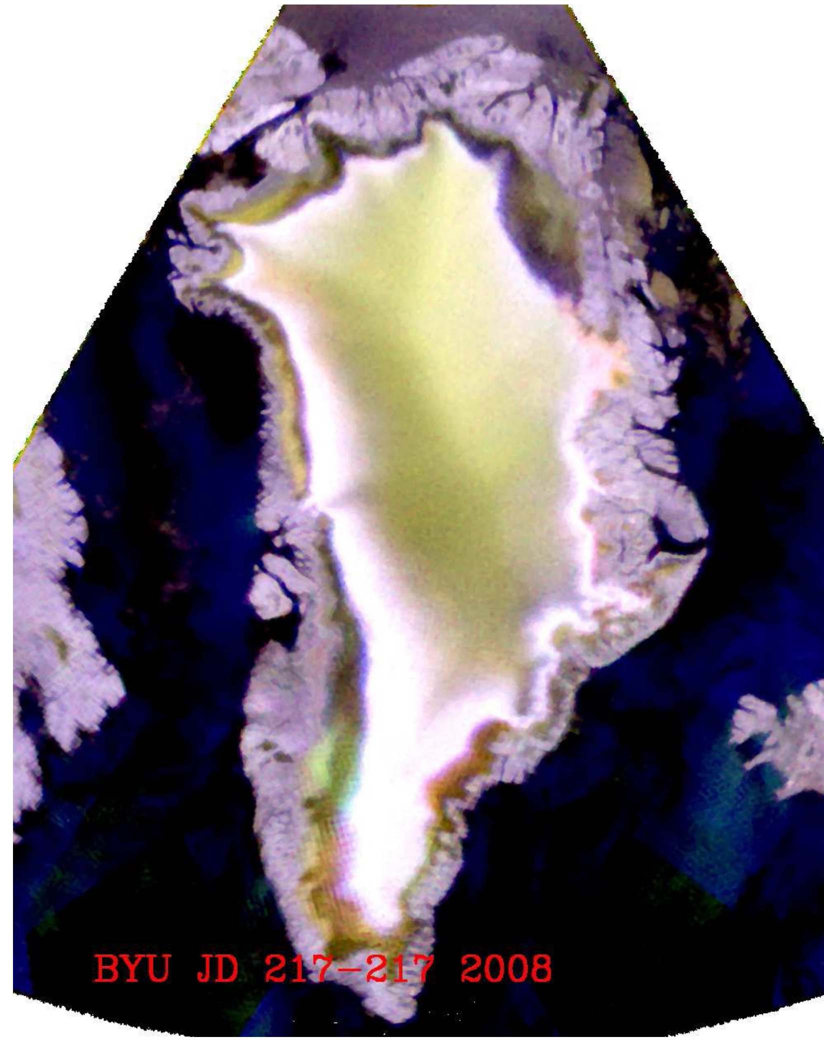
Land Scatterometry

- Multiple frequencies/polarizations can provide greater insight into surface scattering mechanisms – and thus geophysical properties – than single channel systems
  - Higher resolution capability benefits ice edge, oil spills, urban applications, near land/ice winds
  - Increased sensitivity to snow & ice freeze/thaw state
  - ***New insights and new science***

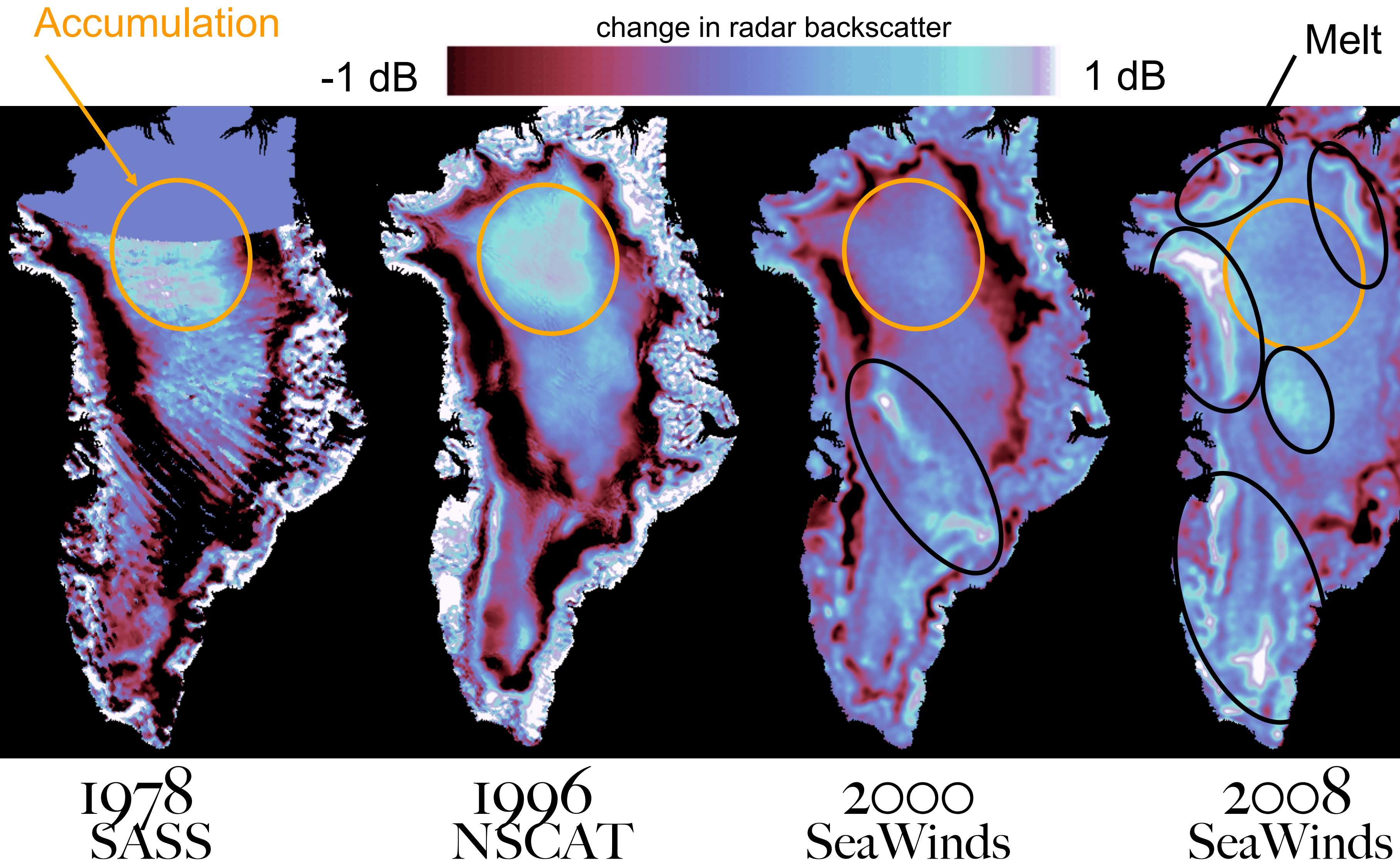
Dual-frequency Scatterometry

- False color image (JD 217, 2008) from **Ku-band** QuikSCAT and **C-band** ASCAT.
  - Red: QuikSCAT h-pol σ^o at 46º
  - Green: QuikSCAT v-pol σ^o at 45º
  - Blue: ASCAT v-pol σ^o at 40º





Greenland Multi-Decade Change

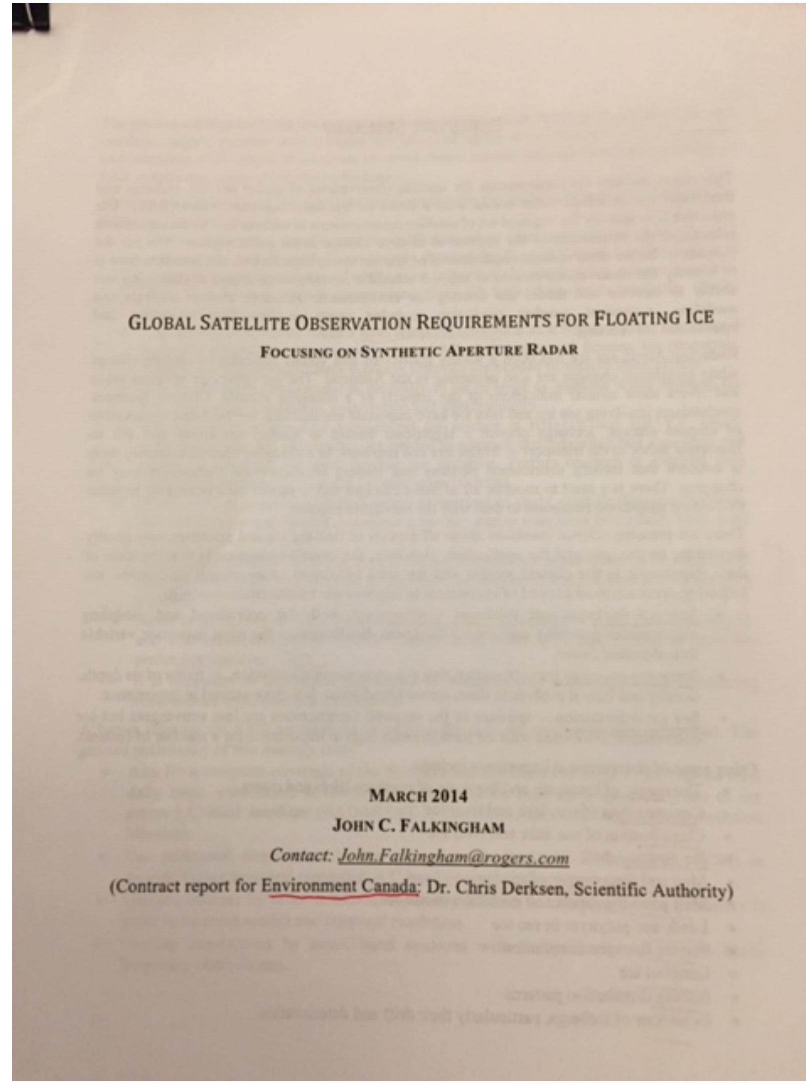


Sample Scatterometer Land/Ice Applications

Key advantages of scatterometry for land/ice observation:
- Global coverage
- Frequent (often better than daily) revisit times
- Long data record (40 yrs: back to 1978 with gaps)
- Multiple azimuth angles and polarization
- Complements passive microwave observations w/higher resolution
- Helps place high resolution SAR observations in larger context

Sea Ice Requirements

- Report from Environment Canada
  - John Falkingham, 2014
- SAR-centric (high resolution, low frequencies)
- Reasonable start point



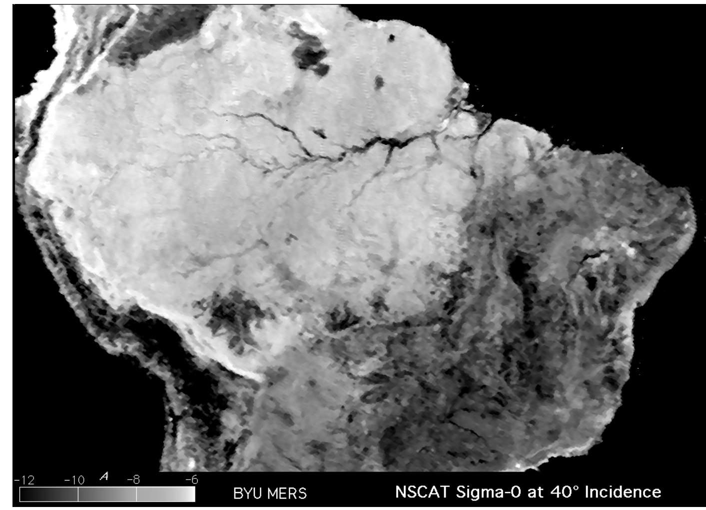
Summary
Sea Ice Requirements

- Polar regions
- 1 day repeat
- Multi-polarization
- Multi-incidence angle (10-50 deg)
- Accuracy:
  - Mean: < 0.1 dB
  - STD: < 0.15 dB
- Resolution:
  - (model resolution 1-3 km)
- Multi-azimuth for polyna winds

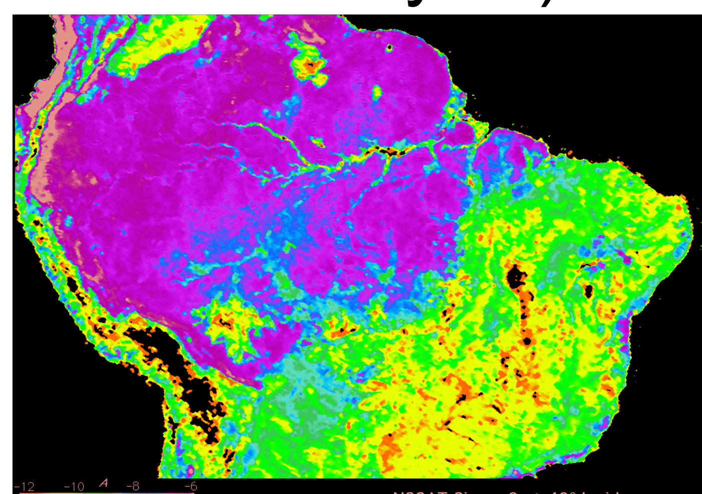
Systems Capabilities		Requirements	Goals
Horizontal cell size		5km	>5km
Mapping uncertainty		1km	0.5km
Ice Products:			
1. Ice Type/Age	Range	Ice free, perennial, all other ice	Ice free, perennial, all other ice
	Uncertainty	10% RMS of daily area error on perennial ice classification 20% RMS of daily area error on all other ice classifications	5% RMS of daily area error on perennial ice classification 10% RMS of daily area error on all other ice classifications
1. Ice Extent	Range	Total ice extent mask	Total ice extent mask
	Uncertainty	20 % RMS of daily area error	10 % RMS of daily area error
3. Melt Onset/ Freeze-up	Range		Total areas of surface melts & refreeze
	Uncertainty	No requirements	10% RMS of daily area within 3 days of melting/freezing
3. Iceberg Observation (90% of time)	Range		
	Uncertainty: Minimum iceberg size	10km	5km
	Location accuracy	5km	2km
	Size estimate accuracy (1σ RMS in two orthogonal axis)	2km	1km
	Orientation of semi-major axis (for icebergs 15km or longer. 1σ RMS	20deg	10deg
Refresh		Once daily	Twice daily
Latency (raw data delay)		100min	60min
Geographical Coverage		Global sea-ice regions	Sea ice and lake ice regions

Land Requirements

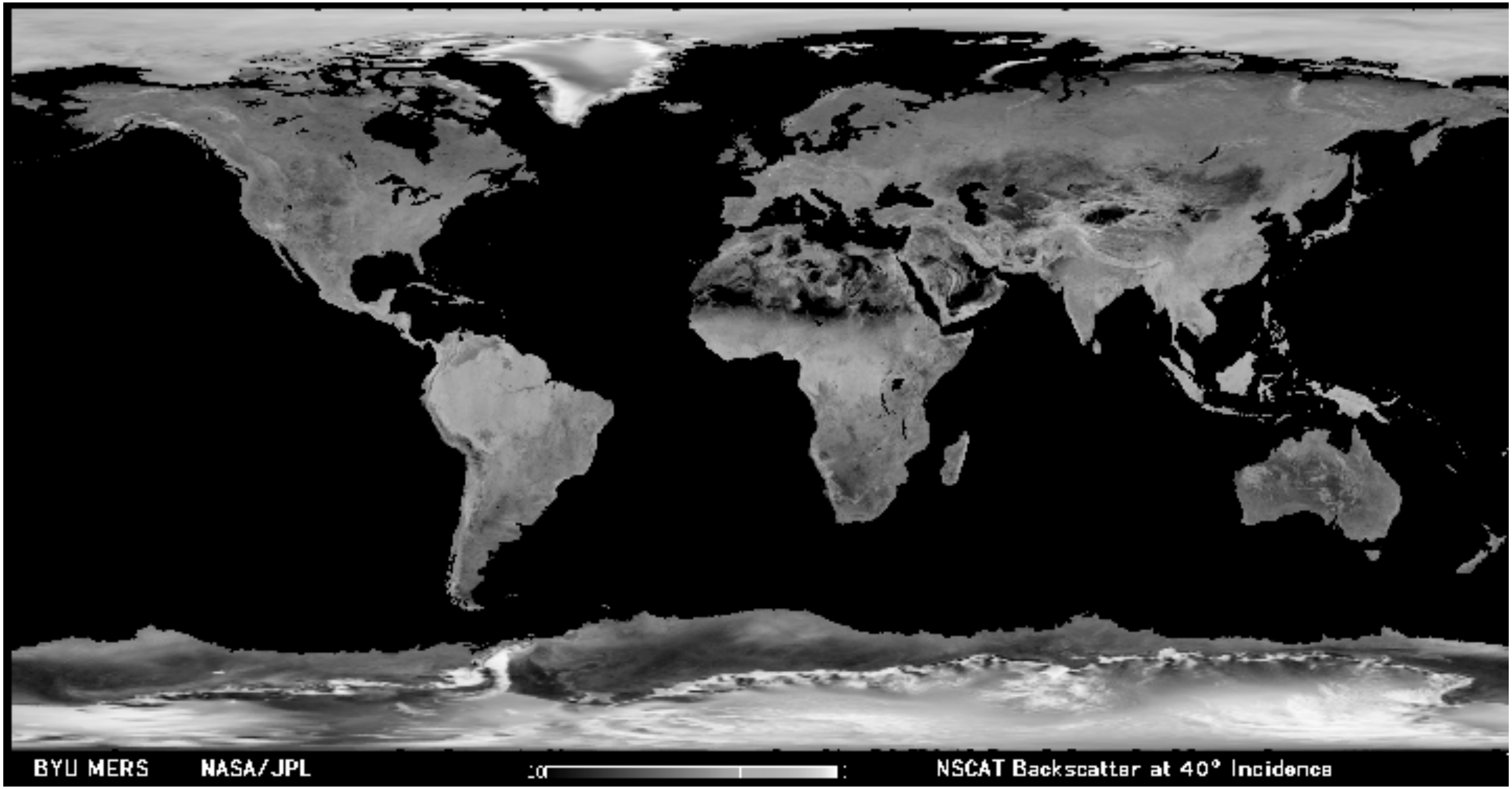
- Daily coverage
- Resolution: (finer is better)
  – TBD: few km
- Accuracy:
  – Mean: <0.1 dB
  – STD: 0.15 dB



- Multi-local-time-of-day (resolve diurnal cycle)
- Multi-azimuth
- Water cycle variables:
  - Diurnal rain, vegetation vigour
- *Add-on capability*



The World at Ku-Band (14 GHz)

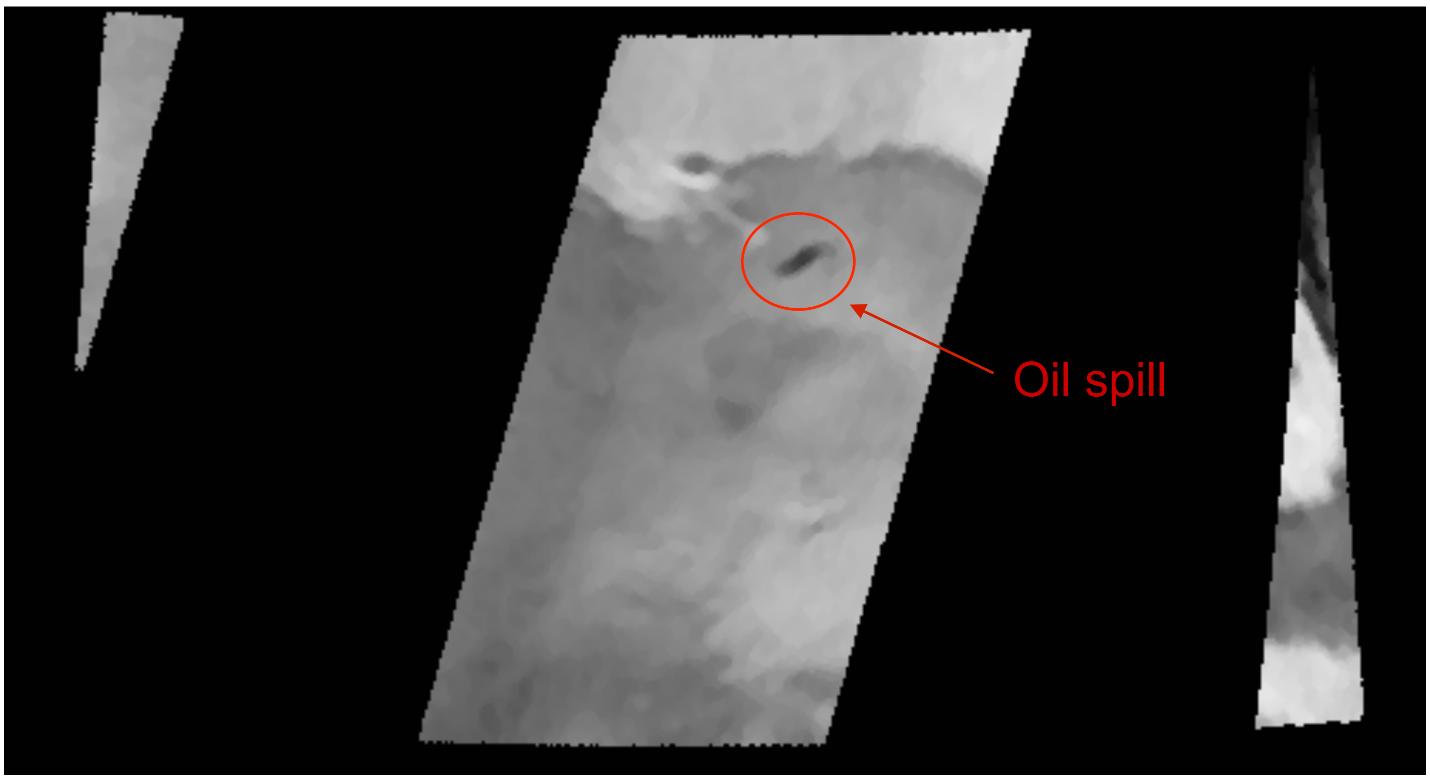


Deepwater Horizon Oil Spill

Enhanced Resolution C-band ASCAT Observations

Oil layer alters wave spectrum, resulting in visible effects in enhanced resolution sigma-0 images

Ka-band oil-spill detection will have higher resolution and be more sensitive than C-band example shown here



JD 119, 2010

Sea Ice Extent

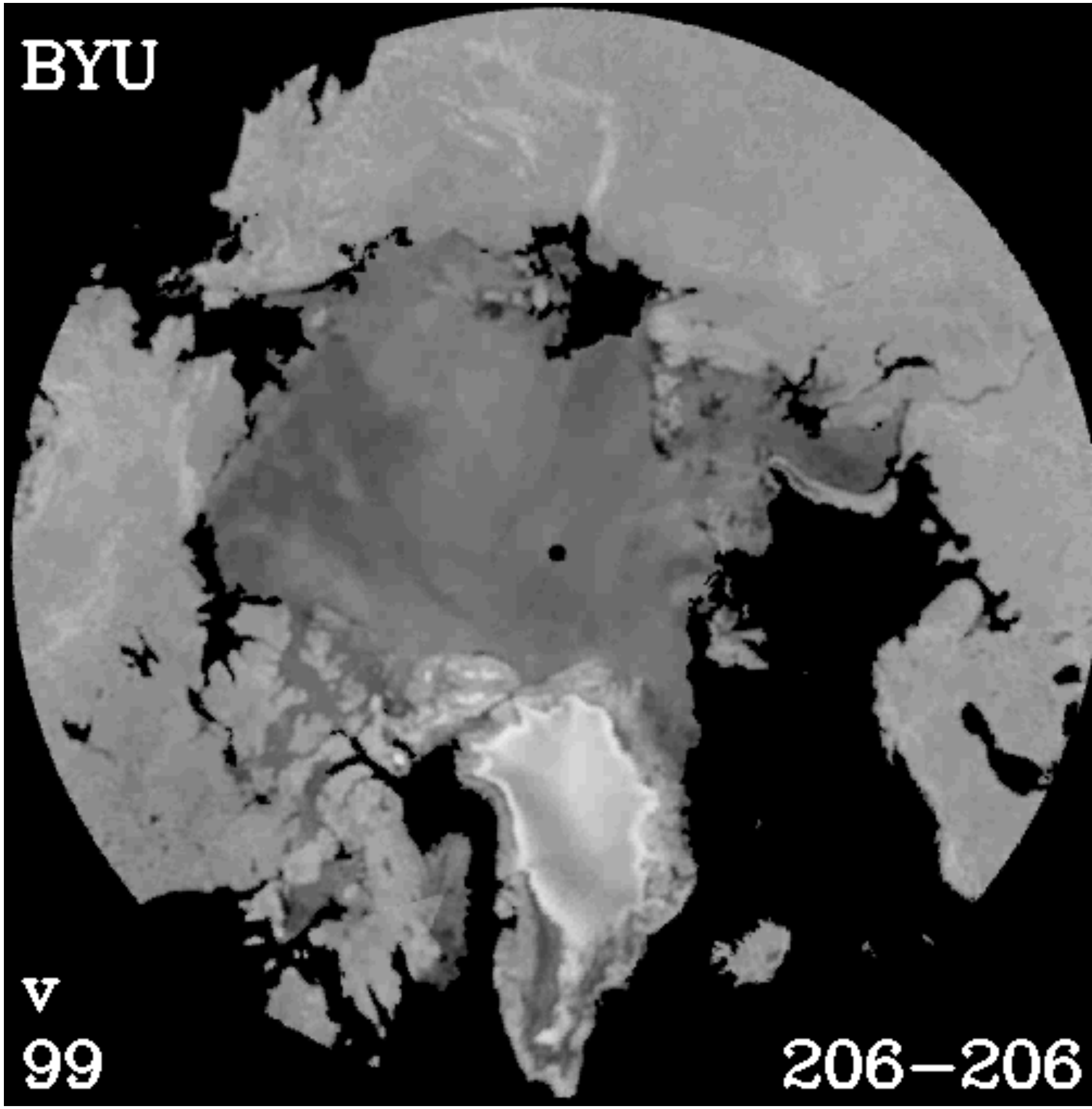
Sea ice mapping vital for shipping & climate studies

Scatterometer data has higher resolution than radiometer data

Can track features within the ice sheet

Ka-band offers finer resolution

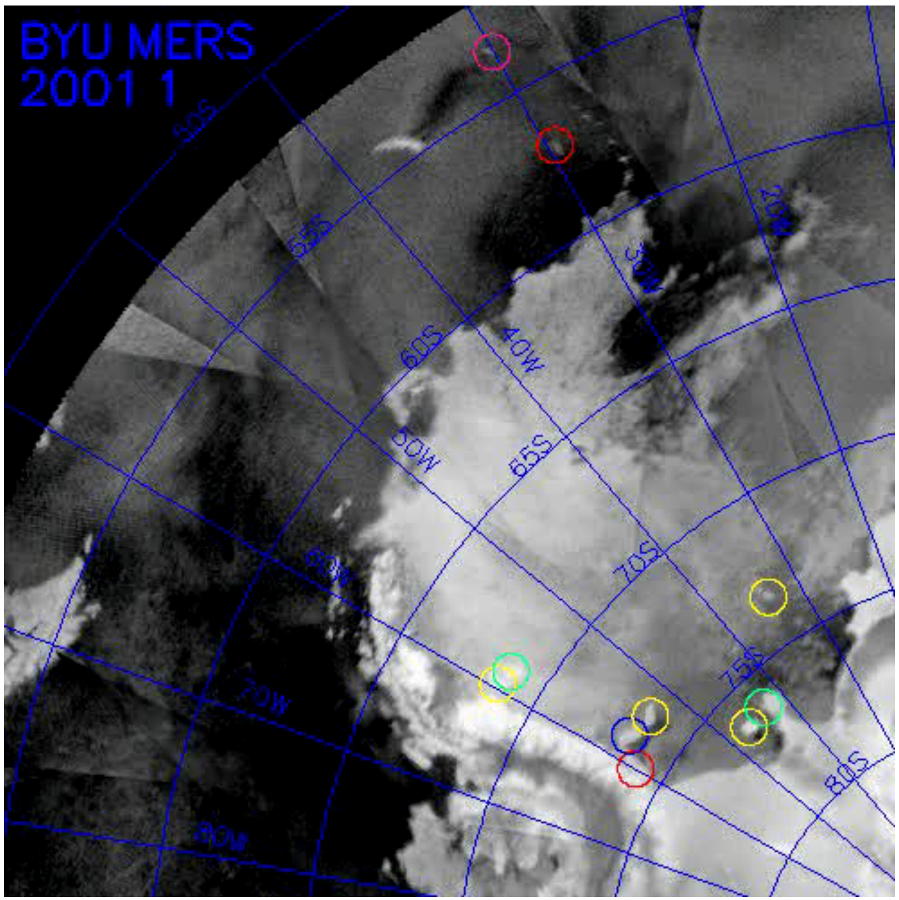
(NOAA/NIC)



year

day

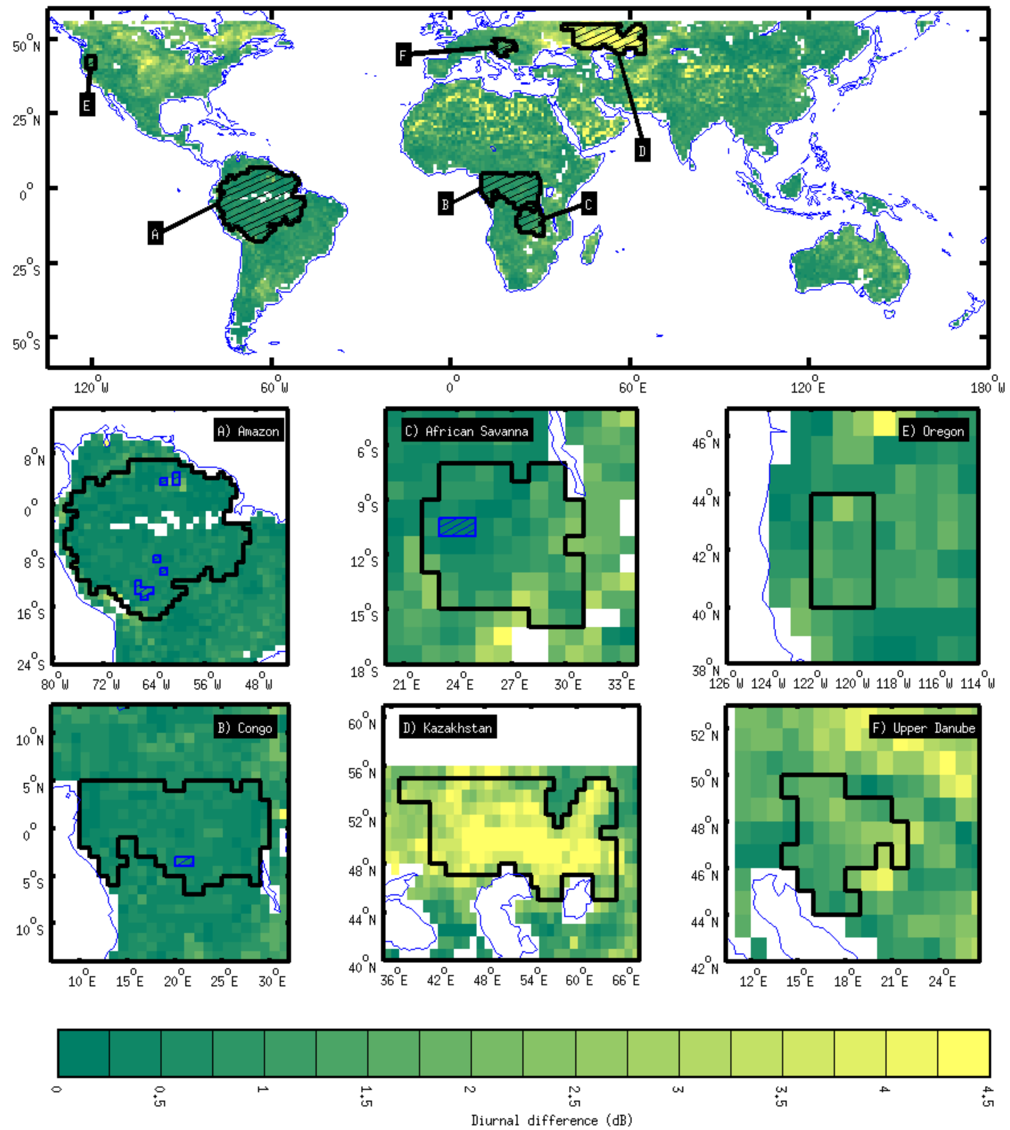
Iceberg Tracking



- Icebergs in radar images
  - Visible due to contrast between ice & ocean
  - Not affected by illumination or cloud cover
  - Tracking likely to be aided by including Ka-band measurements
- Ku- and C-band
- Direct ships to locate and study icebergs *in situ*

RapidSCAT Diurnal Observations of sigma-0 over Land (BYU)

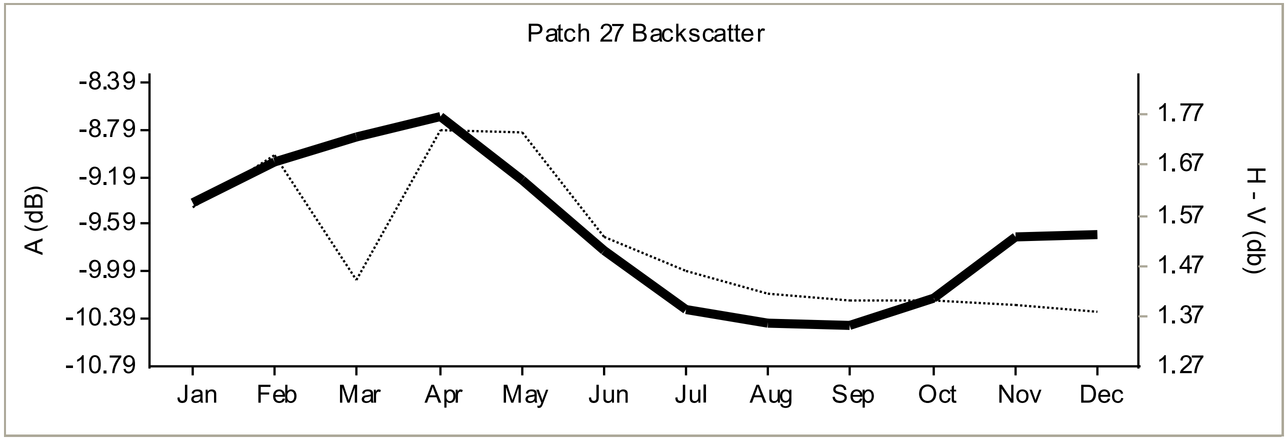
- Past Ku-band scatterometers have measured sigma-0 at different local times-of-day (LTOD)
  - Over land sigma-0 varies with LTOD
- The ISS orbit enabled RapidScat to observe the variation of sigma-0 with the diurnal cycle
  - Enables cross-calibration of the various Ku-band scatterometers
  - Study diurnal vegetation water cycle



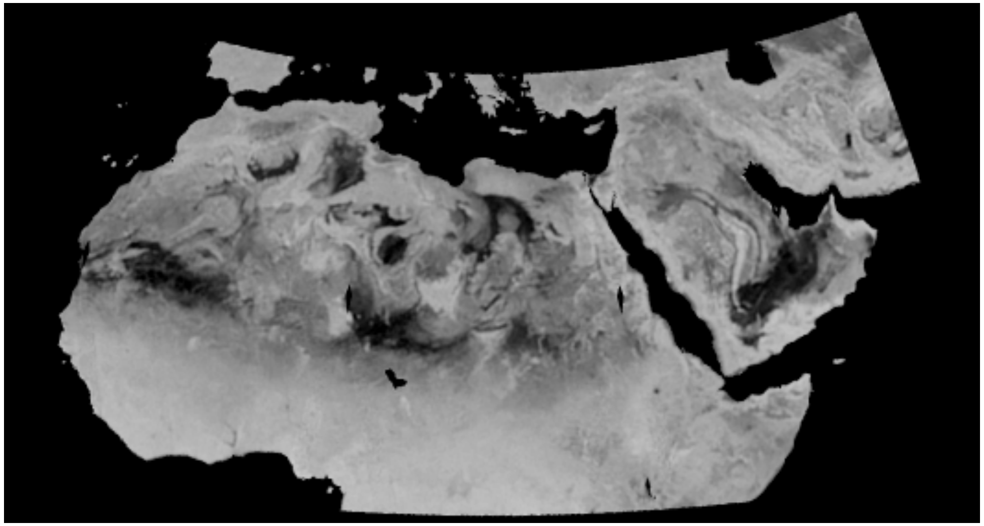
Mapping of inundation

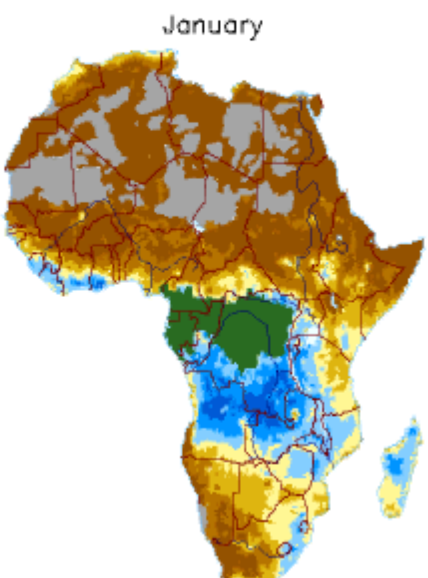
- Grasslands are frequently inundated seasonally. The Brazilian Pantanal is an example.
- During the wet season from October to March, backscatter increases as ground becomes inundated and approaches bright values similar to Tropical Forest. As water recedes, backscatter decreases to yearly lows.

Pantanal during the wet season



Drought & Flood Monitoring
(Malaria Prediction)



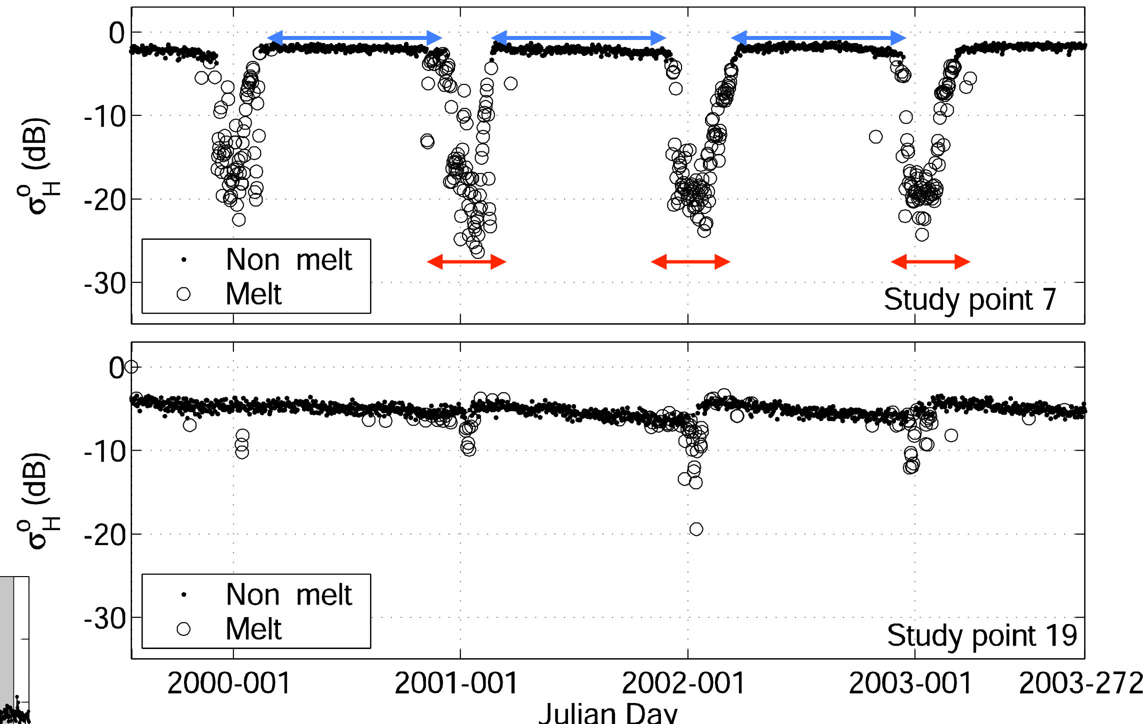


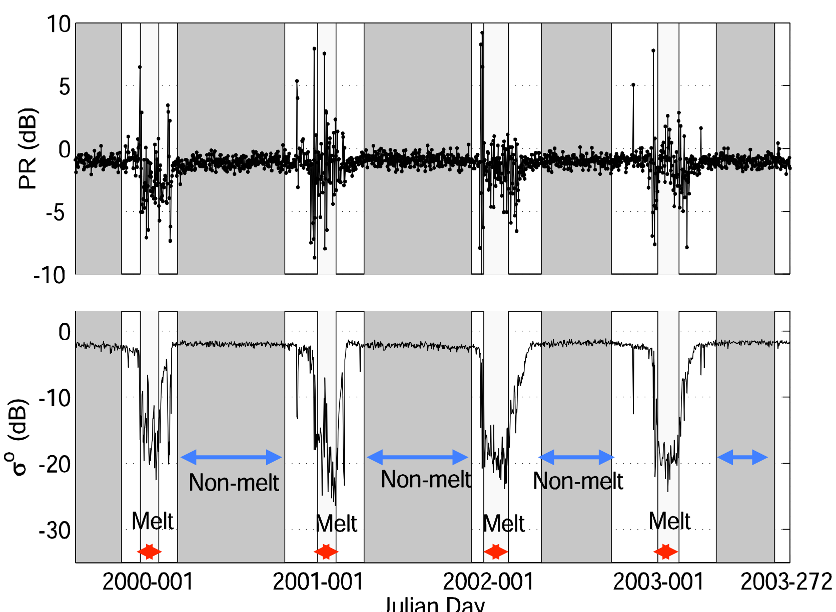
Scatterometer-based mapping of flooding and water inundation is especially useful for malaria risk mapping as mosquitoes begin life as aquatic larvae and adults rarely travel more than 2km from their breeding site in their two to three week lifetime. A number of organizations are using scatterometer data as input to models predicting malaria outbreaks related to flooding conditions.

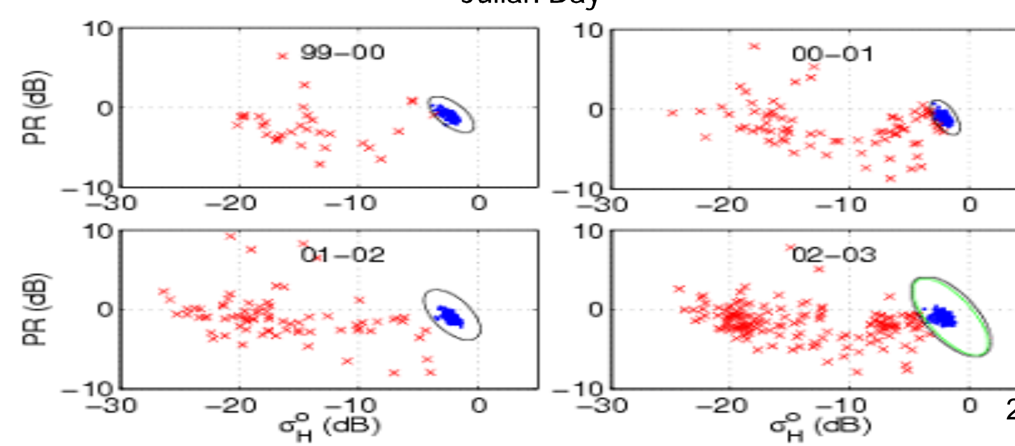
Antarctic Ice Shelf Melt Detection

Example

- Use QuikSCAT backscatter polarization ratio, PR = $\sigma_v - \sigma_h$ (dB), and σ_h time-series
- Compute mean and covariance for specified non-melt and melt periods
- Classify melt state using ML objective function

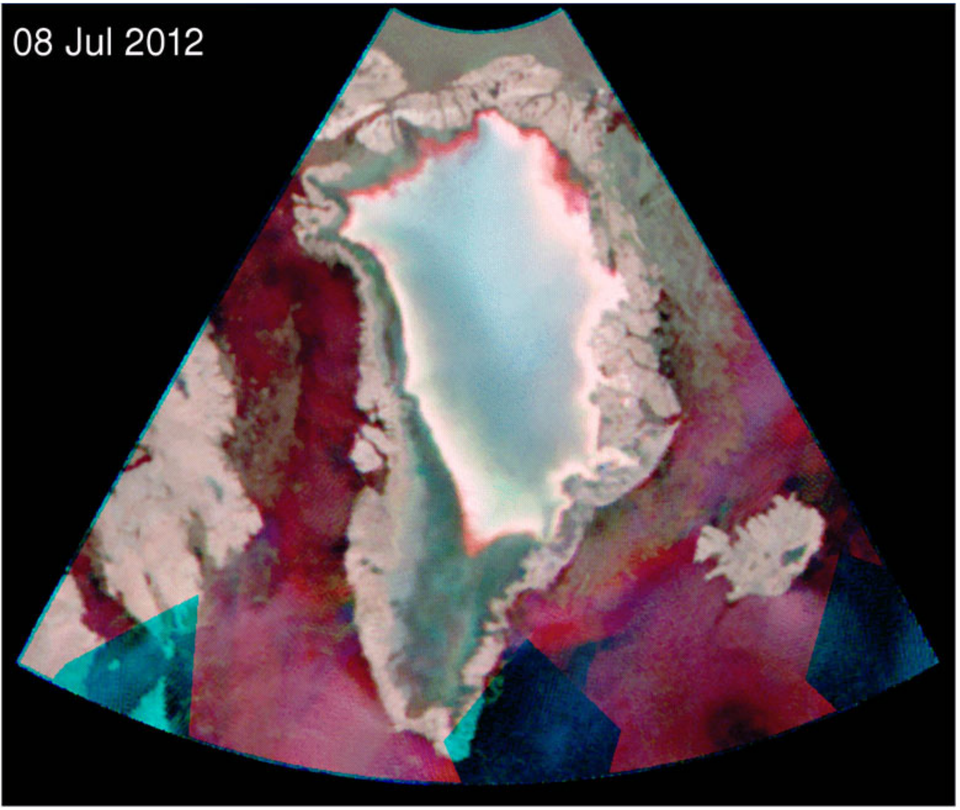


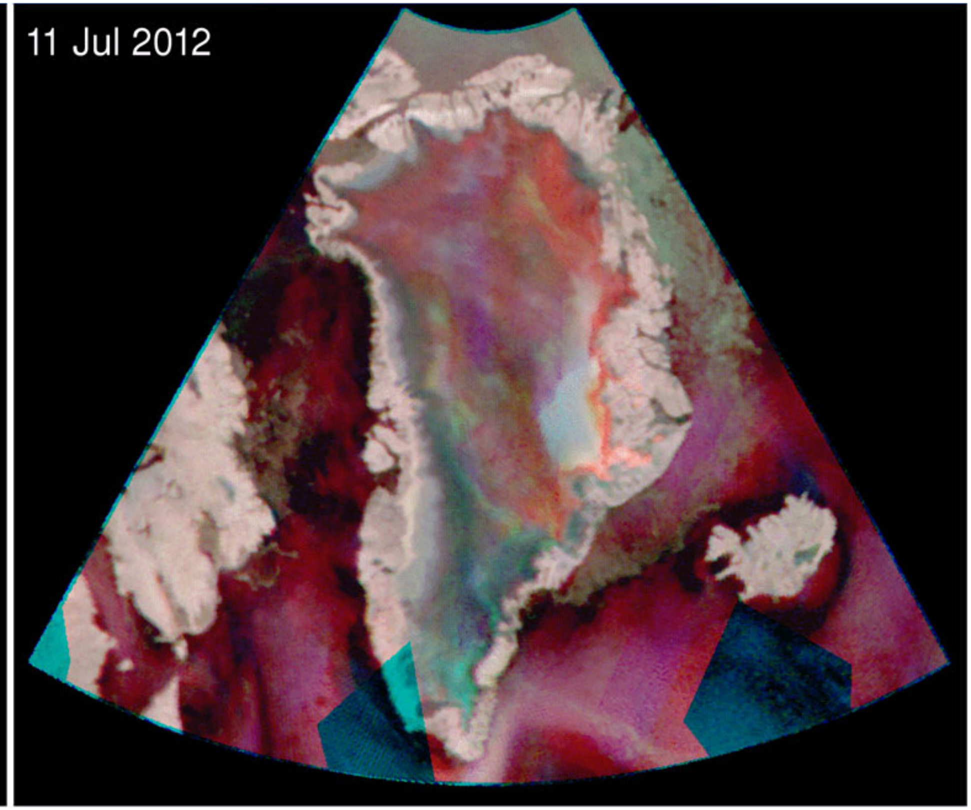




Greenland Summer Melt

During the Summer of 2012, Greenland endured one of the largest areal melt cycle observed in the satellite record. The melt event was recorded by OSCAT and ASCAT.





False color RGB images from a single day of Ku-band data (Oceansat-2 H=Red, V=Grn) and C-band data (ASCAT=Blu). Land shows up as pink-grey. Deep melt is the green. Surface melt is red. Refrozen melt is bright white. Unmelted firn is dark grey/blue.