Land and Ice Applications of Scatterometer Data

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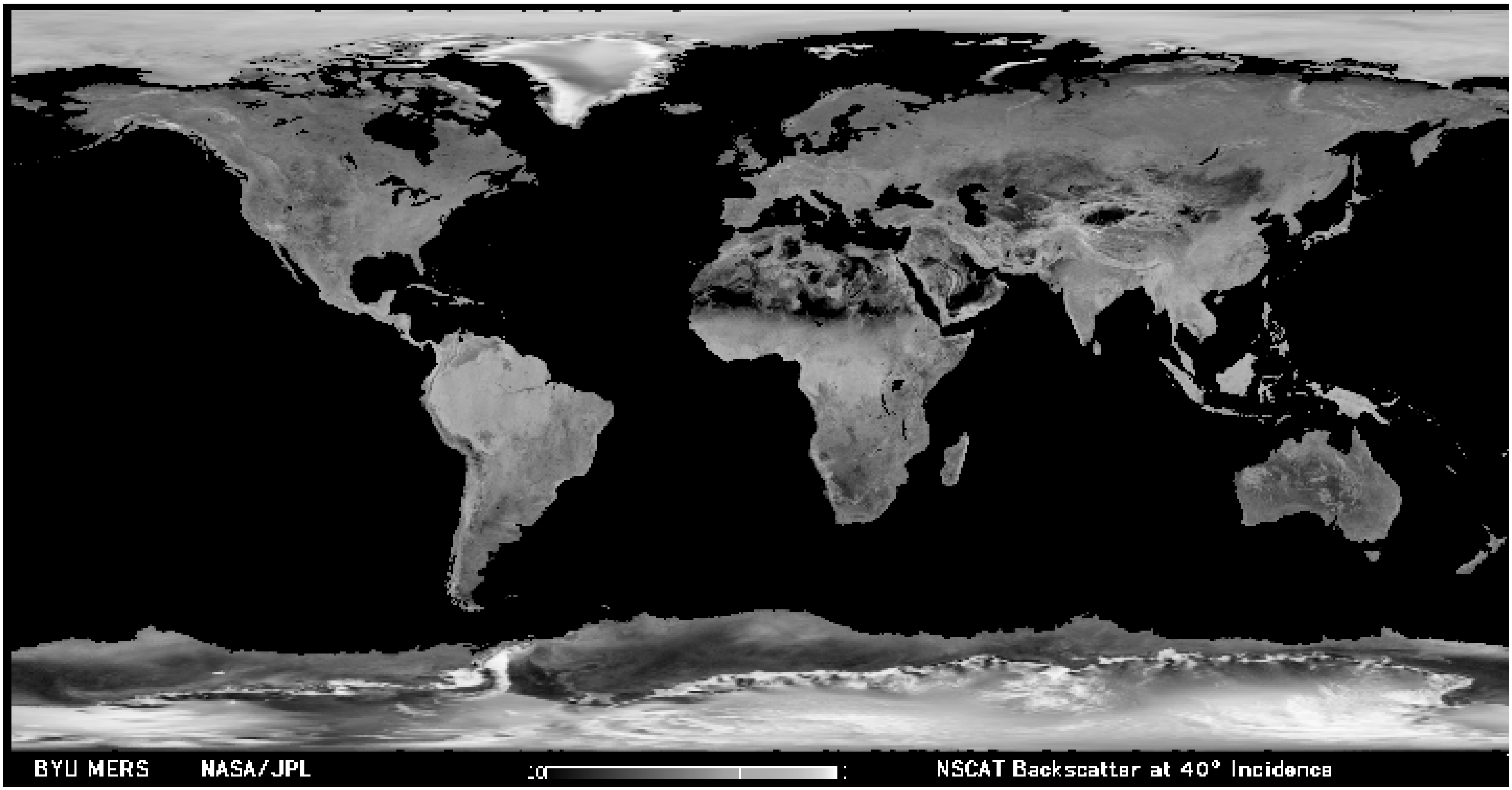
The World at Ku-Band (14 GHz)

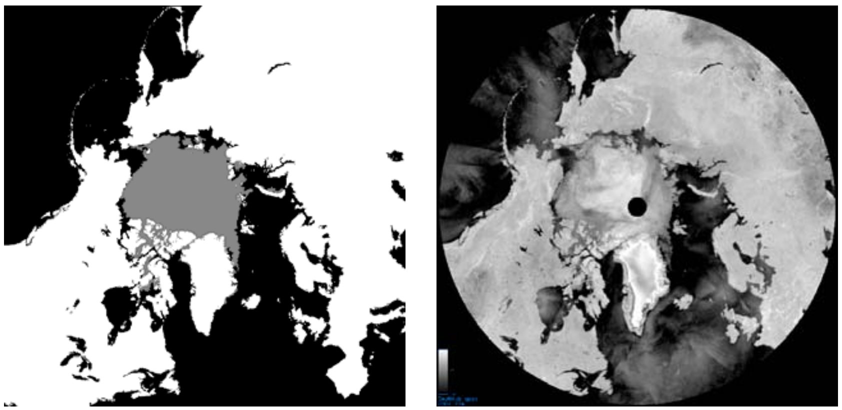


Scatterometers as Land & Ice Observation Instruments

- 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 supports studies of
  - Sea ice extent, age
  - Freeze/Thaw conditions
  - Flooding
  - Oil spills
  - Vegetation mapping
  - Deforestation/change
  - Urban growth
  - "Land/ice winds" (sand and snow dunes)
  - Greenland melt and accumulation

Some Land/Ice Scatterometer Products

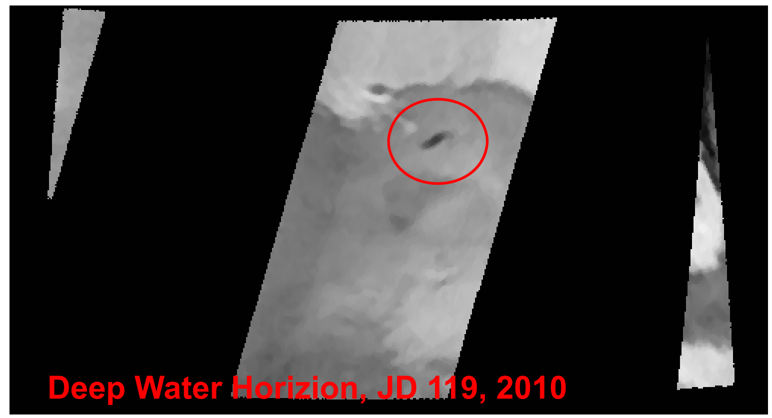
- Sea ice extent & motion



QuikSCAT, OSCAT, ASCAT

- Oil spill monitoring

ASCAT

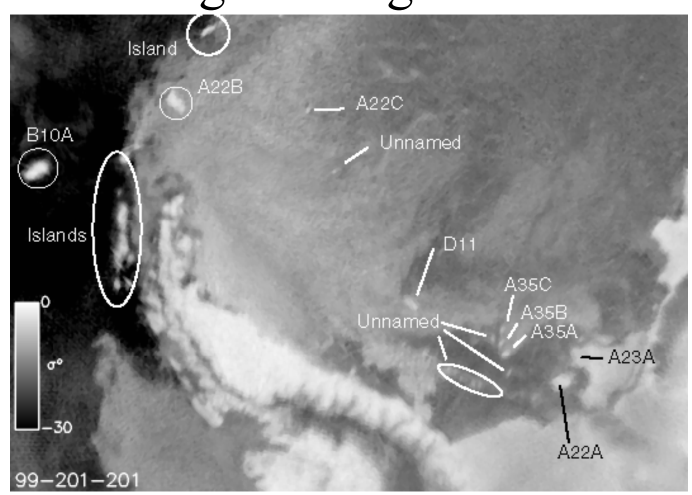


- Great Lakes ice monitoring

QuikSCAT, OSCAT

- Iceberg tracking

QuikSCAT, OSCAT, ASCAT

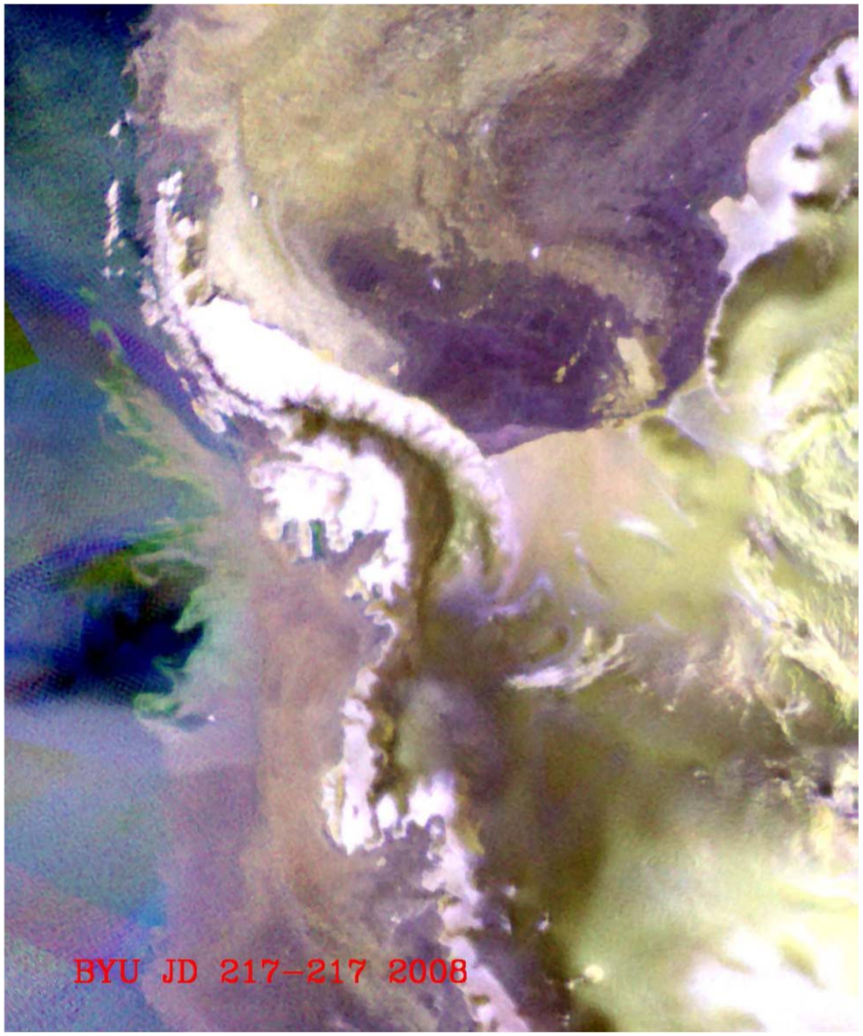


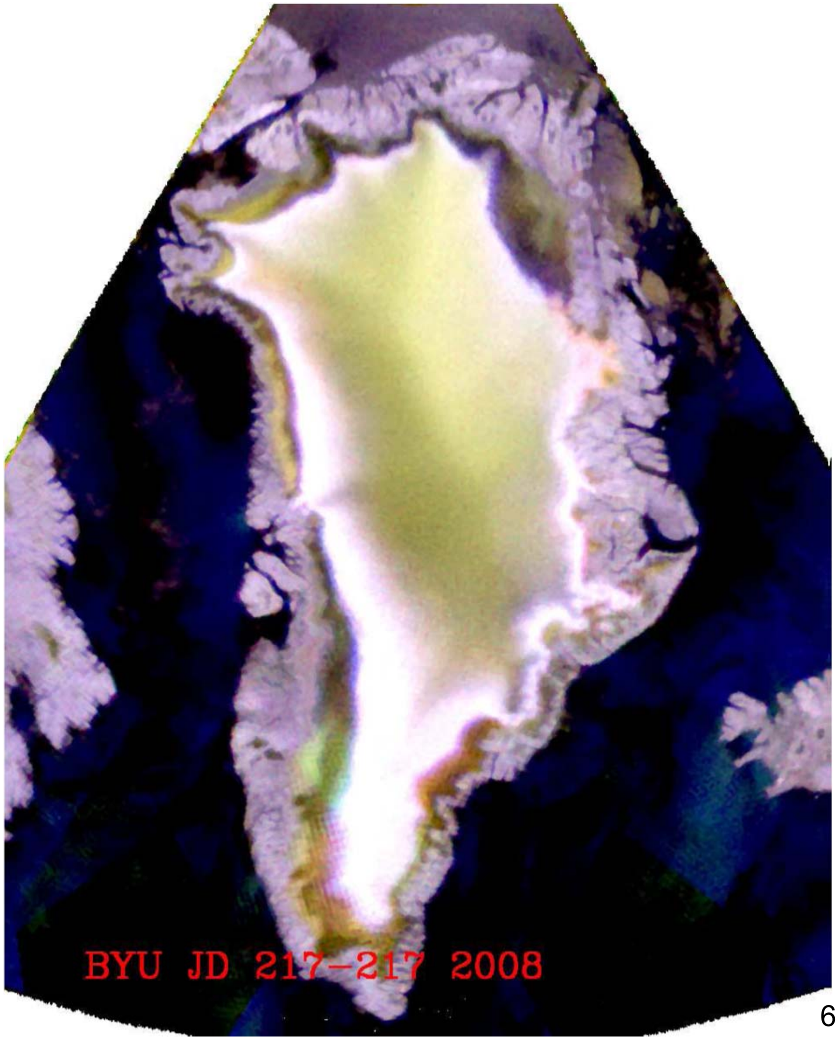
Sea Ice Science

- Sea ice motion related to wind and currents
  - Infer currents (and freshwater transport) from wind and ice motion
- Sea ice characteristics (e.g., ice concentration, thickness, age, snow depth, ponding, drag coefficient, freeze/thaw, sea ice motion) are critical inputs to climate models and studies of air/sea fluxes
  - Scatterometer data has been show to be effective for sea ice observation & to complement passive microwave observations
- Ka-band can enable finer resolution
  - Closer to ice/land wind & flux determination
  - Better sea ice motion inference
  - *Likely* to present new capabilities
    - Further study and validation needed

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





Land Scatterometry

- Multiple frequencies provide greater insight into surface scattering mechanisms – and thus geophysical properties – than single channel systems
- Example land applications at Ku- and C-bands
  - Flooding, snow freeze/thaw, vegetation change, vegetation response to rain and near-coastal winds
- A Ka-band channel offers
  - Higher resolution capability benefits ice edge, oil spills, urban applications, near land/ice winds
  - Increased sensitivity to snow & ice freeze/thaw state
  - May benefit vegetation studies (classification and vigor)
  - ***New insights and new science***

Sample Scatterometer Land/Ice Applications

- Sea ice extent, age
- Freeze/Thaw conditions
- Flooding
- Oil spills
- Vegetation mapping
- Urban growth
- "Land/ice winds" (via sand and snow dunes)
- Greenland accumulation and melt

Key advantages of scatterometry for land/ice observation:

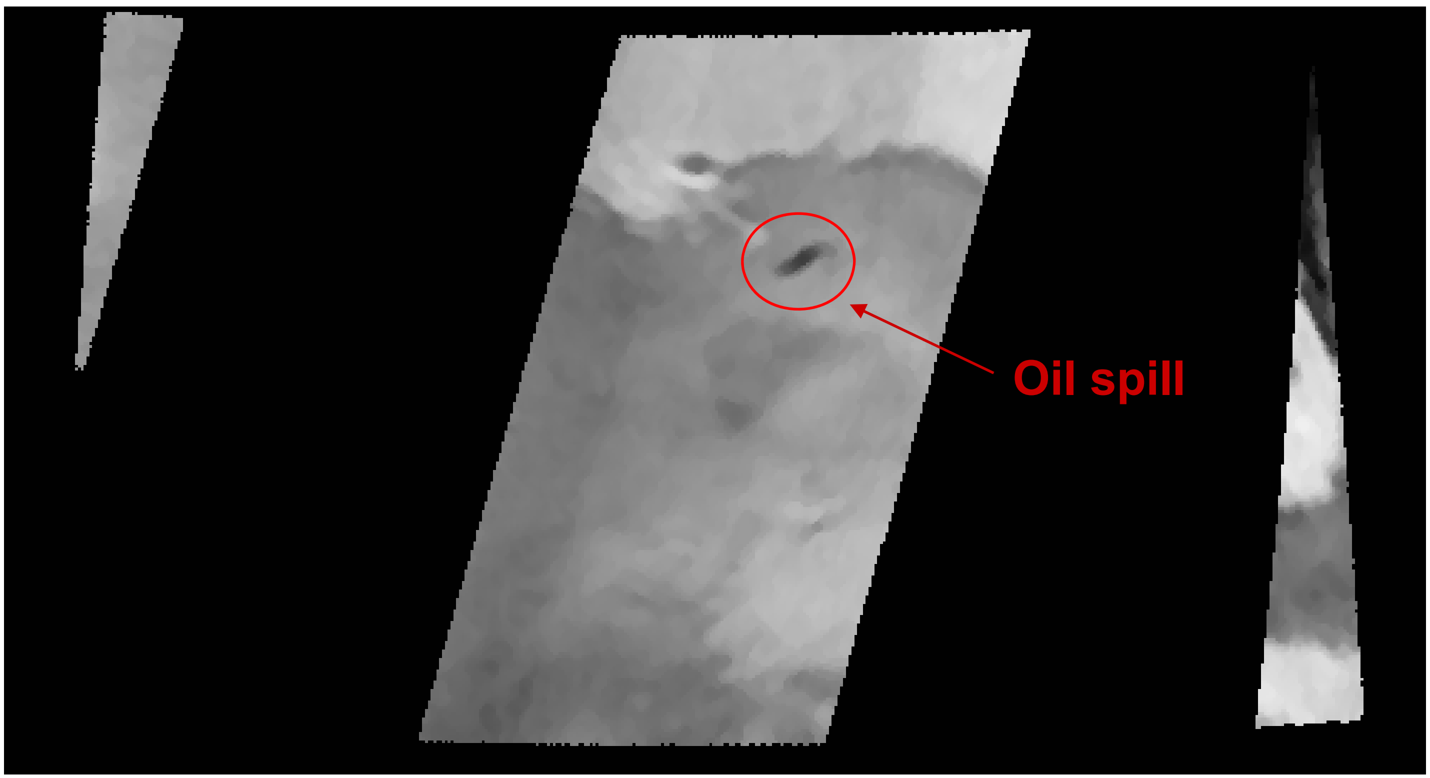
- Global coverage
- Frequent (often better than daily) revisit times
- Multiple azimuth angles and polarization
- Complements passive microwave observations w/higher resolution
- Helps place high resolution SAR observations in larger context

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

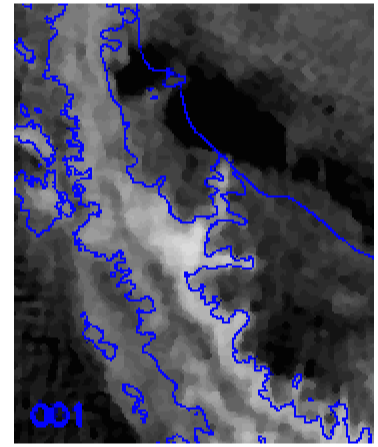


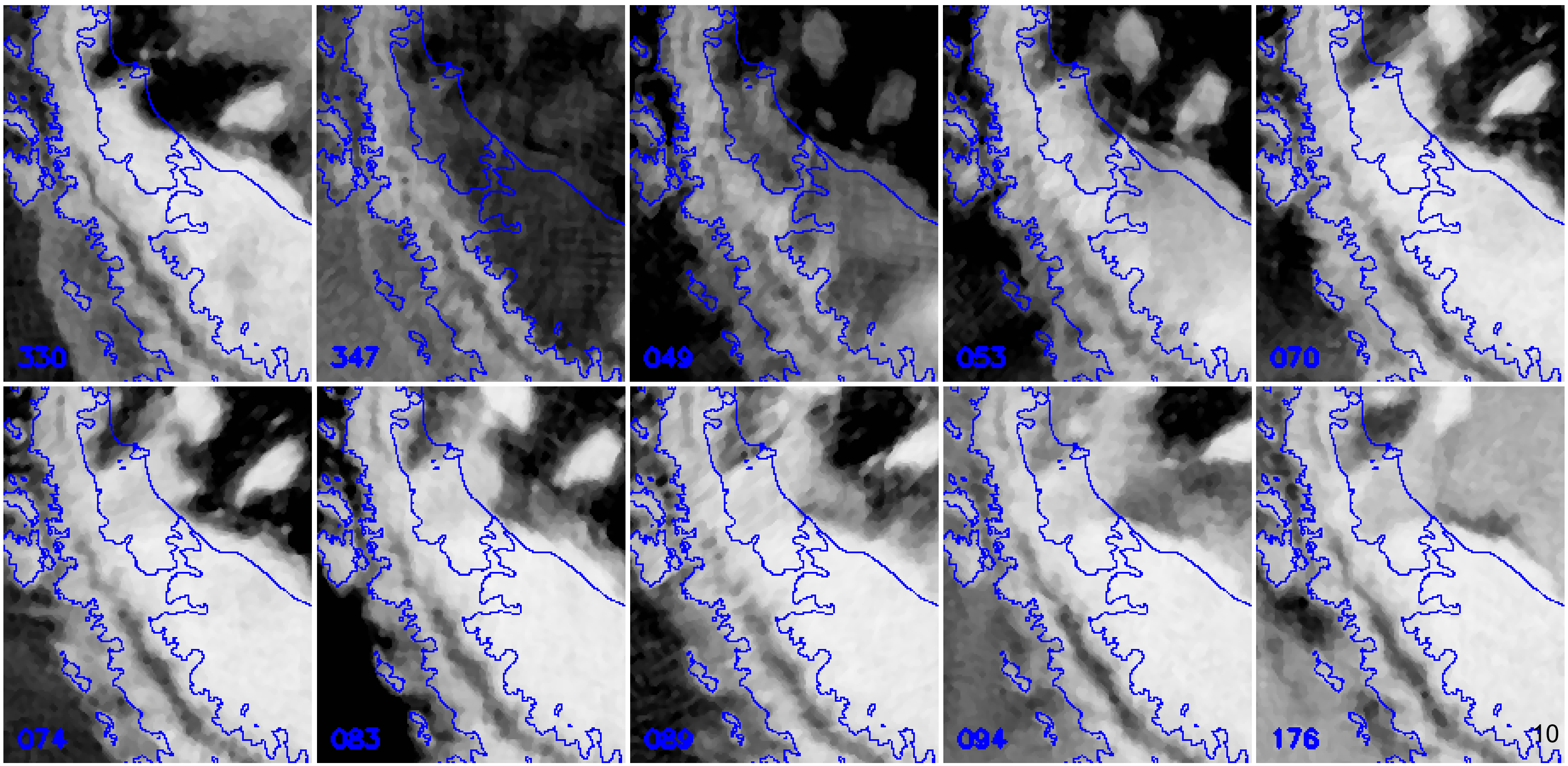
JD 119, 2010

QuikSCAT Observations of the Larsen Ice Shelf Collapse

50 km

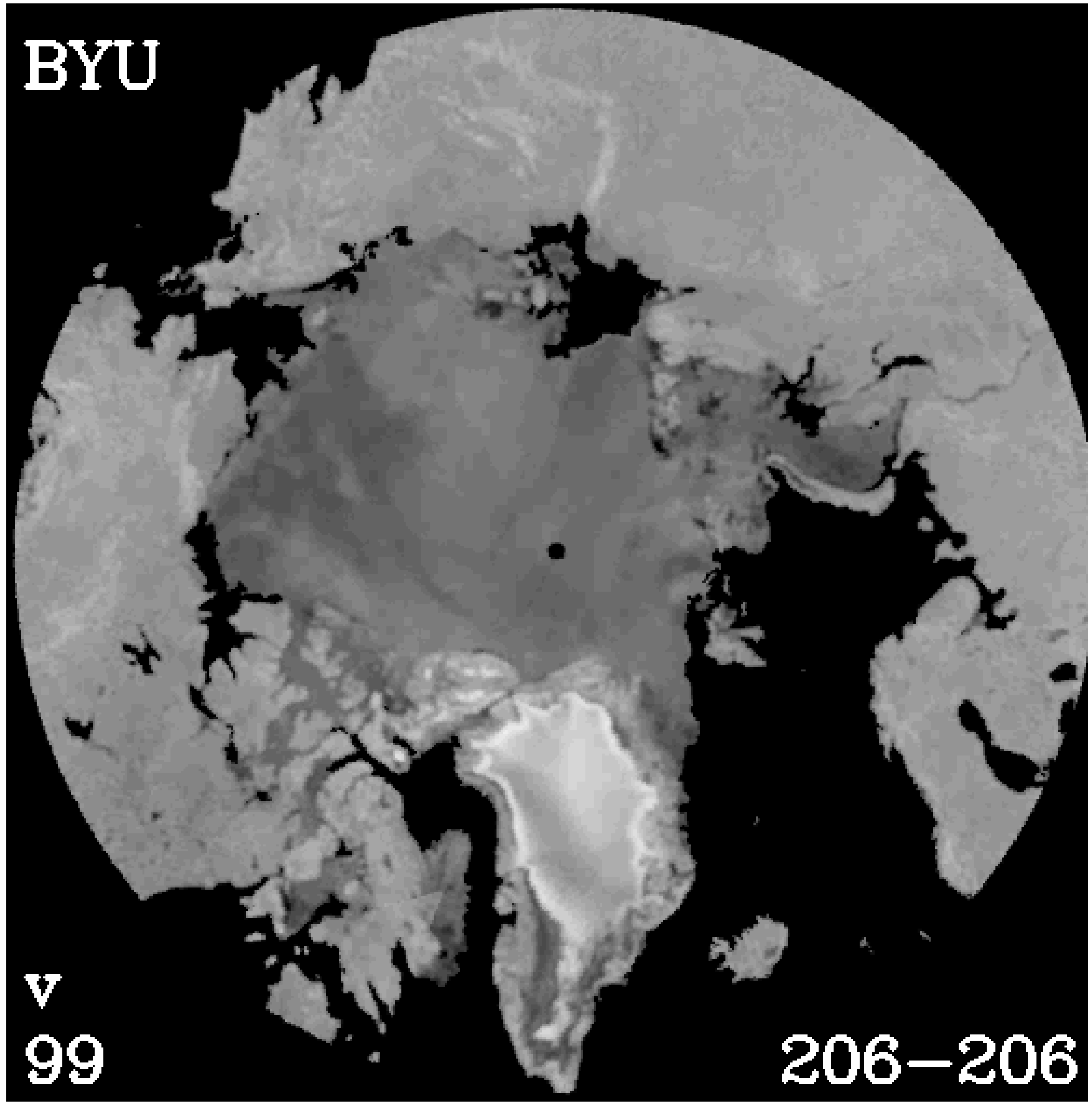
2002



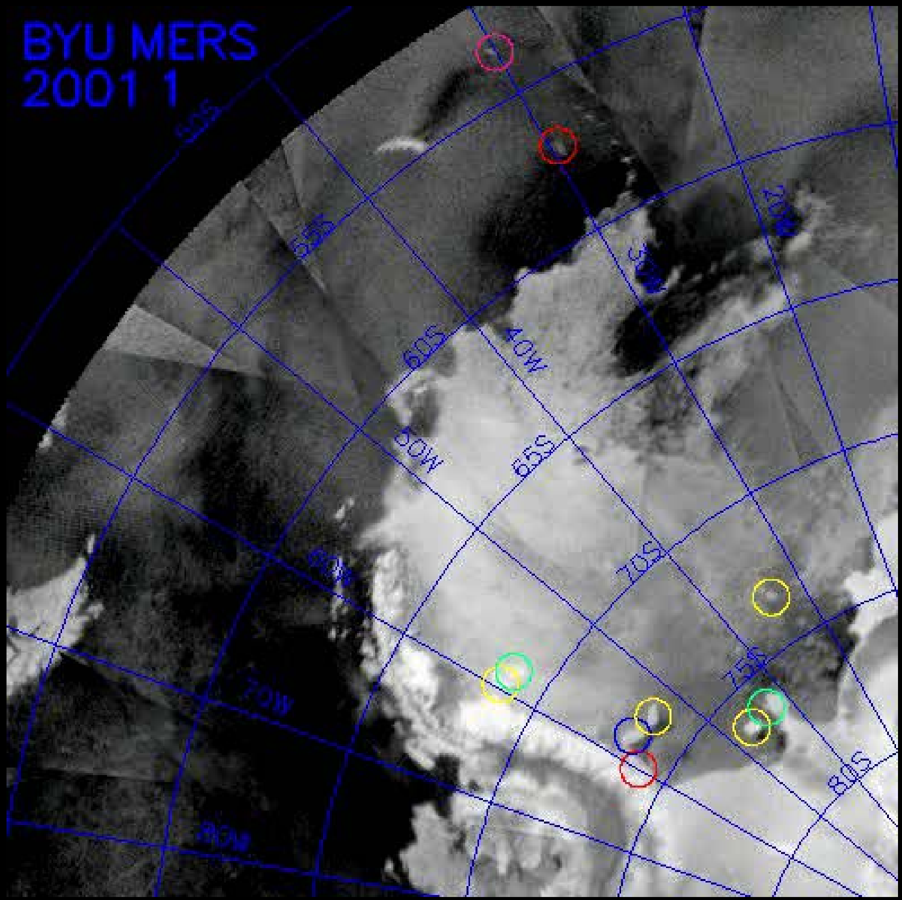


Sea Ice Extent

- 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



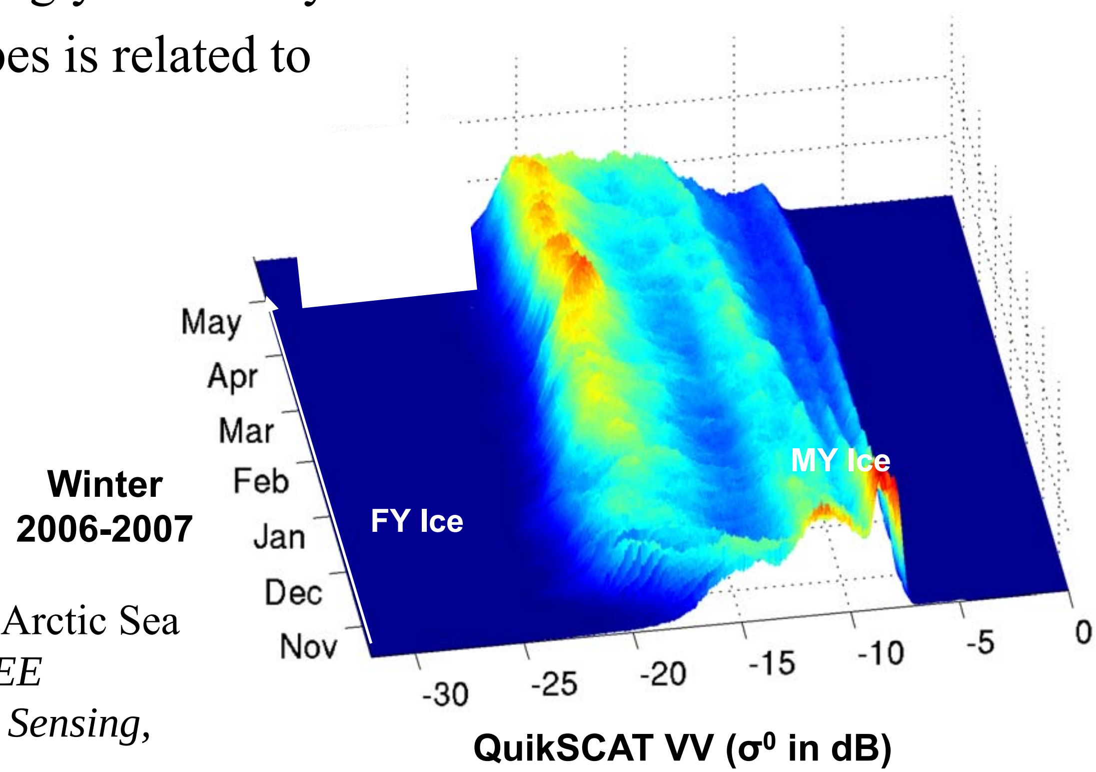
Iceberg Tracking



- 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
- ASCAT iceberg tracking at NOAA using BYU-developed software
- Direct ships to locate and study icebergs *in situ*

QuikSCAT MY Ice Mapping and Temporal Trends in Sea Ice Backscatter

- QuikSCAT sigma-0 histograms (normalized to pdfs) plotted for each day of the year
- Ku-band backscatter is strongly sensitivity to FY and MY ice
- Distinction between ice types is related to
  - Ice salinity
  - Porosity
  - Surface roughness
  - Ridge structure
- Total FY ice grows during winter

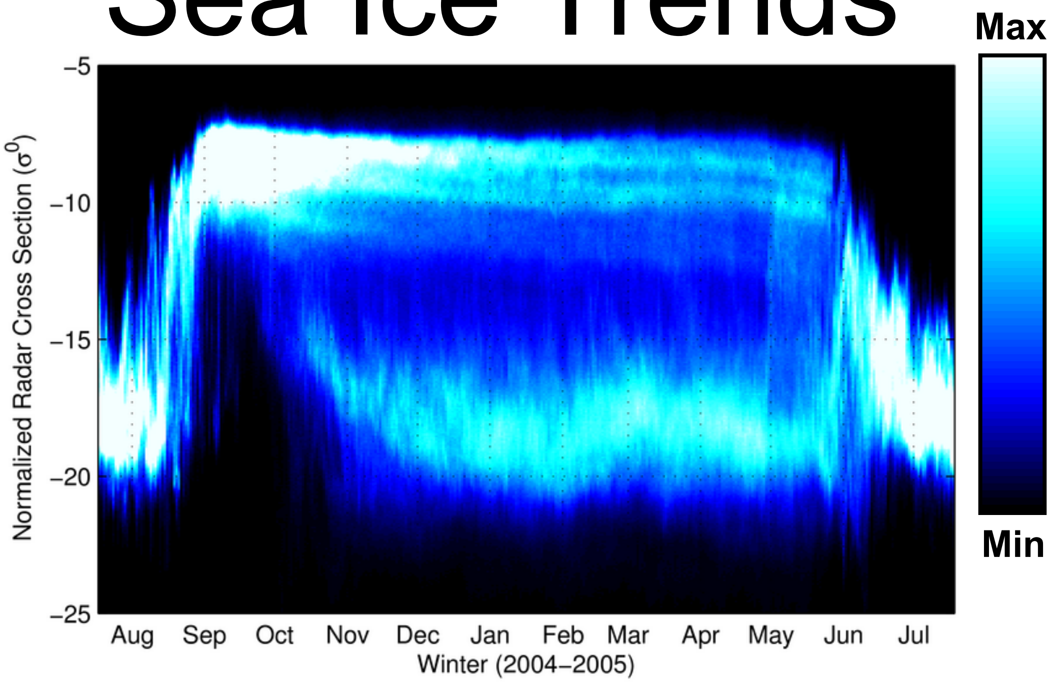


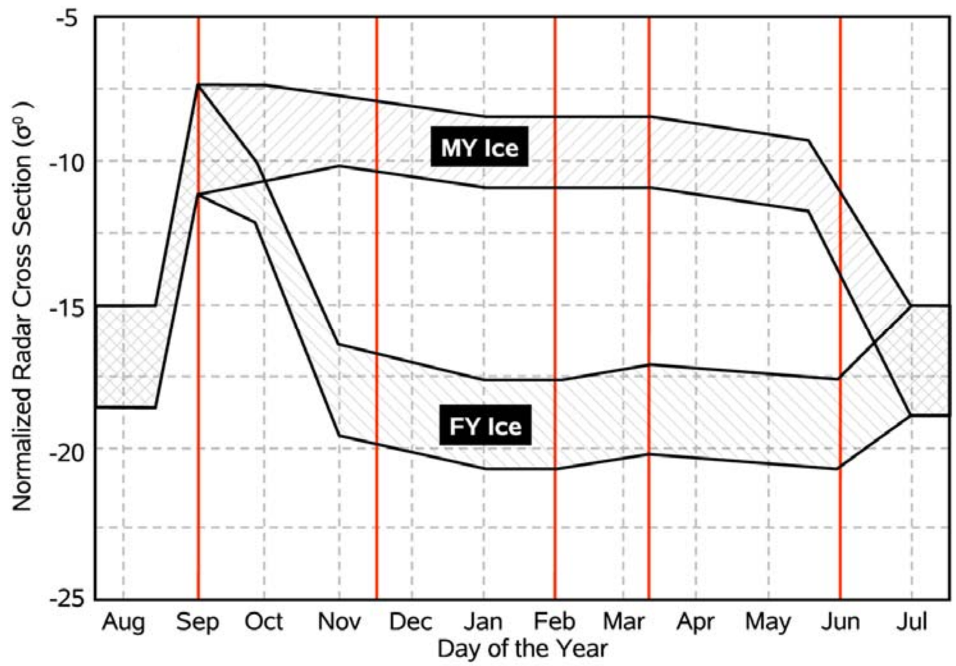
A.M. Swan and D.G. Long, "Multi-Year Arctic Sea Ice Classification Using QuikSCAT," *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 50, No. 9, pp. 3317-3326, 2012.

Sea Ice Trends

Scatterometer Ice Age Classification

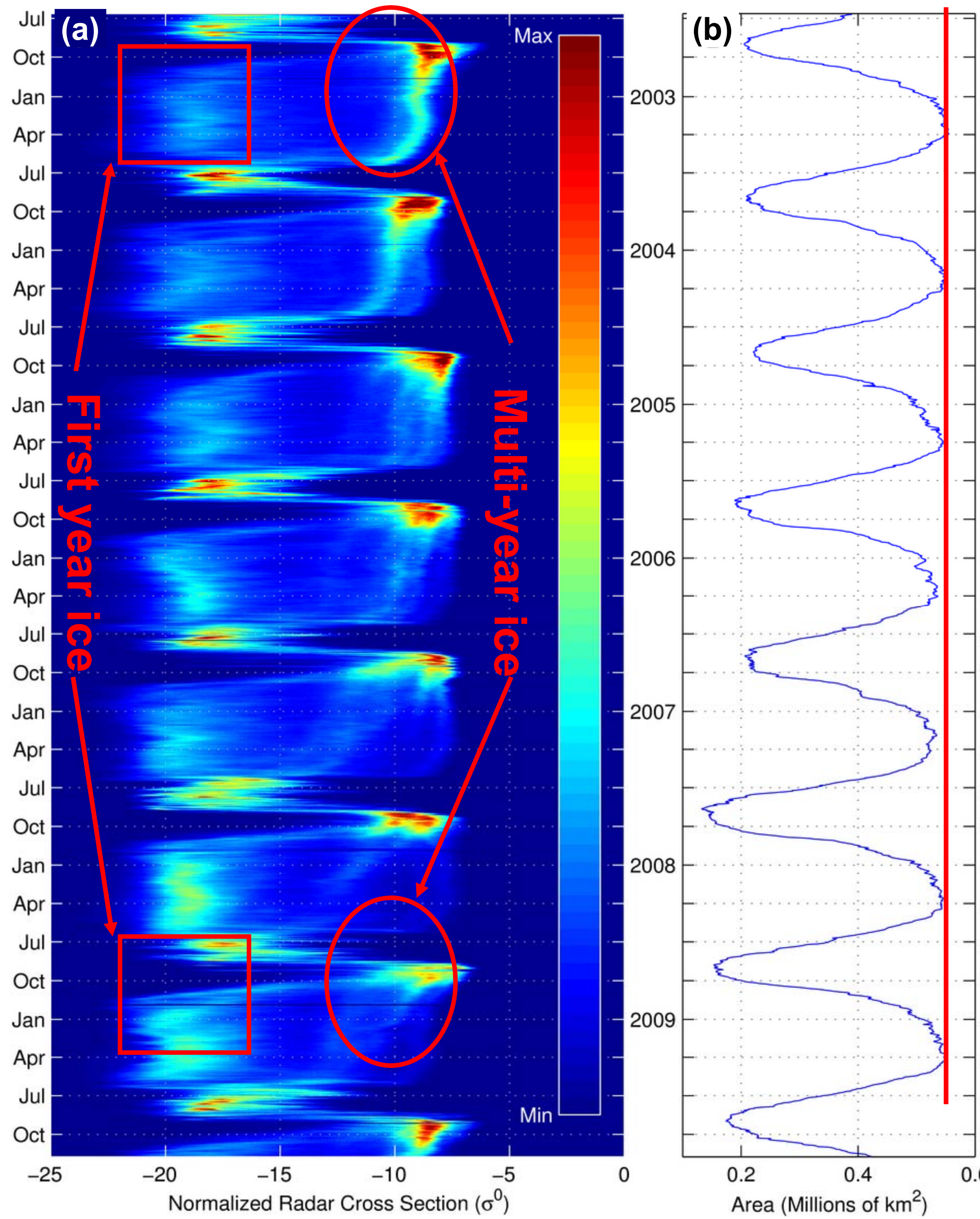
- pdf of backscatter versus time of year
- Seasonal trends in backscatter of FY and MY ice
- The cartoon shows approximate trends observed each year
- FY area grows through winter, MY roughly constant area

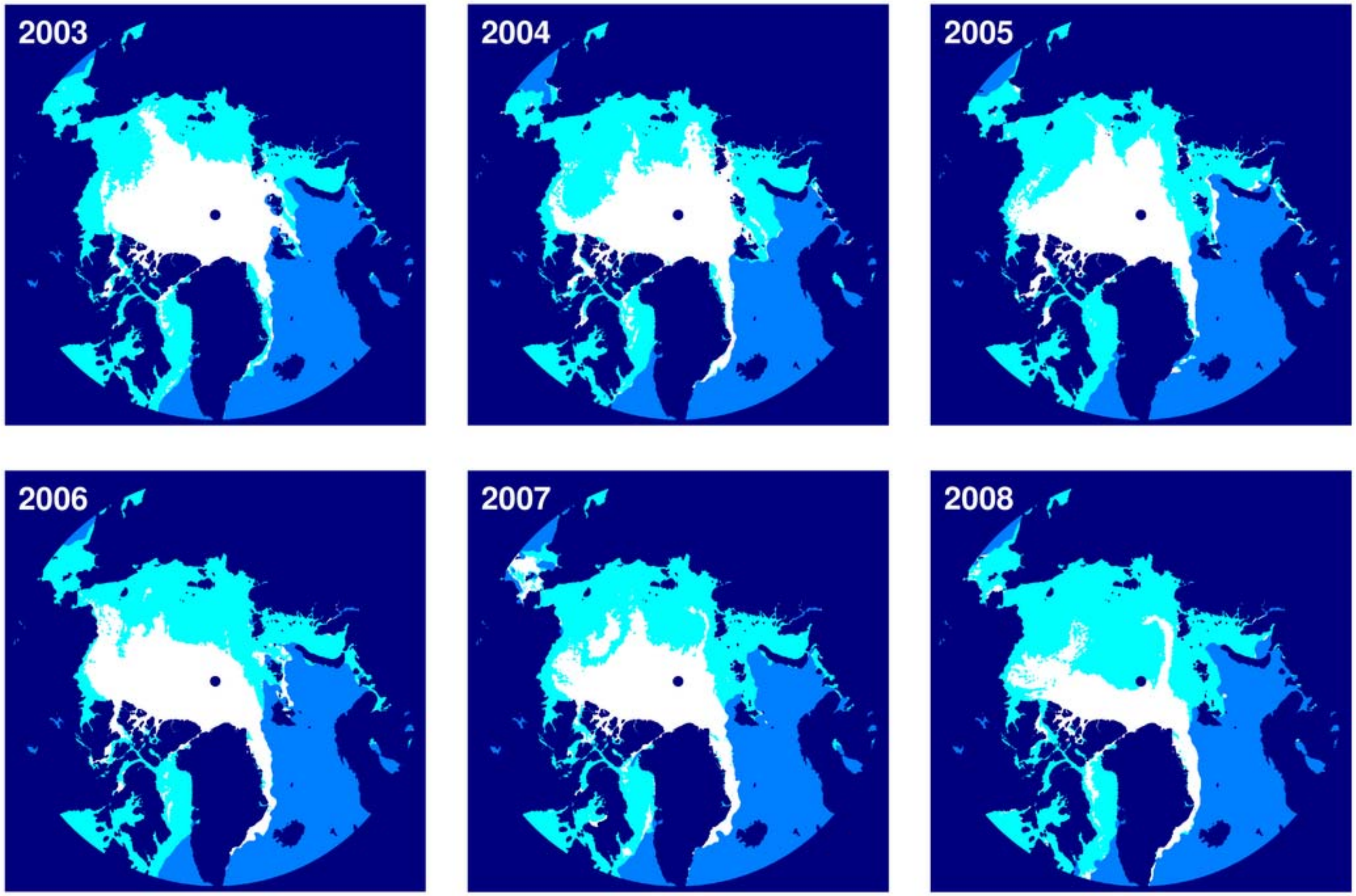




Multi-year Sea Ice Trends

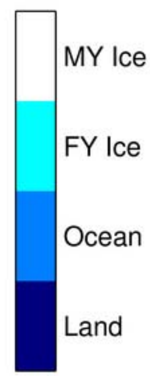
- Distributions in (a) are approximately bimodal
- There is a shift in the modes of FY and MY ice
- Total area of ice in (b) is similar each winter
- Conclude that FY ice is replacing MY ice



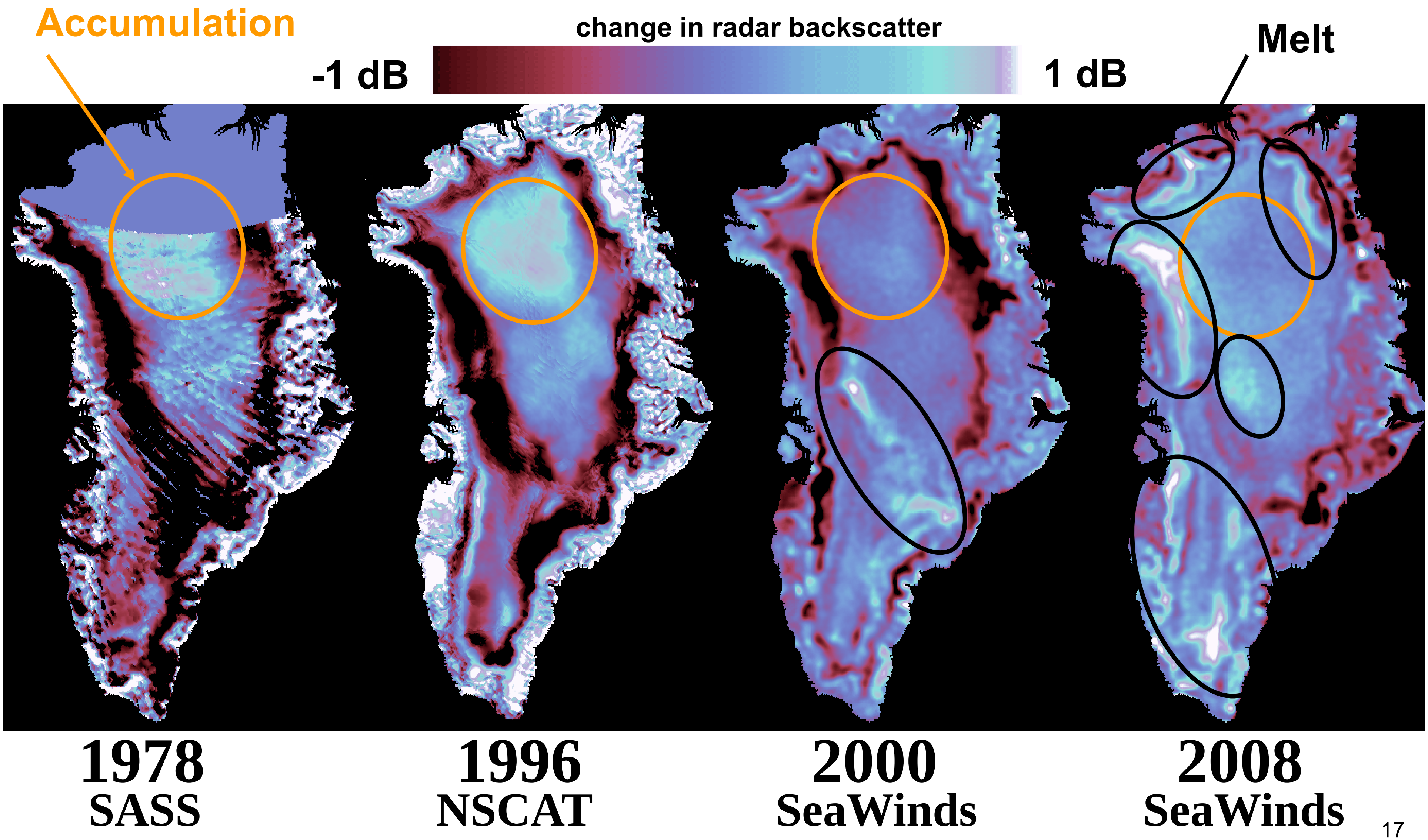


Sea ice Thickness (FY/MY) Mapping

From QuikSCAT

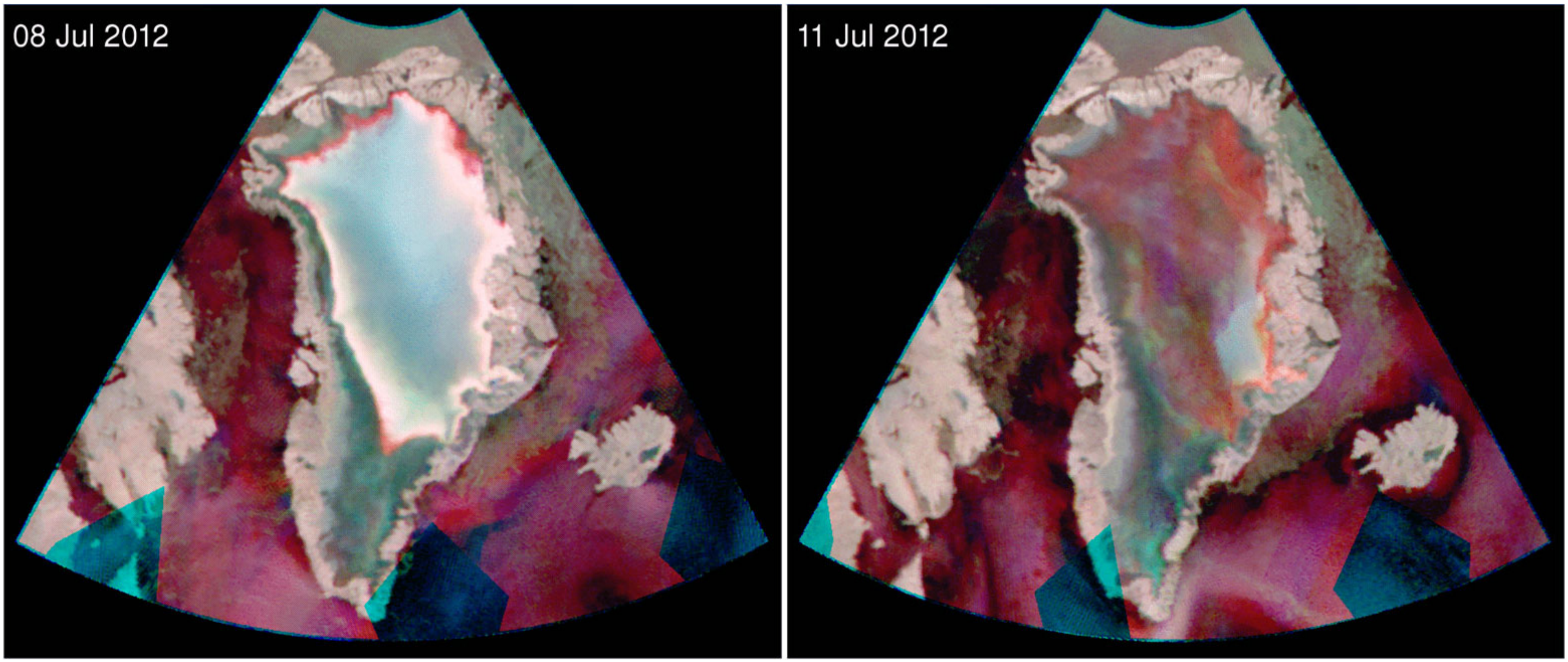


Greenland
Multi-Decade Change



Greenland Summer Melt

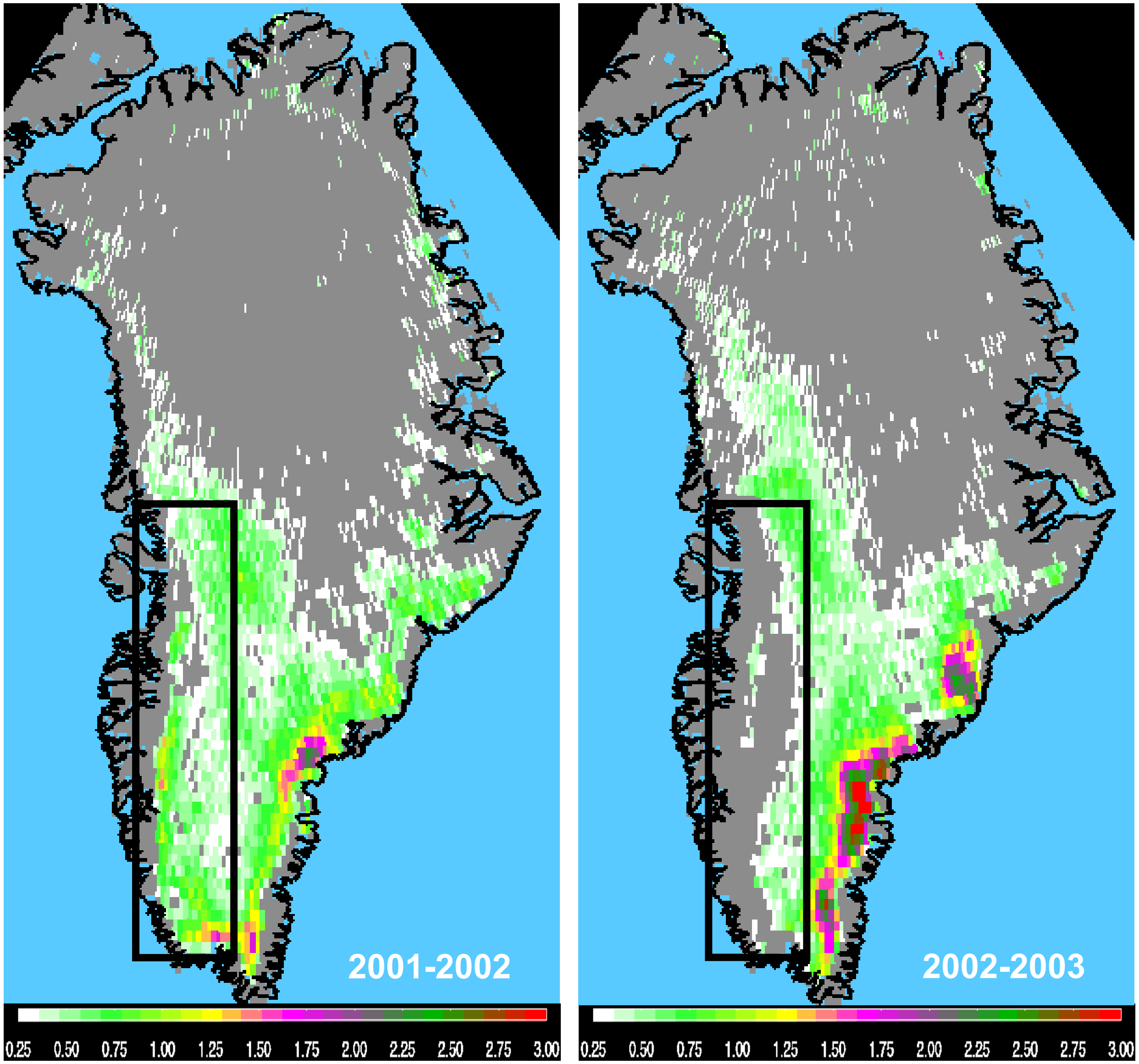
During the Summer of 2012, Greenland endured one of the largest areal melt cycle observed in the satellite record. The melt event was recorded by OSCAT and ASCAT.



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.

QuikSCAT Snow Accumulation Maps

Anomalous accumulation in 2002-2003



First maps of snow accumulations (depth in meter, 5.5 months Oct.-Mar.) in the percolation zone seen by NASA QuikSCAT data.

Satellite results agrees to within 8.6% compared to in-situ data at NASA-SE automatic weather station.

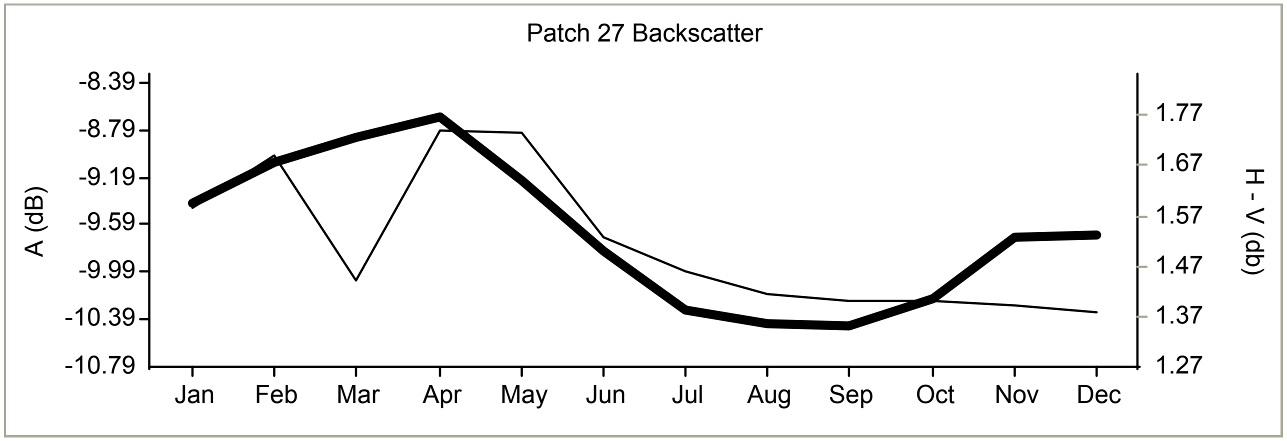
Detection of severe accumulation (~double normal amount) in SE Greenland in 2002-2003.

Less accumulation in SE Greenland in 2002-2003.

Mapping of inundation

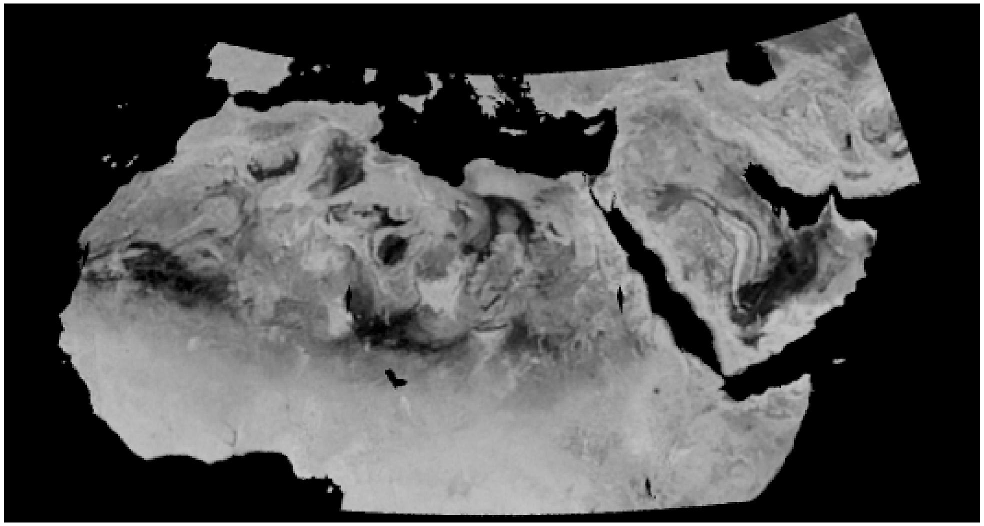
- Grasslands are frequently inundated seasonally. The Brazilian Pantanal is an example.
- During the wet season from October to March, backscatter increases as ground becomes inundated and approaches bright values similar to Tropical Forest. As water recedes, backscatter decreases to yearly lows.

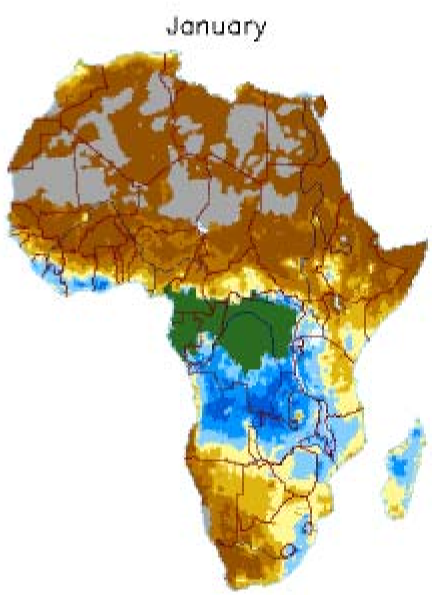
Pantanal during the wet season

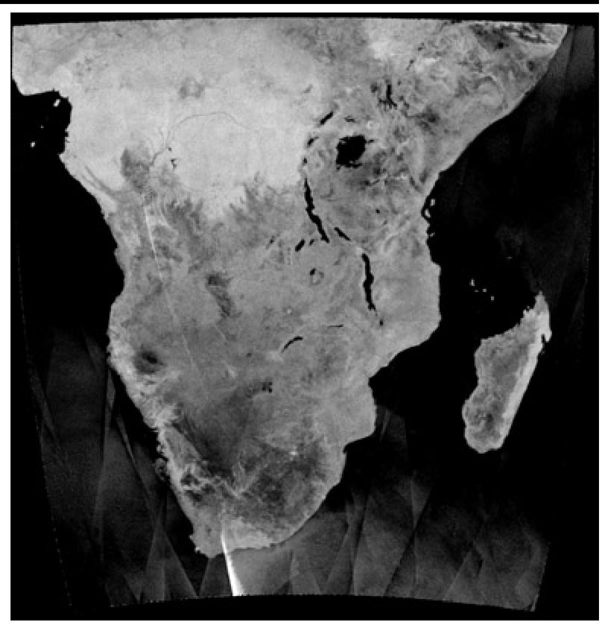


Drought & Flood Monitoring

(Malaria Prediction)

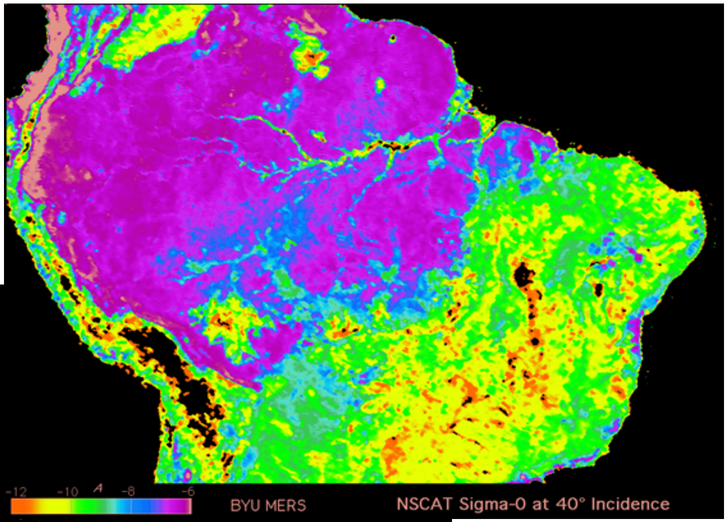


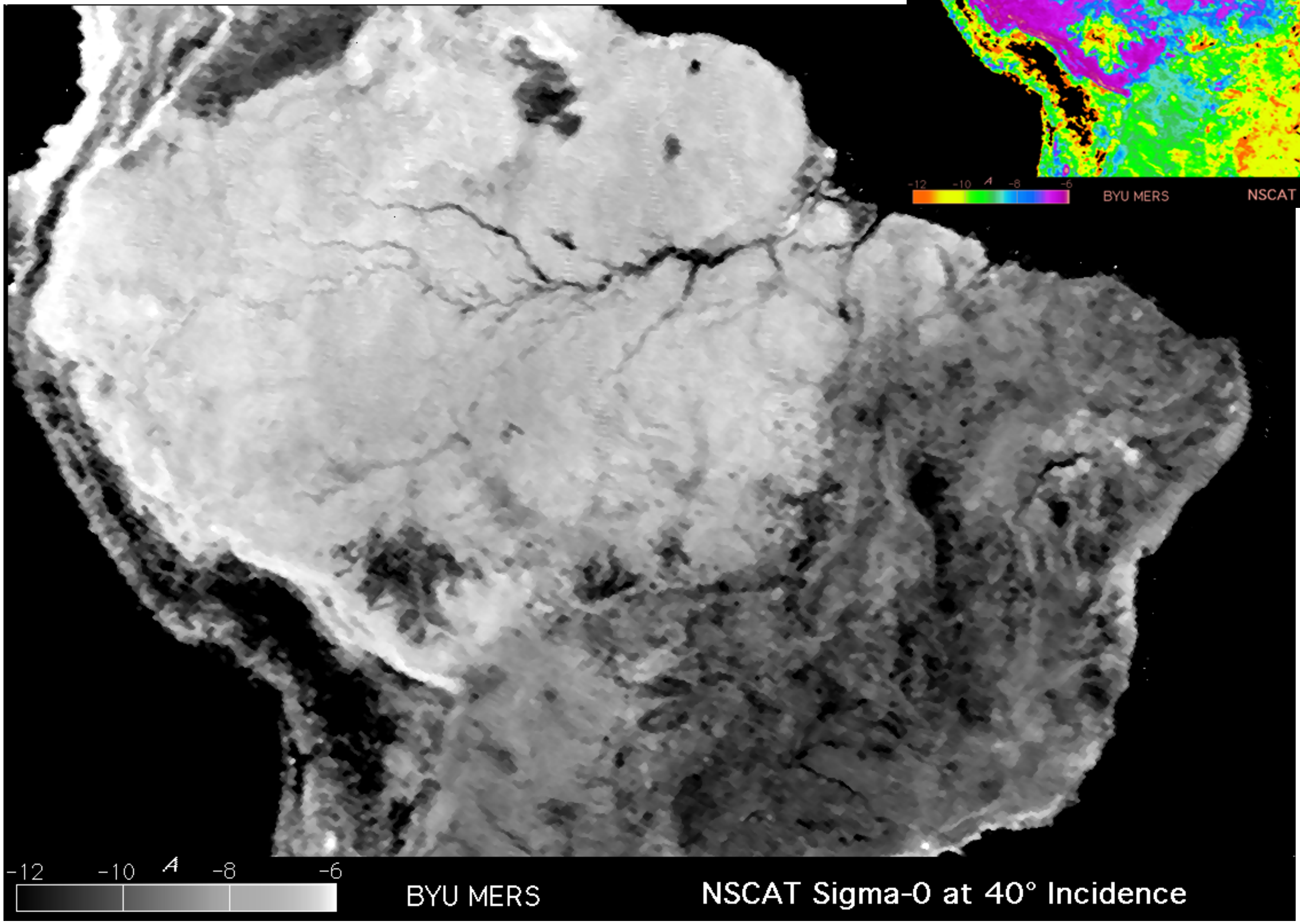




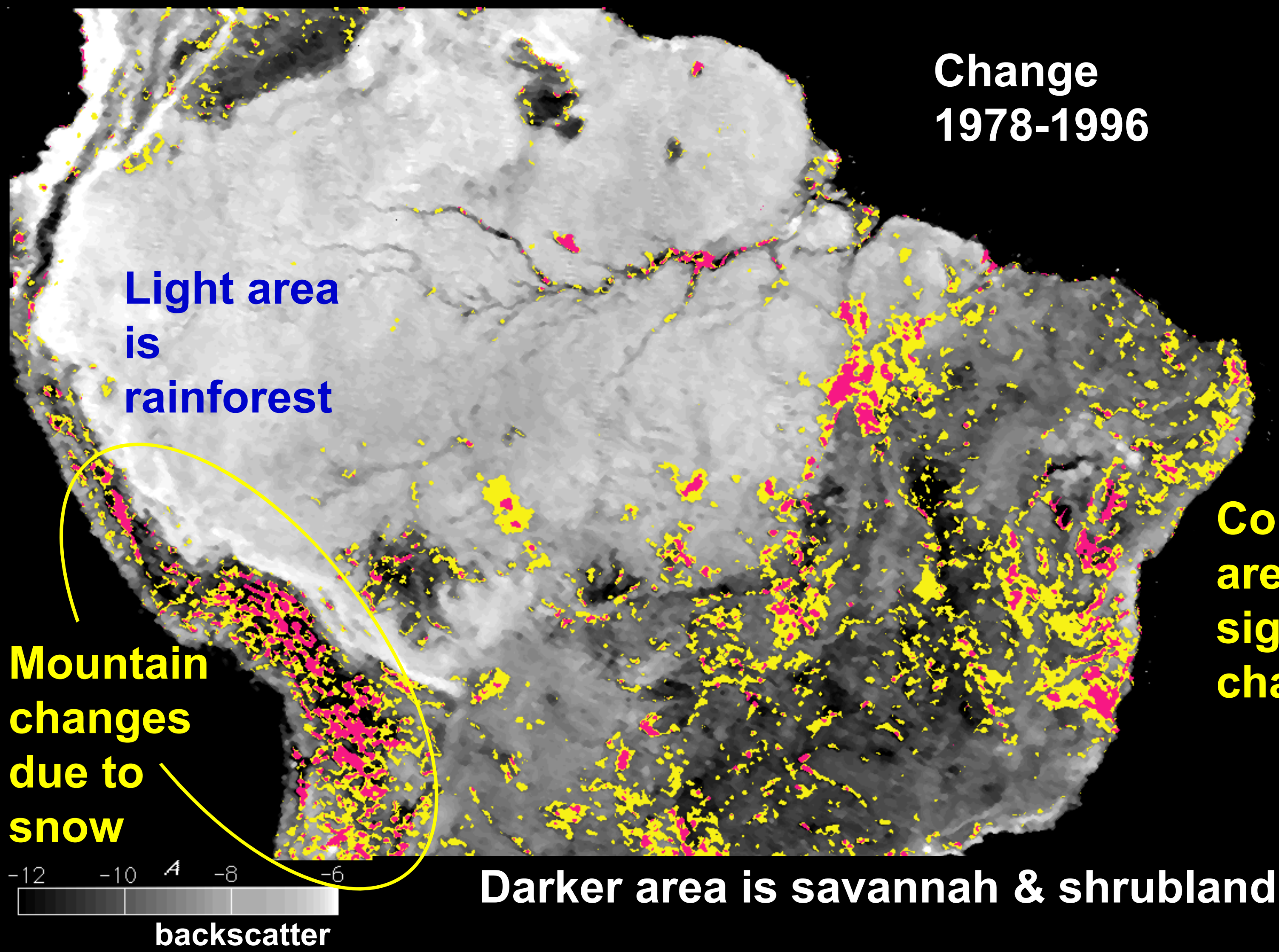
Scatterometer-based mapping of flooding and water inundation is especially useful for malaria risk mapping as mosquitoes begin life as aquatic larvae and adults rarely travel more than 2km from their breeding site in their two to three week lifetime. A number of organizations are using scatterometer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

Vegetation Classification

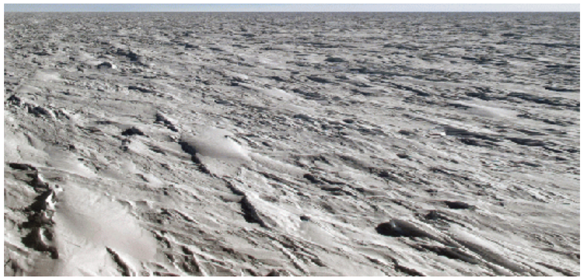




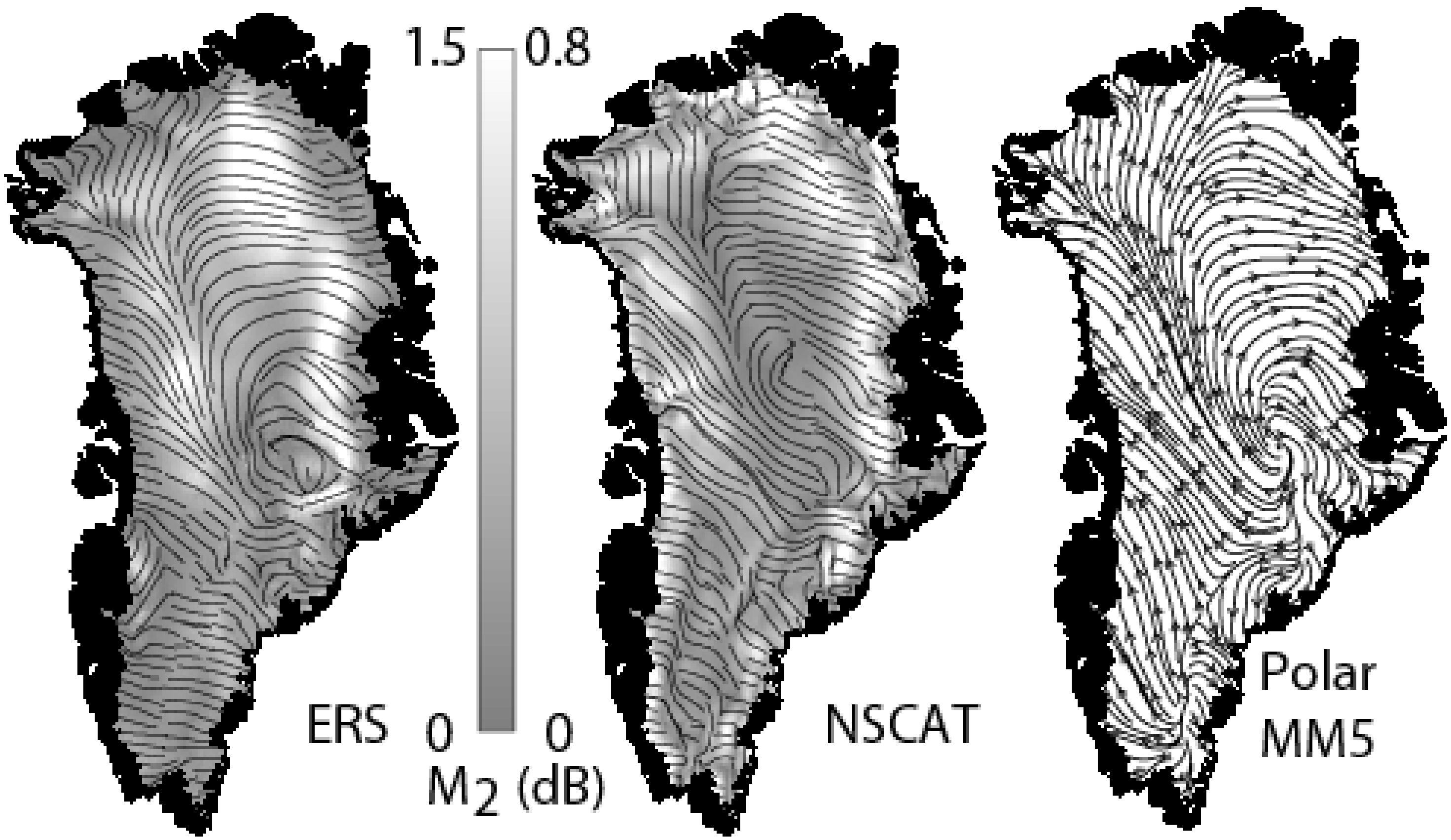
Amazon Deforestation



Wind Direction over Greenland from snow dunes



sastrugi

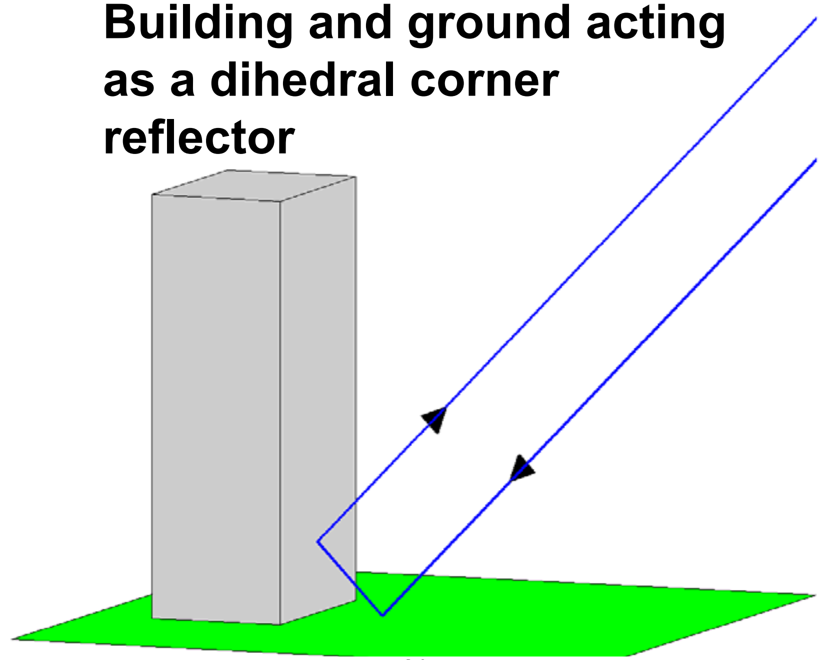


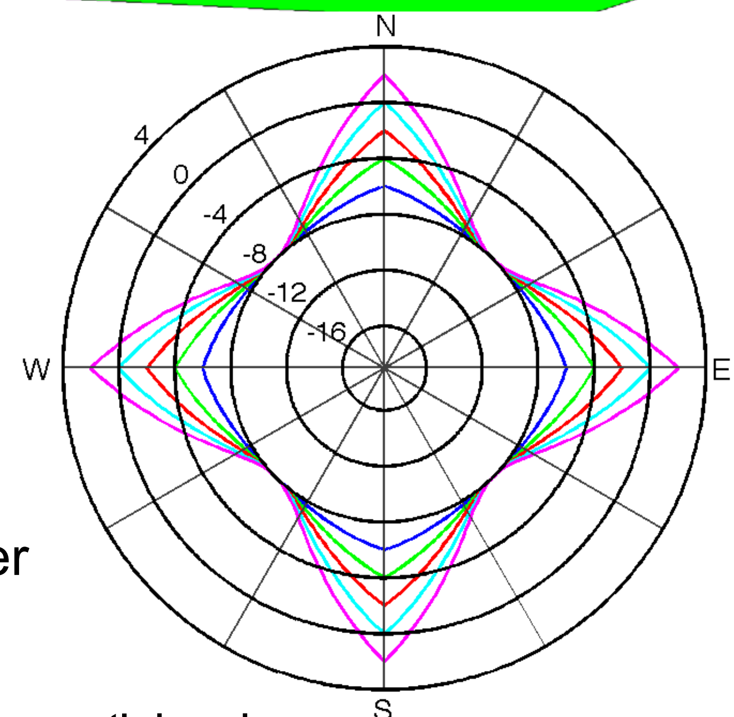
Scatterometer-derived   Katabatic model

QuikSCAT σ^0 Azimuth Response for Urban Areas

- Urban areas with regularly-gridded road systems exhibit σ^0 azimuth responses consistent with dihedral corner reflectors
  - Building orientation consistent with road orientation
- Density of buildings are proportional to signal strength
- Azimuthal variations present to some extent in most urban areas
- Seasonal variations exist for many urban areas
- Each urban area response is unique and evolving over time

Building and ground acting as a dihedral corner reflector



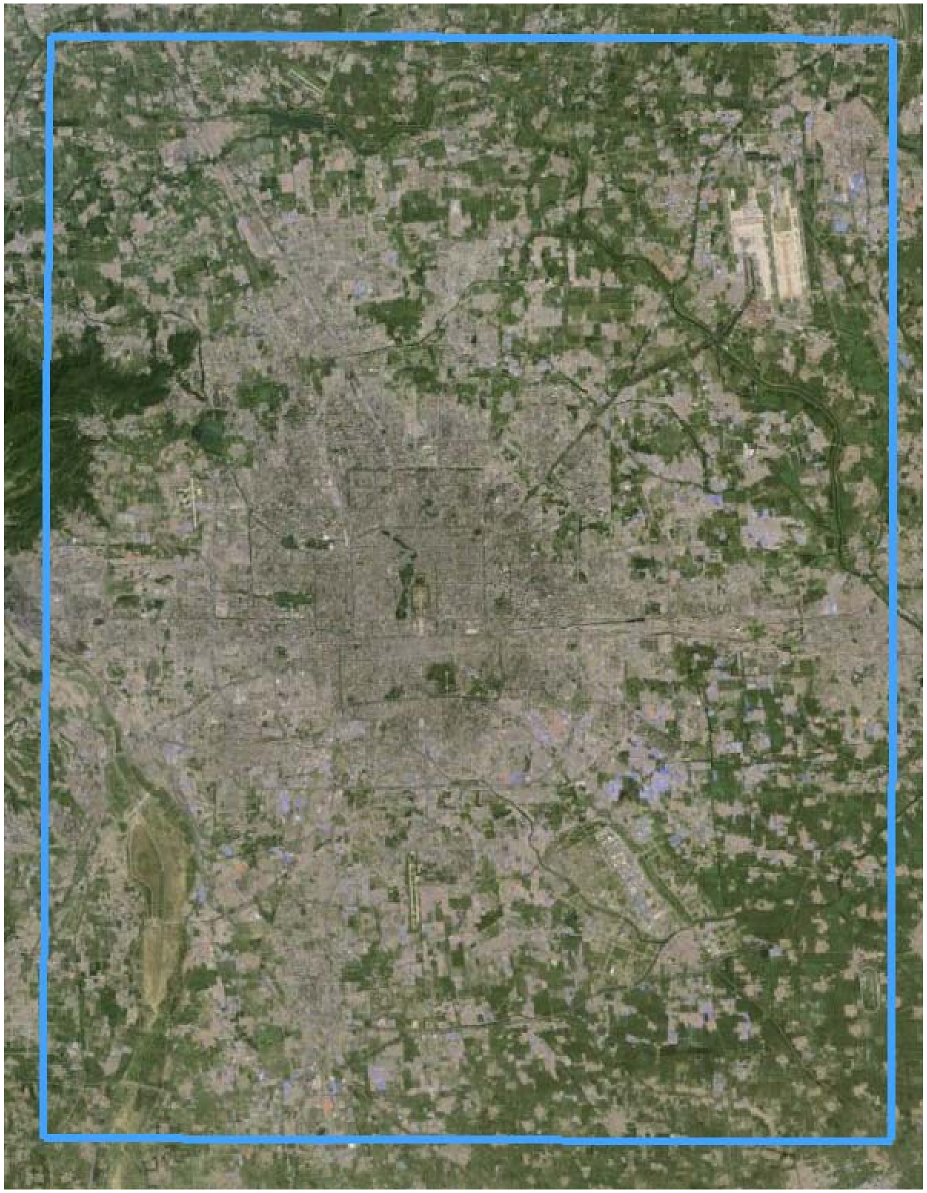


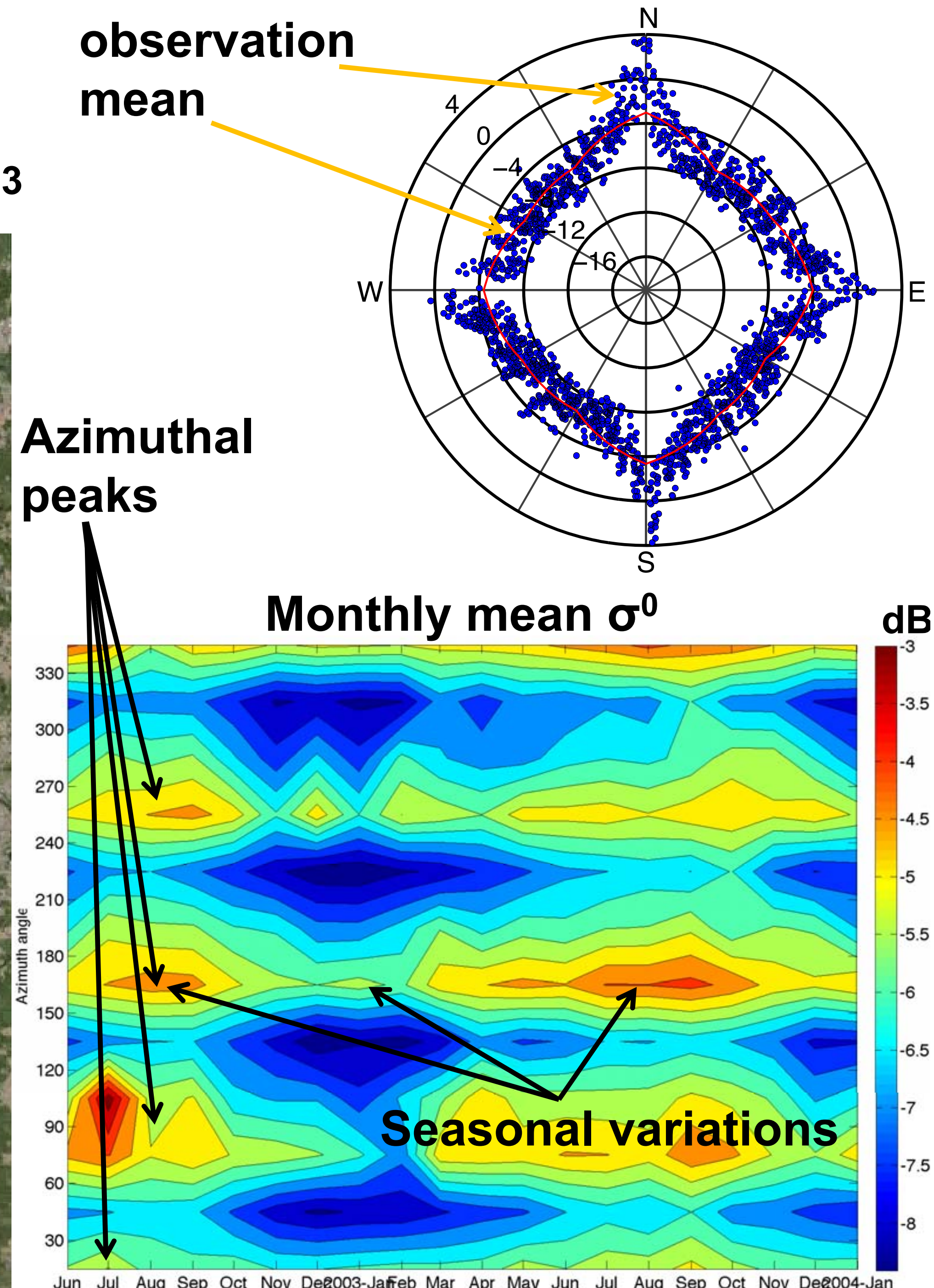
Illustrative observations from all azimuth angles for a single 4-sided dihedral corner reflector such as a building for various magnitude differences.

*** From paper currently in review**

Beijing, China

1922 σ^0 observations from 1 Jul - 31 Aug 2003



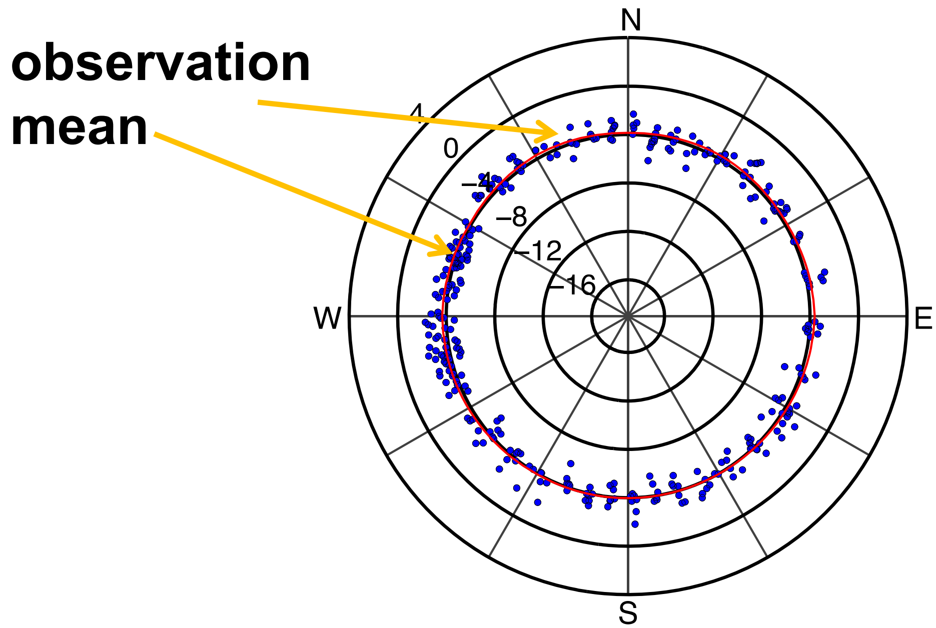


* From paper currently in review

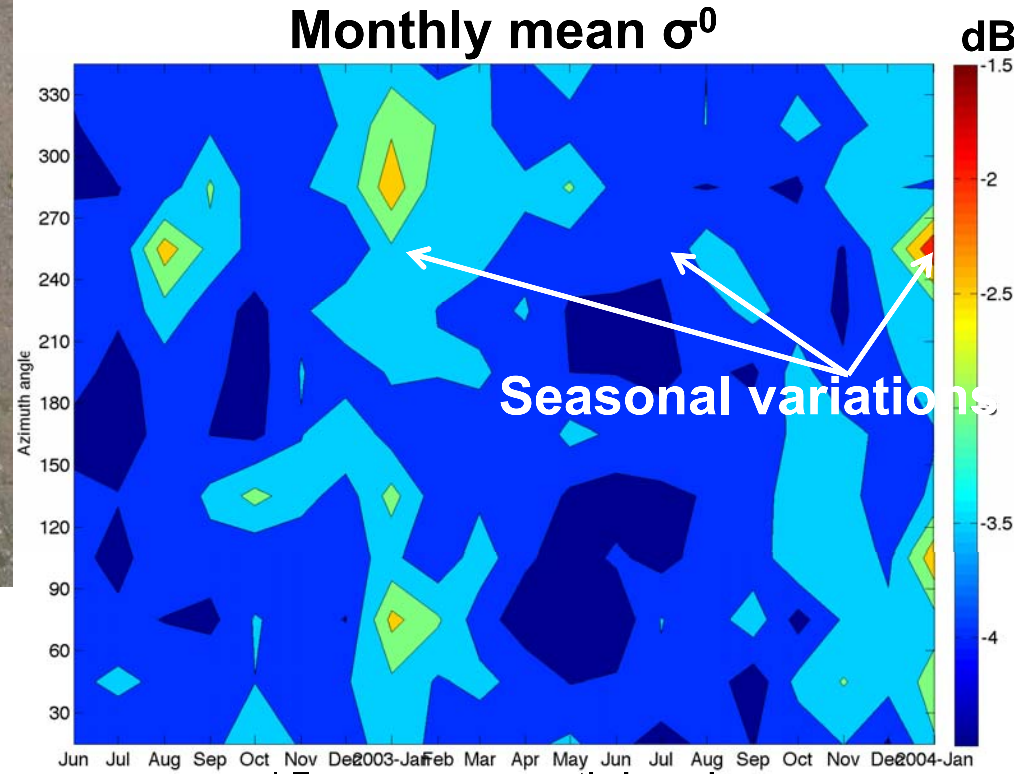
São Paulo, Brazil

333 σ^0 observations from 1 Jul - 31 Aug 2003

No dominant road structure -- no azimuthal peaks



Monthly mean σ^0



* From paper currently in review

Conclusion

- Scatterometer data is effective in land/ice studies
  - Addition of Ka-band will improve sensitivity in many applications
  - Potential to add new insights

- NASA HQ has long recognized the contributions of scatterometry in land/ice observation by including such applications in calls for participation in the Ocean Vector Wind Science Team (OVWST)
  - A number of OVWST members have specialized in such applications
  - Scatterometer Climate Record Pathfinder (www.scp.byu.edu)

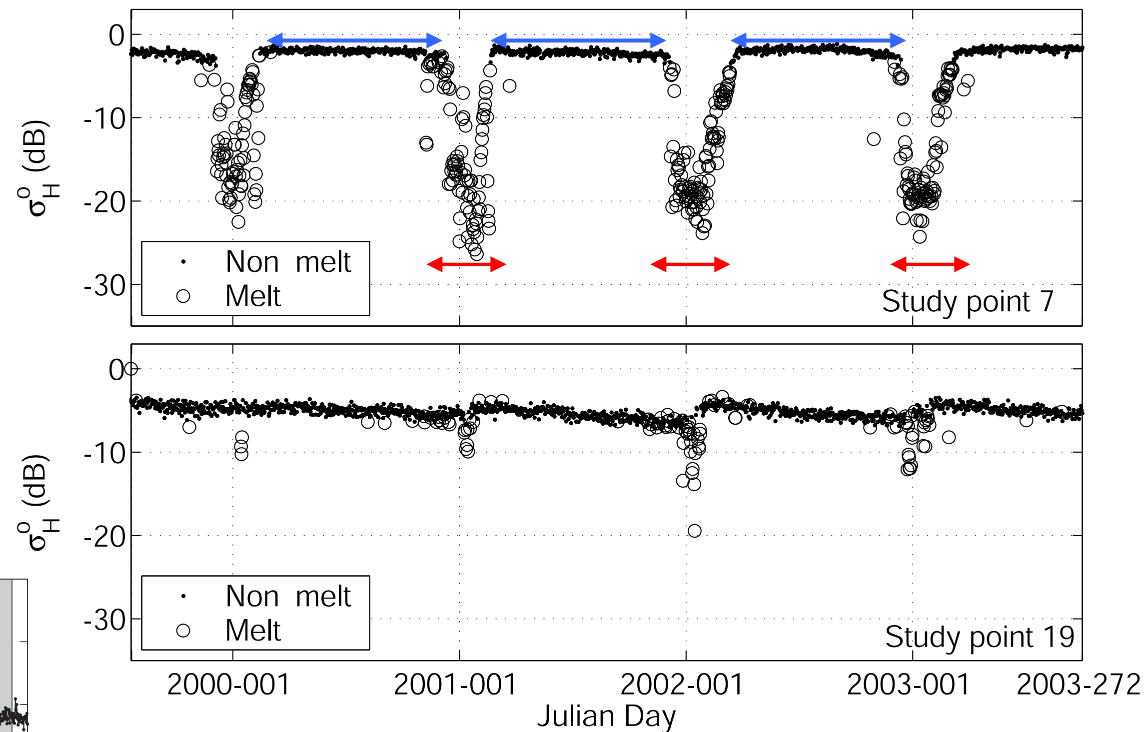
Backup Slides

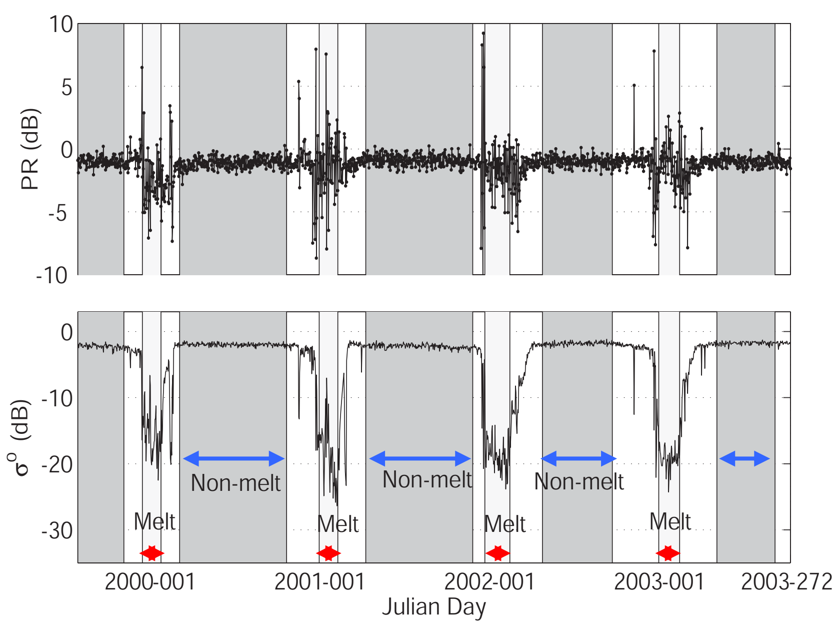
–

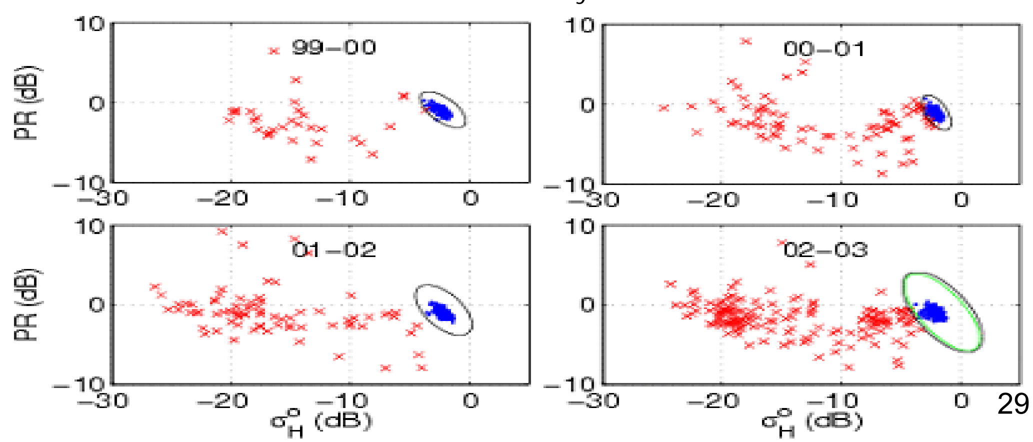
Antarctic Ice Shelf Melt Detection

Example

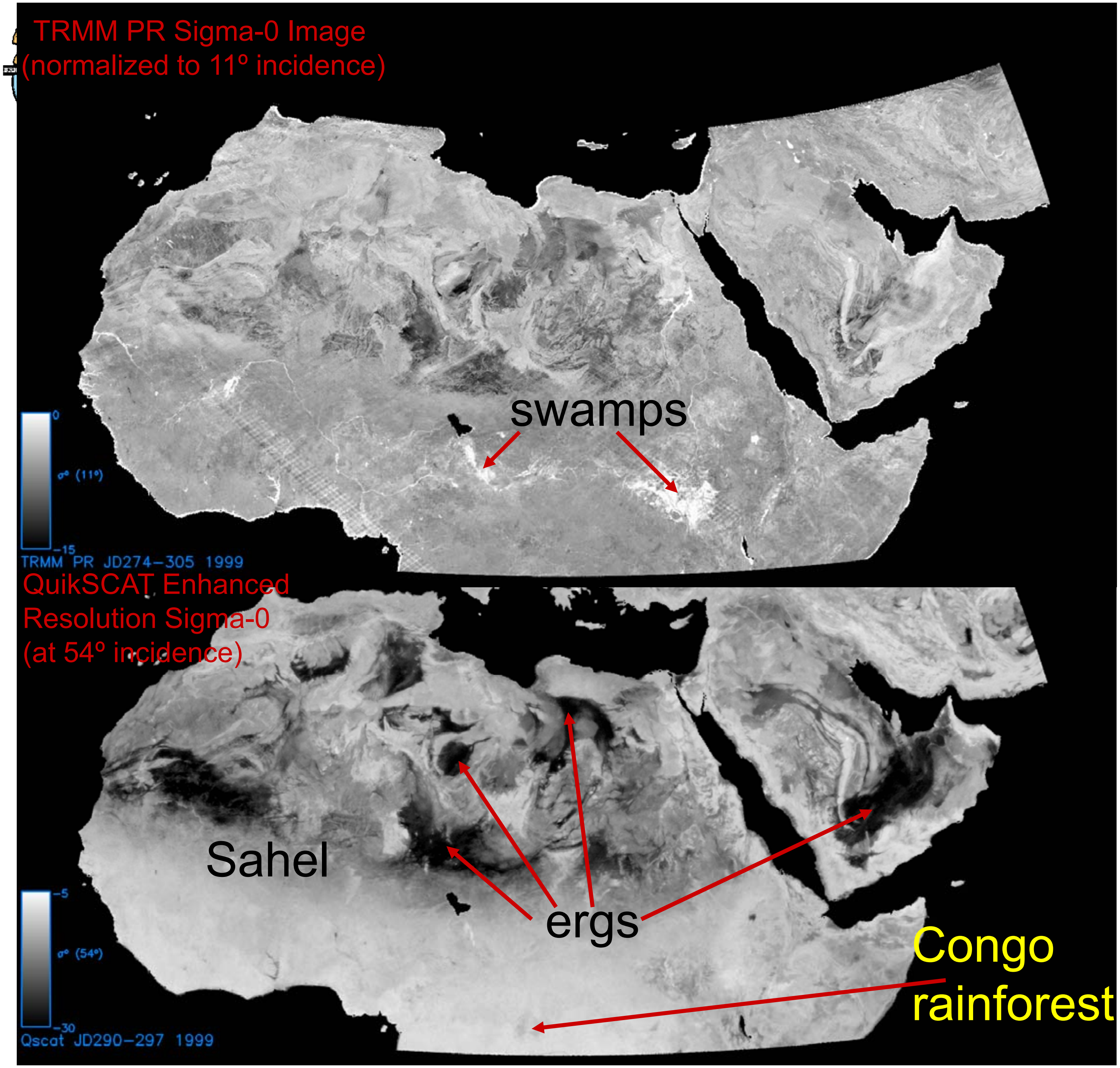
- Use QuikSCAT backscatter polarization ratio, PR = $\sigma_v - \sigma_h$ (dB), and σ_h time-series
- Compute mean and covariance for specified non-melt and melt periods
- Classify melt state using ML objective function





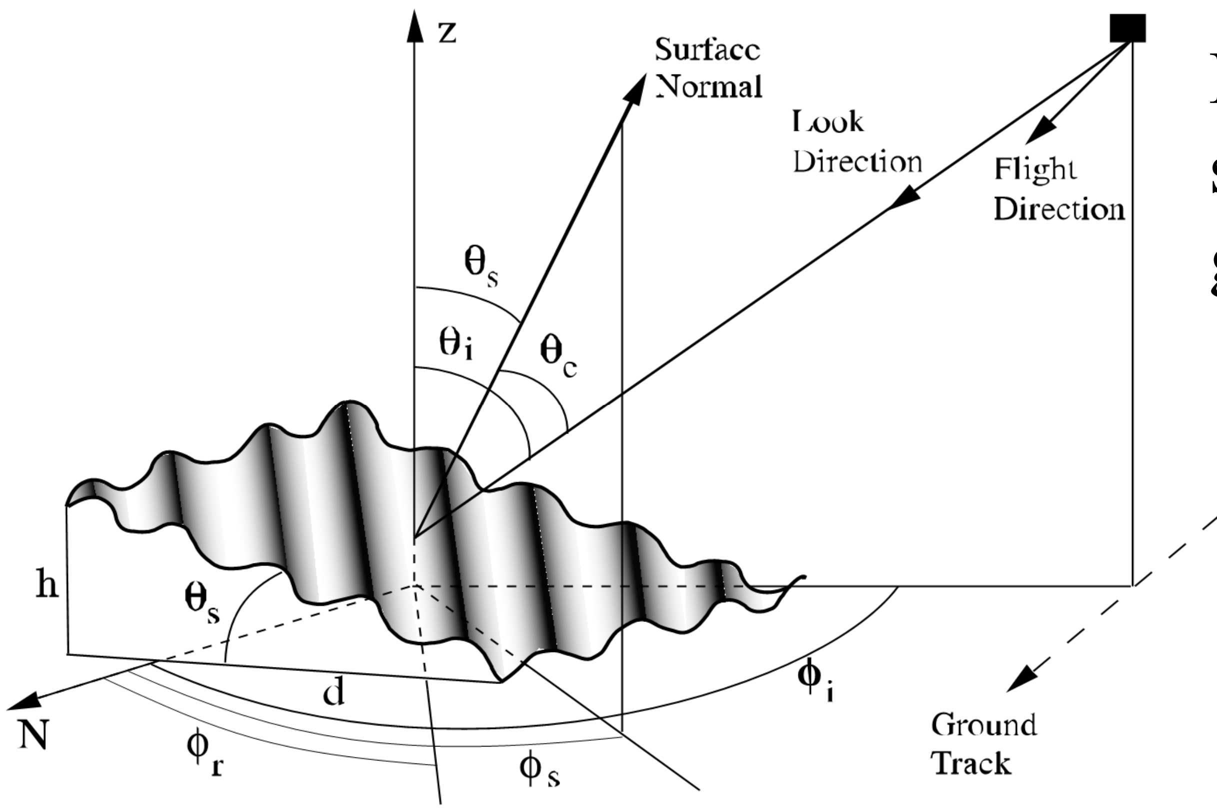


TRMM & QuikSCAT Desert Observations



The TRMM PR and the QuikSCAT scatterometer both operate at Ku-band, though at different incidence angles (0-17 deg vs 46 and 54 deg) and resolutions (4 km vs 25 km). Here the radar backscatter from North Africa is compared. Greater contrast between rocky desert regions and erg seas are evident at high incidence angle due to absorption of the radar signal within the sandy regions. Rivers and other water courses are more evident at low incidence angle due to strong specular scattering.

Surface Roughness Geometry (snow dune wind measurement)



Mean topographic slope with wind-generated sastrugi

sastrugi