Ku- and C-band Scatterometers as Ice Climate Record Sensors

Glacial ice & icebergs

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Ocean Vector Wind Science Team Meeting
19-21 Aug 2009
Ice Shelf Collapse

- On Feb 28, 2002 the Larsen B iceshelf collapsed and over a few weeks virtually exploded into the Weddell Sea
- QuikSCAT observed this collapse and has helped diagnose its cause
- May help predict future collapses
Local warming leads to surface melting

Melt water percolating into cracks in the ice and refreezing weakens the shelf, eventually leading to its collapse

Monitoring melt conditions can help predict the stability of existing ice sheets
QuikSCAT Observations of the Larsen Ice Shelf Collapse

2002

50 km
Overview

- Scatterometer data over land/ice a valuable climate record
  - 3 mons Seasat in 1978 established baseline
  - 9 mons NSCAT in 1996/7
  - 9 years of C-band ERS-1/2
  - 10+ years of Ku-band QuikSCAT
  - 2+ years of C-band ASCAT
- Glacial melt/freeze
- ASCAT Resolution Enhancement
- Iceberg tracking

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Antarctic Ice Shelf Melt Detection

Example

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

Passive & Active Observations

study point 7: 67 °S  61.50 °E

\( \sigma^0_H \) (dB)

- Non melt
- Melt
- HR Melt
- \( T_b \)
- \( \alpha \) Melt
- XPGPR

SSMI/T \( T_b \) (K)

- 19H
- 19V
- 21
- 37H
- 37V
- 85H
- 85V

Julian Day

2000 001 2001 001 2002 001 2003 001 2004 001

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Note early melt onset on the Larsen Ice Shelf for Austral summer of 2000-2001 compared to other years.
Melt-Season Duration

Breakup of the Larsen Ice Shelf in Jan 2002 due to localized warming and melting after longer summer melt season.
Other Studies

Various groups, some products operationally being produced

- Melt onset / Duration / Refreeze
  - Sea ice (both poles)
  - Greenland
  - Antarctica
  - Canadian Arctic ice caps
  - Alaskan and Canadian boreal forests

- Snow accumulation and/or duration
  - Greenland
  - Antarctica
  - Canadian tundra and boreal forest

- Soil moisture & flooding

- Sand dunes

- Vegetation and crops

- Sea ice extent / concentration / motion
  - Scatterometer data complements passive microwave results
  - High resolution (SIR processing) improves motion tracking
Enhanced Resolution Scatterometer Imaging

◆ Images on standard grids
  – Aids in comparison and data fusion with other sensors
  – Standardized incidence angle (ERS-1/2, NSCAT, ASCAT)

◆ Resolution enhanced products
  – none (gridded or ‘drop in the bucket’ averages)
  – AVE
  – SIR

◆ AVE and SIR enable higher spatial resolution
  – Support studies otherwise not possible
  – Finer scale/detail, reduced spatial smearing compared to gridded

◆ Extract azimuth modulation, incidence angle dependence

Global scatterometer images available from the Scatterometer Climate Pathfinder
www.scp.byu.edu
Enhanced Resolution Scatterometer Imaging

- Trade spatial and temporal resolution
  - Combine multiple passes
  - Separate products based on
    - single pass (winds)
    - local time-of-day
    - daily
    - multi-day
  - Longer integrations improve spatial resolution, reduce noise
    - Smooth temporal change

Global scatterometer images available from the Scatterometer Climate Pathfinder
www.scp.byu.edu
How effective is scatterometer spatial resolution enhancement?

JD 200, 2007 QuikSCAT slices

25 km gridded (grd) image “drop in the bucket” average (conventional imaging)
How effective is scatterometer spatial resolution enhancement?

AVE (2.225 km pixels) 25 km gridded (grd)

JD 200, 2007 QuikSCAT slices (one day)
How effective is scatterometer spatial resolution enhancement?

AVE (2.225 km pixels)  SIR (2.225 km pixels)

JD 200, 2007 QuikSCAT slices (one day)
How effective is scatterometer spatial resolution enhancement?

3 day SIR (2.225 km pixels)
JD 200-203, 2007 QuikSCAT slices

1 day SIR (2.225 km pixels)
How effective is scatterometer spatial resolution enhancement?

3 day SIR (2.225 km pixels)
JD 200-229, 2007 QuikSCAT slices

30 day SIR (2.225 km pixels)
Temporal/Spatial Comparison

JD 200, 2007 QuikSCAT slices
JD 200-229, 2007 QuikSCAT slices

1 day GRD (conventional imaging)
1 day SIR
4 day SIR
1 day AVE
2 day SIR
30 day SIR

-30 dB A 0 dB
Temporal Resolution

Larsen Ice Shelf Time Series

H pol backscatter (blue=L1B, red=SIR)

V pol backscatter (blue=L1B, red=SIR)

L1B=egg center within 25 km of SIR pixel center
Partial List of Publications using SCP Data


D.S. Early and D.G. Long, "Azimuth Modulation of C-band Scatterometer Sigma-0 Over
ASCAT Resolution Enhancement

- **ASCAT C-band (5.255 GHz), V-pol only**
  - Six beams covering two 500 km swaths
    - 3 azimuth angles
  - Incidence angle range: outer 34° to 65° inner 25° to 55°
  - SZR = 25 km $\sigma^0$ ~ QuikSCAT ‘eggs’
  - SZF = fine resolution $\sigma^0$ ~ QuikSCAT ‘slices’
- **SZR spatial response function (‘egg’ like)**
  - 25 km Hamming window response
- **SZF spatial response function (‘slice’ like)**
  - Approximate as rectangular box centered at node
    - Length: 6 km node spacing
    - Width: 3 dB beamwidth of antenna pattern
- **Linear model for $\sigma^0$ versus incidence angle**
  \[
  10\log_{10} \sigma^0(\theta) = A + B(\theta - 40^\circ)
  \]
  - Create images of A and B
  - SIR enables spatial resolution enhancement using overlapping swath passes
QuikSCAT egg / ASCAT SZR Comparison
single day, 25 km pixels

QuikSCAT egg V-pol
(Ku-band sigma-0 at 54 deg incidence angle)

ASCAT SZR A
(C-band sigma-0 at 40 deg incidence angle)

JD 214, 2008
$10 \log_{10} \sigma^o(\theta) = A + B(\theta - 40^\circ)$

Volume scattering larger at Ku-band

Greater contrast between percolation and dry snow zones at C-band

Linear model error more apparent at C-band
Incidence Angle Trimming

- SZR (25 km “egg”) data incidence angles: 25°-65°
  - Center beams restricted to 33.9°-55°

- Applied same restriction to SZF (slice) data
  - (Raw data covers broader incidence angle range)
QuikSCAT / ASCAT Slice Comparison

QuikSCAT V-pol
(Ku-band sigma-0 at 40 deg incidence angle)

2.225 km pixels

ASCAT (SZF) A
(C sigma-0 at 54 deg incidence angle)

JD 214, 2008
QuikSCAT / ASCAT Slice Comparison

QuikSCAT V-pol
13.4 GHz
(sigm-a at 54 deg incidence angle)

2.225 km pixels

ASCAT (SZF) A
5.255 GHz
(sigm-a at 40 deg incidence angle)

JD 214, 2008
ASCAT Spatial Resolution Enhancement Plans

- SIR parameter tuning (in progress)
  - Initial values
  - Number of iterations
- Incidence angle model
  - Extend incidence angle range
- Evaluate effective ASCAT slice resolution
  - Slice sizes of QuikSCAT and ASCAT are comparable, yet QuikSCAT slice images have better resolution
- Azimuth versus incidence angle diversity
- Prototype product distribution to begin in Fall
Icebergs at Ku-band & C-band

Single day images

QuikSCAT (v-pol)

ASCAT

(JD 166, 2008)
Iceberg B18
(JD 166, 2008)

QuikSCAT (h-pol)

ASCAT
Ship view of an iceberg

60 feet high

600 feet deep

(John Helly)
Ku-band vs C-band
JD 1-279, 2008
(reduced resolution for animated visualization)

QuikSCAT
(v-pol)

ASCAT
QuikSCAT Iceberg Tracking

- Tabular icebergs visible due to contrast between backscatter from glacial ice and sea ice/open ocean
  - Not limited by illumination or cloud cover
  - Surface melting can reduce contrast
  - High resolution required
- QuikSCAT in operational use at the National Ice Center for iceberg tracking
Iceberg Increase a Sign of Climate Change?

Much of the apparent NIC increase is an artifact of better iceberg tracking technology.

1997 and 2001/2 calvings of Ross and Ronne Ice shelves are within the range of expected variation.

First radar observations: low OK

Major iceberg calving events:

National Ice Center count:

Year

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Summary

◆ QuikSCAT & ASCAT data are proving effective in cryosphere science studies
  - Improved temporal resolution of melt in Greenland and Antarctica
◆ Scatterometer data providing insights into the physical structure of snow and firn
  - Azimuth modulation due to layered snow dunes
  - Seasonal signature
  - Melt progression
Wilkins Ice Shelf Event 2008

March 6, 2008 14:05 UTC

February 28, 2008 13:55 UTC

February 28, 2008 19:30 UTC

March 8, 2008 13:30 UTC

Scambos, NSIDC
Wilkins Ice Shelf Event 2009

Small scale of shelf and limited movement of fragments are limiting factors in this case.

QuikSCAT Observations