Deriving Wind Speed from Synthetic Aperture Radar Images

Jeremy Nicoll
Alaska Satellite Facility
– Engineering Center
Outline

- Bragg scattering
- CMOD algorithms
- Scatterometers
- SAR data
- Applications
  - Hurricanes
  - Gap flow
  - Barrier jets
  - Vortex shedding
  - Internal waves
- Data quality issues
Bragg scattering

- Resonant phenomena when distance between flat surfaces in the direction of view is \( \frac{1}{2} \) the instrument wavelength.
- Assumed the dominant mechanism in radar backscatter over water.

http://earth.esa.int/applications/data_util/SARDOCS/spaceborne/Radar_Courses/Radar_Course_II/bragg_scattering.htm
CMOD algorithms

• All models Radar Cross Section as functions of at least these three:
  – Wind speed (v)
  – Wind direction with respect to sensor (ϕ)
  – Incidence angle (θ)

• Version # (CMOD1-5) refers to different ways of estimating B values

• CMOD5 uses 28 parameters nested in B values.

• Parameterized empirically

\[ \sigma_0^m(v, \phi, \theta) = B_0(v, \theta)(1 + B_1(v, \theta) \cos(\phi) + B_2(v, \theta) \cos(2\phi))^{0.625} \]
Using CMOD

• Invert to yield wind speed by knowing
  – NRCS
  – direction
  – incidence angle

• Necessary to know these parameters (duh!)
  – Not actually easy to know all these well enough.

• For SAR
  – Conversion from VV to HH for RADARSAT-1
  – Band conversion necessary if different from C-band
CMOD5 model at constant wind speed (20 m/s)
CMOD5 model at constant incidence angle (30 degrees)
Scatterometers

- Measure the surface cross section at a number of aspect angles and polarizations.
- Spatial resolutions of only 25–50 km
  - applicable more to the open ocean than to coastal areas.
- Complementary to SAR data.
- SeaWinds (on QuikSCAT)
  - uses a rotating dish antenna with two spot beams
  - sweep in a circular pattern.
  - Radiates in a continuous, 1,800-kilometer-wide band
  - ~ 400,000 measurements, 90% of Earth's surface in one day.

Image courtesy of MERS: http://www.mers.byu.edu/images/Seawinds/seawinds_hires.gif
SAR data

- Resolution 10-100m (native)
- Smaller incidence angle range
- Single azimuth angle
- Radar cross section must be calibrated

- Need wind direction as input
  - Linear features in SAR image (wind rows)
    - Usually successful, but not always
  - From modeling
    - NOGAPS (1° X 1° grid)
    - Uses Scatterometer data in model!
    - Low resolution
    - Time / space mismatch
  - Some other / blended methods
SAR $\rightarrow$ wind speed
Applications

- Where greater precision is needed
- Along coastlines
- Rapidly changing wind speed or direction
- To observe structure of phenomena
Hurricanes, polar lows
Gap flow
Barrier jets
Vortex shedding
Internal waves
Storm fronts
R155312309P40002 with Wind Direction = 135 deg

Lee shadowing

ASF Technical Seminar Series, 10/18/2006
Data quality issues

Beam seams

PRF Ambiguity
Data quality issues

Noise floor

Ice masking
DQ Issues: Wind direction estimates
DQ: model mismatch
DQ: SAR processing errors
Wind speed data flow

• Latencies
  – Downlink & SAR Processing
    • <2 hours
  – Wind speed processing
    • <15 minutes
  – ftp to lower 48
    • 15-30 minutes
  – Waiting latencies
    • ~ 1 hour
Data archives

- Near-real time at ASF (wind.asf.alaska.edu)
  - Since Fall 2005

- Main archive at JHU-APL
  (http://fermi.jhuapl.edu/sar/stormwatch/index.html)
  - Since December 1997
Up and coming

- Google Earth!
- Ice overlays.
- L-band modifications to CMOD algorithm
The END!