Incidence Angle Dependence of EM Bias

Karl F. Warnick, Floyd W. Millet and David V. Arnold
Department of Electrical and Computer Engineering
Brigham Young University

November 10, 2003
Hydrodynamic modulation

Nadir incidence:

More backscattered energy from smoother troughs

Small wave amplitude larger on crests than troughs

Negative EM bias

Off-nadir:

Less backscattered energy from smoother troughs

Smaller or even positive EM bias
Wide-swath altimeter

Wide-Swath Ocean Altimeter Science Working Group Report, Ed. L.-L. Fu, JPL.

Jason-1 SWT - Arles, Nov. 2003
Simple hydrodynamic model [Melville and Felizardo, 1999]:

\[ h_s(\eta) = h_s(0)[1 + S\eta / h_l] \]

where \( S \) is RMS long wave slope, \( h_s \) is small wave surface height standard deviation, and \( \eta \) is displacement from mean sea level.

Physical optics scattering from tilted/modulated surface facets

\[ \text{Bias}(\theta) = \frac{E[\eta\sigma_0(\theta)]}{E[\sigma_0(\theta)]} \]
Tower experiment

*BYU Off-Nadir Experiment (Y-ONE)*
March-April 2003
Gulf of Mexico, Shell Offshore platform
C, Ku band Doppler radars, laser rangefinder
Environmental data including wind, temp
Incidence angles: -3º to 17º, 5 minutes/angle
Results

Predicted bias

Experimental measurements
Error bars are ± one sigma
Mean significant wave height:
SWH = 0.9m
(results are preliminary)

Jason-1 SWT - Aries, Nov. 2003
Time series – EM bias

EM Bias -- April

Time (days)

EM Bias (cm)

0°  4°  10°  16°
Time series - SWH

EM Bias -- April

Significant Wave Height (m) vs Time (days)

- 0°
- 4°
- 10°
- 16°
Bias vs. significant wave height

EM Bias vs Significant Wave Height

Significant Wave Height (m)

EM Bias (cm)

0°
2°
5°
8°
11°

Jason-1 SWT - Arles, Nov. 2003
Relative bias vs. RMS slope

Normalized Bias vs Wave Slope

Normalized Bias (%H)

Wave Slope

YONE – nadir
GME

Jason-1 SWT - Aries, Nov. 2003
Summary/Conclusions

- Experimental measurements and theoretical analysis predict decrease in EM bias as incidence angle increases
- Mean EM bias may change sign at mid-range incidence angles
- Wide-swath instruments may require incidence-angle dependent correction
- Multiple looks at a given surface footprint at different incidence angles may be used to improve bias correction