A Novel Approach to Ocean Altimetry Utilizing the GPS Signal

Cinzia Zuffada, George Hajj and J.B Thomas

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109
USA

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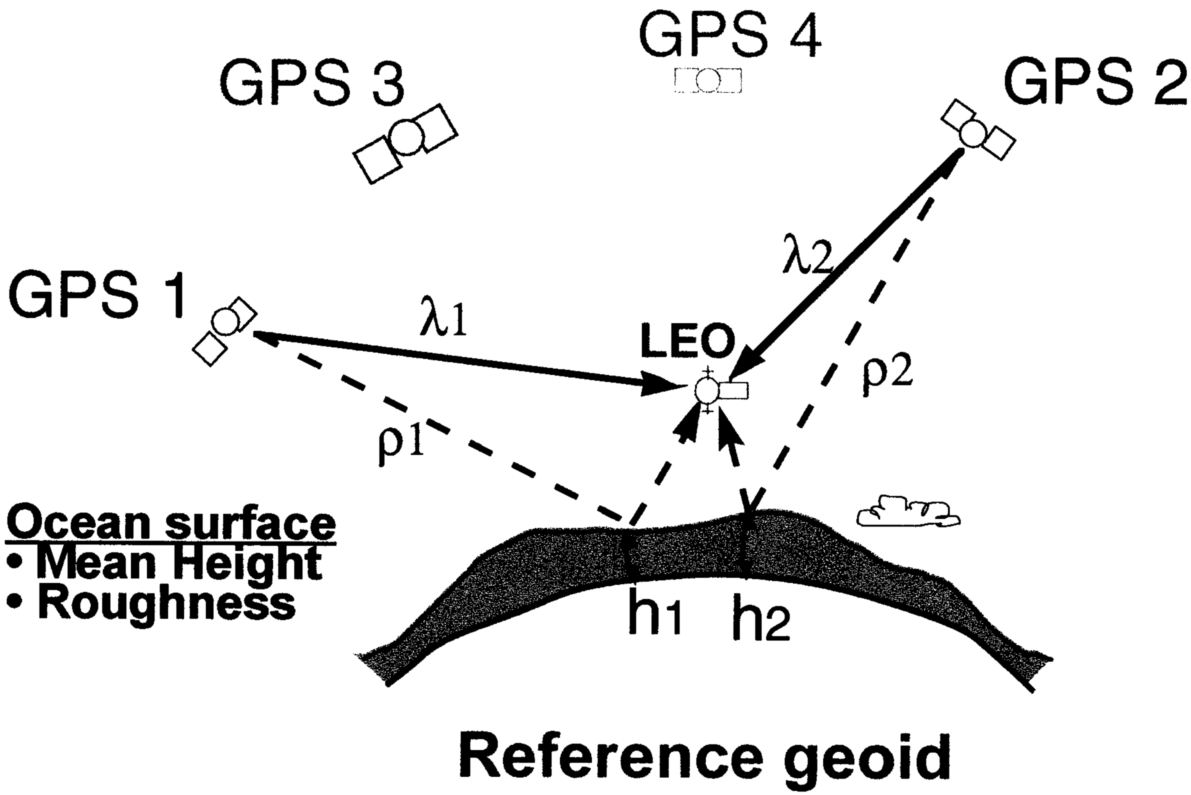
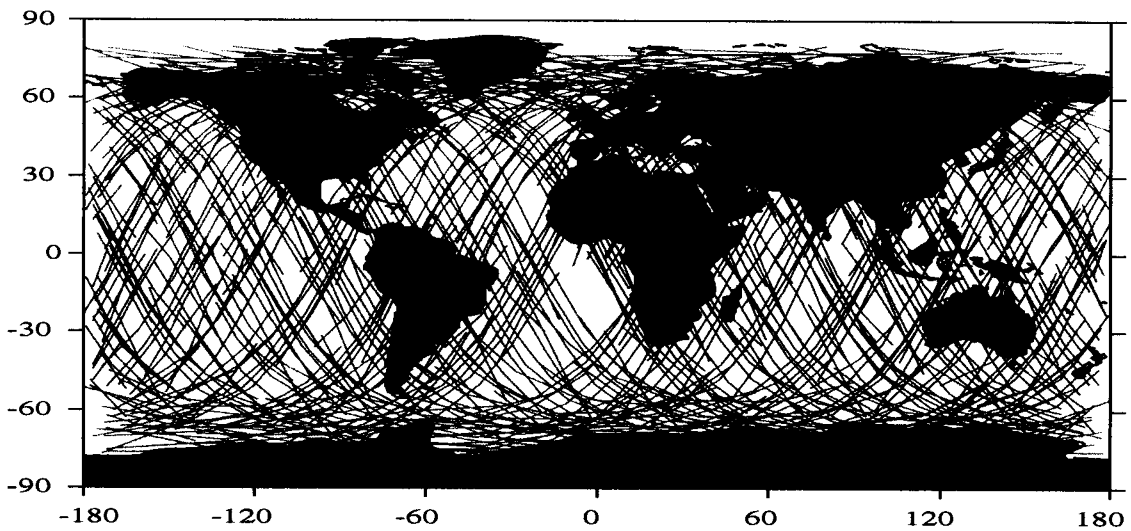
NEW INSTRUMENT GEOMETRY



INNOVATIVE FEATURE

Dense coverage maps into ability to increase spatial/temporal resolution over traditional instruments at reduced costs thus allowing new oceanography

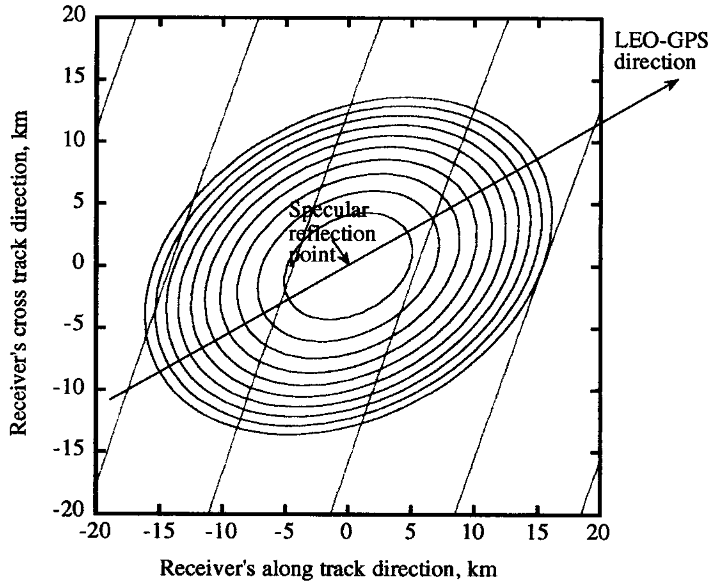


A representative daily coverage

SIGNAL MODELING OBJECTIVES

- predict received signal as a function of
  sea state parameters
  geometry and antenna parameters
  receiver parameters
- perform error analysis and sensitivity studies, identify areas needing focused research
- develop retrieval algorithms
- formulate requirements for receiver developments
- formulate requirements for overall system development

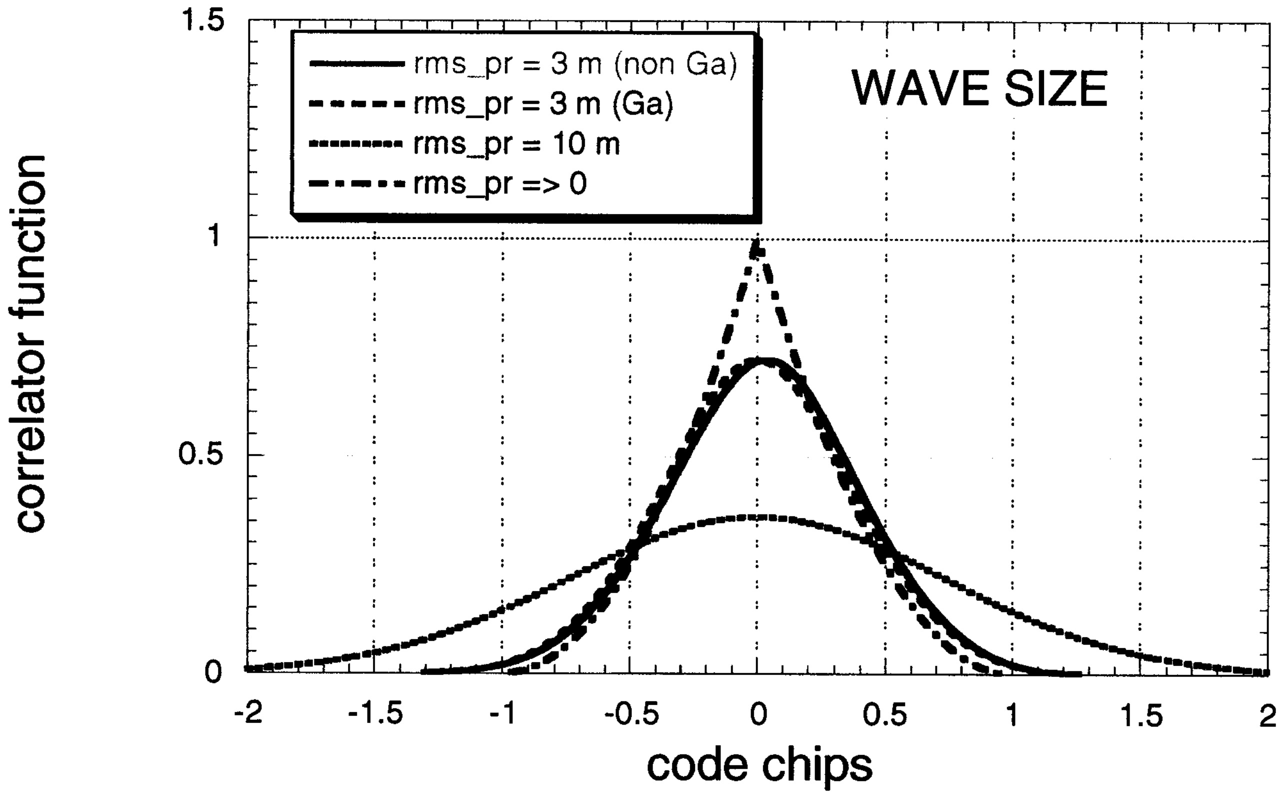
FOOTPRINT OF BISTATIC REFLECTION MEASUREMENTS



$$SNR_V = \frac{P_t}{kTB} \int \frac{\Lambda^2(\tau - (R_1 + R_2)/c)}{(R_1 R_2)^2} \quad \sigma_0(\rho, u_{10}) \quad G_r(\rho) \quad S(f_D) \quad d\rho^2$$

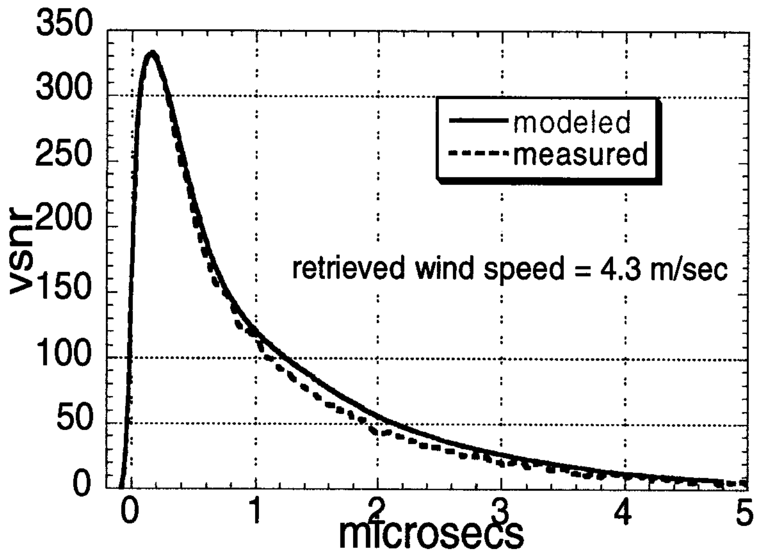
CORRELATOR SCATTERING GAIN DOPPLER

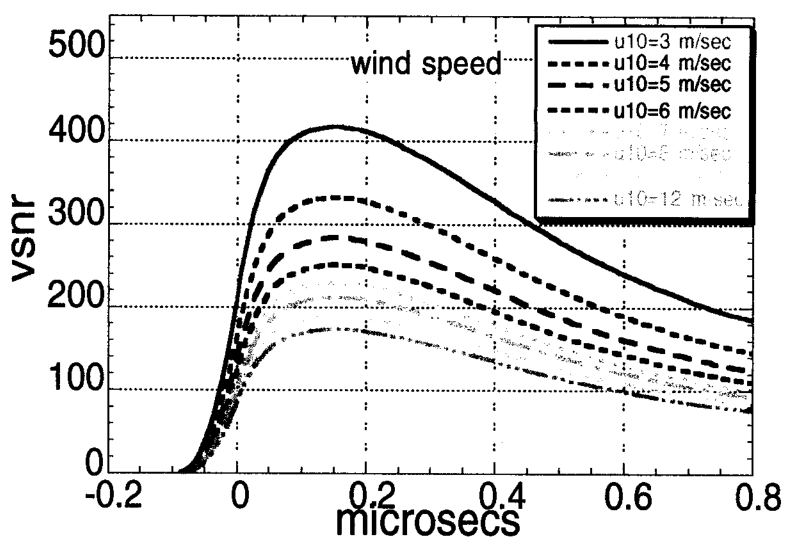
EFFECT OF SEA STATE ON CORRELATOR



rms_pr = wave heights projected along direction of propagation

MODEL - DATA COMPARISON



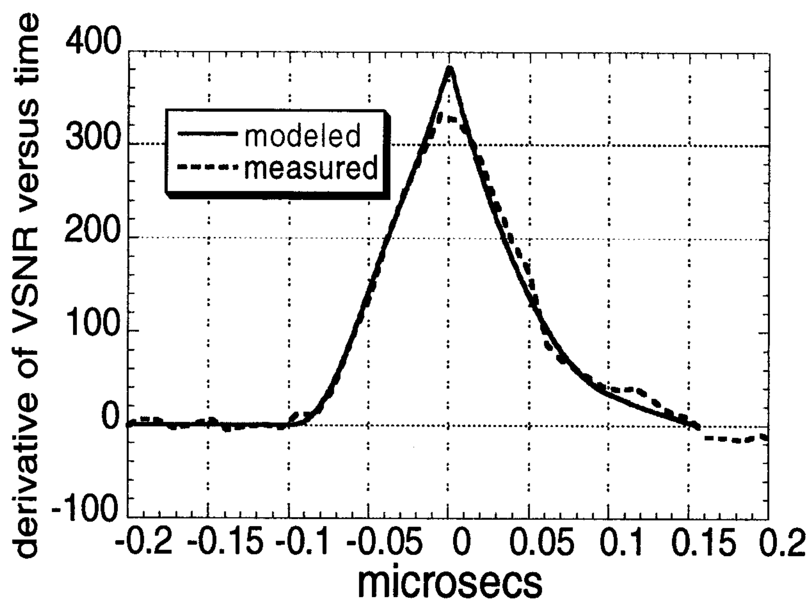


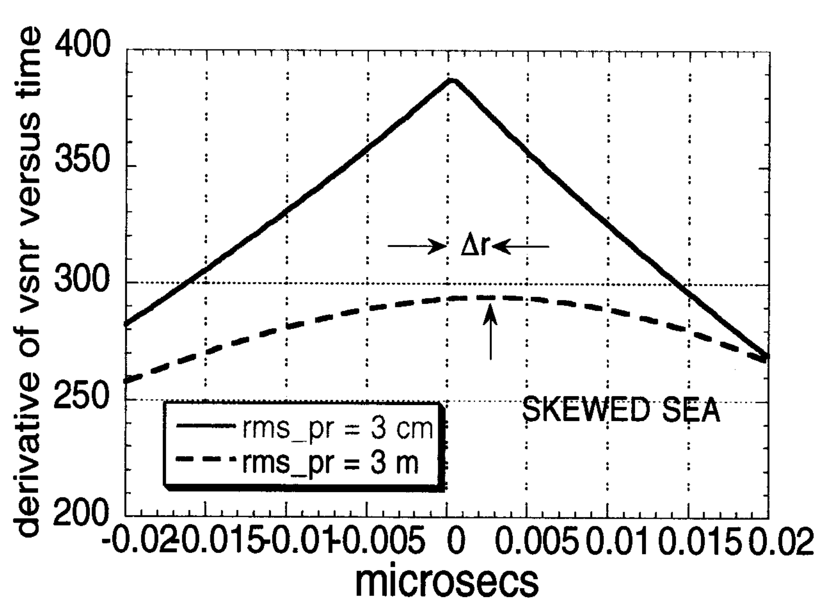
Reflection collected from SIR-C

In space and for high antenna gain the shape is dominated by the antenna pattern high dynamic range

Wind speed estimated by peak value, sensitivity decreases with increasing wind

GPS 'ALTIMETRY WAVEFORM'



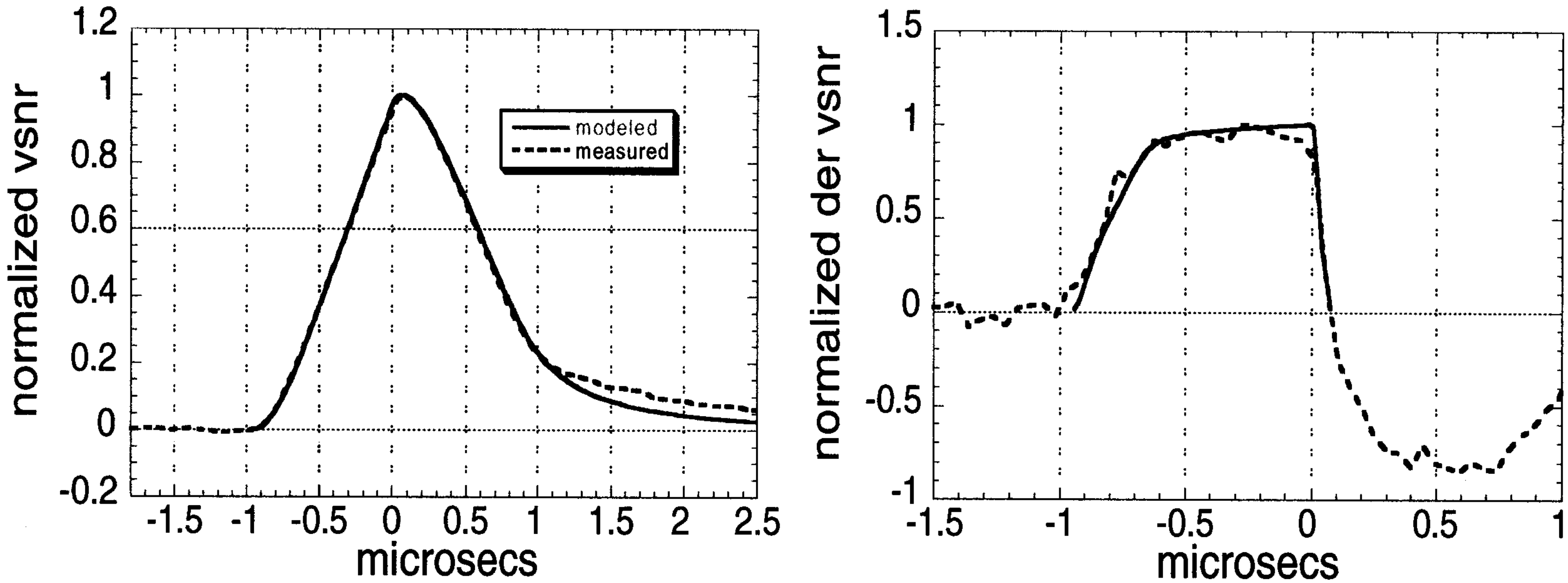


Derivative is more convenient for sea height detection (in space)

Significant wave height (SWH) and skewness affect overall shape and introduce extra delay (EM bias), but bistatic geometry mitigates their effect

Parameter retrieval approach can be used to recover height,wind and SWH

MODEL - DATA COMPARISON



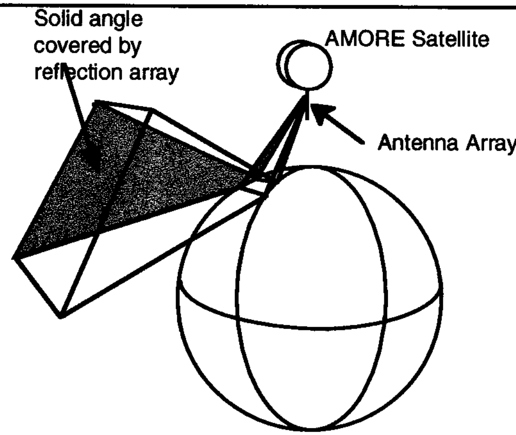
Reflection collected from airplane (Oct. 98)

Significantly different shape from 'space-based' case with lower rise time

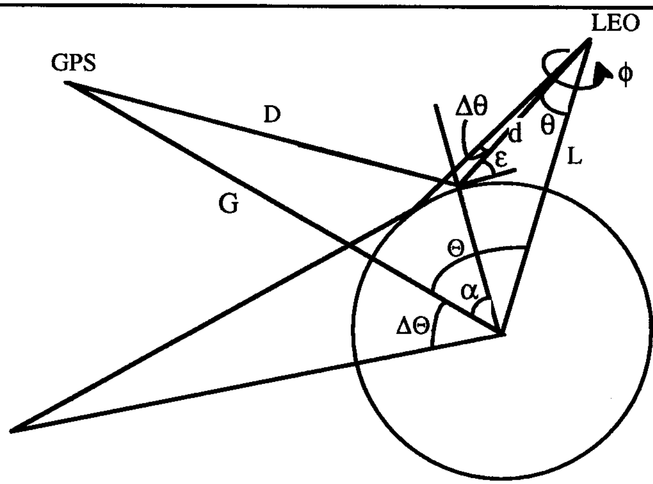
Shape transitions continuosly for increasing receiver height

Derivative no longer advantageous for sea height detection

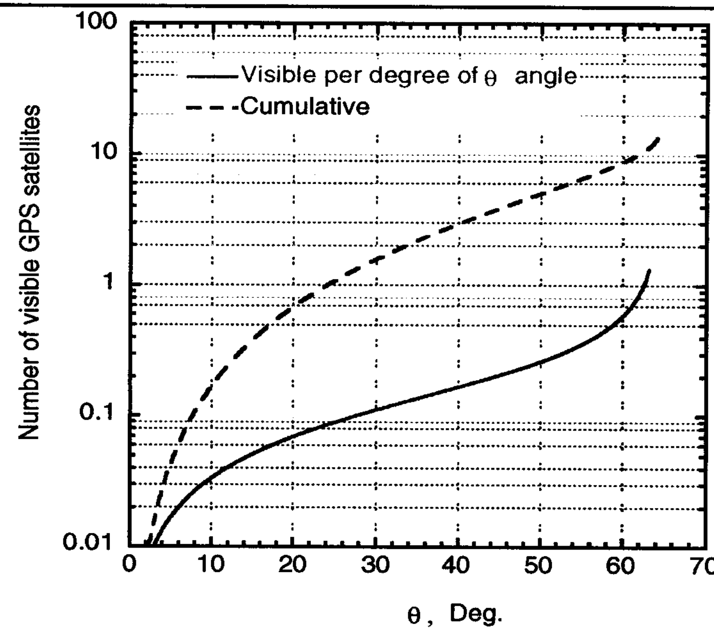
ANTENNA POINTING CHOICE



SOLID ANGLE COVERED BY REFLECTION ANTENNA



GEOMETRY OF BISTATIC REFLECTION



NUMBER OF VISIBLE GPS SATELLITES AS A FUNCTION OF THE VIEWING ANGLE

RATIONALE FOR CHOICE

EXAMPLES OF DIFFERENT ANTENNA FIELDS-OF-VIEW AND THE CORRESPONDING AVERAGE NUMBER OF SIMULTANEOUSLY VISIBLE GPS SATELLITES.

Example 1: 45 deg sweep from nadir	Example2:60deg sweep from nadir	Example 3: Donut shaped antenna beam pointing close to the Earth's limb
$\theta = 0^\circ$	$\theta = 0^\circ$	$\theta = 50^\circ$
$\theta+\Delta\theta = 45^\circ$	$\theta+\Delta\theta = 60^\circ$	$\theta+\Delta\theta = 64.2^\circ$
$\Theta = 0^\circ$	$\Theta = 0^\circ$	$\Theta = 54.5^\circ$
$\Theta+\Delta\Theta = 47.4^\circ$	$\Theta+\Delta\Theta = 74.5^\circ$	$\Theta+\Delta\Theta = 97.3^\circ$
$N_{GPS} = 3.9$	$N_{GPS} = 8.8$	$N_{GPS} = 8.5$

ADVANTAGES OF CHOICE AND ISSUES

- Coherence time increases with increased angle of incidence, thus allowing longer integration time resulting in higher SNR
- Lower antenna gain is required for specified SNR (hence accuracy) resulting in reduced system cost
- Measurements at large angles are sensitive to troposphere and provide a way to correct sea height for atmospheric effects
- Issues:

  Bistatic scattering not characterized for large angles

CONCLUSIONS

- Introduced the concept of bistatic ocean altimetry with the GPS signal and outlined the benefit of the measurement type
- Discussed the features of the GPS altimetry waveform and how to extract height, waves and wind speed
- Discussed some system design issues, including choice of antenna pointing direction to maximize strength of received signal