Aircraft Measurements of Monterey Bay's Ocean Topography

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Outline

- Monterey Bay Experiment
- Altimetric results
- Summary

Experiment Preparation

Goal:

Observe 4-Dimensional ocean topography with simultaneous and co-located ground and air measurements

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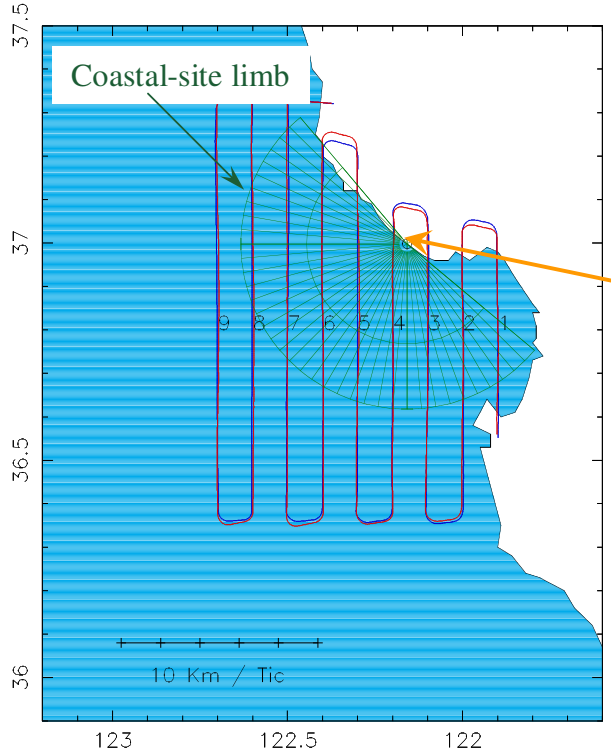


Experiment Preparation

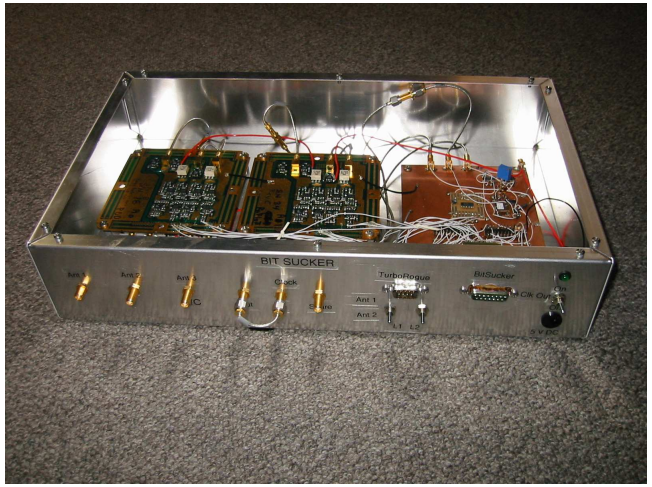
Taking data over several days => New Data Acquisition System

Old Hardware

- Sampler boards produced RFI
  - Often lost aircraft positioning
- Recorder not especially reliable
- 50 GB capacity
- Download takes 1-2 days
- Only 1 operational system max

Experiment Preparation

New Hardware



PC-Based system with Labview

- Extra Blackjack sampler boards (no RF interference)
- MUCH greater reliability
- Much more compact: Path toward ER-2 / Ice flights (?)
  - Used for Huygen's probe data collection!
- In-flight diagnostics
- *Enabled the Monterey Bay experiment's* ***success***

Flight Experiment

Data Summary

- Flew 7 days (1st day: many problems, 2nd day: fewer)
  - 2 flights per day
  - Each flight covered whole bay
- Recorded 8 channels at 20.456 MHz
  - Complex (I/Q) sampling
  - L1 and L2
  - Up-looking and down-looking antennas
- Collected 2 TBytes of open loop data
- Flights + to/from airport, flew 22,500 km

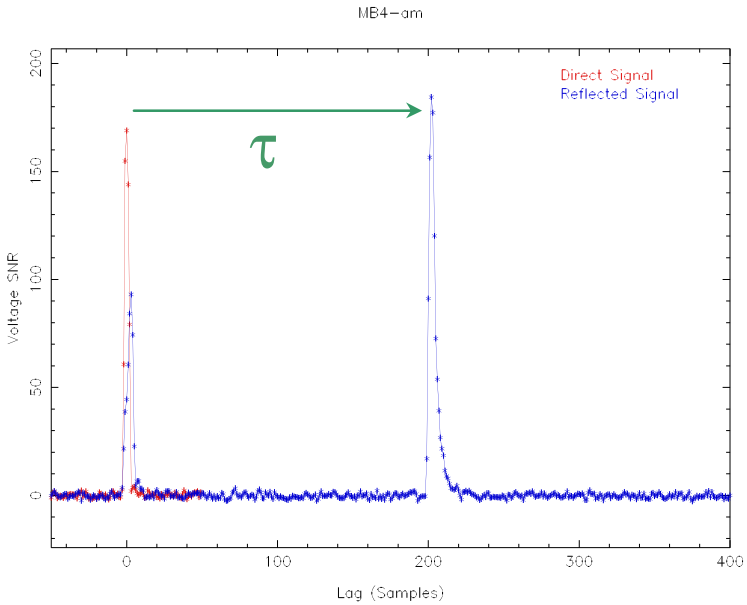
World's most extensive
GPSR aircraft data set

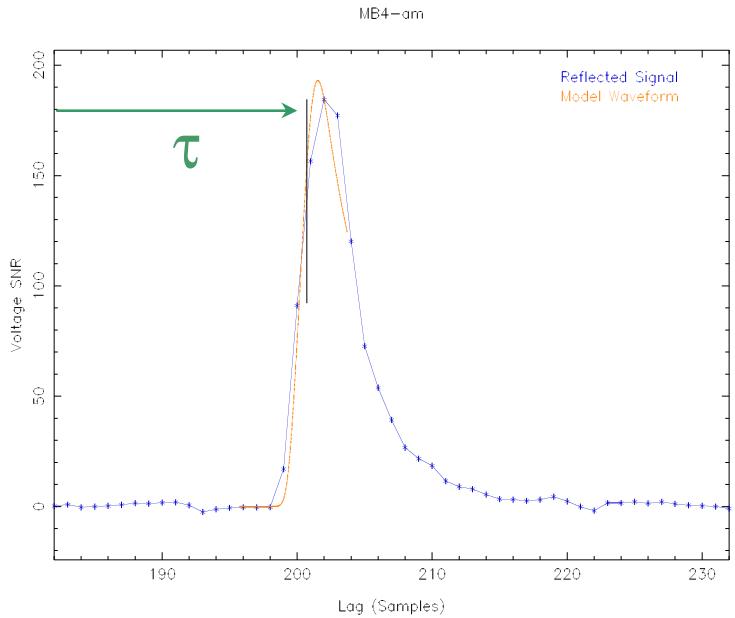
Data Reduction

Software Receiver

- Improved for massive runs
  - Eliminated manual intervention
  - Increased speed
- Fast workstation has run continuously since Aug 2004
  - Have Y-code: processed L1-Y
  - Finished 3rd flight last week
  - 4th flight should finish last step in July
- Now have access to Beowulf cluster
  - Produce L2-Y, L1-C/A waveforms?

Waveform Fitting





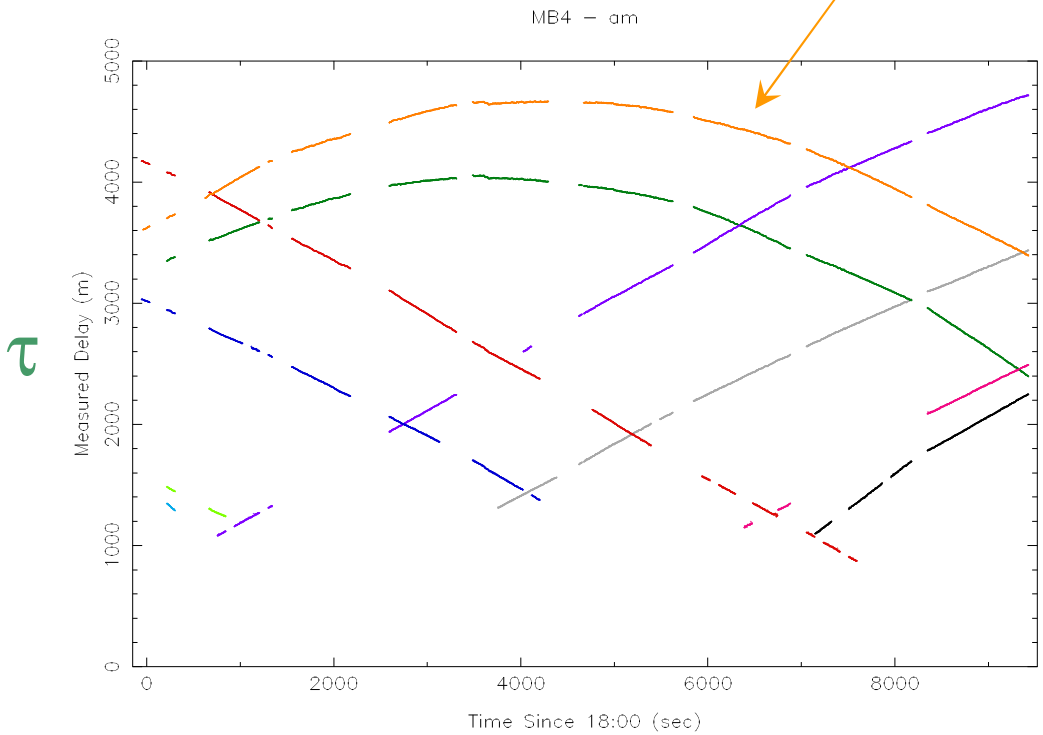
Waveform model includes:

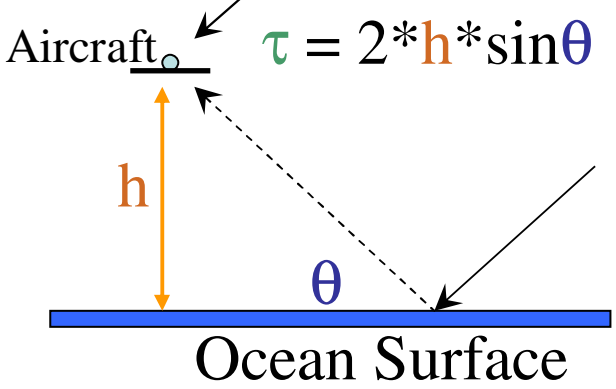
- Zavorotny/Voronovich integral + Ulaby scattering coefficients
- Receiver and transmitter bandpass filters
- Antenna beam pattern
- Surface dielectric and MSS properties
- Amplitude non-linearities in SNR
- Computed for every 2-sec waveform

Delay Measurements (AM Flight)

Color coded by PRN

Delay changes as satellite elevation angle changes





Surface Height Calculation

$$\tau^{meas} = \tau^{geom} + \tau^{clk} + \tau^{prop}$$

τ^{meas} is from waveform fits

τ^{geom} computed from geometry

τ^{clk} accounts for HW, processing delay differences

τ^{prop} atmospheric propagation effects

$$h^{meas}(WGS84) = (\tau^{meas} - \tau^{wgs84}) / 2 / \sin(\theta_{elev})$$
$$= (h^{topo} + h^{tides} + h^{geoid\text{-}wgs84}) + (\tau^{clk} + \tau^{prop}) / 2 / \sin(\theta_{elev})$$

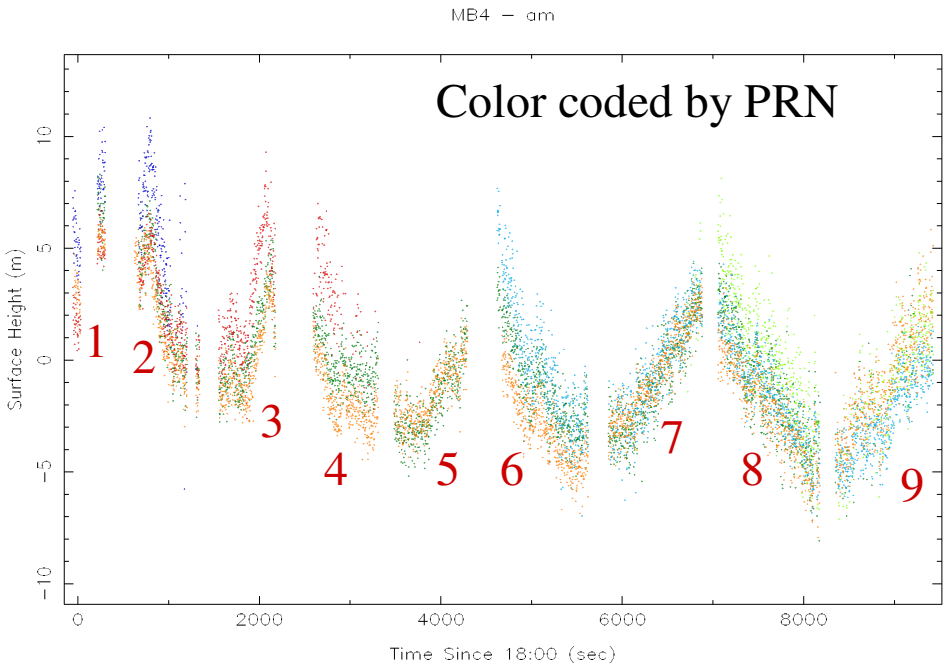
Set to zero for now

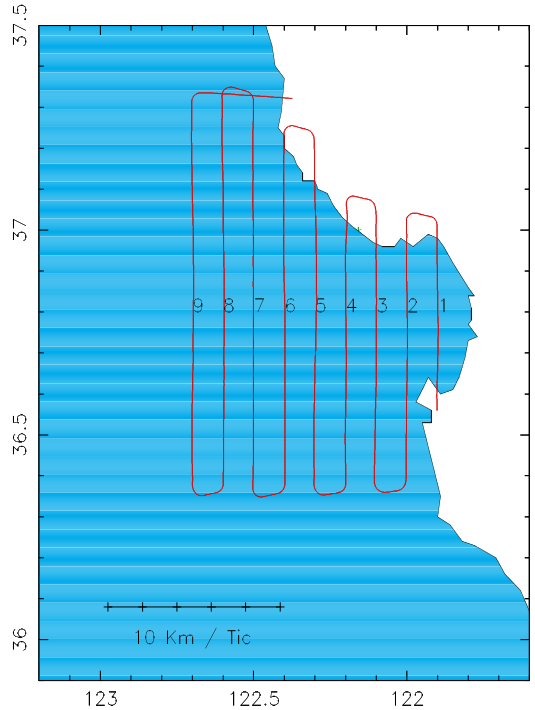
Set to constant (-27 m) for now

$$h^{topo} = \frac{\tau^{meas} - \tau^{wgs84} - \tau^{clk} - \tau^{prop}}{2*\sin(\theta_{elev})} - h^{tides} - h^{geoid\text{-}wgs84}$$

Height vs Time (AM Flight)

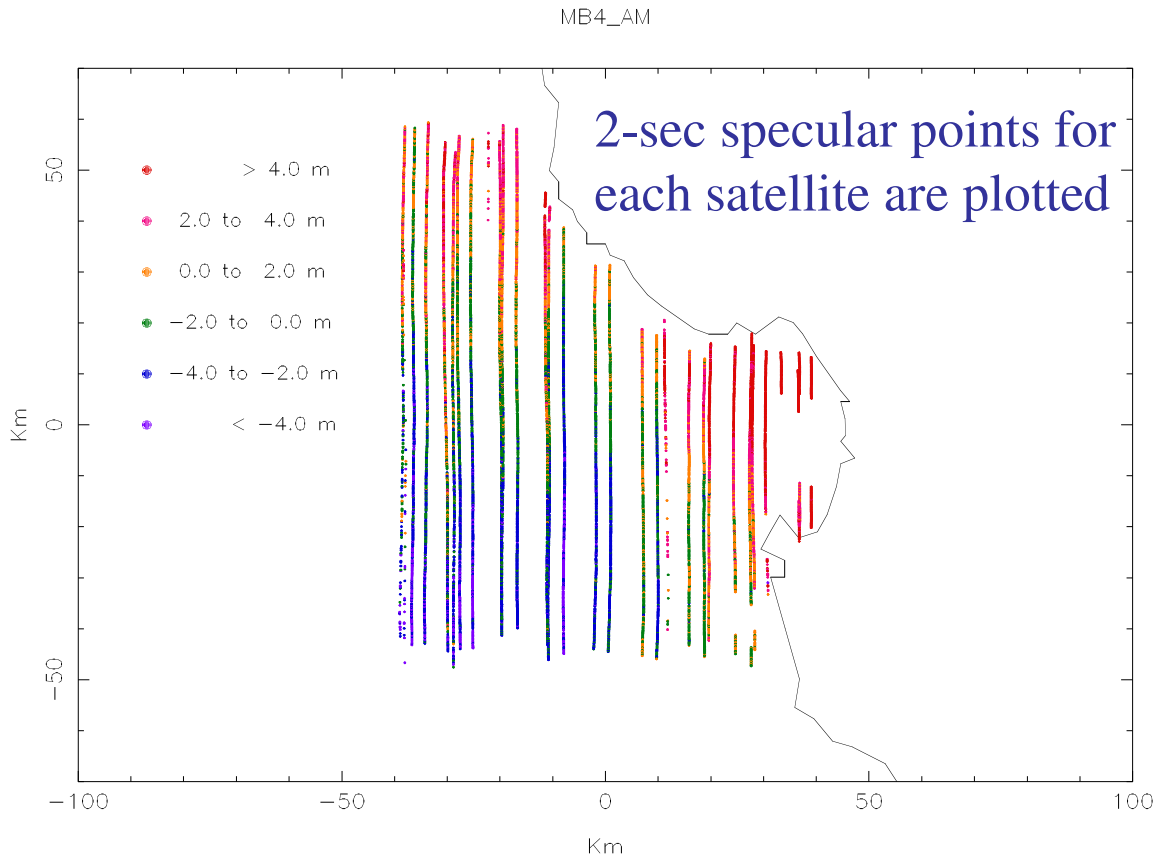
h^{topo}





About a 5-6 m upward slope from S to N, and W to E

Height vs Position (AM Flight)



Surface shows apparent ~6 m slope up to NE relative to WGS84

Delay Measurements (PM Flilght)

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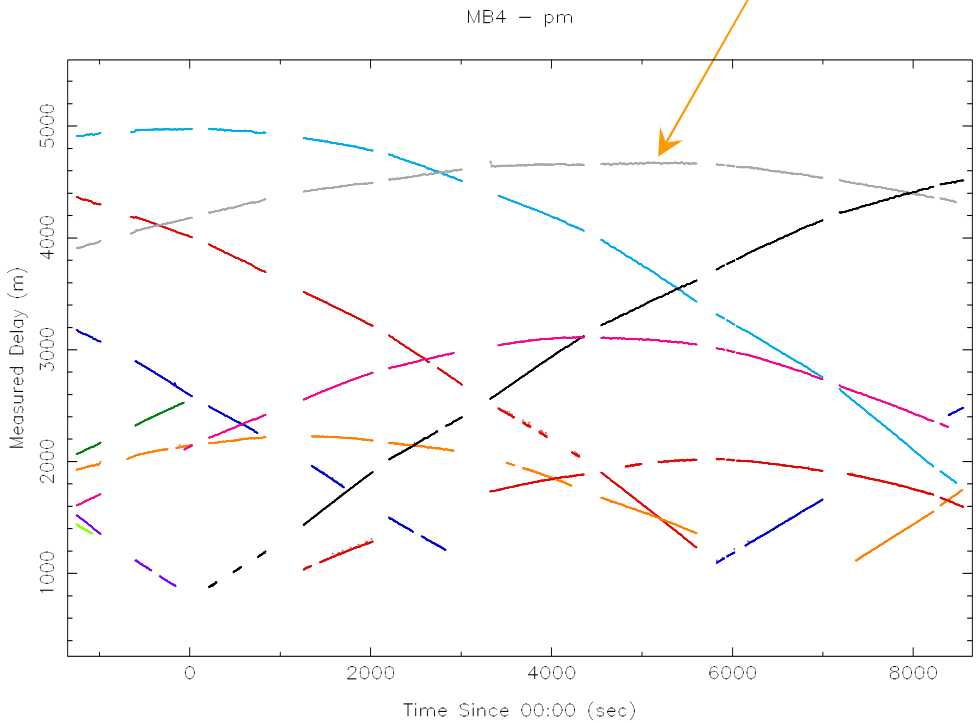
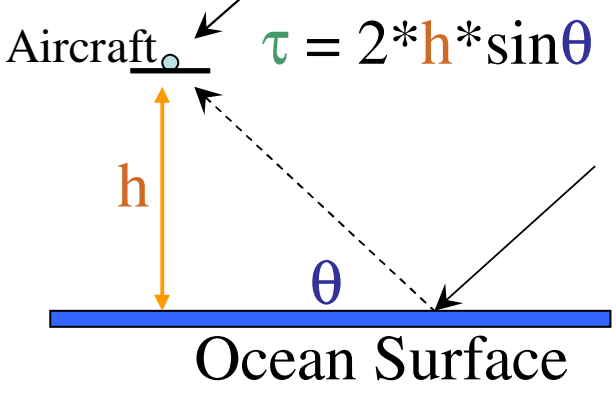
Delay changes as satellite elevation angle changes

τ



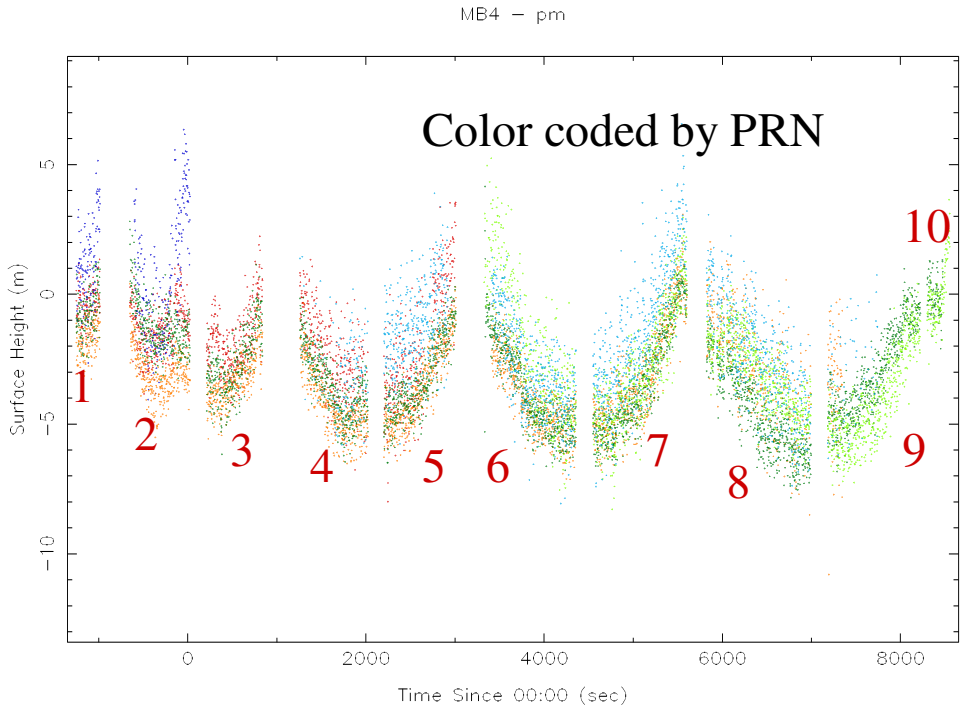


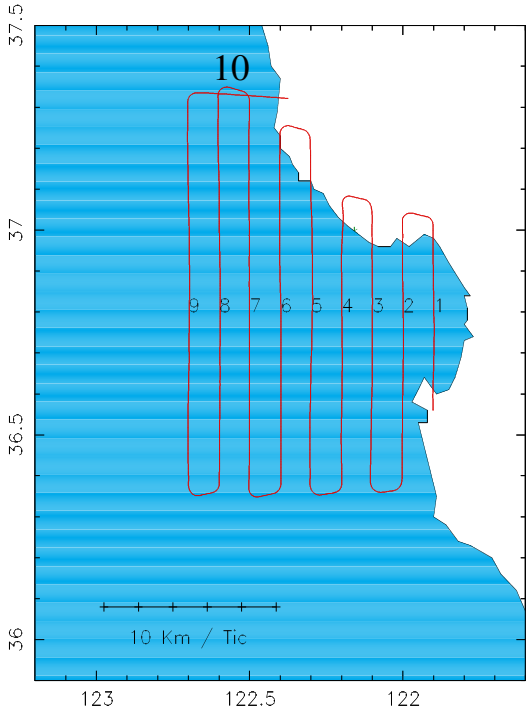
$\tau = 2*h*\sin\theta$

Completely different Geometry from AM

Height vs Time (PM Flight)

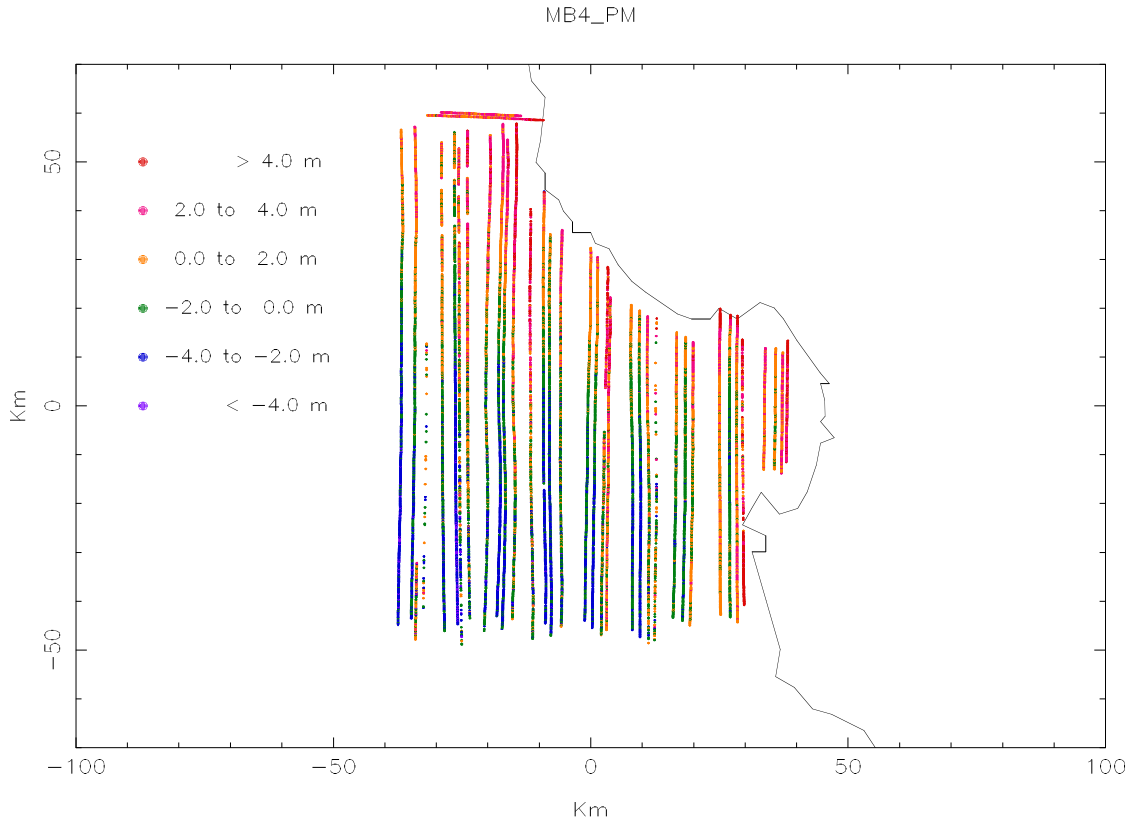
h^{topo}





About a 5-6 m upward slope from S to N, and W to E

Height vs Grid



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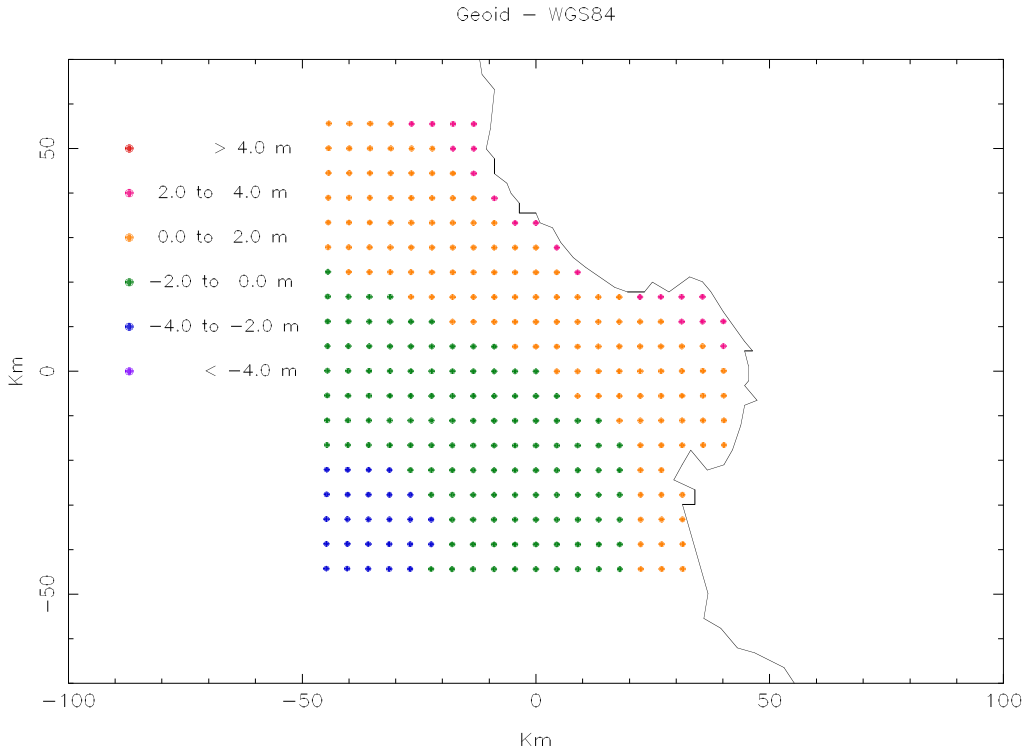
Geoid Relative to WGS84



Geoid shows ~6 m slope up to NE relative to WGS84

=> To lowest order, measuring geoid relative to WGS84

Summary

Aircraft / Coastal Campaign

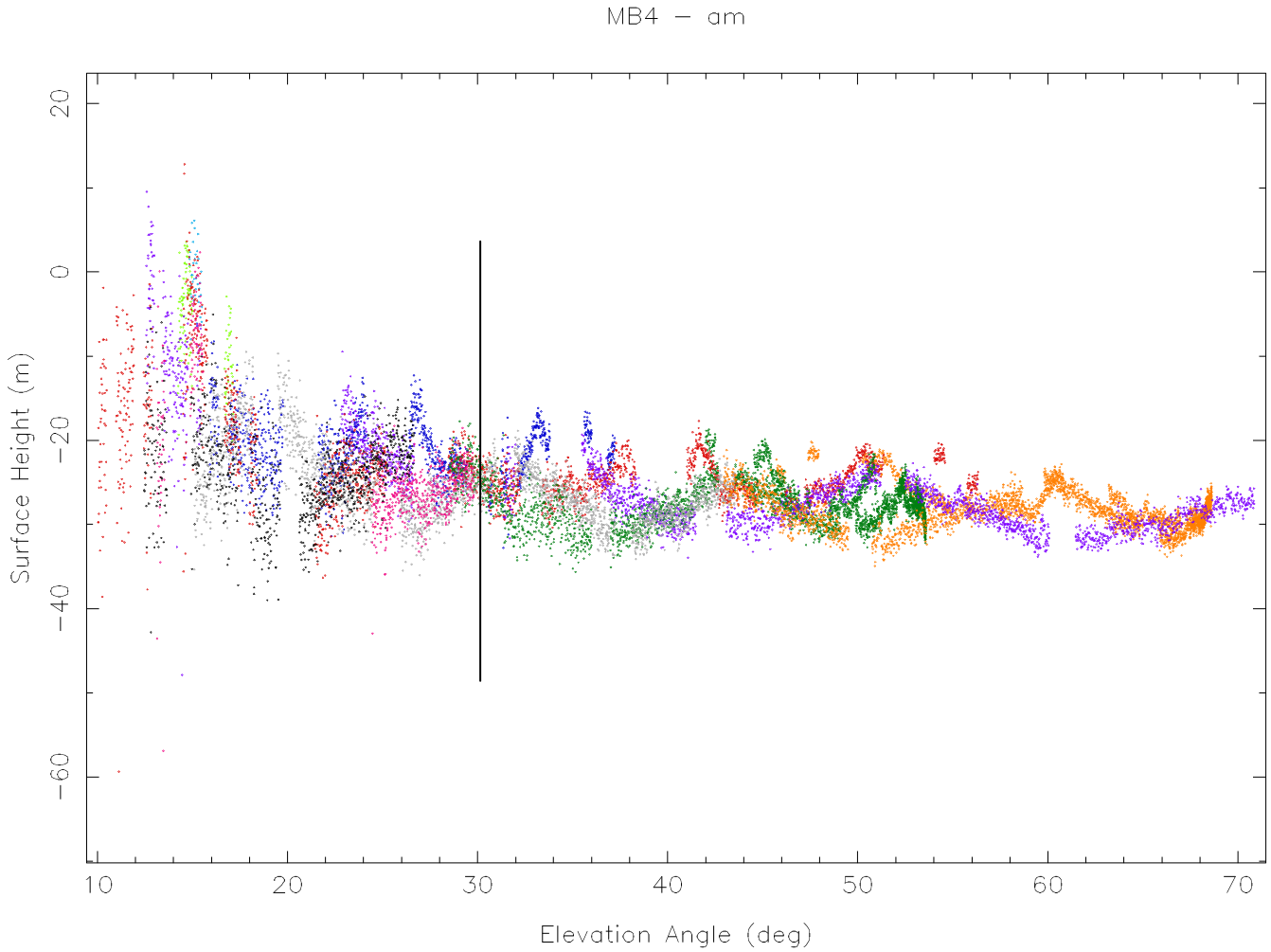
- Developed 3rd-generation DAS
- Two exceptionally large, high-quality data sets (air, land)

Aircraft Analysis

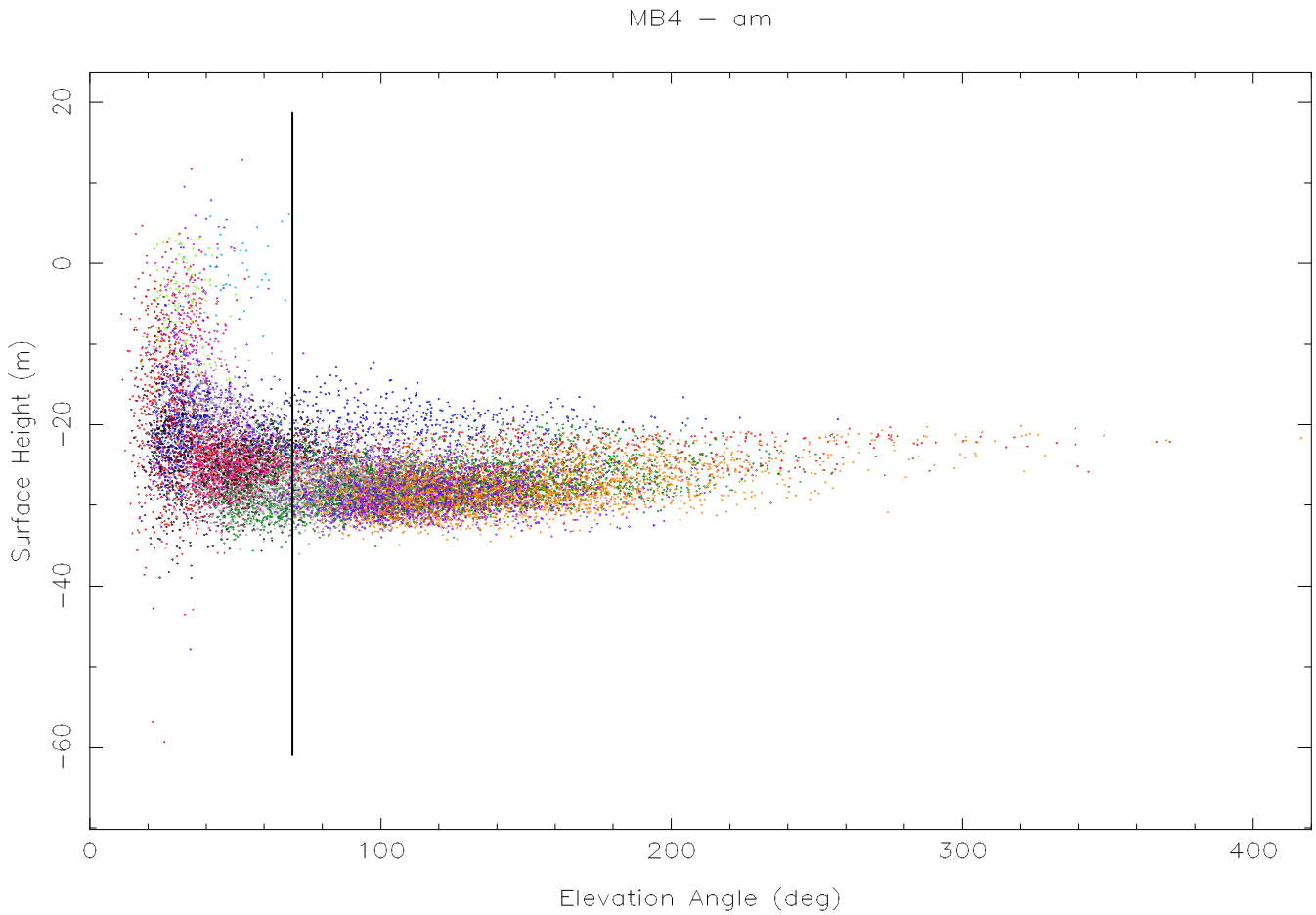
- Just started looking at waveforms, very preliminary, lots of work left to do, etc.
- 3 of 4 days processed with software receiver (2-months for 4th)
- Data show repeatable sensitivity to surface height
  - We observe MSS relative to WGS84
- Need to calibrate clock-like effects, improve troposphere
  - To remove elevation-angle dependence

Extras

Cut on Elevation Angle



Cut on SNR


MB4 – am
Surface Height (m)
20
0
−20
−40
−60
0
100
200
300
400
Elevation Angle (deg)