Bistatic Delay-Doppler Radar Altimeter and Mission Concepts

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GAMBLE Workshop - An EC Thematic Network
to Consider Future Developments in Satellite Altimetry
Themes 1 (Sea surface height) and 3 (Orbit Determination)

Delft Technical University, Delft, The Netherlands

7-8 November, 2002

Bistatic Delay-Doppler Radar Altimeter and Mission Concepts

Delay-Doppler Altimeter (DDA) *Keith Raney, APL*

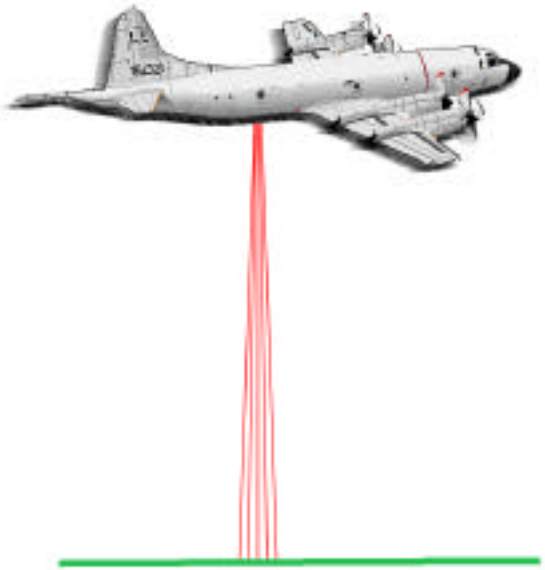
- CRYOSAT - 2005 launch
- WITTEX (3-satellite constellation, GEOSAT orbit) *proposed*
- ABYSS (Altimeter BathymetrY from Surface Slope)
  - Walter Smith, PI, mission *proposed* on International Space Station (ISS) to NASA's ESSP program
- Bistatic WITTEX (3-satellite constellation)
  - *proposed* for NPOESS (Ocean Observer System)

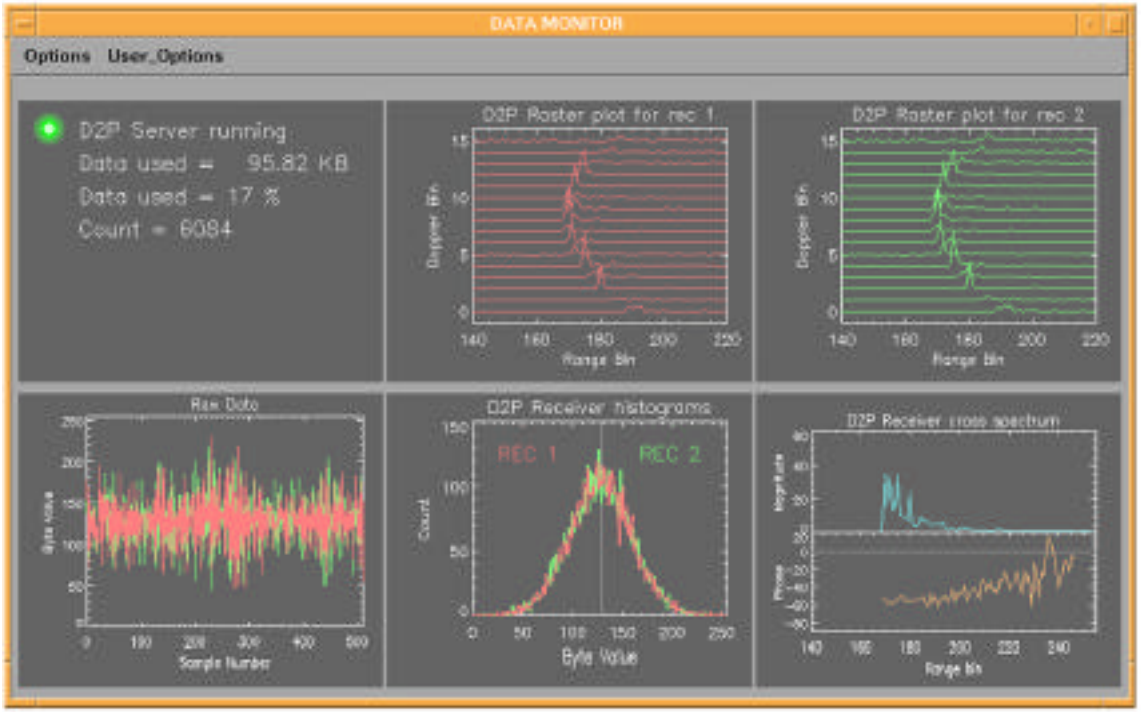
NASA Instrument Incubator Program at JHU/APL:

DDA is a proven design

http://fermi.jhuapl.edu/d2p

Delay-Doppler





R.K.Raney

Altimeters Compared

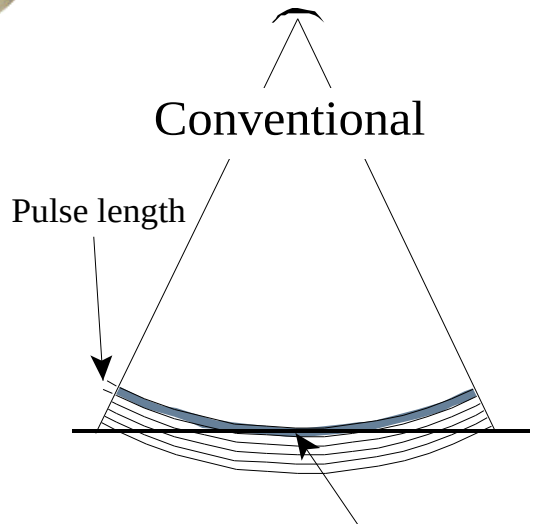
DDA: More averaging => x2 better precision, x10 better efficiency

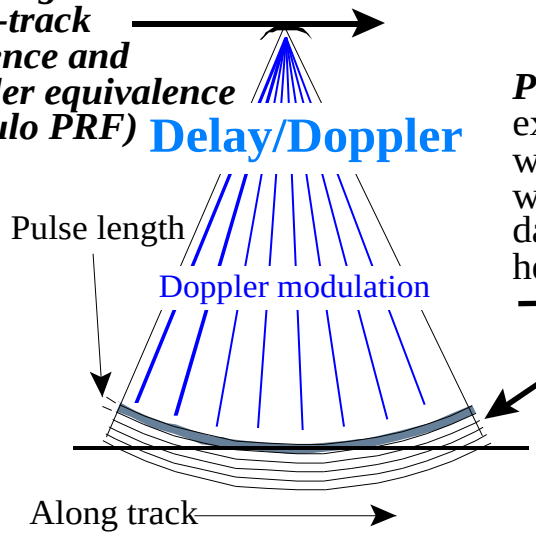
Advantage: along-track incidence and Doppler equivalence (modulo PRF)

Delay/Doppler

Processing remove extra delay due to wavefront curvature, which converts all data along-track to height measurements

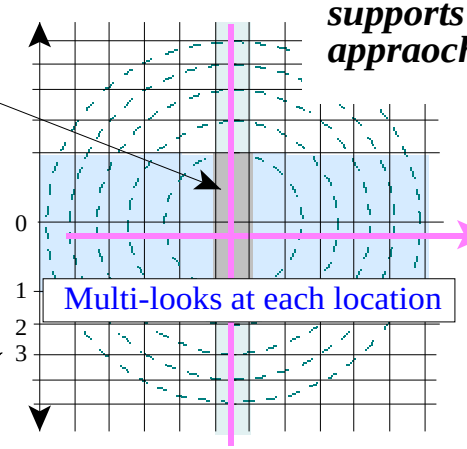
Conventional





Doppler knowledge supports closer appraoch to shore

Pulse-Doppler limited footprint



Two-dimensional section of the angular scattering function at each and every subsatellite point

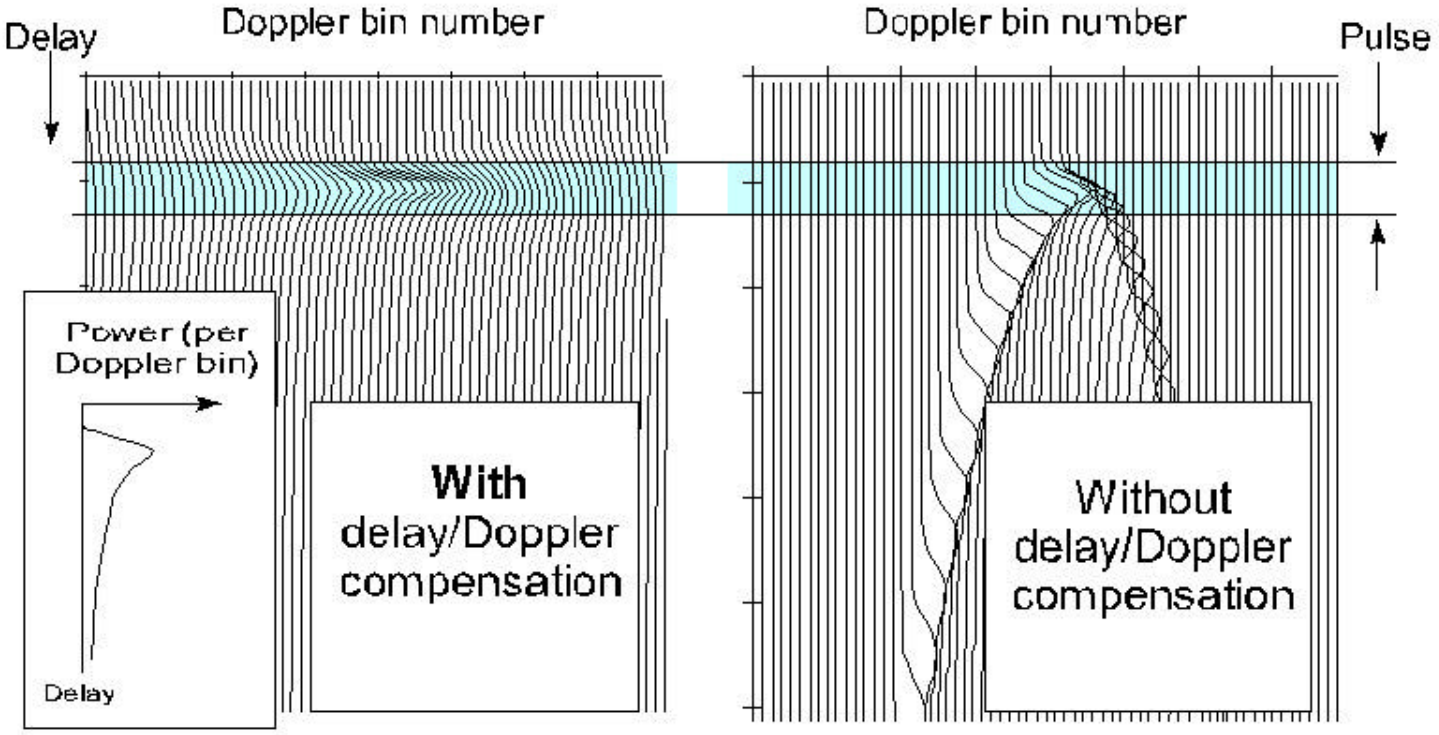
< 2 km proximity to coastlines

New approach to radar altimetry:

Delay Doppler Paradigm

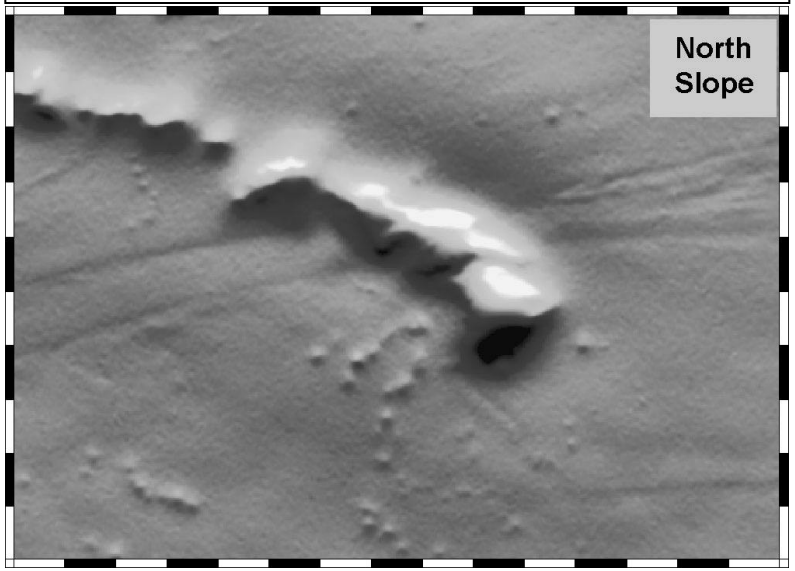
Utilizes Synthetic Aperture Radar techniques

New: FFT's over pulse burst => Data into Doppler bins
New: Unique range curvature correction applied across bins
New: Co-register and incoherent sum over all bins
Range de-ramp and tracking as per conventional altimetry



Existing data have anisotropic slope resolution due to too-polar orbital inclination

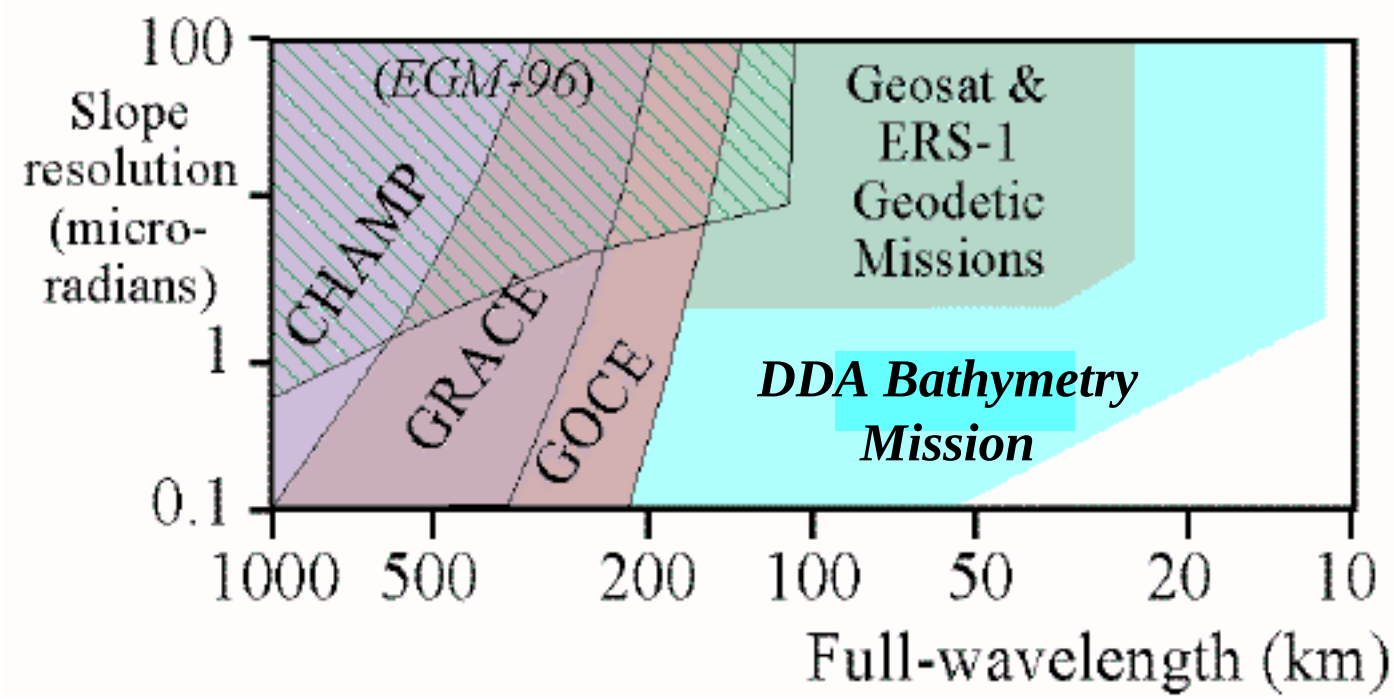
Current altimeters provide ~3 X higher noise in the east slope than in the north slope because of their high inclination orbits.



ABYSS will reduce the noise by a factor of 6 in the east slope and a factor of 3 in the north slope.

DDA Bathymetry Mission - ABYSS

A Delay-Doppler Altimeter in a suitable orbit (~50° or ~125°) would improve slope resolution by an order of magnitude, and spatial resolution by a factor of 3 (avg)



Bathymetry Controls Ocean's Role in Climate: Science Rationale for ABYSS Mission

- **Water, heat, and greenhouse gases are moved by**
  - –Advection (currents)
  - –Diffusion (mixing)
- **Seawater is mostly stratified, so that**
  - –Horizontal movement is primarily by currents
  - –Vertical movement is primarily by mixing
- **Bathymetry is a control on both currents & mixing**
  - –Depth variations steer currents (Fig. F-1)
  - –Bottom roughness enhances mixing (Fig. F-2, bottom)

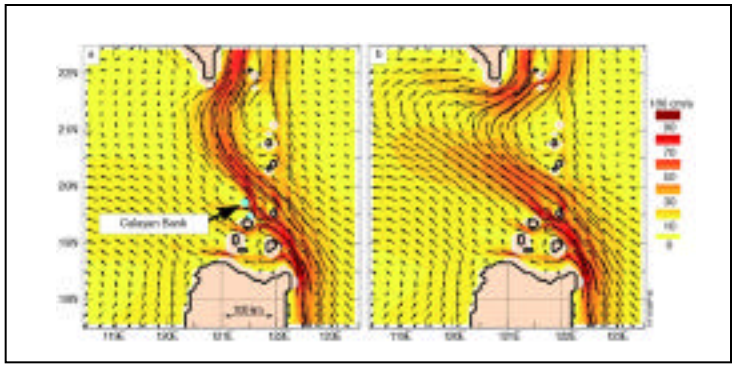


Fig. F-1

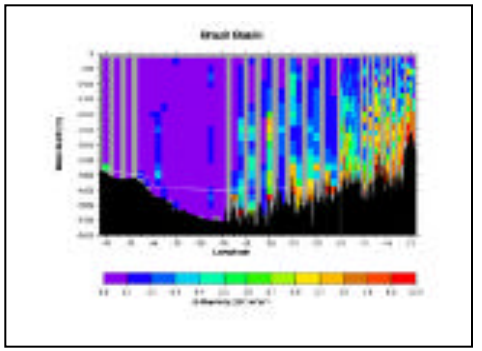


Fig. F-2, bottom

Bistatic Delay Doppler Altimetry and NPOESS

Final Report

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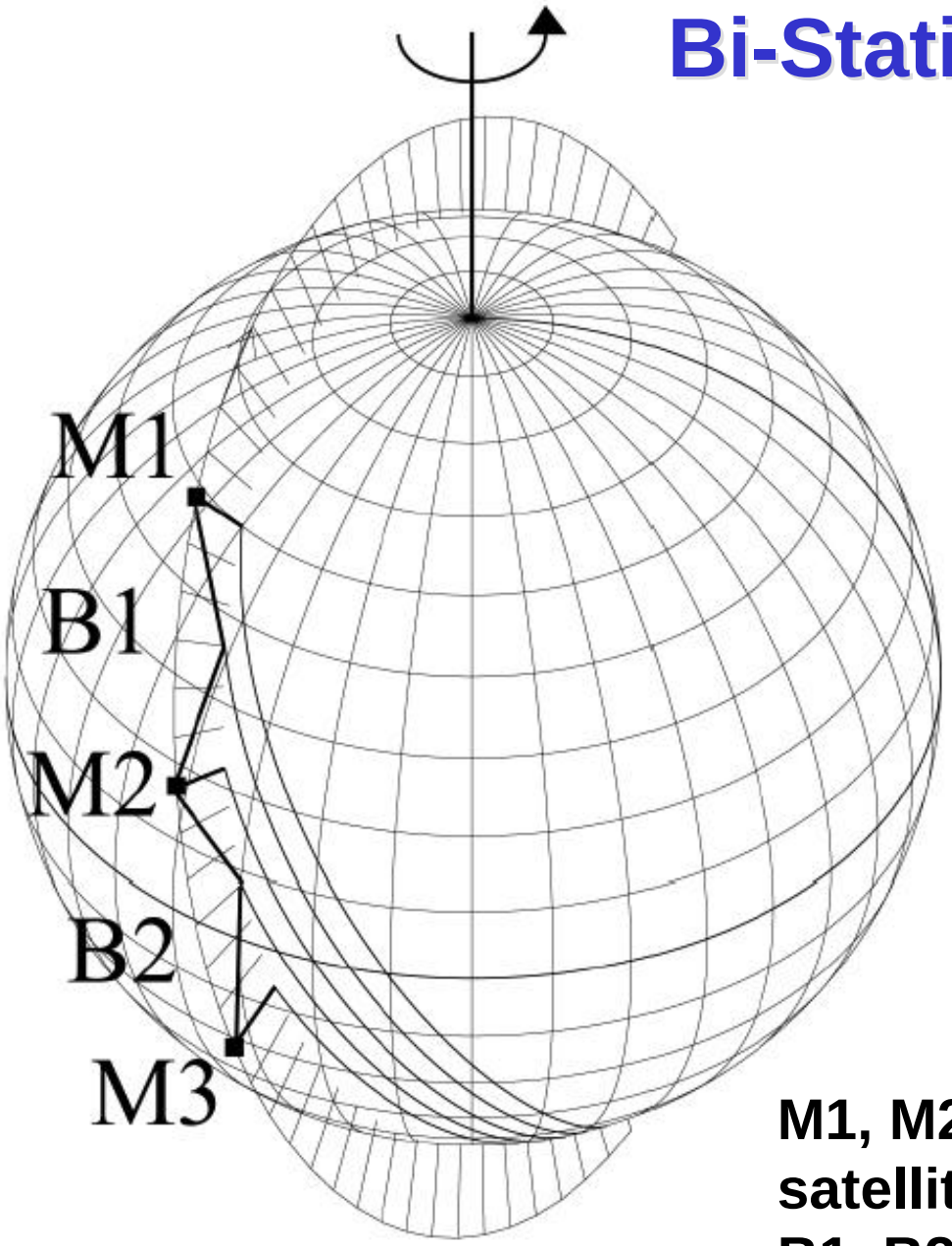
Bi-Static Altimeter Concept



***Monostatic*: Nadir-reviewing:**
***Bistatic:* Cross-link viewing generates "virtual" altimeter tracks in between 2 satellites, (2n-1 tracks, n is no. of s/c)**

- **Bistatic instrument: transmitter and receiver (dual-transmission & receiving to diminish clock error)**
- **Major error sources: timing and cross-track path delay**

M1, M2, M3: 3 Nadir-reviewing satellite constellation
B1, B2: *virtual* altimeter tracks from bistatic altimeter system

Raney et al. [2002]

Bi-Static 3-Geosat Constellation Resolution

Geosat Example

Raney et al. [2002]

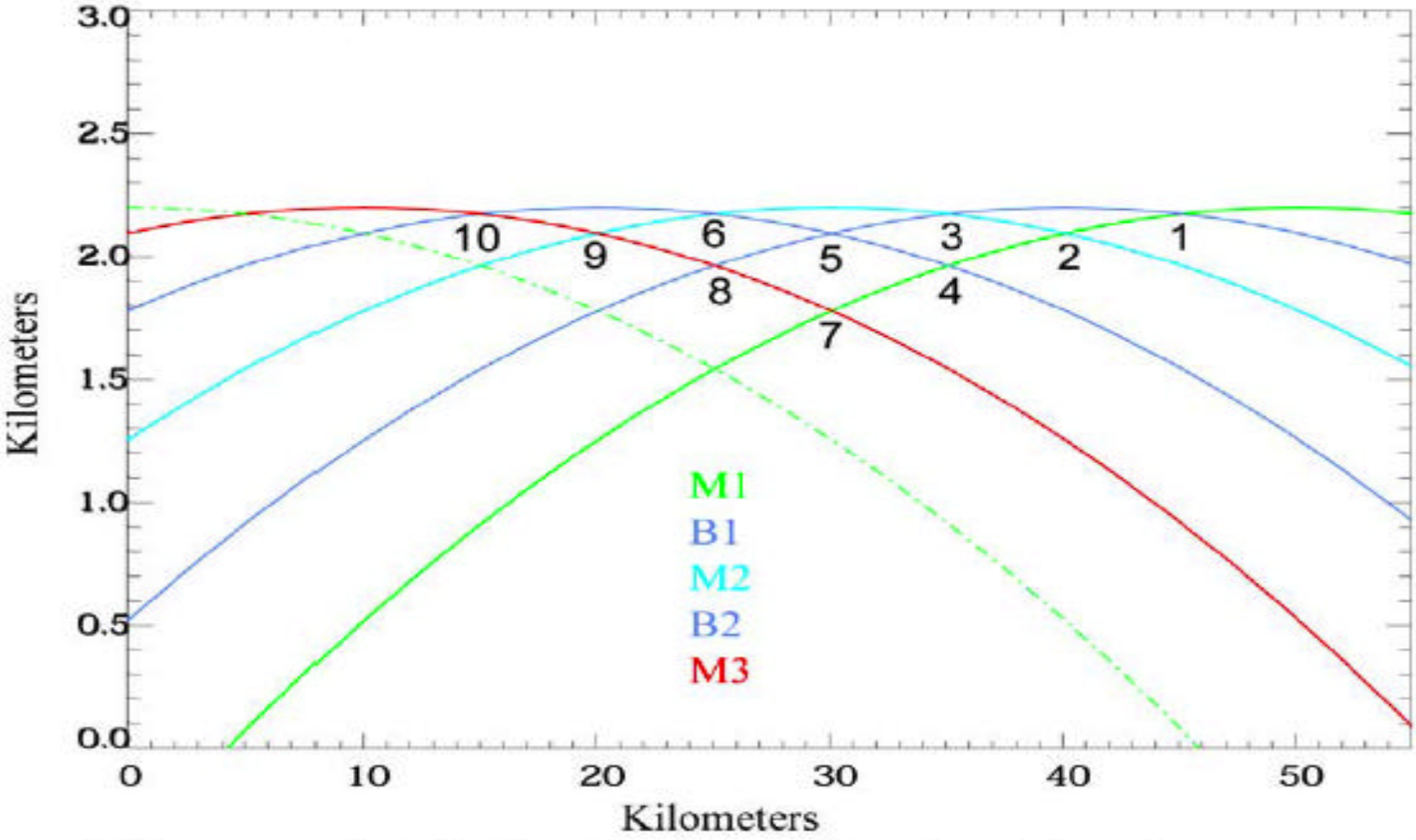


Figure 3. Turnover points for the Geosat ground track are shown in an exaggerated scale in the vertical. The nadir-viewing altimeter's ground tracks are labeled M1, M2, and M3. The bistatic ground tracks are labeled B1 and B2. The intersection points are numbered sequentially in time.

Bi-Static 3-Geosat Constellation Resolution

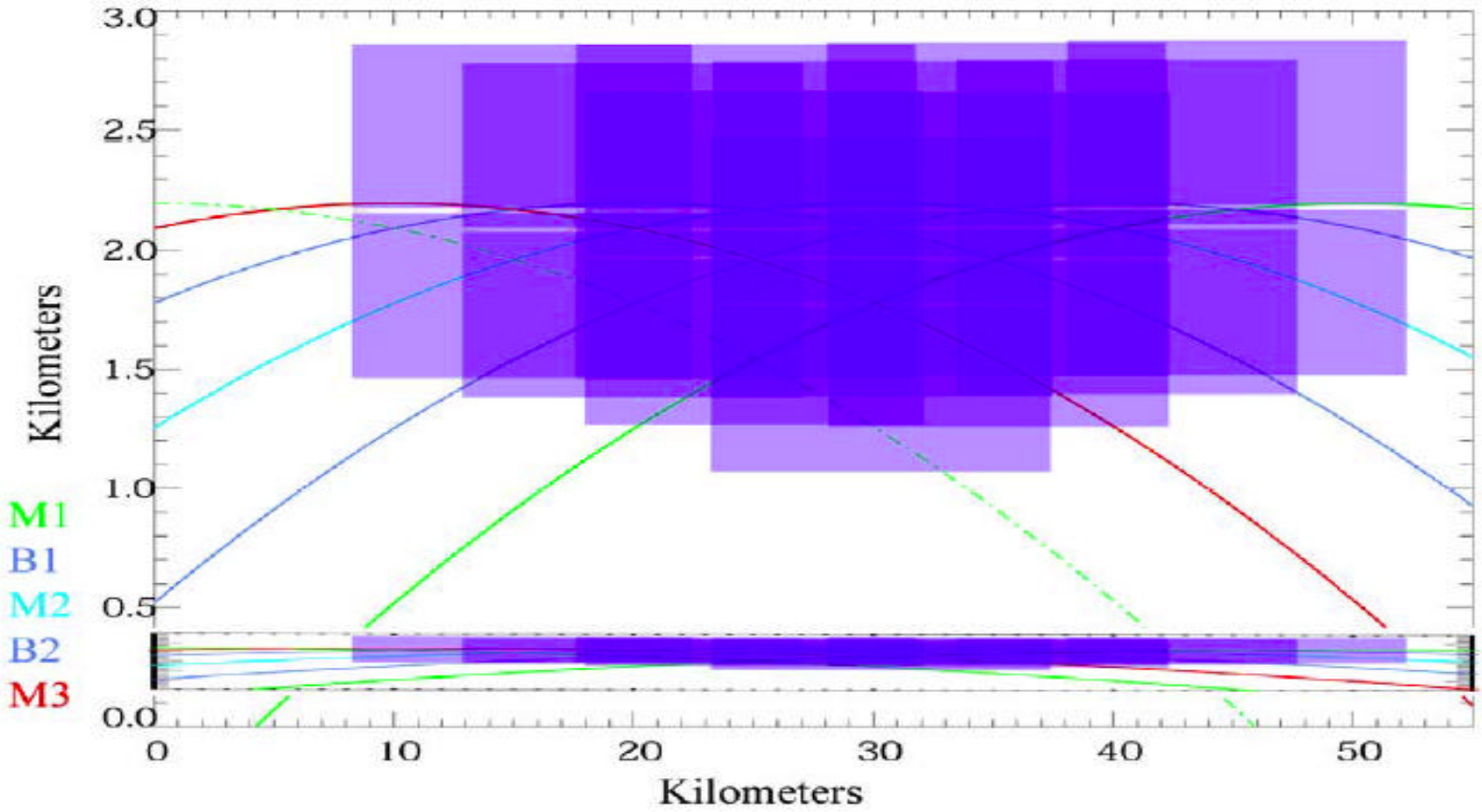


Figure 4. This figure shows the footprint of the crossover points. Each footprint is 1.4 km across track and approximately 14 km along track. The along track direction represents 2 seconds of data collection. The same figure in the correct aspect ratio is shown near the bottom.

Raney et al. [2002]

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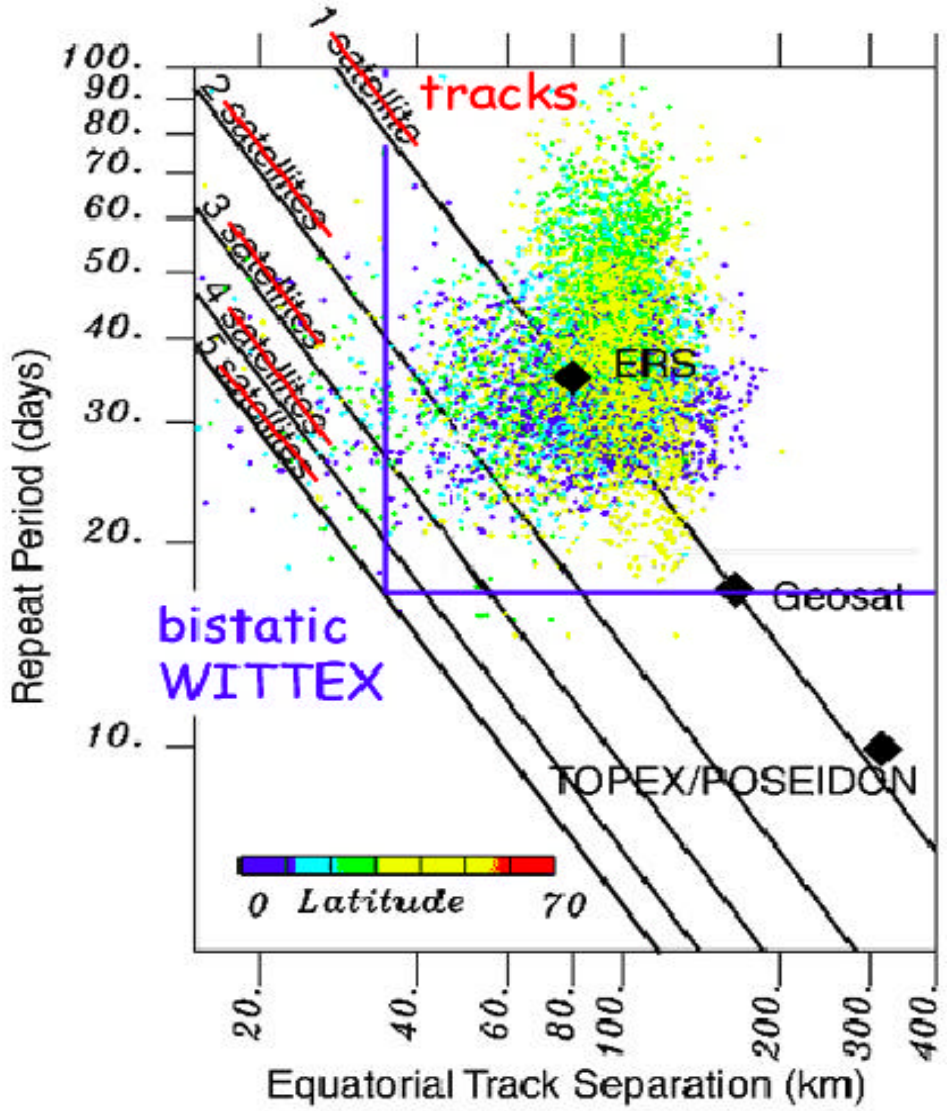
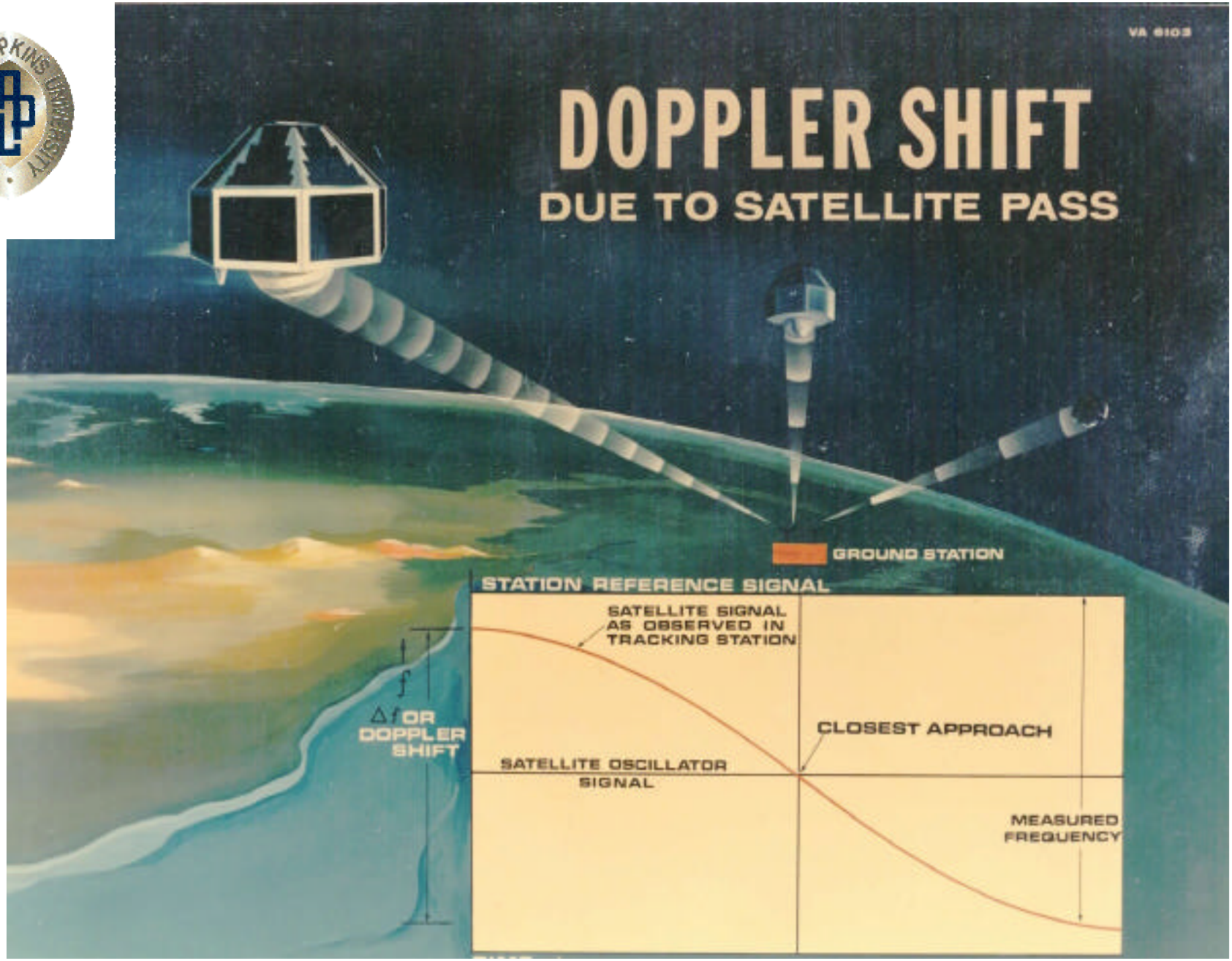


Figure 9. A modified figure from Jacobs, et al. [1999] showing the length and time scales of mesoscale ocean phenomenon as a function of latitude.

Bi-Static WITTEX Resolution Comparison for Mesoscale Variability Observatios

Raney et al. [2002]; Jacob et al. [1999]


VA 6103
DOPPLER SHIFT
DUE TO SATELLITE PASS
GROUND STATION
STATION REFERENCE SIGNAL
SATELLITE SIGNAL
AS OBSERVED IN
TRACKING STATION
CLOSEST APPROACH
SATELLITE OSCILLATOR
SIGNAL
MEASURED
FREQUENCY
f
Δf OR
DOPPLER
SHIFT