Coherence between Altimetric Gravity and Multibeam Bathymetry Grids

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Abstract. In 1994 Smith and Sandwell developed a bandpass filter for bathymetric predictions. At the time, there were not enough areas fully mapped by multibeam to permit its empirical development. Instead, they used a simple theory for the power spectra of bathymetric signals and satellite altimeter errors, and designed the filter to minimize the expected mean-square error in the predictions. The filter has one fixed constant that can be "tuned" to set the wavelength where the signal-to-noise ratio in downward-continued altimetric gravity is expected to be 1-to-1. The constant has been revised once, after they "retracked" radar altimeter echoes to improve the signal-to-noise.

Since 1994, numerous regional multibeam survey grids have become available. We compiled 25 of these grids covering various tectonic regimes throughout the world's oceans. We performed coherence analyses between these grids and satellite gravity grids to test whether the bandpass filter was selecting the most coherent part of the gravity and bathymetry spectrum. We find that coherence varies by tectonic regime and is highest over slow spreading ridges and seamounts, medium over fast and intermediate spreading ridges and trenches, and lowest over continental shelves lacking seamounts. Our results show that the Smith and Sandwell prediction filter was appropriately designed: it passes wavelengths as short as possible without adding undue noise, and so predicts features such as seamounts where they exist.

Data

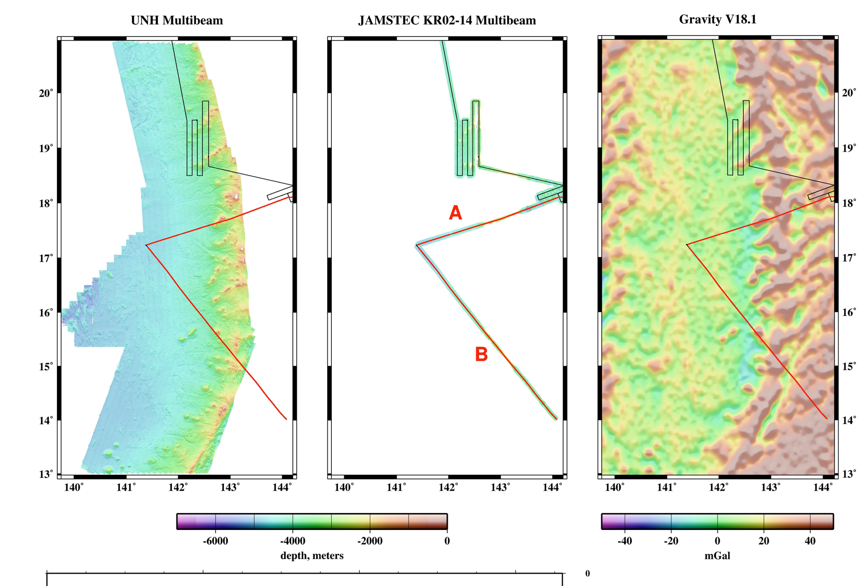
- Multibeam grids from University of New Hampshire Center for Coastal Ocean Mapping/NOAA Joint Hydrographic Center (CCOM-JHC) (http://ccom.unh.edu)
- Satellite gravity grid V18.1 (Sandwell & Smith, JGR 1997; http://topex.ucsd.edu/WWW_html/mar_topo.html)
- Multibeam and gravity xyz data from Japan Agency for Marine Earth Science and Technology (JAMSTEC) ship cruises (http://www.jamstec.go.jp/cruisedata/e/)

We thank the institutions and contributors above for making their products and data freely available.

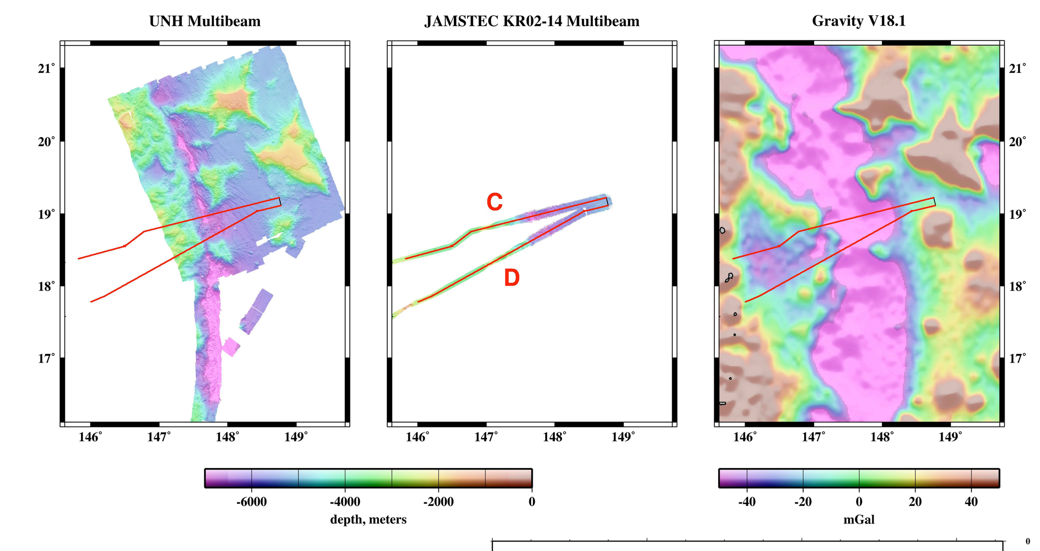
Coherence Analysis

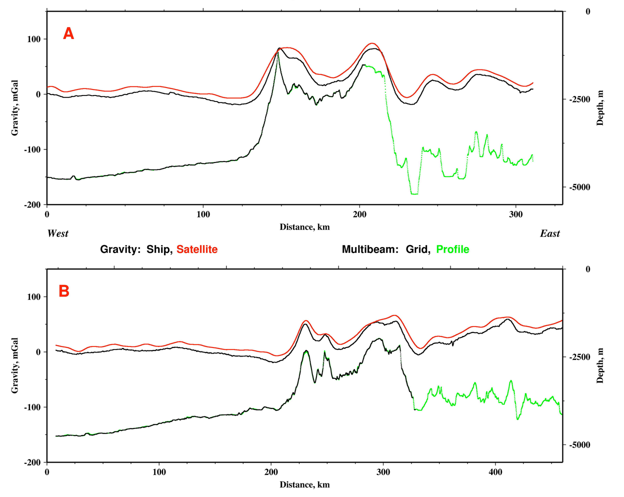
- Cross-spectral coherency between pairs of grids or pairs of data sequences is the linear correlation coefficient as a function of wavelength
- Coherency close to one is a nearly perfect correlation, near zero is the absence of any correlation
- If one data set is noise free while the other has noise, then the coherency is 0.5 where the signal-to-noise ratio in the noisy sequence is 1:1
- For profiles along ship tracks, the coherency is necessarily 1-D and does not account for anomaly sources located away from the track. Coherence from profiles is computed using GMT spectrum1d.
- For grids, coherence can be averaged azimuthally and all anomalies are taken into account. Coherence is computed from grids using GMT gravfft (J. Luis)

West Mariana Ridge

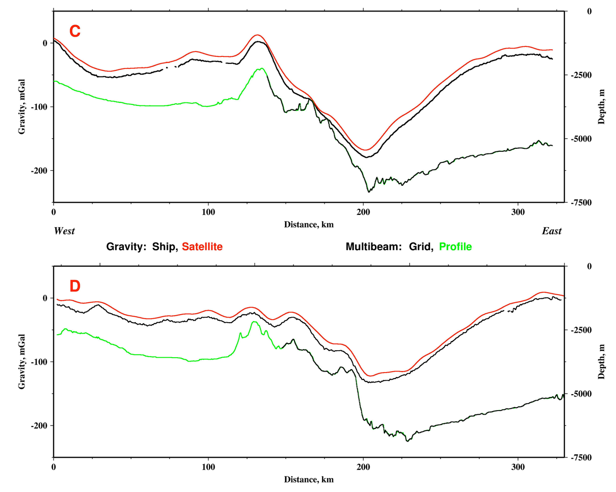


Mariana Trench North

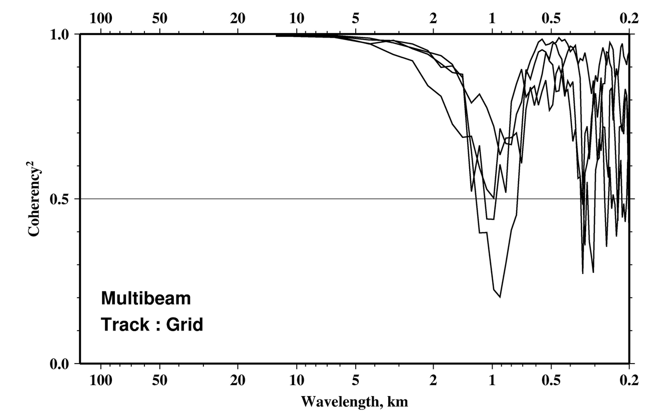




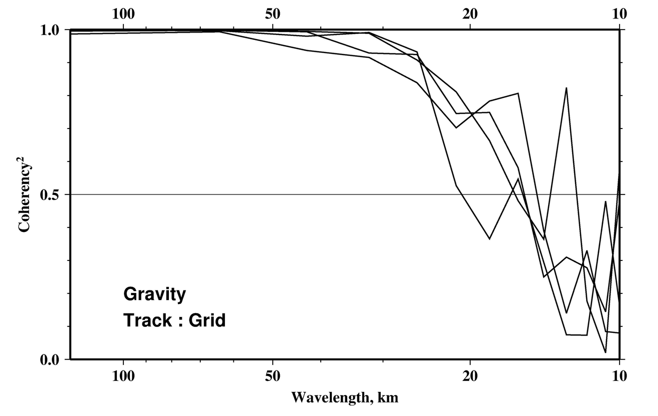
- Profiles A & B, and C & D, show gridded and swath multibeam depths are in excellent agreement at scales plotted
- Gravity anomalies appear partially correlated with changes in depth



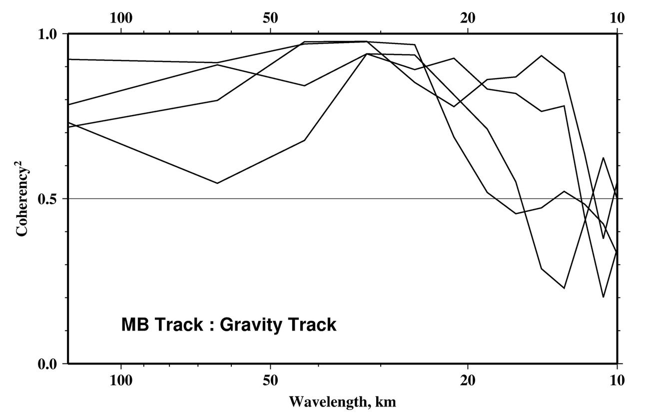
Coherence along Profiles A, B, C, & D



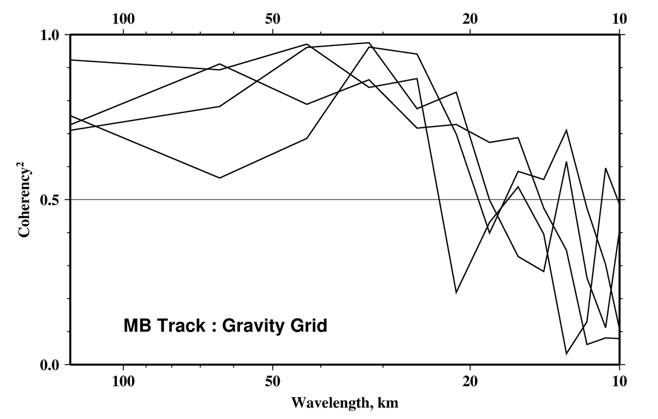
- MB from JAMSTEC ship tracks and corresponding profiles through UNH MB grids
- Nearly perfect correlation down to ~1-2 km wavelength
- Reduced coherence at shorter wavelengths is due to errors in navigation, positioning, measurement device errors, gridding of MB xyz data, interpolation of profiles through grids, etc.



- Gravity from JAMSTEC ship tracks and corresponding profiles through V18.1 satellite gravity grid
- Highly correlated down to ~30 km wavelength
- Satellite gravity is smoother than gravity measured by ship-borne gravimeters, causing the reduced coherence at shorter wavelengths

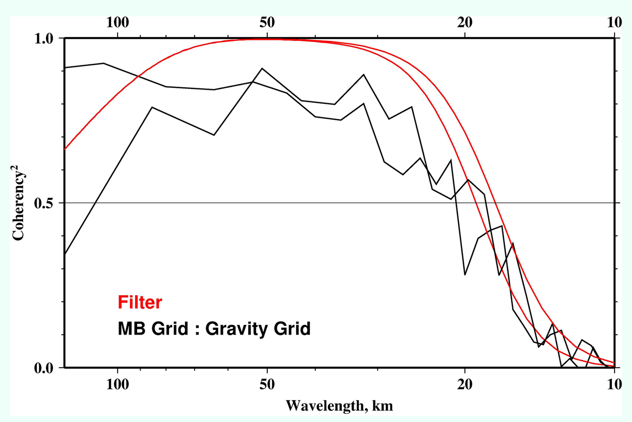


- MB and ship gravimetry from JAMSTEC ship tracks
- Often correlated down to ~18 km wavelength



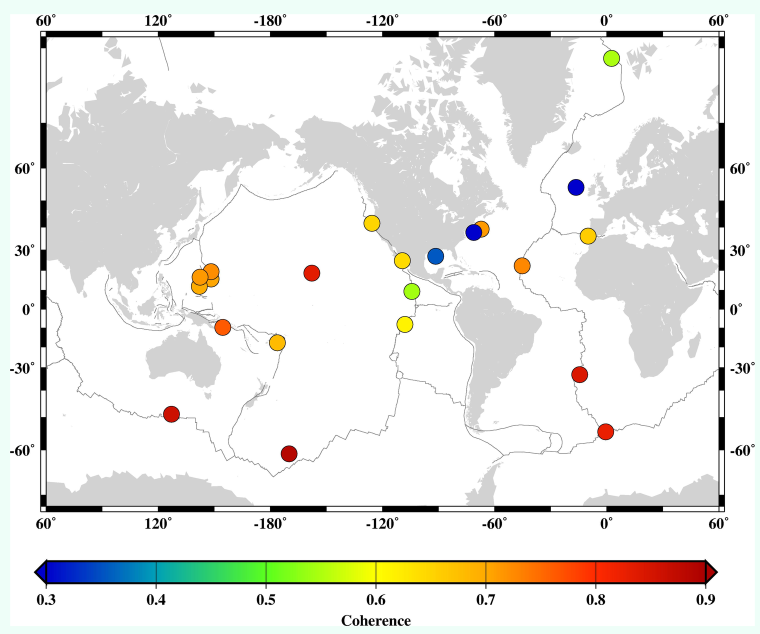
- MB from JAMSTEC ship tracks and corresponding profiles through V18.1 satellite gravity grid
- Highly correlated down to ~25 km wavelength

Coherence from MB & Gravity Grids



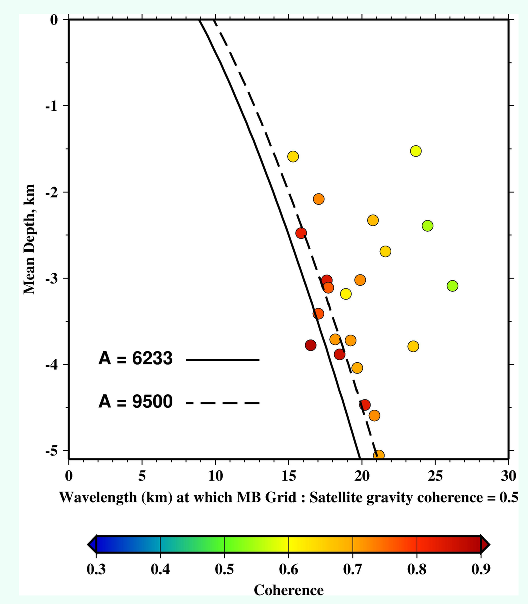
- MB from UNH grids, V18.1 satellite gravity grid
- Coherent down to ~20 km wavelength
- Azimuthally-averaged coherence from grids is better than coherence along profiles because anomalies away from the profile are included
- Red line is filter used by Smith and Sandwell (1994) to pass wavelengths in the bathymetry prediction band
- The filter is based on some fixed assumptions, including a constant called "A" in Smith and Sandwell (JGR, 1994), chosen so that the signal-to-noise ratio approximates the spectral coherency

Regional Coherence Results



- We computed azimuthally-averaged coherence for 25 areas covered by regional multibeam survey grids as well as the satellite gravity grid
- Color dots are mean coherence in the 20-160 km prediction band
- Coherence varies by tectonic regime: high coherence is associated with slow spreading ridges and seamounts, medium coherence with trenches and fast and medium spreading ridges, and low coherence over continental shelf

Filter Constant from Observations



- The bandpass filter used for bathymetric predictions (Smith and Sandwell, 1994) was based on theory and an assumed constant, called "A"
- We test the filter against empirical observations from regional multibeam surveys that were available after 1994, and satellite-derived gravity
- Filter constant "A" has been set to 6233 and 9500 for various bathymetric predictions.
- A smaller value for "A" passes shorter wavelength signal associated with slow spreading ridges and seamounts. The choice of "A" is a careful balance between noise suppression and short wavelength signal

New in this study

- **The use of empirical data to confirm the theoretical filter developed by Smith and Sandwell (1994)**
- **The use of use azimuthally-averaged coherence from grids rather than 1-D coherence along profiles**

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