Aliasing of high-frequency variability by altimeter observations: Evaluation from bottom pressure recorders

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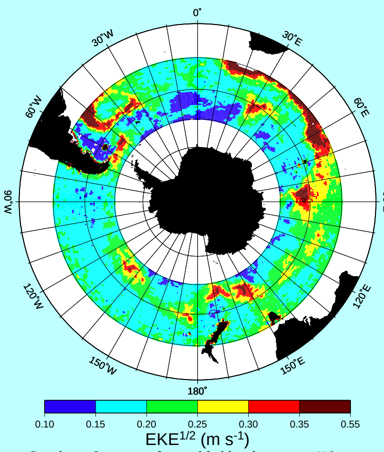
1. Introduction



Southern Ocean surface eddy kinetic energy. What frequencies control this variability?

Topex/Poseidon samples the ocean at 10-day intervals, but the ocean itself varies on a wide range of time scales. How much of the surface eddy kinetic energy measured by Topex is due to variability on frequencies lower than the Nyquist frequency (1 cycle/20 days)?

Recent numerical modeling studies have suggested that 10-day sampling may alias a significant fraction of high frequency variability [Fukumori et al., 1998; Stammer et al., 2000; Tierney et al., 2000]. Other recent modeling studies have pointed out the the pitfalls in relying on Boussinesq ocean models to estimate surface elevation or bottom pressure [Greatbatch, 1994; Huang and Jin, 2000].

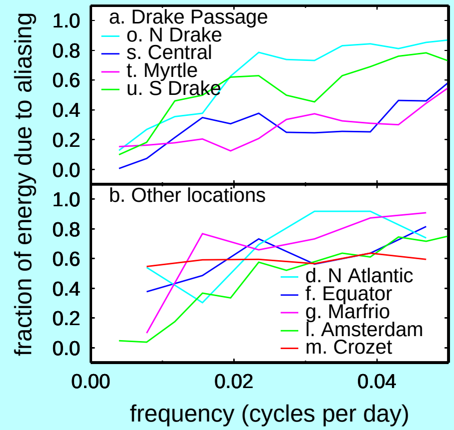
This study provides empirical grounding for estimates of altimetric aliasing by examining bottom pressure recorder measurements.

4. What fraction of energy is aliased by 10-day sampling?

BPR	Duration (days)	Location	Depth	% Energy Resolved
a	164	63.1°N 0.0°W	1579	39
b	163	61.4°N 2.1°W	1025	37
c	153	58.2°N 10.0°W	1870	48
d	294	57.3°N 9.9°W	2004	38
e	218	44.9°N 15.6°W	3164	66
f	600	0.0°S 20.0°W	2700	46
g	449	32.0°S 36.0°W	2604	57
h	1065	35.5°S 11.0°W	4080	47
i	358	37.0°S 14.5°W	3505	48
j	671	38.5°S 11.1°W	3435	47
k	204	28.3°S 66.8°E	3650	60
l	2351	37.9°S 77.6°E	350	80
m	358	46.9°S 53.5°W	3600	42
n	1440	53.5°S 57.0°W	2803	42
o	1840	54.9°S 58.4°W	1052	53
p	320	56.5°S 63.0°W	3925	79
q	357	56.8°S 57.5°W	2096	82
r	724	56.7°S 52.5°W	3150	73
s	730	58.4°S 56.4°W	3776	77
t	1467	59.7°S 55.5°W	3690	74
u	1869	60.8°S 54.7°W	1040	61
v	320	61.5°S 61.3°W	3946	64
w	1101	60.0°S 47.1°W	2180	56

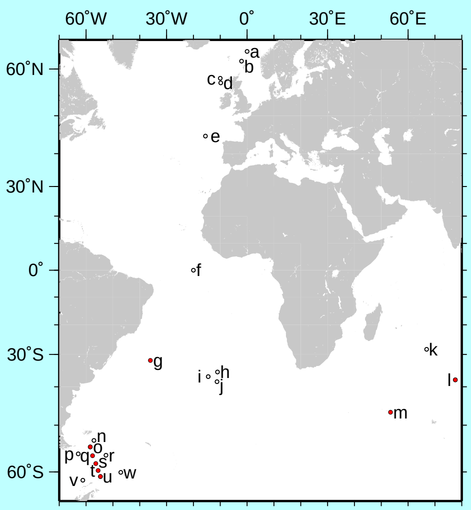
The table shows durations of time series at each BPR location, position and depth, and in the final column the fraction of energy in spectra computed from 10-day records that is not due to aliasing of high frequency variability. If the spectra were strongly red, very little energy would lie at frequencies greater than one cycle per 20 days, and these numbers would be close to 100%. This is not the case, and the fraction of resolved energy varies from 37% to 82%, with a mean of 57%.

The figure shows the fraction of energy in spectra computed from subsampled records that is due to aliasing. While the degree of aliasing varies in different locations, at frequencies greater than 0.5 $\mathcal{N}$, aliased energy exceeds resolved energy for all BPRs outside Drake Passage and for BPRs o and u within Drake Passage. For frequencies less than 0.2 $\mathcal{N}$, the fraction of energy due to aliasing is less than a half everywhere except BPRs d and m.



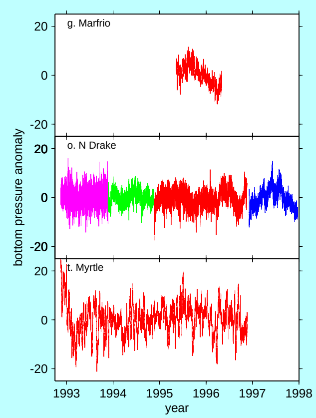
The fraction of spectral energy due to aliasing of unsampled high-frequency variability into frequencies less than one cycle per 20 days exceeds 50% at frequencies greater than about 0.2$\mathcal{N}$ for a wide range of locations.

2. Bottom Pressure Data and Time Series



BPR records from the Atlantic, Indian, and Southern Oceans. A total of 23 records each provide more than 150 days of data. All data have been collected since 1980.

The bottom pressure data used in this study were obtained from the Global Undersea Pressure (GLOUP) dataset, available at www.pol.ac.uk/psmslh/gloup/gloup.html. This is the official IAPSO repository for ocean bottom pressure data, and operates as part of the Permanent Service for Mean Sea Level.



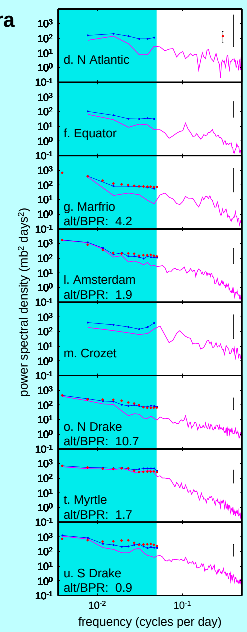
BPR time series show substantial variability on a variety of frequencies. For our analysis, tidal variability has been removed.

3. Bottom Pressure Spectra

For this study, BPR records were demeaned and detided using standard procedures to remove semidiurnal, diurnal, fortnightly, and monthly tides [Bell et al., 1999] . Annual and semi-annual signals are retained, since not all records are sufficiently long to allow their removal.

We computed spectra using the original hourly data and a time series subsampled at 10-day intervals. Timeseries were divided into overlapping segments, a Hamming filter was applied, and spectra were computed. Spectra from subsampled data are consistently more energetic than the original spectra, indicating that energy at frequencies greater than the Nyquist frequency $\mathcal{N}$ is aliased into the subsampled spectra.

Spectra from altimeter data are generally more energetic than spectra from BPR data. The slopes of altimetric spectra match the slopes of subsampled BPR spectra. Here, altimetric spectra (red dots) have been rescaled by the indicated ratios to match subsampled BPR spectra at low energies.



Spectra from hourly BPR observations (magenta), from 10-day BPR observations (blue) and from TOPEX (red).

Summary

- Spectra computed from 10-day altimeter measurements are likely to be representative only for frequencies less than about 0.2$\mathcal{N}$.
- The fraction of aliased energy in spectra increases near the Nyquist frequency, $\mathcal{N}$.
- To avoid aliasing:
  - Carry out analysis in the time domain.
  - Correct using numerical results or by assuming geographic coherence.
  - Filter out frequencies above 0.2 $\mathcal{N}$.

References

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