An M_3 Tidal Resonance in the Great Australian Bight

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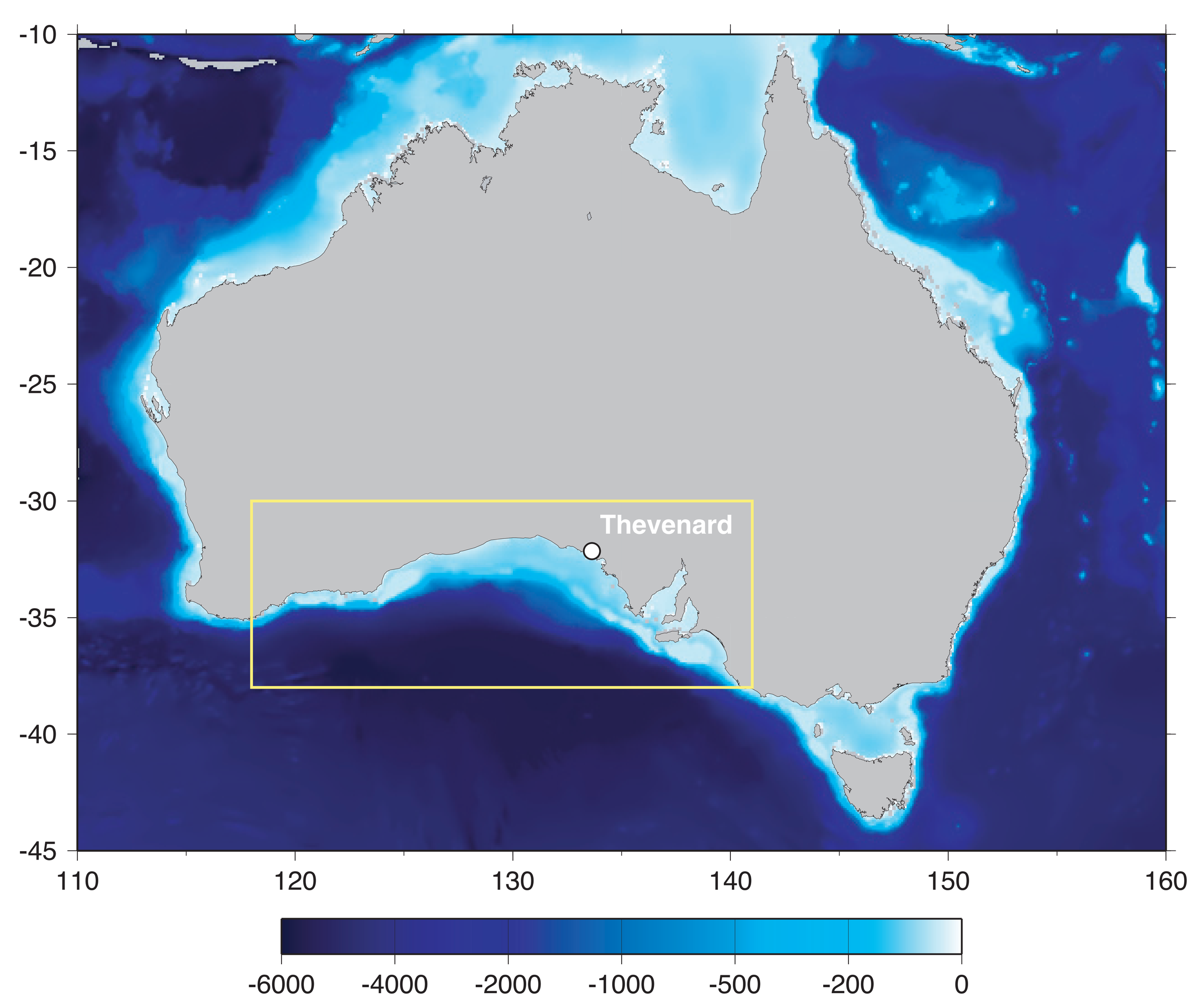
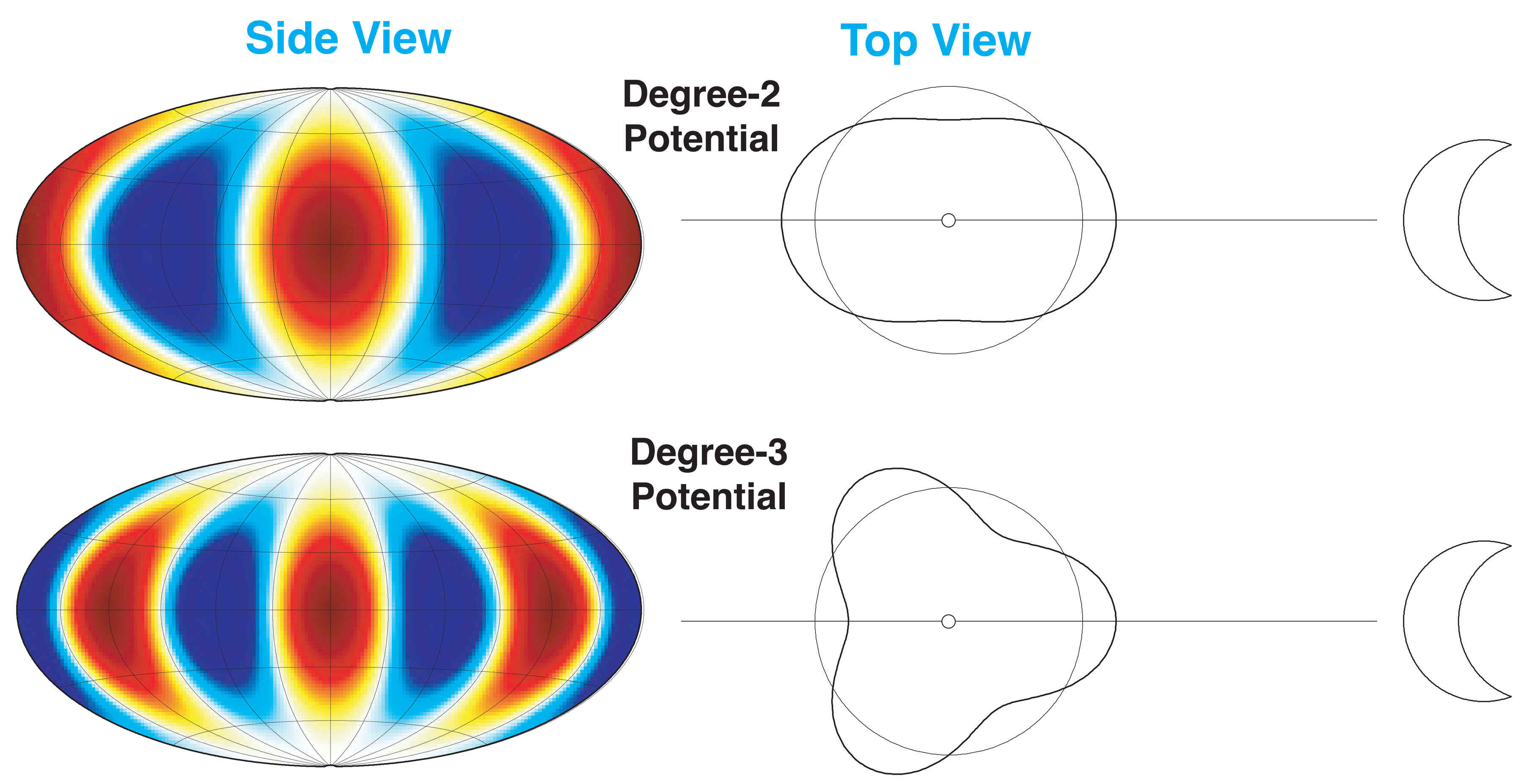
ABSTRACT

The M3 tide is a small, linear, terdiurnal tide, generated by the third-degree term in the moon's tidal potential. It is usually sub-cm in amplitude, but there are at least two known coastal M3 resonances: (1) along the coast of Brazil, where amplitudes reach 15 cm at the coast (Huthnance, 1980), and (2) on the Great Australian Bight (Hutchinson, 1988). A global analysis of the long Topex/Poseidon and Jason time series has been performed to search for such M3 resonances. The resonance on the Great Australian Bight (GAB) appears to be the one of largest spatial extent. It is most pronounced where the shelf reaches its greatest width. Amplitude at the coast is about 11 cm. Further confirmation has been obtained by analyzing 15 years of hourly tide gauge data from Australian station Thevenard. With these data we could also solve for several much smaller terdiurnal tides, and we find that the estimated admittances are quite consistent for all tides, indicating a resonance for the entire (linear) terdiurnal band. The resonance is approximately a quarter-wave "organ pipe" resonance between the coast and the shelf edge.



TIDAL POTENTIAL: DEGREE 2 vs. DEGREE 3



Degree-3 tidal force is smaller than degree-2 force by the factor (a/R), the lunar parallax, which is 1/60, where a = Earth's radius and R = lunar distance. Hence, all deg-3 tides are very small, usually < 1 cm.

ANALYSIS OF THEVENARD GAUGE DATA

Analysis of 15 years of hourly data from the Tevenard tide gauge confirms the large M3 amplitude of 11 cm (cf. Easton 1970). In addition, several other very small linear tidal lines can be reliably estimated—see table at right. Admittance amplitudes |Z| are reasonably consistent across the entire terdiurnal band, while phase lags increase with frequency.

Aside from M3, the largest lines in the band are associated with radiational forcing (i.e. loading by the S3 air tide). The two seasonal side-lines, dubbed T3 and R3, are larger than the central S3 line. This phenomenon has also been seen in the terdiurnal air tide over the USA (Ray & Poulose 2005).

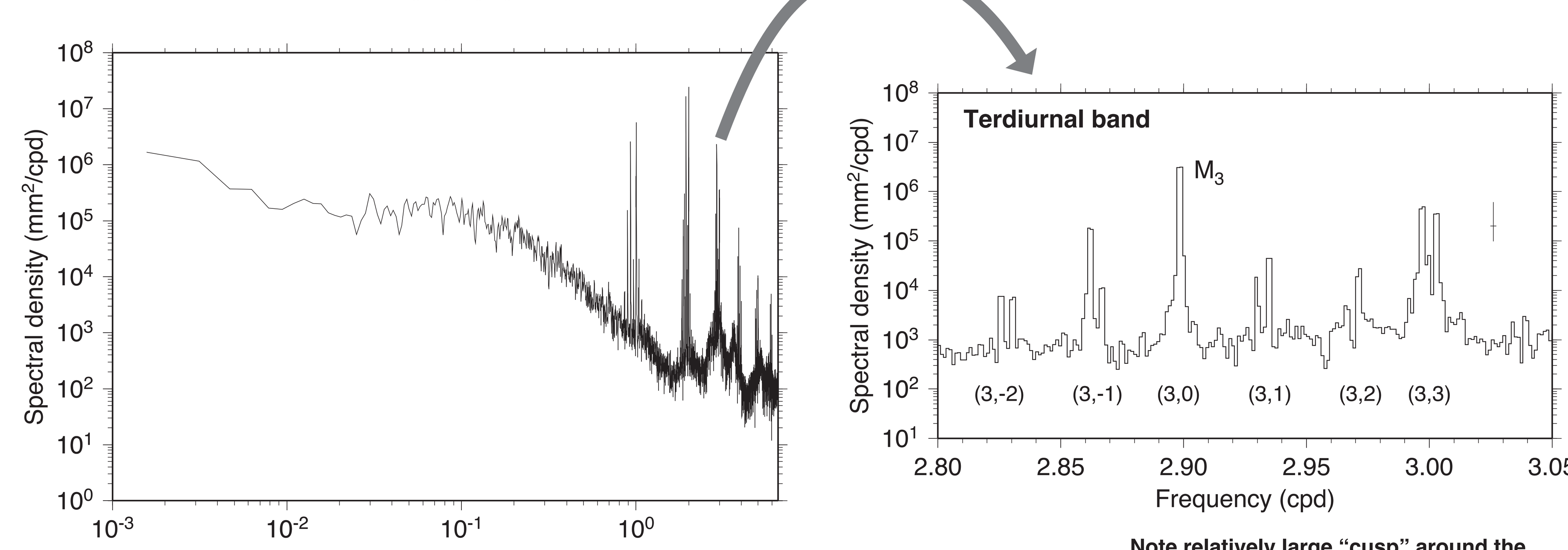
Tide	Source	Speed (°/h)	Doodson no.	H	Amp (mm)	Phase lag (°)	$\|Z\|$
–	Linear	42.3874	3 −2 0 2 0 0	0.4	4.6 ± 0.5	129.6 ± 7.2	12.7 ± 1.4
–	Linear	42.4603	3 −2 2 0 0 0	0.4	3.8 ± 0.5	226.5 ± 8.5	12.2 ± 1.4
MO_3	Nonlinear	42.9271	3 −1 0 0 0 0		10.3 ± 0.5	112.8 ± 3.0	
F_3	Linear	42.9318	3 −1 0 1 0 0	2.1	28.6 ± 0.5	152.2 ± 1.1	13.6 ± 0.3
–	Linear	43.0046	3 −1 2 −1 0 0	0.4	5.8 ± 0.5	150.5 ± 6.9	14.9 ± 1.4
M_3	Linear	43.4762	3 0 0 0 0 0	7.6	107.8 ± 0.5	174.8 ± 0.3	14.1 ± 0.1
SO_3	Nonlinear	43.9430	3 1 −2 0 0 0		8.5 ± 0.7	167.1 ± 5.3	
–	Linear	44.0205	3 1 0 −1 0 0	0.4	4.5 ± 0.7	182.5 ± 9.6	10.4 ± 1.7
MK_3	Nonlinear	44.0252	3 1 0 0 0 0		11.7 ± 0.7	140.2 ± 3.6	
J_3	Linear	44.5742	3 2 0 0 0 0	1.0	13.3 ± 0.7	225.3 ± 3.2	13.3 ± 0.7
T_3	Radiational	44.9589	3 3 −4 0 0 0		43.9 ± 0.9	81.3 ± 1.2	
S_3	Radiational	45.0000	3 3 −3 0 0 0		13.8 ± 0.9	35.9 ± 3.9	
R_3	Radiational	45.0411	3 3 −2 0 0 0		39.1 ± 0.9	259.9 ± 1.4	

$\bar{H}$ = Cartwright-Tayler equilibrium amplitude, in mm.

NB.: Easton's (1970) phase for M3 is in error by 180°, likely owing to an error in his astronomical argument.

Sea Level Spectrum

Thevenard

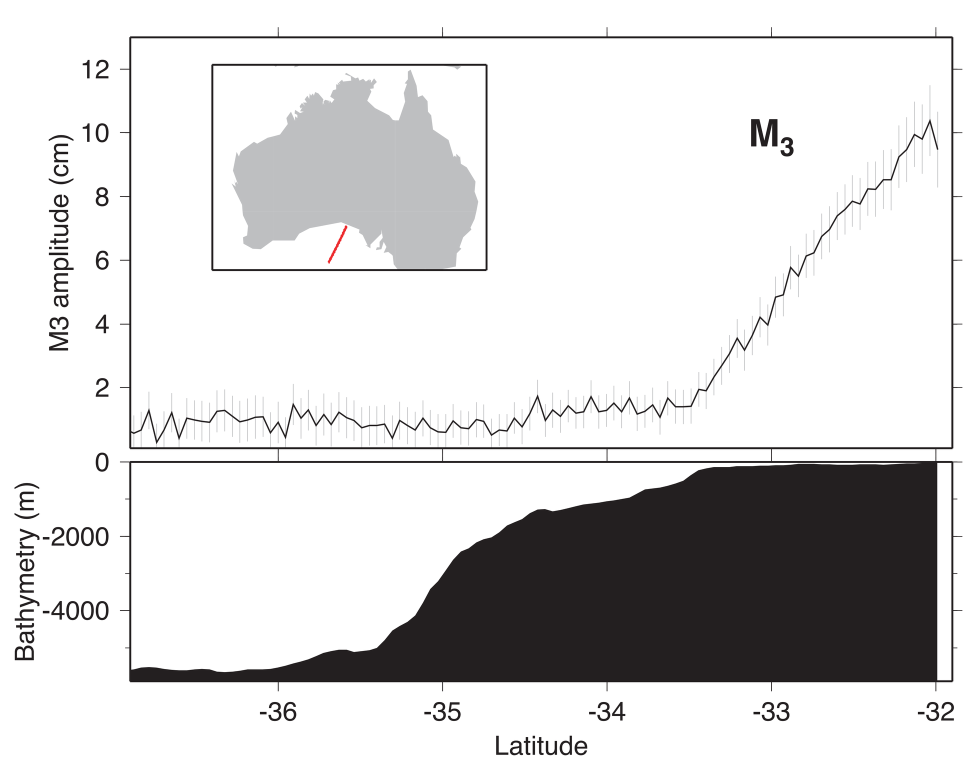


Note relatively large "cusp" around the radiational lines in the (3,3) group.

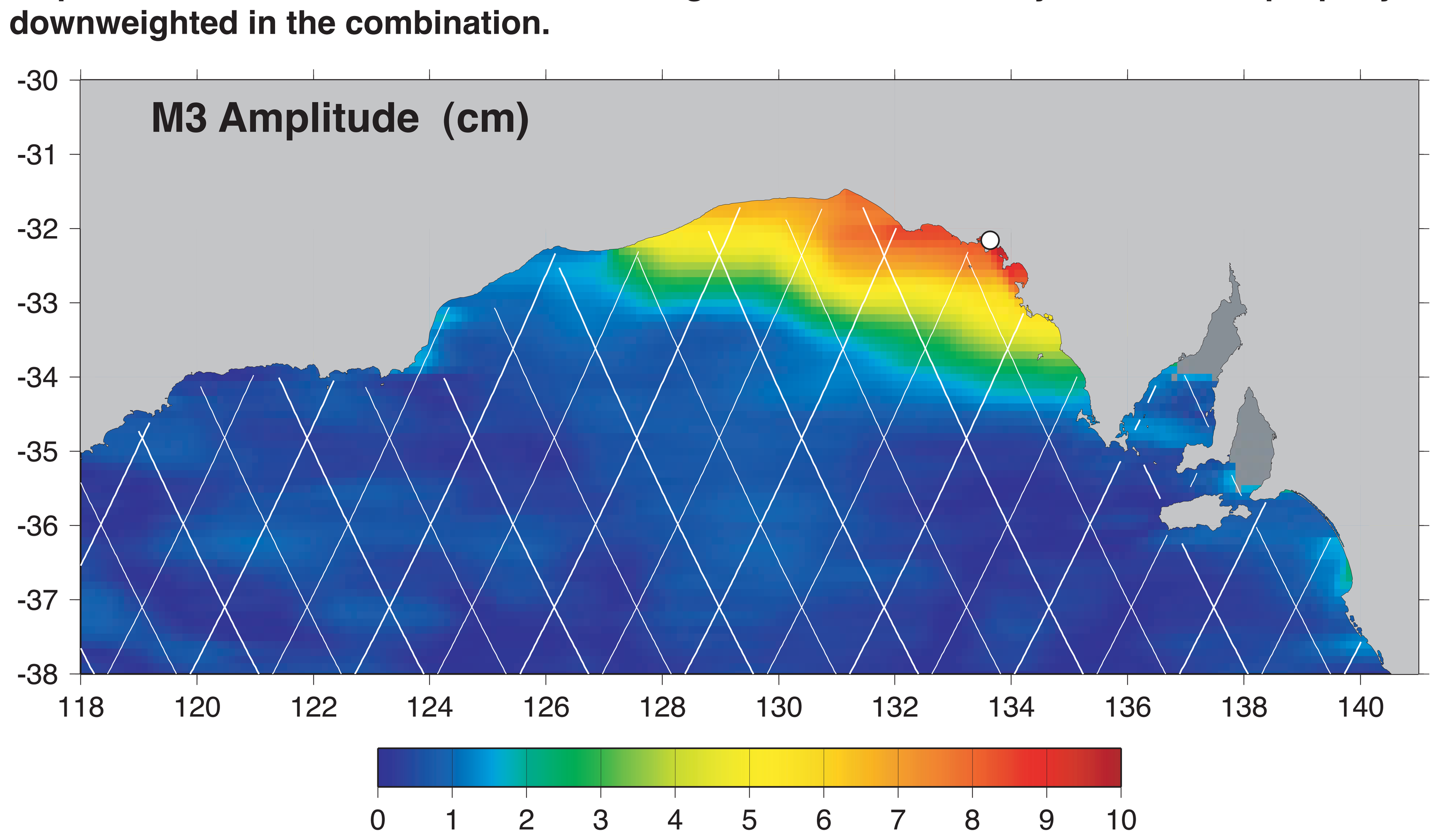
M3 TIDE FROM T/P-JASON ALTIMETRY

M3 tidal amplitudes, estimated every 6 km along T/P track 100, showing resonant amplification on GAB shelf.

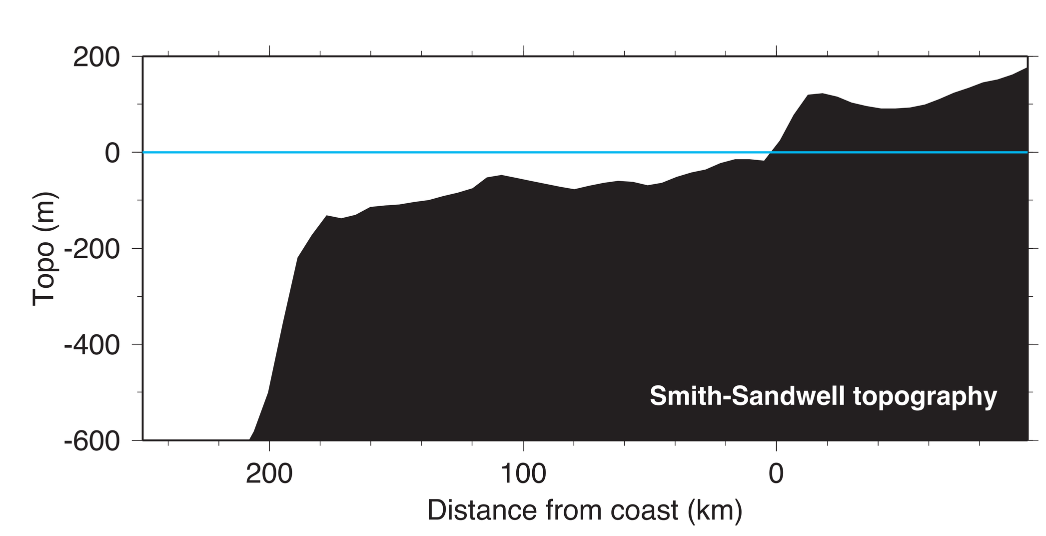
The alias period of M3 in T/P data is 38 days, well separable from other tides, and fairly well extractable from the long T/P-Jason time series. M3 is less easily extracted from the shorter time series along the shifted Topex track.



The M3 tidal amplitude chart (below) was produced by gridding the point-wise tidal estimates obtained along the T/P tracks. The use of the T/P tandem data (lighter tracks) helps delineate the shelf resonance, although these data are noisy and must be properly downweighted in the combination.



A QUARTER-WAVE RESONANCE



The GAB terdiurnal resonance appears to be a classic example of a quarter-wave (organ pipe) resonance:

shelf width ≈ 180 km
mean shelf depth ≈ 70 m

phase velocity $v = \sqrt{gh} \approx 26$ m/s

Thus, wavelength = v/(43°/h) ≈ 800 km, or roughly 4 times shelf width.

Huthnance (1980) developed an analytic model of the Brazilian M3 resonance, which accounts for friction and basin geometry. These ideas can be extended to the GAB in straightforward ways. See also Hutchinson (1988).

Many thanks to David Griffin, CSIRO, for finding the Hutchinson (1988) work.

Thanks also to David Cartwright for useful discussions

The Thevenard tide-gauge data were obtained from the Australian Bureau of Meteorology.

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