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SPURIOUS LONG-PERIOD TIDES DUE TO TIDE GAUGE ERRORS

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Abstract

A combination of tide height errors, and resetting the gauge height to a staff reading at a fixed hour each day, can lead to spurious long-period signals in series of hourly tide heights. These signals can be of the same order as the fortnightly tides. The problem is discussed in relation to the tides at Sydney (Australia), where it is believed to be responsible for an anomalous Msf tide of amplitude 0.5 cm.

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The direct effects of tide gauge errors on tide constants are well known — height scale errors affect the amplitudes, and time errors affect the phases. It might not be so well known that for gauges where the pen is reset to a staff reading each day, a height error can result in spurious long-period tidal effects. The most important of these are fortnightly, where they can be of the same order as the normal fortnightly tides. We discuss such effects for the records from Fort Denison (Sydney, 33°53′ S, 151°13′ E).

The Harrison tide recorder at Fort Denison has been in service since June 1914. It is a conventional float-operated recorder with charts which are changed at 9 a.m. each day. When the chart is changed, the pen is reset to the correct time, and to the height measured by a staff dipped into the tide well. Records are nearly continuous since June 1914, and all have now been digitized.

The recorder has a nominal height scale of 12:1 (12 inches = 1 foot). Assume this ratio is in error, so that the actual ratio is $12(1+e):1$. Then if the 9 a.m. staff height is h_0, the chart reading at any later time on the same chart, when the height is h, will be in error by $e(h-h_0)$. The appearance of h_0 in this expression represents an aliasing of the normal tide, due to sampling it at 24 hour intervals, and leads to the spurious long-period effects.

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The 24 hour sampling defines a Nyquist or folding frequency f_n = (1/48)c/h. The lowest-frequency, or principal, alias of a semi-diurnal tide of frequency f is then $|4f_n-f|$, and for a diurnal tide it is $|2f_n-f|$. For example, M2 with f = 0.0805114 c/h gives a principal alias of 4(1/48) – 0.0805114 = 0.0028219 c/h, which is the frequency of the constituent Msf. Looked at another way, M2 lags 0.067726 cycle each day, so its 9 a.m. amplitude completes one cycle in 14.765 days, which is also the period of Msf.

The aliased frequencies corresponding to the six main tidal constituents are shown in the following table, together with the amplitudes of the aliased signals at Sydney. The amplitudes are e times the relevant constituent amplitude, with $e = 0.03$:

Constituent	Alias		
	Frequency (c/h)	Amplitude (cm)	Comment
K1	0.000114	0.4	Sa
O1	0.002936	0.3	(between Msf and Mf)
P1	0.000114	0.1	Sa
M2	0.002822	1.5	Msf
S2	0.0	0.4	(mean sea level)
N2	0.004334	0.3	(not near a tidal line)

The table shows that M2, usually the dominant constituent, aliases to the same frequency as the fortnightly tide Msf, while O1 aliases to a slightly higher frequency, between Msf and Mf. The alias of N2 is not near a tidal line, and K1 and P1 alias to the annual frequency Sa.

The effects of K1, P1, S2 and N2 are not likely to be important. The alias amplitudes for Sa are small compared to typical Sa amplitudes (e.g. 4 cm at Sydney). The effect of S2 depends on its phase at the sampling hour, but even the maximum value, given in the table, appears to be negligible. The alias of N2 is unlikely to be detected in the usual low-frequency noise.

The effects due to M2 and O1 may be more important in studies of the dynamically interesting long-period tides (e.g. WUNSCH, 1967). But the larger aliased signal, from M2, falls conveniently at the frequency of Msf — a constituent so weak compared to Mf that it would not normally be studied. Since Mf and Msf can be separated in records longer than 6 months, the presence of an abnormal Msf would be merely noted as an anomaly. On the other hand, WUNSCH (1967) looked at Msf for evidence of non-linearity in the ocean's dynamics, since its frequency is the difference of the frequencies of the two most important semi-diurnal constituents, M2 and S2.

The error $e = 0.03$ is admittedly rather large. It resulted from the use of a relatively thick nylon cord, instead of a fine wire, to drive the pen carriage in the Harrison recorder. The pen wire is wound on a small-diameter drum on a countershaft, which in turn is driven by the rise and fall of the float. The height scale factor depends directly on the effective diameter of the combination of drum and wire (or cord). This thick cord had been in use for only the past few years, so presumably the error has been smaller in earlier records.

The actual Msf tide at Sydney shows evidence of the effects discussed above. Since Sydney (33°53′ S) is near the latitude of a node in the equilibrium long-period tides (35°16′), we expect even the Mf tide to be very small, and Msf to be undetectable. Twenty-nine years of the hourly heights for Fort Denison, 1948-1976, have been analysed separately, as part of the quality control in digitizing the records. The vector mean amplitude for Msf was 0.53 cm (significantly different from zero), while that for Mf was only 0.14 cm (not significant). The relatively large amplitude for Msf may be taken as evidence that height scale errors were present during 1948-1976. The mean Msf amplitude suggests an error e of order 0.01 (1 percent). Errors of this order were found in the ruling of the height scale on the charts; these ruling errors have the same effect as mechanical errors.

Other sources of error in the data, mainly due to chart scale printing errors, are discussed in a report on the quality of the data series (HAMON, 1987).

References

HAMON, B.V. (1987): A century of tide records: Sydney (Fort Denison) 1886-1986. *Flinders Inst. Atmospheric and Marine Sci., Flinders University*, South Australia, Int. Report.

WUNSCH, C. (1967): The long-period tides. *Rev. Geophys.*, 5, 447-475.