Review of "Wave-resolving Voronoi model of Rouse number for sediment entrainment equilibrium"

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4:48 PM

This is a difficult paper to review, as the topic of solving dynamic fluid mechanics models ala Navier-Stokes is considered almost intractable in some circles. Insight is not easy to come by when trying to understand a fully 3-dimensional space involving vortices, wave breaking, and turbulence.   So I preface my remarks with this passage that Sir George Stokes wrote in response to reviewing Reynolds' paper on turbulent flow:

> *Dear Lord Rayleigh, I must plead guilty to not having digested Professor Osborne Reynolds's paper, though much time has passed since it was referred to me. I find it very difficult to make out what the author's notions are. As far as I can conjecture his meaning, I must say that I do not think that he has made out his point. He is however an able man, and in his former paper did very good work in showing that the condition of dynamic similarity which follow from the dimensions of the hydro-dynamical equations when viscosity is taken into account are not confined to what I may call regular motions, but continue to apply (in relation to mean effects) even when the motion is of that irregular kind which constituted eddies, and which at first sight appears to defy mathematical treatment. The fact that the author has gone to the expense of printing the paper shows that he himself considers it as of much importance. I confess I am not prepared to endorse that opinion myself, but neither can I say that it may not be true. I do not know if these remarks will be of any use in assisting the Council to come to a decision. Yours very truly, G.G. Stokes [1]*

Hope for progress will be in the ability to effectively model the empirical observations of wave behavior. To that extent the comparison of the measured sea-level heights in the location (Doha Bay) under evaluation against the model results are a vital aspect of the paper. Consider Figure 4 reproduced below. This appears to be a mixed diurnal-semidiurnal tidal time-series as the diurnal period is a shade under one day.

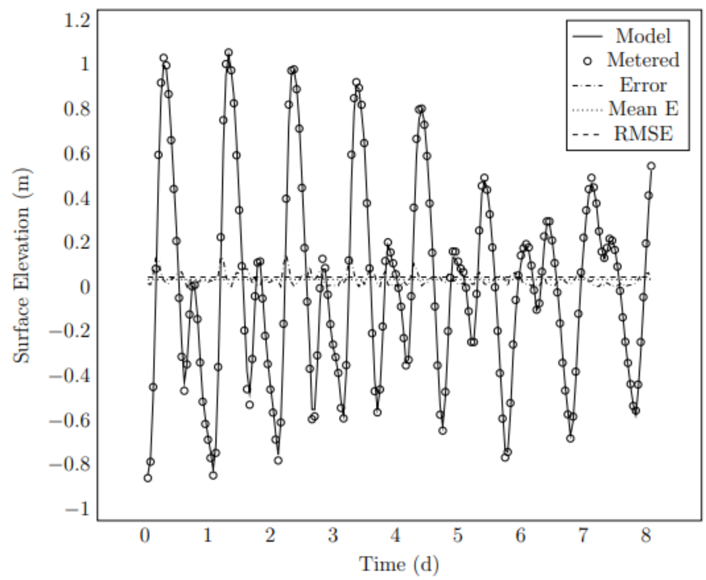
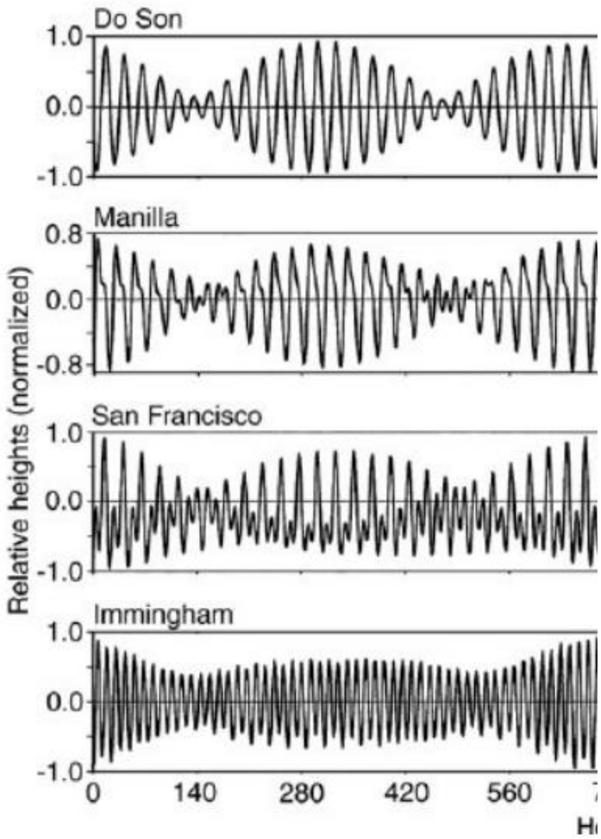


Figure 4: Correlation of simulated and surveyed surface elevation at the location of current meter 2 which also recorded depth, that is, surface elevation in August 2023.

Compare against a typical time-series from other locations such as the following figure [2], where the Manila and San Francisco both show mixed, with the Manila predominately diurnal and San Francisco more semi-diurnal.



Or this from [3] showing again the mixed frequency mode of San Francisco

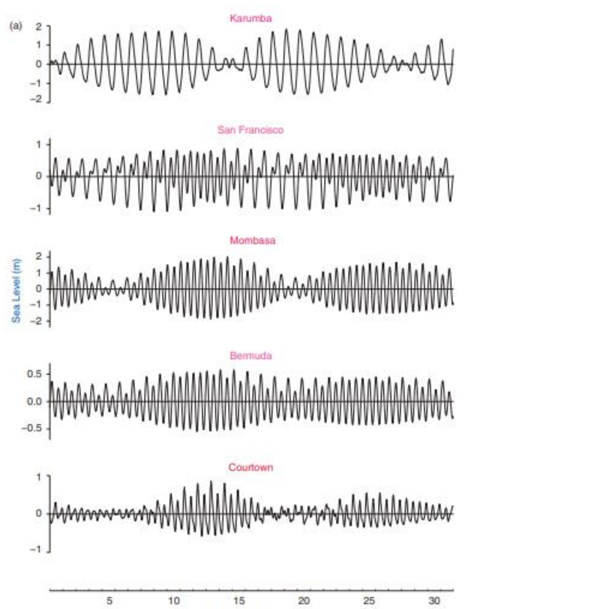


Figure 1.2 (a) Tidal predictions for March 2043 at five sites that have very different tidal regimes. At Karumba, Australia, the tides are diurnal, at San Francisco, United States, they are mixed, whereas at both Mombasa, Kenya, and Bermuda, semidiurnal tides are dominant. The tides at Courtown, Ireland, are strongly distorted by the influence of the shallow waters of the Irish Sea.
(b) The lunar characteristics responsible for these tidal patterns. Solar and lunar tide-producing forces combine at new and full Moon to give large spring tidal ranges every 14.76 days. Lunar declination north and south of the equator varies over a 27.21-day period. Solar declination is zero on 21 March. Lunar distance varies through perigee and apogee over a 27.55-day period. The thumbnail cartoons show the physics of the variations (lunar phase, declination and distance) discussed in detail in Chapter 3.

As these time-series all have similar profiles for specific values of diurnal/semidiurnal mixing levels, it's not clear what the model resolving powers are of the paper's particular fit. In fact, most of the response is a direct response to the sinusoidal composition of the **K1** & **O1** diurnal tidal forcing and the **M2** & **S2** semidiurnal. It's a matter of whether the response was derived from first principles or by a training-validation calibration on an independent set of time-series data. From the text, it appears to be the latter.

> *"Two survey locations served to specify the boundary forcing and three survey locations served to validate the accuracy of the simulation. Given that two seasons have been examined, four time series were available for boundary forcing and six to validate the simulation. "*

As specifying boundary conditions is a euphemism for temporally aligning a forced response, it may be a good bet that the validated set will show a good correlation to a calibrated model. As Doha Bay is in the Persian Gulf, a mixed tidal response are reported as applicable, with the direct gravitational forcing of **K1**, **O1**, **M2**, **S2** applicable:

> *The Persian Gulf, Figure 5.16, is a shallow sea with mixed diurnal and semidiurnal tides [29]. It is a largely enclosed basin with only a limited connection to the Indian Ocean through the Strait of Hormuz. Along the major northwest to southeast axis it has a length of about 850 km. The average depth is approximately 50 m, giving a resonant period near 21 hours, according to Equation 5.5. The Rossby radius at 27° N (c/f) is 335 km, comparable with the basin width. As a result the response to the diurnal forcing through the Strait of Hormuz is a single half-wave basin oscillation with an anticlockwise amphidrome. The semidiurnal tides develop two anticlockwise amphidromic systems, with*

a node or anti-amphidrome in the middle of the basin. Near the centre of the basin the changes in tidal level are predominately semidiurnal, whereas near the semidiurnal amphidromes they are mainly diurnal. At the northwest and southeast ends of the basin the tidal levels have mixed diurnal and semidiurnal characteristics. ***Direct gravitational forcing is probably significant.*** *[3]*

The concern here is that the direct gravitational forcing input is being reflected in the results as a flat or nearly equilibrium response. This is the first-order result of Laplace's tidal equations given a forcing input, and all the other details are aspects of a dynamic natural response or non-linear non-autonomous modulations of the forced response. For example, is there a possibility of detecting an amphidromic response of the Coriolis-effect in the equations to detect an anticlockwise cycle in the non-equilibrium dynamic s? If not that at least provide a Fourier series spectrum of the sea elevation time-series so that any non-linear impacts of the model appear as harmonics or mixed harmonics of the direct forcing. This will likely require a more densely sampled and longer time series.

[1] https://hal.science/hal-03378653/document
[2] Kvale, Erik P. The Origin of Neap-Spring Tidal Cycles, Marine Geology 235 (2006) 5 – 18
[3] Pugh, David., Woodworth, P. L.., Woodworth, Philip. Sea-Level Science: Understanding Tides, Surges, Tsunamis and Mean Sea-Level Changes. United Kingdom: Cambridge University Press, 2014.