

## Improvement of the tide model for Singapore

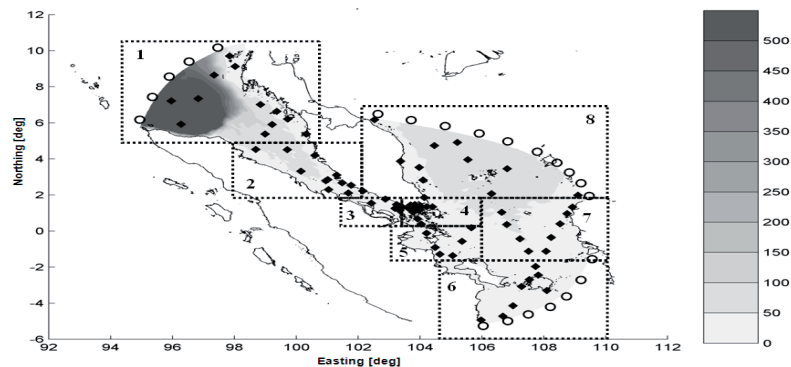


Figure 1: Singapore Regional Model showing boundary support points (big open circles; where tidal and mean level forcing are prescribed and adjusted) and the eight distinct regions with observation locations (diamond's) used for calibrating the model.

### ***Delft3D-flow model application***

The Singapore Regional Model (SRM) is a computer model that is used to study the complex tidal flow interactions in Singapore regional waters. Figure 1 shows the model domain. The model simulates how the tidal wave that enters at the boundary of the region proceeds through the Singapore waters. The software package Delft3D-Flow is used for this simulation. On the northern boundary of the domain, in the Andaman sea, the tide rises and falls twice a day as in most locations on earth (semi-diurnal tide). But on the southern and eastern border of the model domain, the main tide comes only once a day (diurnal tides) with only a minor semi-diurnal variation. The topography of the area, in particular the islands and the narrow end of Malacca Strait, causes strong fluctuations in the tide throughout the Singapore waters. In order to properly simulate this, the depth and bottom friction as well as the properties of the tidal waves at the boundaries need to be known accurately. The values for these parameters can be estimated, but with OpenDA, they can also be determined directly from the observed water levels, which is obviously better.

### ***Determining parameters from observations***

OpenDA is first used to find the properties of the tides along the northern border of the model in six different optimization runs. Secondly, OpenDA is used to adjust the depths and bottom friction in the narrow part of Malacca Straits to make the model better represent the observed tides.

To find these parameters, OpenDA starts with the initial estimates for the parameters and then systematically modifies them and checks whether after each modification, the model results better match the observed tides. The so called 'Goodness of Fit' (GoF) is a measure for the deviation between the model results and the observations: the lower the GoF, the better the model performs. OpenDA can use various built-in methods to reduce the GoF until it cannot find further reduction.

Not all observations are used for this procedure. A significant part of the observations is kept apart and is used to check that the corrected model also better predicts the water levels in locations that were not involved in the parameter estimation procedure. If not, then the model would not have a better predictive capability and has not benefited from the different parameter settings. The improvements in other observation locations are measured in terms of the so called Summed Vector Difference or SVD, which takes into account both the amplitude and the phase (timing) of the tidal wave.

Test	Parameter ( $p$ ) varied	GoF	SVD(M2)	SVD(S2)
		%IMP	%IMP	%IMP
1	Phase of M2 & S2	30.5	14.27	12.27
2	Amp. Of M2 & S2	33.7	18.25	16.08
3	Phase & Amp. Of M2, S2	18.8	6.74	7.40
4	Phase & Amp. Of M2, S2	41.8	6.62	-1.31
5	Phase & Amp. Of M2, S2	19.8	8.44	17.17
6	Phase & Amp. Of M2, S2	10.0	2.40	16.70
7	Depth in Region 3	62.4	30.37	25.26
8	Friction in Region 3	1.3	0.84	1.30
9	Depth, Friction (Region 3)	65.7	33.38	30.43

Table 1. OpenDA simulation results showing the type of parameters varied and the percentage improvement %IMP in GoF reported by OpenDA (for regions used in the optimization procedure). SVD(M2) and SVD(S2) denote the percentage improvement in Vector Difference of two components of the tidal wave, M2 and S2, averaged over all model observation stations

## Results and conclusions

Using OpenDA, significant improvements are made to the Singapore Regional Model. Table 1 shows that improvements of up to 30% are reached, in particular by modifying the values of the model's depth in the narrow part of the Malacca Straits. This shows that OpenDA is a powerful tool to improve models like these.

## References

[www.openda.org](http://www.openda.org)

Kurniawan, A., Ooi S. K., H. Gerritsen and D.J. Twigt. Calibrating the regional tidal prediction of the Singapore Regional Model using OpenDA. Submitted for publication in Proc. 9th Int. Conf on Hydroinformatics, Tianjin, 7-11 Sept. 2010

OpenDa is powered by Deltares, TU Delft and Vortech

More information: [www.openda.org](http://www.openda.org)

