Efficient Calibration of a Global Tide and Surge Model

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Introduction

Global Tide and Surge Model (GTSM) [1] is developed to provide waterlevel forecast globally, which is useful to issue warnings for storm surges as well as for assessment of the potential impacts of sealevel rise. It has been improved in physics, grid resolution and skill in each new version. The parameter uncertainties are currently a major part of the remaining model uncertainty. Parameter estimation is a promising approach to calibrate the model but the required computing speed and memory storage are limiting the possibilities at the moment. An efficient calibration scheme is designed for the high resolution GTSM to estimate the bathymetry.

Parameter Estimation Scheme

In this parameter estimation scheme, as shown in Figure 1, iterative least-squares method, known as Dud [2] in OpenDA [3] is applied with time-series derived from the FES2014 database to calibrate the bathymetry. Even though parallel computing is implemented for GTSM, calibration of the fine grid model directly would still require too much computer time. Therefore, a coarse-to-fine strategy, called Coarse Incremental Calibration is proposed by using coarser grid model to replace the difference between fine model output with and without adjusted parameters in each iteration.

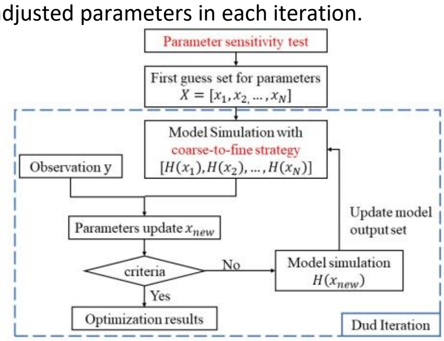

Figure 1: Flowchart for Parameter estimation procedure

Sensitivity Analysis

Sensitivity analysis is performed by perturbing bathymetry to observe the difference in propagation length, as shown in Figure 2. Large propagation length means insensitive. Final parameter dimension is reduced from $O(10^6)$ to $O(10^2)$ by dividing the global ocean into 110 regions with uniform correction factors per region. The distribution shows in Figure 3 (upper right).

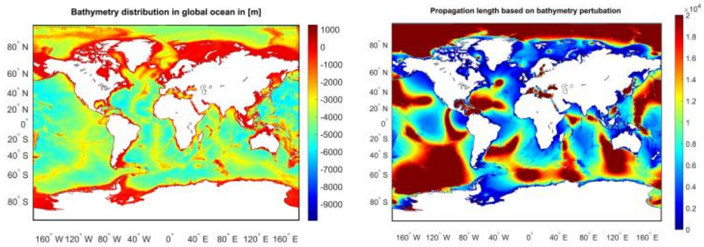

Figure 2: Bathymetry distribution (left) and propagation length based on the perturbation of bathymetry (right)

Experiments and Results

Some experiments are performed here to estimate 110 correction factors for bathymetry simulated from 1 to 14, January 2014. Observations are 1973 time-series from FES2014 dataset. The cost function is sharply reduced initially and little reduced after in Figure 3 (upper left). Final correction factors of bathymtry is constrained to at most 10%. Spatial averaged RMSE in estimation period (Figure 3 lower left) is reduced from 4.85cm to 3.30cm. Forecast in July (Figure 3 lower right) still shows the significant improvement with the RMSE reduced from 4.94 to 3.45cm, which illustrates that estimated bathymetry can be used for the long term forecast and assessment of tide.

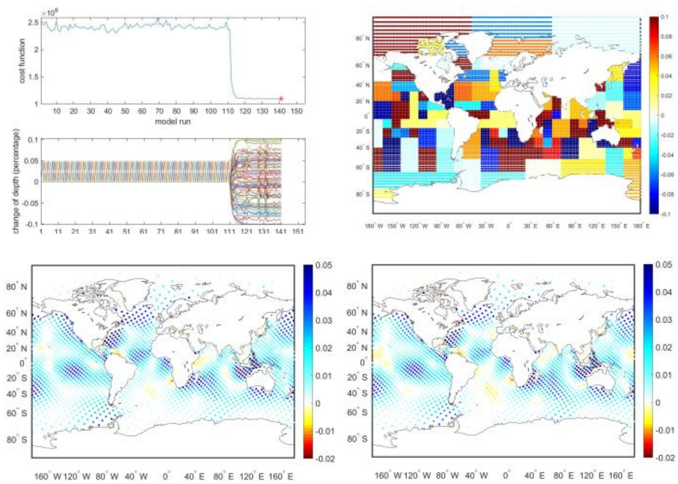

Figure 3: Cost function (upper left); bathymetry difference (upper right); Spatial RMSE difference [m] in the estimation period 1 to 14 January 2014 (lower left); Spatial RMSE difference [m] in the forecast period 1 to 31 July 2014 (lower right), color blue shows improvement.

Conclusion

We present a complete application of parameter estimation for the high-resolution global tide and surge model (GTSM) to estimate bathymetry. We can conclude that:

- Bathymetry estimation significantly improves the accuracy of tides in a global model.
- Computational demand in parameter estimation can be reduced by using coarser grid to replace the model grid and parameter dimension reduction by sensitivity test.
- The estimated model can provide more accurate long term tide forecasts.
- 2 weeks simulation is apparently too short for estimation because of the overfitting in the estimation stage. Longer simulation length is necessary but the required memory will get out of control. Further work will continue on the application of model order reduction in time pattern for parameter estimation to reduce memory requirement.

Reference

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[2] Ralston, M. L., & Jennrich, R. I. (1978). Dud, A Derivative-Free Algorithm for Nonlinear Least Squares. Technometrics, 20 (1), 7-14.

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