Modeling the Mekong Delta at Three Different Scales

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LONG-TERM GOALS

The long-range goals of the project are to learn about the characteristics and behavior of tropical hydrodynamic and morphological systems including large-scale mangrove vegetation, and to build a long-term collaboration between Vietnamese and ONR researchers through joint field research and modeling.

OBJECTIVES

To provide modeling support to Vietnamese and US researchers and to carry out additional model development in order to enhance the understanding of the hydrodynamic and morphological behavior of the Mekong delta at a range of scales. Specifically, the focus in this project will threefold: (1) on modeling flooding of agricultural areas; (2) on long-term morphological change of the main tributaries of the Mekong in Vietnam; (3) the feedback between mangroves and estuarine and open coast morphology.

APPROACH

The Delft consortium is provides access to and training in open-source models, i.e. Delft3D, XBeach and the new unstructured grid model DFlow-FM (Flexible Mesh). Some developments are foreseen to accommodate specific research questions or useful functionalities. The Delft team will liaise with other ONR research groups involved in field research or modeling and facilitate the use of models to enhance understanding and provide synoptic representations, linking in situ observations, which are necessarily limited in space and remote sensing imagery, which is often of limited quantitative accuracy. An important activity is the training and research collaboration with Vietnamese research groups, through 2 workshops in Vietnam and special programs at UNESCO-IHE in Delft, i.e. to collaborate in development and validation of new functionalities. We envisage the following activities:

Workshops
A introductory workshop was held in Vietnam during which all interested ONR and VN parties got together to discuss plans for field experiments and model application and development, and to establish what field experiments need in terms of modeling and vice versa. A first 1-2 day modeling short course was part of the program.
In order to promote the optimal use of a combination of field studies, remote sensing and modeling a mid-term workshop was held in Vietnam devoted to an exchange between the different scientists, where modeling results may lead to new ideas on data analysis and trends from data may point towards new modeling ideas or point out weaknesses in the models.

Special programme selected Vietnamese scientists in the Netherlands
A very effective way to build modeling capacity and strengthen collaboration in our experience is to invite researchers over to Delft for approximately 3 month periods during which, apart from some formal training, they work alongside our staff in developing models for their area of interest and/or help develop and validate new functionality.

Development of Mekong Delta unstructured model
As part of a multi-million euro Next Generation Software project at Deltares, an unstructured-grid, finite volume model accommodating both quadrilateral and triangular cells has been under development for several years and is now in a state where it is being applied and validated in large research projects such as the USGS-led CASCADE II project which looks into future climate and water use impacts on the San Francisco Bay and Delta area. The model approach combines accurate representation of bending channels with extreme flexibility in modeling very complex areas and can handle any combination of 1D networks and 2DH or 3D areas. Like the Sacramento-San Joaquin delta the Mekong delta consists of a combination of very complex networks and larger water bodies with distinctly 3D features. Using the experience at UNESCO-IHE, the development team at Deltares and local Vietnamese know-how on the river network an effective and efficient model for the whole system can be developed.

As part of this project, two developments will be implemented:
(1) Optimizing 1D network generation and conversion tools. Given the complexity and sheer number of branches and nodes it is very helpful to be able to import and convert existing network schematizations or GIS layers into a Delft3D Flexible Mesh schematization. Vietnamese modelers will have a leading role here, and will be assisted by Deltares developers for support regarding Delft3D Flexible Mesh model setup and file formats.

(2) Implementing vegetation effects in Delft3D Flexible Mesh. There is substantial experience with modeling effects of vegetation on hydrodynamics and morphology in Delft3D; this can be readily implemented and the formulations, which have so far mainly been used in flood plains and salt marshes in moderate climates, will be adapted to typical mangrove vegetation characterizations. The latter is a task for the Vietnamese modelers.

We expect an important part of the actual modeling effort to be carried out by the Vietnamese partners, for a large part during their respective stays in Delft. Guidance and education is provided for the largest part by UNESCO-IHE, and by Deltares where Delft3D Flexible Mesh is involved.

Wave transformation modelling in mangrove forests
We propose to investigate the effects of cyclone waves on the mangrove forests of the Mekong Delta. Since, especially on the open coast, both incident-band and infragravity waves are likely to be important in understanding and modeling storm erosion, we propose to use the Delft3D Flow model with wave forcing by the online-coupled XBeach, which was recently developed with ONR funding, and to adapt both short-wave and long-wave dissipation formulations for the effect of mangrove
vegetation. Moreover, these formulations will be tested against in-situ data that are partly already available in Vietnam. Infragravity wave data will have to be collected.

**WORK COMPLETED**

*Special programme selected Vietnamese scientists in the Netherlands*

Over the last 12 months, UNESCO-IHE welcomed a number of Vietnamese scientists for a stay of a number of weeks/months in the framework of the capacity building part of the project. The purpose of their visit was to get acquainted with the Delft3D FLOW and Delft3D Flexible Mesh modeling software, and to assist them in applying the code in their own work. This was done by a combination of a dedicated short course and hands-on work with assistance of UNESCO-IHE staff:

- Nguyen Hoang Phong of VNU - University of Science focused on developing a Delft3D FLOW model able to simulate the hydrodynamics on the Mekong shelf;
- Vo Quoc Thanh of Can Tho University - College of Environment and Natural Resources started to build an unstructured model of the estuarine parts of the Delta, with special focus on the Bassac river. He was accompanied by Van Pham Dang Tri, who joined a week long modeling short course as a visiting scientist.

*Development of Mekong Delta unstructured model*

Boundary conditions (discharge, salinity, water levels) from the upstream boundaries in Cambodia, land boundary data and terrain and bathymetric information for the unstructured grid model were obtained from the Mekong River Comission data portal, and other public domain data sources. The tidal boundary conditions were derived from a tidal inversion model (TMD, Egbert & Erofeeva, 2002) An unstructured grid for the main channels and tributaries of the Mekong (Tien) and Bassac (Hau) rivers was refined, and all the available bathymetry was interpolated on this grid. This allows us to progress with the objective to create a model that will simulate the long-term development of these river branches (objective 2). The first runs to calibrate the water levels in the estuary mouths show the influence of fresh water discharge and roughness variations due to the presence of fines (Figure 1, Figure 2). In a later phase, we envisage to add the flood plains of the Vietnamese Mekong delta area to the grid, in order to be able to perform flooding simulations (objective 1).
To attain objective (3), Deltares has implement dissipation formulations in XBeach with which it is possible to simulate the wave attenuation and water level set up in vegetation. The implementation is done as follows: XBeach (in hydrostatic mode) solves the wave action equation for the short waves separately from the momentum and mass equation for the (time-varying) water levels. In the wave action equation we implemented the Mendez & Losada (2004) formulation which governs the attenuation of the grouped short waves, and which has also been implemented in SWAN for stationary waves. In the flow momentum balance, the drag force term was adapted for the non-linearity of short and long waves.
The new model has been validated on a laboratory data set of wave attenuation and wave-induced set up, kindly provided by Dr. Ozeren of the U. of Mississippi. The XBeach results show good agreement with data and moreover, XBeach is capable of reproducing the zero gradients in the water level. The next steps are to implement the formulations such that it is possible to simulate emerging vegetation, and vegetation with vertically-varying properties such as mangroves which have a root, stem and canopy structure. Further testing of this model on academic and (if available) real observations of mangrove coasts will take place, with a scheduled manuscript on the model formulations.

RESULTS

Getting the flow momentum balance in vegetated areas right is important as Dean and Bender (2006) have shown that the wave-induced water level gradient through a vegetation patch is much smaller and even of opposite sign relative to the classical non-vegetated case. This effect has important consequences for the computation of hydrodynamic impact on vegetation protected shorelines. The innovation is in the implementation of a drag force in the momentum equations which take the skewness effect of the short and long waves on the drag force into account. In this way a non-zero drag force balances the radiation stress gradient due to the dissipating short waves, and results in smaller or even negative water level gradients. In the classical case the radiation stress gradient would have to be balanced by a positive water level gradient.

IMPACT/APPLICATIONS

It is clear that a morphodynamic model which covers the entire Mekong Delta, and which is sufficiently efficient to simulate a few years of change without input schematisation is invaluable for integrated coastal zone and estuarine management purposes. Moreover, we aim at making this model a community model, meaning that we will make it widely available to all interested parties to apply, improve and extend. The fact that Delft3D Flexible Mesh is envisaged to become open source and freely available in 2015 will provide an additional boost to this initiative.

The improved flow momentum balance for vegetated environments will allow to study the morphodynamics of mangrove forest, not only during modal conditions when tidal pumping is the main input mechanism for sediment in these areas, but mainly during tropical cyclones, when infragravity waves are likely the dominating mechanism for the import of fines in tidal wetlands.

RELATED PROJECTS

All the modeling efforts within this project benefit from the field data gathered by the other partners in the DRI, mainly the groups led by Fagherazzi and by Mullarney.

REFERENCES
