Can MODIS Data Calibrate and Validate Coastal Sediment Transport Models?
Rapid Prototyping Using 250 m Data and the ECOMSED Model for Lake Pontchartrain, LA USA

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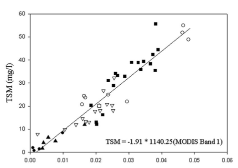
Abstract

Field measurements from small boats and sparse arrays of instrumented buoys often do not provide sufficient data to capture the dynamic nature of bio-geophysical parameters in many coastal aquatic environments. Several investigators have shown that MODIS 250 m images can provide daily synoptic views of suspended sediment concentration in coastal waters to determine sediment transport and fate. However, the use of MODIS for coastal environments can be limited due to a lack of cloud-free images. Sediment transport models are not constrained by sky conditions but often suffer from a lack of in situ observations for model calibration or validation. We demonstrate here the utility of MODIS 250 m to calibrate (set model parameters), validate output, and set or re-set initial conditions of a hydrodynamic and sediment transport model (ECOMSED) developed for Lake Pontchartrain, LA USA.

We present our approach in the context of how to quickly assess or 'prototype' an application of NASA data to support environmental managers and decision makers. The combination of daily MODIS imagery and model simulations offer a more robust monitoring and prediction system of suspended sediments than available from either system alone.

Introduction

The health of coastal aquatic systems is often governed by the concentration and distribution of suspended sediments in the water column. Suspended sediments directly regulate the amount and quality of phytoplankton and submerged vegetation production. Suspended sediments also influence the transport and fate of numerous pollutants, including heavy metals and polycyclic aromatic hydrocarbons. The consequences of natural and anthropogenic events within a watershed are often revealed by significant changes in the dynamics of suspended sediments in the receiving aquatic system. Therefore, it is essential that effective monitoring strategies of suspended sediments are developed to manage these important national assets.

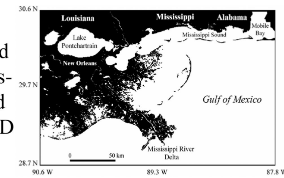


Miller and McKee (2004) demonstrated that NASA MODIS Terra 250 m data could provide near-daily estimates of Total Suspended Matter (TSM) in coastal aquatic waters. Although the MODIS-derived images provided a unique synoptic view of these dynamic systems, clouds often prohibited the use of MODIS or any optical instrument. A robust monitoring program obtains data from multiple sources to account for situations when the use of one data source is limited or ineffective. Therefore, can MODIS 250 data contribute to monitoring suspended sediments in other ways?

The NASA Applied Sciences Program (ASP) works to expand the use of NASA research results (i.e., data, models, and products) by coastal environmental managers and policy makers. A current strategy to support this effort is to quickly assess the efficacy of NASA research results as decision support tools by rapid prototyping the use of results for a specific application. The ASP is establishing a Rapid Prototyping Capability (RPC) to support this approach.

Rapid Prototyping

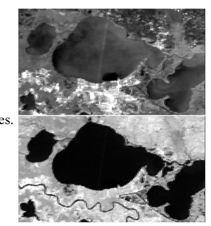
A brief 5 month project was conducted by UNO and NASA to assess whether TSM images derived from MODIS 250 m data could be used to set the initial conditions and additionally calibrate a sediment transport model to yield a more robust monitoring cabability of suspended sediments in a dynamic coastal aquatic environment. The ECOMSED (Estuarine, Coastal and Ocean Modeling System with Sediments) designed to model Lake Pontchartrain, LA, a shallow urbanized estuary, was selected as the test case.



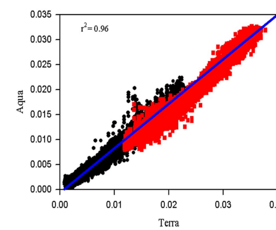
The Lake Pontchartrain estuary adjacent to New Orleans consists of three embayments, Lake Maurepas, Lake Pontchartrain, and Lake Borgne.

MODIS (Moderate Resolution Imaging Spectroradiometer)

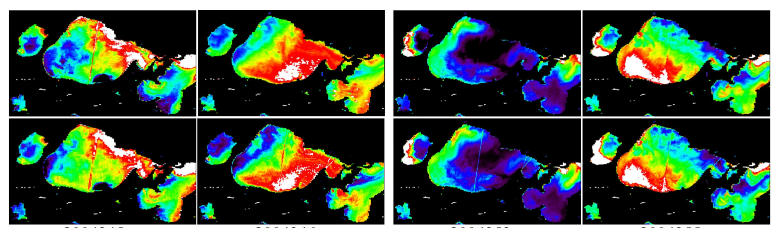
There is a MODIS instrument on the NASA Terra and Aqua spacecraft. The MODIS has 36 spectral bands from 0.4 µm to 14.4 µm. Terra and Aqua are in sun-synchronous orbits. The Terra spacecraft crosses the equator at 10:30 AM local time and the Aqua spacecraft crosses at 1:30 PM local time thereby potentially providing two views of a given area each day. Bands 1 (620 - 670 nm) and 2 (841 - 876 nm) are recorded at a nominal ground resolution of 250 m and are used to generate images of TSM of Lake Pontchartrain following the approach defined by Miller and McKee (2004).



Sample MODIS Aqua band 1 (top) and band 2 (bottom) images.



Aqua/TSM algorithm developed from a comparison between Aqua and Terra band 1 reflectance for 2004353 (black diamonds) and 2004355 (red squares).



2004345 2004346 2004353 2004355

Processed MODIS Terra (top) and Aqua (btm) band1 reflectance images showing short-term variability in suspended sediments. Warm colors indicate high TSM values while cool colors indicate low TSM values. Land is masked to black.

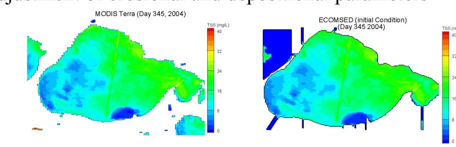
ECOMSED sediment transport model

ECOMSED is a sigma coordinate, free surface model, designed to simulate time-dependent distribution of waters levels, currents, temperature, salinity, tracers, sediments and waves in marine and freshwater systems. It is based on the Princeton Ocean Model (Blumberg and Mellor 1987) as modified for estuaries and coastal oceans (Blumberg 1996) and calibrated for Lake Pontchartrain (Chilmakuri 2005). ECOMSED consists of coupled hydrodynamic and sediment modules. The physics of the hydrodynamic model for Lake Pontchartrain are reasonably well understood and can be initialized with a sparse matrix of in-water and meteorological measurements. However, the ability of the sediment module to accurately model suspended sediment dynamics depends directly on the spatial distribution of initial measurements.

Model initialization and calibration

Initial conditions for the model were generated using MODIS-derived TSM images as previously described. The 250 m TSM images were then resampled to the model domain (ca 400 m). Physical sediment properties were initialized using literature values. Model boundary conditions were set using local tide gauges and wind records. All simulations started at day 345. The spatial calibration of the model was then conducted by repetitive simulation during the selected period. The sequence of MODIS images permitted the adjustment of erosional and depositional parameters

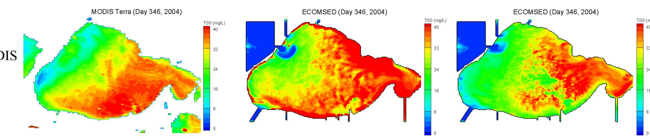
MODIS TSM image (left) and ECOMSED initial suspended sediment concentrations (right) for 2004345 established for ECOMSED runs.



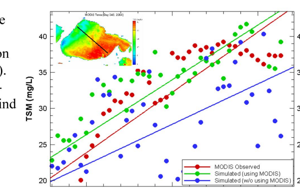
Results

Initial conditions for the model were generated using MODIS-derived TSM images as previously described. The 250 m TSM images were then resampled to the model domain (ca 400 m). Physical sediment properties were initialized using literature values. Model boundary conditions were set using local tide gauges and wind records. All simulations started on day 345. The spatial calibration

MODIS TSM image (left) and ECOMSED results using MODIS (center) and without MODIS (right) data.



Under steady wind forcing, there is a gradient of wave climate in the lake. This occurs primarily on the axis of wind direction (inset). Solid lines represent slope of increase in sediments along the wind (energy) gradient. MODIS and simulated ECOMSED (using MODIS data) show similar responses along this transect.



Parameter	MODIS (Observed)	Simulated (ECOMSED with the use of MODIS data)	Simulated (ECOMSED without the use of MODIS data)
Mean	29.3	31.3	25.8
Standard Deviation	9.0	9.0	8.0
Median	31.7	34.2	25.4
Variance	80.6	80.3	63.4

Statistical summary for comparisons between observed and simulated TSM distributions along the primary axis of the wind direction (see figure left).

Conclusion

The concentration and distribution of suspended sediments can routinely be determined using field, remote sensing, and numerical modeling technologies. There are advantages and limitations to each approach. The most effective method for monitoring suspended sediments in dynamic coastal environments is to integrate all three. This study demonstrated the potential of MODIS 250 m data for establishing the initial concentrations of suspended sediments for a coastal sediment transport model. Moreover, given the 250 m spatial resolution and daily observations, MODIS data can help calibrate or refine parameter coefficients of numerical models to provide better information to environmental managers and policy makers.

References

Blumberg, A. F., and G.L. Mellor. 1987. A description of a three-dimensional coastal model, Three Dimensional Coastal Ocean Models, N. S. Heaps, ed., American Geophysical Union, Washington, D.C., 1-16.

Blumberg, A.F., Z-G Ji, and C.K. Ziegler. 1996. Modeling outfall plume behavior using far field circulation model. Journal of Hydraulic Engineering, ASCE, Vol. 122, No. 11

Chilmakuri, C. 2005. Sediment Transport and Pathogen Indicator Modeling in Lake Pontchartrain, Ph.D. Dissertation, Dept. of Civil and Environmental Engineering, University of New Orleans, New Orleans, LA, 156pp.

Miller, R.L. and B.A. McKee. 2004. Using MODIS Terra 250 m Imagery to Map Concentrations of Total Suspended Matter in Coastal Waters. Remote Sensing of Environment, 93(1-2), 259-266.