Coastal Modeling System (CMS) and C2SHORE
Recent Advancements and Technology Transfer

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ENGINEER RESEARCH & DEVELOPMENT CENTER

Physical processes

The Coastal Modeling System (**CMS**) consists of two independent but couplable modules (CMS-Flow and CMS-Wave) that enable large-scale numerical modeling of hydro- and morphodynamics in coastal, inlet, and estuarine environments. Sediment transport can be computed using **C2SHORE**, among other available formulations, extending its validity from current-dominant environments to wave-dominant environments as well. A variety of features are available in SMS to aid in modeling structural and non-structural alternatives for sediment management and flood risk management engineering projects, including:

- ✓ EWN Toolkit
- ✓ Sediment Volume Management
- ✓ Breakwaters and jetties
- ✓ Sediment layering and mapping

Table 1. Coastal Modeling System (CMS) capabilities and limitations

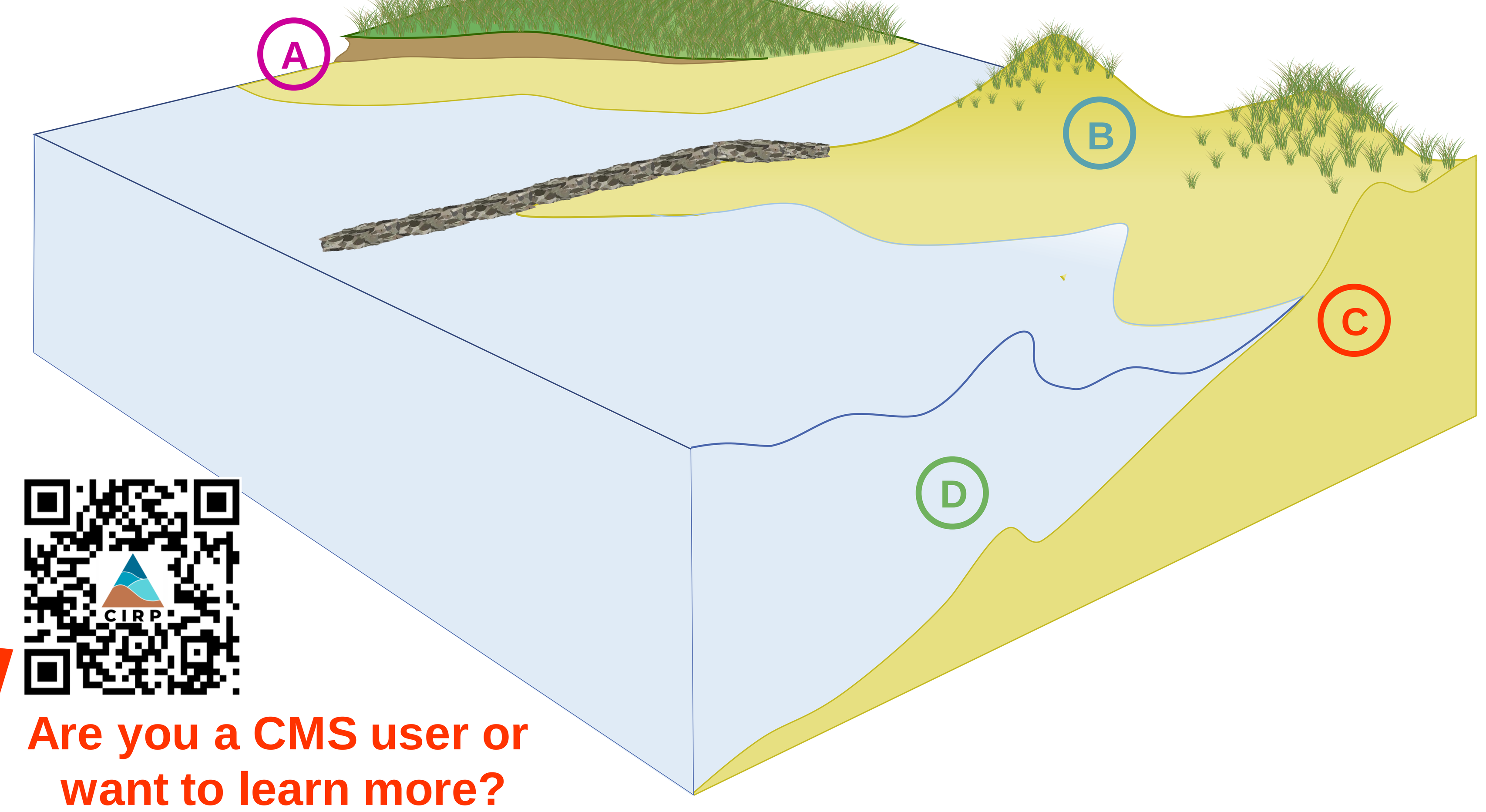
Capability	Intended application	Not available
Flow	WSE and depth-averaged currents	
Waves	Nearshore, phase-averaged	Offshore (deep water); phase-resolving
Sediment transport	Sand, multiple grain sizes; dunes via coupling with Aeolis	Fine grains (silt, mud)
Vegetation	Wave, flow drag	Sediment dynamics (under development)
Salinity, temperature	Scalar concentration advection and diffusion	Multi-phase flow; salt wedge dynamics
Speed	Desktop-friendly (hrs-days)	HPC
Grid cell size	Regional to macro (km-m)	Fine scale (cm-mm)
Numerics	Structured, non-uniform (quadtree); implicit and explicit in time	Unstructured (triangular)

cms2d.readthedocs.io

GitHub

github.com/erdc/cms2d

Now open source!



Are you a CMS user or want to learn more?

Scan the QR code to complete a brief survey to help our team learn about your needs!

Case study – Fire Island Inlet

In collaboration with the New York District, the CMS team (led by Lihwa Lin), developed a coupled CMS-Flow and Wave model of Fire Island Inlet to assess flood risk reduction and sediment management. The model was calibrated and validated using observed waves, wind, water levels, lidar surveys, and bathymetric surveys.

The sediment transport capability of CMS (C2SHORE) was validated by replicating the morphodynamic response of the inlet during Tropical Storms (Irene and Sandy) and annual conditions (April 2019-March 2020). The validated model was used to evaluate various borrow-fill alternatives to support renourishment of Robert Moses State Park and Gilgo Beach.

Figure 1a. Observed bed elevation changes

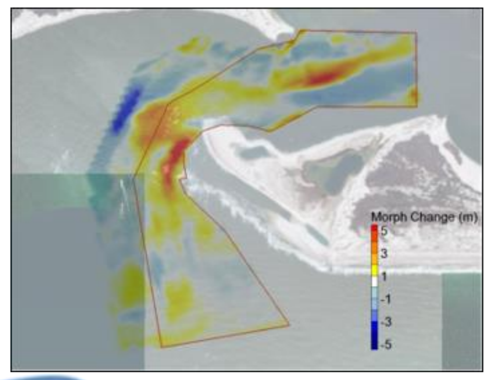
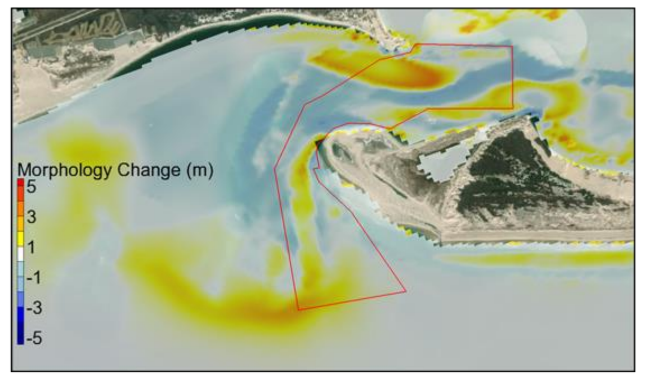


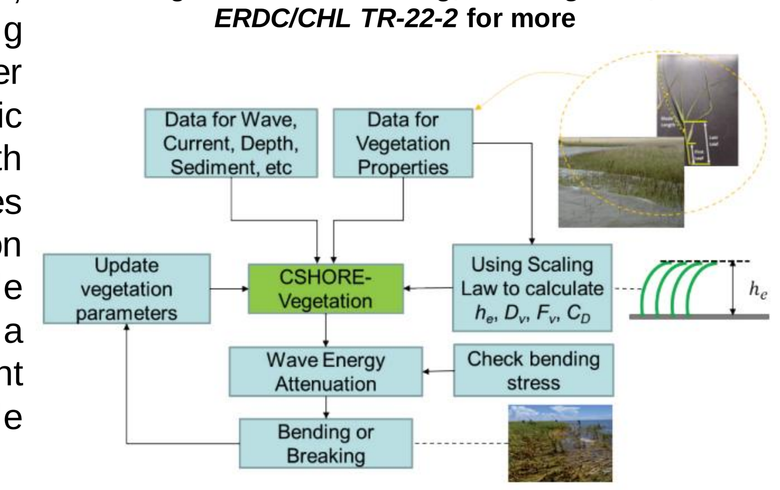
Figure 1b. Modeled bed elevation changes using CMS & C2SHORE



A Wave and mean flow attenuation by vegetation

Recent R&D efforts to better capture flow-vegetation interactions in CMS and CSHORE, led by Yan Ding, have focused on computing wave and mean flow drag forces over vegetation stems. As shown in the schematic (Fig. 2), a new formulation parameterized with species-specific bio-mechanical properties improves the calculation of wave attenuation and current velocity reduction by flexible vegetation stems. The model leverages a novel relationship between the drag coefficient and the Reynolds number, which is applicable for a wide range of species (see Fig. 3).

Figure 2. New method of vegetation-induced drag; see *Ding et al., ERDC/CHL TR-22-2* for more



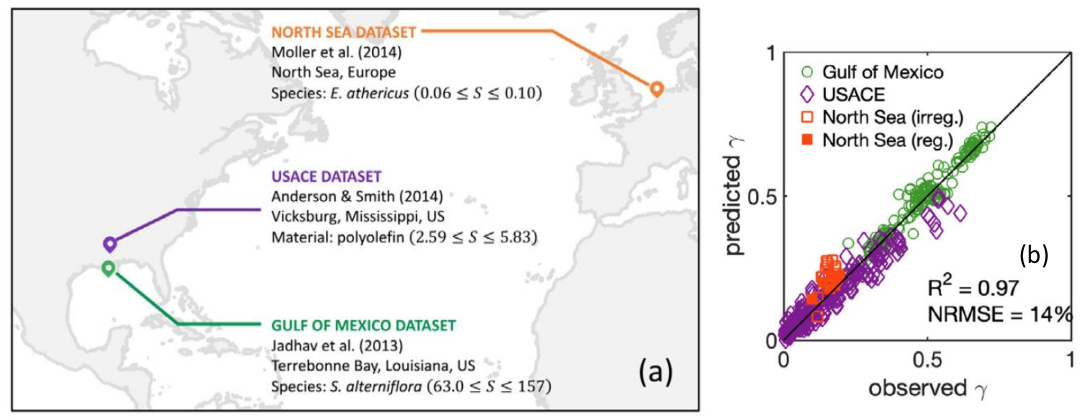


Figure 3. From Zhu, et al. (2022). *Coastal Engineering*. (a) Range of vegetation types used to validate new unified model for drag coefficient (C_d). (b) Comparison of observed and predicted wave attenuation using new unified C_d model, where $\gamma = 1 - H_{rms}/H_{rms0}$

B Wind-driven dune morphodynamics using Aeolis

Although waves and currents are the predominant driver of coastal change, sediment transport driven directly by wind plays a relevant role in landform evolution near the shoreline in sandy coastal environments. Sediment sourced from the intertidal zone or dry beach can be blown by wind into adjacent dune systems or waterways, including into inlets, marinas, or the ocean itself. This wind-driven contribution can increase USACE dredging needs to meet navigational requirements. Recognizing the importance of wind-driven sediment contributions to the littoral dynamics near inlets and other coastal settings, R&D has been focused on (1) advancing capabilities to simulate wind-blown sediment transport in managed coastal systems using the Aeolis model (Hoonhout and de Vries, 2016) and (2) directly coupling the CMS suite with Aeolis to co-simulate nearshore-beach-dune evolution (Fig. 5).

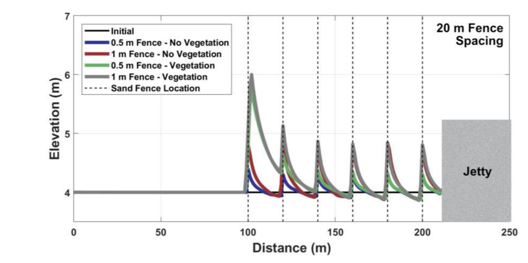


Figure 4. Deposition patterns due to sediment trapping by sand fences simulated by Aeolis at an inlet-adjacent site

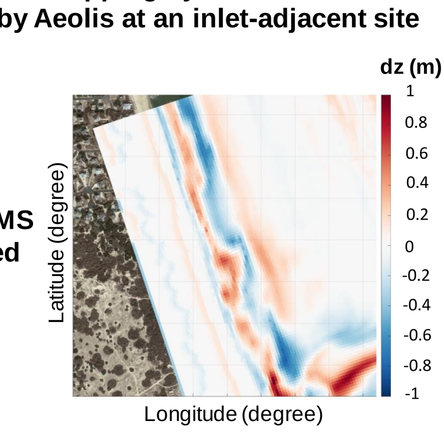
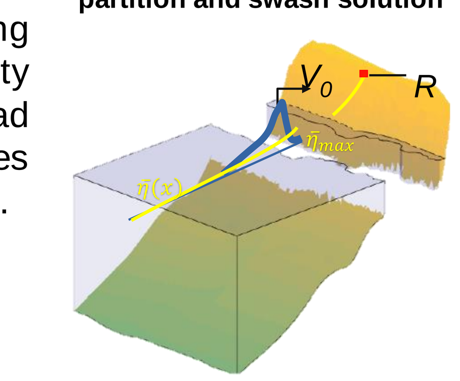


Figure 5. Example coupled CMS – Aeolis bed elevation change output for Duck, NC

C Improved phase-averaged wave runup statistics

Accurately modeling wave runup is required to predict the leading edge of inundation, but is difficult to do in a rapid, generalized manner without high computational expense. A novel time-averaged swash solution has been implemented into CMS to fill this gap. The new CMS model routines were tested against commonly used algebraic and numerical models in predicting runup statistics ($R_{2\%}$) observed at the CHL Field Research Facility (FRF) during the 2015 nor'easter season. The CMS model had the lowest root mean square error (RMSE) and was 3-10 times faster than the more advanced numerical models tested (Table 2).

Figure 7. CMS domain partition and swash solution



$$\frac{\partial M}{\partial x} = \frac{\partial}{\partial x}\{A_0 g h^2\} = -g\bar{h}\frac{\partial z_b}{\partial x} - c_f|U|U$$

$$M \cong A_0 g \bar{h}^2$$

$$A_0 = 2.6 + 4.5\frac{\tan(\beta_f)}{\sqrt{H_{mo}/L_o}}$$

Figure 6. CMS prediction compared to observed

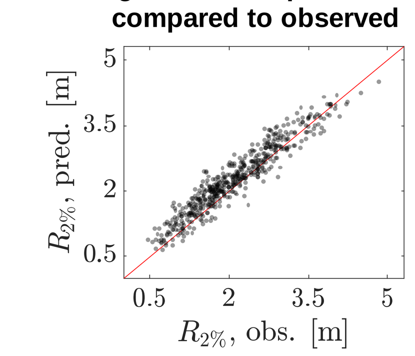


Table 2. Runup model error and speed

	Runtime	RMSE (m)
Stockdon, et al. (2006)	0.18 s	1.01
CSHORE	25.0 s	0.55
CMS	**10 hr**	**0.29**
XBeach-Surfbeat	35.5 hr	0.53
XBeach-NH	124.4 hr	0.45

D Advancing sediment transport by nonlinear waves

Conventional phase-averaged wave models are incapable of computing nonlinear wave velocities in the surf zone and are therefore wholly-dependent on site-specific empirical parameters to predict the magnitude and direction of wave-driven sediment fluxes. A new model component is in development that includes the details of phase-dependent sand entrainment and transport by generating a skewed and asymmetric synthetic fluid velocity time series that is consistent with the phase-averaged balances. Examples of predicted and measured bedload and suspended load from a laboratory study are provided in Fig. 8. Detailed process-based transport predictions can be numerically accumulated and readily included in phase-averaged models.

Figure 8. Model vs observed Q_{sed}

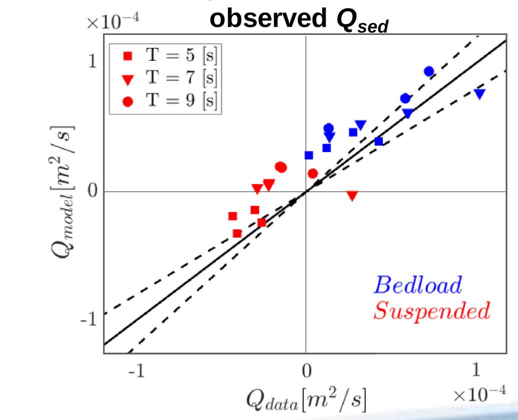
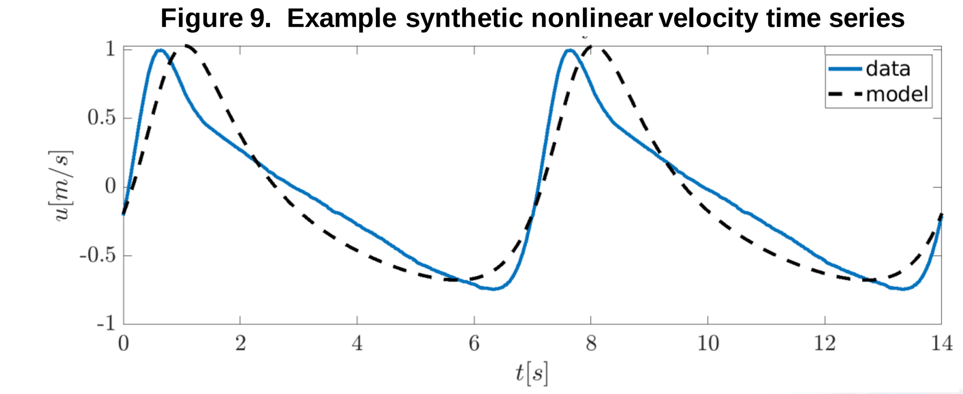


Figure 9. Example synthetic nonlinear velocity time series



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