Modelling Extreme Events (Hurricanes) at the Seafloor in the Gulf of Mexico

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ABSTRACT

Background:

The subsea infrastructure of the US N Gulf of Mexico is exposed to risks of seabed failure and flowage under extreme storm events. Numerical assessments of the likelihood, location and severity of those phenomena would help in planning. A project under BOEM, couples advanced modelling modules in order to begin such a system. The period 2008-10 was used for test data, covering hurricanes Gustav and Ike in the Mississippi to De Soto Canyons region.

Methods:

Currents, tides and surface waves were computed using the Regional Ocean Modeling System (ROMS) and river discharges from WBMsed. The Community Sediment Transport Model (CSTMS) calculated the concurrent sediment erosion-transport-deposition.

Local sediment properties were from the dbSEABED database. The preferred paths of near-bottom sediment flows were based on a TauDEM stream analysis of the bathymetry. Locations and timings of suspended sediment gravity flow were identified by applying energy flow ignition criterea. Wave-induced mass failure and subbottom liquefaction were assessed using a bevvy of marine geotechnical models. These tests of ignition are bundled in the model suite HurriSlip.

The persistence, densities and velocities of turbidity flows yielded by the disruption of the sediment masses were calculated using high-Reynolds Number adaptations of LES/RANS-TURBINS models (Large-Eddy Simulation / Reynolds Averaged Navier-Stokes). A very important step here was the transfer of these advanced models from laboratory to geographic scales.

Results:

As known, much of the shelf sediment mantle is suspended and/or moved during hurricanes, consistent with the modeling results. Many short-lived gravity-flow ignitions occur on the shelf; many at the shelf edge will ignite into fast, erosive and persistent currents. Sediment patchiness and vagaries of hurricane path mean that the pattern of ignitions alters from event to event.

Conclusions:

It is presently impossible to observed seafloor disruption over a wide area under extreme hurricane events. To understand the impact on the deep-water infrastructure, a numerical process-based modelling approach is essential – along the lines this project explored and developed.

A valuable experience in the project was devising workflows and linkages between these advanced, but independent models.

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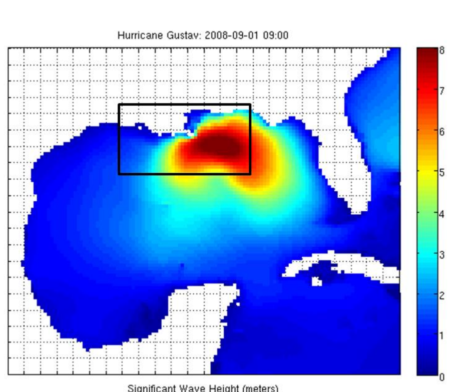
PHYSICAL OCEANOGRAPHY



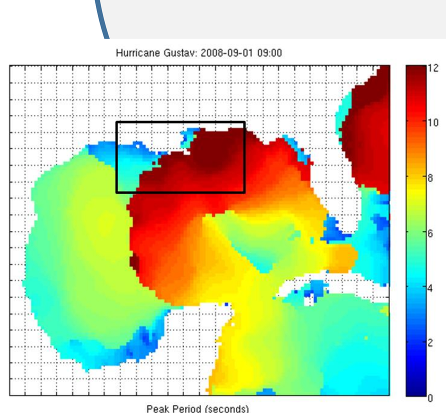
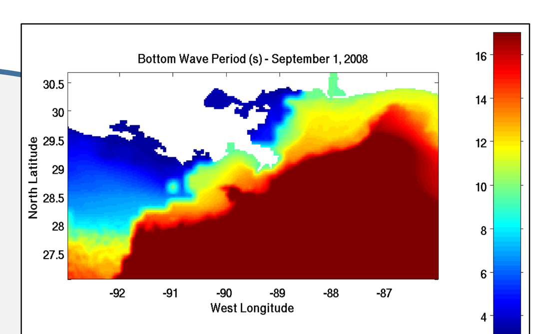


Fig. B-1: Estimates of (a) wave height (m), and (b) wave period (sec) from NOAA-NCEP Wavewatch III model for September 1, 2008, Hurricane Gustav. The black box indicates location of the project ROMS hydrodynamic Grid-f.



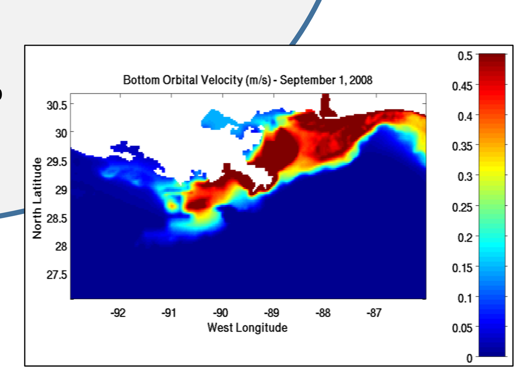


Fig. B-2: Estimates of (a) bottom wave period and (b) bottom orbital velocity from NOAA/NCEP WaveWatch III model following Wiberg and Sherwood (2008) for hydrodynamic Grid-f on September 1, 2008, Hurricane Gustav.

UCSB

FLOW PHYSICS

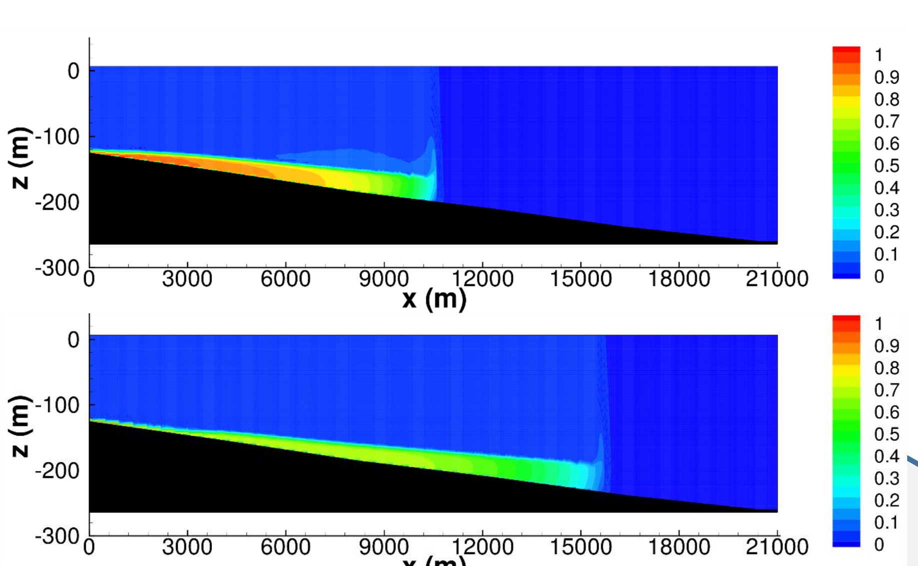


Fig. E-1: Contours of suspended sediment concentration at: a) time = 4 hours, and b) time = 8 hours. Note the modeled runout speed, approx. 2km/hr and slowing.

A major advance in the project was the adaptation of laboratory-scale advanced hydrodynamic modeling methods to the geographic scales of the Gulf of Mexico. Additionally, a 'non-hydrostatic' RANS - Reynolds-averaged Navier–Stokes turbidity current model was successfully developed which can resolve the vertical motions and turbulence.

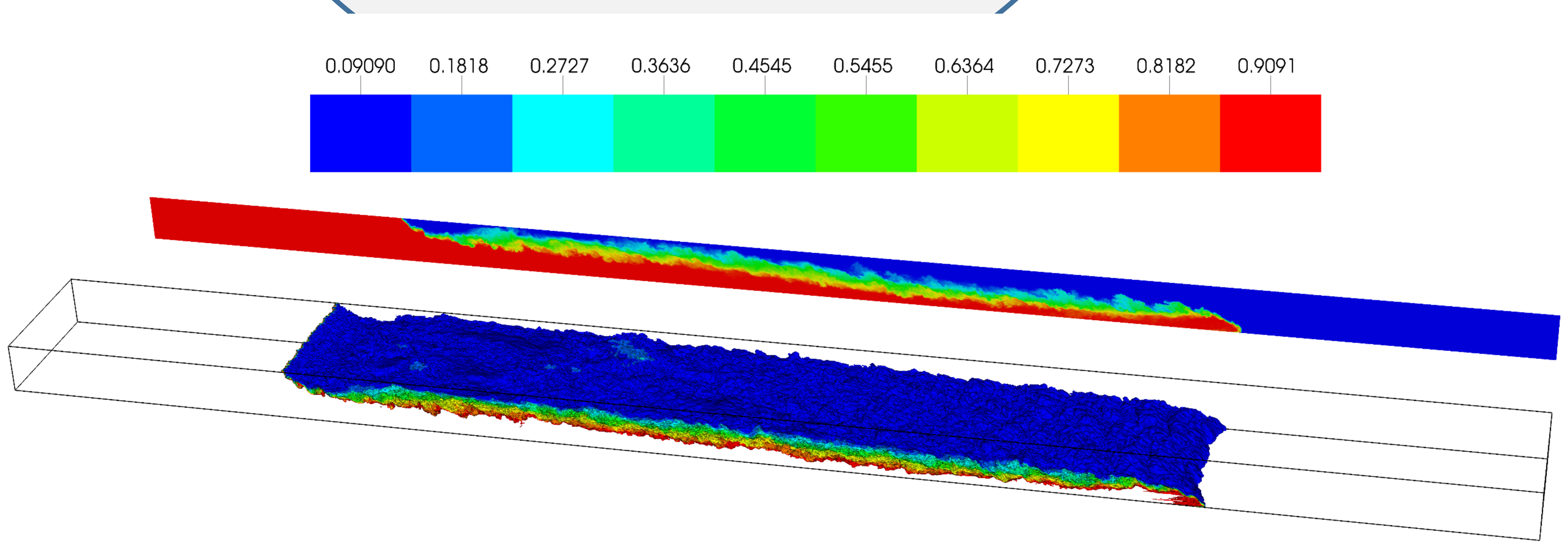


Fig. E-2: Gravity current propagating over a flat terrain. The domain is 30 units long where the length is non-dimensionalized by the height of the domain. At this instant in time, the current occupies approximately 20 units.

HIGHLIGHTS

We show only some of the highlight illustrations from the project.

A project of BOEM Bureau of Ocean Energy Management

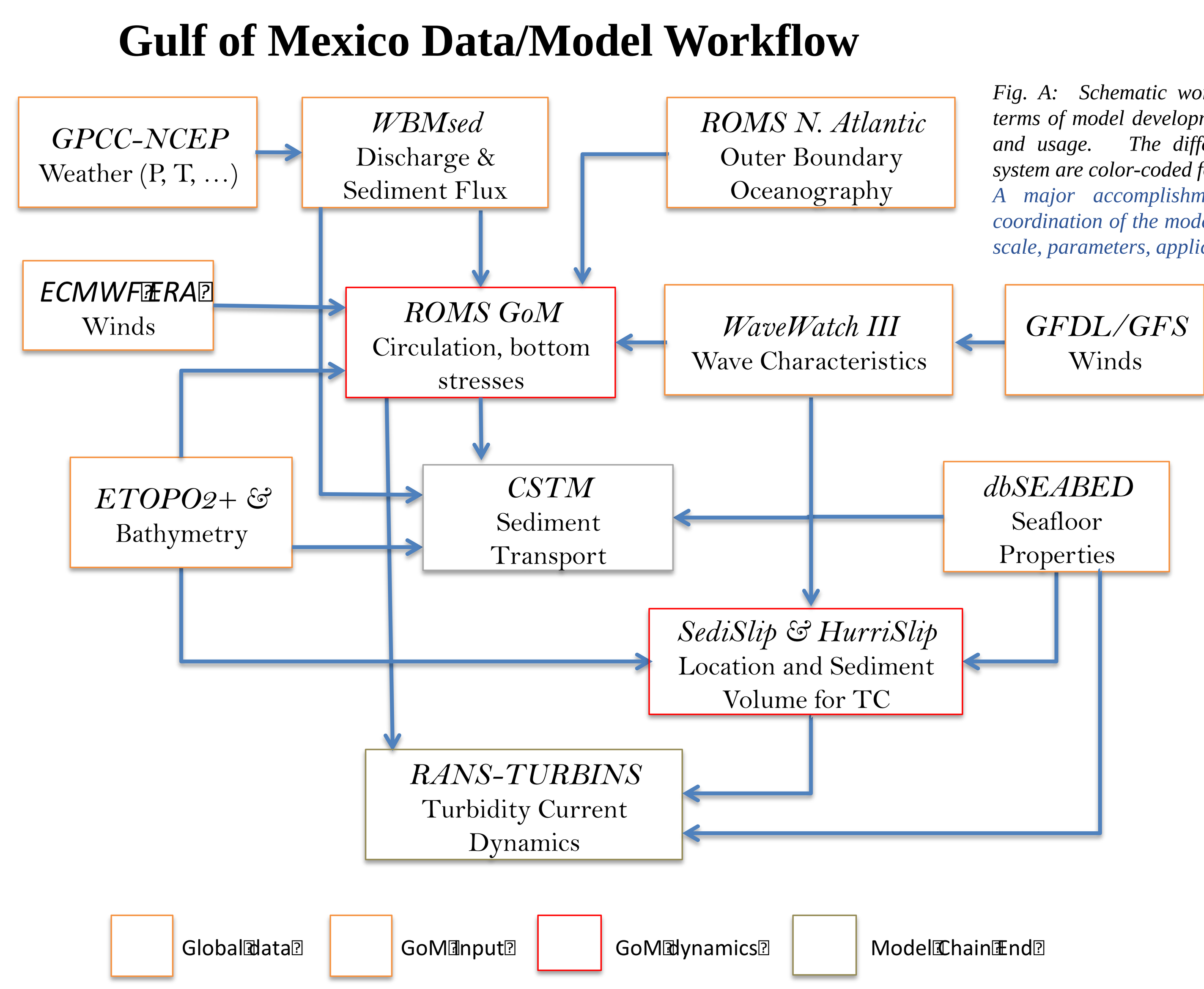


Fig. A: Schematic workflow for the project in terms of model development and data generation and usage. The different components of the system are color-coded for clarity.
A major accomplishment of the study was coordination of the model components in terms of scale, parameters, applicability.

CSDMS/INSTAAR

SEAFLOOR DATA, FLOW IGNITIONS

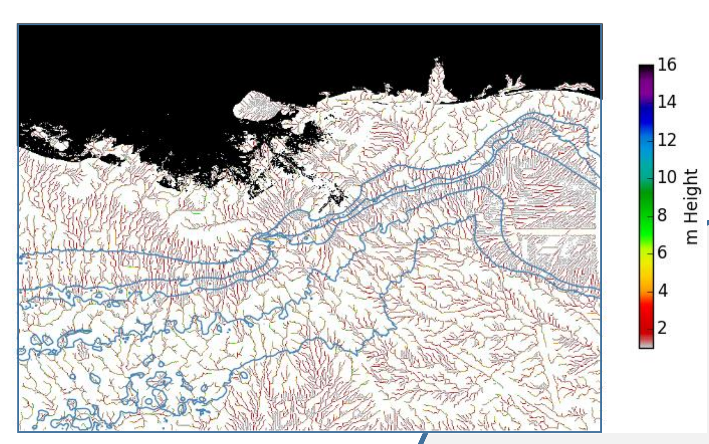


Fig D-1: Topographically defined sediment drainage patterns ('channels') for the project area, computed with TauDem. Grey/red streams have least incised relief and are the most common, green/blue streams have incision up to 15m, measured on km scales.
This data on channel slopes and data on ignition suspended concentrations was supplied to the UCSB models for initialization values.

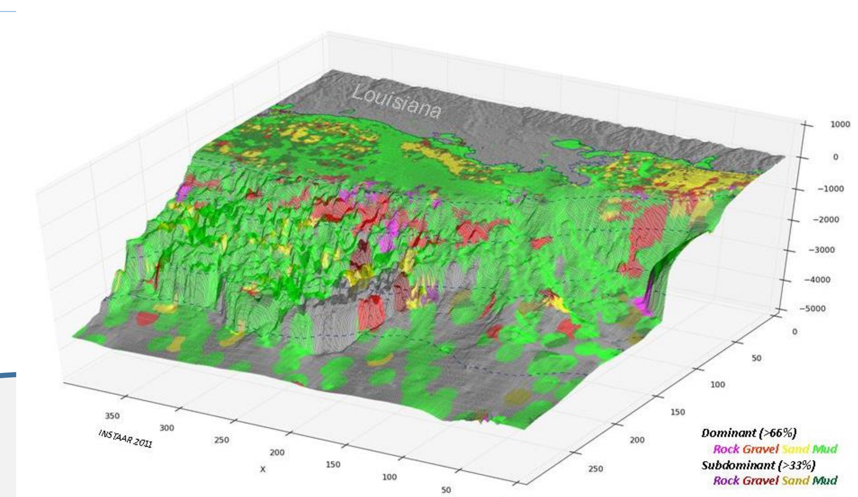


Fig. D-2. Three-dimensional view of the sediment types exposed over Mississippi continental margin.
Substrate type and consolidation directly influence the sediment pickup in an area during an extreme event.

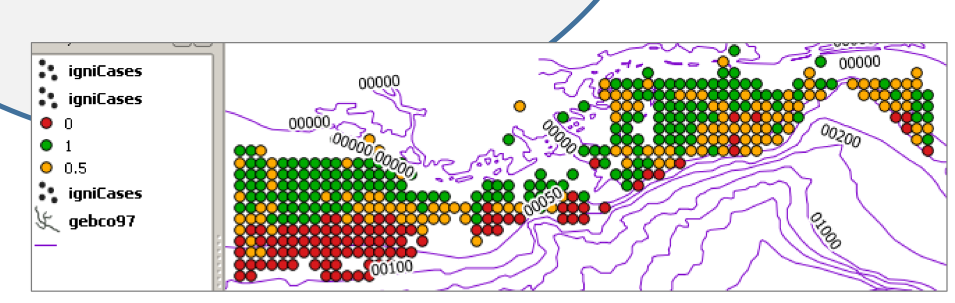


Fig. D-3. GIS display of the distribution of igniting (self-accelerating) flows events - green-probable, orange-possible, red-unlikely - occurring at some time during the run. The criteria were: Richardson Number and Knapp-Bagnold criterion, and Parker energy balance. Only every 1/16th point of the grid was modeled for this map.
Although many ignitions are proposed on the shelf, hardly any will be sustained. The project is interested in cases of ignition close to the top of the slope where gravity flow may be sustained.

VIMS

SEDIMENT TRANSPORT

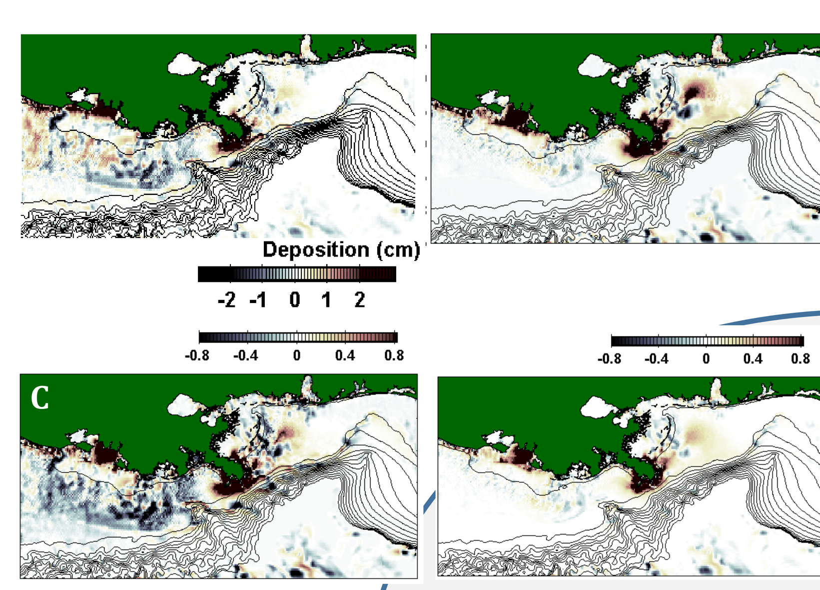


Fig. C-1: a) Net erosion and deposition from suspended sediment transport calculated at the end of the 1-yr simulation, September 20, 2008. Time-integrated deposition and erosion (cm) during b) Hurricane Gustav, and c) Hurricane Ike, and d) and for just the period from Oct 1, 2007 up until August 25, 2008. Bathymetric contours (in black) drawn for depths of 10, and every 100 m up to 1500 m.

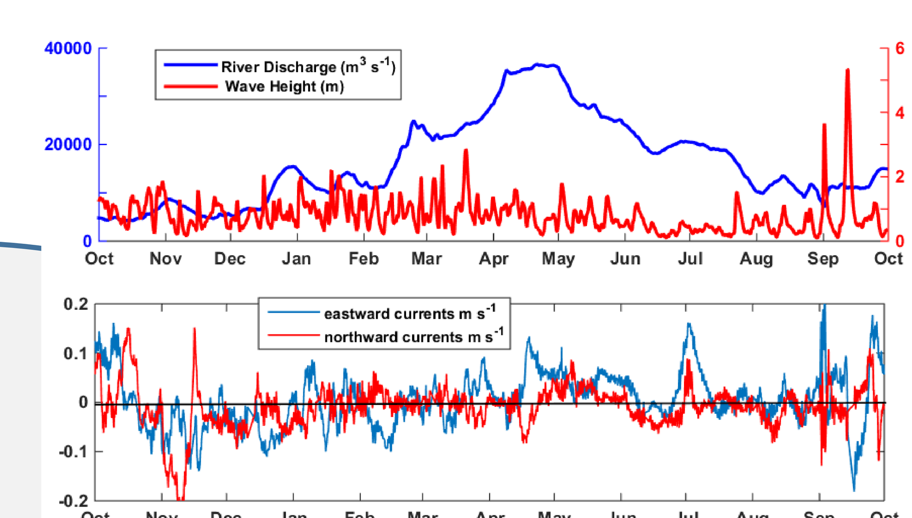


Fig. C-2: Observed discharge, wave, and current conditions during the modeled period (data from the USGS and NOAA's National Data Buoy Center). Hurricanes occurred between August 25-September 4 (Gustav) and September 1–September 14 (Ike), 2008.

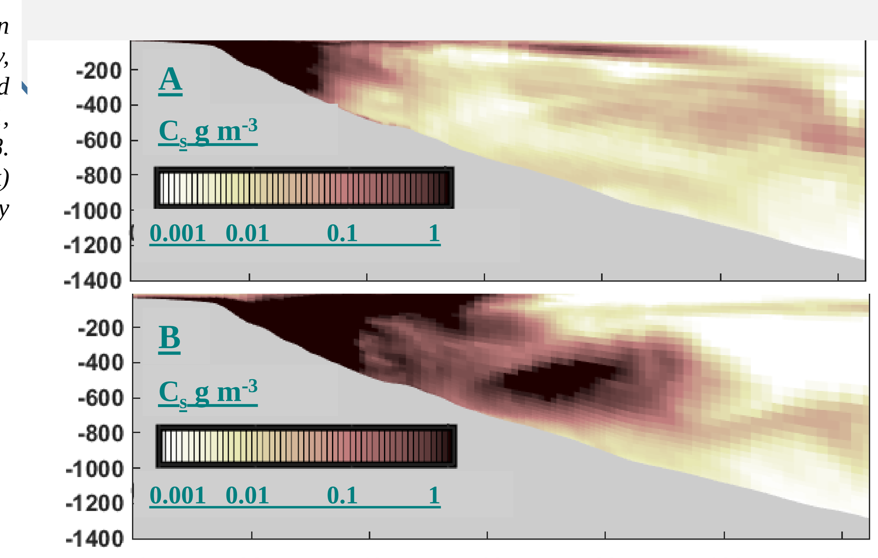


Fig . C-3. Panels A and B show suspended sediment along the Mississippi Canyon transect during and after Hurricane Gustav, 1 September 2008 and 6 September 2008, respectively. The cross-slope distance is in km, while depth is in m.

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