APPLICATION OF REGIONAL SEDIMENT MANAGEMENT TECHNIQUES AT NEW PASS AND BIG SARASOTA PASS, FLORIDA

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ABSTRACT

Sediment, particularly beach quality sand, is an increasingly valuable and, in many cases, a controversial commodity. The Regional Sediment Management Program was initiated based on recommendations from the Coastal Engineering Research Board (CERB) that the Corps of Engineers move away from a project-centric approach and adopt a regional approach to managing sediment, so that project-level decisions are made in the context of a regional sediment strategy. The Jacksonville District (SAJ) was directed to conduct a regional sediment study of a section of the Sarasota County, Florida Gulf Coast shoreline that encompasses New Pass and Big Sarasota Pass and the adjacent beaches to develop an in-depth understanding of wave-forced and tidally-forced sediment transport processes and to configure an analytical model of the two-inlet system that includes regional sediment sources, sinks, and pathways that could be used for evaluating engineering and management alternatives. This paper focuses on an effort to verify CMS-M2D morphological modeling of the two inlet system. Qualitative and Quantitative comparisons of CMS-M2D and LIDAR derived bathymetric changes were conducted, for the period of May to November 2004, to demonstrate the ability of CMS-M2D to simulate the morphology of the area.

INTRODUCTION

Previous District RSM efforts have primarily relied upon existing data and reports along with limited new analyses - essentially combining the results and conclusions of numerous previous studies which occurred over very long time periods. The subject study is the next logical step in the RSM process: developing an in-depth understanding of a sediment system on a scale that is larger than typical project-scale utilizing modern techniques. It is the first RSM effort of this type at SAJ made possible by the provision of a budget independent of any specific project feasibility determination. This study is a cooperative effort between SAJ and Coastal Tech and Coastal Engineering Consultants, who applied the CMS-M2D to evaluate channel relocation and ebb shoal mining alternatives at Big Sarasota Pass, in support of Sarasota County's Comprehensive Inlet Management Program.

Plans for this study include analysis of historical volumetric changes and the application of numerical and analytical computer models (Coastal Modeling System, Inlet Reservoir Model/CASCADE) to investigate the hydrodynamics and sediment transport forcing mechanisms and long term evolution of the inlet. The final goal of the investigation will be the development of a modeling tool, which can be utilized by all interested Federal and non-Federal agencies and groups, to develop specific separable project alternatives in the region, with all recommendations derived within the context of the interconnectedness of the overall sediment transport system.

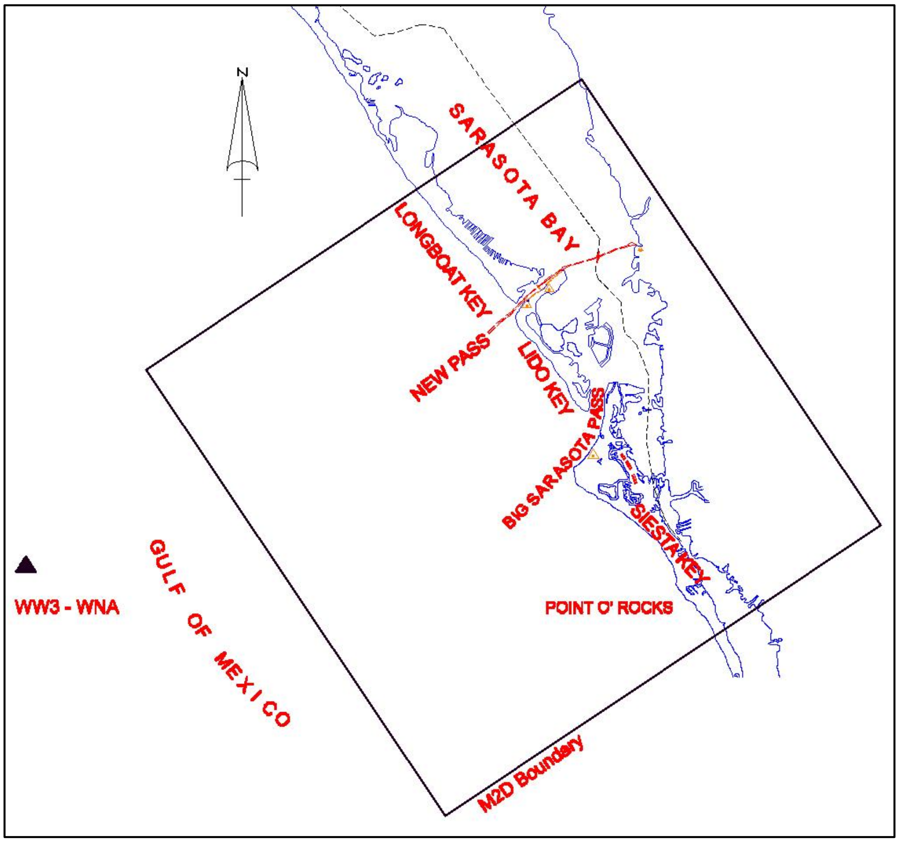

Figure 1. Study Location Map

This paper focuses on the CMS-M2D morphological modeling of the Big Sarasota Pass and New Pass inlet system (Figure 1). Qualitative and Quantitative comparisons of CMS-M2D and LIDAR derived bathymetric changes were conducted, for the period of May to November 2004, to demonstrate the ability of CMS-M2D to simulate the morphology of the area.

BACKGROUND

Big Sarasota Pass is a mixed energy inlet, where the tidal range and mean wave height are about equal in magnitude and interact to control the inlet morphology. Big Sarasota Pass is also an offset inlet, where Lido Key is offset by about 500 m landward compared to the down drift Siesta Key (Figure 2). Net transport in this area is to the Southeast at a net annual average rate of about 100,000 cy per year.

Big Sarasota Pass channel has historically migrated south and the ebb shoal has grown since Lido Key formed (1920) and was nourished periodically. Siesta Key on south side of Big Sarasota Pass channel has been stabilized (1950s) so that the channel no longer migrates to the south (Davis & Wang, 2004). This and the southward longshore transport from nourished beaches to the north (Lido Key and Longboat Key), causes the end of the ebb shoal to grow seaward to a point seaward of the Siesta Key shoreline. This results in a reduced supply of sediment to the northern most 1000 to 1500 ft of Siesta Key, and chronic shoreline erosion, as material is bypassed further south, down the beach. Naturally bypassed material temporarily

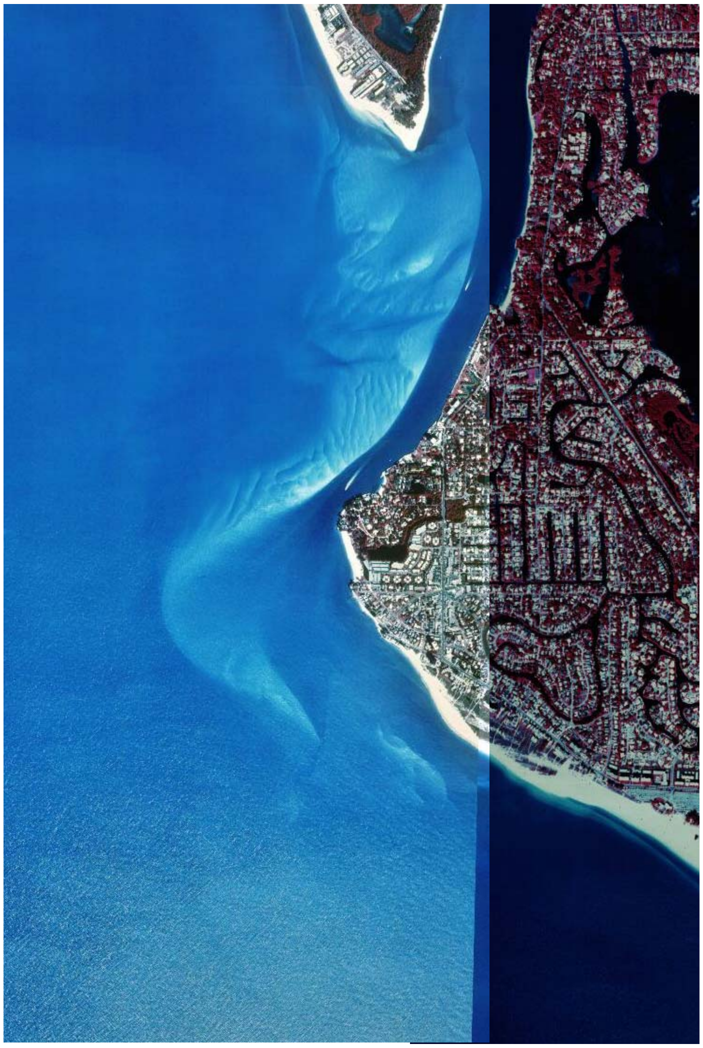

Figure 2. 1995 aerial image of Big Sarasota Pass.

collects in the mouth of the Big Sarasota Pass channel resulting in some shoaling and represents a periodic navigation hazard.

The long, relatively narrow, Big Sarasota Pass channel is hydraulically inefficient so that tidal currents flow across the ebb shoal. Tidal currents measured (Kowalski 1995) about mid way along the length of the Big Sarasota Pass channel and at the mouth, show the effect of the flow in the channel and across the ebb shoal. At the mid point along the channel the ebb and flood tide velocities are similar, while at the mouth, the flood tide velocity is about 25 % of the ebb tide velocity. This indicates that a significant portion of the tidal flux entering the inlet flows across the ebb shoal while a greater portion of the ebb tidal flux exits the inlet within the main channel. Grain size distribution within the channels varies from 1 mm to 8 mm and over the shoals the range is between 0.15 mm to 0.25 mm (Davis and Wang, 2004).

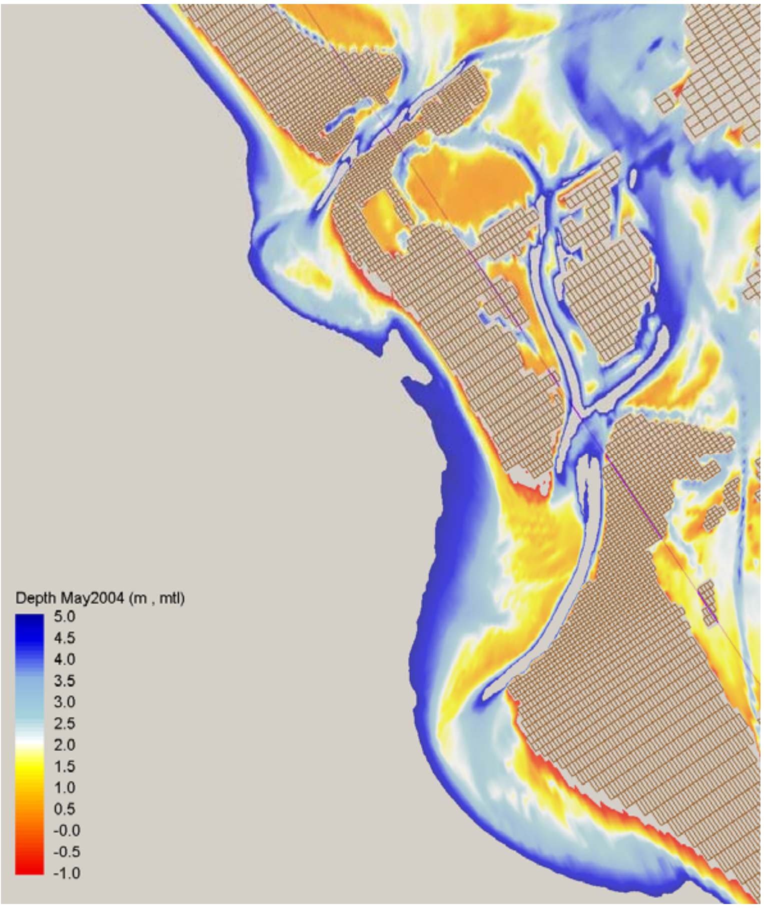

Figure 3. LIDAR bathymetry, May 2004

BATHMETRY DATA

LIDAR bathymetry from May 2004, shown in Figure 3, illustrates the morphological features of Big Sarasota Pass. The main channel, with a depth of up to 8.0 m, runs between the ebb shoal and Siesta Key. The ebb shoal, between 0 and 2.0 m depth, has one larger flood channel about mid-way along it's length and 3 or 4 smaller flood channels adjacent to Lido Key. Bypassing at the southern end of the ebb shoal to Siesta Key is also evident. LIDAR bathymetry from May 2006, shown in Figure 4, illustrates very similar morphological features but the ebb shoal now has two large flood channels.

Observed bathymetric changes, from the differences between LIDAR surveys from May 2004, November 2004, and May 2006, are shown in Figure 5. For the period May to November 2004, erosion and accretion in Area I, is evidence of alongshore shore transport along Lido Key. The erosion in Area A, at the distal portion of the ebb shoal, is due primarily to the wave induced transport during the three hurricanes in September 2004. Much of this material moves south to Area D. Wave induced transport also moves some of this material along the ebb shoal toward the Northeast. Area K shows evidence of bypassed material working its way down drift and shoreward to Siesta Key. Area E shows one bar attached to the Siesta Key shoreline. Many of the same morphological patterns are evident during May 2004 to May 2006, shown in the left

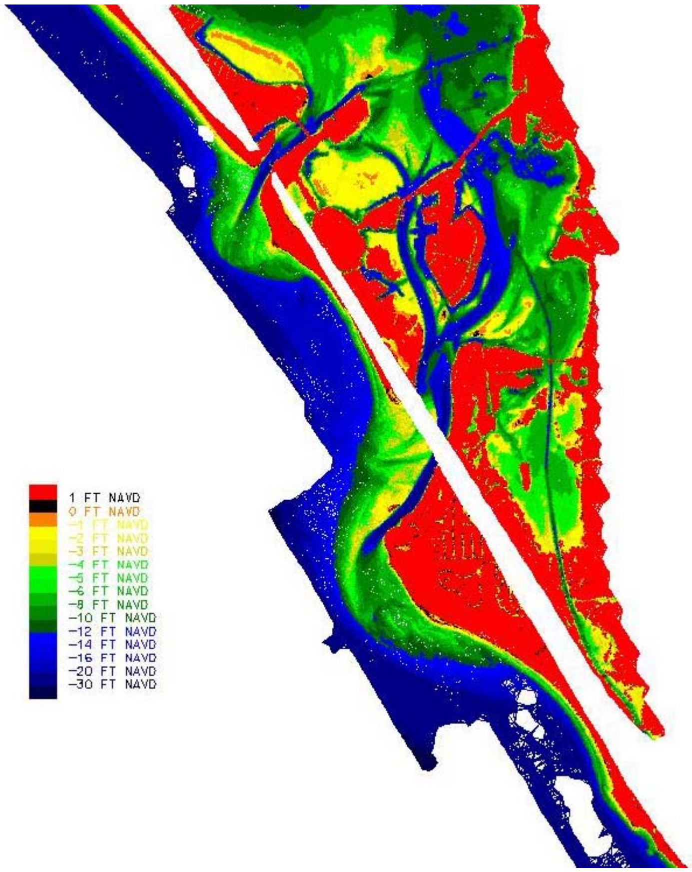

Figure 4. LIDAR bathymetry, May 2006

panel of Figure 5, but with more erosion at the distal portion of the ebb shoal (Area A), increased accretion on the ebb shoal platform and the linear bar (Area B), and increased erosion and accretion in Area K. One noteworthy difference between patterns during the two periods is the predominate accretion at the mouth of the main channel (Area J).

Figure 6 shows the bathymetric change for a 15 year period, from boat survey data collected in 1991 and March 2006. For this period, erosion at the distal portion of the ebb shoal extends well beyond Area A. Accretion along the linear bar at the main channel margin is greater than 10 ft, which indicates that the ebb shoal has migrated into the main channel during this 15 year period.

M2D MORPHOLOGY MODELING

The CMS-M2D was used to simulate the morphological behavior the New Pass and Big Sarasota Pass Inlet systems. This application included the implicit version of the depth averaged hydrodynamic model, CMS-M2D (Buttolph et al. 2004), the Advection-Diffusion sediment transport module, and the steady state finite difference spectral wave transformation model STWAVE (Smith et al. 2000). Limitations of this M2D model application include the requirement to use a uniform grain size and the use of model derived wave parameters for STWAVE input rather than measured spectra.

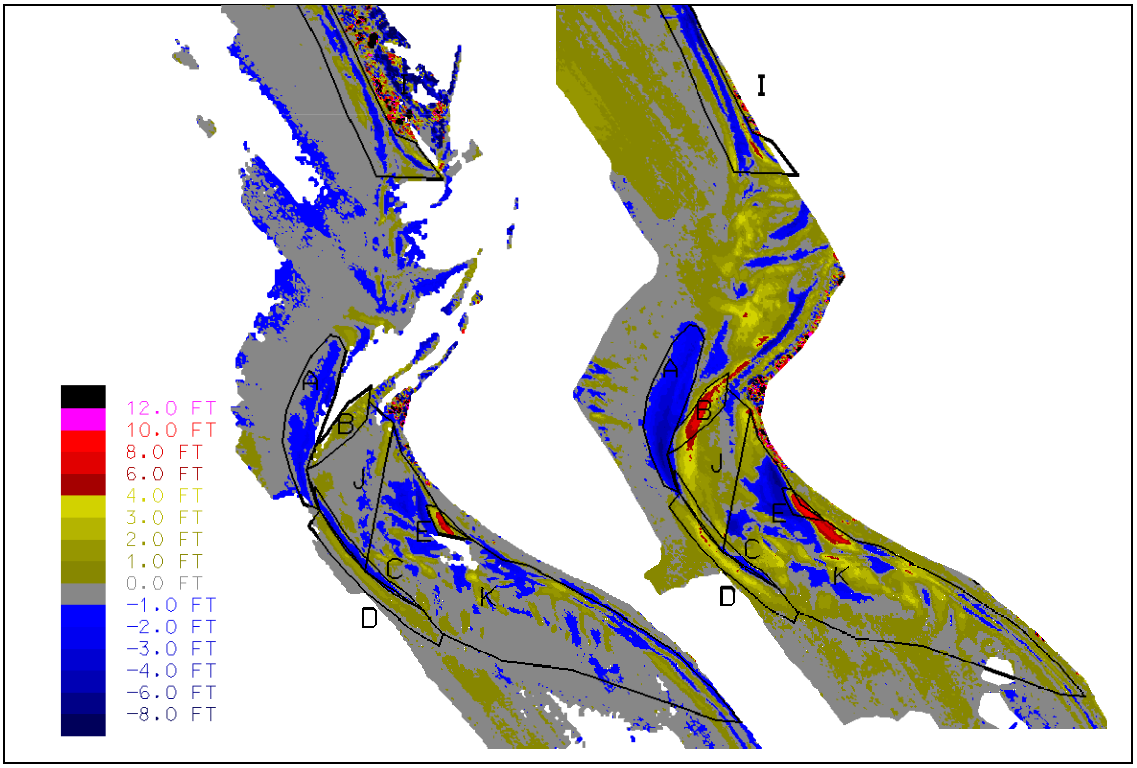

Figure 5. LIDAR Bottom Change - May to Nov 2004 vs May 2004 to May 2006

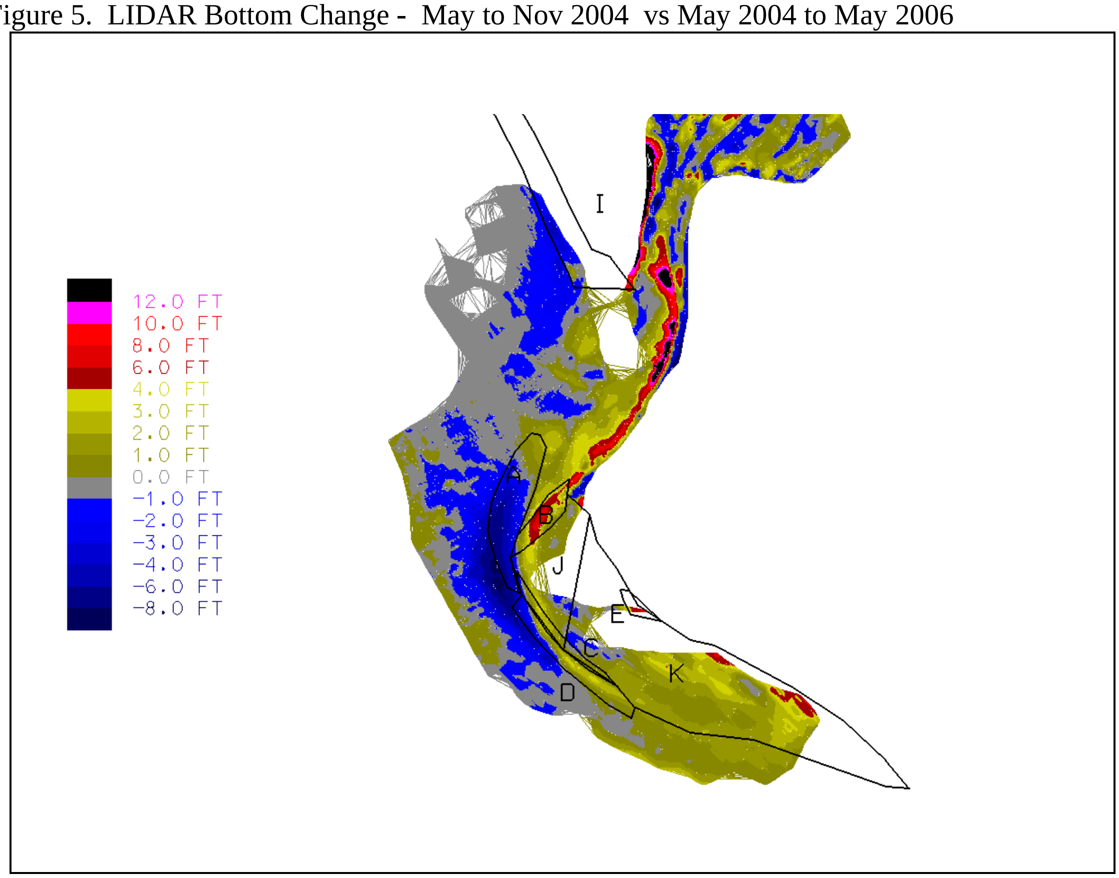

Figure 6. Boat Survey Bottom Change - 1991 to 2006

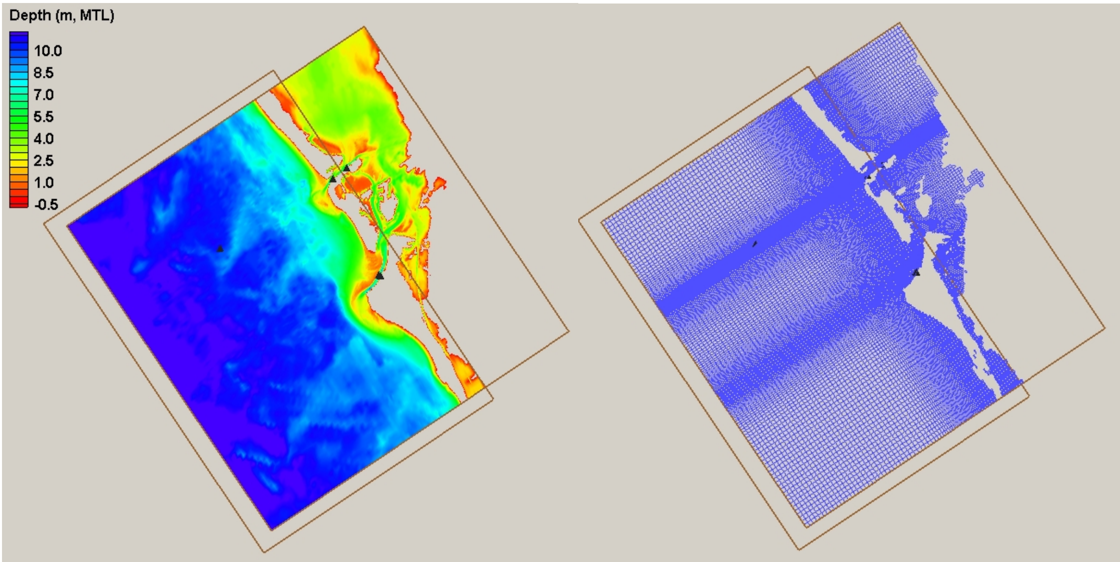

Figure 7. M2D/STwave model grid domains and M2D cell size variation.

Model Setup/Input

The M2D model grid was developed with a variable grid cell size ranging from 200 m on the offshore boundary to 30 m in the New Pass area and 40 m in the Big Sarasota Pass area (Figure 7). The STWAVE grid was developed with a constant grid cell size of 40m throughout the wave model domain. The wave model domain is similar to the M2D model domain from the offshore boundary to the shoreline and inlets but stops where the inlets encounter the back bay. This reduces the required computation time without reducing model accuracy since wave energy in the back-bay is expected to be minimal.

The bathymetry data for M2D and STWAVE was developed by merging survey data from a variety of sources, including, GEODAS Data Base of NOS surveys, USACE LIDAR surveys from 2004 and 2006, and boat surveys in 2006. The NOS survey data, most of which was collected 50 years ago, is used in the offshore area generally between depths of 8 m and 10 m, where no recent LIDAR or boat survey data is available. LIDAR data collected in May 2004 was applied in the throat and ebb shoals of the inlets and in the near-shore areas to a depth of about 8 m along the Longboat, Lido, and Siesta Key shorelines. LIDAR data collected in May 2006 was utilized in the back-bay areas, including Sarasota and Roberts Bays. All model bathymetry was adjusted to the mean tide level reference based on the NOS benchmark at Sarasota Island Park in Sarasota Bay.

CMS-M2D Calibration –May to November 2004

In order to verify the morphology model, simulations were conducted for the period May to Nov 2004. This time period was selected because the availability of LIDAR data in May and November 2004 allows for a comparison of observed bottom changes to the morphology model simulation. This is also a valuable calibration time period because three significant hurricane events, which would be expected to cause large bottom changes, impacted the area during September 2004. Since the month of September 2004 experienced three hurricane events and is expected to represent most of the morphology change between May and November 2004, this

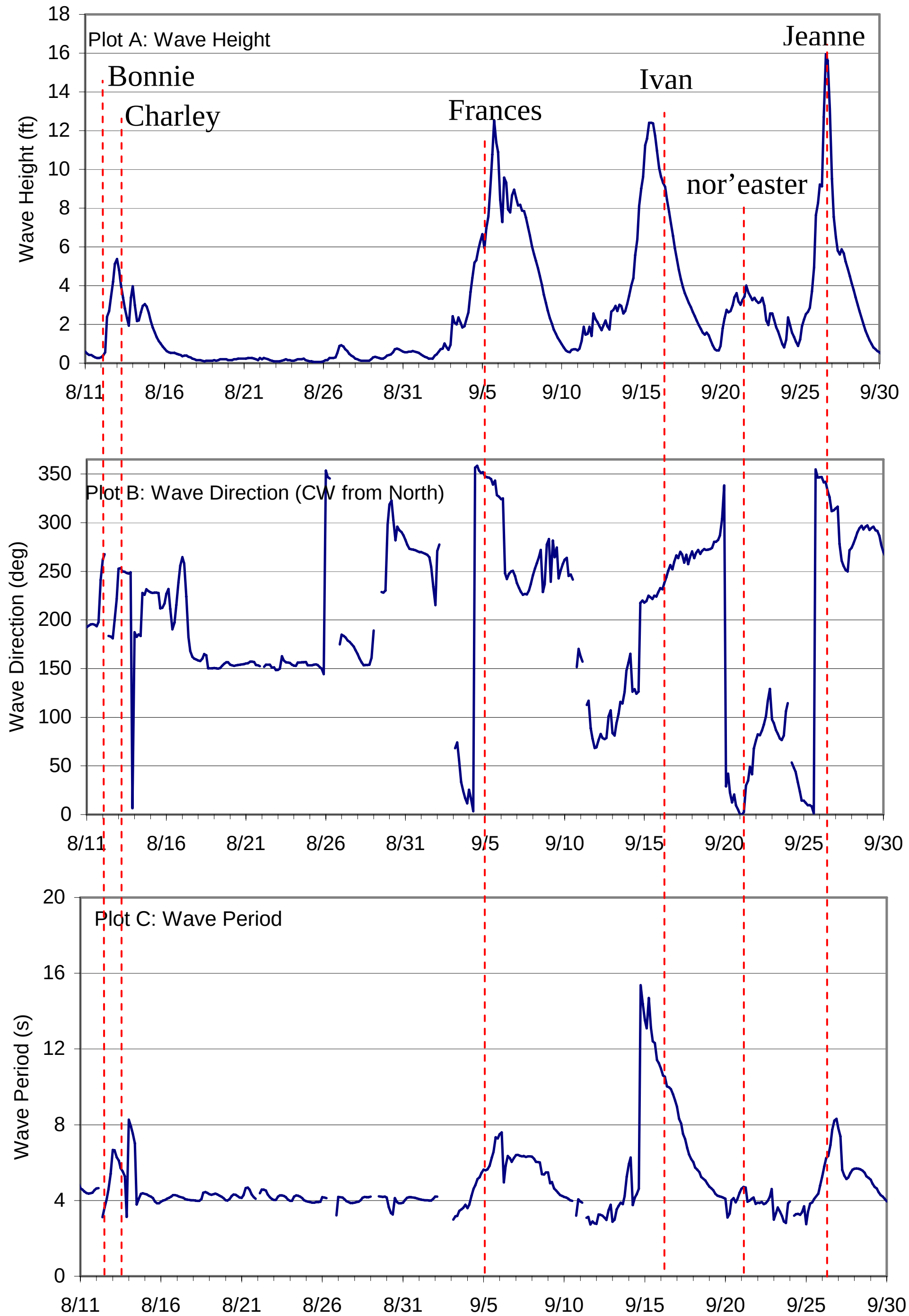

Figure 8. Wave height, direction and period, 11 August through 30 September, 18 miles offshore of the beaches of Manatee County, Florida at location 27.5° N, 083.0° W.

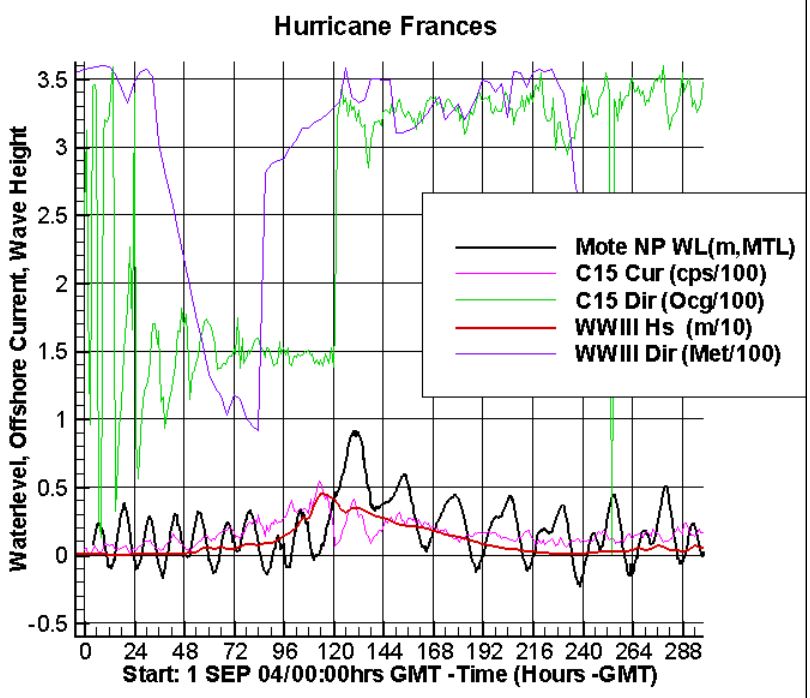

Figure 9. Frances Waves height (m) and direction, offshore current magnitude and direction, and New Pass waterlevel.

period was the initial focus of sensitivity testing. Figure 8 and 9 shows the September 2004 Hurricane timeseries and Hurricane Frances waves winds waterlevels and offshore currents.

Initially the 30 day period from September 1st to September 30th was simulated with grain sizes of 0.15 mm, 0.20 mm, and 0.25 mm and different transport rate coefficients. M2D was forced by water surface elevations, at 15 minute intervals along the offshore and back-bay boundaries and wave driven radiation stress gradients within the model domain. Water surface elevations were developed from measured waterlevels at the Mote Marine gage located in New Pass Inlet and the Port Manatee NOS gage in Tampa Bay (Figure 10). Incident wave parameters were obtained from NOAA's Wave Watch III wave hindcast. The wave parameters were applied to the offshore STWAVE boundary. Wave boundary conditions were updated at 3 hour intervals. The May 2004 LIDAR data was used for the initial bathymetry (Figure 3). Sediment transport rates were calculated every 180 sec and the morphology was updated every hour. Table 1 shows the model parameters used in these simulations.

Table 1. Simulations: May – Nov 2004

Simulation	Circ TS (sec)	Sed Tran TS (sec)	Morph TS (hrs)	Sed Tran Form	Grain Size (mm)	Trans Slope Coeff	Sus Con Profile	Bed Load Scale	Susp Load Scale
Sep04-A	90	180	1.0	AD	0.20	0.25	Lund	2.5	2.5
Sep04-B	90	180	1.0	AD	0.25	0.25	Lund	2.5	2.5
Sep–Nov 04	90	180	1.0	AD	0.20	0.25	Lund	2.5	2.5

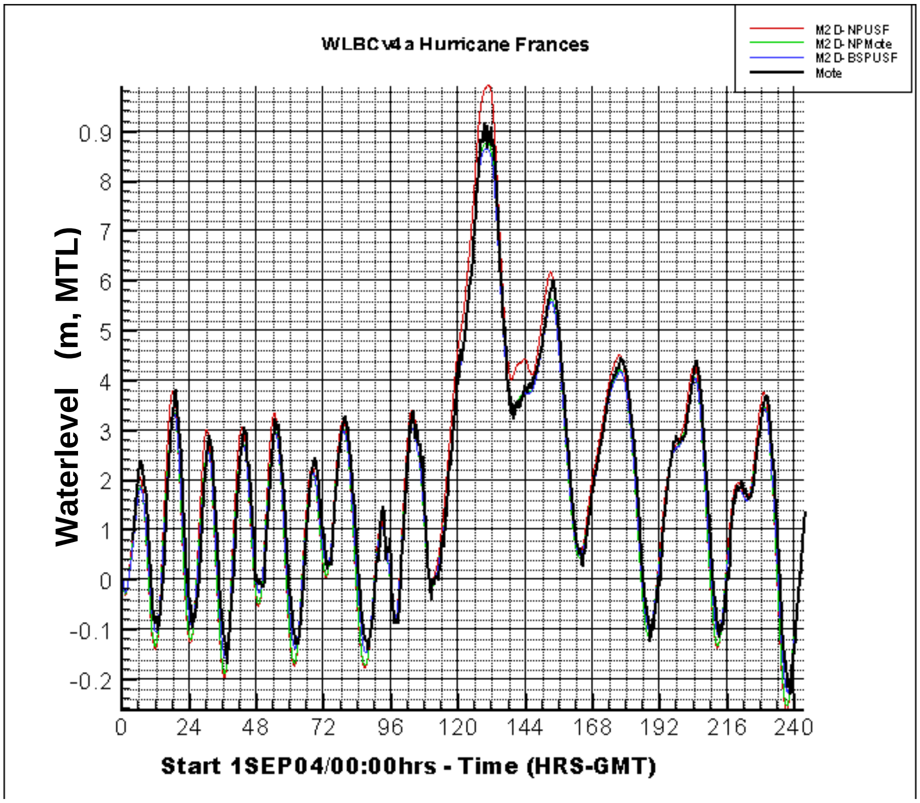

Figure 10. Waterlevel model comparison to observation.

In order to compare the model computational efficiency, the efficiency ratio is defined as the ratio of the physical time simulated to the required computational time. The M2D explicit version has a efficiency ratio of 3 to 1 with a hydrodynamic time step of 2.5 sec. The M2D implicit version has efficiency ratios of 10 to 1, 13 to 1, and 15 to 1, for hydrodynamic time steps of 40 sec, 60 sec, and 90 sec respectively. The September 2004 simulations were conducted on desktop PCs with a 3.2 GHz CPU and 3.0 GB of ram, running Microsoft Windows XP, while the May to Nov 2004 simulation was conducted on a Windows 2003 Server.

<u>September 2004 Simulation Results</u>

Table 2 shows the bottom change volume comparison between the September 2004 model results and the May-Nov 2004 LIDAR difference. The highlighted values, for the areas A through D and I through K, show the volumes for the LIDAR data and the model. Figure 11 shows the definition of the areas. Because the model does not exactly reproduce the shape and dimension of erosion and accretion features compared to the LIDAR data, model areas and LIDAR areas shown in Figure 11 are similar but not identical

Figure 12 shows the bottom change after the 30 day-September 2004 simulation. When compared to the bottom change from the difference between the May and Nov 2004 LIDAR surveys, shown in Figure 5, similar erosional and accretional features are apparent. Similar to longer term LIDAR intervals, LIDAR bottom change from May 2004 to May 2006 (Figure 5) this simulation accretes significant material along the linear bar at the edge of the main channel

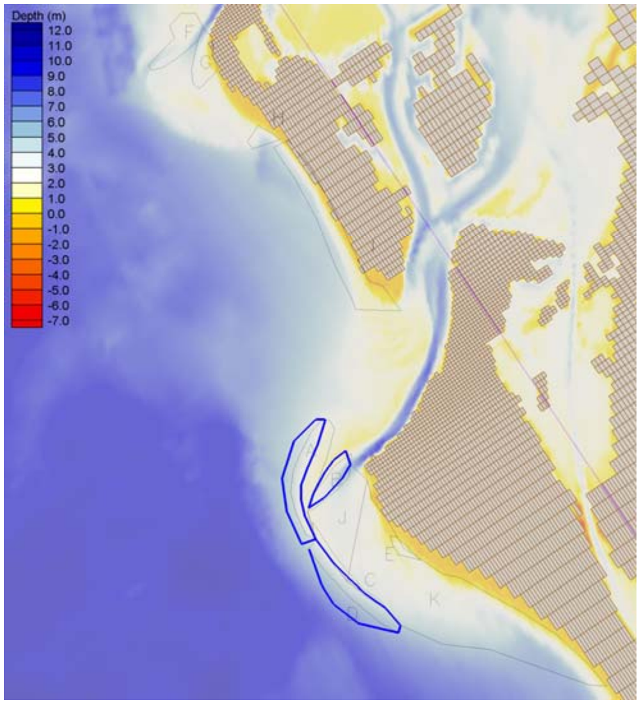

Figure 11. Bottom change comparison areas.

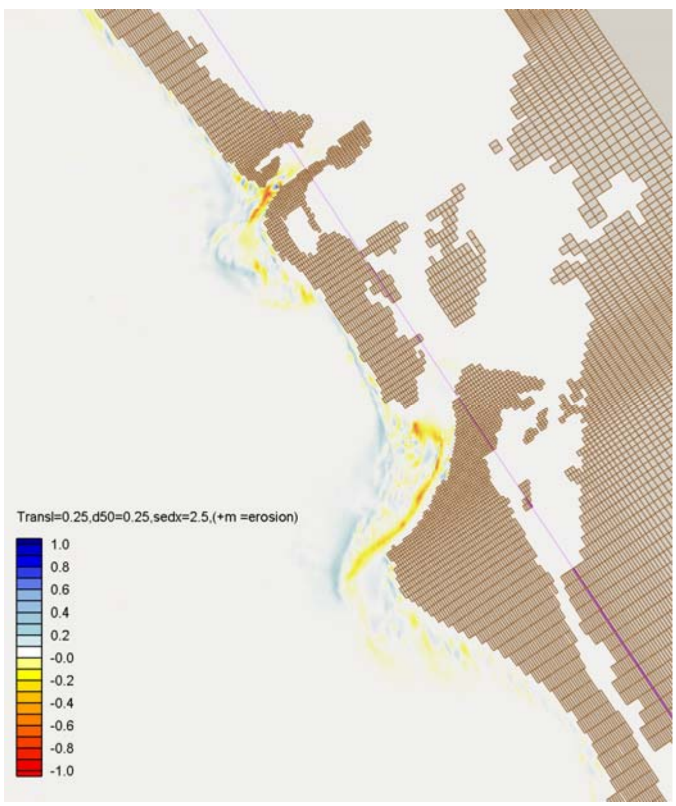

Figure 12. Bottom change from Sep 1 – 30, 2004, 30 day simulation.

adjacent to the ebb shoal (Area B). The erosion in Area A, at the distal portion of the ebb shoal, is due primarily to the wave induced transport during the three hurricanes. Most, but not all of the material, moves south to Area D. Wave induced transport also moves some of this material along the ebb shoal to Northeast. Area D in the simulation is entirely accretional, but in the LIDAR bottom change the accretional feature is much more elongated. Additionally, significant erosion occurs in Area C while the simulated bottom change does not have this feature.
The accretional linear bar feature, at Area B is due to transport across the ebb shoal and the interaction with the main channel flow. The pattern occurs along the inside of the ebb shoal adjacent to the main channel and is also evident in longer term survey intervals (2004 to 2006 LIDAR, 1991 to 2006 Boat surveys). The extent of Area B is limited in this case for model to data comparison due to gaps in the November 2004 LIDAR.

Bottom change volume comparisons are reasonable for Areas A, I, and J, where the accretion/erosion patterns agree and the percent difference in volume is between 20 % and 37%. Measured (-155,400 cy) and simulated (-124,260cy) volumes for Area A are both erosional and similar in value. The simulated volume is about 20 % less than the LIDAR volume. Simulated volumes for Areas B and D, like the LIDAR volumes are accretional, but are 3 times larger than the observed volumes. The simulated volume for Area I, along Lido Key, is 32% less than the observed value. The simulated volume in Area J, at the mouth of the main channel, is 37 % less than the LIDAR volume. The volume comparison in Area K has the largest difference, with the LIDAR indicating 450,000 cy of net erosion, while the simulated volume is an order of magnitude less with about 45,000 cy of net accretion.

Table 2. Volume Comparisons – M2D vs Observed

	Measured Volume Change		SMS Simulation Volume Change*				
	Between LIDAR Surveys		May 04-Nov 04		Sep04 6mo sim	Sep 04 30 day sim	
Areas	May 04 -Nov 04	May 04 -May 06	d50 =0.20mm	Model vs Obs (% dif)	d50 =0.20mm	d50 =0.25mm	Model vs Obs (% dif)
A	-155,400	-352,300	-163,669	5%	-163,108	-124,260	20%
B	12,900	-130,400	73,852	472%	74,033	37,540	191%
C	-54,500	-2,900	392	101%	1,308	-1,066	98%
D	19,100	100,900	90,066	372%	90,383	53,628	181%
F**	87,200	155,800	24,466	72%	48,658	51,404	41%
G**	-60,400	-79,400	7,085	112%	14,780	-8,502	86%
H**	19,600	45,400	47,134	140%	41,725	30,869	57%
I	-163,900	-186,500	-40,934	75%	-59,383	-111,049	32%
J	-107,800	119,900	-67,100	38%	-63,830	-68,016	37%
K	-450,500	45,400	56,113	112%	57,620	44,864	110%

* Regions A,B, and D are similar, but not identical between the measured and simulated volume changes
** New Pass

May to November 2004 Simulation Results

CMS-M2D model setup for the May to November 2004 simulation is identical to the setup for the 30 day-September 2004 setup except that a smaller grain size of 0.20 mm was used. Bottom change from the period May 15 to September 1 of the 6 month simulation demonstrates CMS-M2D ability to simulate a relatively calmer period (Figure 13). Bottom change for this period occurs on the ebb shoal platform and main channel with little change at the distal portion of the ebb shoal. The May 15 to September 1 portion of the 6 month simulation (Figure 14) displays some scouring in the main channel and accretion on the flood ramp. This was not observed in the 30 day-September 2004 simulation (Figure 12), which could be due to the use of a larger grain size (0.25 mm). Figure 17 shows cumulative bottom change from May15 to Oct 1 and May 15 to Nov 4 and bottom change during September and October. The cumulative bottom change plots are very similar and show that much of the bottom change occurs in September during the three hurricane events. This is also evident in the bottom change volumes (Table 2) for September 2004 – 6 month simulation and the May to November 2004 which are within 5 % of each other, except for Area I. The 6 month simulation as shows unrealistic shoaling values, along the linear bar at the edge of the ebb shoal and the attachment at Area E, for simulations of about 3 month or more due to a model error.

CONCLUSIONS

The CMS-M2D is an essential tool for developing an understanding of regional sediment transport processes. The morphology simulations conducted for this study have demonstrated the CMS-M2D's ability to simulate the morphology of Big Sarasota Pass due to a variety of conditions during the period May to November 2004, including the effects of three hurricanes in September 2004. As expected the hurricane events dominated the sediment transport during the period, with about 95% of the volume transported in September. Bottom change volume comparisons b/w the model and observed values have percent differences ranging from 30 % to 200% in the BSP area. CMS-M2D explicit model computational efficiency ratio was about 8 to 1 for a time step of 2.5 sec, while the CMS/M2D implicit model computational efficiency ratios ranged from 10 to 1 to 15 to 1 for time steps ranging from 40 sec to 90 sec.

After calibration of the CMS-M2D is complete, verification will be conducted for the period February to May 2006. The next steps in the RSM process are to simulate several different years which represent the range of conditions this area experiences and incorporate the resulting sediment transport rates and climatology into the CASCADE model to get a long term (10 to 20 years) evaluation of the inlet morphology.

ACKNOWLEGEMENTS

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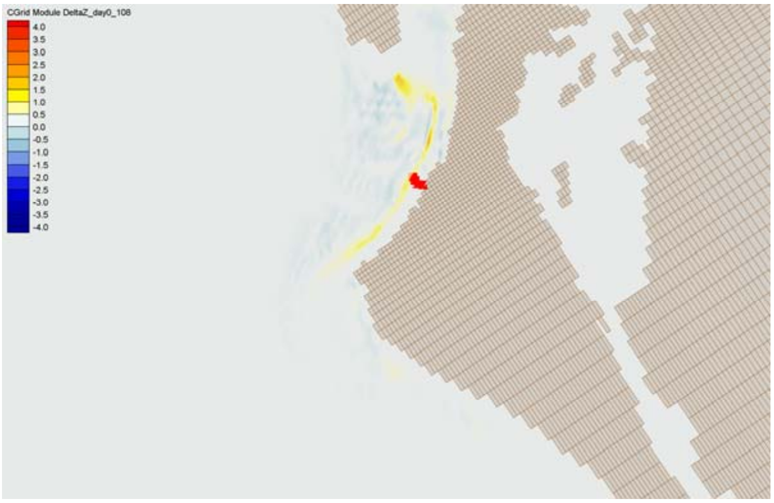
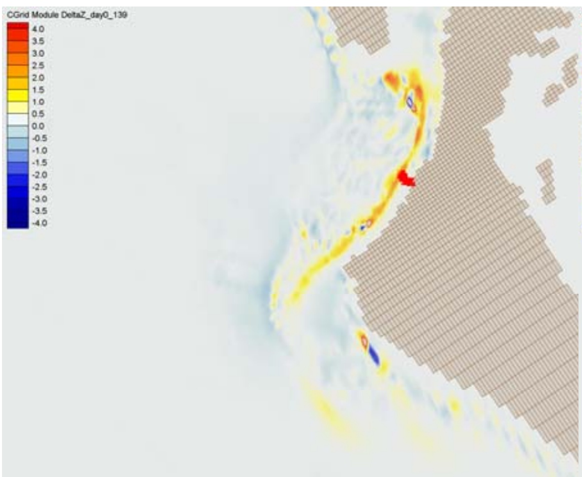
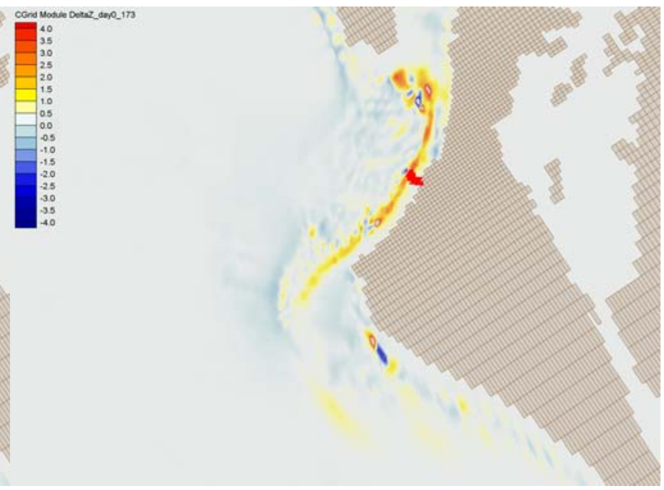


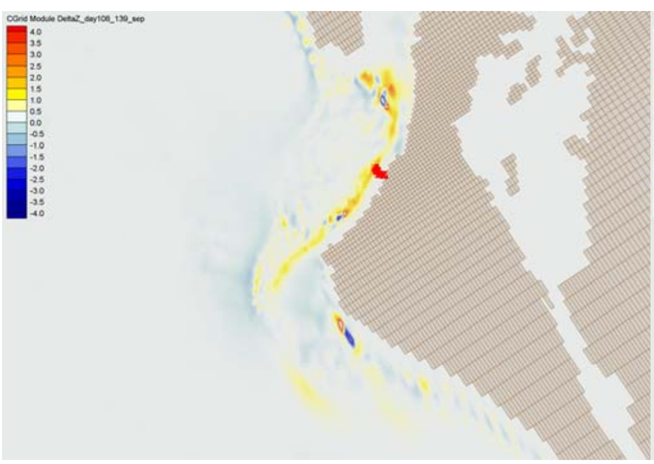
Figure 13. Bottom change from May 15 – Sep 1, 2004 of the 6 month simulation.



Cum May 15 – Oct 1, 2004



Cum   May 15 – Nov 4, 2004



Bathy change from Sep 1 – Oct 1, 2004

Bathy change from Oct 1 – Nov 4, 2004

Figure 14. Bottom change from 6 month simulation May to Nov 2004.

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