Delivery of Sediment to the Continental Slope via Plume Transport and Storm Resuspension: Numerical Modeling for the Northern Gulf of Mexico

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NASA image courtesy MODIS Rapid Response Team, Goddard Space Flight Center.

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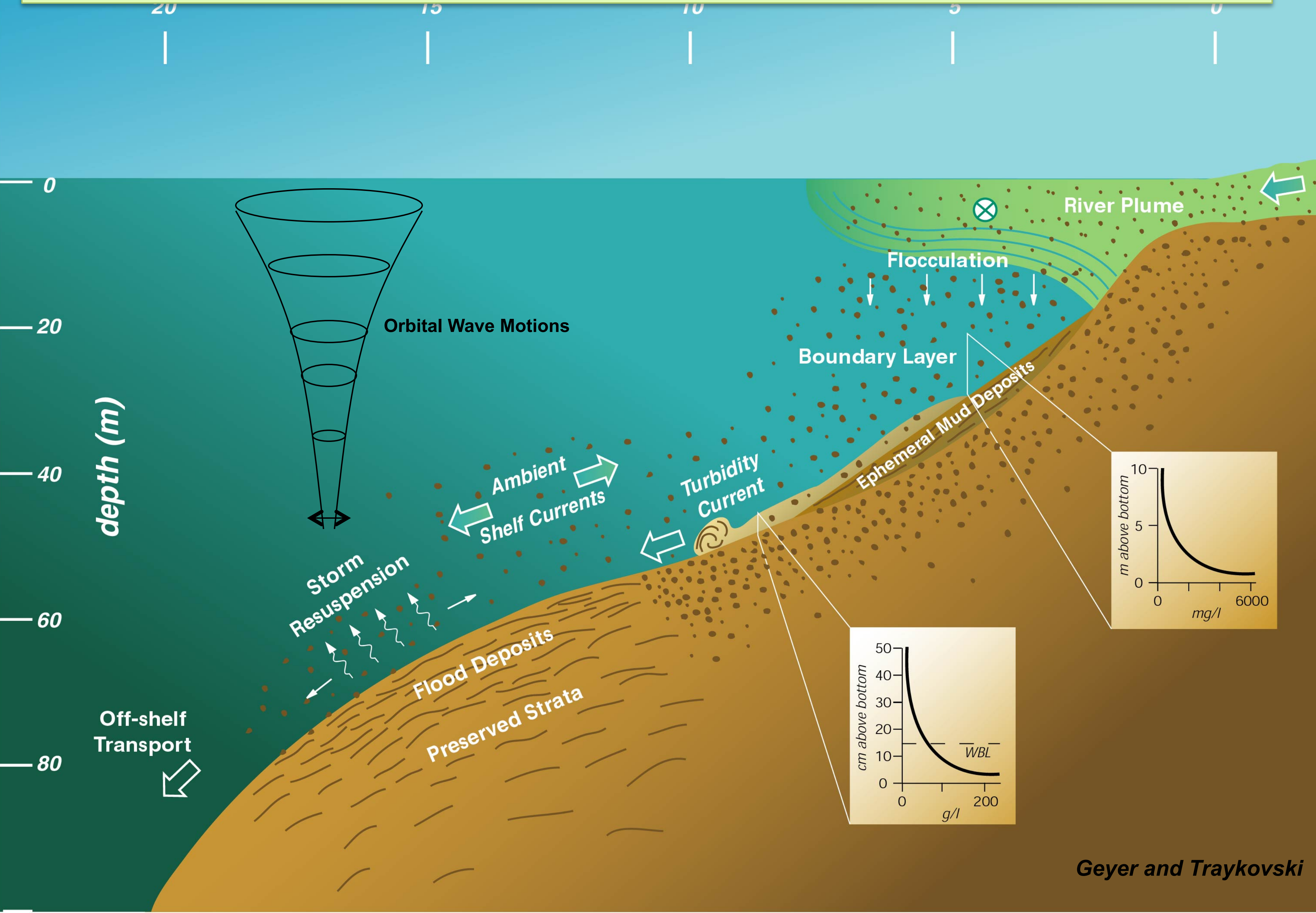
Various Mechanisms Operate along the Transport Pathway



Geyer and Traykovski

Turbidity Current and Suspended Sediment Model Operate at Different Scales

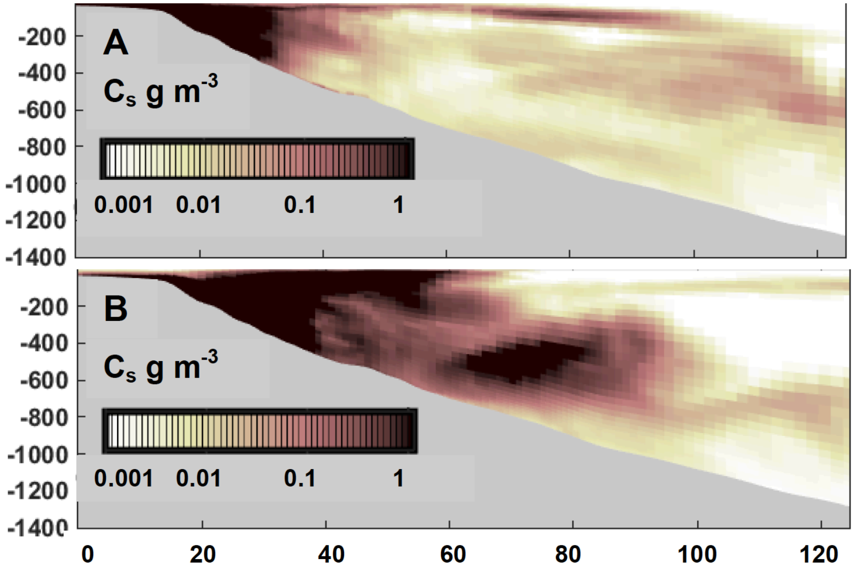
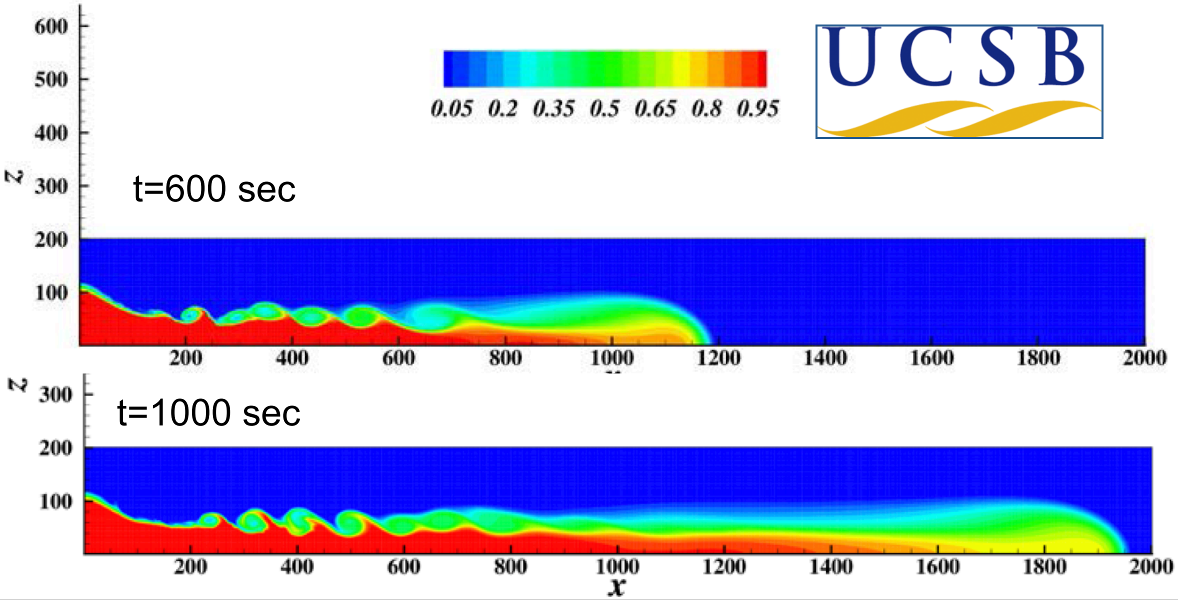


Figure 7.10: *Panels A and B show suspended sediment along the Mississippi Canyon transect (see Fig. 7.6 for location) during and after Hurricane Gustav, 1 September 2008 and 6 September 2008, respectively. The cross-slope distance is in km, while depth is in m.*



Gulf of Mexico Model / Data Workflow

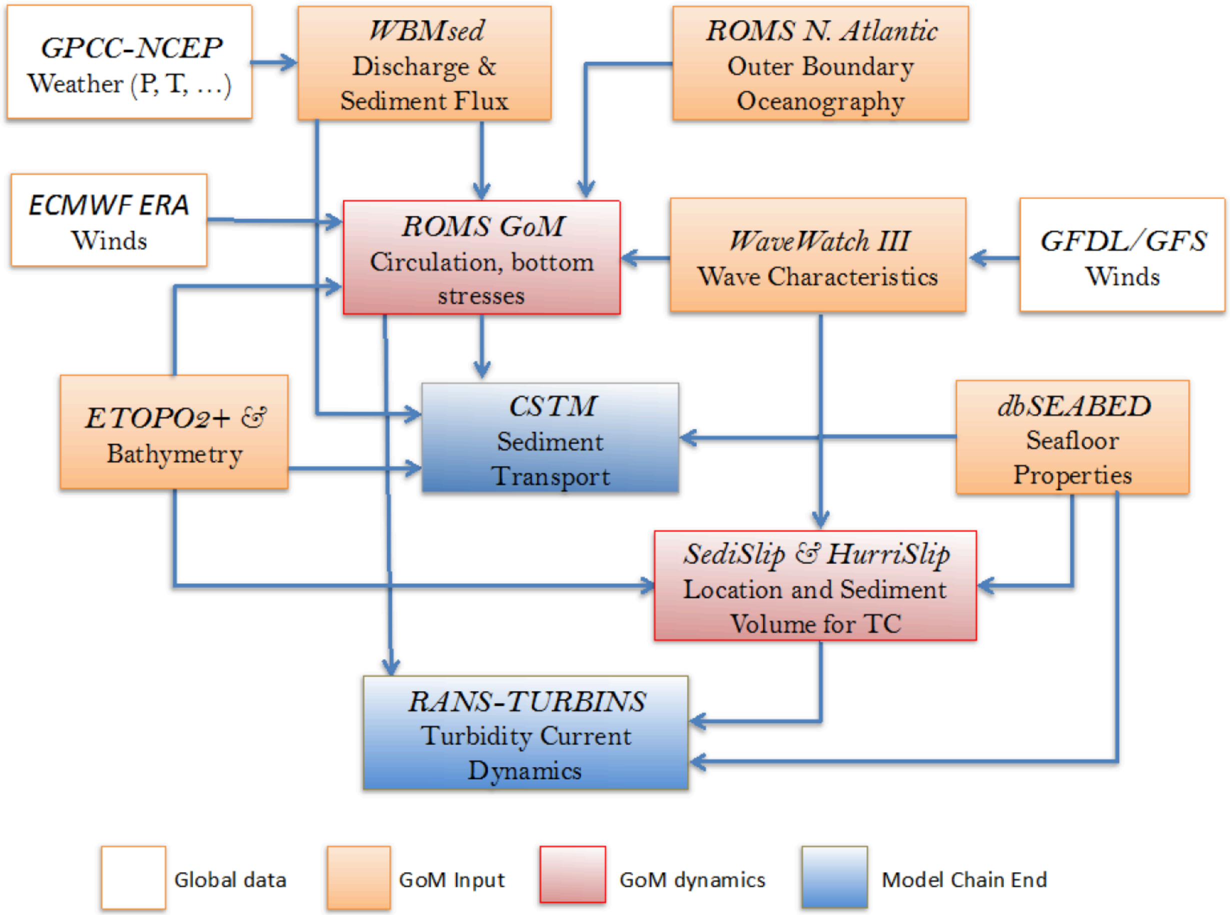
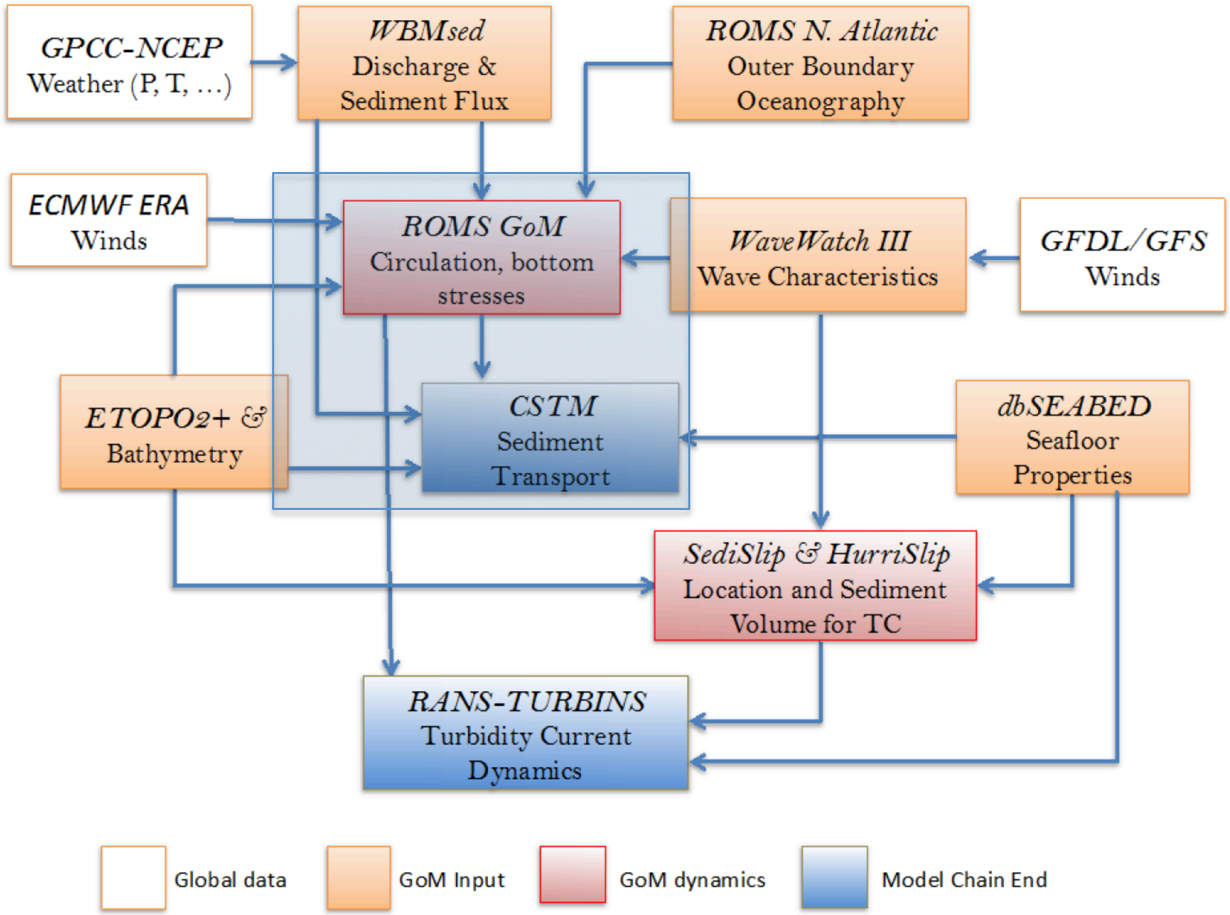


Figure 3.1: *Schematic workflow for the project in terms of model development and data generation and usage. The different component of the system is color coded for clarity.*

Gulf of Mexico Model / Data Workflow



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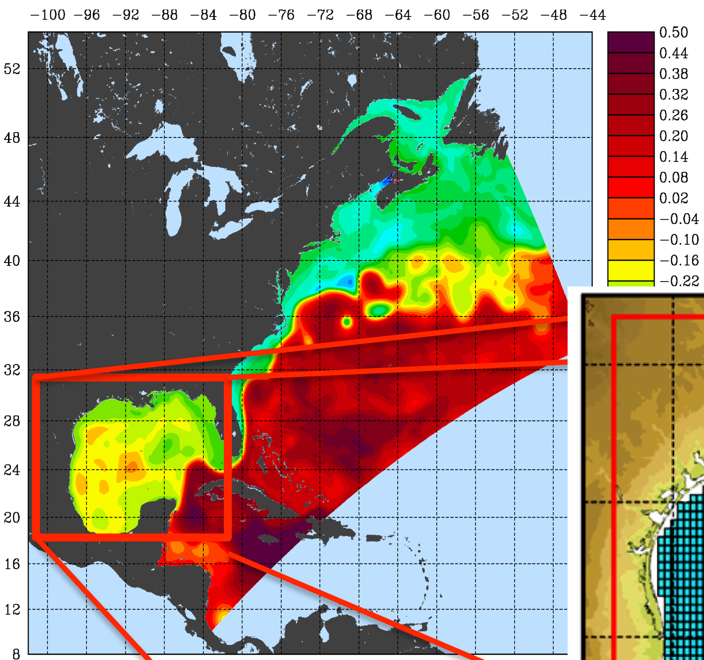
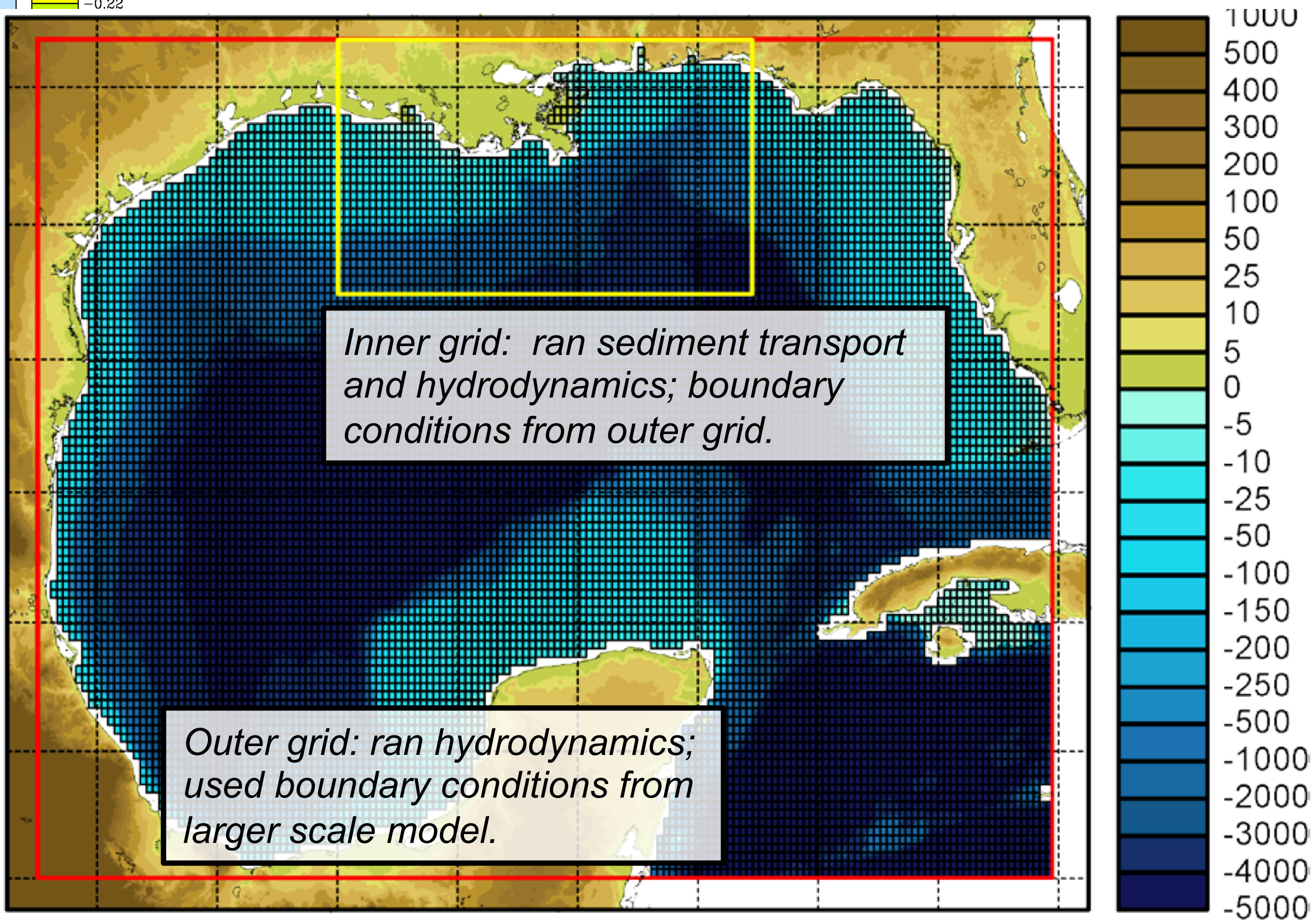
Hydrodynamic Model
Nested Approach

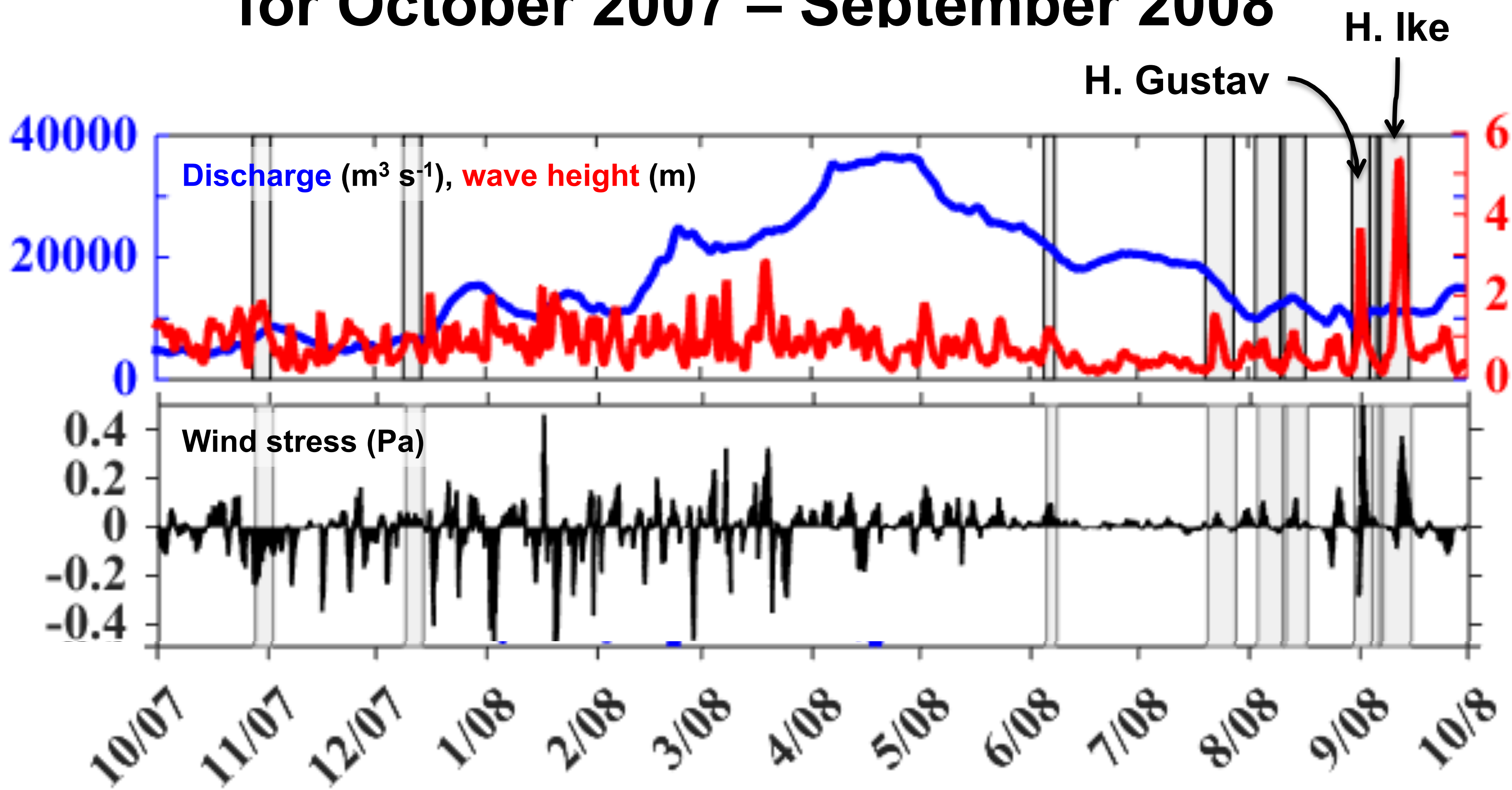


ROMS solution of NW Atlantic (Curchitser, Rutgers) provides initial conditions and open boundary conditions. Shown is the Sea surface height.



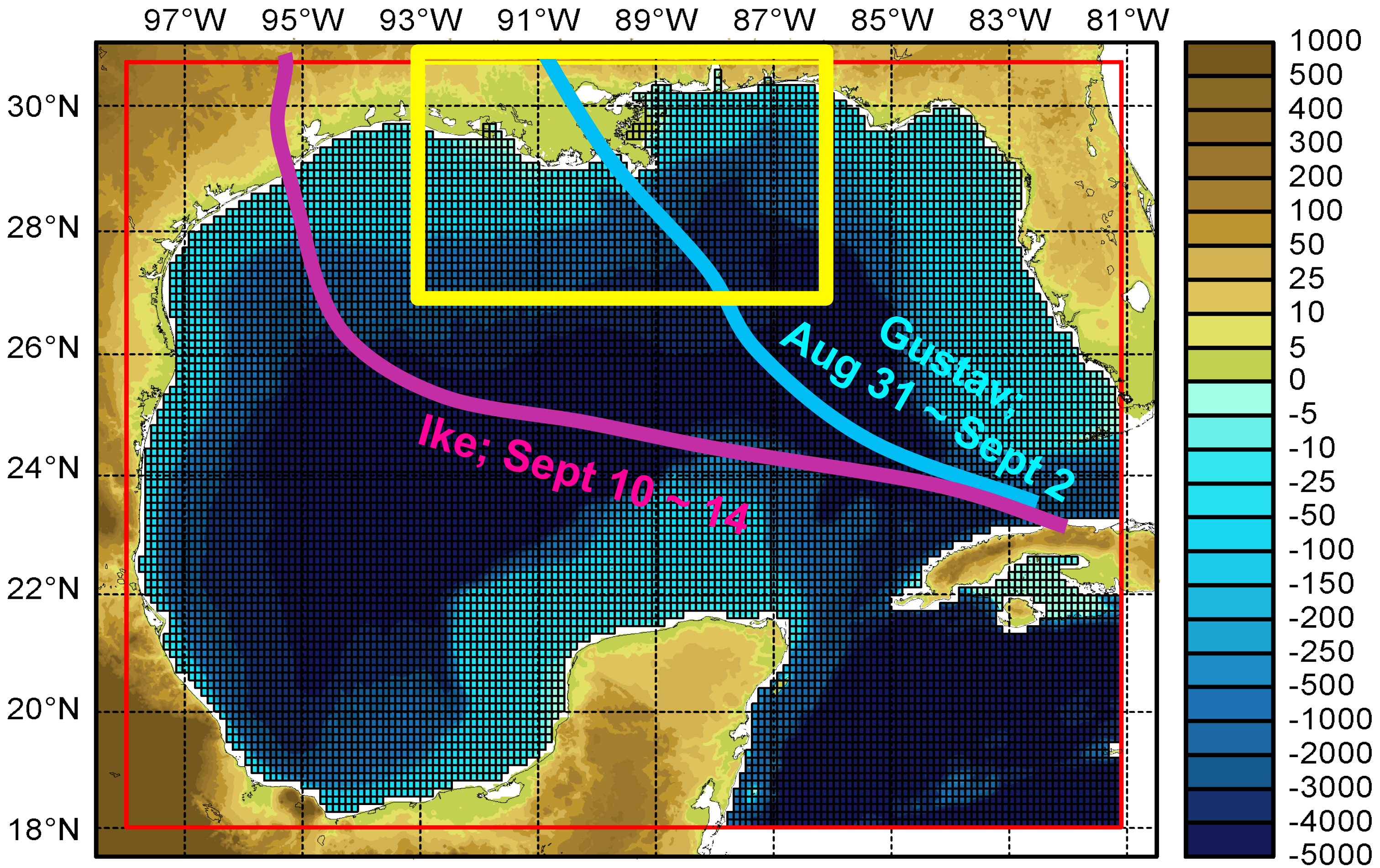
Regional Ocean Modeling System (ROMS)

Forcing Input
for October 2007 – September 2008

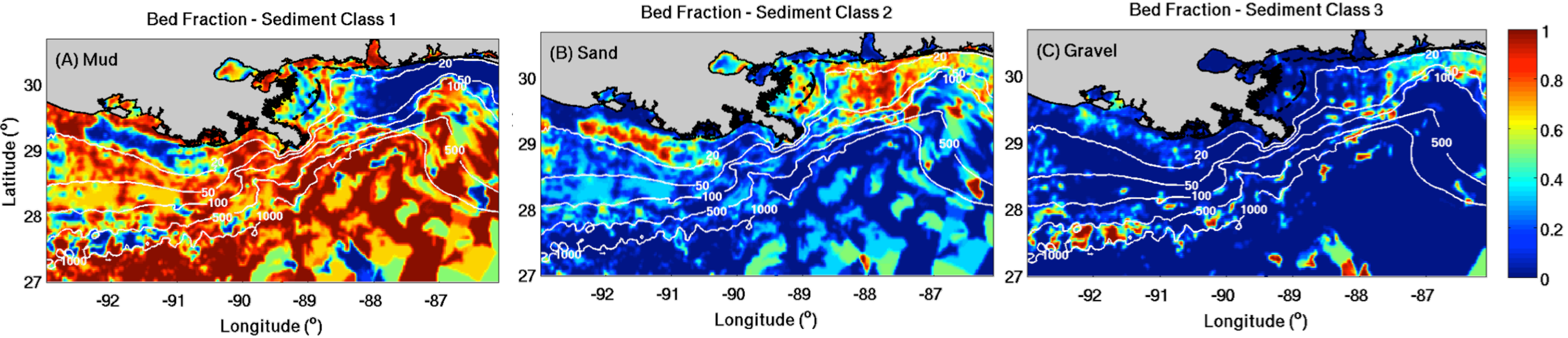


Large Storms in the Record include: H. Noel (10/28-11/2/2007); T.S. Olga (12/9 - 12/14/2007); remnants of H. Arthur (6/5 – 6/7/2008); H. Dolly and T.S. Christobal (7/20 -7/27/2008); T.S. Edouard (8/3 – 8/9/2008); T.D. Fay (8/18-8/26/2008); H. Gustav (8/25-9/4/2008); and H. Ike (9/1- 9/14/2008).

What Drives Suspended Sediment Flux Offshore?

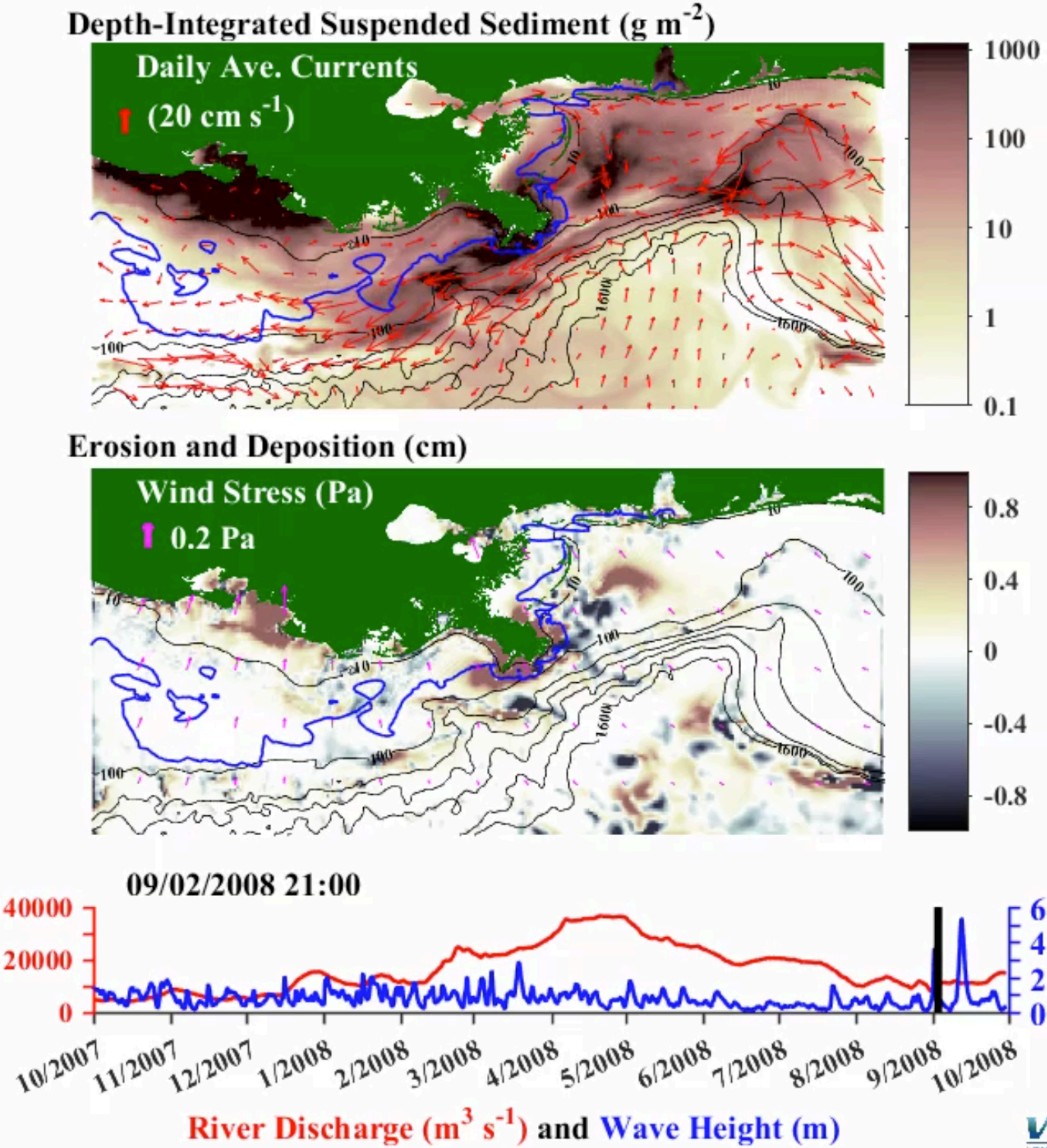


Sediment Transport Model



- Suspended sediment transport model: *following Warner et al. (2008).*
- Differentiated riverine and seabed sediment.
- Spatial seabed distribution based on dbSeabed.
- Riverine input based on USGS gage data.

Class	Source	Sediment Type	D (mm)	t_{cr} (Pa)	w_s (mm/s)
1	Seabed	Mud	0.063	0.11	1.0
2	Seabed	Sand	0.125	0.13	10.0
3	Seabed	Gravel	10.0	10.0	70.0
4	Miss. River	Micro-floc	0.015	0.11	0.1
5	Miss. River	Macro-floc	0.063	0.11	1.0
6	Atch./Mobile Rivers	Micro-floc	0.015	0.03	0.1
7	Atch./Mobile Rivers	Macro-floc	0.063	0.03	1.0



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Time period 1/14/2008 - 3/22/2008

A period of extratropical storms
every 3-7 days
with moderate Mississippi River discharge.

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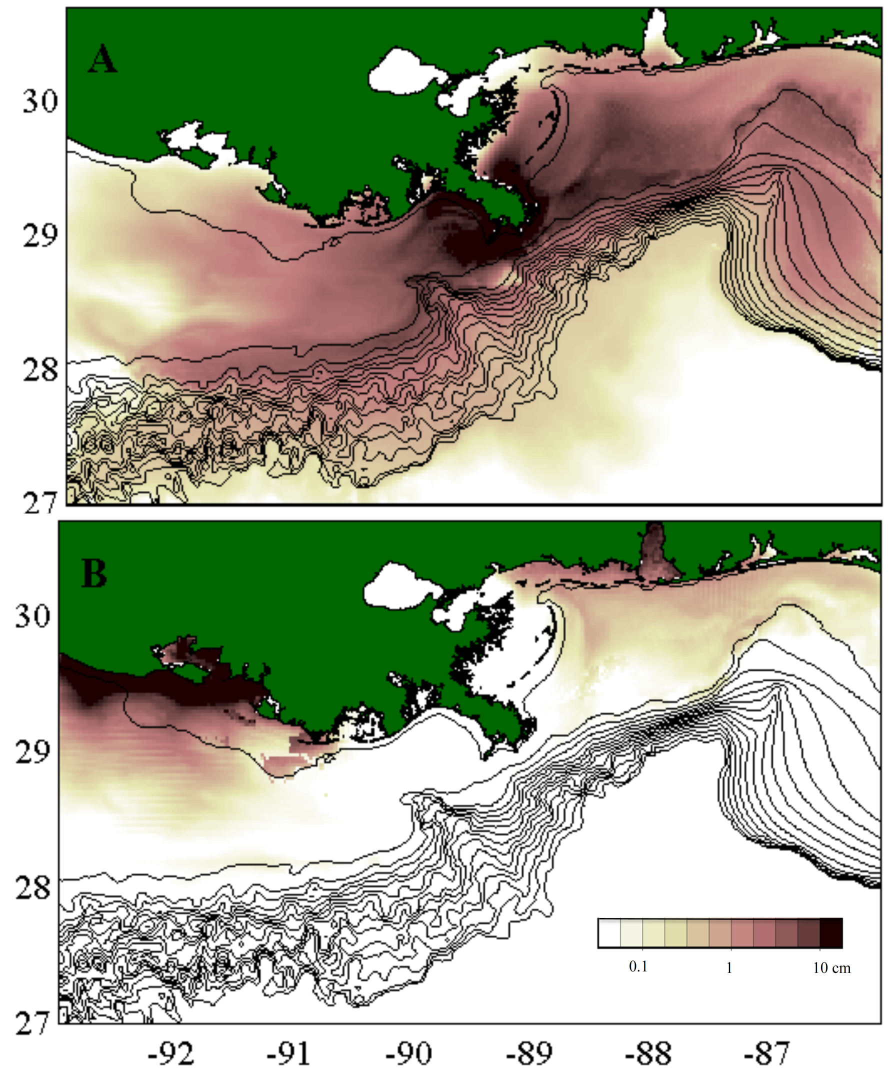
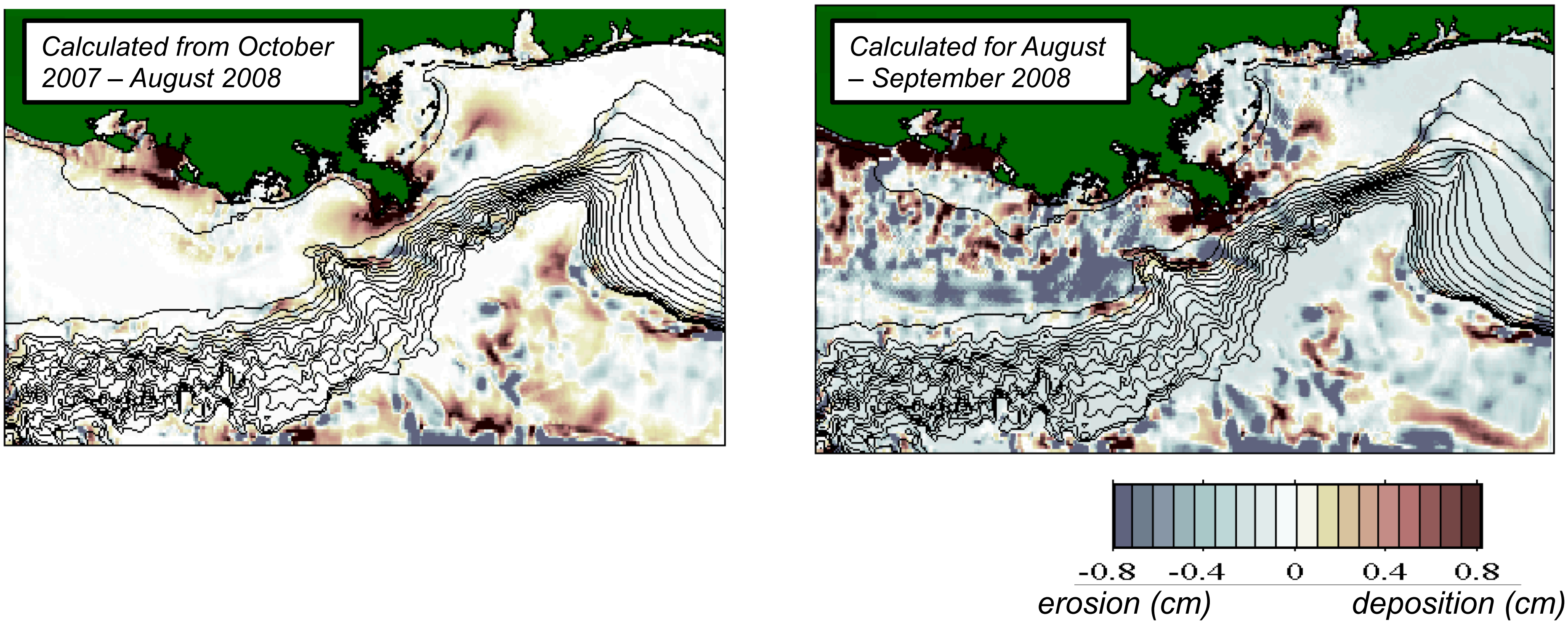
Mississippi Dominates Plume Delivery to the Slope

- ❑ Time-integrated sediment deposition from fluvial sources for year modeled.
- ❑ Atchafalaya and Mobile Rivers deliver little sediment to the Continental Slope.
- ❑ *Consistent with previous model results from Xu et al. (2011).*

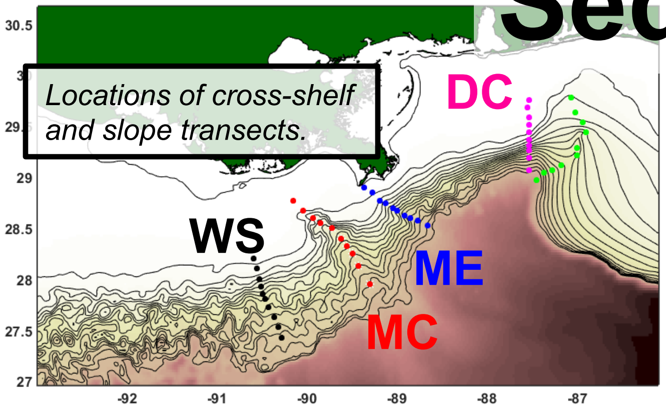


Net Erosion and Deposition

- Most of year dominated by fluvial deposition.
- Hurricanes Gustav and Ike create extensive seabed redistribution in a short time.



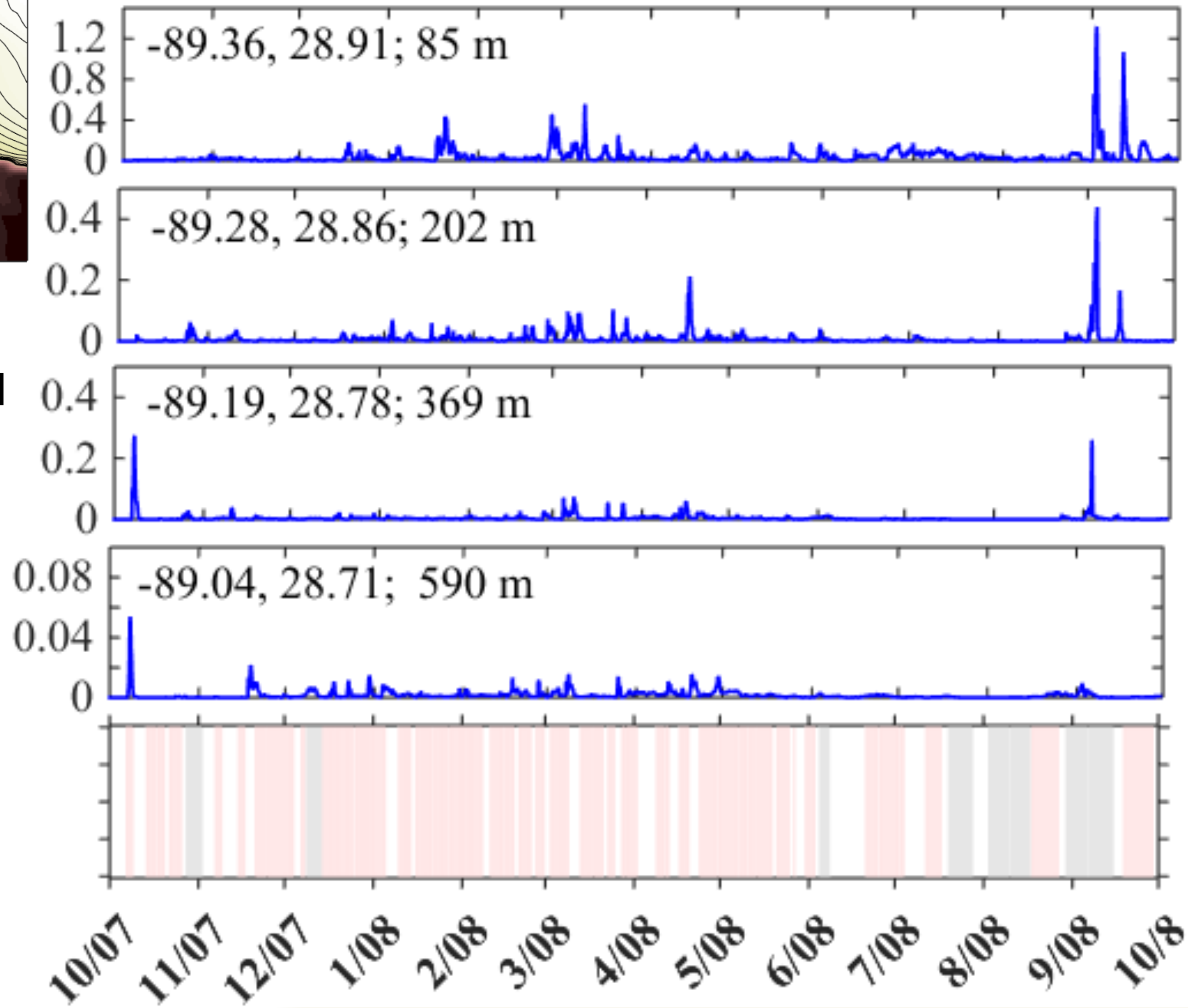
Sediment Flux on the Slope



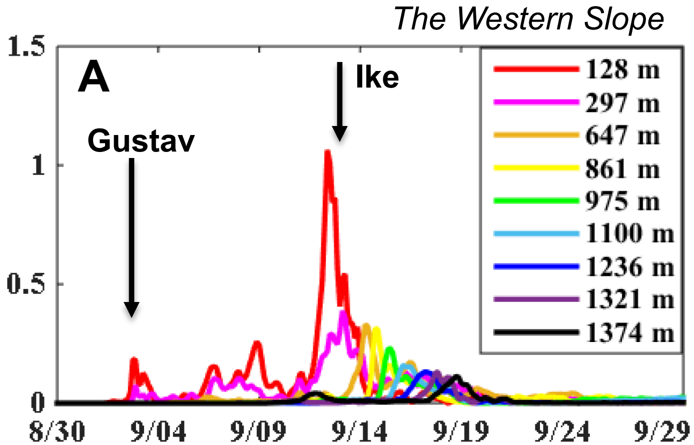
- ❑ Shallower: Flux dominated by large storms.
- ❑ Deeper: Flux dominated by slope currents.

Depth-integrated flux (kg m^{-1} s^{-1}) east of Mississippi Canyon (ME, blue).

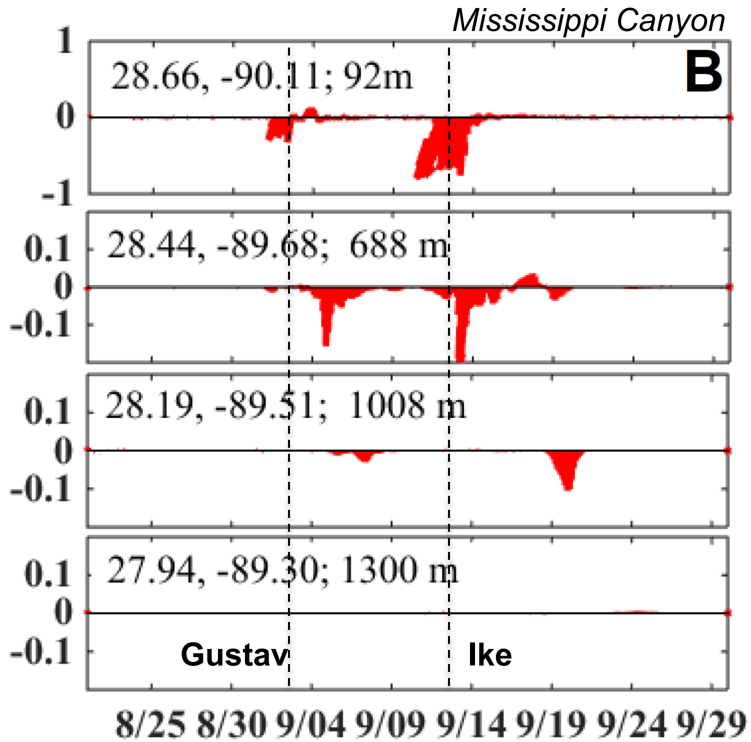
Bottom: 11 tropical storms (gray) and 55 extratropical (pink).

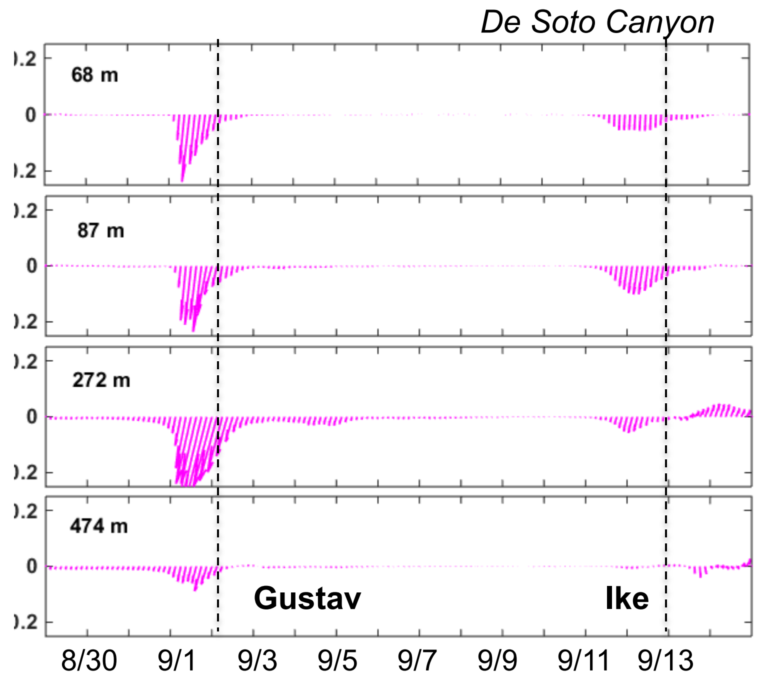


Sediment Fluxes Seaward During Hurricanes

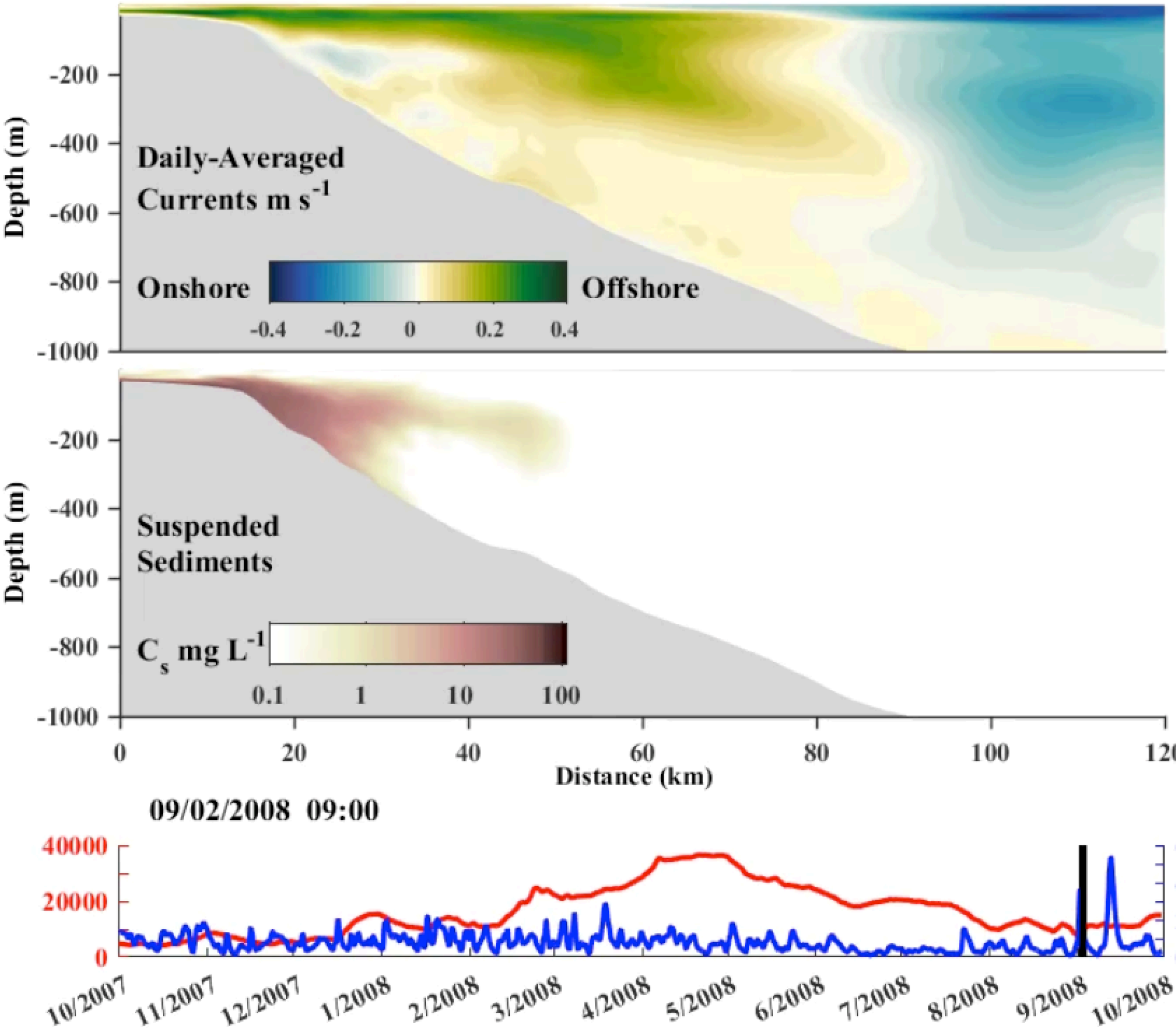


- Time-series of depth-integrated flux (kg m-2 s-1).
- Fluxes mainly seaward.
- Fluxes at depth can lag behind shelf response.





Vector angles correspond to flux direction in accordance with map conventions.


Depth (m)
-200
-400
-600
-800
-1000
Daily-Averaged
Currents m s-1
Onshore
Offshore
-0.4
-0.2
0
0.2
0.4
Suspended
Sediments
Cs mg L-1
0.1
1
10
100
0
20
40
60
80
100
120
Distance (km)
09/02/2008 09:00
40000
20000
0
6
4
2
0
10/2007
11/2007
12/2007
1/2008
2/2008
3/2008
4/2008
5/2008
6/2008
7/2008
8/2008
9/2008
10/2008

Time period 1/14/2008 - 3/22/2008

A period of extratropical storms
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Conclusions: Sediment Fluxes

- Frontal Systems and Plume Delivery
  - Accounted for about 70% of sediment delivered to the continental slope.
  - Disperse but centered around Mississippi Birdfoot Delta.

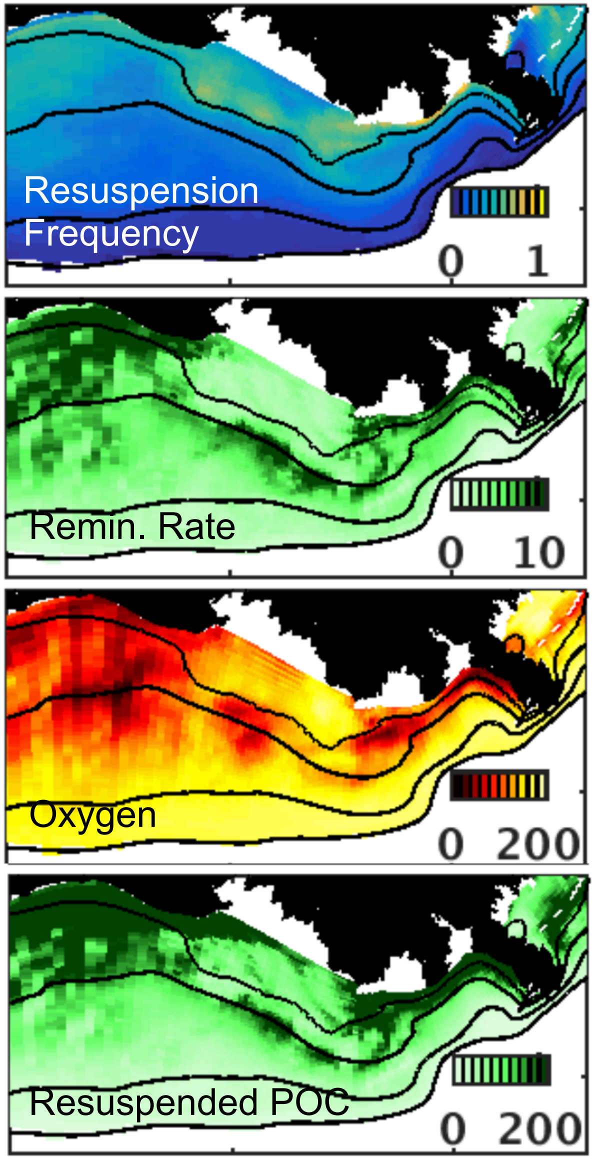
- Hurricane Delivery
  - Hurricane conditions only lasted briefly, but accounted for about 30% of the sediment delivered from the continental shelf to the slope.
  - During hurricanes, suspended sediment fluxes were predominantly offshore in Mississippi and De Soto Canyons.
  - Sediment fluxes were highest in shallower portions.
  - Peak suspended fluxes coexisted with the highest wave – induced bed stresses on the continental shelf, but was delayed relative to this timing with distance down the canyon or continental slope.

Future Directions

- **Joint modeling and field experiments** are needed to develop reliable sediment transport models for the Gulf of Mexico continental shelf and slope.

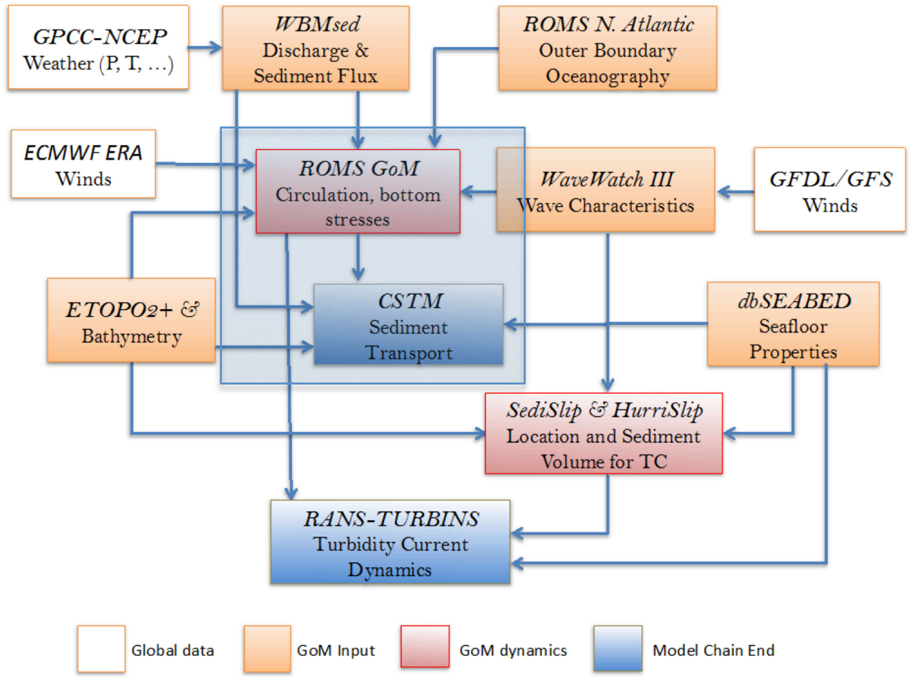
- Coupled hydrodynamics and sediment transport hold promise for a range of **interdisciplinary research questions**.

  Example: Linking sediment processes with biogeochemistry.
  Moriarty, Harris, et al. (in prep). Role of seabed resuspension on nitrogen and oxygen dynamics for the northern Gulf of Mexico: A numerical modeling study.



Using Sediment Transport Model within Workflow

- ❑ **ROMS model estimates of**
  - ❑ Bed stress provided to slope failure model.
  - ❑ Near-bed sediment concentration and turbulence provided to turbidity current model.
- ❑ The model workflow is perhaps one of the more complex attempted.
  - ➢ Research group would like to continue to exercise it.
  - ➢ Workflow at present is one-way.



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For more information:

Details can be found in the final report for this project:

Arango, H.G., D.J. Robertson, C.K. Harris, J.J. Birchler, T.A. Kniskern, J.P.M. Syvitski, C.J. Jenkins, E. Hutton, E. H. Meiburg, and S. Radhakrishnan. 2016. Shelf-Slope Sediment Exchange in the Northern Gulf of Mexico: Application of Numerical Models for Extreme Events. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Headquarters, Sterling, VA. OCS Study BOEM 2016-038. 116 p.

Acknowledgments:

Several people contributed to this work, who are not listed on the title page of this talk; but we appreciate their input. From VIMS, this has included Research Scientist David Forrest; Former M.S. student Justin Birchler (now at the USGS), and former Intern Jessica Sydnor (now at the College of William & Mary).