Lower Mississippi River Modeling and Data Workshop Summary
Monday April 4th and Tuesday April 5th 2016

I. INTRODUCTION

On April 4-5, 2016 the Gulf of Coast Ecosystem Restoration Council (Council) and the NOAA RESTORE Act Science Program (NOAA Science Program) hosted a Lower Mississippi River Modeling Workshop in New Orleans, LA.

The workshop was organized by the Council and the NOAA Science Program as both agencies have approved funding for (or, are going to be funding) projects investigating the lower Mississippi River and/or northern Gulf of Mexico. The Council project, "Lowermost Mississippi River Management" focuses on understanding Mississippi River physical processes to improve navigation, reduce flood risk, and maximize river-based restoration benefits. The NOAA Science Program project, "The central role of the Mississippi River and its delta in the oceanography and ecology of the Gulf of Mexico large marine ecosystem," focuses on the influence of the Mississippi River and its delta on the Gulf of Mexico. Both of the projects include either modeling and data analyses or model development for the lower Mississippi River and/or the larger Gulf of Mexico. Conversations among some of the principal investigators for these projects, other academics/researchers, and the funding programs identified a need to better understand interactions among models used for management of the Mississippi River delta and the larger Gulf of Mexico, and the data to support those models. This workshop was developed to foster dialogue among modelers and data collection practitioners working at the boundaries of the Gulf of Mexico and the lower Mississippi River. Our objectives were to:

- Identify gaps in our understanding of boundary conditions between Mississippi River models and Gulf of Mexico ocean circulation models.
- Discuss opportunities to link river and ocean models.
- Discuss model uncertainties and ways to better communicate results and uncertainties to decision makers.
- Identify ways to improve data assimilation and result dissemination.
- Evaluate the data collection efforts needed to develop coupled river/ocean models.
- Discuss additional opportunities for the modeling community to work together/help one another, for example to review one another's work.
- Provide recommendations to the larger modeling/data community and management on potential future activities/needs.

Sixteen attendees and presenters, listed in Section V of this report, participated over the two-day session and represented scientists from federal resource management agencies, academic institutions, nongovernmental organizations, and the private sector. The agenda for the workshop (Section VI), included 8 technical presentations and 6 hours of facilitated discussions. The following report summarizes those presentations and discussions.

II. BACKGROUND

Numerical models can be used to describe coastal systems by providing information on the physical and environmental conditions of water and can be used to provide predictions of oceanographic variables in coastal, estuarine, and riverine systems. In southern Louisiana and the northern Gulf of Mexico models have been used to predict flooding from coastal storms[1], land building potential from proposed restoration projects[2], impacts to biological resources[3], the location and characteristics of the Gulf Loop Current[4], and they can be coupled with fisheries models to predict impacts of large scale processes or management on fisheries[5].

In order to predict the different processes occurring in the Mississippi River, the Mississippi River delta, and the northern Gulf of Mexico region, a suite of riverine and oceanographic numerical models have been developed to describe the region. Numerical models used in the region include global and coastal ocean models, coastal storm surge models and riverine models. Due to the utility of these models, they have become widely used by state and federal agencies to understand implications of management and restoration. The State of Louisiana, the Army Corps of Engineers, the Navy, and others have been investing in models of the Mississippi River and/or the Gulf of Mexico for many years to manage the river, move ships, and assess restoration activities. Following the 2010 Deepwater Horizon oil spill, as funding for science and restoration becomes available, funding agencies are looking to expand our scientific understanding of natural processes occurring in the region and improve existing tools used to predict the impacts of future management decisions.

This workshop invited numerical modelers and data collectors working on the Mississippi River and the northern Gulf of Mexico to present their models, model results, and data as well as to engage in facilitated discussions to help identify research needs and data collection priorities for the region.

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[1] http://www.erdc.usace.army.mil/Media/Fact-Sheets/Fact-Sheet-Article-View/Article/476697/coastal-storm-modeling-system/

[2] http://thewaterinstitute.org/files/pdfs/Expert_Panel_on_Diversion%20_Planning_and_Implementation-Report6_Final_011316.pdf

[3] http://www.mvd.usace.army.mil/Missions/Mississippi-River-Science-Technology/Mississippi-River-Hydro/

[4] Le Henaff, M., Kourafalou, V., Srinivasan, A. 2009. Enhancing predictability of the Loop Current variability using Gulf of Mexico HYCOM. Layered Ocean Model Workshop, June 3, 2009, Miami, FL. https://hycom.org/attachments/086_lehenaff_lom09.pdf

[5] de Mutsert, K., Steenbeek, J., Lewis, K., Buszowski, J. , Cowan Jr., J.H, Christensen, V. 2016. Exploring effects of hypoxia on fish and fisheries in the northern Gulf of Mexico using a dynamic spatially explicit ecosystem model. *Ecological Modelling*, 331: 142-150. http://dx.doi.org/10.1016/j.ecolmodel.2015.10.013

III. WORKSHOP PROCEDURES

Day 1 – April 4th 2016

The first day of the workshop was dedicated to presentations introducing the different numerical models used in the region and subsequent facilitated discussions regarding critical information addressed by each model, a comparison of the models, and identification of obstacles and potential benefits of model coupling. A final facilitated group discussion revolved around the limitations and uncertainties of hydrodynamic models.

INTRODUCTION TO LOWER MISSISSIPPI RIVER HYDRODYNAMIC MODELS

PRESENTATIONS

Scientists presented on riverine models used for management of the Mississippi River. Presentations addressed the purpose of different models, discussed specific model requirements, and addressed some of the main questions that each model is able to address. Additionally, scientists provided information on some of the model gaps and limitations, and the type of data needed to improve model predictions.

Delft3D and Flow3D (Dr. Ehab Meselhe, The Water Institute of the Gulf)
Dr. Ehab Meselhe presented the Delft3D and Flow3D models, a set of riverside morphodynamic and basin side biophysical models that can be used to understand the existing and future conditions (without project implementation) of the Mississippi River channel, and assess the impacts of restoration alternatives (e.g. dredging and diversions). Delft3D is a three-dimensional modeling system consisting of a number of integrated modules to simulate fluid flow, sediment transport, wave generation and propagation, and morphological changes[6]. These models can be run at a variety of temporal (week, years, and decades) and spatial (~1m to 1000m) scales, providing an efficient decision-support tool for restoration activities in the lower Mississippi River.

Application of FVCOM (Dr. Ioannis Georgiou, University Of New Orleans)
Dr. Ioannis Georgiou presented the Finite Volume Coastal Ocean Model (FVCOM), an unstructured-grid, finite-volume, 3D hydrodynamic model with coupled velocity/density fields. Details of FVCOM can be found in Chen and Liu (2003)[7]. FVCOM can be used for hydrodynamic and salinity modeling, and to assess flow conditions in the river following proposed diversion projects.

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[6] Lesser, G.R., Roelvink, J.A., Van Kester, J.A.T.M., Stelling, G.S. 2004. Development and validation of a three-dimensional morphological model. *Coastal Engineering,* 51: 883-915. http://dx.doi.org/10.1016/j.coastaleng.2004.07.014

[7] Chen, C., Liu, H., Beardsley, R. 2003. An unstructured grid, finite-volume, three-dimensional, primitive equations ocean model: application to coastal ocean and estuaries. *Journal of Atmospheric and Oceanic Technology*, 20: 159-186. *http://dx.doi.org/10.1175/1520-0426(2003)020<0159:AUGFVT>2.0.CO;2*

AdH/SEDLIB (Gary Brown, U.S. Army Corps of Engineers)
Mr. Gary Brown presented the Adaptive Hydraulics/Sediment Transport Library (AdH/SEDLIB) model application developed to understand hydrodynamic interactions in the Mississippi River. AdH is a finite element numerical model applied in 2-D depth averaged mode. AdH/SEDLIB employs Quasi-3D flow and transport formulations[8], allowing for modeling of river and estuarine hydrodynamics, sediment transport and morphological change, as well as relative sea-level rise, primary productivity and salinity modeling in the lower Mississippi River[9].

DISCUSSION OF LOWER MISSISSIPPI RIVER HYDRODYNAMIC MODELS

Model comparisons: Limitations and Challenges of Mississippi River Numerical Models

Workshop participants agreed that there is no single model that can best capture the complexity of the Mississippi River and its delta. Participants agreed that multiple river models should continue to be used as they provide a range of predictions that will help quantify the impacts from restoration alternatives. For example, the numerical models simulate the physics differently; those differences can reveal insights into various fundamental physical processes. The use of multiple models is also beneficial for guiding data collection, as comparing models often highlights data gaps.

Specific model strengths/weaknesses discussed:

- Flow and fine sediment distribution at high flow is predicted well by models discussed.
- Fine sediment movement at low flow remains difficult to quantify.
- Delft3D is able to simulate nutrient distribution in the hydrobasin.
- While all models are able to predict flow distribution, these models are not able to capture sudden large changes/oscillations to river flow, such as high-flow river surging events. Moving forward, there is a desire to improve model sensitivity to predict these sudden large flow changes.

What are the most critical information needs to improve the models discussed?

Flow
In the lower section of the river, participants identified a need to improve our understanding of free water flow from the tributaries and how different processes, such as precipitation, wind, and natural channel migration affect the movement of water out of the river. For example, the influence of wind direction and speed on the flow in the MS river delta is poorly understood, and the fluxes that wind creates are difficult to reproduce. G. Brown highlighted that wind effects occur at both local and remote scales (e.g. Ekman spiral), adding difficulty to incorporating these effects into models. Additionally, there is evidence that discharge in the crevasses near Ft. St Philip has been increasing in the past decade. We do not fully know what

[8] Brown, G. (2008). "Approximate Profile for Nonequilibrium Suspended Sediment." *Journal of Hydraulic Engineering*, 134: 1010-1014.
[9] http://cdn.thewaterinstitute.org/userfiles/file/9_Brown_MRDM%20ADH%20MODEL%20SET%20UP%20080415.pdf

is driving this increase in flow, though it could be the river in early stages of natural channel realignment.

Sediments

Participants identified a need for a better understanding of sediment flow and discharge in the lowermost section of the MS River. Allison et al. (2012)[10] sediment budget data indicates that large volumes of sediment are stored in the lower river channel or in passes near the channel, or are released into the shallow Gulf margins upstream of the deepwater birdsfoot delta passes. Understanding fine sediment distribution and deposition in the lowermost sections of the river and its release to the deeper Gulf or recycling into adjacent wetlands would improve model predictions regarding restoration impacts. Additionally, participants identified a need for more quantitative information on the amount of material dredged at the lower river, and possibly the coast, to improve 1-D models which depend on this information.

Others

- Nutrients: What are the links between sediments and phosphorous? There are different ecological implications for the deposition of different nutrients, these links need to be better understood to improve nutrient uptake scenarios of riverine models and better assess their biological impacts, such as the hypoxic zone in the Gulf.
- Long-term channel evolution: A better understanding of how the channel changes in decadal or multi-decadal scales is needed, especially south of Natchez. This information, as well as how the river responds to these changes, is needed for future transient model simulations.
- Salt wedge dynamics: Additional information is needed regarding the progression and regression of the salt wedge in the lower Mississippi River. This would provide us with better resolution of the interaction between the salt wedge movement and sediment dynamics in the lowermost River. Salt wedge dynamics has implications for particle trapping, navigation and freshwater availability for coastal communities.
- Salinity: AdH is a 2D salinity model, and it was found to underestimate salinity measurements in the bays and offshore areas. Higher resolution of salinity data could improve model's ability to simulate salinity in the bays and understand salinity processes as the river discharges to the offshore areas.

What data is needed to improve models?

Daily sediment data is one of the greatest needs to improve riverine models. Currently, sediment data collection is dispersed as it is collected by different entities and/or researchers and there is no concerted effort or central database to capture available sediment data. We need a better understanding of sediment volume and availability, including whether sediment in the river bed is resistant to movement, and its ability to be transported by river flow.

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[10] Allison et al. 2012. A water and sediment budget for the lower Mississippi–Atchafalaya River in flood years 2008–2010: implications for sediment discharge to the oceans and coastal restoration in Louisiana. J*ournal of Hydrology*, 432: 84-97. http://dx.doi.org/10.1016/j.jhydrol.2012.02.020

Additionally, we need more information regarding groundwater movement from the river into the estuary. While we have evidence of groundwater and surface water loss from the river that is difficult to account for in a water budget, we need more information to quantify and incorporate this information into the models.

Participants also highlighted that there are few data points and direct measurements of nutrient concentration and rates (current data points are: Vicksburg, Pilot Town, and Baton Rouge). It was suggested that tracers could be used to better identify/track nutrients.

INTRODUCTION TO NORTHERN GULF OF MEXICO OCEAN MODELS

PRESENTATIONS

Workshop participants presented on oceanographic models used to understand the Louisiana coastal area and northern Gulf of Mexico (GOM). Presentations addressed the purpose of different models, discussed specific model requirements, and addressed some of the main questions that each model is able to address. Additionally, presenters provided information on the major model gaps and limitations, and the type of data needed to improve model predictions.

Northern Gulf Of Mexico Hycom (Dr. Philip Chu, NOAA)
Dr. Philip Chu presented U.S. Navy's Global Hybrid Coordinate Ocean Model (HYCOM)[11], a global ocean model used to run regional GOM simulations. HYCOM can simulate the loop current and open ocean, but the resolution is not high enough for coastal areas. Currently, HYCOM is the most advanced global ocean model for the GOM region.

Application of FVCOM (Dr. Dubravko Justic, Louisiana State University)
Dr. Dubravko Justic presented an application of the Finite Volume Community Ocean Model (FVCOM), a prognostic, three-dimensional, high resolution coastal ocean model. This model uses an unstructured grid, allowing it to fit complex coastlines better than structured grid models. Examples of the application of FVCOM to the coastal northern Gulf of Mexico are found in Huang et al. (2011)[12] and Justic and Wang (2014)[13].

ADCIRC/CSTORM-MS Surge Modeling (Dr. Ty Walmsley, U.S. Army Corps of Engineers)
Dr. Ty Walmsley presented CSTORM-MS and ADCIRC. CSTORM-MS, Coastal Storm-Modeling System, is an application of multi-scale, highly-skilled numerical models in a tightly integrated modeling system with user friendly interfaces. CSTORM-MS provides for a robust, standardized approach to characterizing storm hazards and allows for accurate assessments of risk to coastal

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[11] https://hycom.org

[12] Huang, H., Justic, B., Lane, R.R., Day, J.W., Cable, J.E. 2011. Hydrodynamic response of the Breton Sound estuary to pulsed Mississippi River inputs. *Estuarine, Coastal and Shelf Science*, 95: 216-231. http://dx.doi.org/10.1016/j.ecss.2011.08.034

[13] Justic, D., Wang, L. 2014. Assessing temporal and spatial variability of hypoxia over the inner Louisiana-upper Texas shelf: Application of an unstructured-grid three-dimensional coupled hydrodynamic-water quality model. *Continental Shelf Research,* 72: 163-179. http://dx.doi.org/10.1016/j.csr.2013.08.006

communities. ADCIRC, Advanced Circulation model, is an unstructured finite element hydrodynamics model that can run 2D and 3D simulations. Additional information on coastal storm modeling and ADCIRC can be found in Massey et al. (2011)[14].

DISCUSSION OF NORTHERN GULF OF MEXICO OCEAN MODELS

Model comparisons: Limitations and Challenges of Oceanographic Models

Workshop participants discussed the strengths and weaknesses of the different oceanographic models. One limitation highlighted was related to the boundary conditions. Most oceanographic models are regional and the model grids don't extend out enough or have adequate data/information to provide appropriate boundary conditions. Since the boundary conditions drive the model, model uncertainty can increase.

Another issue raised was that large and complex modeling efforts that are undertaken by university-based faculty have limitations. It is very expensive to run large-scale model simulations, and continuous funding sources can be an issue for academic researchers. Most models are modified and improved depending on available grants and the objective of grants funding the ongoing project. Due to this, investigators cannot always focus on continuing to improve a single model for a long-term period, rather they must shift their focus depending on funding source, which can prohibit long-term improvements of large-scale complex models.

What are the most critical information needs to improve the models discussed?

Environmental Data

There is a need for continuous environmental data in the coastal and offshore areas of the northern Gulf of Mexico. To address this need, participants proposed:

- Short-term seasonal deployments of observational equipment in the coastal region (data loggers, water quality probes, etc).
- Continuous monitoring stations in the northern Gulf of Mexico region collecting water quality and oceanographic conditions data.
- Common data collection stations that researchers can use to deploy equipment.
- Investments in robust data collection hardware for the offshore deployments.

Participants also highlighted that regardless of the data collection method, it is extremely important that data undergo quality control and that no "poor" data is used for model calibration, validation, or in simulations.

Flows and Currents

Participants continued their discussion of the need for more information on the interaction between flows and currents at the mouth of the Mississippi River, highlighting that there is a lack of information regarding high flow events on the east side of the River, and how changes in

[14] Massey, T.C., Wamsley, T.V., Cialone, M.A. 2011. Coastal Storm Modeling-System Integration. *Solutions to Coastal Disasters*, 99-108. http://dx.doi.org/10.1061/41185(417)10

flow can impact nutrient distribution. It is estimated that approximately 40% of the flow leaves the river between Belle Chasse at Head of Passes (HOP). At HOP, the water flows out in a variety of different directions. Overall, accurate flow distribution from the river can be challenging to estimate and this affects nutrient dissemination. This information is pertinent to the oceanographic modeling and a lack of data increases the model uncertainty. The introduction of diversions will change flow and nutrient distribution, which can potentially impact nutrient uptake and the hypoxic zone. Additional data and improved model resolution to simulate high flow events east of the river would improve prediction of nutrient distribution and the hypoxic zone. Additionally, there is a need for more information on the influence of the loop current in the northern Gulf of Mexico and how it can be incorporated into regional oceanographic models.

Is there potential to link/couple river/coastal and ocean models and use outputs from river/coastal models to force ocean models and vice versa?

Workshop participants agreed that the ability to couple river and ocean models would be beneficial for a variety of modeling purposes. However, participants also stressed that model coupling can be highly complicated and might not always be the best approach. In order to couple models flow partitioning, storm-forcing, and other processes have to be resolved between models. Models that are Earth System Modeling Framework (ESMF) compliant are easier to couple and to transfer/exchange outputs between models. HYCOM is ESMF compliant while FVCOM is not yet ESMF compliant. For models like FVCOM, models are often nested and model upgrades become difficult. Participants cautioned that model coupling, if done incorrectly, can cause more harm than good (such as increasing model uncertainty) and should be done carefully to determine whether it is appropriate for the questions being asked.

DISCUSSION OF LIMITATIONS AND UNCERTAINTIES IN NUMERICAL MODELING

Group discussion regarding the challenges and uncertainties in riverine, coastal, and regional ocean models for the improvement of management decisions related to coastal restoration, river management, and addressing uncertainties.

Model Challenges: Communicating Uncertainties

Participants agreed that one of the biggest challenges that modelers face is translating the uncertainties of model outputs and predictions to coastal managers and the public. The “hurricane cone of uncertainty” has been a successful graphic representation to communicate uncertainties in hurricane model predictions to managers and the public. One approach proposed by the group is to develop a similar method to represent uncertainties of numerical models, particularly for uncertainty related to potential land-building scenarios produced by model simulations. However, even when using graphical representations modelers must consider the background of their audience. For example, managers from a restoration state agency (like the Louisiana Coastal Protection and Restoration Authority) would have a different understanding of model outputs compared to the general public. Moving forward, workshop participants recommended that modelers identify ways to represent uncertainty of model outputs, while always considering the message and audience.

Running the appropriate uncertainty analysis for heavy computational models also remains a challenge for workshop participants. Most of the numerical models presented during this workshop are computationally heavy, which makes running sensitivity and validation analyses difficult and often times impractical. Modelers often have default parameters that are realistic and work for a model run, but may not reflect how the actual system works. The group proposed addressing this by running an uncertainty analysis of default parameters on a simpler model. This could help modelers identify some dominant uncertainties.

Although uncertainty analyses are done for parameters developed from available data, there is also uncertainty in the data itself. Participants highlighted that all data comes with its own uncertainty, and suggested that they develop a way to incorporate the uncertainty of the data collected into uncertainty analyses. One workshop participant underscored this by stating, "No model is perfect and all models come with uncertainty; at one point we must ask, what is the level of uncertainty at which we are willing to accept?" Workshop participants agreed that this level depends on the risk-tolerance of agencies and groups, and the trade-offs between model run-times, model applicability, and levels of uncertainty.

How can we convince decision makers to invest in multiple models?

After some discussion, workshop participants agreed that an effective approach this issue can be to invest in multiple models. Use hurricane models as an example: for hurricane prediction a model ensemble is used to determine the most likely trajectory and evolution of the hurricane, and funding continues to run multiple hurricane models to better predict a hurricane path. The same approach could be used for riverine and oceanographic models that are used to make decisions. Additionally, it was discussed, that by presenting models that show near-perfect agreement with data, modelers may have incorrectly convinced managers and decision-makers that the models are perfect and no longer need new or updated models. It was highlighted that transparency is important; model successes as well as shortcomings should be demonstrated, and modelers should better communicate the processes we are unable to simulate or predict. Essentially, communicating the uncertainty of the models and what is needed to improve the models to support decision making.

Effect of linking and coupling models on uncertainty

Workshop participants discussed, again, that coupling or linking models may not always be a clear solution, as these processes can either compound model errors or diminish errors by canceling uncertainties from each model. Coupling models is not necessarily about which model is better, but rather about learning how each model works and whether outputs will be improved by coupling models. In order to link or couple models, scientists have to identify the ways in which the models differ and make sure that the physical and biological processes from each model are compatible. It was stressed that models are not static items; they are being constantly developed and improved, and coupling models requires understanding the benefits and shortcomings of each model, ensuring that the models are compatible, and determining whether the coupling or linking process will not compound outcomes or uncertainties.

Are there any obvious improvements for model accuracy or the types of questions these models can address?

As models are constantly being developed and improved, it was suggested that creating a community of modelers and data collectors would allow for long-term improvement of commonly used models. Having a community of researchers/modelers that are constantly working to improve a series of models is a way to share information such that all model-users benefit, and could help advance and improve models. The group proposed creating a similar community of data, where people can share available data sources and data collection effort results.

Day 2 – April 5th 2016

The second day of the workshop was dedicated to presentations and facilitated group discussions of ongoing data collection efforts, data availability, and data gaps in the lower MS River and the northern Gulf of Mexico. This discussion was followed by a wrap-up discussion summarizing the main challenges and data gaps that we need to address to improve models moving forward.

INTRODUCTION TO DATA AND DATA GAPS THAT SUPPORT MODELS

Available Data Presentation
(*Dr. Alex Kolker, Louisiana Marine Consortium and Tulane University*)
Dr. Kolker began the second day of the workshop by continuing some of the discussions from the first day of the workshop regarding data. Dr. Kolker stressed that data collection is expensive, and funding for these efforts is limiting. He asked: How do we best guide data collection efforts? What are the most important data needs?

"Model Relevant" Data Collection Projects in the Mississippi River and Interdistributary Basins (*Dr. Mead Allison, The Water Institute of the Gulf and Tulane University*)
Dr. Allison discussed the need for clear data collection goals in support of modeling. Including:

- The importance of local data measurements that are used as input coefficients into the model (using data from a different location to parametrize these model input coefficients can result in inadequate model performance)
- Well defined bathymetry/elevation grid is essential
- Time-series datasets of key model output parameters for calibration/validation are necessary (ex: water level, salinity, turbidity)

Dr. Allison continued by discussing some of the data collection efforts in the Mississippi River and interdistributary basins.

Louisiana Coastal Area Mississippi River Hydrodynamic and Delta Management Study
This was a joint study between the State of Louisiana[15] and the U.S. Army Corps of Engineers[16] to improve knowledge of Mississippi River processes and gather necessary information to improve models. For this project, there were two data collection groups that had a series of separate activities, but tried to collect data in the river simultaneously. Data collection efforts undertaken during this project included: special longitudinal studies following and sampling water parcels throughout different days; bar dynamics, diversions, and sediment capture activities; and sampling rising discharge and lowering discharge. This study was a successful collaboration between the groups collecting data to improve models and provided recommendations such as possible locations for additional monitoring stations.

Basin-wide Model Data Collection Activities
A suite of basin-wide model data collection has occurred in the Barataria Bay and Breton Sound areas since 2014, including:

- Bathymetry of canals and open water bodies (model grid setup)
- Time series network of hydrologic, sediment transport and water quality stations (model calibration and validation)
- Geotechnical and stratigraphic character of "modifiable" unit (model calibration)
- Examination of splay evolution analogue (model hindcasting ability)
- Ecological conditions in estuarine water bodies (model calibration and validation)
- Ecological conditions of wetland vegetation (model calibration and validation)
- There were a series of fixed continuous stations (very expensive to fund) between June 2014-2015 for 12 week periods:
    - Two basins: Barataria and Breton Sound
    - Deployments were 6 weeks long in two different conditions
- Estuarine transects: 1-2 days

SWAMP (System Wide Assessment and Monitoring Program)[17]
The System Wide Assessment and Monitoring Program (SWAMP) is a comprehensive data collection framework in support of CPRA. This framework established specific and relevant goals and objectives for a large-scale monitoring program. The collaborative framework avoids duplication, leverages limited funding, and ensures long-term data collection. SWAMP prioritizes monitoring variables and proposes new data collection programs utilizing survey designs that allow for drawing statistical inferences about the variable or resource of interest.

Monitoring variables in SWAMP include: biotic, water quality, hydrology, weather and climate, physical terrain.

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[15] http://coastal.la.gov/project/hydrodynamic-and-delta-management-study/
[16] http://www.mvn.usace.army.mil/Missions/Environmental/Louisiana-Coastal-Area/Mississippi-River-Hydrodynamic-and-Delta-Management/
[17] http://thewaterinstitute.org/files/pdfs/SWAMP_Version_III.pdf

NOAA-NCEI Data Repositories/Archiving
(Kate Rose, NOAA/National Center for Environmental Information)
As an addendum to the Data Presentations, Kate Rose provided a brief overview of the data repositories and archiving hosted by NOAA at NCEI. This presentation included an overview of the NOAA Plan for Increasing Public Access to Research Results (PARR), and a navigation through the NOAA National Center for Environmental Information (NCEI) data archiving website. These Federal data management policies and resources exist in order to facilitate sharing and re-use of existing data and, ultimately, enhance future research and data collection projects.

DISCUSSION ON FILLING IN THE DATA GAPS

Following the discussion of available, ongoing, and planned data collection efforts in the lower MS River and northern Gulf of Mexico, the group had a discussion on how to best fill data gaps and how to prioritize funding for efficient data collection efforts.

Data needed to better parameterize models:

Monitoring Systems
Workshop participants agreed there is a need to improve current monitoring systems throughout the Gulf of Mexico and in rivers discharging into the Gulf. More information is needed regarding energetics and sediment transport in the lower sections of the rivers, and regarding interchange in restrictive passes between the Gulf and inland water bodies such as Barataria Bay, Terrebonne Bay, and Galveston Bay.

Physical locations of possible monitoring stations should be selected that would benefit multiple users and/or modelers and ideally would allow collaboration among data collators. Participants proposed driving piles for permanent monitoring stations at select locations to provide reliable, continuous long-term monitoring. Also, identifying decommissioned platforms to set them up as monitoring platforms was proposed as an alternative. It was noted that the paperwork required to get permanent sites established might be cumbersome. However, if there were permitted locations available where scientists could set up monitoring devices that would make data collection easier, and would provide more continuous sampling at select locations.

Workshop Participants also proposed having classical shelf and upper shore-face tripod studies. These studies would address the data gap between estuarine and offshore physics which is needed for the models, especially to improve boundary conditions and model calibration/validation.

Salinity Measurements
We have more data regarding salinity process in the coastal region than in the offshore areas. More information is needed regarding salinity in the deepwater. Some of the issues and needs highlighted by participants included:

- Coastwide Reference Monitoring System (CRMS) Stations are valuable, but are constrained by costs.
- Better understanding of movement of salt wedge up the river under climate change and sea-level rise is needed. Unlike many Atlantic coast estuaries, where the salt wedge can regularly propagate 20 - 200 km inland, in the Mississippi River the salt wedge rarely propagates northward of Head of Passes, except during periods of low flow and drought. The irregular position of the salt wedge poses a hazard, as many river communities draw their water from the Mississippi River. Salt wedge dynamics in the Mississippi River will also likely change as the channel is deepened to accommodate post-PANAMAX vessels, and as relative sea level rises, both of which could increase the landward flow of this wedge.
- Salinity calibration for models requires high data resolution.
- Salinity is a conservative measurement and in the offshore areas it can be difficult to simulate. To improve models' ability to simulate salinity, we need increased salinity observations in the offshore, including vertical resolution of salinity movements.

Ground Water Discharge
Groundwater discharge into the Gulf is important and recent studies show that groundwater can discharge from the Mississippi River into adjacent bays. Dr. Kolker highlighted that submarine groundwater discharge entering the ocean and rivers are a source of freshwater and dissolved constituents, including nutrients, to the oceans; noting that subterranean estuaries are important. Additional research is needed on how to quantify submarine groundwater discharge.

WORKSHOP WRAP-UP DISCUSSION

Important Processes that Require Further Studies

Mississippi River Sediment Processes
One of the biggest challenges for model predictions discussed during the workshop was a lack of understanding regarding processes governing suspended sediment load and sediments in the river bed, and how these sediments can be used for restoration. Participants suggested future studies should focus on understanding, at a higher resolution than is currently know, the quantity and distribution of suspended sediment in the lowermost section of the Mississippi River, and the fate, storage, and transport of these sediments. Understanding the characteristics of the suspended sediments in the river would help modelers better predict the impacts of planned diversions and restoration strategies, and reduce uncertainties regarding land-building potential.

Additionally, there is a lack of understanding regarding sediment processes and transport once sediments reach the coast. The current lack of understanding of suspended sediment processes in the lowermost river and the coastal zone is not a technology issue, but rather the result of the lack of time and resources to undertake the appropriate large-scale studies that would include data collection and modeling. Improved understanding of current sediment pathways would allow for better sediment management and more efficient planning of proposed restoration.

Shelf Processes

In order to improve oceanographic models a better understanding of shelf exchange processes, such as wave dynamics, plume dynamics, and processes governing salinity in the shelf is needed. Although a good understanding of salinity circulation in the deep ocean exists, the high resolution data of salinity distribution and circulation in shallow waters, the shelf, and offshore areas is still lacking. Workshop participants agreed that an increase in monitoring stations in these areas would improve temporal and spatial resolution salinity data which could improve model dynamics. Monitoring stations could also provide wave-field measures and information of wave energy and attenuation from the offshore to the coast. As waves are also a main driver of sediment movement, a better understanding of wave processes could help improve sediment dynamic simulations in the coastal and offshore areas.

Biogeochemical Processes

In addition to sediment and shelf processes, the participants identified a need for better understanding biogeochemical processes. For example, the biogeochemical processes in the lowermost river, the plume, and the shelf and their relation to hypoxia and phytoplankton blooms is not well known. As hypoxia continues to be an issue identified in the Gulf, a better understanding of these processes and integrating them into models will improve predictions.

What challenges were identified to improve and couple models?

Participants indicated than when building and validating a model, there are three basic things every modeler should be asking:

- Are your parameters reasonable?
- Have you done a mesh convergence test?
- Have you calibrated/validated to multiple data sources? (For example, has data been calibrated to something besides water lever (like velocity)?)

Participants identified the following challenges when coupling or linking models:

- Temporal output frequency: Trying to couple a model with monthly output to a model that runs daily can be complicated.
- Spatial resolution: There are large spatial differences among watershed, river, and estuarine models.
- Are your parameters constant among the models? If you are coupling multiple models you need to have uniform parameters to drive models together.

Another challenge that remains when coupling riverine and estuarine or oceanographic models, is our lack of understanding of the processes that occur as water moves from the river, through the estuary, to the offshore. Improving our understanding of physical, hydrodynamic, and biogeochemical processes, as discussed throughout the workshop and summarized in this document, would allow for better coupling of models in the future.

IV. RECOMMENDATIONS

How can data collection and modeling efforts better work together?

It was discussed that ocean system simulation experiments could be used to optimize ocean an observing system, and model simulations could be useful to identify and prioritize observation investments in geographic regions with high variability. Models can also be used to identify the most efficient temporal and physical location for observations and the type of information that needs to be collected (i.e., temperature, salinity, etc.) to reduce model uncertainty and improve model outputs.

To foster collaboration and relationships between modeling and data collection efforts, it was suggested that projects could have set times for the different groups to discuss planned and upcoming activities. During the Mississippi River Hydrodynamic Project, for example, teams had a conference call every other week for almost four years. Calls included data collectors, modelers, and others involved in the project. Although this was labor intensive, ultimately it proved to be useful. It was stressed that this approach needs to start during the funding process.

How do we foster ways to bring modeling and data communities together?

Many workshop participants felt that although data collection needs still exist, there has already been a lot of data collected. It was suggested that data managers work to increase awareness of existing data, share the data, and encourage people to use existing data for models and when planning future data collection efforts. Data archives provide a useful mechanism for people to store and share collected data, although there has to be an incentive to publicly share data. It was suggested that having employees (or students, post-docs, etc.) that focus on data mining would help make more efficient use of available data. For example, CALFED funded scholarships for post-docs to specifically work on data mining projects. These type of activities would help scientists, who are already overburdened, to identify publicly available data to improve models. Another approach suggested was the establishment of a data synthesis center located in the Gulf Coast where people could do large data analysis and synthesis projects. A more immediate way is the development of a listserve or online community where people can share the details of data sets collected.

Other agencies, like the Office of Naval Research (ONR), target a set of data collectors and modelers for workshops which provides a venue for scientist and managers to talk about current issues and how best to approach them. Out of these workshops, participants might come out with manuscripts, and sometimes ONR will fund some of the projects proposed during the workshops. There is value to the ONR approach as it is a bottom-up approach that helps produce high quality data sets. Other funding processes with an open RFP often facilitate a top-down process that can produce a scatter of data sets that do not get published. It was suggested that if scientists in the Gulf adopted the ONR approach, this would avoid a scatter of datasets and produce more cohesive project outputs and data sets.

How do we better communicate results as modelers?

Workshop participants provided the following approaches to improve communicating model results and outputs to decision makers:

- Communicate model outputs with probabilities, rather than ranges, based on uncertainty analysis. When it comes to communicating uncertainties, there is a responsibility on both sides: modelers have to be upfront when showing limitations and uncertainties of models, and managers need to communicate those uncertainties to their stakeholders.
- To address uncertainty in models, determine prior expectations and risk-tolerance of those requesting the model outputs. Deciding this ahead of uncertainty and sensitivity analyses would allow modelers to determine at what point they are satisfied with a model and the outputs it provides. Models are not perfect; they provide guidelines but not straight answers.
- Programs (such as the NOAA Science Program and the RESTORE Council) could bring decision makers in to talk to scientists. Scientists and modelers might have preconceived notions of what managers and decision makers need, which may not necessarily reflect their real needs. Meetings and workshops with scientists, managers, and decision makers would allow PIs to discuss science questions and start a dialogue with managers.

V. WORKSHOP PARTICIPANTS

Name	Affiliation
Dubravko Justic	Louisiana State University
Alex Kolker*	Louisiana Universities Marine Consortium/Tulane University
Philip Chu	NOAA Great Lakes Environmental Research Lab
Kate Rose	NOAA/National Center for Environmental Information
Suzanne Van Cooten	NOAA/National Weather Service
Denise Reed	The Water Institute of the Gulf
Ehab Meselhe*	The Water Institute of the Gulf
Mead Allison*	The Water Institute of the Gulf/Tulane University
Ioannis Y. Georgiou	University of New Orleans
Barbara Kleiss	US Army Corps of Engineers
Gary Brown*	US Army Corps of Engineers
Ty Wamsley	US Army Corps of Engineers
Alyssa Dausman**	Gulf Coast Ecosystem Restoration Council Staff
Jessica Henkel**	Gulf Coast Ecosystem Restoration Council Staff/National Academies of Sciences - GRP Fellow
Elizabeth Gomez**	NOAA RESTORE Act Science Program/National Academies of Sciences - GRP Fellow
Julien Lartigue**	NOAA RESTORE Act Science Program

*Workshop Science Leads
**Workshop Coordinators

VI. LOWER MISSISSIPPI RIVER HYDRODYNAMIC MODELING WORKSHOP AGENDA[18]

April 4-5, 2016
500 Poydras Street, Basement Conference Room
New Orleans, LA, 70130

Workshop Science Leads:
Mead Allison, Tulane University and the Water Institute
Gary Brown, US Army Corps of Engineers
Alex Kolker, Louisiana Universities Marine Consortium and Tulane University
Ehab Meselhe, The Water Institute of the Gulf

NOAA RESTORE Act Science Program
Coordinator: Liz Gomez (954-695-8064), NAS-GRP Fellow
RESTORE Council
Coordinator: Jessica Henkel (504-252-7718), NAS-GRP Fellow

Background:

The NOAA RESTORE Science Program (NOAA Science Program) and the Gulf Coast Ecosystem Restoration Council (Council) are funding (or, are going to be funding) two projects investigating the lower Mississippi River. The Council's funded project focuses on understanding Mississippi River physical processes to improve navigation, reduce flood risk, and maximize river-based restoration benefits; while the NOAA Science Program project focuses on the influence of the Mississippi River and its delta on the Gulf of Mexico Large Marine Ecosystem. Both of the projects include either modeling and data analyses or model development of the lower Mississippi River and/or the larger Gulf of Mexico. This workshop was developed from conversations among the PIs for these funded projects and a need to better understand interactions among hydrodynamic models used for management of the Mississippi River delta and the larger Gulf of Mexico.

[18] Note: Following the discussions and presentations given at the 2-Day workshop it was decided to remove "Hydrodynamic" from the workshop title. The workshop summary structure was also edited to better reflect the way workshop discussions unfolded.

Objectives:

The goal of this meeting is to foster dialogue among hydrodynamic modelers working at the boundaries of the Gulf of Mexico and the lower Mississippi River. At the end of this meeting, we want to:

- Identify gaps in our understanding of boundary conditions between Mississippi River hydrodynamic models and Gulf of Mexico hydrodynamic ocean circulation models.
- Discuss opportunities to link hydrodynamic river and ocean circulation models.
- Discuss model uncertainties and ways to better communicate results and uncertainties to decision makers.
- Identify ways to improve data assimilation and result dissemination.
- Evaluate the data collection efforts needed to develop coupled river/ocean models.
- Discuss additional opportunities for the modeling community to work together/help one another, for example to review one another's work.
- Provide recommendations to the larger modeling/data community and management on potential future activities/needs.

Monday, April 4th, 2016

9:00 - 9:30 - Introductions

- Introduction to NOAA RESTORE Act Science Program and Project
  - *Liz Gomez & Julie Lartigue*
- Introduction to RESTORE Council and Project
  - *Jessica Henkel & Alyssa Dausman*
- Around the room

9:30 – 10:30 – Introduction to Lower Mississippi River Hydrodynamic Models

Brief presentations of models being used by different entities in the lower Mississippi River. Presentations will address the following issues:

(1) What is the purpose of the model? (2) Model specifics (temporal scale and frequency, spatial coverage and resolution, typical run time, management questions answered by the model) (3) What are the most important findings? (4) What are the knowledge gaps and limitations? (5) What this model can provide to other models (for either the MS River or northern GoM) or managers)? (6) What data is needed to improve the model? (7) What are the future steps for model development and applications?

- Delft3d and Flow3D - *Ehab Meselhe, The Water Institute* (20 min)
- Application of FVCOM - *Ioannis Georgiou, University of New Orleans* (20 min)
- ADH/SEDLIB - *Gary Brown, U.S. Army Corps of Engineers* (20 min)

10:30 - 10:45 – Break

10:45 - 12:00 – Discussion of Lower Mississippi River Hydrodynamic Models
Group discussion of Mississippi River models presented with a focus on:

Discussion Questions:

- What are the most critical information each model provides?
- Model comparisons: which model is best to answer which question?
- What are the most critical information/drivers each model need?
  - From other models: upstream watershed or oceanographic boundary or
  - From observations: data type, frequency, etc.
- Is there potential to link/couple river/coastal and ocean models and use outputs from river/coastal models to force ocean models and vice versa?

12:00 - 1:00 - Lunch

1:00 - 2:00 – Introduction to Northern Gulf of Mexico Ocean Models
Brief presentations of models being used by different entities in the northern Gulf of Mexico. Presentations will address the similar questions to those presented during morning discussion of hydrodynamic river models:

- Northern Gulf of Mexico HYCOM - *Philip Chu, NOAA* (20 min)
- Application of FVCOM - *Dubravko Justic, Louisiana State University* (20 min)
- ADCIRC/CSTORMS-MS surge modeling - *Ty Walmsley, U.S. Army Corps of Engineers* (20 min)

2:00 – 3:00 – Discussion of Northern Gulf of Mexico Ocean Models
Group discussion of northern GoM models previously presented with a focus on:

Discussion Questions:

- What are the most critical information each model provides?
- Model comparisons: which model is best to answer which question?

- What are the most critical information/drivers each model need?
  - From other models: upstream watershed or oceanographic boundary or
  - From observations: data type, frequency, etc.
- Is there potential to link/couple river/coastal and ocean models and use outputs from river/coastal models to force ocean models and vice versa?

3:00-3:15 - Break

3:15-4:15 - Facilitated Discussion: Limitations and Uncertainties

Group discussion regarding the challenges and uncertainties in linking riverine/coastal models and ocean models for the improvement of management decisions related to coastal restoration alternatives, management of the lower Mississippi River for multiple uses, and addressing uncertainties such as sea level rise, resilience, and adaptation.

- What are the limitations of each model: e.g.
  - Depth averaged (no stratification)
  - Spatial resolution limitations
  - Run time limitations
  - Etc.
- What are the model uncertainties? Have they been quantified? How can we reduce these uncertainties?
  - Have we considered the effect of “linked” models on uncertainty?
  - Have we considered ways to adequately communicate uncertainty to managers?
- Are there any obvious improvements for model accuracy or the types of questions these models can address?

4:15- End of the Workshop’s 1st Day

Tuesday, April 5, 2016

8:30 - 9:00 - Welcome Back - *Jessica Henkel, RESTORE Council*

- Summary of the previous day
- Brief overview of the agenda and our goals for the day

9:00 – 9:30 – Introduction to Data and Data Gaps that support the models -

- Available Data Presentation - *Alex Kolker and Mead Allison, Tulane University and The Water Institute*
  - Mississippi River Hydro: Summary of Data Collection Program
  - Mississippi River Delta Management: Summary of Data Collection Program
  - Overview of the System-wide Assessment and Monitoring Program (SWAMP)
  - Offshore monitoring and data collection activities
  - Data collection capabilities in the northern Gulf of Mexico

9:30-10:30 – Facilitated discussion: Filling in the gaps

- What data would be required to better parameterize these models?
- What data would be required to represent relevant processes that are not currently captured in the available models?
- How do we acquire that data?
- How do we prioritize data collection? Spatial coverage? Temporal coverage?
- What data could be multi-purpose? (i.e. help multiple models and management)
- Data assimilation - the availability of the data that could be useful and should be disseminated - how can we do that without spending a lot of money?

10:30-10:45 – Break

10:45-12:30 - Moving forward and Wrap-up Discussion

Summarizing our findings and discussing the future:

1. Are there any things we can do as a community to help one another, for example to:
   a. "Close the gaps" we've identified?
   b. Explore ways we can review each other's work?
2. How do we communicate results as modelers? How do we translate model uncertainty and results to management in a way that is clear and understandable (i.e. what the model can and cannot be used for?)

3. What overarching recommendations do we have to:
    a. Modelers
    b. Data providers
    c. Management
        i. RESTORE Council
        ii. NOAA RESTORE
4. Next steps? Outcomes from this workshop?

12:30 – End of the workshop

The coordinators will write a workshop summary and send to participants for review/input.