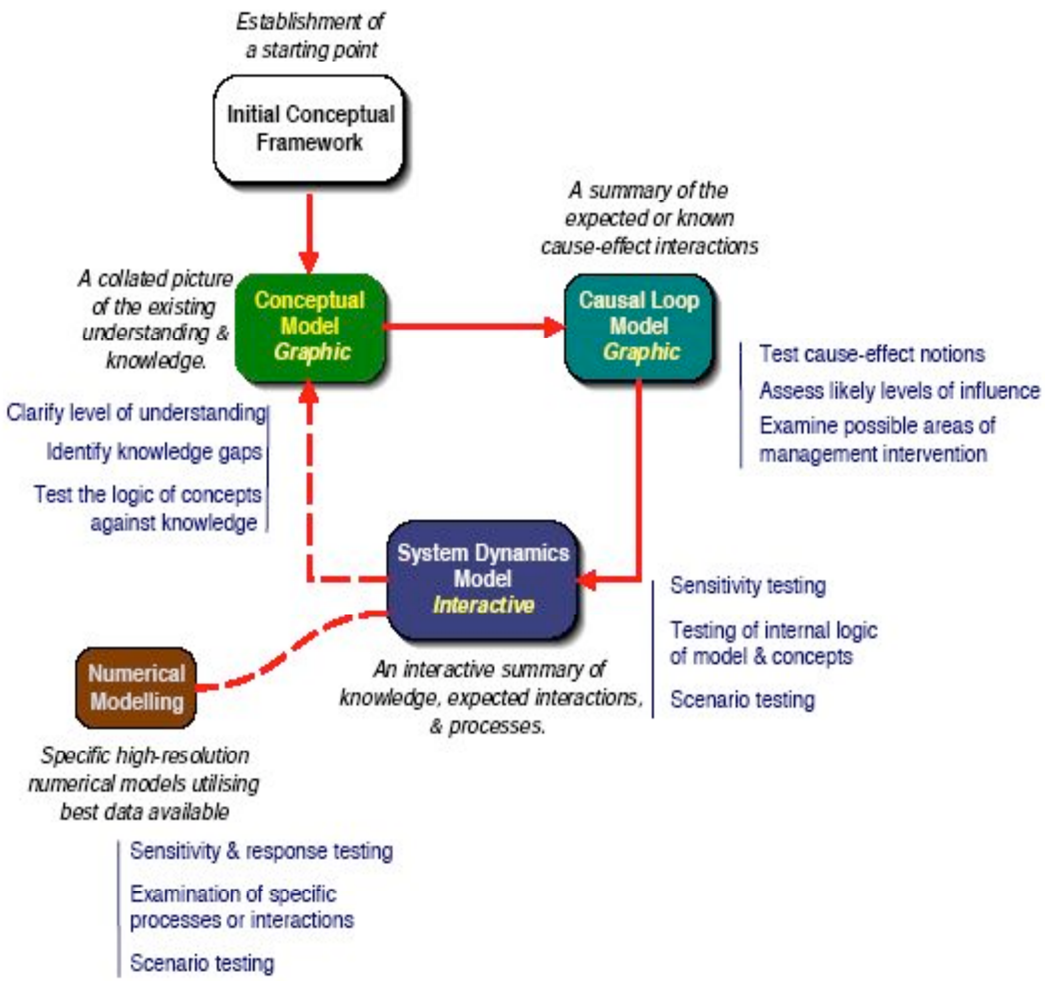
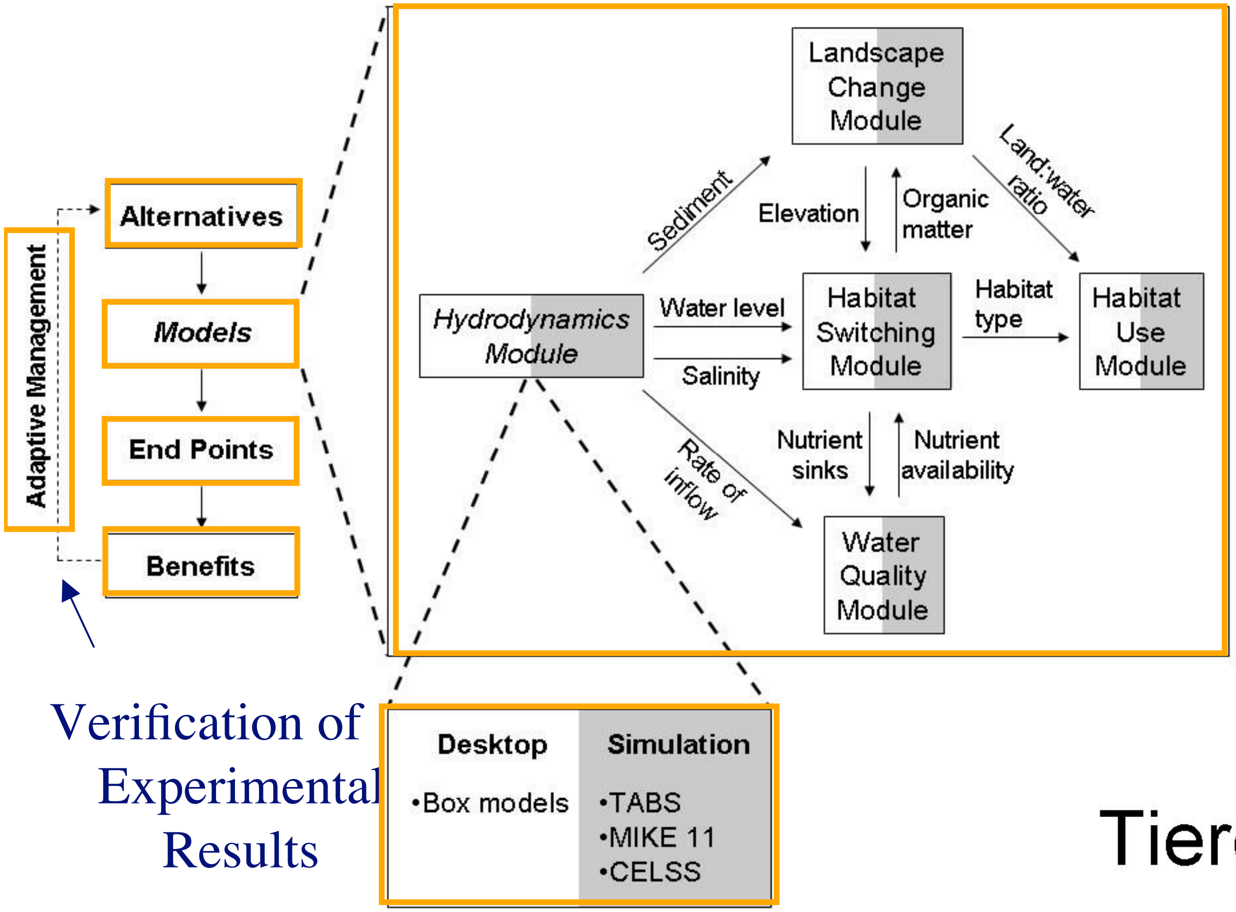
Coastal Louisiana Ecosystem Assessment & Restoration (CLEAR) Program

'Planning and decision-making can be improved by access to reliable forecasts of ecosystem state, ecosystem services, and natural capital. Availability of new data sets, together with progress in computation and statistics, will increase our ability to forecast ecosystem change.'

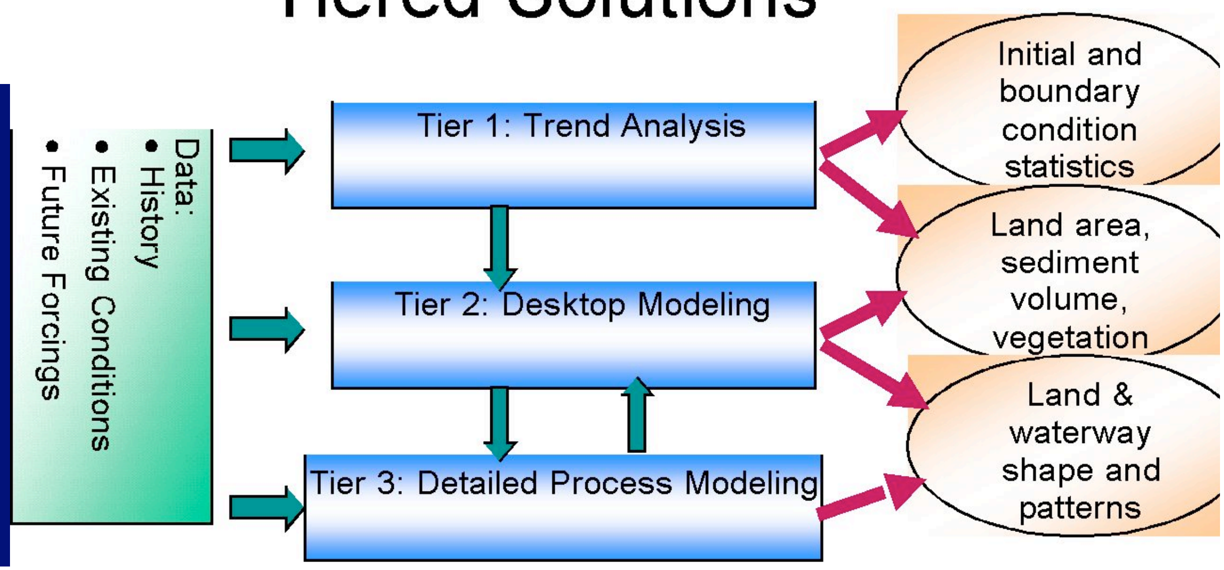


- Diversity of Modeling Approaches
- Transition in this Sequence of Model Development;
- ‘Concept to Construction’



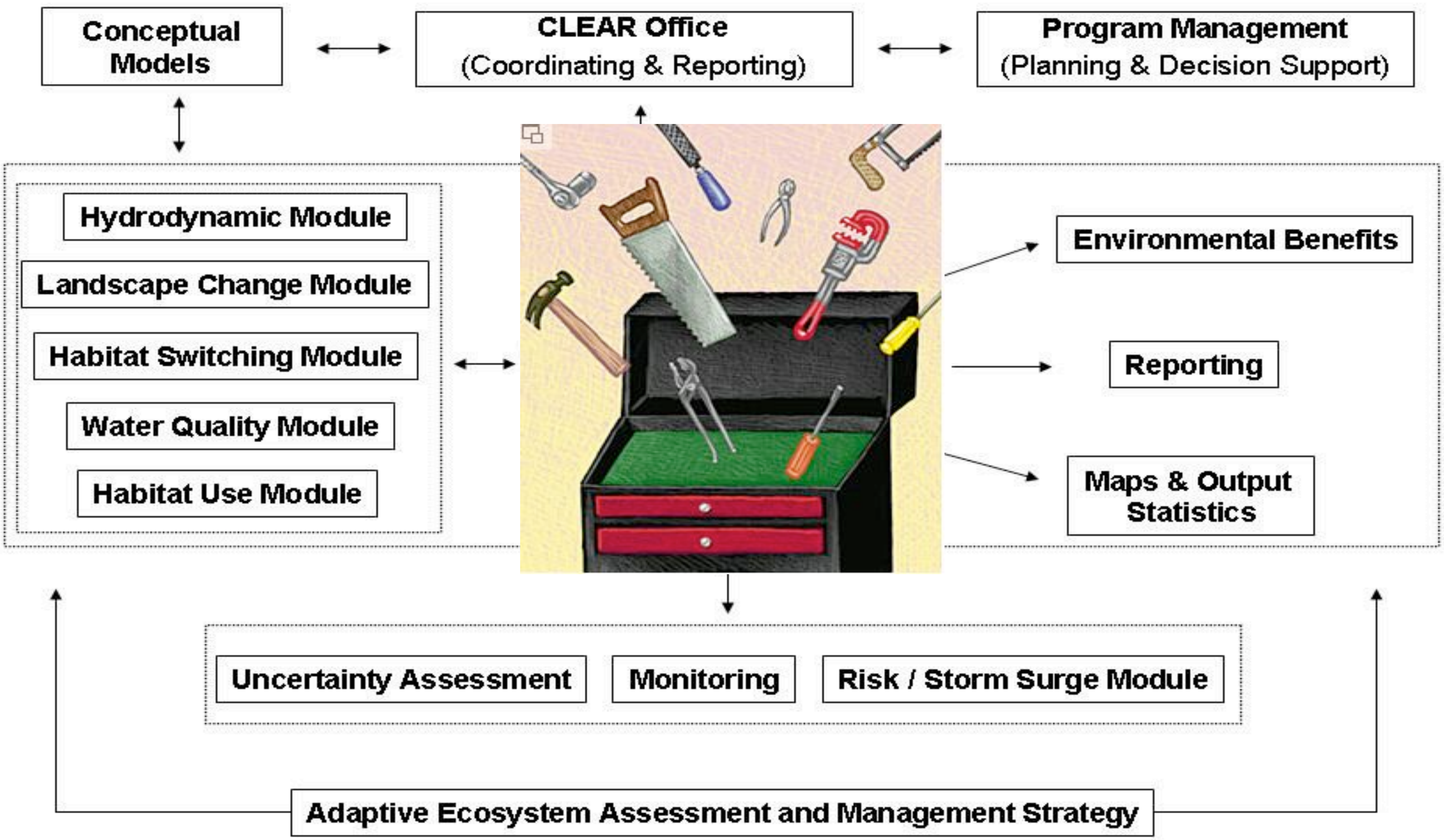
- Identify, confirm cause and effect relationships;
- Formulate and verify predictive models;
- Document assumptions of how the System Works;

Tiered Solutions



- Integrates scientific knowledge for decision-making;

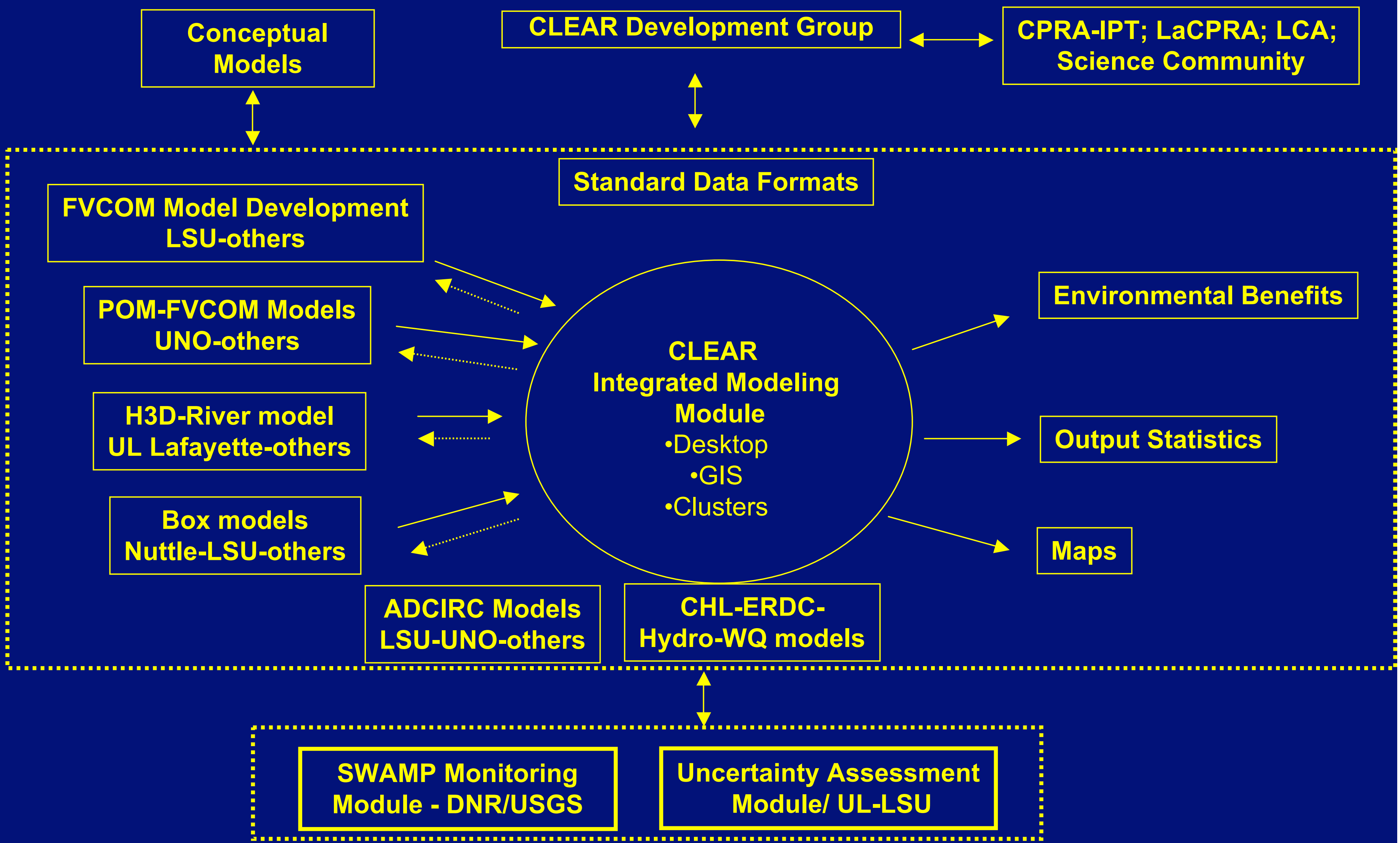
CLEAR Framework: Coastal Ecosystem Forecasting System



CLEAR Program

- Coordinate modeling efforts from variety of sources into an integrated analytical framework;
- Support a variety of modeling, data collection, and reporting needs in integrated network;
- Stimulate collaboration among variety of research groups with variety of modeling tools that will support research and restoration planning efforts;
- Network information needs - monitoring, modeling, and evaluation (grids, model formulation, verification)

Proposed CLEAR Development Group



REDUCING FLOOD DAMAGE IN COASTAL LOUISIANA: COMMUNITIES, CULTURE & COMMERCE

Based on Conceptual Ecological Model Workshop
November 2005

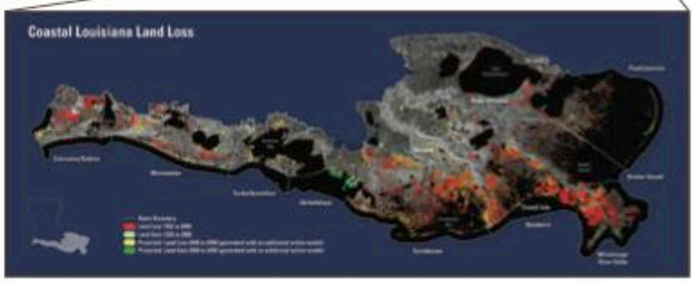
Louisiana's national contribution (% of US total)

- 27% of crude oil
- 15% of natural gas
- 30% of commercial fisheries
- 21% of waterborne commerce

The Mississippi River is the largest and longest river in North America, and its drainage area includes over 1.8 million square miles.

The river provides drainage for 41% of the continental US, including all or part of 31 states and two Canadian provinces.

Of the world's rivers, the Mississippi River ranks third in length, second in watershed area and fifth in average discharge.

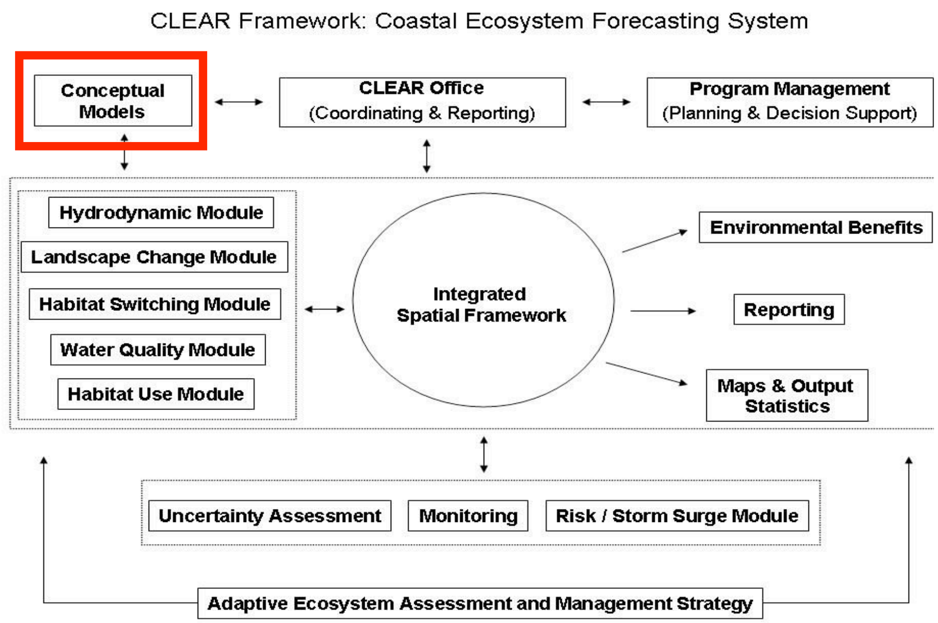


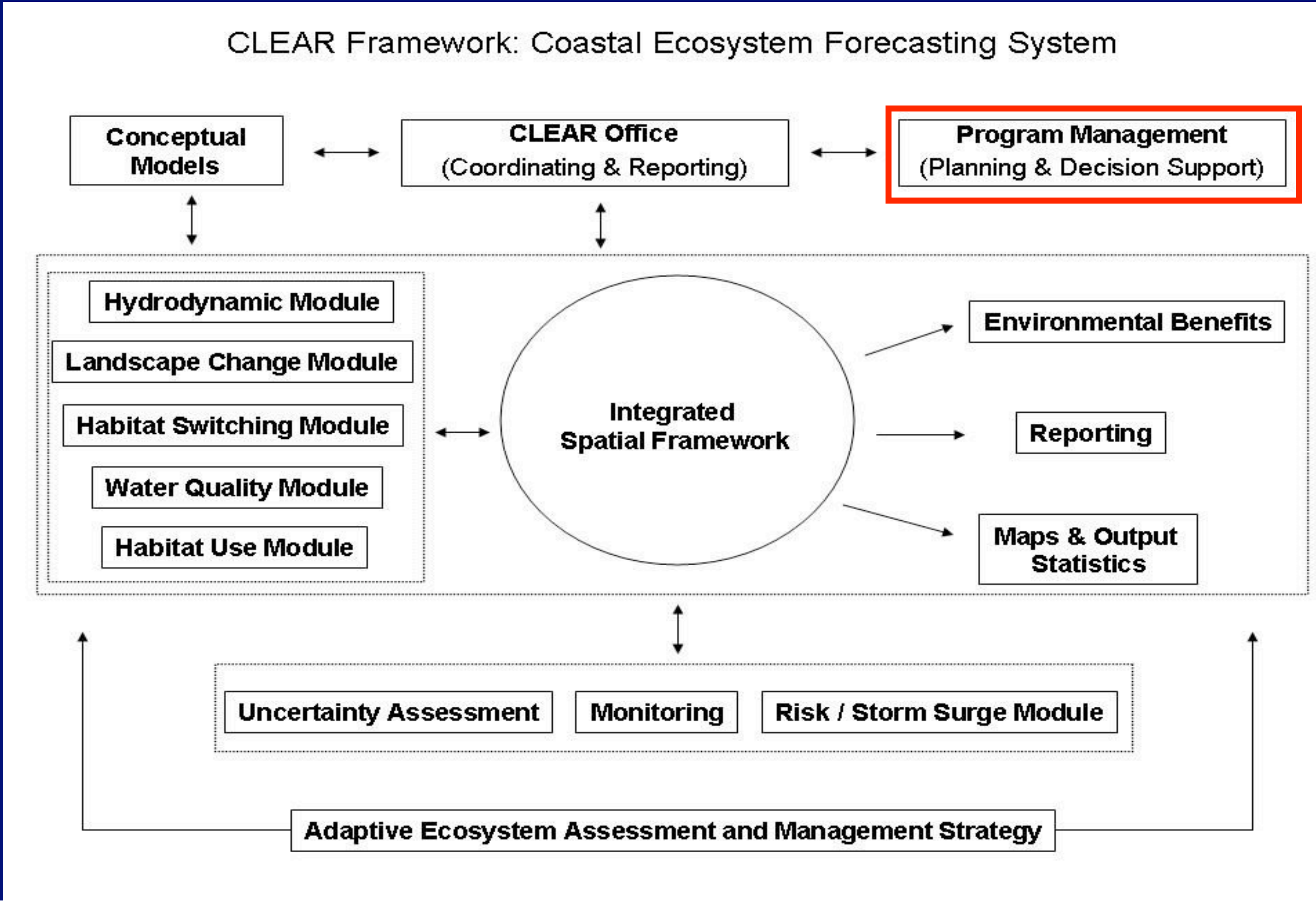
Historical and projected land loss from coastal Louisiana.
Map reproduced from Barras, J., Beville, S., Britsch, D., Hartley, S., Hawes, S., Johnston, J., Kemp, P., Kinler, Q., Martucci, A., Porthouse, J., Reed, D., Roy, K., Sapkota, S., and Suhayda, J. 2003. Historical and projected coastal Louisiana land changes: 1978–2050: USGS Open File Report 03-334, 39 p.

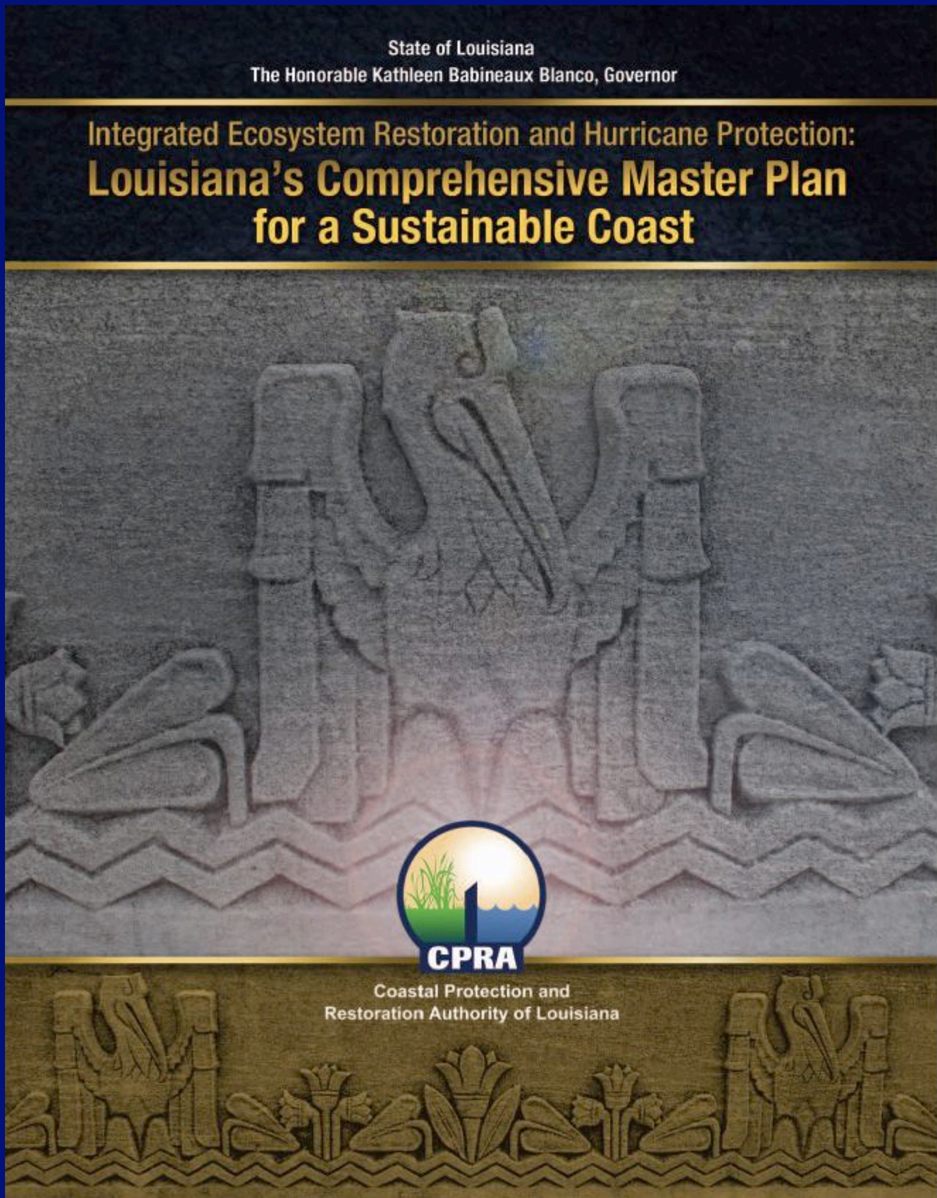
Protection and restoration of coastal Louisiana is a national priority

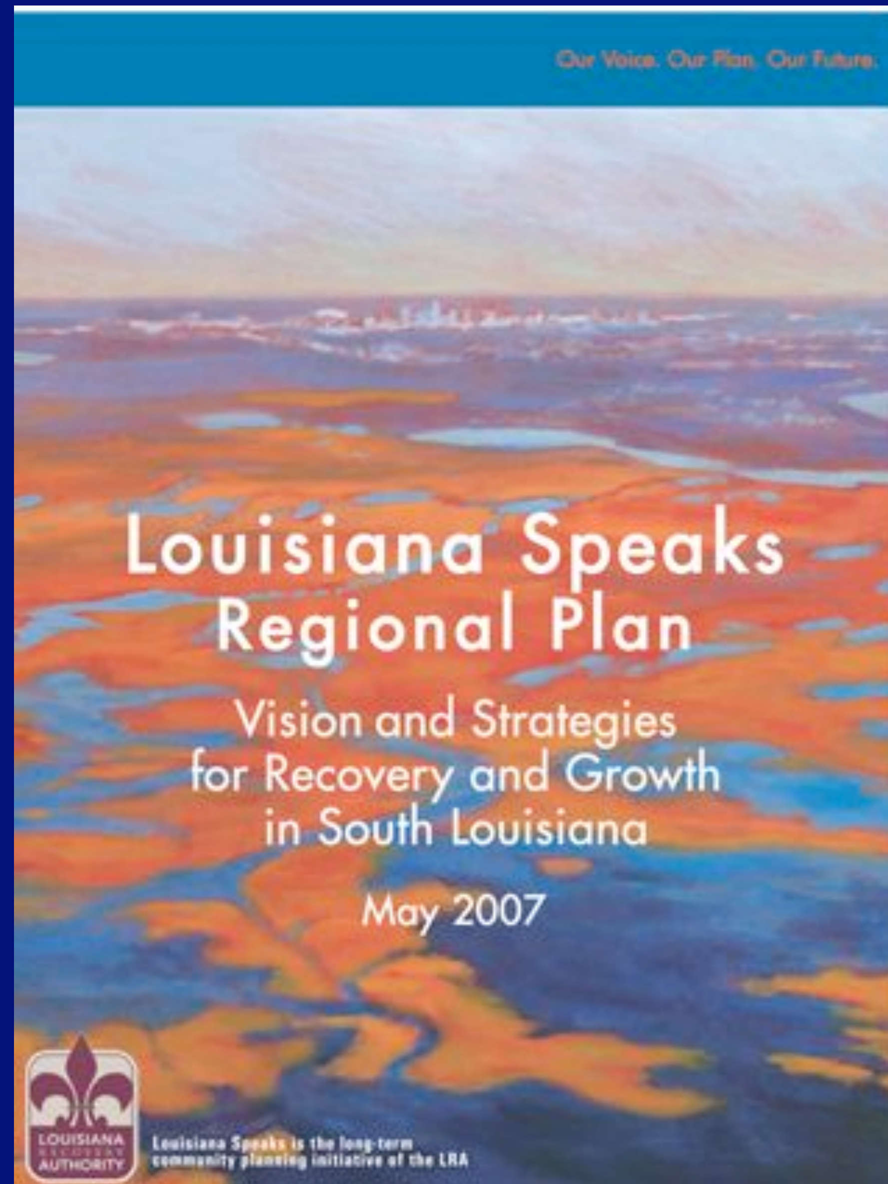
Coastal Louisiana is home to the nation's largest port complex in both tonnage and infrastructure, and produces or transports nearly one-third of the nation's oil and gas supply. In addition, the coastal Louisiana ecosystem provides nationally-important fish and wildlife habitat that supports the nation's second-largest commercial fishery and over $1 billion per year in recreational fishing and hunting revenues. All of these activities are supported in Louisiana because of the close proximity of its skilled workforce to the Gulf of Mexico. Coastal land loss has placed these economic and natural resources at increased risk of loss due to the intense effects of waves and storm surges from hurricanes. Restoration of the coastal ecosystem can work synergistically with levees and floodgates to provide an integrated flood protection system that allows continued resource production and sustains the ecosystem services on which the nation relies.

Flood damage following Hurricanes Katrina and Rita.




CLEAR Framework: Coastal Ecosystem Forecasting System
Conceptual Models
CLEAR Office (Coordinating & Reporting)
Program Management (Planning & Decision Support)
Hydrodynamic Module
Landscape Change Module
Habitat Switching Module
Water Quality Module
Habitat Use Module
Integrated Spatial Framework
Environmental Benefits
Reporting
Maps & Output Statistics
Uncertainty Assessment
Monitoring
Risk / Storm Surge Module
Adaptive Ecosystem Assessment and Management Strategy



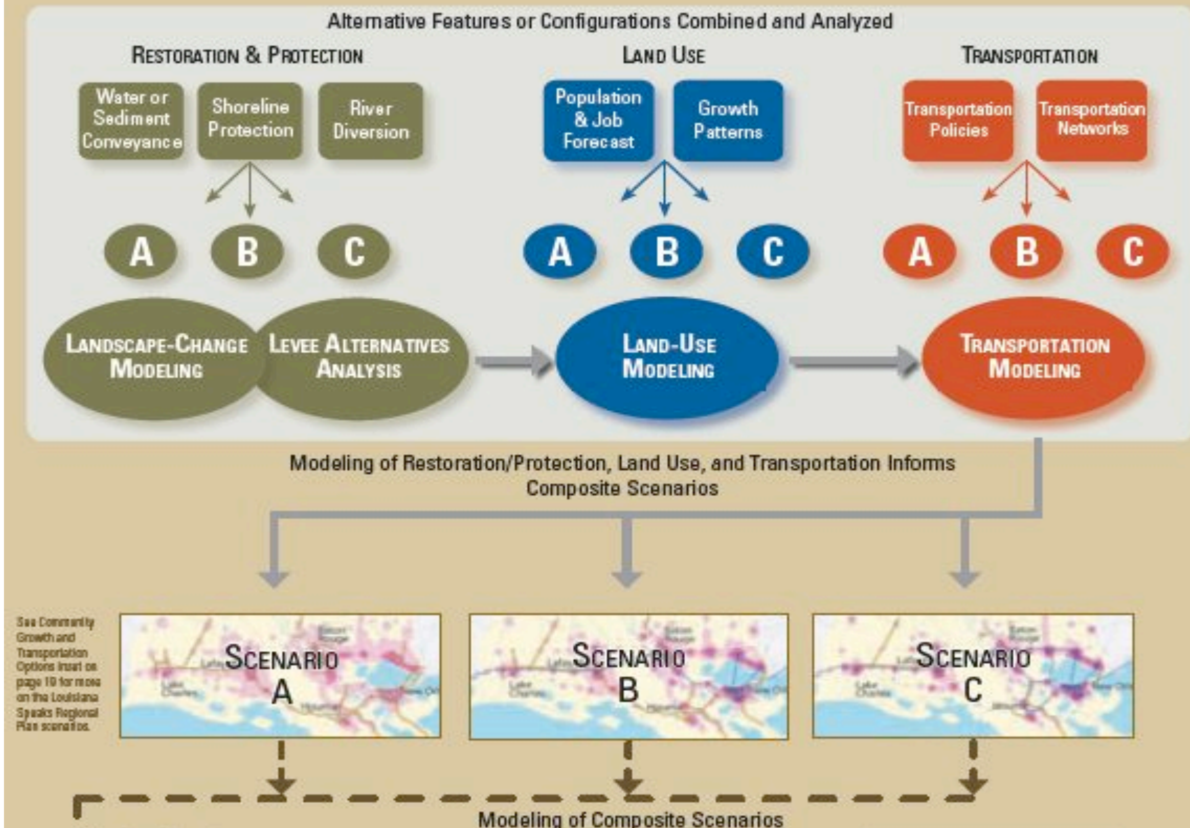


http://www.lacpra.org/

http://www.louisianaspeaks.org/

Modeling Options for the Future

The Louisiana Speaks Regional Planning process utilized computer modeling to test the effects of different land-use, transportation, storm protection, and restoration scenarios for a variety of safety, livability, and transportation indicators. A series of scenarios represent possible futures based on historic patterns, emerging trends, and different policy directions. The following diagram shows some of the key variables and technical models used to develop the scenarios and their modeled consequences. Please see Appendix B for more information on the modeling process.



Indicators

Indicators measure the impacts or consequences of an option. Examples include area of wetland gain or loss, mix of new housing types, commute times, open land developed, new development in floodplains, or the cost of building a new transportation system. The Louisiana Speaks Regional Plan utilized these indicators to compare future options, querying the preferences of Louisiana residents in the 2007 Regional Vision Poll. Louisiana Speaks Regional Plan options and trade-offs are described in further detail in this section.

Sample Indicators

Open Land Developed	*Commute Time*	*Highway Congestion*	*Wetland Gain & Loss*
New Development in Floodplain	*Housing Mix*	*Transit Ridership*	*Infrastructure Costs*
	Annual Household Expenses	*Automobile Emissions*	*Housing Density*

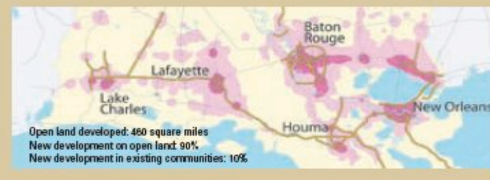
Community Growth and Transportation Options for South Louisiana

The Louisiana Speaks Regional Vision Poll asked citizens to choose one of the following as the best future for the next generation. Each option accommodates the same number of projected people and jobs from December 2005 to the year 2050 (1.7 million new people and 1.3 million jobs). Option A develops the most new land, while Options B and C develop less by placing some developme within existing communities, often at higher densities.

Legend: Low Density | Medium Density | High Density | Regional Road Improvements | Regional Transit

A. Keep Building and Developing as We Are

Currently we build mostly single-family homes, mainly at the edge of metropolitan areas, connected by roadways.



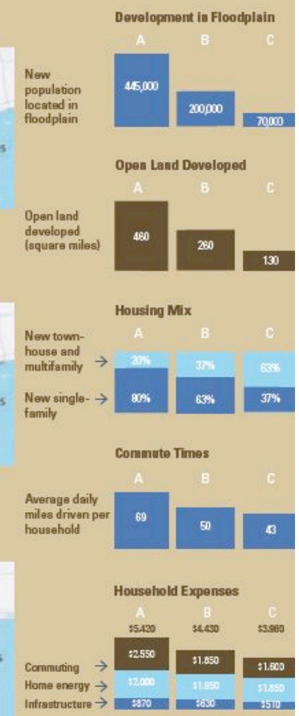
B. Modify Development Patterns

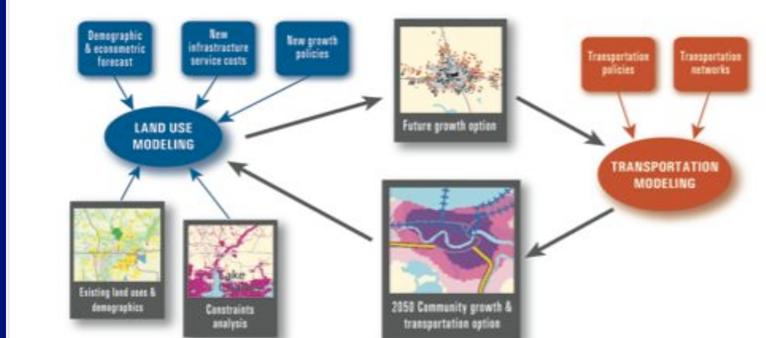
Build more in-town condos, apartments, and townhouses, as well as single-family homes. Balance new public transit with road improvements.

C. Focus Development in Existing Cities and Towns

Build mainly in-town condos, apartments, and townhouses, connected by public transit such as modern buses or commuter and intercity trains.

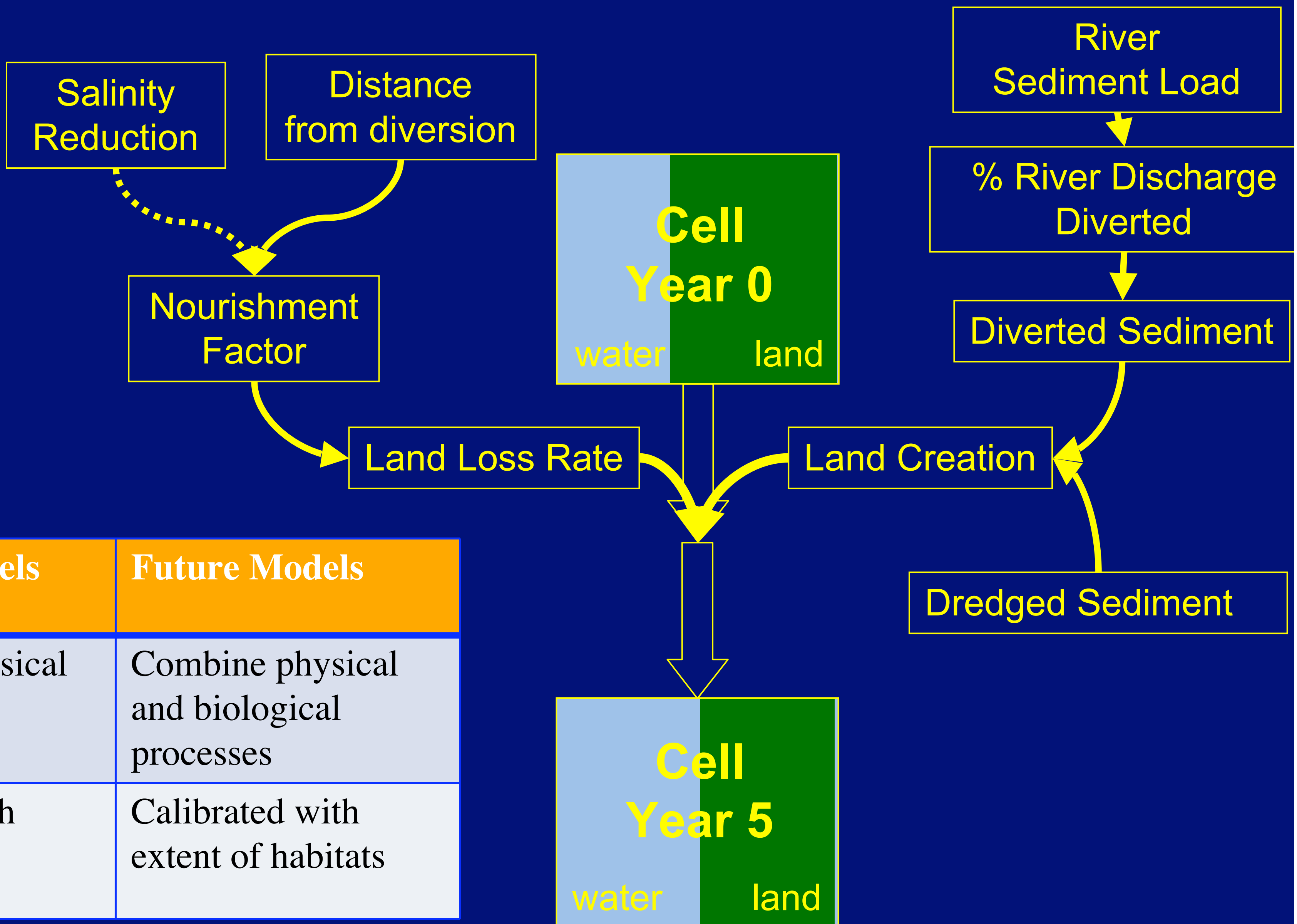
Measuring Consequences





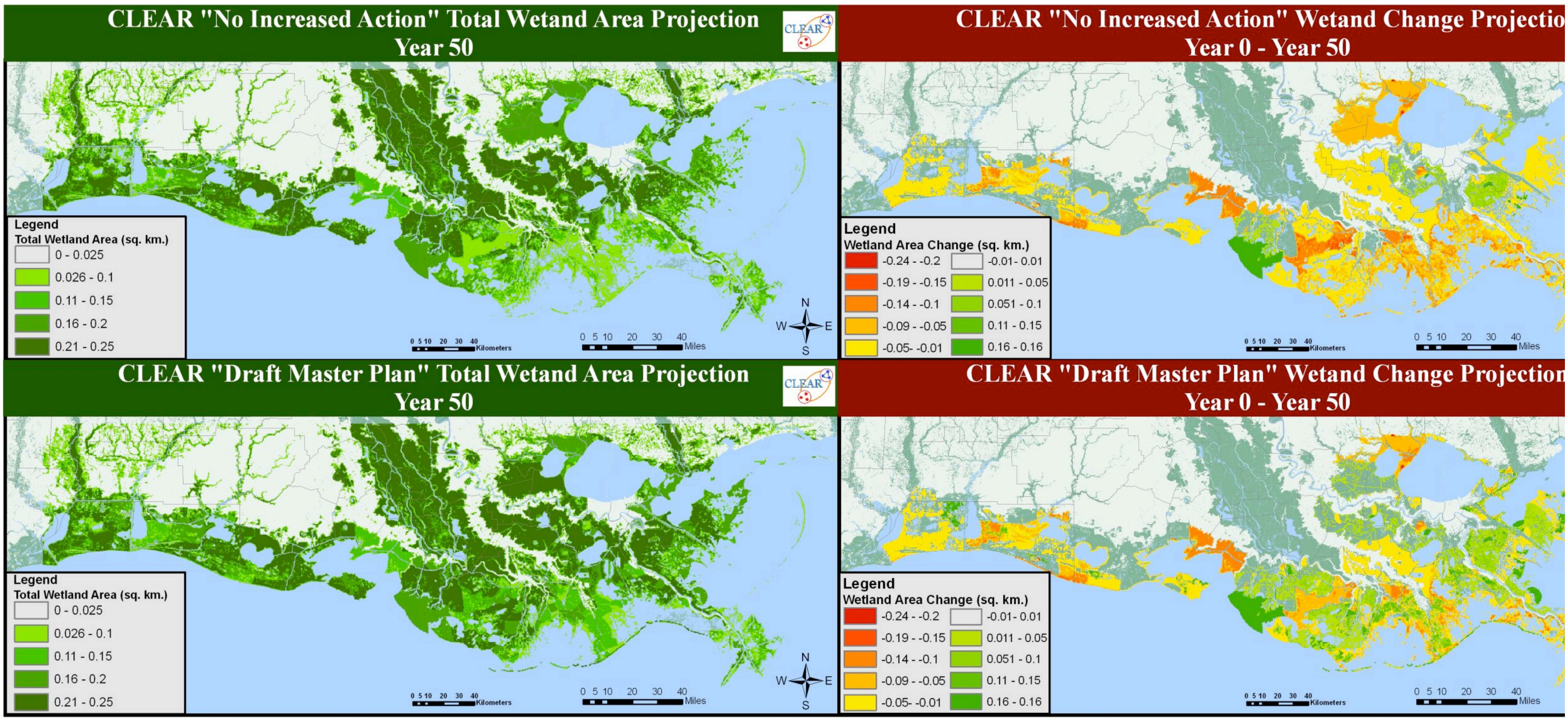
Modeling community growth and transportation options

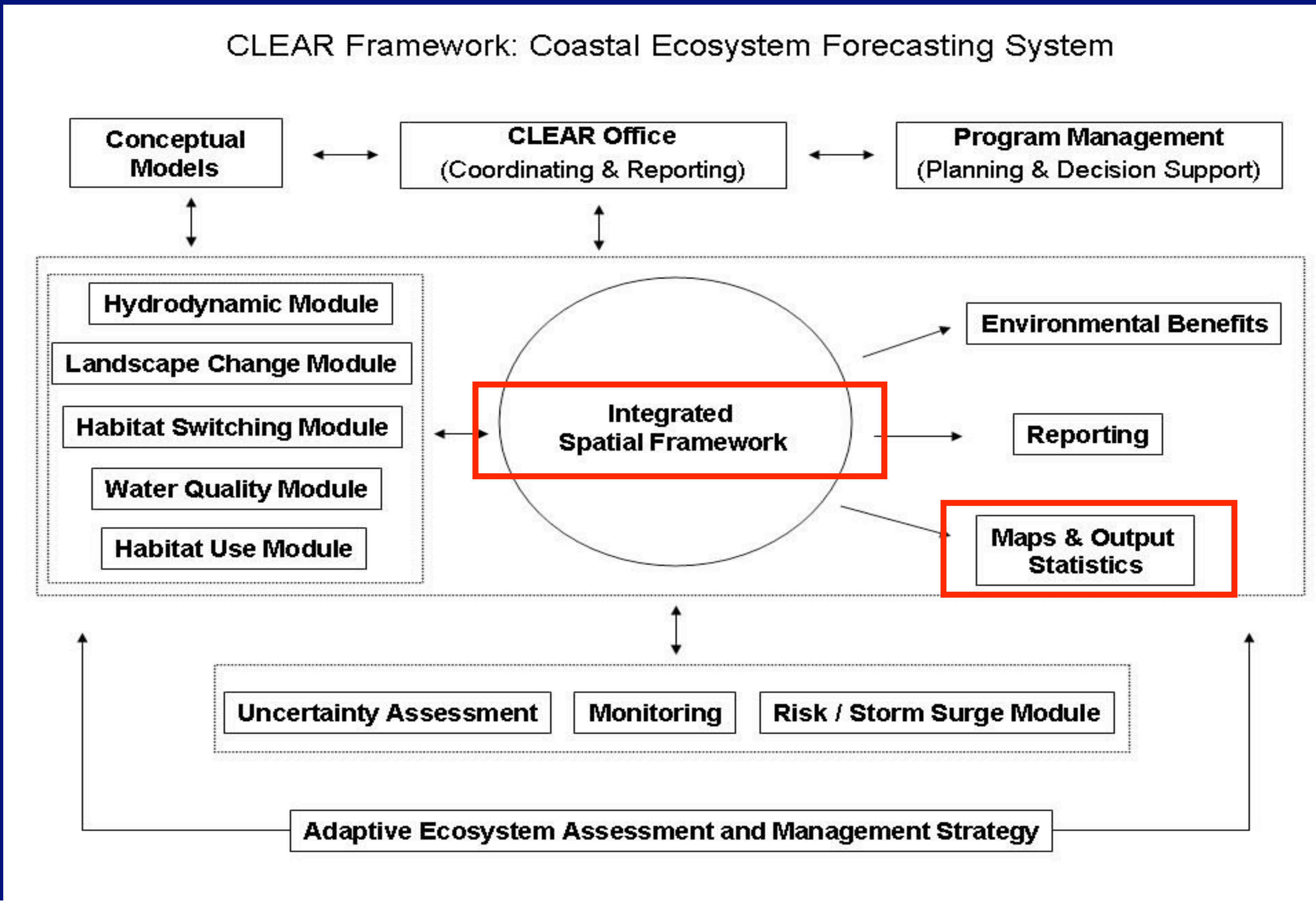
CLEAR Land Change Algorithm



Current Models	Future Models
Driven by physical processes	Combine physical and biological processes
Calibrated with extent of land	Calibrated with extent of habitats

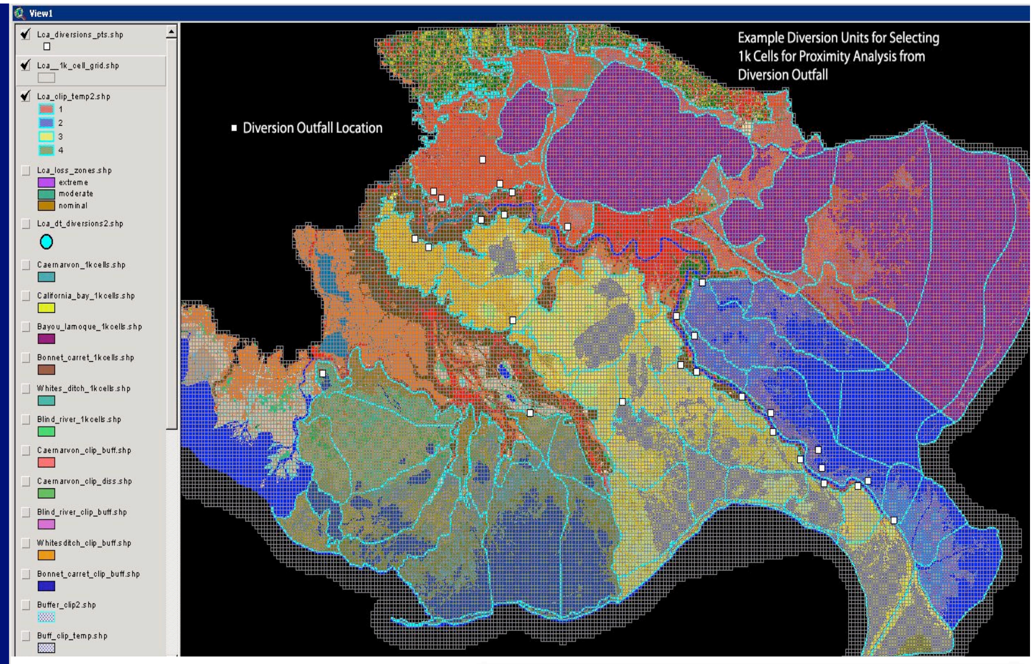
Projections of Landscape Change at Year 50 with restoration plan

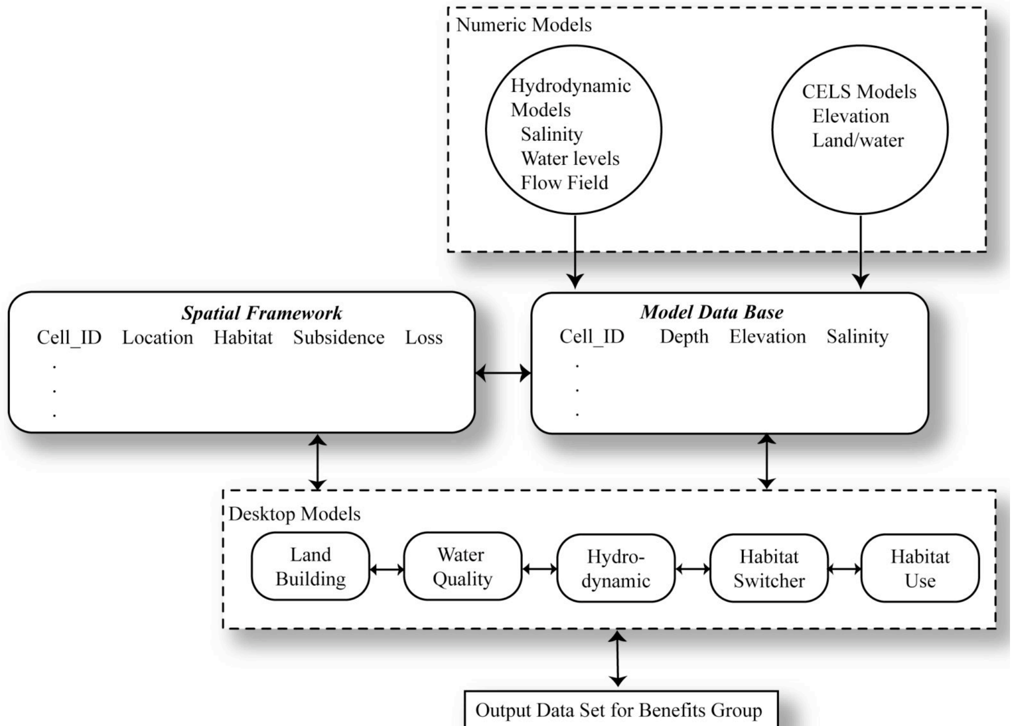



CLEAR Framework: Coastal Ecosystem Forecasting System
Conceptual Models
CLEAR Office (Coordinating & Reporting)
Program Management (Planning & Decision Support)
Hydrodynamic Module
Landscape Change Module
Habitat Switching Module
Water Quality Module
Habitat Use Module
Integrated Spatial Framework
Environmental Benefits
Reporting
Maps & Output Statistics
Uncertainty Assessment
Monitoring
Risk / Storm Surge Module
Adaptive Ecosystem Assessment and Management Strategy

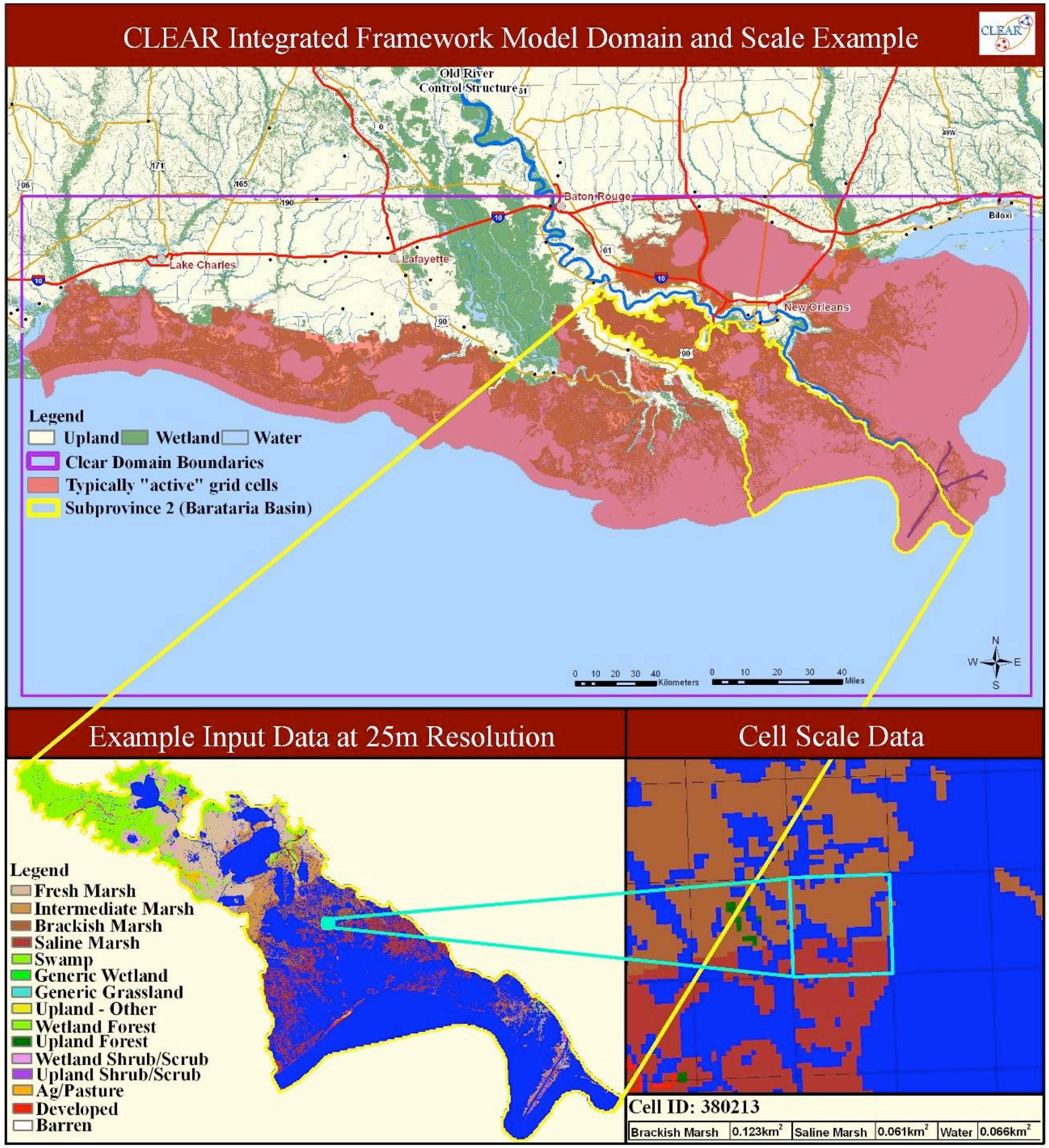
Build a comprehensive data inventory for modeling groups

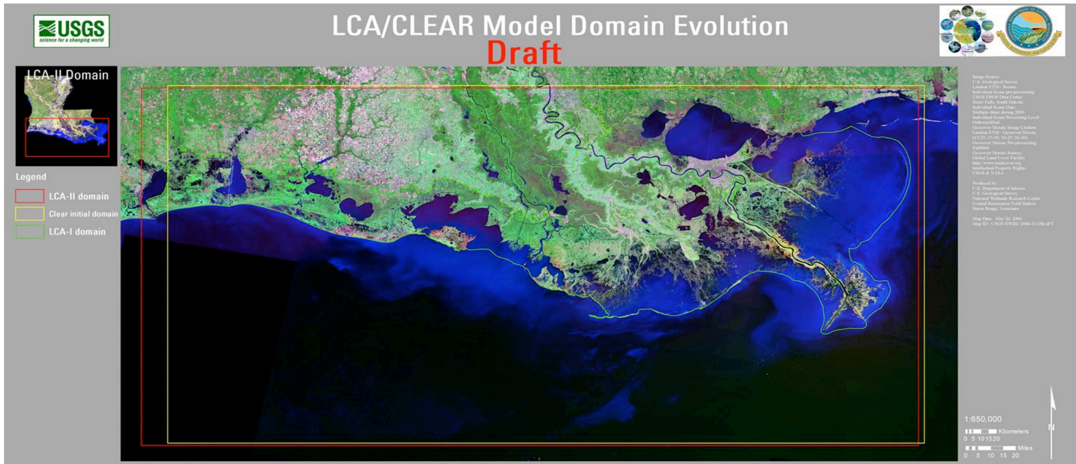
- GIS inventories/DEM;
- CLEAR modeling data in multiple scale resolution;
- Elevation data of landscape; GEOMETRY
- Model output for linked modular models;

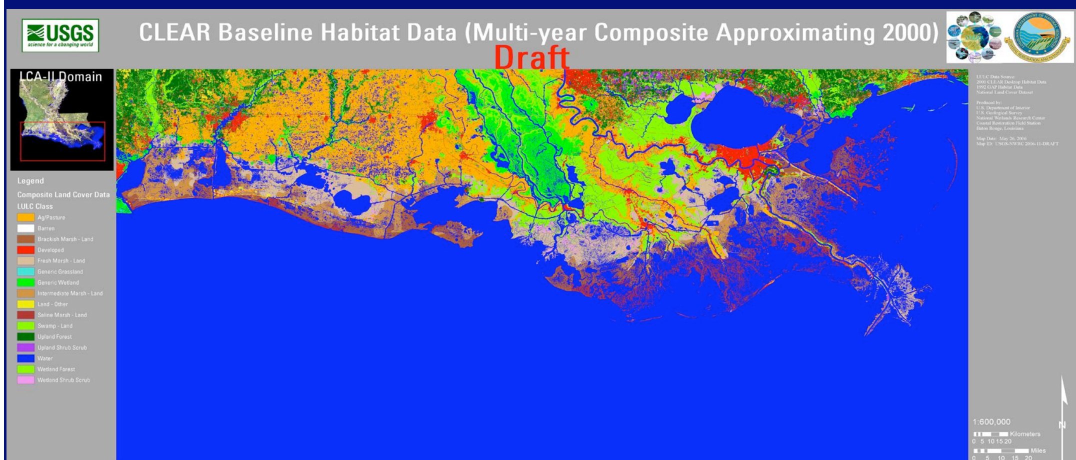


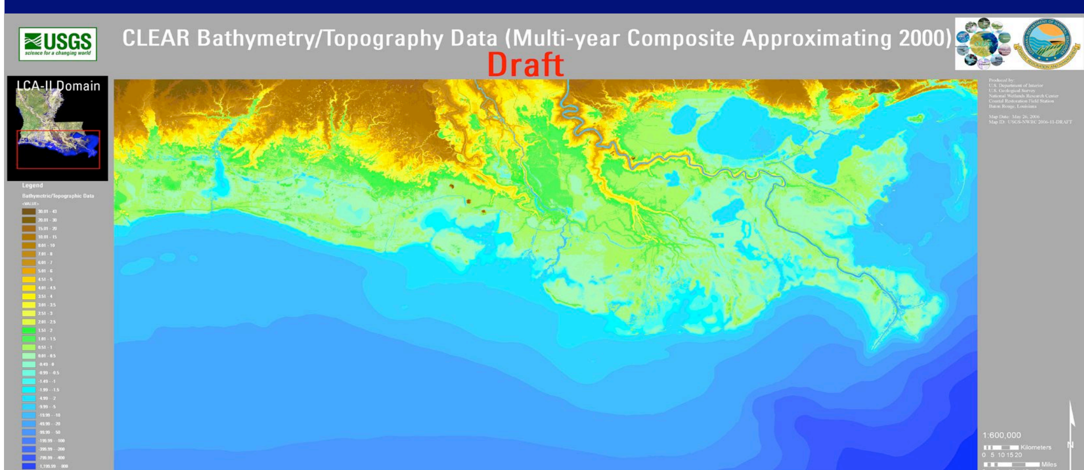


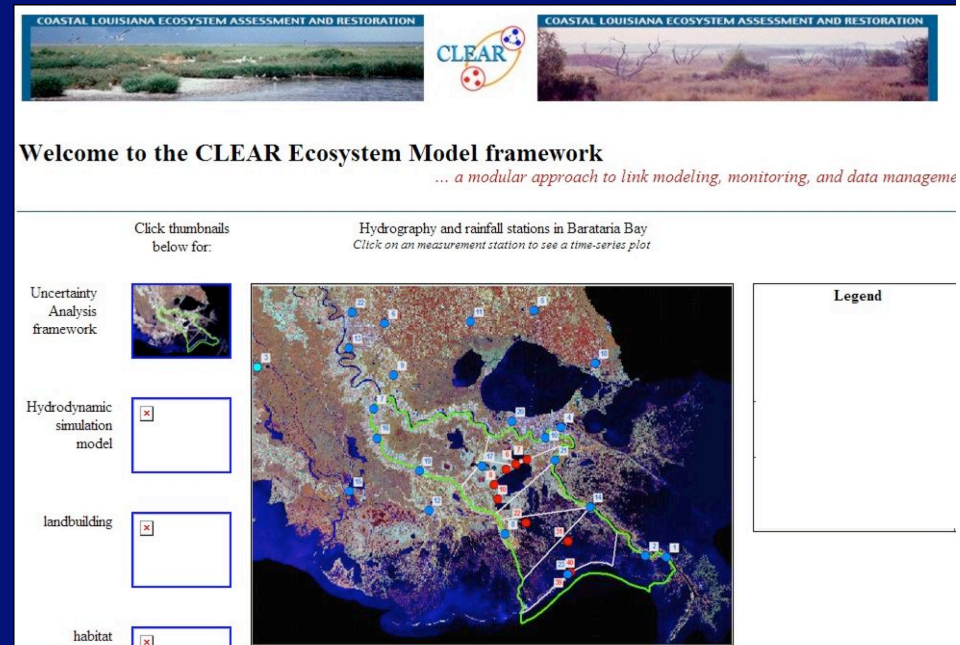
Coastal Processes Modeled (physical, geomorphology, ecological) in 0.25 km2 cells across coastal landscape





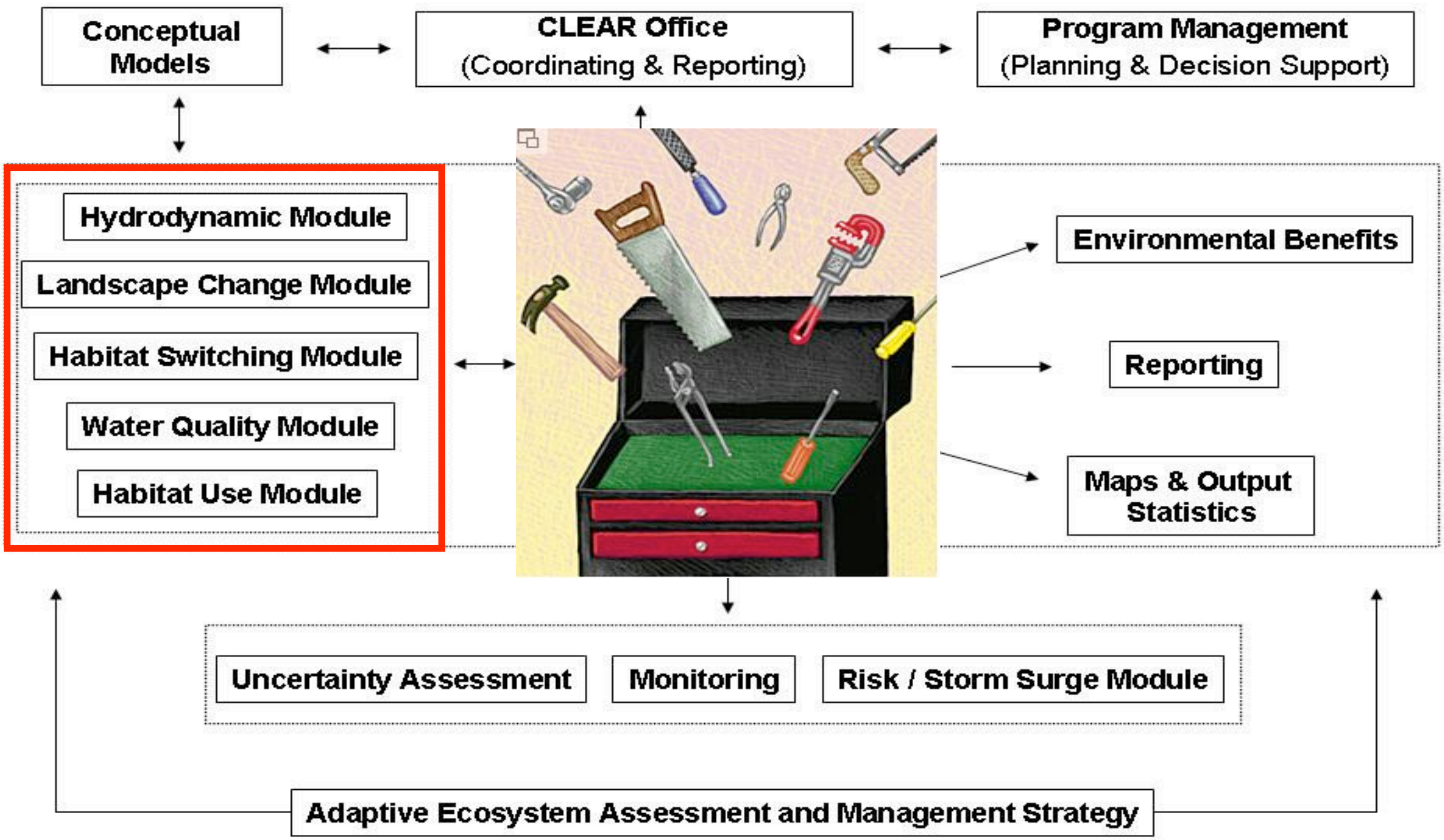






http://maps.clear.lsu.edu/public/data/start/home.html

CLEAR Framework: Coastal Ecosystem Forecasting System



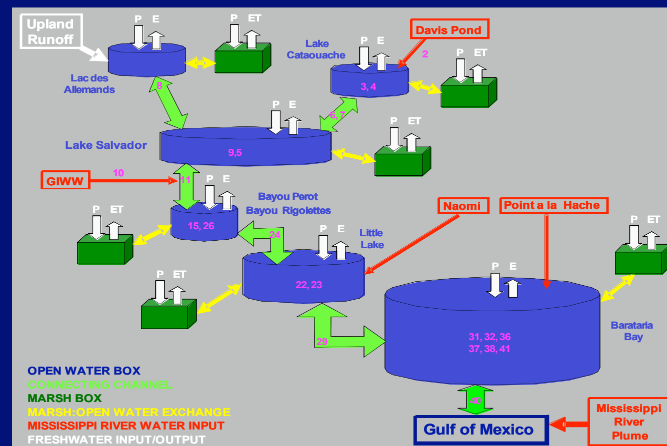
DELTA Ecosystem Forecasting System - Northern Gulf Institute

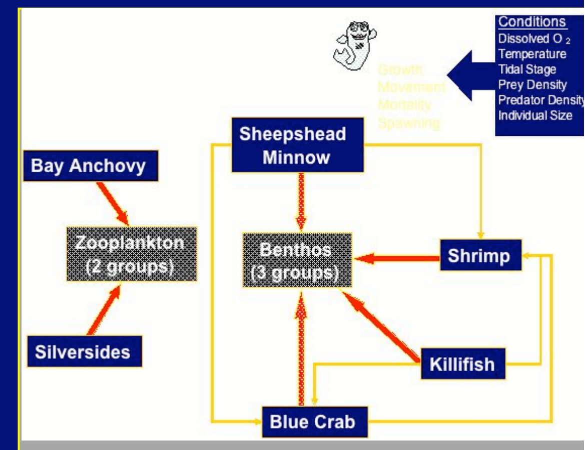
Dubravko Justic, Kenny Rose, Chunyan Li, and Masamichi Inoue
Department of Oceanography and Coastal Sciences, Louisiana State University

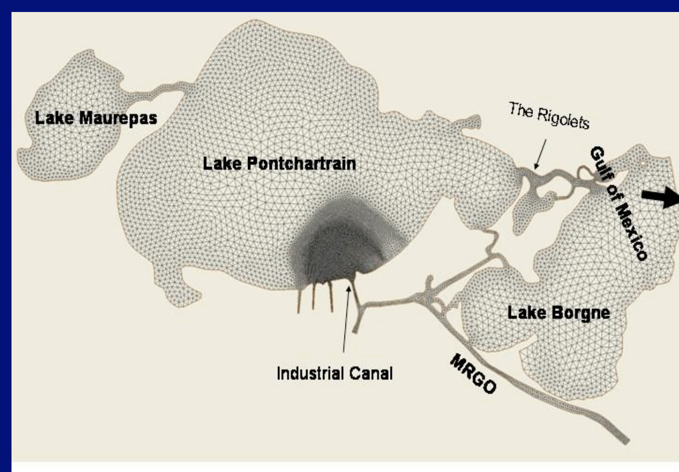
NGI Project File Number: 06-LSU-01

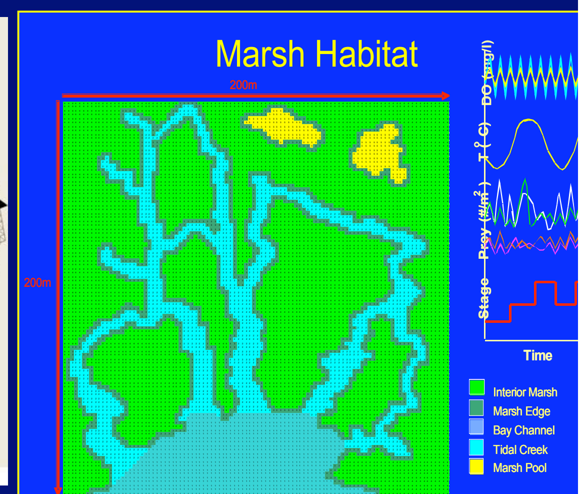
- Our research setting is unique in that we can manipulate the duration and magnitude of water pulses at the landscape scale in two of the coastal basins (Breton Sound and Barataria Basin), and examine biogeochemical and ecological patterns over broad biological, temporal and spatial scales.

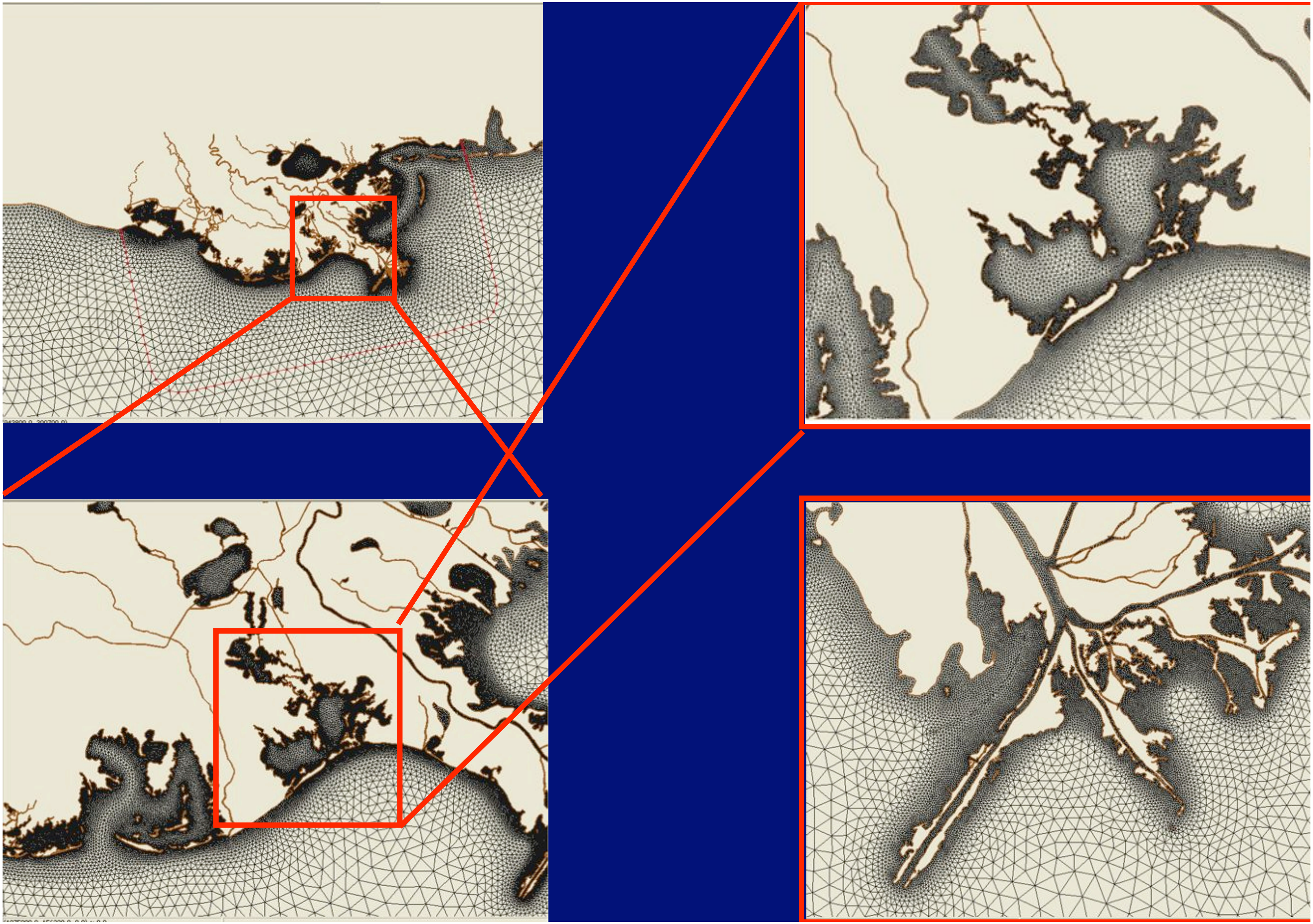
- We will develop and apply a series of linked simulation models that will allow tracking the effects of pulsed freshwater inputs through hydrodynamics, biogeochemical cycling, primary production, zooplankton dynamics, fish growth, and landscape dynamics.







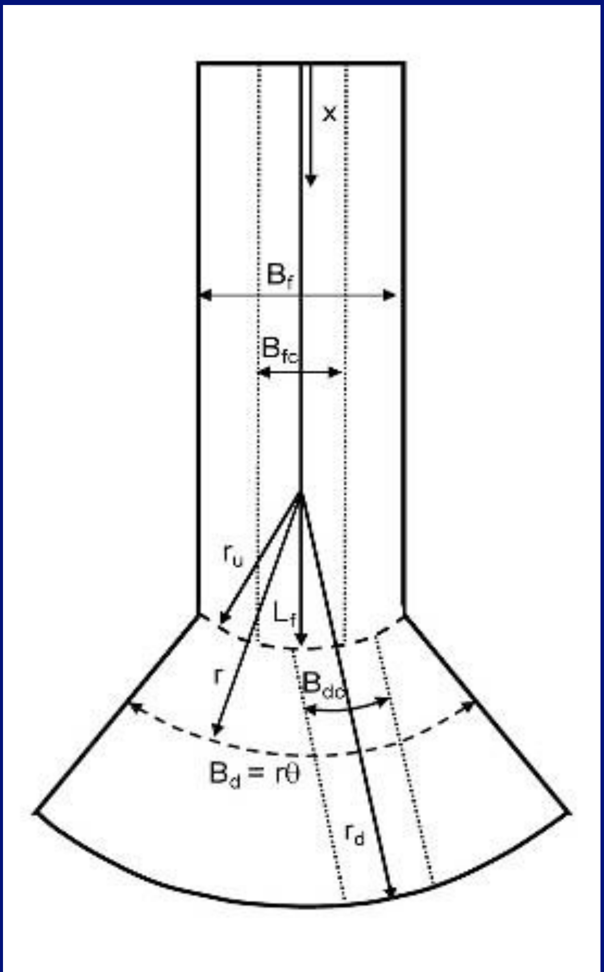


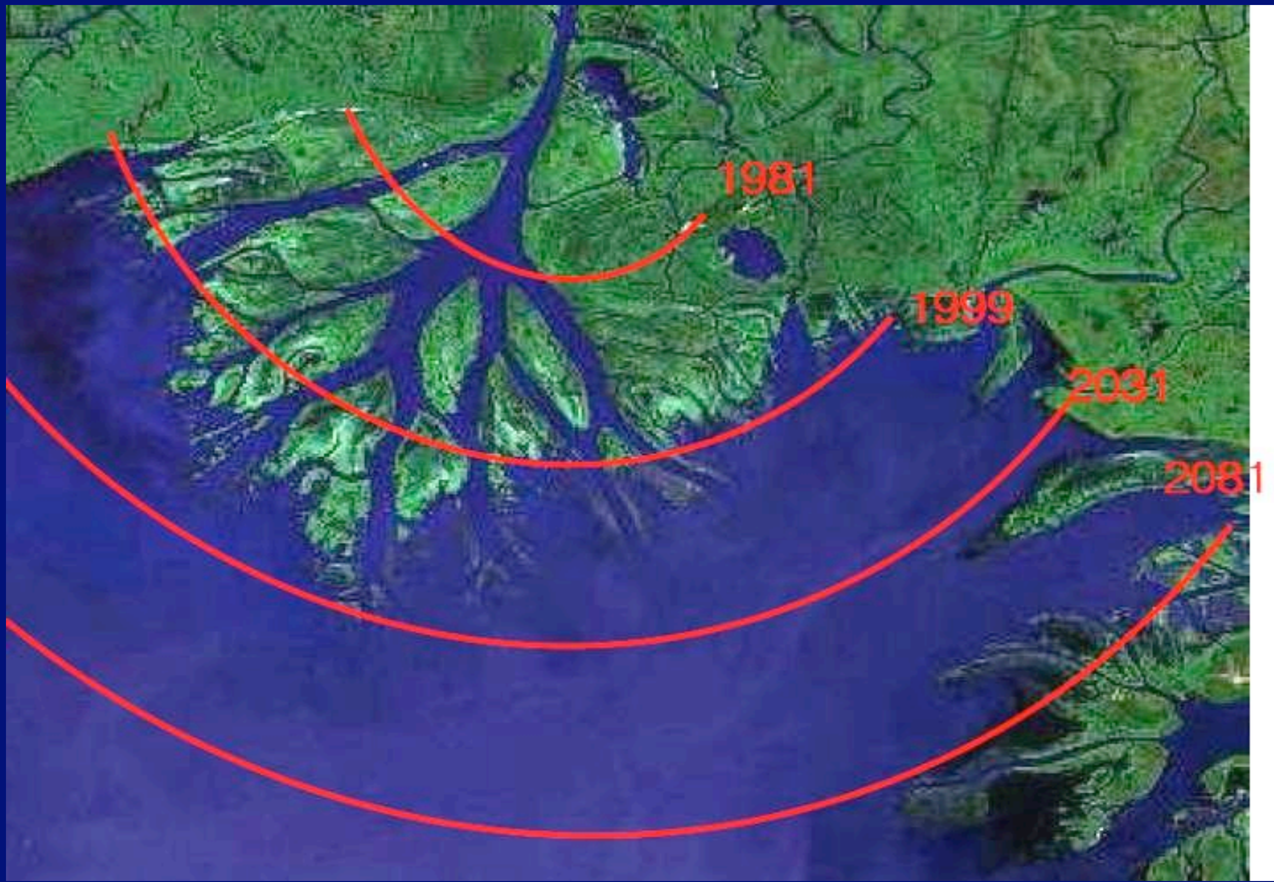


NATIONAL CENTER FOR EARTH-SURFACE DYNAMICS

A NATIONAL SCIENCE FOUNDATION SCIENCE & TECHNOLOGY CENTER

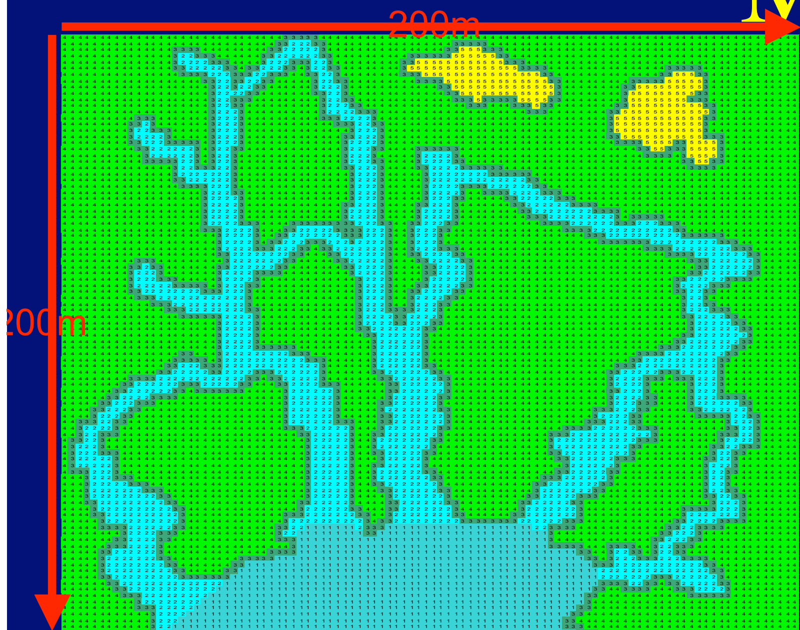
MORPHODYNAMIC MODEL - WAX LAKE DELTA



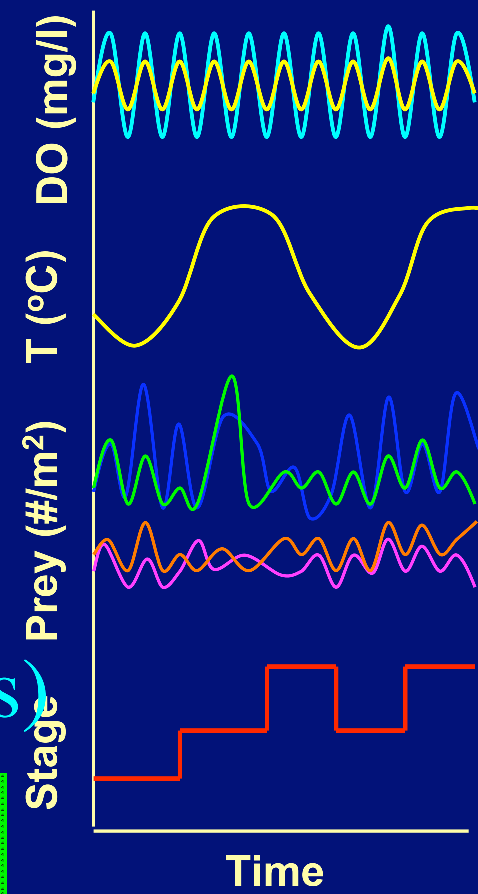


PROJECTION FOR WAX LAKE DELTA FRONT TO 2081

Marsh Habitat



Spatially-Explicit Design and Analysis for Simulating Individual-Level Processes within a Tidal Marsh Community

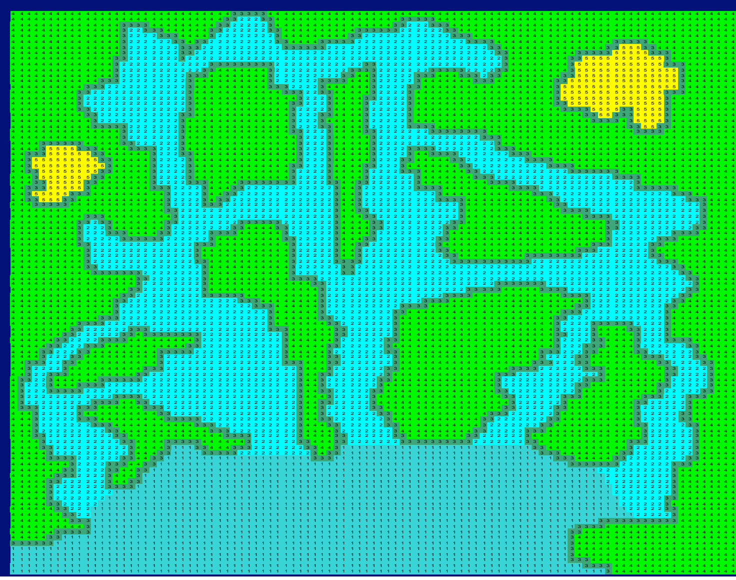


LINK WITH ECOSIM (Carl Walters)

S.E. Sable and K. A. Rose

Department of Oceanography and Coastal Sciences

Louisiana State University



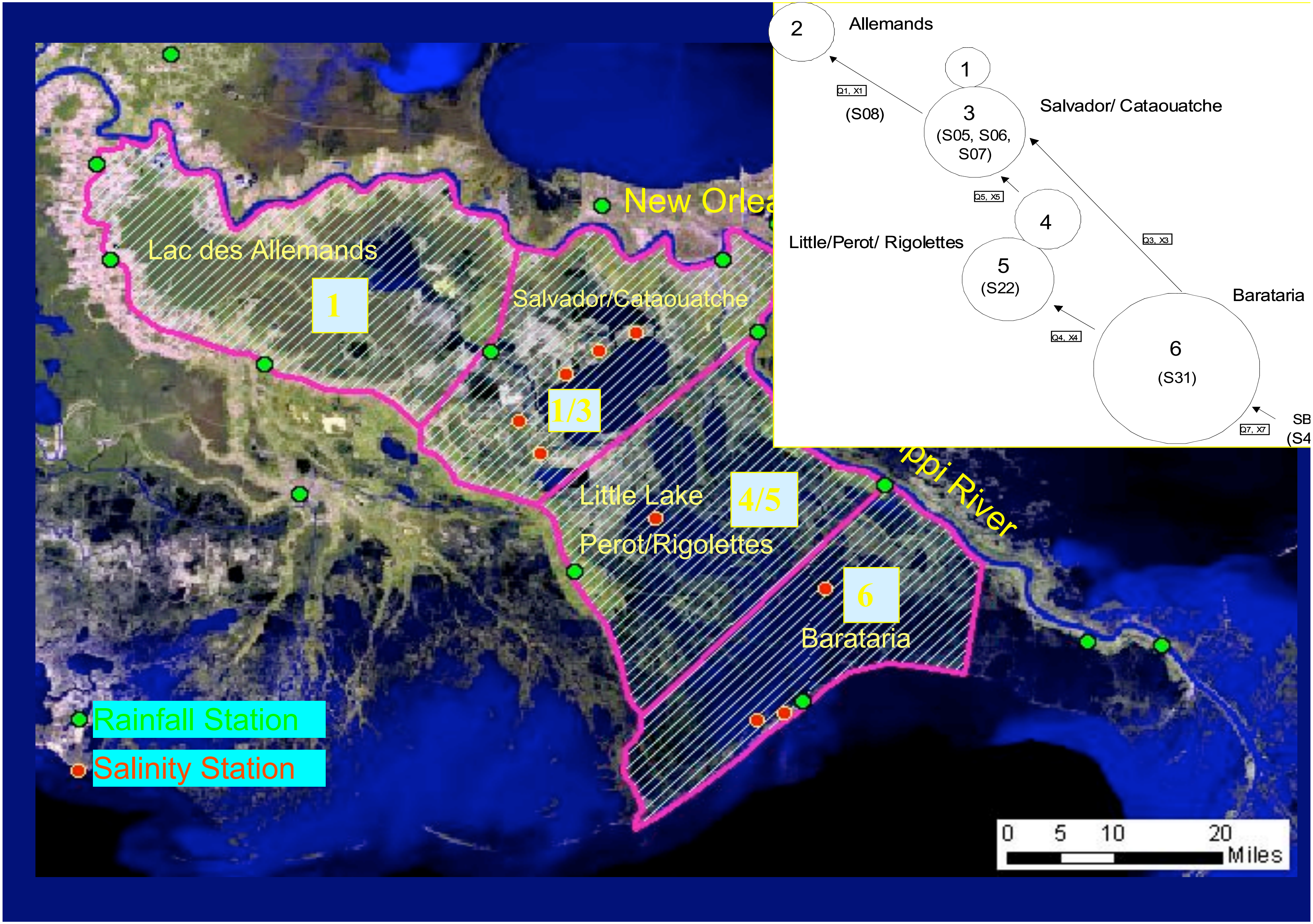
- Interior Marsh
- Marsh Edge
- Bay Channel
- Tidal Creek
- Marsh Pool

Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) Research Facility: Ecosystem Forecasting System Using Barataria Basin as Test Domain

Task 3.5: Box Model/ Water Quality Development

Dubravko Justic[1,2], William Nuttle[3], Erick Swenson[1], Victor Rivera-Monroy[4]
Srikanth Singam[1] and Anindita Das[2]

1 - Coastal Ecology Institute, LSU
2 - Department of Oceanography and Coastal Sciences, LSU
3 – Consultant
4 - Wetland Biogeochemistry Institute, LSU



2
Allemands
1
3
(S05, S06, S07)
Salvador/ Cataouatche
Q1, X1
(S08)
Q5, X5
4
Little/Perot/ Rigolettes
5
(S22)
Q3, X3
Barataria
Q4, X4
6
(S31)
Q7, X7
SB
(S4
New Orlea
Lac des Allemands
1
Salvador/Cataouatche
1/3
Little Lake
4/5
Perot/Rigolettes
ppi River
6
Barataria
Rainfall Station
Salinity Station
0 5 10 20
Miles

Physical and Numerical Modeling of River and Sediment Diversions in the Lower Mississippi River Delta

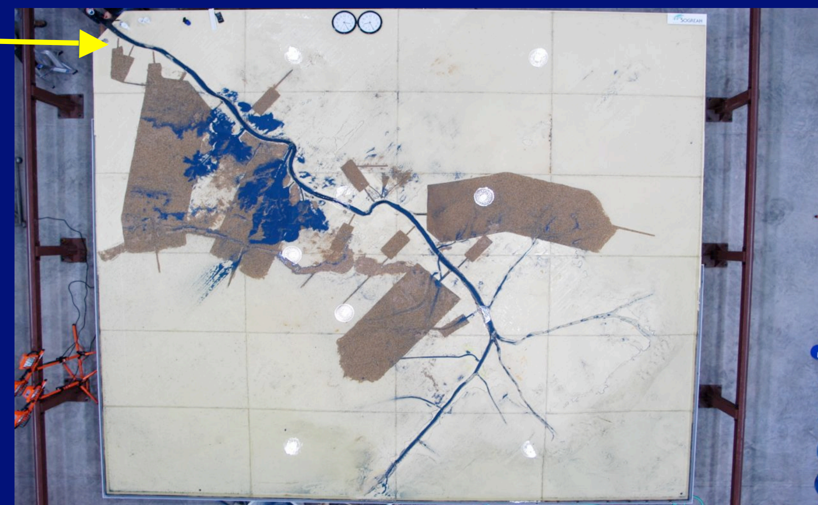
LSU, Department of Civil & Environmental Engineering

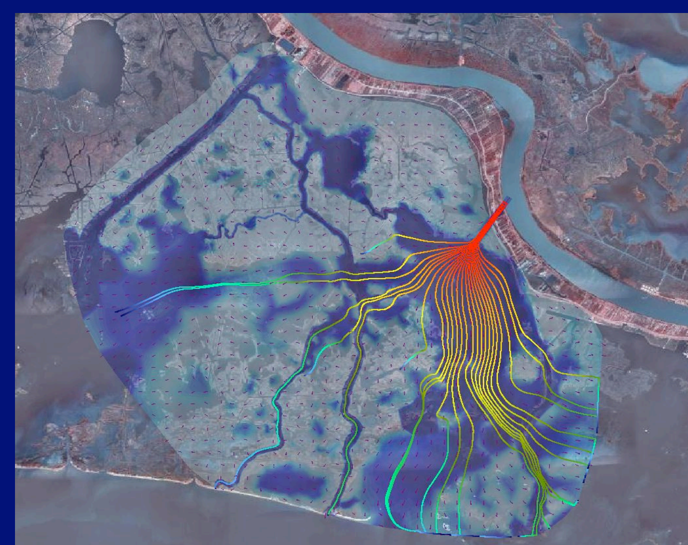
PI: Clinton S. Willson, Ph.D., P.E.

Vincent A. Forte Coastal and River Engineering Research Laboratory

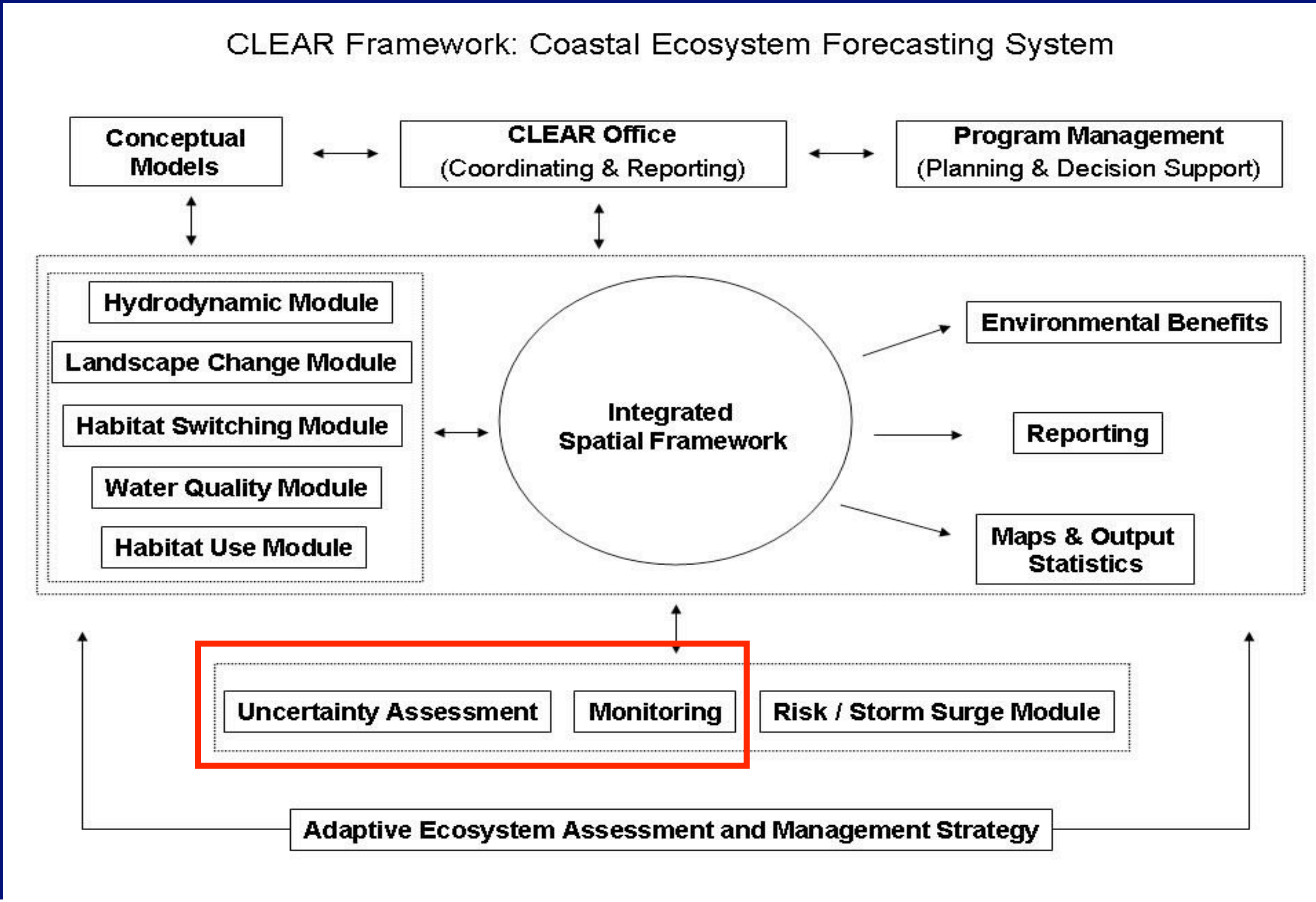
Physical and Numerical Modeling - complimentary tools

Pointe-a-la-Hache

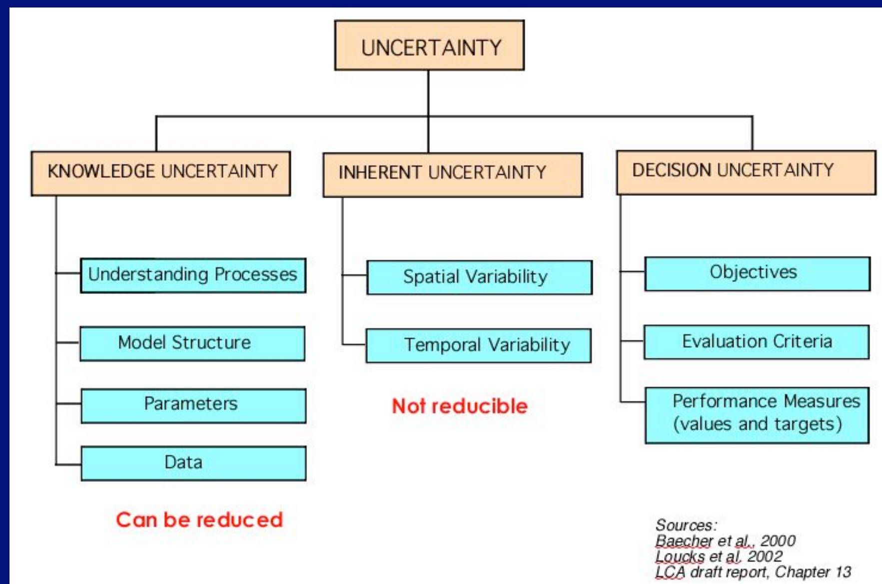


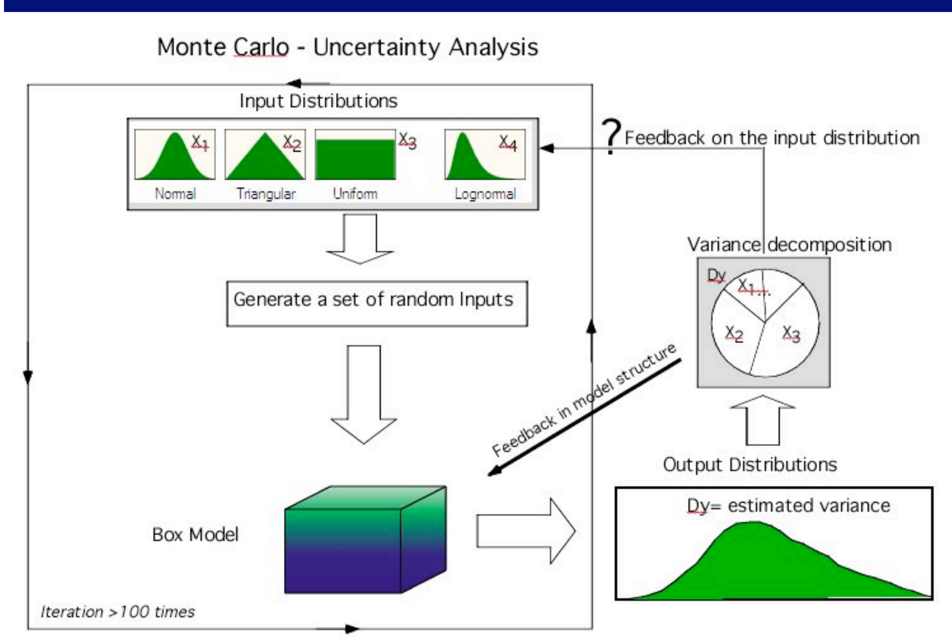


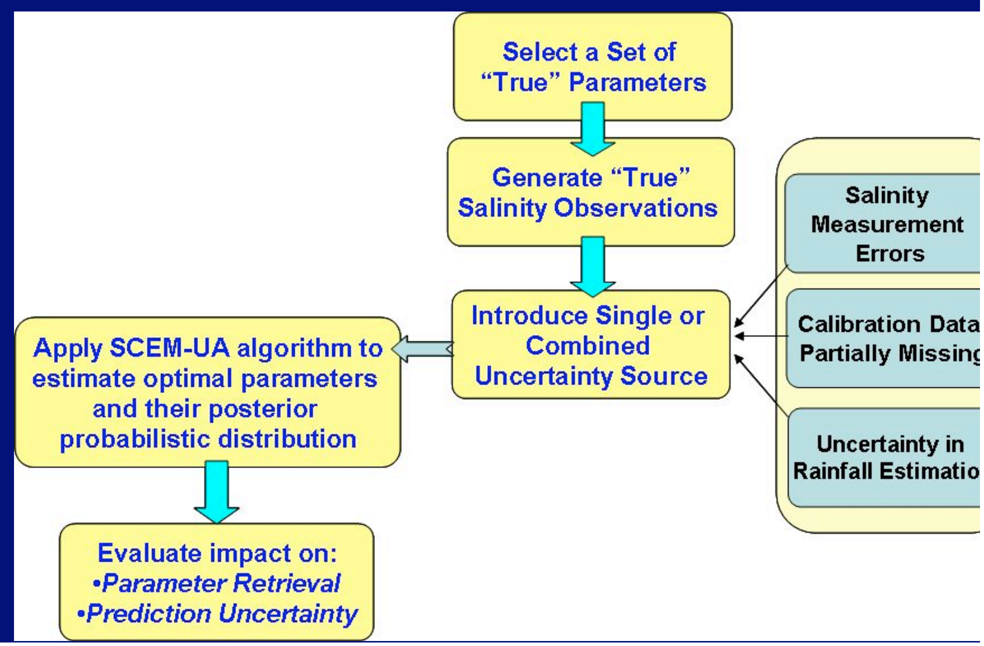
Empire (hypothetical diversion)


CLEAR Framework: Coastal Ecosystem Forecasting System
Conceptual Models
CLEAR Office
(Coordinating & Reporting)
Program Management
(Planning & Decision Support)
Hydrodynamic Module
Landscape Change Module
Habitat Switching Module
Water Quality Module
Habitat Use Module
Integrated Spatial Framework
Environmental Benefits
Reporting
Maps & Output Statistics
Uncertainty Assessment
Monitoring
Risk / Storm Surge Module
Adaptive Ecosystem Assessment and Management Strategy

Uncertainty Analysis of the CLEAR Model







HYDROL 16022
24 December 2007 Disk Used
ARTICLE IN PRESS
No. of Pages 12, Model 6+
Journal of Hydrology (2007) xxx, xxx–xxx

available at www.sciencedirect.com
ScienceDirect
journal homepage: www.elsevier.com/locate/jhydrol

Effect of rainfall spatial variability and sampling on salinity prediction in an estuarine system

Emad Habib [a,*], Boone F. Larson [a], William K. Nuttle [b], Victor H. Rivera-Monroy [c], Brian R. Nelson [d], Ehab A. Meselhe [a], Robert R. Twilley [c]

[a] Center for Louisiana Water Studies, Institute of Coastal Ecology and Engineering, and Department of Civil Engineering, University of Louisiana at Lafayette, P.O. Box 42991, Lafayette, LA 70504, USA
[b] Eco-Hydrology, 11 Craig Street, Ottawa, Ontario, Canada K1S 4B6
[c] Department of Oceanography and Coastal Sciences, Wetland Biogeochemistry Institute, Louisiana State University, Baton Rouge, LA 70803, USA
[d] NOAA National Climatic Data Center, 151 Patton Avenue, Asheville, NC 28801, USA

Received 25 May 2007; received in revised form 20 November 2007; accepted 22 November 2007

KEYWORDS
Salinity modeling;
Rainfall sampling;
Spatial variability;
Uncertainty;
NEXRAD;
Estuary;
Louisiana

Summary Reliable and accurate forecasts of salinity changes are essential for the success of current and future management scenarios aimed at restoring and sustaining natural resources of coastal and estuarine ecosystems. Because of the physical complexity of such ecosystems, information on uncertainty associated with salinity forecasts should be assessed and incorporated into management and restoration decisions. This study focuses on the impact of spatial variability and limited sampling of rainfall on salinity prediction in an estuarine system. The analysis is conducted on the Barataria basin, which is a wetland-dominated estuarine system located directly west of the Mississippi Delta complex on the United States coast of south Louisiana. The basin has been experiencing significant losses of wetland at a rate of nearly 23 km^2/year. Radar-rainfall data with high spatial resolution are used to simulate various scenarios of hypothetical rain gauge sampling densities over the basin. A mass-balance hydrologic salinity model is used to assess the effect of reduced rainfall sampling on salinity prediction in the basin. The results indicated that, due to the critical role played by rainfall in determining the overall balance of the basin freshwater budget, a high degree of uncertainty exists in salinity predictions when using typical average rain gauge densities (e.g., 1.3 gauges/1000 km^2 in the US). These uncertainties decline sharply as the number of available gauges is increased beyond the typically available density. Uncertainties in salinity predictions in the Barataria basin are larger in inland locations and smaller near the mouth of the basin, where salinity conditions in the coastal waters of the Gulf of Mexico exert a large influence. Rainfall uncertainties also affected parameter estimation during model calibration, where the estimation of some parameters

* Corresponding author. Tel.: +1 337 482 0638; fax: +1 337 482 6688.
E-mail address: habib@louisiana.edu (E. Habib).

0022-1694/$ - see front matter © 2007 Published by Elsevier B.V.
doi:10.1016/j.jhydrol.2007.11.034

Please cite this article in press as: Habib, E. et al., Effect of rainfall spatial variability and sampling on salinity prediction in an estuarine system, J. Hydrol. (2007), doi:10.1016/j.jhydrol.2007.11.034

Journal of Coastal Research	23	3	749–763	West Palm Beach, Florida	May 2007

Assessing Effects of Data Limitations on Salinity Forecasting in Barataria Basin, Louisiana, with a Bayesian Analysis

Emad Habib[†], William K. Nuttle[‡], Victor H. Rivera-Monroy[§], Shankar Gautam[†], Jing Wang[††], Ehab Meselhe and Robert R. Twilley[§]

[†]Department of Civil Engineering
University of Louisiana at Lafayette
Lafayette, LA, 70504, U.S.A.

[‡]Eco-Hydrology
11 Craig Street
Ottawa, ON K1S 4B6, Canada

[§]Department of Oceanography and Coastal Sciences
Wetland Biogeochemistry Institute
Louisiana State University
Baton Rouge, LA 70803, U.S.A.

[††]Department of Experimental Statistics
Louisiana State University
Baton Rouge, LA 70803, U.S.A.

ABSTRACT

HABIB, E.; NUTTLE, W.K.; RIVERA-MONROY, V.H.; GAUTAM, S.; WANG, J.; MESELHE, E., and TWILLEY, R.R 2007. Assessing effects of data limitations on salinity forecasting in Barataria basin, Louisiana, with a Bayesi analysis. *Journal of Coastal Research*, 23(3), 749–763. West Palm Beach (Florida), ISSN 0749-0208.

Reliable forecasts of salinity changes are essential for restoring and sustaining natural resources of estuaries ar coastal ecosystems. Because of the physical complexity of such ecosystems, information on uncertainty associated wi salinity forecasts should be assessed and incorporated into management and restoration decisions. The objective this study was to investigate uncertainty in salinity forecasts imposed by limitations on data available to calibra and apply a mass balance salinity model in the Barataria basin, Louisiana. The basin is an estuarine wetlan dominated ecosystem located directly west of the Mississippi Delta complex. The basin has been experiencing signi icant losses of wetland at a rate of nearly 23 km^2/y. A Bayesian-based methodology was applied to study the effect data-related uncertainty on both the retrieval of model parameters and the subsequent model predictions. We focus on uncertainty caused by limited sampling and coverage of salinity calibration data and by sparse rain gauge da within the basin. The results indicated that data limitations lead to significant uncertainty in the identification model parameters, causing moderate to large systematic and random errors in model results. The most significa effect was related to lack of accurate information on rainfall, a major source of fresh water in the basin. The approa and results of this study can be used to identify necessary improvements in monitoring of complex estuarine syste that can decrease forecast uncertainty and allow managers greater accuracy in planning restoration of coastal r sources.

ADDITIONAL INDEX WORDS: *Uncertainty analysis, Barataria basin, coastal Louisiana, rainfall sampling, mod calibration, parametric uncertainty, salinity, restoration.*

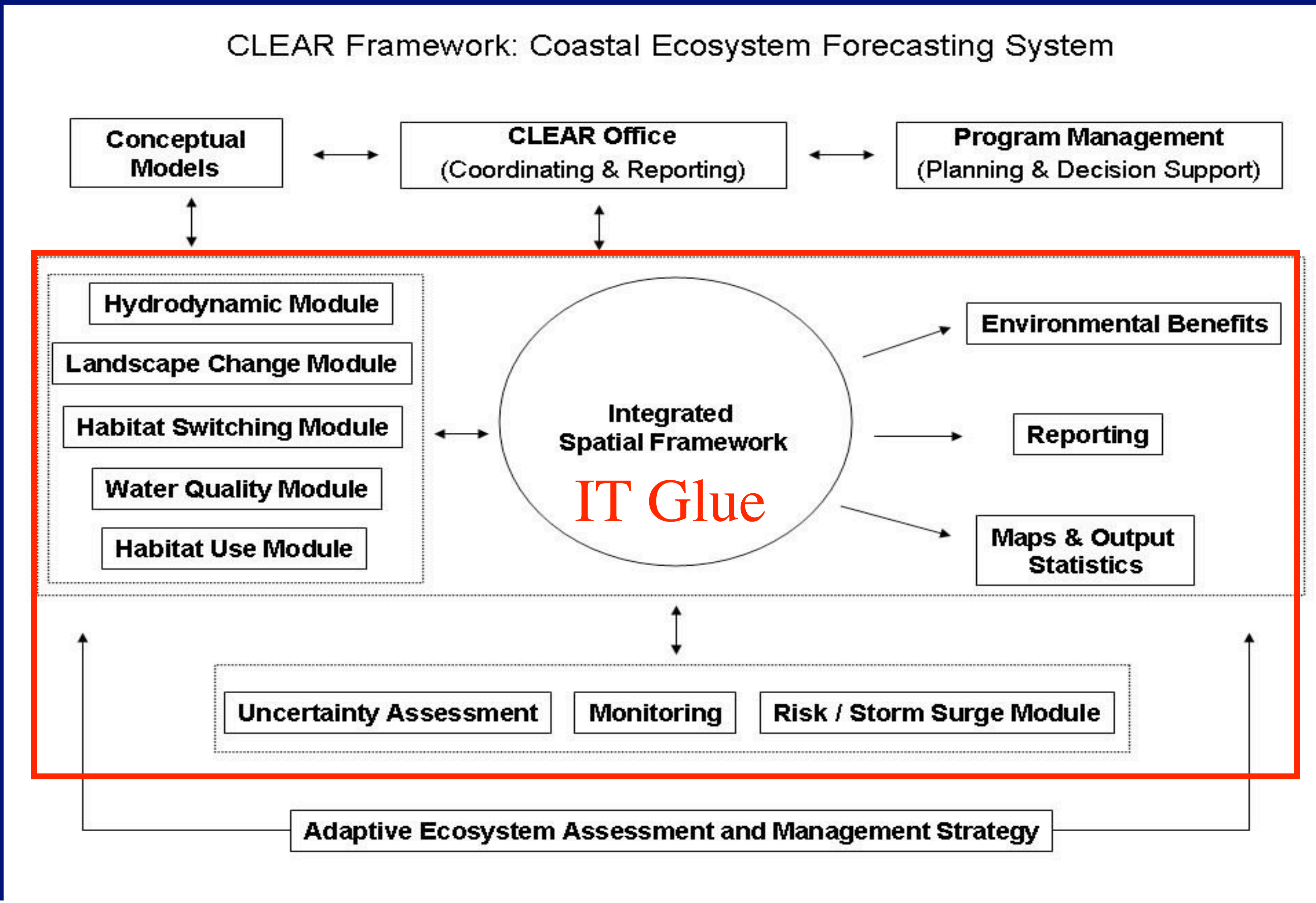
INTRODUCTION

Ecological forecast models play a central role in restoring and sustaining natural resources of estuaries and coastal waters. Ecological forecasts provide quantitative information that managers need to evaluate risks and benefits anticipated from different ecological trajectories and their associated management scenarios (SIMENSTAD, REED, and FORD, 2006). Risk and benefit calculations might be based on ecological performance measures (THOM, 2000) or, as is likely in the wake of hurricanes Katrina and Rita, they might be based on mitigating future losses from coastal flooding (HOUCK, 2006). In any case, managers need information on the uncertainty in the forecasts so that they can judge whether the risks and benefits presented by one trajectory differ significantly from those of another trajectory. The underlying question is whether different approaches to restoring coastal resources will have significantly different results.

Uncertainty that arises in making ecological forecasts fall into the category of "knowledge uncertainty," which is one three general categories of uncertainty that resource ma agers must take into consideration (ENGELUND, XU, an GOTTSCHALK, 2005; LALL *et al.*, 2002; NRC 2002; REF GAARD and STORM, 1996). Other categories are the "inhere uncertainty" that arises from the variability of processes nature and the "decision uncertainty" that is related to u derstanding management goals and the scope of activities r quired to achieve these goals. Ecological forecasting capab ities are limited by factors such as incomplete understandi of the processes involved, inaccuracies in model formulatio and inadequate or erroneous information needed to apply t models (*i.e.*, input and calibration data, and values of mod parameters).

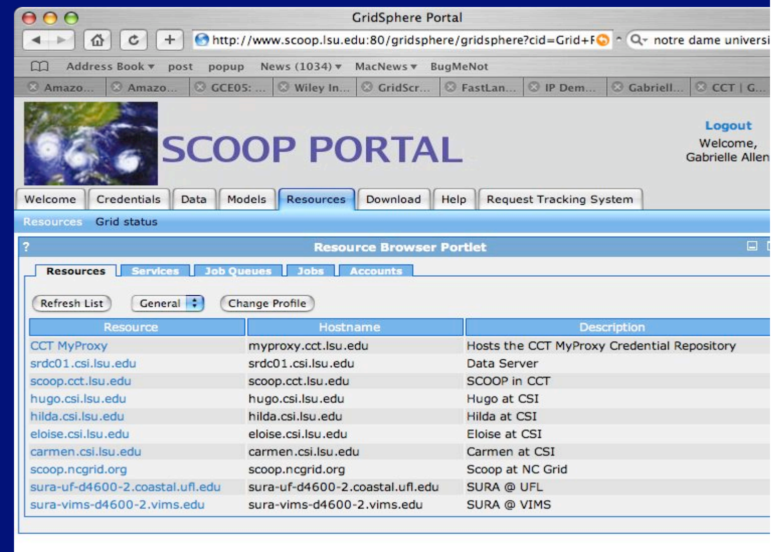
Salinity is an essential characteristic of estuarine an coastal ecosystems, and often, changes in salinity constitu a link in the chain of cause and effect that connects activiti in upstream watersheds to ecological effects along the coas In coastal Louisiana, the salinity of surface waters is reco nized as a primary factor in the productivity of coastal fis eries (*e.g.*, TURNER, 2006) and in determining the extent an

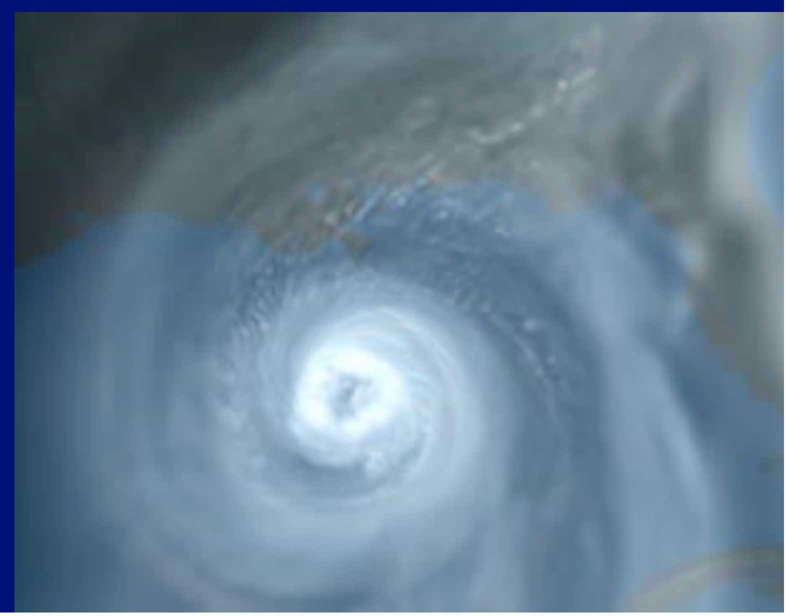
DOI: 10.2112/06-0723.1 received 12 July 2006; accepted in revision 14 September 2006.


CLEAR Framework: Coastal Ecosystem Forecasting System
Conceptual Models
CLEAR Office
(Coordinating & Reporting)
Program Management
(Planning & Decision Support)
Hydrodynamic Module
Landscape Change Module
Habitat Switching Module
Water Quality Module
Habitat Use Module
Integrated Spatial Framework
IT Glue
Environmental Benefits
Reporting
Maps & Output Statistics
Uncertainty Assessment
Monitoring
Risk / Storm Surge Module
Adaptive Ecosystem Assessment and Management Strategy

Hurricanes on the Grid

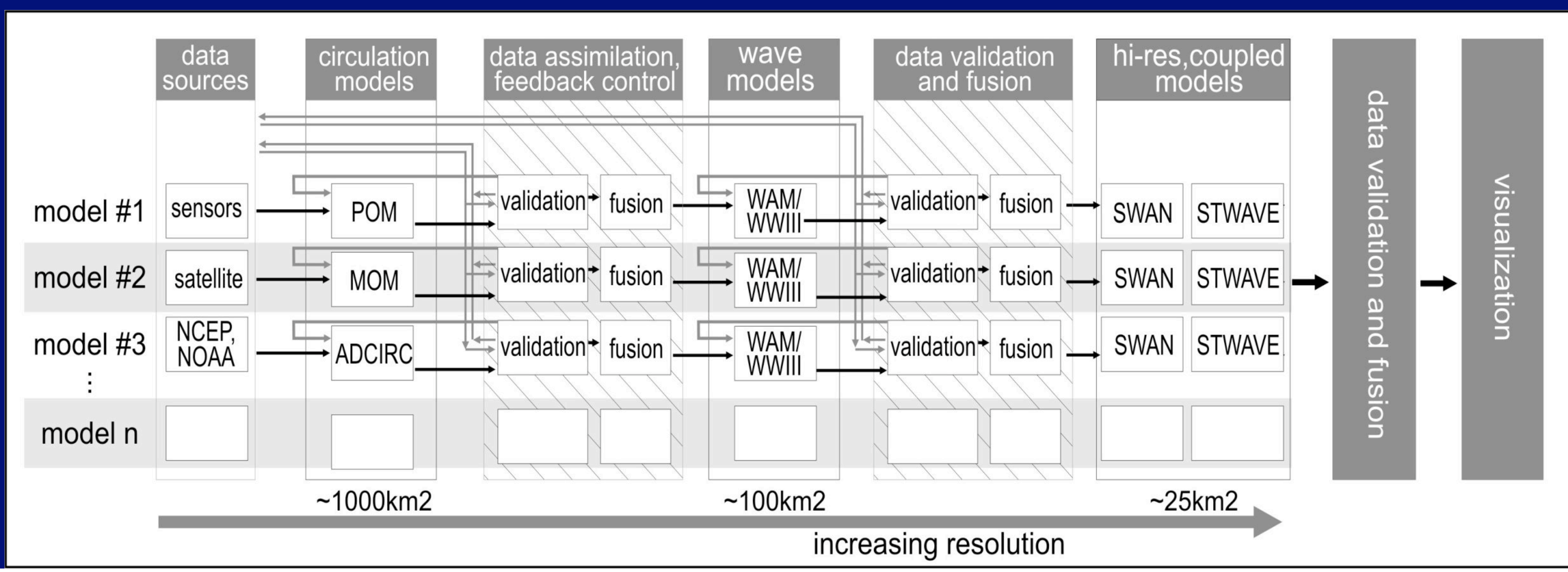
- SCOOP: SURA (NOAA/ONR) project to automate & collect together different operational data sources and models around the SE
- Partners: LSU, GoMOOS, Texas A&M, UaH, UNC/MCNC, U. Florida, U. Miami, VIMS
- Grid data archive and portal at CCT provides wind, surge, wave etc data.
- Automating operational ensembles of models on the SCOOP Grid providing GIS images and verification services.



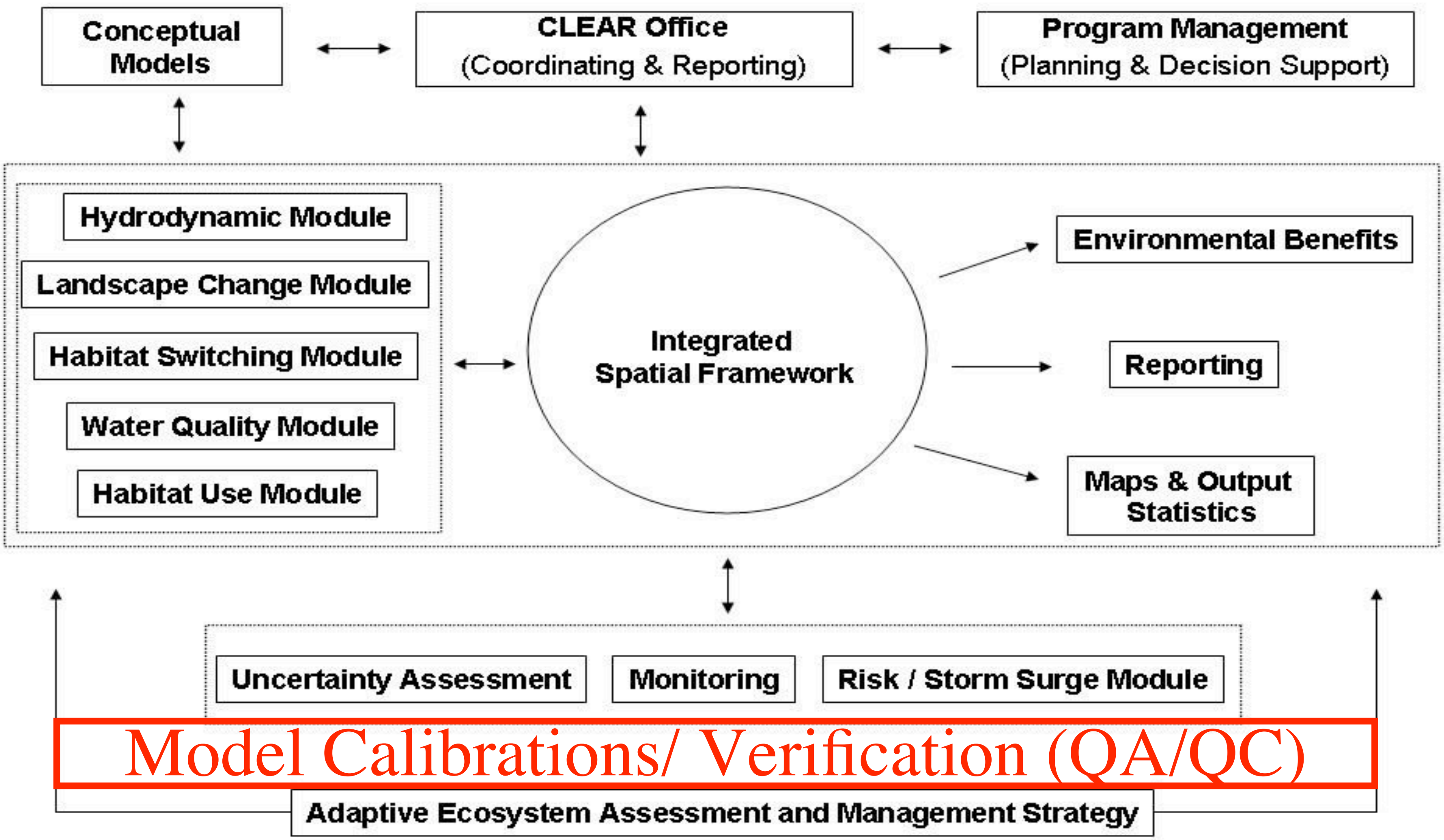


Data Driven Modeling

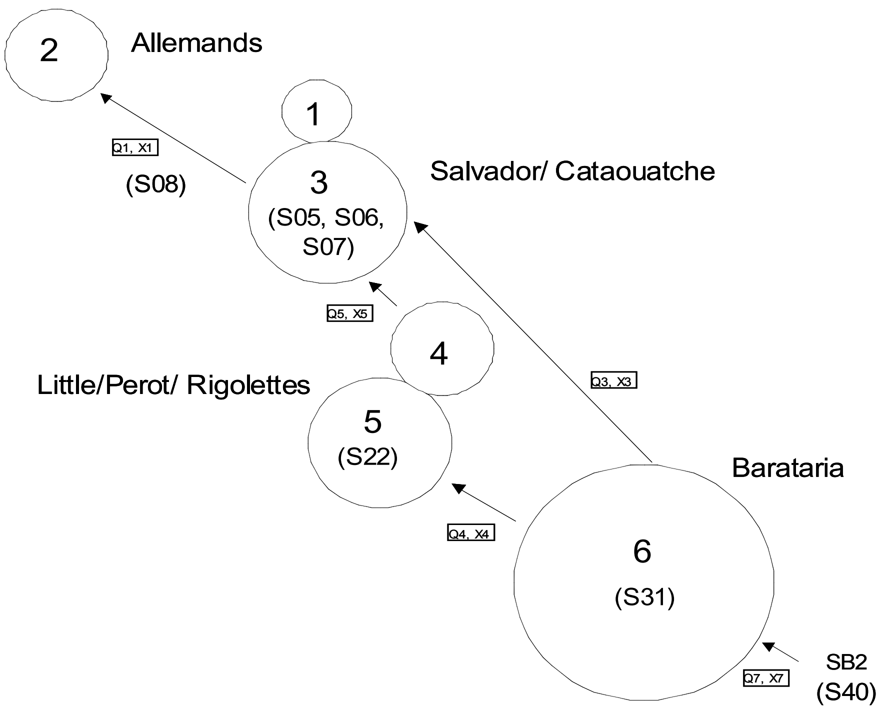
- **DynaCode**: New NSF project to develop “dynamic data driven” infrastructure for coastal and environmental modeling
- Partners: Center for Computation & Technology, LSU Hurricane Center, Coastal Studies Institute LSU, University of Notre Dame
- Coupling coastal models with realtime sensor data
- Adapting algorithms to current conditions.
- Incorporating new Grid capabilities e.g. notification, workflow, steering.
- CCT technologies: Grid Application Toolkit, Cactus Code, Triana, GridSphere Portal.

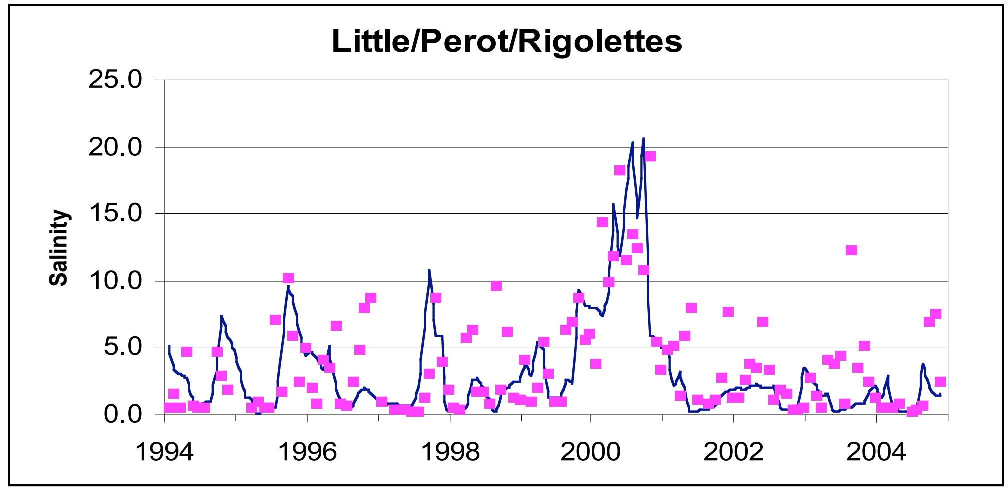


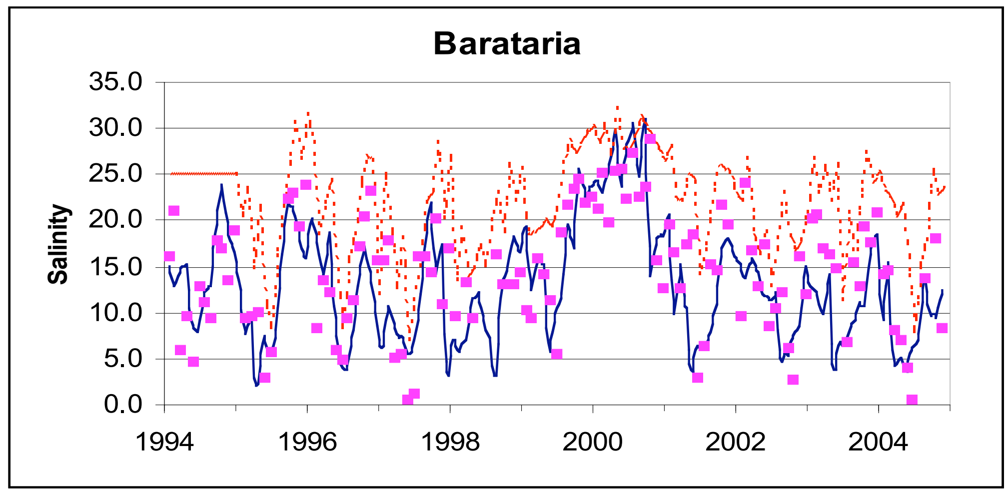
CLEAR Framework: Coastal Ecosystem Forecasting System

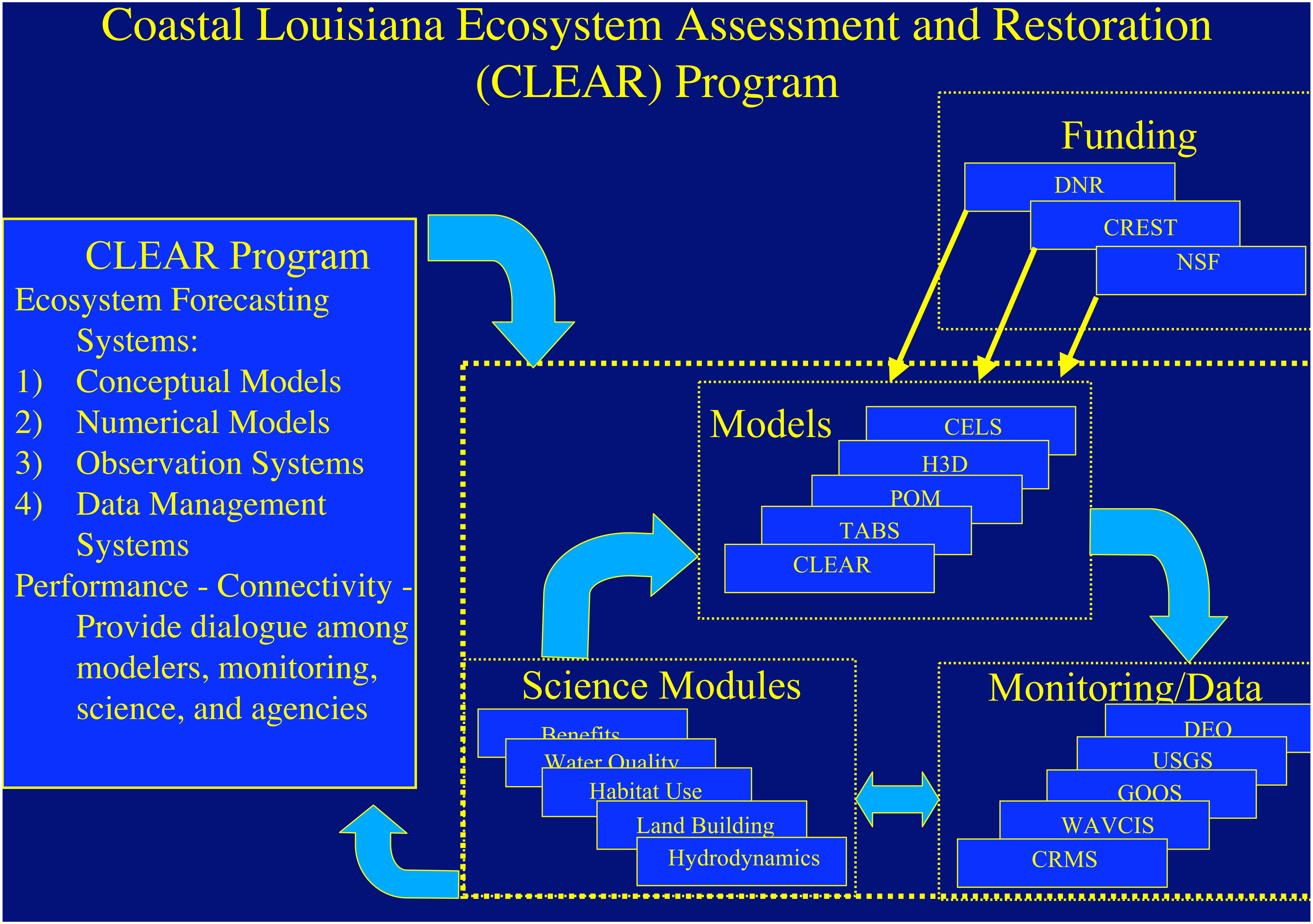


Calibration / Verification








Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) Program
CLEAR Program
Ecosystem Forecasting Systems:
1) Conceptual Models
2) Numerical Models
3) Observation Systems
4) Data Management Systems
Performance - Connectivity - Provide dialogue among modelers, monitoring, science, and agencies
Funding
DNR
CREST
NSF
Models
CELS
H3D
POM
TABS
CLEAR
Science Modules
Benefits
Water Quality
Habitat Use
Land Building
Hydrodynamics
Monitoring/Data
DEQ
USGS
GOOS
WAVCIS
CRMS

Coastal Louisiana Ecosystem Assessment & Restoration (CLEAR) Program

www.clear.lsu.edu