GCOOS Modeling Task Team Report on

Ecological Modeling Workshop 2014

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Introduction

The Modeling Task Team (MTT) for the Gulf of Mexico Coastal Ocean Observing System (GCOOS, http://gcoos.org/) held an "Ecological Modelling Workshop" in Houston, TX on 7-9 April 2014. The current workshop follows on an earlier workshop held in St. Petersburg, FL on 14-16 October 2009. The overall goal of the 2009 workshop was to begin a dialogue on how to advance ecological modeling and the report can be found at http://gcoos.tamu.edu/meetingreports/2009_Oct/documents/EcosystemModelReport.pdf.

The purpose of the 2014 workshop was to advise GCOOS Staff and the Board of Directors on how current ecological models can have uncertainty reduced by incorporating real-time data. The team discussed several other issues, including: for which model outputs which should be served via the GCOOS Products Portal, review the GCOOS Modeling build-out plan, and identify data gaps with current approaches.

The general approach to planning the workshop was to invite experts and stakeholders who could contribute to resolving issues on the agenda (Appendix 1). While a total of 26 people were invited, only 14 people accepted and attended (Table 1). The agenda was organized around two full days of presentations (Appendix 2), reports, and discussion among the group as a whole, and a final half-day was set aside for a smaller group to discuss formulation of a whitepaper detailing the recommendations of the MTT, which was composed of members of the GCOOS MTT (Paul Montagna, Matt Howard, Dubravko Justic, Steve Morey, Jerry Wiggert, and Kyeong Park) (Appendix 3).

Table 1. Meeting Participants.

Name	Area/organization represented	Affiliation
Scott Cross	NODC	NOAA NODC
Jim Gibeaut	Cyberinfrastructure and data management	GRIIDC at HRI
Rob Hetland	physics of coastal areas	Texas A&M University
Matt Howard	GCOOS data	Texas A&M University
Dubravko Justic	Hypoxia	Louisiana State University
Jason Lenes	HABS	University of South Florida
Paul Montagna	Ecological modelling	Harte Research Institute
Steve Morey	Physics of estuary-coastal coupling	Florida State University
Worth Nowlin	GCOOS	GCOOS
Keyong Park	Physics of estuaries	University of South Alabama
Fernando Salas	Cyberinfrastructure and real-time data ingestion	University of Texas
Kristen Thyng	HABs, particle tracking	Texas A&M University
Evan Turner	Ecological modeling	Harte Research Institute
Jerry Wiggert	Biogeochemistry and remote sensing	University of Southern Mississippi

The workshop had four major themes:

1. Can we reduce uncertainty in current models by incorporating real-time data?
2. Need to identify data needs for models.
3. Need to resolve how we recover, archive, or make available biological, nutrient, and other biogeochemical data.
4. Need to resolve formatting (i.e., dictionaries) needed for models.

In the introductory remarks, several general points were described. 1) Different models need different kinds of data, and it is useful to classify models. For example, we could start with distinguishing physical and ecological models. 2) The word model is also used loosely to encompass empirical (i.e., statistical) models and mechanistic models. 3) The spatial and temporal scales used in physical and ecological models that are based primarily on biological processes are different. Often ecological models are conducted at coarser scales and longer times steps than physical models because of constraints in both ecological data and understanding of mechanistic processes. 4) There is a general need to identify the key issues in the Gulf of Mexico that ecological models can be used for. For example there are many models for fisheries dynamics, hypoxia, water borne pathogens, harmful algal blooms (HABs), and carbon cycling, but theses may not be the only important issues, and many topics are under studied. 5) For ecology, building the conceptual models can illustrate important ecological principals (i.e., sources, fates, and effects) that need quantification.

Hydrodynamic Modeling

There is a wide variety of uses for physical models in which GCOOS could be interested (Fig. 1). An inventory of physical models operating in the Gulf of Mexico finds five models running gulf-wide and 11 in localized regions (Morey, Appendix 2). These models all have different websites and interfaces which complicates modeling and data aggregation (Table 2). A solution is for GCOOS to provide a mechanism to interactively display these results and observations of these models in a singular viewer or portal. An issue with this approach is the availability of these models may be sporadic with significant downtime. Additionally, many of these systems are actively upgrading and altering their website interfaces, which could lead to broken links. But the ability to click on portions of maps and grab data would be very powerful.

1. Loop current, eddy forecasts
2. Search and rescue
3. Oil spill source and trajectory
4. HABs
5. Hypoxia
6. Debris and pollutants
7. Fishery stock
8. Pollutant transport
9. Weather prediction
10. Transportation
11. Extrapolation and interpolation of climate and extremes

Figure 1. Uses of physical models.

Table 2. Survey of Hydrodynamic models in the Gulf of Mexico.

Model	Type	Location	URL
GomexPPP	3D	GOM	http://abcmgr.tamu.edu/gomexppp/
Global Hycom	2D	Global	https://hycom.org/global
RTOFS	2D	Global	http://polar.ncep.noaa.gov/global/
AMSEAS	2D+3D	GOM + Atlantic	http://www.northerngulfinstitute.org/edac/oceanNomads/AmSeas.php
SABGOM	2D	GOM + Atlantic	http://omgsrv1.meas.ncsu.edu:8080/ocean-circulation/
NGOFS	1D	GOM	http://tidesandcurrents.noaa.gov/ofs/ngofs/ngofs.html
TBOFS	1D	Tampa Bay	http://tidesandcurrents.noaa.gov/ofs/tbofs/tbofs.html
GBOFS	1D	Galveston Bay	http://tidesandcurrents.noaa.gov/ofs/gbofs/gbofs.html
NWGOFS			
NEGOFS			
WFOFS			
TGLO			
TXBLEND	2D	Texas Bays	http://www.twdb.texas.gov/surfacewater/bays/models/
WFS ROMS	2D	West Florida	http://ocgmod1.marine.usf.edu/WFS/
WFS FVCOM N/F	2D	West Florida	http://ocgweb.marine.usf.edu/Models/FVCOM/fvcom_index.html
WFCOM	2D	West Florida	http://ocgweb.marine.usf.edu/hab_tracking/HAB_trajectories.html

Currently the DeepC Viewer housed at Florida State University and developed with gulf of Mexico Research Initiative (GOMRI) funding can display Hycom based model data (http://viewer.coaps.fsu.edu/DeepCProject/mapviewer). This system is open source and extensible. The path forward is to set up a viewer on a GCOOS server and add new capabilities, such as NDBC, and ADCP real-time observations, NOAA AVHRR, and Leben altimetry. Progress would be limited by funding levels. The Viewer will be adapted and populated as models come and go. Hope to use forecast and hindcast data, but this is depending on input models at the time.

Ecological Modeling

Coupled Models for Hypoxia

One current focus is in forecasting hypoxia in inland waters, estuaries, the continental shelf, and deeper offshore oxygen minimum zone (i.e., the OMZ at depths of 300 m – 800 m) (Justic, Appendix 2). The area of hypoxia in the Gulf of Mexico "dead zone" is large, and it is necessary to monitor 50 - 60 km^2. A complication is that hypoxia is temporally ephemeral and dissolved oxygen can quickly recover from 0 to 7 mg/L within a few days. This makes shipboard grab samples problematic, so continuous records are therefore necessary for monitoring of hypoxia.

There are many hypoxia models and these can be found at the NGOMEX hypoxia model inventory (http://www.ncddc.noaa.gov/activities/healthy-oceans/gulf-hypoxia-stakeholders/workshop-2013/). Additionally, the Sulis system at Mississippi State University collects output from 40 to 50 regional hypoxia models and them available online (http://www.ngi.msstate.edu/sulis/apps/CommunityModels/index2.htm) (NGI 2010).

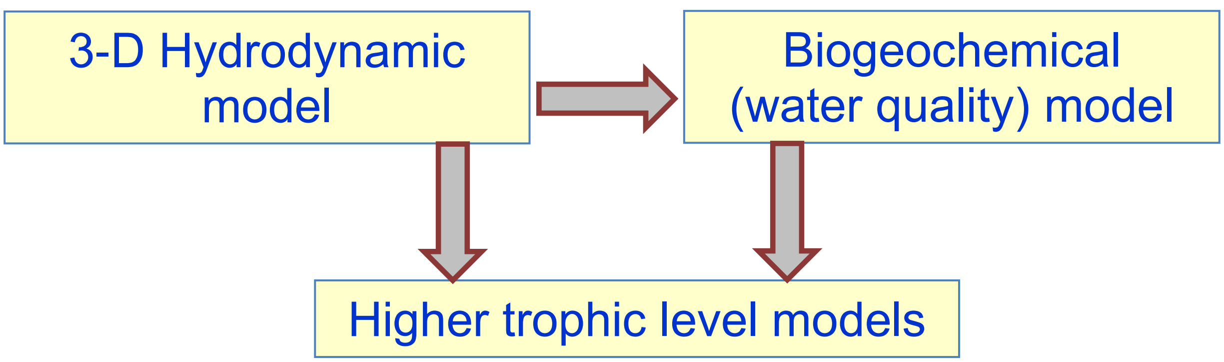

Figure 2. Ecological modeling framework.

The basic framework for modeling biogeochemistry is coupling a 2-D/3-D hydrodynamic model with higher trophic, or an individual based model (IBM) fish model (Fig.2) . Population displacements due to hypoxia are an issue to model because fish will move away from low oxygen waters (Rose et al., 2009). There are several implementations of this approach (Table 3).

Table 3. Coupled Biogeochemical Models

Model	Biological Parameter	URL
GoMDOM	DO	http://www.epa.gov/med/grosseile_site/gulf_mexico_rp_pp.pdf
FVCOM LATEX	NPZ	http://fvcom.smast.umassd.edu/research_projects/LTShelf/
GulfBreeze (EPACOM_GEM)	DO	http://www.epa.gov/med/grosseile_site/gom.html
NGOMEX	DO	http://www.cop.noaa.gov/stressors/pollution/current/gomex-factsheet.aspx

Ecological models are different from physical models in that there are no physical constants, so there are many different data products required to build coupled biogeochemical models. One must have data on initial conditions and model parameters, for examples, the data products needed include:

Hydrodynamic model forcing

- heat flux
- winds
- tides
- river discharge
- boundary fluxes

Biogeochemical model forcing

- light (e.g., incident solar radiation, PAR)
- temperature
- external loads (e.g., riverine nutrients, carbon, TSS, CDOM)
- boundary fluxes (e.g., nutrients, carbon, chlorophyll, DO)

Other Ecological Modeling Approaches

Many kinds of ecological models exist but they fall into five general categories: bioenergetics, paths, dynamic multispecies, whole ecosystems, and dynamic systems (Montagna Appendix 2).

Bioenergetics models are based on the first principle of thermodynamics: that energy and matter are conserved (Winberg 1956). Bioenergetics models are useful in that they can be applied to address a variety of ecological questions, such as nutrient regeneration (Kraft, 1993;

Chips and Bennett, 2000), food web interactions (He et al., 1993), benthic productivity (Kim and Montagna 2009, 2012), larval fish consumption rates, habitat suitability, predator-prey interactions, consumption of resources by fish populations, optimizing aquaculture conditions, and pollution effects (Montagna and Li 1997). These models are often simple in structure and the model input data needed is data most frequently collected by biologist. Data needed for bioenergetics models include: water temperature, habitat (thermal history and response), size at age (growth curves), size or age at sexual maturity, and mortality rates.

Path models are commonly used to examine the ecological pathways in an ecosystem. These models examine all input and output between "compartments" within an ecosystem. Compartments can represent species or trophic groups, while energy or nutrients are often used as model currency. Thus, path models, and path analysis statistics, are very useful for estimating the strength and direction of all factors that affect the functioning of an ecosystem. Because these models are effective in representing a complex ecosystem via simplified compartments, they have been used in a variety of ways covering a variety of different ecosystem types.

Dynamic multispecies models focus only on interactions between species, though some models can incorporate physical or environmental forcing. Examples are: Minimally Realistic Models (MRM), Multispecies Virtual Population Analysis (MSVPA), Individual-Based Models (IBM), and Globally Applicable Area-Disaggregated General Ecosystem Toolbox (GADGET).

Whole ecosystem models are built "to represent all trophic levels in an ecosystem in a balanced way" (Plaganyi, 2007). These types of models include all trophic levels in an ecosystem, aiming to represent each system component in a mass-balanced way. The most common approach is to use the Ecopath suite of software (Pauly et al. 2000). Many studies can be found on the Ecopath website (http://ecopath.org/).

Dynamic system models incorporate lower trophic levels and environmental factors. The environmental factors are often represented by biogeochemical reactions. Higher trophic levels are usually left out, or included with minimal detail only. Some models also incorporate age structure and/or spatial aspects. Nutrient-Phytoplankton-Zooplankton (NPZ) and Atlantis are examples of dynamic system models based on biogeochemistry.

The NPZ based model is often used within coupled models because each specific model has different fundamental biogeochemical relationships. Although NPZ models are not as realistic as more complex models with more components (i.e., boxes), they can provide realistic insight into the dynamics of an ecosystem (Franks 2002). Requirements for biogeochemical models are: irradiance, temperature, external loads, boundary fluxes, initial conditions, and rate parameters.

Atlantis is an ecosystem model that considers all parts of marine ecosystems - biophysical, economic and social (http://atlantis.cmar.csiro.au/). Atlantis is a deterministic biogeochemical whole of ecosystem model. It's overall structure is based around the

Management Strategy Evaluation (MSE) approach, where there is a sub-model (or module) for each of the major steps in the adaptive management cycle.

Error in Ecosystem Models

There is a paramount need to develop ecosystem models with trusted fidelity (Wiggert, Appendix 2). Error can be introduced in several ways, for example through a lack of data to calibrate parameters, through model formulation, or lacking to capture the variability in calibration data.

It is often assumed that more complex models that capture more processes will be create models with better performance, but this is not always the case. For example, Friedrichs et al. (2007) compared 12 lower trophic level models of varying complexity in two oceanic regions (equatorial Pacific and Arabian Sea). The models contained consistent implementation for pelagic assimilation of chlorophyll-a, nitrate, export, and primary productivity meaning they were NPZ-type biogeochemical models. When a single pelagic regime is considered, the simplest models fit the data as well as those with multiple phytoplankton functional groups. A similar result shown that simpler NPZ models can predict more accurate results in estuaries than more complex models (Turner et al. 2014). However, one caution is that more complex models may be more portable to other regions because a simple model can't adapt to the new region (Friedrichs et al. 2007).

Data availability is always a constraint in ecological modeling. Data assimilation is crucial to objectively and quantitatively comparing and assessing ecosystem model performance (Wiggert Appendix 2). There is also a need to assess model performance by more than just how well the model reproduces the data used to tune the model.

Another issue that leads to error is stochasticity, meaning the unknowns and random processes that are simulated but are very difficult to simulate correctly. How do we deal with random processes? One example is behavior in IBMs. In general, chaos causes the random responses, but simple patchiness in spatial and temporal distribution could also appear to be chaotic behavior.

Model Validation

How well do models represents the truth? Validation is used to determine how well a model represents the truth, but we often don't know the truth about what, scales, processes, or state variables (Morey Appendix 2). So perhaps a better term would be verification. Validation should be quantitative not qualitative (visual matching), it should include direct comparison of predicted and observed values, and there must be statistical comparisons to determine certainty. Uncertainty must be careful not to mask biases that may be caused by large seasonal or interannual variability.

There are many data need to validate models, but necessarily it may not be possible to always obtain what is needed. In these cases proxies are useful. For example is it valid to use grab samples of pigment measurements to validate Chlorophyll-a, which is a derived variable. Water quality variables and biological variables may be patchy as well, which introduces stochasticity. Sensor drift or instrument errors can make it difficult to use field data as well. There are also mathematical and statistical constraints, for example: How can a map of numbers be reduced into a single number for validation?

There is a growing disparity between what ecological models can do and what we can measure in the environment. For example, computer power is becoming large, speedy and cheap, but ecological lab data is slow, expensive, and harder to produce. Future needs include: more experimental measurements and more time series data. One possible solution is advances in data collection, such as gliders. However, it is going to be expensive, and we need to build a constituency for creating the data.

Current Database Activities to Support Modeling

GRIDDC

The goal of the Gulf of Mexico Research Initiative Information & Data Cooperative (GRIIDC) is to support the documentation of data generated by the Gulf of Mexico Research Initiative (GoMRI) (https://data.gulfresearchinitiative.org/, Gibeaut Appendix 2). This will ensure a data and information legacy that promotes continual scientific discovery and public awareness of the Gulf of Mexico ecosystem. GRIIDC is required to: 1) implement a fully accessible database of results and metadata, 2) ensure that all data are accessible with minimum time delay, and 3) that all data are submitted to national database centers. This is accomplished if data or pointers to data are submitted to GRIDDC.

GRIIDC endeavors to promote timely submission of data and model outputs by principal investigators (PI) the GoMRI "Research Database" and existing national repositories. It uses existing data standards and management systems as much as practicable. It employs the best practices for data policy and data management as elucidated by NSF and NOAA or other agencies. It has a strong commitment to data management by each participating PI

GRIIDC is unique in that it is promoting a data sharing culture. It has not been uncommon for investigators to hoard or closely hold data so this is a relatively new concept to coastal and marine scientists. GoMRI uses both a "carrot and a stick" approach to encourage data sharing. Sharing is encouraged by: 1) providing an efficient service making submission easy, 2) assigning Digital Object Identifiers (DOI) to datasets which makes them publicly available and easily citable, which provides credit to the PI, 3) providing data use statistics to the PI, and 4) providing a public monitoring matrix showing status of datasets. However, data sharing is also tied to funding, and if a PI does not share data, then the PI is not eligible for future GoMRI funding.

GCOOS

The GCOOS Data Portal (http://data.gcoos.org/) supports GCOOS (Howard Appendix 2). The data portal is a system of: 1) near real-time collection including over 1800 sensors with about 1.4 million observations per month since 2008, 2) historical data ranging from 1900 to 2000, 3) modeling resources, and 4) NCEP forecasts of winds, river discharge, SSH, and temperature and salinity.

New on the horizon is filling 2000+ data gaps from the year 200 to present, adding water quality data, and coastal meteorology. Work has begun and a new hypoxia-nutrient data portal. This is important because nutrient measurements in rivers of Gulf of Mexico are necessary to understand nutrient fluxes from these boundaries.

NOAA, NODC, & NCDDC

The National Oceanic and Atmospheric Administration (NOAA) collects enormous amounts of data and it is available through several websites (Cross, Appendix 2). The National Ocean Data Center (NODC, www.nodc.noaa.gov) is the overall parent, while the National Coastal Data Development Center (NCDDC, http://www.ncddc.noaa.gov/) is the coastal division of the NODC and located at the Stennis Space Center.

NOAA is guided by it Ecological Forecasting Roadmap that has four focus areas: harmful algal blooms, hypoxia, pathogens, and species distributions and habitats. NODC has a goal of scientific data stewardship with three tiers: 1) Ocean Archive System; 2) QA/QC'ed data sets, e.g., Regional Climatology, WOD; and 3) Analyzed products, e.g., WQA. Thus through scientific data stewardship is creating scientific products from raw data to analyzed products.

Water Web Services

Water Web Services is the data product of the Consortium of Universities for the Advancement of Hydrologic Science, Inc (CUAHSI, https://www.cuahsi.org/) (Salas Appendix 2). The CUAHSI Water Data Center (WDC) employs the CUAHSI Hydrologic Information System (HIS) to facilitate data access and publication (https://www.cuahsi.org/wdc). CUAHSI invented the WaterML language for water resources times series data. The Open Geospatial Consortium (OGC) creates and maintains standards, and in 2012 adopted WaterML2 as the international encoding standard. WaterML2 will be rebranded as a TimeSeriesML for any kind of time series data. The USGS water services (http://waterservices.usgs.gov/) uses WaterML to serve its stream discharge time series data. The Water Web Service are used to integrate water flows and runoff into geospatial map services to support a hydrological modeling of basins.

Role of Modeling in the GCOOS Build-out Plan

GCOSS is a private non-profit organization and has been working on a build-out plan since 2011. The build-out is mostly for physical and marine meteorological observational data, but the intention is to include a plan for a complete system, which would include application of the data. The current plan however does not include any ecological components, and there is a desire to identify a major component for organismal observing. This leads to an important question: what data is needed for ecosystem modeling?

There is also a need to develop sensors that would meet requirements to deploy on offshore oil and gas platforms. The platform operators require that there be minimal electrical output and not endangered the platform itself. Challenges include interference from the platform, high nutrients, low DO, high fish and fouling communities. There is a need for more work on sensor development to resolve these challenges. Ecological observing that could benefit by sensors includes: hypoxia research that needs DO, temperature, and salinity sensors; and HABs research that need nutrient sensors. Optical sensors are particularly sensitive to fouling, which is another challenge to solve. Alliance for Coastal Technology (ACT) is testing and evaluating sensor technology.

Summary of Discussion Topics

- Can we reduce uncertainty in current models by incorporating real-time data?

In general, the ability to model gets cheaper, while observing gets more expensive. However, observation does not follow data needs, but financial and logistical imperatives. In part, sensor development has not kept pace with the need for ecological modeling data.

There may not be a lot of opportunities to incorporate real-time data in ecological models. It is generally thought that this was important but especially difficult to study hypoxia. However, it is more likely that chlorophyll from satellite data may be useful for water quality monitoring, e.g., pathogens, and species specific satellite data for HABs. There may also be some use for physical data in biogeochemical process studies.

- How do we recover, archive, or make available biological, nutrient, and other biogeochemical data?

Everyone is aware of legacy datasets, and they are extremely important for temporal change research because they can identify conditions in an earlier time that may be different from the current time. However, it is extremely difficult to obtain these datasets and it could be very expensive to put them into existing databases.

There are at least three types of legacy archival data: 1) ongoing data collections (and we can get those relatively easily and adapt to existing databases), 2) historical data from large projects (again, easy to get and archive); 3) individual ownership data collections (and these are the type that will take a lot of effort, and be very expensive to acquire them). Thus it may be useful to focus on ongoing and historical data first.

There have data recovery projects for nutrients and benthic indicators sponsored under the Gulf of Mexico Alliance (GOMA) program. There has also been several local activities within states.

For obtaining legacy data, you don't necessarily need to resolve formatting (i.e., dictionaries) needed for models. But, you have to get the metadata standard, complete, and accurate because that is what enables data discovery.

- What cyberinfrastructure is necessary to ingest GCOOS data into models and then output forecasts?

When building case-studies for web programmers, it is necessary to create a work flow from a user point of view. This will allow you to understand if existing services meet your needs. Thus, modelers need to create use-cases and work flow descriptions. This would serve the purpose of making it easier to find and use data.

- What kinds of GCOOS products (i.e., data, model output, and merging and fusing diverse datasets) are needed for ecological models?

One need not currently met is for coastline and bathymetry data.

- Is there a "Big Data" issue?

The term "big data" has come into vogue and refers to new insights that can be gleaned by statistical analysis of very large data sets. However, large data sets often are difficult to fuse and summarize. For GCOOS data, this may not be a problem, but there is a data mining and data integration issue. In the end, it is possible that linear programming and regression modeling, all of which are empirical, may tell us the answers to some of the questions we are asking.

- Is overfit a problem?

Many ecosystem models have many parameters, but we do not necessarily know how many parameters are needed. We also do not always know if all the processes need to be included in models. It is important to know if some parameters are more controlling or more sensitive than others.

Identified Ecological Model Data Gaps

Boundary Conditions

Current model boundaries are almost exclusively calculated from USGS stream gage flow. Calculated nutrient flux from the USGS data is essential to ecological models, but often difficult to obtain since it is calculated by different groups using disparate methods. At a minimum, existing data should be made more available to modelers.

Parameter Rates

Published parameter rates are effectively non-existent for the Gulf of Mexico region. Obtaining parameter rates involves small experiments with columns of water and benthos to discover parameter rates of growth, uptake, or saturation. In general, most rates are taken from literature reviews as tables from classic experiments conducted in different areas.

Important parameter rates to Eco Modeling:

1. Phytoplankton/Zooplankton/Benthos Growth and Death
2. Half Saturation Constants
3. Remineralizaton Rates

Calibration and Validation Observation Data

Monitoring data is patchy, hard to find, and difficult to sustain funding. However, there is data in the Gulf in various dbases in disparate formats. Most of this data, however, is coastline and not shelf observations. We also require time series data and that necessitates ongoing monitoring activities. Combining data from multiple sources is difficult because different methods and sensors have different errors and accuracy. The quality of data for wet chemistry methods are preferred, followed by in-situ. Satellite data is the least preferred for ecological modeling due to accuracy.

Table 4. Important observations to Ecological Modeling:

Observation	Availability	Typical Collection
Nutrients	Most Lacking	Wet Chemistry/In-situ
Chlorophyll-α	Available in low quality	Satellite
DO/pH	Sporadic along coastline	In-Situ
Phyto/Zoo Grabs	Single Experiments	In-Situ
Temp/Light	Most Available	Satellite/In-situ

Modeling Task Team Recommendations

Modeling Capability has Outpaced Data

Our technical capabilities to model and forecast biogeochemical phenomena have outpaced the collection of in-situ data in the Gulf of Mexico. Hydrodynamic modeling, by contrast, has matured due to the availability of high resolution satellite data.

Targeted Data Collections

Ecological models require boundary conditions as input, parameter rates of biogeochemical processes for calibration, and observational values for validation. Although most focus is placed on the collection of monitoring observation, very little attention is focused on parameters and boundary data. Model fitness would be greatly improved with parameter experiments conducted in the Gulf of Mexico. Also, an identified task is to collect calculated nutrient flux boundary data. Finally, targeted time series observations of high quality biological data should be investigated.

Downscaling 3D Models

The current trend in modeling is coupling large scale physical 3D models to biogeochemical processes. This is impractical for our needs due to the unavailability of required data in the Gulf of Mexico. Additionally, the science/social question at hand may not require a 3D model to be answered. A better solution is a downscaled 2D or 1D ecological model that can fit within our data availability and defined problem.

Real Time Ecological Modeling

No group is currently conducting, or in preparations for real time ecological modeling. This is due to lack of available data and the time to process high quality data required for ecological models.

Systems Ecology vs. Monitoring

An important distinction between ecological modeling data needs and ‘monitoring’ is the rationalization and impact. We require data to calibrate and validate models not for the purpose of monitoring.

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Appendix 1: Workshop Agenda

- Day 1 (half day starting at 1 PM)
    - Introduction, ground rules, etc. (30 min)
    - Survey or model types and data needs (2 hours)
        - Physical – Summary/overview of other group is working on physical models – Steve Morey and Matt Howard
        - Ecological – Paul Montagna and Dubravko Justic
            - Biogeochemical
            - Ocean color
            - Trophic (Ecopath)
            - Fisheries modeling
            - Individual/population
            - Community relationships
    - Types and sources of errors in models (2 hours)
        - Complexity that lacks observational support (Jerry Wiggert)
        - Stochasticity (Kenny Rose)
        - Validation (Steve Morey)
        - Discussion, synthesis, writing
- Day 2 (full day 8 am to 5 pm)
    - Ecosystem modeling element of the GCOOS Build-out Plan (2 hours)
    - Existing data warehouses (2 hours)
        - GRIIDC (Jim Gibeaut)
        - GCOOS (Matt Howard)
        - NOAA: NODC and NCDDC (Scott Cross)
        - BCODOM (biological and chemical oceanography data management office) (Matt Howard)
        - Small biological databases (Simons, Gulfbase)
    - Cyberinfrastucture solutions (2 hours)
        - Water Web services (Fernando Salas)
        - IOOS Web services (Matt Howard
    - Discussion, synthesis, writing (2 hours)
- Day 3 (half day 8 am to noon)
    - Executive Committee meeting for synthesis and writing.

Appendix 2: Oral Presentations

1. Steve Morey, “Viewer for GoMex Ocean Hydrodynamic Models”
2. Dubravko Justic, “An Overview of Gulf’s Hypoxia Models and Their Data Requirements”
3. Paul Montagna, “Ecological Modeling Approaches”
4. Jerry Wiggert, “Error in Ecosystem Models: Observational Support for Model Complexity”
5. Steve Morey, “Model Validation”
6. James Gibeaut, “Gulf of Mexico Research Initiative Information and Data Cooperative (GRIIDC)”
7. Matt Howard, “GCOOS Data”
8. Scott Cross, “NODC and NCDDC for GCOOS Ecosystem Modeling”
9. Fernando R. Salas and David R. Maidment, “Water Web Services”

Appendix 3: Modeling Workshop Paper

Title: Improving access to data for ecosystem model initialization, parameterization, forcing, and assessment

Authors: All participants.

Potential journals:

Ecological Indicators http://www.journals.elsevier.com/ecological-indicators/ ,

Ocean and Coastal Management http://www.journals.elsevier.com/ocean-and-coastal-management/ ,

Marine Technological Society Journal https://www.mtsociety.org/MTS_Journal_public/ ,

Sea Technology (editorially reviewed)

Introduction:

- Motivation is IOOS and they can be a key resource for obtaining modeling data. Describe observing in a generic way. Describe specific observing networks in Gulf (map) as an example of a regional network. (Matt)

- The Gulf is complex in unique ways, semi-enclosed sea (like Mediterranean), but there is large river causing strong salinity gradients and transitional zones, every kind of estuary ranging from lagoons, reverse estuaries, etc., complex geology, loop current. Mean conditions hard to define because of high variability. Three regions in the northern Gulf, etc. Finally, high demand for uses and conflicting uses. (Steve)

- Had a workshop to answer following questions: There are several major stressors, diverse modeling approaches. Why we need models, why we cannot just go out and measure stuff, because large areas and highly dynamic. End by saying we need both. (Kyeong)

Results:

- Definitions and distinctions of modeling types: ecosystem, ecological, bigeochemical, water quality, etc. We often use ecosystem and ecological modeling synonomously. (Paul)
- Diversity of models. Systems modeling vs. data mining. (Paul for trophic and landscape), (Justic for biogechemical), (Paul for data mining)
- Integrating physical and ecology into a systems model (Jerry)
- Model complexity (Jerry)
- Kinds of questions, needs, and case studies (For each case: identify issue and questions, modeling approaches, data needs, data gaps, how it is unique in the GOM)
    - Hypoxia (Justic)
    - HABS (Lenes)
    - Fisheries (Paul)
    - Acidification (Paul)

Discussion:

- Cross-walking data needs, and contrast with previous laundry lists.
- What do we have? (Matt)
- Continuous vs. grab sampling. How most biological data is grab, in contrast most physical is continuous. (Paul)
- Need for new technologies i.e., sensors, bug watchers, to obtain continuous data need more anti-biofouling technology. (Jerry, Justic, Kyeong, Paul, Steve)
- Need for greater monitoring coverage: (spatial for shallow water), which could be accomplished using gliders. Need all modes: ships of various sizes and capabilities, buoys, gliders, etc. (Kyeong)
- Priorities based on low hanging fruit (most cost effective, could be put on existing platforms easily, most needed and most used by modeling community), for build out to add to existing networks to serve ecosystem modeling.
- Common data gaps: What is the state of observing assets today versus the needs. Maintaining existing stuff. Maintaining infrastructure. (Matt)
    - Data for initial conditions (Justic)
    - parameter estimates (Justic)
    - assessment (i.e., validation, verification, skill assessment) (Steve)

Conclusions and Recommendations:

- Opportunities.
- Importance for LT monitoring. Need for monitoring to support modeling. Need for modeling 1) to advance basic science (i.e., understanding of processes), 2) to support resource management, 3) create now-casts and forecasts, 4) evaluating long-term trends,

5) defining base-line trends so we can understand change after an incident such as DWH. (Paul, Scott Cross)

- What we could do today, tomorrow, and the future in terms augmentation of data acquisition. (Cadillac vs. VW approach, what do we do if with varying amounts of resources) sensor development needs.
  - Rescue legacy data. (Montagna)
  - Enhancement of existing data portals, not data bases, use of webservices for metadata for discovery. (Matt, Gibeaut, Scott Cross)
- Restore act. (Paul)