Annual Progress Report

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Using Satellite Data and Fully Coupled Regional Hydrologic Ecological and Atmospheric Models to Study Complex Coastal Environmental Processes

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This proposal seeks to improve our understanding of how linked upland and estuarine ecosystems respond to combined changes in the hydrological and nutrient cycles that result from changes in climate and land use/land cover (LULC). Within this broad framework we will focus on five specific questions: 1) What is the relationship between global climate forcing and seasonal-to-interannual climate variability and extreme storm events over the Gulf Coast region? 2) What are the spatial patterns in LULC change as defined by satellite data in the Gulf Coast region? 3) How does riverine nutrient export to Gulf Coast estuaries vary with LULC patterns and hydrologic conditions? 4) What is the relationship between the frequency of extreme events in the hydrologic and nutrient cycles and the mean productivity and the resiliency of productivity in Gulf Coast estuaries? 5) Can we use the answers to the questions above to predict the response of Gulf Coast estuaries to future climate perturbations?

The following text summarizes what has been accomplished during the second report period.

1. **Preparation of downscaled NEXRAD precipitation for the Gulf Mexico Coastal region**

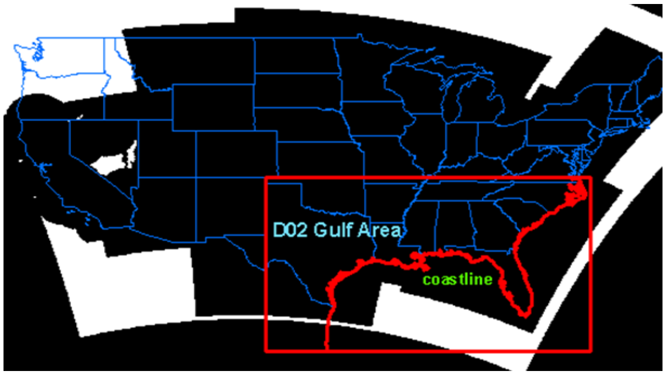


Figure 1. NEXRAD Stage IV data covering the Gulf Mexico Coastal region for the period of 2004 – 2007.

To provide more improved and accurate precipitation as input to the Noah land surface model (LSM), we have examined and processed NEXRAD data for the Guadalupe and San Antonio River Basins and then the Gulf of Mexico coastal region (Figure 1) as defined in the proposal. Hourly 4-km NEXRAD Stage IV data are spatially downscaled to 1-km based on parsimonious physically-based multivariate-regression algorithm, which includes rain pixel clustering and optimizing (Guan et al., 2007). By incorporating rain gauge measurements, we have explored four methods to improve the NEXRDA precipitation accuracy as follows: bias adjustment (BS), simple kriging with varying local means (SKlm), kriging with external drift (KED), and regression kriging (RK). These methods have been evaluated using percentage bias, mean absolute error coefficient of determination, and Nash-Sutcliffe efficiency. Figure 2 shows one example of hourly rainfall maps from these methods as compared with the original NEXRAD rainfall map. This precipitation data are now ready to use as input to the Noah LSM.

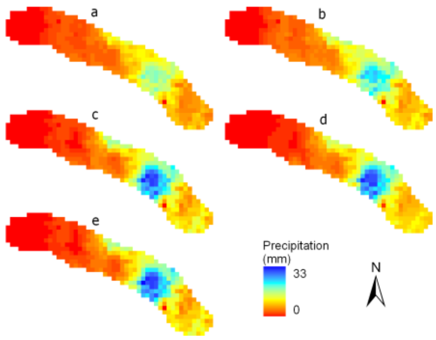


Figure 2. Spatial precipitation estimated by different methods (b: BA, c: SKlm, d: KED, e: RK) compared with the original NEXRAD map (a) in the same 8th hour on April 24, 2004.

2. Developing the community Noah land surface

model with multi-physics options and its application to Texas River Basins.

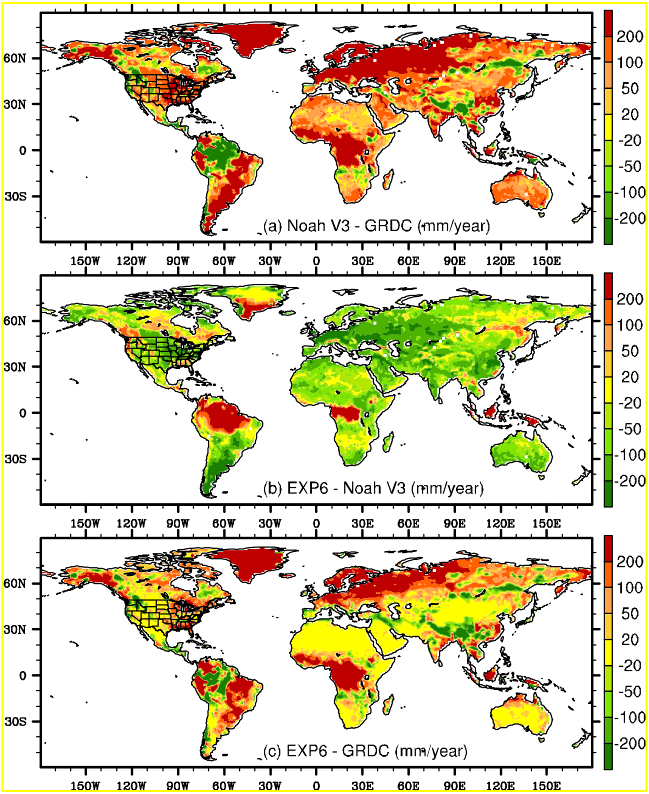


Figure 3. Differences of annual runoff climatology, a) Noah baseline model minus GRDC, b) modified Noah (EXP6) minus Noah baseline model, and c) modified Noah minus GRDC.

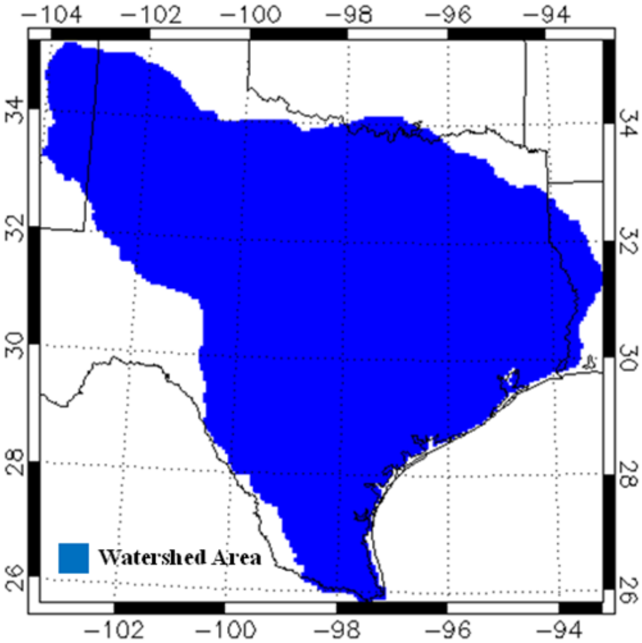


Figure 4. Study domain (Region 12) and the watershed area over Texas.

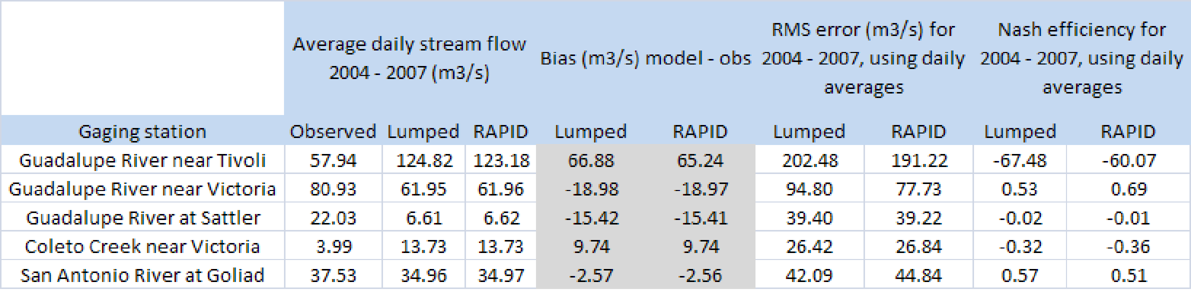
While the NEXRAD precipitation was processed, the widely-used community Noah LSM has been restructured by allowing various physics options for vegetation and soil processes. The major improvements of the LSM include the following: 1) application of a separated canopy layer that distinguishes the canopy temperature from the ground temperature, 2) a modified two-stream radiation transfer scheme for the 3-D canopy structure effects on radiation transfer, 3) a Ball-Berry type stomatal resistance scheme, 4) a short-term dynamic vegetation model which accounts for photosynthesis, allocation of the assimilated carbon to various carbon pool such as leaf, stem, and wood, respiration of each carbon pool, 5) application of a simple TOPMODEL-based runoff scheme and groundwater model (Niu et al., 2005; Niu et al., 2007), 6) a physically-based 3-layer snow model to accommodate snowpack internal processes, and 7) a more permeable frozen soil to separate a grid cell into a permeable fraction and an impermeable fraction. The global runoff simulations have been evaluated with Global Runoff Data Center (GRDC) runoff estimates over the 50 largest river basins over the world as shown in the Figure 3. From these experiments, we accomplished 20% increase of global runoff which is more accurate than those from the Noah baseline model.

Using this enhanced Noah LSM, we have finished the 4-year model simulations for the Guadalupe and San

Antonio river basins to provide simulated runoff as input to a river routing model to estimate streamflow. The Noah LSM is also being configured for a bigger river basin area (Region 12) which covers almost the entire area of Texas (Figure 4). Work is under way to process various vegetation parameters from remote sensing data such as MODIS.

3. Application of runoff simulations to RAPID

In order to establish a hydrologic connection between climate change and coastal ecosystem response, a new river routing scheme–Routing Application for Parallel computatIon of Discharge (RAPID)–has been used to produce streamflow estimation with runoff simulations from the newly developed Noah LSM. The coupling of the RAPID and the Noah LSM is facilitated through a flux coupler which is designed to covert the gridded runoff into a total volume of water inflow to the NHDplus river network, using to a map of contributing catchments. The water inflow was used to force RAPID and compute 3-hourly flow in all river reaches of Guadalupe and San Antonio river basins in Texas. Then, the quality of the river flow simulation has been evaluated using USGS daily stream flow measurements. Table 1 shows the statistical parameters that were computed, using mean, bias, root mean square error, and Nash-Sutcliffe efficiency.



	Average daily stream flow 2004 - 2007 (m3/s)			Bias (m3/s) model - obs		RMS error (m3/s) for 2004 - 2007, using daily averages		Nash efficiency for 2004 - 2007, using daily averages	
Gaging station	Observed	Lumped	RAPID	Lumped	RAPID	Lumped	RAPID	Lumped	RAPID
Guadalupe River near Tivoli	57.94	124.82	123.18	66.88	65.24	202.48	191.22	-67.48	-60.07
Guadalupe River near Victoria	80.93	61.95	61.96	-18.98	-18.97	94.80	77.73	0.53	0.69
Guadalupe River at Sattler	22.03	6.61	6.62	-15.42	-15.41	39.40	39.22	-0.02	-0.01
Coleto Creek near Victoria	3.99	13.73	13.73	9.74	9.74	26.42	26.84	-0.32	-0.36
San Antonio River at Goliad	37.53	34.96	34.97	-2.57	-2.56	42.09	44.84	0.57	0.51

Table 1. Evaluation of modeled stream flow at five locations in the Guadalupe and San Antonio River Basins

4. Nutrient Export Study

For assessments of nutrient export to estuaries, we increasingly conducted based-flow sampling on the Guadalupe, San Antonio, Mission, and Aransas rivers in an effort to better characterize variations in nitrogen concentrations with flow. In particular, this effort was motivated by a scarcity of data on dissolved organic matter concentrations in the Texas Commission on Environmental Quality (TCEQ) archive. While base-flow sampling was conducted monthly during the first year of the project, we collected samples weekly during June through August, 2008, and every two weeks from September 2008 to present. We also continued to target storm flows in our ongoing effort to improve overall water quality data coverage for these critical, yet under-represented, events. The importance of quantify organic matter dynamics is exemplified by data from the Mission and Aransas rivers. Dissolved organic nitrogen (DON) concentrations increase as runoff increases, maintaining values between ~25 and 55 micromoles per liter during high flow. In contrast, nitrate and ammonium concentrations dilute as runoff increases, maintaining values below 5 micromoles per liter during high flow (Figure 5).

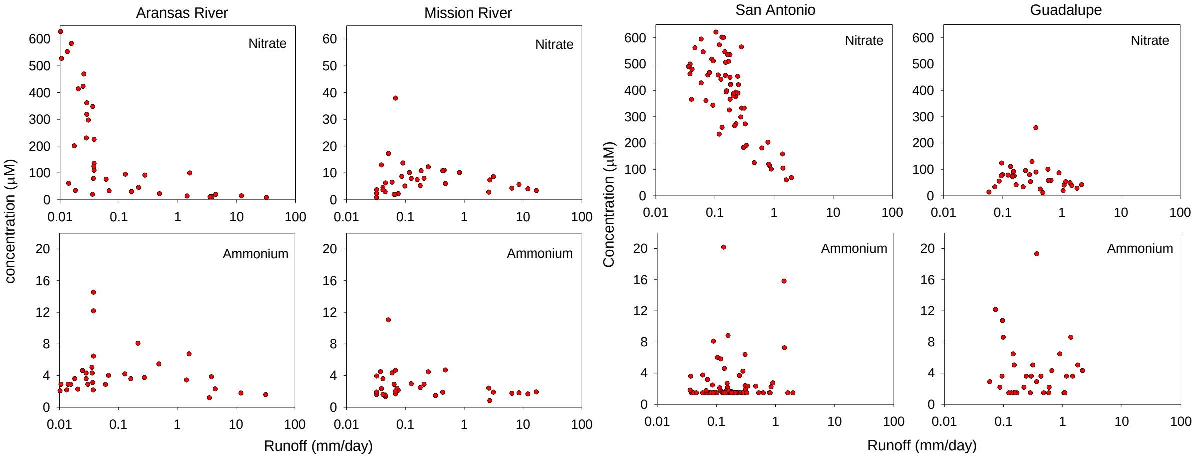


Figure 5. Changes in nitrate and ammonium concentrations in the Mission, Aransas, San Antonio, and Guadalupe rivers as a function of runoff.

A few large storms account for most of the annual runoff carried by these rivers. Thus, most of the nitrogen exported from the Mission and Aransas watersheds is in the form of DON. Nitrate and ammonium also dilute during high flow in the Guadalupe and San Antonio rivers (Figure 5). However, the dilution effect is more evident for nitrate than ammonium. DON analyses for the Guadalupe and San Antonio are not yet complete, but it is likely that they will be similar to those observed in the Mission and Aransas rivers. Although their watersheds are very different in size (Figure 6), the hydrographic characteristics of the four rivers are quite similar. While the general patterns of dissolved inorganic nitrogen dilution and organic nitrogen enrichment during storm flows are similar across all four rivers, major differences in nitrate concentrations among rivers

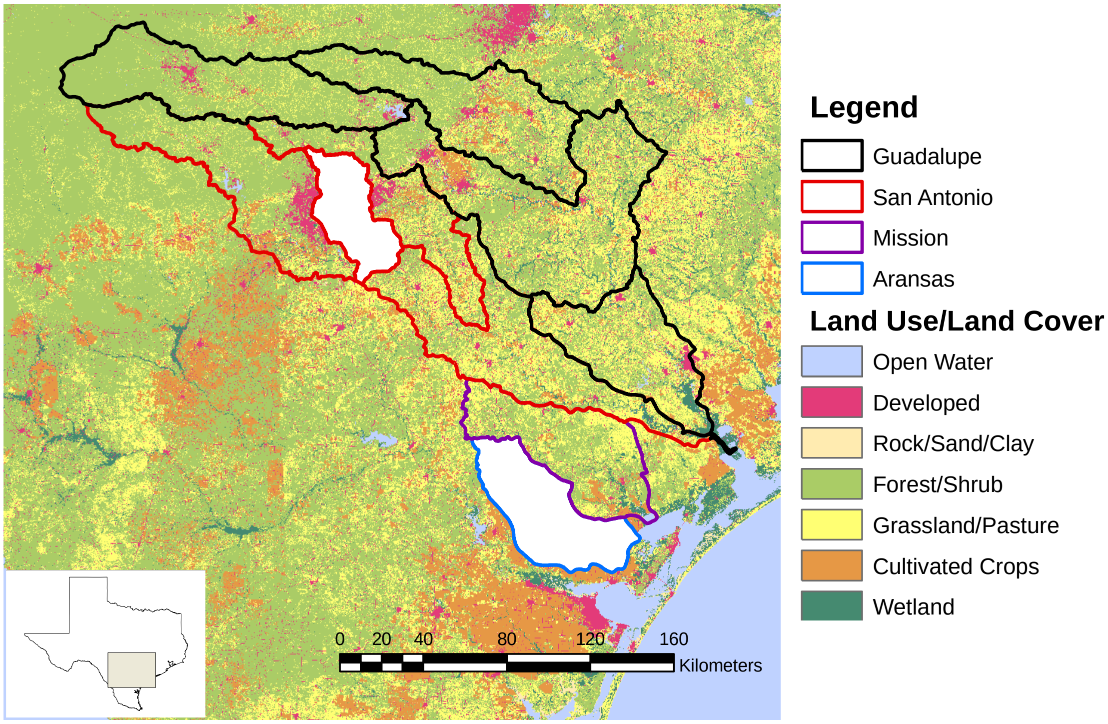


Figure 6. Watersheds of the Guadalupe, San Antonio, Mission, and Aransas rivers with major land use/ land cover

(particularly during low flow) reflect differences in anthropogenic nitrogen sources. Most notably, the human population density is much higher in the San Antonio River watershed (Figure 6). High nitrate concentrations in the Aransas River could be attributed to a high proportion of surrounding land under cultivation (Figure 6). However, a sewage outfall near Skidmore has been identified as the most likely source.

In addition to our work on watershed export, we compiled water quality data for Copano Bay to support the estuarine ecosystem modeling component of the project. Data coverage within Copano Bay is exceptional because the Mission Aransas National Estuarine Research Reserve (MANERR) maintains monitoring stations in the bay that record temperature, salinity, dissolved oxygen, and chlorophyll continuously. Nutrients and organic matter are also measured periodically at these stations. We have supplemented these measurements with targeted sampling for nutrients and organic matter in the bay after storm events. After the estuarine ecosystem model has been fully developed and tested within this data-rich environment, it will be applied in the San Antonio Bay system.

5. Modeling Estuary Community Biomass and Production

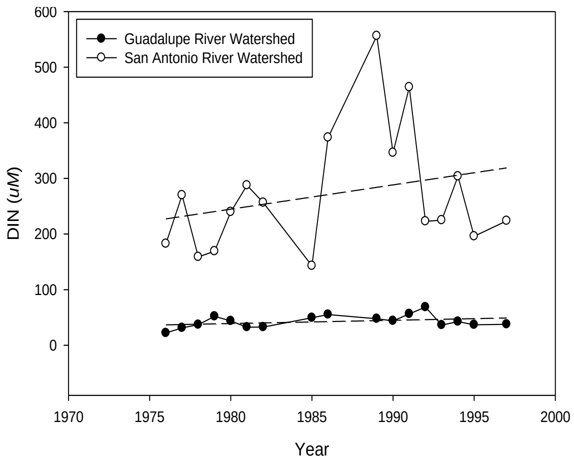


Figure 7. Annual aveage DIN_in the lower San Antonio and Guadalupe river watershed during 1976 - 1997

We have accomplished quarterly sampling in July 2008, October 2008, January 2009, and April 2009 and investigation of land-ocean coupling processes in the Guadalupe Estuary, Texas. We examined land-use characteristics, climatic condition and nutrient flux using historical time series data sets. The nutrient loadings based on different environmental and climatic settings were used to drive a generic ecosystem model to investigate effects of watershed loadings on ecosystem responses. We found nitrogen flux derived from the two coastal hydrological units (HUCs) clearly revealed a difference in nutrient loadings (Figure 7), which is correlated to development (e.g., human activities). The differing loadings were also found to cause different subsequent estuarine ecosystem responses with respect to timing, duration and magnitude of phytoplankton blooms (Figure 8). The findings were presented at the Sixth International Conference on Ecoinformatics in December 2008, and will be submitted to a professional journal (Ecological Informatics) in Spring 2009. Currently, the model is being implemented with thorough calibration/validation processes. This completes all modeling tasks scheduled within the project year.

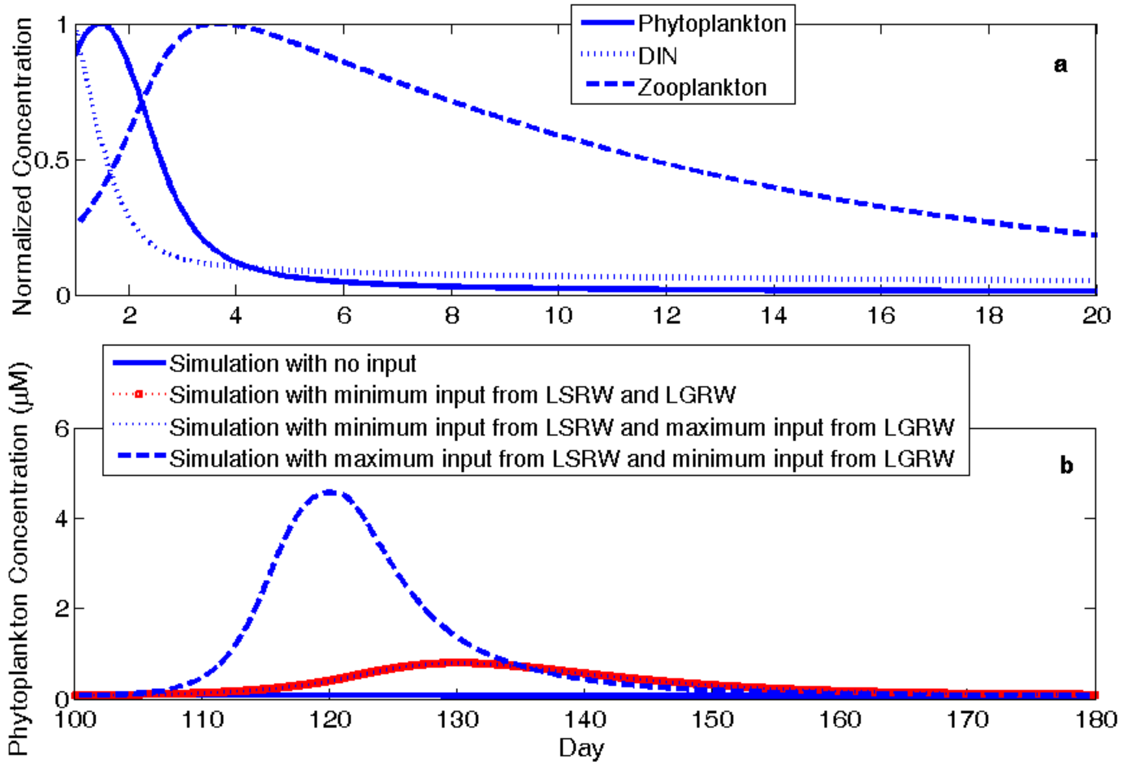


Figure 8. a. Normalized nitrogen concentration of each ecological components under the reference condition (no DIN input from outside box). b. Simulated results based on three tests: reference simulation with minimum loadings from both lower San Antonio River Watershed (LSRW) and lower Guadalupe River Watershed (LGRW); simulation with minimum from LSRW and maximum loading from LGRW, and simulation with maximum from LSRW and minimum loading from LGRW.

6. References

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