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

(NASA Award Number, NNX07AL79G)

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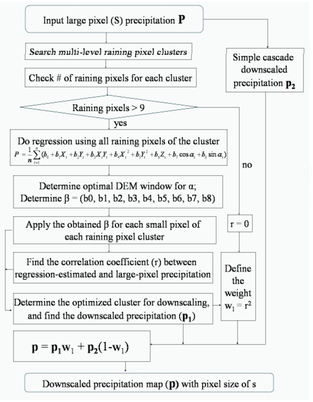
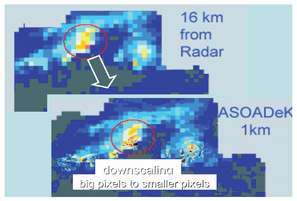
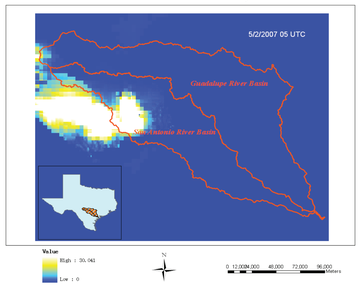
A physically-based multivariate-regression approach is developed to downscale NEXRAD precipitation

Flowchart of downscaling algorithm [Guan et al., 2008]





Downscaled NEXRAD 1×1 km^2 resolution rainfall (mm/hour) on 2 May 2007



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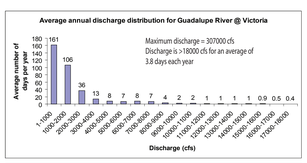
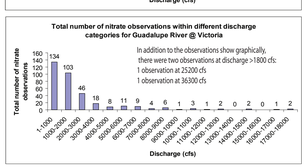
An emperical regression relationship between river flow and nutrient export to coastal water is defined in Texas watersheds





Comparison of average annual discharge distribution (top panel) to the total number of nitrate observations in each discharge category (bottom panel) over the 1963-2007 period. Discharge is below 3000cfs for 303 days each year, and nitrate is well represented for these low flow conditions. It is evident that nitrate data coverage drops off quickly at higher flows. Other constituents show similar patterns. We have implemented a sampling program that targets storm events to remedy this deficit.

	Coefficient value	Std. Dev.	t-ratio	p-value
Ammonium				
a_0	5.0277	0.1963	25.62	<0.001
a_1	0.9431	0.1206	7.84	<0.001
a_2	0.2771	0.1357	2.04	0.0315
a_3	0.0961	0.1816	0.53	0.5633
a_4	-0.2278	0.1800	-1.27	0.1721
Nitrate				
a_0	8.3040	0.1502	55.29	<0.001
a_1	0.807	0.0958	8.42	<0.001
a_2	-0.1488	0.1044	-1.42	0.1259
a_3	0.2706	0.1429	1.89	0.0449
a_4	-0.3655	0.1384	-2.64	0.0066
Total organic N				
a_0	8.8433	0.1522	58.11	<0.001
a_1	1.1193	0.0981	11.41	<0.001
a_2	-0.1060	0.0732	-1.45	0.0820
a_3	0.1115	0.1780	0.63	0.4300
a_4	0.1887	0.1219	1.55	0.0649
Total organic C				
a_0	10.3248	0.1445	71.44	<0.001
a_1	1.2988	0.1475	8.81	<0.001
a_2	-0.0179	0.1268	-0.14	0.8794
a_3	0.0722	0.1500	0.48	0.6046
a_4	-0.1134	0.1375	-0.82	0.3767
Total P				
a_0	6.4922	0.1390	46.71	<0.001
a_1	1.4024	0.0908	15.45	<0.001
a_2	-0.0431	0.0981	-0.44	0.6317
a_3	0.1289	0.1323	0.97	0.2918
a_4	-0.1449	0.1317	-1.10	0.2347

Model coefficients and statistics for $ln\ (export) = a_0 + a_1\ lnQ + a_2\ lnQ_2 + a_3 Sin(2nd_{time}) + a_4 Cos(2nd_{time})$ as applied to ammonium, nitrate, total organic nitrogen (TON), total organic carbon (TOC) and total phosphorus (TP) export in kg/d from the Guadalupe River at Victoria. Regression relationships were determined using archived data from 2000-2007 for ammonium, nitrate and TP, 1990-1994 for TON, and 1977-1981 for TOC. The model explains ~75%, 80%, 97%, 74%, and 91% of the variation in daily export of ammonium, nitrate, TON, TOC, and TP respectively.

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Abstract

An integrated interdisciplinary study of environmental changes in the Gulf Coast region has been funded by NASA interdisciplinary Science Program from 2007 to 2010. The final results will be a suite of models that link the upland and estuarine ecosystems into a single model framework that will allow simulating, reproducing, and projecting natural and anthropogenic impacts in a comprehensive matter. The first year progress has provided a sound base for their future integtion.

Objectives

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).

Integrate research expertise from a diversity of fields that includes climate modeling, remote sensing analysis, biogeochemical cycling in watersheds, surface hydrology and estuary ecology.

Key Science Questions

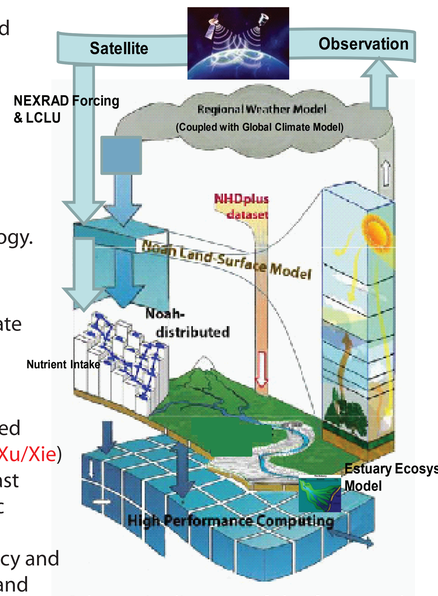
(1) What is the relationship between global climate forcing and seasonal-to-interannual climate variability and extreme storm events over the Gulf Coast region? (Yang/Niu/Xie)

(2) What are the spatial patterns in LULC as defined by satellite data in the Gulf Coast region? (Yang/Xu/Xie)

(3) How does riverine nutrient export to Gulf Coast estuaries vary with LULC patterns and hydrologic conditions? (McClelland/Maidment)

(4) What is the relationship between the frequency and magnitude of extreme events in the hydrologic and nutrient cycles and the mean productivity and the resiliency of productivity in Gulf Coast estuaries? (Montagna/McClelland)

(5) Can we use the answers to the questions above to predict the response of Gulf Coast estuaries to future climate perturbations? (All)



Schematic diagram of the framework consisting of a regional weather model, a hydrologically-enhanced Noah distributed land surface model, an empirically-based water chemistry model, and an estuary ecosystem model, in conjunction with in situ, NEXRAD and satellite observations.

References

Gochis, D.J. and F. Chen, 2003: Hydrological enhancements to the Community Noah land surface model: Technical Description. + NCAR Science and Technical Note, TN-454+STR.

David, C.H., D.J. Gochis and D.R. Maidment, 2008: Using NHDPLUS as the land base for the Noah-distributed model, in preparation

Guan, H., H. Xie, and J. Wilson, 2008: A physically-based multivariate-regression approach for downscaling NEXRAD. precipitation in mountainous terrain, Journal of Hydrometeorology (to be submitted).

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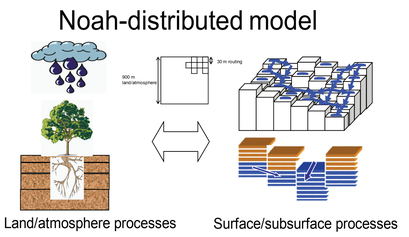
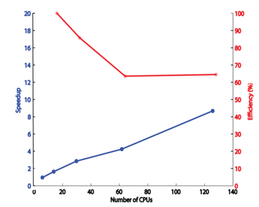
Noah-d is a fully distributed 3-dimentional land surface hydrological modeling system [Gochis and Chen, 2003]



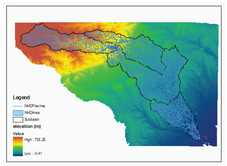
In the Guadalupe River basin, we have created high resolution (30 m) land base raster files for basin mask, elevation, flow direction, pour points, streammask, and stream order [David et al., 2008]. These Noah-d land base files are referenced to the USGS Alberts projected coordinated system. We are processing NEXRAD precipitation and NARR weather data, and a prototype simulation is being developed.



Speedup and efficiency relative to 16 CPUs at TACC Lonestar. The code is fully parallelized for high performance applications.

A river routing model is being developed to calculate stream flow using Noah-d runoff outputs

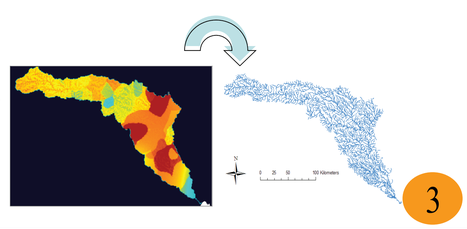
Guadalupe River Basin



NHDPlus data

2,959 river reaches
One major reservoir (Canyon Lake)
Large aquifer (Edwards Aquifer)
Flows into the Gulf
18,000 km^2
740 m elevation drop

Coupling Noah-d with routing model



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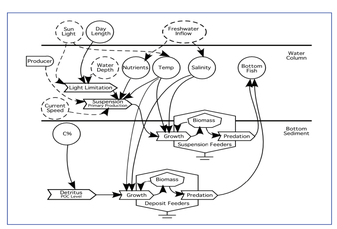
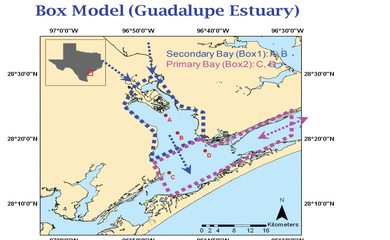
Modeling estuary community biomass and production



Schematic representation of the estuary ecosystem model. Solid lines represent model components that are currently in places and dashed lines represent proposed components. Monte Carlo analysises were used to derive unknown parameteyrs presented in the model equations (i.e. state equations and parameterizations).

Box Model (Guadalupe Estuary)



Since 1987, quarterly sampling has been conducted in the Guadalupe Estuary for environmental (temperature, salinity, pH, secchi depth, meteorological data, etc) and biological variables (benthic fauna, chlorophyll, nutrients etc). Given the information, we developed a box-model having two compartments in between upstream and downstream boundary (San Antonio and Guadalupe river, and Gulf Inlet).

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