Satellite Assessment of CO_2 Distribution, Variability and Flux and Understanding of Control Mechanisms in a River Dominated Ocean Margin
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GulfCarbon 2
CRUISE PLAN
R/V Cape Hatteras 19 April – 1 May 2009

Overview:

The primary hypothesis of our proposed research is that **large river margin water columns exhibit extreme seasonal and spatial variability in air-sea CO_2 fluxes, characterized by localized uptake driven largely by high rates of autotrophic production and loss of CO_2 driven by high terrestrial inputs and heterotrophic respiration.** Our plan of work will involve a multi-disciplinary but focused research approach comprised of four major activities including: 1) *continuous, shipboard, assessments of carbon system properties and air-sea fluxes of CO_2* and relationships to other variables (pH, DIC, TAlk, DO, nutrients, Chlorophyll, Chlorophyll fluorescence, etc) in the river margin shelf ecosystem of the Mississippi- Atchafalaya River, 2) *satellite-derived assessments of regional scale pCO_2 and air-sea carbon fluxes* that will be used to quantify and assess spatial and temporal variations; 3) *targeted process measurements* of plankton community net community metabolism and carbon fixation rates, and phytoplankton pigment composition and size structure at representative sites, which will provide information about the net metabolic balance and composition of the plankton community, and 4) *box-model exercises* simulating plume mixing (estuarine mixing model, Officer, 1979, 1980; Cai et al. 2000), acid-base chemistry (using CO2SYS) and an inverse model to describe biological processes mediating carbon cycling and air-sea flux of CO_2 (Green et al. 2006). A listing of observational efforts is given in Table 1.

Logistics
The ship will be going in and out of Pascagoula, MS. We will load on Saturday, April 18 and are scheduled to depart at 0900 CDT on April 19 and return on May 1 at 1400 CDT. The ship will be docking at the NOAA pier in Pascagoula on Saturday at the following address:

NOAA Gulf Marine Support Facility
151 Watts Avenue
Pascagoula, MS 39567-4102

NOAA personnel who can provide information or assistance are:

George Morris (Port Engineer) TEL: 228-769-1155, cell 228-447-5239 Dale Burgin (Port Office) TEL: 228-769-0307, cell 228-235-0968 Tim Burrell (Port Office Electronics) TEL: 228-769-1130.

Table 1. *Sampling Activities*	
Type of Observation	*Variable Measured*
Underway surface shipboard surveys	*p*CO_2, dissolved oxygen (DO), Temperature (T), salinity (S), chlorophyll fluorescence, transmissometry
In situ particulate and dissolved absorption	WETLabs, Inc. ac9 WETLabs, Inc. ac9 profiled with and without 0.2 µm filter cartridge; ac-s without filter
Backscattering	WETLabs, Inc. ECO BB9 - backscattering at nine wavelengths WETLabs, Inc. ECO VSF3 - backscattering at three wavelengths and three angles
Above Water Hyperspectral Radiometry	Satlantic HyperSAS with discrete UV sensors Analytical Spectral Devices, Inc. FieldSpec Handheld Spectroradiometer
Profiling Radiometry	Satlantic HyperPro and MicroPro
Particulate absorption (discrete samples)	Quantitative filterpad absorption method, Perkin-Elmer Lambda 18 UV/Vis Spectrometer with a RSA-PE-18 Reflectance Spectroscopy Accessory
Aerosol Optical Thickness	Microtops II Sunphotometer
Chromophoric Dissolved Organic Matter absorption (discrete samples)	Spectrophotometric assay, Perkin Elmer Lambda 2
Inorganic Carbon Chemistry	Dissolved Inorganic Carbon (DIC), Alkalinity, pH
Phytoplankton Pigments	High Performance Liquid Chromatography, Waters System
Particle Size Distribution	Sequoia Scientific, Inc. LISST-100
Primary Production	P-E Parameters (^{14}C-HCO3) Community respiration and net production (oxygen-based)

Measurements:

***Underway pCO*$_2$ *monitoring*.** The flow-through system is attached to a "shower head equilibrator plus infrared detector (Li7000)" system to measure sea surface *p*CO_2 with field temperature (Wang and Cai 2004). Air *p*CO_2 will be measured continuously with another Li7000.

Air-sea ***CO_2 flux*** calculation will follow standard methods (Wanninkhof, 1992; McGillis et al., 2001; Lohrenz and Cai, 2006). Continuous wind speed records will be available from the ship as well as from several NOAA National Data Buoy Center meteorological stations. Wind fields can also be characterized using QuikSCAT scatterometer imagery.

pH will be measured on board with an Orion Ross glass electrode (Wang and Cai, 2004).

***DIC and TAlk**.* See Wang and Cai (2004). Samples taken from Niskin bottles will be measured for TAlk on board ship and they will be preserved with $HgCl_2$ and brought back to lab for analysis of DIC. Both analyses have a precision of 0.1% and are calibrated using the Certified Reference Material (CRM) from A. G. Dickson.

DO will be measured underway with an Aanderaa DO sensor. Water samples from the Niskin bottles will also be measured by Winkler titration on board ship with a precision of 0.1-0.2% (a modification of Pai 1993).

***Isotope Tracers**.* Additionally, on selected water samples, ◎^{13}C(DIC) (indicates biological processes, Spiker 1980; Coffin et al. 1994) and ◎^{18}O and D/H ratio (water mass tracers; Fairbanks, 1982) will be measured at the UGA Center for Applied Isotope Study. Preliminary ◎^{18}O and D/H ratio data from the June 2006 cruise indicate that waters in the area are largely a mixture of the Mississippi River water and seawater with some additional inputs.

Community respiration. Water samples (in 300-mL acid clean bottles) will be incubated in darkness at ambient temperature for 24 hours. Both DIC increase and O_2 decrease (Winkler method) will be measured. Rates will be determined from the difference between the intact group and the $HgCl_2$-killed reference group (each 3-5 bottles).

Net metabolic balance (P/R) of surface waters. The upper water column-integrated balance between plankton community gross production (Pg) and respiration (R) defines the net metabolic status of the surface waters. Rates of Pg and R will be based on depth-integrated light/dark bottle O_2 incubations (described in detail in Smith and Kemp, 2003). Briefly, integrated rates of Pg (defined as O_2 changes in light bottles plus dark bottles minus initial bottles) will be determined in 8-12 h simulated in situ incubations for average light levels over the depth of the euphotic zone. Integrated rates of R will be determined by extrapolating volumetric rates (described above) to 24 h and summing over the depth of the euphotic zone. This measurement can be compared to the net metabolic rate constrained from surface water CO_2/DIC mass balance.

Characterization of Phytoplankton Pigment Composition. Phytoplankton pigments will be determined by filtering through GF/F filters and storage in liquid nitrogen. HPLC analysis will follow the protocol of Wright et al. (1991) on a Waters HPLC system. Phytoplankton counts will be determined from water preserved in 0.5% glutaraldehyde and refrigerated for 1 h, and filtered onto 0.2-, and 5-µm polycarbonate filters, the larger size fraction stained with proflavin and counted using epifluorescence microscopy (Dortch et al. 1992, 1997).

Nutrient Analyses and Total Suspended Matter (TSM) Analyses. Inorganic nutrients (NH_3, NO_2/NO_3, PO_4, and Si) will be quantified in samples collected from the underway flow-through mapping effort, and in discrete samples collected from the CTD/Niskin casts. In order to understand the variability in the river (source), we will rely on monitoring data provided by the U.S. Geological Survey at various river sites (http://toxics.usgs.gov/hypoxia/real_time.html). Discrete samples collected on the cruises for inorganic nutrients will be analyzed using an Astoria-Pacific 2+2. Nutrient Analyzer. For TSM, samples will be filtered onto pre-tared 0.45 µm polycarbonate filters (Poretics), rinsed with isotonic ammonium formate to remove sea salt, and dried until weight is stable.

Inherent and Apparent Optical Properties. Optical measurements and modeling will provide a basis for the interpretation of satellite ocean color and its relationship to biogeochemical constituents and will provide ancillary information in support of satellite-based estimations of primary production. Optical profiles of inherent optical properties (IOPs), including total absorption, scattering, backscattering and attenuation, will be made using a package equipped with various sensors. A WETLabs ac-s will provide estimates of in situ spectral absorption and beam attenuation at 99 wavelengths. An ac-9 can be equipped with a filter cartridge to provide simultaneous measurements of absorption by CDOM (Twardowski et al., 1999). The optical package also contains a backscattering sensor (WETLabs, Inc. ECO BB9). Aerosol optical thickness at selected locations will be determined using a Microtops Sunphotometer II. Measurements of IOPs can be used to model irradiance fields using semi-analytical (e.g., Morel, 1991, Lohrenz et al., 2002) or radiative transfer (Hydrolight 4.1, Sequoia Scientific) models. Validation of this approach will be achieved by comparing modeled apparent optical properties with measurements made using Satlantic MicroPro and HyperPro profiling spectroradiometers. Underway hyperspectral above water radiometry will be determined using a Satlantic HyperSAS radiometer with additional discrete UV sensors. Additional hyperspectral above water radiometery measurements will be made using an ASD, Inc. FieldSpec Handheld Spectroradiometer. The measurements of particulate and dissolved absorption will be made on discrete samples. Particulate spectral absorption will be determined by the quantitative filter pad absorption technique (Lohrenz, 2000; Mitchell et al., 2000, Lohrenz et al., 2003). Spectral absorption of chromophoric dissolved organic matter (CDOM) is determined by filtering samples through a rinsed 0.2 ◎m polycarbonate membrane (Poretics) filter and scanning in a dual beam instrument using 10 cm quartz cuvettes.

Primary Production. At selected stations, photosynthesis-irradiance (P-E) parameters will be determined by incubation with 14C-HCO3- similar to that described in Lohrenz et al. (1994). The derived photosynthetic parameters will be used in conjunction with biomass and irradiance distributions to model water column-integrated primary production in the system. Lohrenz has successfully used a wavelength-integrated (WIM) model (after Behrenfeld and Falkowski, 1997) for estimation of primary production on the Texas shelf (Chen et al., 2000), and a wavelength-resolved model (WRM) in shelf waters off North Carolina (Lohrenz et al., 2002; Carr et al., 2006). These models will be implemented at various spatial scales using observations from vertical profiles, underway-mapped surface distributions, and satellite imagery. A large database of photosynthetic parameters for the Mississippi delta region (Lohrenz et al. 1994) is available and will be supplemented by additional measurements in this study.

Cruise Personnel and Affiliations:

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Steven Lohrenz	Male	University of Southern Mississippi (USM)	Steven.Lohrenz@usm.edu	985-788-0130
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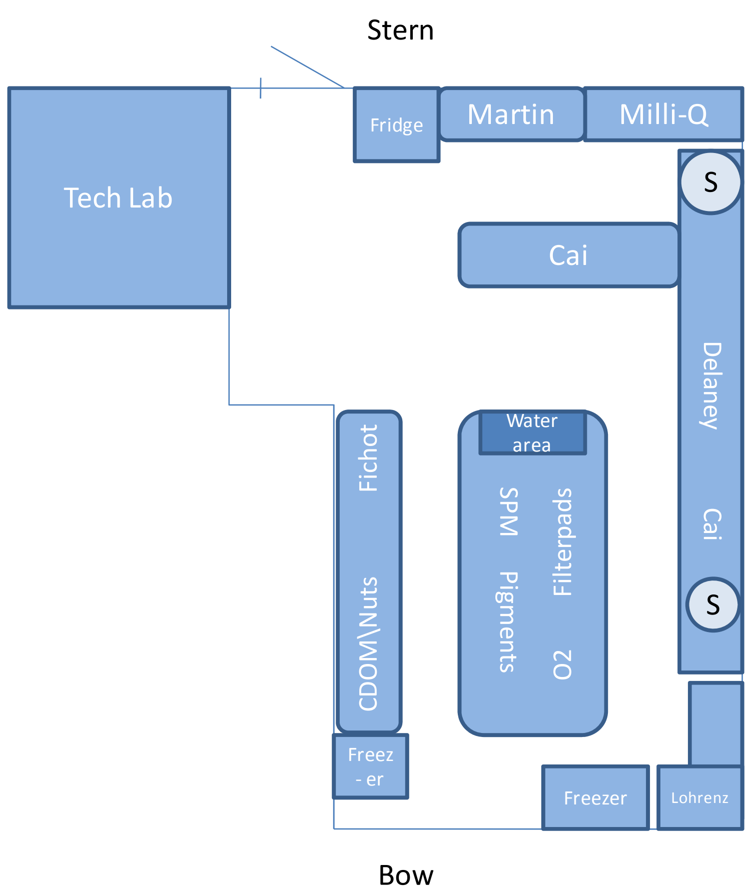
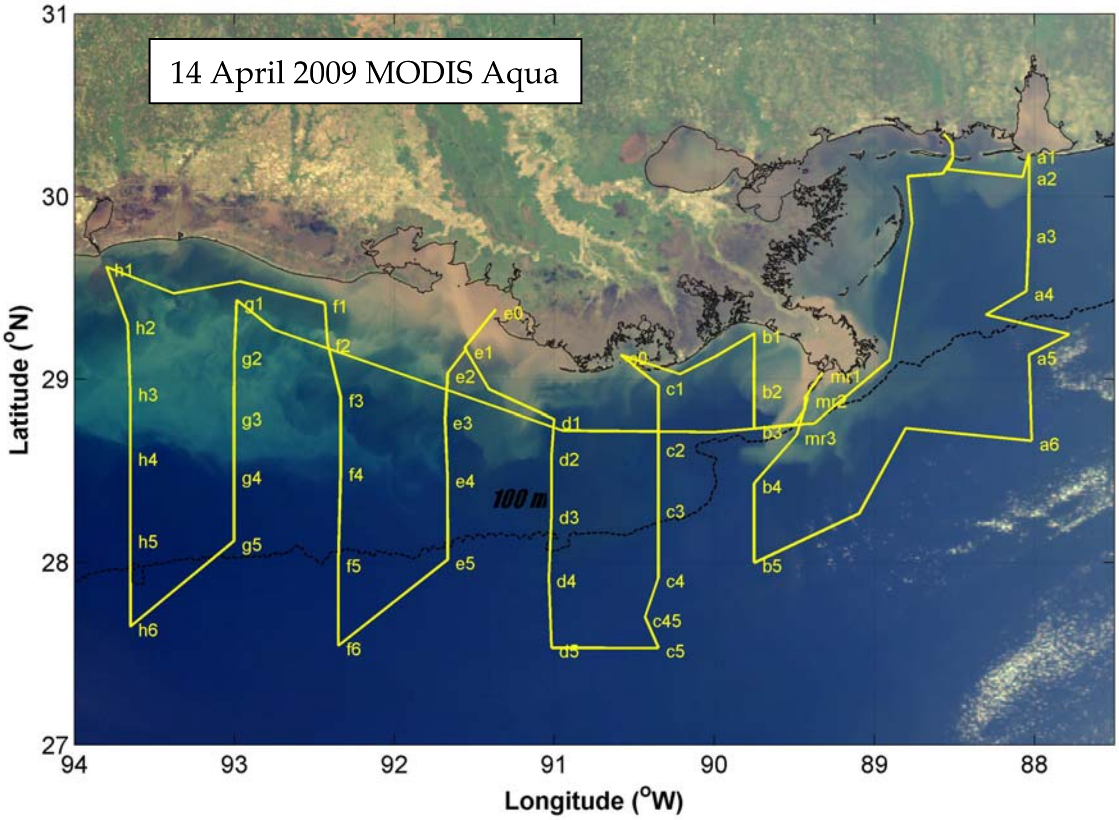
Jenny Delaney	Female	University of South Florida	jadelane@mail.usf.edu	815-871-8575

Proposed Lab Plan



Route Maps



14 April 2009 MODIS Aqua
Latitude (°N)
Longitude (°W)
100 m
a1
a2
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b2
b3
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f4
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mr1
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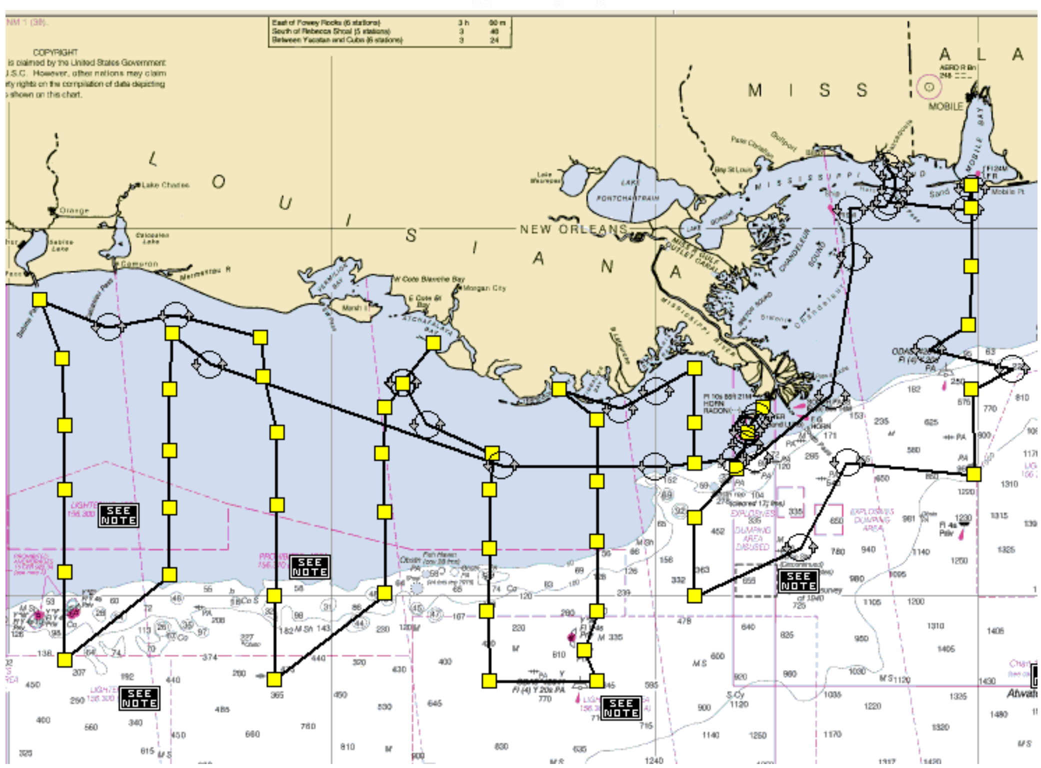

L O U I S I A N A
M I S S
A L A
NEW ORLEANS
SEE NOTE

Route Plan (tentative)

Leg No., Name	Ending Waypoint Lat/Lon	Dist.	Bearing	Speed	Time	Completion	Pause
1, Point 1	30° 20.621′ N 088° 34.027′ W			0	0:00:00	4/19/2009 14:00	0:00:00
2, Point 2	30° 17.267′ N 088° 30.911′ W	4.3	142.68	5	0:51:36	4/19/2009 14:51	0:00:00
3, Point 3	30° 12.656′ N 088° 30.619′ W	4.62	178.32	9	0:30:47	4/19/2009 15:22	0:00:00
4, Point 4	30° 09.043′ N 088° 32.586′ W	3.99	206.65	9	0:26:36	4/19/2009 15:48	0:00:00
5, Point 5	30° 06.453′ N 088° 04.372′ W	24.54	97.47	9	2:43:36	4/19/2009 18:32	0:00:00
6, a1	30° 14.079′ N 088° 02.023′ W	7.89	16.65	5	1:34:40	4/19/2009 20:07	2:00:00
7, Point 7	30° 13.474′ N 088° 02.121′ W	0.61	189.77	9	0:04:04	4/19/2009 22:11	0:00:00
8, a2	30° 07.026′ N 088° 02.024′ W	6.45	181.04	9	0:42:59	4/19/2009 22:54	2:00:00
9, a3	29° 48.082′ N 088° 02.099′ W	18.94	181.97	9	2:06:16	4/20/2009 3:00	1:00:00
10, a4	29° 29.061′ N 088° 03.002′ W	19.04	184.09	9	2:06:56	4/20/2009 6:07	1:00:00
11, Point 11	29° 21.224′ N 088° 18.254′ W	15.42	241.14	9	1:42:48	4/20/2009 8:50	0:00:00
12, Point 12	29° 14.819′ N 087° 47.004′ W	27.99	104.71	9	3:06:35	4/20/2009 11:56	
13, a5	29° 08.001′ N 088° 02.040′ W	14.79	244.39	9	1:38:35	4/20/2009 13:35	2:00:00
14, a6	28° 40.070′ N 088° 01.054′ W	27.94	179.87	9	3:06:16	4/20/2009 18:41	2:00:00
15, Point 15	28° 44.123′ N 088° 48.361′ W	41.69	277.17	9	4:37:55	4/21/2009 1:19	1:00:00
16, Point 16	28° 16.162′ N 089° 05.741′ W	31.86	209.7	10	3:11:09	4/21/2009 5:30	
17, b5	28° 00.015′ N 089° 45.081′ W	38.27	245.84	10	3:49:37	4/21/2009 9:20	
18, b4	28° 26.029′ N 089° 45.082′ W	26.01	0.32	10	2:36:03	4/21/2009 11:56	
19, mr3	28° 42.013′ N 089° 29.098′ W	21.27	41.66	10	2:07:37	4/21/2009 14:04	
20, mr2	28° 54.016′ N 089° 25.089′ W	12.51	16.9	9	1:23:24	4/21/2009 15:27	1:00:00
21, Point 21	28° 54.233′ N 089° 25.913′ W	0.75	287.39	5	0:09:00	4/21/2009 16:36	0:00:00
22, Point 22	28° 54.674′ N 089° 25.514′ W	0.56	39.08	5	0:06:43	4/21/2009 16:43	0:00:00
23, Point 23	28° 55.886′ N 089° 24.631′ W	1.44	33.15	5	0:17:16	4/21/2009 17:00	0:00:00
24, Point 24	28° 57.153′ N 089° 23.738′ W	1.49	32.33	5	0:17:52	4/21/2009 17:18	0:00:00
25, Point 25	28° 59.376′ N 089° 21.856′ W	2.77	37.19	5	0:33:14	4/21/2009 17:51	0:00:00
26, mr1	29° 02.217′ N 089° 19.504′ W	3.51	36.62	5	0:42:07	4/21/2009 18:33	1:00:00
27, Point 27	28° 59.342′ N 089° 21.920′ W	3.57	217.05	9	0:23:47	4/21/2009 19:57	0:00:00
28, Point 28	28° 57.214′ N 089° 23.728′ W	2.65	217.32	9	0:17:40	4/21/2009 20:15	0:00:00
29, Point 29	28° 55.945′ N 089° 24.624′ W	1.49	212.37	9	0:09:56	4/21/2009 20:25	0:00:00
30, Point 30	28° 54.717′ N 089° 25.506′ W	1.45	212.84	9	0:09:40	4/21/2009 20:34	0:00:00
31, Point 31	28° 54.279′ N 089° 25.945′ W	0.58	221.89	9	0:03:51	4/21/2009 20:38	0:00:00
32, Point 32	28° 50.103′ N 089° 26.109′ W	4.18	182.61	9	0:27:51	4/21/2009 21:06	0:00:00
33, Point 33	28° 45.407′ N 089° 30.142′ W	5.88	217.6	9	0:39:12	4/21/2009 21:45	0:00:00
34, b3	28° 44.020′ N 089° 45.070′ W	13.16	264.53	9	1:27:43	4/21/2009 23:13	2:00:00
35, b2	28° 57.053′ N 089° 45.038′ W	13.03	0.52	9	1:26:51	4/22/2009 2:40	1:00:00
36, b1	29° 15.087′ N 089° 45.025′ W	18.03	0.46	9	2:00:12	4/22/2009 5:40	1:00:00
37, Point 37	29° 07.632′ N 089° 59.437′ W	14.62	239.82	9	1:37:27	4/22/2009 8:17	0:00:00
38, Point 38	29° 01.706′ N 090° 12.926′ W	13.19	243.59	5	2:38:16	4/22/2009 10:56	0:00:00
39, c0	29° 08.007′ N 090° 35.026′ W	20.32	288.18	5	4:03:50	4/22/2009 14:59	1:00:00
40, c1	28° 58.051′ N 090° 21.088′ W	15.73	129.13	5	3:08:45	4/22/2009 19:08	1:00:00
41, c2	28° 38.061′ N 090° 21.093′ W	19.99	180.03	9	2:13:15	4/22/2009 22:21	1:00:00

42, c3	28° 18.013′ N	090° 21.055′ W	20.05	179.89	9	2:13:39	4/23/2009 1:35	1:00:00
43, c4	27° 55.075′ N	090° 21.053′ W	22.94	179.94	9	2:32:56	4/23/2009 5:08	1:30:00
44, c45	27° 42.062′ N	090° 26.077′ W	13.75	198.76	9	1:31:39	4/23/2009 8:10	2:00:00
45, c5	27° 32.024′ N	090° 21.057′ W	10.98	155.92	9	1:13:11	4/23/2009 11:23	2:00:00
46, d5	27° 32.049′ N	091° 01.065′ W	35.51	269.9	9	3:56:43	4/23/2009 17:20	2:00:00
47, d4	27° 55.059′ N	091° 02.003′ W	23.02	357.35	9	2:33:28	4/23/2009 21:53	2:00:00
48, d3	28° 16.071′ N	091° 01.086′ W	21.03	1.65	9	2:20:12	4/24/2009 2:13	1:30:00
49, d2	28° 35.043′ N	091° 01.055′ W	18.97	0	9	2:06:27	4/24/2009 5:50	1:00:00
50, d1	28° 47.025′ N	091° 00.065′ W	12.01	3.67	9	1:20:04	4/24/2009 8:10	1:00:00
51, Point 51	28° 56.780′ N	091° 24.534′ W	23.54	294.03	9	2:36:56	4/24/2009 11:47	0:00:00
52, Point 52	29° 10.347′ N	091° 33.643′ W	15.73	328.89	5	3:08:45	4/24/2009 14:55	0:00:00
53, e0	29° 23.006′ N	091° 22.033′ W	16.21	37.87	5	3:14:31	4/24/2009 18:10	1:00:00
54, Point 54	29° 10.512′ N	091° 33.504′ W	16.01	218.05	5	3:12:07	4/24/2009 22:22	0:00:00
55, e1	29° 10.021′ N	091° 33.085′ W	0.61	142.54	5	0:07:19	4/24/2009 22:29	1:00:00
56, e2	29° 02.007′ N	091° 40.045′ W	10.06	216.41	9	1:07:04	4/25/2009 0:36	1:00:00
57, e3	28° 47.011′ N	091° 41.035′ W	15.02	182.44	9	1:40:08	4/25/2009 3:17	1:30:00
58, e4	28° 28.009′ N	091° 40.098′ W	19.02	176.62	9	2:06:48	4/25/2009 6:53	2:00:00
59, e5	28° 01.003′ N	091° 40.057′ W	27.01	179	9	3:00:04	4/25/2009 11:53	2:00:00
60, f6	27° 32.764′ N	092° 21.018′ W	45.94	231.11	9	5:06:15	4/25/2009 19:00	2:00:00
61, f5	28° 00.073′ N	092° 21.018′ W	27.31	358.55	9	3:02:03	4/26/2009 0:02	2:00:00
62, f4	28° 30.086′ N	092° 20.073′ W	30.02	0.17	9	3:20:08	4/26/2009 5:22	2:00:00
63, f3	28° 54.049′ N	092° 20.077′ W	23.96	358.63	9	2:39:43	4/26/2009 10:02	1:30:00
64, f2	29° 12.073′ N	092° 25.038′ W	18.54	345.14	9	2:03:36	4/26/2009 13:35	1:00:00
65, f1	29° 25.026′ N	092° 26.015′ W	12.98	354.88	9	1:26:31	4/26/2009 16:02	1:00:00
66, Point 66	29° 32.186′ N	092° 58.166′ W	28.89	283	9	3:12:35	4/26/2009 20:14	1:00:00
67, Point 67	29° 28.327′ N	093° 22.809′ W	21.79	258.11	10	2:10:44	4/26/2009 23:25	
68, h1	29° 37.005′ N	093° 48.026′ W	23.59	289.61	10	2:21:32	4/27/2009 1:47	
69, h2	29° 18.091′ N	093° 40.029′ W	20.16	157.55	10	2:00:57	4/27/2009 3:48	
70, h3	28° 56.014′ N	093° 39.099′ W	22.09	175.72	10	2:12:32	4/27/2009 6:00	
71, h4	28° 35.041′ N	093° 39.095′ W	20.97	177.8	10	2:05:49	4/27/2009 8:06	
72, h5	28° 08.010′ N	093° 39.055′ W	27.03	177.71	10	2:42:10	4/27/2009 10:48	
73, h6	27° 39.037′ N	093° 39.019′ W	28.97	177.69	10	2:53:49	4/27/2009 13:42	
74, g5	28° 07.065′ N	093° 00.089′ W	44.38	48.56	10	4:26:16	4/27/2009 18:08	
75, g4	28° 29.071′ N	093° 00.068′ W	22.01	358.22	9	2:26:44	4/27/2009 20:35	2:00:00
76, g3	28° 48.090′ N	093° 00.068′ W	19.02	358.2	9	2:06:48	4/28/2009 0:42	2:00:00
77, g2	29° 08.016′ N	093° 00.020′ W	19.93	358.35	10	1:59:34	4/28/2009 4:41	
78, g1	29° 26.044′ N	092° 59.083′ W	18.05	0.85	10	1:48:17	4/28/2009 6:30	
79, Point 79	29° 16.298′ N	092° 45.364′ W	15.43	127.47	9	1:42:52	4/28/2009 8:12	0:00:00
80, Point 80	28° 43.369′ N	090° 56.951′ W	100.38	107.58	9	11:09:11	4/28/2009 19:22	0:00:00
81, Point 81	28° 42.872′ N	089° 59.981′ W	49.97	90.15	9	5:33:08	4/29/2009 0:55	0:00:00
82, Point 82	28° 45.679′ N	089° 22.606′ W	32.89	85.33	9	3:39:15	4/29/2009 4:34	0:00:00
83, Point 83	29° 06.367′ N	088° 54.211′ W	32.34	50.89	9	3:35:36	4/29/2009 8:10	0:00:00
84, Point 84	29° 51.035′ N	088° 45.909′ W	45.25	10.22	9	5:01:39	4/29/2009 13:11	0:00:00
85, Point 85	30° 06.621′ N	088° 47.575′ W	15.65	355.93	9	1:44:19	4/29/2009 14:56	0:00:00
86, Point 86	30° 07.577′ N	088° 34.272′ W	11.55	86.49	9	1:17:00	4/29/2009 16:13	0:00:00

87, Point 87	30° 12.803´ N 088° 30.562´ W	6.13	32.93	5	1:13:33	4/29/2009 17:26	0:00:00
88, Point 88	30° 17.388´ N 088° 30.861´ W	4.59	358.23	5	0:55:04	4/29/2009 18:21	0:00:00
89, Point 89	30° 20.604´ N 088° 34.005´ W	4.21	321.28	5	0:50:31	4/29/2009 19:12	0:00:00

R/V CAPE HATTERAS BERTHING PLAN

Cruise Name/Number: Lohrenz USM/CH-02-09

Date, Time, & Place Of Departure: 0900: 19 April 2009 - Pascagoula, MS

Date, Time, & Place Of Arrival: 1400: 01 May 2009 - Pascagoula, MS

Instructions to Chief Scientist: Fill in cruise information above. Provide each scientist last name in block listing for Scientist Rooms below. The Chief Scientist normally resides in Room 2, however that is not a requirement.

Crew Rooms	Occupant
1	Captain
3	Chief Mate
5	2nd Mate - AB
7	AB - AB
9	Steward - Messman
11	Assistant Engineer
13	Chief Engineer

Scientist Rooms	Occupant
2	Wang
	Hu
4	Lohrenz
	Gundersen
6	Epps
	Reader
8	Huang
	Cai
10	Chakraborty
	Martin
12	Fichot
	Tech
14	Thomas
	Delaney