Cruise Report

NOAA Ship RONALD H. BROWN
Cruise RB-01-01
GasEx 2001

24 January - 8 March 2001

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NOAA RESEARCH CRUISE: GasEx 2001

NOAA Ship RONALD H. BROWN
Area: Eastern Equatorial Pacific

Cruise Number RB-01-01
Itinerary
Leg 1A Charleston-Miami d. 24 Jan a. 26 Jan
Leg 1B Miami-Panama d. 28 Jan a.2 Feb
Leg 1C Panama-Honolulu (official start of GasEx 2001) d. 2 Feb a. 8 Mar

Participating Organizations

NOAA/PMEL	*Pacific Marine Environmental Laboratory*
NOAA/AOML	*Atlantic Oceanographic and Meteorological Laboratory*
NOAA/ETL	*Environmental Technology Laboratory*
WHOI	*Woods Hole Oceanographic Institution*
UW/APL	*University of Washington – Applied Physics Lab*
MBARI	*Monterey Bay Aquarium Research Institute*
UM	*University of Montana*
U. Miami	*University of Miami/RSMAS*
UH	*University of Heidelberg*
URI	*University of Rhode Island*
UG	*University of Groningen*
CCIW	*Canadian Centre for Inland Waters*

1.0 Cruise Description and Objectives

The GasEx 2001 study took place aboard the *NOAA Ship RONALD H. BROWN (RHB)* in the Eastern Equatorial Pacific along 3°S between 125°W-130°W. The primary objective was to use direct gas flux measurements to improve our understanding of the forcing functions on the kinetics of air-sea gas exchange. A second focus was to determine the physical, chemical, and biological factors controlling pCO_2 in the surface water. The region is a CO_2 source with relatively low wind speeds offering a strong contrast with the first Gas-Ex study conducted in 1998 conducted in the North Atlantic in an area of high winds and large CO_2 sink.

The Equatorial Pacific has been a focal point for chemical and physical studies such as JGOFS and TOGA because it has a major influence on climate variability through the ENSO cycle. The questions about mesoscale CO_2 dynamics in this region relate to biological versus physical control, and remote versus local influences. Near the upwelling center it seems that the patterns in pCO_2 are dominated by physics while further off-axis biological control becomes more important. The pCO_2 in the surface water relates directly to upwelling strength, but regional fluxes are strongly influenced by remote factors such as the capping off of the upwelling system by the low salinity water advecting from the West. Diurnal heating, tropical instability waves, variations in biological productivity, and trace metal limitations on productivity are also important.

1.1 Personnel

PERSONNEL Leg 1A CHIEF SCIENTIST Chris Fairall NOAA/ETL
Charleston-Miami

#	NAME	TITLE	Project	Institute	SEX	NAT.
1	Chris Fairall	Chief Scientist	BROWN meteorology	NOAA/ETL	M	US
2	Kara Sterling	Meteorologist	BROWN meteorology	UC	F	US
3	Andrey Grachev	Meteorologist	BROWN meteorology	NOAA/ETL	M	Russian
4	Dana Lane	Meteorologist	BROWN meteorology	NOAA/ETL	F	US
5	Catherine Russell	Meteorologist	BROWN meteorology	NOAA/ETL	F	US
6	Michelle Ryan	Meteorologist	BROWN meteorology	NOAA/ETL	F	US
7	Brian Templeman	Meteorologist	BROWN meteorology	NOAA/ETL	F	US
8	Bill Asher	Co-Chief Scientist	IR remote sensing	U. Washington	M	US
9	Trina Litchendorf	Physical Oceanographer	IR remote sensing	U. Washington	F	US

PERSONNEL Leg 1B CHIEF SCIENTIST Rik Wanninkhof NOAA/AOML
Miami-Panama Wade McGillis (Co-Chief Scientist) WHOI

#	NAME	TITLE	Project	Institute	SEX	NAT.
1	Rik Wanninkhof	Co-Chief Scientist	Core CO_2/Hydrography	NOAA/AOML	M	US
2	Wade McGillis	Co-Chief Scientist	CO_2	WHOI	M	US
3	Lisa Dilling	Program Manager		NOAA/OGP	F	US
4	Kristy McTaggart	Physical Oceanographer	Core CO_2/Hydrography	NOAA/PMEL	F	US
5	Marilyn Roberts	Chemist	Core CO_2/Hydrography	NOAA/PMEL	F	US
6	Pete Strutton	Biologist	Primary/New Production	MBARI	M	Australian
7	James Smith	Biologist	Primary/New Production	MBARI	M	US
8	Brian Ward	Physical Oceanographer	Skin DeEP	NOAA/AOML	M	Irish
9	Robert Castle	Chemist	pCO_2 variability	NOAA/AOML	M	US
10	Mike DeGrandpre	Chemist	pCO_2 variability	U. Montana	M	US
11	Nelson Frew	Marine Chemist	LADAS	WHOI	M	US
12	Robert Nelson	Marine Chemist	LADAS	WHOI	M	US
13	Erik Bock	Physical Oceanographer	LADAS	U. Heidelberg	M	US
14	Uwe Schimpf	Physical Oceanographer	LADAS	U. Heidelberg	M	German
15	Christoph Garbe	Physical Oceanographer	LADAS	U. Heidelberg	M	German
16	Tetsu Hara	Physical Oceanographer	LADAS	U. RI	M	Japanese
17	Nick Witzell	Engineer	LADAS	WHOI	M	US
18	Sean McKenna	Physical Oceanographer	BROWN meteorology	WHOI	M	US
19	Bill Asher	Physical Oceanographer	IR remote sensing	U. Washington	M	US
20	Craig Neill	Chemical Oceanographer	IR remote sensing	U. Washington	M	US
21	Trina Litchendorf	Physical Oceanographer	IR remote sensing	U. Washington	F	US
22	Jon Ware	Engineer	CO_2/meteorology/SPIP/pCO_2	WHOI	M	US
23	Chris Zappa	Physical Oceanographer	Heat Flux/SPIP	WHOI	M	US
24	Will Drennan	Physical Oceanographer	ASIS	U. Miami	M	Canadian
25	Gene Terray	Physical Oceanographer	ASIS	WHOI	M	US
26	Joe Gabrielle	Engineer	ASIS	CCIW	M	Canadian
27	Charlie Fisher	Chemical Oceanographer	Nutrients	NOAA/AOML	M	US
28	Kevin Sullivan	Chemical Oceanographer	CO_2	NOAA/AOML	M	US
29	Calvin Mordy	Chemical Oceanographer	Nutrients	NOAA/PMEL	M	US
30	Jenny Hanafin	Physical Oceanographer	M-AERI	U. Miami/RSMAS	F	Irish
31	Henk Zemmelink	Biologist	DMS/SPIP	U. Groningen	M	Dutch
32	Jeff Evans	Biologist	DMS/SPIP	WHOI	M	US
33	John Dacey	Biologist	DMS/SPIP	WHOI	M	Canadian

PERSONNEL Leg 1C CHIEF SCIENTIST Richard Feely NOAA/PMEL
Panama-Honolulu Wade McGillis (Co-Chief Scientist) WHOI

#	NAME	TITLE	Project	Institute	SEX	NAT.
1	Richard Feely	Co-Chief Scientist	Core CO_2/Hydrography	NOAA/PMEL	M	US
2	Wade McGillis	Co-Chief Scientist	CO_2	WHOI	M	US
3	Chris Sabine	Chemist	Core CO_2/Hydrography	NOAA/PMEL	M	US
4	Kristy McTaggart	Physical Oceanographer	Core CO_2/Hydrography	NOAA/PMEL	F	US
5	Marilyn Roberts	Chemist	Core CO_2/Hydrography	NOAA/PMEL	F	US
6	Dana Greeley	Chemist	Core CO_2/Hydrography	NOAA/PMEL	M	US
7	Pete Strutton	Biologist	Primary/New Production	MBARI	M	Australian
8	James Smith	Biologist	Primary/New Production	MBARI	M	US
9	Brian Ward	Physical Oceanographer	Skin DeEP	NOAA/AOML	M	Irish
10	Robert Castle	Chemist	pCO_2 variability	NOAA/AOML	M	US
11	Mike DeGrandpre	Chemist	pCO_2 variability	U. Montana	M	US
12	Nelson Frew	Marine Chemist	LADAS	WHOI	M	US
13	Robert Nelson	Marine Chemist	LADAS	WHOI	M	US
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16	Christoph Garbe	Physical Oceanographer	LADAS	U. Heidelberg	M	German
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18	Nick Witzell	Engineer	LADAS	WHOI	M	US
19	Mike Rabozo	Marine Technician	LADAS/ASIS	U. Miami	M	US
20	Jeff Hare	Meteorologist	BROWN meteorology	NOAA/ETL	M	US
21	Sean McKenna	Physical Oceanographer	BROWN meteorology	WHOI	M	US
22	Craig Neill	Chemical Oceanographer	IR remote sensing	U. Washington	M	US
23	Trina Litchendorf	Physical Oceanographer	IR remote sensing	U. Washington	F	US
24	Jon Ware	Engineer	CO_2/meteorology/SPIP/p CO_2	WHOI	M	US
25	Chris Zappa	Physical Oceanographer	Heat Flux/SPIP	WHOI	M	US
26	Will Drennan	Physical Oceanographer	ASIS	U. Miami	M	Canadian
27	Gene Terray	Physical Oceanographer	ASIS	WHOI	M	US
28	Joe Gabrielle	Engineer	ASIS	CCIW	M	Canadian
29	Charlie Fisher	Chemical Oceanographer	Nutrients	NOAA/AOML	M	US
30	Calvin Mordy	Chemical Oceanographer	Nutrients	NOAA/PMEL	M	US
31	Jenny Hanafin	Physical Oceanographer	M-AERI	U. Miami/RSMAS	F	Irish
32	Henk Zemmelink	Biologist	DMS/SPIP	U. Groningen	M	Dutch
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Explanation of abbreviations:

ASIS – Air-Sea Interaction Spar Buoy
DMS – Dimethylsulfide
SPIP – Surface Processes Instrument Platform
LADAS – Air-Sea Interaction Catamaran
SMS – Surface Microlayer Sampler
SPMR – Satlantic 13 Channel Profiling Radiometer
FRRF – Fast Repetition Rate Fluorometer
FSTP- Fine-Scale Temperature Profiler

2.0 OPERATIONS

Leg 1A was a 1-1/2 day transit between Charleston and Miami, and was used as training for both ETL and UW personnel. Most Leg1A scientists disembarked in Miami.

Leg 1B began in Miami and ended in Panama. Most scientists participating in the GasEx 2001 cruise embarked in Miami for the duration of the cruise to Honolulu; however, several scientists were aboard for testing and training purposes and disembarked in Panama.

Leg 1C was the primary leg of GasEx 2001. The operations during the GasEx 2001 cruise were multi-faceted with high demands on ship's operations. A wide range of intensive over-the-side measurements were performed including: the LADAS catamaran, the ASIS platform, CARIOCA/SAMI buoy, and FSTP buoys, zodiac SMS and SPIP operations, CTD/Niskin sampling, underway seawater surface measurements and SPMR biological profiler measurements. In addition, atmospheric measurements were made using equipment mounted on the bow tower, which is aft of the jackstaff; additional atmospheric measurements were made from a bow boom.

A description of each ocean and atmospheric measurement follows:

2.1 Over-the-side Operations

One test CTD was conducted at 1°53.2'N, 89°43.2'W during the transit to 3°S, 125°W. Upon arrival at the primary study site at 3S, 125W on 2/13/01, we conducted the first butterfly survey, taking stations within 75 km in both latitude and longitude. On 2/15/01 the ASIS and CARIOCA buoys were deployed. We then began CTD's commencing with 24-hr intensive study at 3°S /125°W on 02/16/01. As we began our westerly transit, we conducted daily operations of FSTP buoys, zodiac SMS and SPIP operations, LADAS catamaran deployments, CTD operations, and underway seawater surface measurements and SPMR biological profiler operations. The timing of these operations changed from day to day due to weather conditions and equipment turnaround requirements. The ASIS buoy was retrieved on 02/23/01 and a second butterfly survey was performed on 02/21-22/01. A second 24-hr intensive study was conducted around 2.5°S, 128°W on 02/25-26/01. At the end of the 3°S line (2.5°S, 131°W) all of the over-the-side instruments were recovered on 03/01/01, and we then began a series of eight 500m CTD's in direct line to Honolulu between 2°S -5°N. Appendix 1 shows a map of the GasEx 2001 Cruise trackline.

2.1.1 ASIS Operations (E. Terray, W. Drennan, J. Gabriele, and M. Rabozo)

The Air-Sea Interaction Spar (ASIS) is a hybrid spar buoy designed to provide a stable platform for near-surface measurements of air-side and water-side fluxes. During GasEx 2001 it was deployed on four separate occasions – the table below lists the deployment times and locations. The top of the meteorological tower on the spar is roughly 5.5 meters above the mean water level (MWL), while the base of the spar is approximately 6.5 m below MWL. The buoy was equipped along its length with a variety of meteorological and oceanographic sensors, including sonic anemometers, CO_2 and water vapor sensors, and sensors to measure air temperature, relative humidity, barometric pressure, short- and long-wave radiation, surface waves (having wavelengths greater than 2 m), and near-surface profiles of temperature and current along the spar. In addition, we deployed a downward-looking ADCP at the base of the spar. This instrument measured current profiles to a depth of approximately 40 m. An inventory of the data collected is given in summary form in the second table below.

Anticipated data products on the air-side are the mean wind speed and direction, temperature, humidity, barometric pressure, pCO_2, and solar & infrared radiation. In addition, we intend to compute the fluxes of momentum, sensible and latent heat, and CO_2 via direct eddy-correlation. On the water-side we expect to compute density and current profiles, and spectra of wave height and direction for the energy-containing waves. In addition, we will attempt to estimate turbulent fluxes and dissipation rates over the depth range from 1-5 m.

ASIS DEPLOYMENT TIMES/LOCATIONS

Deployment	Yday	UTC	Date	Latitude	Longitude
Start I	041	1710	2/10	02° 40.160'S	110° 00.360'W
End	042	0100	2/11	02° 46.802'S	110° 00.388'W
Start II	045	2335	2/14	03° 00.020'S	125° 59.997'W
End	054	1750	2/23	02° 27.938'S	128° 40.765'W
Start III	056	1810	2/25	02° 25.510'S	129° 41.320'W
End	057	1750	2/26	02° 27.720'S	130° 09.210'W
Start IV	058	1708	2/27	02° 21.414'S	130° 42.311'W
End	060	0100	3/01	02° 17.590'S	131° 28.796'W

ASIS DATA INVENTORY

Measurements	Deployments			
Meteorological	I	II	III	IV
Wind u, v, w, c	X	X	X	X
Air Temperature	X	X	X	X
Humidity	X	X	X	X
Barometric Pressure		X	X	X
pCO_2	X	X	X	X
Radiation (Solar + IR)	X	1^{st} day only	X	X
Oceanographic				
Surface Waves	X	X		X
Current Profiles	1-4 m	6-40 m	1-40 m	1-40 m
Temperature Profiles*	1 m	2-6 m	1-6 m	1-6 m
Salinity*, O_2*, pCO_2*	X	X	X	X

*See DeGrandpre

2.1.2 LADAS (Surface Films and Sea Surface Roughness)

LADAS is a remotely-operated catamaran designed for air-sea interaction studies. It carries several instrument packages including a scanning laser slope gauge (SLSG), infrared imaging system, surface microlayer sampler (SMS), a fluorometry and extraction system (SCIMS), sonic anemometer, attitude measuring unit (AMU) and acoustic Doppler velocimeter. The LADAS team consists of individuals from Woods Hole Oceanographic Institution (N. Frew, R. Nelson, N. Witzell), the University of Heidelberg (E. Bock, U. Schimpf, and C. Garbe), and the University of Rhode Island (T. Hara). The LADAS team was augmented with the generous help of M. Rabozo (University of Miami) and Joe Gabriel (Canada Centre for Inland Waters) during deployment and recovery operations.

Three primary instrument packages were used together to study the modulation of heat and gas exchange rates by small-scale waves and surface films. The SLSG provided short-wave slope measurements for wavelengths between 0.5 cm and 15 cm, with frequencies up to 208 Hz. The data can be used to obtain wavenumber-frequency spectra, directional wavenumber spectra, and wavenumber-binned mean square slope. The infrared imaging system provides images sequences of sea-surface temperatures (domain size 40 x 40 cm) with a resolution 0.15 cm. These sequences can be processed to obtain heat flux estimates on very short time-scales (~ 1 sec). Additionally, motion analysis of the image sequences allows sea surface drift measurements. In the context of a surface renewal model, the data will provide estimates of spatial and temporal statistics of near-surface mixing and bulk temperature. Scaling of the heat flux using appropriate Prandtl and Schmidt numbers will allow estimates of the gas transfer coefficient. The surface microlayer sampler and fluorometry package provided estimates of surface chemical enrichments using CDOM fluorescence. An automated extraction system processes both microlayer and subsurface (10 cm) flow streams from the sampler and extracts surfactants for later analysis by mass spectrometry. LADAS was successfully deployed 14 times during the process study period. LADAS was typically operated at a distance of 0.2-0.4 nm from the ship, thus minimizing any influences from the ship, including flow distortion. LADAS' heading was generally held to within 20 degrees of the wind direction in order to minimize perturbation of the wave field, current, and wind speed measurements by the platform. While the measured wind speeds are not suitable for wind stress estimates due to the low mast height (2 m), they will provide a good measure of the instantaneous wind forcing (gustiness, intermittency). The quality of ADV current measurements appears to be high, since sufficient scatterers were present in the water. The LADAS deployments during GasEx 2001 represent the first spatially and temporally coincident measurements of small-scale wave statistics, heat and gas fluxes, and surface film enrichments.

In addition to LADAS deployments, we twice deployed a microlayer sampler from the Zodiac, collecting large volume microlayer and subsurface samples. These samples were processed using both a foam stripping tower and a solid phase extraction system to isolate surface-active compounds for later laboratory analysis.

Water samples were also collected from surface bottles during CTD casts at 25 stations. These will be analyzed in Woods Hole laboratory for soluble surfactant levels using a polarographic technique.

2.1.3 SPIP/SMS Operations (C. Zappa, W. McGillis, S. McKenna, J. Ware, E. Terray, M. DeGrandpre, H. Zemmelink, J. Evans)

The Surface Processes Instrument Platform (SPIP) is a 15-foot, remotely-operated Hobie® Wave catamaran used to measure the atmospheric gradients of CO_2, temperature, water vapor, and momentum very close to the air-water interface. SPIP is deployed as a self-contained unit to determine the processes that effect these air-sea exchanges and has supporting measurements of the water-side forcing. SPIP has the advantage of measuring gradients right at the surface that the Brown mast may miss and with potentially less flow distortion than the Brown mast. Operationally, SPIP has a mast with fixed and traveling atmospheric sensors. The fixed atmospheric sensors are located at the top of the mast while a second set of identical sensors are mounted to a motorized traveler with 3 meters of range on the mast track from the top of the mast to 30 cm above the water surface. From the measured gradients, we calculate the CO_2, latent, sensible, and momentum fluxes as well as the appropriate transfer coefficients for comparison to the direct covariance measurements and bulk formulae.

A total of 10 deployments were made. The traveling sonic anemometer died during the 5th Deployment. DMS gradients were measured during Deployments 6 and 7. Deployment 8 was cut short because the generator died. Post-processing is required for all measurements.

Instrument	**Data Products**	**Data Return**
2 Gill 2-D sonic anemometers	Wind Speed; Wind Speed Profiles; friction velocity; momentum flux	All for Deployments 1-4; Wind Speed only for 5-10
2 Licor closed path	Absolute, profiles of, fluxes of, and transfer	Deployments 1-7, 9, 10

sensors	coefficients of CO_2 and water vapor	
2 Vaisala RH/T microprocessors	Absolute, profiles of, fluxes of, and transfer coefficients of water vapor and temperature	Deployments 1-7, 9, 10
2 Aspirated Thermocouples	Absolute, profiles of, fluxes of, and transfer coefficients of temperature profiles	Deployments 1-7, 9, 10
YSI probe	Water Temperature, Salinity at 30 cm depth	Deployments 1-7, 9, 10
3rd Licor closed path Aqueous system	Aqueous pCO_2 at 30 cm depth	Deployments 1-7, 9, 10
Sontek Pulse-Coherent ADP	Near-surface water velocities (top 30 cm); shear profiles	Deployments 1-7, 9, 10
2 Sontek ADV	High frequency (25-Hz), point-source 3-D water velocities at 30 cm depth; near-surface turbulence	Deployments 2-7, 9, 10
RDI ADCP	Current/shear profiles from 30 cm down to 10 m	Deployments 1-7, 9, 10

Deployment	Julian Day	Start Time	End Time	Start Time	End Time
1	47	47.945	48.019	22:41	0:28
2	51	51.879	51.967	21:06	23:12
3	54	54.908	55.012	21:48	0:17
4	56	56.081	56.200	1:57	4:48
5	56	56.911	56.951	21:51	22:48
6	58	58.054	58.106	1:17	2:33
7	58	58.797	58.856	19:07	20:33
8	59	59.147	59.153	3:32	3:41
9	59	59.520	59.656	12:28	15:45
10	60	60.116	60.219	2:48	5:16

2.1.4 SkinDeEP - Skin Depth Experimental Profiler (Brian Ward and Rik Wanninkhof)

During GasEx 2001, there were two SkinDeEPs - the original referred to as SkinDeEP1, and the new instrument specifically constructed for GasEx 2001, SkinDeEP-2. Both profilers were similar, but the second was a much better system in that it had more on-board battery power; contained more ports for sensors in its top end cap; had no connections to the bottom end cap; had more weight located towards the bottom of the profiler, and had its buoyancy engine located closer to the top, thus providing a more appropriate center of gravity for an upwardly-rising profiling instrument.

SkinDeEP is an autonomous profiler that carries temperature and conductivity sensors capable of resolving sub-millimeter scalar fluctuations. A schematic of the instrument is shown in Figure 1. The transport vehicle for the sensors and associated instrumentation is an anodized aluminum cylinder with two detachable, hemispheric end-caps. Each end cap has a groove to accommodate an o-ring where it meets the cylinder, thus providing a watertight seal. When assembled, the total length of the instrument shell is 1.1 m and 1.6 m, for SkinDeEP1 and SkinDeEP2, respectively. A distortion in the stratification occurs within one diameter of a moving body, and thus the sensors protrude 30 cm from the end cap, which is twice the diameter of the profiler. A protection guard of maximum diameter 35 cm is situated just below the sensors to prevent damage to the probes.

The profiler has the capability to change its density so that it can rise and sink autonomously. Once sealed, the instrument is negatively buoyant by only a few grams when the neoprene bladder, attached to the outside of the profiling cylinder, is deflated. Positive buoyancy is achieved by inflation of the bladder, accomplished by pumping air from within the vehicle through a port, thereby expanding the sleeve. Deflation is accomplished by allowing this air to return into the interior. Before deployment, the profiler must be partially evacuated to allow a pressure gradient to exist between the bladder and the interior of the cylinder.

When deployed, the instrument is attached with 50 m of synthetic line to a spar buoy that is equipped with a flashing beacon and a VHF transmitter. In case of failure of the buoyancy system, the buoy will hold the profiler at the end of its tether line.

The two SkinDeEP instruments were equipped with the following sensors:

- Pt-wire micro-thermometer
- Thermometrics FP07 thermistor
- Micro-conductivity sensor
- Bulk conductivity sensor
- Pressure sensor
- Tilt-x and -y sensors

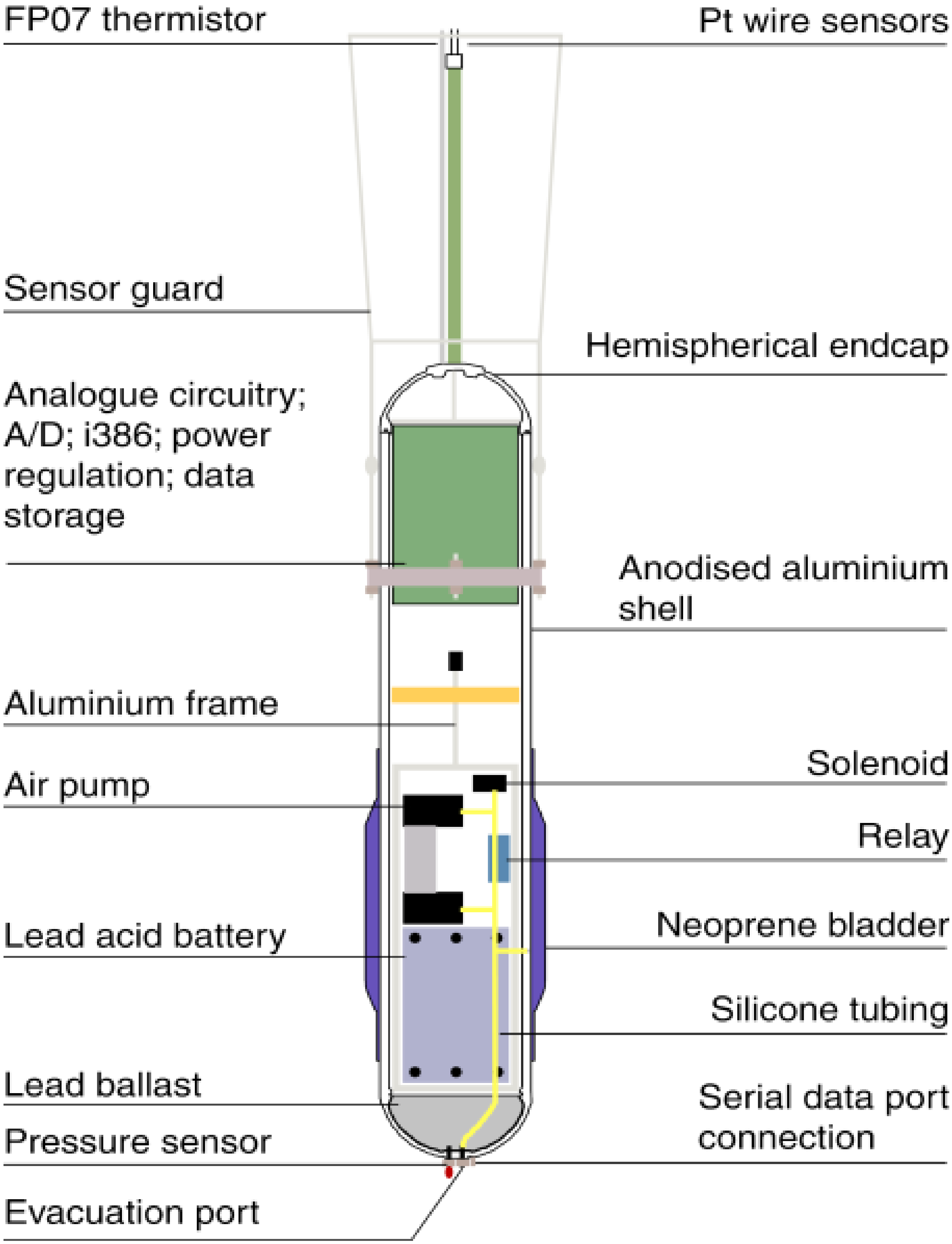


Figure 1: Schematic of SkinDeEP showing the main components of the instrument.

SkinDeEP Profiles taken on GasEx 2001

Date	Time UTC
Feb05	2009--2116
Feb08	2023--2201
Feb10	1928--2358
Feb11	0001-0100
Feb15	2253--2358
Feb15	2218--2359
Feb16	0000--0610
Feb16	2205--2308
Feb17	2333--2349
Feb18	0005--0850
Feb18	2000--2241
Feb19	1839--1947
Feb23	2343--2358
Feb24	0001--0035
Feb24	0809--1740
Feb25	0137--2354

However, there may not be full profiles during all these measuring periods due to mis-ballasting and problems associated with drag.

Some problems occurred with the profilers during the GasEx 2001 campaign, most notably a water breach as a result of a shark attack, rendering the electronics irreparable. After rebuilding a single system from both profilers, this rebuilt system was unfortunately lost during a recovery operation.

2.1.5 Drifting and underway pCO_2 / O_2 sensors

WHOI, AOML and the University of Montana scientists collaborated in the development of new technology for autonomous ocean biogeochemical measurements for air-sea flux calculations and development of upper ocean carbon cycle models. The sensors included:

1. Underway pCO_2 at bow (~YD 28-66) – autonomous CO_2 system tapped into seawater line at the bow, and;
2. ASIS/Carioca/Drogue in-situ measurements of pCO_2, O_2, Temperature, Salinity, PAR, chl-a fluorescence (see table below).

Platform/depth/dates	Instruments	Comments
ASIS/1.0 m/YD 46-60	2 SAMI-CO_2s/YSI (DO, T, S), PAR, fluorescence	pCO_2 (light contam. some data lost), O_2 (questionable), Chl-a, T, S (complete coverage)
ASIS/5 m/YD 46-60	1 SAMI-CO_2, PAR, fluorescence	pCO_2, PAR, fluor. (complete coverage)
Carioca/1.0 m/YD 46-60	1 SAMI-CO_2, YSI (DO, T, S, depth, Turb, Chl-a, pH) (excl. Rik's sensors)	pCO_2 (3-6 days, biofouling), no O_2 data, still need to look at other YSI data
Drogue/5 m/YD 46-60	1 SAMI-CO_2, YSI (DO, T, S, depth)	pCO_2 (~7-8 days, biofouling), O_2, T, S, D (complete cov.)
Drogue/30 m/YD 46-60	1 SAMI-CO_2, YSI (DO, T, S, depth)	pCO_2 (complete cov.), O_2, T, S, D (complete cov.)

2.1.6 CTD and Underway Operations (Rik Wanninkhof, Robert Castle, Charlie Fisher, Brian Ward, Mike DeGrandpre, Pete Strutton, Jimmy Smith, Greg Johnson, Kristy McTaggart, Marilyn Roberts, Dana Greeley, Calvin Mordy, Jia-Zhong-Zhang, Craig Neill, Chris Sabine, and Richard Feely)

CTD/Niskin casts were performed daily to 500m. In addition, two butterfly surveys and two intensive time series were conducted during the cruise. Discrete CTD/Niskin samples were drawn for the measurements of dissolved oxygen, pCO_2, DIC, nutrients, DOC, DON, salinity, chlorophyll, ^{14}C, ^{15}N and POC. The FRRF biological profiler was mounted on the CTD rosette and replaced one Niskin bottle slot. During the cruise we collected approximately 6700 samples from 51 CTD casts. A list of the CTD stations is given in Appendix 2.

Underway surface water measurements were an important component of the cruise. Water flows from the bow were maintained at 50 L/min or above at all times. During transit to and from the study site, the CARIOCA/ SAMI buoy was operated and calibrated on deck. Water was supplied continuously to the buoy using a header tank supplied by flow from the underway seawater line. The ship's TSG was run continuously. Quality control included logging and comparison of TSG data with the CTD signal when the CTD was at the surface (nominally 3-6m depth). AOML, in collaboration with PMEL scientists and the CST, provided the underway measurements from the bow intake system including: temperature and salinity (TSG), chlorophyll, oxygen, and partial pressure of pCO_2, DIC, and nutrients. In addition, a SAMI autonomous CO_2 sensor and a liquicel based IR system were installed at the seachest. Five to ten L/minute of water was shunted from a flange forward of the seachest and returned to the main line in the seachest. A small impeller pump was used to pump the water through the two instruments.

The nutrient autoanalyzer – and associated chemistry and standardization procedures – were designed after instruments and procedures utilized on the WOCE and JGOFS programs. Those programs typically achieved precision of 1-2% for all parameters. The W.S. Ocean Nitrate Monitor was connected to the ship's underway seawater system, and was programmed to regenerate the cadmium column, analyze a standard and analyze a sample every 30 min.

Instrument	Data products	Data return	Availability
Autoanalyzer	Concentrations of phosphate, silicic acid, nitrate and nitrite	Discrete samples from the CTD (n =745), the High-Resolution Profiler (n = 39), and the underway seawater system (n = 55) with replicate analysis on about 1/3 of the samples.	Post-processing required.
Underway Nitrate Monitor	Concentration of nitrate	Continuous data collection: every 30 minutes 2/7/01-3/7/01. Precision was about 0.2 μM	Post-processing required

The purpose of the MBARI biological measurements was to quantify the biological component of the carbon cycle during GasEx 2001. The data collected were primarily from the CTD casts and consisted of the following:

Chlorophyll: Profiles of usually 11 depths from 0 to 200m at every station – provide an estimate of total phytoplankton biomass.
Productivity (^{14}C uptake): Profiles of 7 depths from 0 to ~120m and column-integrated production at almost every station – provide an estimate of biological inorganic carbon uptake.
New production ($^{15}NO_3$ and $^{15}NH_4$ uptake): Profiles of 6 depths from 0 to ~80m and column-integrated new production at one station per day – provide an estimate of biological nitrate and ammonium uptake and an approximation of export production.

Particulate Organic Carbon: Profiles of 7 depths from 0 to ~120m at every station.
Biogenic silica: Discrete samples at ~5m and ~50m from almost every station – useful as an indicator of the amount of silica fixed in diatom frustules.
Ammonium: Profiles of 7 depths from 0 to ~120m at one station per day – necessary for the ammonium uptake measurements but also of interest for comparison with Calvin Mordy's nutrient data, plus other physical and biological parameters.
Fast Repetition Rate Fluorometry - photosynthetic parameters: Profiles of 1m binned and 'bottle' data from the FRR fluorometer. The parameters logged by the FRR can be used to quantify phytoplankton photosynthetic efficiency, and may also provide indicators of nutrient stress. One of the aims of the MBARI GasEx 2001 work is to derive relationships between FRR parameters and ^{14}C or ^{15}N productivity estimates.
Underway measurements: When the FRR was not deployed on the CTD package it was run in underway mode in the lab. Between Panama and the GasEx 2001 site, underway measurements of surface chlorophyll were made for comparison with the underway FRR and turner fluorometer data.
Satellite data: During the cruise, high-resolution SeaWiFS images were obtained and archived whenever possible. These data provide a large-scale picture of the chlorophyll distribution in the GasEx 2001 study area.
Optical profiles: In addition to the CTD-based measurements, daily profiles were performed with a SeaWiFS Multispectral Profiling Radiometer (SPMR). The SPMR measures 13 wavelengths (~410nm to 780nm) of upwelling radiance (Lu) and downwelling irradiance (Ed) from a profiling instrument (to a maximum depth of 200m) and a floating surface reference instrument. These profiles can be used, with appropriate algorithms, to obtain continuous profiles of chlorophyll (*cf* the discrete CTD data) and perhaps other parameters such as estimates of productivity and colored dissolved organic matter. The profile data are also used to derive normalized water-leaving radiance (Lwn) estimates for SeaWiFS validation.

2.1.7 High-Resolution Profiler (Chris Sabine, Dana Greeley, Kristy McTaggart)

High-resolution profiles of temperature, salinity, dissolved oxygen, pCO_2, DIC, and nutrients were conducted using an internally recording CTD approximately 4 times during the cruise. The information gathered from this study is being used to study diurnal stratification in surface waters. The pressure, temperature and salinity measurements were made using in-situ instruments on a low-profile CTD package to allow sampling within 1 m of the surface. The remaining parameters were collected using discrete samples collected from a water pumping system attached to this CTD package.

2.2 ADCP Measurements

A ship-mounted ADCP system was used to continuously measure the currents in the upper ocean along the trackline. Data from the ADCP was logged from the start of the transit until secured just prior to the pier in Honolulu. For calibration purposes it was essential that bottom tracking be activated at the start and end of this cruise when in water depths shallower then 500m.

2.3 Atmospheric Measurements

2.3.1 WHOI Bow System on the Ronald H Brown (W. McGillis, S. McKenna, J. Ware, C. Zappa)

The WHOI bow boom/mast system is a meteorological and CO_2 sensing system used to obtain measurements of the air-sea fluxes of momentum, CO_2, and latent and sensible heat. The bow system consists of a suite of fixed sensors at the end of the bow boom and a second set of profiling sensors located on a vertical mast at the end of the boom. The end of the boom is nominally 10 m from the ship bow rail to reduce flow distortion from the ship, and the vertical profiling mast is nominally 6 m in height. The fixed system consists of high sample rate measurements of the 3-d wind vector, RH, air temperature, water vapor, and CO_2. An integrated 6 degree-of-freedom motion-sensing system allows for the necessary removal of ship motions from the measured wind vector. A laser altimeter at the end of the boom provides the vertical distance between the sea surface and the boom measurements. The fixed system is used to obtain direct measurements of momentum, water vapor, and CO_2 fluxes using the eddy correlation technique. The profiling mast system is comprised of a set of sensors mounted to a traveler that moves up and down the mast, and an identical set of reference sensors that are fixed at the end of the boom. Mean profiles of air temperature, water vapor, and CO_2 were obtained from measurements at 4 heights along the mast. These measured gradients will be used to infer the air-sea fluxes of these quantities.

Data return:
The boom fixed system was continuously operational during the period YD 044 – YD 065 except for occasional down times during mast and/or boom recovery or system maintenance. The profiling system was used during the period YD 046 – YD 059 in an episodic sense. In total, 93 profiles were obtained during this time frame.

Data products available immediately:
30 minute averages of the following meteorological quantities:
True wind speed
True wind direction
Relative wind direction
Relative humidity
Air temperature
Ship heading

Data products available after processing refinement:
Friction velocity (eddy correlation, bulk aerodynamic, and inertial dissipation estimates)
Sensible and latent heat fluxes (eddy correlation, profiling method, and bulk estimates)
CO_2 flux from eddy correlation method and profiling method
Significant wave height (2 independent estimates: laser altimeter, microwave)

2.3.2 Bulk meteorology and turbulent fluxes (Jeff Hare and Chris Fairall)

During GasEx 2001, ETL deployed a suite of instrumentation on the bow jackstaff and bow tower for the purpose of measuring the mean meteorology and eddy correlation turbulent fluxes of momentum, latent heat, and sensible heat over the air-sea interface. In addition, two open-path gas analyzers were deployed to make direct covariance measurements of the flux of CO_2. Below is a list of the flux system sensors deployed:

Ultrasonic anemometer/thermometer (Gill)
Motion measurement (Systron Donner)
Infrared hygrometer (Ophir)
Infrared CO_2/H_2O analyzer (Licor 7500)
Infrared CO_2/H_2O analyzer (KNMI IFM)
Mean air temperature and humidity (Vaisala)
Mean sea surface (10cm) temperature (ETL)
Downwelling solar irradiance - pyranometer (Eppley)
Downwelling infrared irradiance - pyrgeometer (Eppley)
Rain gauge (STI)

The flux system was calibrated against the Brown IMET system (on SCS) and with daily hand-held calibrations.

The ship's 915MHz wind profiling radar (ETL) was run during GasEx 2001 to measure the winds within the marine boundary layer for the purpose of determining the structure and modulation of the boundary layer throughout the expedition.

A laser ceiliometer made measurements of cloud base height over the course of the experiment. Both the wind profiler and the ceilometer were mounted on the 02 deck aft, near the winch house.

System:	**Turbulent Flux - continuous products from 2/2 to 3/7**
Products:	Air temperature *Many products include mean and standard deviation
	Sea surface temperature
	Wind speed
	True wind direction
	Relative wind speed
	Relative wind direction
	Relative humidity
	Downwelling solar irradiance
	Downwelling IR irradiance
	Rain rate
	Ship heading
	Course
	Ship speed over ground
	Ship speed over water
	Covariance, bulk, and inertial-dissipation wind stress
	Covariance, bulk, and inertial-dissipation sensible heat flux
	Covariance, bulk, and inertial-dissipation latent heat flux
	Bulk surface roughness length
	Bulk thermal roughness
	Bulk moisture roughness
	Bulk and inertial-dissipation Monin-Obukhov length
	Bulk model skin temperature and humidity depression
	Bulk model warm layer thickness
	Bulk drag coefficient
	Bulk thermal and moisture transfer coefficients
	Velocity, temperature, and moisture structure function parameters
Availability:	Means are immediately available
	Preliminary turbulent fluxes immediately available
	Other turbulence statistics available within 2 months.

System:	**Ceiliometer - continuous products 2/2 to 3/7**
Product:	Cloud base height
Availability:	Immediately

System:	**Wind Profiler - continuous products from 2/10 to 3/7**
Product:	Wind vs. height
Availability:	2 months

System:	**Radiosonde - twice daily (0000Z and 1200Z) from 2/8 to 3/2**
Products:	Pressure
	Temperature profile
	Humidity profile
	Wind profile
Availability:	Immediate

2.3.3 Infrared Remote Sensing (William Asher and Trina Litchendorf)

Infrared Remote Sensing will measure the fraction of surface area that the thermal boundary layer is disrupted by microbreaking waves. This is obtained by thresholding the IR image using a passive IR imager. These instruments were mounted on the bow tower. The primary objective of this project is to record IR image sequences of temporal decay of temperature in a patch heated by laser for a variety of conditions. We are interested in correlating decay rate of the patch with changes in wind speed, net heat flux, sensible heat flux and presence or absence of cool skin layers. We are also directing the IR towards sensing of microbreaking waves that occur with high aerial coverage at low to moderate wind speeds. Although microbreaking is difficult to objectively identify by visual appearance, the potential for IR imaging techniques to detect and quantify the process has been demonstrated.

We are also continuously gathering sea surface temperatures with CIRIMS, and examining rain events with SONRAD, a Doppler radar system.

Data: Recorded IR video image data will need to be analyzed before preliminary data can be released. Estimated time is within 3 months to 1 year. CIRIMS sea surface temperatures for GasEx 2001 should be available within 1 month.

A list of Controlled Flux Technique, CFT, data sets that were collected during GasEx 2001 is given in Appendix 3.

2.3.4 Shipboard CO_2/H_2O/DMS flux measurements (Henk Zemmelink, Jeff Evans, John Dacey)

Shipboard CO_2/H_2O/DMS flux measurements were made with atmospheric profiles from a mast on the boom that extends approximately 10m off the bow. A sensor container (1m x 1m x 1.5m) was mounted on the bow next to the bow tower.

During GasEx 2001 DMS fluxes were measured with the Gradient Flux technique. Air was sampled at three different elevations for 30 min at a flow rate of 300 ml min^{-1}. The sampled air was stored in Tedlar bags, and analysed for DMS using a Sievers GC equipped with a sulfur chemiluminescence detector. These measurements are used to estimate the transfer velocity and will be compared with flux measurements of CO_2 and with commonly used wind speed parameterisations. The data products produced from this effort includes the DMS sea-are flux and Gas Transfer Velocity. Measurements also include aqueous DMS measurements and a CTD water column gradient of DMS.

2.3.5 Radiosonde launches (Jeff Hare and Jonathan Shannahoff)

Manual launches were done from the staging bay 2 times a day.

2.3.6 Interferometer Measurements (Jenny Hanafin and Peter Minnett)

Marine-Atmosphere Emitted Radiance Interferometer (M-AERI) is a well calibrated, infrared spectroradiometer that measures the radiance emitted from the sea surface and the atmosphere over the wavelength range 3-20µm at a spectral resolution of 1cm^{-1}. From these data, high accuracy sea surface skin temperatures and air temperatures are derived. Air temperatures are remotely sensed over the water and are therefore not as susceptible to “heat island” effects as those from a ship’s mast. The sea surface skin temperature is more appropriate for use in air-sea heat and mass exchange calculations than the bulk SST, as it is that of the interface across which the exchange occurs and includes the effects of both the cool skin and warm diurnal layers.

Instrument	Data products	Data return	Availability
Marine-Atmosphere Emitted Radiance	Sea surface skin temperature, air	Continuous data collection: every ten minutes from	Temperature data available immediately.

Interferometer	temperature, sky and sea surface infrared emission spectra	2/7/01-2/17/01 and from 2/27/01-3/8/01 apart from occasional gaps due to weather	
Sky camera	Cloud type, height and fraction	Continuous data collection: every ten minutes 2/7/01-3/8/01	Post-processing required
Hard hat SST	Sea surface temperature at approximately 10cm depth	Episodic between 2/14/01-3/1/01	Available immediately
Portable radiation package (Brookhaven National Lab)	Aerosol optical depth and hemispheric long-wave and short-wave downwelling atmospheric radiation.	Continuous data collection between 2/7/01-3/8/01	Available on request from BNL.

3.0 DISPOSITION OF DATA AND REPORTS

3.1 Data Responsibilities

The Chief Scientists are responsible for the disposition, feedback on data quality, and archiving of data and specimens collected on board the ship for the primary project. As representative of the program manager, the Chief Scientists will also be responsible for the dissemination of copies of these data to participants in the cruise. The Chief Scientists will receive all original data gathered by the ship for the primary project, and this data transfer will be documented on NOAA Form 61-29 "Letter Transmitting Data". The Chief Scientists in turn will furnish the ship a complete inventory listing all data gathered by the scientific party detailing types and quantities of data.

Individuals in charge of piggyback projects conducted during the cruise have the same responsibilities for their project's data as the Chief Scientists have for primary project data. All requests for data should be made through the Chief Scientists.

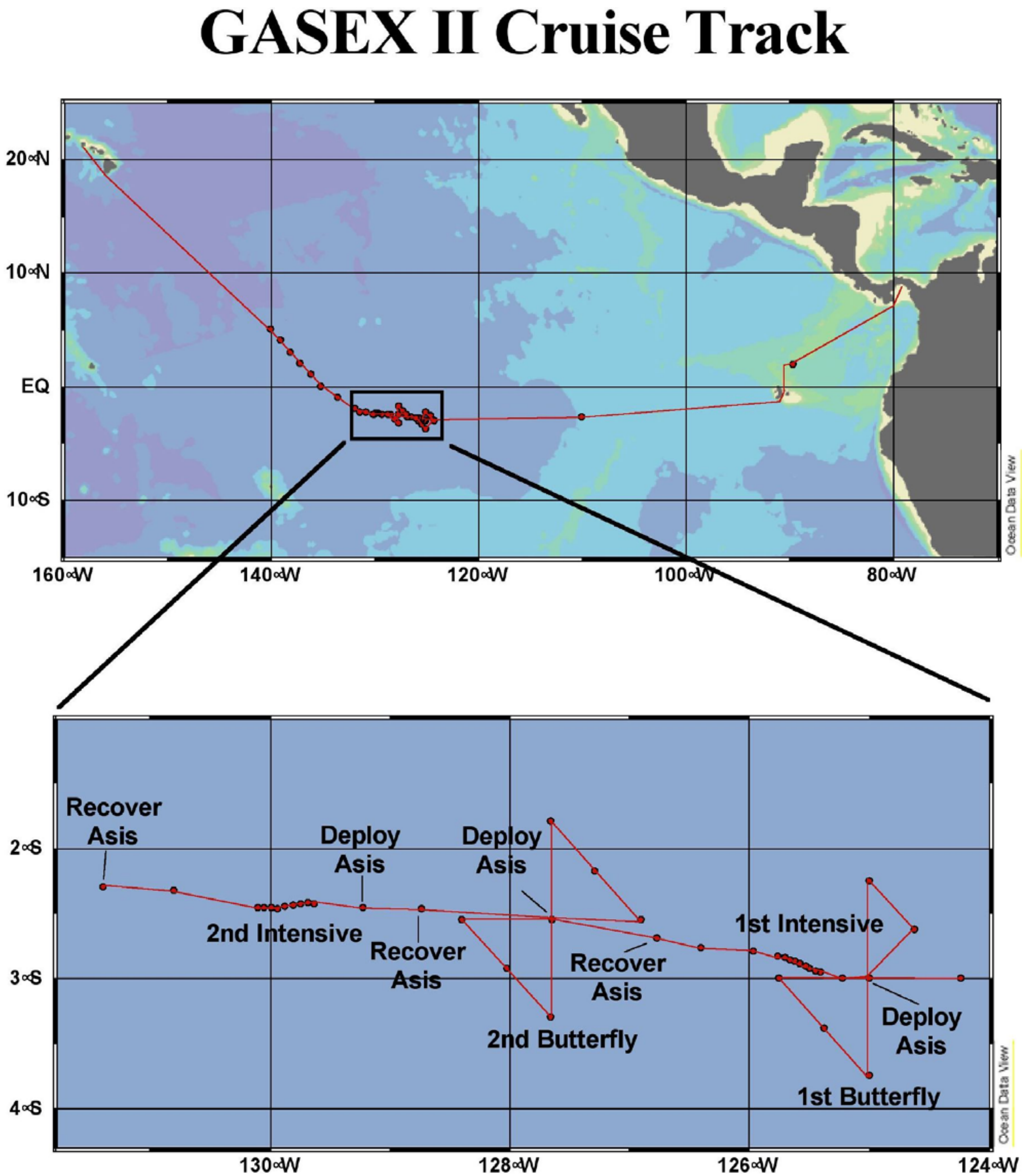
The Commanding Officer is responsible for all data collected for ancillary projects until those data have been transferred to the project's principal investigators or their designees. Data transfers will be documented on NOAA Form 61-29. Copies of ancillary project data will be provided to the Chief Scientists when requested. Reporting and sending copies of ancillary project data to NESDIS (ROSCOP) is the responsibility of the program office sponsoring those projects.

4.0 Contacts

Important phone numbers, fax numbers and e-mail addresses:

Co-Chief Scientist: Richard A. Feely (feely@pmel.noaa.gov) 206-526-6214
Co-Chief Scientist: Wade McGillis (wmcgillis@whoi.edu) 508-289-3325
Co-Chief Scientist: Rik Wanninkhof (Wanninkhof@aoml.noaa.gov) 305-361-437

5.0 APPENDICES
Appendix 1. GasEx 2001 Cruise Trackline



Appendix 2. - CTD locations

Station	Cast	date time	Lon [E]	Lat [N]	day of year
1	1	2/5/01 19:26	-89.7233	1.8867	36.81
2	1	2/10/01 22:58	-110.0033	-2.7200	41.96
3	1	2/13/01 16:19	-124.2283	-3.0000	44.68
4	1	2/13/01 20:31	-125.0000	-3.0000	44.85
5	1	2/14/01 0:29	-125.7517	-3.0000	45.02
6	1	2/14/01 4:08	-125.3732	-3.3800	45.17
7	1	2/14/01 7:48	-125.0000	-3.7500	45.32
8	1	2/14/01 15:42	-125.0000	-2.2500	45.65
9	1	2/14/01 19:10	-124.6233	-2.6233	45.80
10	1	2/15/01 20:33	-125.2183	-3.0000	46.86
11	1	2/16/01 8:11	-125.4000	-2.9517	47.34
11	2	2/16/01 11:11	-125.4483	-2.9433	47.47
11	3	2/16/01 14:06	-125.4933	-2.9300	47.59
11	4	2/16/01 17:06	-125.5300	-2.9083	47.71
11	5	2/16/01 20:07	-125.5717	-2.8900	47.84
11	6	2/16/01 23:08	-125.6165	-2.8700	47.96
11	7	2/17/01 2:11	-125.6615	-2.8592	48.09
11	8	2/17/01 5:03	-125.7033	-2.8433	48.21
11	9	2/17/01 8:09	-125.7567	-2.8300	48.34
12	1	2/17/01 20:13	-125.9617	-2.7917	48.84
13	1	2/18/01 20:11	-126.4033	-2.7683	49.84
14	1	2/19/01 20:11	-126.7700	-2.6883	50.84
15	1	2/20/01 20:13	-127.1800	-2.5650	51.84
16	1	2/21/01 19:05	-127.6400	-2.5533	52.80
17	1	2/21/01 23:15	-128.4017	-2.5500	52.97
18	1	2/22/01 2:43	-128.0250	-2.9250	53.11
19	1	2/22/01 6:09	-127.6500	-3.3000	53.26
20	1	2/22/01 14:10	-127.6500	-1.8000	53.59
21	1	2/22/01 17:41	-127.2833	-2.1750	53.74
22	1	2/22/01 21:22	-126.9017	-2.5483	53.89
23	1	2/23/01 20:14	-128.7367	-2.4667	54.84
24	1	2/24/01 20:12	-129.2250	-2.4600	55.84
25	1	2/25/01 14:11	-129.6250	-2.4267	56.59
25	2	2/25/01 17:12	-129.6750	-2.4233	56.72
25	3	2/25/01 20:10	-129.7450	-2.4283	56.84
25	4	2/25/01 23:10	-129.8017	-2.4383	56.97
25	5	2/26/01 2:10	-129.8683	-2.4483	57.09
25	6	2/26/01 5:19	-129.9383	-2.4650	57.22
25	7	2/26/01 8:09	-129.9883	-2.4617	57.34
25	8	2/26/01 11:12	-130.0467	-2.4567	57.47
25	9	2/26/01 14:13	-130.0950	-2.4583	57.59
26	1	2/27/01 21:19	-130.7983	-2.3317	58.89
27	1	2/28/01 21:10	-131.3933	-2.2983	59.88
28	1	3/1/01 11:30	-131.8500	-2.0000	60.48
29	1	3/1/01 20:15	-133.4583	-1.0000	60.84
30	1	3/2/01 5:15	-135.1300	-0.0050	61.22
31	1	3/2/01 12:04	-136.1183	1.0017	61.50
32	1	3/2/01 19:15	-137.1000	2.0000	61.80
33	1	3/3/01 2:21	-138.0833	3.0000	62.10
34	1	3/3/01 9:08	-139.0500	4.0000	62.38
35	1	3/3/01 18:25	-139.9967	4.9633	62.77

Appendix 3. The following is a list of Controlled Flux Technique, CFT, data sets that were collected during GasEx 2001.

02/10/01 02:09 - 02:19
02/10/01 02:32 - 02:39
02/14/01 00:45 - 00:52
02/14/01 04:02 - 04:14
02/14/01 07:41 - 07:48
02/14/01 07:52 - 08:03
02/15/01 02:09 - 02:20
02/15/01 03:53 - 04:03
02/15/01 04:25 - 04:35
02/15/01 04:57 - 05:07
02/15/01 05:25 - 05:35
02/15/01 05:53 - 06:03
02/15/01 07:42 - 07:55
02/15/01 10:49 - 11:00
02/15/01 13:09 - 13:18
02/15/01 14:46 - 14:56
02/16/01 02:46 - 02:53
02/16/01 03:17 - 03:22
02/16/01 03:44 - 03:49
02/16/01 04:14 - 04:21
02/16/01 04:45 - 04:51
02/16/01 06:31 - 06:37
02/16/01 07:22 - 07:27
02/16/01 08:03 - 08:10
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02/24/01 03:40 - 03:49
02/24/01 04:09 - 04:19
02/24/01 04:40 - 04:49
02/24/01 05:09 - 05:19
02/24/01 05:39 - 05:47
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02/25/01 03:40 - 03:48
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02/25/01 04:36 - 04:46
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02/26/01 08:22 - 08:31
02/26/01 09:53 - 09:58
02/26/01 11:13 - 11:17
02/26/01 11:26 - 11:31
02/26/01 13:41 - 13:47
02/26/01 14:37 - 14:42
02/26/01 17:10 - 17:14
02/27/01 02:09 - 02:27
02/27/01 02:52 - 03:01
02/27/01 03:22 - 03:31
02/27/01 03:54 - 04:02
02/27/01 04:18 - 04:27
02/27/01 04:45 - 04:53
02/27/01 05:15 - 05:23
02/27/01 05:42 - 05:50
02/27/01 06:13 - 06:21
02/27/01 08:38 - 08:48
02/27/01 09:45 - 09:54
02/27/01 10:48 - 10:56
02/27/01 12:17 - 12:22
02/27/01 14:45 - 14:52
02/27/01 15:30 - 15:39

02/28/01 03:15 - 03:24
02/28/01 03:44 - 03:53
02/28/01 04:14 - 04:22
02/28/01 04:45 - 04:53
02/28/01 05:15 - 05:24
02/28/01 05:45 - 05:53
02/28/01 06:50 - 06:58
02/28/01 07:59 - 08:08
02/28/01 08:59 - 09:08
02/28/01 09:59 - 10:08
02/28/01 11:04 - 11:09
02/28/01 13:32 - 13:37
02/28/01 14:03 - 14:08
02/28/01 14:40 - 14:45
02/28/01 18:44 - 18:53
03/01/01 02:33 - 02:41
03/01/01 03:00 - 03:08
03/01/01 03:30 - 03:39
03/01/01 04:00 - 04:08
03/01/01 04:29 - 04:37
03/01/01 05:00 - 05:08
03/01/01 05:30 - 05:38
03/01/01 06:00 - 06:08
03/01/01 06:59 - 07:08
03/01/01 07:28 - 07:39
03/01/01 11:34 - 11:42
03/01/01 11:46 - 11:51
03/02/01 05:06 - 05:15
03/02/01 05:19 - 05:28
03/02/01 12:11 - 12:20
03/02/01 12:22 - 12:30
03/03/01 08:58 - 09:07
03/03/01 09:11 - 09:20
03/03/01 15:57 - 16:05
03/03/01 16:15 - 16:25
03/03/01 16:47 - 16:56
03/03/01 17:08 - 17:17
03/03/01 17:24 - 17:34
03/03/01 17:58 - 18:07
03/03/01 18:12 - 18:21

Appendix 4. GasEx Scientific Party - photo.