Lamont-Doherty Earth Observatory of Columbia University

EW-9803 Data Summary

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Project Summary

Structure, tectonics and sediment flow into the Lesser Antilles subduction zone

This investigation is designed to examine the deep structure of the Lesser Antilles subduction zone. The investigation will acquire coincident large-aperture seismic refraction data and high quality seismic reflection data to accurately image and interpret the deep structure of the Lesser Antilles forearc.

While extensive geophysical and geological studies have centered around processes at the toe of the accretionary wedge of subduction zones, questions regarding the tectonics of shallow to intermediate segments of subduction zones remain unanswered. What is the fate of the sediment that is subducted beyond the toe of the slope with the subducting plate? What comprises the buttress or backstop that serves to prevent the accretionary wedge from being carried farther down the subduction zone with the subducting plate? What effect does the backstop geometry have on deformation within the accumulating crustal material of the accretionary wedge? It is within the deeper segments of the subduction zone that questions regarding inter-plate seismicity, the tectonic interaction of the backstop with the accretionary wedge, and material and fluid fluxes must be examined. Previous geophysical and geological work shows the Lesser Antilles offers a prime location for examining these questions because of the unusual opportunity here to image deep within the subduction zone without interference from the seafloor multiple. Prior studies also provide a firm basis to relate the proposed work to the tectonics of the subduction zone.

The overall objective is to examine three subduction problems in this setting. First, to examine the flow of subducting elements where the crystalline crust of the overriding Caribbean plate passes over the subducting American plate. For this, seismic reflection data will be acquired to image the plate-boundary detachment fault, or decollement, beneath the entire accretionary wedge to 10 km below seafloor where it meets the overriding crystalline forearc basement. Accurate location of the detachment is imperative for understanding material and fluid fluxes into the mantle because the position of the decollement determines whether the subducting sediment is underplated to the base of the accretionary wedge, or subducted beneath the crystalline basement of the overriding plate and carried to even greater depth. Furthermore, an accurate image of the structure of the subducting oceanic crust will illustrate the role of the basement structures in deep-level sediment subduction. The second objective is to image the geometry and structure of the forearc basement which controls the transmission of stresses from the arc crust to the accretionary wedge and ultimately may control the accretionary wedge and forearc basin deformation. Third, the seismic data will provide details of the structural development of the deformation zone between the accretionary wedge and the forearc basin. It is these structures that will indicate the role of the interaction between the forearc basin and the landward slide at the back of the wedge, and the interaction between the forearc basin and the landward slide of the accretionary wedge. The comprehensive examination and analysis of structures within this setting will be possible with the coincident refraction and reflection data, which has shown to be extremely effective for other margins.

Navigation Processing

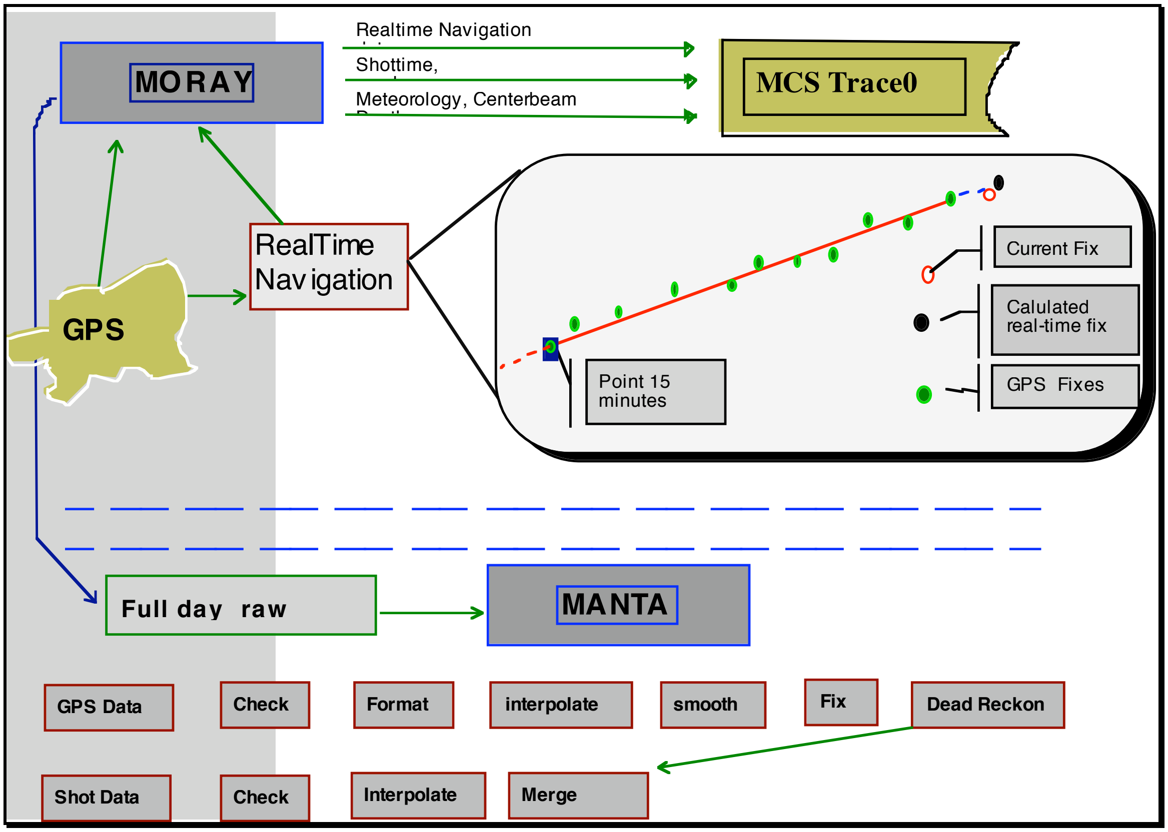

Figure 1. *Navigation Processing Pipeline*

1. **Logger** (Sparc 2, SunOS 4.1)
   Moray is the system responsible for logging all the real-time data from an array of serial ports. *Hydrosweep is the exception and is logged from a UDP broadcast from a SGI running IRIX*.
   Each data record logged by an instrument is time tagged with the CPU current time, which is synched every minute with one of the UTC receivers. The GPS records are also time-tagged, but the time of position comes from the times established by the receiver for the position.

   Moray also controls the firing of the guns. In order to determine the time to fire, as well as the precise location the guns were fired, it relies on the *Real-time Navigation Process.*

2. **Real-time Navigation Process**
   One GPS is selected to be the receiver for the cruise, usually the TASMAN P(Y) Code GPS Receiver. The GPS data is logged to disk once every ten seconds.
   In order to shoot by distance, and also to predict where the shot occurred, we take two points (X seconds apart) from the specified GPS. From these two points, an average velocity is determined, and a "real-time" navigation position is output as the GPS fix. **See Figure 1.** The output of the real-time navigation is a file containing the following, used for real-time shot position and MCS data:

   - The last lat/lon position (directly from the GPS) and the time (in seconds) of the last fix
   - ship speed in the east direction, ship speed in the west direction

- Furuno speed and heading
- Meteorological data

From this velocity we determine the location of the shot when the shot-time does not fall precisely on a GPS fix; which is always. We also use this "RT Navigation" to determine our next "shot-by-distance". We determine our current velocity, the time it will take to travel x meters, and then set the shot-clock for that amount of time.

3. **GPS Post Processing**
Navigation data is post-processed in order to accurately determine our position due to selective availability, and in the case of the P(Y) Code receiver, eliminate some of the effects of the rolling of the ship.. This post-processed navigation is then applied to all position-specific data to provide consistent positions for all devices: *Magnetometer, Gravimeter, Hydrosweep Centerbeam*.

- Check data for mutant records and inconsistent times, and convert from GPS format to human-readable format.
- Interpolate data where GPS coverage is missing for any amount of time 3 minutes or *less*.
- When differential coverage is in effect, throw away fixes that are not differentially corrected.
- Smooth the values with a 9 point running average algorithm.
- Fix the values to 1 minute intervals
- Perform dead reckoning based on the furuno for any gaps in the data. At this point, if there are any gaps, they will be gaps greater than 3 minutes. Output the set and drift for those points; also fixed at one minute intervals.

```
97+295:03:49:00.000 N  8 59.9698 W 104  9.7289   gp2  56.0   0.1
97+295:03:50:00.000 N  8 59.9459 W 104  9.7394    dr   1.8   0.3
```

- Decimate the data to 20 minute fixes, then re-fix at 1 minute intervals using dead reckoning. This is done to smooth out peaks due to selective availability. This is the final navigation.

4. **Shot Data Post Processing**

- Check the raw navblock file for mutant records and inconsistent times.
- Interpolate any missing shots using a simple interpolation algorithm which does not correct for changes in latitude. Interpolated shots are marked with a **-** in the cpu time field.
- Merge the shot times with the final navigation prepared in **Step 2**. The shot-point is calculated using the final 1 minute navigation fixes and the difference in time from the closest fix:

```
lat = final_nav[i].lat + (final_nav[i+1].lat - final_nav[i].lat) * (navblock_sec / (final_nav[i+1].tot_secs - final_nav[i].tot_secs));

lon = final_nav[i].lon + (final_nav[i+1].lon - final_nav[i].lon) * (navbock_sec / (final_nav[i+1].tot_secs - final_nav[i].tot_secs));
```

Data Collected During this Cruise

Data Type	File Header	Description	Days Collected

Streamer Compass Block	cb1	Compass direction of each compass bird in streamer	All lines (except strike8)
Sea Temp	ct	Sea Temperature	073-097
Gun Depth	dg	Gun Depth per shot-time	All lines
Furuno	fu		073-097
Tasman GPS	gp1	Ycode GPS	073-097
Trimble GPS	gp02	Standard GPS	073-097
Magnavox GPS	gp3	Standard GPS	073-097
Hydrosweep Centerbeam	hb	Centerbeam depth	074-096
Hydrosweep Swath	hs	Full Hydrosweep	074-096
Magnetics	mg	Varian Magnetometer	All lines
Navblock (Shots)	nb	Shot time/lnumber/position	All lines
TrueTime	tr1	CPU time synched w/ True	073-097
ShotTime	ts2	CPU Time vs Shot Time	All lines
Bell Gravity	vc	Bell Gravimeter data	073-097
Weather Station	wx	Variety of weather instrumentation	073-097

File Formats

cb1. - Streamer Compass block data ***(Only For MCS Cruises)***

97+286:00:01:01.148 arad-4 122158 N 08 58.9350 W 104 13.1772
CPU Time Line Shot # Latitude Longitude

N 00 00.0000 E 000 00.0000 270.9 C01 260.6 ...

Tail buoy Lat Tailbouy Lon Headg Compass # Compass Heading

hb.n - interpolated center beam merged with navigation

yy+ddd:hh:mm:ss:mmm N 12 12.1234 E 123.1234 2222.0
yr day time lat lon depth (meters)

m. - merged bathymetry, magnetics, gravity with final navigation.

```
yy+ddd:hh:mm:ss.mmm N 14  9.0555 W  67  2.3969   gp3 276.9  0.2
yr   day  time                 lat          lon            id     set   drift

5034.9   37401.8    17.2        -1.6    978349.0   13.1     9.1   13.2
depth    mag tot    mag         grv.    raw_grv    eotvos   tot   dc
         intensity  anomaly     faa                         drift shift
```

mg.n - interpolated values merged with final navigation anomalies 1995 IGRF

```
yy+ddd:hh:mm:ss.mmm N 12 12.1234 E 123 12.1234     41200.8   -367.1
yr day   time               lat             lon            total      anomaly
                                                           intensity
```

ts.n - Shot time/Navigation Block data merged with final navigation.

```
yy+ddd:hh:mm:ss.mmm 000913 N 53 17.4459 W 166 59.4171   MCS_LINE1
yr day    shot time        shot #   latitude         longitude        line name
```

ts.n.status - Shot status. Statistics of the shot file *(first, last, missing, errors)*

```
linename        first       last       Time of First Shot            Time of Last Shot
                shot        shot
LINE ABC1:    065479 .. 070819    yy+ddd:hh:mm:ss.mmm  ..    yy+ddd:hh:mm:ss.mmm
          MISSING: 66791, 67749, 67907
```

vt.n - merged BGM-3 gravity with final nav.

```
yy+ddd:hh:mm:ss.mmm N 16  0.4273 W  73 20.3055  1980   -4.1
yr   day  time              lat             lon            theog  FAA

978416.9   27.6   9.9   13.2     -2.7   3.9     -2.8   3.8
 raw_grav  eotvos drift  dc       raw_vel        smooth_vel
                         shift    N      E        N    E
```

Instruments

True Time Clock

Instrument Kinemetric/TrueTime Division Model GPS-DC GPS Synchronized Clock
Logging 1 minute intervals
Science Data None

The True Time clock is used to adjust the CPU clock of the logging computer. The logging computer captures the continuous time records from the clock and provides these as a service to the rest of the network via a UDP broadcast. This enables the computers on the network to adjust their CPU times to UTC time.

Day	Time	Comments
073	1510	Start Logging True time
097		End Logging True time

Speed and Heading

Instrument Furuno CI-30 2-axis Doppler speed log, Sperry MK-27 gyro

Logging 3 second intervals
Processing Mean value of all good values within the same minute.
Science Data: None

Day	Time	Comments
073	1510	Start Logging of Furuno Data
097		End Logging of Furuno data

Sea Temperature

Instrument Omega DP10 Series
Logging 1 minute intervals
Checking none
Smoothing none
Science Data none

Day	Time	Comments
073	1510	Start Logging Sea Temperature
097		End Logging Sea Temperature

Weather Station

Instrument R.M./. Young Precision Meteorological Instruments 26700 Series
Logging 1 minute interval
Final Data raw.
Notes Bird 2 is no longer used
Science Data none

Day	Time	Comments
073	1510	Start Logging Weather Data
097		End Logging Weather Data

Shot Times

Logging Varying intervals
Processing Shot point data was shot by distance, using two points 12 seconds apart to determine the velocity, and calculate the time needed to fire the next shot. Processing is done by taking the 1 minute processed navigation fixes and determining the actual shot location from the time.
Science Data *ts.n*

Day	Time	Line	Shots
076	1611	strike8	0002 .. 0685
077	0000	strike8	0686..1417
077	0853	mtest	0002..0289
077	1200	strike3	0002..1044
078	0000	strike3	1045..1306
078	0304	strike2	0001..1566
078	2053	strike1	0002..0282
079	0000	strike1	0283..2286
079	2305	dip2	0002..0151

080	0000	dip2	0152..4001
083	2152	strike7	0002..0153
084	0000	strike7	0154..1172
084	1449	strike6	0001..0634
085	0000	strike6	0635..1017
085	0539	strike5	0001..1084
085	2122	strike4	0001..0182
086	0000	strike4	0183..1055
086	1325	S4ToD4	0002..0734
087	0000	S4ToD4	0735..0880
087	0211	dip4	0001..3377
087	2134	dip3	0001..0385
088	0000	dip3	0386..2940
088	1455	dip2.5	0002..1627
089	0000	dip2.5	1628..2603
089	0532	dip1	0001..2861

GPS Fixes

Instruments gp1: TASMAN P(Y) GPS Receiver
gp2: GPS Trimble NT200D
gp3: Magnavox MX-4200 Global Positioning System

Logging 1 second fixes on TASMAN, 10 second intervals on all others

Checking

- Minimum number of SATs: 3
- Dilution of precision maximum: north = 4.0, east = 4.0
- Speed maximum: 20.0
- Reject fixes with high drifts in navigation, based on comparison with Furuno smooth speed and heading.

Processing ***See Navigation Processing***

Science Data gp**x**.n

Notes Final Navigation is based on TASMAN, gp1 See File GPS_ERRORS for times when the Pcode dropped to S/A mode.

Day	Time	Comments
073	1510	Started Logging of GPS Data
096	2359	End Processing of GPS Data
097		End Logging of GPS Data

Bathymetry

Instrument Krupp Atlas Hydrosweep Center Beam
Logging Each ping is logged, and center beam data is extracted and logged separately.
Processing Use only good centerbeam records that were acquired in *survey* mode. Produce a median value for each even minute
Final Data Merge the median with the one-minute navigation fixes.
Notes The following chart shows all discontinuities greater than 5 minutes.
Science Data *hb.n*

Day	Time	Comments
074	1000	Start logging Hydrosweep data
096	2359	End Processing Hydrosweep Data
097		End Logging Hydrosweep Data

Magnetics

Instrument Geometrics G-8866 Marine Magnetometer
Logging 8 second fixes
Processing Remove spikes, produce a median value for each even minute
Final Data Merge the median with the one-minute navigation fixes.
Science Data *mg.n*

Day	Time	Comments
074	1415	Start logging Magnetics data
080	2200	End Logging Magnetics
083	2151	Start Logging Magnetics data
089	2200	End Logging Magnetics data

Gravity

Instrument Bell Gravity Meter (BGM-3)
Logging 1 second intervals, raw gravity counts
Processing Check gravity, run through 1 minute Gaussian filter and output mGals at 6 second intervals to display output spikes. Run through a second 6 minute gaussian filter. Using the smoothed data, get the median value of every minute and output as the final gravity.
Final Data Merge this with the navigation and remove the EOTVOS errors. Also remove spikes due to hard course changes.
Science Data *ts.n*

Gravity Ties

It is usual practice to have a gravity tie to a gravity reference base station during the port stay. A portable gravity metter (Lacoste Model G #70) is used to make a pierside reading, a reading at the reference station, and then another pierside reading. The pierside gravity value, adjusted in value according to the height of the BGM gravity meter is compared to the BGM gravity meter reading. By comparing these readings with the reference station we can determine the drift of the gravity meter from one por t to the next. We determine the drift and divide that drift by the number of days on the cruise and come up with an average drift/day. This amount is added to the gravity readings over the course of each day. Normally the drift/day is less than 0.1 mgals.

EW-9802 Bridgetown, Barbados, West Indies

Pier/Ship	Latitude	Longitude	Reference	Latitude	Longitude
				13 06.4N	59 37.9W

Pier/Ship: Bollard 23, same pier as reference pier

Reference: Bollard 34. 3rd Bollard from north end of breakwater at the deep water harbor.

	Id	Date	Mistie	Drift/Day	DC Shift
Pre Cruise	EW9801	2/13/98	1.70	0.01	1.56
Post Cruise	EW9802	3/12/98	1.87	0.01	1.70
Total Days		27.00	0.17		

Time	Entry	Value	
16:58	CDeck Level BELOW Pier	0.33	meters
16:58	Pier 1 L&R Value	1969.80	L&R
17:09	Reference L&R Value	1970.40	L&R
17:16	Pier 2 L&R Value	1969.83	L&R
	Reference Gravity	978294.44	mGals
	Gravity Meter Value (BGM Reading)	978297.50	mGals
	Potsdam Corrected	0	1 if corrected

Gravity meter is ***5.5*** *meters below CDeck*

Difference in meters between Gravity Meter and Pier — 5.83 meters

Height Cor = Pier Height * FAA Constant

5.83	0.31			1.81	mGals/min

Difference in mGals between Pier and Gravity Meter

Delta L&R = Pier (avg) - Reference * 1.06 L&R/mGal

1969.82	1970.40	1.06		-0.62	mGals

Pier Gravity = Reference + Delta mGals [+ Potsdam]

978294.44	-0.62	0.00		978293.82	mgals

Gravity @meter = Pier Gravity+Height Correction

978293.82	1.81			978295.63	mGals

Current Mistie = BGM Reading - Calculated Gravity

978297.50	978295.63			1.87	mGals