Lamont-Doherty Earth Observatory of Columbia University

EW9709 DATA REDUCTION CRUISE SUMMARY

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Project Summary

The purpose of this cruise is to survey potential Ocean Drilling Project sites which will be used to investigate the nature of tropical wind-driven circulation during the earliest Eocene, a time of extreme warmth, and to trace the effects of cooling through the Eocene on the winds and ocean currents. Because of the northward motion of the Pacific plate the tropical Pacific provides a unique opportunity to sample early Cenozoic sediments derived from the equatorial high prroductivity zone in a location where they are not deeply buried and subject to diagenetic alteration.

The early Eocen hot -house world posses an enigma to paleoceaanographers and paleoclimatologists. What sort of atmospheric and oceaanic circulation patterns existed to maintain these warm conditions, and how could they be maintained over such a broad latitudinal zone? We propose to focus efforts on the tropical part of the climates system, where the tradewinds and surface ocean circulation appear to be so clearly linked.

If we are to evaluate the history of equatorial ocean circulation, we need to evaluate the history of the tradewinds. The Intertropical Cenvergence (ITCZ) marks the meeting of the southeastern and northeastern tradewinds, and the latitudinal position of the ITCZ indicates the contrast in the poe-to tropic temperature gradients of the northern compared as to the southern hemisphere. The few data that we have seem to suggest that the ITCZ was far north of its present position through much of the Cenozoic.

Today, and through much of the Cenozoic, the tradewind patterns have given rise to equatorial upwelling that over the eons has produced a broad equatorial bulge of biogenic-rich sedimentss. However, there is scant evidence for the existence of this bulge in the warmer Eocene times.

The 9709 cruise has been laid out to complete two latitudinal transects (Figure 1) in the central tropical Pacific along longitudes corresponding to two crustaal ages: 40Ma (middle Eocene) and 55Ma (lower Eocene/Paleocene). Planned are 15 survey and coring sites along these transects that could serve as site surveys for fututre drilling by the Ocean Drilling Program. We are using the hydrosweep, magnetometer, the 80 cubic inch watergun, the short (4 channel) streamer, and the 3.5 kHz reflection profiles in the transect and during the surveys.

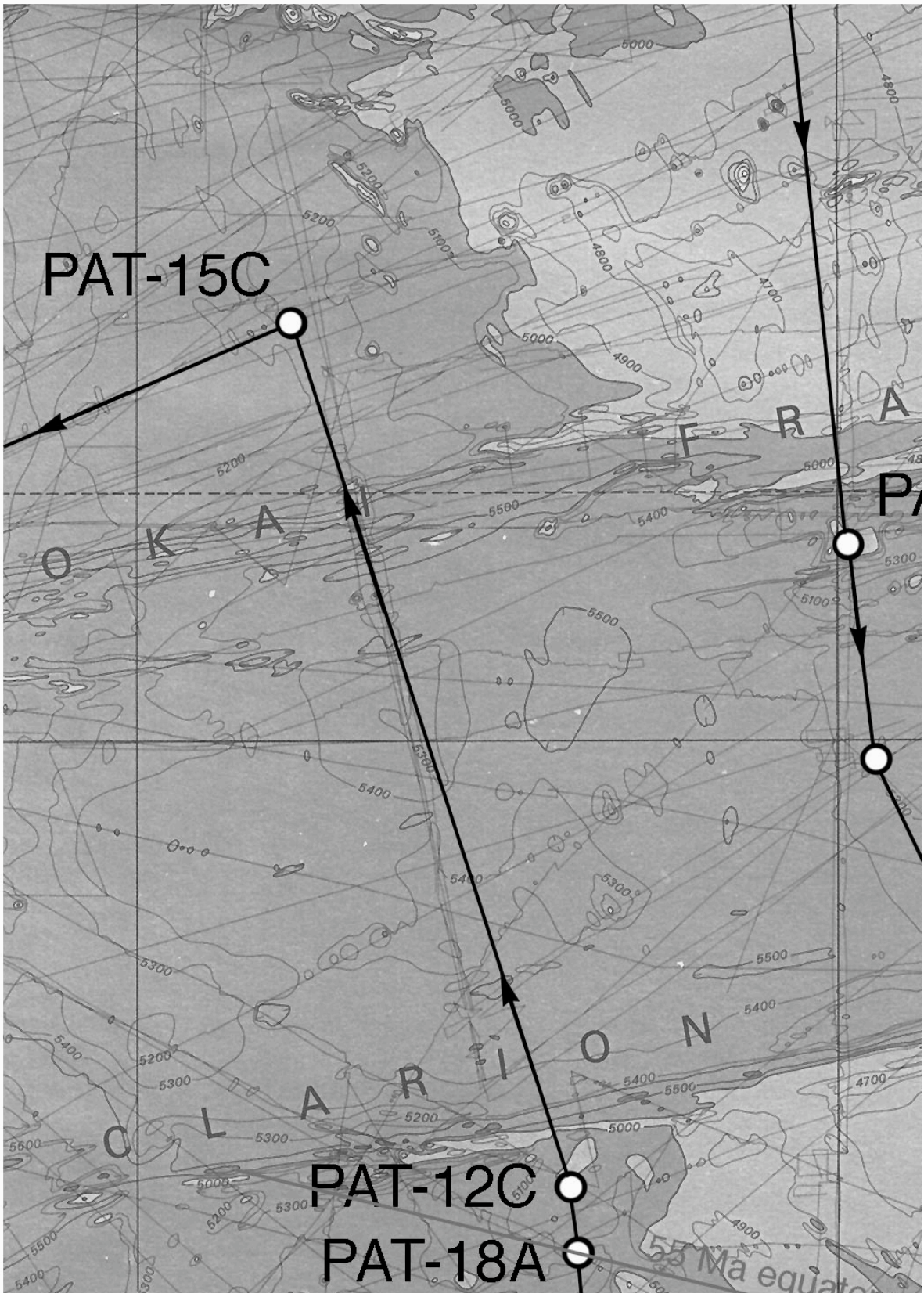
PAT-15C
PAT-12C
PAT-18A
O K A I
C L A R I O N
F R A
55 Ma

Figure 1. *Ew9709 survey area*

Navigation Processing

The following pages describe the GPS and shot processing pipeline used to create all the navigation based files: shot, hydrosweep centerbeam, magnetic, gravity, as well as the MCS navigation data.

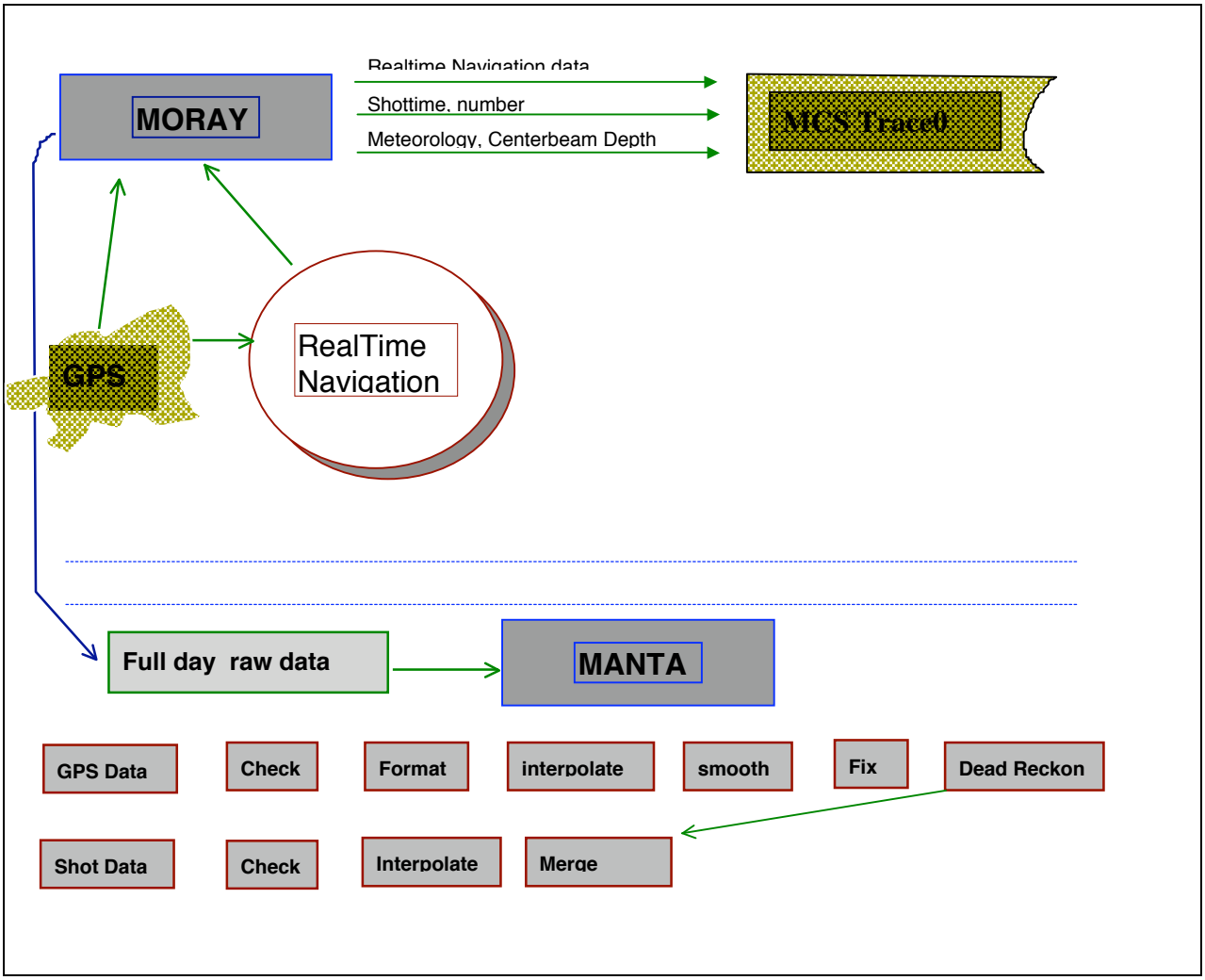

Figure 2. *Navigation Processing Pipeline*

Navigation Pipeline [refer to figure 1]

1. Logger
   Moray is the main logging system and is responsible for logging all the real-time data as well as controlling the intervals in which it is logged. This is also the system which 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
   This process uses the navigation from the selected GPS to provide a means of removing some of the randomness of the selective availability GPS by determining our current speed based on two points taken *filter_length* minutes apart. If available, the same information for the tailbuoy is reported. Simultaneously, the meteorological information and centerbeam data is collected. The output from this process (for both ship and tailbuoy) is:

   - 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

3. Using this data, ***MORAY*** determines the shot position based on the shot time and the time of the last GPS position fix. All this data is then passed on to the MCS system for Trace Zero data.

4. For non-real-time processing, raw gps data is transferred to Manta and processed. Navigation data is processed, then merged with all location specific information: hydrosweep center beam, shot-time, magnetic, and gravity. However, not all data is accumulated on every cruise.

5. GPS Processing

   - Check Data for mutant records and inconsistent times
   - Format the data into a standard format

     NMEA: Time Lat/Lon gps string

     Magnavox: Time PMVXG proprietary NMEA string

   - Interpolate the data where GPS coverage has been lost for any amount of time 3 minutes or less. In the case where differential coverage is in effect, throw away all values that are not differentially corrected before interpolation. Average the fixes into 30 second intervals:

     97+297:00:08:00.000 N 10 19.2790 W 104 25.4930

     97+297:00:08:30.000 N 10 19.4500 W 104 25.4380

   - Smooth the values with a 9 point running average algorithm. Output remains fixed at 30 second intervals
   - 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.

     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 the peaks due to selective availability. This is the final navigation.

6. Shot Data

- Check the raw navblock file for mutant records and inconsistent times.
- Interpolate between any missing shots using a simple interpolation algorithm, not correcting for latitude. Interpolated shots are marked with a "-" in the time header field.
- Merge the shot times with the final navigation prepared in the *Step 5*. The distance traveled between the two fixes is determined, allowing us to calculate the point where the shot was fired based on the time:

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

Data Collected During Cruise

All times are specified in GMT.

Data Files

The data delivered to the research consists of the following subdirectories:

File/Directory Name	Description
processed	Processed data
raw_gps	Raw GPS files at 10 second fixes for days 97,346 - 98,017
xbt	XBT Raw data and the generated velocity profiles

The processed directory consists of the following files for each day of data:

n. - 1 minute navigation from the "x." file and "fu.s" file

```
yy+ddd:hh:mm:ss.mmm N 12 12.1234 E 123 12.1234   gp1 123.1 12.1
yr day   time                    lat                  lon                  id      set      drift
```

id strings: "gp1" = GPS Trmble NT200D
"gp3" = GPS Magnavox MX4200D Receiver #1
"gp4" = GPS Magnavox MX4200D Receiver #2
"dr" = Dead Reckoned position

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
```

mg.n - interpolated values merged with final nav. ; 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
```

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)
```

ts.n - Shot time/Nav Block data remerged with final nav.

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

m. - merged bathy, maggie, gravity with final nav.

```
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
```

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
346	1800	Start Logging True time
017		End Processing True time

Sound Velocities

Instrument Sparton Expandable BathyThermograph (5 & 7) *XBT*
Processing Data is processed using the MB-System 4.3 to convert the depth/temperature readings to depth/sound velocity.
Science Data XBT and velocity profiles in *xbt* subdirectory

XBT	Location	
9709001	32.32N	-141.12W
9709002	22.55N	-140.00W
9709003	19.46N	-138.54W
9709004	16.52N	-138.06W
9709005	13.58N	-136.41W
9709006	12.13N	-131.01W
9709007	08.47N	-135.22W
9709008	00.00eq	-138.42W
9709009	04.26N	-140.50W
9709010	06.19N	-141.37W
9709011	07.45N	-141.56W
9709012	10.10N	-142.49W
9709013	12.02N	-143.42W
9709014	12.57N	-143.44W
9709015	18.48N	-145.30W
9709016	20.41N	-146.06W
9709017	26.06N	-147.55W

Guns

Logging Varying intervals

Processing Gun Shot data is created initially with a fifteen minute filter for the navigation data to reduce the effects of the selective availability. This data is then combined with the one-minute navigation and corrected for course and speed to produce the final formatted data. For site locations see Figure 1.

Science Data *ts.n*

Day	Time	Line	Shots
354	03:54	Pat14a Starts	1191 .. 8531
355		Pat14a Ends	8532 .. 9962
355	03:59	Pat13c Starts	1 .. 7204
356		Pat13c Ends	7205 ..138822
356	18:33	Pat19 Starts	1 .. 1957
357		Pat19	1958 .. 10597
358		Pat19 Ends	10598 ..12070
358	04:06	Pat20 Starts	1 .. 7166
359		Pat20 Ends	7667 .. 9747
359	07:11	Pat11 Starts	1 .. 6054
360		Pat11 Ends	6055 .. 8637
360	07:11	Pat21 Starts	1 .. 6051
361		Pat21 Ends	6052 .. 8872
361	07:51	Pat08 Starts	1 .. 3727
362		Pat08 Ends	3729 .. 7887
362	14:31	Pat23 Starts	1 .. 3413
363		Pat23 Ends	3414 .. 5064
363	04:36	Pat4b Starts	1 .. 6354
364		Pat4b	3655 .. 14994
365		Pat4b	14995..23634
001		Pat4b Ends	23635 ..23967
001	01:19	Pat5 Starts	1 .. 8162
002		Pat5 Ends	8163 .. 13198
002	14:01	Pat24 Starts	1 .. 3594
003		Pat24 Ends	3595 .. 5434
003	05:07	Pat6 Starts	1 .. 6795
004		Pat6 Ends	6796 .. 13431
005	01:55	Pat17	13433 .. 2559
005	09:04	Pat09 Starts	5 .. 5378
006		Pat09	5379 .. 11637
007		Pat09	11638 ..20277
008		Pat09 Ends	20278 ..22211
008	05:23	Pat18 Starts	1 .. 6701
009		Pat18 Ends	6702 .. 11768

009	14:05	Pat12 Starts	1 .. 3568
010		Pat12 Ends	3569 .. 7499
010	18:50	Pat15 Starts	1 .. 1858
011		Pat15	1859 .. 10498
012		Pat15	10499 ..16638
013		Pat15	16639 ..25278
014		Pat15	25279 ..33918
015		Pat15 Ends	33919 ..36264

Speed and Heading

Instrument Furuno CI-30 2-axis Doppler speed log, Sperry MK-27 gyro
Logging 3 second intervals
Processing The raw Furuno data is processed by taking the mean of all values within the even minute range and outputting the speed and heading on the even minute. All values taken during the 30 seconds before and after the even minute are used to calculate the median.

Science Data: None

Day	Time	Comments
346	1800	Start Logging of Furuno Data
017		End Processing of Furuno data

GPS SATELLITE FIXES:

Instruments gp1: GPS Trimble NT200D
gp3/4: Magnavox MX-4200 Global Positioning System
Logging 10 second intervals on all receivers
Checking
gp3/4: 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
Processing **See Navigation Processing Pipeline**
Science Data *n.*

Day	Time	Comments
346	1800	Started Logging of GPS Data
017		End GPS Data Logs

BATHYMETRY:

Instrument Krupp Atlas Hydrosweep Center Beam
Logging Each Hydrosweep Ping is logged, and center beam data is extracted and logged separately.
Processing Raw data is checked to process only good centerbeam records that were acquired in *survey* mode.
This data is then processed to produce a median value for each even minute.
The median is the median of all records 30 seconds before and after the even minute.
Final Data The median is merged with the one-minute navigation fixes to provide the final centerbeam data.
Notes During the cruise, hydrosweep data was occasionally turned off while coring.
The following chart shows all breaks greater than 5 minutes.
Science Data: *hb.n*

Day	Time	Comments
346	1800	Data logging/processing begins
361	2200 - 0200	No Data due to shutoff of Hydrosweep
017		Data processing ends

SEA TEMPERATURE:

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

Day	Time	Comments
346	1800	Sea temperature logging began
017		Logging ends

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
346	1800	Logging Begins
017	2359	Ends

BGM-3 GRAVITY:

Instrument Bell Aerospace BGM-3 marine gravity meter
Logging 1 second intervals

Science Data *vt.n (Observed, Eotvos, Free Air Anomaly value at 00 seconds of each minute)*
m.n (merged bathy, maggie, gravity with final nav.)

Merge with navigation calculate Eotvos correction and Free Air Anomaly.
Checking Visual check of plot of data to determine satisfactory Eotvos corrections, reject spikes of data at turns.
Velocity smoothing 5 point running average throughout the cruise.
Processing

Since current BGM-3 output has double counts every few minutes the following scheme has been implemented until the hardware and interface code has been fixed:

1. Run a 1 minute Gaussian filter through the data. This will narrow the output spikes and make them stand out better. Output interval has been hard-wired to every 15 seconds.
2. Pass the output through filter1d (see gmtsystem) using -FG480 (an 8 minute Gaussian filter with robust option, i.e., ignore "outlier" points (i.e. the spikes).

Calculations

eotvos_corr = 7.5038 * vel_east * cos(lat) + .004154 * vel*vel
corrected_grv = raw_grv + eotvos_corr - drift - dc_shift
faa = corrected_grv - theoretical_grv

1980 theoretical gravity formula

$Y_0 = 978.0327 \times (1 + .0053024 \times \sin(\square) \times \sin(\square) - .0000058 \times \sin(2 \times \square) \times \sin(2 \times \square))$

DAY	TIME	COMMENTS
346	1800	gravity gyros fixed, started logging/processing
017		end of cruise, stopped logging/processing

EW-9709 Honolulu, Hawaii OFFICIAL

Pier/Ship	Latitude	Longitude	Reference	Latitude	Longitude
	21 18.062N	157 51.96W		N	W

Honolulu, Hawaii
Ship is docked at pier #1 reading was taken across from door #33 at 1150' mark.

Reference station is at pier #2 Honolulu harbor opposite door #41 of the Diamond head terminal bldg. Site is midway between berth #2A and #2E along the west side of bldg. The site is 18" from edge of pier.

	Id	Date	Drift	Drift/Day	Total Drift
Pre Cruise	EW9708	12/5/97	0.00	0.00	0.00
Post Cruise	EW9709	1/24/98	1.56	0.03	1.56
Total Days		50.00			

Time	Entry	Value	
11:21	CDeck Level BELOW Pier	0.00	meters
11:21	Pier 1 L&R Value	2578.41	L&R
11:33	Reference L&R Value	2579.70	L&R
11:38	Pier 2 L&R Value	2578.41	L&R
Jan-04	Reference Gravity	978926.40	mGals
16:48	Gravity Meter Value (BGM Reading)	978941.90	mGals
	Potsdam Corrected	1	1 if corrected

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

Difference in meters between Gravity Meter and Pier: 5.50 meters

Height Cor = Pier Height * FAA Constant

5.50 * 0.31 = 1.71 mGals/min

Difference in mGals between Pier and Gravity Meter

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

2578.41 - 2579.70 * 1.06 = -1.37 mGals

Pier Gravity = Reference + Delta mGals [+ Potsdam]

978926.40 + -1.37 + 13.60 = 978938.63 mgals

Gravity @meter = Pier Gravity+Height Correction

978938.63 + 1.71 = 978940.34 mGals

Current Mistie = BGM Reading - Calculated Gravity

978941.90 - 978940.34 = 1.56 mGals