Project ‘AHOLO: A Hawaiian Ocean Landslide Observatory

R/V Kilo Moana
Southeast Flank, Kilauea Volcano, Hawai’i

Leg 1: Deployment
October 15-22, 2005

CRUISE PARTICIPANTS

Science Party:
Benjamin Brooks (University of Hawai’i), Co-Chief Scientist
Paulo Calil (University of Hawai’i) Co-Chief Scientist

Mark Behn (WHOI)
Jeff McGuire (WHOI)
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Wendy Smith (12th grader, Kamehameha High School)
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Keoni Kaleiwahea (11th grader, Kamehameha High School)

Tim McGovern (KM Marine Technician)
Gabe Foreman (KM Marine Technician)

R/V Kilo Moana Crew:
Rick Meyer (KM Captain)
Eric Shoenberg (Chief Mate)
Steve Haugland (2nd Mate)
Gary Haugland (3rd Mate)

Mark Behn, Jeff McGuire, Matthew Gould, and Ben Brooks w/ steam from active Kilauea lava flows observed in background.

CRUISE OVERVIEW

Massive slope failure and debris avalanches on the flanks of oceanic volcanoes have been linked to tsunami generation in the Pacific and Atlantic Oceans. However the process by which the flanks of active volcanoes deform remains poorly understood. One of the best-studied active volcanic landslides is the Hilina slump on the southeast flank of Kilauea volcano, Hawaii. Geodetic measurements and field observations on land show that the Hilina slump breaks away along a system of seaward dipping normal faults that transport material to the southeast at rates of ~10 cm/yr (Figure 1). This extension may represent the upper-flank expression of a massive slump sliding coherently seaward. Alternatively, several recent studies have proposed that volcanic spreading associated

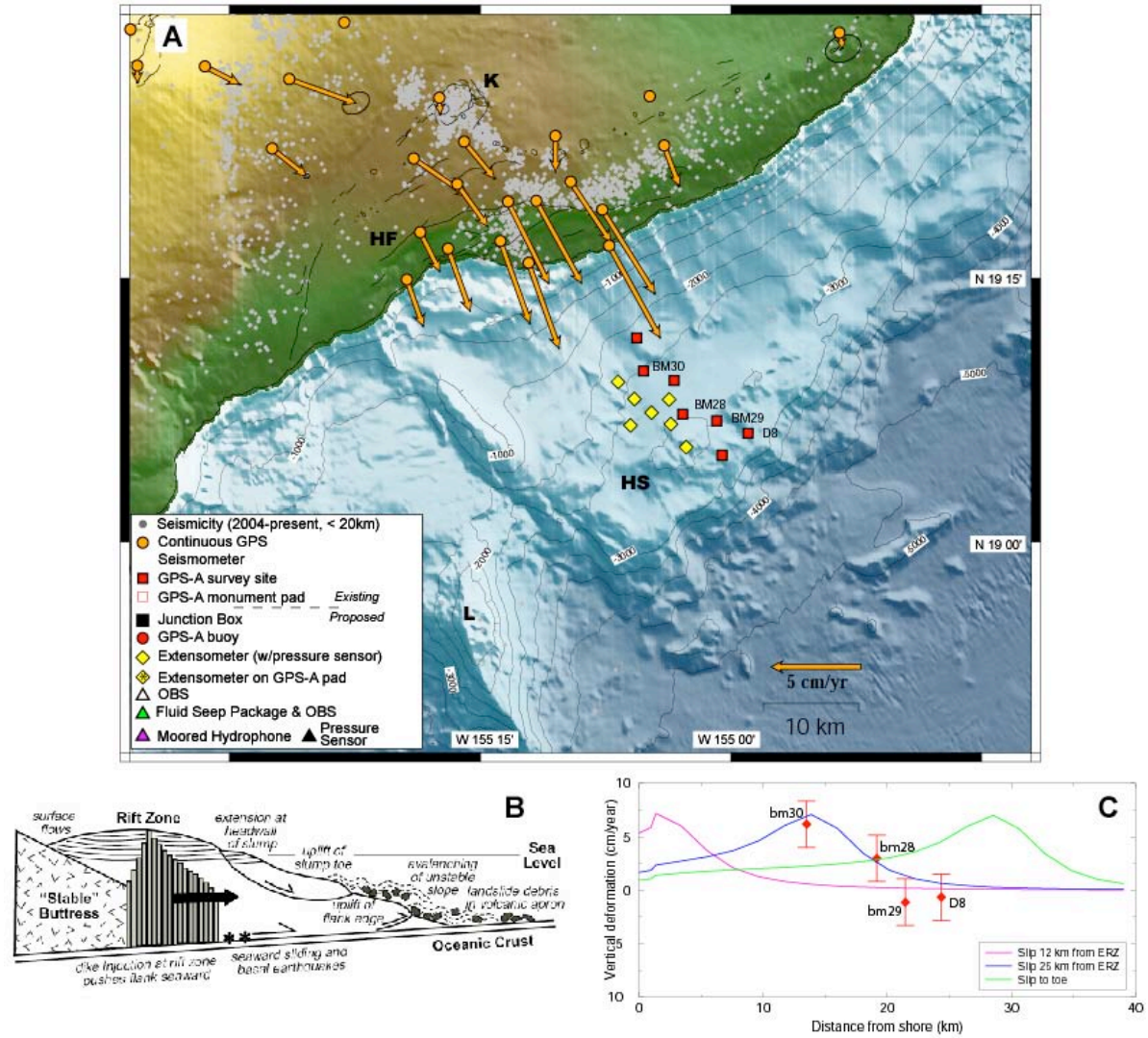


Figure 1. a) Location map showing location of extensometer network (yellow diamonds). Earthquakes since 2004 shown by grey dots. Existing GPS-A infrastructure depicted by red diamonds. K, Kilauea caldera; HF, Hilina Faults; OW, Ocean Entry; HS Hilina Slump. **b)** Schematic cross-section (location indicated on a) of the Hilina slump from *Morgan et al.* [JGR, 2003]. **c)** Recent results of vertical displacements from GPS-A occupations from *Phillips et al.* [Eos. 2004]. Occupations were performed in November 2000, April 2002, and August 2004.

with magma injection at the summit of Kilauea places the upper subaerial flanks in extension, while simultaneously generating compression and thrust faulting in the lower submarine flanks. If correct, this model implies a more stable flank configuration, with less potential for massive landslides and tsunami-genesis. Distinguishing between these models for the Hilina slump has been difficult because much of the deformation appears to be accommodated aseismically and prior to this cruise no submarine geodetic measurements have resolved horizontal motions on the flank.

The goal of Project ‘AHOLO* (**A** **H**awaiian **O**cean **L**andslide **O**bservatory) was to deploy a new acoustic extensometer system under development at WHOI to monitor deformation in Kilauea’s submarine flank. The rapid deformation rates combined with the localized region of compression predicted by the volcanic spreading model offer the possibility of resolving horizontal motions during our 6-month deployment. The continuous time series obtained by the extensometer network will be compared to onshore continuous GPS data to look for correlations between transient periods of deformation. The data collected in this study will also be used to improve future seafloor geodetic studies, including those associated with the ORION seafloor observatory initiative. Finally, new high-resolution multi-beam bathymetry and backscatter data was collected during the deployment cruise using the R/V Kilo Moana’s EM120 swath system. This imagery will be analyzed and integrated with previous seismic reflection data to provide new insights into the tectonic setting of the Hilina slump.

Project ‘AHOLO was funded through a combination of sources including WHOI’s Deep Ocean Exploration Institute, the National Science Fundation, and a University of Hawai’i grant for R/V Kilo Moana ship time. The deployment cruise was conducted aboard the R/V Kilo Moana from October 15-22, 2005 out of Sand Island, Honolulu, HI. Cruise time was shared with University of Hawai’i physical oceanography graduate student Paolo Calil, who was leading a near surface current survey off the southern coast of the Big Island. The extensometer recovery leg is planned for late spring 2006.

* *‘Aholo* is the Hawaiian word for landslide.

CRUISE LOG

October 13, 2005

AM: Behn, Brooks, and Gould arrive at Sand Island, unpack container, and load extensometers onto R/V Kilo Moana.

PM: Vacuum was checked and found to be good on all spheres. McGuire arrives in evening.

October 14, 2005

AM: Behn, Gould, and McGuire use deck connection to check transceiver and transponder settings:

Interrogation Period:	120 minutes
Return Full Waveform:	Every 6 interrogations
Initial Transceiver Wake-Up Delay:	300 minutes
Transponder Wake-Up Period:	96 seconds
Transceiver C1 Map:	Transponders P1, P2, P3, & P4
Transceiver C2 Map:	Transponders P4 & P5

All previous data files were deleted on each transceiver and initial data file name was set to DATA1.DAT.

PM: Behn, Gould, and McGuire tested acoustic modem connection. All tests were successful after using RS484/422 to RS232 connection from PC to modem.

October 15, 2005

0800: Depart Sand Island, Honolulu, Hawai’i

1000-1300: U.H. MVP trials offshore Honolulu.

1340: Begin acoustic release test. 8 releases (S/Ns: 14748, 14737, 14142, 14134, 14147, 14159, 14152, 14125, 14147) placed on rosette and lowered to 1145 m. All releases confirm enable, slant range, release, and disable commands. 120 kHz secured during tests. For S/N 14147 the ship was declutched in order to get good responses.

1448: Wire up and rosette secured

1500-1900: MVP Trials

1900-2100: Releases secured to tripods (P1-S/N 14748 (9 kHz), P2-S/N 14159 (11 kHz), P3-S/N 14142 (9 kHz), P4-S/N 14152 (11 kHz), P5-S/N 14134 (9 kHz), C1-S/N 14147 (11 kHz), C2-S/N 14737 (9 kHz)).

2000: Small boat transfer to return MVP crew to Honoulu

2100-2359: Transit to Big Island

October 16, 2005

0000-1600: Transit to Big Island

1600-2300: EM120 multi-beam survey of southeast flank of Kilauea. See Figures 2 & 3

2300-2359: Transit to extensometer deployment site.

October 17, 2005:

00:28:00: Deployed Transponder P5 (19º 9.725’N x 155º 4.004’W). For first deployment we remained on site for entire freefall to bottom. Average drop rate was 75 m/minute.

01:33:30: Deployed Transponder P4 (19º 9.286’N x 155º 3.512’W).

02:01:27: Deployed Transponder P3 (19º 9.335’N x 155º 3.019’W).

02:39:14: Deployed Transponder P2 (19º 8.918’N x 155º 3.565’W).

03:03:16: Deployed Transponder P1 (19º 8.707’N x 155º 2.879’W).

03:34:50: Deployed Transponder C1 (19º 9.083’N x 155º 3.325’W).

04:11:03: Deployed Transponder C2 (19º 9.471’N x 155º 3.739’W).

04:15: Waypoint #0 for surveying locations of tripods (19º 9.471’N x 155º 3.741’W).

05:00: Waypoint #1 for surveying locations of tripods (19º 9.098’N x 155º 4.269’W).

05:45: Waypoint #2 for surveying locations of tripods (19º 9.936’N x 155º 4.374’W).

06:18: Waypoint #3 for surveying locations of tripods (19º 9.922’N x 155º 3.321’W).

06:45: Waypoint #4 for surveying locations of tripods (19º 9.290’N x 155º 2.605’W). After surveying all Edgetech releases were disabled. Edgetech S/N 14147 has poor connection and requires ship to be declutched.

0700-2359: ADCP/MVP Survey.

October 18, 2005:

0000-1200: ADCP/MVP Survey.

12:40: Returned to Transceiver C2 (19º 9.512’N x 155º 3.713’N) to upload first data file and confirm successful link to Transponders P4 & P5. Modem was deployed from the A-frame. Uploaded DATA1.DAT (243,673 bytes) in 12 minutes. Transceiver C2 was returned to data collection mode. Both P4 & P5 had synched to C2 on first attempt. See Figures 4 & 5.

13:45: Returned to Transceiver C1 (19º 9.119’N x 155º 3.330’W) to upload data file and confirm link to Transponders P1, P2, P3, & P4. Uploaded DATA1.DAT (503,589 bytes). Only 394 kbytes uploaded in 19 minutes before modem connection crashed. Transceiver C1 was returned to data collection mode. All transponders had synched (P4 on first attempt, P2 & P3 on second attempt, and P1 on third attempt). See Figures 4 & 5.

14:49: Waypoint #5 for surveying locations of tripods (19º 8.415’N x 155º 3.166’W). After surveying all Edgetech releases were disabled. Modem was deployed from the A-frame and connection was improved relative to waypoints 0-4 when the modem was deployed directly from stern.

1500-1700: Plankton tow.

1700-2359: ADCP/MVP Survey.

October 19, 2005:

0000-2359: ADCP/MVP Survey.

October 20, 2005:

0000-2359: ADCP/MVP Survey.

October 21, 2005:

0000-1400: ADCP/MVP Survey.

1400-2359: Transit to Honolulu.

October 22, 2005:

0000-0800: Transit to Honolulu.

0800: Arrive in Port, Sand Island, Honolulu, HI.

INITIAL DATA

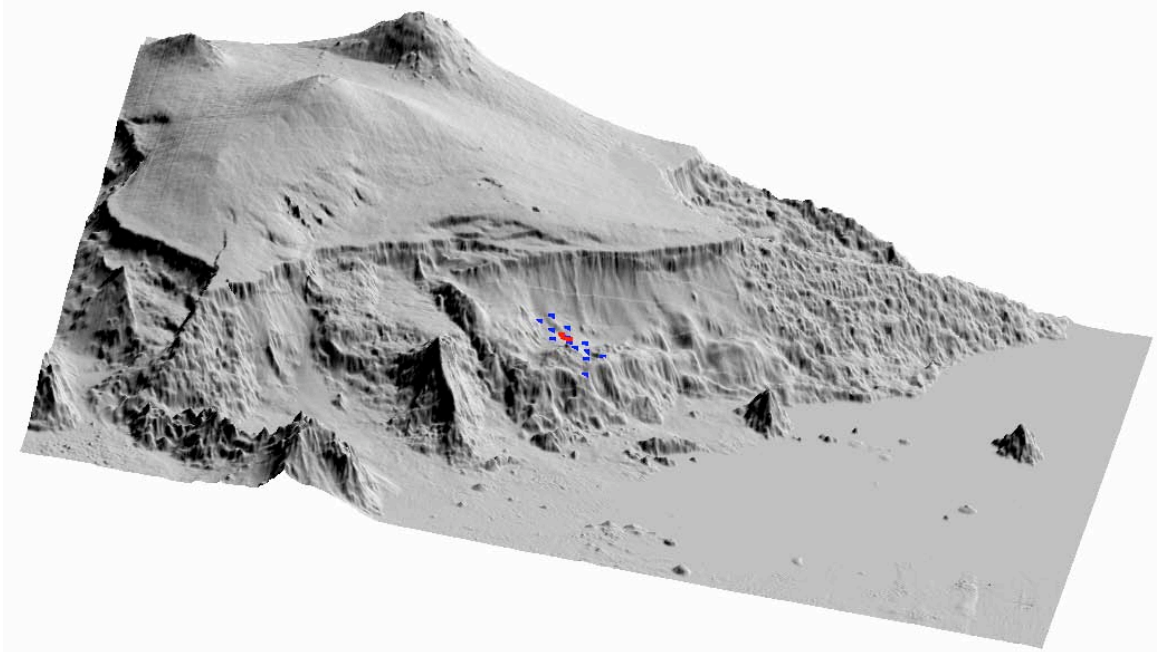


Figure 2. Shaded relief map of southeast flank of Kilauea. Location of extensometer network is shown in red. GPS-A station locations of *Phillips et al.* [Eos. 2004]. are shown in blue. Extensometer network was situated on mid-slope bench of the Hilina slump system.

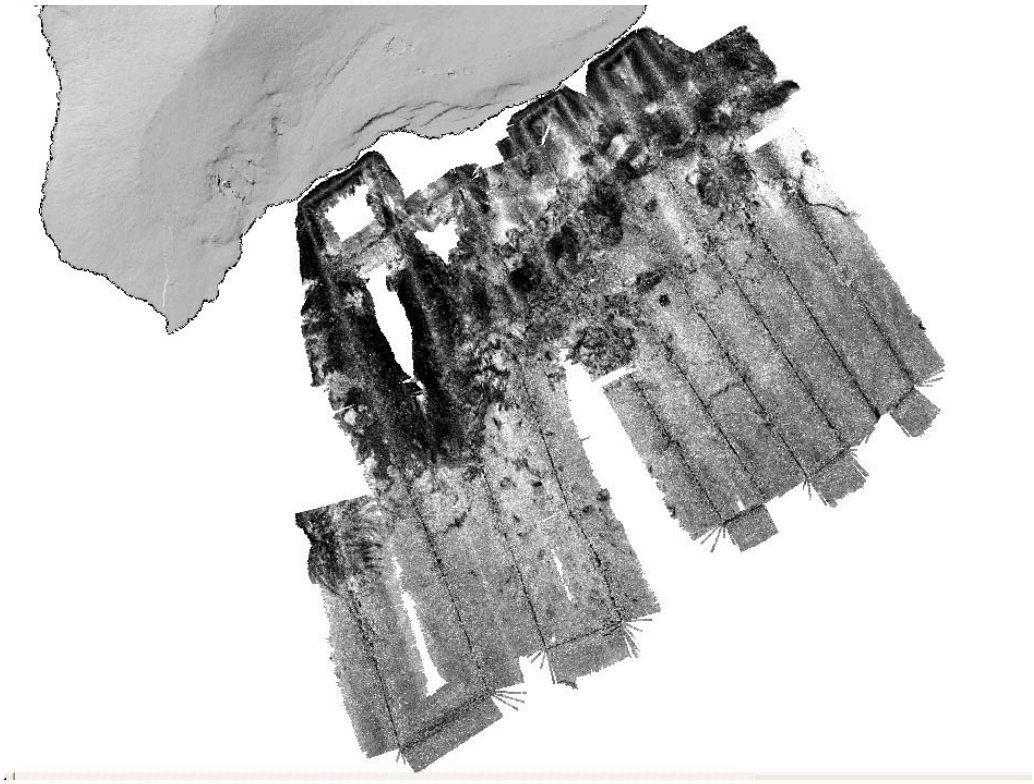


Figure 3. Acoustic backscatter map of southeast flank of Kilauea constructed from data collected during the cruise using the Kilo Moana’s EM120 system.

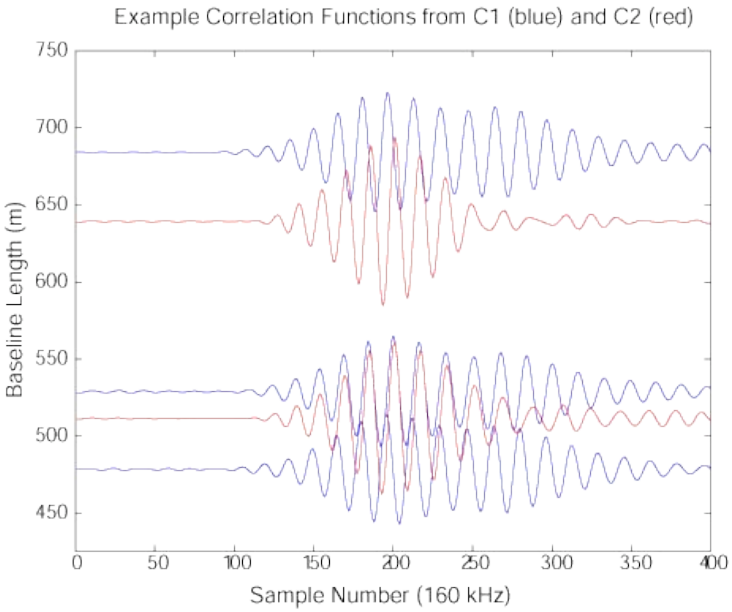


Figure 4. Examples of the cross-correlations between outgoing and incoming signals for baselines C1-P2, C1-P3, C1-P4, C2-P4, C2-P5. The baselines associated with C2 are shown in red and have very clean correlation functions similar to the theoretically expected values for a single arrival. The baselines associated with C1 are more complicated regardless of distance indicating that C1 landed in a region of less smooth seafloor.

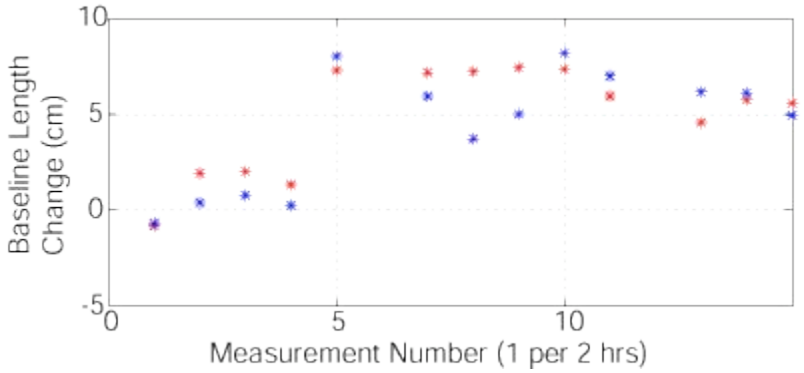
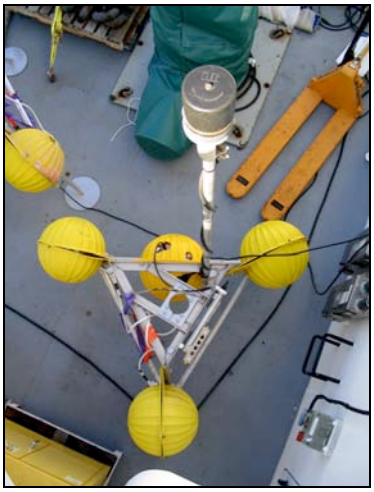


Figure 5. The first day’s measurements for the baselines C2-P4 (red) and C2-P5 (blue). Travel-time picks were made from picking the peak of the correlegram and converted to distance using a constant sound velocity of 1500 m/s. The highly correlated nature of the two baselines indicates that the majority of the variability results from variations in sound velocity that will be corrected once the CTs are retrieved.

CRUISE PHOTOS

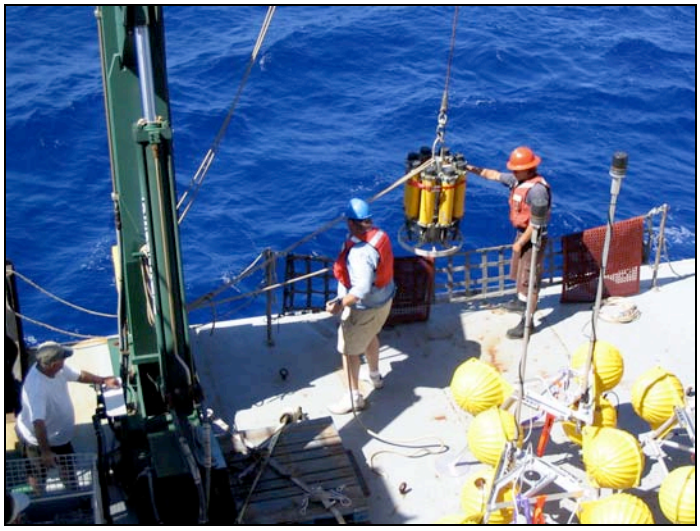
Leaving Honolulu…



Transponder P2 on deck.

Jeff McGuire describing the extensometer system to students from Kamehameha High School.

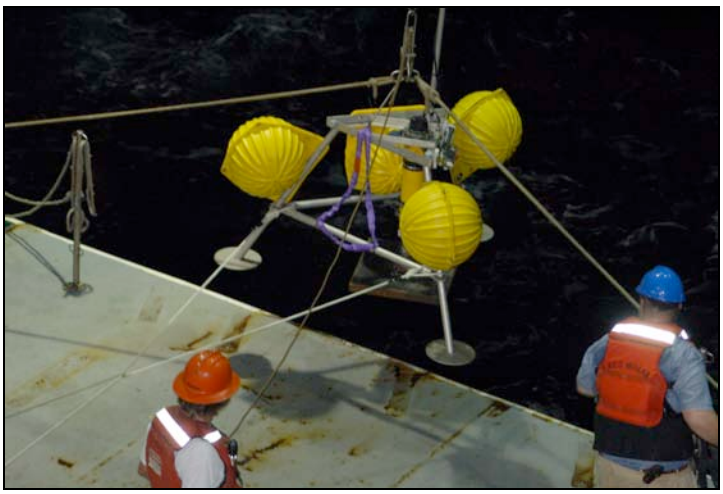

Chief scientist Ben Brooks (Univ. Hawai’i) giving an overview of the tectonics of Kilauea Volcano and the Hilina slump system.

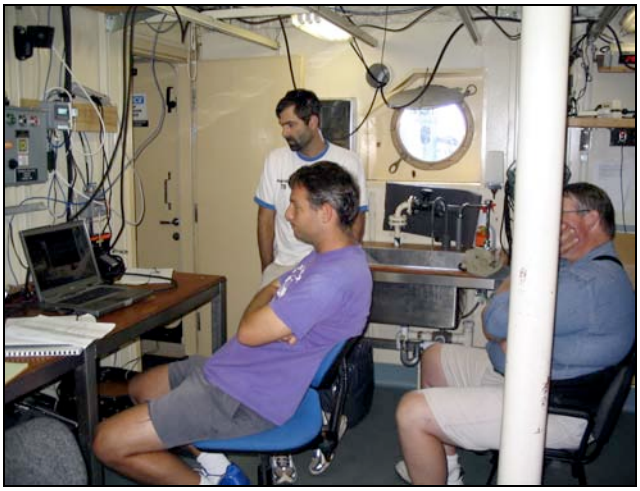


Day 1: Acoustic release test of Honolulu.

Steam from lava entry off Kilauea Volcano.

The big day. After 3+ years Jeff finally gets to deploy his extensometers. (top) Jeff and Matthew attach anchor to base of tripod. (left) Kamehameha high school senior Jason Patterson completes final pre-deployment checklist. (bottom) Away she goes…





One day later. Waiting for the first data file…

R/V Kilo Moana science technician Gabe Foreman and Kamehameha students deploying plankton tow net.

Kilauea at night.

Appendix A: Transceiver/Transponder Deployment Data Sheets

Transponder P1

Edgetech
- Serial Number: 14748
- Interrogation Frequency: 9.0 kHz
- Reply Frequency: 14.5 kHz
- Release Code: 447031 (14)
- Disable Code: 475051 (14)
- Enable Code: 475072 (0)

Recovery Aids
- Radio Frequency: 160.725

Date/Time of Power On: 290 12:49:00 GMT

Drop Position
- Lat/Lon Position: 19º 8.707’N x 155º 2.879’W
- Time: 290 13:03:16 GMT

Interrogation during freefall

Time	Slant Range (m)
13:05:05	139
13:06:08	216
13:07:08	295
13:15:30	963
13:16:00	1003
13:40:08	2815
13:40:32	2815
13:45:00	2812

Average Drop Rate: 79 m/minute

Transponder P2

Edgetech
- Serial Number: 14159
- Interrogation Frequency: 11.0 kHz
- Reply Frequency: 10.5 kHz
- Release Code: 445504 (14)
- Disable Code: 471115 (14)
- Enable Code: 471136 (0)

Recovery Aids
- Radio Frequency: 159.480

Date/Time of Power On: 290 12:18:00 GMT

Drop Position
- Lat/Lon Position: 19º 8.918’N x 155º 3.565’W
- Time: 290 12:39:14 GMT

Interrogation during freefall

Time	Slant Range (m)
12:41:00	135
12:43:00	291

12:47:30	650	
13:08:15	2658	
13:08:30	2675	
13:10:30	2807	
13:14:00	2969	
13:14:30	2969	Average Drop Rate: 79 m/minute

Transponder P3

Edgetech
- Serial Number: 14142
- Interrogation Frequency: 9.0 kHz
- Reply Frequency: 13.5 kHz
- Release Code: 445164 (14)
- Disable Code: 470162 (14)
- Enable Code: 470200 (0)

Recovery Aids
- Radio Frequency: 159.480

Date/Time of Power On: 290 11:35:00 GMT

Drop Position
- Lat/Lon Position: 19º 9.335’N x 155º 3.019’W
- Time: 290 12:01:27 GMT

Interrogation during freefall

Time	Slant Range (m)	
12:03:12	106	
12:03:46	169	
12:05:00	260	
12:07:00	427	
12:09:00	588	
12:11:00	755	
12:45:00	2847	
12:45:30	2848	
12:46:00	2848	Average Drop Rate: 83 m/minute

Transponder P4

Edgetech
- Serial Number: 14152
- Interrogation Frequency: 11.0 kHz
- Reply Frequency: 8.5 kHz
- Release Code: 443133 (14)
- Disable Code: 463316 (14)
- Enable Code: 463335 (0)

Recovery Aids
- Radio Frequency: 160.725

Date/Time of Power On: 290 10:35:00 GMT

Drop Position
Lat/Lon Position: 19º 9.286’N x 155º 3.512’W
Time: 290 11:33:30 GMT

Interrogation during freefall

Time	Slant Range (m)	
11:34:00	105	
11:35:00	110	
11:37:00	266	
11:39:00	417	
11:41:00	577	
11:42:00	655	Average Drop Rate: 69 m/minute

Transponder P5

Edgetech
Serial Number: 14134
Interrogation Frequency: 9.0 kHz
Reply Frequency: 9.5 kHz
Release Code: 444300 (14)
Disable Code: 466433 (14)
Enable Code: 466456 (0)

Recovery Aids
Radio Frequency: 160.785

Date/Time of Power On: 290 10:11:35 GMT

Drop Position
Lat/Lon Position: 19º 9.725’N x 155º 4.004’W
Time: 290 10:28:00 GMT

Interrogation during freefall

Time	Slant Range (m)	
10:30:00	181	
10:32:00	316	
10:33:00	393	
10:35:00	550	
10:37:00	705	
10:39:00	863	
10:41:00	1019	
10:45:00	1344	
10:47:00	1494	
10:49:00	1653	
10:51:00	1809	
10:55:00	2113	
10:57:00	2280	
10:59:00	2427	
11:01:00	2593	
11:03:00	2641	
11:05:00	2642	Average Drop Rate: 75 m/minute

Transceiver C1

Edgetech
- Serial Number: 14147
- Interrogation Frequency: 11.0 kHz
- Reply Frequency: 7.5 kHz
- Release Code: 443464 (14)
- Disable Code: 464545 (14)
- Enable Code: 464566 (0)

Recovery Aids
- Radio Frequency: 160.725

Date/Time of Power On: 290 12:30:17 GMT

Drop Position
- Lat/Lon Position: 19º 9.083’N x 155º 3.325’W
- Time: 290 13:34:50 GMT

Interrogation during freefall

Time	Slant Range (m)	
13:36:30	124	
13:37:00	171	
13:38:00	253	
13:43:00	673	
13:43:30	716	
14:21:30	2822	
14:21:45	2820	Average Drop Rate: 84 m/minute

Transceiver C2

Edgetech
- Serial Number: 14737
- Interrogation Frequency: 9.0 kHz
- Reply Frequency: 8.0 kHz
- Release Code: 447012 (14)
- Disable Code: 475017 (14)
- Enable Code: 475034 (0)

Recovery Aids
- Radio Frequency: 160.785

Date/Time of Power On: 290 13:30:00 GMT

Drop Position
- Lat/Lon Position: 19º 9.471’N x 155º 3.739’W
- Time: 290 14:11:03 GMT

Interrogation during freefall

Time	Slant Range (m)	
14:14:11	250	
14:14:40	292	
14:20:00	744	Average Drop Rate: 86 m/minute

Appendix B: Location of the Tripods on the Seafloor Using the Edgetech Ranging System

Two-way travel time measurements for each tripod are given below in order from waypoint zero to waypoint 5. The position of the ship’s GPS antenna (over the bridge) is given in degrees and decimal minutes. The Edgetech transponder was actually located off the aft deck. Waypoints 0-4 were surveyed on 10/17/2005 and waypoint 5 was surveyed on 10/18/2005.

Estimated Instrument Locations:

Instrument	Lat	Lon	Depth (m)	Drift (m)	at Azim (deg)
C1	19.1502	-155.0571	2671	219	234
C2	19.1569	-155.0639	2668	202	237
P1	19.1439	-155.0497	2656	231	233
P2	19.1472	-155.0613	2640	256	231
P3	19.1543	-155.0519	2690	219	230
P4	19.1535	-155.0602	2670	222	231
P5	19.1610	-155.0682	2660	202	237

Ranging Data:

Transceiver C1
Ranging data taken on: 2005-10-08 13:29:37.443623
Cruise: Kilauea_Oct05
Site: 1
Instrument: C1
Drop Point (Latitude): 19 09.083 N
Drop Point (Longitude): 155 03.325 W
Depth (meters): 2656
Comment:
==========

1894 msec. Lat: 19 09.4710 N Lon: 155 03.7410 W Alt: 00.00
2035 msec. Lat: 19 09.0960 N Lon: 155 04.2680 W Alt: 00.00
2379 msec. Lat: 19 09.9270 N Lon: 155 04.3940 W Alt: 00.00
2098 msec. Lat: 19 09.9210 N Lon: 155 03.3180 W Alt: 00.00
2048 msec. Lat: 19 09.2910 N Lon: 155 02.6050 W Alt: 00.00
1938 msec. Lat: 19 08.4160 N Lon: 155 03.1660 W Alt: 00.00

Transceiver C2
Ranging data taken on: 2005-10-08 13:29:37.443623
Cruise: Kilauea_Oct05
Site: 1
Instrument: C2
Drop Point (Latitude): 19 09.471 N
Drop Point (Longitude): 155 03.739 W
Depth (meters): 2660
Comment:
==========

1778 msec. Lat: 19 09.4730 N Lon: 155 03.7430 W Alt: 00.00
1888 msec. Lat: 19 09.0980 N Lon: 155 04.2680 W Alt: 00.00
1991 msec. Lat: 19 09.9240 N Lon: 155 04.4100 W Alt: 00.00
1974 msec. Lat: 19 09.9210 N Lon: 155 03.3180 W Alt: 00.00
2286 msec. Lat: 19 09.2900 N Lon: 155 02.6050 W Alt: 00.00
2287 msec. Lat: 19 08.4140 N Lon: 155 03.1670 W Alt: 00.00

Transponder P1
Ranging data taken on: 2005-10-08 13:29:37.443623
Cruise: Kilauea_Oct05
Site: 1
Instrument: P1
Drop Point (Latitude): 19 08.707 N
Drop Point (Longitude): 155 2.879 W
Depth (meters): 2656
Comment:
==========

2222 msec. Lat: 19 09.4700 N Lon: 155 03.7420 W Alt: 00.00
2383 msec. Lat: 19 09.0960 N Lon: 155 04.2680 W Alt: 00.00
2406 msec. Lat: 19 09.9210 N Lon: 155 03.3180 W Alt: 00.00
1989 msec. Lat: 19 09.2910 N Lon: 155 02.6040 W Alt: 00.00
1790 msec. Lat: 19 08.4160 N Lon: 155 03.1660 W Alt: 00.00

Transponder P2
Ranging data taken on: 2005-10-08 13:29:37.443623
Cruise: Kilauea_Oct05
Site: 1
Instrument: P2
Drop Point (Latitude): 19 08.918 N
Drop Point (Longitude): 155 3.565 W
Depth (meters): 2640
Comment:
==========

1921 msec. Lat: 19 09.4710 N Lon: 155 03.7420 W Alt: 00.00
1916 msec. Lat: 19 09.0970 N Lon: 155 04.2680 W Alt: 00.00
2369 msec. Lat: 19 09.9290 N Lon: 155 04.4150 W Alt: 00.00
2243 msec. Lat: 19 09.9200 N Lon: 155 03.3180 W Alt: 00.00
2228 msec. Lat: 19 09.2890 N Lon: 155 02.6030 W Alt: 00.00
1920 msec. Lat: 19 08.4140 N Lon: 155 03.1670 W Alt: 00.00

Transponder P3
Ranging data taken on: 2005-10-08 13:29:37.443623
Cruise: Kilauea_Oct05
Site: 1
Instrument: P3
Drop Point (Latitude): 19 09.335 N
Drop Point (Longitude): 155 3.019 W
Depth (meters): 2690
Comment:
==========

1946 msec. Lat: 19 09.4700 N Lon: 155 03.7420 W Alt: 00.00
2248 msec. Lat: 19 09.0970 N Lon: 155 04.2670 W Alt: 00.00
2482 msec. Lat: 19 09.9300 N Lon: 155 04.4190 W Alt: 00.00
1980 msec. Lat: 19 09.9210 N Lon: 155 03.3170 W Alt: 00.00
1888 msec. Lat: 19 09.2920 N Lon: 155 02.6050 W Alt: 00.00
2068 msec. Lat: 19 08.4140 N Lon: 155 03.1680 W Alt: 00.00

Transponder P4
Ranging data taken on: 2005-10-08 13:29:37.443623
Cruise: Kilauea_Oct05
Site: 1
Instrument: P4
Drop Point (Latitude): 19 09.286 N
Drop Point (Longitude): 155 3.512 W
Depth (meters): 2665
Comment:
==========

1806 msec. Lat: 19 09.4680 N Lon: 155 03.7400 W Alt: 00.00:
1940 msec. Lat: 19 09.0970 N Lon: 155 04.2680 W Alt: 00.00:
2193 msec. Lat: 19 09.9300 N Lon: 155 04.4160 W Alt: 00.00:
2006 msec. Lat: 19 09.9210 N Lon: 155 03.3140 W Alt: 00.00:
2131 msec. Lat: 19 09.2910 N Lon: 155 02.6050 W Alt: 00.00
2090 msec. Lat: 19 08.4130 N Lon: 155 03.1680 W Alt: 00.00

Transponder P5
Ranging data taken on: 2005-10-08 13:29:37.443623
Cruise: Kilauea_Oct05
Site: 1
Instrument: P5
Drop Point (Latitude): 19 09.725 N
Drop Point (Longitude): 155 04.004 W
Depth (meters): 2650
Comment:
==========

1831 msec. Lat: 19 09.4700 N Lon: 155 03.7400 W Alt: 00.00 :
1914 msec. Lat: 19 09.0960 N Lon: 155 04.2670 W Alt: 00.00 :
1834 msec. Lat: 19 09.9290 N Lon: 155 04.4150 W Alt: 00.00:
2010 msec. Lat: 19 09.9220 N Lon: 155 03.3150 W Alt: 00.00:
2522 msec. Lat: 19 09.2880 N Lon: 155 02.6050 W Alt: 00.00:
2576 msec. Lat: 19 08.4090 N Lon: 155 03.1670 W Alt: 00.00 :

For the Log:

WayPoint	Day	Survey Time (UTC)
0	290	14:15:00.00
1	290	15:00:00.00
2	290	15:45:00.00
3	290	16:18:00.00
4	290	16:45:00.00
5	291	22:40:00.00