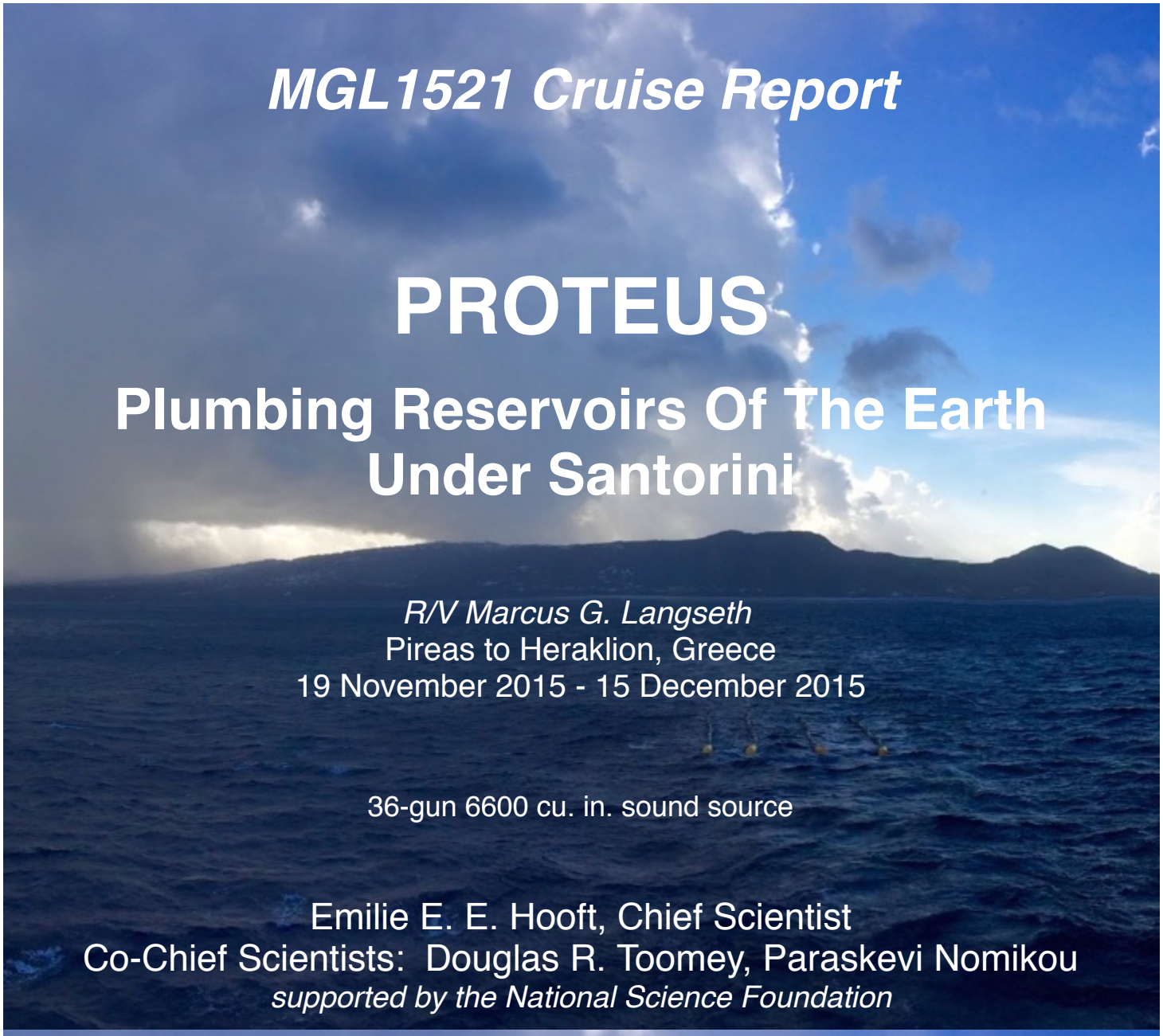


MGL1521 Cruise Report

PROTEUS

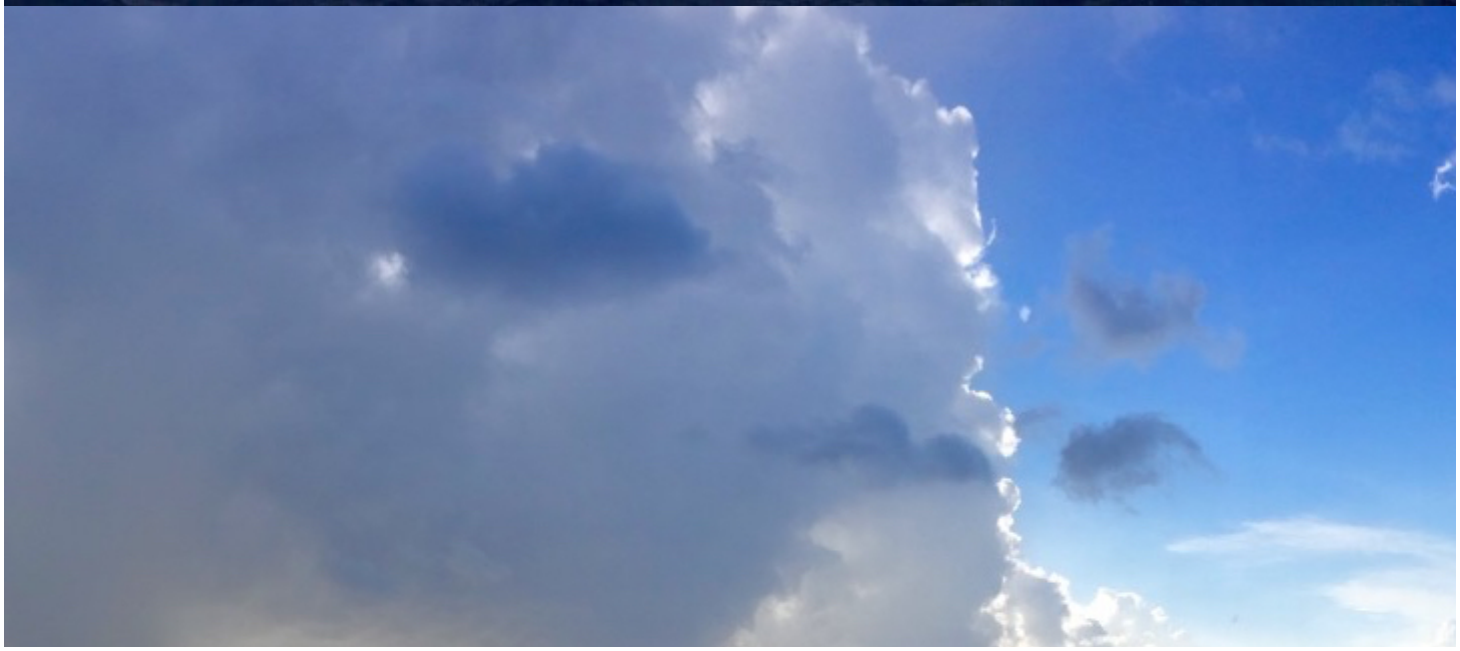
Plumbing Reservoirs Of The Earth Under Santorini

R/V Marcus G. Langseth
Pireas to Heraklion, Greece
19 November 2015 - 15 December 2015

36-gun 6600 cu. in. sound source

Emilie E. E. Hooft, Chief Scientist
Co-Chief Scientists: Douglas R. Toomey, Paraskevi Nomikou

supported by the National Science Foundation



Summary

PROTEUS
Plumbing Reservoirs Of The Earth Under Santorini

"One must wait until the evening, to see how splendid the day has been." Sophocles

On this research expedition the *R/V Marcus G. Langseth* leg MGL1521 collected dense seismic data at Santorini volcano in the eastern Mediterranean, Aegean Sea. The study was supported by the National Science FoundationGrant number (1548026)*. During the 26-day expedition, 91 four-component, ocean bottom seismometers (OBSs) were throughout the area to record seismic energy from the 36-element, 6600 cu. in. airgun array of the *R/V Marcus G. Langseth*. The data will be used for 3D, anisotropic seismic tomography and full seismic waveform inversion.

The goal of the research project is to examine the entire crustal magma plumbing system beneath an arc volcano. The magma geometry and connections throughout the crust are physical parameters that control magma migration, storage, and eruption and are thus important to understand geohazards. More broadly, this study will help answer questions about how the processing of magma at arc volcanoes forms the rock compositions that dominate the lower continental crust.

The ocean bottom receivers were from the NSF-supported Ocean Bottom Seismograph Instrument Pool (OBSIP); 61 and 30 OBSs were provided by the Scripps Institution of Oceanography (SIO) and the Woods Hole Oceanographic Institution (WHOI) OBSIP groups, respectively. Of the 91 OBS 90 were successfully recovered. By site, the data return rate appears to be somewhat lower than is typical for active source short-period deployments. The seismic source throughout the experiment was the *Langseth's* 36-gun array, with a total volume 6600 cu. in. Airgun data were collected along 2500 km of track line an average shot spacing of 144 to 165 m. In addition to the seismic data, swath bathymetry, gravity and magnetics data were collected throughout the region.

The structure of this report is as follows: The sections prior to the appendices briefly summarize the scientific and operational objectives, the events that transpired during the cruise, and the overall quality and characteristics of the seismic data. The remainder of the report contained in the appendices is primarily of a technical nature and useful to someone working with the PROTEUS data.

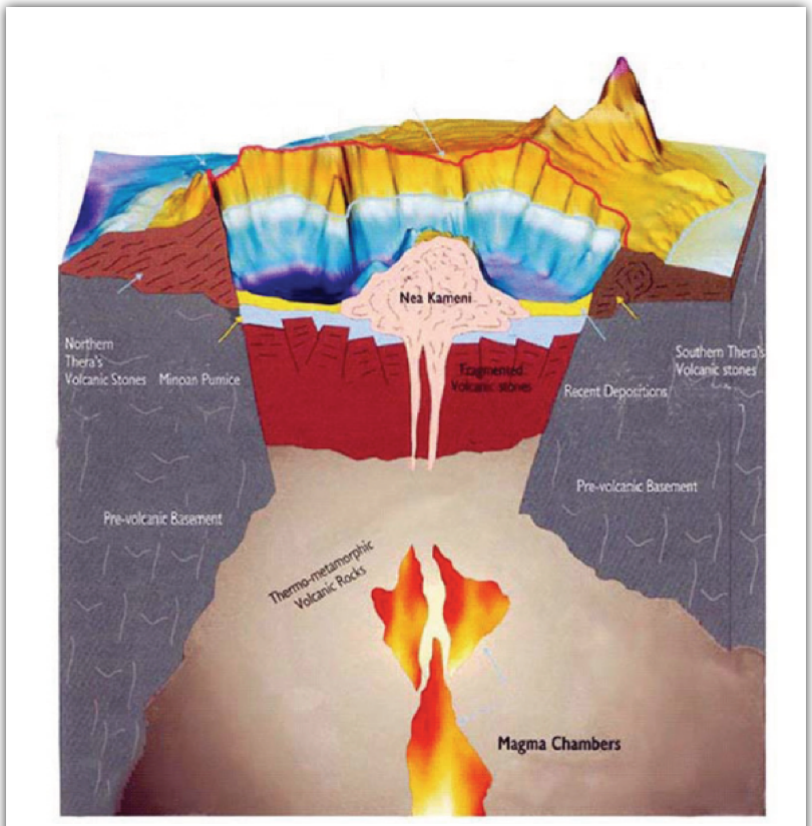
*Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Scientific Objectives

- The goal of the Santorini Active Source Seismic Experiment is to examine the entire crustal magma plumbing system beneath Santorini volcano. Santorini is unique for this study because it recently experienced significant unrest; inflation of the ground and intense earthquake swarms during 2011-2013. It is also geologically well-studied. It is an ideal location because is a semi-submerged volcanic system which makes it possible to collect dense 3D marine-land seismic data. We will record sound sources from the US R/V Langseth on 93 short period ocean bottom seismometers and 26 land seismometers.

  Santorini provides millions of dollars to the Greek economy annually, and any renewed volcanism and/or seismicity would not only impact the communities on Santorini and the neighboring islands but also have a substantial economic impact. This research will inform the Greek public and civil authorities about volcanic, earthquake, and tsunami hazards and would help inform disaster management planning.

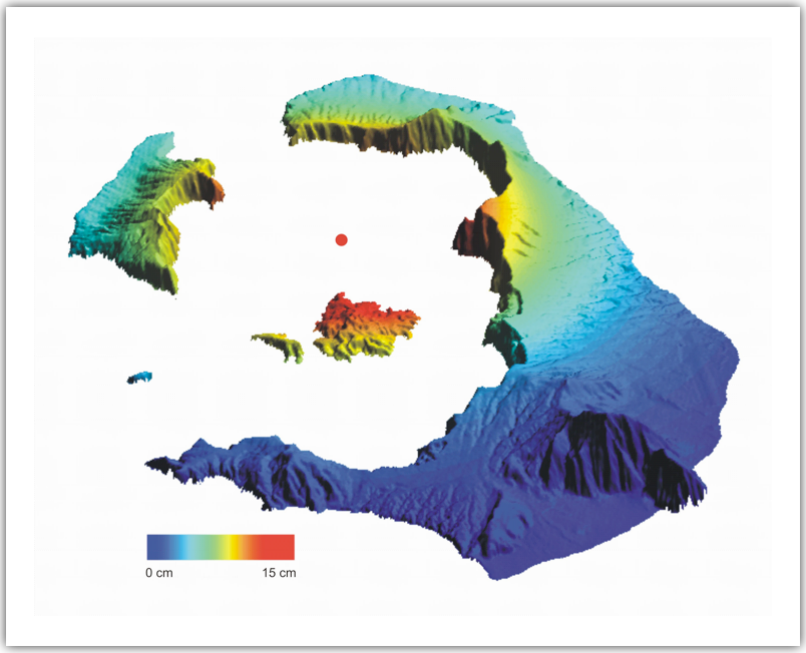
  The proposed high-density spatial sampling of the seismic wavefield and state-of-the-art travel time and waveform inversion methods will provide new insights into the structure of the whole crustal magmatic system and its surroundings. This will allow the scientists to determine the magma geometry and connections throughout the crust – physical parameters that control magma migration, storage, and eruption and are thus important to understand geohazards. More broadly, this study will also help scientists answer questions about how the processing of magma at arc volcanoes forms the rock compositions that dominate the continental crust.



Hypothetical cross section of Santorini magmatic system (Source: VolcanoCafe.wordpress.com).

Vertical deformation of Santorini during the period of unrest in 2011 – 2012, determined by Michelle Parks (University of Oxford) from measurements of the deformation field across the islands. The

deformation is best explained by the intrusion of magma about 4 km below the red dot.



Operational Objectives

Overview

The primary operational objectives of the marine component of the PROTEUS Project were to deploy 91, four-component ocean bottom seismometers (OBSs) in and around Santorini volcano in order to record active source data from the airgun array of the *R/V Marcus Langseth*, which is owned by the *National Science foundation* and operated by the Lamont-Doherty Earth Observatory.

The PROTEUS Project also includes an onshore deployment of over 70, three-component seismometers; these are located on the islands of Thira, Anafi, Anhydros, and Christiana.

Data from the offshore-onshore seismic arrays will be used to image the 3-D seismic structure of the crust and topmost mantle beneath Santorini and nearby volcanic lineaments and tectonic features. The experiment will image the magmatic system throughout the crust as well as the regional tectonic structures.

Summary of Operations

The primary operational goals of the PROTEUS Project were as follows:

a. Deploy 91 ocean bottom seismometers at 91 sites.

b. Record seismic energy from the Langseth's 36-gun, 6600 cu. in. airgun array.

c. Recover 91 ocean bottom seismometers.

d. Produce SEGY files of all OBS data.

e. Complete post-acquisition editing of all Simrad EM122 multibeam data.

f. Collect underway geophysical data, including magnetics and gravity.

g. Archive all cruise-related data and finalize report.

Cruise Narrative

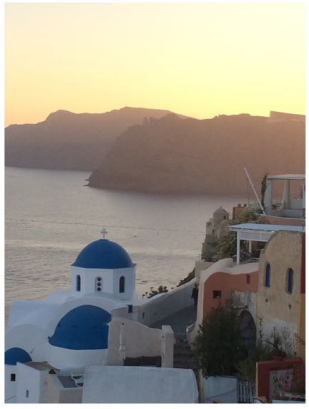
Santorini Island: Nov 3 - Nov 10, 2015

Tuesday Nov 3rd

- Profs. Emilie Hooft and Doug Toomey flew AMS-ATH. Grad student Joe Byrnes was on the same flight having come from Oregon earlier that day. From Athens Emilie & Doug flew on to Santorini and Joe took the Metro to Pireas with the intention of taking a ferry to Santorini on Friday to participate in the land seismometer deployments on Anafi.
- In Santorini Profs. Joanna Morgan and Mike Warner picked Emilie and Doug up in a small jeep. After settling in to the charming family run King Thiras hotel, they went for dinner joined by Prof. Costas Papazachos, Costas XX (of the Tech. Univ Athens who was was doing gravimeter measurements, Kony (Costas P's technician), Evthigia (Costas P's grad student), Danae (Prof Nomikou's grad student). A fun and long dinner in the garden restaurant.
- We also found out that the ferries would be striking the next 3 days and Joe would not be able to get to Anafi with the work team if he waited till the ferry strikes were resolved. Emilie emailed Joe to fly directly to Santorini the following day, which he did.

Wednesday Nov 4th

- Costas was taking the military helicopter to Anhydrous and Christiana this day! Perfect calm clear weather for the trip. In fact on leaving the hotel we could see Anafi and Anhydrous in the distance, but not Amorgos.
- Emilie and Doug take the spare jeep and Tim Druitt's field guide and explore the geologic features of the north part of the island: Imerovigli and Oia and the areas in between. This includes the graben structure and dikes.
- Over a glass of retsina we saw the sun set and the military helicopter circling in the caldera as it returned with Costas et al from Christiana.



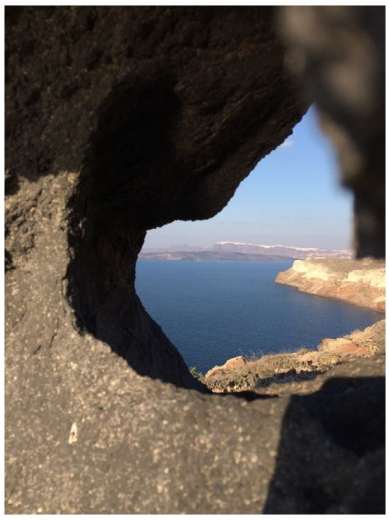
- 3 stations were put on the one part of Anhydros, the remainder of the island being too rough for the helicopter to land and separated from the other part of the island by the scree slope of a fault cutting right through the island. At Christiana two stations were installed, also in the most accessible portion, the remainder being very steep.

Thursday Nov 5th

- Today Doug and Emilie headed off to the south part of the island. Great views of the caldera from the rim - the lighting better when viewing from the south than looking into the sun from the north.

- At the lighthouse at the southern tip of the island there is an amazing variety of rocks in color and tortured formations. These stem from the earliest formation of the island and are important for understanding the evolution of

the edifice.



- We examine the beautifully layered tuffs at the beach at Mesa Pigadia where summer houses are built into the walls of the cliffs.

- *Friday Nov 6th*
  - Joanna and Joe and other students are leaving for Anafi on the ferry very early tomorrow morning.
  - Other students are arriving for the fieldwork in Santorini
  - Doug and Emilie spend time working in the morning and visit the harbor at Ormos Ammoudiou to examine the terrifying sequences of lavas.
  - 

Saturday Nov 7th

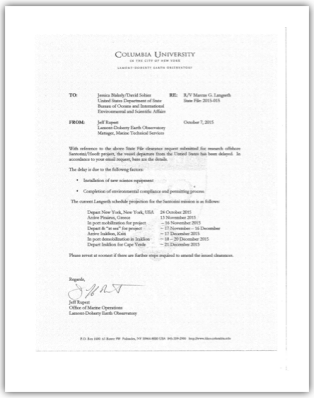
- Doug and Emilie visit the metamorphic core complex during the morning. After picking up intern Amelie van Lynden they complete this tour of the preAlpine basement with a visit to the modern harbor at Athinios. The importance of these rocks to the structure of the island is striking.
- 

Sunday Nov 8th

- Training is led to install the seismometers by Mike Warner
-  
- 

Monday Nov 9th

- Evi lets Emilie know that the Director of the Navy was told that the Greek Ministry of Foreign Affairs is not aware of the 5 week delay for the research program.
  - message:%3C8e0045d9df129f903623f7078901caea.squirrel@webmail01.uoa.gr%3E
  - Skype*: I have informed from Mr Floros that the Greek Ministry of Foreign Affairs didn't know anything about the new schedule of the cruise! So I will send them tomorrow morning by fax an official letter saying that it is the same research programme that had been approved by EXAETH but due to some chronological issues it will be done from 17/11 up to 15/12! We didn't they send an official letter from the American Embassy?*
  - *Ok..because I just received an official email saying that I need to inform the Greek Ministry of Foreign Affairs! I will for sure tomorrow early in the morning..and I will also talk to Mrs Tourantzof the secretary of EXAETH*
  - *[11/9/15, 7:09:22 PM] Paraskevi Nomikou: They need to be informed officially that the cruise regarding the research programme will be occurred at this period of time!!!*
    [11/9/15, 7:10:32 PM] Paraskevi Nomikou: I will prepare the letter in Greek and signed by me! But it will be also good if you also send an email to the American Embassy and be forward to the Greek ministry!
    [11/9/15, 7:11:14 PM] Paraskevi Nomikou: I will be at my home in an hour
    [11/9/15, 7:12:44 PM] Paraskevi Nomikou: They need to be informed for the new ship schedule! That's all!!
- Emilie informs Lamont and Jeff Rupert starts following up on the information that he sent to the State Department on Oct 7th.
- Delay Letter 7 Oct.pdf



COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK
LAMONT-DOHERTY EARTH OBSERVATORY

TO: Jessica Blakely/David Sobon
United States Department of State
Office of Marine Conservation
Environmental and Scientific Affairs

RE: R/V Marcus G. Langseth
State File: 2015-005

FROM: Jeff Rupert
Lamont-Doherty Earth Observatory
Manager, Marine Technical Services

October 7, 2015

With reference to the above State File clearance request submitted for research offshore Santorini/Nisyrh project, the vessel departure from the United States has been delayed. In accordance to your email request, here are the details.

The delay is due to the following factors:

- Installation of new science equipment
- Completion of environmental compliance and permitting process

The current Langseth schedule projection for the Santorini mission is as follows:

Depart New York, New York, USA	26 October 2015
Depart Piraeus, Greece	13 November 2015
In port mobilization for project	~ 14 November 2015
Depart & "at sea" for project	~ 17 November – 16 December
In port for project	~ 16 – 18 December 2015
In port demobilization in Heraklion	~ 18 – 20 December 2015
Depart Heraklion for Cape Verde	~ 21 December 2015

Please revert at soonest if there are further steps required to amend the noted clearances.

Regards,

Jeff Rupert
Office of Marine Operations
Lamont-Doherty Earth Observatory

P.O. Box 1000, 61 Route 9W · Palisades, NY 10964-8000 USA · 845-359-2900 · http://www.ldeo.columbia.edu

- Doug and Emilie walk the caldera rim trail from Thira to Oia. This allows a good view of the Skaros lavas and the cinder cones that formed on the northern part of the island.
- 

Tuesday Nov 10th

- Sean Higgins prepares a letter for the Greek Ministry of Foreign Affairs and has trouble sending it by fax. Eventually he emails it to Evi who sends it via Mr Flores, Director of the Navy.
- Doug and Emilie visit the Kameni islands - the newest source of volcanism; while the students install a seismometer on Palea Kameni
- 
- 
-

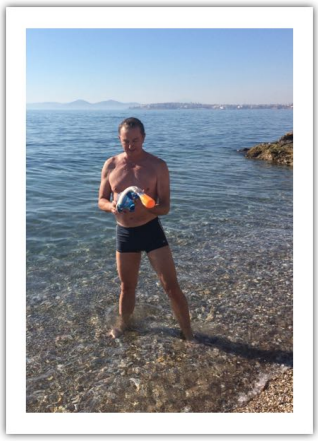
Athens-Pireas: Nov 11 - Nov 18, 2015

Wednesday Nov 11th

- Evi and the US Embassy staff both receive abrupt phone calls from the Greek Ministry of Foreign Affairs
- It becomes clear that a letter is needed from the US Embassy regarding the new dates of the research cruise.
- Doug and Emilie fly from Santorini to Athens.
- Call with Jeff Rupert while in the taxi from the airport. He has had trouble getting action on the US side because today is Veteran's day and the US Government and all embassies are closed. He emails the name of the person at the US Embassy who has been dealing with the paperwork for the cruise: Mrs Lamnatou. This proves very valuable.
  - message:%3C2EC927F4-6422-4A2B-A56A-DBBF193E0910@ldeo.columbia.edu%3E

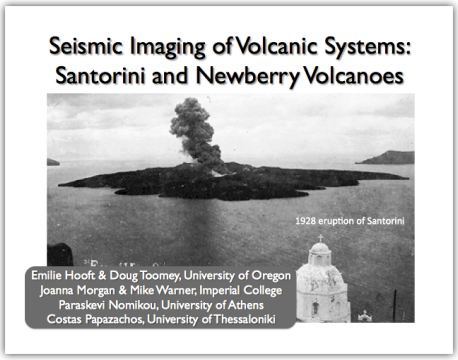
Thursday Nov 12th

- Emilie prepares for talk at Univ. of Athens, while Doug buys provisions. Nice lunch on the terrace with Pantelis.
- The R/V Marcus Langseth arrives in the afternoon but cannot dock in Pireas because of a dock workers strike. It can be seen lying at anchor off of Salamis from Pantelis' apartment.
- Emilie calls with Mrs Touratzof at the Greek Foreign Ministry. This lady explains that they received a new Note from the US Embassy but are not satisfied with the wording.
- Emilie calls Mrs Lamnatou at the US Embassy in Athens, who personally contacts Mrs Touratzof to understand what wording they require.
- The US Economic Section staff are invited to tour the ship. The US ambassador was sent an invitation for the talk and a ship tour earlier (Nov 9th).
- message:%3CDB940751-9EED-4B78-9A88-668423E5B3F9@uoregon.edu%3E
- message:%3CD8E24F79-B464-4438-9EED-BD85439775A8@uoregon.edu%3E
- Swimming on the beach in front of Pantelis' apartment with Pantelis, who demonstrates how to catch and eat sea urchins.
  - thumb_IMG_5777_1024.jpg



- thumb_IMG_5780_1024.jpg

- *Friday Nov 13th*
  - Early in the morning the R/V Langseth docks in Pireas, terminal E11.
  - The 5 grad students flying in from Oregon have their flights rescheduled because of strikes with Lufthansa and they were all flying together through Paris. They are now arriving at 3 separate times; two today and one tomorrow. Taxi rides to the AirBnB are rearranged by Doug.
  - 9 am Prof. Paraskevi Nomikou (Evi) picks up Doug and Emilie to go to the University. Doug talks to Prof. Papanikolaou while Emilie calls Mrs Touratzof at the Greek Foreign Ministry. She confirms that the desired Note has now been received. She also informs Emilie and Evi that now the EXATH science committee will reconsider the matter on Monday morning!
    - message:%3C3C38BEA1-8B69-4CBE-9D8B-00C0E714EFB0@uoregon.edu%3E
  - Doug has a lengthy discussion with Prof. Papanikolaos
  - 11 am Emilie's talk is well attended and well received. Many questions afterwards that are followed by individual discussions and emails.
    - Santorini_UnivAthens2015_Talk_reduced.pdf



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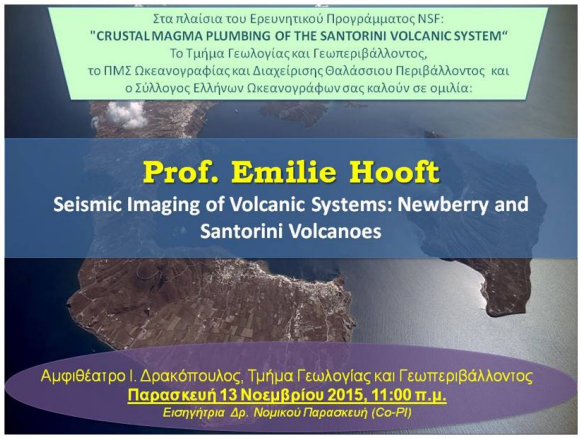

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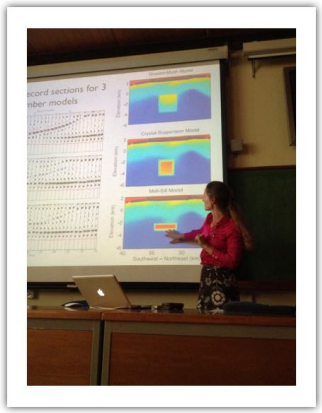

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- 1 pm Emilie is called by Paul Narain, Deputy Economic Consul, who explains that the information from the State department never reached the US Embassy. He also says that his department and he himself are doing their best for us.
  - message:%3C60BA3830-EBB4-4F92-A13A-A5B2C03F13E2@uoregon.edu%3E
- 2:30 - 5:30 pm Fun “lunch” with the Columbo scientists group at a wonderful restaurant in the part of Athens where all the people from Asia Minor were settled in 1922.
- quiet evening at the apartment

Saturday Nov 14th

- Emilie and Doug are tired today
- Morning walk through the neighborhood to buy some good and find a haircut for Doug in the late morning.
- Attempts to call Pantelis from 11 am onwards fail.
- Early lunch and taxi to the ship to check in. All is very quiet Doug and Emilie only see the OBS crews on board. They leave belongings in their cabin.
- thumb_IMG_5800_1024.jpg

- Afternoon, Emilie & Doug buy some needed items for use on the ship.

Sunday Nov 15th

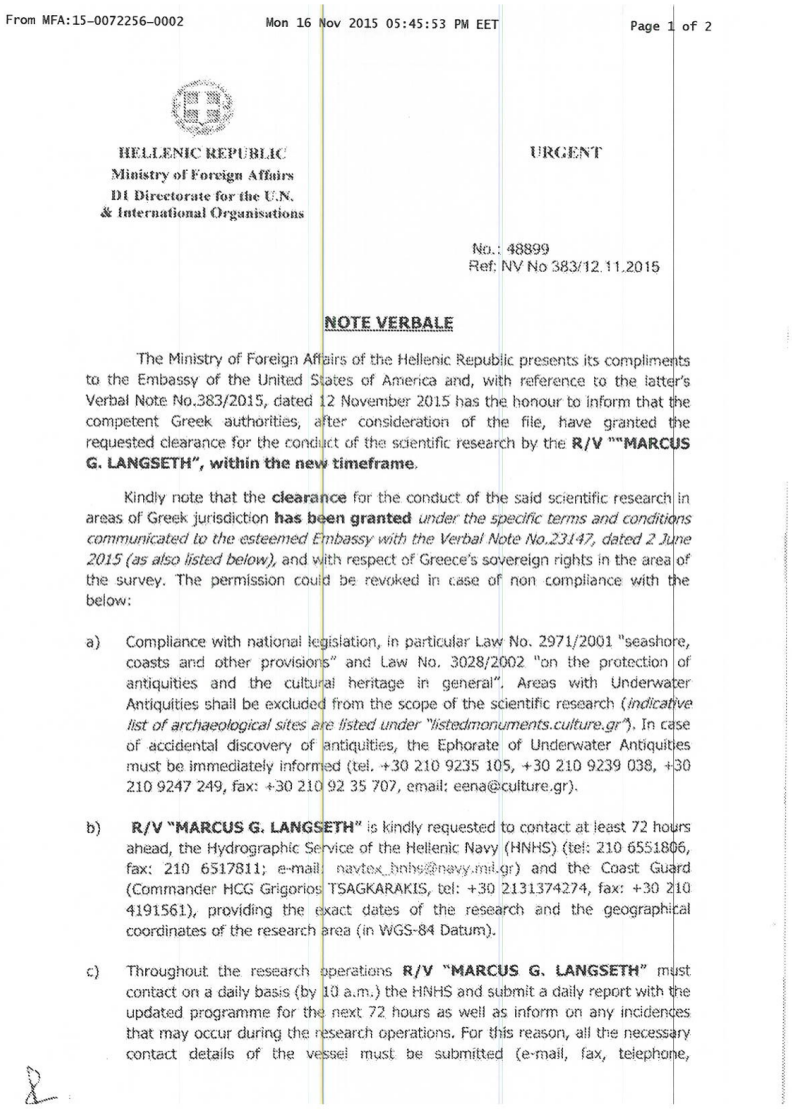
- 9 am Emilie and Doug go to the vessel by taxi. Meet with Chief Science Officer Robert Steinhaus and others.
- 11 am Ship tours: Evi arrives with 36 students from the Univ, Athens Masters in Oceanography AND several staff members with their children and spouses come. They are all delighted and the Embassy staff stays a long time. The children receive large bowls of ice-cream with chocolate sauce in the galley from Doug!
- Embassy posted the visit on their Facebook page using text Emilie sent: https://www.facebook.com/USEmbassyAthens/posts/10153438145594064
- Emilie moves the SIO rosette test to near OBS 20.

Monday Nov 16th

- Doug and Emilie arrive with luggage at the ship.
- The captain and chief science office inform that without the new Foreign Clearance Letter the ship cannot order, load, or take on fuel. This process will take 12 hrs.
- 1 pm science meeting with students to plan tasks.

Doug and Emilie inspect detailed OBS plots for bathymetry.
- Brandon and Gillean work on OBS refinement.
- Evi sends ferry schedule to Captain
- Danai inspects bathymetry for shoals.

- The EXATH science committee approves the rescheduled research - now the letter is needed! The US Embassy continues to press the Greek Foreign Ministry to sign the letter.
- We receive the Foreign Clearance letter from the US Embassy at 6 pm!
  - message:%3C45DA64C0943F48429261C73C71B354C5760622DB@athensex01.eur.state.sbu%3E
  -



From MFA:15-0072256-0002 Mon 16 Nov 2015 05:45:53 PM EET Page 1 of 2

HELLENIC REPUBLIC
Ministry of Foreign Affairs
D1 Directorate for the U.N.
& International Organisations

URGENT

No.: 48899
Ref: NV No 383/12.11.2015

NOTE VERBALE

The Ministry of Foreign Affairs of the Hellenic Republic presents its compliments to the Embassy of the United States of America and, with reference to the latter's Verbal Note No.383/2015, dated 12 November 2015 has the honour to inform that the competent Greek authorities, after consideration of the file, have granted the requested clearance for the conduct of the scientific research by the **R/V ""MARCUS G. LANGSETH", within the new timeframe**.

Kindly note that the **clearance** for the conduct of the said scientific research in areas of Greek jurisdiction **has been granted** *under the specific terms and conditions communicated to the esteemed Embassy with the Verbal Note No.23147, dated 2 June 2015 (as also listed below)*, and with respect of Greece's sovereign rights in the area of the survey. The permission could be revoked in case of non compliance with the below:

a) Compliance with national legislation, in particular Law No. 2971/2001 "seashore, coasts and other provisions" and Law No. 3028/2002 "on the protection of antiquities and the cultural heritage in general". Areas with Underwater Antiquities shall be excluded from the scope of the scientific research (*indicative list of archaeological sites are listed under "listedmonuments.culture.gr"*). In case of accidental discovery of antiquities, the Ephorate of Underwater Antiquities must be immediately informed (tel. +30 210 9235 105, +30 210 9239 038, +30 210 9247 249, fax: +30 210 92 35 707, email: eena@culture.gr).

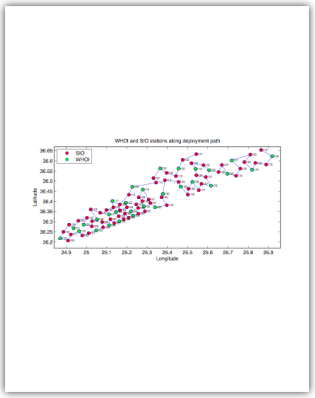
b) **R/V "MARCUS G. LANGSETH"** is kindly requested to contact at least 72 hours ahead, the Hydrographic Service of the Hellenic Navy (HNHS) (tel: 210 6551806, fax: 210 6517811; e-mail: navtex_hnhs@navy.mil.gr) and the Coast Guard (Commander HCG Grigorios TSAGKARAKIS, tel: +30 2131374274, fax: +30 210 4191561), providing the exact dates of the research and the geographical coordinates of the research area (in WGS-84 Datum).

c) Throughout the research operations **R/V "MARCUS G. LANGSETH"** must contact on a daily basis (by 10 a.m.) the HNHS and submit a daily report with the updated programme for the next 72 hours as well as inform on any incidences that may occur during the research operations. For this reason, all the necessary contact details of the vessel must be submitted (e-mail, fax, telephone,

- 4 pm IHA meeting with LDEO rescheduled to 5 pm due to A.M. traffic jams in NY
  - Responses to specific questions are:
    - message:%3CEB2E8003-0769-4676-BB58-12F7F4944358@ldeo.columbia.edu%3E
  - Monitoring of two types of birds also required:
    - message:%3C94B59F46-B71F-4EE7-9856-95E24684BD87@ldeo.columbia.edu%3E

- *Tuesday Nov 17th*
  - Chief scientist is informed by the Captain that there is a small hole in the hull that must be reparied/inspected. This causes further delays and complications.
  - message:%3C7070FF6D-9F3D-46F0-BADC-9C65778B2929@uoregon.edu%3E
  - message:%3C564B3E17.6090909@ldeo.columbia.edu%3E
  - message:%3C8BBFD29E-44C3-48EC-8C48-5CB41ED9CD6F@uoregon.edu%3E
  - 1 pm science meeting with OBS technicians, science officers and captain.
  - PM OBS location refinement is completed and checked.
- *Wednesday Nov 18th*
  - OBS locations provided to chief science officer and OBS technicians.
  -

OBSDeploymentPath_v6.pdf



- Santorini_ShotLines_v6-Modified_RJS.xls

- Shot lines refined and provided to chief science officer, who provides chief scientist with timelines for various speeds.
  - Santorini_ShotLines_v6

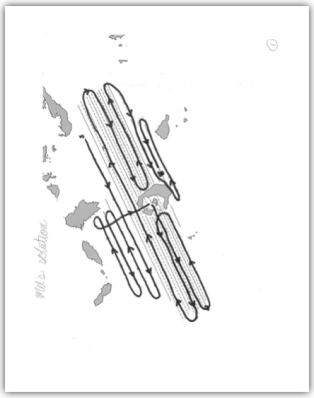
- Chief scientist submits request to LDEO re cruise schedule and impact from delays.
  - message:%3C0BB5994B-38E2-4935-8ADA-555A51190526@uoregon.edu%3E
- Science party goes into Athens for sightseeing and a group photo is made.
- Requirement to be on board so that the ship can move to anchorage for the repair work to happen is delayed till the following morning.
- Emilie has been emailing with the land team (Joanna Morgan & Mike Warner) about the impacts of the delays on the start and end date of shots and land station battery life. Conclusion is that we should be OK unless delayed till next week. Various potential solutions for that scenario are discussed.
  - message:%3CCB143C46768AE346BF05AD05AA2E7E444F869D65@icexch-m5.ic.ac.uk%3E
- Doug and Emilie buy a goPro at Media Mart to document the research work.
- Chief scientist receives more unfortunate news from the captain upon returning to the vessel:
  - 1. the 2nd person in the engineering department got sick and was taken to the hospital.
  - 2. the Greek authorities want to come on board in the morning to check the passports of all the scientists, so this will make things go slower in the morning.
- Emilie discusses requirements of Greek foreign clearance letter with the captain.

Cruise Week 1: Nov 19 - Nov 26, 2015

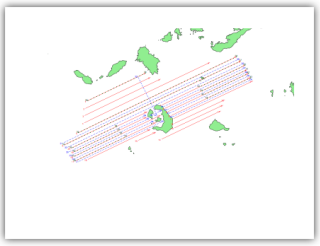
- *Thursday Nov 19th*
  - 8:30 We all muster in the science lab - eventually no passport check was done.
  - 10:30 The R/V Marcus Langseth casts off from the dock and moves to anchorage off the island of Salamis
  - Evi contacts the Hellenic Navy Hydrographic Service and receives clarification of the reporting requirements.
    - message:%3C03F6FB4A-9C2F-48DF-ADDF-1FDAF6546BF4@uoregon.edu%3E
  - The divers in a tug boat are alongside during the afternoon and make the necessary repairs to the hull. This is done in wet suits with oxygen from hoses and other tools on hoses for the underwater welding. They also have an underwater camera to document the work.
  - 13:00 Fire and Boat drill is completed.
  - The 1st engineer returns on board.
  - Evi finally reaches the Commander of the Greek Coast Guard and informs him of our imminent departure. No further reporting to them is needed.
    - message:%3C1EE9C064-6688-49D4-A310-9873CE055AC9@uoregon.edu%3E
  - The ABS inspector approves the divers' repairs and we are clear to leave.
  - 19:30 after some difficulty loosening the anchor we are off!
  - We prepare the OBS deployment sheets.
    - OS_DeploymentSheet.xlsx

  - Optimize the shooting order for the shotlines
    - ShotLineOrder

    - ShotlinePath.pdf



- ShotLinesNumbered

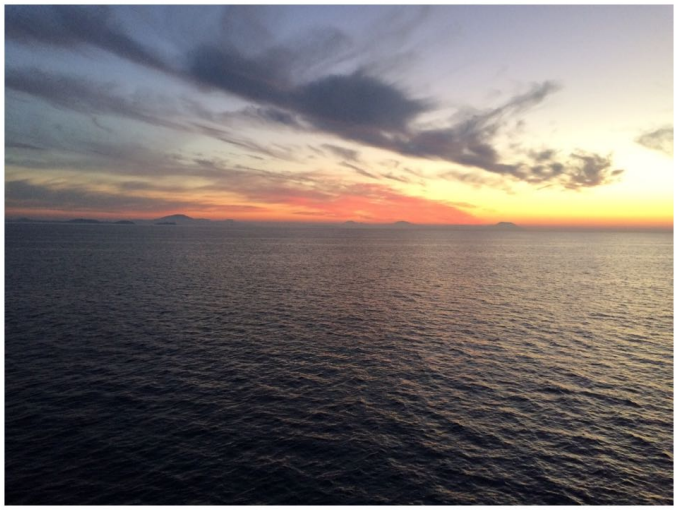


- Estimate ETA for tomorrow's work.
  - OBSDeployment_v6Timeline.xls

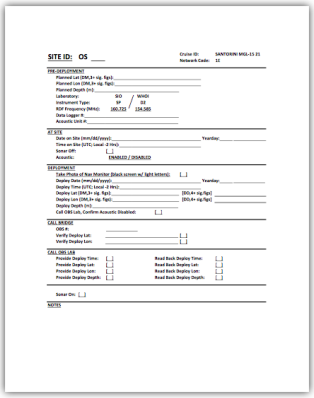
- ETA to study area is 07:00 tomorrow. ETA to SIO rosette site is 08:30; to be done in 600-700 m water depth.
- We anticipate deploying OBS at a rate of one per hour so the next 72 hours are going to be busy.
- Emilie reports to Sean Higgins and Jeff Rupert re the ongoing lack (almost) of internet on the Langseth.
  - message:%3C84BAD981-374D-4624-975B-3D6179FC1147@uoregon.edu%3E
- Joanna Morgan reports that Anafi is all switched on.

Friday Nov 20th

- 06:34 LT arrive in the study area and enable multi beam and Knudsen
- A beautiful very calm day with a delightful sunrise viewing the three mountains on Amorgos.



- 07:00 XBT done in 276m water depth
- 08:34 LT SIO rosette test site - issues with ship's transducers.
  - Arrive and deploy 1st rosette test. There are issues with the ship's transducers. WHOI puts a new connector on the ship's transducer cable, while SIO uses the over-the-side transducer to communicate with the acoustic releases. However it is not possible to get an outgoing signal from the ship's transducers. 1st and 2nd rosette test completed. Robert informs that this transducer was likely shorted and burned out on the previous cruise.
- 12:00 LT starting OBS deployments: Deployed 19 OBS today!:
  - OS119, OS153, OS173, OS154, OS174, OS 135, OS 120, OS121, OS155, OS175, OS156, OS122, OS136, OS123, OS109, OS104, OS110, OS124, OS137
- Deployment procedure, record keeping sheets, and OBS table are refined.
  - OS_worksheet.pdf



SITE ID: OS ____ Cruise ID: SANTORINI MSG-15 21
Network Code: 1E

PRE-DEPLOYMENT
Planned Lat (DMLH- sig. figs): _____
Planned Lon (DMLH- sig. figs): _____
Planned Depth (m): _____
Lakemistry: SIO / WHOI
Instrument Type: SP / EE
ROF Frequency (MHz): 160.715 / 154.565
Data Logger #: _____
Acoustic Unit #: _____

AT SITE
Date on Site (mm/dd/yyyy): _____ Yearday: _____
Time on Site (UTC; Local -2 Hrs): _____
Sonar Off: [_]
Acoustic: ENABLED / DISABLED

DEPLOYMENT
Take Photo of Rov Marker (black screen w/ light letters): [_]
Deploy Date (mm/dd/yyyy): _____ Yearday: _____
Deploy Time (UTC; Local -2 Hrs): _____
Deploy Lat (DMLH- sig. figs): _____ (DDLH- sig figs) _____
Deploy Lon (DMLH- sig. figs): _____ (DDLH- sig figs) _____
Deploy Depth (m): _____
Call OBS Lab, Confirm Acoustic Disabled: [_]

CALL WHOI#
OBS #: _____
Verify Deploy Lat: _____ [_]
Verify Deploy Lon: _____ [_]

CALL OBS LAB
Provide Deploy Time: [_] Read Back Deploy Time: [_]
Provide Deploy Lat: [_] Read Back Deploy Lat: [_]
Provide Deploy Lon: [_] Read Back Deploy Lon: [_]
Provide Deploy Depth: [_] Read Back Deploy Depth: [_]

Sonar On: [_]

NOTES

- New shotline order provided to Robert, longer line changes will be transits. We will run in to all the lines on line. Increment shot # by 500 for a new line and for the reshoots increment by 1000.
- Doug and various students have been recording deployments (and the sunrise) with the GoPro. A great set of movies already.
- We will do the caldera deployments tomorrow morning. We will wait outside the caldera until light to be able to see the surroundings on entering to work there.

Saturday Nov 21st

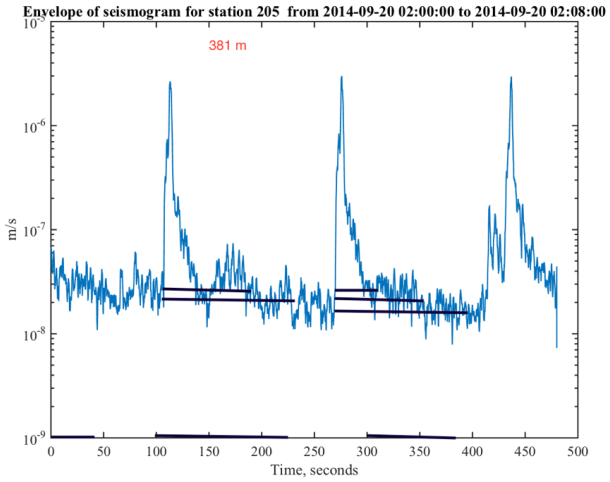
- Change deployment sequence in the early morning to add OS103 into the sequence: 1. To allow the ship to offload sewage beyond the 3 mi limit and 2. to allow the SIO group a needed break.
- Caldera work:
  - 8 am wait to enter the caldera until a large white cruise ship with glass balconies in front of each cabin to come in.
  - Spent the morning deploying OBS within the caldera and verifying the water depths on the eastern underwater caldera rim. Shallows at the southernmost point will require deviating off the southernmost line 800m to the north and south of the line north of that one by ~400 m.
- Hull transducer issues fixed:
  - 13:10 pm The OBS groups have wired the second hull transducer and successfully test it during the deployment of OS126. Now the over-the-side transducer will not be needed and this will speed up WHOI deployments as well as the entire OBS recovery procedure.
- Deployed **24** OBS today:
  - Deployed OS140, 160 and 179 in the caldera and 180, 161, and 141 on the eastern underwater caldera rim. Then to the west of Santorini OS 115, 126, 142, 162, 181, 182, 183, 184, 165, 164, 163, 143, 127, 144, 145, 146, 166, 185,
- Adding the OBS, waiting for the cruise ship and exploring the caldera rim has us about 3 hrs behind our projected schedule. Anticipated end of OBS deployments is Sunday 22:00 pm LT. We will need to wait till Monday morning to start up the airguns and will do some bathymetry surveying during that night.
- SIO OBS may not all be deployable:
  - 7:30 pm LT Ernie Aaron tells Chief scientists that two SIO OBS may not be deployable due to issues with the new data logger boards. 9:20 pm LT Sean McPeak has solved the problem with one of the instruments without having to use parts from the other one. 10:00 pm Sean McPeak soldering a broken wire. 11:15 pm the second SIO datalogger is also now functioning and about to be deployed at OS185.
- OBS contingency plans.
  - Emilie, Doug, Ben and Brandon discuss the pros and cons and logistics of dropping certain stations. Thought is to drop 185 and 172 (switching 193 from an SIO to a WHOI station). However, we decide to only drop 172 (switching 193 from an SIO to a WHOI station), when dropping a station immediately is not required. Stations 102 and 101 were also under discussion and can be dropped later if further problems arise.
- Emilie writes email to Sean and Jeff requesting an extension to the cruise schedule since time spent in port repairing the ship is not contingency for at-sea operations.

Sunday Nov 22nd

- Took an XBT on the edge of the Cretan sea in the early am
- Shot interval and spacing and vessel speed: Decide that 90 seconds and 3.5 knots with 165 m shot spacing is preferable.
  -

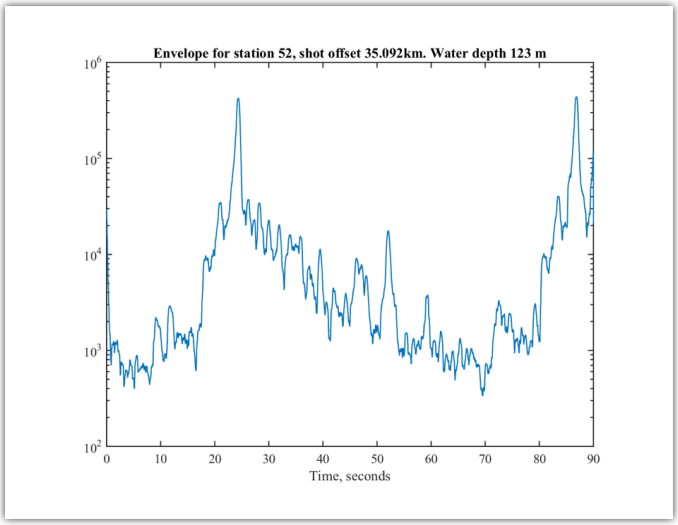
Shot spacing (m)		Shot interval (sec)			
Ship speed(knts)	60	70	80	90	100
3	93	105	120	135	154
3.5	108	123	144	162	180
4.0	123	144	165	185	206
4.5	139	162	185	208	232
5.0	154	180	206	232	257

- Envelopes from previous experiments
  -

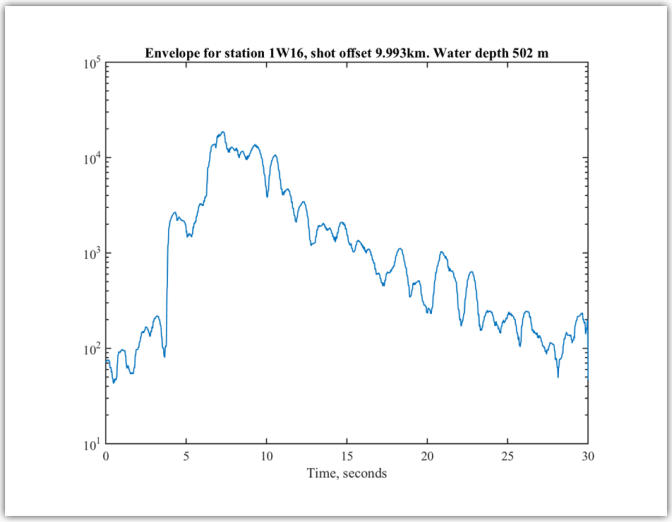


One ENAm station is between 100-600 m water depth:

- Oregon coast from Anne Trehu

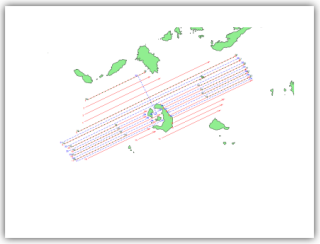


- Costa Rica - at 502 m

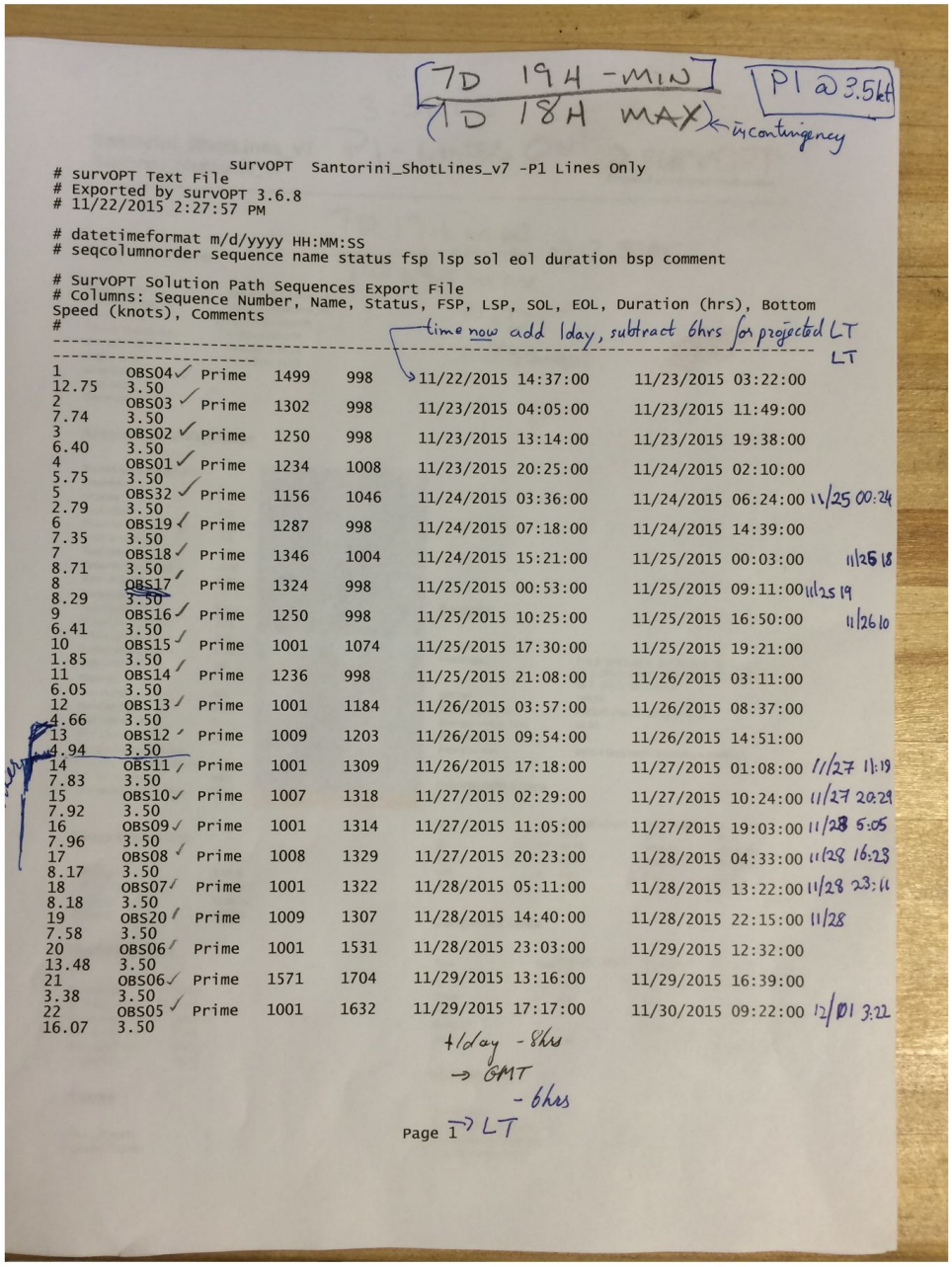


- Pattern of shooting using students design

- ShotLinesNumbered



- Current Plan using students design
  - Do Pattern 1 at 3.5 knots = 8.3 days. Use ~90 sec rep. rate. Shot interval = 162 m shot spacing. Use 165 m spacing?
  - Do Pattern 2 and 3 at at 4 knots = 4.2 and 3.4 days. Keep 90 sec rep rate and increase shot spacing to 185 m.
  - Using the students' shooting pattern this gives a total length of 15.9 days - no contingency. If things do not go well we can drop 1-2 days from the reshoot.
- Science meeting:
  - Plan for ending deployments and starting shooting.
    Go over rep rate; shot spacing; shooting speed
    Length of shooting the survey; and pattern of shooting.
    Ben to make sheet of anticipated timing for each line
    Claire make maps of the deployed locations and deployment path, with colors for SIO and WHOI
    Multibeam surveying during the night - make a plan for this. Speed is 10 knots? If we have 3-4 hrs; then 4 hrs of gun deployment and marine mammal observing
    Giles to instruct on MBsystem data editing.
    Photo request from OBSIP: A folder in Public/Photos/Photos4OBSIP
    Photos on public folder & GoPro directory - start editing
    UO blog: *Miles* to request access for everyone in the science party. *Ben* to make individual entires be individual Web pages.
    GoPro-ing of the airgun deployment - starting at 3 am. Make plans and talk to Tom Spotto to execute. *Miles & Doug*
    Weather - storm from W anticipated on Thurs to Sat.
- Robert Steinhaus uses SurvOpt to calculate an alternative pattern for the Shot Lines
  - Pattern 1 line at 3.5 knots takes 7d 19h (9d 18h w contingency). And puts us to the east of Santorini for the anticipated days of bad weather. The 1st shooting through the caldera should take place in great weather and during the middle of the night. The second shooting also in good weather and at ~6 pm.
  - Pattern 2 & 3 at 4 knots takes 6d 12 h (8d 15 h w contingency). Patterns 2 & 3 are currently intermingled. Pattern 3 Reshooting is on position and so if at 4 knots will need to reduce rep rate to ~80 sec.
  - **Get estimates for Pattern 2 and Pattern 3 sequentially.**
  - *Total time estimate is 14d 7h* (1d 15h less than with the students' plan). With contingency it is 18d 9h.
- Decide on shooting plan for Pattern 1 from SurvOpt output.
  - IMG_6064.jpeg



7D 19H -MIN
(7D 18H MAX) ← in contingency
P1 @ 3.5kt

survOPT Santorini_ShotLines_v7 -P1 Lines Only

survOPT Text File
Exported by survOPT 3.6.8
11/22/2015 2:27:57 PM

datetimeformat m/d/yyyy HH:MM:SS
seqcolumnorder sequence name status fsp lsp sol eol duration bsp comment

SurvOPT Solution Path Sequences Export File
Columns: Sequence Number, Name, Status, FSP, LSP, SOL, EOL, Duration (hrs), Bottom Speed (knots), Comments
#

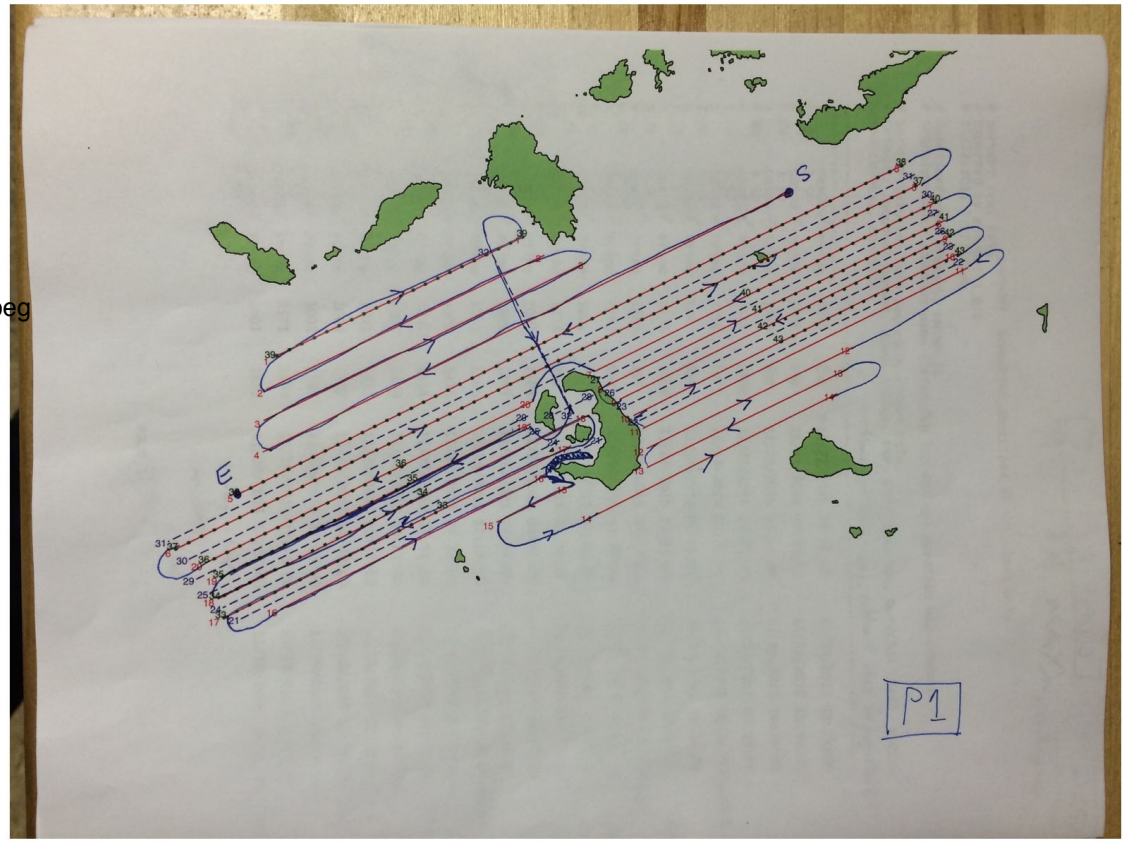
time now add 1day, subtract 6hrs for projected LT

1	OBS04	Prime	1499	998	11/22/2015 14:37:00	11/23/2015 03:22:00	12.75	3.50
2	OBS03	Prime	1302	998	11/23/2015 04:05:00	11/23/2015 11:49:00	7.74	3.50
3	OBS02	Prime	1250	998	11/23/2015 13:14:00	11/23/2015 19:38:00	6.40	3.50
4	OBS01	Prime	1234	1008	11/23/2015 20:25:00	11/24/2015 02:10:00	5.75	3.50
5	OBS32	Prime	1156	1046	11/24/2015 03:36:00	11/24/2015 06:24:00	2.79	3.50
6	OBS19	Prime	1287	998	11/24/2015 07:18:00	11/24/2015 14:39:00	7.35	3.50
7	OBS18	Prime	1346	1004	11/24/2015 15:21:00	11/25/2015 00:03:00	8.71	3.50
8	OBS17	Prime	1324	998	11/25/2015 00:53:00	11/25/2015 09:11:00	8.29	3.50
9	OBS16	Prime	1250	998	11/25/2015 10:25:00	11/25/2015 16:50:00	6.41	3.50
10	OBS15	Prime	1001	1074	11/25/2015 17:30:00	11/25/2015 19:21:00	1.85	3.50
11	OBS14	Prime	1236	998	11/25/2015 21:08:00	11/26/2015 03:11:00	6.05	3.50
12	OBS13	Prime	1001	1184	11/26/2015 03:57:00	11/26/2015 08:37:00	4.66	3.50
13	OBS12	Prime	1009	1203	11/26/2015 09:54:00	11/26/2015 14:51:00	4.94	3.50
14	OBS11	Prime	1001	1309	11/26/2015 17:18:00	11/27/2015 01:08:00	7.83	3.50
15	OBS10	Prime	1007	1318	11/27/2015 02:29:00	11/27/2015 10:24:00	7.92	3.50
16	OBS09	Prime	1001	1314	11/27/2015 11:05:00	11/27/2015 19:03:00	7.96	3.50
17	OBS08	Prime	1008	1329	11/27/2015 20:23:00	11/28/2015 04:33:00	8.17	3.50
18	OBS07	Prime	1001	1322	11/28/2015 05:11:00	11/28/2015 13:22:00	8.18	3.50
19	OBS20	Prime	1009	1307	11/28/2015 14:40:00	11/28/2015 22:15:00	7.58	3.50
20	OBS06	Prime	1001	1531	11/28/2015 23:03:00	11/29/2015 12:32:00	13.48	3.50
21	OBS06	Prime	1571	1704	11/29/2015 13:16:00	11/29/2015 16:39:00	3.38	3.50
22	OBS05	Prime	1001	1632	11/29/2015 17:17:00	11/30/2015 09:22:00	16.07	3.50

+1day -8hrs
→ GMT
-6hrs
→ LT

11/25 00:24
11/25 18
11/25 19
11/26 10
11/27 11:19
11/27 20:29
11/28 5:05
11/28 16:23
11/28 23:11
11/28
12/01 3:22

IMG_6063.jpeg



SurvOPT Text File — SurvOPT Santorini_ShotLines_v7 -P1 Lines Only
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SurvOPT Solution Path Sequences Export File
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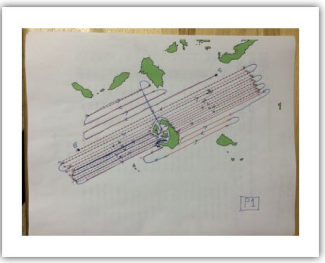
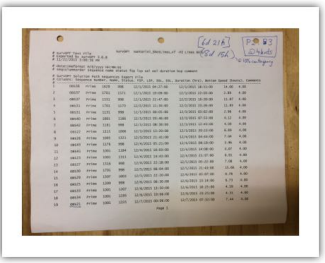
3	244-OBS02	Prime	1250	998	11/23/2015 13:14:00	11/23/2015 19:38:00	6.40	3.50	
4	64-OBS01	Prime	1234	1008	11/23/2015 20:25:00	11/24/2015 02:10:00	5.75	3.50	
5	154-OBS32	Prime	1156	1046	11/24/2015 03:36:00	11/24/2015 06:24:00	2.79	3.50	
6	244-OBS19	Prime	1287	998	11/24/2015 07:18:00	11/24/2015 14:39:00	7.35	3.50	
7	64 OBS18	Prime	1346	1004	11/24/2015 15:21:00	11/25/2015 00:03:00	8.71	3.50	
8	244 OBS17	Prime	1324	998	11/25/2015 00:53:00	11/25/2015 09:11:00	8.29	3.50	~320M SOUTH OF LINE
9	64 OBS16	Prime	1250	998	11/25/2015 10:25:00	11/25/2015 16:50:00	6.41	3.50	
10	244 OBS15	Prime	1001	1074	11/25/2015 17:30:00	11/25/2015 19:21:00	1.85	3.50	
11	64 OBS14	Prime	1236	998	11/25/2015 21:08:00	11/26/2015 03:11:00	6.05	3.50	
12	244 OBS13	Prime	1001	1184	11/26/2015 03:57:00	11/26/2015 08:37:00	4.66	3.50	
13	64 OBS12	Prime	1009	1203	11/26/2015 09:54:00	11/26/2015 14:51:00	4.94	3.50	
14	244OBS11	Prime	1001	1309	11/26/2015 17:18:00	11/27/2015 01:08:00	7.83	3.50	
15	64 OBS10	Prime	1007	1318	11/27/2015 02:29:00	11/27/2015 10:24:00	7.92	3.50	
16	244OBS09	Prime	1001	1314	11/27/2015 11:05:00	11/27/2015 19:03:00	7.96	3.50	
17	64OBS08	Prime	1008	1329	11/27/2015 20:23:00	11/28/2015 04:33:00	8.17	3.50	
18	244OBS07	Prime	1001	1322	11/28/2015 05:11:00	11/28/2015 13:22:00	8.18	3.50	
19	244 OBS20	Prime	1009	1307	11/28/2015 14:40:00	11/28/2015 22:15:00	7.58	3.50	
20	64 OBS06	Prime	1001	1531	11/28/2015 23:03:00	11/29/2015 12:32:00	13.48	3.50	
21	64 OBS06	Prime	1571	1704	11/29/2015 13:16:00	11/29/2015 16:39:00	3.38	3.50	
22	244OBS05	Prime	1001	1632	11/29/2015 17:17:00	11/30/2015 09:22:00	16.07	3.50	

IMG_6062.jpeg

- Pattern 2 & 3 shooting plan at 4 knts
  - IMG_6063.jpeg



  - IMG_6171.jpeg



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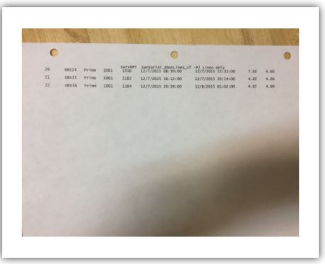
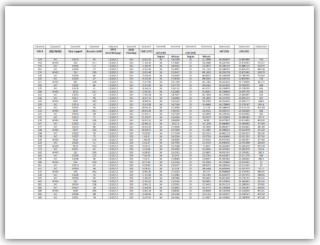
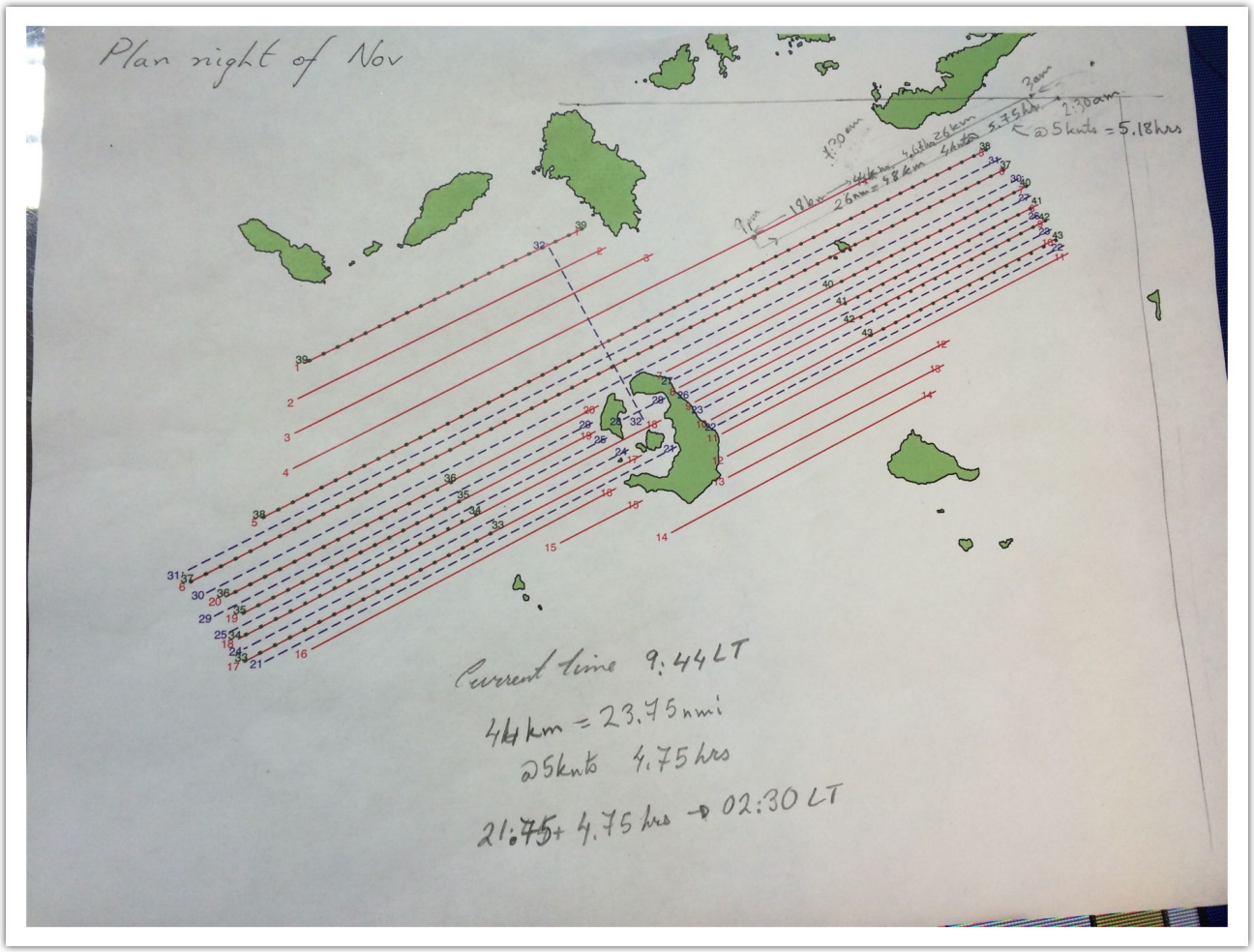


- At 21:09 the last OBS is deployed!
- OBSDeploymentTable_V5.xlsx

- OBSDeploymentTable_V5.pdf



- Multibeam survey during the night in the Amorgos basin.
  - Execution different than pla



- from OS101 to the east between shot lines 4 and 5 at 5 knots. Will turn at ~02:30 am and be ready to deploy the guns at 03:00am. Will be inline with shotline 4 and going at 3 knots for the airgun deployment. PSOs say they will start observing at 6:30 am and could give all clear at 7 am. Can then build gun volume (1/2 hr) until 7:30 am and have it laid out to be at the start of the line at this time. If delayed can make a rectangle around the line start.

- Cruise end date:
  - Emilie receives emails from Joanna with concerns that the 2.5 days of delay will not be made up.
    - message:%3CE1a0awi-0008BJ-53@smtp1.cc.ic.ac.uk%3E
    - message:%3C44FC5715-A8A2-444D-BDDA-CF1CDD534508@uoregon.edu%3E
  - Emilie emails Joanna and co-PIs and Sean et al. Seeks advice from Debbie Smith at NSF as well. William sends his opinion.
    - message:%3CC952278E-767A-436A-B900-A166124B9216@uoregon.edu%3E
    - message:%3C9BFB3D31-0A32-442D-AF97-A113F9202C9B@uoregon.edu%3E

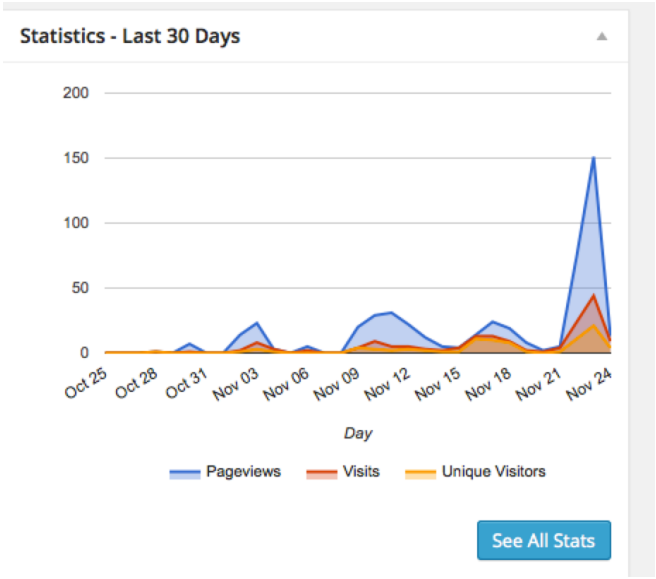
- *Monday Nov 23rd*
  - multi beam survey conducted in Amorgos basin during the night
  - sound source deployment started at 01:30 LT and PSO observations started at 06:30 LT, airgun array ramp from 07:00 to 07:30 LT.
  - Shooting at 165 m shot spacing at 07:33 LT and doing line4
  - For a brief while the program Spectra was not writing the shooflies, but the raw files exist and Gilles wrote the shooflies from them.
  - Finished shooting line 4 just after midnight
  - Some source repairs during the line change at midnight and the GoPro removed
  - Science meeting - make plans for the future
    - To do 1/2 hr log (including weather, grab, mag) as well as SOL,EOL, gun issues and maintenance, XBTs; multi beam changes.
    - to read and discuss some papers
      1. Royden and Papanikolaou: slab tectonics
      2. local tectonics e.g. Anafi
      3. metamorphic rocks
      4.

Santorini geology/volcanology
- Bad weather:
  - watch Atlantis video
  - Columbo videos
- Talk for crew
- Visit Engine room
- Documenting the cruise: interviews with people

- Increased the multi beam beam angle to 75 from 68 to obtain more bathymetry coverage during turn from line 4 to line 3 in this region of sparse seismic lines.
- OBS deployment table receives edits from OBS groups.
  - OBSDeploymentTable_V6

Tuesday Nov 24th

- Completed line 3 in the morning., lines 2, and 1 and started on line 32 shortly before midnight.
- Giles explained how to do the multi beam processing.
  - **get copy of instruction script**
- Organized watches to record shot lines and keep track of expected timeline
  -
- Discussion on shotline priorities and overall timeline
  - message:%3C6405C95A-5718-4249-A35D-E509E8106E93@uoregon.edu%3E
  - message:%3C18C8CDB8-A2EA-4FA5-8282-CBEAC0B0B504@uoregon.edu%3E
- Lay out Notebook for Cruise Report. To assign tasks.
- Santorini webpage is getting attention:
  - receive email from US Embassy: Re: U.S. Embassy-How's it going?
  -



Wednesday Nov 25th

- Evi informs the Santorini Port Authority that we will be in the caldera at about 2 am this night. Also calls re a fishing vessel. She will call again tonight before we enter.
- Daily email to navy HNHS Navtex specifies when we will be in the caldera tonight.
- Giles corrects OBS Deployment Table:
  - OBSDeploymentTable_V6_corrected
  - Have Claire plot OBS locations
- Call to inform Costas Papazachos of our progress.
  - He says they see our shots (probably from last night) loud and clear on Thirasia. He plans to locate them and send something. I will send him times when we were farther away.
  - message:%3C2D83E4F7-1C68-4C1E-BD15-CB5CB5A44A88@uoregon.edu%3E
- Documenting hotlines and monitoring the speed on lines and turns for efficient work.
- Students assigned different portions of the cruise report to work on.
-

Weather remains outstanding - some more clouds and winds as the day passes - wind and waves anticipated for the next 3 days with the worst weather on Saturday (3-6 m waves)

Thursday Nov 26th

- It appears that the order in which we were to shoot the lines had been negotiated beforehand, but the details never passed on to the chief scientist. Upheaval, of course, late at night on the eve of Thanksgiving. The chief scientists and chief science officer stay up into the early morning producing a new shooting plan that satisfies the requirements and proceed to implement it.
- THANKSGIVING: A nice meal served in the galley and everyone appreciated the special occasion. Some of the graduate student cohort even wore special USA shorts!
-

Cruise week 2: Nov 27 - Dec 3, 2015

Friday Nov 27th

- A beautiful day. Headed past N Santorini and between Amorgos and Anhydros then turned south and back toward Santorini today. Acquired Lines 05, and 11. Gun maintenance in between.
- Issues re the order of lines appear to be getting resolved, Though Sean has several errors in his email messages that make the PIs look incompetent. Robert has a long conference call with Sean and then discussion with Doug and Emilie. This seems to lead to a resolution/compromise on the situation. Most significantly the specific shooting order of the version 6 plan was never passed on to the Chief Scientist or the Chief Science Officer. Furthermore a specific maximum line length was permitted for the cruise, but this was never documented either. The plan is to shoot until midnight ending on Dec 7th and then recover OBS in 4 days.
- The current shooting plan adheres to the conditions that led to the development of the version 6 plan. It does not exceed the maximum shooting line length. It puts the end of shooting exactly at the time when shooting must be done. Note the word contingency is used different in cruise planning where it means days to make up time if something goes wrong than in environmental permitting where it means the need to reshoot lines that did not work out. The environmental permitting does not take time constraints into consideration.
- Sean offers to help and Robert asks him to look into allowing us to come in to Heraklion later in the day on Dec 15th, which would give us an 8 hrs flexibility margin.

Saturday Nov 28th

- We continue to the east side of Santorini and complete profiles in this area. Much anticipation of bad weather today, but we are in the lee of Santorini for the highest winds. Apparently waves in the bay of Santorini are considerable. Will this make noise on the shallow water stations on the west side of the volcano? Will OBS 180 be lifted off the seafloor?
  - IMG_6358.jpeg

- Tour of the engine room with the Chief Engineer at 10 am
  - IMG_6341.jpeg

- The compressors bring the air pressure up to 1980 PSI in 5 stages. The pipes get narrower at each stage.

- IMG_6346.jpeg

- IMG_6348.jpeg

- *Sunday Nov 29th*
  - The weather has completely settled down again.
    - IMG_6365.jpeg

    - History Channel documentary on Atlantis Discovered to be shown at 10 am and 1 pm, with a small intro by the star Evi
    - Another tour of the engine room also at 10 am
    - We complete a long line from east to west of the volcano and are headed back to the west side with a bend around the north part of the island to complete line here in the upcoming day.
- *Monday Nov 30th*
  - There is a stiff northerly breeze throughout the day, but the waves remains small with little whitecaps.
  - Provide captain with new ferry schedule
    -

DATE		DEPARTURE	ARRIVAL	NAME		DEPARTURE	ARRIVAL	NAME
Tuesday	01/12/2015	14:00 (30/11/2015 Piraeus)	03:10 (Santorini)	Adam Korais		07:00 (Santorini)	19:40 (Piraeus)	Adam Korais
		07:25 (Piraeus)	15:10 (Santorini)	Blue Star Delos		15:30 (Santorini)	23:25 (Piraeus)	Blue Star Delos
Wednesday	02/12/2015	21:00 (1/12/2015 Piareus)	05:50 (Santorini)	Prevelis		06:20 (Santorini)	20:40 (Rhodes)	Prevelis
		07:25 (Piraeus)	15:10 (Santorini)	Blue Star Delos		15:30 (Santorini)	23:25 (Piraeus)	Blue Star Delos
Thursday	03/12/2015	14:00 (2/12/2015 Piraeus)	03:10 (Santorini)	Adam Korais		07:00 (Santorini)	19:40 (Piraeus)	Adam Korais
		07:25 (Piraeus)	15:10 (Santorini)	Blue Star Delos		15:30 (Santorini)	23:25 (Piraeus)	Blue Star Delos
		05:00 (Rhodes)	19:45 (Santorini)	Prevelis		20:30 (Santorini)	05:15 (Piraeus)	Prevelis
Friday	04/12/2015	07:25 (Piraeus)	15:10 (Santorini)	Blue Star Delos		15:30 (Santorini)	23:25 (Piraeus)	Blue Star Delos
Saturday	05/12/2015	18:00 (4/12/2015 Piraeus)	02:50 (Santorini)	Prevelis		03:40 (Santorini)	00:40 (Rhodes)	Prevelis
		07:25 (Piraeus)	14:55 (Santorini)	Blue Star Delos		15:30 (Santorini)	23:25 (Piraeus)	Blue Star Delos
		07:15 (Piraeus)	18:00 (Santorini)	Adam Korais				
Sunday	06/12/2015	07:25 (Piraeus)	15:10 (Santorini)	Blue Star Delos		15:30 (Santorini)	23:25 (Piraeus)	Blue Star Delos
						07:00 (Santorini)	20:10 (Piraeus)	Adam Korais
Monday	07/12/2015	03:00 (6/12/2015 Rhodes)	00:01 (Santorini)	Prevelis		00:40 (Santorini)	09:45 (Piraeus)	Prevelis
		07:25 (Piraeus)	14:55 (Santorini)	Blue Star Delos		15:30 (Santorini)	23:25 (Piraeus)	Blue Star Delos
Tuesday	08/12/2015	14:00 (7/12/2015 Piraeus)	03:10 (Santorini)	Adam Korais		07:00 (Santorini)	19:40 (Piraeus)	Adam Korais
		07:25 (Piraeus)	15:10 (Santorini)	Blue Star Delos		15:30 (Santorini)	23:25 (Piraeus)	Blue Star Delos
Wednesday	09/12/2015	21:00 (8/12/2015 Piareus)	05:50 (Santorini)	Prevelis		06:20 (Santorini)	20:40 (Rhodes)	Prevelis
		07:25 (Piraeus)	15:10 (Santorini)	Blue Star Delos		15:30 (Santorini)	23:25 (Piraeus)	Blue Star Delos
Thursday	10/12/2015	14:00 (9/12/2015 Piraeus)	03:10 (Santorini)	Adam Korais		07:00 (Santorini)	19:40 (Piraeus)	Adam Korais
		07:25 (Piraeus)	15:10 (Santorini)	Blue Star Delos		15:30 (Santorini)	23:25 (Piraeus)	Blue Star Delos
		05:00 (Rhodes)	19:45 (Santorini)	Prevelis		20:30 (Santorini)	05:15 (Piraeus)	Prevelis
Friday	11/12/2015	07:25 (Piraeus)	15:10 (Santorini)	Blue Star Delos		15:30 (Santorini)	23:25 (Piraeus)	Blue Star Delos
Saturday	12/12/2015	18:00 (11/12/2015 Piraeus)	02:50 (Santorini)	Prevelis		03:40 (Santorini)	00:40 (Rhodes)	Prevelis
		07:25 (Piraeus)	14:55 (Santorini)	Blue Star Delos		15:30 (Santorini)	23:25 (Piraeus)	Blue Star Delos
		07:15 (Piraeus)	18:00 (Santorini)	Adam Korais				
Sunday	13/12/2015	07:25 (Piraeus)	15:10 (Santorini)	Blue Star Delos		15:30 (Santorini)	23:25 (Piraeus)	Blue Star Delos
						07:00 (Santorini)	20:10 (Piraeus)	Adam Korais
Monday	14/12/2015	03:00 (13/12/2015 Rhodes)	00:01 (Santorini)	Prevelis		00:40 (Santorini)	09:45 (Piraeus)	Prevelis
		07:25 (Piraeus)	14:55 (Santorini)	Blue Star Delos		15:30 (Santorini)	23:25 (Piraeus)	Blue Star Delos
Tuesday	15/12/2015	14:00 (14/12/2015 Piraeus)	03:10 (Santorini)	Adam Korais		07:00 (Santorini)	19:40 (Piraeus)	Adam Korais
		07:25 (Piraeus)	15:10 (Santorini)	Blue Star Delos		15:30 (Santorini)	23:25 (Piraeus)	Blue Star Delos

- Completed P1 shooting pattern today!
  - survOPT Santorini_ShotLines_v7 -P1 Lines Only-Complete.txt
- Started P2 shooting pattern; changed to 4 knots and 144m shot spacing.
  - survOPT Santorini_ShotLines_v7 -P2 Lines Only-Revised2-Start.txt
- Science meeting to recap status and make sure assigned cruise report, data processing, and cruise documenting tasks are being completed.
- Send status report to Joanna and Mike
  - message:%3C21ADBF81-5D79-404D-BA8B-7CD2F105C2FA@uoregon.edu%3E

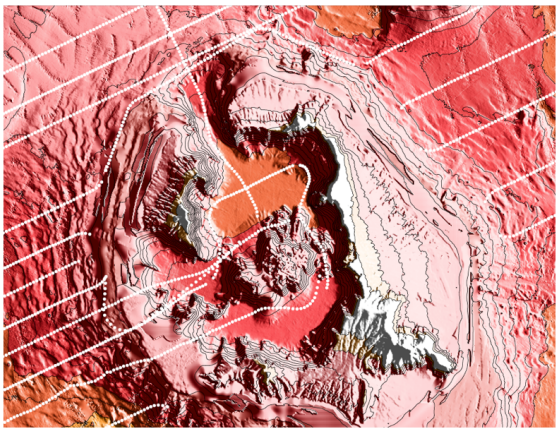
- *Tuesday Dec 1st*
  - A calm day with great visibility at the start - The three mountain ranges on Crete can be see spread across the SE horizon.
  - Just after midnight local time communication to gun string 3 fails. It is pulled on board while continuing to sail along line 31 and shoot with ~3/4 of the array volume: 4,950 cu. in vs full volume of 6,600 cu. in. In all 41? shots were made at reduced or variable volume. Detailed notes:
    - Notes on airgun string 3 failure 11/30/2015 (times in UTC):
      22:02 sp. 25509 String three recorded a failure
      22:20 String three being brought on board for repair. Speed raised to try to straighten string coming in. Shots continue with strings 1,2 and 4. Volume reduced from 6600 cu. in. to 4950 cu. in.
      22:30 String 3 on board. Not fully out of the water with tail still in.
      Jumper cable from gun001 found dislodged causing error. Also cable tow had slipped significantly and XBT wire had become tangles around the string.
      22:49 String repaired. Testing individual guns on deck. gun008 successful fire. Gun007 successful fire.
      22:54 Redeploying string 3. Speed reduced to 3 kt
      23:00 String three in the water. Speed increased to 4 kt. Sp. 25549 missed while rearming the guns from the control room. Testing all guns sp. 25550 sucsessful
      23:05 Airguns firing normally.
  - Line 31 finished at 02:00.Planned gun maintenance performed during extended turn on strings 1 and 2. Nothing unusual noted.
  - A beautiful sunset with Crete still visible.
  - There are numbers of cargo ships and ferries - how will the impact noise levels on the seismometers?
    - A large cargo ship passing us at the end of line OBS25 at 221° bearing to the ship at 2.3 mmi closest approach; ship's position: 36° 14.8135N, 24°54.8467E 12/1 YD335 15:43:51 UTC.

- 4-5 pm LT Sent out correction to NavTex email since we will be in Santorini caldera tonight and not tomorrow night.
- Evi called Santorini Port Authority that we will be in the caldera 2 am to 6 am. Prevails ferry coming in from Pireas and the north around 5 am and leaving around 6:20 am by the west.
- Plan to do a transit line from the end of OBS 24 to OBS 28, the EW line within the caldera, then a transit line down to OB S21 in the southern caldera and out. The transit lines to be shot at 70 seconds at 5.5 knots or whatever speed the bridge does in the caldera (this would give ~200 m shot spacing).

Wednesday Dec 2nd

Made track through the caldera as planned.

Plot of shots within the caldera so far:



Encounter with ferry right on the shallowest portion of the western sill of the caldera,

- we divert somewhat to the south, but keep the gear off the bottom. Schedule has the ferry coming in from the north at 5:50 am and leaving through the west at 6:20 am - not clear why he was coming in at the west.

Converted land site locations from Joanna's KML to a text file:

- LandSites.dat

At mitigation volume for 5 shots this morning.

- Dolphin detection within Greece's 6nmi radius at 1.6 km - no take. Shot points 29987-29991; 08:08-08:17 UTC; volume 40 cu. in.
- There was also a dolphin PAM detection during the night - very brief (8sec).

- OBS recovery order
- Emailed Jun Korenaga asking about doing the calibration using the bowtie/crosssing transects.
- At end of day we cross over Coloumbo seamount and launch one XBT at the center of the caldera and one at the northern end where we see the hydrothermal chimneys in the backscatter images. There are also a number of dikes and pumice into which the 3.5 kHz penetrates 100m.

Thursday Dec 3rd

Knudsen SEGY records and fence plots

- Melissa has fence plots of Knudsen data in SU using code that Giles wrote. She is continuing to work on this.

OBS recovery plan

Considerable effort goes into finding a path that:

1. minimizes the time
2. starts near the end of the last line (OBS178 or OBS181)
3. ends at the western end of the array (OBS 172)
4. Recovers the caldera OBS during the day (OBS141, OBS161, OBS180, OBS179, OBS160, OBS 140)

- Doug and Gillean find a solution, Doug with Excel, Gillean with Matlab, Emilie with Matlab shortest path calculator.
- Emilie discusses the recovery procedure and timing constraints with the Captain, Chief Science Office and OBS technicians, to arrive at the numbers to use.
- OBSs to be recovered during the day on Dec 8th.
- Workboat will be in the water to assist with recoveries.

Chief Scientist gives 25 minute overview talk of the experiment for the crew and technicians.

- Talk is appreciated and well attended. Held in the main lab at the conference table because the Mac (with Quicktime movies) cannot connect to the monitor in the movie room. OK considering the level of engine noise in the movie room.

Reshoot lines - shot spacing

- Doug and Emilie discuss Mike Warner's advice and decide to follow it and interleave the shots for the reshoot: 82.5 m spacing!

Emilie discusses implementing this with the Chief Science Officer and works with Ben to calculate the 82.5 m offset and with the seismic navigators to implement

- XBTs and sounding velocity
  - Chief scientist instructs Mariaeleni how to do this in Matlab.

Cruise week 3: Dec 4 - Dec 10, 2015

Friday Dec 4th

- Completed shooting of P2 interleaving lines today. Started on P3 reshoot lines.
- Chief Scientist works with seismic navigators and Chief Science Officer to ensure that there is no confusion during especially the inner turns.
- Magnetics data:
  - Chief Scientist works with Dan O'Hara on correcting the magnetics data. We make some progress, but it is not quite correct. Receive Figure 8 correction paper from Will Sager.
- Gravity data:
  - Access to this data is restricted for non-US citizens/green card holders.
  - Brandon verifies the range of the gravity measurements that we are making using a linear correction - the range is +/- 200 mGal which seems reasonable.
- Send an update to Joanna, Mike, and Costas with a request for photos.
- Chief Scientist writes "marine geophysics in action" report from the field for DoGS newsletter. With photos.
  - DoGS Report from Santorini

- Regular internet is no longer functioning, chief science officer sets up fleet broadband locations for crew and others to use to email.
- Turkey day has passed :(

Saturday Dec 5th

- Eve of St. Nicholas in Greece and the Netherlands time to put your shoe out!
- Internet continues to be down, fleet broadband very slow.
- Evi found a serious virus (cryptoLock) on her PC during the night.
  - 800 files are locked for ransom and not recoverable (no backups). She uses her Vodaphone connection to download virus software and the database and scan and clean her computer and drives.
  - All her files from the shared drive and that ended up on laptops are deleted. Her students and Dan are of particular concern because they also have PCs.
- Noon LT. Serious compressor issues cause a change of shooting plan:
  - Chief Science Officer informs Chief Scientists that the engine of the starboard compressor has a damaged cylinder. Chief Engineer transfers us to the barely functioning port compressor. This compressor is normally only run 6-9 hrs at a time,
- The Chief Science Officer suggests that we stop our current line and transit to the 3 Anafi lines since these are primary objectives. This way we have a hope of achieving these before the compressors stop entirely.
  - Chief Scientists consider it important to complete the lines commissioned by Imperial College.
  - The break is made 1/2 way through line 37 (reshoot of line 6). We are directly north of the Santorini caldera and make a 180° turn.
  - Transit to line 12 with the compressors off to enable work. PSOs continue usual monitoring.
  - Gun ramp up starts at 3 pm LT and we start shooting line 12 at 3:35 pm LT.
  - Anticipated that 3 Anafi lines will be completed at 7-8 am LT Sunday. Then we will transit back to Line38 (reshoot of line 5).
- Magnetics:
  - Dan O'hara's corrections are better now. Is a function of cos and cos2 ships heading. There are still some large cross-over errors. Dan is looking into possible diurnal variations.
- XBT and sounding velocity
  - Emilie helps Mariaeleni with the Matlab coding to plot this.
  - *Doug*: since velocity only drops with depth ray bending may be different than at a mid-ocean ridge. Might be worth modelling this with Stingray.
- Knudsen plots
  - Melissa is making slow progress here and working through the scripts in su/plotting in GMT.

Sunday Dec 6th

- 1:43 am LT port compressor blows safety valve of the 4th stage piston during transit from line 13 to line 14 - transit extended out to the SW to repair. Mitigation volume fired every 5 min on remaining pressurized air.
- The port compressor functioned for less than 12 hrs before requiring repairs. Normally these compressors run for 10,000 hrs before requiring servicing.

- 3:35 LT line 14 started with long run-in from the SE; compressor back up; delay of 2 hrs incurred.
- Decision to cut off the start of line 38 (reshoot of line 5) by 12 km to save 1.5 hrs of shooting time. We head straight north from line 14.
- OBS recovery plan given to OBS groups and to the bridge in the AM
- During transit the filters on the spare compressor are cleaned and gun strings 1 and 2 are serviced. Gun string 2 has a small airleak in the solonoid that is replaced. The bolt of the 1st large double guns is also coming out and is tightened. 12 shots recorded at the end of the transit (70 sec rep. rate and 5.5 knots).
- Reshooting interspacing of shots not working in all cases on the east side:
  - Maps of reshoot show that interleaving the shots when shooting in the direction opposite to the 1st time does not result in offsets of 1/2 rather the offsets are 1/4 of the shot spacing. ***This is because shots mapped out starting from the assigned starting lat & long that a line is shot from. Thus the assigned end lat & long has no meaning. We were adjusting the lat & long of the point on the line where we were starting the reshoots, thus the end point for lines shot in reverse.***
- **1** pm science meeting to go over recent events and upcoming plans.
- 8 pm. Chief Science Officer informs Chief Scientist that we will exceed the max # of km allowed in the environmental permit if we continue as planned. While the original planned lines were 3-7 km short of this limited, line run-ins and run-outs have added significant kms, in spite of lines or line portions that were dropped.
- The shooting plan is modified to stay within the limit: We immediately cut the reshoot of line 5 (line 38) short and transit to line 36 (reshoot of line 12). The western ends of lines 36,35,34, and 33 are all trimmed by 2.9 km to achieve the assigned limit.
- This will cut ~7 hrs from our shooting plan.
- Emilie & Ben successfully recalculate the interspacing of the reshoots on the west side:
  - All reshoots on the west side will be shot in the direction opposite to that done originally.
  - Fix by finding last in-line shot of the original line and moving this over by 82.5 m and updating this as the starting lat&long for the reshoots. Then for a line starting 1/2 way along the original profile the appropriate shot is chosen once this line is selected.
- OBS recovery plan is reconfigured by Emilie & Brandon:
  - to include 7 more OBS at the start - modifications are easy because we are within the densely clustered stations on the west side of the volcano. This will allow flexibility to add or drop recoveries in order to work in the caldera during daylight on Tuesday Dec 8th.
- Excitement and preparation for going out in the workboat during caldera recoveries is building and the workboat has been worked on over the last few days.

Monday Dec 7th

- “A Day that will Live in Infamy” - today is the Pearl Harbor anniversary. It is also the deadline to stop shooting. This is anticipated for 12:48 UTC = 2:50 pm LT. Then we plan to do the magnetometer figure 8 calibration and to recover the airguns.
- Shooting continues on the port compressor, repairs on the starboard compressor are almost complete.
- 11:30 am LT port compressor is shut off just after starting line 33. Cracked fitting on the stage 3 pressure chamber. Shoot mitigation gun every 5 minutes while steaming at 3 knots along line 33.
- Shooting completed at 4 pm LT: 2149.95 km out of 2150 allowed km of line shot. Total of 14246 shots logged!
- **1** pm science meeting.
  - **1.1** Doug comes up with an acronymn for the cruise: **PROTEUS - Plumbing Reservoirs Of The Earth Under Santorini**
- Magnetic calibration bowtie sailed.
- Guns recovered.
- OBS recoveries started at 6:30 pm LT and 7 OBS on board by the end of the day. Weather is good - calm conditions, cold wind picking up.
- Recoveries going very efficiently - even faster than planned. Effort put into readjusting the order to ensure that we arrive outside of the caldera after sunrise and can launch the workboat tomorrow morning.

Tuesday Dec 8th

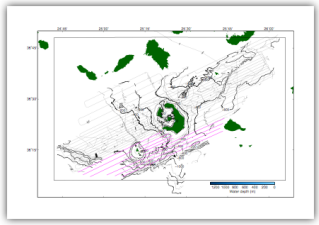
- Today was the day in the caldera!
- Recoveries during the night continued well - one SIO instrument took 1 hr to release (secondary burn worked). In shallow water the communication was difficult until right over the OBS.
- After breakfast and recovery of OBS141 off of Thirasia, the workboat was put in the water with Robert Steinhaus, Doug Toomey, Evi Nomikou and Joshua. They were armed with cameras GoPros and food and water for 3 days!
- **OBS180** surfaced 200 feet to the east of the deployed location. Pay attention to relocating it separately before and after the storm or during the duration of the experiment.
- Many photos and videos were taken and are on the shared drive. Excellent shots and movies of the Langseth and the OBSs within the caldera
- We are averaging 49 minutes per OBS; 57 minutes per OBS was the estimated average in this area of closely spaced

instruments. These small differences add up over 91 station: 8*91/24 = 12 hrs!

- 29 OBSs recovered in the last 24 hrs; 36 since the start of recovery.
- Make plans for a geophysical surveying of up to 24 hrs - 3 hr, 9 hr and 24 hr options discussed. Will include bathymetry, gravity and magnetics. Stay within IHA box for sonar to be on.

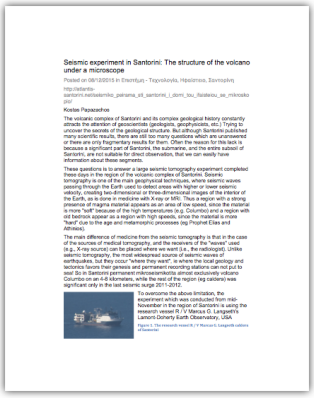
Wednesday Dec 9th

- large number of OBS recovered today.
- **OS 116 (SIO) weak response to enable, did not release**. Will leave on the seafloor and return after the other recoveries are complete.
- Shot Log Files: resolve issue of duplicate shot numbers
- Post-Recovery Geophysical Survey pick lines and send to bridge.
  - mgl1521_contours_surveyPoints_v2.pdf



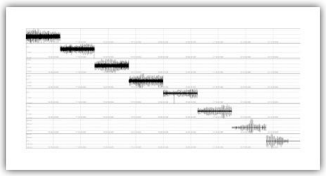
  - SurveyLineLengths_v2.xlsx

- XBTs - Doug working with Mariaeleni. Cleanup needed and done.
  - files not correctly edited - cut the files once they hit bottom.
  - spatial variations mapped out by Emilie and sounding velocity determined.
  - We take a number of XBTs on the north side of the volcano due to perceived problems with XBT 13 on the outer flank of Thirasia.
  - We notice that all were processed with a salinity of 34.8 ppt instead of the 38.8 to 39.1 ppt that is applicable here. Do a number of XBTs including some repeats from before.
- Costas publishes post on Atlantis-Santorini web site about the experiment.
  - http://atlantis-santorini.net/seismiko_peirama_sti_santorini_i_domi_tou_ifaisteiou_se_mikroskopio/
  - Seismic experiment in Santorini.pdf



Seismic experiment in Santorini: The structure of the volcano under a microscope

- Mike sends a plot of initial data downloads from Santorini.
  - All
    The attached is from a Santorin station in the SE on fairly solid rock. It is the southern-most but one line between Anafi and Santorini on December 5. The boat is sailing WSW towards southern-most Santorini I think. The pieces of data are all one hour long. Each block is gained independently of the others - the noise level is probably constant, so the amplitudes are rising as the ship gets closer to the station. Shooting ended about 23.30 half way through the last piece. The data are unfiltered. I don't have any means to filter it here - all I can do at present is make these very simple plots but at least they show that things are working.
    Mike
  - snap05.jpg

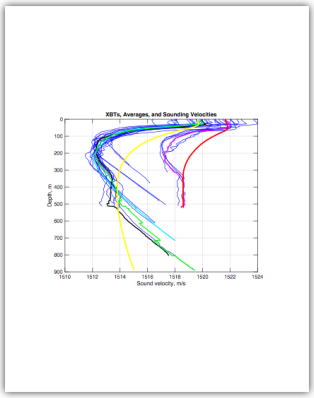


Thursday Dec 10th

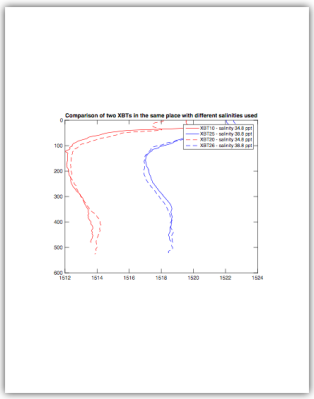
- OBS recoveries continue: *Average time remains 50 min per site.* Estimated completion is midnight 12/10 - one day ahead of initial plans.

discuss with Robert plans for last ditch attempt at grappling for OBS116 (SIO)

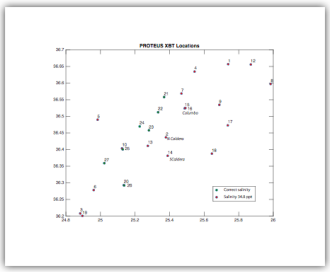
- XBTs - errors and spatial variation are not going to matter for the seismology
  - This affects the water sound speed by about 4 m/s, but the effect on travel time through the shallow water is only 1 sec.
  - vel_profile.m
  - XBT-Averages-Sounding.pdf



  - XBT-salinityComparison.pdf



  - XBTLocations-annotated.pdf



  - plot_XBT_locations.m

- **sent corrections to Costas and work on formal press r.elease**
- corrected shot log files given to OBS groups - no duplicates found
- Discuss possible plans to drag the seafloor for OS 116 with the caption and Chief Science Officer. After some thought a plan is laid and preparations are done so as to be prepared if this becomes necessary.
- Jimmy Elsenbeck (WHOI) makes initial plot of ALL segy data for WHOI OBS 164. Can see energy out to either side of the station across the array - all stacked on top of each other and plotted 5-80 Hz, so hard to know more. Significant slowing of energy through the volcano!
- Starboard engine out for a while around dinner time
- It looks like we will be done around 8 - 9 pm LT tonight. Then 2 hr transit back to OS116 (SIO).
- Joanna sends a plot of initial data downloads from Anafi - too large to download
  - All
    Attached are data from four stations on the west of Anafi. Boat is between Anafi and Santorini; 1800-1900 on day 339. It's a bit difficult to comment on station to station coherency without some proper software. We have recovered 24 stations and, so far, I have checked 19 of them. They all have recorded for the whole time period and they all have data that looks like the plots in the attached.
    cheers Jo
- Recoveries complete at 9 pm LT- 3/4 day faster than estimated. Average time per site was 50 minutes versus 60

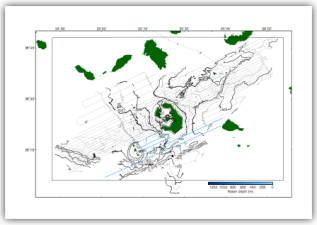
minute estimate

- Ben discovers that in removing the repeated shots from the OBSIP log files a carriage return is missing leading to one lost shot in the OBSIP workflow and this is corrected.
- **Knudsen issue discovered**:
  - Dates are all one day ahead of the true date, both the month-day date and the year day.
  - Giles improves the conversion and plotting program to make it easier to plot subregions.
- Pick new start point for geophysical survey: 25.1970 E; 36.2792 N
- Returning to OS 116 (SIO) to attempt to recover.
  - Arrive 11 pm LT; sonar survey done 1st but OBS not visible on multi beam or 3.5 kHz. Dan makes blowup plots of bathymetry it is on a slope going up to the NE at 10 m over 50 m. Melissa makes Knudsen plots - the topography looks smooth. Are just to the east show significant slumping - interesting transition.
  - From 11:28 to 07:37 UTC repeated burn commands are sent to the instrument. It fails to release but occasional weak responses are heard (very occasionally stronger ones). So it is still there!

Cruise week 4: Dec 11 - Dec 15, 2015

Friday Dec 11th

- Attempt to recover OS116 (SIO)
  - From 01:28 to 07:00 UTC we make two attempts at dragging the instrument to get it to release. Ships chain is attached to 1 km of spare spectra rope at intervals of 50 m and a U-shape is sailed. We are not successful but bring up some clayey mud and a few bits of plastic thread.
  - Up to 07:37 UTC repeated burn commands continue to be sent to the instrument. It fails to release but occasional weak responses are heard (very occasionally stronger ones). So it is still there!
- We explore the option of using the Greek ROV on the small HMRC boat to recover OS 116 (SIO)
  - message:%3CAC1026E3-A863-4389-92CC-75503036204B@ucsd.edu%3E
- New geophysical survey points determined - decreasing the density of the planned lines.
  - SurveyLineLengths_v3.xlsx
  - mgl1521_contours_surveyPoints_v3.pdf



- Transit to southern end of Crete MCS line will start at midnight LT and take 18 hrs.
- Magnetometer briefly out and cable and magnetometer replaced.
- Geophysical survey ended abruptly between 4 and 6 pm LT apparently not permitted; transit to Crete line commenced.

Saturday Dec 12th

- Deployment of MCS streamer commenced at 8 am LT. Cold N wind. and decent swell. 15:15 LT MCS streamer deployed. Mitigation gun out before dark and shooting started on the line in the evening.
- SIO SEGY data
  - OS 129 & OS187 have time break and buffer errors and need to be processed at SIO. Looks like all the data is there.
  - OS152 had CF card write errors
  - received 22 segy files all the older 4x4 data logger (datalogger # starts with SP).
- Received all WHOI SEGY files
- Started data quality control with Ben Heath

Sunday Dec 13th

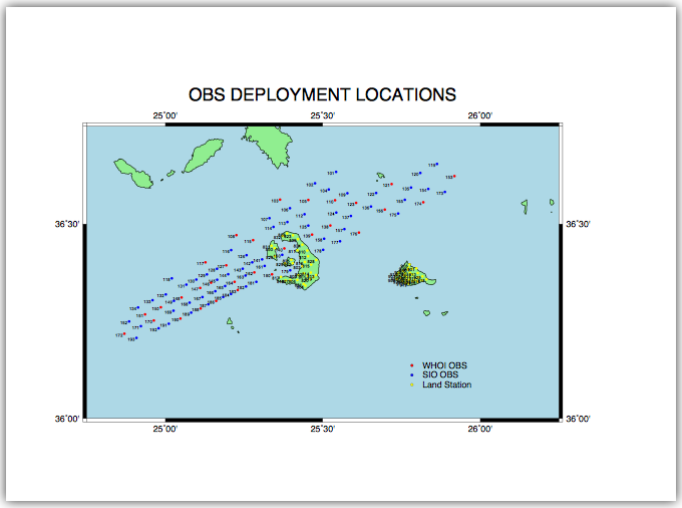
- MCS line to be completed at 20:00 tonight. Waves and wind starting to come down.
- Work on completing multi beam and magnetic data processing
- Work on cruise report and press release.
- Plan is to recover the streamer starting around 11:30 pm or midnight LT.
- Should arrive in Heraklion at 13:00 LT Monday Dec 14th.

OBS Operations and Data Quality

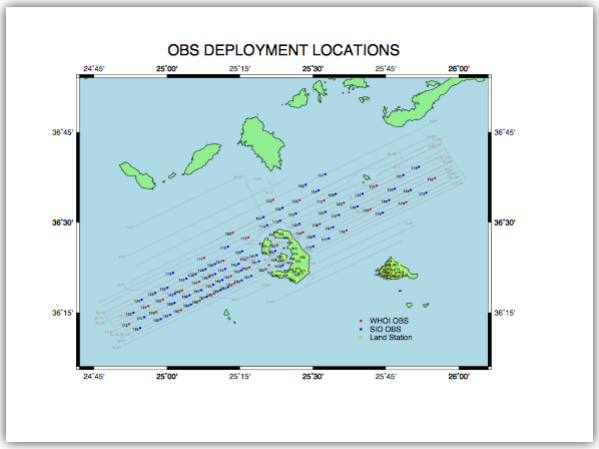
- **OBS Summary Table.xlsx**

- **Land Sites**
  - LandSites.dat
  - final-sites.kml

- AllStation_OBSLand

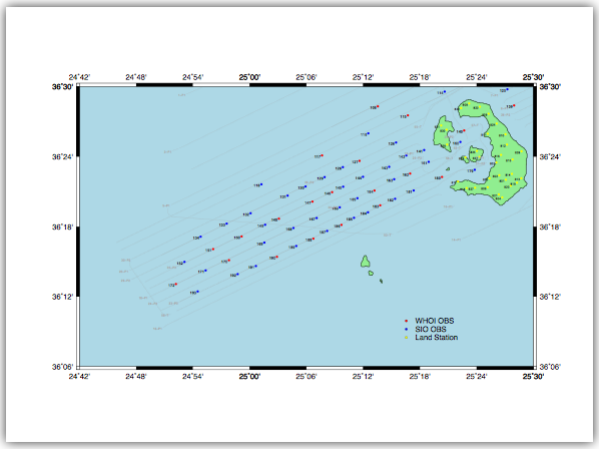


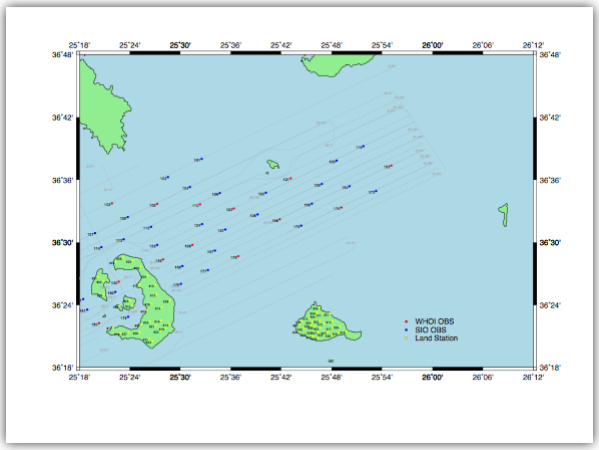
- FullMap AllStations AllShots



- SWCorner

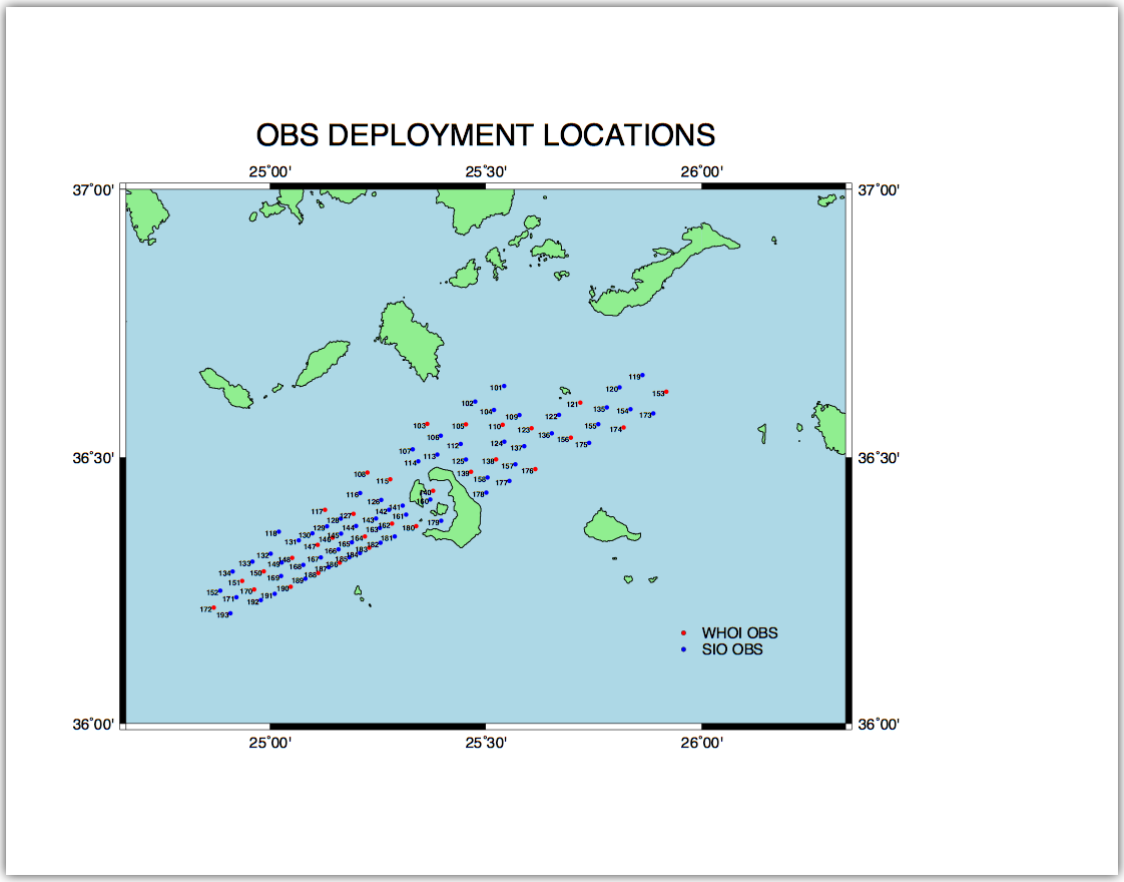
NECorner


24°42'
24°48'
24°54'
25°00'
25°06'
25°12'
25°18'
25°24'
25°30'
36°30'
36°24'
36°18'
36°12'
36°06'
WHOI OBS
SIO OBS
Land Station


25°18'
25°24'
25°30'
25°36'
25°42'
25°48'
25°54'
26°00'
26°06'
26°12'
36°48'
36°42'
36°36'
36°30'
36°24'
36°18'
WHOI OBS
SIO OBS
Land Station

A1: OBS Deployment Summary

OBS location Maps

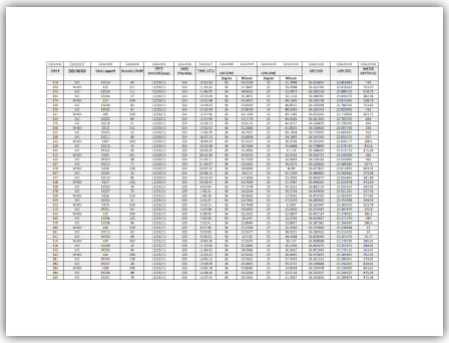


OBSDeploymentMap.pdf

Deployment Table

- OBSDeploymentTable_V6_corrected

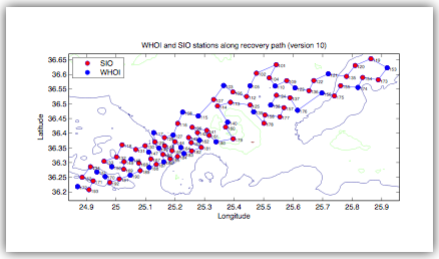
- OBSDeploymentTable_V6_corrected Sheet1.pdf



Recovery Plan and Execution

- MGL1521_Caldera_Plan1512071953_UpatedTimes.xlsx

- OBSRecoveryPath_v10.pdf


WHOI and SIO stations along recovery path (version 10)
SIO
WHOI
Latitude
Longitude
36.65
36.6
36.55
36.5
36.45
36.4
36.35
36.3
36.25
36.2
24.9
25
25.1
25.2
25.3
25.4
25.5
25.6
25.7
25.8
25.9

A2: Seismic Survey Summary

Santorini_ShotLineTable

Included in Appendix A2 are the following:

1. **1.** Description of the survey
2. **2.** Seismic Line naming convetion
3. **3.** Shot log file description
4. **4.** Maps of the seismic survey
5. **5.** Interweaving between shot lines comparison between East and West side.
6. **6.** The airgun data quality is described in the section "Airgun Operations and Source Reliability".
7. **7.** The SEGY file formats are described in Appendix A5 and A6 for the SIO and WHOI instruments, respectively.
8. **8.** Reading of the OBSIP log files and SEGY files is described in Appendix A13

1. Description of Survey

- The Santorini Seismic Experiment provides multi-tiered imaging of the Santorini Volcano magmatic system and associated terranes. Shot lines are divided into 3 categories (P1,P2,P3)
  - *P1*: P1Shot lines are the primary shot lines and compose lines deemed most important for understanding the deep magmatic system. Ship speed for P1 lines was 3.5 knots (ship turns will be at 5.5 knots). Shot interval was ~90 seconds yielding a shot spacing of 165 meters
  - *P2*: P2 shot lines are lines in between primary shot lines, which increase shot density and hopefully seismic resolution. Ship speed for P2 lines was 4 knots (ship turns will be at 5.5 knots). Shot interval was ~70 seconds. This yields a shot spacing of 144 meters.
  - *P3*: P3 shot lines are reshoots of the ends of some of the P1 shot lines. Reshooting lines allows for stacking of traces and better picking of arrivals. This will allow for the creation of a better travel time tomographic model. Ship speed for P3 lines was 4 knots (ship turns will be at 5.5 knots). Shot interval was ~70 seconds. This yields a shot spacing of ~165 meters. Shots were interleaved with the shots from the original shooting of these lines.
- Airguns were towed at ~12 m water depth throughout the experiment for enhanced low frequency content

2. Seismic Line Naming Convention

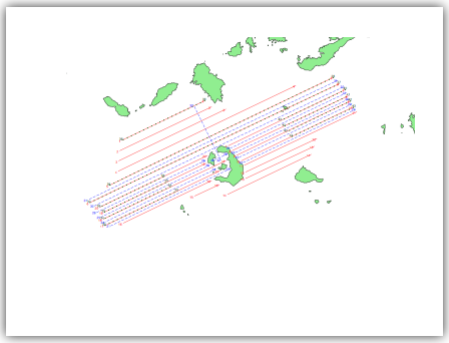
- Shot lines are named in the order they were shot. All shot log names begin with the heading OBS. For example OBS06 was the sixth shot line. Transit shotline (shot lines shot while in transit between main lines) were labeled with a T followed by a number (e.g OBST01 was transit 01). For our srEvent files, the id is the shot line number. Transits are labeled as the transit number + 50 (e.g. transit 01 has id 51). This is to have unique ids for all events that still retain relative shot line info.

3. Shot log file description

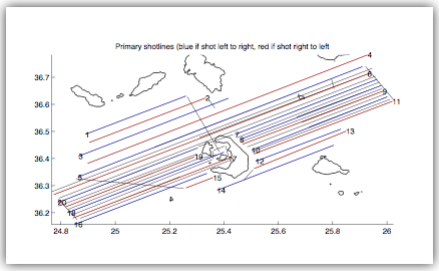
- Each shotlog file is named after the line shot (eg. MGL1521OBS02.shotlog for line 02). Each file contains: shotnumber, date, time, sourceLat, sourceLon, shipLat, shipLon, waterDepth, sciTag. Further description is provided in A13

4. Maps for seismic survey:

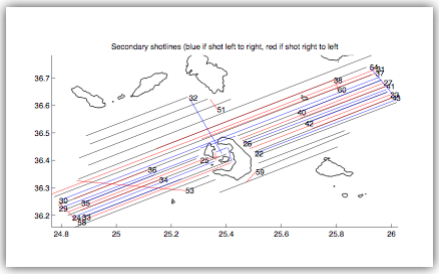
- Shot Lines: This shows the proposed lines and does not reflect the order that they were shot.



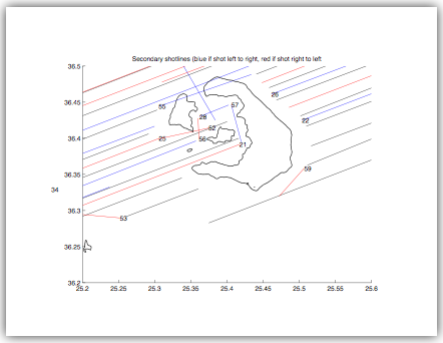
- Primary shotlines colored by shooting direction: Note all lines are drawn as straight lines from first to last shots. Lines are colored depending on whether the first shot is to the left of the last (blue) or if the first shot is to the right of the last shot (red)



- Secondary and tertiary shotlines colored by shooting direction



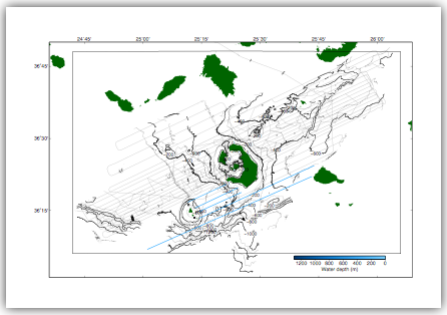
- Secondary and tertiary caldera centered lines colored by shooting direction.



5. Interweaving between shot lines comparison between East and West side.

A3: Post Recovery Geophysical Survey

- mgl1521_contours_surveyPoints_v3.pdf



- SurveyLineLengths_v3.xlsx

- Survey ended abruptly after magnetometer malfunction near the island of Anafi

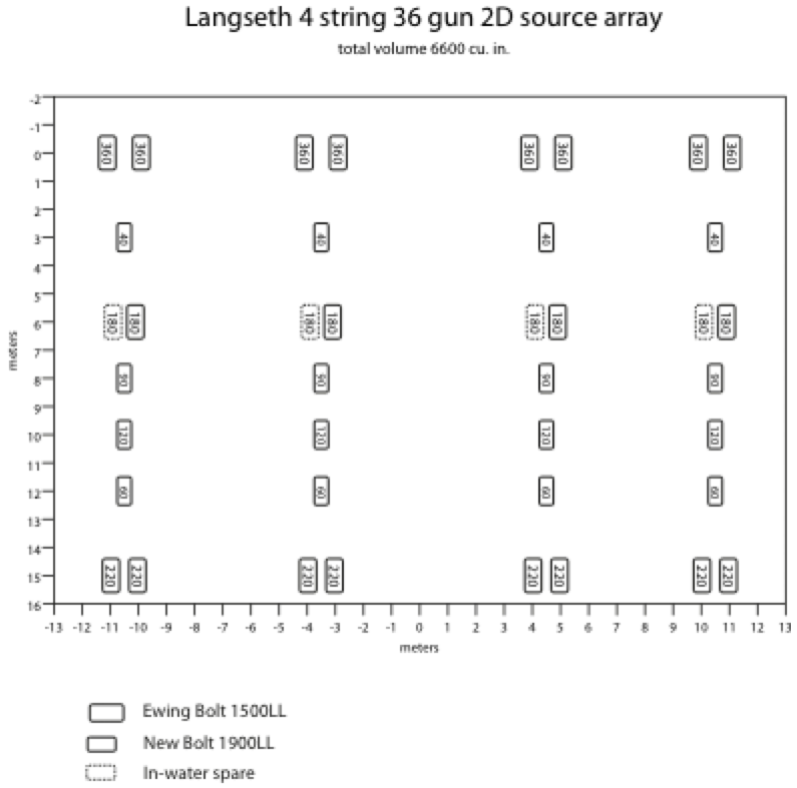
A4: R/V Marcus G. Langseth Sound Source

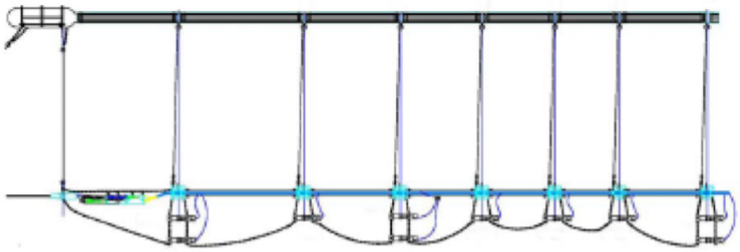
MGL1521 Airgun Operations

The R/V Langseth airgun array consists of 36 air guns with a total volume of 6600 in3 at 2000 psi. To enhance power and low frequencies the airguns were run at depths of 12 m for the duration of the experiment. During airgun operations the towing speed of the Langseth was 3.5 or 4 kt.

The R/V Langseth seismic source consists of four identical linear arrays, or strings each of which has ten air guns. Nine air guns per string were fired on all four strings simultaneously, while the tenth was kept in reserve as a spare to be turned on in case of the failure of another air gun. Shots were fired at predetermined coordinates while on the shot lines and a 60 s intervals during transects between lines. Typically, on each string gun 5 is kept as a spare, but if there were issues with one of the other guns, gun 5 on the string in question was put in service and the other gun was shut off.

Seven different volumes of Bolt Models 1500LL & 1900LLXT Long Life Air Guns are used. Guns 1 & 2 are 360 in3 and are used in parallel. Gun 3 is 40 in3. Guns 4 & 5 are 180 in3 and are used in parallel. Gun 6 is 90 in3. Gun 7 is 120 in3. Gun 8 is 60 in3. Guns 9 & 10 are 220 in3 and are used in parallel.



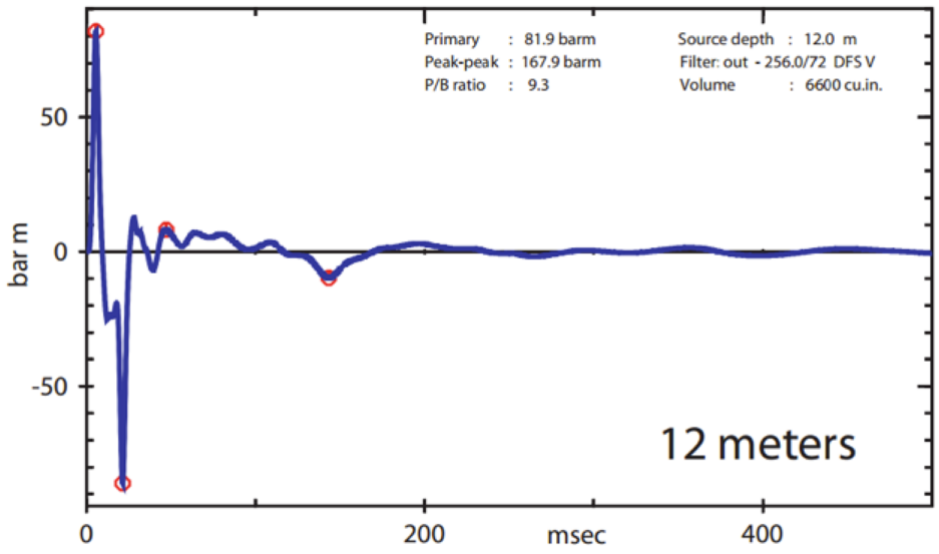


One linear airgun array, drawn to scale for towing depth of 6 meters.

GUN	TYPE	X(m)	Y(m)	Z(m)	VOL(cu)	PR(psi)
1	1500LL	0	0	5.4	360	2000
2	1500LL	0	0	6.6	360	2000
3	1900LLX	3.23	0	6	40	2000
4	1500LL	5.59	0	5.6	180	Spare
5	1500LL	5.59	0	6.4	180	2000
6	1900LLX	8.23	0	6	90	2000
7	1900LLX	10.69	0	6	120	2000
8	1900LLX	13	0	6	60	2000
9	1500LL	16	0	5.53	220	2000
10	1500LL	16	0	6.47	220	2000

Figure 1: Schematic R/V Langseth gun array layout. The array comprises four identical but separately towed strings, each with ten air guns. (a) Each string is made up of three two-gun clusters and four individual guns. The purpose of the clusters is to provide a larger, more slowly reverberating residual air bubble (which improves overall array tuning) while at the same time reducing the amplitude of that bubble's reverberation, which further improves tuning. One of the 180 in3 air guns within the central cluster is normally turned off and held in reserve as a spare. (b) Detailed side view of the towing arrangement for one of the four identical source strings on the R/V Langseth, drawn to scale for a towing depth of 6 meters.

The airgun array signature depends on the towing depth (Fig. 2). We used a towing depth of 12 m.



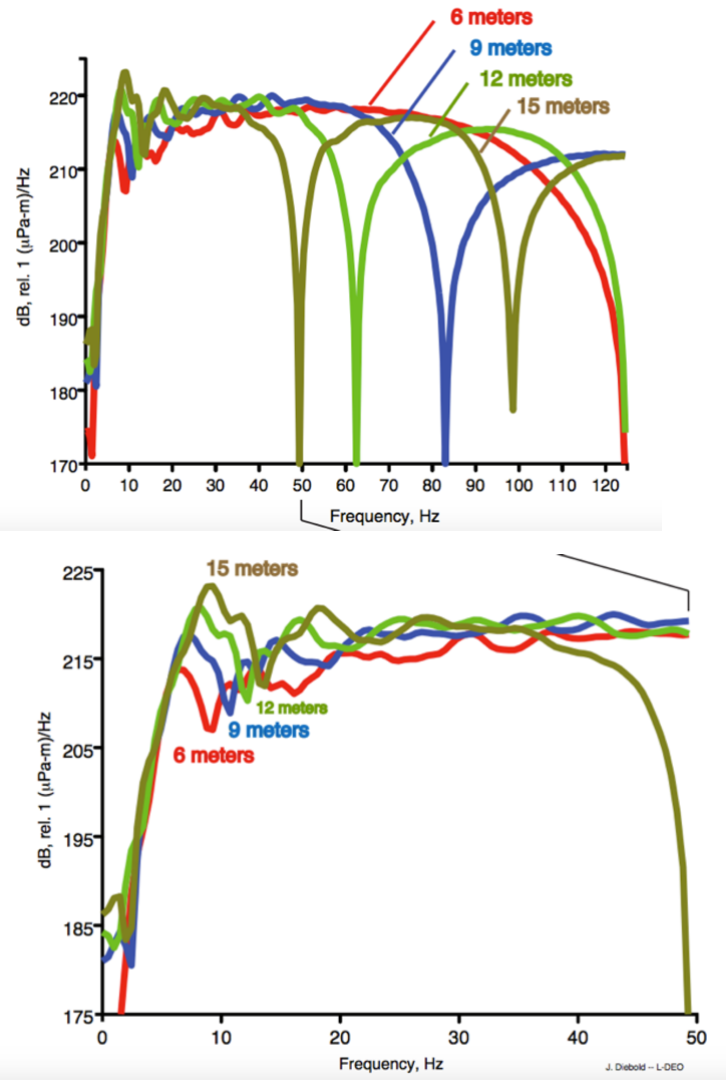


Figure 2: Airgun signature modeled for 12-m tow depth and the frequency response at 4 different tow depths by John Diebold –LDEO using gunsig.

The rate at which sound levels decay around the airgun source depends on the towing depths. Acoustic received levels were quantified using sound exposure level (SEL) calculations. In the U.S.A. the current standard for mitigation is root-mean-square (RMS). The RMS amplitude, typically expressed as dB referenced to 1 mPa, is a measure of the average pressure over the duration of the pulse. It is calculated as the square root of the sum of the squared pressures within a given time window and therefore depends on the selection of this window and its duration. SEL is a measure of the energy flux density of an arrival, defined as the product of signal intensity and duration. Its decibel value (dB referenced to 1 Pa2s) will equal the RMS decibel amplitude if calculated for a 1 s duration window: SEL(dB) = RMS(dB) + 10 log10 (T), where T is the RMS integration time in seconds. For signals with durations <1 s, as expected for an air gun pulse, the SEL value will be less than the RMS. Current practice is to use 170 dB SEL as a proxy for 180 dB for the RMS sound exposure level used in permitting.

Models predicting acoustic levels for the full array were tested using a 6 m towing depth for deep water (~1600 m), intermediate water depth on the slope (~600–1100 m), and shallow water (~50 m) in the Gulf of Mexico (GoM) in 2007–2008 (Tolstoy et al. 2009; Diebold et al. 2010). Simple scaling factors were calculated using the deep water model in order to calculate acoustic levels for a 12 m tow depth (FIG. 3). During power downs a single 1900LL 40-in(_^3) airgun will be used which falls into the low energy source category (Table 1).

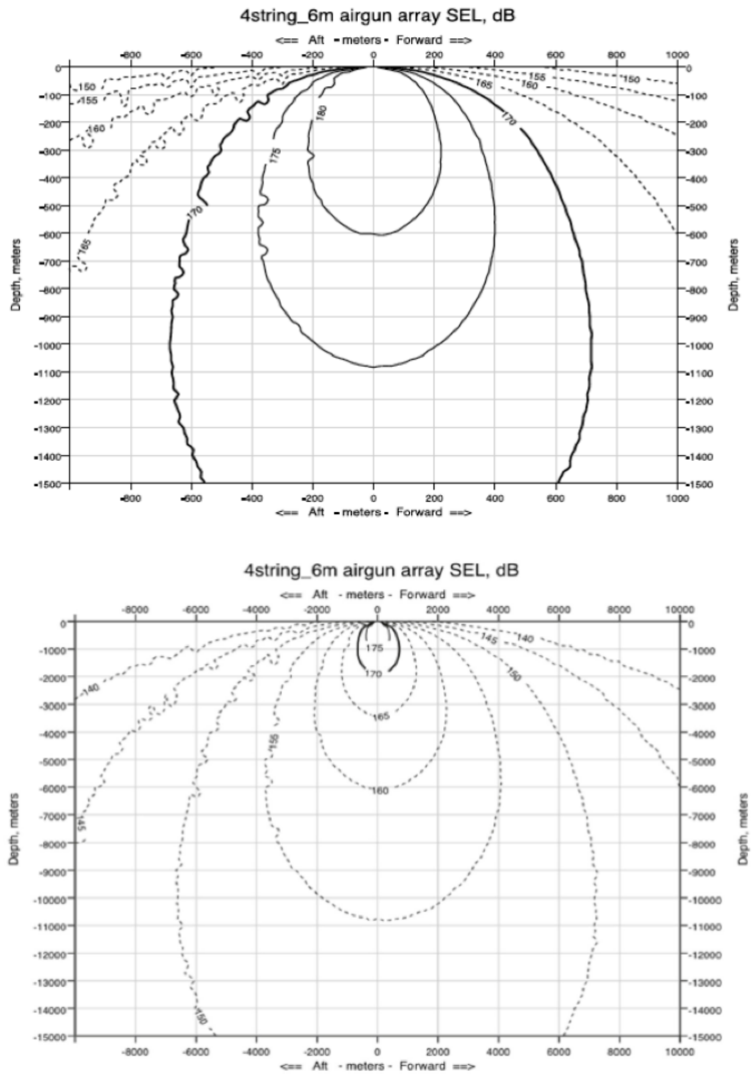


Figure 3: Decibel sound level for the airgun source towed at 9 and 15 m. The contours are SEL (sound exposure level), which is similar to EFD (energy flux density) and RMS sound exposure level with a fixed 1-second integration window.

Table 1: Predicted distances to which sound levels ≥ 190-, 180-, and 160-dB re 1 µ Parms are expected to be received during the proposed survey in the eastern Mediterranean Sea. From the IHA and EA

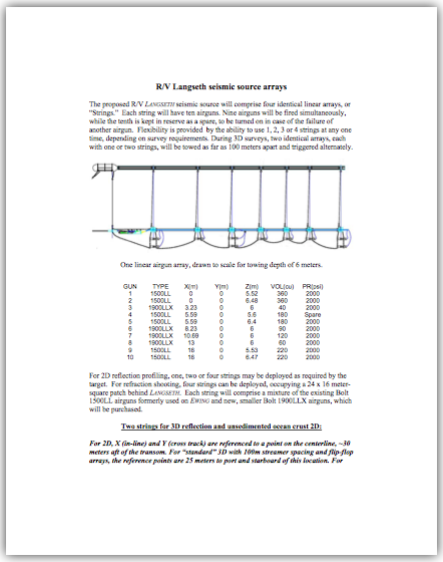
Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted rms Radii (m) 190 dB	180 dB	160 dB
Single Bolt airgun, 40 in^3	9 or 12	>1000 m	100	100	431[1]
		100–1000 m	100	100	647[2]
		<100 m	27[3]	96[3]	1041[3]
4 strings, 36 airguns, 6600 in^3	9	>1000 m	286[1]	927[1]	5780[1]
		100–1000 m	429[2]	1391[2]	8670[2]
		<100 m	591[3]	2060[3]	22,580[3]
4 strings, 36 airguns, 6600 in^3	12	>1000 m	348[1]	1116[1]	6908[1]
		100–1000 m	522[2]	1674[2]	10,362[2]
		<100 m	710[3]	2480[3]	27,130[3]

[1] Distance is based on L-DEO model results.
[2] Distance is based on L-DEO model results with a 1.5 x correction factor between deep and intermediate water depths.
[3] Distance is based on empirically derived measurements in the GoM with scaling applied to account for differences in tow depth.

- MGL1521_Offsets_Source_Only.xls

- MGL1521 Airgun Operations

- Langseth_source_description.pdf



R/V Langseth seismic source arrays

The proposed R/V *LANGSETH* seismic source will comprise four identical linear arrays, or "Strings." Each string will have ten airguns. Nine airguns will be fired simultaneously, while the tenth is kept in reserve as a spare, to be turned on in case of the failure of another airgun. Flexibility is provided by the ability to use 1, 2, 3 or 4 strings at any one time, depending on survey requirements. During 3D surveys, two identical arrays, each with one or two strings, will be towed as far as 100 meters apart and triggered alternately.

One linear airgun array, drawn to scale for towing depth of 6 meters.

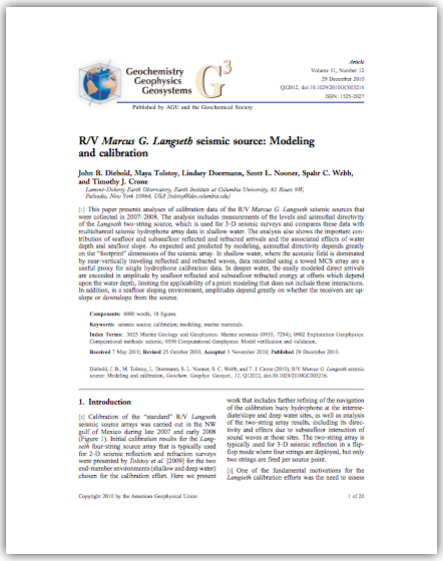
GUN	TYPE	X(m)	Y(m)	Z(m)	VOL(cu)	PR(psi)
1	1500LL	0	0	5.52	360	2000
2	1500LL	0	0	6.48	360	2000
3	1900LLX	3.23	0	6	40	2000
4	1500LL	5.59	0	5.6	180	Spare
5	1500LL	5.59	0	6.4	180	2000
6	1900LLX	8.23	0	6	90	2000
7	1900LLX	10.69	0	6	120	2000
8	1900LLX	13	0	6	60	2000
9	1500LL	16	0	5.53	220	2000
10	1500LL	16	0	6.47	220	2000

For 2D reflection profiling, one, two or four strings may be deployed as required by the target. For refraction shooting, four strings can be deployed, occupying a 24 x 16 meter-square patch behind *LANGSETH*. Each string will comprise a mixture of the existing Bolt 1500LL airguns formerly used on *EWING* and new, smaller Bolt 1900LLX airguns, which will be purchased.

Two strings for 3D reflection and unsedimented ocean crust 2D:

For 2D, X (in-line) and Y (cross track) are referenced to a point on the centerline, ~30 meters aft of the transom. For "standard" 3D with 100m streamer spacing and flip-flop arrays, the reference points are 25 meters to port and starboard of this location. For

- Langseth_shot_model.pdf



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R/V *Marcus G. Langseth* seismic source: Modeling and calibration

John B. Diebold, Maya Tolstoy, Lindsey Doermann, Scott L. Nooner, Spahr C. Webb, and Timothy J. Crone

Lamont-Doherty Earth Observatory, Earth Institute at Columbia University, 61 Route 9W, Palisades, New York 10964, USA (tolstoy@ldeo.columbia.edu)

[1] This paper presents analyses of calibration data of the R/V *Marcus G. Langseth* seismic sources that were collected in 2007–2008. The analysis includes measurements of the levels and azimuthal directivity of the *Langseth* two-string source, which is used for 3-D seismic surveys and compares these data with multichannel seismic hydrophone array data in shallow water. The analysis also shows the important contribution of seafloor and subseafloor reflected and refracted arrivals and the associated effects of water depth and seafloor slope. As expected and predicted by modeling, azimuthal directivity depends greatly on the "footprint" dimensions of the seismic array. In shallow water, where the acoustic field is dominated by near-vertically traveling reflected and refracted waves, data recorded using a towed MCS array are a useful proxy for single hydrophone calibration data. In deeper water, the easily modeled direct arrivals are recorded in amplitude by seafloor reflected and subseafloor refracted energy at offsets which depend upon the water depth, limiting the applicability of a priori modeling that does not include these interactions. In addition, in a seafloor sloping environment, amplitudes depend greatly on whether the receivers are up-slope or downslope from the source.

Components: 6000 words, 18 figures.

Keywords: seismic source; calibration; modeling; marine mammals.

Index Terms: 3025 Marine Geology and Geophysics: Marine seismics (0935, 7294); 0902 Exploration Geophysics: Computational methods: seismic; 0550 Computational Geophysics: Model verification and validation.

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1. Introduction

[2] Calibration of the "standard" R/V *Langseth* seismic source arrays was carried out in the NW gulf of Mexico during late 2007 and early 2008 (Figure 1). Initial calibration results for the *Langseth* four-string source array that is typically used for 2-D seismic reflection and refraction surveys were presented by *Tolstoy et al.* [2009] for the two end-member environments (shallow and deep water) chosen for the calibration effort. Here we present work that includes further refining of the navigation of the calibration buoy hydrophone at the intermediate slope and deep water sites, as well as analysis of the two-string array results, including its directivity and effects due to subseafloor interaction of sound waves at those sites. The two-string array is typically used for 3-D seismic reflection in a flip-flop mode where four strings are deployed, but only two strings are fired per source point.

[3] One of the fundamental motivations for the *Langseth* calibration efforts was the need to assess

- Tolstoy_et_al_G3_2009.pdf

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Data Brief
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Data Brief Article

Broadband calibration of the R/V *Marcus G. Langseth* four-string seismic sources

M. Tolstoy, J. Diebold, L. Doermann, S. Nooner, and S. C. Webb
Lamont-Doherty Earth Observatory, Earth Institute at Columbia University, 61 Route 9W, Palisades, New York 10964-8000, USA (tolstoy@ldeo.columbia.edu)

D. R. Bohnenstiehl
Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh, North Carolina 27695-8208, USA

T. J. Crone and R. C. Holmes
Lamont-Doherty Earth Observatory, Earth Institute at Columbia University, 61 Route 9W, Palisades, New York 10964-8000, USA

[1] The R/V *Marcus G. Langseth* is the first 3-D seismic vessel operated by the U.S. academic community. With up to a four-string, 36-element source and four 6-km-long solid state hydrophone arrays, this vessel promises significant new insights into Earth science processes. The potential impact of anthropogenic sound sources on marine life is an important topic to the marine seismic community. To ensure that operations fully comply with existing and future marine mammal permitting requirements, a calibration experiment was conducted in the Gulf of Mexico in 2007–2008. Results are presented from deep (~1.6 km) and shallow (~50 m) water sites, obtained using the full 36-element (6600 cubic inches) seismic source. This array configuration will require the largest safety radii, and the deep and shallow sites provide two contrasting operational environments. Results show that safety radii and the offset between root-mean-square and sound exposure level measurements were highly dependent on water depth.

Components: 5618 words, 14 figures, 1 table.

Keywords: calibration; Langseth; seismic.

Index Terms: 1035 Exploration Geophysics: Seismic methods (3025, 7294); 3025 Marine Geology and Geophysics: Marine seismics (0935, 7294).

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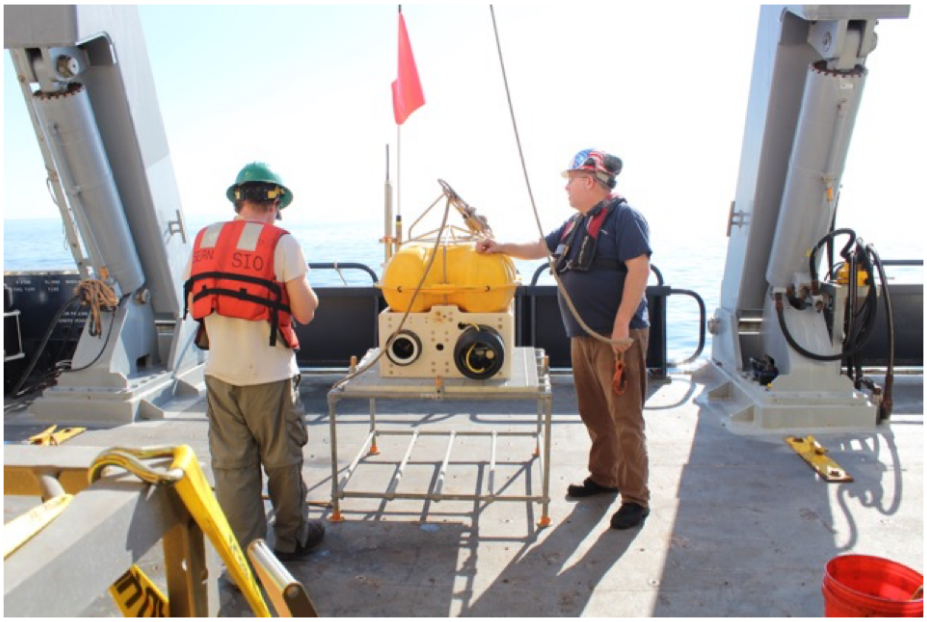
Tolstoy, M., J. Diebold, L. Doermann, S. Nooner, S. C. Webb, D. R. Bohnenstiehl, T. J. Crone, and R. C. Holmes (2009), Broadband calibration of the R/V *Marcus G. Langseth* four-string seismic sources, *Geochem. Geophys. Geosyst.*, *10*, Q08011, doi:10.1029/2009GC002451.

1. Introduction

[2] Anthropogenic sound in the marine environment is an area of increasing concern for the conservation of marine animals [e.g., *Tyack*, 2008]. As a result, the marine seismic community, which uses acoustic energy to image the structure of the crust and upper mantle, has come under increased scrutiny [e.g., *Gordon et al.*, 2004]. In an effort to better understand and mitigate the impacts

A5: SIO OBS Configurations & Performance Summary

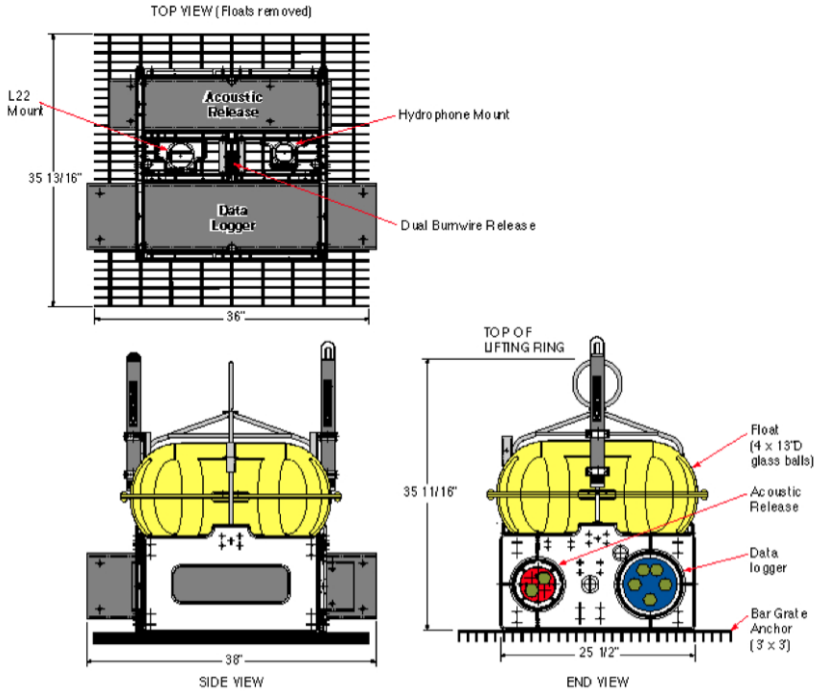
- For the ETOMO experiment, the Scripps Institution of Oceanography (SIO) OBSIP IIC provided 61 short-period ocean-bottom seismometers (OBSs). The SIO team at sea included Ernie Aaron, Mark Gibaud and Sean McPeak.



OBS Configuration

- The Institute of Geophysics and Planetary Physics at Scripps Institution of Oceanography (IGPP/SIO) in conjunction with the Ocean Bottom Seismology Instrument Pool (OBSIP) provided 61 of the 91 total instruments for the Santorini study. The sensors used on the SP-OBS are an Sercel L28 gimbaled 3-component geophone, and a hydrophone. Each instrument is comprised of a 100-pound anchor, a four-ball McLane glass float assembly on which the lifting bail is attached, two syntactic foam blocks are added for additional floatation to aid positive buoyancy, a polyethylene frame holding the sensors, an acoustic release transponder, and two types of mechanical release systems. Two types of data loggers are used. Of the 91 OBSs deployed 26 contain a LC4x4 data logger (data logger labelled *13###*) and 35 contain “new electronics” (data logger labelled *SP###*). According to the SIO OBS team, there is no operational difference between the two loggers.
- The SP-OBS float and frame components are stored separately in a custom rack system and are assembled and tested prior to deployment on a raised preparation platform, which is secured to the deck. The complete instrument weighs approximately 400 pounds in air (with anchor). The anchor is a 100-pound iron grate held to the base of the poly frame by a single 2“ oval quick-link when the release mechanism is cocked and secured. When the anchor is released for recovery, the four 12” glass spherical floats, as well as the syntactic foam blocks provide sufficient buoyancy to lift the instrument at about 45 m/min to the sea surface. To increase visibility at the surface, an orange flag on a 48“ fiberglass-resin staff is attached to the floats. The recovery aids also include a Novatech low-pressure activated strobe beacon and radio, which operates at 160.725 MHz.
- The acoustic release transponder developed in conjunction with ORE/EdgeTech is comprised of a main circuit board, a SIO developed alkaline battery pack, and an ITC-3013 transducer manufactured by International Transducer Corp. These are all installed in and on a 4-5/8” aluminum pressure case. All SIO transponders interrogate at 11 kHz and respond at 13 kHz. The alkaline batteries provide 18 volts power for the burn cycle, 12 volts power for the transponder, and 9 volts power for the circuit board logic. The release mechanisms include a single ORE burnwire and a MELT release system (designed for use in multiple environment types—not salt water specific). The ORE burnwire is the default release mechanism and the MELT release system is included as a backup. The acoustic battery pack provides up to 18 volts to one of two release wires. Release of the anchor typically occurs within 6-7 minutes.

SIO OBS Schematic



SIO SEGY Files

- ***Check Format Post-Processing***
- SIO SEGY files contain one channel per file. For each OBS there are four SEGY files. The naming of the SEGY files and numbering of the data channels is as follows (where ### is the OBS number):
  - OS###_sanshots_L28X.segy; Channels 0 & 1 = horizontals
  - OS###_sanshots_L28Y.segy; Channels 0 & 1 = horizontals
  - OS###_sanshots_L28Z.segy; Channel 2 = vertical
  - OS###_sanshots_HYD.segy; Channel 3 = hydrophone

Hardware-specific FIR Filters

Performance Summary

- OBS 116 not recovered since it would not release
- OBS 107 all data bad
- OBS 152 CF card write error
- OBS 182 no good data - signal issue
- OBS 187 time break errors - perhaps recoverable at SIO
- OBS 129 time break errors - perhaps recoverable at SIO
- OBS 149 hydrophone bad

A6: WHOI OBS Configurations & Performance Summary

- For the Santorini study, the Woods Hole Oceanographic Institute (WHOI) OBSIP IIC provided 30 short-period ocean-bottom seismometers (OBSs). The WHOI team at sea included Alan Gardner, Tim Kane, Jimmie Elsenbeck.

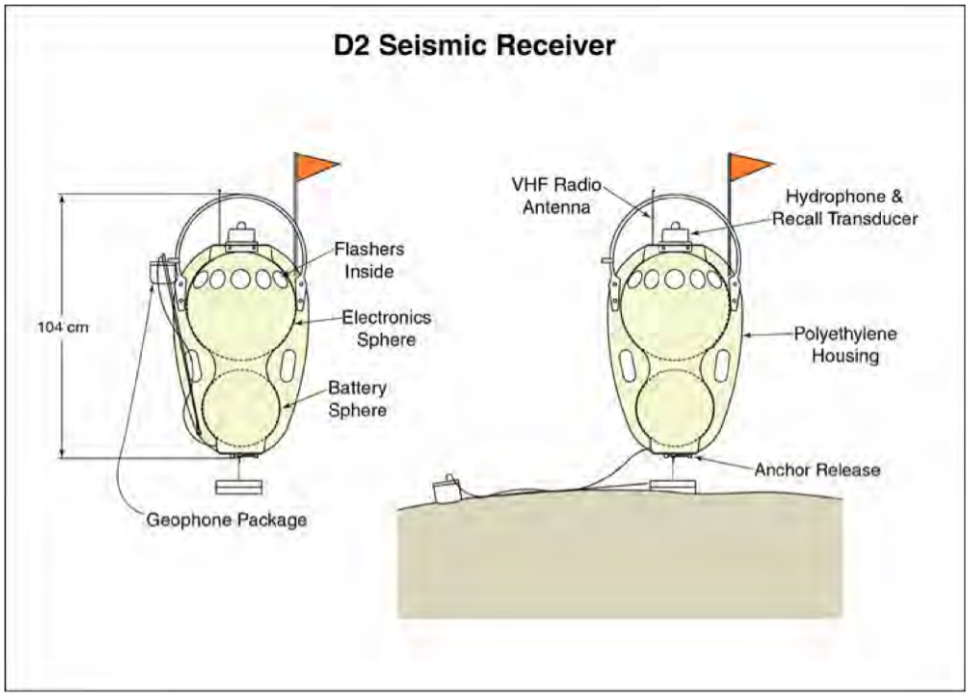
OBS Configuration

- The WHOI short-period OBS, “D2”, is a compact, relatively lightweight system, which allows recording of three components of ground motion and one of pressure at sampling rates of up to 200 Hz. Physically, D2 is comprised of two glass balls containing electronics and batteries enclosed within a rigid plastic housing. The system stands 39“ high and weighs approximately 115 lb in air (with anchor).
- The upper glass ball (17” diameter) contains a Quanterra Q330 data engine, a Quanterra Packet Baler storage device with 20 GB hard disk and Ethernet hub, an EdgeTech acoustic release board, recovery aids, and custom electronics. A Seascan clock is located on a system control board and is accessible via a serial ASCII current loop. Recovery aids include four flashers and a programmable VHF radio with a minimum range at sealevel of ~2 nm. The VHF antennae is attached to the inside surface of the glass ball. The Q330 includes operating software, a low-power analog-to-digital converter with 140 dB dynamic range, digital filters, clock, and 8-16 Mbytes of buffer memory. Engineering data and four channels of signal are continuously recorded and intermittently logged via an Ethernet connection onto the disk drive in miniSEED format. For this experiment, we used a sample rate on all data channels of 200 Hz. In the lower glass ball (10“ diameter) are battery packs comprised of both alkaline and lithium cells that supply power separately to the Q330 and hard drive, the recovery electronics board and aids, and to the EdgeTech release board (separate cells for acoustic ranging and releasing). Ethernet connections can be used to program the operating software and to recover data from the hard drive.
- The external plastic case or ”hard hat“ provides protection for the glass balls and structural rigidity. An ITC 12 kHz acoustic transponder is attached to the upper cover of the case. Next to the transponder is a HighTech

model HTI 1-90-U hydrophone. Three orthogonally mounted 4.5 Hz geophones are mounted in a 5” diameter (5.5“ high) titanium case, which is attached by a weighted cable through the plastic case to the upper electronics ball. The case is filled with high viscosity silicone oil. Internal gimbals allow the geophones to passively orient themselves with respect to gravity through 180 degrees of motion. Prior to deployment, a bail is screwed to the seismometer case, and the bail is hooked to the tip of a 23” long fiberglass wand. The bottom of the wand is attached to the base of the plastic housing by a rotatable joint. The tip of the wand and the seismometer are raised and attached to the side of the plastic housing by a galvanic link that dissolves in seawater after ~4 hours. When the link dissolves, gravity carries the sensor can out and away from the D2. The sensor can slips from the tip of the wand, which is then pulled up and away from the can by a bungee cord.

- The D2 has ~25 lb of buoyancy and is weighted by a 55 lb steel plate anchor (6“x15”x2“). A 9” length of stainless steel wire rope to a 2“ diameter ring connects the anchor plate. The ring is held to the D2 by a lever arm. One end of the lever arm is attached to the D2 base plate by a burn-wire that can be severed by an electric current triggered by a coded acoustic signal to the EdgeTech transponder. A battery that is separate from the battery supplying power to the Q330 and the hard drive powers the burn-wire and the release electronics.

▼ WHOI OBS Schematic



WHOI SEGY Files

- *****Check Format Post-Processing*****

▼ WHOI SEGY files contain all four channels in one file. For each OBS there is one SEGY files. The naming of the SEGY file and the numbering of the data channels is as follows (where ### is the OBS number):

- 1E_OS###_ELZ_EL1_EL2_EDH.segy (E1 is the IRIS DMC network code)
- Channel 1 = vertical
- Channels 2 & 3 = horizontals
- Channel 4 = hydrophone
- ***This is different from the numbering system used in the SIO SEGY headers**

Hardware-specific FIR Filters

OBS Performance Summary

- OBS 180 was noisey due to shallow water depth at deployment site.
- OBS 172 had a flooded can and the vertical did not record good data. The hydrophone did.

A7: EM122 Multibeam Collecting & Processing

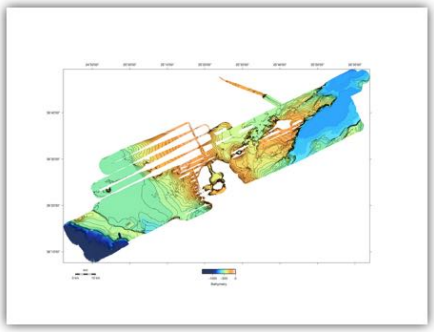
- **A. Figures**
- **B. Data Collection**
  - The bathymetric data was collected using R/V Marcus Langseth's Simrad EM122 12kHz multibeam echo sounder. The vessel entered the survey boundary at 11/20/2015 04:34:34.394 JD 324, 36°.7947N 25°3953E, where the data acquisition commenced.

    During the deployment and the recovery of the OBSs the EM 122 was disabled at each site to avoid interference with the acoustic release and ranging of the OBSs. Moreover, after the deployment of W140 and S160 OBSs additional survey lines were conducted on south west side of caldera to determine the appropriate path to enter in order to avoid shallow water area and ensure that the string of guns towed at 12m below the sea surface did not hit the sea bottom.

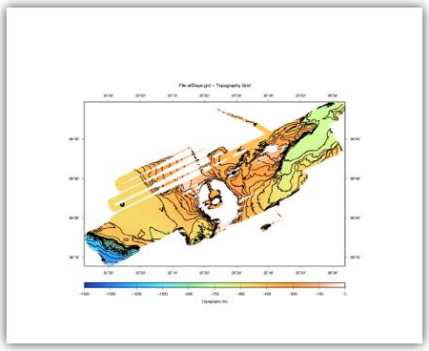
    The EM 122 has a maximum swath width up to 6 times the water depth depending on the sea state. During the first days of the survey, especially when shooting the outer lines (1-4) the data was of very good quality, the center and outermost beams didn't have significant scatter. The data was of poorest quality when heading into rough seas and the outermost beams had significantly more scatter than the inner ones. The ping mode was set to SHALLOW and the swath angle to 75° (depths < 450m) and then narrowed down to 68° (depths > 450m) to achieve highest possible resolution. During the cruise 28 XBT's were launched but only the first 19 imported in the SVP editor (except the 15th and 16th that were launched into the Kolumbo and the 17th that malfunctioned). Moreover, on 12/03/2015 at 1:48am the EM 122 crashed for one minute, worthwhile taking into account while processing. After the recovery of the OBSs and multiple attempts to recover OBS 116, additional survey lines were conducted at the southern part of Santorini.

    Data was acquired by the EM 122 system into half hour Simrad ".all" files with the filenames ####_YYYYMMDD_HHMMSS_Langseth, where "####" is a sequential file starting with "0000" and ending with "0968".The files were processed with MB-SYSTEM.

- allDays_preprocessed-reduced.jpg



- allDays_manualProcessed.grd



- **A. Processing Performed at Sea**
  - Processing of the raw multibeam data was performed using the open source software package MB-System (http://www.ldeo.columbia.edu/res/pi/MB-System/). Gilles Guerin (Marine Tech.—ACQ) provided the well-commented document 'multibeam_processing' (under **D. Routines**) that provides descriptions and examples of the MB-System commands used to covert raw files, clean the data, and generate .grd files for GMT.

The first step in processing was the definition of a vessel configuration file "langseth.hvf". Because the EM122 system includes corrections for the relative positions of sensors on the boat, the Heave, Pitch, Roll, Gyro and Navigation sensors were assigned coordinates in meters [X(positive to Forward), Y(positive to Standboard), Z(positive Downward)] of [0,0,0] and in degrees [Roll, Pitch , Heading]. The correct values for the Transducer were set to [20.925, 0.570, 8.459] and [0.1603, -0.0772, 359.99]. The correct values for the Receiving transceiver were set to [16.068, 0.050, 8.535] and [0.1603,-0.0772, 0.00] and the Waterline was set to Z=+1.94.

The MB-SYSTEM processing steps applied during the cruise comprised:

B. Generation of a Preliminary ".grd" Grid and GMT Maps

MB-SYSTEM is an open source software package for the processing and display of bathymetry and backscatter imaginary data. Some pre-processing steps are required before the bathymetric data can be processed using MB-System. Firstly the vendor format should be recognised. The onboard *RV MARCUS LANGSETH* hull-mounted Kongsberg EM122 uses the format ID 58, whereas the format 59 is needed for further processing with MB-System.
Every raw file was converted as followed:

1. Converting the data

- Extract file names and use it for output

#file name
is /data/CruiseData/MGL1521/raw/multibeam/MGL1521/2015/11/23/0195_20151123_233959_Langseth.all
sed replaces the _ by spaces
awk combines words 2 and 3 (20151123 and 233959)

```
set file59 = `echo $file  | sed s/_/" "/g | awk '{print $2$3}'`
```

- Convert the raw file to the required format

mbcopy -I file -F58/59 -O output.mb59 (This works for one file for an entire datalist use mbm_copy)
-F58/59 means convert form raw format mb58 to mb59
-O is for the name of the output file

2. Cleaning the data

- Create a list of all the files

```
ls *.mb59 > files.mb59
mbclean  -C60/2 –S60/3/2  -I files.mb59  -F-1 –M2
```

-C defines the maximum slope accepted between beams -2 is the unit (1 = radian; 2 = degrees) -60/2 means 60 degrees
-S defines what qualifies as spikes -same convention as C the unit (1 = radian; 2 = degrees) -60/3/2 means 60 degrees and that spikes can be identified in both directions (3), across track and along track.
-F format – negative value means list of files
-G can be used to flag data where depth is different from median beam –G0.8/1.2 will limit beams with depth between 0.8x median_beam and 1.2xmedian_beam

3. mbprocess to clean the data flagged by mbclean

- Generates files with the same name and a p before the extension (processed) (i.e. p.mb59)

```
mbprocess  –I files.mb59  -V  -P
```

-I defines the input list
-V when added the program works in a "verbose" mode and outputs the used program
Version
-P every file will be processed

4. Generate Grid File

- First create the list with the processed files

```
Sed s/.mb59/p.mb59/g files.mb59 > processed_files.mb59

mbgrid  –A2  –I processed_files.mb59  –E50/50  –O  grid1  –N
```

-A2 means bathymetry data are given negative values

-O is for the name of the output file
-E50/50 is the grid size cell
-N is to ensure that missing data are filled with NaN to be ignored

- To generate the grid for the raw data

mbgrid –A2 –I files.mb59 -E50/50 -O files_raw.grd -N -R25.9/26.1/36.7/36.8
-R defines the limits, which is necessary for the "raw"

This command creates a .cmd file and when executed produces a postscript showing a preliminary plot of the grid file.

Every produced grid was checked and several files were further processed as followed:

- **Create a list:** ls *p.mb59 > datalist_p59 containing all the files that need more detailed processing
- **Create the ancillary files:** mbdatalist -F-1 -I datalist_p59 -V –N

-F format –negative values means list of files
-I Input list of files
-N generates the three ancillary files (*inf; *fbt; *fnv)
-V when added the program works in a "verbose" mode and outputs the used program version

- **Examination of data points and flagging:** mbedit, mbeditviz
- **Process the data:** mbprocess -I datalist_p59 –V –P

-I defines the input list
-V when added the program works in a "verbose" mode and outputs the used program version
-P every file will be processed

mbprocess will generate files with the same name and a second p before the extension meaning that the file was twice processed.

- **Create a new list:** ls *pp.mb59 > datalist_pp59

Generate Grid: mbgrid –A2 –I datalist_pp59 –E50/50 –O grid1 –N
-A2 means bathymetry data are given negative values
-O is for the name of the output file
-E50/50 is the grid size cell
-N is to ensure that missing data are filled with the NaN to be ignored

NOTE: Due to the abrupt changes in the seafloor morphology (basins, volcanic edifices, fault zones) the command mbclean sometimes flagged correct beams. It is recommended to get a first impression of the dataset by generating a plot.

mbm_plot -F-1 –I datalist –G2 –N –PA4
-F format –negative values means list of files
-G2 colour fill swath plot is turned on and the style of the plot is defined, different modes. In this case Mode 2 = colour shaded relief bathymetry, Mode 1 = colour fill of bathymetry data
-N causes a navigation track plot
-PA4 page size A4

C. MB-System Processing not Performed at Sea

MB-System can be used for additional processing.

1. 1.Interactive Flagging of Bathymetry using mbeditviz and mbedit
2. 2.Generate grids (mbgrid) using thin plate spline interpolation and choosing between the available gridding algorithms.
3. 3.Export the acoustic backscatter and the sidescan sonar data for further analysis.

D. Outstanding Questions/Tasks

1. 1. Verify that the Vessel Configuration is correct
2. 2. Ensure that there are not systematic spatial or temporal changes in the water column velocity. Reprocessing using mbvelocitytool.
3. 3. Additional processing as mentioned above.

E. Routines

- bathymetry.sh

- run_mbgrid.sh
- multibeam_processing

```
------------ 1 - converting raw files (*Langseth.all)-----------------
58 is the original format
if you don't know the format use mbinfo
mbinfo -I /data/CruiseData/MGL1521/raw/multibeam/
MGL1521/2015/11/23/0195_20151123_233959_Langseth.all

#for one file
mbcopy -I file -F58/59 -O output.mb59
-F58/59 means convert form raw format mb58 to mb59
-O is for the name of the result

#shell command using sed and awk to extract file names and use it for output
#file name is /data/CruiseData/MGL1521/raw/multibeam/
MGL1521/2015/11/23/0195_20151123_233959_Langseth.all
# sed replaces the _ by spaces
#/data/CruiseData/MGL1521/raw/multibeam/MGL1521/2015/11/23/0195 20151123
233959 Langseth.all
# awk combines words 2 and 3 (20151123 and 233959)

foreach file (/data/CruiseData/MGL1521/raw/multibeam/MGL1521/2015/11/23/
*.all)
set file59 = `echo $file  | sed s/_/" "/g | awk '{print $2$3}'`
mbcopy -I $file -F58/59 -O "$file59".mb59
end

---------------- 2 - cleaning the data  ----------------
#first create a list of the files
ls *.mb59 > files.1123

mbclean -C60/2 -S60/3/2 -I files.1123 -F-1 -M2
# -C  defines the maximum slope accepted between beams - 2 is the unit (1 =
radian; 2 = degrees) -60/2 means 60 degrees
# -S  defines what qualifies as spikes - same convention as C the unit (1 =
radian; 2 = degrees) -60/2 means 60 degrees
# spikes can be identified only acrosstrack (1) along track (2) or in both
directions (3)
# -M defines the mode for cleaning - 1 flags only furthest beam - 2 flags two
beams associated with slope
# -F format - negative value means list of files
# -G can be used to flag data where depth is different from median beam -
G0.8/1.2 will limit beams with depth bewtween 0.8xmedian_beam and
1.2xmedian_beam

----------3 - mbprocess to clean the data flagged by mbclean --------
mbprocess -I files.1123 -F-1
# this generates files with the same name and a p before the extension (i.e.
p.mb59)

----------4 - mbgrid to create a .grd file that can be read in GMT
----------
# first create list with the processed files
sed s/.mb59/p.mb59/g files.1123 > processed_files.1123
mbgrid -A2 -I processed_files.1123 -E50/50 -O 1123_processed -N

# -A2 means bathymetry data are given negative values
# -E50/50 is the resolution of the grid 50mx50m
# -O is for the name of the output file (1123_processed will become
1123_processed.grd )
# -N is to ensure that missing data are filled with NaN to be ignored
```

- Appendix A6-V3
- EdittingTasksTable.pdf

Dan O'Hara coordinated the workflow, checked and gathered all the files to create the preliminary grid.

SWATH EDITING		
Year-Day	Person	Swath Files Edited
2015-328	Claire	20101647p
	Gillean	20111824p
		20131104p
		20101030p
2015-329	Marialena	21191922p
		21221521p
	Melissa	21024053p
		21083454p
		21224521p
		21232430p
		21232430p
		21231328p
	Danai	21173917p
		21176320p
2015-330	Claire	22102411p
		22113303p
		22021956p
2015-331	Gillean	23023958p
		23031001p
		23104003p
		23193959p
		23224002p
		23233959p
2015-332	Melissa	24021002p
		24004001p
		24023959p
		24033959p
		24034000p
		24041000p
		24111001p
	Claire	24164001p
		24204001p
		24213001p
		24214000p

A8: Knudsen 3.5 kHz Processing

KNUDSEN PROCESSING.docx

This Appendix contains the following sections:

- **1.** Where to find things
- **2.** Issues with the Knudsen data
- **3.** Initial processing of the Knudsen data
- **4.** Useful pieces of code

1. Where to find things:

- Knudsen raw files are found in MGL1521/raw/knudsen/.
- Processed files are in MGL1521/processed/knudsen
- The processing flow and fortran files described below are in MGL1521/public/knudsen_processing
- The Windows software by Knudsen for processing and converting the files is locations in MGL1521/public/knudsen_processing/Knudsen_software

2. The were several issues with the Knudsen data:

- **1.** the time headers are not stored at a constant offset, but vary depending on the seafloor topography.
- **2.** Shallow sea also means the Knudsen subbottom profiler pings at a higher frequency.
- **3.** All Knudsen files were logged one day ahead of the actual date (the computer date-time was ahead one day), this holds for both the month-day and yearday format.

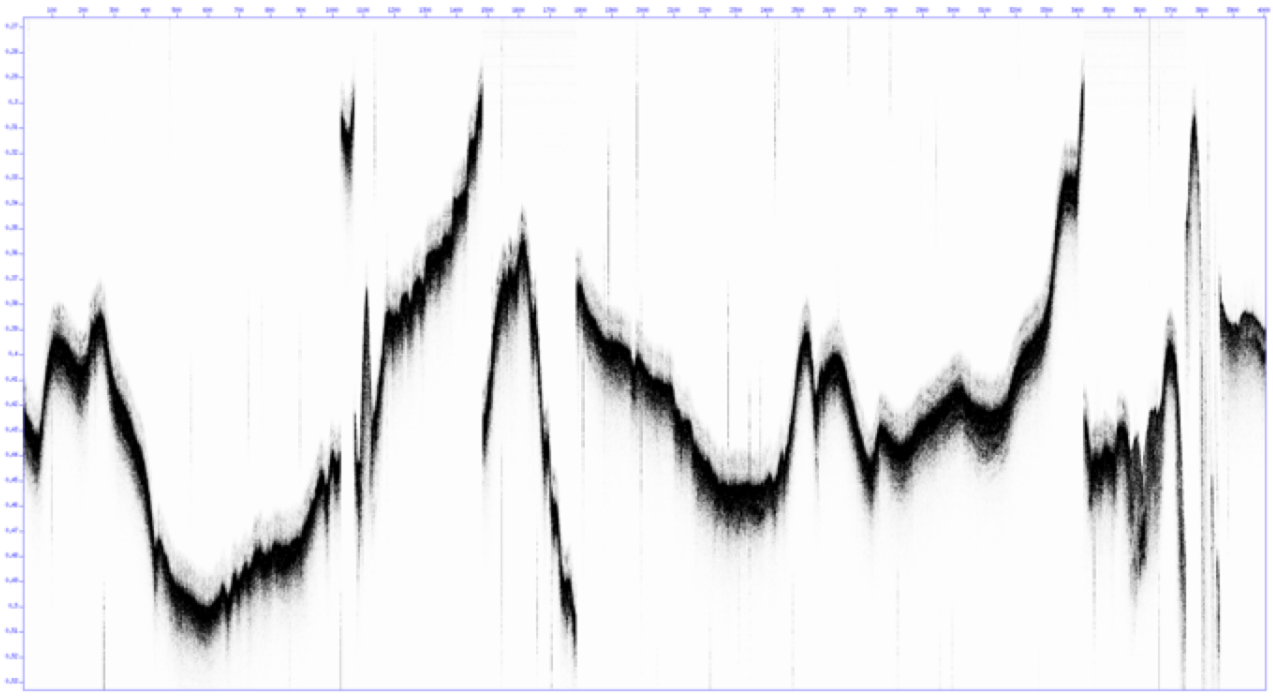


Figure 1: segy image of Knudsen 3.5kHz data for 1 half-day data file
In an attempt to work around this problem, we have processed the data using a Fortran code rather than in traditional seismic processing software.

3. Initial processing of the Knudsen data was carried out using the following steps:

1. Data was converted from its raw form (.keb) to segy using the onboard SounderSuite conversion utility.

2. A code (attached) written by Gilles Geurin then converted the segy files to .su format. The data were sampled in time by 0.5 and in space by using 1 in every 5 traces in order to reduce computational cost. There

were some issues with the headers of the Knudsen data in that they contained a different sampling rate than the true sampling rate for reasons unknown

3. The seafloor was then extracted from the files. A basic filter of 10,100,2000,2100 was applied to make seafloor picking easier and the gain increased, and data normalized in order to make the automated seafloor picking easier. These steps were done as a QC as some data were quite noisy, and the processed, subsampled smoother data was checked to make sure in coincided with the general sea floor depth in the raw data files.

4. A fortran code, mgl_pinger2xyz, also written by Gilles Guerin then converted the data to xyz format in order to plot the results in GMT. The section of the code works as follows:

```
mgl_pinger2xyz << eoi
n
xxxxxxx
xxxxxxx
xxxxxxx
xxxxxxx
x_min x_max y_min y_max
eoi
```

With n – the number of su files you wish to plot.
xxxxxxx – the name of the .su files.
x_min x_max – minimum and maximum longitude to be plotted.
y_min y_max – minimum and maximum latitude to be plotted.
eoi – signals the end of input and allows the code to run.

5. Fence diagrams are then plotted after the user specifies:
i. azi – horizontal angle of view from 0 = north
ii. theta – vertical angle from 0 (side) to 90 (top)
limits – these must be the same as x_min x_max y_min y_max specified above.

6. The code then creates a .ps file, and then converts it to a .png to reduce memory as well as rendering the background transparent, which is useful for overlaying the plots.
An example follows:

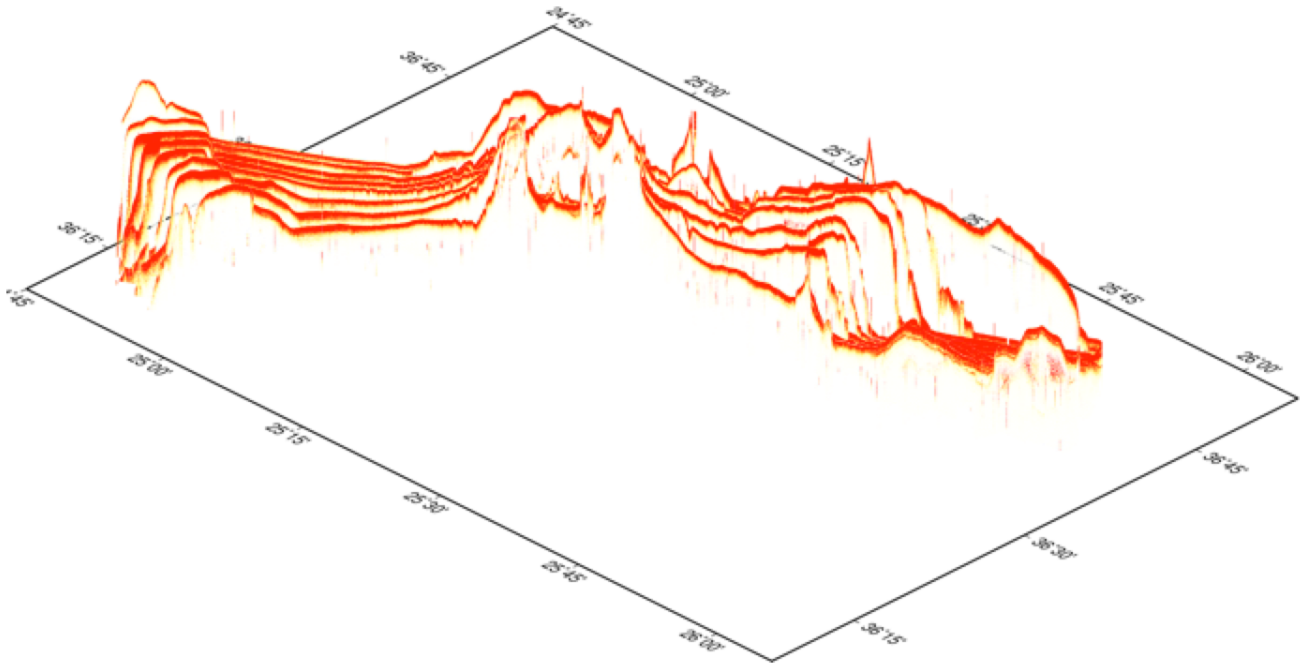


Figure 2: Plot of 12 .su files of Knudsen data

This plot is made using 12 data files; 3390648.su, 3381903.su, 3380820.su, 3372207.su, 3371524.su, 3370220.su, 3361332.su, 3360304.su, 3351656.su, 3351656.su, 3342308.su and 3341027.su

From the plot we can see the central region of Santorini, as well as the 2 basins either side as well as several fault zones.

By editing the x_min x_max y_min and y_max values, we can ‘zoom in’ on the fault zone to the elft of Figure 1.

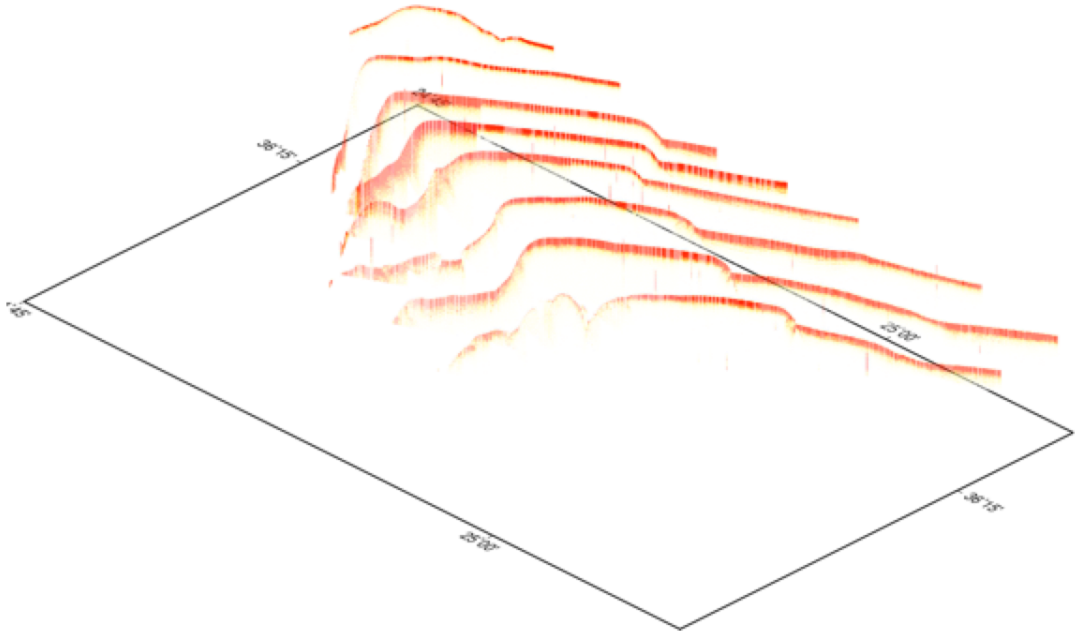


Figure 3: Zoomin of fault zone to the left of Figure 1

Doing so allows us to look at the fault to gain some insight into the sediments below and the onlapping features in order to determine whether the fault is still active.

- A later update was added to the procedure in order to map specific areas more conveniently. This is useful especially when adjusting the sampling so that we are using all data without subsampling, which uses more computational cost. The command is outlined at the end of the EchoSounder_plotting.v2 document under ‘**** New procedure****’. Here we can specify the name of the file we are creating by changing ‘prefix’. We then input the angles we wish to view the map by changing the ‘deg’ for azimuth and elevation and west/east/north/south should be replaced by the latitude and longitude coordinates required for your plot. This update means that the data in the specified area is resampled for maximum resolution rather than resampling the whole area which may lead to a loss in resolution.

4. Useful pieces of code:

- EchoSounder_plotting.v2
- plot_knudsen
- mgl_pinger2xyz.f
- amplitude.cpt
- 3.5kHz.cpt

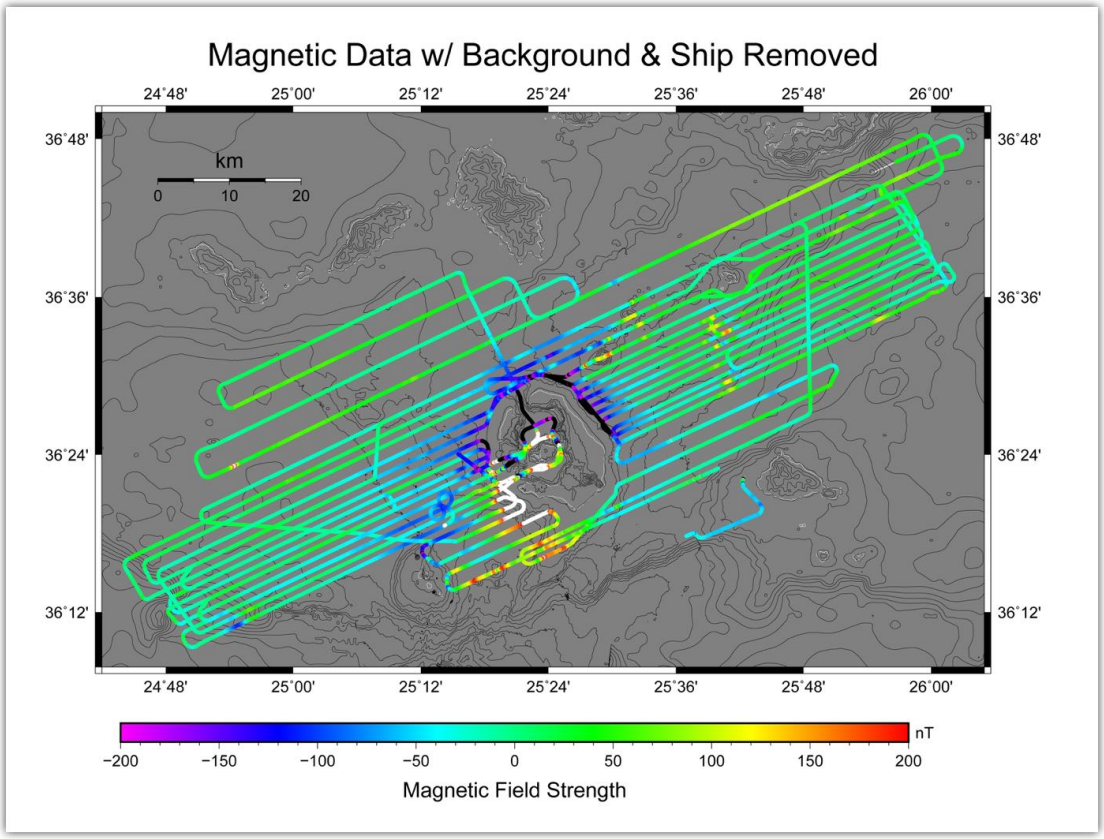
A9: Magnetics Processing

MAGNETICS

This appendix contains the following sections:

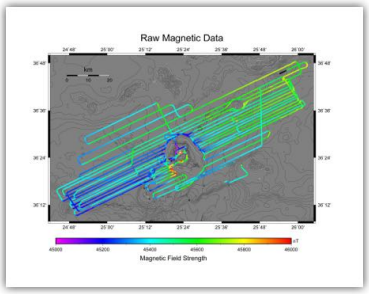
- **1.** Plots
- **2.** Instrument detail
- **3.** Processing Methodology
  - Collection
  - Merging
  - Filtering and quality control
  - Background magnetic field removal
  - Ship magnetic field removal
  - Final data and output
- **4.** Useful codes

1. Plots

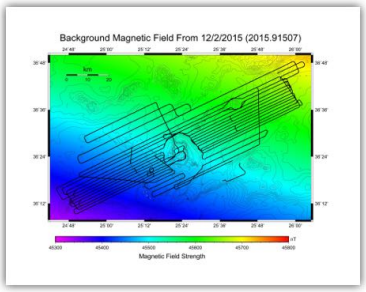


Magnetic_corrected.jpg

Magnetic_raw.jpg



Magnetic_background.jpg



2. Instrument Detail:

- The magnetic field was recorded using a GeoMetrics 882 magnetometer towed nominally 60 meters astern of the vessel on starboard side. Data was logged to the LDEO data logging system. The system performed well during the survey. Approximately 1,380,000 points of data were collected.

  Instrument: GeoMetrics 882 Cesium Marine Magnetometer System Specifications
  Operating Principle: Self-oscillating split-beam Cesium Vapor (non-radioactive)
  Operating Range: 20,000 to 100,000 nT
  Operating Zones: The earth's field vector should be at an angle greater than 6° from the sensor's equator and greater than 6° away from the sensor's long axis. Automatic hemisphere switching is standard.
  CM-221 Counter Sensitivity: <0.004 (nT/√Hz) rms. Up to 10 samples per second
  Heading Error: ±1 nT (over entire 360° equatorial and polar spin)
  Absolute Accuracy: <3 nT throughout range
  Output: RS-232 at 1,200 to 19,200 Baud
  Mechanical: Sensor Fish: Body 2.75 in. (7 cm) dia., 4.5 ft (1.37 m) long with fin assembly (11 in. cross width), 40 lbs. (18 kg) Includes Sensor and Electronics and 1 main weight. Additional collar weights are 14lbs (6.4kg) each, total of 5 capable
  Tow Cable: Kevlar Reinforced multiconductor tow cable. Breaking strength 3,600 lbs, 0.48 in OD, 200 ft maximum. Weighs 17 lbs (7.7 kg) with terminations.
  Operating Temperature: -30°F to +122°F (-35°C to +50°C)
  Storage Temperature: -48°F to +158°F (-45°C to +70°C)
  Water Tight: O-Ring sealed for up to 9000 ft (2750 m) depth operation
  Instrument Location: The towfish was an approximate 60 m behind the NRP (navigation reference point where the vessel position is resolved) as detailed in the Offsets Configuration file (Attachment 4).

3. Processing Methodology:

Data processing was completed using a series of Matlab functions and script files (see schematic, fig. 1). All processing was completed through the header function UpdateAll (Attachment 1). Each step of processing is outlined below.

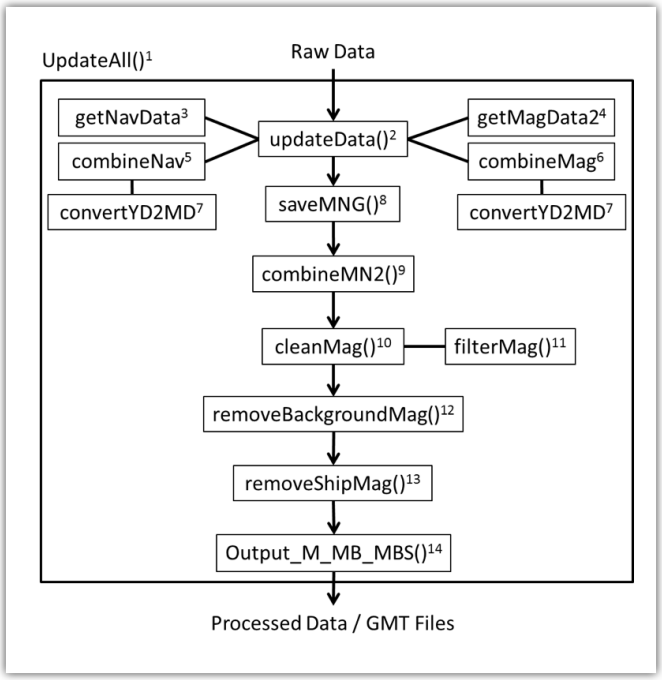


Figure 1. Schematic of Matlab files used during magnetic data processing steps.

- **Collection**: Raw magnetic (date, time, field strength) and CNav navigation (date, time, latitude, longitude, heading) data was collected from each separate day of the cruise (Attachments 2, 3, 4). Afterwards, data from the separate days were formatted and combined to a single magnetic and navigation table (Attachments 5, 6, 7 8). Main formatting at this stage involved converting the date and time format of the raw data (Year, Yearday, Hour, Minute, Second) to a serial date format.
- **Merging**: Raw magnetic data was merged with the CNav navigation data using the serial date data field (Attachment 9). Since the magnetic and navigation data were collected at separate frequencies (0.1 and 1 Hz, respectively), data was matched to the closest second.
- **Filtering and Quality Control**: Data was automatically checked for missing or erroneous values which fell outside 0.4 standard

deviation away from the mean (Attachment 10). Afterwards, high-frequency features were filtered out of the data using a 10m moving-window average (Attachment 11).

- **Background Magnetic Field Removal**: We estimated the background magnetic field during the cruise using the International Geomagnetic Reference Field 2012 (IGRF 2012) model and a predictive model of the secular variation for adjusted dates between 2015 and 2020. We created a 10m grid of background magnetic variation using the midway cruise date (12/2/15, 2015.91507) and subtracted it from the raw data (Attachment 12). Values in the grid ranged [45310, 45734] nT (fig. 2). Across the cruise dates (11/22/15 – 12/15/15), the magnetic field at the grid boundaries (latitude: [24.7353, 26. 0488], longitude: [24.7353, 26.7353]) varied <3 nT.

- **Ship Magnetic Field Removal**: Using the method of Buchanan et al. (1996), we further corrected the data by removing the ship's magnetic field (Attachment 13). The magnetic field of the ship (f_s) at a given heading (in azimuth) is given by the equation:

$$f_s = a_1 + a_2 \cos\left[(h+\theta)\right] + a_3 \cos\left[(2(h+\theta))\right] \quad (1)$$

Where h is the ship heading, θ is the angle of the magnetometer relative to the ship, and a_1, a_2, and a_3 are constant coefficients. From the raw magnetic field with the background signal removed, we collected the mean and standard deviation of field values over 2 degrees of heading from measurements located away from the Santorini caldera to remove bias from extreme maxima and minima (fig. 3, black dots). Using the mean and standard deviation values (fig. 3, white diamonds, purple lines, respectively), we used a least squares approach to calculate the coefficients a_1, a_2, and a_3. Afterwards, we fit different values of θ to the equation to find the value that best shifted the curve to match the data. The least squares method found coefficient values of -55.9669, -116.7476, and 42.7715, respectively, after three iterations with a relative residual of 6.3 x10-15. Furthermore, we found a θ value of -8° best matches the observed data (fig. 3, green line). Thus, our corrections for ship magnetic field are defined by the equation:

$$f_s = -55.9669 - 116.7476 \cos(h-8) + 42.7715 \cos\left[(2(h-8))\right] \quad (2)$$

For each data measurement, the ship's magnetic field was calculated from the measurements heading and was subsequently removed.

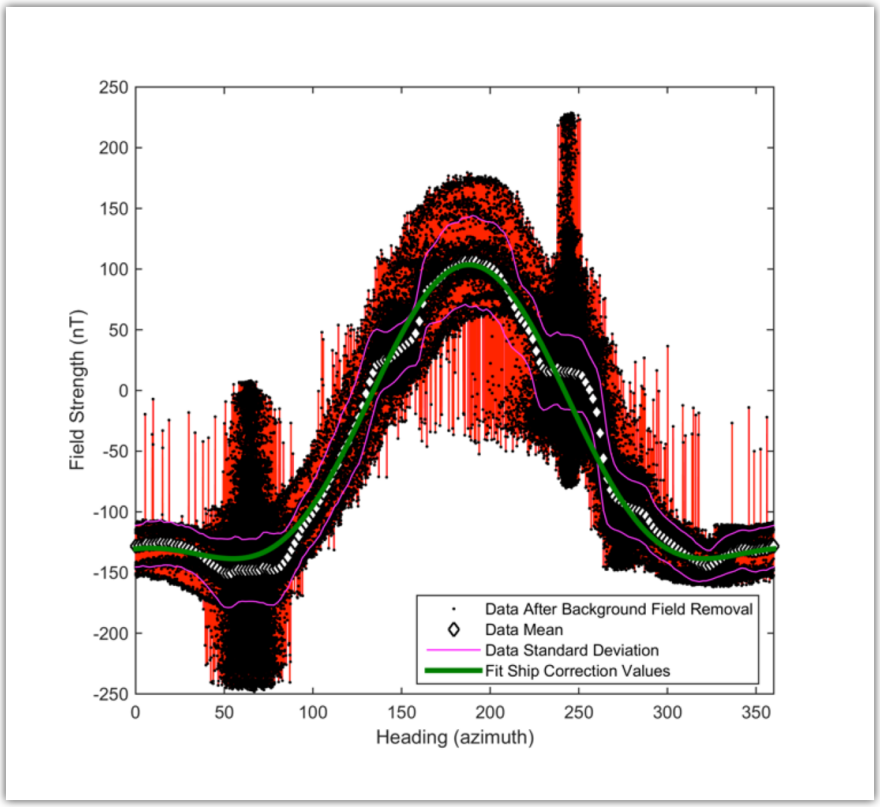


Figure 2. Ship magnetic field correction. Black dots with red lines are raw data with background field removed. White diamonds are mean field strength taken at 2° intervals with standard deviation above and below the mean given by purple lines. Green line is the fit to the data using equation (2).

- **Final data and output**: The final data contains the navigation position and the corrected total field readings after background and ship magnetic field correction in one second intervals matched to the navigation GPS timestamp at the nearest second. The latitude, longitude, and total field strength is then output to data files to use in map generation (Attachement 14).

4. Useful codes:

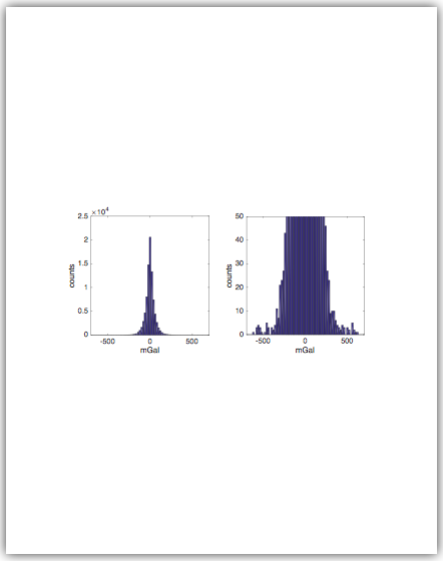
- cleanMag.m
- combineGN2.m
- combineMag.m

- combineMN2.m
- combineNav.m
- convertYD2MD.m
- filterMag.m
- getMagData2.m
- getNavData.m
- output_M_MB_MBS.m
- removeBackgroundMag.m
- removeShipMag.m
- saveMNG.m
- UpdateAll.m
- updateData.m

A10: Gravity Processing

- The gravity field was recorded using a Bell Aerospace BGM-3 marine gravimeter. Gravity data was collected throughout the duration of the experiment with measurements taken every 1-second. Gravity measurements were displayed in real-time on a monitor in the main lab. The gravimeter appeared to be functioning properly and producing good quality data. Only the raw data is available upon completion of the cruise. All data processing is performed by LDEO science support staff following the cruise.
- The raw data can be found in: MGL1521/raw/serial/. All the file names are formated as follows: MGL-vc01.yxxxxdzzz where xxxx is the year and zzz is the Julian day on which the samples were collected.
- **Instrument Detail**
  - Bell Aerospace BGM-3 Marine Gravity Meter
  - Data is output at 1-second intervals and logged on a LDEO logger system
  - The raw gravity measurements are stored as counts. Counts are linearly mapped to mGals using routines kept by LDEO.
  - The raw data for each day is stored in a text file. These files have the following format:
    - *vc01 year:Julian_day:hour:min:sec (to 4 decimal place) XX:counts YY*
    - The leading “vc01” identifies the document as gravity readings; “XX” is the output frequency (Hz); The “counts” value is the raw gravity reading (unitless); and “YY” is the sensor status (unitless).
  - The location of the gravimeter relative to the navigation reference point (NRP) of the *R/V M. G. Langseth* is detailed in the attached document, “MGLSensorConfiguration”.
    - MGLSensorConfiguration

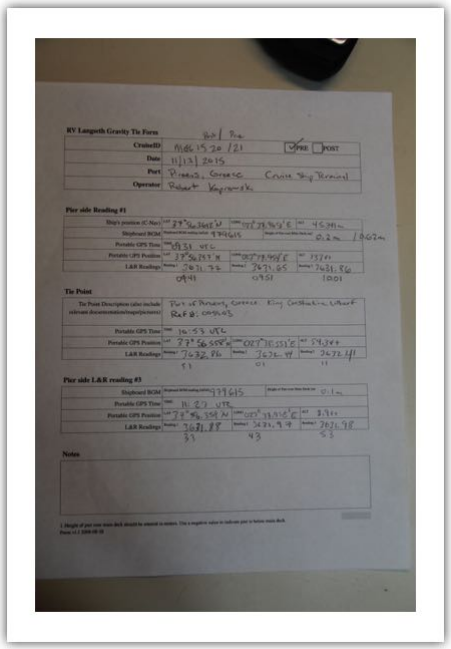
- **Quality Control**
  - Calibration: We could not obtain information on the gravitmeter calibration.
  - Dropped Scans: All data logged is checked for droped scans using “checktimes_rev”, a LDEO program that checks the time difference between each sample.
  - Spot-checks: Occasionally, the raw gravity counts for a given day were converted to mGals and plotted as a histogram as a first-order check of the data quality (verifying a reasonable range of gravity values is recorded). The attached pdf shows the raw gravity measurements for Julian day 320 of the cruise. A reasonable range of values is recorded with some outliers.
    - RawGravHist_y2015d320.pd



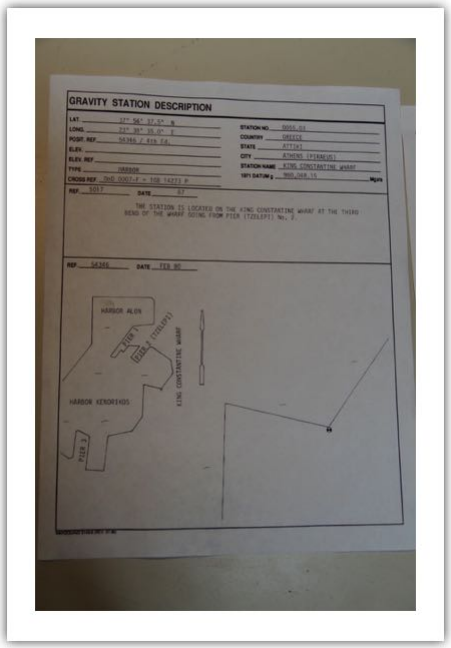
  - Gravity Ties: A gravity tie was performed at the cruise ship terminal in Piraeus, Greece on 2015/11/13 at an absolute gravity tie point prior to departure using a LaCoste Romberg G portable gravimeter by LDEO science personnel, Robert Koprowski. A second gravity tie was performed at the

conclusion of the experiment in Heraklion on 2015/21/15 (performed in same manner as the first). The gravity tie form and documents describing the station locations are attched below.

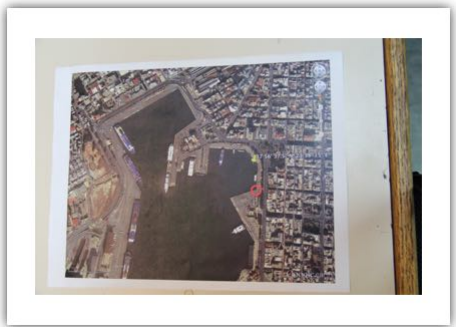
- Start of Missions Docs
  - MGL1521_Start_Mission_Gravity_Tie_Form.jpg



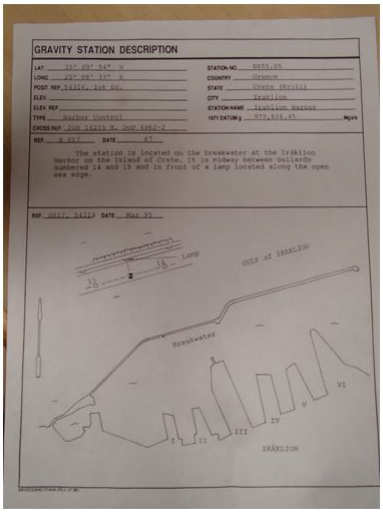
  -



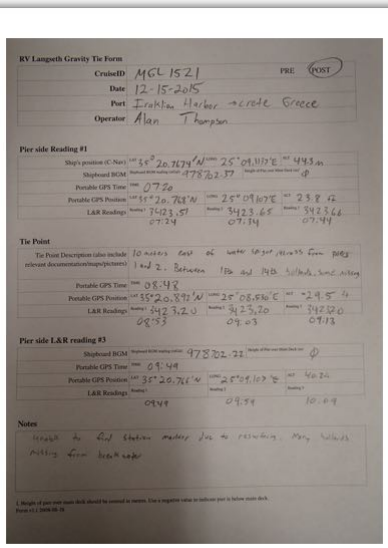
  - MGL1521_Start_Mission_Gravity_Tie_StationDescription.jpg
  - MGL1521_Start_Mission_Gravity_Tie_Map.jpg



- End of Mission Docs
  - MGL1521_End_Mission_Gravity_Tie_PG1.JPG



- MGL1521_End_Mission_Gravity_Tie_PG2.JPG



- PC151618.JPG

- Drift: Based on the first gravity tie (**date**), the initial DC shift calculated on **YYYY/MM/DD** is **XX** mGals. Based on the second gravity tie (**date**), the final DC shift calculated on **YYYY/MM/DD** is **YY** mGal. From the inital and final DC shifts, the estimated drift of the gravimeter is **ZZ** mGals/day. **Potsdam correction was removed from the absolute gravity tie point as the BGM-3 outputs uncorrected gravity values.**

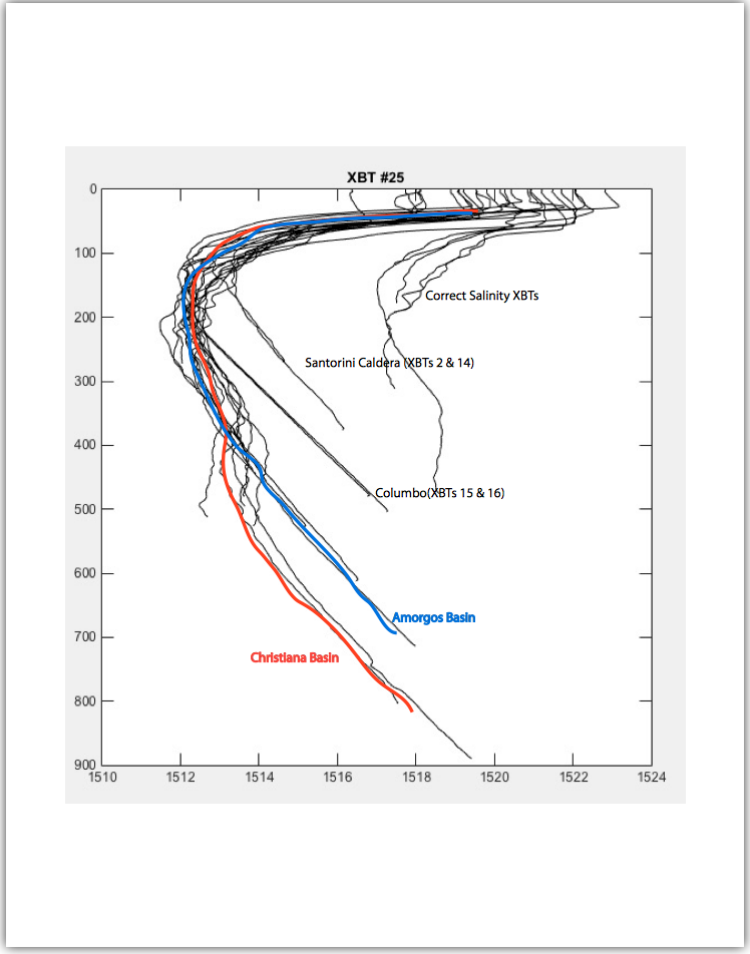
Processing Methodology

- NOTE! All processing and data reduction is performed by LDEO science support staff following the completion of the cruise. None of the processing routines are available aboard the Langseth. At the time of the cruise completion, only the raw data (see **Instrument Detail** for raw data format) is available.

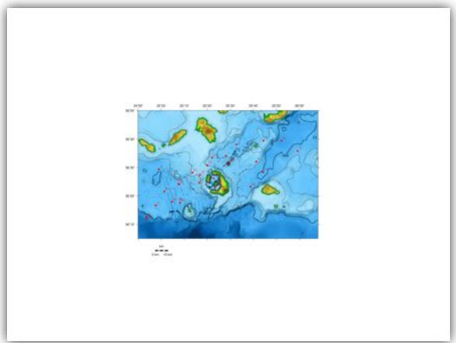
- The raw 1-second gravity counts are filtered with a 360-second Gaussian filter. Counts are converted to mGal via a linear relationship. The gravity data is merged with the navigation attributes (latitude, longitude, course, and veocity) via the GPS time stamp. Eotvos correction is then applied to the dataset. Data plots are generated and visually checked to determine satisfactory Eotvos corrections. Data spikes caused by turns and other anomalies are deleted from the dataset. The Free-air anomaly (FAA) is then calculated using the 1987 International Gravity Formula (IGF). The final dataset is decimated to one-minute samples.
- EOTVOS Correction: Corrects for artificial gravity effects due to changes in the ship's coarse and speed. The correction is given by:
  - EOTOVS = [7.5038 * V_E* cos(phi)] + [0.004154 * V_T]
  - Where V_T is the ship speed in knots, V_E is the eastward component of the ship's velocity, and phi is latitude in degrees. These velocities are derived from a smoothed GPS navigation using LDEO developed scripts.
- Free-air Anomaly: The FAA reduces the gravity measurements by removing the gravitational effects of the reference ellipsoid. This will be done using an LDEO program. The 1987 IGF is:
  - g(phi) = 978032.68 * [1 + 0.00193185138639 * $\sin^2$(phi)]/sqrt[1 - 0.00669437999013 * $\sin^2$(phi)]
  - Where g is absolute gravity and phi is latitude.
  - Historical Note: Earlier cruises have used the 1980, 1967, and 1930 gravity formula in calculating the FAA. Since these all differ by a constant, it is necessary to check the formula used in a particular survey prioir to merging data across multiple experiments.

A11: XBT Profiles

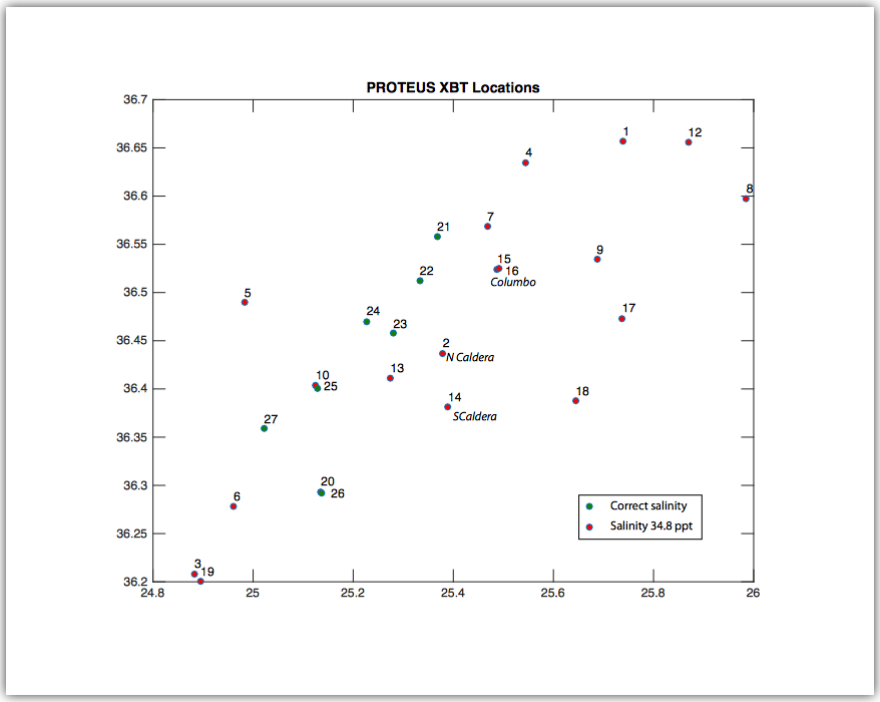
- During the PROTEUS project, the water's temperature versus depth was measured using XBT's (T-7 & T-5), Expendable Bathythermographs. XBT's were dropped at various points in the survey area every single day. Using this information, the sound velocity and temperature was found for the water column.
- **Water velocity and Sounding Velocity**: Figure 1 showing the XBT data collected during the PROTEUS project. The recorded file during the launch is edited and then imported to MultiBeam System. The blue lines show the sound velocity for each XBT launch. The black shows the average sound velocity for Christiana basin while the cyan shows the average sound velocity for Amorgos basin. The green line shows the average sound velocity for salinity value 34.8 ppt (first measurements were conducted with this value) and the magenta line shows the average for salinity value 38.8 (corrected after 20th XBT). Yellow line shows the sounding velocity for 34.8 ppt and the red one shows the sounding velocity for 38.8 ppt. Mean OBSs depth is between 400 m and 600 m. Sounding velocity does not vary over this depth range. Travel time difference between the two different velocities is dt = 0.5/1.514 - 0.5/1.5186 = 1 msec.
- AllXBTs.pdf



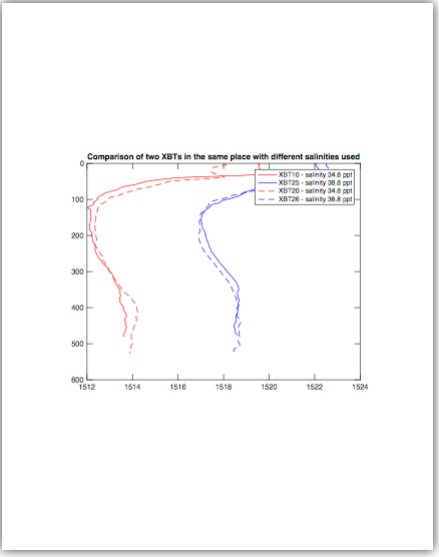
- xbt_loc.jpg



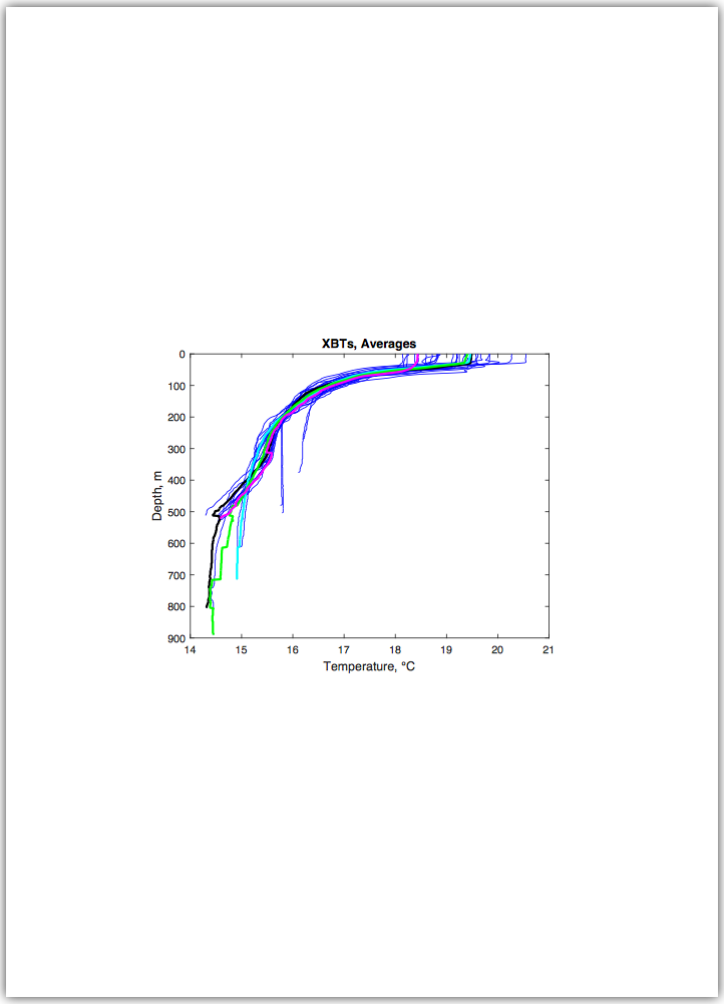
- XBTLocations-annotated.pdf



- XBT-salinityComparison.pdf



- **Temperature distribution**: Figure 2 showing the temperature measurements collected from XBTs launches. The blue lines show the temperature distribution for each XBT. The black shows the average temperature for Christiana basin while the cyan shows the average for Amorgos basin. The green line shows the average temperature for salinity value 34.8 ppt and the purple line shows the average temperature for 38.8 ppt.
  - Figure 2.pdf

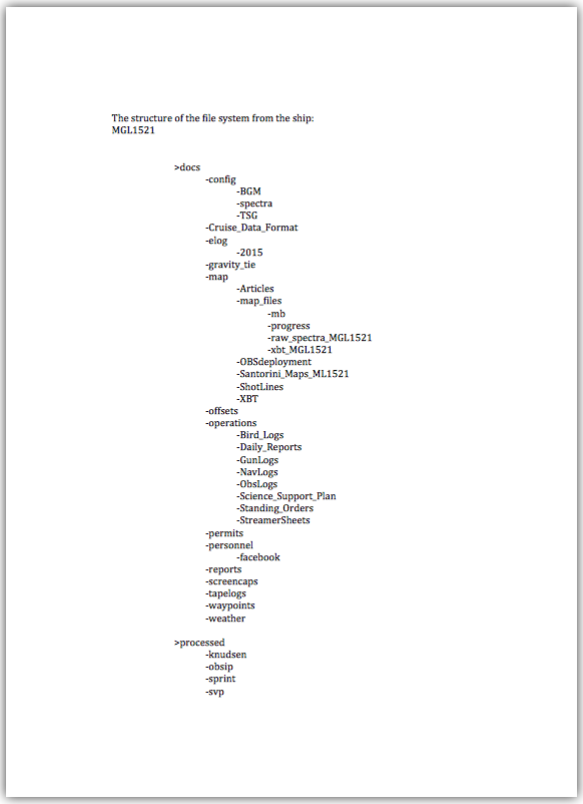


- **Procedure for collecting XBTs**: The MK-21/ISA Bathythermograph Data Acquisition System, employed during this study, is a portable data acquisition system that measures and outputs ocean temperature, conductivity and sound velocity versus depth using expendable probes that are launched from surface ships. The Sippican expendable probe is a small oceanographic sensor, which measures the water temperature. The probes free-fall in the ocean at a known rate while collecting the data.
- **To launch a probe from a vessel**, the canister containing the probe is first inserted into a Sippican Hand-Held Launcher. Contacts on the canister provide the electrical connections to the launcher which is connected by cable to the MK21 interface board. When the probe is ready to be launched, the operator pulls a release pin out of the canister, and the probe slides out of the canister into the water. The probe's hydrodynamic shape allows it to descend through the water at a stable and known rate, enabling continuous calculation of its depth throughout the entire descent. As the probe descends, its sensors continuously measure the water temperature. The measurements are transmitted by a wire back to the MK21 interface board. The wire de-reels both from a spool in the probe as the probe descends and from a spool in the canister as the vessel from which the probe was launched moves along the surface. This dual spooling technique enables the wire to remain stationary in the water. Soon after the probe reaches its maximum depth, its wire breaks and the probe continues its descent to the ocean floor.

- XBT'S.xlsx
- vel_profile.m

A12: R/V Marcus G. Langseth Sensor Configuration & Data Formats

File system structure from the ship: the MGL1521 folder

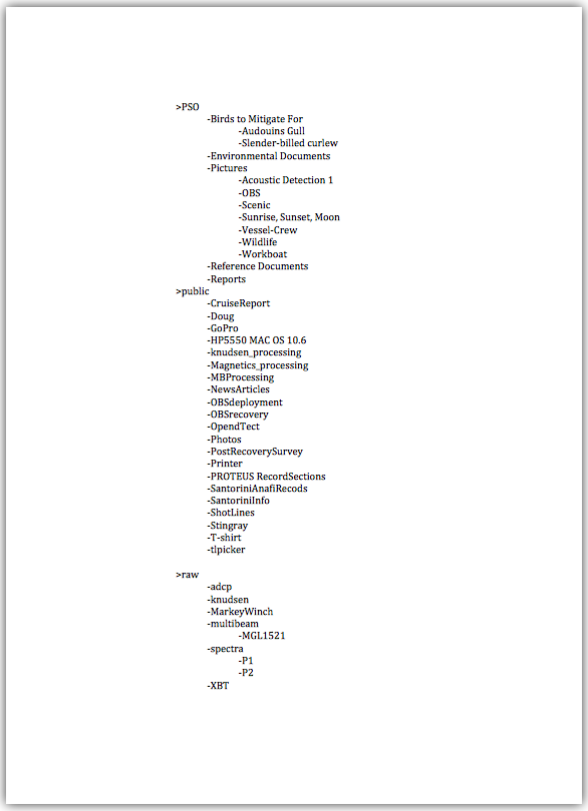


The structure of the file system from the ship:
MGL1521

>docs
-config
-BGM
-spectra
-TSG
-Cruise_Data_Format
-elog
-2015
-gravity_tie
-map
-Articles
-map_files
-mb
-progress
-raw_spectra_MGL1521
-xbt_MGL1521
-OBSdeployment
-Santorini_Maps_ML1521
-ShotLines
-XBT
-offsets
-operations
-Bird_Logs
-Daily_Reports
-GunLogs
-NavLogs
-ObsLogs
-Science_Support_Plan
-Standing_Orders
-StreamerSheets
-permits
-personnel
-facebook
-reports
-screencaps
-tapelogs
-waypoints
-weather

>processed
-knudsen
-obsip
-sprint
-svp

Page 1



>PSO
-Birds to Mitigate For
-Audouins Gull
-Slender-billed curlew
-Environmental Documents
-Pictures
-Acoustic Detection 1
-OBS
-Scenic
-Sunrise, Sunset, Moon
-Vessel-Crew
-Wildlife
-Workboat
-Reference Documents
-Reports
>public
-CruiseReport
-Doug
-GoPro
-HP5550 MAC OS 10.6
-knudsen_processing
-Magnetics_processing
-MBProcessing
-NewsArticles
-OBSdeployment
-OBSrecovery
-OpendTect
-Photos
-PostRecoverySurvey
-Printer
-PROTEUS RecordSections
-SantoriniAnafiRecods
-SantoriniInfo
-ShotLines
-Stingray
-T-shirt
-tlpicker

>raw
-adcp
-knudsen
-MarkeyWinch
-multibeam
-MGL1521
-spectra
-P1
-P2
-XBT

Page 2

Sensor Configuration

- Excel spreadsheet with diagram showing:
  - towing configuration
  - airgun array offsets
  - vessel sensor offsets (gravity meter, GPS antennas)
  - acoustic offsets
  - gun configuration

- MGL1521_Offsets_Source_Only.xls 

Data Formats

- AML Oceanographic - MicroX SV-Xchange Sensor Data.pdf 
- Applanix POSMV GPS-MRU Data.pdf 
- Bell Aerospace BGM-3 Gravimeter Data.pdf 
- C-Nav 2000 GPS System Data.pdf 
- C-Nav 3050 DGNSS GPS Recieve Data.pdf 
- Furuno DS-50 Doppler Speedlog Data.pdf 
- Furuno FE700 Echosounder Data.pdf 
- Geometrics G-882 Cesium Marine Magnetometer Data.pdf 
- Kongsberg EM122 Multibeam - Centerbeam Depth Data.pdf 
- Kongsberg Seapath 200 GPS-MRU Data.pdf 
- Lamont Data Systems - UDP Port Datagrams.pdf 
- Lamont-Doherty pCO2 (Merge) Data.pdf 
- Lamont-Doherty pCO2 Data.pdf 
- OBSIP Shotlog Format.pdf 
- RM Young Meteorological Station Data.pdf 
- Seabird Electronics - SBE 45 - Thermosalinograph.pdf 
- Simrad GC-80 Gyro Data.pdf

Vaisala WXT-520 Weather Station Data.pdf

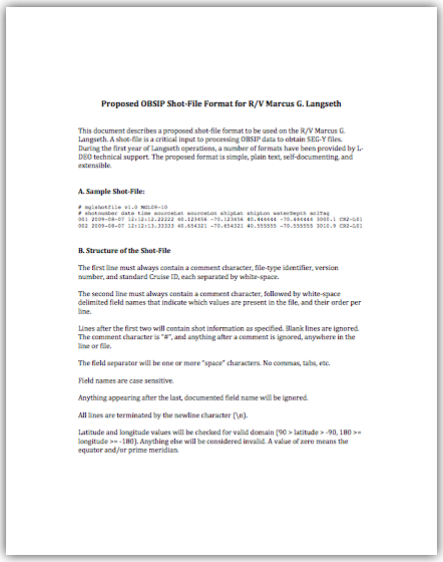
A13: Reading OBSIP log Files and SEGY Files

Included in this appendix are the following:

- **1.** Description of the shot log files and MATLAB function to read this format.
- **2.** Description of the SEGY file naming, channel labeling conventions, and SEGY documentation
- **3.** MATLAB files to read the SEGY files into tlPicker

1. Shot Log Files

- For each line the seismic survey is a shot log. The log files are named according to the convention: MGL1521OBS##.obsip or MGL1521T##.obsip, where ## is the seismic line number. In the former case, the line number goes from 01 to 43, whereas the latter goes from 01 to 10. This naming convention is described in Appendix A2: MGL1521 Seismic Survey Summary.
- WHOI provided the following description of the OBSIP shot logs for the ETOMO experiment. This description is also applicable to the shot logs generated during the PROTEUS experiment.
- OBSIPshotFile



Proposed OBSIP Shot-File Format for R/V Marcus G. Langseth

This document describes a proposed shot-file format to be used on the R/V Marcus G. Langseth. A shot-file is a critical input to processing OBSIP data to obtain SEG-Y files. During the first year of Langseth operations, a number of formats have been provided by L-DEO technical support. The proposed format is simple, plain text, self-documenting, and extensible.

A. Sample Shot-File:

```
# mglshotfile v1.0 MGL09-10
# shotnumber date time sourcelat sourcelon shiplat shiplon waterdepth multag
001 2009-08-07 12:12:12.22222 40.123456 -70.123456 40.444444 -70.444444 3000.1 CN2-L01
002 2009-08-07 12:12:13.33333 40.654321 -70.654321 40.555555 -70.555555 3010.9 CN2-L01
```

B. Structure of the Shot-File

The first line must always contain a comment character, file-type identifier, version number, and standard Cruise ID, each separated by white-space.

The second line must always contain a comment character, followed by white-space delimited field names that indicate which values are present in the file, and their order per line.

Lines after the first two will contain shot information as specified. Blank lines are ignored. The comment character is "#", and anything after a comment is ignored, anywhere in the line or file.

The field separator will be one or more "space" characters. No commas, tabs, etc.

Field names are case sensitive.

Anything appearing after the last, documented field name will be ignored.

All lines are terminated by the newline character (\n).

Latitude and longitude values will be checked for valid domain (90 > latitude > -90, 180 >= longitude >= -180). Anything else will be considered invalid. A value of zero means the equator and/or prime meridian.

- MATLAB function to read OBSIP shot logs, entitled read_obsip_shotlog_proteus.m
  - read_obsip_shotlog_proteus.m

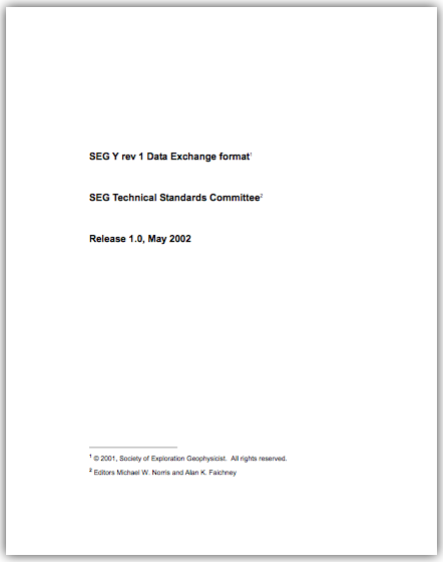
- Script to run read_obsip_shotlog.m and save the LAT-LON coordinates of each shot as an .xyz file for use with GMT; the script is entitled shotlog2GMT.m.
  - shotlog2GMT.m

2. SEGY Files

- SEGY file naming convention
  - **SIO SEGY files** contain one channel per file. For each OBS there are four separate SEGY files. The naming of the SEGY files and numbering of the data channels is as follows (where ### is the OBS Number):
    - OS###_MGL1521_L28X.segy; Channels 0 & 1 = horizontals
    - OS###_MGL1521_L28Y.segy; Channels 0 & 1 = horizontals
    - OS###_MGL1521_L28Z.segy; Channel 2 = vertical
    - OS###_MGL1521_HYD.segy; Channel 3 = hydrophone
  - **WHOI SEGY files** contain all four channels in one file. For each OBS there is one SEGY file. The

naming of the SEGY file and the numbering of the data channels is as follows:

- 1E_OS###_ELZ_EL1_EL2_EDH.segy (1E is the IRIS DMC ID assigned to the experiment and ### is the OBS number).
  - Channel 1 = vertical
  - Channels 2 & 3 = horizontals
  - Channel 4 = hydrophone
  - • *This is different from the numbering system used in the SIO SEGY headers*
- Documentation on the SEGY format
  - seg_y_rev1.pdf



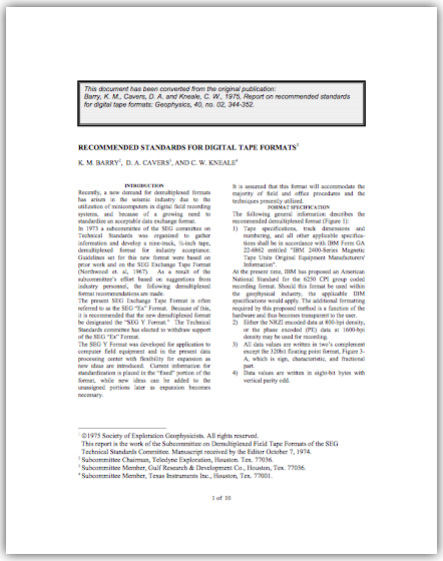
SEG Y rev 1 Data Exchange format[1]

SEG Technical Standards Committee[2]

Release 1.0, May 2002

[1] © 2001, Society of Exploration Geophysicist. All rights reserved.
[2] Editors Michael W. Norris and Alan K. Faichney

  - seg_y_rev0.pdf



This document has been converted from the original publication:
Barry, K. M., Cavers, D. A. and Kneale, C. W., 1975, Report on recommended standards for digital tape formats: Geophysics, 40, no. 02, 344-352.

RECOMMENDED STANDARDS FOR DIGITAL TAPE FORMATS[1]

K. M. BARRY[2], D. A. CAVERS[3], AND C. W. KNEALE[4]

INTRODUCTION

Recently, a new demand for demultiplexed formats has arisen in the seismic industry due to the utilization of minicomputers in digital field recording systems, and because of a growing need to standardize an acceptable data exchange format. In 1973 a subcommittee of the SEG committee on Technical Standards was organized to gather information and develop a nine-track, ½-inch tape, demultiplexed format for industry acceptance. Guidelines set for this new format were based on prior work and on the SEG Exchange Tape Format (Northwood et. al., 1967). As a result of the subcommittee's effort based on suggestions from industry personnel, the following demultiplexed format recommendations are made.

The present SEG Exchange Tape Format is often referred to as the SEG "Ex" Format. Because of this, it is recommended that the new demultiplexed format be designated the "SEG Y Format." The Technical Standards committee has elected to withdraw support of the SEG "Ex" Format.

The SEG Y Format was developed for application to computer field equipment and in the present data processing center with flexibility for expansion as new ideas are introduced. Current information for standardization is placed in the "fixed" portion of the format, while new ideas can be added to the unassigned portions later as expansion becomes necessary.

It is assumed that this format will accommodate the majority of field and office procedures and the techniques presently utilized.

FORMAT SPECIFICATION

The following general information describes the recommended demultiplexed format (Figure 1):

1) Tape specifications, track dimensions and numbering, and all other applicable specifications shall be in accordance with IBM Form GA 22-6862 entitled "IBM 2400-Series Magnetic Tape Units Original Equipment Manufacturers' Information".

At the present time, IBM has proposed an American National Standard for the 6250 CPI group coded recording format. Should this format be used within the geophysical industry, the applicable IBM specifications would apply. The additional formatting required by this proposed method is a function of the hardware and thus becomes transparent to the user.

2) Either the NRZI encoded data at 800-bpi density, or the phase encoded (PE) data at 1600-bpi density may be used for recording.
3) All data values are written in two's complement except the 32(8)0 floating point format, Figure 3-A, which is sign, characteristic, and fractional part.
4) Data values are written in eight-bit bytes with vertical parity odd.

[1] ©1975 Society of Exploration Geophysicists. All rights reserved.
[2] This report is the work of the Subcommittee on Demultiplexed Field Tape Formats of the SEG Technical Standards Committee. Manuscript received by the Editor October 7, 1974.
[3] Subcommittee Chairman, Teledyne Exploration, Houston, Tex. 77036.
[4] Subcommittee Member, Gulf Research & Development Co., Houston, Tex. 77036.
[5] Subcommittee Member, Texas Instruments Inc., Houston, Tex. 77001.

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- **3. MATLAB functions to read the binary SEGY files into tlPicker:**
  - read_segy.m will load one of four channels of the SEGY (and the shot range specified) data where:
    - Channel 1 = vertical
    - Channels 2 & 3 = horizontals
    - Channel 4 = hydrophone
  - read_segy.m file to read SEGYs
    - read_segy.m
  - Creating a SEGY catalog for tlPicker
    - Santorini_create_segyCatalog.m

- catalogSegy_santorini.m

A default menu for tlPicker menu window

- default_menu_Santorini.m

A14: Daily Science Reports from Chief Science Officer

- 11142015_V1_DR_MGL1521 - Daily Science Report.pdf
- 11152015_V1_DR_MGL1521 - Daily Science Report.pdf
- 11162015_V1_DR_MGL1521 - Daily Science Report.pdf
- 11172015_V1_DR_MGL1521 - Daily Science Report.pdf
- 11182015_V1_DR_MGL1521 - Daily Science Report.pdf
- 11192015_V1_DR_MGL1521 - Daily Science Report.pdf
- 11202015_V1_DR_MGL1521 - Daily Science Report.pdf
- 11212015_V1_DR_MGL1521 - Daily Science Report.pdf
- 11222015_V1_DR_MGL1521 - Daily Science Report.pdf
- 11232015_V1_DR_MGL1521 - Daily Science Report.pdf
- 11242015_V1_DR_MGL1521 - Daily Science Report.pdf
- 11252015_V1_DR_MGL1521 - Daily Science Report.pdf
- 11262015_V1_DR_MGL1521 - Daily Science Report.pdf
- 11272015_V1_DR_MGL1521 - Daily Science Report.pdf
- 11282015_V1_DR_MGL1521 - Daily Science Report.pdf
- 11292015_V1_DR_MGL1521 - Daily Science Report.pdf
- 11302015_V1_DR_MGL1521 - Daily Science Report.pdf
- 12012015_V1_DR_MGL1521 - Daily Science Report.pdf

12022015_V1_DR_MGL1521 - Daily Science Report.pdf

12032015_V1_DR_MGL1521 - Daily Science Report.pdf

12042015_V1_DR_MGL1521 - Daily Science Report.pdf

12052015_V1_DR_MGL1521 - Daily Science Report.pdf

12062015_V1_DR_MGL1521 - Daily Science Report.pdf

12072015_V1_DR_MGL1521 - Daily Science Report.pdf

12082015_V1_DR_MGL1521 - Daily Science Report.pdf

12092015_V1_DR_MGL1521 - Daily Science Report.pdf

12102015_V1_DR_MGL1521 - Daily Science Report.pdf

12112015_V1_DR_MGL1521 - Daily Science Report.pdf

12122015_V1_DR_MGL1521 - Daily Science Report.pdf

12132015_V1_DR_MGL1521 - Daily Science Report.pdf

12142015_V1_DR_MGL1521 - Daily Science Report.pdf

12152015_V1_DR_MGL1521 - Daily Science Report.pdf

12162015_V1_DR_MGL1521 - Daily Science Report.pdf