Using OBSs in Active Source Experiments

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Note: I got many figures for this presentation from Gail Christeson (UTIG)
Most data and activities depicted are from NSF-funded projects
Some Uses for Marine Wide-Angle Seismic Data

• Crustal scale velocity structure based on travel-time inversion.
  – The combination of dense source points from airguns and OBS spacing of 10 to 15 km is very effective for this. Great for active and passive continental margins and oceanic crust.

• Upper crust, accretionary prism, sedimentary section velocity.
  – With closer instrument spacing and dense shooting this can be effective for identifying lithologic variations and effects of fluids and gases using velocities and amplitude vs offset.

• Shear wave and Vp/Vs analysis
  – Shear waves are frequently recorded in active source OBS data. The primary limitation is whether they are consistently generated or only on sporadic instruments (this is often the case).

• Direct imaging (with reflections) and waveform inversion
  – These techniques are possible, but instrument spacing frequently limits their effectiveness. The large varieties of arrivals in OBS data tend to be “noise” for reflection imaging.
Outline of Presentation

• Uses of marine wide-angle seismic data [DONE]
• Brief review of active source marine seismic methods
  – Seismic sources, reflection acquisition, OBS data acquisition
• Some characteristics of active source OBS data
• Examples of OBSs and OBS operations
• Considerations for cruise planning (1 or 2 ships?, MCS/OBS?)
• Issues associated with OBS and MCS acquisition
• Example of cruise layout and scheduling
• Post cruise tasks
Marine Active Source Methods

Streamer Recording (MCS)

Seismic Reflection

Seismic Refraction (+ wide-angle reflection)

OBS Recording
Explosive release of high pressure air into the surrounding water. Less dangerous than explosives, very repeatable, and timing can be accurately recorded.
Air Guns: Linear array on R/V Langseth

Air guns on deck prior to deployment

Firing linear air gun array (4 linear sub-arrays)
Langseth Gun Arrays

- For crustal scale work, all 4 sub-arrays would typically be used (if possible)
- In favorable environments, signals from this array may be recorded at > 200 km
- For shallow velocity structure, one sub-array or even a set of 2-3 smaller airguns may be used
Marine Multichannel Seismic Reflection Data:

(A few informational slides)
• Inside the cable are hydrophones that measure pressure
• Streamers are often 6-8 km long
• Deployment may take 12+ hours
• **Can’t deploy or recover OBSs with the streamer out **
Basic Seismic Reflection Recording Geometry

reflection points
Basic Seismic Reflection Recording

Geometry

After a while, reflection points are sampled by many source receiver combinations.

Redundant sampling means that data can be stacked to increase signal to noise ratio.
Normal move out correction

1. A “Normal move out” correction accounts for different path length with offset. This flattens the arrivals so they can be stacked.

2. A product of NMO is a subsurface velocity estimate.

3. Velocity information is limited in depth by streamer length--deeper velocity control requires longer offsets.

Sort data with common midpoint --combine multiple source positions and receivers
(Thin) Crustal-scale seismic reflection example

The image is good, but it is distorted due to velocity variations: We need to determine the velocities and convert to depth -- however, the streamer is way too short for crustal velocities.
A very useful combination: Detailed structure from crustal-scale reflection data, and crust-upper mantle velocity structure from OBS tomography.
Marine wide-angle seismic work
Basic Idea of Marine Active Source OBS acquisition

- Shots from larger offsets will sample deeper parts of the lithosphere
Basic Idea of Marine Active Source OBS acquisition

Closer to reality: Hundreds of shots, many OBSs

- More shots and OBSs will provide more continuous ray coverage across the profile
Seismic refraction data are often displayed with a vertical axis of reduced travel time.

- Very useful for quick assessment of apparent velocity
- Important for large offsets—records may be 30 s long
Useful OBS Facts

- Direct arrivals (water waves) mark 1-way travel time from source to OBS
- Reflections at near offset occur at 1-way time in the water column plus 2-way time in the subsurface
- Multiples are very well-recorded in OBS data. They frequently obscure deep, near-offset reflections, but in many cases multiples excited by large-offset arrivals may assist interpretation of primary arrivals
Useful OBS Facts

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- Reflections at near offset can be tied directly to MCS sections—the MCS water bottom needs to be aligned with the direct arrival
Example of OBS record section offshore Taiwan

Note: OBS data are critical for onshore/offshore crustal-scale profiling
What do you do with the OBS data?
Pick all travel times from all receiver gathers from a wide-angle seismic line and use them together in a tomographic inversion. Tomography may use first arrivals only, or jointly with reflected arrivals. (Also other inversions or forward modeling.)
Commonly used Modeling Programs

- RayInvr, FAST  Developed by Colin Zelt and others
- “The Hole Code”  Developed by John Hole
- Tomo2d  Developed by Jun Korenaga
- “Van Avendonk Code”  Developed by Harm van Avendonk
Examples of OBSs and OBS operations
Small OBSs on deck ready for deployment
Scripps OBS Ready for Launch
OBS Deployment on R/V Langseth
For recovery an acoustic signal is sent to the OBS. The release command sends current through a burn wire, which releases the OBS from the anchor.
Recovery aids include a flag, radio, and light (for night recoveries).
Cruise Planning

Note: Information is available on OBSIP website
Considerations for OBS Cruise Planning

- What are the dimensions of the target?
  - (regional, crustal scale → shallow gas hydrate studies)
- What instrument spacing is required? Some factors:
  - Close enough for required horizontal resolution
  - Shallow structure better determined near OBS
  - Probably not all instruments will record good/full data sets
  - (bad surface condition, recording failure, instrument lost)
- How many sets of OBS deployments are required?
  - Depends on spacing, line length, number of lines, # of OBSs
  - Should generally be minimized
- Are seismic reflection data going to be acquired?
  - There are conflicts between MCS and OBS (discussed next)
- Are two ships available? (source ship, OBS ship)
- How long will it take for OBS operations and data acquisition?
- Is this a reasonable length of time?
Reflection data are generally acquired with shots every 25 to 50 m, depending on the depth of the target (longer for deeper). This typically means shooting every 12 – 20+ seconds. OBS data are contaminated by noise from previous shots. It is therefore often desirable to shoot at intervals of 60 to 120 seconds. Unfortunately, this means shot spacing of 100 – 300 m, resulting in fewer shots, poorer lateral resolution, and less coherent arrivals from shot to shot.

What are the solutions?

Shoot the line two times – short spacing for reflection, longer for OBS acquisition. Most effective but expensive.

Shoot at intermediate spacing, e.g., 40-50 seconds or 80-100 m.

This is a compromise for both, but may be acceptable for some targets, especially shallow or upper crust.

Shoot at short or intermediate spacing and use refraction interferometry to extend/enhance arrivals (e.g., Bharadwadj et al., 2012, GJI).
Previous shot noise (PSN) at near offsets due to short, MCS shot interval.
PSN occurs at larger offsets-- ~80-90 km with 60 s shot interval

Other noise sources: passing ships, shallow subsurface structure that excites reverberations, etc.
Example of cruise layout, logistics, and scheduling
Cruise Logistics Considerations

- Example:
  - Seismic transects are 300-500 km long
  - How many OBSs are required?
    - 30-50 @ 10 km spacing; 20-33 @ 15 km spacing
  - How long will it take to do this program?
    - Each line has to be traversed 3 times
      - [deploy, shoot, recover].
    - Need to account for deployment time for each OBS
    - Need to account for recovery time for each OBS
    - Need to know ship speed between deployment/recoveries
    - Need to know ship speed during shooting

- To put this together in an accurate way generally requires using
  a detailed spreadsheet – see examples next slides...
Logistics: how to make the plan (use spreadsheet)

## OBS Operations

**Assumptions:**

- **Transit Speed (knots):** 10.5
- **Shooting Speed (knots):** 3.7
- **Deployment Time (min):** 10.0
- **release time (min):** 5.0
- **rise time rate (m/min):** 45.0
- **recovery time (min):** 20.0
- **air gun array:** 6.0
- **transit to/from Gulf:** 6.0

**Start Date:** 10/24/2010 18:00 GMT

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Use a spreadsheet such as this to make a detailed plan and to monitor progress throughout the cruise.

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Science Party Responsibilities for OBS Cruise

- Provide detailed array plan to OBS operators and develop efficient deployment/shooting/recovery plans
- Assist OBS technicians as directed with deployment/recovery
  - Help spot OBSs when they surface for recovery
- Record detailed logs including deployment/recovery times, locations, and water depths (this is very helpful for OBS relocation)
Other OBS Tasks

• OBS relocation
  – Currents may cause OBSs to drift from their deployment site
  – Large numbers of instruments preclude “surveying in”
  – Use direct (water) waves to invert for OBS position below line
    • the minimum time is where OBS is closest to the shotline
    • one strategy is to use a grid search using bathymetry
    • other strategies use joint inversions with traveltime minima
      and horizontal component amplitude variations

• OBS orientation and rotation of horizontals
  – Horizontals can be oriented based on amplitude variation
  – Oriented horizontals can be rotated to radial/transverse

• OBS signal processing – some processes used:
  – Frequency (bandpass) filtering,
  – Gain adjustment (function of time, offset, or AGC)
  – Deconvolution and/or spectral whitening
  – Trace mixing or stacking
  – Other noise suppression techniques
Other OBS Issues

- OBS data are likely to be saved in a variant of SEG-Y format
  - Not all header information may be present or correct
  - Users will likely need to be able to change/add header info.
  - Users need to be able to read/view/pick SEG-Y data
Questions?

The End