Along- and across-shore propagation properties of nonlinear internal waves from a broad array of bottom pressure sensors in Massachusetts Bay

Jenny Thomas, Jim Lerczak, Jim Moum
Oregon State University, Corvallis, OR, USA

1. Our goal

Use a broad array of bottom pressure sensors to study temporal and spatial variations in propagation properties of tidally-generated, nonlinear, high-frequency internal waves west of Stellwagen Bank in Massachusetts Bay (Figure 1).

2. Methods: Processing internal wave bottom pressure (P_{IW}) and verifying internal wave presence

- Data collection period: July 20 – July 27, 2009
- Pressure sampled at 1 Hz with 10^-5 dbar resolution [Moum and Nash, 2008]
- Band-pass filtered from 2 – 30 min. (P_{IW}) to remove tides and surface waves
- 13 internal wave packets observed (Figures 2 and 3)
- Arrival times marked at the minimum within each arriving wave’s first trough

3. Methods: Calculating internal wave direction and speed

I. Triangle method:
- Calculated the best plane wave speed and direction for each triangle using arrival time lags, t, and horizontal spatial lags, x, of the triangle elements

II. Plane wave method:
- Calculated wave direction assuming plane waves using arrival time lags, t, and spatial horizontal lags, x, for each of the along-shore lines

4. Methods: Calculating variance of P_{IW} as a proxy for HF internal wave packet energy (E_p)

- E_p = var_{P_{IW}} - var_{BG}, where var_{P_{IW}} is the variance of a particular internal wave packet and var_{BG} is a background variance in P_{BG}
- var_{BG} was calculated over periods where there were no discernible internal waves

5. Results: Internal wave direction and speed

I. Triangle method (Figure 4):
- Direction results are in earth coordinates (270° is due west, Figure 1)
- Propagation speed:
  - Speeds ranged from 36 – 63 cm/s
  - Mean increase in speed from northern to southern ends of array

II. Plane wave method:
- Propagation direction ranges similar to triangle method
  - Clockwise rotation from offshore to inshore lines for each wave

6. Results: Proxy for internal wave packet energy (E_p)

- E_p results are plotted against a spatial reference frame in line with the array (station 6 = origin, LXS = x-axis, Figure 1) (Figures 5 – 6)
- E_p generally greatest for southern stations of along-shore lines (Figure 5)
- E_p generally increases from the offshore to the inshore line

7. Conclusions

Propagation properties of internal waves can be analyzed using filtered bottom pressure

Propagation direction:
- Across our array, average internal wave propagation direction was 252° (Figures 1 and 4a)
- Clockwise rotation as waves propagate onshore, perhaps due to shoaling bathymetry
- Clockwise shift from south to north: wave fronts have curvature

Propagation speed:
- Average internal wave speed was 53 cm/s (Figure 4b)
- Speeds increase from north to south, inconsistent with bathymetric shoaling (Figure 1)

Wave energy:
- Wave energy is highest in the locations of the southern stations (Figure 5)
- Wave energy significantly decreases upon propagation into a depth ≤ 40 m (Figure 6)

There are wave-to-wave differences in direction, speed, and energy

References:
- We thank Zen Kurokawa for his work in data collection and processing and the National Science Foundation, grant OCE-1155709.