Drifting float measurement of pressure change by tsunami

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Recently a new instrument, named MERMAID (Mobile Earthquake Recording in Marine Areas by Independent Divers), was developed to measure acoustic signals converted from seismic waves at the seafloor. The MERMAID is a Lagrangian drifter equipped with a hydrophone and drifts passively at 1,500 −2,000 m depth until an earthquake signal is detected. If this is identified as a strong P wave, the MERMAID ascends at speed of 10 cm/s for transmission of the recorded waveform within time window of a hundred seconds before and after the P wave arrival as well as its global positioning system (GPS) coordinates at the surface. After transmitting the data via satellite links, the MERMAID descends at speed of 5 cm/s to monitor earthquake signals at 1,500 −2,000 m depth again.
It was reported that tsunamis were recorded by hydrophones (e.g. Okal et al., 2007), notably in frequency bands extending outside the range of the Shallow Water Approximation. If MERMAID floats can cover the oceans as dense as the Argo project of which almost 4000 floats are now drifting to measure temperature and salinity in the oceans, we acquire valuable tsunami data. Here we estimate what signals are observed by a MERMAID, by comparing to the pressure change of the 2010 Chile Tsunami measured by a differential pressure gauge (DPG) at about 4800 m deep seafloor.
We assume linearized water wave with period T, amplitude H, and phase velocity c as shown in Figure 1. Phase velocity c is given by $c = (g \tanh(kD)/k)^{1/2}$, where k is horizontal wavenumber $k = \omega/c$, $\omega = 2\pi/T$ is angular frequency and g is gravity. The wavenumber $k(\omega, D)$ of the water waves in a constant depth ocean as a function of a wave period is obtained by the recursion equation. The water wave height $W(x, t)$ as the function of time t and horizontal position x is expressed as
$W(x,t) = H e^{i(kx-\omega t)}$
The MERMAID is Lagrangian float drifting at a depth of z ($0 > z > -D$) and measures Lagrangian pressure of water, where D is water depth.
Lagrangian pressure $\delta p(x, z, t)$ is given by
$\delta p(x, z, t) = -\{H\rho_o g \sinh(kz)/(\sinh(kD)\cosh(kD))\} e^{i(kx-\omega t)}$
Eulerian pressure is given by
$p'(x, z, t) = \{H\rho_o g \cosh(k(D+z))/\cosh(kD)\} e^{i(kx-\omega t)}$
Therefore, pressure measured by a DPG at seafloor is expressed as
$p'(x,-D, t) = \{H\rho_o g/\cosh(kD)\} e^{i(kx-\omega t)}$
and the pressure $\delta p(z)$ measured by a MERMAID at z depth can be related
with the DPG pressure $p'(D)$ by
$\delta p(z) = R\, p'(-D)$, $R = -\sinh(kz)/\sinh(kD)$
If T is large enough that k is close to 0, R becomes close to z/D. Figure 2 shows the R as the function of T for floats at 1000 (blue) and 2000 (red) m depth, suggesting the R acts as a low-pass filter. Figure 3 shows the predicted pressure changes observed floats drifting at 1000 (blue) and 2000 (red) m depth. In the presentation, we will discuss availability of tsunami measurement by a float.

Keywords: tsunami, float, hydrophone, differential pressure gauge

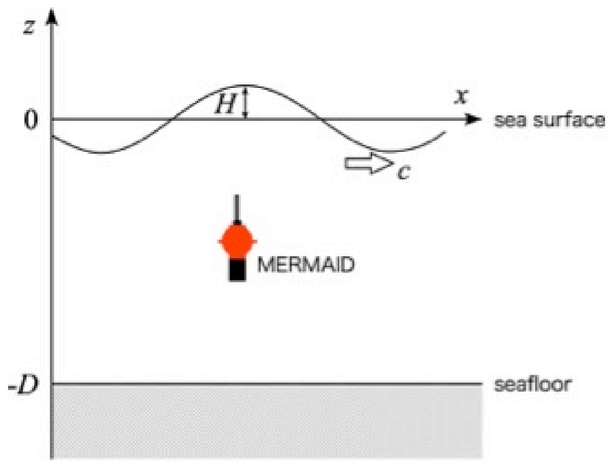

Figure 1. Problem setting

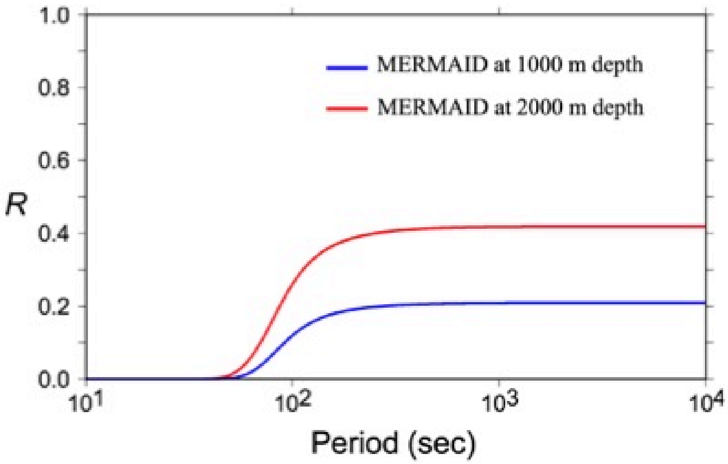

Figure 2. R as the function of period T

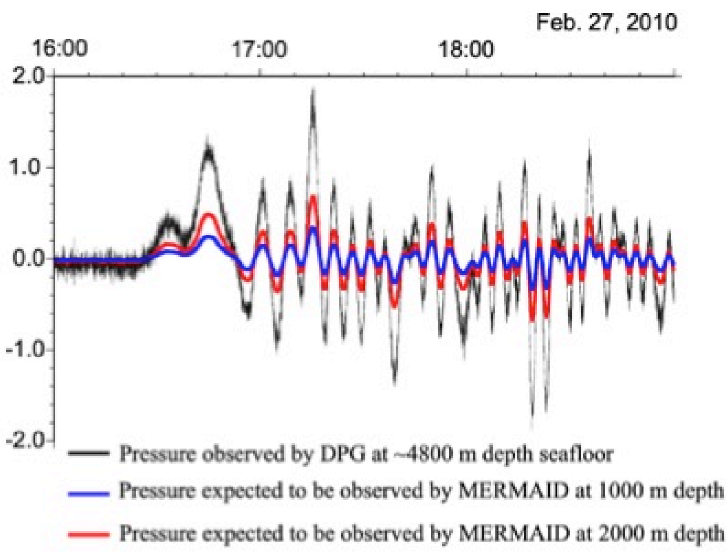

Figure 3. Predicted pressure changes observed by MERMAIDs at 1000 and 2000 m depth.