Seafloor Compliance
(and Admittance)

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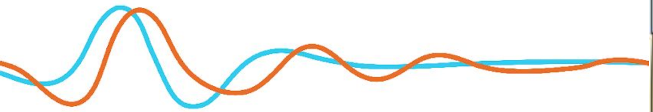
Theory

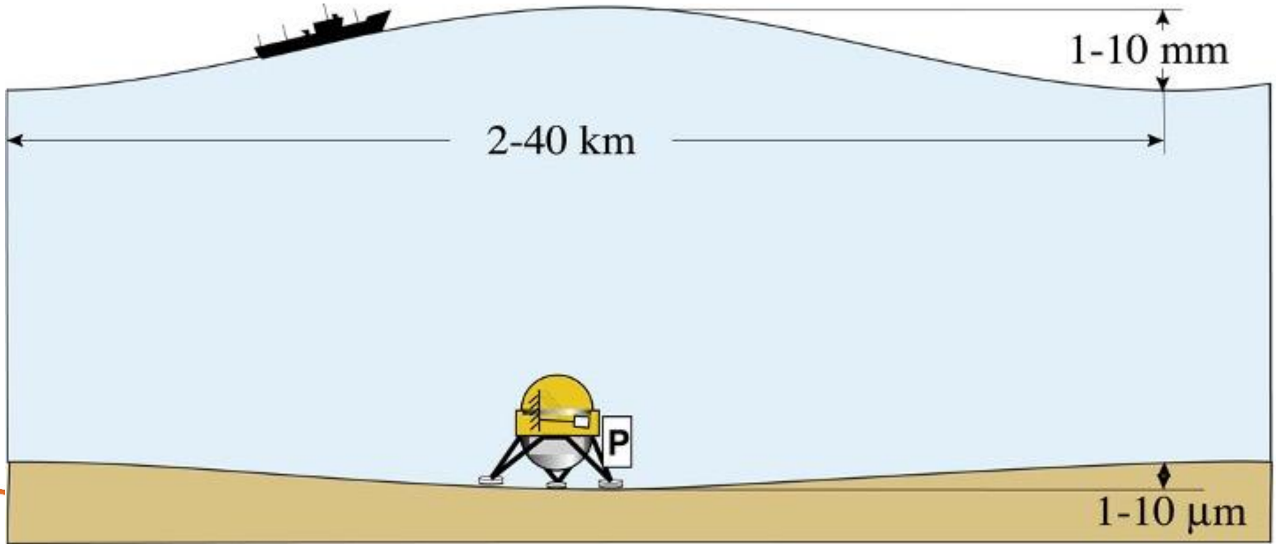
What is compliance?

Compliance is the ratio of seafloor motion to pressure forcing from long-wavelength ocean surface “infragravity” waves

Units of normalized compliance are 1/Pa, and compliance is approximately proportional to 1/2μ

Depth sensitivity is a function of frequency





Some details of infragravity waves

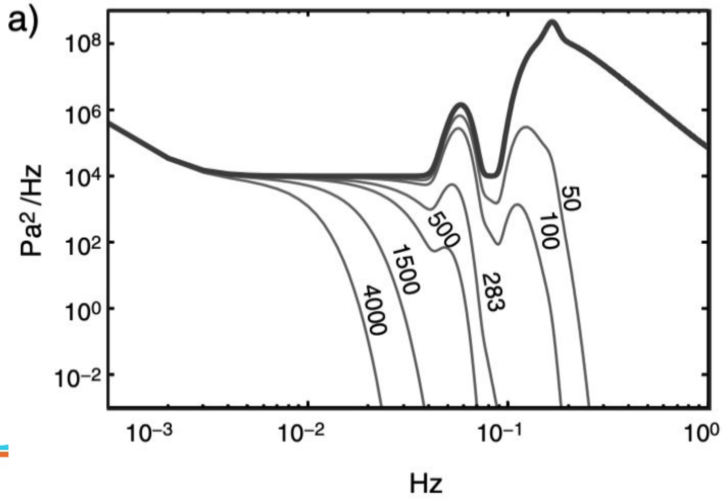
Linear ocean surface gravity waves at lower frequencies than “wind waves”

Generated by wave-wave interactions near coasts (like microseisms)

Speed depends on water depth (H) and frequency (f)

- General dispersion equation: $\omega^2 = gk\tanh(kH)$
- Deep water solution (kH>>1): $c_w = g/\omega$
- Shallow water solution (kH<<1): $c_w = \sqrt{gH}$

To be detectable at the seafloor, wavelengths must be longer than the ocean depth



Webb & Crawford [2010]

Seafloor compliance: basic equations

Normalized compliance definition $$\eta \equiv \left.\frac{k\mathbf{u}}{\sigma_{zz}}\right|_{z=0}$$

- Units are 1/Pa

Analytic solution for a uniform half space

$$\eta = \frac{-i}{2(\lambda+\mu)}\hat{x} + \frac{(\lambda+2\mu)}{\boxed{2\mu}(\lambda+\mu)}\hat{z} \qquad c_x \ll \alpha, \beta$$

The general solution is calculated on a computer using surface wave equations (1D: minor vector method; 2/3D: finite differences or elements)

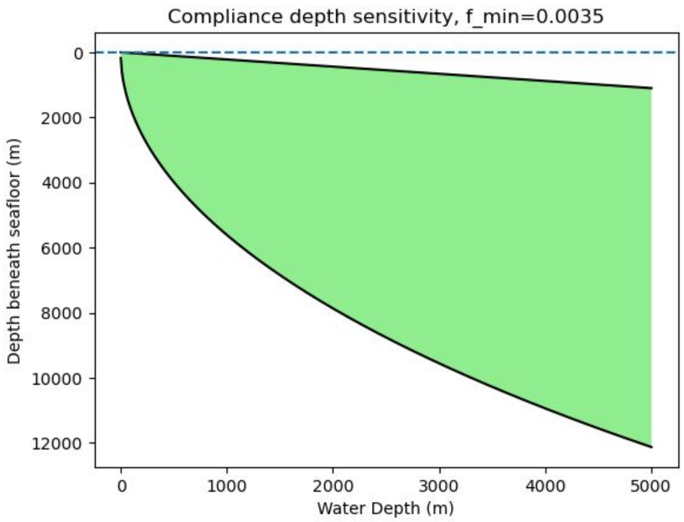
Depth sensitivity limits

Depends on the wavelengths of the measured compliance function

- The shortest are around 1.1x*H*
- The longest are around $sqrt(gH)/f_{min}$

Each wavelength is most sensitive to structures at about 1/5th the corresponding wavelength

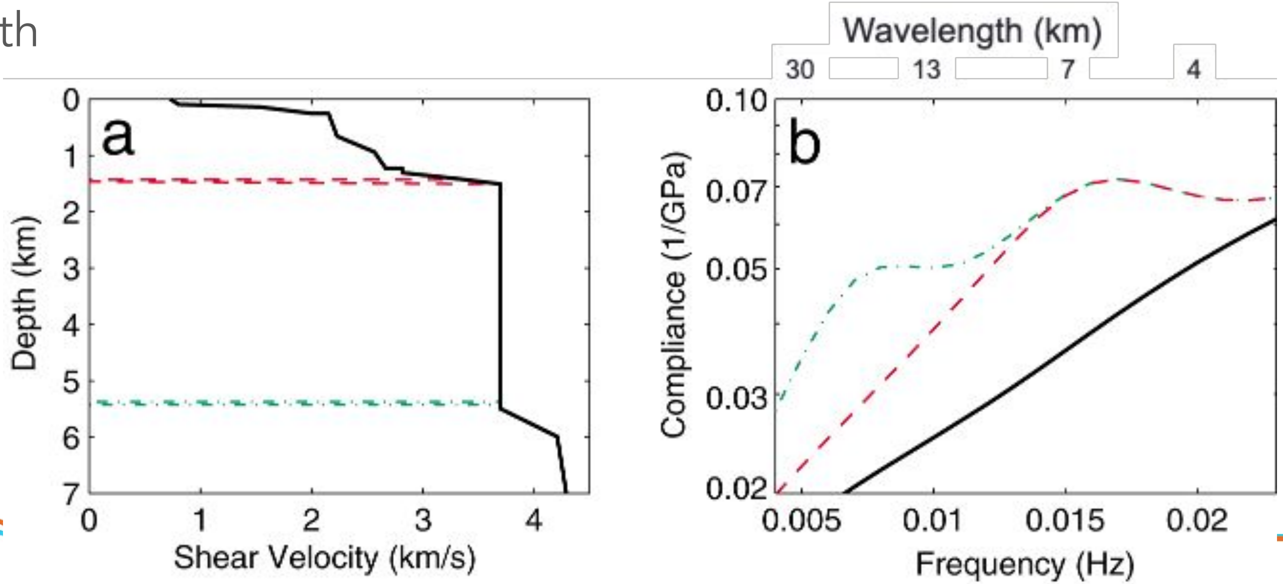
=> Approximate depth sensitivity range:
0.2*H* to 180*sqrt(H)*



Example 1D compliances

If the shear modulus increases with depth, compliance will increase with frequency

Low velocity zones create compliance peaks whose frequency depends on the zones' depth

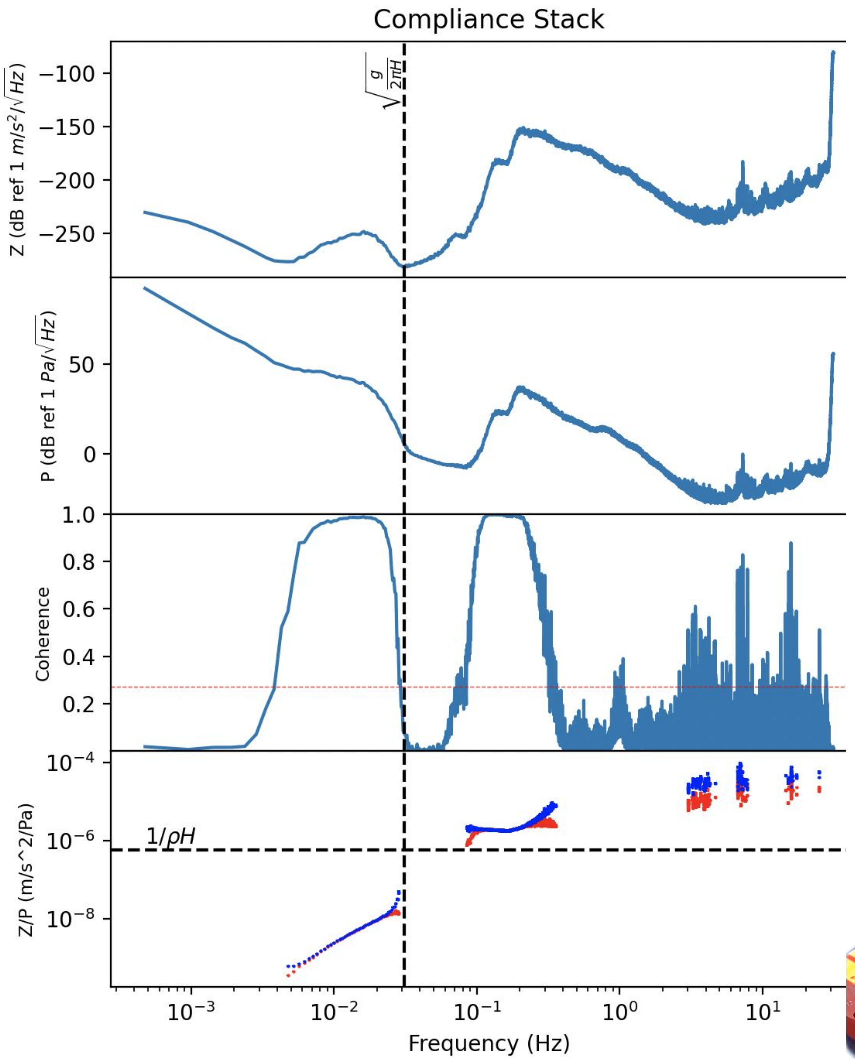


Measuring seafloor compliance

Measuring compliance

First information:

- Z spectral levels
  - Do we see a “bump”?
- P spectral levels
  - Do we see a “cliff?”
- Z-P coherence
  - Is it significant? Close to 1?
- Z/P transfer function
  - Is there compliance?
  - Is the instrument correctly calibrated? (m/s^2/Pa ratio should be 1/ρH for LF microseisms)



Processing

Exclude Large Events

- Use global EQ catalogs

Tilt Reduction, Coherent Noise Remo

- See “Noise” lecture

Pressure Gauge Calibration

- In-situ calibrations, compare LF admittance

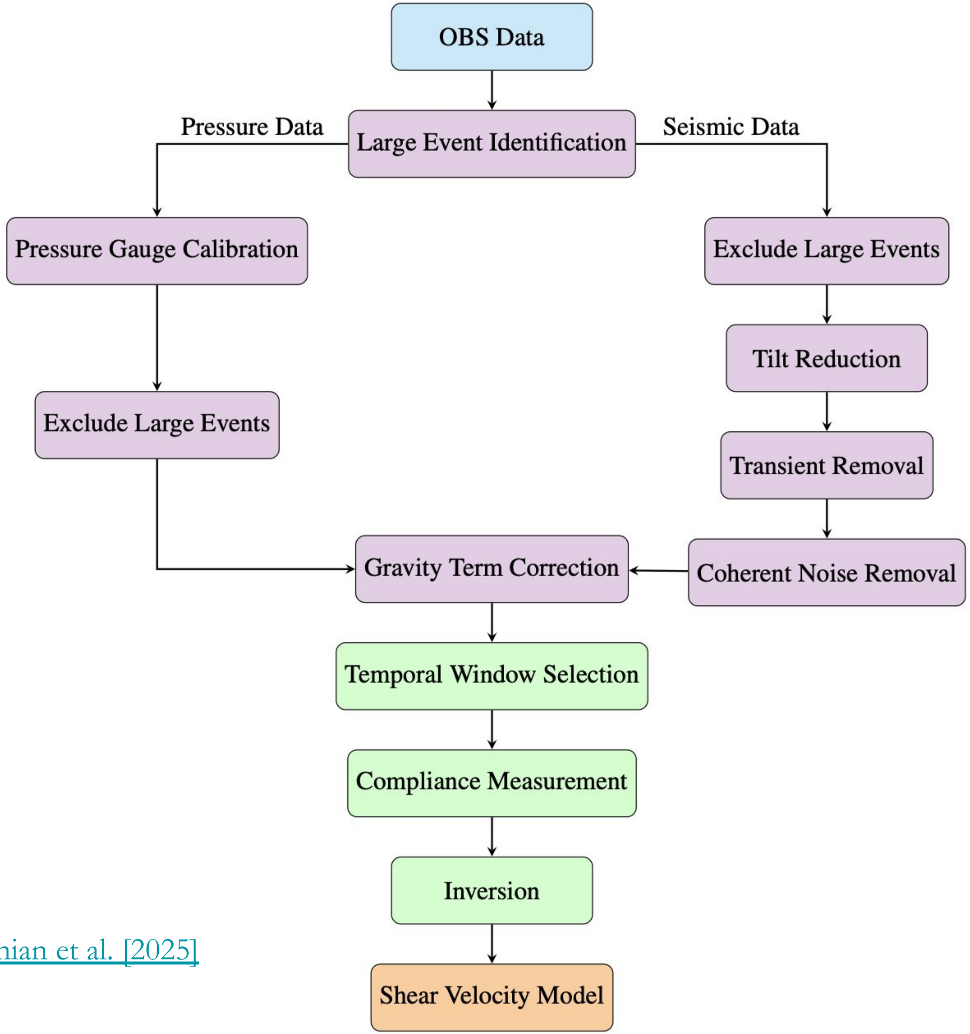
Gravity Term Correction:

- Crawford et al. [1998]

Temporal window selection

- Compy, BRUIT-FM toolbox

Aminian et al. [2025]



Temporal Window Selection

Some time frames have a better compliance signal than others, should select the best ones

Most codes use the Z-P correlation/coherence to select windows:

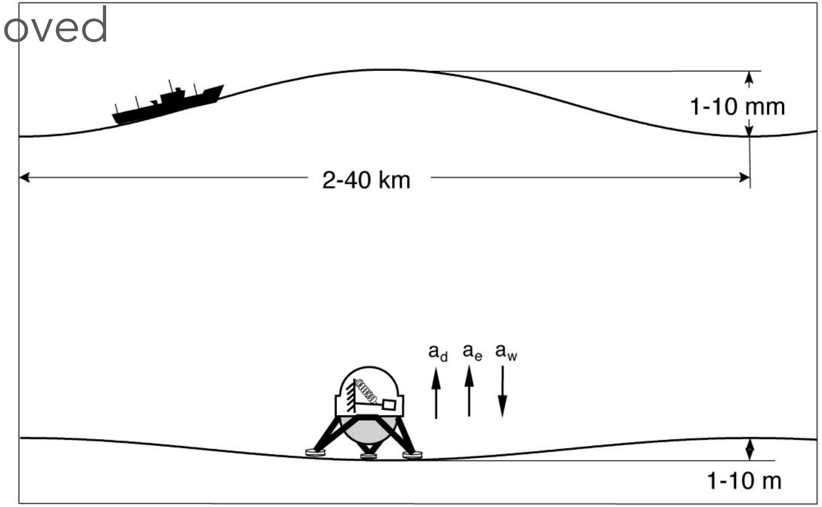
- BRUIT-FM toolbox (Rebeyrol et al., 2024)
- Compy (Aminian et al., in press)
- ATACR (Janiszewski et al., 2019)
- tiskitpy (basic z-score)

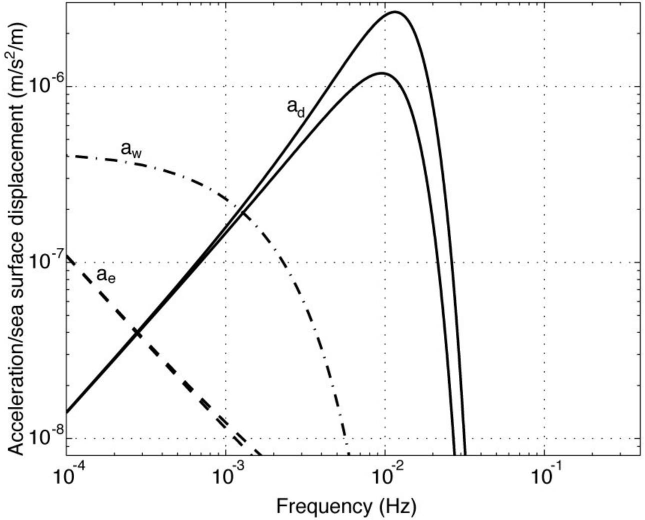
Gravity term correction

In addition to the displacement we want to measure, there are two gravitational acceleration terms that should be removed

$$
\begin{aligned}
a_d &= -\omega^2 D_f, \\
a_e &\approx \frac{2GM_E D_f}{{r_e}^3}, \\
a_w &= 2\pi G \rho_w e^{-2\pi k H} h_w
\end{aligned}
$$

Crawford et al. [1998], corrected



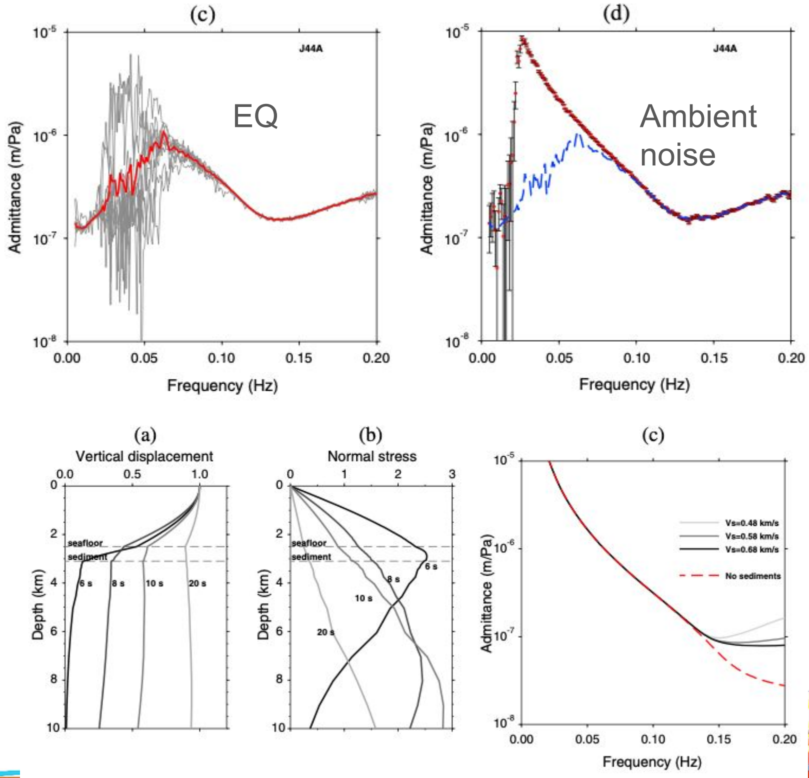


Admittance

Ruan et al. [2014]

Uses the Z/P ratio in the microseism band

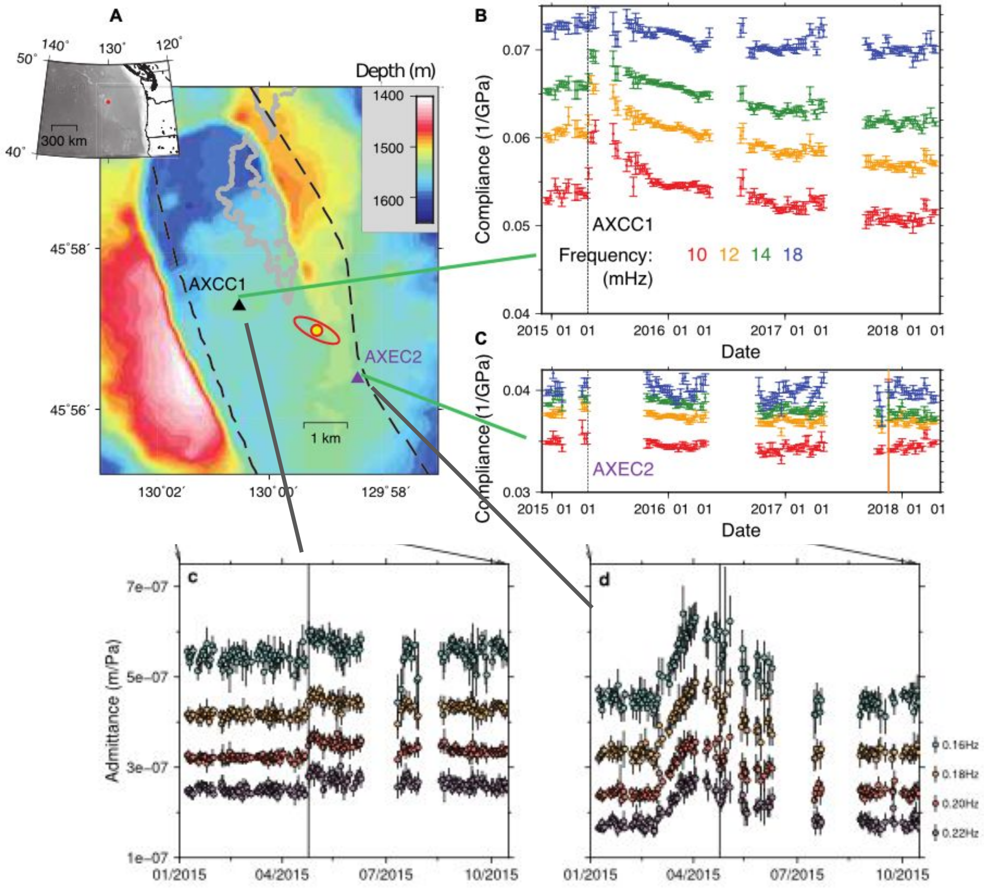
- At low frequencies, this is just 1/ρH, but at high frequencies it is related to the shear velocity below
- Can use ambient noise or teleseisms (compact broadband OBSs)
- Only a few studies performed, don't know the advantages/disadvantages with respect to compliance



Time-varying structure

Permanent seafloor networks with broadband sensors allow us to study changes in shear-velocity structure over time.

Compliance [Doran & Crawford, 2020]



Admittance [Wang et al, 2025]