Anelasticity of the asthenosphere inferred from GPS observations of ocean tide loading displacements in western Europe

Machiel Bos\textsuperscript{1}, Peter Clarke\textsuperscript{2}, Nigel Penna\textsuperscript{2}, Trevor Baker\textsuperscript{3}

\textsuperscript{1}University of Beira Interior, Portugal; \textsuperscript{2}Newcastle University, UK; \textsuperscript{3}National Oceanography Centre, Liverpool, UK
SUMMARY

• Observed M2 ocean tide loading vertical displacements differ systematically from predictions by up to 2-3 mm in western Europe
• Discrepancies cannot be explained by credible model changes in ocean tides or elastic Earth parameters
• Anelastic dispersion with asthenospheric $Q_\mu$ constant from 1 Hz to ~2 cpd reduces discrepancies to ~noise
  – $Q \approx 70-80$, leading to 8-10% reduction in $\mu$ at M2 period

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Quality of GPS observations of OTL displacement

Effect of noise on 13.96 hr vector difference

\[ r = 0.80 \]

See Penna et al. poster G04p-137
Residual OTLD

0.7 mm mean, 2.8 mm max

Modelled OTLD
259 sites

Observed OTLD
0.7 mm mean, 2.8 mm max

Ocean tide model
Density of sea water 1030 kg/m³

Earth structure
Ocean tide model errors

- DTU10, EOT11a, FES2012, GOT4.7, HAMTIDE, TPXO8 interpolated on to 1/16° grid and mean computed
- Standard deviation of $M_2$ vector differences from the mean shown here
- FES2012 agreements with coastal tide gauges and bottom pressure recorders:

<table>
<thead>
<tr>
<th>Region</th>
<th>Mean (mm)</th>
<th>Stdev (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornwall</td>
<td>16</td>
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</tr>
<tr>
<td>Celtic Sea</td>
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<td>English Channel</td>
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<tr>
<td>West France</td>
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<td>North Sea</td>
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<td>Bristol Channel</td>
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<tr>
<td>Irish Sea</td>
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</tr>
<tr>
<td>West Scotland</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Iberia</td>
<td>23</td>
<td>6</td>
</tr>
</tbody>
</table>
Dziewonski & Anderson (1981), PEPI
Holder & Bott (1971), GJRAS
Kustowksi et al (2008), JGR
Kennett et al (1995), GJI
Empirical Green’s function

- Surface: 50-80 km
- 15 km
- 24.4 km
- 80 km
- 50-80 km

- Scaling of \( \mu \) ↓ 10-11%

- 340-350 km
- 220 km

0.3 mm mean, 1.5 mm max
Shear dissipation and $Q$

- PREM seismic velocities valid at 1 Hz
- $Q$ is constant from seismic to tidal frequencies?
- Shear modulus change, $\delta \mu$ (for freq $\omega$, with $\omega_0 = 1$ Hz):
  \[ \delta \mu(\omega) = \frac{\mu}{Q_\mu} \left[ \frac{2}{\pi} \ln(\omega/\omega_0) + i \right] \]
- Our empirical $\delta \mu/\mu$ of -10% for M2 implies $Q \approx 70$
- $Q_{\text{PREM}}$ has a min of ~80 in asthenosphere, reduces $\mu$ by 8.5% 
  - above this, $Q_{\text{PREM}} \approx 600$, so effect of anelasticity is less
  - below, $Q_{\text{PREM}} \approx 150$, but depth too great to affect OTL values
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- Anelastic dispersion with asthenospheric $Q_{\mu}$ constant from 1 Hz to $\sim$2 cpd reduces discrepancies to $\sim$noise.
  - $Q\approx$70-80, leading to 8-10% reduction in $\mu$ at M2 period.
