Supplementary Material for

GPS Interferometric Reflectometry: Using a Low Cost Antenna to Measure Water Levels

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In the main article we compared the GPS-IR derived sea level heights with those from the co-located tide gauge at Rosses Point, Sligo. We found a scale error between the two datasets that we attributed to the tide gauge rather than the GPS-IR measurements. The justification for this was based on a comparison between tidal parameters derived from the tide gauge from an earlier period (1st August 2008 to 15th August 2013) and that from the “modern” period of 11th October 2017 onwards. This comparison also revealed a scale error between the two tide gauge periods. However, the gap of four years between the two datasets meant we couldn’t quite rule out that the tidal parameters hadn’t varied naturally (or due to local engineering works) during that gap in the data.

Figure 1. Location of the three extra tide gauges used in this supplementary material for comparison with the tide gauge at Sligo.

Fortunately, Marine Ireland installed three other gauges nearby at approximately the same time that did not suffer from a gap in the record (Figure 1). The three gauges, Killybegs, Aranmore and Ballyglass are 39 km, 76 km and 86 km from Sligo respectively. For each gauge we took a year of tide gauge measurements and fit 57 tidal harmonics suitable for the region and for a year of data. We then time stepped the data forward a month at a time. While this led to a considerable overlap between each set of estimated harmonics it allows us to see if there is a common variation amongst the nearby gauges. From the estimated harmonics we chose the three with the largest amplitude M2, S2 and N2. The table below shows the average amplitudes (mm) for the period before 15th August 2013 (when the first Sligo data stops). The two Sligo columns are for (1) hourly data and (2) 6 minute data.

<table>
<thead>
<tr>
<th></th>
<th>Aranmore</th>
<th>Ballyglass</th>
<th>Killybegs</th>
<th>Sligo¹</th>
<th>Sligo²</th>
</tr>
</thead>
<tbody>
<tr>
<td>M2</td>
<td>1182.8</td>
<td>1117.5</td>
<td>1205.4</td>
<td>1204.6</td>
<td>1207.0</td>
</tr>
<tr>
<td>S2</td>
<td>440.0</td>
<td>415.2</td>
<td>449.3</td>
<td>444.7</td>
<td>445.2</td>
</tr>
<tr>
<td>N2</td>
<td>242.1</td>
<td>227.5</td>
<td>245.1</td>
<td>243.7</td>
<td>243.9</td>
</tr>
</tbody>
</table>

We then plot the “residual” amplitudes (estimated amplitudes minus the average) for all series (Figure 2, overleaf). We see that for all gauges the amplitude variations correlate with each other extremely closely. However, the amplitudes from the modern Sligo data (green and purple dots) show the same variations but are approximately 30, 10 and 5 mm too high for M2, S2 and N2 respectively. The Sligo data is correlated the most with Killybegs, the nearest alternative tide gauge. If we calculate the scaling parameter required for the modern Sligo data to match the Killybegs amplitudes (in a least square sense) we get a value of 0.9761. The scaled amplitudes are plotted as squares in Figure 2. If we assume, for simplicity, that the scaling error is due to an incorrect water density set at Sligo and that it was set to the factory setting of 999.972 kg m⁻³ then if it was set to 1024.5 kg m⁻³ then we would have got tidal amplitudes more like that at the other gauges and the earlier Sligo data. The scaling from the GPS-IR results was 9.9721 which would equate to a density of 1028.7 kg m⁻³. The average, 2018, density predicted for this region from the 1/4° x 1/4° weekly Copernicus Marine Environment Monitoring Service (CMEMS) Global Sea Surface Density L4 Reprocessed Data Set (MULTI OBS_GLO_PHY_REP_015_002) (Droghei et al., 2016) is 1026.6 kg m⁻³ (ranging from 1025.9 kg m⁻³ to 1027.1 kg m⁻³). These are sufficiently close to assume that an error in setting the density at Sligo after...
restarting observations is a likely choice for the scaling error.

References