Vertical Crustal Motion in the North Pacific and Implications for Tide Gauge Records and Sea Level Rise

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Calibrating Sea Level Rise

- Relative Sea Level as measured by tide gauges depends on:
  - Global sea level rise
  - Local geoid change
  - Local vertical crustal motion
- Must average over all oceans for good measure of global sea level change
- GPS and tide measurements may allow a calibration for these tide gauges
Problem with the North Pacific

- North Pacific region has not been used for global averages because of large crustal motions
- Post Little Ice Age deglaciation along coastal SE Alaska causes rapid uplift
  - And associated geoid change (see GRACE)
- Vertical tectonic motion associated with the subduction earthquake cycle affects the rest of the south coast of Alaska
Tide Gauges and Earthquakes
Tide Gauge RSL Records

Larsen et al. (2003)
GPS Vertical Velocities

- Linear velocities over time period
  - 1992-2005 far from Denali Fault
  - 1992-2002 near Denali Fault
- Based primarily on campaign GPS surveys
- GIPSY (GOA4) network solutions using JPL “non-fiducial” orbits, then transformed to ITRF2000
GPS Uplift Rates
Impact of Melting Ice

GPS Uplift Rate

Total Uplift (m)

Larsen et al. (2003)
Ice Thinning Rate

Larson et al. (2005) based on Arendt et al. (2002)
# Tide Gauge – GPS Comparison

<table>
<thead>
<tr>
<th>Location</th>
<th>GPS Difference</th>
<th>Tide Gauge Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ketchikan*</td>
<td>0 ± 1</td>
<td>-0.2 ± 1</td>
</tr>
<tr>
<td>Sitka*</td>
<td>3 ± 1</td>
<td>2.9 ± 1</td>
</tr>
<tr>
<td>Juneau</td>
<td>13.6 ± 1</td>
<td>17.8 ± 3</td>
</tr>
<tr>
<td>Skagway</td>
<td>17.1 ± 1</td>
<td>22.7 ± 5</td>
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<tr>
<td>Yakutat</td>
<td>13.7 ± 1</td>
<td>13.3 ± 1</td>
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<tr>
<td>Cordova</td>
<td>3.8 ± 1</td>
<td>1.6 ± 2</td>
</tr>
<tr>
<td>Valdez*</td>
<td>12.9 ± 1</td>
<td>10.2 ± 1</td>
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<tr>
<td>Seward</td>
<td>10.4 ± 1</td>
<td>5.3 ± 2</td>
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<tr>
<td>Seldovia*</td>
<td>9.6 ± 1</td>
<td>12 ± 1</td>
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<tr>
<td>Nikiski</td>
<td>0.5 ± 1</td>
<td>8.1 ± 1</td>
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<tr>
<td>Anchorage</td>
<td>10.4 ± 1</td>
<td>4.8 ± 1</td>
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<tr>
<td>Kodiak*</td>
<td>5.4 ± 1</td>
<td>6.8 ± 1</td>
</tr>
<tr>
<td>Sand Point</td>
<td>0.1 ± 1</td>
<td>0.8 ± 2</td>
</tr>
</tbody>
</table>
Subduction Zone
Subsidence and Locked Zone

- Basic model (Savage, 1983)
  - Shallow part of fault slips only in earthquakes
  - Deeper part slips steadily at long-term rate
  - Earth deforms as elastic body

![Graph showing effect of locked subduction zone](image)

- **Horizontal**
- **Vertical**
- **Locked**
- **Creeping**
Subduction Zone
Conclusions

- Vertical motions are extremely rapid due to
  - Glacial Isostatic Adjustment (post-LIA)
  - Variations in locked shallow subduction zone
- GPS velocities agree very well with tide gauges, especially for continuous GPS
  - When combined with GRACE, can separate sea level rise, land level rise and geoid change
- Ice melting in and near Alaska contributes roughly as much to present sea level rise as Antarctica and Greenland combined