Annual Cycle in Coastal Sea Level from Tide Gauges and Altimetry

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Ocean Surface Topography From Space
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Introduction

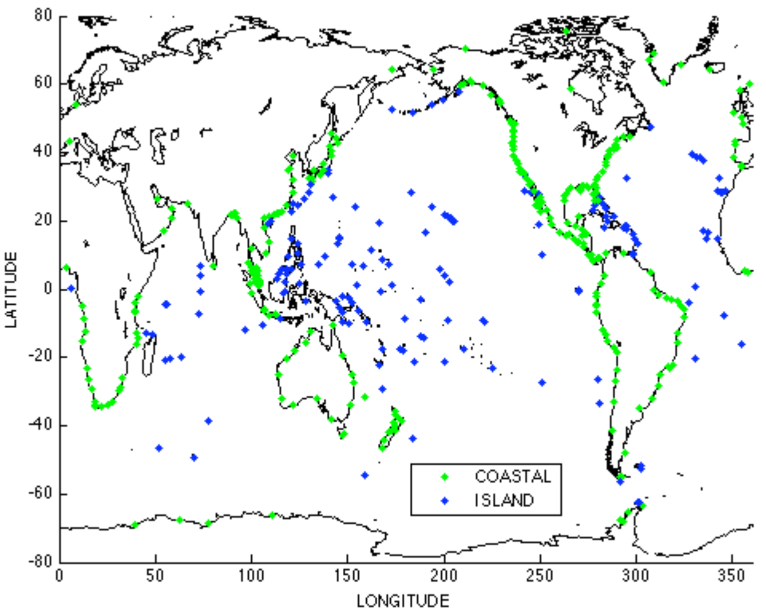

Figure 1: SSH observations, coastal TG (green dots), and island TG (blue dots).

Tide gauges (TG) provide a unique dataset extending many decades back in time, but coverage is restricted to continental boundaries and a few oceanic islands, and the extent to which the tide gauge records can be used to infer low-frequency, large-scale sea level behavior remains unclear.

We compare coastal and island TG locations and nearby shallow and deep ocean, as inferred from altimetry (Figure 1), in order to explore the applicability of TG records in studying open ocean variability, and the potential use of altimetry in near-coastal waters on annual period.

Data and Methods

346 TGs from Permanent Service for Mean Sea Level (PSMSL) were used to compute mean annual cycle from monthly-averaged series for the period 01/1992-12/2001

The PO.DAAC (NASA/JPL) along-track SSH product from TOPEX/POSEIDON (T/P) was monthly-averaged to compute mean annual cycle at each point, with along-track spatial resolution ~7 km.

All suitable T/P data were collected in the proximity of every TG. The T/P data were split into "shallow" and "deep" sets relative to 200 m isobath – a typical outer limit of the continental shelf. Annual cycles within each T/P set were averaged to produce mean "shallow" and "deep" annual cycles. We compare SSH annual cycles in:

- TG
- Shallow ocean (T/P at depth <200m)
- Deep ocean (T/P at depth >200m)

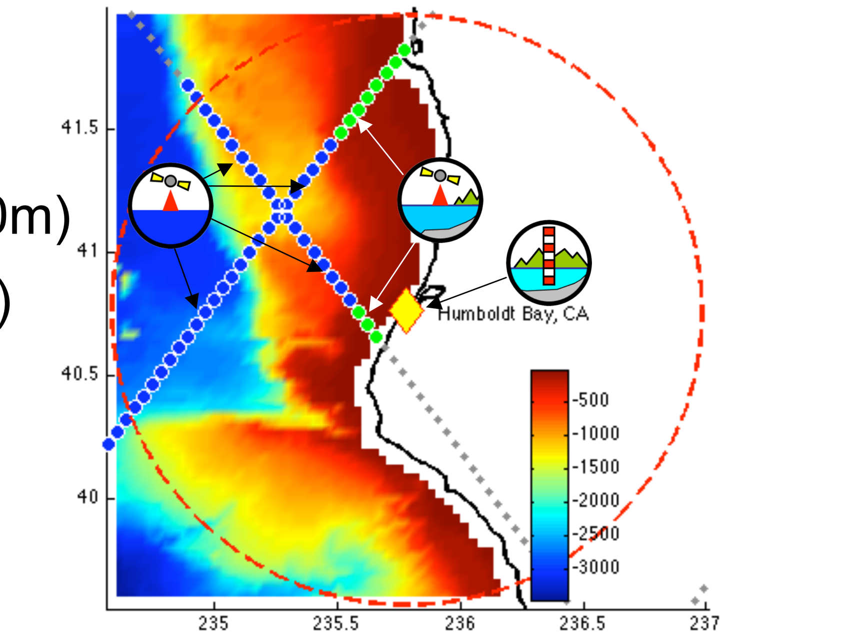

Figure 2: Spatial averaging of T/P data in vicinity of TG. Green dots constitute "shallow" data (<200m); blue dots are "deep" data (>200m). Bathymetry is shown by color.

For shallow and deep T/P sets, standard deviations from their mean values provide an estimate of spatial variability in amplitudes and phases.

Annual Amplitudes

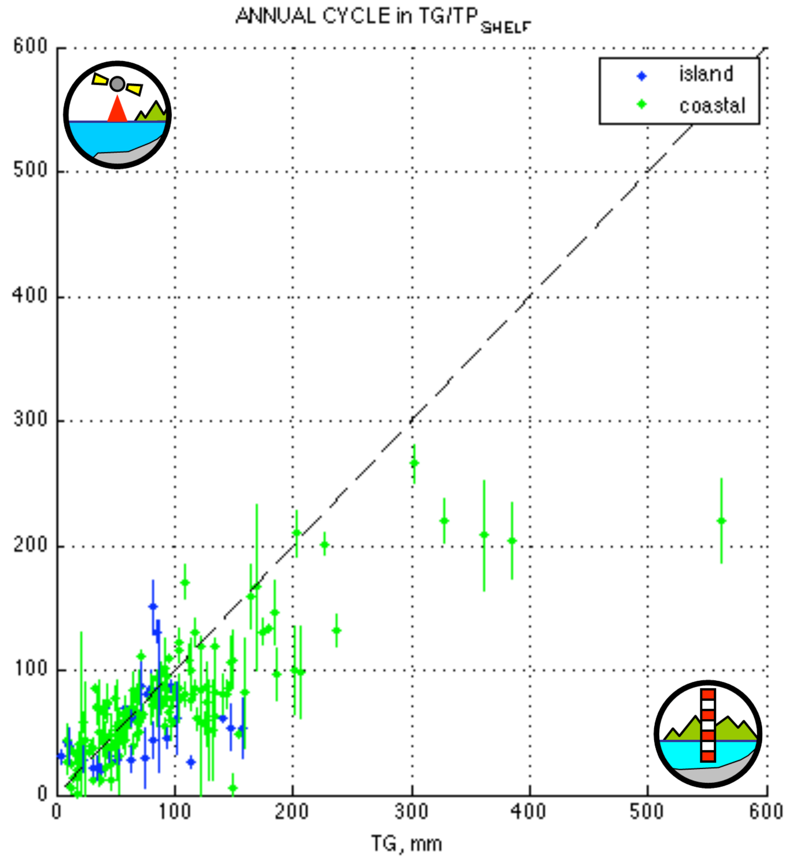

Figure 3: TG vs shallow T/P. Blue dots are to coastal TG, green dots are island TG. Error bars are ±1 std.

- **TG vs shallow T/P**, R = 0.79 (Figure 3)
- TG amplitudes (a few mm to 0.2 m) tend to be larger
- Some TG signals reach 0.5 m (e.g., Ganges River delta)
- TG amplitudes are smaller than shallow T/P on the US East Coast, Chinese East Coast, South Australian Coast
- "Coastal" TG correlate with T/P better than "islands" (0.82 vs 0.42)
- Standard deviations of the mean T/P values are usually <10 mm

- **Shallow vs deep T/P** , R = 0.64 (Figure 4)
- Differences can exceed standard deviations
- Most outliers are in the US Pacific Northwest

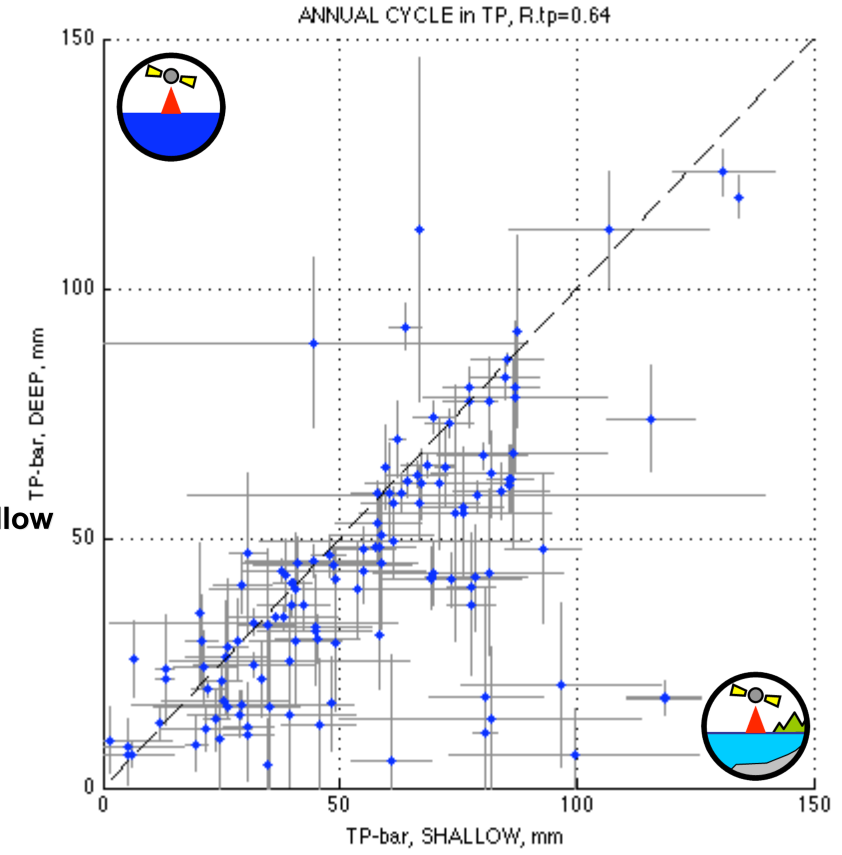

Figure 4: shallow vs deep T/P.

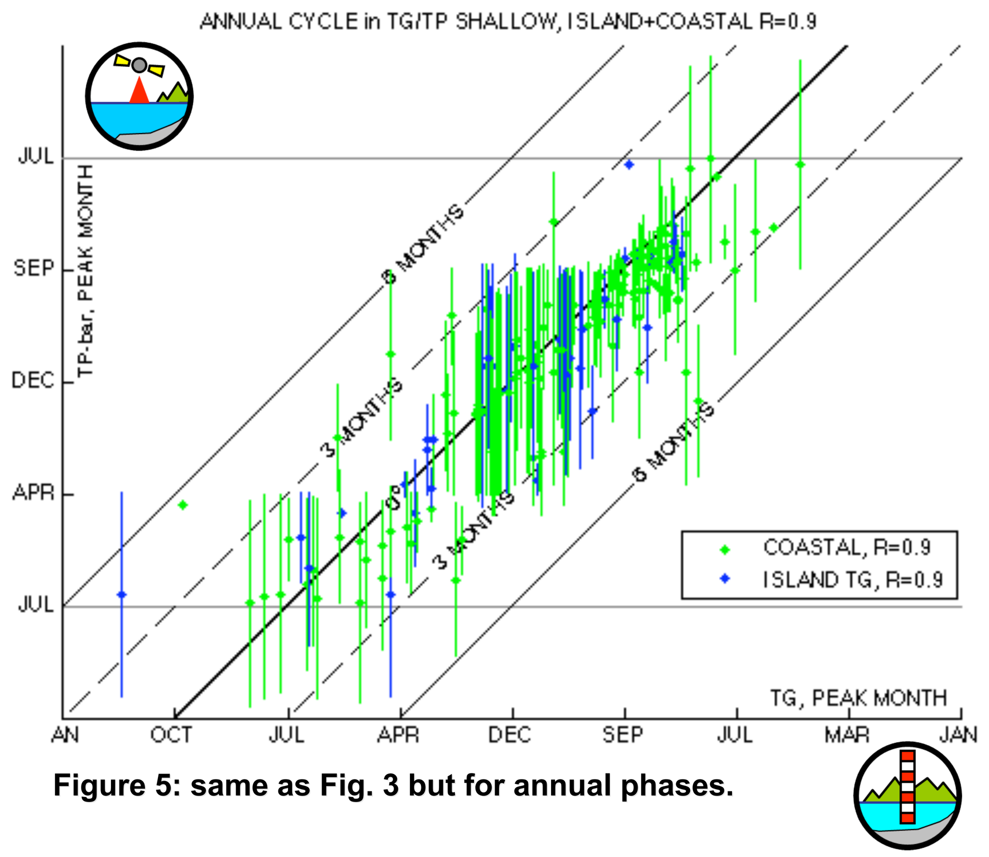

Figure 5: same as Fig. 3 but for annual phases.

Annual Phases

- **TG vs shallow T/P**, R = 0.90 (Figure 5)
- Phases in TG and T/P are better correlated than amplitudes
- Spatial variability in shallow T/P is 1-2 months
- Island stations usually have less spatial variability
- Out-of-phase outliers are not necessarily amplitude outliers (exceptions are western boundary currents, South Australian Coast)

- **Shallow vs deep T/P**, R = 0.92 (Figure 6)
- Standard deviations are higher in shallow areas
- Best correspondence for islands (R=0.97)
- Noticeable differences:
  - Thai coast in Indian Ocean,
  - South Australian Coast

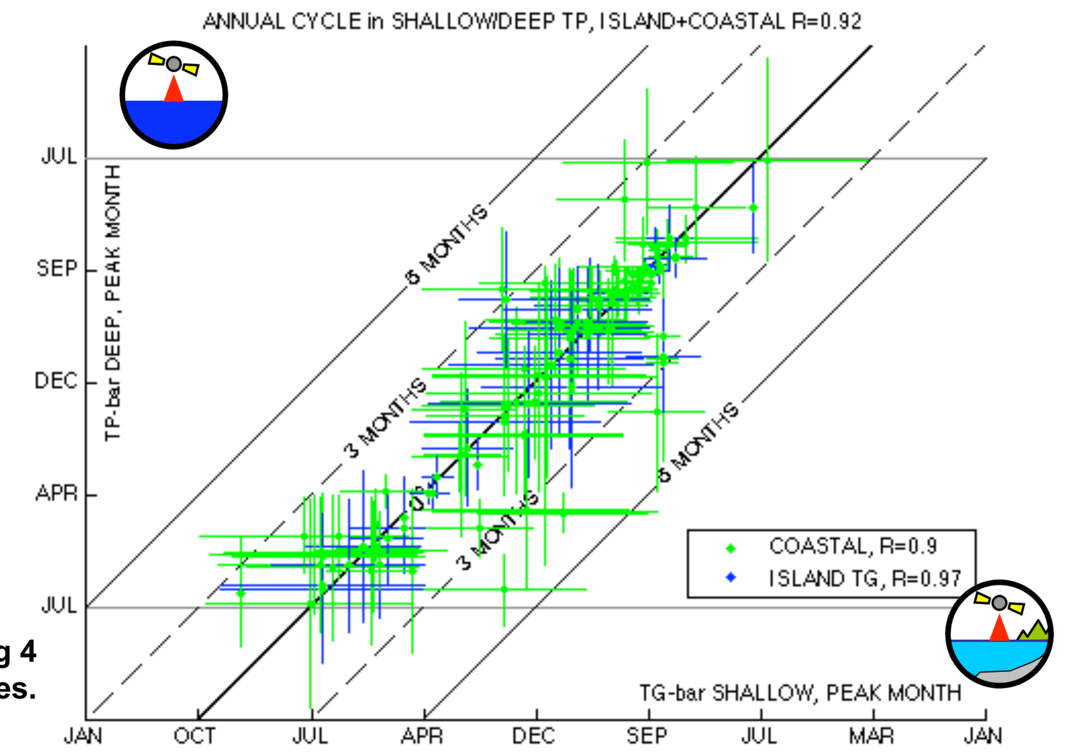

Figure 6: same as Fig 4 but for annual phases.

Example of Near-Coastal SSH Variability

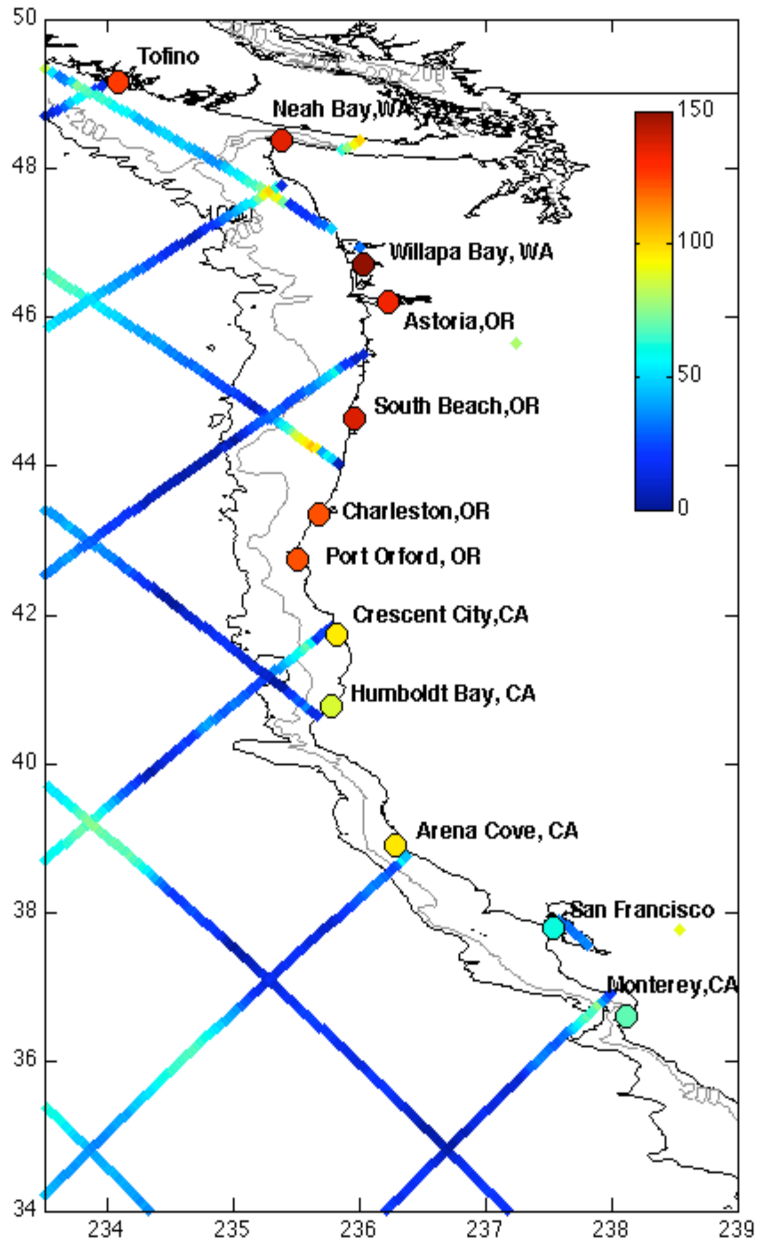

Figure 7: California/Oregon/Washington coast: annual amplitude in TG and T/P. Isobaths shown are 200m (thin curve) and 1000m (thick curve).

Figure 7 shows the annual cycle in T/P and TG along the CA/OR/WA coast. T/P data show substantial spatial variability in the area of the California Current. Another important factor is upwelling, which contributes to the thermosteric cycle in SSH. Most TG stations at the coast exhibit much higher annual amplitudes (11-19 cm).

- Strong along-shore currents may isolate annual variability at the coast from the offshore, leading to notable differences in both amplitudes and phases across the shelf.
- Spatial structure of the annual cycle may rapidly change on the scale of just 7 km.

Some Conclusions

- Local effects like inner harbor dynamics, river outflow, and land-based atmospheric forcing make SSH annual variability at the coast different from the ocean.
- Some ocean islands may exhibit large differences with nearby circulation due to positioning of TG in very shallow and semi-enclosed harbors and lagoons.
- The difference between annual cycle patterns at the TG stations and nearby T/P data makes TG generally unsuitable for inferring the mean annual cycle in nearby open waters.
- The TG annual cycles may provide an important data constraint for high-resolution coastal ocean models.
- The along-track T/P data provides a robust estimate of the annual cycle even in very shallow waters, making it suitable for use in constraining ocean models.
- Combining TG and T/P data with high-resolution models involving oceanic, terrestrial, and atmospheric dynamics may provide a better understanding of the complexity in SSH annual cycle near the coast.