Slope Correction for Ocean Radar Altimetry

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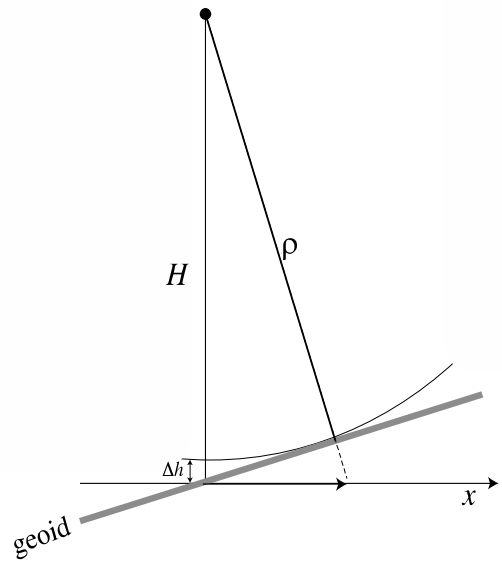
What is the slope correction?



An altimeter measures the range to the mean scattering surface, ρ, which is not necessarily the range to nadir, *H*. If the mean surface is inclined to the ellipsoid, the height of the surface at nadir is over-estimated and needs to be reduced by a correction $\Delta h = H - \rho$.

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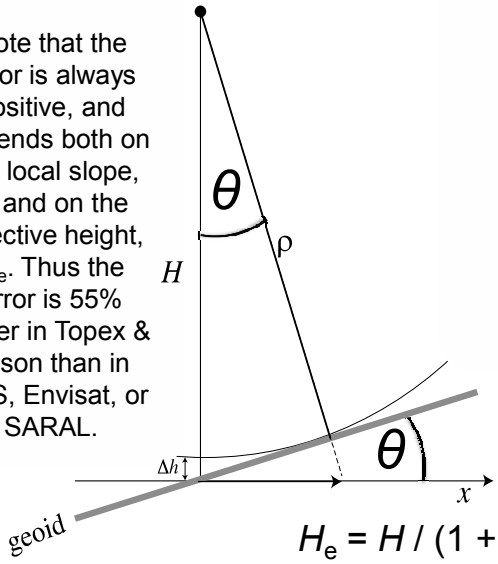
Why haven't oceanographers heard of this?

Note that the error is always positive, and depends both on the local slope, θ, and on the effective height, H_e. Thus the error is 55% larger in Topex & Jason than in ERS, Envisat, or SARAL.



$\Delta h = |\tan\theta|^2 H_e/2$. Altimetry of land and grounded ice uses the correction because θ is large in those areas. Oceanographers have assumed that θ is small, but the geoid slope over seamounts, trenches, and continental shelves produces Δh up to 5 cm.

$H_e = H / (1 + H/R)$, R = Earth radius

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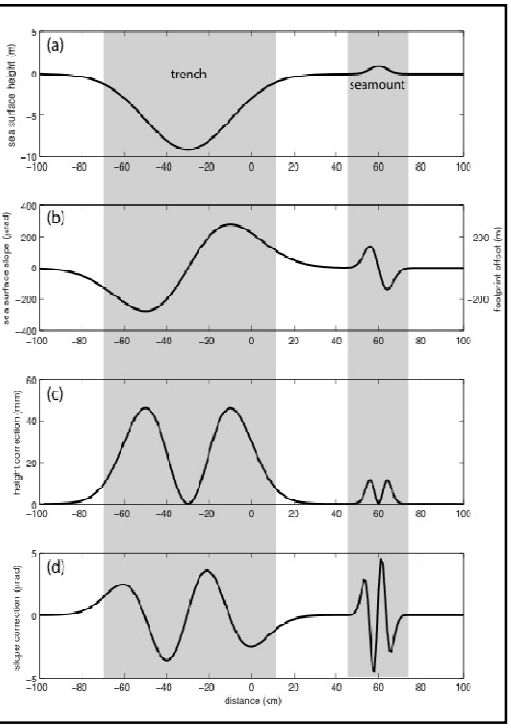
Examples

Geoid anomalies over seamounts & trenches, (a),

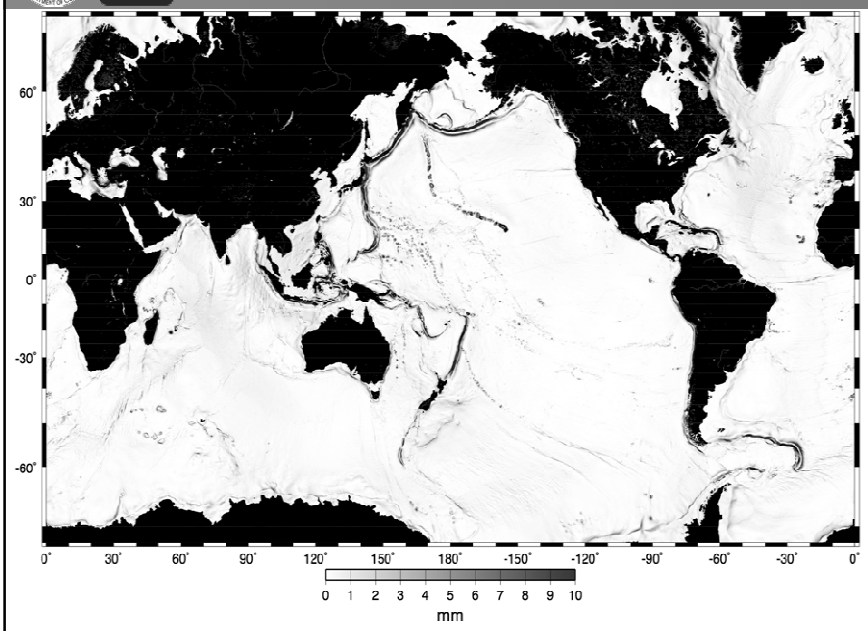
produce slopes of a few 100 μrad, (b),

causing Δh of a few cm, (c). Note that Δh is always positive.

The along-track sea surface slope is in error by up to 5 μrad, (d).



Nominal correction scaled to H_e = 1000 km.



The error exceeds 1 cm over shelf edges, trenches, and seamounts, and can reach 5 cm in some places.

(The error is about 0.7 of this for SARAL and about 1.1 of this for Jason.)

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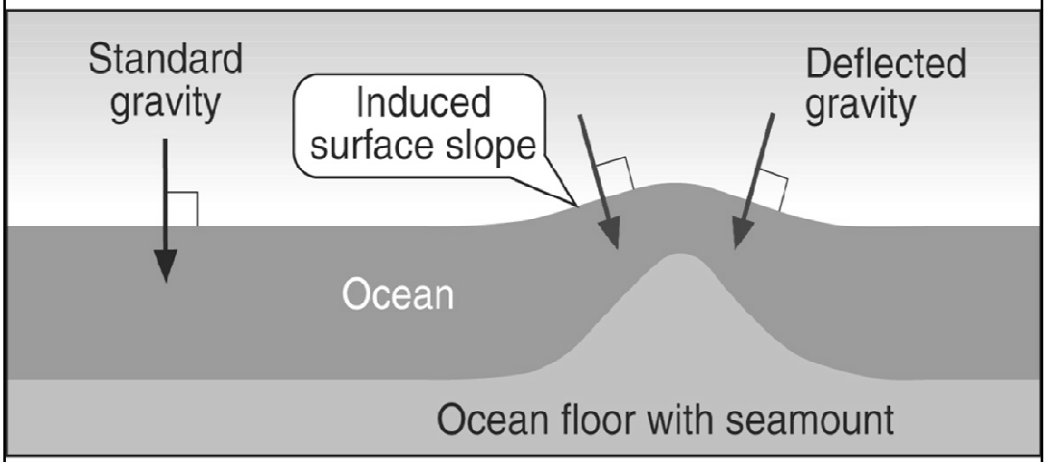
The correction matters for geodesy



Geodetic altimetry needs to measure the true sea surface slope. Slope errors in the latest marine gravity models from altimetry are now ~2 μrad, smaller than the along-track slope of Δ*h*. Thus geodesists now must make this correction.

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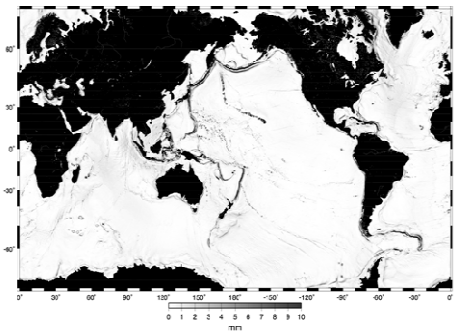
Does it matter for physical oceanography?



Since the error is geographically fixed, it should be the same on every cycle of an exact-repeat orbit. Errors then cancel in along-track height anomaly computed with respect to a time average of along-track height.

However, when combining profiles into a mean sea surface model, if the correction is not made then: (1) implied dynamic topography is wrong by a few cm; and (2) there will be problems combining data from satellites with different H_e.

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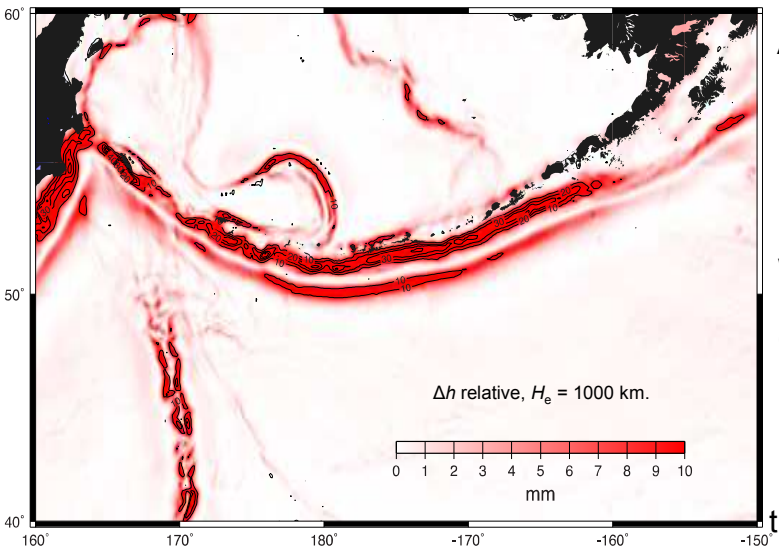
How wrong is the height? North Pacific



The height error Δh reaches 4 cm in the Aleutian Trench. If this error is in the mean dynamic topography and we assume MDT shows geostrophic flow, we will have erroneous clockwise circulation along the contours here.

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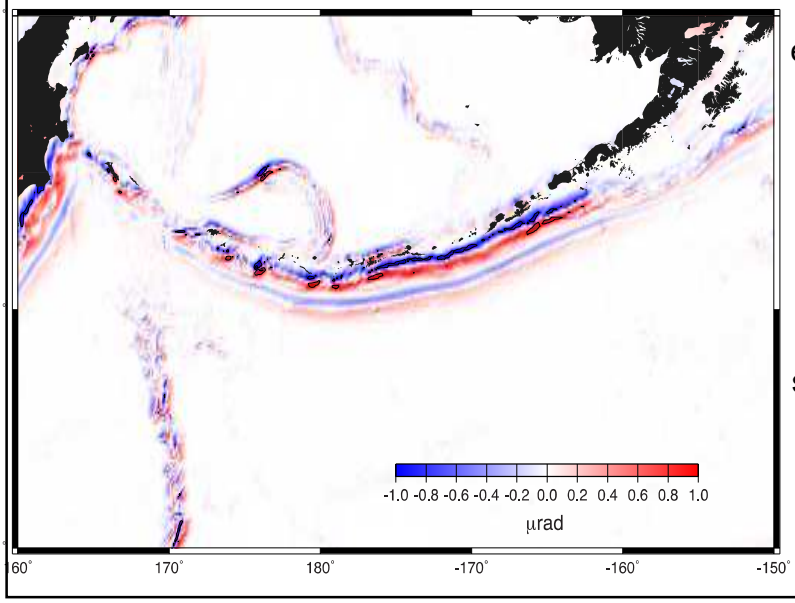
How wrong is the slope? North Pacific



The slope error exceeds 1 μrad in the Aleutian Trench. If we convert 1 μrad of slope error to an equivalent geostrophic velocity, we get 8.5 cm/sec. The sense of the error is that eastward flow along the Aleutians is over and under estimated.

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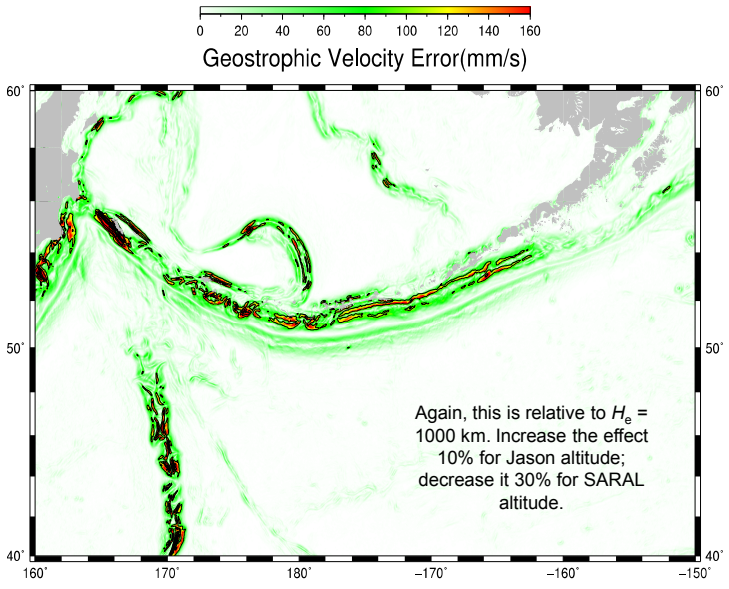
How wrong is the speed? North Pacific



Converting Δ*h* into a geostrophic velocity potential and then looking at the magnitude of the potential's gradient gives a scalar estimate of the error in geostrophic velocity magnitude. This is 8 cm/s along the trench, with peaks > 16 cm/s in some areas.

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But does it really matter?

- The geostrophic approximation only holds on space scales >= a Rossby radius scale.
- Geoid slopes are largest over localized features, so Δh errors are also localized.
- We have illustrated Δh as errors in currents, but we do not know whether the geostrophic approximation holds in our examples.
- It is clear that geodesy can no longer ignore Δh.
- We do not know if it matters to oceanographers.

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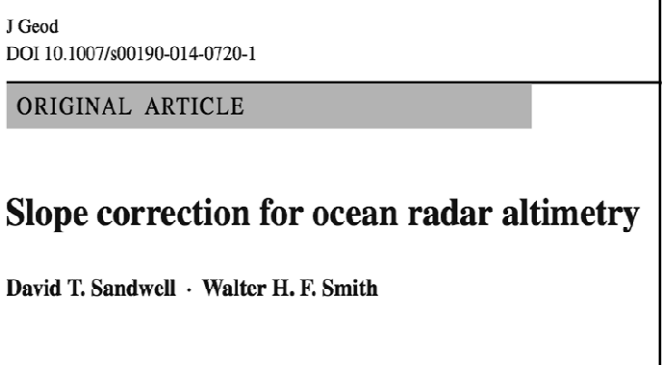
Acknowledgements

We thank Ole Andersen for presenting this paper in our absence. We regret that we could not join you at OSTST.

Those who wish a fuller explanation are referred to the published paper in Journal of Geodesy.



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