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The SQG model with quasi-realistic stratification

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The surface quasi-geostrophic (SQG) formalism has been used to study the evolution of temperature anomalies near the tropopause and density anomalies at the ocean surface. Generally it is assumed that the background stratification is linear with height (depth), yielding a constant Brunt-Vaisala frequency. However, the ocean stratification is strongly surface-intensified, and is closer to an exponential function of depth than a linear one.

Here we consider analytical SQG solutions with exponential stratification, and compare the results to those obtained with constant stratification. The SQG solutions with exponential stratification decay more rapidly in the vertical and have weaker near-surface velocities. This then compounds the previously-noted problem that SQG under-predicts the velocities associated with a given surface density anomaly.

Ocean variability is often analyzed instead in terms of baroclinic modes. Thus we also consider how the SQG solutions project onto these modes. With constant stratification, SQG waves larger than deformation scale project primarily onto the barotropic mode, and to a lesser degree on the first baroclinic mode. But with exponential stratification, the largest projection is on the first baroclinic mode. The effect is even more pronounced over rough bottom topography. So large scale SQG waves will "look" like the first baroclinic mode and vice versa, with realistic stratification.