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An Unravelling of the Resonant Instabilities of a Stratified Gravity Wave

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The resonant instability of a finite-amplitude, internal gravity wave is a thoroughly investigated process in geophysical flows. It is a known curiosity that numerical stability calculations using Floquet/Fourier methods result in a number of stability eigenvalues, for each disturbance wavenumber, that is determined by the numerical Fourier resolution (# of modes). This number is seemingly in contradiction with the underlying linear dispersion relation of gravity waves for which the expected frequency multiplicity should be just two.

We have related this paradoxical behaviour to branch cuts in the spectral theory for Floquet operators. This suggested computing the complex-analytic Riemann surface for the stability eigenvalues as a function of Fourier wavenumbers — an exercise that results in a numerical selection principle for identifying the two physically-relevant values. The stability diagrams of the (complex-valued) frequency-wavenumber relation so produced are now continuous in the disturbance wavenumber and the finite-amplitude of the original gravity wave. In addition, a parameter window of four-wave resonances was discovered which undoubtedly added unexpected difficulty in previous interpretations of this stability calculation.