Gravity Waves with Wind

1. **Basic State with Constant Wind** Modify the analysis of gravity waves shown in class to consider a basic state with a constant horizontal wind $\vec{U} = U \hat{x}$.

   a) Obtain the linearized equations and the dispersion relation.

   b) The “intrinsic frequency” is defined as $\omega_i = \omega - kU$, where $\omega$ is the actual frequency and $k$ is the horizontal wavenumber. Show that the dispersion relation for the intrinsic frequency for arbitrary $U$ is identical to the dispersion relation for the actual frequency in the case where the basic state has $U = 0$.

   c) What does this result tell you about gravity waves with a mean wind? Think about the phase speed of the wave and ideas about reference frames.

2. **Topographically Forced Stationary Waves** Consider a sinusoidal topography with wavenumber $k_0$ in the $x$-direction. Wind blowing over such a topography can excite resonant stationary waves. Here, resonant means the waves have the same horizontal wavenumber as the topography, $k = k_0$, and stationary means they are independent of time and so have zero frequency, $\omega = 0$.

   a) Using your results from problem 1, solve for the vertical wavenumber $m$ for such stationary waves in terms of the parameter that defines the physical setup, $k_0$, and parameters that define the basic state, $U, N$.

   b) Determine which conditions give rise to waves and which give rise to modes which exponentially grow and decay in $z$. 