Advection terms in the equations of motion are some of the terms potentially responsible for VM in our model, the other terms being the hyperviscous terms. Per Early et al, 2021 (see Appendix C), we can use the WaveVortexModel to identify the energy flux due to these nonlinear terms (EnergyFluxAtTimeInitial). This code includes the neglected term in C16 of the manuscript which is necessary for a flux at the initial condition. The resulting values do not tell where the energy is being transferred from, just that energy is transferred into or out of each wave number for each component (IW/VM).

The run analyzed below is using the Winters model, where we start with a GM IW field, let it adjust for 24 hours, then restart with internal waves only. After another 24 hours of allowing things to adjust again, we restart with IW only and then begin analysis.

Chart, bar chart

Description automatically generatedFigure 1

In figure 1, we see that when starting with initially no energy in the VM field, it is fluxed in fairly evenly across all scales. We now further investigate this by seeing exactly which interactions are responsible for this flux.

Chart, histogram

Description automatically generatedFigure 2

In figure 2, we see an initial peak of total energy fluxing into the vortical mode field (black curve) with the most important interactions being wave-wave (orange curve), wave-geostrophic (purple curve), and wave-io (yellow curve). Initially the wave-geostrophic interactions are not as important as wave-io, but they quickly flux more energy into the geostrophic and become responsible for almost as much flux as the wave-wave interactions.

We next investigate the scales at which energy is fluxed into the VM field due to each interaction.

Chart, bar chart

Description automatically generatedFigure 3

In figure 3, we see the energy flux due to wave-wave interactions where the energy is fluxed into the vortical mode across all scales fairly evenly for the initial condition.

Chart, bar chart

Description automatically generatedFigure 4

In figure 4, we see the energy is fluxed into the VM field at the low-mid vertical wavenumbers, and the mid-high horizontal wavenumbers for the initial condition.

Chart

Description automatically generatedFigure 5

In figure 5, there is no initial flux due to wave-geostrophic interactions because there is no energy in the geostrophic field, so we look at the time immediately following the initial condition. \* note color bar scale. Here we see a flux out of the wave and inertial oscillations as a result of these wave-geostrophic interactions. In the wave field, we notice these specific wavenumbers that the most energy is drawn out of. Is there any intuition on this piece of such specific wavenumbers? The negative energy flux does not appear to be balanced by a positive energy flux into the vortical mode field for this interaction so we next look to see where this energy could be going. Is it balanced by a positive energy flux in some other interaction? Is it balanced by a different term in the energy equation?

Chart, histogram

Description automatically generatedFigure 6

In figure 6, we see the overall energy flux is in steady state (black curve) and is positive, where the working theory is that this positive energy flux is balanced by a negative energy flux from another term in the energy equation (dissipation for example). Here there is an initial flux of energy due to wave-wave interactions (peak of orange curve at the very beginning) which is balanced by an initial negative flux of energy due to wave-geostrophic interactions (trough of purple curve at the very beginning). Is there a physical explanation for what is happening here? I am finding it difficult to make sense physically of how the energy is drawn from the wave field in the wave-geostrophic interactions, but then it is fed into the geostrophic field in the form of wave-wave interactions.

Below is a video of the first 10 times of the run. Here we see the VM field initially gaining energy and filling out higher wavenumbers (for wave-wave, top plots) which aligns with the wave and IO fields losing more energy and filling out higher wavenumbers in the bottom plots (wave-geostrophic). This is then followed by the positive energy flux at higher wavenumbers (wave-wave geostrophic flux) migrating to lower wavenumbers.

