

Weather Clim. Dynam. Discuss., referee comment RC1
<https://doi.org/10.5194/wcd-2022-30-RC1>, 2022
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Comment on wcd-2022-30

Dennis Hartmann (Referee)

Referee comment on "Robust poleward jet shifts in idealised baroclinic-wave life-cycle experiments with noisy initial conditions" by Felix Jäger et al., Weather Clim. Dynam. Discuss., <https://doi.org/10.5194/wcd-2022-30-RC1>, 2022

This paper is an interesting contribution to the literature on the impact of baroclinic shear on baroclinic lifecycles. Rather than using a single wavenumber to initialize the experiments, the authors add varying degrees of spatial white noise to the initial state. In cases of weak noise longer wavelengths grow via wave-wave interactions, (2,4,6) in the case of a base wavenumber of 6. These longer wavelengths are able to propagate toward the equator and lead to net poleward momentum flux in the case with large cyclonic barotropic shear (LC2) case as well as the LC1 case without the added cyclonic barotropic shear (LC1). If a high level of noise is added, shorter wavelengths, which are presumably more linearly unstable than wave 6, also develop early in the simulation and appear to break poleward in both the LC1 and LC2 cases. This leads to a situation where an initial stage of poleward wave breaking always occurs, but is always followed by equatorward wave propagation and breaking as the energy cascades to longer wavelengths that can propagate across the barotropic shear to the tropics. This leads one to conclude that equatorward wave propagation, poleward momentum flux, and poleward jet propagation must be a dominant feature of the general circulation, as is required by the global angular momentum balance.

Figure 3 , panels c and g are chosen at a particular time when wavenumber 4 dominates the image of PV. This misled me into thinking that wave 4 was growing by linear instability, which is not the thesis of the paper. Looking at Fig. 6 it is more obvious that this particular time is special. It would be good to note at this point that wave 2 is also evident in Fig. 3g or make some other comments to say that the dominance of wave 4 at this time is just transitory.

This is an interesting contribution and is fairly clearly written, with some exceptions that are noted below on a line-by-line and figure basis.

Comments on text:

Line 99: 'gradually'

115: Not sure what is meant by the initial phrase "Consistent with the energetics of the systems, "

117: Would a linear analysis of the zonal mean state at this time reveal that the most unstable wavenumber is 4? Is the energy of wave 4 coming from the mean state or WMF interactions?

Fig. 3 in both cases, wavenumber 4 emerges as dominant around day 22-24. Why? It would be good at this point to say that you have picked out a particular time when wave 4 was dominant, and also point out that wavenumber 2 can also be seen at this time in panels C and G. The choice of time makes it look like it is mostly linear growth of wave 4, which is not consistent with the nonlinear theory that is actually the thesis of the paper.

135: Is that because wavenumber 4 (and 2) can propagate toward the equator, while wavenumber 6 cannot in the LC2 state?

138: On first reading, I did not quite get the physical reason for the emergence of wavenumber 4, which seems to be key. I don't see any reason for a state consisting of wavenumber 0 and 6 to create wavenumber 4 through nonlinear exchange, but if I look back at Fig. 3 panel G, I can see some wavenumber 2. It might help to point that out. Wavenumber 4 can propagate toward the equator and produce an LC1 outcome in the end.

174: If the wave breaking event creates a spectrum of wavenumbers, why is the initial noise so important to the evolution of the flow after the first wave-breaking phase?

Fig. 6 The legend "Specified wave 4" is unclear. The other experiment was Specified wave 6, but it was allowed to evolve nonlinearly, whereas the curves for 4 and 3 seem to be extrapolations of their infinitesimal linear growth rates.

Fig. 6 If it is nonlinear wave exchange responsible for the growth of 2 and 4, why is their growth rate independent of the amplitude of wave 6? Their growth looks exponential, like they were linearly unstable.

194: Did you mean to say, "In contrast to experiments with weak noise," As it is, it confused me. So in a case with white noise initialization, shorter wavelengths grow faster and tend to exhibit LC2 initial evolution, until the larger scales develop, which are able to propagate toward the equator, ending in a poleward jet shift and a more LC1-like final state.

265: One might imagine a region of parameter space where the baroclinic growth of shorter wavelengths would be fast compared to the cascade to longer wavelengths in which the cyclonic state could be maintained by the poleward breaking of these shorter waves. It might also be possible that the shorter waves contribute their energy to a stationary wave, such as in the blocking ridge situation.

Clearly for the general circulation to work, the dominant direction of eddy propagation and breaking must be toward the equator to satisfy the angular momentum balance.