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Tropical Background and Wave Spectra: Contribution of Wave–Wave Interactions in a Moderately Nonlinear Turbulent Flow

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Variability in the tropical atmosphere is concentrated at wavenumber–frequency combinations where linear theory indicates wave modes can freely propagate, but with substantial power in between. This study demonstrates that such a power spectrum can arise from small-scale convection triggering large-scale waves via wave–wave interactions in a moderately turbulent fluid. Two key pieces of evidence are provided for this interpretation of tropical dynamics using a nonlinear rotating shallow-water model: a parameter sweep experiment in which the amplitude of an external forcing is gradually ramped up, and also an external forcing in which only symmetric or only antisymmetric modes are forced. These experiments do not support a commonly accepted mechanism involving the forcing projecting directly onto the wave modes with a strong response, yet still simulate a power spectrum resembling that observed, though the linear projection mechanism could still complement the mechanism proposed here in observations. Interpreting the observed tropical power spectrum using turbulence offers a simple explanation as to why power should be concentrated at the theoretical wave modes, and also provides a solid footing for the common assumption that the background spectrum is red, even as it clarifies why there is no expectation for a turbulent cascade with a specific, theoretically derived slope such as −5/3. However, it does explain why the cascade should be toward lower wavenumbers, that is an inverse energy cascade, similar to the midlatitudes even as compressible wave modes are important for tropical dynamics.
It also explains why in satellite observations and reanalysis data, the symmetric component is stronger than the anti-symmetric component, as any bias in the small-scale forcing from isotropy, whether symmetric or antisymmetric, leads to symmetric bias in the large-scale spectrum regardless of the source of variability responsible for the onset of the asymmetry.

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