Geophysical Research Abstracts
Vol. 18, EGU2016-17452, 2016
EGU General Assembly 2016

Role of entrainment in convectively-coupled equatorial waves in an aquaplanet model

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Equatorially-trapped waves are known to be one of the key phenomena in determining the distribution of convective precipitation in the tropics as well as being crucial to the dynamics of the Madden-Julian Oscillation. However, numerical weather prediction models struggle to sustain such waves for a realistic length of time, which has a significant impact on forecasting precipitation for regions such as equatorial Africa.

It has been found in the past that enhancing the rate of moisture entrainment can improve certain aspects of parametrized tropical convection in climate models. A parameter F controls the rate of entrainment into the convective plume for deep- and mid-level convection, with $F = 1$ denoting the control case. Here it is found in an aquaplanet simulation that $F > 1$ produces more convective precipitation at all zonal wavenumbers. Furthermore, Kelvin wave activity increases for waves with low frequency and zonal wavenumber but is slightly suppressed for shorter, higher-frequency waves, and vice versa for westward-propagating waves.

A change in entrainment rate also brings about a change in the basic state wind and humidity fields. Therefore, the question arises as to whether changes in wave activity are due directly to changes in the coupling to the humidity in the waves by entrainment or due to changes in the basic state. An experiment was devised in which the convective parametrization scheme is allowed to entrain a weighted sum of the environmental humidity and a prescribed zonally-symmetric climatology, with a parameter α controlling the extent of the decoupling from the environment.

Experiments with this new mechanism in the parametrization scheme reveal a complex relationship. For long waves at low frequency (period $> \sim$13 days), removing zonal asymmetry in the humidity seen by the entrainment scheme has very little influence on the ratio of eastward- to westward-propagating power. At higher frequencies and zonal wavenumbers, removing this zonal asymmetry acts to suppress wave activity. Enhanced entrainment rate relative to the control case is also shown to slow the phase speed of Kelvin waves by around 20%. The phase speed depends also on the decoupling parameter α, with the minimum speed occurring around the special case $\alpha = 1 - 1/F$, when the basic state humidity is entrained at the enhanced rate and perturbations from it are entrained at the control rate.