1.4 MODELS FOR CONVECTIVELY COUPLED TROPICAL WAVES

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The tropical Western Pacific is a key area with large input on short-term climate. There are many recent observations of convective complexes feeding into equatorially trapped planetary waves Wheeler, Kiladis (1999) and Wheeler, Kiladis, and Webster (2000), which need a theoretical explanation and also are poorly treated in contemporary General Circulation Models (GCM's). This area presents wonderful new research opportunities for applied mathematicians interested in nonlinear waves interacting over many spatio-temporal scales. This talk describes some ongoing recent activities of the speaker related to these important issues.

A simplified intermediate model for analyzing and parametrizing convectively coupled tropical waves is introduced in Majda and Shefter (2001). This model has two baroclinic modes of vertical structure, a direct heating mode and a stratiform mode. The key essential parameter in these models is the area fraction occupied by deep convection, σ_c. The unstable convectively coupled waves that emerge from perturbation of a radiative convective equilibrium are discussed in detail through linearized stability analysis. Without any mean flow, for an overall cooling rate of 1 K/day as the area fraction parameter increases from $\sigma_c = 0.001$ to $\sigma_c = 0.0014$ the waves pass from a regime with stable moist convective damping (MCD) to a regime of "stratiform" instability with convectively coupled waves propagating at speeds of roughly 15 m s^{-1}, instabilities for a band wavelengths in the super-cluster regime, O(1000) to O(2000) km, and a vertical structure in the upper troposphere lags behind that in the lower troposphere-thus, these convectively coupled waves in the model reproduce several key features of convectively coupled waves in the troposphere processed from recent observational data by Wheeler and Kiladis (1999, 2000). As the parameter σ_c is increased further to values such as $\sigma_c = 0.01$, the band of unstable waves increase and spreads toward mesoscale wavelengths of O(100) km while the same wave structure and quantitative features mentioned above are retained for O(1000) km.

A detailed analysis of the temporal development of instability of these convectively coupled waves is presented here. In the first stage of instability, a high CAPE region generates deep convection and front-to-rear ascending flow with enhanced vertical shear in a stratiform wake region. Thus, these intermediate models may be useful prototypes for studying the parametrization of upscale convective momentum transport due to organized convection Moncrieff (1992), Moncrieff and Klinker (1997). In the second stage of instability, detailed analysis of the CAPE budget establishes that the effects of the second baroclinic mode in the stratiform wake produce new CAPE, which regenerates the first half of the wake cycle. Finally, since these convectively coupled stratiform waves do not require a barotropic mean flow, a barotropic mean flow which alters the surface fluxes, is added to study the effect of their stability. These effects of a barotropic mean flow are secondary; an easterly mean flow enhances instability of the eastward propagating convectively coupled waves and diminishes the instability of the westward propagating waves through a WISHE mechanism.

Finally, new models for treating the equatorial wave guide Majda and Shefter (2001), Majda and Khouider (2001) which are intermediate between full meriodonal resolution and the equatorial long wave approximation will be discussed. If time permits, the use of these models in efficient numerical schemes which allow for cloud resolving modeling Grabowski (1999), but also include large scale interaction in the equatorial wave guide will be outlined Majda and Khouider (2001).

References

Grabowski, W.W., 1999: Towards cloud resolving modeling of large scale tropical circulation: a simple cloud microphysics parametrization. *J. Atmos. Sci.,* **55,** 3283-3298.

Majda, A.J., and B. Khouider, 2001: A numerical strategy for efficient modeling of the equatorial wave guide. *Proc. Nat. Acad. Sci.* February 13, 2001 **98**, 1341-1346.

Majda, A.J., and M.G. Shefter, 2001: Waves and instabilities for model tropical convective parametrizations. *J. Atmos. Sci.,* April 15 issue.

Majda, A.J. and M.G. Shefter, 2001: Models for stratiform instability and convectively coupled waves. *J. Atmos. Sci.* (in press).

Moncrieff, M.W., 1992: Organized convective systems: Archetypal dynamical models, mass and momentum flux theory, and parametrization. *Quat. J. Roy. Met. Soc.*, **118**, 819-850.

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Moncrieff, M.W. and E. Klinker, 1997: Organized convective systems in the tropical western Pacific as a process in general circulation models: A TOGA-COARE case study. *Quat. J. Roy. Met. Soc.,* **123**, 805-827

Wheeler, M., and G.N. Kiladis, 1999: Convectively coupled equatorial waves: analysis of clouds and temperature in the wavenumber-frequency domain. *J. Atmos. Sci.*, **56**, 374-399.

Wheeler, M., G.N. Kiladis, and P. Webster, 2000: Large scale dynamical fields associated with convectively-coupled equatorial waves. *J. Atmos. Sci.*, **57**, 613-640.