JP8.15 COMBINING REPRESENTATIONS OF ENTRAINMENT AND ORGANIZATION TO BETTER MODEL ATMOSPHERIC VARIABILITY

Richard B. Neale* and Brian E. Mapes
NOAA-CIRES Climate Diagnostics Center, Boulder, Colorado

1. INTRODUCTION

This study aims to demonstrate the importance of realistic entrainment and organization when considering convective parameterization. Rather than having the somewhat idealistic goal of using observed values of entrainment and modelling organization explicitly, we aim to represent the overall *information flow* associated with realistic convective phenomena.

The main motivation behind this approach is the general observation that convection involves a significant amount of mixing and organization. More specifically convectively coupled wave-like disturbances (e.g., the MJO) involve the organization of convection at a variety of spatial scales leading to coherent and long-lived disturbances (Wheeler and Kiladis, 1999). Prior to an organization phase, convection is often limited due to its ubiquitous mixing with the environment. The time-scales of these processes combine to determine the magnitude and propagation characteristics of the wave-like features. We show results from a model developed around this *information-flow* paradigm for convection.

2. ENTRAINMENT

The model study considers the *successive entrainment* of a number of convective plumes. In this approach, entraining plumes are assumed to always undergo strong mixing with their immediate environment, but that environment is allowed to deviate from the large-scale mean properties.

Specifically, plumes entrain exactly two types of air: saturated up to the level of previous cloud tops; environmental air above that. This representation appears to be a better description of convective potential than just referring to the energy (CAPE) of an undilute parcel ascent, which can be negatively correlated with convective activity. This method significantly reduces the possibility of the deepest undilute plumes existing when convective development is in its very early stages.

3. ORGANIZATION

Current parameterization schemes (e.g., Arakawa and Schubert, 1974) often consider the current convective forcing response to be in some quasi-equilibrium with the current large-scale forcing - this allows a purely diagnostic parameterization scheme to be formulated. In reality the convective response at any instant is responding to the integrated large-scale forcing over some previous time-scale. In order to account for memory due to the organization of convection we introduce an additional prognostic variable.

We use the explicit representation of the prognostic gust-front areal coverage in each model grid-box as derived in Qian et al. (1998), but generalize it somewhat. Since it is not possible to know the true geometry of the gust-front features within a particular grid-box, we consider a characteristic virtual temperature gradient driving gust-front features within a convecting grid-box. Downdrafts maintain this gradient, whereas differential surface fluxes break it down. Therefore, convection is able to be self-sustaining, or organized, once it becomes established. Importantly, this allows for strong convection to persist in weak large-scale forcing conditions.

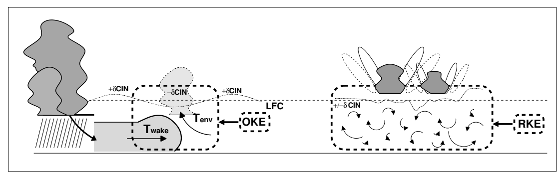


Figure 1. Schematic illustrating the contribution of organized kinetic energy (OKE) and random kinetic energy (RKE) to the cloud-base mass flux in the convection scheme.

Determination of the cloud-base mass flux in the convection scheme is based on turbulent kinetic energy (TKE) associated with random (RKE) and organized (OKE) boundary-layer energy (Fig. 1). RKE is the energy associated with boundary-layer eddies independent of convection, whereas OKE is the energy associated with gust-fronts in the presence of convection.

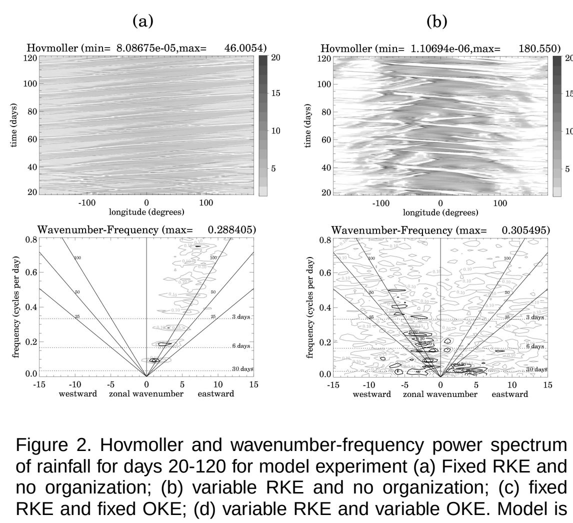
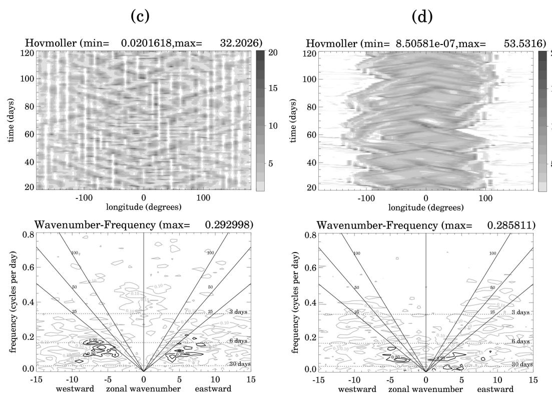


Figure 2. Hovmoller and wavenumber-frequency power spectrum of rainfall for days 20-120 for model experiment (a) Fixed RKE and no organization; (b) variable RKE and no organization; (c) fixed RKE and fixed OKE; (d) variable RKE and variable OKE. Model is 2D along equator. SST = 300 K +/- 0.5 K wavenumber 1 SSTA.

* *Corresponding author address:* Richard B. Neale,
NOAA-CIRES Climate Diagnostics Center,
325 Broadway, Boulder, CO 80305-3328
e-mail: richard.neale@noaa.gov

The dynamical component of the model used is an adapted version of that used in Zhu et al. (2001), a hydrostatic, beta-plane model. The simple 4-level configuration exploits the ‘trimodal’ spectrum structure of tropical convection frequently observed in the tropics. The model runs are integrated for 120 days, with the first 20 days being discarded.



4. MODEL RESULTS

4.1 Effects of Organization

In the absence of any organization parameterization and with fixed RKE (Fig. 2(a)), the rainfall variability is strongly tied to the principle dynamical mode of the model (Kevin wave) and locks into a very fast and regularly repeating mode over the whole domain. This is similar to the pattern of the ‘too fast and Kelvin-wave looking’ wave modes produced in GCMs. With the introduction of a varying element of RKE, tied to the boundary-layer stability profile (Fig. 2(b)), the model is able to generate variability over a much wider range of space and time-scales. Most importantly power increases for slower and larger spacial scale modes. However, variability at the largest zonal spatial scales remains small. Introducing a constant value for organization everywhere (Fig. 2(c), with constant RKE also) completely damps power of the natural dynamical modes of the system as a consequence of the convective response becoming decoupled from the large-scale forcing.

The most promising result comes from varying both RKE and OKE in time (Fig. 2(d)). This results in a power spectrum with significant variability coincident with the natural modes of the system, but with the dominant power being located at low wavenumbers (1-5) and low-frequencies (30 days+) - more reminiscent of the real atmosphere.

4.2 Effects of Entrainment

Two further experiments are shown which increase by 5 times and 10 times (Fig. 3(a) and (b)) the entrainment rate used for the successive generation calculations in the convection scheme. They appear to further improve the variability shown in Fig. 2(d). Low-wavenumber slow disturbances appear to spontaneously initiate, propagate, and die within the warm water region of the domain. This feature appears very similar to an MJO-type disturbance. The higher sensitivity to a dry troposphere, as expressed through the stronger entrainment, allows the longer time-scale of tropospheric humidification to slow-down the propagation speed. Mid-tropospheric humidity and temperature fields (not shown) clearly show that the disturbance time-scales are being set by the evolution of the humidity field.

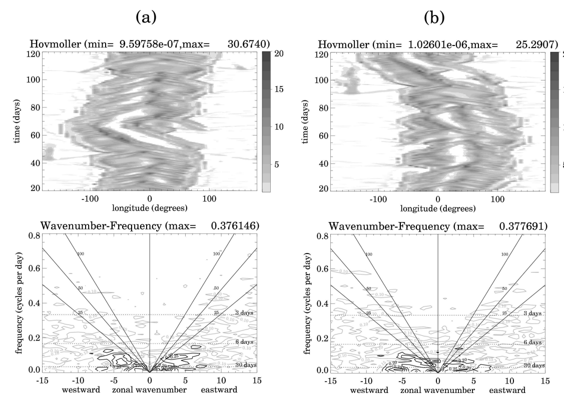


Figure 3. As Fig 2(d) except run uses (a) using 5 times standard entrainment (b) using 10 times standard entrainment.

5. CONCLUSIONS

In these relatively simple 2D model experiments we have shown that modelling the *information flow* associated with the interaction of entrainment and organization can lead to realistic looking tropical precipitation variability. We do not pretend that we have the correct values for organization area fraction, entrainment variation etc. (if they could ever be known), but we hope to have captured the correct sensitivities.

Transferring these ideas to a GCM convective parameterization would involve the introduction of at least one additional prognostic parameter. This would be a small price to pay for the potential improvements in large-scale tropical variability.

References

Arakawa, A., and W. H. Schubert, 1974: Interaction of a cumulus ensemble with the large-scale environment, part I. *J. Atmos. Sci.,* **31,** 674-701.

Qian, L., G. S. Young, and W. M. Frank, 1998: A convective wake parameterization scheme for use in general circulation models. *Mon. Wea. Rev.,* **126,** 456-469.

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.

Zhu, H., R. K. Smith, and W. Ulrich, 2001: A minimal three-dimensional tropical cyclone model. *J. Atmos.*