13C.8

DECOUPLING OF CONVECTIVELY COUPLED KELVIN WAVES: SUPER CLOUD CLUSTERS VERSUS MOIST KELVIN WAVES

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1. INTRODUCTION

The high correspondence between Matsuno's (1966) modes and the OLR spectral peaks associated with the ITCZ variability, as seen on a wavenumber-frequency diagram, was found by Wheeler and Kiladis (1999, WK99) and ever since the concept of Convectively Coupled Equatorial Waves (CCEWs) has been widely used. In particular, the term of Convectively Coupled Kelvin Waves (CCKWs) applies to the overlay between the Matsuno's Kelvin curves and the power associated with observed "superclusters" or "super cloud clusters" (SCCs; Nakazawa 1988).

Several theories have been proposed to explain the dynamics of SCCs/CCKWs, such as wave-CISK, WISHE, and stratiform instability. However, a drawback on the approach of these studies is that they can be applied to self-sustained systems (either at their strengthening or mature stage), but not to their formation, weakening or dissipation.

Another framework to study tropical variability involves numerical models with realistic representation for all processes except for some conditions such as absence of topography, fixed SST distribution and no seasonality. The purpose of this work is to conduct such idealized simulations for analyzing the dynamics associated with the life cycle of SCCs/CCKWs.

2. MODEL AND SIMULATIONS

Simulations with the WRF model are performed in an equatorial β-channel with 139km resolution over a rectangular domain of 40,000km x 13,300km. The grid extends meridionally to the equivalent of 60º with free-slip walls, and has periodic boundary conditions in the zonal direction. We call this configuration an "aquachannel".

The Tiedtke cumulus parameterization is used. The model is integrated for 2 years from initial rest, and the second year is considered for the analysis. Two prescribed symmetric SST profiles are used to force the model: these are the control (CTRL) and observed (OBS) profiles from the Aquaplanet Experiment (Blackburn and Hoskins 2013). The main feature arising from a analysis of ITCZ convection produced by both aquaplanet and aquachannel simulations is the CCKW mode as the dominant one, as evidenced by power spectra in the wavenumber-frequency space; this contrasts with the multiple wave types found in observations (WK99). We present results for the OBS simulations since very similar ones are obtained for the CTRL case.

3. RESULTS

A tracking algorithm was developed to investigate the propagation of CCKW signals along the tropics. Surface pressure (PSFC) propagates on average at 19.68 m/s, while OLR at 16.58 m/s, and 500mb Q_{total} (total cloud condensate) at 13.74 m/s. When a new SCC develops, the PSFC and OLR waves are nearly in phase, but due to their different propagation the second lags behind the first (Fig. 1). Eventually, when the separation is sufficiently large, the system breaks or dissipates, as can be inferred from the algorithm tracking a new wave.

The analysis of raw Hovmoller diagrams for the same pair of variables (Fig. 2) provides additional advantages: there is no more dependence on constraints or sensitivities as in the algorithm and details of the horizontal structure are provided, rather than simply the location of the wave axis. A similar perspective is obtained by analyzing sequences of horizontal distributions of OLR and PSFC in the tropics (not shown), with further details of the multiscale structures of the SCCs.

A subsequent analysis found that *mse* plays a fundamental role in the life cycle of SCCs (not shown). At 1000mb *mse* propagates as fast as

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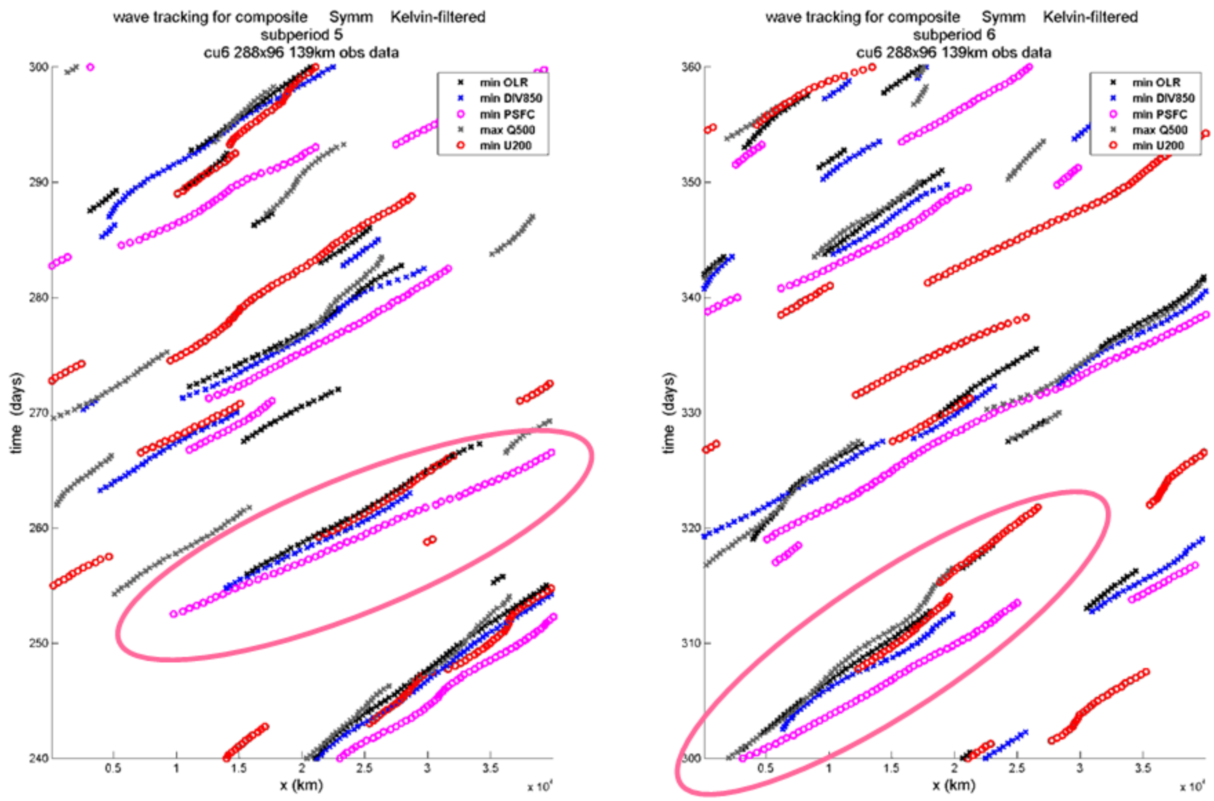

Figure 1. Hovmoller diagrams of the CCKW axis evolution, using different variables as trackers, for days 240-360.

the pressure wave (i.e.: a moist Kelvin wave), but the speed magnitude decreases with height. When heat and moisture positive anomalies are treated separately, it was found that both propagate similarly as MSE1000. The surface fluxes that contribute to positive MSE1000 anomalies east of the SCC are a key element of the WISHE (wind-evaporation feedback) theory, and also of the moisture mode theory for the MJO.

We propose a conceptual model to illustrate the evolution of a CCKW (Fig. 3) with clear distinctions between the SCC and the moist Kelvin wave. The first two stages (a,b) are characterized by a continuous intake of heat and moisture that feeds the SCC. Eventually, after a sufficiently long separation between the SCC and the moist Kelvin wave, the *mse* positive anomaly structure breaks into mid-level and boundary layer components, starting the weakening process (c). Then, individual storms and even mesoscale structures (cloud clusters, CCs) continue to generate, although in a more scattered, disorganized way, until most of convection is suppressed (d). In turn, the fast-moving moist Kelvin wave favors new development of storms that organize into larger mesoscale features first (d), and later originating a new SCC (a). Although not shown in Fig.3, the decaying and strengthening SCCs often coexist in time, as shown in Fig. 2. The a-d cycle repeats itself, although in occasions, the moist Kelvin wave decays as well inhibiting SCC formation.

4. REMARKS

After our analysis, we conclude that the CCKWs are neither the SCCs nor the moist Kelvin waves alone, but the system as a whole, and its peculiar coupling nature. The “CCKW” term has mostly replaced SCC in literature since WK99, although both labels have been often interchangeably used. We believe that the equivalence can still be kept in most cases, not only because precipitation is typically the variable of interest when studying CCKWs, but also because all structures are coherently coupled in a time average sense (even composites of pressure and *mse* to a first order approximation). However, when the CCKW system is analyzed in detail in terms of time evolution, a distinction becomes apparent.

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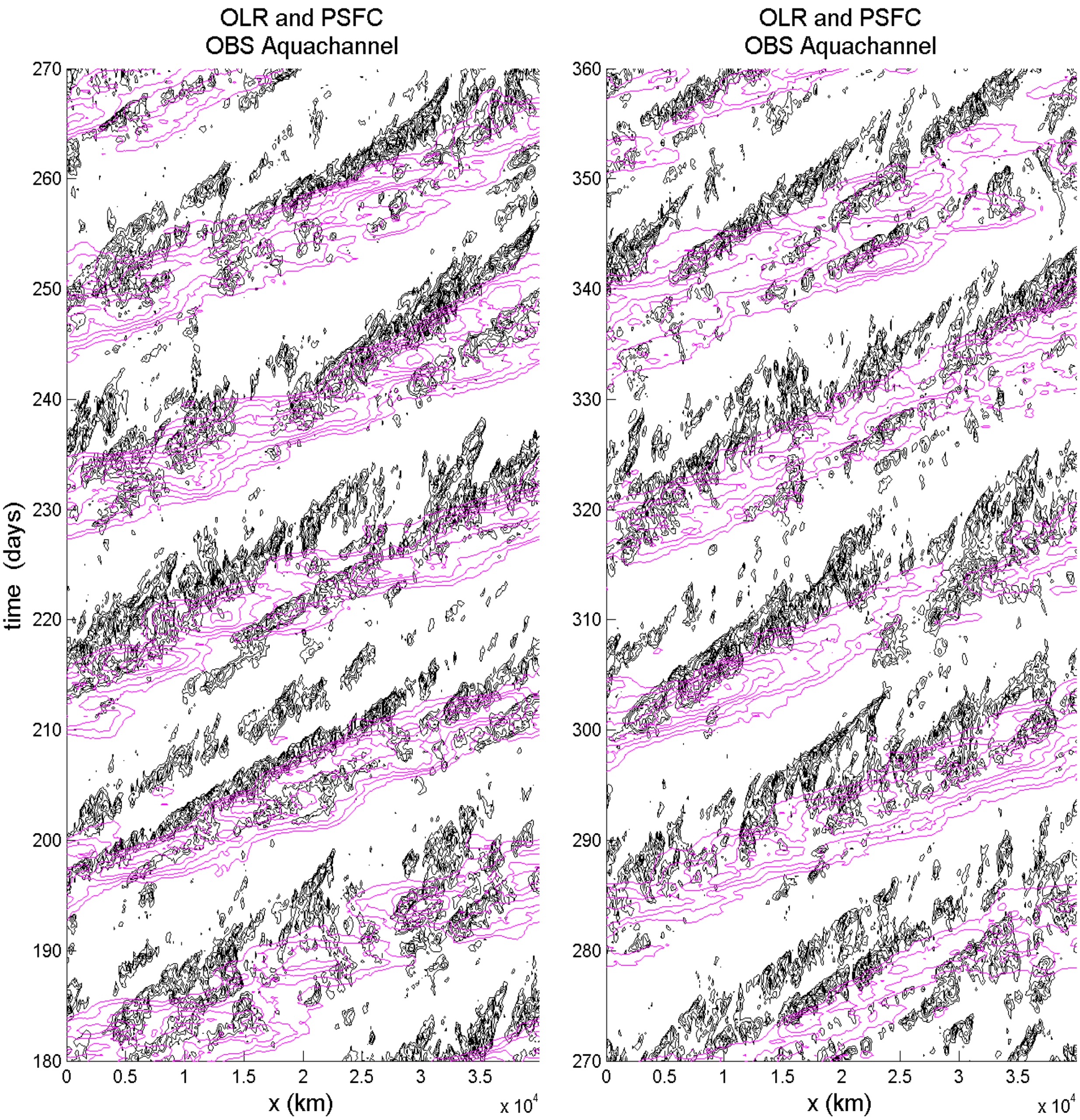

Figure 2: Hovmoller diagrams of OLR (black) and PSFC (pink) troughs averaged in the 15°S to 15°N band, for days 180-360.

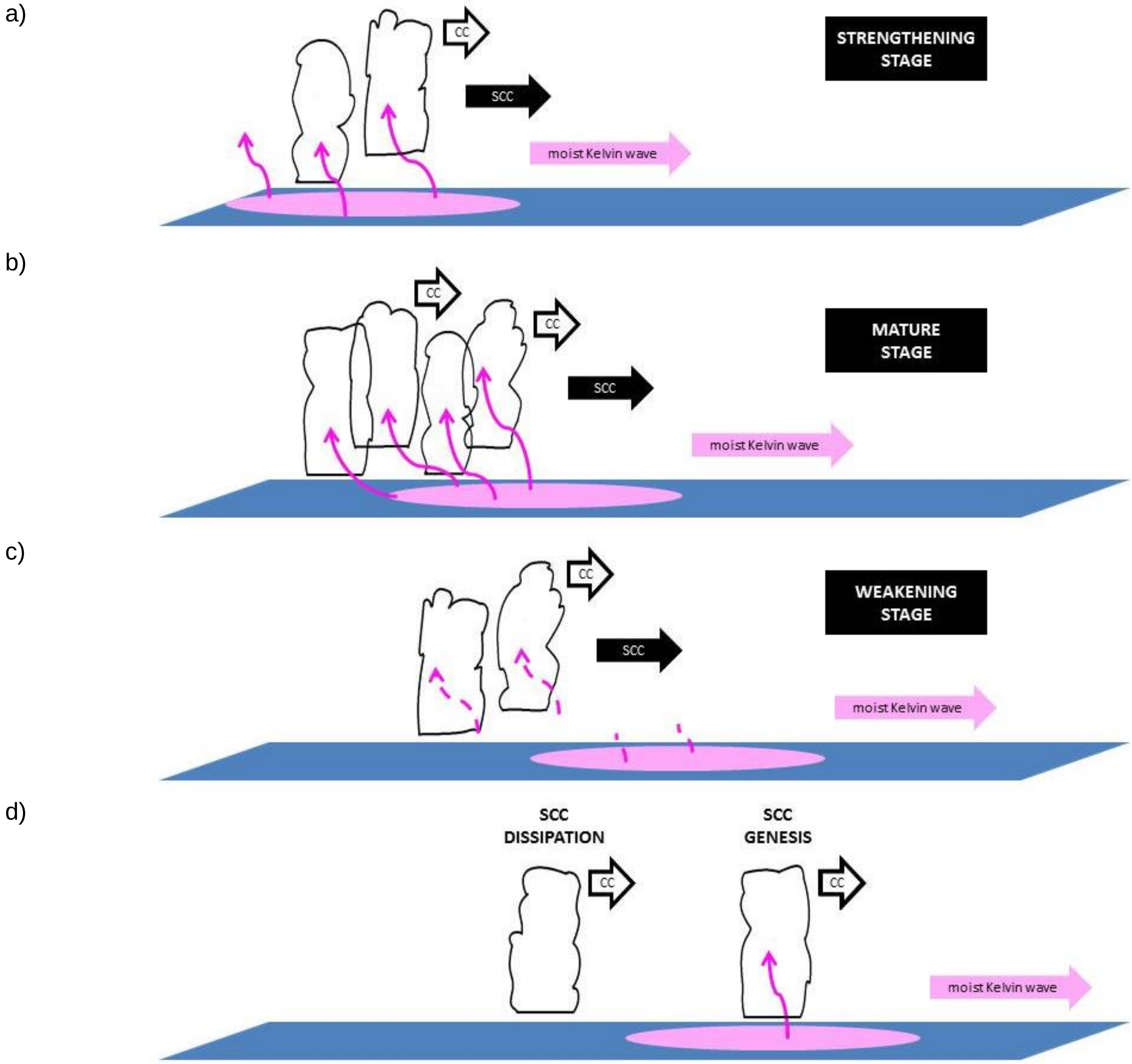

Figure 3: Conceptual model for the CCKW evolution.