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Free and Convectively Coupled Equatorial Waves Simulated by CMIP5 Climate Models

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It is well known that precipitation in the equatorial belt does not occur randomly, but is often organized into synoptic to planetary–scale disturbances with time scales smaller than a season. Several studies have shown that a large fraction of the convection variability in such disturbances is associated with dynamical Equatorial Waves, such as the Kelvin, Equatorial Rossby, Mixed Rossby-Gravity, Eastward and Westward Inertio-Gravity waves (e.g. *Kiladis et al., Rev. Geophys., 2009*). The horizontal structures and dispersion characteristics of such Convectively Coupled Equatorial Waves (CCEWs) correspond to the solutions of the shallow water (SW) equations on an equatorial β-plane obtained by *Matsuno* (*J. Meteor. Soc. Japan, 1966*). CCEWs have broad impacts within the tropics, but their simulation in general circulation models is still problematic.

Using space–time spectral analyses of a proxy field for tropical convection (e.g. outgoing long wave radiation (OLR)), it has been shown the existence of spectral peaks aligned along the dispersion curves of equatorially trapped wave modes of SW theory, which have been interpreted as the effect of equatorial wave processes (e.g. *Takayabu, J. Meteor. Soc. Japan, 1994; Wheeler and Kiladis, JAS, 1999*). However, different equatorial modes may not be well separated in the wavenumber–frequency domain due to a vertical variation of the horizontal basic flow, that may introduce Doppler shiftings and changes in the vertical heating profiles which may distort the theoretical dispersion curves (*Yang et al., JAS, 2003*).

In this communication, we present a new methodology for the diagnosis of CCEWs, which is based on a pre-filtering of the geopotential and horizontal wind, via three–dimensional (3–D) normal mode functions of the adiabatic linearized equations of a resting atmosphere, followed by a space–time power and cross spectral analysis applied to the 3–D normal mode filtered fields and the OLR (or other fields that may be proxies of tropical convection) to identify the spectral regions of coherence. The advantage of such an approach is that the theoretical vertical as well as horizontal structure functions are taken into account in the projection method, and so the structures obtained are better defined with respect to the theoretical normal modes of a 3–D atmosphere compared to other approaches.

The methodology has been applied to the (u, v, Φ) and OLR fields simulated by various of the most recent climate models (CMIP5). The methodology has been also applied to the ERA-Interim geopotential and horizontal wind fields and to the interpolated OLR data produced by the National Oceanic and Atmospheric Administration, against which model simulations are evaluated. This new diagnosis method permits a direct detection of various types of equatorial waves, compares the dispersion characteristics of the coupled waves with the theoretical dispersion curves and allows an identification of which vertical modes are more involved in the convection. Moreover, it is able to show the existence of free dry waves and moist coupled waves with a common vertical structure, which is in conformity with the effect of convective heating/cooling on the effective static stability, as deduced from the *gross moist stability* concept (*Kiladis et al., Rev. Geophys., 2009*). The methodology is also sensitive to wave's interactions. Deficiencies found in the models' simulations should help the identification of which physical processes need to be improved in climate models.