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Comment on wcd-2021-21

Anonymous Referee #1

Referee comment on "Observed wavenumber-frequency spectrum of global, normal mode function decomposed, fields: a possible evidence for nonlinear effects on the wave dynamics" by André Seiji Wakate Teruya et al., Weather Clim. Dynam. Discuss., <https://doi.org/10.5194/wcd-2021-21-RC1>, 2021

Review of Observed wavenumber-frequency spectrum of global, normal mode function decomposed, fields: a possible evidence for nonlinear effects on the wave dynamics by André Seiji Wakate Teruya et al., WCD MS No.: wcd-2021-21

Summary:

This is an interesting paper that combines linear wave theory on the sphere using MODES software of Å½agar et al. 2015 with linear time filtering using the Fourier time series decomposition by Wheeler and Kiladis 1999 software.

The paper is a combination of two parts. The first part presents outputs of the normal-mode function decomposition of ERA-Interim data by MODES, that has been explored in the previous studies by the same group. The second and main part of the paper applies the Wheeler-Kiladis software to frequency decompose time series of Rosby and gravity modes including the equatorial Kelvin and mixed Rossby-gravity waves.

Not surprisingly, the authors find that the Wheeler-Kiladis diagrams of 200 hPa zonal wind differ from expectations based on the linear propagation of wave signals. Unfortunately, the results provide little new understanding of dynamics. Conclusions that discrepancies between linear theory and Wheeler-Kiladis diagrams must come from nonlinear processes can hardly be called a new result. It is therefore the opinion of this review that the paper is not publishable in WCD.

Further comments are provided.

Detailed comments:

The authors combine the normal-mode function decomposition of ERA-Interim circulation by MODES software to identify global circulation in terms of linear modes. This is a powerful method which was successfully applied in several earlier studies, including Å½agar et al. (2009, Mon Wea Rev), Castanheira and Marques (2015, QJRMS), Å½agar and Franzke (2015, GRL), Marques and Castanheira (2018, Math. Geosci.), Blaauw and Å½agar (2018, ACP), Kitsios et al. (2019, J Atmos Sci), Raphaldini et al (2020, GRL), etc. The classical method has recently experienced a revitalisation by the work of groups at Universities of Tsukuba, Aveiro and Hamburg. It has to be noted that this approach isolates the spatial structure of Rossby and gravity waves by assuming the basic state of rest. This is likely one of the reasons that associated frequencies from linear theory have not been much explored.

There are a number of lacking definitions and inconsistencies in sections 2-3. For example, the expansion of ERA-Interim data in section 3.1 is presented by infinite time series in all 3 directions. The parameter α which distinguishes the wave types is not clearly defined in relation to meridional mode. The vertical mode $m=0$ is used in section 3 as the barotropic mode but omitted in the results. Even with all math corrected, it can be questioned if one needs a detailed repetition of the theory of normal-mode function expansion from Å½agar et al. (2015) or Kasahara's earlier papers. A shorter summary would probably suffice in application studies like here.

Equatorial wave filtering by Wheeler and Kiladis (1999, J Atmos Sci) and its variants or similar procedures, for example Roundy (2004, J Atmos Sci), Gehne and Kleeman (2012, J Atmos Sci), combine linear filtering in time and longitude to produce frequency-wavenumber diagrams of equatorial waves.

The application of the Wheeler-Kiladis diagrams (WK) in this study is described very briefly, in a single paragraph section 3.2. It omits important details of the default setup of the software and their implications on the results. The authors refer almost exclusively to the previous WK analysis of OLR data, but relevant application studies are much wider and include reanalysis data and climate model simulations. If the work is continued or resubmitted, it would be useful to refer to previous studies using WK with the zonal wind and other dynamical variables.

My main comment on the results is about the lack of discussion of the eastward-propagating signals in WK diagrams using 200 hPa wind from the westward-propagating linear modes, and vice versa. This is striking in all figures, and especially the fact that most of the signal has the barotropic tropospheric structure, such as in figure 7b.

For example, how can one understand results of section 4.6 and figure 13 on mixed Rossby-gravity waves? The authors say that they analyzed the zonal wind at 200 hPa, which is expected to be rather small for the mixed Rossby-gravity mode, but the amplitude of its variance in figure 13 exceeds the variance in any other plot, including the total zonal wind. I assume that the same scaling is applied in all WK diagrams, as the amplitudes are not discussed and colour bars not explained, but I may be wrong. These things should be paid attention to.

For a similar result with westward gravity modes, the authors write in the final discussion section that "a combination of moist-convective and nonlinear processes might explain the spectral peaks associated with equatorial Rossby waves, barotropic Rossby waves, MJO, and Kelvin waves found in the observed wavenumber-frequency spectrum of the westward inertio-gravity wave field." Similarly, "gravity waves often have their propagation "slaved" to other modes" . This is appropriately a final discussion section, as there are no clear new results or explanation why WK diagrams look the way they do in this case.

In the case of MJO, Kitsios et al. (2019, J Atmos Sci) used coherence of various modes to explain interactions of modes. Such or similar effort might be a way to proceed for a better process understanding.

Equivalent depths are often missing in WK diagrams and are not mentioned in the discussion. For example, it is not mentioned what equivalent depth corresponds to the strongest variance in the eastward-propagating sector that is associated with the Kelvin wave. A variance signal that looks like tha of the Kelvin wave appears in the analysis of other modes, even in the mixed Rossby-gravity mode (figure 13b), but it is less obvious in the analysis of Kelvin wave zonal wind in figure 11. This should be explained.

Visualisation of energy in Fig. 4,6,8,10,12 is unusual and it is unclear why these figures are relevant and what one should learn from them.

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