Popular Summary

Title: Comments on the Terminology of "Convectively-Coupled Kelvin Waves"
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The terminology "convectively-coupled Kelvin waves" has been used frequently in the literature to refer to the 15 m/s eastward-moving planetary and large-scale waves in the tropics. This note points out that this terminology is not appropriate, since these waves contain Rossby waves and mixed Rossby-gravity waves also. The significance of pointing out this misnomer is that a better understanding of these waves may contribute to the search for their cause.

Comments on the Terminology of "Convectively-Coupled Kelvin Waves"

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In the recent literature the terminology "convectively-coupled Kelvin waves" has been used frequently (e.g., Wheeler and Kiladis 1999; Wheeler et al. 2000; Straub and Kiladis 2002, 2003a, 2003b; Majda et al. 2004) to refer to the eastward waves of about 15 m/s in the wave number-frequency analysis of outward-going long wave (OLR) data. These waves were previously analyzed by Wallace (1971), Zangvil and Yanai (1980), and Takayabu (1994), among others, and were simply referred to as Kelvin waves. Recent authors added the modifier "convectively-coupled" to distinguish them from Kelvin waves in the dry atmosphere. I would like to point out that this terminology is not correct. The modifier "convectively-coupled" is correct, but the term "Kelvin" is not correct.

Before I present my arguments, it is useful to first review the Gill (1980) shallow water solution revised such that the heating source moves zonally at a prescribed constant speed instead of being stationary. Yamagata (1987) and Chao (1987; see also Appendix A of Chao 1995) have provided such a solution. When the heating source is symmetric with respect to the equator, the solution has two components: a forced Kelvin wave and a forced Rossby wave. If the speed of the heating source is intermediate between the speeds of the free Kelvin wave and the free Rossby wave, the forced Kelvin wave exists within the heating region and to its east, and the forced Rossby wave exists within the heating region and to its west. These forced waves are stationary within the frame of reference moving with the heating source. These forced waves are not the same as the normal mode free waves as presented by Matsuno (1966) in the sense that they decay outside the heating region and they travel at the speed of the prescribed heating source, which is completely independent of the speeds of the free Kelvin and free Rossby waves. If the heating source is traveling eastward at the speed of the free Kelvin wave or faster, the forced Kelvin wave does not exist east of the heating region; and if the heating source is traveling westward at the speed of the free Rossby wave or faster, the forced Rossby wave does not exist west of the heating region. If the heating source is anti-symmetric with respect to the equator and traveling at a prescribed speed, the Gill solution has no forced Kelvin wave or forced Rossby wave but it has a forced mixed Rossby-gravity wave.

As shown in Fig. 5 of Wheeler et al. (2000) and Fig. 16 of Straub and Kiladis (2002), the composite wind fields associated with "convectively-coupled Kelvin waves" have sizeable meridional wind components, especially in the convective region. If one approximates these composite wind fields with the Gill type of solution with a heating source moving eastward at a constant speed instead of stationary--i.e., a heating source that approximates the heating source found through the composite method by Straub and Kiladis 2002, and which can be decomposed into components symmetric and anti-symmetric with respect to the equator--one gets a wind field that is a combination of forced Kelvin waves, forced Rossby waves and forced mixed Rossby-gravity waves, which all travel eastward at the speed of the observed composite convective heating. Therefore, the "convectively-coupled Kelvin waves" are not Kelvin waves but a combination of forced Kelvin, Rossby, and mixed Rossby-gravity waves. By the same reasoning the terms "convectively-coupled Rossby waves" and "convectively-coupled mixed Rossby-gravity waves" are not correct either.

As a result of the above clarification, the speed of the "convectively-coupled Kelvin waves" cannot be equated with that of any Kelvin wave, and the meaning of the corresponding equivalent depth based on their speed (e.g., Takayabu 1994, Wheeler and Kiladis 1999) should be re-assessed. Some authors also refer to "convectively-coupled Kelvin waves" as "moist Kelvin waves" (which is another misnomer) and refer to the equivalent depth computed from their speed as the equivalent depth for the moist atmosphere. Now that we know that the "convectively-coupled Kelvin waves" cannot be identified as any kind of Kelvin waves, the equivalent depth computed from their speed does not really have any clear meaning.

As mentioned earlier, the mobile heating source Gill solution with symmetric heating shows that if the heating pattern moves at the speed of free Kelvin wave or greater, the solution has no perturbation east of the heating region. (Also, a Gill solution with anti-symmetric heating pattern has no Kelvin wave perturbation.) If the heating pattern moves at a speed slightly slower than that of the free Kelvin wave, the perturbation ahead of the heating pattern is weak and is confined to a much smaller region. The fact that a composite of the "convectively-coupled Kelvin waves" shows a prominent Kelvin-wave type of flow pattern ahead of the convective region (Fig. 16a of

Straub and Kiladis 2002) demonstrates that "convectively-coupled Kelvin waves" are moving at a speed much slower than that of free Kelvin waves. Indeed, the observed speed of "convectively-coupled Kelvin waves" is 15 m/s and that of free Kelvin waves is estimated to be around 50 m/s.

One may give any phenomenon any name; what is wrong with continuing to use the name "convectively-coupled Kelvin waves"? The name Kelvin wave implies that the wave is symmetric and has no meridional wind component. One may tolerate a little meridional wind component and still use the name Kelvin wave. But the waves that Straub and Kiladis (2002) studied in the eastern Pacific have obvious anti-symmetric components--heating being on one side of equator--and a sizeable meridional wind component, and the eastward-moving waves that Wheeler et al. (2000, see its Fig. 5) studied in the western Pacific and Indian Ocean--though fairly symmetric--also have a large meridional wind component. Therefore, the term "convectively-coupled Kelvin waves" is not appropriate.

What then would be a better term for "convectively-coupled Kelvin waves"? I would suggest "convectively coupled nonlinear 15 m/s eastward-moving mixed waves". The modifier "mixed" is used to recognize the fact that there are different wave components. The modifier "nonlinear" is used to recognize the fact that the westward-moving meso-scale systems in these waves are integral parts of the waves and that any explanation for the cause of these waves must take into account the nonlinear interaction between the meso-scale waves and the waves as a whole. The modifier "15 m/s" is used to distinguish these waves from the Madden-Julian oscillation. If this name is too long, one can simply call them "tropical 15 m/s eastward-moving waves."

The significance of pointing out the above misnomer is that knowing the identity of a wave better contributes to a better understanding of it and to the search for its cause. It often happens when a new research area is established, new nomenclature appears and it takes a while for people to assess whether the new nomenclature is reasonable and consistent, and whether it should be revised.

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References

Chao, W. C., 1987: On the origin of the Tropical Intraseasonal Oscillation. *J. Atmos. Sci.*, **44**, 1940-1949. Corrigendum, **45**, p. 1283.

Chao, W. C., 1995: A critique of Wave-CISK as an explanation for the 40-50 day Tropical Intraseasonal Oscillations. *J. Meteor. Soc. Japan*, **73**, 677-684.

Gill, A. E., 1980: Some simple solutions for heat-induced tropical circulation. *Q. J. Roy. Meteor. Soc.*, **106**, 447-462.

Majda, A. J. B. Khouider, G. N. Kiladis, K. H. Straub and M. G. Shefter. 2004: A Model for Convectively Coupled Tropical Waves: Nonlinearity, Rotation, and Comparison with Observations. *J. Atmos. Sci.,* **61**, 2188–2205.

Matsuno, T., 1966: Quasi-geostrophic motions in the equatorial area. *J. Meteor. Soc. Japan*, **44**, 25-43.

Straub, K. H. and G. N. Kiladis. 2002: Observations of a Convectively Coupled Kelvin Wave in the Eastern Pacific ITCZ. *J. Atmos. Sci.,* **59**, 30–53.

Straub, K. H. and G. N. Kiladis. 2003a: Extratropical Forcing of Convectively Coupled Kelvin Waves during Austral Winter. *J. Atmos. Sci.,* **60**, 526–543.

Straub, K. H. and G. N. Kiladis. 2003b: The Observed Structure of Convectively Coupled Kelvin Waves: Comparison with Simple Models of Coupled Wave Instability. *J. Atmos. Sci.,* **60**, 1655–1668.

Takayabu, Y. N., 1994: Large-scale cloud disturbances associated with equatorial waves. Part I.: Spectral features of the cloud disturbances. *J. Meteor. Soc. Japan*, **72**, 433-448.

Wallace, J. M., 1971: Spectral studies of tropospheric wave disturbances in the tropical western Pacific. *Rev. Geophys. Space. Phys.* **20**, 557-612.

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

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

Yamagata, T. 1987: A simple moist model relevant to the origin of intraseasonal disturbances in the tropics. *J. Meteor. Soc. Japan*, **65**, 153-164.

Zangvil, A., and M. Yanai, 1980: Upper tropospheric waves in the tropics. Part I: Dynamical analysis in the wavenumber-frequency domain. *J. Atmos. Sci.*, **37**, 283-298.