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The Kelvin and Mixed Rossby Gravity waves on the spherical Earth

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Two of the most prominent wave features of the tropical atmosphere and oceans are the equatorial Kelvin wave and the Mixed Rossby Gravity (MRG, AKA Yanai) wave (Kiladis et at., 2009). The existence of these waves was predicted theoretically as solutions of the linearized Shallow Water Equations on both the equatorial β-plane (Matsuno, 1966) and on the sphere (Longuet-Higgins, 1968). While the theory developed by Matsuno for the equatorial β-plane allows for exact analytic solutions, the corresponding theory developed by Longuet-Higgins on the sphere can only be solved analytically at some asymptotic limits. In the present work we revisit the Kelvin and MRG waves on the sphere using two complementary forms of analysis: (i) Special ad hoc analytic solutions that yield accurate approximations for the latitude-dependent amplitudes and dispersion relations of the Kelvin and MRG waves over a wide range of the parameter space. (ii) A Schrödinger formulation that provides a classification for the waves in terms of the mode numbers of the associated Sturm-Liouville problem. While the equatorial β-plane provides an acceptable approximation for the latitude-dependent amplitudes and frequencies of tropical waves on a sphere, it disregards two qualitative features that distinguish the dynamics on the sphere: (i) There exist no non-dispersive eastward propagating gravity wave on a sphere, only a nearly non-dispersive one (i.e. non-dispersive only at high zonal wavenumber), classified as the lowest eastward propagating Inertia-Gravity wave. (ii) Unlike the equatorial β-plane where a wave that propagates westward with phase speed that equals the (negative of) gravity waves' phase speed does not exist for any zonal wavenumber, on a sphere there exist a particular wavenumber in which the phase speed equals the negative of gravity waves' phase speed and at this wavenumber the westward Inertia-Gravity branch is connected smoothly with the Rossby branch of the MRG wave.