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Scale Analysis for the Large-Scale Tropical Atmospheric Dynamics

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Even sixty years after a successful scale analysis for the midlatitude large-scale dynamics, strangely enough, no equivalent work has been performed for the tropical atmosphere, at least in published literature.

To be precise, Juale Charney pursued a similar analysis for the tropical atmosphere in his short note to JAS in 1963. However, his note remains a sketch, and it also is in virtual contradiction with a commonly accepted view with a dominance of equatorial waves.

A systematic scale analysis is performed for the large-scale tropical atmosphere in order to resolve the issue. It turns out that the scale analysis is inherently subtle for the tropical atmosphere due to a strong dependence of a nondimensional beta-parameter on the horizontal scale: simply a modification of the horizontal scale by factor three leads to a modification of beta parameter by factor ten.

At the scale equal to or less than L=1000 km with a typical wind speed U=10 m/s, the original scale analysis of Charney is recovered: the tropical atmosphere is non-divergent to the leading order, thus it is dictated by the vorticity equation. The thermodynamic equation is treated to be stationary to the leading order (balance condition).

Effects of diabatic heating associated with convection as well as stratification-driven equatorial waves can be taken into account as slow time-scale modulations. It is important to emphasize that these slow time–scale effects may induce catalytic effects to the leading order.

At the scale equal to or greater than L=3000 km with a typical wind speed, say, U=3

m/s, a commonly accepted dynamical regime is recovered: linear equatorial waves coupled with moist convection.

However, considering a general nature of asymptotic expansion methods, it is hard to imagine that the tropical atmosphere sharply transits from one regime (non-divergent balance) to another (wave), that makes a question of the dominant dynamic regime in the tropical atmosphere inherently unsettled.

In order to, at least, partially to answer this regime question, a data analysis is performed. The results imply that the tropical atmosphere is rather non-divergent and in balance for much wider horizontal scales than a formal application of the above scale analysis would suggest.