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Dynamical Meteorology in the Topics: Asymptotic Nondivergence?

J.-I. Yano
CNRM, Météo-France, Toulouse Cedex, France (jun-ichi.yano@zmaw.de)

The large-scale tropical atmospheric dynamics are often considered to be dominated by divergent flows associated with moist convection. No balance condition exists in the large-scale tropical atmosphere, but they are reduced to a set of linear equatorial waves in dry limit to a good approximation. Various large-scale convective coherencies, among them, the best known example would be the so-called Madden-Julian oscillation, are considered as under a consequence of coupling between wave dynamics and deep moist convection.
However, a systematic scale analysis indicates there is an alternative possibility: a system dictated by a vorticity conservation law with nondivergence to a leading-order approximation. Such an alternative regime is identified at a scale smaller than the regime for the convectively-coupled linear equatorial waves only by factor of three: the latter is identified at the horizontal scale of 3000km, where as the former at 1000km. The result reflects a fundamental subtlety in the tropical scale analysis due to a strong sensitivity of a nondimensional beta parameter on the horizontal scale.
Probably, the most surprising aspect of this alternative regime is asymptotic nondivergence: i.e. the tropical large-scale dynamics is dominated more by the vorticity than the divergence. This tendency is systematically analyzed by using the TOGA-COARE LSA gridded data set. It is found that the ratio of the root-mean square divergence for the transient component to that of the vorticity is the smallest for the scales of 20-80 days and 1500 km, indicating that the Madden-Julian oscillation is more dominated by vorticity than divergence. The RMS ratio goes down close to 0.2 at the Madden-Julian scale. At the synoptic scale of a day and 1000 km, the RMS ratio is larger with a value closer to 0.3.
This relatively weak divergence poses, however, an irony when the same analysis is theoretically repeated both for free and forced linear equatorial waves with varying wavenumbers and frequencies. Rather surprisingly, the corresponding RMS ratio between the divergence and the vorticity is much smaller, and less than 0.1 everywhere, for free Rossby waves and also for free Kelvin waves in planetary scale limits. The same conclusion is obtained for the forced waves except for narrow ranges where a "resonance" of inertial-gravity waves with forcing occurs. Thus, the observed RMS ratio is not consistent with the linear wave theories.
Another important aspect of the alternative regime is that the system can be described by the conservation of the absolute vorticity in a self-contained manner to the leading order without effects of divergence. In order to verify this point, a systematic vorticity budget analysis is performed with use of the global NCEP analysis data. The analysis overall confirm the scale analysis, but it also demonstrates a non-negligible contribution of transient eddies in the budget.

References:
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