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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "On the role of thermal expansion and compression in large scale atmospheric energy and mass transports" *by* Melville E. Nicholls and Roger A. Pielke Sr.

Anonymous Referee #2

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Review of

On the role of thermal expansion and compression in large scale atmospheric energy and mass transports

By M. E. Nicholls and R. A. Pielke

The manuscript discusses the role of gravity waves and especially acoustic waves in transporting mass and energy in response to atmospheric disturbances caused by diabatic heating. It makes use of physical arguments, didactic examples, and numerical experiments. These are important ideas, and, given the increasing use of fully compressible equation sets in operational and research models, it is timely to re-emphasize

them. That said, the key ideas involve basic, well-understood fluid dynamics, though they may be obscured by the acoustically filtered equation sets often used in meteorology. Moreover, much of the present manuscript seems to be re-iterating points made in previous work (Nicholls and Pielke 1994a,b, 2000). One of my main points is that the manuscript should be revised to minimize this repetition and to emphasize the new ideas and results.

Main points

1. As mentioned above, repetition of previous work should be minimized and the new results emphasized.

2. It would be useful to relate the ideas and experiments discussed here to the ideas of hydrostatic and geostrophic adjustment, e.g., Gill A. E. (1982), pp 191-, Bannon, P. R., (1995) J. Atmos. Sci., 1743-1752. In particular, Gill (p194) discusses the energy carried away by Poincare waves in the (shallow water) geostrophic adjustment process.

3. The full version of equation (15) involves the initial profiles \bar{\rho} and \bar{\theta}_v, so some approximation to the full fluid dynamical equations seems to be involved. This then raises the question of whether the full version of (15) has exact, or only approximate, mass and energy conservation properties. These properties seem to be crucial to the whole exercise, but I wasn't able to quickly track this information down by looking at the references given.

4. The full version of (15) is compared with one that omits the first three terms on the RHS. This omission eliminates the thermal compression waves under study, but at the cost of sacrificing mass and energy conservation. Strong arguments have been made that numerical models, should solve 'dynamically consistent' equation sets, retaining appropriate conservation laws, including mass and energy, even when those equation sets are approximate. For example, the hydrostatic equations and at least some versions of anelastic and pseudo-incompressible equations are dynamically consistent in this sense, and they are widely used. It would therefore be of great interest to under-

stand how such equation sets respond to a local diabatic heating, and how the energy budget is to be interpreted in such models. (It is conceivable that a similar adjustment process occurs to that in the fully compressible case, but instantaneously rather than at the speed of sound.) I believe that a comparison of the full equation set with hydrostatic and/or anelastic equations would be of much wider interest than the artificial system that involves dropping the RHS of (15).

5. P3 lines 16-17: 'This decomposition tacitly makes the assumption...' Actually the decomposition (3) is correct, but the tactit assumption is often made when interpreting (3). I think part of the problem is imprecise use of terminology in the community: the 'transients' in (3) morph into 'eddies' (a bit ambiguous) which morph into 'turbulence' (definitely wrong for the compression waves discussed here). See also section 2.4.

6. Section 2.4. I think part of the problem is that, because of the historical use of acoustically filtered equation sets such as anelastic, or hydrostatic in pressure coordinates, the term 'heat flux' has become identified with the potential temperature flux, which in turn is closely related to the entropy flux. Thus the energy and entropy budgets have become confounded in our thinking. But, while entropy is carried along with the fluid, to a good approximation, energy is not. See also the discussion in Nicholls and Pielke 1994b. If the paper can help to clarify these issues then that would be a useful service to the community.

7. I found the results section hard work. I think it could be better organized to emphasize the points the authors wish to make, and to help the reader to make comparisons between different experiments.

Minor points

P6 line 14: frequency should be period (or change 5 min to 2 pi / 5 min).

P7 line 16: greater than 0?

Section 2.7: I am perfectly happy with the idea that these disturbances are waves,

and for me this section is unnecessary (though perhaps the authors have met some resistance to the idea and so feel that the section is necessary).

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