CORRESPONDENCE

Comments on "Preconditioning Deep Convection with Cumulus Congestus"

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ABSTRACT

The hypothesis that cumulus congestus clouds in the tropics moisten dry layers above the boundary layer and promote the formation of deep moist convection was tested by Hohenegger and Stevens. This comment asks whether their hypothesis is also true for cumulus congestus clouds and deep moist convection in the midlatitudes. This comment also requests clarification on how their expression for moisture convergence is calculated and used in their article, especially in light of previous studies showing that moisture flux convergence is a less-than-adequate diagnostic for convection initiation and that deep moist convection requires sufficient lift and instability, in addition to sufficient moisture.

Hohenegger and Stevens (2013) present compelling multiple arguments that indicate that the time scale is much too slow for congestus to precondition or moisten the atmosphere for deep moist convection, that environments with prolonged occurrence of congestus clouds are not more likely to grow into deep moist convection, and that the presence of congestus does not lead to greater probability of deep moist convection. Their intriguing results leave three questions unaddressed, which are raised within this comment.

First, operational forecasters in the U.S. National Weather Service sometimes discuss the importance of midlatitude cumulus congestus clouds leading to moistening of dry air above the planetary boundary layer and the eventual development of deep moist convection. The argument posed by Hohenegger and Stevens (2013) is for the tropics. The question remains how applicable their ideas are for the midlatitudes.

Second, Hohenegger and Stevens (2013) use the term "moisture convergence" throughout their article. In operational forecasting in the United States, moisture convergence is often used to refer to "moisture flux convergence" (Banacos and Schultz 2005, p. 352), which is defined as MFC in their Eqs. (4) and (5):

$$\mathrm{MFC} = -\nabla \cdot (q\mathbf{V}_h) = -\mathbf{V}_h \cdot \nabla q - q\nabla \cdot \mathbf{V}_h \quad \text{and}$$

$$\mathrm{MFC} = \underbrace{-u\frac{\partial q}{\partial x} - v\frac{\partial q}{\partial y}}_{\text{advection term}} \underbrace{-q\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right)}_{\text{convergence term}}.$$

Here, q is the mixing ratio, $\mathbf{V}_h = u\mathbf{i} + v\mathbf{j}$ is the horizontal wind, and $\nabla = \mathbf{i}(\partial/\partial x) + \mathbf{j}(\partial/\partial y)$. This expression for moisture flux convergence is composed of two terms: the advection of moisture term and the mass convergence term. How Hohenegger and Stevens (2013) define their term moisture convergence is ambiguous. Is it equivalent to the MFC expression, or is it simply the convergence term alone? The implications of this calculation are considerable, as the next point identifies.

Third, Banacos and Schultz (2005, their section 3c) found that, despite all the operational uses of moisture flux convergence for short-term (0–3 h) forecasting the initiation of convective storms, the term was largely untested. Moreover, a scale analysis showed that the moisture flux convergence on the convective scale is dominated by the mass convergence (Banacos and Schultz 2005, their section 4). On the basis of these and other arguments, Banacos and Schultz (2005) concluded that mass convergence is a better diagnostic for convection initiation,

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albeit with the caveats that Hohenegger and Stevens (2013) note about the feedback between convection and convergence itself. A concept in forecasting called ''ingredients-based forecasting'' says that deep moist convection requires lift, instability, and moisture (e.g., Johns and Doswell 1992). Saying that moisture flux convergence is present is mostly a statement that lift (indicated by surface mass convergence) is present. So, moisture flux convergence conflates two of the ingredients and confuses the forecaster. Furthermore, because a field of uniform specific humidity would have no advection term, a uniform field of $20\,g\,kg^{-1}$ humidity or a uniform field of $5\,g\,kg^{-1}$ specific humidity would produce very different outcomes in terms of the ability to produce convection, although the moisture flux convergence terms would only be directly proportional to the specific humidity (in this case, a factor of four difference). In another illustration, if convective storms form, and the moisture content were doubled but the mass convergence were halved, would convective storms still form? In these two cases, mixing ratio times mass convergence is the same, even though the potential for formation of convective storms may be drastically different.

With that background, some of the sentences in Hohenegger and Stevens (2013) are ambiguous. For example, they say, ''The associated moisture convergence enhances the input of moisture into the atmospheric column and forces the transition'' (p. 451). If the advection term is zero, all the convergence term can do is deepen the layer of high moisture, not increase its mixing ratio (e.g., Markowski and Richardson 2010, p. 195, 197). Furthermore, moisture flux convergence does not address the instability or lift (unless the authors are implying that moisture convergence is equivalent to mass convergence). Again, clarification of this point would be valuable to the readers.

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