The influence of thermal damping timescales on climate variability and the extratropical circulation

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In recent years, there has been considerable interest in the climate science community on the impacts of global warming to atmospheric circulations [e.g. *Lorenz and DeWeaver* (2007), *Butler et al.* (2010), *Yin* (2005), *Arblaster and Meehl* (2006)]. One way to understand these impacts is by using "dry core" general circulation models (GCMs), which parameterize the e˙ects of radiation, latent heating, and sensible heating with a simple relaxation term. This requires the selection of a zonally symmetric "radiative equilibrium temperature" field and an associated *e*-folding timescale for the damping, which we call the "diabatic timescale." The most widely used standard for the equilibrium temperature was introduced by *Held and Suarez* (1994), although modified versions that simulate a more realistic stratosphere and tropopause were introduced by *Polvani and Kushner* (2002) and *Vallis et al.* (2015). By contrast, relatively little attention is paid to the diabatic timescale – it is typically set to a constant value of 40 days (or somewhat faster near the tropics and the surface, to account for boundary layer processes). In our view, the diabatic timescale is worthy of closer examination.

We reveal the structure and strength of the diabatic timescale field has considerable influence on (1) the steady-state characteristics of the extratropical circulation, (2) internal climate variability, and (3) the response of the circulation to diabatic forcing. Faster timescales tend to intensify baroclinic waves and strengthen the eddy components of the Lorenz energy cycle, until shutting o˙ entirely for a critical diabatic timescale. We also perturb diabatic timescales in the stratosphere alone, whose thin optical depth and lack of moisture make thermal damping a more realistic approximation (*Newman and Rosenfield*, 1997). Finally, we conduct similar experiments with the frictional timescale (which damps winds in the model boundary layer), and test the robustness of our results against di˙erent background equilibrium temperatures. We develop theoretical explanations for these results, and consider their implications for future climates under anthropogenic forcing.

Key words: circulation, extratropics, variability, climate, GCMs.

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