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Storm track response to climate change: Insights from simulations using an idealized dry GCM.

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The midlatitude storm tracks, where the most intense extratropical cyclones are found, are an important fixture in the general circulation. They are instrumental in balancing the Earth's heat, momentum, and moisture budgets and are responsible for the weather and climatic patterns over large regions of the Earth's surface. As a result, the midlatitude storm tracks are the subject of a considerable amount of scientific research to understand their response to global warming. This has produced the robust result showing that the storm tracks migrate poleward with global warming. However, the dynamical mechanisms responsible for this migration remain unclear. Our work seeks to broaden understanding of the dynamical mechanisms responsible for storm track migration.

Competing mechanisms present in the comprehensive climate models often used to study storm track dynamics make it difficult to determine the primary mechanisms responsible for storm track migration. We are thus prompted to study storm track dynamics from a simplified and idealized framework, which enables the decoupling of mean temperature effects from the effects of static stability and of tropical from extratropical effects. Using a statistically zonally symmetric, dry general circulation model (GCM), we conduct a series of numerical simulations to help understand the storm track response to global mean temperatures and to the tropical convective static stability, which we can vary independently. We define storm tracks as regions of zonally and temporally averaged maxima of barotropic eddy kinetic energy (EKE). This storm track definition also allows us to use previously found scalings between the magnitude of bulk measures of mean available potential energy (MAPE) and EKE, to decompose MAPE, and to obtain some mechanistic understanding of the storm track response in our simulations.

These simulations provide several insights, which enable us to extend upon existing theories on the mechanisms driving the poleward migration of the storm tracks. We demonstrate a poleward migration of the midlatitude storm tracks in dry atmospheres with fixed pole-equator temperature contrast and increasing radiative equilibrium mean temperature, without changes in convective static stability. We also show scalings between the location of maxima of surface MAPE and of barotropic EKE. In the simulations where we independently vary tropical convective static stability, we find a marked poleward migration of the storm tracks. However, our decomposition shows that meridional temperature gradients, and not static stability, determine the location and the intensity of the storm tracks. This suggests that although the storm tracks are sensitive to tropical convective static stability, it influences them indirectly. Furthermore, our simulations show that the storm tracks generally migrate in tandem with the terminus of the Hadley cell. Therefore, we hypothesize that it is possible that the Hadley cell provides the tropical-extratropical communication necessary to generate the storm track response to tropical convective static stability we observe in the simulations.

The results contained herein could be used to supplement ongoing storm track research in moist atmospheres using comparatively more comprehensive GCMs to understand storm track dynamics in earth-like environments.