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Recent atmospheric circulation trends: two major flaws in reanalyses and in climate models

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The weakening of the Hadley cell and of the midlatitude eddy heat fluxes are two of the most robust responses of the atmospheric circulation to increasing concentrations of greenhouse gases. These changes have important global climatic impacts, as the large-scale circulation acts to transfer heat and moisture from the tropics to polar regions. Here, we examine Hadley cell and eddy heat flux trends in recent decades: contrasting model simulations with reanalyses, we uncover two important flaws -- one in the reanalyses and other in the model simulations -- that have, to date, gone largely unnoticed.

First, we find that while climate models simulate a weakening of the Hadley cell over the past four decades, most atmospheric reanalyses indicate a considerable strengthening. Interestingly, that discrepancy does not stem from biases in climate models, but appears to be related to artifacts in the representation of latent heating in the reanalyses. This suggests that when dealing with the divergent part of the large-scale circulation, reanalyses may be fundamentally unreliable for the calculation of trends, even for trends spanning several decades.

Second, we examine recent trends in eddy heat fluxes at midlatitudes, which are directly linked the equator-to-pole temperature gradient. In the Northern Hemisphere models and reanalyses are in good agreement. In the Southern Hemisphere, however, models show a weakening while reanalyses indicate a robust strengthening. In this case, the flaw is found to be with the climate models, which are unable to simulate the observed multidecadal cooling of the Southern Ocean at high-latitudes, and the accompanying increase in sea-ice. While the biases in modeled Antarctic sea ice trends have been widely reported, our results demonstrates that such biases have important implications well beyond the high Southern latitudes, as they impact the equator-to-pole temperature and, as a consequence, the midlatitude atmospheric circulation.