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Saturation of poleward atmospheric heat transport in warm climates and the low-gradient paradox.

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The equable climates of the deep past featured higher atmospheric greenhouse gas concentrations, greater global-mean surface temperatures and much weaker equator-to-pole temperature contrasts than today. Climate models readily reproduce the higher mean temperatures, given sufficient increases in greenhouse gases, but they have proved incapable of matching the low meridional gradients indicated by proxy data. A crucial step in resolving this 'low-gradient paradox' is understanding why climate models fail to reproduce the correct feedback between global mean temperature and its meridional gradient. Though models do achieve some reduction in temperature gradients, mostly through snow and sea-ice albedo feedback, the remaining discrepancy must be accounted for by either more exotic forms of radiative forcing feedback, which are not represented in current models, or by more efficient oceanic and/or atmospheric poleward heat transports, which the models for some reason do not capture. This latter feature is especially puzzling for the atmosphere, since there are plausible reasons to expect atmospheric energy transport to be be considerably more efficient in a warmer climate. We explore this issue by systematically studying the response of atmospheric heat transpor in a GCM to a very broad range of global mean temperatures and meridional gradients. We find that heat transport increases with global mean temperature when the latter is less than about 15C; above this value, heat transport saturates, becoming insensitive to surface temperature. This behavior has a dynamical origin traceble to changes in the structure of the atmosphere's general circulation. Mean tropospheric static stability increases with surface temperature, reducing baroclinicity and suppressing storm-track eddy activity. Furthermore, as temperature increases the storm-tracks as a whole migrate poleward over cooler waters, and thus do

not experience the full global-mean surface temperature increase. These results appear to rely on physically robust mechanisms not obviously connected with questionable parameterizations in the GCM.