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Does data assimilation destroy or enhance the Tropopause Inversion Layer?

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The thermal structure of the upper troposphere / lower stratosphere region is characterized by a thin layer of very high stratification and strong horizontal mixing directly above the tropopause, known as the tropopause inversion layer (TIL). The TIL results from a not-entirely-understood combination of radiation and dynamics, and affects both stratosphere-troposphere exchange and planetary wave propagation. However, the TIL is difficult to capture in models (because of their relatively low vertical resolution) and reanalyses, presumably because the assimilation process smoothes the sharp temperature gradient of the TIL to the resolution of the assimilating model. On the other hand, data assimilation forces a model's wind and temperature fields closer to reality and should thereby improve large-scale flow features, such as the Brewer-Dobson circulation, that contribute to the formation of the TIL.

By examining how a model responds to assimilated observations that resolve the TIL, we can illuminate the mechanisms by which the TIL forms. Here, we compare the ERA-Interim reanalysis, which has a relatively weak TIL, to the Whole Atmosphere Community Climate Model (WACCM), which has a much stronger TIL – as long as data are assimilated. We find that accurate representation of the Brewer-Dobson circulation is key to capturing the TIL, and that the two analysis products have similar wind and temperature fields but still differ significantly in their residual winds, E.P. flux, and heating rates -- all of which can lead to very different representations of the TIL. This leads to two opposing effects in how well data assimilation treats the TIL: the primary effect is to smooth the stratification profile around the tropopause, but this can be overshadowed by a secondary effect where data assimilation improves the TIL by correcting the larger-scale flow.