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Thermodynamic cycles in the stratosphere

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Large-scale overturning mass transport in the stratosphere can be deduced from the distribution of long-lived chemical species and is commonly explained through the action of potential vorticity (PV) rearrangement in the flank of the stratospheric jet. Large-scale Rossby waves, with wave activity source primarily in the troposphere, stir and mix PV and an overturning circulation arises to compensate the zonal torque imposed by the breaking waves. In this view, any radiative heating is relaxational and the circulation is mechanically driven. Less attention has been devoted to the thermodynamical implications of a middle-atmosphere circulation driven primarily by differential heating. This component of the circulation can be deemed to be mechanically damped and thermodynamically direct. A thermodynamic analysis of these phenomena is presented. The analysis is based on data obtained from ERA-Interim. Stream functions in a thermodynamic, log-pressure-temperature space are computed. In the middle and upper stratosphere thermodynamically indirect and direct circulations coexist, with prominent semiannual cycle. Results suggest that the basic, weakly perturbed overturning circulation in the stratosphere is largely thermodynamically direct while tropospheric waves induce the indirect component of the flow. Circulation in the lower stratosphere is found to be thermodynamically indirect.