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The annual cycle in (tropical) lower stratospheric temperatures revisited

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The intriguing observation of an annual - rather than semi-annual - cycle in tropical temperatures between about 125 hPa (uppermost troposphere) and 10 hPa (lower stratosphere) has attracted much scientific interest. In an influential paper, Yulaeva, Holton and Wallace (1994; henceforth YHW94) related the observed annual cycles in tropical and extratropical lower stratospheric temperatures to hemispheric asymmetries in the strength of the stratospheric (winter) circulation. They analysed MSU-4 data (weighting centered in the lower stratosphere) and found the amplitude of the global mean annual cycle to be an order of magnitude smaller than that in either the tropics or extratropics. They concluded that this near-cancellation between tropical and (combined) extratropical temperature variations implies that temperature variations are predominantly linearly related to diabatic mass flux variations. Consequently, mass conservation yields to a high degree temperature conservation, an elegant result that greatly helps to understand feedbacks between dynamics, chemistry, radiation and temperatures in this important layer of the atmosphere.

Here, we show that the MSU-4 channel integrates over atmospheric layers with quite different characteristics, and the resulting mix is quite a toxic cocktail. While temperature variations in the extratropics show similar amplitude and coherent phase over the full depth of the MSU-4 channel they do not so in the tropics. Consequently, tropical MSU-4 temperature variations are strongly attenuated, whereas those in the extratropics are not, and the temperature conservation found in MSU-4 temperatures is largely fortuitous.

YHW94 already anticipated that the residual imbalance is a consequence of ozone variations in the tropics; however, the dynamical-chemical-radiative feedbacks are much stronger than anticipated in their analysis. We show that much of the beauty of the original analysis can be retained if the leading order impact of ozone variations on tempertures is taken into account: instead of temperature conservation it is temperature departure from radiative equilibrium that is conserved to a high degree. The latitudinal structure of annual temperature variations is a textbook example for dynamical-chemical-radiative feedbacks. We propose that this structure provides an important and convenient test for the accuracy of feedback processes in (Chemistry) Climate models, which in turn is crucial for reliable forecasts of climate change. A survey of results from a set of state-of-the art CCMs reveals substantial differences, which may affect the reliability of climate forecasts from these models.