How Well Do Stratospheric Reanalyses Reproduce High-Resolution Satellite Temperature Measurements?

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Atmospheric reanalyses are weather and climate models which assimilate the observational record, using a fixed analysis scheme to simulate an extended period (typically decades). They are widely used in all branches of the atmospheric sciences as proxies for the state of the atmosphere in the recent past, particularly in the stratosphere where historical observations are sparse. Here, we oversample stratospheric temperature data from the CFSR, ERA-5, ERA-Interim, JRA-55, JRA-55C and MERRA-2 reanalyses to produce synthetic satellite observations, which we directly compare to retrieved temperatures from the COSMIC, HIRDLS and SABER instruments and to brightness temperatures from the AIRS instrument for the period 2003-2012. We explicitly sample standard public-release reanalysis products rather than full-resolution internal products, in order to better assess their suitability for typical use cases. We first show that, for the current generation of reanalysis products, a full-3D sampling approach is always required to produce meaningful synthetic AIRS observations, is almost never required to produce synthetic HIRDLS observations, and for synthetic SABER and COSMIC observations is required in equatorial regions and regions of high gravity-wave activity but not otherwise. All-time all-latitude correlations between limb sounder observations and synthetic observations from full-input reanalyses (i.e. excluding JRA-55C, which does not assimilate stratospheric data) are 0.97-0.99 at 30km altitude, falling to 0.84-0.94 at 50km. The highest correlations are seen at high latitudes and the lowest in the sub-tropics, but root-mean-square (RMS) differences are highest (10K or greater) in high-latitude winter. At all latitudes, correlations decrease and RMS differences increase with increasing height. Differences become especially large during disrupted periods such as the post-sudden stratospheric warming recovery phase, where zonal-mean differences can be as high as 18K between different datasets. Finally, and most intriguingly, we see evidence that the full-input reanalyses are more tightly correlated with each other than with observations, even observations which they assimilate. Analysis of co-located observations does not show a similar degree of internal similarity, and thus our results may indicate that the reanalyses are over-tuned to match their comparators. If so, this presents significant implications for future development in these areas.

Key words: reanalyses, satellite data, temperature, stratosphere