Reply

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Free and Seidel (2007) have considered several questions regarding the radiosonde and satellite temperature trends discussed in Randel and Wu (2006, hereafter RW). The specific points raised are all valid discussion topics, and overall their comment provides useful additional discussion and information on these issues. We agree with the majority of the comments in Free and Seidel (2007), but have specific replies to two points.

1. Are the discontinuities in the difference series in the stratosphere due to errors in the sonde data or the satellite data?

The authors discuss the fact that several of the satellite–radiosonde difference time series show discontinuities at similar times (1987–88 and 1993–1996), which roughly correspond to satellite transition times (in 1987 and 1995). They then suggest that it is "not immediately clear whether the differences shown in RW are due to problems with radiosondes or satellites." We believe this is an overstatement. The fact that similarly timed differences are not seen at all stations, together with a lack of spatial structure in the satellite trends, argues strongly against large discontinuities at some stations originating with the satellites. We agree that there could easily be satellite uncertainties in addition to radiosonde errors, but these must be relatively small (compared to the discontinuities identified in RW on the order of 1 K) or else they would be evident in each of the difference time series, and especially in averages from many stations. This is not the case for the Lanzante et al. 2003 (hereafter LKS) and Integrated Global Radiosonde Archive (IGRA) data discussed in RW, as confirmed by comparison between the satellites and aggregated time series for radiosonde stations that do not exhibit large discontinuities (about half of the LKS stations). Figure 1 shows such a comparison, showing deseasonalized time series of microwave sounding unit (MSU) channel-4 data [from version v5.2 of the University of Alabama in Huntsville (UAH); Christy et al. 2003] compared with vertically integrated radiosonde results for averages calculated over 35 individual LKS stations that do not exhibit large satellite-radiosonde trend biases (specifically, stations from Table 1 of RW with difference trends less than 0.3 K decade^{-1}). If there were substantial discontinuities in the satellite data, we expect they would be evident in these differences averaged over many stations (unless identical jumps occurred in the radiosonde data from all of these stations). However, the difference time series in Fig. 1 shows little evidence of systematic jumps or discontinuities (confirmed by statistical breakpoint analysis), which argues against large discontinuities in the satellite data. Note especially the lack of obvious systematic changes in 1987 and 1995 in Fig. 1. Thus, we disagree with the summary statement in Free and Seidel (2007, their first paragraph in the conclusions) that the large stratospheric differences highlighted in RW could arguably be the result of errors in the satellite data.

As a note, the results in Fig. 1 are substantially different from a recent analysis of Christy and Norris (2006), who identify statistically significant break points and trends in satellite (MSU channel 4) minus radiosonde time series, based on a different group of radiosonde data (specifically, a group of 31 stations that use a homogeneous set of VIZ/Sippican radiosondes). Christy and Norris (2006) suggest that some of these discontinuities could result from systematic errors in the satellite data. The reason for the differences between their results and the lack of significant discontinuities or trends in Fig. 1 (based on the adjusted LKS radiosonde data) is unclear.

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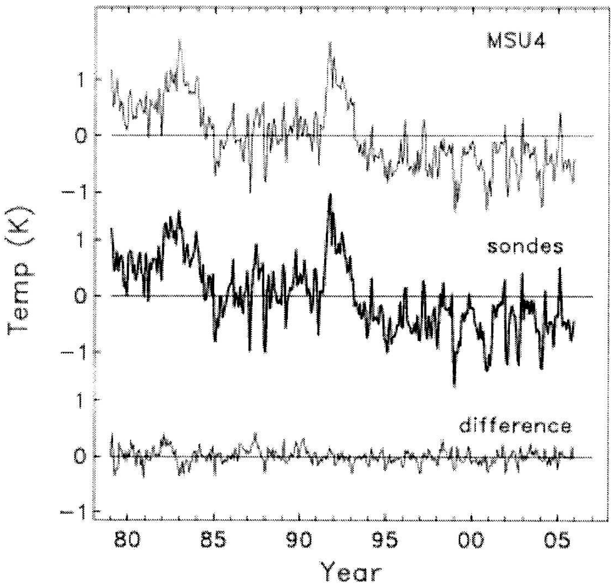

Fig. 1. Comparison of deseasonalized temperature anomalies calculated from MSU4 satellite data (top plot), vertically integrated radiosonde data (middle plot), and their difference (bottom plot). The radiosonde results are averages over 35 individual stations over 60°N–60°S, using a subset of the LKS stations that do not exhibit large satellite–sonde trend biases (specifically, stations from Table 1 of RW with difference trends less than 0.3 K $decade^{-1}$). The MSU channel 4 data are from UAH (Christy et al. 2003), sampled at each of the radiosonde station locations and averaged (similar to the radiosonde time series). Note the lack of any apparent jumps or discontinuities in the difference time series. The trend of the difference time series is -0.02 ± 0.03 K $decade^{-1}$ (2σ uncertainty).

2. Do biases seen in the stratosphere affect tropospheric trends?

Although the section with this title in Free and Seidel (2007) involves tropospheric trends, the focus is the *lower* troposphere, as defined by MSU channel 2LT. This primarily involves the altitude range ~0–6 km (~1000–400 hPa). The results in RW mainly highlighted stratospheric temperature biases (MSU channel 4), where differences are large and discontinuities in time series are obvious. The effects are also apparent in MSU channel 2 data (~0–12 km), partly because of the small extension of MSU channel 2 into the lower stratosphere and also because the radiosonde biases appear to extend into the upper troposphere, down to ~8 km (at least in the Tropics). However, for the layer corresponding to MSU channel 2LT, the satellite–radiosonde biases are very small (RW, their Fig. 7); there are not significant trend differences for stations segregated according to stratospheric biases (RW, their Fig. 8). We agree with the conclusion in Free and Seidel (2007) that the biases and discontinuities seen in the stratosphere are not reliable measures of biases in the lower troposphere. However, biases that are evident in the upper troposphere (especially in the Tropics) may significantly influence the fingerprint of temperature profile trends (e.g., Santer et al. 2005).

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