How Well Do Reanalyses Capture the Lower Stratosphere Temperature Hiatus from 1994 to Present?

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Abstract:

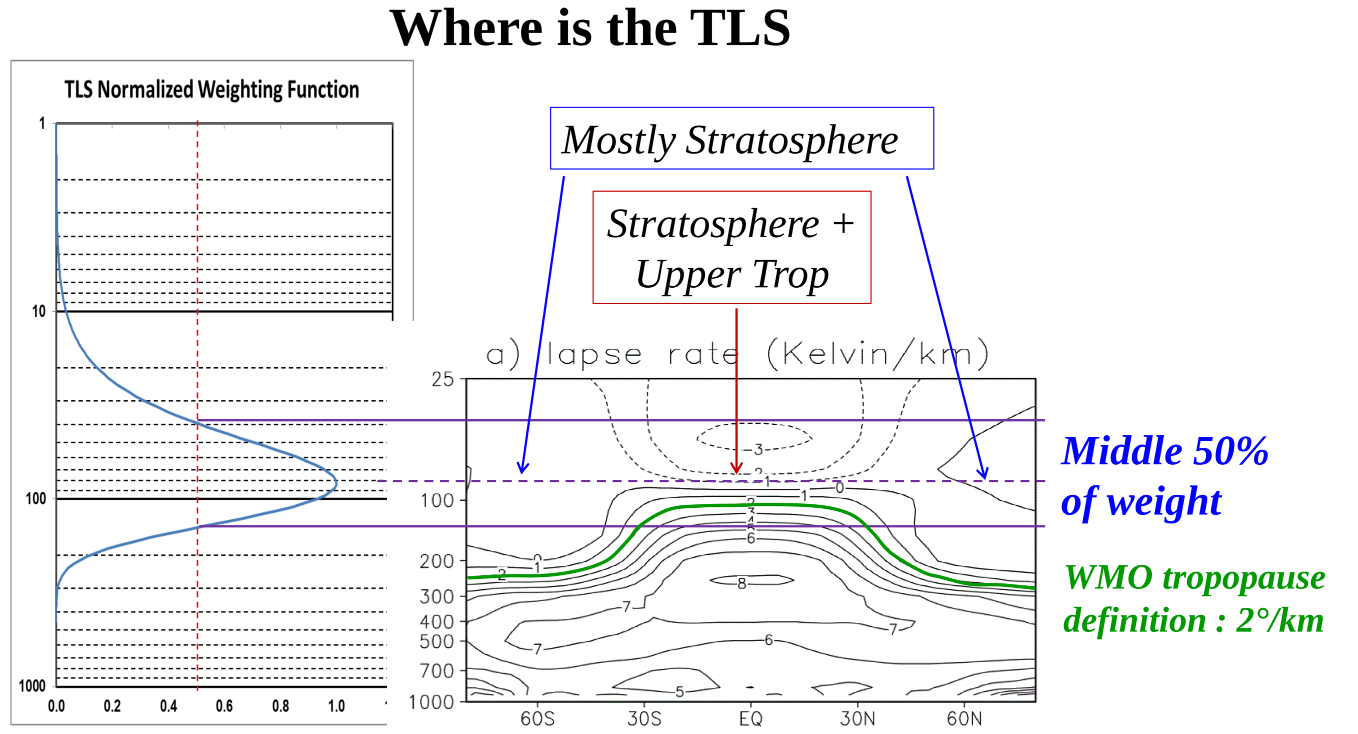
The globally averaged temperature of the lower stratosphere (TLS) as observed by satellites having the MSU channel 4 and AMSU channel 9 has been relatively flat since the thermal impacts of Mt Pinatubo were reduced in 1994. This flat trend or 'hiatus' has been shown to be a cancelation of the warming effects due to increasing ozone amounts and the cooling effects due to increasing greenhouse gases in the lower stratosphere.

Users of reanalysis data need to know how well the TLS layer is observed by the more recent reanalyses.

The TLS layer is interesting in that it is comprised of the upper troposphere and lower stratosphere in the tropics, and is entirely comprised of the lower stratosphere in the mid and high latitudes. 2016 was an interesting year in that there was tropical cooling in the lower stratosphere and warming in the upper troposphere due to the strong El Nino as well as tropical cooling in the lower stratosphere due to persistent Quasi-Biennial Oscillation descending westerlies. The four most recent reanalyses (CFSR, MERRA-2, ERA-Interim, and JRA-55) are compared against each other and satellite measurements to see how well they capture the TLS layer.

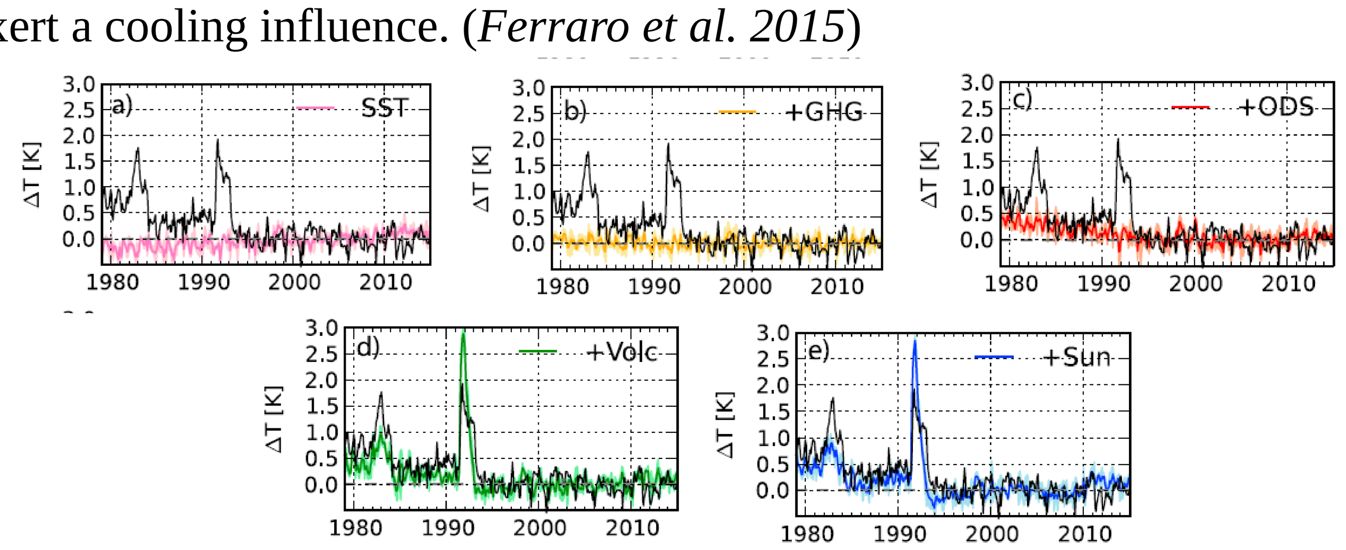
Take away message : Always be careful using reanalysis data for any trend detection!

Where is the TLS



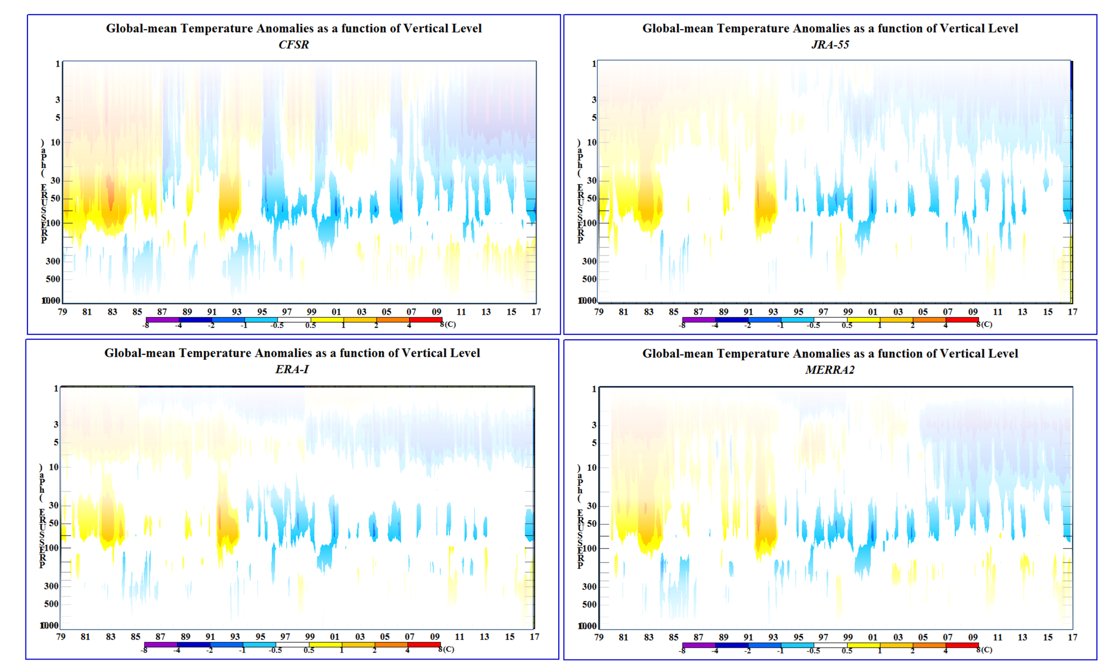
What impacts the temperature trends in the TLS

Increasing CO_2 concentrations cools the stratosphere by increasing net infrared emissions. Ozone depleting substances (ODS) have been decreasing. Ozone absorbs solar and infrared radiation. A decrease in ozone concentrations therefore drives stratospheric cooling. Consequently, an increase in ozone concentration will result in stratospheric warming. In the future concentrations of ODS will decrease acting to warm the lower stratosphere, whereas greenhouse gases will exert a cooling influence. (*Ferraro et al. 2015*)

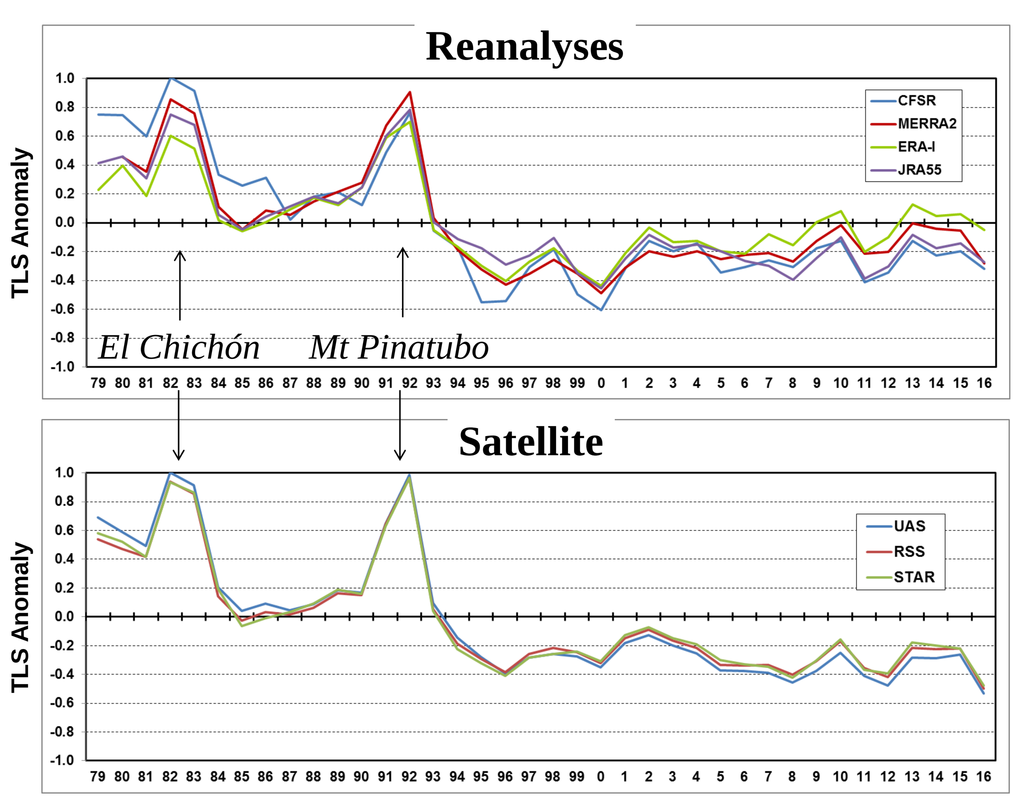


Additive effects of sea surface temperatures (SST), green house gases (GHG), ozone depleting substances (ODS), volcanic aerosols (Volc), and solar cycle (Sun) upon the MSU4 temperature anomalies (*Aquila et al., 2016*).

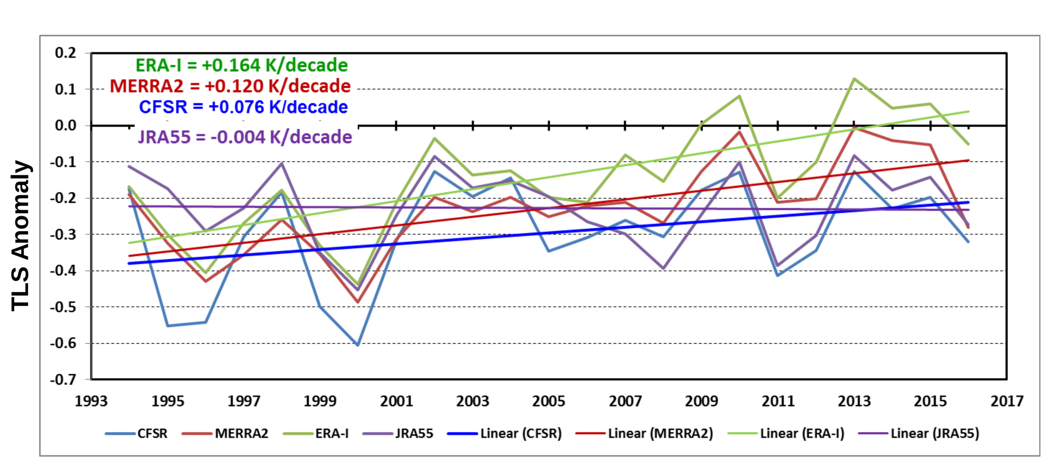
Global Temperature Anomalies



Time vs Pressure plots of global temperature anomalies (1979-2016 climatology) for four recent reanalyses. Most transparent altitude range is in the middle 50% of the TLS weight. El Chichón and Mt Pinatubo volcanic aerosol impacts on the temperatures is apparent. After the Mt Pinatubo eruption only minor anomalies are present. There is a prominent negative anomaly in the lower stratosphere for most of 2016. This negative temperature anomaly is most likely due to the strong El Niño and the persistent descending westerlies of the QBO. The positive El Niño temperature anomalies in the tropical upper troposphere are within the TLS layer but have minor weight.

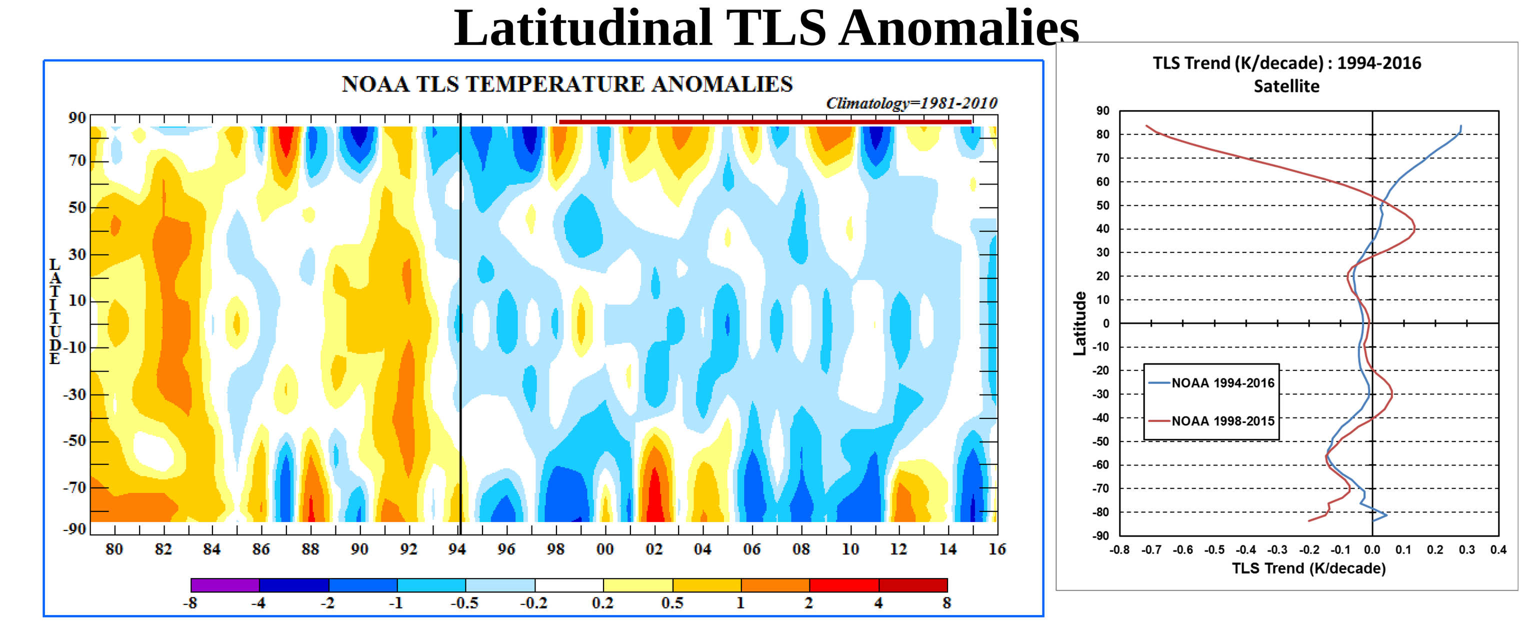


Time series of the annual global TLS anomalies from the 1981-2010 climatology of the four reanalyses (top) and three satellite centers (bottom). The satellite centers have very good agreement with UAH differing slightly from the NOAA/STAR and RSS anomalies. The 1994-2016 global trends for the satellites are slightly negative at: -0.071(UAH), -0.042(RSS), and -0.022(NOAA) ºC/decade. Note that there is greater spread in the reanalyses anomalies. A closer look at the 1994-2016 period is presented below:

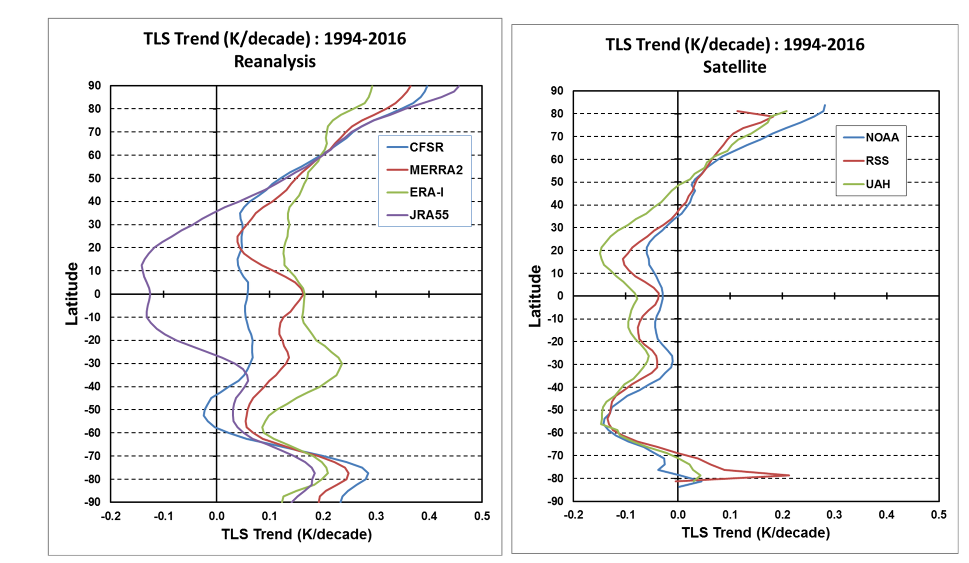


ERA-I, MERRA-2 and CFSR have positive trends since 1994. Only JRA-55 has a slightly negative trend. Probable causes for these positive trends include the transition from TOVS to ATOVS instruments beginning in late 1998, the use of AIRS data beginning in 2002, and the use of GPSRO beginning in 2006, and increasing use of unbias corrected radiosonde data.

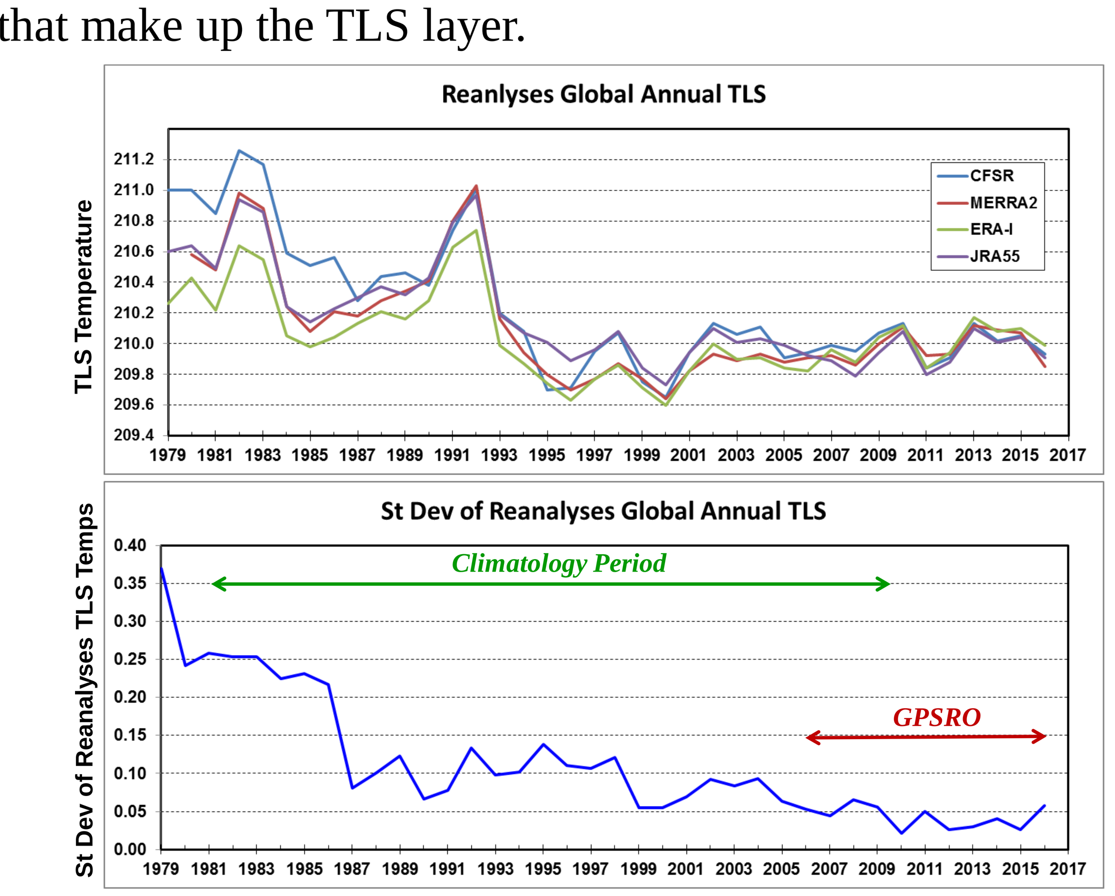
Latitudinal TLS Anomalies



Time vs Latitude plot of annual TLS temperature anomalies for the NOAA/STAR CDR. Note that there is large variability in the high latitudes. The annual anomaly is impacted mostly by the severity of the winter/spring temperatures. Trends derived at these latitudes will have a large σ. The large variability in the high latitudes impacts the trend depending upon the years chosen. The red zonal mean trend line is used by *Randel et al., 2016* and spans the years (1998-2015). Between 60N and 60S the trends from the two time periods are more agreeable.



Zonal TLS trend per decade of the four reanalyses varies considerably with latitude compared to the small variability of the three satellite CDRs. Reanalyses assimilate much more data than the MSU4 / AMSU9 channels. Bias/unbias adjusted radiosondes, aircraft, GPSRO, AIRS and IASI radiances complicate the temperatures that make up the TLS layer.



The problem with using a climatology to generate anomalies is that it assumes that the properties of the values have not changed during that period. ***This is not the case for reanalyses!*** Multiple data changes have occurred during the 1981-2010 period. The **GOOD** news is that GPSRO has really anchored the temperatures in the UTLS. Since 2006 there is much greater agreement in TLS temperatures.

Citations:

Aquila, V., W. H. Swartz, D. W. Waugh, P. R. Colarco, S. Pawson, L. M. Polvani, and R. S. Stolarski (2016), Isolating the roles of different forcing agents in global stratospheric temperature changes using model integrations with incrementally added single forcings, J. Geophys. Res. Atmos., 121, 8067–8082, doi:10.1002/2015JD023841.

Ferraro, A. J., M. Collins, and F. H. Lambert (2015), A hiatus in the stratosphere?, Nat. Clim. Change, 5(6), 497–498, doi:10.1038/nclimate2624.

Randel, W. J., A. K. Smith, F. Wu, C.-Z. Zou, and H. Qian, 2016: Stratospheric temperature trends over 1979–2015 derived from combined SSU, MLS, and SABER satellite observations. J. Climate, 29, 4843–4859, doi:10.1175/JCLI-D-15-0629.1