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Atmospheric Chemistry and Physics Discussions

# *Interactive comment on* "Analysis of SAGE II ozone of the middle and upper stratosphere for its response to a decadal-scale forcing" *by* E. Remsberg and G. Lingenfelser

**E. Remsberg and G. Lingenfelser**

Ellis.E.Remsberg@nasa.gov

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General comments: Paragraph 2: Section 1 of the manuscript states clearly why we focused on analyses of SAGE II data from 1991 to 2005, i.e., to see whether we would find an 11-yr response profile for the low latitudes that was similar to what we reported from the HALOE data (Remsberg, 2008). Soukharev and Hood (2006) had already reported on analyses of SAGE II data from 1984 through 2003, and Lee and Smith (2003) analyzed SAGE II data from 1984 to 2000. More specifically, Lee and Smith noted that they had to account for the significant anomalies in the ozone time series due to the Pinatubo event of 1991. Modeled solar responses disagree with their findings



in some respects. To first order, we have demonstrated the effects of that episodic forcing by conducting analyses from 1991 to 2005 and then repeating the analyses by removing the first year of data, September 1991 to September 1992. The 14-yr span of our time series also minimizes the effects of the significant forcings on ozone in the upper stratosphere due to increasing levels of reactive chlorine in the 1980s. If we were to include the data from 1984 to 1991, we would need to account for both of those non-periodic forcings and provide an estimate of their uncertainties. Although we agree that such a short time series can be a limitation for resolving the 11-yr term, we found that it was essentially in-phase with that of solar flux proxies and that the profile of its amplitude agrees reasonably with that from the HALOE time series.

Paragraph 3: All of the terms in our regression analyses are periodic, except for the linear trend. Note that interannual (QBO and subbiennial) and solar cycle forcings are not based on proxies but have been approximated as periodic, 28-month, 21-month, and 11-yr terms, respectively. This approach means that all those terms are orthogonal and that we are able to generate their uncertainties. However, it should also be clear that there must be no significant structure in the residuals, and we checked for that. One significant problem for the analysis is the presence of an apparent, northern subtropical ozone anomaly in the first year of the dataset, presumably due to the forcings from Pinatubo in some way. This end point anomaly has a significant impact on the linear trend term, and the 11-yr term is aliased. We demonstrated that impact by repeating the analyses after deleting the first year of data. If you wish, we can include a table of the confidence levels (in %) that we obtained for the 11-yr and linear trend terms over the latitude/altitude domain for the final version of our manuscript. In general, the seasonal and interannual terms are highly significant.

Paragraph 4: The SAGE II regression analysis approach is the same as that used for the HALOE ozone. Section 2.2 of Remsberg (2008) describes the HALOE ozone analysis in detail, including the fact that we account for the effects of serial correlation at lag-1. We followed the two-step approach of Tiao et al. (JGR, 1990), which requires a transformation of the variables to include the effects of the lag-1 autoregression coefficient that we obtain from step one. This method is analogous to that of the Cochrane-Orcutt estimator.

Other comments: Paragraph 1: Although we found first year anomalies in the SAGE II ozone time series near 30 km at northern subtropical latitudes, such effects were not evident elsewhere in the latitude/altitude domain.

Paragraph 2: We did not "invent" a 21-mo subbiennial term; it is clearly evident in a Fourier analysis of the residuals of our preliminary, de-seasonalized time series. It is unrelated to orbit periodicities of the SAGE II sampling. The physical basis of a subbiennial term is due to the interaction of the annual cycle and the QBO cycle, as pointed out by Dunkerton (JAS, 2001), among others. Although it is well-known that the QBO period of the tropical winds is somewhat variable (26 to 30 months) in the lower stratosphere, the QBO is more regular and has nearly a 28-month period in the middle and upper stratosphere. That is why we approximated the effects of the QBO as a 28-month periodic term for our analyses. Consequently, the associated subbiennial terms are also nearly periodic and are approximated as a 21-month term throughout our analysis domain. We found that the amplitude of the subbiennial term is often of the same order as that of the QBO term and is similarly significant at the low latitudes.

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