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Merging of ozone profiles from SCIAMACHY, OMPS and SAGE II observations to study stratospheric ozone changes

Carlo Arosio et al.

Correspondence to: Carlo Arosio (carloarosio@iup.physik.uni-bremen.de)

This documents presents some plots to support the ones shown in the paper.

Fig. S1 shows in panel (a) the Pearson correlation coefficient between the merged anomalies data set and MLS over the period 2005-20016. Values are extensively above 0.7 at most of the altitudes and latitudes; they are however slightly lower with respect to the correlation computed using the plain-debiased data set, due to the removed seasonal cycle. The zonal drift of the merged anomalies with respect to MLS anomalies has been computed as linear trend of the differences defined by Eq. 7 in the paper and shown in panel (b) of this picture. As found for the plain-debiased data set, the drift is non-significant and close to zero at most of the altitudes and latitudes.

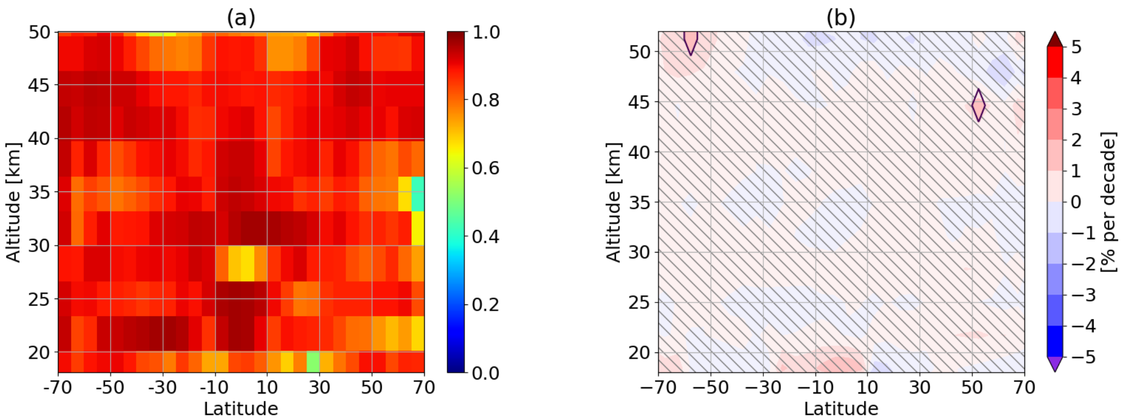

Figure S1: Panel (a): Pearson correlation coefficient of the merged anomalies data set with respect to MLS time series over 2005–2016. Panel (b): drift of the merged anomalies time series with respect to MLS, in terms of % per decade; dashed areas identify regions where the drift is not statistically significant.

In Fig. S2 longitudinally resolved drifts of the merged anomalies time series with respect to MLS anomalies are shown, i.e. altitude vs latitude linear changes in all the longitude bins. Only in few bins mainly above 40 km the drift is found to be significant. We also notice a longitudinal asymmetry in the values above 30 km: generally non-significant negative values are found in the [0°, 80°] longitude band, whereas positive trends, yet mostly non-significant, are detected within [80 °, 240 °] longitude and close to zero values elsewhere. This pattern is more evident in the map shown in the lower panel, diplaying the drift at 41.3 km.

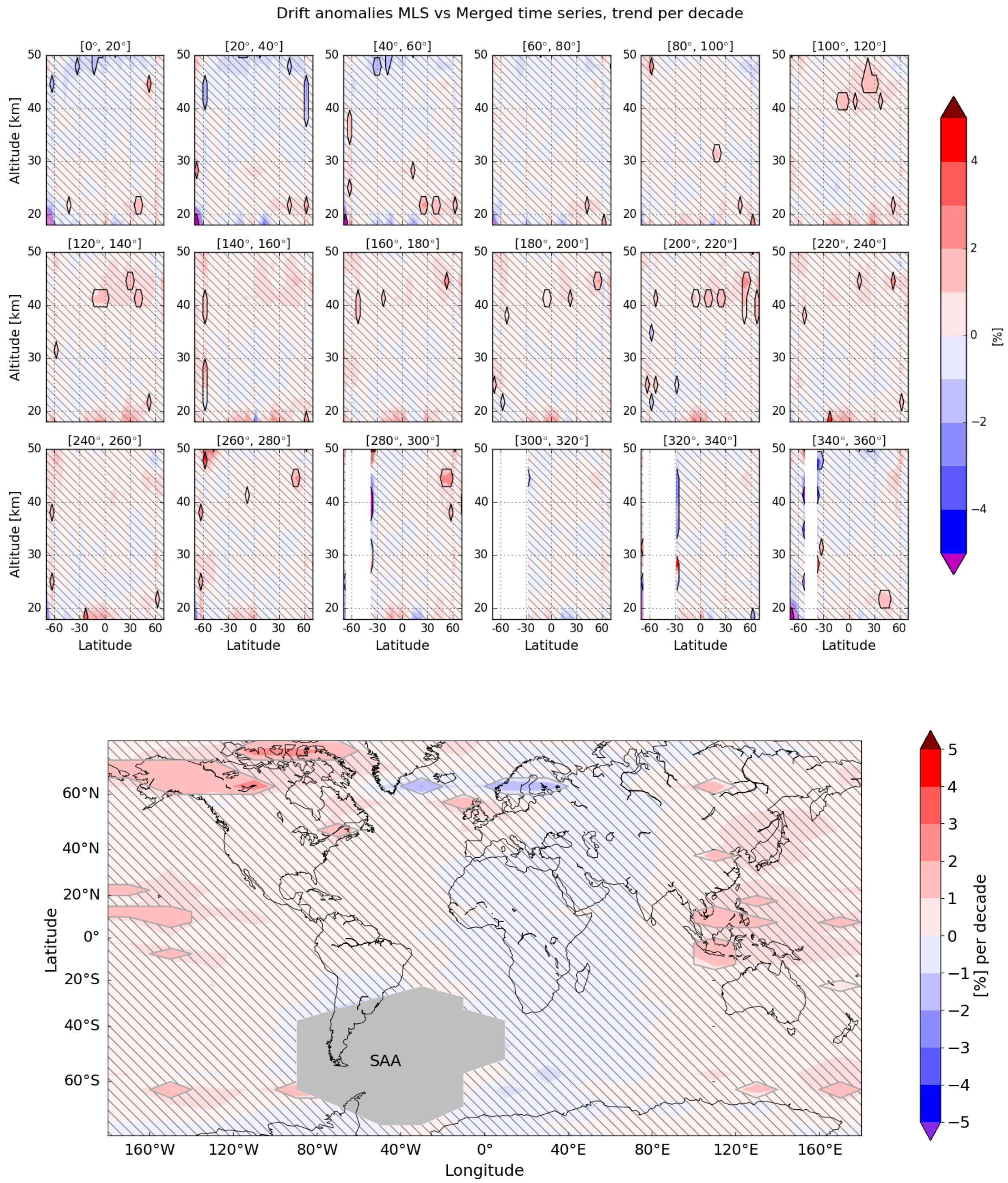

Figure S2: In the upper panel longitudinally-resolved drifts of the merged plain-debiased time series with respect to MLS over 2005–2016 as a function of latitude and altitude, in terms of % per decade. Dashed areas indicate non-significant trends. The title of each sub-plot indicates the longitude bands over which the profiles are averaged. The longitudinally-resolved drift is plotted in the lower panel at the altitude of 41.3 km.

In Fig. S3 longitudinally resolved ozone trends are shown, i.e. altitude vs latitude linear ozone changes in all the longitude bins. The hemispheric asymmetry in this plot is more evident than in Fig. 6 of the paper, especially around 40 km, where in some longitude bands the positive trends are reduced at southern mid-latitude with respect to the northern hemisphere. In the lower tropical stratosphere negative trends are significant only in few longitude bins. Comparing this plot with Fig. S2 we see that there is no evident correlation between the drift values and the trend patters.

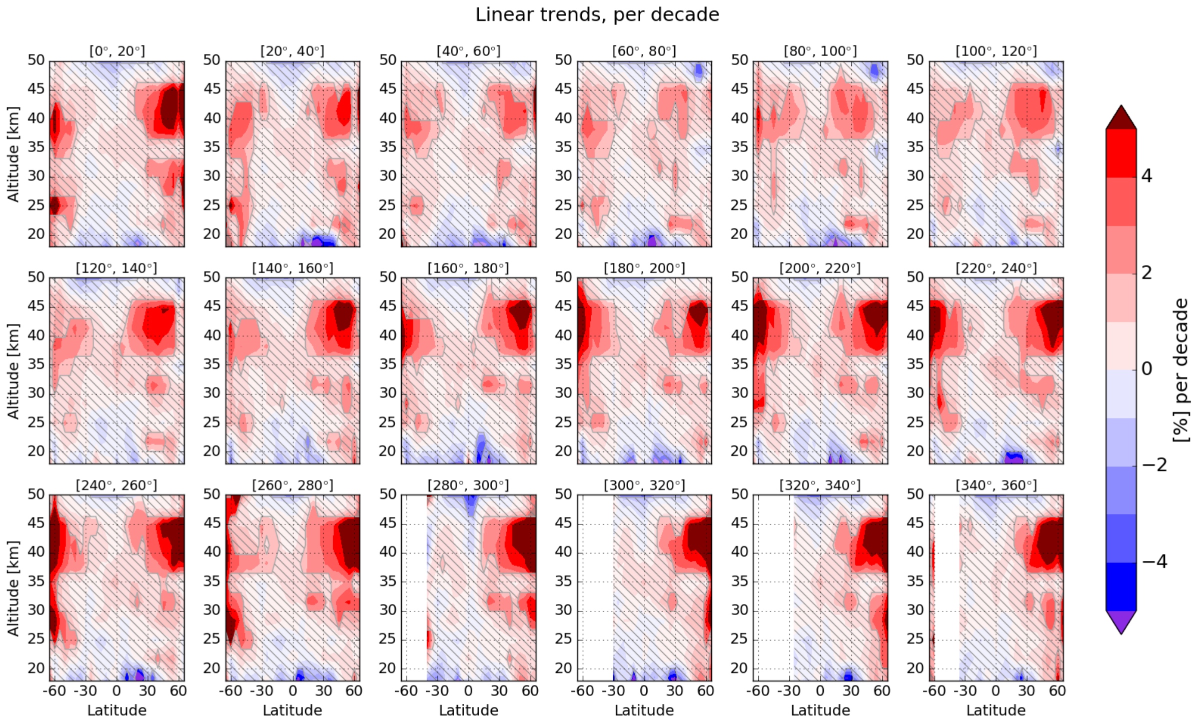

Figure S3: Longitudinally resolved linear long-term ozone variations over 2003–2018 as a function of latitude and altitude using the plain-debiased data set. Dashed areas indicate non-significant trends. The title of each sub-plot indicates the longitude bands over which the profiles are averaged.

In Fig. S4 and Fig. S5 longitudinally resolved ozone trends are shown at 21.7 and 34.8 km respectively. At the lower altitude, we notice the negative trends in the tropics and positive at mid-latitudes, in both cases mostly non-significant. This picture is more enhanced going down to 18.4 km. This is a possible indication of the speed-up of the BDC, which transports more efficiently ozone towards higher latitudes. At 34.8 km we recognize a similar distributions of the values as at 38–44 km, with significant positive trends only in the southern hemisphere. At northern mid- and high-latitudes a kind of two-cell structure is found, featuring positive values over Europe and Canada and negative over Russia, even though largely non-significant.

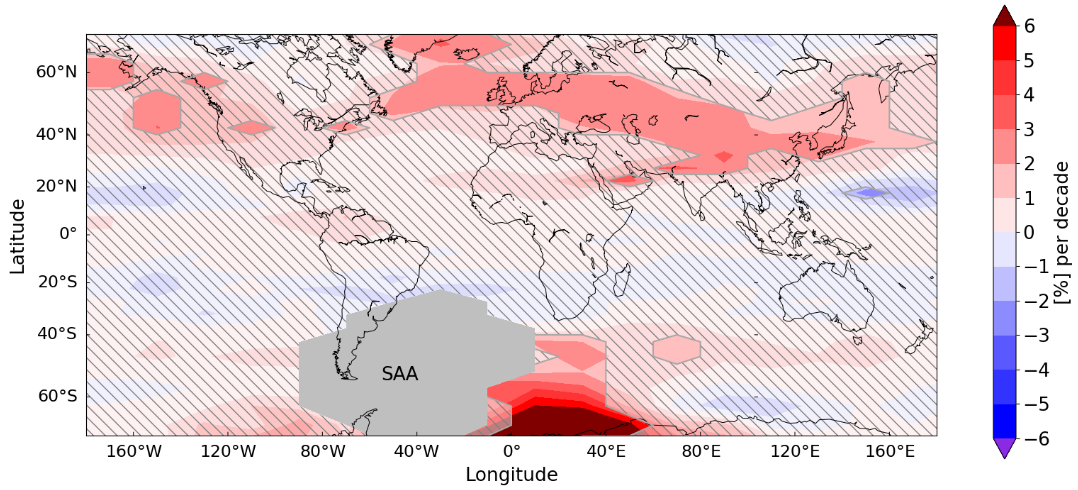

Figure S4: Longitudinally resolved linear long-term ozone variations 2003–2018 at 21.7 km, computed using the anomalies merged data set. Dashed areas indicate non-significant trends.

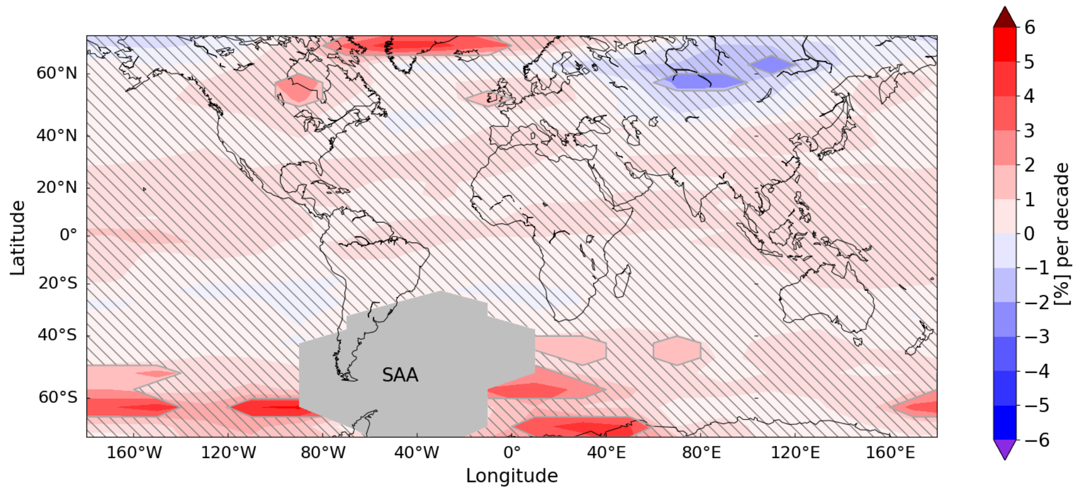

Figure S5: Longitudinally resolved linear long-term ozone variations 2003–2018 at 34.8 km, computed using the anomalies merged data set. Dashed areas indicate non-significant trends.

Fig. S6 shows the cross sections of the trends over 2003-2018 at 0° (panel a) and 60° S (panel b) as a function of altitude and longitude. We notice that in the tropics the longitudinal structure is smoother compared to mid-latitudes, with a variation of 1–3 % at most and non-significant values overall. At southern mid-latitudes, we see a vertically consistent region of positive trends in the upper stratosphere with a longitudinal variability not as strong as at northern mid-latitudes (see Fig. 8 in the paper).

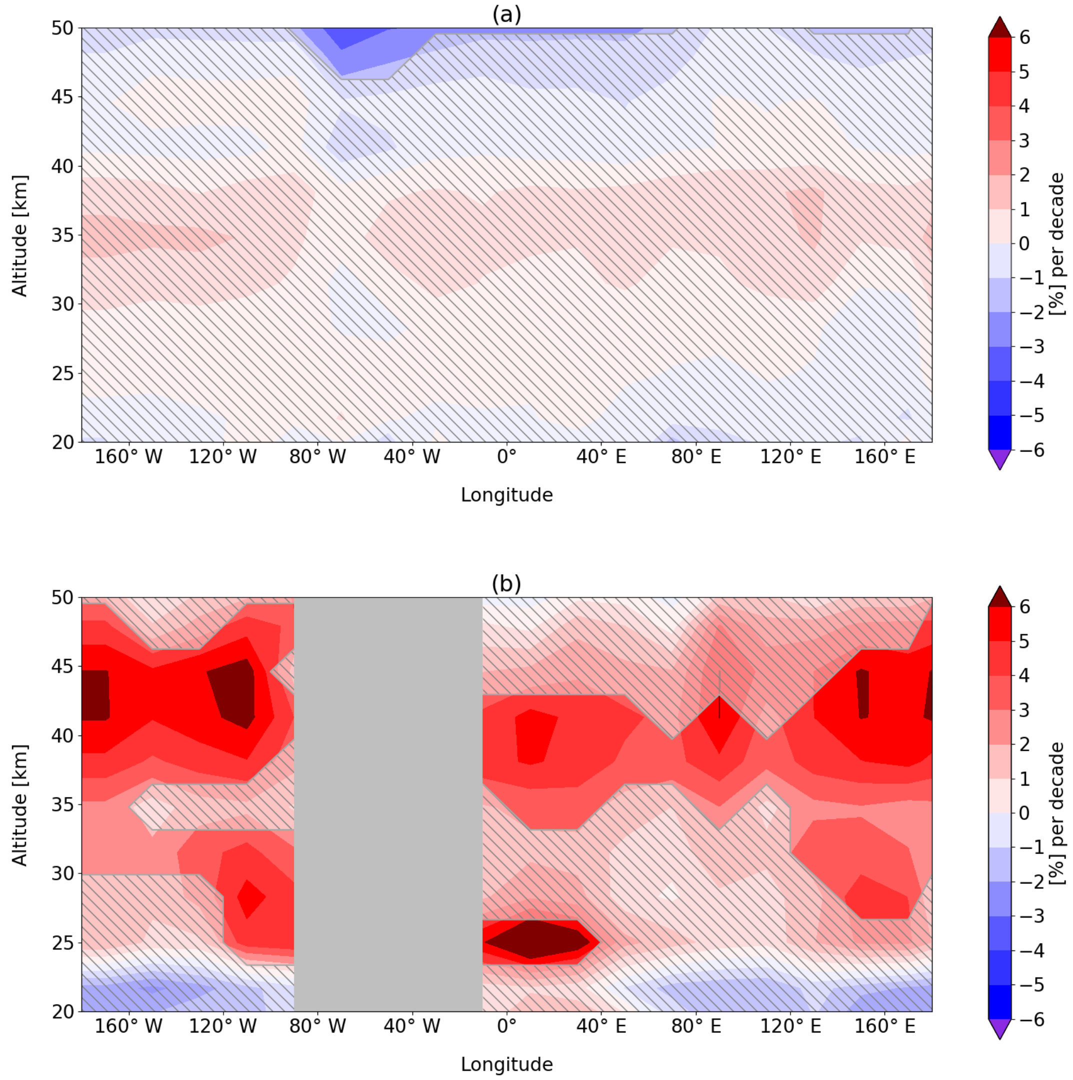

Figure S6: Longitudinal cross sections of long-term ozone variations over 2003-2018, at 0° in panel (a) and at 60° S in panel (b), using the plain-debiased merged data set. Dashed areas indicate non-significant trends. The gray area in panel (b) corresponds to the region affected by SAA.

To investigate the effect of the interference between the solar and the trend term, we calculated zonal trends over 2004-2011 following two methods:

- fitting all the proxies in this short time window (as done in the paper);
- fitting all the proxies but the linear term over 2003–2018 and then computing the linear trends over 2004-2011.

Fig. S7 the comparison between the zonal trends computed using both methods: in panel (a) the same as the plot presented in the paper (Fig. 9, panel c) and in panel (b) using the wider time range to fit all the non-trend terms.

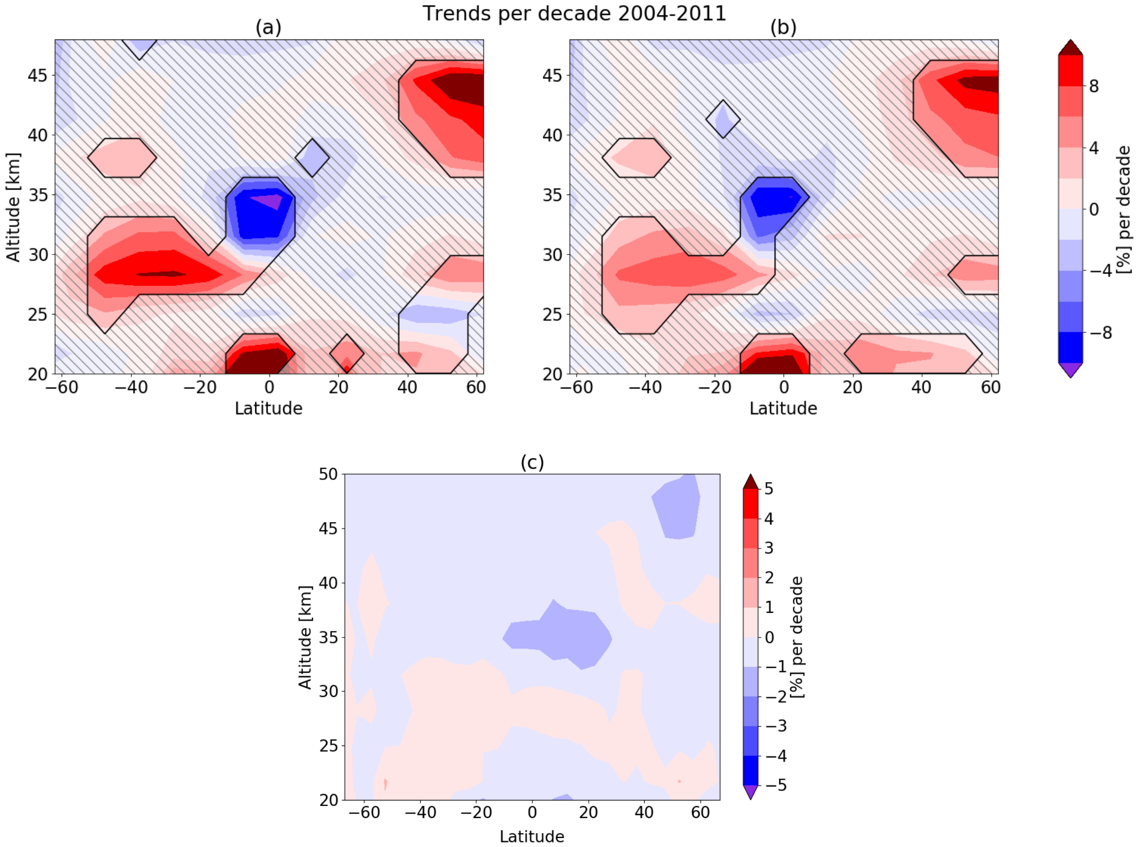

Figure S7: In panel (a) the trends are computed fitting all the terms over the 2004-2011 period (as done in the paper), in panel (b) all the non-trend terms were fitted over the 2003-2018 period. In panel (c), we present the differences of zonal trends over the period 2003-2018, with and without considering the solar proxy.

The changes are generally not relevant, even though the bipolar pattern found in the tropics and southern mid-latitudes is less pronounced using the second strategy. In order to evaluate the magnitude of the effects of the solar proxy on long-term ozone variations, we computed trends over 2003–2018 without considering the solar proxy in the fit: panel (c) of this figure, shows the difference between the results of this calculation and panel (b) of Fig. 6 in the paper. The differences are within $\pm$ 1% at most altitudes and latitudes, so that we expect that the interference between the solar and trend term is smaller than this threshold.