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Stratospheric impact on the Northern Hemisphere winter and spring ozone interannual variability in the troposphere

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Method of calculating the ozone IAVs (anomalies) and their magnitude average over North America or Europe.

Step 1: calculate the seasonal mean climatology at each sonde site. To get a better representation of climatological situation, we did not include ozone records between 1990 and 1995.

e.g.: ozone winter climatology at the station_j averaged from year 1995 to 2006

$$\bar{X}_{djf,sta\_j} = (\sum_{i=1995}^{i=2016} X_{djf,year\_i,sta\_j})/22$$

Step 2: calculate ozone anomaly at the station_j by removing the respective seasonal mean climatology from the ozone time series.

$$A_{djf,year\_i,sta\_j} = X_{djf,year\_i,sta\_j} - \bar{X}_{djf,sta\_j}$$

Step 3: calculate the regional mean ozone anomaly averaged over n stations.

$$\bar{A}_{djf,year\_i,region} = (\sum_{j=1}^{j=n} A_{djf,year\_i,sta\_j})/n$$

To quantify the magnitude of IAVs, we adopt the standard deviation (SDs) of these ozone anomalies. The standard deviation is $\sigma = \left[\frac{\sum_1^{ny}(y-\bar{y})^2}{ny-1}\right]^{\frac{1}{2}}$, where y is ozone anomalies, ny is the number of data points.

		DJF	**MAM**
200 hPa	Std_{na} (Std_{eu})	44 (44)	57 (54)
	F-test	0.99	0.82
400 hPa	Std_{na} (Std_{eu})	**3.08 (2.34)**	**4.94 (2.54)**
	F-test	**0.17**	**0.001**
700 hPa	Std_{na} (Std_{eu})	**2.94 (1.59)**	**2.56 (1.73)**
	F-test	**0.002**	**0.05**

Table S1: Standard deviations and F-test statistics of the observed O_3 anomalies over N. American sites (Std_{na}) and European sites (Std_{eu}), to assess whether there is significant regional difference in the amplitude of IAVs between North American and European sites.

		North America	**Europe**
200 hPa	Std_{djf} (Std_{mam})	**44 (57)**	**44 (54)**
	F-test	**0.19**	**0.28**
400 hPa	Std_{djf} (Std_{mam})	**3.08 (4.94)**	2.34 (2.54)
	F-test	**0.02**	0.69
700 hPa	Std_{djf} (Std_{mam})	2.94 (2.56)	1.59 (1.73)
	F-test	0.5	0.66

Table S2: Standard deviations and F-test statistics of the O_3 anomalies in DJF (Std_{djf}) and MAM (Std_{mam}), to assess whether there is significant seasonal difference in the IAVs.

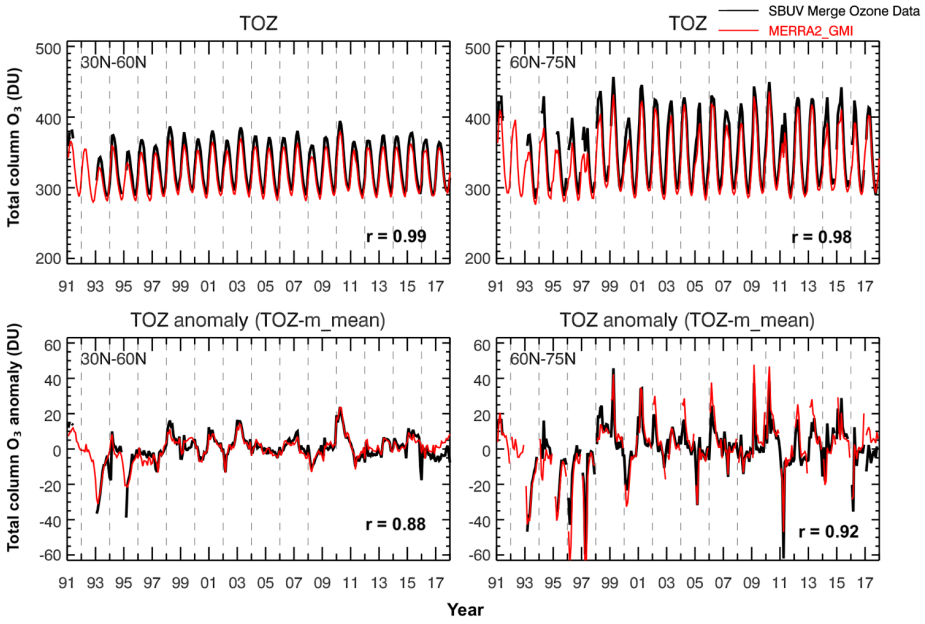

Figure S1: Monthly zonal mean of total column ozone (top) and its anomalies (bottom) averaged over (left) 30°N-60°N and (right) 60°N-75°N from the observations of the SBUV version 8.6 merged total ozone datasets (black lines) and the MERRA2-GMI simulations (red lines) from 1991 to 2016. The anomalies are calculated by removing the monthly mean averaged from 1991 to 2016.

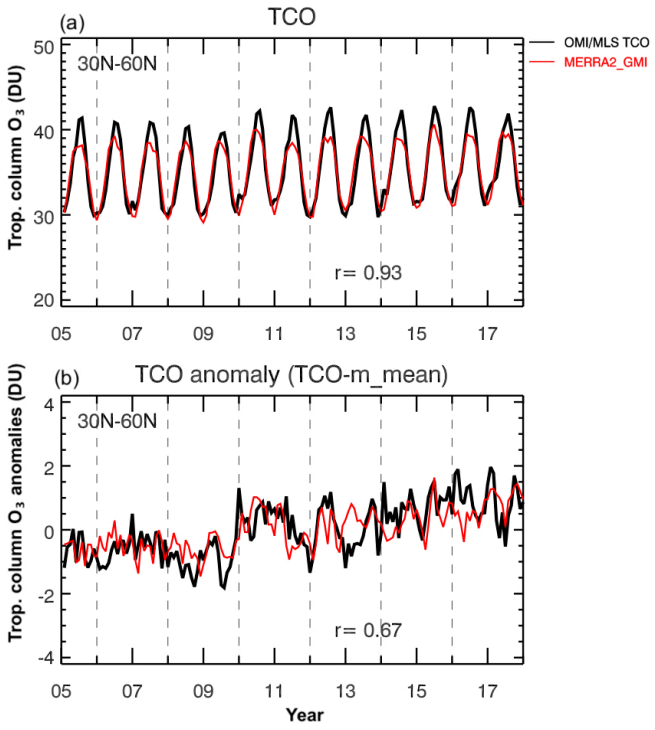

Figure S2: Monthly zonal mean of total column ozone (top) and its anomalies (bottom) averaged over 30°N-60°N from the observations derived from OMI/MLS residual analysis (black lines) and the MERRA2-GMI simulations (red lines) from 2005 to 2017. The anomalies are calculated by removing respective monthly mean averaged from 1991 to 2017.

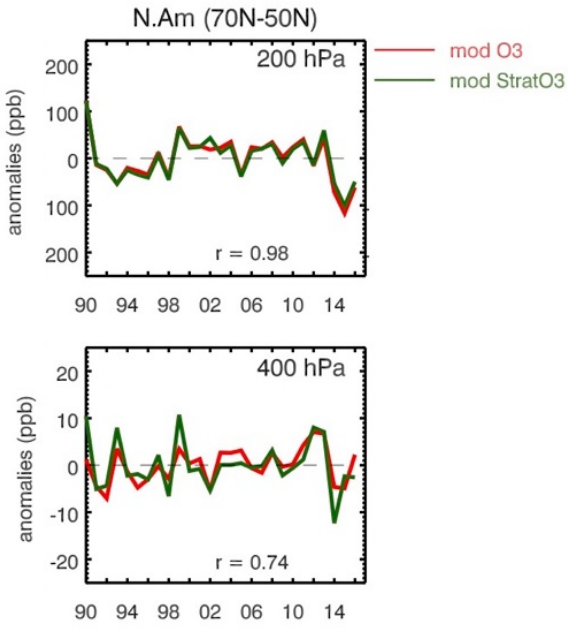

Figure S3: Time series plots of simulated ozone (red) and StratO_3 (green) anomalies (unit: ppb) at 200 hPa (top), 400hPa (bottom) averaged from the selected ozonesonde sites over the 50°N - 70°N sub-region of North America in winter from 1990 to 2016.

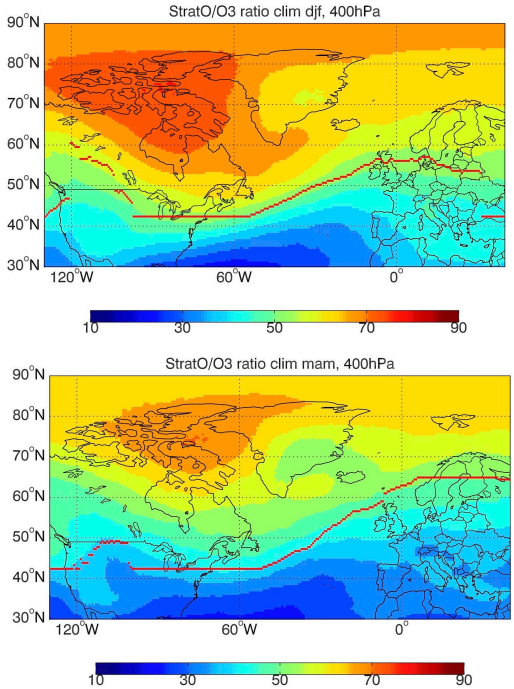

Figure S4: Spatial maps of simulated StratO_3/O_3 ratio climatology at 400 hPa in DJF (top) and MAM (bottom) averaged from 1990 to 2016. Red thick lines indicate the climatological jet locations, where the strongest winds are.

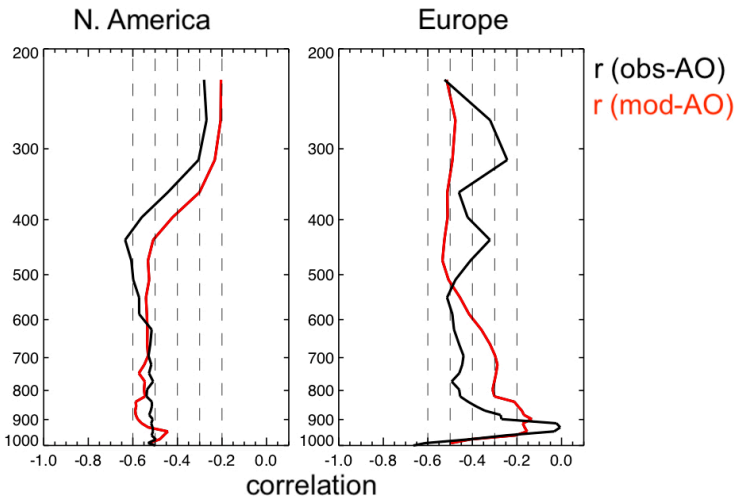

Figure S5: Profiles of correlations between O_3 and AO index in winter from 1990 to 2016 averaged over the North American and the European stations.