A new dynamical index representing short-term equatorial ozone and temperature variability

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Reliable estimates of long-term stratospheric ozone trends are important to quantify the impacts of climate change and the effect of reducing ozone depleting substances following the Montreal protocol[1]. To make an accurate assessment using multi-linear regression (MLR), variability needs to be well understood. Prior to 1998, upper stratospheric equatorial ozone showed a decline[2]. While it appears to be increasing since then[2], the uncertainty on the profile trend, related to internal variability, still makes any firm conclusions difficult[3].

We have found short, sharp synchronized ozone and temperature changes in the equatorial stratosphere lasting just a few weeks, which are related to changes in the meridional (Brewer-Dobson) circulation apparently initiated by perturbations in the mid-latitudes (**box ❶**). The identification of this mode of variability in stratospheric temperature and ozone has allowed us to develop a new index[4] that partially accounts for internal variability of the system (**box ❷**). This index will lead to an increase of variability accounted for in temperature and ozone, above 20 hPa, by 40% and 25%, respectively (**box ❸**), and a reduction in the error estimates of temperature and ozone by similar amounts (**box ❹**). This index, then, will help improve the error estimates of trends and variability in the stratosphere.

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Fig. 1: We investigate detrended (removing the 13-month running mean) and deseasonalised ozone and temperature monthly variability from the ERA-Interim-nudged-SOCOL model[5,6]. We identify 60 equatorial 'events' at 2.5 hPa when temperature (top row) exceeded the 90th percentile while ozone (bottom) was less than the 10th percentile, or vice versa (high-T JJA, orange circles; low-T JJA, light-blue; high-T DJF, red; low-T, blue). From these events, we locate regions which highly correlate with all months in the southern (SH; a,d) or northern (NH; b,e) upper stratosphere. Combining SH May-Oct and NH Nov-Apr months leads to regressions in (c,f). The index is shown in Fig. 3.

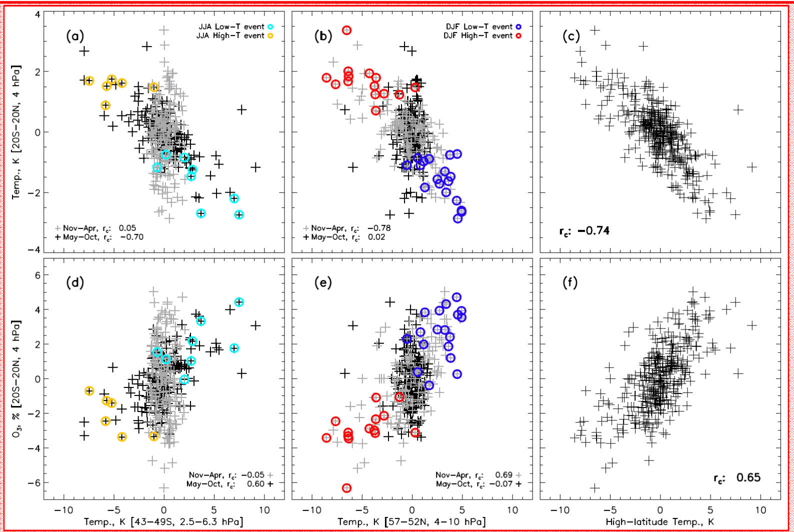
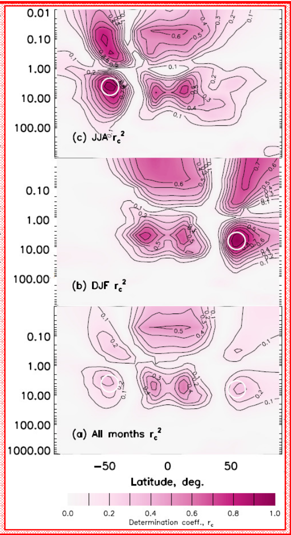


Fig. 2: Coefficient of determination (R^2) of the mid-latitude stratosphere dynamical (MLSD; Fig. 3) index with nudged-SOCOL model temperature. For (a) all months (n=370), (b) DJF and (c) JJA months. White circles represent the approximate region that the MLSD index is derived from.



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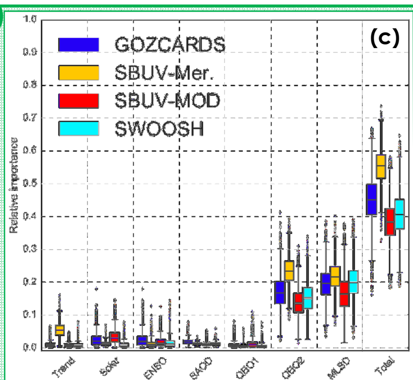

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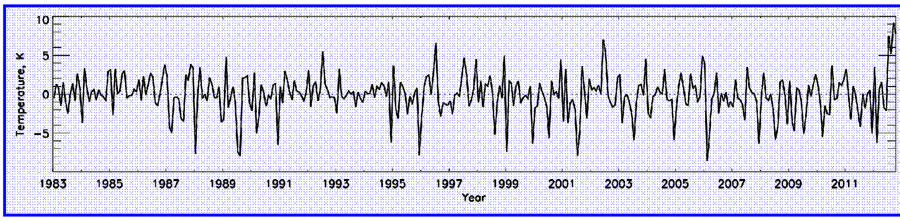

Fig. 3: The Mid-Latitude Stratosphere Dynamical (MLSD) Index time series from the nudged-SOCOL model as derived in Fig. 1.

Fig. 4: (**a**) Using MLR & bootstrapping, we calculate the relative importance (proportion of the total coefficient of determination, R^2) of 6 regressors at 4.6 hPa and 20S-20N without (blue distributions) and with (orange) the MLSD index for SSU temperature[7]; the summed total is on the right – the MLSD index accounts for more than 40% of the variance. (**b**) The total (annual) and seasonal variance of all regressors with and without the MLSD index. (**c**) Ozone as for (a), but only with the MLSD index, for 4 ozone composites (see legend [8,9,10,11]).

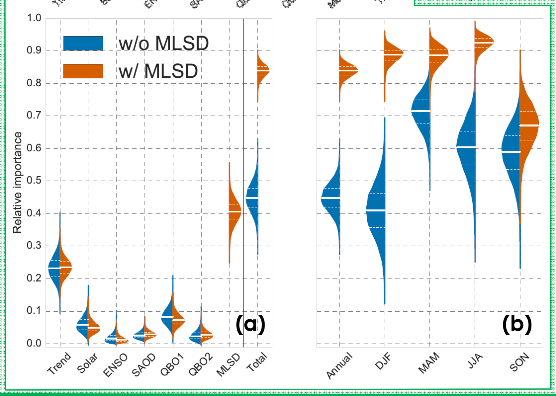

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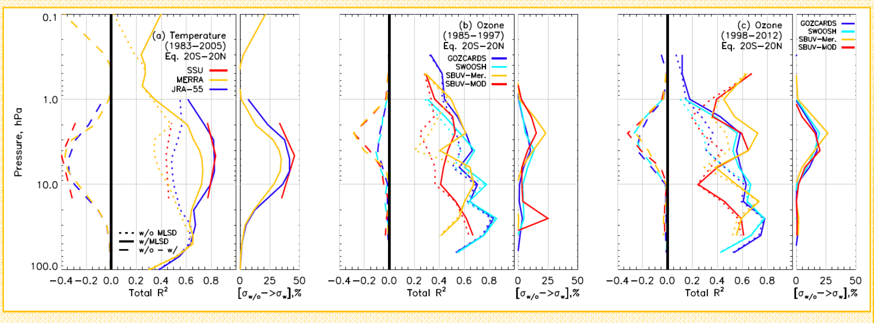
Fig. 5: These plots show how the MLSD index improves how much regressors account for equatorial (20S-20N) stratospheric variability and error-reduction in MLR analysis. (**a**) Temperature trends estimated from three sources of observations or reanalysis (see legend). (**b**) Ozone trends (1985-1997) from four ozone composites (see legend). (**c**) Ozone trends as in (b) for 1998-2012. In each sub-figure: the middle panel represents the total R^2 as a function of pressure (dotted line without MLSD; solid, with MLSD); the left panel is the difference between R^2 with and without the MLSD index; the right plot shows the reduction in the Student's t-test-based error estimated from the MLR analysis.



References: [1]Egorova, T., et al. 2013, ACP, 13, 3811–3823; [2]WMO: Scientific Assessment of Ozone Depletion: 2014; [3]Harris et al., 2015, ACP, 15, 9965-9982; [4]Ball et al., 2016 (in review), ACPD; [5]Dee at al., 2011, QJRMS, 137, 553-597; [6]Stenke, A. et al., 2013, GMD, 6, 1407-1427; [7]Zou, C.-Z., 2014, JGR-A, 119, 13; [7]Froidevaux, L. et al., 2015, ACP, 15, 10471-10507; [8]Wild, J.D. & Long, C.S., 2016 (in prep); [9]Frith et al., 2014, JGR-A, 119, 9735-9751; [10]Davis et al., 2016, ESSD, 1-59

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