



Supplement of

Surface impacts of the Quasi Biennial Oscillation

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Figure S1: Height profile (left panel) and principal component time-series (right panel) of the first two Empirical Orthogonal
Components (EOFs) of the FUB zonally-averaged equatorial zonal winds between 10-70 hPa for the period 1958-2016. EOF-1 is in dark blue and EOF-2 is in light blue.



Figure S2. Height – time series of zonally-averaged equatorial zonal winds for the period 1958-2016 from the observed FUB winds (top panel) and reconstructed from the first two EOFs shown in figure S1 (bottom panel).



Figure S3: Sample time-series of equatorial wind anomalies (normalised) employed to characterise the QBO in the regression analysis using different values of ϕ from $\phi = +90^{\circ}$ (top panel) to $\phi = -90^{\circ}$ (bottom panel).



Figure S4: Diagram showing correlation coefficients between time-series (1958-2016) employed in the regression analyses based on
the derived u* (see text) at different values of φ (abscissa) and based on the equatorial zonally-averaged zonal wind anomalies at heights between 10-70 hPa from the FUB dataset (ordinate).



Figure S5: Regression based QBO-W minus QBO-E differences: height – latitude cross-sections of zonally-averaged zonal winds (ms^{-1}) for November – March from the period 1958-2016. Rows (a) – (c) show results using $\phi = +60^{\circ}$, $\phi = 0^{\circ}$ and $\phi = -60^{\circ}$ respectively in the definition of the QBO index (see text) which are approximately equivalent to using $U_{eq} = 20$ hPa, 40 hPa and 70 hPa as the QBO index, respectively. Contours in panel (a) show the climatological values. White (black) dots indicate 99% (95%) statistical significance.



Figure S6: Regression based QBO-W minus QBO-E differences: latitude-longitude distribution of mean sea level pressure (hPa) for November – March from the period 1958-2016. Rows (a) – (c) show results using $\phi = +60^{\circ}$, $\phi = 0^{\circ}$ and $\phi = -60^{\circ}$ respectively in the definition of the QBO index (see text). Values of $\phi = +60^{\circ}$, 0° and -60° are broadly equivalent to using $U_{eq} = 20$ hPa, 40

5 hPa and 70 hPa as the QBO index, respectively. White (black) dots indicate 99% (95%) statistical significance.



Figure S7: Latitude – longitude distributions of monthly-averaged W-E QBO differences from the regression analysis of total precipitation data (mm per day) from the ERA-I dataset for 1979-2016. The QBO index was defined by the equatorial zonal wind time-series U_{eq} at 70 hPa. These monthly-averaged distributions were averaged together to produce the right hand column of figure 8. White (black) dots indicate 99% (95%) statistical significance.



Figure S8: as Figure S7 but using the EOF-based approach to define the QBO index, using $\phi = -60^{\circ}$ which is approximately equivalent to defining the QBO as $U_{eq} = 70$ hPa. White (black) dots indicate 99% (95%) statistical significance.