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Supplement of

Simulating the atmospheric response to the 11-year solar cycle forcing with the UM-UKCA model: the role of detection method and natural variability

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S1. Supporting analysis of the composite vs MLR differences

As described in Sect. 2.4, the time evolution of a variable, y(t), is defined in the MLR analysis as:

$$y(t) = b_{(offset)} \cdot offset + b_{(trend)} \cdot trend(t) + b_{(ESC)} \cdot ESC(t) + b_{(QBO)} \cdot QBO(t) + b_{(QBO\_orth)} \cdot QBO\_orth(t) + b_{(ENSO)} \cdot ENSO(t) + b_{(SAD)} \cdot SAD(t) + b_{(TSI)} \cdot TSI(t) + R(t) \quad \text{(Eq. 1)}$$

In comparison, the composite response is calculated simply by detrending the y(t) timeseries, followed by subsampling the SMAX and SMIN years. Clearly, this approach does not separate the influences of other processes and interannual variability that are explicitly accounted for by the various terms in MLR.

One can estimate the contribution of forcings other than the solar cycle to the calculated solar composite response. In particular, this can be done by subsampling the same SMAX and SMIN years from each of the $b_{(forcing)} \cdot forcing(t)$ timeseries, as first derived from MLR. The resulting differences between SMAX and SMIN years for each of the individual forcings in Eq. 1, scaled to represent changes per 1 Wm^{-2}, are shown in Fig. S3 and S4 for the yearly mean temperature and zonal wind, respectively. As expected, the sums of the SMAX-SMIN differences attributed to the individual forcings in Fig. S3(a-e)/S4(a-e), i.e. the solar cycle, volcanoes, ENSO, QBO (two regressors) and the residual, are similar to the composite solar responses discussed in Sect. 3 (not shown).

The analysis of the yearly mean temperature response to the solar cycle forcing in Sect. 5.1, shows that while no detectable tropical temperature response was found from MLR in the troposphere, composites yield a small, but statistically significant, tropical tropospheric warming of up to ~0.2 K/Wm^{-2}. As shown in Fig. S3, a large part of this temperature dipole structure in the tropical troposphere/lower stratosphere in composites is attributed to the residual term in MLR (e), with smaller contributions from the influence of ENSO (c) and QBO (b). See Sect. 5.1 for further discussion, as well as Fig. S4 for an analogous analysis of the yearly mean zonal mean changes.

S2. Supplementary figures

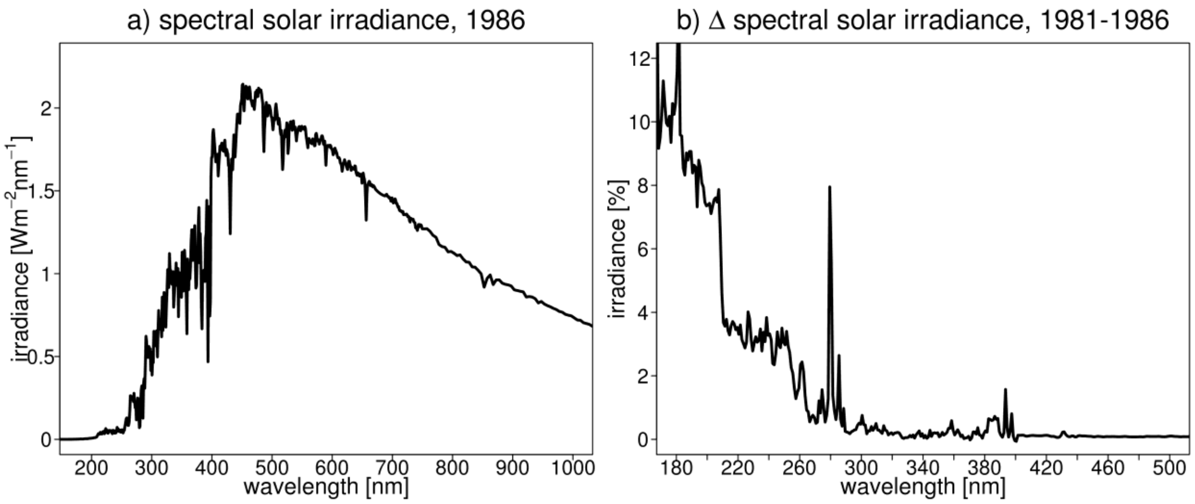

Figure S1. (a) Yearly mean spectral solar irradiance [Wm^{-2}nm^{-1}] in 1986 (solar minimum year) according to the CMIP5 recommendations (http://solarisheppa.geomar.de/cmip5; Lean, 2000; Wang et al., 2005; Lean, 2009). (b) As in (a) but for the difference [%] between the years 1981 and 1986 (solar maximum and solar minimum, respectively).

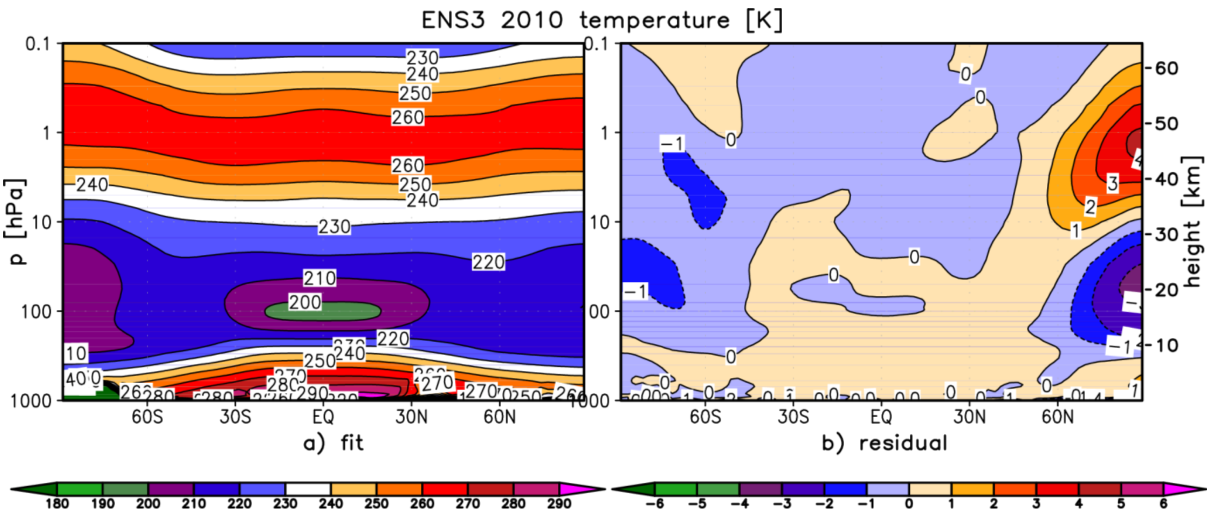

Figure S2. Multiple linear regression fit (a) and the residual (b) of the yearly mean zonal mean temperature derived from the analysis of the combined UM-UKCA ensemble for the example case of the year 2010 simulated by ENS3.

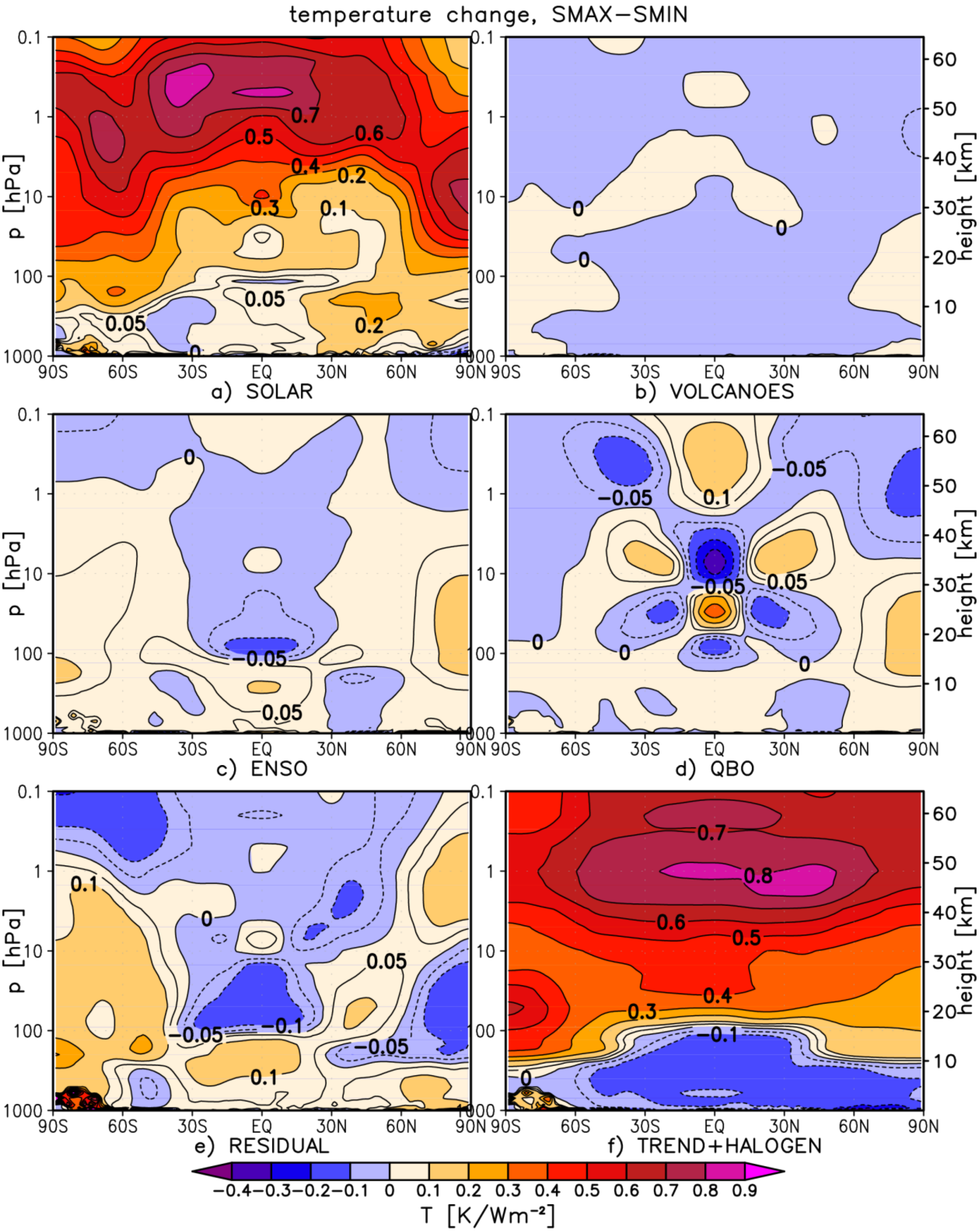

Figure S3. Yearly mean SMAX-SMIN change in zonal mean temperature [K/Wm^{-2}] attributed to the various terms in the MLR model. Note that (d) is the sum of the QBO and QBO_orth terms in Eq. 1. Note the extra contours at ±0.05 K/Wm^{-2}.

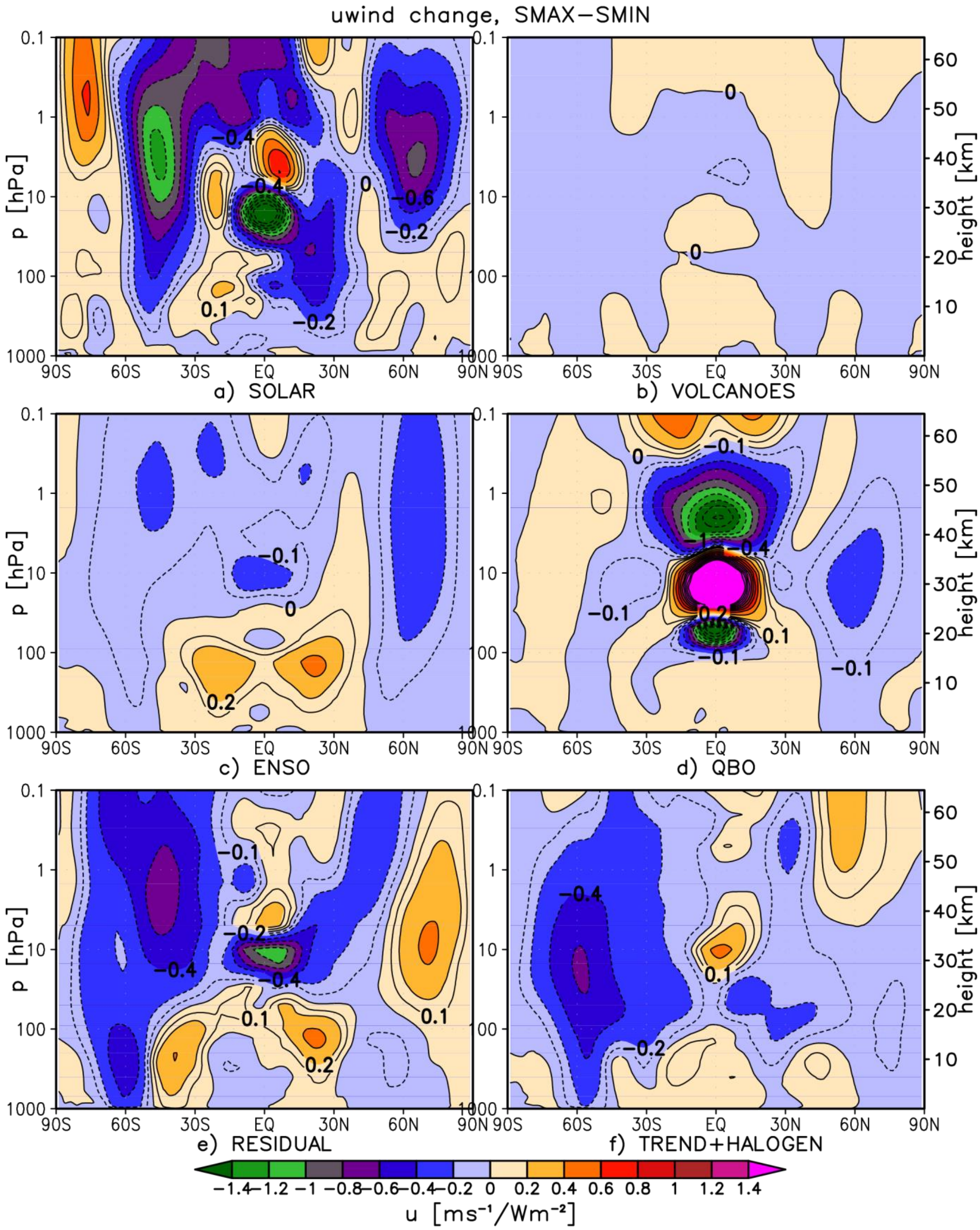

Figure S4. As in Fig. S3 but for the zonal mean zonal wind [ms^{-1}/Wm^{-2}] change. Note the extra contours at ±0.1 ms^{-1}/Wm^{-2}.

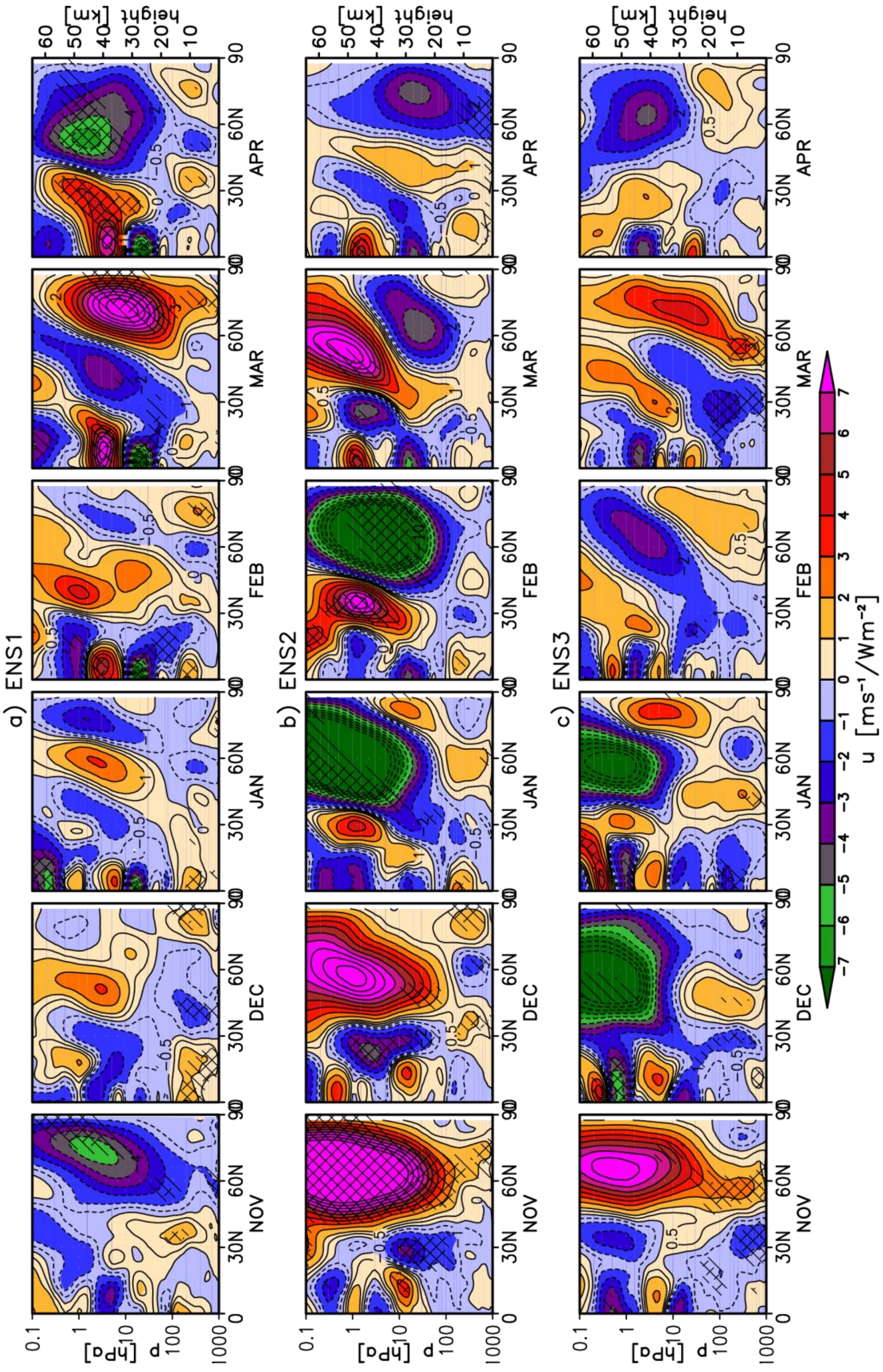

Figure S5. Monthly mean November-April zonal mean zonal wind response [ms^{-1}/Wm^{-2}] in UM-UKCA derived using MLR for individual ensemble members (ENS1-3). Single and double hatching indicates statistical significance on the 90% and 95% level (t-test). Note the extra contours at ±0.5, ±8, ±9 and ±10 ms^{-1}/Wm^{-2}.