

Supplementary information for

**The major stratospheric final warming in 2016: Dispersal of vortex air
and termination of Arctic chemical ozone loss**

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(See the main text for additional information regarding the methods and analysis used to generate these figures.)

Supplementary Animation 1, CAVE-ART Identification of Vortices

This animation demonstrates how CAVE-ART (see main text) identifies individual polar vortex regions during the 2016 Arctic major final warming (MFW). The greyscale and red background field is scaled potential vorticity (sPV) from MERRA-2 at 490 (left) and 850 K (right). The purple contour lines represent the vortex edges as “seen” by CAVE-ART after filtering out extraneous small regions; CAVE-ART uses sPV thresholds of $1.4 \times 10^{-4} \text{ s}^{-1}$ and $1.94 \times 10^{-4} \text{ s}^{-1}$ as the vortex edge values at 490 and 850 K, respectively, throughout the season. The vortex equivalent ellipses plotted are derived from the 2D moment diagnostics (see, e.g., Matthewman et al., 2009) incorporated into CAVE-ART, and are shown with labels plotted at the location of the vortex centroids.

Note that in cases when individual vortex regions are very small or distorted, it is possible for 1) the centroids to fall completely outside the vortex region, and/or 2) the equivalent ellipse to not fit the vortex region very well (see, for example, the pieces of the vortex “tail” at 850 K around 11 Mar 2016, ~26 seconds into video). Also note that CAVE-ART filters out any individual high sPV regions (i.e., sPV above the aforementioned thresholds) having an equivalent latitude greater than 84° , corresponding to an area less than roughly 0.5% of a hemisphere. This is the reason why regions can seem to die out too early (see, for example, the vortex labeled 3 at 490 K around ~31 seconds into video, which moves over Canada and repeatedly goes above/below the area threshold, taking on labels 4 through 8).

Supplementary Animation 2, Scatterplots of Function M vs sPV

This animation shows the evolution of the “horseshoe” patterns seen in scatterplots of function M versus sPV that are shown for a few days in the main text (Figs 9-11) during the MFW period from 24 February to 15 April at 490 (left), 550 (middle), and 850 K (right). The vertical red lines plotted are the sPV values used to define the vortex edge in CAVE-ART, which correspond to $1.4 \times 10^{-4} \text{ s}^{-1}$ for 490 K, $1.62 \times 10^{-4} \text{ s}^{-1}$ for 550 K, and $1.94 \times 10^{-4} \text{ s}^{-1}$ for 850 K. Note that the units for the function M (y-axes) are distances in megameters (Mm, 10^6 m), and that the limits of the x and y axes are different for each isentropic surface.

(Animations are by Z. D. Lawrence)

References

Matthewman, N. J., Esler, J. G., Charlton-Perez, A. J., and Polvani, L. M.: A New look at stratospheric sudden warmings. Part III: Polar vortex evolution and vertical structure, J. Clim., 22, 1566–1585, 2009.