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Drivers of Mars' northern winter polar vortex

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Mars' polar vortices play a mjaor role in determining the global-scale transport of trace gases and the composition of the polar caps. Potential vorticity (PV) is a key quantity in determining their dynamical and transport properties. Mars' winter polar vortices are annular in PV, a direct contrast to Earth's stratospheric polar vortices, whose PV values increase monotonically towards the poles. Given that a ring of high PV is known to be barotropically unstable, the persistence of this phenomenon in observations, simulations and reanalyses is somewhat surprising. Condensation of atmospheric carbon dioxide at the winter pole has been shown to be necessary to maintain the annulus in Martian Global Circulation Models (MGCM). Dust is also known to be a cause of internal and interannual variability in the polar vortices, but given the relatively few years of observations available, it is not yet fully understood. Here we present results of an attribution study of the driving mechanisms of the northern hemisphere Martian polar vortex. Using a reanalysis dataset and an idealized MGCM, we investigate the combined effects of dust, latent heat release, and topography on the polar vortex.

We show that the vertical PV structure of the polar vortex in the reanalysis is dependent on the observations assimilated, and that high atmospheric dust loading (such as that seen during a global dust storm) can disrupt the vortex and cause the destruction of PV in the low-mid altitudes. We also demonstrate that high dust loading can significantly reduce eddy activity within the core of the vortex over the course of a Martian winter. Latent heat release from carbon dioxide condensation is an important driver of variability within the polar vortex, but it is dust in the model that primarily drives the eddy activity throughout the Martian year.