A climatology of the martian northern polar vortex

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Introduction
- Mars’ atmosphere contains polar vortices: regions of cold air surrounded by powerful jets
- These play a crucial role in controlling transport of atmospheric aerosols and chemical species
- Their intensity and morphology have a complex relationship with atmospheric dust loading
- We combine a Mars Global Climate Model (MGC) with eight martian years’ worth of Mars Climate Sounder (MCS) data to investigate the seasonal behaviour of Mars’ north polar vortex, and its relationship with dust storm activity, in particular A and C type regional storms.

A and C storm effects
- A storms consistently reduce PV on the outer edge of the vortex and increase PV over the pole, indicating a compressed vortex and reduced annularity
- C storms have a similar but less consistent effect, likely linked to their later timing and the fact that the vortex is already undergoing seasonal decay
- In general, storm effects appear closely linked to the already existing structure of the meridional circulation
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- Storms closer in time to the strongest south-to-north Hadley cell at L=270° have the greatest compressive effect.

Summary
- Eight martian years of northern polar vortex activity reveal a high degree of interannual similarity in vortex behaviour and structure
- However some small-scale temporal variation in PV is apparent
- Large-scale interannual variability in the vortex is linked to dust activity
- GDS timing (equinoctial vs solstitial) is key; former caused significant disruption, latter far more limited impacts (Streeter et al., 2021)
- A and C regional storms have similar effects but the latter cause greater disruption to the annular structure of the vortex, likely due to the later seasonal timing.

Multi-year climatology
- The northern polar vortex shows a high degree of interannual repeatability
- In an average year, the vortex first develops around L=150-180° and grows in intensity, with a peak in PV intensity between L=210-330°
- The characteristic annular PV structure of the vortex only appears around L=210° and persists until approximately L=330°; this is visible in Fig. 1 as a PV maximum present at around 80°N, with a local PV minimum over the pole itself
- Intermittent vortex variability is linked to dust activity at tropical/mid-latitudes
- The MY 28 (solstitial) GDS caused large-scale disruption to the vortex, while the MY 34 (equinoctial) GDS had more limited impacts.
- There is an apparent dichotomy between A and C storm effects (see left).

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OpenMARS
The OpenMARS reanalysis dataset v1.0
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Methods
- We use data assimilation to combine the LMD-UK MGCM with MCS temperature retrievals and derived column dust products
- We investigate eight martian years, Mars Year (MY) 28-35, including two Global Dust Storms (GDS) and numerous regional dust storms
- We use potential vorticity (PV) as a diagnostic for the polar vortex; PV is a conserved dynamical quantity related to atmospheric rotation and vertical temperature stratification.