Mars' Annular Polar Vortex

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1. Background

The Martian polar vortex has recently been shown to be annular in nature, with a local minimum in potential vorticity (PV) at the winter pole. This barotropically unstable state is persistent in observations, simulations and reanalyses. It has been shown that its annular nature may be due to the release of latent heat from CO_2 condensation, CO_2 clouds, changes in dust distributions, and the strength of the Hadley circulation, with many of these being interlinked.

2. Introduction

Here we present results from analysis of the Open access to Mars Assimilated Remote Soundings (OpenMARS) reanalysis database [1]. We characterise the structure and variability of the northern winter polar vortex by considering profiles of potential vorticity, q, and eddy enstrophy, Z. Further, we present preliminary PV profiles of the Martian winter polar vortex from simulations using the Isca modelling framework [4].

3. Zonal Asymmetry in Reanalysis Data

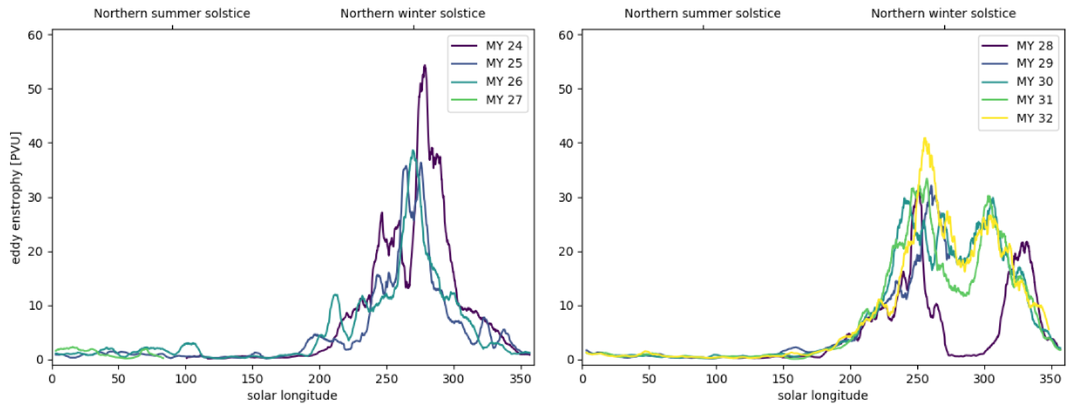

Figure 1: Yearly evolution of eddy enstrophy on the 350K surface in the latitudinal band 60-80°N, calculated from the OpenMARS dataset. To clarify the data, a 3-sol smoothing has been applied, and the data have been separated into the left and right panels, which show Martian years (MY) 24-27 and 28-32, respectively.

- Integrated eddy enstrophy is a measure of the flow's rotational energy and is useful in understanding the transience of the flow.
- Eddy enstrophy is given by $Z = \frac{1}{4\pi}\int q'^2 dA$, where $q' = q - \bar{q}$ is the departure from the zonal-mean potential vorticity.
- The large variance in eddy enstrophy seen around northern winter solstice indicates that there is more internal variability within the flow during these times. During northern summer solstice, there is remarkably little variation in eddy enstrophy in every year of data.
- The increase in mean enstrophy suggests that there is increased eddy activity during these times.

4. Mars GCM simulations

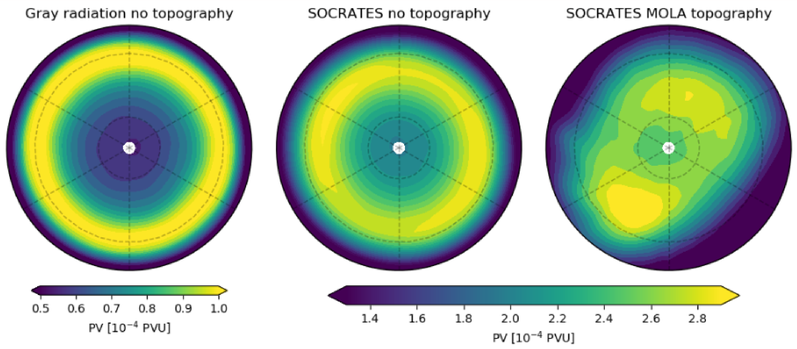

Figure 2: Polar stereographic projection (from 50°N to the northern pole) of PV on the 350K potential temperature surface for a 30-sol average about Ls=270. A vertical scaling of PV has been applied according to [2]. The radiation scheme and topography used is a gray radiation scheme with no topography (left), SOCRATES with no topography (center), and SOCRATES with topography from the Mars Orbiter Laser Altimeter (MOLA) (right).

- The SOCRATES radiation scheme [3] produces slightly higher PV values than the gray scheme, closer in value to those in reanalysis data.
- All three simulations display a local PV minimum at the pole, although this is a weaker minimum than those found in reanalysis data.
- Currently, there is no representation of latent heating from CO_2 condensation in Isca, which has been shown to relate to the annular shape of the vortices.

5. The Northern Winter Polar Vortex in Reanalysis Data

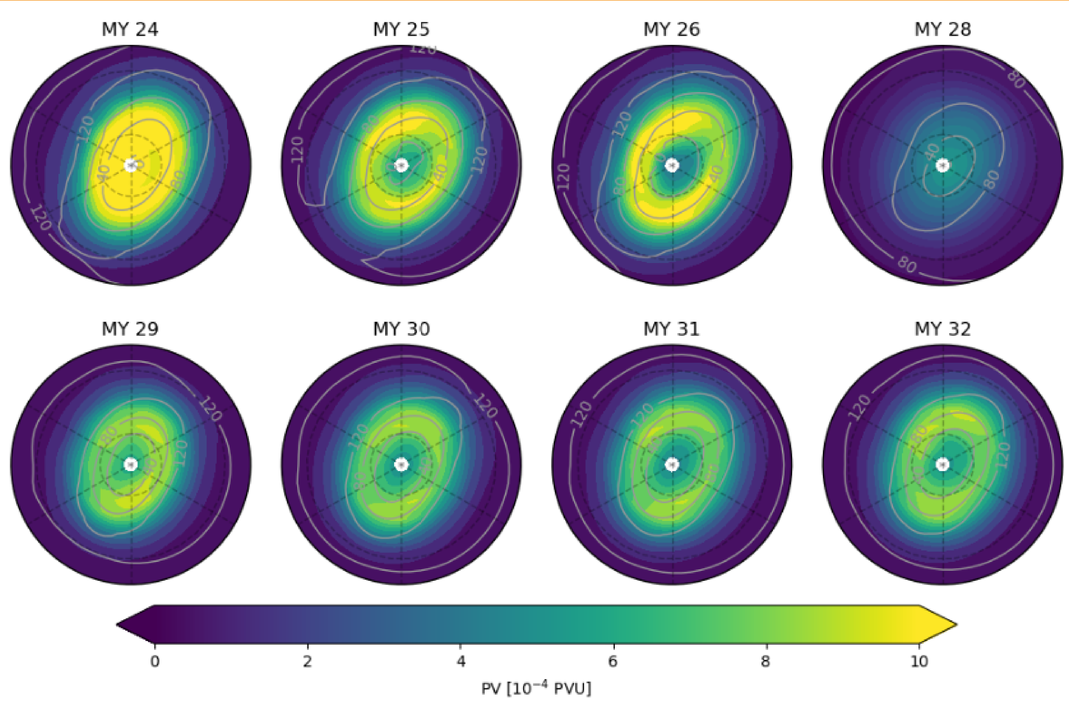

Figure 3: The northern winter polar vortex in MY 24-26 and 28-32, using the OpenMARS reanalysis product. Shading and scaling the same as in Figure 2, with the addition of zonal wind contours (ms^{-1}).

- MY 24-26 use observations from the Thermal Emission Spectrometer (TES) and years 28-32 use those from Mars Climate Sounder (MCS), both combined with a Mars GCM.
- Planet-encircling dust storms occurred during the winters of MY 25 and 28, possibly contributing to the weakening of the vortex in MY 28.
- The local PV minimum near the north pole is a persistent feature in almost all years of OpenMARS data.

6. Conclusions

- In the northern winter polar regions, we have found that there is more zonal asymmetry in the flow than during other times of the year, and that there is more variability in the flow.
- The annular nature of Mars' northern winter polar vortex is persistent in almost all years of reanalysis data.

Future work will include integrating representations of dust and latent heating from CO_2 condensation into Isca to more accurately represent the Martian atmosphere. These factors have both been linked to the annular structure of the Martian polar vortex (see for example [5]).

References

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