EPSC Abstracts
Vol. 8, EPSC2013-877, 2013
European Planetary Science Congress 2013

Polar Vortices on Mars and Earth from Atmospheric Reanalyses

L. Montabone (1, 2), D. M. Mitchell (2), S. I. Thomson (3), and P. L. Read (2)
(1) Laboratoire de Météorologie Dynamique, Université Pierre et Marie Curie, Paris, France, (2) Department of Physics, University of Oxford, Oxford, UK, (3) Department of Applied Mathematics and Theoretical Physics, University of Cambridge, Cambridge, UK (montabone@atm.ox.ac.uk)

Abstract

We use data from atmospheric reanalyses for both the Earth and Mars to characterize the climatology and variability of their respective polar vortices, particularly in relation to their morphology.

1. Introduction

Polar vortices seem to be ubiquitous atmospheric structures. In the Solar System, Earth, Mars, Venus, Saturn and its moon Titan are known to have well developed vortices in their polar regions (see [5] in this issue for a study of Venus' polar vortices). On Earth as well as on Mars, the increased latitudinal temperature gradients observed during the polar winter gives rise to strong westerly winds peaking at about 60° latitude N/S. The peaking altitudes of these circumpolar westerlies are also remarkably similar, being located around 50 km altitude in the Terrestrial stratosphere and in the Martian mesosphere.
Reanalyses combine state-of the-art global climate models with observations to produce a best estimate of the atmospheric state throughout a historical period. They allow access to variables which are not directly observed, such as wind components or vorticity, dynamically balanced with observed variables such as temperature. For the Earth, we use the Modern Era Retrospective-analyses for Research and Applications (MERRA[1]), from 1979 to 2011. For Mars, we use the Mars Analysis Correction Data Assimilation (MACDA[2], [3]) from 1999 to 2004 (almost three Martian years, covered by data from the Thermal Emission Spectrometer on board NASA's Mars Global Surveyor).

[1] http://gmao.gsfc.nasa.gov/merra/
[2] http://dx.doi.org/10.5285/78114093-E2BD-4601-8AE5-3551E62AEF2B

2. Results

The comparison shows that, despite a very different thermal structure between Earth's stratosphere-lower mesosphere and Mars' mesosphere, the zonal-mean zonal wind structure and the meridional mass stream function have common features, which explain similarities in the climatological structure of Earth's and Mars' polar vortices (See Figs. 1 and 2).
In order to study the variability of the polar vortex morphology on Mars and Earth, we use potential vorticity (in the modified form proposed by Lait, [1]) and vortex centric diagnostics [2]. This allows the relative characteristics of the polar vortices to be compared at different altitudes and across planets, providing meaningful results despite the intrinsic differences between Mars and Earth.
We show that Martian polar vortices present lower variability than their Terrestrial counterpart (at least over the available reanalysis period for Mars), when looking at area, aspect ratio, centroid latitude and orientation.
Despite this, episodes of "sudden polar warming" in the northern hemisphere can be induced on Mars by regional dust storms occurring in the southern hemisphere (see also [4] in this issue). We will discuss possible similarities and differences with respect to Terrestrial "Stratospheric Sudden Warming" (SSW) events.

3. Summary and future work

We have used the comparative planetology approach to investigate similarities and differences specifically related to the morphology of the polar vortices on Mars and on the Earth. The focus here is on the climatology and its observed variability. Future work might be devoted to study the dynamics and transport. One limitation for Mars is the short period of available MACDA reanalysis (only about three Martian years) as well as its relative coarse spatial resolution (5° longitude x 5° latitude for 25 vertical levels extending from the ground to about 100 km).

Future work will try to reduce the limitations for the case of Mars, by extending the reanalysis of the Martian atmosphere to the period covered by the Mars Climate Sounder on board NASA's Mars Reconnaissance Orbiter, and increasing the spatial resolution both in the horizontal and in the vertical.

Acknowledgements

We acknowledge insightful discussions with several colleagues, including (in alphabetic order) L. Grey, J. Hollingsworth, M. McIntyre, E. Millour, S. Osprey, A. Spiga, Y. Takahashi, D. Waugh, J. Wilson.

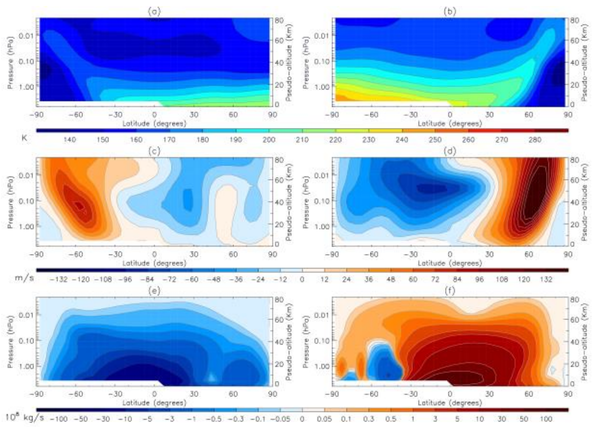

Figure 1: This picture shows climatological zonal means of temperature (panels a-b), zonal wind (c-d), and meridional mass stream function (e-f) for Mars' troposphere and lower mesosphere. Data are extracted from the MACDA reanalysis during the period 1999-2004 (Martian years 24-26). Left panels (a-c-e) are time averaged around northern summer solstice (solar longitude 85°-95°), right panels (b-d-f) are time averaged around northern winter solstice (solar longitude 265°-275°). The pseudo-altitude scale has been calculated using the formula $z_p = -H\cdot\log(p/p_{ref})$, where H=10 km (reference Martian scale height) and p_{ref} =6.1 hPa. Because of the elevated Martian topography in the southern hemisphere, the lowest pressure levels might be located below the surface. We do not plot zonal mean values at a particular latitude and pressure level when more than half of the longitude points have missing values.

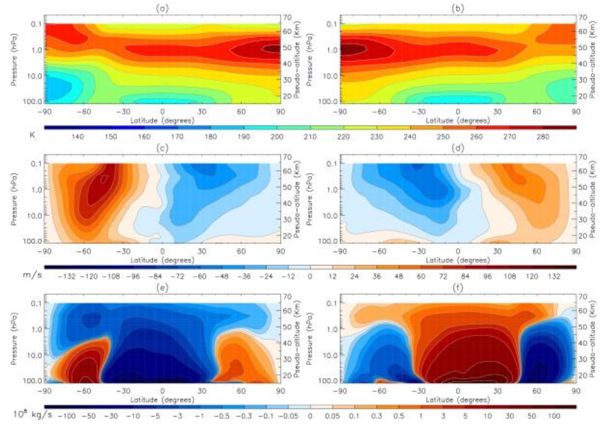

Figure 2: This picture shows climatological zonal means of temperature (panels a-b), zonal wind (c-d), and meridional mass stream function (e-f) for the Earth's stratosphere and lower mesosphere. Data are extracted from the MERRA reanalysis during the period 1979-2011. Left panels (a-c-e) are time averaged in June-July-August (JJA), right panels (b-d-f) are time averaged in December-January-February (DJF). The pseudo-altitude scale has been calculated using the formula $z_p = -H\cdot\log(p/p_{ref})$, where H=7 km (reference Earth scale height) and p_{ref}=1013 hPa.

References

[1] Lait, L.: An alternative form for the potential vorticity, J. of Atmos. Sci. 51 (12), 1754-1759, 1994.

[2] Mitchell, D., Charlton-Perez, A., and Gray, L.: Characterizing the variability and extremes of the stratospheric polar vortices using 2d moment analysis, J. of Atmos. Sci. 68, 1194-1213, 2011.

[3] Montabone, L., Lewis, S. R., Read, P. L.: Mars Analysis Correction Data Assimilation (MACDA): MGS/TES v1.0, NCAS British Atmospheric Data Centre, doi:10.5285/78114093-E2BD-4601-8AE5-3551E62AEF2B, 2011.

[4] Montabone, L., Thomson, S. I., Wilson, R. J., Forget, F., Lewis, S. R., Millour, E.: Using Reconstructed Dust Climatology to Study the Impacts of Martian Dust Storms on Dynamics, this issue.

[5] Montabone, L., Mendonca, J., Lebonnois, S., Wilson, C.: The Seasonality of the Atmospheric Polar Vortices on Venus compared to Earth, Mars, and Titan, this issue.