EPSC Abstracts
Vol. 11, EPSC2017-229-2, 2017
European Planetary Science Congress 2017


# A singular double baroclinic vortex on Mars

**A. Sánchez-Lavega** [agustin.sanchez@ehu.eus] (1), A. Garro (1), T. del Río-Gaztelurrutia (1), R. Hueso (1), I. Ordoñez-Etxeberria (1), H. Chen Chen (1), A. Cardesín-Moinelo (2), D. Titov (3), S. Wood (4), M. Dias Almeida (5)

(1) Dpto. Física Aplicada I, Escuela de Ingeniería de Bilbao, UPV/EHU, Bilbao, Spain, (2) European Space Agency, ESAC, Madrid, Spain, (3) European Space Agency, ESTEC, Noordwijk, Netherland, (4) European Space Agency, ESOC, Darmstadt, Germany, (5) Dias Almeida Data Processing and Systems, Ittigen, Switzerland

## Abstract

We report on a singular double vortex observed in Mars from June 6 to July 9, 2012 ($L_s$ ~ 125°) using images obtained by the Visual Monitoring Camera (VMC) and MARCI onboard Mars Express and Mars Reconnaissance Orbiter, respectively. The vortex pair was placed at latitude ~60°N and moved northeast with a velocity ~ 3 $ms^{-1}$. The sizes of both vortices were in the range 600-800 km, showing a well developed central region free of clouds with a radius ~ 250-350 km where the tangential velocity reached values in the range of 5-20 $ms^{-1}$. Their whitish color indicates that they are formed by water-ice with their cloud density decreasing with local time. Both vortices are cyclonic, in gradient wind balance, and we interpret them as a wavenumber 5 baroclinic wave, typically found during the Martian northern summer season.

## 1. Introduction

Spiral and annular synoptic weather systems have been reported in Mars images since the first convincing observations by Viking orbiter in 1979 [1]-[3]. They occur during the regression of the North Polar hood in the summer season (northern hemisphere) when the meridional temperature gradient becomes large at latitudes close to the ice cap deposits [4]-[5]. These vortices have been identified as transient extratropical baroclinic eddies formed by a mixture of dust and water-ice clouds [1]-[3]. A particular yearly recurrent "annular" cloud system was observed in 1999 using Hubble Space Telescope images and then in 2001 using MOC-Mars Global Surveyor images, exactly at the same aerographical location and epoch [2]. Here we report observations of a similar system in 2012, when it developed a singular double annular ring. We base our analysis on images obtained with the Visual Monitoring Camera (VMC) [6] and MARCI [7] instruments onboard Mars Express and Mars Reconnaissance Orbiter respectively (Figure 1).

## 2. Measurements

The VMC-MEx and MARCI-MRO images showing the double vortex were orthographic polar projected and navigated using the methods and techniques described in Sánchez-Lavega et al. [8]. They correspond to the period from June 6 to July 9, 2012 ($L_s$ =120.8°-136.6°, MY = 31).

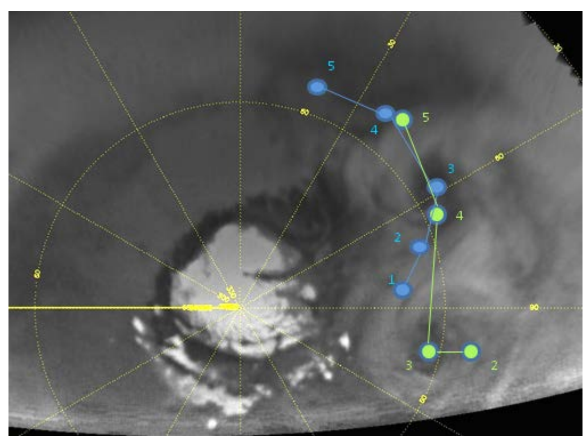

Figure 1: The double annular vortex is shown in a VMC-MEx image taken on June 18th, 2012. The track of the two storms is indicated by blue and green dots in June from 15th (position 1) to 23rd (position 5).

The size of the vortices, as traced by the clouds at their approximate circular outer edge, was in the range 600-800 km, with both vortices showing a well developed central region, free of clouds, that had a radius ~ 250-350 km. It is worth noticing that the cloud structure of the vortices changed with Martian Local Time, as had been observed previously for the single vortex case [2]. Cloud density was high and extended in area in early morning (~6 hr LT), then dissipated and broken in fragments during the afternoon (~16 hr LT). We have tracked the motion of the center of both annulus vortices (i.e. the center of the area devoid of clouds) and we find that the pair moves northeast with a speed of ~3 $ms^{-1}$. In addition, we have identified and measured the motions of individual clouds in image pairs on VMC and MARCI images, retrieving the wind vectors relative to the center of the vortices. We used visual cloud identification and tracking and a supervised brightness cross-correlation method [9] to measure the cloud displacements. The velocity vectors reveal the cyclonic rotation of both vortices with tangential velocities in the range 5 to 20 $ms^{-1}$ and peak vorticities of ~ $4x10^{-5}$ $s^{-1}$.

## 3. Interpretation

The VMC and MARCI color images show that both vortices are whitish and thus made mainly of water-ice condensate clouds instead of dust, that would show a yellowish color in these images [2], [8].

Adopting that distances between the cyclone vortices centers ~45° is half wavelength the resulting wavenumber is 4. If we assume that the vortices are in gradient wind balance [1], it follows that [10]

$$\frac{V^2}{r} + f\,V = \left|\frac{1}{\rho}\frac{\partial P}{\partial r}\right|$$

where $V$ is the tangential velocity (15 $ms^{-1}$), $r$ is the vortex radius (300 km), $f=2\Omega \sin\varphi = 1.2\times10^{-3}$ $s^{-1}$ is the Coriolis parameter ($\Omega = 7.08\times10^{-4}$ $s^{-1}$, Martian angular rotation) for latitude $\varphi$ (60°N), and $\rho$ is the mean density (0.018 $kgm^{-3}$). We derive a radial gradient pressure $\partial P/\partial r \sim 6\times10^{-4}$ mbar $km^{-1}$, which is about one-two orders of magnitude lower than the standards of Earth's extratropical cyclones [10].

## 4. Conclusions

We are exploring baroclinic models to explain the nature of this vortex pair and its evolution, the recurrent formation of vortices in the same region and compare their behavior with similar vortex pairs observed on Earth. The models under exploration are based on the available temperature data from different space missions and from predictions by a GCM [11].


## Acknowledgements

This work has been supported by the Spanish project AYA2015-65041-P (MINECO/FEDER, UE) and Grupos Gobierno Vasco IT-765-13. HCC and IO-E were supported in part by Aula EspaZio Gela under contract from Diputación Foral de Bizkaia. AG was supported by ESA Contract No. 4000118461/16/ES/JD, Scientific Support for Mars Express Visual Monitoring Camera.


## References


[1] Hunt, G. E., James, P. B.: Martian extratropical cyclones, Nature, 531-532, 1979.

[2] Cantor, B., Malin, M., Edgett, K. S.: Multiyear Mars Orbiter Camera (MOC) observations of repeated martian weather phenomena during the northern summer season. J. Geophys. Res. Planets 107, E35014, 2002.

[3] Wang, H., Ingersoll, A. P.: Martian clouds observed b Mars Global Surveyor Mars Orbiter Camera, J. Geophys. Res., 107, E10, 5078, 2002.

[4] Barnes, J. R.: Linear Baroclinic Instability in the Martian Atmosphere, J. Geophys. Res., 41, 1536-1550, 1984.

[5] Barnes, J. R. et al: Mars Atmospheric Dynamics as Simulated by the NASA Ames General Circulation Model 2. Transient Baroclinic Eddies, J. Geophys. Res., 98, 3125-3148, 1993.

[6] Ormston, et al: An ordinary camera in an extraordinary location: Outreach with the Mars Webcam, Acta Astronautica 69, 703-713, 2011.

[7] Bell, J. F., et al. Mars Reconnaissance Orbiter Mars Color Imager (MARCI) : Instrument description, calibration and performance, J. Geophys. Res. 114, E08S92, 2009.

[8] Sánchez-Lavega A., et al: Limb clouds and dust on Mars from images obtained by the Visual Monitoring Camera (VMC) onboard Mars Express, Icarus (submitted).

[9] Hueso, R. et al: The jovian anticyclone BA. II. Circulation and interaction with the zonal jets, Icarus, 203, 499-515, 2009.

[10] Sánchez-Lavega A., An Introduction to Planetary Atmospheres, Taylor-Francis, CRC Press Boca Raton, Florida, 2011.

[11] Forget, F., et al: Improved general circulation models of the Martian atmosphere from the surface to above 80 km, J. Geophys. Res., 104, 24155–24175, 1999.