A singular yearly persistent double vortex on Mars

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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]. Some of 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 detailed observations using the Visual Monitoring Camera VMC/MEx [6] of a similar system in 2012, when it developed a singular double annular ring (Figure 1). In addition we analyze images obtained in different Martian years using MARCI/MRO [7] and MOC/MGS [2].

Measurements: 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). 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 (Figure1). 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), and dissipated and broke 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 to measure the cloud displacements [9]. 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}.

Figure 1: The double annular vortex is shown in a VMC-MEx image taken on June 18th, 2012.

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

Adopting that the longitude distance 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]

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

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 φ (60°N), and ρ 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 standard values of Earth's extratropical cyclones [10].

Models: It is important to note that the formation of this double vortex recurrently at a well-defined latitude and longitude is related to the orographic control of the subpolar meridional circulation [4],[5]. Mesoscale numerical simulations that incorporate the water ice behaviour, have shown that an annular vortex similar to the one reported, forms in this region at the epoch of interest (L_s = 120°) [11].

Additionally, we are exploring a baroclinic model, under the slope-surface condition, 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 [12].

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