New Insights into the Hemispheric Vortex Structure and the Cloud Level Circulation of Venus observed by the Venus Monitoring Camera on Venus Express Orbiter.
S. S. Limaye[1], R.J. Krauss[1], Chris Rozoff[1] and W.J. Markiewicz, [1]Affiliation (Space Science and Engineering Center, University of Wisconsi, 1225 W. Dayton Stree, Madison, WI 53706, USA), [2]Max-Planck-Institut für Sonnensystemforschung, Max-Planck-Str 2, 37191 Katlenburg-Lindau, Germany.

Introduction: Since April 2006, the long term imaging coverage of Venus from the Venus Monitoring Camera (VMC) [1] on the Venus Express Orbiter [2] continues to provide new insights into the dynamics of the Venus atmosphere. The dynamical and morphological similarities between the two hemispheric vortices and terrestrial hurricanes or tropical cyclones have been reported previously [3,4]. The almost daily monitoring of the southern hemisphere of Venus from VMC through low resolution ultraviolet images (365 nm) indicate that the core region of the vortex has a variable rotation rate; spin-up and spin-down associated with the evolution of the dynamical instability features seen in the images.

While the hemispheric view VMC images are available only on the day-side, the entire vortex spannign the day and night side was imaged by VIRTIS, the Visible Infrared Thermal Imaging Spectrometer [5] also onboard the Venus Express Orbiter. Figure 1 compares the VIRTIS view with Hurricane Ileana (Day 235, 2006) in the Eastern Pacific.

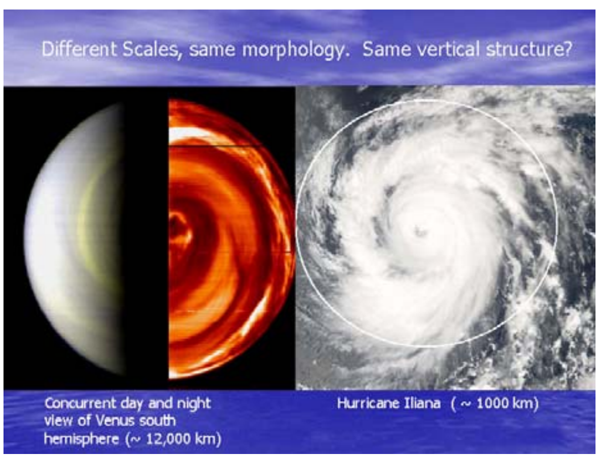

Figure 1. Venus hemispheric vortex observed by VIRTIS during the insertion orbit in 2006 (left) and tropical cyclone Ileana (right).

The nearly six years of monitoring of the southern hemisphere reveals that the vortex is not always symmetric about the rotation pole of Venus and often shows considerable asymmetry over the entire hemisphere. Similar asymmetry has been seen only in the inner core of the vortex in the VIRTIS data [6].

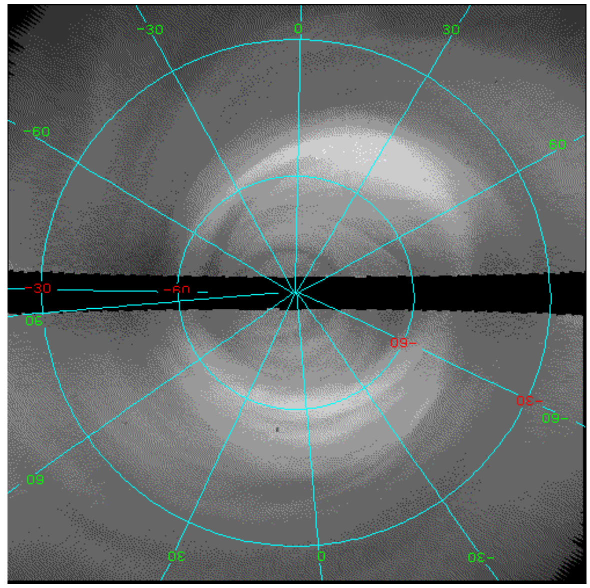
Figure 2. A composite view of the southern hemisphere of Venus from polar stereographic projections of brightness normalized VMC ultraviolet images two days apart.

From animations of polar composite views created from polar stereographic projections of images acquired over consecutive orbits (Figure 2) , we see outward propagating waves that we now interpret as vortex Rossby waves that are associated with the spiral bands in tropical cyclones. This analogy is crucial in understanding the recent measurements of cloud motions from low resolution VMC images which yield a day-side longitudinal average zonal flow at all measured latitudes to be considerably slower than the magnitude of the balanced flow calculated from the radio occultation thermal structure data [7,8]. It is known that the vortex Rossby waves move slower than the ambient wind in tropical cyclones, hence we believe that the low resolution images used for cloud tracking [9,10] from the Pioneer Venus Orbiter Cloud Photopolarimeter (OCPP) and VMC [11] yield the vortex Rossby wave speed, not the ambient flow. Thus, the short term variations in the measured cloud motions are associated with the vortex evolution morphology. It is also possible that the overall cloud top altitude for the measured motions may be undergoing small changes as the vortex evolves and thus the measured speeds may vary due to the vertical shear.

While cloud tracked winds measured near infrared images of Venus on day and night side which reveal the circulation at a lower level than the ultraviolet cloud tops are available [12, 13], not much is known about the vertical structure of the vortex circulation on Venus, but given that the morphological and dynamical similarities are found in the horizontal structure, we may hence also expect some vertical structure similarities between the two vortices. Thus, we should anticipate strong secondary circulation cells with updrafts and downdrafts in the core region about the rotation pole.

Observations and measurements to determine the vertical structure of the vortex circulation are needed to for a better understanding of the global circulation and its connection to the vortex dynamics. Crucial questions such as how deep is the circulation require precision measurements of the meridional flow at other (lower) levels.

References: [1] Markiewicz et al., 2007, PSS, 55, 1701-1711; [2] Svedhem et al., 2007, PSS, 55, 1636-1652; [3] Limaye et al., 2009, Geophys. Res. Lett., 36, L04204, doi:10.1029/2008GL036093. [4] Suomi, V.E. and S.S. Limaye, 1978, *Science*, 201, 1009, 1011 [5] Drossartet al., 2007, Planetary and Space Sci. 55, 1653-1672; [6] Luz et al., 2011, Science, Vol. 332 no. 6029 pp. 577-580; [7] Limaye et al., *Icarus*, 73, 193-211; [8] Piccialli et al., 2011, Icarus, 217, 669–681; [9] Limaye, 1985, Adv. Space Res., 5 51–62; [10] Rossow et al., 1990, J. Atmos. Sci., 47, 2053-2084; [11] Moissl et al., 2008, J. Geophys. Res., 114 p. JE00B31; [12] ; [13] Sanchez-Lavega *et al*.(*2008*). GRL,35, L13204.

Acknowledgments: This work was supported by NASA Grant NNX09AE85G (Limaye).