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Properties and circulation of Jupiter's circumpolar cyclones as measured by JunoCam

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Abstract

JunoCam has taken the first high-resolution visible images of Jupiter's poles, which show that each pole has a cluster of circumpolar cyclones (CPCs), each one separated in longitude by roughly equal spacing [1]. There are five at the south pole and eight at the north pole. These configurations, including their asymmetries and the characteristics of individual cyclones, have remained stable over 7 months from perijove 1 to perijove 5 as of this writing. Each cyclone has a circular outline with a prominent system of trailing spiral arms. In the north, the internal morphology of adjacent cyclones alternates from one to the next. Angular motions within each cyclone appear to be similar to each other but quite different from vortices at lower latitudes.

1. Introduction

Although nominally intended as a vehicle for Juno-mission outreach, the JunoCam instrument is Juno's visible-light camera, providing the first high-resolution (50-70 km/pixel) imaging of Jupiter's poles. These revealed a visibly darker background than banded structure at lower latitudes, with mostly brighter features that were dominated by cyclonic features that included chaotic "folded filamentary features" (FFRs) and more compact ovals. One of the surprises in these images was the appearance of clusters of circular spirals within 6° of both of Jupiter's poles, a morphology not seen elsewhere on the planet. These were labelled as circumpolar cyclones (CPCs). We report here a more detailed study of their properties over the orbits since their characterizaion in the first perijove (PJ1) by Orton et al. [1]. JunoCam observations are limited to the daylight portion of the polar hemisphere and so are complementary to JIRAM observations of 5-μm thermal emission from polar regions covering all longitudes but limited to fewer perijoves.

2. Data

JunoCam is rigidly mounted on the spinning spacecraft. That way, it can take a full panorama within about 30 seconds consisting of up to 82 narrow exposures. Usually, it takes partial panoramas of the target of interest. The camera has a horizontal field of view of about 58°, and Kodak KAI-2020 CCD sensor with four filter stripes, a red, a green, a blue and a narrow-band 890-nm infrared filter attached on the 1600x1200 light-sensitive pixels. For each of the four filters, there is an according readout region of 1600x128 pixels which can be transferred into the resulting raw image. This transfer isn't immediate, but the 12-bit data number of each pixel is encoded as an 8-bit value, and tiles of 16x16 pixels are compressed either lossy or lossless. Usually, the encoding of the 12-bit data as an 8-bit value is nonlinear according to a companding function. Motion blur is mostly avoided by a technique called time delay integration (TDI). In RGB mode, for each exposure, three of the four readout regions are added as stripes to the raw image. Further details about the instrument and its operation are available in Hansen et al. [2]

Observations were made in both north and south polar regions in perijoves PJ1, PJ3, PJ4, PJ5, and we anticipate more subsequent to this writing. Polar imaging in PJ5 was and PJ6 is scheduled over extended periods of time in order to cover more longitudes as the planet rotates through daylight, and to enable time-lapse measurments that include measurements of rotation of the CPCs.

3. Methods

With an approximate geometrical camera model, including its pointing for each exposure, the appropriate 3D vector was calculated for each pixel in a given reference frame, e.g. J2000. Position and pointing information are inferred from SPICE data, with some manual adjustment. Jupiter is modeled as a

MacLaurin spheroid on Jupiter's 1-bar level. A planetocentric coordinate system assigns a 3D position to each longitude/latitude pair. The 3D vector, pointing from Juno to the 3D position, completes the connection of each longitude / latitude pair to color information. With this method, each raw JunoCam image of Jupiter is reduced to an approximately geometrically calibrated polar map projection.

Because Jupiter is rotating and Juno is moving rapidly, the illumination for each JunoCam image changes rapidly. Comparison of images requires approximate normalization of the images. For now, this is achieved in a heuristic way, essentially stretching contrast over regions of approximately similar solar incidence angles, subtracting the mean brightness for these bins, and accounting for changing light scattering of a presumed haze layer as a function of emission angle, which can be obtained for sufficiently small crops by high-pass filtering. Further nonlinear brightness stretch and saturation enhancement brings out detail, and helps distinguish bluish haze from reddish cloud tops. Additional registering and stacking enhanced the signal-to-noise ratio. Similar processing of consecutive images allows for animations revealing motion, as well as for quantitative analysis of cloud velocities. Figure 1 shows an example from PJ4.

4. Results

We confirm the results of the initial JunoCam report [1] that the CPCs are clustered around each pole with approximately equal spacing in longitude. At the south pole, a cluster of five CPCs has an additional cyclone at the center, but it is slightly offset from the position of the pole. The center of the north polar cluster of eight CPCs is not seen, as it is in darkness at this time. The configuration of the CPCs in both poles appears to be stable over the perijoves (PJs) observed as of this writing (PJ1, PJ3, PJ4, PJ5), spanning 27 August 2016 through 27 March 2017. The cyclones are all roughly circular with prominent trailing spiral arms whose cyclonic appearance is verified by time-lapse imaging. They very much resemble terrestrial hurricanes but are larger, with diameters of ~5800-8000 km. The northern cyclones have alternating properties from one to the next, as suggested by PJ1 observations. Angular rotation rates and wind speeds within the cyclones have been measured over intervals of 15-72 minutes as a function of radius; they appear quantitatively similar to each other, but remarkably different from vortices at lower latitudes.

As of this writing, we continue to work on the quantitative details and interpretation of these intriguing and unexpected features that will be discussed in detail in our presentation.

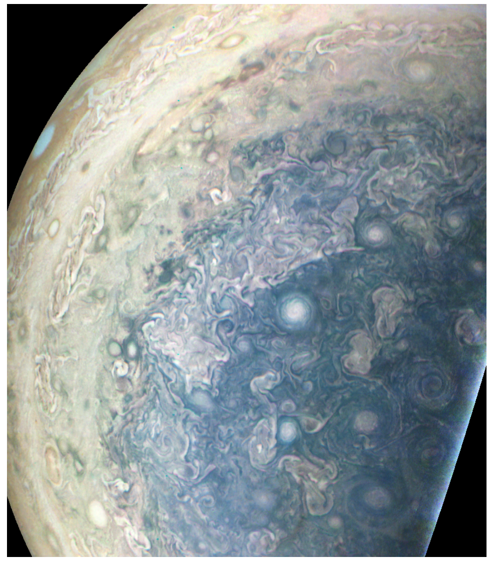

Figure 1. Map-projected color image of Jupiter centered over the south pole from PJ4 with first-order corrections for solar illumination angle variations and processing to enhance details. CPCs surround the pole in the lower right.

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References

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