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Dynamics of Jupiter's South Polar Region on the Basis of JunoCam Images

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Abstract

For each perijove from PJ1 to PJ19 thus far, except for PJ2, JunoCam took images of the south polar region. The image sequences of each of those PJs is sufficiently well resolved to allow for a quantitative short-term analysis of the cloud velocity field. Short-term observations of each PJ can be compiled into long-term observations of the morphology of the south polar region, as well as of the corresponding cloud velocity field. Short-term, as well as long-term changes can be visualized by animations in an intuitive way.

The availability of a sequence of quantitative velocity field data, together with a stable cluster of southern circumpolar polar cyclones is raising the question, whether the chaotic dynamics between consecutive PJs, time-spaced by 53 days, can be interpolated by an appropriate fluid dynamical model on the basis of JunoCam images.

1. Introduction

On 2016-08-27, during the Perijove 1 Jupiter flyby of NASA's Juno spacecraft, Juno's visible light camera JunoCam [1] took images of Jupiter's south polar region. Those images have been resolved well enough to show Jupiter's south polar circumpolar cyclones (CPCs). Moreover, those images resolved the short-term motion of the cloud structure of these cyclones for the very first time.

Except for Perijove 2, each perijove (PJ) pass until PJ19 on 2019-04-06 thus far, JunoCam returned a sequence of images of the south polar region. From each of these sequences, short-term cloud motion can be resolved in the south polar region.

A sequence of maps, one for each perijove, can be assembled into a time-lapsed animation, with one still frame each about 53 days. This sequence is showing a surprisingly stable cluster of southern CPCs, and fast, apparently chaotic motion elsewhere. The southern CPC cluster shows a slow systematic long-term rotation, with some mid-term wobbling of individual CPCs, and of the whole cluster [2].

2. Quantitative Measurements of the Cloud Velocity Fields

2.1. Preparing the Maps

For each perijove, each of the considered images is transformed into a south polar, azimuthal planetocentrically equidistant map. The maps are first illumination-adjusted, and then high-pass filtered in a context-sensitive way, which tries to adjust for local contrast by dividing away the standard deviation of some appropriate environment. The resulting maps are mostly cleaned from observation-specific colorization, and the structure of the clouds is easier to compare by algorithmic methods. (See Figure 1, left).

2.2. Correlating the Maps

Image correlation is restricted to common footprints defined by the camera's field of view, suitable emission and incidence angle. Maps are registered either manaully, or else by a first correlation run, and subsequent 2-dimensional linear regression.

Image correlation itself is perfomed by a hybrid Monte-Carlo / hill-climbing method on circular Gauss-weighted tiles of reducing sizes. Local velocities and angular velocities are approximated iteratively. Cloud features are assumed to move approximately linearly within the image sequence considered for one PJ pass.

Analysing a set of images at a time, instead of just a pair, reduces noise and improves resolution.

Two kinds of velocity fields are considered: One version is essentially free of restrictions. The other approach builds up a vector potential, essentially restricting the velocity field to a 2-dimensional steady flow. The first approach is able to reveal convective features. The latter approach is particularly useful for constraining noisy data to consistent divergence-free results. Steady streamfunctions are a good basis for long-term stable continuous distortions (morphs) of maps. However, they are too restricted to model changes of the velocity field, e.g. the motion of vortices themselves.

2.3. Cross-Checking by Animations

Similarities and discrepancies of animations compiled from actual JunoCam images compared to animations derived from the inferred velocity field reveal the accuracy of the inferred velocity data.

3. Abstraction and Database-Management Systems

Steady streamfunctions can be abstracted down to their topology of minima, maxima, saddle points, and paths of steepest descent and ascent from saddle points to extrema (see Figure 1, right). The resulting graphs connect continuous fluid dynamics with discrete mathematics and database-management systems. Nodes and edges of the resulting discrete structures can be enriched by physical properties attributed to these entities. The transition of streamfunctions between PJs can be modeled by structure-preserving maps (morphisms) between enriched graphs. A similar structure can describe uncertainties, including uncertainties of the discrete abstraction.

4. Extrapolation, Interpolation, Fluid Dynamics

Steady streamfunctions are very suitable for extrapolating the morphology to the past or to the future. A simple Euler method corrected by an adjustment to contour lines of the streamfunction works very well to visualize the according motion. However, a 53-days extrapolation shows that two PJs cannot be interpolated that easily. That's also obvious by comparing the inferred streamfunctions of two consecutive PJs.

In principle, an unsteady streamfunction could tranform from PJ to PJ. But besides near the centers of the CPCs, a canonical interpolation of the respective steady streamfunctions is not obvious due to the chaotic features in the polar region.

Applying computational fluid dynamics (CFD) is more promising. So, the inferred cloud velocity field of a PJ can be considered for an initial value of an initial-value problem described by a system of partial differential equations. The Euler equation for 2-dimensional incompressible fluids is a possible starting point for according numerical experiments. More general is the family of Navier-Stokes momentum equations. Intersecting ensembles of initial and terminal-value problems of consecutive PJs may be able to find an interpolation between PJs.

Abstractions to discrete structures help to reduce to a finite number of cases.

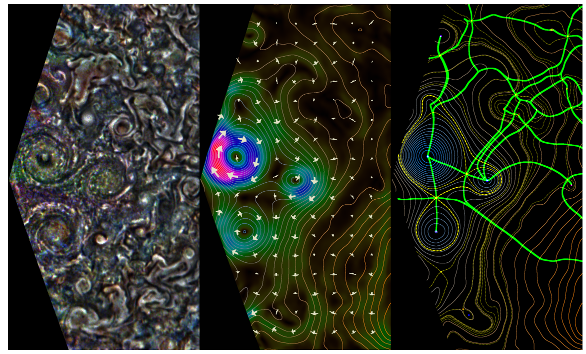

Figure 1: PJ19, cropped version of south polar region 75° to 90° south: high-passed map (left), contour lines of streamfunction with velocity map (center), towards abstraction to graph of extrema and steepest paths (right).

5. Summary and Conclusions

JunoCam images taken over the south polar region allow for short and long-term animations of the morphology itself, as well as for derived cloud velocity fields. JunoCam data provide constraints on the meteorology of Jupiter's south polar region. Associated questions about data abstraction and long-term weather interpolation by means of fluid dynamics and related fields like topology, discrete mathematics, and database theory are discussed.

Acknowledgements

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References

[1] C.J. Hansen, M.A. Caplinger, A. Ingersoll, M.A. Ravine, E. Jensen, S. Bolton, G. Orton. *Junocam: Juno's Outreach Camera.* Space Sci Rev 2013:475-506, 2017

[2] F. Tabataba-Vakili, J.H. Rogers, G. Eichstädt, G.S. Orton, C.J. Hansen, et al. *Long-term Tracking of Circumpolar Cyclones on Jupiter From Polar Observations with JunoCam.* (Submitted, 2019)