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Fluid Dynamical 2D Simulations of Jupiter's South Polar Region Based On JunoCam Image Data

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During almost every perijove pass in more than three years of Juno's ~53-day polar orbits around Jupiter, its wide-angle visible-light camera, JunoCam [1], has imaged Jupiter's south polar region [2].

We sought to determine whether these images could be used for prognostic “weather forecasts” in Jupiter. One of the simplest fluid dynamical models suitable for forecasting dynamical behavior of essentially barotropic incompressible flows of very low viscosity is the 2D Euler fluid. Vortex methods [3] are particularly suitable for modeling the resulting turbulence.

Sequences of images taken with a cadence of several minutes reveal small motions of the cloud tops within the illuminated area of the pole. The south pole itself has been visible in the twilight.

Raw JunoCam image data are transformed into an equidistant south-polar azimuthal map, roughly illumination-adjusted, high-passed with local contrast-normalization, and registered.

A streamfunction describing the velocity field approximately is derived from a sequence of consecutive maps of a common perijove flyby. Running a Monte-Carlo approach for stereo correlation repeatedly with different pseudo-random number sets returns an ensemble of streamfunctions.

The Laplacian of a streamfunction returns the vorticity values for a randomized 2D vortex particle seed as initial conditions of a grid-free vortex method. Applying the Biot-Savart law [3, p.19ff] on a 2-spherical geometry to the vorticity field returns the velocity field. A single-step explicit Runge-Kutta method of order 4 or 5 and fixed time steps advects the 4th-degree Gaussmollified vortex particles. Measuring the area of their Voronoi cells (Dirichlet/Thiessen polygons) reassesses the radius of the vortex particles. The method allows for some divergence. An approximately inviscid and incompressible 2D-flow is simulated over 2 up to 54 real-time days or about one Juno orbital period. The randomized nature of the method induces simulation ensembles for a given streamfunction by repeated runs.

Reducing the streamfunction to a Morse-Smale complex returns idealized model vortex seeds.

JunoCam images of the south polar region taken during a perijove pass provide an ensemble of

dynamical data. These initial conditions extend to ensembles of forecast runs of the 2-spherical dynamics of the visible cloud tops in Jupiter's south polar region. We find that JunoCam images of Jupiter's south polar region allow for reasonably plausible forecasts of the dynamics of the observed area with grid-free 2D vortex methods over at least a few days.

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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*. Icarus 335, 113405, 2020.

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