



Polar vortex crystals on Jupiter: Simulating Jupiter's atmosphere using a Quasi-Geostrophic model

Ting-Juan Liao and Andrew Ingersoll

Caltech, Division of Geological and Planetary Sciences, United States of America (tingjuanliao@caltech.edu)

Juno spacecraft observed persistent polygonal patterns of large cyclones at both the north and south poles ^[1]. These patterns have been studied by plasma physics, but they are the first of their kind on a planet. Siegelman used a one-layer quasi-geostrophic (QG) model with initial turbulence to study the formation of vortex crystals ^[2]. Li used a one-layer shallow water (SW) model with initial large-scale vortices to demonstrate the importance of vortex shielding ^[3]. Chen et al. used the SW equations starting with initial turbulence to study the vertical structure of the layer. ^[4] However, these simulations all began with an initial disturbance and did not include continuous forcing balanced by dissipation, which is closer to the real situation on Jupiter. We intend to use a QG model at the pole of a rotating planet to study the evolution of vortices under the influence of forcing and dissipation. An important parameter of the models is the radius of deformation R_d , where g is the gravitational acceleration, h is the thickness of the weather layer, ρ is the fractional density difference between the weather layer and the deep abyssal layer below, and Ω is the planetary rotation. To get vortex crystals, the models starting with initial turbulence require large values of R_d , implying stable stratification and a thick weather layer penetrating down into the abyssal layer. Whether this requirement applies when the flow is continuously forced and balanced by dissipation is an important result of this study.

[1] Adriani, A., A. Mura, G. Orton, et al., Clusters of cyclones encircling Jupiter's poles. *Nature* 555, 216–219. <https://doi.org/10.1038/nature25491> (2018).

[2] Siegelman, L., W.R. Young, A.P. Ingersoll, Polar vortex crystals: Emergence and structure, *Proc. Natl. Acad. Sci. U.S.A.* 119 (17) e2120486119, <https://doi.org/10.1073/pnas.2120486119>(2022).

[3] Li, C., A.P. Ingersoll, A.P. Klipfel, H. Brettle, Modeling the stability of polygonal patterns of vortices at the poles of Jupiter as revealed by the Juno spacecraft, *Proc. Natl. Acad. Sci. U.S.A.* 117 (39) 24082-24087, <https://doi.org/10.1073/pnas.2008440117>(2020).

[4] Chen, S., A. P. Ingersoll, and C. Li, Vortex crystals at Jupiter's poles: Emergence controlled by initial small-scale turbulence. *Icarus* 429 (2025): 116438.