

The background of the slide is a photograph of the Juno spacecraft in orbit around Jupiter. The planet's characteristic bands and storms are visible in shades of brown, white, and blue. The spacecraft, with its large solar panels and antenna, is positioned in the foreground, partially obscuring the planet.

Convectively Generated Zonal Jets by Thunderstorms on Jupiter (and Other Gods)

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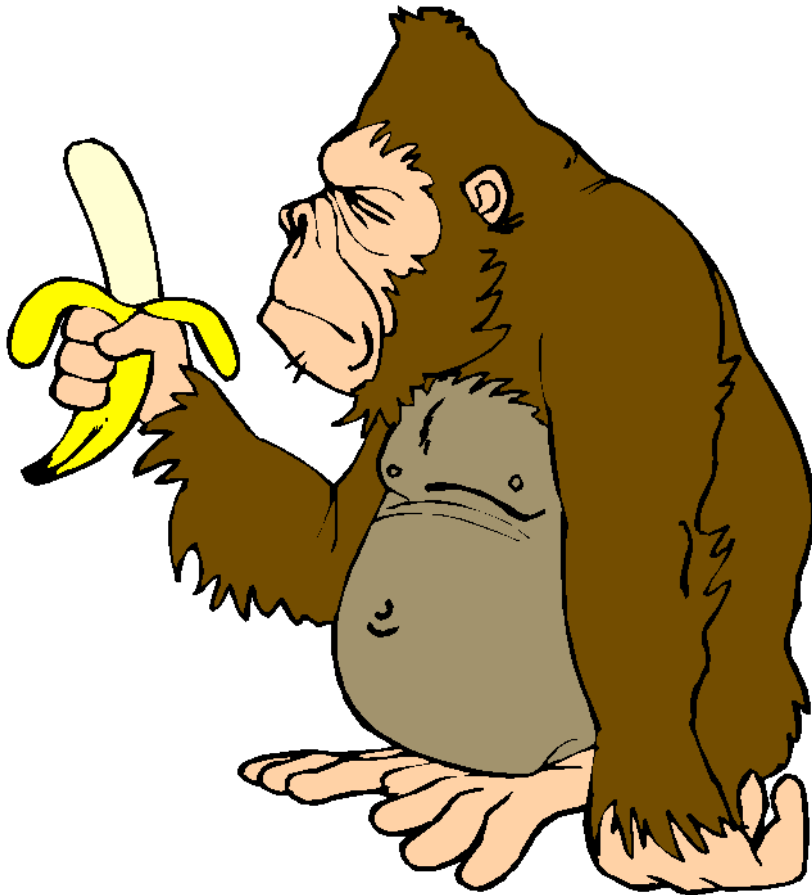
¹ Caltech, ² U Arizona

ISIMA 2011

14 Hours Before the JUNO Launch

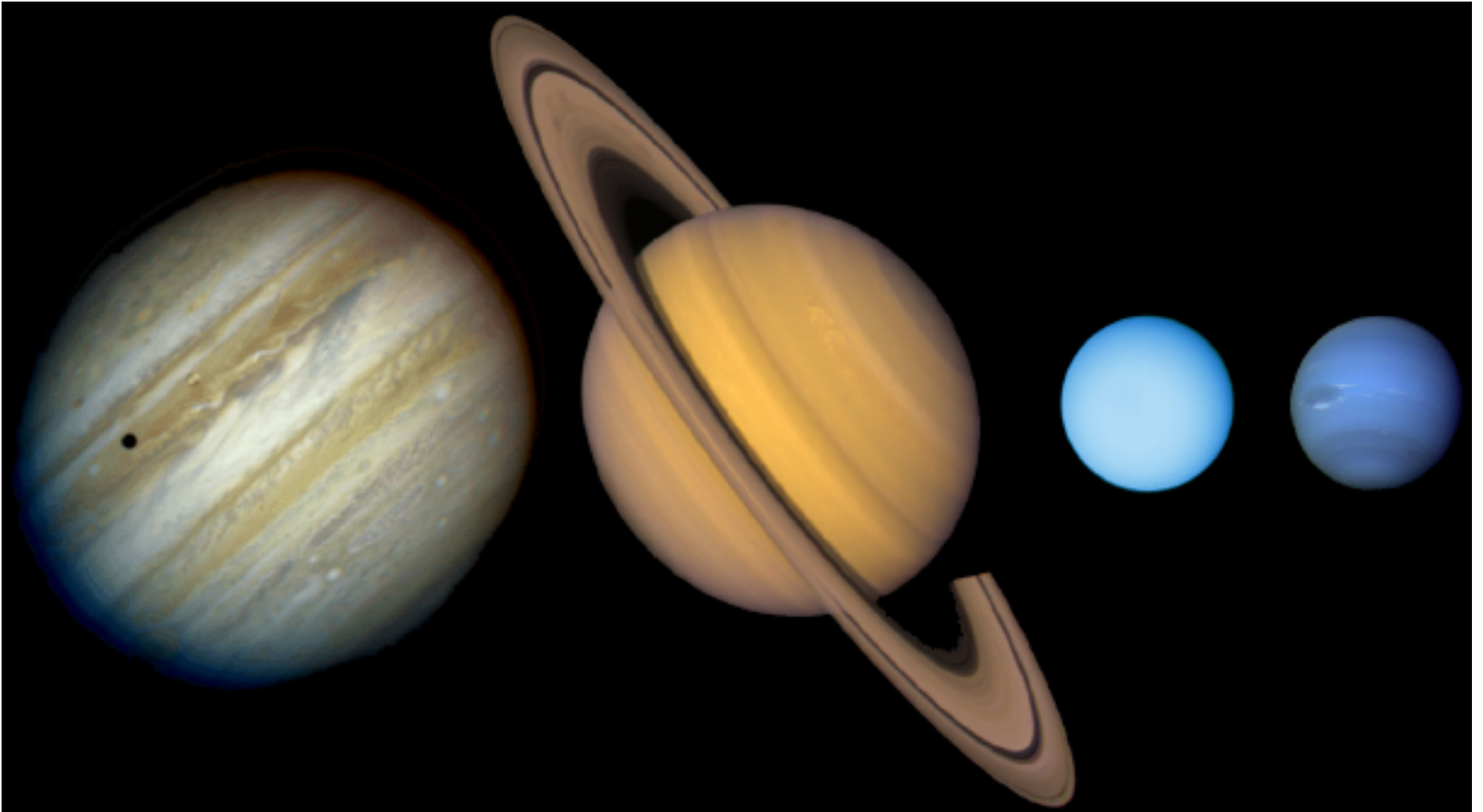
Keywords: Zonal Jets, Thunderstorms, Shallow-water Model, and ... Banana

Why do we care?

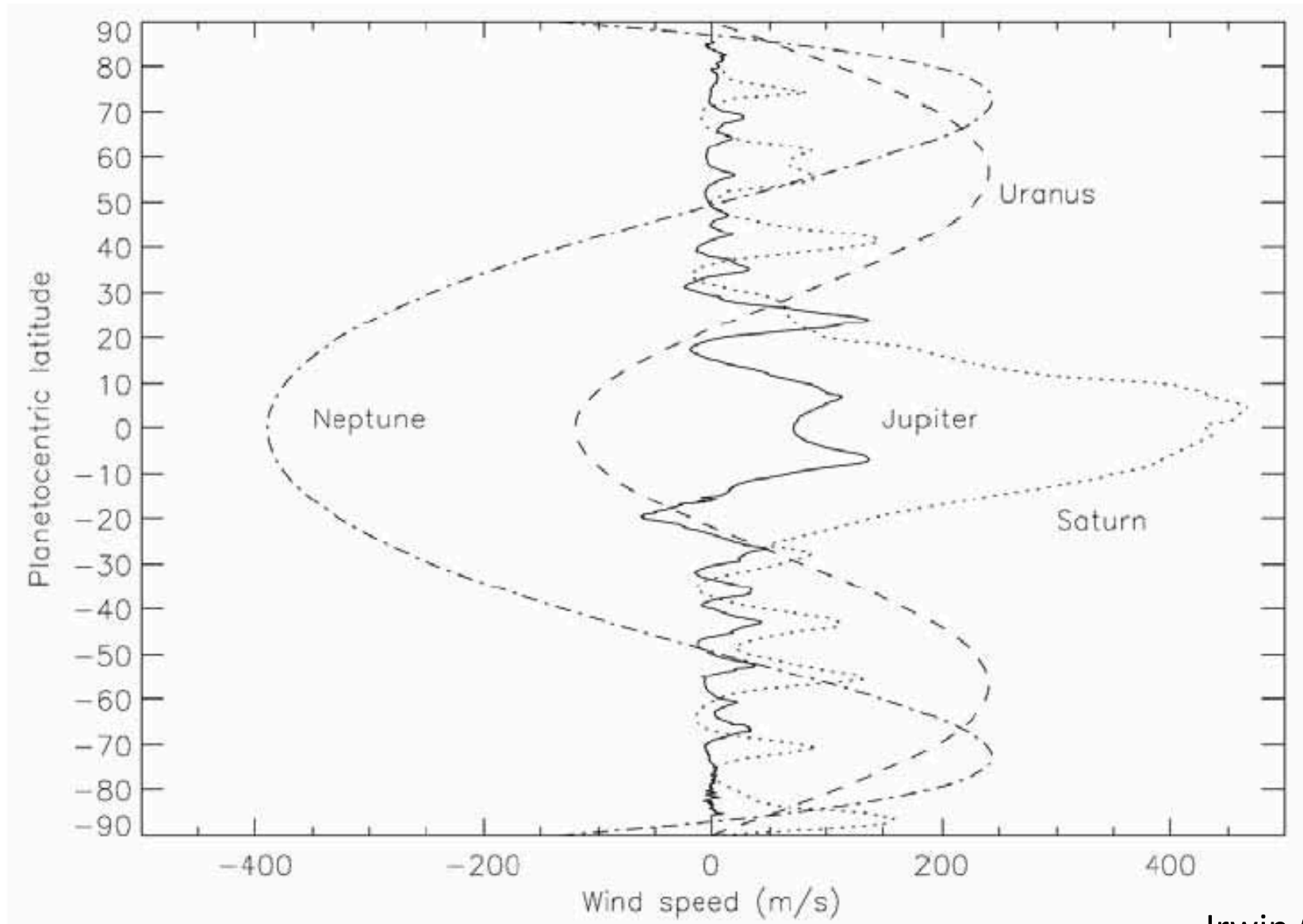


Vasavada & Showman (2005)

And more...

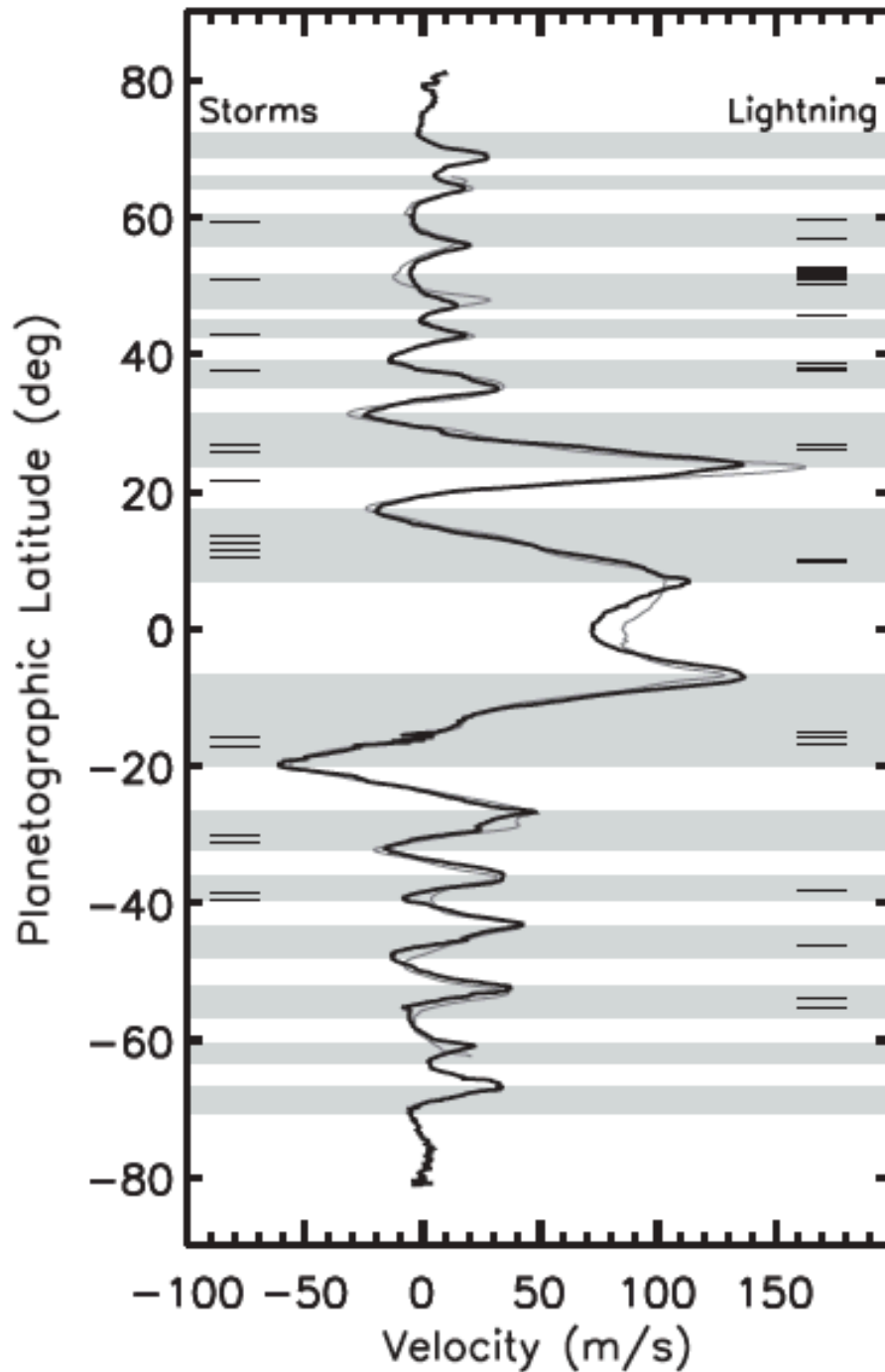


Zonal Wind



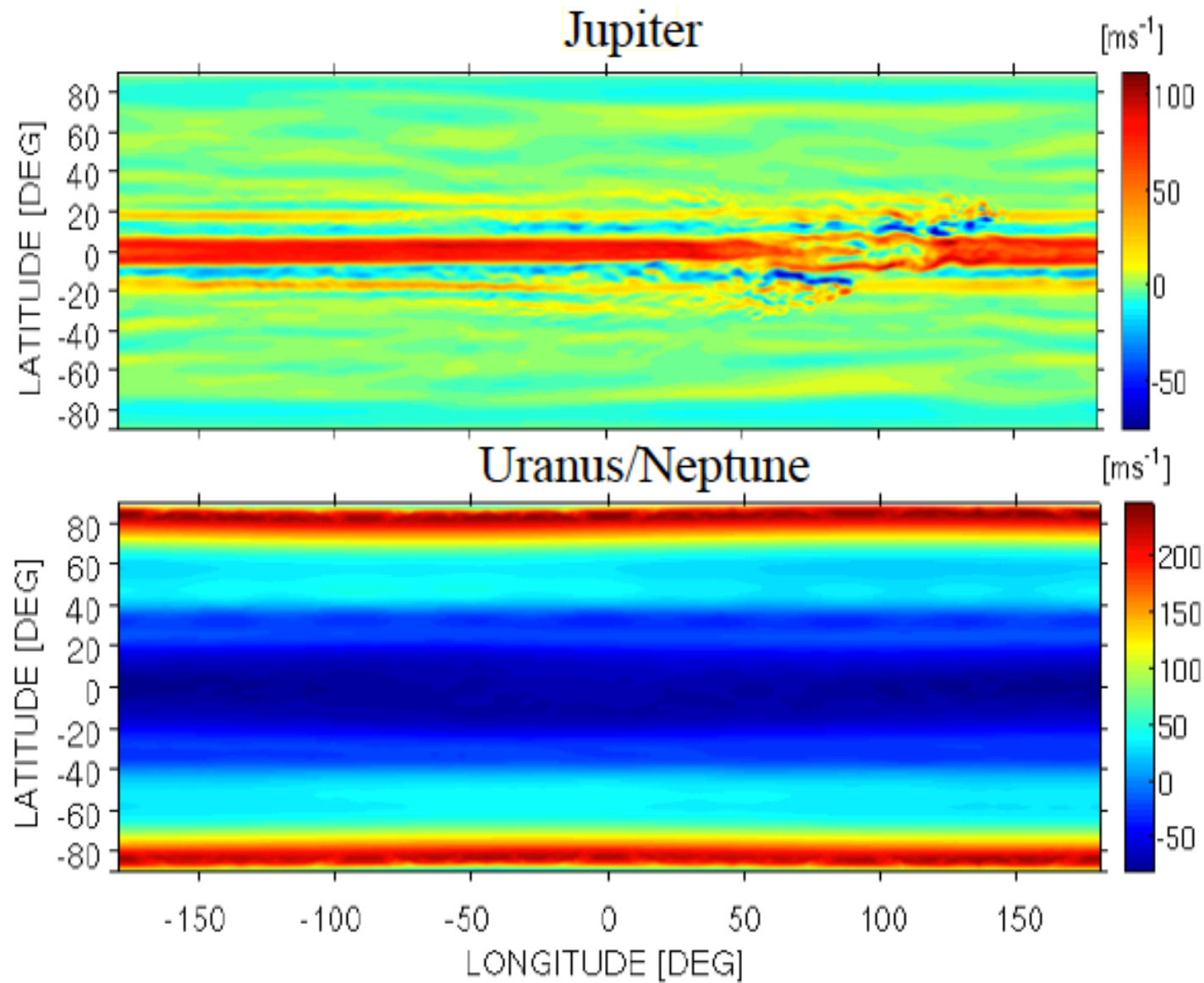
Irwin (2009)

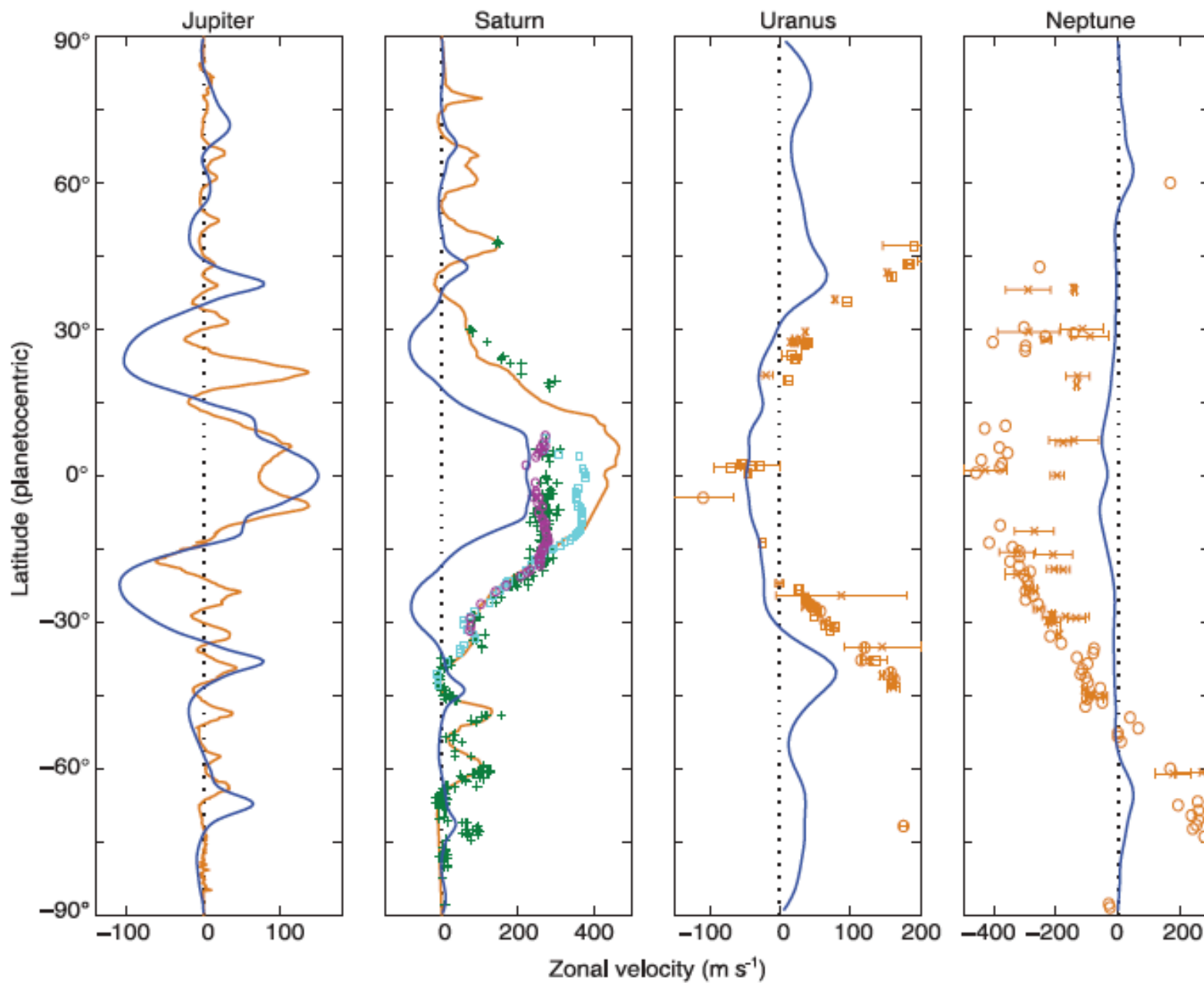
Jupiter Jets



Vasavada & Showman (2005)

GCM Simulations





Liu & Schneider (2010)

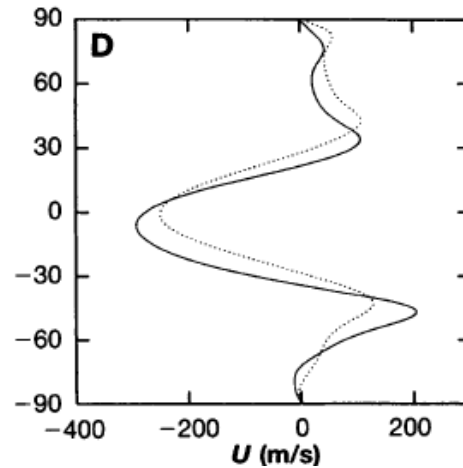
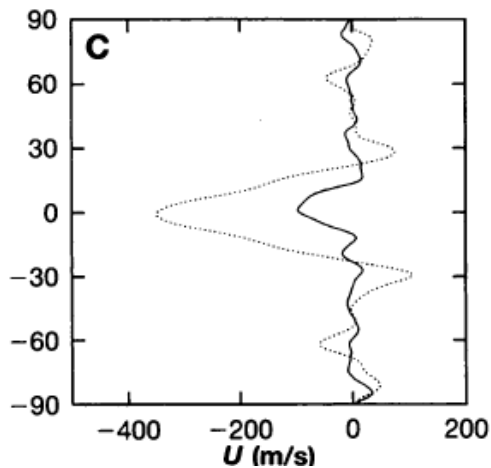
Shallow-Water System?

Momentum:

$$\frac{Du}{Dt} + f \times u = -g\nabla\eta$$

Continuity:

$$\frac{\partial h}{\partial t} + \nabla \cdot (hu) = 0$$



Free Decaying Shallow
Water System
(Cho & Polvani, 1996)

Forced-Dissipative System?

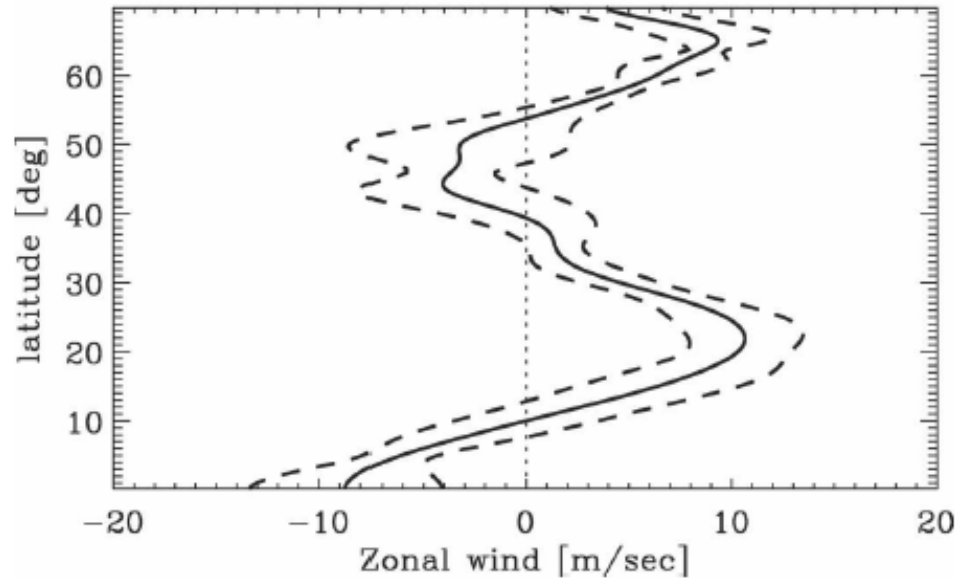
The Vorticity Form:

$$\frac{\partial \zeta}{\partial t} + \nabla \cdot (u \zeta_a) = -\zeta / \tau_{drag} + \text{bananas}$$

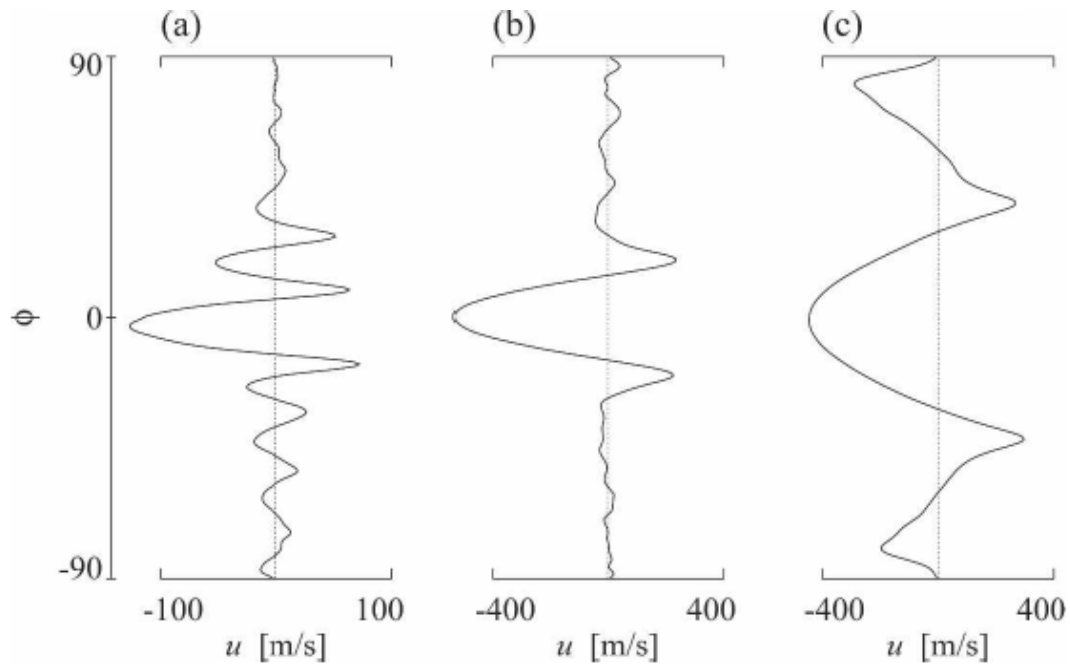
$$\frac{\partial \delta}{\partial t} - k \cdot \nabla \times (u \zeta_a) = -\nabla^2 (E + gh) - \delta / \tau_{drag}$$

$$\frac{\partial h}{\partial t} + \nabla \cdot (uh) = -h' / \tau_{rad} + \text{bananas}$$

Most cases failed...

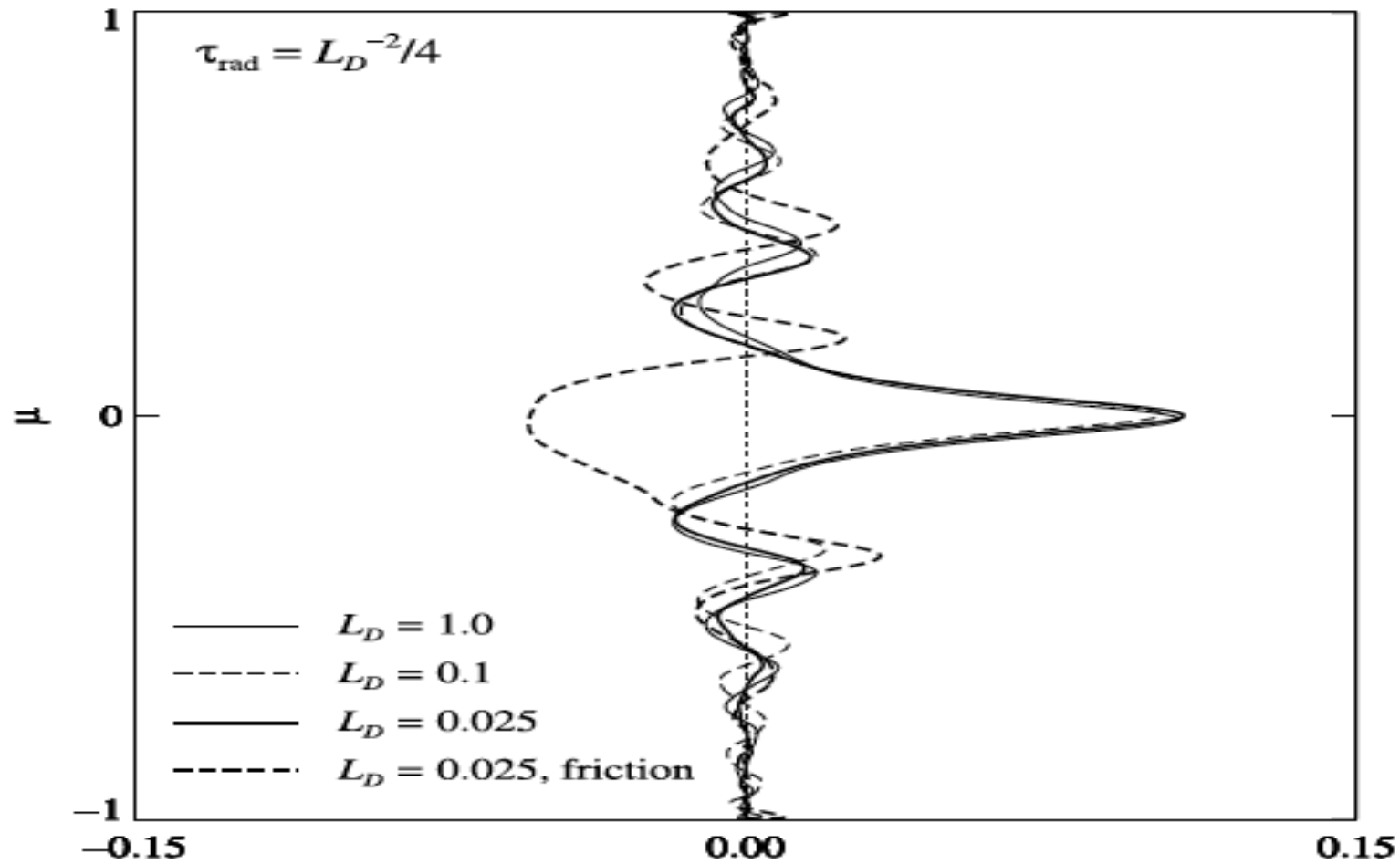


Showman (2007)



Scott & Polvani (2007)

Except...



Deformation Radius: $L_D = \sqrt{gH}/2\Omega$ Vorticity Forcing (Scott & Polvani, 2008)

Our Model

- STSWM (Hack & Jakob, 1992), no friction
- Resolution: T170 (512×256)
- Forced by Random Thunderstorms

$$s_{\text{storm}} = s_{\text{max}} \exp \left[-\frac{r^2}{r_{\text{storm}}^2} - \frac{(t - t_0)^2}{\tau_{\text{storm}}^2} \right]$$

$$S_{\text{max},h} = 0.05 - 1 \text{ m}^2 \text{ s}^{-3}$$

$$\tau_{\text{rad}} = 100 \text{ day}$$

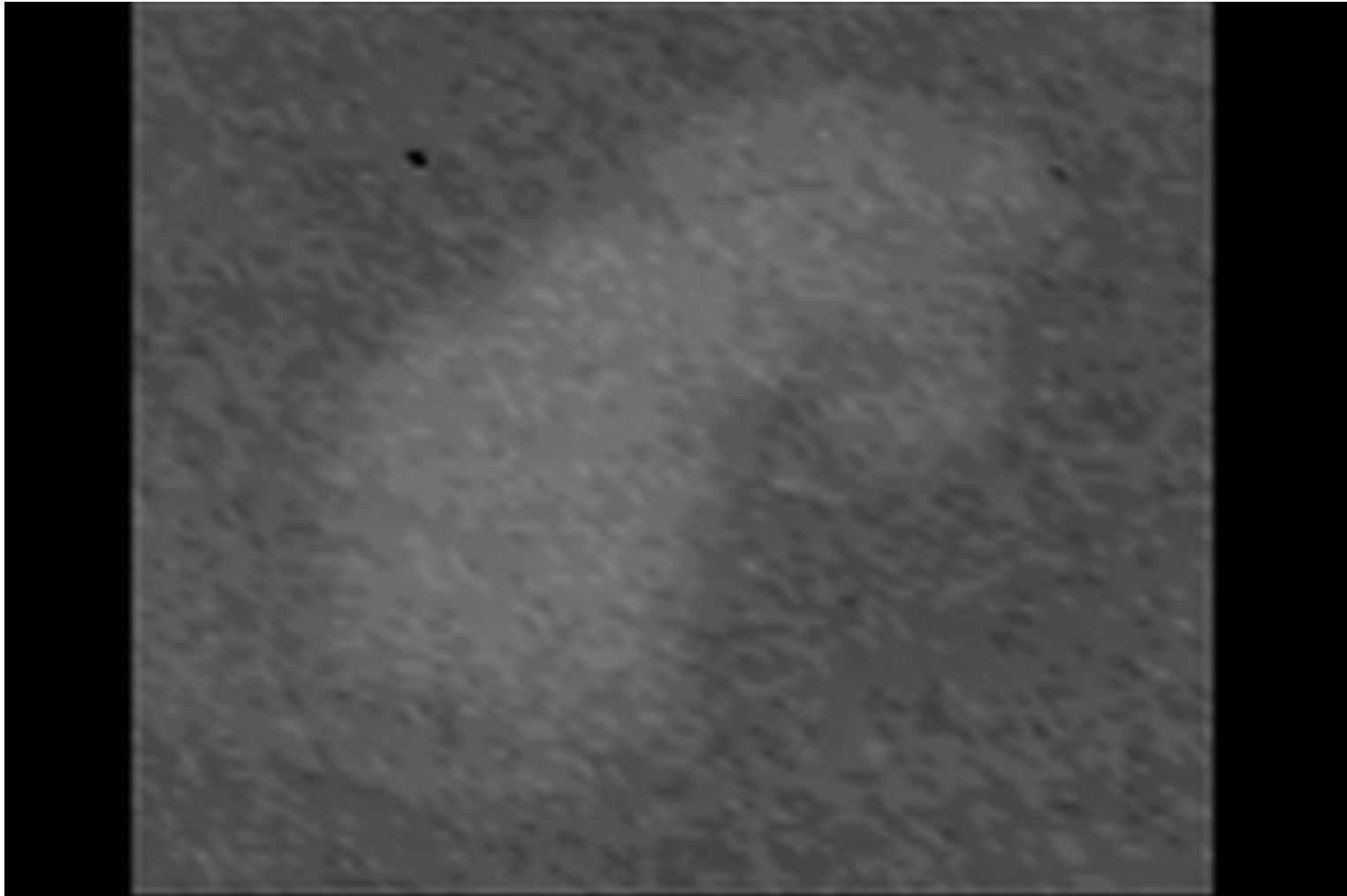
$$r_{\text{storm}} = 2^\circ - 4^\circ$$

$$\tau_{\text{int}} = 10^4 - 10^5 \text{ s}$$

$$S_{\text{max},\zeta} = (0.5 - 1) \times 10^{-9} \text{ s}^{-2}$$

$$\tau_{\text{storm}} = 10^5 \text{ s}$$

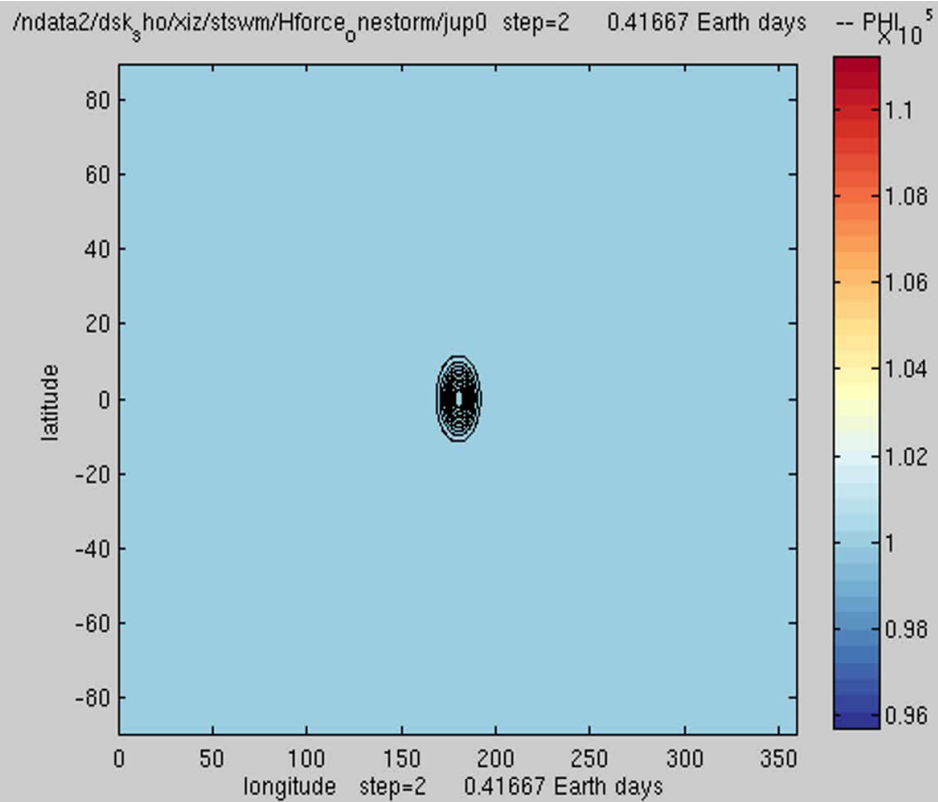
Lightning on Saturn



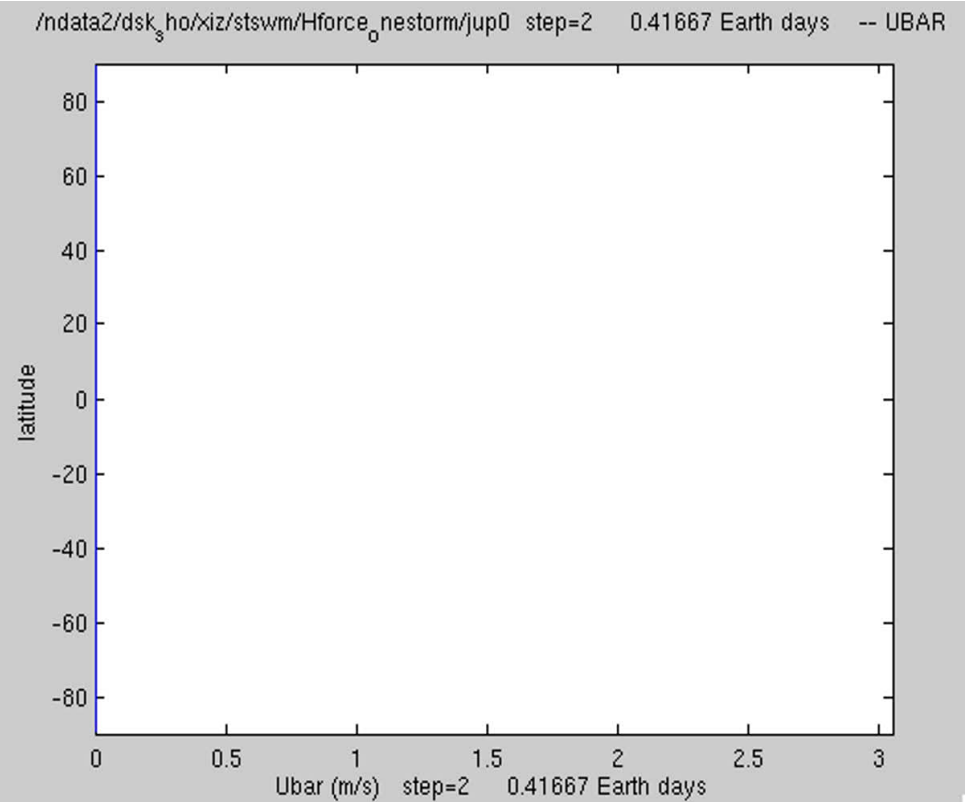
Credit: NASA/JPL/SSI/University of Iowa

H forcing on Equator

gh



\bar{U}

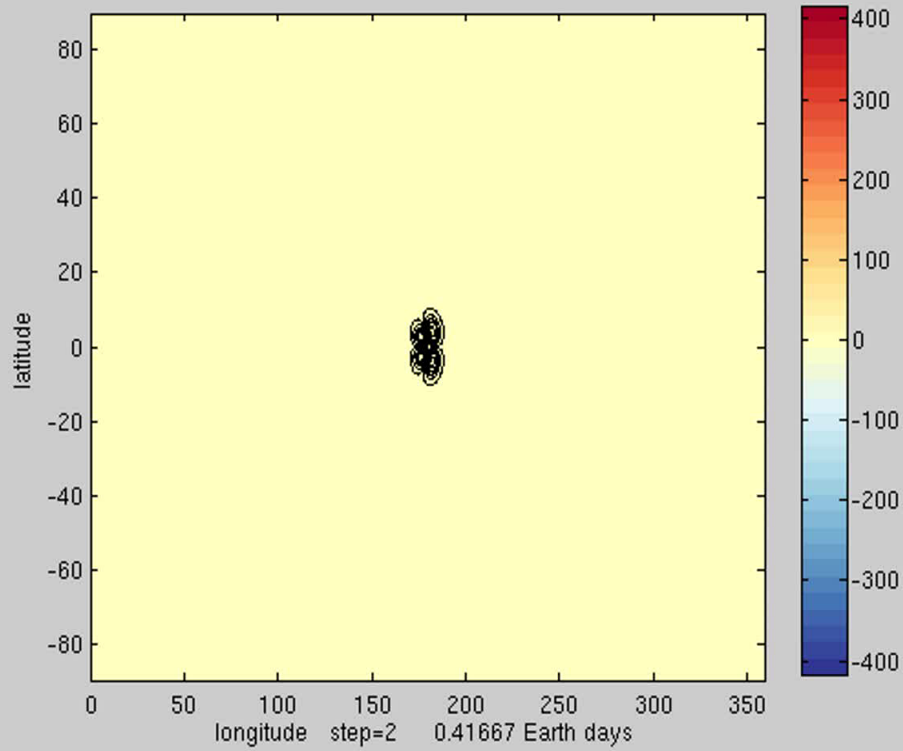


Eddy Momentum

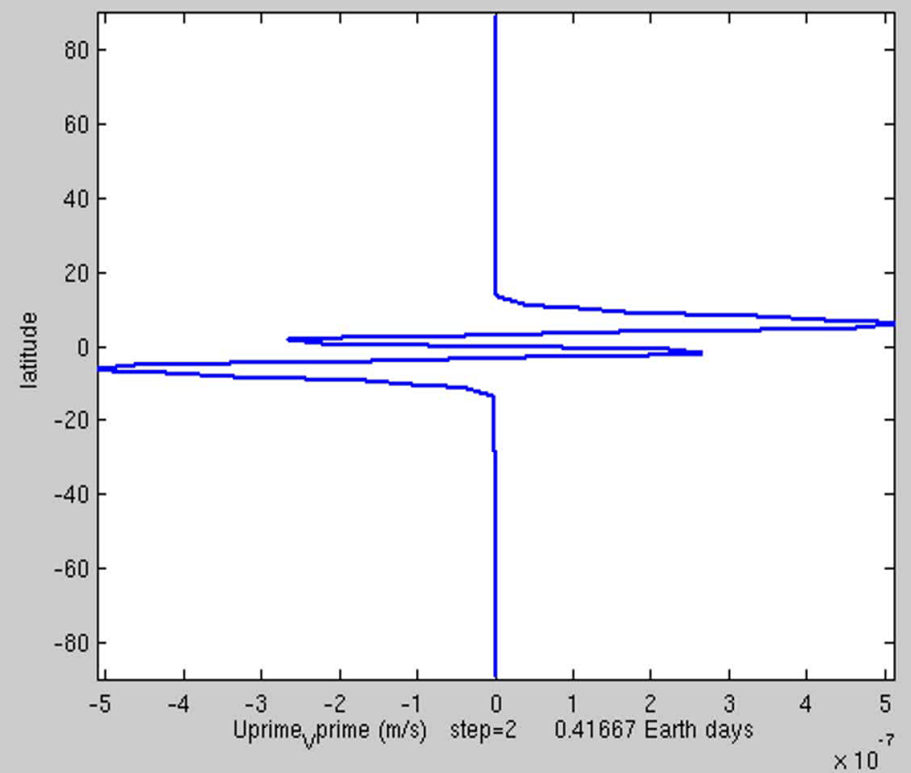
$$U'V'$$

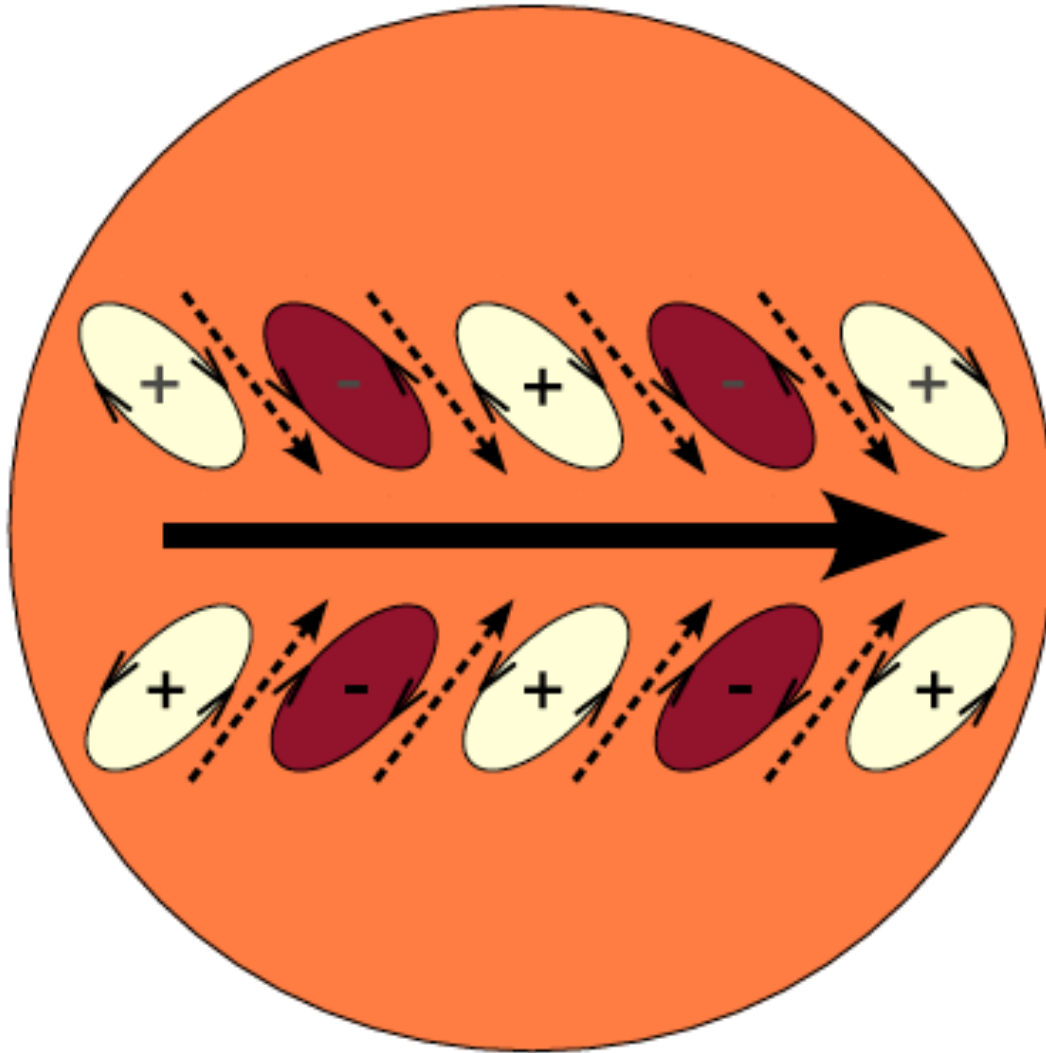
$$\overline{U'V'}$$

data2/dsk_ho/xiz/stswm/Hforce_nestorm/jup0 step=2 0.41667 Earth days -- uprime_v_prime



/ndata2/dsk_ho/xiz/stswm/Hforce_nestorm/jup0 step=2 0.41667 Earth days -- UVBAR



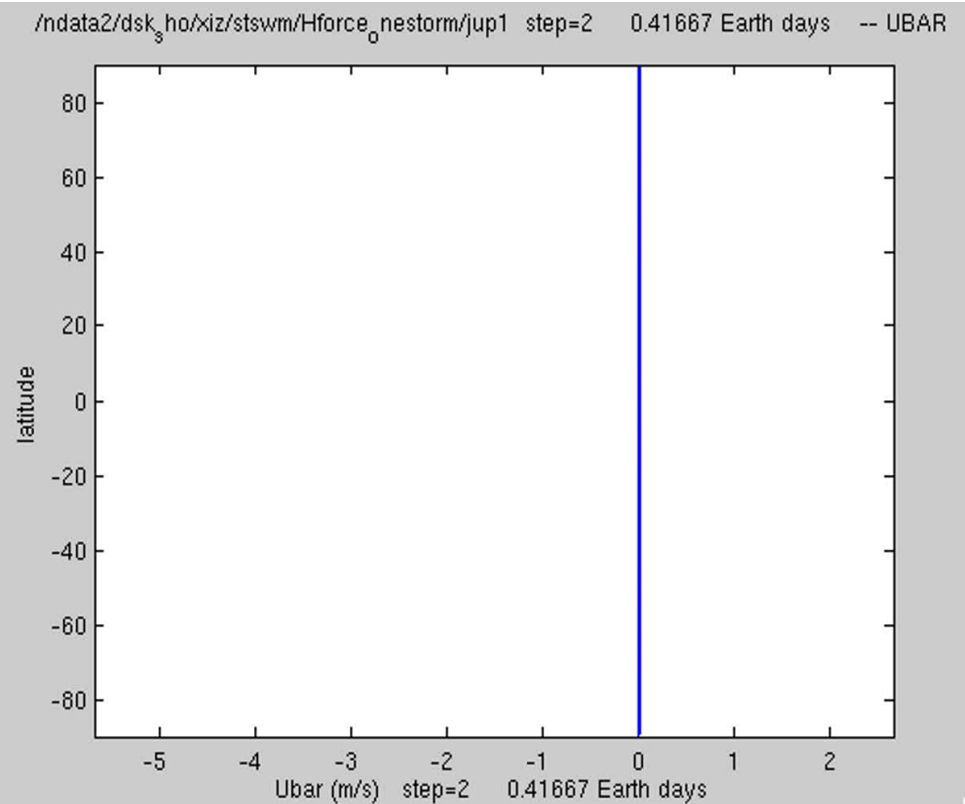
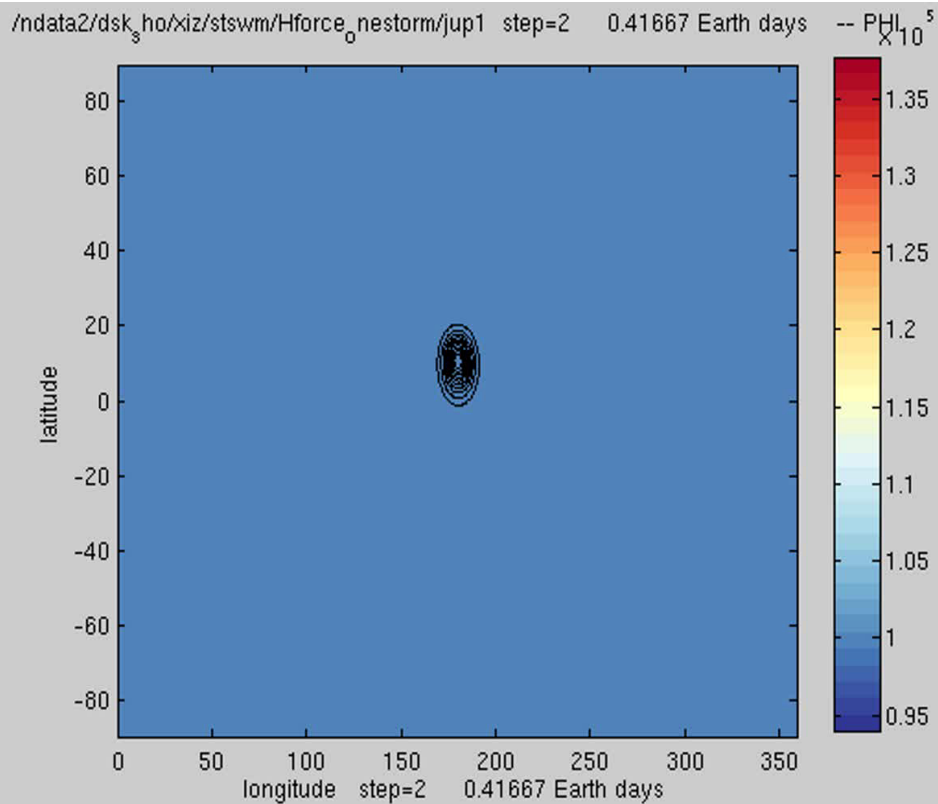


Showman & Polvani (2011)

H forcing on 10N

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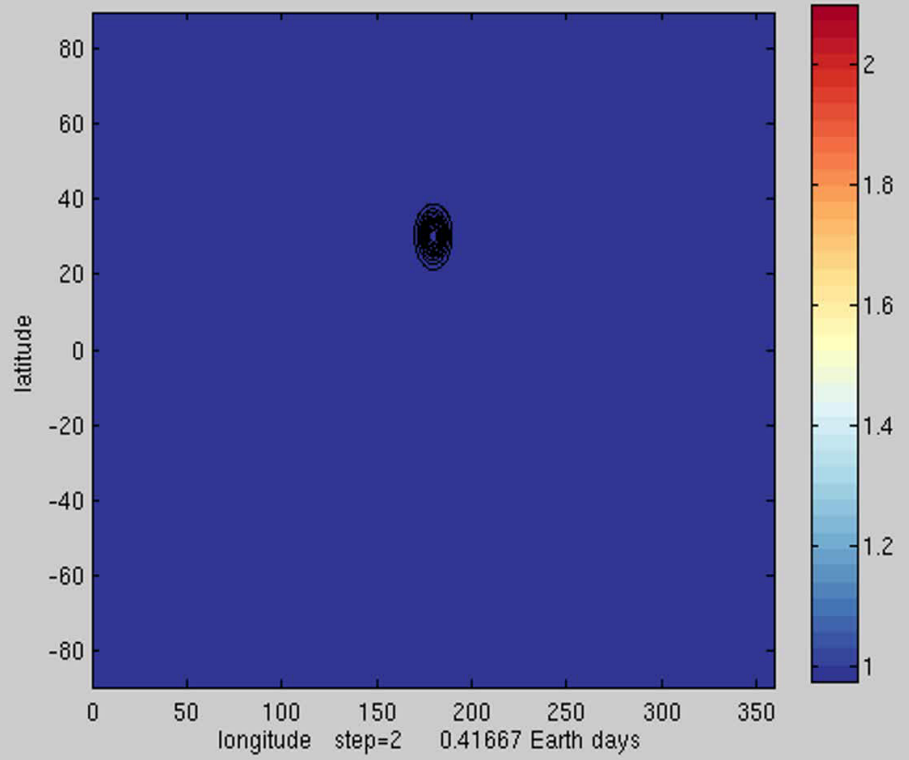


H forcing on 30N

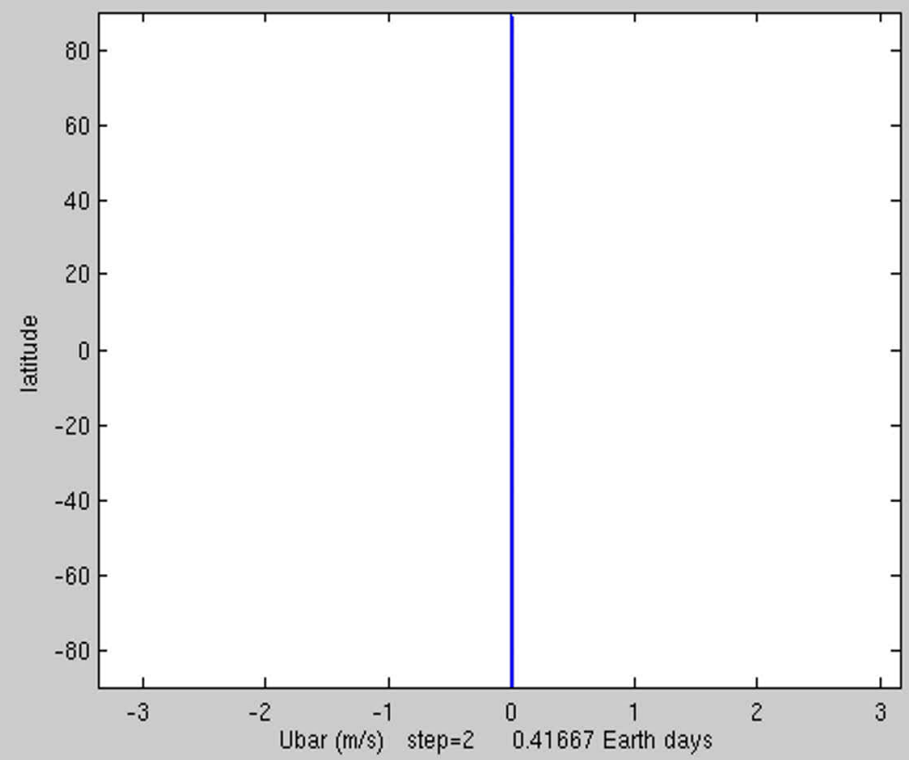
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/ndata2/dsk_ho/xiz/stswm/Hforce_nestorm/jup3 step=2 0.41667 Earth days -- $PHL \times 10^5$

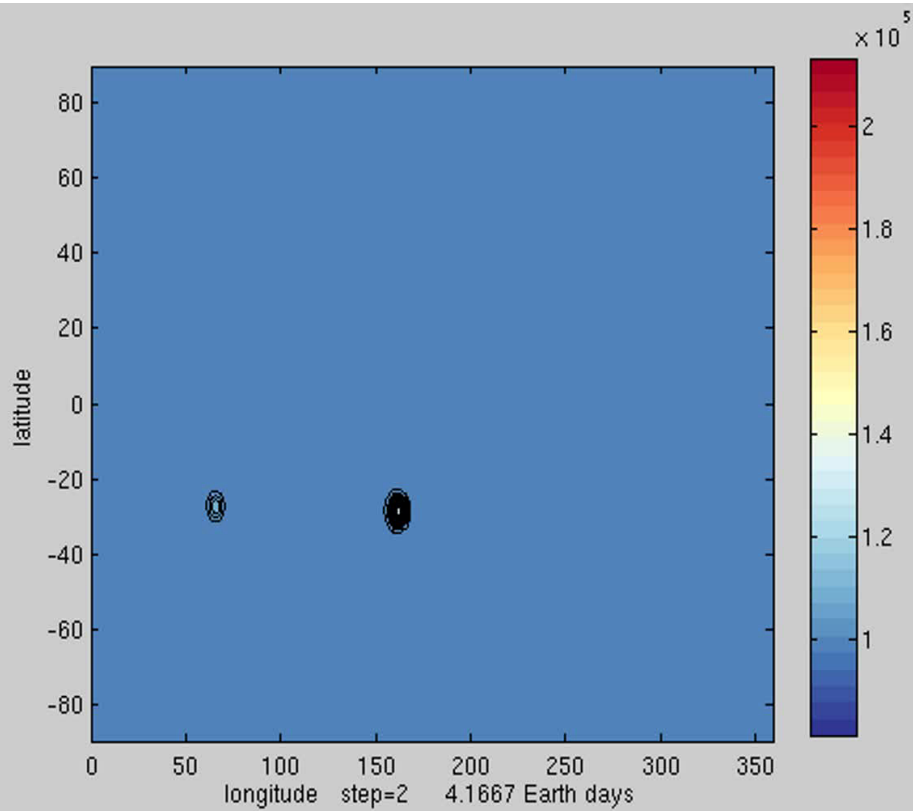


/ndata2/dsk_ho/xiz/stswm/Hforce_nestorm/jup3 step=2 0.41667 Earth days -- UBAR

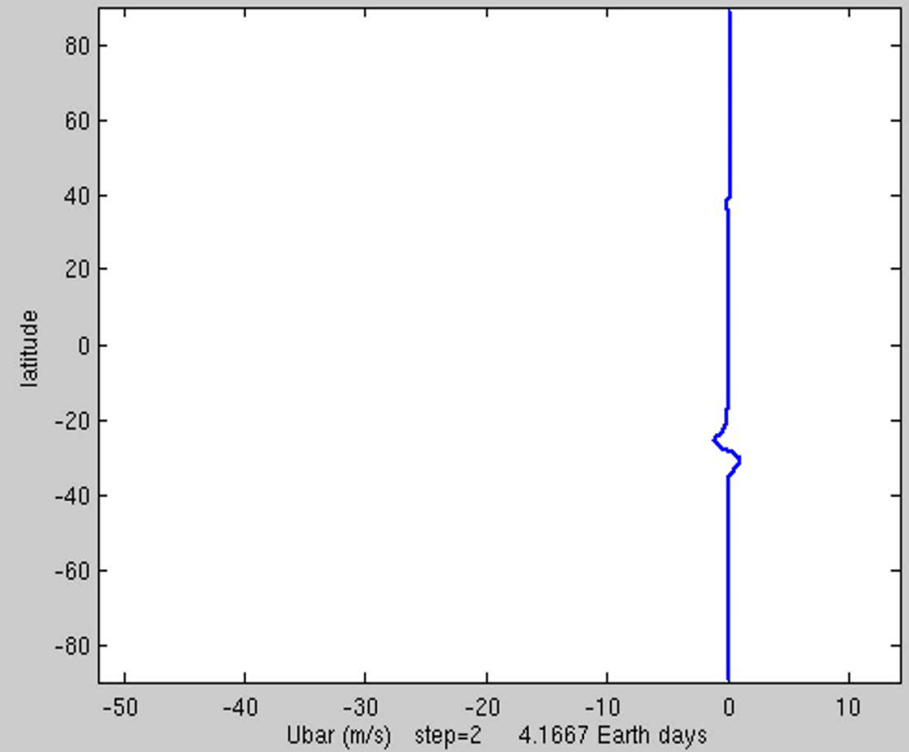


H forcing (50S - 50N)

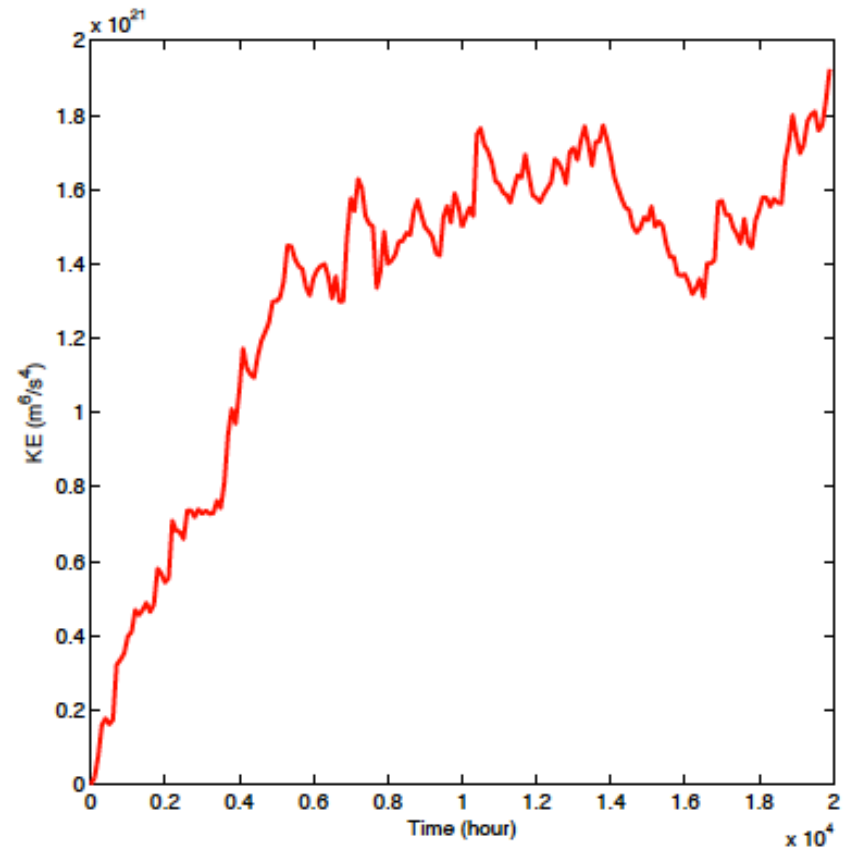
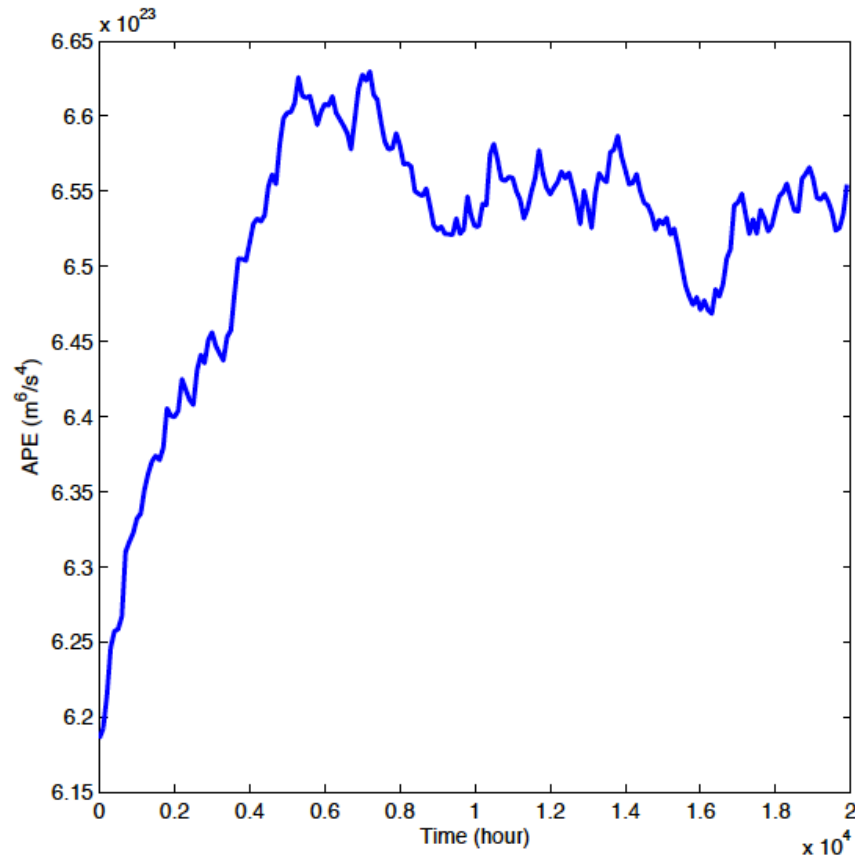
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Energy (APE & KE)

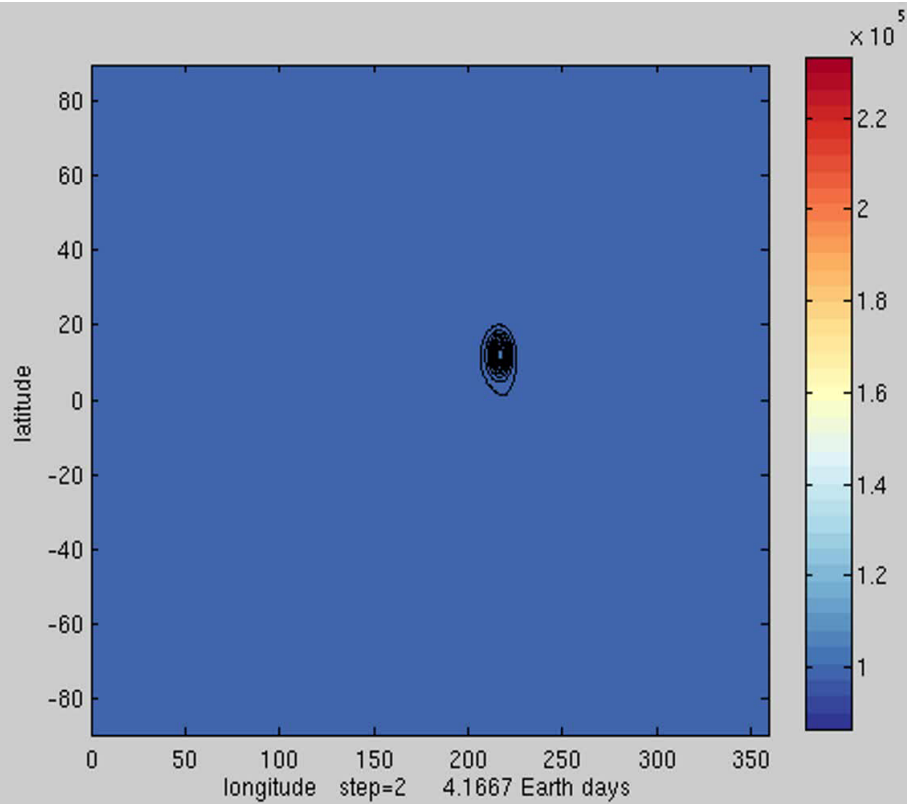


$$E_{\text{APE}} = \frac{1}{2} \int (g \eta)^2 - \langle g \eta \rangle^2 dA$$

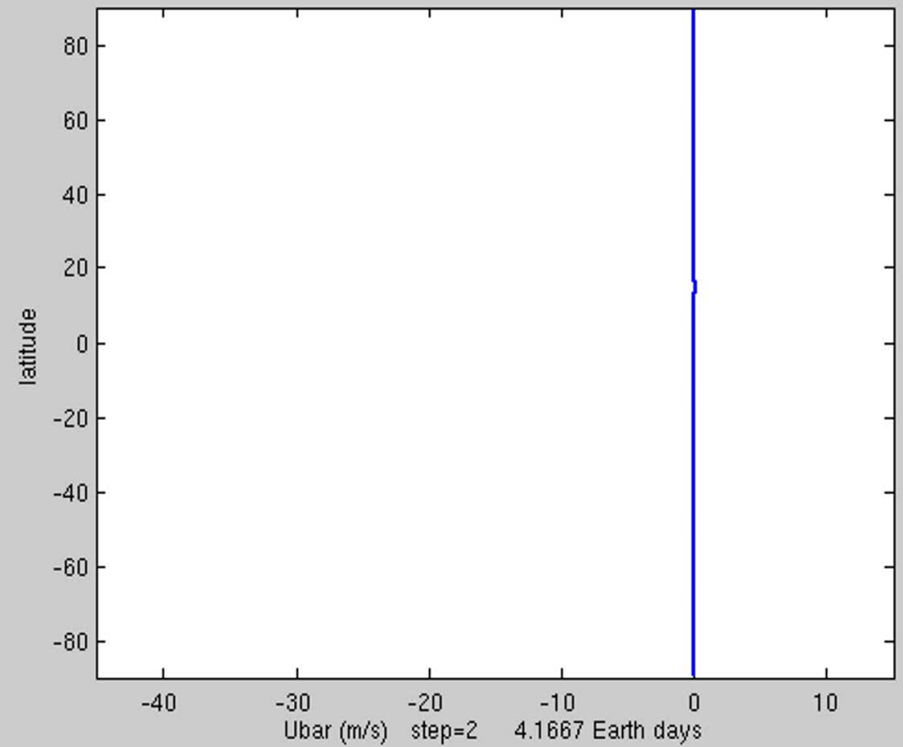
$$E_K = \frac{1}{2} \int gh(u^2 + v^2) dA$$

H forcing (Belts)

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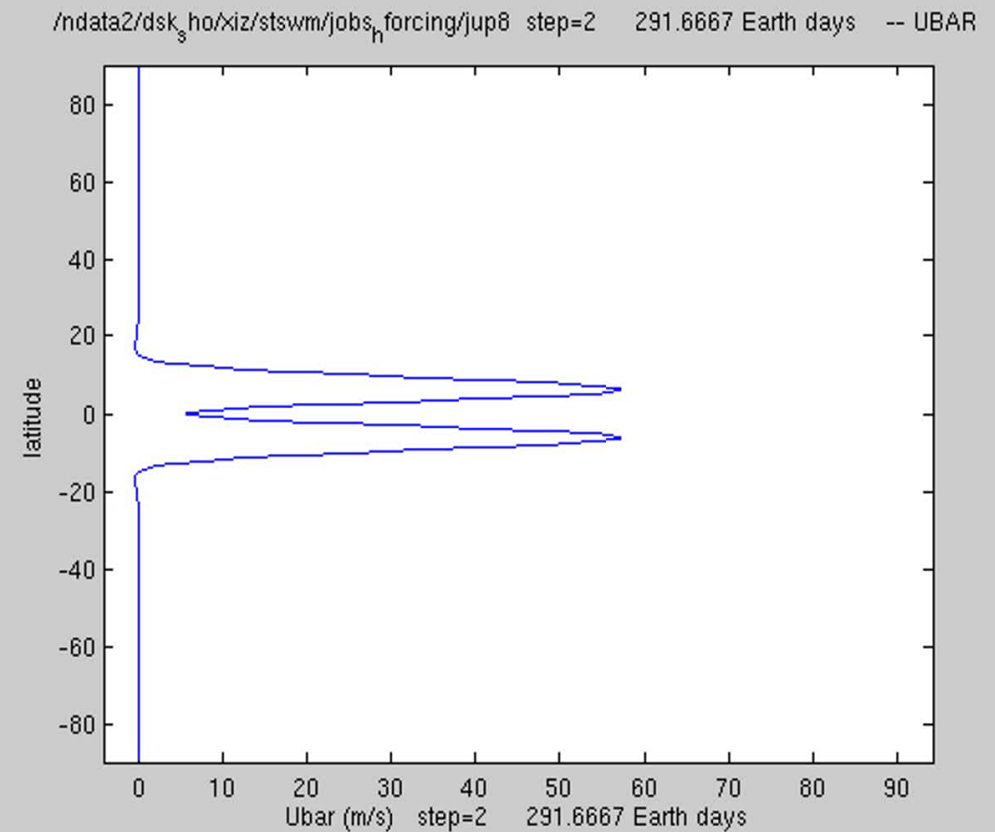
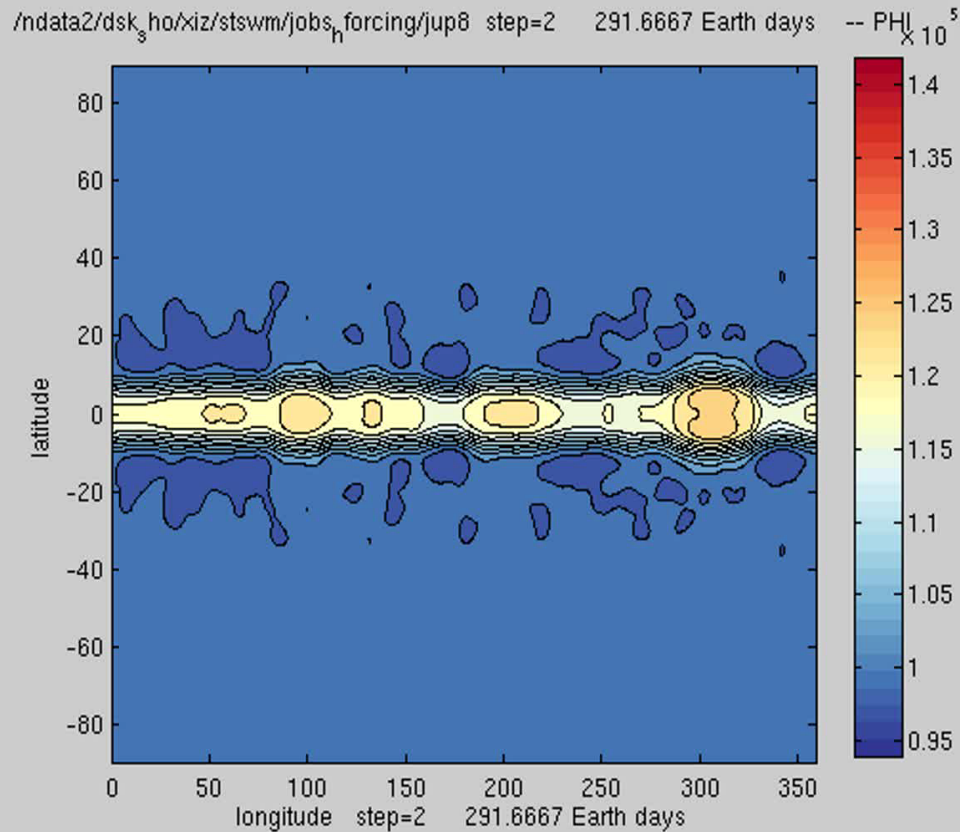
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H forcing (Equator)

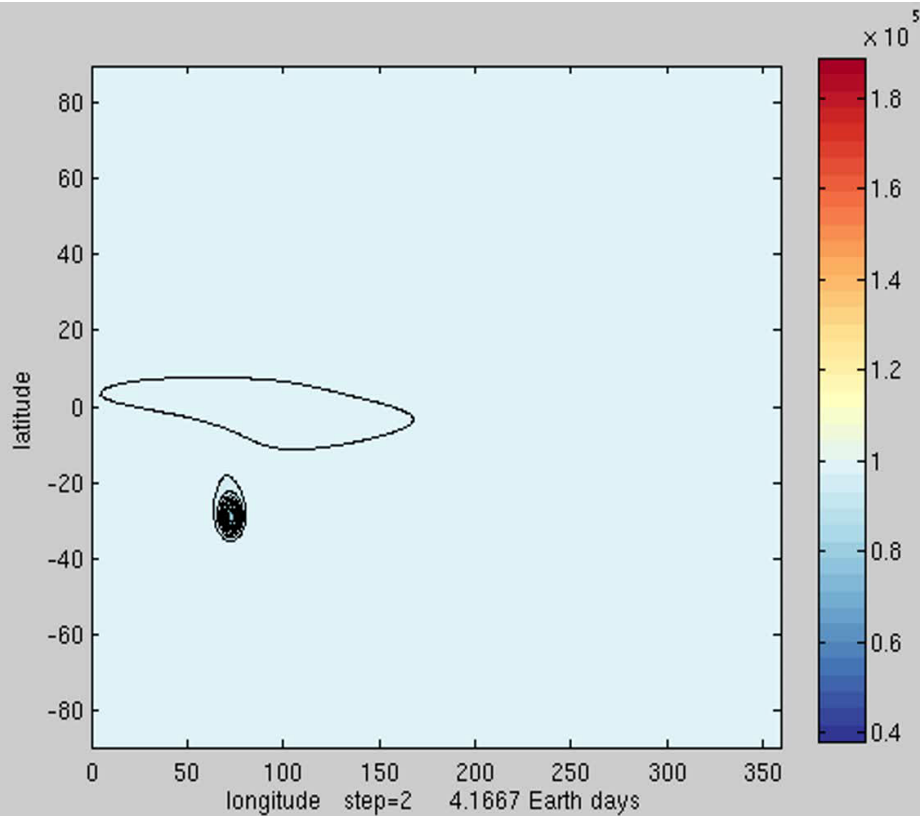
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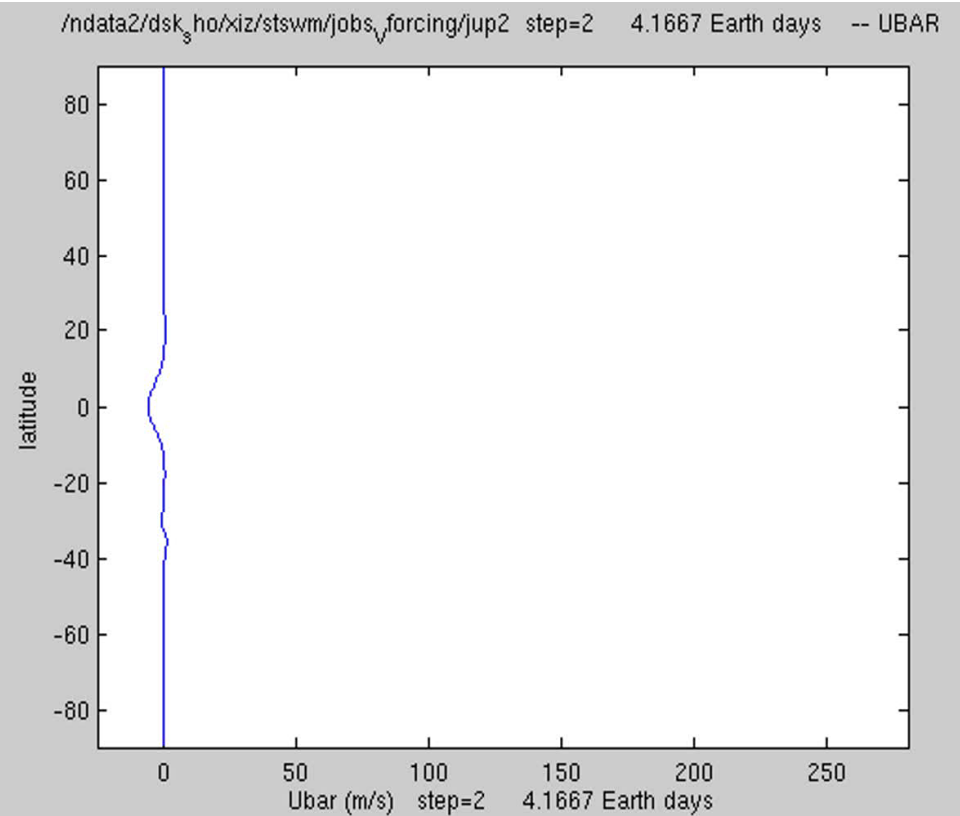


Vorticity Forcing (Random Sign)

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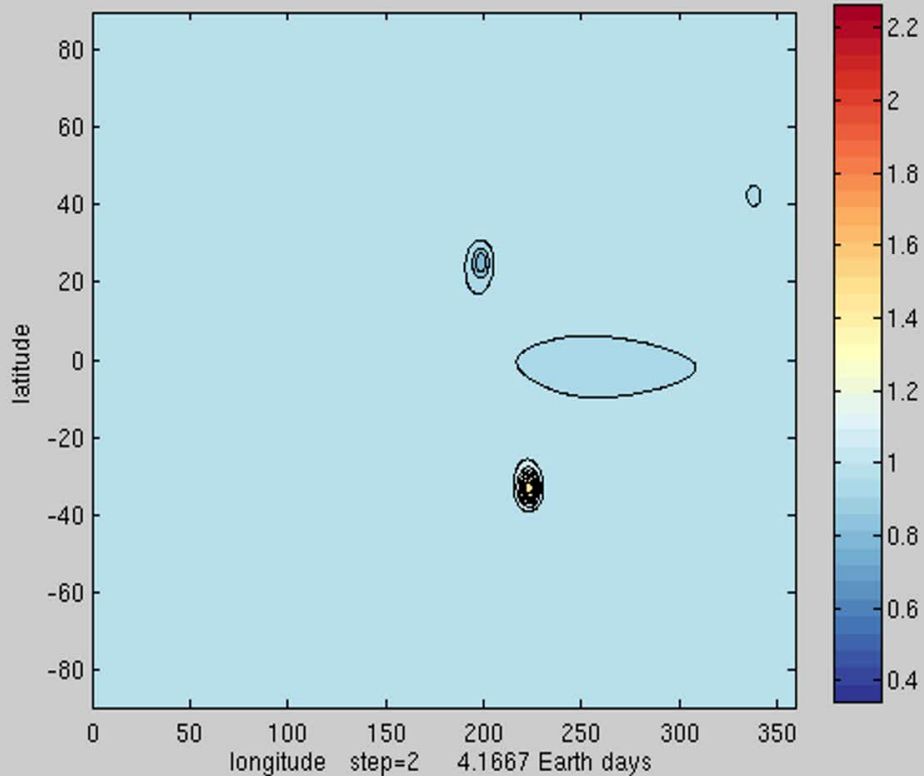


Vorticity Forcing (positive)

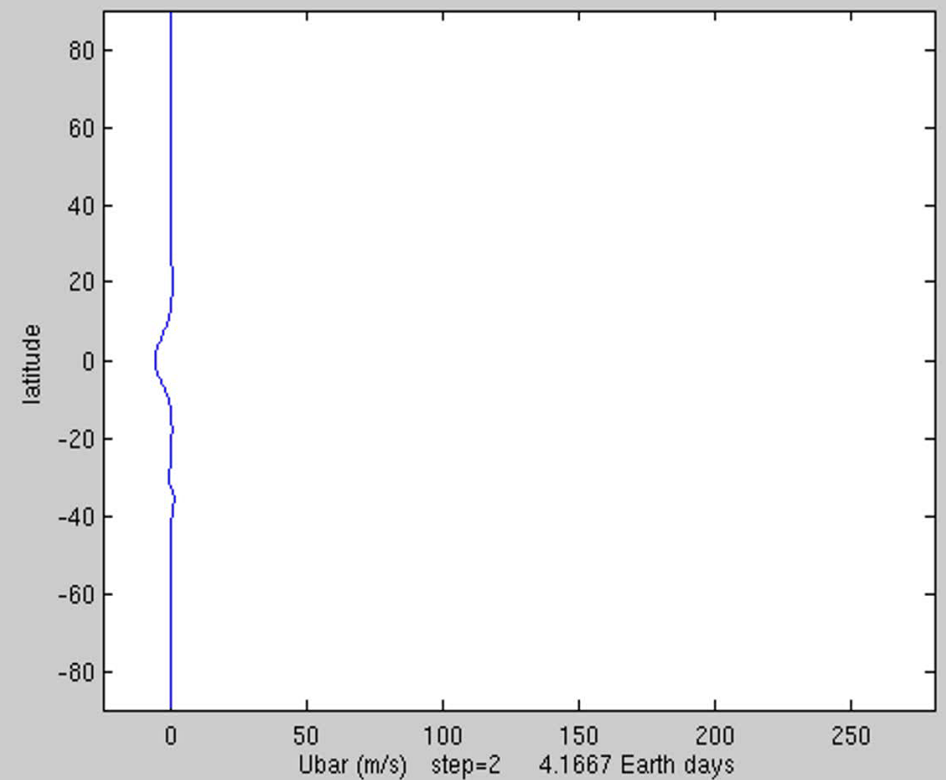
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/ndata2/dsk_ho/xiz/stswm/jobs_v_forcing/jup2 step=2 4.1667 Earth days -- PHI $\times 10$

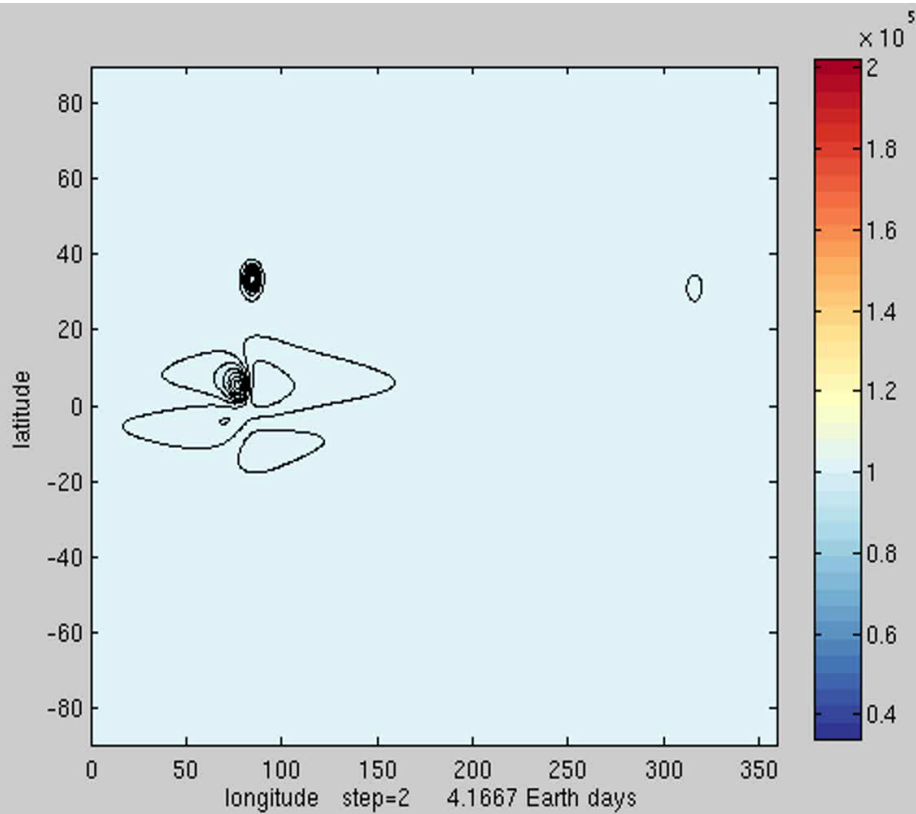


/ndata2/dsk_ho/xiz/stswm/jobs_v_forcing/jup2 step=2 4.1667 Earth days -- UBAR

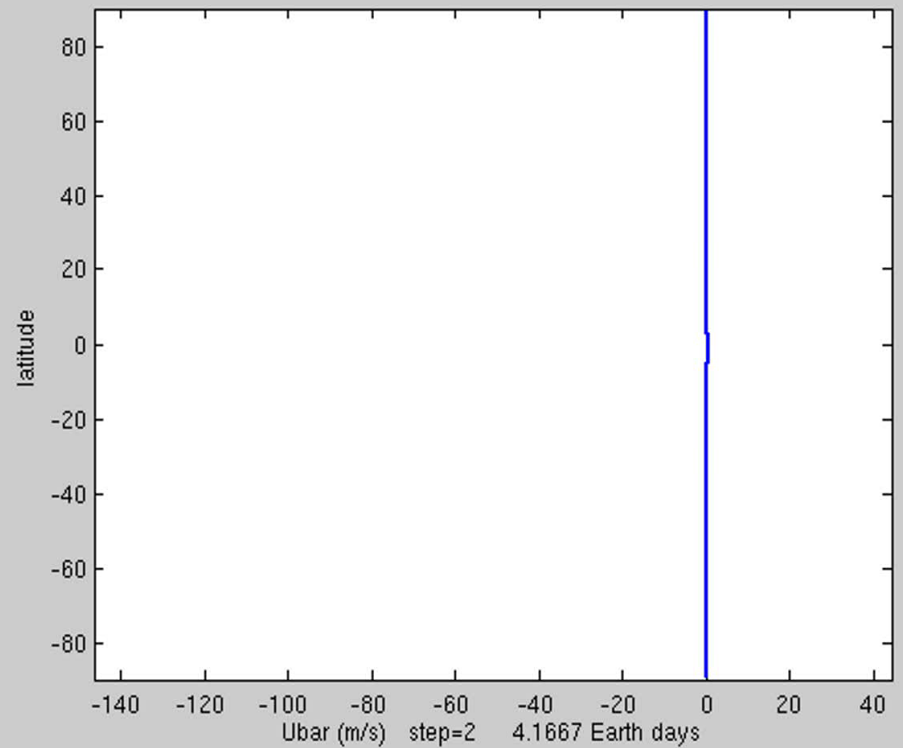


Not a steady solution!

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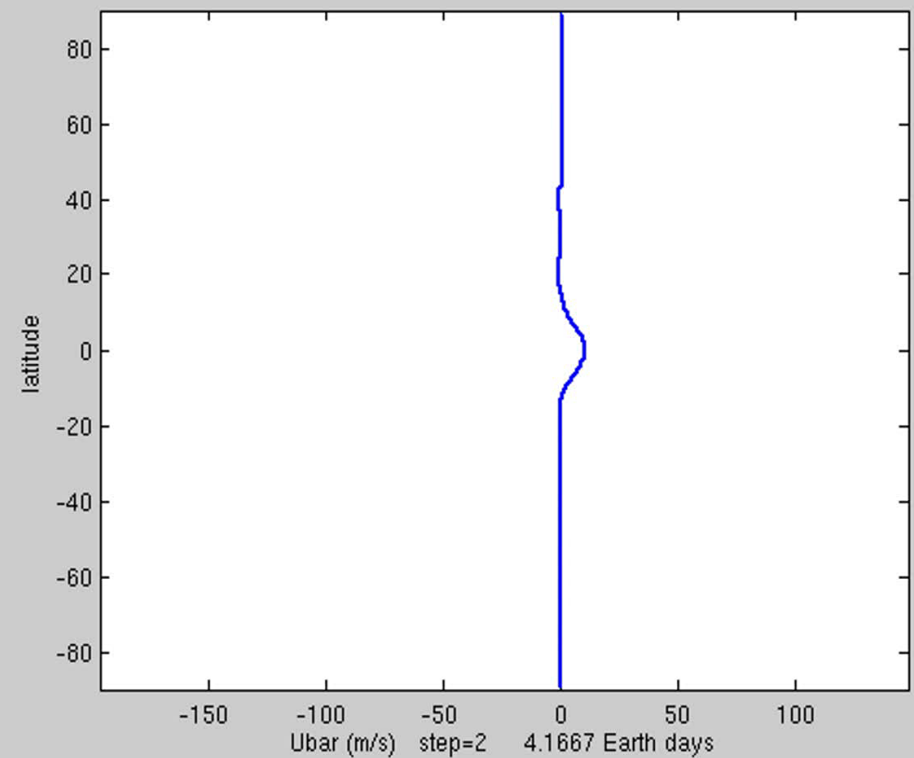
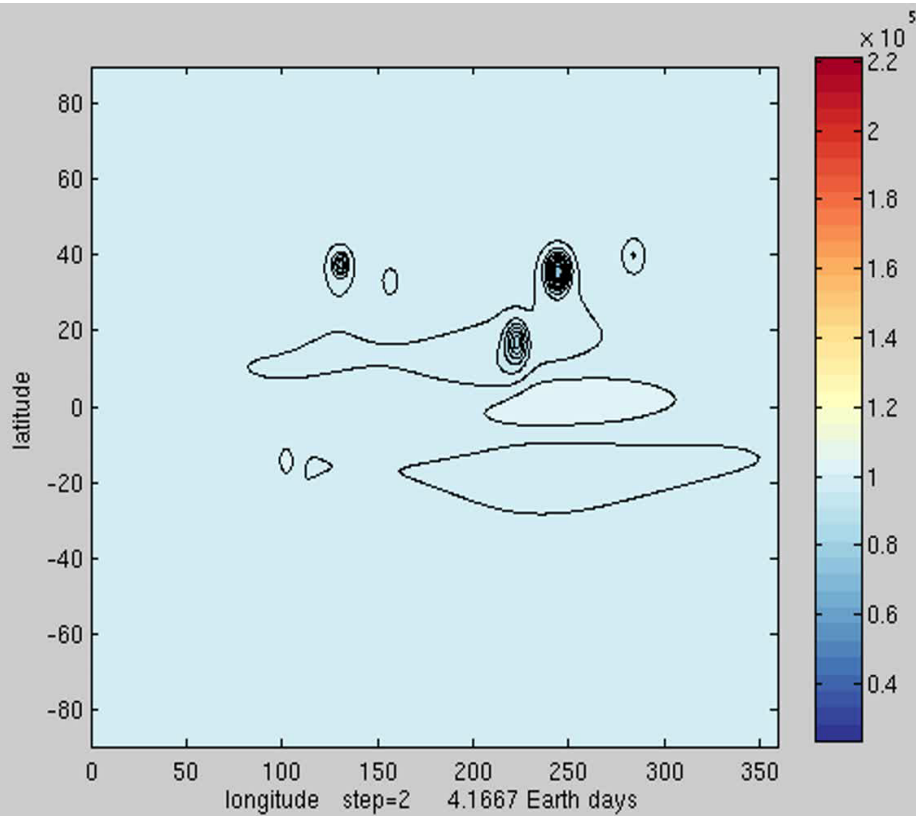
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Vorticity Forcing (Belts)

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Conclusion & Future Work

- No eastward jet seen in the Mass Forced-Dissipative Shallow Water System
- Vorticity Forced-Dissipative Shallow Water System is able to produce eastward jet under some condition, but the mechanism is not clear
- The effect of drag (friction) on the system
- Higher resolution run

A composite image featuring the Juno spacecraft in the foreground, orbiting the planet Jupiter. The spacecraft is shown from a perspective that highlights its three large solar panels and its distinctive antenna structure. The planet Jupiter, with its characteristic orange, white, and brown bands, is the background. The text is overlaid in a bright yellow color.

Fingers Crossed for Juno!!!

&

Happy QiXi Festival!!!