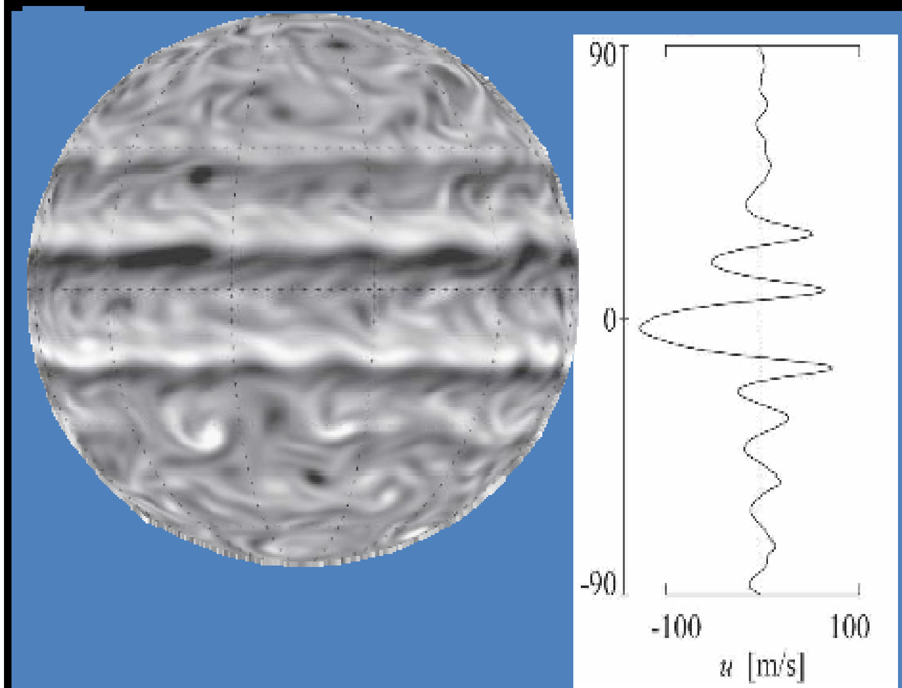
Tropospheric & Deep Models

Tropospheric Models

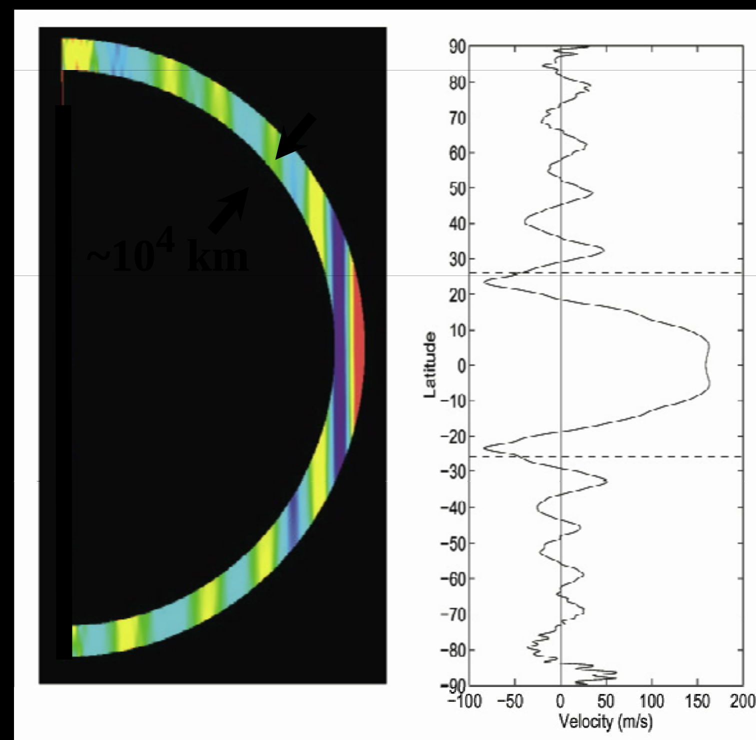
Rotating turbulence in ~2D weather layer (~10 km thick)

Deep Convection Models

Rotating convection in 3D envelope (~10,000 km thick)

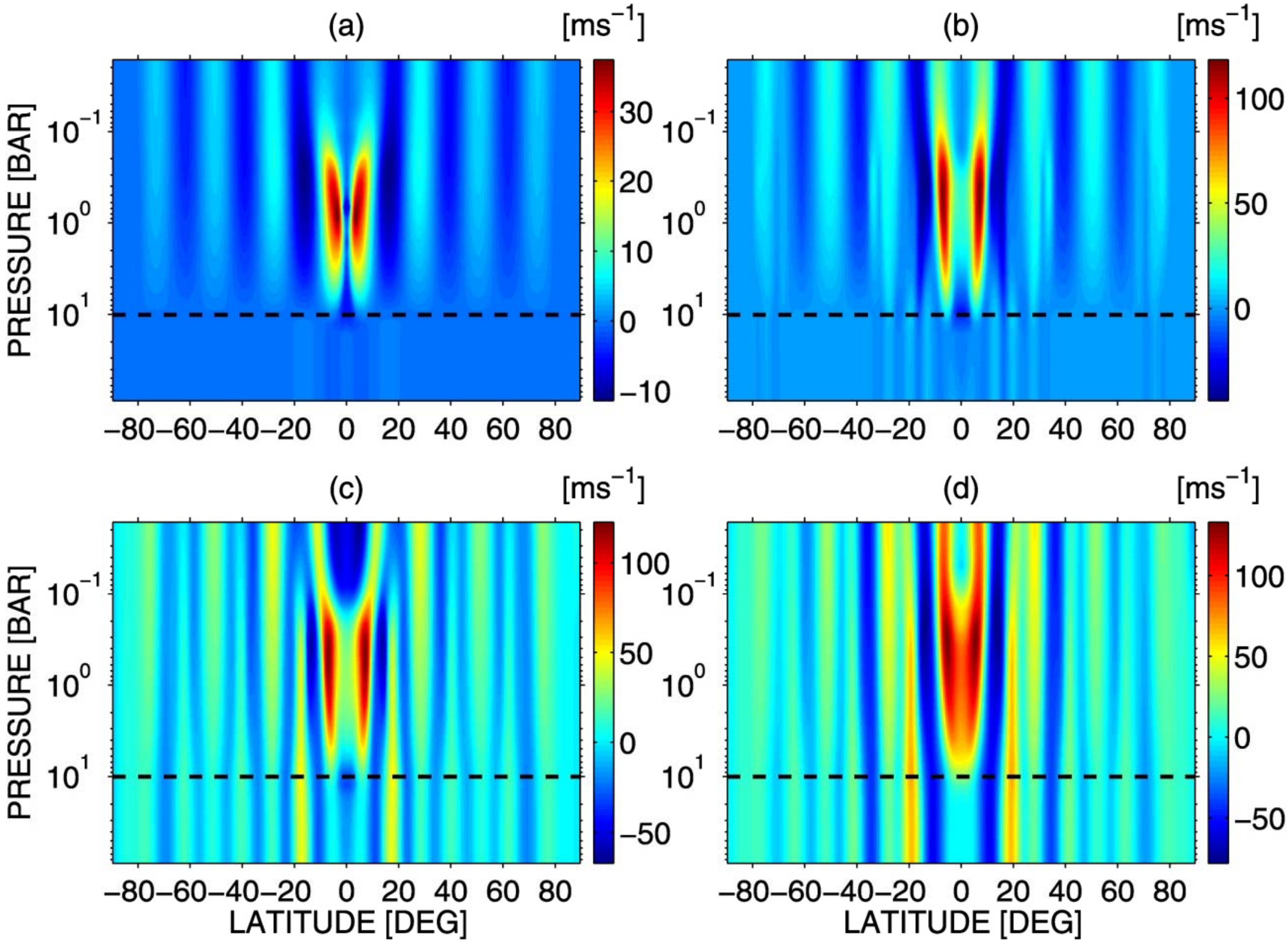


Scott & Polvani *JAS* 07



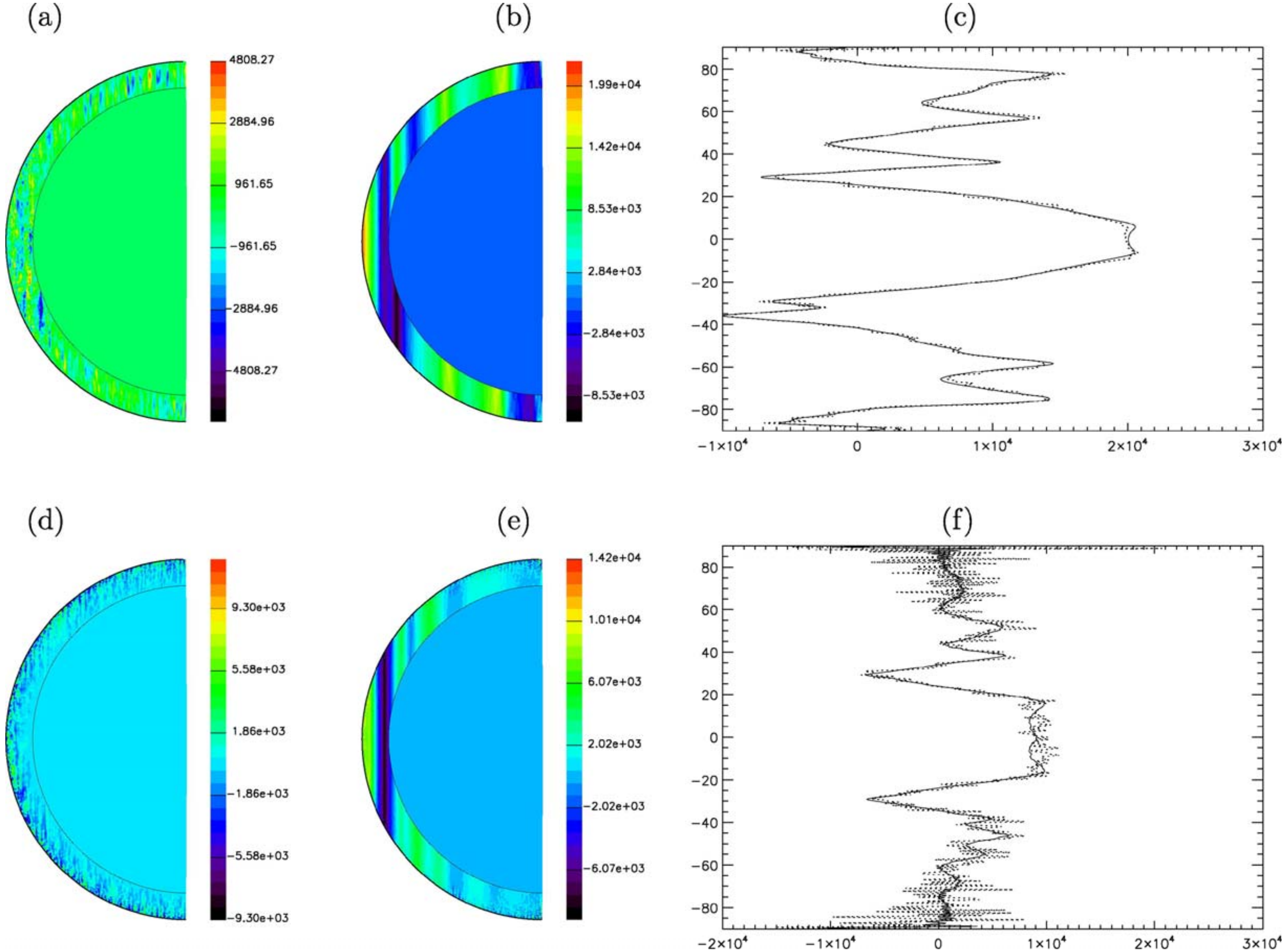
Heimpel et al. *Nature* 05

- Both capture aspects of the observations; No coupled models presently exist



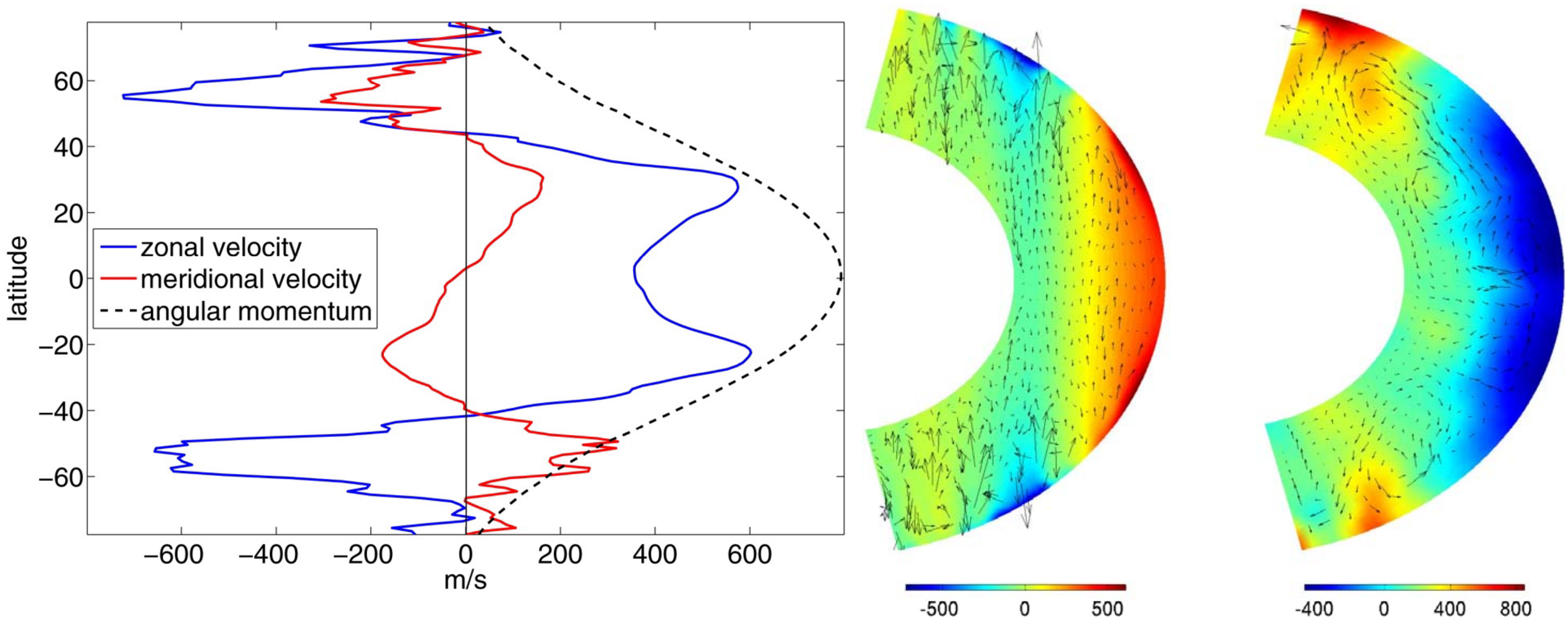
Lian and Showman (2008). Deep zonal winds can be driven by shallow thermal forcing.

Anelastic Model



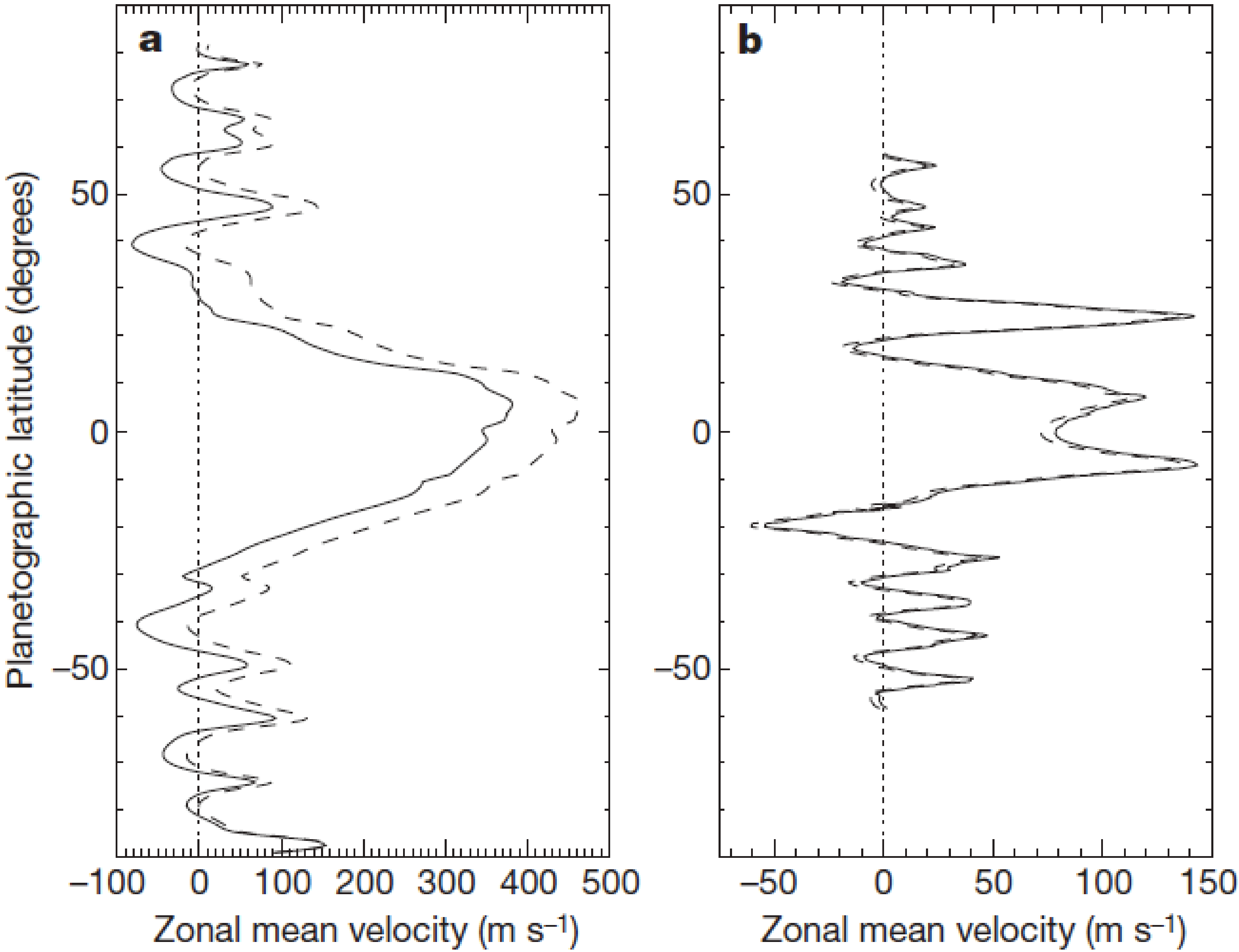
Jones and Kuzanyan (2009) Zonal flow is almost independent of the *z*-coordinate parallel to the rotation axis.

Anelastic Model



Kaspi et al. (2009) Columnar structure modified by compressibility effects. The motion is still aligned with the direction of the axis of rotation as in a barotropic rotating fluid, but the wind structure has a vertical shear with stronger winds in the atmosphere than in the interior. This shear is associated with baroclinic compressibility effects.

It is easy to produce Jupiter-like zonal winds with very different models.
Modeling is unlikely to settle questions about the depth of Jovian zonal flows, the forcing mechanism, etc. Observations, such as those provided by Jovian seismology, are needed to unravel the dynamics of the atmosphere/interior.


a
b
Planetographic latitude (degrees)
50
0
–50
–100
0
100
200
300
400
500
Zonal mean velocity (m s–1)
–50
0
50
100
150
Zonal mean velocity (m s–1)

Forcing of Jovian p-Modes

Interior Convection
Impacts like Comet Shoemaker-Levy
Thunderstorms

Energy Released in Thunderstorm/Comet SL-9 Energy Release= 10^{22} ergs/10^{27} ergs ?

Convection

Jupiter's intrinsic power = L_J = 3.35 × 10^{24} erg s^{-1}
Jupiter's intrinsic flux = F_J = 5440 ergs s^{-1} cm^{-2}
Jupiter's intrinsic power/mass = 1.764 × 10^{-6} erg s^{-1} g^{-1}

Sun's intrinsic power = $L_\odot$ = 3.845 × 10^{33} erg s^{-1}
Sun's intrinsic flux = $F_\odot$ = 6.317 × 10^{10} ergs s^{-1} cm^{-2}
Sun's intrinsic power/mass = 1.933 erg s^{-1} g^{-1}

$L_J/L_\odot$ = 0.87 × 10^{-9}

$F_J/F_\odot$ = 0.86 × 10^{-7}

$(L_J/M_J)/(L_\odot/M_\odot)$ = 9.126 × 10^{-7}

Convection

Saturn's intrinsic power = L_S = 2.075 × 10^{23} erg s^{-1}
Saturn's intrinsic flux = F_S = 2010 ergs s^{-1} cm^{-2}
Saturn's intrinsic power/mass = 3.649 × 10^{-7} erg s^{-1} g^{-1}

Sun's intrinsic power = $L_\odot$ = 3.845 × 10^{33} erg s^{-1}
Sun's intrinsic flux = $F_\odot$ = 6.317 × 10^{10} ergs s^{-1} cm^{-2}
Sun's intrinsic power/mass = 1.933 erg s^{-1} g^{-1}

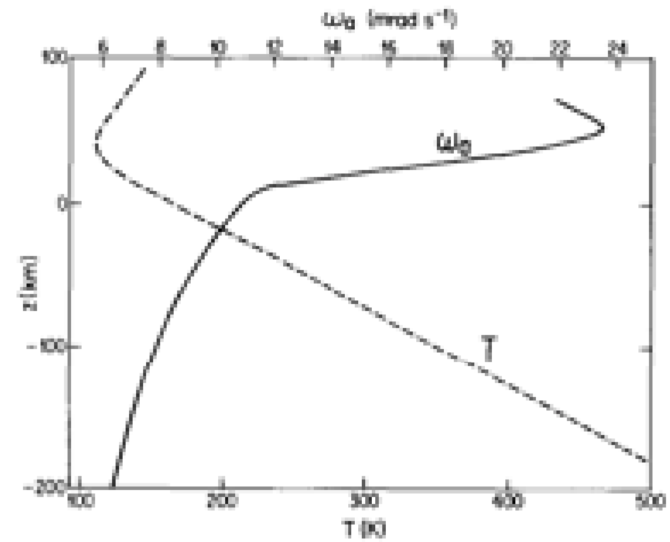
$L_S/L_\odot$ = 0.540 × 10^{-10}

$F_S/F_\odot$ = 3.182 × 10^{-8}

$(L_S/M_S)/(L_\odot/M_\odot)$ = 1.888 × 10^{-7}

Comments on Forcing by Convection from Bercovici and Schubert (1987)

Upward propagating acoustic waves with periods between about 4.5 and 9 minutes should be reflected downwards from the region of Jupiter's tropopause.



Periods of turbulent convective eddies. For convective velocities between 10 and 80 m s^{-1} and length scales on the order of a scale height (≈ 20 km at 1 bar) periods of convective motions are 4-33 minutes.

The power per unit volume W radiated by turbulence into acoustic modes is

$$W = (\rho u^3/\lambda)(M^3 + M^5)$$

u is the eddy velocity
λ is the eddy wavelength
M is the Mach number

Equate $W\lambda$ with the acoustic energy flux $\rho c u_0^2$ to get

$$u_0 = uM^2(1 + M^2)^{0.5}$$

c is the sound speed
u_0 is the acoustic wave velocity

For Jupiter M is about 0.08 and **u_0 is 0.5 m s^{-1}**

For Saturn M is about 1.

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Wave Disturbances from the Comet SL-9 Impacts into Jupiter's Atmosphere

R. L. Walterscheid, D. G. Brinkman, and G. Schubert[1]

Space and Environment Technology Center, The Aerospace Corporation, Los Angeles, California
E-mail: richard.walterscheid @aero.org

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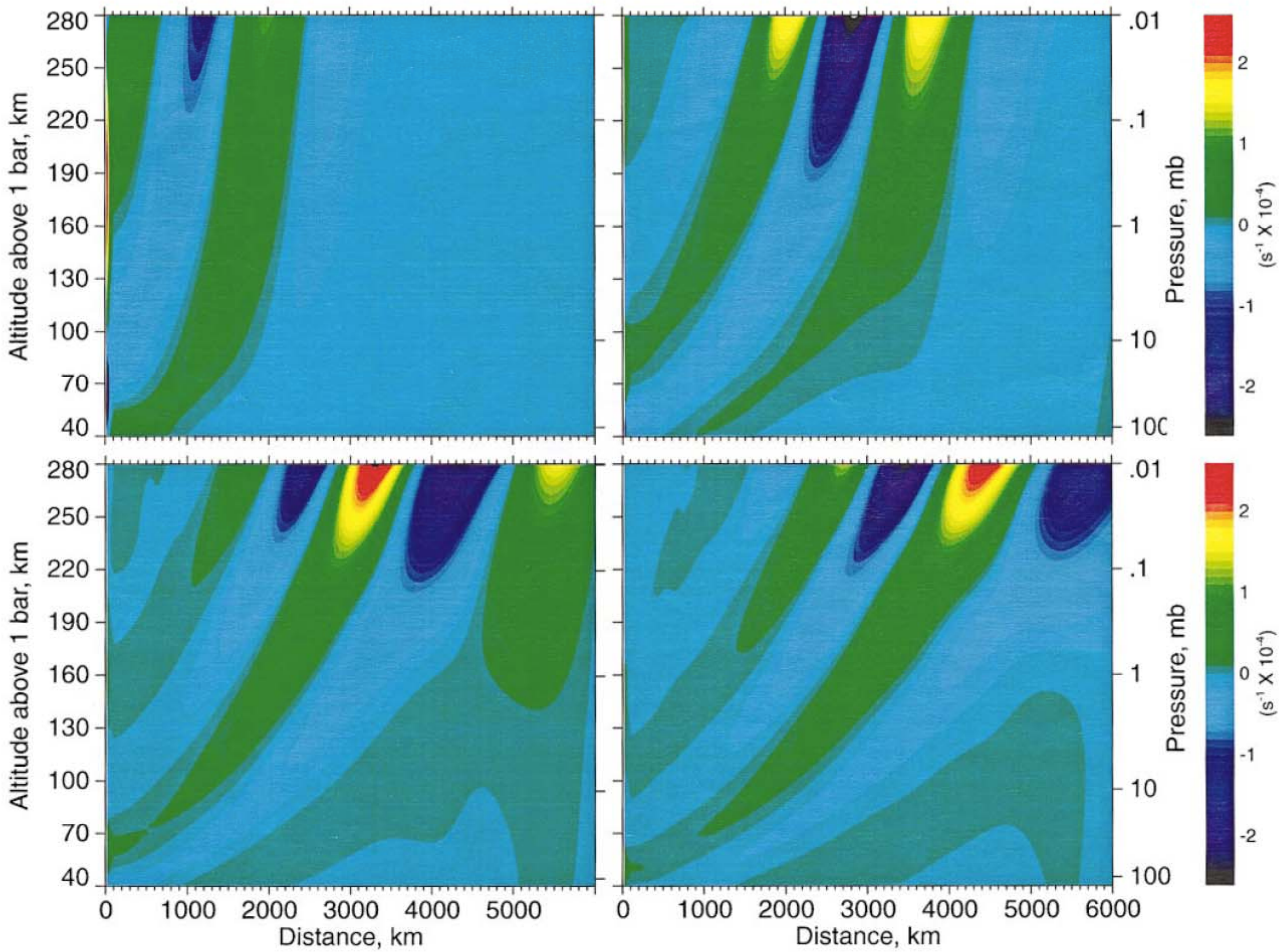
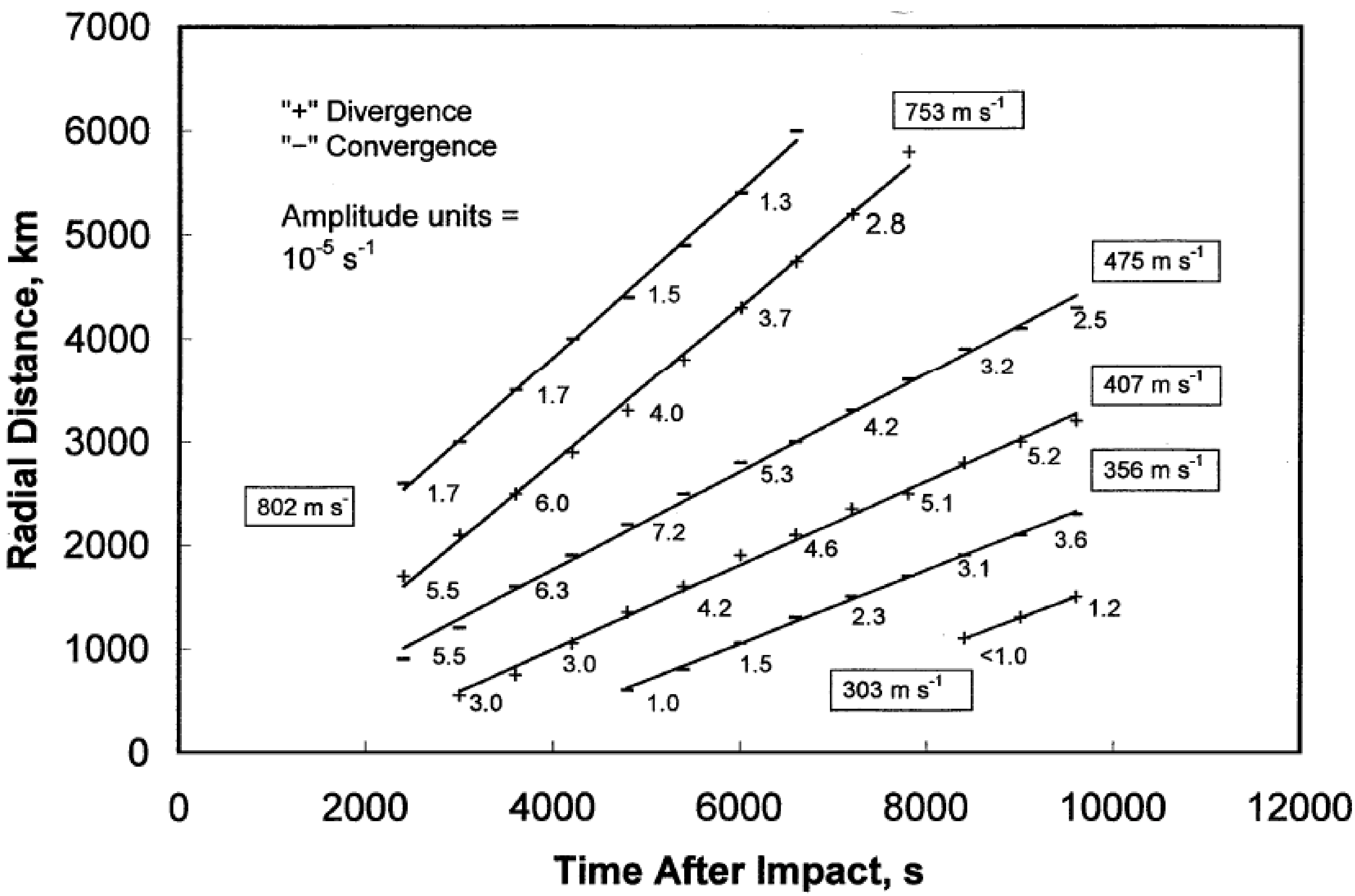
Wave disturbances due to the Shoemaker–Levy 9 (SL-9) cometary impacts into Jupiter's atmosphere have been simulated with **a fully compressible (nonhydrostatic), time-dependent, nonlinear, axisymmetric, f-plane, finite difference computational scheme.** Energy is released in a cylindrical region with a radius of 250 to 1000 km as suggested by models of the reentry of impact ejecta following the initial explosion. **The model produces outward moving ducted gravity waves at stratospheric altitudes with speeds and relative amplitudes in agreement with observations**. The waves emerge from a cylindrical region of alternating inflow and outflow that extends high into the atmosphere in the main region of energy release. The disturbances originate as horizontally propagating waves at the periphery of this region, thereby providing an explanation for the observed large initial radius (»450–700 km) of the main ring. **The model results suggest that the waves are made visible by the inflow of particulate impact debris into outward moving rings of wave horizontal convergence.** The inner edge of the extensive clear zone outside of the main dark ring may be the divergence phase of the leading fast wave.


Altitude above 1 bar, km
280
250
220
190
160
130
100
70
40
Pressure, mb
.01
.1
1
10
100
$(s^{-1} \times 10^{-4})$
2
1
0
-1
-2
0 1000 2000 3000 4000 5000
0 1000 2000 3000 4000 5000 6000
Distance, km


"+" Divergence
"−" Convergence
Amplitude units =
10-5 s-1
753 m s-1
475 m s-1
407 m s-1
356 m s-1
303 m s-1
802 m s-1
1.3
2.8
1.5
3.7
2.5
3.2
1.7
4.0
4.2
5.2
1.7
6.0
5.3
5.1
7.2
4.6
3.6
5.5
6.3
3.1
4.2
1.2
2.3
5.5
3.0
1.5
<1.0
3.0
1.0
Radial Distance, km
Time After Impact, s
0
1000
2000
3000
4000
5000
6000
7000
2000
4000
6000
8000
10000
12000

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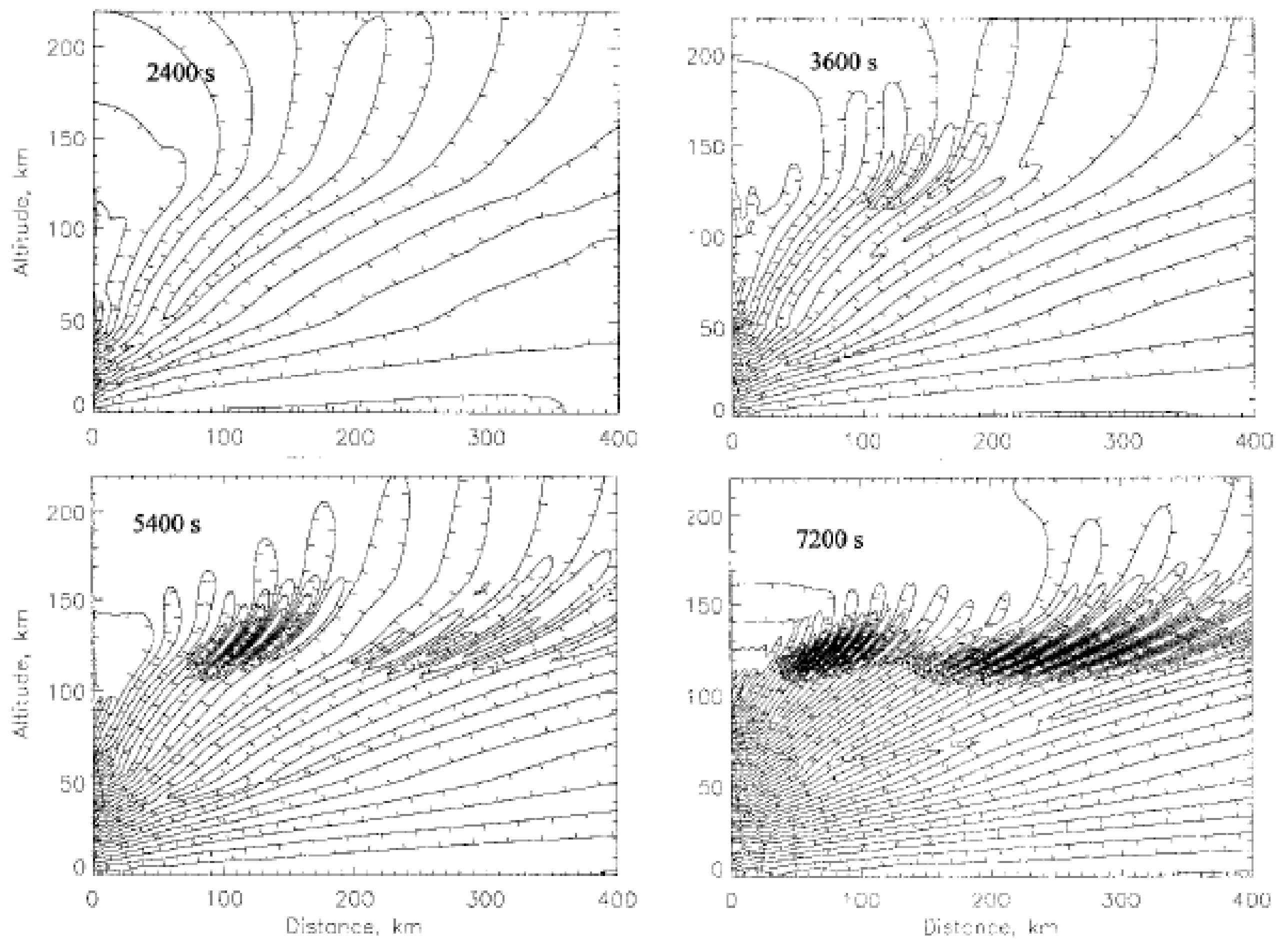
Small-scale gravity waves in the upper mesosphere and lower thermosphere generated by deep tropical convection

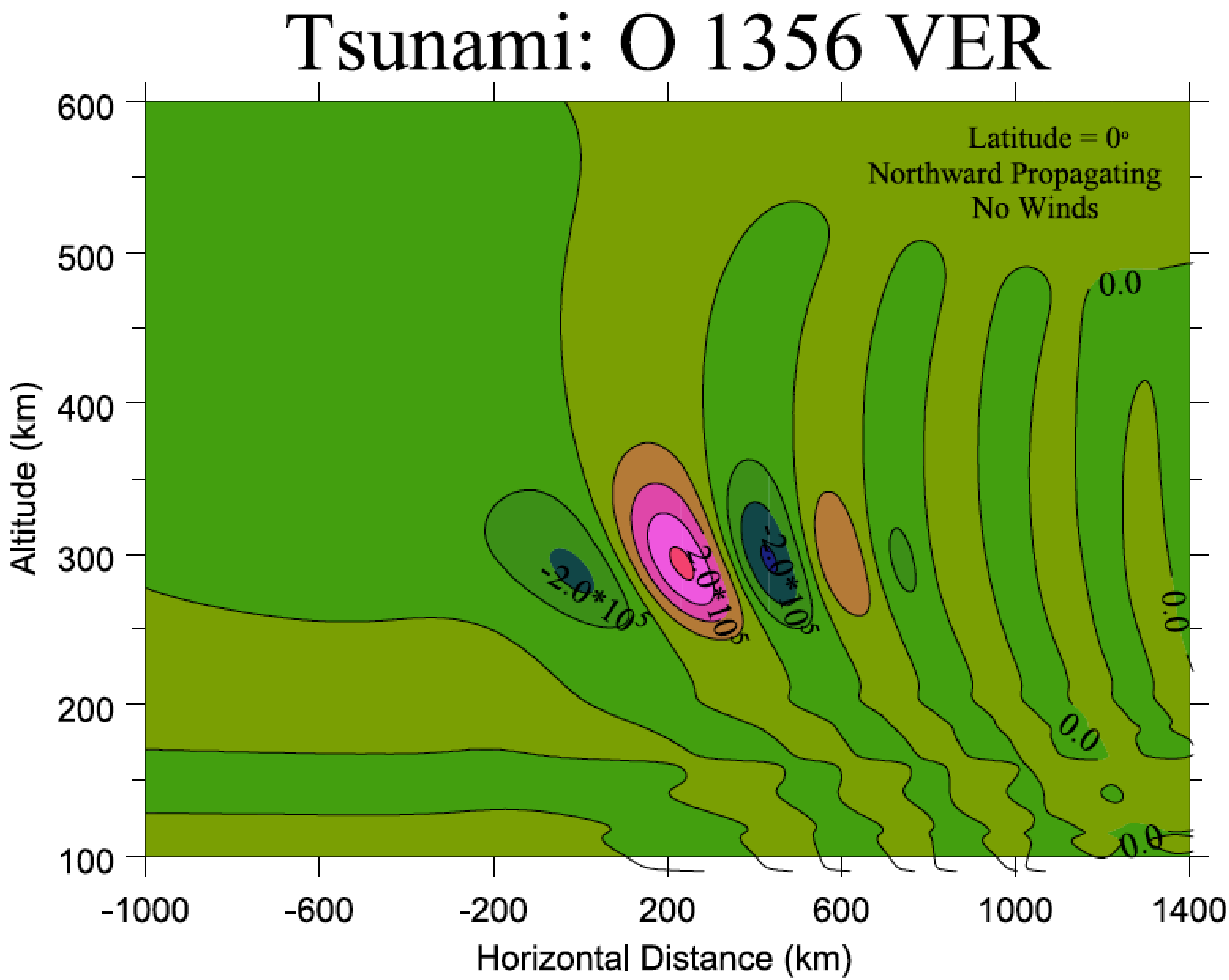
R. L. Walterscheid,[1] G. Schubert,[1,2] and D. G. Brinkman[1]



Atmospheric Airglow Fluctuations due to a Tsunami-Driven Gravity Wave Disturbance

M. P. Hickey[1], G. Schubert[2,3], and R. L. Walterscheid[3]

In press in JGR Space Physics


Tsunami: O 1356 VER
Latitude = 0°
Northward Propagating
No Winds
Altitude (km)
600
500
400
300
200
100
Horizontal Distance (km)
-1000
-600
-200
200
600
1000
1400
-2.0*10-5
2.0*10-5
-2.0*10-5
0.0
0.0
0.0
0.0