

Axisymmetric and nearly inviscid
models of the atmosphere

$$0 = -\nabla \cdot (\mathbf{v} M) + \frac{\partial}{\partial z} \left(\nu \frac{\partial M}{\partial z} \right),$$

where

$$M = \Omega a^2 \cos^2 \theta + u a \cos \theta$$

$$u_M \equiv \Omega a \sin^2(\theta) / \cos(\theta).$$

$$\nu \partial_y M = 0$$

Radiative
equilibrium

Angular momentum
conservation

For equinoctial Held and Hou model

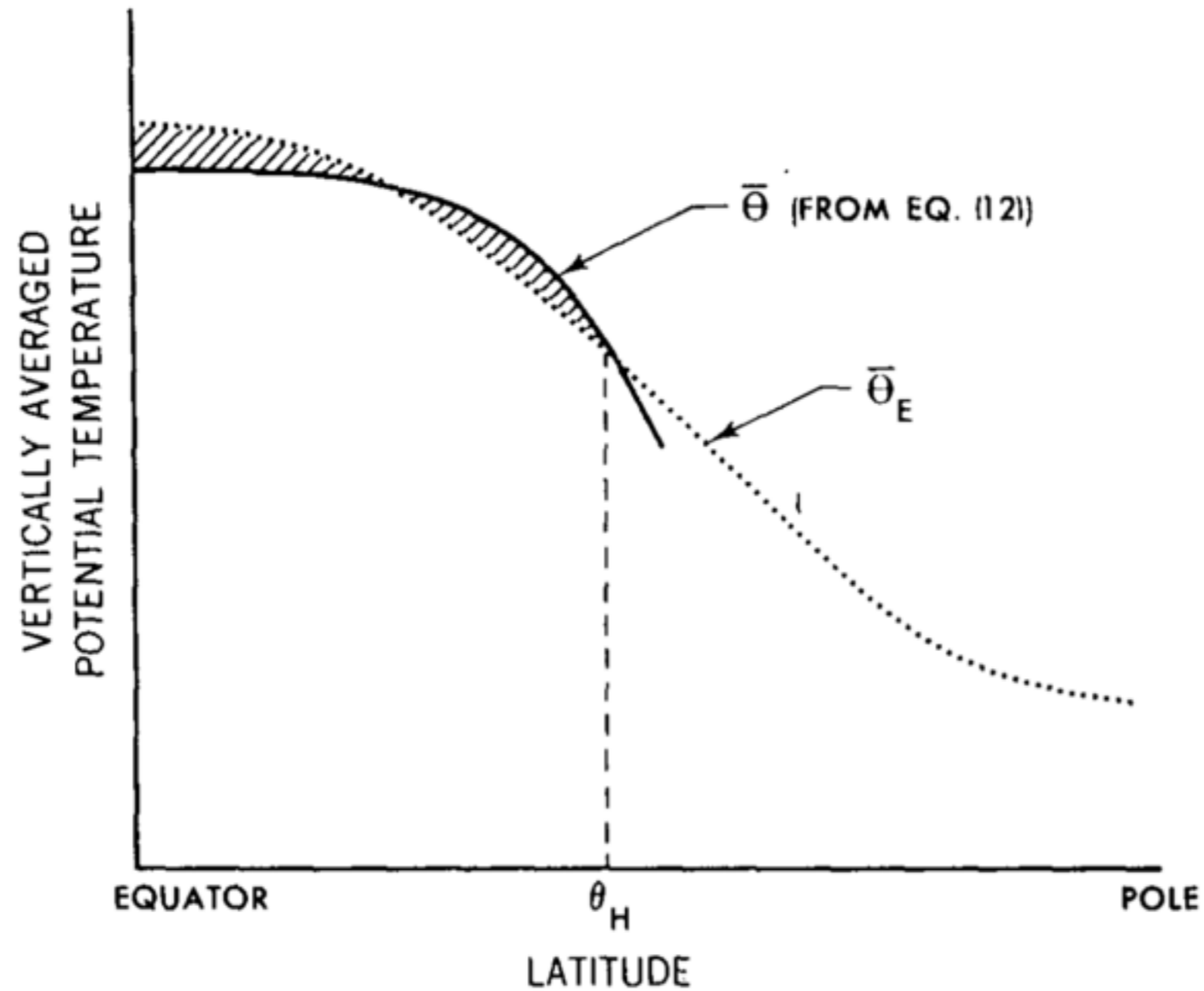


FIG. 1. The equal-area geometric construction equivalent to the argument of Section 4a. The two shaded areas are equal.

$$fu + \frac{\tan \phi}{a} u^2 \approx -\frac{1}{a} \frac{\partial \Phi}{\partial \phi},$$

v must be hemispherically asymmetric
since M is constant around the equator,
 u is hemispherically symmetric
hence
temperature is hemispherically symmetric

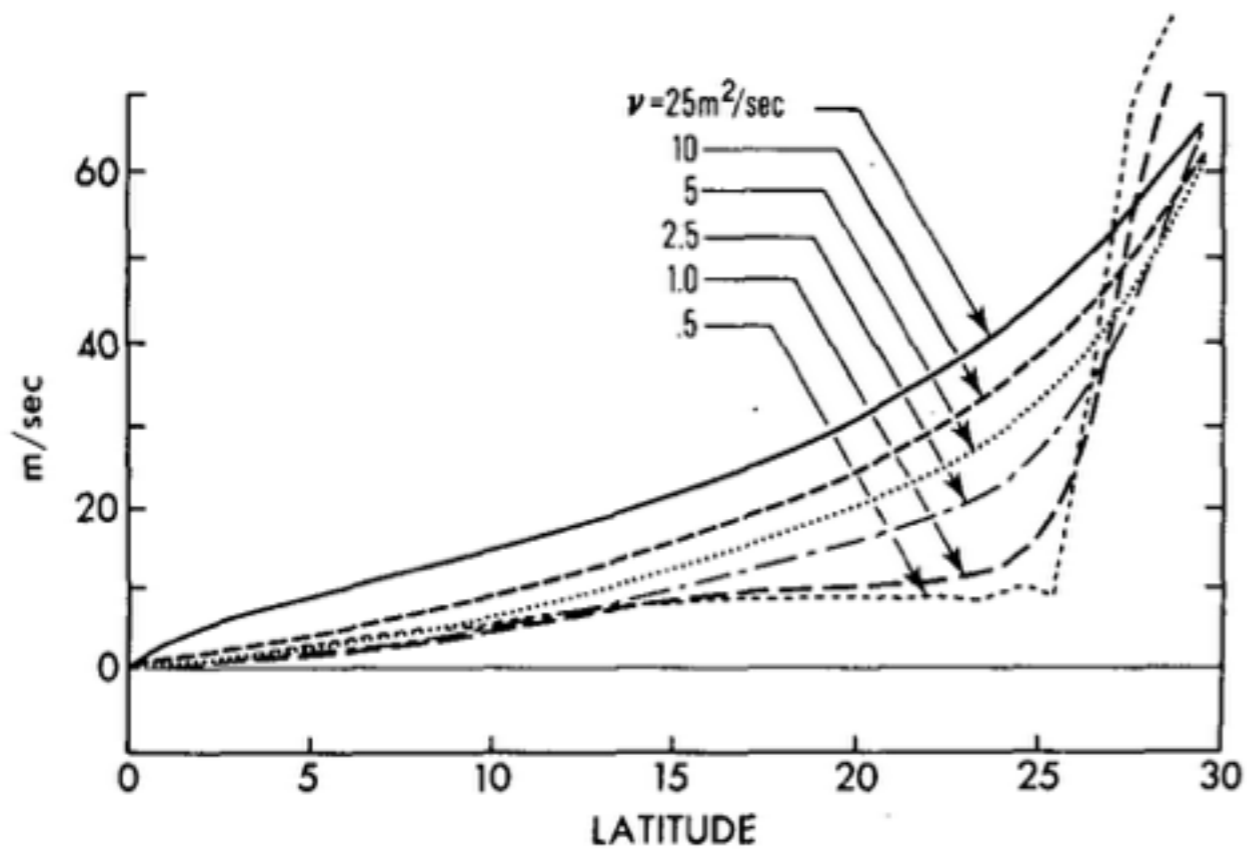


FIG. 6. $\Omega a \sin^2(\theta) - u \cos(\theta)$ at $z = H$ for various values of ν in the standard case.

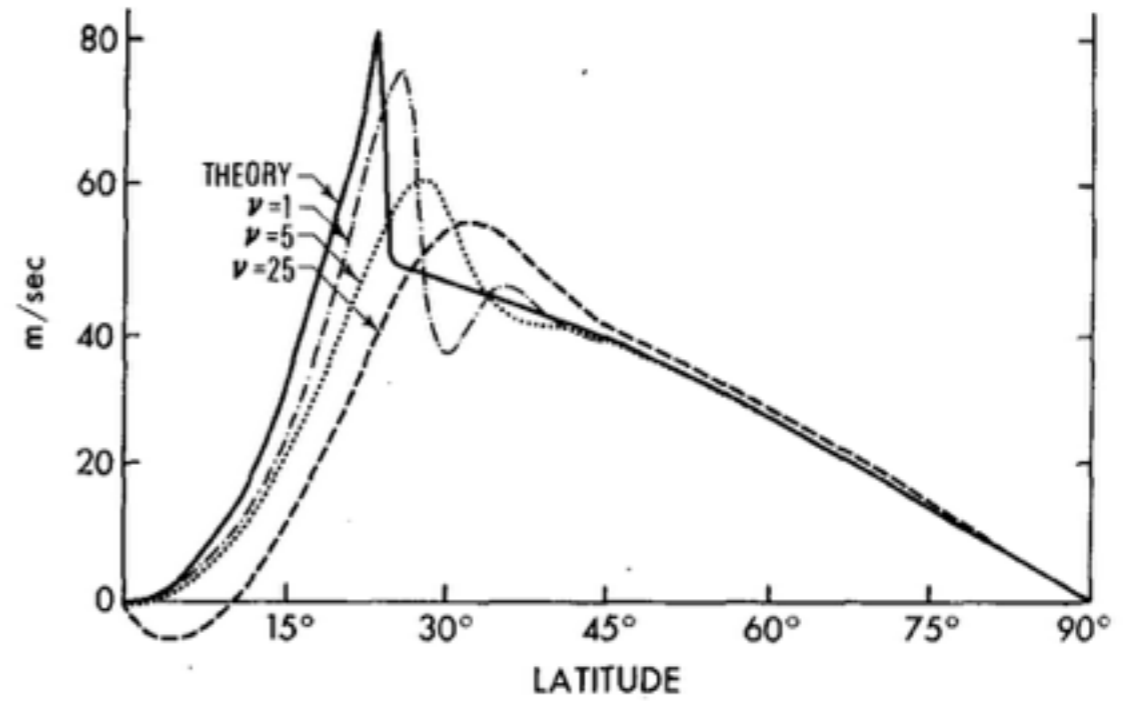


FIG. 5. Zonal winds at $z = H$ in the standard case for three values of ν , compared with the theoretical prediction for $\nu \rightarrow 0$.

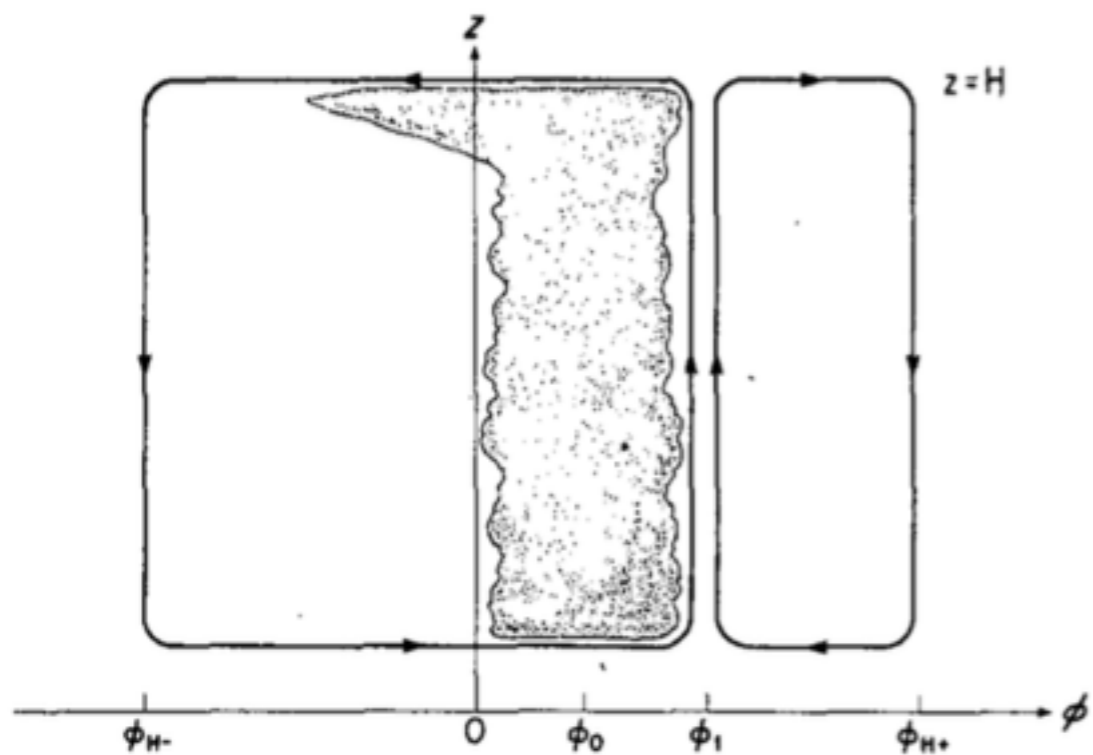


FIG. 3. Schematic illustration of the Hadley circulation.

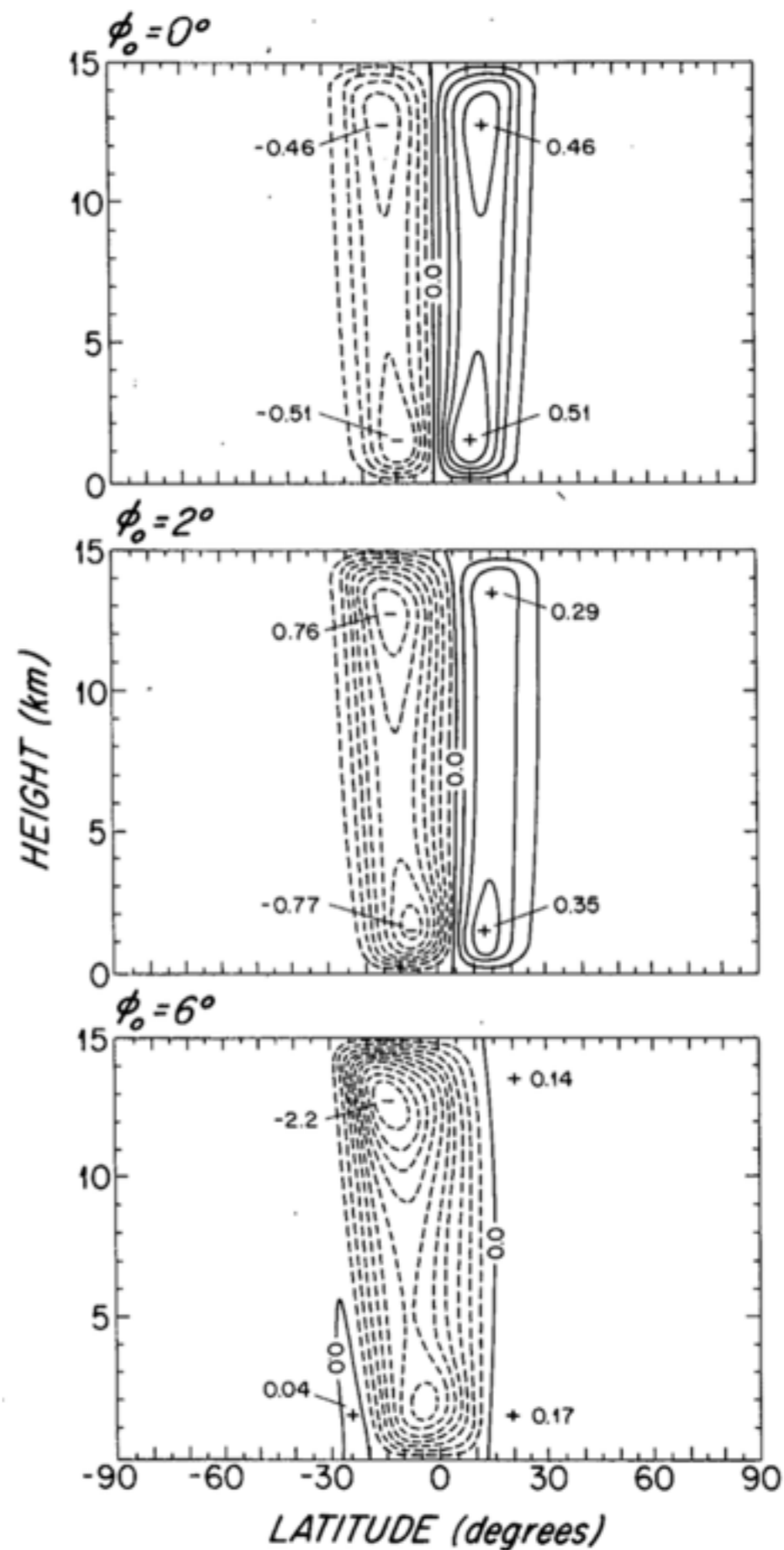


FIG. 9. Numerical model results for ψ for (a) $\phi_0 = 0^\circ$, (b) $\phi_0 = 2^\circ$, and (c) $\phi_0 = 6^\circ$. Units are in $10^{10} \text{ kg s}^{-1}$ and the contour interval is $0.1 \times 10^{10} \text{ kg s}^{-1}$ for (a) and (b); twice this value for (c).

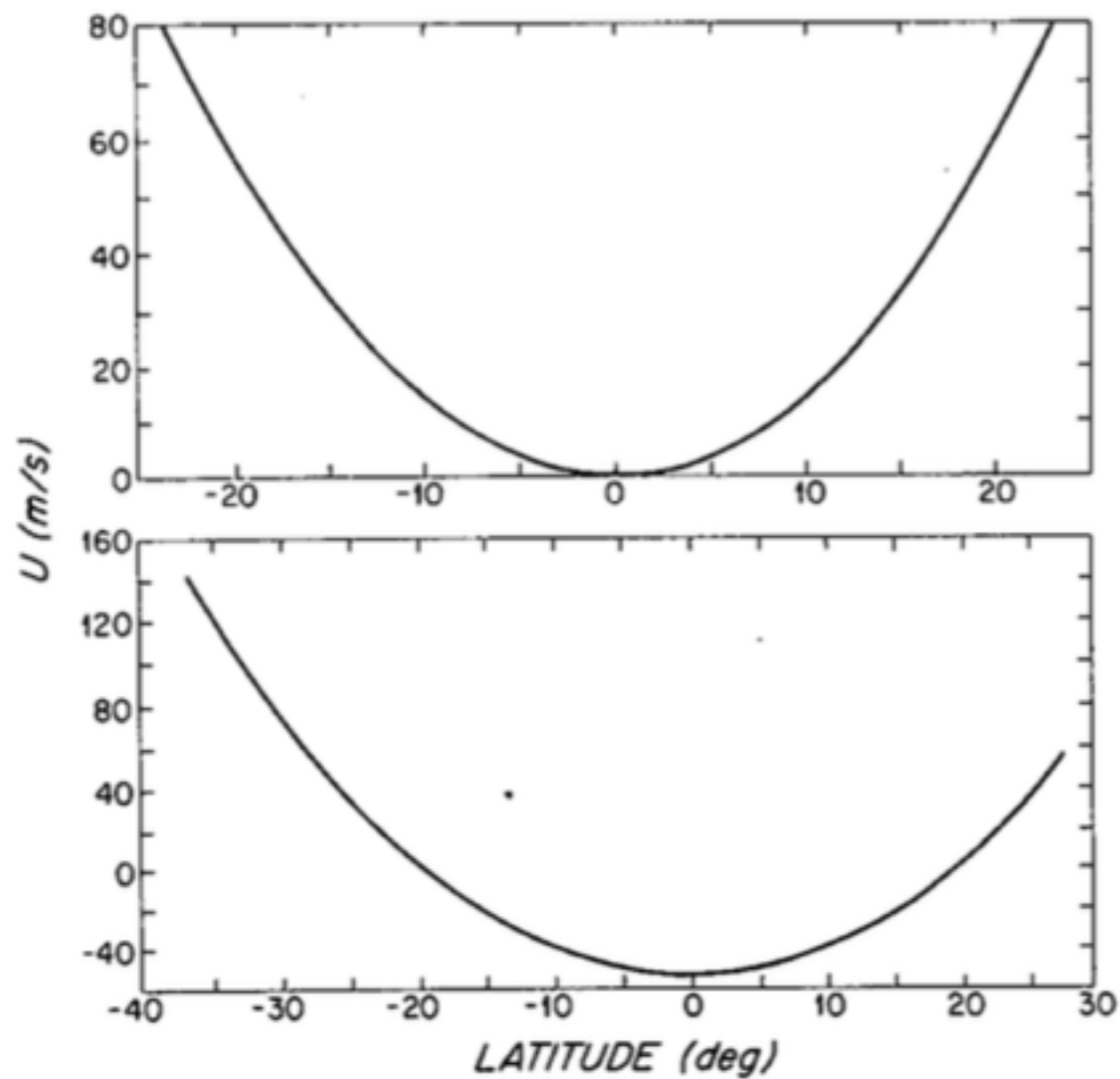


FIG. 6. $u(H, \phi)$ as a function of ϕ using the simple model. (a) $\phi_0 = 0$. (b) $\phi_0 = 6^\circ$.

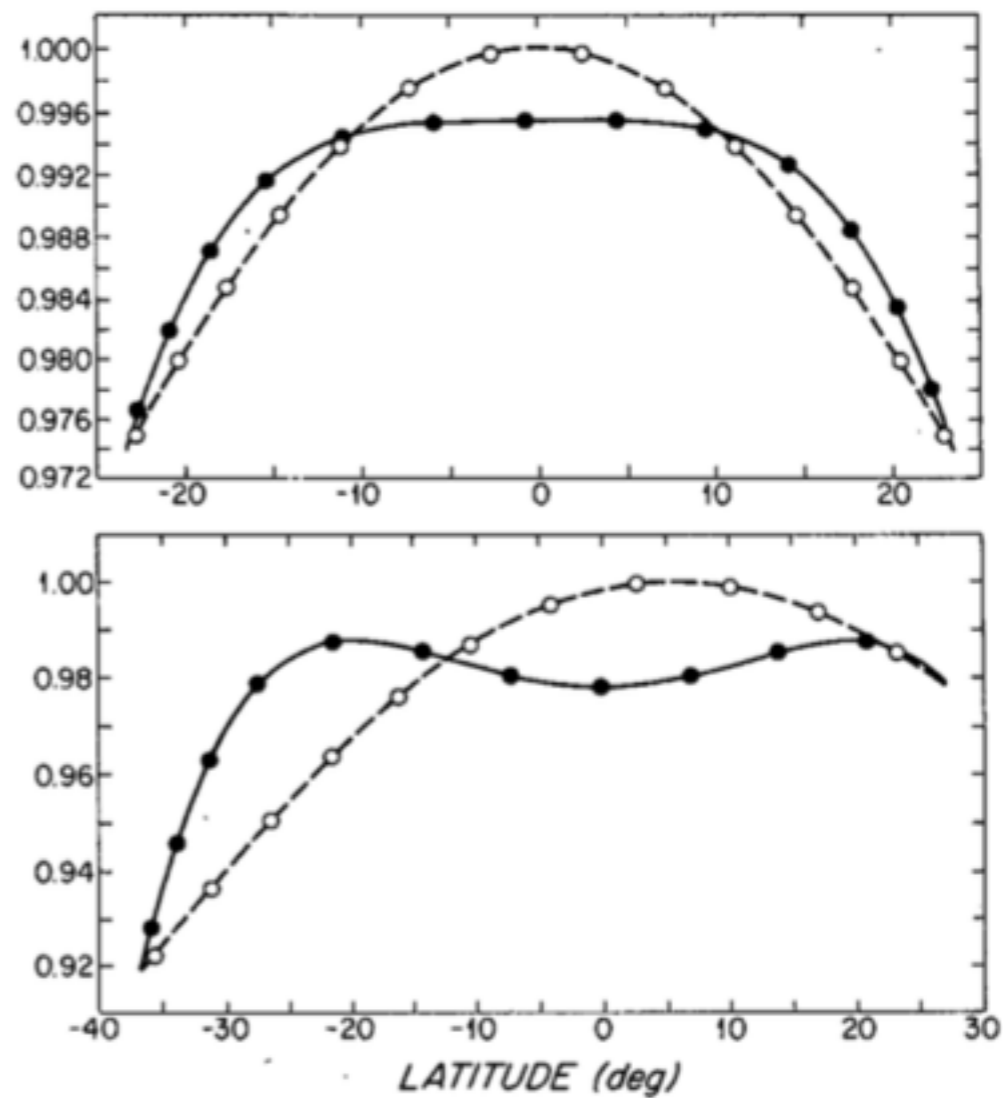
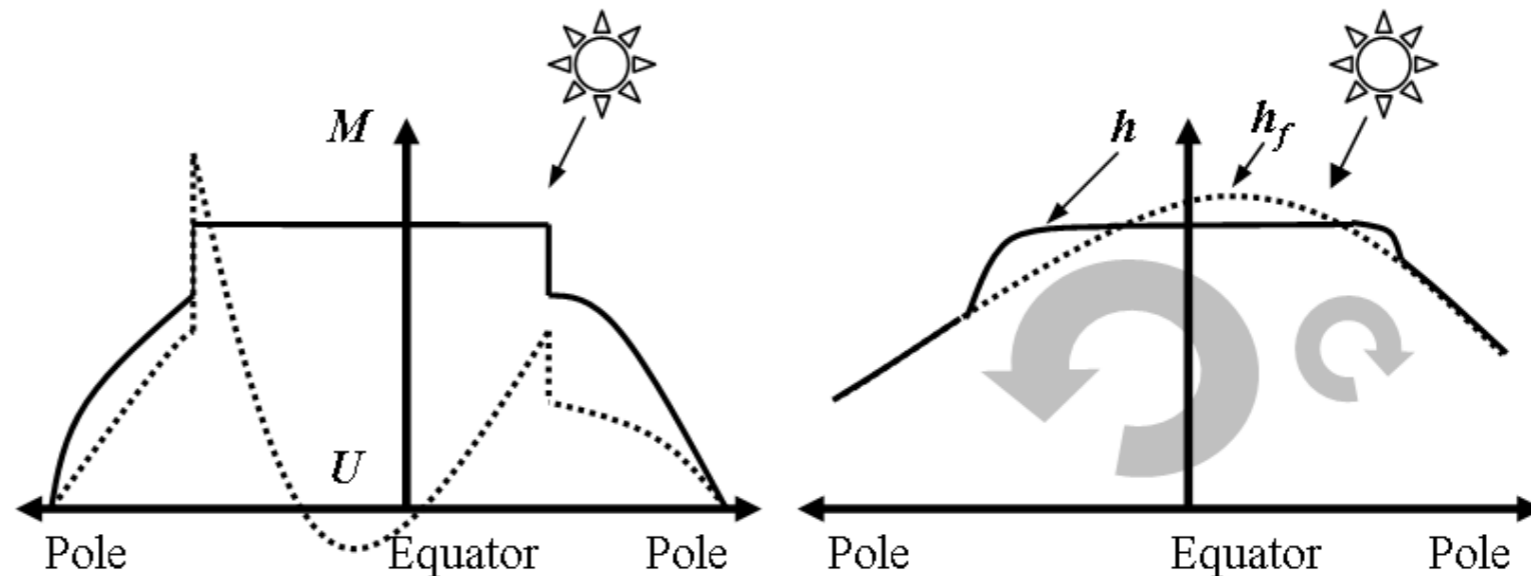
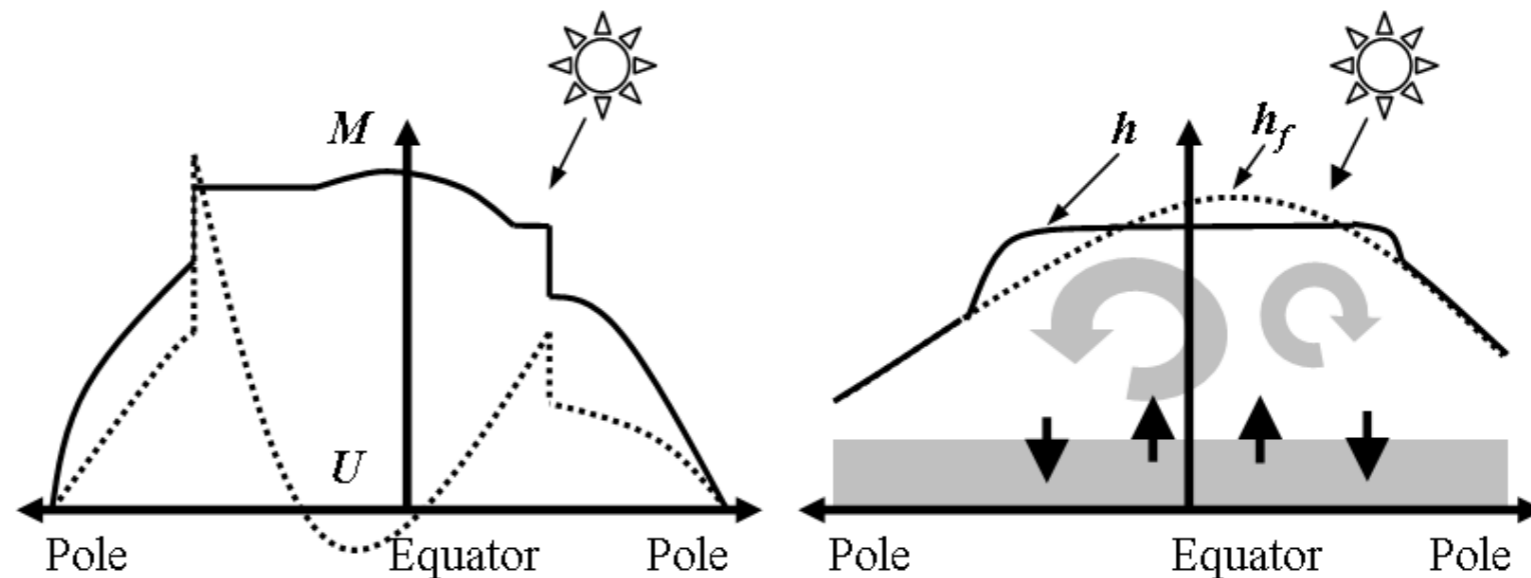


FIG. 5. $\bar{\theta}/\theta_0$ (solid line) and $\bar{\theta}_E/\theta_0$ (dashed line) as functions of ϕ using the simple model. (a) $\phi_0 = 0$. (b) $\phi_0 = 6^\circ$.

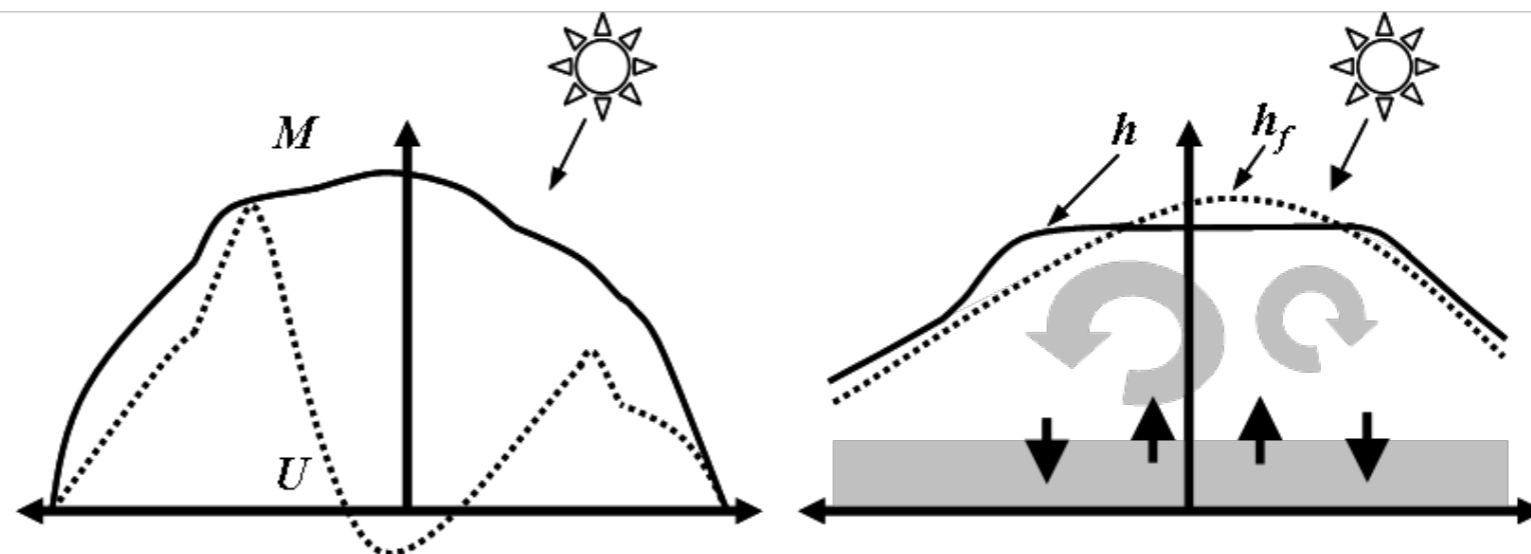
inviscid



nearly inviscid
vertical advection
of momentum



eddy permitting



key points

Equinoctial (Held and Hou 1980):

- mean circulation accounts for about half of the heat transport
- thermally direct circulation must exist at the deep tropics.
- radiative equilibrium can exist only outside the tropics

Off equatorial heating (Lindzen and Hou 1988)

- strong winter Hadley cells and negligible summer cells
- (too strong) easterlies at the equator.