Atmospheric Dynamics

Lect. 9: Laboratory studies and equatorial circulations

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Scope of Lecture

- Rotating “dishpan” experiments
- Axi-symmetric flow and conservation of angular momentum
- Origin of subtropical jets and of easterlies in low latitudes.

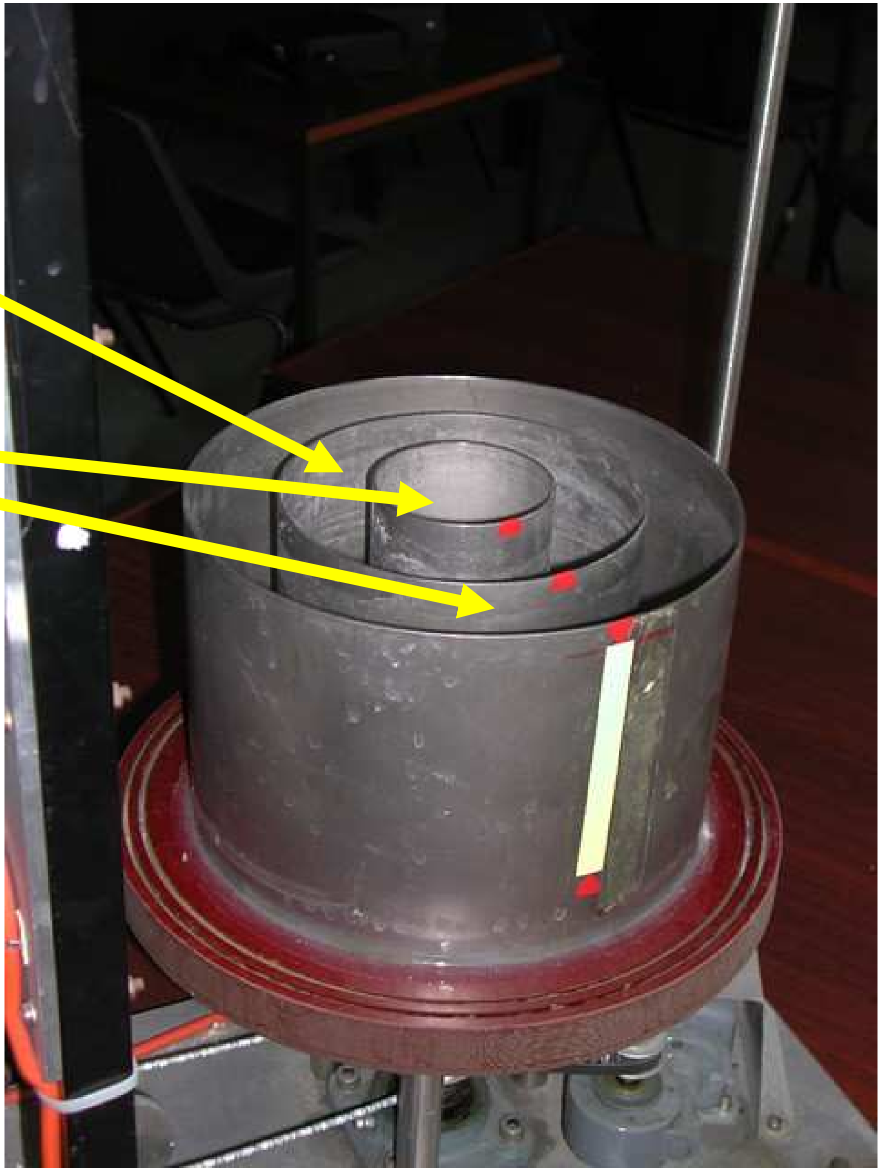
Rotating "dishpan"

Working fluid is between inner and middle cylinders.

Inner cylinder and outer annulus are filled with fluid at constant (different) temperatures.

Whole apparatus rotates

Camera (or equivalent) rotates with the system



Motions generated

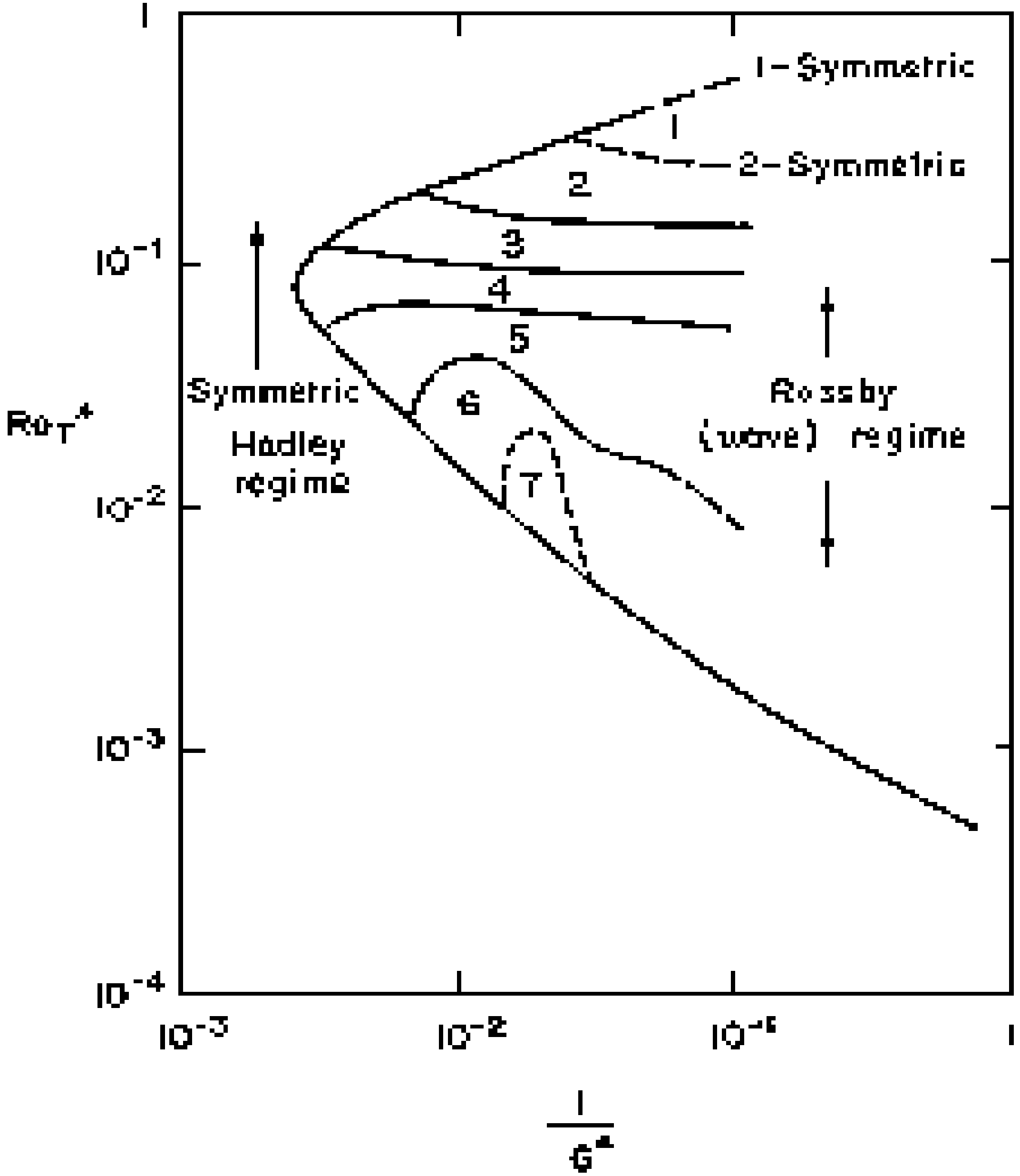
At this point in the presentation some examples of flow are shown, corresponding to different rotation rates and temperature contrasts between the inner and outer cylinders.

In the examples shown, the inner cylinder is heated and the outer annulus is kept cool

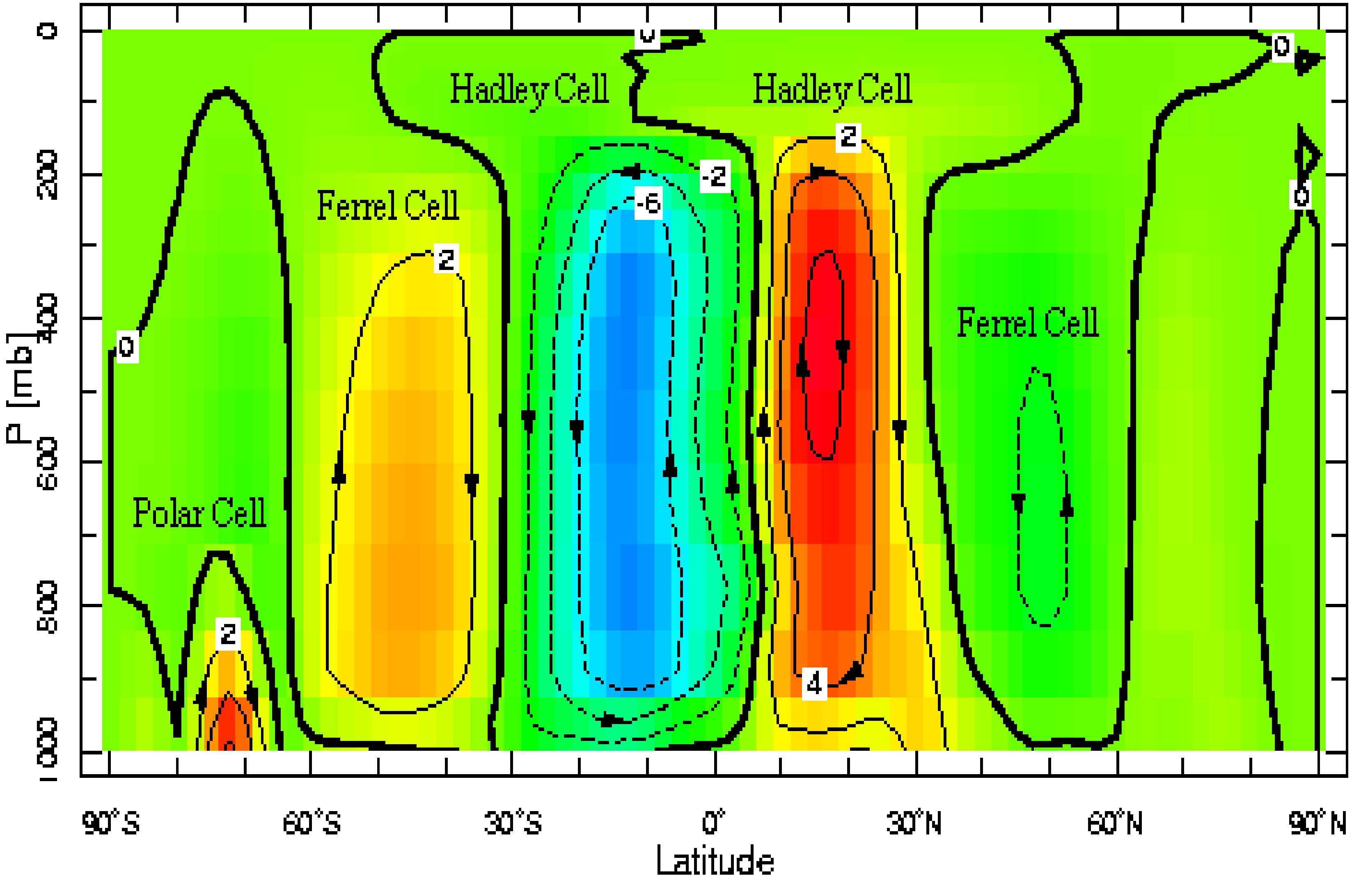
Circulation regimes

$$\text{x-Axis} \propto \Omega^2$$

$$\text{y-Axis} \propto \frac{\Delta T}{\Omega^2}$$

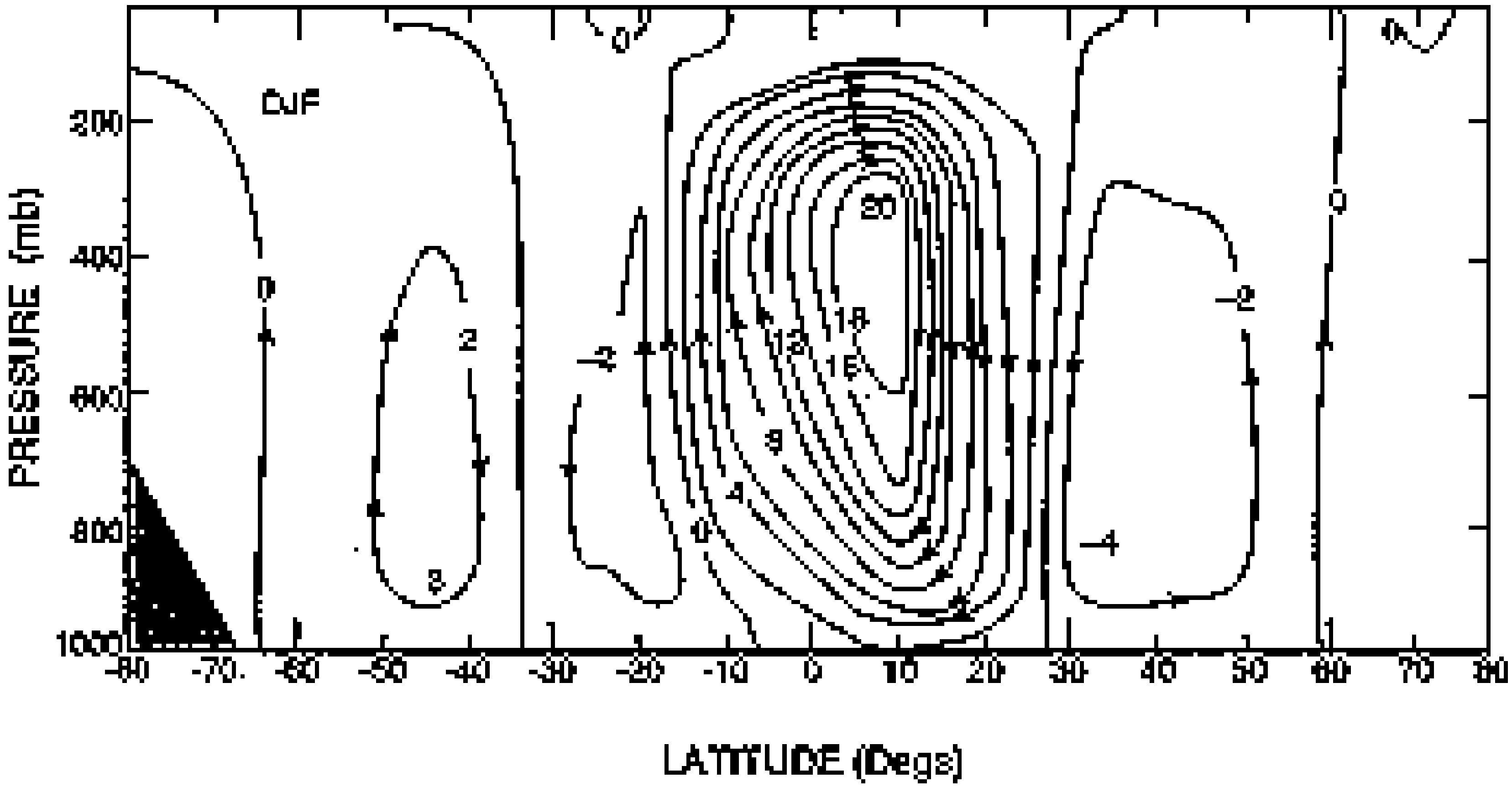


Mean meridional circulation



Tropical circulations

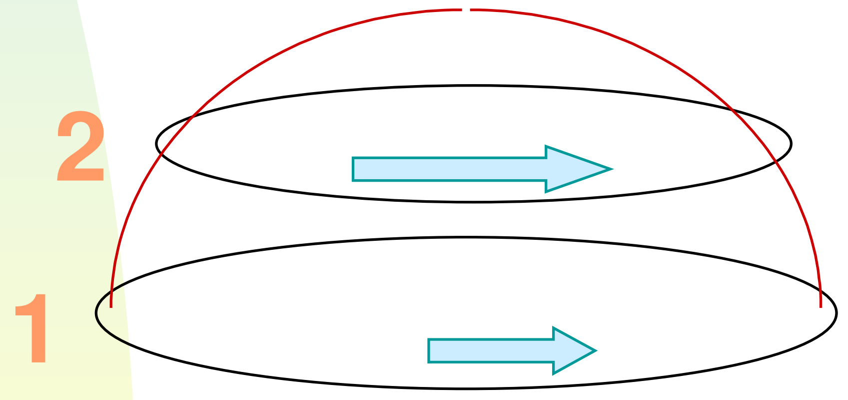
Zonal mean meridional circulation (Streamlines)



N. Hemi. Winter solstice

Tropical circulations: cont.

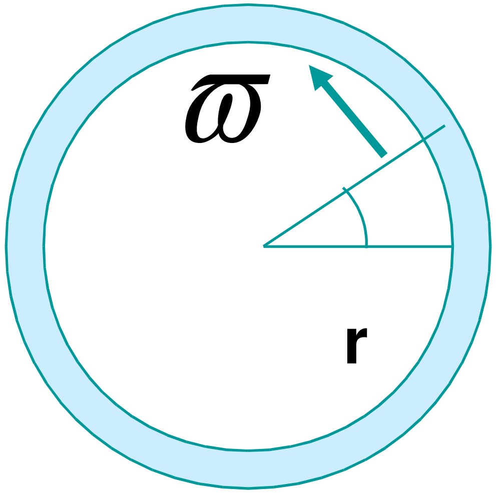
- Dishpan experiments suggest small longitudinal variations in tropics
- Hence rings of air initially at same latitude move as rings
- Ring moves from position 1 to position 2 due to Hadley circulation



Conservation of angular momentum

View from

Pole star



ϖ Is angular velocity of ring

$$\varpi m r^2 = const \qquad \varpi r^2 = const$$

$$\varpi = \Omega + \frac{u}{r} \qquad r = (a+z)\cos\phi$$

$$\left[\Omega + \frac{u}{(a+z)\cos\phi}\right](a+z)^2\cos^2\phi = const$$

But a>>z $\longrightarrow$ $\Omega a \cos^2\phi + u\cos\phi = const$

Equinox case

Sun overhead at equator

Rising motion at equator

Friction makes u small near to the surface.

As first approx take u=0 at surface, so thereafter

$$\Omega a \cos^2\phi + u\cos\phi = \Omega a$$

$$u = \Omega a\left(1-\cos^2\phi\right)/\cos\phi$$

RHS>0, so westerlies develop as ring of air moves poleward

Solstice case

Sun overhead at subtropics

Rising motion at subtropics

As first approx take u=0 at surface where $\phi = \phi_o$

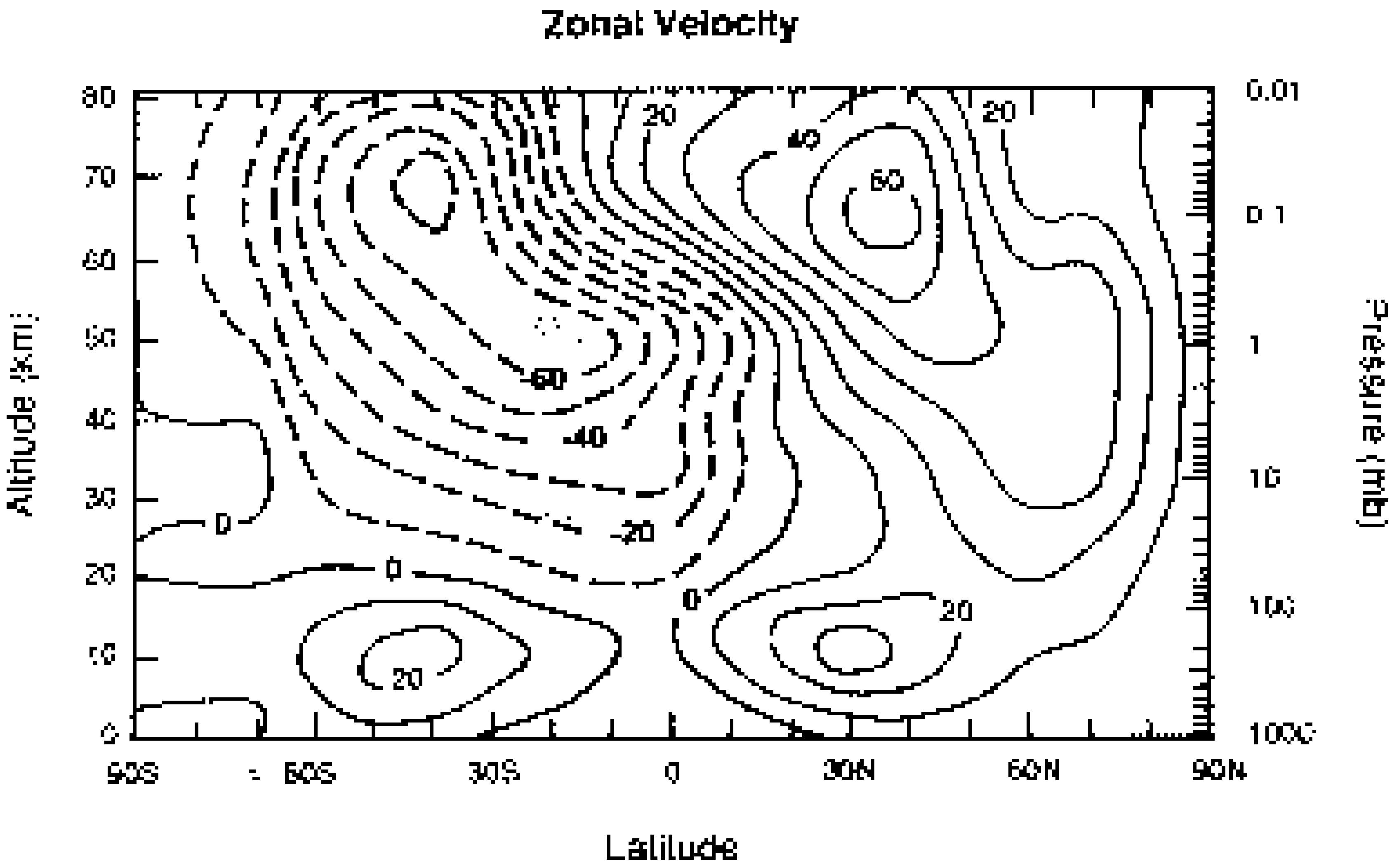
so thereafter

$$\Omega a \cos^2 \phi + u \cos \phi = \Omega a \cos^2 \phi_o$$

Note that aloft at equator

$$u = \Omega a \left(\cos^2 \phi_o - 1 \right) < 0$$

Zonal mean zonal wind component



N. Hemi. Winter solstice westerlies (i.e. w-e) +ve