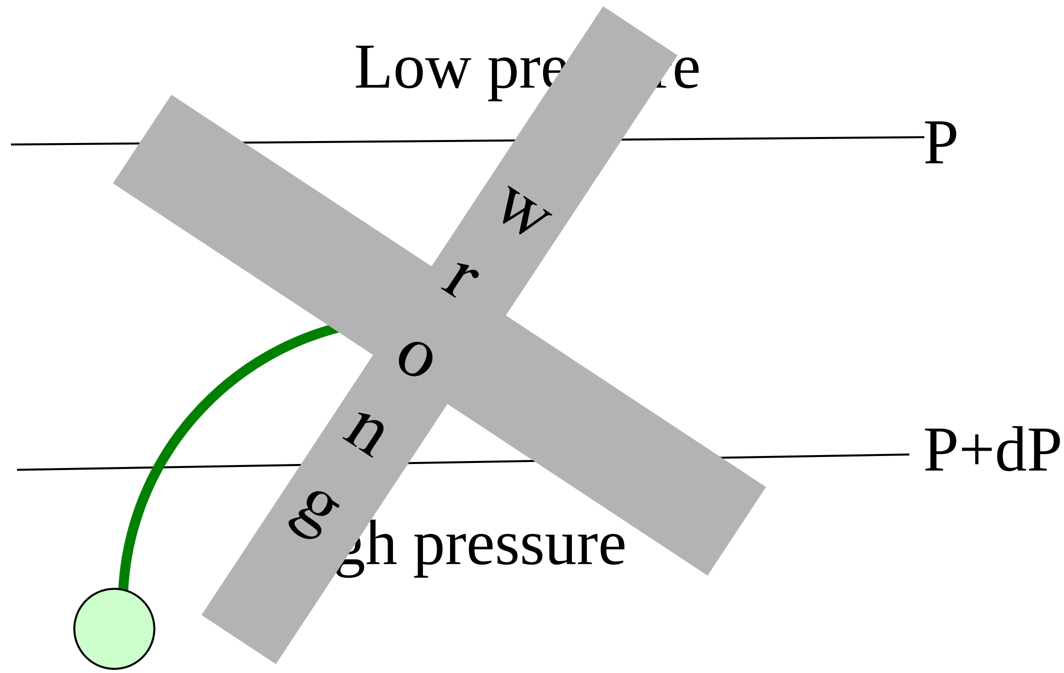
Dynamic meteorology without tears

Part IV: Three kinds of jet streams

3. Acceleration of the wind in a constant pressure field

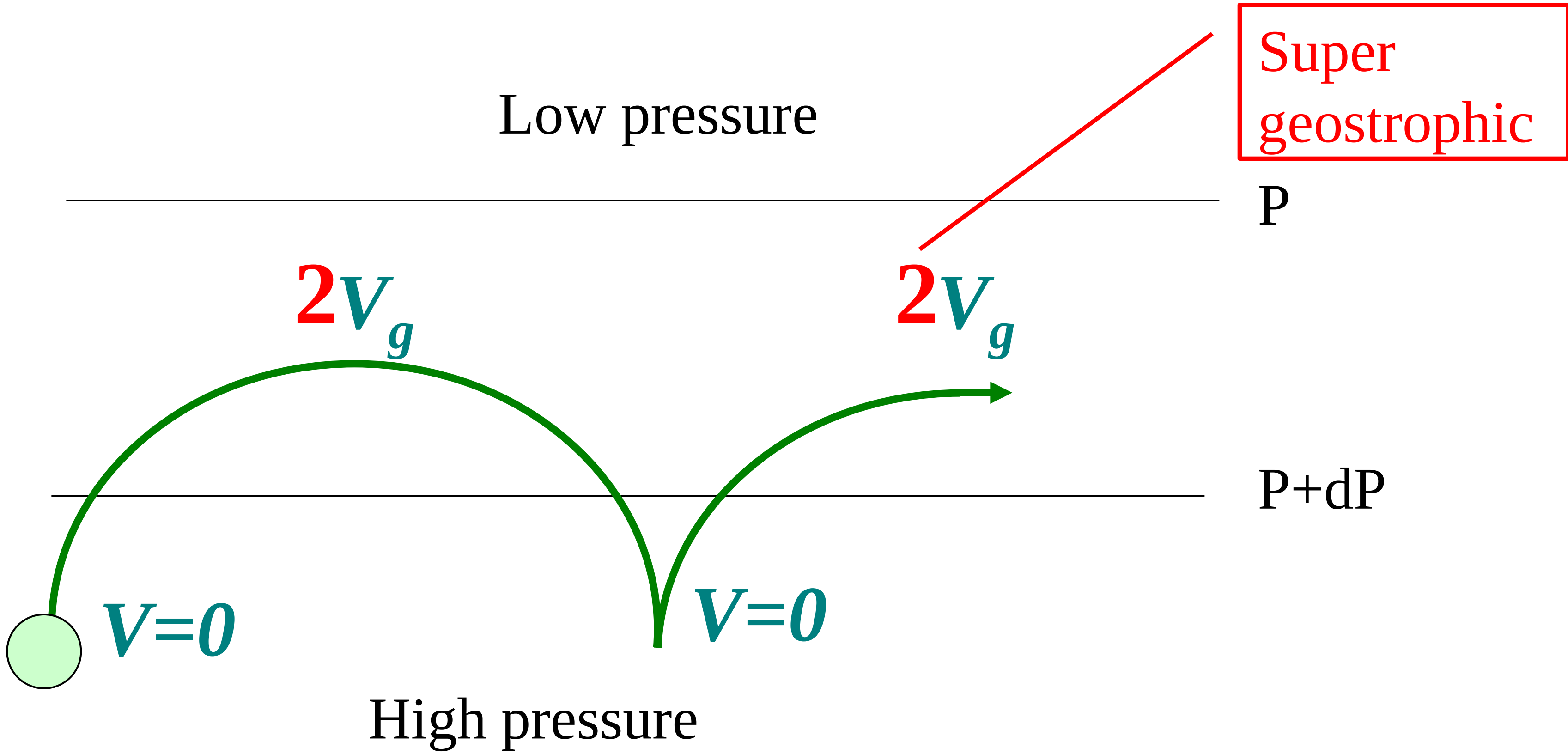
$$\frac{du}{dt} - fv = 0$$

$$\frac{dv}{dt} + fu = -\frac{\partial P}{\rho \cdot \partial y}$$



The common textbook (erroneous) interpretation gives an image of a smooth "well behaved" approach to geostrophic balance

The real image looks more like a case of "road rage" when the super geostrophic winds turn to the right



This is no "playing with mathematics" but the basis for an understanding of different types of jet streams

Three important jet streams:

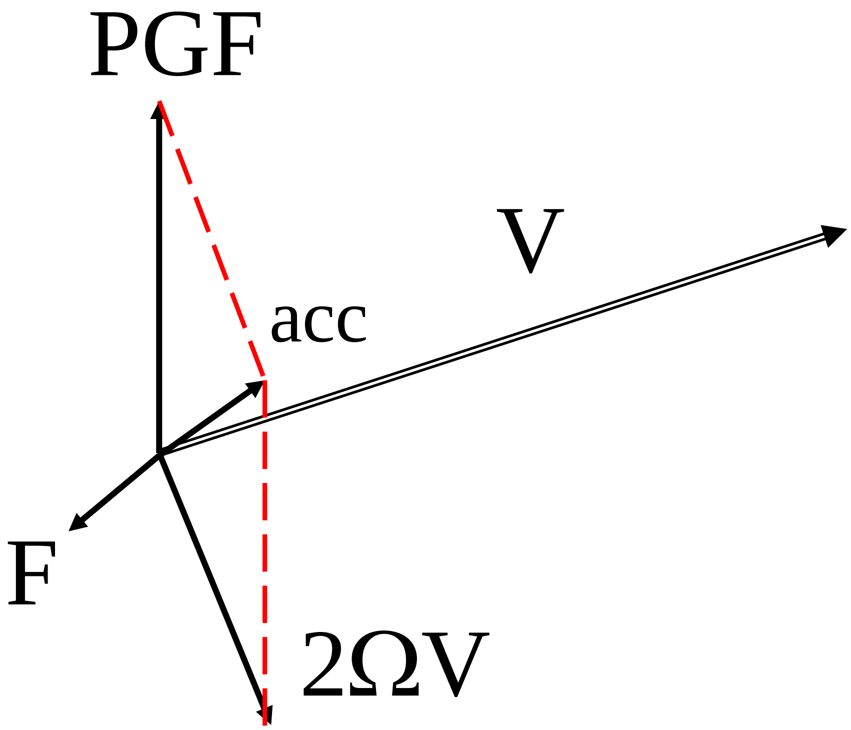
1. **Nocturnal jet stream**

2. **Synoptic scale jet streams**

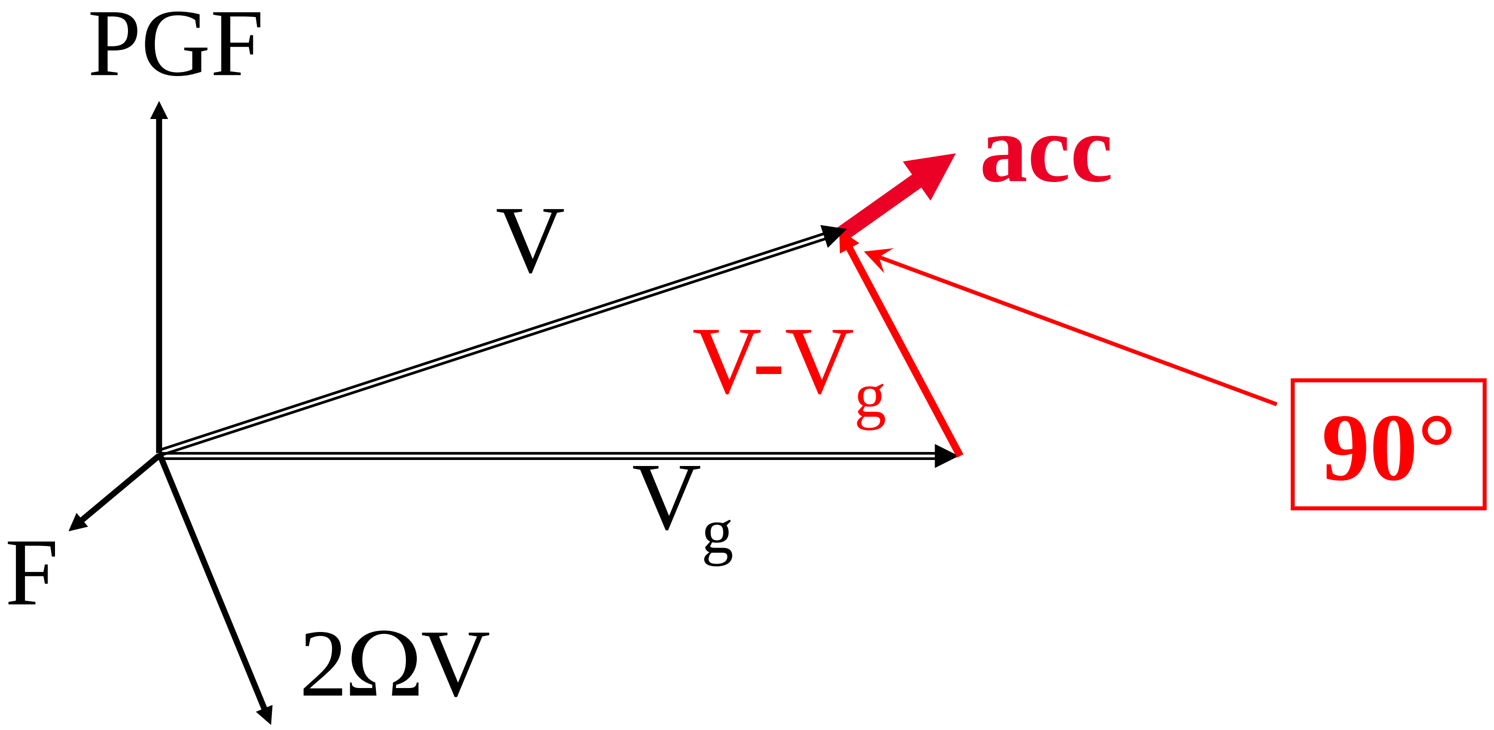
3. **The subtropical jetstream**

1. Nocturnal jet streams

The forces on an air parcel, pressure gradient force (PGF), Coriolis force (2ΩV) and friction, balance each other



We now introduce the difference between the geostrophic and ageostrophic winds $V\text{-}V_g$

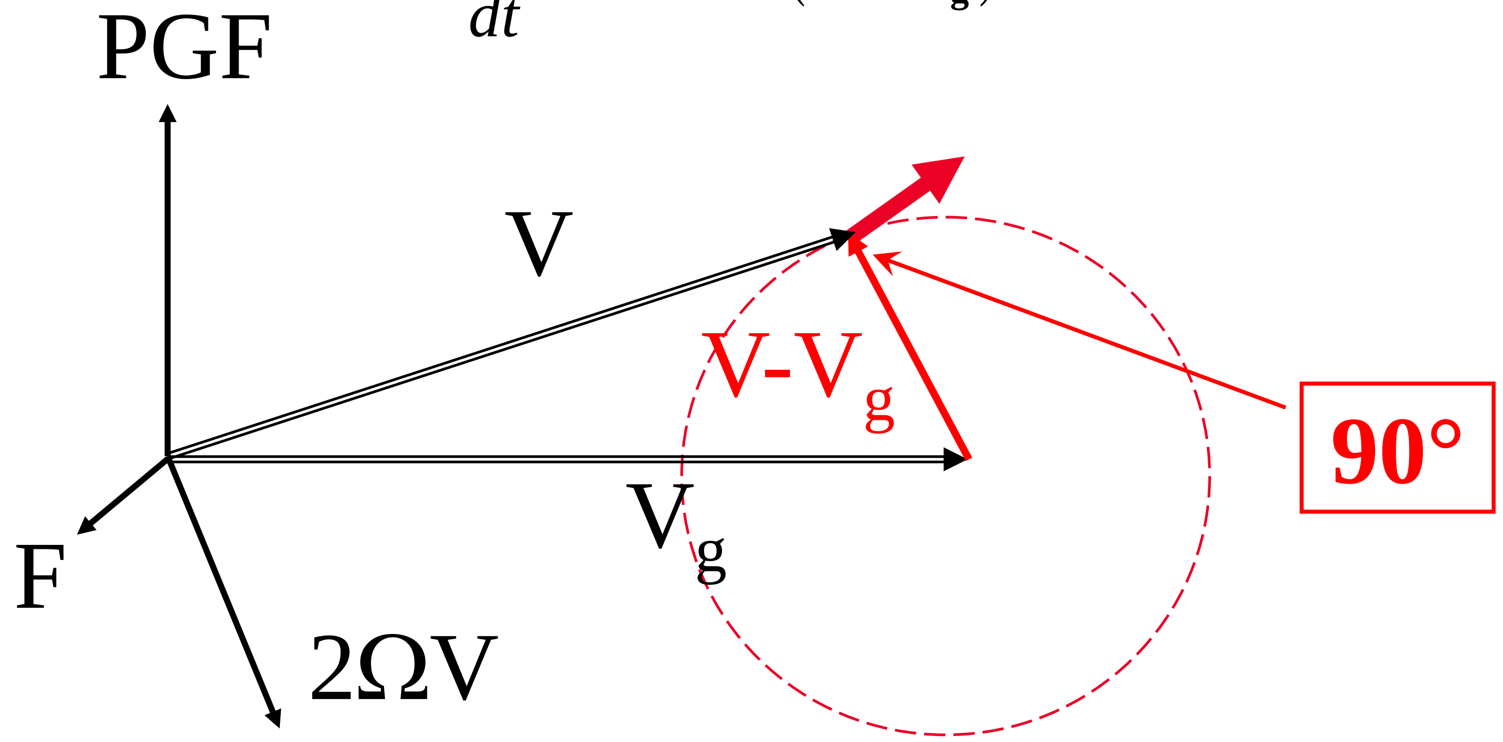


$$acc = \frac{d\mathbf{V}}{dt} = -f\,\mathbf{k} \times \left(\mathbf{V} - \mathbf{V_g}\right)$$

"The Heart of Dynamic Meteorology"

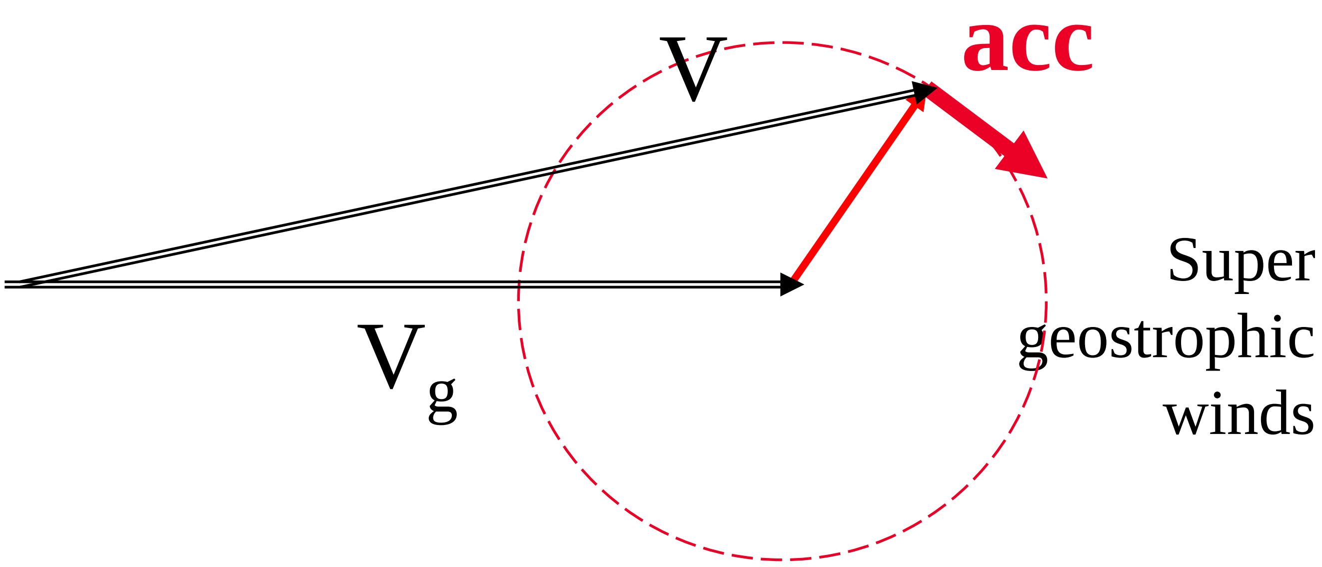
R.C.Sutcliffe, 1981

$$\frac{d\mathbf{V}}{dt} = -f\,\mathbf{k}\times\left(\mathbf{V}-\mathbf{V_g}\right)$$

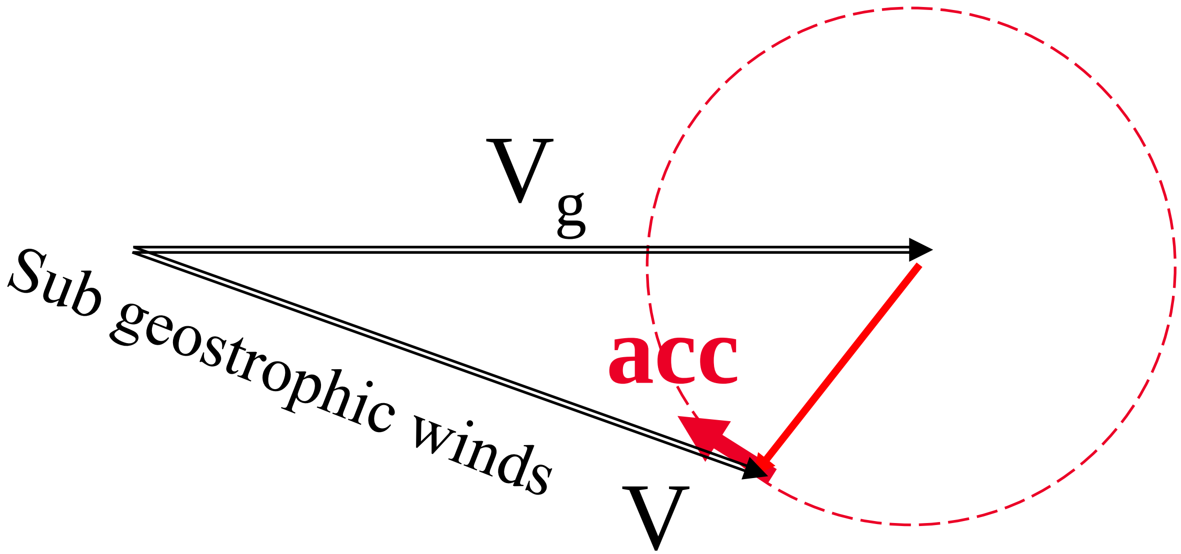


The acceleration, orthogonal to the ageostrophic wind drives the wind hodograph into a circular orbit

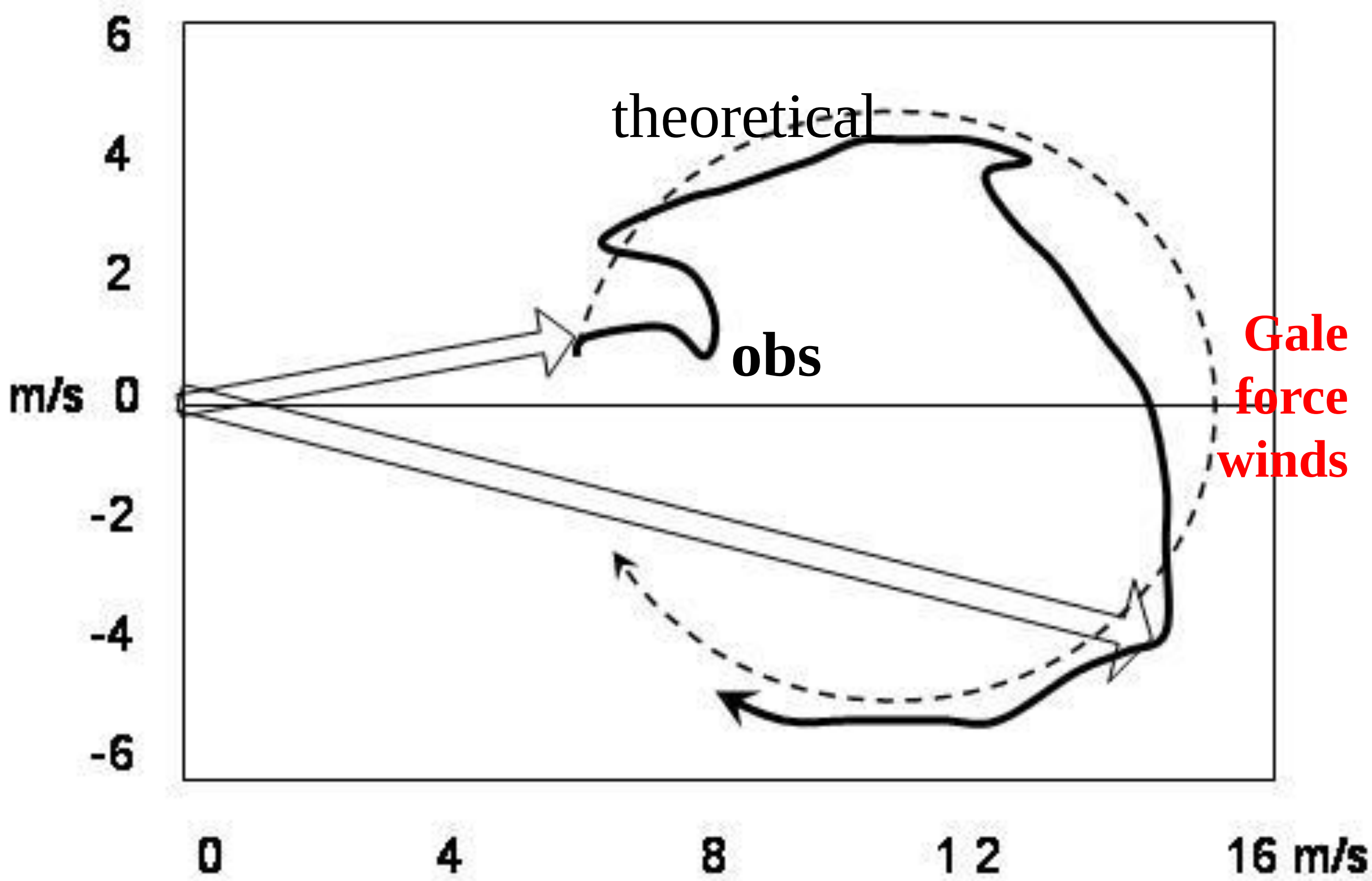
The acceleration carries the air parcel around in a circular motion



The acceleration carries the air parcel around in a circular motion



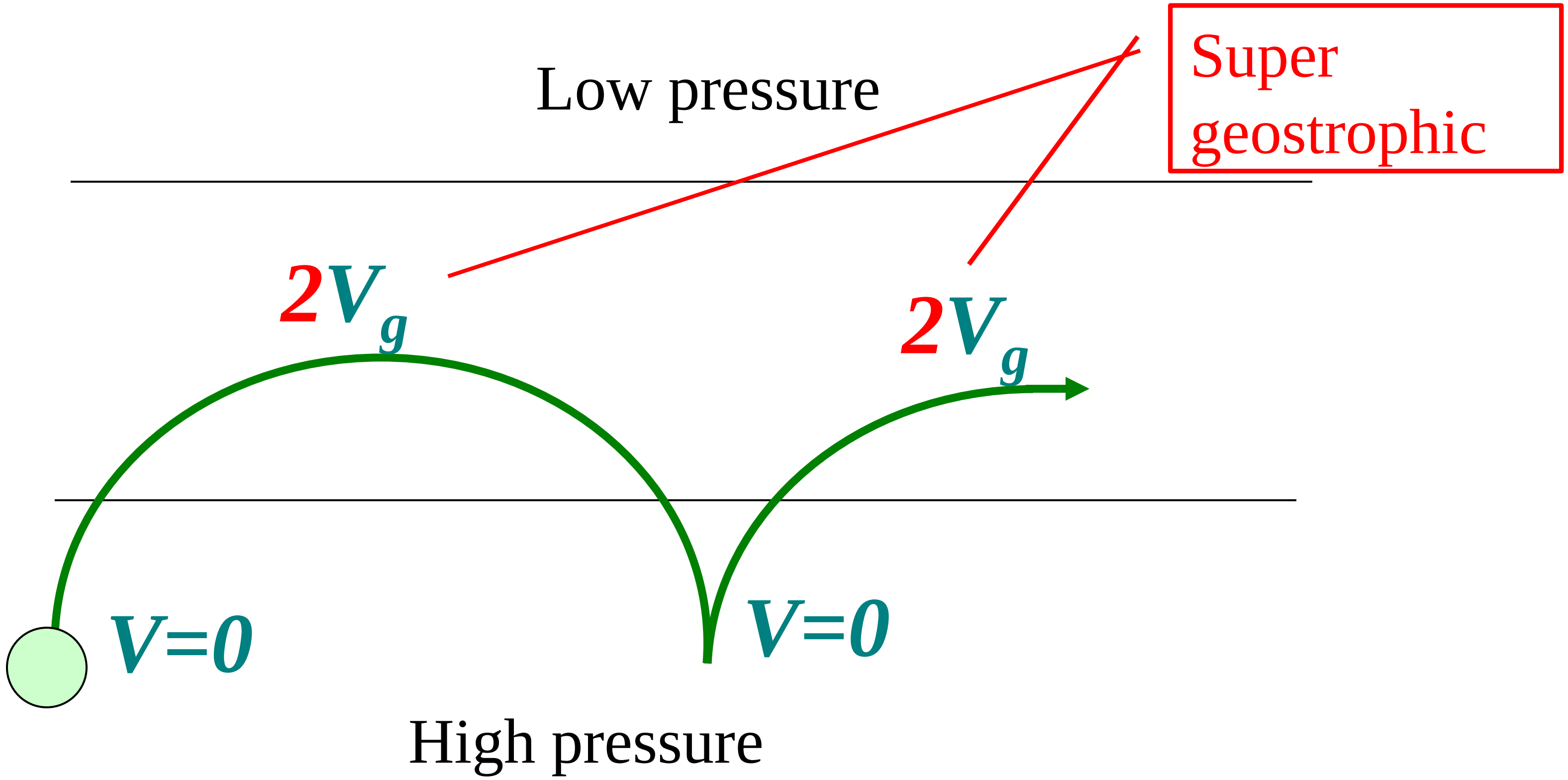
Authentic inertial oscillation, “nocturnal jet” over 14-15 hours (Netherlands)



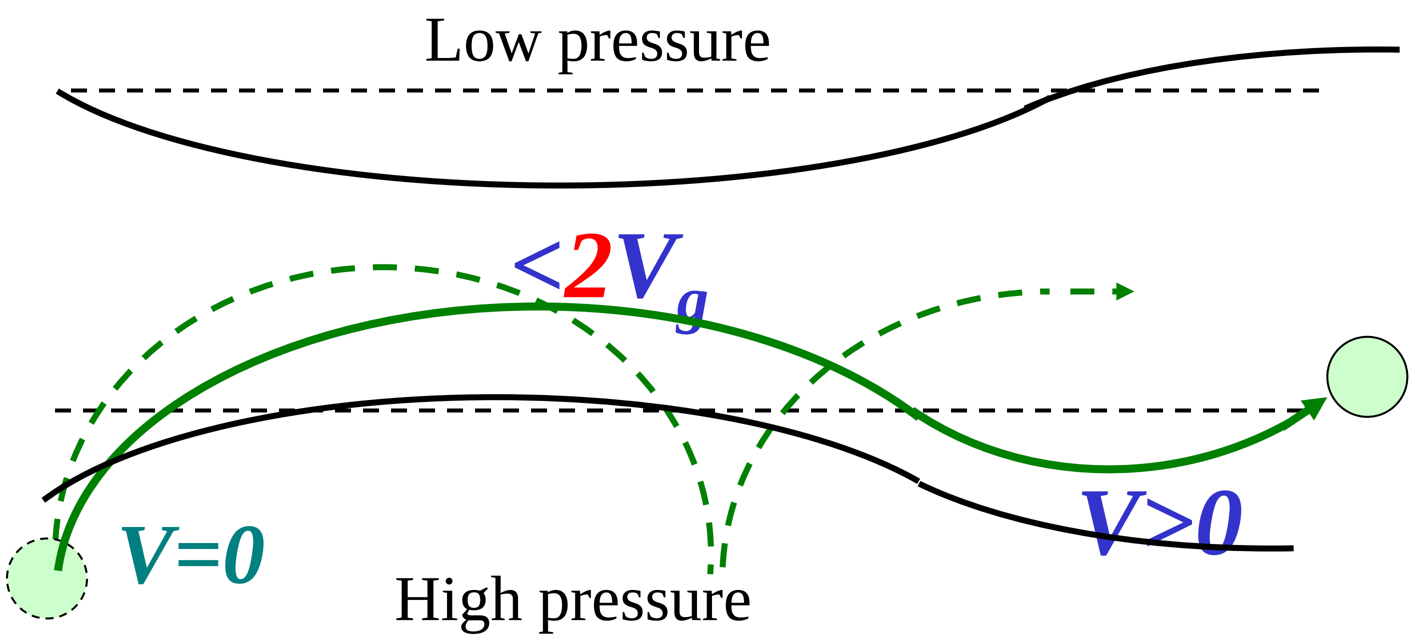
In this nocturnal jet the wind varies between 5 and 16 m/s

2. Synoptic jet streams

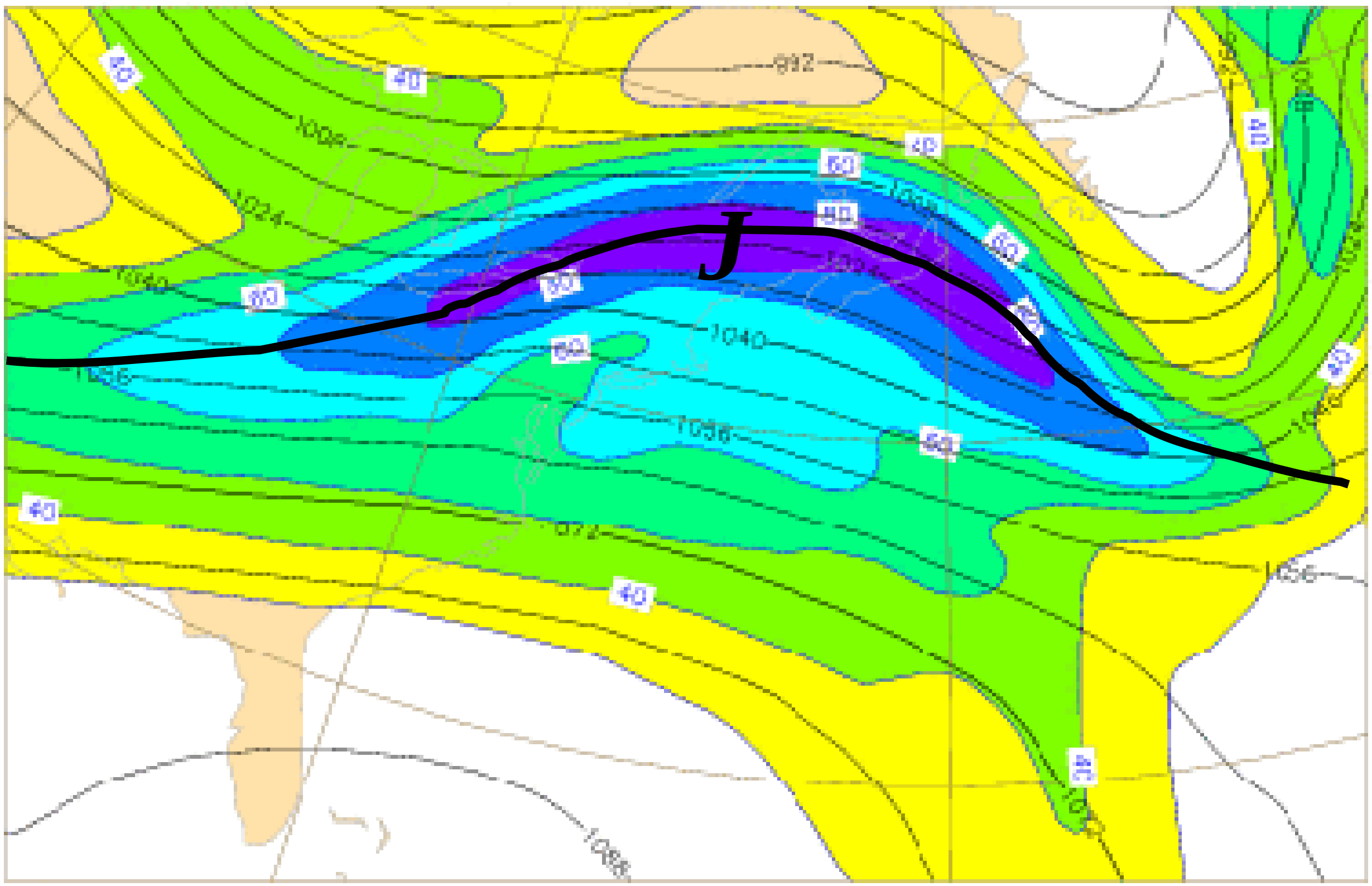
The real image of motion of an air parcel in a **constant** pressure field



The pressure field and the winds will **mutually** adjust to each other and stretch the cycloid from a **normal** to a **curtate**



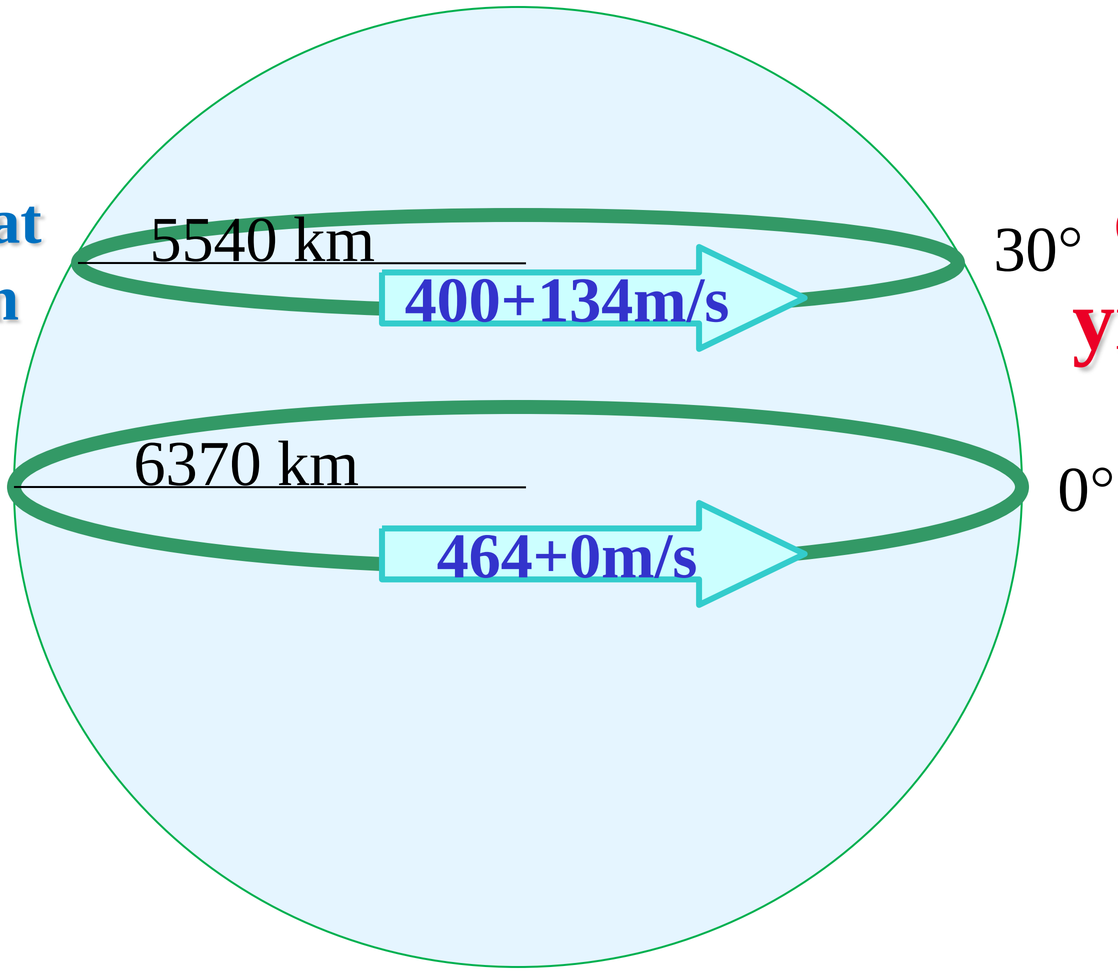
The unperturbed mid-latitude jetstream (similar to the Subtropical in appearance)



3. The Subtropical Jet Stream and its seasonal variations

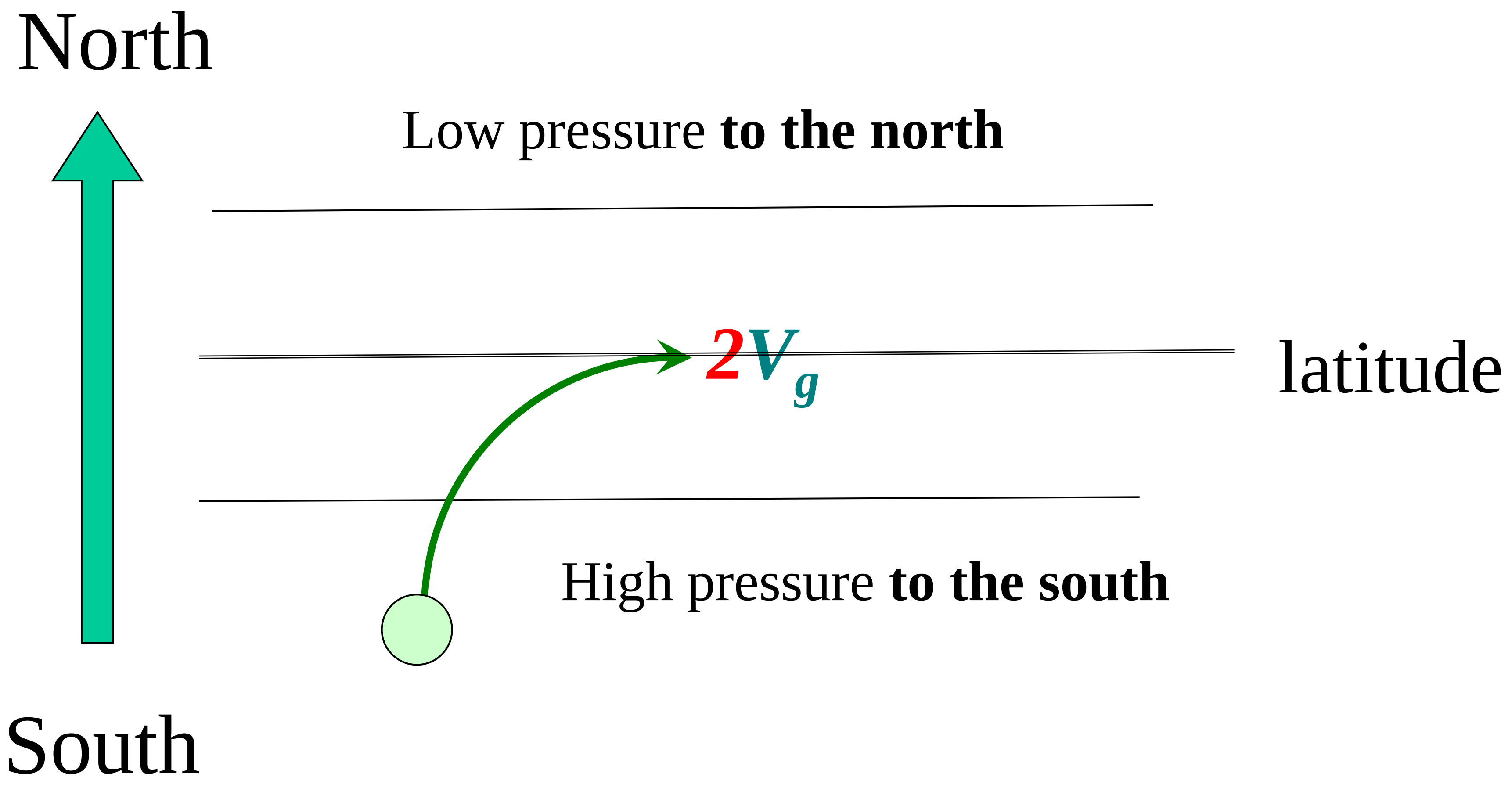
The problem with angular momentum conservation

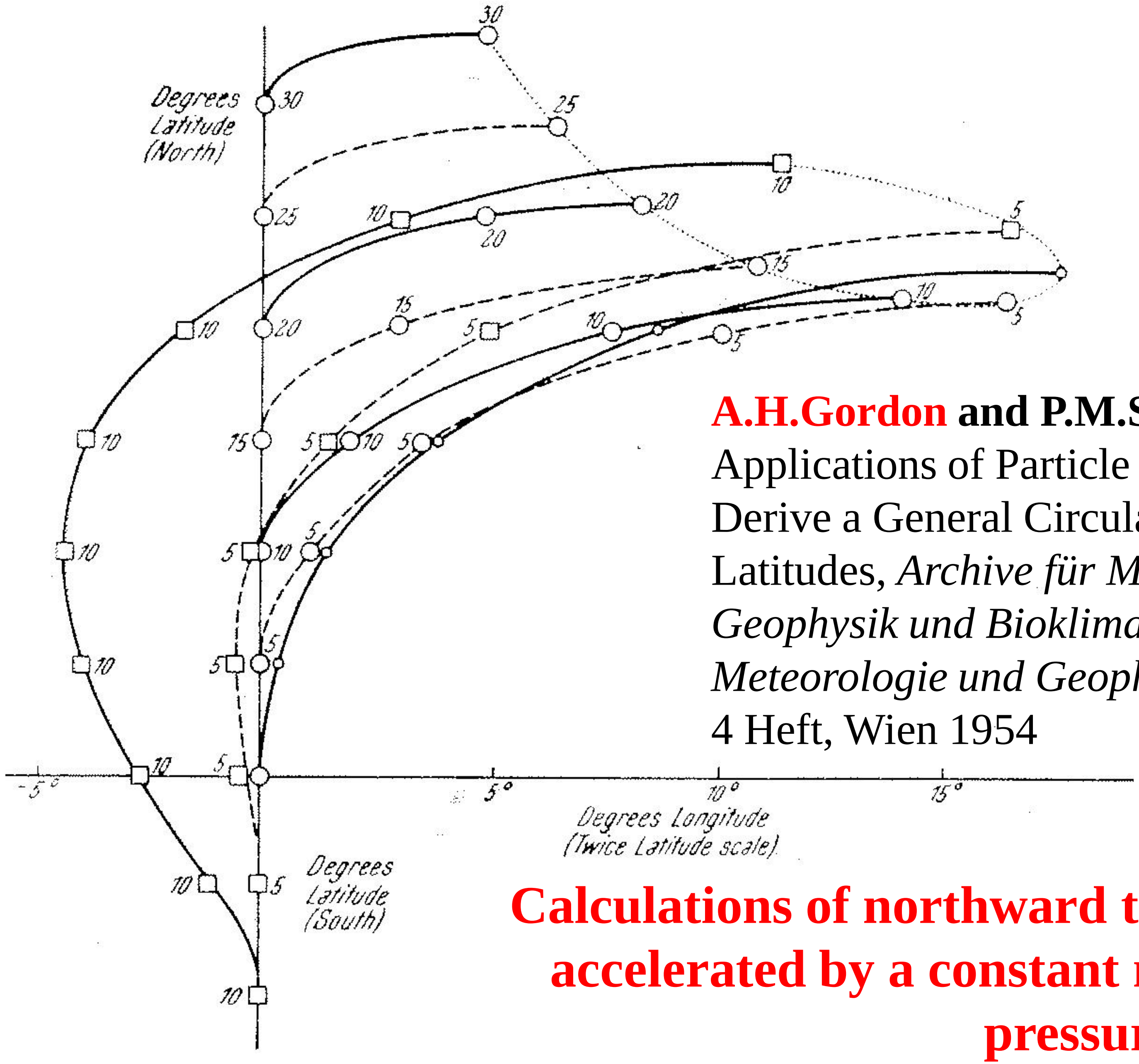
An equatorial ring of air at rest is given an impulse and is displaced to 30° latitude



Angular momentum conservation yields 134 m/s at 30° latitude, double to what is observed.

Assume the isobars are latitude parallel

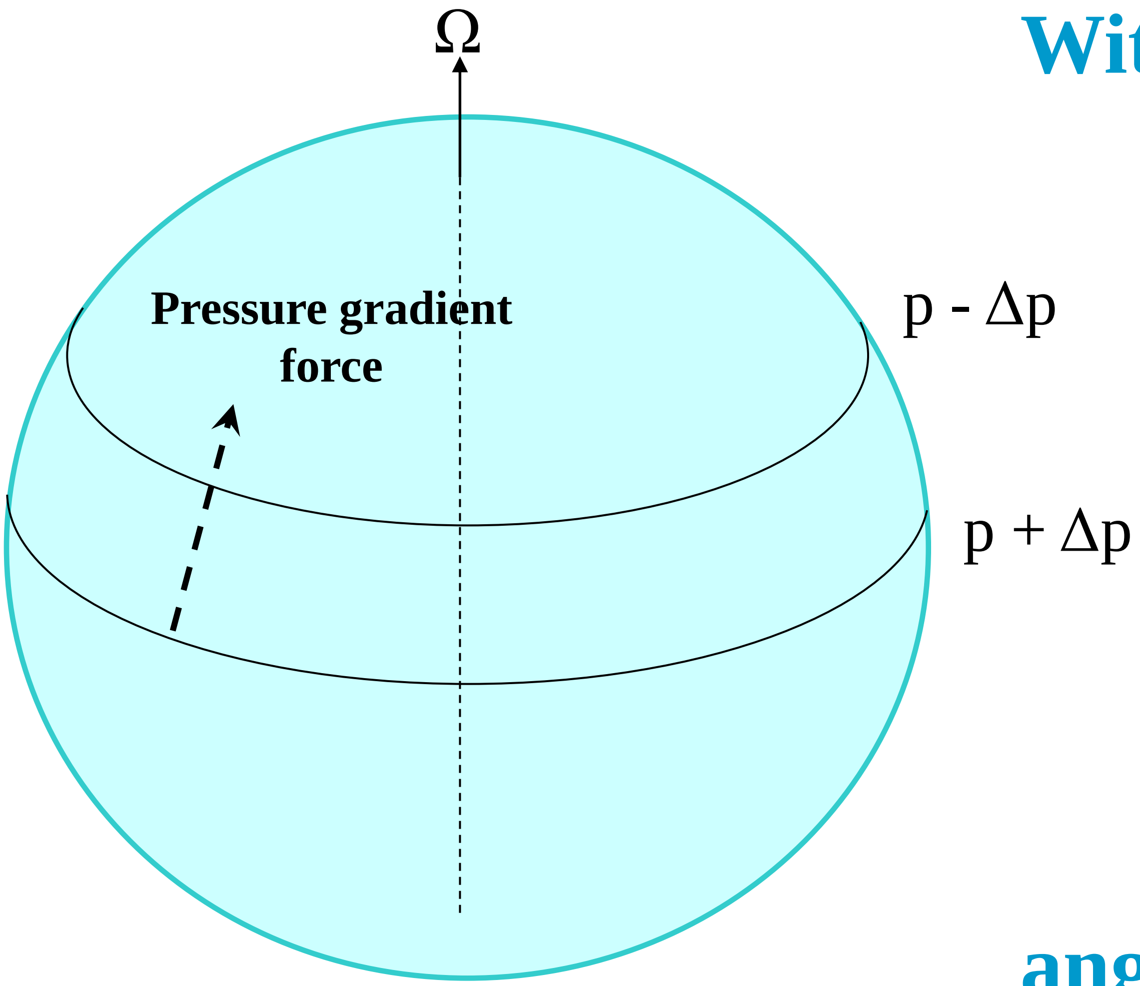




A.H.Gordon and P.M.Shaw, 1954: Applications of Particle Dynamics to Derive a General Circulation in Low Latitudes, *Archive für Meteorologie, Geophysik und Bioklimatoligie, Serie A: Meteorologie und Geophysik*, Band 6, 3-4 Heft, Wien 1954

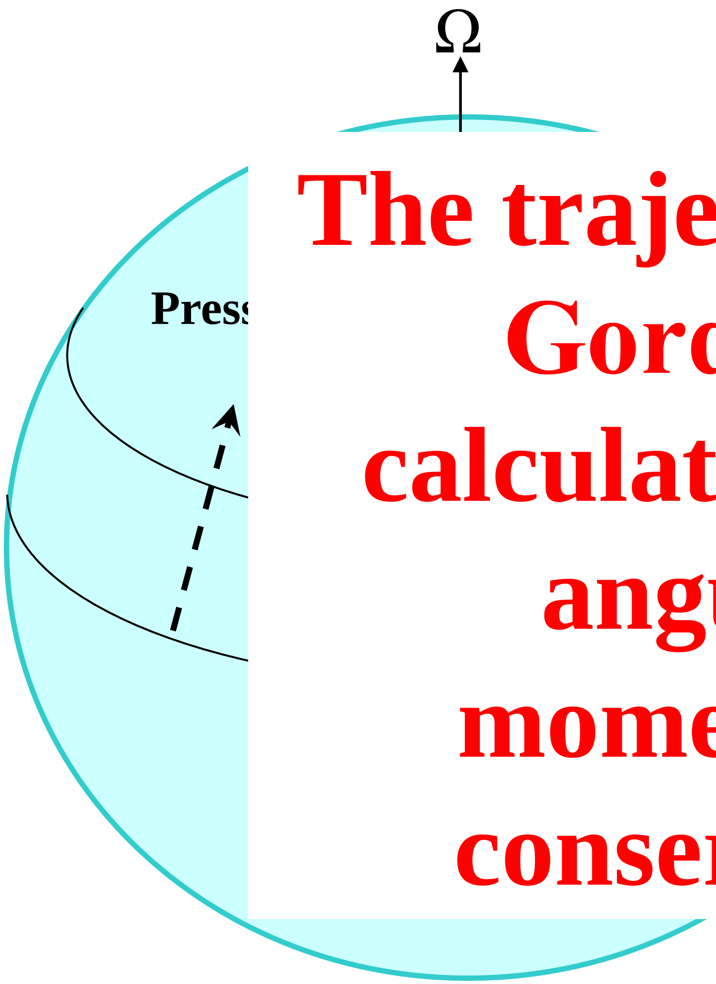
Calculations of northward trajectories accelerated by a constant meridional pressure gradient

THE GREAT REVELATION:



With isobars running parallel to the latitudes the pressure gradient force will <u>not</u> produce a torque that would change the absolute angular momentum

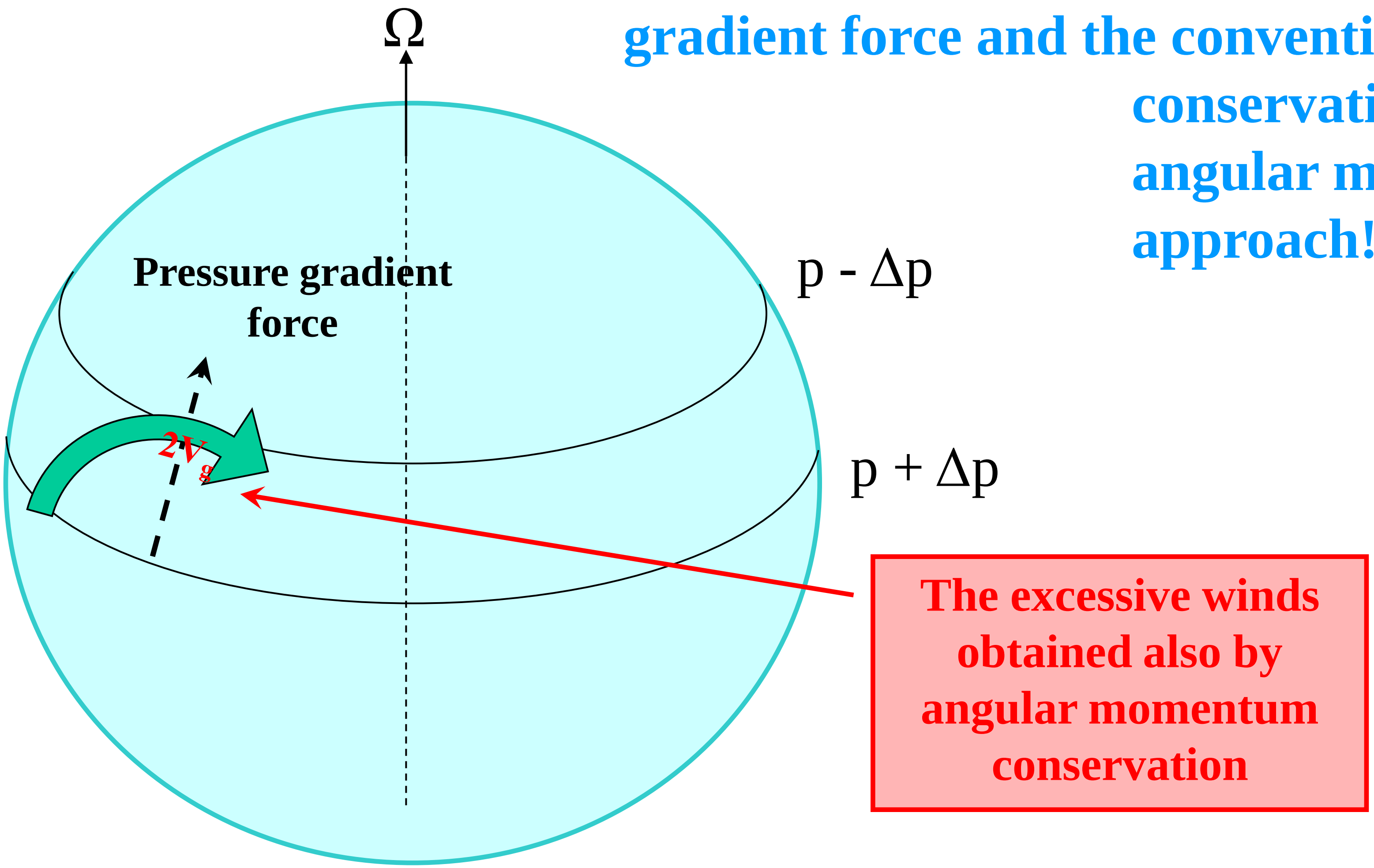
THE GREAT REVELATION:

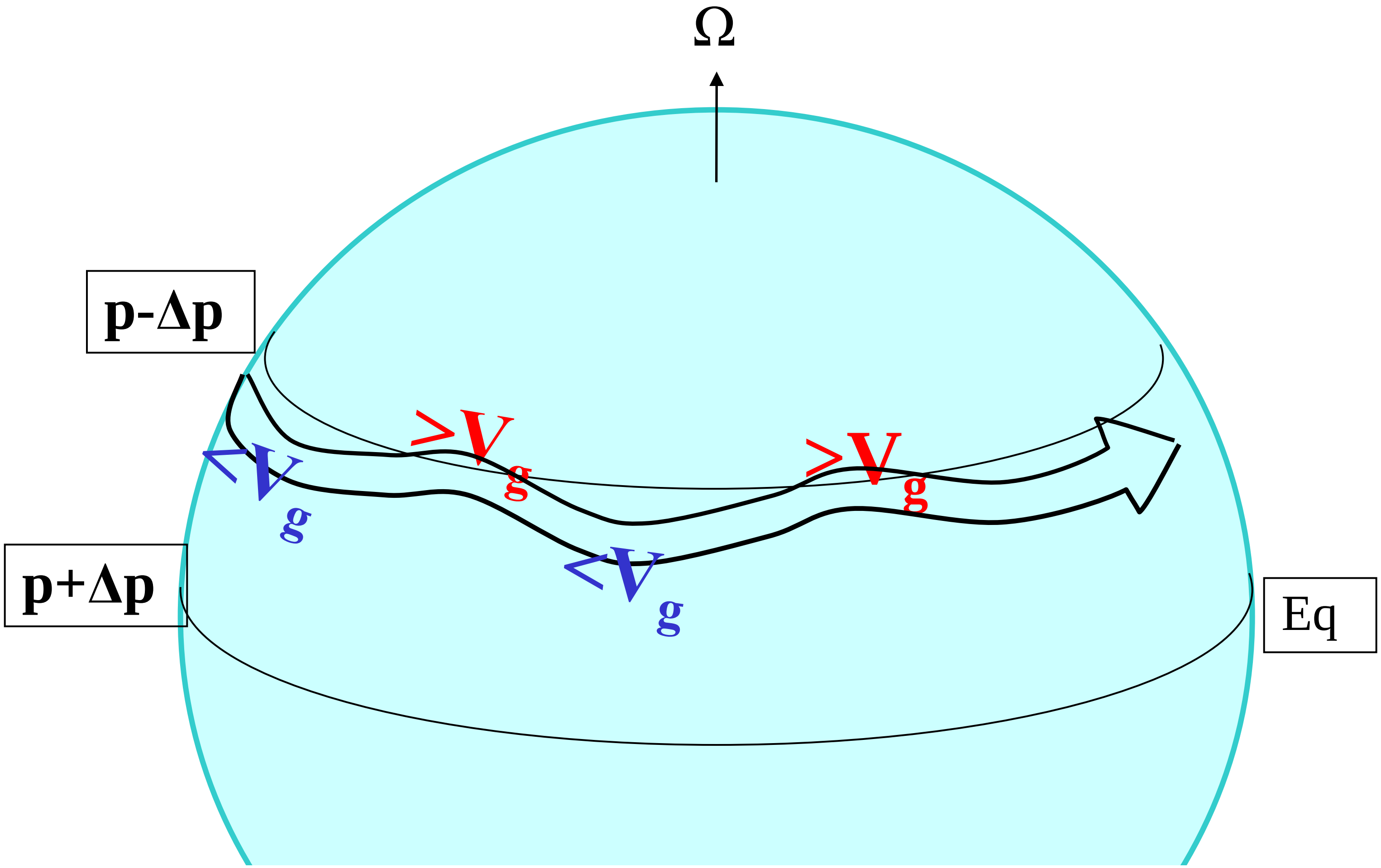


The trajectories in Gordon's calculations are angular momentum conserving!

With isobars running parallel to the latitudes the pressure gradient force will <u>not</u> produce a torque that would change the absolute angular momentum

Calculations showed a compelete agreement between Gordon's wind increases due to a meridional pressure gradient force and the conventional conservation of angular momentum approach!



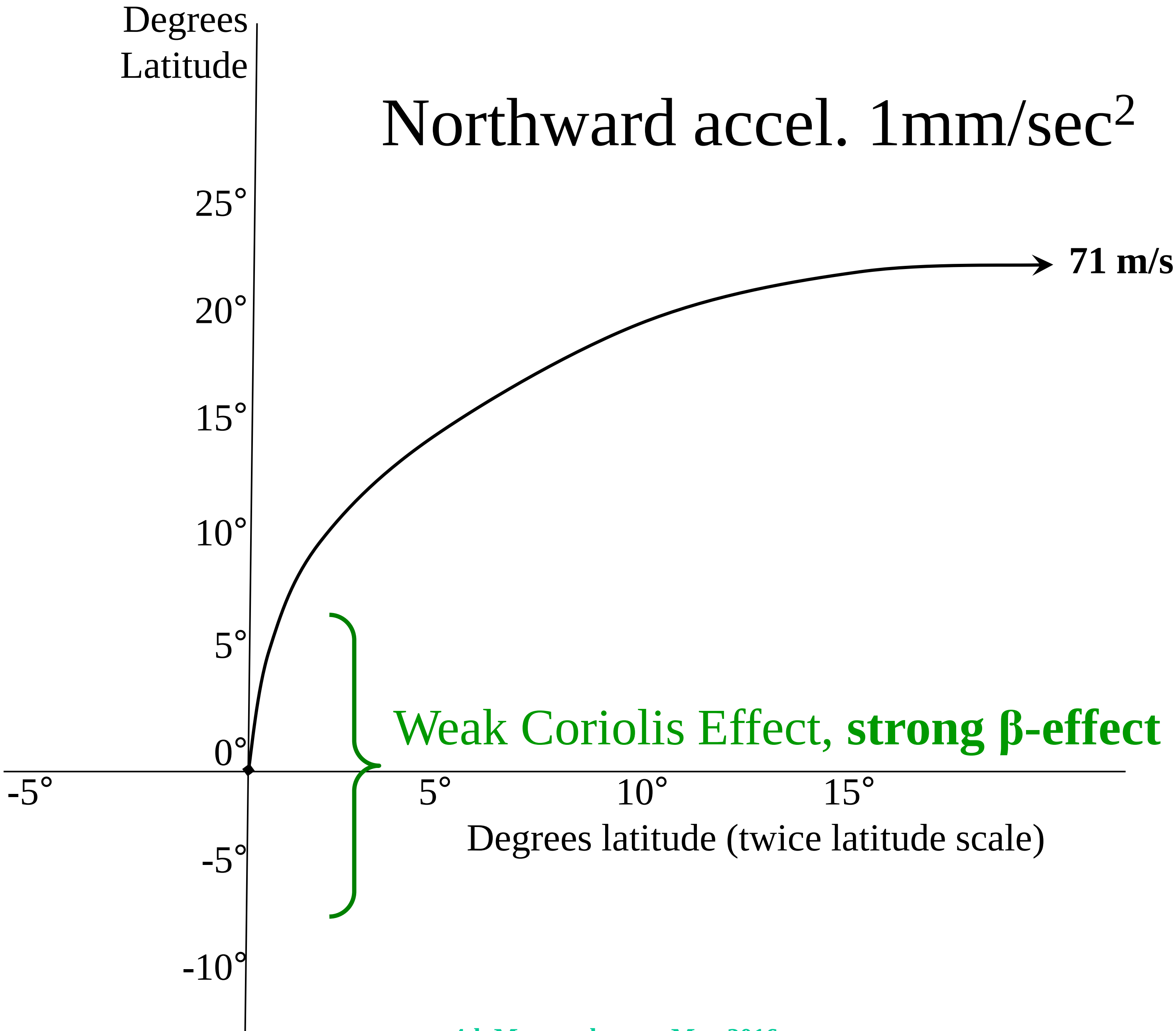


Like normal super geostrophic winds the “excessive” winds adjust toward geostrophy!

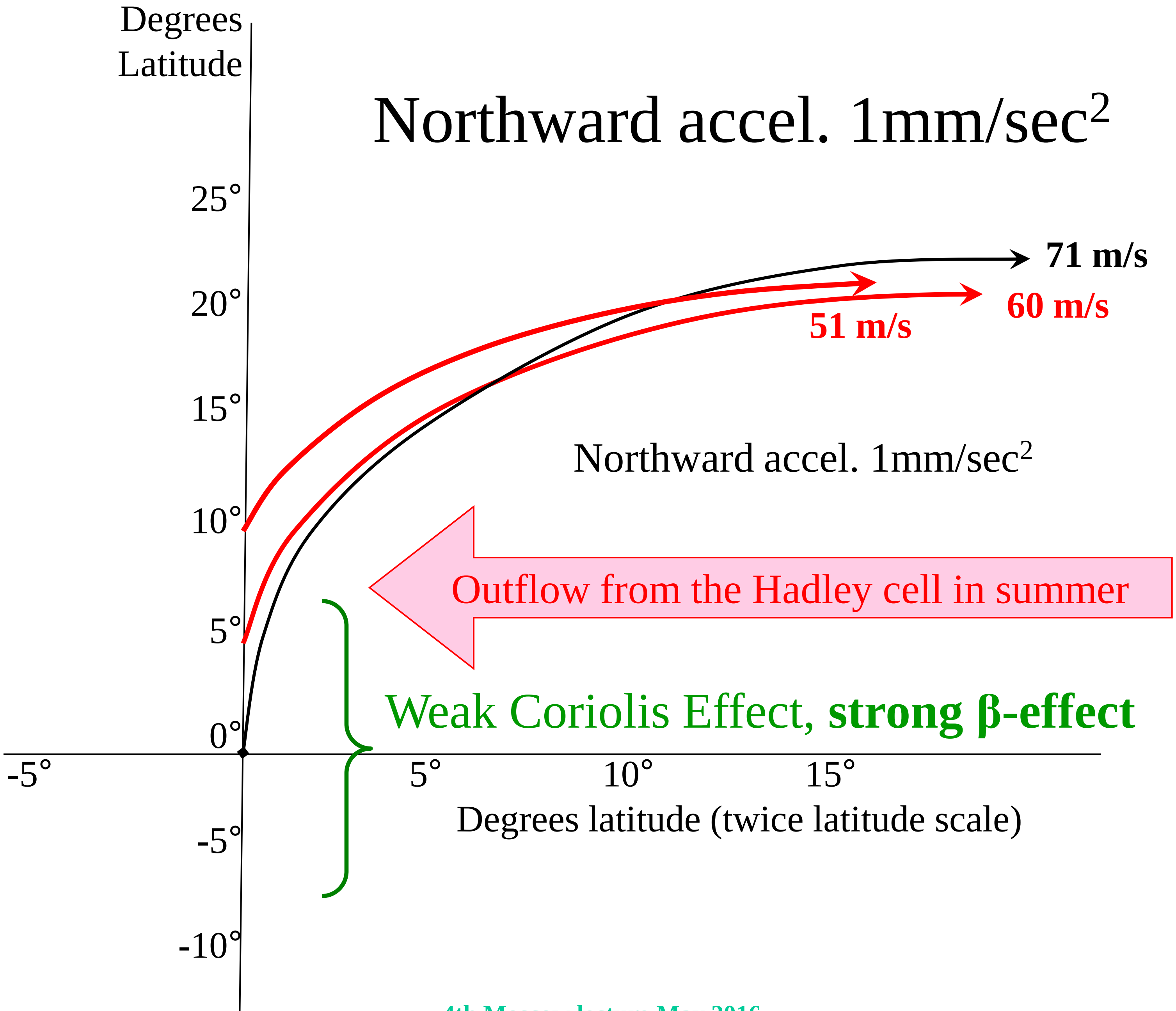
There is no need to invoke friction etc.

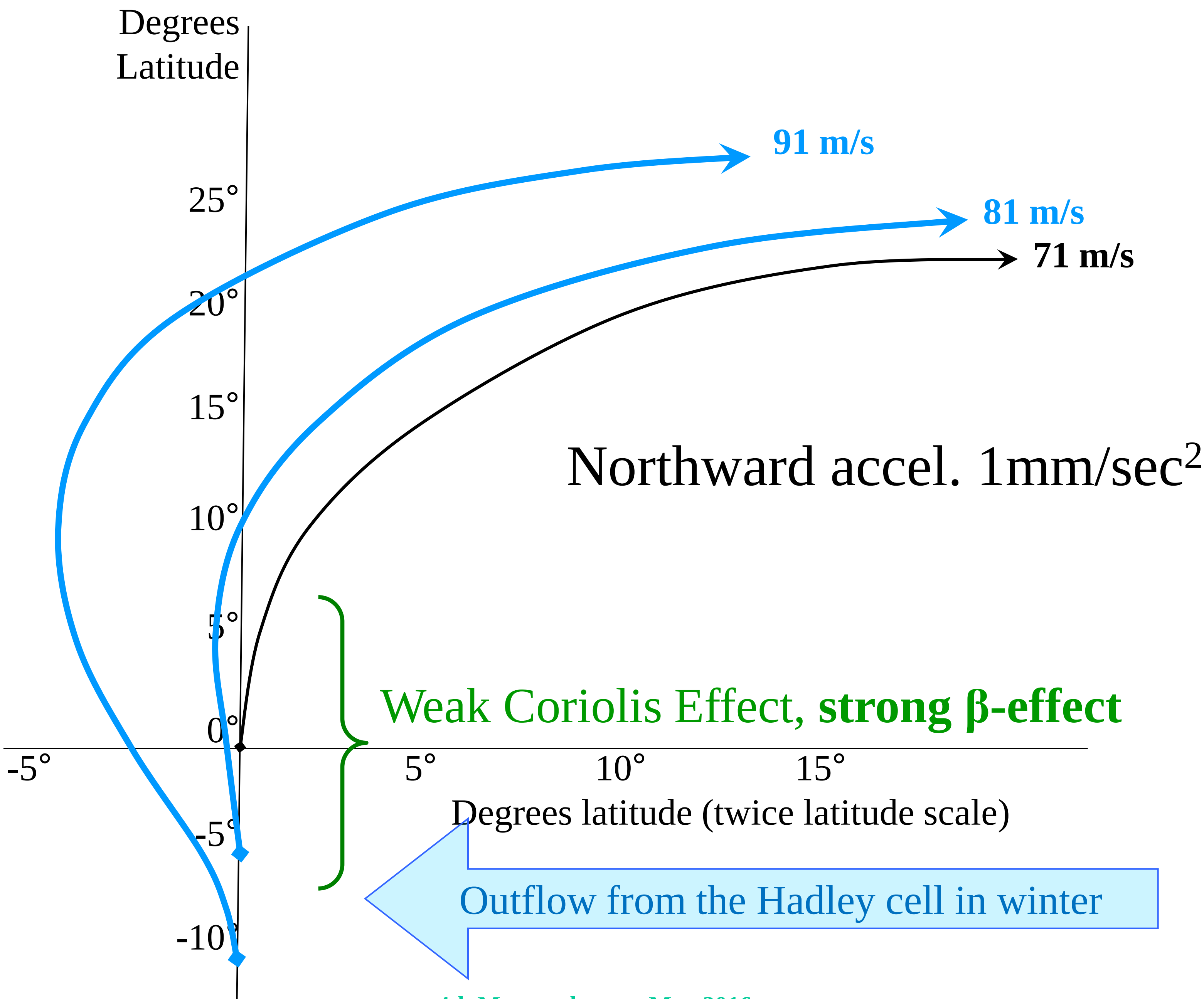
The Subtropical Jet Stream is created.

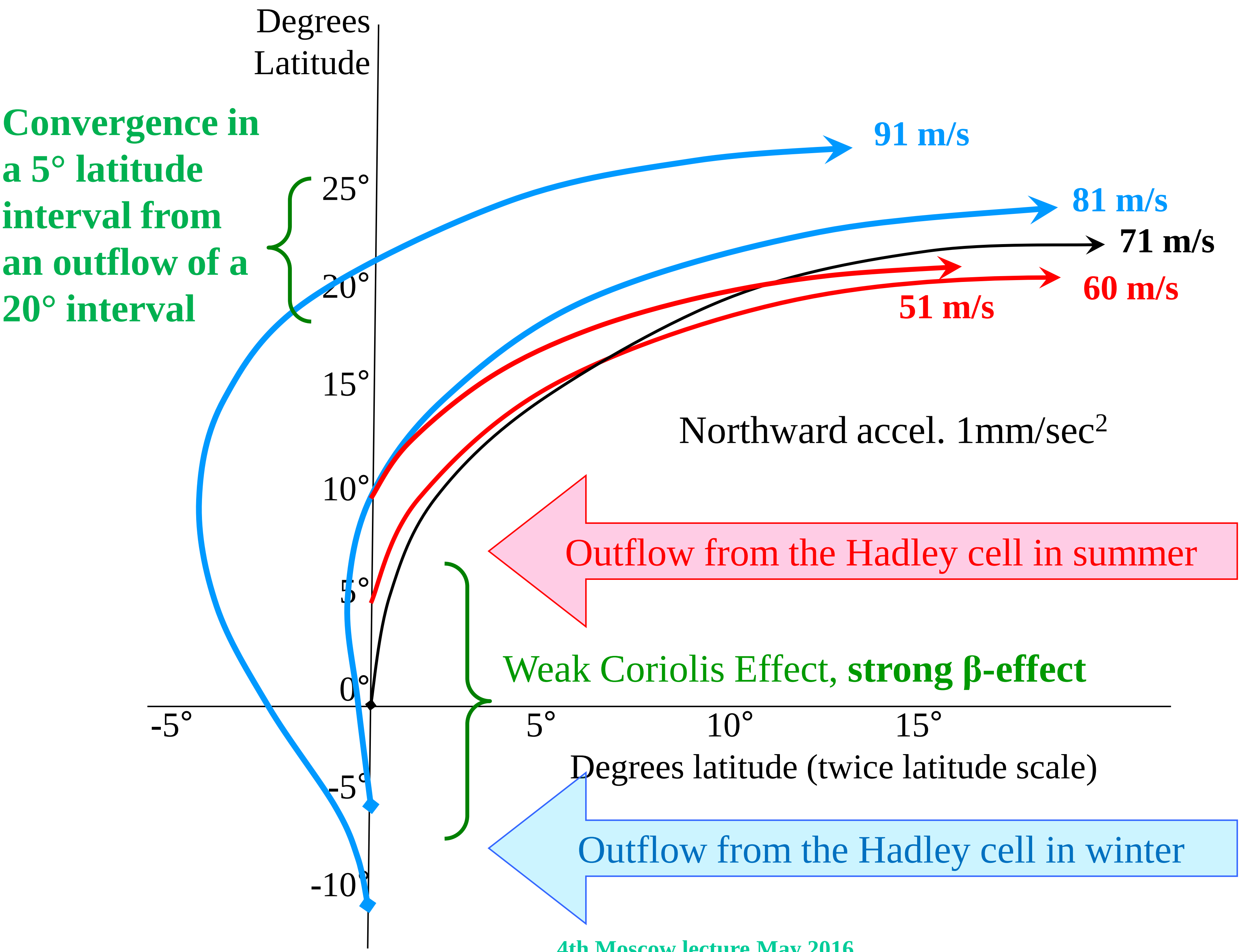
Northward accel. 1mm/sec^2



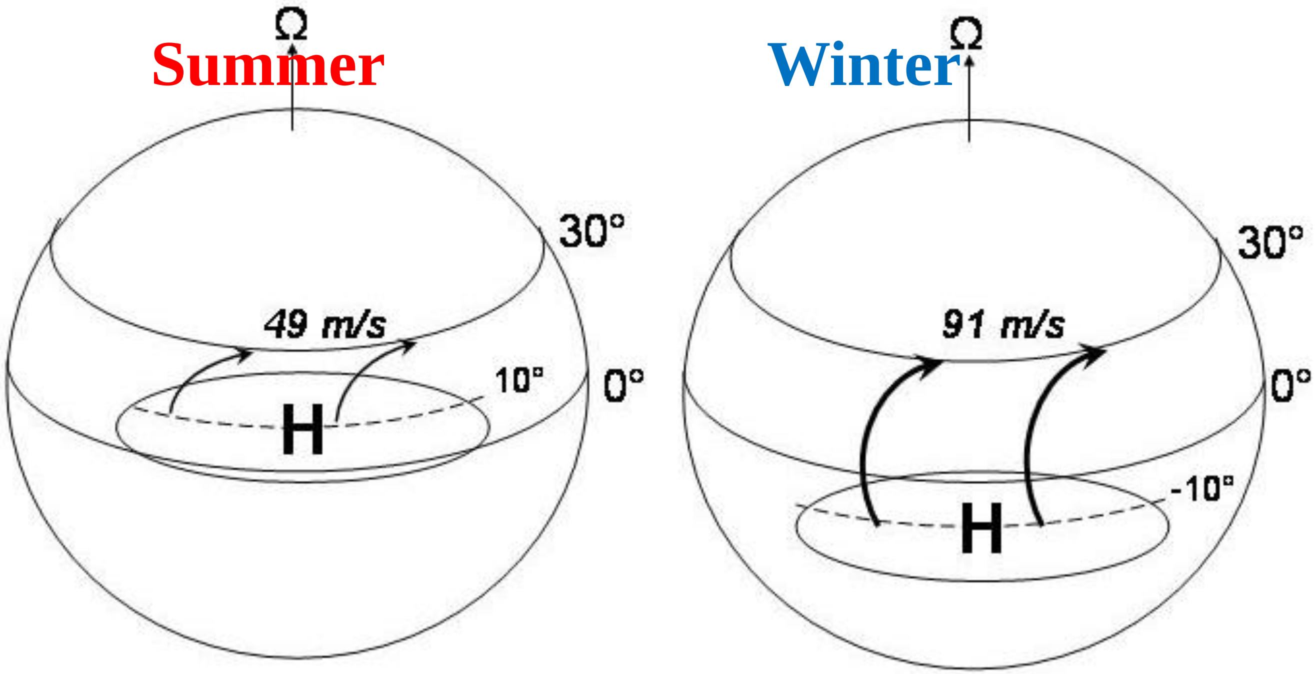
Northward accel. 1mm/sec^2



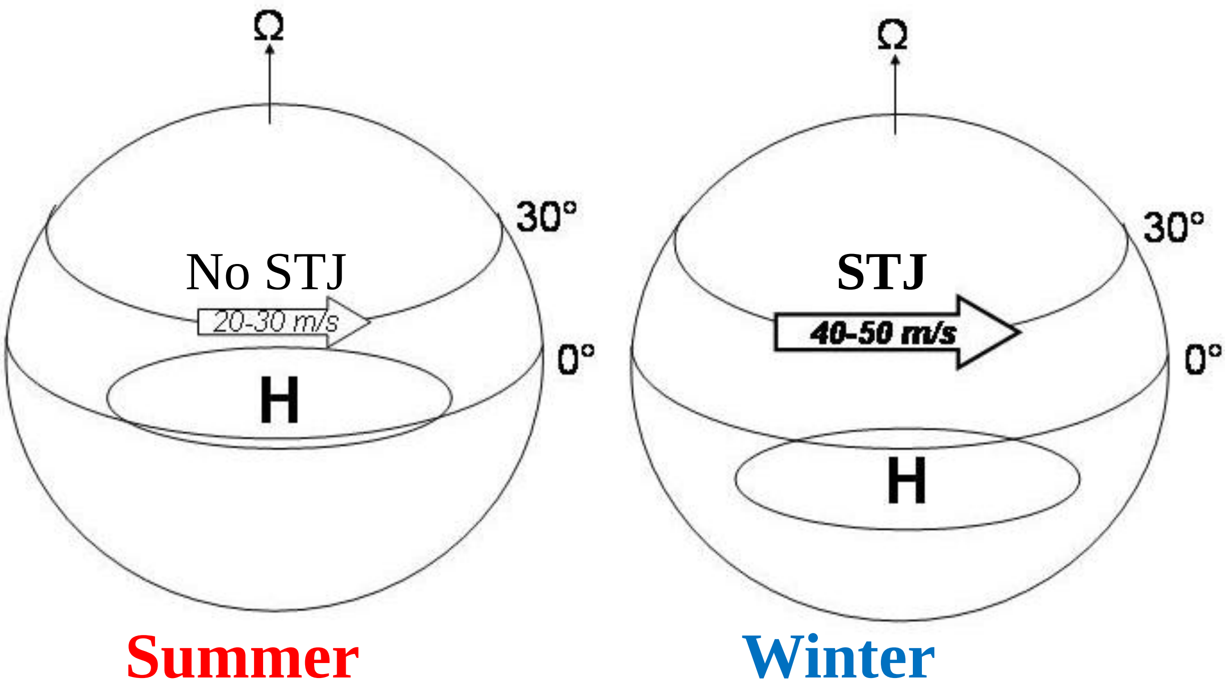

Degrees
Latitude
91 m/s
81 m/s
71 m/s
25°
20°
15°
10°
5°
0°
-5°
-10°
-5°
5°
10°
15°
Northward accel. 1mm/sec^2
Weak Coriolis Effect, **strong β-effect**
Degrees latitude (twice latitude scale)
Outflow from the Hadley cell in winter



Degrees Latitude
Convergence in a 5° latitude interval from an outflow of a 20° interval
91 m/s
81 m/s
71 m/s
60 m/s
51 m/s
25°
20°
15°
10°
5°
0°
-5°
-10°
-5°
5°
10°
15°
Northward accel. 1mm/sec²
Outflow from the Hadley cell in summer
Weak Coriolis Effect, **strong β-effect**
Degrees latitude (twice latitude scale)
Outflow from the Hadley cell in winter



Winds accelerated without adjustment to the pressure field (Gordon and Shaw, 1954)



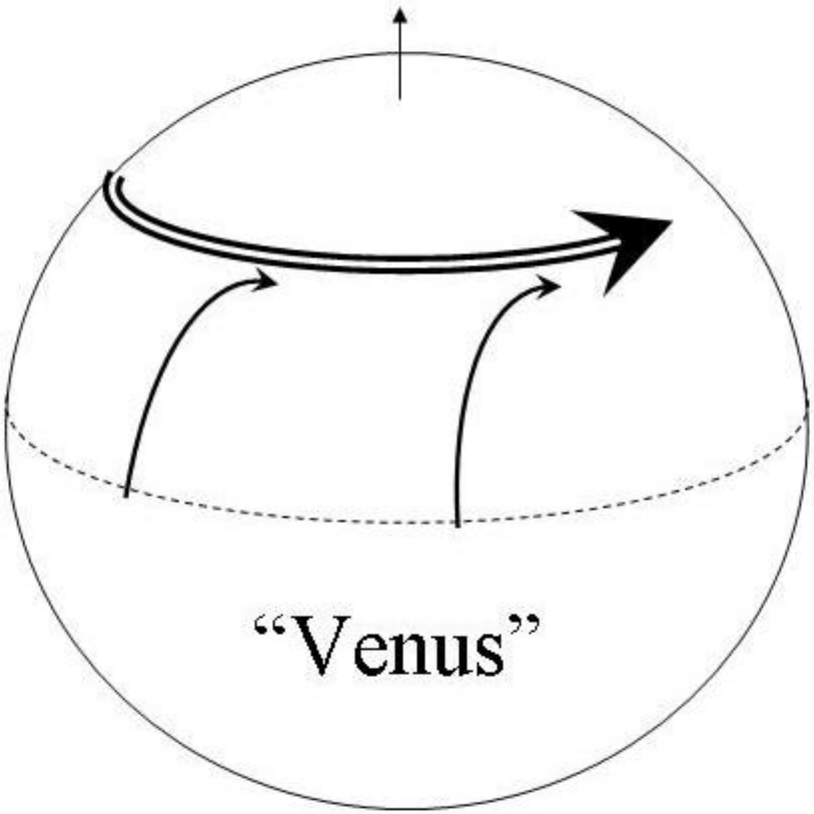
In case of geostrophic mutual adjustment speeds are reduced to half

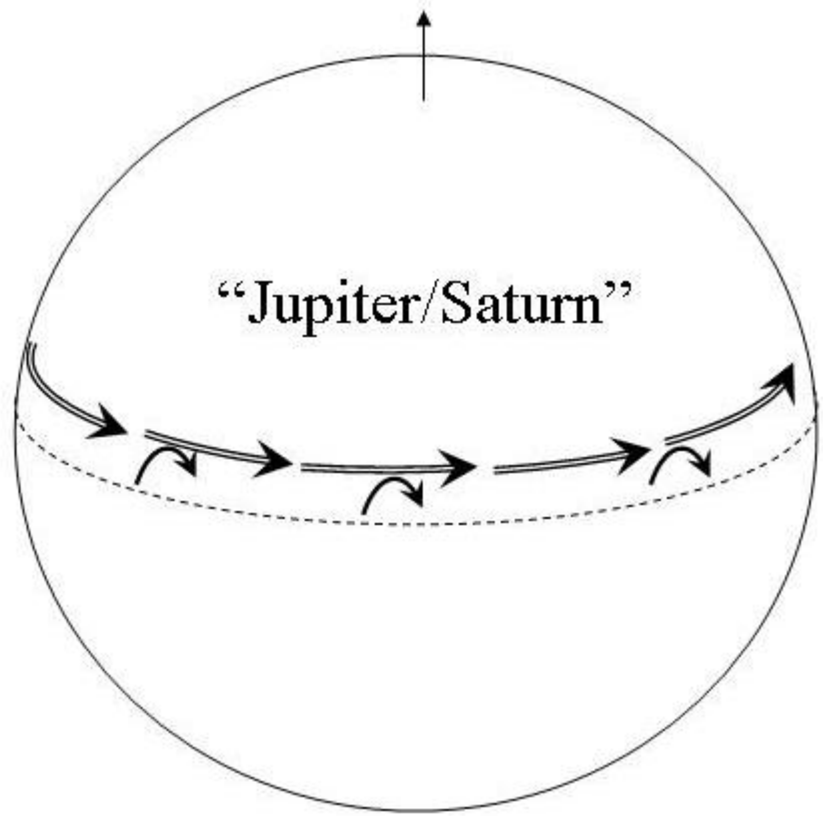
(Chester Newton, 1959)

A comparison with slow and fast rotating planets

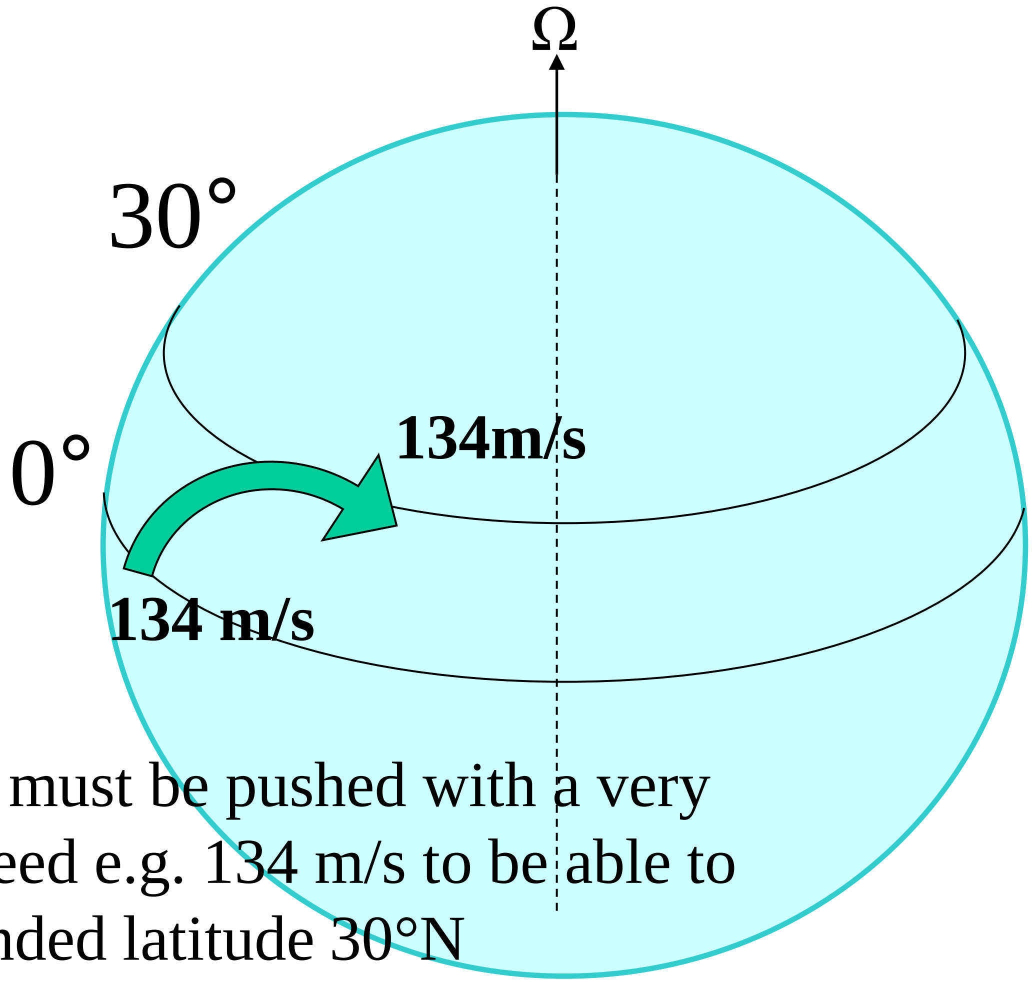
Slow rotating planet
Strong "STJ"

Rapidly rotating planets
Weak "STJ"



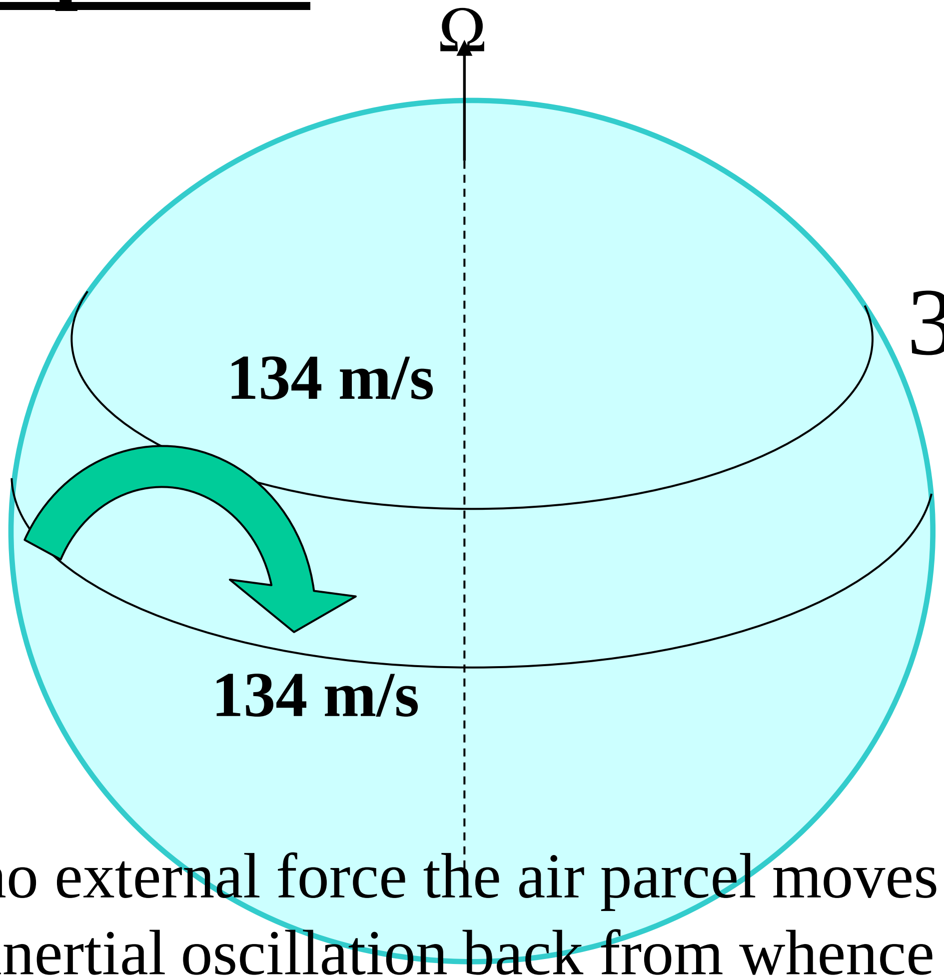


The conventional angular momentum conservation assumes <u>impulsive</u> and not forced motion



The air parcel must be pushed with a very high initial speed e.g. 134 m/s to be able to reach the intended latitude 30°N

The conventional angular momentum conservation assumes <u>impulsive</u> and not forced motion



With no external force the air parcel moves under some inertial oscillation back from whence it came

End