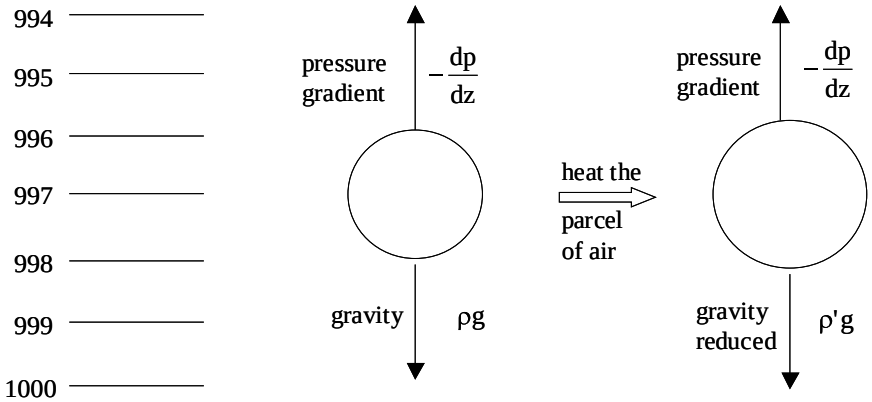
The atmosphere in motion

All atmospheric motion of significance originates from differential heating between low and high latitudes, land and ocean masses etc, the energy for which comes from absorbed solar energy. However, to gain an understanding of the changes in wind patterns over periods of a few days for example, we need to consider balances and imbalances of the forces action on the atmosphere. These forces are:

1) gravity (the atmosphere has mass)
2) pressure gradients (air wants to move from high to low pressure)
3) friction (due to the roughness of the surface)
4) the Coriolis force (an apparent force resulting from the rotation of the earth)

As an example, buoyant rise of air parcels results from an imbalance between gravity and the gradient of pressure in the vertical



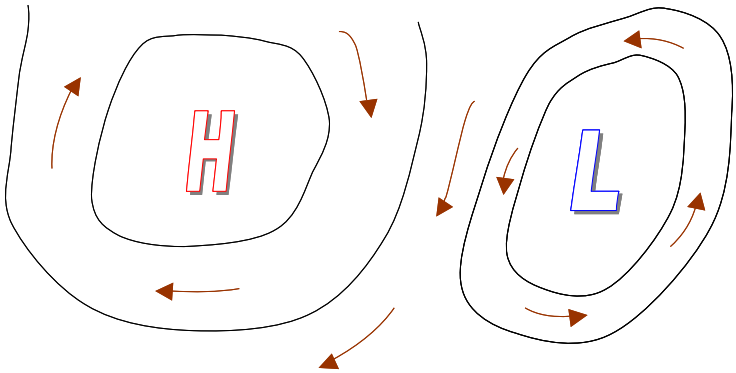
Hydrostatic balance

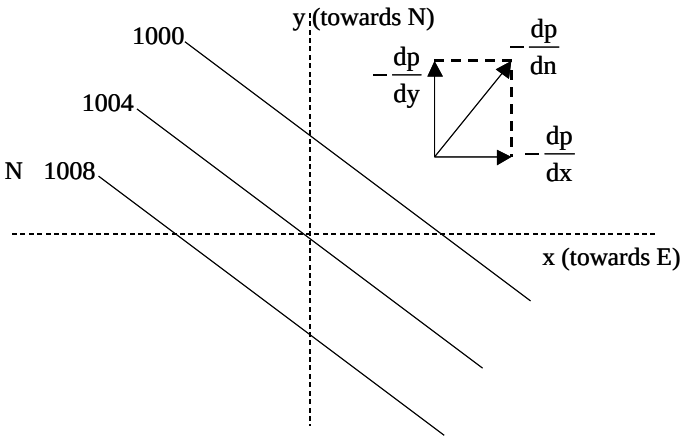
$$\frac{dp}{dz} = -\rho g$$

$\rho' < \rho$

The warmed parcel of air decreases in density as it expands so that the gravitational force decreases and is overpowered by the upward pressure gradient. An upward acceleration would result.

Wind motions are predominantly in the horizontal direction because of the constraint of the earth's surface. The driving force is the horizontal pressure gradient.





$-\frac{dp}{dn}$ is the pressure gradient in the direction perpendicular to the isobars and directed towards lower pressure. The minus sign appears because the force is in the direction of decreasing pressure (the positive n-direction).

Comparing pressure gradients in the vertical and horizontal directions, we quickly see that there is an enormous difference in their magnitudes.

Near the ground

$$\frac{dp}{dz} \approx -1 \text{ mb/10 m}$$

whereas, inspection of surface weather charges reveals that the horizontal pressure gradient

$$\frac{dp}{dn} \approx -1 \text{ mb/100 km}$$

which is a factor of 10^4 smaller. Yet, horizontal air motion is much stronger than vertical motion. Horizontal winds are often tens of m/s over very large areas, while large-scale vertical motions rarely exceed a few cm/s.

The difference, of course, is that the vertical pressure gradient is almost exactly balanced by gravity, while air is much more free to move horizontally without such restriction.