INTRODUCTION TO ATMOSPHERIC BOUNDARY LAYERS

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1. Generation of Wind

Wind is moving air. The movement of the air is primarily caused by temperature differences. These temperature differences are caused by differences in heating of the Earth's surface by the sun on all kinds of scales: from the equator to the poles (the polar front) or from water to land (sea breeze). The differences in temperature induce differences in density and consequently in pressure. This is illustrated in Figure 1. The air at the equator is warmer than at the pole. As a result the air density at pole is larger and the air pressure decreases faster with height than at the equator. So the height of the isobars (plane with equal air pressure) is inclined and slopes downward to the pole, in other words, at equal height there is a pressure gradient.

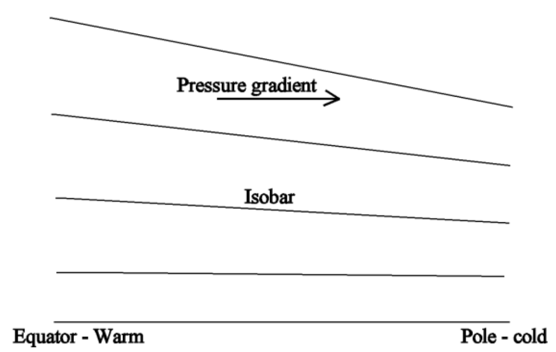

Figure 1. The pressure gradient of the polar front resulting from difference in heating between the equator and the poles.

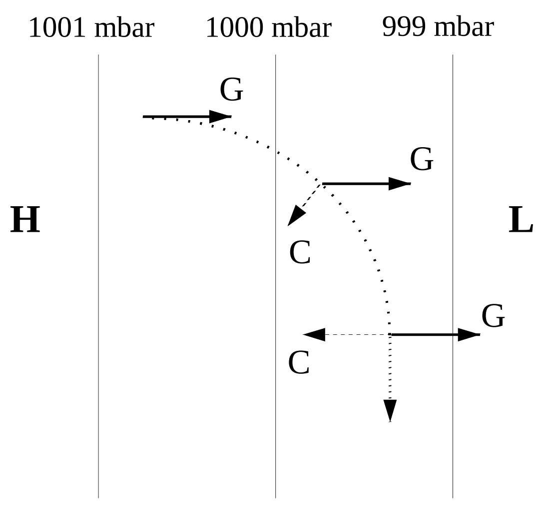

Figure 2. The effect of the Coriolis force on the movement of the air.

The mean height "at which the weather takes place" is about 5 km and this is also the height where the wind is generated. It is not possible to deduce the large-scale temperature differences at this height from temperature measurements at the surface. The mean input of observations for weather models are radio sondes simultaneously launched all around the globe probing the entire atmosphere. Low pressure systems are called depressions. On weather maps air pressure is usually expressed in millibar (mbar) or hecto-Pascal (hPa). At sea level the air pressure is usually between 970 and 1030 hPa.

The pressure gradient exerts a force on the air. The strength of this gradient force or acceleration (G) can be expressed as:

(1) $$G = -\frac{1}{\rho}\frac{dP}{dx} \quad (\text{m s}^{-2}),$$

where ρ is the density of air (kg m^{-3}), dP/dx is the pressure gradient (N m^{-3}). Once air has been set in motion by the pressure gradient force, it undergoes an apparent deflection from its path, as seen by an observer on the Earth. This apparent deflection is called the "Coriolis force" and is a result of the Earth's rotation. As air moves from high to low pressure in the northern hemisphere, it is deflected to the right by the Coriolis force. In the southern hemisphere, air moving from high to low pressure is deflected to the left by the Coriolis force. The amount of deflection the air makes is directly related to both the speed at which the air is moving and its latitude. Therefore, slowly blowing winds will be deflected only a small amount, while stronger winds will be deflected more. Likewise, winds blowing closer to the poles will be deflected more than winds at the same speed closer to the equator. The Coriolis force is zero right at the equator. This is the reason why the dynamics of weather is so different at mid-latitude and the tropics. The strength of the Coriolis force can be expressed as:

(2) $$C = U \cdot 2\Omega sin\phi = Uf \quad (\text{m s}^{-2}),$$

where U is the wind speed (m s^{-1}), Ω is the angular velocity of the Earth's rotation (2π/24 hours) and ϕ is the

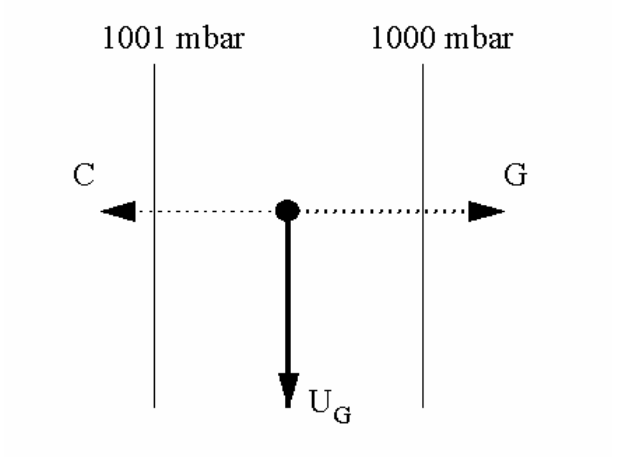

Figure 3. The geostrophic equilibrium. G is the gradient force, C the Coriolis force and U_G is the geostrophic wind speed.