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Evolution of Pressure Variations in the Neutral Atmosphere Acquired by Radiosondes

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Abstract
The variation in pressure is investigated with equation of state and hydrostatic equation in the neutral atmosphere of the earth with radiosondes. It is shown that under isothermal conditions, $P_{(d)} = P_{(d_0)} \exp\left[-\left(\frac{z-z_0}{H}\right)\right]$, which implies that the pressure of dry air decreases exponentially with scale height H. while $P_{(z)} = P_{(z)} - \frac{P_{(d)}}{H} z$, showing that pressure decreases linearly with height z above mean sea level (msl).
Keywords: Pressure Variation, Isothermal, Scale height, Radiosondes, Hydrostatic, Equation of State.

Introduction
Neutral atmosphere is non-dispersive and are characterized by a decreasing temperature and pressure. The measure of decrease $\beta = -\frac{dT}{dh}$ is called lapse rate. The lapse rate varies throughout the atmosphere, but is frequently constant in thick layers (Haltiner and Martins, 1957; and White, 2008).

The radiosonde is a balloon-borne instrument platform with radio transmitting capabilities. Originally named a radio-meteorograph, the instrument is now referred to as a radiosonde. The radiosonde contains instruments capable of making direct in-site measurement of air temperature and pressure with height, typically to altitudes of approximately 30km. These observed data are transmitted instantaneously to the ground by a radio transmitter located within the instrument package. The ascent of a radiosonde provides an indirect measure of the wind speed and direction at various levels throughout the troposphere (Houghton, 2000).

This study is aimed at investigating the evolution of pressure of dry-air from equation of state and hydrostatic equilibrium equation in the neutral atmosphere with radiosondes.

Method and Discussion
The Governing Equations are as follows:
Consider the isothermal condition of the neutral atmosphere from which equation of state is obtained. The pressure is given as (Aysegiil, 2006):

$$P = \rho R_i T \tag{1}$$

Where the specific gas constant R_i is defined by

$$R_i = \frac{R}{M_i} \tag{2}$$

The atmosphere is said to be in hydrostatic equilibrium if the vertical forces on any slice of a column of air with thickness dz is equal to zero (Haltiner and Martin, 1957).
The hydrostatic equation is given by

$$g\rho dz + (P + dp) = P \tag{3}$$

$$dp = -g\rho dz \tag{4}$$

Where P is the pressure of the particle; ρ is the density of the particle, R_i is the specific gas constant of the mixture; M_i is the mean molecular mass of the mixture; dz is the height above mean seal level; g is the gravitational acceleration.
Solving Equation 1 and Equation 4, two approximations were considered.
(a) First approximation
To obtain the pressure variation of dry-air, Equation 4 is divided by Equation 1

$$\frac{dp}{P} = -\frac{g}{R_d T} dz \tag{5}$$

Then, Equation 1 reduces to

$$\rho g_m H = \rho R_d T \tag{6}$$

Making H the subject of the formula, we have

$$H = \frac{R_d T}{g_m} \tag{7a}$$

Or

$$\frac{1}{H} = \frac{g_m}{R_d T} \tag{7b}$$

Equation 7 is the scale height (km).
Substituting Equation (7b) into Equation 5, it yields

$$\frac{dp}{P} = -\frac{dz}{H} \tag{8}$$

This may be integrated to yield

$$\int \frac{dp}{P} = -\frac{1}{H} \int_{z_0}^{z} dz \tag{9a}$$

Or

$$P_{(d)} = P_{(d_0)} \exp\left[-\left(\frac{z - z_0}{H}\right)\right] \tag{9b}$$

Where $P_{(d`)}$ = the pressure of dry gas; $P_{(d_0)}$ = the pressure of dry gas at the base;
H = the scale height.
Equation 9 indicates that pressure of dry-air in the neutral atmosphere decreases exponentially with scale height H. While under isothermal condition, pressure decreases exponentially with height.

(b) Second approximation,
To acquire the pressure of the dry-air, Equation 5 reduces to

$$dp = -\frac{g_m p_{(d)}}{R_d T} dz \tag{10}$$

$$dp = -\frac{p_{(d)}}{H} dz \tag{11}$$

Which integrates to

$$P_{(z)} = \int \left(-\frac{p_{(d)}}{H}\right) dz \tag{12}$$

$$P_{(z)} = -\frac{P_{(d)}}{H} z + P_{(z_0)} \tag{13a}$$

Or

$$P_{(z)} = P_{(z_0)} - \frac{P_{(d)}}{H} z \tag{13b}$$

Equation (13b) shows that pressure decreases linearly with height z.

CONCLUSION
The pressure of the dry-air $P_{(d)}$ and the pressure of the dry-air at the base of the layer $P_{(d_0)}$ in the neutral atmosphere (troposphere) are related by the equation;

$$P_{(d)} = P_{(d_0)} \exp\left[-\left(\frac{z - z_0}{H}\right)\right] \tag{14}$$

Equation 14 indicates that the pressure of dry-air in the neutral atmosphere as investigated by radiosondes decreases exponentially with scale height H . On the other hand, the pressure at the top of any slice of a column decreases linearly with height z (Haltiner and Martin, 1957).
In both cases, it is enormously necessary to presume that in a neutral atmosphere, there is a pressure variation with height as recommended by the radiosondes investigation of the neutral atmosphere (kleijer, 2004).

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