Unit 2

Application of gas laws in atmospheric sciences

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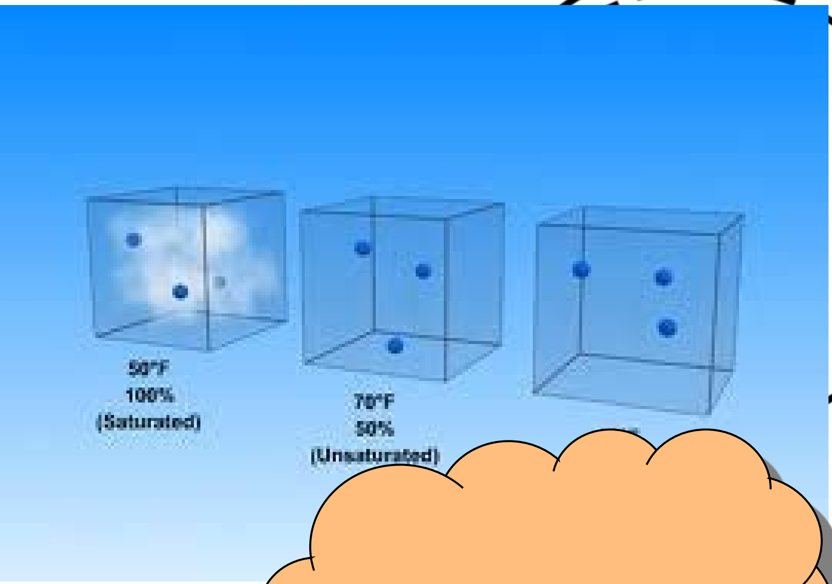
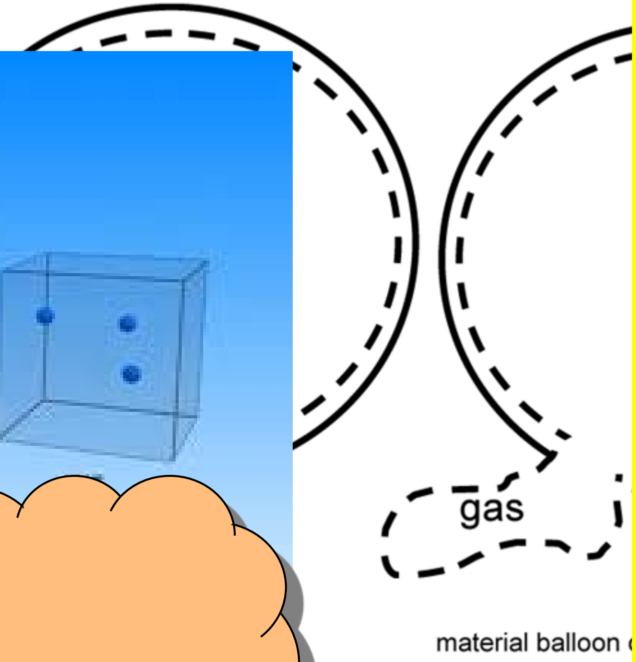
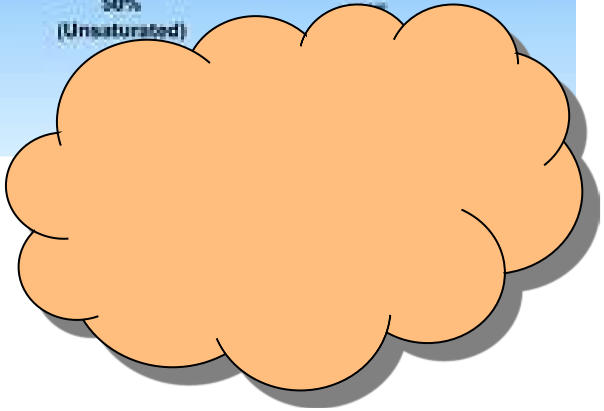
System in meteorology:
Air parcel or atmosphere

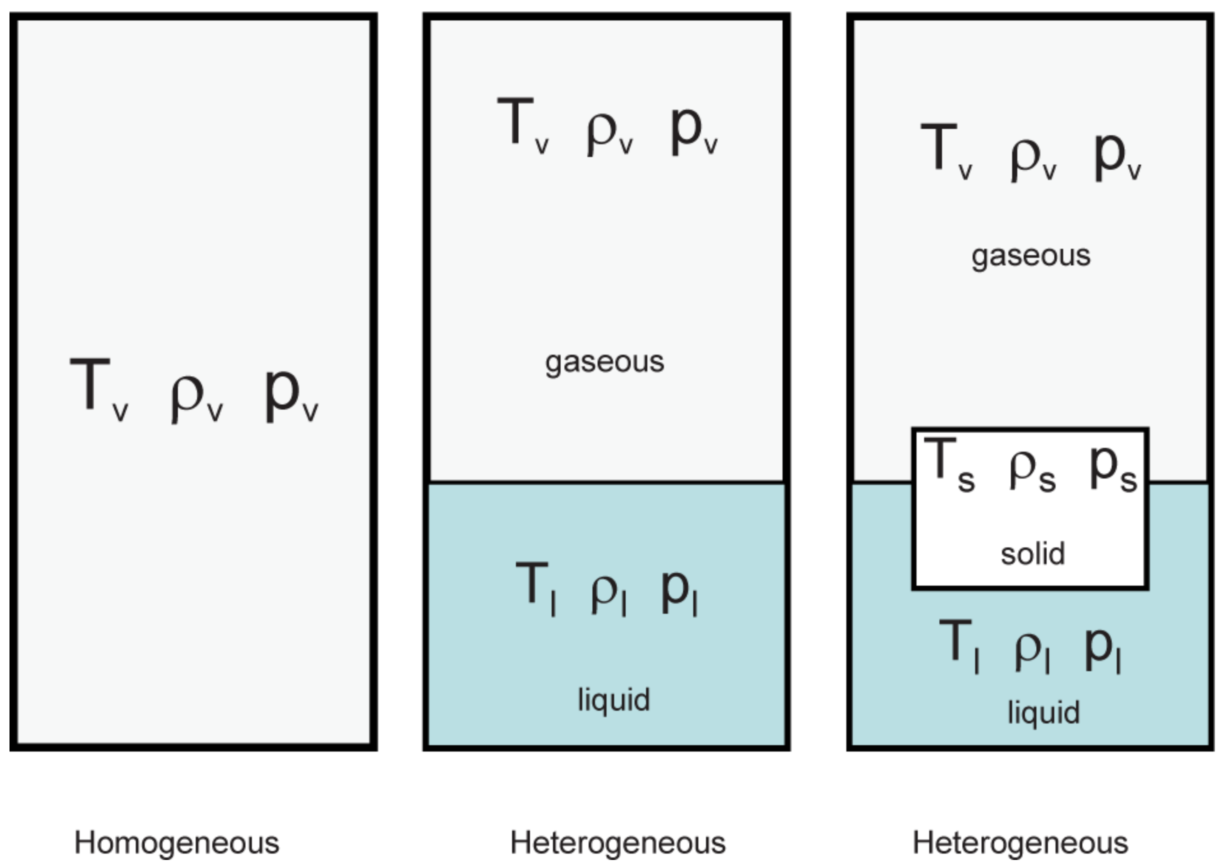






On Earth age time scale, atmosphere is an open system (cf. unit 1)

In atmospheric sciences we consider homogeneous and heterogeneous systems, their equilibria or change in response to their lack of being in equilibrium



Intensive variables

For an intensive variable A

$$A(n + m) = \frac{m_1 A(n) + m_2 A(m)}{m_1 + m_2}$$

For intensive variables no conservation laws apply!

Extensive variables

For an extensive variable B

$B(n)=n(B(1))$

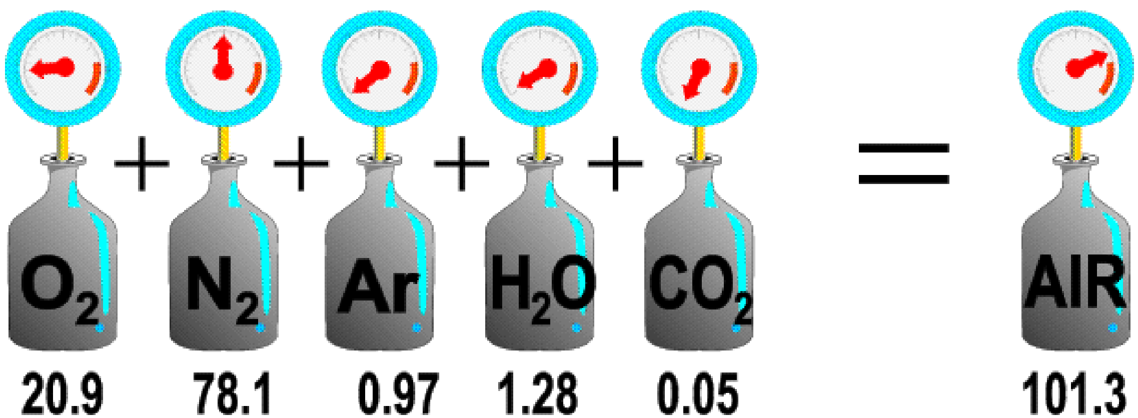
$B(0)=0$

Gas laws: Transfer to atmospheric sciences

$$pV = nR^*T$$

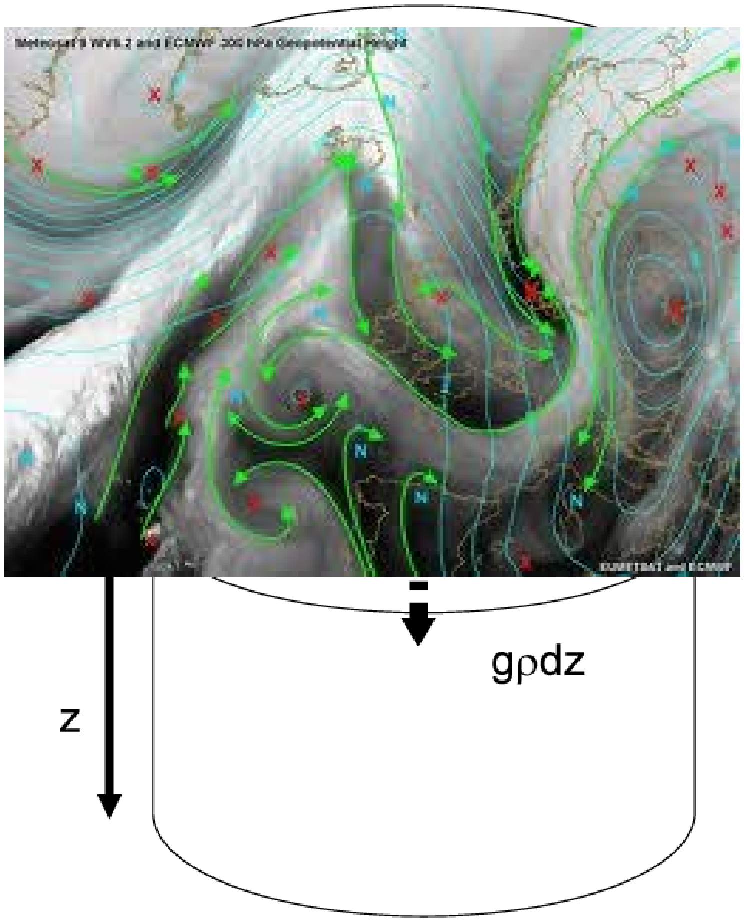
$$M_v = M_H + M_H + M_O = 18.016 \cdot 10^{-3} kgmol^{-1}.$$

$$p = \rho_d R_d T$$



http://resources.yesican-science.ca/plp/csa/trans_daltons_law1.gif

Application of Archimedes law leads to the hydrostatic equation



$$\frac{\partial p}{\partial z} = -g\rho$$

$$p(z) = -\int_{p(z)}^{p(\infty)=0} dp = \int_{z}^{\infty} g(z)\rho(z)dz$$

$$\Phi(z) := \int_0^z g dz$$

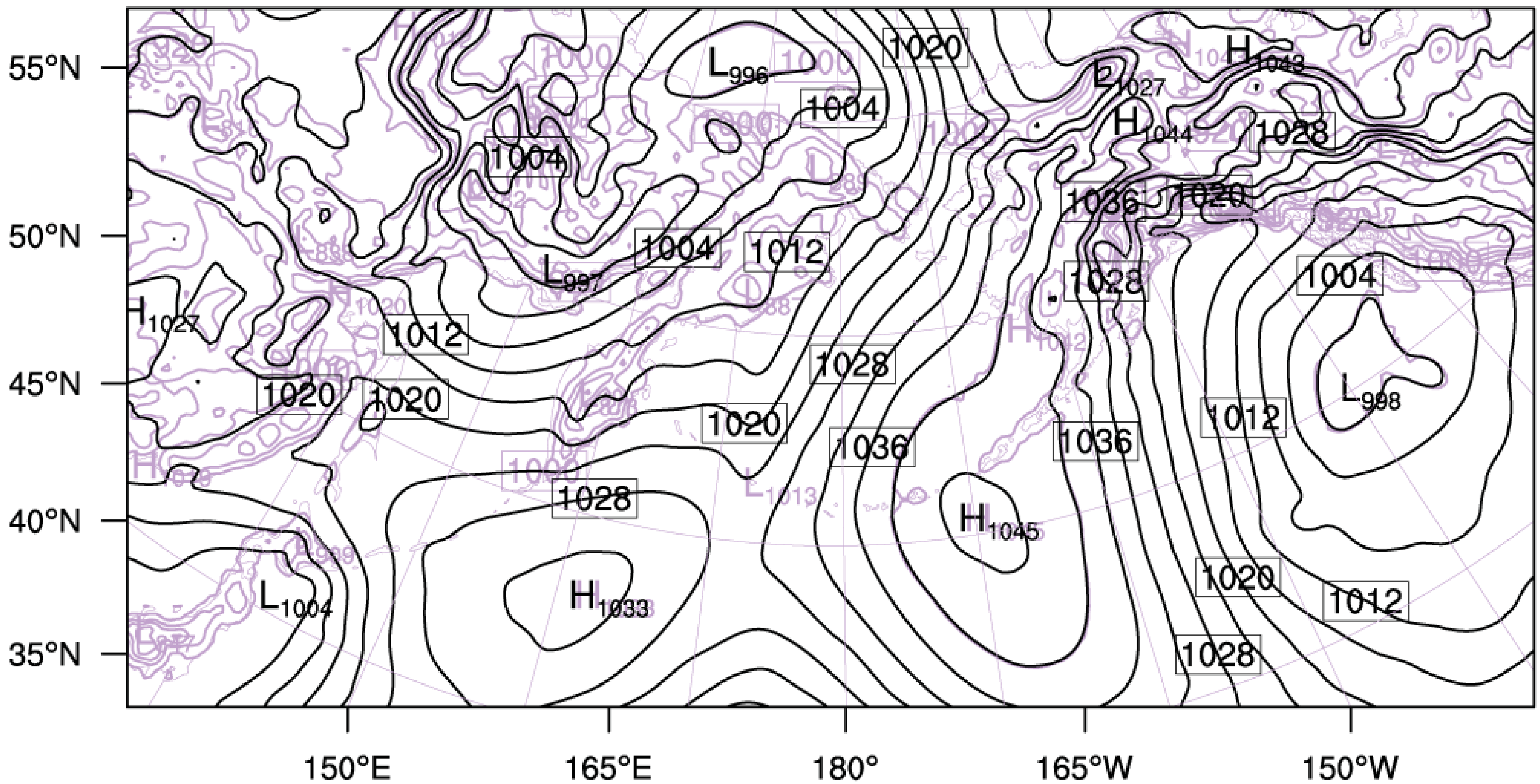
$$g dz = -\frac{1}{\rho}dp = -RT\frac{dp}{p} =: d\Phi$$

$$\int_{p_0}^{p} \frac{dp}{p} = -\rho g \int_{z_0}^{z} dz = -\frac{g}{RT}\int_{z_0}^{z} dz$$

$$p = p_0 exp(-\frac{g(z-z_0)}{RT})$$

$$H = \frac{RT}{g}$$

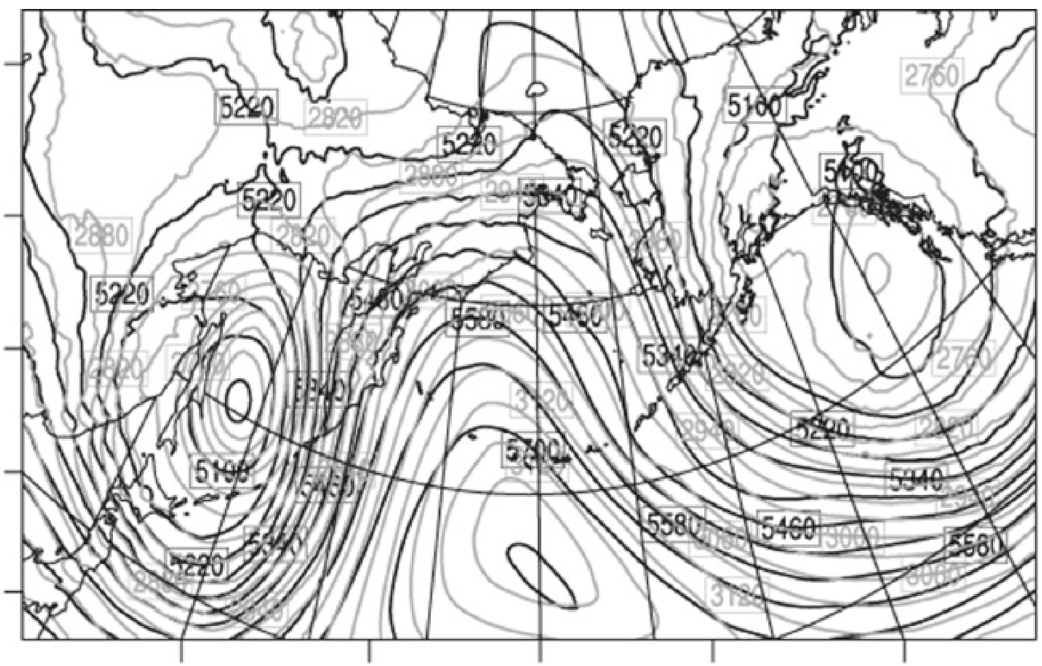
Reduction of pressure to MSL by previous last eq. eliminates the "terrain" to be visible in surface pressure maps

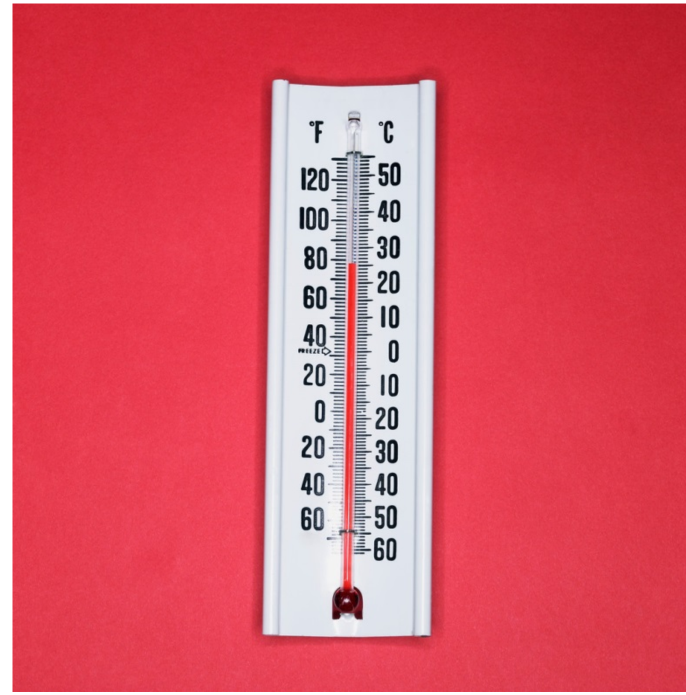


Hypsometric equation

$$\overline{T} = \frac{\int_{p_2}^{p_1} T d(lnp)}{\int_{p_2}^{p_1} d(lnp)}$$

$$\Delta z = z_2 - z_1 = \frac{R\overline{T}}{g} ln(\frac{p_1}{p_2})$$





Assume homogeneous atmosphere, i.e. density is constant

$p=\rho R_d T$

$$\frac{\partial p}{\partial z} = R\rho\frac{\partial T}{\partial z} = -g\rho$$

Actual lapse rate > -3.416K/100m

From Shaw

http://www.cycleback.com/mirage1.JPG

Polytrop atmosphere

- Assume T linearly decreases like $T(z)=T_0-\gamma\ (z-z_0)$ where $T(z_0)=T_0$ is temperature at lower boundary of the polytrop layer @ z_0
- Insert into the hydrostatic eq.

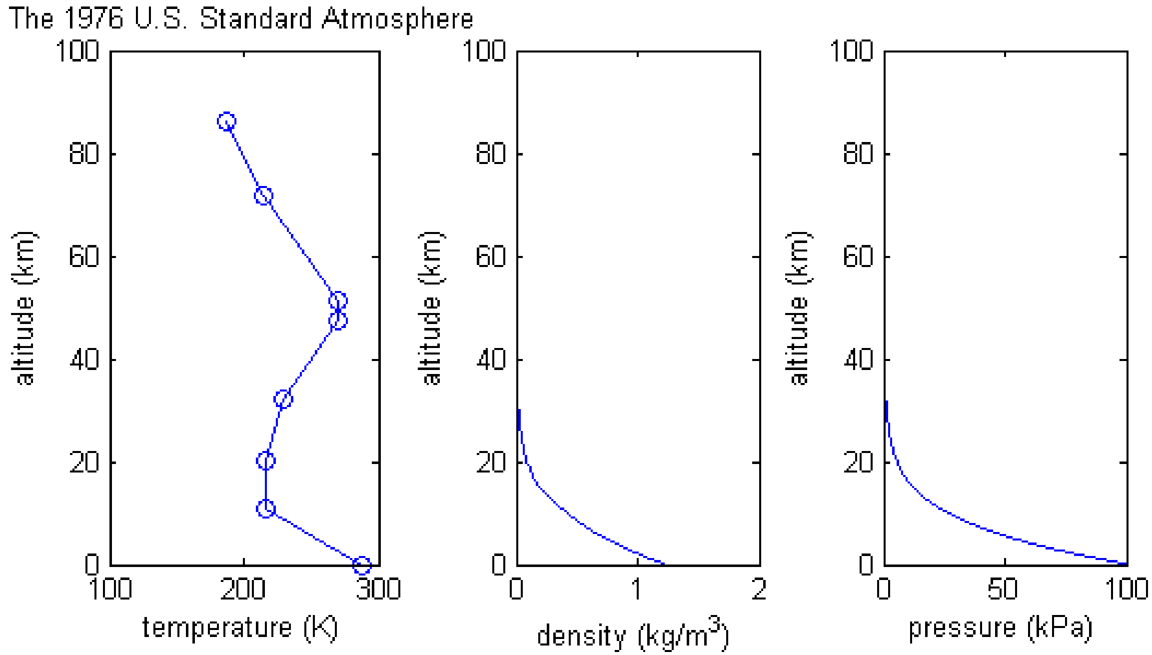
$$\frac{dp}{p} = -\frac{g}{R_d}\frac{dz}{T_0-\gamma z}$$

- Integrate from p_0 to the top of the polytrop layer

$$z = z_0 + (\frac{T_0}{\gamma}(1-(\frac{p}{p_0})^{\frac{R_d\gamma}{g}})$$

- Relation of temperature gradient of homogeneous atmosphere g/R_d & actual atmosphere γ
  - Typical value for exponent = 0.19

U.S. standard atmosphere



http://upload.wikimedia.org/wikipedia/commons/2/21/Us_standard_atmosphere_model.png