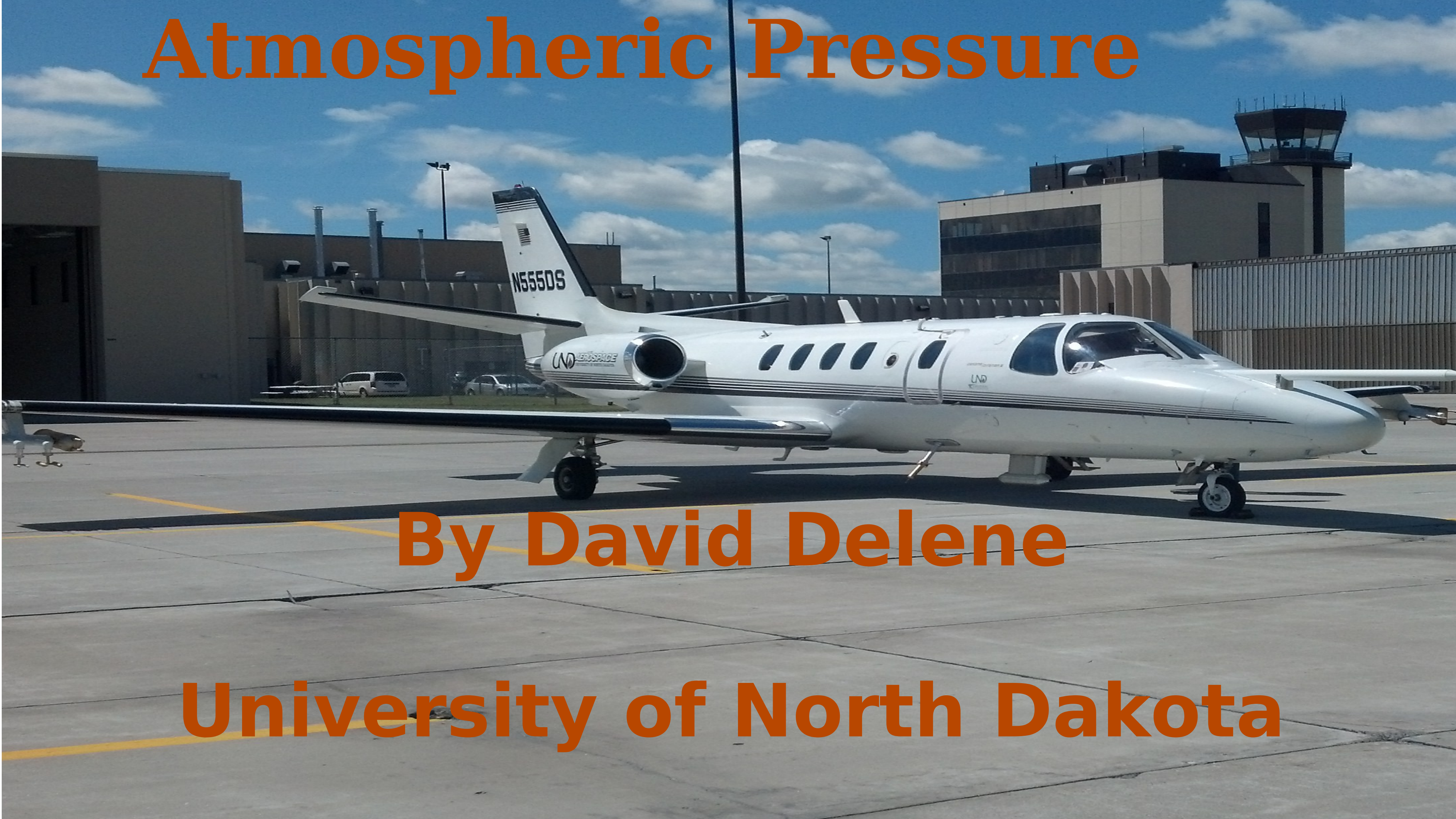
Atmospheric Pressure

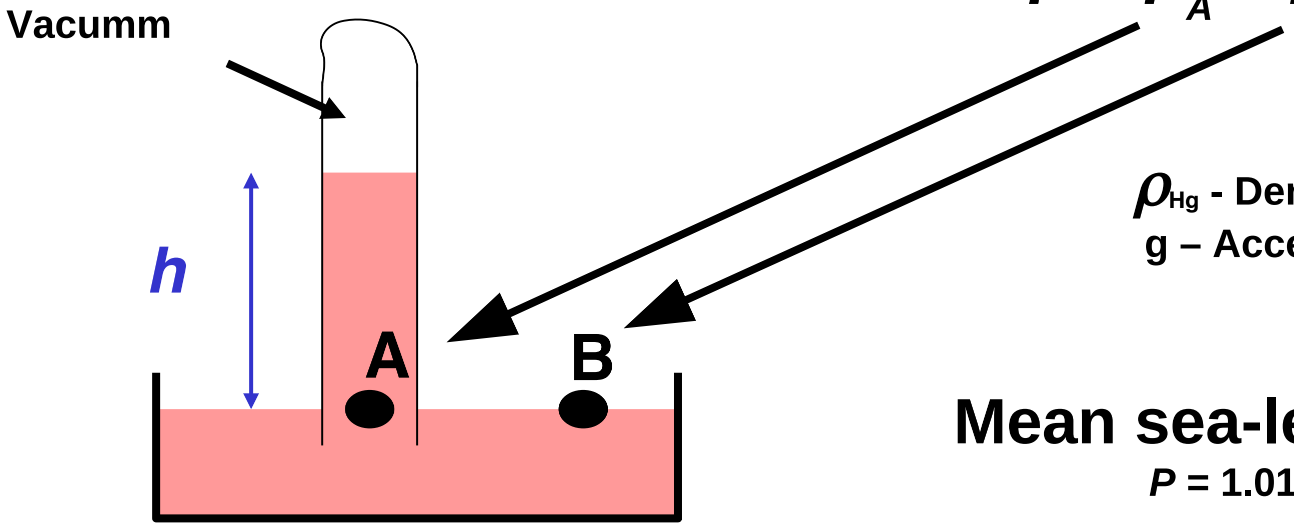


By David Delene

University of North Dakota

Measurement of Atmospheric Pressure

Describe concept of pressure.



Mercury Barometer

Atmospheric Pressure (P)

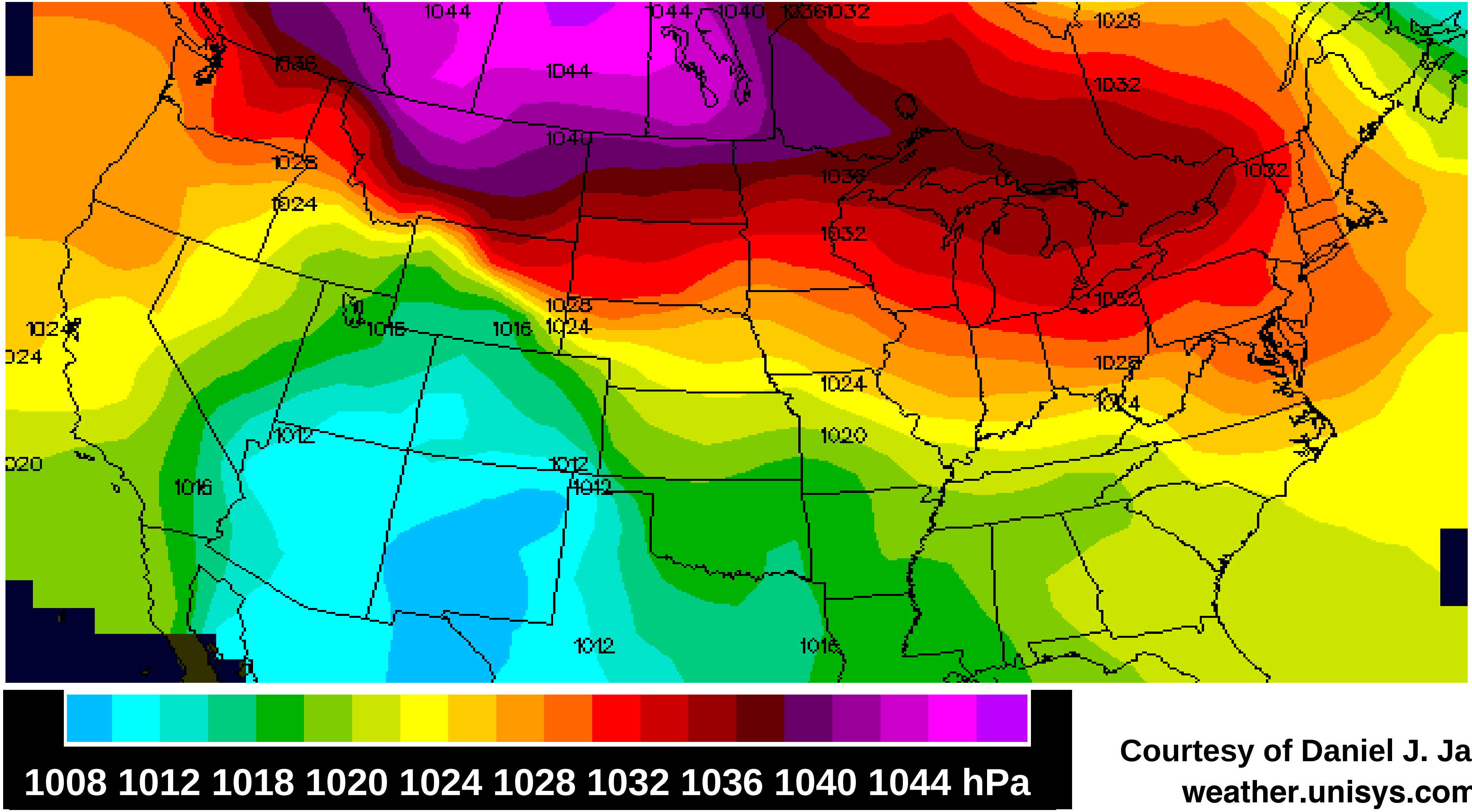
$$P = P_A = P_B = \rho_{Hg}\,gh$$

ρ_{Hg} - Density of Mercury
g – Acceleration of Gravity

Mean sea-level pressure:

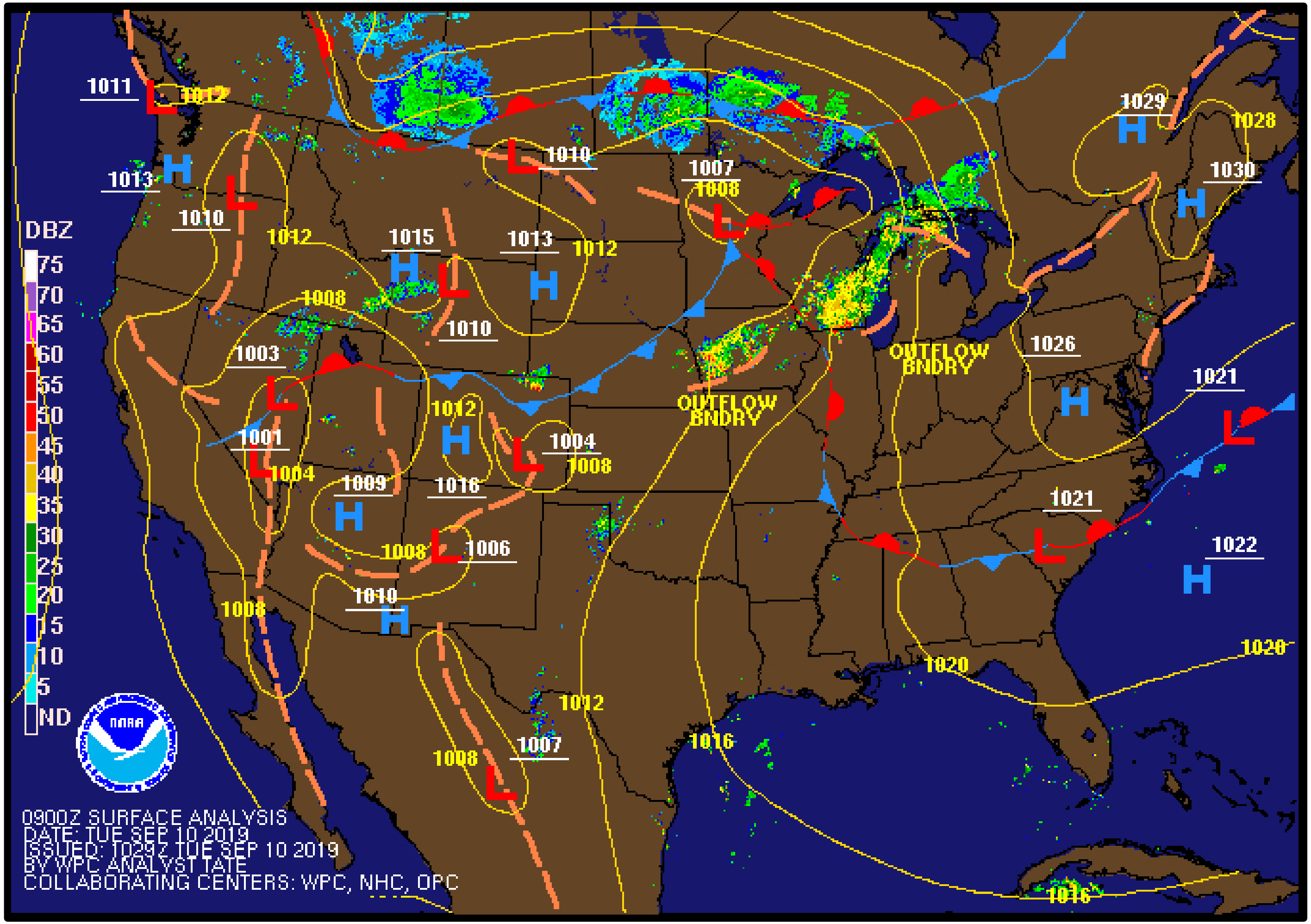
P = 1.013x10^5 Pa = 1013 hPa
= 1013 mb
= 1 atm
= 760 mm Hg (torr)

Sea Level Pressure Map (1/31/11, 11Z)



Courtesy of Daniel J. Jacob
weather.unisys.com

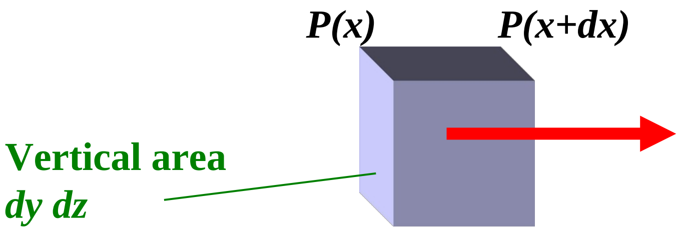
Surface Weather Map



Can you explain all the ways surface pressures is depicted on the above weather map?

SEA-LEVEL PRESSURE CAN'T VARY OVER MORE THAN A NARROW RANGE: 1013 ± 50 hPa

Consider a pressure gradient at sea level operating on an elementary air parcel *dx dy dz*:



Newton's Second Law $F = m\gamma$ **F – Force, m – Mass, γ - Acceleration**

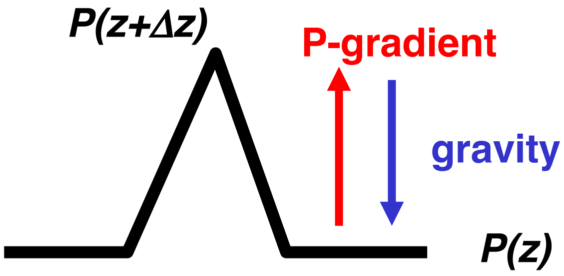
Pressure-gradient Force $d\mathbf{F} = (P(x) - P(x+dx))\,dy\,dz$

Acceleration $\gamma = -\frac{1}{\rho}\frac{dP}{dx}$ Density - $\rho = 1.2041\ \mathrm{kg/m^3}$

For ΔP = 10 hPa over Δx = 100 km, $\gamma \sim 10^{-2}\ \mathrm{m\ s^{-2}}$ hence 100 km/h wind in 3 h!

Effect of wind is to transport air to area of lower pressure, therefore dampen ΔP Is this correct?

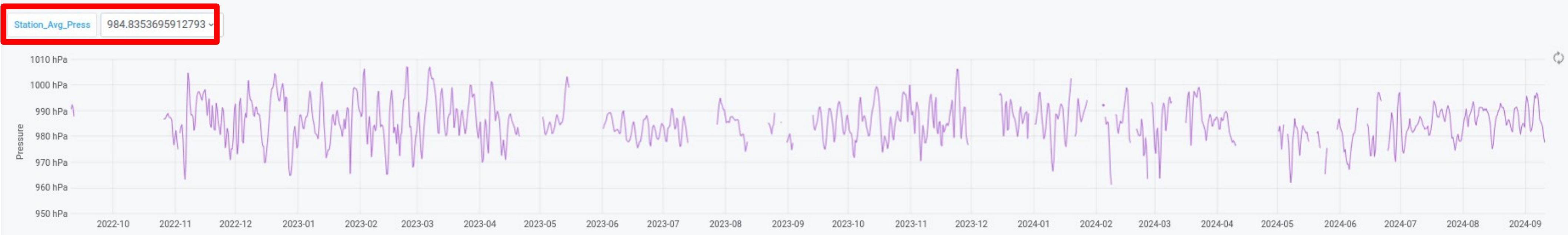
On mountains, however, the surface pressure is lower, and the pressure-gradient force along the Earth surface is balanced by gravity:



This is why weather maps show "sea level" isobars even over land; the fictitious "sea-level" pressure assumes an air column to be present between the surface and sea level

Courtesy of Daniel J. Jacob

MetTrailer Pressure (2022/09/10 - 2024/09/10)



Last Pressure	Min. Pressure	Avg Pressure	Max. Pressure	Station Med.	Station Avg.	Station Std.	T-Counts	3 hr Change		
990.51 hPa	836.24 hPa	981.39 hPa	2611.07 hPa	985.52 hPa	985.35 hPa	6.97 hPa	301398	-0.803 hPa	High	Slowly Decreasing

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Mass (m_a) of the Atmosphere

Radius of Earth:
6380 km

Mean pressure at Earth's surface:
984 hPa

$$m_a = \frac{4\pi R^2 P_{Surface}}{g} = 5.13 \times 10^{18}\,\mathrm{kg}$$

Total number of moles of air in atmosphere:

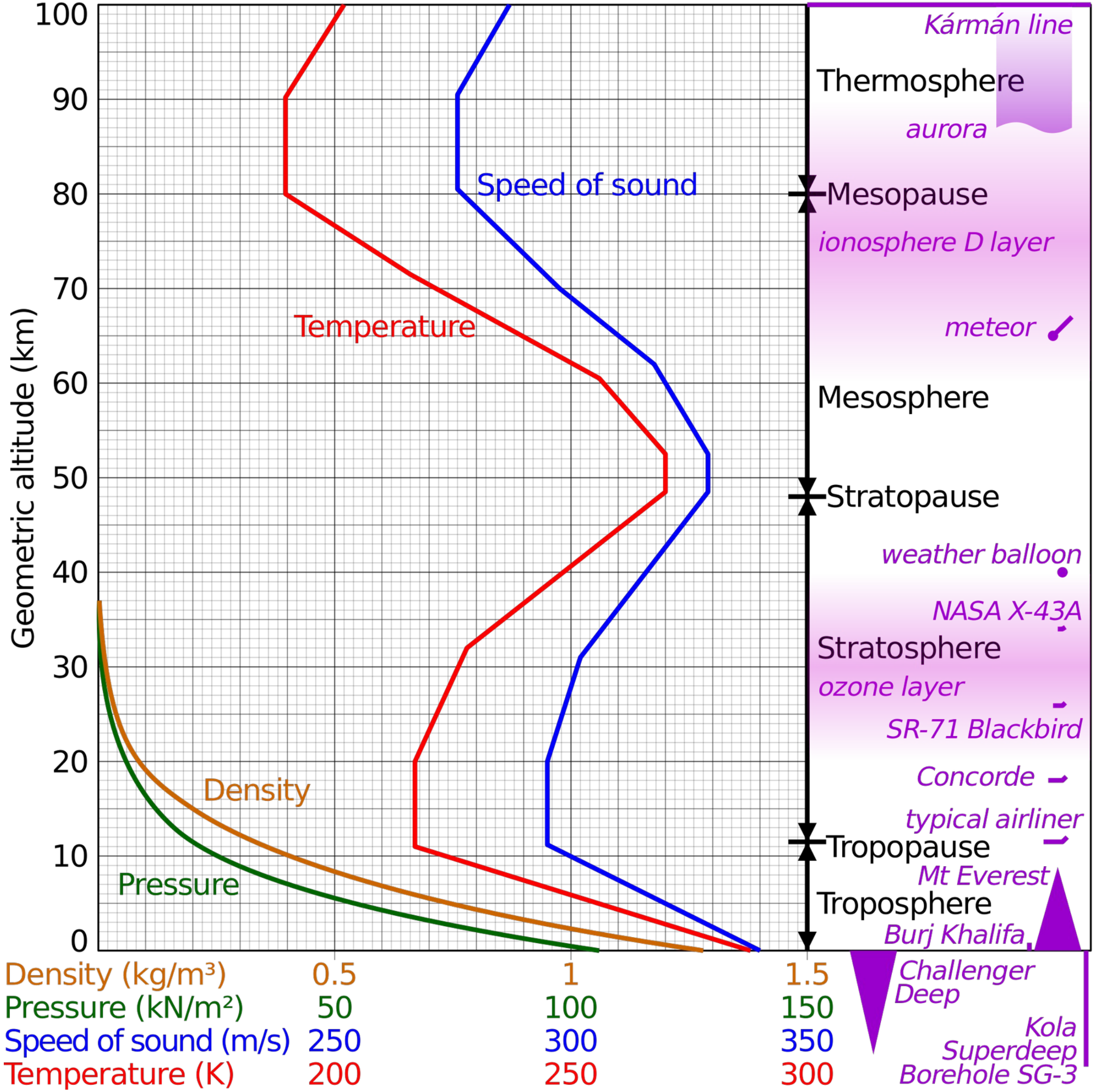
$$N_a = \frac{m_a}{M_a} = 1.8 \times 10^{20}\ \text{moles}$$

What is a mole again?

Mol. wt. of air: 29 g mole^{-1} = 0.029 kg mole^{-1}

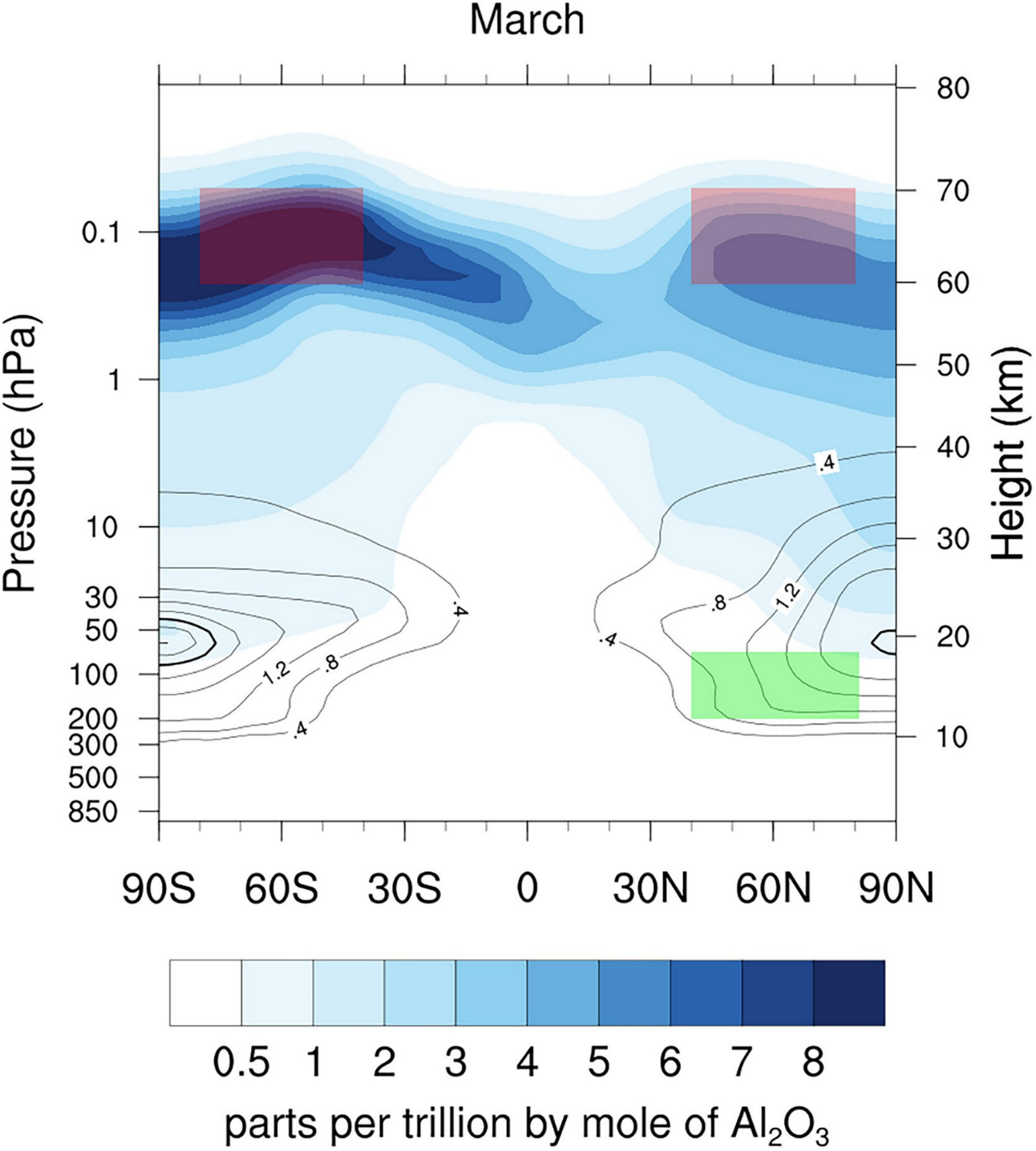
Courtesy of Daniel J. Jacob

Vertical Profile (US Standard Atmosphere)



} **Rocket/Satellite Burned-up**

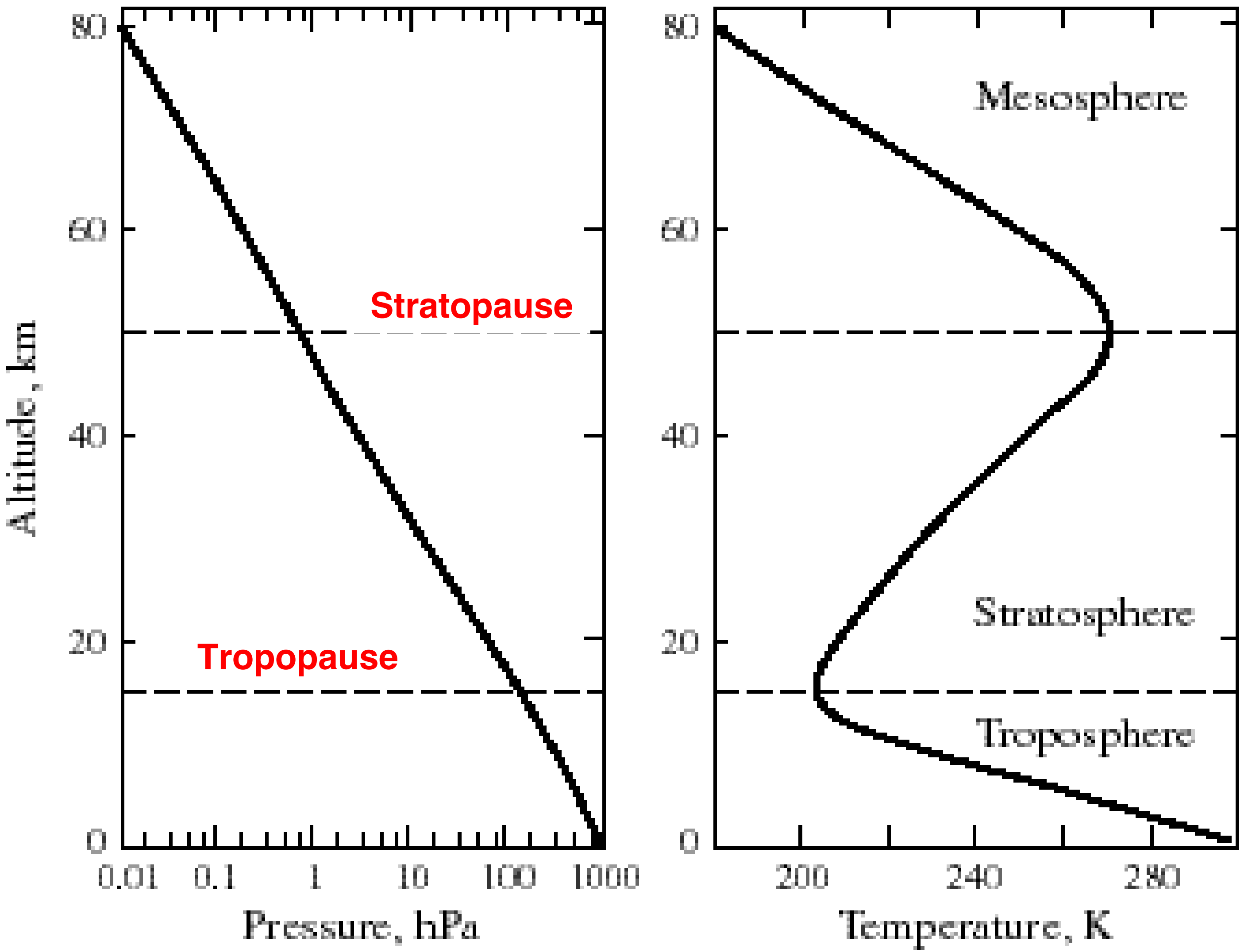
Metals from Spacecraft Reentry in Stratospheric Aerosol Particles



March monthly average concentrations of reentry Al_2O_3 for the 15-y reentry emission simulation. Colored filled contours show the mass mixing ratio and the contour lines show the mass density in 10^{-16} g cm^{-3}. The bold contour is 2.4×10^{-16} g cm^{-3}. Red boxes show the assumed ablation region for the simulation, and the green box shows the region in which most of the SABRE sampling occurred. A September average (SI Appendix, Fig. S4) also shows descent at high latitudes but with significantly higher concentrations at Southern high latitudes.

Figure 5 of Murphy, D. M., and Coauthors, 2023: Metals from spacecraft reentry in stratospheric aerosol particles. Proceedings of the National Academy of Sciences, 120, e2313374120, https://doi.org/10.1073/pnas.2313374120.

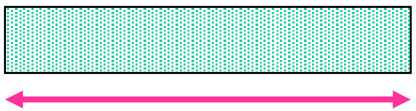
Vertical Profile of Pressure and Temperature (Mean Values for 30 ^{0}N, March)



Courtesy of Daniel J. Jacob

Barometric Law (Variation of Pressure with Altitude)

- **Consider Elementary Slab of Atmosphere:**



$$P(z) = P(z+dz) + \rho_a g dz \Rightarrow \boxed{\frac{dP}{dz} = -\rho_a g}$$

Hydrostatic Equation

Ideal Gas Law: $$\rho_a = \frac{PM_a}{RT} \Rightarrow \frac{dP}{P} = -\frac{M_a g}{RT} dz$$

Assume *T* = Constant, Integrate:

$$\boxed{P(z) = P(0)e^{-z/H}}$$ with **scale height** $$H = \frac{RT}{M_a g} \approx 7.4 \text{ km } (T = 250 \text{ K})$$

Barometric Law

$$\boxed{n_a(z) \approx n_a(0)e^{-z/H}}$$

Number Density

$$P(z+H) = \frac{P(z)}{e}; \quad P(z + 5\text{km}) \approx \frac{P(z)}{2}$$

Courtesy of Daniel J. Jacob

Barometric Law Application
The Sea-Breeze Effect

Temperature (T)
Pressure (P)
Land (L)
Sea (S)
Scale Height (H)

Why does the Sea-Breeze form clouds over land?

Courtesy of Daniel J. Jacob