

**NATS 101**  
**Section 4: Lecture 2**

**Atmospheric Composition and  
Structure**

# Composition of the Dry Atmosphere

<u>Gas</u>	<u>Chemical symbol</u>	<u>% of Atmosphere</u>
Nitrogen	N <sub>2</sub>	78.08
Oxygen	O <sub>2</sub>	20.95
Argon	Ar	0.93
Neon	Ne	0.0018
Helium	He	0.0005
Hydrogen	H <sub>2</sub>	0.00006
Xenon	Xe	0.000009

Chemically  
active

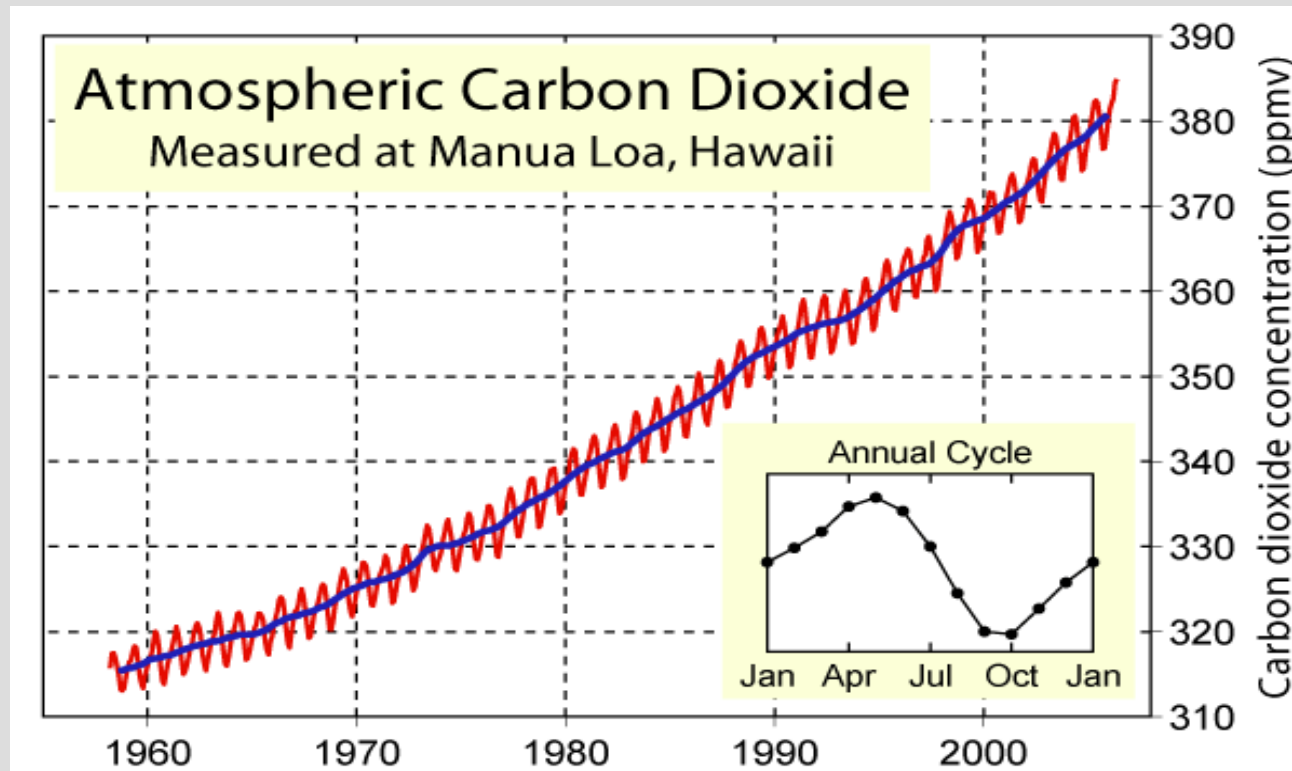
Inert gases  
(not reactive)

# Important Trace Gases

<u>Gas</u>	<u>Chemical symbol</u>	<u>Concentration (ppm)</u>
Carbon dioxide	CO <sub>2</sub>	380 (at present)
Methane	CH <sub>4</sub>	1.7
Nitrous Oxide	N <sub>2</sub> O	0.3
Ozone	O <sub>3</sub>	0.04
Particulates		0.01-0.15
Chloroflourocarbons	CFCs	0.0002

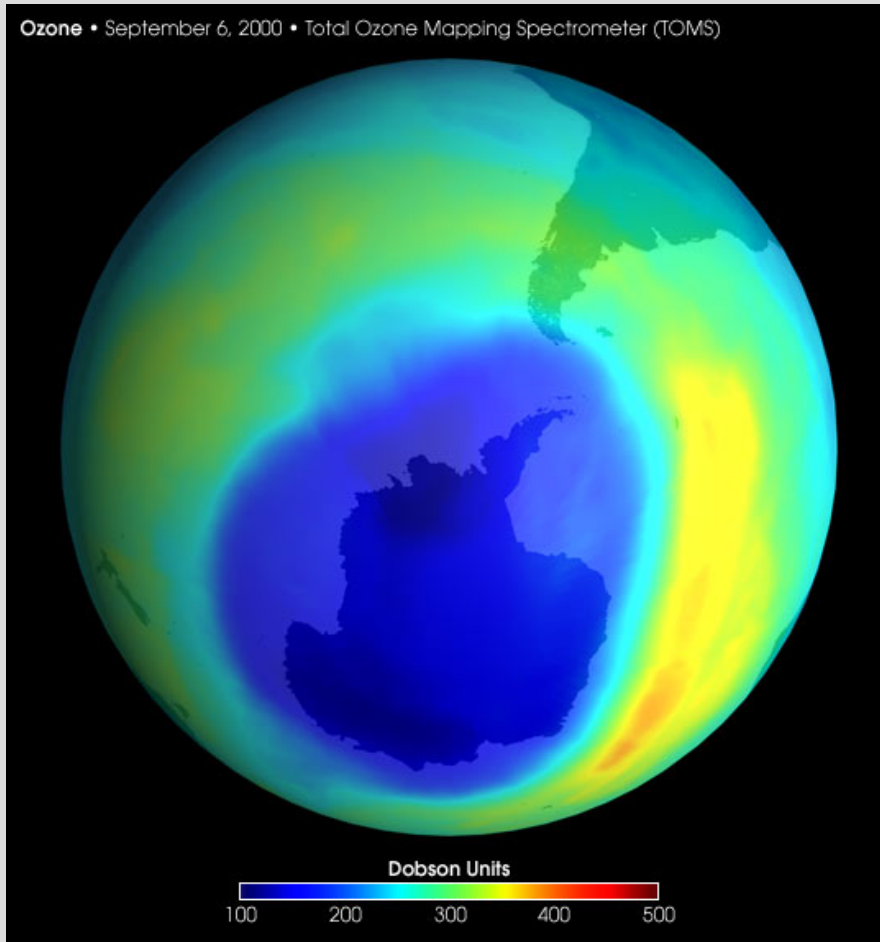
ppm = parts per million

# Carbon Dioxide (CO<sub>2</sub>)



The “Keeling curve” shows increase in atmospheric carbon dioxide at Mauna Loa since 1950s

# Stratospheric Ozone and CFCs



(NASA imagery)

Stratospheric ozone protects from Sun's UV rays.

An **ozone hole** occurs over the polar regions because of:

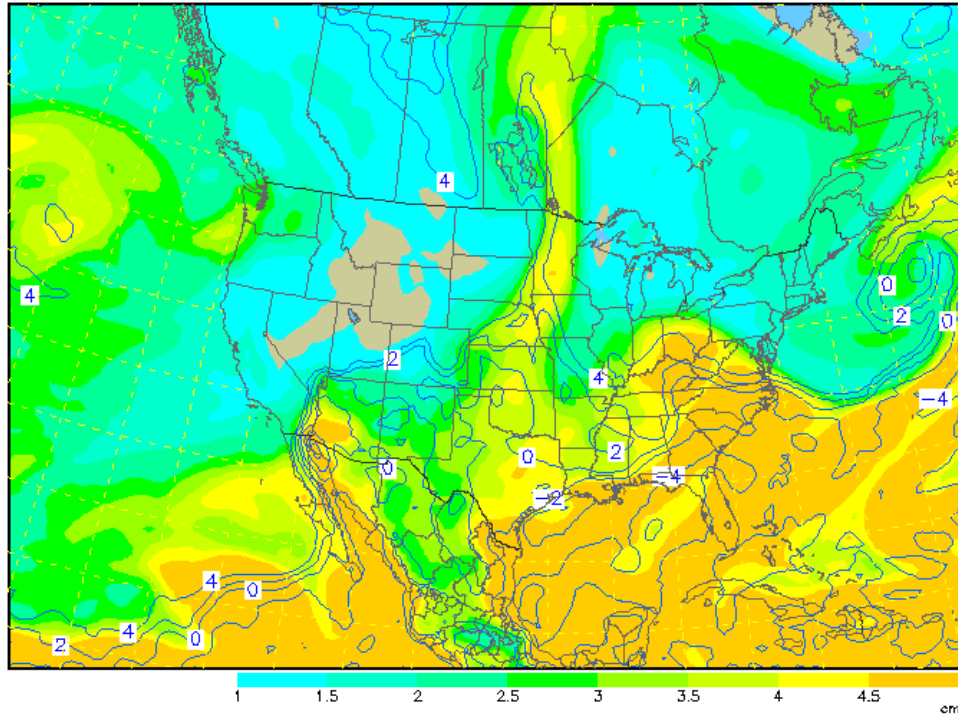
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# Water Vapor

Precipitable Water (cm) / Lifted Index (°C)

24-hour forecast valid 1200 UTC Wed 27 Aug 2008

NAM (YRF-NMM) (12z 26 Aug)



Model forecast output (from NCAR).

Water vapor is highly dependent on the given weather conditions and local climate.

It also plays a **big** role in the Earth's energy budget, as we'll see later...

What is measure which is typically used in the weather report??

# **Mass, Force, Weight, Density, and Pressure**

# What is mass?

Mass is an intrinsic property based on the molecular composition of matter. ***As long as the amount of matter does not change, its mass remains constant—regardless of location.***

SI units of mass: grams (g) or kilograms (kg)

*SI Units = Système Internationale Units*



# Some SI Units we'll use in next few lectures

<u>Quantity</u>	<u>Name (Symbol)</u>	<u>SI Units</u>
Length	meter	m
Time	second	s
Mass	grams or kilograms	g or kg
Area		
Volume		
Density		
Frequency		
Velocity or speed		
Acceleration		
Force		
Pressure		
Energy		

ALL quantities  
are derived from:

LENGTH  
TIME  
MASS

*Fill in the blanks on  
the unit measures,  
with appropriate  
notation, on your  
own as an exercise.*

**FORCE =**

*Or, as an equation...*

***F =***

**SI Units: kg m s<sup>-2</sup> or (named after which famous physicist?)**

# What is weight?

NOT the same as mass!

The concept of weight is a specific application of the concept of force:

Weight ( $W$ ) is the force on an object to the gravitational acceleration ( $g$ ):

$$W =$$
$$\text{Weight} =$$

Try to verify the correct SI units in the calculation...

# Weight is dependent on the size of the attracting body...

Newton's law of gravitation indicates that the gravitation acceleration is dependent on the size of the body. The more massive, the bigger  $g$ .



$g$  of Earth =  $9.8 \text{ m s}^{-2}$



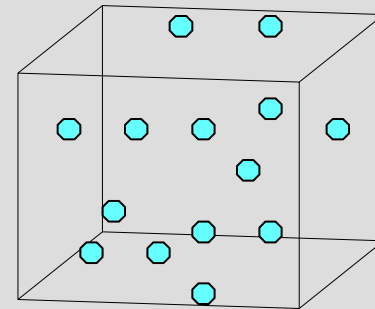
$g$  of Moon =  $1.6 \text{ m s}^{-2}$   
(About 1/6 of Earth)

# What is density?

Density ( $\rho$ ) is the mass ( $m$ ) per unit volume ( $V$ ):

$$\rho = \frac{m}{V}$$

SI Units:



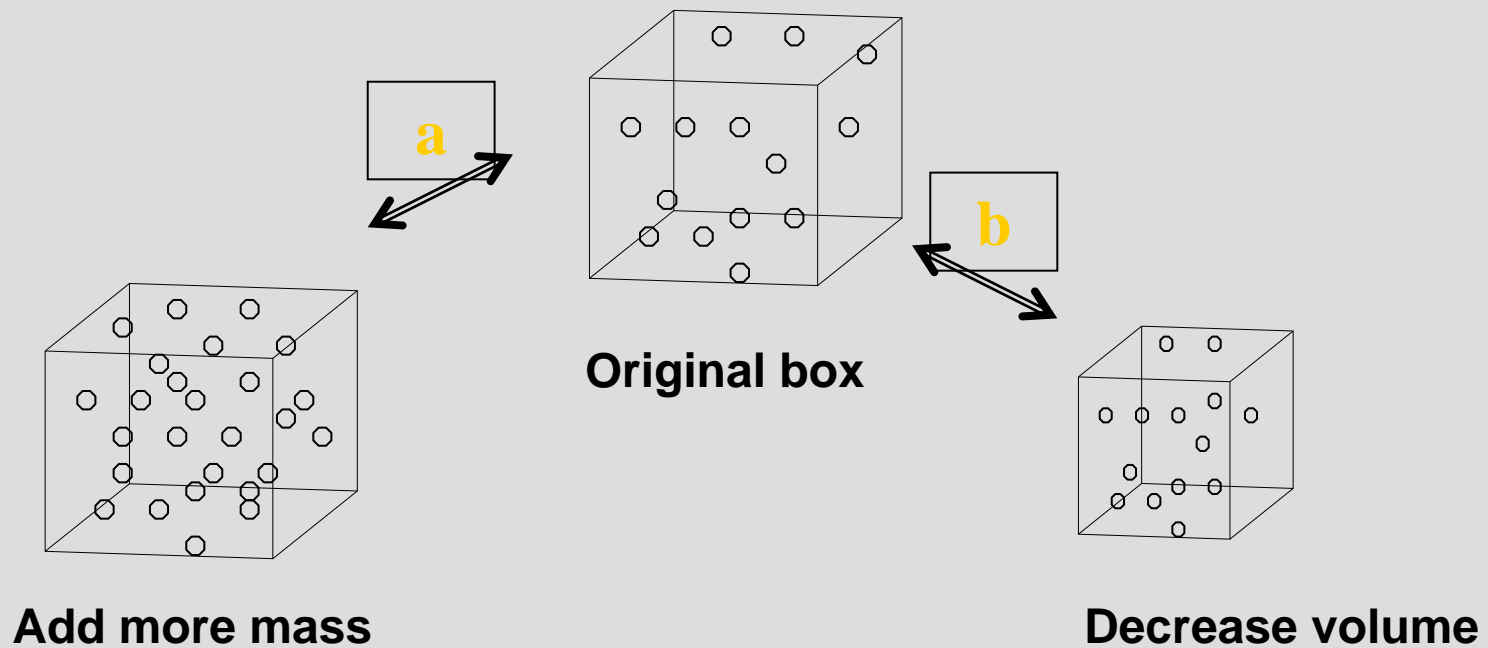
# Changes in density

Density **DECREASES** when:

Mass decreases or volume increases

Density **INCREASES** when:

Mass increases or volume decreases



# What is pressure?

Pressure ( $P$ ) is the force per unit area ( $A$ )

$$P = \frac{F}{A}$$

SI Units:

The typical unit of atmospheric pressure is millibars

1 mb = (SI unit of pressure from above)

**The air pressure at the surface of the Earth at sea level is defined as 1 Atmosphere (Atm):**

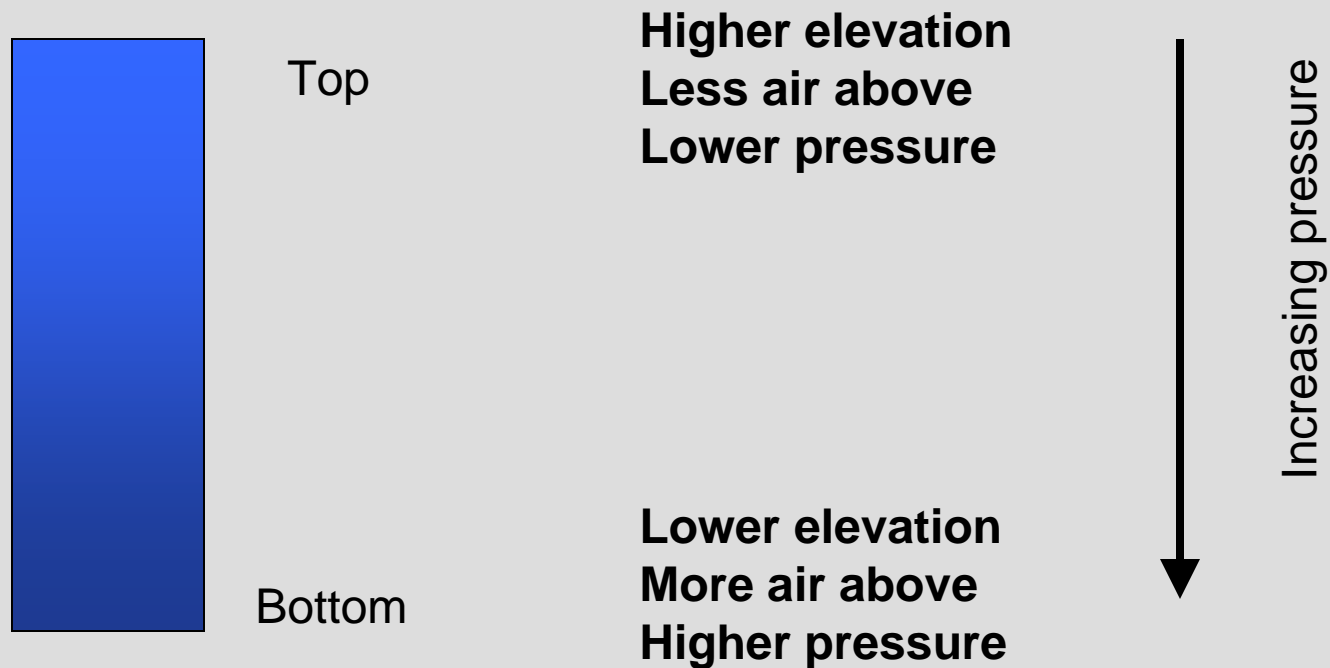
**“Atmosphere” → 1 Atm =**



Blaise Pascal

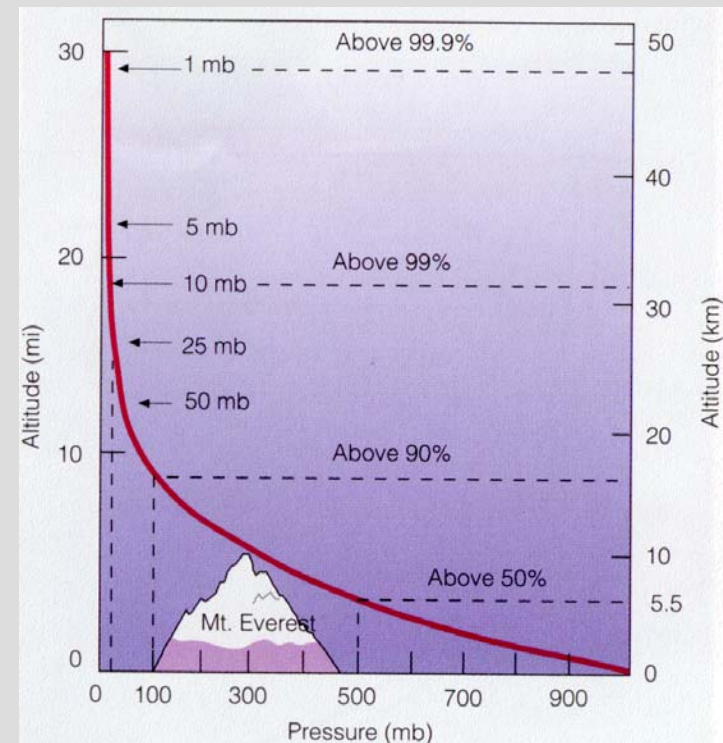
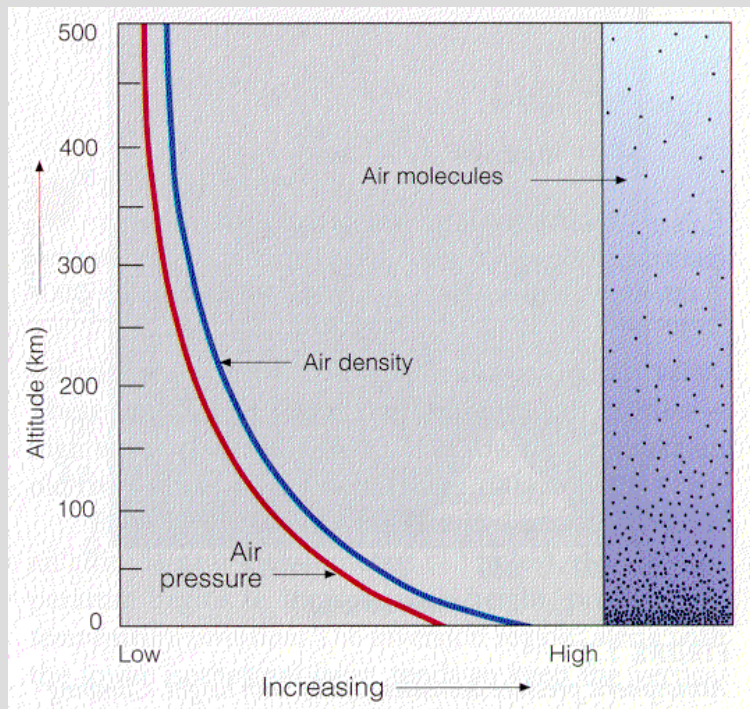
# Air pressure

Given the mathematical definitions we've already discussed, ***air pressure can be thought of as the weight of a column of air above you.***





# Change in density and pressure with height



Density and pressure decrease ***exponentially*** with height. For each 16 km in altitude, the pressure decreases by a factor of 10..

# Equation for pressure variation

Given that we know atmospheric pressure changes exponentially with height, we can apply this relationship to derive the air pressure at various altitudes above sea level:

$$P = P_{MSL} \times 10^{\left(\frac{-Z}{16 \text{ km}}\right)} \quad \underline{\text{OR}} \quad P = P_{MSL} \times e^{\left(\frac{-Z}{8 \text{ km}}\right)}$$

*e = exponential function = 2.71828....*

Z= Elevation in kilometers

P = pressure in mb at location

$P_{MSL}$  = mean sea level pressure in mb =

# Surface pressure Tucson vs. Humphrey's Peak



**Humphrey's Peak:**  
Elevation 3850 m  
*Highest Point in AZ*

**Tucson:**  
Elevation 728 m

# Using equation for pressure variation

## TUCSON

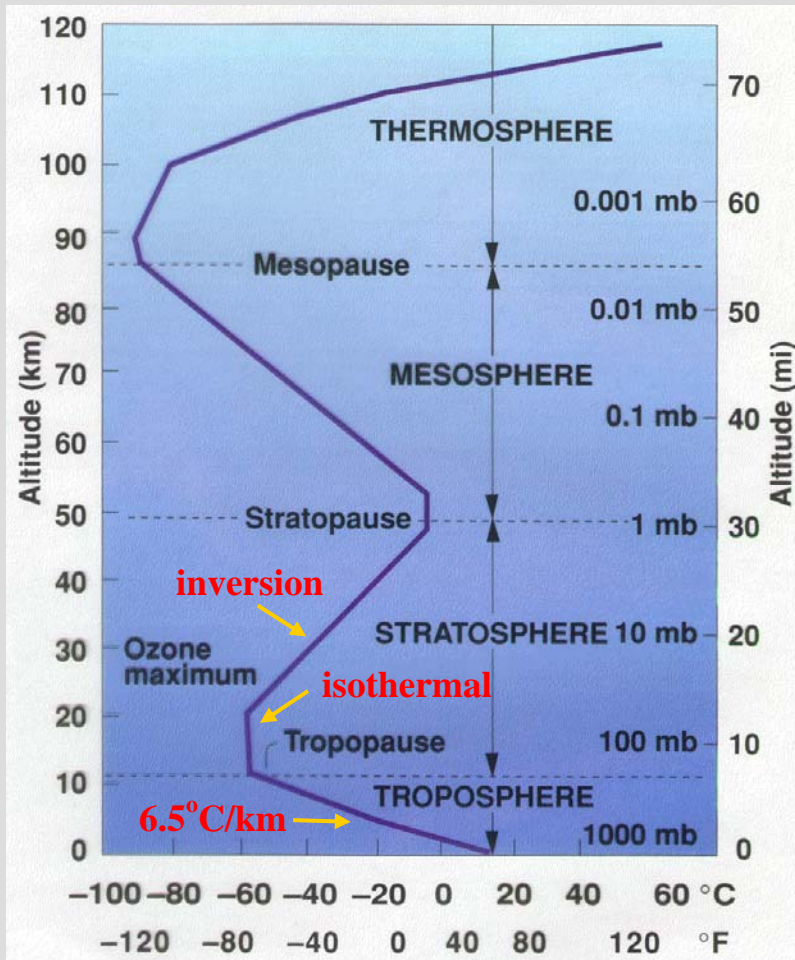
$$P = P_{MSL} \times 10^{\left(\frac{-0.728 \text{ km}}{16 \text{ km}}\right)}$$

$$P = (1013 \text{ mb}) \times 10^{\left(\frac{-0.728 \text{ km}}{16 \text{ km}}\right)}$$

$$P = 912 \text{ mb}$$

## HUMPHREY'S PEAK

# Change in Temperature with Height



Changes in temperature are more complicated and have to do with the radiative processes in different parts of the atmosphere (more on that later...)

The rate of change of temperature with height is called the *lapse rate*. Positive lapse rate mean temperature decrease with height.

The places where the sign of the lapse rate changes defines the different levels of the atmosphere.

# Atmospheric Layers

- **Troposphere** (surface – 11 km): Nearly all of what we think of as “weather” happens here. Lapse rate of 6.5 °C per km.  
“Tropo” = Greek for
- **Stratosphere** (11 km – 50 km): Where the ozone layer is located and Sun’s UV rays are absorbed by photodissociation.  
“Strato” = Greek for
- **Mesosphere** (50 km – 90 km)
- **Thermosphere**: (90 km – 500 km): Ionization of atmospheric gases
- **Exosphere** (500 km): Basically outer space...

# Summary of Lecture 2

The atmosphere is composed of chemically active and inert gases. The “important” gases affect the Earth’s energy budget and/or atmospheric chemistry. Carbon dioxide, water vapor, and ozone are good examples.

We defined mass, force, weight, density, and pressure. Know how each of these are derived, what they physically mean, and their SI units of measurement.

Pressure can be thought of as the weight of a column of air above you, and it decreases exponentially with height. A simple equation was presented with relates the variation in pressure with height.

Temperature changes with height are more complicated and have to do with radiative processes in different parts of the atmosphere. Places where the lapse rate changes define the various atmospheric layers.