ATMOSPHERE: THE GASEOUS ENVELOPE THAT SURROUNDS A PLANET OR ANY OTHER CELESTIAL BODY.

AIR: THE INVISIBLE, ODORLESS MIXTURE OF GASES AND SUSPENDED PARTICLES THAT SURROUNDS ONE SPECIAL PLANET.

*Air is the Earth Atmosphere*
The composition of Earth’s atmosphere has changed over time. Changes in the oxygen and carbon dioxide contents, in particular, were driven by photosynthesis and other life processes.
COMPOSITION OF THE ATMOSPHERE

1. Mixture of gases
2. Aerosols
   ✓ Suspended Particles

- Oxygen ($O_2$): 20.95%
- Argon ($Ar$): 0.93%
- Nitrogen ($N_2$): 78.08%

All other gases, 0.04%

<table>
<thead>
<tr>
<th>Substance</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide ($CO_2$)</td>
<td>0.035%</td>
</tr>
<tr>
<td>Neon ($Ne$)</td>
<td>0.0018%</td>
</tr>
<tr>
<td>Helium ($He$)</td>
<td>0.00052%</td>
</tr>
<tr>
<td>Methane ($CH_4$)</td>
<td>0.00014%</td>
</tr>
<tr>
<td>Krypton ($Kr$)</td>
<td>0.00010%</td>
</tr>
<tr>
<td>Nitrous oxide ($N_2O$)</td>
<td>0.00005%</td>
</tr>
<tr>
<td>Hydrogen ($H_2$)</td>
<td>0.00005%</td>
</tr>
<tr>
<td>Ozone ($O_3$)</td>
<td>0.000007%</td>
</tr>
</tbody>
</table>

Variable substances

- Water vapor ($H_2O$): 1-4% variable
- Aerosols
VARIABLES USED TO DETERMINE THE STATE OF THE ATMOSPHERE

1. Temperature
2. Air pressure
3. Humidity
4. Cloudiness
5. Wind speed and direction
TEMPERATURE: A MEASURE OF THE AVERAGE KINETIC ENERGY OF ALL THE ATOMS IN A BODY.

HEAT: THE TOTAL KINETIC ENERGY (ENERGY OF MOTION) OF ALL ATOMS IN A SUBSTANCE.

INSOLATION: IS THE ENERGY FROM THE SUN THAT ACTUALLY REACHES THE EARTH'S SURFACE.

The atmosphere gets its heat energy from the Sun. The flux of energy coming from the Sun is 1370 W/m². This is the energy flux that would be measured by a satellite orbiting the Earth outside the atmosphere.
**What is the relationship between wavelength and energy?**

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Gamma Ray</th>
<th>X-Ray</th>
<th>UV Visible</th>
<th>Infrared</th>
<th>Microwave (Radar)</th>
<th>Radio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.03</td>
<td>300</td>
<td>400</td>
<td>700</td>
<td>10^6 (1 mm)</td>
<td>3x10^8 (30 cm)</td>
<td></td>
</tr>
</tbody>
</table>

\[ \lambda \]

\[ E \]

- **Gamma Ray**: 0.03 nm
- **X-Ray**: 300 nm
- **UV Visible**: 400 nm
- **Infrared**: 700 nm
- **Microwave (Radar)**: 10^6 (1 mm)
- **Radio**: 3x10^8 (30 cm)

- **Wavelength (nm)**: 400, 500, 600, 700
- **Colors**: Blue, Green, Red
Short-wavelength radiation from the Sun passes through the glass roof (or the atmosphere) and heats the ground. Some of the heat from the ground then warms the air in the greenhouse; the rest is re-radiated back as infrared radiation, which is then trapped by the glass roof, producing additional heating inside. The warmed air emits long-wavelength radiation which passes through the glass and escapes into the atmosphere. When a balance is reached, the incoming radiation equals the escaping radiation.
The percentage of a given wavelength range absorbed is indicated by the height of the peak, from 0 to 100 percent. The bottom panel is the sum of all the panels above. Note that, except for its longest wavelengths, ultraviolet radiation is almost fully absorbed.
Life-protecting layers of O, O₂, and O₃ in the atmosphere absorb lethal ultraviolet radiation.
The atmosphere is divided into four temperature zones. The outermost zone, the thermosphere, continues to an altitude of about 700 km.
• Temperature in this zone decreases with altitude.
• Absorption of reradiated long-wavelength infrared rays is most effective at the bottom of the atmosphere where the air is most dense.
• Also, air at the bottom is continually warmed by the ground and the ocean.
• Convection of air happens all the time.

Tropopause: The top of the troposphere.
• Temperature increases with altitude.
• Ozone absorbs ultraviolet radiation coming from the Sun.
• This absorption converts the energy of the UV rays into longer wavelength radiation, which heats the air.
• UV absorption is maximum at the top of the stratosphere, so this is where the highest temperatures are found.
• As the Sun's rays pass through this zone, less and less UV is left to be absorbed, so the lowest temperature are found.
• Temperature decreases with increasing altitude.
• The chemicals are in an excited state, as they absorb energy from the Sun.
• The mesosphere is the coldest layer.
• This is also the layer in which a lot of meteors burn up while entering the Earth's atmosphere.
- Temperature increases with altitude.
- High absorption of solar radiation by gases.
- High bombardment of gas molecules by protons and electrons given off by the Sun.
The Earth's atmosphere is divided into several layers based on temperature and altitude:

- **Troposphere** (0-20 km): The lowermost layer where weather phenomena occur. It is the coldest layer at its base and gets warmer with altitude. The tropopause marks its upper boundary.
- **Stratosphere** (20-50 km): Above the troposphere, this layer is relatively stable with a slight warming trend. It contains the ozone layer, which protects the Earth from harmful ultraviolet radiation.
- **Mesosphere** (50-80 km): This layer is further divided into the mesopause, which is the coldest point in the atmosphere.
- **Thermosphere** (80 km and above): This layer is characterized by high temperatures due to solar radiation. It is where the auroras occur and where weather balloons can travel.
Sketch of a simple mercury barometer. Air pressure on the surface of the open bowl holds up the column of mercury in the glass tube. The downward pressure exerted by the air exactly balances the downward pressure exerted by the column of mercury on the bowl. When the air pressure changes, the height of the column adjusts in response.
Air pressure decreases smoothly with altitude.

If a helium balloon 1 m in diameter is released at sea level, it expands as it floats upward because of the pressure decrease. If the balloon did not burst, it would be 6.7 m in diameter at a height of 40 km.
LATENT HEAT
Amount of heat absorbed or released from a gram of H₂O during a change of state.
Water vapor (water in gas phase) gets into air by evaporation. But some of the gas molecules in the vapor will also move back into liquid. When the # of molecules that evaporate (going from liquid to gas) are equal to the number that condense (going from gas to liquid) the vapor is saturated.
It is a term used to describe the amount of water vapor (water in gas phase) that exists in a gaseous mixture of air and water. The relative humidity of an air-water mixture is defined as the ratio of the partial pressure of water vapor in the mixture to the saturated pressure of water vapor at a prescribed temperature.

\[
\text{Relative Humidity} = \frac{\text{actual vapor pressure}}{\text{saturation vapor pressure}} \times 100
\]
Example:

An air at 20 °C with a water vapor pressure of 1.403 kPa
Saturated air at 20 °C has a water vapor pressure of 2.338 kPa

Therefore,

Relative Humidity = \( \frac{1.403}{2.338} \times 100 \)

= 60%

If the vapor pressure exceeds the capacity, condensation occurs.
EVAPORATION AND WATER VAPOR IN THE ATMOSPHERE

Annual effective evaporation

- 0 to 500mm
- 500 to 1500mm
- 1500 to 2500mm
Cloud Formation

- **Sun's Heat**
  - Cooling, Rising, Condensing Air Parcel (Blue dots represent moisture)
  - Rising Warm Air Parcel
  - Warm Air Above The Ground
  - Warm Ground
  - **Ground**
A. Density lifting causes a convection cell as warm, low-density air rises and cold, higher-density air sinks.

B. Frontal lifting. A warm front occurs when flowing warm air overrides cold air and is forced upward.

C. Frontal lifting. A cold front occurs when a wedge of forward-moving cold air slides under warm air and forces it upward.

D. Orographic lifting occurs when flowing air is forced upward by mountains or other sloping ground.

E. Convergence lifting occurs when masses of air collide and are forced upward.
A cold front is defined as the transition zone where a cold air mass is replacing a warmer air mass. Cold fronts generally move from northwest to southeast. The air behind a cold front is noticeably colder and drier than the air ahead of it.
CLASSIFICATION AND ALTITUDE OF CLOUDS

- Cirrus
- Cirrocumulus
- Altocumulus
- Altostratus
- Nimbostratus
- Stratus
- Cumulus
- Stratocumulus
- Anvil head
- Cumulonimbus

Altitude (km)
CUMULUS

STRATOCUMULUS
Clouds are white because their water droplets or ice crystals are large enough to scatter the light of the seven wavelengths (red, orange, yellow, green, blue, indigo, and violet), which combine to produce white light.
REMOTE SENSING OF THE ATMOSPHERE
DOPPLER RADAR

VIGILANTE
En Todas Nuestras Ediciones
El radar Doppler más poderoso de la TV

SUPER-DOPPLER

Isabela
Mayaguez
San Juan
Orocovis
Ponce
NATIONAL WEATHER SERVICE DOPPLER RADAR STATIONS

HTTP://RADAR.WEATHER.GOV/
EXAMPLE OF A DOPPLER RADAR IMAGE

Image of Irene approaching Puerto Rico from NWS Composite radar

ENHANCED LOW-COST MONITORING

Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere
ENHANCED LOW-COST MONITORING
OF EXTREME WEATHER
AUGUST 9, 2010

OTG radars at UPRM

NWS Nexrad
TROPICAL RAINFALL MEASURING MISSION
TRMM

• Precipitation Radar
• TRMM Microwave Imager
• Visible-Infrared Radiometer
• Cloud and Earth Radiant Energy Sensor
• Lightning Imaging Sensor
UARS was a NASA-operated orbital observatory whose mission was to study the Earth’s atmosphere, particularly the protective ozone layer. It was deployed from Space Shuttle Discovery during the STS-48 mission on 15 September 1991. It entered Earth's orbit at an operational altitude of 600 kilometres (370 mi), with an orbital inclination of 57 degrees.

The original mission duration was to be only three years, but was extended several times. When the mission finally ended in June 2005 due to funding cuts, 14 years after the satellite's launch, six of its ten instruments were still operational. A final orbit-lowering burn was performed in early December 2005 to prepare the satellite for deorbit. On 26 October 2010, the International Space Station performed a debris-avoidance maneuver in response to a conjunction with UARS.

The decommissioned satellite re-entered Earth's atmosphere on 24 September 2011. Considerable media attention surrounded the event, largely due to NASA's predictions that substantial parts of the satellite might reach the ground, potentially endangering inhabited areas. However, the satellite ultimately impacted in a remote area of the Pacific Ocean.
[Temperature and Transport] | [Pollutants] | [The Ozone Layer] | [Antarctic Ozone Hole] | [CFCs] | [Development of the Ozone Hole] | [Ozone Hole Mapping] | [CLO Variations] | [Polar Ozone Destruction] | [Tropical Water Vapor Ascent] | [Equatorial Winds] | [Sulfur Dioxide from Mt. Pinatubo] | [Variations in Solar UV] | [Tidal Winds] | [Jakarta Barometric Pressure] | [Barometer] | [Tidal Variation in Airglow] | [Upper Tropospheric Water Vapor and El Nino] | [Gravity Wave Breaking in the Mesosphere] | [High Clouds in the Tropics]
Total Ozone Mapping Spectrometer

Code 916: Atmospheric Chemistry and Dynamics Branch

TOMS 1978-2005

Nimbus 7 Observatory
OZONE CONCENTRATION AS MEASURED WITH TOMS
The OMI instrument (onboard Aura Satellite) can distinguish between aerosol types, such as smoke, dust, and sulfates, and measures cloud pressure and coverage, which provides data to derive tropospheric ozone.

Visible: 350 - 500 nm
UV: UV-1 = 270 to 314 nm
UV-2 = 306 to 380 nm

2011 Arctic ozone hole
A combination of extreme cold temperatures, man-made chemicals and a stagnant atmosphere were behind what became known as the Arctic ozone hole of 2011, a new NASA study finds.
The Ozone Mapping and Profiler Suite (OMPS) is the next generation of back-scattered UltraViolet (BUV) radiation sensors. The first OMPS is currently flying onboard the Suomi NPP spacecraft and has a dual mission to provide NOAA with critical operational ozone measurements while continuing the nearly 40 year NASA records of total column and profile ozone created by previous BUV sensors. OMPS is composed of three different sensors, two nadir-looking and one looking at the limb.