Lecture 1       Atmospheric Composition and Structure.

### TABLE 1.1 Composition of the Atmosphere Near the Earth’s Surface (EOM)

<table>
<thead>
<tr>
<th>Permanent Gases</th>
<th>Percent (by Volume) Dry Air</th>
<th>Gas (and Particles)</th>
<th>Variable Gases</th>
<th>Percent (by Volume)</th>
<th>Parts per Million (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>N₂</td>
<td>Water vapor</td>
<td>H₂O</td>
<td>0 to 4</td>
<td></td>
</tr>
<tr>
<td>Oxygen</td>
<td>O₂</td>
<td>Carbon dioxide</td>
<td>CO₂</td>
<td>0.036</td>
<td>360*</td>
</tr>
<tr>
<td>Argon</td>
<td>Ar</td>
<td>Methane</td>
<td>CH₄</td>
<td>0.00017</td>
<td>1.7</td>
</tr>
<tr>
<td>Neon</td>
<td>Ne</td>
<td>Nitrous oxide</td>
<td>N₂O</td>
<td>0.00003</td>
<td>0.3</td>
</tr>
<tr>
<td>Helium</td>
<td>He</td>
<td>Ozone</td>
<td>O₃</td>
<td>0.000004</td>
<td>0.04**</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H₂</td>
<td>Particles (dust, soot, etc.)</td>
<td>N₂O</td>
<td>0.000001</td>
<td>0.01–0.15</td>
</tr>
<tr>
<td>Xenon</td>
<td>Xe</td>
<td>Chlorofluorocarbons (CFCs)</td>
<td>N₂O</td>
<td>0.00000002</td>
<td>0.0002</td>
</tr>
</tbody>
</table>

*For CO₂, 360 parts per million means that out of every million air molecules, 360 are CO₂ molecules.

**Stratospheric values are about 5 to 12 ppm.

- Atmosphere primarily N₂, O₂, small quantities of other ‘permanent’ gases whose concentrations do not vary significantly over space or time. Trace permanent gases, except hydrogen (H), are inert.
- ‘Variable’ gases - concentrations vary with location, time due to exchange with sea, land surfaces, geological, biological and human activities.
Variable gases - $\text{H}_2\text{O}$ and $\text{CO}_2$

- Moisture source: evaporation, plant transpiration.
  - sink: precipitation
- Warm air can hold much more water vapor:
  - Tropics - Air is 2-4% water vapor by volume
  - Poles (winter), high altitudes - Under 0.1%
- $\text{CO}_2$ largely biological in origin, cycled through ocean, rocks.
- $\text{CO}_2$ has risen 30% from 280 ppm in 1800 to over 375 ppm today, mainly due to fossil fuel burning.
- $\text{CO}_2$ also outgassed in volcanic eruptions. This may have helped maintain $\text{CO}_2$ at several times current concentrations 50-100 million years ago.
Ozone (O₃)

- At the surface, naturally occurring O₃ concentrations are very low (0.02-0.05 ppm). However, O₃ is main constituent of photochemical smog, and causes lung, plant irritant at levels above 0.1 ppm.
- 97% of ozone in upper atmosphere, mainly at heights above 20 km, sunlight splits oxygen molecules (O₂) into O atoms, which recombine with O₂ molecules to produce ‘lots of’ (10+ ppm) O₃.
- Here, it shields surface life by absorbing UV and splitting (‘photodissociating’) into O₂ + O
- Ozone is also destroyed by nitric oxide (high altitude jet planes). Chlorine (CFCs) also destroys ozone in extreme cold - Antarctic ozone hole.
Air pressure

- Supports weight of air column above.
- At surface -
  
  Column 1 inch on side weighs 14.7 lb,
  Column 1 cm on side weighs 1013 g,
  \[\Rightarrow\text{Air pressure is } 1013 \text{ g/cm}^2 = 1013 \text{ milli-bars (mb)}.\]
- Air pressure decreases with height, reflecting smaller mass (weight) of overlying air column.
- Only 50% of the mass of molecules in the atmosphere is above 5.5 km, so pressure at 5.5 km is 50% that at surface, or about 500 mb.
- Only 1% of mass above 30 km, where pressure is 10 mb, 1% of surface pressure.
Layers of the Atmosphere

- Warmed due to UV absorbed by ozone
- Ozone maximum
- Tropopause
- Stratopause
- Mesopause
- Thermosphere
The Outer Atmosphere

Figure 1.8  (EOM)
Layers of the atmosphere based on temperature (red line), composition (green line), and electrical properties (blue line).