Indian Institute of Technology, Kanpur

Department of Earth Sciences

ESO213A: Fundamentals of Earth Sciences

Lecture 36. Atmosphere

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Aims of this lecture

- Early Atmosphere
- Present Atmosphere, composition and layers

Reading:
- Grotinger & Jordan's book (Chapter 15)

The Atmosphere

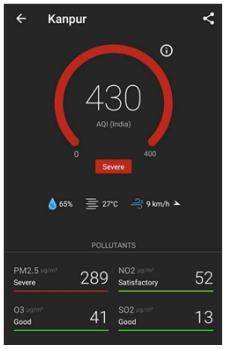
- The gaseous envelope that surrounds a planet and/or other celestial body
- AIR: Mixture of gasses and suspended particles that surrounds Earth
- The composition of Atmosphere is important as

  (1) we breath it;
  (2) maintains Earth's surface temperature; control the weather and overall climate.
  (3) ozone to protect from UV

The Aerosols

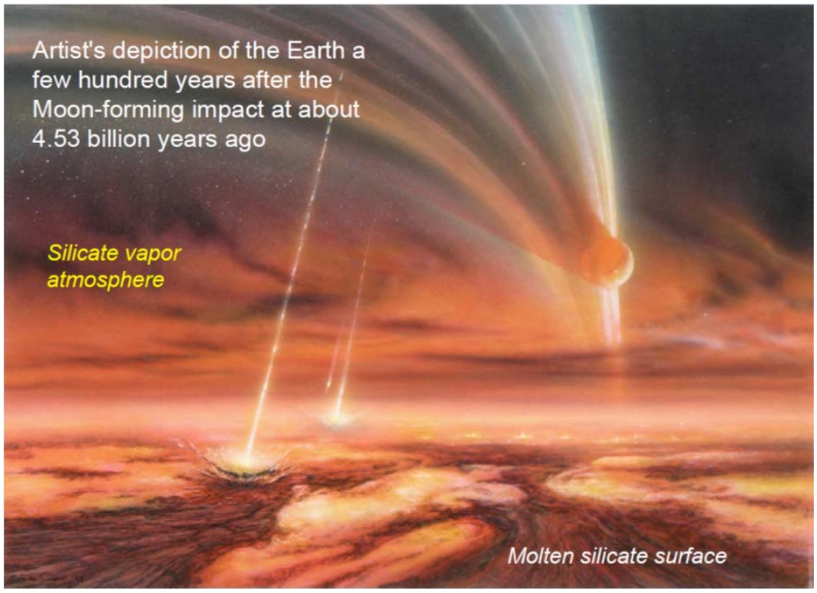
- There are also aerosols in the atmosphere
- Tiny droplets or solid particles, so small to remain suspended in the air

  Smoke
  Sea-salt crystals
  Ice-crystals
  Dust
  Volcanic emissions
  Industrial pollution



- Some aerosols (soot) absorb solar radiation: heating
- Some aerosols (sulfur) reflect incoming radiation: cooling
- Some aerosols form clouds..

The surface of the Earth since it's birth



- Molten surface, very hot, silicate rain !
- The carbons also left by degassing and the concentration of carbon in the atmosphere was very high !
- The greenhouse effect was enormous.
- What brought back the carbons inside the Earth again? When?

The early Atmosphere

- Earth's first atmosphere was most likely comprised of hydrogen and helium (two most abundant gases found in the universe!)
- Through the process of *outgassing*, the outpouring of gases from the earth's interior, many other gases were injected into the atmosphere -
  - Water vapour
  - Carbon dioxide
  - Nitrogen
  - Oxygen (not a product of degassing !)
- As outgassing occurred over a period of millions of years, the atmosphere evolved to its current state

Photo: S.Misra

The Contributions from Volcanoes

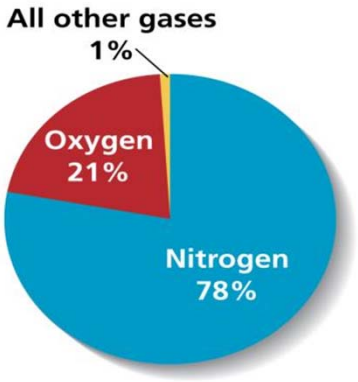
GNS Science, NZ

The Contributions from Volcanoes

Volcano Tectonic Style Temperature	**Kilauea Summit** Hot Spot 1170°C	**Erta` Ale** Divergent Plate 1130°C	**Momotombo** Convergent Plate 820°C
Water Vapor H_2O	37.1	77.2	97.1
Carbon Dioxide CO_2	48.9	11.3	1.44
Sulfur Dioxide SO_2	11.8	8.34	0.50
Hydrogen H_2	0.49	1.39	0.70
Carbon Monooxide CO	1.51	0.44	0.01
Hydrogen Sulfide H_2S	0.04	0.68	0.23
Hydrochloric Acid HCl	0.08	0.42	2.89
Hydrofluoric Acid HF	---	---	0.26

Examples of volcanic gas compositions, in volume percent concentrations (from Symonds et. al., 1994)

The Contributions from Volcanoes



Gas	Percentage by Volume
Nitrogen (N_2)	78.084
Oxygen (O_2)	20.946
Argon (Ar)	0.934
Carbon dioxide (CO_2)	0.037
Neon (Ne)	0.00182
Helium (He)	0.00052
Methane (CH_4)	0.00015
Krypton (Kr)	0.00011

Less, but also important

What happened with all CO_2 and H_2O that come from volcanoes?

Fate of Volcano generated water

Atmosphere cannot hold all water vapour injected from volcanoes

The water vapour condensed into clouds and over time formed the oceans

If we consider the volume, it would be a very small ball in front of the total mass of the earth.

Reservoir	Volume (million Km3)	Percent of Total	Reproduction Rate Cu.Km/ year
Oceans & Seas	1370	96.5	452
Ice caps & Glaciers	24	1.74	3
Ground water	60	1.74	12
Rivers, Lakes & Swamp	0.2812	0.0132	39
Soil moisture	0.083	0.001	83
Water vapour	0.014	0.001	525
Biosphere	0.0011	0.0001	39
Total	1454.3793	99.9953	1153

HH Lamb, 1972

Fate of Volcano generated CO_2

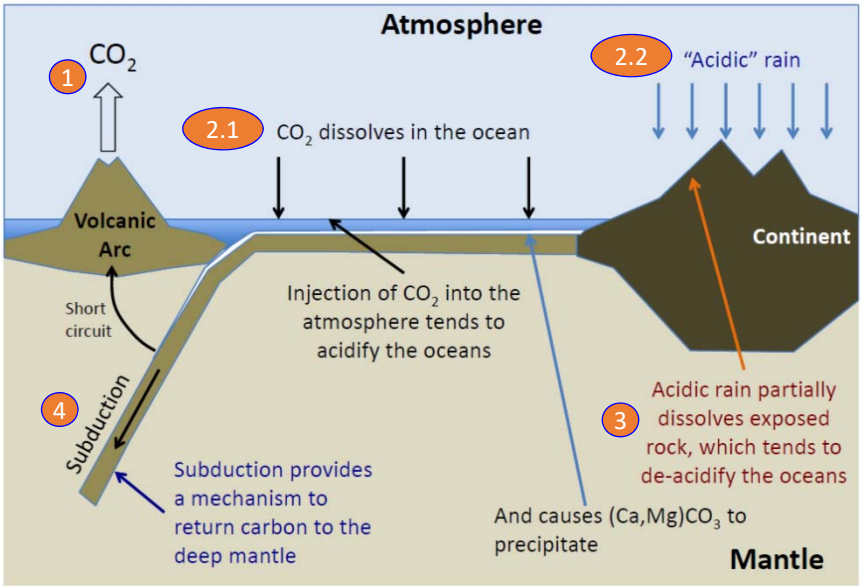
CO2 is removed from the atmosphere by

- Biosphere
- Dissolution in oceans
- Chemical weathering
- Tectonic processes
- Into the rocks

	Relative units
Biosphere	**2**
Atmosphere (as CO_2)	**70**
Oceans (as dissolved CO_2)	**4000**
Fossil Fuels	**800**
Shales	**800,000**
Carbonate Rocks	**2,000,000**

PK weys, 197o

Climate-regulating carbon cycle



Source of Nitrogen, Argon and Oxygen

Very small amount injected from volcanoes, but nitrogen is almost chemically inert and also not soluble in sea water

Nitrogen stays in the atmosphere and there is almost no removal

Radioactive decay in the rocks

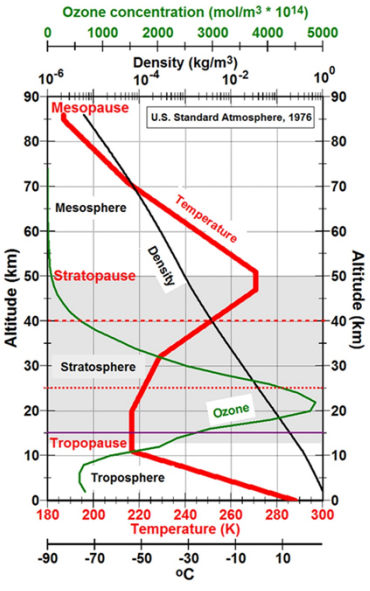
Similar process of nitrogen

Photosynthesis

Now the O2 concentration is about 20% and it was maximum (~35%) 550 myr ago.

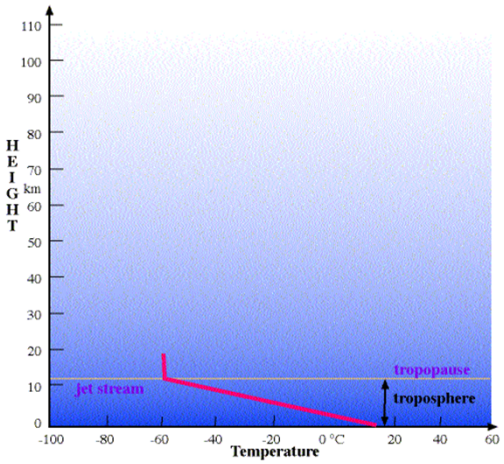
The Atmosphere

The atmosphere is comprised of layers based on temperature. These layers are the troposphere, stratosphere, mesosphere and thermosphere. A further region at about 500 km above the Earth's surface is called the exosphere.



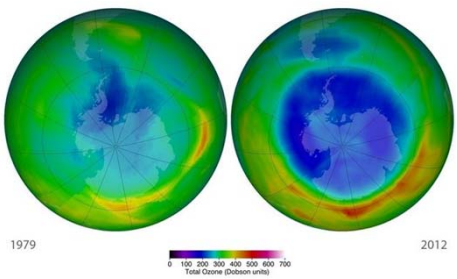
The Troposphere

- Temperature decreases with height (lapse rate: 6.5 °C/km).
- Extends from surface to about 10-12 km (increases in summer).
- The height of the troposphere varies from the equator to the poles. At the equator it is around 11-12 miles (18-20 km) high, at 50°N and 50°S, 5½ miles and at the poles just under four miles high.
- top of troposphere is called the tropopause that separates troposphere from stratosphere.
- Very unstable, where all the weather occurs.

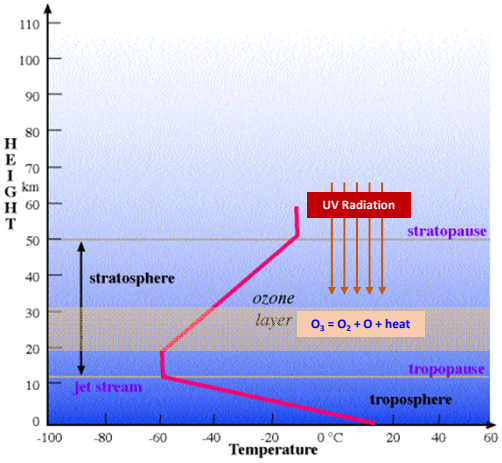


The Stratosphere

- Temperature increases with height (inversion layer). WHY?
- Extends from the tropopause to about 40-50 km
- Holds about 19% of the atmospheric gases; but almost no water vapour.
- Contains the ozone layer (20-30 km).

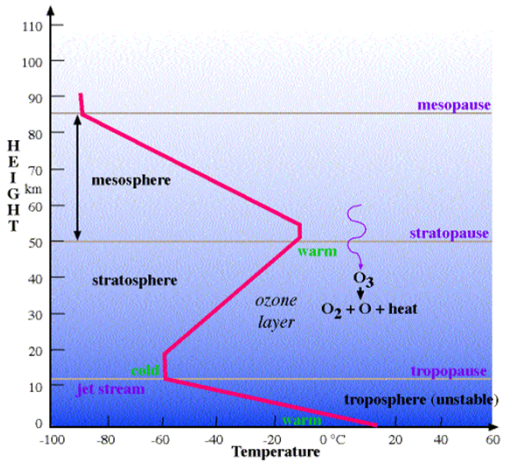


1 Dobson unit : a layer of gas of 10 µm thick at constant PT. Image source: NASA



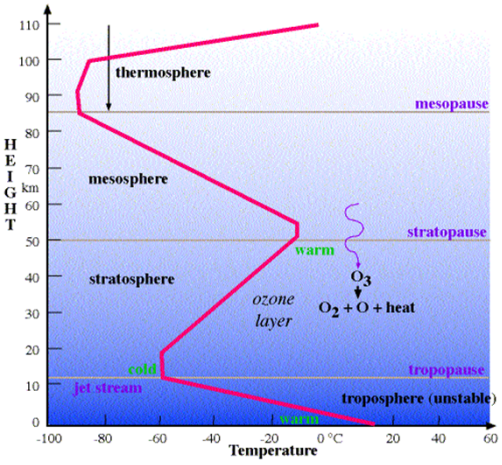
The Mesosphere

- Temperature decreases with height.
- Extends from the stratosphere to about 40-50 km
- The gases, including the oxygen molecules, continue to become thinner and thinner with height.
- the gases in the mesosphere are thick enough to slow down meteorites hurtling into the atmosphere, where they burn up, leaving fiery trails in the night sky.
- the mesopause is the coolest layer in the atmosphere.



The Thermosphere

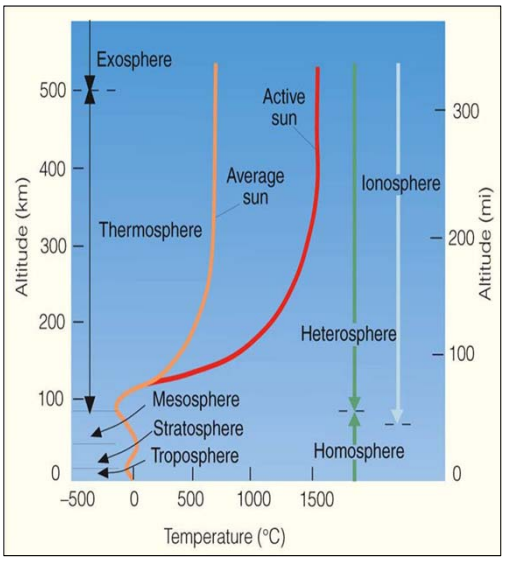
- Temperature increases with height (reaches about 2000 °C).
- Extends from the mesosphere to about 350 km
- The gases of the thermosphere are increasingly thinner than in the mesosphere. Only the higher energy ultraviolet and x-ray radiation from the sun is absorbed.



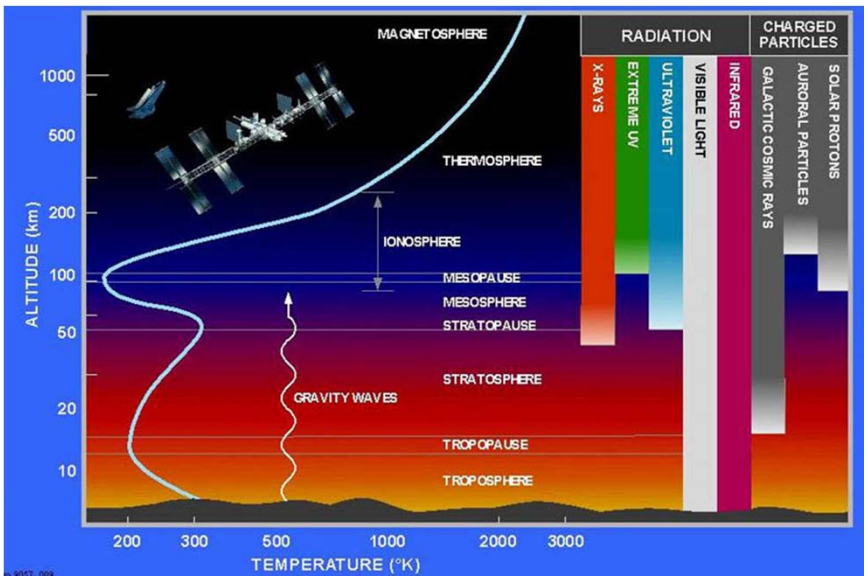
The Ionosphere

- An electrified region within the upper atmosphere.
- contains large concentrations of ions (charged particles) and free electrons.
- The ionosphere is important for radio wave propagation.

Photo: S. Misra



Stratification & anatomy of atmosphere



Additional readings

Short- and Long-term variations of climate (Regional and Global)

Pages 417-423; Grotinger & Jordan's book