Teacher Background Information: The Earth's Atmosphere

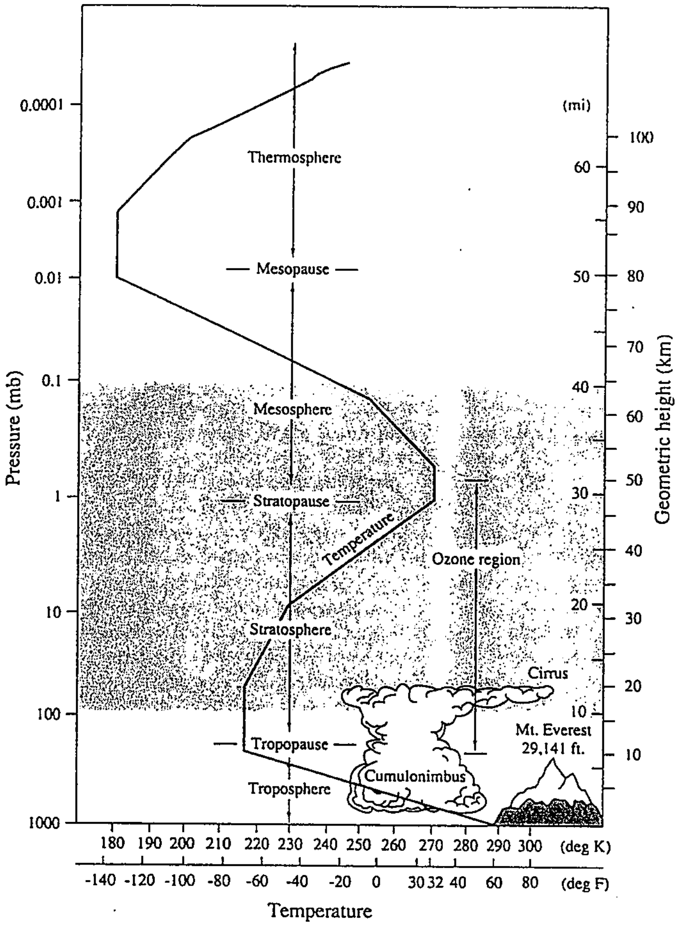
I. Composition of the Atmosphere: The atmosphere is a mixture of gases called *air* which are held on the Earth's surface by the gravitational attraction of the Earth. Approximately 80% of the atmospheric mass is found within about 32 km of the surface, in the troposphere. Here gas molecules are squeezed together by the gases above causing *atmospheric pressure*. Pressure declines with increasing altitude, and modern jet aircraft require cabin pressurization.

The major constituents of the atmosphere, nitrogen (N), oxygen (O), carbon dioxide (CO_2), and argon (Ar) are relatively unreactive gases and show nearly uniform concentrations and relative long residence times. In addition, there are trace amounts of helium (He), hydrogen (H), neon (Ne), ozone (O_3), krypton (Kr), water vapor (H_2O), methane (CH_4) and other gases. In addition to gaseous components, the atmosphere contains particles, known as *aerosols*, that arise from a variety of sources: volcanic eruptions, soil erosion, sea spray, soot from fires, pollutants from human activity, organic particles and smaller particles produced by the reactions between gases. The table that follows gives the globally averaged composition of the atmosphere. While the concentration of N and O are nearly unchanging, the concentration of the other constituents vary in time and space.

CONSTITUENT	FORMULA	CONCENTRATIONS
Nitrogen	N_2	78.1%
Oxygen	O_2	20.9%
Argon	Ar	0.93%
Carbon dioxide	CO_2	0.035%
Neon	Ne	0.0018%
Helium	He	0.0005%
Methane	CH_4	0.00017%
Krypton	Kr	0.00011%
Hydrogen	H_2	0.00005%
Ozone	O_3	0.000001–0.000004%

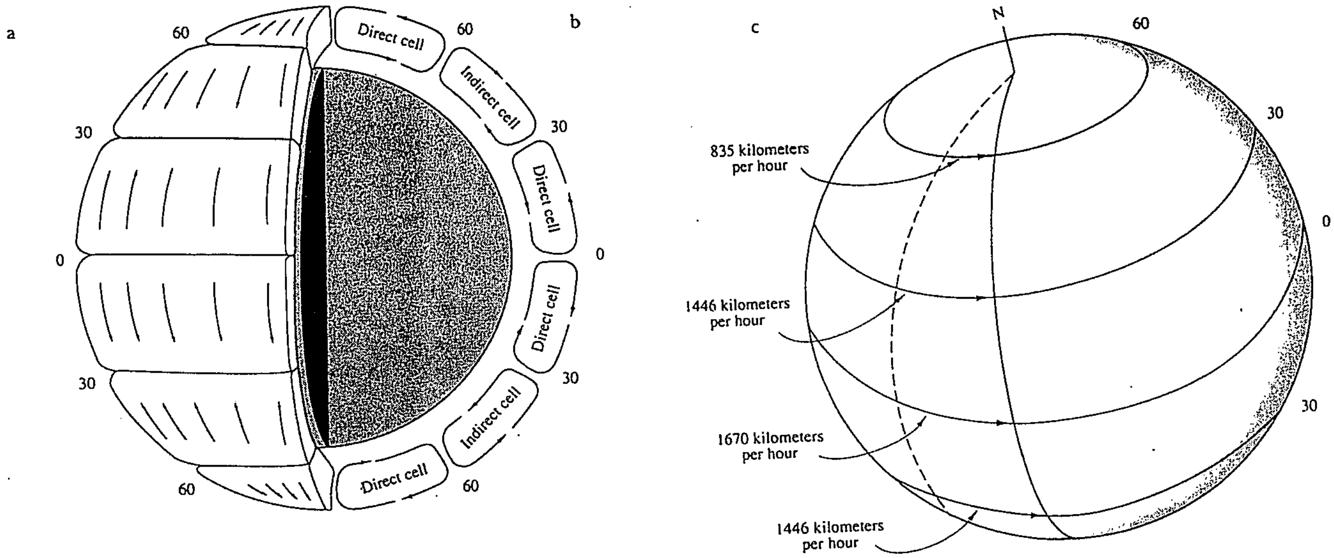
Composition of the Earth's atmosphere

II. Structure of the Atmosphere: Scientists divide the atmosphere into four main layers based on temperature. The lowest and generally warmest layer, the *troposphere*, starts at the surface and extends to approximately 15 km. The thickness of this layer varies seasonally and with latitude; the top of the troposphere extends to between 10-15 km.. Temperatures in the troposphere gradually decrease with altitude until reaching the tropopause, the top of the troposphere where the decrease stops. At the poles the temperature is about -55 degrees C. The thermal (heat) instability of the troposphere is largely responsible for the global patterns of atmospheric circulation and ultimately, Earth's weather.



Temperature profile of the Earth's atmosphere to 100 km.

The large annual receipt of solar radiation at the equator causes warming of the atmosphere and the evaporation of large amounts of water, carrying heat from the tropical oceans and rain forests. As this warm, moist air rises, it cools, producing large amounts of precipitation in equatorial areas. Having lost its moisture, the rising air mass moves both north and south, away from the equator, until reaching a belt centered on approximately 30 degrees N or S latitude. The cooled air then sinks back to the surface where it undergoes heating. A similar, but much weaker, circulation pattern is found at the poles, where cold air sinks and moves N or S along the Earth's surface to the lower latitudes. These tropical and polar circulation patterns are known as *direct Hadley cells,* and drive an indirect circulation between 40 and 50 degrees latitude, producing the cyclonic storm systems and the prevailing west winds that are experienced in the temperate zone. As air masses move across the different latitudes, they are deflected to the right by the *Coriolis force*, which is a result of the different speed of the Earth's rotation at different latitudes.



Generalized patterns of global circulation showing (a) surface patterns, (b) vertical patterns and (c) origin of the Coriolis effect. Note the change in speed of the Earth's surface moving in an eastward direction going from the equator to either pole.

Above the troposphere, the second layer, the *stratosphere* is defined by a zone in which the temperatures increase with altitude, extending to about 50 km. The lower part of the stratosphere is as cold as the tropopause; it warms up steadily to its top, or *stratopause.* This increase in temperature is largely due to the absorption of ultraviolet light by ozone, in an area known as the *ozone layer.* The air in the stratosphere is clear and dry, with strong steady winds and few weather changes. The upward (vertical) mixing of the gases in the stratosphere is limited, as well as the exchange across the boundary between the troposphere and the stratosphere, the *tropopause.* The exchange that does occur between the troposphere and the stratosphere is driven by several processes. First, the height of the troposphere varies seasonally, especially in the direct Hadley cells. When the height of the troposphere changes, tropospheric air enters the stratosphere, or vice versa. Second, rising air masses, particularly in the tropical Hadley cells, carry tropospheric air to the stratosphere and thirdly, large scale wind movements and thunderstorms carry air across the tropopause.

The third and fourth layers of the atmosphere are the *mesosphere* and the *thermosphere.* Temperatures drop again in the mesosphere and rise in the thermosphere as a result of the absorption of solar energy by nitrogen and oxygen atoms. The top of the thermosphere is around 500 km above the surface of the Earth.

Located in the altitude range between 80 and 400 km, and therefore coinciding with portions of the thermosphere and the mesosphere. is an electrically charged layer known as the *ionosphere*. Here atoms of oxygen and molecules of nitrogen are ionized as they absorb high-energy, short-wave solar energy. In this process each affected molecule or atom loses one or more electrons and becomes a positively charged ion, and the electrons are set free to travel as electric currents. The auroras take place in the ionosphere. The *aurora borealis* (northern lights) and the *aurora australis* (southern lights) appear in a wide variety of forms and are closely correlated in time with solar flare activity and in geographic location, with the Earth's magnetic poles. Solar flares are massive magnetic storms on the Sun that emit enormous amounts of energy and great quantities of fast-moving atomic particles. As the clouds of protons and electrons from the solar storm approach the Earth, captured by the Earth's magnetic field, which in turn, guides them toward the magnetic poles. As the ions impinge on the ionosphere, they energize the atoms of oxygen and the molecules of nitrogen and cause them to emit light- the glow of the auroras. Because the occurrence of solar flares is closely correlated with sunspot activity, auroral displays increase conspicuously at time when sunspots are numerous.

From a scientific standpoint, the atmosphere is the simplest of the Earth's chemical systems to study, perhaps because the atmosphere permits relative isolation of the chemical constituents from one another, so the action of each can be determined with precision. Such is seldom the case with the chemistry of the other Earth systems - the chemistry of water at or beneath the Earth's surface or the chemistry of the rocks and soils. In these systems, solids, liquids and gases are inextricably combined, biological systems are generally present to add their own chemical complexity, and sampling is often a formidable task. Atmospheric chemistry as a scientific discipline is less than a quarter-century old and much has ,been learned. It is clear however, that an incredibly complex array of chemical species, emissions, sources and reactions, combined with the multiplicity of phases and the interactions among them, leave much yet to understand.