Planetary Atmospheres (Chapter 10)

Atmospheres of terrestrial worlds and moons of jovan planets are small fractions of planetary mass, unlike atmospheres of jovian planets. Common atmospheric gases include carbon dioxide, nitrogen, and oxygen in the terrestrial planets and hydrogen, helium, water, methane, and ammonia in the jovian planets. Sources of atmospheric gas include volcanic outgassing, evaporation/sublimation from surface liquids/ices, and vaporization of small amounts of material during impacts. Atmospheres can lose gas to space (thermal escape, swept along by solar wind, and effects of impacts) and the surface (condensation and chemical reactions).

Earth's atmosphere is transparent to visible light. Visible photons from the Sun are not absorbed until they reach the surface. The surface emits infra-red photons upwards as thermal radiation. These are absorbed by the atmosphere, which then re-emits infra-red photons upwards and downwards. In order for Earth to emit as much radiation to space as it receives from the Sun, the surface must be hotter than it would be without an atmosphere. This heating of the surface by the atmosphere is called the greenhouse effect. It occurs in all atmospheres. Molecules are much stronger greenhouse gases than atoms are, because they can store the energy of infra-red photons in rotation and vibration of their bonds. The greenhouse effect makes Venus's surface much hotter, Earth's surface hotter, and Mars's surface slightly hotter then they would be without their atmosphere.

Mars has a CO_2 atmosphere with surface pressure <1% Earth's and average surface temperature of -50 ^{o}C. Mars has a similar axial tilt to Earth, a similar length of day, but an elliptical orbit, making the northern and southern summers different. At each pole, Mars has a small, year-round cap of water ice. During winter, CO_2 condenses out of the atmosphere and covers the water-ice cap with a larger, seasonal cap of carbon dioxide.

Venus has a CO_2 atmosphere with surface pressure 900x Earth's and surface temperature of 750K. It has no axial tilt and a circular orbit, so has no seasons. The thick atmosphere is so efficient at transporting heat from the equator to the poles that the whole surface has the same temperature. This makes winds very slow. Venus has experienced a runaway greenhouse effect that makes its atmosphere very different from Earth's. Both planets outgassed lots of CO_2 and H_2O. Earth is further from the Sun and cooler, so Earth's H_2O formed liquid oceans. Earth's CO_2 dissolved in the oceans and formed carbonate rocks. Since all of Earth's H_2O is below its ozone layer, it is not broken apart by UV light. On Venus, the H_2O stayed in the atmosphere, so the CO_2 had to as well. Venus's H_2O was broken apart by UV light and the low mass H atoms were easily lost to space, while the O atoms chemically reacted with surface rocks. Venus was left with a thick CO_2 atmosphere.

Earth's atmosphere is mostly N_2 because the more abundant H_2O and CO_2 are elsewhere, in oceans and rocks. Oxygen in Earth's atmosphere will be chemically destroyed in a few million years without a continuous source - life. The amount of oxygen in Earth's atmosphere has changed over time, closely linked to the amount of life on Earth.