ATMOSFERAS PLANETARIAS

Las atmósferas son conglomerados de partículas en procura del equilibrio.

Clasificación:

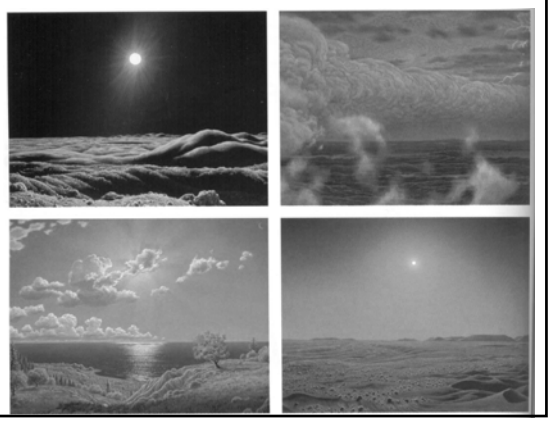
- “Planetas” terrestres: Venus, Tierra, Marte, Titan
- Atmosferas tenues: Mercurio, Luna, Io, Triton, Pluton
- Planetas jovianos

Figure 5. The elongated nucleus of Halley's Comet, as seen in a composite of 60 images from the Giotto spacecraft. Resolution varies from 800 m at lower right to 80 m at the base of the jet at upper left. The Sun is toward the left, and material in the bright jets streams sunward. Measuring 16 by 8 km, Halley's nucleus is much larger than that of a typical comet.

Bien fuera del equilibrio…

1. PLANETAS TERRESTRES

- Atmósferas secundarias, las originales fueron barridas por el viento solar TTauri



ESTRUCTURA GENERICA

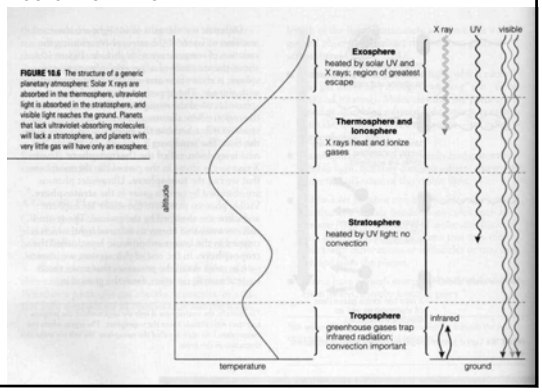
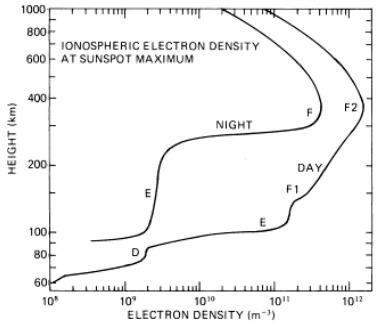


FIGURE 10.6 The structure of a generic planetary atmosphere: Solar X rays are absorbed in the thermosphere, ultraviolet light is absorbed in the stratosphere, and visible light reaches the ground. Planets that lack ultraviolet-absorbing molecules will lack a stratosphere, and planets with very little gas will have only an exosphere.

Dia versus noche



EXÓSFERA: casi no hay colisiones entre las moléculas

TERMÓSFERA: todos los gases absorben rayos X

ESTRATÓSFERA: no hay convección, se requiere un buen absorbente de UV

TROPÓSFERA: moléculas con mas de 2 átomos son buenas absorbentes de IR

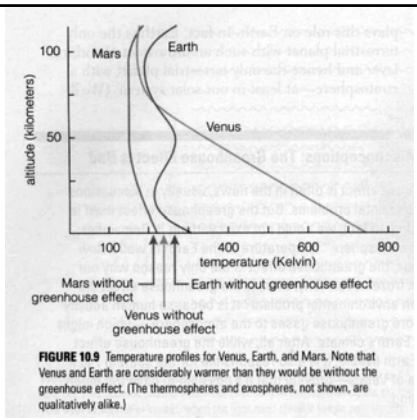


FIGURE 10.9 Temperature profiles for Venus, Earth, and Mars. Note that Venus and Earth are considerably warmer than they would be without the greenhouse effect. (The thermospheres and exospheres, not shown, are qualitatively alike.)

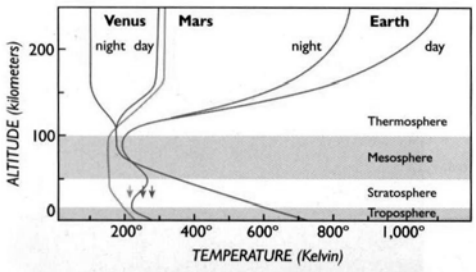


Figure 2. **A key diagnostic of an atmosphere's overall character is its temperature as a function of altitude. For example, based on its temperature profile, Earth's atmosphere divides into several distinct layers (horizontal bands) that the other planets do not share. In addition, the upper atmospheres of Venus and Earth exhibit a striking diurnal cycle (day-night pairs of curves). Arrows indicate the cooler surface temperatures that would occur in the absence of any greenhouse warming.**

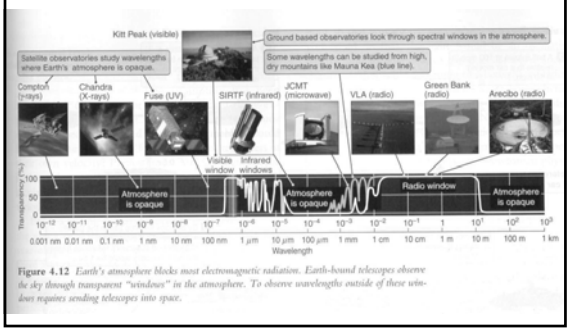
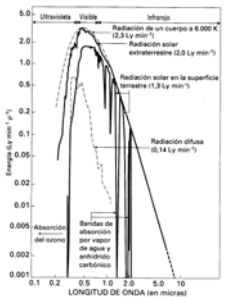
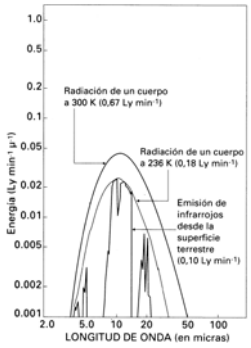


Figure 4.12 *Earth's atmosphere blocks most electromagnetic radiation. Earth-bound telescopes observe the sky through transparent "windows" in the atmosphere. To observe wavelengths outside of these windows requires sending telescopes into space.*

RADIACION SOLAR RECIBIDA EN EL TOPE DE LA ATMOSFERA Y EN LA SUPERFICIE TERRESTRE



RADIACION TERRESTRE



Pérdida selectiva de gases

$$V_{Escape} = \sqrt{\frac{2GM_P}{R_P}}$$

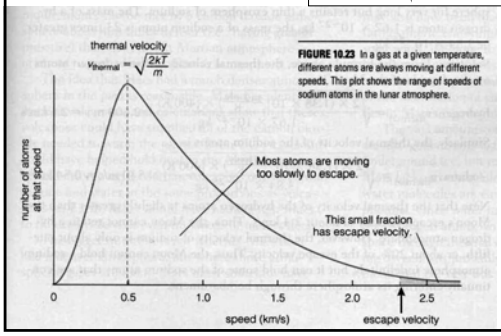


FIGURE 10.23 In a gas at a given temperature, different atoms are always moving at different speeds. This plot shows the range of speeds of sodium atoms in the lunar atmosphere.

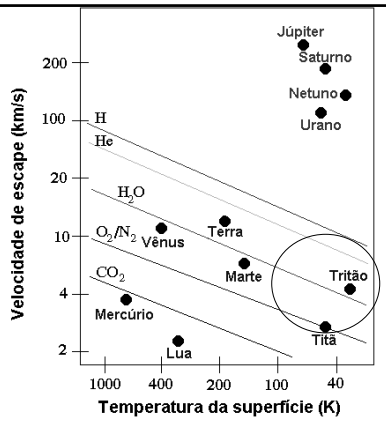


Table 10.1 Atmospheres of the Terrestrial Worlds

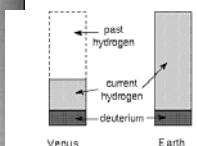
World	Composition	Surface Pressure*	Winds, Weather Patterns	Clouds, Hazes
Mercury	Atoms of helium, sodium, oxygen, potassium	10^{-15} bar	None: too little atmosphere	None
Venus	96% CO_2, 3.5% N_2	90 bars	Slow winds, no violent storms	Sulfuric acid clouds
Earth	77% N_2, 21% O_2, 1% argon, H_2O (variable)	1 bar	Winds, hurricanes	H_2O clouds, pollution
Moon	Atoms of sodium, potassium	10^{-15} bar	None: too little atmosphere	None
Mars	95% CO_2, 2.7% N_2, 1.6% argon	0.007 bar	Winds, dust storms	H_2O and CO_2 clouds, dust

*1 bar ≈ the pressure at sea level on Earth.

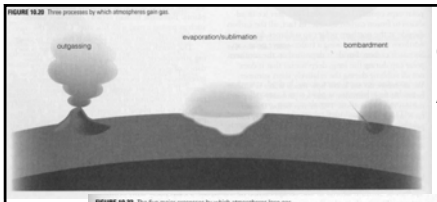
Atmospheric Compositions Compared

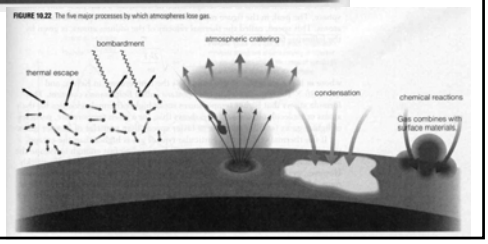
Planet	Molecule	Abundance (bars)	Fraction of total
Venus	CO_2	86.4	0.96
	N_2	3.2	0.035
	Ar	0.0063	0.000070
	H_2O	0.009	0.000100
Earth	N_2	0.78	0.77
	O_2	0.21	0.21
	H_2O	0.01	0.01
	Ar	0.94	0.0093
	CO_2	0.000355	0.00035
Mars	CO_2	0.0062	0.95
	N_2	0.00018	0.027
	Ar	0.00010	0.016
	H_2O	3.9×10^{-7}	0.00006

Table 1. The atmospheres of Earth, Venus, and Mars contain many of the same gases — but in very different absolute and relative abundances. Some values are lower limits only, reflecting the past escape of gas to space and other factors.



Proportions of hydrogen to deuterium on Venus and Earth are very different—ordinary hydrogen isotope was preferentially removed on Venus.





GENERACIÓN Y PÉRDIDA DE ATMÓSFERA

Densidad

- La densidad de una atmósfera es el resultado del balance entre los procesos de GENERACIÓN y PÉRDIDA
- Marte cesó su actividad volcánica: atmósfera tenue
- Venus debe tener actividad volcánica reciente pues presenta una atmosfera muy densa

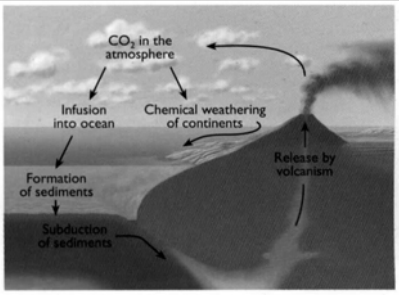


Figure 16. On Earth, carbon dioxide cycles between land and sky. Gaseous CO_2 is removed from the atmosphere to form sea-floor sediments; plate tectonism causes these sediments to be subducted into the upper mantle, and subduction-zone volcanism later releases the CO_2 back into the atmosphere. A balance thus exists between the loss of atmospheric CO_2 and its resupply, though the gas's actual abundance in the atmosphere may vary over time.

➢La atmósfera de las primeras épocas de la historia de la Tierra estaría formada por vapor de agua, dióxido de carbono(CO_2) y nitrógeno, junto a muy pequeñas cantidades de hidrógeno (H_2), H_2S, SO_2 y monóxido de carbono pero con ausencia de oxígeno.

➢Era una atmósfera ligeramente reductora hasta que la actividad fotosintética de los seres vivos introdujo oxígeno y ozono (a partir de hace unos 2 500 o 2000 millones de años) y hace unos 1000 millones de años la atmósfera llegó a tener una composición similar a la actual.

CIRCULACIÓN

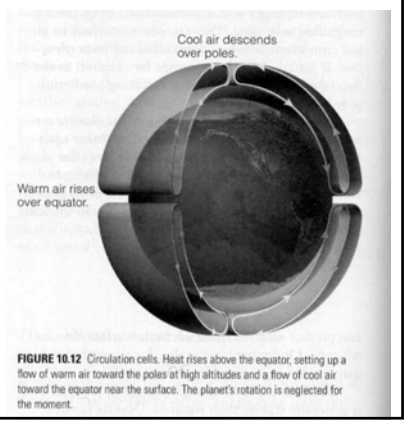
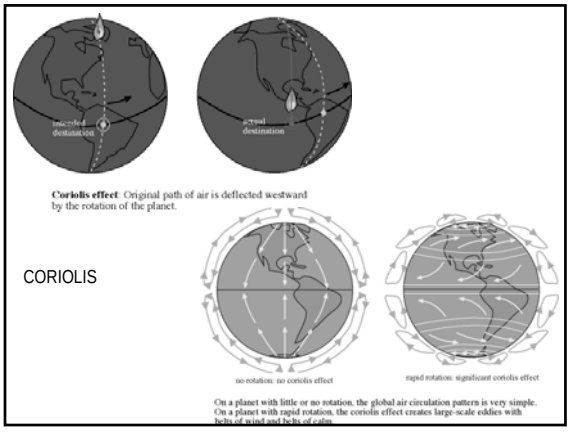


FIGURE 10.12 Circulation cells. Heat rises above the equator, setting up a flow of warm air toward the poles at high altitudes and a flow of cool air toward the equator near the surface. The planet's rotation is neglected for the moment.

CORIOLIS



Coriolis effect: Original path of air is deflected westward by the rotation of the planet.

On a planet with little or no rotation, the global air circulation pattern is very simple. On a planet with rapid rotation, the coriolis effect creates large-scale eddies with belts of wind and belts of calm.

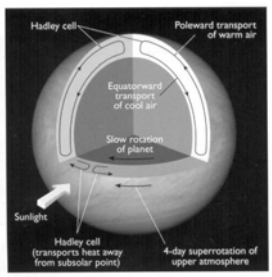


Figure 7. Rising motions occur wherever the strongest atmospheric heating occurs — near the subsolar latitude of Mars and Earth, and on the day side of Venus (as shown here). This movement is balanced by sinking parcels of air elsewhere, creating a net flow that keeps gases and heat from building up at any one location.

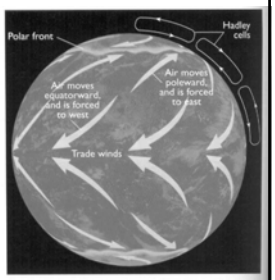
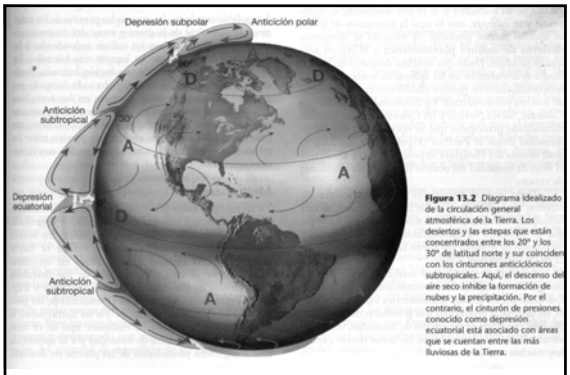
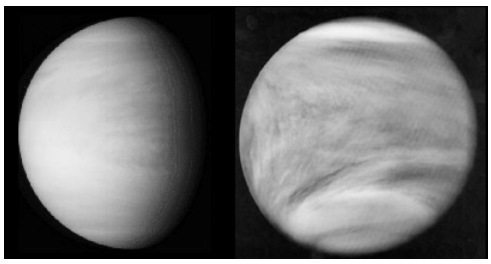


Figure 8. Zonal winds (along lines of constant latitude) result on Earth from the Coriolis force. Air is redirected eastward when it moves toward either pole and westward when it moves toward the equator. These east-west motions are analogous to the belts and zones in outer-planet atmospheres.



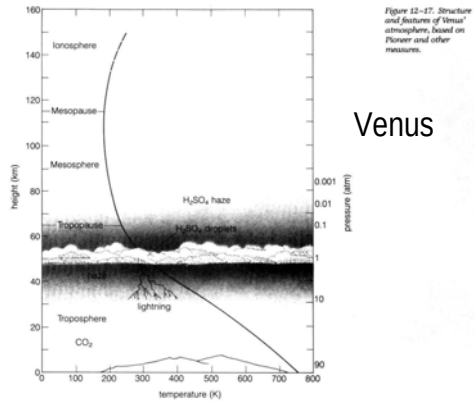
CIRCULACIÓN: generada por la INSOLACIÓN y la ROTACIÓN (Coriolis)



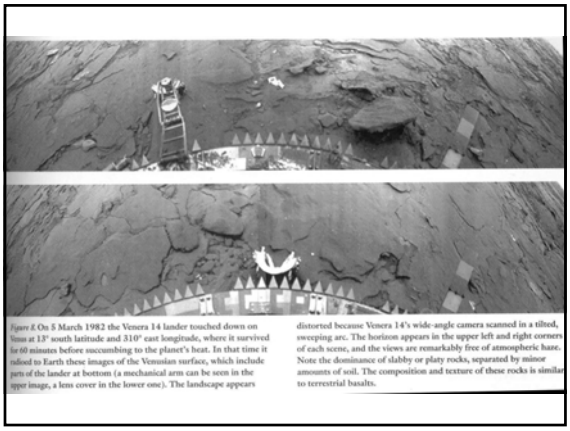
La alta atmosfera de Venus circula con un período de 4 dias provocada por la diferencia de temperatura entre el dia y la noche. Esta rotación frena al planeta pudiendo ser la causa de la escasa velocidad de rotación.

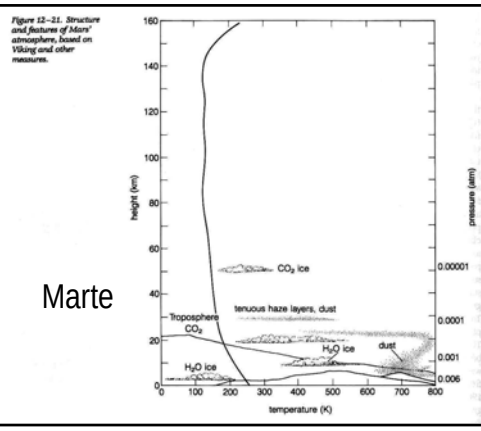
Generación de nubes:

- La temperatura superficial genera convección
- La convección es la responsable de la formación de nubes (líquido o cristales)
- Venus está cubierto de nubes de H2SO4 debido a sus altas temperaturas que generan una fuerte convección
- No posee estratósfera que absoba UV por lo tanto pierde H_2O. A su vez el SO_2 se combina en el suelo.
- Debe tener actividad volcánica
- Otra forma de generar nubes: viento sobre montañas como en Marte



Venus





Marte

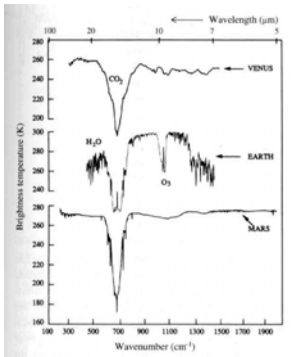


FIGURE 4.6 Thermal infrared emission spectra of Venus, Earth and Mars. The Venus spectrum was recorded by Venera 15, the spectrum of the Earth by Nimbus 4 and that of Mars by Mariner 9. (Adapted from Hanel *et al.* 1992)

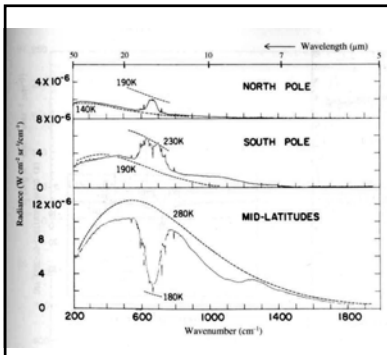
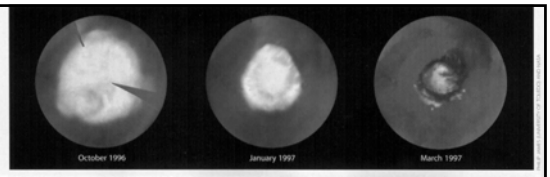
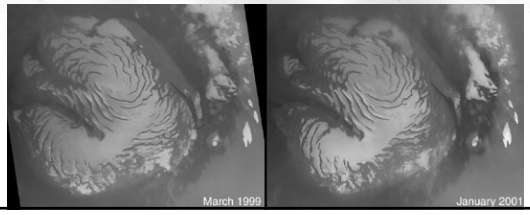


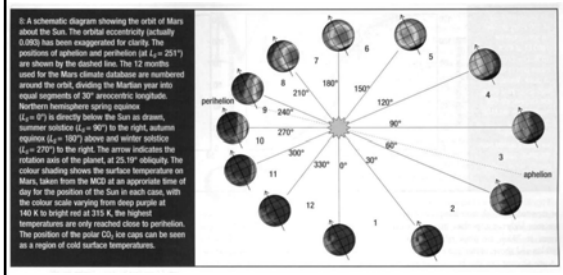
FIGURE 4.7 Thermal infrared spectra of the poles and mid-latitudes on Mars. The data were taken by the Mariner 9 spacecraft when it was late spring in the southern hemisphere. Blackbody curves at various temperatures are indicated for comparison. Note that the CO_2 feature is seen in emission in the polar spectra, while in absorption at mid-latitudes. (Adapted from Hanel *et al.* 1992)

Marte: gases CO_2 y H_2O sublimados en equilibrio con fase sólida.

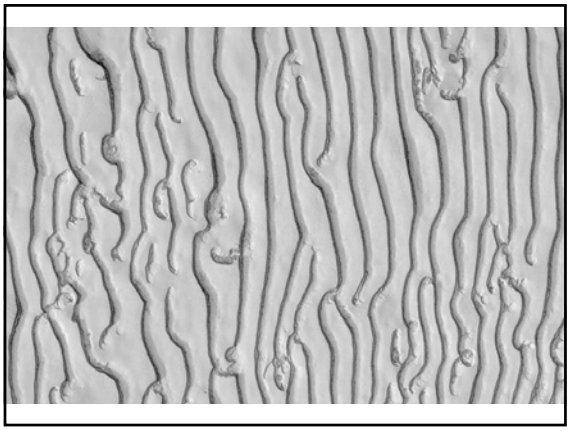


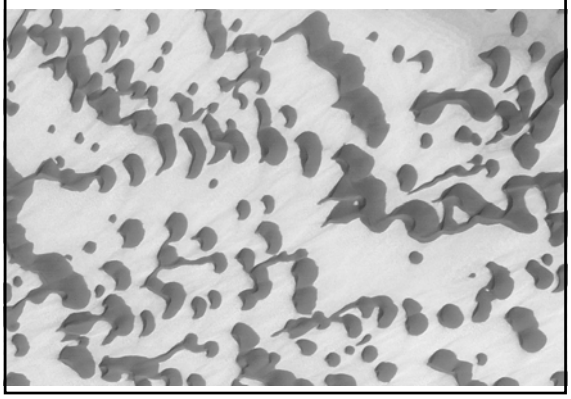
During local winter, a broad area surrounding the north pole of Mars is covered with a meter-thick layer of frozen carbon dioxide (left). But as spring arrives (middle and right), the seasonal blanket of dry ice returns to the atmosphere, revealing an underlying "permanent" polar cap consisting of water ice. These pole-on views were assembled from reprojected Hubble Space Telescope images.





5: A schematic diagram showing the orbit of Mars about the Sun. The orbital eccentricity (actually 0.093) has been exaggerated for clarity. The positions of aphelion and perihelion (at L_s = 251°) are shown by the dashed line. The 12 months used for the Mars climate database are numbered around the orbit, dividing the Martian year into equal segments of 30° areocentric longitude. Northern hemisphere spring equinox (L_s = 0°) is directly below the Sun as drawn, summer solstice (L_s = 90°) to the right, autumn equinox (L_s = 180°) above and winter solstice (L_s = 270°) to the right. The arrow indicates the rotation axis of the planet, at 25.19° obliquity. The colour shading shows the surface temperature on Mars, taken from the MCD at an approriate time of day for the position of the Sun in each case, with the colour scale varying from deep purple at 140 K to bright red at 315 K, the highest temperatures are only reached close to perihelion. The position of the polar CO_2 ice caps can be seen as a region of cold surface temperatures.





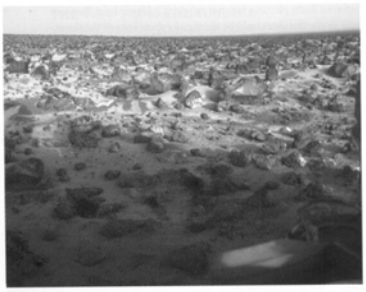


Figure 5. Patches of frost surround the Viking 2 lander in this view taken in 1977 during the spacecraft's first Martian winter. Here the icy layer is perhaps no more than a few hundredths of a millimeter thick. The frost probably arose from water vapor transported to the site during dust storms. Dust-water aggregates precipitated onto the surface when carbon dioxide froze out of the atmosphere and adhered to them.

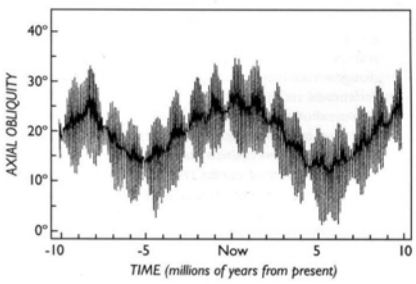


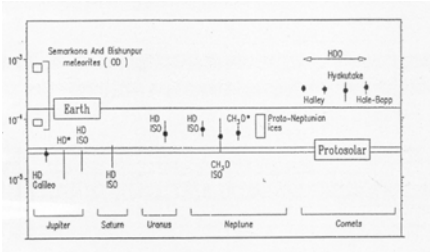
Figure 20. Calculations show that the axial obliquity of Mars oscillates with a period of about 100,000 years, with even wider excursions occurring every million years or so. These swings change the energy balance at the planet's poles, causing water and CO_2 to move into the polar regions and back out again.

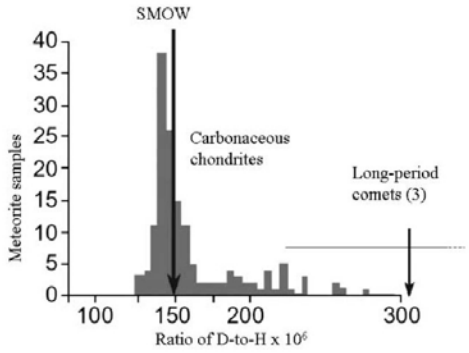
Agua

- En Venus nunca condensó (si la hubo). La UV destruyó las moléculas de H2O escapando el H2.
- En la Tierra el vapor de agua de las erupciones volcánicas saturó la atmósfera provocando precipitaciones y los océanos.
- En Marte al cesar la actividad volcánica el agua no pudo retornar a la atmósfera.

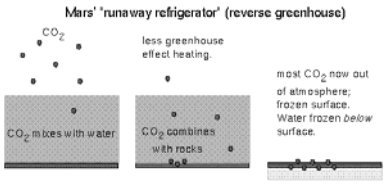
Origen cometario

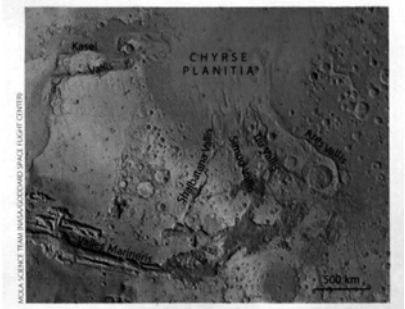
- La relación D/H en tres cometas ***(Halley, Hyakutake, Hale Bopp)*** es casi 2 veces la del agua terrestre (cuidado: muestra pequeña) '**the water problem'**



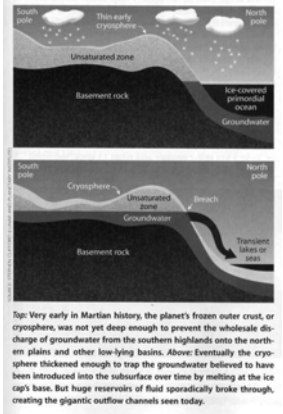


El agua en Marte





Throughout the middle of Martian geologic history, evidence suggests that catastrophic outflows repeatedly discharged huge floods onto Chryse Planitia ("Plain of Gold") from storage reservoirs in the planet's southern highlands. Similar events, elsewhere on the planet, may have occurred within the past billion years.



Top: **Very early in Martian history, the planet's frozen outer crust, or cryosphere, was not yet deep enough to prevent the wholesale discharge of groundwater from the southern highlands onto the northern plains and other low-lying basins.** *Above:* **Eventually the cryosphere thickened enough to trap the groundwater believed to have been introduced into the subsurface over time by melting at the ice cap's base. But huge reservoirs of fluid sporadically broke through, creating the gigantic outflow channels seen today.**

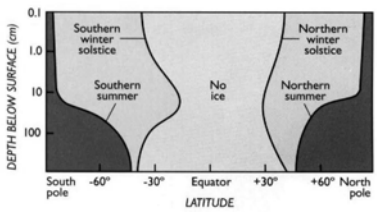
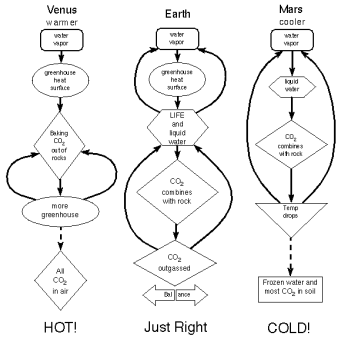


Figure 9. **Today liquid water does not exist anywhere on the Martian surface, and the stability of water ice depends largely on its subsurface depth and latitude. For example, ice is unstable within about 30° of the equator (tan); over time, near-surface materials at these latitudes have probably lost any water that might have been originally present down to depths of more than 100 m. Farther to the north and south (light blue), ice could exist within 1 m of the surface during local winter but would be driven into the atmosphere as vapor at other times. In the polar regions (dark blue), water ice is always stable down to kilometer depths. This model assumes that the Martian atmosphere is well mixed and carries only enough water vapor to create a layer on the surface 12 microns thick.**



Venus has runaway greenhouse effect and no water left. Earth has life and liquid water keeping temperature balanced and most of its CO_2 in the rocks. Mars has runaway refrigerator with water frozen in permafrost layer and most of its CO_2 in the rocks or frozen on the surface.

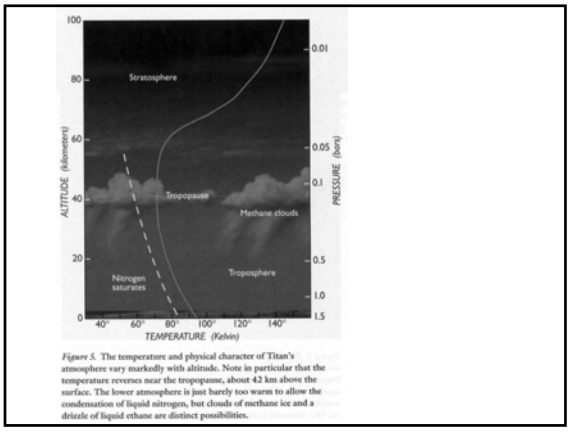


Figure 5. The temperature and physical character of Titan's atmosphere vary markedly with altitude. Note in particular that the temperature reverses near the tropopause, about 42 km above the surface. The lower atmosphere is just barely too warm to allow the condensation of liquid nitrogen, but clouds of methane ice and a drizzle of liquid ethane are distinct possibilities.

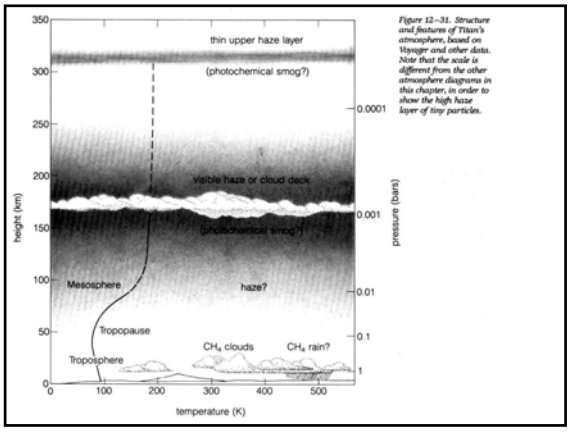


Figure 12–31. Structure and features of Titan's atmosphere, based on Voyager and other data. Note that the scale is different from the other atmosphere diagrams in this chapter, in order to show the high haze layer of tiny particles.

2. ATMÓSFERAS TENUES

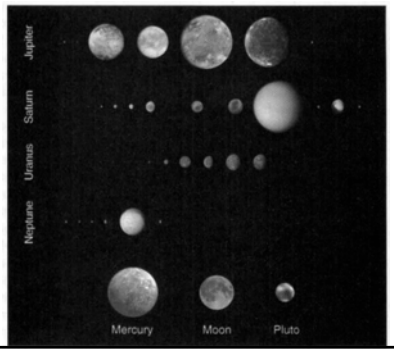


TABLE 4.4 Composition of Planets and Satellites with Tenuous Atmospheres[a].

Planet	Constituent	Abundance (cm^{-3})	References
Mercury	O	4×10^4	1
	Na	3×10^4	
	He	6×10^3	
	K	500	
	H	23 (suprathermal)	
		230 (thermal)	
	Ca	~30	2
Moon	He	2×10^3 (day)–4×10^4 (night)	1, 3, 4
	Ar	1.6×10^3 (day)–4×10^4 (night)	
	Na	70	
	K	16	
Pluto	N_2		5
	CO	trace	
	CH_4	trace	
Triton	N_2		6
	CH_4	trace	
Io[b]	SO_2	10^{11}–10^{12}	7
	SO	trace	
	Na		8
	K		
	O		

Impactos Cometarios, Viento Solar, Fotones

Gas sublimado en equilibrio con fase sólida

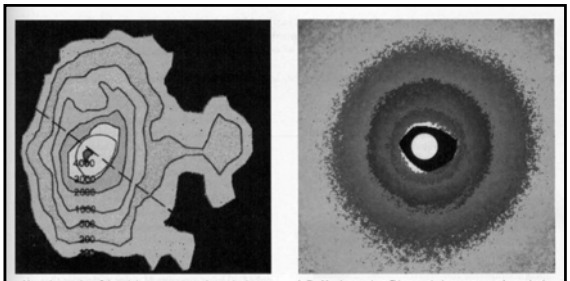


FIGURE 10.24 The atmospheres of Mercury and the Moon—which are essentially exospheres only—viewed through instruments sensitive to emission lines from sodium atoms. Although these are extremely low-density atmospheres, they extend quite high.

a Mercury's atmosphere. Color-coded contours represent the gas density from lowest (black) to highest (red). Mercury's partially illuminated disk is indicated as the gibbous-shaped blue contour near the center (just within the yellow region); the Sun lies to the left along the direction of the dashed line.

b The Moon's atmosphere. This composite image represents the gas density from lowest (green) to highest (red). The Moon itself was blocked to make this image, resulting in the central black area of no data. The Moon's size is shown schematically by the white circle.

Mercurio y Luna

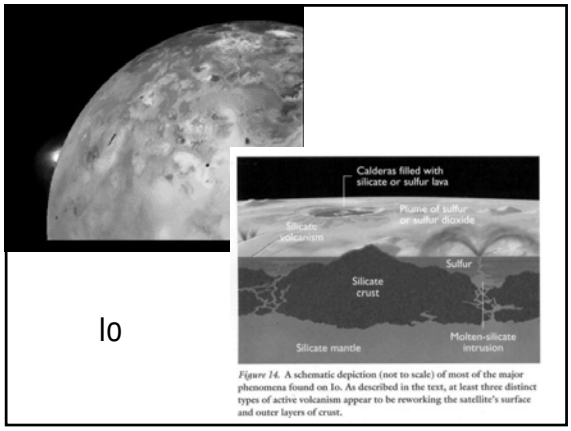


Figure 14. A schematic depiction (not to scale) of most of the major phenomena found on Io. As described in the text, at least three distinct types of active volcanism appear to be reworking the satellite's surface and outer layers of crust.

Io

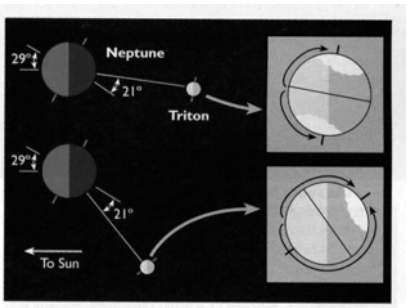
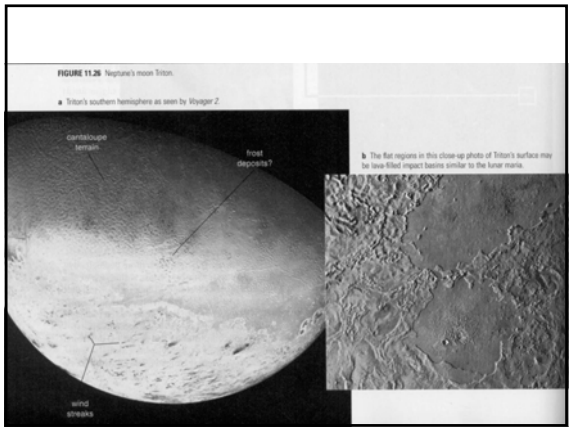
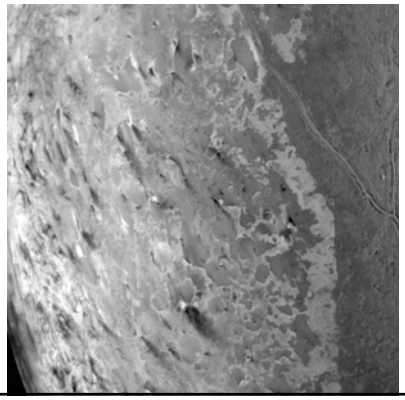


Figure 9. At certain times in Triton's 688-year climate cycle the Sun is almost directly over the equator (upper half), which causes atmospheric gases to migrate toward a pair of polar caps. But at the seasonal extremes (lower half) one cap basks in constant sunlight and disappears, while the other, in shadow, accumulates large deposits of ice condensing from the atmosphere.

Tritón





Plutón y Caronte

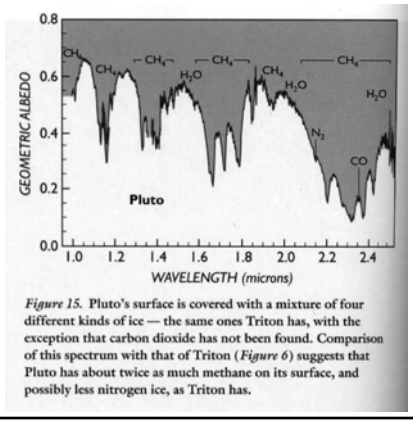


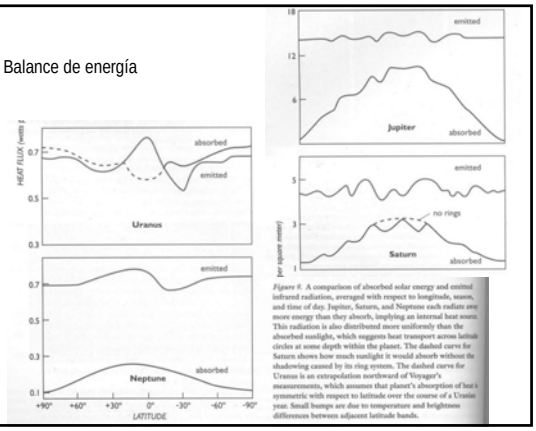
Figure 15. Pluto's surface is covered with a mixture of four different kinds of ice — the same ones Triton has, with the exception that carbon dioxide has not been found. Comparison of this spectrum with that of Triton (*Figure 6*) suggests that Pluto has about twice as much methane on its surface, and possibly less nitrogen ice, as Triton has.

Figure 8. Ammonia-water eutectic melt, a probable outer solar system lava, is mobile even at 176° K and flows like cold honey (or basaltic magma).

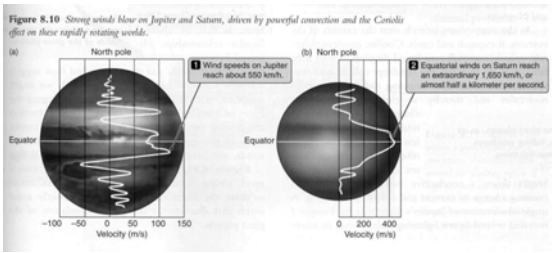
3. PLANETAS JOVIANOS

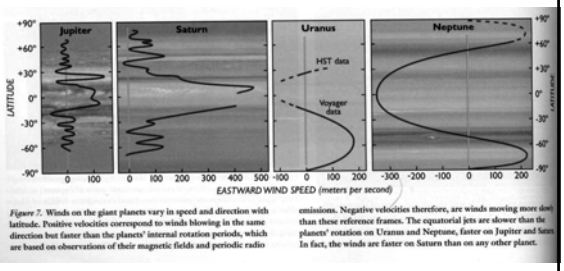
- Atmósferas primordiales, gases capturados de la nebulosa solar

Balance de energía

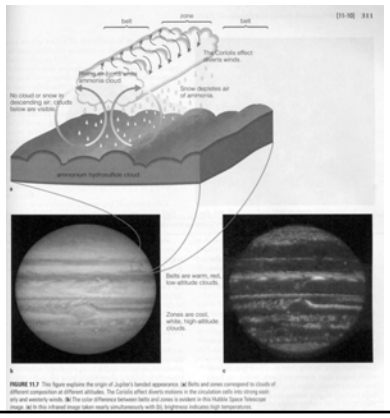


Coriolis genera fuertes vientos

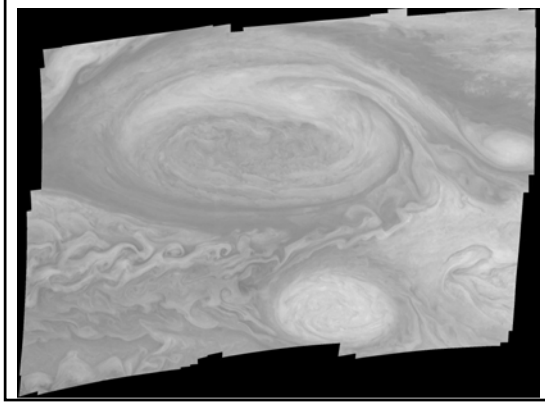


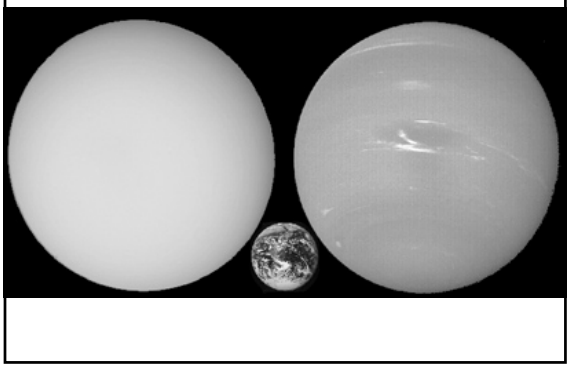


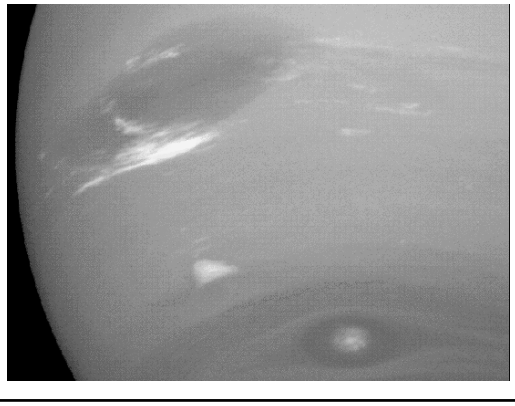
Urano y Neptuno tienen una circulación diferente



Zonas (blancas) y Cinturones



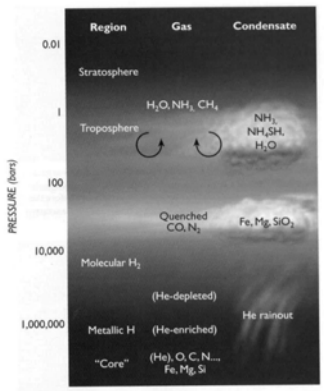




Compositions of Outer-Planet Atmospheres

Molecule	Sun	Jupiter	Saturn	Uranus	Neptune
H_2	84	86.4	97	83	79
He	16	13.6	3	15	18
H_2O	0.15	(0.1)	—	—	—
CH_4	0.07	0.21	0.2	2	3
NH_3	0.02	0.07	0.03	—	—
H_2S	0.003	0.008	—	—	—

Table 1. Percentage abundances (by number of molecules) for the giant planets' atmospheres below the clouds. Listed are six of the 11 most abundant elements in the Sun (and the universe). The others are the noble gases neon (Ne) and argon (Ar), and the metals silicon (Si), magnesium (Mg), and iron (Fe), all of which are believed to reside in these planets' cores. Here *Sun* refers to a mixture with the same proportion of elements as the primordial Sun, but cooled to planetary temperatures so that the elements combine to form the compounds listed. Values for Jupiter are from the Galileo probe; others are from remote sensing. All numbers are uncertain in the least significant figure and more so for Jupiter's water content. Dashes indicate unobserved compounds.



ESTRUCTURA GENÉRICA

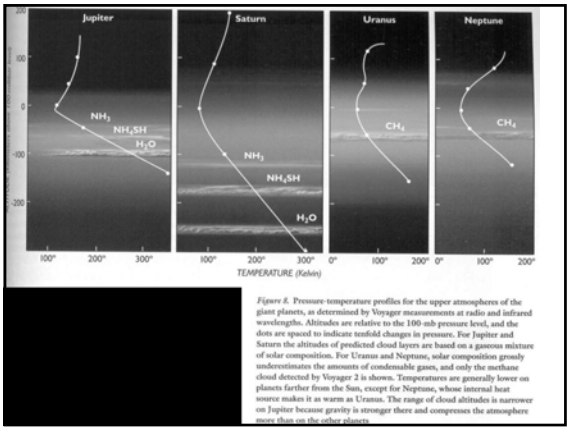


Figure 8. Pressure-temperature profiles for the upper atmospheres of the giant planets, as determined by Voyager measurements at radio and infrared wavelengths. Altitudes are relative to the 100-mb pressure level, and the dots are spaced to indicate tenfold changes in pressure. For Jupiter and Saturn the altitudes of predicted cloud layers are based on a gaseous mixture of solar composition. For Uranus and Neptune, solar composition grossly underestimates the amounts of condensable gases, and only the methane cloud detected by Voyager 2 is shown. Temperatures are generally lower on planets farther from the Sun, except for Neptune, whose internal heat source makes it as warm as Uranus. The range of cloud altitudes is narrower on Jupiter because gravity is stronger there and compresses the atmosphere more than on the other planets.

Nubes de metano