Chapter 9

Earth's atmosphere and environment

	page
Radiation environment	232
Galactic cosmic radiation	232
Solar high energy particle radiation	232
Trapped radiation	233
Solar irradiance	236
Visible and infrared radiation	236
Ultraviolet and X-ray radiation	236
The solar spectrum	237
The international reference atmosphere	238
Altitude variation of atmospheric constituents	239
Opacity of the atmosphere	240
US standard atmosphere	241
Structure of the upper atmosphere	243
Earth's magnetosphere	244
Bibliography	244

© Cambridge University Press • Provided by the NASA Astrophysics Data System

Galactic cosmic radiation

Flux at sunspot minimum:	~ 4 protons $cm^{-2} s^{-1}$ (isotropic)
Integrated yearly rate:	$\sim 1.3 \times 10^8$ protons cm^{-2}
Flux at sunspot maximum:	2.0 protons $cm^{-2} s^{-1}$ (isotropic)
Integrated yearly rate:	$\sim 7 \times 10^7$ protons cm^{-2}
Energy range:	40 MeV–10^{13} MeV; predominantly 10^3–10^7 MeV
Integrated dose (without shielding):	$\sim$4–10 rad yr^{-1}

Solar high energy particle radiation

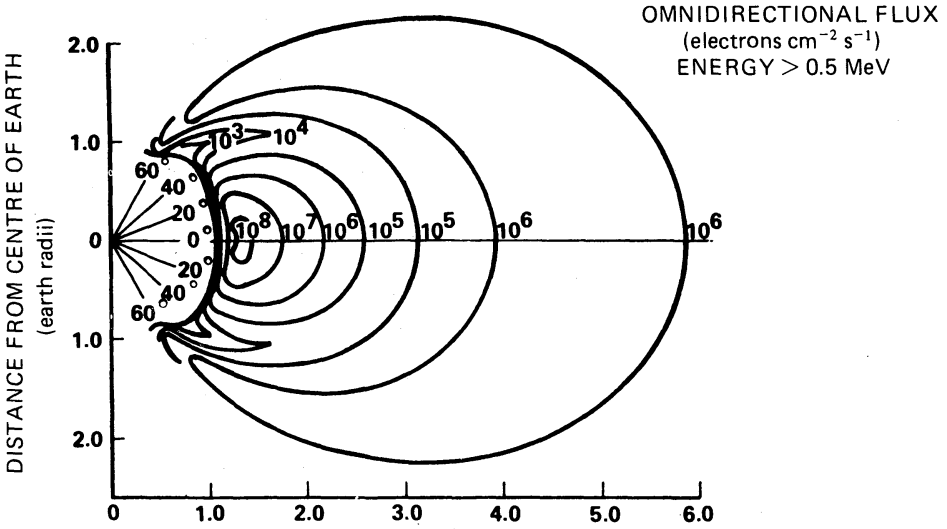
Composition: predominantly protons (H^+) and alpha particles (He^{++}).
Integrated yearly flux at 1 AU:

Energy >30 MeV,	$N \approx 8 \times 10^9$ protons cm^{-2} near solar maximum
	$N \approx 5 \times 10^5$ protons cm^{-2} near solar minimum
Energy >100 MeV,	$N \approx 6 \times 10^8$ protons cm^{-2} near solar maximum
	$N \approx 5 \times 10^4$ protons cm^{-2} near solar minimum

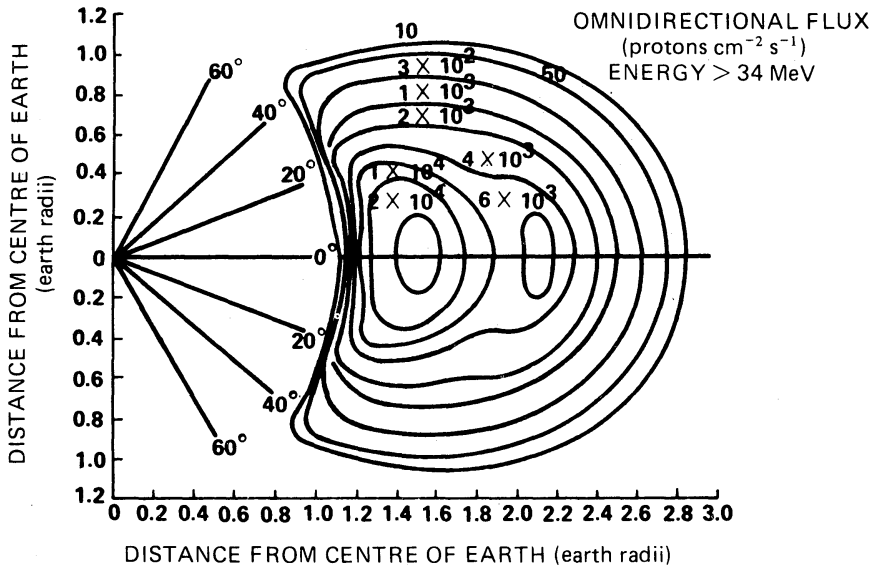
Maximum dosage with shielding of 5 g cm^{-2} (equivalent thickness): $\sim$200 rad per week (3 flares), skin dose at a point detector.

© Cambridge University Press • Provided by the NASA Astrophysics Data System

Electron distribution in the Earth's field. (Published by Vette in August 1964.)



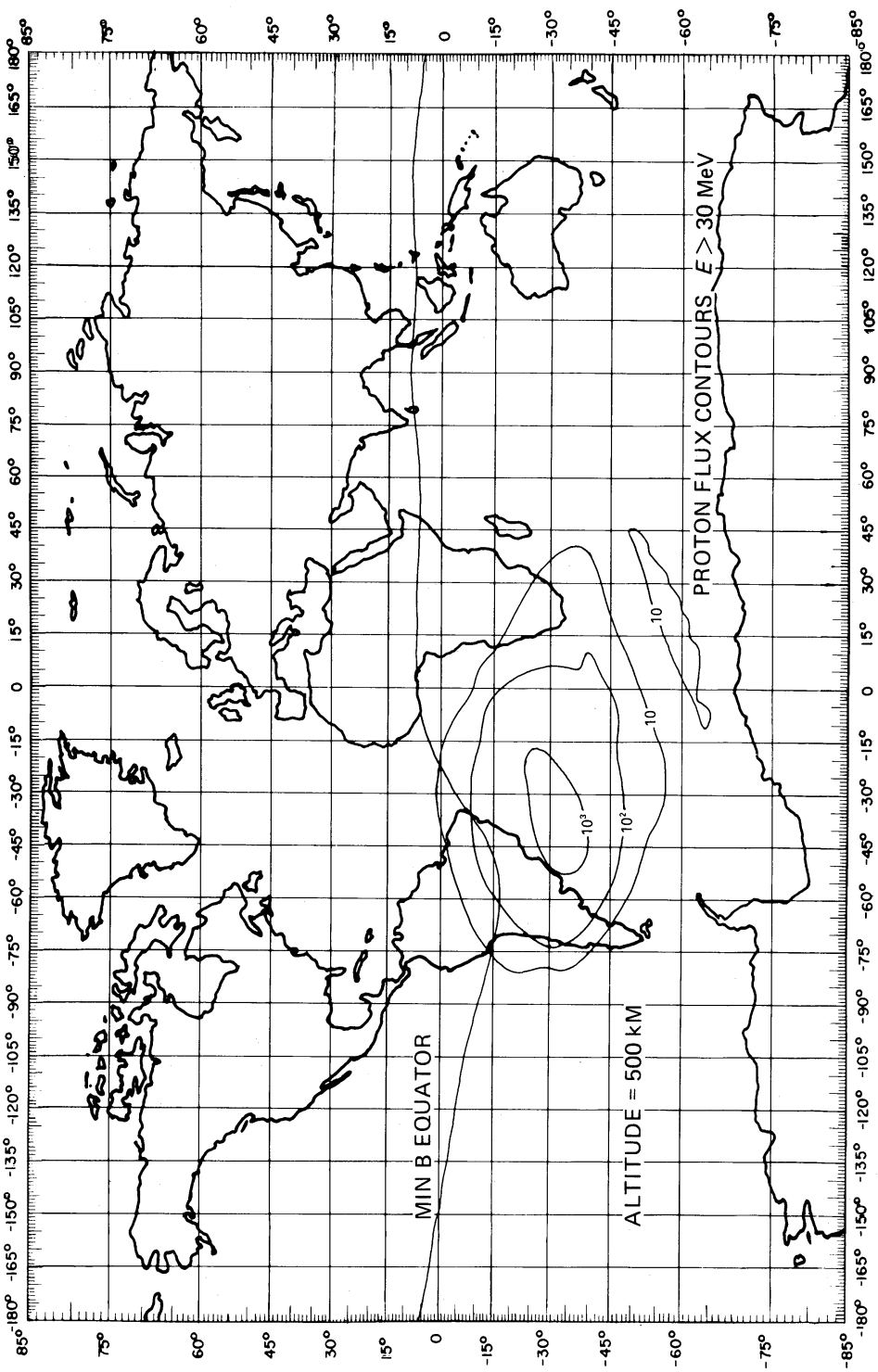
Proton distribution in the Earth's field. (Published by Vette in September 1963.)



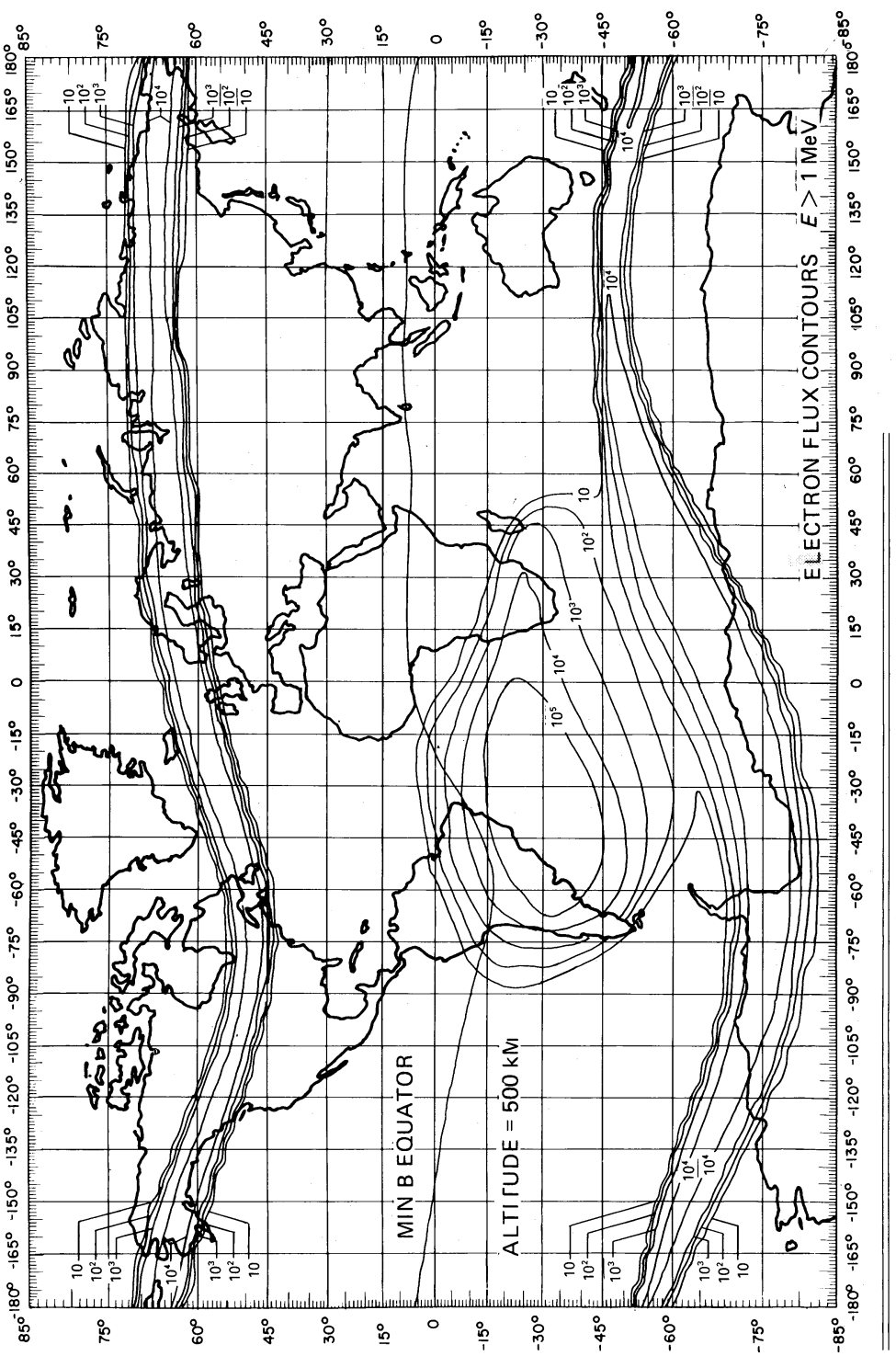
© Cambridge University Press • Provided by the NASA Astrophysics Data System

Trapped radiation (*cont.*)

Omni-directional flux in protons $cm^{-2}\ s^{-1}$. (Adapted from Stassinopoulos, E. G., *World Maps of Constant B, L, and Flux Contours*, NASA SP-3054, 1970.)



© Cambridge University Press • Provided by the NASA Astrophysics Data System



Omni-directional flux in electrons $cm^{-2}\ s^{-1}$. (Adapted from Stassinopoulos, E. G., *World Maps of Constant B, L, and Flux Contours*, NASA SP-3054, 1970.)

© Cambridge University Press • Provided by the NASA Astrophysics Data System

Solar irradiance (1 AU)

Visible and infrared radiation

Radiant energy distribution:

approximated by that from a 5800 K blackbody

Fraction of solar radiation:

Above 7000 Å = 53.12%
Above 4000 Å ~ 91.28%
3000 Å–30 000 Å = 96.62%

Ultraviolet and X-ray radiation

Fraction of solar radiation:

Below 4000 Å = 8.72%
Below 3000 Å = 1.21%
Below 2000 Å = 0.008% (variable)
Below 1000 Å = 10^{-4}% (variable)

Principal line emission fluxes at 1.0 AU:

Lyman Alpha H I (1215.67 Å): 51.0×10^{-4} W m^{-2}
He II (303.8 Å): 2.5×10^{-4} W m^{-2}
H I (1025.72 Å): 0.60×10^{-4} W m^{-2}
C III (977 Å): 0.50×10^{-4} W m^{-2}

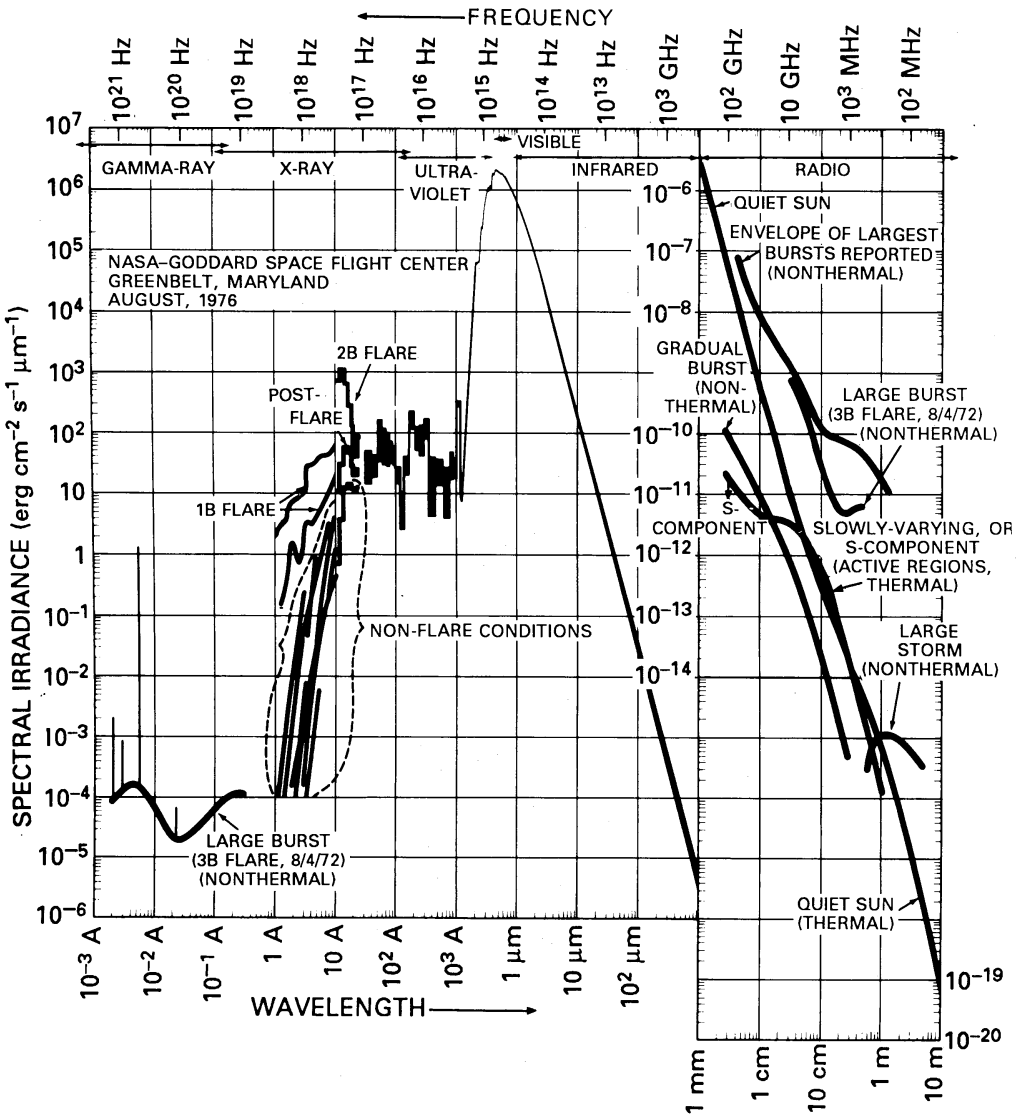
X-ray flux (W m^{-2}):

	1–8 Å	8–20 Å	20–200 Å
Sunspot min	1×10^{-8}	1×10^{-7}	$\sim 1 \times 10^{-4}$
Sunspot max	3×10^{-6}	2×10^{-5}	$\sim 1 \times 10^{-3}$
Flare activity (large flares)	1×10^{-4}	5×10^{-4}	$\sim 1 \times 10^{-2}$

© Cambridge University Press • Provided by the NASA Astrophysics Data System

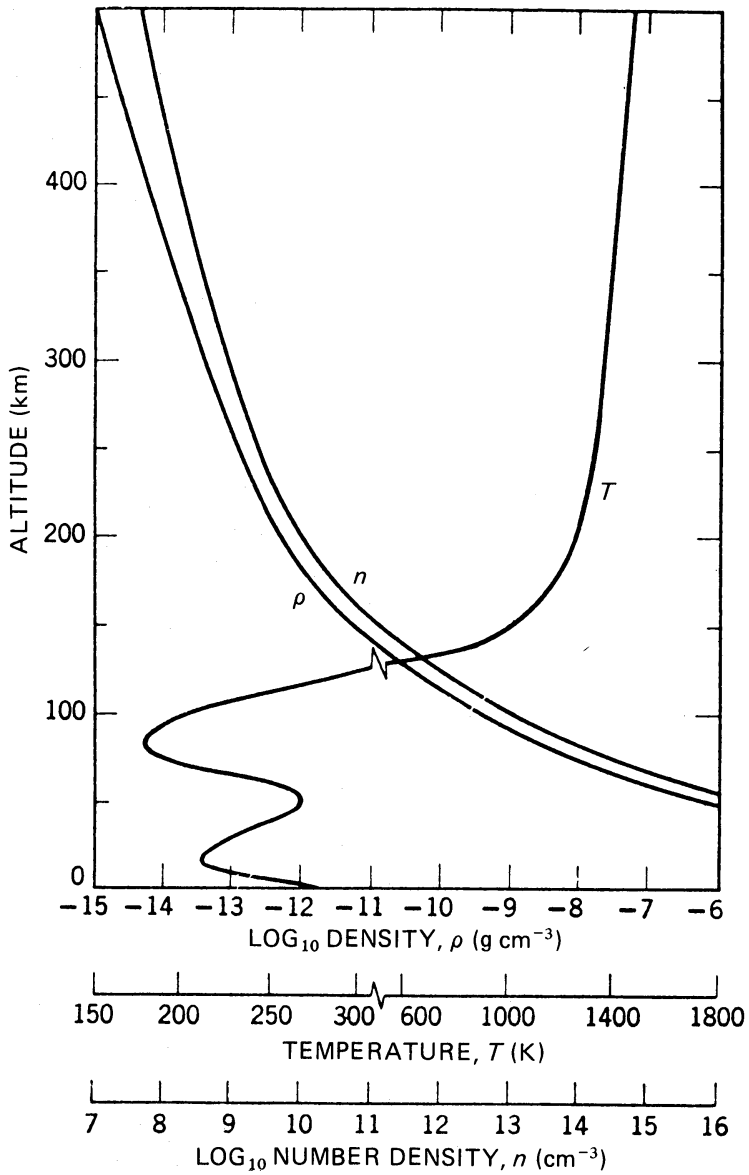
The solar spectrum

The solar spectral irradiance from radio waves to gamma-rays. (Courtesy H. Malitson and the National Space Science Data Center.)



© Cambridge University Press • Provided by the NASA Astrophysics Data System

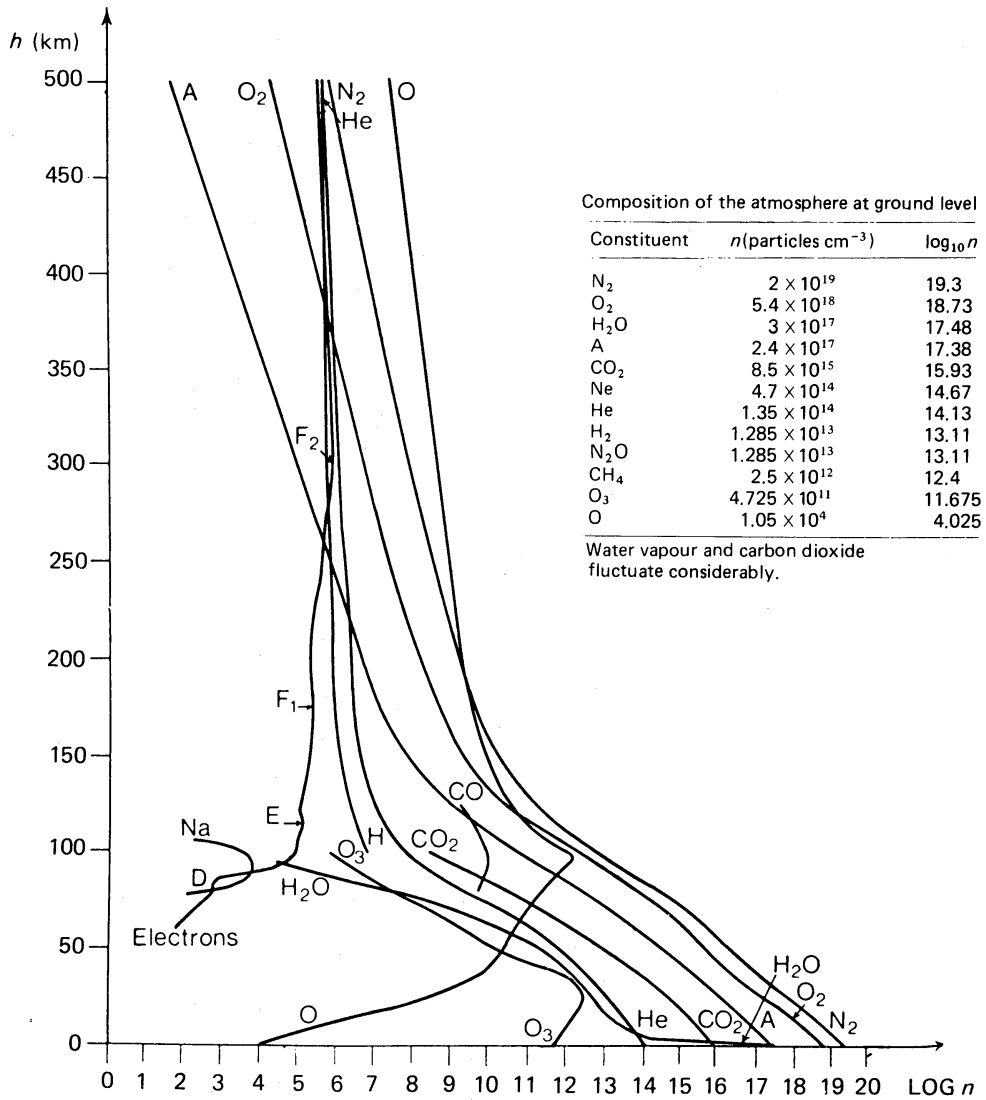
(COSPAR International Reference Atmosphere, 1961.)



© Cambridge University Press • Provided by the NASA Astrophysics Data System

Altitude variation of atmospheric constituents

Variation with altitude of the various constituents of the atmosphere. The horizontal scale is the logarithm of the particle density n in particles cm^{-3}. (Adapted from Pecker, J., *Space Observatories*, D. Reidel Publishing Company, Dordrecht, 1970.)

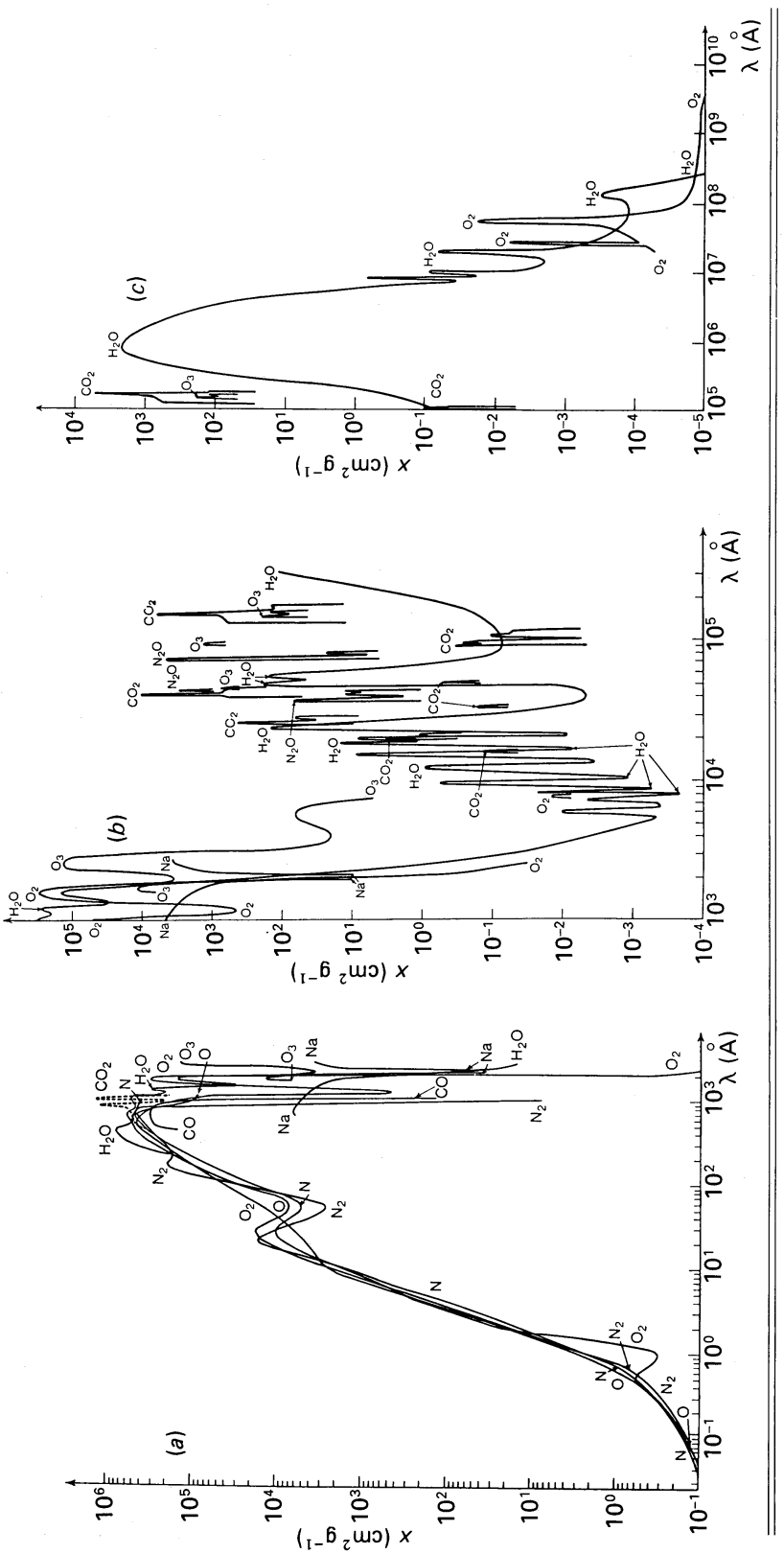


Composition of the atmosphere at ground level

Constituent	n(particles cm^{-3})	$\log_{10} n$
N_2	2×10^{19}	19.3
O_2	5.4×10^{18}	18.73
H_2O	3×10^{17}	17.48
A	2.4×10^{17}	17.38
CO_2	8.5×10^{15}	15.93
Ne	4.7×10^{14}	14.67
He	1.35×10^{14}	14.13
H_2	1.285×10^{13}	13.11
N_2O	1.285×10^{13}	13.11
CH_4	2.5×10^{12}	12.4
O_3	4.725×10^{11}	11.675
O	1.05×10^{4}	4.025

Water vapour and carbon dioxide fluctuate considerably.

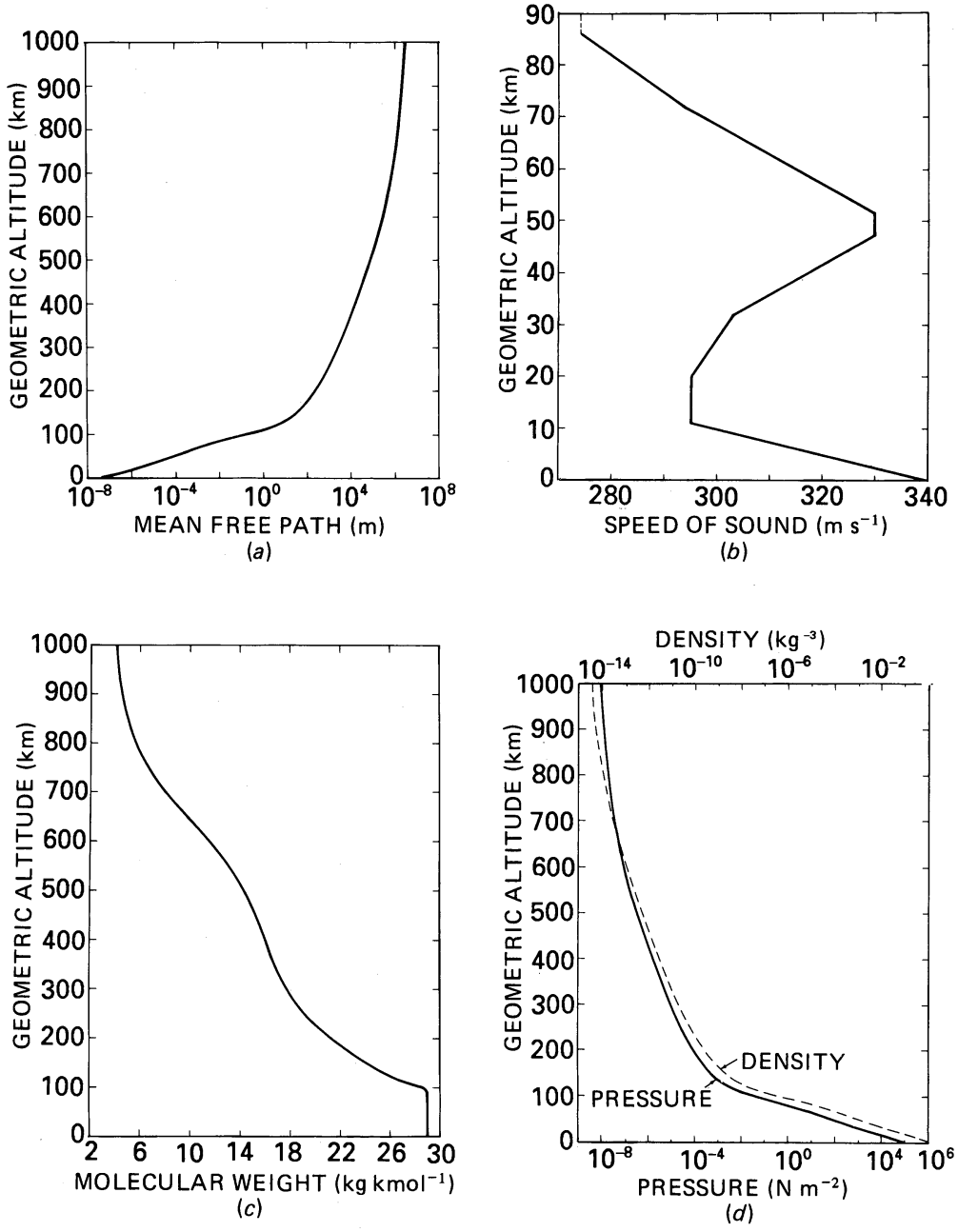
© Cambridge University Press • Provided by the NASA Astrophysics Data System



Attenuation of photons as a function of wavelength for various constituents of the atmosphere. The ordinate is the mass attenuation coefficient in $cm^2\ g^{-1}$. (*a*) X-ray and EUV region; (*b*) UV, visible, and infrared region; (*c*) radio region. (Adapted from Pecker, J., *Space Observatories*, D. Reidel Publishing Company, Dordrecht, 1970.)

© Cambridge University Press • Provided by the NASA Astrophysics Data System

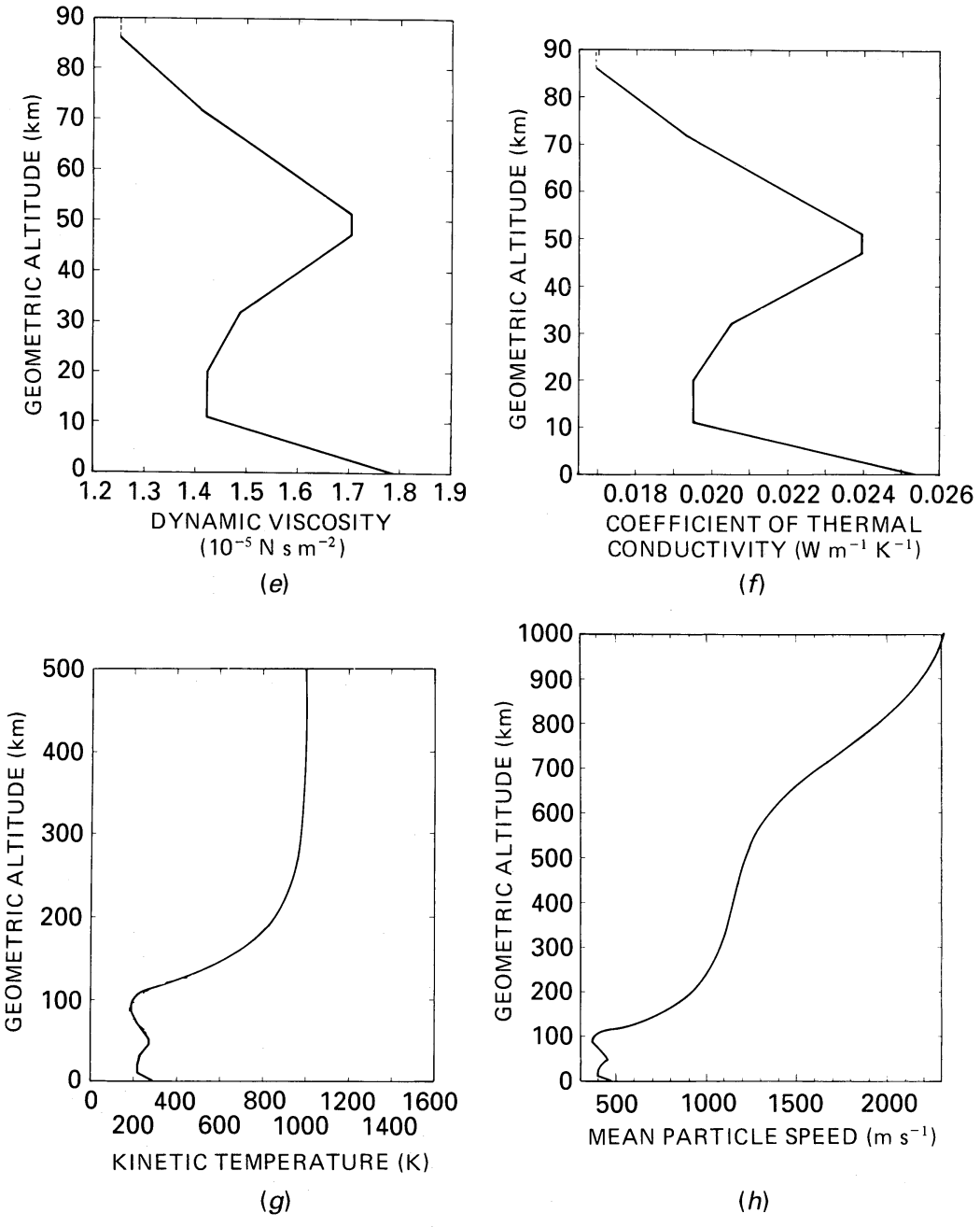
(*a*) Mean free path as a function of geometric altitude. (*b*) Speed of sound as a function of geometric altitude. (*c*) Mean molecular weight as a function of geometric altitude. (*d*) Total pressure and mass density as a function of geometric altitude.



© Cambridge University Press • Provided by the NASA Astrophysics Data System

US standard atmosphere, 1976 (*cont.*)

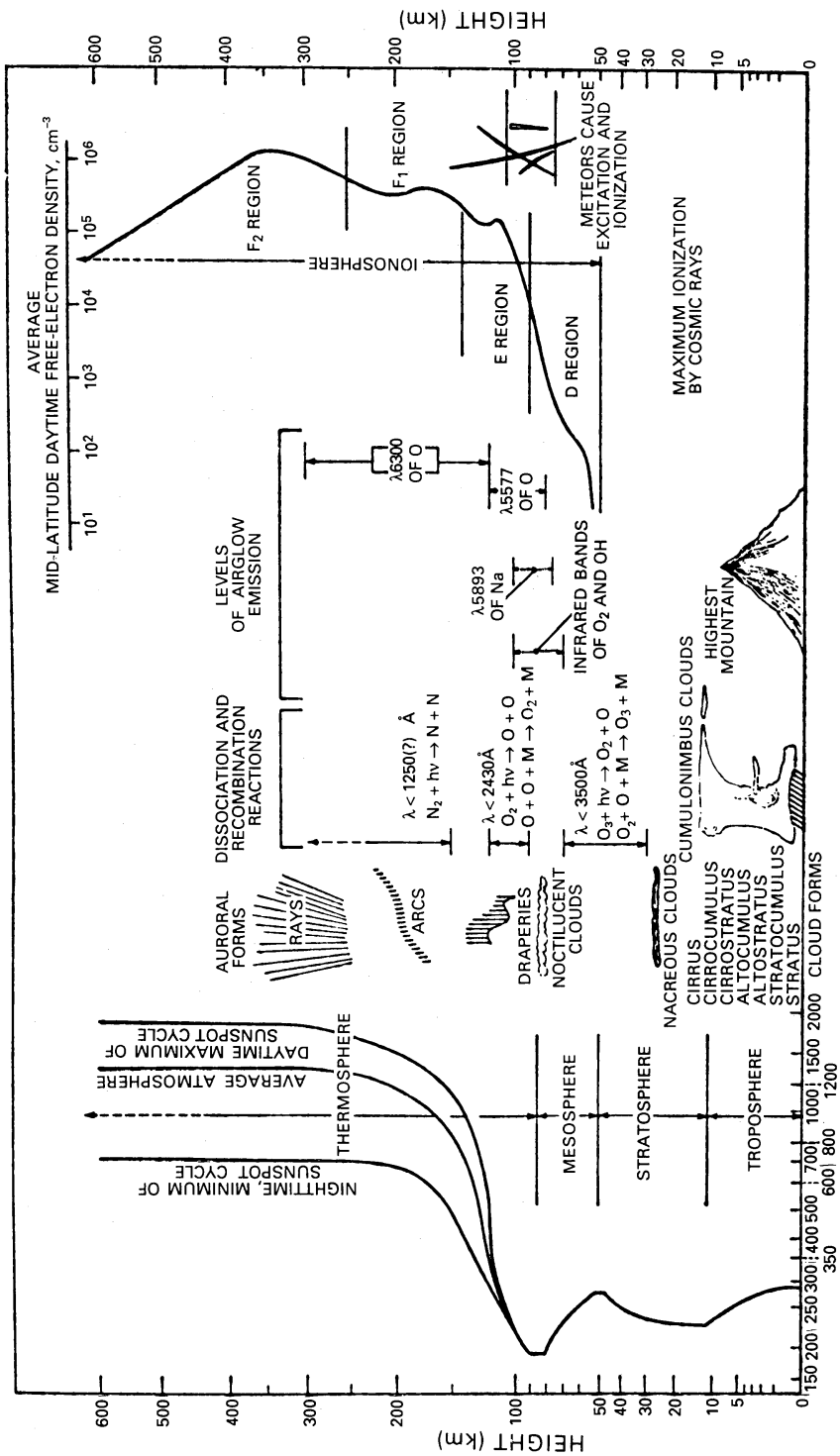
(*e*) Dynamic viscosity as a function of geometric altitude. (*f*) Coefficient of thermal conductivity as a function of geometric altitude. (*g*) Kinetic temperature as a function of geometric altitude. (*h*) Mean air-particle speed as a function of geometric altitude.



© Cambridge University Press • Provided by the NASA Astrophysics Data System

Structure of the upper atmosphere

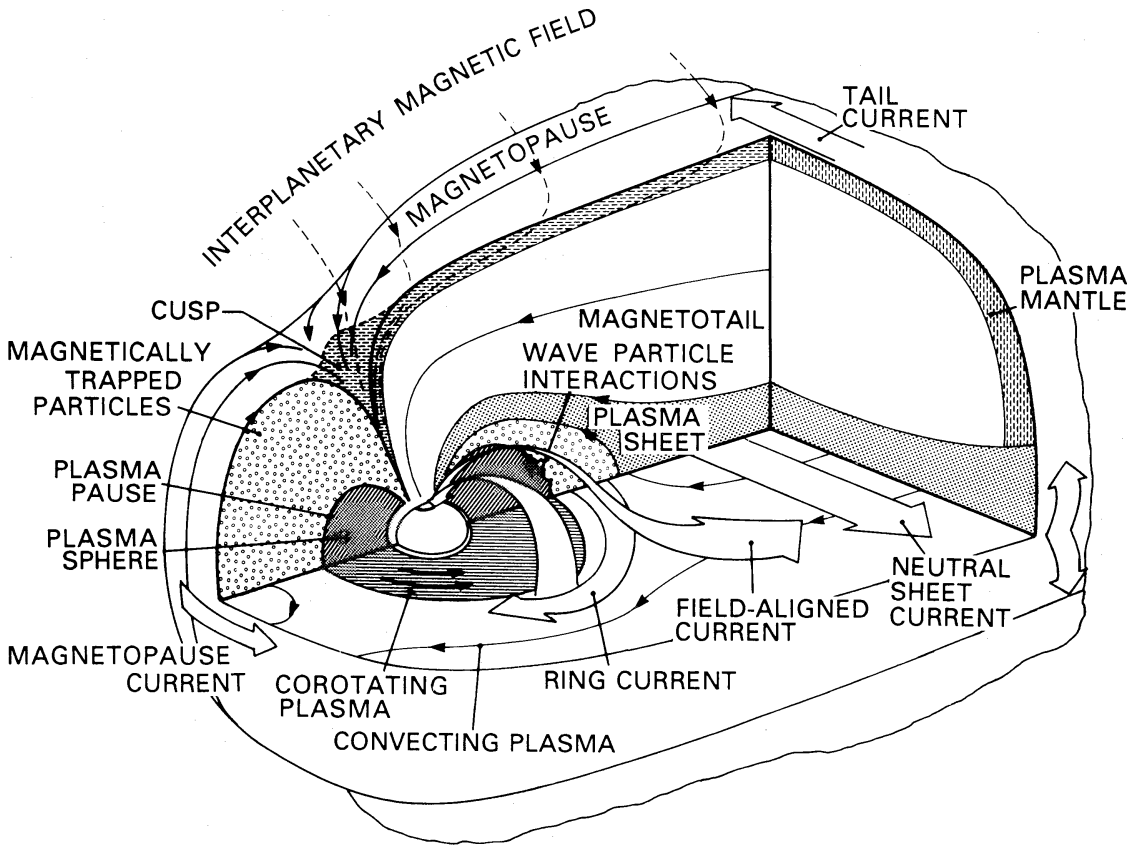
(Adapted from Harris, M. F. in *American Institute of Physics Handbook*, D. E. Gray, ed., McGraw-Hill Book Company, 1972.)



© Cambridge University Press • Provided by the NASA Astrophysics Data System

Earth's magnetosphere

Schematic view of the Earth's magnetosphere.



(From NASA)

Bibliography

World Maps of Constant B, L, and Flux Contours, Stassinopoulos, E. G., NASA SP-3054, 1970.

US Standard Atmosphere, 1976, 1976-0-588-256, US Government Printing Office.

Satellite Environment Handbook, F. S. Johnson, ed., Stanford University Press, 1965.

© Cambridge University Press • Provided by the NASA Astrophysics Data System