Physical Meteorology

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Part 3

Radiative Transfer

in the Atmopshere

Outline of Material

Headings follow Wallace & Hobbs.
We will not cover everything!

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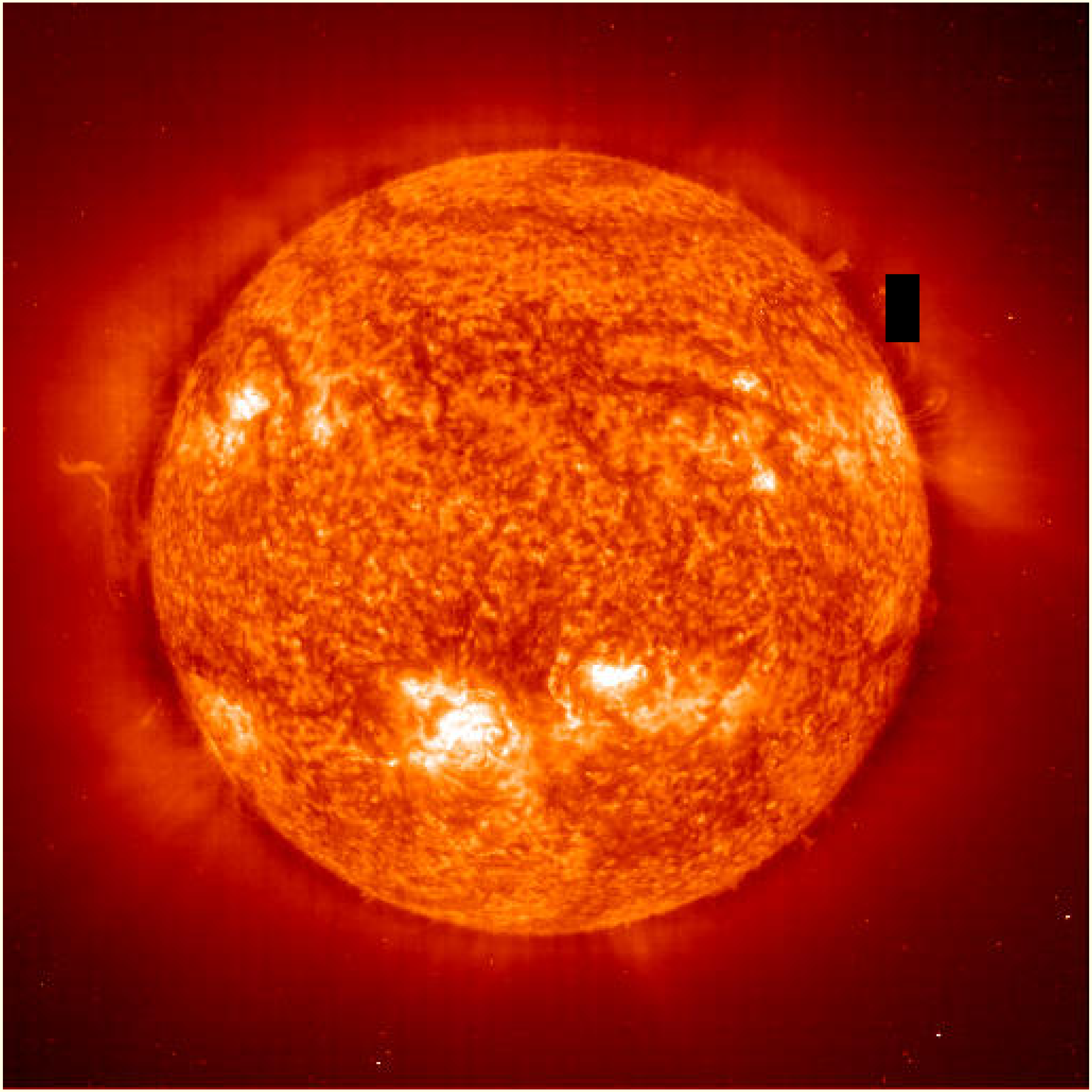
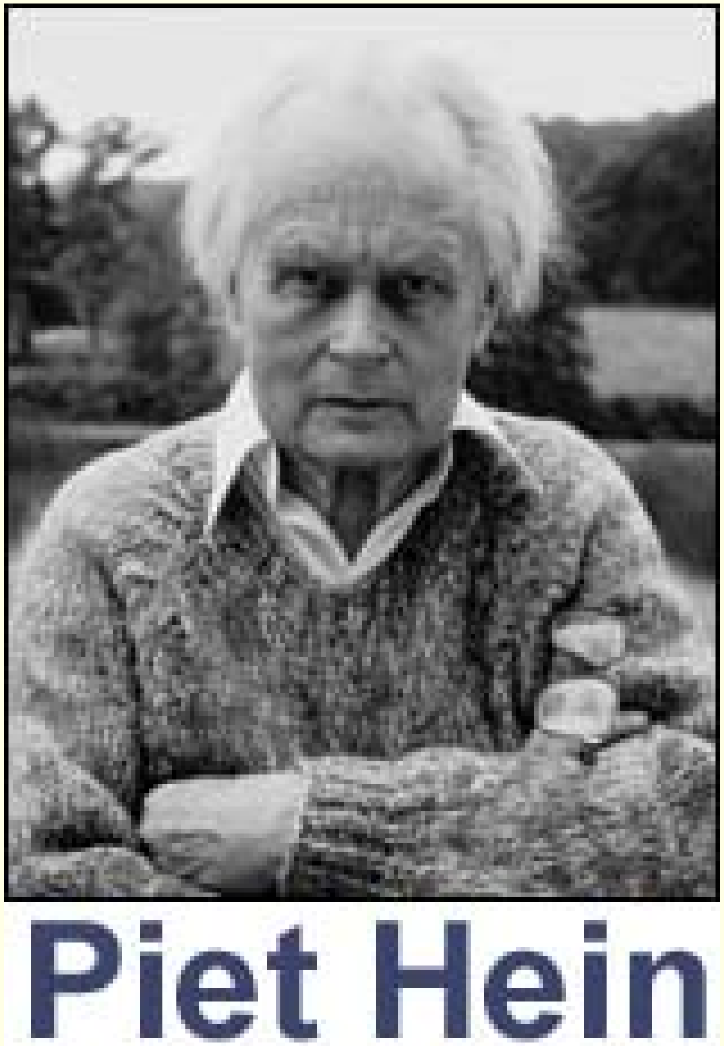
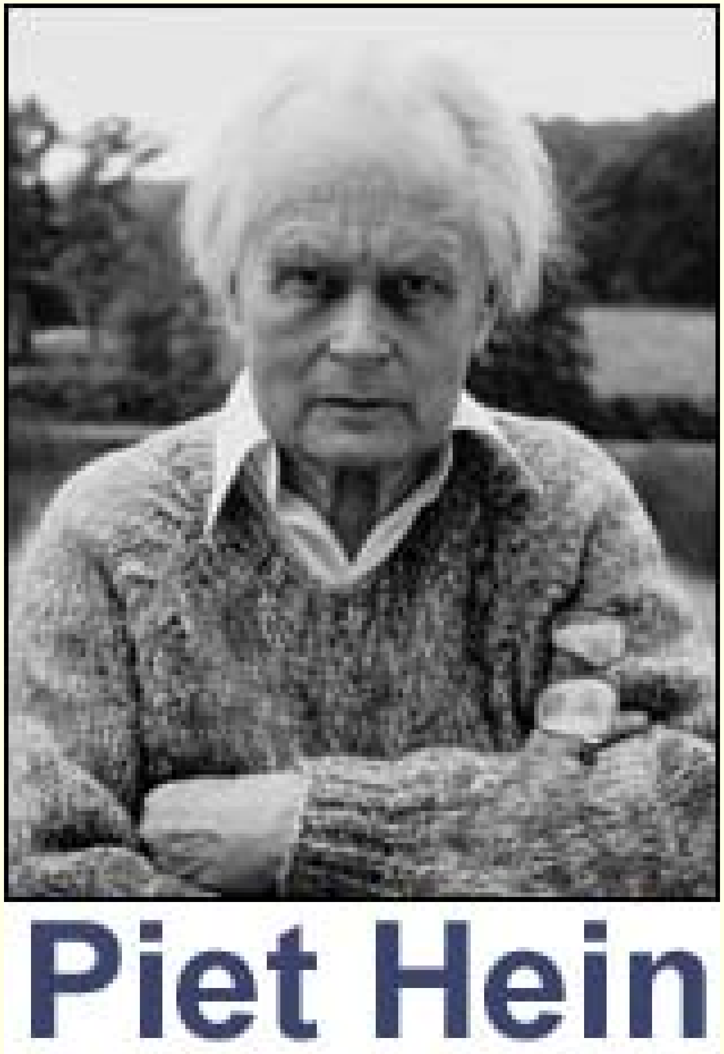
- **0. Introduction**
- **1. The Spectrum of Radiation**
- **2. Quantitative Description of Radiation**
- **3. Blackbody Radiation**
- **4. Scattering and Absorption**
- **5. Radiative transfer in planetary atmospheres**
- **6. Radiation balance at the top of the atmosphere**





A *Grook* by
Piet Hein
(1905–1996)



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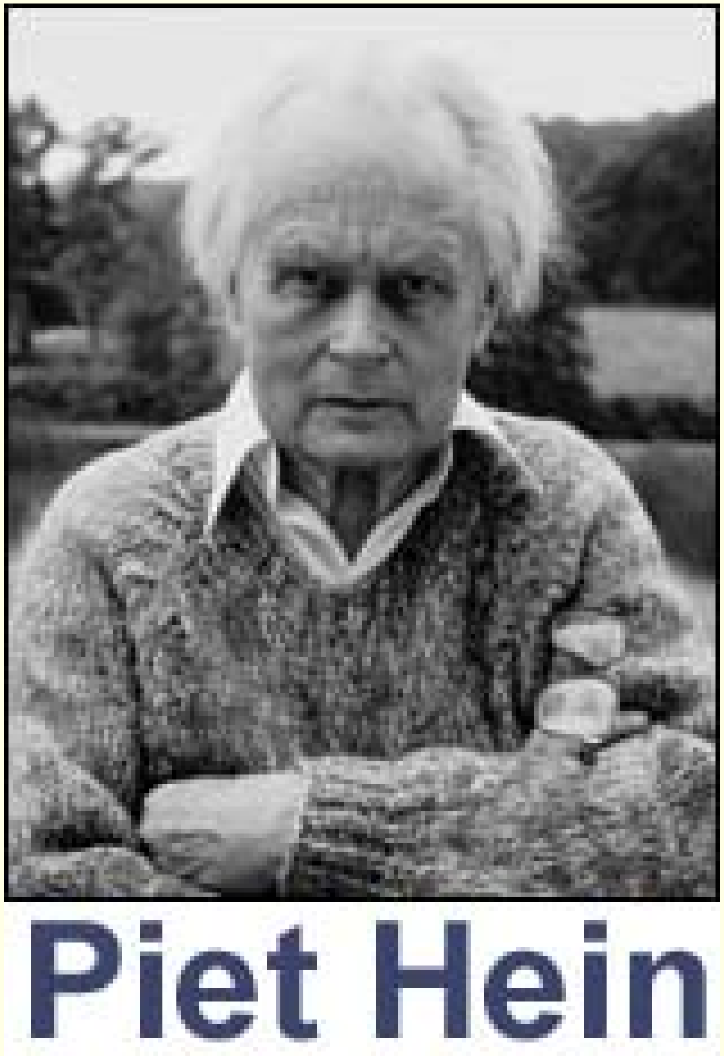

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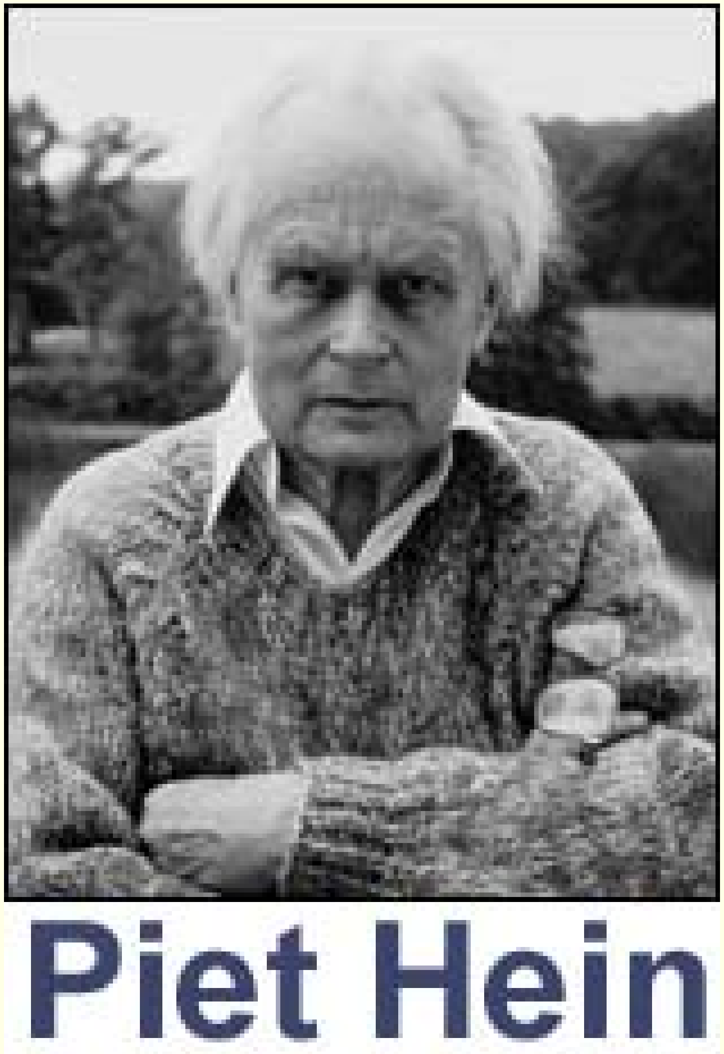
Sun, that givest all things birth, shine on everything on Earth.

But if that's too much to demand, shine, at least, on this our land.



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Sun, that givest all things birth, shine on everything on Earth.

But if that's too much to demand, shine, at least, on this our land.

If even that's too much for thee, shine, at any rate, on me.

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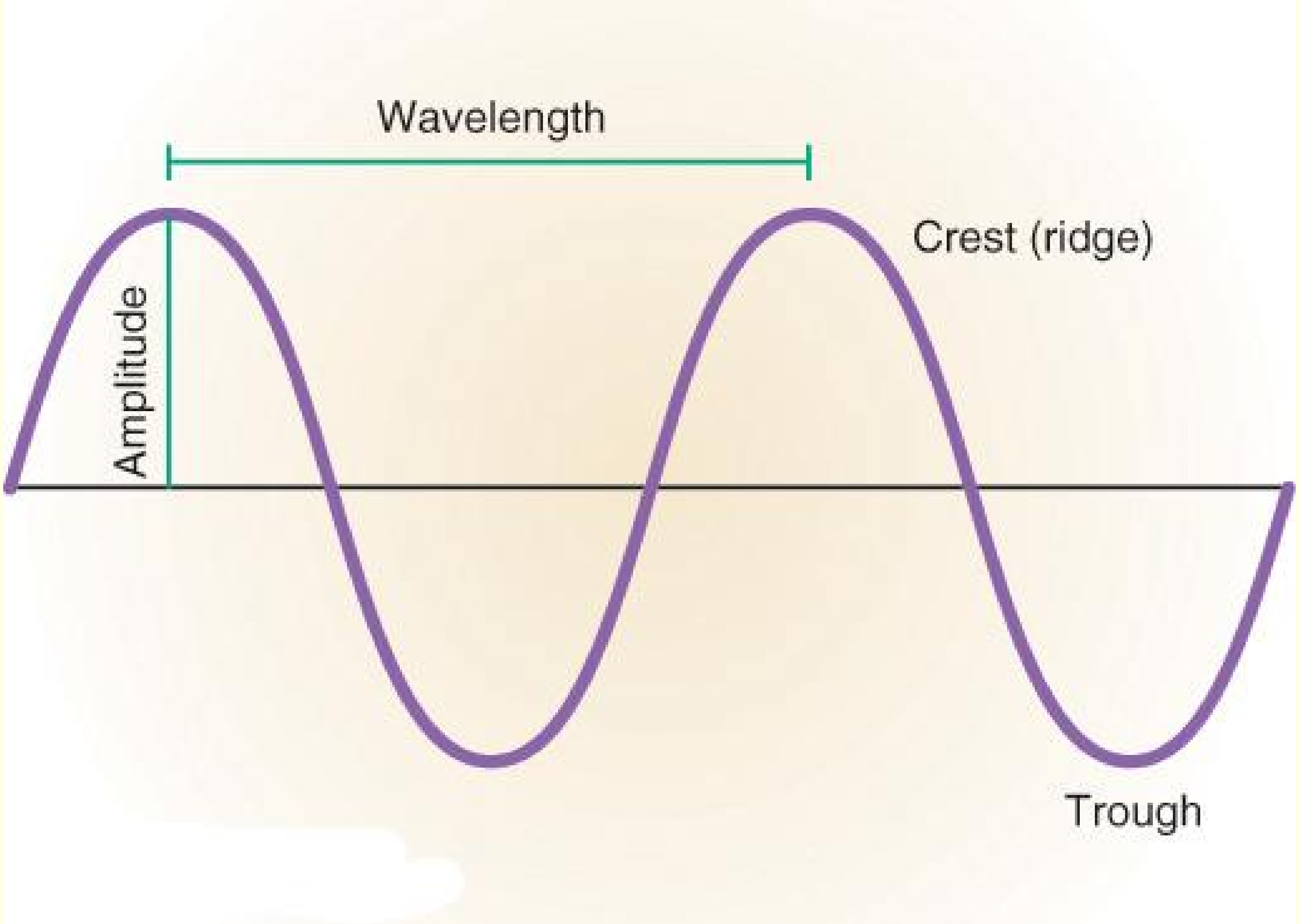
It is extremely convenient that the overlap between solar radiation and terrestrial radiation is very small, so that we can consider them separately.



Review of the parameters describing a wave

Radiation and Matter

Review of the fundamentals of

- **Wave-particle duality**
- **Energy levels in atoms**
- **Absorbtion and emission**
- **Atomic spectra**
- **Molecular vibrations**
- **QED**

The Electromagnetic Spectrum

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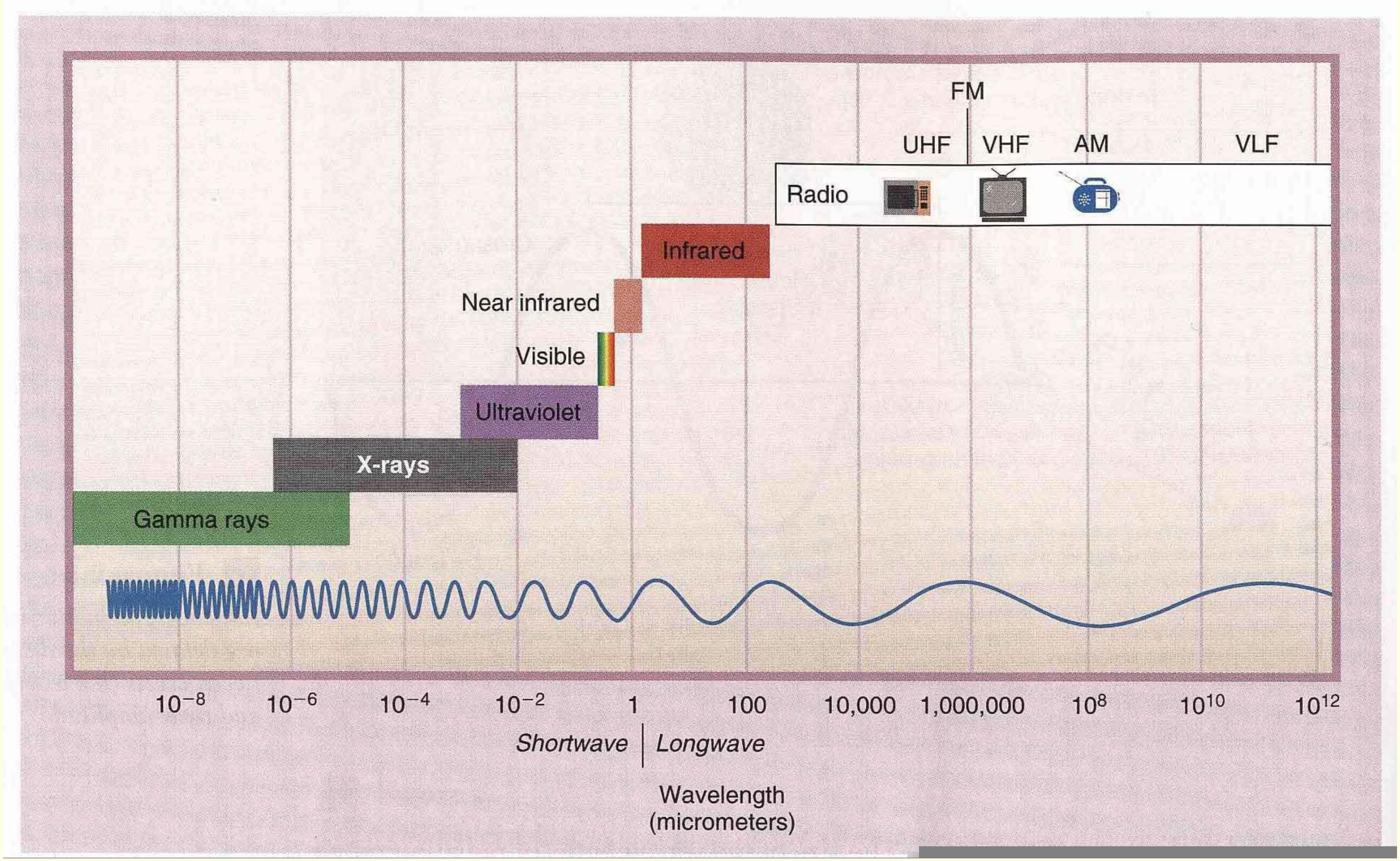
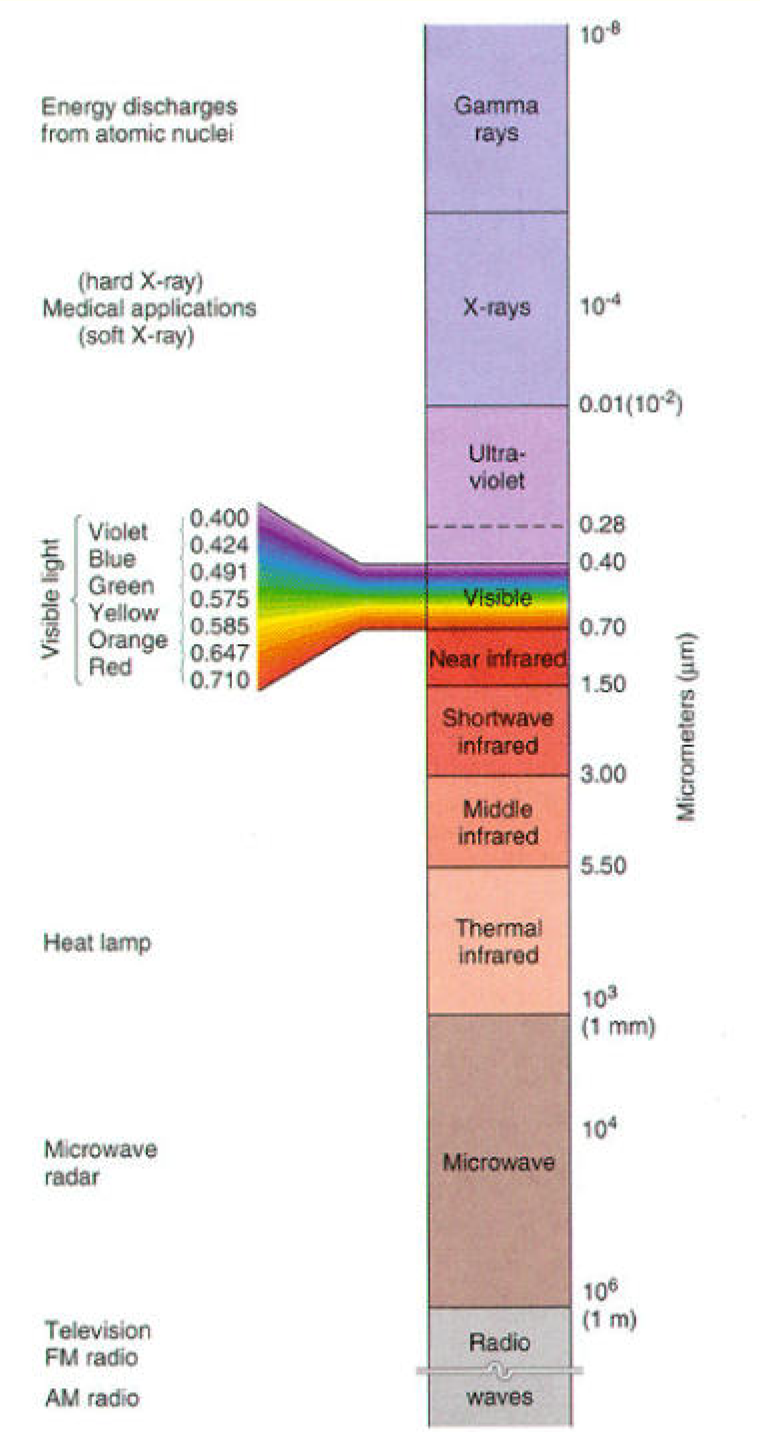
- **Radio waves: Wavelengths about $\mathbf{10^{-2}}$–10^{4}m**

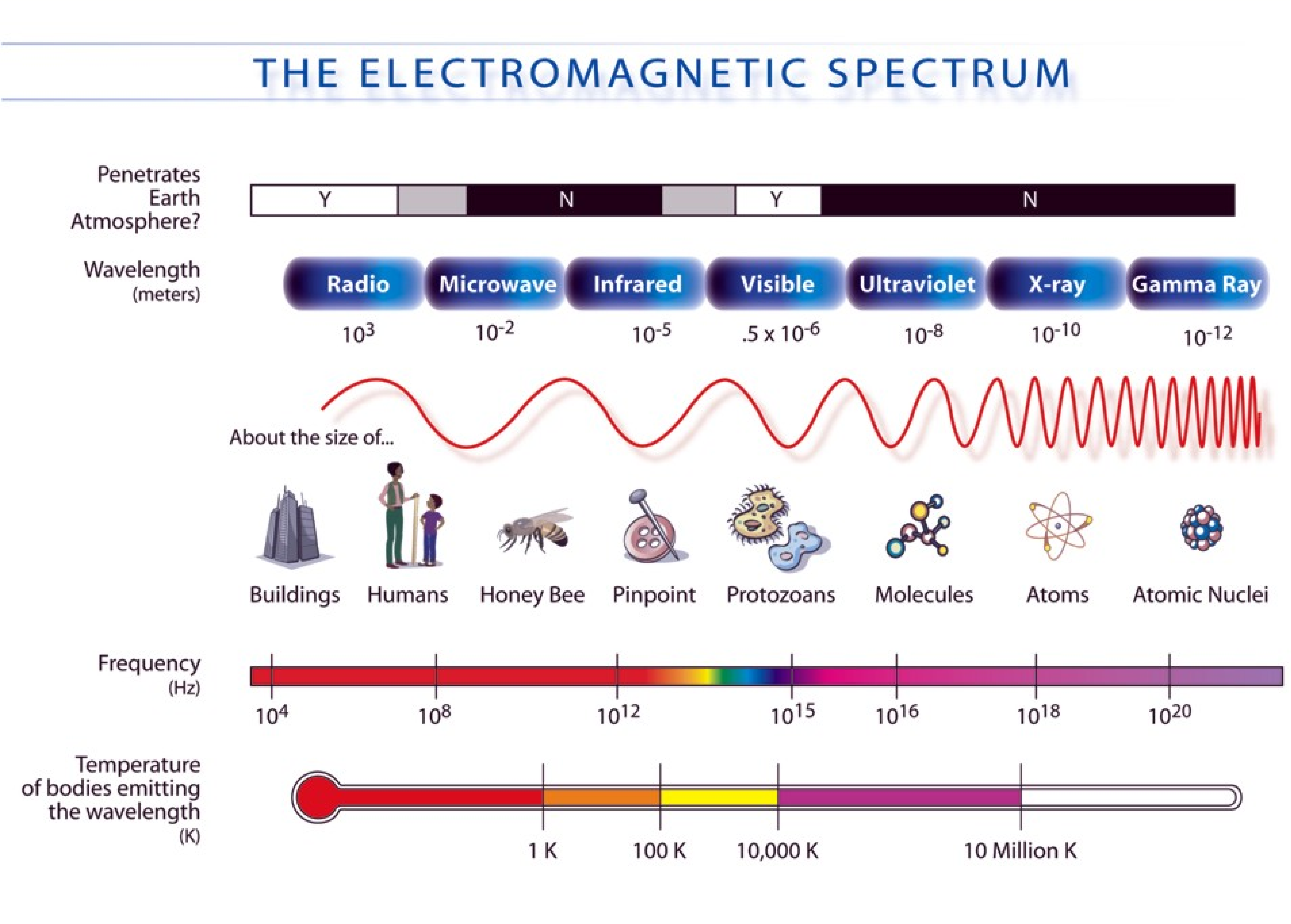


The Electromagnetic Spectrum



source: Christopherson (2000) *Geosystems*

The Electromagnetic Spectrum.


THE ELECTROMAGNETIC SPECTRUM
Penetrates Earth Atmosphere?
Y
N
Y
N
Wavelength (meters)
Radio
Microwave
Infrared
Visible
Ultraviolet
X-ray
Gamma Ray
10^{3}
10^{-2}
10^{-5}
$.5 \times 10^{-6}$
10^{-8}
10^{-10}
10^{-12}
About the size of...
Buildings
Humans
Honey Bee
Pinpoint
Protozoans
Molecules
Atoms
Atomic Nuclei
Frequency (Hz)
10^{4}
10^{8}
10^{12}
10^{15}
10^{16}
10^{18}
10^{20}
Temperature of bodies emitting the wavelength (K)
1 K
100 K
10,000 K
10 Million K

The Stefan-Boltzmann Law

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The *area* of the Sun is about 10,000 times larger than that of the Earth, so the ratio of the total radiation emitted is about $160,000 \times 10,000 = 1.6 \times 10^9$**, or more than one billion.**

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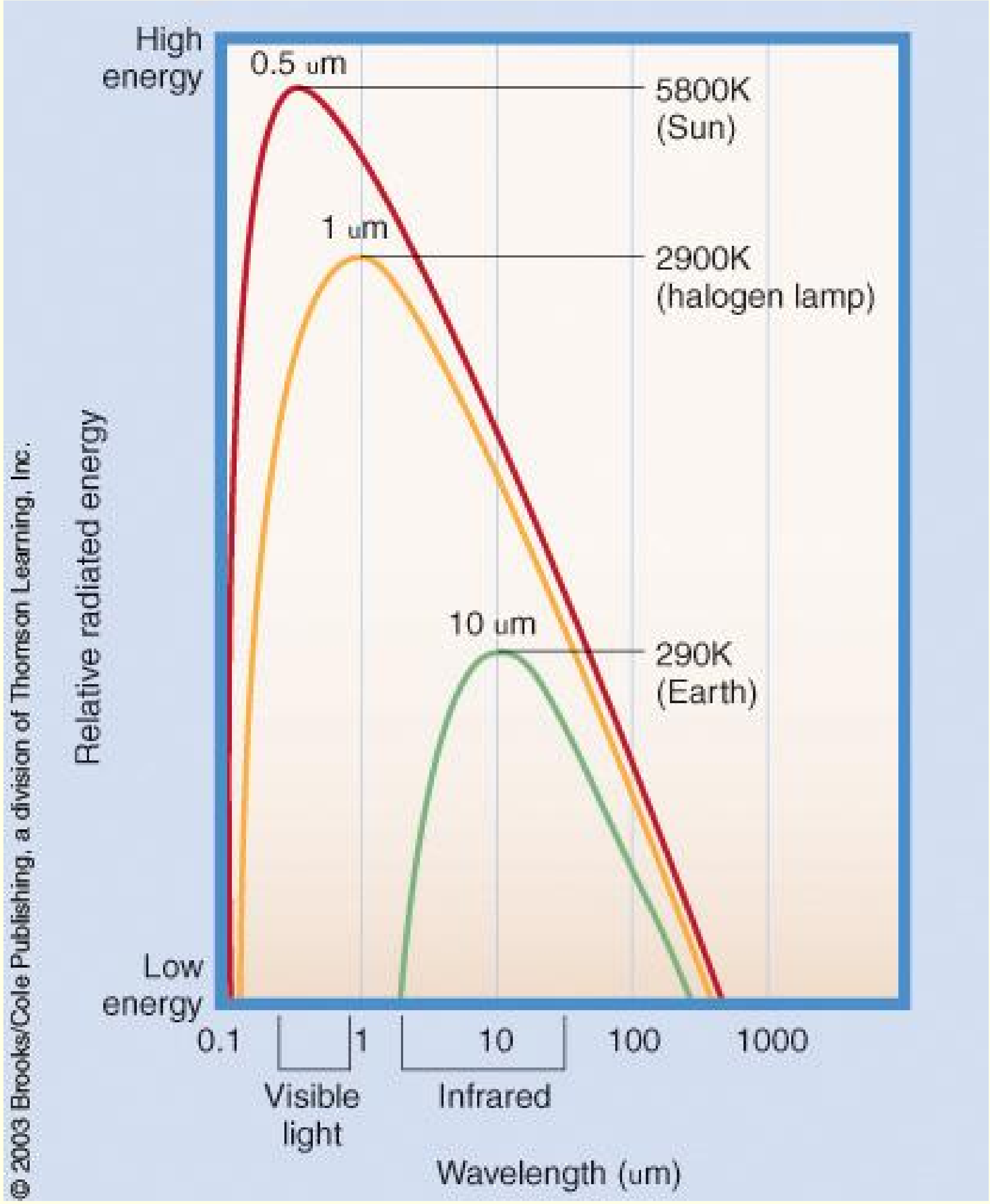
For example, the Earth's temperature is (about) 290 K, so the wavelength of maximum emitted radiation is about 10 μm.

The temperature of the Sun is (about) 5800 K, so the wavelength of maximum emitted radiation is about 0.5 μm.



High energy
Low energy
0.5 um
5800K (Sun)
1 um
2900K (halogen lamp)
10 um
290K (Earth)
Relative radiated energy
0.1
1
10
100
1000
Visible light
Infrared
Wavelength (um)
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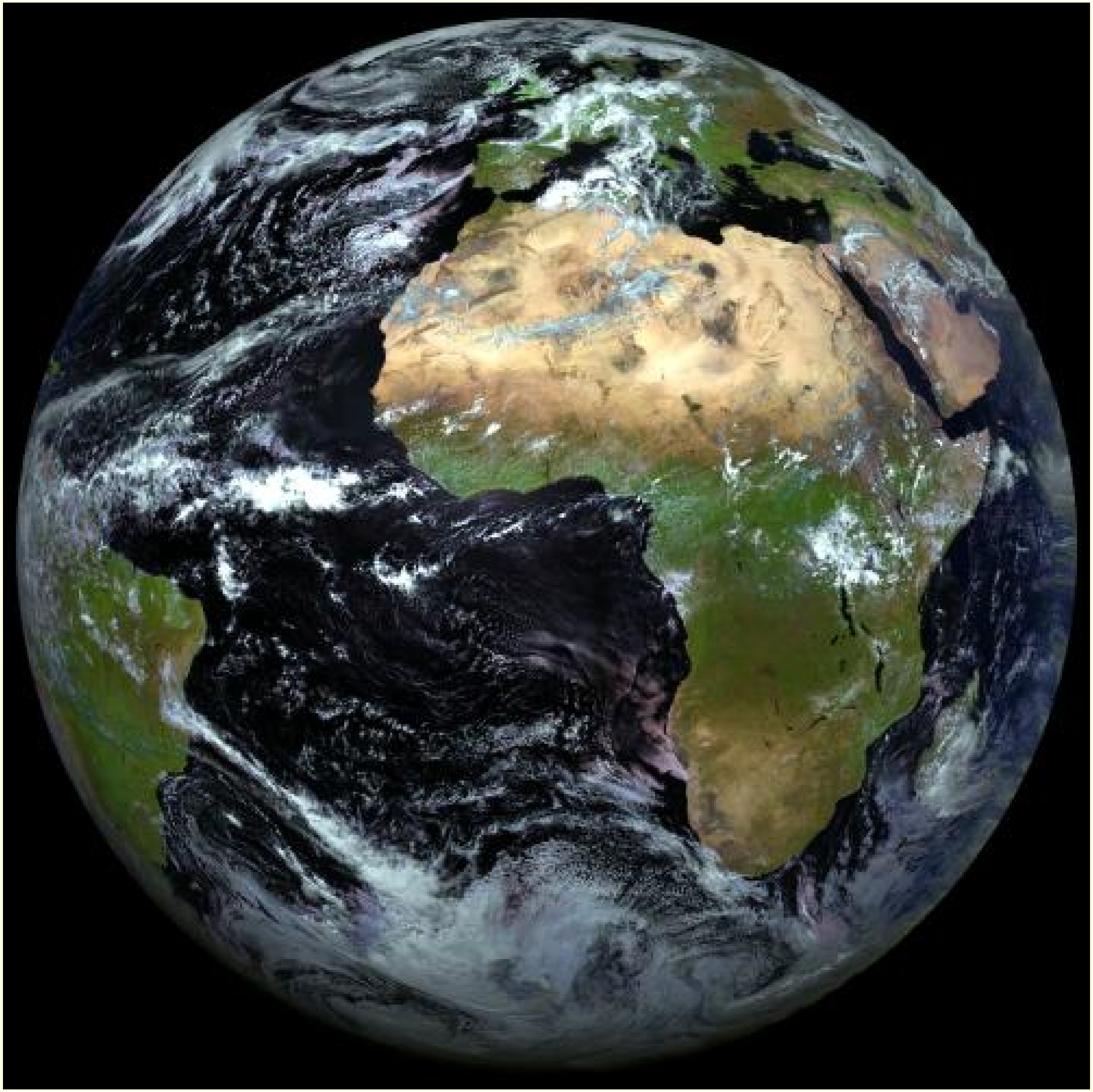
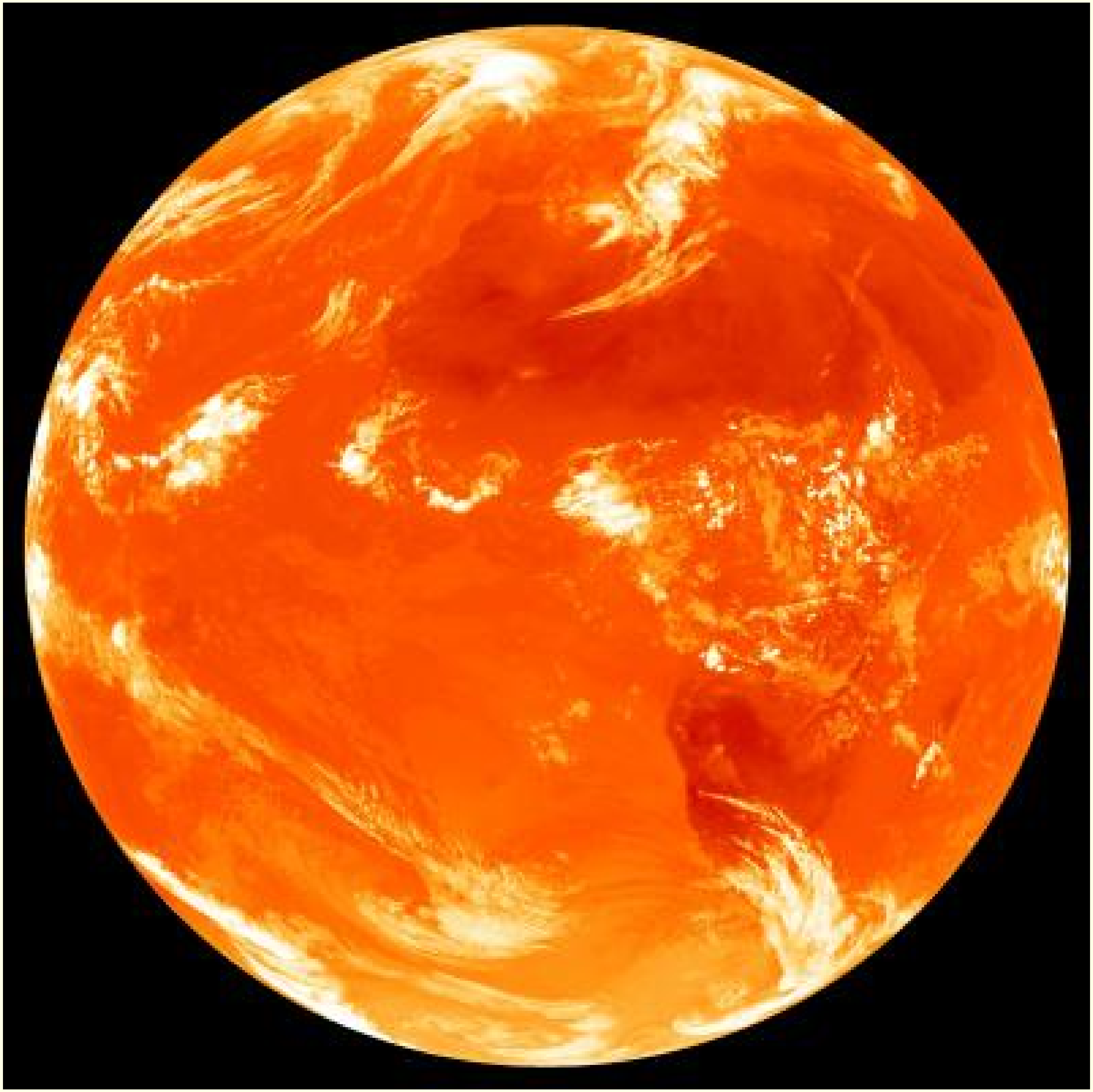
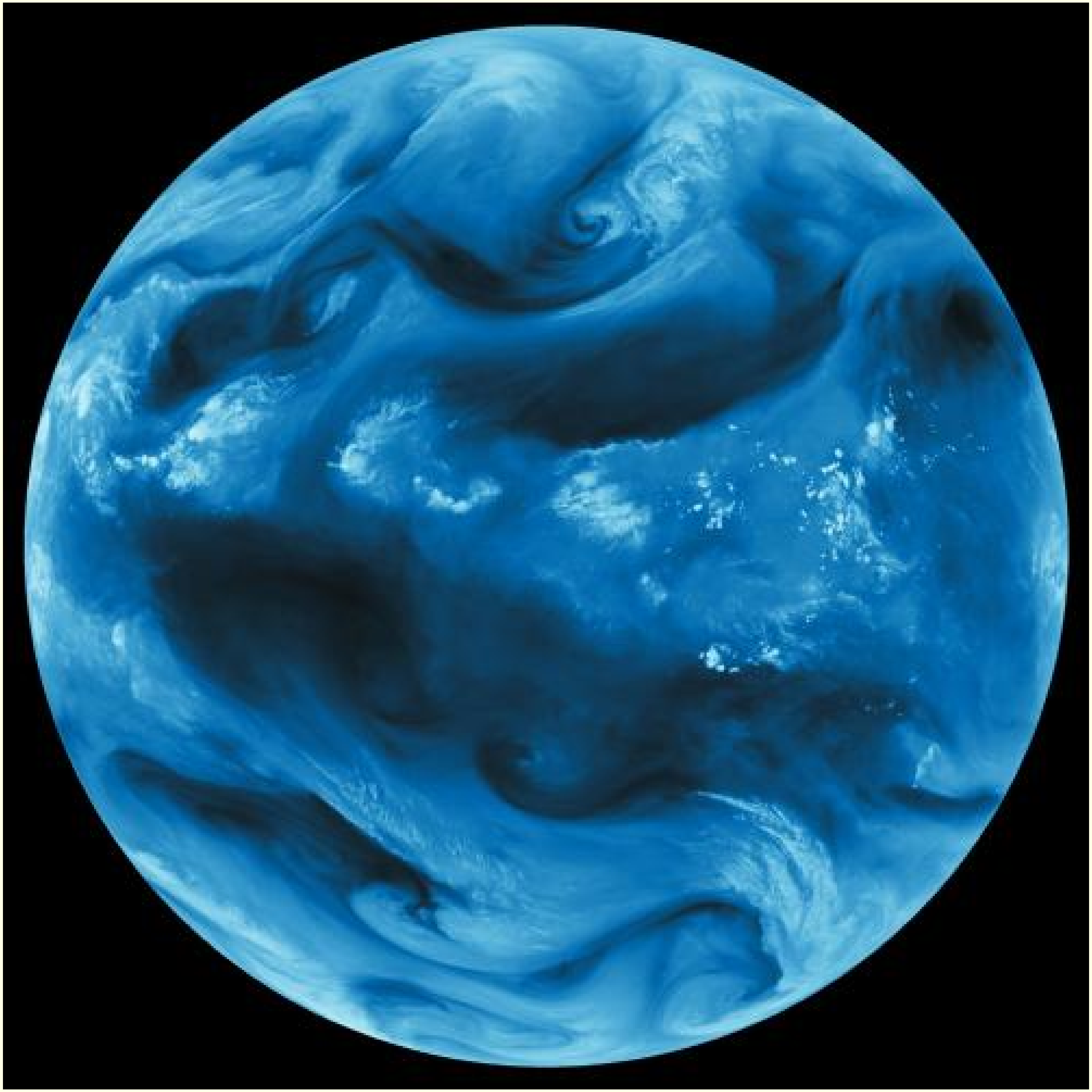
Infra-red photograph of a man holding a burning match

Infra-red photograph of a man holding a burning match

It's true: shades make you cool!



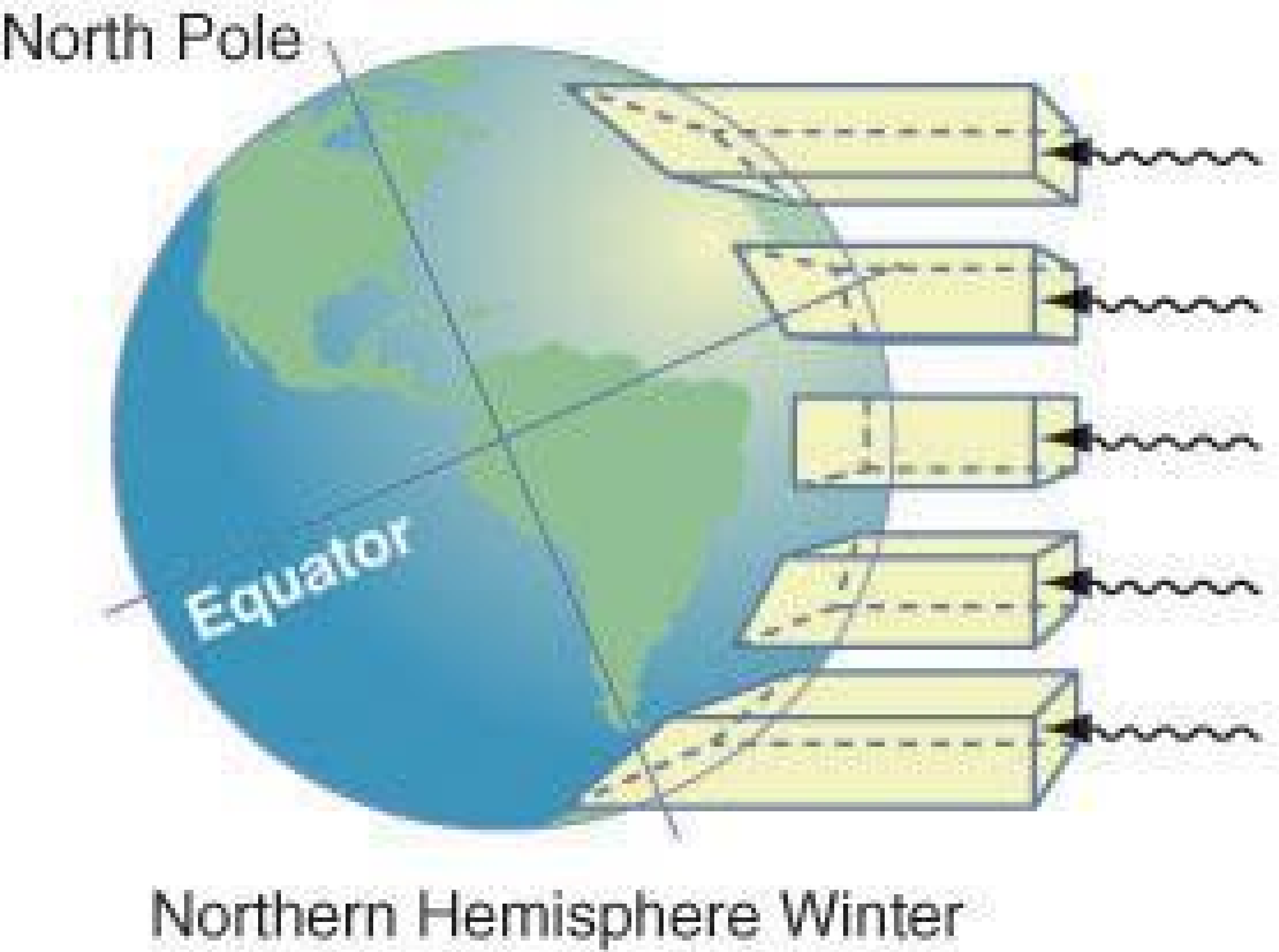


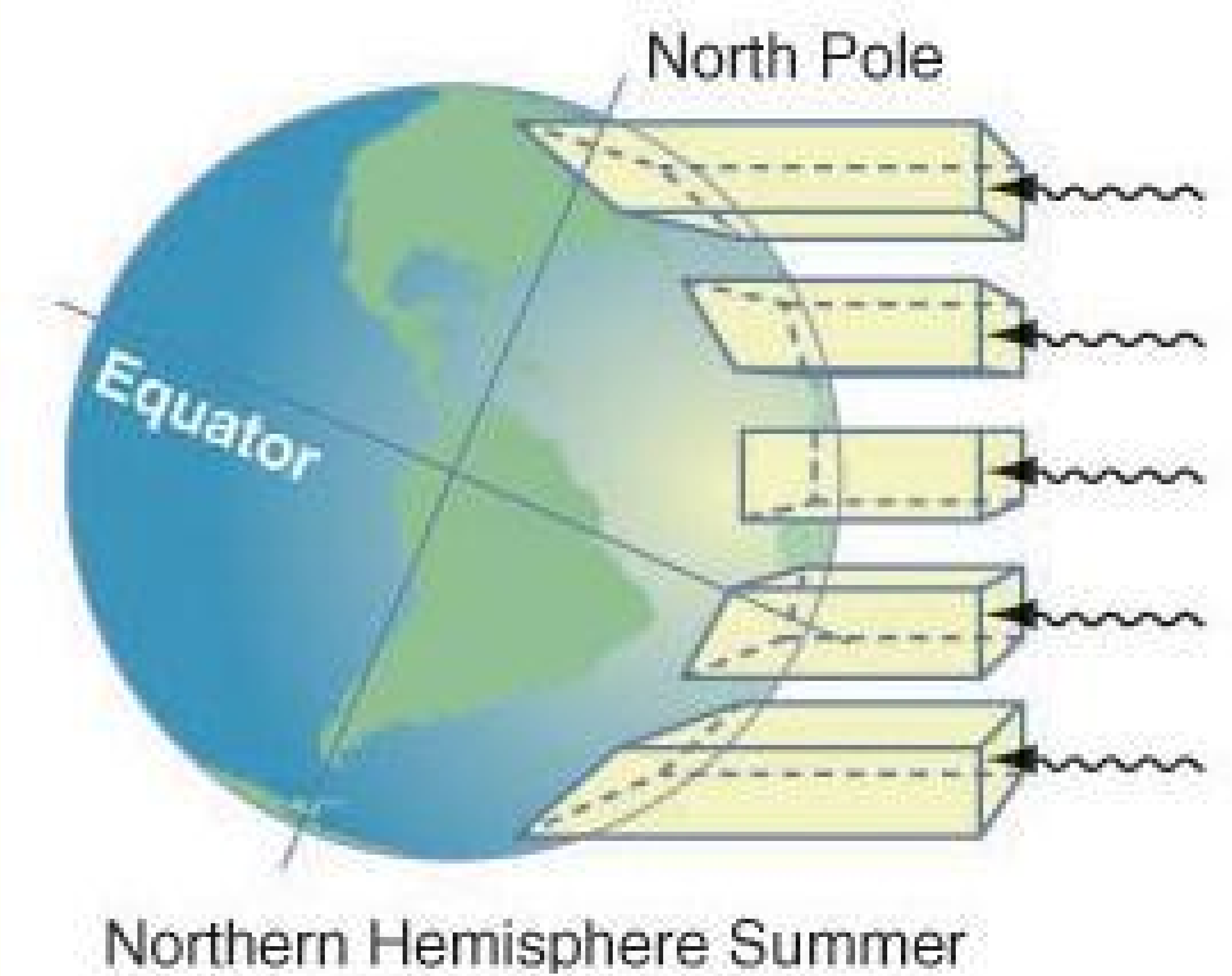


Images from Ackerman & Knox

Meteorology:

Understanding the Atmosphere


North Pole
Equator
Northern Hemisphere Winter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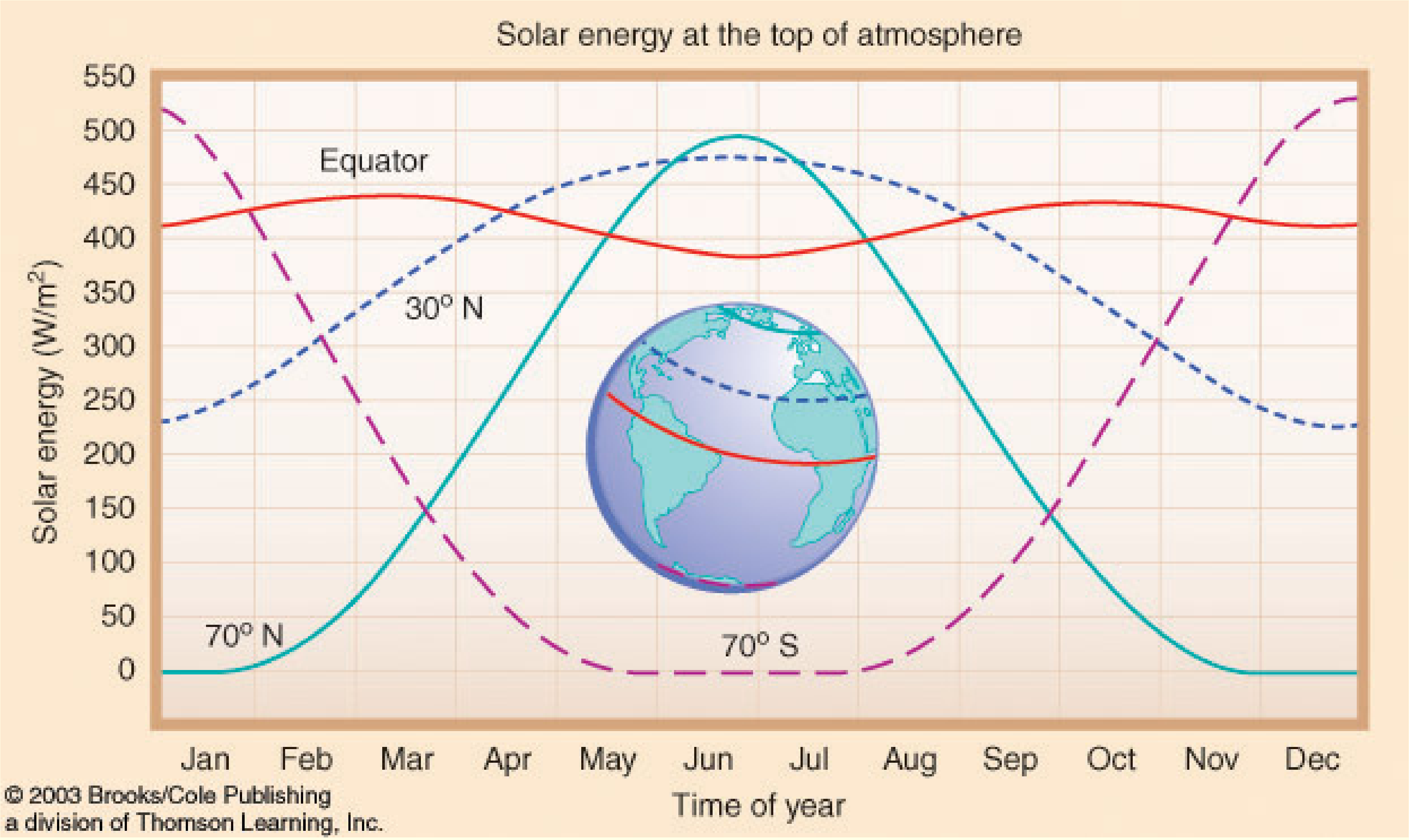
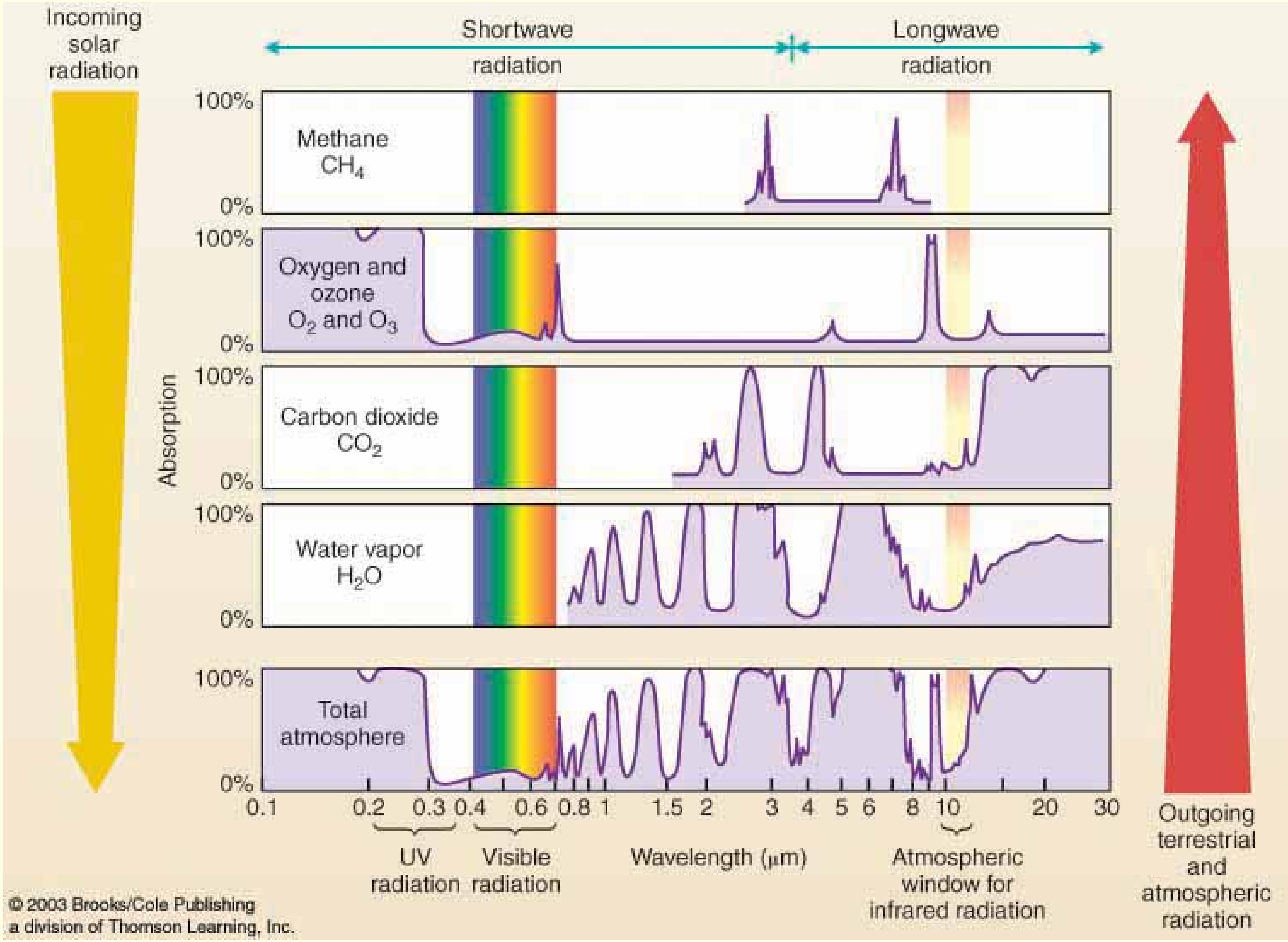


Solar energy reaching the top of the atmosphere at four latitudes



Incoming solar radiation
Shortwave radiation
Longwave radiation
100%
0%
Methane
CH4
Oxygen and ozone
O2 and O3
Carbon dioxide
CO2
Water vapor
H2O
Total atmosphere
Absorption
0.1 0.2 0.3 0.4 0.6 0.8 1 1.5 2 3 4 5 6 8 10 20 30
UV radiation
Visible radiation
Wavelength (μm)
Atmospheric window for infrared radiation
Outgoing terrestrial and atmospheric radiation
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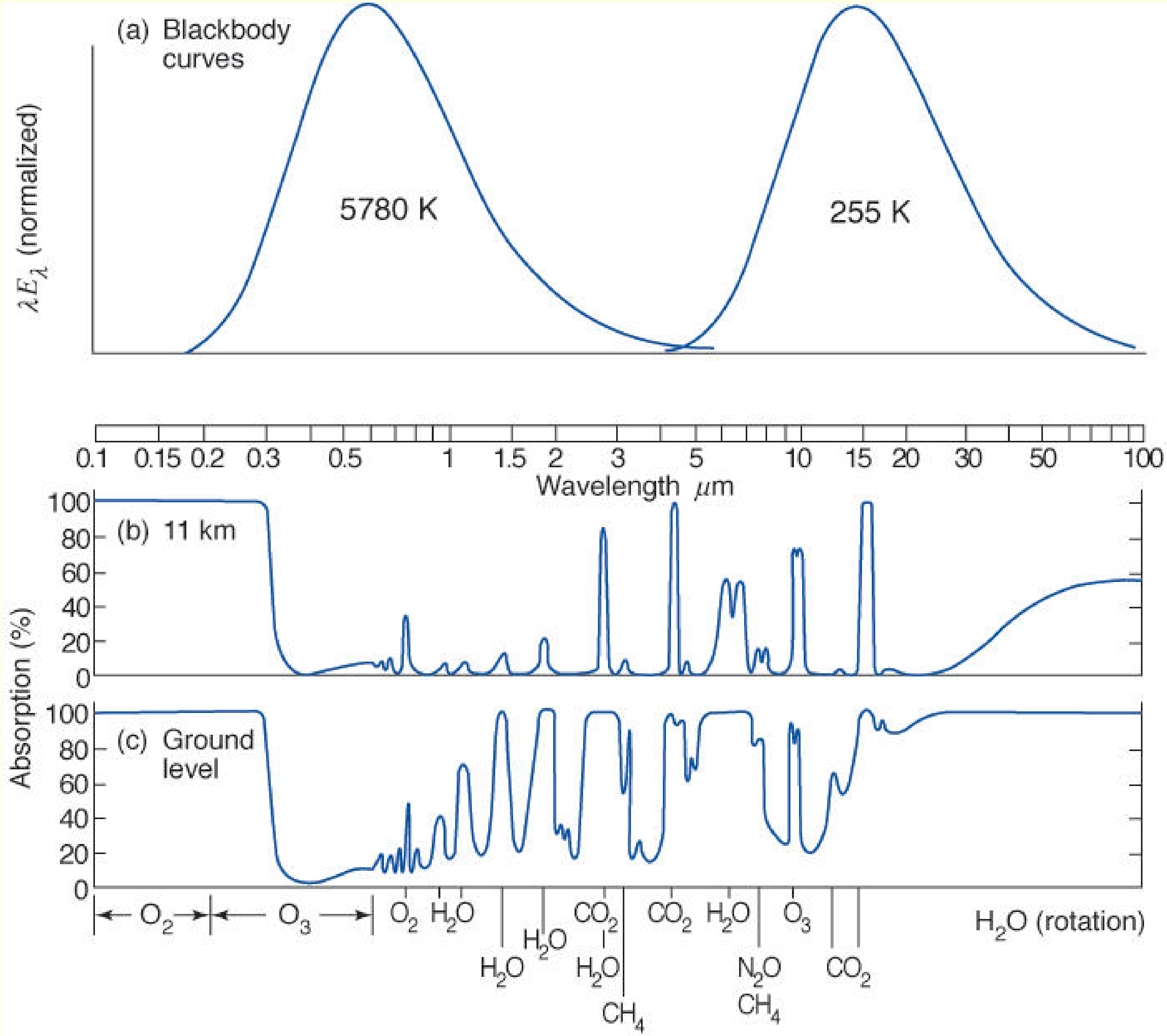
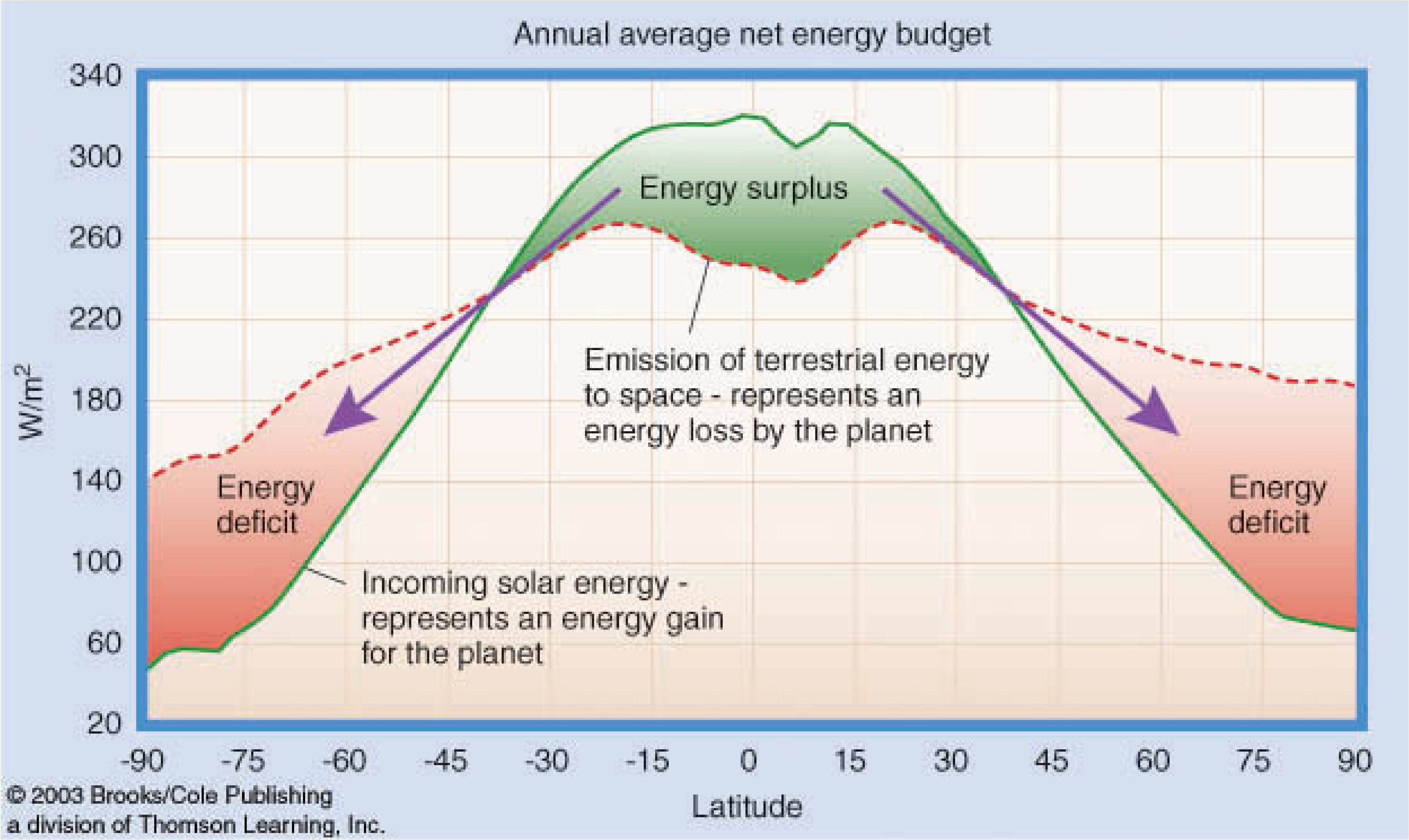
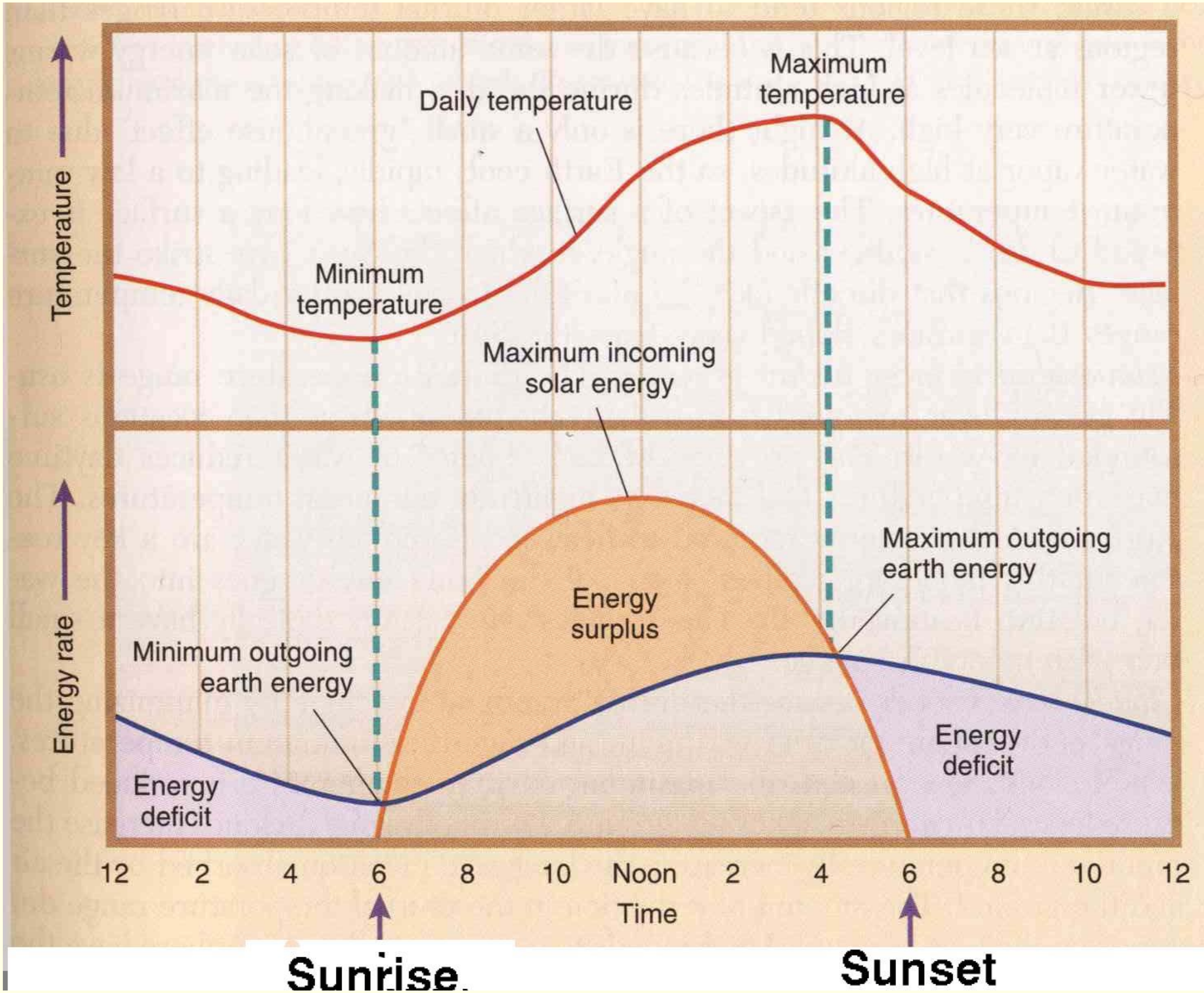
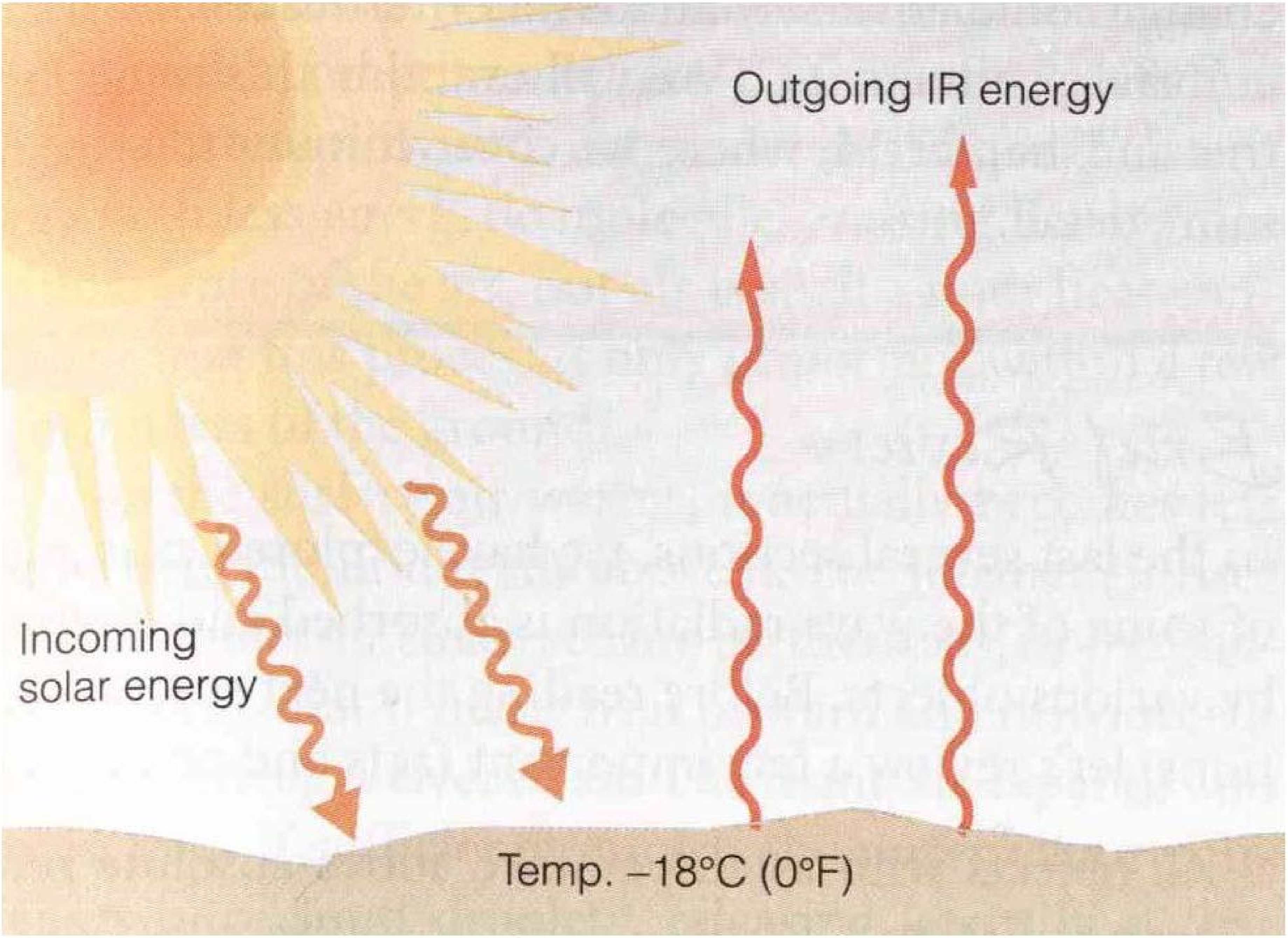


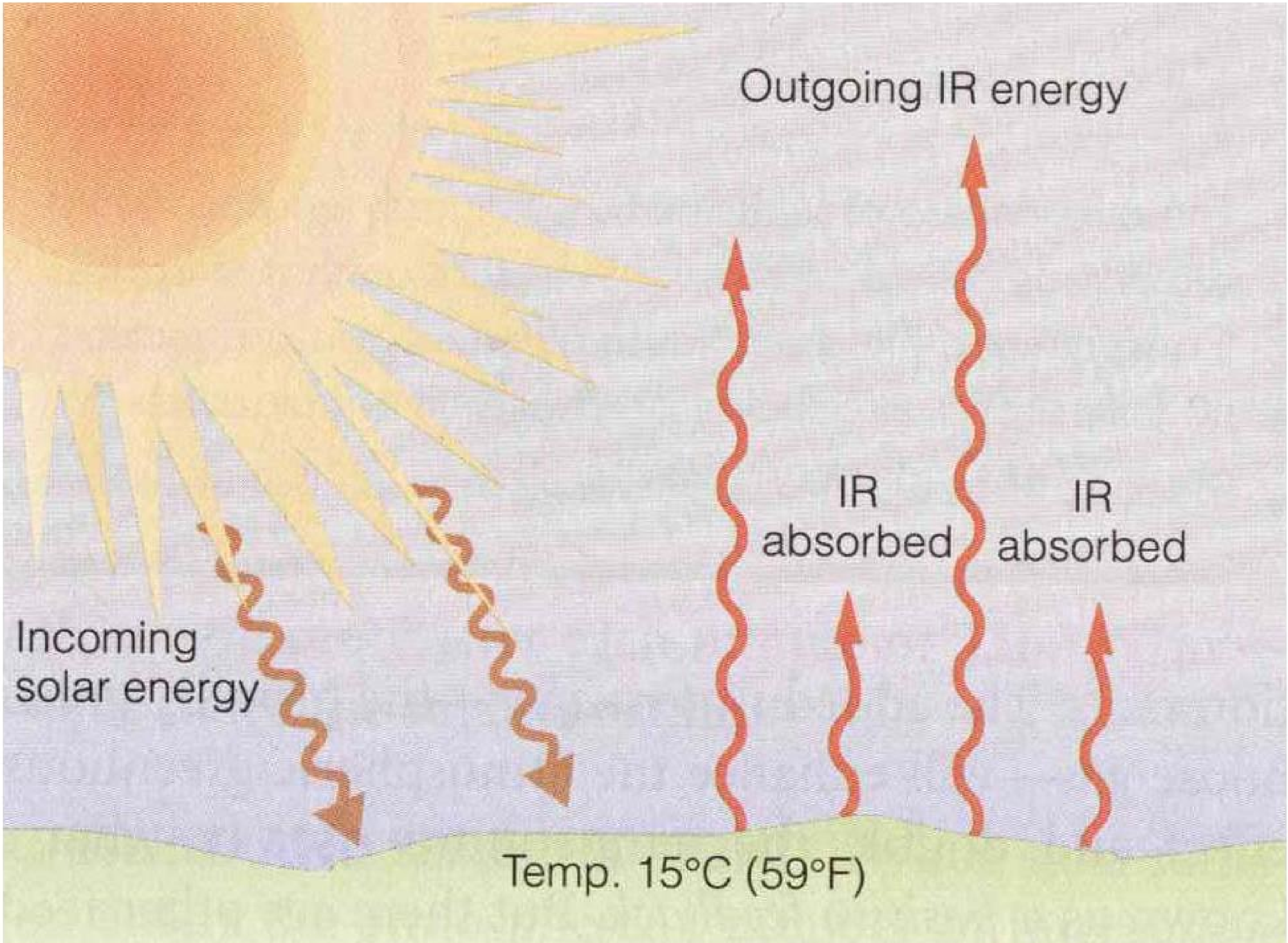
Absorbtion of Solar and Terrestrial Radiation.



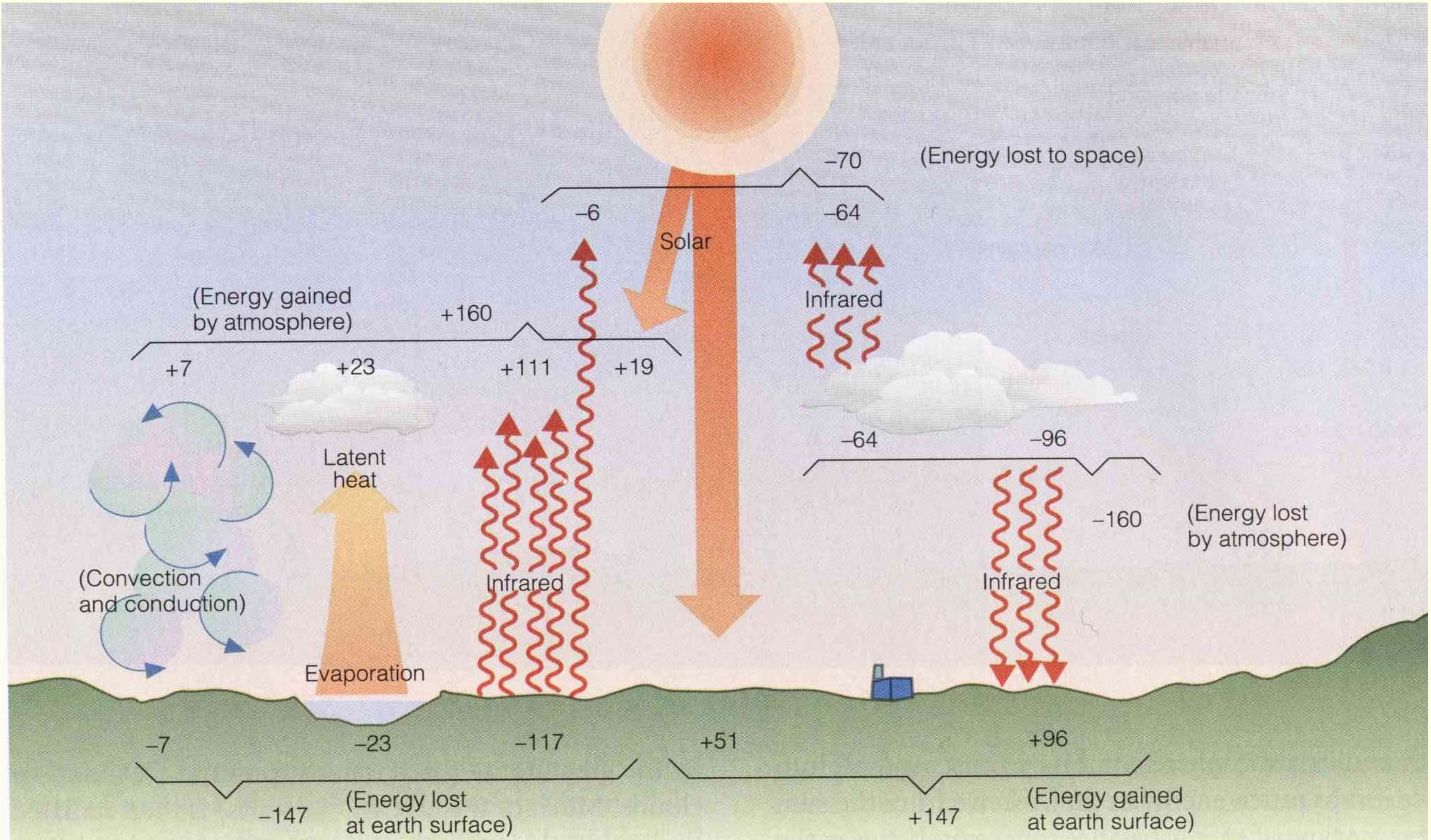
Energy budget as a function of latitude


Maximum
temperature
Daily temperature
Temperature
Minimum
temperature
Maximum incoming
solar energy
Maximum outgoing
earth energy
Energy
surplus
Minimum outgoing
earth energy
Energy rate
Energy
deficit
Energy
deficit
12
2
4
6
8
10
Noon
2
4
6
8
10
12
Time
Sunrise
Sunset


Outgoing IR energy
Incoming
solar energy
Temp. –18°C (0°F)



Outgoing IR energy
IR
absorbed
IR
absorbed
Incoming
solar energy
Temp. 15°C (59°F)



Energy budget of the atmosphere

End of Introduction.