Goals for today:

19 Sept., 2011

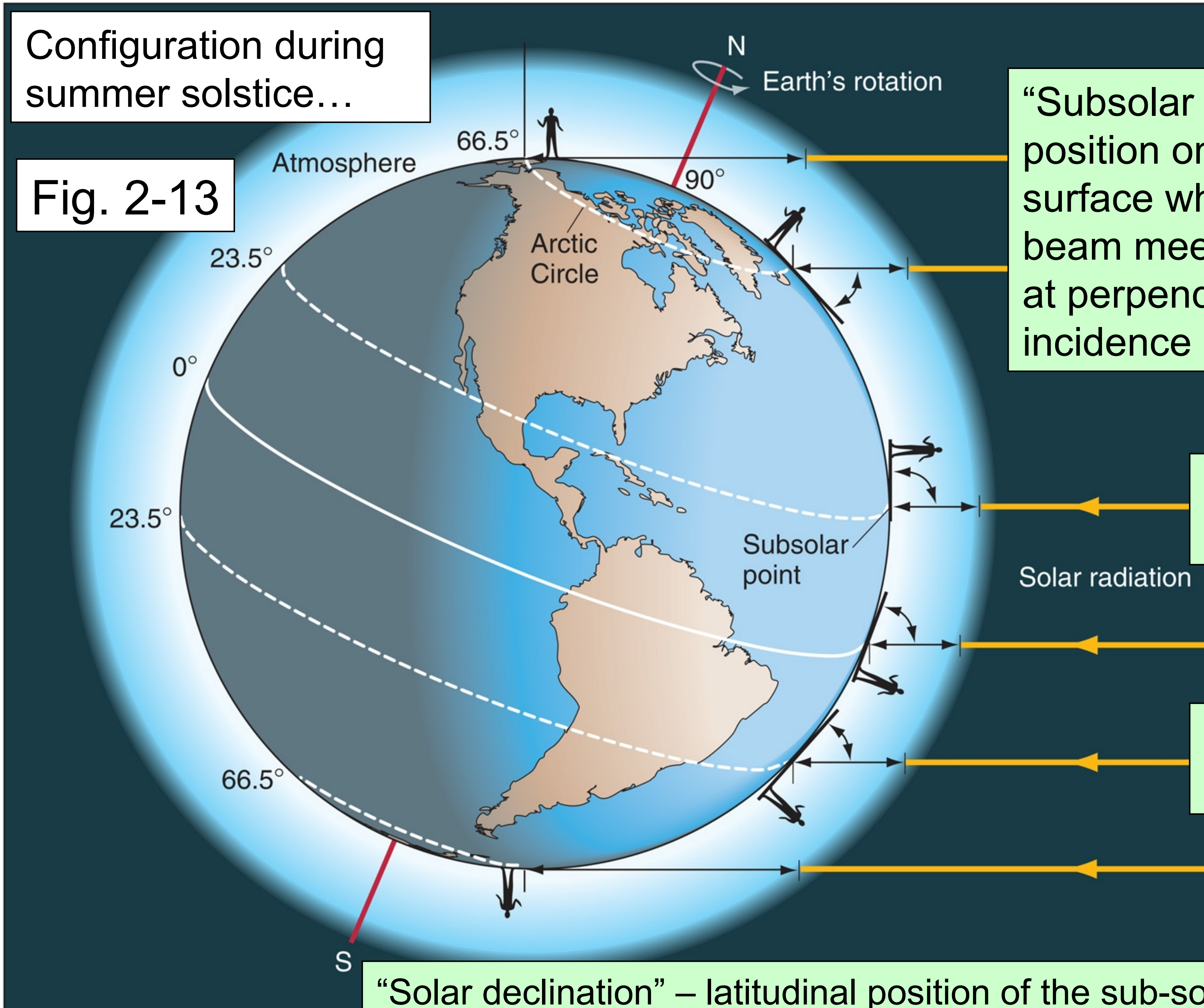
Finish Ch 2 “Solar Radiation & the Seasons”
Start Ch 3 “Energy Balance & Temperature”

Ch 3 will take us through:

- atmospheric influences on insolation & the fate of solar radiation
- interaction of terrestrial radiation with atmospheric gases
- global climatology of longwave and net (allwave) radiation
- convective energy transport and the surface energy balance in relation to the near-ground temperature profile

Configuration during summer solstice…

Fig. 2-13



"Subsolar point" – position on earth's surface where solar beam meets surface at perpendicular incidence

Tropic of Cancer

Tropic of Capricorn

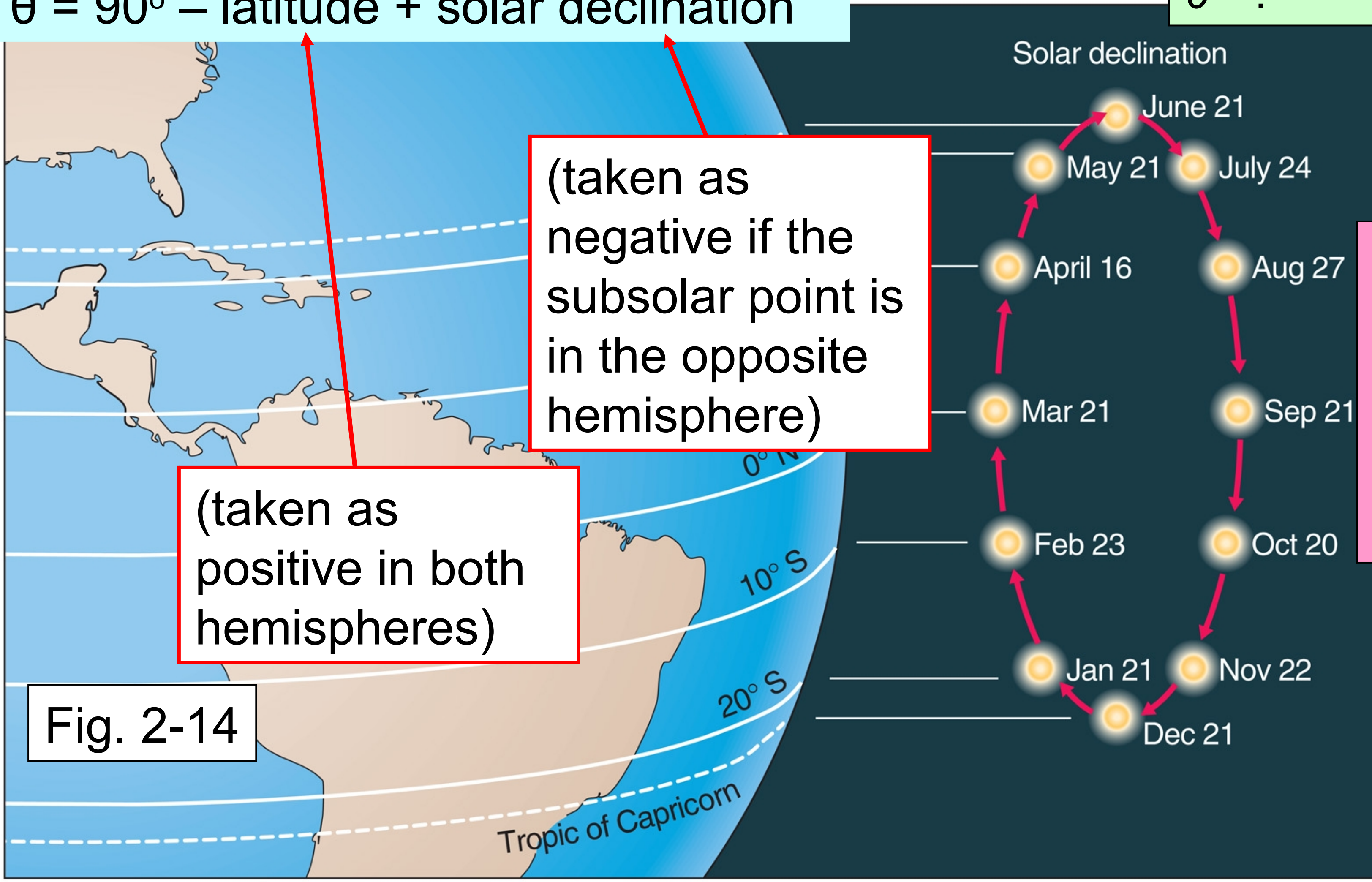
"Solar declination" – latitudinal position of the sub-solar point. It depends only on time of year

Noontime solar elevation angle (p50):

θ = 90° – latitude + solar declination

Edmonton, Jun 21:

θ =?



(taken as negative if the subsolar point is in the opposite hemisphere)

(taken as positive in both hemispheres)

annual migration of the sub-solar point

Fig. 2-14

Sydney, Australia (34°S),
Jun 21: θ =90 – 34 + (-23.5) = 32.5°
Dec 21: θ =90 – 34 + (23.5) = 79.5°

Edmonton, Dec 21:

θ =?

Noontime solar elevation angle (p50):

θ = 90° – latitude + solar declination

Edmonton, Jun 21:

$\theta = 90 - 53.5 + 23.5 = 60^{\circ}$

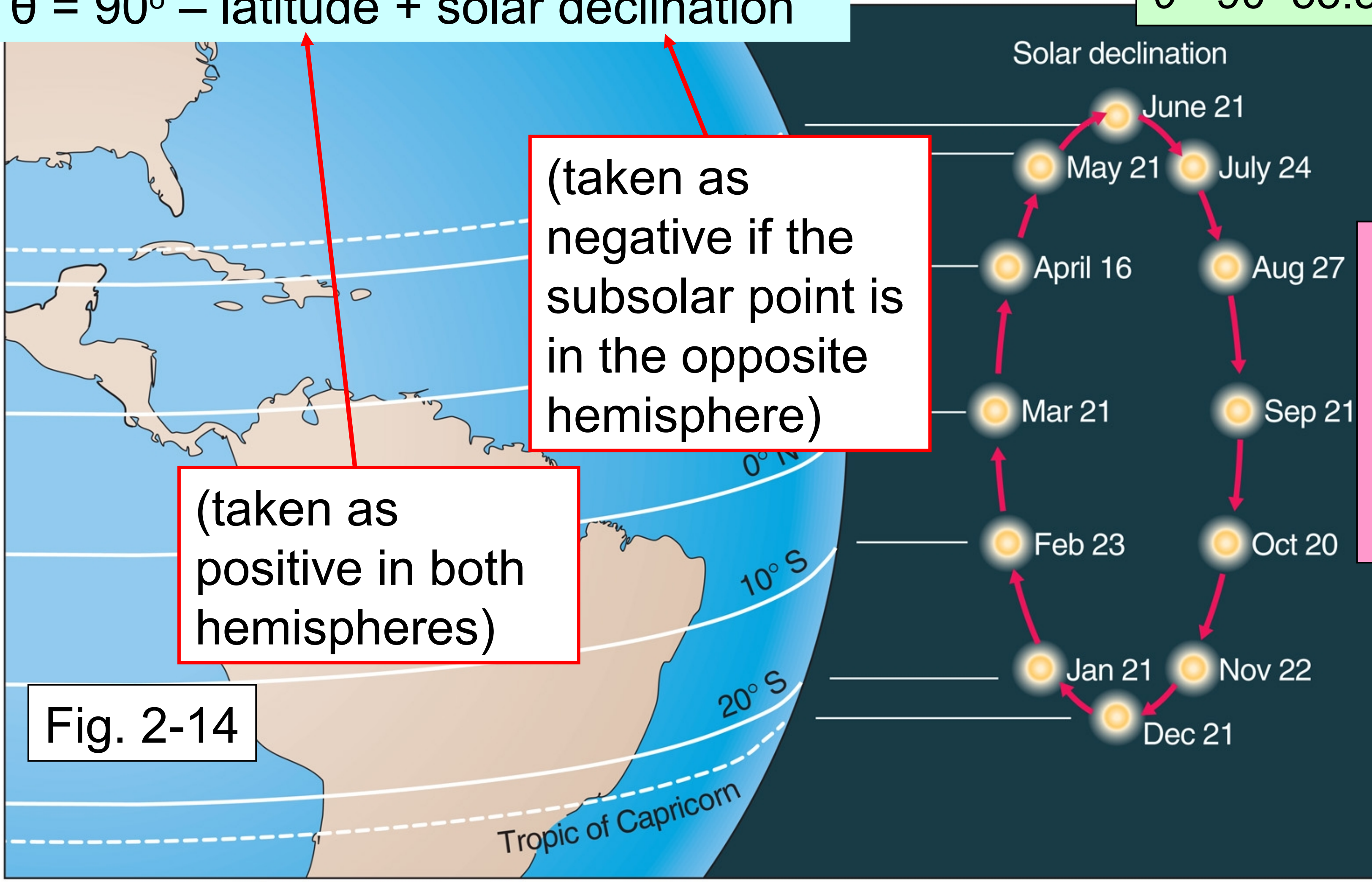


Fig. 2-14

(taken as positive in both hemispheres)

(taken as negative if the subsolar point is in the opposite hemisphere)

annual migration of the sub-solar point

Sydney, Australia (34°S),

Jun 21: $\theta = 90 - 34 + (-23.5) = 32.5^{\circ}$

Dec 21: $\theta = 90 - 34 + (23.5) = 79.5^{\circ}$

Edmonton, Dec 21:

$\theta = 90 - 53.5 + (-23.5) = 13^{\circ}$

Beam spreading: intensity of the incident beam proportional to sin(θ), i.e. to the "sine" of the solar elevation angle

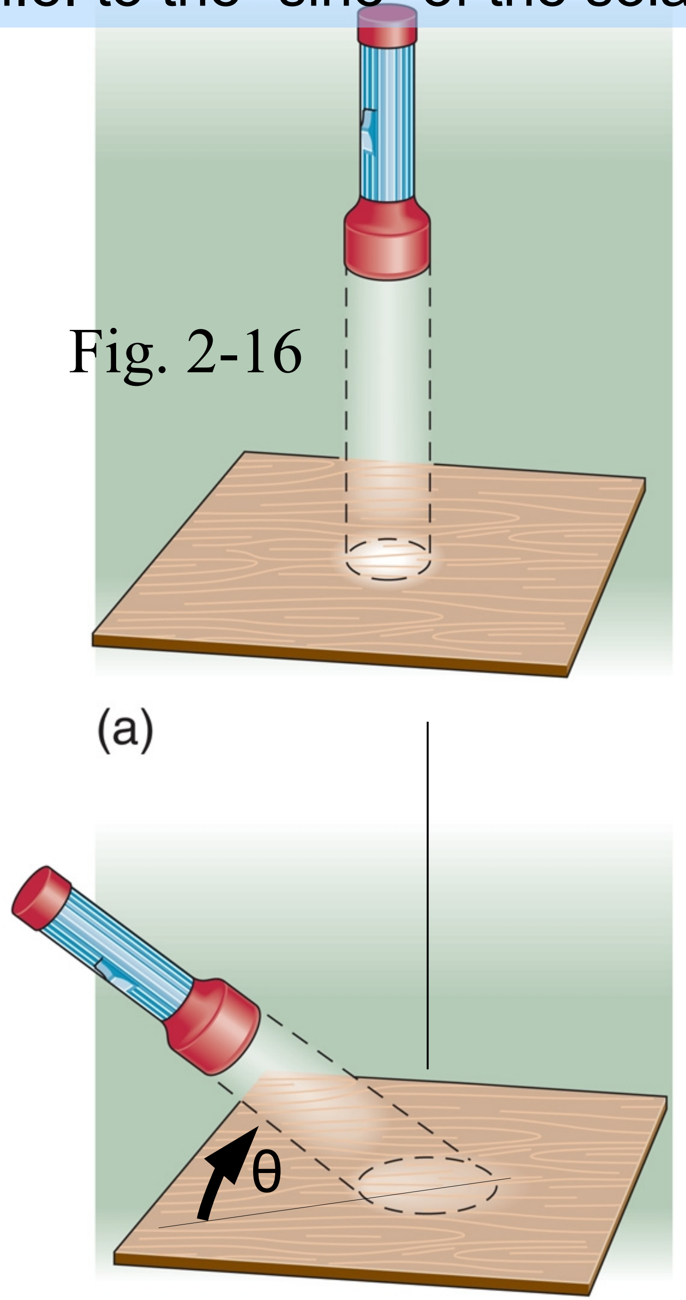
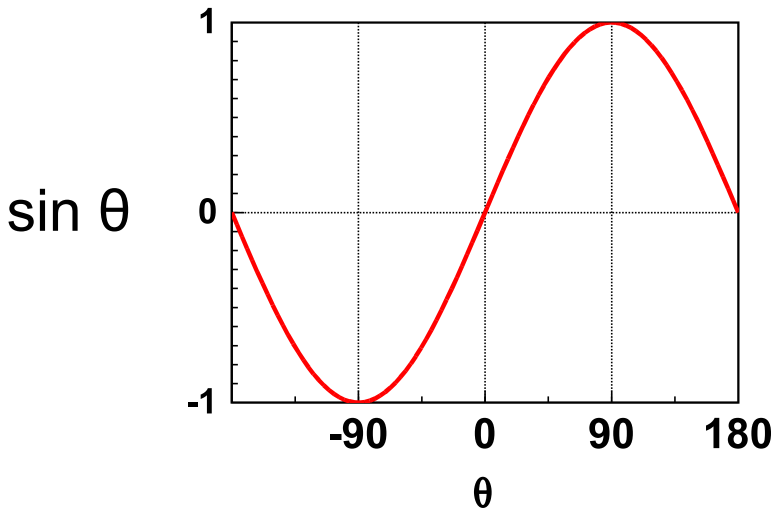


Fig. 2-16

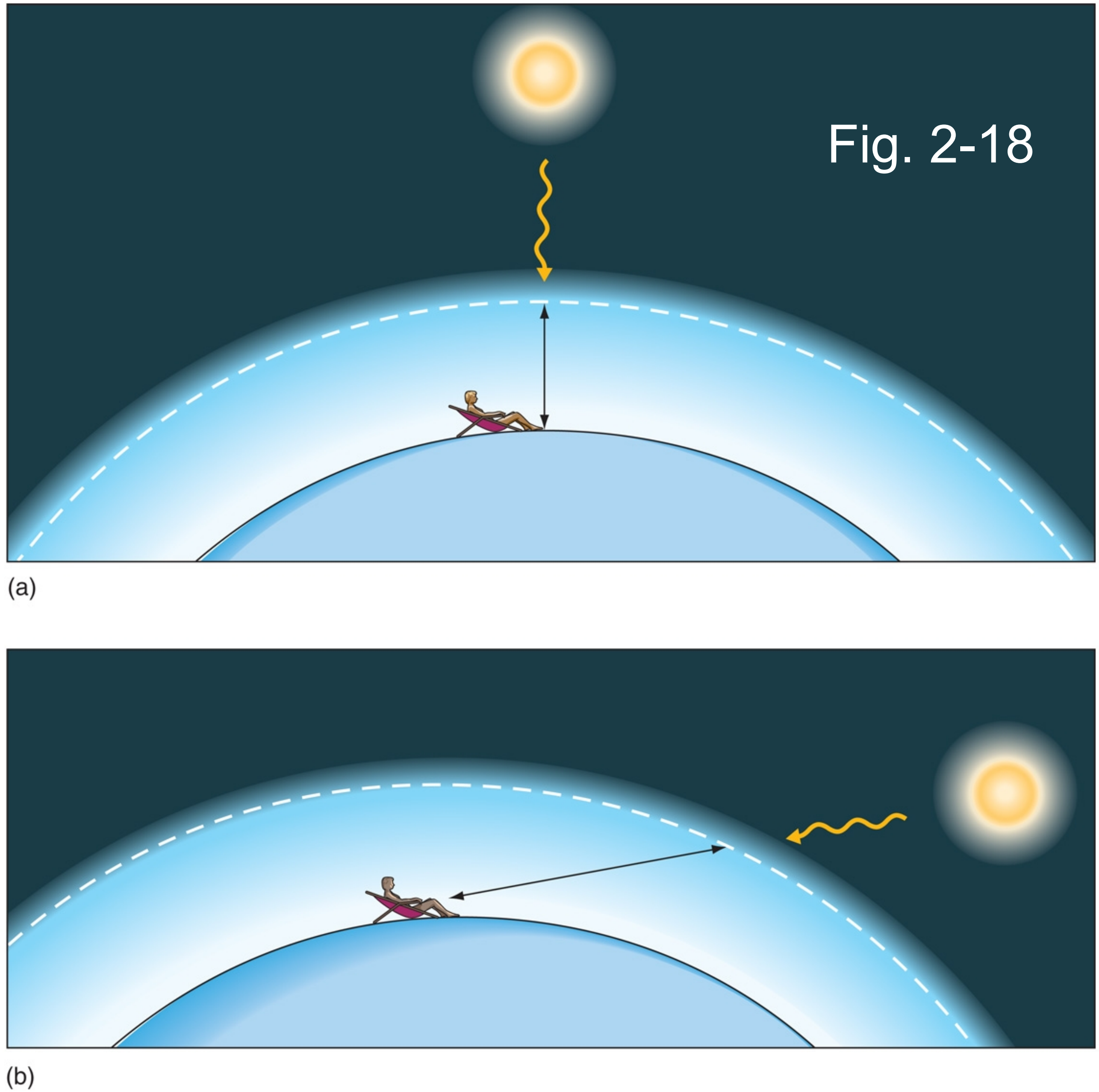


If solar elevation θ=90°, sin(90)=1, so ignoring absorption/scattering of the solar beam, intensity at surface is 1367 W m^{-2}

If solar elevation θ=30°, sin (30)=1/2, so ignoring absorption/scattering of the solar beam, intensity at surface is 684 W m^{-2}… i.e. oblique incidence spreads the incident beam energy over a greater intersecting area, reducing intensity

Beam depletion…

- the longer the path through the atmosphere, the greater the proportion of energy absorbed and scattered out of the solar beam



- absorption and scattering are non-uniform in wavelength (covered Ch 3)

TABLE 2–2 Variations in Solar Angle and Daylength

	SOLAR ANGLE AT NOON	LENGTH OF DAY	TOTAL RADIATION FOR DAY (Megajoules/m^2)
December 21			
Winnipeg	16.5°	7 hr, 50 min	7.44
Austin	36.5°	10 hr, 04 min	12.18
June 21			
Winnipeg	63.5°	16 hr, 10 min	37.15
Austin	83.5°	13 hr, 56 min	35.97

- Sun emits immensely more energy per unit surface area per unit time than does earth – understandable from Stefan-Boltzmann Law in view of sun's temperature (sensitive to fourth power of temp.)

- And the bulk of the solar radiation lies at much shorter wavelengths than does the energy in terrestrial radiation (Wien's law)

Ch 2 dealt with sun-earth geometry in relation to solar radiation: now, we cover interaction of radiation with atmosphere… have to consider absorption and scattering by gases & particulates

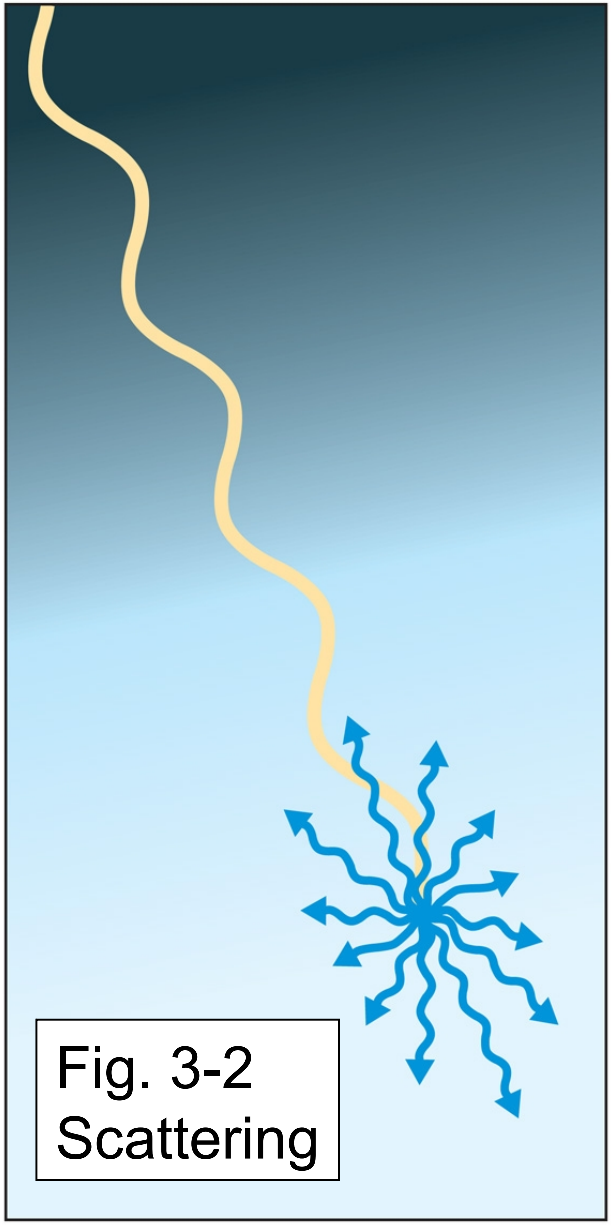
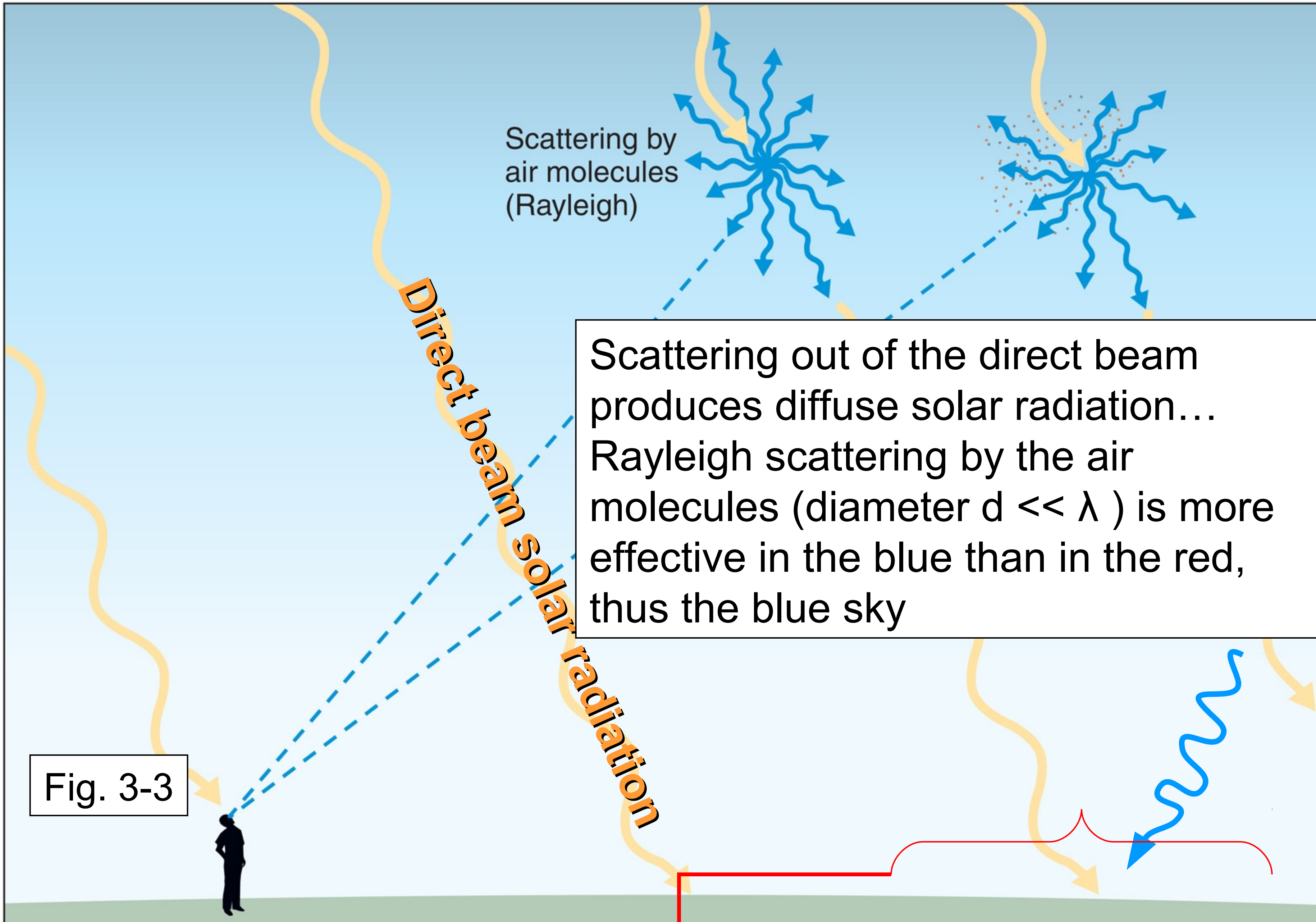


Fig. 3-2 Scattering

- absorption implies energy loss from the beam and direct heating of the air
  - almost 100% absorption of u.v. by O_3
  - "minimal" absorption of vis. by clear air
  - greater fraction of i.r. is absorbed than of vis.
  - NIR (0.7 – 4 μm) strongly absorbed by water vapour

- scattering (same as "diffuse reflection") does not heat the air



Scattering out of the direct beam produces diffuse solar radiation… Rayleigh scattering by the air molecules (diameter $d << \lambda$) is more effective in the blue than in the red, thus the blue sky

Incident solar intensity at gnd $K\downarrow$ [W m^{-2}] is sum of beam + diffuse

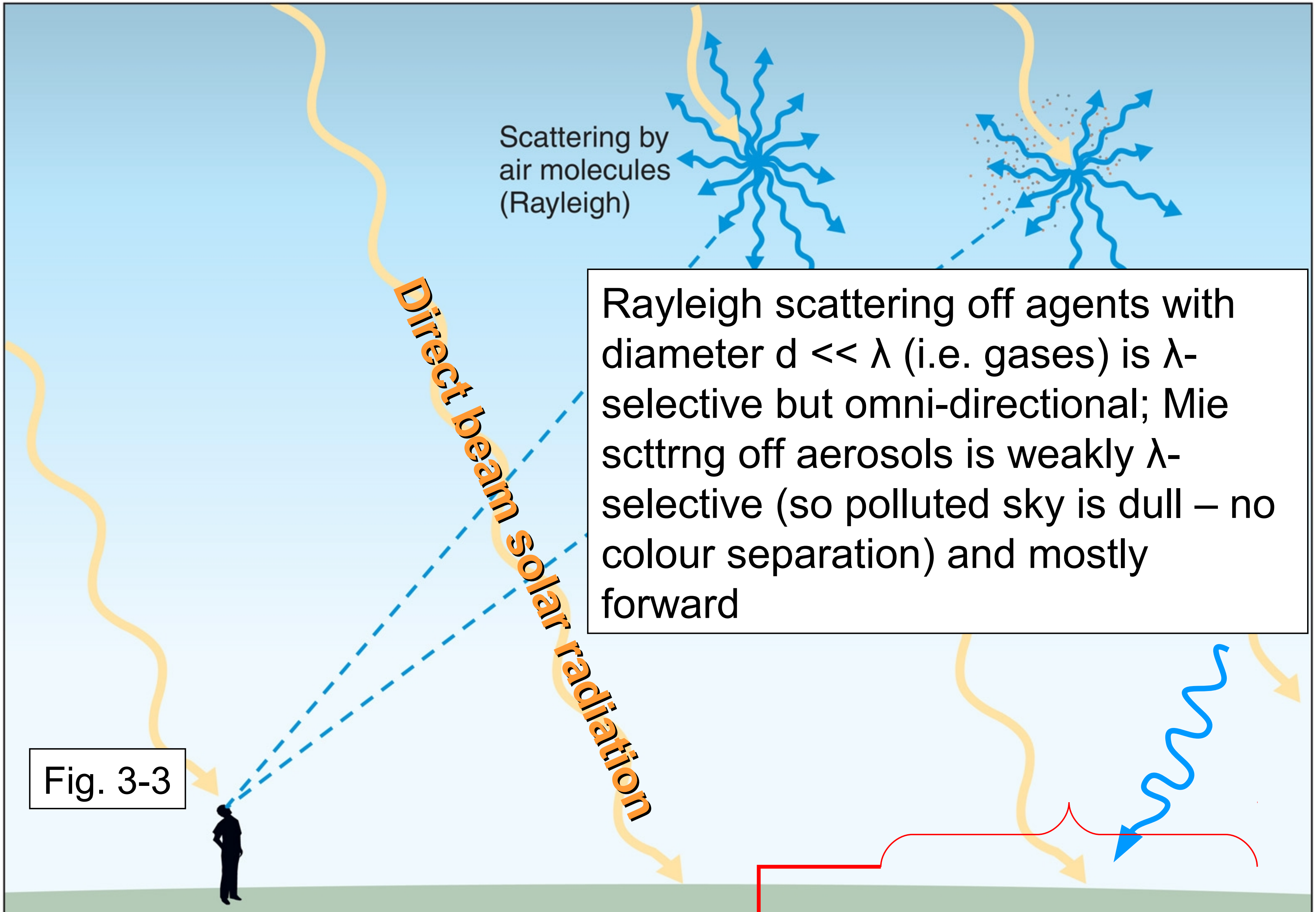


Fig. 3-3

Rayleigh scattering off agents with diameter d << λ (i.e. gases) is λ-selective but omni-directional; Mie scttrng off aerosols is weakly λ-selective (so polluted sky is dull – no colour separation) and mostly forward

Incident solar intensity at gnd K↓ [W m^{-2}] is sum of beam + diffuse

Global-annual (climatological) disposition of solar radiation

- sfc takes 45%
- atmos takes 25%

70%

- clouds reflect 19%
- atmos reflects 6%
- gnd reflects 5%

30% — planetary albedo

(But a clear, dry atmosphere may deliver ~ 80% of solar energy to the surface)

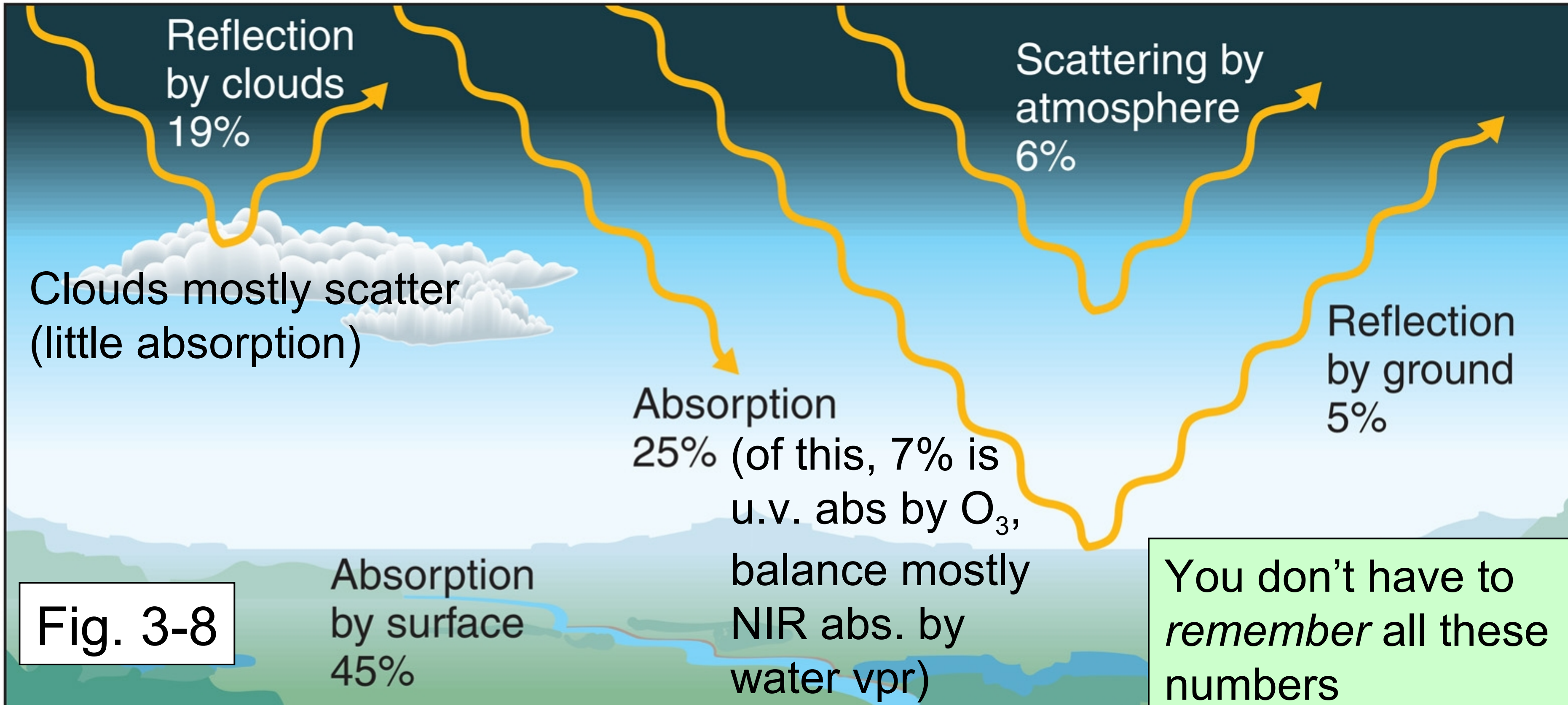


Fig. 3-8

You don’t have to *remember* all these numbers

Shortwave radiation is heating the ground… but we're not getting hot feet… how come?... Because the surface is losing energy in other forms…

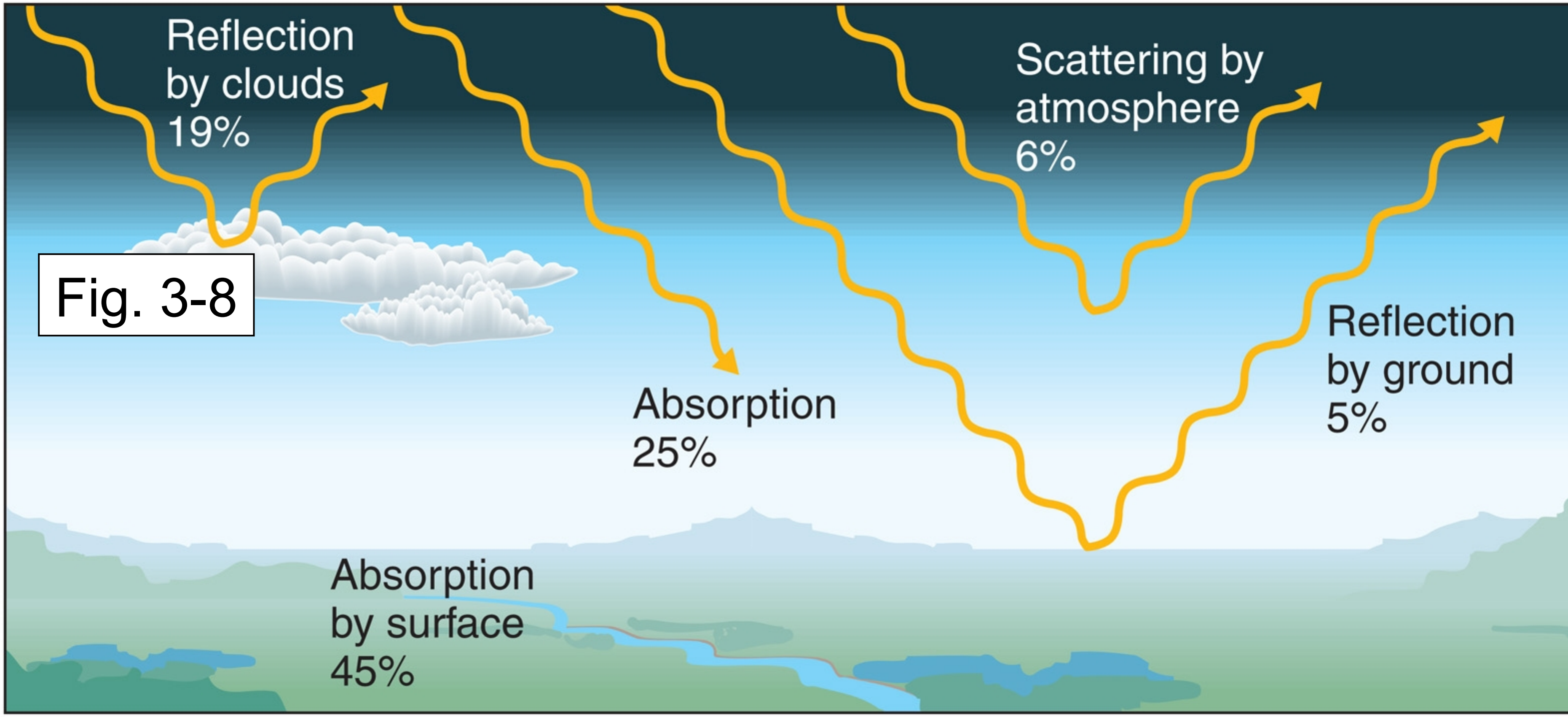


Fig. 3-8

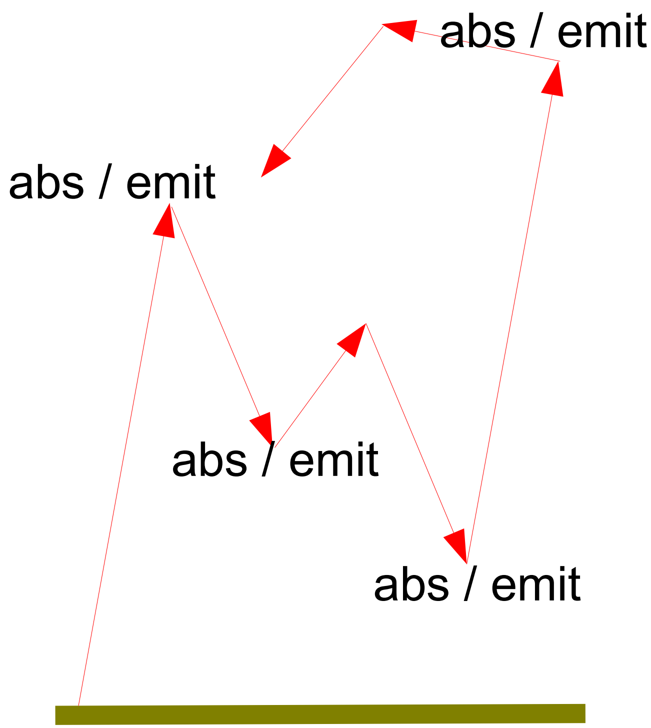
Longwave Radiation

• longwave rad'n emitted by sfc largely absorbed by atmos, which re-radiates (at same wavelengths) isotropically (i.e. in all directions equally)

• thus there is an "infinite cycle of exchange" (atmos-atmos, atmos-grnd,…)

• however the atmos gases are relatively transparent in the 8-12 μm "window"

• which however is "closed" by clouds, which absorb virtually all longwave and re-emit as a grey body

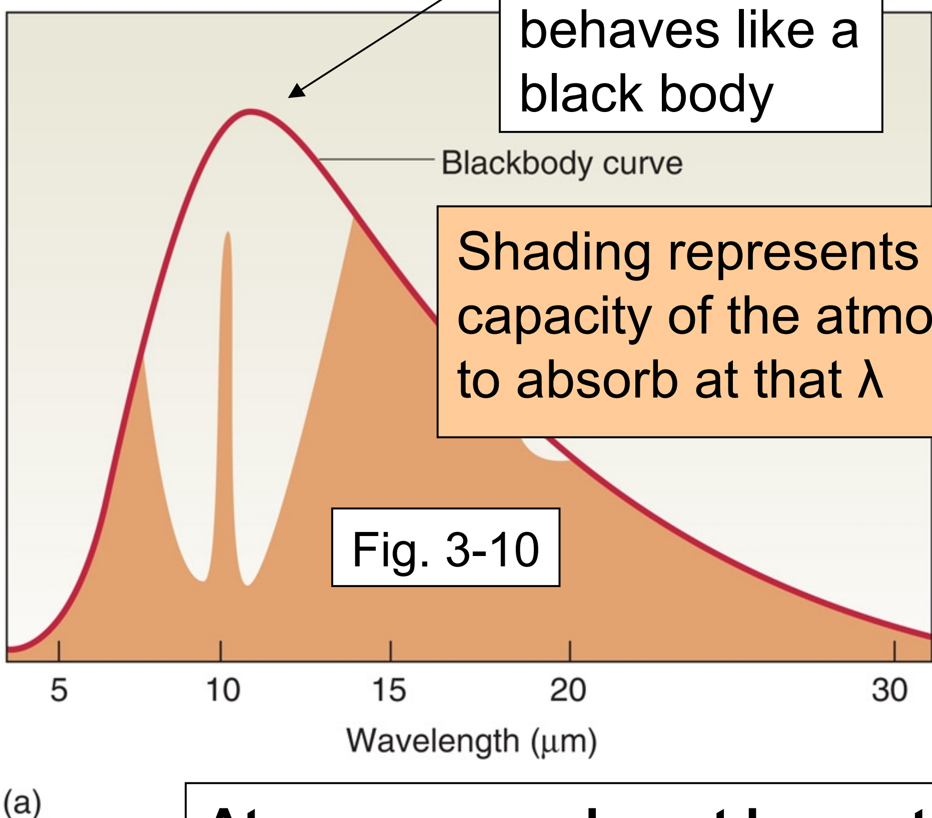


(gases emit "isotropically", ie. equal probability in all directions, so ½ up, ½ down)

Longwave Radiation

- longwave rad'n emitted by sfc largely absorbed by atmos, which re-radiates (at same wavelengths) iosotropically

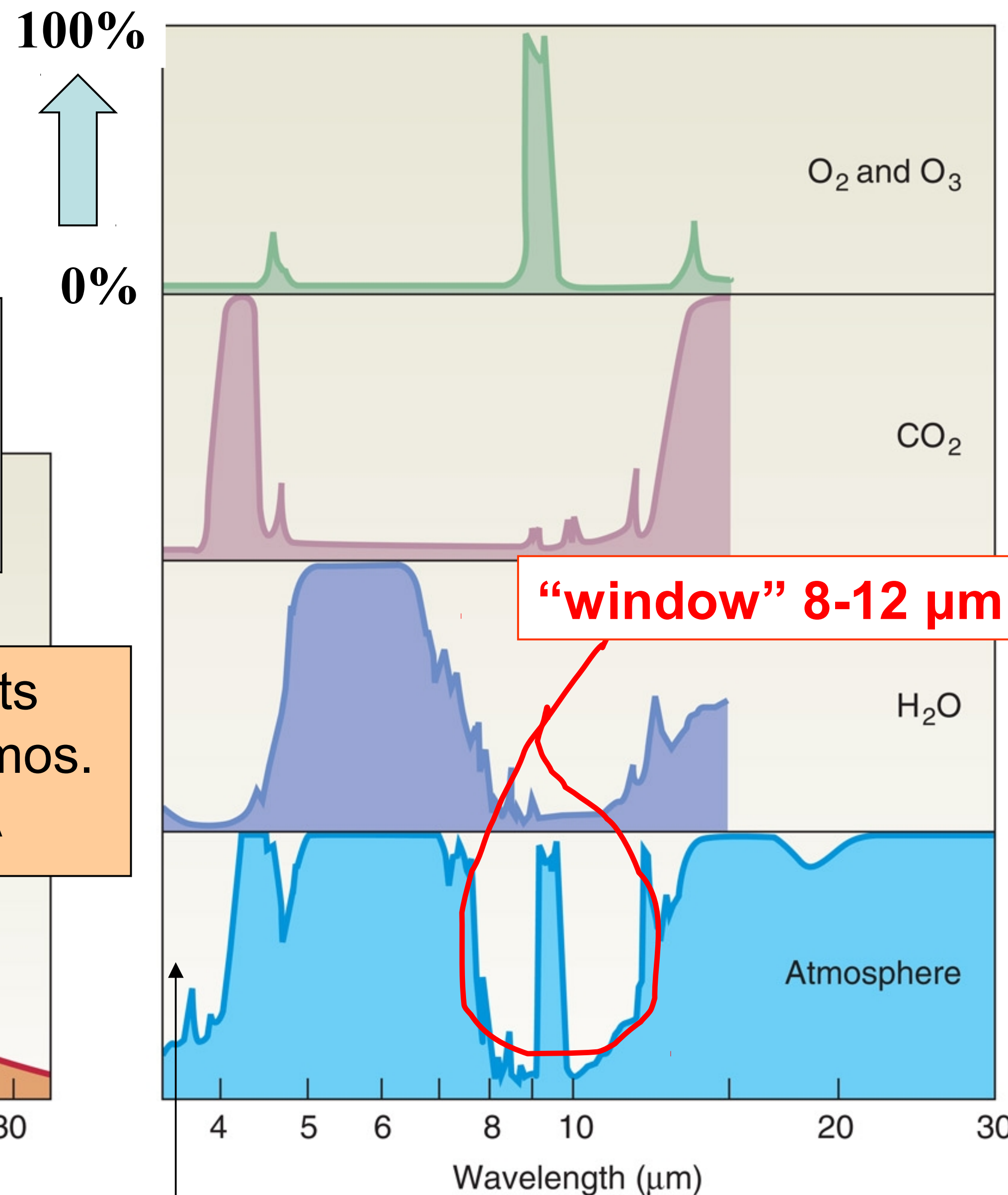
Earth's surface behaves like a black body



Shading represents capacity of the atmos. to absorb at that λ

Fig. 3-10

Spectral absorptivity of atmos. gases



Atmos. gases do <u>not</u> have strong absorption bands in the visible

Global-annual (climatological) disposition of longwave radiation