CH EN 3453 – Heat Transfer

Radiation: Solar and Environmental Radiation

Sections 12.7 - 12.10

News…

- Homework #10 due Today
- Homework #11 due Monday after Thanksgiving
  - No help session
- Final report draft report due today
  - Email to report@chen3453.com in Microsoft Word format
  - Name the file "Lastname_Firstname.docx"
    - Can also be in .doc format
  - For the subject, write
    "Lastname Firstname - Heat Transfer Draft Report"
  - Send by 8:00 PM today
- Final exam Wednesday, December 17 at 8 am
  - approx. 60% review of conduction and convection
  - approx. 40% radiation
- Part-time job opportunity – International Energy Agency
  - More administrative than scientific
  - Ca. 5 hours per week
  - Let Kevin Know

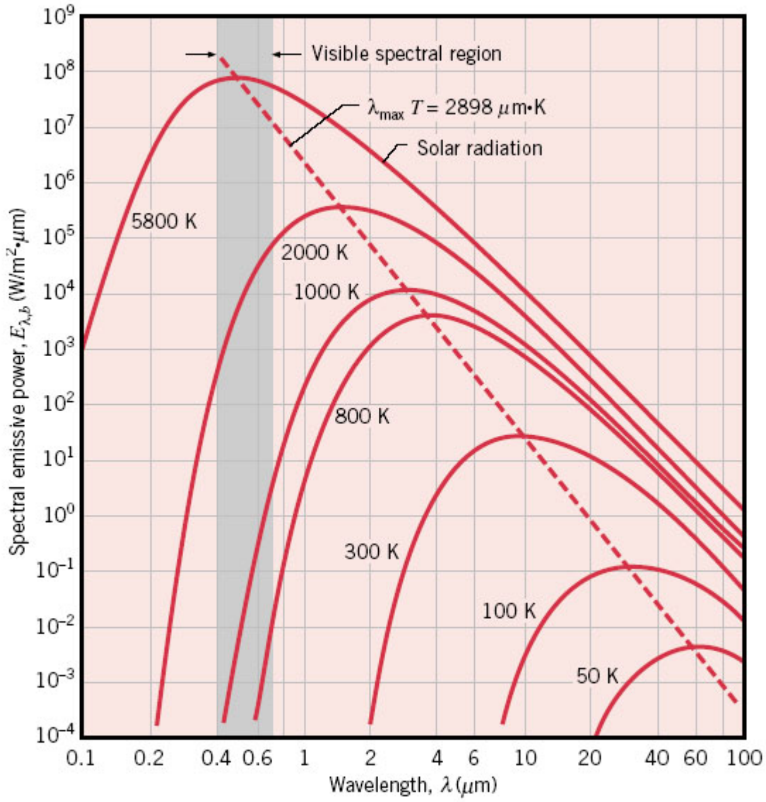
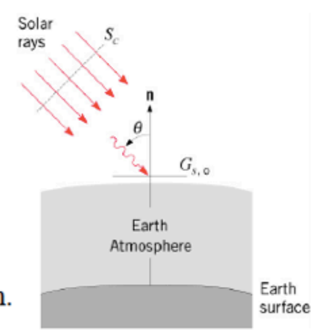


FIGURE 12.12 Spectral blackbody emissive power.

Solar Radiation

- The sun is a nearly spherical source of radiation whose outer diameter is 1.39×10^9 m and whose emissive power approximates that of a blackbody at 5800 K.
- The distance from the center of the sun to the center of the earth varies with time of year from a minimum of 1.471×10^{11} m to a maximum of 1.521×10^{11} m, with an annual average of 1.496×10^{11} m.
- Due to the large sun-to-earth distance, the sun's rays are nearly parallel at the outer edge of the earth's atmosphere, and the corresponding radiation flux is

$$q_S'' = f \times S_c$$



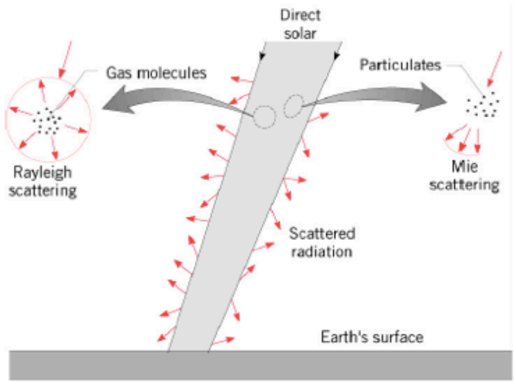
$S_c \rightarrow$ the solar constant or heat flux $\left(1353\ \text{W/m}^2\right)$ when the earth is at its mean distance from the sun.

$f \rightarrow$ correction factor accounting for eccentricity of the earth's orbit $(0.97 < f < 1.03)$

- Extraterrestrial irradiation of a surface whose normal is at a zenith angle θ relative to the sun's rays is

$$G_{S,o} = f \times S_c \times \cos\theta$$

- Interaction of solar radiation with earth's atmosphere:
  - Absorption by aerosols over the entire spectrum.
  - Absorption by gases (CO_2, H_2O (v), O_3) in discrete wavelength bands.
  - Scattering by gas molecules and aerosols.



Terrestrial Radiation

- Emission by Earth's Surface:

$$E = \varepsilon\sigma T^4$$

  - Emissivities are typically large. For example, from Table A.11:

Sand/Soil:	$\varepsilon > 0.90$
Water/Ice:	$\varepsilon > 0.95$
Vegetation:	$\varepsilon > 0.92$
Snow:	$\varepsilon > 0.82$
Concrete/Asphalt:	$\varepsilon > 0.85$

  - Emission is typically from surfaces with temperatures in the range of $250 < T < 320$ K and hence concentrated in the spectral region $4 < \lambda < 40\,\mu$m, with peak emission at $\lambda \approx 10\,\mu$m.

- Atmospheric Emission:
  - Largely due to emission from CO_2 and H_2O (v) and concentrated in the spectral regions $5 < \lambda < 8\ \mu$m and $\lambda > 13\,\mu$m.

- Although far from exhibiting the spectral characteristics of blackbody emission, earth irradiation due to atmospheric emission is often approximated by a blackbody emissive power of the form

$$G_{atm} = \sigma T_{sky}^4$$

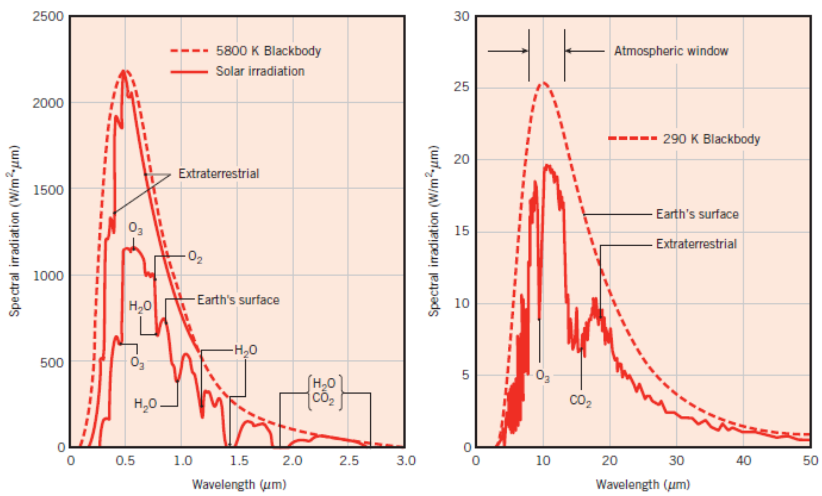
$T_{sky} \rightarrow$ the effective sky temperature

$230 \text{ K} < T_{sky} < 285 \text{ K}$

↳ Cold, clear sky ↳ Warm, overcast sky

- Can water in the natural environment freeze if the ambient air temperature exceeds 273 K? If so, what environmental conditions (wind and sky) favor ice formation?

Solar Radiation



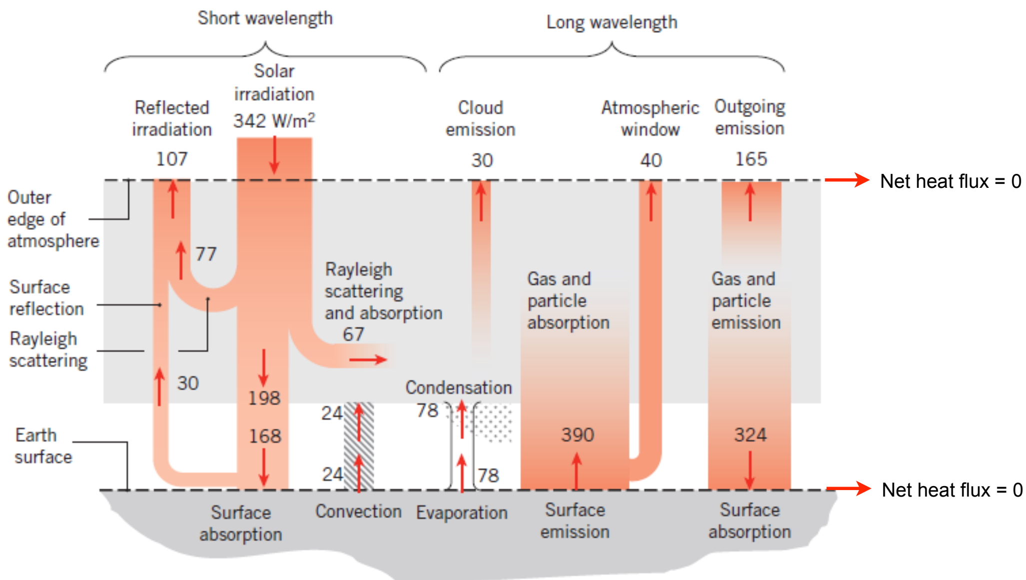
Solar radiation (short wavelengths)

- Extraterrestrial solar irradiation is modified spectrally by absorption and scattering by atmospheric components.
- Irradiation at Earth's surface is less than at the top of the atmosphere.

Earth emission (long wavelengths)

- Emission from Earth's surface is similar to that of a blackbody at 290 K.
- Emission is modified spectrally by absorption and scattering by atmospheric components.
- Emission at the top of the atmosphere is less than at Earth's surface.

Solar Radiation



- An equilibrium energy balance. Heat fluxes are both surface- and time-averaged.
- If the chemical constituents of the atmosphere change, atmospheric absorption and scattering will change, potentially resulting in net heating or cooling of the atmosphere.
- If the chemical constituents of the atmosphere change, radiation fluxes will change, and surface convection and condensation heat fluxes may be affected. Weather patterns may change.