6.6 Radiation Balance of the Atmosphere
(p. 114)

Net vertical flux of radiation $F_{net} = F^{\downarrow} - F^{\uparrow}$

The vertical (radiative heat flux) divergence $\frac{\partial F_{net}}{\partial z} \cdot \Delta z = \Delta z \rho c_p \left(\frac{\partial T}{\partial t}\right)_{radiation}$

will cause a change of temperature T over time t, e.g.

c_p specific heat J/kg/K
ρ density of air kg/m³

$$\left(\frac{\partial T}{\partial t}\right)_{radiation} = \frac{1}{\rho c_p} \frac{\partial F_{net}}{\partial z}$$

long-wave radiation ⟶ net cooling ~ 2.5 °C/day
short-wave radiation ⟶ net warming ~ 0.5 °C/day
2.0 °C/day deficit

steady state atmosphere thus requires energy transfer from the earth's surface from sensible and latent heat flux

NO CLOUDS	short waves	long wave radiation
day	large warming	medium
night	0	~~medium~~ cooling

clouds act as "thermal blankets" to longwave radiation (heat emitted from earth).

CLOUDS	short	long
day		medium warming
night	0	medium warming

ABSORBERS of radiation matter most

in 8-12 μm range, the atmosphere is almost transparent
→ atmospheric spectral window

6.7 Radiation Balance at Earth' Surface
(p. 116)

Net flux of radiation at surface results from a balance of solar and terrestrial fluxes

$$\overline{F}^{surface}_{radiation} = \overline{F}_{SW} + \overline{F}_{LW}$$

short wave radiation (mostly solar) — long wave radiation (mostly terrestrial)

$A_{surface} = \dfrac{F_{SW}\uparrow}{F_{SW}\downarrow}$ surface albedo

$$\underset{\text{total}}{F_{SW}} = \underset{\text{incoming}}{F_{SW}^{\downarrow}} - \underset{\text{outgoing}}{F_{SW}^{\uparrow}} = (1 - A_{surface})\, F_{SW}^{\downarrow} \quad \text{short wave radiation}$$

$$F_{LW} = F_{LW}^{\downarrow} - F_{LW}^{\uparrow} \quad \text{long wave radiation}$$

$F_{SW}^{\downarrow}$ = incoming solar short wave radiation = direct + diffuse — strongly affected by clouds

$F_{SW}^{\uparrow}$ outgoing solar short wave radiation $= A_{surface} \cdot F_{SW}^{\downarrow}$ — surface albedo reflected

[strong diurnal cycle, e.g., $F_{SW} = 0$ at night]

$F_{LW}^{\downarrow}$ comes from atmosphere and depends on
[little diurnal variations]
(1) vertical density stratification
(2) clouds
(3) vertical distribution of absorbers

$$F_{LW}^{\uparrow} = \varepsilon \sigma T^4$$

Stefan-Boltzmann Law (integral of Planck's law) for a grey body (emissivity ε)
[follows surface temperature which has diurnal cycle]

Put together gives

(6.39) $$F_{radiation}^{surface} = F_{SW}^{\downarrow}(1 - albedo) - \varepsilon\sigma T^4 + F_{LW}^{\downarrow}$$

This (net) flux heats or cools the surface

[Fig. 3.6 of Knauss, 1997]
heat flux, cycles

There thus are 4 types of energy flux at the earth's surface

(1) net radiation flux
(2) (direct) sensible heat flux $F_{SH}^{\uparrow}$
(3) (indirect) latent heat flux $F_{LH}^{\uparrow}$
(4) heat flux into the ground $F_g^{\downarrow}$
(5) melt/freeze snow, ice, water F_M

(6.40) Energy Budget : $$F_{radiation}^{surface} - F_{SH}^{\uparrow} - F_{LH}^{\uparrow} - F_g^{\downarrow} - F_M = 0$$

Next: Look closely at what happens at the ocean-atmosphere interface
→ ocean optics
ocean color

Liam Gumley Lectures
Nov. 26-29, 2002

1. Introduction + Radiation + Products
2. Terra Modis Images by Band
3. Scanner Charecteristics, Bowtie, Striping
4. Reprojection, True Color
5. Realtime level-1 processing (calibration, validation)
6. Cloud Masking
7. MODIS Precipitable Water Vapor

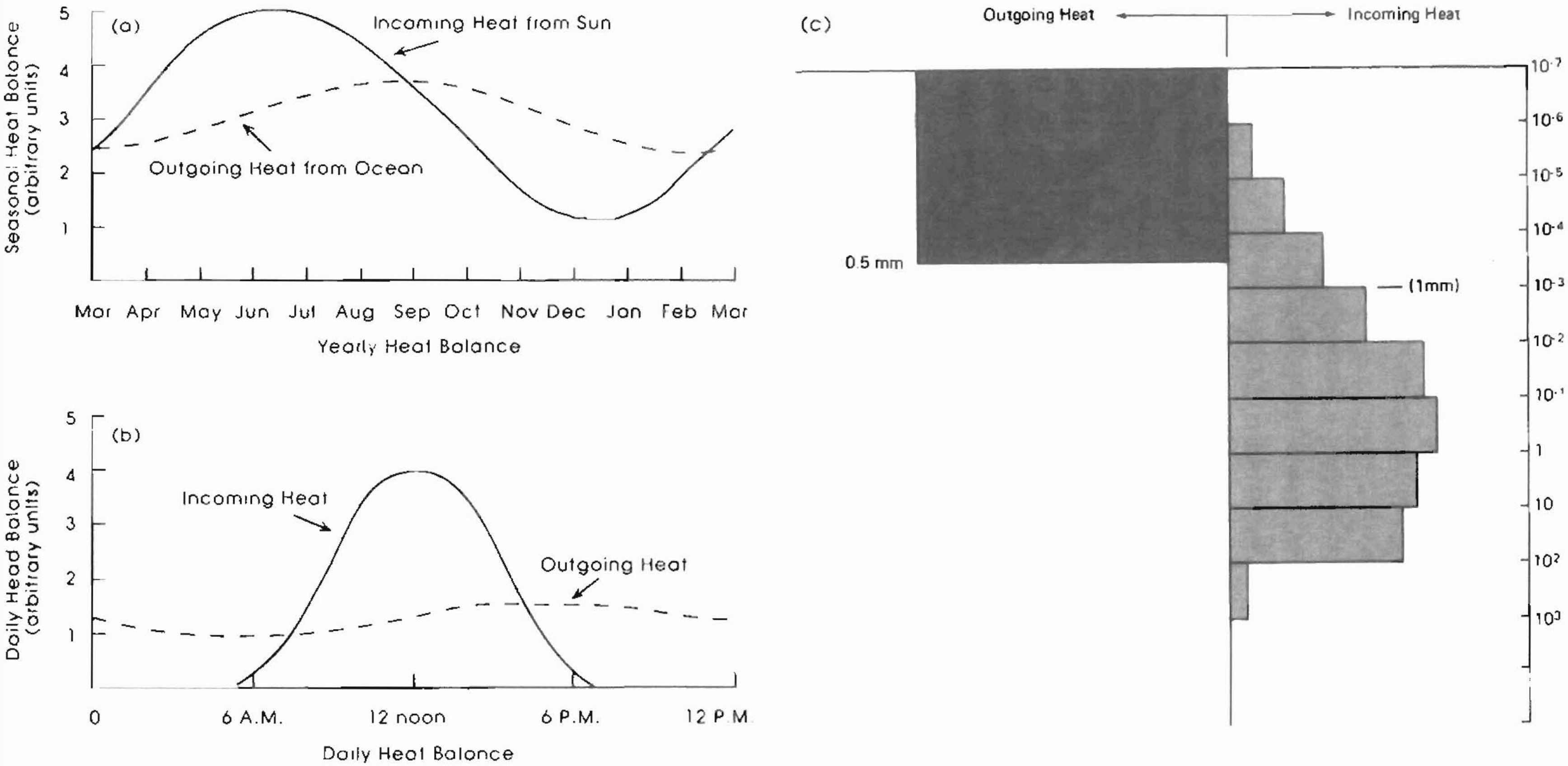

Figure 3.6 Schematic sketches of incoming heat energy from the sun and the heat loss from the ocean at a typical midlatitude site in the Northern Hemisphere. (a) There is a net gain of heat from March through August and a net loss during the rest of the year. (b) During any 24-h period, there is a relatively steady heat loss of heat from the ocean surface which is balanced by a heat gain from the sun during daylight hours. (c) Heat "sources" and "sinks" in the ocean surface layer. Note that the heat flux to the atmosphere is across the ocean/atmosphere boundary layer while the heat from the sun is absorbed in the upper 100 m. As a result there is a time-averaged net upward flux of heat in the top millimeter of the ocean.

from Knauss (1997) Introduction to Physical Oceanography