

Schematic energy balance of ideal surface

$$R_N = H_S + H_L + H_G$$

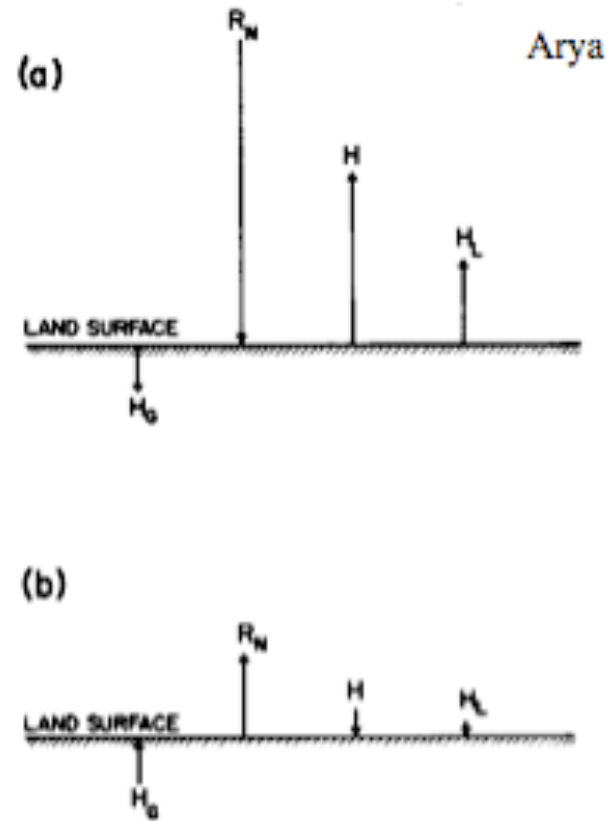


Fig. 2.1 Schematic representation of typical surface energy budgets during (a) daytime and (b) nighttime.

Energy balance: Dry desert lakebed

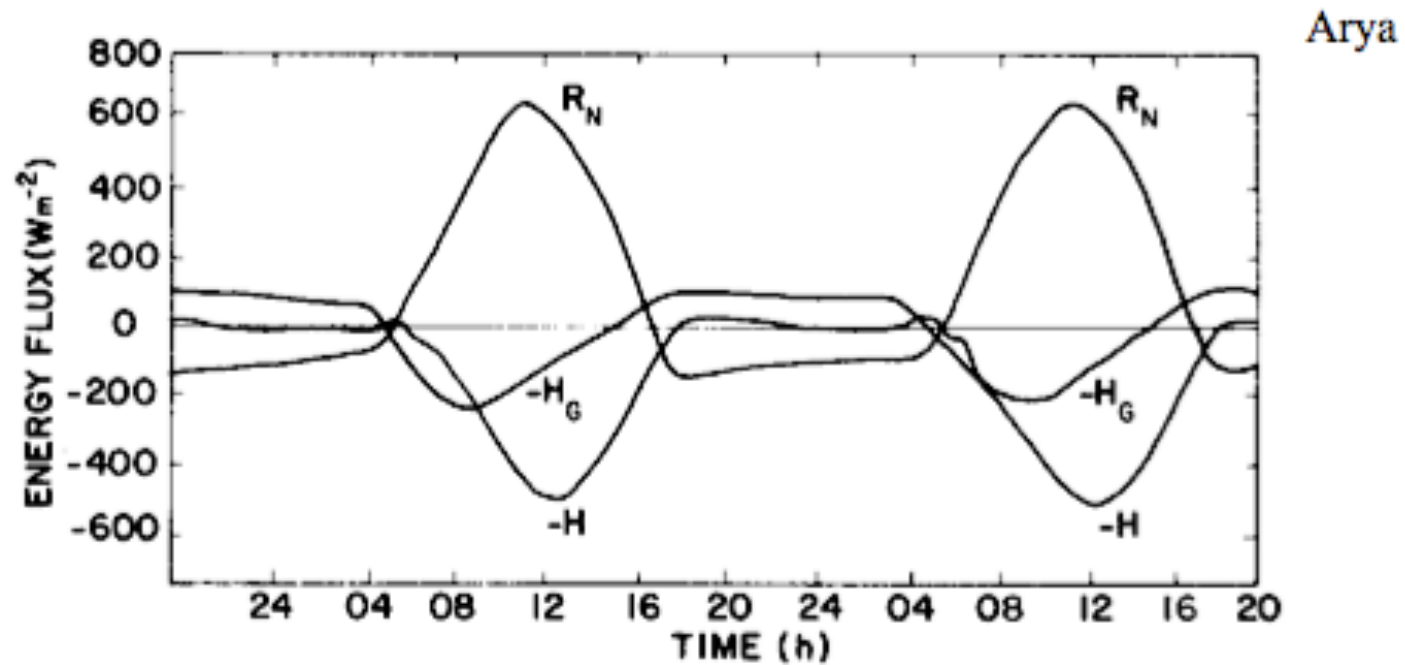


Fig. 2.3 Observed diurnal energy balance over a dry lake bed at El Mirage, California, on June 10 and 11, 1950. [After Vehrencamp (1953).]

Surface energy balance: barley field

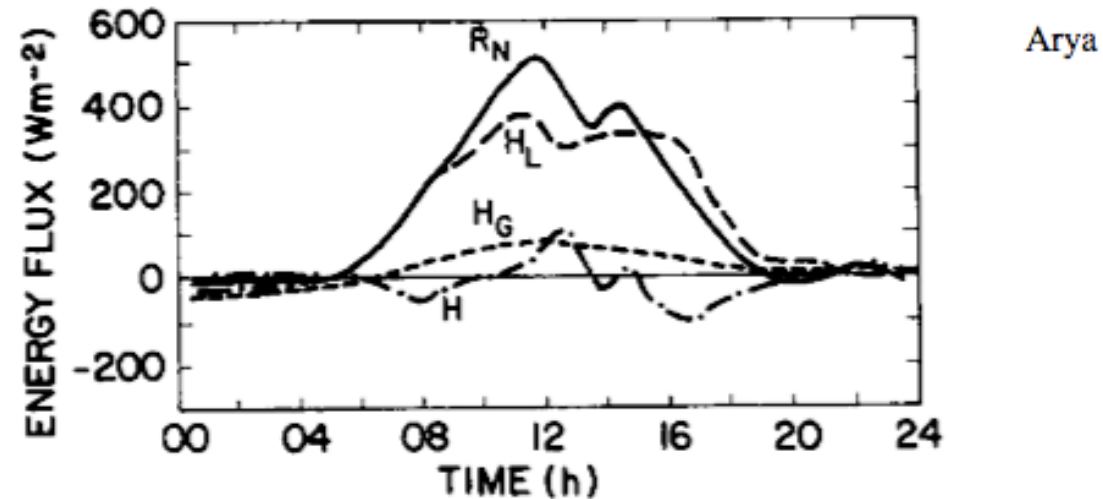
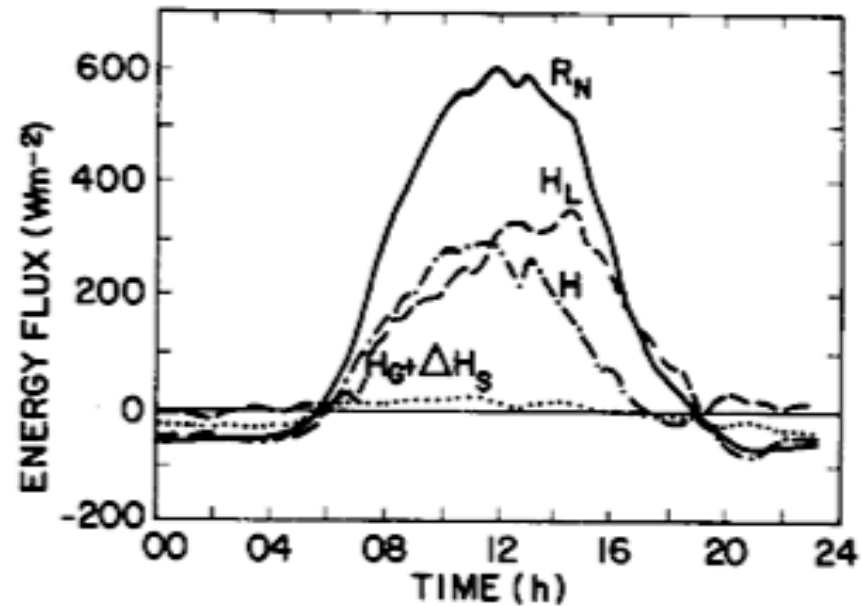


Fig. 2.4 Observed diurnal energy budget of a barley field at Rothamsted, England, on July 23, 1963. [From Oke (1987); after Long *et al.* (1964).]

Energy budget: Fir canopy



Arya

Fig. 2.5 Observed energy budget of a Douglas fir canopy at Haney, British Columbia, on July 23, 1970. [From Oke (1987); after McNaughton and Black (1973).]

Table 3.1
Radiative Properties of Natural Surfaces^a

Surface type	Other specifications	Albedo (<i>a</i>)	Emissivity (<i>e</i>)
Water	Small zenith angle	0.03–0.10	0.92–0.97
	Large zenith angle	0.10–0.50	0.92–0.97
Snow	Old	0.40–0.70	0.82–0.89
	Fresh	0.45–0.95	0.90–0.99
Ice	Sea	0.30–0.40	0.92–0.97
	Glacier	0.20–0.40	
Bare sand	Dry	0.35–0.45	0.84–0.90
	Wet	0.20–0.30	0.91–0.95
Bare soil	Dry clay	0.20–0.35	0.95
	Moist clay	0.10–0.20	0.97
	Wet fallow field	0.05–0.07	
Paved	Concrete	0.17–0.27	0.71–0.88
	Black gravel road	0.05–0.10	0.88–0.95
Grass	Long (1 m)	0.16–0.26	0.90–0.95
	Short (0.02 m)		
Agricultural	Wheat, rice, etc.	0.10–0.25	0.90–0.99
	Orchards	0.15–0.20	0.90–0.95
Forests	Deciduous	0.10–0.20	0.97–0.98
	Coniferous	0.05–0.15	0.97–0.99

^a Compiled from Sellers (1965), Kondratyev (1969), and Oke (1978).

Diurnal cycle of surface radiative flux components

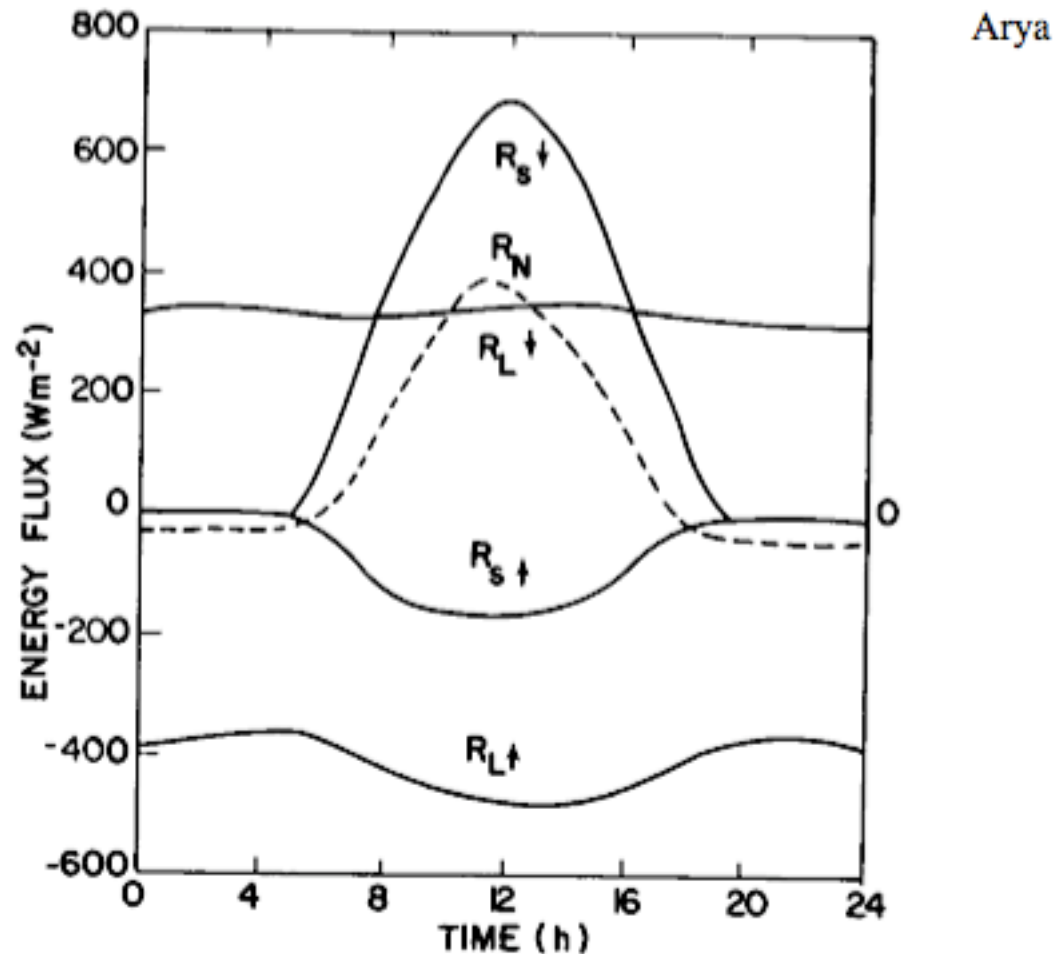


Fig. 3.4 Observed radiation budget over a 0.2-m-tall stand of native grass at Matador Saskatchewan, on July 30, 1971. [From Oke (1987); after Ripley and Redmann (1976).]

Diurnal cycle of subsurface temperature

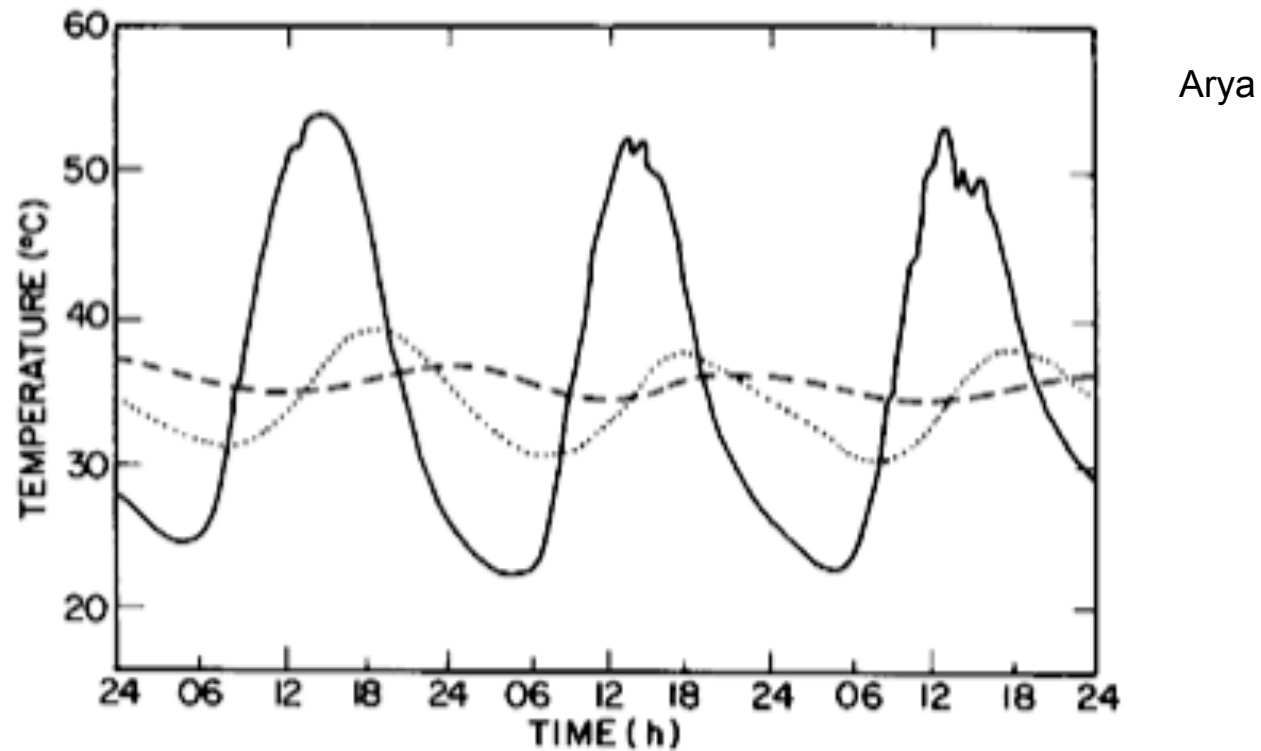


Fig. 4.1 Observed diurnal course of subsurface soil temperatures at various depths in a sandy loam with bare surface. —, 2.5 cm; ····, 15 cm; ---, 30 cm. [From Deacon (1969); after West (1952).]

Annual cycle of subsurface temperature

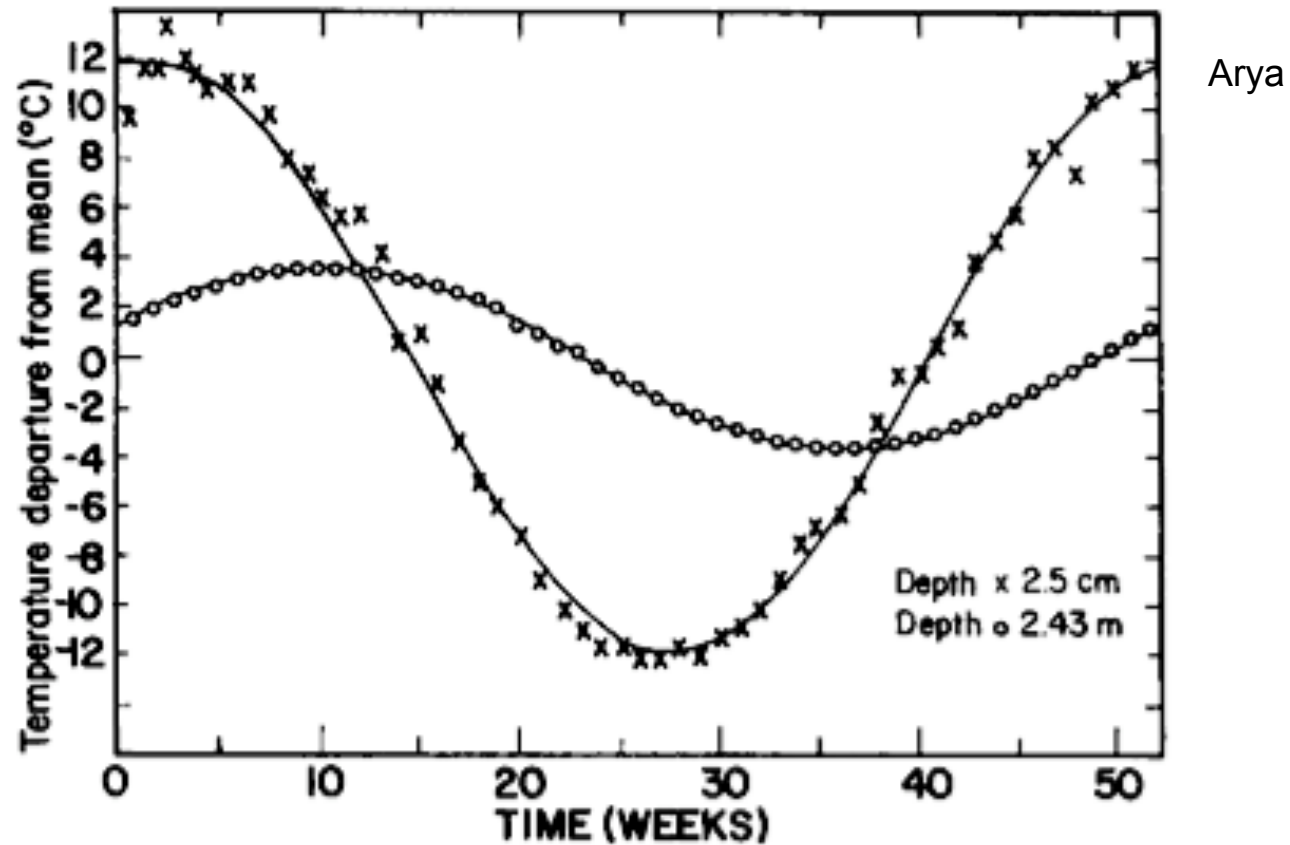


Fig. 4.2 Annual temperature waves in the weekly averaged subsurface soil temperatures at two depths in a sandy loam soil. ×, 2.5 cm; ○, 2.43 m. Fitted solid curves are sine waves. [From Deacon (1969); after West (1952).]

Surface material properties

Table A7. *Representative values of the thermal conductivity k_s , specific heat c_s , density ρ_s and thermal diffusivity κ_s for various types of surface based mainly on Table 11-3 in Pielke (1984)* Garratt

Data for clay and sand are approximately consistent with Eq. A24, in which C_{si} is equal to 2.7×10^6 and $2.2 \times 10^6 \text{ J m}^{-3} \text{ K}^{-1}$ for clay and sand respectively; C_w is equal to $\rho_w c_1$, with $\rho_w = 1000 \text{ kg m}^{-3}$ and $c_1 = 4186 \text{ J kg}^{-1} \text{ K}^{-1}$; and η_s is taken from Table A9. The reader should also consult e.g. Geiger (1965, Table 10), Hillel (1982, Table 9.3) and Oke (1987, Table 2.1).

Surface	k_s ($\text{W m}^{-1} \text{ K}^{-1}$)	c_s ($\text{J kg}^{-1} \text{ K}^{-1}$)	ρ_s (kg m^{-3})	κ_s ($10^{-6} \text{ m}^2 \text{ s}^{-1}$)
<i>Sand soil</i>				
dry	0.3	800	1600	0.23
$\eta = 0.2$	1.9	1260	1800	0.84
$\eta = 0.4$	2.2	1480	2000	0.74
<i>Clay soil</i>				
dry	0.25	890	1600	0.18
$\eta = 0.2$	1.1	1170	1800	0.52
$\eta = 0.4$	1.6	1550	2000	0.52
<i>rock</i>	2.9	750	2700	1.4
<i>ice</i>	2.5	2100	910	1.3
<i>snow</i>				
old	1.0	2090	640	0.7
new	0.1	2090	150	0.3
<i>water</i>	0.6	4186	1000	0.14

Idealized temperature wave vs. depth

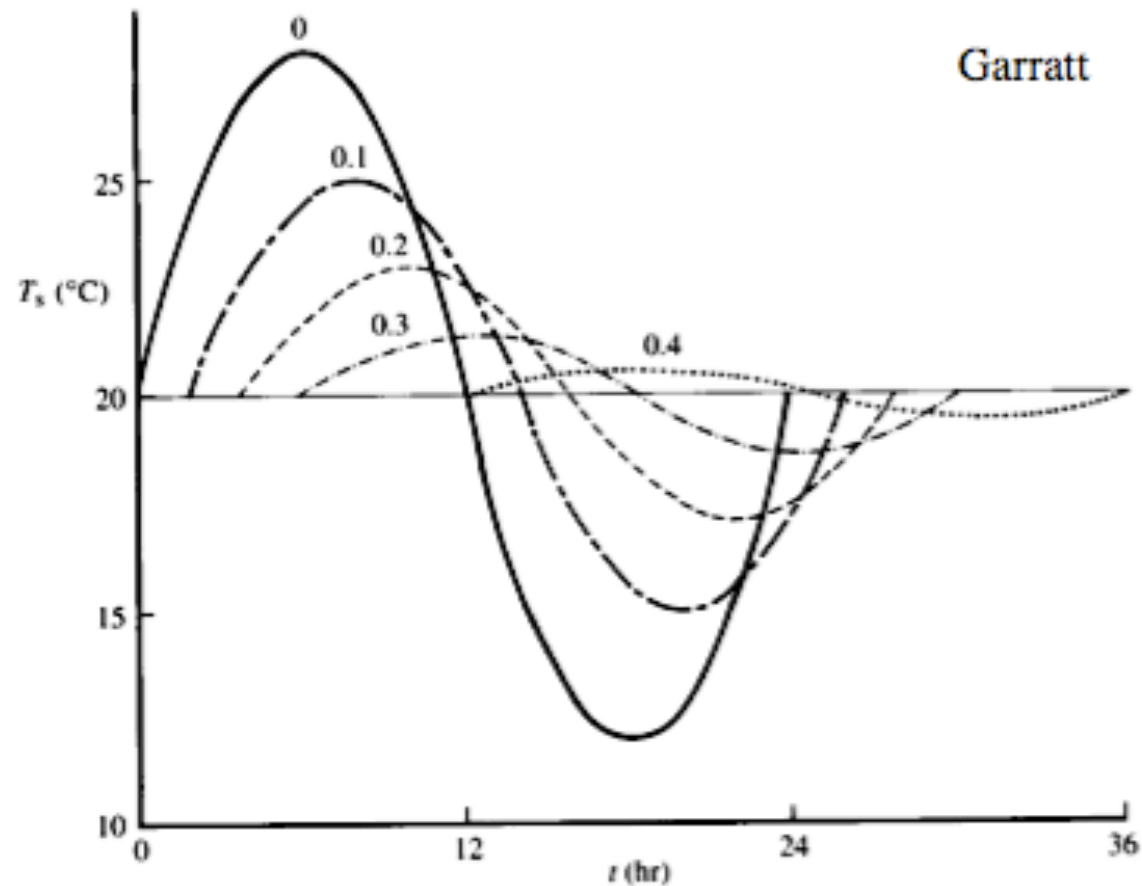


Fig. 5.1 Idealized variation of soil temperature through a diurnal cycle for several depths in the soil (indicated in metres). The curves represent the solutions to Eq. 5.7 for sinusoidal forcing; these are given by Eq. 5.8. A uniform soil is assumed with $\kappa_s = 0.8 \times 10^{-6} \text{ m}^2 \text{ s}^{-1}$ and $k_s = 1.68 \text{ W m}^{-1} \text{ K}^{-1}$.

Annual observed temperature wave vs. depth

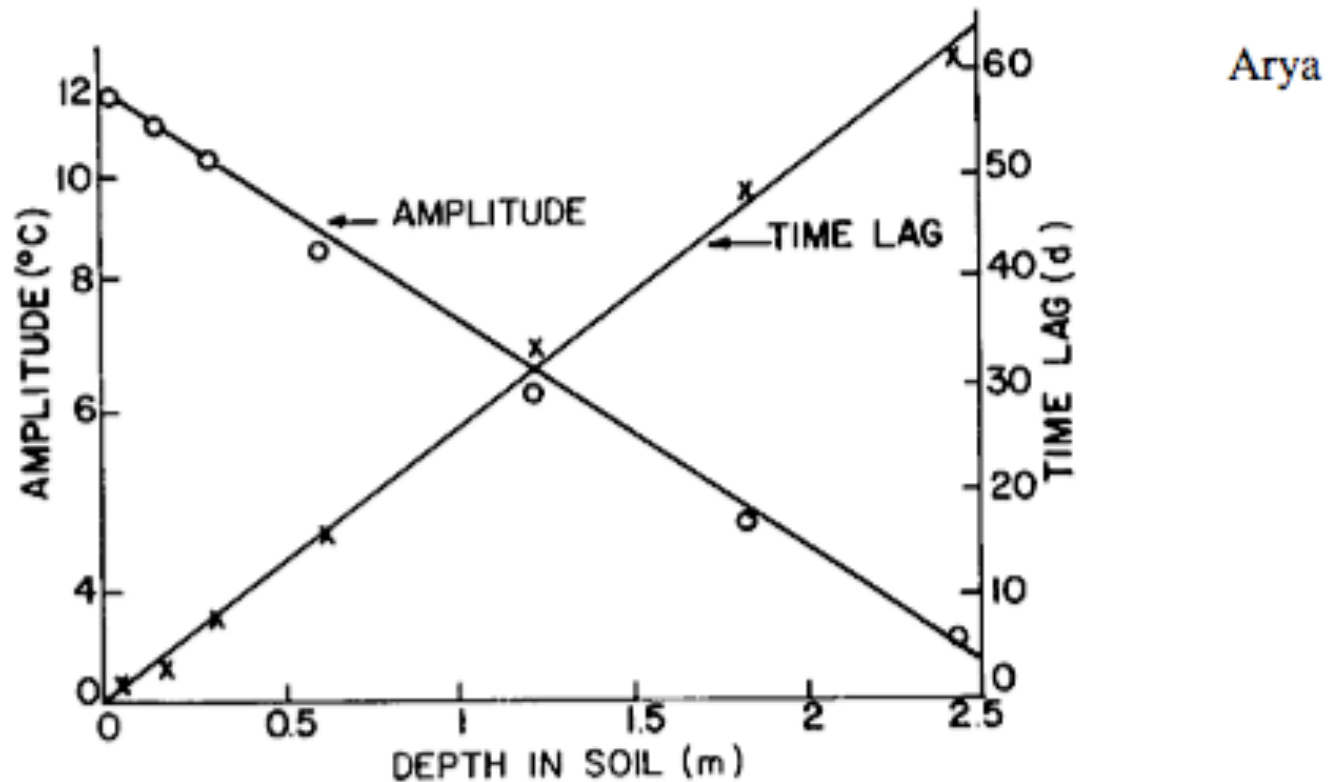


Fig. 4.4 Variations of amplitude and time lag of the annual soil temperature waves with depth in the soil. [From Deacon (1969).]