General temperature patterns in the biosphere are rather closely associated with radiant energy patterns since solar energy is essentially the only source of energy input into the atmosphere. As solar radiation increases in the summer, more energy is absorbed by both soil and atmosphere, and temperatures rise. As solar energy decreases in the winter, less energy is absorbed and atmospheric and soil temperatures fall. This temperature pattern is predictable from season to season, although the magnitude of the temperature differences varies between seasons.

Local topographic, vegetation, and surface water characteristics affect both spatial and temporal temperature distributions. Large bodies of water ameliorate the climate because water has a high heat capacity; time is required for warm-up in the spring and for cooling-off in the fall.

Temperature is an index to but not an expression of the amount of heat energy in a substance. The latter must consider the specific heat of the substance; two materials may be at the same temperature, but if one has a specific heat of 1.0 and the other 0.5 , the former will contain two times the heat energy of the latter. This is an important distinction ecologically, especially so because of the high specific heat (1.0) of water which is found in such a wide variety of parts, from cells to oceans, of the eco-system.

Temperature is measured on interval scales, and various scales, including Fahrenheit, Celsius, and Kelvin, are in use. Whatever scale is used, the numbers of degrees are not proportional to heat energy in relation to animals. A temperature of 40 is not two times warmer than 20 , nor is 20 four times warmer than 5. Interval scales are useful only in identifying a position relative to a fixed point on the scale; the numbers themselves are arbitrary.

Temperature patterns may be recognized in both time and space. Daily and seasonal temperature patterns are discussed in UNIT 1.1, TEMPORAL TEMPERATURE PATTERNS. Horizontal and vertical temperature patterns are discussed in UNIT 1.2, SPATIAL TEMPERATURE PATTERNS.

Daily and seasonal temperature patterns are very definitely related to daily and seasonal patterns of solar energy flux. There is a lag between peak solar energy flux and peak temperatures, however, due to the thermal and mechanical resistances of the soil and atmosphere. Heat flow through the soil is not instantaneous; conduction takes time. The major portion of heat transfer into the atmosphere is by convection or eddy diffusion. This is a mechanical process, a mixing of air with different densities due to differences in thermal energy distribution. There is friction between air molecules so eddy diffusion is not an instantaneous process either.


Daily temperature patterns. Clear-day solar energy flux is symmetrical around the peak at solar noon (See earlier illustration in UNIT 1.1), while peak temperatures occur two to four hours after solar noon. Part of the lag can be attributed to the presence of dew, which absorbs solar energy in the early hours after sunrise, dissipating some of the energy in vaporization. Part of the lag can be attributed to the thermal lag in the soil, plants, and the atmosphere.


The generalized curves shown above are seldom realized in the natural world because of large-scale movements of air masses and changes in atmospheric conditions. They are useful for expressing overall patterns of relationships, however. If general patterns can be analyzed, then the effects of deviations can also be analyzed.

Seasonal temperature patterns. Seasonal temperature patterns exhibit lag characteristics just as daily patterns do. Maximum solar radiation is received on about June 21 in the northern hemisphere, but maximum temperatures usually occur in July or August. This is illustrated by the observed mean monthly temperatures for 1942-1966 at Ithaca, NY that are plotted (solid line) in the figure below. The maximum mean monthly temperature occurs in July and the minimum 6 months later, in January. The August mean is nearly as high as the July mean, and the February mean nearly as low as the January mean.


The pattern of mean monthly temperatures in Celsius may be approximated by a sine wave and expressed as a continuous function in very much the same way as weights were expressed in PART I. The equation is:

$$
\text { MMTC }=7.8+\{\sin [(J D A Y)(0.9863)-103.3]\}[12.8]
$$

General temperature patterns represented mathematically in such a way are useful, not for predicting air temperature on a particular day, but for evaluating the effects of changing temperatures through the year. If such evaluations can be made for general patterns, they can also be made for short-term transient conditions by substituting observed values for calculated ones.

Monthly temperatures are sometimes expressed as average lows and highs rather than a single average. The table below, from a Canada travel information $1981 / 82$ brochure, provides monthly lows and highs for 40 points across Canada.

|  | Jan. |  | Feb |  | Mar. |  | Apr. |  | May |  | June |  | July |  | Aug. |  | Sept. |  | Oct . |  | Nov |  | Dec |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1 | H | L | H | 1 | H | 1 | H | L | H | L | H | 1 | H | 1 | H | L | H | 1 | H | L | H | L | H |
| British Columbia |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Kamloops | 10 | - 2 | -5 | 4 | - 1 | 10 | 3 | 16 | 7 | 22 | 11 | 26 | 13 | 29 | 12 | 28 | 8 | 23 | 4 | 14 | $\cdot 1$ | 6 | -6 | 1 |
| Penticton | -6 | 0 | -3 | 4 | -2 | 9 | 2 | 16 | 6 | 21 | 10 | 25 | 12 | 29 | 11 | 27 | 7 | 22 | 3 | 14 | 0 | 6 | -3 | 2 |
| Prunce Rupert | 1 | 4 | 0 | 5 | 1 | 7 | 3 | 10 | 6 | 14 | 8 | 15 | 10 | 17 | 11 | 17 | 9 | 15 | 6 | 11 | 3 | 8 | 1 | 5 |
| Vancouver | 0 | 6 | 2. | 9 | 3 | 11 | 6 | 14 | 9 | 18 | 12 | 21 | 14 | 24 | 13 | 23 | 11 | 23 | 7 | 15 | 4 | 10 | 2 | 7 |
| Vicioria | 2 | 6 | 3 | 9 | 4 | 11 | 6 | 14 | 8 | 18 | 10 | 21 | 11 | 24 | 11 | 23 | 10 | 20 | 8 | 15 | 5 | 10 | 3 | 8 |
| Alberta |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Banl | . 16 | 6 | -13 | - 1 | -10 | 3 | . 4 | 8 | 1 | 14 | 4 | 18 | 7 | 22 | 6 | 21 | 2 | 16 | - 1 | 10 | -8 | 1 | -13 | 4 |
| Cailgary | . 17 | -5 | -13 | -2 | . 10 | 1 | - 3 | 10 | 3 | 16 | 7 | 19 | 10 | 24 | 8 | 22 | 4 | 17 | -1 | 12 | -8 | 3 | . 13 | -2 |
| Edmonton | . 19 | . 10 | -16 | -6 | . 10 | -1 | -2 | 10 | 5 | 17 | 9 | 20 | 12 | 23 | 10 | 22 | 5 | 17 | 0 | 11 | -8 | 0 | . 15 | -6 |
| Jasper | -17 | -7 | -13 | 0 | - 9 | 4 | - 3 | 10 | 1 | 16 | 5 | 20 | 8 | 23 | 7 | 22 | 3 | 17 | -1 | 11 | - 8 | 4 | - 14 | . 5 |
| Lethbridge | . 15 | -4 | -11 | 0 | -8 | 3 | . 1 | 12 | 4 | 18 | 9 | 21 | 11 | 26 | 10 | 25 | 6 | 20 | 1 | 14 | -6 | 5 | 11 | 0 |
| Yukon |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Whitehorse | - 23 | -15 | . 18 | -8 | $-13$ | -1 | 5 | 7 | 1 | 15 | 6 | 20 | 8 | 21 | 7 | 19 | 3 | 14 | $\cdot 3$ | 5 | . 12 | - 5 | -20 | -12 |
| Northwest Territories |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fiobisher Bay | -30 | . 22 | -30 | -21 | . 27 | . 18 | -19 | -9 | -7 | 0 | 0 | 7 | 4 | 12 | 4 | 10 | . 3 | 5 | -8 | -2 | -16 | -9 | -24 | -16 |
| muvik | . 35 | . 24 | -35 | -24 | . 30 | . 18 | -21 | - 8 | - 6 | 4 | 4 | 16 | 7 | 19 | 5 | 16 | $\cdot 1$ | 7 | -11 | -4 | -25 | - 77 | . 32 | . 22 |
| Yellowknite | -33 | -25 | . 30 | -21 | . 24 | . 12 | -14 | 1 | .1 | 9 | 7 | 17 | 11 | 21 | 10 | 19 | 4 | 11 | -4 | 2 | -18 | 13 | -28 | -20 |
| Saskatchewan |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Prince Albert | -27 | -15 | -24 | -10 | . 17 | -4 | -4 | 8 | 2 | 17 | 7 | 21 | 11 | 25 | 9 | 23 | 4 | 17 | -2 | 10 | -12 | -3 | -22 | -11 |
| Regina | -23 | . 12 | -20 | -9 | . 14 | -4 | -3 | 9 | 3 | 18 | 9 | 22 | 12 | 26 | 10 | 25 | 4 | 19 | -2 | 12 | - 10 | -1 | -18 | . 8 |
| Saskaloon | . 23 | -13 | - 19 | . 9 | . 13 | -3 | . 2 | 10 | 4 | 18 | 9 | 22 | 12 | 26 | 11 | 25 | 5 | 18 | 0 | 12 | 9 | -1 | -18 | -9 |
| Manitoba |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Churehill | . 31 | . 24 | -29 | 23 | -25 | . 16 | -15 | -7 | -6 | 1 | 2 | 11 | 7 | 17 | 8 | 16 | 3 | 9 | -3 | 2 | -15 | -8 | -25 | . 18 |
| Winnipeg | -23 | . 13 | -21 | -10 | . 13 | -3 | 2 | 9 | 4 | 17 | 10 | 23 | 14 | 26 | 12 | 25 | 7 | 18 | 1 | 12 | -8 | 1 | -18 | -9 |
| Ontario |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Hamulon | -8 | 0 | 8 | 1 | -4 | 5 | 2 | 13 | 8 | 19 | 14 | 25 | 17 | 28 | 16 | 27 | 11 | 22 | 6 | 16 | 1 | 8 | 5 | 2 |
| Kirchener | -10 | 3 | -10 | -2 | -5 | 3 | 1 | 12 | 7 | 18 | 12 | 25 | 14 | 27 | 14 | 26 | 10 | 21 | 5 | 15 | - 1 | 6 | . 7 | $-1$ |
| 1 Iondon | -10 | -2 | - 10 | -2 | -5 | 3 | 1 | 12 | 7 | 18 | 12 | 24 | 15 | 26 | 14 | 26 | 10 | 21 | 5 | 15 | - 1 | 7 | -7 | 0 |
| Otlawa | -15 | -6 | -14 | -4 | -7 | 2 | 1 | 11 | 7 | 19 | 13 | 24 | 15 | 27 | 14 | 26 | 10 | 20 | 4 | 14 | -1 | 6 | -11 | -3 |
| Sauli Sie. Marie | . 14 | - 5 | -14 | 4 | -9 | 1 | -1 | 8 | 4 | 14 | 9 | 21 | 12 | 24 | 12 | 23 | 9 | 18 | 4 | 13 | -3 | 4 | -11 | - 3 |
| Sudbury | . 18 | 7 | -16 | 5 | . 10 | 1 | . 1 | 9 | 6 | 17 | 11 | 23 | 14 | 25 | 13 | 24 | 9 | 19 | 4 | 12 | 3 | 4 | -12 | - 4 |
| Thunder Bay | 20 | -9 | -19 | -6 | -11 | 0 | -3 | 8 | 2 | 15 | 7 | 20 | 12 | 24 | 11 | 23 | 7 | 17 | 2 | 12 | - 5 | 2 | . 14 | 6 |
| Ioronio | 9 | 3 | -10 | 2 | -3 | 3 | 2 | 12 | 7 | 18 | 13 | 25 | 17 | 27 | 16 | 26 | 12 | 22 | 7 | 15 | 2 | 7 | -5 | 0 |
| Windsor | -8 | -1 | . 7 | 0 | -3 | 5 | 3 | 14 | 8 | 20 | 14 | 26 | 17 | 28 | 16 | 27 | 12 | 23 | 6 | 17 | 1 | 8 | 5 | 1 |
| Québec |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gaspé | - 15 | -6 | . 15 | . 5 | . 10 | -1 | -3 | 5 | 3 | 12 | 8 | 18 | 13 | 23 | 11 | 22 | 6 | 18 | 2 | 12 | 3 | 4 | 11 | 3 |
| Montreal | 13 | -6 | -11 | 4 | -5 | 1 | 2 | 11 | 9 | 18 | 15 | 24 | 17 | 26 | 16 | 25 | 12 | 20 | 6 | 14 | 0 | 6 | 9 | - |
| Québer, City | $\cdot 15$ | . 7 | . 13 | - 6 | . 7 | 0 | 0 | 8 | 6 | 17 | 12 | 22 | 15 | 25 | 14 | 24 | 9 | 19 | 4 | 12 | -2 | 4 | . 11 | -5 |
| New Brunswick |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| fredericion | 14 | 4 | -14 | 2 | . 7 | 3 | 1 | 10 | 4 | 17 | 9 | 23 | 13 | 26 | 12 | 24 | 8 | 20 | 2 | 13 | 3 | 6 | 11 | 2 |
| Moncton | -13 | $\cdot 3$ | -12 | 2 | -7 | 3 | 2 | 9 | 4 | 16 | 9 | 22 | 13 | 25 | 12 | 24 | 8 | 20 | 3 | 14 | 2 | 7 | -10 | - 1 |
| Sam John | -11 | -2 | . 10 | 1 | $-5$ | 3 | 0 | 9 | 5 | 15 | 9 | 19 | 12 | 23 | 13 | 23 | 10 | 19 | 5 | 14 | 0 | 7 | 7 | 0 |
| Nova Scotia |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Halliax/Dartmouth | -7 | -2 | 7 | . 2 | -4 | 2 | 1 | 7 | 5 | 14 | 10 | 20 | 14 | 23 | 14 | 23 | 11 | 19 | 7 | 13 | 2 | 7 | . 4 | 1 |
| Yarmouth | -6 | 1 | . 6 | 1 | 3 | 4 | 1 | 8 | 5 | 13 | 9 | 17 | 12 | 21 | 12 | 21 | 10 | 18 | 6 | 14 | 2 | 9 | 4 | 3 |
| Prince Edward Island |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Charlottetown | 10 | -3 | . 11 | - 3 | 6 | 1 | - 1 | 7 | 4 | 14 | 10 | 20 | 14 | 24 | 14 | 23 | 10 | 19 | 5 | 13 | 1 | 7 | -7 | 0 |
| Newfoundland/Labrador |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Corner Brook | - 9 | 2 | -10 | -2 | -7 | 1 | 2 | 6 | 3 | 11 | 7 | 17 | 12 | 22 | 12 | 21 | 8 | 17 | 4 | 11 | 0 | 6 | -5 | 0 |
| Goose Bay | -21 | -12 | -20 | . 10 | -14 | $\cdot 3$ | 6 | 3 | 0 | 10 | 6 | 17 | 11 | 21 | 10 | 19 | 5 | 14 | 0 | 9 | . 7 | 0 | . 16 | -8 |
| St John's | 7 | 0 | -7 | 0 | 5 | 1 | -2 | 5 | 2 | 11 | 6 | 16 | 11 | 21 | 12 | 20 | 8 | 17 | 4 | 12 | 1 | 7 | -4 | 3 |

Very limited data are sometimes available or given, but general patterns make first approximations possible. Meagher (1973) for example, gives a mean temperature in Yellowstone National Park for January of $18.0^{\circ} \mathrm{F}$ $\left(-7.8^{\circ} \mathrm{C}\right)$ and for July, $62.8^{\circ} \mathrm{F}\left(17.1^{\circ} \mathrm{C}\right)$, the coldest and warmest months, respectively. The mean annual temperature was $39.8^{\circ} \mathrm{F}\left(4.3^{\circ} \mathrm{C}\right)$. These temperatures suggest a pattern. The midpoint between the low and high is $4.7^{\circ} \mathrm{C}$, very close to the mean annual temperature. The amplitude of the varlation above and below this midpoint is 12.5 (coincidentally, nearly the same as for Ithaca, NY; see p. 20). The equation for a first approximation is:

$$
\text { MMTC }=4.7+\{\sin [(J D A Y)(0.9863)-103.3]\}[12.5]
$$

The calculated temperatures will be very close to measured ones, a good first approximation. Meagher points out that temperatures at this station averaged $5^{\circ} \mathrm{F}\left(2.8^{\circ} \mathrm{C}\right)$ above those for most of the park. If you wish to make a correction, subtract [4.7-2.8 = 1.9] and simply substitute 1.9 as the annual average for 4.7.

The WORKSHEETS that follow provide opportunities for calculating expected average temperatures for any day of the year. The data for Ithaca, N.Y., points in Canada, and Yellowstone National Park may be used to verify the derivation procedures. You are encouraged to derive equations for your local study areas a1so.

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## TEMPORAL TEMPERATURE PATTERNS

## SERIALS


JFUSA 63--7 523529 odvi swamp coni yards, michigan verme, 1j 1965
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XPNWA 277-- $1 \quad 6 \quad$ ceel diurnl temp, conifer stand edgerton,pj; mcco 1976
MWREA 61-- 251259 ---- study long-time temp trend kincer,jb 1933
NPSMD 1---- 1161 bibi bison, yellowstone nat1 pk meagher,mm 1973

Temperature patterns over the annual cycle
Temperature patterns over the annual cycle may be approximated by fitting mean monthly temperatures to a sine wave. The formula for the average daily temperature in Celsius (ADTC), based on monthly averages, is:

$$
\mathrm{ADTC}=\mathrm{MPTE}+\{\sin [(J D A Y)(0.9863)+\mathrm{PRPC}]\} \text { TERA/2 }
$$

where $A D T C=$ average daily temperature in Celsius,
MPTE = midpoint temperature,
TERA = temperature range over the year, and
PRPC $=$ primary phase correction.
Determine the primary phase correction, PRPC, by:

$$
\sin [(J D M A)(0.9863)+P R P C]=1.0
$$

where JDMA $=$ JDAY at maximum.
Since $\sin 90=1.0$,

$$
\begin{aligned}
{[(\mathrm{JDAY})(0.9863)+\mathrm{PRPC}] } & =90 \\
90-(\quad)(0.9863) & =-104,3
\end{aligned}=\mathrm{PRPC}
$$

MPTE in this example is 7.8 , TERA is +20 to -5 and TERA/2 $=25 / 2=12.5$.
Substitute the values of MPTE, TERA, and PRPC in the formula for ADTC above for the Ithaca, N.Y. data below. Compare the calculated temperatures with the observed ones by tabulating the results and ploting the curve on the next page.

| Month | JDAY | Observed | Calculated |
| :---: | :---: | :---: | :---: |
| January | 16 | - 5.0 | $-4.7$ |
| February | 45 | - 4.4 | $-3.0$ |
| March | 75 | $+0.6$ | 1.5 |
| Apri1 | 105 | + 7.2 | 7.6 |
| May | 136 | +12.8 | 140 |
| June | 166 | +18.3 | 18,6 |
| Ju1y | 197 | +20.6 | 20,3 |
| August | 228 | +19.4 | 18,6 |
| September | 258 | +15.6 | 11,0 |
| October | 289 | +10.6 | 7.6 |
| Noveber | 319 | + 3.9 | 1.5 |
| December | 350 | - 2.8 | $-3.1$ |



CHAPTER 14, WORKSHEET 2.1b
Average daily maximum and minimum temperatures over the annual cycle

The format used in the previous WORKSHEET may also be used to express average maximum and minimum temperatures for the Canada data on p. 21. Fill in the following blanks, derive the equations for low and high temperatures, and plot the calculated annual rhythms. The resulting corridor includes the predicted daily temperature range.

Location:



The equations:
AMXT $=$

ANT $=$
Plot the calculated annual rhythms and the monthly values given on p. 23 in the grids below and on the next page. Note the larger span of the grid on the next page.


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$+30$

$\begin{array}{lllllllllllll}15 & 46 & 74 & 105 & 135 & 166 & \begin{array}{lllll}196 \\ \text { JDAY }\end{array} & 227 & 258 & 288 & 319 & 349 & 15\end{array}$

CHAPTER 14, WORKSHEET 2.lc
Predicted annual temperature rhythms, Yellowstone National Park

Using the data given on page 24 and the procedures described in the previous WORKSHEETS, derive the equation for annual temperature rhythm in Yellowstone National Park. Substitute the numbers in the blanks below the formula.

$$
\begin{aligned}
& \mathrm{ADTC}=\operatorname{MPTE}+\{\sin [(\mathrm{JDAY})(0.9863)+\operatorname{PRPC}][\text { TERA } 2]\} \\
& \mathrm{ADTC}=\underline{Z}+\{\sin [(\mathrm{JDAY})(0.9863)+\underline{-\mid 5 \varphi}][12.5 / 2]\}
\end{aligned}
$$

Plot the sine curve in the grid below.


Another grid is given on the back of this page for your local data.


Idealized temperature patterns, with a high in the afternoon and a low in the early morning, occur when air masses are stable and neither cold nor warm fronts are moving through. The daily temperature curve may be approximated with a sine wave, stressing again the idea that patterns are being emphasized at this point. If the patterns can be evaluated in relation to animal response through time, then deviations can be evaluated also.

Use the procedures described in previous WORKSHEETS for determining sine wave equations and plot your selected temperature patterns below and in the grid on the next page.



## UNIT 2.2: SPATIAL TEMPERATURE PATTERNS

There are spatial patterns to the temperature distribution over the earth's surface because of changes in angles of the sun's rays over the earth's spherical surface (horizontal patterns), and because of the decreasing density of the atmosphere at increasing elevations above the earth's surface (vertical patterns).

## HORIZONTAL TEMPERATURE PATTERNS

The highest temperatures should theoretically occur in the equatorial regions and the lowest temperatures in the polar regions because of the spherical shape of the earth. This general pattern occurs, and the pattern would be quite uniform if the earth had a homogenous and smooth surface. Topographic features, especially altitude and surface water distribution, alter local atmospheric temperatures, however. Large bodies of water ameliorate the climate, raising average temperatures and reducing the range of temperature variations because of the high heat capacity of water. Such maritime climates usually result in high levels of primary productivity. Continental climates, beyond the influence of major bodies of water, have wide temperature fluctuations. The lack of large bodies of water along with clearer skies allow more intense direct solar radiation to reach the earth's surface and more infrared radiation to be dissipated into space, resulting in cooler temperatures at the earth's surface.

The 40 locations in Canada with monthly lows and highs given on page 23 provide good examples of different temperatures as a result of geographic location. Notice the differences in the amplitudes of the temperature variations through the year and in the midpoint temperatures at locations in the interior with a cold continental climate, and on the coast, with a maritime climate.

## VERTICAL TEMPERATURE PATTERNS

The vertical dimension of the atmosphere is an important meteorological consideration. Under stable atmospheric conditions, temperatures decrease $6.5^{\circ} \mathrm{C}$ per 1000 meters. This is known as the normal lapse rate (Trewartha 1968: 46). Thus high mountain slopes are cooler than the valleys; snowfields persist throughout the summer months at higher elevations. A major factor determining the vertical temperature distribution is the reduction in atmospheric density at greater distances from the earth's surface. A thinner atmosphere has less of a blanketing effect, so even though more solar energy is received as the thinner atmosphere at higher elevations filters less out than the thicker atmosphere at lower elevations, infrared dissipation is greater and the net energy absorbed is less. The result is cooler temperatures.

Vertical temperature gradients occur on a small scale too. A warmed soil on a bright sunny day heats the air next to it, resulting in a vertical temperature gradient. The warmer air rises, of course, but this is not instantaneous. As a result, a thermal boundary region, which may be defined as the layer of air with temperature differences due to the influences of the warmer surface, develops.

Temperature profiles over flat bare soil, rough bare soil, snow, and short grass at night are discussed by Oke (1970). A smooth bare soil that has a high absorption coefficient for solar energy is warmed as the sun's energy is absorbed and the air near the soil warmed. The temperature profile patterns are expected to develop on a sunny day as shown below.


Morning


Noon


Afternoon

Note how the air temperature near the soil surface increases as the soil is warmed. The profile reverses as the soil is cooled.

Air temperatures profiles above a snow surface may show a minimum temperature at an elevated point on the profile. This is due to the absorption of the sun's energy at the snow surface, increasing the temperature of the air near the snow, resulting in a minimum temperature above the snow surface as shown below.


Elevated minimum temperatures may also be observed above grass. The vegetation functions as insulation, protecting the soil from heat loss at night, resulting in the profile pattern shown below.


The reverse occurs when the sun shines on the vegetation and it shades the soil from the solar energy. Then, the profile looks like this.


Increasing AITE $\rightarrow$
The generalized air temperature profiles discussed above provide insights into the distribution of energy in relation to energy inputs and the configuration of the habitat. The basic profile patterns can be predicted, but actual profiles at a point in space and time cannot, of course. The generalized profiles are given here to call attention to the behavior of temperature profiles in different habitats, and as background information for further discussions of temperature profiles through deer hair in CHAPTER 16. Similarities in profile patterns over vegetation and over hair will call attention to common functions, but on different scales, which results in greater understanding of the distribution of energy and matter.

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SPATIAL PATTERNS

BOOKS
TYPE PUBL CITY PAGE KEY WORDS------------------------ AUTHORS/EDITORS-- YEAR
aubo gidr leru 210 the thermal balance of vegetatn rauner, yl1972

SERIALS

CODEN VO-NU BEPA ENPA KEY WORDS--------------------------------- AUTHORS
AMGBA 12--1 95108 radiant heat flux div, heat re gaevskaya,gn; ko/ 1962 AMGBA 18... 305324 surface temp, infrred rad, spru lorenz,d; baumgar 1970

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## Comparison of annual temperature rhythms in dry continental climates and warm coastal climates

Select two locations in Canada from the data given on page 23 which represent extremes due to geographic location in the interior and on the coast. Complete the blanks below, derive the equations, and plot the calculated results in the grid below. Another set of blanks and a grid is given on the next page.

Location:

| Monthly <br> Maximum | Low | High | TERA | MPTE | AMPL | PRPC |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| Minimum | - | - | - | - | - | - |

The equations:
$\mathrm{AMXT}=$
AMNT $=$
Plot the calculated annual rhythms and the monthly values given on $p$. 21 in the grids below and on the next page. Note the larger span of the grid on the next page.


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Location:

| Month1y <br> Maximum | Low | High | TERA | MPTE | AMPL | PRPC |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| Minimum | - | - | - | - | - | - |

The equations:
$\mathrm{AMXT}=$
AMNT $=$


## UNIT 2.3: BAROMETRIC PRESSURE

Air, the mixture of gases in the atmosphere, has weight, so pressure is exerted on the earth's surface by this fluid mass. There is decreasing atmospheric pressure with increasing altitude above sea level because the height of the column of air at increased altitudes is obviously less. The decrease must occur on the basis of atmospheric volume alone. The air is also thinner at higher altitudes since air is a gas which expands and contracts in relation to the volume to be occupied.

Another factor contributing to the pressure exerted by the atmosphere is the temperature effect on the density of a gas. Warmer air is less dense than cool air, resulting in rising warm air and reduced atmospheric pressure. This results in small scale "thermals" which provide lift to glider pilots and soaring birds. Changes in barometric pressure over large areas result in large-scale wind systems. Thus temperature, barometric pressure, and wind patterns all interact to cause land weather conditions.

Barometric pressure is measured with barometers. One type of barometer has a column of mercury which balances with the weight of the atmosphere. Another type of barometer has a sealed elastic chamber which contracts and expands as atmospheric pressure increases and decreases. This is commonly called the aneroid barometer. It needs to be calibrated at regular intervals with the mercury barometer. A third type of barometer is the hypsometer, which functions on the basis of the relationship between the boiling point of a liquid as a function of atmospheric pressure.

Recording barometers are called barographs. Aneroid barameters are especially suited to recording as the contraction and expansion of the chamber may be connected mechanically to a pen and chart system.

Errors associated with the use of barometers and descriptions of different kinds of instruments and standardized readings taken are discussed by Stringer (1972:66ff). The units bar and millibar are used in measuring atmospheric pressure. The bar is defined as a force of $10^{6}$ dynes per square cm , and the millibar is $10^{3}$ dynes per square cm . Atmospheric pressure is about 1000 mb at sea level and drops vary rapidly with height (Stringer 1972:65). At 10,000 feet it is about 700 mb , and at 1100 feet, 500 mb .

Changes in barometer pressure are indicators of changes in approaching weather systems. A drop in barometric pressure, for example, indicates that windy, stormy, and unsettled weither may be approaching. Relationships between barometric pressure and animal behavior are not well understood and documented, although subjective evidence indicates that animals do respond to atmospheric pressure changes and anticipate changes in weather. Perhaps they have sensory capabilities that we humans either don't have or don't use. The convenience of ready-made forecasts available at the flick of a switch tends to relegate our more primitive instincts to disuse.

## LITERATURE CITED

Stringer, E. T. 1972. Foundations of Climatology. W. H. Freeman and Company, San Francisco. 586 p.

REFERENCES, UNIT 2.3
BAROMETRIC PRESSURE

SERIALS


