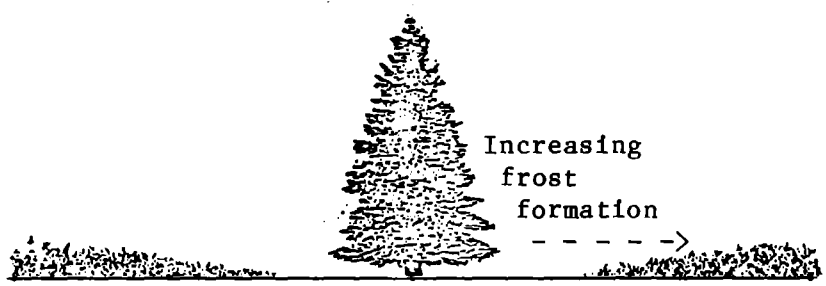
TOPIC 4: ATMOSPHERIC HUMIDITY

Water vapor is a very important component of the atmosphere because it is part of small scale daily rhythms in condensation and evaporation, and large scale atmospheric events in the hydrologic cycle. Daily rhythms in condensation and evaporation result in dew formation and dissipation. These phase changes of water are significant when considering thermal characteristics of the atmosphere since large quantities of heat energy--575 to 595 calories--are absorbed when a gram of water is vaporized at the atmospheric temperatures observed at the earth's surface. This heat energy is called the heat of vaporization, and is absorbed in vaporization and released upon condensation. Heat energy--about 80 calories per gram--is released when water freezes too: this is called the heat of fusion. The melting of ice and snow requires the absorption of heat energy equal to the heat of fusion.

Radiant energy discussed in UNITS 1.1 and 1.2 has a marked effect on the distribution of dew and frost. Patterns of frost accumulation at night may be observed from the base of a tree outward as illustrated below, indicating the role of infrared energy from the tree in preventing condensation and crystallization. Watch for this pattern the next time you are out the morning after a frost. The distribution of frost is related to the distribution of infrared energy, described in Moen (1968).



The energy-absorbing and energy-releasing processes of vaporization, condensation, fusion, and melting obviously have important roles in the lives of plants and animals exposed to the atmosphere. Some plants have life cycles that are directly dependent on moisture characteristics of the atmosphere. Mosses and fungi, for example, depend on thin films of water for parts of their reproductive strategies. Some depend on atmospheric water vapor characteristics for their structural characteristics. Lichens, for example, are dehydrated and stiff in a dry atmosphere, and rather soft and pliable in a moist atmosphere. When dry, they are not readily eaten by reindeer and caribou. When moist, they may be a major component of the diet.

Terms expressing atmospheric moisture characteristics are discussed in UNIT 4.1, followed by some humidity calculations in UNITS 4.2 and 4.3 that may be useful in later analyses of energy balances.

LITERATURE CITED

Moen, A. N. 1968. Thermal energy exchange of a birch tree and spruce tree at night. Ecology. 49(4):145-147.

UNIT 4.1. TERMS EXPRESSING HUMIDITY

Some fairly standardized meteorological terms are used to express humidity relationships, and are defined in general meteorology texts (see Taylor 1954, for example). These are expressed as four-letter symbols and defined below.

Specific humidity. Specific humidity (SPHU) is the ratio of the mass of water vapor in a sample of air (MAWV) to the total mass of air (TMAI), including both water vapor and air in the sample. In symbol form:

$$SPHU = MAWV/(MAWV + TMAI)$$

It is expressed in units of mass such as grams (actually a fraction of one gram) of vapor per gram of moist air. Note that specific humidity is a ratio of mass.

Mixing ratio. This term is used for the ratio of mass of water vapor per unit mass of dry air. It is different from specific humidity only in the denominator; specific humidity includes the total mass of air, including the water vapor, and mixing ratio only the dry air. Numerically, the ratios are almost always within 1% or so because the actual mass of water vapor involved is a very small part of the total air mass; the denominators are very close numerically.

Absolute humidity. Absolute humidity (ABHU) is the ratio of the mass of water vapor to the total volume of moist air (TVMA) in which it is contained. In symbol form:

$$ABHU = MAWV/TVMA$$

It is a ratio of mass to volume; units used are grams of water vapor per cubic meter of moist air.

Relative humidity. Relative humidity (REHU) is a ratio expressing the observed or actual vapor pressure of the air (AVPA) compared to the saturation vapor pressure (SAVP) of the air at that temperature:

$$REHU = AVPA/SAVP$$

It is a dimensionless ratio, usually expressed as a percent, that can be interpreted only when air temperature is given because saturation vapor pressure is a function of air temperature.

LITERATURE CITED

Taylor, G. F. 1954. Elementary Meteorology. Prentice-Hall, Inc., NY. 364 p.

REFERENCES, UNIT 4.1

TERMS EXPRESSING HUMIDITY

CODEN VO-NU BEPA ENPA KEY WORDS---------- AUTHORS---------- YEAR

UNIT 4.2: THE CONCEPT OF SATURATION

Saturation suggests a fullness, a state in which something can hold no more; its space is occupied. Applying this concept to the atmosphere, saturation occurs when a gaseous component of the atmosphere is in equilibrium with a source of the gas, and molecules are exchanged equally between the source and the atmosphere. When the atmosphere is not in equilibrium with the source, molecules enter the atmosphere faster than they leave it. There must be a deficit for that to occur. These two ideas--saturation and deficit--are discussed below.

Water molecules continually escape from liquid water surfaces and enter the atmosphere, and water molecules from the atmosphere are continually absorbed by liquid water surfaces. The water vapor component of the atmosphere has weight and therefore exerts pressure on the earth's surface, just as the other gases in the atmosphere do. The water component of atmospheric pressure is called vapor pressure. When the molecular movement of water vapor is equal in both directions between the atmosphere-liquid interface, the atmosphere is saturated. Saturation vapor pressure is an expression of the vapor pressure component of such air. The vapor pressure may be expressed in mm of Hg, as in Moen (1973:102) or in mb, as in Rosenberg (1974:131).

Gates (1962) has an abbreviated table of vapor pressure values, shown below.

Vapor Pressure Values (mb)

	T					
R.H.	0°C	10°C	20°C	30°C	40°C	50°C
100%	6.1	12.3	23.4	42.4	73.8	123.4
50%	3.1	6.2	11.7	21.2	36.9	61.7

Note that the vapor pressure at 50% relative humidity is one-half that at 100%, except for rounding errors. The vapor pressure increases as temperature increases but the per cent relative humidity remains constant. The amount of evaporation that will occur depends on, among other things, the amount of additional vapor that the atmosphere can hold. This is often expressed as a vapor pressure deficit, and is simply the difference between the saturated vapor pressure and the actual vapor pressure at a given temperature.

Saturation vapor pressures (SAVP) increase with increasing air temperatures, and the relationship is exponential. In simple terms, warm air can hold more moisture than cool air. The logarithmic equation for determining saturation vapor pressure from air temperature calculated by Moen

(1973:102) based on data in the Handbook of Chemistry and Physics (Weast 1967) is, in mm Hg:

$$\log_e \text{SAVP} = (1.580 + 0.062 \text{ AITC})$$

which can be rewritten as:

$$\text{SAVP} = e^{(1.580 + 0.062 \text{ AITC})}$$

where SAVP = saturation vapor pressure, and
AITC = air temperature in Celsius.

This equation predicts the values tabulated in the Handbook of Chemistry and Physics with acceptable accuracy for ecological purposes; deviations range from 0.8% to 6.0%.

The vapor pressure deficit is the difference between the saturation vapor pressure SAVP, and the water vapor pressure of the air at a particular temperature. Since the ratio of actual vapor pressure to saturation pressure is the familiar term relative humidity, the saturation vapor pressure (SAVP) equation can be combined with the relative humidity ratio and the vapor pressure deficit, VPDE, determined. The formula is:

$$\text{VPDE} = \text{SAVP } [(100 - \text{PTRH})/100]$$

where PTRH = percent relative humidity. The equation, from Moen (1973: 102) is:

$$\text{VPDE} = e^{(1.580 + 0.062 \text{ AITC})}[(100 - \text{PTRH})/100]$$

Note that the first part of this equation is the saturation vapor pressure, and the second part, within the square brackets, the difference between 100 and observed percent relative humidity, which is converted to a decimal fraction by dividing by 100.

VPDE is expressed in mm of Hg, just as SAVP is. Complete the calculations for the two variables in this equation, AITC and PTRH, on the WORKSHEETS that follow.

LITERATURE CITED

Moen, A. N. 1973. Wildlife Ecology. W. H. Freeman Company, San Francisco. 458 p.

Rosenberg, N. J. 1974. Microclimate: The Biological Environment. John Wiley & Sons, N.Y. 315 p.

Weast, R. C., ed. 1967. Handbook of Chemistry and Physics. 48th ed. Cleveland: The Chemical Rubber Co.

REFERENCES, UNIT 4.2

THE CONCEPT OF SATURATION

SERIALS

CODEN	VO-NU	BEPA	ENPA	KEY WORDS----------	AUTHORS----------	YEAR
HYSBA	11--1	34	42	compar evaporatio fr snow, soil	hutchison,ba	1966
JGREA	67-12	4673	4682	evaporation of rain drops	abraham,ff	1962
MWREA	67--4	4	11	determin evapor, lnd, watr surf	thornthwaite,cw;	1939
PHDSA	2----	55	82	evaporation from land surfaces	king,km	1961
PHDSA	2----	135	167	evaporation comp, prair resrvoi	mckay,ga; stichli	1961
PHDSA	2----	8	30	energy budget, mass trans theor	munn,re	1961
XATBA	817--	1	145	measuring evap fr lnd, wat surf	thornthwaite,cw;	1942

OTHER PUBLICATIONS

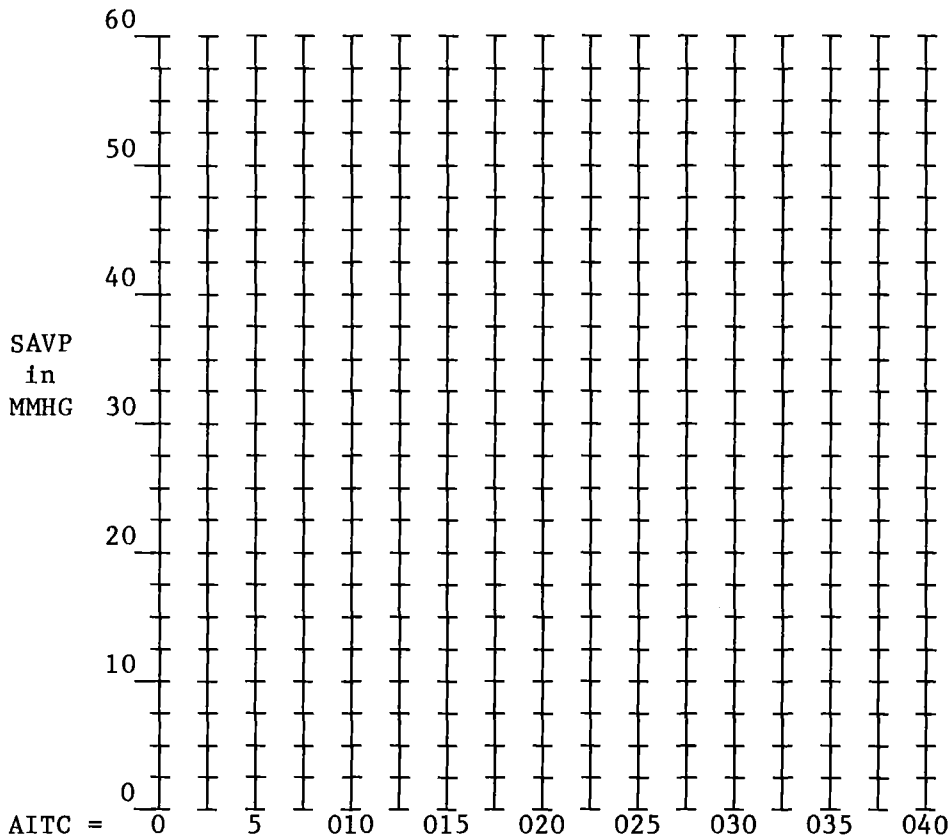
Thornthwaite, C. W. 1957. Instructions and Tables for Computing Potential Evapotranspiration and the Water Balance. Publications in Climatology, Laboratory of Climatology. Vol. 10, No. 3.

CHAPTER 14, WORKSHEET 4.2a

Saturation vapor pressure

A formula was given in UNIT 4.2 for saturation vapor pressure (SAVP). Air temperature in Celsius (AITC) is the independent variable. Use the formula below to calculate the saturation vapor pressure in mm of mercury (MMHG) for temperatures from 0 to 40°C and plot the curve.

$$SAVP = e^{(1.580 + 0.062\ AITC)}$$



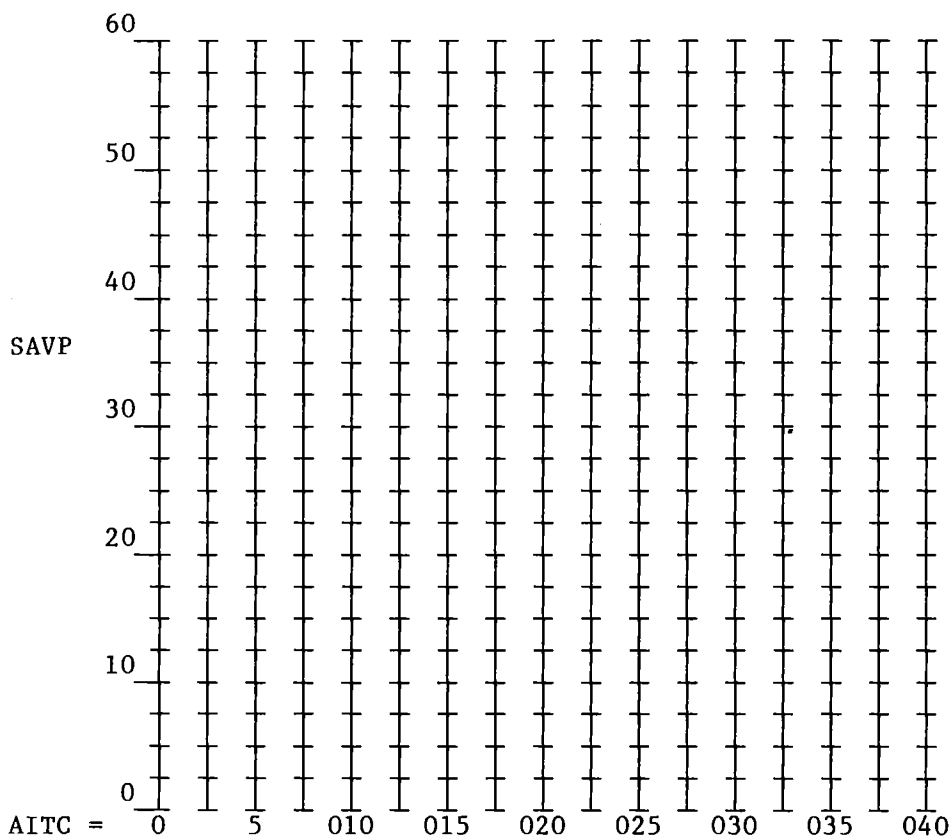
CHAPTER 14, WORKSHEET 4.2b

Vapor pressure deficits

Saturation vapor pressures, SAVP, were calculated in WORKSHEET 4.2a. Vapor pressure deficits are calculated by multiplying SAVP by relative humidity expressed as a decimal fraction and subtracting the product from SAVP. The equation is:

$$VPDE = e^{(1.580 + 0.062\ AITC)}[(100 - PTRH)/100]$$

Complete the calculations of VPDE for a family of curves for REHU = 10-90% and plot them below.

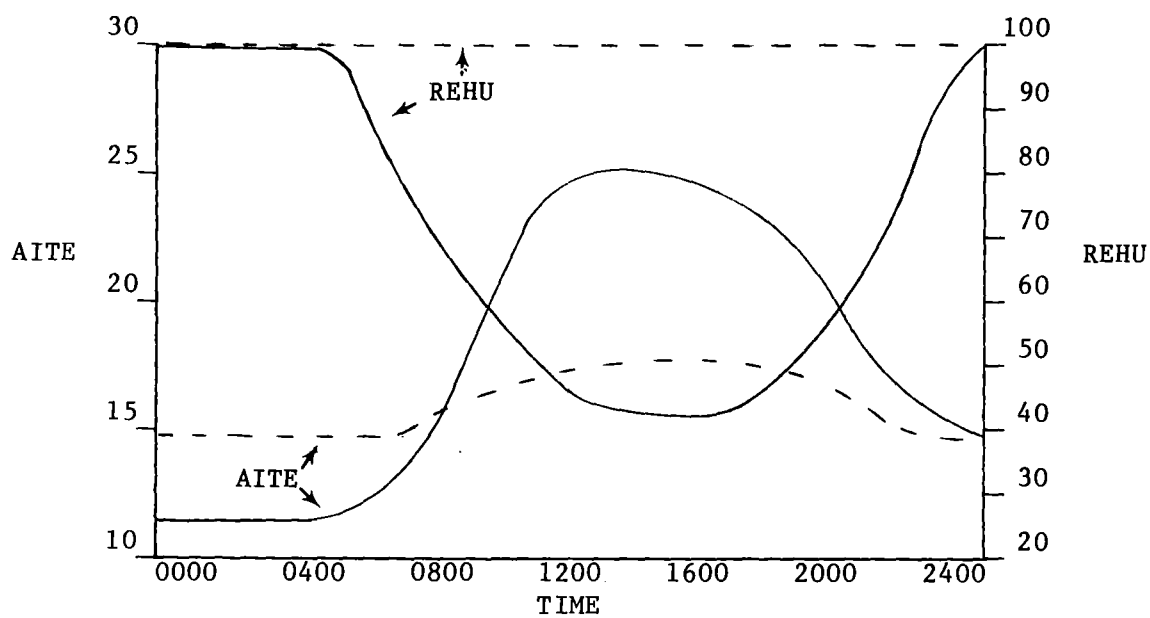


UNIT 4.3: TEMPORAL PATTERNS OF ATMOSPHERIC HUMIDITY

There are daily and seasonal patterns to the amounts of water vapor in the atmosphere. The warmer air characteristic of mid-afternoon has the potential for holding more water vapor than the cooler morning, evening, and night-time air. Warmer summer atmospheres have the potential for holding more water vapor than cooler winter atmospheres.

An interesting and sometimes overlooked relationship exists between the temporal patterns of relative humidity, vapor pressures, and vapor pressure deficits through daily and seasonal cycles. The atmosphere at the earth's surface is at or near saturation at night when skies are clear. Then, there is a large amount of radiational cooling, and dew forms as atmospheric water vapor condenses on cool vegetation surfaces. The relative humidity is at or near 100%. After the sun rises the atmospheric temperature tends to rise, dew evaporates, and relative humidity goes down. However, the vapor pressure may actually increase because the warmer air can hold more water vapor than the cooler air. Further, the vapor pressure deficit will actually increase, too, if there is not enough moisture available for atmospheric absorption. Thus the pattern of relative humidity, being it is so temperature dependent, is not a good indicator of atmospheric moisture, and expressions of relative humidity without air temperatures are of little use for ecological purposes.

Results of air temperature and relative humidity measurements are shown below for two combinations of air temperature and relative humidity. Note that relative humidity dropped to minimum when air temperature reached maximum on a warm sunny afternoon (solid line), and that relative humidity remained at 100% on a day when air temperature changed very little (dashed line).



REFERENCES, UNIT 4.3

TEMPORAL PATTERNS OF ATMOSPHERIC HUMIDITY

BOOKS

TYPE	PUBL	CITY	PAGE	ANIM	KEY WORDS----------	AUTHORS/EDITORS--	YEAR
edbo	pepr	oxen	813		p. 381-390, sym for hydro	sopper,we; lull,h	1967
edbo	pepr	oxen	813		p. 451-462, sym for hydro	sopper,we; lull,h	1967

SERIALS

CODEN	VO-NU	BEPA	ENPA	KEY WORDS----------	AUTHORS----------	YEAR
AJBOA	29-10	828	832	species diff, water absorption	kramer,pj	1942
FOSCA	1....	258	264	soil water depletion by fo stan	zahner,r	1955
FOSCA	4---3	178	184	water depletion hardwood unders	zahner,r	1958
IAXNA	128..	----	----	evaluati hamon meth, pot evapo	russell,rl; bogge	1964
JECOA	51--1	191	203	stud water relati, p sylvestris	rutter,aj	1963
JFUSA	50-10	746	747	evaporation in nature	stone,el,jr	1952
JFUSA	59--3	175	181	water use by brush, groun, gr-f	rowe,pb; reimann,	1961
JGREA	65-10	3391	3413	potential evapotransp esti meth	tanner,cb; pelton	1960
JGREA	68-20	5719	5724	infl soil water transpor by pla	gardner,wr; ehlig	1963
JYCEA	87...	107	120	HY3, pt 1, est pot evaporatrans	hamon,wr; asce,a	1961
PRSLA	193..	120	145	natur evaporat wat, soil, grass	penman,hl	1948
SSSAA	21--5	464	468	rel soil, plant met fac, evapor	lemon,er; glaser/	1957
TACEA	117--	974	987	forest range vegeta, use of wat	rich,lr	1952
WRERA	2---1	71	84	conc mod stomat contr mechanism	woo,kb; stone,ln	1966
WRERA	2---1	85	97	dynamic simu model transpi proc	woo,kb; boersma,	1966
XAMPA	257--	1	97	water util by trees, no tempera	raber,o	1937

OTHER PUBLICATIONS

Thornthwaite, C. W. 1954. A re-examination of the concept and measurement of potential evapotranspiration. Publications in Climatology, Lab. of Climatology. Vol. 8(1): 200-209.

CHAPTER 14, WORKSHEET 4.3a

Temporal patterns of air temperature, relative humidity, and vapor pressure deficit

The tracings of air temperatures and relative humidities given in UNIT 4.3 may be used to determine hourly vapor pressure deficits for these days. Read the grids, calculate VPDE using the formula below from UNIT 4.2, and plot the results.

$$VPDE = e^{(1.580 + 0.062\ AITC)}[(100 - PTRH)/100]$$