Lab

5

Atmospheric Moisture

Concepts about atmospheric humidity will be introduced in this lab along with the role of atmospheric moisture in the formation of clouds and precipitation.

Moisture

In terms of weather, **water vapor** is the most important of all atmospheric gases. The amount of moisture present in an air mass has a direct influence on cloud formation and possible precipitation within that air mass. The presence of this water vapor is referred to as **humidity**, and its measurement at a particular time and place may be expressed in several ways. Each of these provides different information about the amount of water present

- Vapor pressure (mb) is the pressure exerted by water vapor molecules.
- Dew point (°C or °F) is the temperature at which condensation begins as an air parcel cools (assuming no change in moisture).
- Relative humidity (%) is the moisture content relative to the saturation point.

Relative Humidity is the most common measurement of water vapor content within the air. Briefly defined, relative humidity (R.H.) is the amount of water vapor actually present in the air relative to the capacity amount it is capable of holding at a given temperature. The **capacity** (or maximum) amount of gaseous water vapor is known as the saturation amount. At **saturation**, the relative humidity is equal to 100 percent. Temperature is a critical factor in influencing the point at which saturation is reached. To determine the R.H., the actual number of water molecules present in a given amount of air is divided by the maximum number of water molecules possible in that amount of air (at the same temperature).

$$\frac{\text{Actual Water Vapor}}{\text{Capacity (maximum)}} * 100 = \text{Relative Humidity (\%)} \qquad \text{OR}$$

$$\text{Actual Water Vapor} = \frac{\text{Relative Humidity (\%)} * \text{Capacity}}{100}$$

At any given temperature, there is an upper limit on the amount of water that can exist as a gas. When that limit is reached, the atmosphere is said to be saturated; any additional water condenses to liquid. The saturation point increases with increasing temperature and decreases with decreasing temperature. When water vapor reaches the saturation point, the air temperature at which this occurs is termed the **dew point** temperature. Although dew point is a temperature, it also indicates moisture content. If dew point is low, the atmosphere is considered dry. If dew point is high, the atmosphere is moist. Dew point is always less than or equal to the current air temperature.

Water vapor molecules exert a certain amount of pressure on the surrounding atmosphere. This **water vapor pressure** varies according to the amount or concentration of water molecules in a given parcel of air. We can measure this amount of vapor pressure in **millibars** (mb) and also utilize this measure to determine saturation and relative humidity. We can substitute these terms in the previous R.H. equation:

$$\frac{\text{Actual Vapor Pressure (mb)}}{\text{Saturation Vapor Pressure (mb)}} * 100 = \text{Relative Humidity (\%)}$$

Therefore, the maximum possible or "upper limit" of atmospheric vapor pressure is referred to as **saturation vapor pressure**. As the temperature of a parcel of air increases, the saturation vapor pressure will increase proportionally.

Recap:

Saturation amounts may be expressed as a percentage (R.H.), or as millibars of vapor pressure or as weights of water vapor per weight of dry air. The pressure exerted by water vapor at saturation is called saturation vapor pressure. When the air is saturated with water vapor its relative humidity has reached 100% and the air temperature is the same as the dew point. The higher the dew point, the greater the amount of water vapor in the air.

A commonly used term by meteorologists to express humidity is the **mixing ratio**. The capacity amount of water vapor using the mixing ratio is known as the **saturation mixing ratio**.

Useful equations to determine R.H. are summarized below:

Water Vapor Pressure (mb)

$$\frac{\text{Actual water vapor pressure (mb)}}{\text{Saturation water vapor pressure (mb)}} * 100 = \text{Relative Humidity (\%)}$$

Mixing Ratio

$$\frac{\text{Actual mixing ratio (g/kg)}}{\text{Saturation mixing ratio (g/kg)}} * 100 = \text{Relative Humidity (\%)}$$

Figure 5.1 (next page) is a graph, which shows the relationship between air temperature (x – axis) and the capacity of the air to hold water vapor (y-axis) at different temperatures. This graph shows that as air becomes warmer, its capacity to hold moisture increases, and it increases at a geometric rate.

Figure 5.1 Temperature & Water Vapor Capacity (Mixing Ratio)

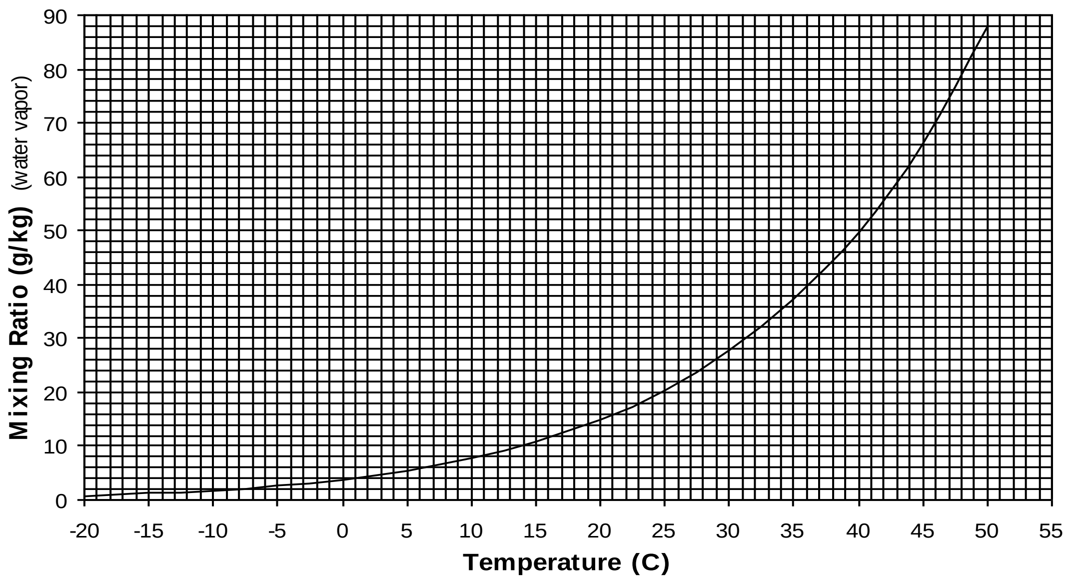

Table 5.1 (next page) provides the Saturation Mixing Ratio (or capacity of the air to hold moisture at a given temperature).

One can find the relative humidity of the air if you know the amount of water vapor in the air and the temperature of the air. For example, using Table 5.1: if the air is 15° C and there are 5 grams of moisture in the air the relative humidity will be:

$$\textbf{Relative Humidity} = \frac{\textbf{Actual Water Vapor}}{\textbf{Capacity (maximum)}} \quad \frac{(5)}{(10)} = 0.5 * 100 = 50\%$$

One can also find the actual water vapor of the air if you know the relative humidity and the temperature of the air. For example, using Table 5.1: if the air is 15° C and the relative humidity is 50%, the actual water vapor will be:

$$\textbf{Actual Water Vapor} = \frac{\textbf{Relative Humidity * Capacity}}{100}$$

Actual Water Vapor = (50 * 10)/100 = 500/100 = 5 grams

A Note on Temperature Scales (°F and °C):

There are three main temperature scales: Celsius (metric), Fahrenheit (English), and Kelvin (scientific). In labs we will be using both the Celsius and the Fahrenheit scales.

Conversions:

°F – (1.8 * °C) + 32 $\qquad$ $°C = \frac{°F - 32}{1.8}$ $\qquad$ °K = °C + 273

Melting Point of Ice	=	0 °C,	32 °F,	273 °K
Boiling Point of Water	=	100 °C,	212 °F,	373 °K

Exercise #5a Lab Activity Name: ______________________________

Moisture Lab Section: ______________________________

Please show your work. If necessary please use additional paper to show work.

Table 5.1 Capacity Table (Saturation Mixing Ratio) (at Sea-Level Pressure)

Temperature	°C	*(°F)*	Capacity *(Saturation Mixing Ratio g/kg)*
	-40	(-40)	0.1
	-30	(-22)	0.3
	-20	(-4)	0.75
	-10	(14)	2
	0	(32)	3.5
	5	(41)	5
	10	(50)	7
	15	(59)	10
	20	(68)	14
	25	(77)	20
	30	(86)	26.5
	35	(95)	35
	40	(104)	47

✏ 1. Based on Table 5.1, what is the **Capacity** (Saturation Mixing Ratio) of:

a. -30 °C air mass ______________________________

b. 5°C air mass ______________________________

c. 40°C air mass ______________________________

✏ 2. What pattern do you notice with the Capacity as air temperature rises?

✏ 3 If a parcel of air at 20°C contains 5 grams of water vapor per kilogram of air, what is its relative humidity?

✏ 4. If a parcel of air at 30°C contains 5 grams of water vapor per kilogram of air, what is its relative humidity?

✏ 5. If the same parcel of air (30°C) dropped in temperature to 5°C, how would the relative humidity change?

✐ 6. If a parcel of air at 15°C contains 10 grams of water vapor per kilogram of air, what is its relative humidity?

✐ 7. What is the actual water vapor amount in 20°C air when the relative humidity is 50%?

✐ 8. If a 25°C air mass is saturated, what is the actual water vapor amount?

✐ 9. What is the dew point of a 25°C parcel of air containing 14 grams of water vapor per kg of air?

✐ 10. On a cold day in December the relative humidity measures 20% and on a hot day in August, the relative humidity also measures 20%. Does this indicate the same water vapor presence on both days? Explain your answer.

✐ 11. During the winter months, cold air is brought into homes and heated. Explain how this process changes the relative humidity in the house. In order to compensate for this phenomenon many homes utilize an appliance to keep their surroundings comfortable; what might this be?

✐ 12. An air mass with a temperature of 5°C is saturated. If this air is brought into a house and heated up to 25°C, what is the relative humidity of this air in the house?

✐ 13. Cold, continental polar air is often described as being dry even when its relative humidity is very high. Why is this so?

Determining Relative Humidity and Dew Point Temperature based on the Sling Psychrometer

The sling psychrometer is an easy and accurate instrument for making observations of relative humidity and dew point temperature. The instrument is made up of two thermometers. One of the thermometers has a wet cloth, or "sock," over it and is known as the **wet bulb**, while the other has nothing on it and is known as the **dry bulb**. The dry bulb and the wet bulb are swung together in the air and the dry bulb records the air temperature while the resulting evaporation of water from the "sock" reduces the temperature of the wet bulb.

The temperature of the wet bulb is either the same as or less than the dry bulb. When water is evaporated from the sock, the cooling effect of evaporation reduces the temperature of the wet bulb. The greater the difference between the wet bulb and the dry bulb, the drier the air is because more water is able to evaporate and thus there is more of a cooling effect on the wet bulb. When the air is near saturation, that is, has a high relative humidity, very little water will evaporate from the wet bulb and thus the temperature of the two thermometers will be close to each other. The difference in temperature between the two bulbs equals the **wet bulb depression** (**WBD**). The wet bulb depression and the air temperature (dry bulb reading) are used with specific tables to find either the dew point temperature or the relative humidity, or both. Table 5.2 (Relative Humidity Table) and Table 5.3 (Dew Point Table) will be used in the following exercise.

Dry Bulb Temperature = Air Temperature

Dry Bulb Temperature – Wet Bulb Temperature = Wet Bulb Depression

Example: finding Relative Humidity and Dew Point Temperature using the Sling Psychrometer:

If the dry bulb temperature reading is 70° F and the wet bulb reading is 60° F, then the wet bulb depression is found as follows: 70° F - 60° F = 10° F. Now go to table 5.2 (Relative Humidity Table) and read **down** the left hand column (air temperature, which is dry bulb temperature) to 70° F and then read **across** the top of the table (wet bulb depression) to a value of 10° . You get your answer by tracing the column down from 10° (wet bulb depression) to where it meets the row from 70° F air temperature. The reading will be **55%** Relative Humidity.

Doing the same with the Dew Point Table (Table 5.3) you should get the answer **53° F** for the dew point temperature.

Exercise #5b Lab Activity Name: ______________________________

Moisture Lab Section: ______________________________

Please show your work. If necessary please use additional paper to show work.

Using Tables 5.2 and 5.3 answer the following questions.

✎ 1. With a sling psychrometer, you measure an air temperature of 60° F (dry bulb temperature) and a wet-bulb temperature of 55°F.

a. What is the wet-bulb depression? ______________________________

b. What is the dew point temperature? ______________________________

c. What is the relative humidity of the air? ______________________________

✎ 2. An air mass has a temperature of 80°F and a depression of 13 degrees, what is:

a. The wet-bulb depression? ______________________________

b. The relative humidity of the air? ______________________________

c. The dew point temperature of the air? ______________________________

✎ 3. If the relative humidity of an air mass is 70% and the temperature of the air is 20°F,

a. what is the wet bulb temperature? ______________________________

b. what is the dew point temperature of the air? ______________________________

✎ 4. If the amount of water vapor in the air decreases and the temperature of the air stays constant, will the dew point temperature increase, decrease, or stay the same and why?

✎ 5. If the amount of water vapor in the air stays constant and the temperature of the air decreases, will the RH increase, decrease, or stay the same and why?

Table 5.2 Relative Humidity Chart

Relative Humidity (in percent)

Air Temperature °F	Depression of Wet-Bulb Thermometer (°F) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
0	67	33	1																																
5	73	46	20																																
10	78	56	34	13	15																														
15	82	64	46	29	11																														
20	85	70	55	40	26	12																													
25	87	74	62	49	37	25	13	1																											
30	89	78	67	56	46	36	26	16	6																										
35	91	81	72	63	54	45	36	27	19	10	2																								
40	92	83	75	68	60	52	45	37	29	22	15	7																							
45	93	86	78	71	64	57	51	44	38	31	25	18	12	6																					
50	93	87	74	67	61	55	49	43	38	32	27	21	16	10	5																				
55	94	88	82	76	70	65	59	54	49	43	38	33	28	23	19	11	9	5																	
60	94	89	83	78	73	68	63	58	53	48	43	39	34	30	26	21	17	13	9	5	1														
65	95	90	85	80	75	70	66	61	56	52	48	44	39	35	31	27	24	20	16	12	9	5	2												
70	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36	33	29	25	22	19	15	12	9	6	3										
75	96	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	21	18	15	12	9	7	4	1							
80	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44	41	38	35	32	29	26	23	20	18	15	12	10	7	5	3					
85	96	92	88	84	81	77	73	70	66	63	59	57	53	50	47	44	41	38	36	33	30	27	25	22	20	17	15	13	10	8	6	4	2		
90	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49	47	44	41	39	36	34	31	29	26	24	22	19	17	15	13	11	9	7	5	3
95	96	93	89	86	82	79	76	73	69	66	63	61	58	55	52	50	47	44	42	39	37	34	32	30	28	25	23	21	19	17	15	13	11	10	8
100	96	93	89	86	83	80	77	73	70	68	65	62	59	56	54	51	49	46	44	41	39	37	35	33	30	28	26	24	22	21	19	17	15	13	12
105	97	93	90	87	84	81	78	75	72	69	66	64	61	58	56	53	51	49	46	44	42	40	38	36	34	32	30	28	26	24	22	21	19	17	15
110	97	93	90	87	84	81	78	75	73	70	67	65	62	60	57	55	52	50	48	46	44	42	40	38	36	34	32	30	28	26	25	23	21	20	18
115	97	94	91	88	85	82	79	76	74	71	69	66	64	61	59	57	54	52	50	48	46	44	42	40	38	36	34	33	31	29	28	26	25	23	21
120	97	94	91	88	85	82	80	77	74	72	69	67	65	62	60	58	55	53	51	49	47	45	43	41	40	38	36	34	33	31	29	28	26	25	23
125	97	94	91	88	86	83	80	78	75	73	70	68	66	64	61	59	57	55	53	51	49	47	45	44	42	40	38	37	35	33	32	30	29	27	26
130	97	94	91	89	86	83	81	78	76	73	71	69	67	64	62	60	58	56	54	52	50	48	47	45	43	41	40	38	37	35	33	32	30	29	28

Table 5.3 Dew Point Chart

Temperature of Dew Point (Fahrenheit)

Air Temperature (°F)	Vapor Pressure (In.)	Depression of Wet-Bulb Thermometer (°F)															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	0.0383	−7	−20														
5	0.0491	−1	−9	−24													
10	0.0631	5	−2	−10	−27												
15	0.0810	11	6	0	−9	−26											
20	0.103	16	12	8	2	−7	−21										
25	0.130	22	19	15	10	5	−3	−15	−51								
30	0.164	27	25	21	18	14	8	2	−7	−25							
35	0.203	33	30	28	25	21	17	13	7	0	−11	−41					
40	0.247	38	35	33	30	28	25	21	18	13	7	−1	−14				
45	0.298	43	41	38	36	34	31	28	25	22	18	13	7	−1	−14		
50	0.360	48	46	44	42	40	37	34	32	29	26	22	18	13	8	0	-13
55	0.432	53	51	50	48	45	43	41	38	36	33	30	27	24	20	15	9
60	0.517	58	57	55	53	51	49	47	45	43	40	38	35	32	29	25	21
65	0.616	63	62	60	59	57	55	53	51	49	47	45	42	40	37	34	31
70	0.732	69	67	65	64	62	61	59	57	55	53	51	49	47	44	42	39
75	0.866	74	72	71	69	68	66	64	63	61	59	57	55	54	51	49	47
80	1.022	79	77	76	74	73	72	70	68	67	65	63	62	60	58	56	54
85	1.201	84	82	81	80	78	77	75	74	72	71	69	68	66	64	62	61
90	1.408	89	87	86	85	83	82	81	79	78	76	75	73	72	70	69	67
95	1.645	94	93	91	90	89	87	86	85	83	82	80	79	78	76	74	73
100	1.916	99	98	96	95	94	93	91	90	89	87	86	85	83	82	80	79
105	2.225	104	103	101	100	99	98	96	95	94	93	91	90	89	87	86	84
110	2.576	109	108	106	105	104	103	102	100	99	98	97	95	94	93	91	90
115	2.975	114	113	112	110	109	108	107	106	104	103	102	101	99	98	97	96
120	2.425	119	118	117	115	114	113	112	111	110	108	107	106	105	104	102	101
125	3.933	124	123	122	121	119	118	117	116	115	114	112	111	110	109	108	106
130	4.504	129	128	127	126	124	123	122	121	120	119	118	116	115	114	113	112