The Origin of the Atmosphere

- The gases that made up our early atmosphere likely came from volcanoes through the process of ***outgassing***.

- Large amounts of water vapor from these volcanoes eventually condensed to form the oceans.

- The first life forms converted carbon dioxide into oxygen to form our modern atmosphere.

The Structure of the Atmosphere

- The atmosphere is made up of four layers:

    - Troposphere: the lowest layer, ***where all weather occurs*** and where most of the gases are found

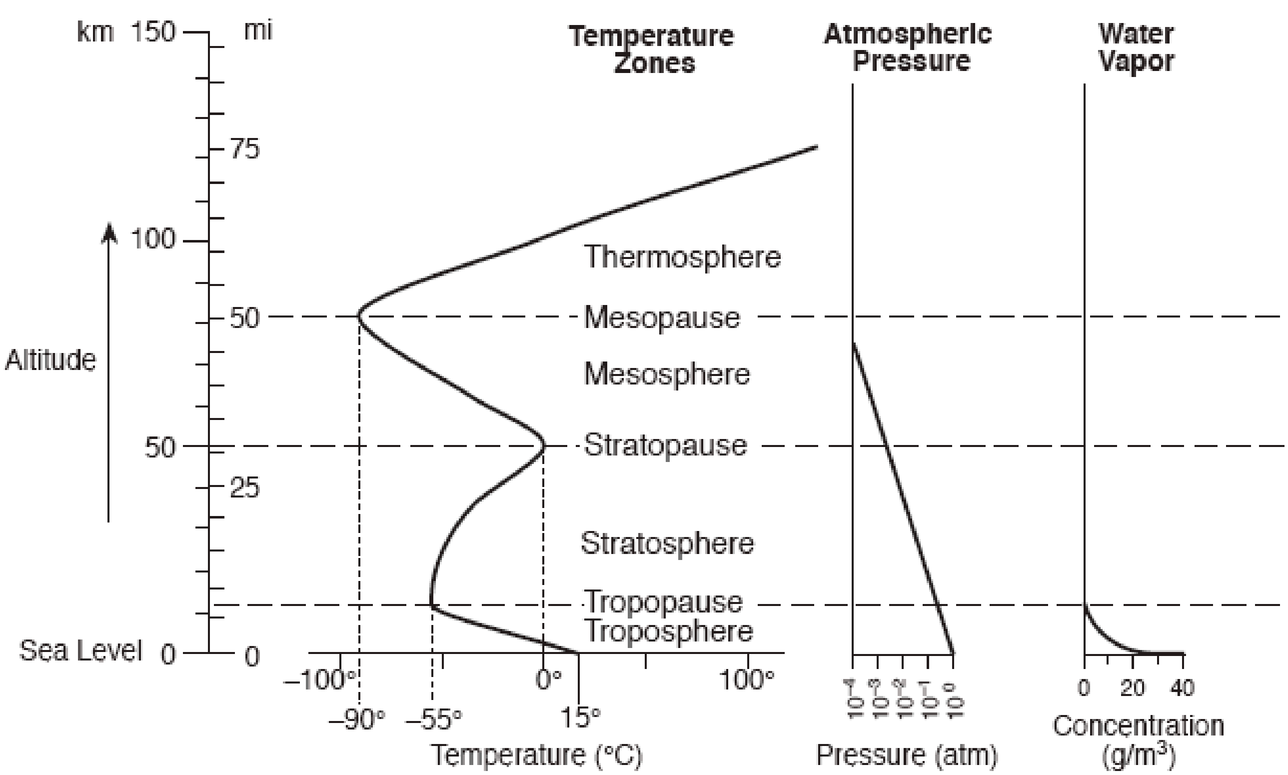
    - Stratosphere: the second layer up, ***where the ozone layer is found***

    - Mesosphere: the third layer up

    - Thermosphere: the fourth layer up

- These layers are all separated by ***pauses*** (i.e. the tropopause, stratopause, etc.)

- "*Selected Properties of the Earth's Atmosphere*" in the ESRTs will illustrate how temperature, air pressure, and water vapor concentration change as you travel up through these layers.

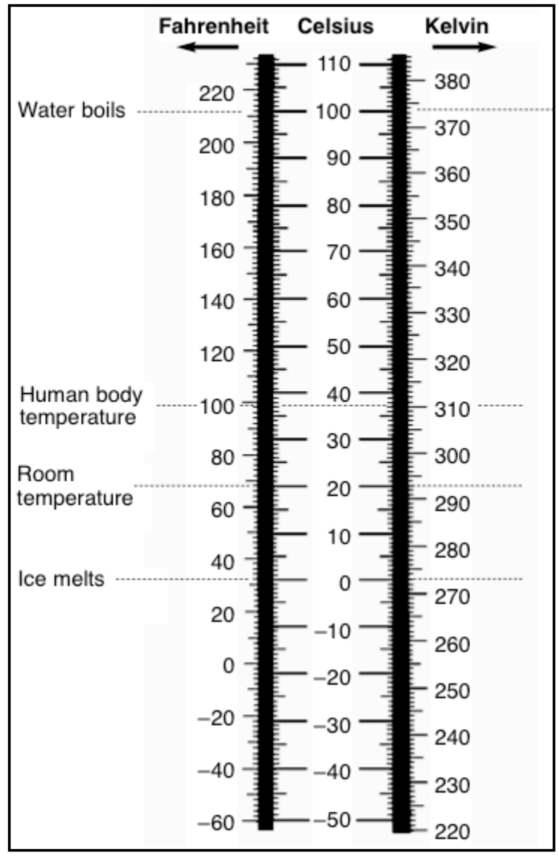


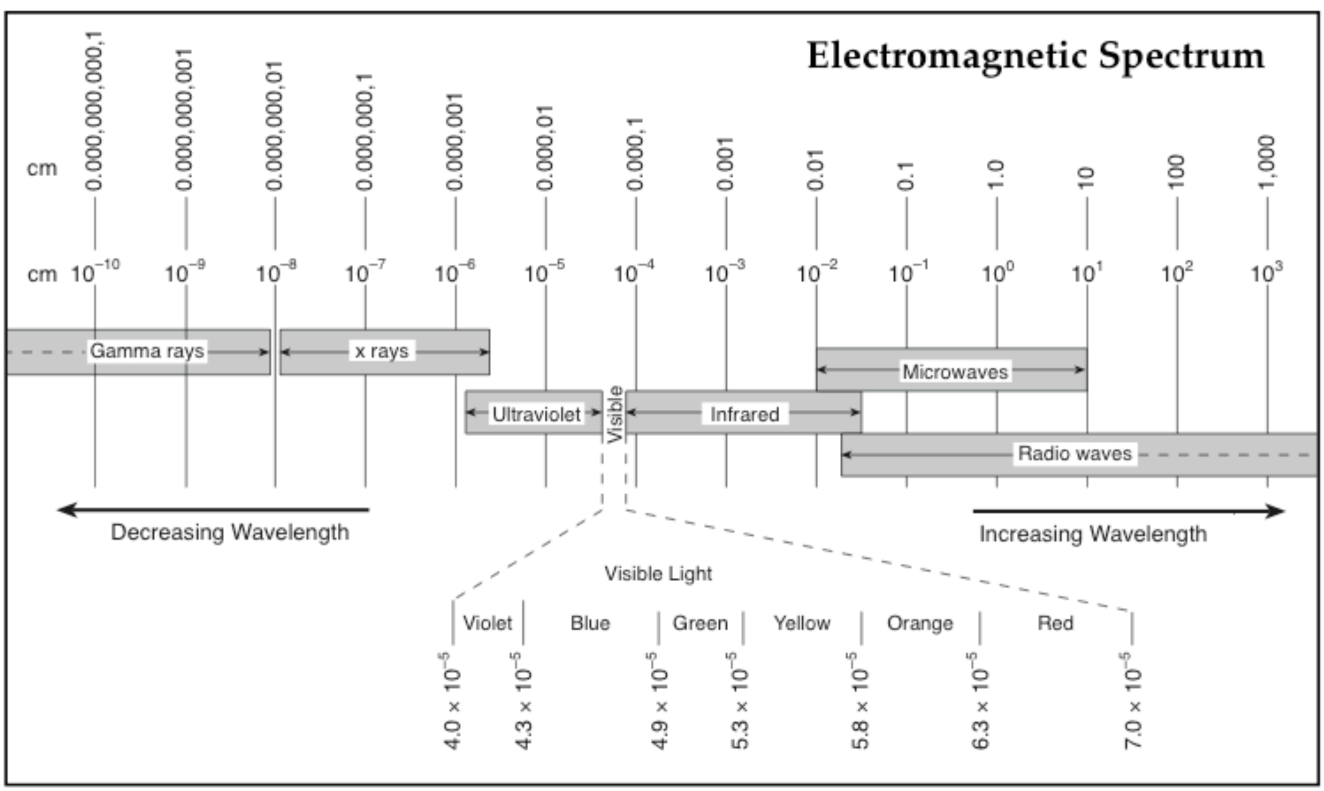
Changes in Air Temperature

- Temperature changes are generally cyclic.
    - It is generally colder in the early morning and warmer in the afternoon

      and

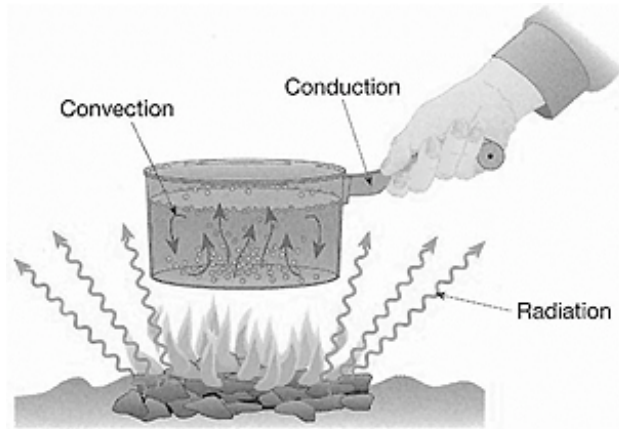
    - It is generally colder in the winter and warmer in the summer (in the N. hemisphere)
- Temperate is measured with an instrument called a ***thermometer***.
- The three temperature scales are ***Fahrenheit***, ***Celsius***, and ***Kelvin***. Conversions between each scale can be made using the "*Temperature*" diagram in the ESRTs
- Everything emits energy as long as it has a temperature above absolute zero (0°K), the temperature at which all molecular motion stops..
- All types of energy (electromagnetic radiation) can be found on the "*Electromagnetic Spectrum*" in the ESRT's.



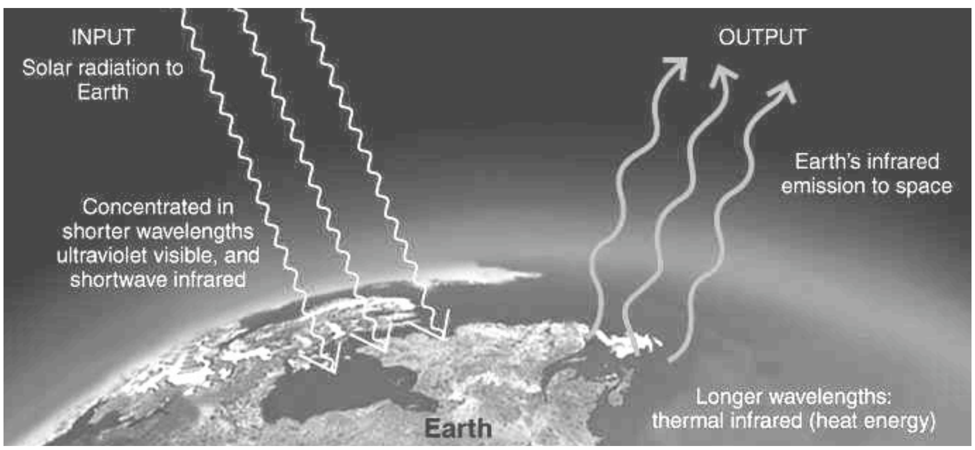


How Does Heat Energy Travel?

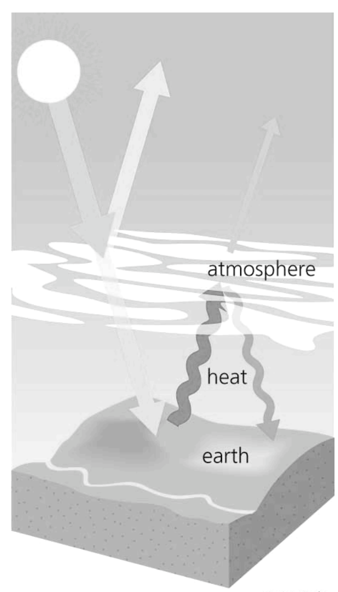
- The energy that heats the Earth comes from the Sun and is called ***insolation***. 90% of insolation is in the form of visible light (short-wave)
- Insolation travels from place to place in one of three ways:
  - ***Convection***- heat transfer caused by differences in density (LIQUID/GAS)
  - ***Conduction***- heat flow resulting from contact between two substances (SOLID)
  - ***Radiation***- heat flow in the form of waves through space (NO MEDIUM REQUIRED)



- Heat always flows from ***source*** (hot) to ***sink*** (cold)



- Insolation reaches the Earth through radiation, It comes to the Earth as short-wave visible light is absorbed and then emitted back out as long-wave infrared.



- ***Dark, rough surfaces absorb high amounts of energy.***
- ***Light, smooth surfaces reflect high amounts of energy.***
- As insolation travels through the Earth's atmosphere, some passes through to the surface, some is ***reflected*** back to space, some is ***scattered*** throughout the atmosphere, and some is ***refracted***, or bent.
- The Earth's atmosphere allows visible light to enter, but increasing levels of carbon dioxide are trapping the infrared causing global temperatures to rise. This is called the ***Greenhouse Effect***.

Specific Heat

- ***Specific heat*** is the amount of heat energy required to heat up a substance,
- The higher the specific heat, the longer it takes to heat up and cool down.
- The lower the specific heat, the faster it heats up and cools down.
- Water has the highest specific of any substance on Earth which means it takes a lot of energy and a long time to raise it's temperature. Additionally, it means that water will hold on to heat energy for a long time (it will cool slowly).
- Oceans remain cooler in the summer and warmer in the winter which keeps coastal locations from having extreme climates.
- Substances like metals generally have low specific heats meaning they will heat up quickly and cool off quickly.

Specific Heats of Common Materials

MATERIAL	SPECIFIC HEAT (Joules/gram • °C)
Liquid water	4.18
Solid water (ice)	2.11
Water vapor	2.00
Dry air	1.01
Basalt	0.84
Granite	0.79
Iron	0.45
Copper	0.38
Lead	0.13

- The specific heats of common substances can be found on the cover of the ESRTs.

Properties of Water

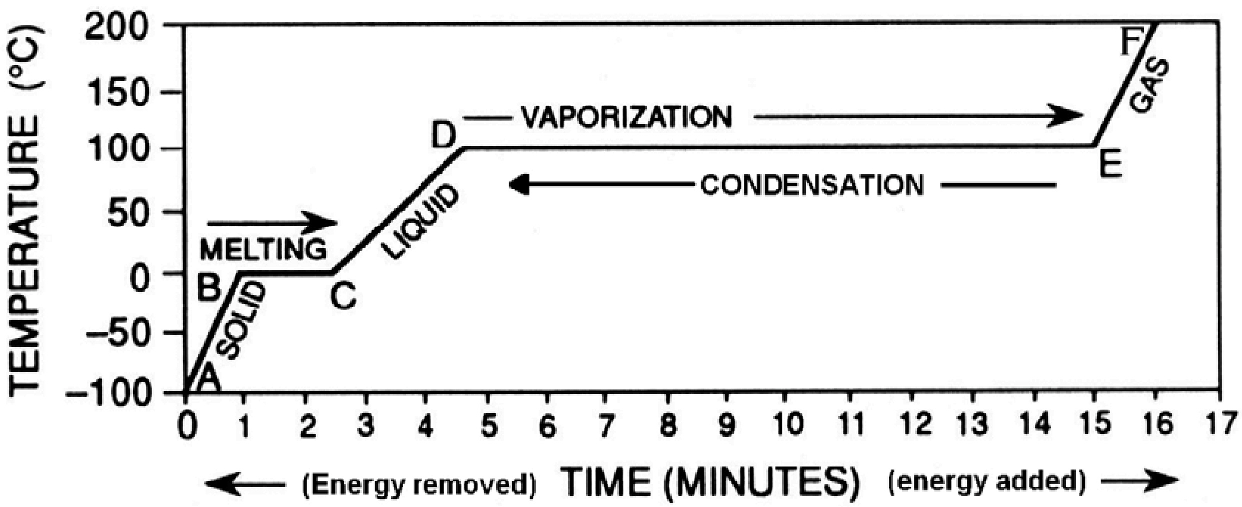
Heat energy gained during melting	334 J/g
Heat energy released during freezing	334 J/g
Heat energy gained during vaporization	2260 J/g
Heat energy released during condensation	2260 J/g
Density at 3.98°C	1.0 g/mL

Phase Changes of Water

- Water exists on Earth in three phases: solid, liquid, and gas.

- Phase changes:
    - solid to liquid: melting
    - liquid to gas: evaporation
    - gas to liquid: condensation
    - liquid to solid: freezing
    - solid to gas: sublimation
- Adding or removing energy from the water will result in a phase change.

- The graph below illustrates these phase changes.



- From left to right, equal amounts of heat energy (in joules) are being added to the water each minute.
- From right to left, equal amounts of heat energy (in joules) are being removed from the water each minute. This heat goes into the environment.

- Left to Right (heat energy being added):
- From A to B, ice is warming (temperature change)
- From B to C, ice is melting (phase change)
- From C to D, water is warming (temperature change)
- From D to E, water is evaporating or vaporizing (phase change)
- From E to F, water vapor is warming (temperature change)

- Right to Left (heat energy being removed):
- From F to E, water vapor is cooling (temperature change)
- From E to D, water vapor is condensing (phase change)
- From D to C, water is cooling (temperature change)
- From C to B, water is freezing (phase change)
- From B to A, ice is cooling (temperature change)

- Note: The most energy is gained or lost between points D and E (E and D).

Moisture in the Atmosphere (Dew-point)

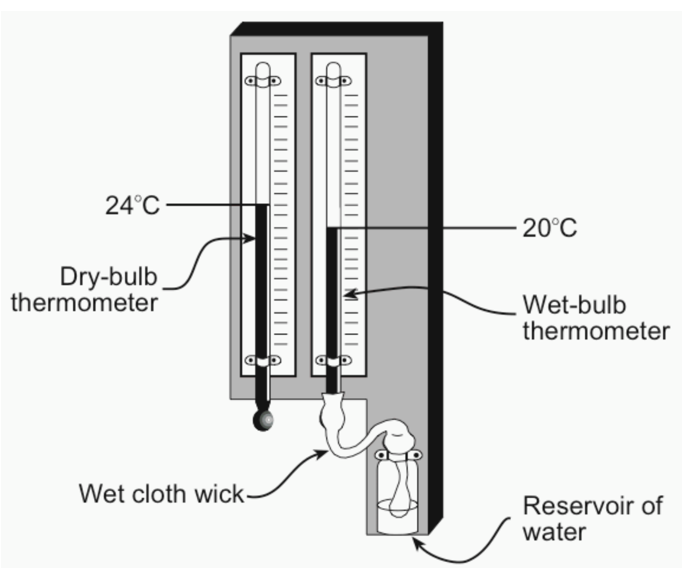
- When the air is holding as much moisture, or water vapor, as it can, it is said to be ***saturated***.
- Hotter air is able to hold much more moisture than colder air. As air warms, for every 10°C increase in temperature, the air can hold twice as much moisture.
- If you take an ***unsaturated*** air mass and cool it, it will eventually become saturated. The temperature at which it becomes saturated is known as the ***dew-point***.

Measuring Moisture in the Atmosphere

- A ***sling psychrometer*** is used to measure the amount of moisture in the air.
- To calculate the dew point, you must also use the "*Dew-point Temperatures*" ESRT.
- A sling psychrometer is made of two thermometers connected together on a handle that allows them to be swung through the air. One thermometer has a wet piece of cloth over the bulb (known as the ***wet-bulb***), the other is dry (known as the ***dry-bulb***). As you swing the psychrometer around the water on the wet-bulb will evaporate, removing heat energy from the air causing that thermometer to record a lower temperature. The dry-bulb simply records the actual air temperature. The wet-bulb temperature will always be lower than the dry-bulb temperature.

Dewpoint Temperatures (°C)

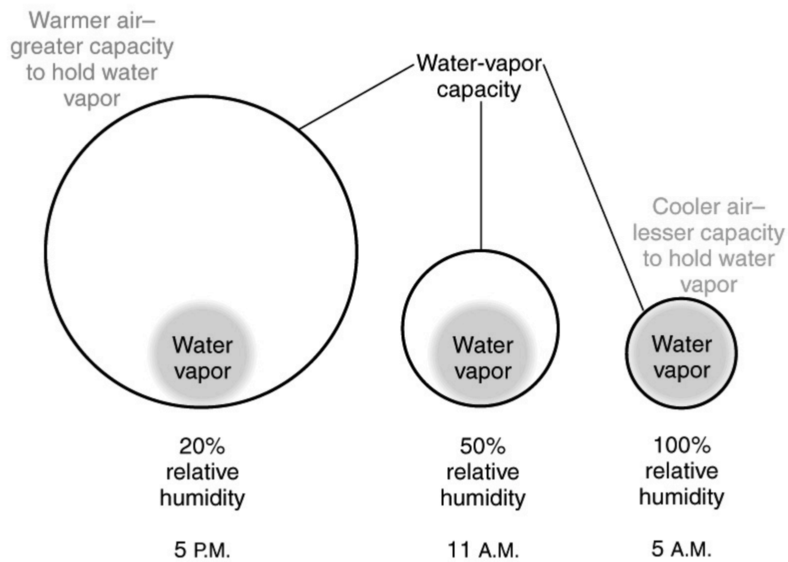
Dry-Bulb Temperature (°C)	Difference Between Wet-Bulb and Dry-Bulb Temperatures (C°)															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
−20	−20	−33														
−18	−18	−28														
−16	−16	−24														
−14	−14	−21	−36													
−12	−12	−18	−28													
−10	−10	−14	−22													
−8	−8	−12	−18	−29												
−6	−6	−10	−14	−22												
−4	−4	−7	−12	−17	−29											
−2	−2	−5	−8	−13	−20											
0	0	−3	−6	−9	−15	−24										
2	2	−1	−3	−6	−11	−17										
4	4	1	−1	−4	−7	−11	−19									
6	6	4	1	−1	−4	−7	−13	−21								
8	8	6	3	1	−2	−5	−9	−14								
10	10	8	6	4	1	−2	−5	−9	−14	−28						
12	12	10	8	6	4	1	−2	−5	−9	−16						
14	14	12	11	9	6	4	1	−2	−5	−10	−17					
16	16	14	13	11	9	7	4	1	−1	−6	−10	−17				
18	18	16	15	13	11	9	7	4	2	−2	−5	−10	−19			
20	20	19	17	15	14	12	10	7	4	2	−2	−5	−10	−19		
22	22	21	19	17	16	14	12	10	8	5	3	−1	−5	−10	−19	
24	24	23	21	20	18	16	14	12	10	8	6	2	−1	−5	−10	−18
26	26	25	23	22	20	18	17	15	13	11	9	6	3	0	−4	−9
28	28	27	25	24	22	21	19	17	16	14	11	9	7	4	1	−3
30	30	29	27	26	24	23	21	19	18	16	14	12	10	8	5	1



- To find the dew-point, record the dry and wet-bulb temperatures. Find the dry-bulb temperature on the left side of the "*Dew-point Temperatures*" ESRT, then find the ***difference between the wet and dry-bulbs***, also known as the ***wet-bulb*** depression, on the top of the chart. Where these rows meet, you will see the dew-point.
- The drier the air, the further the dew-point will be from the actual temperature.
- The more moisture in the air, the closer the dew-point will be to the air temperature.
- When the dew-point equals the air temperature, the air is saturated, clouds will form and precipitation is likely.

Absolute and Relative Humidity

- ***Absolute humidity*** refers to the measured amount of moisture in the air (i.e. 50 ml)
- ***Relative humidity*** refers to how full of moisture the air is."
- It is a comparison of how much moisture there is in the air, compared to how much it would take for the air to be saturated at that temperature.
- **Remember!** Warmer air can hold more moisture than cooler air.
- When air is saturated, it is said to have a relative humidity of 100%.
- If the relative humidity is 50%, it means the air is holding half as much moisture as it is capable of at that temperature.
- Generally speaking, as temperature decreases, relative humidity will go up because colder air has less available "space" to hold the moisture.
- Both the amount of moisture and the temperature affect the relative humidity.



- ***As the temperature of the air drops closer to the dew-point, the relative humidity approaches 100%.***

Calculating Relative Humidity

Relative Humidity (%)

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

- Determining the relative humidity is the same process as determining dew-point, except you must use the relative humidity chart instead of the dew point chart.
- Refer to the "*Relative Humidity*" chart in the ESRTs