ISSN XXXX XXXX © 2017 IJESC

Research Article Volume 7 Issue No.12

The Method for Forecasting Relative Humidity with Height

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Abstract:
75% of our world is made up of ocean, seas and freshwater resources. Therefore, water is a very important compound in our atmosphere. The water vapor passes through the atmosphere via the evaporation of water. That is, when a water molecule on the liquid water surface gains sufficient energy, it evaporates into the air immediately above it and evaporates. Measuring the amount of water vapor in the atmosphere is important in many respects. In this study, attempts were made to estimate the change in relative humidity by using several physics law (Dalton's Law of Partial Pressures) and meteorological parameters.

Keywords: Forecasting relative humidity, actual temperature, dew point temperature, partial pressures.

1. INTRODUCTION:

Why is important to measure the amount of water vapor in the atmosphere? It is possible to give 3 different answers to this question. First, water vapor is the source of all cloud and rainfall. Cloud formation potential and damping depends on the amount of water vapor in the atmosphere. Second, the amount of water vapor in the atmosphere determines the amount of evaporation. The amount of evaporation is very important for air, plants and people. Last, water vapor is the major co-factor of long-wave radiation. The ratio of the actual vapor pressure applied by the water molecules to the equilibrium vapor pressure at the same temperature is an indication of how close the air is to the equilibrium. This rate is called the saturation rate and when we hit the saturation rate to 100 we find the relative humidity [1].

$$e = 6.112\, x\, \exp\left(\frac{17.67xT_d}{243.5 + T_d}\right) \qquad e_s = 6.11\, x\, \exp\left(\frac{17.67xT}{243.5 + T}\right)$$

e = Actual vapor pressure (mb)
e_s = Saturated vapor pressure (mb)
T = The actual temperature of air (℃)
Td = Dew-point temperature (℃) [1].

If we know the actual temperature of the air, we can also know how much water the air can hold. For example; assume that the air temperature is 20˚C. In this case the saturated vapor pressure will be 23.34 mb. If we take the air temperature as 20˚C, we find the saturated vapor pressure as 12.27 mb. So if the temperature drops, the maximum amount of water vapor that air can hold is reduced. However, the relative humidity will increase as the amount of water vapor present in the air does not change instantaneously. The relative humidity and temperature are inversely proportional to the above. So when the relative humidity is rising, the air temperature will decrease. The air temperature reaches the peak point during the day and the relative humidity is at the minimum point. AWOS (Automatic Meteorological Observation Stations) measures the dew point temperature using dew point hygrometer. This measure is the same as we can observe that the bath mirror is fogged when the temperature is the same as the dew point temperature when bathing or showering. The dew point hygrometer uses a light beam focused on a mirror. The light is also reflected to a receiver that measures the intensity of the reflected light. Then the mirror surface is cooled. When the surface of the mirror cools down to the dew point temperature, dew formation starts on the surface. Water droplets (or ice crystals, if reached at the frost point) prevent the light from reaching the detector. This is interpreted as if the mirror is at dew point temperature. The temperature of the mirror is measured with a platinum wire in a similar way as to measure the ambient temperature. The mirror is then heated to a temperature above the dew point in order to vaporize the dew that has accumulated on the surface and cooled for a new measurement. The weakness of this approach is that dew can form on the surface of the mirror in other materials and can block the laser beam. This hygrometer can be mistaken as if it had reached the dew point. After the dew point temperature is reached, the relative humidity is calculated by comparing with the actual air temperature.

2. STUDY AREA, DATA AND METHODOLOGY:

In meteorology, it is very important to know how the temperature changes with height. Because with this knowledge, it is assigned that the atmosphere is stable or unstable. The cloud base height can be determined and the location is very important in the weather forecast. observations are made at 7 locations in Turkey in ravinsonde for this measurement. Ravinsonde expresses exactly how to obtain information about pressure, temperature, humidity and wind with altitude in the atmosphere. There are some approaches used in meteorology to change the temperature (lapse rate). A steep lapse rate indicates that the environmental temperature is rapidly decreasing with height. If an air parcel is adiabatically raised, assuming there is no humidity in it (dry adiabatic lapse rate) -9.8 °C/km. In other words, it can be said that the temperature decreased by 9.8 degrees centigrade at 1000 meters. If the chalice continues to be cooled by becoming saturated, it will be a secret heat coming out of the chalice. This causes the temperature drop rate to be less than the dry adiabatic lapse rate. The saturated adiabatic lapse rate is 6.5 ˚C/km. We can carry the heat with this height. But that's just an approach. Since we do not have any information about how the temperature changes with altitude, we can get it with the above assumptions. Since we want to obtain the knowledge of what the relative humidity will be at different heights, we still need the values of temperature and dew point temperature at these altitudes. We cannot move the dew point temperature up to the current air temperature. The lapse rate rates mentioned above are for the atmospheric temperature. We can estimate the actual vapor pressure for the upstream levels, since we know that the relative vapor current is the ratio of the saturated vapor pressure to the saturated vapor pressure, rather than guessing what the dew point temperature will be for the upstream levels. First, we can find out how much of the saturated vapor pressure, ie the maximum water vapor that the air can carry, represents to what extent the total atmospheric pressure is from the air temperature we find for the upstream levels. As we recall from the examples above, if we take the air temperature to 10 ° C, we find the saturated vapor pressure to be 12.27 mb. By estimating the actual vapor pressure after finding the saturated vapor pressure, we can find the desired relative humidity value for the desired height. The first thing we have to do is to estimate the actual vapor pressure for this level. It is difficult to predict the actual vapor pressure. Because the closeness of these levels to the water and the direction of the air current are very important. For example, the water vaporized from a nearby ladder can reach the point at which we want to calculate the actual vapor pressure with the convection of the vapor, making the relative humidity of that region much higher than predicted. However, it would be pointless to distribute the relative humidity to an entire map by interpolating and extrapolating it without adding topography effects. For this, when estimating the current vapor pressure of a point, we can make an estimate by neglecting the proximity of the water resources to that point.

3. RESULTS AND DISCUSSION:

We have to remember the partial pressure law of Daltons in order to be able to carry out the operations mentioned above. This law states that the total pressure of a gas mixture (air) is equal to the sum of the partial pressures of the gases forming the mixture. For example, assume a pressure of 1009 mb, measured at a station with a 500 meter radius and reduced to sea level. We can directly use the values from the pressure sensors. At the station, the current air temperature is 8˚C and the relative humidity is 50%. In this case the saturated vapor pressure will be 10.73 mb. As the relative humidity is 50%, the actual vapor pressure will be 5.365 mb. 5,365 mb of the 1009 mb atmospheric pressure is made by water vapor. Assuming that the ratio of water vapor to total atmospheric pressure is equal at different levels, let's find the actual vapor pressure at the point of 900 meters in height. But before we go through this process, we need 900 meters of pressure calculation. We can use the formula below to find out what the atmospheric pressure will be at a height of 900 meters.

$$P = P_b\, x \left[1 + \frac{L_b}{T_b} x\,(h - h_b)\right]^{\frac{-g_0 * M}{R * L_b}}$$

P_b = Pressure reduced to sea level measured at the station (hPa)
T_b = Temperature at the station (℃)
L_b = Lapse rate (rate of change temperature with height) (K/m) (-0.0065 K/m)
h = The height of the point we want to move the pressure (m)
h_b = The height of the station (m)
R = Universal gas constant (8.31432 N.m/mol.K)
g_0 = The gravitational acceleration (m/s^2)
M = Molar mass of the earth atmosphere (kg/mol)
The part of the equation above the component on the right side of the equation consists of constants and when necessary calculations are made, $(-g_0*M)/(R*Lb)\approx 5.256$. Now we can find out what the pressure will be when we use the equation to increase the pressure level from 1009 mb to 900 m from 500 m. When the necessary operations are performed, the pressure value for this point is 960.912 mb. Assuming that we find the pressure value at a height of 900 meters, we assume that the current vapor pressure does not change the ratio of the total atmospheric pressure to the desired point; we can calculate the actual vapor pressure for this height. We can use the right proportion for this. If there is 5.365 mb of actual vapor pressure at 1009 mb, how much will this rate be at 960.912 mb?

e = (960.912 mb / 1009 mb)*5.365 mb = 5.11 mb.

We calculated the actual vapor pressure for the 960.12 mb level. We can calculate the actual air temperature using saturated adiabatic lapse rate (-6.5 ˚C/km), which we use when considering standard atmospheric conditions, based on the height of that level. The difference is 400 meters because we will carry 900 meters of heat from 500 meters. There will be a temperature drop of 2.6˚C at 400m. In this case, we can assume that the current air temperature at this level will be 5.46˚C. Calculate the saturated vapor pressure at this temperature;

e_s = 6.11*exp((17.67*T)/(243.5+T))
= 6.11*exp((17.67*5.46)/(243.5+5.46)) = 9.002 mb

What will be the relative humidity when the actual vapor pressure is 5.11 mb and the saturated vapor pressure is 9.002 mb at 900 m altitude and 960.12 mb?

RH (%) = 100*e/e_s = 100*5.11/9.002 = 56.765%.

At a pressure of 1009 mb at a height of 500 meters, a relative humidity of 50% at 8 °C, 900 m. When we went to the level of 960.912 mb, the humidity increased to 56.765%. It is expected that the increase of the humidity with the increase of the height is expected. Even with this calculation, we can even find the cloud base height. Cloud formation at the level where the relative humidity is 100% will start to be observed.

5. REFERENCES:

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