Evaporation from Water Bodies

Clearly, in nature, evaporation from a water body like an ocean or a lake must depend on a number of factors. In the conceptual experiment we ran in class, we kept the temperature of the liquid constant and then watched how evaporation created an “atmosphere” of water vapor at roughly the same temperature.

In nature, air masses can be warmer or colder than the underlying ocean. Also, the temperature of the ocean or lake will govern how much water vapor will “try” to evaporate and the amount of water vapor thus evaporated does not vary linearly with temperature.

Finally, the relative humidity of the overlying air (as a measure of how much water vapor is already present in the overlying atmosphere) clearly will be important. If the overlying air is saturated, then the ability for net evaporation to take place from the water body will be limited.

One equation that has seen some success in quantifying these things is the so called “Lake Mead Equation”:

$$E = 0.0331\, V\, (e - e_s)\, [1 - 0.03\, (T - T_w)]\ 24\ \text{h day}^{-1} \qquad (1)$$

where E is evaporation rate (mm/day); V is the wind speed in the lowest 0.5 m above the ground (km/h), e is vapor pressure (the equation is setup to use the English system unit mm Hg), e_s is saturation vapor pressure, T is the atmospheric temperature above the water surface in C, and T_w is the water temperature in C.

Equation (1) says that the evaporation rate is directly related to wind speed, and the greater the difference between the vapor pressure and saturation vapor pressure (the lower the relative humidity). Notice that no evaporation would occur if the relative humidity is 100%.

Wind speed is included, but is actually related to relative humidity. On a calm day, the skin surface layer of the atmosphere can saturate quickly and evaporation from the water body would cease. The wind replenishes the supply of non-saturated air so that evaporation can proceed. Stronger wind speeds are also associated with larger turbulence that brings and mixes drier air with the surface air, thus encouraging more evaporation.

The influence of temperature in the equation is more difficult to put into words. If the water temperature is less than the atmospheric temperature the term $- 0.03\, (T - T_w)$ will be negative. When the water temperature is greater than the temperature of the atmosphere, that term will be positive.

The term $[1 - 0.03\, (T - T_w)]$ would therefore work this way: it would always contribute to the evaporation rate by increasing it. But the greatest increases would come when the water temperature is larger than the temperature of the overlying atmosphere.

Here are two examples:

Suppose the vapor pressure is 15 mm Hg, saturation vapor pressure is 15 mm Hg, wind speed is 25/km h, air temperature is 29 C, and water temperature is 27 C.

Inserting these values into Equation (1) (leaving off units since they cancel) gives

$E = 0.0331 \text{ X } 25 (30 – 15) [1 – 0.03 (29 – 27)] 24 \text{ h day}^{-1} = 11.66 \text{ mm/day}$

Leaving all values the same except inserting an ocean temperature of 34C into the equation gives

$E = 0.0331 \text{ X } 25 (30 – 15) [1 – 0.03 (29 – 34)] 24 \text{ h day}^{-1} = 111.2 \text{ mm/day}$

In this case, just increasing the sea surface or water temperature by 7C increased the evaporation rate tenfold.