WATER and WEATHER

The word “weather” describes conditions and activities of the atmosphere. Water is important to weather because water in the atmosphere can be solid, liquid, or gas. These phases affect atmospheric conditions, and each can absorb or release heat, the most important form of energy involved in weather.

WATER and ENERGY

As water evaporates, it absorbs heat, cooling the air and forming water vapor that makes the air humid. The water vapor carries this absorbed energy, called latent heat. Later, when latent heat is released, it drives a variety of atmospheric activities.

Latent heat is released when water vapor in the air condenses to form clouds and rain, or, if the air is colder, when water vapor deposits to form hail, frost and snow. This release of heat warms the air, causing it to expand and rise like a hot air balloon. Cold air from above then sinks to replace it. This is called convection. Convection creates winds that are part of every storm.

DESCRIPTING WEATHER

A good weather report includes the temperature, barometric pressure, cloud cover, wind speed & direction, relative humidity and dew-point. It also includes how those are expected to change in the near future.

Temperature, barometric pressure and wind velocity do not measure water directly, but they do affect how water behaves. Cloud cover indicates how much liquid water is present as clouds. Relative humidity describes how much water vapor is in the air. Dew-point measures the temperature when humid air will begin to condense liquid water or form dew.

HUMIDITY

The more water vapor in the air, the higher the humidity. Water will evaporate more when it is hot, so the humidity will be higher, as long as there is an excess of liquid water available to evaporate. Water will evaporate less when it is cold, so the humidity will be lower.

Relative humidity compares how much water vapor is present with how much water vapor could be present if there were an excess of liquid water evaporating at that same temperature.

When the air contains as much water vapor as possible from evaporation, the relative humidity is 100%. When the air contains less water vapor than what is possible from evaporation, the relative humidity is less than 100%. When the air contains only half the water vapor possible, the relative humidity is 50%.

If water is abundant, hot days will be humid, and cold days will be less humid, but both could have 100% relative humidity because both could have as much water vapor as possible from evaporation at each temperature. If water is scarce, the air can be hot and dry, like in the deserts of Arizona in the middle of summer, when the relative humidity can be less than 10%.

DEW-POINT

Dew-point measures the temperature when humid air will begin to condense liquid water, or dew.

At ASU, during the summer monsoon season, chilled water pipes and water-cooled equipment in the laboratories often

Water and Weather, Supplementary Information

Other forms of energy are involved in weather: Electrical energy in lightning, sound energy in thunder, kinetic energy in wind and potential energy in gravity. Gravity causes cold air to fall and hot air to rise through a process called convection, which creates wind.

Water influences weather in other ways too. Water and ice shape the land through erosion. When landforms change, local weather can change because wind patterns are affected by the terrain. When water evaporates from a lake or ocean, it leaves behind minerals that were dissolved, making that body of water more “saline” or salty. When a body of water becomes very salty, like the Dead Sea or Great Salt Lake, local weather patterns are affected by desertification of the surrounding area.

“Latent” means “hidden” or “stored”. The latent heat in water vapor is what keeps the water in the form of a gas instead of a liquid or solid, even though they could be at the same temperature. The latent heat in liquid water is what keeps it from turning to ice, even though both could be at the same temperature.

Phase Relations in Water -- Water is solid, liquid or gas, depending on how much heat it contains. Changing the amount of heat will cause water to change its phase depending on the temperature and pressure. Each of these changes is called a “phase transition”. These relationships are summarized in a phase diagram.

Melting: When solid absorbs heat to form liquid. Liquid contains more heat than solid. “Slush” is a slurry mixture of snow and liquid that is produced when snow melts, but not completely.

Freezing: When liquid releases heat to form solid. Solid contains less heat than liquid. “Sleet” is made from raindrops that have frozen in the air, or from snow that has melted in the air then frozen again.

Evaporation: When liquid absorbs heat to form gas. Gas contains more heat than liquid. Water vapor creates humidity in the air, and this humidity carries the heat from evaporation.

Condensation: When gas releases heat to form liquid. Liquid contains less heat than gas. Condensation forms clouds, which are suspensions of tiny droplets of liquid in the air. When these tiny droplets grow so large they can no longer remain aloft, they fall to the earth as rain. Fog is similar to a cloud, but very close to the ground. Condensation happens when humid air cools quickly. Raindrops often form around dust particles, which serve to “nucleate” the process of condensation.

Sublimation: When solid absorbs heat to form gas directly, without melting first. Gas contains more heat than solid. Sublimation is driven mostly by the energy of sunlight. Ice sublimes faster in bright, dry windy conditions, and at high altitudes, where the air pressure is lower. Sublimation is one way glaciers shrink over time.

Deposition: When gas releases heat to form solid. Solid contains less heat than gas. Deposition creates ice clouds made from tiny ice crystals that are so small they remain suspended in the air. Deposition also creates snow, which forms in the air and falls to the ground, and frost, which forms directly on cold surfaces. Hail is a special kind of snow. A hailstone forms in layers as it circulates within a thundercloud and eventually grows so large it falls to the ground. Like condensation, deposition is often nucleated by dust particles.

Psychrometry -- The relationship between relative humidity and wet/dry bulb temperatures is indicated in a psychrometric chart.

Relative Humidity and the Wet/Dry Thermometer -- Relative humidity can be measured with two thermometers. One thermometer bulb is wrapped with cotton gauze and soaked with water. The other bulb is kept dry. The dry-bulb thermometer measures the temperature of the air, while the wet-bulb thermometer is cooled by water evaporating from the wet gauze. If the air is dry, the water evaporates faster, cooling the wet-bulb more, resulting in a temperature below the dry bulb temperature. The drier the air, the faster the evaporation, the cooler the wet-bulb temperature. If the air is humid, the water evaporates slowly, if at all, cooling the web-bulb slowly, resulting in a temperature much closer to the dry-bulb temperature. The difference between the dry-bulb and wet-bulb temperatures indicates the relative humidity.

Swamp cooling -- An evaporative cooler, also called a “swamp” cooler, uses evaporation to cool a home. This also makes the air inside more humid, and in an arid climate, this is quite comfortable. However, when the summer rains begin, the air becomes very humid and evaporation is no longer an efficient source of cooling, so air conditioners become necessary. In Arizona, the summer weather reports include the “evaporative cooling index”, which is similar to the heat index. The evaporative cooling index measures how cold a swamp cooler will be able make your house depending on the relative humidity. An air conditioner uses a refrigeration cycle to cool the air in a home. Hot humid air is blown over a chilled section of the system which cools the air and also causes the humidity to condense, drying the air. The air that enters the home is cool and “dehumidified”, which is very comfortable.

“Black ice” is formed when liquid water on a dark road freezes to form a thin, transparent, bubble-free layer of ice. Drivers can’t see it so they don’t know to reduce speed. Black ice is very slippery and causes many deadly car accidents.

Steam from deep inside the earth carries heat to the surface where it is released to the atmosphere from hot springs, geysers and volcanoes. Factories, power plants, forest fires and combustion of fossil fuels also produce heat and steam. Steam from any source increases the heat content and humidity of the atmosphere. Steam is very dangerous because it contains a large amount of heat that causes severe burns.

Glaciers contain ice that formed at different times in history, and so are important to scientists who study weather patterns over long times.

The Triple Point -- It is possible, at a very particular temperature and pressure, for water to exist in all three phases at the same time. This is called the “triple point” of water. The triple point is a standard reference point on the international temperature and pressure scales. At the triple point, all the phase transitions happen at the same time, so all three phases remain in contact with each other.

Mirage -- In a hot arid desert, travelers often see what appears to be a shimmering lake in the distance. However, when they arrive at that location, there is only hot sand. The appearance of water was a mirage. A mirage is an optical effect produced by hot air rising from the ground during convection. Hot air acts like a lens that bends light in strange ways when hot and cold air are mixed.