Review of Concepts

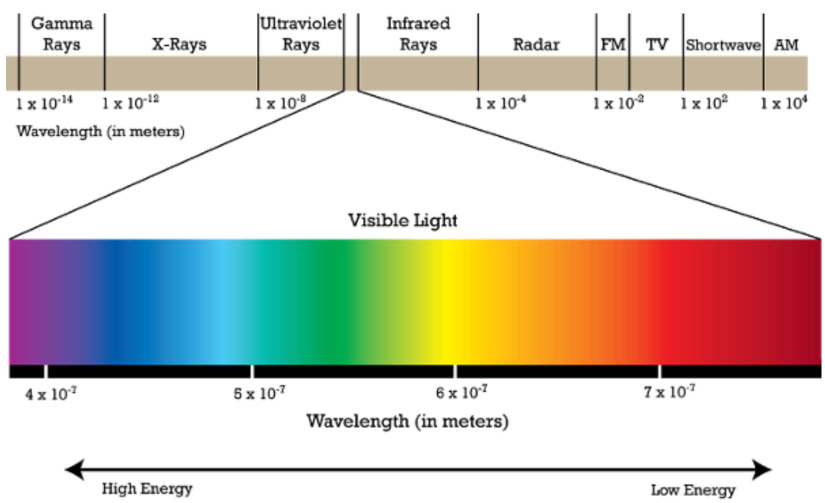
This field guide goes into depth on how MaRTy works and mentions many scientific concepts that may be new to the reader. The goal of the Sac Metro Air District is for MaRTy to be useable for planners and policymakers who may not have a background in environmental science. MaRTy measures radiative inputs, air temperature, relative humidity, and wind speed. Below is an overview of the physical processes behind those measurements and how they contribute to human comfort.

Keywords

- **Electromagnetic waves**
- **Radiation**
- **Shortwave radiation**
- **Longwave radiation**
- **Albedo**
- **Evapotranspiration**
- **Latent heat of evaporation**
- **Relative humidity**
- **Thermoregulate**
- **Convective cooling**

Radiative Inputs

The sun emits **electromagnetic waves,** and they carry energy. **Radiation** is the transfer of heat energy by electromagnetic waves of different wavelengths.



https://waves.neocities.org/spectrum

MaRTy's sensors detect two forms of radiative input: shortwave and longwave. Distinguishing between the different wavelengths that add up to the total radiative input help inform the sources of the heat energy. Simply put, **shortwave radiation (SW)** is direct or reflected radiation from the sun, and **longwave radiation (LW)** is heat that has been absorbed and reemitted. As you can see from the chart, UV rays (ultraviolet) are a form of SW that you are probably already familiar with. On the opposite end of the spectrum, infrared rays are a form of longwave radiation. This is what you feel radiating from a hot parking lot.

Albedo refers to how much a surface reflects versus absorbs electromagnetic radiation, and it corresponds with how light or dark the surface is. Albedo is a fraction—the highest albedo equals 1 and the lowest equals 0. An albedo of 1 is pure white and reflects all incoming electromagnetic waves, whereas 0 is pure black and absorbs all electromagnetic waves. On a sunny day with the air temperature below freezing, snow does not melt despite intense incoming SW because its high albedo reflects radiation instead of absorbing it and heating up the snow. Unshaded asphalt parking lots get so hot because their low albedo causes them to absorb most of the incoming SW, heat up, and emit LW.

MaRTy measures SW and LW inputs coming from 6 directions through its 3 net radiometers: one up-down, one left-right, and one front-back. Sources of SW can include direct sunlight, reflective surfaces like windows, or materials with high albedo, and sources of LW are surfaces and building materials with low albedo. These radiative measurements used to calculate the mean radiant temperature (MRT), which is discussed in the MRT Equation section.

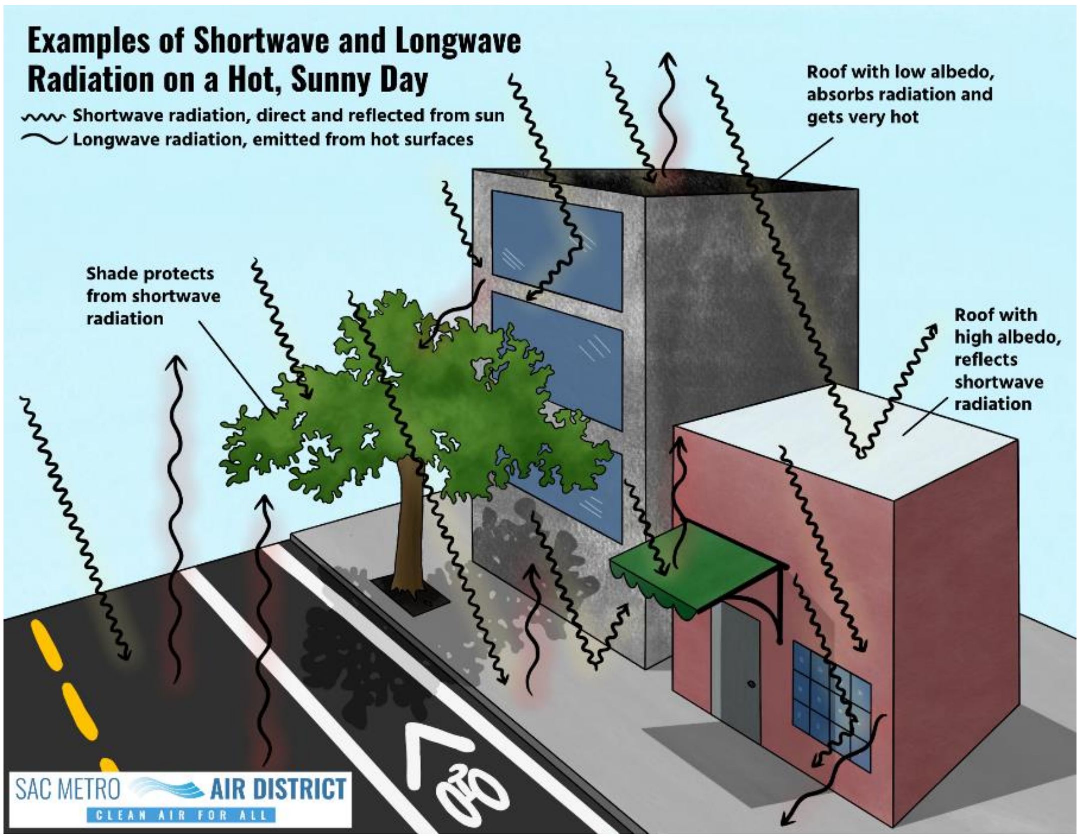
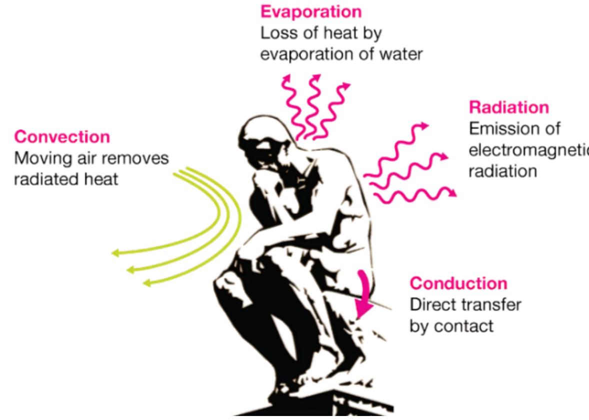


Illustration by Fiona McLaughlin

On a global scale, some incoming SW from the sun is reflected by high albedo surfaces like the polar ice caps and most of it is absorbed by the rest Earth's surface. This causes the Earth to emit large amounts of LW. Some of it is released into space, and some of it is absorbed by greenhouse gases and reemitted back to the Earth's surface, which keeps our atmosphere at a livable temperature. (The existence of greenhouse gases is a good thing—it is excessive emissions of greenhouse gases by humans that make our atmosphere too hot and cause rapid climate change). Clouds both protect us from incoming SW from the sun and emit LW towards the Earth's surface. On the hottest days of the year in dry climates like Sacramento, it usually is not cloudy, and the main source of incoming radiation is SW from the sun. Because of this, it is important that it is sunny and cloudless on the days data is collected with MaRTy.

Air Temperature, Relative Humidity, and Windspeed



https://xaktly.com/HeatTransfer.html

There are several reasons why air temperature measurements on a hyper-local scale can vary from site to site. It could be influenced by land surface temperature, which as discussed, is caused by the absorption and emission of radiation. Another important factor is evapotranspiration and the latent heat of evaporation.

Evapotranspiration is the combined processes of transpiration and evaporation that move water from the ground into the air through plants. Transpiration is when plants pull water from the ground and release it through their leaves. The water then evaporates off the leaves and enters the atmosphere as water vapor. This phase change from liquid to gas requires energy. Heat is energy, so pulling energy from the surrounding atmosphere to complete the phase change pulls heat from the air. The result is that through evaporation, plants literally pull heat out of the air. The amount of energy it requires to evaporate, or the "lack of heat" caused by this process, is referred to as the **latent heat of evaporation (LE)**. While MRT does not measure LE, understanding this process can explain why the air temperature is usually cooler around vegetation. In urban heat mitigation planning, there are many arguments towards the benefits of increasing vegetation, and this is one of the reasons why.

Due to the same process of LE, one way our bodies cool themselves is from the evaporation of sweat. How humid it is affects the ability of sweat to evaporate. The more water vapor that is already in the air, the harder it is for sweat to evaporate, and therefore calculating **relative humidity (RH)** is important for gauging the "feels like" temperature of a location. RH is measured by percentage, and it describes the amount of water vapor in a parcel of air compared to the maximum amount of water vapor it can hold. Even if the air temperature is the same, lower humidity feels cooler and higher humidity feels warmer. MaRTy is most accurate in dry climates like Arizona and Sacramento because RH usually doesn't play a large role in the "feels like" temperature.

Humans also **thermoregulate** (keep our body temperatures within certain boundaries despite the outside environment) through convection, or the movement of air. This makes wind speed another important measurement for the "feels like" temperature, because it contributes to **convective cooling**. Our bodies produce heat and emit radiation. When the air around us is still, a layer of air around our bodies is heated by the radiation we produce and keeps us warm. Wearing layers makes us warmer because it traps that radiated heat close to our bodies. Convective cooling removes the heated layer of air and replaces it with colder air. The stronger the wind speed, the more convective cooling occurs, which makes the air temperature feel colder. The wind chill in weather reports predicts how cold the temperature outside will feel when convective cooling is accounted for.