THERMAL MODEL COMPARISON OF FINE GRAIN SIZED SEDIMENTS WITH RESPECT TO MOISTURE CONTENT.

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Introduction: All known biological systems rely on a common resource: liquid water [1]. Thus, determining if liquid water exists on Mars is crucial to assessing the probability of the planet in harboring life. Although research on the geology and historical climate of Mars indicates that the planet could have supported a global hydrological system [2], evidence of the current presence of liquid water is not concrete. Thermal analysis using orbital data (THEMIS) from the surface of Mars could potentially be used to verify the existence of water in liquid form both on and underground.

The goal of the Mars Outreach for North Carolina Students (MONS) research program in 2011 was to find the effects of water moisture on the thermal inertias of various grain size sediments to develop a model that could determine the moisture saturation levels present in a designated area. Our team was responsible for conducting experiments on fine grain sized sediments for this project.

We hypothesized that as the moisture content of a sample of fine sediment increased, the sample's resistance to changes in temperature would also increase due to water's high specific heat. We predicted that, with a source of constant heat, fine sediments with high moisture content should reach lower stable temperatures sooner than those with low saturation.

Methods: We obtained deposits from the Old Pleasant Greenridge Dam at the Eno River in North Carolina. We sieved the sediments to separate enough fine sands from other the other grain sizes to fill up a plastic 5-gallon bucket that was cut down to a height of 10 centimeters with a diameter of 20 centimeters (a volume of 3141 cm^3), which would serve as the sample container. The sediment was put in an aluminum pan and then placed in an oven at high temperature for several hours to take away moisture. The sediment was left to cool inside the oven for several more hours to restore the sediment to room temperature.

After the moisture removal process, the sample of fine sediment was prepared in the sample container so that it was either dry or saturated with water from the bottom of the container to 2, 4, 6, 8, or 10 cm of the sample (saturated with water 8, 6, 4, 2, and 0 cm from the surface of the sediment). Samples were properly saturated if the further addition of water would cause pooling on the surface of the sediment. The prepared sample in its container was placed on the ground 40 centimeters below a 100-watt heat lamp, which was used to provide the source of constant heat. A continuously running infrared thermometer was attached to a stand so that the thermometer was reading the temperature of the center of the top surface of the sample. The thermometer was displaced from this point horizontally by 30 centimeters and vertically by 40 centimeters. Before the lamp was turned on, 3 initial temperature readings of the sample were obtained, each being made 30 seconds apart. Once the initial temperatures were recorded, the lamp was turned on. Temperatures of the sample were recorded every 30 seconds until the sample "stabilized" or did not fluctuate in temperature more than 1 degree Celsius for 10 consecutive minutes. Once the sample was stable, the light was turned off, temperatures were recorded every 30 seconds until the sample was stable again. An infrared camera was used every 1 to 2 minutes to confirm the accuracy of the measurements obtained by the thermometers (camera readings generally came within 1 degree Celsius of those of the thermometers). After each run of the experiment, the sediment was transferred into an aluminum pan to dry and cool for the next run. The experiment was run 16 times so that each level of saturation was run at least twice. The data acquired was entered into logger pro to plot and form models.

Results: The data acquired from the experiment was entered into Logger Pro 3 to plot and form models. The complete set of data collected for the experiment is displayed in Figure 1.

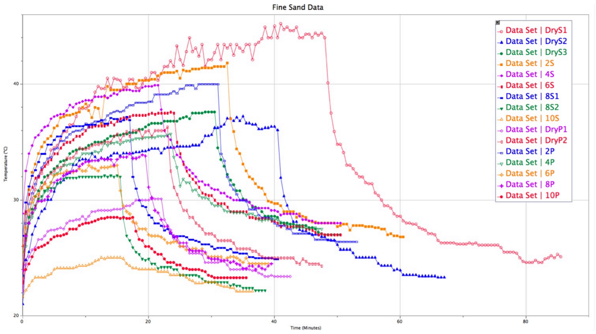

Figure 1: Plotted data in Logger Pro 3 for all runs of the experiment for fine sediment.

All graphs were set up so that the independent variable (displayed on the x-axis) was time and that the dependent variable (displayed on the y-axis) was temperature in degrees Celsius.

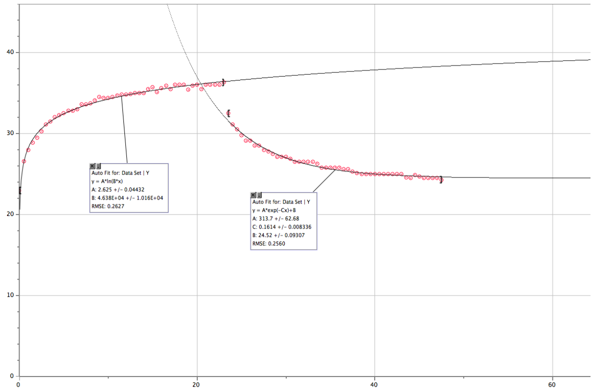

Figure 2: Plot (red dots) and fit (black curves) for a dry run of fine sediment (10/7/11).

We found that the heating phases of each run followed a natural logarithmic trend while the cooling phases reflected an inverse exponential trend. Figure 2 shows how such models fit on the actual plots of data with minimal error. For each level of saturation, the models of the data were averaged to produce an average model. These average models for each saturation level were then compared. With the exception of the average model for the dry runs, stable temperatures decreased with increasing levels of saturation. With the exception of average models for the dry sample and the sample saturated with water to 2 cm from the surface, the time taken to reach stability also decreased with increasing moisture content.

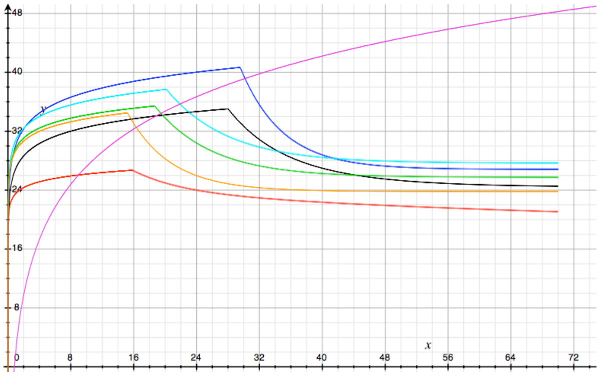

Figure 3: Average models for fine sand at varying saturation levels with trend for stable points. Black: dry. Dark blue: 2 cm saturated. Light blue: 4cm saturated. Green: 6cm saturated. Orange: 8cm saturated. Red: 10cm saturated. Purple: trend for stable points.

As evident in Figure 3, the stable points seem to follow a general logarithmic trend with the time and temperature of stability both increasing with decreasing saturation.

Discussion: Overall, the results of our experiment followed our prediction that the variances in temperature would decrease with increasing saturation of water in samples of fine sediments. Deviations of dry and 8cm saturation data from our predictions could have been the result of many factors that could not be controlled during the experiment such as air conditioning.

The experiment shows with some certainty that the thermal inertias of fine sediments as determined by infrared thermometers are indeed affected by moisture content. The logarithmic trend in the stable points for the average models for the various levels of moisture content, from dry to fully saturated (10cm) indicate that the rate at which the samples of fine sediment become stable increases more slowly as water content increases. The stable point trend also indicates that the magnitude of the change in temperature decreases more rapidly with increasing saturation.

Future Study: We would like to continue studying the effects of moisture on thermal inertia by analyzing heating and cooling patterns of specific types of rocks and minerals, similar in type to those that compose the surface of the planet Mars. We would like to do this with a larger variety of grain sizes and moisture contents in order to refine our models for determining the presence of liquid water in a sample of Martian deposit. We would also like to use our models to analyze data obtained by satellite images of Mars.

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References:

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