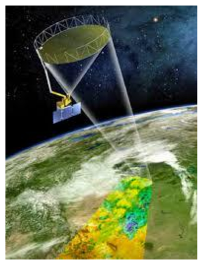
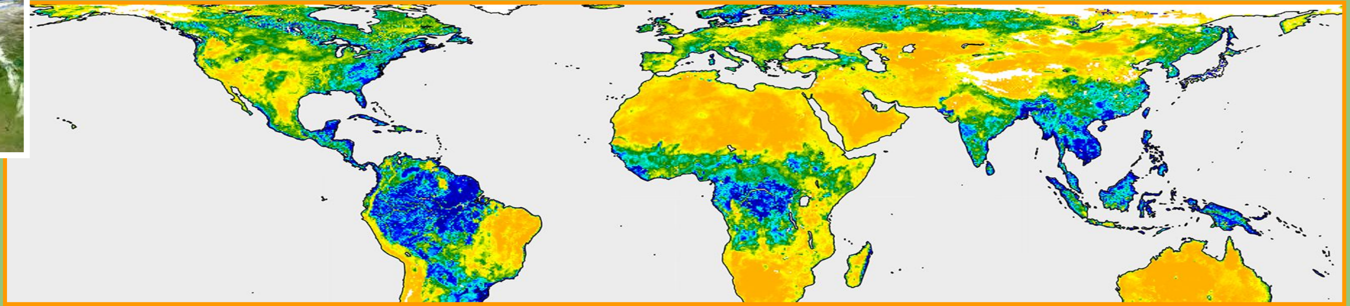
Studying Soil Moisture From Within & Above

Bowling Green State University





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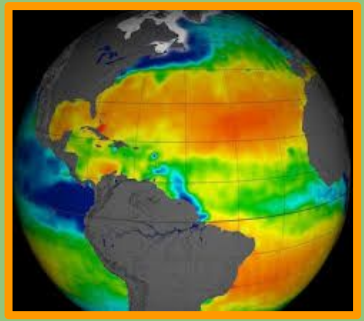
Why Is Investigating Soil Moisture Important?

In the environment, soil moisture influences atmosphere conditions and vice versa, because soil acts as a sponge. Understanding soil moisture in specific locations allows for improved predictions for floods, droughts, weather forecasts, carbon models, and crop productivity. NASA satellites monitor the Earth's environment in order to study and ultimately protect and sustain it. The GLOBE Program offers the standardized methods for students and citizen scientists around the world to monitor some of these same environmental factors. Using our GLOBE soil and atmosphere data, we were able to compare our local data to NASA's satellite data and examine the relationships among variables and over time.

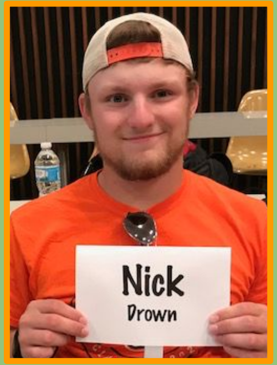
How Does Soil Moisture relate to Surface Temperature, Cloud Cover, and Relative Humidity?

- **Soil Moisture & Surface Temperature**
  - Surface temperature drives out soil moisture. Soil moisture can also increase the surface temperature and variance over a few hotspots, but this impact varies in different regions and times of day. (Berg, Lintner, Findell, Malyshev, Loikith, and Gentine, 2014).
- **Soil Moisture & Cloud Cover**
  - Overcast skies result in greater soil moisture while clear skies result in lower soil moisture. (Dai, Trenberth, and Karl, 1999)
  - When cloud cover is present, the soil is not exposed to as much sun, therefore the moisture in the soil does not evaporate as rapidly as it does on a sunny day. (Mudiare, Gray, and McKay, 1982)
- **Soil Moisture & Relative Humidity**
  - Since Humidity is caused from the evaporation of water from the soil, the drier the soil is, the more humidity the air will have. Likewise, the higher the soil moisture, the less humid the air will be. (Ravi, Et. al, 2004)
  - Higher levels of humidity in the air will lead to more water readily available to precipitate as the water condenses in the atmosphere by reaching colder layers of air (De Wit, 2015)
- **Soil Moisture and Climate Change**
  - NOAA and EPA Climate models predict that wet regions and wet seasons (Ohio spring, winter, and fall) will get wetter and dry places and dry seasons (Ohio summer) will get drier (Reardon, 2017; US EPA 1997).



Research Questions

1. How does our BGSU soil moisture data compare to NASA SMAP satellite data?
2. How does our BGSU soil moisture data compare to the 2015 & 2016 BGSU data?
3. What is the relationship among soil moisture, cloud cover, relative humidity, and surface temperature?



Materials

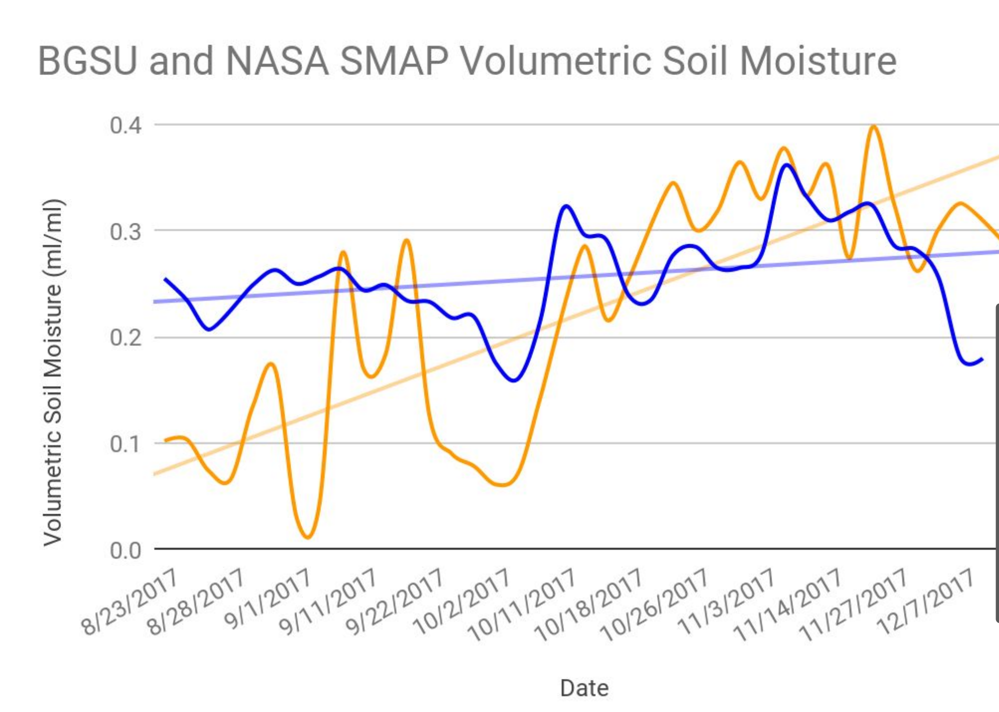
- Aluminum cans
- Hammer
- Wooden block
- Cling wrap
- Plastic bags
- Soil Oven
- GPS App w/ iPhone
- GLOBE Cloud Chart
- 500 ml graduated cylinder
- Digital scale (.01g)
- Hand trowel (shovel)
- Digital hygrometer
- Infrared (IR) thermometers
- Spray paint for grid marking

Methods: Over a 14 week period on the days with a satellite overhead, we:

1. Recorded GPS coordinates, elevation, and pre-set a 3m x 3m grid.
2. Removed the surface area of grass and placed a can open side down into the ground and tapped it with a hammer until soil filled can. Removed the can using a shovel and leveled off the top. Wrapped for safe transport.
3. Observed and recorded other soil and atmosphere measurements beyond the scope of this study.
4. Using an IR thermometer, we observed and recorded **surface temperature** from 9 linear spots, 5 paces apart near the soil moisture collection site.
5. Recorded measurements of **humidity** taken from the digital hygrometer inside the shelter.
6. Used GLOBE Observer app to identify and record **cloud type & cover**.
7. Took soil samples to lab and recorded the wet weight. Placed the can in the 85ºC soil oven for 2 - 4 days, then re-weighed (dry weight).
8. Determined the volume of each sample using a graduated cylinder.
9. Calculated **soil moisture** (gravimetrically and volumetrically) and reported data.
10. Repeat steps 2-9 for the sample site on each day the NASA SMAP (Soil Moisture Active Passive) satellite was overhead, moving to the next position, 15 cm away on the grid.

*** All data submitted to the GLOBE database.*

Results: How does our BGSU **soil moisture** data compare to NASA SMAP Satellite data?

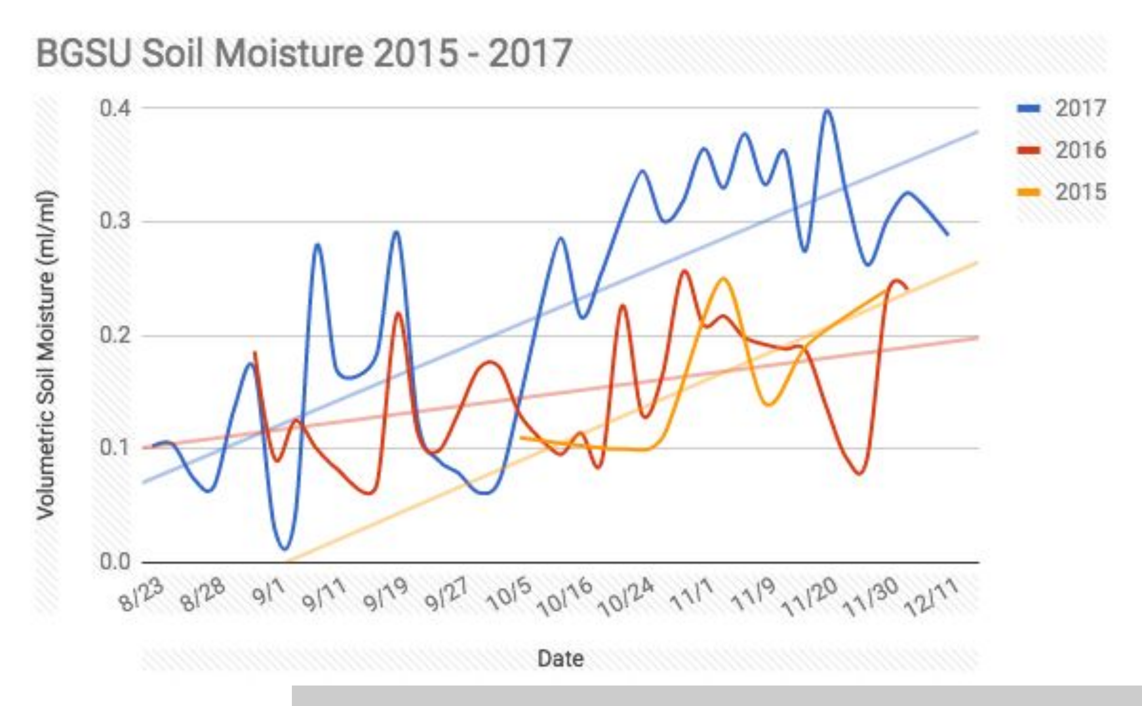


***r* = 0.625**

Conclusion:

- The BGSU and NASA SMAP data were strongly **correlated**.
- BGSU recorded more extreme measures with both lower and higher soil moisture values reported than detected by the larger scale NASA Satellite data.
- The BGSU data show LOCAL precipitation patterns as opposed to regional.

Results: How does **2017** BGSU soil moisture data compare to **2015 & 2016**?

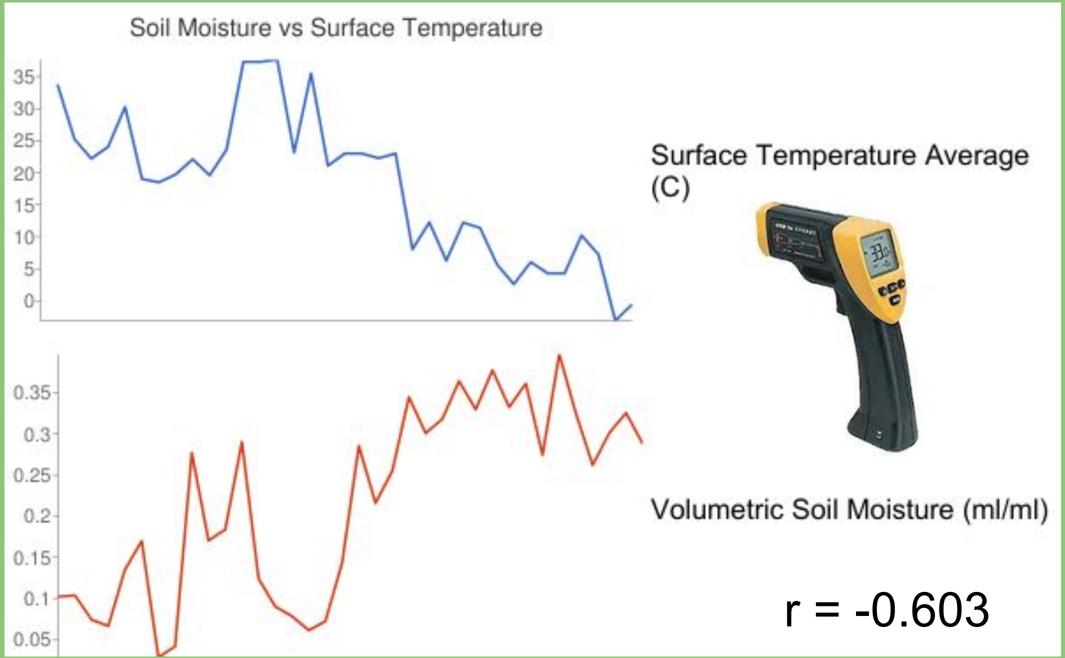


$p = 0.005$ showing the means from 2017 - 2016 are statistically different.
(Ttest statistic, 2015 omitted due to only 7 data points)

Conclusion:

- Overall, we had a wetter year this year than the last 2 years as shown by a higher soil moisture, especially as summer turns into fall.

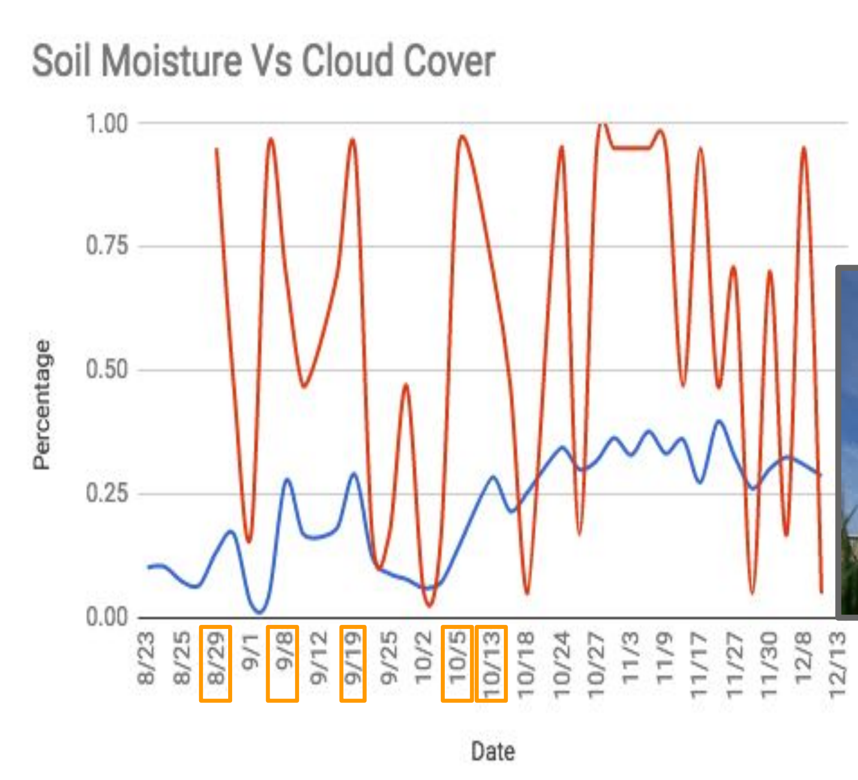
Results: How does soil moisture relate to **surface temperature**?



Conclusion:

- Soil moisture and surface temperature are inversely related as shown by the strong negative correlation coefficient.
- The large decrease in soil moisture in the middle of the data lines right up with a spike in surface temperature.
- Surface temperature appears to be the driver of soil moisture variations.

Results: How does soil moisture relate to **cloud cover**?

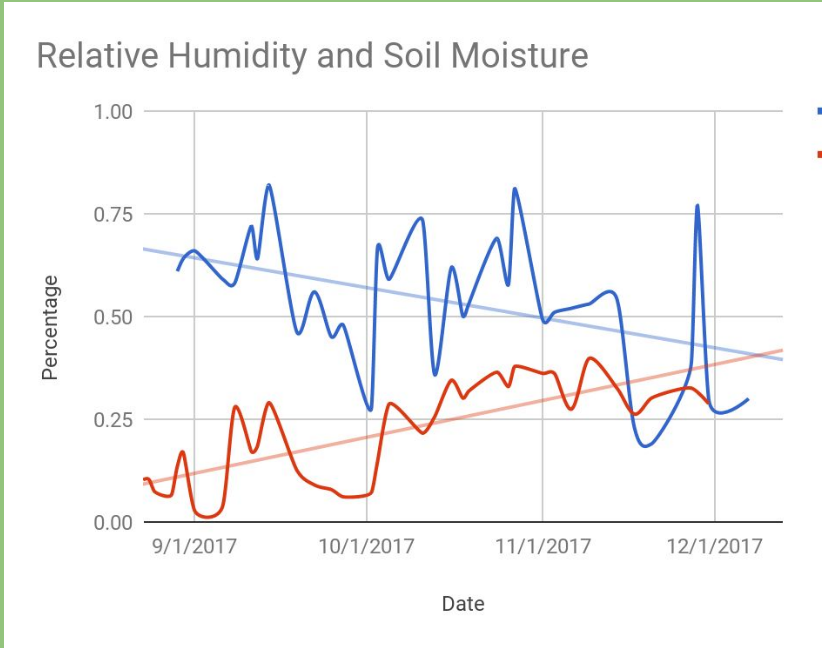


$r_s = 0.319$

Conclusion:

- Overall, Soil Moisture and Cloud Cover are have a slight positive correlation (Spearman Correlation Coefficient).
- On 8/29, 9/8, 9/19, 10/5, and 10/13 there was a spike in the soil moisture and a spike in cloud cover.
- After a high amount of cloud coverage you can see the subsequent consecutive days have a higher soil moisture.

Results: How does soil moisture relate to **relative humidity**?



Conclusion:

- Based on this graph, soil moisture and relative humidity were found to have a slight negative correlation.
- Soil acted like a sponge by giving up its moisture to the air, as seen by the soil spikes preceding the humidity spikes.
- Soil moisture is ultimately determined by factors other than just relative humidity, such as surface temperature & cloud cover.

Discussion:

- Our data was highly consistent with the NASA data. While Satellite models provide valuable information, measuring LOCALLY is also important so that we can better understand the LOCAL vs regional impacts.
- Based on our findings, surface temperatures seem to drive the water cycle in our region. Warm surface temperatures increase evaporation and decrease soil moisture.
- Soil gives up its moisture to the air, as shown by increased cloud cover and relative humidity.
- As we move from the hot summer to the fall, soil moisture increases.
- As predicted by early and current EPA and NOAA climate models, the fall season in Ohio has become wetter over the last three years.
- Atypical soil moisture fluctuations can be harmful to agricultural practices in our region and ultimately impact the length of the growing season.

Limitations & Next Steps

<u>Limitations-</u>

- Did not collect data every day or at a consistent time (followed satellite overhead flight schedule).
- The soil was not always left in the oven for the same amount of time.
- Hand troweled soil occasionally (when too dry to scoop entire can).

<u>Next Steps-</u>

- Continue to gather more soil moisture data to track the trend.
- Collecting/ testing different sites to see if NASA’s predictions and our findings hold true over a larger geographic region.
- Compare our data to the data that other neighboring GLOBE schools found (partner with GLOBE Schools to coordinate a study).
- Compare number of days of precipitation and daily total precipitation over 2015 - 2018 to see if there are more rain events or stronger rain events.

References:

- Aiguo Dai, Trenberth, and Karl. Effects of Clouds, Soil Moisture, Precipitation, and Water Vapor on Diurnal Temperature Range. 1999. Retrieved from: https://journals.ametsoc.org/doi/full/10.1175/1520-0442%281999%29012%3C2451%3AEOCSMP%3E2.0.CO%3B2
- Mudiare, O. J., Gray, D. M., & McKay, G. A. (1982). Influence Of Cloud Cover On Evapotranspiration Demand. Retrieved April 2, 2018, from https://www.usask.ca/hydrology/papers/Gray_et_al_1986_2.pdf
- NASA Worldview. Retrieved from: https://worldview.earthdata.nasa.gov/
- Ravi, S., D'Odorico, P., Over, T. M., & Zobeck, T. M. (2004, May 06). On the effect of air humidity on soil susceptibility to wind erosion: The case of air-dry soils. Retrieved March 13, 2018, from http://onlinelibrary.wiley.com/doi/10.1029/2004GL019485/full
- Reardon, Kelly. NOAA Climate Projections: What Will Ohio Be like before the Year 2100? *Cleveland.com*, Cleveland.com, 23 Jan. 2017, www.cleveland.com/weather/blog/index.ssf/2017/01/noaa_climate_projections_what_1.html
- Soil Moisture Active Passive Satellite Mission. The GLOBE Program. Retrieved from: http://www.globe.gov/web/smap
- Soil Moisture Active Passive - Why it Matters. NASA Jet Propulsion Laboratory. Retrieved from: http://smap.jpl.nasa.gov/mission/why-it-matters
- US Environmental Protection Agency (USEPA). 1998. Climate Change and Ohio. Available Online http://yosemite.epa.gov/oar/GlobalWarming.nsf/UniqueKeyLookup/SHSU5BVJVM/$File/o h_impct.pdf. US Fish and Wildlife