NORTH CAROLINA CLIMATEOFFICE

Land Use and Soil Type Impacts on Multi-Level Soil Temperature Measurements for the North Carolina ECONet

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Introduction

- Soil temperature plays a vital role for numerous applications
  - Environmental modeling:
    - How quickly will air temperatures warm given the current soil temperature.
  - Agricultural modeling:
    - Soil temperature can give a sense on how much moisture a soil can absorb.
  - Transportation safety:
    - In winter, how cold is the surface for snow to stick/accumulate?
- Accurate soil temperature data are vital to understand important land-surface processes that affect these applications. While obtaining soil temperature data can be done via remote sensing, very few *in situ* weather and climate monitoring networks collect this information.
- Multi-depth soil temperature measurements improve the understanding of the thermal properties of soils and the associated heat fluxes in a region.
  - Sandy soils are effective at mirroring air temperature more closely due to their high albedo and higher thermal diffusivity.
  - Clay soils have a more muted daily oscillation of soil temperature than sandy soils due to slower drainage and higher heat capacity.
- Performing quality control on soil temperature data is also challenging.
  - Basic checks can be applied to soil temperature to verify the values are within climatological and sensor specification ranges.
  - Spatial checks prove ineffective in heterogeneous soil areas, such as in North Carolina, where soil types change over regions of a few kilometers.

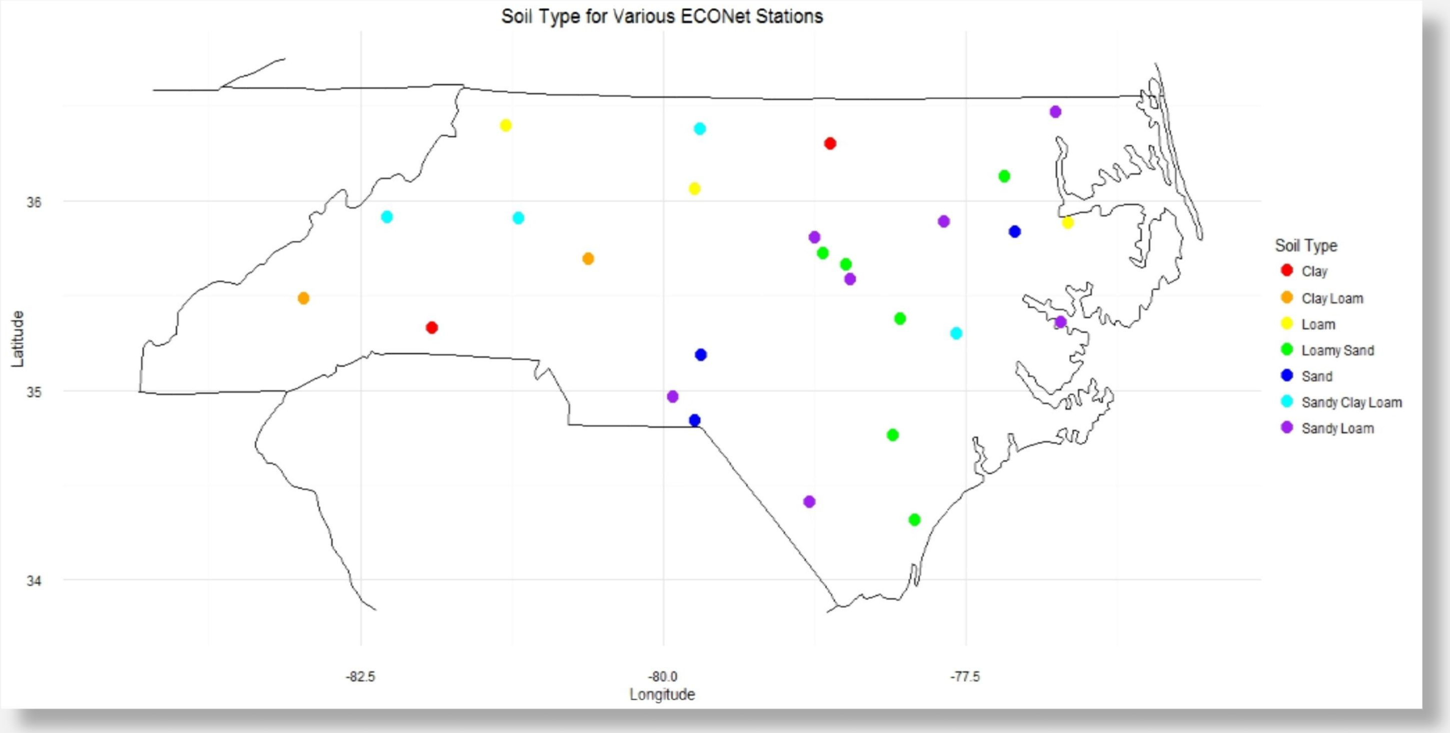
Sensors

- Soil temperature readings were obtained by two different sensors:
- Campbell Scientific 107 sensor (CS107; top photo)
  - Installed at 10cm below the surface
  - Consists of thermistor encapsulated in an epoxy-filled aluminum housing
  - Measures the ratio of measured voltage to excitation voltage

- North Carolina State Climate Office multi-depth soil temperature probe (SCO-ST; bottom photo)
  - Measures soil temperature at depths of 10cm, 20cm, 30cm, and 40cm
  - Consists of four (4) separate thermocouples inside a 0.5” diameter PVC pipe.
  - Converts analog voltage into soil temperature by using a multiplier and offset

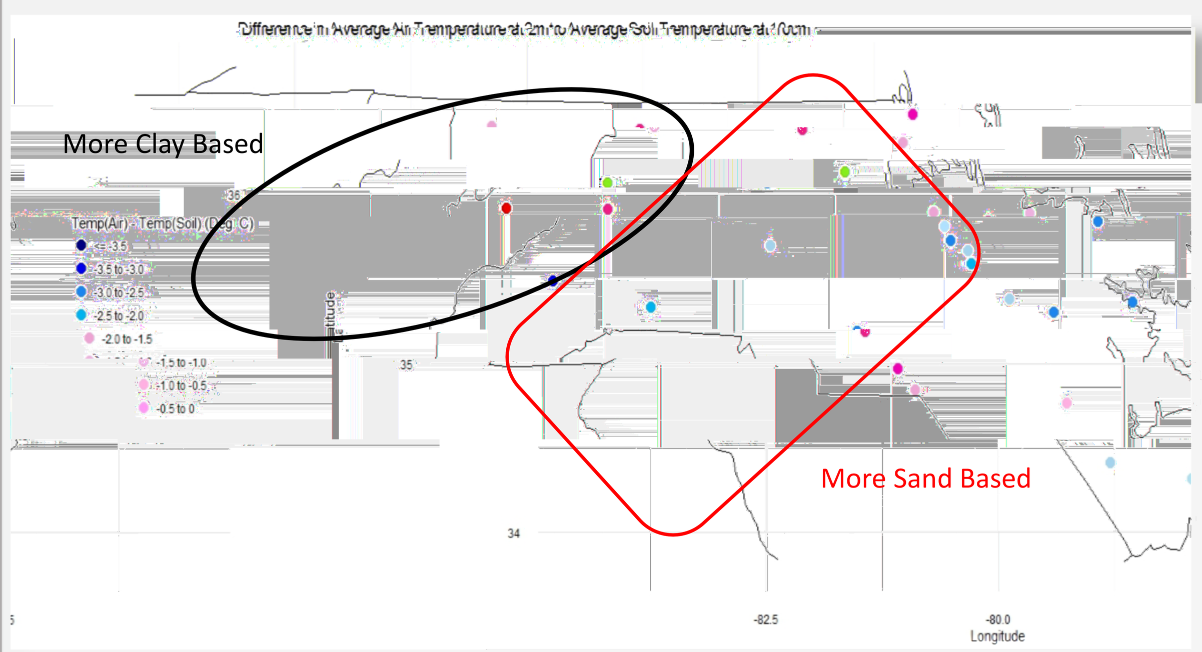
Data and Methodology

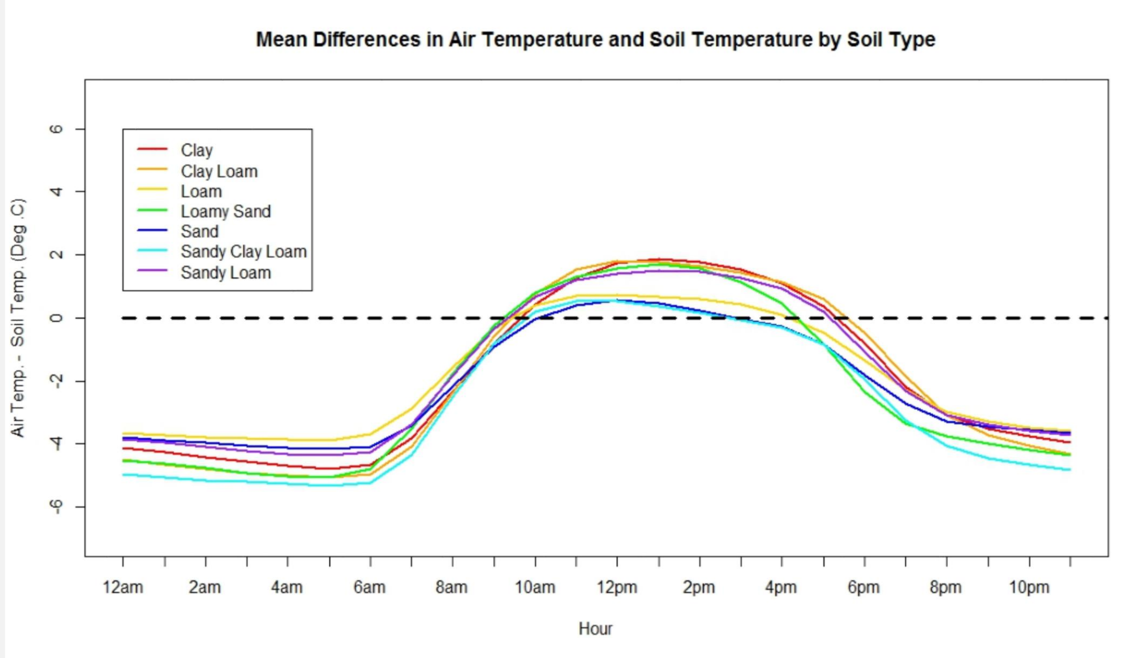
- Soil temperature from the CS107 and SCO-ST, as well as air temperature from a Vaisala WXT520 were analyzed from January 1, 2014 through November 14, 2016 at 27 stations from the NC Environment and Climate Observing Network (ECONet) at one minute intervals.
  - Soil types for each site were obtained through soil analysis documented in Pan et al. (2012)
  - Automated and manual quality control routines were used to eliminate erroneous data from any of the three sensors.
- Three separate comparisons were analyzed:
  - Air Temperature vs. Soil Temperature
  - Soil Temperature (CS107) vs. Soil Temperature (SCO-ST)
  - Soil Temperature at 10 cm (SCO-ST) vs. Soil Temperature at other depths (SCO-ST)



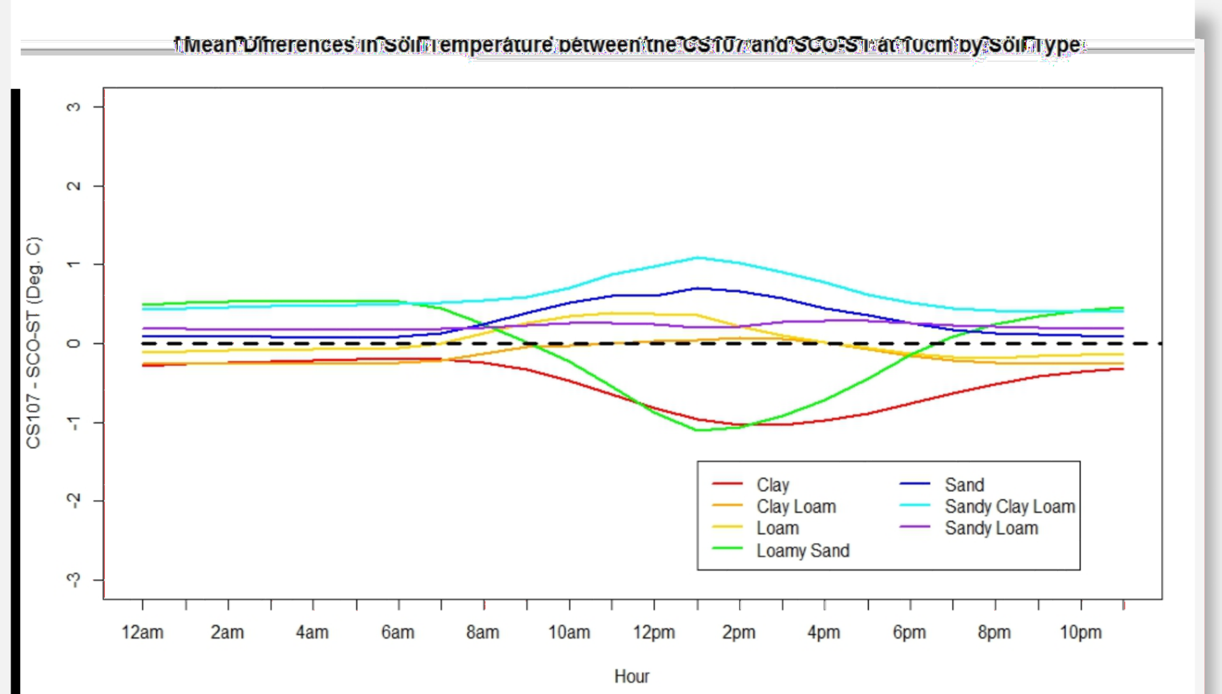
Results

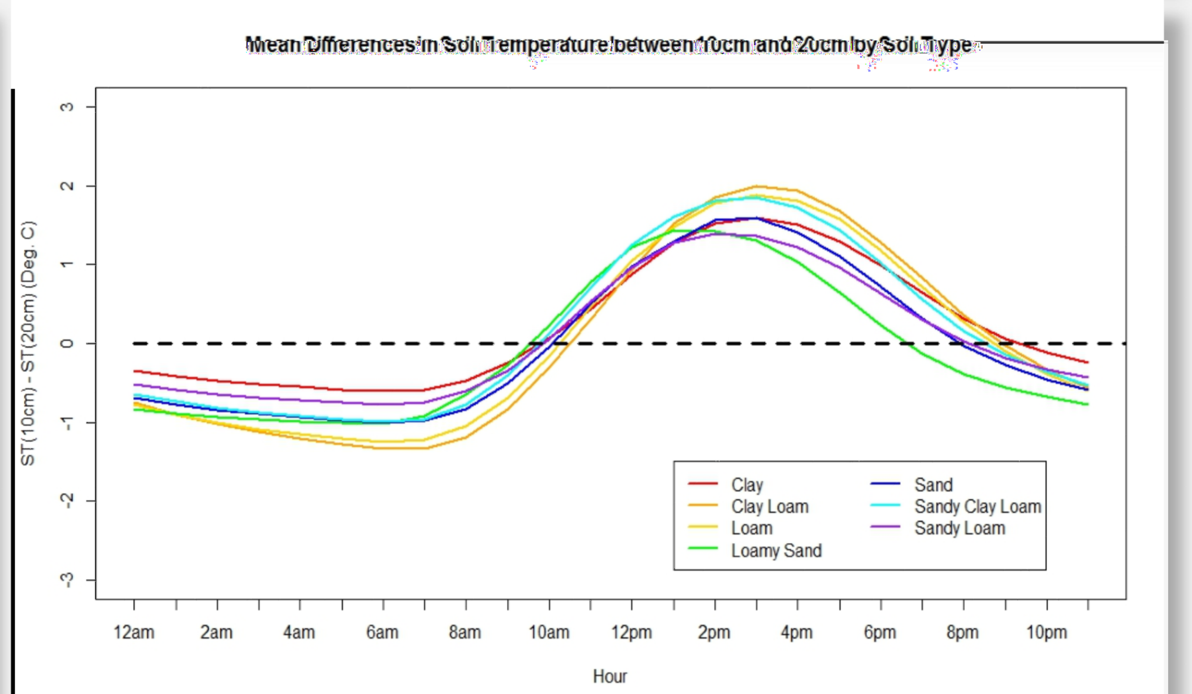
Air Temperature vs. Soil Temperature



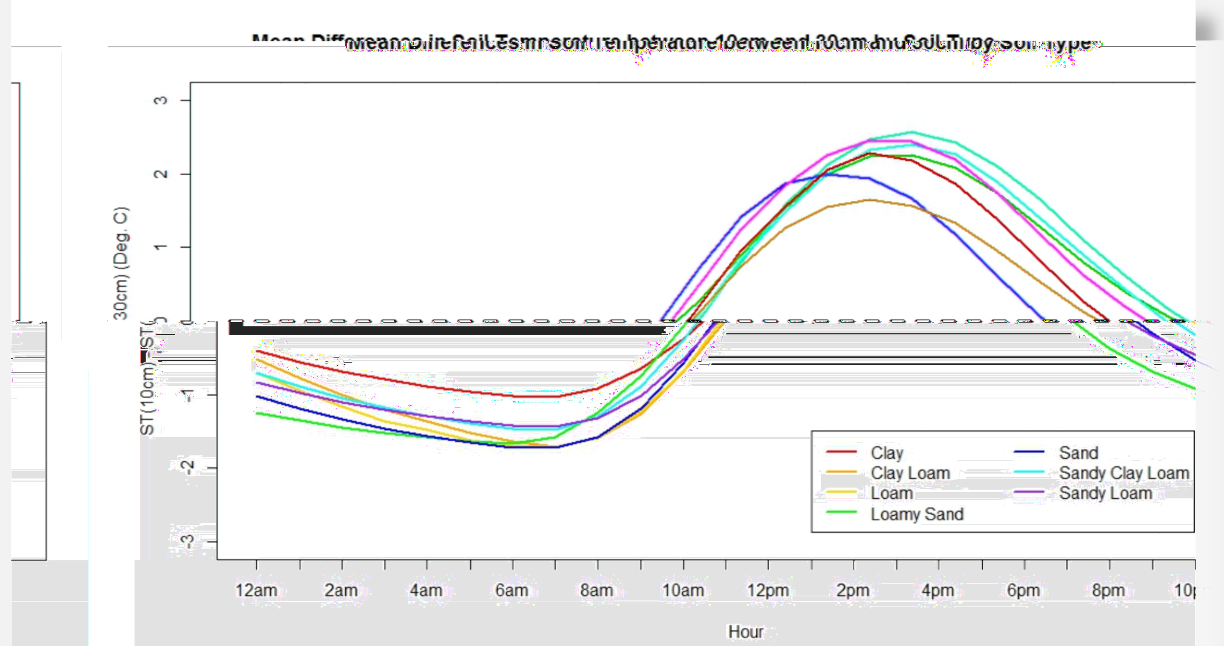


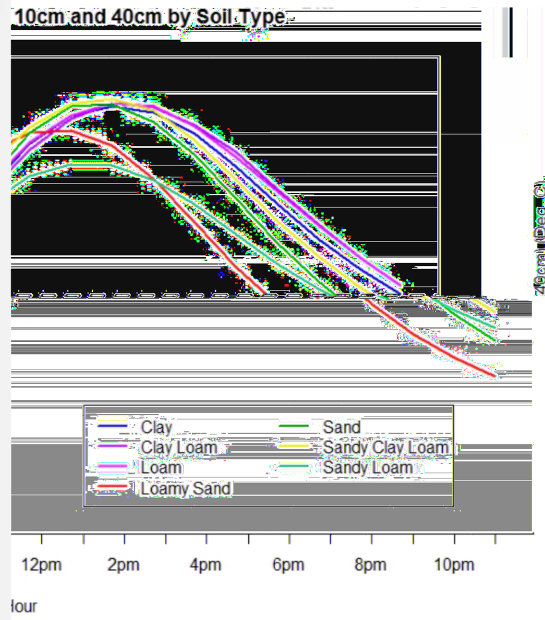
Soil Temperature Vs. Soil Temperature at 10cm and 20cm

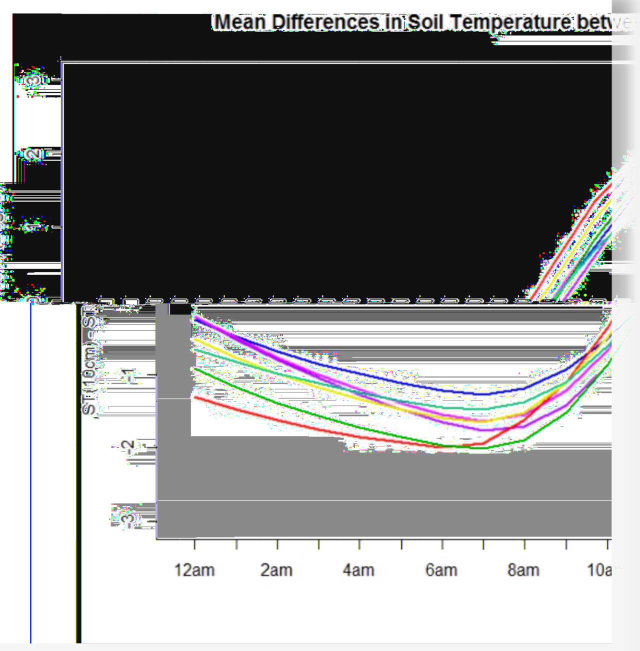




Soil Temperature vs. Soil Temperature at 30cm and 40cm







Conclusions

1) Differences between soil temperature and air temperature are more attributed to the topography than the soil, with larger differences in the mountains of western NC. However, during daylight hours, clay based soils show larger differences to air temperature than sandy based soils

2) The differences between the two sensors are nearly negligible. The SCO-ST sensor was warmer than the CS 107 in clay-based soils, while the CS107 was warmer than the SCO-ST in sandy-based soils. This difference *could* be related to the measuring principles of each sensor.

3) As expected, the maximum differences between soil temperature at varying depths happen in the early afternoon. Moreover, the timing of this maximum difference appears to be dependent on depth rather than soil type. Maximum soil temperature differences between 10cm and 20cm occur around 3pm LST, while the maximum differences between 10cm and 30cm, as well as 10cm and 40cm, occur approximately 1 hour later, at 4pm LST.

4) The largest minimum soil temperatures, where the deeper ST measurement is warmer than the 10cm ST measurement, occur in the early morning hours. However, this magnitude is marginally smaller than the maximum soil temperatures. This may be related to a slower release of longwave radiation in the overnight hours.

Future Work

1) Use this new information to create rigorous quality control mechanisms that take the lag into account when comparing soil temperatures at different depths.
2) Soil temperature measurements currently only extend to 40cm below the surface. Work to obtain soil temperature data at 60cm, or even 100cm below surface.
3) Validate soil temperature profiles in 1D land surface models to verify that models are reproducing what the *in situ* observations are reporting.
4) Explore other datasets that measure multi-level soil temperature and verify that our sensors are producing similar results as other networks.

References

Pan, W., R. P. Boyles, J. G. White, and J. L. Heitman, 2012: Characterizing Soil Physical Properties for Soil Moisture Monitoring with the North Carolina Environment and Climate Observing Network. *J. Atmos. Ocean. Tech.* **29**, 933-943

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