Grand Rapids Temperature Loggers 2019-2023

The Grand Rapids Soil Survey office established soil temperature probes from 2019 to 2023 at 4 locations representing high and low elevations and northern and southern latitudes within the Manistee National Forest with the goal of confirming a different soil temperature regime (mesic vs. frigid).

I initially attempted several global linear and random forest models to hindcast soil temperature regimes for two different 30-year periods. The global models optionally used case weights to compensate for the higher number of records in the NOAA air temperature data versus soil temperature station. The results compared to actual temperatures were very good. However, extrapolating the results to the earlier timeframes was inconsistent with hindcast estimates based on a more careful approach from individual station differences. It appeared that in the model only one soil temperature site with consistently within the frigid temperature regime (less than 8°C) for the cooler 1961-1990 reference temperature period. However, the manual calculations using the temperatures relative to Cadillac and Big Rapids, the nearest NOAA stations with long term air temperature records, suggests that both northern sites were frigid. However, the high elevation site to the south when compared to the differences from Big Rapids was mesic, unlike what we had anticipated when we established the new MLRA boundaries.

For the manually calculated hindcasts below, the 30-year average air temperature of the nearest NOAA station was compared to the average annual air temperature based on averaging by months for only the days when both soil temperature and air temperature stations were active. The time of overlap is variable depending on station, and the annual temperature averages the monthly temperatures equally irrespective of the number of days per month.

|  |  |  |
| --- | --- | --- |
| time period | station | temperature (°C) |
| 1961-1990 | Cadillac Air | 5.8 |
| cadillac X GRR1 | GRR1 @50 cm | 7.8 |
| cadillac X GRR1 | Cadillac | 7.3 |
| adjusted to 1990 | GRR1 @50 cm | 6.3 |

|  |  |  |
| --- | --- | --- |
| time period | station | temperature (°C) |
| 1961-1990 | Cadillac Air | 5.8 |
| cadillac X GRR2 | GRR2 @50 cm | 9.1 |
| cadillac X GRR2 | Cadillac | 7.1 |
| adjusted to 1990 | GRR2 @50 cm | 7.8 |

|  |  |  |
| --- | --- | --- |
| time period | station | temperature (°C) |
| 1961-1990 | Big Rapids Air | 7.1 |
| bigrapids X GRR5 | GRR5 @50 cm | 9.0 |
| bigrapids X GRR5 | Big Rapids Air | 7.8 |
| adjusted to 1990 | GRR5 @50 cm | 8.3 |

|  |  |  |
| --- | --- | --- |
| time period | station | temperature (°C) |
| 1961-1990 | Big Rapids Air | 7.1 |
| bigrapids X GRR6 | GRR6 @50 cm | 9.3 |
| bigrapids X GRR6 | Big Rapids Air | 8.0 |
| adjusted to 1990 | GRR6 @50 cm | 8.3 |

A second approach, “soildiff”, was to use a random forest model to estimate the air to soil annual temperature differential for just the stations with soil data, use random forest model to extrapolate this diffential for stations lacking this data, and then develop projection expected annual air temperature for each location. All stations that had air temperature available were in open areas, whereas GRR office soil-only stations were all under forest cover.

A third approach, “airdiff”, was to project the annual soil temperature for 2010-2022 timeframe for which partial data exists for multiple soil temperature stations, then develop another random forest model to estimate temperature changes between the 2010-2022 period and earlier periods using only the long term air temperature stations as inputs.

Global models including every attribute that might related to geographic and temporal differences in temperature attributed an average of 0.59°C reduction in annual soil temperature due to forest cover for 4 forested station. The influence of forest cover status on the model decreases with distance from the only forested stations, so the actual effect of forest cover is not well established further away.

Results

“Soildiff” approach yielded several frigid stations in the north central interior of the Lower Peninsula, during the 1961-1990 period. including the high elevation Briar Hills station, GRR1, but only when forested conditions were modeled. Under open conditions, soil temperature was projected to have been frigid only in Pellston and Vanderbilt, MI. During the 1981-2010 period, fewer stations qualified as frigid compared to the earlier period, and only one (Vanderbilt) remains as frigid under open conditions. The soil temperatures among the stations under open conditions was 1.5 to 2.8°C higher than measured air temperatures at those locations. Conservatively, this value added to PRISM gridded annual air temperature could approximate a soil temperature map. Assuming forested conditions, a reduced portion of MLRAs 94A and 94C is frigid during the 1961-1990 period, and under open conditions, only the highest hilltops would likely remain frigid. But it should be noted measured soil temperature difference between the GRR1 and GRR2 representing high and low elevations respectively in the Briar Hills was -1.0°C, whereas PRISM’s 1981-2010 air temperature model suggests that the higher site is 1.4°C colder.

“Airdiff” approach failed to show any of the GRR stations as frigid during any of the time periods. The difference in air temperature between the 1961-1990 and the 2010-2022 periods was 0.6 to 0.7°C colder. However, individual stations such as Big Rapids, it is only 0.4°C colder, while at Cadillac the earlier period was 1.2°C colder.

Without proper control for air temperature and forest cover conditions, any analysis to hindcast soil temperature is very sensitive to methodology. Also, given the potential for soil temperature to vary by snow cover in winter and deciduous tree cover in summer, and the sparse availability of data, classification of ecosystem by soil temperature is of questionable value. Optimal photosynthesis for a given species is likely more of a function of air temperature during the growing season, and for cold sensitive species, extreme winter cold is likely a limitation its distribution over some portion of their range.

Random forest model to fill in missing data:

Covariables:

decdate = decimal date (year and fractional time of year).

nt = the mean regional NOAA air temperature average for the time period

ns = soil temperature of the mean regional NOAA air temperature based on linear model of stations that include both air temperature and 50 cm soil temperature, using 45 day running average air temperature and 5 and 22 day running averages of positive-only air temperature as inputs (optimized from several options in number of days to average)

forest = forested status of temperature probe. The soil temperature stations were all considered open except the NRCS stations which were under forest cover.

Soil50 = Whether temperature probe was at 50 cm depth (any other soil temperatures taken at 10 cm). Air = Whether soil versus air temperature.

rf <- ranger(t ~ nt+ns+forest+

air+soil50+sin0+

lat+lon+elev+decdate

, data=alldata.50, num.trees=200, sample.fraction = 0.5)

alldata.50 <- alldata.50 |> mutate(t.rf = predictions(predict(rf, data=alldata.50)))

mean((alldata.50$t - alldata.50$t.rf)^2)^0.5

mean error = 1.171905 m

