Maladaptive plastic responses of flowering time to geothermal heating (Cerastium 2)

Analyses with logger data

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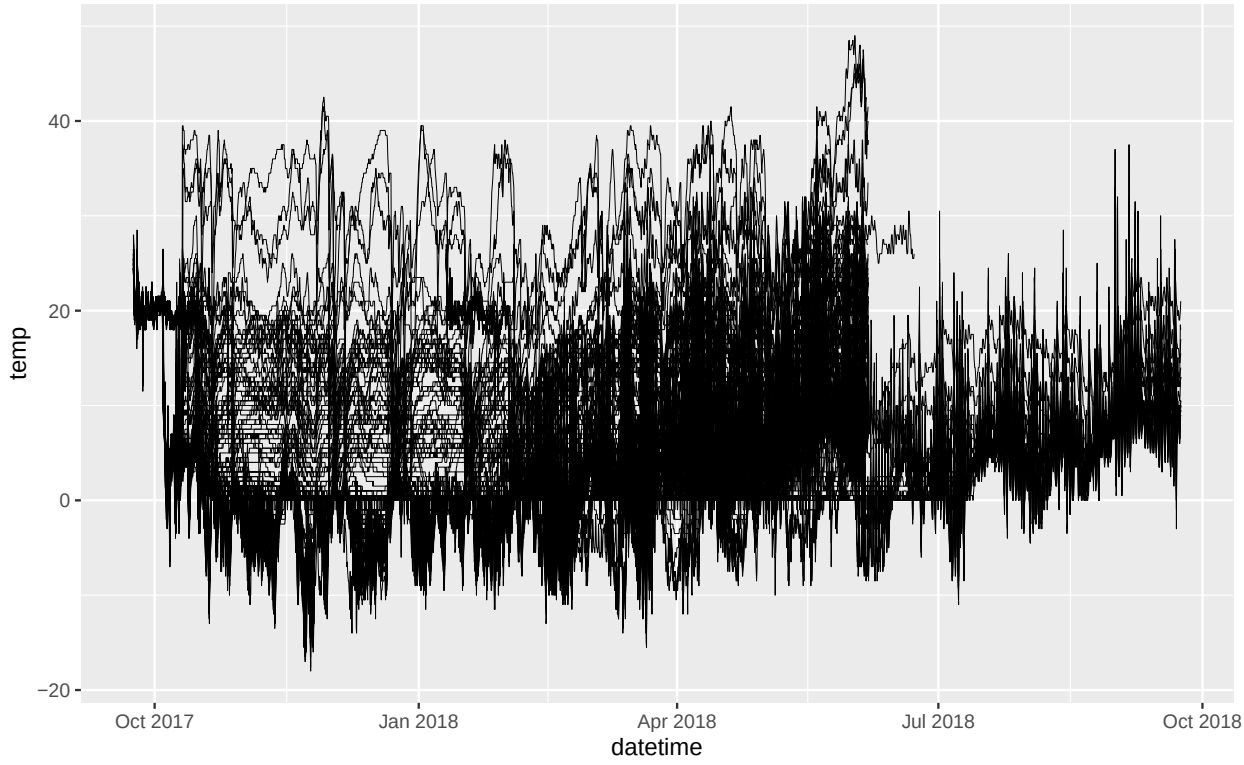
Contents

Read data

Plot with all logger data, one line per logger id

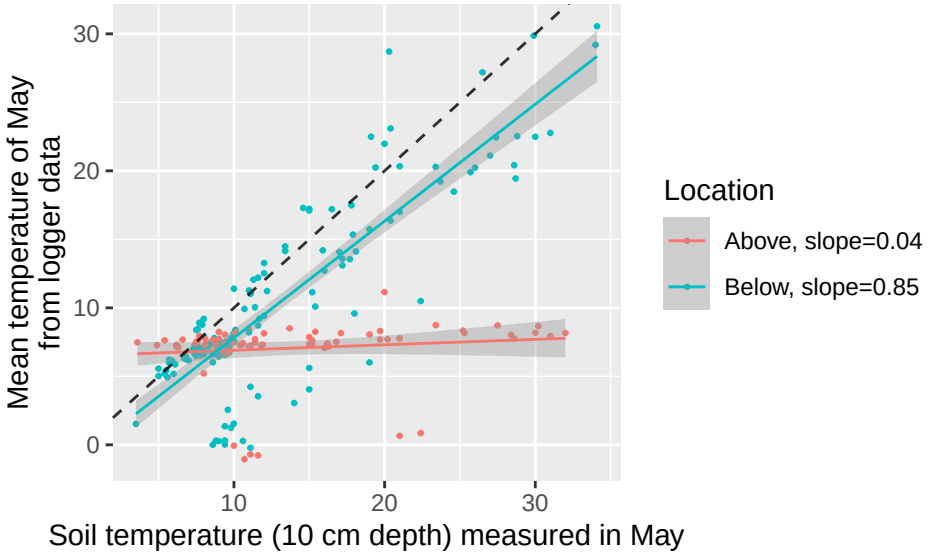


Q1: Are instantaneous measures of soil temperature representative for the conditions during the entire spring/growing season?

Correlations logger temperature - instant temperature

May

For each logger_nr, get mean temperature during May 2017 and compare with temp_term (which was measured with a thermometer at 10 cm depth on May 2017):



Observations	78
Dependent variable	meanmay_logger
Type	OLS linear regression

F(1,76)	1.233
R^2	0.016
Adj. R^2	0.003

	Est.	S.E.	t val.	p
(Intercept)	6.507	0.547	11.900	0.000
temp_term	0.040	0.036	1.111	0.270

Standard errors: OLS

Observations	141
Dependent variable	meanmay_logger
Type	OLS linear regression

F(1,139)	399.799
R^2	0.742
Adj. R^2	0.740

	Est.	S.E.	t val.	p
(Intercept)	-0.727	0.625	-1.163	0.247
temp_term	0.853	0.043	19.995	0.000

Standard errors: OLS

Correlation mean temperature of may from logger data and soil temperature measured in may with thermometer:

```
## [1] 0.6446784
```

Correlation mean temperature of may from logger data (only belowground loggers) and soil temperature measured in may with thermometer:

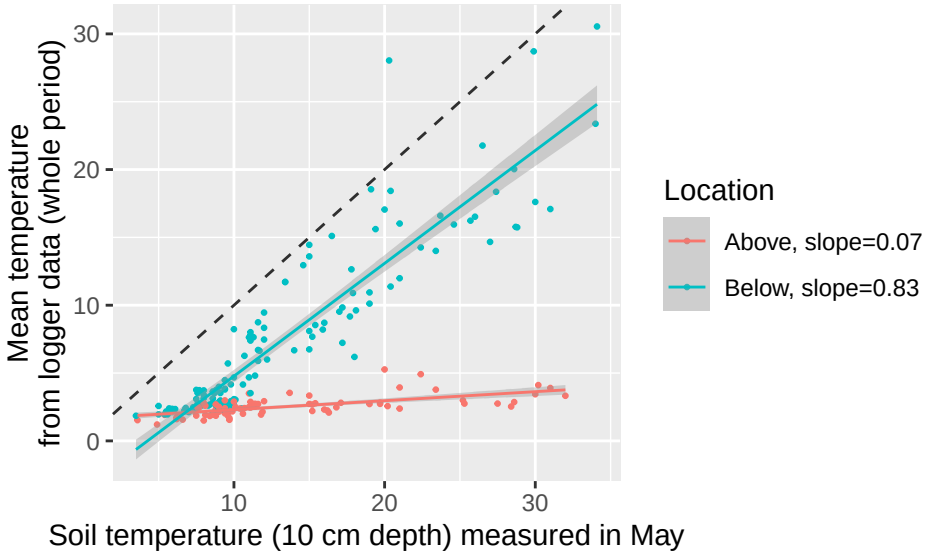
```
## [1] 0.8614051
```

Correlation mean temperature of may from logger data (only aboveground loggers) and soil temperature measured in may with thermometer:

```
## [1] 0.1263677
```

Whole period

For each logger_nr, get mean temperature during the whole period available and compare with temp_term (which was measured with a thermometer at 10 cm depth on May 2017):



Observations	78
Dependent variable	mean_logger
Type	OLS linear regression

F(1,76)	54.027
R^2	0.416
Adj. R^2	0.408

	Est.	S.E.	t val.	p
(Intercept)	1.633	0.138	11.819	0.000
temp_term	0.066	0.009	7.350	0.000

Standard errors: OLS

Correlation mean temperature from logger data and soil temperature measured in may with thermometer:

Observations	141
Dependent variable	mean_logger
Type	OLS linear regression

F(1,139)	686.807
R^2	0.832
Adj. R^2	0.830

	Est.	S.E.	t val.	p
(Intercept)	-3.547	0.465	-7.623	0.000
temp_term	0.832	0.032	26.207	0.000

Standard errors: OLS

```
## [1] 0.6700633
```

Correlation mean temperature from logger data (only belowground loggers) and soil temperature measured in may with thermometer:

```
## [1] 0.9119648
```

Correlation mean temperature from logger data (only aboveground loggers) and soil temperature measured in may with thermometer:

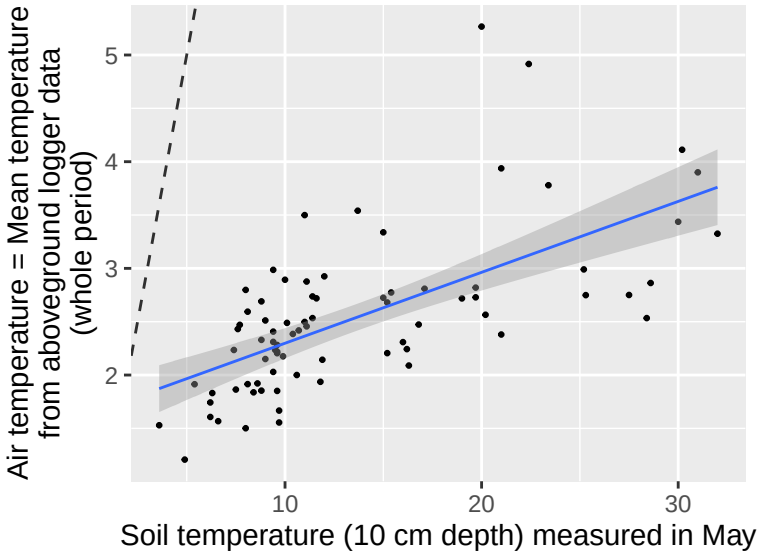
```
## [1] 0.6445959
```

The correlation values seem to indicate that the temperature measured with a thermometer represents quite well longer-term conditions

Q2: Do differences between soil and air temperatures change with soil temperature?

For the plants with aboveground loggers, we have air temperature and soil temperature measured at the same exact location (air temperature measured by the aboveground logger and soil temperature measured with the thermometer). We use these plants to test for correlations between air and soil temperature, using all temperature values.

Logger data for the whole period:



Observations	78
Dependent variable	mean_logger
Type	OLS linear regression

F(1,76)	54.027
R^2	0.416
Adj. R^2	0.408

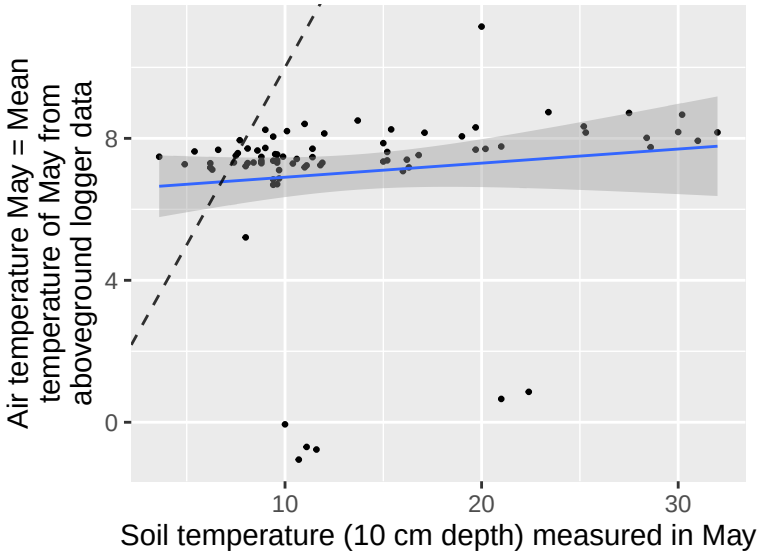
	Est.	S.E.	t val.	p
(Intercept)	1.633	0.138	11.819	0.000
temp_term	0.066	0.009	7.350	0.000

Standard errors: OLS

```
## Linear hypothesis test
##
## Hypothesis:
## temp_term = 1
##
## Model 1: restricted model
## Model 2: mean_logger ~ temp_term
##
##   Res.Df    RSS Df Sum of Sq     F    Pr(>F)
## 1     77 3339.5
## 2     76   23.6  1    3315.9 10658 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The slope is significantly different from 1: differences between soil and air temperature change with soil temperature, being larger at higher soil temperatures.

Logger data for May:



Observations	78
Dependent variable	meanmay_logger
Type	OLS linear regression

F(1,76)	1.233
R^2	0.016
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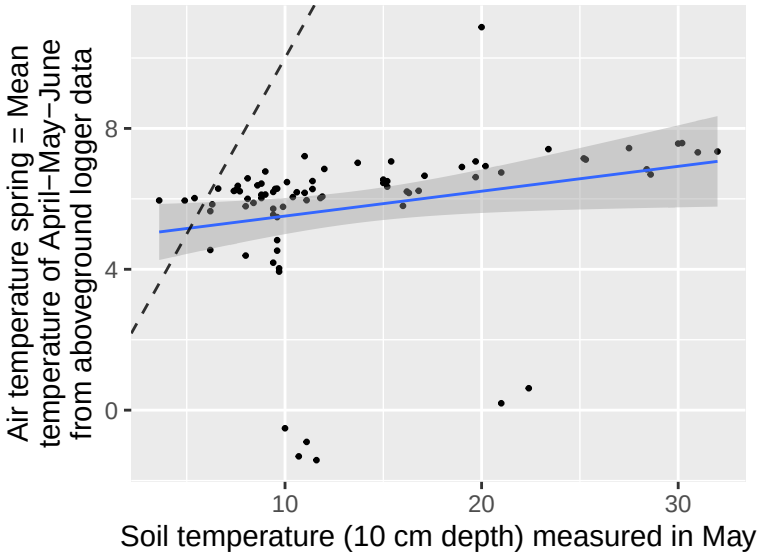
	Est.	S.E.	t val.	p
(Intercept)	6.507	0.547	11.900	0.000
temp_term	0.040	0.036	1.111	0.270

Standard errors: OLS

```
## Linear hypothesis test
##
## Hypothesis:
## temp_term = 1
##
## Model 1: restricted model
## Model 2: meanmay_logger ~ temp_term
##
##   Res.Df    RSS Df Sum of Sq      F    Pr(>F)
## 1     77 3878.6
## 2     76  370.1  1    3508.5 720.54 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

When looking only at air temperature in May, the slope is also significantly different from 1. But it is not significantly different from zero! So there is no relationship between soil and air temperature.

Logger data for April-May-June:



Observations	78
Dependent variable	meanspring_logger
Type	OLS linear regression

F(1,76)	4.642
R^2	0.058
Adj. R^2	0.045

	Est.	S.E.	t val.	p
(Intercept)	4.805	0.501	9.592	0.000
temp_term	0.071	0.033	2.154	0.034

Standard errors: OLS

```
## Linear hypothesis test
##
## Hypothesis:
## temp_term = 1
##
## Model 1: restricted model
## Model 2: meanspring_logger ~ temp_term
##
##   Res.Df    RSS Df Sum of Sq      F    Pr(>F)
## 1     77 3597.1
## 2     76  310.6  1    3286.5 804.06 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

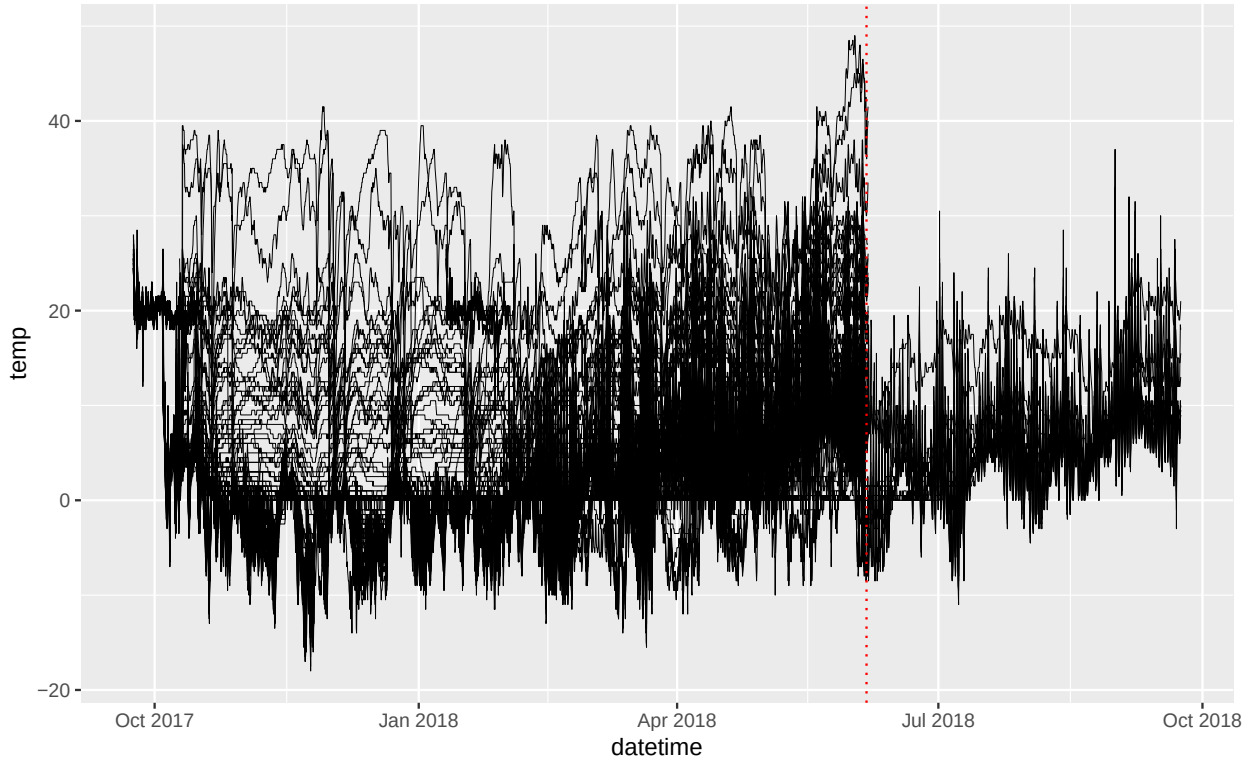
When looking at air temperature in the period April-May-June, the slope is also significantly different from 1: differences between soil and air temperature change with soil temperature, being larger at higher soil temperatures.

Q3: Do correlations between soil and air temperature vary with soil temperature?

Or: How useful soil temperature is as a cue for air temperature, i.e., as a cue for spring advancement?

We test this using logger pairs.

Plot with all paired logger data, one line per logger id




```
## # A tibble: 146 x 3
##    logger_nr  pair last_date
##        <dbl> <dbl> <dttm>
##  1       103     1 2018-06-06 12:11:00
##  2       105     1 2018-06-06 13:44:00
##  3       101     2 2018-06-06 11:34:00
##  4       104     2 2018-06-06 13:16:00
##  5       108     3 2018-06-06 12:52:00
##  6       113     3 2018-06-06 11:02:00
##  7       111     4 2018-06-06 12:59:00
##  8       115     4 2018-06-06 12:04:00
##  9       117     5 2018-06-06 10:43:00
## 10       122     5 2018-06-06 13:36:00
## # ... with 136 more rows
```

Most loggers (131 out of 145) end up on June 6th, so using data until this date.

Plot all logger pairs, to see how each of them looks.

Make one plot for each logger pair and save all as a pdf in output folder.

After looking at the plots, make a new variable pair_problem: - 0 = no problem - 1 = some problems (remove)

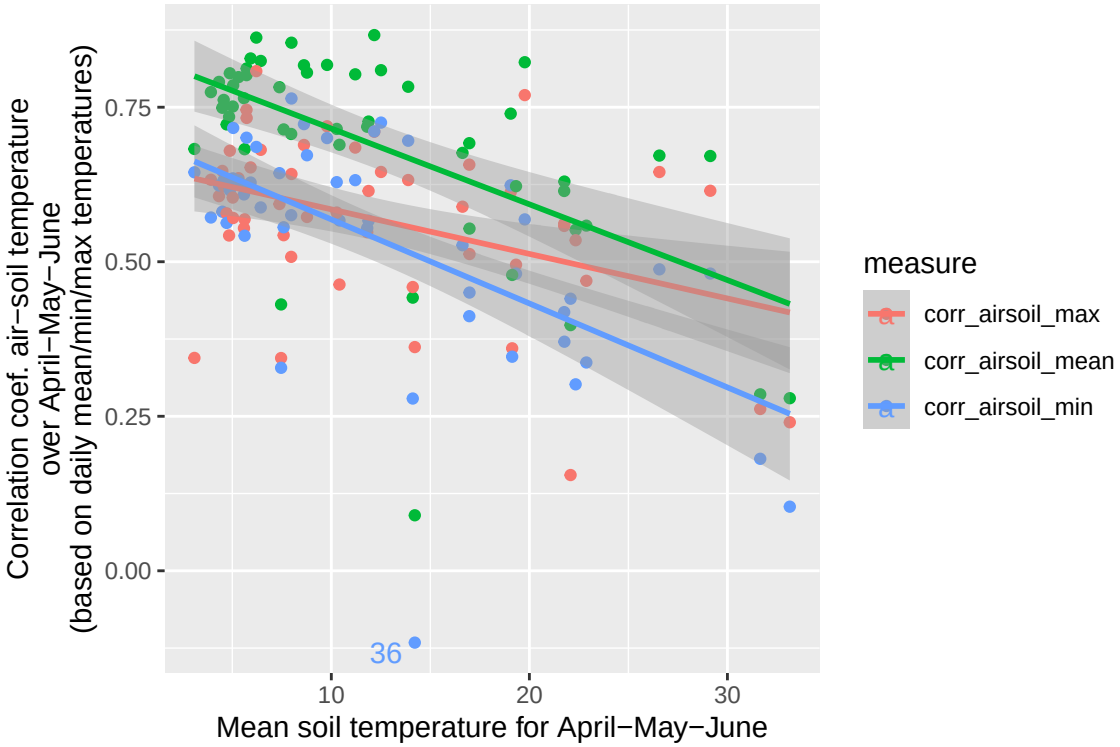
Use only logger pairs with no problems (52 pairs out of 73): pairs 1-4,11,13-16,21-62,70.

We probably should also use only loggers with no problems for the analyses in Q1 and Q2.

Correlations soil-air temperature over the period April-May-June

For each date and logger pair, calculate mean, max and min of air and soil temperature (from, respectively, the above and belowground logger). Then, calculate the correlation coefficient for air and soil temperatures over the period April-May-June. Finally, regress these correlation coefficients on mean soil temperature (from the belowground logger) **for the same period (April-May-June)**.

Using only data till June 5th, included (as most loggers stop on June 6th).



Most of the pairs with negative correlations have disappeared when considering only pairs without problems!

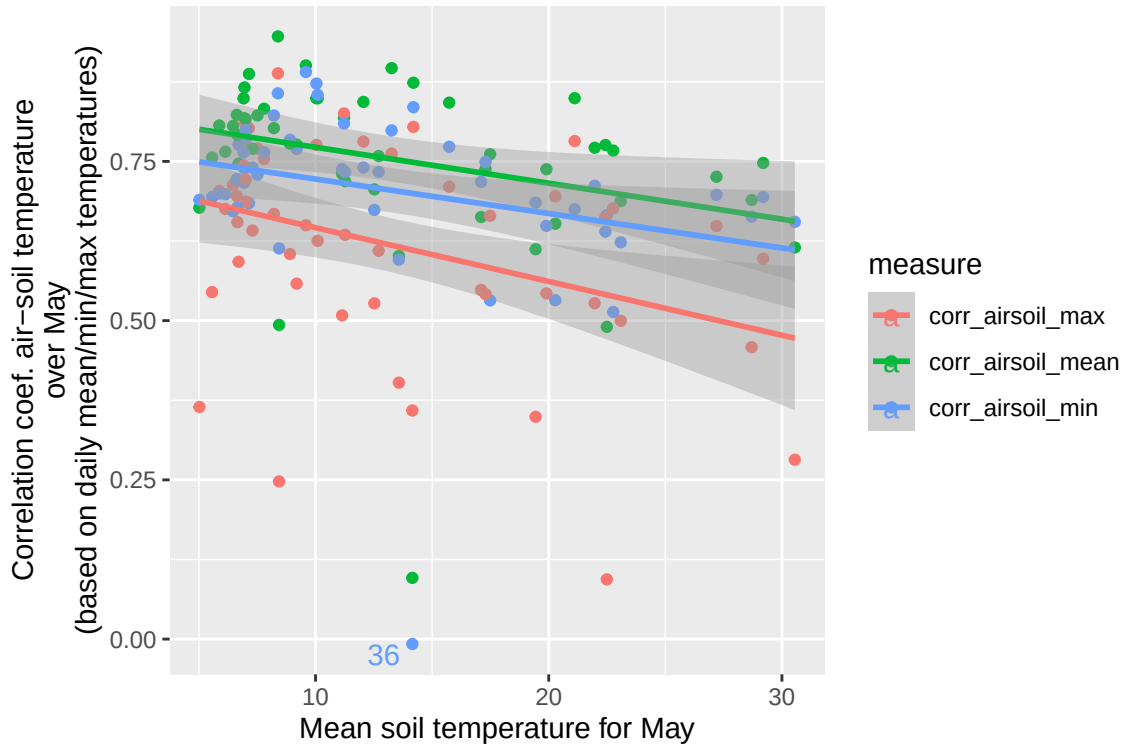
Linear models testing the effect of soil temperature on correlations between soil and air temperature:

measure	term	estimate	std.error	statistic	p.value
corr_airsoil_max	(Intercept)	0.6568341	0.0319380	20.565933	0.0000000
corr_airsoil_max	meansoiltemp	-0.0072069	0.0021963	-3.281420	0.0018870
corr_airsoil_mean	(Intercept)	0.8381035	0.0345061	24.288540	0.0000000
corr_airsoil_mean	meansoiltemp	-0.0122582	0.0023729	-5.165940	0.0000042
corr_airsoil_min	(Intercept)	0.7043187	0.0350510	20.094122	0.0000000
corr_airsoil_min	meansoiltemp	-0.0135863	0.0024104	-5.636639	0.0000008

All significant.

Correlations soil-air temperature for May only

For each date and logger pair, calculate mean, max and min of air and soil temperature (from, respectively, the above and belowground logger). Then, calculate the correlation coefficient for air and soil temperatures over the month of May. Finally, regress these correlation coefficients on mean soil temperature (from the belowground logger) **for the same period (May)**.



Linear models testing the effect of soil temperature on correlations between soil and air temperature:

measure	term	estimate	std.error	statistic	p.value
corr_airsoil_max	(Intercept)	0.7303409	0.0450862	16.198769	0.0000000
corr_airsoil_max	meansoiltemp	-0.0084423	0.0030049	-2.809453	0.0070638
corr_airsoil_mean	(Intercept)	0.8286498	0.0376102	22.032561	0.0000000
corr_airsoil_mean	meansoiltemp	-0.0056441	0.0025067	-2.251634	0.0287701
corr_airsoil_min	(Intercept)	0.7763669	0.0370992	20.926806	0.0000000
corr_airsoil_min	meansoiltemp	-0.0054087	0.0024726	-2.187446	0.0334132

All significant.

Session Info