Data Overview: Predicting Future Springs

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1 Overview of the data

This is a quick description of the data we will use at our working group. The goal of our working group is to understand (the) underlying cause(s) of the recent finding that results obtained from observational versus experimental studies make radically different predictions for future plant phenology (Wolkovich et al. 2012). The underlying cause of this discrepancy is curently unclear, and to address this we have compiled phenology and climate data for experimental and observational studies.

There are two main files with the phenological data, one file with the experimental climate data, and a folder with temperature data for the observational sites. They can all be downloaded at `https://github.com/AileneKane/radcliffe`. The phenology data files and experimental climate data file are found in the "radmeeting" folder. The temperature data for the observational sites are found in the "Observations/Temp."

A note about the data: they are still being cleaned and compiled so please let Ailene know if you find any mistakes or notice anything strange!

```
> setwd("~/GitHub/radcliffe")
> obsdata <- read.csv("radmeeting/obspheno.csv", header=TRUE)
> expdata <- read.csv("radmeeting/exppheno.csv", header=TRUE)
> expclim<-read.csv("radmeeting/expclim.csv", header=TRUE)
```

We'll walk through the experimental phenology data first. We selected experimental studies that used active warming methods (including above-canopy heating, as well as combined air and soil warming methods) to apply temperature treatments. We additionally limited studies to those that either/both: 1) applied atleast 2 different levels of warming, in addition to controls; and/or 2) measured soil moisture or humidity in all treatments. In many cases those studies that measure soil moisture also manipulate precipitation/moisture through an experimental treatment (i.e. drought and/or increased precipitation treatments).

1.1 Phenology Data from Experiments

```
> head(expdata)
```

```
     site plot event year genus species doy
1 marchin    1   bbd 2011  Acer  rubrum  88
2 marchin    1   bbd 2011  Acer  rubrum  83
3 marchin    1   bbd 2011  Acer  rubrum  96
4 marchin    1   bbd 2011  Acer  rubrum  79
```

```
5 marchin    1   bbd 2011  Acer  rubrum  83
6 marchin    1   bbd 2011  Acer  rubrum  80
```

The phenology data file has the following columns:

site: the first author's name (usually)

plot: the plot or chamber number, given by the author; this can be used to identify the treatment with the "expclim.csv "file, which contains plot and treatment codes, and the "expsiteinfo.csv" file, which contains details on the experimental treatment. For full details on each experiment, see the individual site folders in the "Experiments" folder.

event: phenological event (bbd=first leaf budburst date,lod=first leaf out date, lud= first leaf unfolding date,ffd=first flower date,ffrd=first fruiting date,sd= first seeds dispersing date,col=first date leaf coloration observed, sen=first date senesence observed,drop=leaf drop)

genus and species:

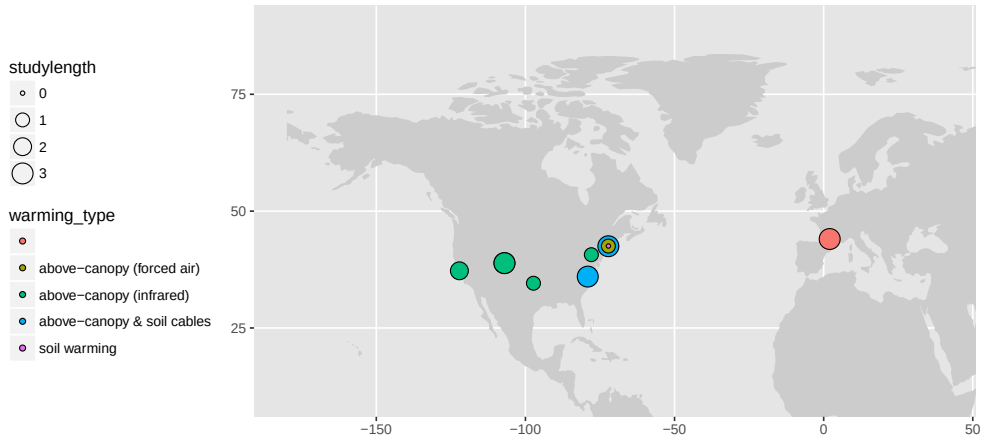
doy: day of year that the phenological event first occured

Each row is an observation of an individual or plot (whatever the finest scale of observation for that study)

The experimental data come from 8 different sites (see "expsiteinfo.csv" file for details on the locations)

```
> unique(expdata$site)
```

```
 [1] marchin        bace           farnsworthharv cleland        clarkduke
 [6] clarkharvard   oklahoma       rmbl           chuine         force
[11] harvardellison dunnermbl
12 Levels: bace chuine clarkduke clarkharvard cleland dunnermbl farnsworthharv ... rmbl
```



Ten different phenological events were monitored across all sites:

```
> table(expdata$site, expdata$event)
```

```
                bbd   col  drop   ffb   ffd  ffrd   lod   lud    sd   sen
bace            243     0     0     0     0     0   254   256     0     0
chuine            0     0     0  3367  3284  2238     0     0     0     0
```

```
  clarkduke       8304     0     0     0     0     0 12573 13989     0     0
  clarkharvard    2527     0     0     0     0     0  4503  3698     0     0
  cleland            0     0     0     0  2368     0     0     0     0     0
  dunnermbl          0     0     0     0  9117   938     0     0     0     0
  farnsworthharv   262    45     0     0    12    20   305   170     0     0
  force              0     0     0     0   585   388  1333     0   179   551
  harvardellison    68     0   146     0     0     0   196    91     0   214
  marchin          849     0     0     0   280     0     0     0     0     0
  oklahoma           0     0     0     0   623   671     0     0     0     0
  rmbl               0     0     0     0  1071   650     0     0   476     0
```

1.2 Phenology Data from Observational Studies

Next, the observational data.

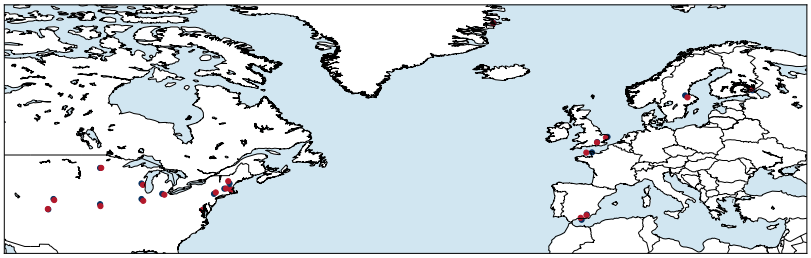
```
> head(obsdata)
```

```
    site plot event year doy       date genus   species scrub varetc cult
1 fitter <NA>   ffd 1954 130 1954-05-10  Acer campestre     0     NA   NA
2 fitter <NA>   ffd 1955 131 1955-05-11  Acer campestre     0     NA   NA
3 fitter <NA>   ffd 1956 137 1956-05-16  Acer campestre     0     NA   NA
4 fitter <NA>   ffd 1957 121 1957-05-01  Acer campestre     0     NA   NA
5 fitter <NA>   ffd 1958 128 1958-05-08  Acer campestre     0     NA   NA
6 fitter <NA>   ffd 1959 129 1959-05-09  Acer campestre     0     NA   NA
```

The observational data come from 15 sites (see "obssiteinfo.csv" file for details).

```
> unique(obsdata$site)
```

```
 [1] fitter   harvard  hubbard  konza    niwot    mikesell concord  mohonk   marsham
[10] fargo    washdc   bolmgren gothic   uwm      rousi
15 Levels: bolmgren concord fargo fitter gothic harvard hubbard konza ... washdc
```



And include 7 phenological stages:

```
> table(obsdata$site, obsdata$event)
```

	bbd	ffd	fld	L75mdoy	L95mdoy	lod	lud
bolmgren	0	1622	0	0	0	0	0
concord	0	9320	0	0	0	0	0
fargo	0	4725	0	0	0	0	0
fitter	0	13721	0	0	0	0	0
gothic	0	162352	0	0	0	0	0
harvard	483	284	0	0	0	0	0
hubbard	72	0	0	0	0	72	0
konza	0	3403	0	0	0	0	0
marsham	0	2131	660	0	0	0	0
mikesell	445	0	0	0	0	549	554
mohonk	0	673	0	0	0	0	0
niwot	648	371	0	0	0	0	0
rousi	1021	147	0	0	0	0	0
uwm	414	0	0	415	415	0	0
washdc	0	7455	0	0	0	0	0

```
> obsdata$doy <- as.numeric(obsdata$doy)
> obsagg <- aggregate(obsdata[c("doy")], obsdata[c("site", "year")], FUN=mean, na.action = na.omit)
> # simple plot, need to add a legend
> obsitez <- unique(obsdata$site)
> somecolors <- rainbow(length(obsitez))
> plot(doy~year, data=obsagg, type="n")
```

```
> for (i in seq_along(obsitez)){
+      subby <- subset(obsagg, site==obsitez[i])
+      lines(doy~year, data=subby, col=somecolors[i])
+ }
```

1.3 Climate Data from Experiments

We compiled daily air and soil temperature, whenever possible, as well as soil moisture or humidity data for all sites.

```
> head(expclim)
```

```
     site temptreat preciptreat plot year doy airtemp_min airtemp_max soiltemp1_min
1 marchin         1        <NA>    1 2010   1       2.932       30.87         4.596
2 marchin         1        <NA>    1 2010  10          NA          NA            NA
3 marchin         1        <NA>    1 2010 100       6.683       32.76            NA
4 marchin         1        <NA>    1 2010 101       5.883       36.37            NA
5 marchin         1        <NA>    1 2010 102       7.922       36.90            NA
6 marchin         1        <NA>    1 2010 103       9.980       40.81            NA
  soiltemp2_min soiltemp1_max soiltemp2_max soiltemp1_mean  soilmois gdd_soil gdd_air
1            NA          8.97            NA          6.783 0.1777083   -3.217  6.9010
2            NA            NA            NA             NA        NA       NA      NA
3         12.16            NA         15.18             NA 0.1608333       NA  9.7215
4            NA            NA            NA             NA 0.1558333       NA 11.1265
5            NA            NA            NA             NA 0.1513333       NA 12.4110
6         13.58            NA         17.03             NA 0.1463333       NA 15.3950
```

The experimental climate data file has the following columns:

temptreat: temperature treatment level (1-9; these levels are defined in "expsiteinfo.csv")

preciptreat: temperature treatment level (1-2; these levels are defined in "expsiteinfo.csv")

plot

year

doy: day of year

airtemp-min: minimum daily air temperature (degrees C), measured

airtemp-max: maximum daily air temperature (degrees C), measured

soiltemp1-min: minimum daily soil temperature (degrees C), measured, depth closest to the soil surface

soiltemp2-min: minimum daily soil temperature (degrees C), measured, depth second closest to soil surface

soiltemp1-max: maximum daily soil temperature (degrees C), measured, depth closest to the soil surface

soiltemp2-max: maximum daily soil temperature (degrees C), measured, depth second closest to soil surface

soiltemp1-mean: mean daily soil temperature (degrees C), measured, depth closest to the soil surface (some studies only have data for mean, rather than min or max)

soilmos: soil moisture (percent)

1.4 Climate Data for Observational Studies

We extracted temperature data from Berkeley Earth Surface Temperatures (BEST) `http://berkeleyearth.org/`. The BEST data are daily gridded tmax and tmin, covering (for most areas) 1880-2013. We took the latitudes and longitudes for the observational phenological data sites, and found the closest BEST grid cell with at least 25 percent land area coverage (in some cases the absolute nearest grid cell was ocean, for where there are no data. Hence the land fraction threshold). The data are in comma delimited text files in Observations/Temp on github; one file for tmax and one for tmin for each site. Each row is a year and each column is a day of year (1-365 for a normal year, 1-366 for a leap year). Some sites do have missing data for some years, but most are pretty much complete.

Note: the data are too extensive to compile into a single datafile of observational climate data, so we have left them in separate files.

Here is a summary of the site info and associated BEST gridcell information (from file distinfo-site-BEST-.csv):

	X	Lat..Site.	Lon..Site.	Dist..km.	Lat..BEST.	Lon..BEST.	Frac.Land
1	fitter	51.42000	-0.540000	9.320189	51.5	-0.5	1.00
2	concord	42.27000	-71.210000	34.959232	42.5	-71.5	1.00
3	fargo	46.51000	-96.280000	16.879558	46.5	-96.5	1.00
4	bolmgren	60.13000	16.950000	48.043302	60.5	16.5	1.00
5	harvard	42.53000	-72.190000	25.634244	42.5	-72.5	1.00
6	hubbard	43.94000	-71.750000	52.906733	43.5	-71.5	1.00
7	konza	39.13000	-96.430000	41.593559	39.5	-96.5	1.00
8	mohonk	41.77000	-74.160000	41.241097	41.5	-74.5	1.00
9	niwot	40.30000	-105.360000	25.209401	40.5	-105.5	1.00
10	gothic	38.57000	-106.590000	11.042735	38.5	-106.5	1.00
11	marsham	52.37000	1.180000	26.076351	52.5	1.5	0.59
12	washdc	38.40000	-76.700000	20.669903	38.5	-76.5	0.70
13	mikesell	41.33000	-84.090000	39.079552	41.5	-84.5	1.00
14	uwm	43.23000	-88.220000	37.610769	43.5	-88.5	1.00
15	rousi	61.80000	29.316700	34.745032	61.5	29.5	0.76
16	siernev1	36.87000	-3.690000	44.507990	36.5	-3.5	0.29
17	siernev2	37.36000	-2.560000	16.449278	37.5	-2.5	1.00
18	zacken	74.46667	-20.566667	4.205057	74.5	-20.5	0.71
19	bock	49.46344	-2.596667	79.354125	49.5	-1.5	0.44
20	augspurger	40.15000	-88.166667	48.110043	40.5	-88.5	1.00

The other file, map-sites.eps, plots the locations of the phenology sites (in red) and the chosen BEST gridcell (in blue):

```
> ## look at species numbers and overlap
> expdata$latbi <- paste(expdata$genus, expdata$species)
> obsdata$latbi <- paste(obsdata$genus, obsdata$species)
> length(unique(expdata$latbi))
```

```
[1] 219
```

```
> length(unique(obsdata$latbi))
```

```
[1] 2143
```

```
> unique(expdata$latbi)[which(unique(expdata$latbi) %in% unique(obsdata$latbi))]
```

```
  [1] "Acer rubrum"                  "Carya tomentosa"
  [3] "Quercus alba"                 "Vaccinium pallidum"
  [5] "Vaccinium stamineum"          "Quercus rubra"
  [7] "Chimaphila maculata"          "Hieracium venosum"
  [9] "Thalictrum thalictroides"     "Betula lenta"
 [11] "Fagus grandifolia"            "Acer pensylvanicum"
 [13] "Vaccinium corymbosum"         "Castanea dentata"
 [15] "Prunus serotina"              "Vaccinium vacillans"
 [17] "Viburnum acerifolium"         "Viburnum lentago"
 [19] "Bromus hordeaceus"            "Geranium dissectum"
 [21] "Vicia sativa"                 "Vulpia myuros"
 [23] "Pinus taeda"                  "Nyssa sylvatica"
 [25] "Liquidambar styraciflua"      "Pinus strobus"
 [27] "Liriodendron tulipifera"      "Pinus virginiana"
 [29] "Fraxinus americana"           "Quercus velutina"
 [31] "Acer saccharum"               "Quercus phellos"
 [33] "Cornus florida"               "Juniperus virginiana"
 [35] "Diospyros virginiana"         "Betula alleghaniensis"
 [37] "Carya ovata"                  "Ilex opaca"
 [39] "Quercus falcata"              "Quercus nigra"
 [41] "Carya glabra"                 "Quercus stellata"
 [43] "Quercus coccinea"             "Magnolia virginiana"
 [45] "Cercis canadensis"            "Ulmus americana"
 [47] "Betula papyrifera"            "Prunus pensylvanica"
 [49] "Achillea millefolium"         "Andropogon gerardii"
 [51] "Erigeron strigosus"           "Panicum virgatum"
 [53] "Claytonia lanceolata"         "Campanula rotundifolia"
 [55] "Erythronium grandiflorum"     "Eriogonum subalpinum"
 [57] "Ipomopsis aggregata"          "Lathyrus leucanthus"
 [59] "Amaranthus retroflexus"       "Setaria viridis"
 [61] "Lolium perenne"               "Alliaria petiolata"
 [63] "Allium vineale"               "Ambrosia artemisiifolia"
 [65] "Amphicarpa bracteata"         "Arctium minus"
 [67] "Boehmeria cylindrica"         "Carduus acanthoides"
 [69] "Celastrus orbiculatus"        "Cirsium arvense"
 [71] "Cirsium vulgare"              "Clematis virginiana"
 [73] "Clinopodium vulgare"          "Conyza canadensis"
 [75] "Cornus racemosa"              "Desmodium nudiflorum"
 [77] "Desmodium paniculatum"        "Epilobium ciliatum"
 [79] "Erechtites hieraciifolia"     "Erigeron philadelphicus"
 [81] "Fragaria virginiana"          "Galium aparine"
 [83] "Galium circaezans"            "Galium triflorum"
 [85] "Geum canadense"               "Geranium maculatum"
 [87] "Hackelia virginiana"          "Hamamelis virginiana"
 [89] "Houstonia longifolia"         "Hypericum punctatum"
 [91] "Ilex verticillata"            "Lactuca serriola"
 [93] "Lepidium campestre"           "Lindera benzoin"
```

```
 [95] "Lobelia inflata"               "Lysimachia quadrifolia"
 [97] "Maianthemum canadense"         "Melampyrum lineare"
 [99] "Mitchella repens"              "Oenothera biennis"
[101] "Oenothera perennis"            "Ostrya virginiana"
[103] "Oxalis stricta"                "Phytolacca americana"
[105] "Plantago major"                "Potentilla canadensis"
[107] "Populus grandidentata"         "Potentilla norvegica"
[109] "Podophyllum peltatum"          "Populus tremuloides"
[111] "Prunella vulgaris"             "Pseudognaphalium obtusifolium"
[113] "Rhus glabra"                   "Rosa multiflora"
[115] "Rubus occidentalis"            "Sassafras albidum"
[117] "Sambucus canadensis"           "Sisyrinchium mucronatum"
[119] "Sonchus asper"                 "Solidago canadensis"
[121] "Solidago juncea"               "Solidago nemoralis"
[123] "Solidago rugosa"               "Symphyotrichum pilosum"
[125] "Trifolium aureum"              "Trifolium pratense"
[127] "Ulmus rubra"                   "Uvularia perfoliata"
[129] "Veronica officinalis"          "Verbascum thapsus"
[131] "Verbena urticifolia"           "Viola blanda"
[133] "Vicia cracca"                  "Viburnum prunifolium"
[135] "Trifolium repens"              "Veronica serpyllifolia"
[137] "Viola pubescens"               "Rumex acetosella"
[139] "Viburnum cassinoides"          "Artemisia tridentata"
[141] "Delphinium nuttallianum"       "Erigeron speciosus"
[143] "Helianthella quinquenervis"    "Potentilla hippiana"
[145] "Festuca thurberi"              "Eriogonum umbellatum"

>
```