Data User's Guide: Warming acts through earlier snowmelt to advance but not extend alpine community flowering

Meredith D. Jabis, Daniel E. Winkler, Lara M. Kueppers

Data Summary

This data package contains values used to support conclusions drawn in "Warming acts through earlier snowmelt to advance but not extend alpine community flowering", by Jabis *et al.* 2020. The study was conducted in the Alpine site of the Alpine Treeline Warming Experiment (ATWE), on Niwot Ridge, Colorado, USA.

The file types in this archive include six comma-separated-values (.csv) files, one Microsoft Word (.docx) file, one portable document format (.pdf), one plain text file (.txt), and one rich-text-format file (.rtf), all compressed within "Jabis_etal_2020Ecology_Data.zip".

The .csv files can be opened with either Microsoft Excel, R, or a simple text-editor program. The .txt and .rtf files can also be opened by simple-text-editing softwares. The .docx file can be opened by Microsoft Word, and the .pdf file can be opened by Adobe Acrobat Reader, or any software compatible with the file format.

There are also two geospatial datasets also associated with this archive: a .kml file containing four placemarks bounding the field site, and a compressed file containing two ESRI shapefiles (.shp). The .kml file can be opened with either Google Maps or Google Earth, and the shapefiles can be opened using any geographic information system applications, including the entire ESRI ArcGIS suite, and QGIS.

_AdQ_SDD_alldata.csv

- This file contains all phenology data collected on twenty Niwot Ridge alpine field sites between the years of 2010-2013, compared with data collected in 2009.
- Variables include dates of first and last flower, species, plot and treatment information, etc.
- *NOTE: Empty cells are intentional and can be treated as NA*

_AllyearsFinal_FirstLastDuration_C_H.csv

- This file contains phenology data extracted from "_AdQ_SDD_alldata.csv", also found in this archive.
- Data extracted only include the control and heated plots. Variables include first and last dates of flowering, duration of flowering, species information, among others.
- This data file was used to create part of *Fig. 1* of the publication.

_AllyearsFinal_FirstLastDuration_HW_W.csv

- This file contains phenology data extracted from "_AdQ_SDD_alldata.csv", also found in this archive.
- Data extracted only include the watered and heated + watered plots. Variables include first and last dates of flowering, duration of flowering, species information, among others.

- This data file was used to create part of *Fig. 1* of the publication.

Appendix_S1_FINAL.docx and Appendix_S1_FINAL.pdf

- The contents of these two files are identical; both contain the same supplementary tables and additional information that complement the publication. Two file types are provided for increased accessibility.
- Some tables in this file are in the published journal, and are described in greater detail in the text.

ATWE_ALP0_Plot_information.csv

- This file contains plot number and treatment information for all twenty ATWE alpine-only ("ALPO") plots.

productivitydatabase_DW.csv

- This file contains metrics that were used to calculate adequate moisture days during flowering.
- Metrics include plot and treatment information, adequate moisture days, percent cover of vegetation, etc.

R_code_TablesFigures.rtf

- This file contains the R code that was used for statistical analyses, and for generating tables and figures in the publication/supplementary materials files.
- Additional information with specifics are stated in the file itself.

ReadMe_Jabis.txt

- This is a brief metadata/description file containing a summary of the data within this archive.

Sp_Earlylate_lifeform.csv

- This file contains information for the name, phenology coding, and type of life form of examined species.
- Metrics include species abbreviations, phenology, and life form type.

ALP_bbox.kml

- This kml file contains four corner points bounding the research site.

Alpine_only_GIS.zip

- This compressed folder contains twelve items that comprise of two ESRI shapefiles (.shp). The folder contains a bounding box polygon encompassing the entire study site, as well as a layer containing point data for plot locations.
- The projection associated with these files are *NAD 83/UTM zone 13N, EPSG: 26913*.

Project Description

We asked whether active heat would advance alpine flowering phenology, and whether the influence on onset of spring flowering phenology would occur directly through increased temperature, or indirectly through advanced snowmelt or drier soils. We also considered how the flowering phenology of various functional groups (lifeform and early-late onset groups) would respond to warming. To accomplish this, we used infrared heaters to induce earlier snowmelt and to warm plants and soil, and manual watering to offset warming-induced decreases in soil moisture.

We recorded the flowering phenological state of each plant species in 20 plots on a weekly basis following snowmelt at the alpine site of the Alpine Treeline Warming Experiment on Niwot Ridge, CO. To disentangle the role of temperature from snowmelt and soil moisture, we recorded soil temperature and moisture every 15 minutes at 5-10 cm depth. Date of snowmelt was recorded within plots as days with greater than 0.5°C diel soil temperature variability, and confirmed with field snow surveys conducted twice per week.

Data and Documentation Access

- Data files can be accessed through the U.S. Department of Energy's ESS-DIVE earth science data archive and on the Dryad Digital Repository, at https://doi.org/10.5061/dryad.f1vhhmgtd.
- The full journal article as well as supplementary information can be accessed online via the Ecology website: https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1002/ecy.3108

Table of Contents

1. Data Characteristics

Spatial Coverage

Research was conducted within the alpine site of the Alpine Treeline Warming Experiment (ATWE), on Niwot Ridge in the Front Range of the Colorado Rocky Mountains, USA. The field site is located on a shallow 15º south-southeast facing slope, approximately 400 meters above treeline. The coordinates provided below are in WGS 84 decimal degrees and in degrees, minutes, and seconds (º ‘ “N, º ‘ “ W).

ATWE site location at plot center

Site	Location in Degrees, Minutes, Seconds	Decimal Degrees N	Decimal Degrees W	Elevation
Alpine (ALP)	40º 3' 14.84" N, 105º 35' 37.71" W	40.054122	-105.593808	3540m

ATWE study site bounding box coordinates (decimal degrees)

Site	Northwest Coordinates	Southeast Coordinates	Northeast Coordinates	Southwest Coordinates
Alpine (ALP)	40.0545378322, -105.5942618300	40.0536736148, -105.5933524590	40.0545378322, -105.5933524590	40.0536736148, -105.5942618300

Temporal Coverage

Data were collected across five years, over the years of 2009-2013. Field surveys were conducted during the growing season, between June and September. Flowering phenology surveys were conducted weekly, and were initiated when quadrants were at least 50% snow-free, as determined by weekly snow surveys. Data collection ceased when all plants in a species reached at least one category of senescence. Details regarding phenology surveys and their categorizations are outlined in the publication and in the “Data Acquisition and Methods” section below.

2. Data File Organization

There are three main files associated with this archive:

- Jabis_etal_2020Ecology_Data.zip
- ALP_bbox.kml
- Alpine_only_GIS.zip

Within the compressed file named "Jabis_etal_2020Ecology_Data", there are ten files: six comma-separated values (.csv) files, one Microsoft Word document (.docx), one portable document format (.pdf), one rich text format file (.rtf), and one text file (.txt):

- _AdQ_SDD_alldata.csv
- _AllyearsFinal_FirstLastDuration_C_H.csv
- _AllyearsFinal_FirstLastDuration_HW_W.csv
- Appendix_S1_FINAL.docx
- Appendix_S1_FINAL.pdf
- ATWE_ALP0_Plot_information.csv
- productivitydatabase_DW.csv
- R_code_TablesFigures.rtf
- ReadMe_Jabis.txt
- Sp_Earlylate_lifeform.csv

Geospatial files:

- ALP_bbox.kml contains four placemark points, all combined within one file.
- Alpine_only_GIS.zip contains twelve files, contributing to two shapefiles:
    - ALP_bbox.shp
        - ALP_bbox.cpg
        - ALP_bbox.dbf
        - ALP_bbox.prj
        - ALP_bbox.qpj
        - ALP_bbox.shp
        - ALP_bbox.shx
    - ALPO_plots.shp
        - ALPO_plots.cpg
        - ALPO_plots.dbf
        - ALPO_plots.prj
        - ALPO_plots.qpj
        - ALPO_plots.shp
        - ALPO_plots.shx

3. Data Dictionary

The file names, column headings, and units/formatting within csv files within this archive are described below.

Additional information regarding data organization and naming conventions can be found in "ReadMe_Jabis.txt", from this archive. Methods and statistical analyses can be found in the publication itself and in the "Data Acquisition and Methods" section of this guide.

"_AllyearsFinal_FirstLastDuration_C_H.csv" and "_AllyearsFinal_FirstLastDuration_HW_W.csv" both contain data extracted from "_AdQ_SDD_alldata.csv".

"_AdQ_SDD_alldata.csv" contains data for all 30 headings listed in the table below, while "_AllyearsFinal_FirstLastDuration_C_H.csv" and "_AllyearsFinal_FirstLastDuration_HW_W.csv" contain data for 16 headings, from "plotquadname" to "w". The heading "yearC" is omitted in these two latter files.

File name: _AdQ_SDD_alldata.csv, _AllyearsFinal_FirstLastDuration_C_H.csv, _AllyearsFinal_FirstLastDuration_HW_W.csv

** NOTE: Empty cells are intentional and can be treated as NA*

Heading	Units/Format	Description
plotquadname	##xXXXX (plot, quadrat, four-letter species code)	Combined code with plot number, quadrat (lowercase letter; a, b, c, or d), and four-letter species code as indicated in Table S10 in "Appendix_S1_FINAL.docx" of this archive.
plot	##	Plot number; see "ALP0_Plot_information.csv" within this archive for additional information
name	XXXX; first two letters of genus, first two letters of species	Four-letter species code corresponding to the species list provided in Table S10 of "Appendix_S1_FINAL" in this archive. Plant codes may not directly match the USDA Plants database species codes.
year	2010, 2011, 2012, or 2013	Year of data collection
yearC	YYYYa	Year; the "a" forces the year to be used as a categorical variable.
quad	a, b, c, or d	Quadrat of field site
first	ddd	Day of year of first flower
last	ddd	Day of year of last flower
fdate	mm/dd/yy	Calendar date of first flower

ldate	mm/dd/yy	Calendar date of last flower
duration	dd, days	Flowering duration
prefirst	ddd	Day of year of first flower in 2009, pre-experiment
prelast	ddd	Day of year of last flower in 2009, pre-experiment
preduration	dd, days	Flowering duration in 2009, pre-experiment
treatment	H, HW, C, W	Plot experimental treatment; H = heated, HW = heated and watered, C = control, W = watered
h	y, n	Plot heating, y = yes; n = no
w	y, n	Plot watering, y = yes; n = no
colnummean	##	How climate data were transposed from original format; not a true data column
id	##xYYYY (plot number, quadrat, year)	Combined id
meltdate	ddd	Day of year of plot snowmelt; determined by days greater than 0.5ºC diel soil temp variability
dopf	ddd	Day of year of peak flowering
plotID	ALP_##_X; site_plot_quadrat (A, B, C, or D)	ALP = alpine site. Used when experimental data were transposed from original format
colnum	##	How climate data were transposed from original format; not a true data column
fSDD	ºC	Soil degree-days to the date of first flower. Not used in final analysis
lSDD	ºC	Soil degree-days to the date of last flower. Not used in final analysis
TmeanF	ºC	Mean soil temperature to date of first flower
TmeanL	ºC	Mean soil temperature to date of last flower
TmeanD	ºC	Mean soil temperature to peak flowering
adqF	dd, days	Adequate moisture days to date of first flower, defined as the total number of days where mean daily VWC was over threshold of $\Theta v > 0.13$ m^3 m^{-3}
adqL	dd, days	Adequate soil moisture days to date of last flower,

		with same definition as above.

Example data record

```
plotquadname,plot,name,year,yearC,quad,first,last,fdate,ldate,duration,prefirst,prelast,preduration,treatment,h,w,colnummean,id,meltdate,dopf,plotID,colnum,fSDD,lSDD,TmeanF,TmeanL,TmeanD,adqF,adqL
41aARSC,41,ARSC,2010,2010a,a,202,216,7/21/10,8/4/10,14,196,217,21,C,n,n,3,41a2010,172,210,ALP_41_A,2,340.8,528.3,10.99354839,11.74,11.75384615,26,34
41aBIBI,41,BIBI,2010,2010a,a,202,216,7/21/10,8/4/10,14,,,,C,n,n,3,41a2010,172,210,ALP_41_A,2,340.8,528.3,10.99354839,11.74,11.75384615,26,34
41aGERO,41,GERO,2010,2010a,a,189,216,7/8/10,8/4/10,27,203,217,14,C,n,n,3,41a2010,172,210,ALP_41_A,2,168,528.3,9.333333333,11.74,11.75384615,18,34
41aLEPY,41,LEPY,2010,2010a,a,196,202,7/15/10,7/21/10,6,,,,C,n,n,3,41a2010,172,210,ALP_41_A,2,254.7,340.8,10.188,10.99354839,11.75384615,25,26
41aMIOB,41,MIOB,2010,2010a,a,189,223,7/8/10,8/11/10,34,196,229,33,C,n,n,3,41a2010,172,210,ALP_41_A,2,168,613.5,9.333333333,11.79807692,11.75384615,18,41
41aRAAD,41,RAAD,2010,2010a,a,174,181,6/23/10,6/30/10,7,175,196,21,C,n,n,3,41a2010,172,210,ALP_41_A,2,16.1,87.3,5.366666667,8.73,11.75384615,3,10
41bARSC,41,ARSC,2010,2010a,b,196,216,7/15/10,8/4/10,20,203,196,,C,n,n,4,41b2010,172,210,ALP_41_B,3,260.6,539.4,10.424,11.98666667,12.00512821,25,32
41bBIBI,41,BIBI,2010,2010a,b,202,216,7/21/10,8/4/10,14,,,,C,n,n,4,41b2010,172,210,ALP_41_B,3,348.8,539.4,11.2516129,11.98666667,12.00512821,25,32
41bCHJA,41,CHJA,2010,2010a,b,202,216,7/21/10,8/4/10,14,,,,C,n,n,4,41b2010,172,210,ALP_41_B,3,348.8,539.4,11.2516129,11.98666667,12.00512821,25,32
41bGERO,41,GERO,2010,2010a,b,189,216,7/8/10,8/4/10,27,196,217,21,C,n,n,4,41b2010,172,210,ALP_41_B,3,172.6,539.4,9.588888889,11.98666667,12.00512821,18,32
41bLEPY,41,LEPY,2010,2010a,b,196,216,7/15/10,8/4/10,20,,,,C,n,n,4,41b2010,172,210,ALP_41_B,3,260.6,539.4,10.424,11.98666667,12.00512821,25,32
41bMIOB,41,MIOB,2010,2010a,b,189,230,7/8/10,8/18/10,41,196,229,33,C,n,n,4,41b2010,172,210,ALP_41_B,3,172.6,720.3,9.588888889,12.20847458,12.00512821,18,43
41bRAAD,41,RAAD,2010,2010a,b,174,181,6/23/10,6/30/10,7,175,196,21,C,n,n,4,41b2010,172,210,ALP_41_B,3,17.1,90.4,5.7,9.04,12.00512821,3,10
41bSIPR,41,SIPR,2010,2010a,b,189,216,7/8/10,8/4/10,27,196,222,26,C,n,n,4,41b2010,172,210,ALP_41_B,3,172.6,539.4,9.588888889,11.98666667,12.00512821,18,32
41cARFE,41,ARFE,2010,2010a,c,202,238,7/21/10,8/26/10,36,,,,C,n,n,5,41c2010,172,211,ALP_41_C,4,342.2,808.8,11.03870968,12.07164179,11.775,25,53
41cARSC,41,ARSC,2010,2010a,c,202,216,7/21/10,8/4/10,14,203,217,14,C,n,n,5,41c2010,172,211,ALP_41_C,4,342.2,527.8,11.03870968,11.72888889,11.775,25,32
41cBIBI,41,BIBI,2010,2010a,c,202,216,7/21/10,8/4/10,14,,,,C,n,n,5,41c2010,172,211,ALP_41_C,4,342.2,527.8,11.03870968,11.72888889,11.775,25,32
41cGERO,41,GERO,2010,2010a,c,189,216,7/8/10,8/4/10,27,196,217,21,C,n,n,5,41c2010,172,211,ALP_41_C,4,172.5,527.8,9.583333333,11.72888889,11.775,18,32
41cLEPY,41,LEPY,2010,2010a,c,196,202,7/15/10,7/21/10,6,203,217,14,C,n,n,5,41c2010,172,211,ALP_41_C,4,257.7,342.2,10.308,11.03870968,11.775,25,25
41cLUSP,41,LUSP,2010,2010a,c,196,216,7/15/10,8/4/10,20,,,,C,n,n,5,41c2010,172,211,ALP_41_C,4,257.7,527.8,10.308,11.72888889,11.775,25,32
```

File name: ATWE_ALP0_Plot_information.csv

Heading	Units/Format	Description
Plot	##	Plot number within ALPO (“Alpine-only”) sites
Treatment	C, H, HW, W	Plot treatment: C = control, H = heated, HW = heated and watered, W = watered

Example data record

```
Plot,Treatment
41,C
46,C
56,C
67,C
77,C
42,H
63,H
64,H
```

File name: productivitydatabase_DW.csv

Heading	Units/Format	Description
id	x##YYYY (quadrat [a, b, c, or d], plot number, year of data collection [2010, 2011, 2012, or 2013])	Plot ID code
spid	##xXXXX (plot number, quadrat [a, b, c, or d], species code)	Plot ID including species information. The four-letter species code used in this column corresponds to Table S10 of "Appendix_S1_FINAL.doc" within this archive.
year	YYYY	Year of data collection
plot	##	Plot number
quad	a, b, c, or d	Quadrat letter
name	XXXX; first two letters of genus, first two letters of species, or first four letters of genus	Name of species, in four-letter species code corresponding to the species list provided in Table S10 of "Appendix_S1_FINAL" file in this archive. Plant codes may not directly match the USDA Plants database species codes.
cover	#.##, percent	Percent cover of species visually estimated in a $1m^2$ survey grid
biomass	##.##, grams	Aboveground vascular biomass weight, after being dried for 48 hours at 60ºC
treatment	c, h, hw, or w	Plot treatment. c = control, h = heated, hw = heated and watered, w = watered
h	y, n	Plot heating. y = yes, n = no
w	y, n	Plot watering. y = yes, n = no
gooddays	##, days	Adequate moisture days to date of peak flowering
gdd0	ºC	Growing degree days; sum of mean daily temperatures for days above 0ºC between snowmelt and peak aboveground productivity
meltdate_old	ddd	Snowmelt date in day of year
elevation	meters	Elevation in meters
slength	dd, days	Growing season length, from the day of snowmelt until day of peak productivity

dopf	###	Day of year when peak flowering occurred
nspecies	##	Number of species per quadrat
prebiomass	grams	Pre-treatment biomass weight estimates (only used in 2009 data)
group	forbs, cushions, succulents, graminoids	Plant group

Example data record

```
id,spid,year,plot,quad,name,cover,biomass,treatment,h,w,gooddays,gdd0,meltdate_old,elevation,slength,dopf,nspecies,prebiomass,group
a412010,41aARFE,2010,41,a,ARFE,2,3.11,c,n,n,26,458.1166667,172,3552.262,38,210,12,6.27,forbs
a412010,41aARSC,2010,41,a,ARSC,1.5,2.605,c,n,n,26,458.1166667,172,3552.262,38,210,12,5.865,forbs
a412010,41aBIBI,2010,41,a,BIBI,3,4.85,c,n,n,26,458.1166667,172,3552.262,38,210,12,4.85,forbs
a412010,41aCHJA,2010,41,a,CHJA,0.5,0.755,c,n,n,26,458.1166667,172,3552.262,38,210,12,0.2875,succulents
a412010,41aGERO,2010,41,a,GERO,29,81.27,c,n,n,26,458.1166667,172,3552.262,38,210,12,134.66,forbs
a412010,41aLEPY,2010,41,a,LEPY,0.25,0.0825,c,n,n,26,458.1166667,172,3552.262,38,210,12,0,succulents
a412010,41aLUSP,2010,41,a,LUSP,0.25,0.21,c,n,n,26,458.1166667,172,3552.262,38,210,12,0,graminoids
a412010,41aMIOB,2010,41,a,MIOB,8,45.17,c,n,n,26,458.1166667,172,3552.262,38,210,12,56.67,cushions
a412010,41aRAAD,2010,41,a,RAAD,3.5,8.4,c,n,n,26,458.1166667,172,3552.262,38,210,12,8.4,forbs
a412010,41aTRPA,2010,41,a,TRPA,0.25,0.595,c,n,n,26,458.1166667,172,3552.262,38,210,12,1.12,forbs
a412010,41aTRSP,2010,41,a,TRSP,0.25,0.21,c,n,n,26,458.1166667,172,3552.262,38,210,12,1.66,graminoids
b412010,41bARFE,2010,41,b,ARFE,3.5,5.48,c,n,n,25,468.034375,172,3552.262,38,210,10,16.54,forbs
```

File name: Sp_Earlylate_lifeform

Heading	Units/Format	Description
name	XXXX; first two letters of genus, first two letters of species, or first four letters of genus	Four-letter species code corresponding to the species list provided in Table S10 of "Appendix_S1_FINAL" file in this archive. Plant codes may not directly match the USDA plant codes.
earlylate	early, middle, or late	Phenology functional group designation (approximate): early = species that initiated flowering in May or June; middle = flower initiation in July; late = August initiation, past peak productivity for most other species
lifeform	aforbs, cushions, graminoids, or succulents	Type of life form as categorized in Table S10 of "Appendix_S1_FINAL" file in this archive. The life form "forbs" was named "aforbs" as it was the group compared to other life form groups.

Example data record

```
name,earlylate,lifeform
ANSE,early,aforbs
ARFE,middle,aforbs
ARSC,middle,aforbs
BIBI,middle,aforbs
CAMP,late,aforbs
CAOC,middle,aforbs
ERAR,early,aforbs
ERSI,middle,aforbs
GERO,early,aforbs
HYGR,middle,aforbs
LLSE,early,aforbs
ORAL,early,aforbs
PESC,late,aforbs
PHCO,middle,aforbs
PODI,middle,aforbs
```

4. Companion Files

The publication and its supporting appendix can be found online, at https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1002/ecy.3108.

5. Quality Assessment

All phenology data entered from field sheets and notebooks were visually verified prior to use in analysis. Automated soil moisture and temperature measurements were processed using automated and manual QA/QC procedures.

6. Data Acquisition and Methods

Study site and experimental design

Our study was conducted on Niwot Ridge in the Colorado Rocky Mountains (40°3'14.84'' N, 105°35'37.71'' W; 3540 m), on a shallow (15°) south-southeast facing slope 400 m above timberline. The growing season is approximately 3–4 months (June–September; Greenland 1989) and average annual precipitation and temperature are 966 mm and 2.15°C, with a majority of precipitation falling as snow (Blanken et al. 2009). Variability in local snow depth is determined by westerly winds and local topography (Litaor et al. 2008).

In 2008–2009, we established 20 3 m diameter plots, approximately 5–10 m apart, within the alpine tundra and assigned them to four treatment groups: control (C), heated (H), watered (W), and heated + watered (HW). Each plot was divided into four 1×1 m^2 quadrants for observations. Six infrared heaters (Mor Electric Heating, Comstock Park, Michigan, USA) were suspended 1.2 m aboveground in hexagonal arrays surrounding each H and HW plot (Kimball et al. 2007). Heaters were activated in October 2009 and delivered 215 W/m^2 to the plots March–November under low wind conditions, and, except in 2009–2010, were reduced November– March to avoid hydrological impacts and intermittent snowpack (Meromy et al. 2015). High wind speeds (mean 5.8 m/s during the snow-free season; Kueppers et al. 2017) diminished heating efficiency relative to that under low wind conditions (Kimball et al. 2007) and limited overall warming effects to an average of +1.5°C at 5–10 cm depth in the soil during the snow-free season. Winkler et al. (2016) describes the heating treatment in more detail. Infrared radiation (IR) is primarily absorbed by surfaces so our aim was to increase growing season plant and soil temperatures and not to modify air temperature. While they do not elevate air temperature except very near the ground surface, IR heaters are advantageous as compared with passive heating designs (Elmendorf et al. 2012, Oberbauer et al. 2013) because they preserve the ambient wind regime and advance the timing of snowmelt (Aronson and McNulty 2009) by realistically altering snow energy balance (Meromy et al. 2015). We applied 2.5 mm of water weekly to the HW and W groups when soil moisture dropped below ~0.2 m^3/m^3 (2–3 weeks after snowmelt until mid to late September), to offset soil drying due to heating, and to study the impacts of increased growing season soil moisture. Annual water addition totaled ~30 mm, which is roughly 20% of mean June–September precipitation from 1951–1980 on Niwot Ridge (Greenland 1989).

Phenology observations

We conducted weekly flowering phenology surveys of 39 species in the community starting when a quadrant was at least 50% snow-free, as determined by weekly snow surveys. Each week, the phenological stage of each species was recorded as one of the following: (1) vegetative bud, (2) flower (defined by visible stamen or stigmatic surfaces), (3) senescence, (4) bud and flower, (5) bud and senescence, (6) flower and senescence, (7) bud, flower, and senescence. A stage was recorded when at least one individual of a species in a quadrant entered that stage. Data collection ended when all plants in a species had reached phenological stage 3, 6, or 7, typically mid to late August. Surveys were conducted each growing season from 2009 (pre-treatment) through 2013. Day of flower initiation (first flower) and senescence (last flower) were determined by the first flower occurrence and the last flower senescing for each species across all plots and quadrants, respectively; and flowering duration was calculated as the period between first and last flower.

Climate and microclimate observations

Air temperature, relative humidity (HMP45C; Vaisala, Helsinki, Finland) and wind speed were measured at 2 m height via a meteorological tower erected at the center of the site (03101-L; RM Young, Traverse City, Michigan, USA). Precipitation was measured at a nearby LTER meteorological station approximately 500 m away, elevation 3,528 m (data available online at http://www.nrcs.usda.gov/). Soil moisture and temperature were recorded every 15 minutes averaged over a 5–10 cm probe depth (ECTM or 5TM; Decagon Devices, Pullman,Washington,USA) at the center of each quadrant. Soil probes were calibrated in the laboratory to volumetric water contents (m^3/m^3) ranging from dry to saturated using soil collected adjacent to plots. We determined melt date of quadrants within plots as days with greater than 0.5°C diel soil temperature variability, and confirmed that these temperature-based snow cover determinations were consistent with twice each week field snow surveys. Mean daily (diel) soil temperature (5-10 cm) was calculated between day of snowmelt and: (1) day of first flower, (2) day of last flower, and (3) day of peak flowering (also the day of peak aboveground biomass) for each species in the community and for each quadrant. Adequate soil moisture days were calculated as the total number of days when mean daily volumetric water content was above a threshold of $\Theta_v > 0.13$ m^3/m^3, which corresponded to midday water potentials of approximately –1.5 MPa for limber pine seedlings at our site (Moyes et al. 2013) and to decreased productivity in another alpine community (Billings and Bliss 1959). We used the same time periods described above for mean soil temperature. Each of these climate variables, calculated for the relevant phenological stage, was used for analyses of first flower, last flower, and flowering duration respectively.

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Publication

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Appendix 1

Previous version of read me file:

ReadMe file for:
Warming acts through earlier snowmelt to advance but not extend alpine community flowering.
Jabis, Meredith D., Winkler, Daniel E., Kueppers, Lara M.

09/16/2021

This readme file describes the data files that accompany the above publication, located within the Alpine Treeline Warming Experiment (ATWE) on Niwot Ridge, Mountain Research Station, CO.
For any further information, please contact: meredith.jabis@gmail.com or lmkueppers@berkeley.edu

Contents:

1. _AdQ_SDD_alldata.csv
    - this file contains most of the phenology data during 4 years of work from 2010-2013 from 20 plots (with 4 quadrats)
    - Empty cells are intentional and can be treated as NA
2. productivitydatabase_DW.csv
    - summary information used primarily for adequate moisture days (flowering duration only)
3. Sp_Early_late_lifeform.csv
    - summary information for early, middle and late coding
4. ATWE_ALPO_Plot_information.csv
    - plot and quadrant information for the ATWE alpine site
5. _AllyearsFinal_FirstLastDuration_C_H.csv
    - a file used to create figure 1 (only phenology data from control and heated plots)
6. _AllyearsFinal_FirstLastDuration_HW_W.csv
    - a file used to create figure 1 (only phenology data from heat + watered and watered plots)
7. R_code_TablesFigures.rtf
    - the R code for tables and figures
8. Appendix_S1_FINAL.docx
    - supplemental tables accompanying the manuscript. These are provided here for reference only; described in the manuscript text
9. Alpine_only_GIS.zip
    - "ALP_bbox.shp" - contains a shapefile of the perimteter of the alpine site
    - "ALPO_plots.shp" - contains point locations for non-seeded plots at the alpine site
10. alp_bbox.kml
    - google maps/google earth compatible file that contains x,y coordinates of 4 corners of the alpine site perimeter; corresponds with the perimeter shape-file "ALP_bbox.shp"

Descriptions of contents within each file:

1. _AdQ_SDD_alldata.csv

plotquadname	the number of the plot joined to the quadrat (a,b,c,d) and the species 4-letter code (see Appendix_S1_FINAL.docx, Table S10, for full species names)
plot	unique numeric ID of the plot, one of 20 possible (see ATWE_ALPO_Plot_information.csv)
name	species 4-letter code
year	year of data collection (2010, 2011, 2012, or 2013)
yearC	year with "c" concatenated - to force year to be used as a categorical variable
quad	the quadrat designation (a,b,c,d) for a particular plot
first	day of year (DOY) of first flower (by species, plot, and quad)
last	day of year (DOY) of last flower - or senescence (by species, plot, and quad)
fdate	calendar date of first flower
ldate	calendar date of last flower
duration	duration of flowering (period between date of first flower and last flower (senescence)
prefirst	date of first flower in 2009, pre-experiment
prelast	date of last flower in 2009, pre-experiment
preduration	flowering duration in 2009, pre-experiment

** last 3 variables (prefirst, prelast, and preduration) included as covariates to to control for pre-existing variation across plots

treatment	experimental treatment (C=control, H=heat, W=water, HW=heat+water)
h	heat treatment (y=yes, n=no)
w	water treatment (y=yes, or n=no)
colnummean	used when climate data was transposed here from a different original format
meltdate	DOY plot melted. This was determined as days with greater than 0.5°C diel soil temperature variability, confirmed with bi-weekly field snow surveys.
dopf	DOY of peak flowering
plotID	site, plot, and quadrat data concatenated; used when climate data was transposed here from a different original format
colnum	used when climate data was transposed here from a different original format
fSDD	soil degree days to date of first flower (not used in the final analysis)
lSDD	soil degree days to date of last flower (not used in the final analysis)
TmeanF	mean soil temperature to date of first flower
TmeanL	mean soil temperature to date of last flower
TmeanD	mean soil temperature to peak flowering
adqF	adequate moisture days to date of first flower, calculated as the total number of days when mean daily volumetric water content was above a threshold of $\Theta v > 0.13$ m3 m−3
adqL	adequate moisture days to date of first flower (calculated as above but to last flower DOY)

2. productivitydatabase_DW.csv

*the only column used (gooddays) is explained here. the rest of the columns are data from Winkler et al. 2016 (see literature cited)

gooddays	adequate moisture days to date of peak flowering (used for continuous duration models)

3. Sp_Early_late.csv

name	species 4-letter code. (see Appendix_S1_FINAL.docx, Table S10, for full species names)
Earlylate	phenology functional group designation. Species that initiated flowering (on average) in May or June were designated as “early”, those that commenced in July were designated as “mid”, and those that initiated in August, past peak productivity for most species, were designated as “late”
lifeform	lifeform designation (forb, cushion, graminoid, or succulent). Note that the lifeform "forbs" was changed to "aforbs" so it would be the group compared to other lifeform groups in contrasts.

4. ATWE_ALPO_Plot_information.csv

Plot	unique numeric ID of the plot
Treatment	experimental treatment designation (C=control, H=heat, W=water, HW=heat+water)

5. _AllyearsFinal_FirstLastDuration_C_H.csv

6. _AllyearsFinal_FirstLastDuration_C_H.csv

*both of these files contain the same first 16 columns as _AdQ_SDD_alldata.csv, and were used solely to create Figure 1. See ‘R_code_TablesFigures.rft’ for details to create Figure 1.