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Skiing in the 21st Century

An Analysis of Eastern Ski Resorts

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Anthropogenic Climate Change was first recognized in the 1950's. Since then, more research has led to an increased understanding of our planets climate system, and the impacts our industrial emissions have on it. Greenhouse gasses such as Carbon Dioxide, Methane, and Nitrous Oxides, insulate our planet, absorbing and reflecting outgoing long-wave radiation back to earth, causing the earth to become slightly warmer; 0.65 to 1.06 degrees Celsius from the period of 1880 to 2012 *(IPCC The Physical Science Basis 2013)*. This small temperature increase would seem barely noticeable, but paleoclimatological records show that over the period of 130 years, this rate of temperature change is unprecedented. Paleoclimate is reconstructed using proxy (indirect) data.

An example would be the ice core data from Antarctica. Each layer of ice represents one year of deposition, snow falling, melting, refreezing, and turning into glacial ice. What is measured in the sheets of ice, are the isotopic ratio of Oxygen 16 to Oxygen 18. Oxygen 18 is heavier (having 2 more neutrons) than Oxygen 16. This means water molecules with O18 in their structure are less likely to be evaporated in a cooler environment relative to water molecules with O16 in their structure. This manifests itself in glacial ice as O18/O16 ratio; lower ratio meaning a cooler environment, higher ratio a warmer one *(IPCC).* Atmospheric CO2 levels in these ancient environments are inferred from air bubbles trapped between annual ice layers. The CO2 concentration in the air bubbles correspond to the O18/O16 ratio in a given ice layer and from this, the temperature, and atmospheric CO2 concentration for a given time in history can be reconstructed. It has been found that atmospheric CO2 and climate over the past 800,000 years are highly correlated, with an increase in temperature following closely behind an increase in atmospheric CO2 levels, and a decrease in temperature following a decrease in CO2 concentration.

Another example of proxy data used to reconstruct past climate are diatoms, small freshwater microorganisms, which create unique, siliceous (glass) cell walls, making different species easy to recognize, and when they die, easily preserved. Similar to the above example, cores are taken from the bottom of lakes; by knowing the temperature preference of different species of diatoms, past climates can be reconstructed in this way *(Ian Walker UBCO).*

A warmer planet can potentially affect many aspects of our society, from where we live, to what we eat. The purpose of my research is much less doom and gloom than anything I have read in IPCC reports, or heard in the news. What will happen to the ski resorts, which many of us use for winter recreation in higher latitudes of our planet. My goal with this course is to use the skills I learn to help manipulate the large datasets, which are output by the climate modeling software used to infer future climate for a location, as well as to create data visualizations for the output of climate models, which is essential in conveying the message of my work effectively.

For the term project, I analyzed 105 resorts in Eastern North America. These resorts along with their elevation were taken from "onthesnow.com"; location in decimal degrees was taken from "Google Earth". This is then entered into a .csv spreadsheet.

ID1	**ID2**	**lat**	**long**	**el**
Ski_Sundown	Connecticut	41.884685	72.946699	450
Ski_Sundown	Connecticut	41.884685	72.946699	763
Ski_Sundown	Connecticut	41.884685	72.946699	1075
Big_Squaw_Mtn_Ski	Maine	45.507123	69.700081	1750
Big_Squaw_Mtn_Ski	Maine	45.507123	69.700081	2475
Big_Squaw_Mtn_Ski	Maine	45.507123	69.700081	3200
Cambden_Snow_Bowl	Maine	44.217181	69.134669	150
Cambden_Snow_Bowl	Maine	44.217181	69.134669	615
Cambden_Snow_Bowl	Maine	44.217181	69.134669	1080

Table 1: Showing three resorts which are in the .csv file input into "ClimateNA"

The .csv is read into "ClimateNA" which is run twice, once for the "Normal Period" for the years 1901 to 2014, and once for future projections, the years 2025, 2055, and 2085 *(Spittlehouse, 2016).* The output for 'Normal Period' is 35,569 rows by 62 columns (BJ). For the future projections output, there are 28,8081 rows and 62 columns.

For the "Normal Period" data, the output for each resort is three lists of years from 1901 to 2014, one for each elevation on the mountain (bottom, middle and top).

For future projections, each resort has the output from each GCM (Global Circulation Model), for each year, 2025, 2055, and 2085. There are fifteen GCM's. These GCM's are also subdivided into two classes, RCP45 and RCP85.

Year	ID1	ID2	Latitude	Longitude	Elevation
1901	Alpine_Mountain	Pennsylvania	41.113054	75.225571	650
1902	Alpine_Mountain	Pennsylvania	41.113054	75.225571	650
1901	Alpine_Mountain	Pennsylvania	41.113054	75.225571	900
1902	Alpine_Mountain	Pennsylvania	41.113054	75.225571	900
1901	Alpine_Mountain	Pennsylvania	41.113054	75.225571	1150
1902	Alpine_Mountain	Pennsylvania	41.113054	75.225571	1150

Table 2: Showing output from 'ClimateNA' for the 'Normal Period. The real list goes from 1901-2014 before repeating again for the next elevation at a given resort.

RCP45 and 85 represent different estimates for how much global warming will occur, based on the emission scenarios from the IPCC reports. RCP85 is a business as usual approach, with continued growth and no efforts to switch to renewable energy, while RCP45 would be a gradual shift to renewable energy (*Spittlehouse 2012).*

GCM	ID1	ID2	Latitude	Longitude	Elevation
ACCESS1-0_rcp45_2025	Alpine_Mountain	Pennsylvania	41.113054	75.225571	650
CanESM2_rcp45_2025	Alpine_Mountain	Pennsylvania	41.113054	75.225571	650
ACCESS1-0_rcp45_2055	Alpine_Mountain	Pennsylvania	41.113054	75.225571	650
CanESM2_rcp45_2055	Alpine_Mountain	Pennsylvania	41.113054	75.225571	650
ACCESS1-0_rcp45_2085	Alpine_Mountain	Pennsylvania	41.113054	75.225571	650
CanESM2_rcp45_2085	Alpine_Mountain	Pennsylvania	41.113054	75.225571	650
ACCESS1-0_rcp85_2025	Alpine_Mountain	Pennsylvania	41.113054	75.225571	650
CanESM2_rcp85_2025	Alpine_Mountain	Pennsylvania	41.113054	75.225571	650
ACCESS1-0_rcp85_2055	Alpine_Mountain	Pennsylvania	41.113054	75.225571	650
CanESM2_rcp85_2055	Alpine_Mountain	Pennsylvania	41.113054	75.225571	650
ACCESS1-0_rcp85_2085	Alpine_Mountain	Pennsylvania	41.113054	75.225571	650
CanESM2_rcp85_2085	Alpine_Mountain	Pennsylvania	41.113054	75.225571	650

*Table 3: Showing output from 'ClimateNA' for future projections at Alpine Mountain in Pennsylvania. The GCM column shows**, GCM – Emission scenario – Year** in that order. There are 15 GCM's that run for each emission scenario, year, and elevation for a given resort.*

These large files must be organized, and put into a excel workbook which calculates averages and standard deviations for climate variables for specific years and emission scenarios. To do this, I created two new tabs in the workbook that calculates averages, and copy pasted the output for normal, and future periods. The data then had to be sorted, since the output was not in a format that could be copied in one chunk into the workbook. For the "Normal Period":

1. **Sort By:** ID1 → A-Z
2. **Sort By:** Elevation → Ascending
3. **Sort By:** Year → Ascending

For future scenarios, output was organized by GCM, emission scenario, and years 2025, 2055 & 2085. Since GCM, emission scenario and year are all in the same column; it could not be sorted in a way that would copy directly into the calculations workbook. I used conditional formatting to change the color of the cell, and text so that multiple sorts could be ran on the same column.
Conditional Formatting → Custom → Specific Text → Containing

1. **'45_2025'** → Green Cell
2. **'45_2055'** → Orange Cell
3. **'45_2085'** → Red Cell
4. **'85_2025'** → Green Text
5. **'85_2055'** → Orange Text
6. **'85_2085'** → Red Text

With more fields to sort on in the GCM column, I organized the data as follows;

1. **Sort By:** ID1 → A-Z
2. **Sort By:** Elevation → Ascending
3. **Sort By:** GCM → Green Cell on Top
4. **Sort By:** GCM → Orange Cell on Top

5. **Sort By:** GCM → Red Cell on Top
6. **Sort By:** GCM → Green Text on Top
7. **Sort By:** CGM → Orange Text on Top
8. **Sort By:** GCM → Red Text on Top

With the data correctly formatted, I copied the data for the first resort into the spreadsheet for both the 'Normal Period' and the future projections. The resort which was copied, was then deleted from the source page of the excel workbook, priming the new resort in row 2. This was saved as the name of the resort, and a macro was used from here;

1. Copy the averaged climate variables I plan to use from the calculations workbook into a new sheet of the workbook.
2. Copy the 'Normal Period' data for the next resort and past it in the appropriate spot in the workbook for each elevation.
3. Copy the future projections data for the same resort into the appropriate spot in the workbook for each elevation.
4. Delete the data you just copied from the source sheets of the workbook, priming the next resort to row 2.
5. Stop recording macro
6. Save output as resort name, and rerun macro.

This allowed me to process 105 resorts at about he same speed it took me to do eight (I did a similar analysis for a directed studies 3 years ago). The workbook averages the output for the 'Normal Period' and future projections based on year and emissions. This allows for a comparative analysis; to what degree are temperature, degree-days below zero, and precipitation as snow projected to change from the 'Normal Period' into the future, and is there a spatial pattern to these changes. Since the Macro created copied the relevant climate variables into a new sheet in the workbook, it is easy to take them, and format them into a .csv file, which reads into ArcGIS.

Data Visualization Using ArcGIS:

Spreadsheets were created for the 'Normal Period', 2055, and 2085. The climate variables, which were used, are Average Temperature in degrees Celsius, Precipitation As Snow in centimeters, and Degree Days Below Zero, which is a measure of how cold it is over a given period of time, where only days that have an average temperature below zero are counted towards the total. For the analysis in ArcGis, 97 of the original 105 resorts were used (some resorts were smaller than hills here on campus).

RID	Lat	Long	elev	Resort	Tave_45	DD_0_45	PAS_45	Tave_85	DD_0_85	PAS_85
1	42.298674	-74.256905	2300	Windham_NY	-6.5	636.6	286.4	-5.7	571.1	271.2
2	44.264384	-71.239449	3006	Wildcat_NH	-14.1	1298.7	987.5	-13.4	1211.3	1018.5

Table 4: Showing the .csv file for 2055, which is read into arc map. The 45 and 85, which come after the climate variables, are to identify the emission scenario to which the variable belongs. For all maps and statistics, RCP_85 emission scenarios were used. RID was created in all the worksheets as a unique field which attribute tables for the different years can be joined on in ArcGIS.

For ArcGIS to properly place the resorts, a geographic coordinate system was used (WGS1984). All other layers added to the map were transformed to this coordinate system. A geodatabase was created to store the three tables. Without storing them in a common geodatabase, joins and relates between tables cannot be performed. Average temperature was mapped using IDW (Inverse Distance Weighting) Interpolation. Maps were created for each table, and show how average temperature is projected to change from the 'Normal Period' to 2085 (results fig. 2).

Degree-days below zero were mapped using graduated symbols. The periods of 2055 to 2085 were normalized by degree-days below zero during the 'Normal Period' in ArcMap. This created a map that shows larger symbols, and smaller values in the legend, for resorts, which experience a greater change in degree-days relative to the 'Normal Period'. Inversely, smaller symbols and larger values in the legend indicate less change in degree-days from the 'Normal Period' to 2055/2085 (results fig. 3).

Precipitation as snow is different form average temperature and degree-days, in that it increases, and decreases from the normal period, whereas average temperature increase for all resorts, and degree-days below zero decrease for all resorts (decrease in degree days below zero indicates fewer cold days). To map this I joined the table for 'Normal Period' to the table for 2055, and 2085 separately. Then created a new column where precipitation in 2055 and 2085 were subtracted from the normal period. This created positive values for increases in snowfall, and negative values for decreases. This was mapped as both unique values for the individual resorts, and a IDW interpolation isoline map (results fig. 4).

Using the ArcMap query builder, I created nine queries to isolate, and export each state and province to the map as a layer. The tables for the 'Normal Period', 2055, and 2085 were joined together, and clipped to each region (results fig. 5). Then, using summary statistics in Arcmap, averages were calculated for all relevant climate, and geographic variables for each location (table 1 in results).

Testing Results Using R:

This raised the question, does the temperature increase vary given different geographic regions in my analysis. A t-test in R-studio would be the best way to compare the means of different regions. Using the excel files which were originally input into ArcMap, climate variables for all years and emission scenarios were put into one .csv file. Rather than comparing climate variables directly between regions, four new columns were created, and the difference in average temperature and degree-days below zero between the 'Normal Period' and 2055/2085 were calculated (Tave_2055 – Tave_Norm). Then the file was sorted, first by latitude, ascending. A new column was created called ID, and the first 48 rows were given an ID equal to 1, the next 49 were given an ID equal to 2. This file was saved, and then sorted on Elevation ascending, and the first 48 rows were give an ID equal to 1, with the next 49 an ID = to 2, then saved. Using R-studio, the means for the change in average temperature and degree-days were tested using an unpaired T-test (results).

The t-tests showed that for latitude, $P << 0.05$, for both average temperature, and degree-days below zero in the years 2055 and 2085. For Elevation, $P < 0.05$ for average temperature. For degree-days, $p > 0.05$ in 2055 and 2085. This result suggests different latitudes in my study area, will warm differentially from the 'Normal Period' to the years 2055 and 2085.

For different elevations in the study range, the results of the t-test suggest that climate change will result in differential increases to average temperature, but for degree-days below zero, there is no difference to the means between the two groups, and therefore, the change to degree-days below zero from the 'Normal Period' will not differ significantly by elevation, and will decrease equally given different elevations in the study area.

Results:

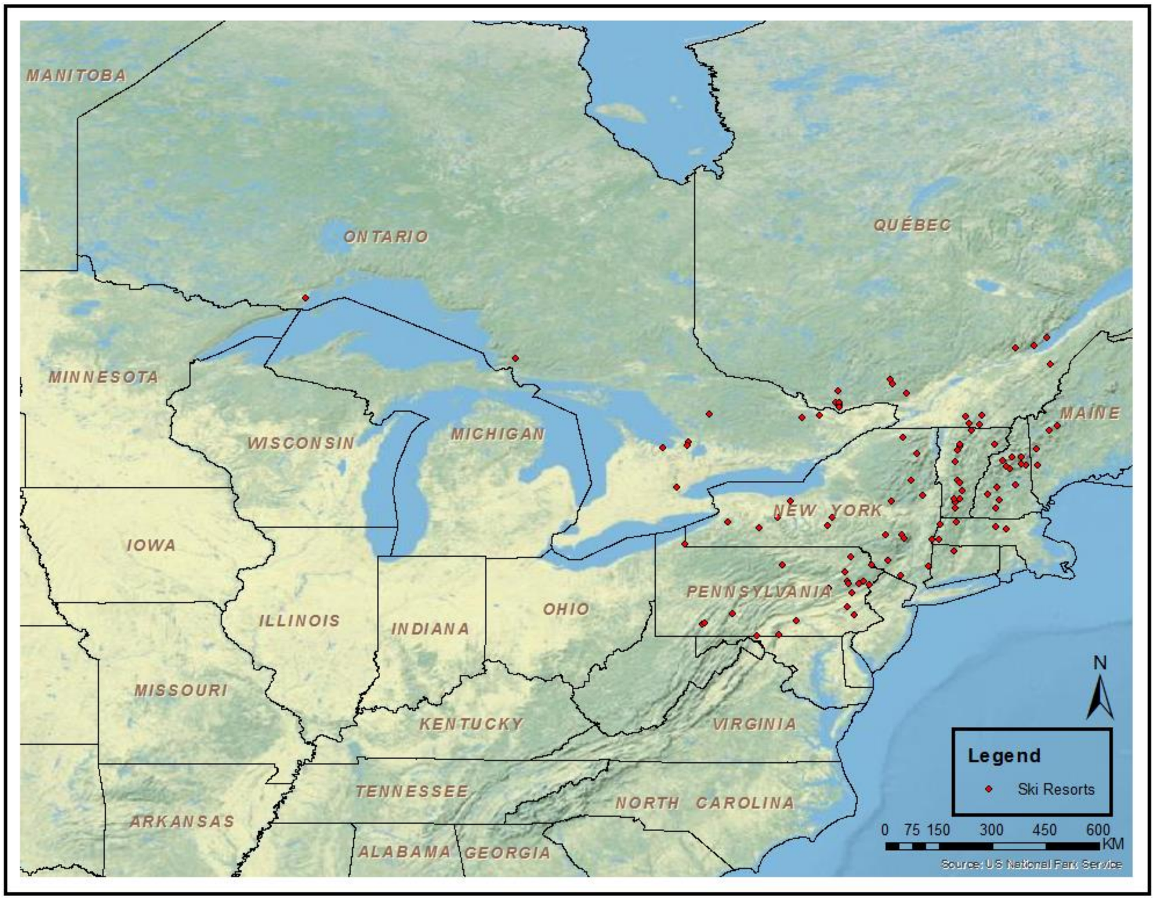

Fig. 1: Showing a topographic map of the study region. Ninety-Seven ski resorts are shown on the map

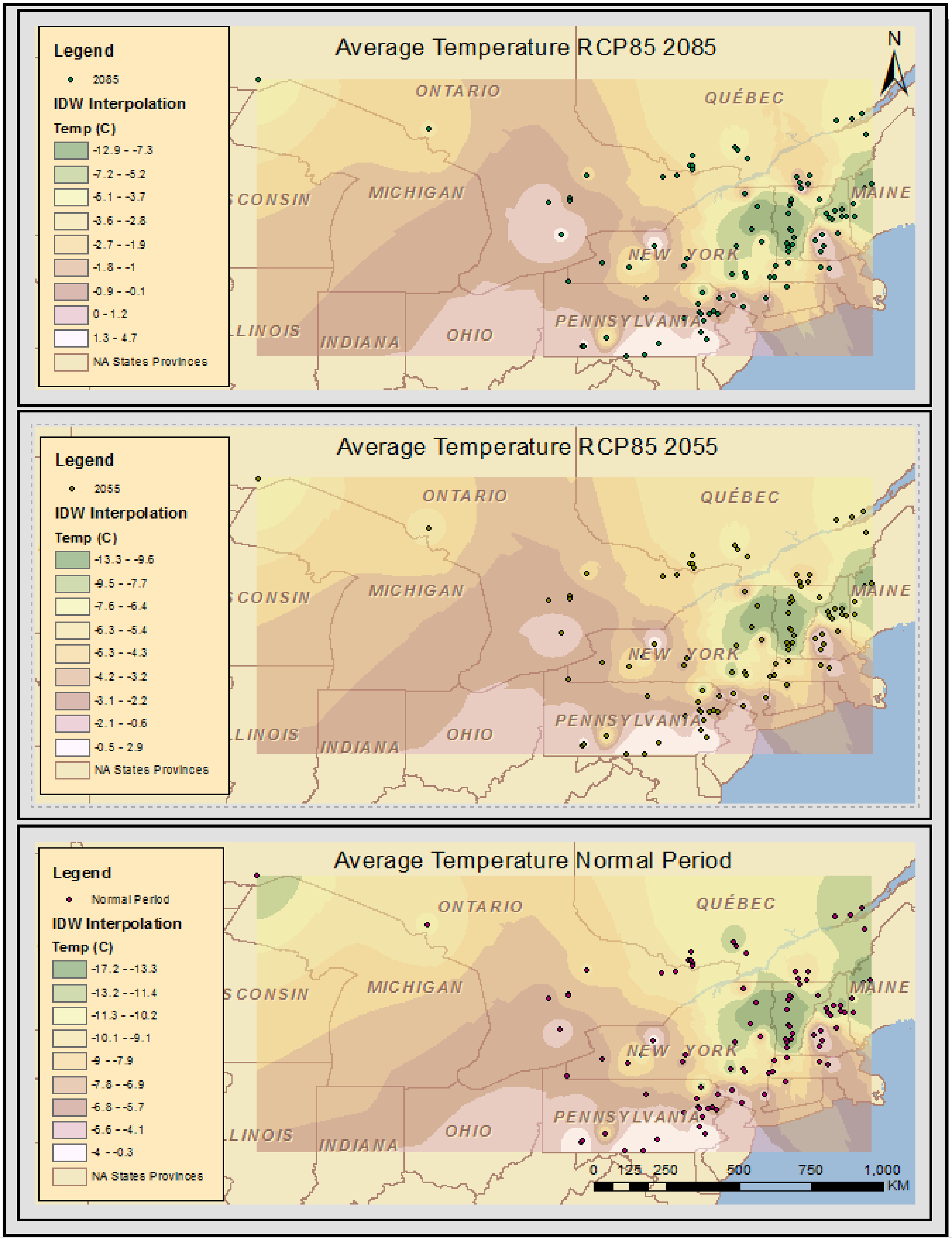

Fig. 2: Showing average temperature using IDW Interpolation methods. Legend shows increase in temperature from 'Normal Period' into future periods.

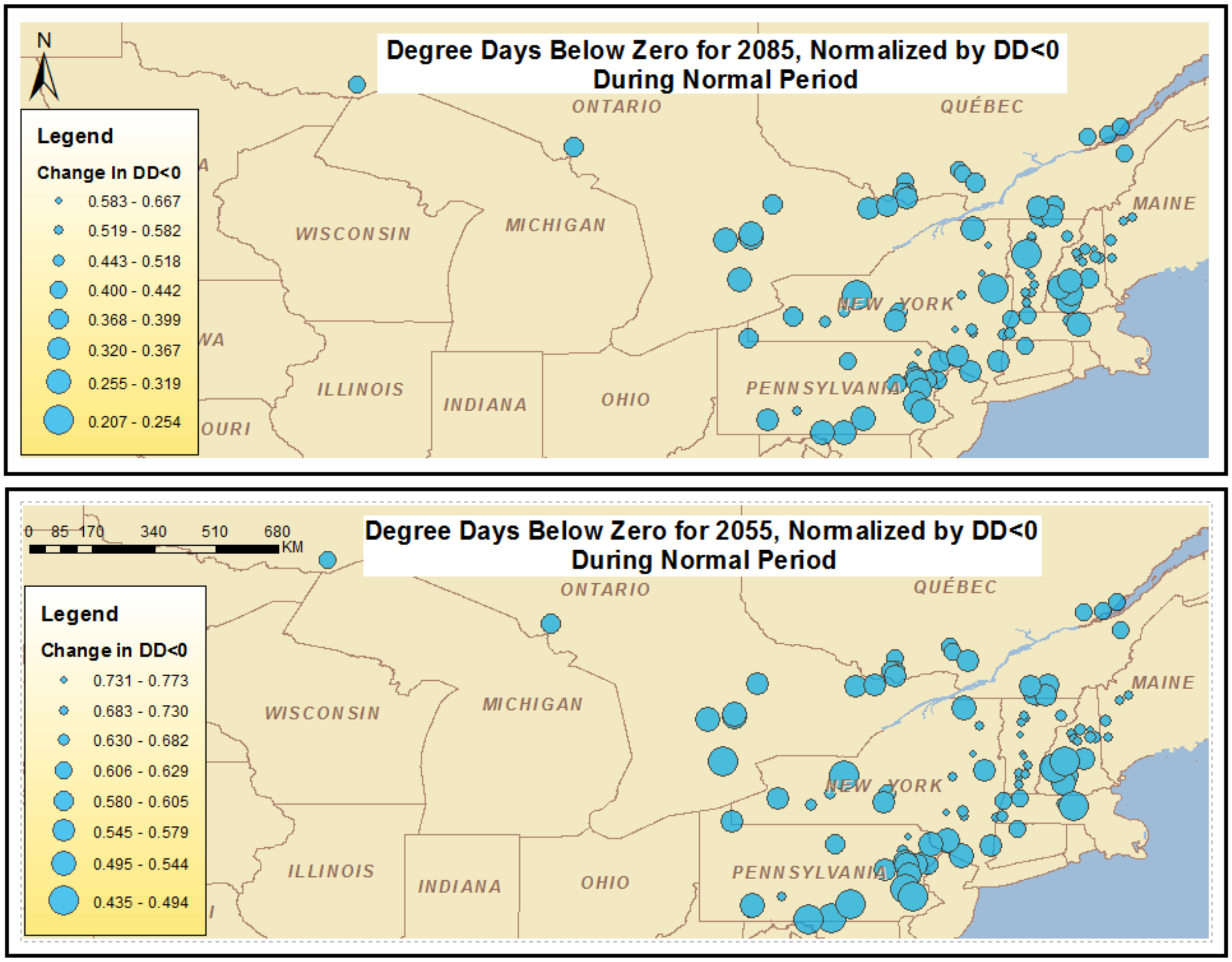

Fig3: Showing degree-days below zero for future periods, normalized by 'Normal Period' degree-days below zero. Smaller numbers, and larger symbols indicate a greater departure from 'Normal Period' degree-day measurements (reduction).

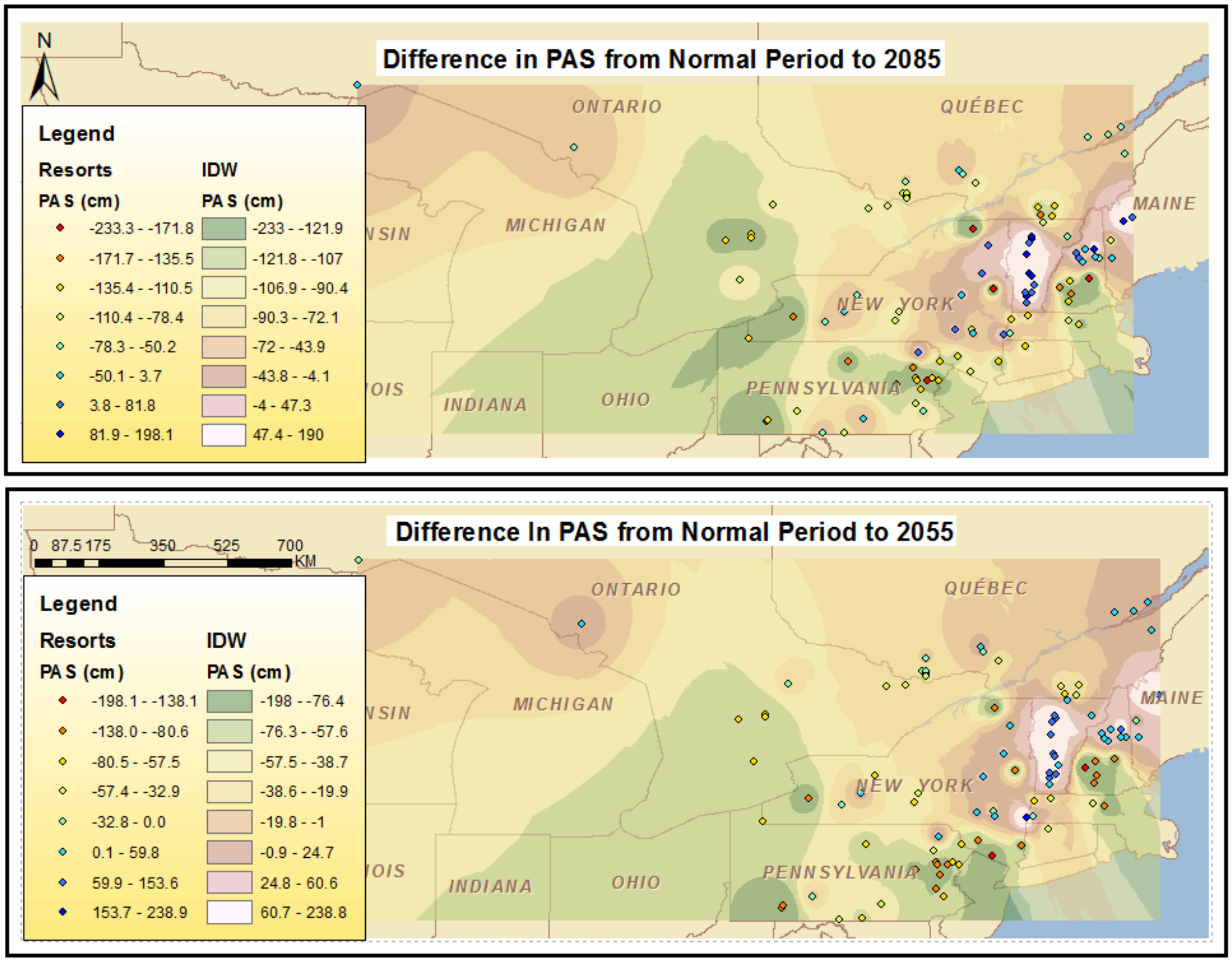

Fig. 4: Showing precipitation as snow for the study area. The resorts are shown as graduated values, and the isolines are from an IDW weighted regression. Positive values indicate an increase in PAS, while negative values signify decrease.

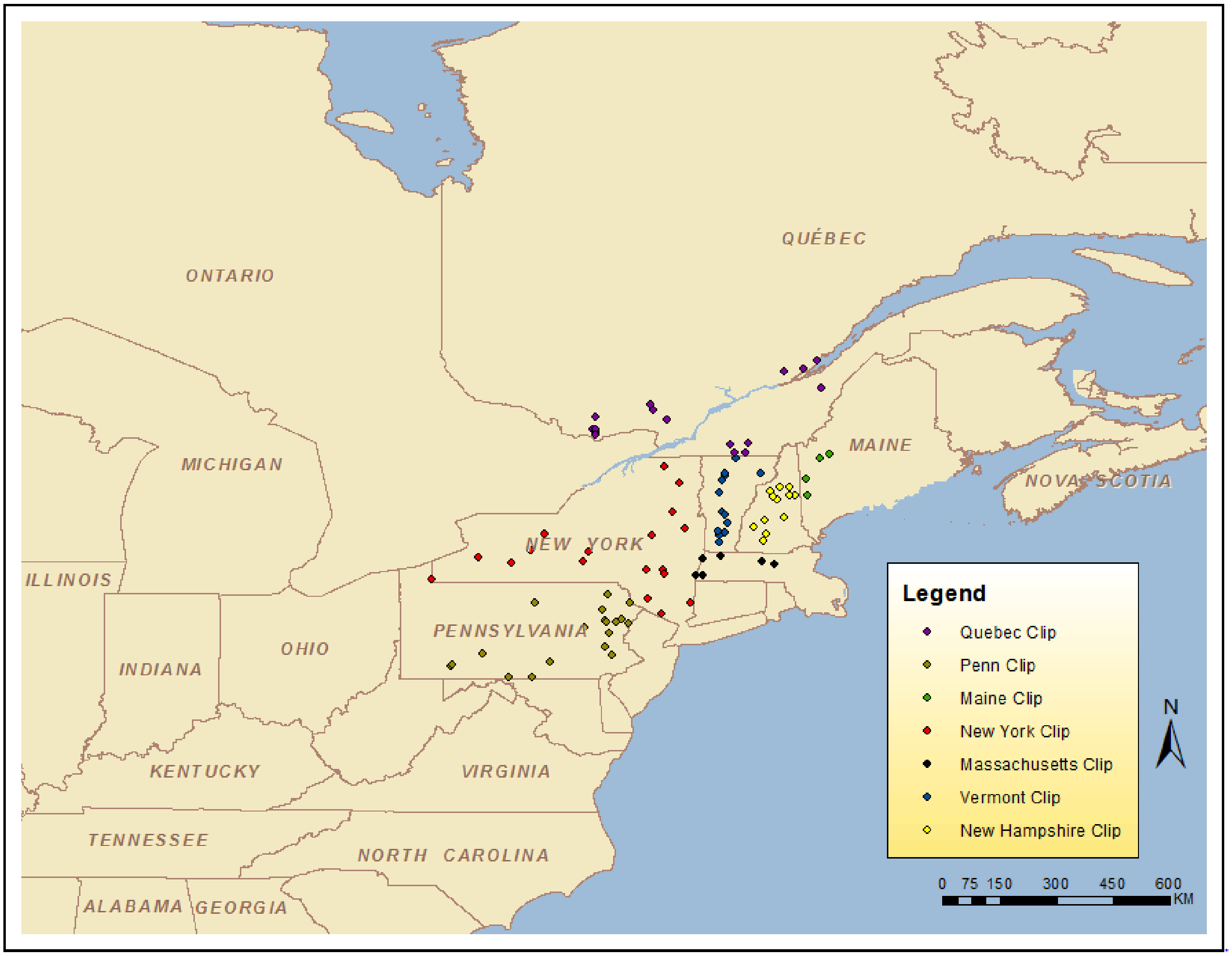

Fig. 5: Map showing the resorts clipped to their specific region.

ONTARIO

OBJECTID *	FREQUENCY	Mean_Lat	Mean_Elev	Tave_Norm	DD<0_Norm	PAS_Norm	Tave_2055	DD<0_2055	PAS_2055	Tave_2085	DD<0_2085	PAS_2085
1	9	45.3	303.11	-8.43	791.41	164.61	-3.89	443.24	123.24	-1.31	283.54	70.96

QUEBEC

OBJECTID *	FREQUENCY	Mean_Lat	Mean_Elev	Tave_Norm	DD<0_Norm	PAS_Norm	Tave_2055	DD<0_2055	PAS_2055	Tave_2085	DD<0_2085	PAS_2085
1	16	45.9	420.81	-10.62	971.81	228.16	-5.83	578.81	208.4	-3.14	388.05	143.49

PENNSYLVANIA

OBJECTID *	FREQUENCY	Mean_Lat	Mean_Elev	Tave_Norm	DD<0_Norm	PAS_Norm	Tave_2055	DD<0_2055	PAS_2055	Tave_2085	DD<0_2085	PAS_2085
1	19	40.7	1522.16	-5.11	543.93	198.23	-1.81	321.92	134.27	0.084	226.67	92.88

NEW YORK

OBJECTID *	FREQUENCY	Mean_Lat	Mean_Elev	Tave_Norm	DD<0_Norm	PAS_Norm	Tave_2055	DD<0_2055	PAS_2055	Tave_2085	DD<0_2085	PAS_2085
1	18	42.7	1748.06	-8.71	822.57	274.66	-4.97	532.56	232.75	-2.92	389.19	197.59

MASSACHUSETTS

OBJECTID *	FREQUENCY	Mean_Lat	Mean_Elev	Tave_Norm	DD<0_Norm	PAS_Norm	Tave_2055	DD<0_2055	PAS_2055	Tave_2085	DD<0_2085	PAS_2085
1	6	42.41	1260.17	-7.93	747.97	256.07	-4.3	472.25	254.45	-2.23	335.22	177.85

VERMONT

OBJECTID *	FREQUENCY	Mean_Lat	Mean_Elev	Tave_Norm	DD<0_Norm	PAS_Norm	Tave_2055	DD<0_2055	PAS_2055	Tave_2085	DD<0_2085	PAS_2085
1	13	43.87	2636.54	-14.3	1291.33	587.58	-10.28	938.36	667.02	-7.19	703.12	650.4

NEW HAMPSHIRE

OBJECTID *	FREQUENCY	Mean_Lat	Mean_Elev	Tave_Norm	DD<0_Norm	PAS_Norm	Tave_2055	DD<0_2055	PAS_2055	Tave_2085	DD<0_2085	PAS_2085
1	12	43.78	1855.08	-9.31	872.8	335.75	-5.48	574.77	315.27	-3.38	428.74	281.58

MAINE

OBJECTID *	FREQUENCY	Mean_Lat	Mean_Elev	Tave_Norm	DD<0_Norm	PAS_Norm	Tave_2055	DD<0_2055	Pas_2055	Tave_2085	DD<0_2085	PAS_2085
1	4	44.63	2338.75	-13.23	1196.22	492.3	-9.13	840.65	547.95	-6.78	652.63	516.75

Table 1: Showing summary statistics calculated in ArcMap for each region. All statistics are mean values. Connecticut was excluded from this, as it only has one resort inside its borders.

For Elevation

	Tave 2055	Tave 2085	DD<0 2055	DD<0 2085	Elevation	Latitude
ID = 1	0.65	1.05	82.50	133.46	387.04	2.29
ID = 2	0.36	0.59	52.80	90.21	552.91	1.32
ID = 1 or 2	0.55	0.88	68.77	113.16	902.67	1.90

Table 2: Showing standard deviation for the population used in the t-test, ID = 1 are lower elevations and ID = 2 are higher elevations.

	Tave 2055	Tave 2085	DD<0 2055	DD<0 2085	Elevation	Latitude
ID = 1	4.14	6.44	-311.54	-456.22	674.02	43.88
ID = 2	3.78	5.95	-307.58	-463.48	2188.61	43.02
ID = 1 or 2	3.96	6.18	-309.88	-460.87	1470.00	43.44

Table 3: Showing mean for the population used in the t-test. ID = 1 are lower elevations and ID = 2 are higher elevations.

For Latitude

	Tave 2055	Tave 2085	DD<0 2055	DD<0 2085	Elevation	Latitude
ID = 1	0.26	0.42	50.23	88.91	692.53	1.05
ID = 2	0.40	0.78	43.02	70.61	1036.76	1.13
ID = 1 or 2	0.55	0.88	68.77	113.16	902.67	1.90

Table 3: Showing Standard deviation for the population used in the t-test, ID = 1 are lower latitudes, and ID = 2 are higher latitudes.

	Tave 2055	Tave 2085	DD<0 2055	DD<0 2085	Elevation	Latitude
ID = 1	3.51	5.49	-256.91	-377.71	1601.40	41.80
ID = 2	4.36	6.78	-357.37	-536.98	1341.56	44.91
ID = 1 or 2	3.96	6.18	-309.88	-460.87	1470.00	43.44

Table 4: Showing mean for the population used in the t-test. ID = 1 are lower latitudes, and ID = 2 are higher latitudes

T-test for Tave Latitude

```
> t.test(Tave_Diff_2055~ID, data = Lat, alternative = c('two.sided'), mu = 0, paired = FALSE)

        Welch Two Sample t-test

data:  Tave_Diff_2055 by ID
t = -12.726, df = 87.072, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.9969136 -0.7275753
sample estimates:
mean in group 1 mean in group 2 
       3.506383        4.368627 

>
> t.test(Tave_Diff_2085~ID, data = Lat, alternative = c('two.sided'), mu = 0, paired = FALSE)

        Welch Two Sample t-test

data:  Tave_Diff_2085 by ID
t = -11.842, df = 84.517, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -1.570030 -1.118581
sample estimates:
mean in group 1 mean in group 2 
       5.485106        6.829412 
```

Fig 6:

Ho*: There is no difference in the means for change in average temperature between groups ID = 1, and ID = 2 from the 'Normal Period' to 2055 and 2085*

Ha*: There is a difference in the means for change in average temperature between groups ID = 1 and ID = 2 from the 'Normal Period' to 2055 and 2085*

Result*: For both 2055 (top) and 2085 (bottom) P << 0.05, reject Null Hypothesis, there is Significant difference in the means of the two groups; latitude affects mean value for average change in temperature.*

T-test for DD<0 Latitude

```
> t.test(DD_0_Diff_2055~ID, data = Lat, alternative = c('two.sided'), mu = 0, paired = FALSE)

	Welch Two Sample t-test

data:  DD_0_Diff_2055 by ID
t = 10.682, df = 90.336, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
  82.84683 120.69986
sample estimates:
mean in group 1 mean in group 2 
      -256.9149       -358.6882 

>
> t.test(DD_0_Diff_2085~ID, data = Lat, alternative = c('two.sided'), mu = 0, paired = FALSE)

	Welch Two Sample t-test

data:  DD_0_Diff_2085 by ID
t = 9.6692, df = 88.075, p-value = 1.706e-15
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 126.9775 192.6738
sample estimates:
mean in group 1 mean in group 2 
      -377.6979       -537.5235 
```

Fig 7:
***Ho**: There is no difference in the means for average change in degree days below zero from the 'Normal Period' to both 2055 and 2085 for groups ID = 1 and ID = 2*
***Ha**: There is a difference in the means for average change is degree days below zero from the 'Normal Period' to both 2055 and 2085 for groups ID = 1 and ID = 2.*
***Result**: For both 2055 (top) and 2085 (bottom) P << 0.05, there is a difference in the means between groups. Latitude explains variation in mean value for change in degree-days below zero.*

T-test for Tave Elevation

```
> t.test(Tave_Diff_2055~ID, data = Elev, alternative = c('two.sided'), mu = 0, paired = FALSE)

        Welch Two Sample t-test

data:  Tave_Diff_2055 by ID
t = 3.2554, df = 70.788, p-value = 0.001739
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 0.1363953 0.5676514
sample estimates:
mean in group 1 mean in group 2 
       4.138298        3.786275 

>
> t.test(Tave_Diff_2085~ID, data = Elev, alternative = c('two.sided'), mu = 0, paired = FALSE)

        Welch Two Sample t-test

data:  Tave_Diff_2085 by ID
t = 2.7931, df = 71.657, p-value = 0.006691
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 0.1406525 0.8421593
sample estimates:
mean in group 1 mean in group 2 
       6.440426        5.949020 
```

Fig 8:
***Ho**: There is no difference in the means for change in average temperature between groups ID =1 and ID = 2 between the 'Normal Period' and 2055 and 2085.*
***Ha**: There is a difference in the means for change in average temperature between groups ID = 1 and ID =2 between the 'Normal Period' and 2055 and 2085.*
***Result**: P < 0.05, Reject null hypothesis, there is a difference in the means between average temperature when comparing the 'Normal Period' and 2055 (top) and 'Normal Period' and 2085 (bottom). Elevation affects mean value for average change to temperature.*

T-test for DD<0 Elevation

```
> t.test(DD_0_Diff_2055~ID, data = Elev, alternative = c('two.sided'), mu = 0, paired = FALSE)

        Welch Two Sample t-test

data:  DD_0_Diff_2055 by ID
t = -0.22348, df = 77.336, p-value = 0.8238
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -31.64521  25.25848
sample estimates:
mean in group 1 mean in group 2 
      -311.5404       -308.3471 

>
> t.test(DD_0_Diff_2085~ID, data = Elev, alternative = c('two.sided'), mu = 0, paired = FALSE)

        Welch Two Sample t-test

data:  DD_0_Diff_2085 by ID
t = 0.38067, df = 79.865, p-value = 0.7045
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -37.75296  55.61170
sample estimates:
mean in group 1 mean in group 2 
      -456.2255       -465.1549 
```

Fig. 9:
Ho*: There is no difference in the means for change in average degree-days below zero between groups ID = 1 and ID = 2 between the 'Normal Period' and 2055 and 2085.*
Ha*: There is a difference in the means for change in average degree-days below zero between groups ID =1 and ID =1 between the 'Normal Period' and 2055 and 2085.*
Result*: P > 0.05 Fail to reject the null hypothesis; there is no difference between the mean values for degree-days below zero. Elevation has no effect on the mean value of change to degree-days below zero for 2055 (top) and 2085 (bottom).*

Citations:

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