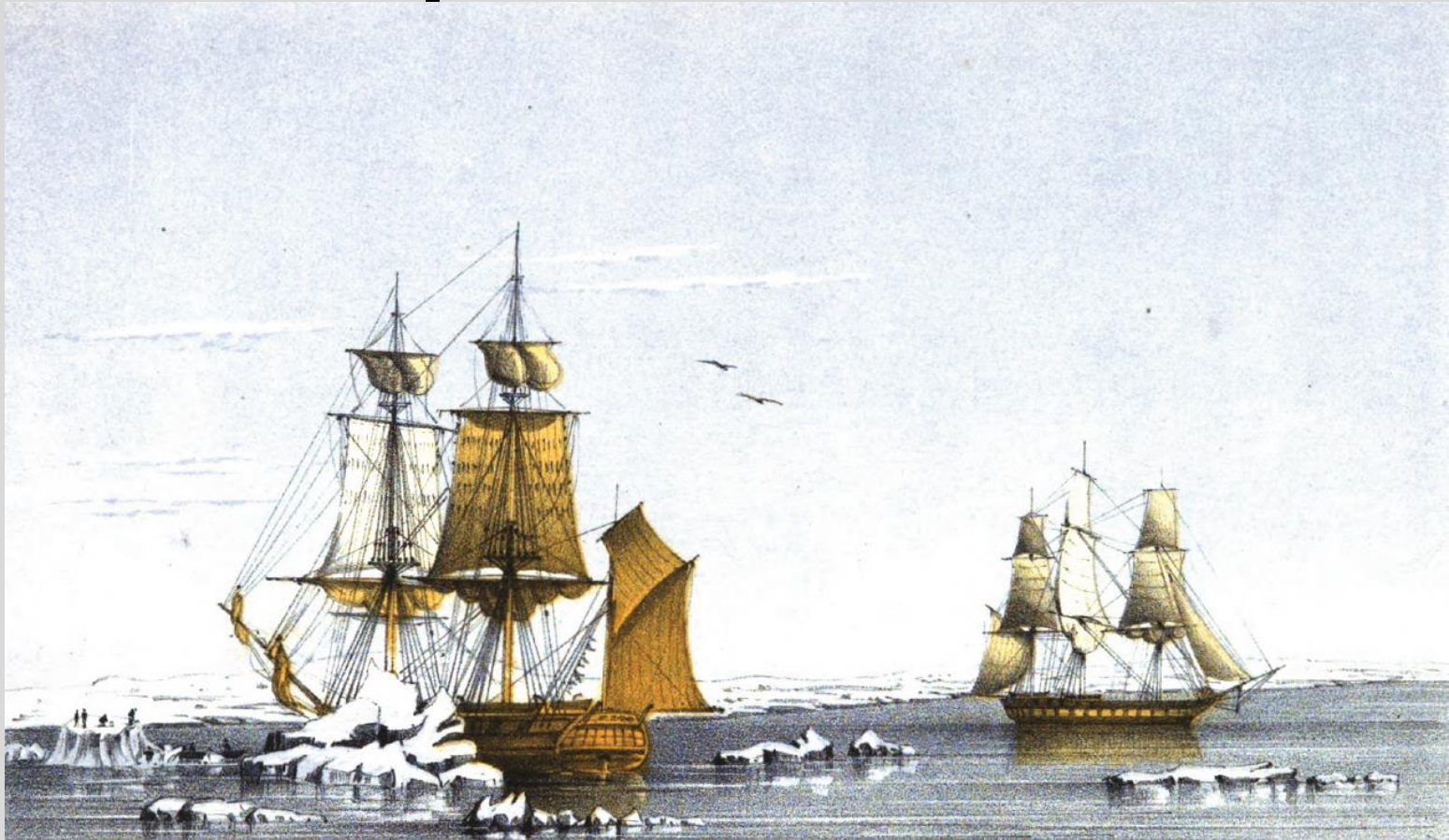


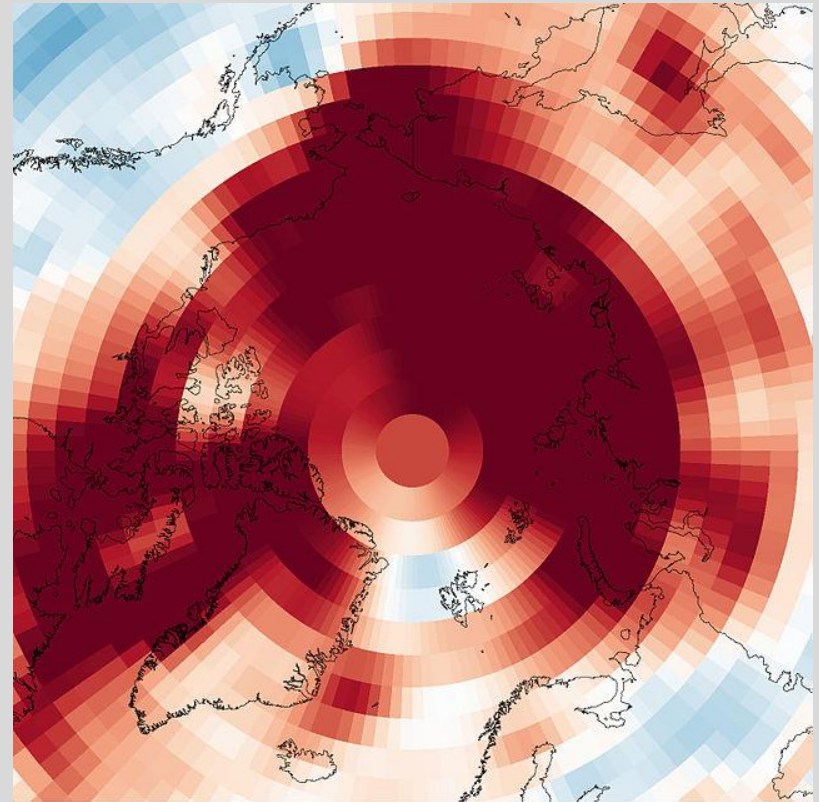
Experimental Assessment of Screen Bias in an Early Arctic Air Temperature Time Series



Jason Bak // Daniel Hosseinian

Arctic Climate Change

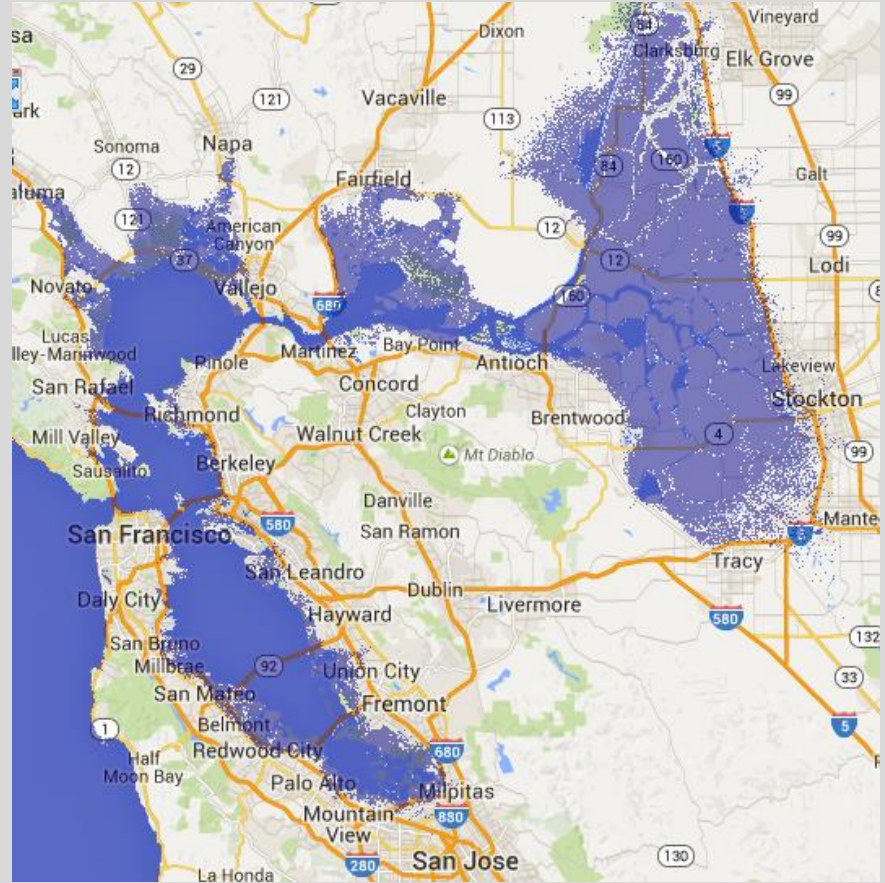
- Characterized by a change of a few degrees (1 – 3 °C)
- Estimated \$9 billion per year of damage from weather extremes caused by climate change
- Arctic is warming twice as quickly as world average



Temperature difference from long term average (since 1981)
Red – Warmer
Blue – Cooler

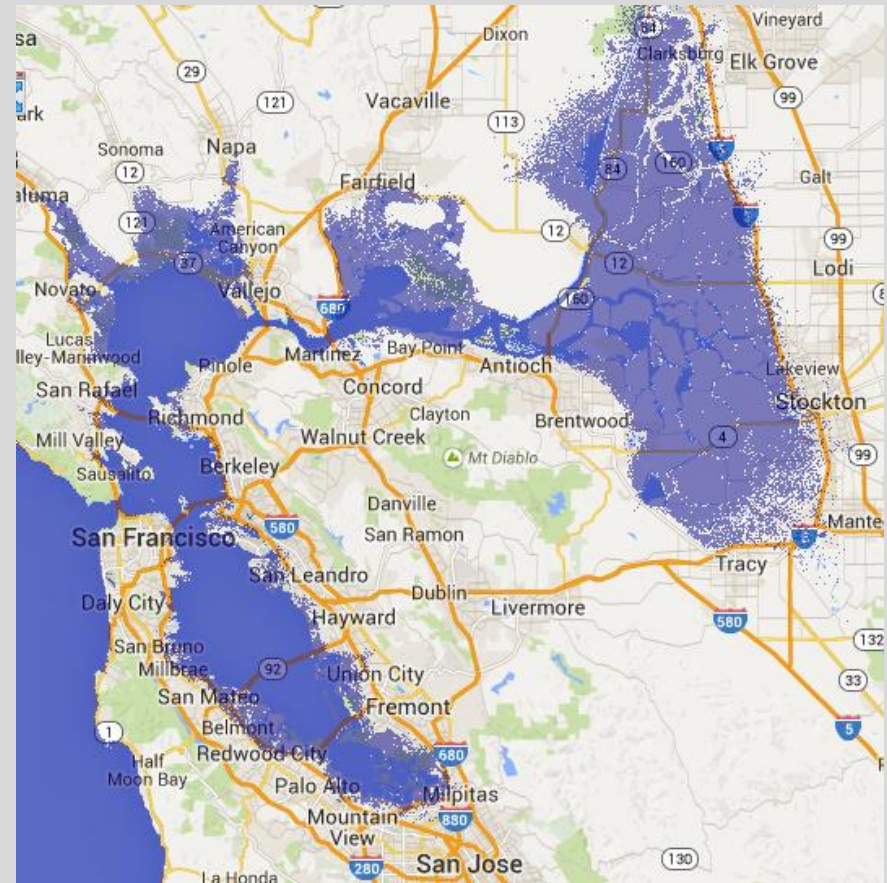
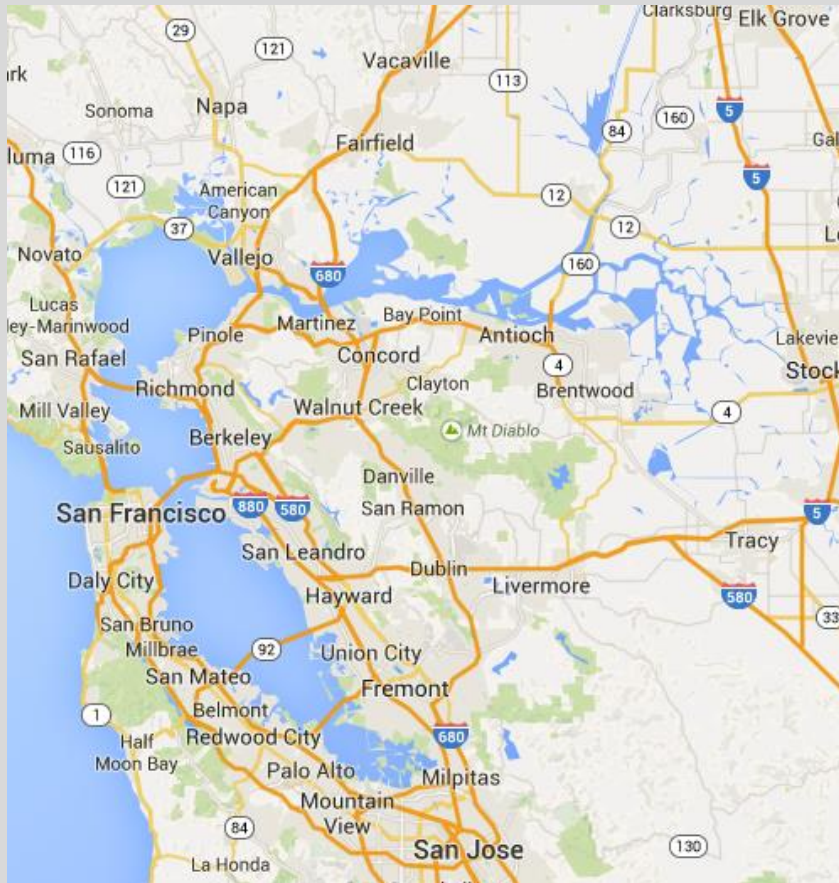
Inundation Dangers

- Intergovernmental Panel on Climate Change (IPCC) projected 18 to 59 cm sea level rise in 21st century
- 8.5 million Americans are in inundation zones (59 cm rise)



Blue areas demonstrate inundation zones in the San Francisco Bay Area, CA with a 1 m sea level rise based on elevation.

Inundation Dangers

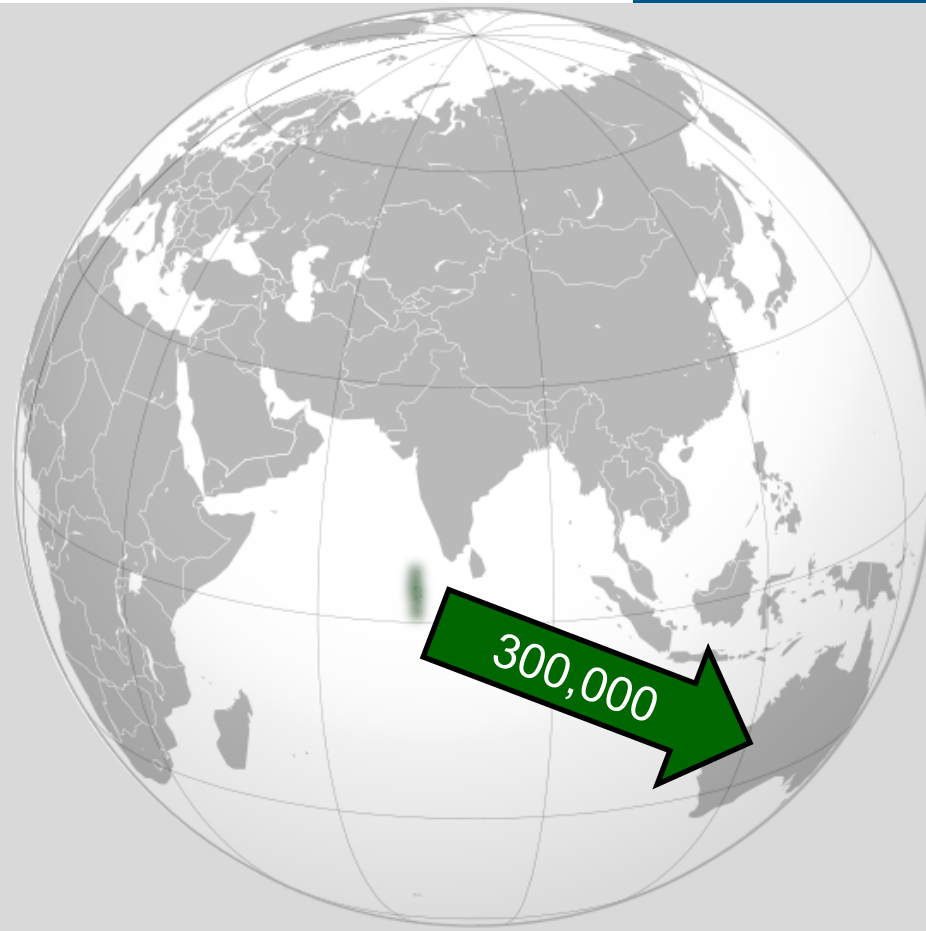


Blue areas demonstrate inundation zones in the San Francisco Bay Area, CA with a 1 m sea level rise based on elevation.

Maldives

Paradise almost lost: Maldives seek to
buy a new homeland

theguardian
Winner of the Pulitzer prize



Her Majesty's Ship (HMS) *Plover*

- Stationed at Point Barrow, Alaska from 1852 to 1854
- Hourly air temperature measurements
- Thermometer used was encapsulated in a radiation screen (results in bias)



1852

1854

Plover Screen

- Shelters instruments from outside environment
- Bias measurements recorded within
- Information about how air temperature data was collected (metadata)



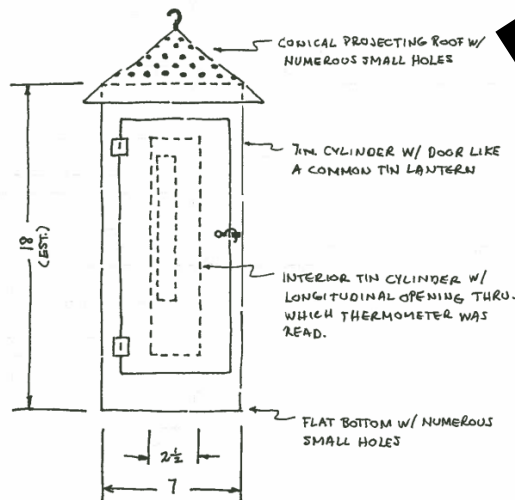
Purpose

- To determine the screen bias of the *Plover* screen on temperature readings under certain environmental conditions
- To correct inaccuracies present in the original *Plover* data set

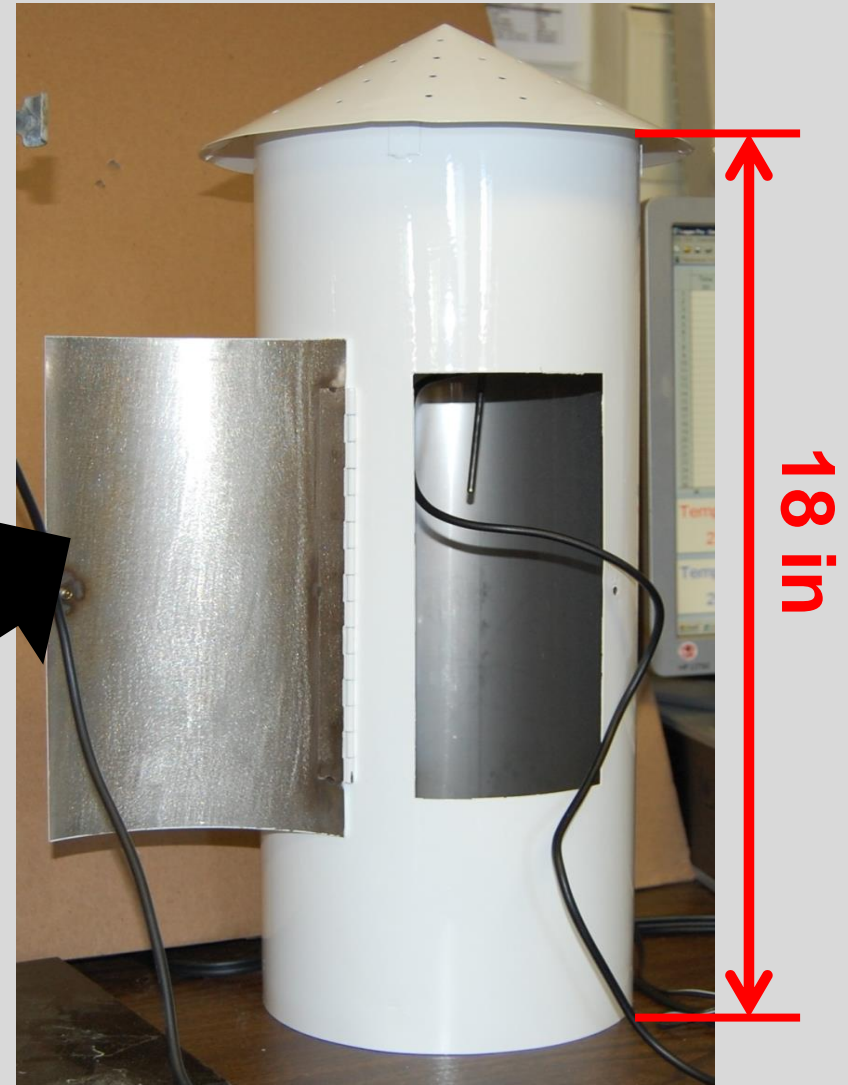
Replica Plover screen

February 1854 -
 49 - Weather clear & cold temp. has been high as -35 within the Greenland Mountains
 of Peaterville. Heavy frost - Aurora - Bright in an arch over head & visible in better
 four nations about equator the usual number of a score of comets & shooting stars -
 20 - Sky more cloudy today & the high rose to -25 after noon. This makes a mean of -30 for the
 first days of the month just passed, & the remainder is not likely to be so warm as not to
 leave it our eldest month - Native report says two men females belonging to Cape Roy
 have finished their work
 21 - Weather cloudy again since noon - temp -25 & it has today +6 at noon being a cold
 day up on shore to smoke but the black wood did not take a heat enough to melt
 fine particles of snow upon it - Native for Eskimoes was one - I tried to find out
 how his wife & Kaitak's widow lives & both sleep in a snow hut not high
 for cover of lean as I had before understood that the most death of his house
 made it "unhealthy" for him to sleep in his hut but that she sleeps in a snow hut
 not so much as she is in the day, and that she should go back again
 when the winter season is in - Kaitak had been home a large seal, & a
 large seal.

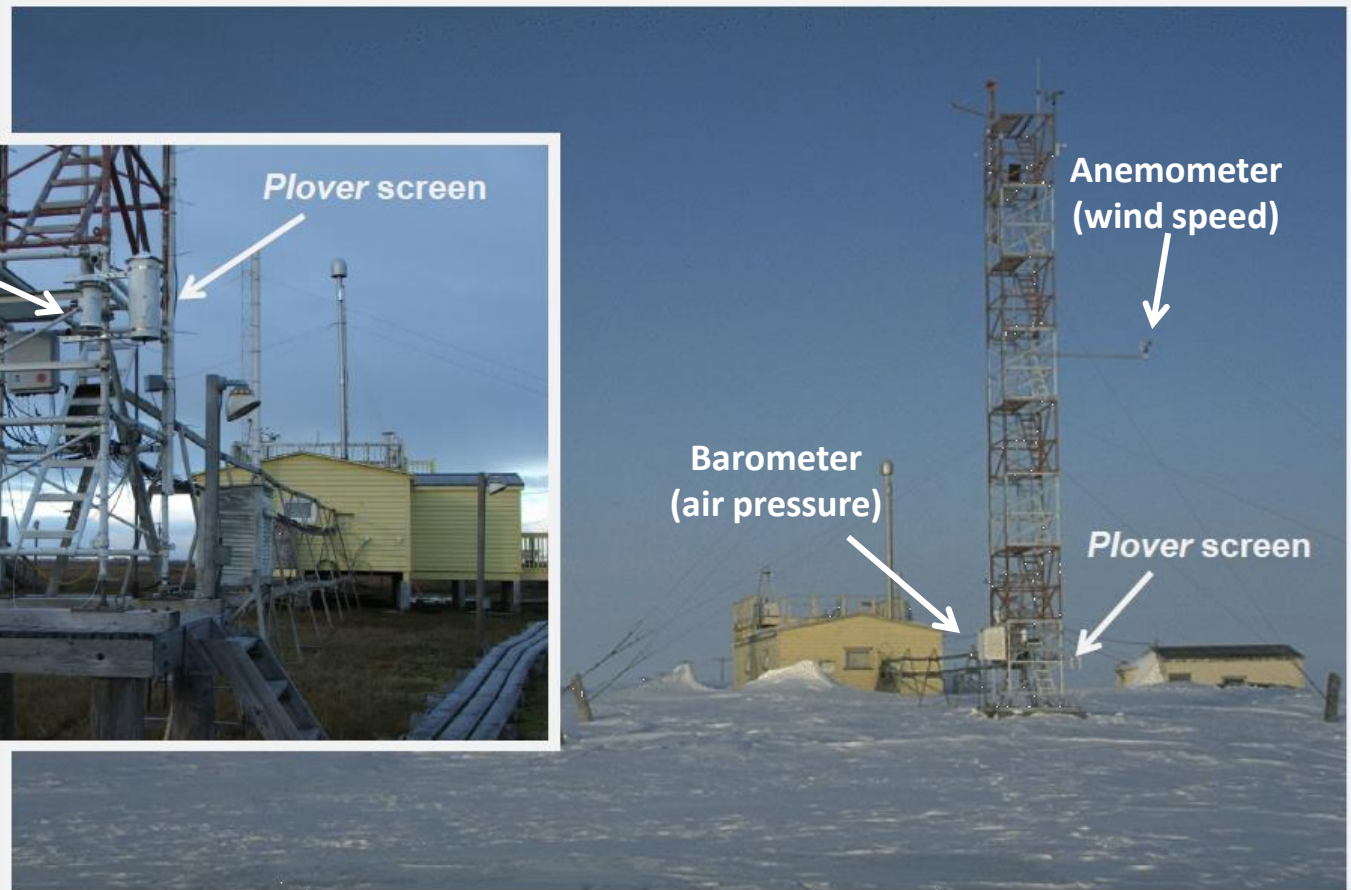
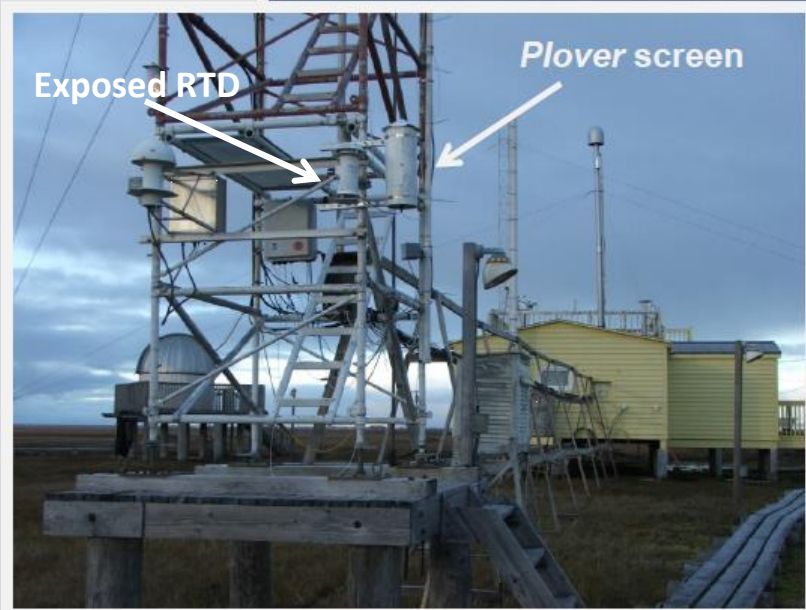
THERMOMETER SHELTER, HMS PLOVER (1852-1854)



NOTE CONSTRUCTED OF TIN, EXTERIOR PAINTED WHITE.



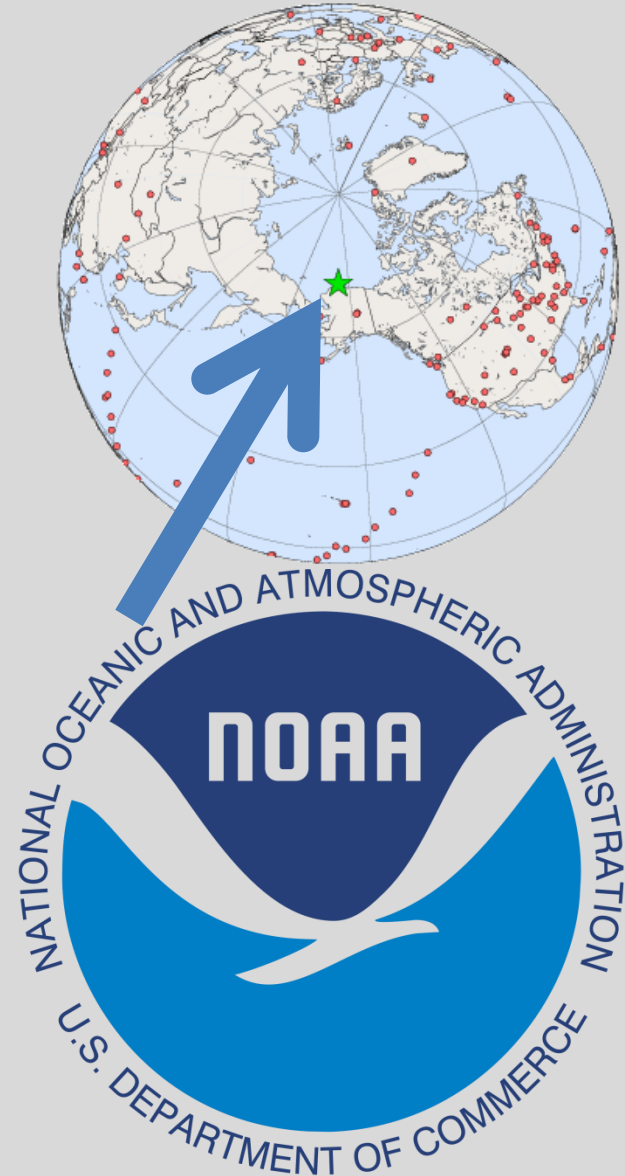
Experimental Setup



Site of data collection. Replica *Plover* screen RTD and exposed RTD are noted.

Experimental Setup

- Data collected at Barrow, Alaska at the NOAA
- Two Resistance Thermocouple Devices (RTDs)
- Replica *Plover* screen sent to the NOAA observatory
 - Houses an RTD alongside an exposed RTD
- Modern day meteorological equipment recorded atmospheric pressure, wind speed at 10 m, and wind direction at 10 m



The screenshot displays a Microsoft Excel spreadsheet with a table of meteorological data for Station #199 (Barrow Baseline Observatory). The table has the following columns: Local Date and Time, Unit ID, Date, Time, GPS Date, GPS Time, Wind Speed 2m, Wind Direction 2m, Wind Gust 2m, Std. Wind Dir 2m, and Wind Speed 10m. The data is organized into rows, with the first row being the header and subsequent rows containing numerical data. A black arrow points to the 'Time' column header, and a red arrow points to the 'GPS Time' column header. The spreadsheet is titled 'Station #199 (Barrow Baseline Observatory), Baseline Observatory' and is located in the file 'file:///C:/Users/Daniel/Desktop/Plover/aaTest.txt'.

Local Date and Time	Unit ID	Date	Time	GPS Date	GPS Time	Wind Speed 2m	Wind Direction 2m	Wind Gust 2m	Std. Wind Dir 2m	Wind Speed 10m
1/30/2012 23:59	199	12/1/1931	0:00:00	9999	9999	3.8	141	4	2	9999
1/31/2012 0:00	199	12/1/1931	0:01:00	9999	9999	3.9	136	4	2	9999
1/31/2012 0:01	199	12/1/1931	0:02:00	9999	9999	4.3	139	4.4	2	9999
1/31/2012 0:02	199	12/1/1931	0:03:00	9999	9999	4.3	143	4.5	1	9999
1/31/2012 0:04	199	12/1/1931	0:04:00	9999	9999	4.5	146	4.7	1	9999
1/31/2012 0:05	199	12/1/1931	0:05:00	9999	9999	4.6	148	4.7	1	9999
1/31/2012 0:06	199	12/1/1931	0:06:00	9999	9999	4.4	151	4.5	2	9999
1/31/2012 0:07	199	12/1/1931	0:07:00	9999	9999	4.2	156	4.4	2	9999
1/31/2012 0:08	199	12/1/1931	0:08:00	9999	9999	4.2	157	4.4	2	9999
1/31/2012 0:09	199	12/1/1931	0:09:00	9999	9999	4.2	154	4.4	2	9999
1/31/2012 0:10	199	12/1/1931	0:10:00	9999	9999	4.2	152	4.4	2	9999
1/31/2012 0:11	199	12/1/1931	0:11:00	9999	9999	4.1	148	4.3	2	9999
1/31/2012 0:12	199	12/1/1931	0:12:00	9999	9999	4.1	142	4.3	1	9999
1/31/2012 0:13	199	12/1/1931	0:13:00	9999	9999	3.9	148	4.2	2	9999
1/31/2012 0:14	199	12/1/1931	0:14:00	9999	9999	4.1	152	4.4	3	9999
1/31/2012 0:15	199	12/1/1931	0:15:00	9999	9999	4.2	154	4.4	2	9999
1/31/2012 0:16	199	12/1/1931	0:16:00	9999	9999	4.2	156	4.4	2	9999
1/31/2012 0:17	199	12/1/1931	0:17:00	9999	9999	4.1	145	4.3	2	9999
1/31/2012 0:18	199	12/1/1931	0:18:00	9999	9999	4.1	142	4.3	1	9999
1/31/2012 0:19	199	12/1/1931	0:19:00	9999	9999	4.1	145	4.3	2	9999
1/31/2012 0:20	199	12/1/1931	0:20:00	9999	9999	4.1	145	4.3	2	9999
1/31/2012 0:21	199	12/1/1931	0:21:00	9999	9999	4.4	150	4.6	2	9999
1/31/2012 0:22	199	12/1/1931	0:22:00	9999	9999	4.2	155	4.5	3	9999
1/31/2012 0:23	199	12/1/1931	0:23:00	9999	9999	4.1	155	4.4	2	9999
1/31/2012 0:24	199	12/1/1931	0:24:00	9999	9999	4.2	154	4.4	2	9999
1/31/2012 0:25	199	12/1/1931	0:25:00	9999	9999	4.2	154	4.4	2	9999
1/31/2012 0:26	199	12/1/1931	0:26:00	9999	9999	4.1	156	4.4	3	9999
1/31/2012 0:27	199	12/1/1931	0:27:00	9999	9999	4.1	158	4.4	3	9999
1/31/2012 0:28	199	12/1/1931	0:28:00	9999	9999	4.2	151	4.3	3	9999
1/31/2012 0:29	199	12/1/1931	0:29:00	9999	9999	4.2	149	4.2	3	9999
1/31/2012 0:30	199	12/1/1931	0:30:00	9999	9999	4.4	140	4.2	1	9999
1/31/2012 0:31	199	12/1/1931	0:31:00	9999	9999	3.8	145	4	3	

The screenshot displays a Microsoft Excel spreadsheet with a table of meteorological data. The table is titled "Station #199 (Barrow Baseline Observatory), Baseline Observatory". The columns are: Local Date and Time, Unit ID, Date, Time, GPS Date, GPS Time, Wind Speed 2m, Wind Direction 2m, Wind Gust 2m, Std. Wind Dir 2m, and Wind Speed. The data is organized into rows, with the first row being the header and subsequent rows containing numerical data. A black arrow points to the "Time" column header. The spreadsheet is open in the "File" menu, and the "Home" tab is selected. The "Clipboard" group is visible, showing "Cut", "Copy", and "Paste" options. The "Font" group shows "Calibri" font and "11" size. The "Alignment" group shows "Left" alignment. The "Formulas" group shows "L29" and "156". The "Data" group shows "A" through "G". The "Review" group shows "A" through "G". The "View" group shows "A" through "G". The "Status Bar" at the bottom shows "Sheet22", "Sheet23", "Sheet24", "Sheet25", "Sheet26", "Sheet27", and "Sheet28".

Local Date and Time	Unit ID	Date	Time	GPS Date	GPS Time	Wind Speed 2m	Wind Direction 2m	Wind Gust 2m	Std. Wind Dir 2m	Wind Speed
1/30/2012 23:59	199	12/1/1931	0:00:00	9999	9999	3.8	141	4	2	9999
1/31/2012 0:00	199	12/1/1931	0:01:00	9999	9999	3.9	136	4	2	9999
1/31/2012 0:01	199	12/1/1931	0:02:00	9999	9999	4.3	139	4.4	2	9999
1/31/2012 0:02	199	12/1/1931	0:03:00	9999	9999	4.3	143	4.5	1	9999
1/31/2012 0:04	199	12/1/1931	0:04:00	9999	9999	4.5	146	4.7	1	9999
1/31/2012 0:05	199	12/1/1931	0:05:00	9999	9999	4.6	148	4.7	1	9999
1/31/2012 0:06	199	12/1/1931	0:06:00	9999	9999	4.4	151	4.5	2	9999
1/31/2012 0:07	199	12/1/1931	0:07:00	9999	9999	4.2	156	4.4	2	9999
1/31/2012 0:08	199	12/1/1931	0:08:00	9999	9999	4.2	157	4.4	2	9999
1/31/2012 0:09	199	12/1/1931	0:09:00	9999	9999	4.2	154	4.4	2	9999
1/31/2012 0:10	199	12/1/1931	0:10:00	9999	9999	4.2	152	4.4	2	9999
1/31/2012 0:11	199	12/1/1931	0:11:00	9999	9999	4.1	148	4.3	2	9999
1/31/2012 0:12	199	12/1/1931	0:12:00	9999	9999	4.1	142	4.3	1	9999
1/31/2012 0:13	199	12/1/1931	0:13:00	9999	9999	3.9	148	4.2	2	9999
1/31/2012 0:14	199	12/1/1931	0:14:00	9999	9999	4.1	152	4.4	3	9999
1/31/2012 0:15	199	12/1/1931	0:15:00	9999	9999	4.2	154	4.4	2	9999
1/31/2012 0:16	199	12/1/1931	0:16:00	9999	9999	4.2	156	4.4	2	9999
1/31/2012 0:17	199	12/1/1931	0:17:00	9999	9999	4.1	148	4.3	2	9999
1/31/2012 0:18	199	12/1/1931	0:18:00	9999	9999	3.9	161	4.2	3	9999
1/31/2012 0:19	199	12/1/1931	0:19:00	9999	9999	4.1	156	4.4	2	9999
1/31/2012 0:20	199	12/1/1931	0:20:00	9999	9999	4.1	152	4.4	3	9999
1/31/2012 0:21	199	12/1/1931	0:21:00	9999	9999	4.1	145	4.5	2	9999
1/31/2012 0:22	199	12/1/1931	0:22:00	9999	9999	4.4	150	4.6	2	9999
1/31/2012 0:23	199	12/1/1931	0:23:00	9999	9999	4.2	153	4.5	3	9999
1/31/2012 0:24	199	12/1/1931	0:24:00	9999	9999	4.1	155	4.4	2	9999
1/31/2012 0:25	199	12/1/1931	0:25:00	9999	9999	4.2	154	4.4	2	9999
1/31/2012 0:26	199	12/1/1931	0:26:00	9999	9999	4.2	156	4.4	2	9999
1/31/2012 0:27	199	12/1/1931	0:27:00	9999	9999	4.1	158	4.3	2	9999
1/31/2012 0:28	199	12/1/1931	0:28:00	9999	9999	4.2	151	4.3	3	9999
1/31/2012 0:29	199	12/1/1931	0:29:00	9999	9999	4.2	148	4.3	2	9999
1/31/2012 0:30	199	12/1/1931	0:30:00	9999	9999	4.4	140	4.2	1	9999

Results (Solar Influences)

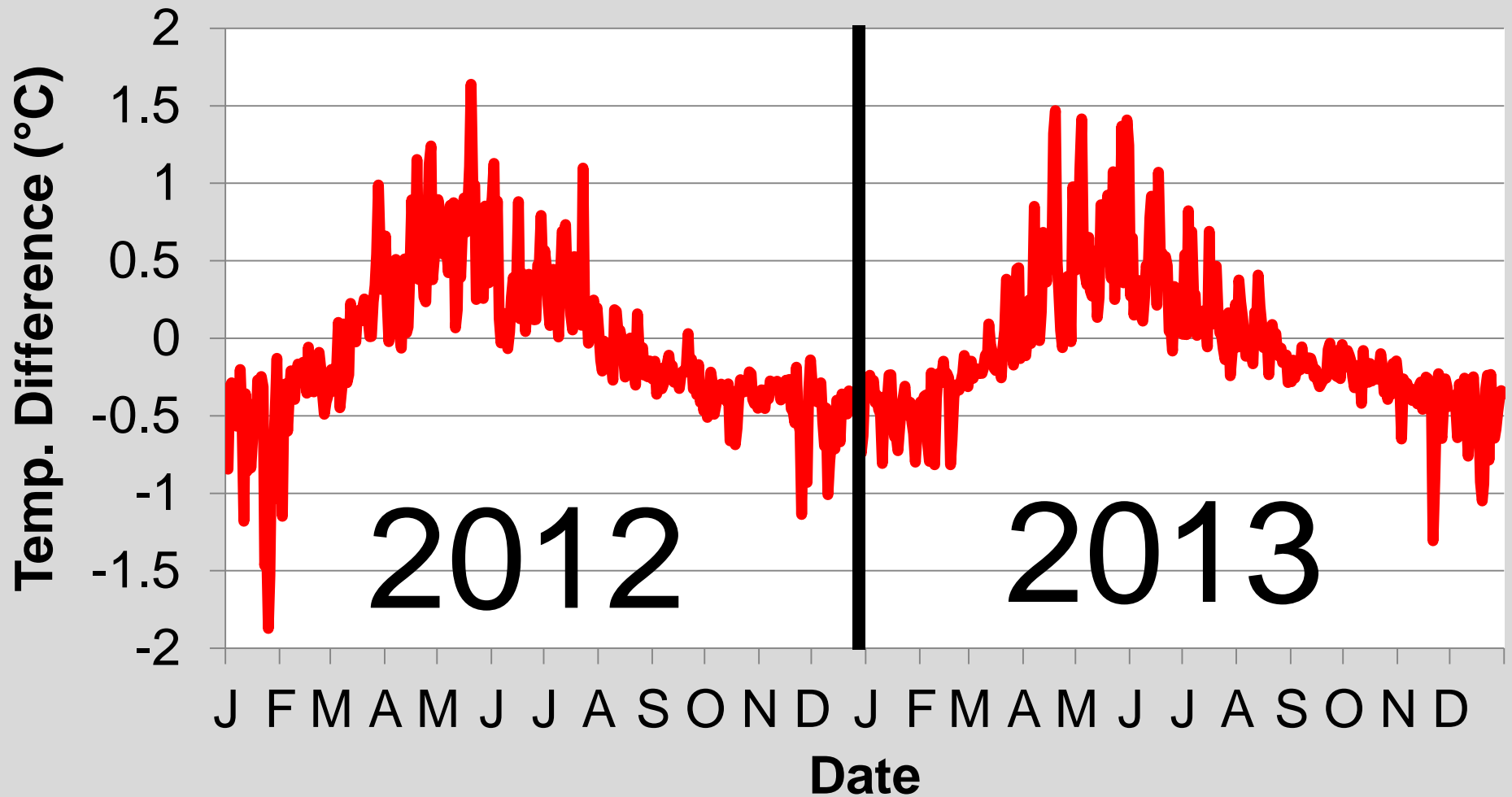
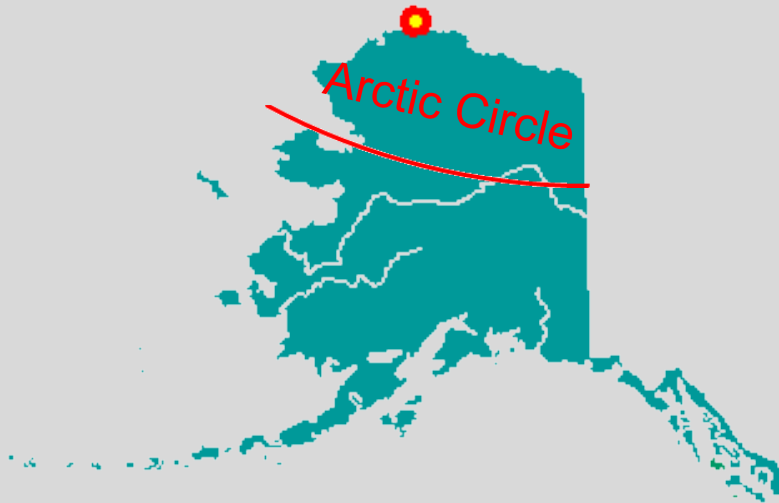


Figure 1 Plot of temperature difference (°C) of Plover RTD and RTD 2m for 2 years (2012-2013) by Julian day

Seasonal Solar Radiation



- Summer months: screen records higher temperatures
 - More sun exposure
- Winter months, screen records lower temperatures
 - No heating element

Results (Solar Influences)

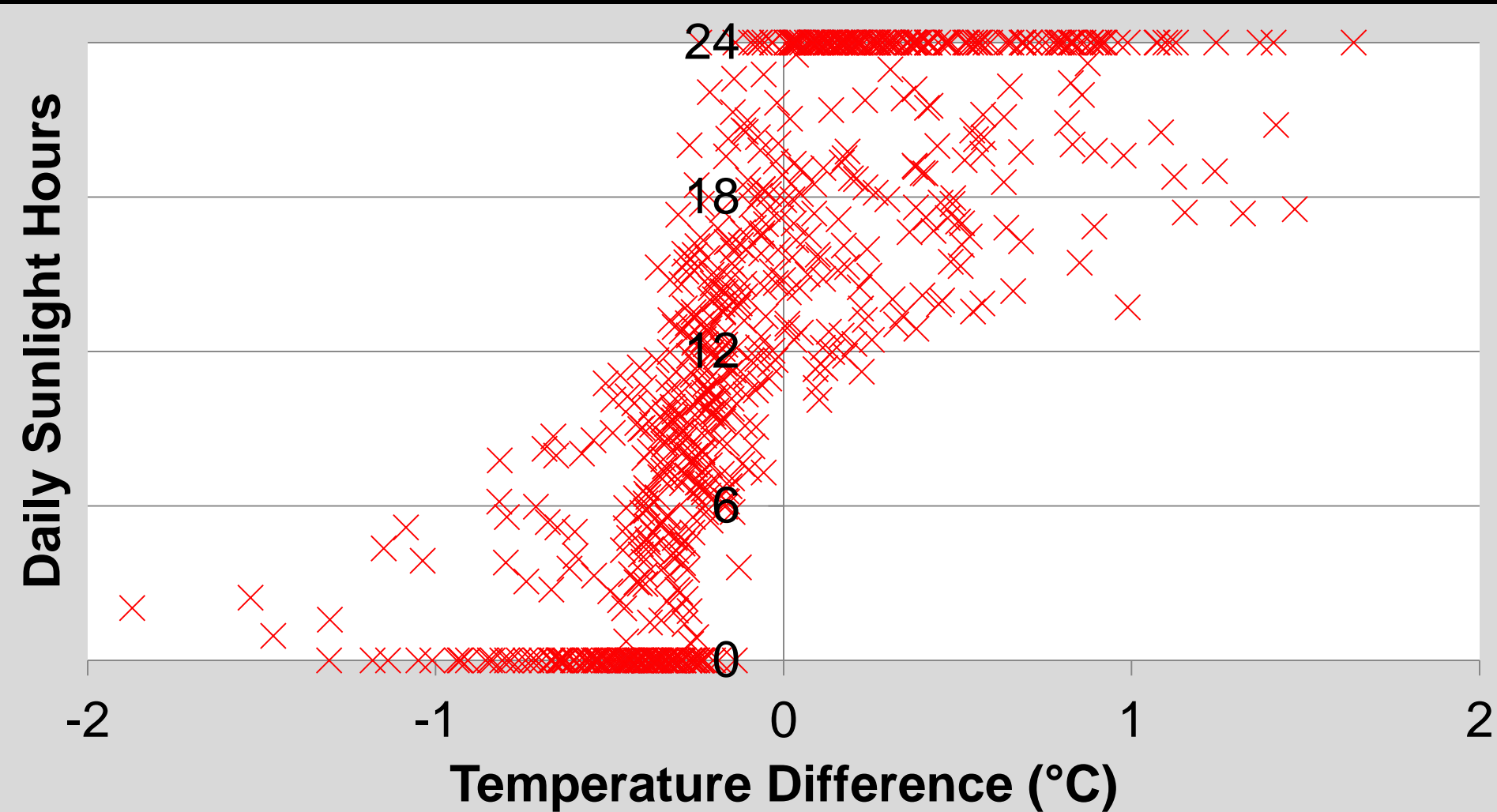


Figure 2 Temperature difference (°C) of Plover RTD and RTD 2m against daily sunlight hours

Results (Wind)

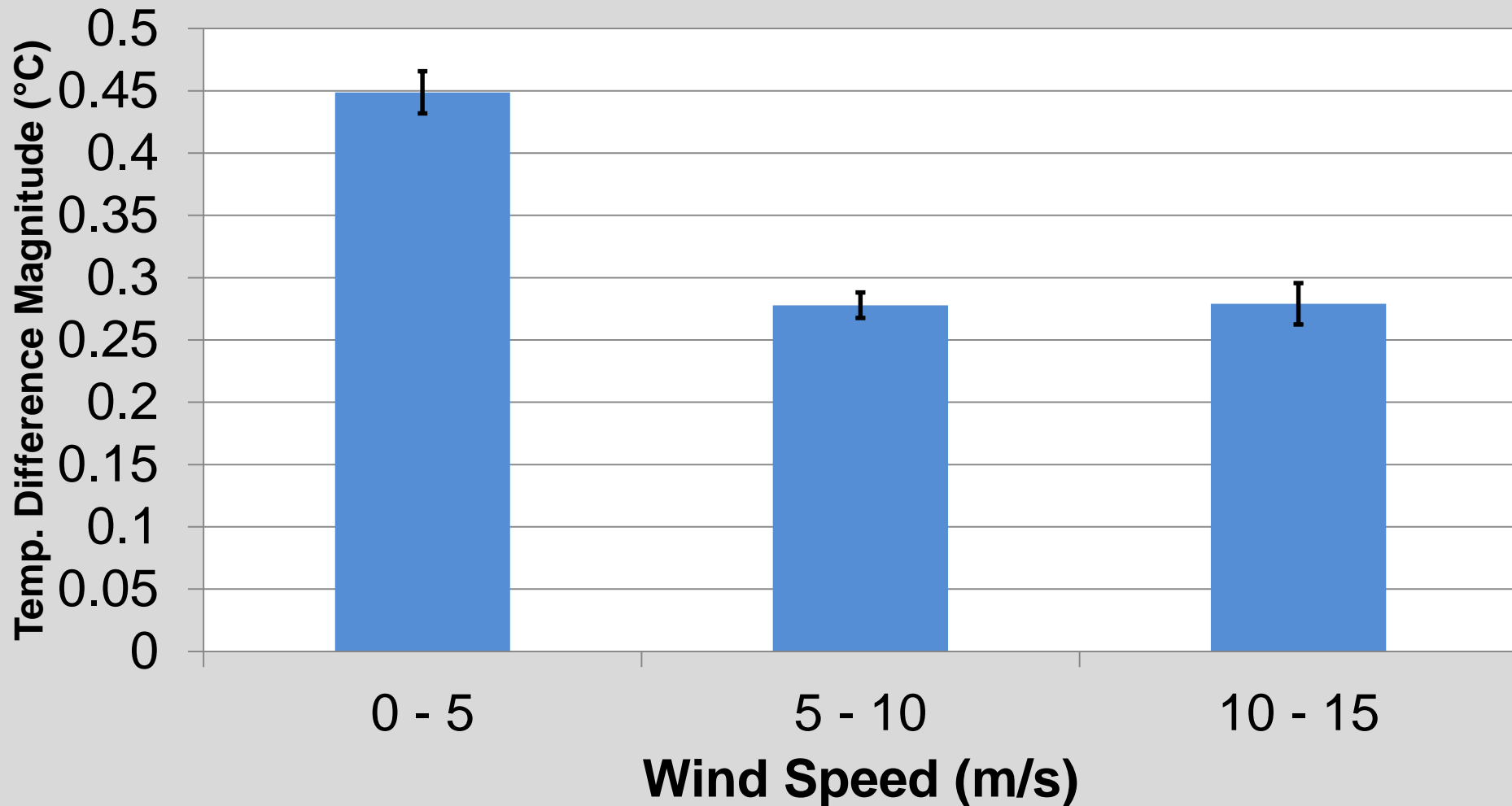


Figure 3 Average temperature difference (°C) at different wind speed intervals; **P < 0.05**
(Error bars = standard error)

Results (Wind)

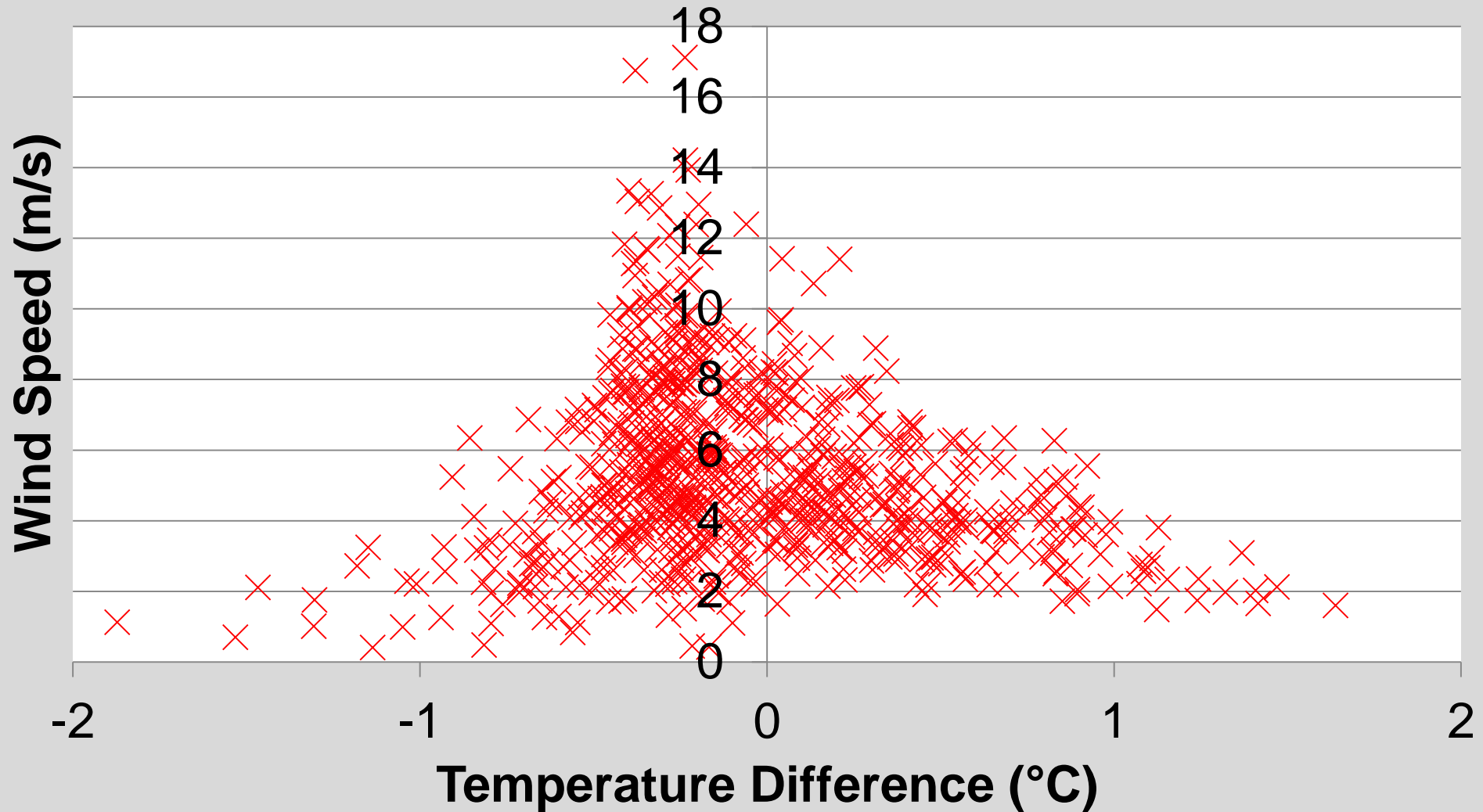


Figure 4 Temperature difference (°C) of Plover RTD and RTD 2m against wind speed (m/s)

Results (Barometric Pressure)

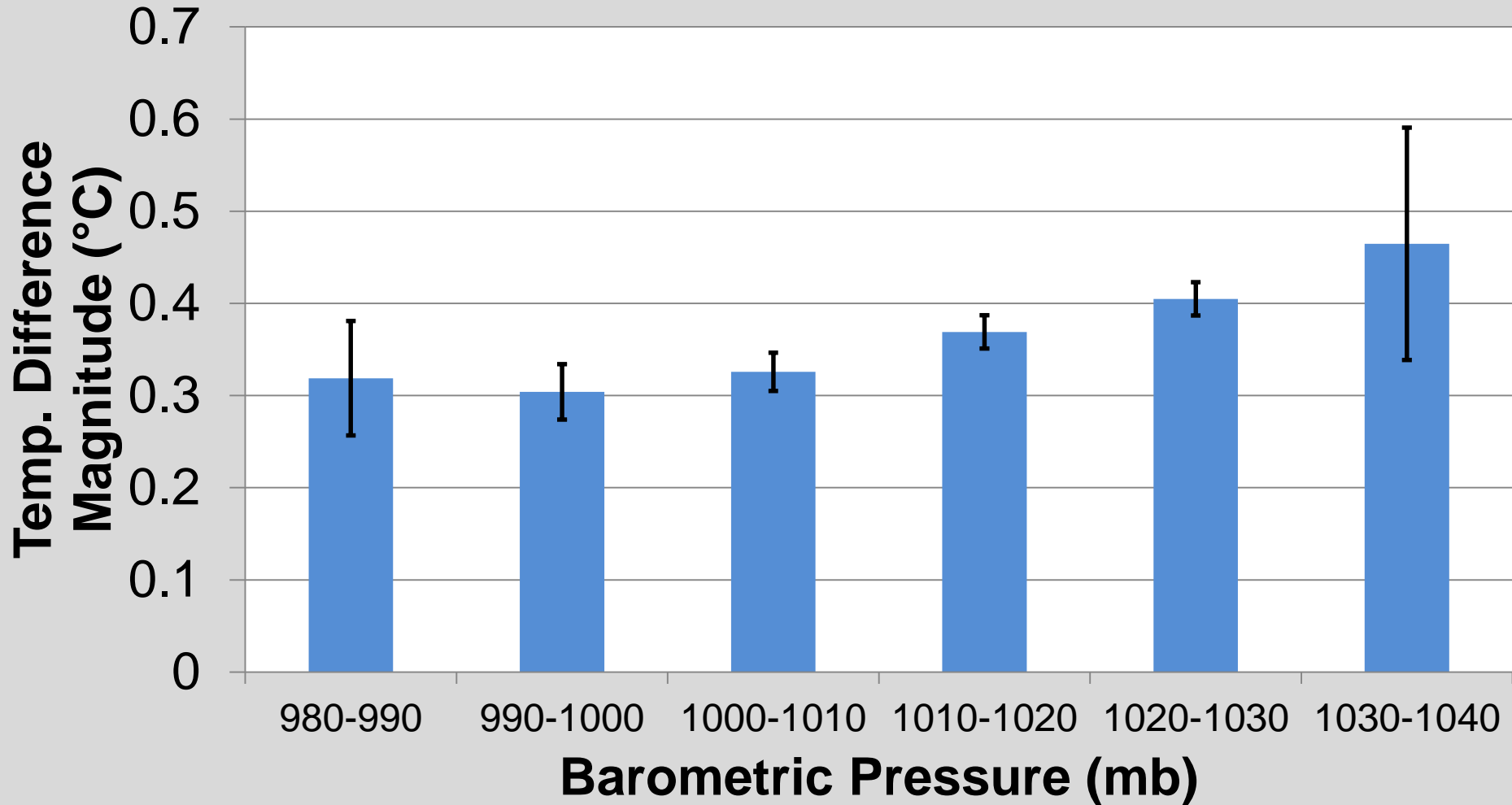


Figure 5 Average temperature difference (°C) at different air pressure intervals;
(Error bars = standard error)

Results (Barometric Pressure)

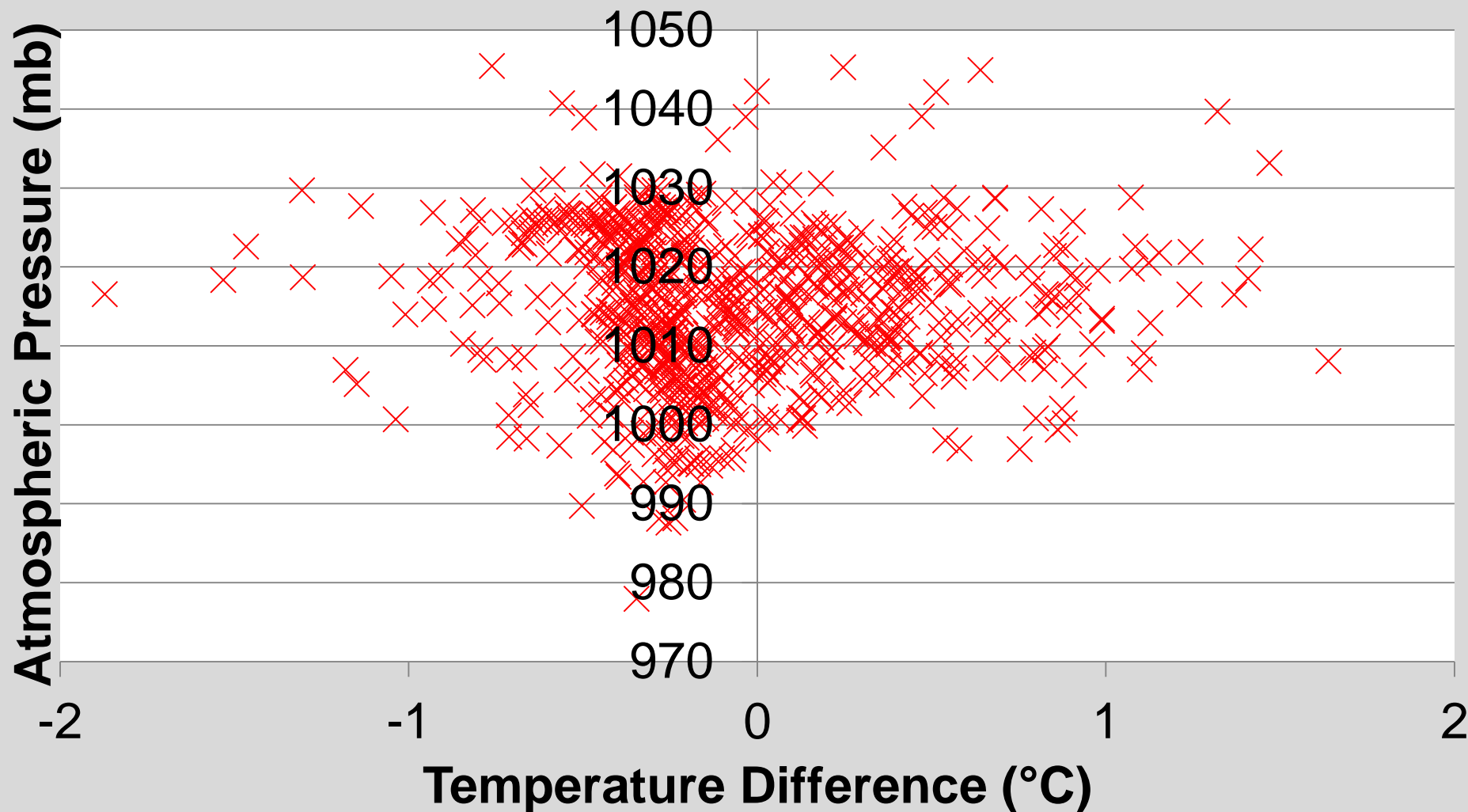


Figure 6 Temperature difference (°C) of Plover RTD and RTD 2m against atmospheric pressure (mb)

Results (Actual Temperature)

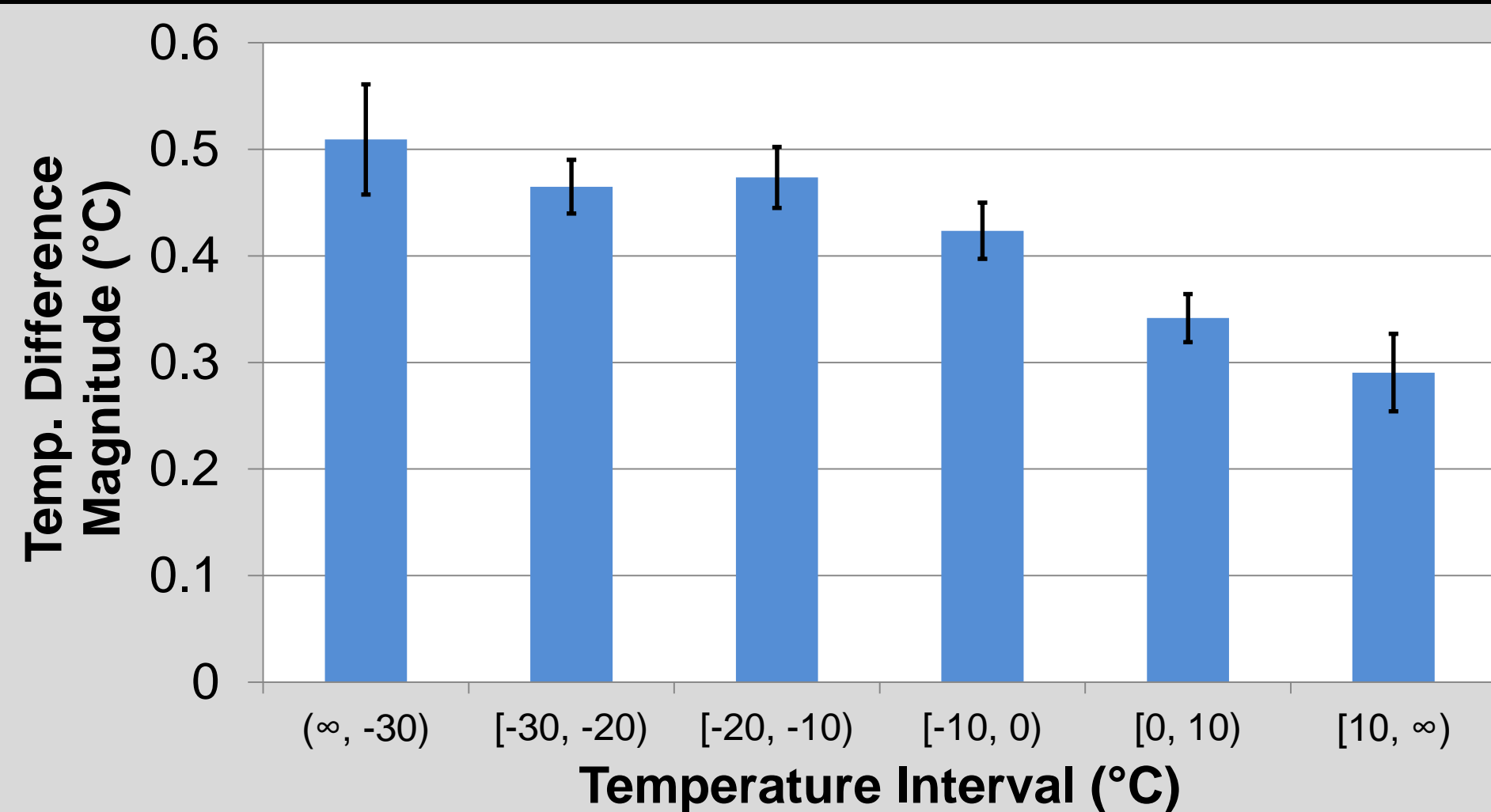


Figure 7 Average temperature difference (°C) of exposed and encased thermometers at different interval

Results (Actual Temperature)

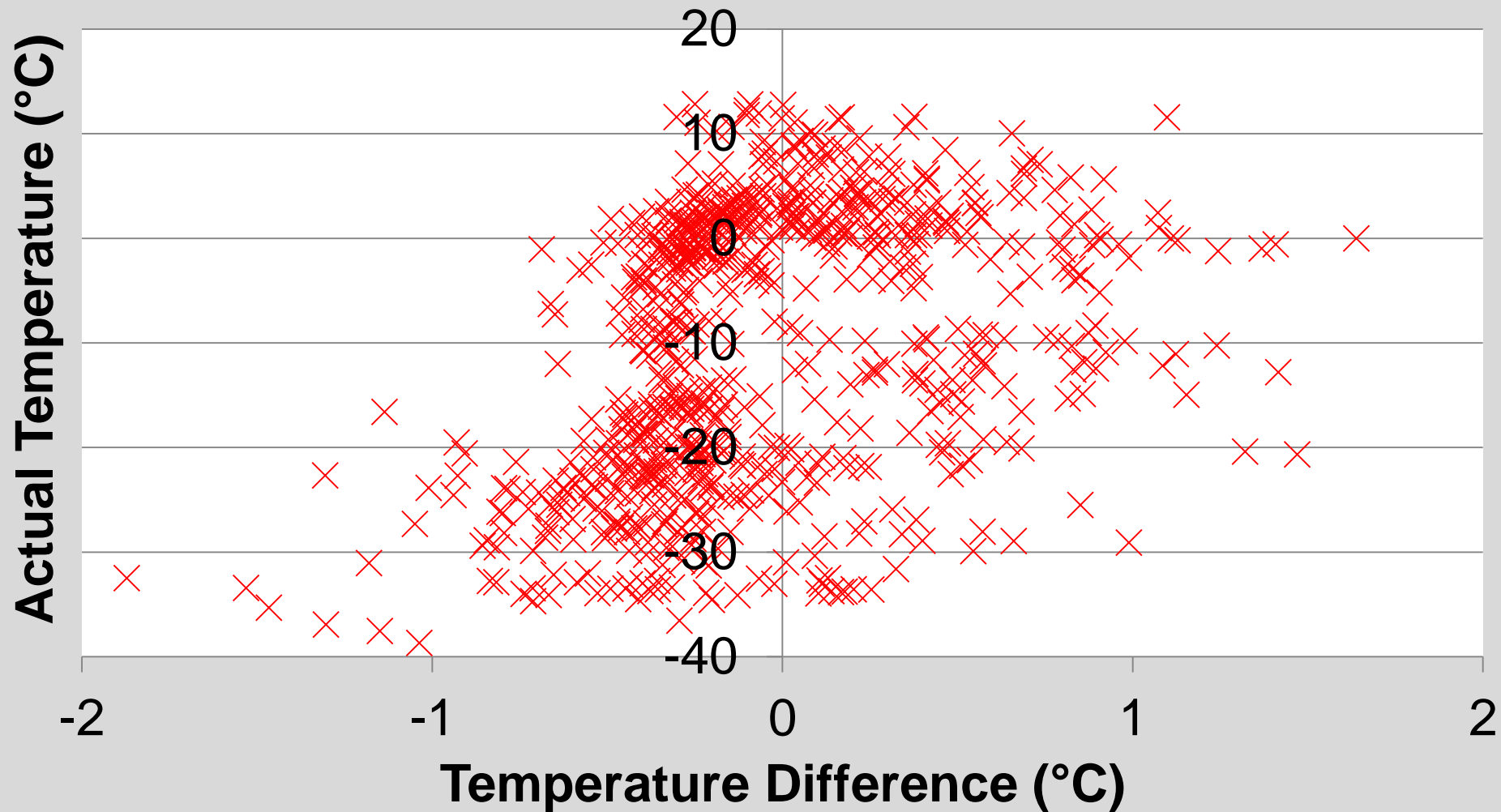


Figure 8 Temperature difference (°C) of Plover RTD and RTD 2m against actual temperature (°C)

Conclusion

Screen Bias?

Yes	No
Sun exposure	Different temperatures
Low wind speeds	Different barometric pressures

Implications

- Conduct rare comparison study between *Plover* data (located at Duke Special Collections Library) and modern data to seek changing climate patterns in the Arctic
- Gain better insight to Arctic climate change
 - How fast is it?
 - What actions should we be taking?

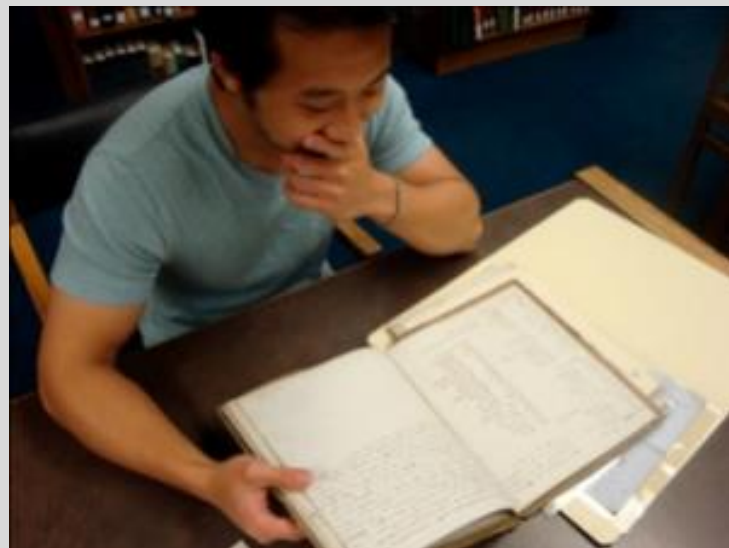
The image shows two photographs of handwritten data tables. The top photograph shows a large table with 12 columns and 12 rows of data. The bottom photograph shows a smaller table with 4 columns and 4 rows of data.

1	2	3	4	5	6	7	8	9	10	11	12
28	29	27	27	28	29	29	30	31	31	31	31
39	38	38	37	35	34	35	37	35	34	32	31
39	38	38	37	35	34	35	37	35	34	32	31
39	37	35	33	32	32	33	34	30	30	29	27
22	21	19	17	14	14	16	17	21	21	23	24
35	35	30	33	34	34	36	36	37			
42	43	43	43	43	43	43	43	42	42		
44	45	45	45	45	45	45	44	44	43		
42	41	41	41	41	41	41	40	40	40		
30	28	26	26	24	24	25	26	25	26		
17	16	16	15	13	13	13	14	15	15		
17	21	24	25	26	27	28	30	31	31		
35	35	35	35	35	36	36	36	36	34		
30	37	38	37	38	37	37	37	36	34		
21	20	20	19	18	18	17	16	15	15		
23	23	22	21	22	22	22	22	22	22		
38	37	38	38	38	38	39	40	39	37		
34	35	33	32	32	32	29	28	28	28		

9	10	11	12	1	2	3	4
31	31	31	31	32	32	36	36
35	34	32	31	33	35	33	32
35	34	35	35	36	36	36	39
30	30	29	27	26	26	25	25
21	21	23	24	25	26	29	30
36	37	38	38	38	38	39	40
42	43	43	41	42	42	42	43

Future Research

- Develop computer program to effortlessly compare both data sets
 - Will use correction algorithms designed from this study
- Program will be applicable for other comparison investigations
 - Still needs experimental study for each case



Manual transcription at Duke University Special Collections Library

Acknowledgments

Dr. Kevin Wood, NOAA Affiliate – Advisor

Mr. Richard Kurtz and Dr. Lorraine Solomon –
Science Research Teachers

Mrs. Kristen Holmes – Computer Science Teacher

Selected References

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Computer Program

Data posted on NOAA FTP
database



Files downloaded and
converted to Excel Files



A Java computer program was
designed to organize and analyze
 $\sim 10^6$ data points

Computer Program Code

```
//Importation of JXL API is important for reading of Excel files
import java.io.*;
import jxl.*;
import jxl.read.biff.BiffException;

public class Excel {
    public static void main(String [] args) throws IOException, BiffException{

        int dLim; //Days per month
        //Loop through two years
        for(int y = 12; y <= 13; y++){
            //Loop through twelve months
            for(int m = 1; m <= 12; m++){
                //The following if statements determine the number of days in a month
                if((m == 1) || (m == 3) || (m == 5) || (m == 7) || (m == 8) || (m == 10) ||
(m == 12)){
                    dLim = 31;
                }
                else if((m == 2) && (y % 4 == 0)){
                    dLim = 29;
                }
                else if((m == 2) && (y % 4 != 0)){
                    dLim = 28;
                }
            }
        }
    }
}
```

Computer Program Code

```
else{
    dLim = 30;
}
//Loop through specified number of days in month
for(int d = 0; d < dLim; d++){
    //Finds Excel file
    Workbook workbook = Workbook.getWorkbook(new
File("c:\\users\\daniel\\desktop\\Plover\\NOAAX\\" + m + y + ".xls"));
    //Finds sheet (based on format)
    Sheet sheet = workbook.getSheet(d);
    int row = 2; //Starts at row 2
    //Declarations
    double totalPlover = 0;
    double totalTwoM = 0;
    double totalBarPress = 0;
    double totalWind = 0;
    double totalDirection = 0;
    int divisor = 0;
    //Infinite loop until reaches empty cell error
    while(true){
        try{
            String ploverRTD = sheet.getCell(32, row).getContents(); //Obtain
contents of cell
            double ploverTemp = Double.parseDouble(ploverRTD); //Convert contents
to type double
```


Computer Program Code

```
totalPlover += ploverTemp;
String twoM = sheet.getCell(24, row).getContents();
double twoMTemp = Double.parseDouble(twoM);
totalTwoM += twoMTemp;
String barPress = sheet.getCell(18, row).getContents();
double barPressTemp = Double.parseDouble(barPress);
totalBarPress += barPressTemp;
String wind = sheet.getCell(10, row).getContents();
double windTemp = Double.parseDouble(wind);
totalWind += windTemp;
String direction = sheet.getCell(11, row).getContents();
double directionTemp = Double.parseDouble(direction);
totalDirection += directionTemp;
divisor++; //Later to be used to find average
row++;
}
catch (ArrayIndexOutOfBoundsException e){
    break;
}
catch (NumberFormatException e){
    break;
}
}
//The following find averages
double avgPlover = totalPlover / ((double) divisor);
```

Computer Program Code

```
double avgTwoM = totalTwoM / ((double) divisor);  
double avgBarPress = totalBarPress / ((double) divisor);  
double avgWind = totalWind / ((double) divisor);  
double avgDirection = totalDirection / ((double) divisor);  
double diff = /*Math.abs(*avgPlover - avgTwoM/*)*/;  
System.out.println(avgWind);  
workbook.close();
```

```
}
```

```
}
```

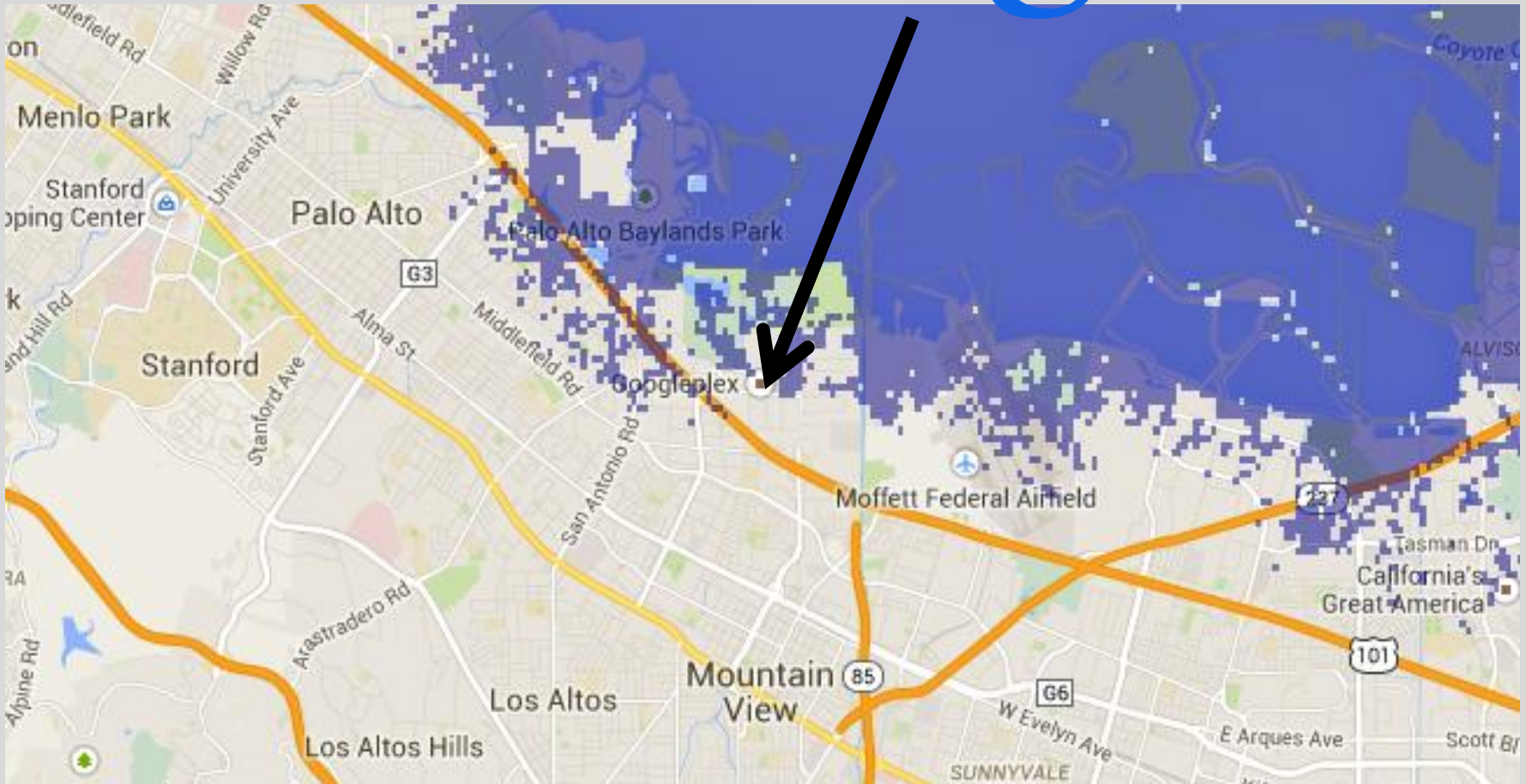
```
}
```

```
}
```

```
}
```

Mountain View Inundations

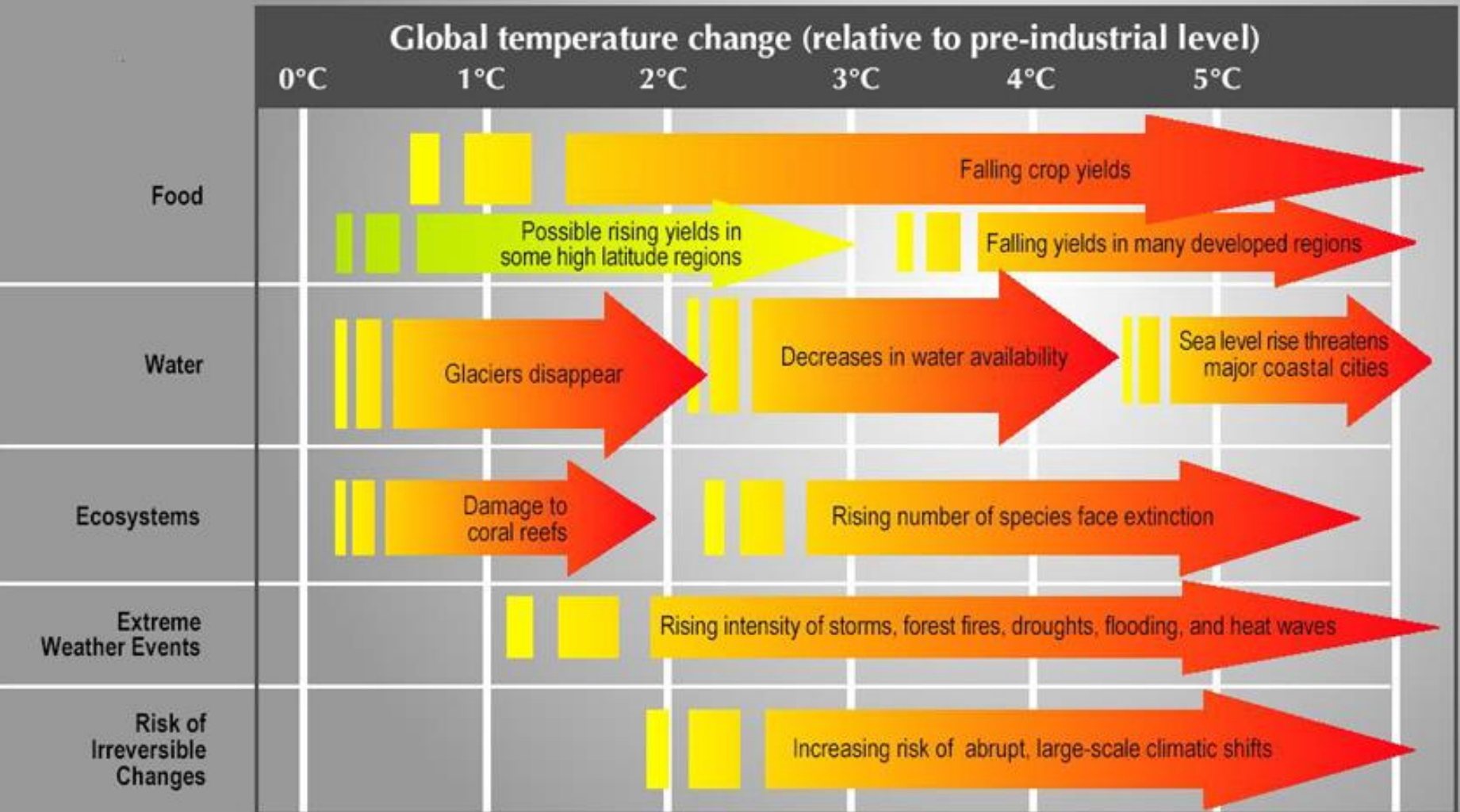
Google



Canals in Boston?



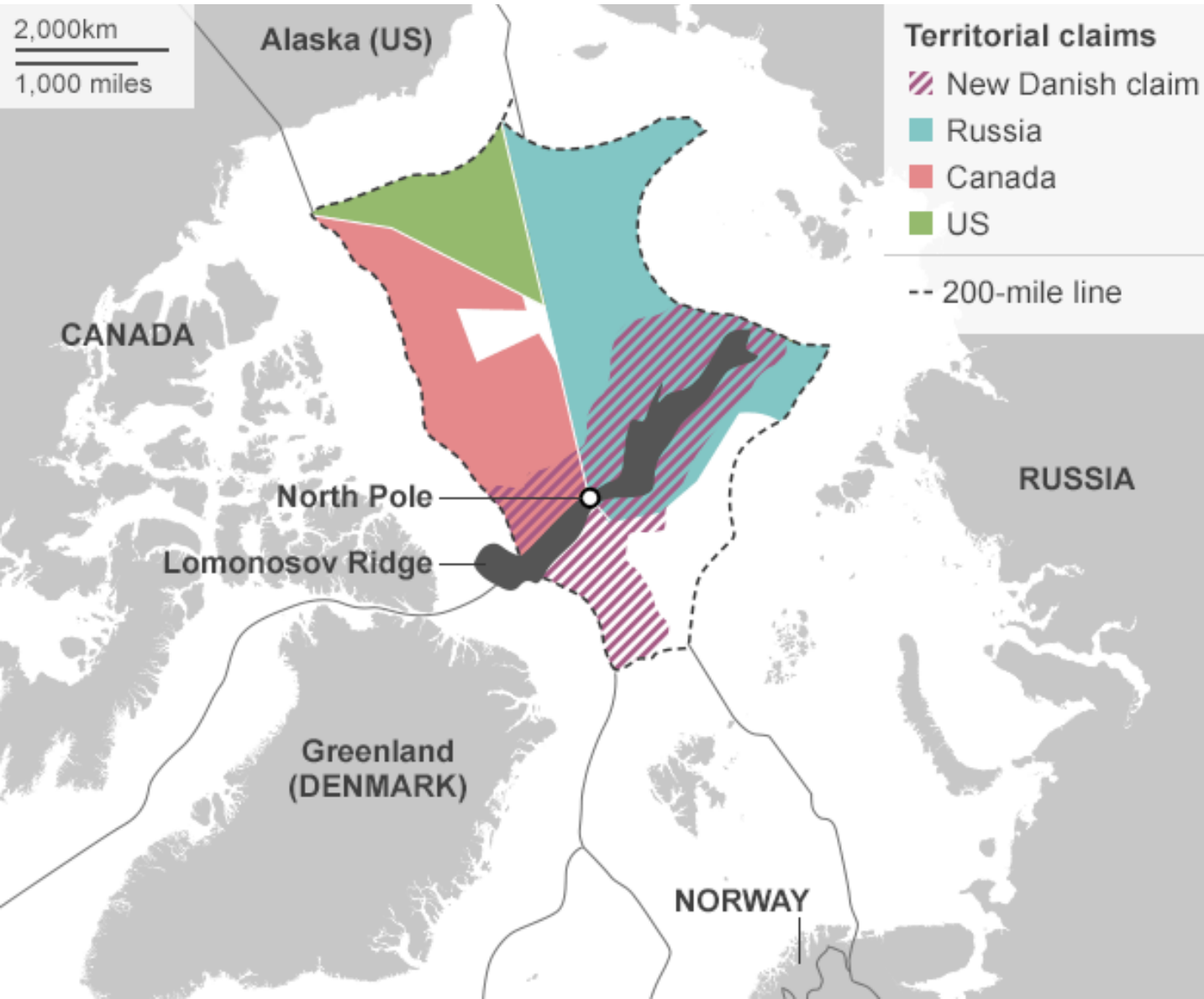
Projected Impacts of Climate Change



C = Celsius; CO₂ = Carbon Dioxide

Source: Adapted from the *Stern Review on the Economics of Climate Change*.

Denmark challenges Russia and Canada over North Pole



Was Dr. Simpson right?

“The arrangement so made was to protect the instrument from the wind and snow-drift, and from the influence of the sun, while admitting the easy access of air.”

- Dr. Simpson

