“Most of the global average warming over the past 50 years is *very likely* due to anthropogenic GHG increases…”

How does the IPCC know whether the statement about global warming’s cause is *extremely likely*, *very likely*, or *more likely than not*? How does the IPCC consistently, across many different disciplines (scientific, technical, and socio-economic), quantify uncertainty? The IPCC uses three different approaches for uncertainty, depending on whether the data are qualitative, quantitative, or based on expert judgment. For the quantitative assessments, most often used in the scientific disciplines, the IPCC uses a Likelihood Scale to consistently define the probability, or likelihood of occurrence. The Likelihood Scale is based on statistics and probability. Statistics is the language that scientists generally use to objectively, and consistently make conclusions about their data – despite uncertainty that is inherent in all datasets. However, statistics is not the best way to communicate findings to a broad audience for the purpose of making new policies or educating the public. By using the Likelihood Scale, the IPCC can effectively communicate what we know and what we don’t know about global climate change.

In this exercise, you will use statistics to analyze a dataset from Lake Mendota that spans the last 150 years. Every year, since 1855, someone has recorded when the lake froze (ice on), and when the lake thawed (ice off). We are going to use these data to ask, ‘Is ice off date on Lake Mendota earlier?’ To answer this question and at the same time quantify the uncertainty around the answer, you will use one of the most basic statistical techniques – a t-test.

The learning objectives for this lab are to:

1) Analyze a historical, climatic dataset *qualitatively* and then *quantitatively*, using a probabilistic technique – the t-test.

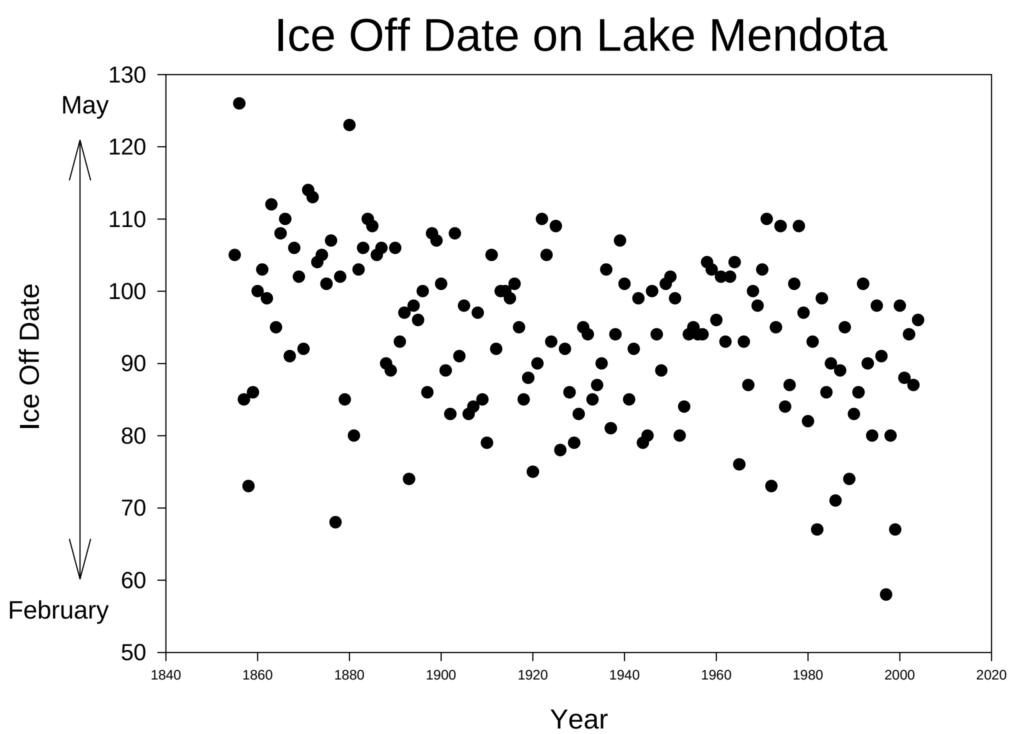
2) Relate statistical results to the IPCC Likelihood Scale.

3) Consider how statistics provide a consistent, objective way of making conclusions despite uncertainty in scientific data.

Qualitative analysis

Historical climate data show a substantial amount of year-to-year variation. This variation is one form of uncertainty when scientists analyze for trends in climate data. For example, if you were alive in 1920 and you looked back at the data would you say, with certainty, ice off date is earlier? Think about how you determine your level of confidence – especially considering the year-to-year variation.

- Study the graph below to make a *qualitativ*e assessment of ice off date. Record whether ice off date today is earlier than it was in the 1850's. Report your level of certainty (using the language from the IPCC Likelihood Scale).



Is ice off date earlier today?	
Level of certainty	

Quantitative analysis

Without quantitative, probabilistic analysis, it is difficult to analyze data with certainty. Now that you have qualitatively analyzed Mendota's ice off data, you will *quantitatively* analyze the same data. The dataset is provided as an excel file, and is divided into several twenty year sections. You are going to ask, using statistics, 'Is ice off date on Lake Mendota earlier?'. First, you will ask the question as if you were alive in 1914 (Is the first twenty year section statistically different from the second twenty year section), and then again in 1934, and so on until 1994. In this way, you will be able to visualize how the level of certainty changes as time goes on.

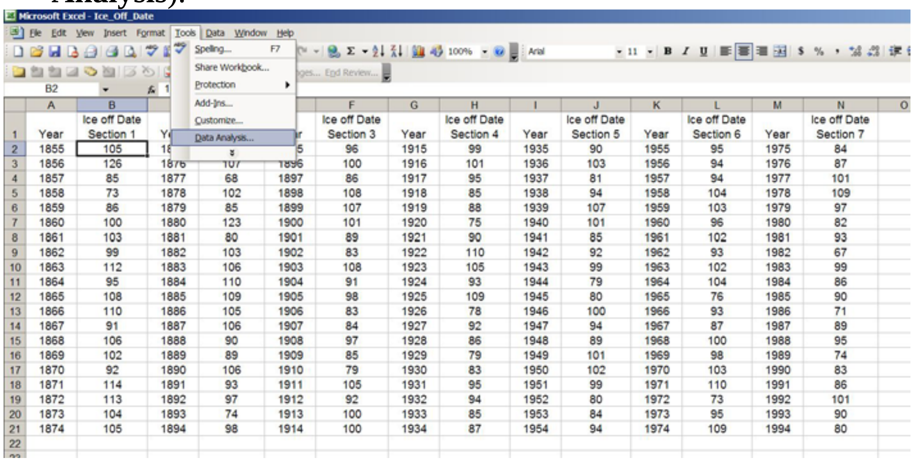
You will use a very basic statistical test, the t-test to answer these questions. A t-test compares means between two samples, while also considering the variation around each mean. You will use Excel to run the t-test, but it is important to note the actual equation Excel is using:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{s_{\overline{X}_1 - \overline{X}_2}} \text{ where } s_{\overline{X}_1 - \overline{X}_2} = \sqrt{\frac{s_1^2 + s_2^2}{n}}$$

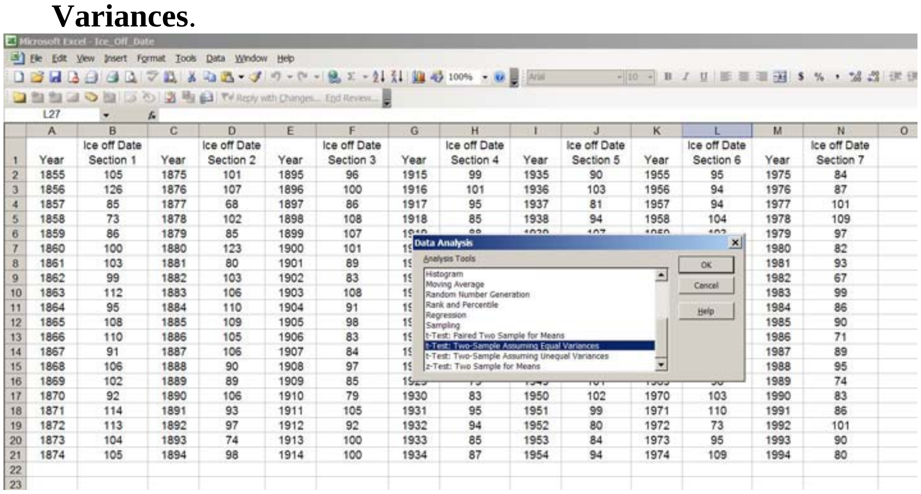
Where X = sample mean and s = standard deviation, and n = sample size.

Statistical analysis

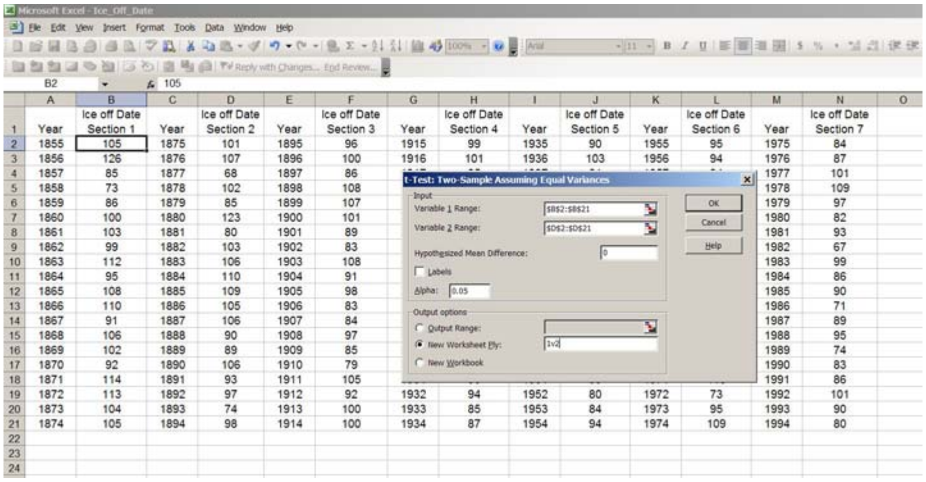
1. Open the Excel spreadsheet **Ice_Off_Date.xls**
2. Click on **Tools** and then click on **Data Analysis**. (Note: If you don't see **Data Analysis**, then select **Add-ins** under the Tools tab, and click on the **Analysis TookPak** the click **OK**. Now go back to click on **Tools** and you should see **Data Analysis**).



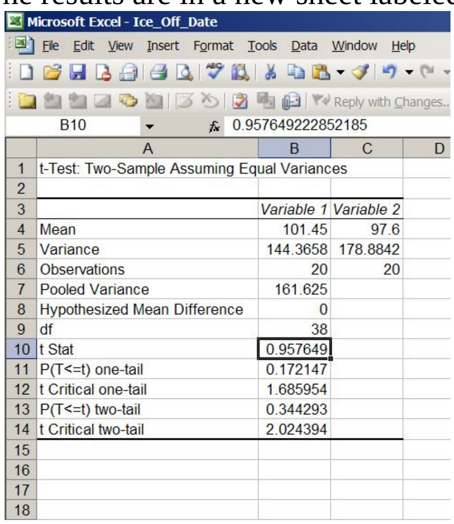
3. Scroll down towards the bottom and select **t-Test: Two-sample Assuming Equal Variances**.



4. A dialogue box will open with Input and Output options. Click on the first box for **Variable 1 Range**. Now move your cursor over to the first entry for **'Ice Off Date Section 1'** (cell B2), left click and drag to the last entry for the column (cell B21). Now click on the box for **Variable 2 Range**. Select the data in **'Ice Off Date Section 2'** column (cells D2:D21).
5. Now enter 0 in the box for **Hypothesized mean difference**.
6. Keep the **labels** box unchecked.
7. Keep the **alpha** level at 0.05.
8. In the output section, select **New Worksheet Ply** and enter 1 vs. 2 in the box.
9. Click **OK**.



Excel has calculated a t-statistic to determine whether mean ice off date has changed on Lake Mendota from the time period in section 1 (1855-1874) compared to the time period in section 2 (1875-1894). The results are in a new sheet labeled **1 vs. 2** and should look like this:



t-Test: Two-Sample Assuming Equal Variances		
	Variable 1	Variable 2
Mean	101.45	97.6
Variance	144.3658	178.8842
Observations	20	20
Pooled Variance	161.625	
Hypothesized Mean Difference	0	
df	38	
t Stat	0.957649	
P(T<=t) one-tail	0.172147	
t Critical one-tail	1.685954	
P(T<=t) two-tail	0.344293	
t Critical two-tail	2.024394	

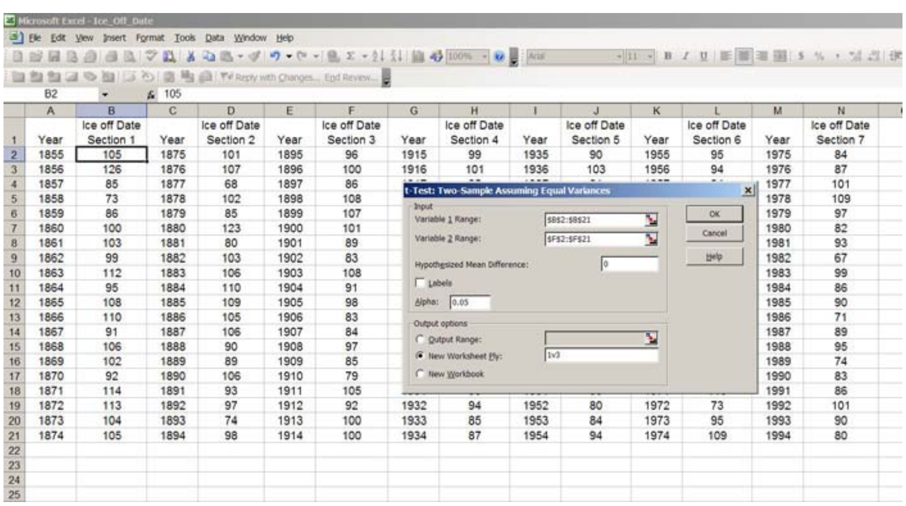
The **t Stat**, in cell B10 is the number we are interested in analyzing. Statisticians use a look-up table to determine whether a particular t-statistic, with a particular sample size, shows that two samples actually differ. The IPCC has basically taken this same look-up table and added their own language to describe the likelihood of various climatic changes in a consistent way.

t-statistic	Probability of occurrence	IPCC Likelihood Scale
0.681	75%	Likely
0.851	80%	
1.05	85%	
1.303	90%	Very Likely
1.684	95%	Extremely Likely
2.021	97.5%	
2.123	98%	
2.423	99%	Virtually Certain
2.704	99.5%	
2.971	99.75%	
3.307	99.9%	
3.551	99.95%	
3.790	99.99%	

The t-statistic for our analysis (0.958) says that the probability that ice off date changed between the two sections of time is somewhere between 80 – 85%. The IPCC would then conclude, "It is *likely* that by the year 1894, ice off date was earlier on Lake Mendota in Wisconsin."

- Hypothesize how likelihood will change as you move along in time, based on looking at the graph of ice off data.

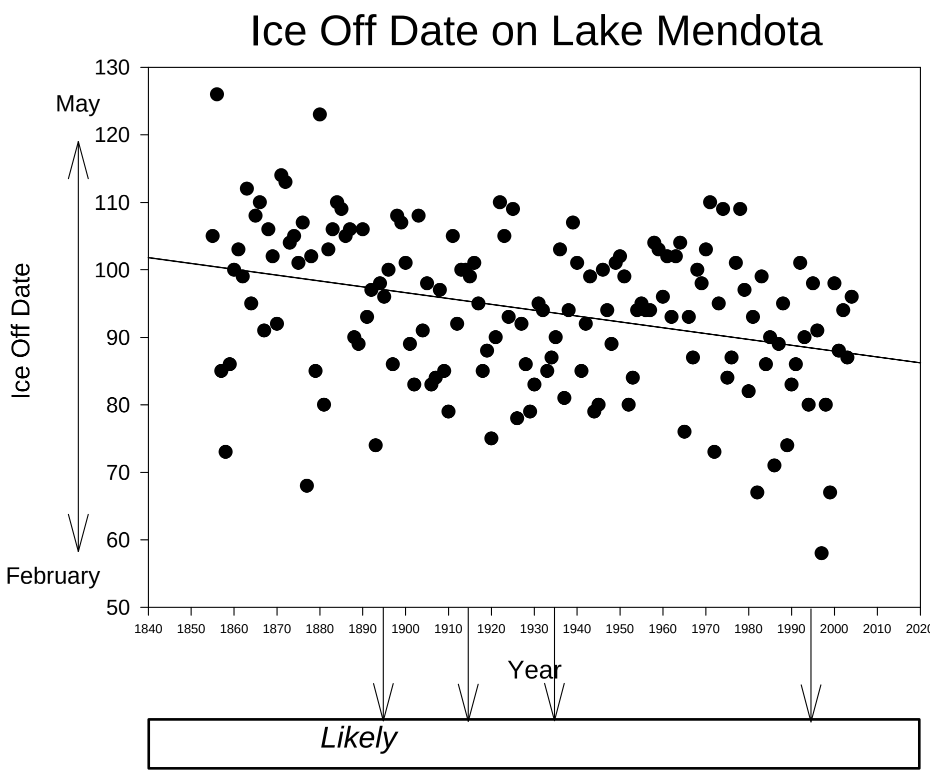
- Run the same analyses to test for differences in ice off date between section 1 and subsequent sections (1 vs. 3 then 1 vs. 4 and finally 1 vs. 7). When you click on Tools and select Data Analysis, the dialog box should open with your last specifications still in place. All you need to change is the **Variable 2 Range** (F2:F21 for section 3, H2:H21 for section 4, N2:N21 for section 7) and the **New Worksheet Ply** (1 vs. 3, 1 vs. 4, and 1 vs. 7).



- Enter your results on a table like this:

Which comparison?	T Stat	Probability of Occurrence	IPCC Likelihood Scale
1 vs. 2	0.958	< 85%	Likely
1 vs. 3			
1 vs. 4			
1 vs. 7			

- Report the Likelihood Scale results on the graph below:



- Did the certainty level for 1994 match the certainty level you reported for the *qualitative* analysis? Why or why not?

- Did the level of certainty change over time as you hypothesized it would?