NAME_____

IPCC LIKELIHOOD ACTIVITY: "Most of the global average warming over the past 50 years is *very likely* due to anthropogenic GHG increases…" (IPCC 2007)

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. By using the Likelihood Scale, the IPCC can effectively communicate what we know or don't know about climate change using words rather than numbers.

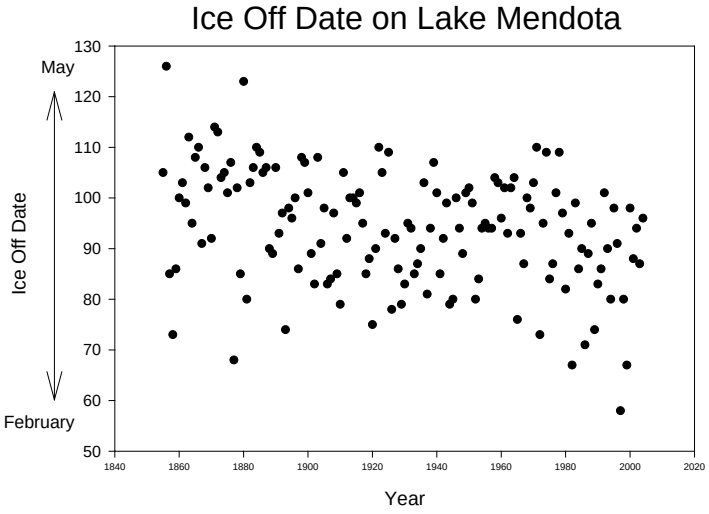
In this exercise, you will use statistics to analyze a dataset from Lake Mendota in Madison Wisconsin that spans the last 160 years. Every year, since 1855, someone has recorded when the lake froze (ice on), and when the lake thawed (ice off). We are going to use these data to ask, 'Is ice off date on 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 activity are:

1) Analyze a historical, climatic dataset *qualitatively* and then *quantitatively*..
2) Relate statistical results to the IPCC Likelihood Scale.
3) Consider how statistics provide a consistent, objective way of making conclusions despite uncertainty.

Qualitative analysis

Historical climate data show a substantial amount of year-to-year variation. This variation is one form of uncertainty when scientists analyze trends in climate data. Study the graph below to make a *qualitativ*e assessment of ice off date. Record whether ice off date in the 2000's is earlier than it was in the 1850's. Report your level of certainty using the language from the IPCC Likelihood Scale.



IPCC Likelihood Scale	
Virtually Certain	> 99% probability of occurrence
Extremely likely	> 95% probability of occurrence
Very likely	> 90% probability of occurrence
Likely	> 66% probability of occurrence
More likely than not	> 50% probability of occurrence
Unlikely	< 33% probability of occurrence
Extremely unlikely	< 5% probability of occurrence

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 data. Using 160 years' worth of ice off data categorized into several twenty year columns and a powerful statistics webapp, you are going to ask, 'Is ice off date on Lake Mendota earlier?'.

Year	Day	Year	Day	Year	Day	Year	Day	Year	Day	Year	Day	Year	Day	Year	Day
1855	105	1875	101	1895	96	1915	99	1935	90	1955	95	1975	84	1995	98
1856	126	1876	107	1896	100	1916	101	1936	103	1956	94	1976	87	1996	91
1857	85	1877	68	1897	86	1917	95	1937	81	1957	94	1977	101	1997	58
1858	73	1878	102	1898	108	1918	85	1938	94	1958	104	1978	109	1998	80
1859	86	1879	85	1899	107	1919	88	1939	107	1959	103	1979	97	1999	67
1860	100	1880	123	1900	101	1920	75	1940	101	1960	96	1980	82	2000	97
1861	103	1881	80	1901	89	1921	90	1941	85	1961	102	1981	93	2001	74
1862	99	1882	103	1902	83	1922	110	1942	92	1962	93	1982	67	2002	93
1863	112	1883	106	1903	108	1923	105	1943	99	1963	102	1983	99	2003	87
1864	95	1884	110	1904	91	1924	93	1944	79	1964	104	1984	86	2004	95
1865	108	1885	109	1905	98	1925	109	1945	80	1965	76	1985	90	2005	83
1866	110	1886	105	1906	83	1926	78	1946	100	1966	93	1986	71	2006	86
1867	91	1887	106	1907	84	1927	92	1947	94	1967	87	1987	89	2007	101
1868	106	1888	90	1908	97	1928	86	1948	89	1968	100	1988	95	2008	82
1869	102	1889	89	1909	85	1929	79	1949	101	1969	98	1989	74	2009	85
1870	92	1890	106	1910	79	1930	83	1950	102	1970	103	1990	83	2010	93
1871	114	1891	93	1911	105	1931	95	1951	99	1971	110	1991	86	2011	71
1872	113	1892	97	1912	92	1932	94	1952	80	1972	73	1992	101	2012	101
1873	104	1893	74	1913	100	1933	85	1953	84	1973	95	1993	90	2013	102
1874	105	1894	98	1914	100	1934	87	1954	94	1974	109	1994	80	2014	93

First, you will ask the question as if you were alive in 1894 (Is the first twenty year section statistically different from the second twenty year section), and then again every 20 years until 2014. In this way, you will be able to visualize how the level of certainty changes over time.

Note – the "ice-off day" are Julian dates which represent a continuous count of days starting on January 1 each year. For example, Day 93 indicates the 93rd day of the year.

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 a *webapp* to run the t-test, but it is important to note the actual equation that the application 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.

The webapp tool and the ice-off data is located on-line at
http://cimss.ssec.wisc.edu/climatechange/globalCC/lesson9/activity.html

The **t stat** 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 table and added their own language to describe the likelihood of various climatic changes in a consistent way. (The webapp also calculates the ***p*-value,** a measure of how extreme an observation is, and the standard deviation.)

t-statistic	P-value	Probability of occurrence	IPCC Likelihood Scale
0.681	0.25	75%	Likely
0.851	0.20	80%	
1.05	0.15	85%	
1.303	0.10	90%	Very Likely
1.684	0.05	95%	Extremely Likely
2.021	0.025	97.5%	
2.123	0.02	98%	
2.423	0.01	99%	Virtually Certain
2.704	0.005	99.5%	
2.971	0.0025	99.75%	
3.307	0.001	99.9%	
3.551	0.005	99.95%	
3.790	0.0001	99.99%	

The t-statistic from comparing the first two columns of ice-off data is 0.958 which indicates 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 over 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, 1 vs. 4 etc…)
- Enter your results in this table:

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. 5			
1 vs 6			
1 vs 7			
1 vs 8			

1) Did the certainty level for 1994 and 2014 match the certainty level you reported for the *qualitative* analysis? Why or why not?

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

3)Why do you think the period from 1955 to 1974 (column 7) results in a lower probability of occurrence than comparisons with the 20 years before or the 20 years after?

4) Briefly comment on the significance between the 2001 IPCC report that stated "most of the global average warming over the past 50 years was *likely* due to anthropogenic greenhouse gas increases…"
to the 2007 IPCC report when they changed the wording in the same phrases to "*very likely*".

5) The 2013 IPCC report concluded that "Warming of the climate system is unequivocal" does this correspond to your findings?

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http://cimss.ssec.wisc.edu/climatechange/globalCC/lesson9/activity.html