# Are the Beliefs of the Climate Change Deniers, Skeptics, and Trivializers supported by the Hourly Temperature Data? Evidence from Alaska

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# The Organization of this Talk

1) A brief summary of the scientific consensus .

2) A review of the polling data.

3) A discussion of the drivers of the weather/climate system.

4) Background on the data reported at the Barrow Observatory in Alaska.

5) Overview of the methodology.

6)An analysis of the energy balance at Barrow Alaska over the period May 1993 through 2015.

7) An analysis of the hourly temperature data  at Barrow Alaska over the period 1985 through 2015.

8) Conclusions.

# 1) According to the IPCC's Fifth Assessment,

- The warming of the climate system since the 1950s has been unequivocal.

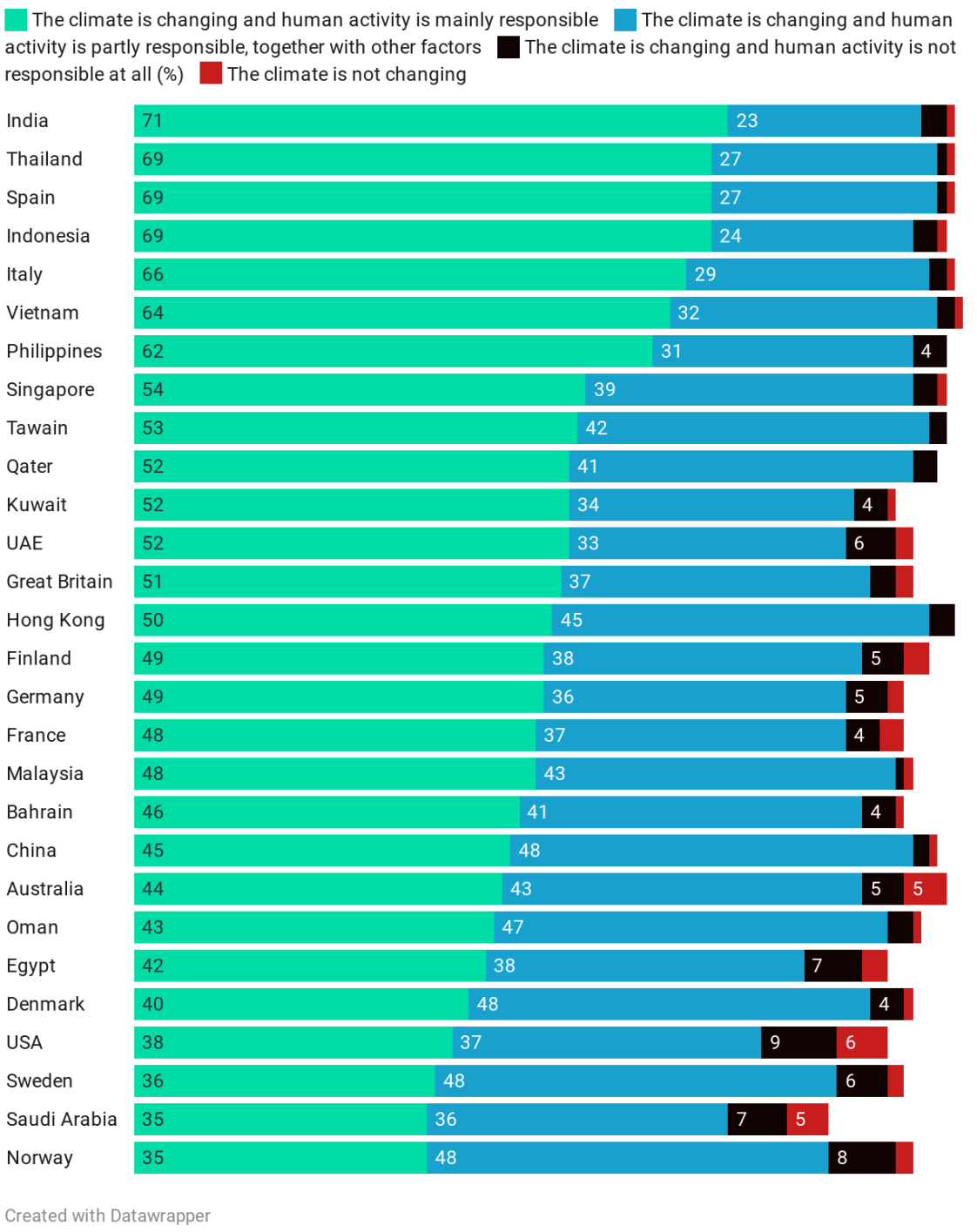
- It is further noted that "…It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century."

# 2) The Polling Data

Responses to a 2019 YouGov survey question posed to 30,000 people in 28 countries

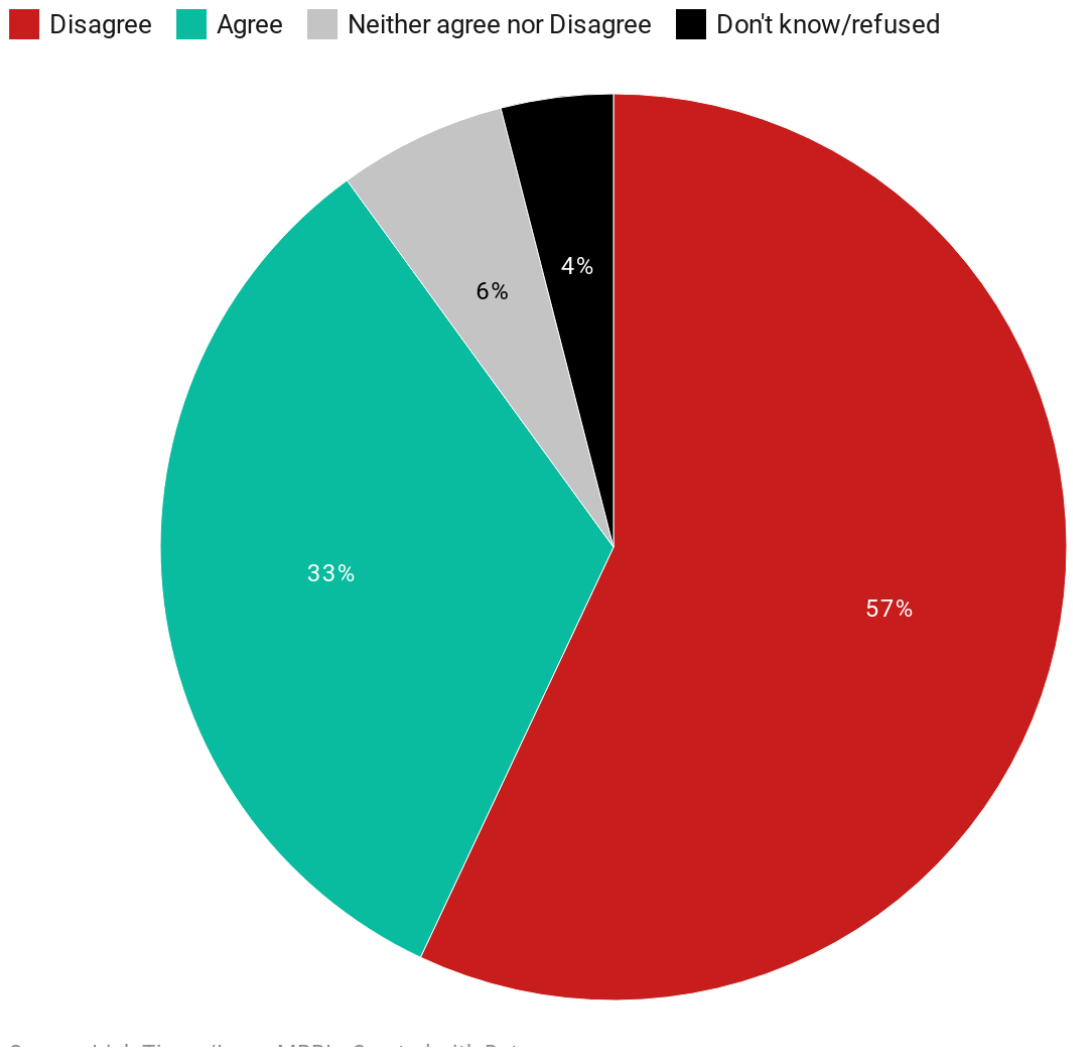
**“Thinking about the global environment…In general, which of the following statements, if any, best describes your view?”**

Source: https://today.yougov.com/topics/science/articles-reports/2019/09/16/global-climate-change-poll



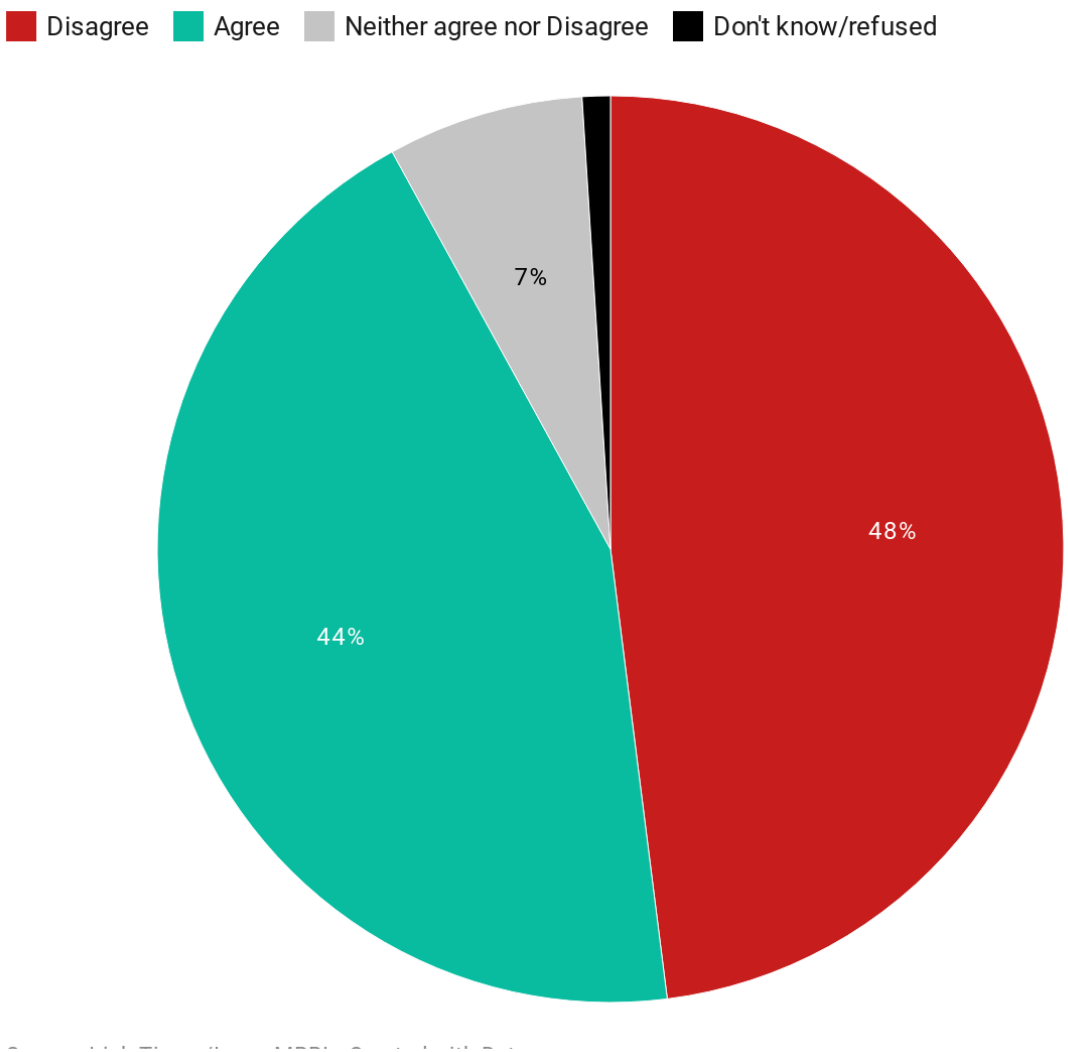
Response to the following statement in a 15 October 2019 Irish Times/Iposos MRBI poll:

# I don’t think climate change will be as bad as some say so I’m not that worried about it.”



Response to the following statement in a 15 October 2019 Irish Times/Iposos MRBI poll:

“ I am okay with the price of oil, gas, petrol and diesel increasing to help tackle climate change.”



# 3) The Drivers of the Weather/Climate System

- **Downward total solar irradiance** - This is the total solar radiation that arrives at the Earth’s surface. Because of its spectral range, this form of energy is also often referred to as downward shortwave irradiance. This variable is the fundamental driver of the world's weather/climate system.

- **Upward solar irradiance** - is the downward solar irradiance that is reflected off the earth's surface.

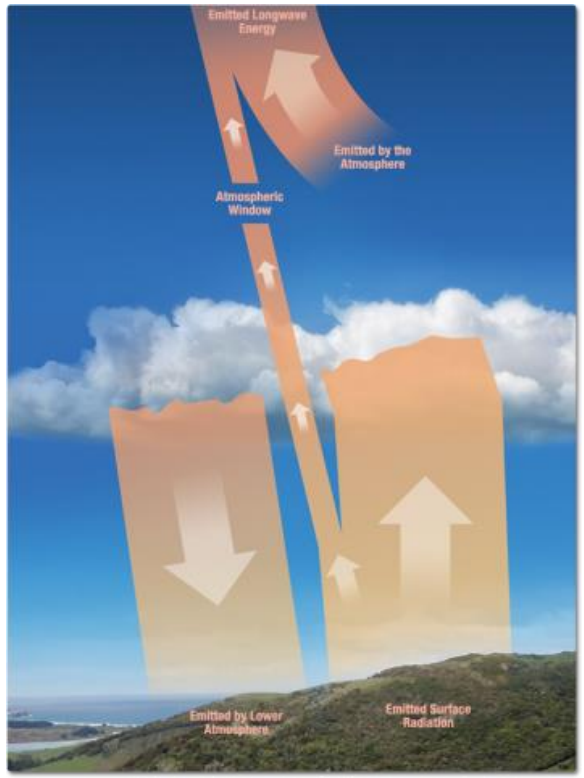
- **Downward longwave irradiance** - This quantity is the thermal irradiance emitted in all directions by the atmosphere. Because of its spectral range, this form of energy is often called downward longwave irradiance.

- **Upward longwave irradiance** - This is the thermal irradiance emitted from the earth's surface into the atmosphere measured at a representative distance above the ground

# The Drivers of the Weather/Climate System

**Shortwave Radiation**


**Longwave Radiation**




National Aeronautics and Space Administration, Science Mission Directorate. (2010). The Earth's Radiation Budget. Retrieved *July 10, 2020* from NASA Science website: http://science.nasa.gov/ems/13_radiationbudget

# The Energy Balance

- **NET Inward Energy = Energy in – Energy out**

- Energy in = $\mathbf{SW_{Down}}$ + $\mathbf{LW_{Down}}$

- Energy out = $\mathbf{SW_{Up}}$ **+** $\mathbf{LW_{Up}}$

- Net Inward Energy = $\mathbf{SW_{Down}}$ **+** $\mathbf{LW_{Down}}$ **-** $\mathbf{SW_{Up}}$ **-** $\mathbf{LW_{Up}}$

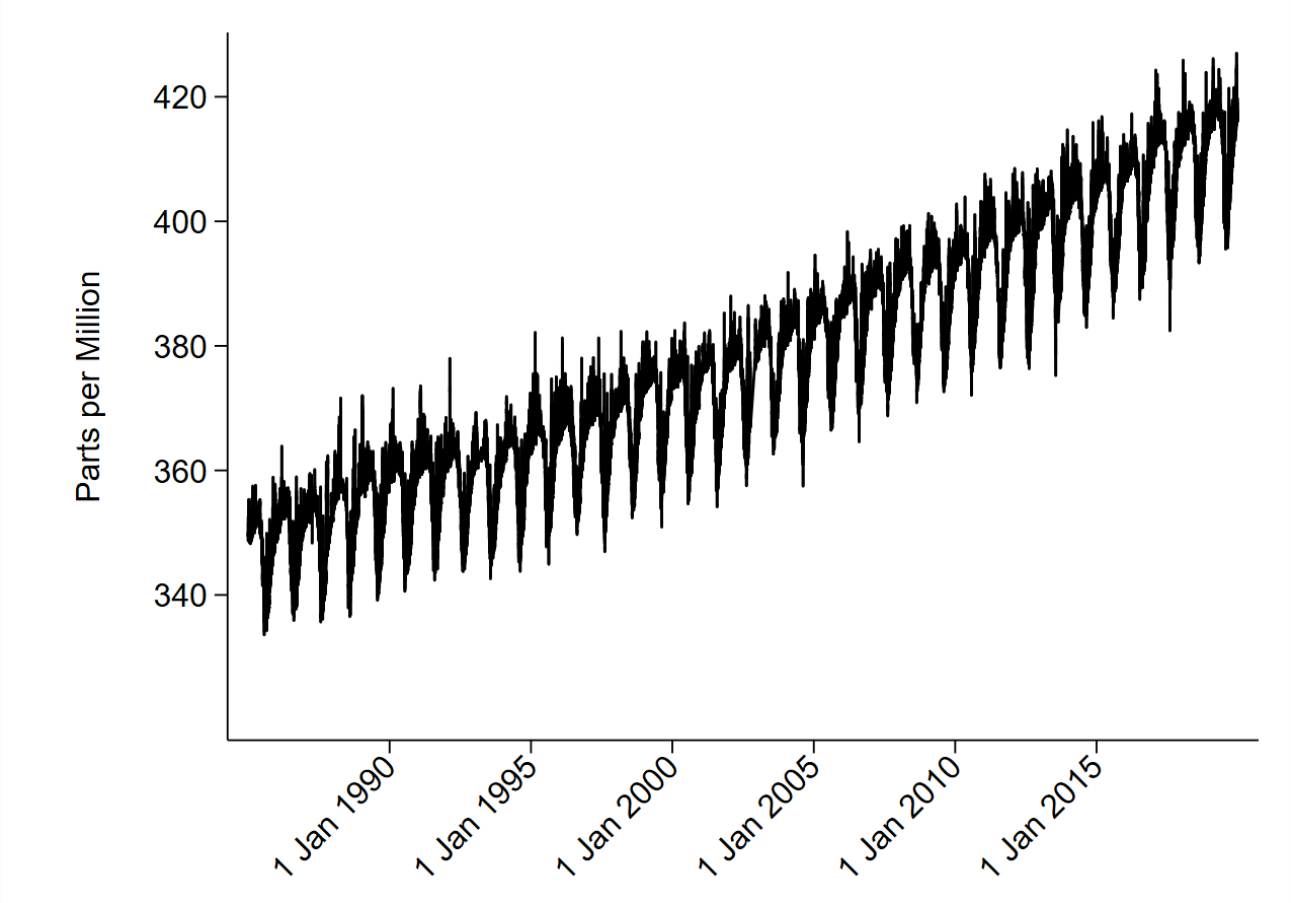
There is almost no discussion of the energy balance in the popular press. Yet, according to the IPCC, it plays a critical role in the CO2/climate relationship. In its words,

> "The radiation budget of the Earth is a central element of the climate system.…Anthropogenic influence on climate occurs primarily through perturbations of the components of the Earth radiation budget."

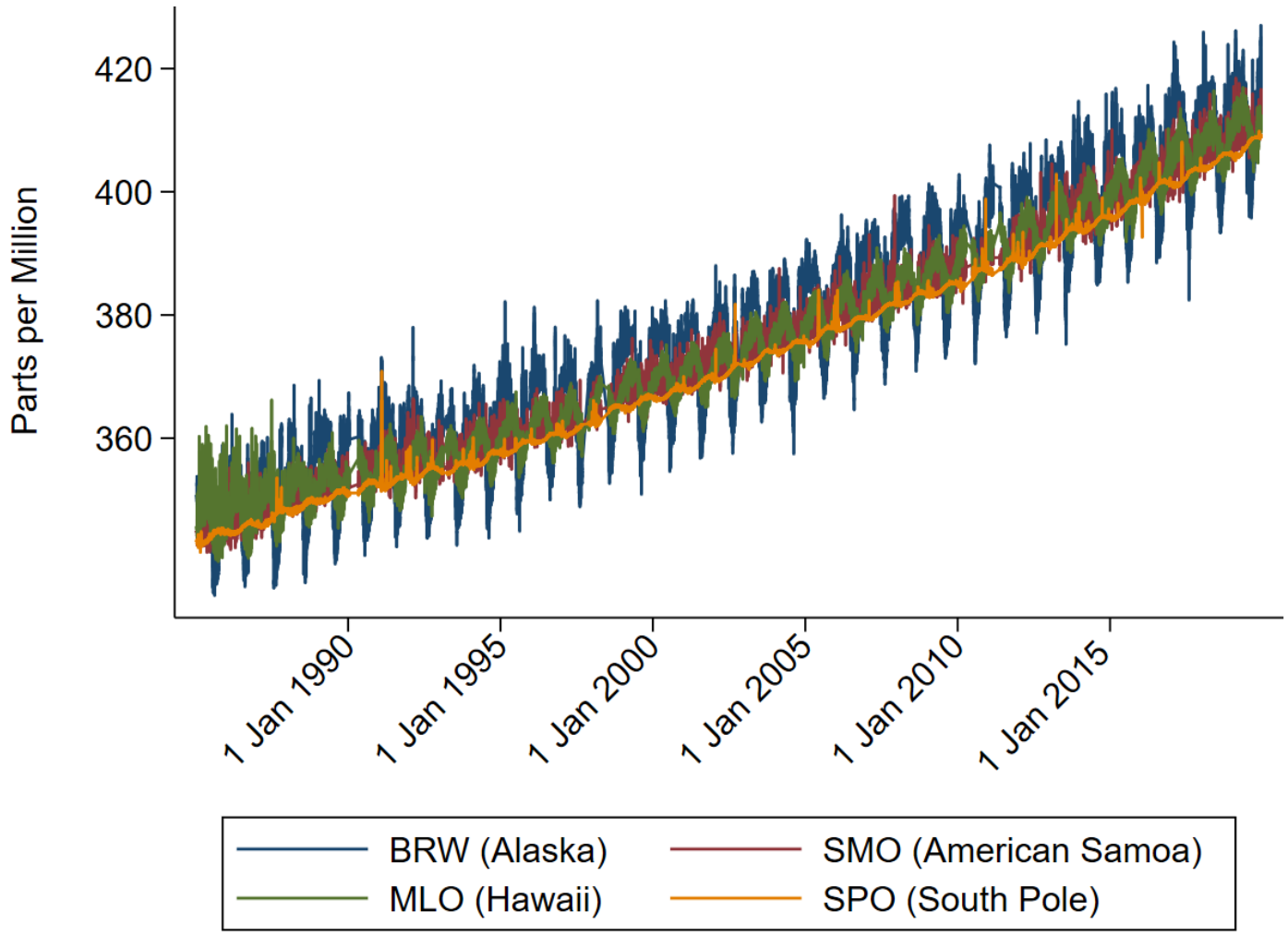
IPCC, 2013 p. 180

# 4.Background on the data reported at the Barrow Observatory in Alaska

# Hourly $CO_2$ Concentration Levels at the Barrow Observatory in Alaska, 1 Jan 1985 – 31 Dec 2019




- Observe $CO_2$'s high degree of seasonality
- Also observe the significant upward trend

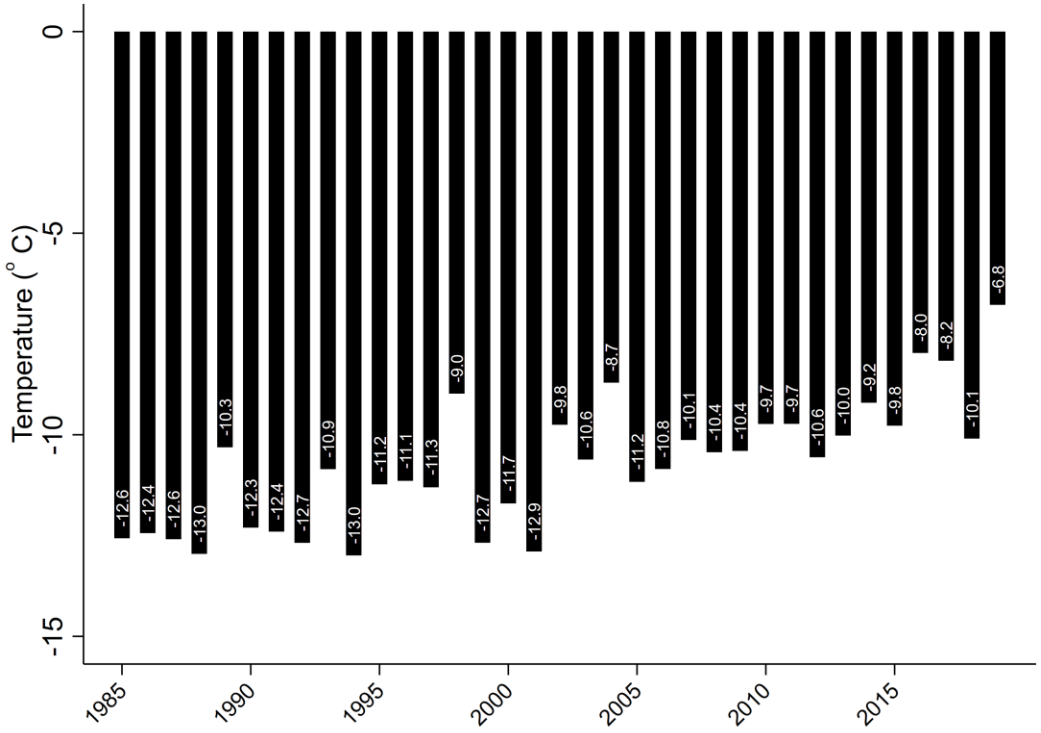



There is a common trend in the hourly level of the $CO_2$ concentrations across locations

# The Trend in Hourly Average Temperature at the Barrow Observatory, 1985 - 2019

The annual temperature increased by about 5.8 $^{o}$C between 1985 and 2019.

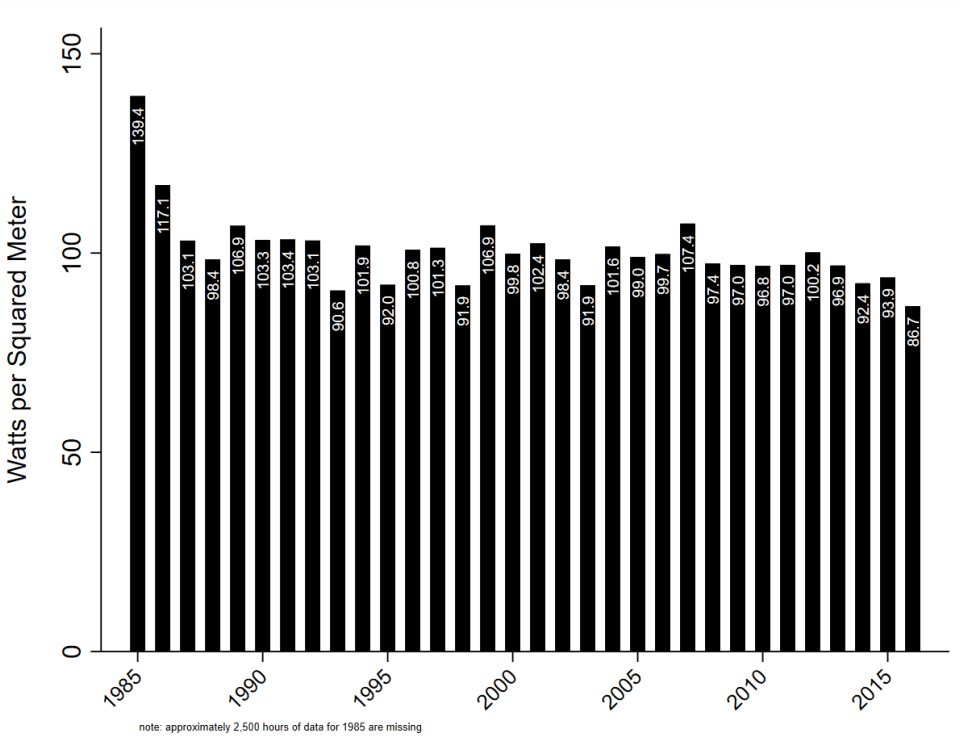
The upward trend in temperature is more extreme than at lower altitudes because of a phenomena known as “Arctic Amplification”



# The Trend in Total Downward Short-Wave Radiation in at the Barrow Observatory, 1985 - 2019

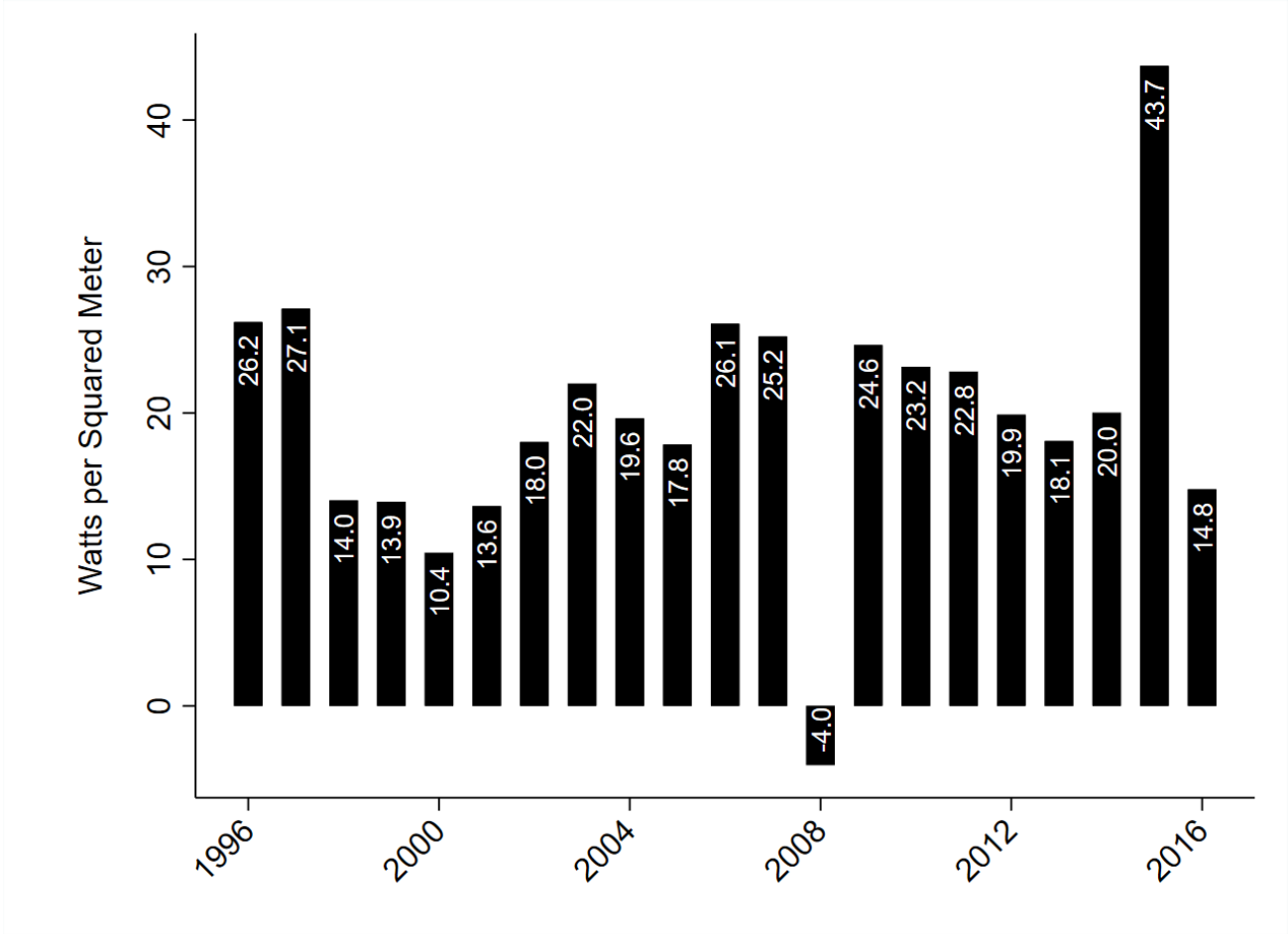
- Visible inspection of the data suggests that changes in Downward Short-Wave Radiation is not a driver of the increase in temperature.

- The data reported by Met Éireann for the Valentia Observatory over the period 1955 – 2019 are consistent with the figure on the right.



# The net inward energy imbalance at Barrow, 1996 - 2016

- Except for 2008, the net inward energy imbalance has been positive.
- In other words, except for 2008,  less energy left the surface of the earth at Barrow than arrived at the earth's surface.



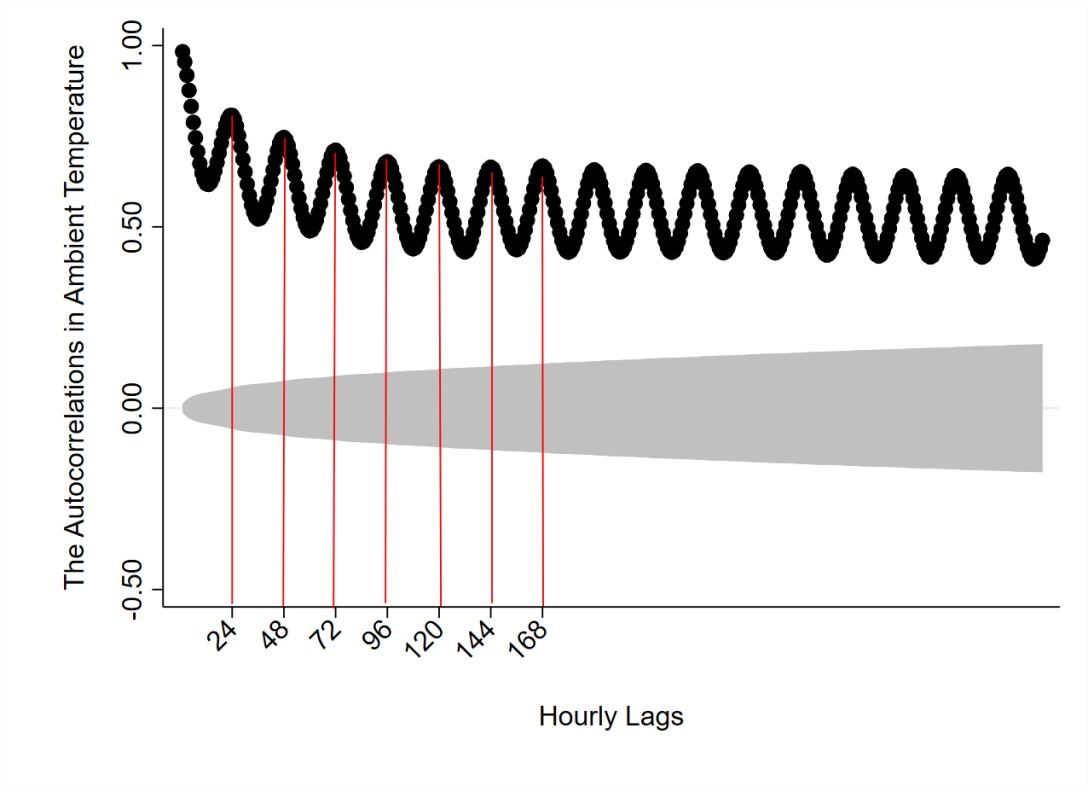
# 5) Methodology

- The approach employed here relies heavily on the concept of autocorrelation. Autocorrelations occurs when the outcome in the current period  is correlated with the outcomes in the earlier periods.

- The autocorrelations represent information about the relationship between the current period and past outcomes

- This information  is helpful in predicting the immediate future.

# The autocorrelation in the hourly temperature data is visually apparent in the case of Dublin Ireland over the period 1 Jan 2015 – 31 Dec 2018

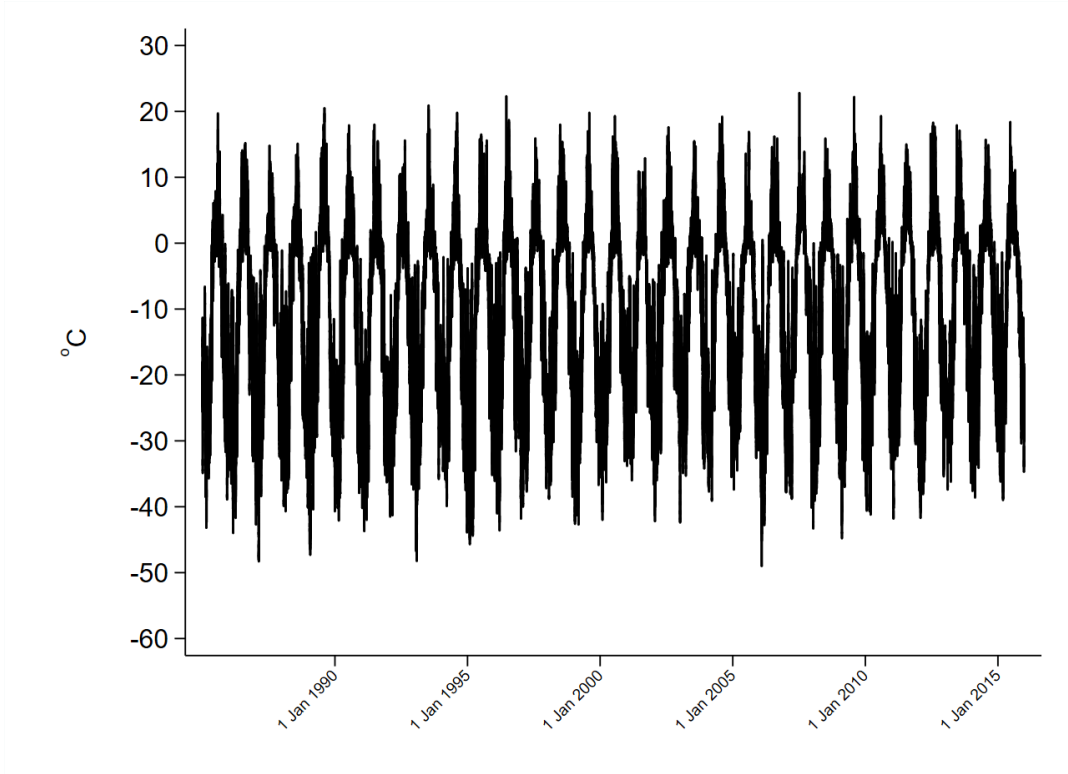



- Observe that the temperature in hour t is correlated with the temperatures in previous hours.
- For example, the temperature in hour t is highly correlated with the temperature in hour t- 24.
- In this case, the autocorrelations are large and do not monotonically decline.
- Since the past is known, this nature of the data presents an opportunity to make accurate predictions.

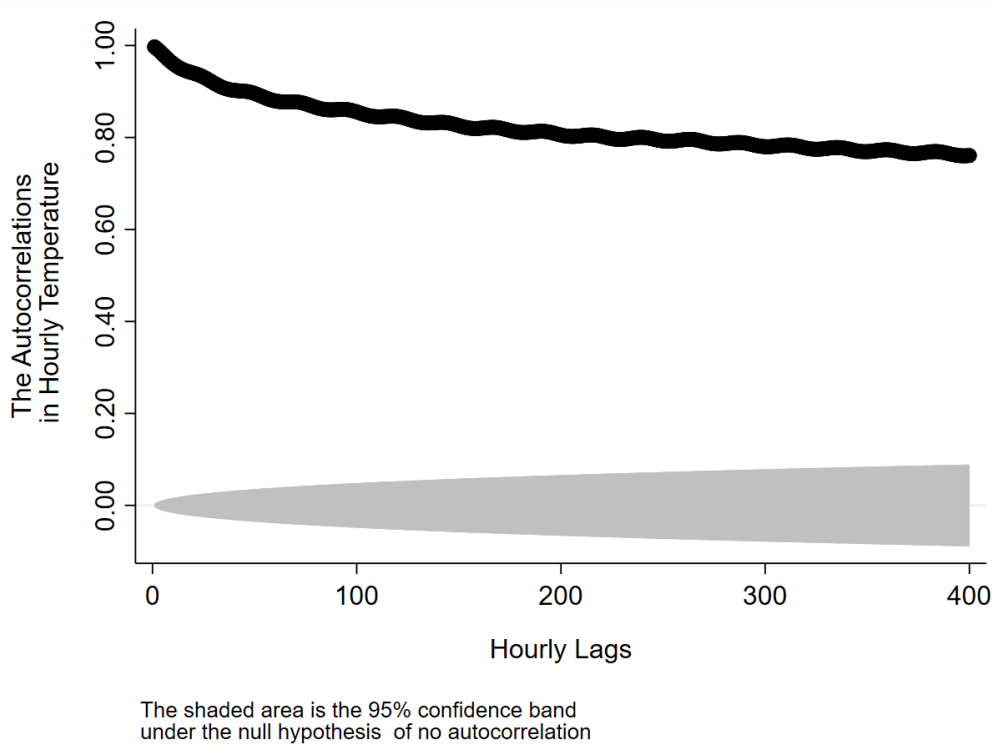
Source: Met Éireann

# An analysis of the hourly temperature data at Barrow Alaska over the period 1985 through 2015.

**The Hourly Temperature is Highly Variable**

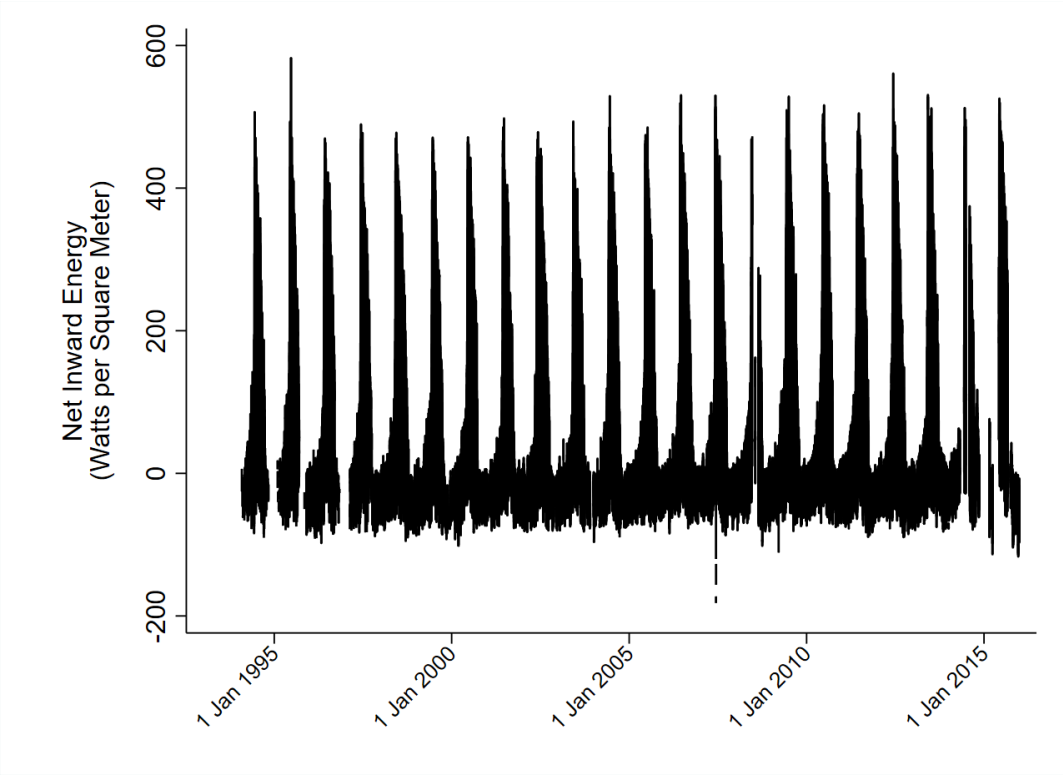



**Yet, the Autocorrelations in Hourly Temperature are Highly Significant.**

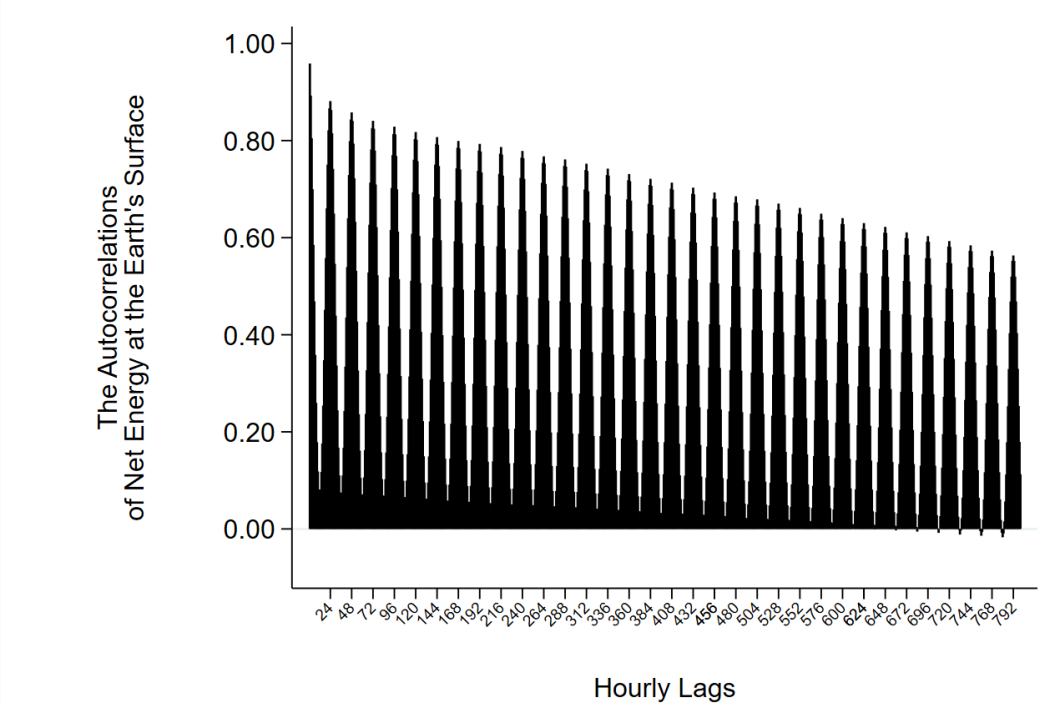


# The Properties of the Data Representing the Net Inward Hourly Energy at Barrow Alaska over the period 1994 through 2015

**Because of Cloud Coverage Considerations, the Hourly Net Inflows of Energy are Highly Variable**




**Yet, the Autocorrelations in the Net Energy Inflows are Highly Significant. Recognition of this nature of the data greatly facilitates its analysis.**



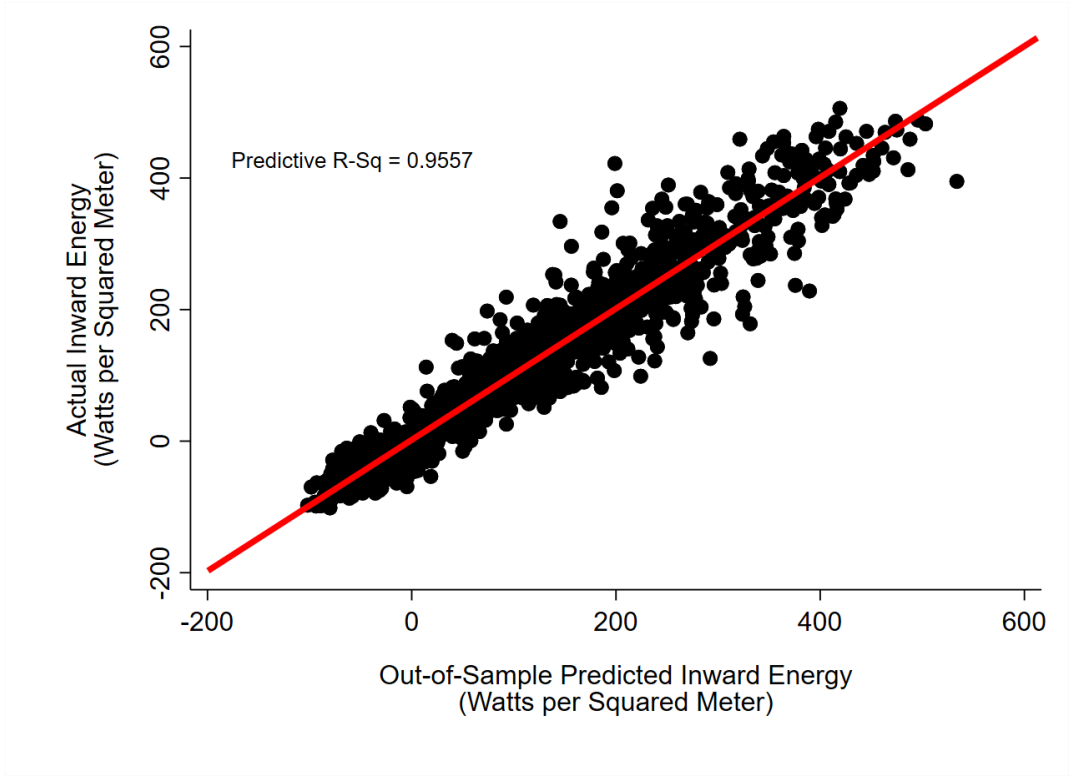

Indicative of the magnitude of the autocorrelations, the autocorrelation between the value of net energy at hour t and hour t-24 equals 0.88

# 6) A Model to Explain the Net Level of Inward Energy

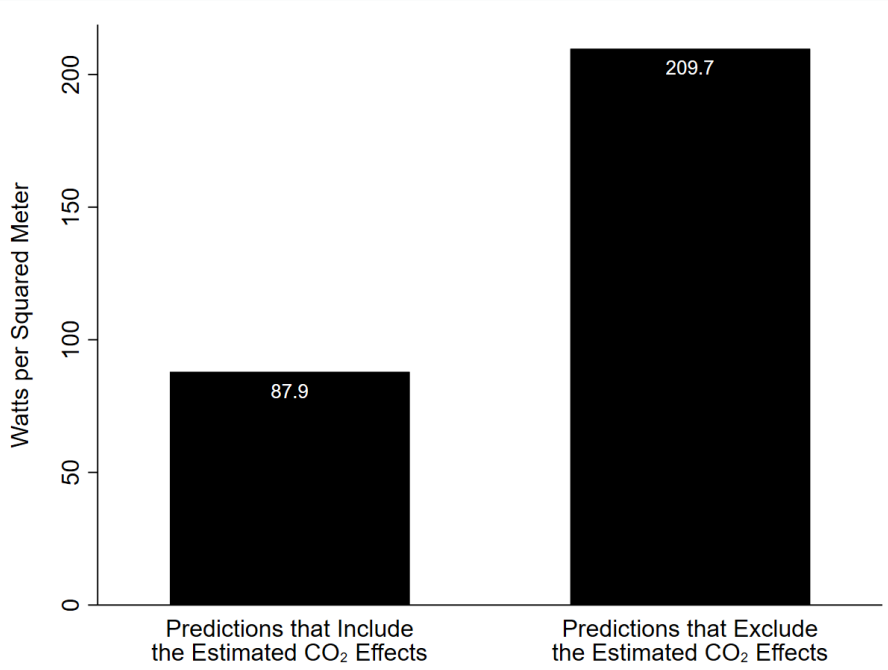
- Explanatory variables: $CO_2$ concentrations, measures of meteorological conditions, binary variables to control for year.
- The model also include numerous time-series variables to capture the autoregressive nature of the data.
- The model does not presume linearity.
- The model was estimated using hourly data over period May 1993 through Dec 2015. There are 146,170 observations in the sample.
- The model's explanatory power is equivalent to an R-Squared of 0.9448. This is encouraging but it is noted that the true adequacy of a model can only be determined by considering how well it performs on data that were not used in its estimation.

# The Energy Model's Out-of-Sample Performance

**The full Model's Out-of-Sample Performance (Jan 2016 – Aug 2017)**




**The RMSEs in the out-of-sample structural predictions of Net Energy**




**Consistent with causality, the out-of-sample predictions that incorporate the statistically significant effects of $CO_2$ are more accurate**

# 7) A Model to Explain Temperature

- The dependent variable in the model is the natural logarithm of the hourly temperature at Barrow measured in Kelvin

- One could employ the net energy imbalance as an explanatory variable. But this would not be useful given that the upward shortwave, upward longwave, and downward longwave are each driven by temperature.

- Instead, the model will employ downward shortwave radiation and $CO_2$ concentrations as explanatory variables.

# A Model to Explain Temperature (Continued)

- The model also includes binary variables for year, season, and hour of the day.
- The binary variables for year are included to control for the possibility that there are alternative drivers of the increase in temperature.
- The model also include numerous time-series variables to capture the autoregressive nature of the temperature data.
- The model does not presume linearity.
- The model was estimated using hourly data over period 1 Jan 1985 through 31 Dec 2015. There are 228,085 observations in the sample.

# Modeling Results

- There is a statistically significant relationship between $CO_2$ concentrations and temperature.

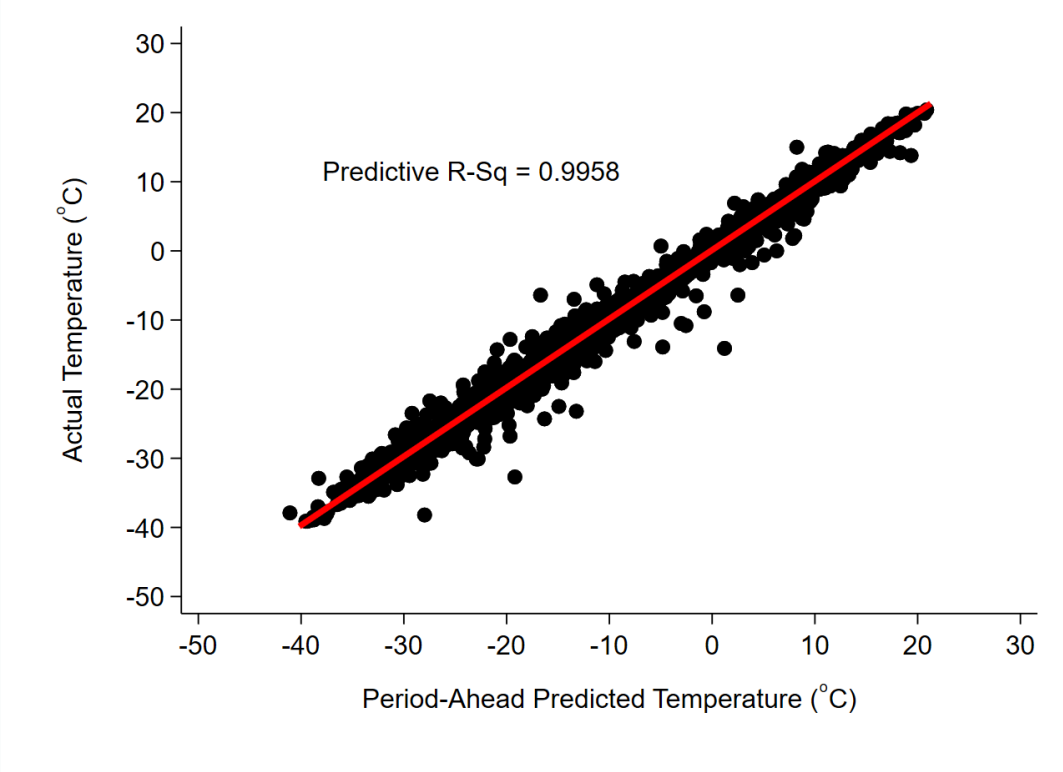
- The coefficients on the binary variables for year  are largely statistically insignificant.

- The model's explanatory power is equivalent to an R-Squared of 0.9952. This is encouraging but it is again noted that the true adequacy of a model can only be determined by considering how well it performs on data that were not used in its estimation.

# Out-of-sample hour ahead predicted and actual temperature at Barrow Alaska, 1 Jan 2016 – 31 August 2017

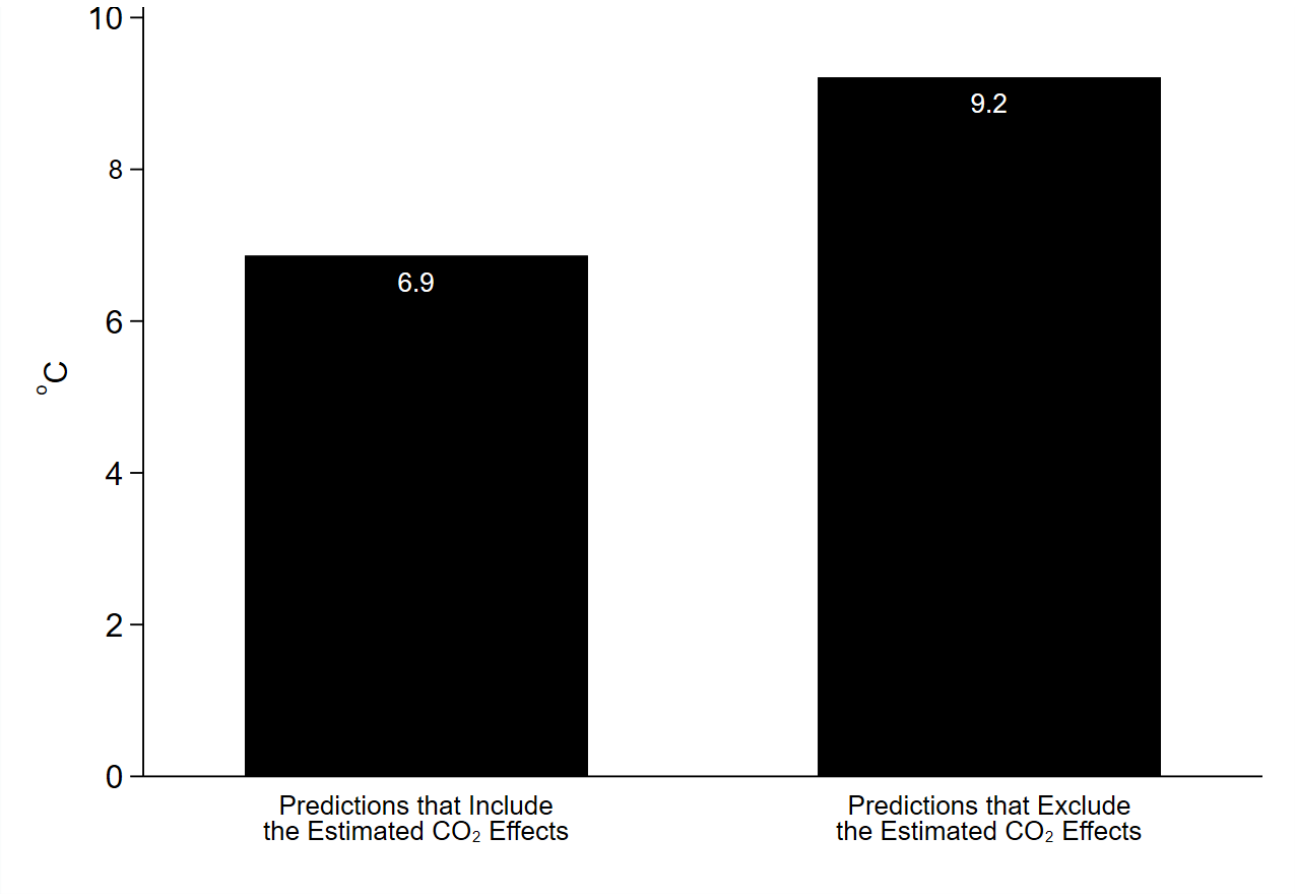
The Out-of-Sample Hour Ahead Predictions have a Predictive R-Square of 0.9958

**Out-of-Sample Predicted and Actual Temperatures, 1 Jan 2016 – 31 Aug 2017**



# The RMSEs in the out-of-sample structural predictions of temperature

Consistent with causality, the out-of-sample predictions that incorporate the statistically significant effects of $CO_2$ are more accurate



# 8) Summary and Conclusion

- The polling data suggests that support for aggressive climate policy actions is weak relative to the challenge. This may represent a significant impediment to the adoption of polices to reduce emissions.

- The inward surface energy imbalance at Barrow has been largely positive even though the energy arriving on the surface from the Sun has been approximately constant. This is an easily understood metric that the energy system  at Barrow is out of balance.

- Evidence has been presented that the inward surface energy imbalance at Barrow can be explained by a model in which $CO_2$ concentrations play an important role.

- With respect to temperature, the Beliefs of the Climate Change Deniers, Skeptics, and Trivializers are <u>not</u> supported by the hourly temperature data in Alaska.

- These findings are consistent with Climate Science. They are not easily explained away by Climate Change Deniers, Skeptics, and Trivializers.