

# U72A-0004 Polar Climate Change in Recent Observations and in Global Climate Models

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## Is the Arctic Sea Ice Disappearing Because of Increasing Greenhouse Gases?

### Introduction

According to recent publications, the Arctic sea ice cover is both shrinking in area and thinning. Satellite data show the Arctic ice has decreased in area about 1 million square km since 1976. Submarine-based measurements show that ice thickness has decreased by up to 45% in the central Arctic Ocean and the Beaufort Sea. Some of the thinning sea ice is also associated with the warm phase of the Arctic Oscillation observed since 1987.

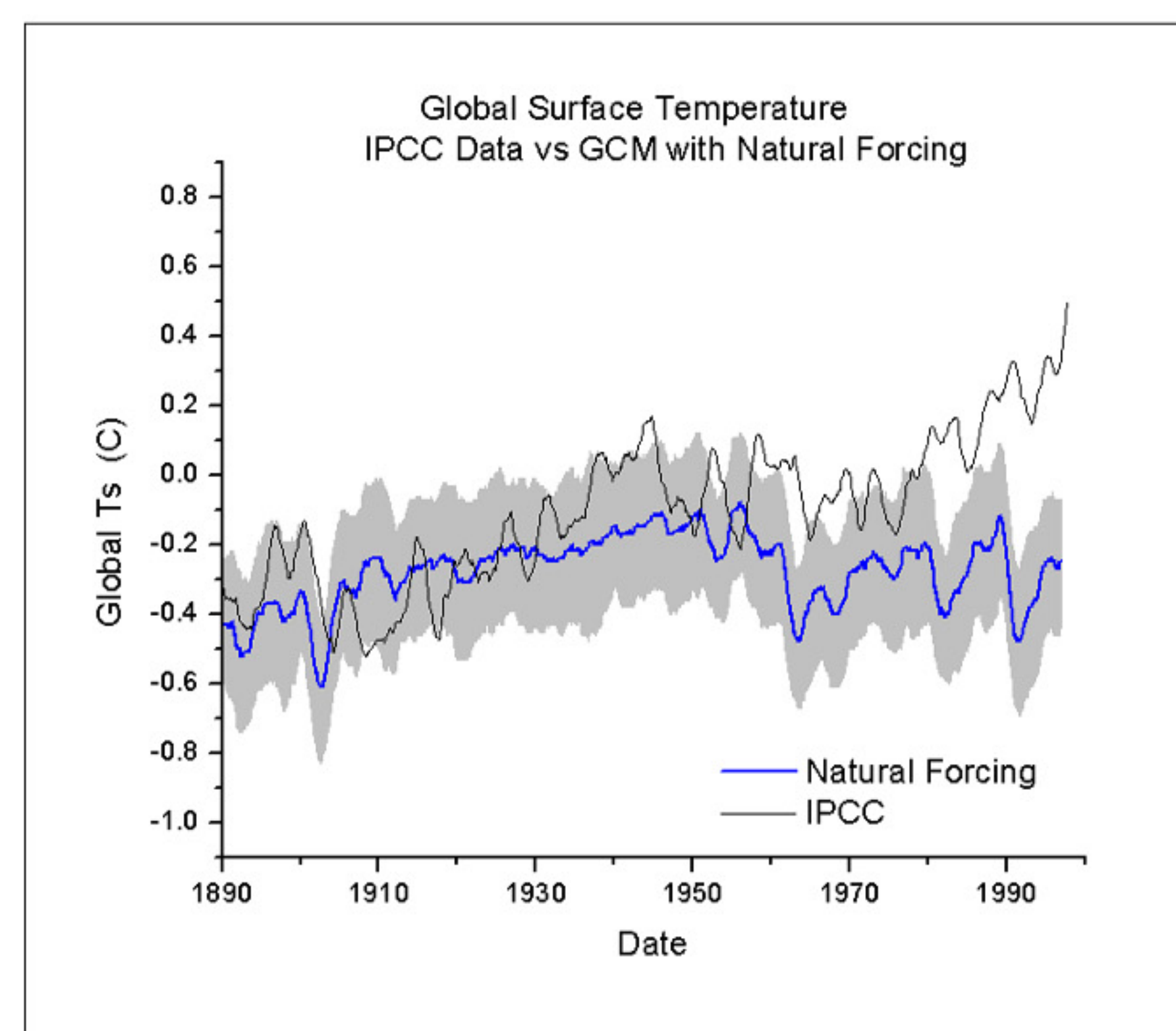
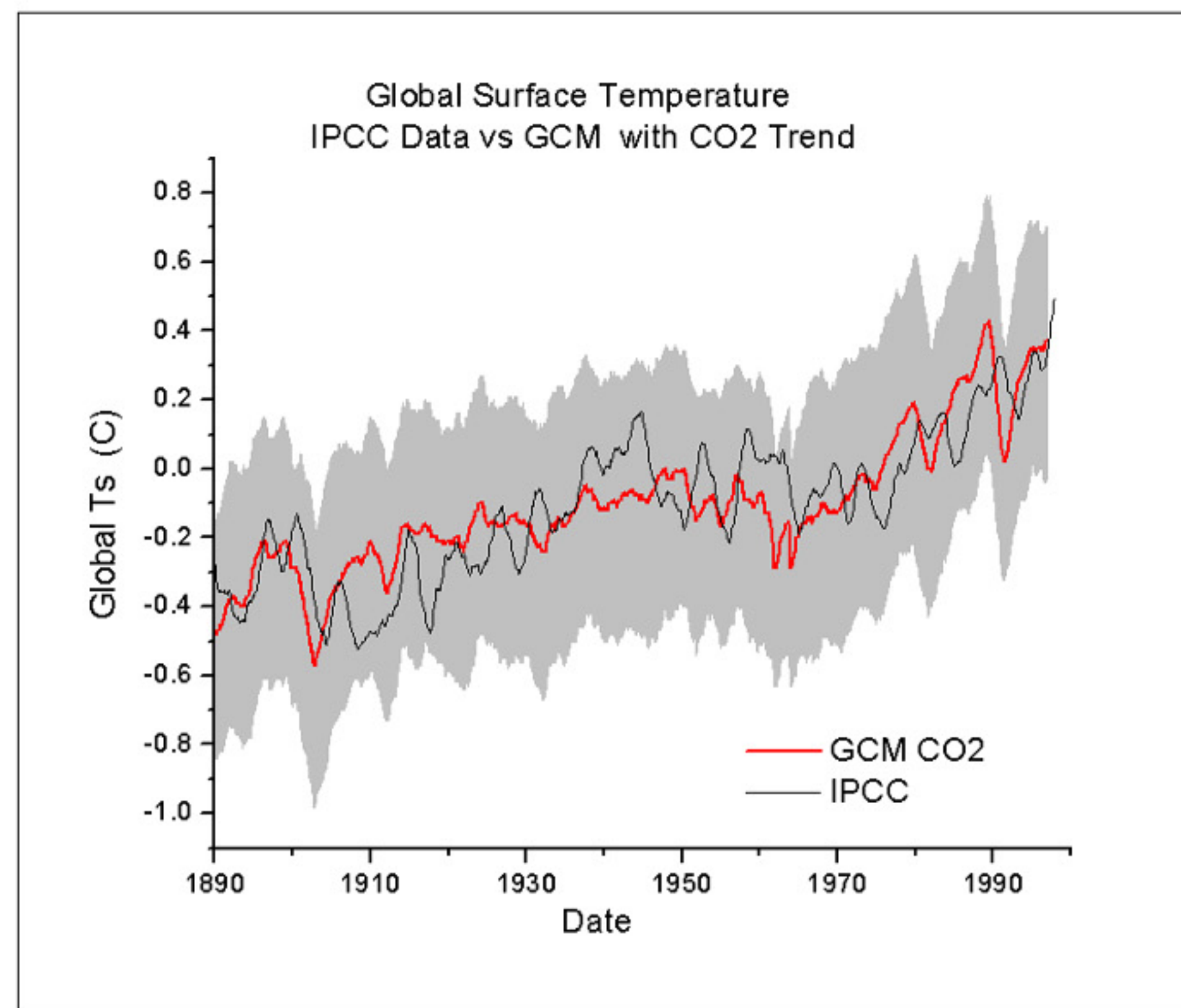
Global climate models (GCM) simulations with increasing greenhouse-gas concentrations predict the Arctic sea ice cover decreasing in response to a warming global climate. Can the GCMs help explain whether the current trends in ice cover are caused by greenhouse gases?

### Global Climate Model and Experiments

The Parallel Climate Model version 1 (PCM1) is composed of the NCAR Community Climate Model version 3 (CCM3) atmospheric GCM at  $2.8^\circ \times 2.8^\circ$  resolution and 18 vertical levels, the Parallel Ocean Program (POP) global ocean GCM with an average horizontal resolution of  $0.66^\circ$  and 31 vertical levels, and a dynamic-thermodynamic sea ice model. The CCM3 atmospheric GCM includes the radiative effects of a series of greenhouse gases: CO<sub>2</sub>, O<sub>3</sub>, CH<sub>4</sub>, NO<sub>x</sub>, CFC-11, CFC-12, and H<sub>2</sub>O, and the direct reflective effect of sulfate aerosols. The sea ice thermodynamics include one internal ice temperature and one snow-layer temperature. The sea-ice mass is represented by a single mean thickness per grid cell, without an evolving thickness distribution. More complete descriptions of the Parallel Climate Model and its sea ice component are given in Washington and others (2000) and Weatherly and Zhang (2000).

Simulated global temperature changes of the 20<sup>th</sup> Century, when forced with greenhouse gas trends, agree with the observed warming better than with natural forcing.

IPCC Data (Black) of global temperature anomalies from P. Jones et al.



### Greenhouse Forcing Case (Red)

- Trends in CO<sub>2</sub>, Methane, NO<sub>x</sub>, CFCs, Ozone
- Industrial Sulfate Aerosols
- Solar Irradiance Changes
- Volcanic Aerosols

- Range of 4 Greenhouse ensemble runs (Grey)

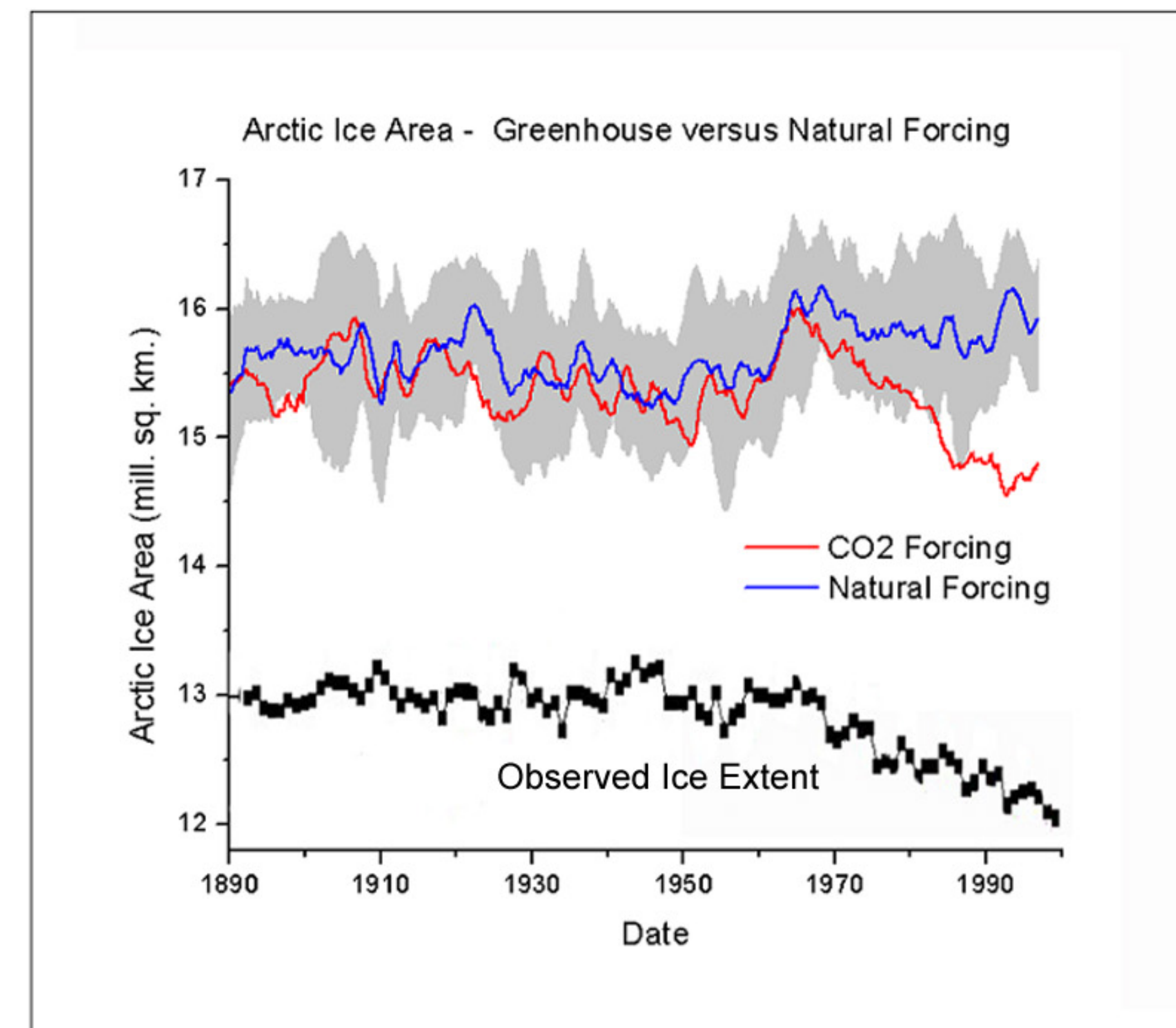
### Natural Forcing Case (Blue)

- Fixed Greenhouse Gases, Sulfate Aerosols, Ozone

- Solar Irradiance Changes
- Volcanic Aerosols

- Range of 4 Natural ensemble runs (Grey)

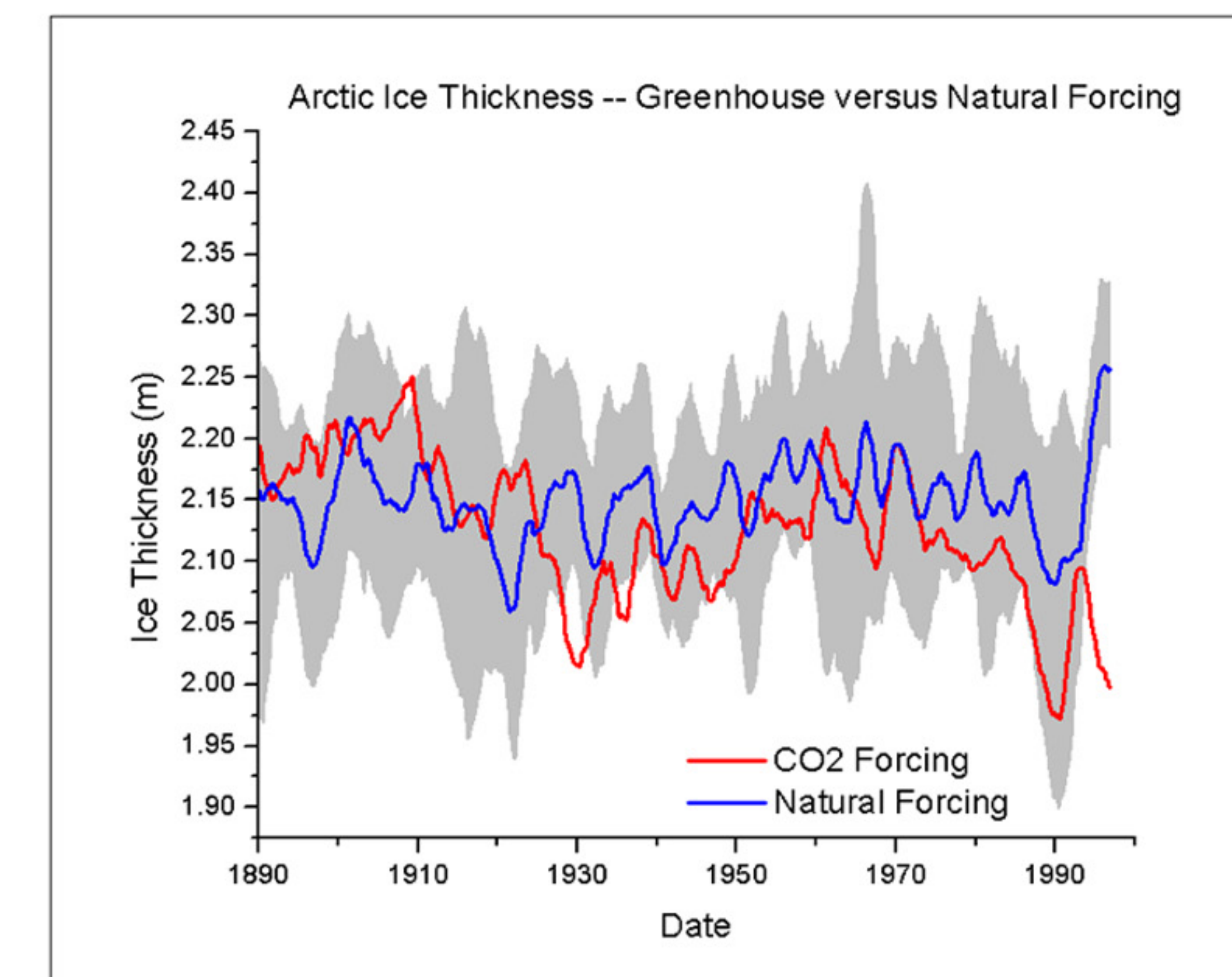
### Changes in the Arctic Ice Cover



Arctic sea ice area decreases by 1 million sq. km in the Greenhouse case (Red) over 1970-2000, lower than the range (Grey) of the Natural Forcing cases.

The modeled areas are biased higher than the observed ice extent (Black), but show a similar decrease.

Observed ice extents from J. Walsh and W. Chapman



The Arctic ice thickness also decreases by about 5% in the Greenhouse case (Red), but barely below the range (Grey) of the Natural Forcing ensemble cases.

Observational studies have reported thinning of Arctic ice between 32% and 43% between the 1970's and 1990's.

### Conclusions

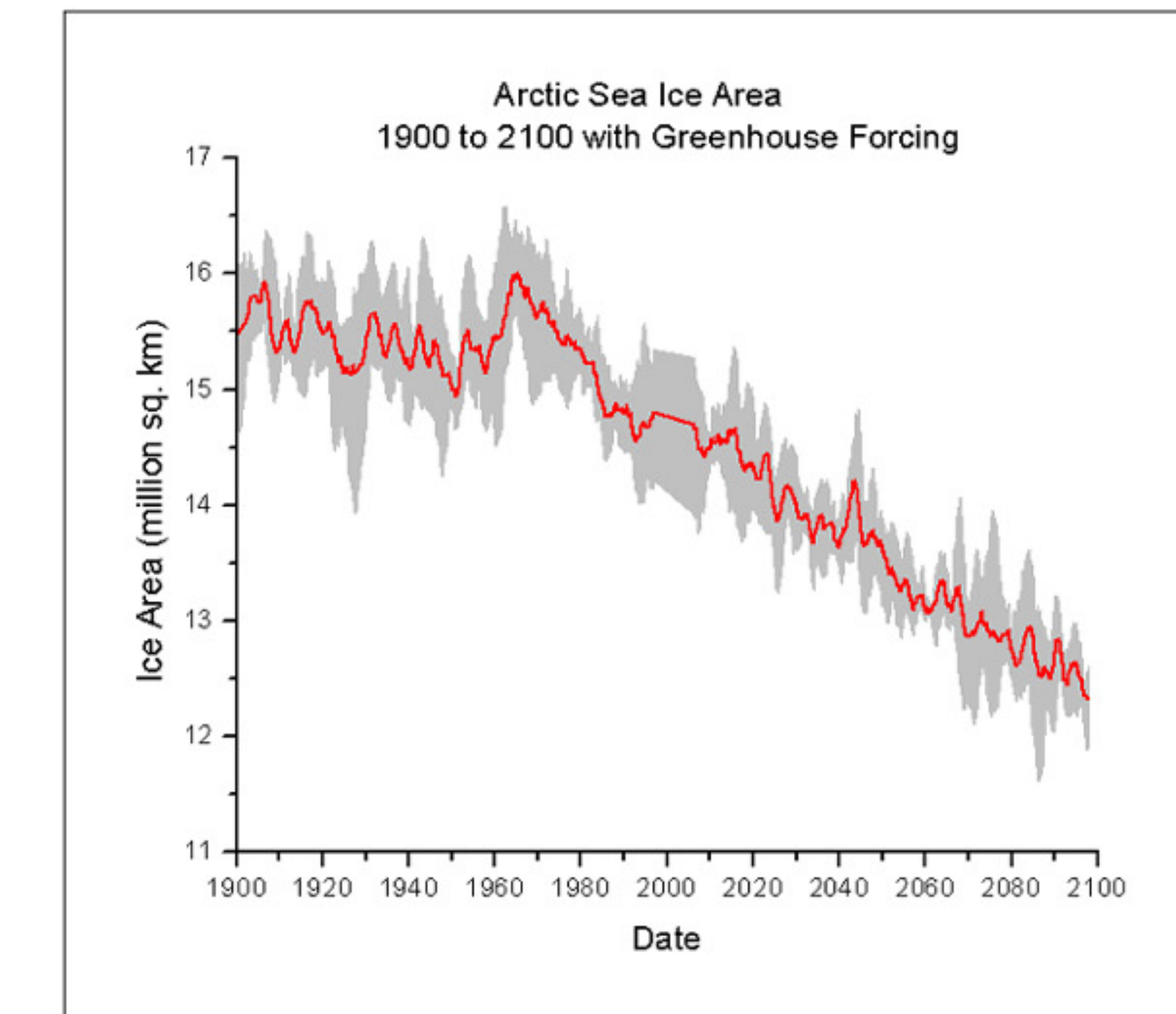
The area of Arctic sea ice in the GCM decreases by 7% over 1970 – 2000 in response to anthropogenic Greenhouse forcing, not Natural forcing, including solar variability.

Observations show the Arctic ice extent has decreased by about 7%, which may be attributed to increased greenhouse gas concentrations.

Thinning of Arctic sea ice by 5% can be attributed to greenhouse forcing in the model. Observations show thinning of 32% to 43%, some of which represent the natural modes of variability in the Arctic.

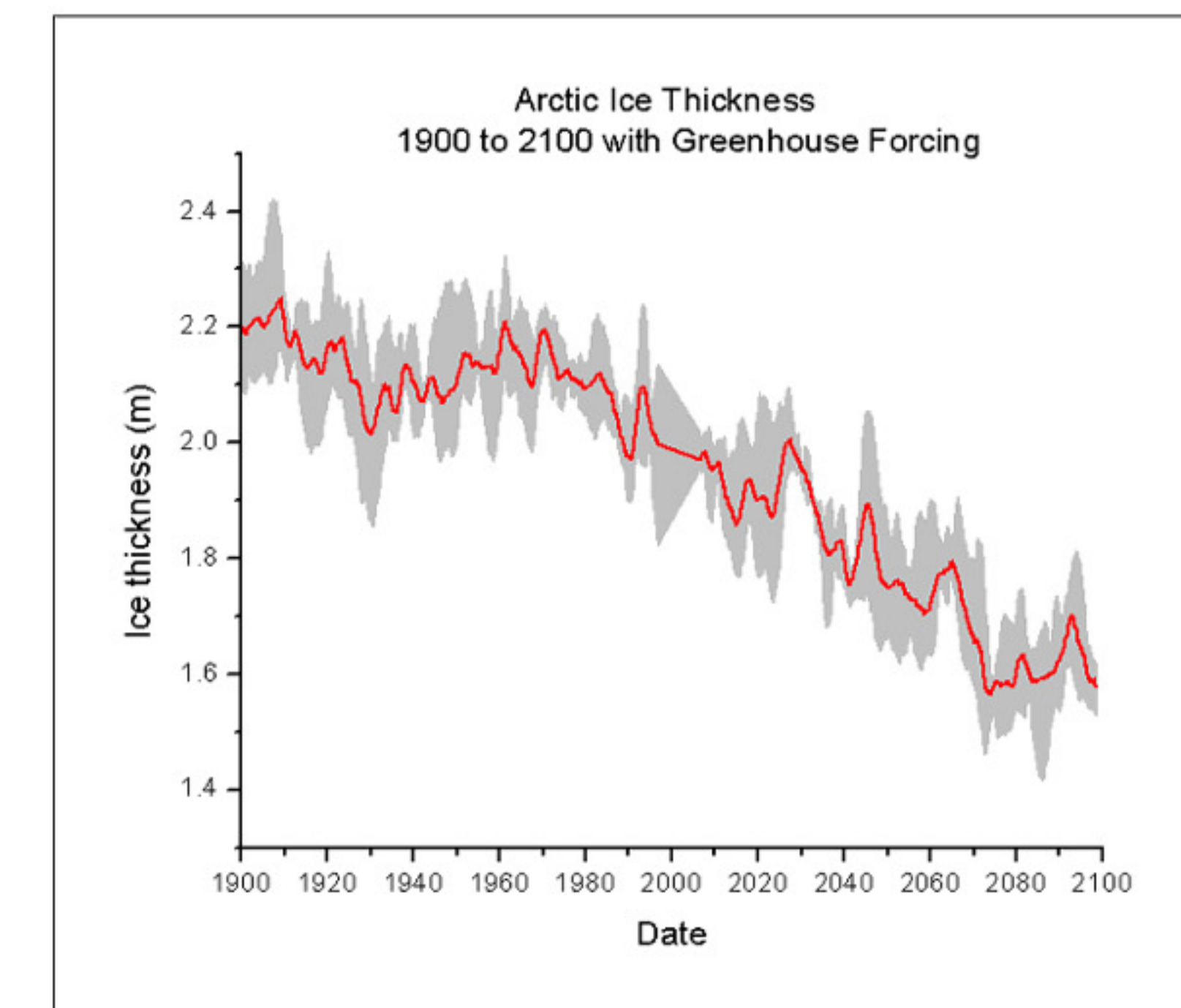
Thinning and shrinking of the Arctic ice cover continues beyond the year 2000 in GCM simulations with increasing greenhouse gases.

### Predictions of the Next 100 years

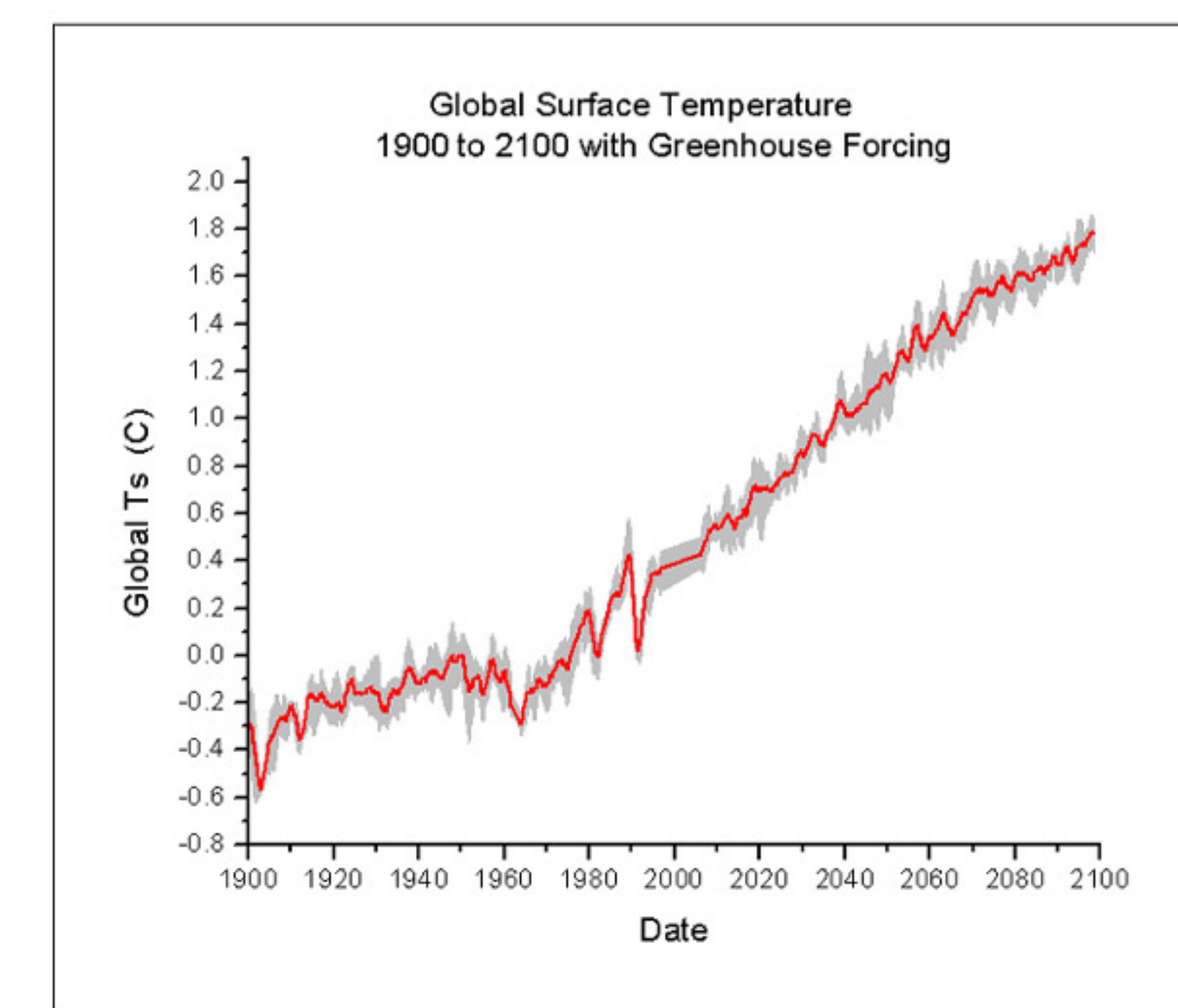


GCM simulations for 1900 to 2100 with increasing Greenhouse gases, with the doubling of present-day CO<sub>2</sub>.

Arctic ice area decreases by over 15% by the year 2100.



Ice thickness decreases by 25% by the year 2100.



Global mean surface temperature increases by 1.8°C.

### Acknowledgements

The Parallel Climate Model experiments were performed by the NCAR Climate Change Research group headed by Warren Washington and Jerry Meeh. Thanks to Tom Bettge, Gary Strand, Julie Arblaster, Vince Wayland, and Aiguo Dai.

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