Virtual Academy for Sustainability

WBGU
German Advisory Council on Global Change

Lecture 3: Climate Change

Episode 1: Basic facts about global warming

Prof. Stefan Rahmstorf
Potsdam University *and* Potsdam Institute for Climate Impact Research,
Potsdam (Germany)

DBU
Deutsche Bundesstiftung Umwelt

Lecture 3: Overview

Episode 1: Basic facts about global warming

Episode 2: Impacts of climate change and mitigation

Episode 3: Interview

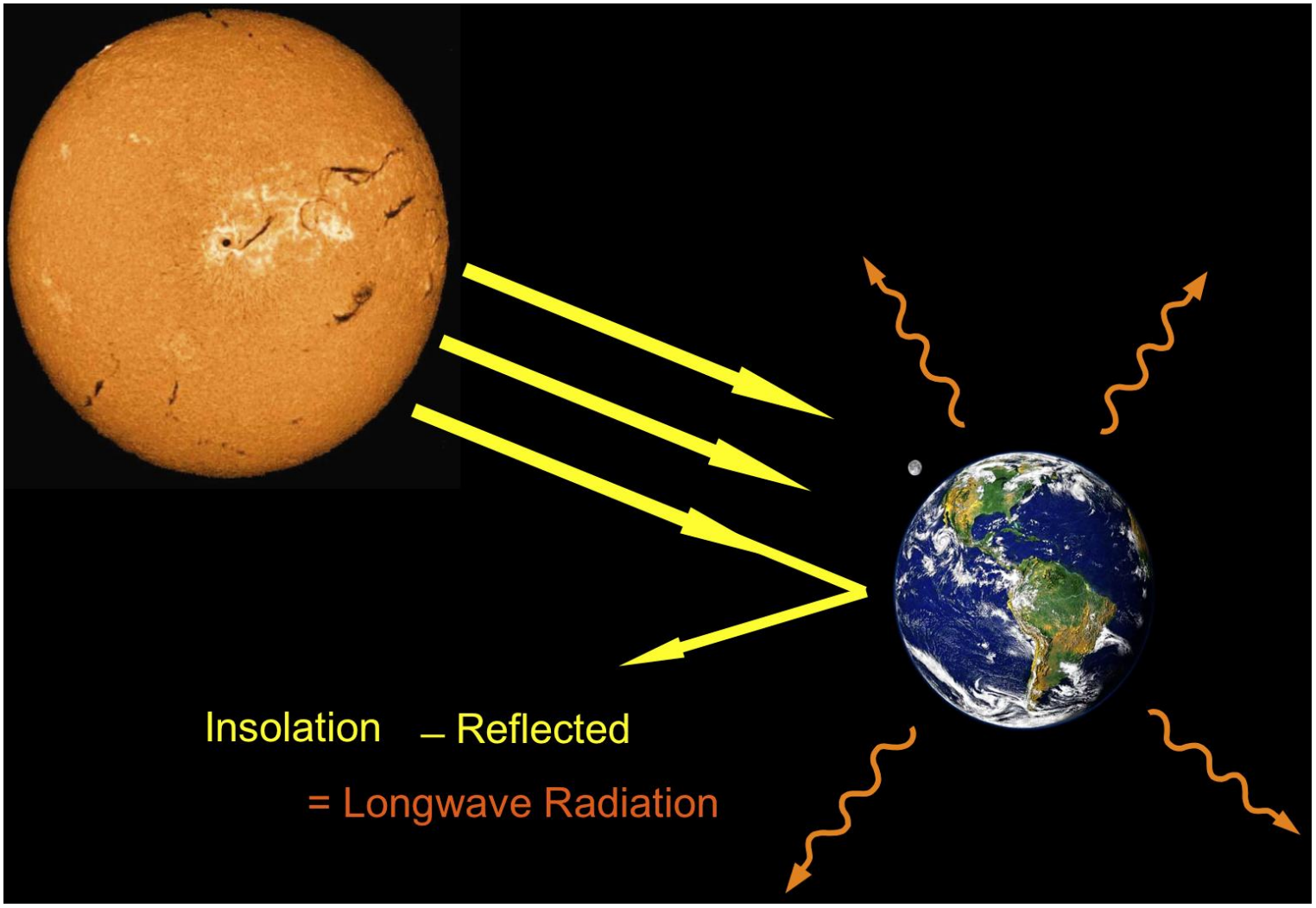
Learning Outcomes

1. Understand the fundamental role played by the Earth's energy budget in setting the global average temperature, and understand how this energy budget works.
2. Understand how global temperature has increased over the last hundred years and which change in the Earth's energy budget has driven that.
3. Understand how future changes in greenhouse gas concentration will affect global temperatures.

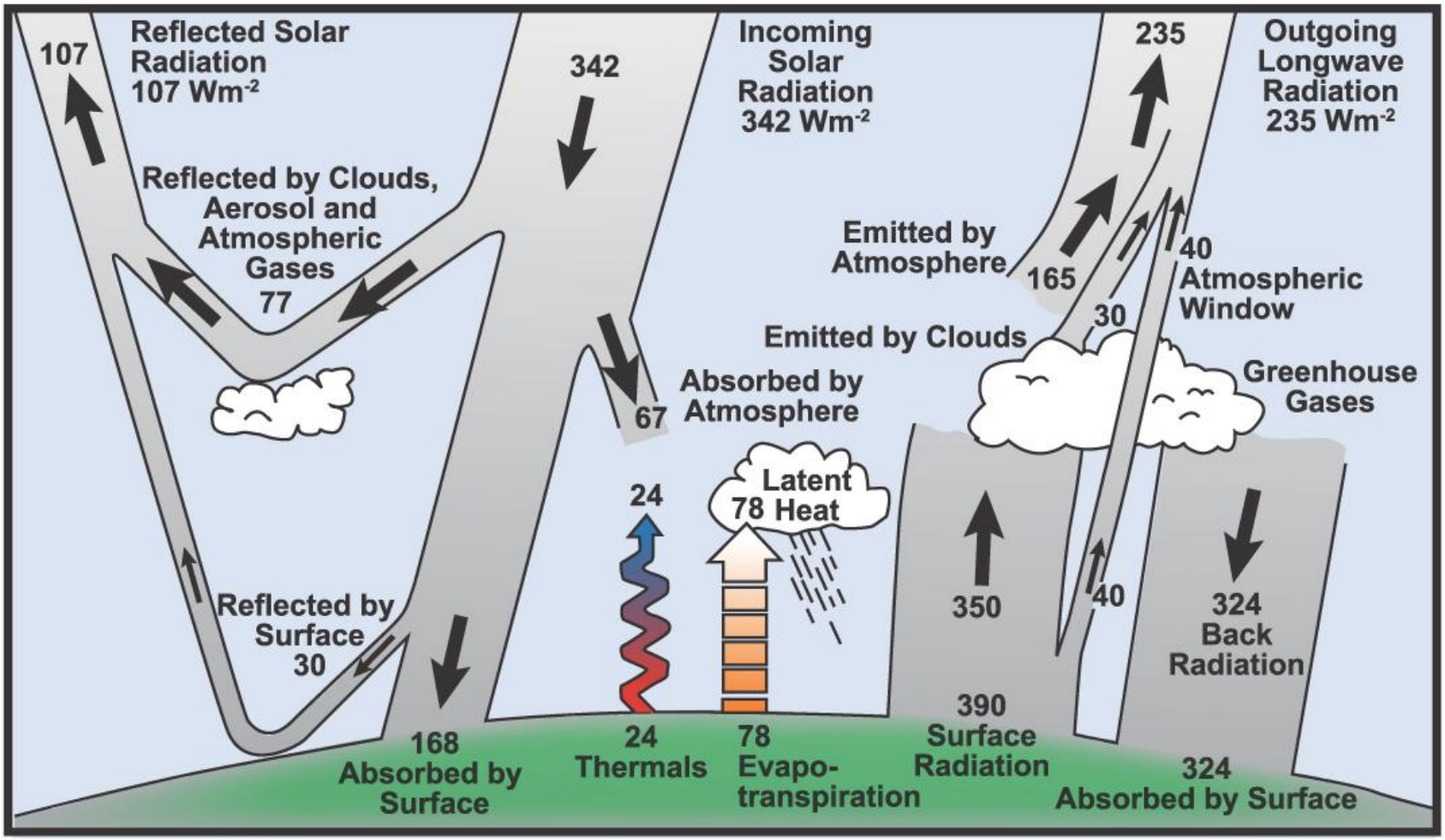
Content

- Earth's energy balance
- The rise of CO_2 concentration
- Global temperature
- Loss of glaciers and sea ice
- Scenarios of future warming

Climate results from an energy balance

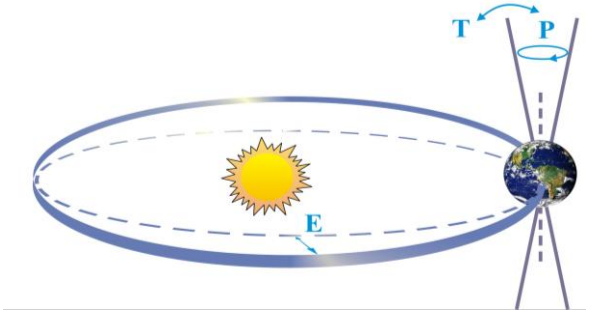


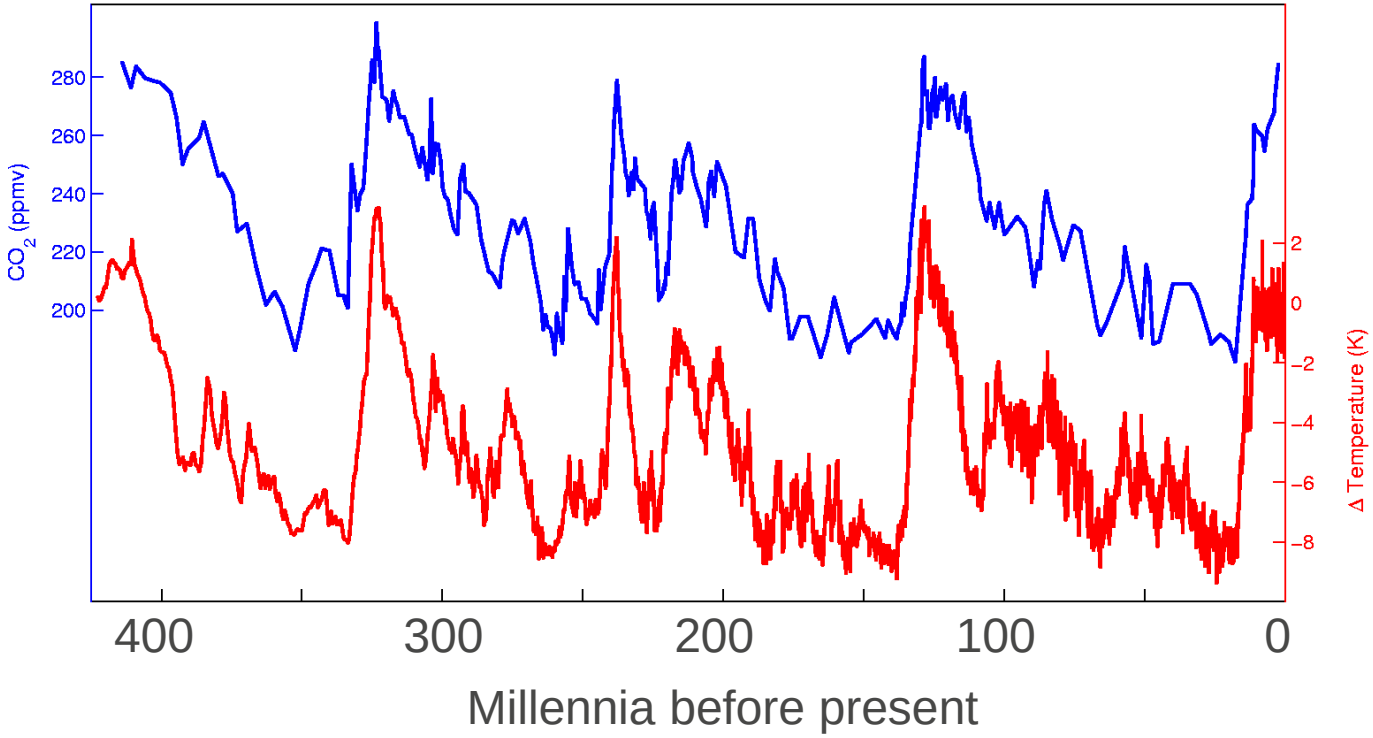
Earth's Energy Budget



Source: IPCC 2007

Orbital Cycles





Source: after Petit et al. 1999

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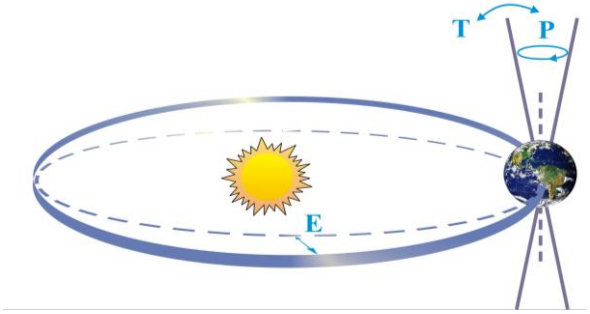

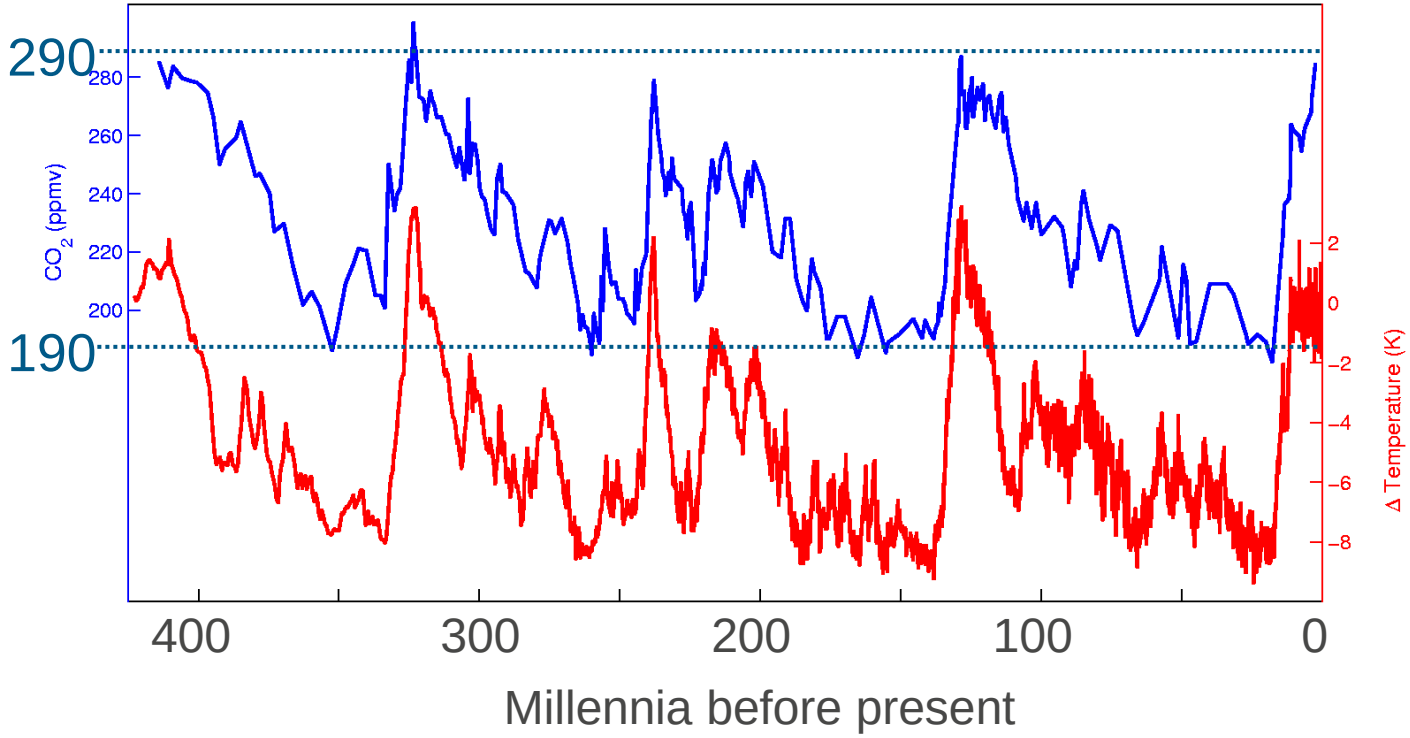

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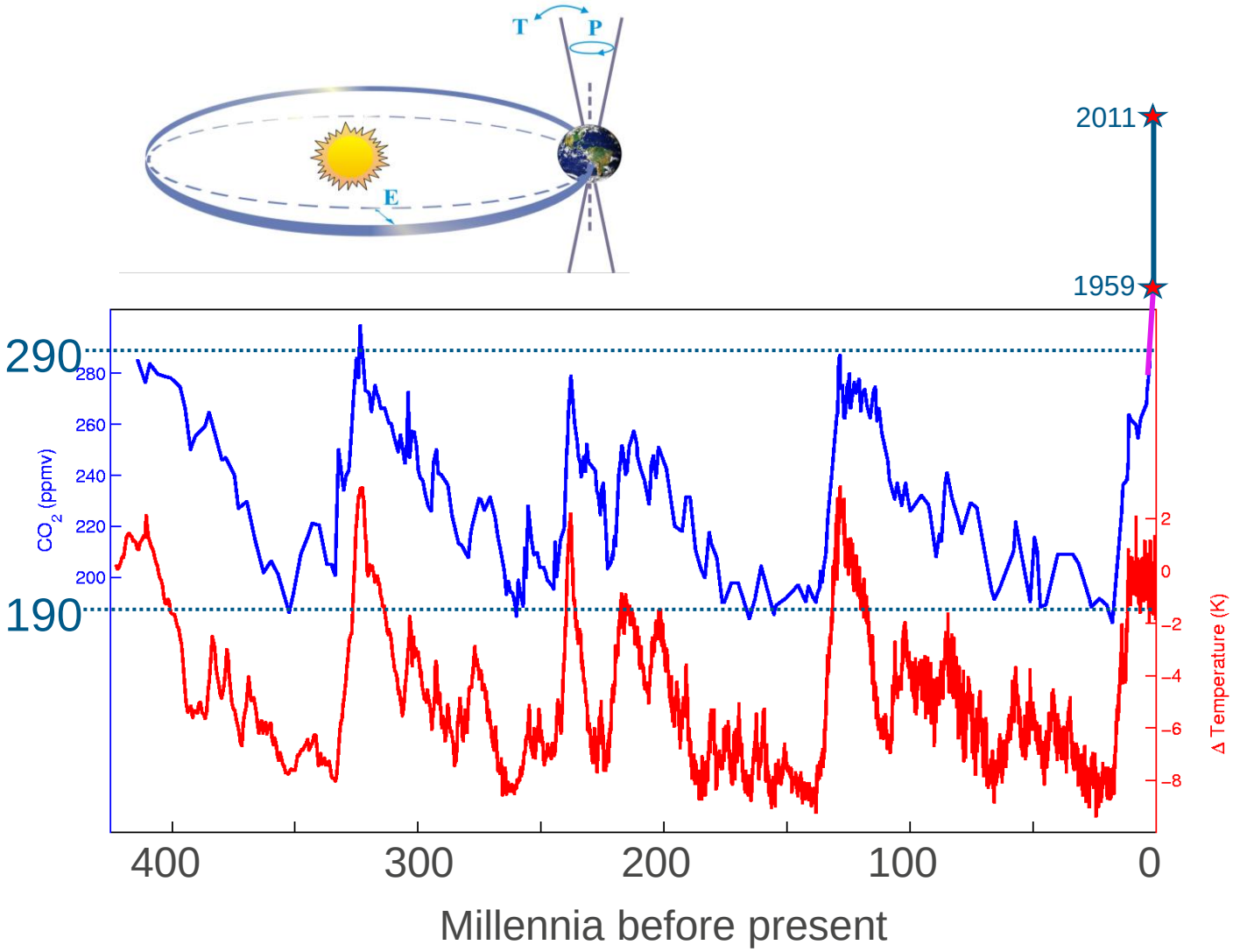

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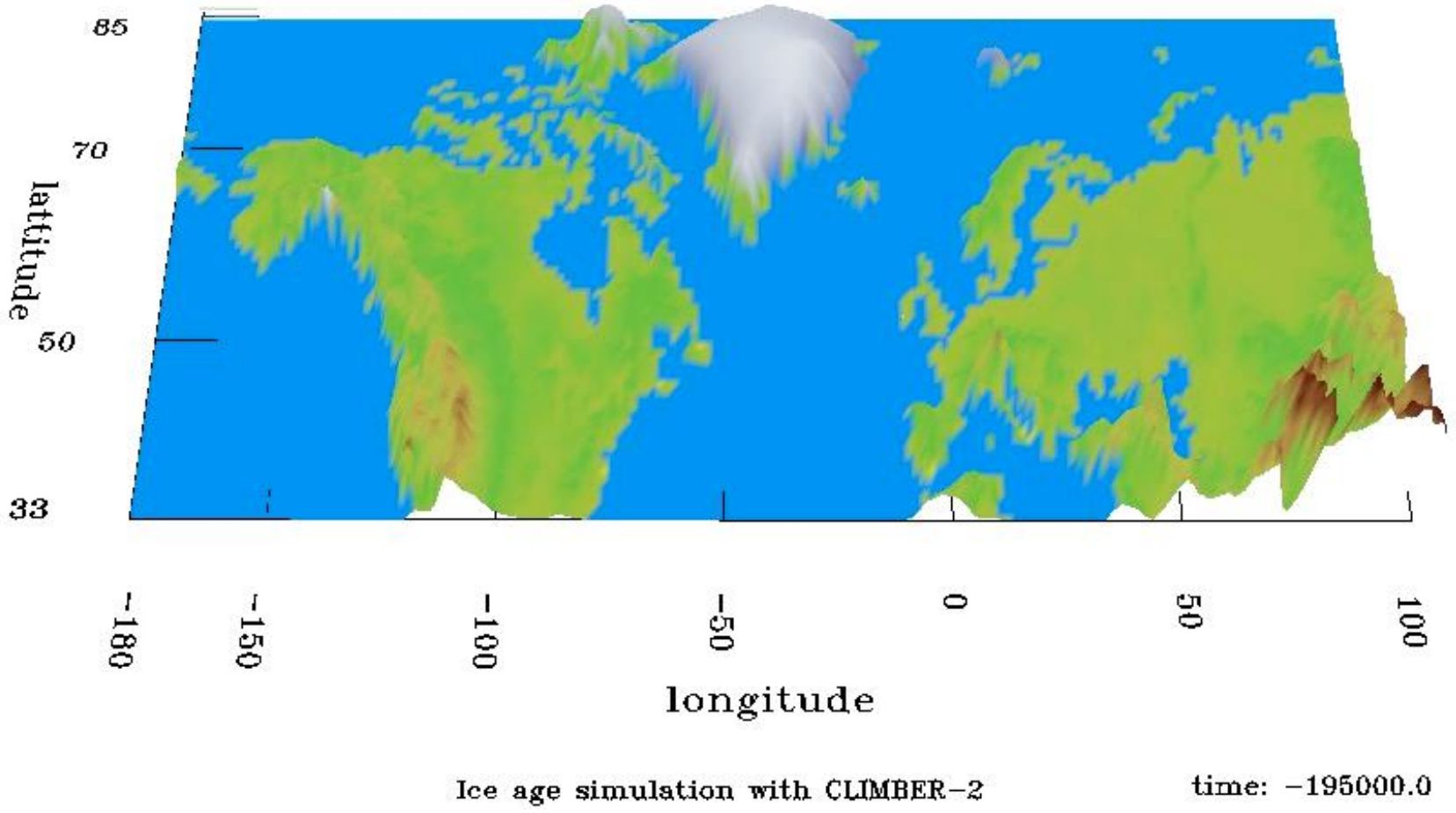
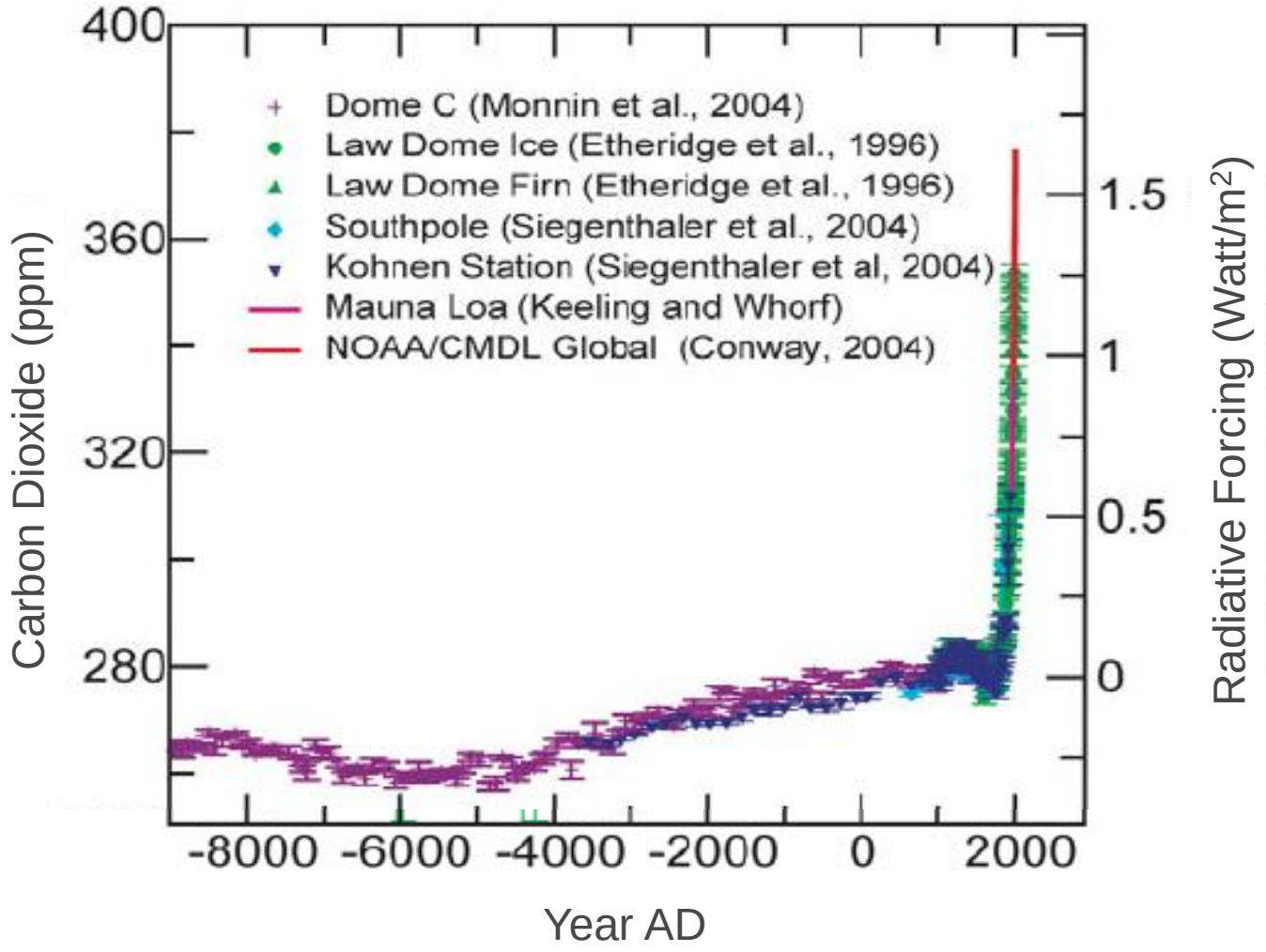


Source: Ganopolski et al. 2010

Rising CO_2-Concentration

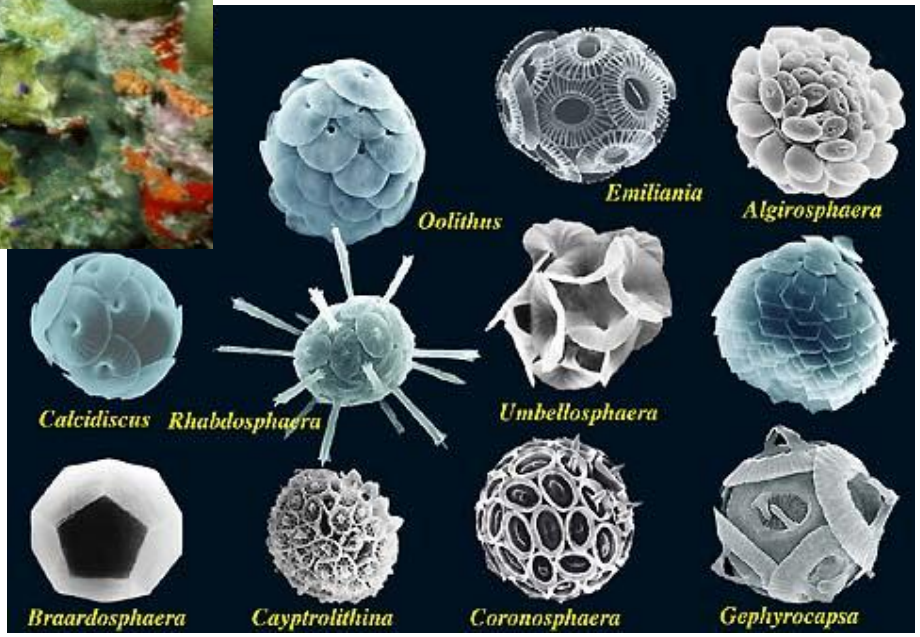


Source: IPCC 2007

Oceans Are Getting More Acidic

- Acidification due to CO_2 is a threat to marine ecosystems

Plankton



Coral Reefs

A Historic Reminder

Alexander von Humboldt, 1844

Man changes climate „by cutting forests [...] and by emitting large amounts of steam and gas at the centers of industry"

Portrait by François Gérard
Background: NASA

Source: Von Humboldt 1844

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Man changes climate „by cutting forests [...] and by emitting large amounts of steam and gas at the centers of industry"

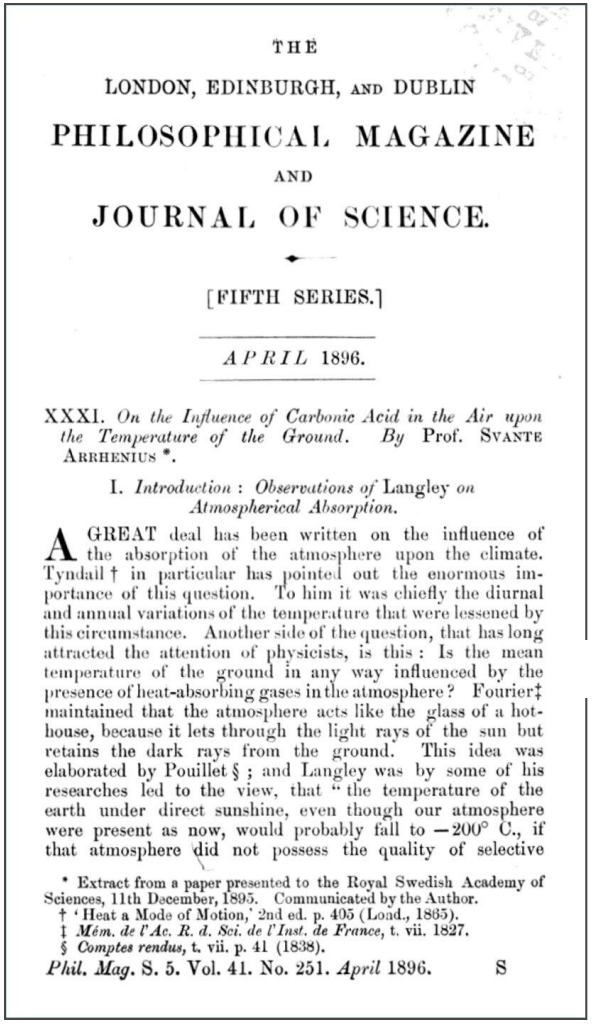
John Tyndall, 1859

„The atmosphere admits of the entrance of solar heat, but checks its exit; and the result is a tendency to accumulate heat at the surface of the planet.“

Portrait by K. Ensikat

Source: Tyndall 1859

Climate Effect of CO2



THE

LONDON, EDINBURGH, AND DUBLIN

PHILOSOPHICAL MAGAZINE

AND

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[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS *.

I. *Introduction: Observations of* Langley *on Atmospherical Absorption.*

A GREAT deal has been written on the influence of the absorption of the atmosphere upon the climate. Tyndall † in particular has pointed out the enormous importance of this question. To him it was chiefly the diurnal and annual variations of the temperature that were lessened by this circumstance. Another side of the question, that has long attracted the attention of physicists, is this: Is the mean temperature of the ground in any way influenced by the presence of heat-absorbing gases in the atmosphere? Fourier‡ maintained that the atmosphere acts like the glass of a hot-house, because it lets through the light rays of the sun but retains the dark rays from the ground. This idea was elaborated by Pouillet §; and Langley was by some of his researches led to the view, that "the temperature of the earth under direct sunshine, even though our atmosphere were present as now, would probably fall to −200° C., if that atmosphere did not possess the quality of selective

* Extract from a paper presented to the Royal Swedish Academy of Sciences, 11th December, 1895. Communicated by the Author.
† 'Heat a Mode of Motion,' 2nd ed. p. 405 (Lond., 1865).
‡ *Mém. de l'Ac. R. d. Sci. de l'Inst. de France*, t. vii. 1827.
§ *Comptes rendus*, t. vii. p. 41 (1838).

Phil. Mag. S. 5. Vol. 41. No. 251. *April* 1896. S

Source: Arrhenius 1896

Svante Arrhenius

Portrait by K. Ensikat

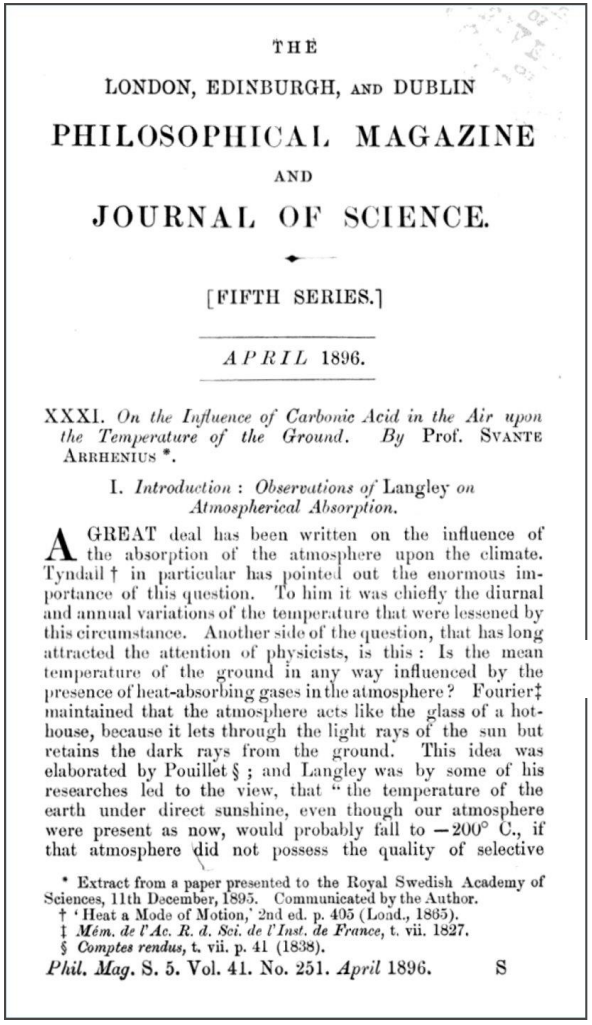
Arrhenius 1896 (4-6 ºC)

Effect of CO_2-doubling:

"climate sensitivity"

3 ± 1 ºC

Climate Effect of CO2



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Arrhenius 1896 (4-6 ºC)

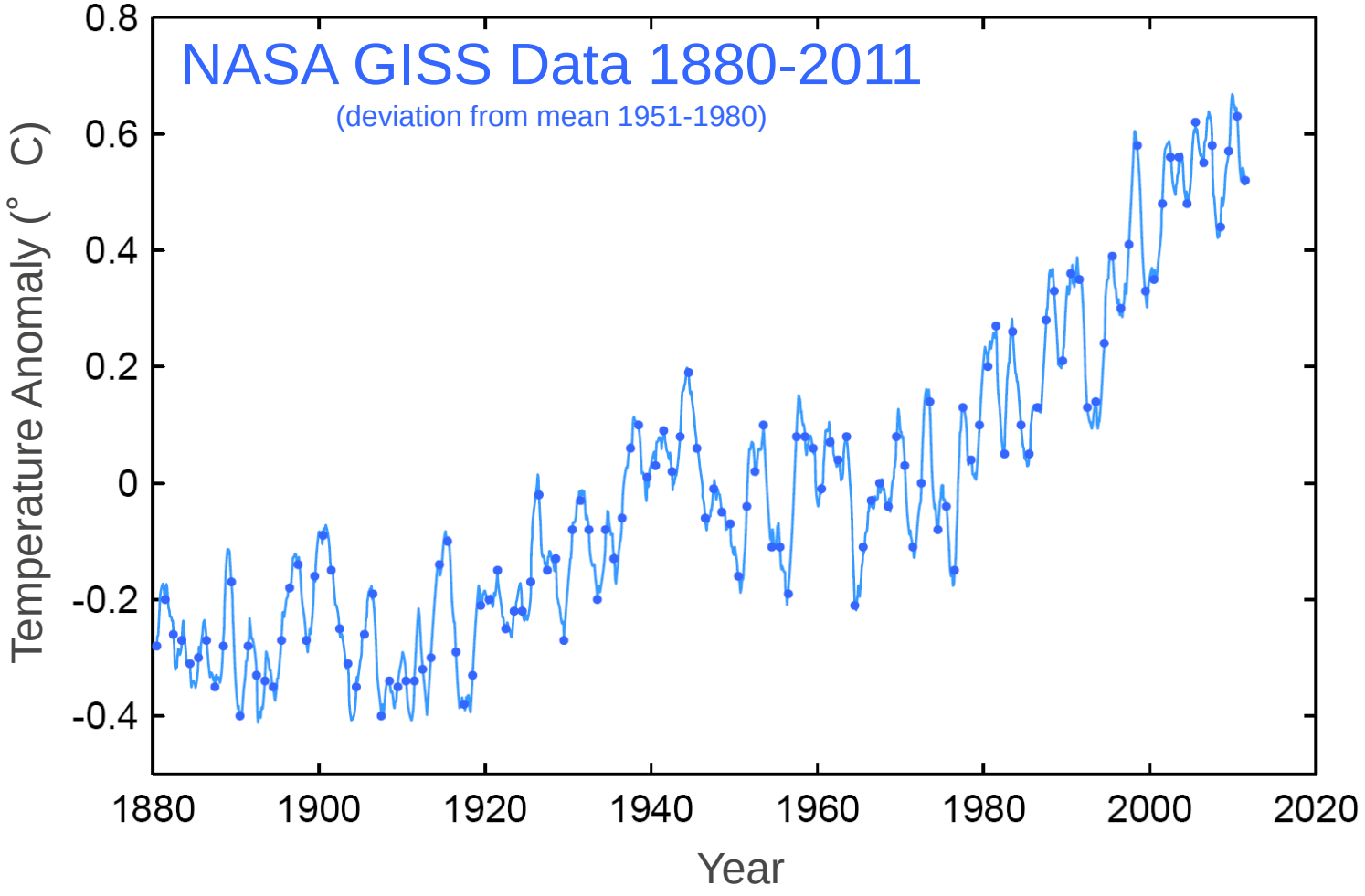
Effect of CO_2-doubling:

"climate sensitivity"

3 ± 1 ºC

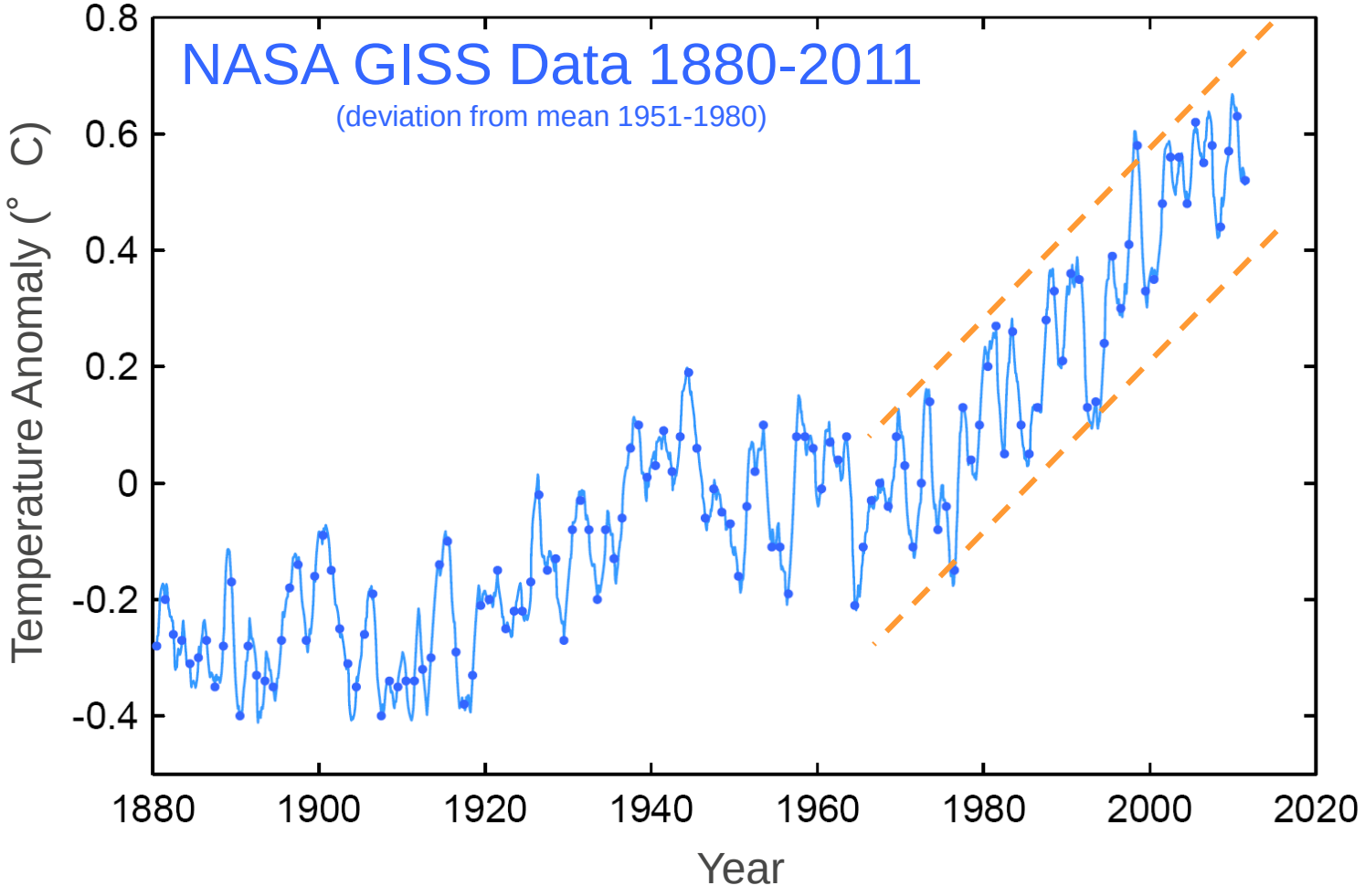
Anthropogenic emissions should have caused 0.7 to 0.9 ºC warming to date

Global Temperature



Data Source: Goddard Institute for Space Studies

Global Temperature



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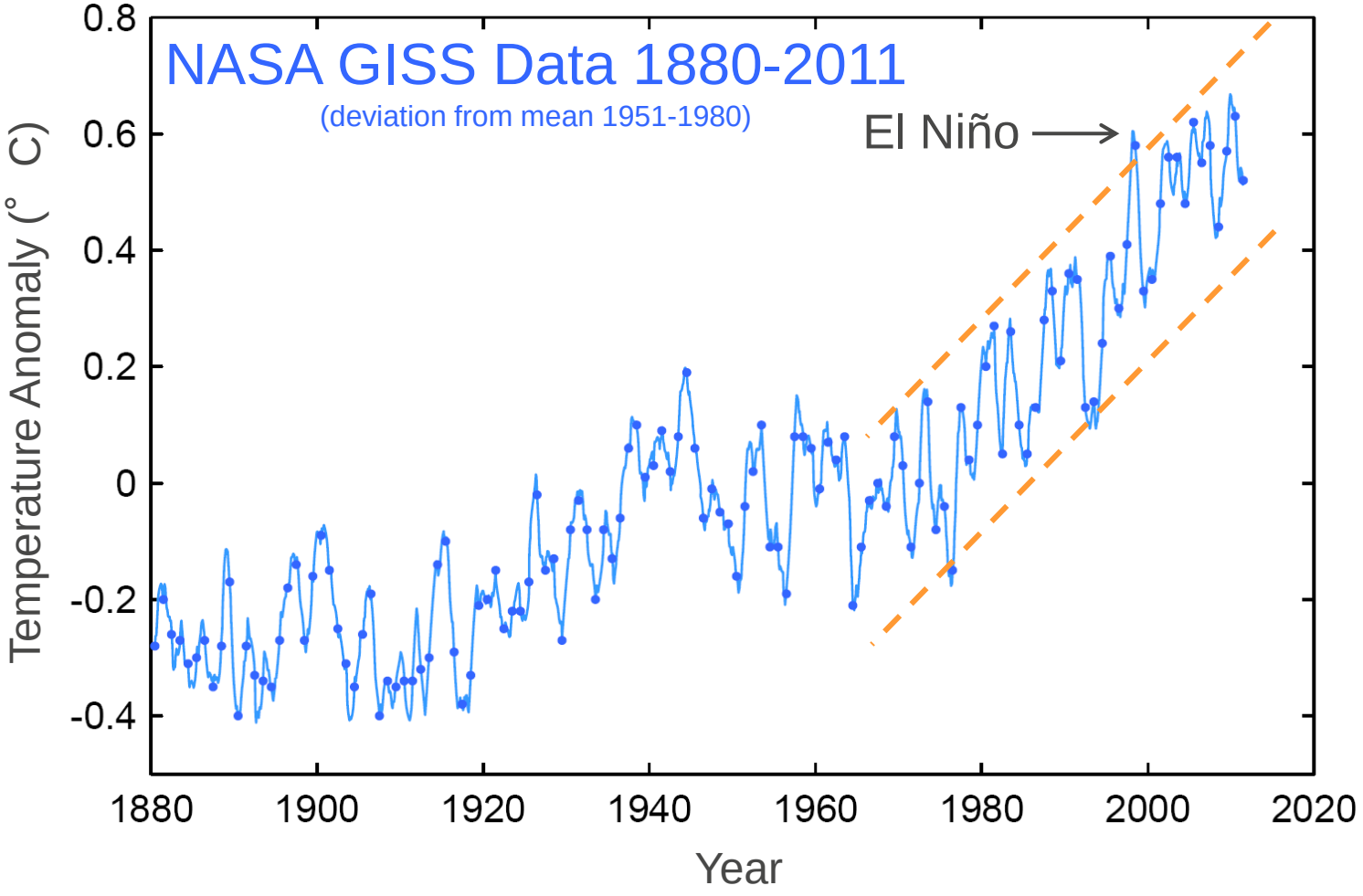

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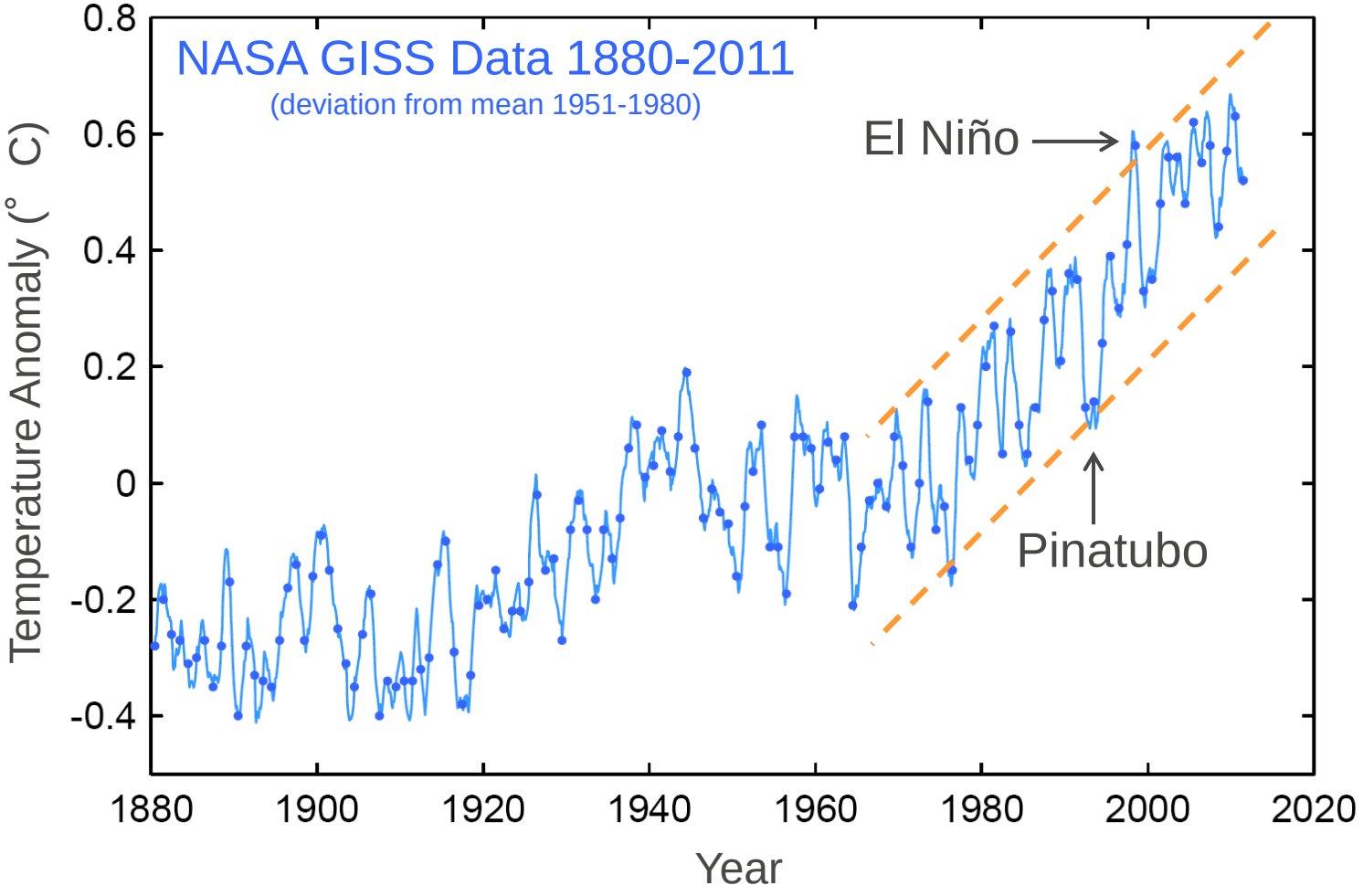
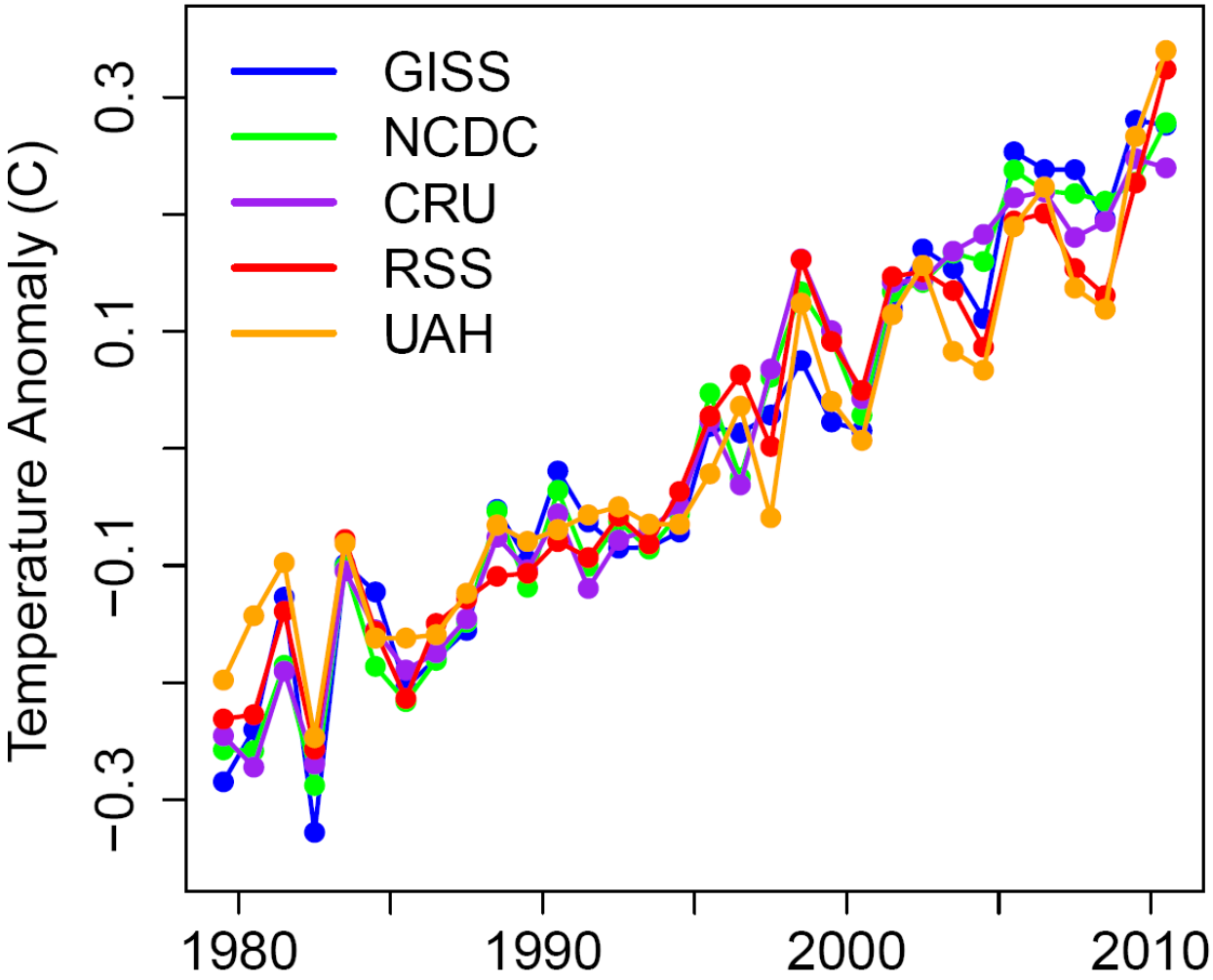


Data Source: Goddard Institute for Space Studies

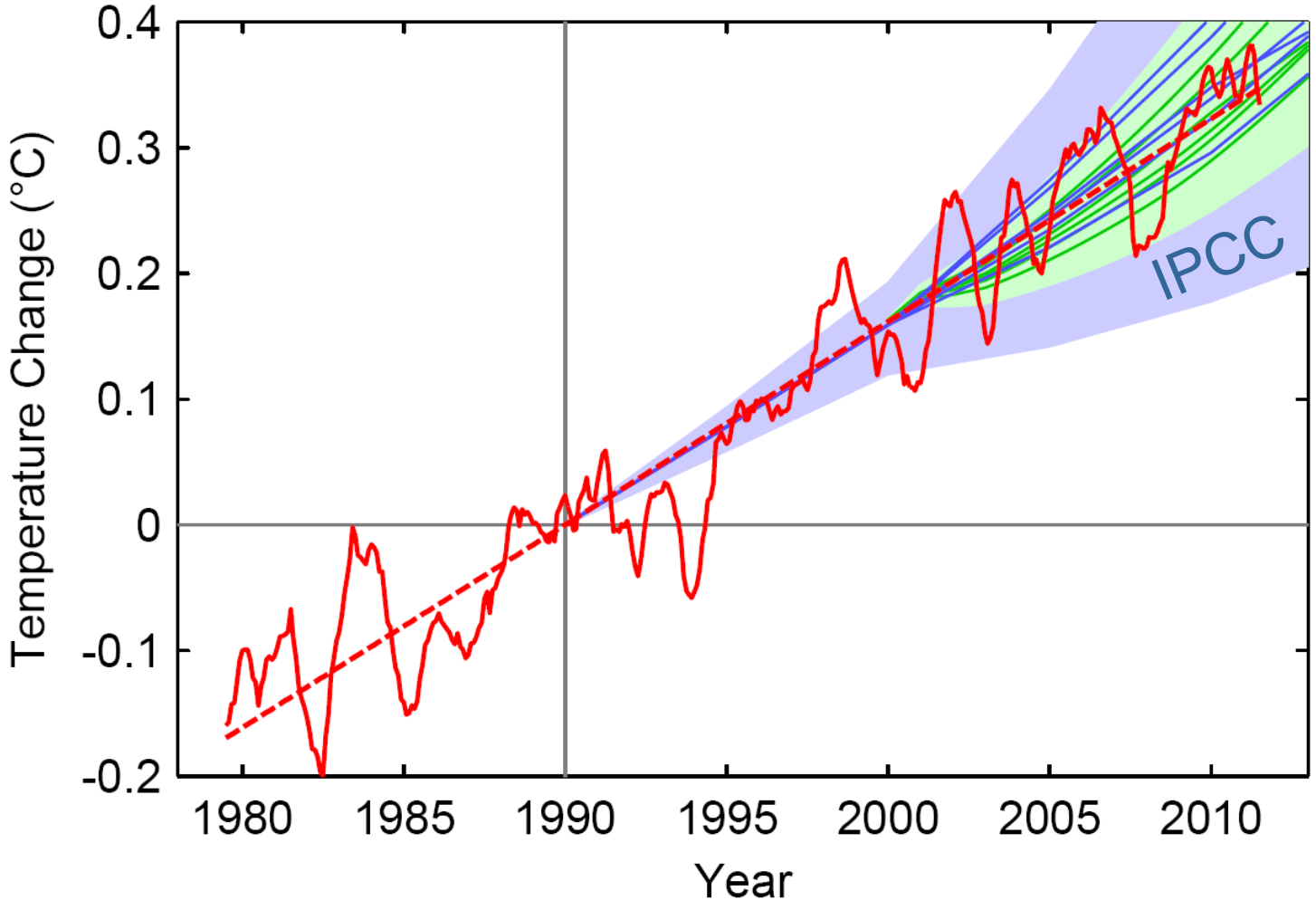
Global Temperature

With effect of El Niño, Volcanos und solar activity removed



Source: Foster and Rahmstorf, 2011

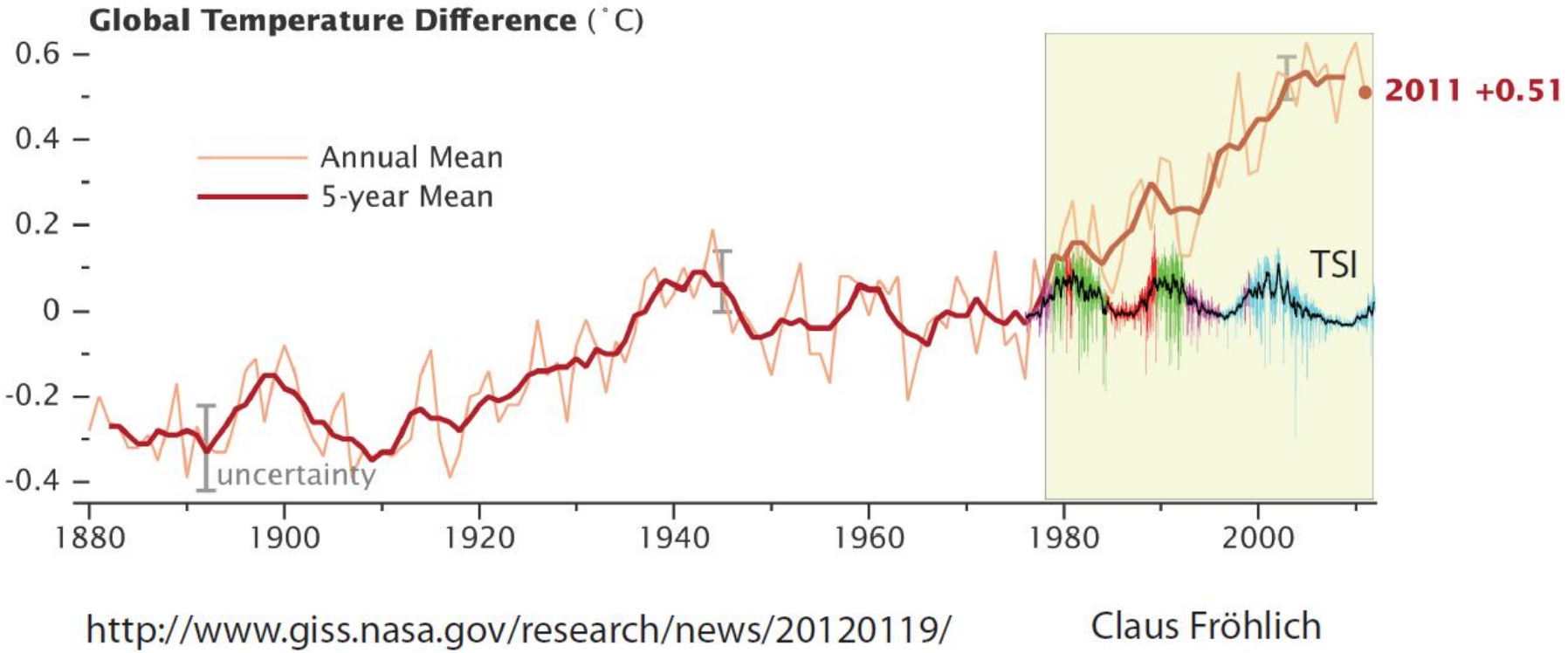
Global Temperature



Source: Rahmstorf et al., submitted

The Sun and Global Temperature

Amplitude of solar effect: ± 0.04 ° C



Source: Claus Fröhlich, World Radiation Center, Davos

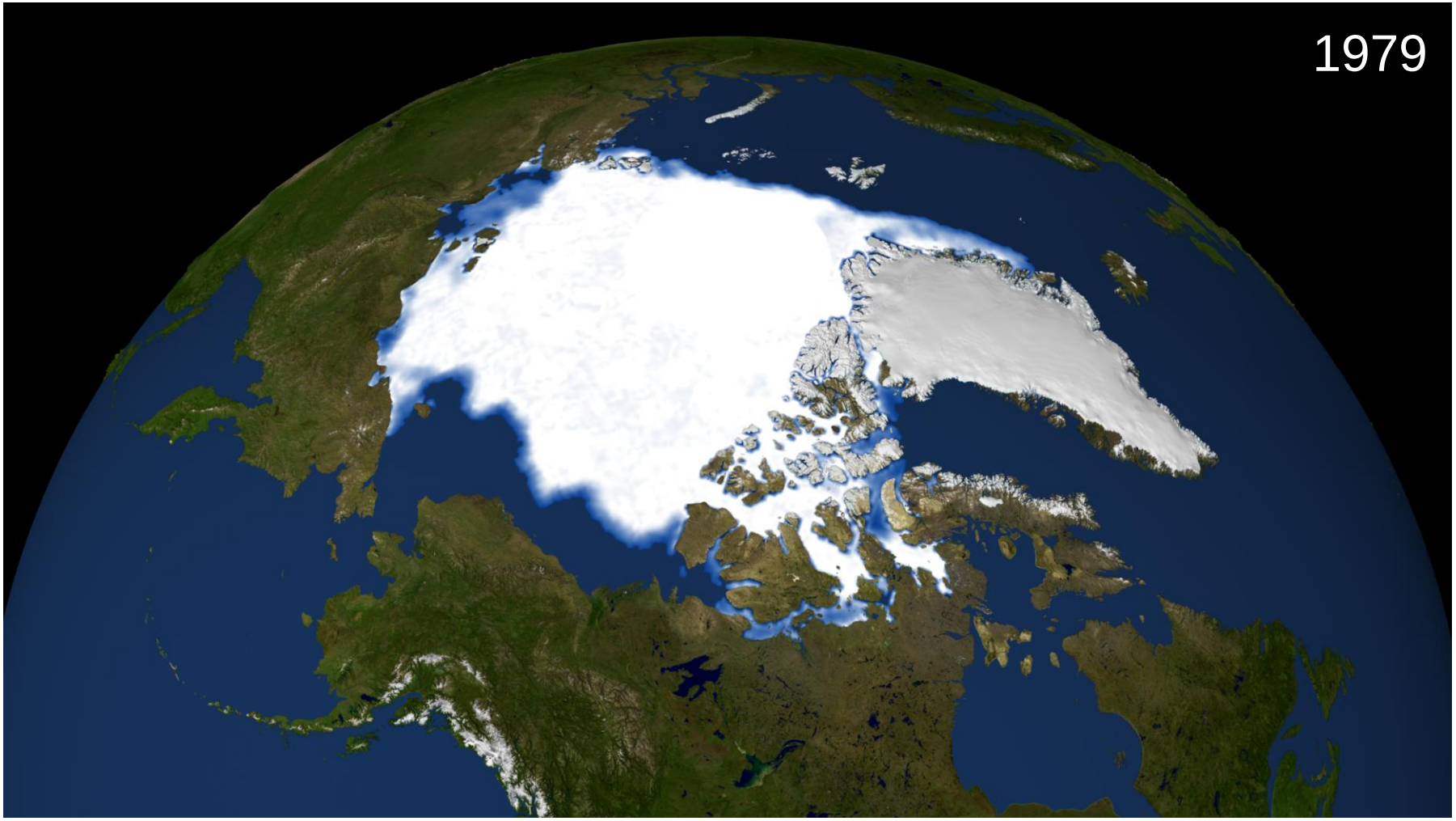
Loss of Mountain Glaciers

Foto: S. Rahmstorf

Loss of Mountain Glaciers

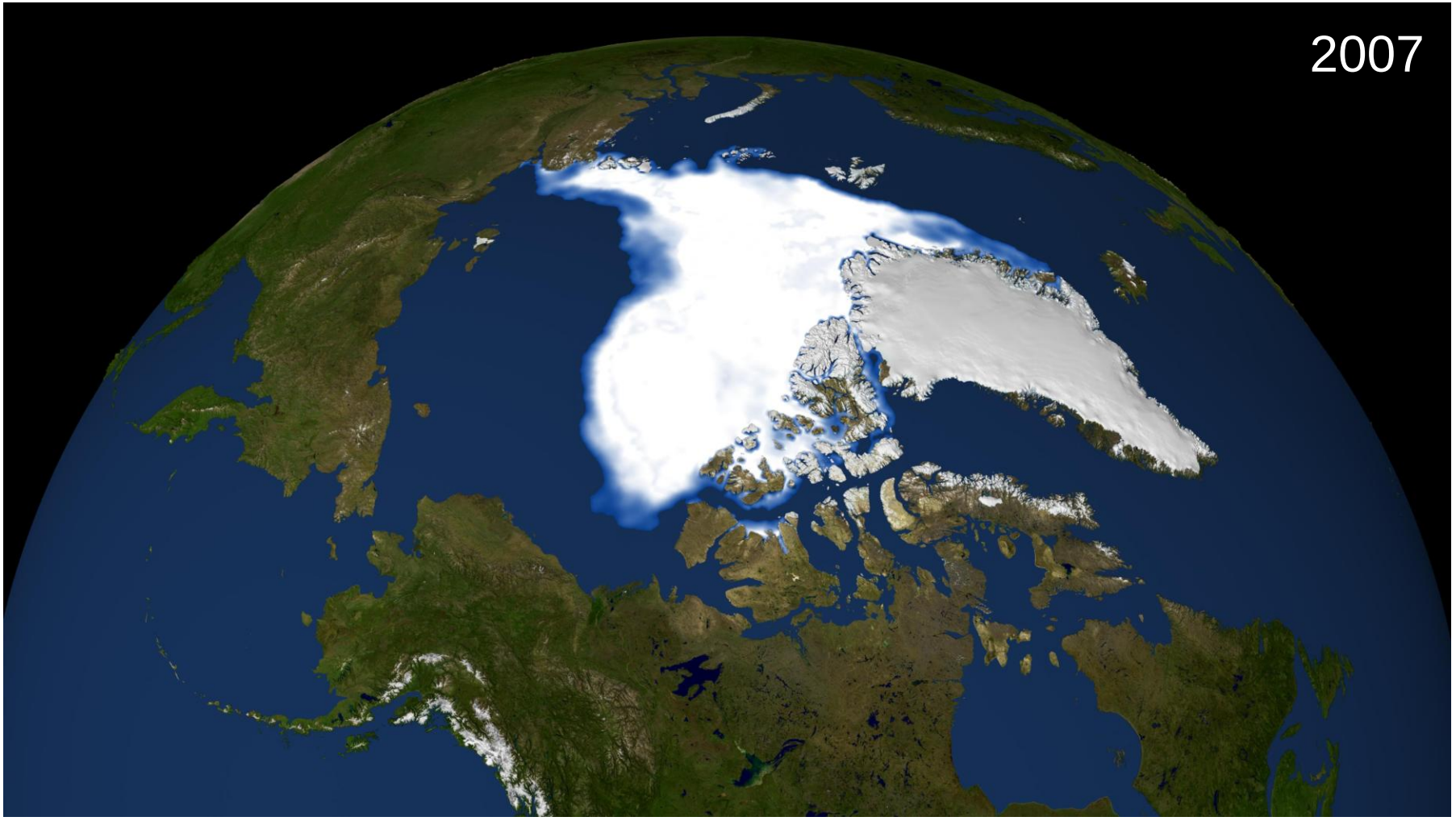
Foto: S. Rahmstorf

Loss of Arctic Sea Ice



Source: NASA

Loss of Arctic Sea Ice



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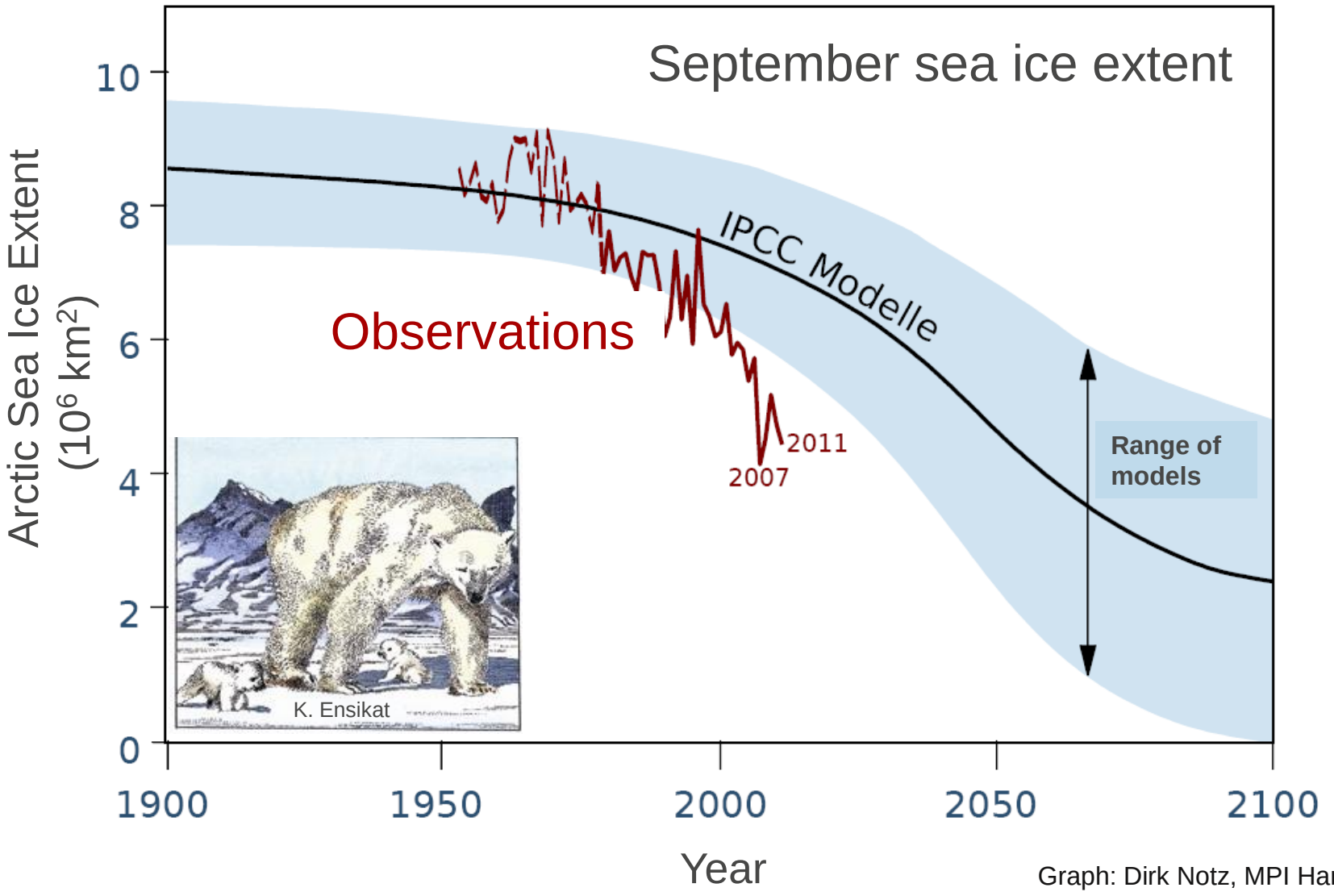
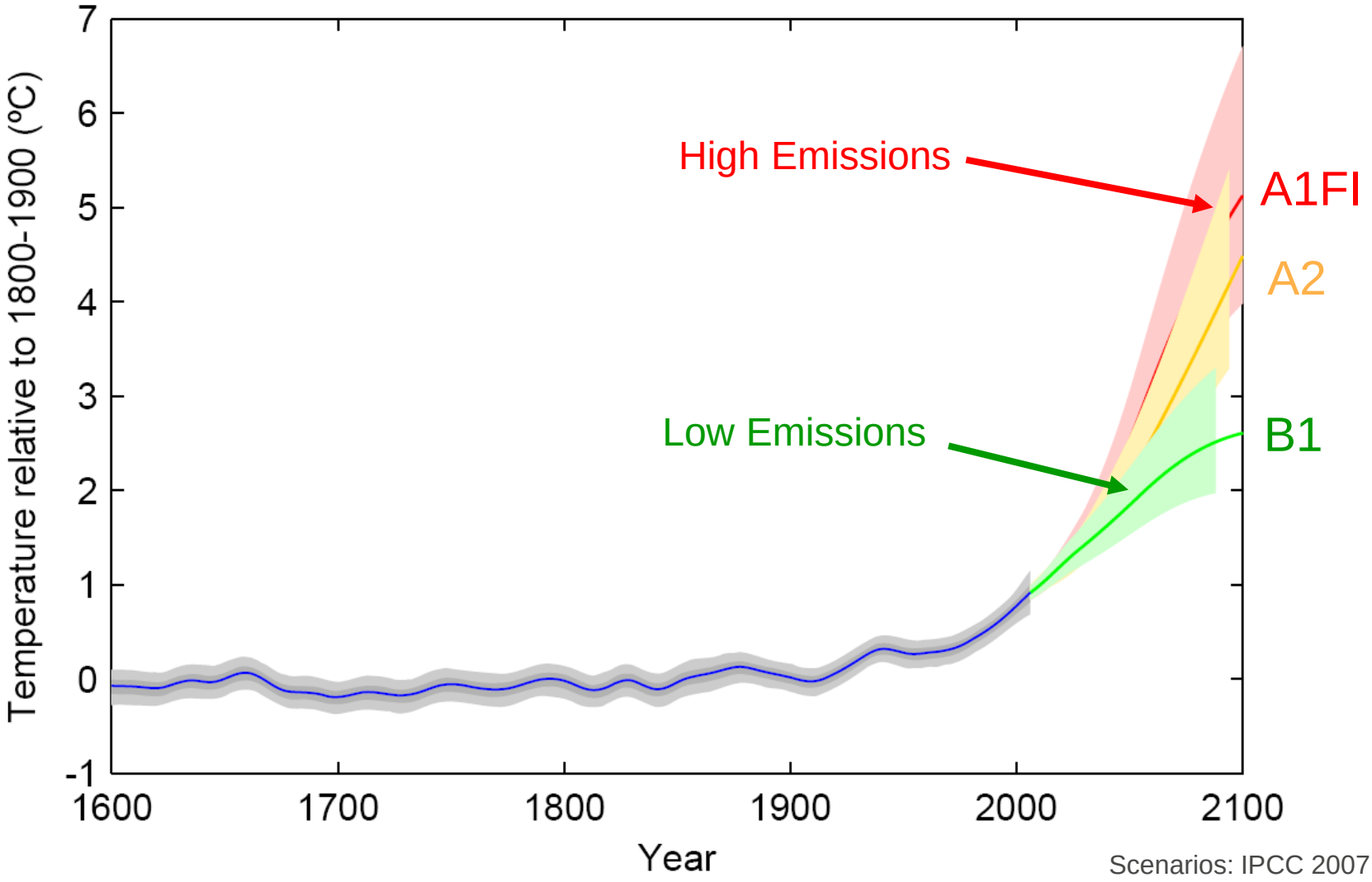
Loss of Arctic Sea Ice



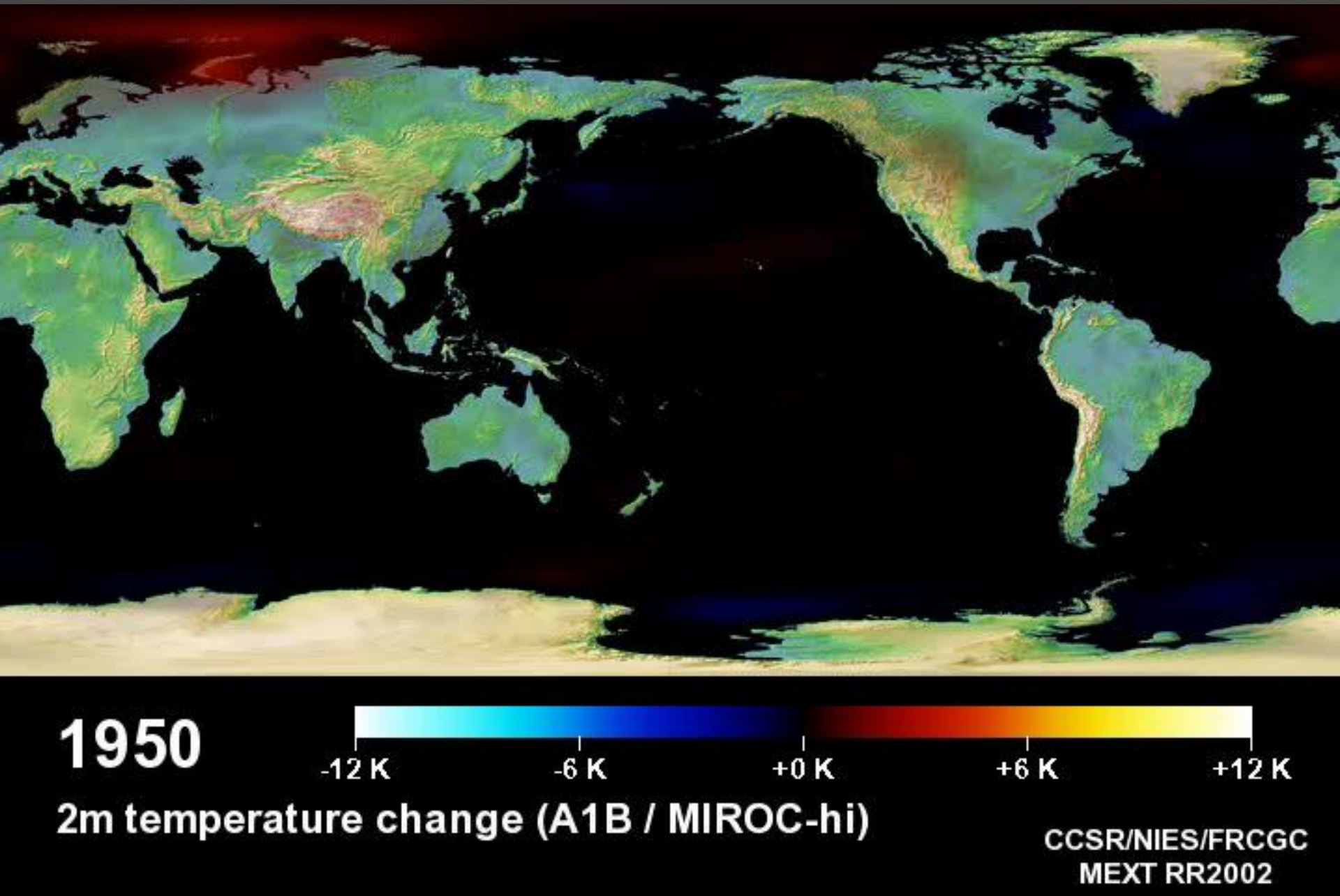
Graph: Dirk Notz, MPI Hamburg

The Next 100 Years



Scenarios: IPCC 2007
Past data: Mann et al. 2008

The Next 100 Years



Exercises for self study

1. Have a close look at the slide showing Earth‘s Energy Budget and understand how the budget adds up at the top of the atmosphere, within the atmosphere and at the Earth‘s surface.

2. What role does the greenhouse effect play for the climate on Venus?

3. CO2 is not the only greenhouse gas. Have a look at Fig. SPM.2 of the Summary of the IPCC 4th Assessment report: (http://www.ipcc.ch/publications_and_data/ar4/wg1/en/spm.html). Understand the contributions of different factors in driving modern climate change.

Exercises for Self Study

4. In addition to changes in the Earth‘s radiation balance, internal variability (El Niño – Southern Oscillation being the most prominent one) can also affect surface climate to some extent by accessing heat stored in the oceans. If global surface temperatures warm up due to heat released from the ocean, do you expect the ocean overall to warm or cool? How does that compare to what happens in modern global warming?

5. A little history: have a look at early scientific papers predicting greenhouse warming: Sawyer (Nature 1972) and Broecker (Science 1975). To what extent did they correctly predict what has happened since then?

6. When researching climate change issues on the internet, what criteria would you use to distinguish sound scientific information from the many agenda-driven „climate sceptics“ websites?

References

The illustrations by K. Ensikat are from the book: Wolken, Wind & Wetter, by Stefan Rahmstorf, DVA (2011)

Basic reading:

- Archer, D, Rahmstorf, S (2010) The Climate Crisis. Cambridge University Press.
- WBGU (2011) World in Transition: A Social Contract for Sustainability, chapter 1. Berlin. www.wbgu.de

Sources used:

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