



A Century of Arctic Climate Change: An Abisko Perspective



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Updated: 9 December 2019



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200 km north of the Arctic Circle





Abisko Scientific Research Station

Unique environmental record-meteorological monitoring (1913 to present)



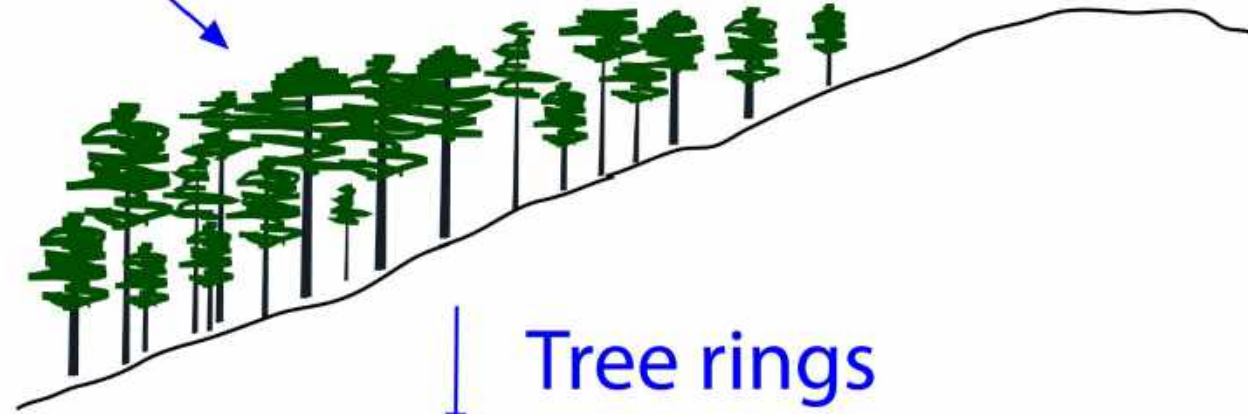
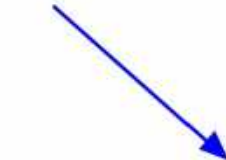
Aerial Photo: Nils Åke Andersson, others by Keith Larson

How do we know about the past climate before we built weather stations?

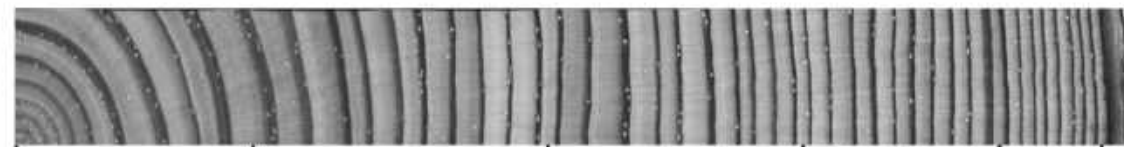


Weather and climate is written in wood

Climate



Tree rings

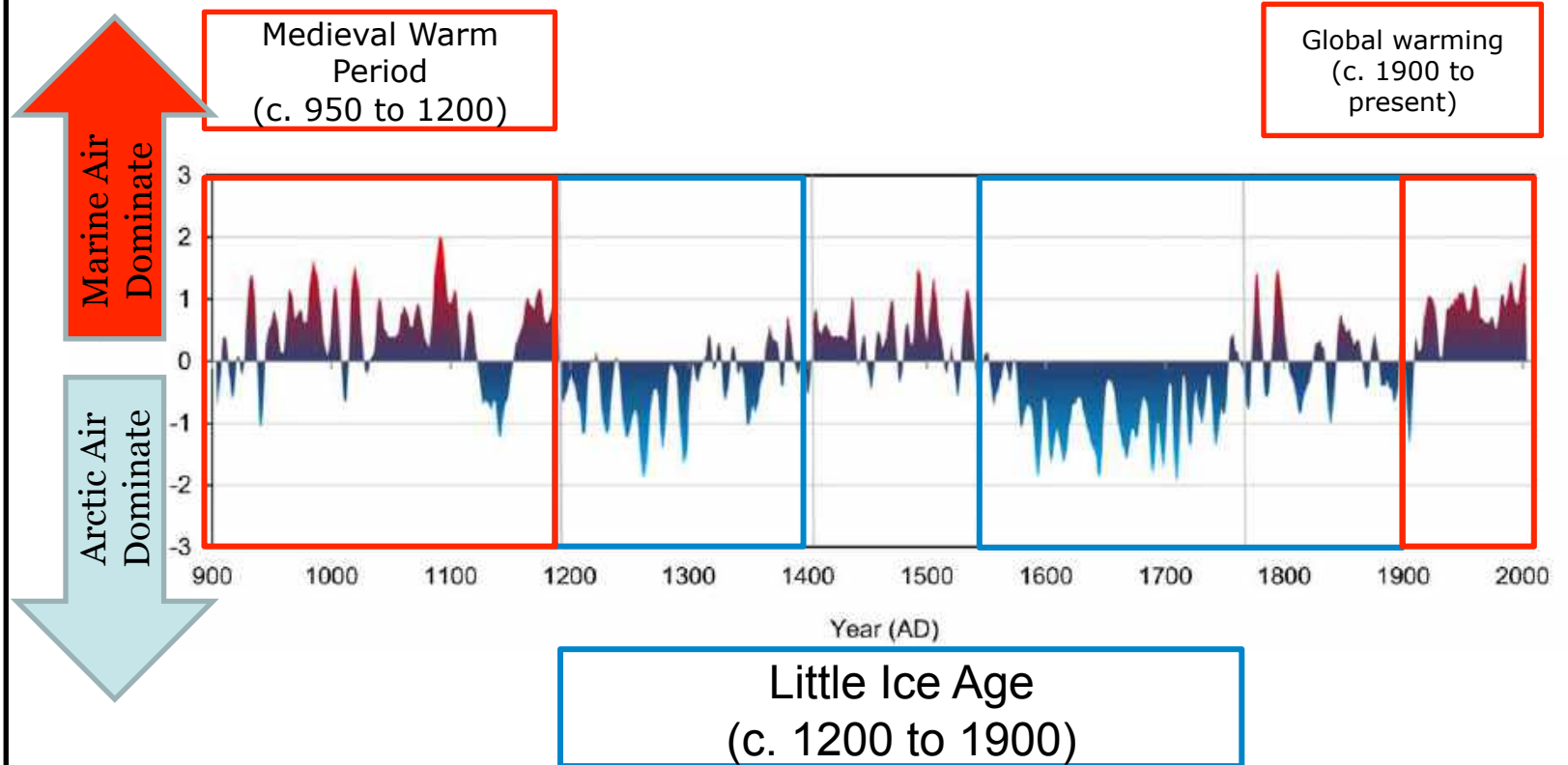


1960 1970 1980 1990 2000 2008

How far back can we go?

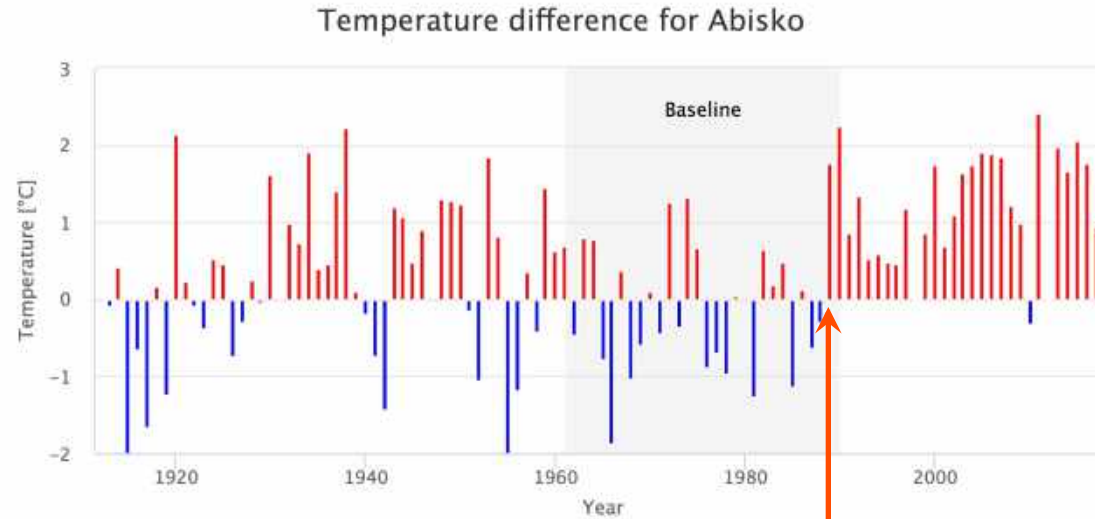


Abisko long-term climate regimes



No evidence for globally coherent warm and cold periods during the preindustrial era

Arctic warming



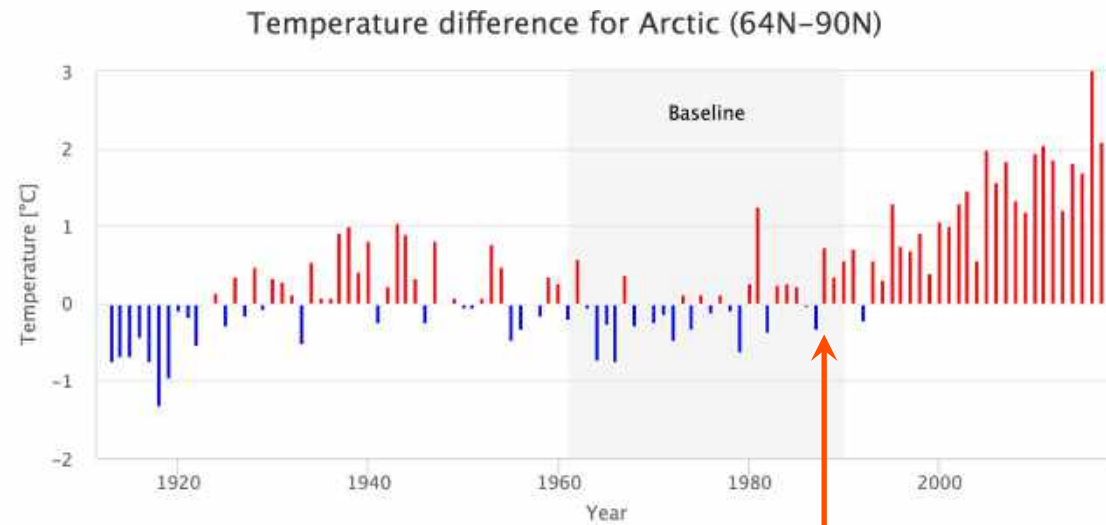
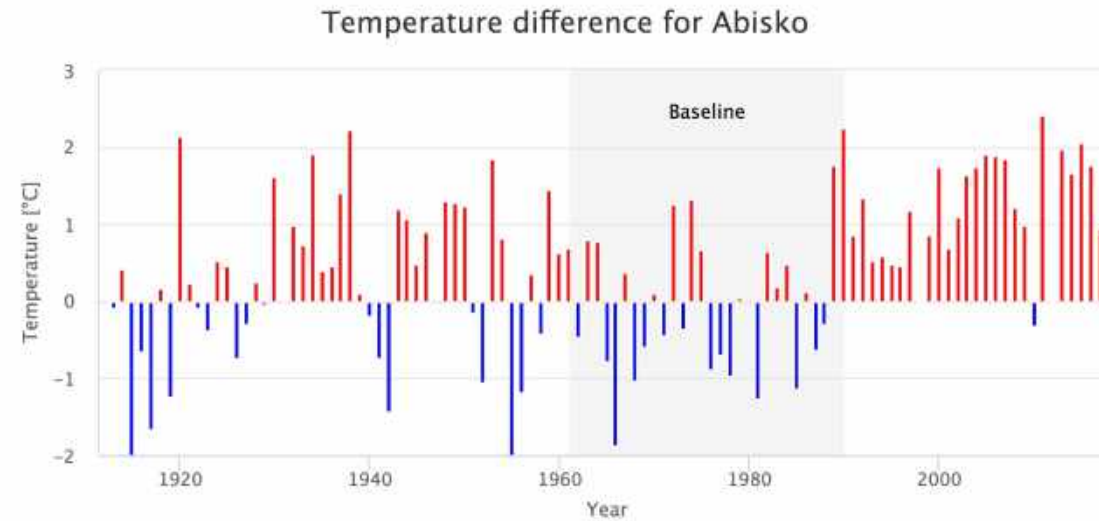
Abisko temperatures

1989

Abisko temperatures have risen 1.7°C since 1913



Arctic Warming



1986

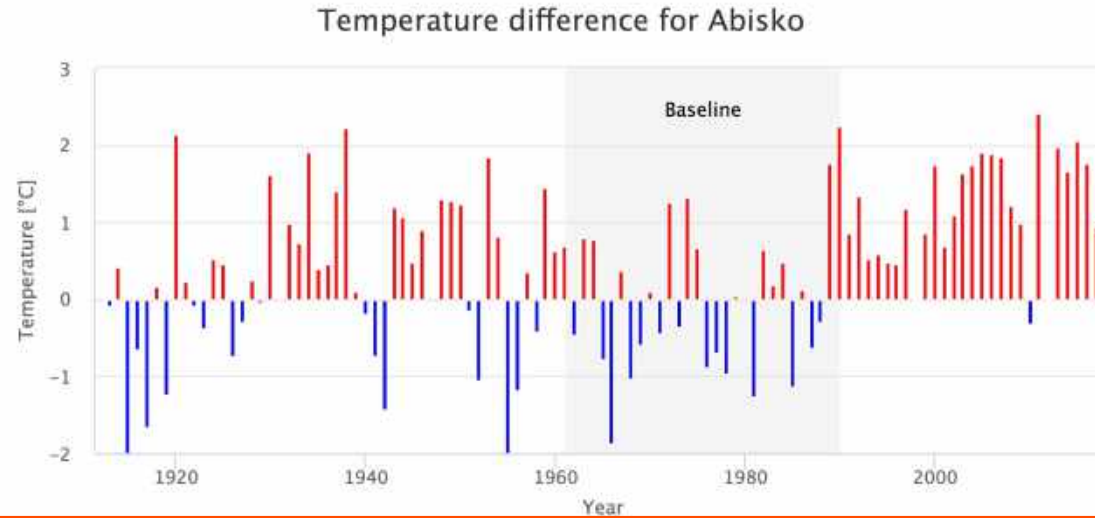
ANS (unpublished data 2018); GISTEMP (v4, 2018)



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Arctic amplification



Arctic temperatures are rising at twice the global rate





Torneträsk Ice Cover – Sweden's Sea Ice



Long-term reduction of over 44 days per year

ANS (unpublished data 2018)

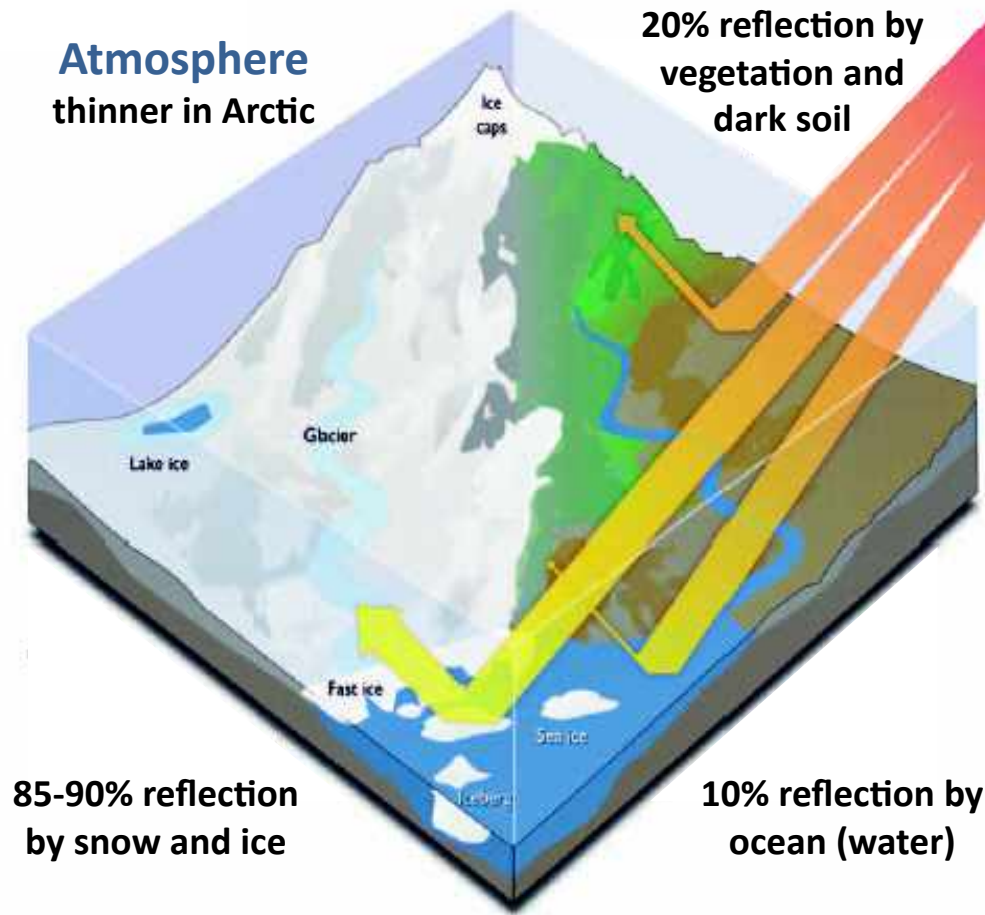


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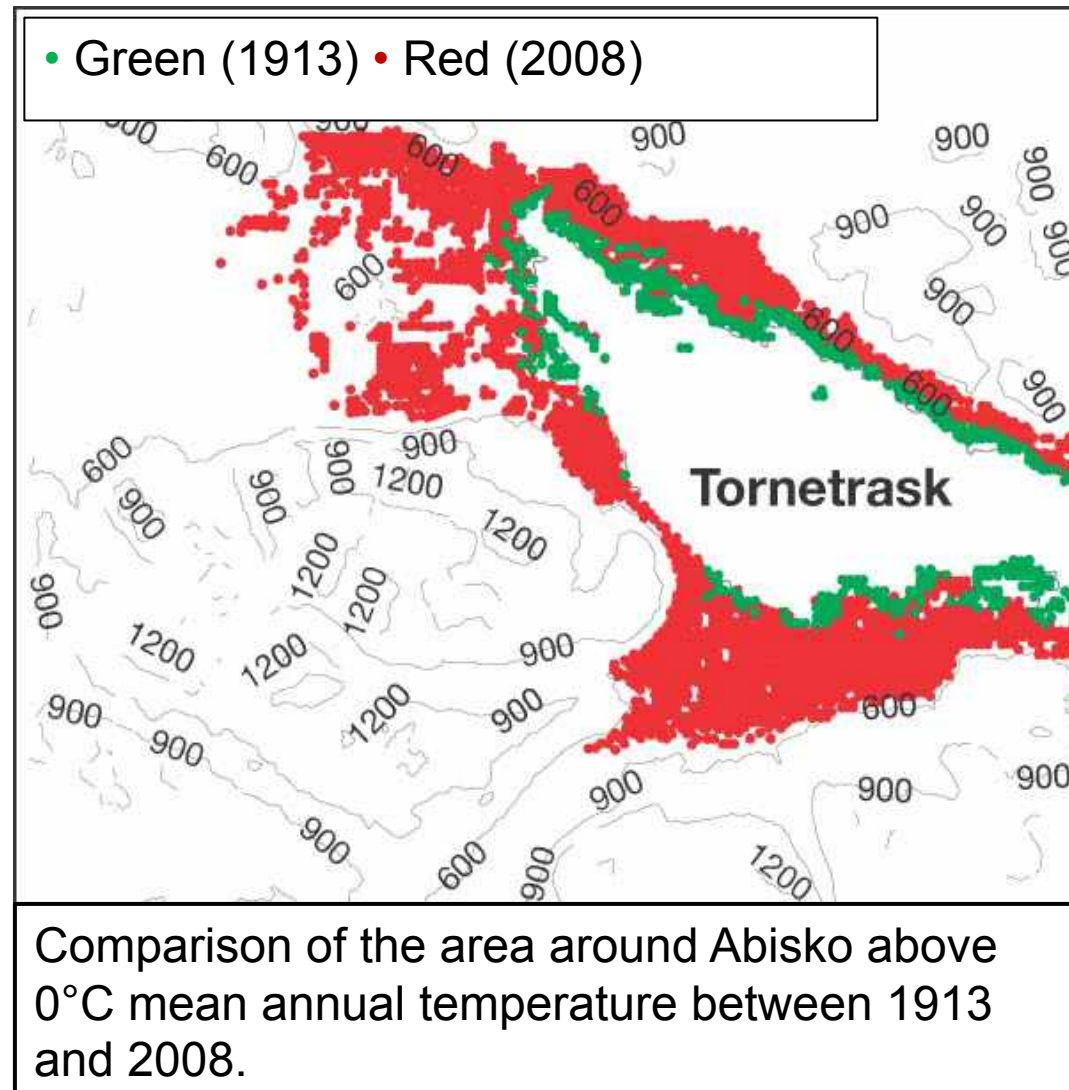
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Accelerated warming of the Arctic

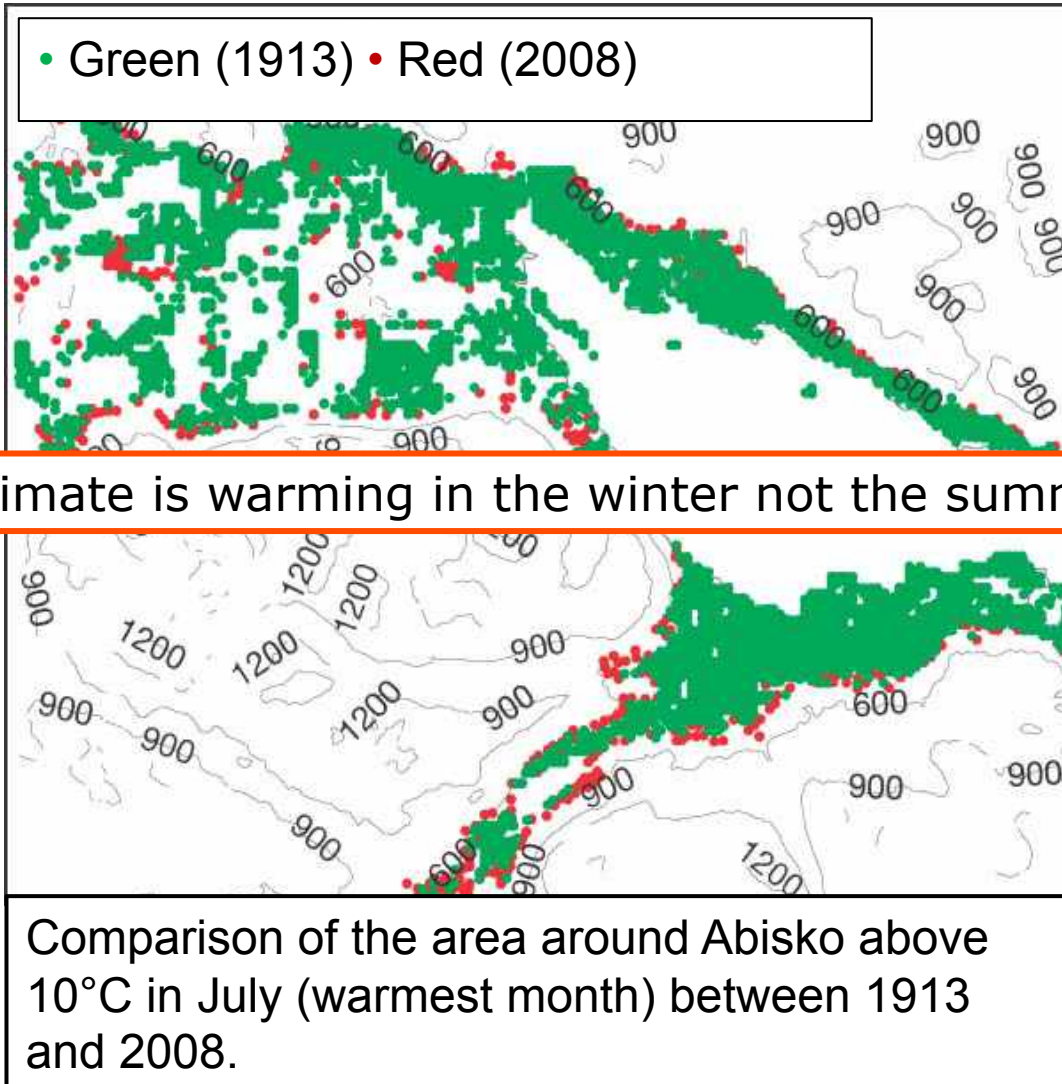


- Melting of snow and ice
- greater absorption of heat
- warming of thinner atmosphere
- Positive feedback!

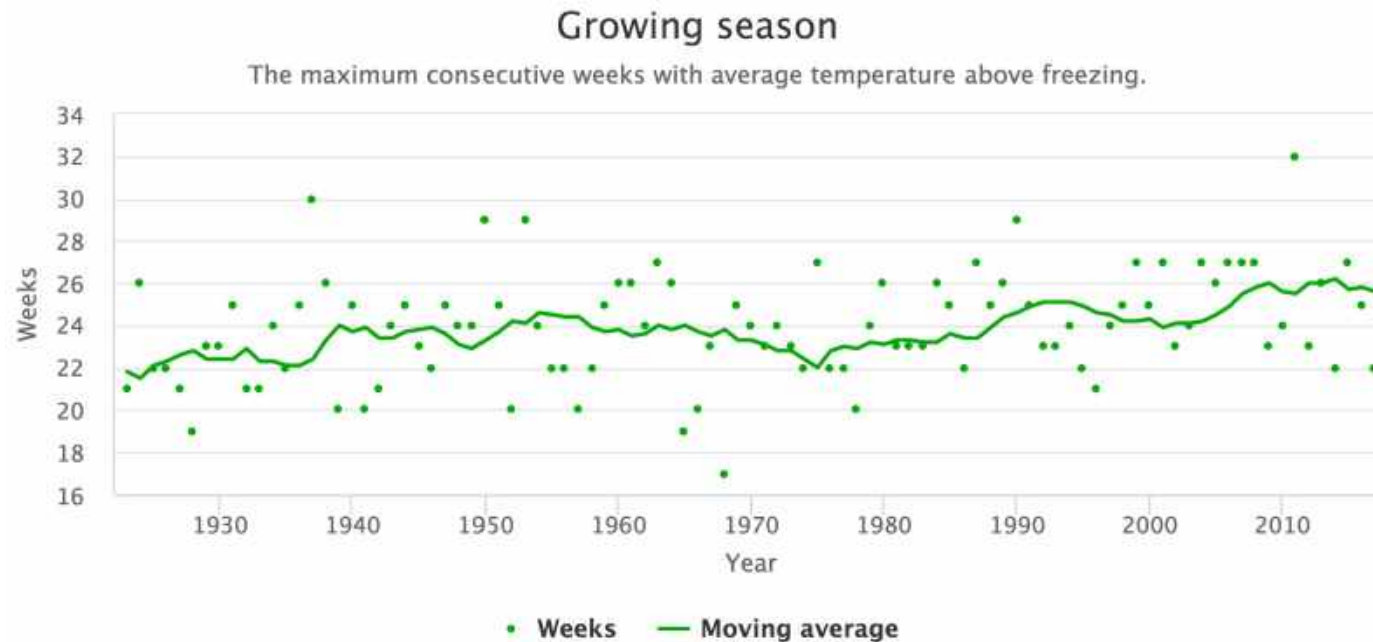
When is the warming occurring?



Warming across the year?



Growing season change from 1913 to 2017



4 weeks longer over the last 100 years

* Mean weekly temperature above 0°C (Körner 2012)

ANS (unpublished data 2018)

Species shifting their distributions

Approximately 230 m, 30 m elev.

21 February 1925



21 February 2017

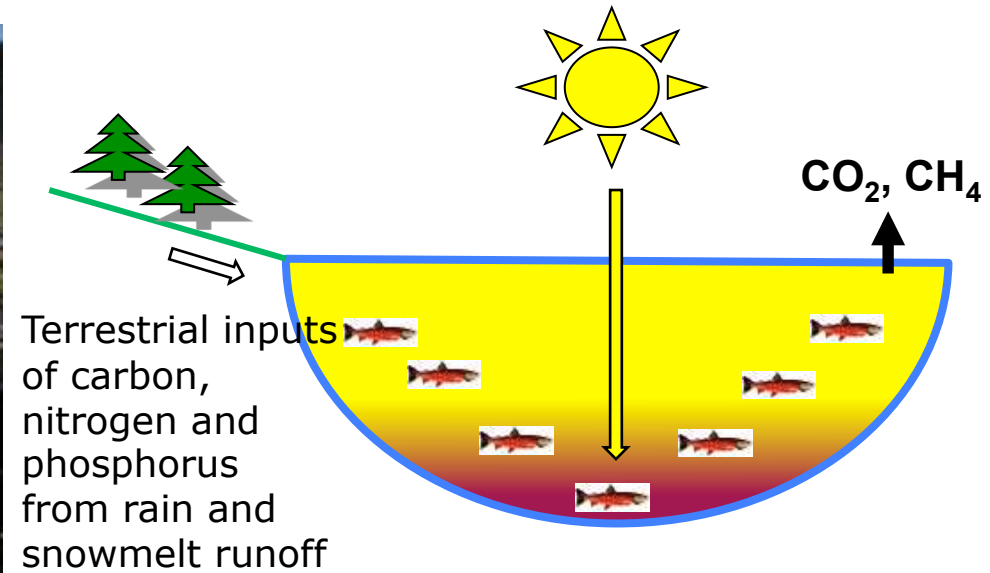


How do climate changes impacts?

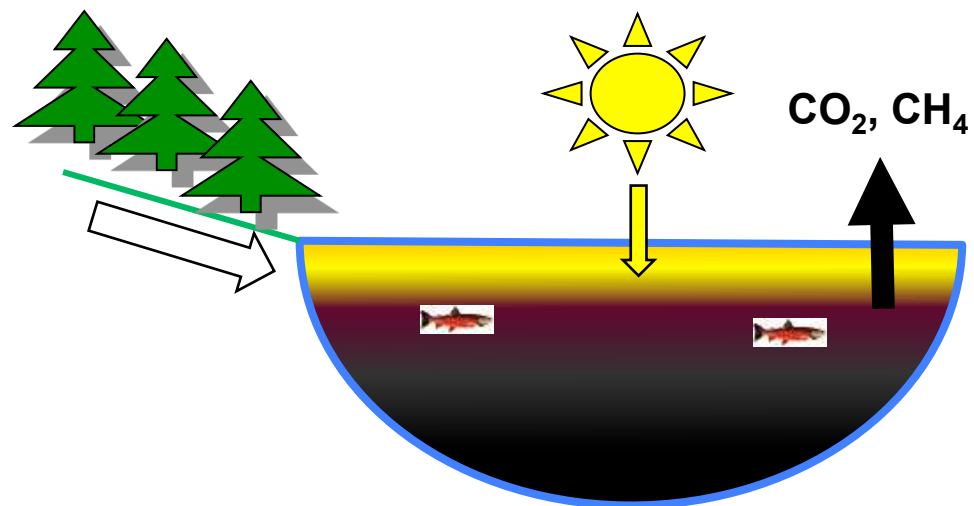
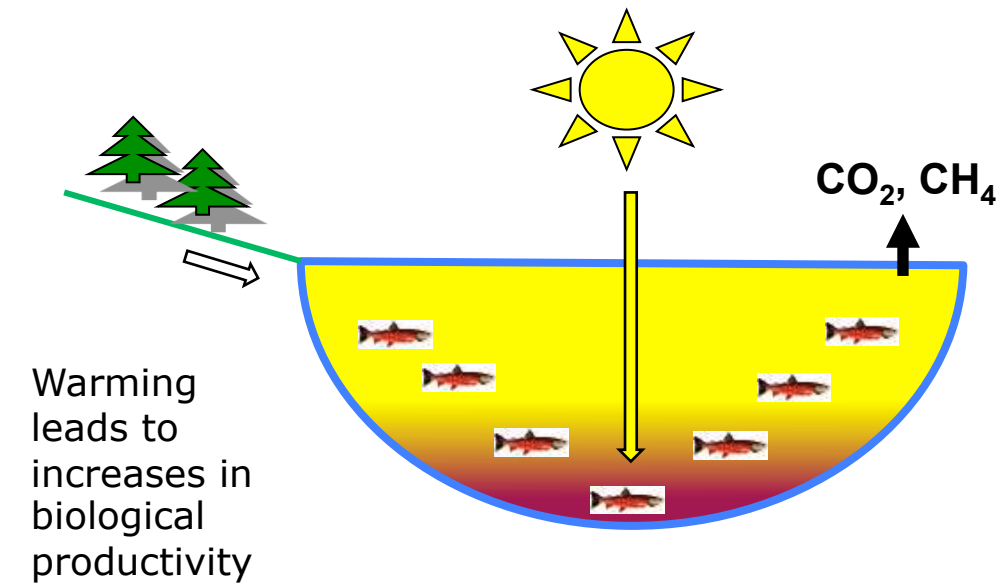
- natural climate gradients
 - temperature
 - precipitation
- experiments



Case Study 1: Climate change induced regime shifts in northern lake ecosystems



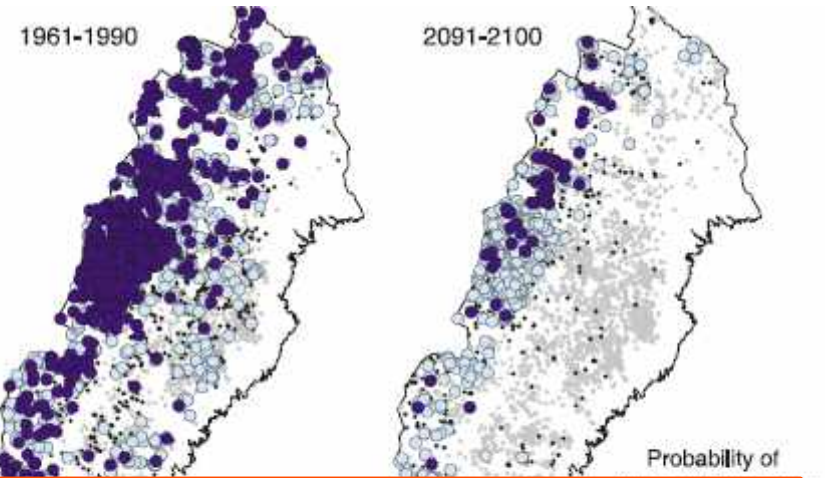
Results: Climate change induced regime shifts in northern lake ecosystems



Results: Warming leads to changes in fish communities



Arctic Char
Röding
(*Salvelinus alpinus*)



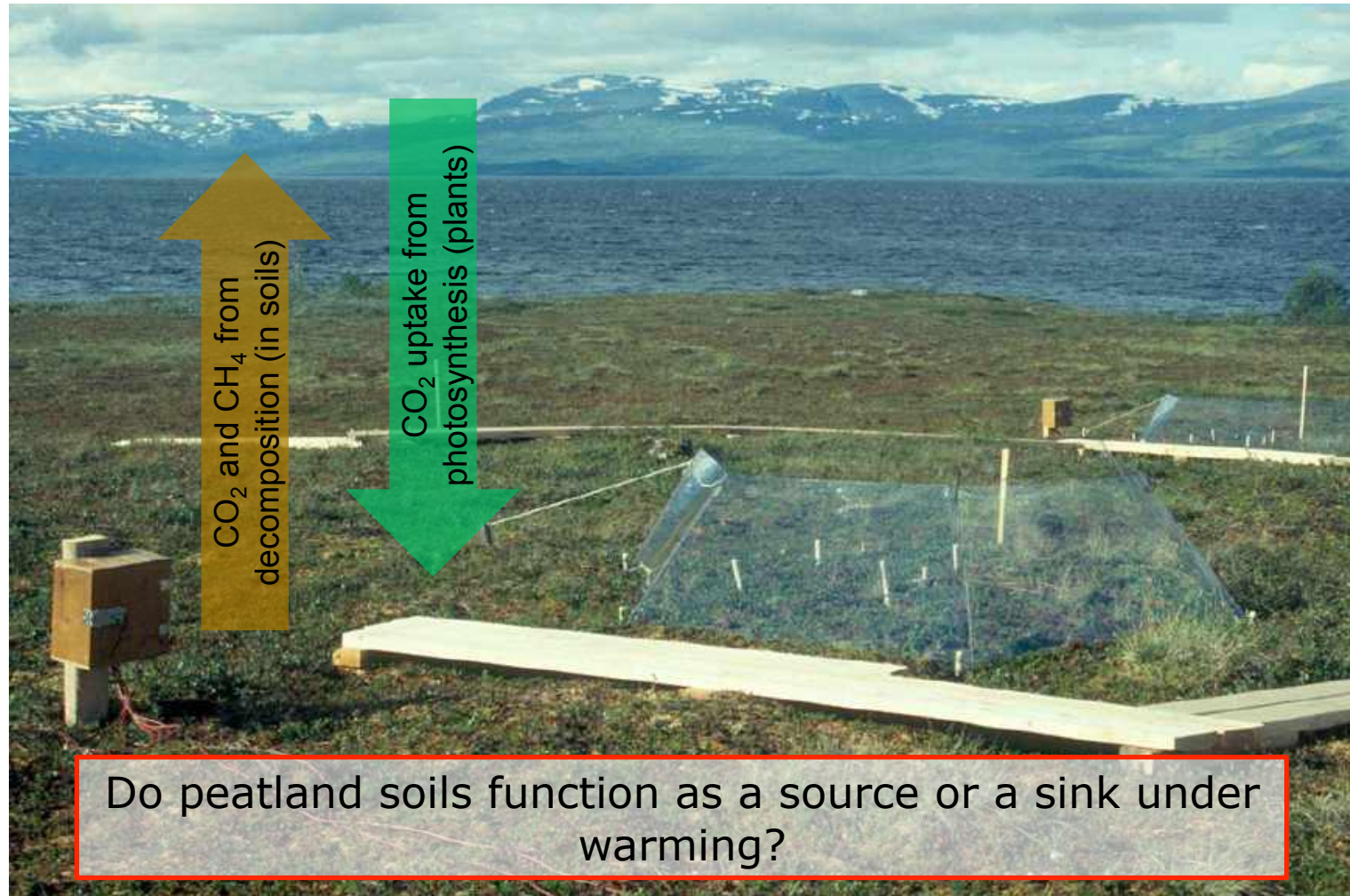
Arctic char predicted to lose 73% of its range by 2100



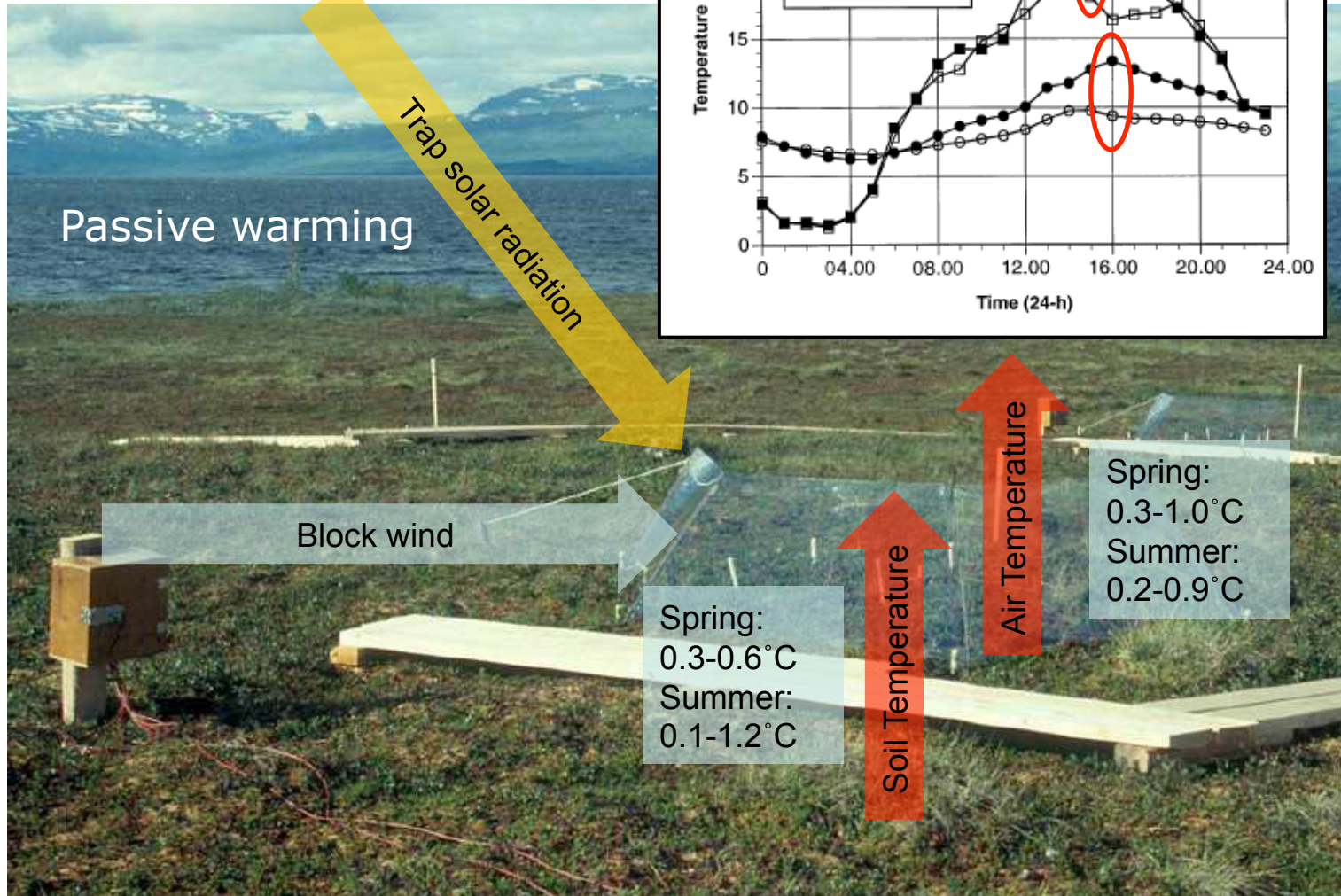
Northern Pike
Gädda
(*Esox lucius*)



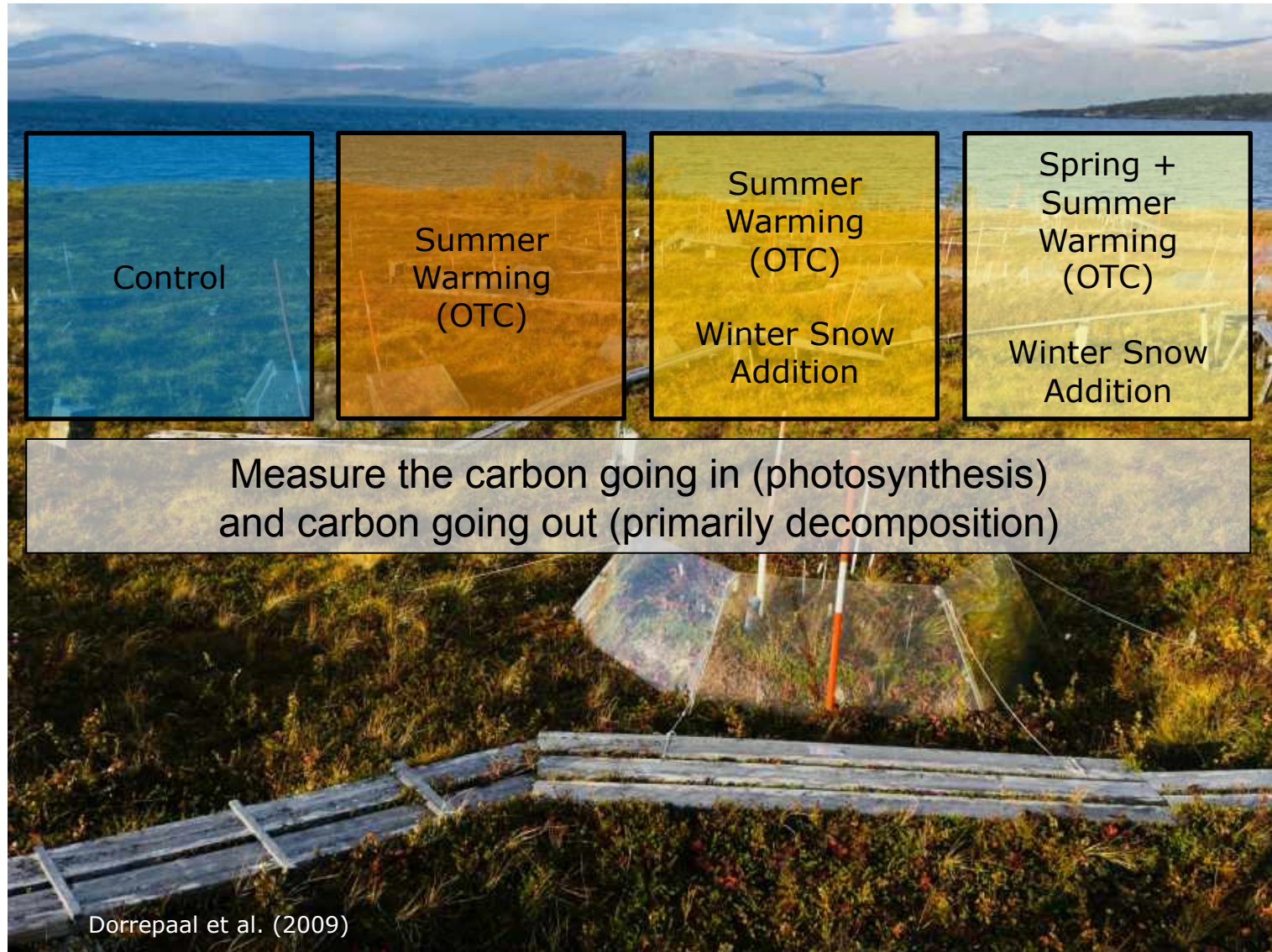
Experiment Study 1: How does increasing temperatures effect carbon emissions?



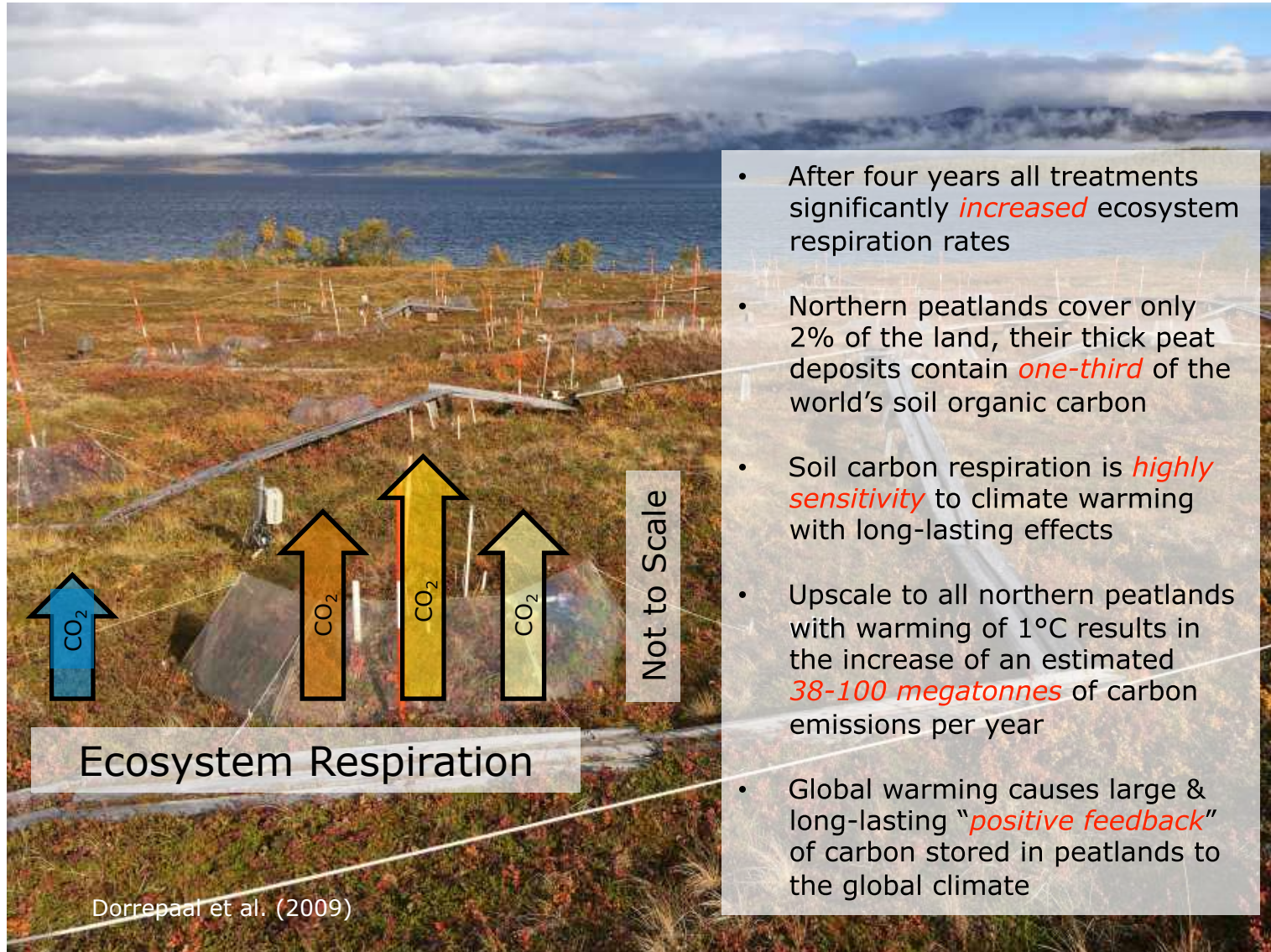
How do open-top chambers work?



Experimental design



Results: Increased net ecosystem respiration



- After four years all treatments significantly *increased* ecosystem respiration rates
- Northern peatlands cover only 2% of the land, their thick peat deposits contain *one-third* of the world's soil organic carbon
- Soil carbon respiration is *highly sensitivity* to climate warming with long-lasting effects
- Upscale to all northern peatlands with warming of 1°C results in the increase of an estimated *38-100 megatonnes* of carbon emissions per year
- Global warming causes large & long-lasting "*positive feedback*" of carbon stored in peatlands to the global climate

Experiment Study 2: Effects of increasing snow depth on permafrost

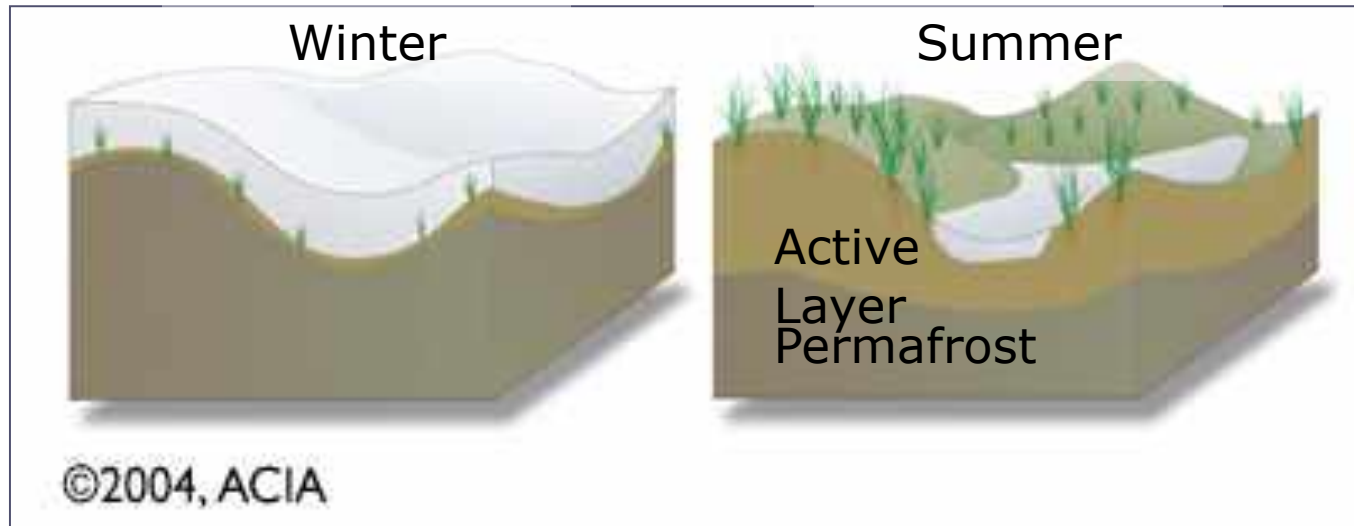
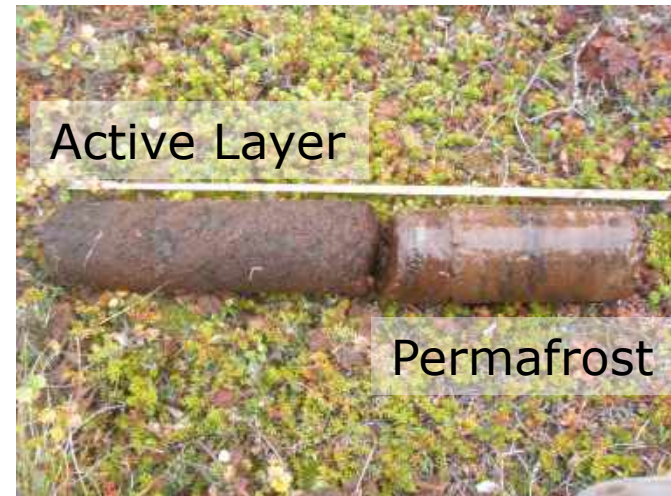


Permafrost: Earth material that remains at or below 0°C for at least 2 consecutive years

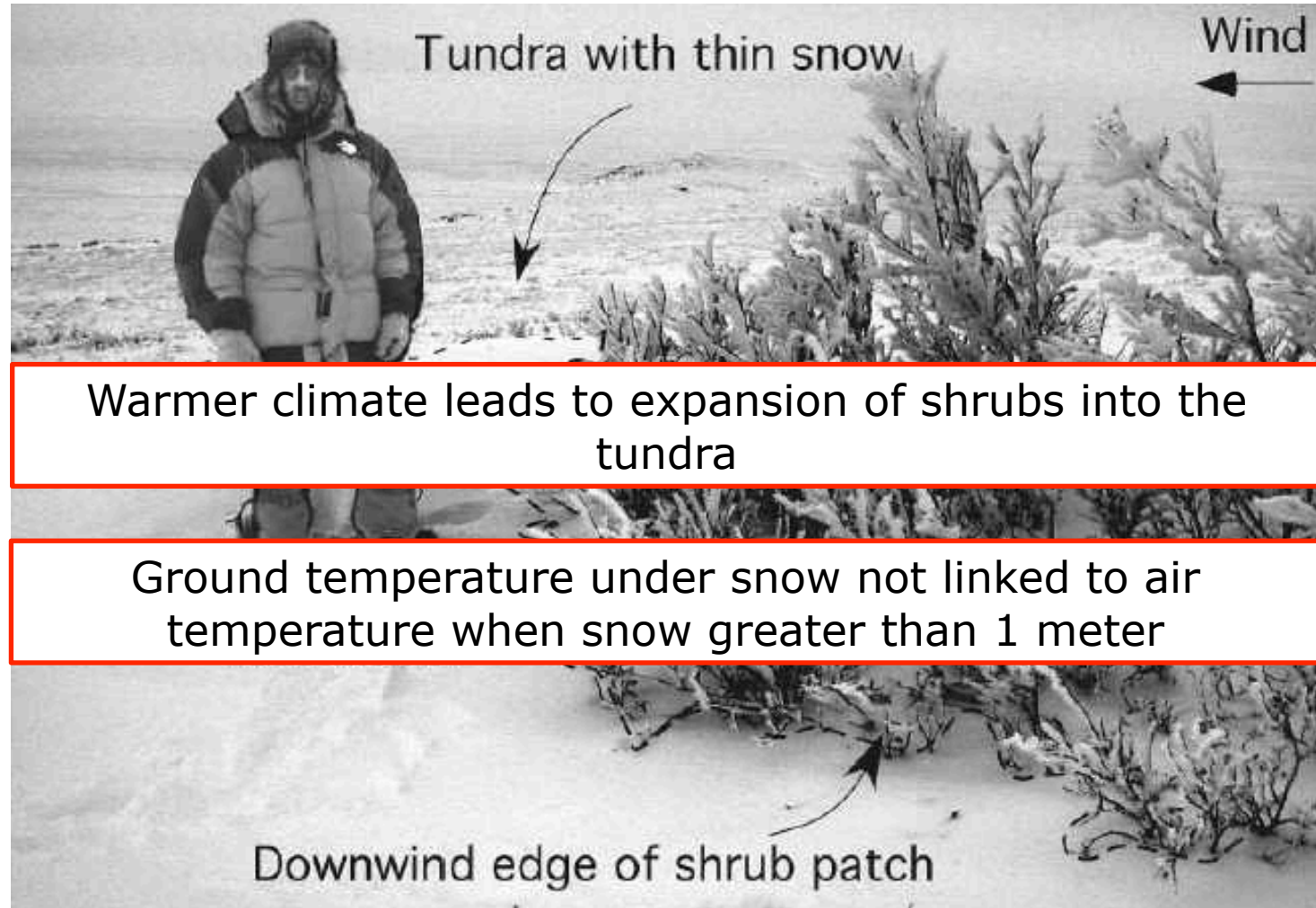
Aerial view of permafrost mire



Active layer: the top layer of permafrost that thaws each year during the warm season and freezes again in winter



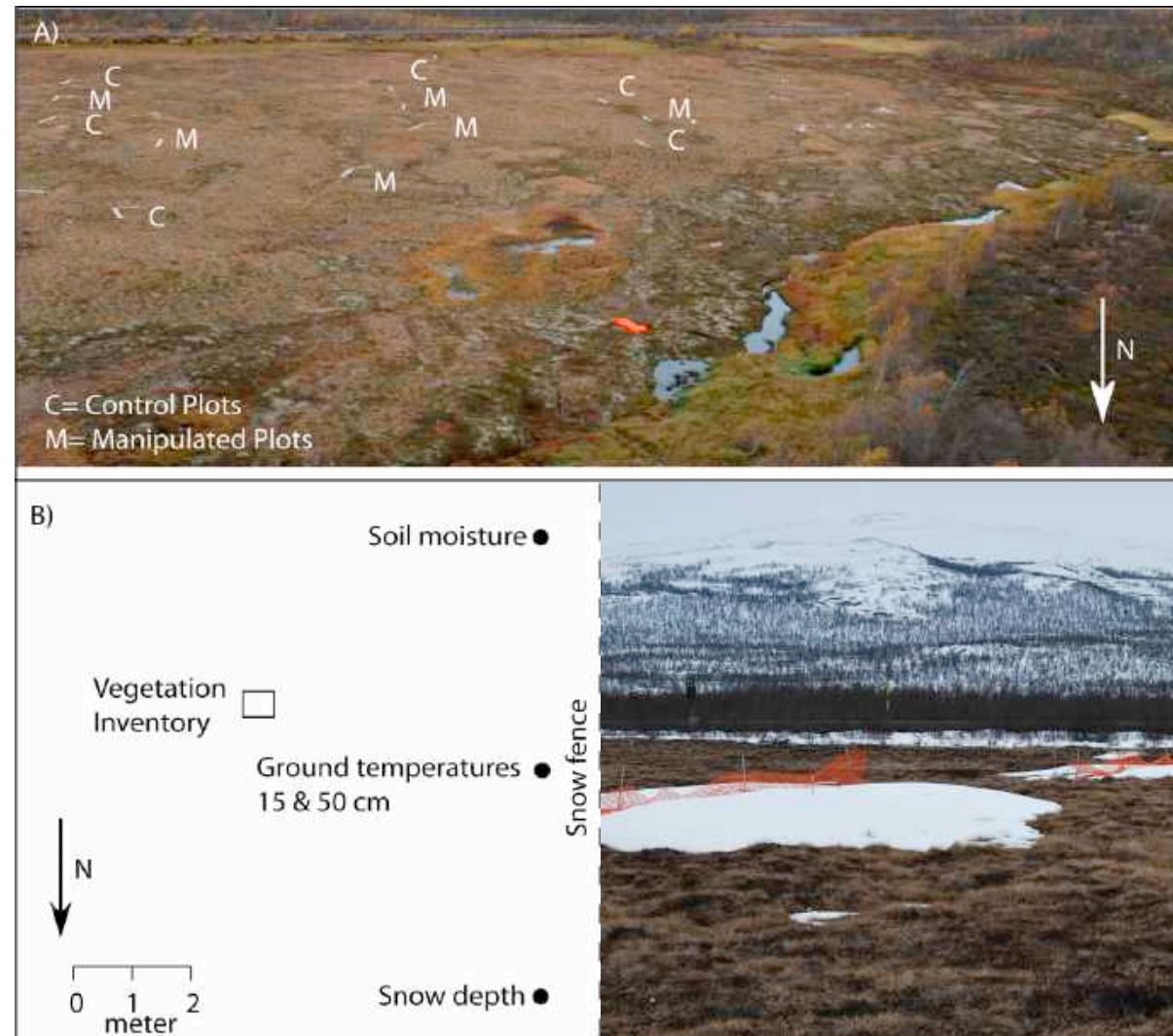
Warming increases biological productivity



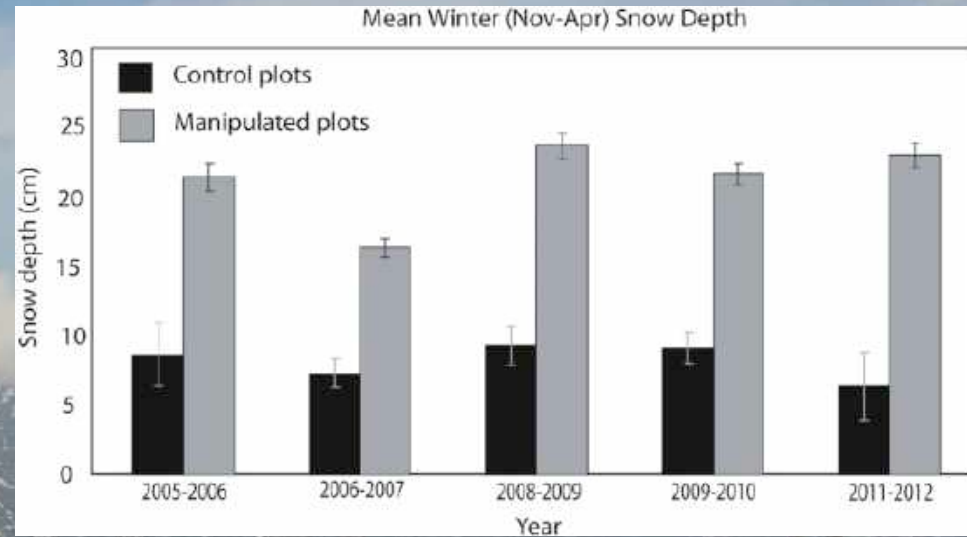
Warmer climate leads to expansion of shrubs into the tundra

Ground temperature under snow not linked to air temperature when snow greater than 1 meter

Snow fence experimental design

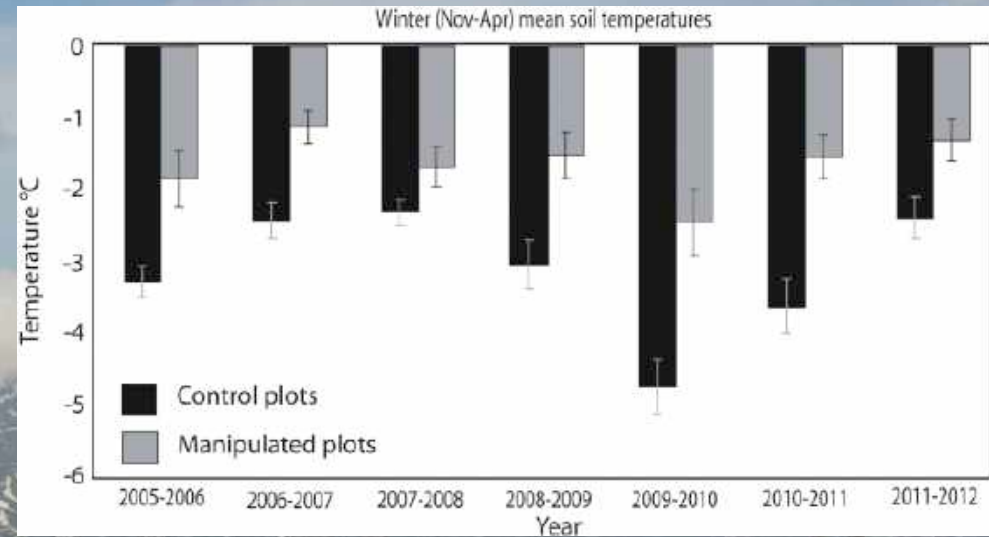


Snow depth increases



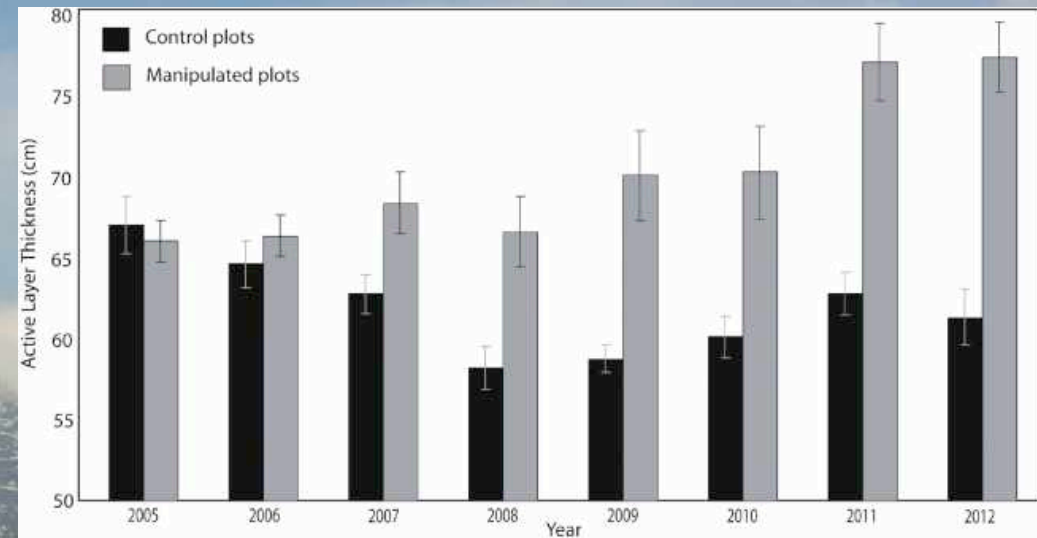
Johansson et al. (2013)

Below ground temperatures decreases

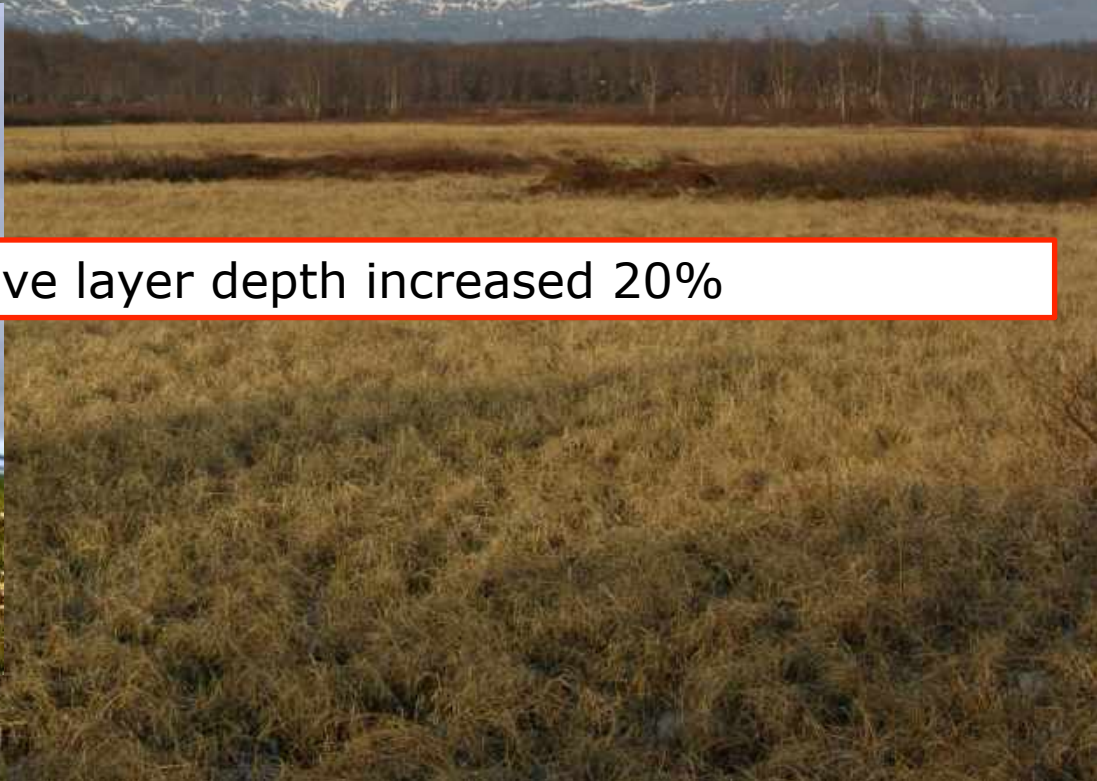


Below ground temperatures increased 1.5 C

Active layer depth increases

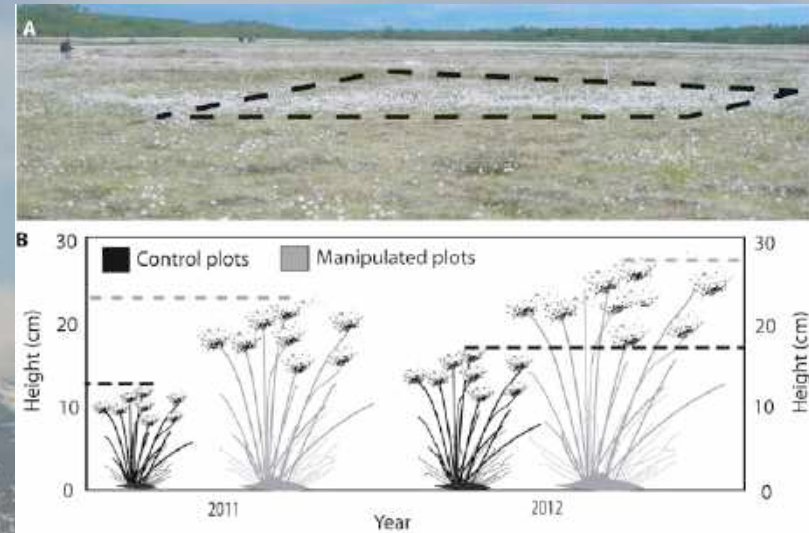


Active layer depth increased 20%



Johansson et al. (2013)

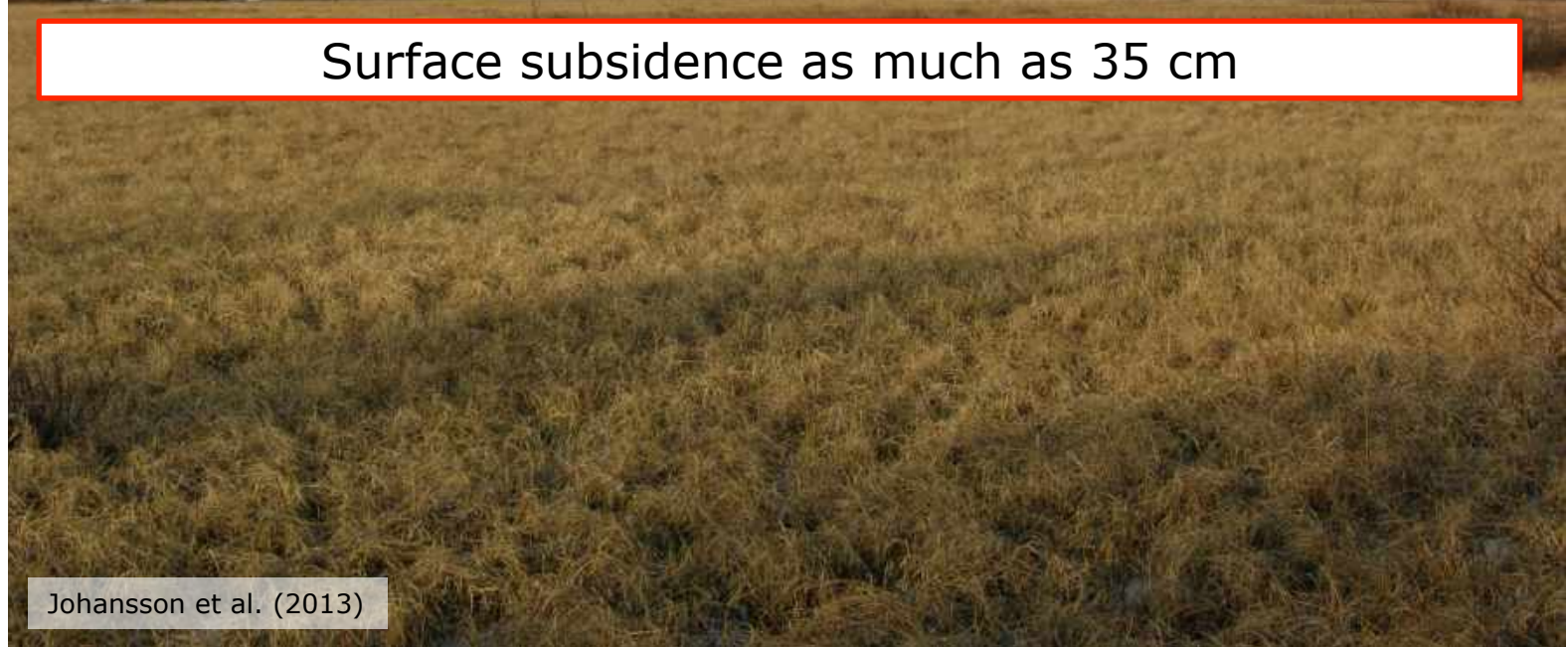
Increasing biological productivity



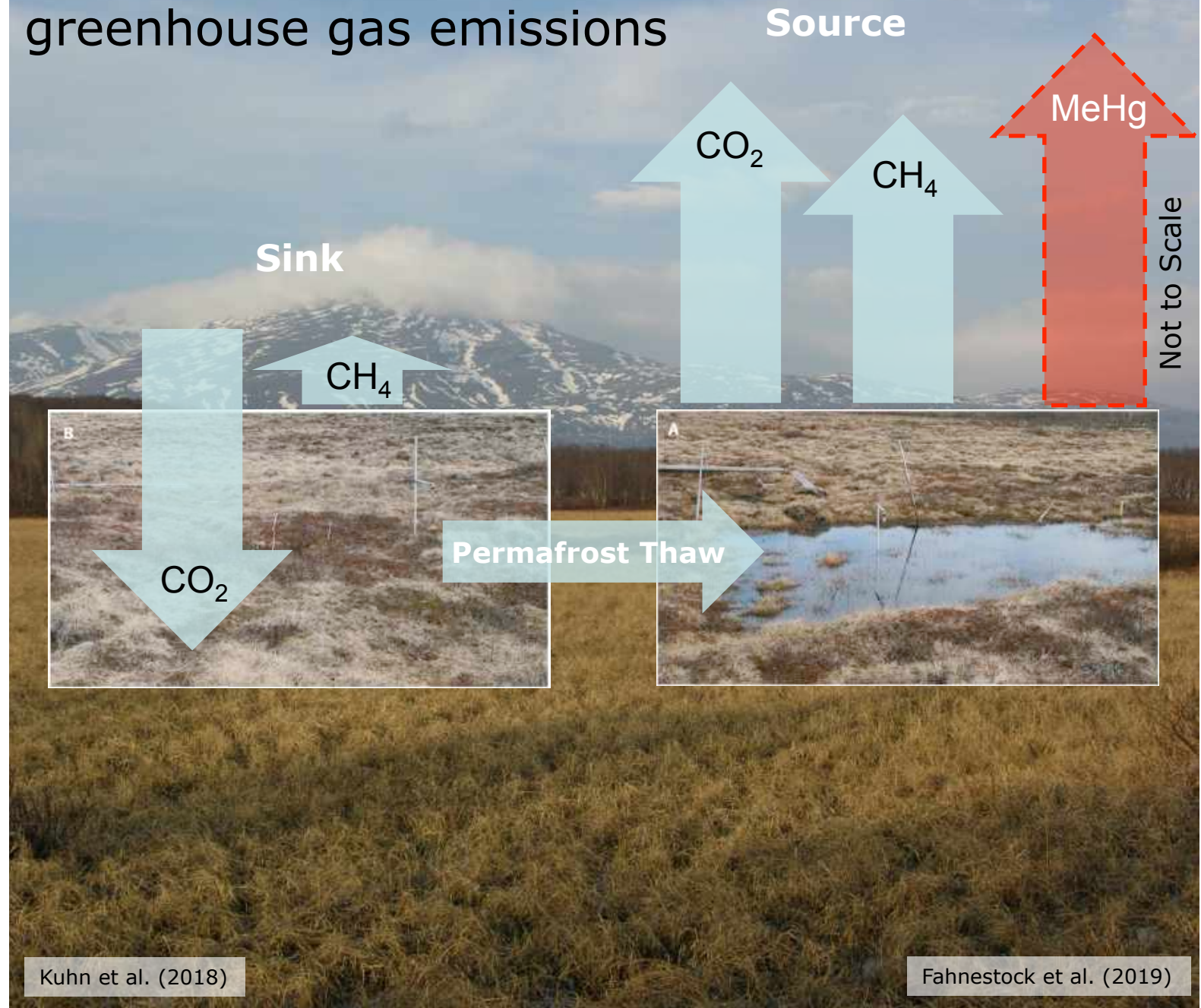
Surface subsidence leads to thaw ponds



Surface subsidence as much as 35 cm



Thaw ponds lead to significant changes in greenhouse gas emissions

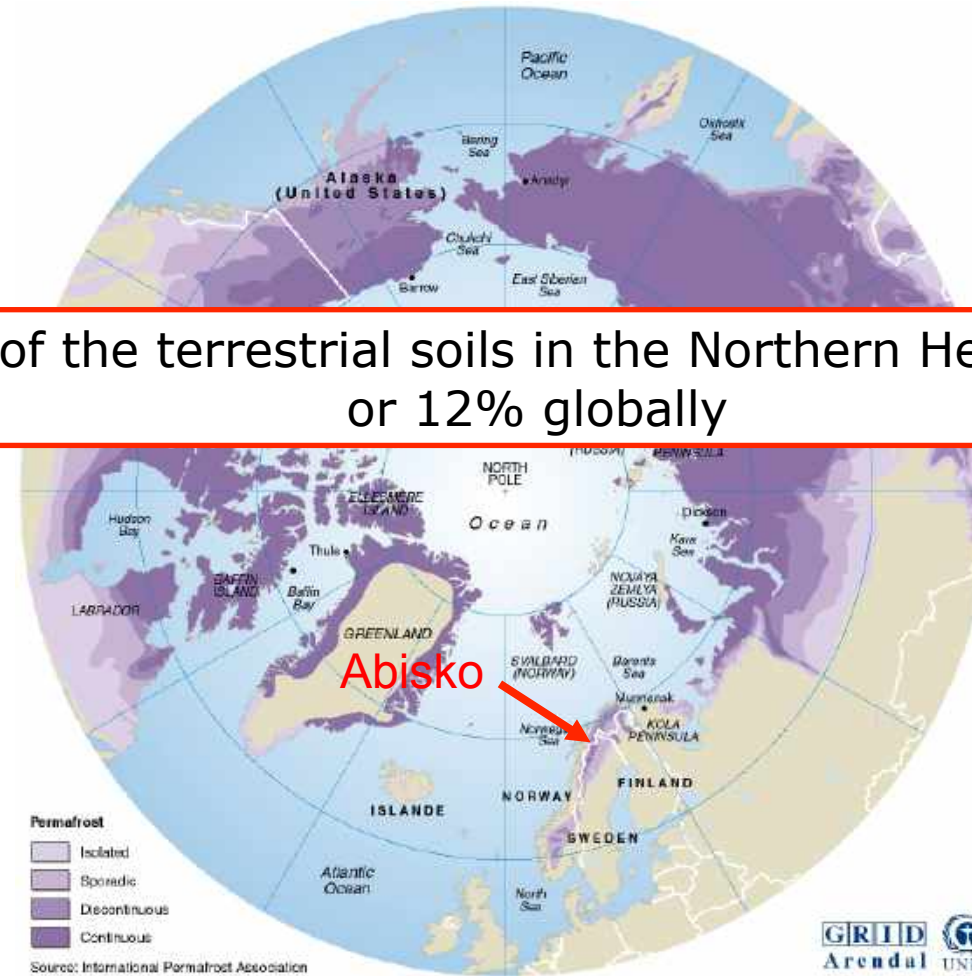


Kuhn et al. (2018)


Fahnestock et al. (2019)

Feedbacks from the Arctic: Permafrost

24% of the terrestrial soils in the Northern Hemisphere
or 12% globally



Total amount of soil carbon in permafrost regions

- 
- Approx. **1,035 billion tons** in top 3 m
 - **50%** of global soil organic C pool
 - Approx. **twice** the amount of C in atmosphere
 - Forecast: **13-28%** will thaw in Arctic by 2050
 - Slow climate feedbacks **not** incorporated in the global climate models

Permafrost crater in Siberia

Batagaika crater



Permafrost crater in Siberia

Batagaika crater



The Arctic region gives off more heat to space than it absorbs from outside, which helps cool the planet.

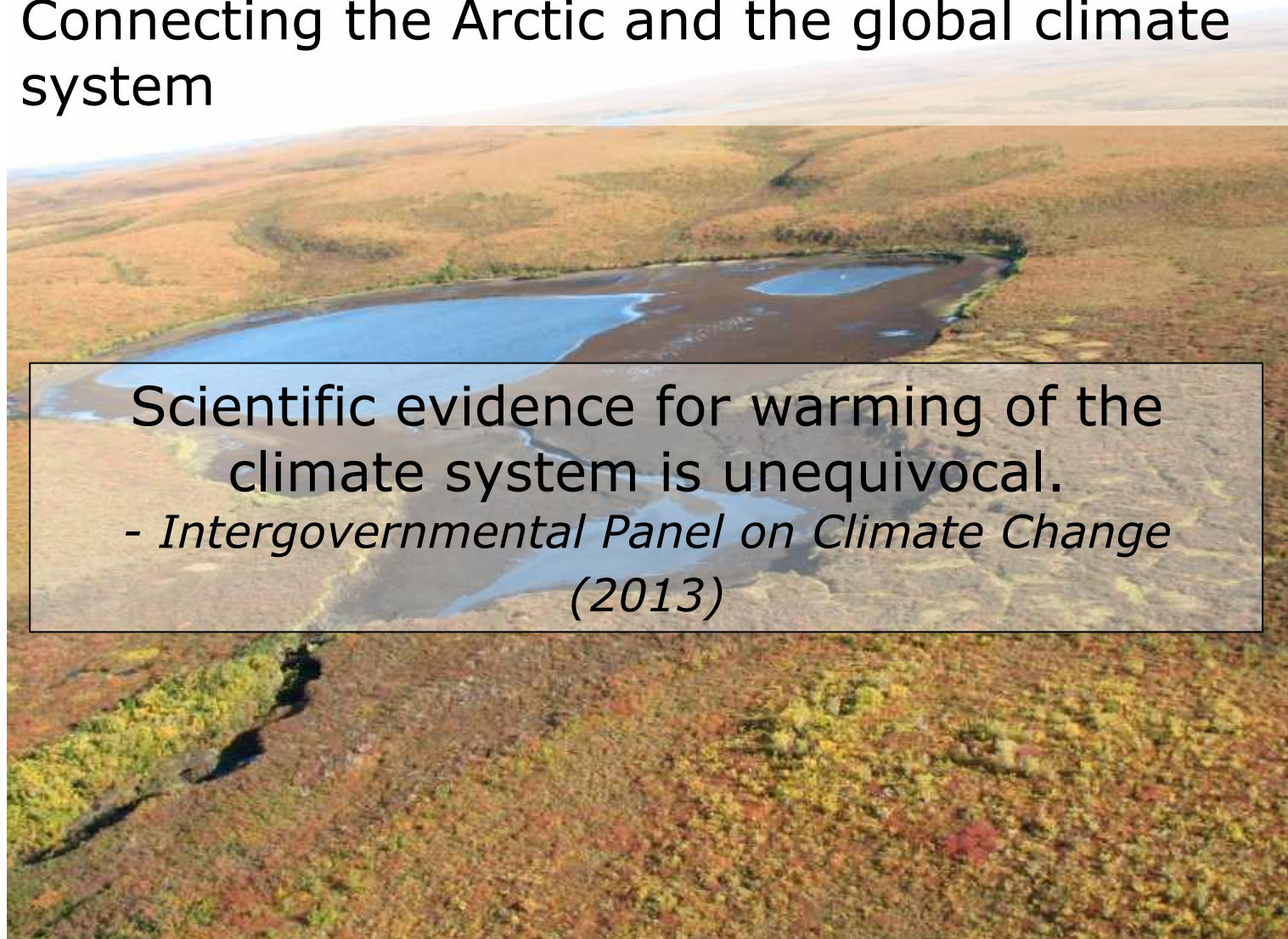
The Arctic functions as the earth's cooling system

Changes in the Arctic climate are significant globally!





Connecting the Arctic and the global climate system



Scientific evidence for warming of the climate system is unequivocal.
- *Intergovernmental Panel on Climate Change (2013)*

Carbon Dioxide

↑ 411.6
Parts per million

Global Temperature

↑ 1.1 °C
Since 1880

Arctic Temperature

↑ 1.8 °C
Last 30 years

Arctic Ice Minimum

↓ 12.8
Percent per decade

Ice Sheets

↓ 413.0
Gigatonnes per year

Sea Level

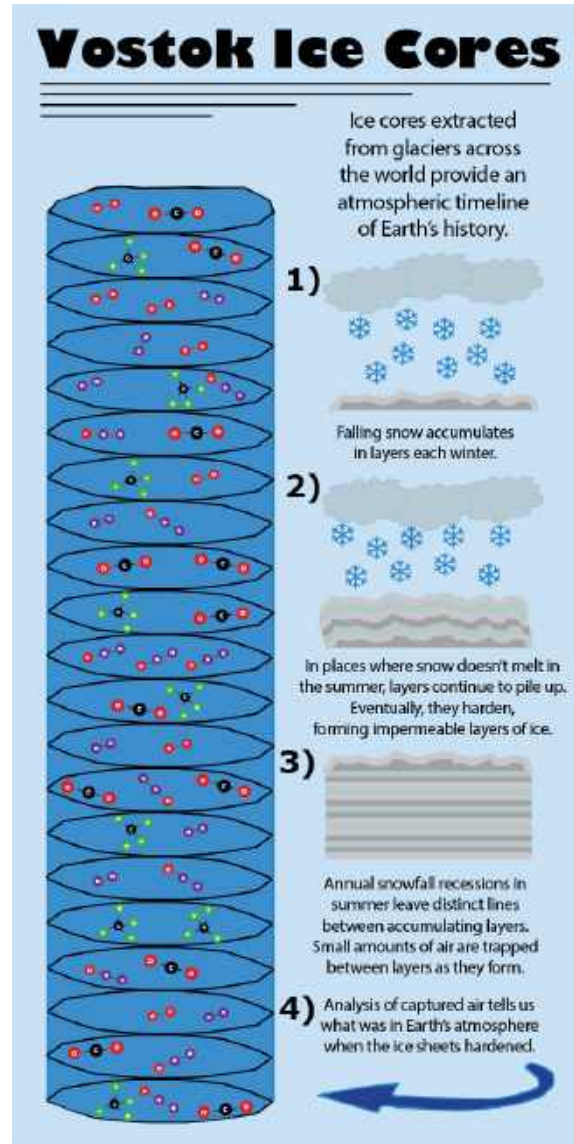
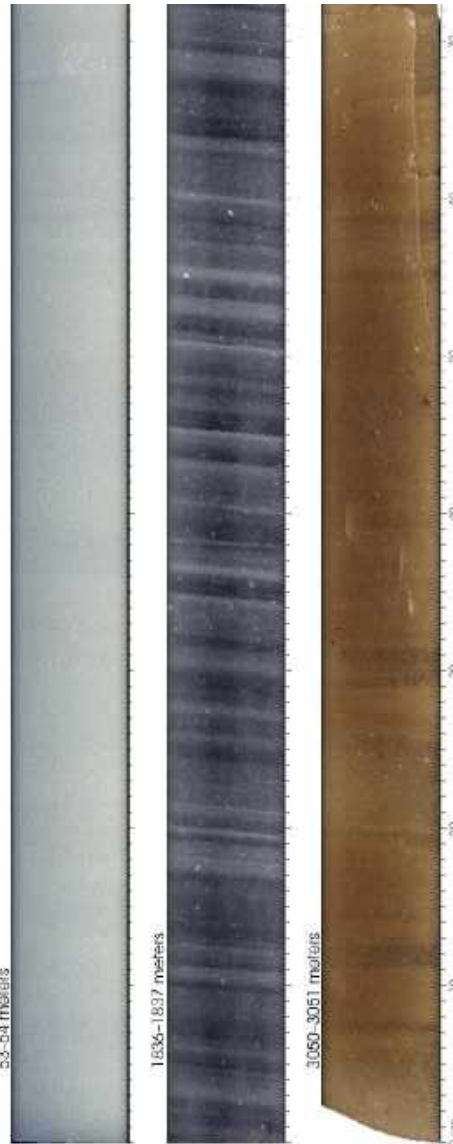
↑ 3.3
mm per year

Our Global Climate

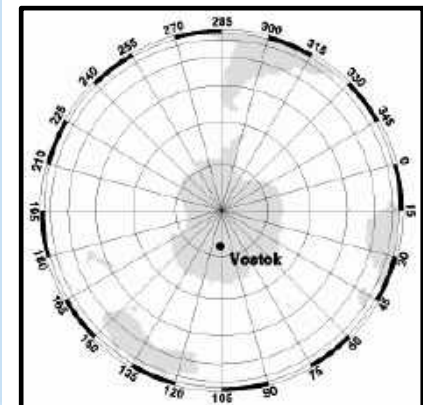
- Greenhouse gases effect global temperatures!
- Average temperature on earth is + 15°C
- Without greenhouse gases -18°C



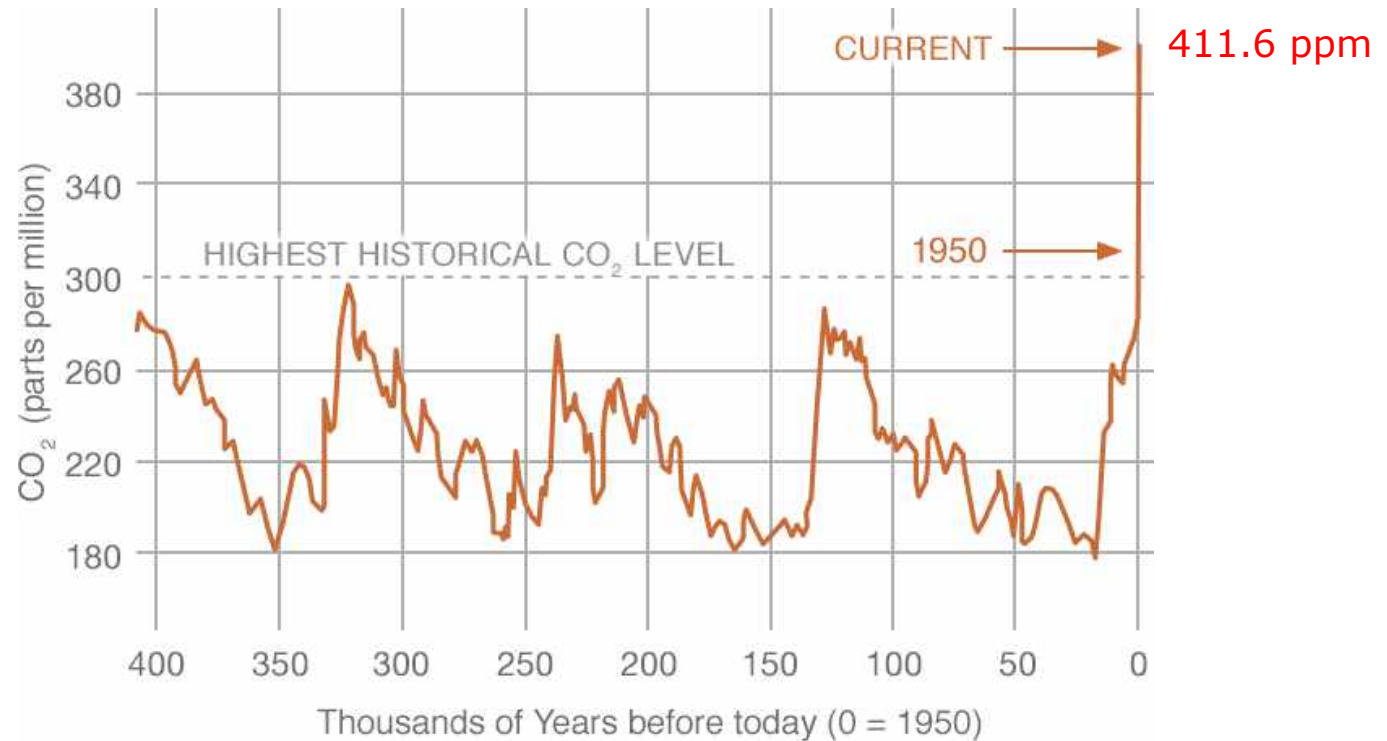
How do we understand past climate changes?



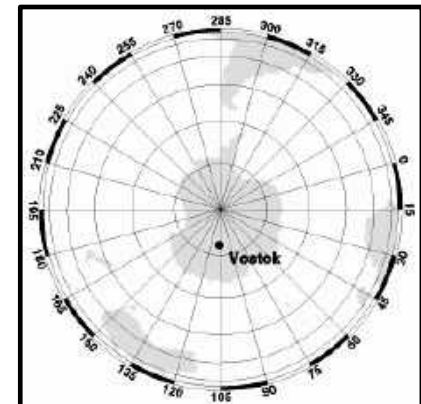
Vostok, Antarctica
 78°28' S,
 106°48' E
 3488 m amsl



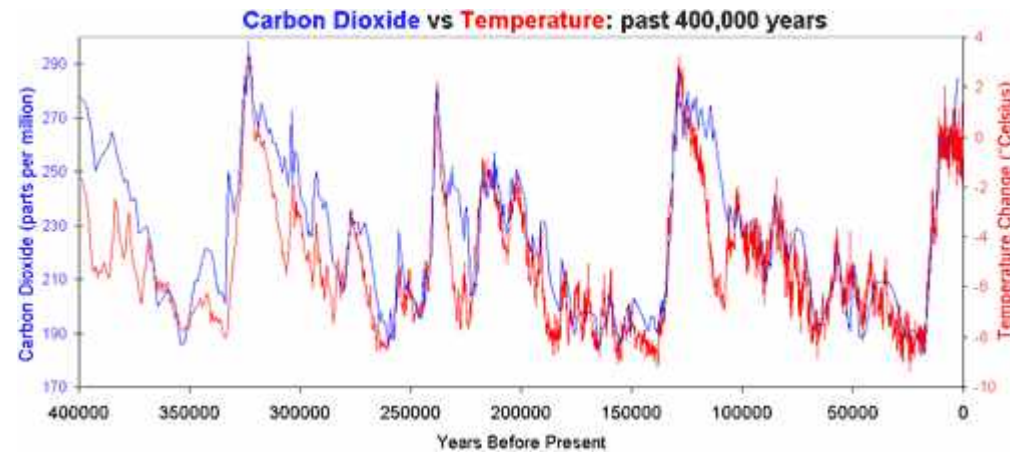
What does history tell us using the Vostok Ice Core?



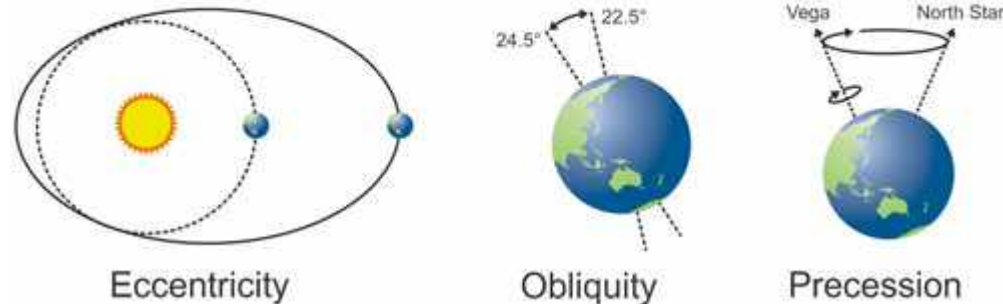
Vostok, Antarctica
78°28' S,
106°48' E
3488 m amsl



Why does temperature lag CO₂ atmospheric concentrations?

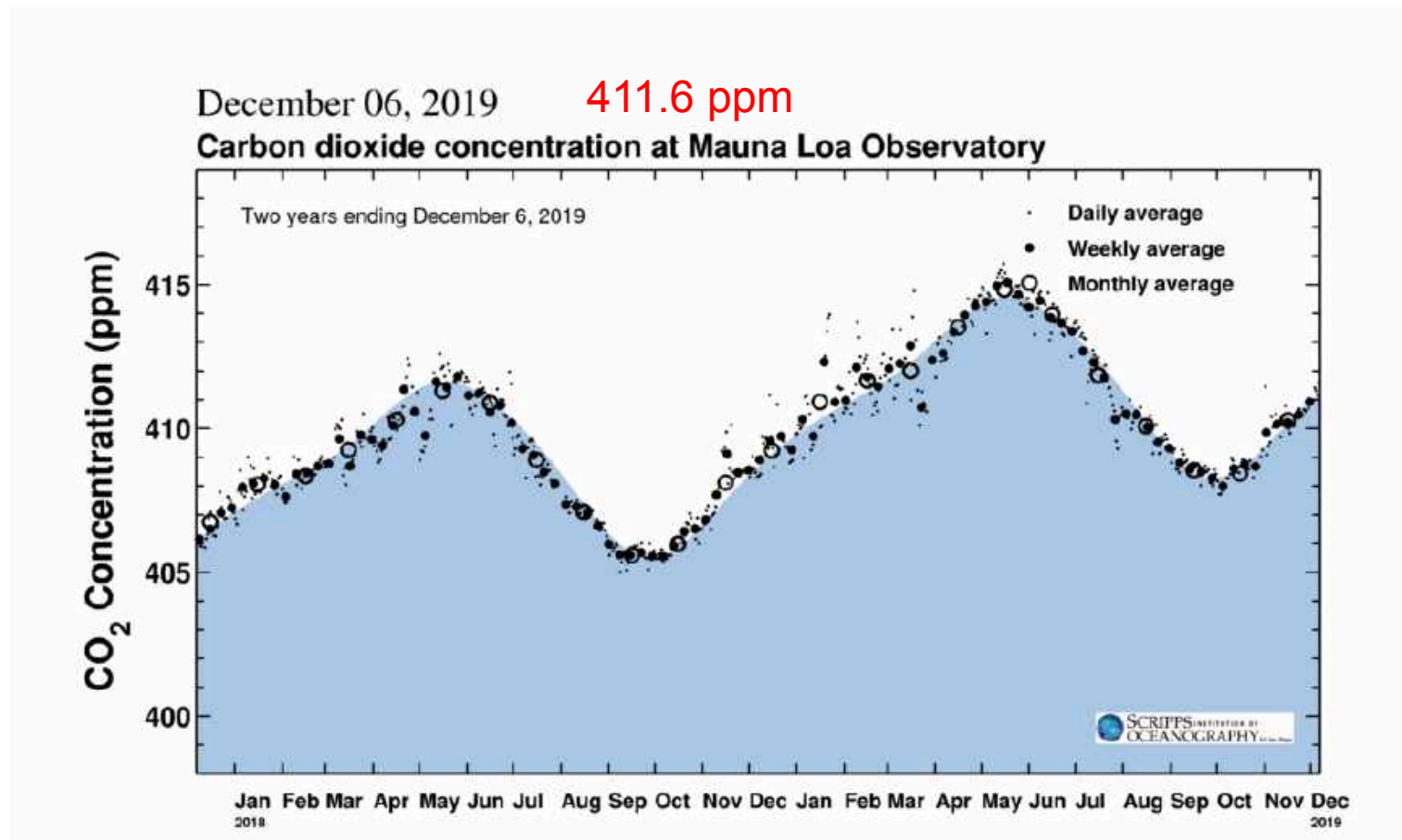


Milankovitch Cycles



- Deglaciation (warming) is not initiated by CO₂ but by orbital cycles
- CO₂ amplifies warming which is not explained only by orbital cycles
- CO₂ spreads warming throughout the planet

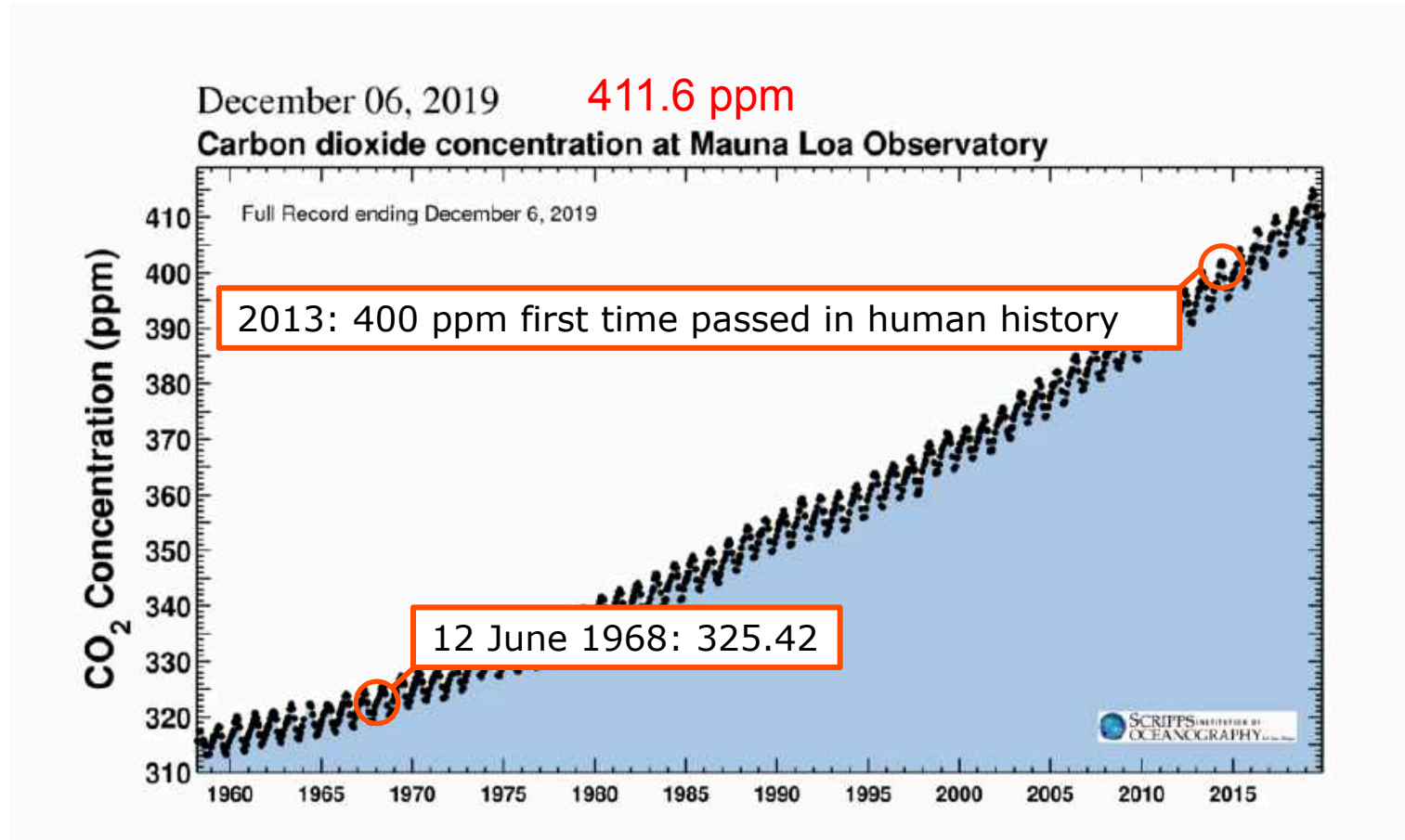
Current Atmospheric CO₂



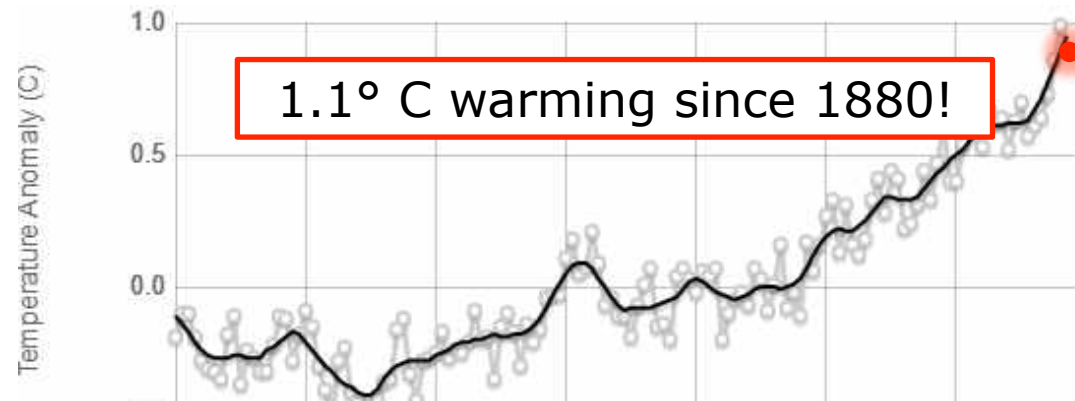
“We were witnessing for the first time nature’s withdrawing CO₂ from the air for plant growth during the summer and returning it each succeeding winter.”

- Charles David Keeling (1998)

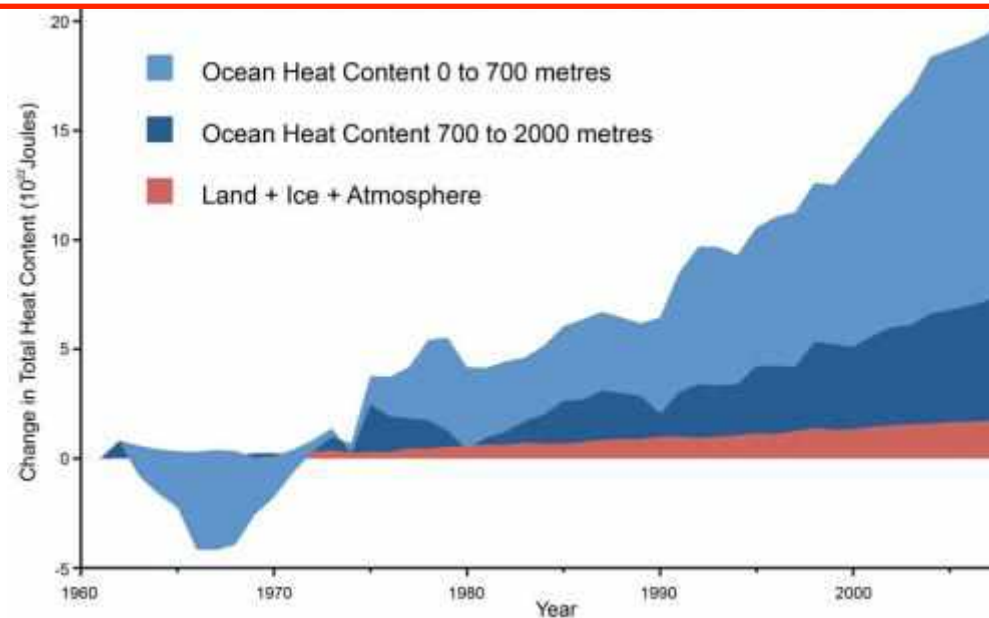
Recent Atmospheric CO₂



NASA's global temperature record



The oceans have taken up over 90% of the warming and approximately 1/3 of carbon dioxide released since the pre-industrial period

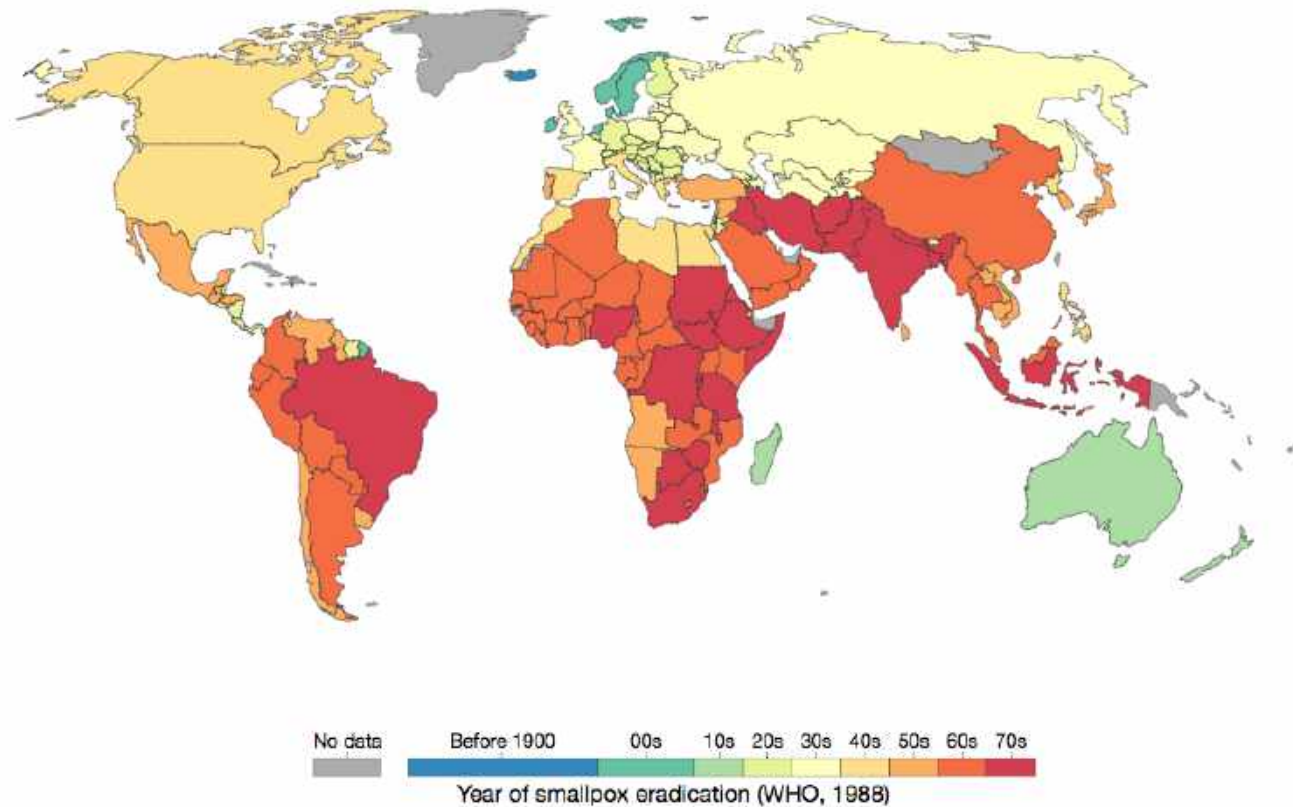


How do we tackle big problems?

Scientific Evidence → Global Collaboration

Decade in which smallpox ceased to be endemic by country

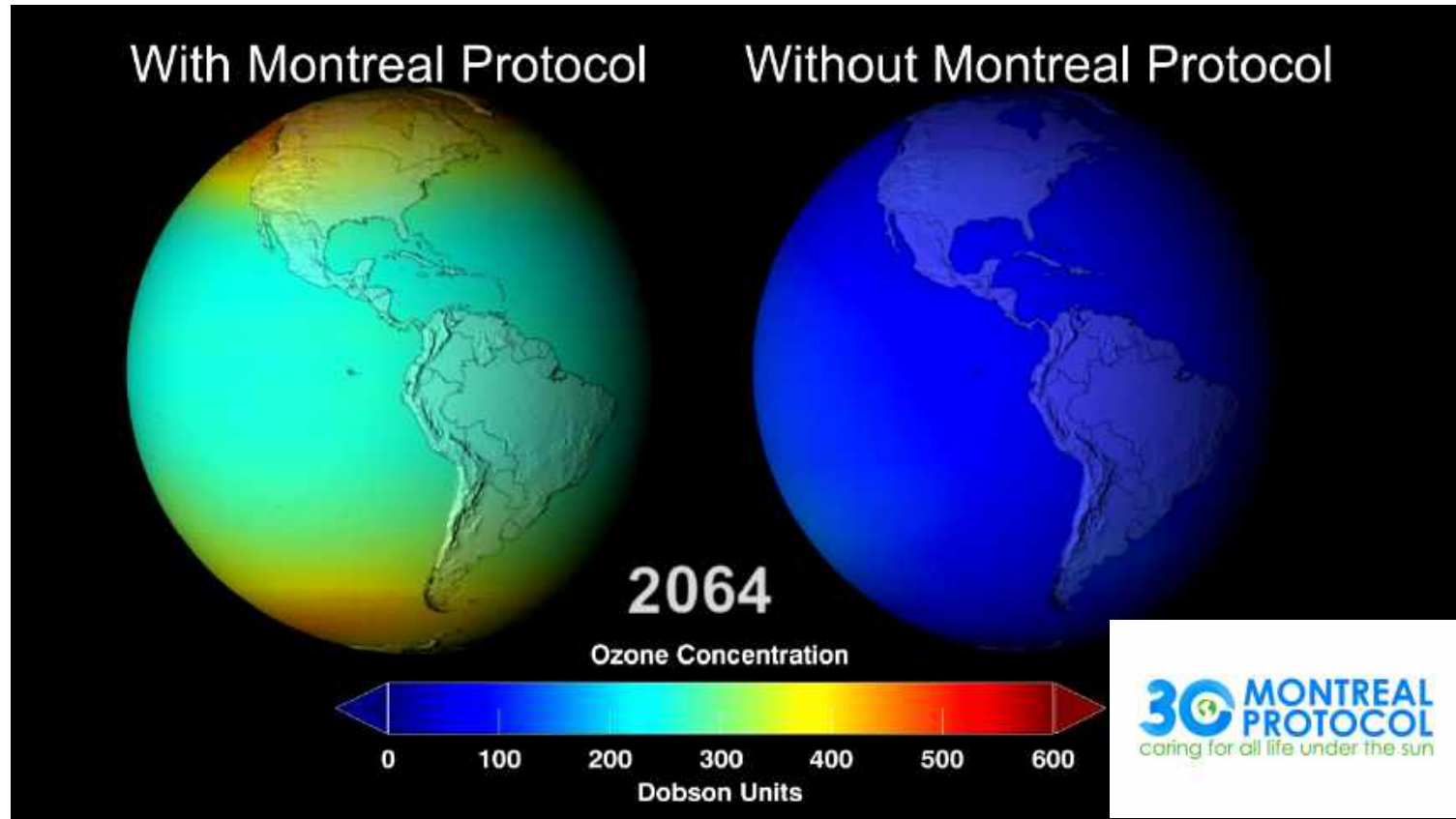
Smallpox was globally eradicated in 1977 – This map shows the year of eradication of Smallpox



- The first successful vaccine to be developed, Edward Jenner in 1796
- 192 years between first vaccination and eradication (1988)

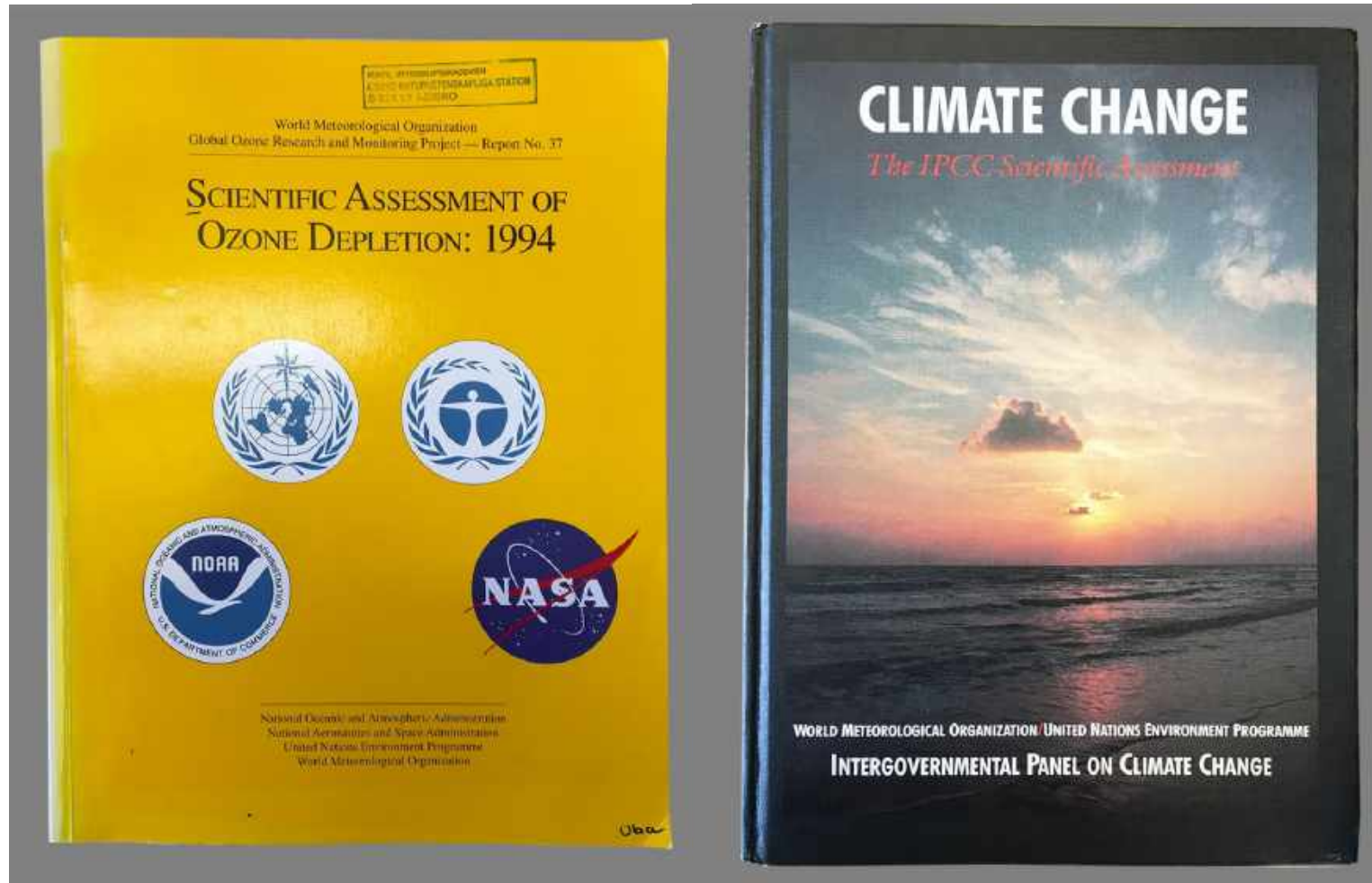
How do we tackle big problems?

Scientific Evidence → Global Collaboration

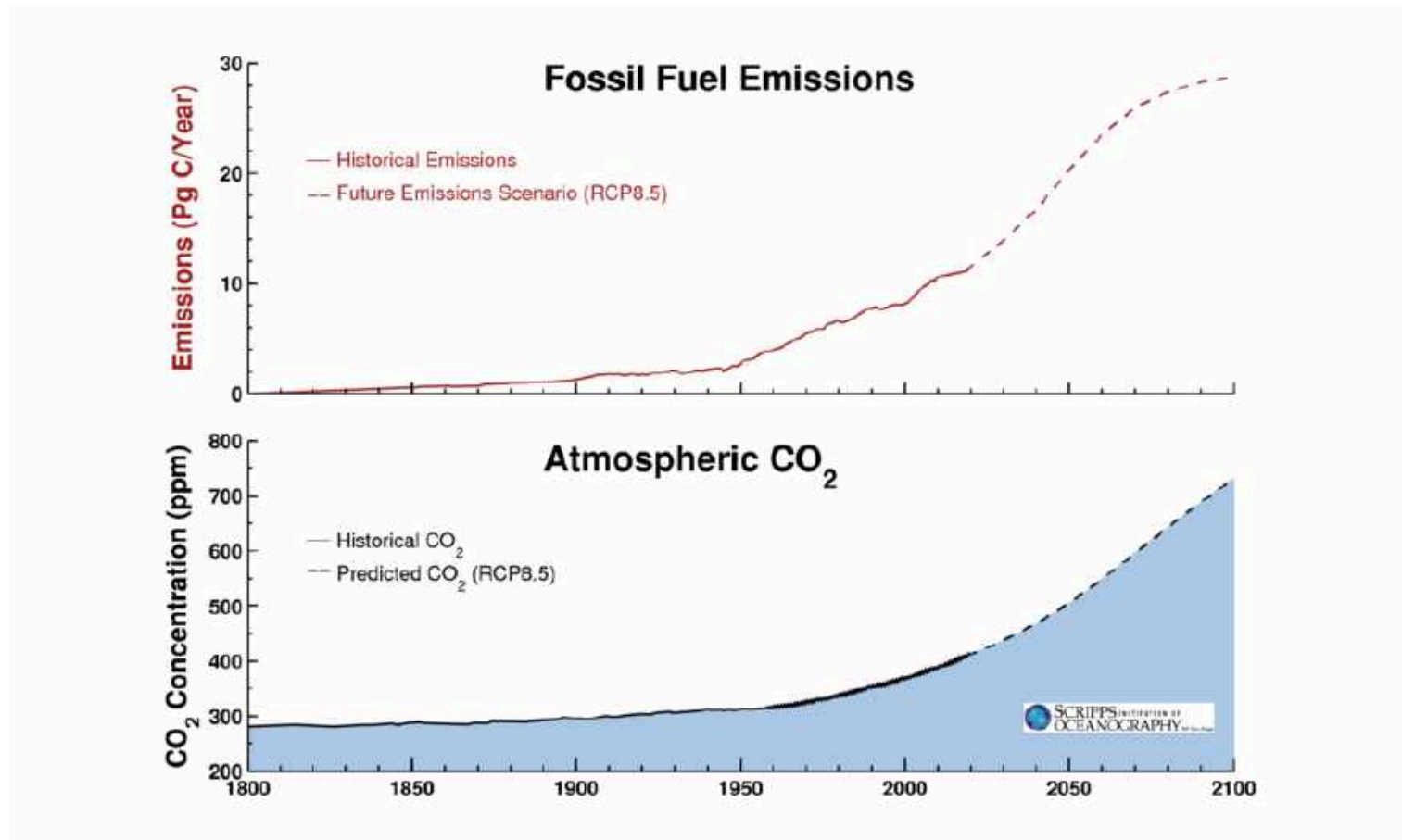


- The first universally ratified treaties in United Nations history.
- 14 years between research discovery in 1973 and the international agreement in 1987.

Lack of compelling narratives



Our current trajectory



Estimated emissions in 2019: 36.8 billion tons

*emissions have grown by 62% since international climate negotiations began in 1990 to address the problem



Lack of Action

Environmental Research Letters

EDITORIAL

Global energy growth is outpacing decarbonization

R B Jackson¹, C
B Zheng⁵

- ¹ Department of Earth and Space Sciences, Stanford, CA 94305
- ² Tyndall Centre for Climate Change Research, Exeter, UK
- ³ CICERO Center for International Climate Research, Oslo, Norway
- ⁴ Global Carbon Project, CSIRO Ocean and Atmosphere, Canberra, ACT 1401, Australia
- ⁵ Laboratoire des Sciences du Climat et de l'Environnement, Paris, France

comment

Carbon dioxide emissions continue to grow amidst slowly emerging climate policies

A failure to recognize the factors behind continued emissions growth could limit the world's ability to shift to a pathway consistent with 1.5 °C or 2 °C of global warming. Continued support for low-carbon technologies needs to be combined with policies directed at phasing out the use of fossil fuels.

G. P. Peters, R. M. Andrew, J. G. Canadell, P. Friedlingstein, R. B. Jackson, J. I. Korsbakken, C. Le Quéré and A. Peregón

Global fossil CO₂ emissions grew at 0.9% per year in the 1990s, accelerated to 3.0% per year in the 2000s, but have returned to a slower rate of 0.9% per year since 2010, with pronounced slowdown from 2014 to 2016. Despite modest declines in emissions in the United States and the European (EU) over the past decade, the growth in emissions in China, India and many developing countries has dominated emission trends over the past 20 years. Global Carbon Budget projection¹ is that global fossil CO₂ emissions will grow by 0.6% (range -0.2% to 1.5%) in 2017, with emissions projected to decline in the United States and the EU28, but projected to increase in China, India and the rest of the world (Fig. 1a).



PERSPECTIVE

Persistent fossil fuel growth threatens the Paris Agreement and planetary health

OPEN ACCESS

Received: 21 November 2016

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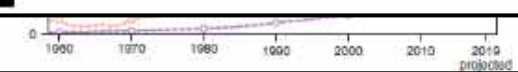
Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal name and year.



R B Jackson¹, P Friedlingstein^{2,3}, R M Andrew⁴, J G Canadell⁵, C Le Quéré⁶ and G P Peters¹

- ¹ Department of Earth System Science, Woods Institute for the Environment, and Program Institute for Energy, Stanford University, Stanford, CA 94305-2210, United States of America
- ² College of Engineering, Mathematics and Physical Sciences, University of Exeter, Exeter EX4 4QE, United Kingdom
- ³ Laboratoire de Métronologie Dynamique, Institut Pierre-Simon Laplace, CNRS-ENS-UPMC-X, Département de Géosciences, Ecole Normale Supérieure, 24 rue Lhomond, F-75005 Paris, France
- ⁴ CICERO Center for International Climate Research, PO Box 1129 Blindern, NO-0316 Oslo, Norway
- ⁵ Global Carbon Project, CSIRO Ocean and Atmosphere, Canberra, ACT 1401, Australia
- ⁶ Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich Research Park, Norwich, NR4 7TL United Kingdom

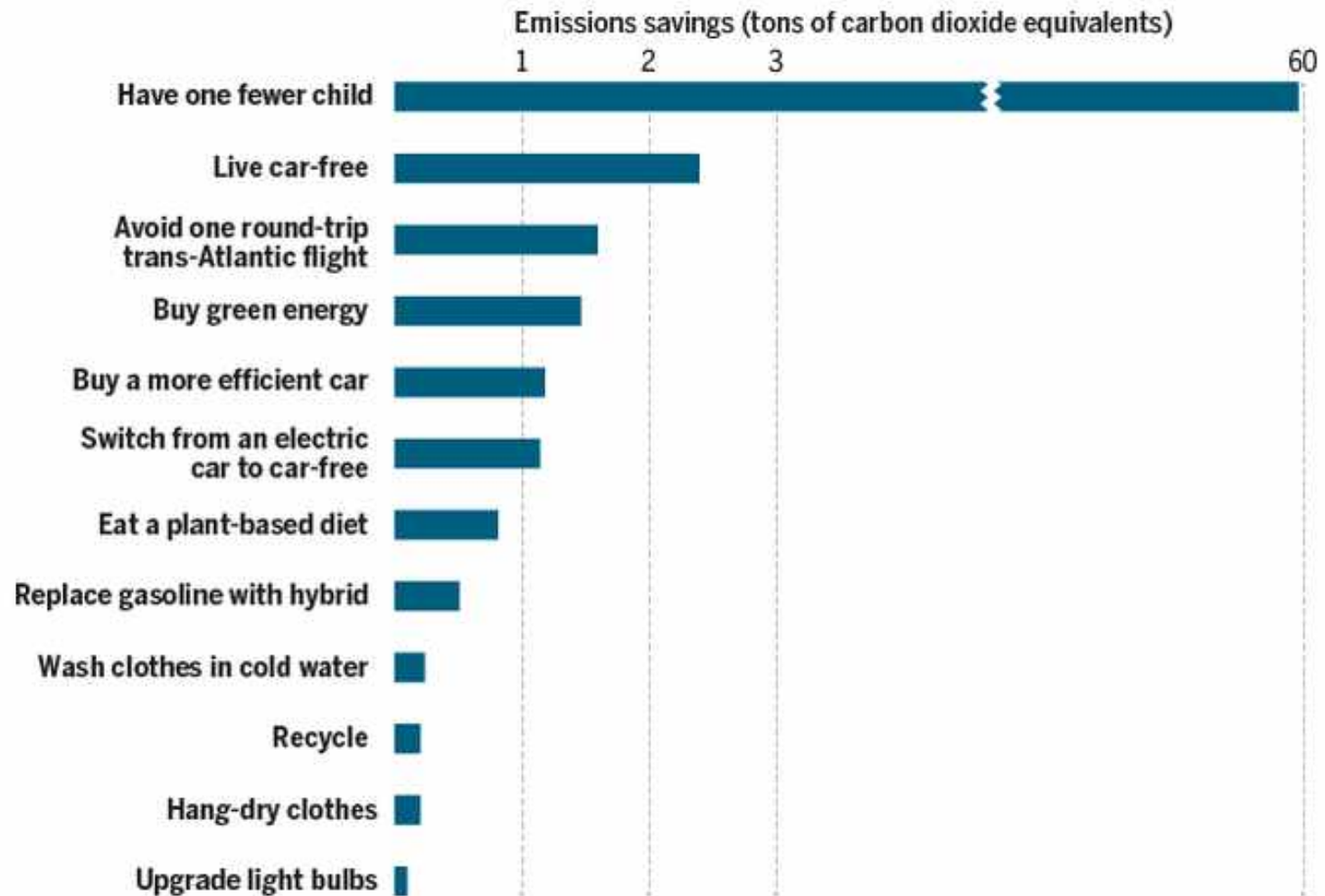
Keywords: CO₂ emissions, coal, oil and natural gas, fossil fuels, climate change, global warming, energy



Climate Action / Lack of Action



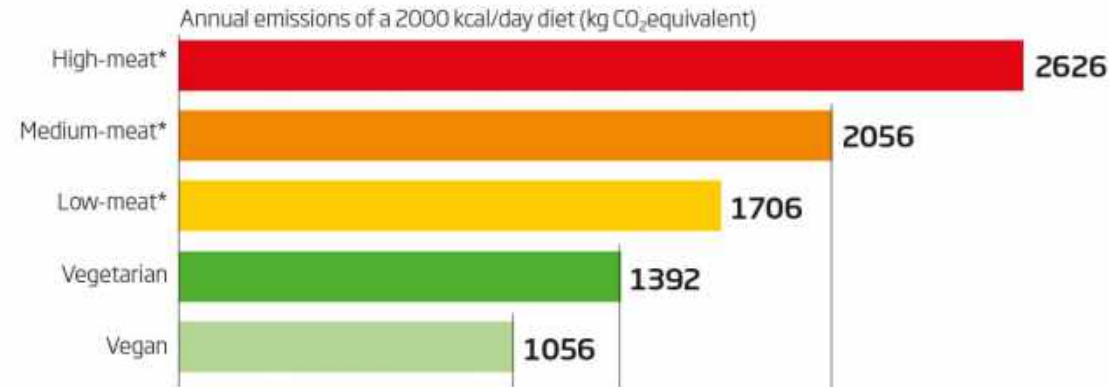
How do we make sense of this?



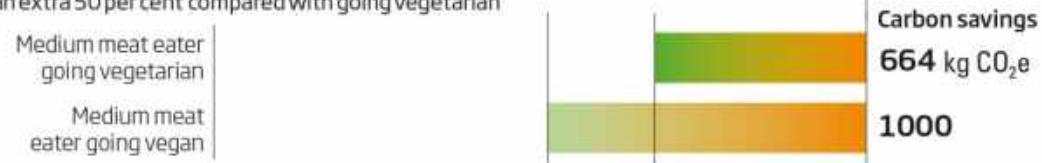
How do we make sense of this?

Your choice for a healthy planet

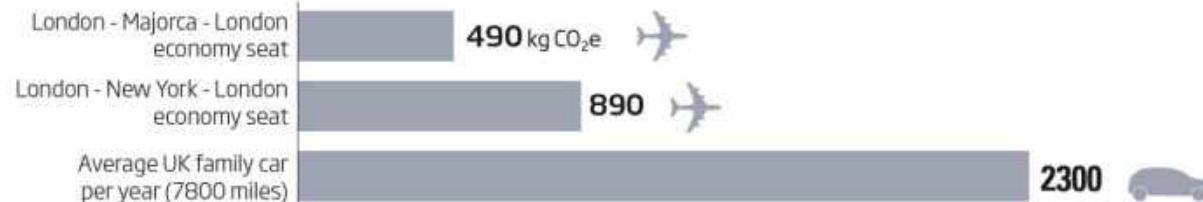
Most adults in the UK eat 110 grams of meat a day, making them high meat eaters.
The carbon footprint of their diet is more than twice that of a vegan



A medium meat eater who decides to go vegan would cut their diet's carbon footprint by an extra 50 per cent compared with going vegetarian



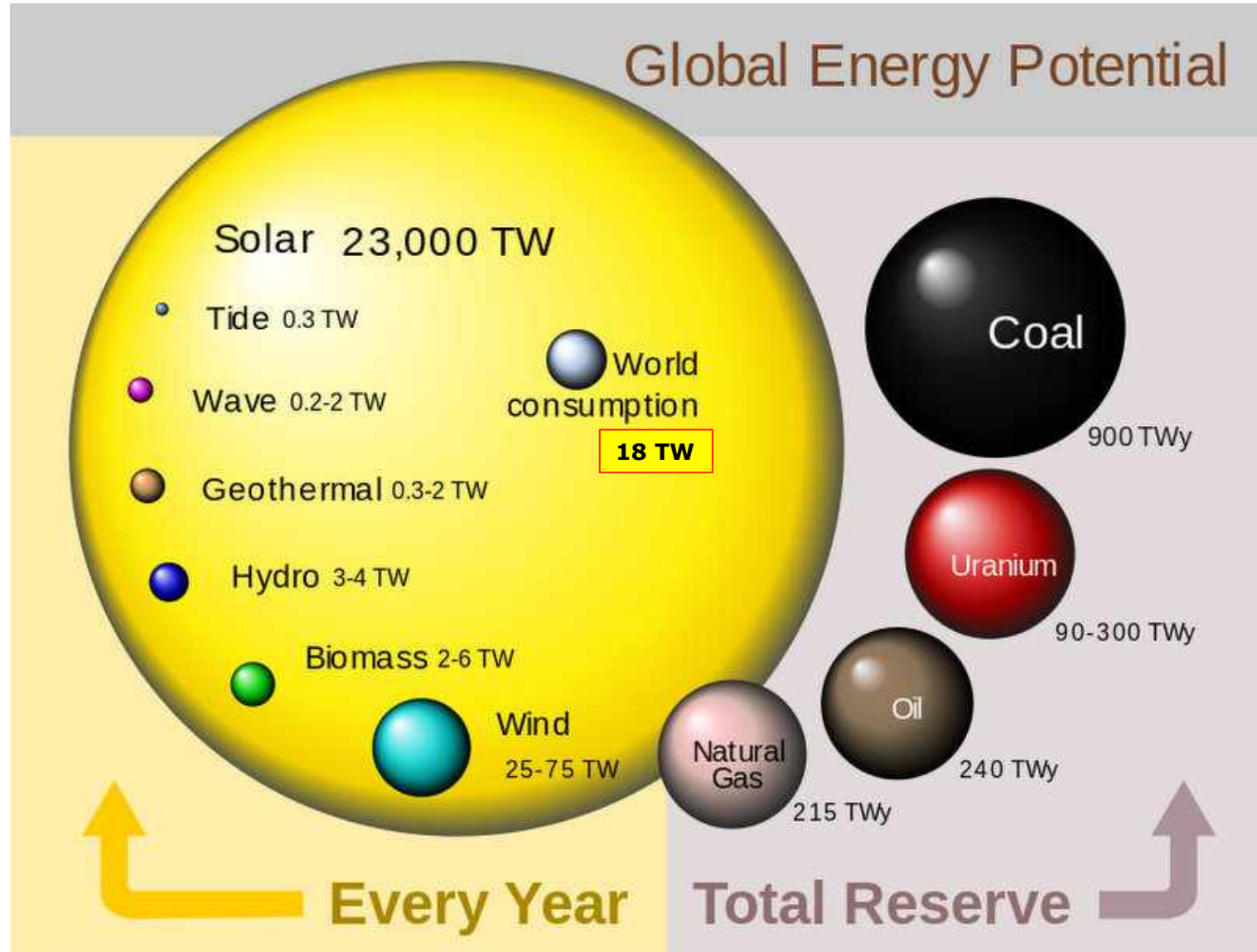
Alternatively, you could just choose not to take that holiday in Majorca this summer



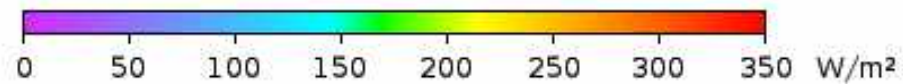
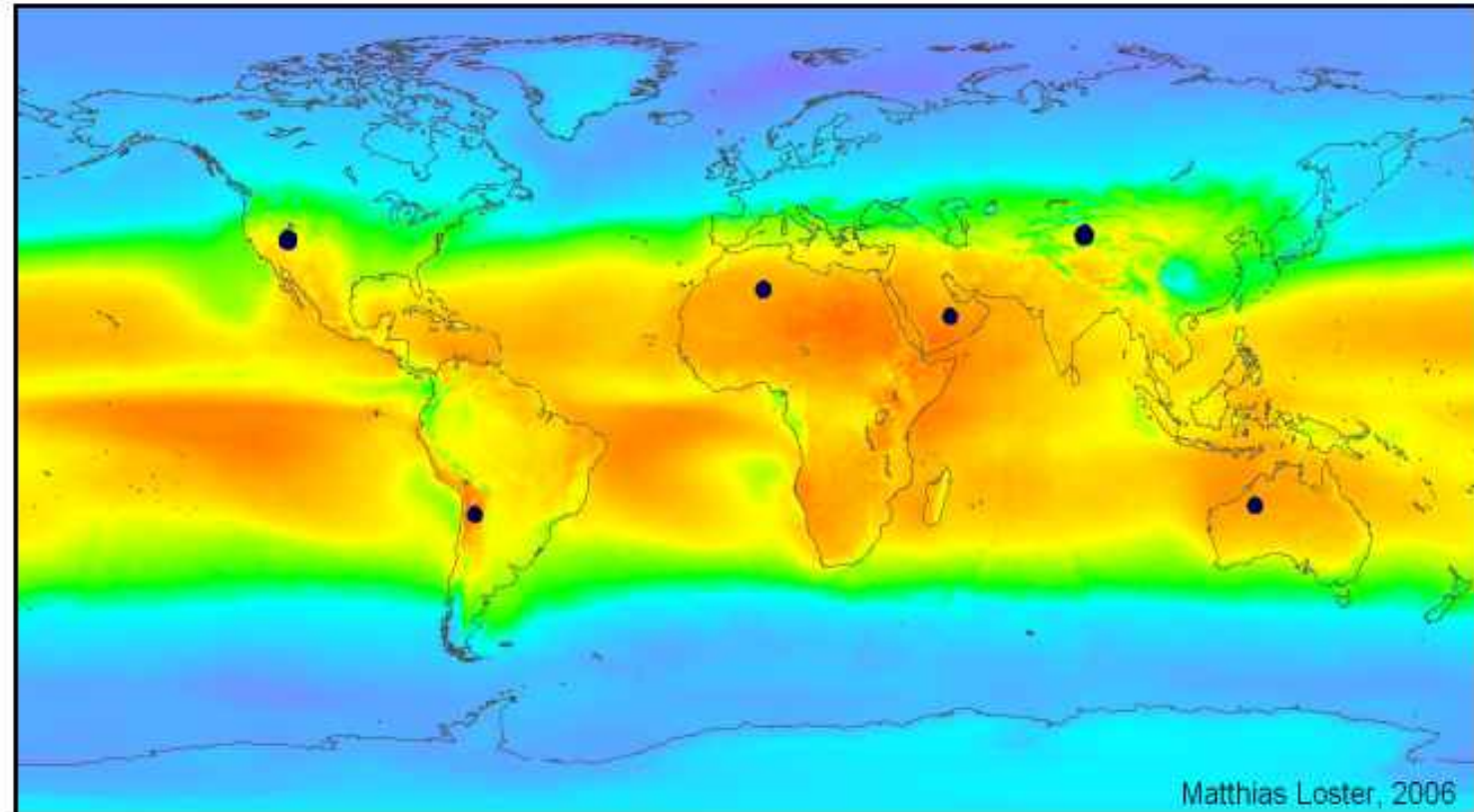
*High meat ≥100g/day *Medium meat = 50-99g/day *Low meat ≤ 50g/day

DOI:10.1007/s10584-014-1169-1

A path to renewal "clean" energy



A path to renewal "clean" energy



$\Sigma \bullet = 18 \text{ TWe}$



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A path to renewal “clean” energy



theguardian

home > **environment** > climate change > wildlife > energy > pollution

Renewable energy
Global warming

Reasons to be cheerful: a full switch to low-carbon energy is in sight

Climate change optimism is justified - a complete transition from carbon to solar and wind power looks practical and affordable within a generation.



Colle des Mées solar farm in Alpes-de-Haute-Provence is the biggest in France and consists of 112,780 panels and represents 100 MW of power. Photograph: Jean-Paul Pelissier/Reuters



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The solar future is here!

How Tesla's big battery is bringing Australia's gas cartel to heel

South Australia's big gamble on grid-scale battery storage may pay for itself in just a year if it continues to prevent massive price spikes

● Giles Parkinson is editor of **RenewEconomy**



On Sunday 14 January something very unusual happened.



Population: 7.75 billion (human)
Number of species: 8.7 million (estimated)



Taken by Apollo 17 crew 7 December, 1972

02 January 2019



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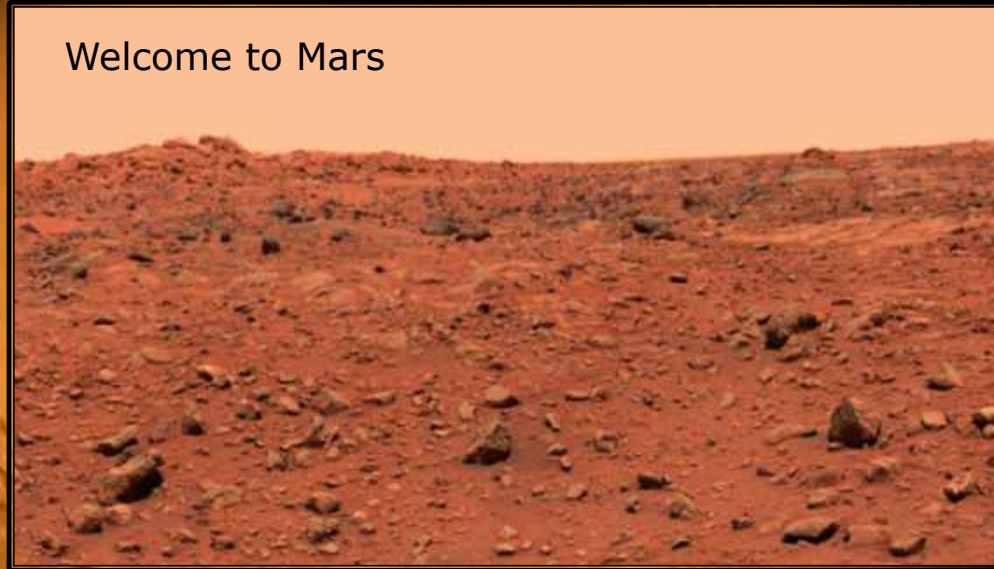
POLARFORSKNINGS
SEKRETARIATET

SWEDISH POLAR RESEARCH SECRETARIAT



Population: 5 (non-human)
Number of species: unknown

Welcome to Mars



“We are running out of space, and the only places to go to are other worlds.”
— Stephen Hawking



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Taken by NASA Mars Maven Mission 2014

02 January 2019



If you were to really *internalize*
that we are the first generation to
see the effects of climate change...

and the last generation
to be able to do anything
about it...

would you change
your life?



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Young people are the most politically liberated force globally right now.

You have less to lose than any other generation, and everything to gain.

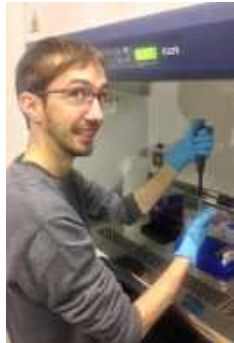
You can be radical.
You can be visionary.





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Climate Impacts Research Centre



Climate Impacts Research Centre on Social media



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