

# Dr. Ian Clark

Emeritus Professor

A Reality Check on Climate & NetZero



# A Reality Check on Climate and Net-Zero

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We are facing a global climate crisis.

We must reduce CO<sub>2</sub> emissions to **net-zero** by 2050.

Notwithstanding that CO<sub>2</sub> is essential for life.

# A Reality Check on Climate and Net-Zero

Is the climate changing?

Is CO<sub>2</sub> driving global warming?

Can we achieve net-zero?



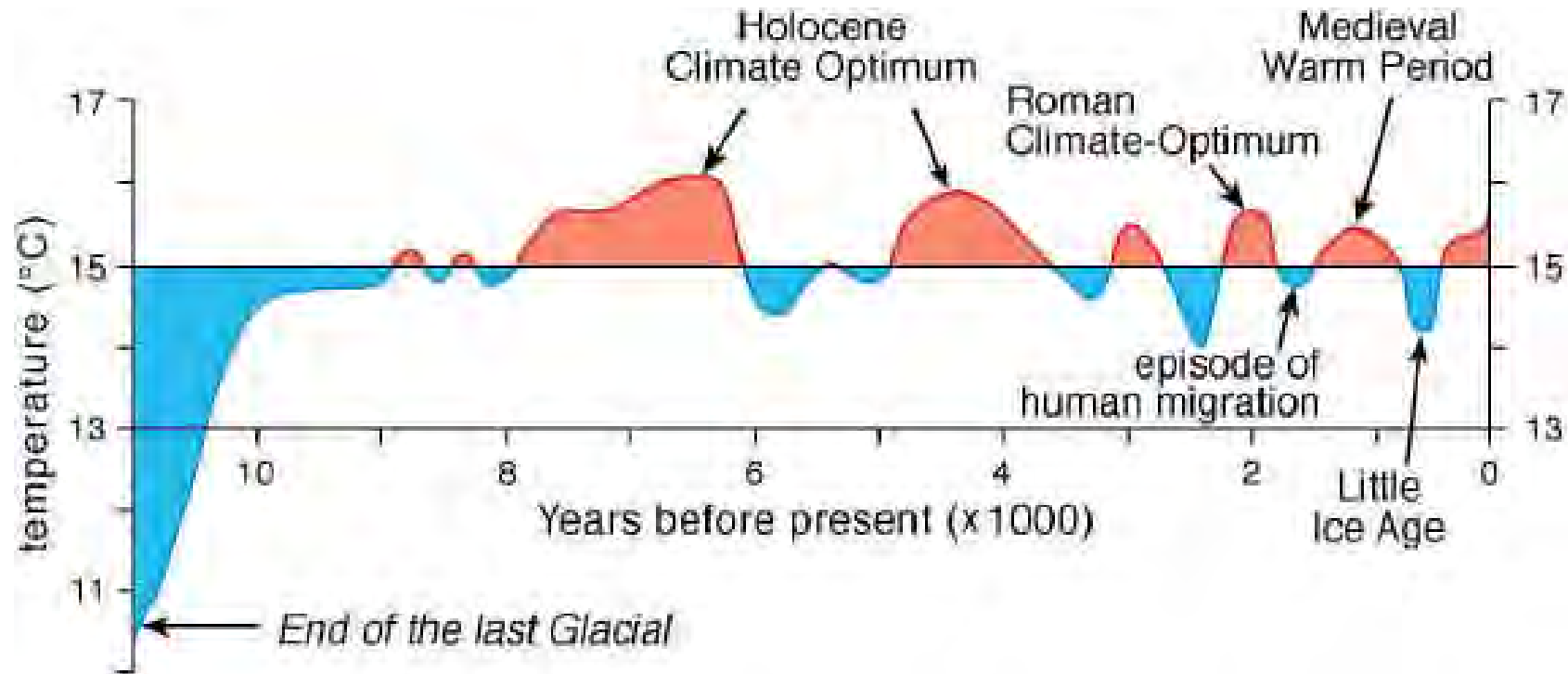
# Is the climate changing?

- Yes



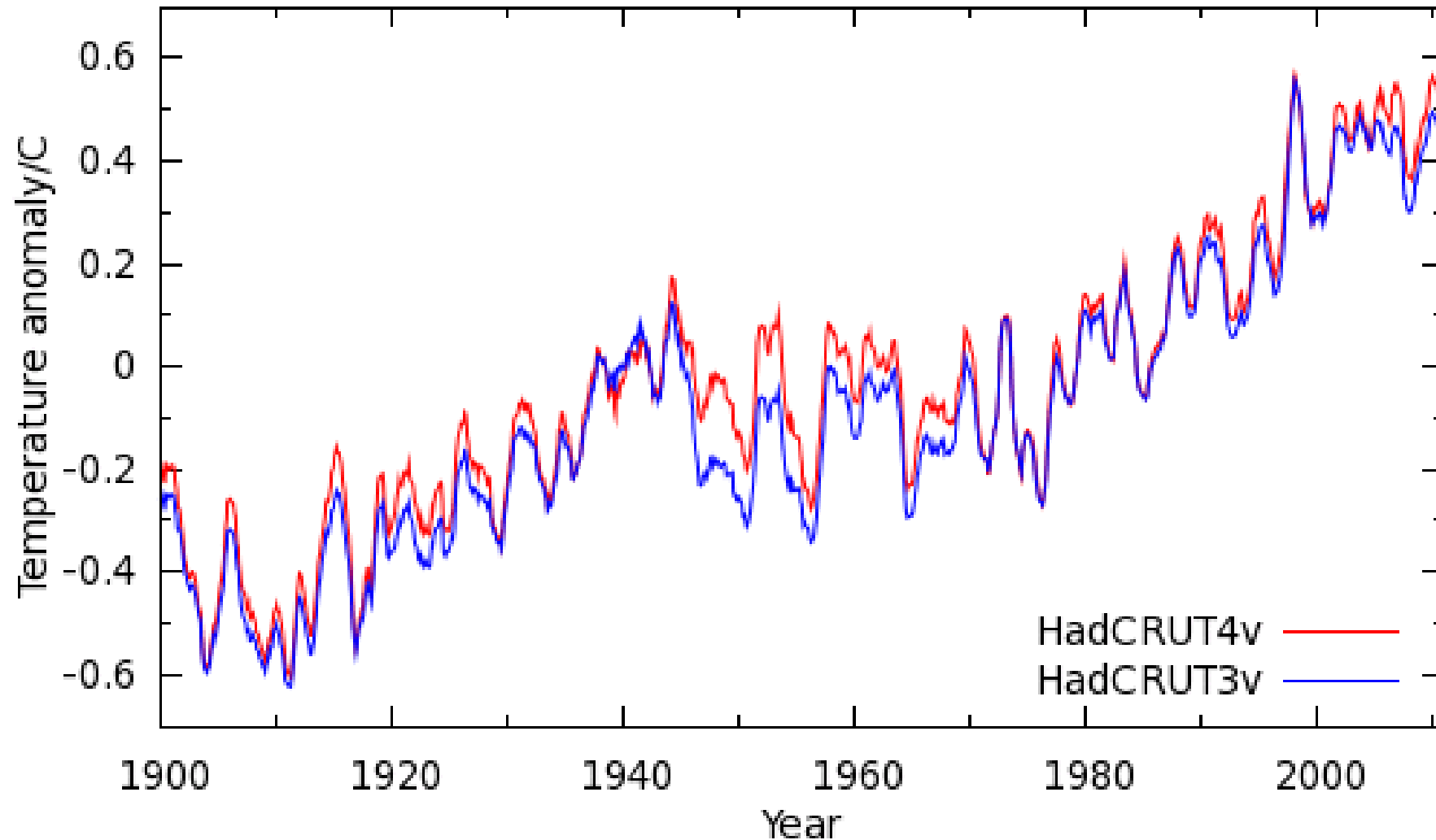


# Holocene climate cycles

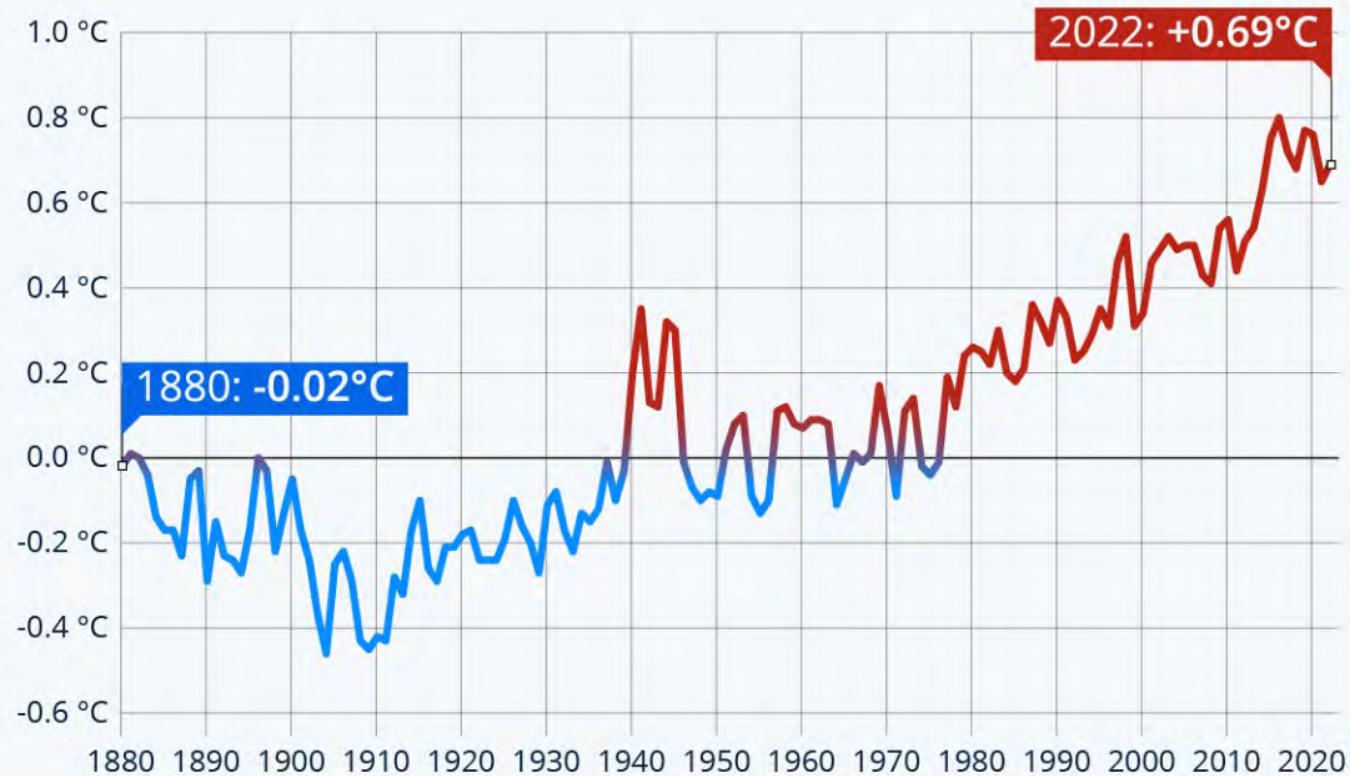


*Average near-surface temperatures of the northern hemisphere during the past 11,000 years (after Dansgaard et al., 1969, and Schönwiese, 1995)*

# Global Measured Surface Temperatures Since the Little Ice Age



# Global ocean warming since the Little Ice Age

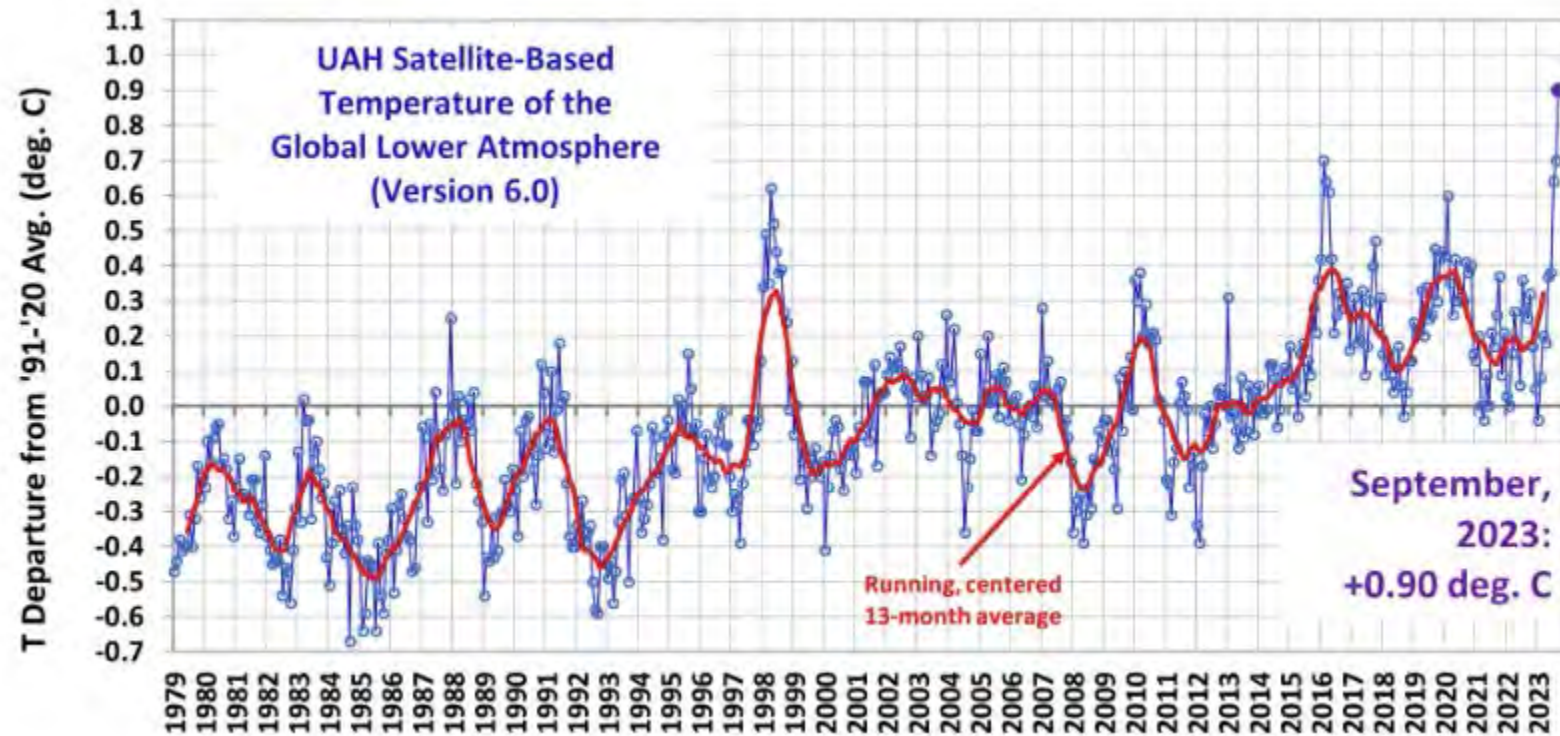


Source: NOAA National Centers for Environmental Information (NCEI)





# Satellite Atmospheric Measurements Since 1979



## Is the climate changing?

- Yes
- Are extreme events unprecedented?

# How climate change is fuelling hurricanes

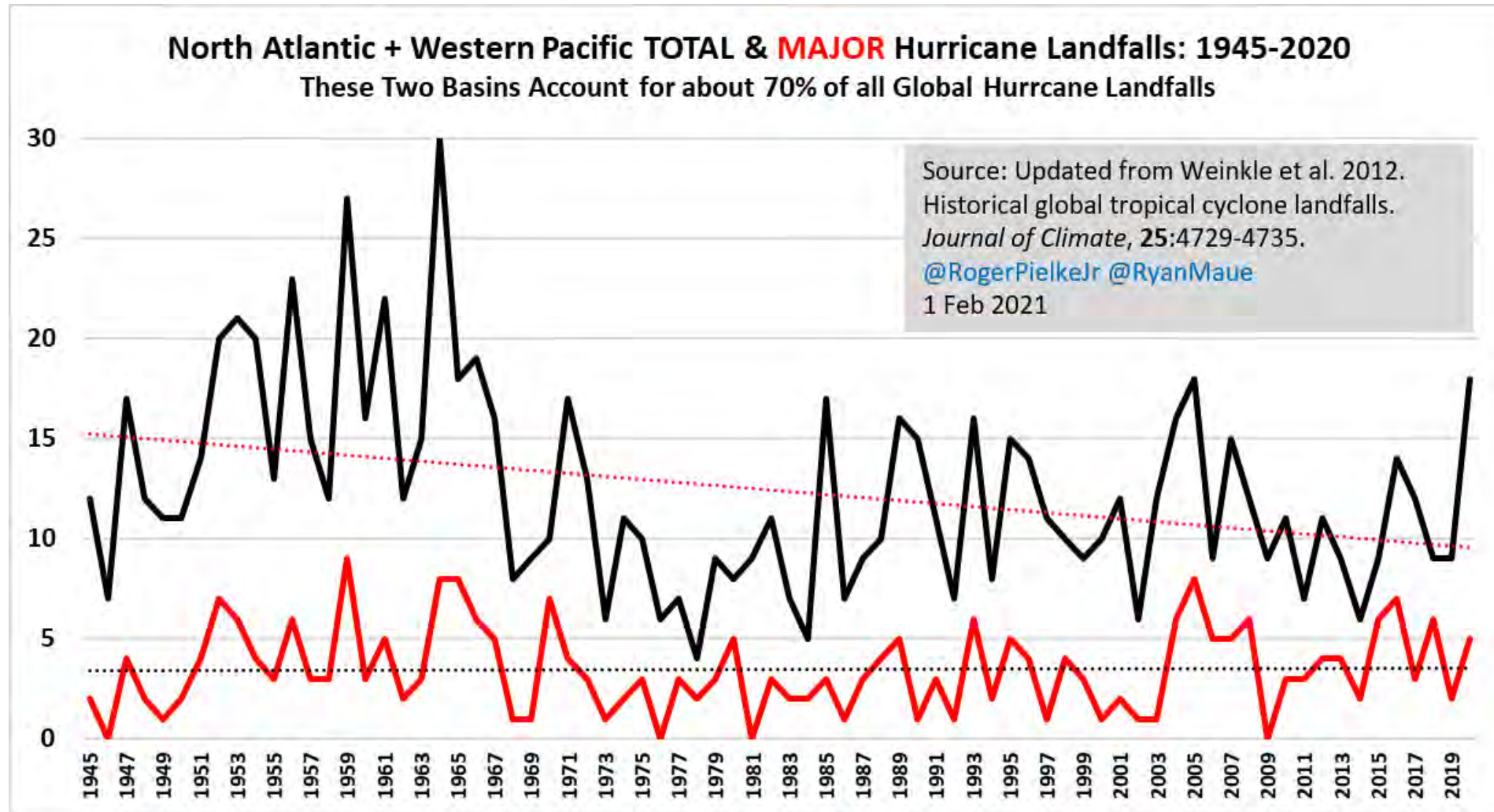
GLORIA DICKIE

REUTERS

PUBLISHED SEPTEMBER 24, 2022

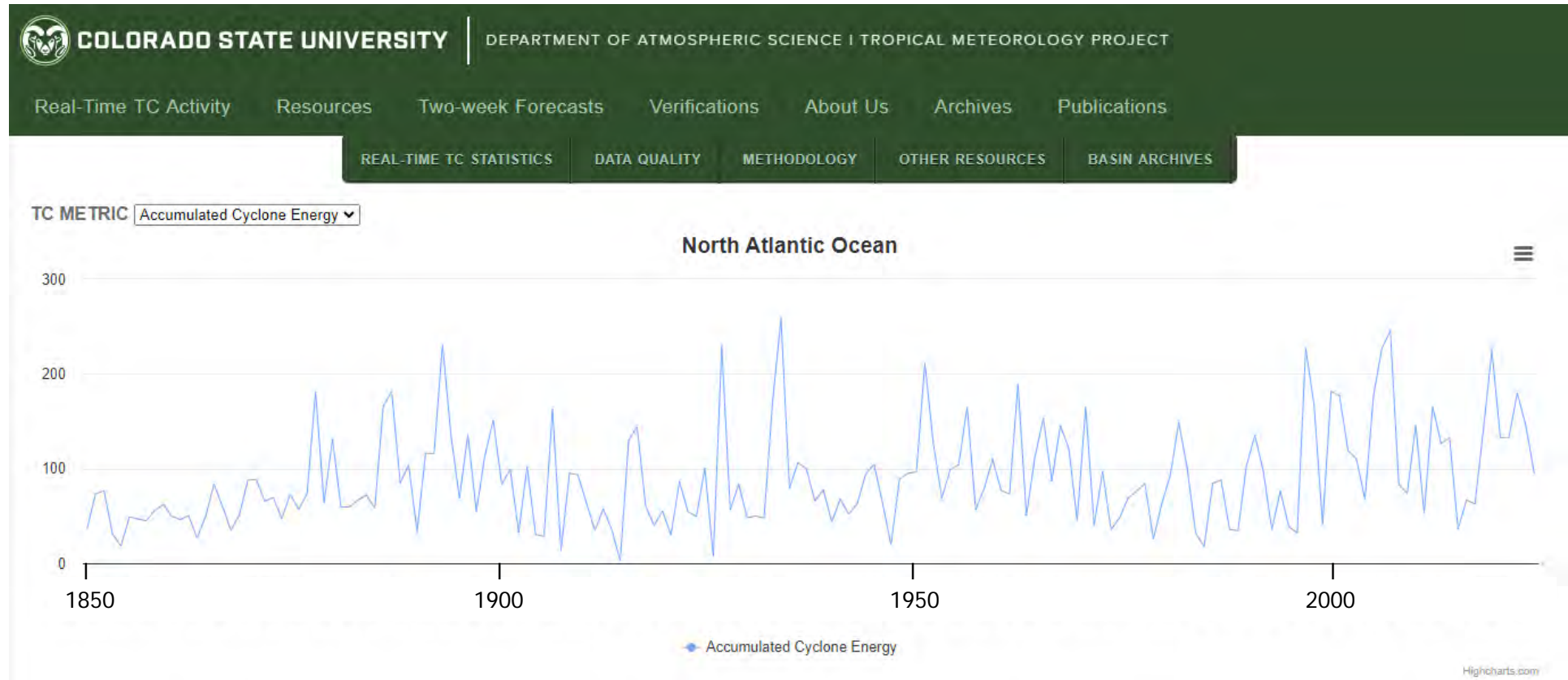


# Hurricanes: the historical record





# Hurricanes: the historical record



# Severity and sweep of Prairie droughts could spiral as climate changes



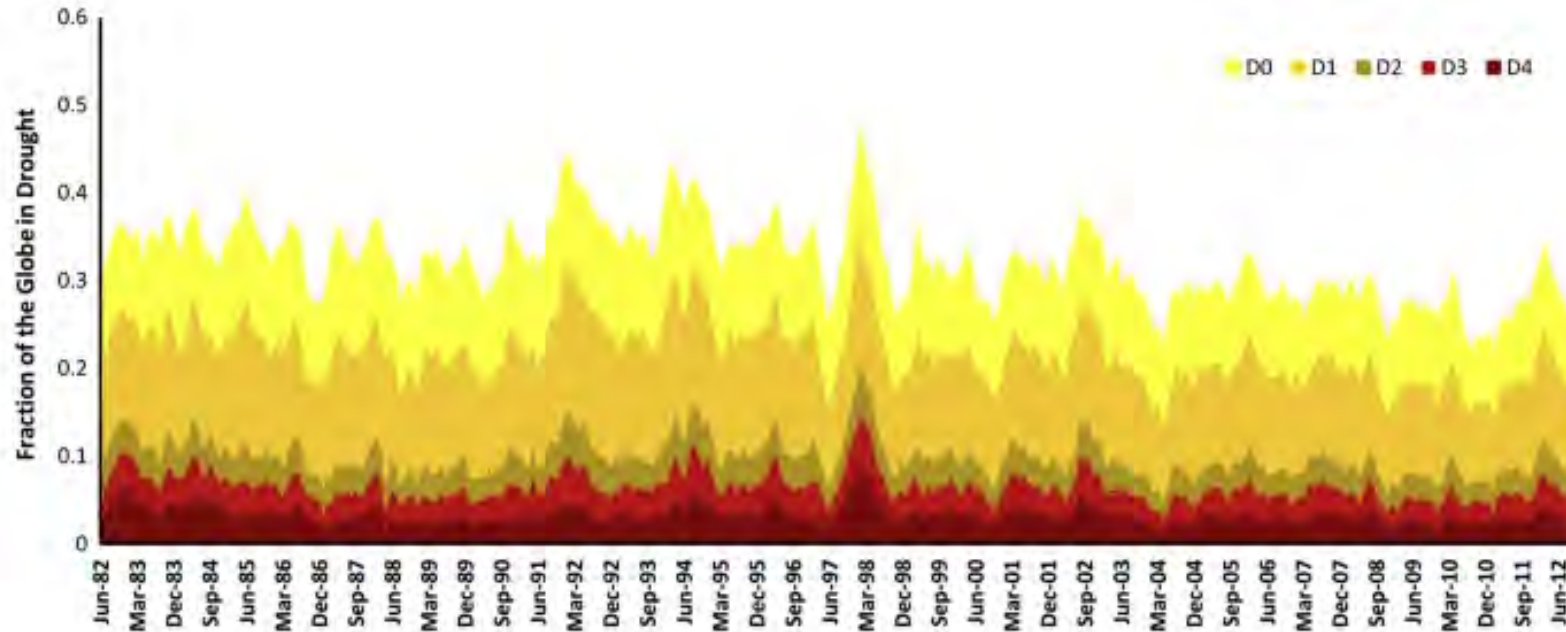
'The drought that we just went through in 2021, it was as severe and as extensive as 1961'



[Christy Climenhaga](#) · CBC News · Posted: Mar 28, 2022 9:00 AM EDT | Last Updated: March 28, 2022



# Drought: What are the historical trends?



Fraction of the global land in D0 (abnormally dry), D1 (moderate), D2 (severe), D3 (extreme), and D4 (exceptional) drought condition (Data: Standardized Precipitation Index data derived from MERRA-Land).

## Global integrated drought monitoring and prediction system

Zengchao Hao, Amir AghaKouchak [✉](#), Navid Nakhjiri & Alireza Farahmand

[Scientific Data](#) **1**, Article number: 140001 (2014) | [Cite this article](#)

41k Accesses | 280 Citations | 301 Altmetric | [Metrics](#)

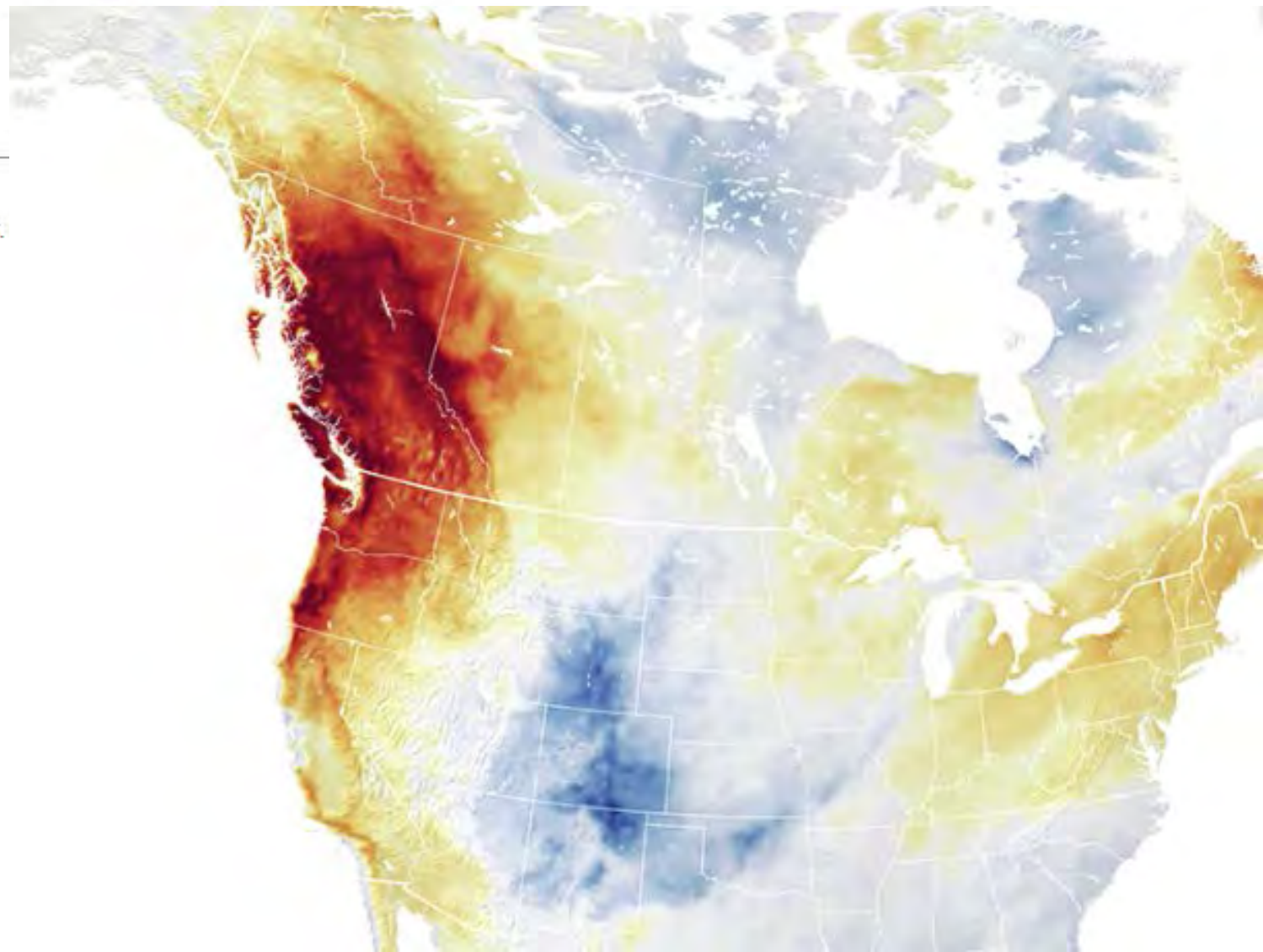


# Inside June's Deadly Heat Dome. And Surviving the Next One



Jen St. Denis / 14 Mar 2022 / [TheTyee.ca](https://thetyee.ca)

Jen St. Denis is The Tyee's Downtown Eastside reporter.





# Heat domes: unique to the present?

JULY 15, 1936  
TELEGRAPH-HERALD

## JULY HEAT LOOKS LIKE NEW RECORD

Previous Mark Established Two Years Ago

Des Moines, Ia.—(AP)—Iowa weather bureau statisticians today chalked up a heat wave record half again as long as the previous mark, and predicted that unless there is a drastic change for the remainder of the month it will be the hottest July Iowa ever has experienced.

From July 2 through July 14, for 12 consecutive days, temperatures of 100 degrees or more were registered by thermometers at Des Moines and most Iowa weather bureau stations.

The previous record was established in 1934, when the mercury reached or exceeded the 100 mark for eight days from July 18 through July 25.

A study of records of July 1 through July 14 for the last 10 years shows the period this year not only had the longest sustained maximum temperature record but also the highest average temperature mark.

**Mean Average**

At Des Moines, which was considered typical of the state as a whole, the mean temperature average over the period was 80 degrees. Mean temperature is the half-way mark between each day's high and low point.

Argus-Press - Jul 15, 1936

## 1,000 Perish on 12th Day of Hot Spell in Nation

Temperature in Owosso Drops 51 Degrees in 12 Hours

### IS NO RAIN HERE

Property Damaged, 3 Hurt in Storms Which Whip Michigan

**Drought at a Glance**

(By The Associated Press)

Detroit.—Cool breezes and scattered rain storms and seven days of 100-degree heat in Michigan with more than 640 dead. Seventy-two die in single day in Detroit before mercury slides from 104 to 75.

St. Paul.—Rains scattered over Central and Northwestern Minnesota, with a light shower at Minneapolis, reduced record-breaking temperatures warned for more than 360 deaths in the state.

Chicago.—Resettlement Administrator Rexford G. Tugwell, arriving from Washington by plane, boards train for Bismarck, N. D., to coordinate resettlement aid in states hard hit by crop and livestock losses.

Milwaukee.—Cool winds sent temperatures down to 76 and local showers were promised as Wisconsin figured its death total at upwards of 303.

Chicago.—Rain and hail in Clinton, a downpour at Springfield and cool breezes at Chicago alleviated torridity which had sent the Illinois death toll past the 250 mark.

The Bulletin - Jul 25, 1936

## Heat Wave Toll Over 12,000 in 86 Cities in Week

Washington, July 25 (AP)—The first official figures on the death toll of last week's heat wave indicated today that literally thousands of lives were lost in the temperatures of 100 degrees and higher throughout a large part of the nation.

The census bureau released mortality statistics today for the week ending July 18 showing 3332 more deaths in 86 cities than in the worst heat week of 1934.

For the week ended July 18, the bureau reported 12,183 deaths this year compared with 8,851 deaths in the same 86 cities for the week ended July 28 in 1934. The present drought was blamed for a 65 per cent rise in deaths as compared with the corresponding 1935 week, when 7439 deaths were reported during that week of normal temperatures.

"From the standpoint of mortality, the 1936 heat wave was much more severe than the 1934 wave," the bureau said in giving the first official notice of the death dealing effects of the present heat wave.

The 8,851 deaths for the week in 1934 was an excess of mortality of 19 per cent over the same normal week in 1935, the bureau said.



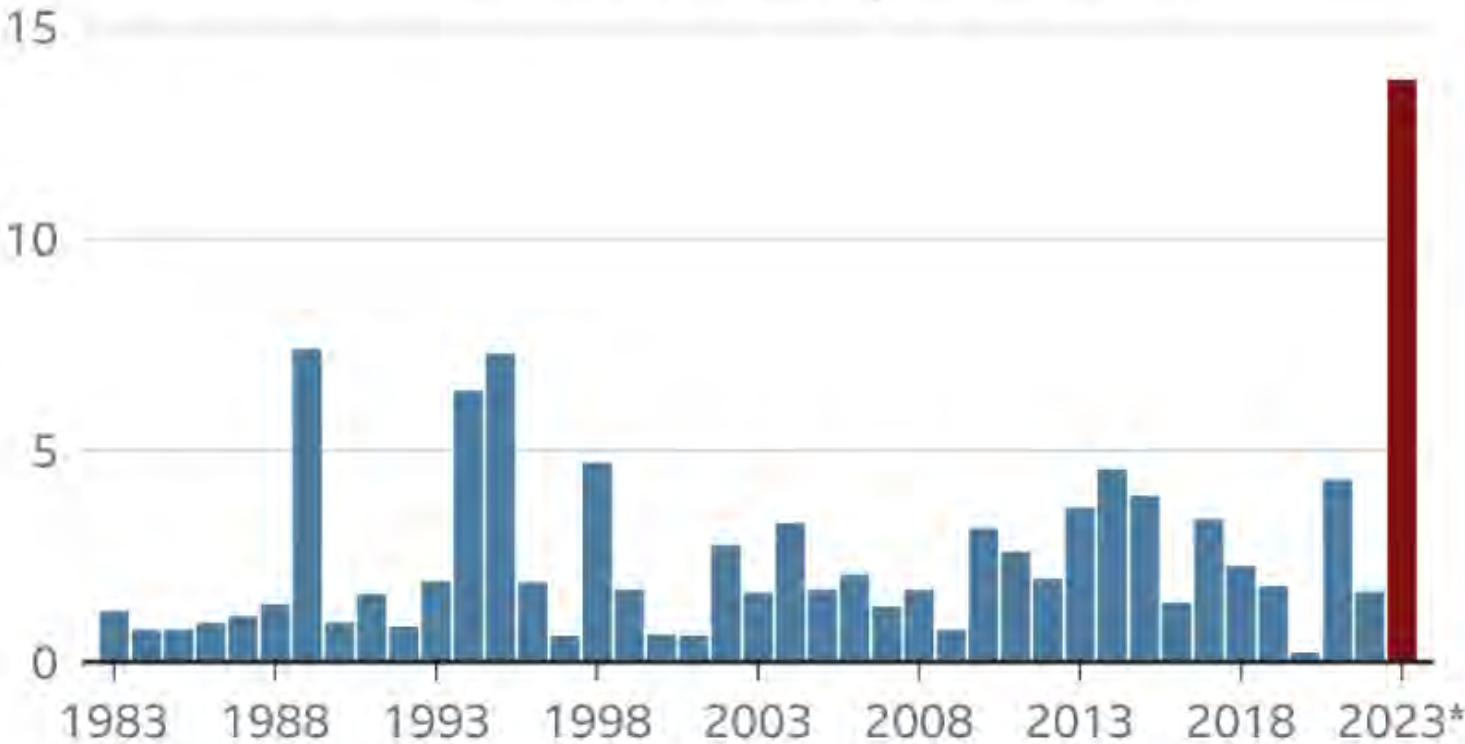
Alberta wildfires: Climate change increasing risk of fires and other extreme weather events

Watch

Uploaded: May 17, 2023  
Scientists say Alberta's 2023 wildfire season isn't a one-off. Because of climate change, we will see all the worst parts of hot weather in the summer to come. Morgan Black has more on what to expect

# Canada is having its worst year for wildfires

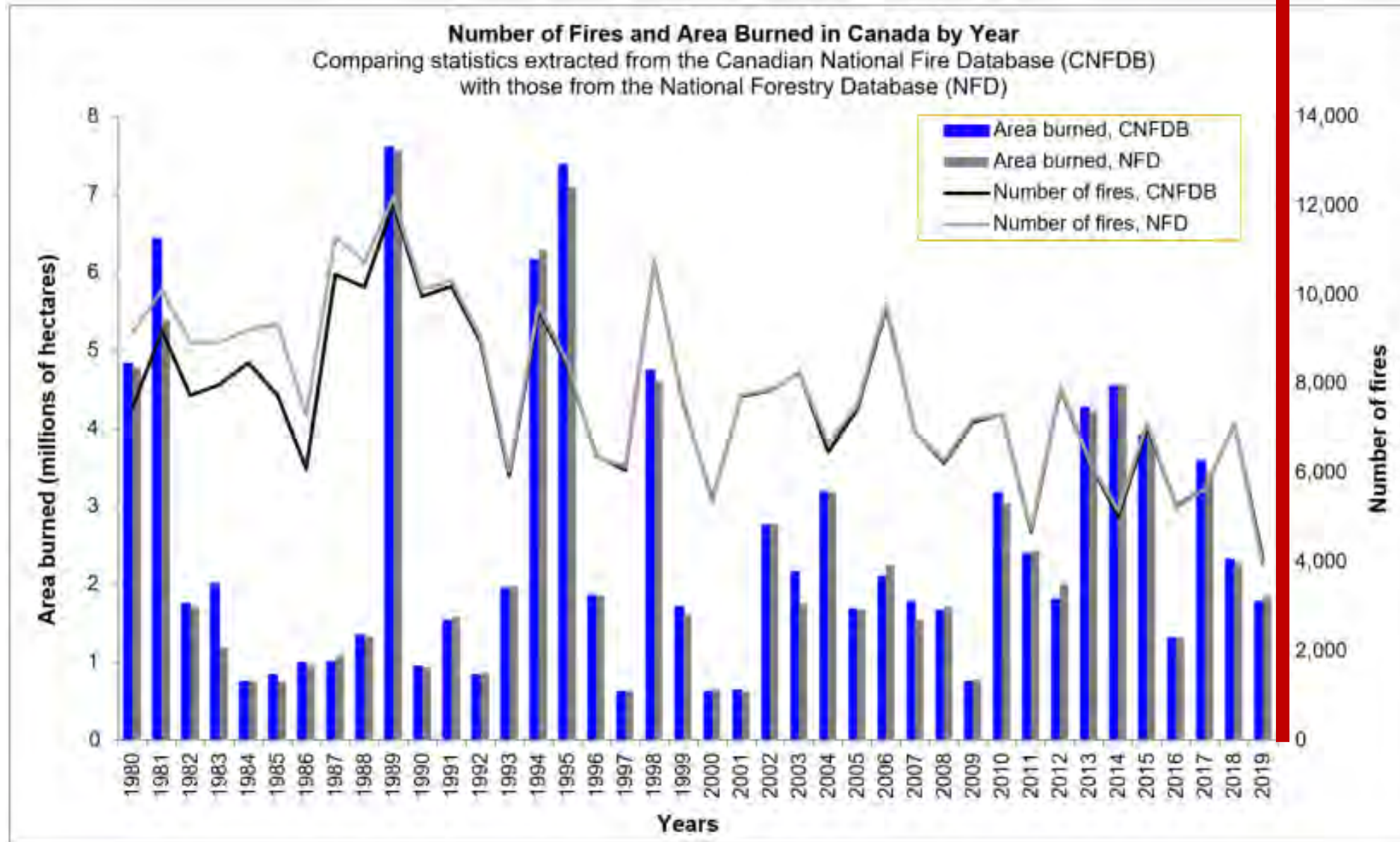
Area burned in million hectares each year since 1983



\*Provisional data for 2023 up to 17 August

Source: Canadian Interagency Forest Fire Centre

2023





# Forever changed – 10 years after the flood

Postmedia News

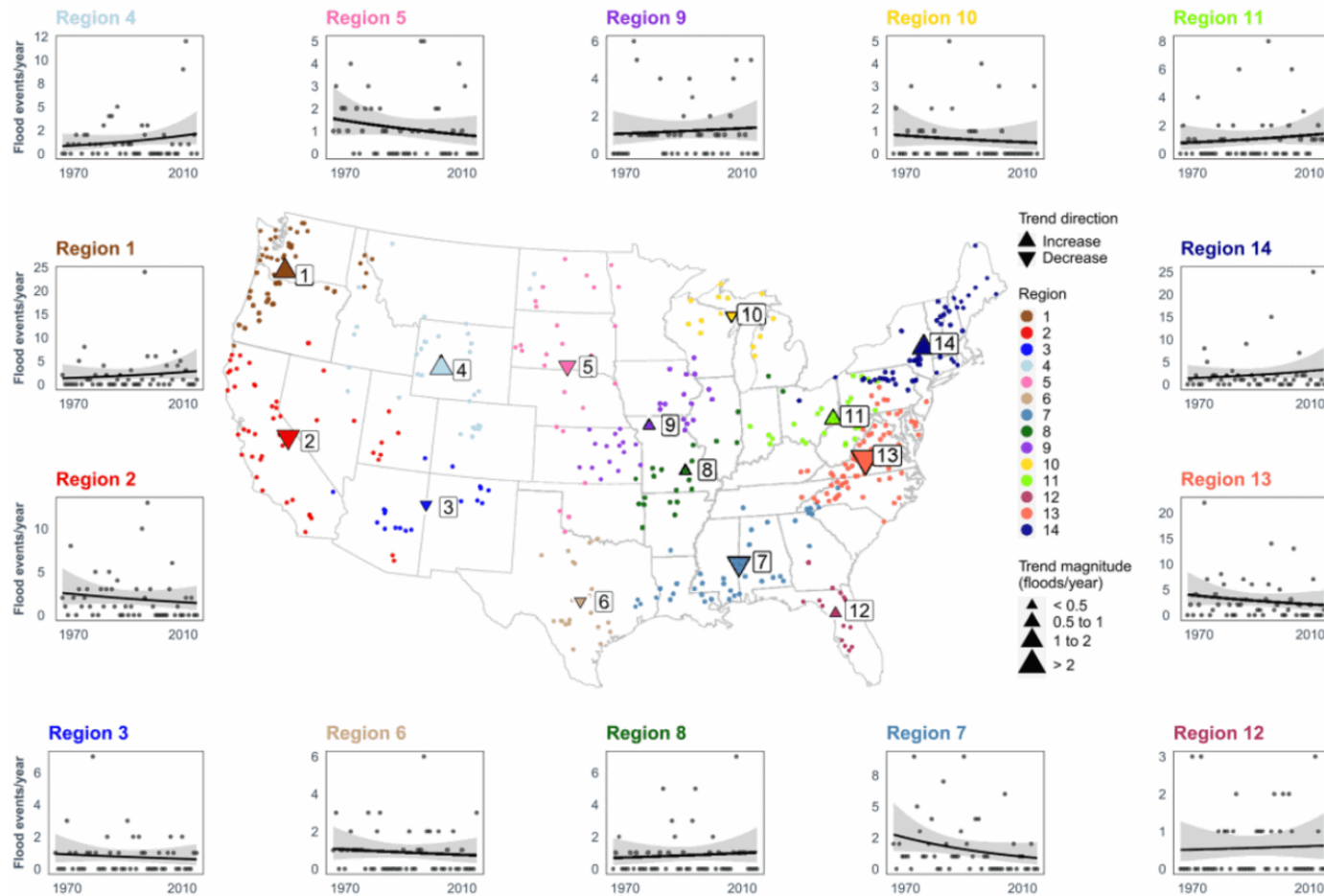
Published Jun 14, 2023 • Last updated Jun 21, 2023 • 2 minute read

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The Scotiabank Saddledome and surrounding areas in Calgary are submerged by floodwaters on June 21, 2013. Stuart Dryden/Postmedia file





The study team found little evidence that large floods have become more or less frequent from 1966 to 2015

Is the climate changing?

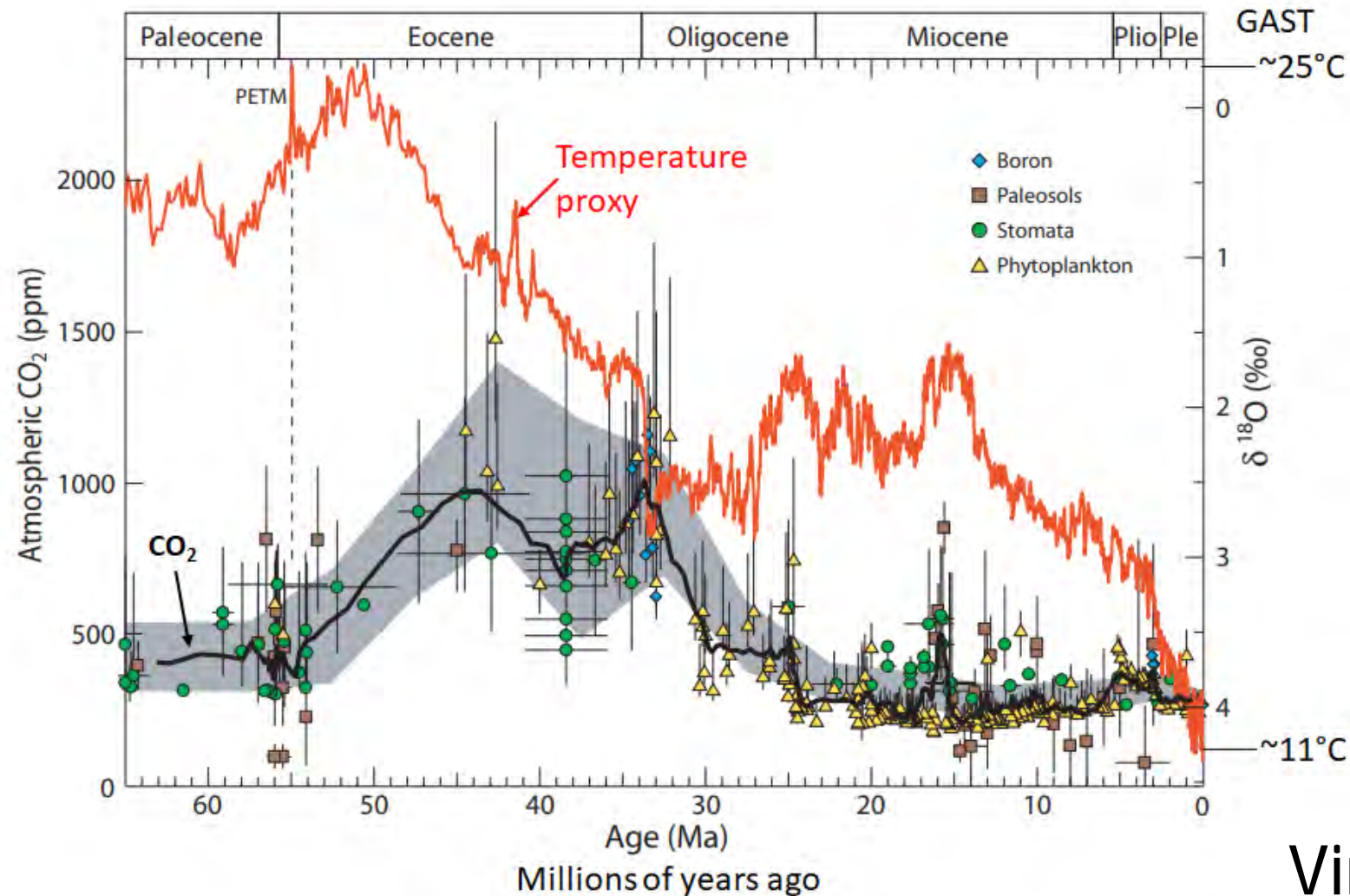
Is CO<sub>2</sub> driving global warming?

Can we achieve net-zero?

## Is CO<sub>2</sub> driving global warming?

- No evidence from the past that CO<sub>2</sub> is a driver

# CO<sub>2</sub> and Temperature during the Cenozoic (last 65 million years)

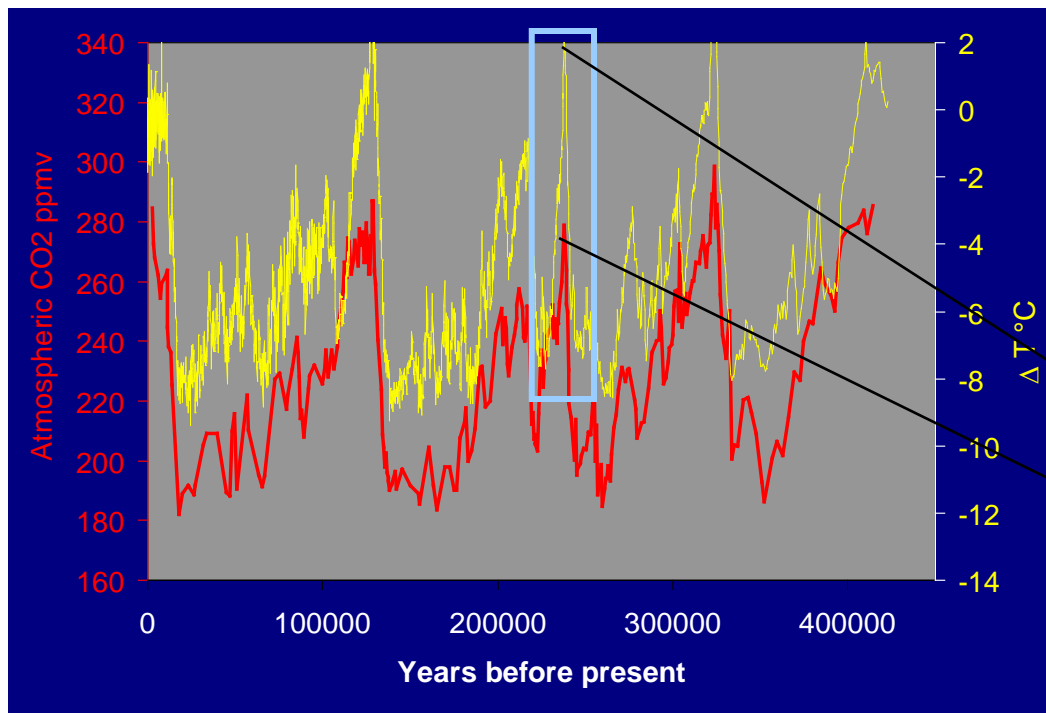


Vinós, 2022



T and CO<sub>2</sub> from ancient air bubbles in ice cores  
during the Ice Ages (last 400,000 years)

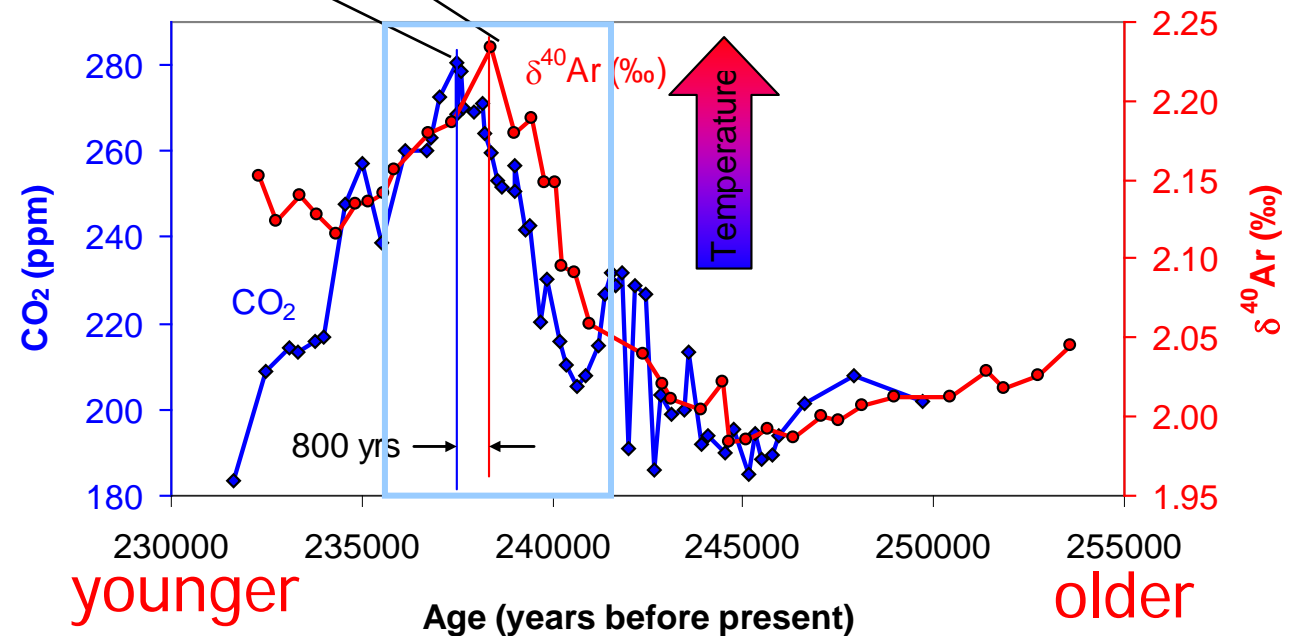




CO<sub>2</sub> lags behind temperature by ~800 years.

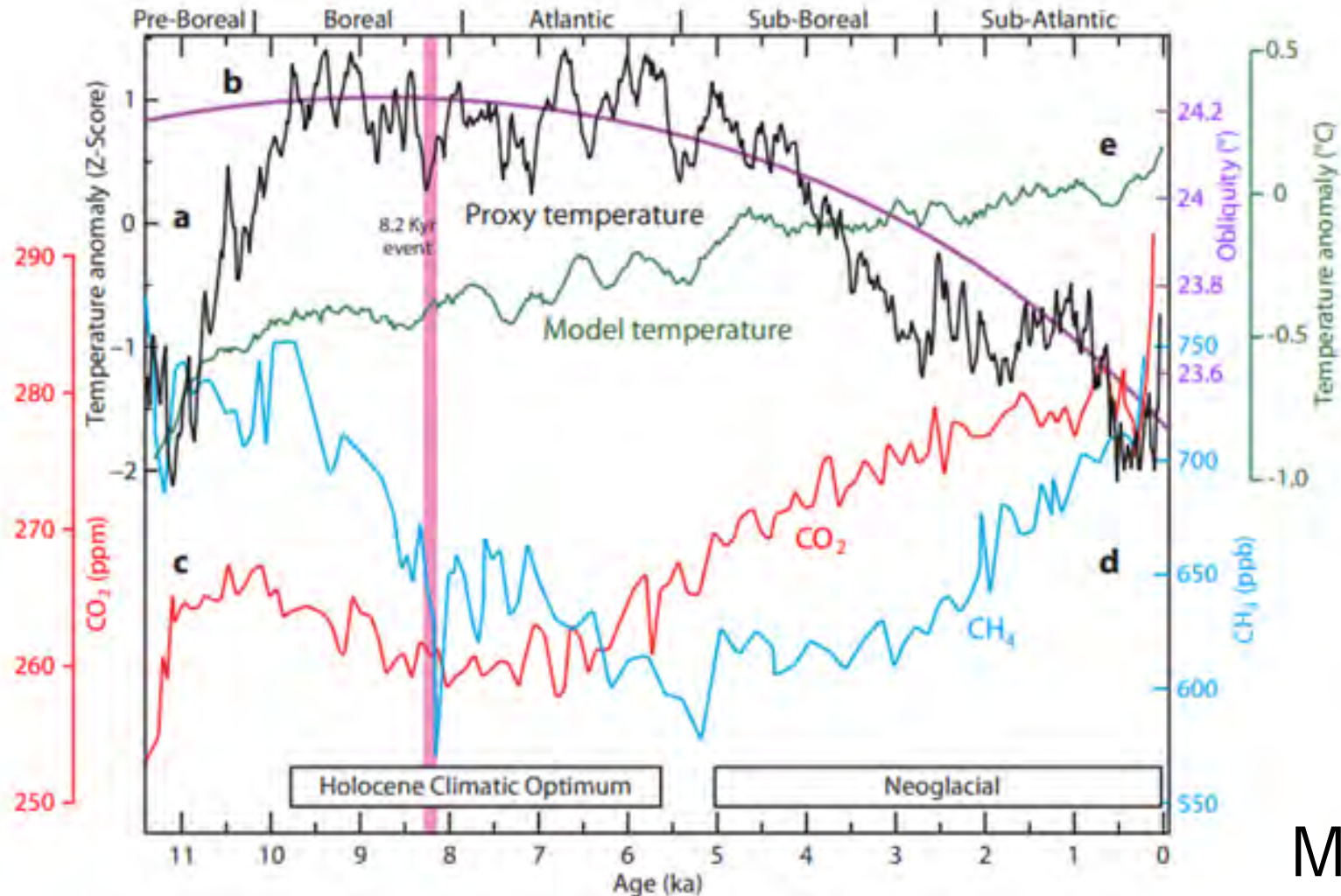
Temperature is driving CO<sub>2</sub>

Fischer et al., 1999, Science 283, 1712

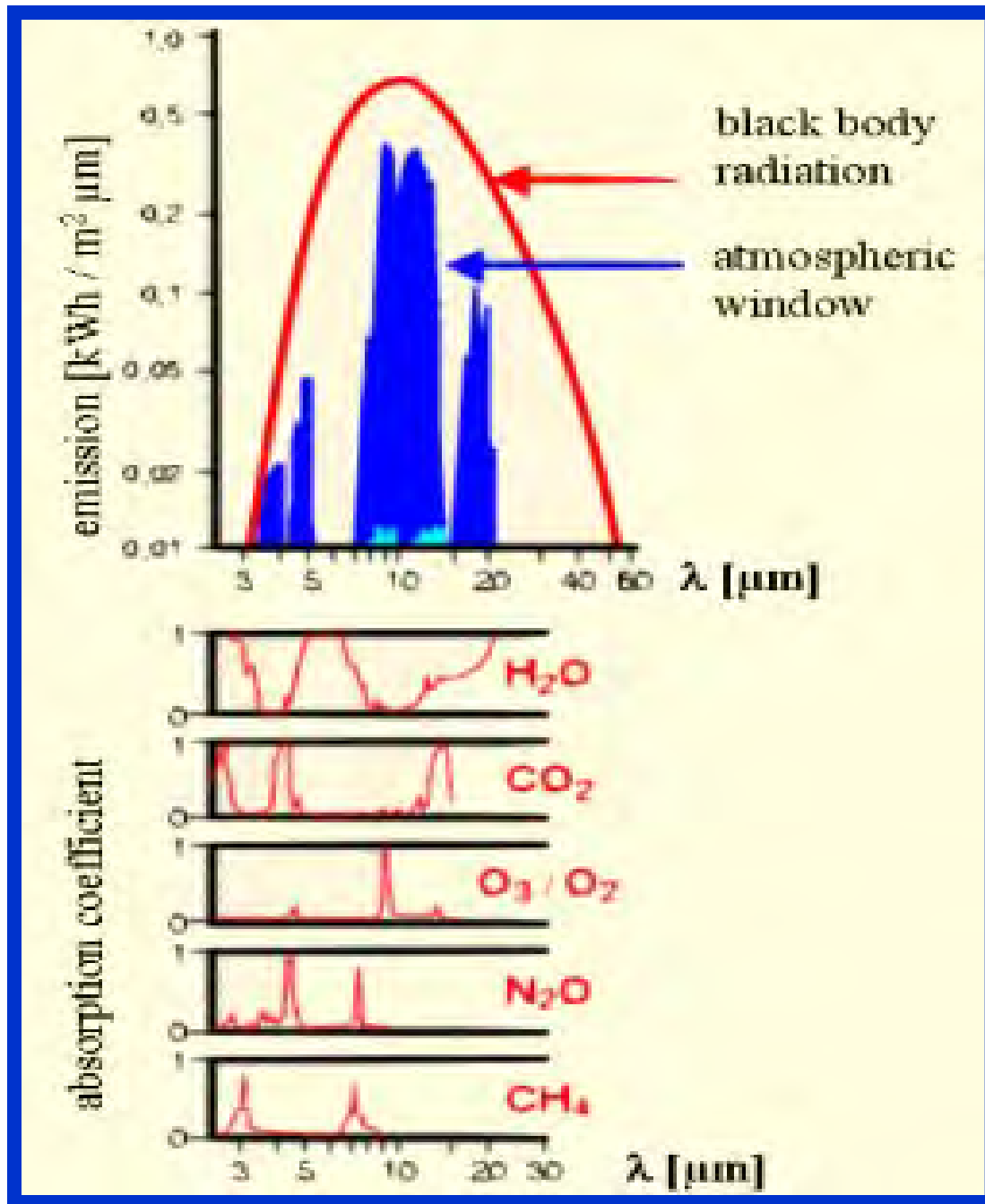


Caillon et al., 2003, Science

# CO<sub>2</sub> and Temperature during the Holocene Interglacial (last 12,000 years)



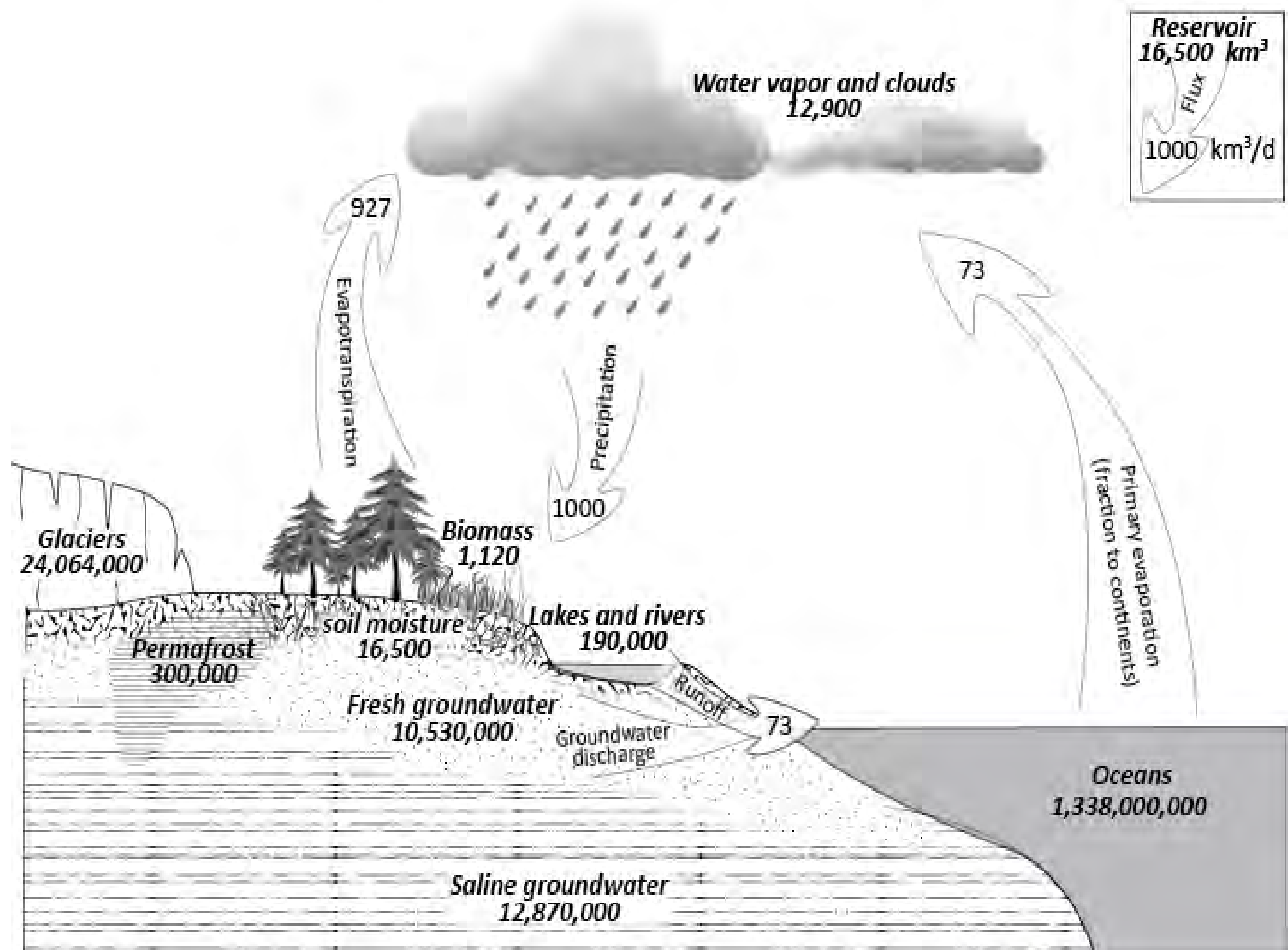
Monnin, 2004



## Is CO<sub>2</sub> driving global warming?

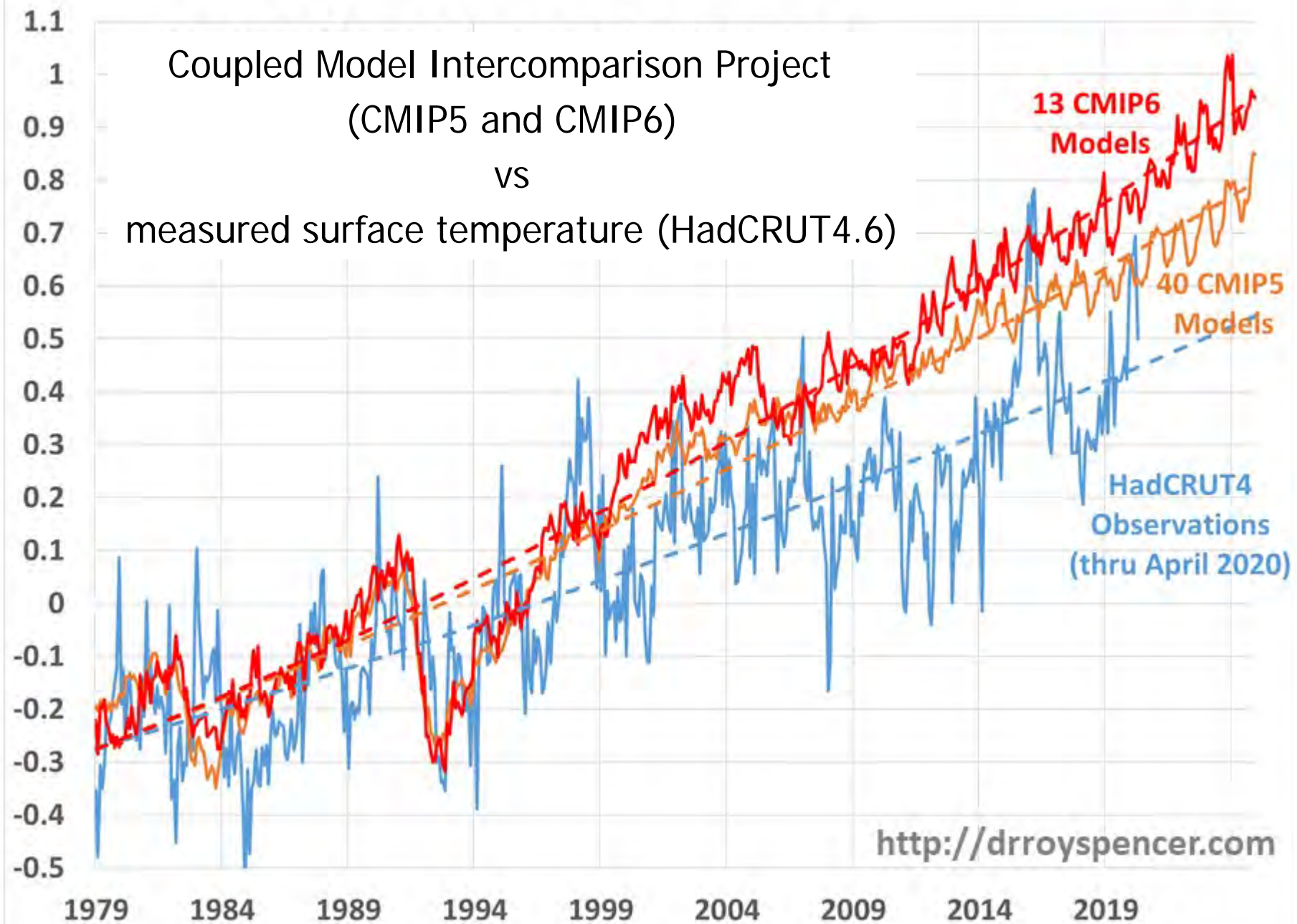
- CO<sub>2</sub> is a minor greenhouse gas
  - 420 ppm
  - Narrow absorption band
- H<sub>2</sub>O is the main GHG
  - 25,000 ppm
  - Broad absorption band





## Is CO<sub>2</sub> driving global warming?

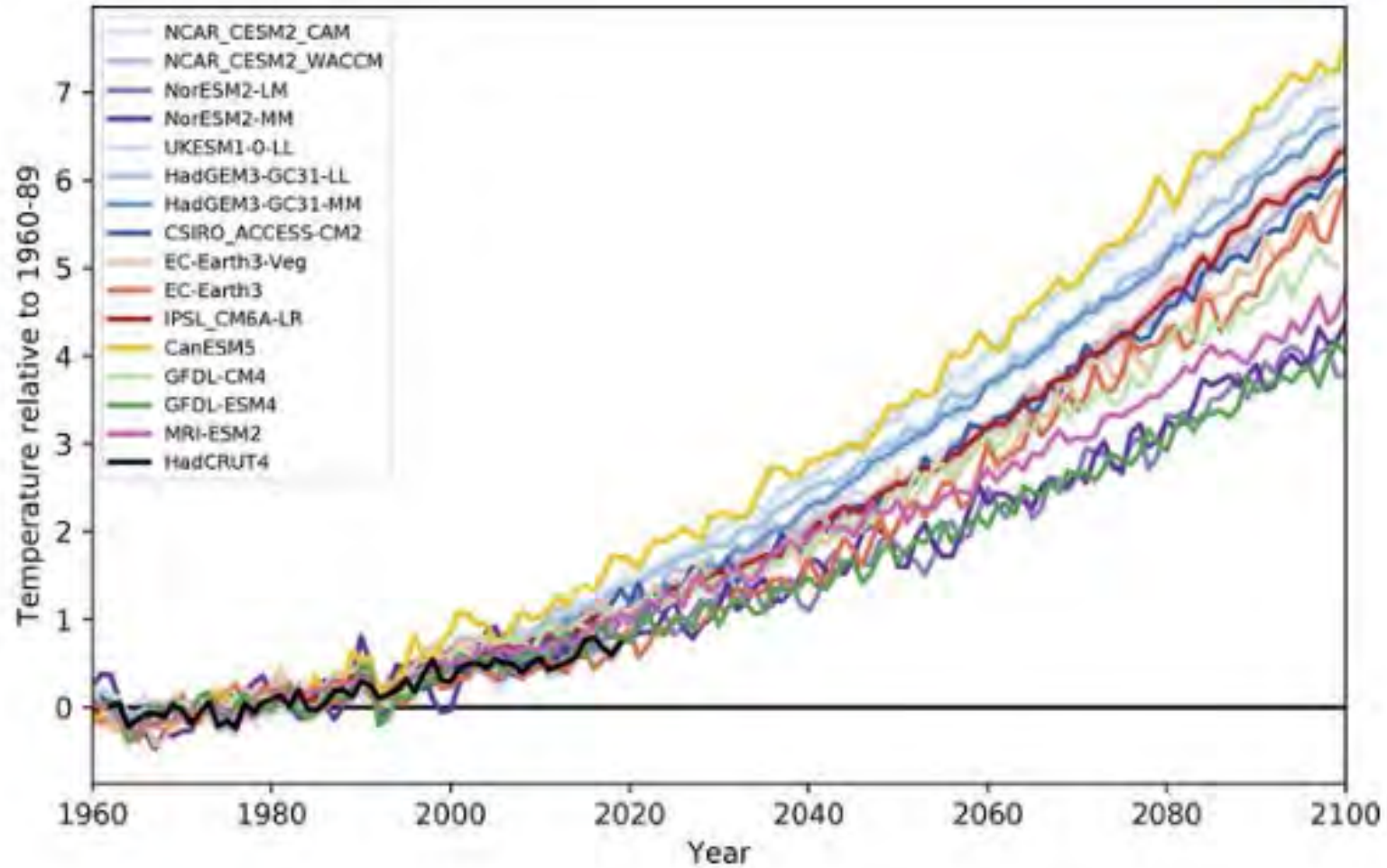
- No evidence in the geologic record
- Climate models amplify CO<sub>2</sub> warming with H<sub>2</sub>O
  - Minor CO<sub>2</sub> warming brings more water vapour into the atmosphere – a water vapour feedback
  - This suggests that the CO<sub>2</sub> cycle is driving the much larger water cycle, which is absurd
  - No scientific evidence, unproven hypothesis
  - Therefore, climate models run too hot



# Coupled Model Intercomparison Project 5 (CMIP5)

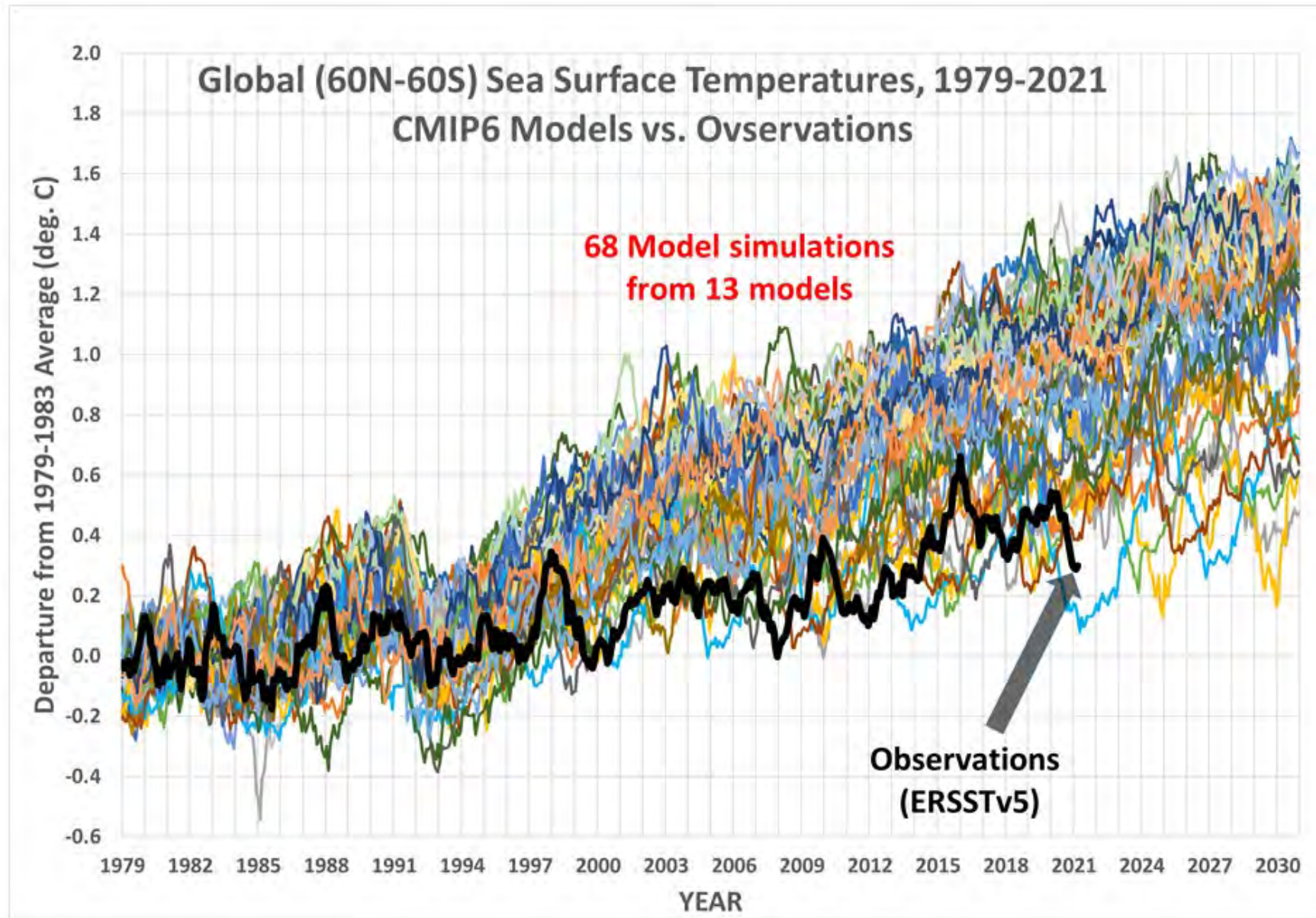
vs

Measured surface temperature (HadCRUT4.6)



Models tend to run hot.

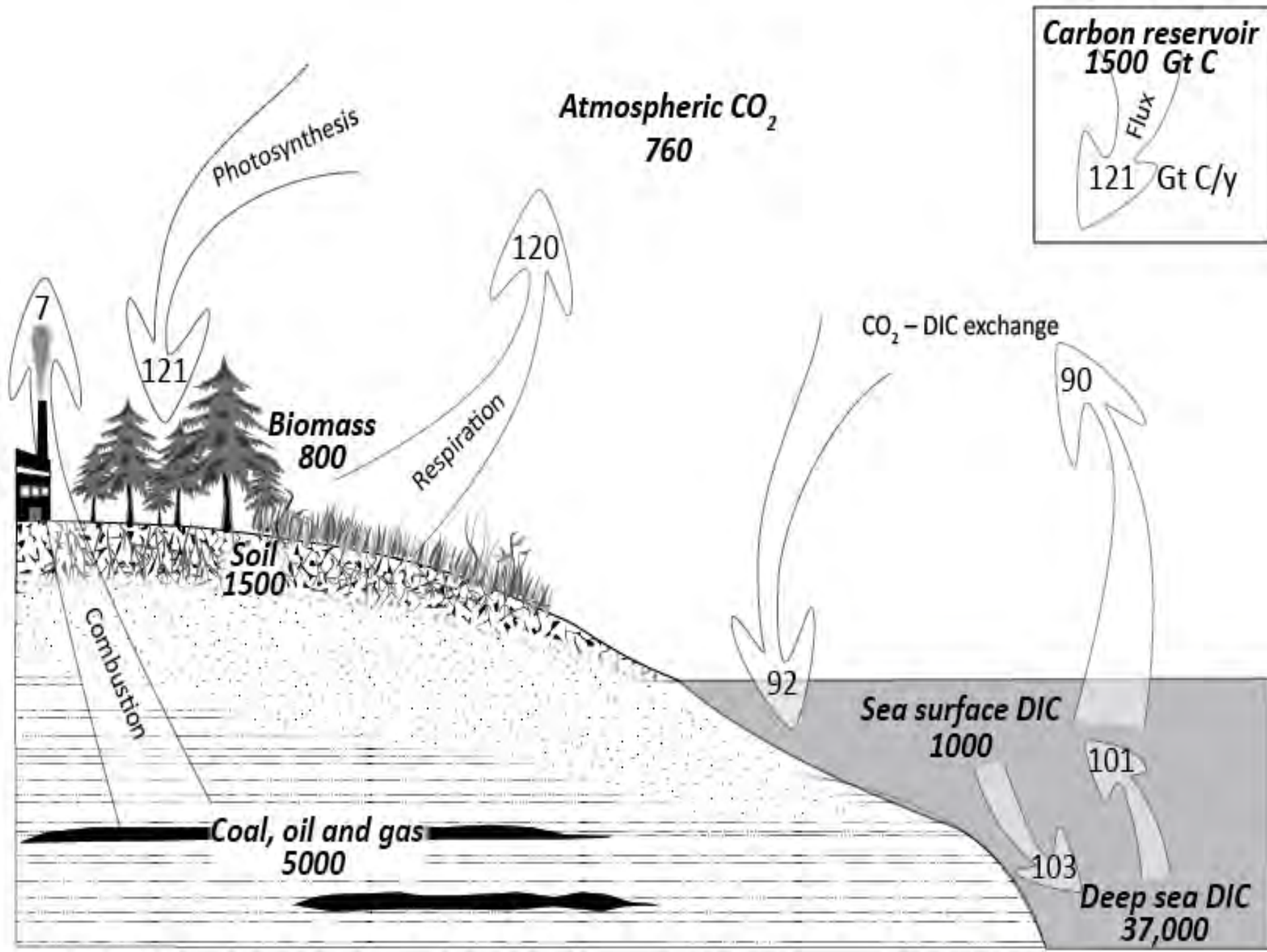


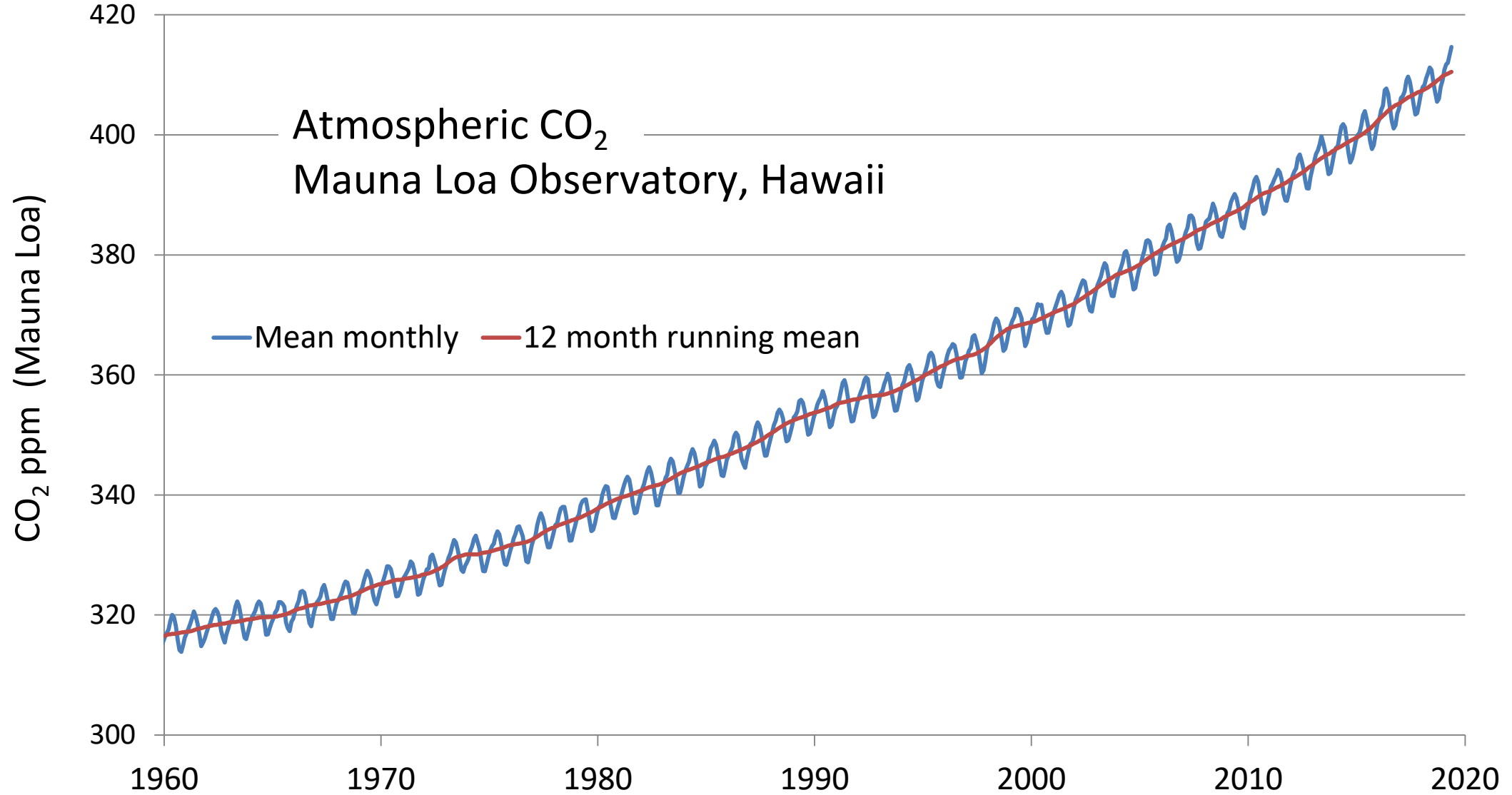


Models tend to run hot.

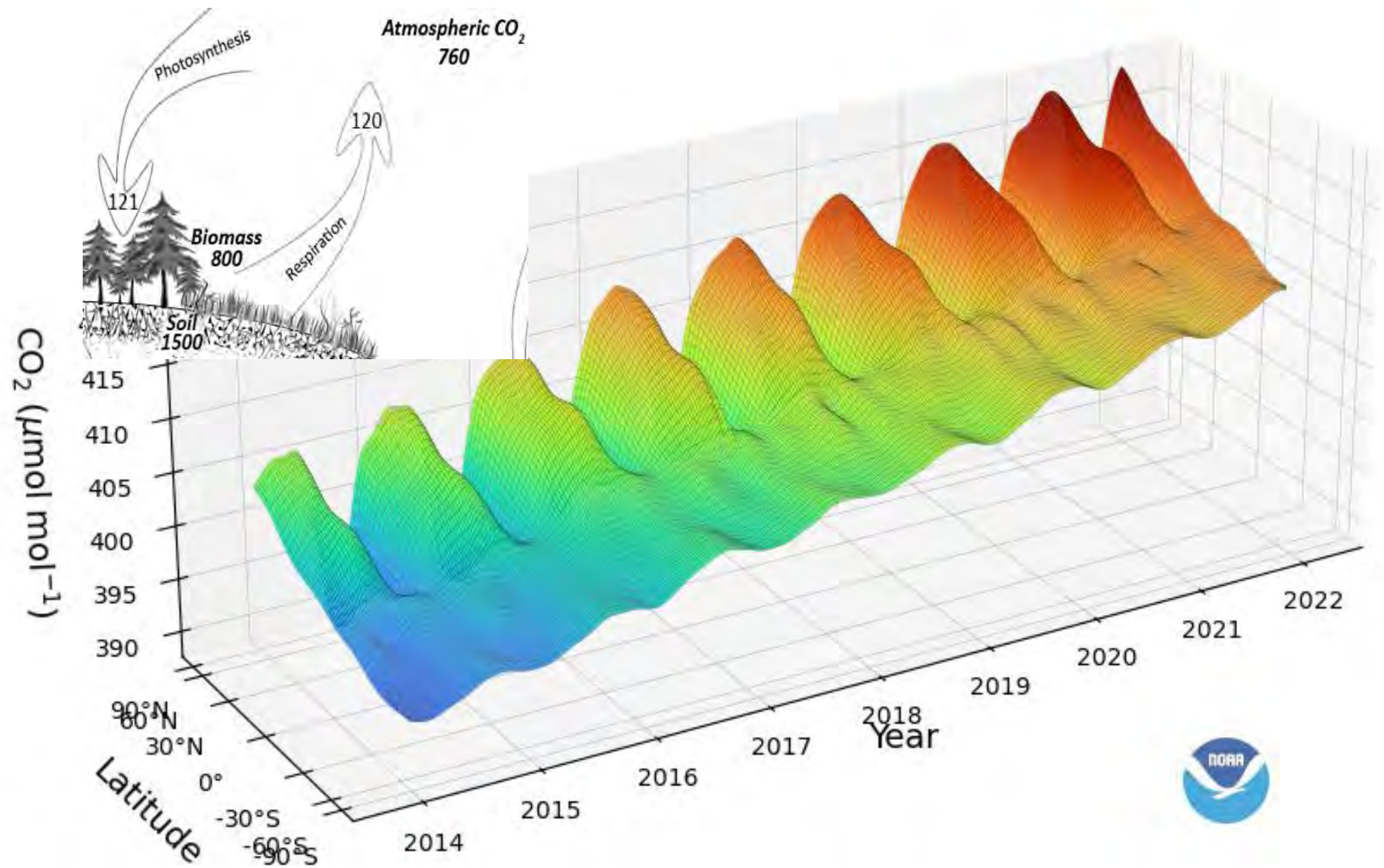
## Is CO<sub>2</sub> driving global warming?

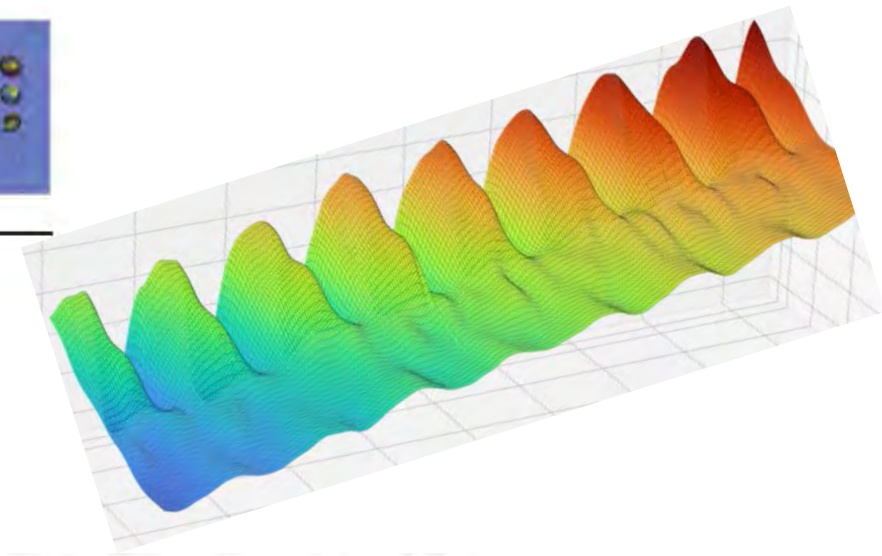
- No evidence in the geologic record
- Climate models amplify CO<sub>2</sub> with H<sub>2</sub>O
- Annual CO<sub>2</sub> cycles are driven by temperature






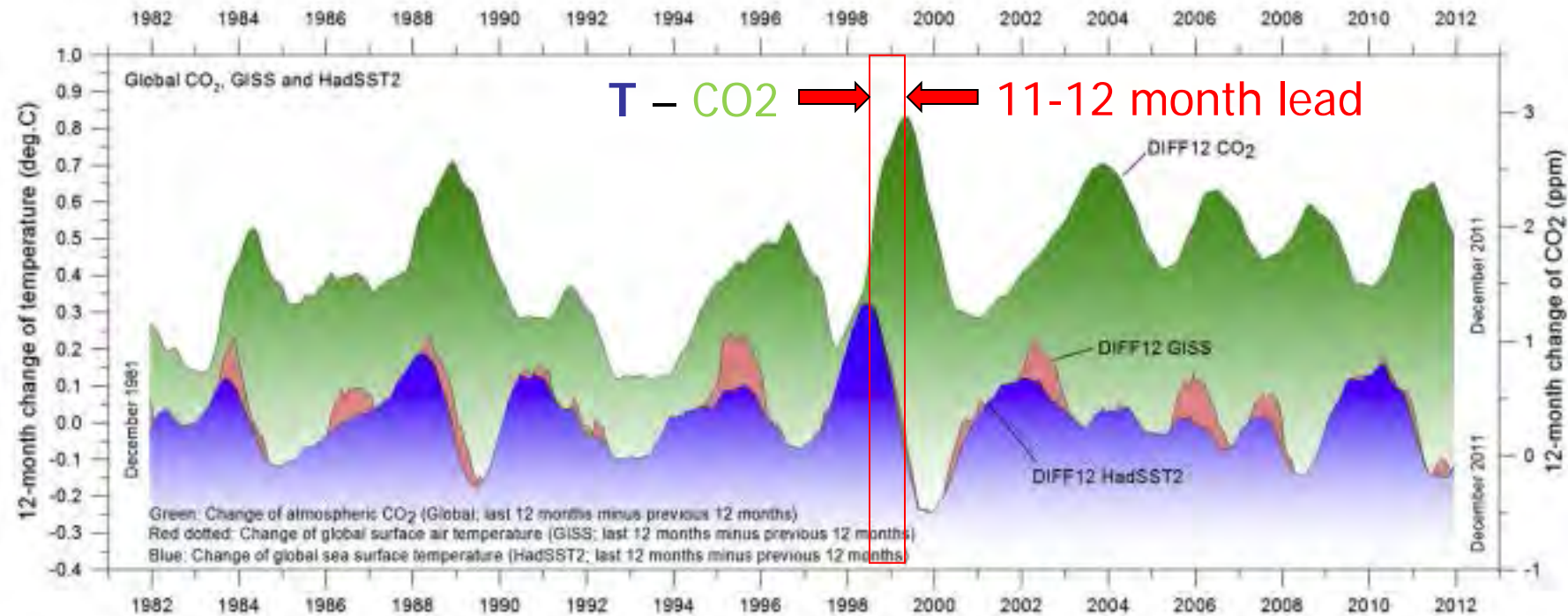






# The phase relation between atmospheric carbon dioxide and global temperature

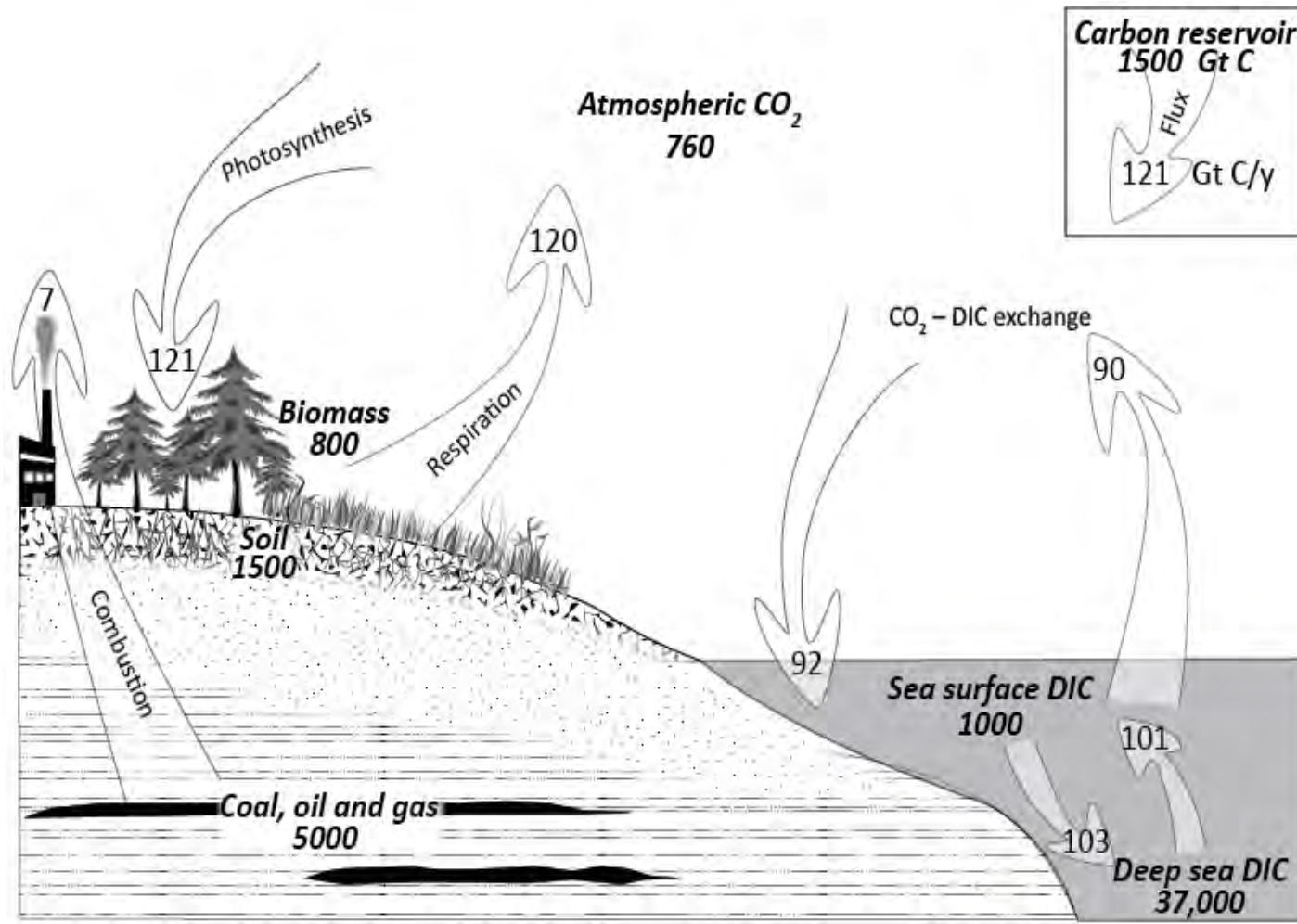
Ole Humlum <sup>a, b</sup>, , Kjell Stordahl <sup>c</sup>, Jan-Erik Solheim <sup>d</sup>





# Atmospheric CO<sub>2</sub>

- Mixing with 4x larger biosphere with a 4 year turn-over
- Concentration over time controlled by photosynthesis/respiration (T) and ocean solubility (T)

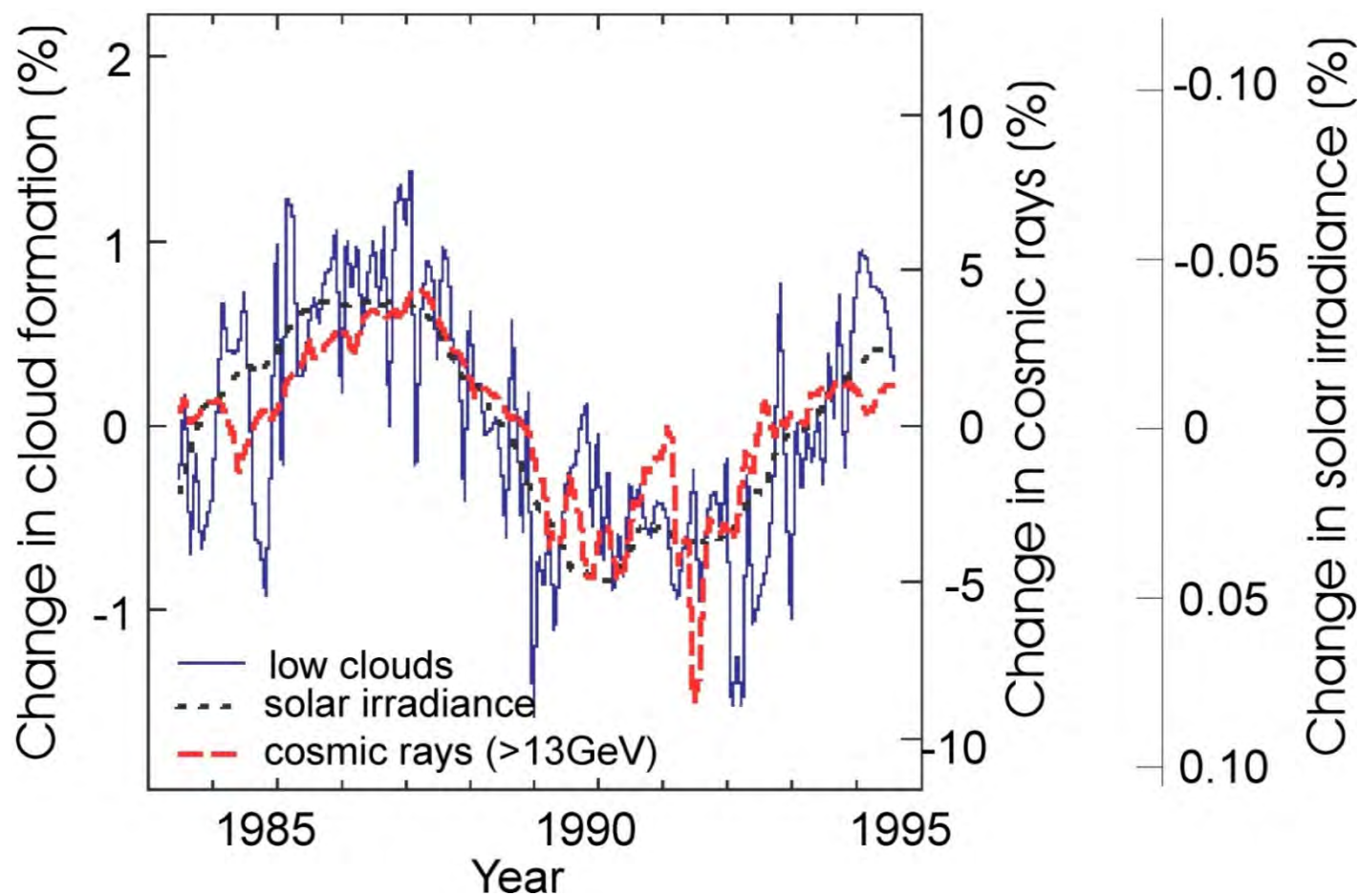


## Is CO<sub>2</sub> driving global warming?

- No evidence in the geologic record
- Climate models amplify CO<sub>2</sub> with H<sub>2</sub>O
- Annual CO<sub>2</sub> cycles are driven by temperature
- Temperature is driven by solar activity and cloudiness





# Higher solar activity = reduced cloud cover



N.Marsh, H.Svensmark, (2000).

# Radiative Energy Flux Variation from 2001–2020

by  Hans-Rolf Dübal <sup>1,\*</sup>  and  Fritz Vahrenholt <sup>2</sup>  

<sup>1</sup> Am Langenstück 13, 65343 Eltville, Germany

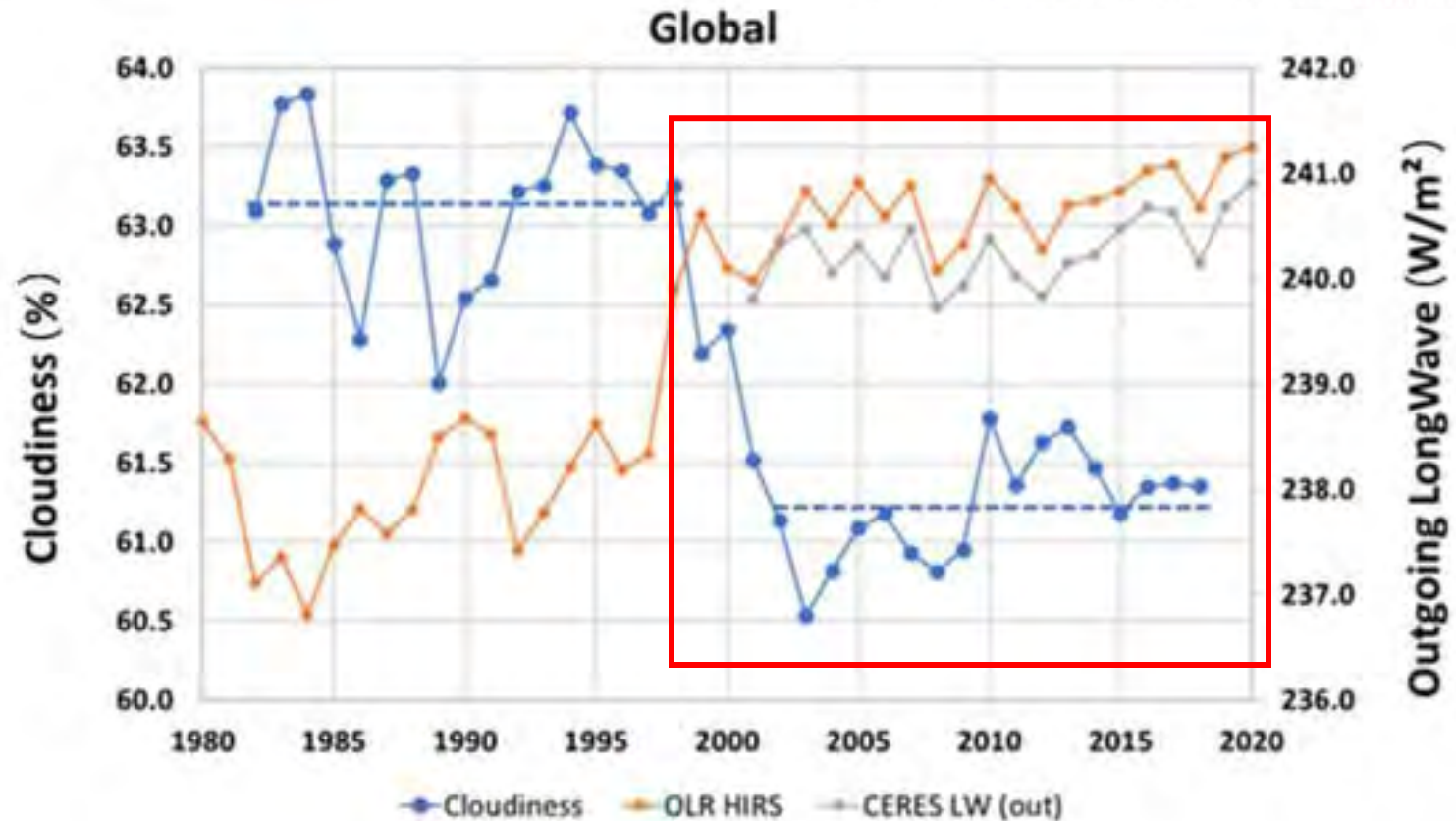
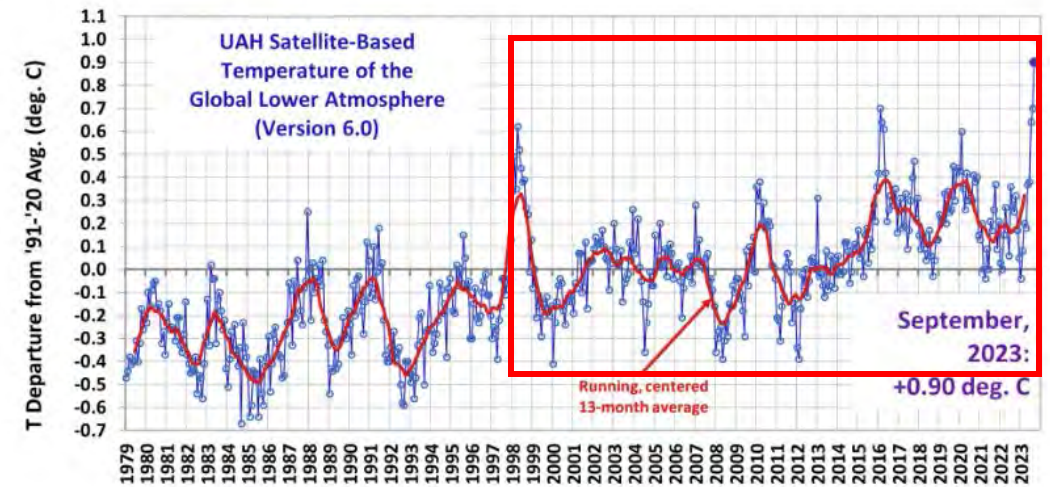
<sup>2</sup> Department of Chemistry, University of Hamburg, Papenkamp 14, 22607 Hamburg, Germany

\* Author to whom correspondence should be addressed.

*Atmosphere* **2021**, *12*(10), 1297; <https://doi.org/10.3390/atmos12101297>

Received: 1 September 2021 / Revised: 30 September 2021 / Accepted: 1 October 2021 /

Published: 5 October 2021



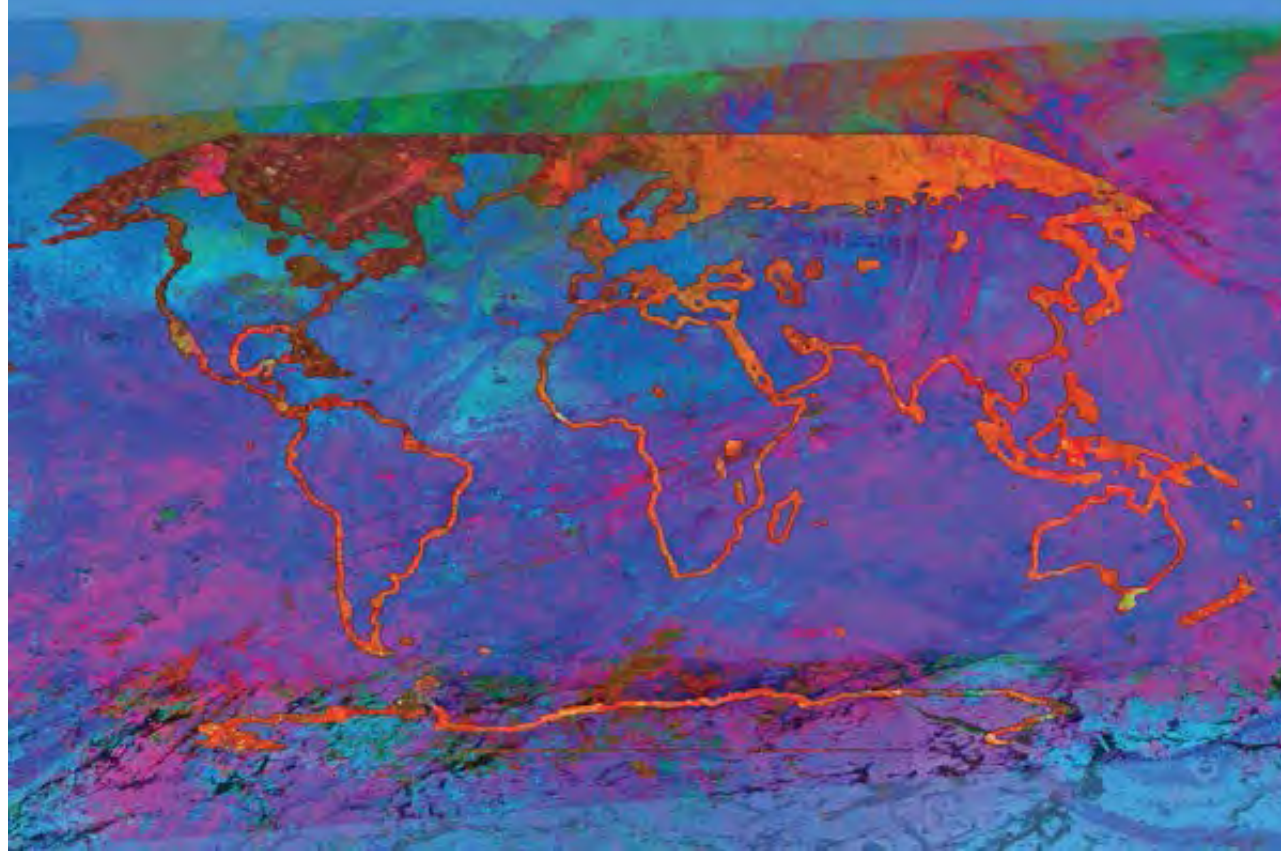
## Is CO<sub>2</sub> driving global warming?

- No evidence in the geologic record
- Climate models amplify CO<sub>2</sub> with H<sub>2</sub>O
- Annual CO<sub>2</sub> cycles are driven by temperature
- Temperature is driven by cloudiness
- IPCC attributes only 25% of warming to CO<sub>2</sub>



# Climate Change 2021

## The Physical Science Basis



### 3.3.1.1 Surface Temperature

Surface temperature change is the aspect of climate in which the climate research community has had most confidence over past IPCC assessment reports. This confidence comes from the availability of longer observational records compared to other indicators, a large response to anthropogenic forcing compared to variability in the global mean, and a strong theoretical understanding of the key thermodynamics driving its changes (Collins et al., 2010; Shepherd, 2014). The AR5 assessed

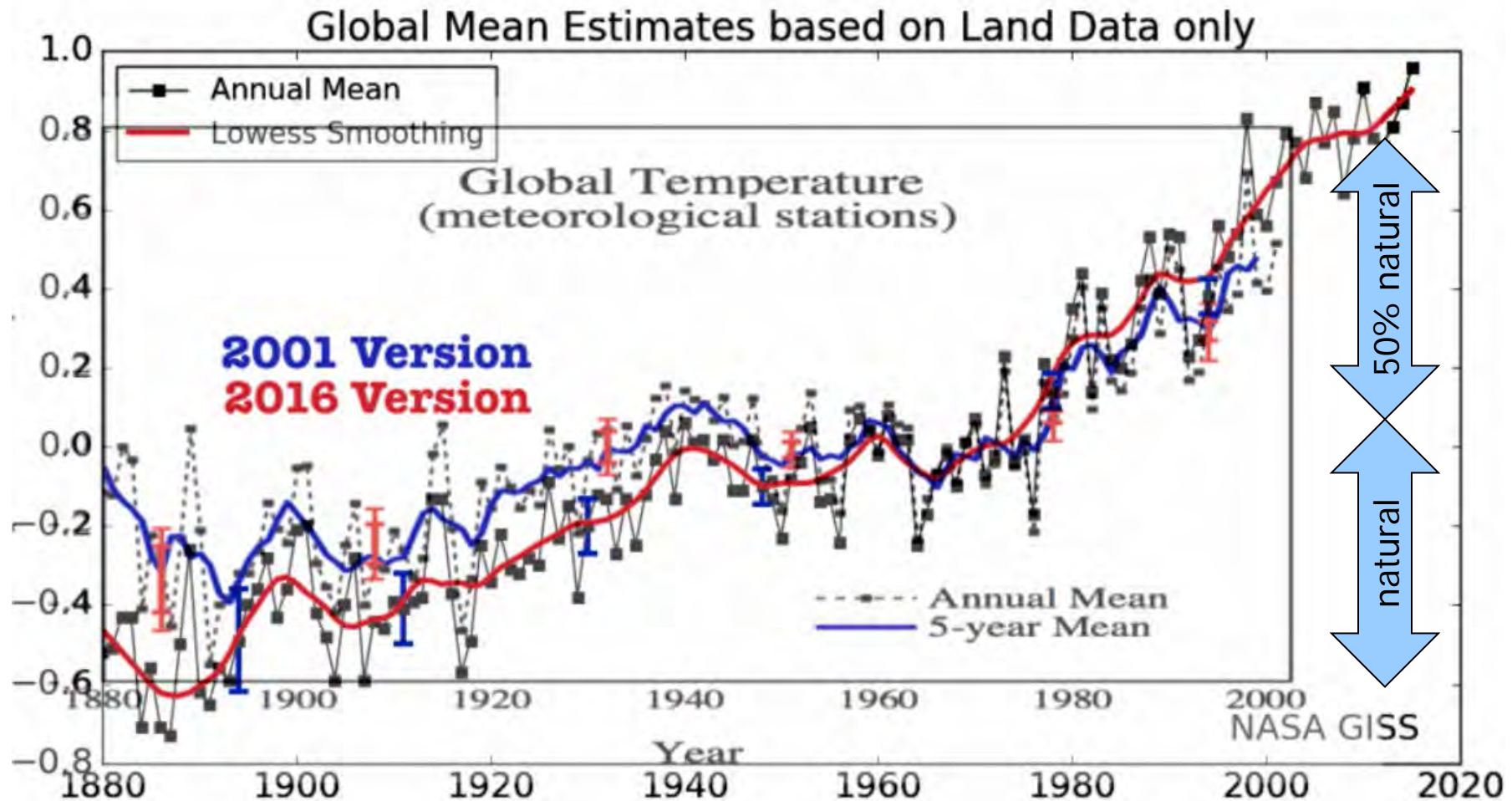
that it was *extremely likely* that human activities had caused more than half of the observed increase in global mean surface temperature from 1951 to 2010, and *virtually certain* that internal variability alone could not account for the observed global warming since 1951 (Bindoff et al.,

2013). The AR5 also assessed with *very high confidence* that climate models reproduce the general features of the global-scale annual mean surface temperature increase over 1850–2011 and with *high confidence* that models reproduce global and Northern Hemisphere temperature variability on a wide range of time scales (Flato et al., 2013). This section assesses the performance of the new generation CMIP6 models (see Table AII.5) in simulating the patterns, trends, and variability of surface temperature, and the evidence from detection and attribution studies of human influence on large-scale changes in surface temperature.



## IPCC attribution of 1.5°C warming since the Little Ice Age

- LIA to mid-20<sup>th</sup> Century is considered by IPCC to be natural
- Up to half the warming in late 20<sup>th</sup> Century is attributed by models to CO<sub>2</sub>
- ~75% of all warming since the LIA is natural



Is the climate changing?

Is CO<sub>2</sub> driving global warming?

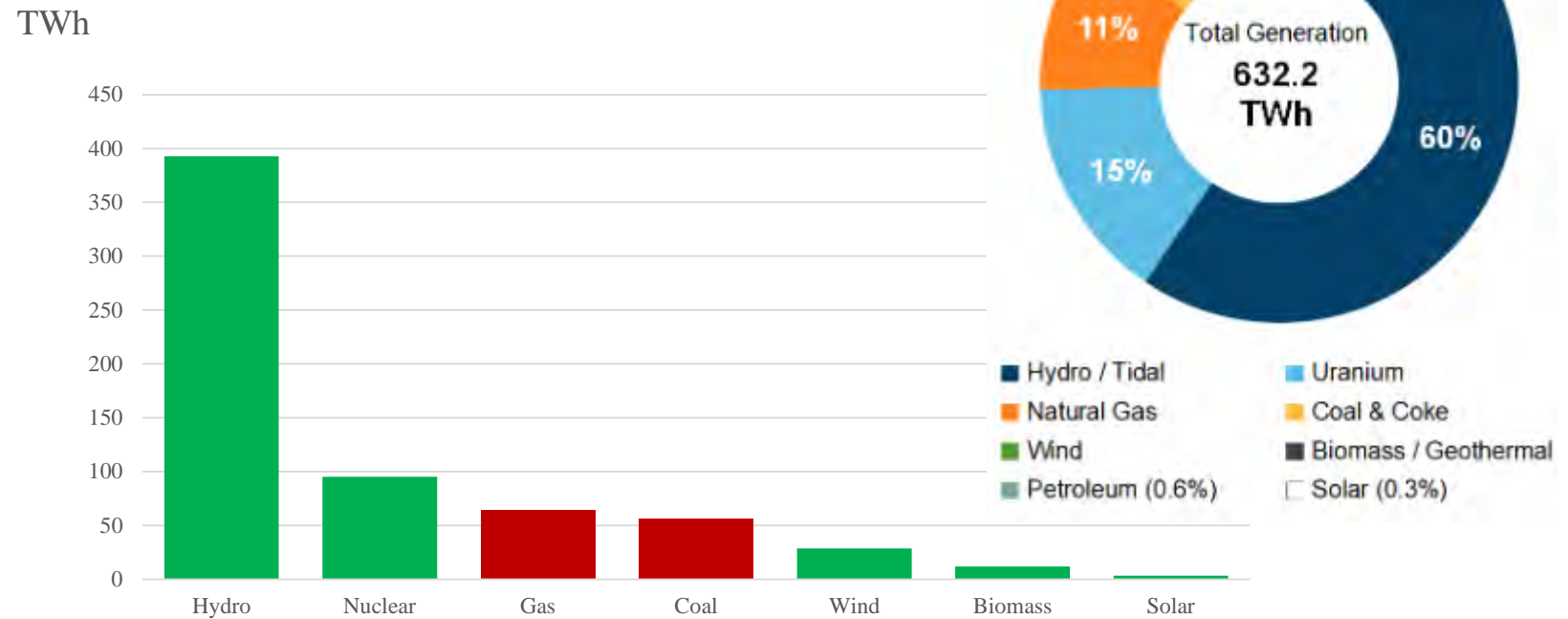
Can we achieve net-zero?

## Can we achieve net-zero?

- Where are we and where do we need to go?

# Canada's Electrical Mix

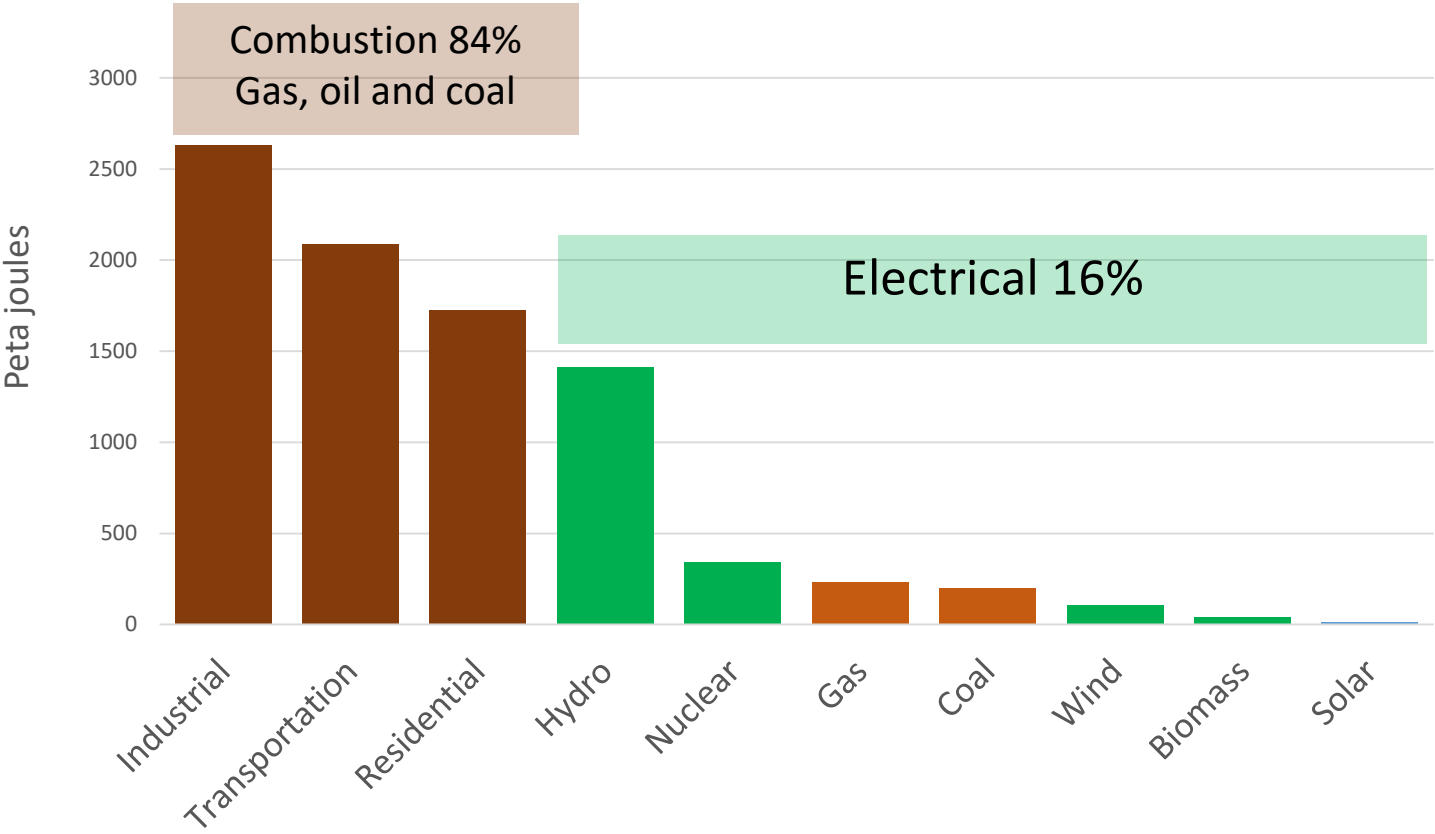
Total = 632 TWh  
81.5% green



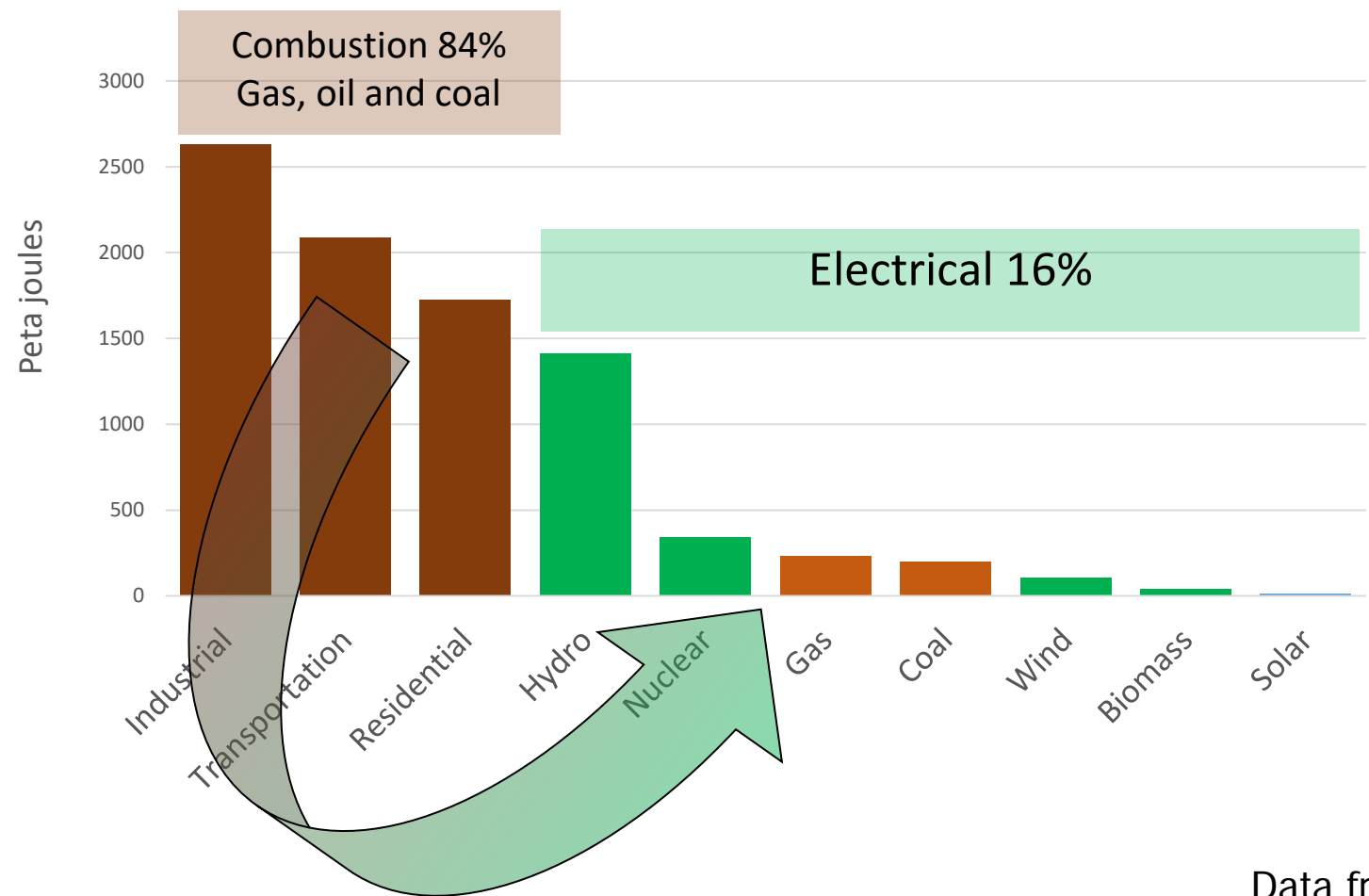
Source NRCAN



# Canada's Energy Demand, PetaJoules

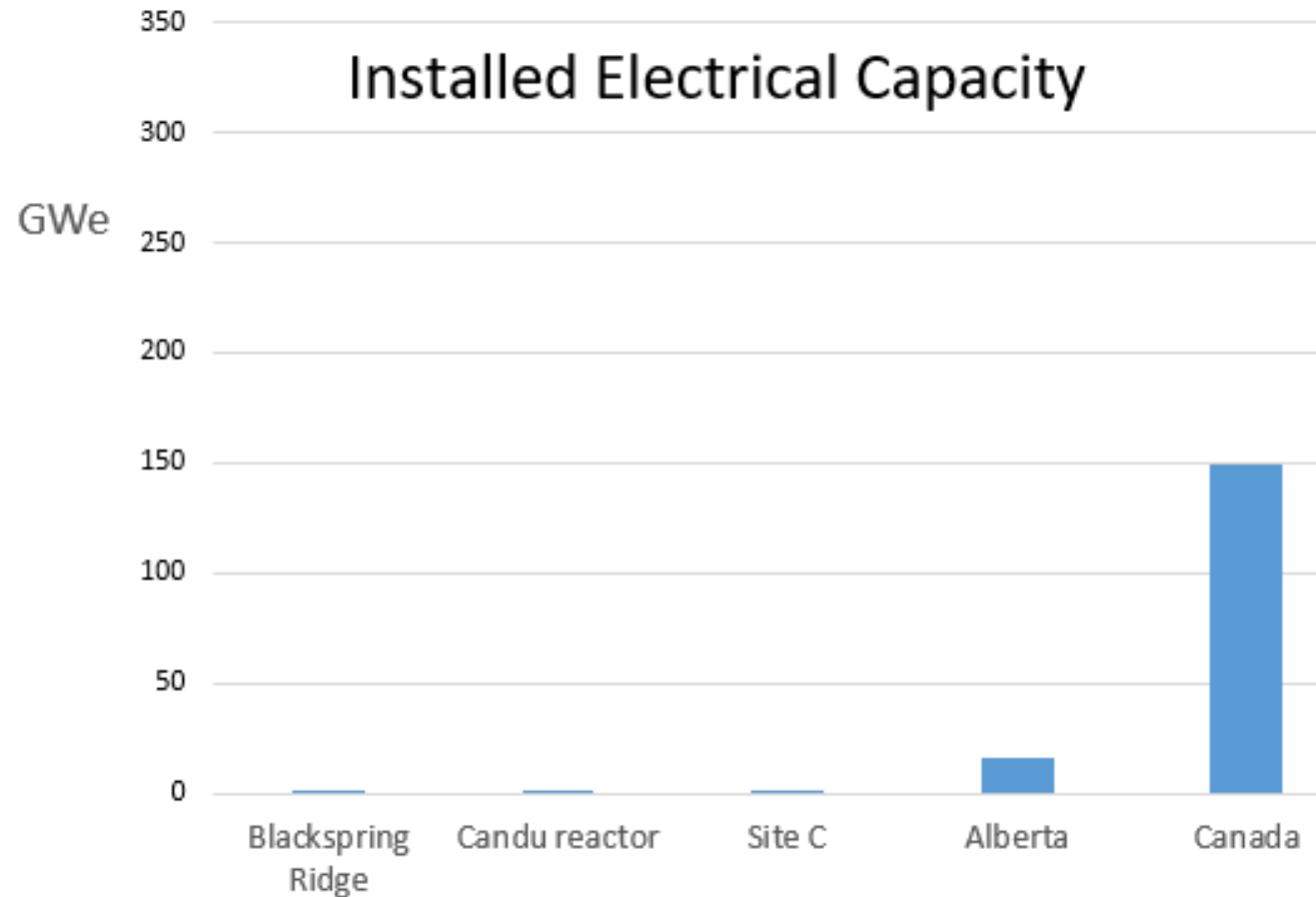


# Canada's Net Zero Transition



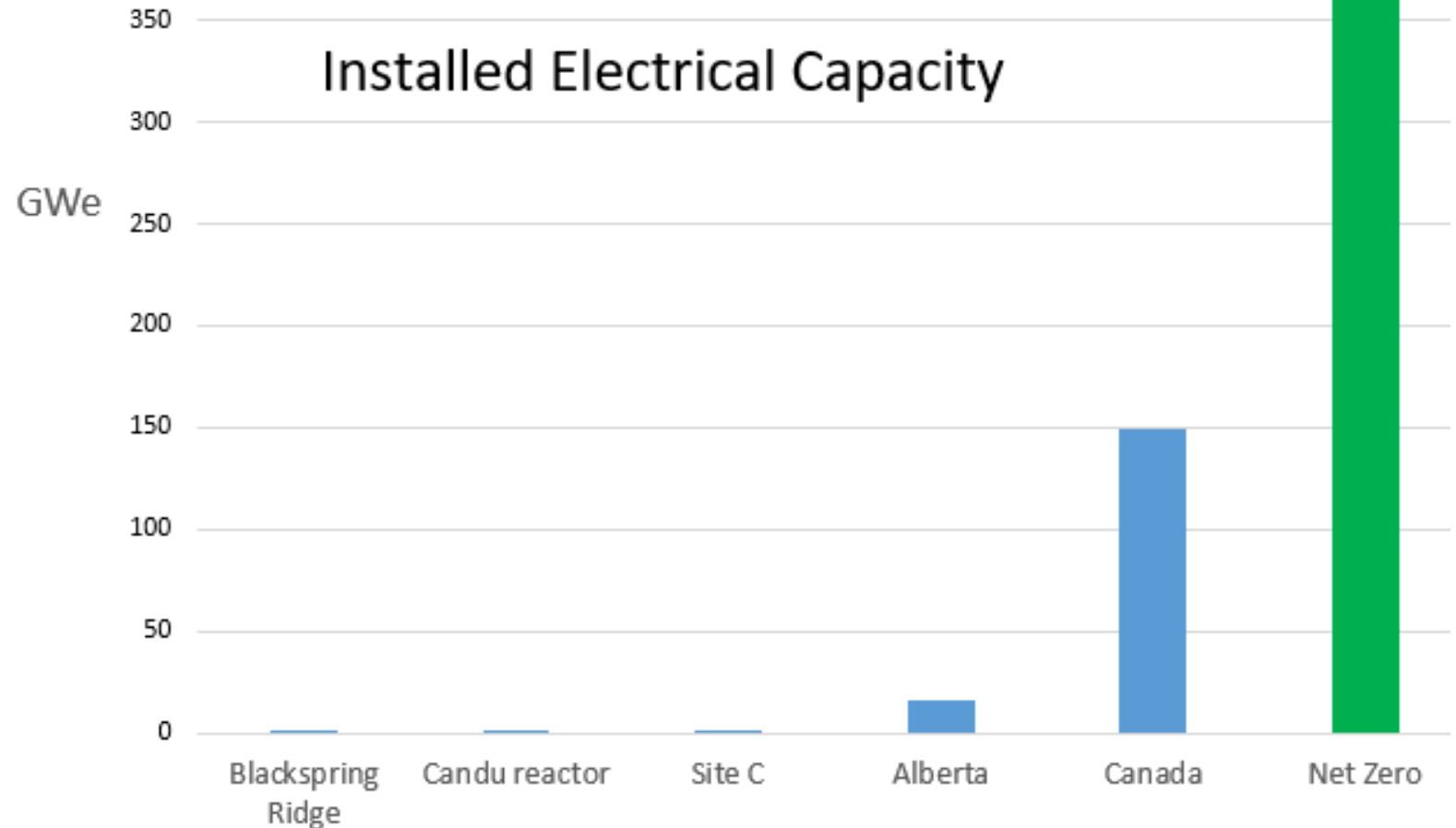
## Can we achieve net-zero?

- Where are we and where do we need to go?



## Can we achieve net-zero?

- Where are we and where do we need to go?
- We require a 3-fold increase in electricity







**CANADA'S MID-CENTURY  
LONG-TERM LOW-GREENHOUSE GAS  
DEVELOPMENT STRATEGY**

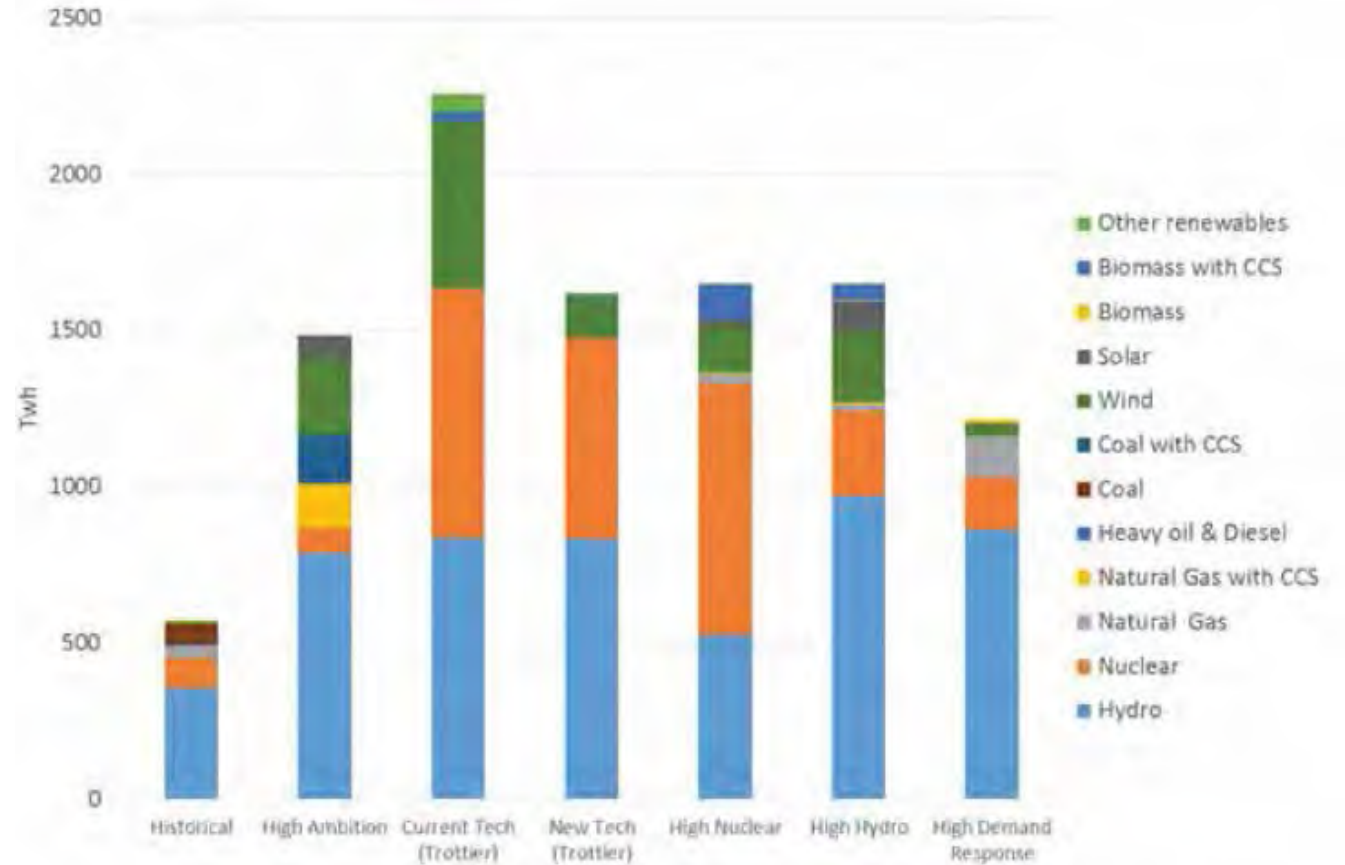




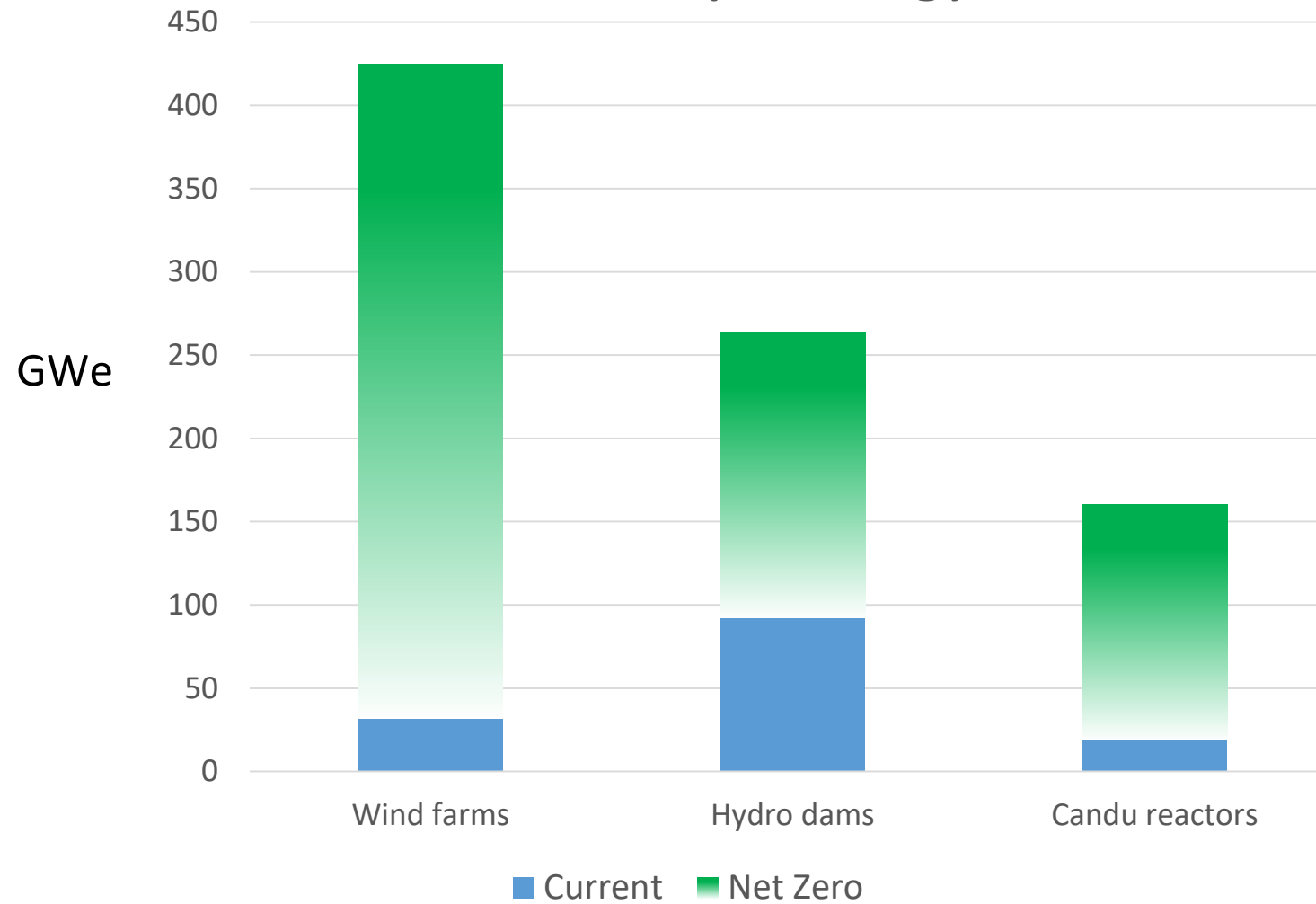
## Can we achieve net-zero?

- Where are we and where do we need to go?
- We require a 3-fold increase in electricity
- Within 25 years

CANADA'S MID-CENTURY  
LONG-TERM LOW-GREENHOUSE GAS  
DEVELOPMENT STRATEGY



## New builds to get to Net-Zero mix in Mid-Century Strategy







# Big Wind





## Big Wind in Net-Zero Mid-Century Strategy

- 350 new wind farms like Blackridge Spring
- 10 times more turbines
- 5 years of global production of Nd
- 50 years of global production of Dy
- Requires backup from gas or coal



# Big Hydro



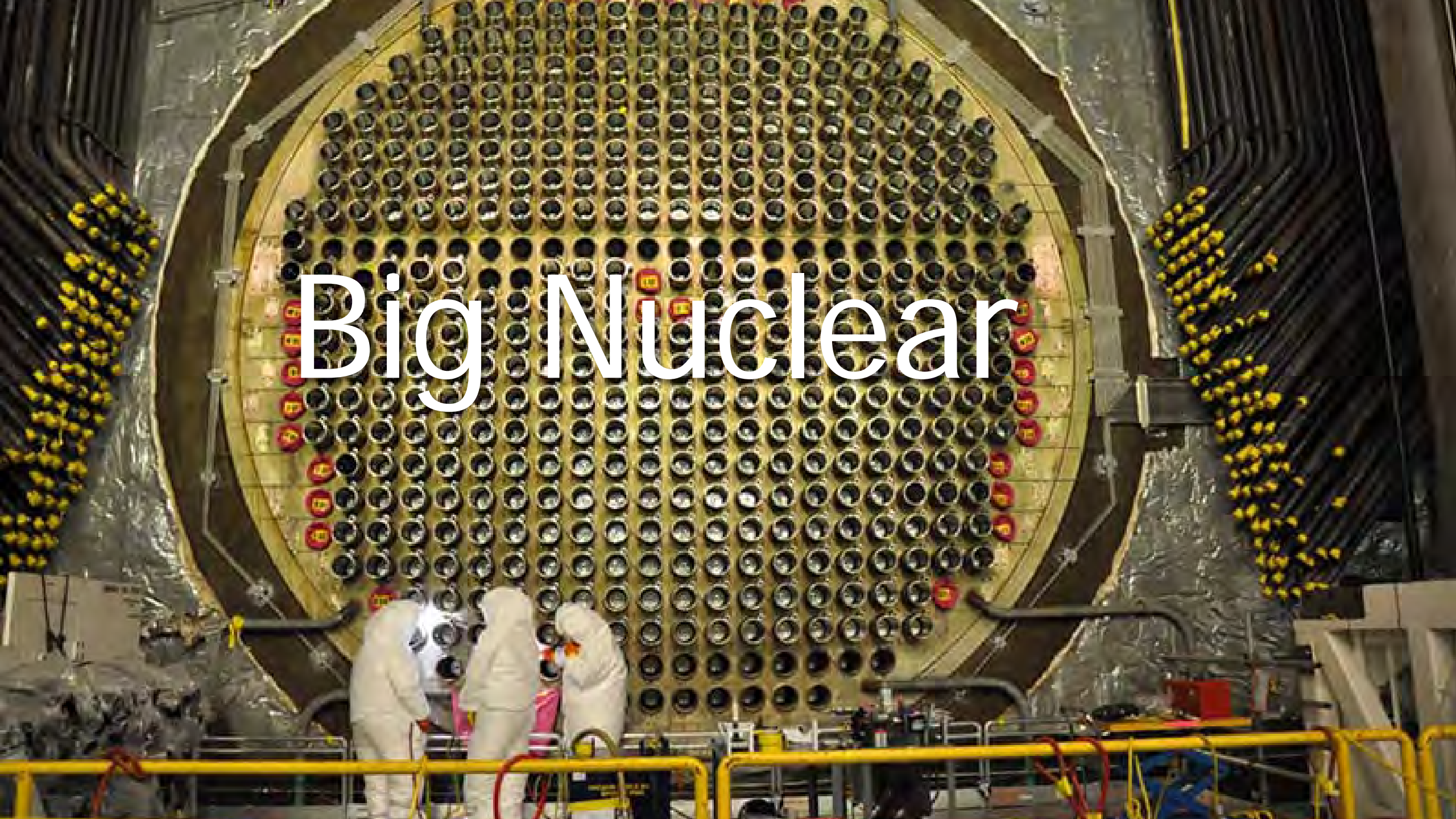




## Big Hydro in Net-Zero Mid-Century Strategy

- Site C is a 1.1 GW project
- Site C construction 2015-2025
- ~ 30 new dams on scale of Site C. Where??
- Net-Zero would flood over 8000 km<sup>2</sup>

# Big Nuclear



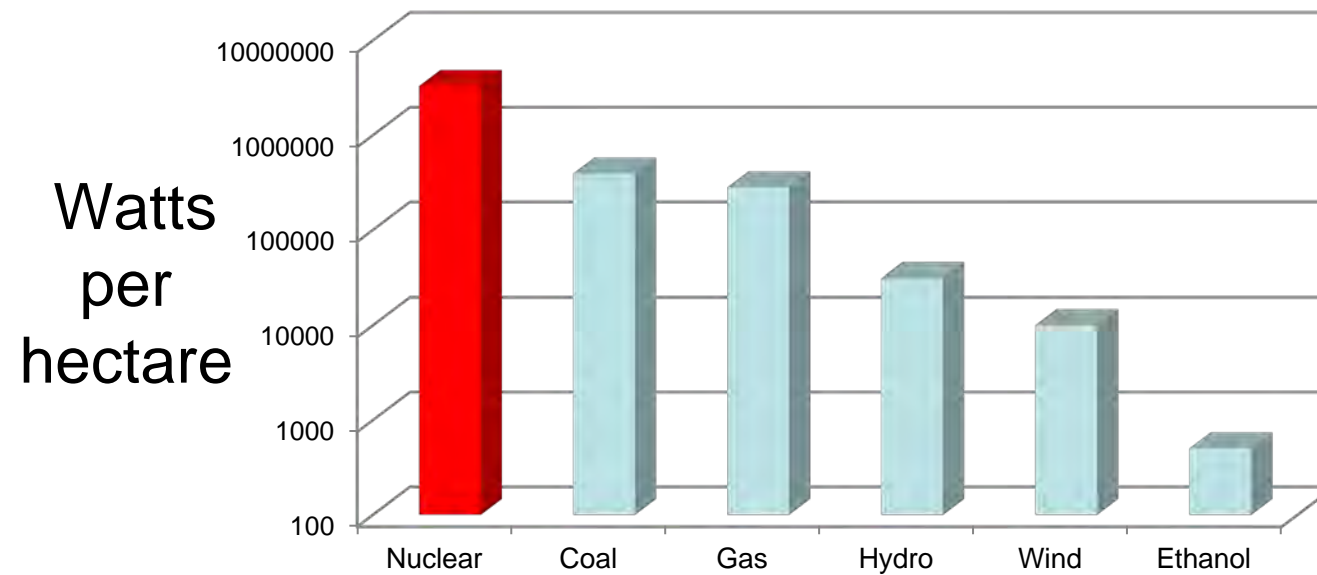




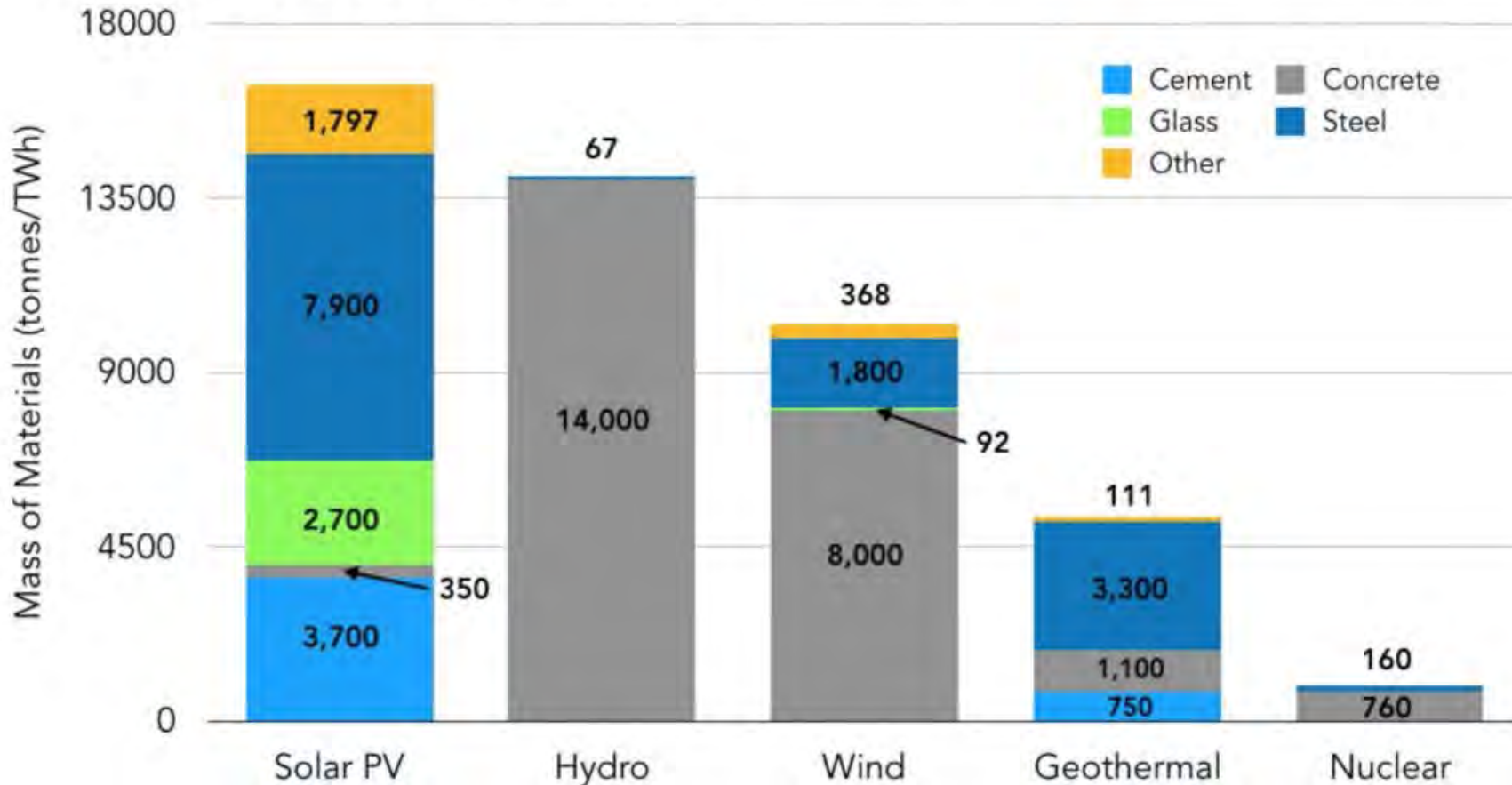
## Big Nuclear in Net Zero Mid-Century Strategy

- 150 new reactors
- 20 new nuclear power stations
- \$600 Billion
- **Full nuclear (only realistic option):**
  - >400 new reactors
  - \$2.2 Trillion (our GDP)

# Lowest land-use footprint



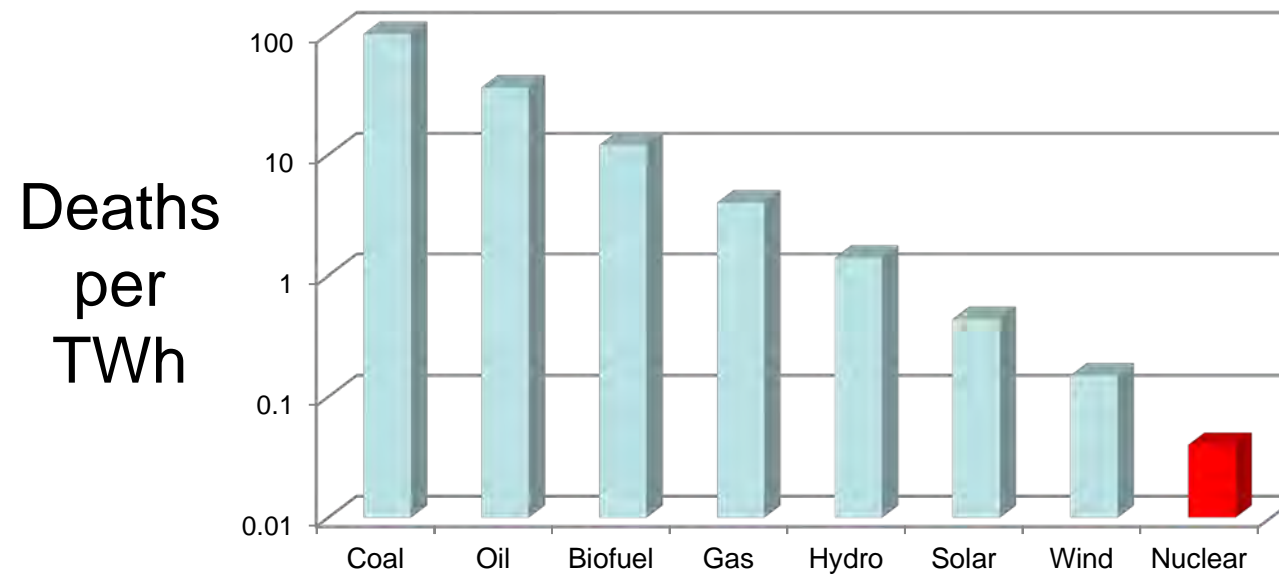
# Lowest requirement for construction material



"Quadrennial Technology Review: An Assessment of Energy Technologies and Research Opportunities," Table 10. September 2015. United States Department of Energy. Nuclear and hydro require 10 tonnes/TWh and 1 tonne/TWh of other materials, respectively, but are unable to be labeled on the graph.

Source: Dr. Elizabeth Anderson

# Best safety record



ExterneE, Externalities of Energy, National Implementation, European Commission, Directorate General XII; 1999. See <http://externe.jrc.es>  
nextbigfuture.com

# Storage of nuclear waste a 'global crisis': report



Date created : 30/01/2019 - 18:48



AFP/File

Nuclear waste is piling up around the world even as countries struggle to dispose of spent fuel that will remain highly toxic for many thousands of years, Greenpeace detailed in a report



# Proposed site for disposal of nuclear waste

- Target horizon at 650 m in sedimentary rock
- Detailed geological investigations 2007-12
- 250 million year old waters
- Site approved by Canadian Nuclear Safety Commission

e Michigan

Lake Huron

DGR



## What can we conclude?

- Climate change is a reality of our planet
- CO<sub>2</sub> is not an apparent driver
- Yet, Canada is committed to net-zero
- Nuclear is our only real non-emitting option
- We need a lot
- Good luck . . .

## And some final thoughts . . .

- Better areas to invest our environmental goodwill (land use, biodiversity, peak water . . . )
- CO<sub>2</sub> is not a contaminant, it is the essence of life.
- Thanks to increased T and CO<sub>2</sub> we have a greener planet.



2000 - 2018