Greenhouse Gas Emissions and Future Sea-Level Rise

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"# @bobkopp

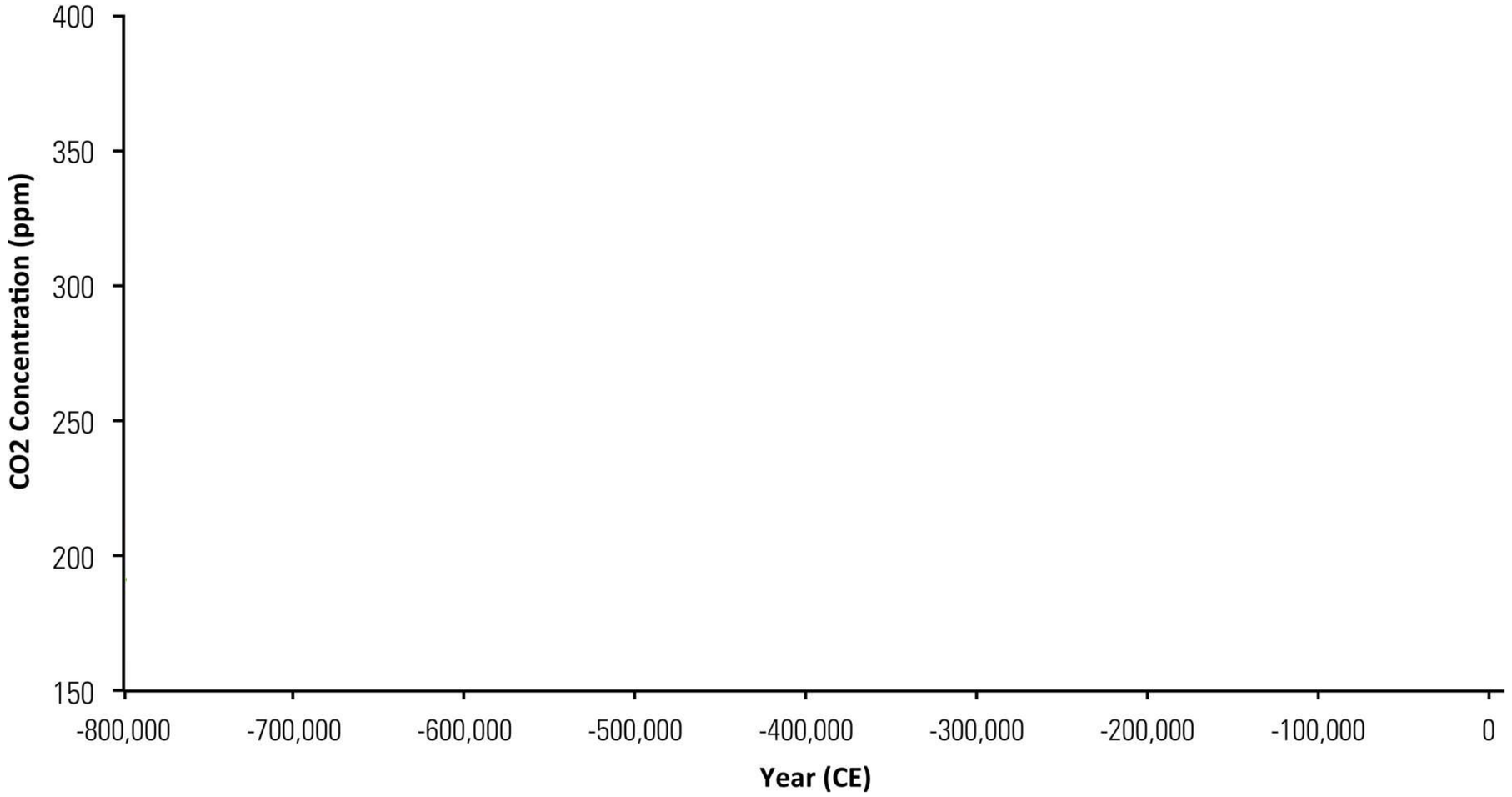
Southeast Florida's 2019 Unified Sea Level Projection: The Foundations
June 18, 2020

Four questions

- How are climate and sea level changing today?
- What's driving the sea-level rise?
- What sea-level rise can we anticipate in the future?
- What do we do about sea-level rise?

How are climate and sea-level changing today?

For over 800,000 years, carbon dioxide concentrations in the atmosphere stayed between about 180 parts per million (during ice ages) and 300 parts per million (during warmer ‘interglacial’ periods)



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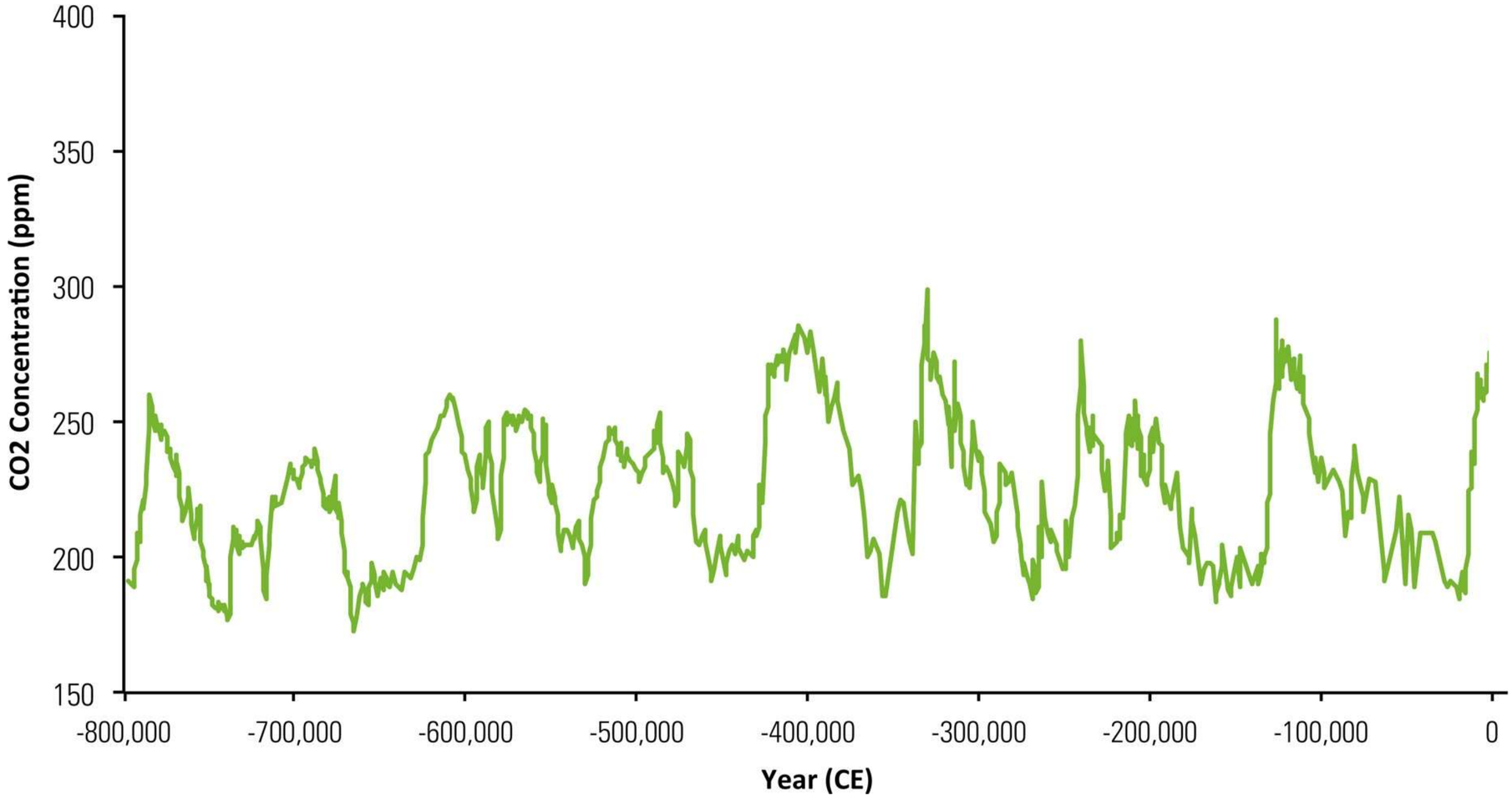
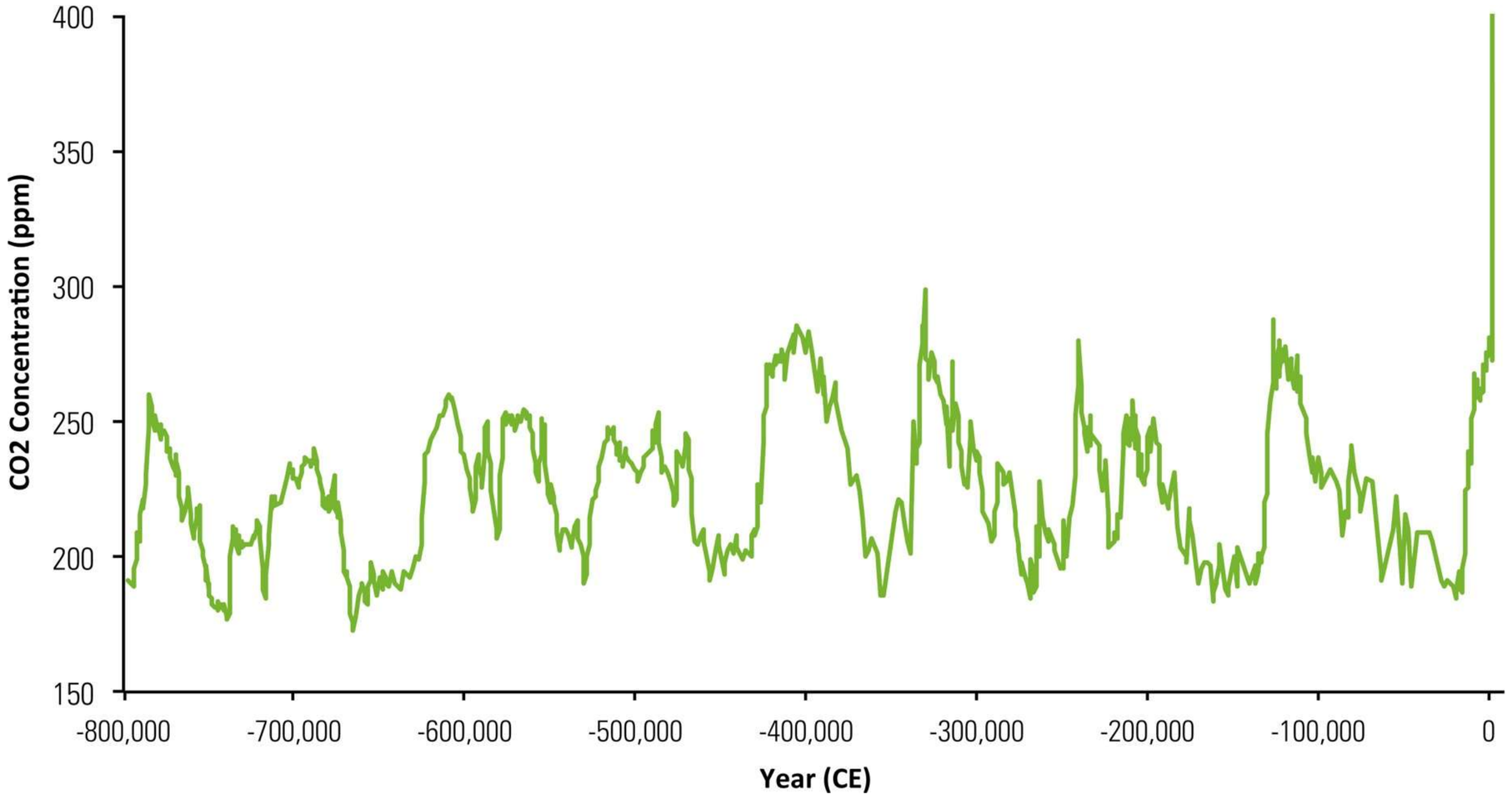


In 1913, carbon dioxide concentration surpassed 300 ppm. In spring 2014, they surpassed 400 ppm for the first time in well over 800 thousand years.



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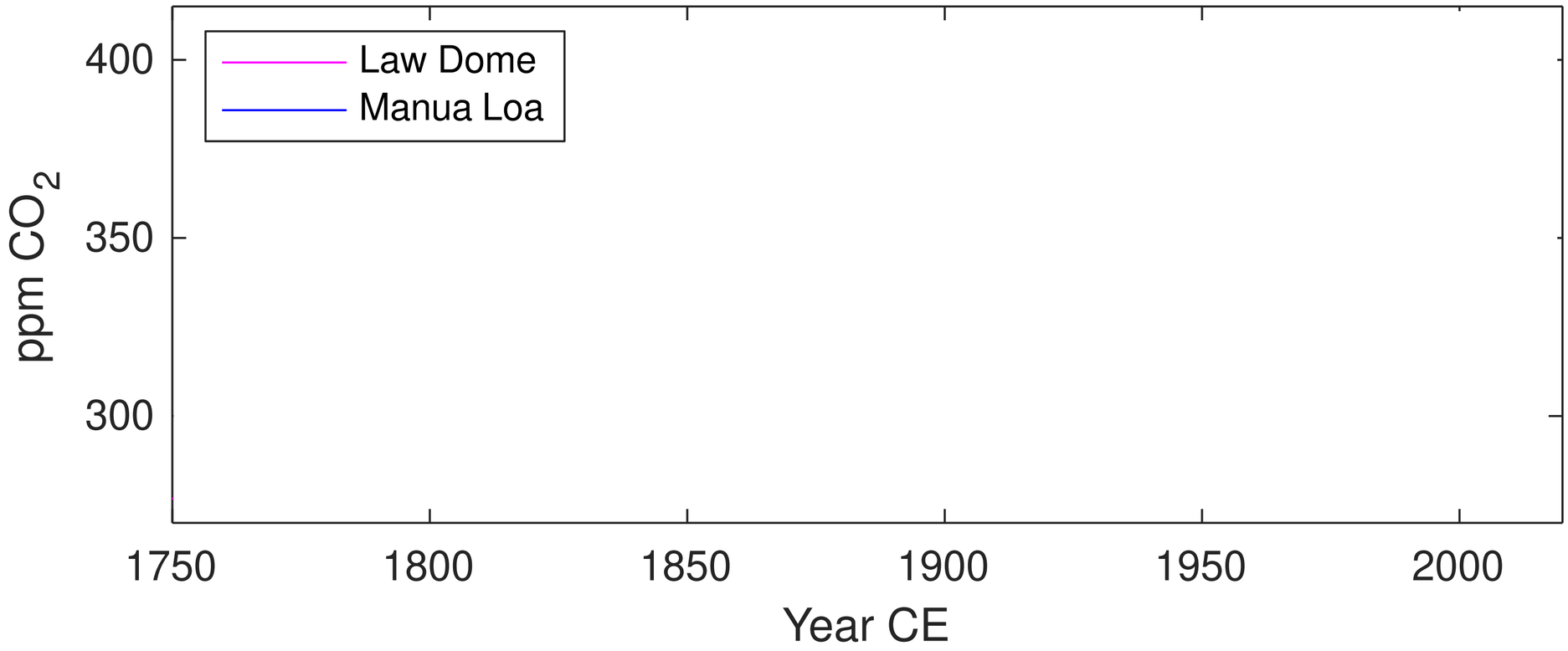

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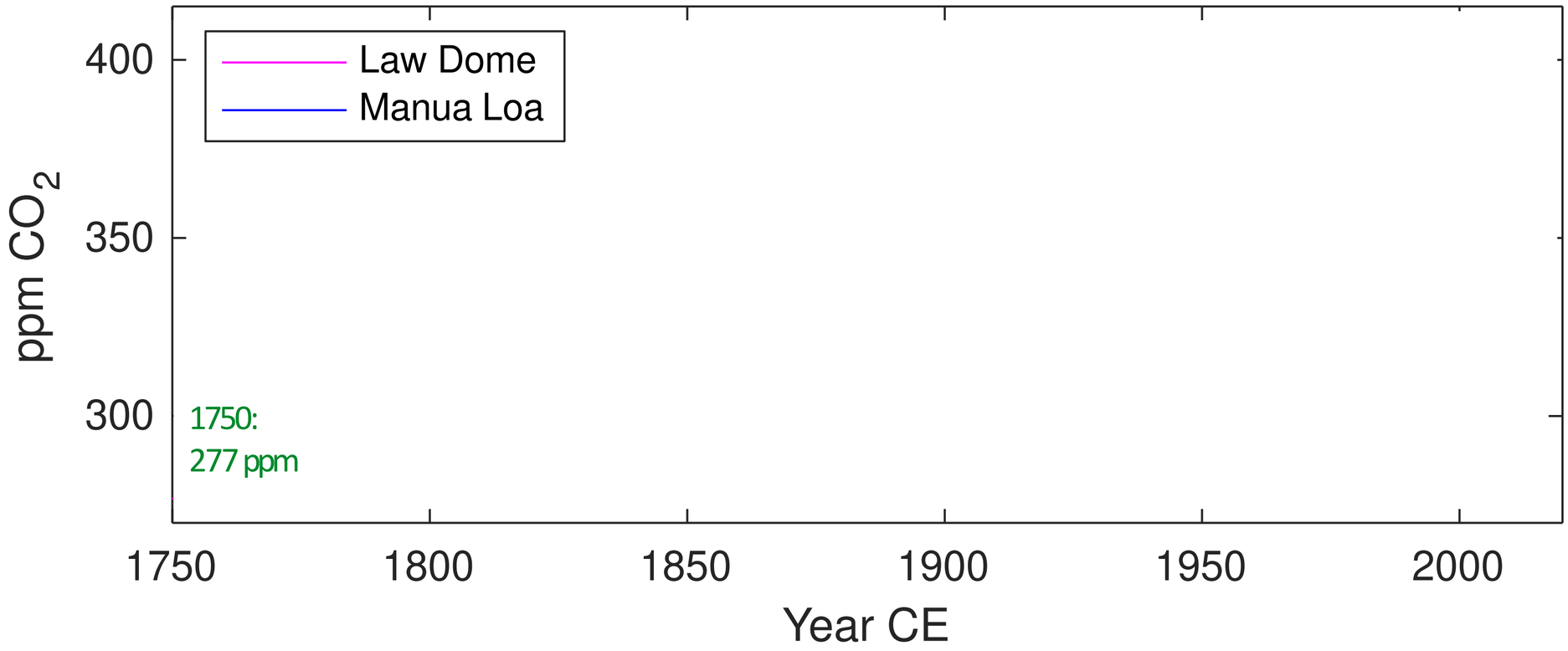

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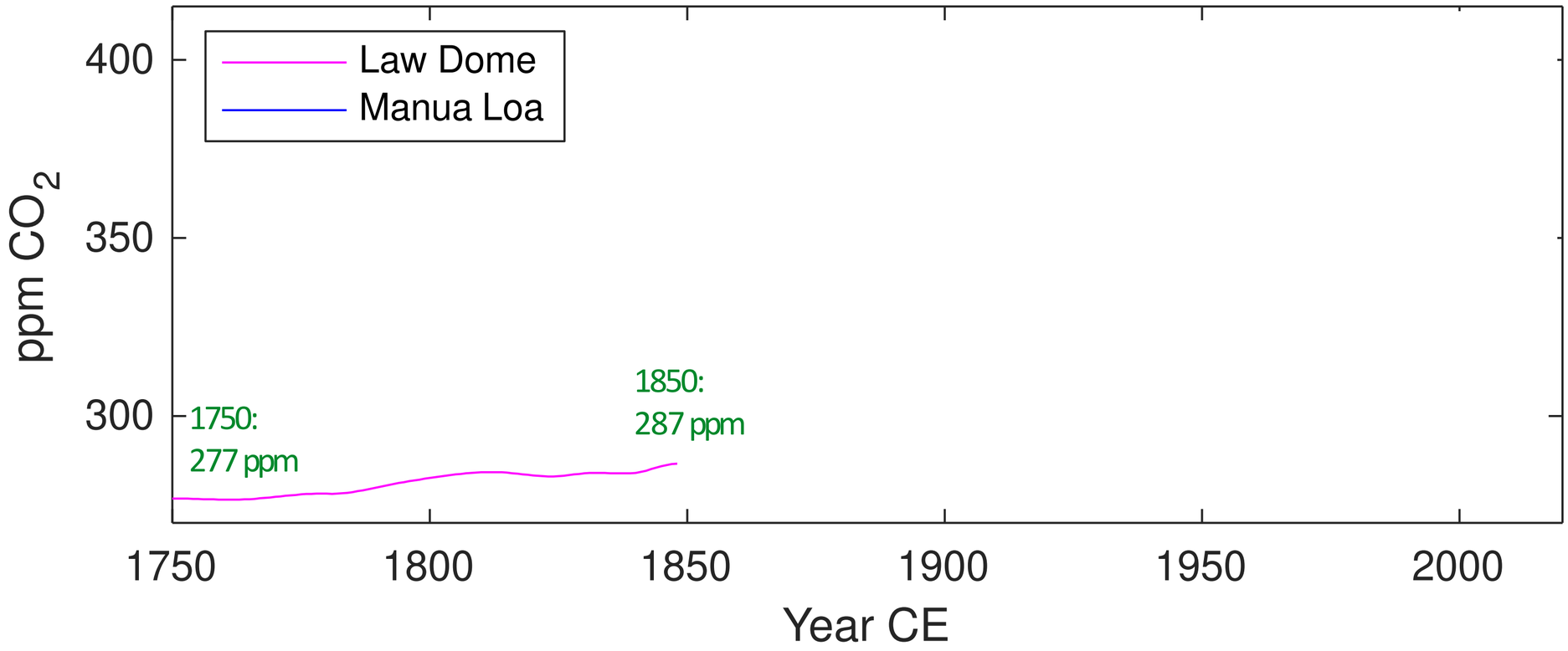

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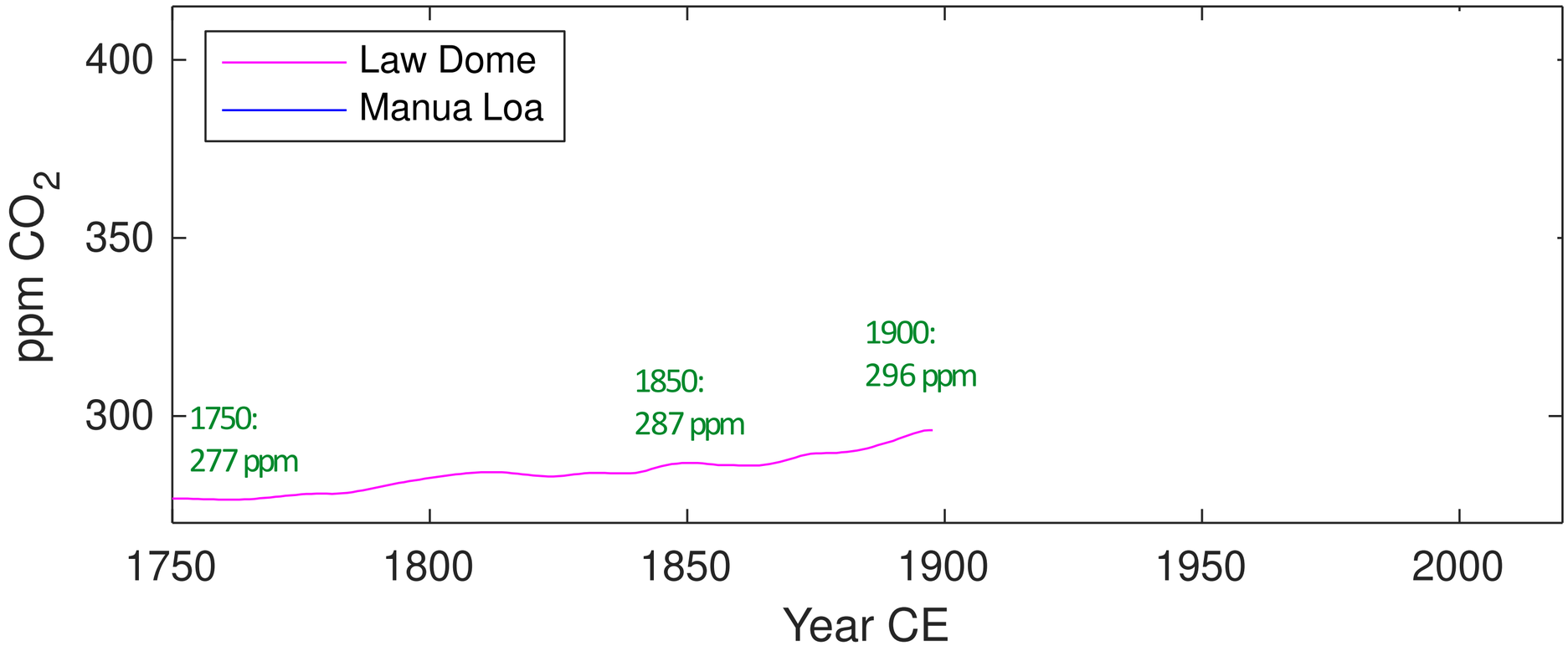

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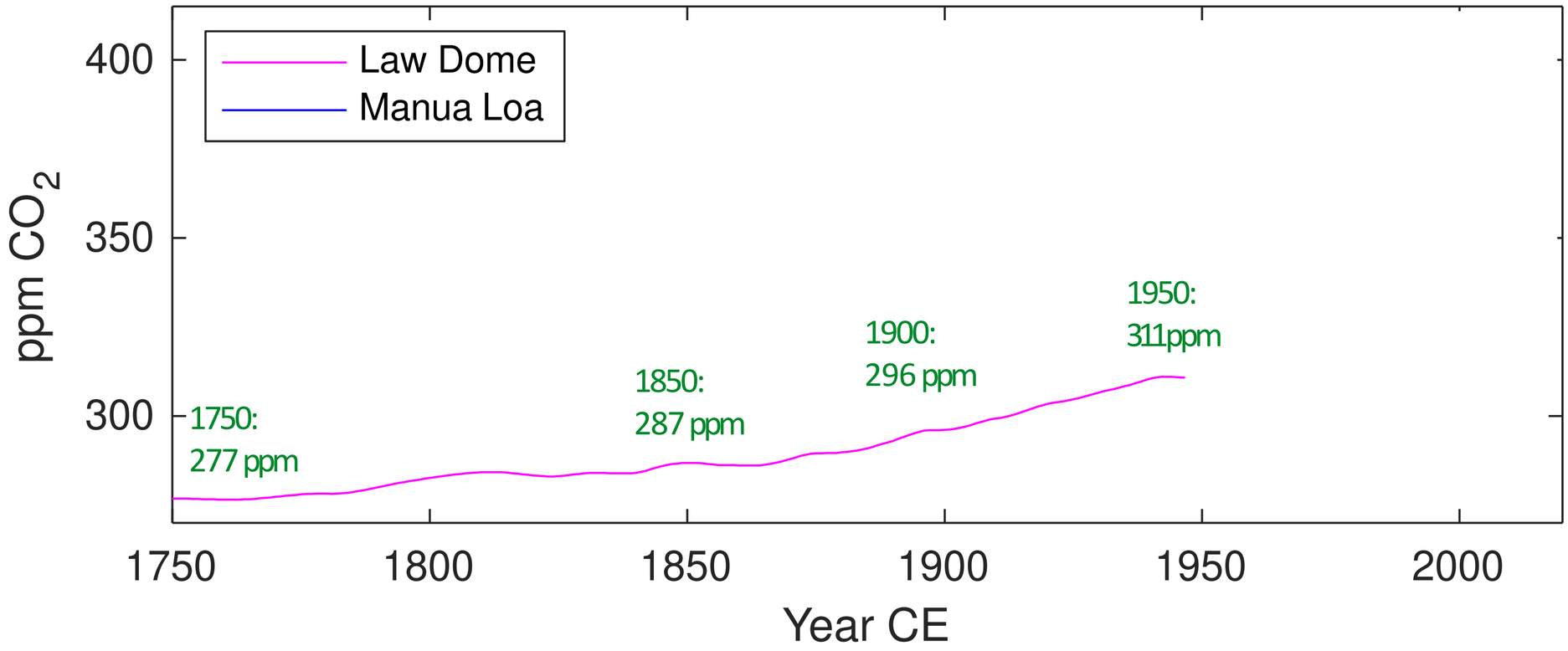

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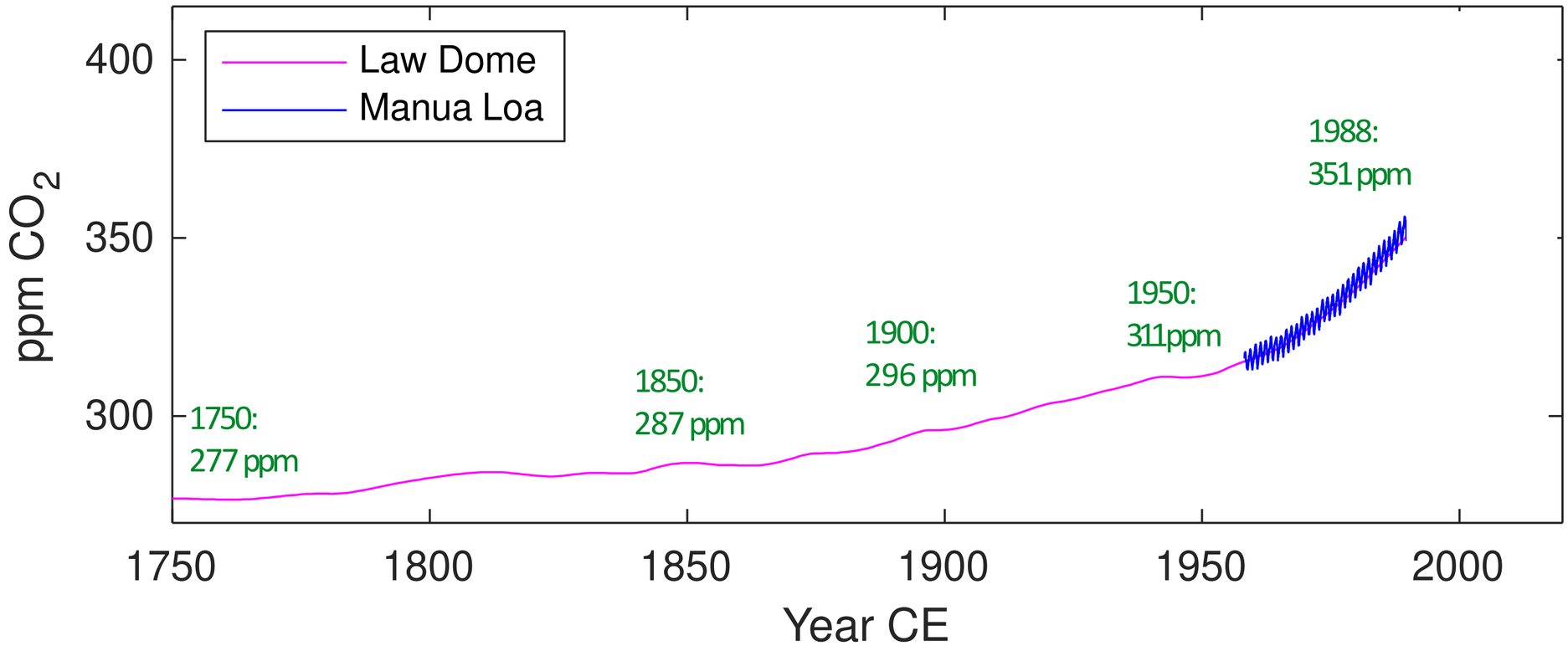

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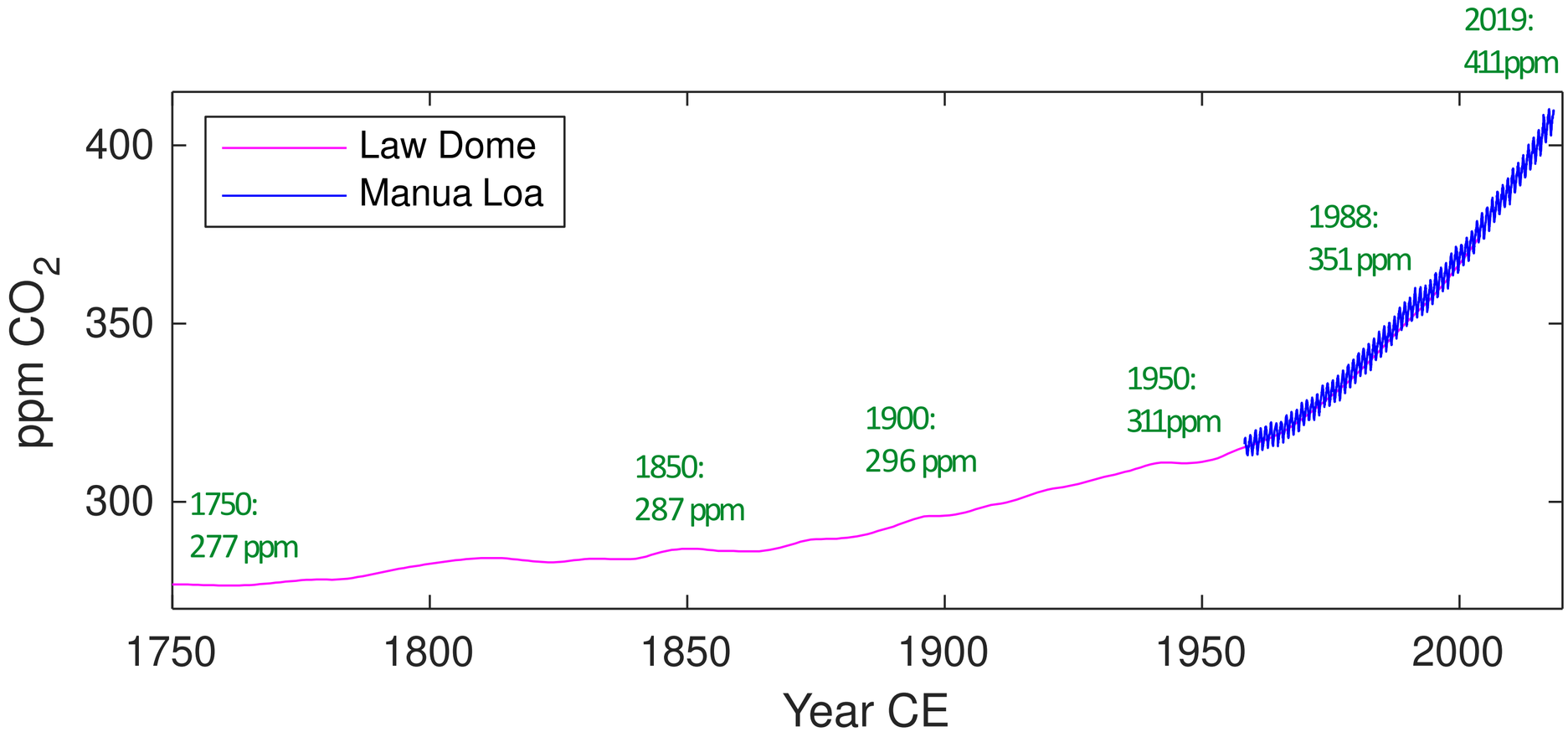

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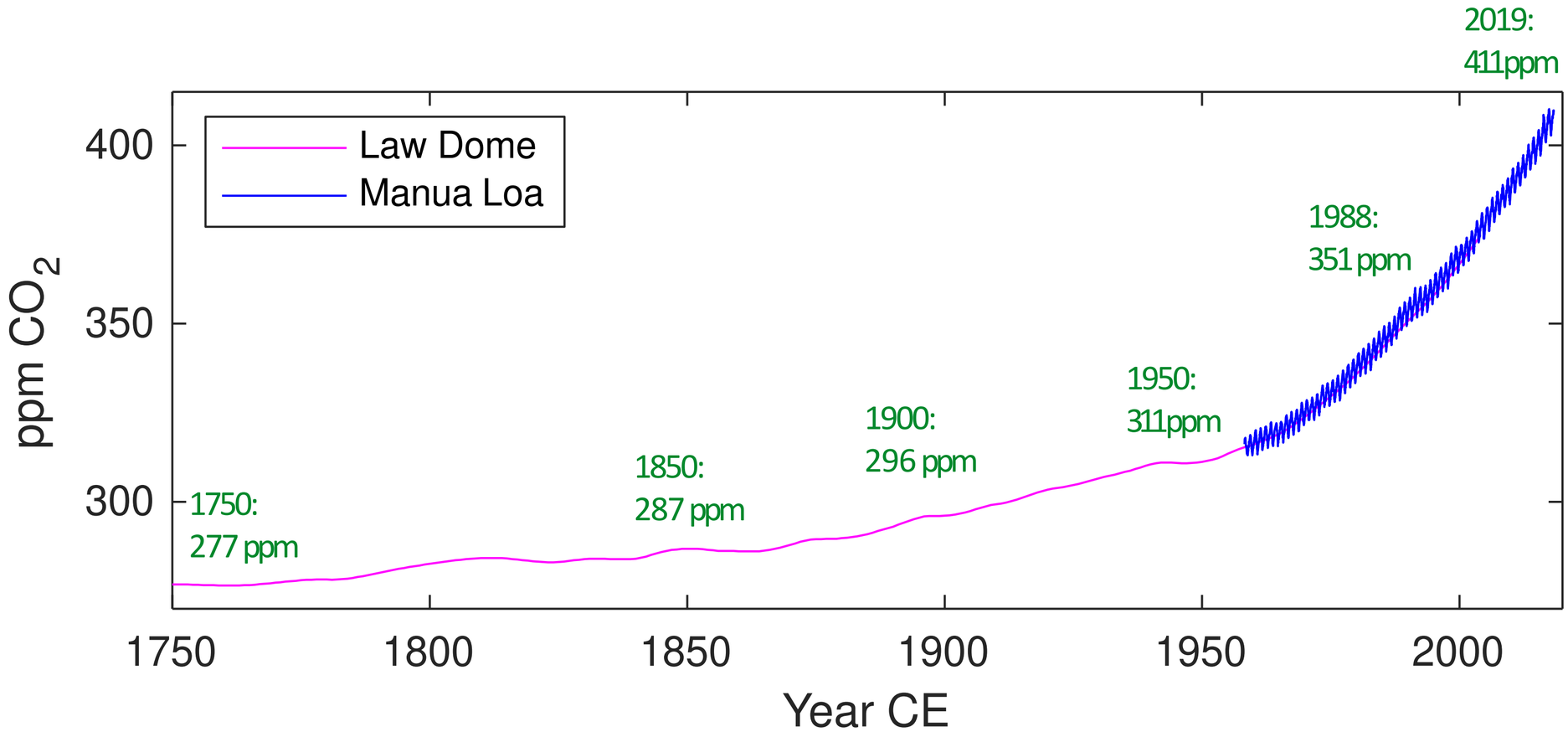
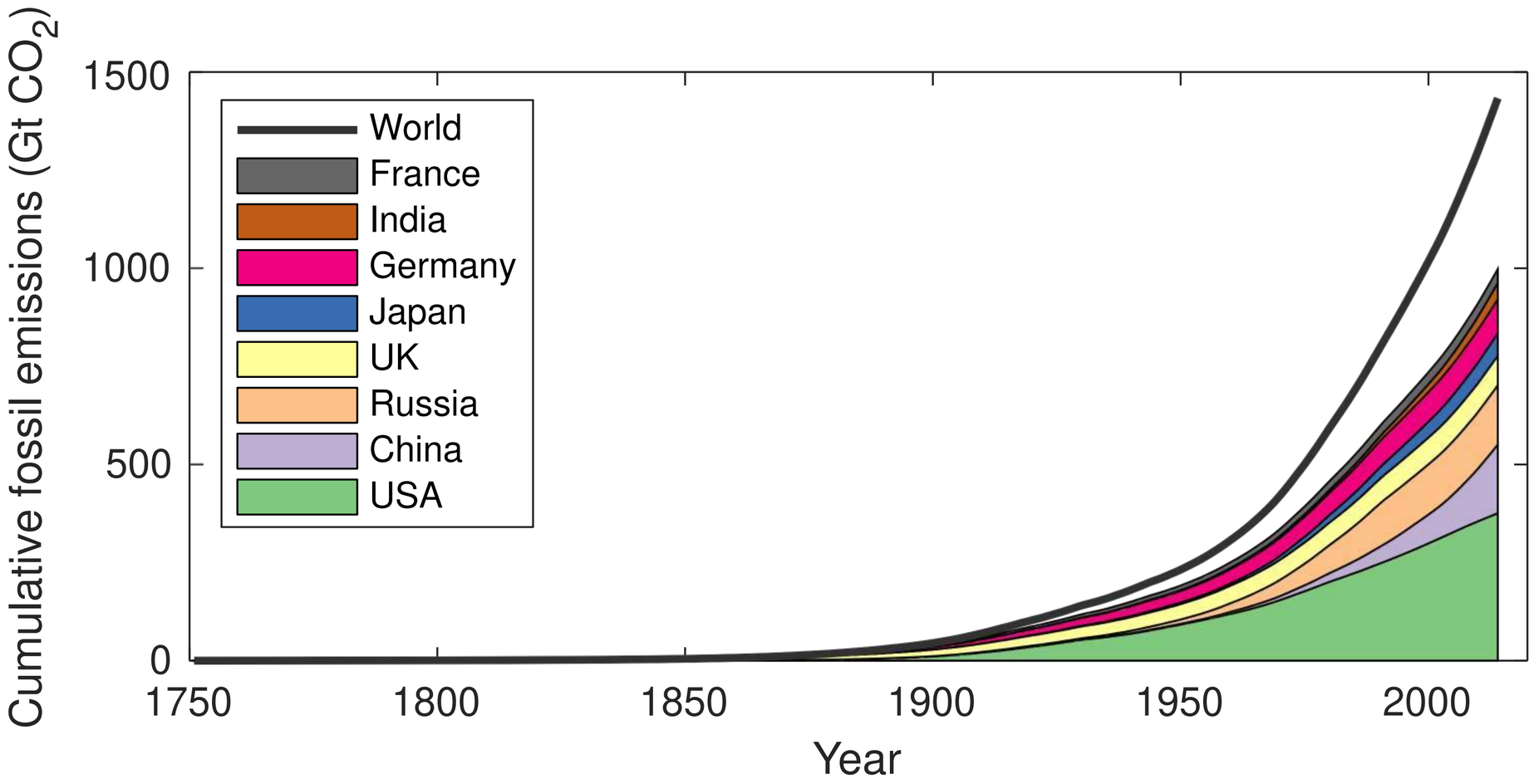


Most of the increase above the pre-industrial level of about 280 ppm has happened since the mid 1980s.

Most of the fossil carbon ever emitted has been emitted since1988.

Billions of tonnes of carbon dioxide per year
Global emissions in 2018: about 42 billion tonnes



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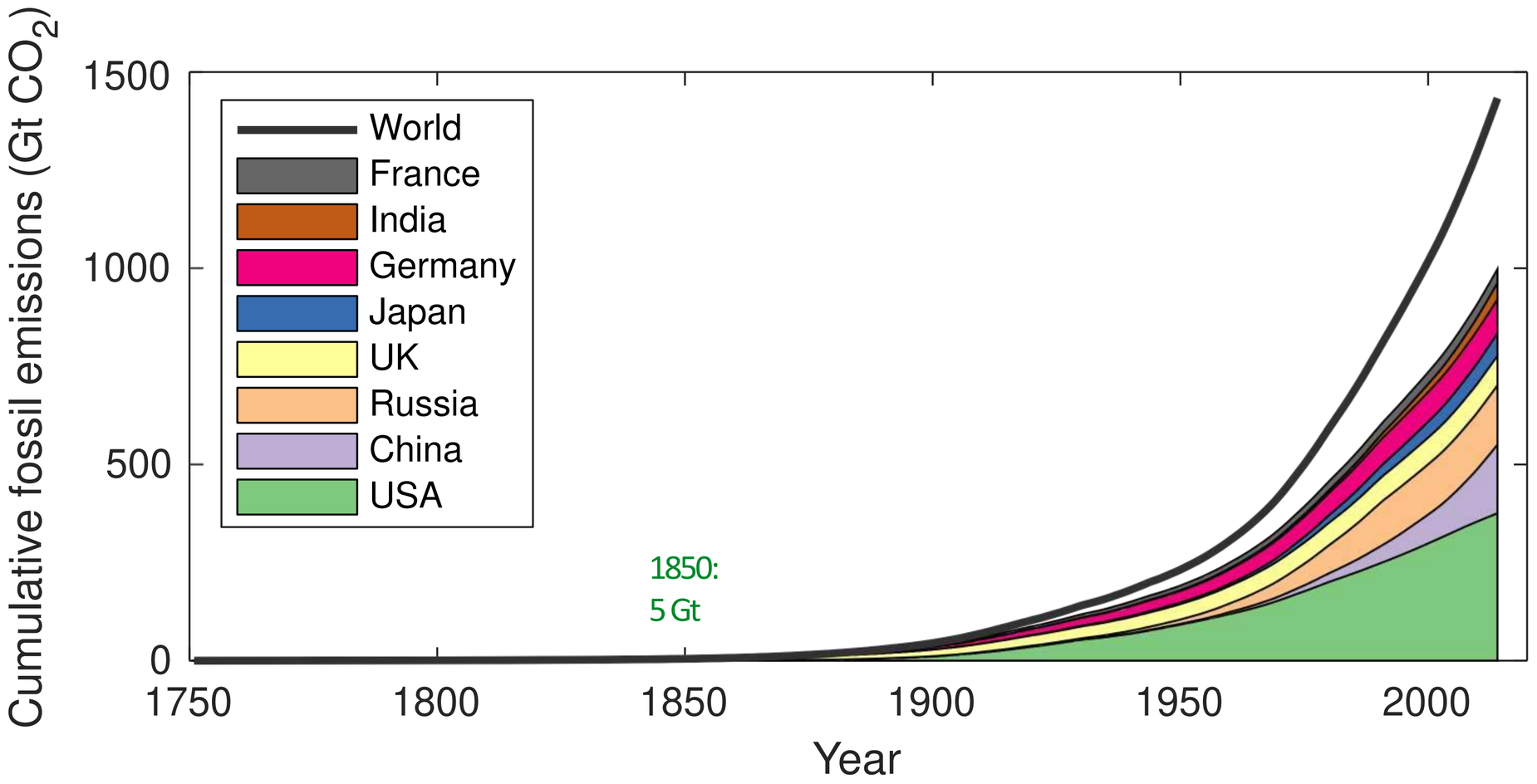

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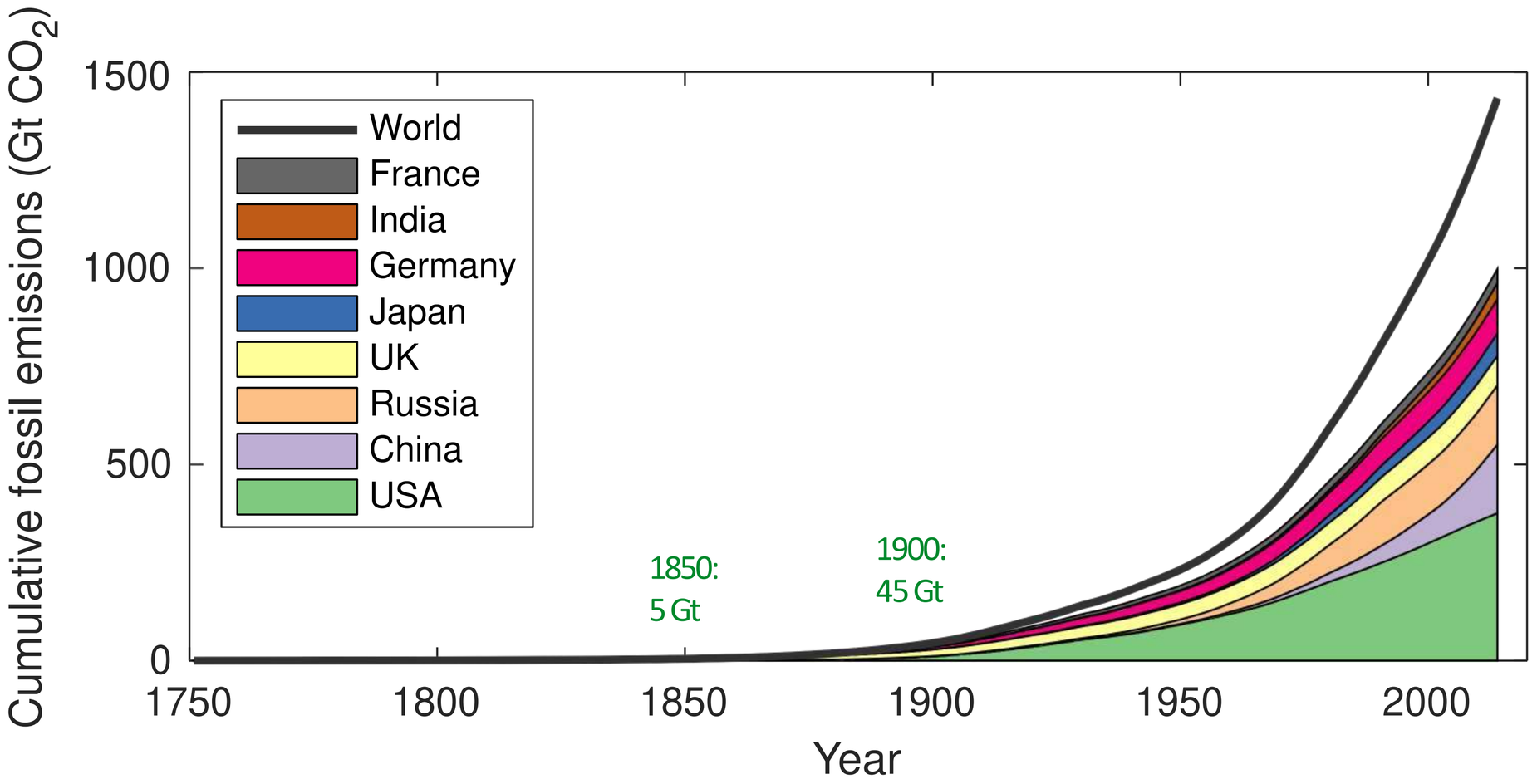

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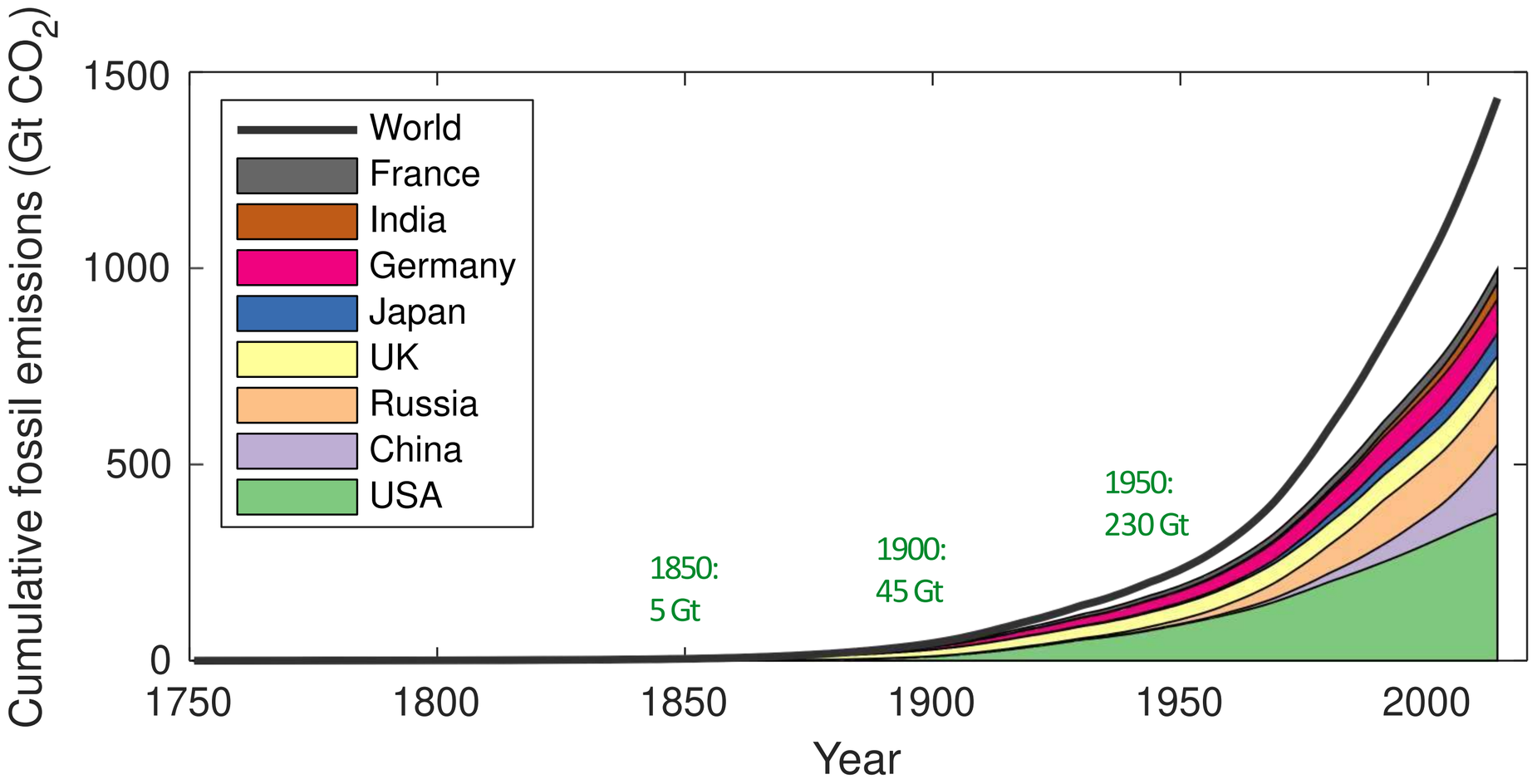

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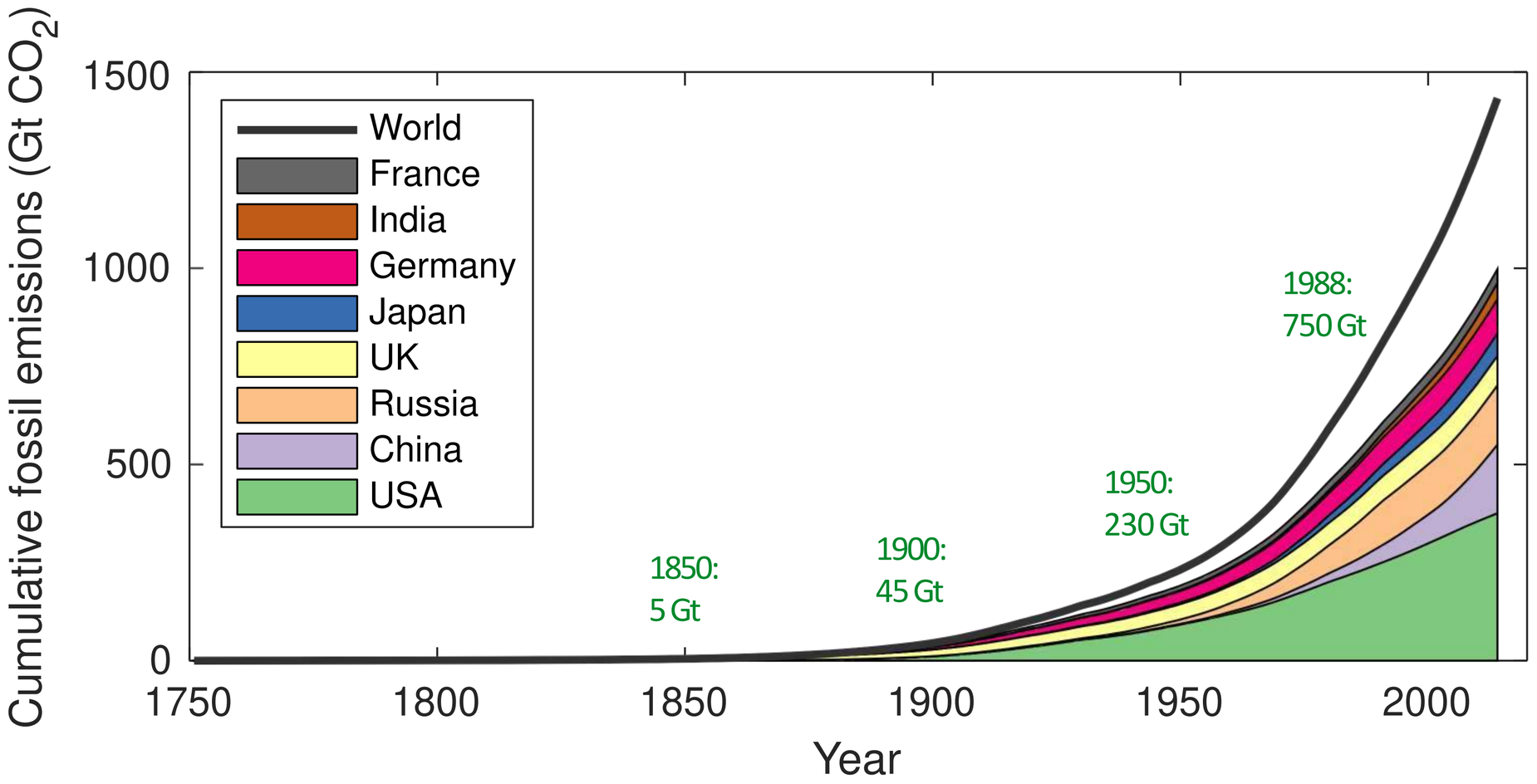

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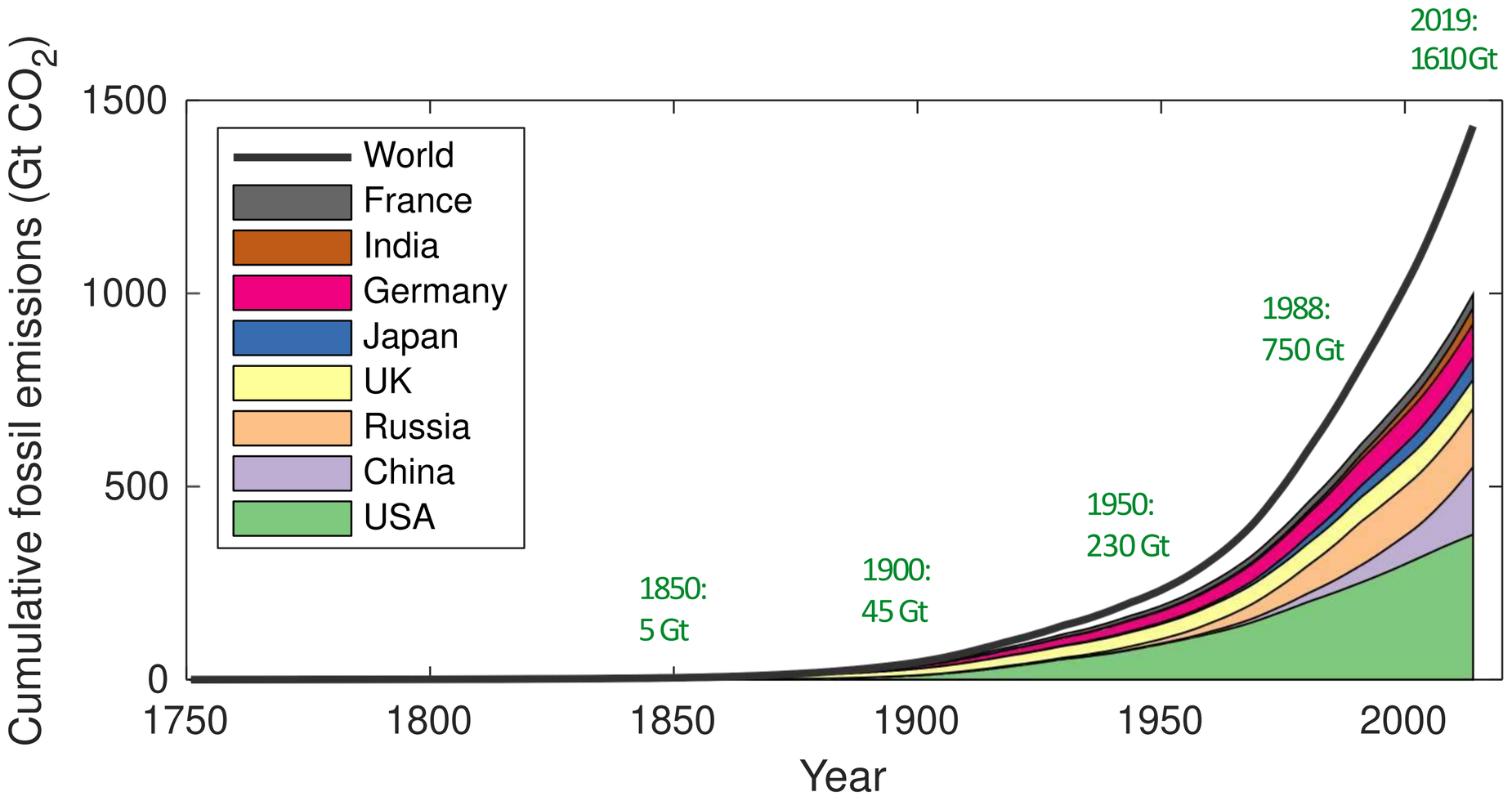

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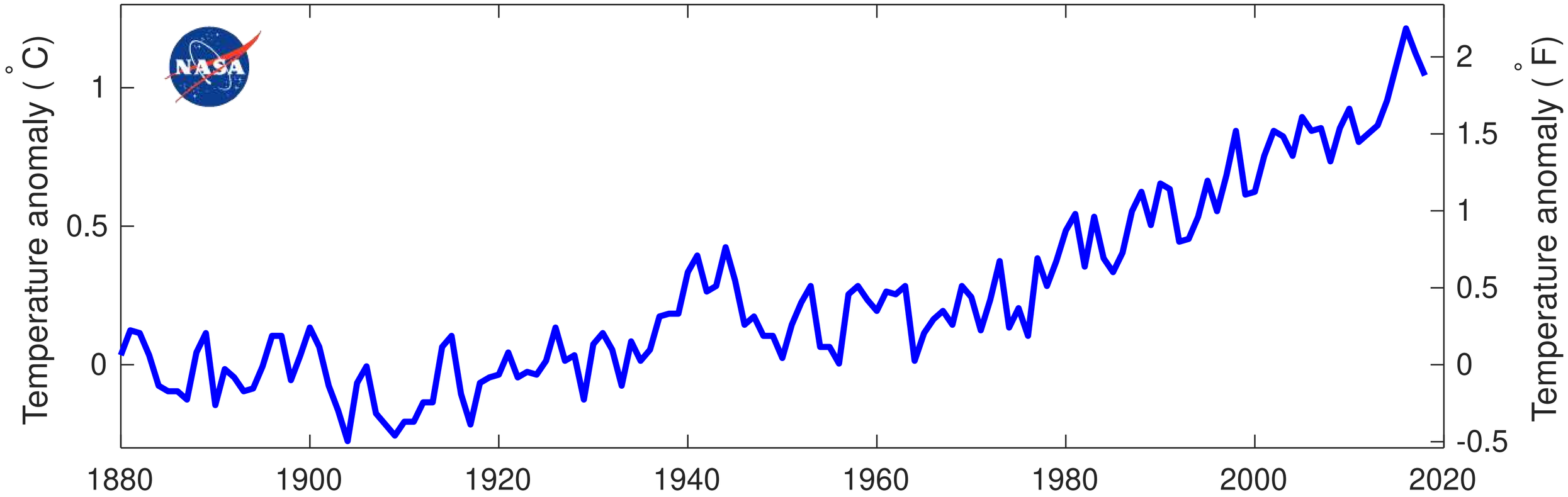
Our planet is running a fever.

Annual average global average temperatures (relative to 1880-1900)



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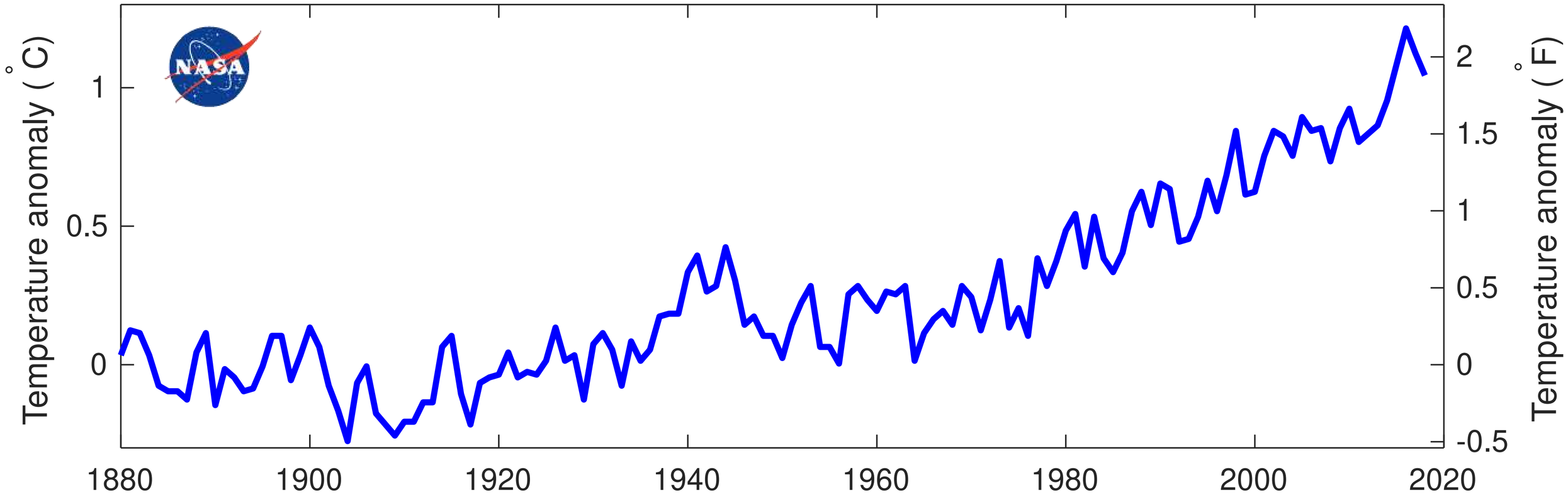
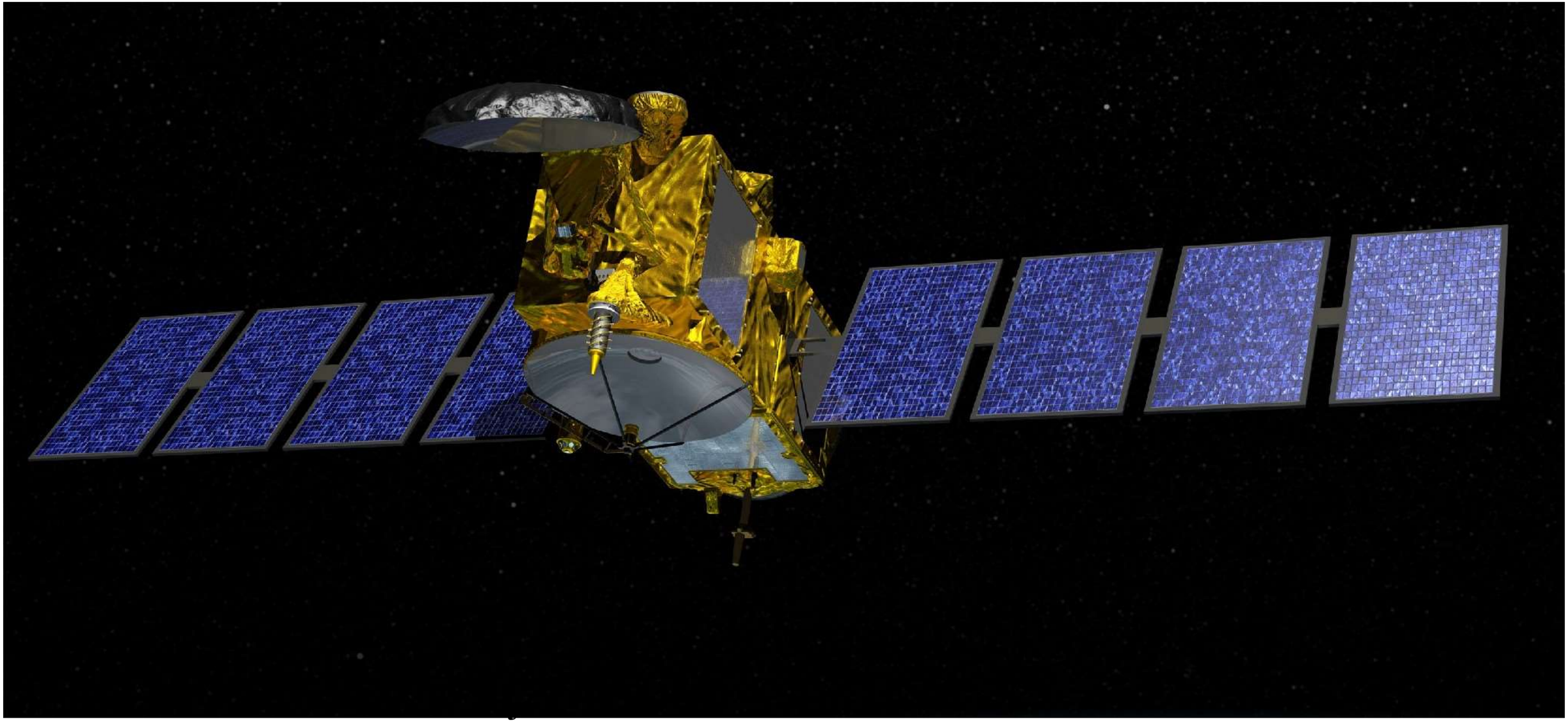


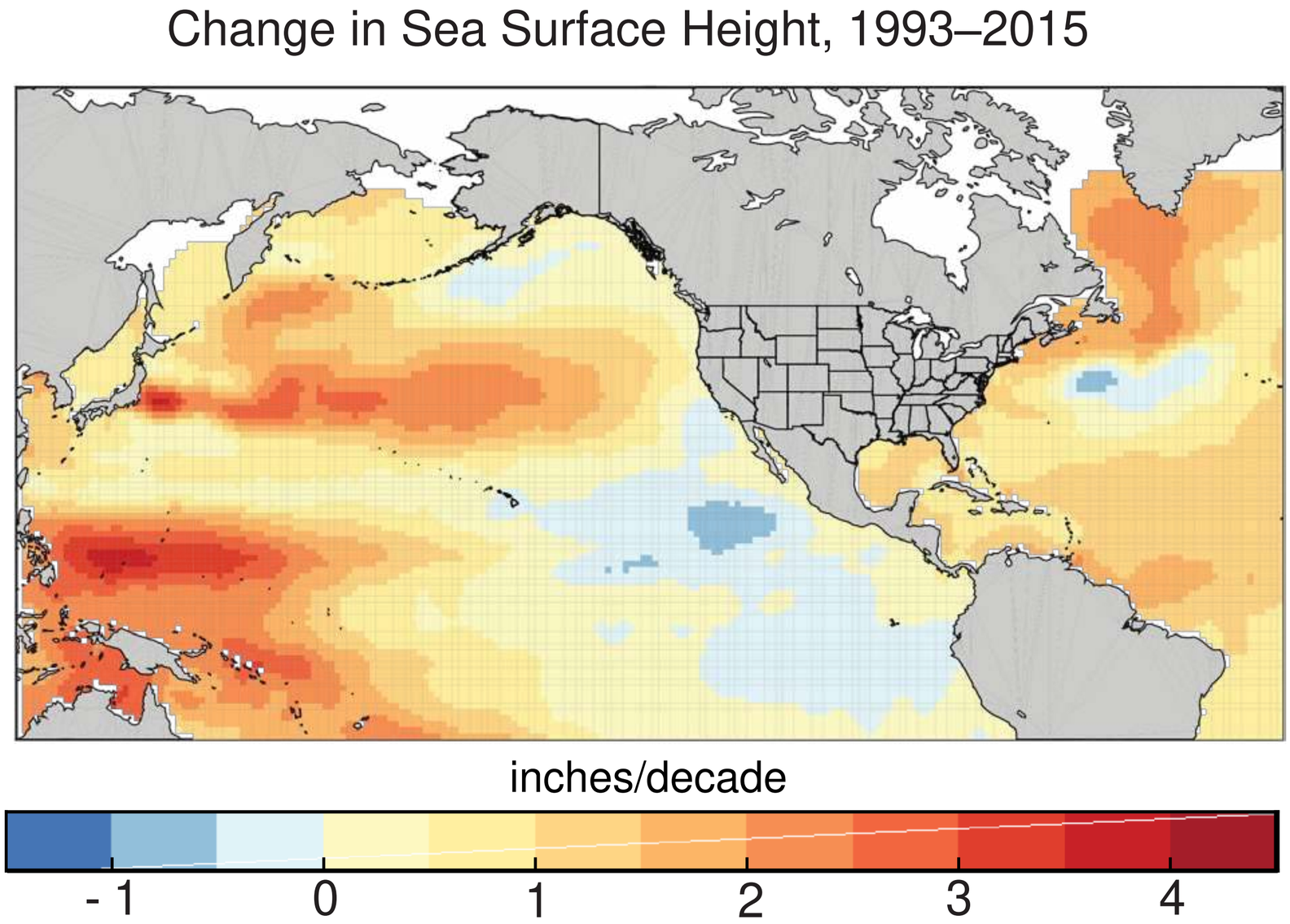
Between 1980 and 2018, temperatures rose at an average rate of about 0.2°C (0.3°F) per decade. The 2018 average global temperature was about 1.1°C (2°F) above the late nineteenth century average. The last five years are most likely the warmest five years on record.

Since the early 1990s, scientists have measured changes in the height of the sea surface using satellite-borne radars.

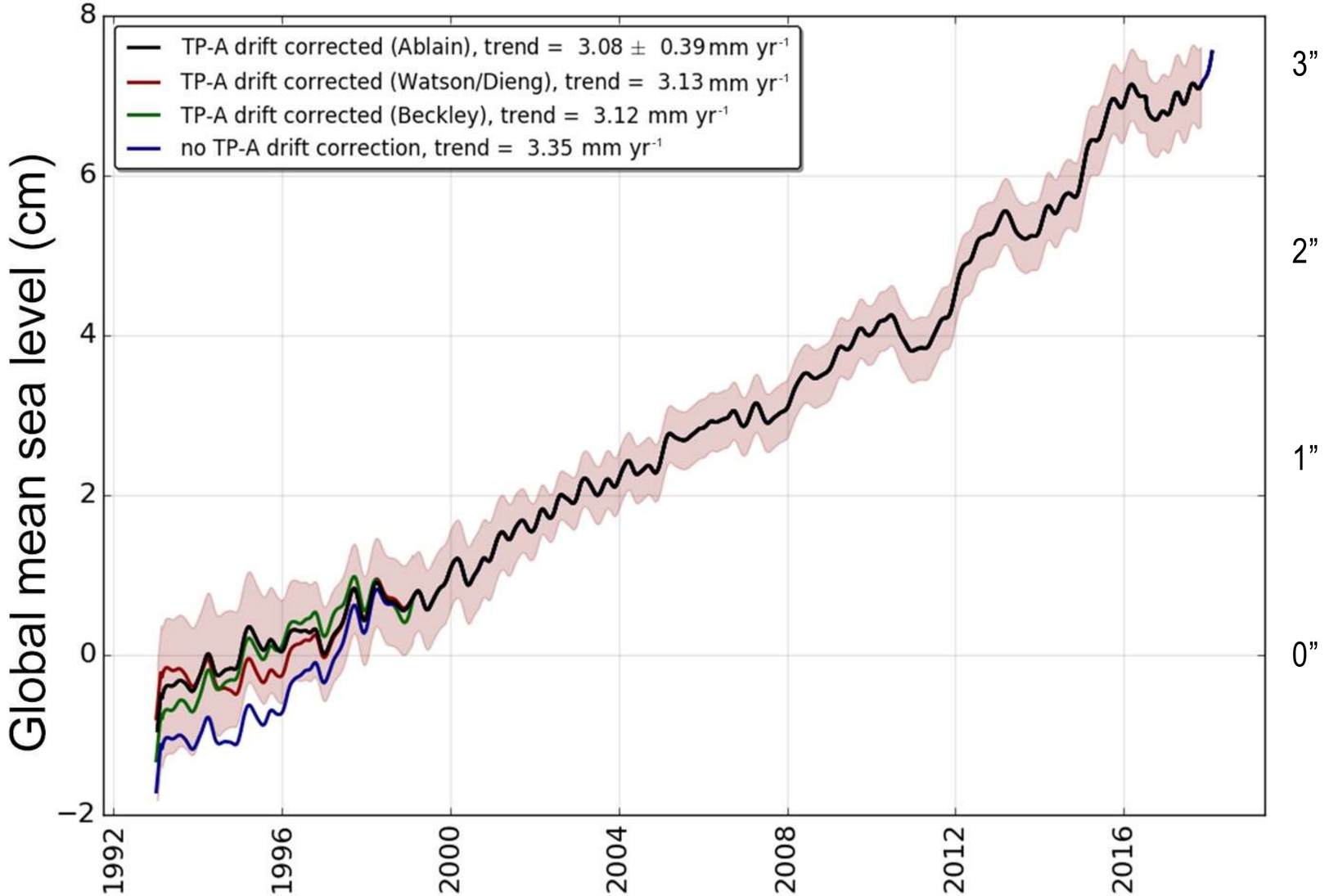


Artists rendition of Jason-3: NASA/JPL

Sea level is rising at different rates in different places.



But the global trend is clear:
Global average sea level is rising at an accelerating rate.



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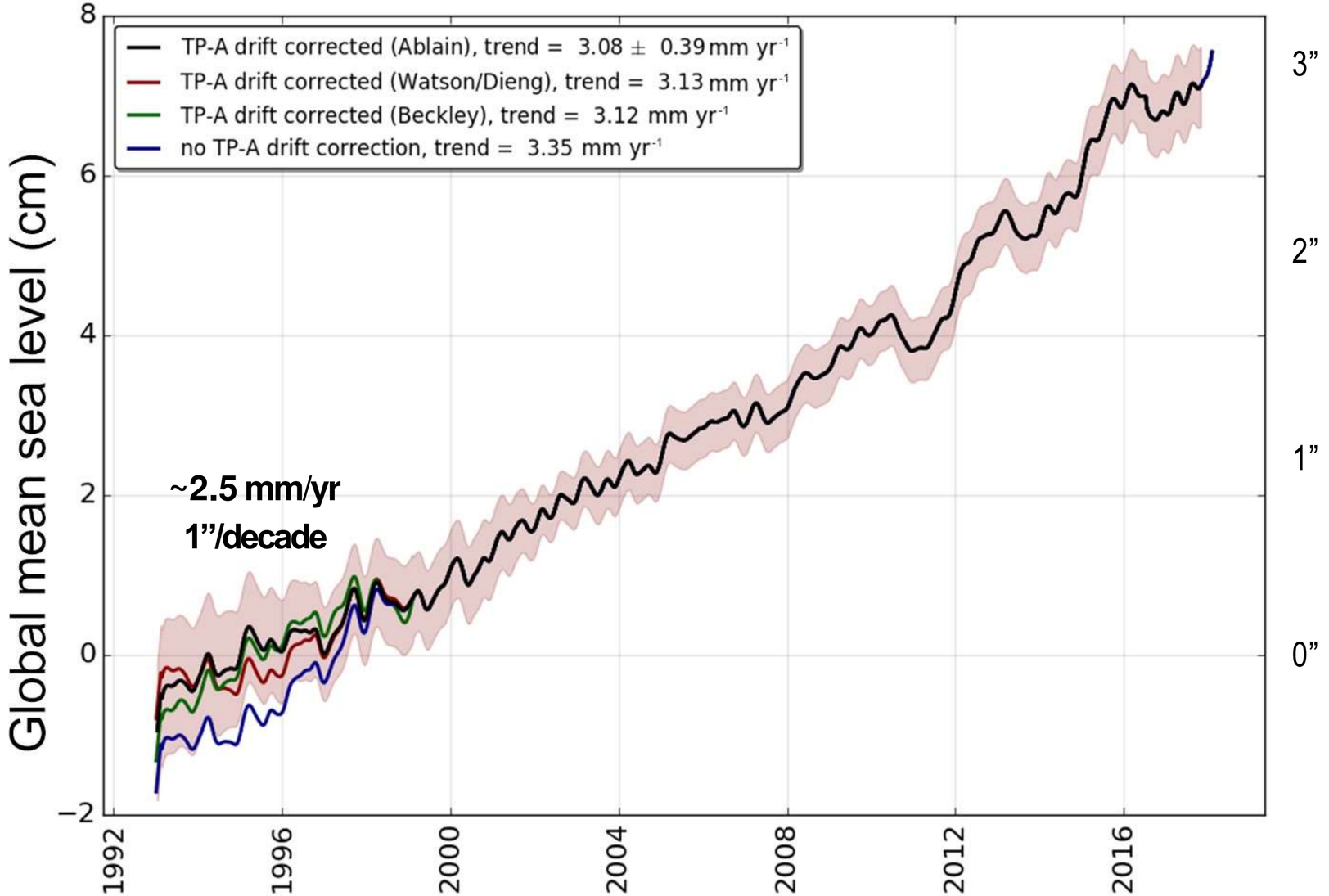

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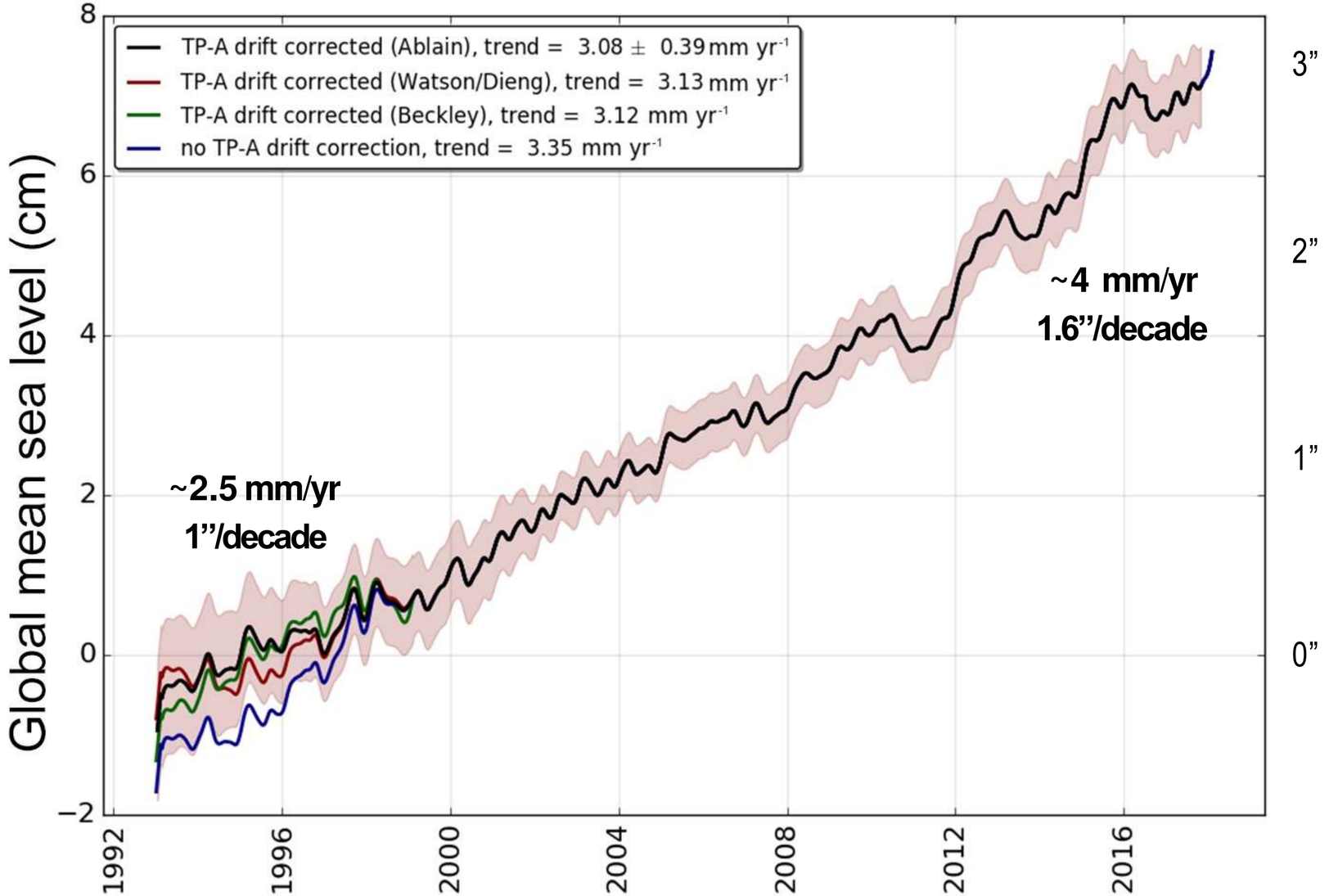

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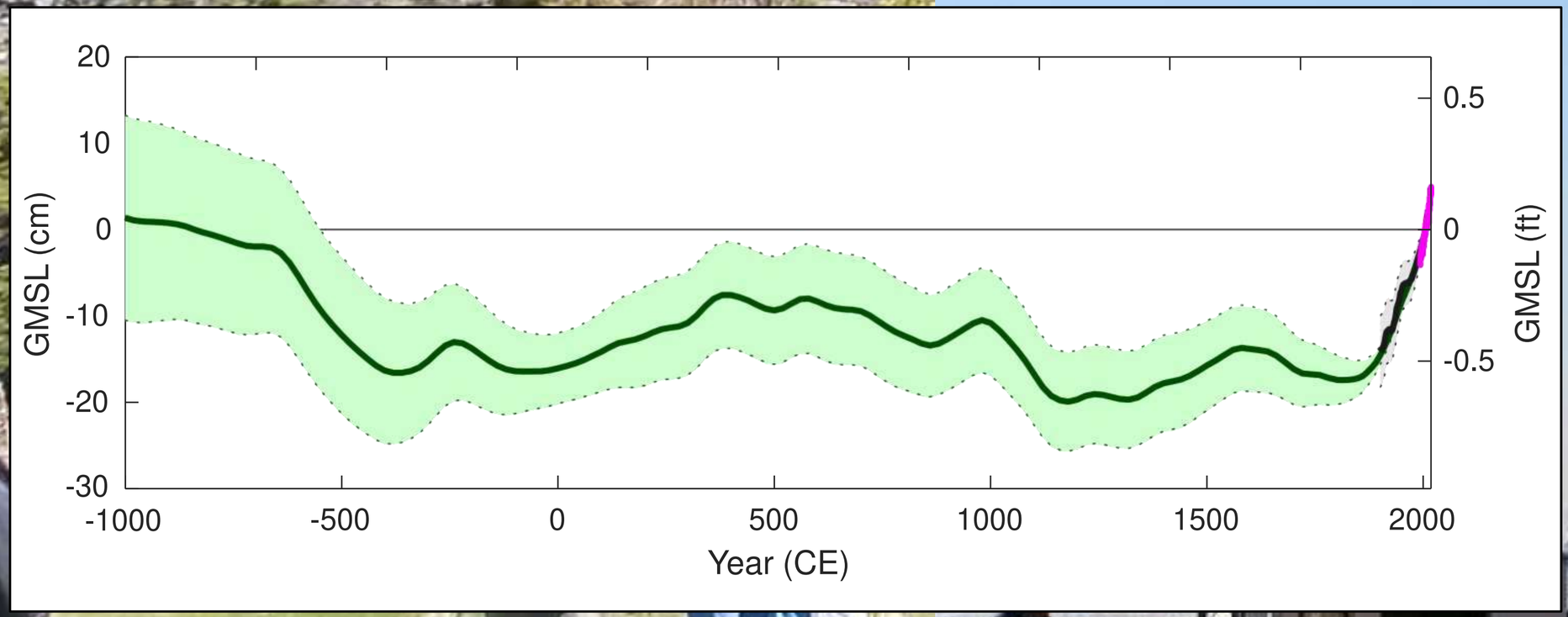

Kopp et al. (2016); Kemp et al. (2018); instrumental data from Hay et al. (2015) and Nerem et al. (2018)

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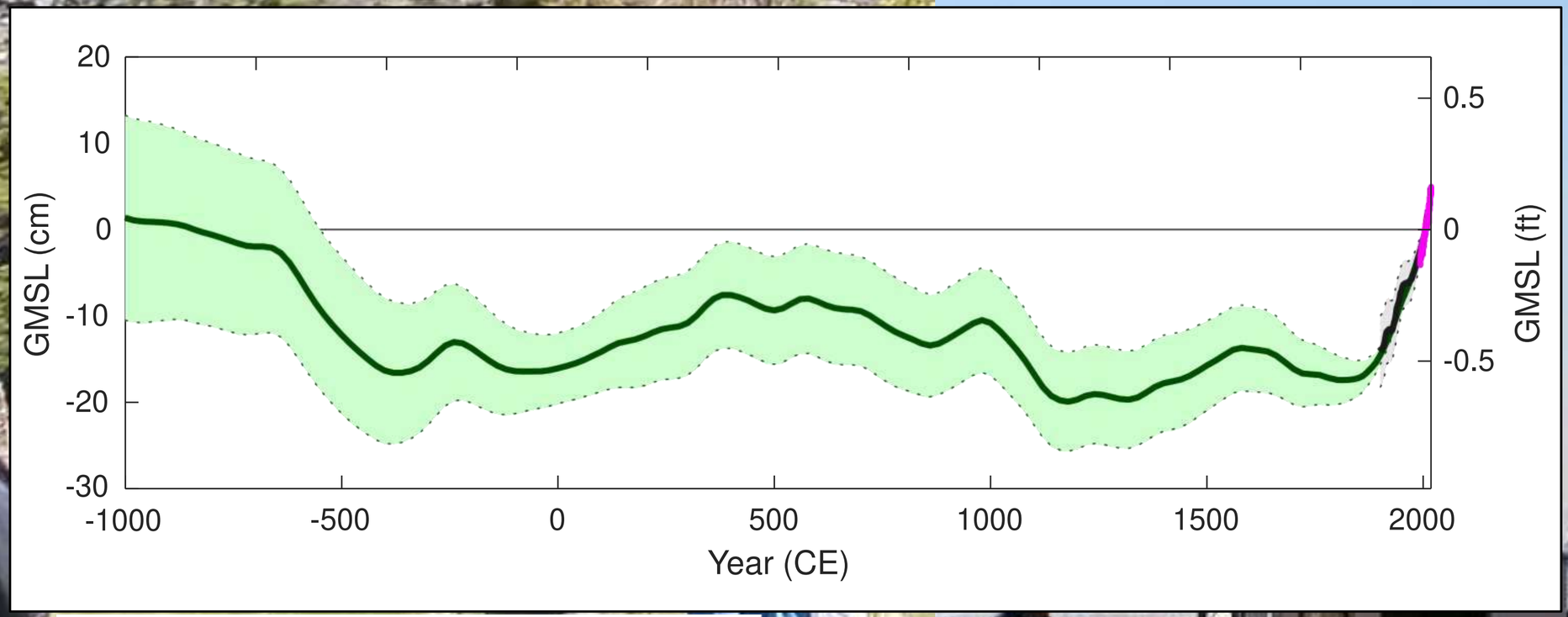

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Sea-level rise is making high-tide flooding more common.

https://commons.wikimedia.org/wiki/File:South_Beach_flood,_kayak_in_street.jpg

Sweet et al. (2018)

The number of high-tide flooding days in Miami Beach have increased by about a factor of four since the 1990s.

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So what's driving sea-level rise?

Shrinking ice sheets and glaciers are responsible for a majority of the 3 inches of global average sea-level rise from 1993-2017.

(photo: Knut Christianson)

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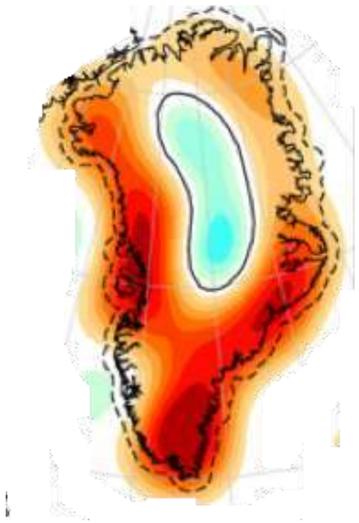
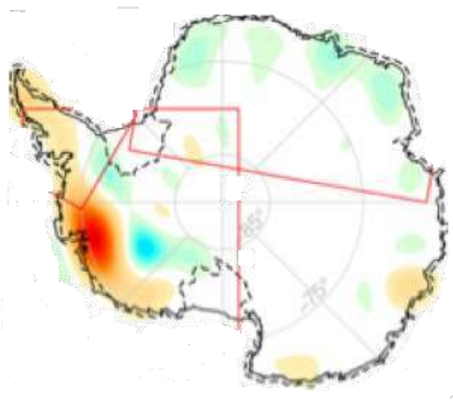


Greenland:
About 0.5 inches since 1993



Antarctica:
About 0.3 inches since 1993

Mountain glaciers:
About 0.7 inches since 1993

Harig et al. (2015, 2016); WCRP (2018); Rignot et al. (2019)

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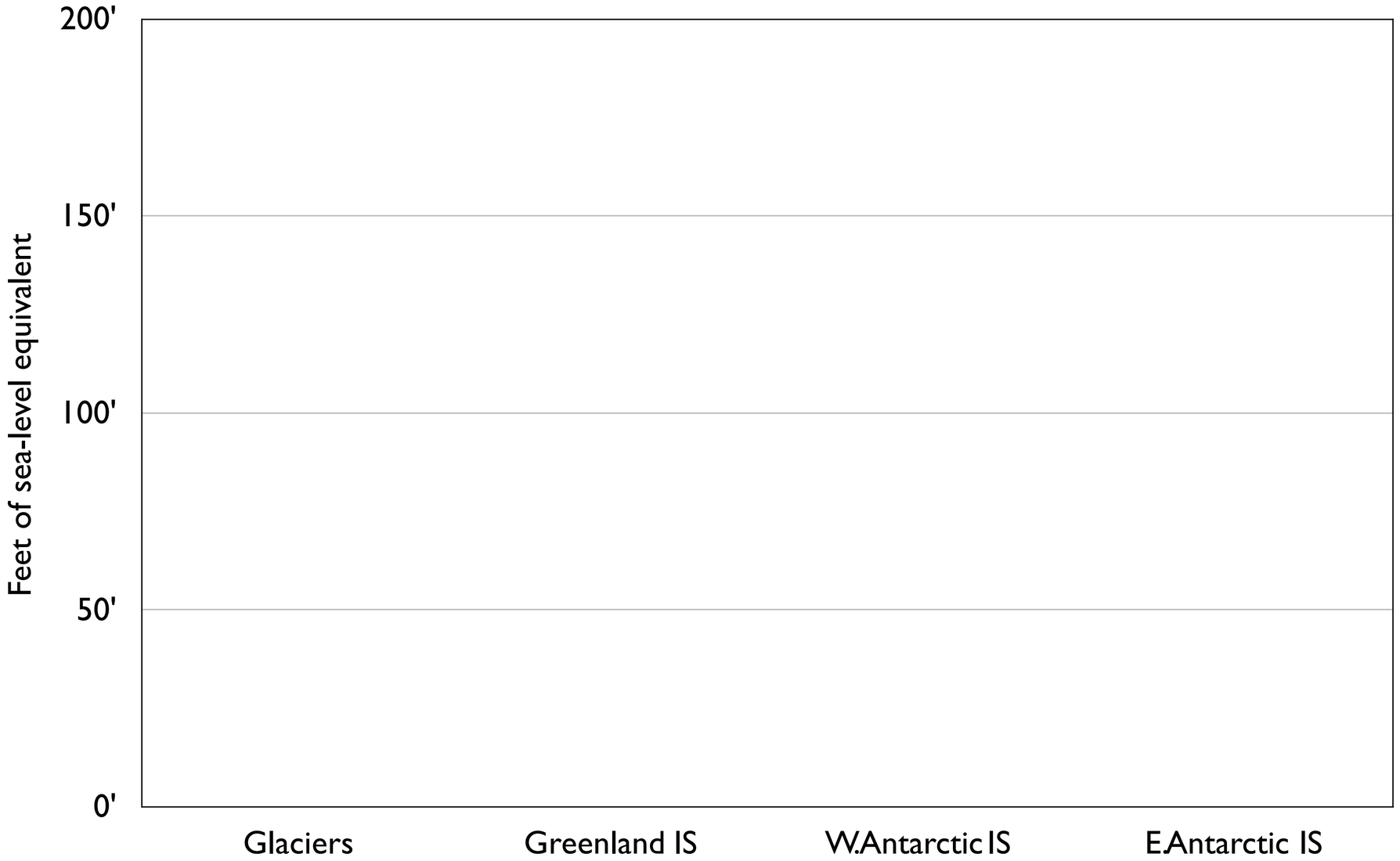

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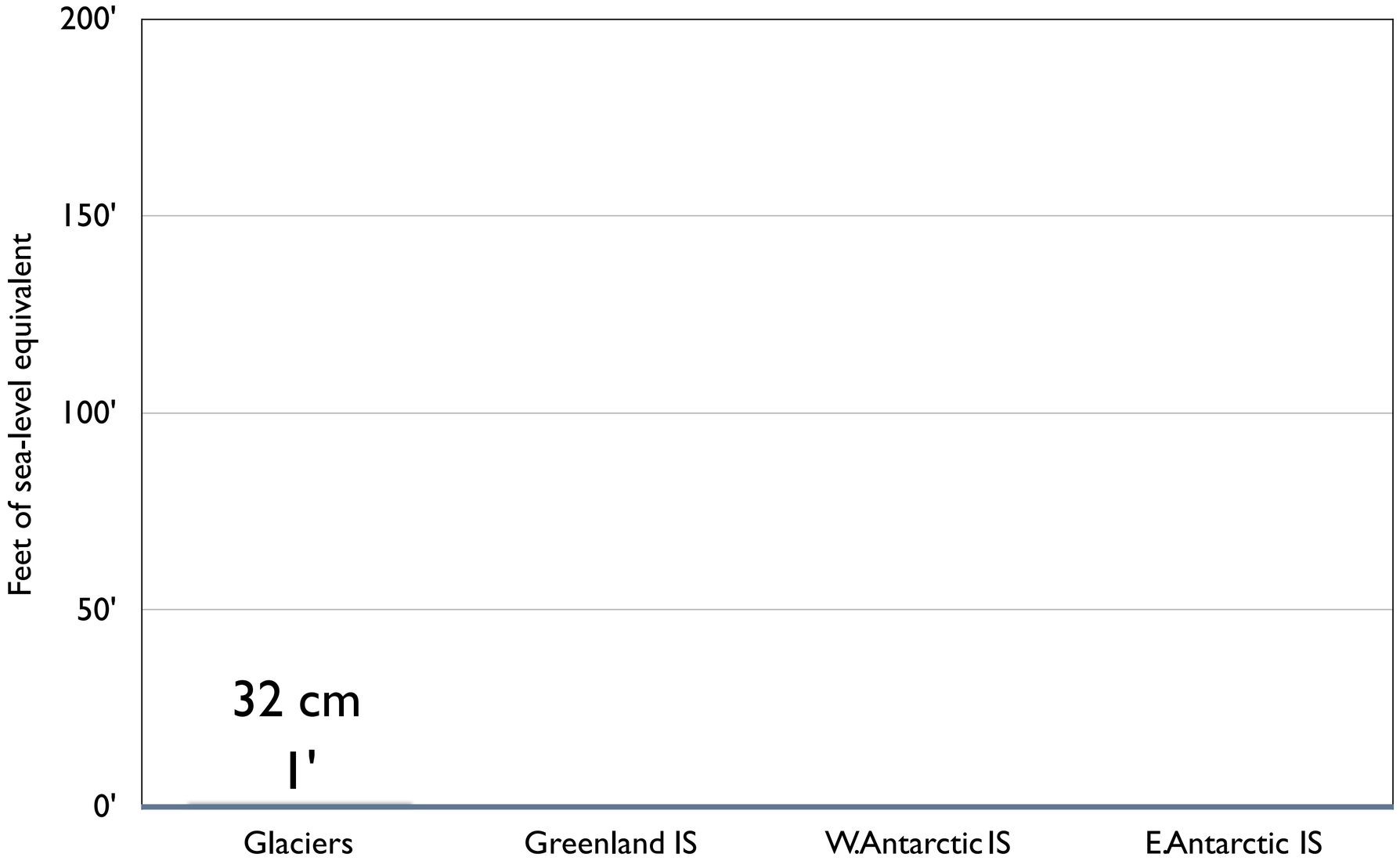

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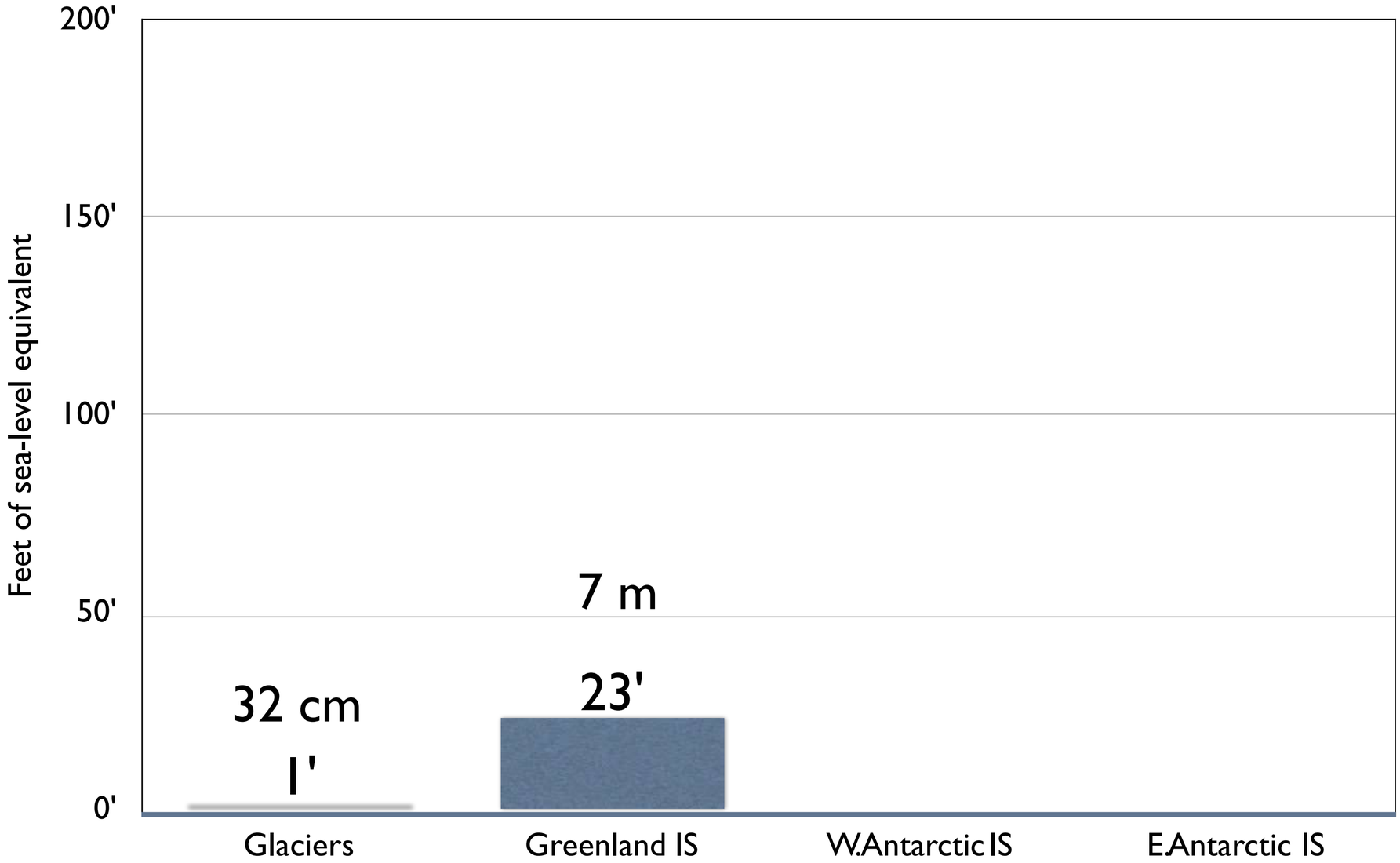

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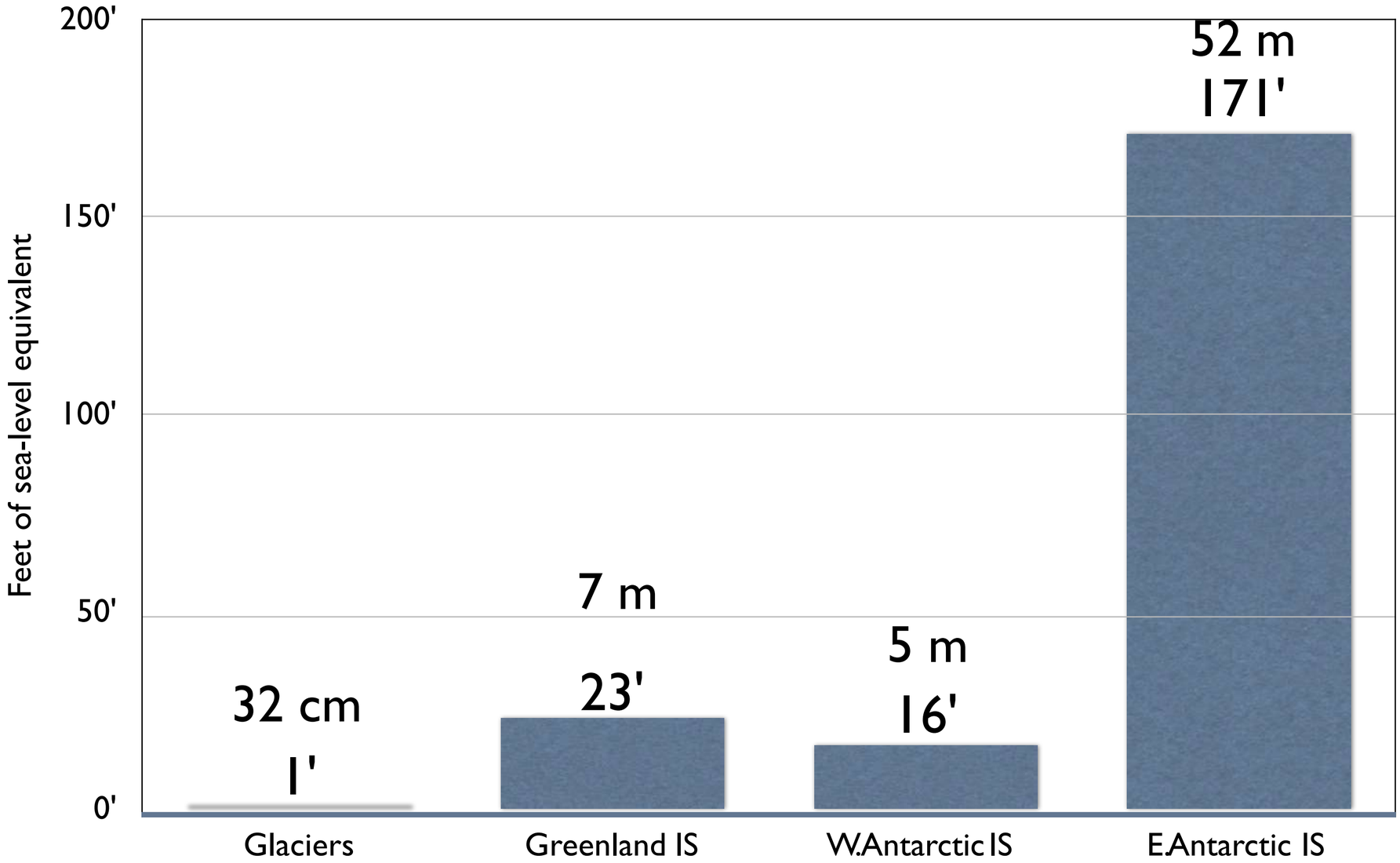

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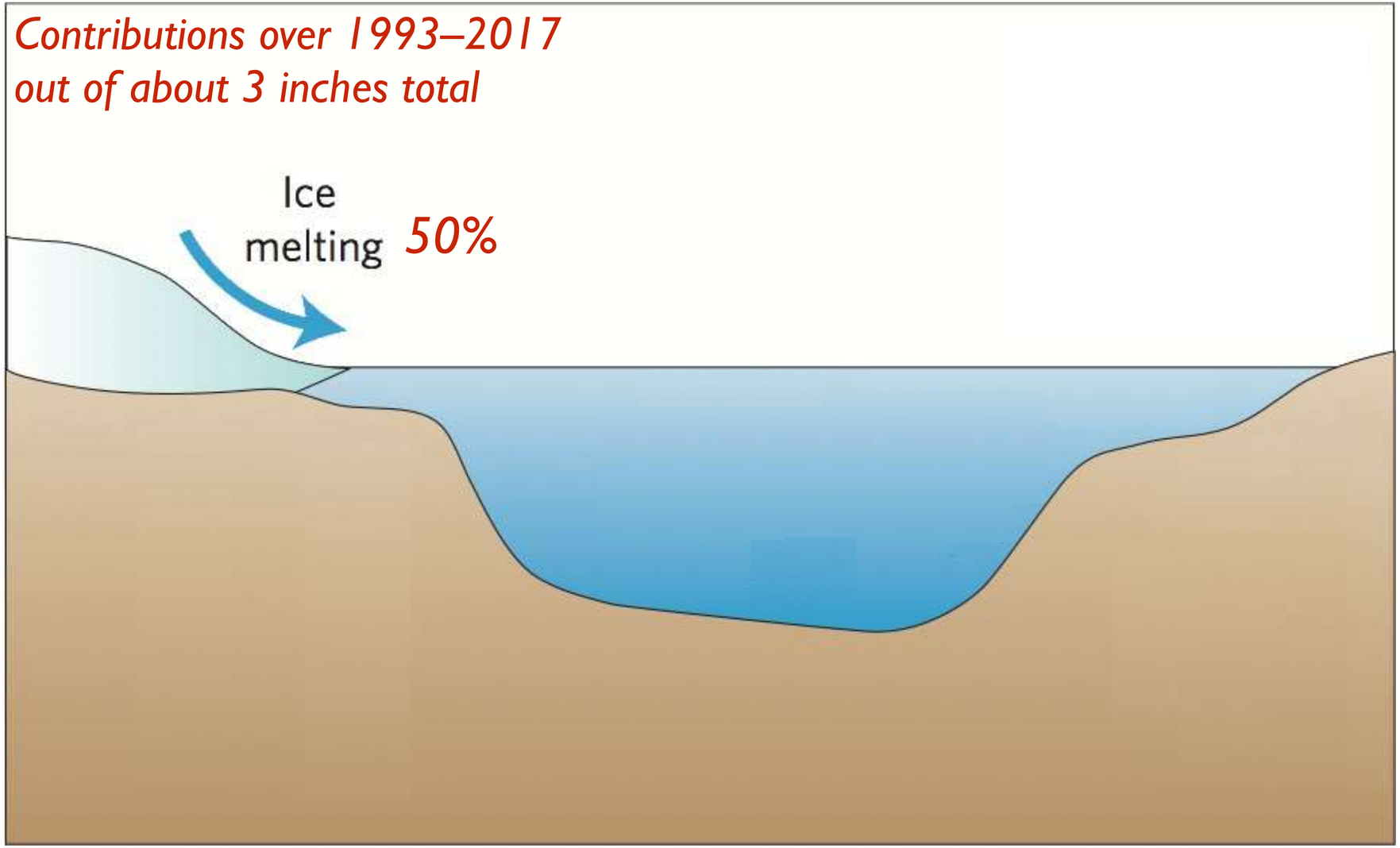
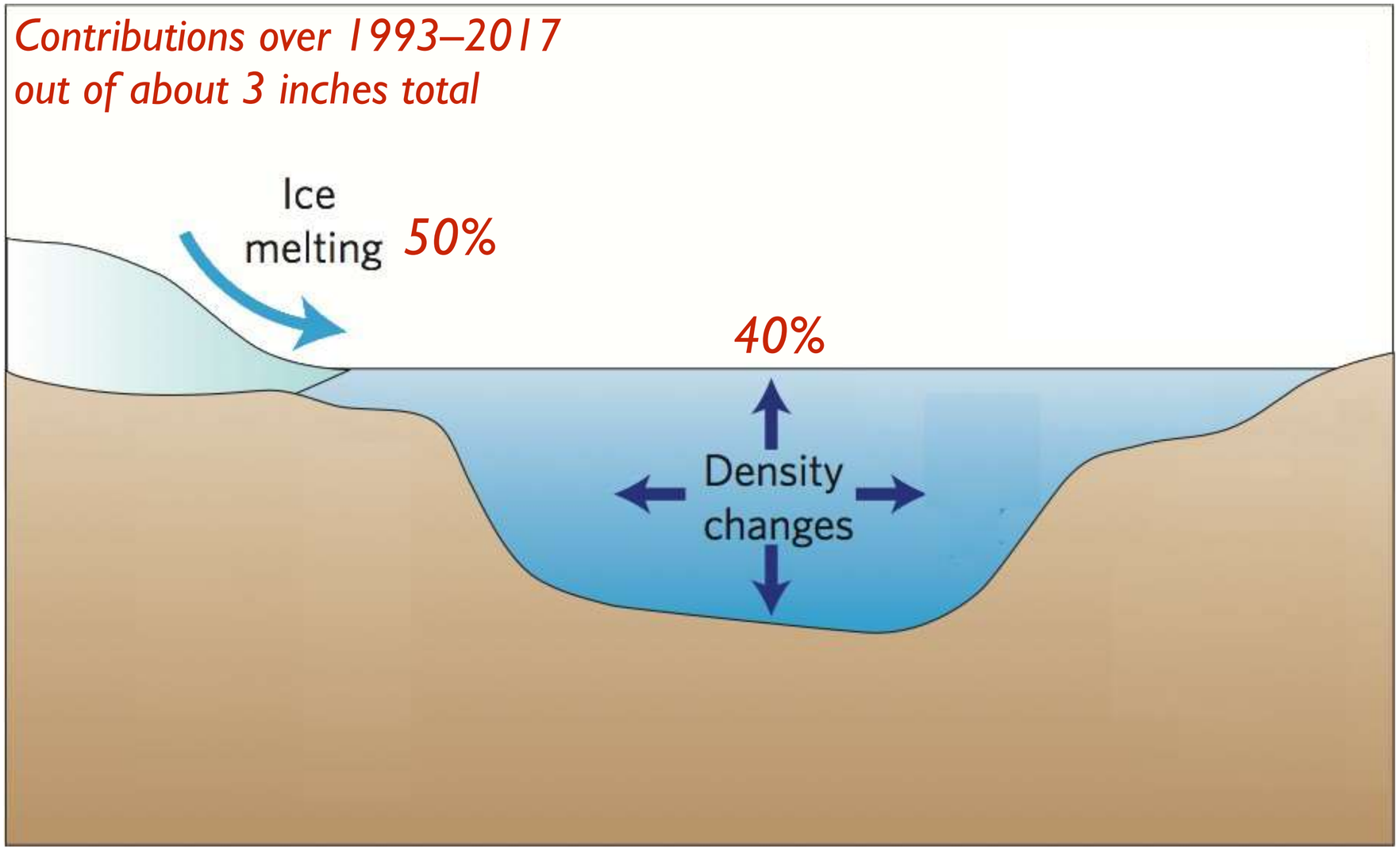


Milne et al. 2009

Most of the rest of global rise is due to the ocean expanding in volume as it warms.



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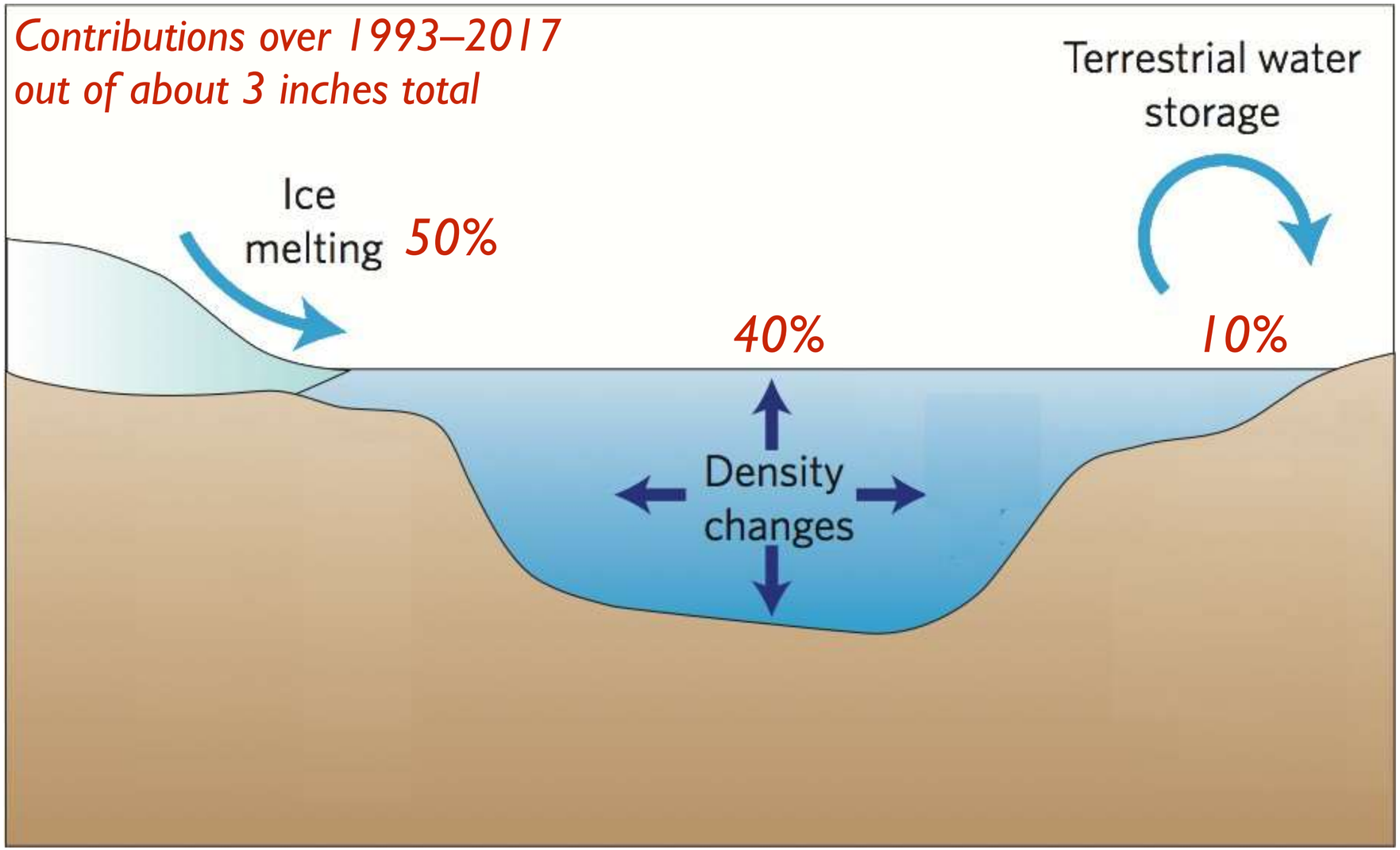
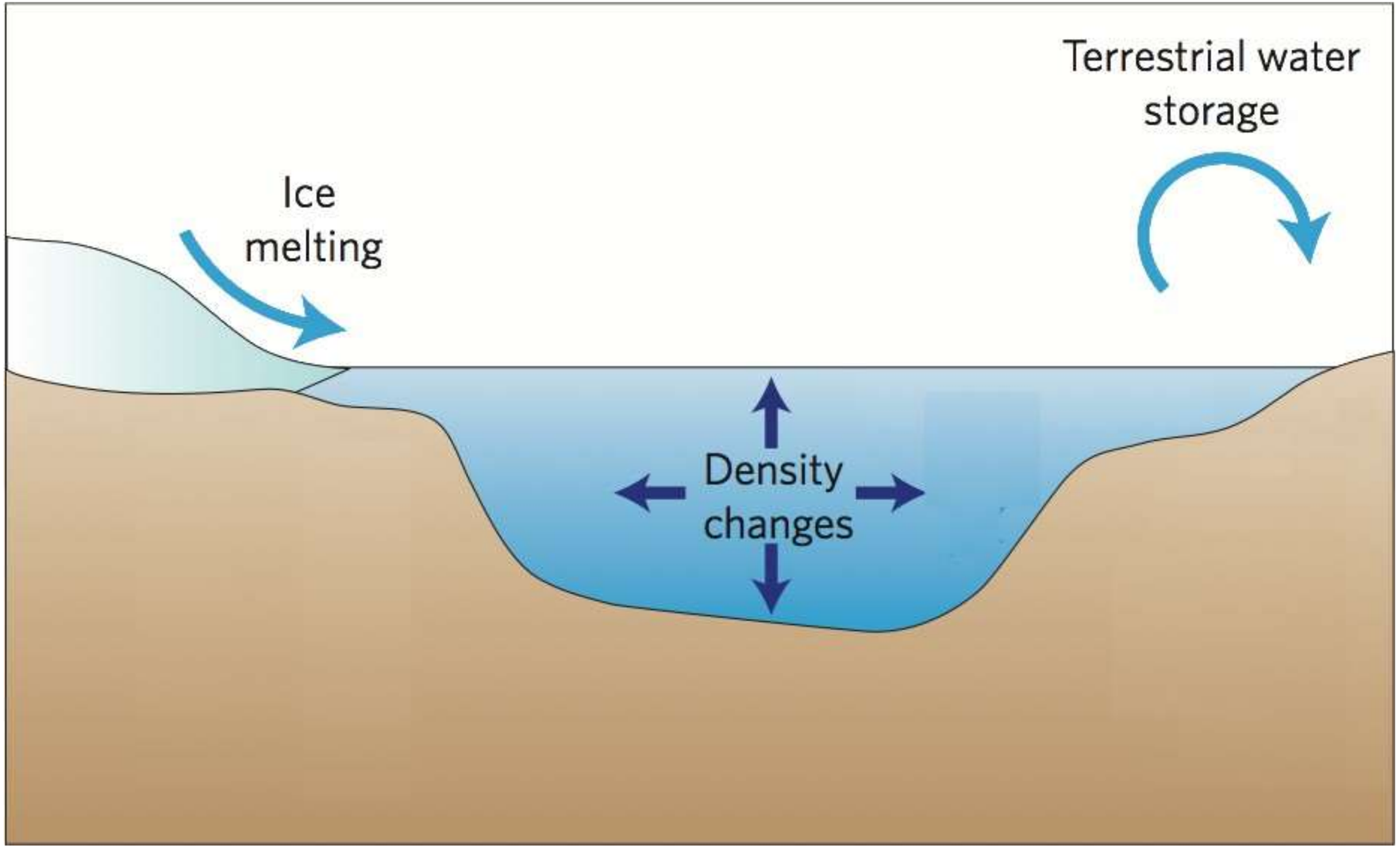
Changes in the water stored on land (e.g., in groundwater) accounts for a small amount.



Milne et al. 2009; budget based on WCRP Global Sea Level Budget Group (2018)) and Rignot et al. (2019)

The story becomes more complex when you start looking at specific places!



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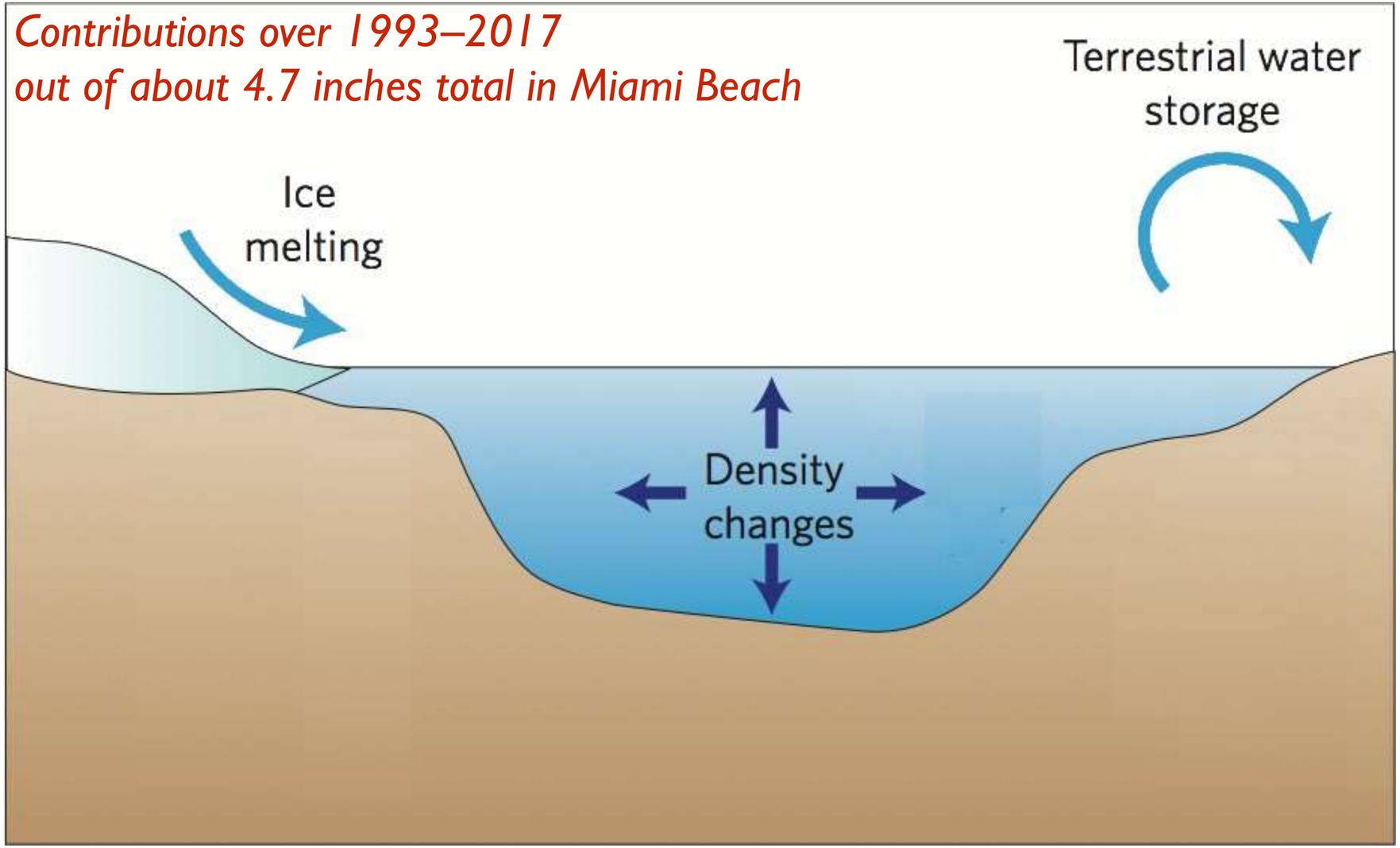

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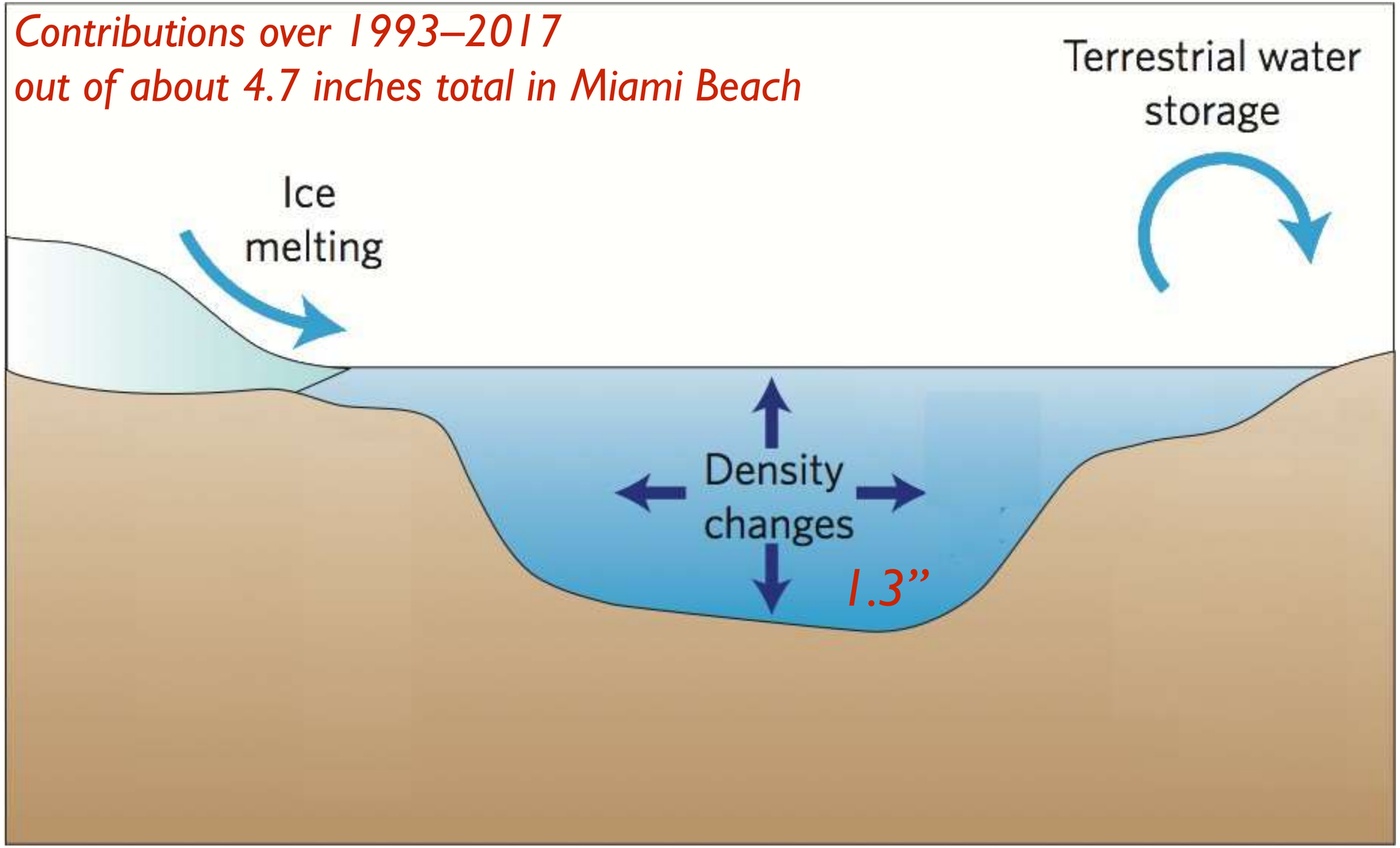
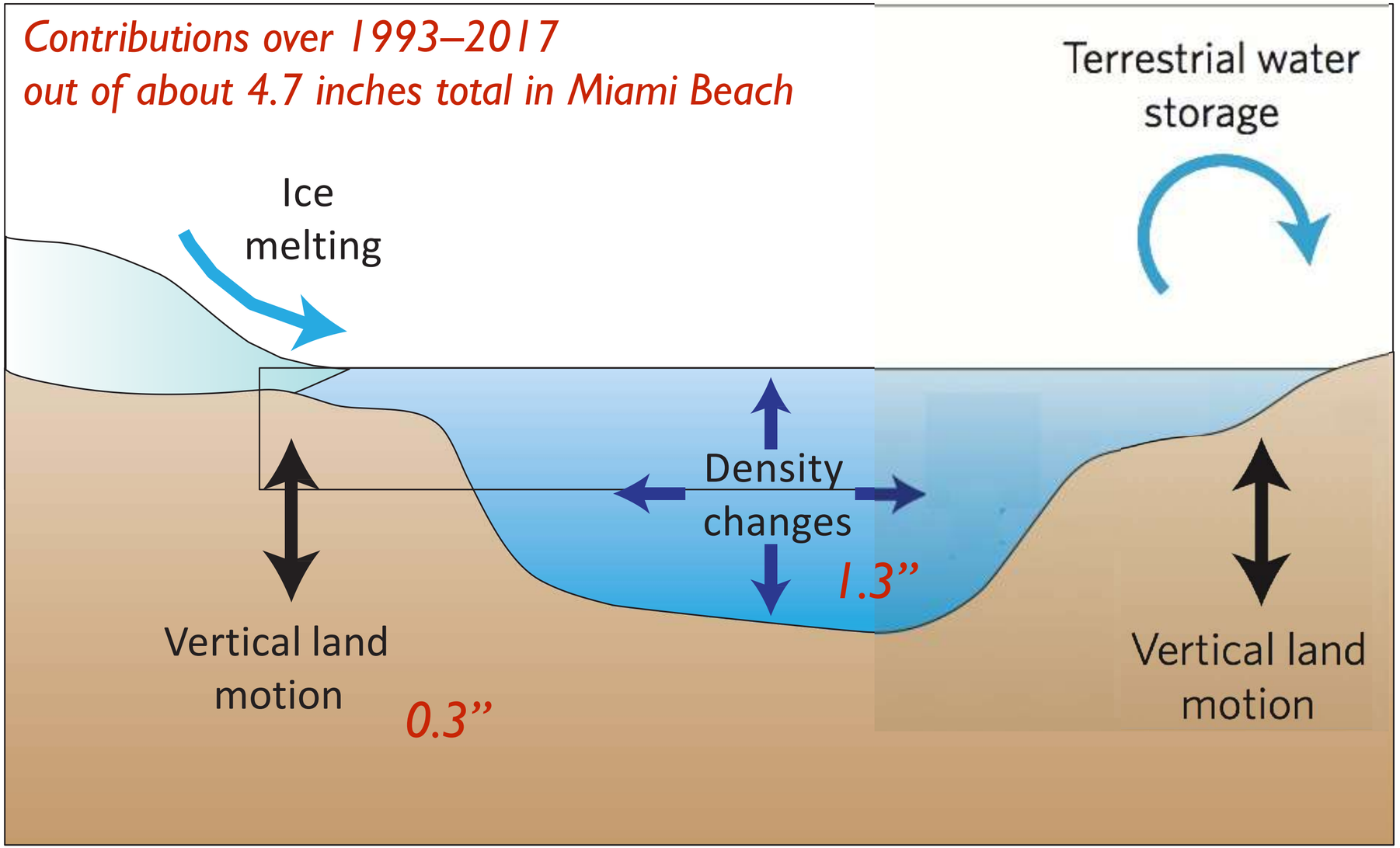


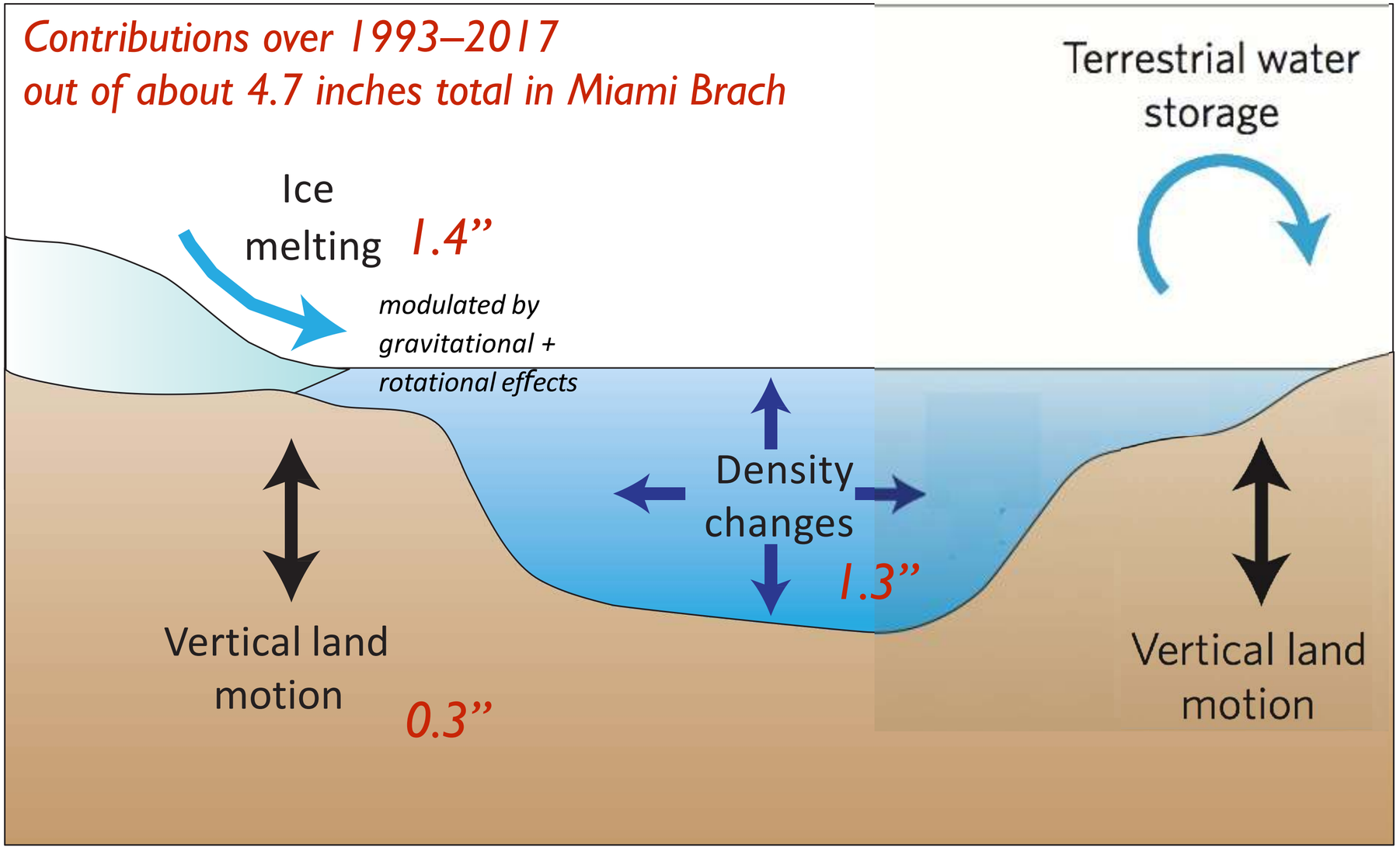
Milne et al. 2009

In parts of Florida, the land is sinking slightly due to natural processes.



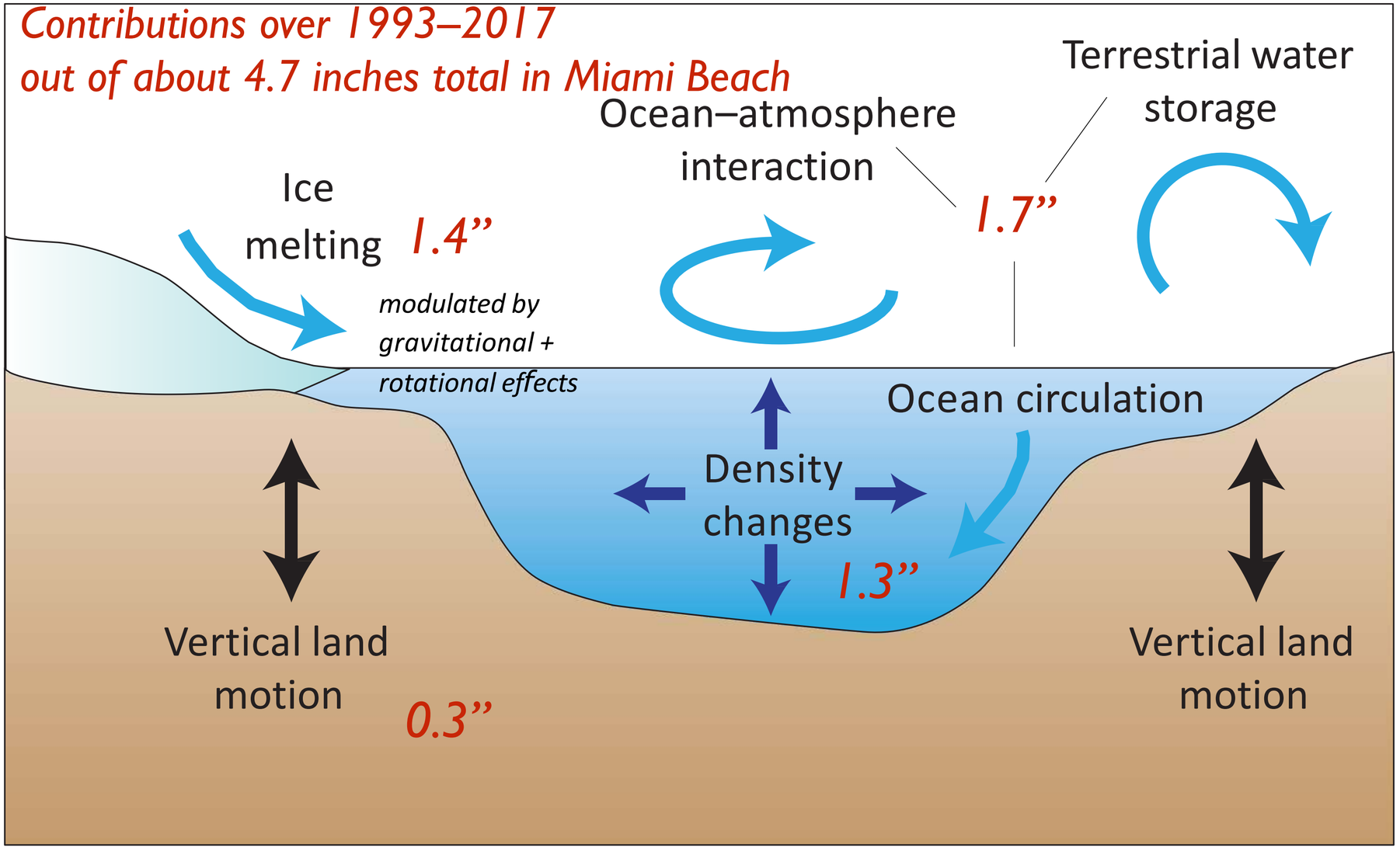
Milne et al. 2009

Shrinking land ice does not cause the same amount of sea-level rise everywhere.



Milne et al. 2009

Changes in winds and currents also contribute to regional sea-level rise.



Milne et al. 2009

What sea-level rise can we anticipate in the future?

To project future changes, we need to project all these processes.

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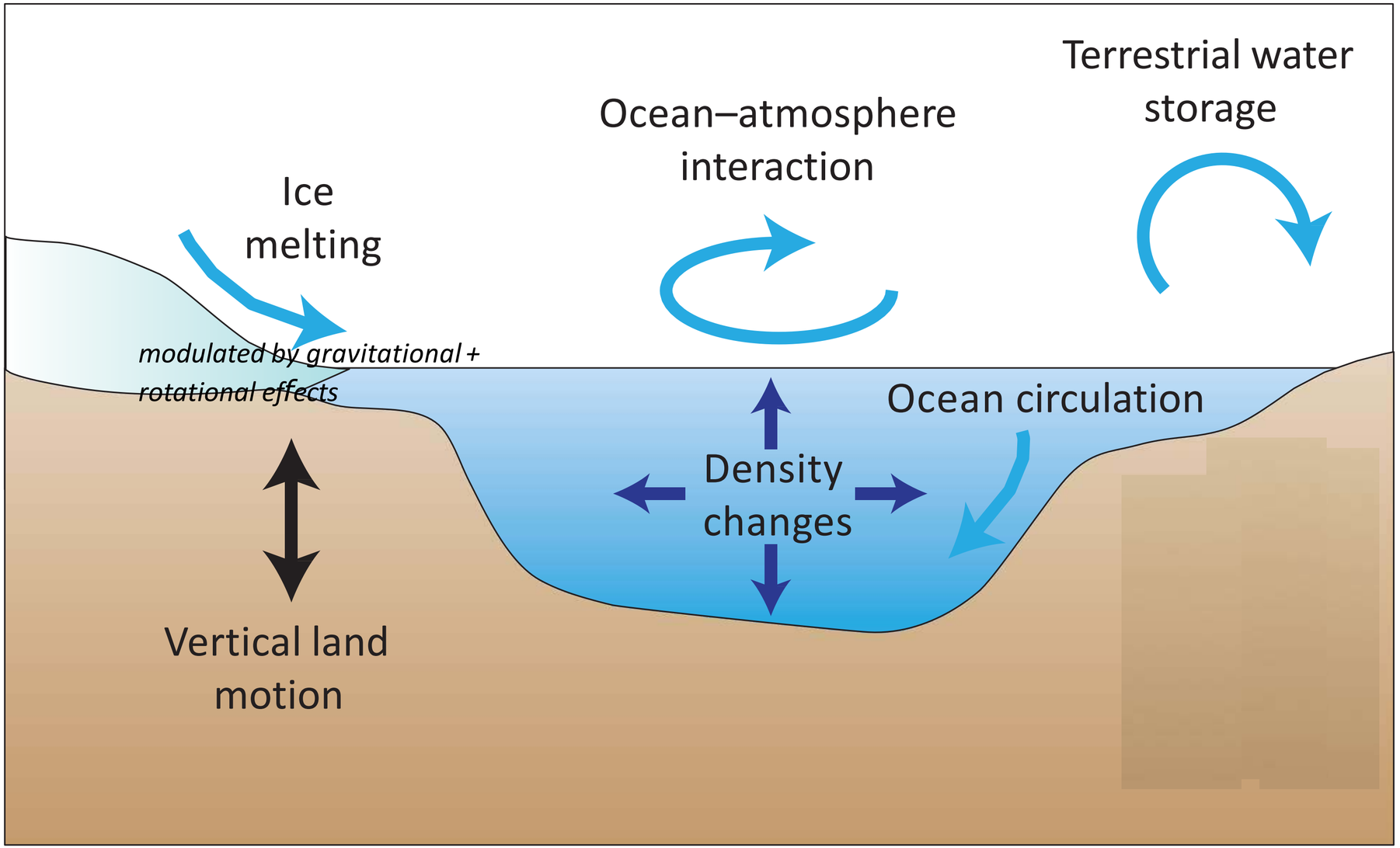

Framework of Kopp et al. (2014)

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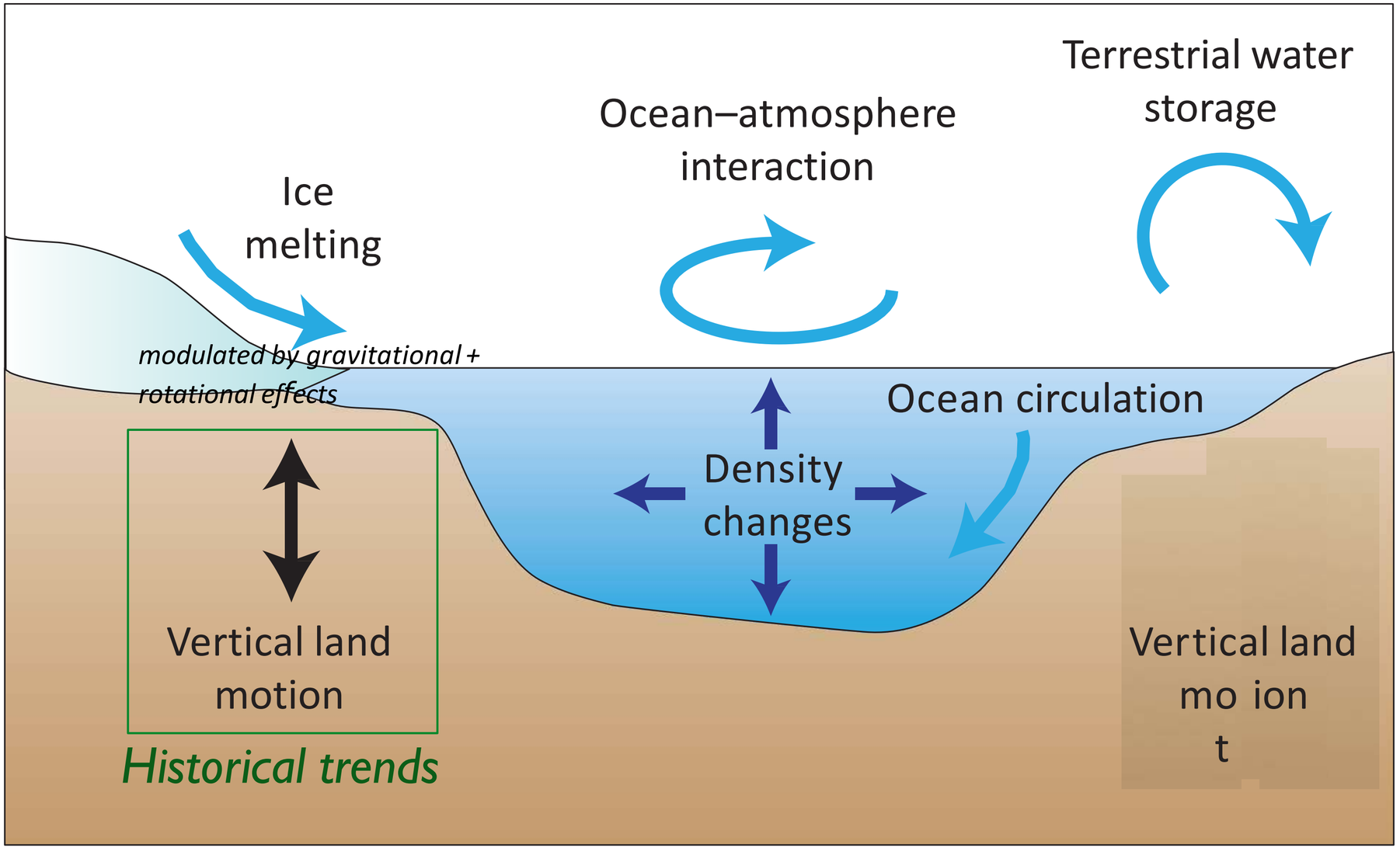

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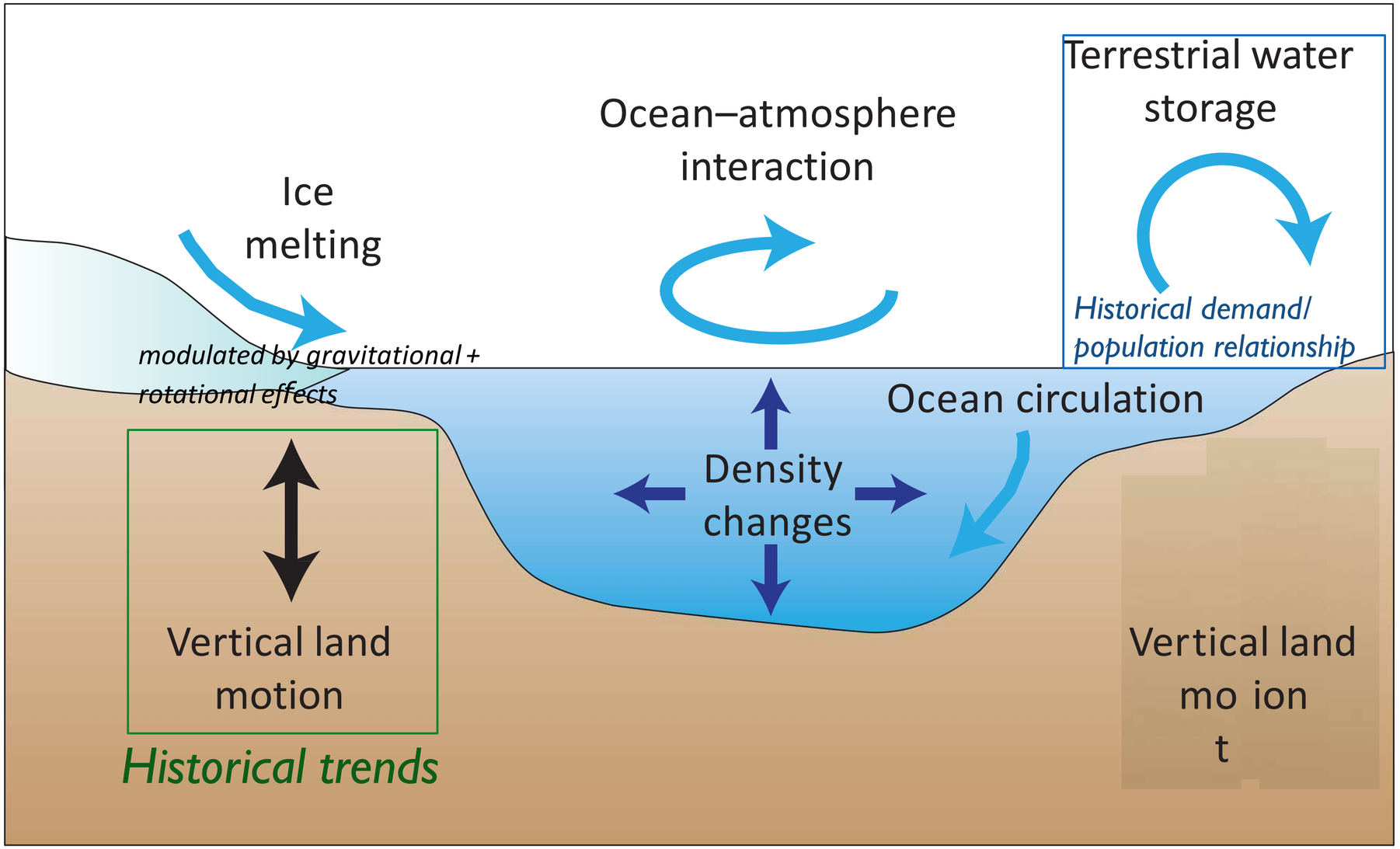

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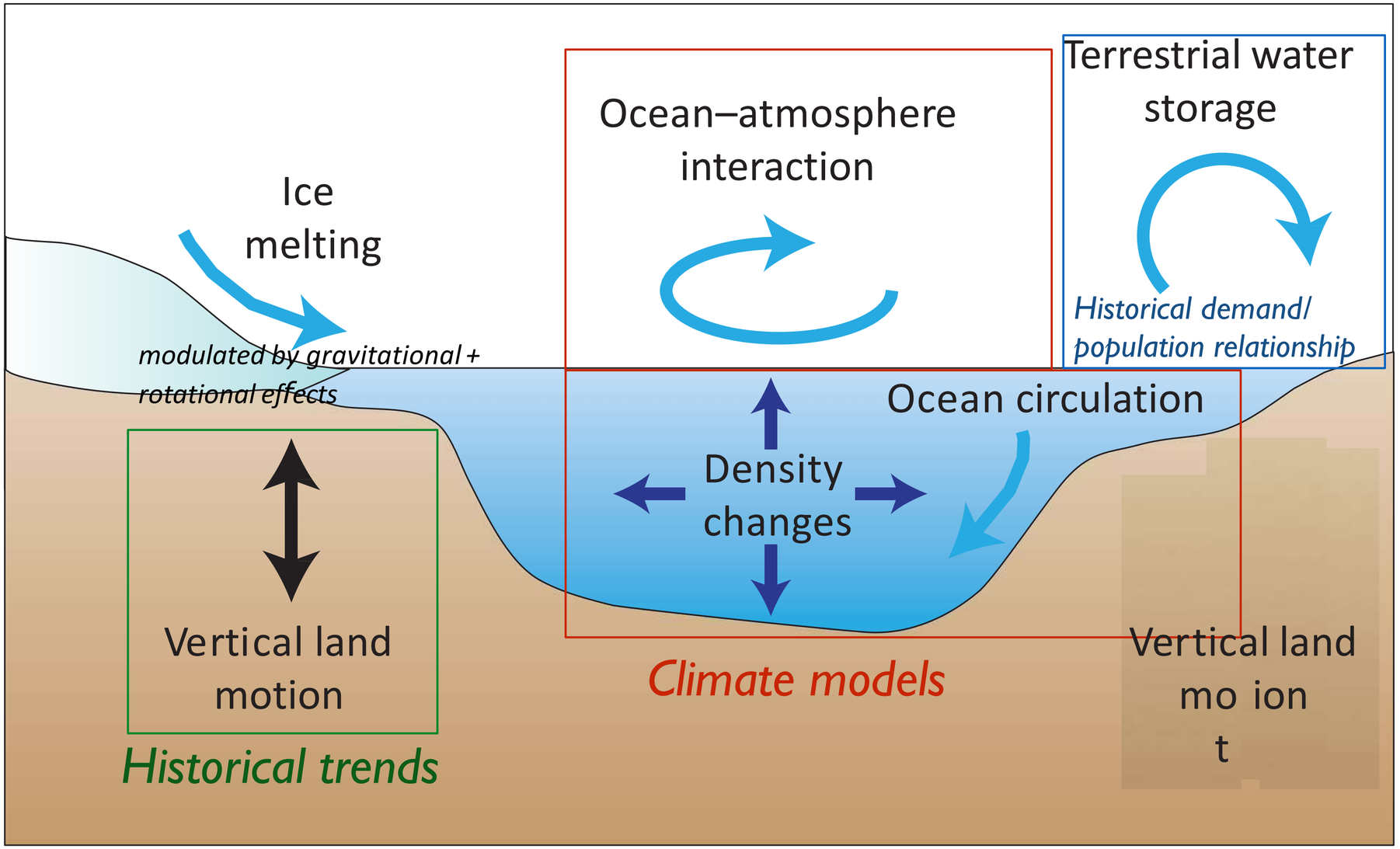

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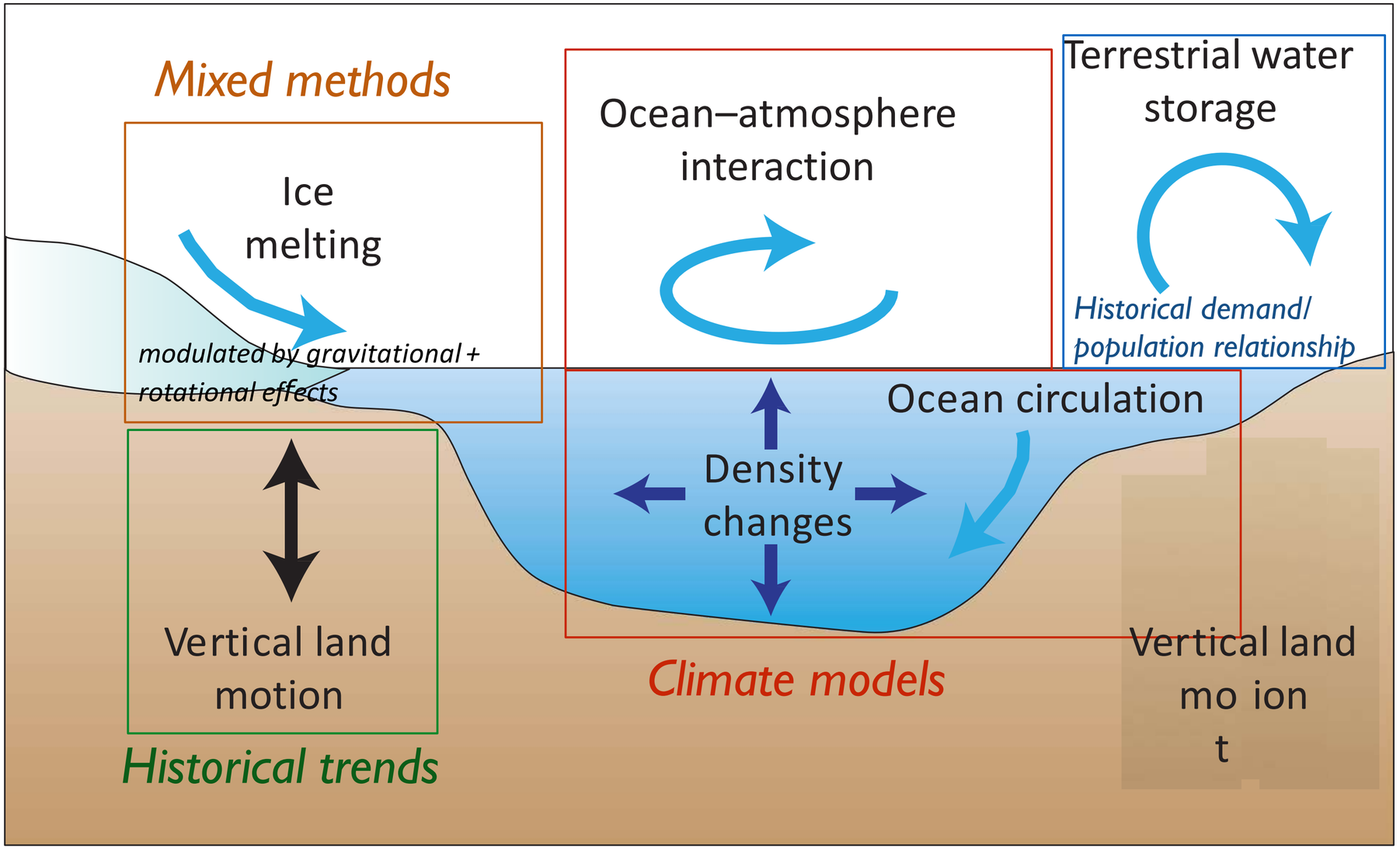

Framework of Kopp et al. (2014)

Our open-source framework (± modifications) has been widely used in US stakeholder-driven assessments

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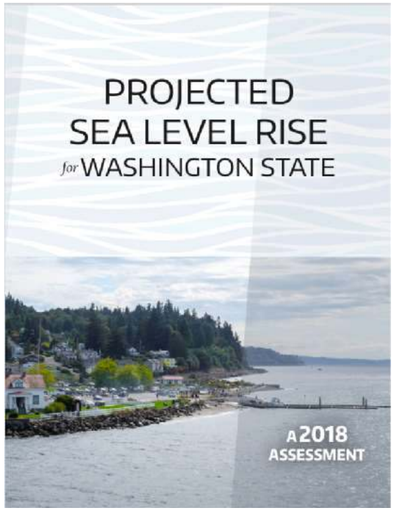
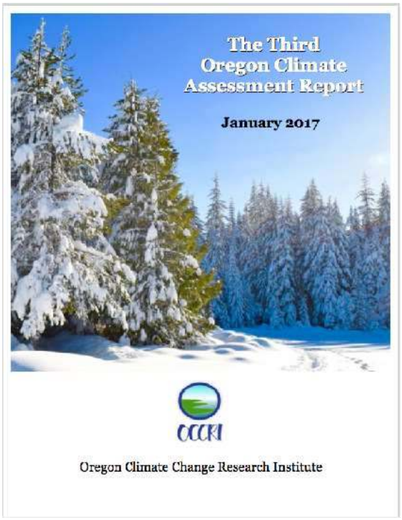
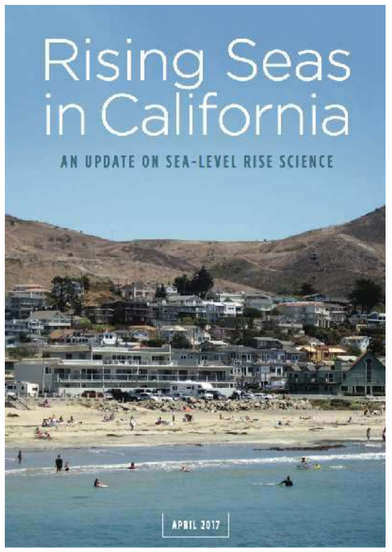
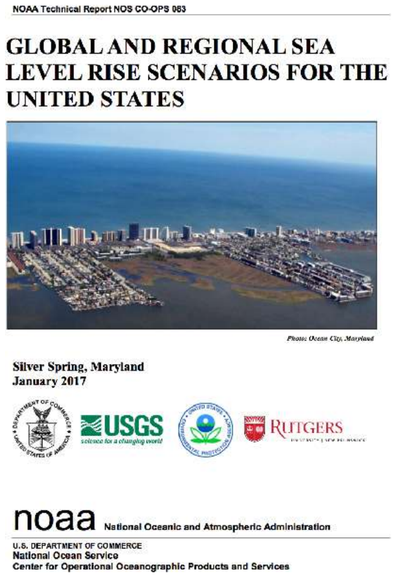
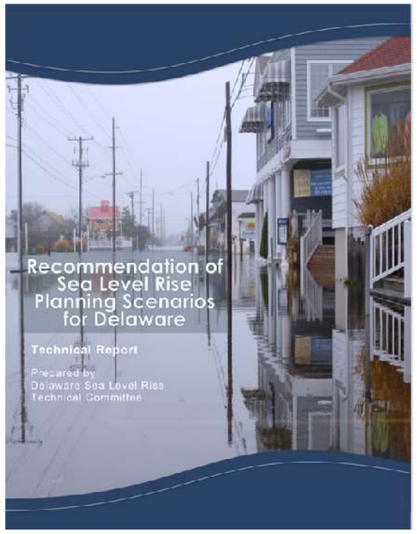
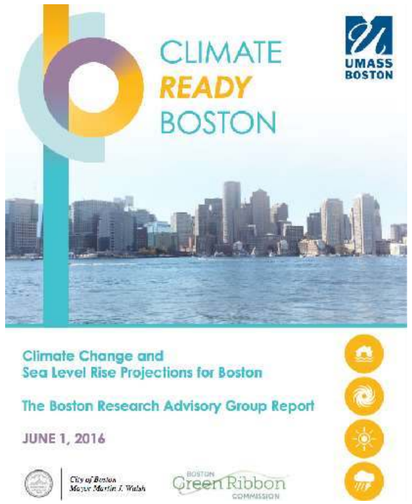


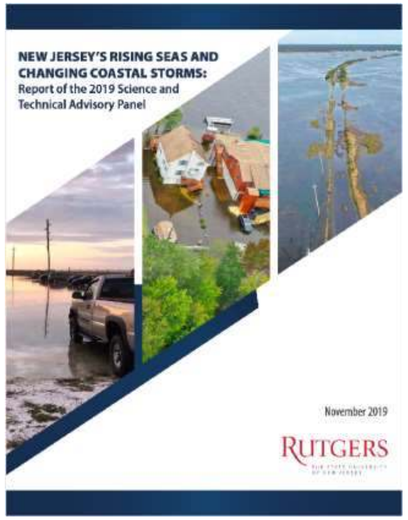






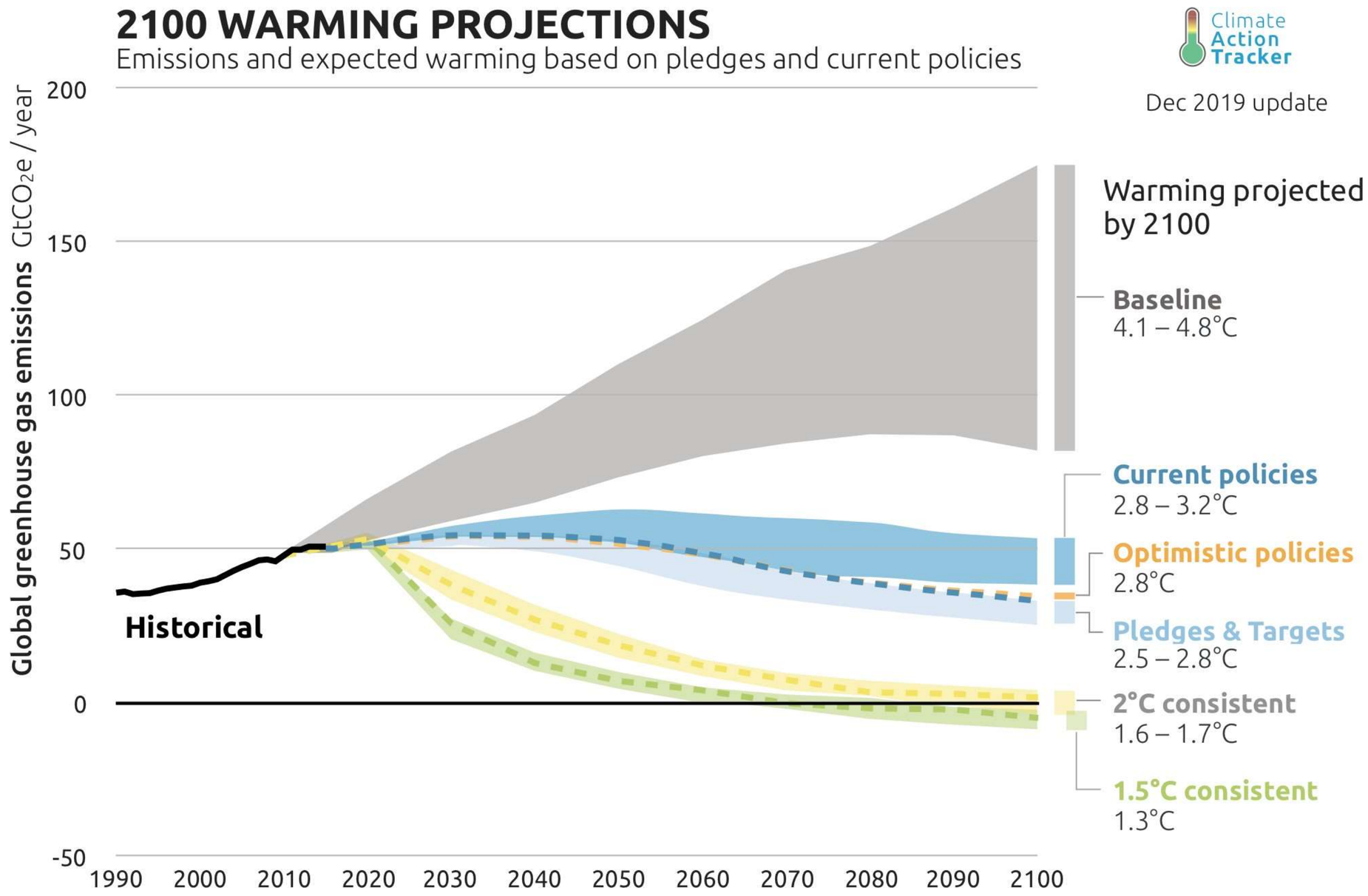






0 github.com/bobkopp/LocalizeSL

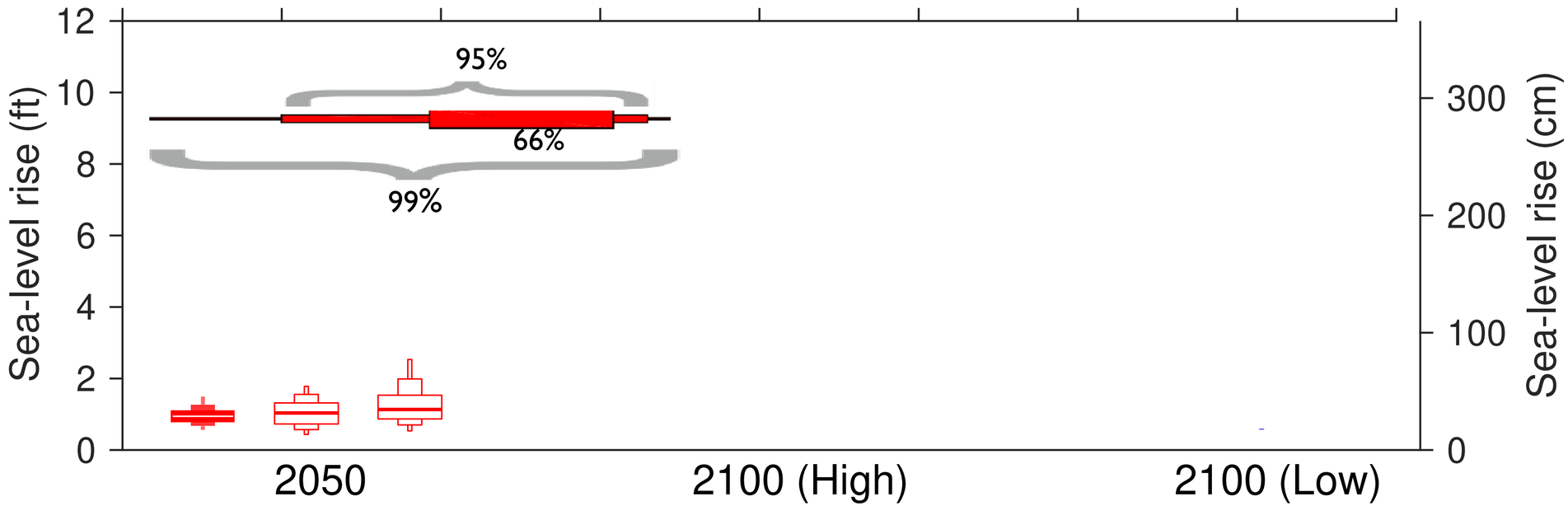
A key driver of the range of possible futures is the range of possible human emissions.



Another key driver of the range of projections is the incomplete, rapidly evolving scientific understanding of how ice sheets and the ocean interact.


(photo: Knut Christianson)

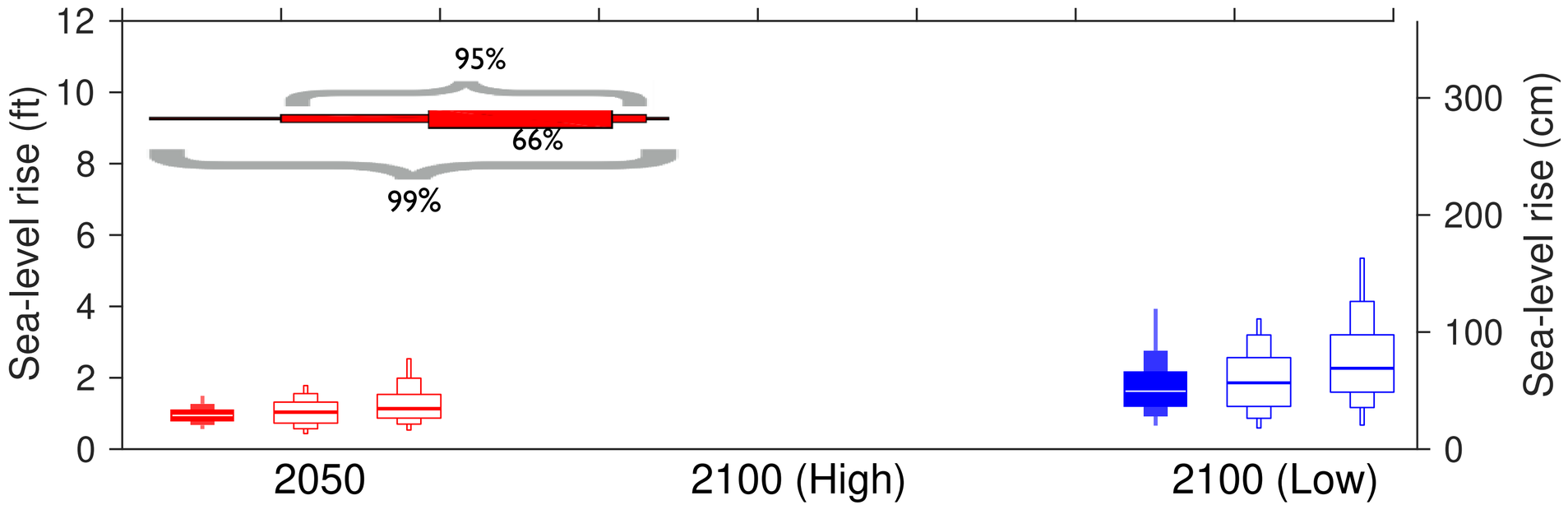
Different ice sheet treatments give similar global projections through 2050



Likely range projections	2050
K14 (sluggish ice)	0.7-1.1 ft
DP16 (fast ice)	0.5-1.3 ft
B19 (structured expert judgement)	0.7-1.5 ft

Kopp et al. (2014, 2017), Bamber et al. (2019)

Different ice sheet treatments give similar projections under low emissions

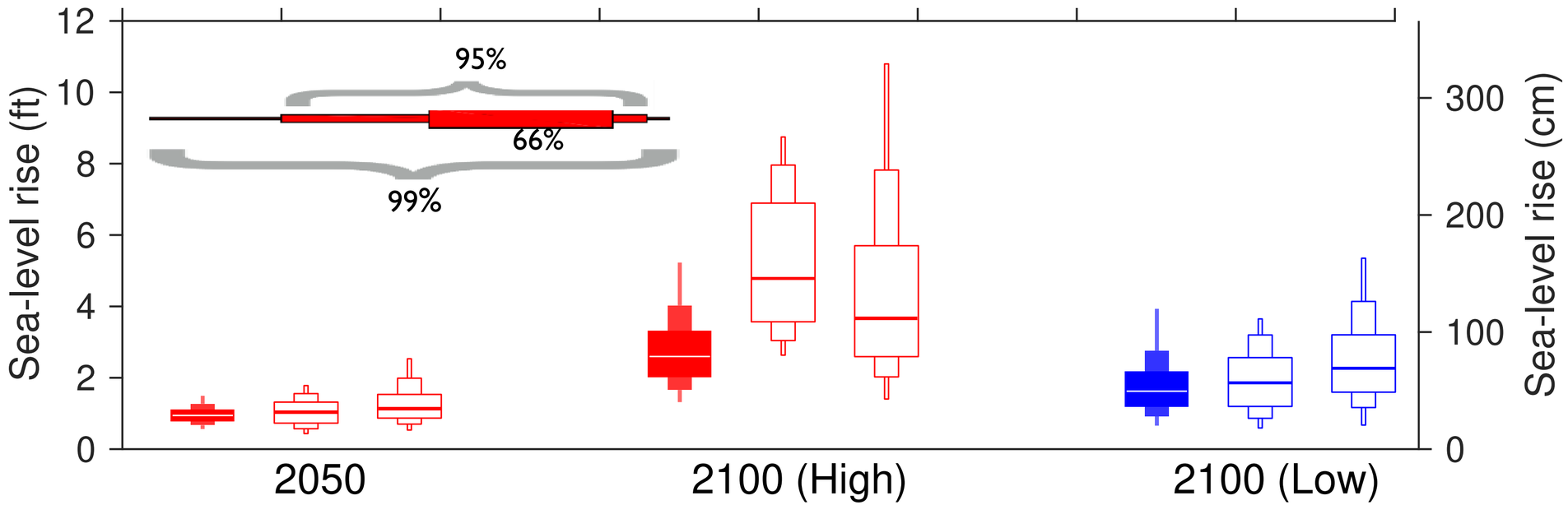


Likely range projections	2050
K14 (sluggish ice)	0.7-1.1 ft
DP16 (fast ice)	0.5-1.3 ft
B19 (structured expert judgement)	0.7-1.5 ft

2100 Low emissions
1.2-2.2 ft
1.2-2.6 ft
1.6-3.2 ft

Kopp et al. (2014, 2017), Bamber et al. (2019)

High emissions makes the system much harder to project



Likely range projections	2050	2100 High emissions	2100 Low emissions
K14 (sluggish ice)	0.7-1.1 ft	2.0-3.3 ft	1.2-2.2 ft
DP16 (fast ice)	0.5-1.3 ft	3.6-6.9 ft	1.2-2.6 ft
B19 (structured expert judgement)	0.7-1.5 ft	2.6-5.7 ft	1.6-3.2 ft

Kopp et al. (2014, 2017), Bamber et al. (2019)

What do we do about sea-level rise?

Do we modify our communities to accommodate occasional flooding?

Manasquan, NJ – Tony Cenicola, The New York Times (https://www.nytimes.com/2017/06/16/realestate/hurricane-sandy-rebuilding-jersey-shore-

Do we modify our communities to accommodate occasional flooding?

Manasquan, NJ

Remember: elevating houses is of limited value if you don't also protect critical infrastructure!

Manasquan, NJ – Tony Cenicola, The New York Times (https://www.nytimes.com/2017/06/16/realestate/hurricane-sandy-rebuilding-jersey-shore-

Do we harden?

BIG-Bjarke Ingels Group (2017)

Do we harden?

But remember: you also need to plan for those occasions when hard protection fails.

BIG-Bjarke Ingels Group (2017)

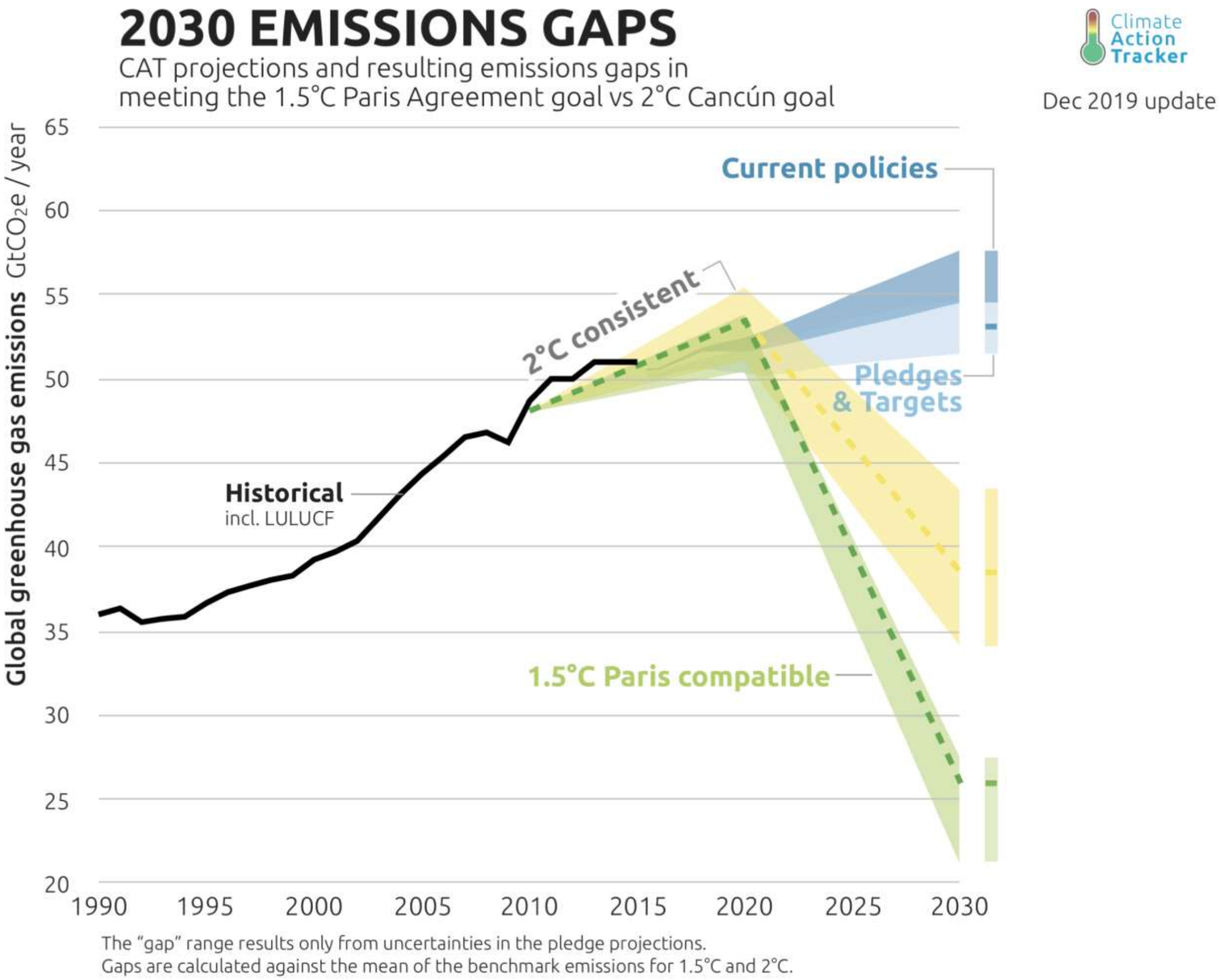
Do we expand protective natural infrastructure?

Photo: Jamaica Bay Ecowatchers

Do we relocate to higher ground?

Nathan Kensinger, Curbed (https://ny.curbed.com/2016/10/27/13431288/hurricane-sandy-staten-island-wetlands-climate-change)

However we chose to adapt, the starting point is climate change mitigation.



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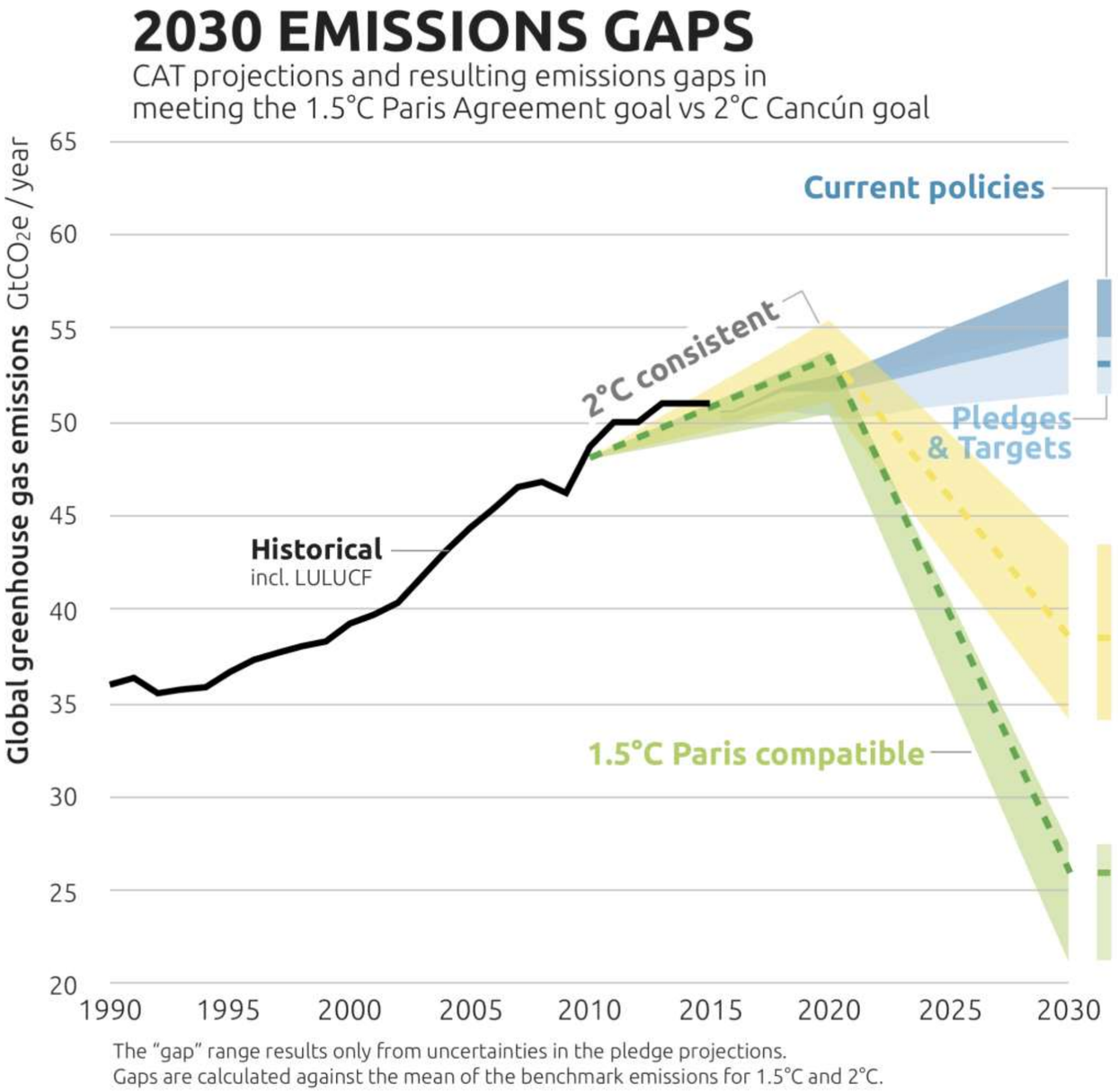
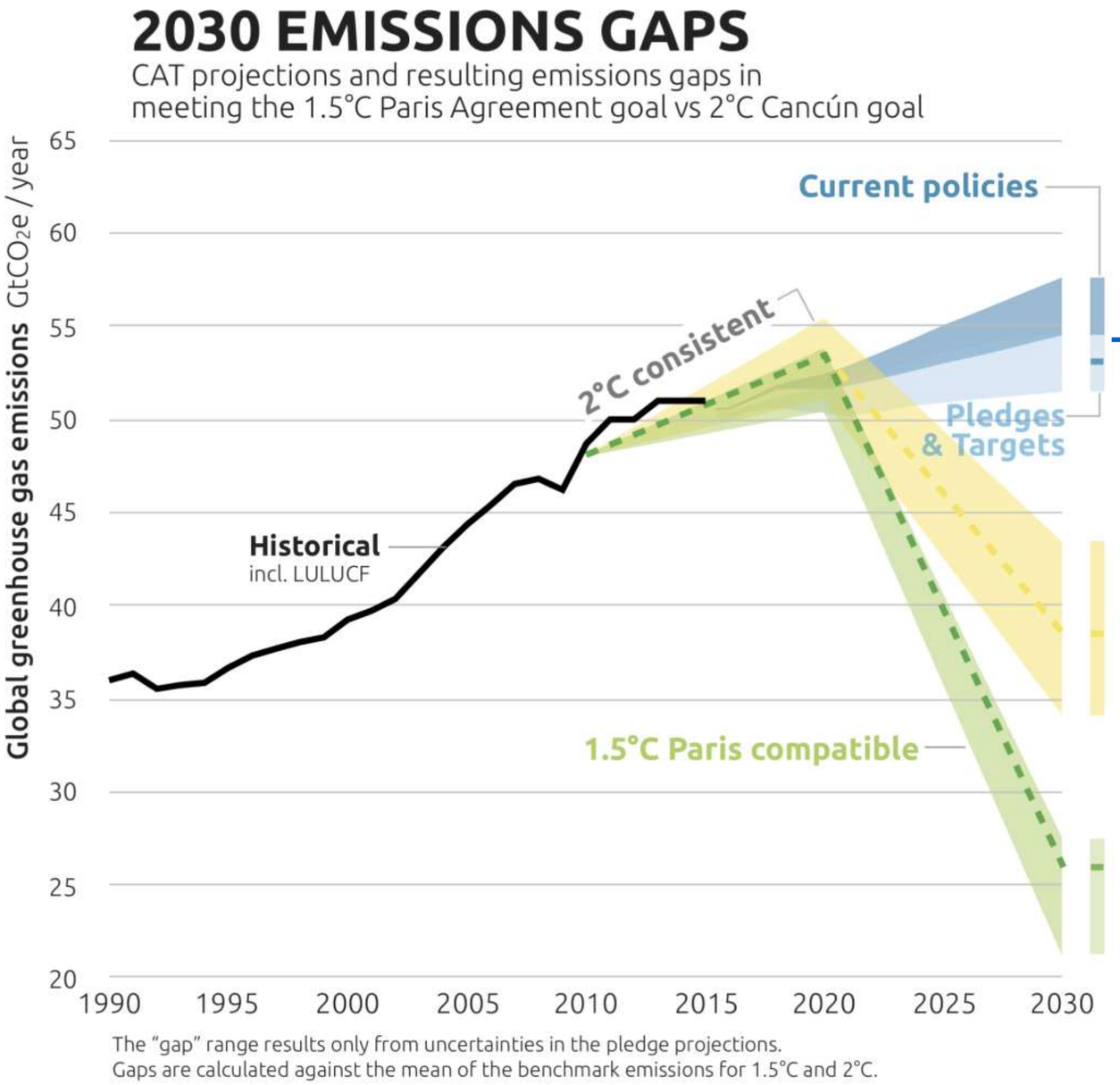


Climate Action Tracker

Dec 2019 update

Regardless of emissions, likely global mean sea-level rise of about 0.5-1.5 ft between 2000 and 2050.

However we chose to adapt, the starting point is climate change mitigation.



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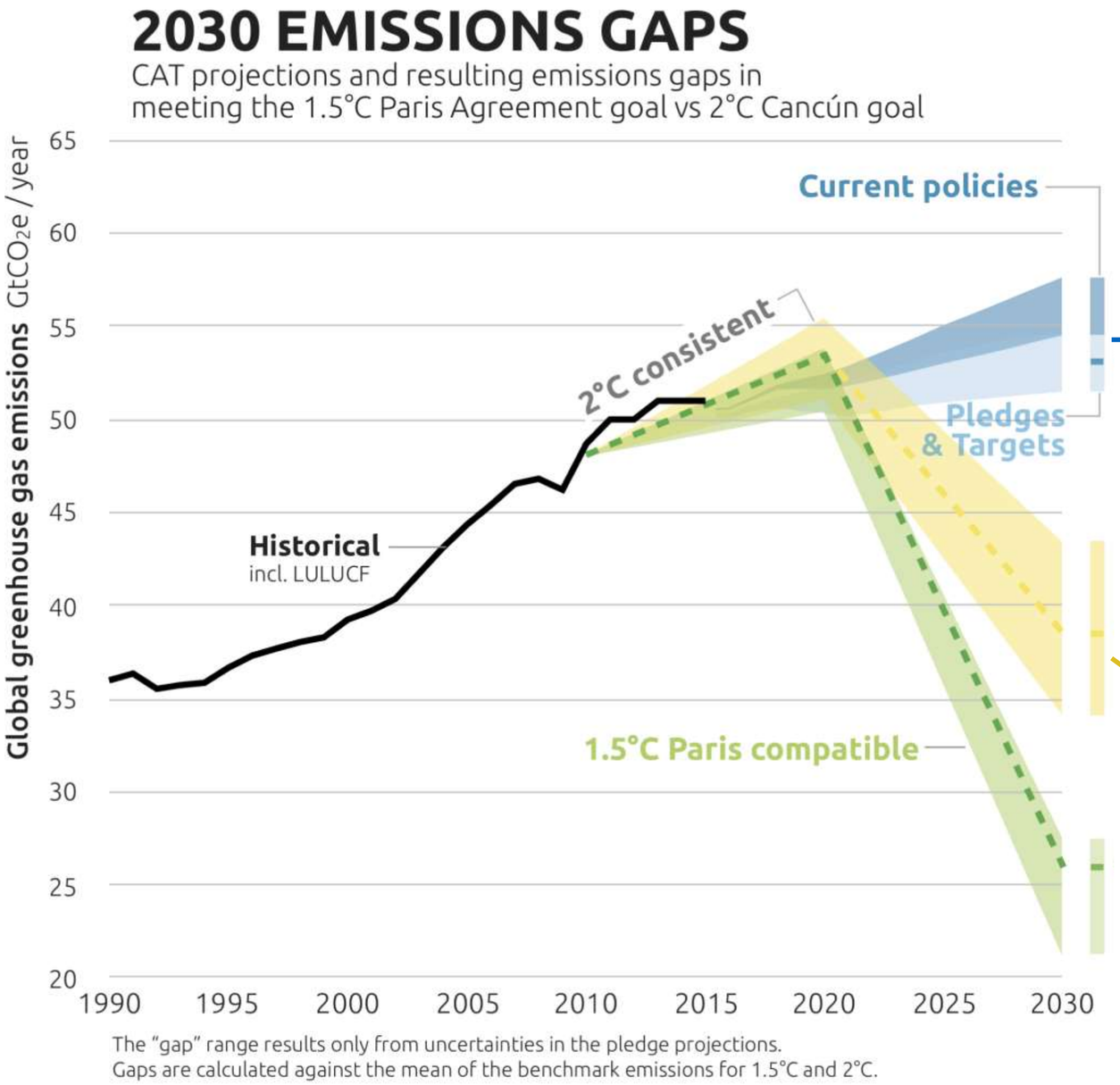
Under current emissions, likely about 2-5 ft by 2100 (high-end of 6 ft).

However we chose to adapt, the starting point is climate change mitigation.



Regardless of emissions, likely global mean sea-level rise of about 0.5-1.5 ft between 2000 and 2050.

Under current emissions, likely about 2-5 ft by 2100 (high-end of 6 ft).

Under low emissions, likely about 1-3 ft by 2100 (high-end of 4 ft).

Greenhouse Gas Emissions and Future Sea-Level Rise

Robert Kopp

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Climate Impact Lab

!S robert.kopp@rutgers.edu
"# @bobkopp

Southeast Florida's 2019 Unified Sea Level Projection: The Foundations
June 18, 2020