Late Miocene Arctic Warmth and Terrestrial Climate Recorded by North Greenland Speleothems

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Late Miocene Arctic warmth and terrestrial climate recorded by North Greenland speleothems

Research briefing

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Caves record permafrost-free North Greenland under moderate Late Miocene CO_2 levels

Our analysis of mineral deposits in a cave in North Greenland reveals a sensitive High Arctic Late Miocene climate at moderate CO_2 levels, balanced between wetter and warmer permafrost-free conditions and ephemeral glacier expansion.

The problem

Understanding Earth's climate system during former episodes of elevated global temperatures and atmospheric CO_2 concentrations is crucial for improving predictions of future change. One relevant period is the Late Miocene (approximately 11.6–5.3 million years ago), when Earth's palaeogeography was similar to today, and atmospheric CO_2 levels and global temperatures were similar to near future projections[1]. Despite the high sensitivity of the Arctic to climate change, our knowledge of its climate and environmental conditions during the Late Miocene remains limited. However, improving this knowledge is critically important and of global relevance, given the profound and far-reaching impacts that changes in the Arctic will have worldwide in the coming centuries.

The solution

To investigate climate variability during the Late Miocene in North Greenland (80 °N), we sampled and analysed carbonate mineral deposits known as flowstones, which are a type of speleothem, in Cove Cave (Eqik Qaarusussuaq in Kalaallitsut)[2]. In today's polar desert, such mineral deposits cannot form owing to a lack of water and the presence of frozen ground. Dating the timing of speleothem deposition therefore yields information about environments below these thresholds. Following each of these hiatuses in speleothem growth, spikes in trace elements were recorded in the speleothems, which are thus interpreted as signals of the presence of early North Greenland ephemeral glaciers that existed prior to ~6.3 and ~5.6 million years ago. Time-series of $\delta^{18}O$ (the ratio of ^{18}O to ^{16}O) further support the strong role of obliquity (the angle between Earth's equatorial and orbital planes) during the Late Miocene, whereas sodium levels indicate that sea ice was at its greatest extent (in our records) during phases of transient glacial–interglacial cycles approximately 5.6 million years ago.

The implications

Our findings highlight the sensitivity of North Greenland's climate and environment under moderate atmospheric CO_2 conditions. Although temperatures in the Late Miocene were often substantially higher than current temperatures (more than 14 °C above present), the Late Miocene terrestrial climate and environment of North Greenland appears to have fluctuated between warmer, wetter conditions without permafrost and periods of possible glacial or permafrost expansion. Our findings have broad implications for understanding the environment and sensitivity of the High Arctic climate to globally warm conditions.

Our analyses are constrained by the epi-sodic nature of speleothem growth, which

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(b) Annual mean temperature change (°C) relative to 1850–1900

Across warming levels, land areas warm more than ocean areas, and the Arctic and Antarctica warm more than the tropics.

Simulated change at **1.5°C** global warming

Simulated change at **2°C** global warming

Simulated change at **4°C** global warming

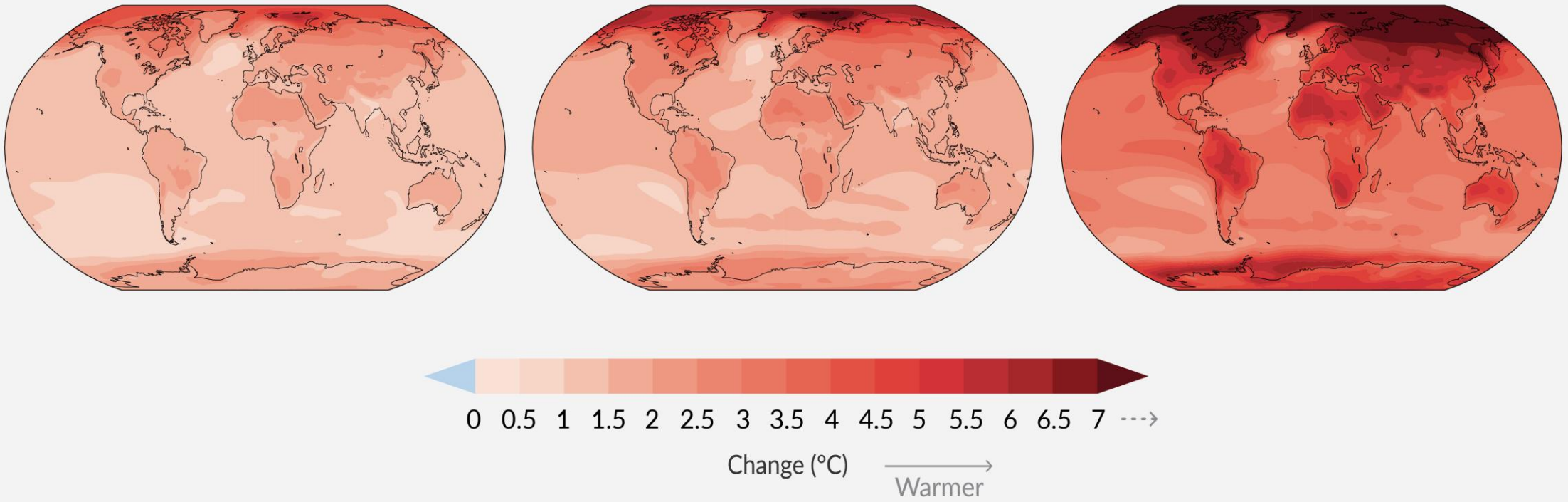
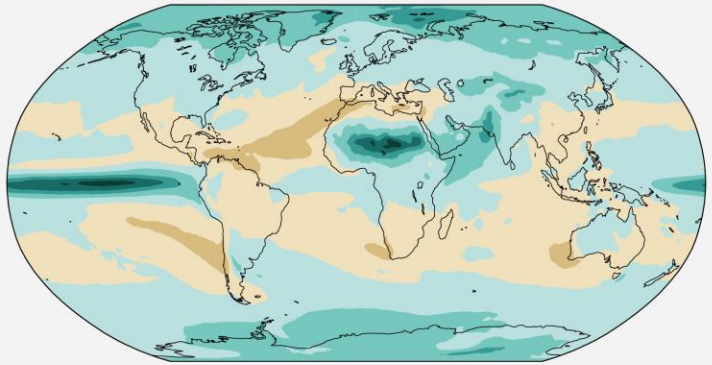


Fig. SPM.5, IPCC AR6 WG1 (2021)

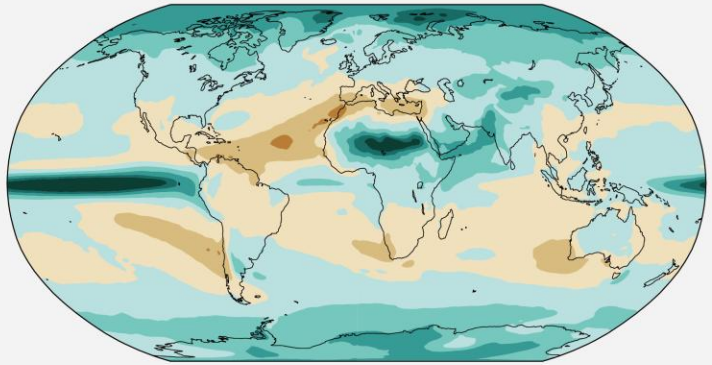
(c) Annual mean precipitation change (%) relative to 1850–1900

Precipitation is projected to increase over high latitudes, the equatorial Pacific and parts of the monsoon regions, but decrease over parts of the subtropics and in limited areas of the tropics.

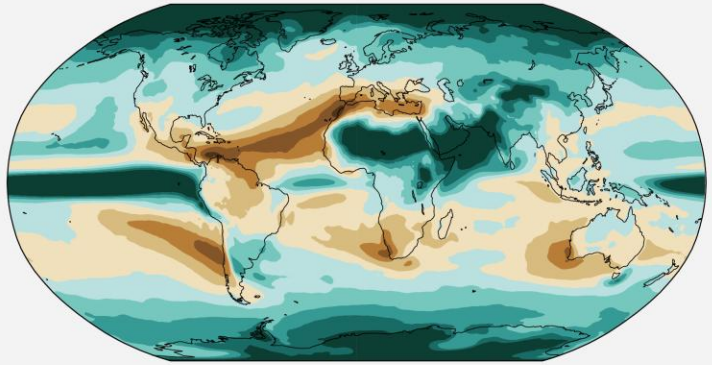
Simulated change at **1.5°C** global warming



Simulated change at **2°C** global warming



Simulated change at **4°C** global warming



Relatively small absolute changes may appear as large % changes in regions with dry baseline conditions.

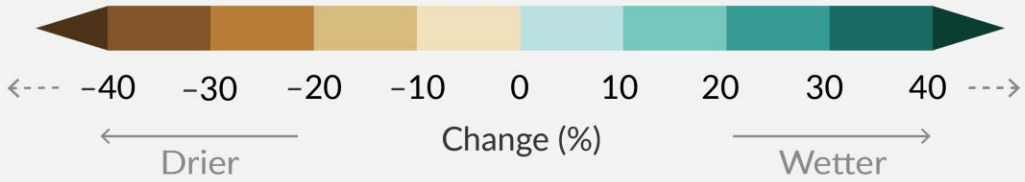
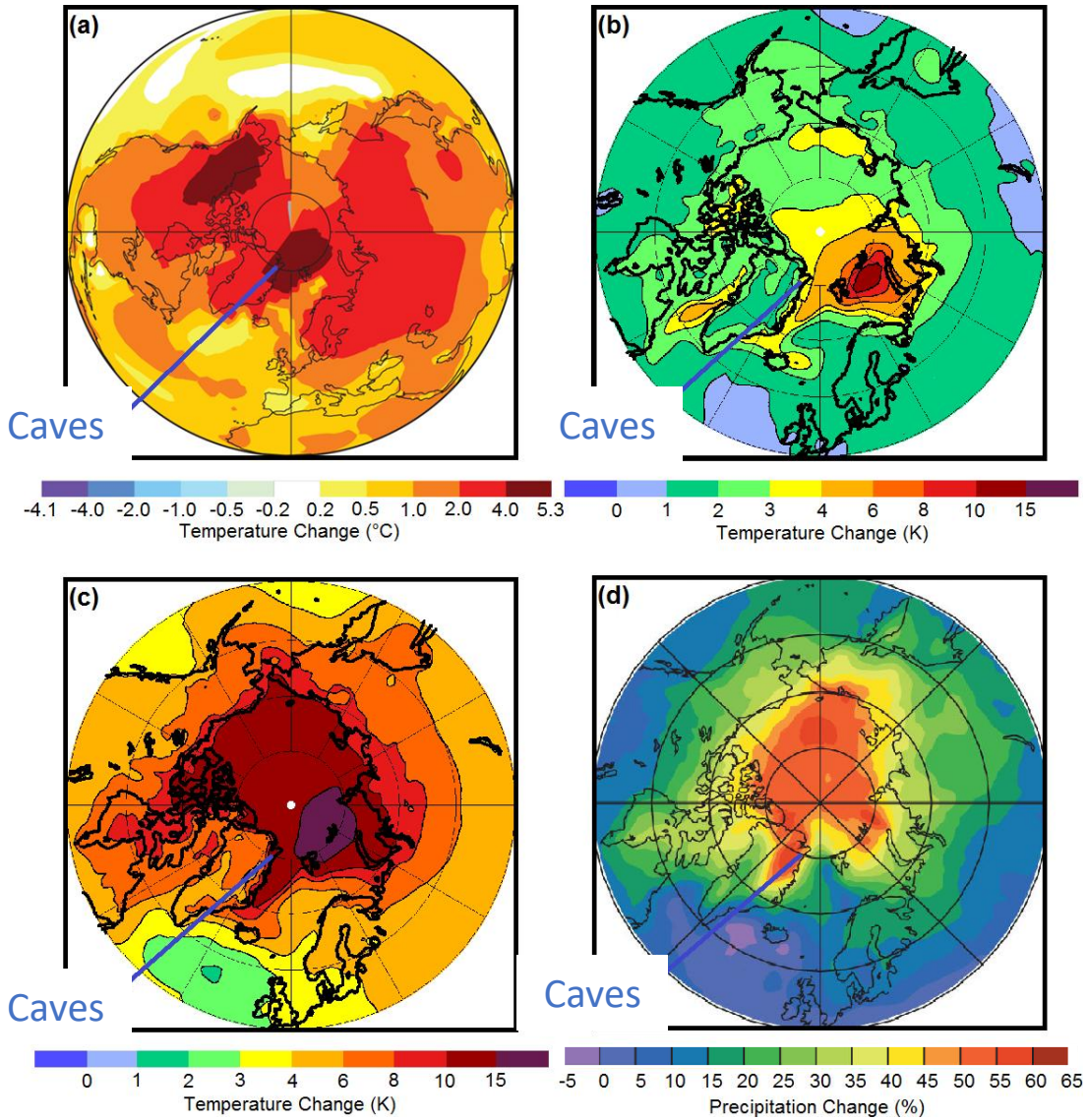
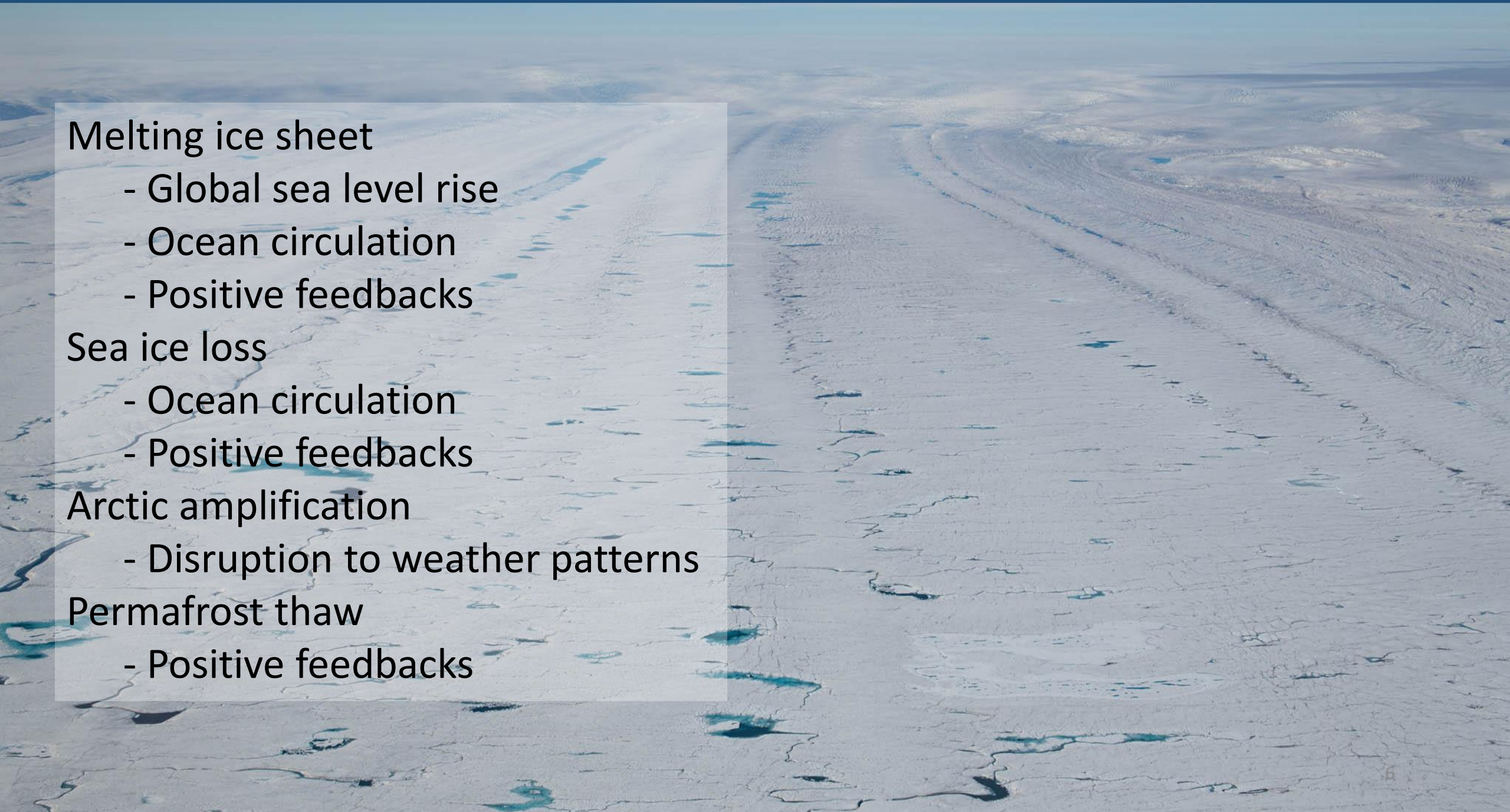


Fig. SPM.5, IPCC AR6 WG1 (2021)

Predicted Changes in a Future Warmer World



a. *GISTEMP Team, 2016*
b. *Koenigk et al., 2013*
c. *Koenigk et al., 2013*
d. *Bintanja and Selten, 2014*

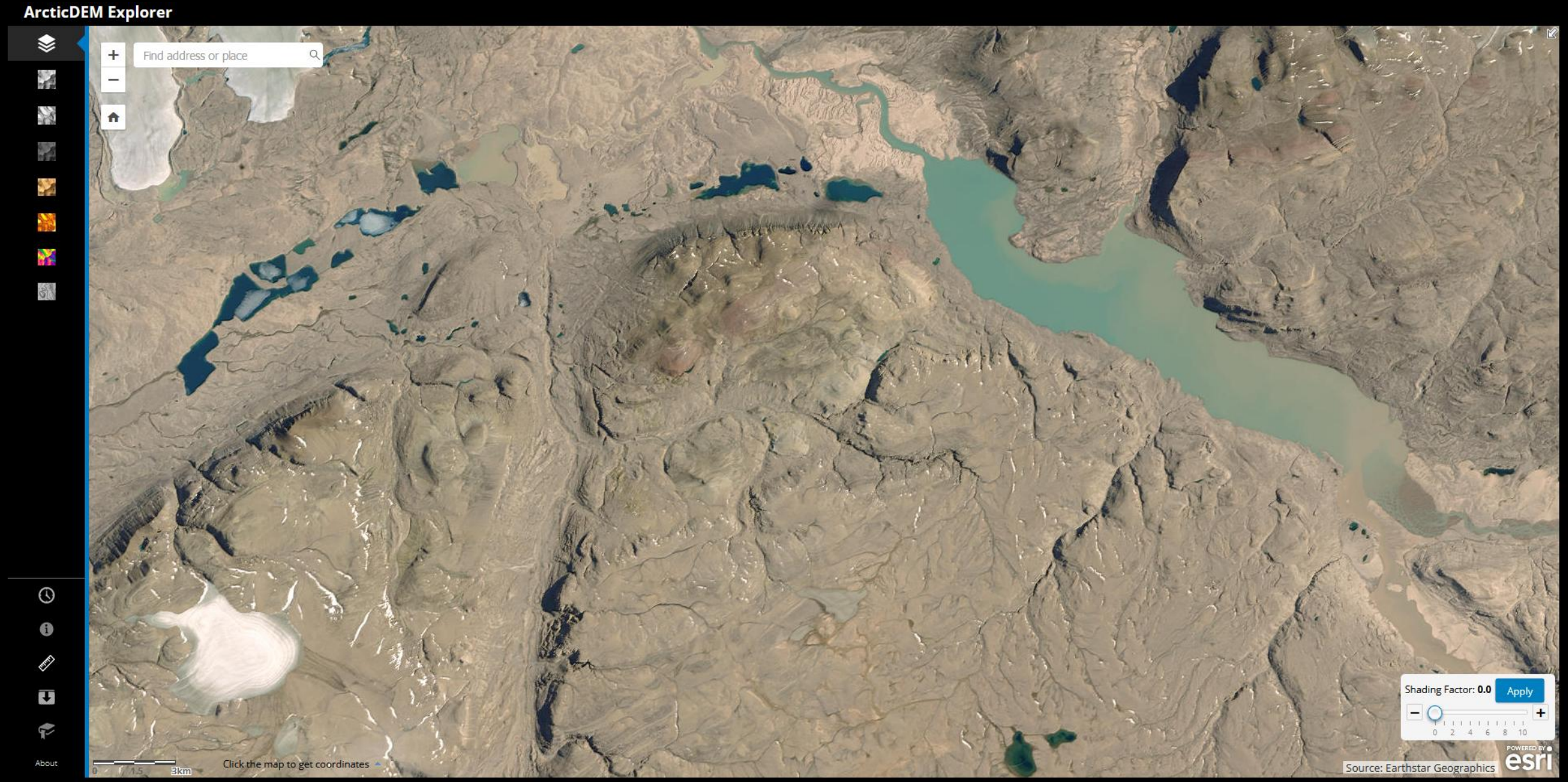


Melting ice sheet
- Global sea level rise
- Ocean circulation
- Positive feedbacks

Sea ice loss
- Ocean circulation
- Positive feedbacks

Arctic amplification
- Disruption to weather patterns

Permafrost thaw
- Positive feedbacks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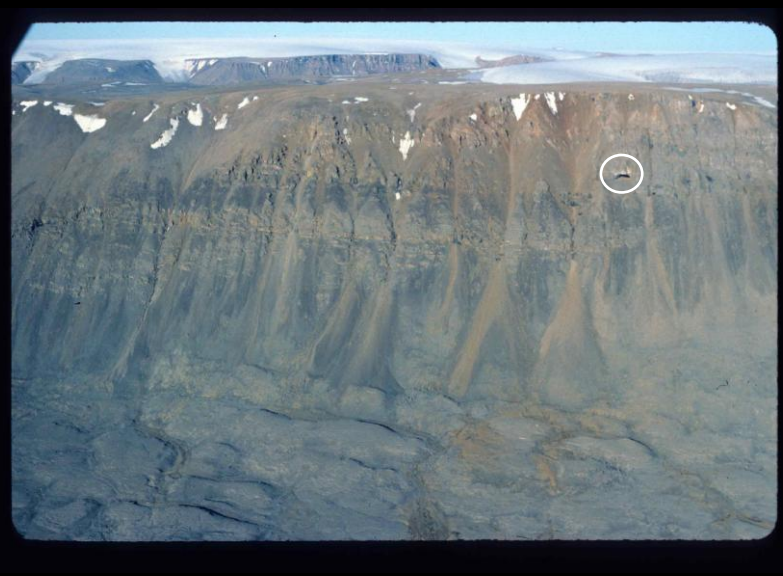

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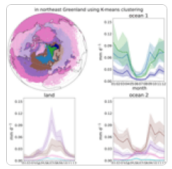
Research article | 14 Jan 2021

Lagrangian detection of precipitation moisture sources for an arid region in northeast Greenland: relations to the North Atlantic Oscillation, sea ice cover, and temporal trends from 1979 to 2017

Lilian Schuster, Fabien Maussion, Lukas Langhamer, and Gina E. Moseley



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Short summary

Precipitation and moisture sources over an arid region in northeast Greenland are investigated...

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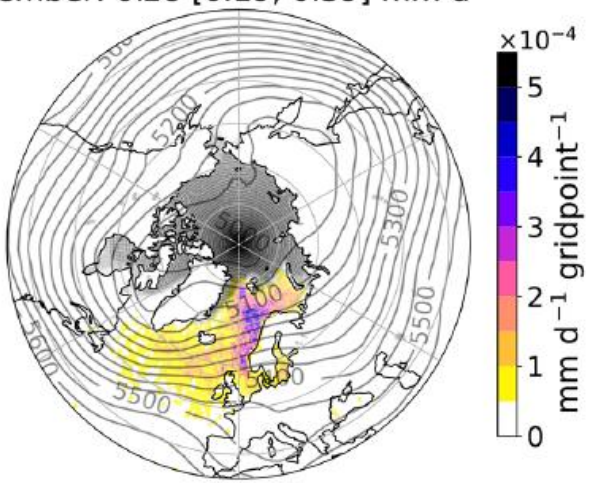
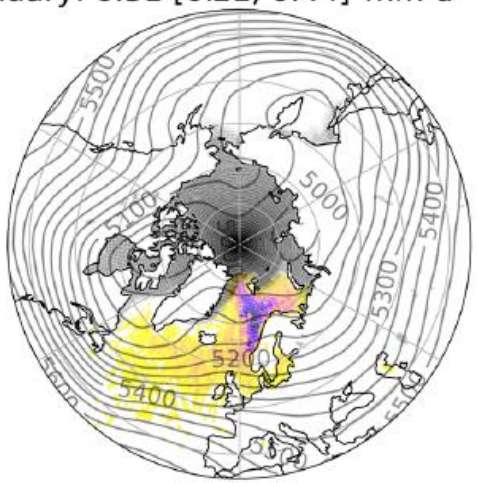
- Mean precipitation 207 mm/yr (192 to 224 mm/yr)
- 5 wettest days in a year produce 24% of the total annual precipitation
- 16 days produce 50% of the total annual precipitation
- Precipitation gradient between NE Greenland and SE Greenland
- Precipitation occurs throughout the year, but May and June are slightly drier whereas September is wettest

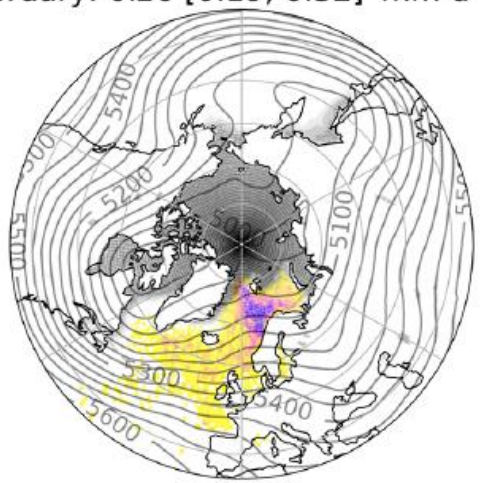
December: 0.28 [0.19, 0.39] mm d^{-1}



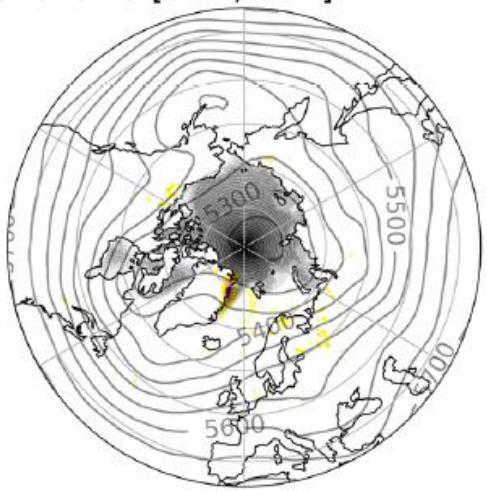
January: 0.31 [0.21, 0.44] mm d^{-1}



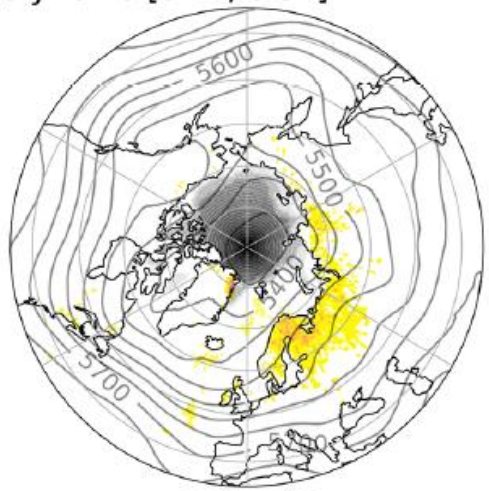
February: 0.26 [0.19, 0.32] mm d^{-1}



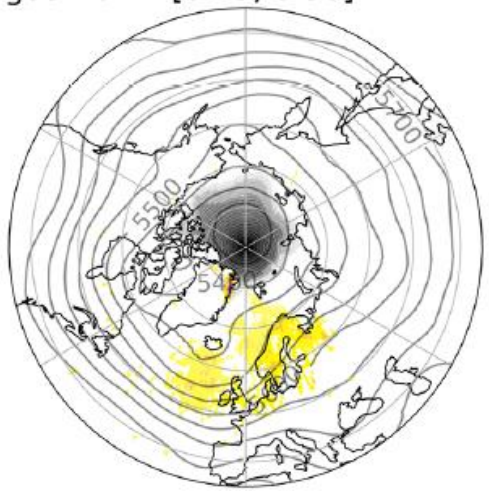
June: 0.19 [0.14, 0.24] mm d^{-1}



July: 0.26 [0.21, 0.32] mm d^{-1}



August: 0.24 [0.19, 0.30] mm d^{-1}



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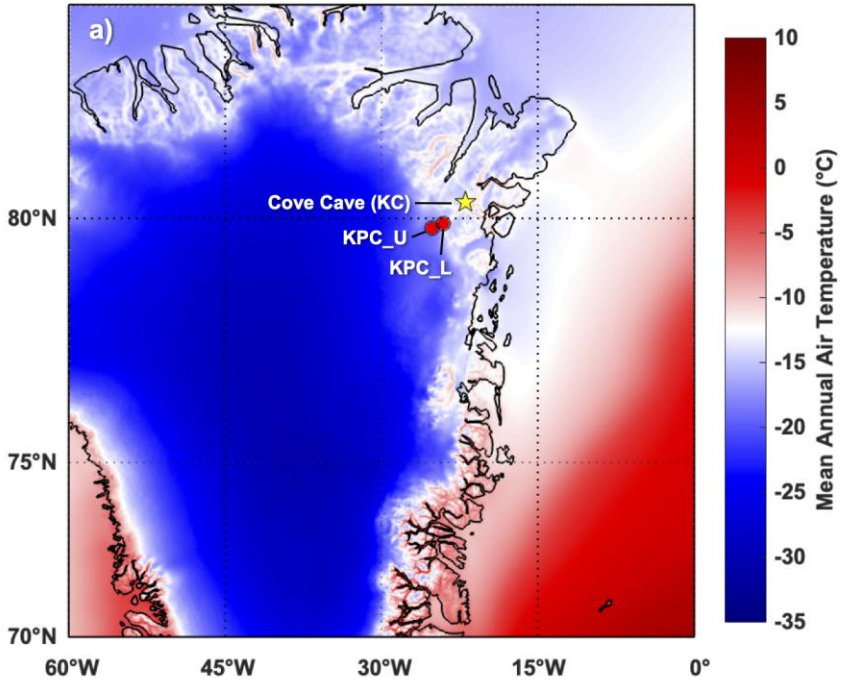
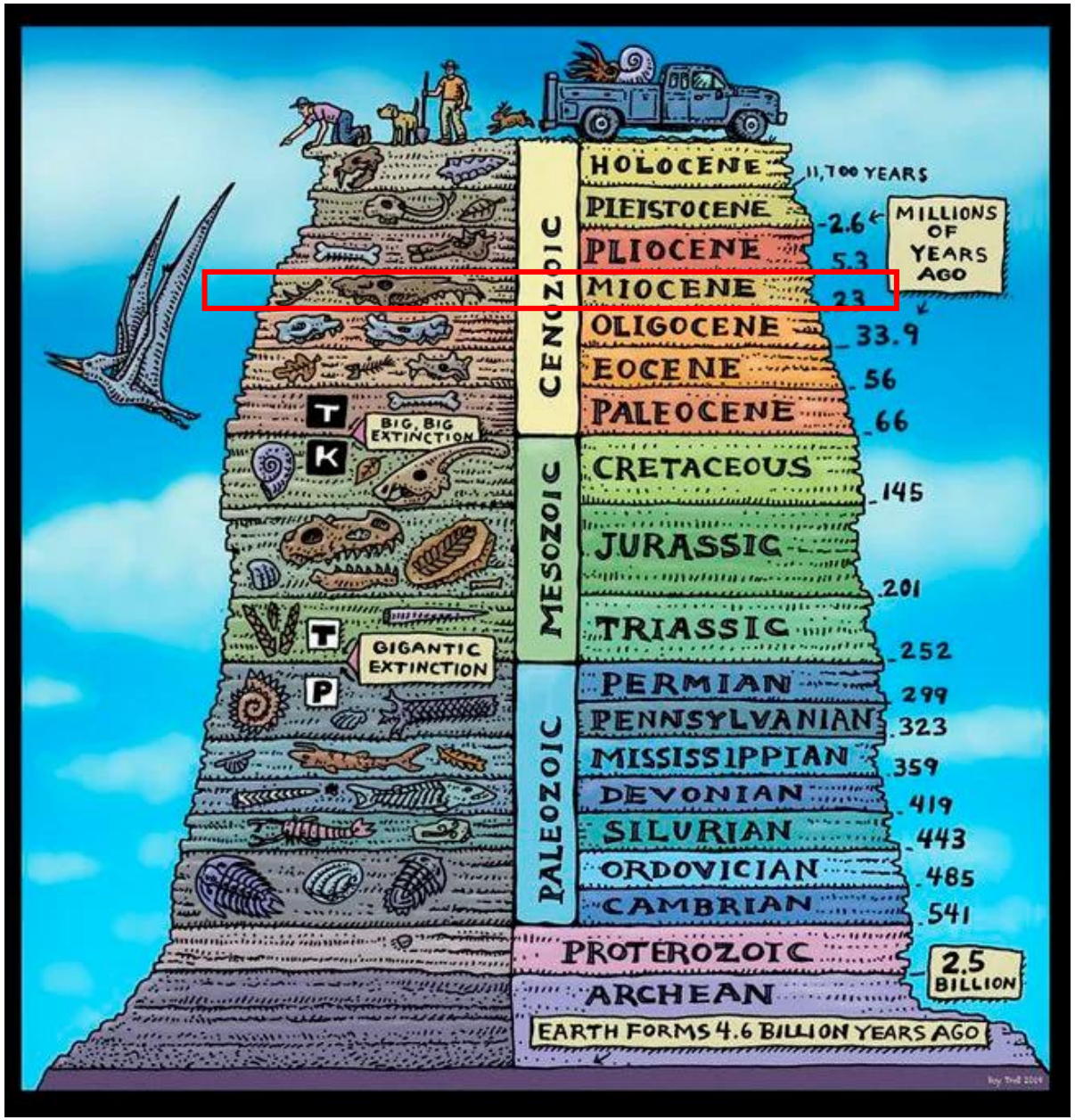


Modern environment

Modern environment

Modern environment



Miocene epoch (23.03–5.33 Ma)

CO_2 – 300 to 600 ppm

- Covers CO_2 levels already surpassed and near-future projections

Antarctic ice sheet already well established

Evidence of glaciation in the Northern Hemisphere

1st apes evolved

- Later first Hominins

Plants and animals evolved towards modern species

Similar paleogeography to today

Field Site- Eqik Qaarusussuaq

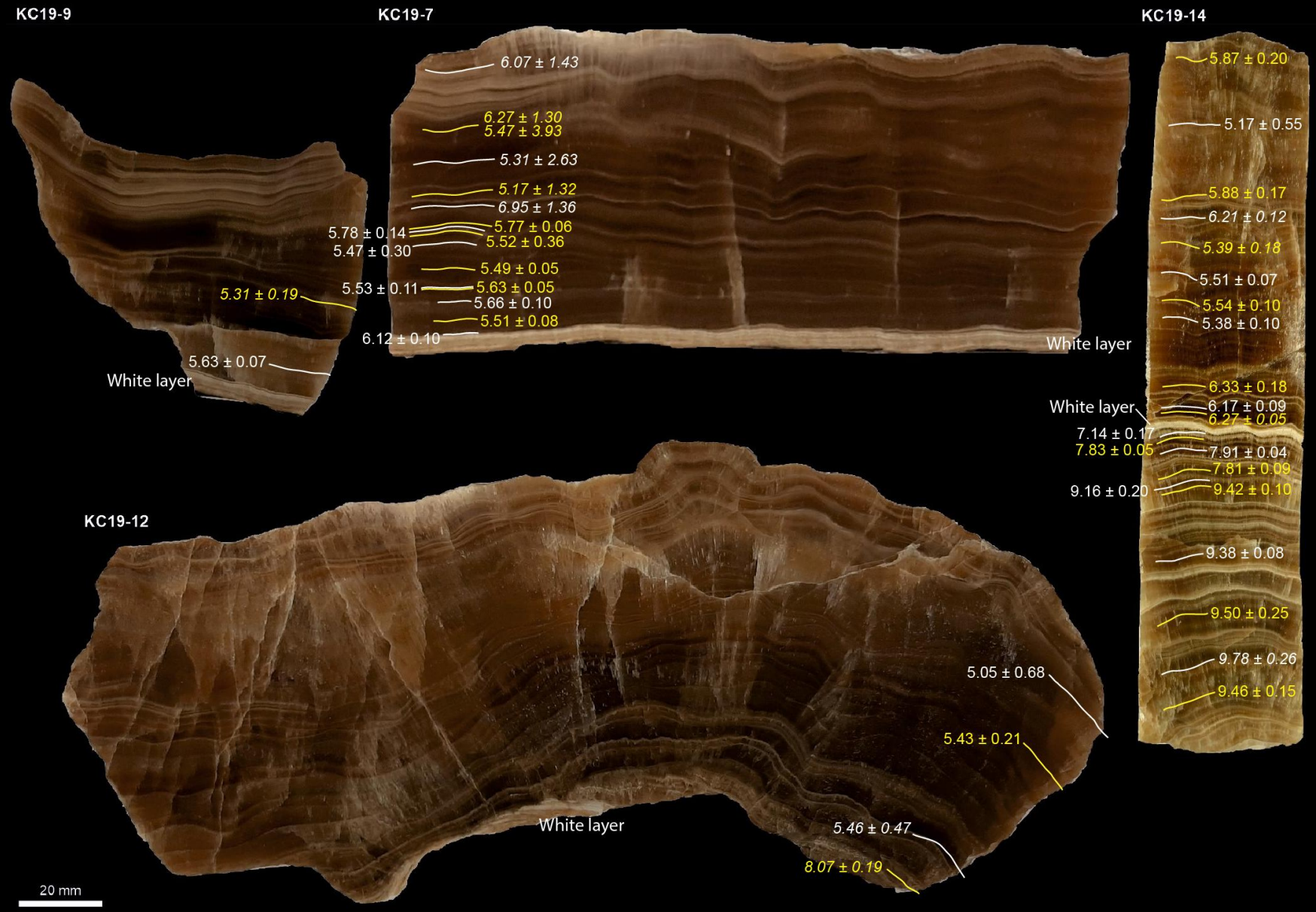
Field Site- Eqik Qaarusussuaq

Field Site- Eqik Qaarusussuaq

Field Site- Eqik Qaarusussuaq

Field Site- Eqik Qaarusussuaq

North Greenland Speleothem Growth during the Miocene



- Speleothem growth in North Greenland between 9.5 to 7.8, 6.3 to 6.1, and 5.6 to 5.3 million years ago

- Mean annual air temperature >14 °C higher than today

- CO_2 threshold of 310 +96/-73 ppm
  - Today 425 ppm

- Two growth hiatuses between 7.8 to 6.3, and 6.1 to 5.6 million years ago
  - CO_2 decline and drop in sea surface temperature
  - Evidence for first ephemeral glaciations in North Greenland

- Limited evidence for speleothem growth after 5.3 Ma during the Pliocene and Quaternary

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GREENLAND CAVES PROJECT

Thank You!