Learning Statistics through Ice Core Isotopes and Polar Research

Penny Rowe[1], Lea Fortmann[2], James Bernhard[2], Jacob Price[2], Timothy Chalberg[3], Steven Neshyba[2], John P. Woodward[2], Anna Van Boven[2], Danielle Dolan[2]

[1]NorthWest Research Associates (NWRA), [2]University of Puget Sound, [3]Science And Math Institute (SAMi)

Earth Educators Rendezvous
Online, July 14, 2021

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Since 1984

PENGUIN

Polar ENgagement through GUided INquiry

- The richness and interdisciplinary nature of polar research and the importance of polar regions for climate change suggests a potential to enhance student learning.
- Bring polar research into undergraduate courses on a variety of topics.
- Give students hands-on experience with real data.
- Give students experience with a computational tool.

PENGUIN

Polar ENgagement through GUided INquiry

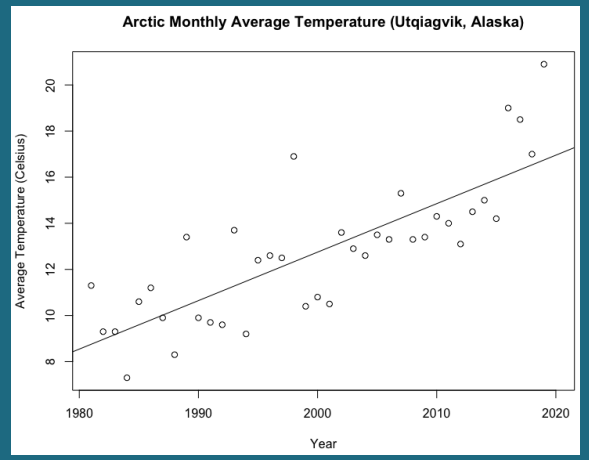
- Survey results indicate that students and instructors feel that they learned from the modules.
- New goal: test student knowledge gains.
- Mechanism: New module for statistics - many students take freshman-level statistics, including non-STEM students.
- Develop module and survey that tests student knowledge.

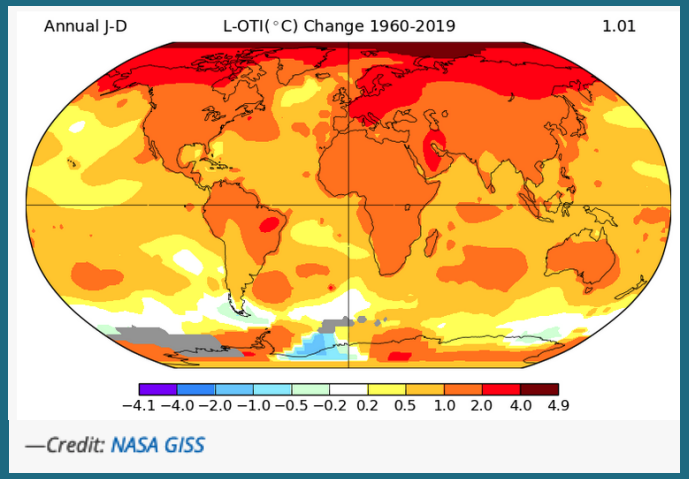
Statistics

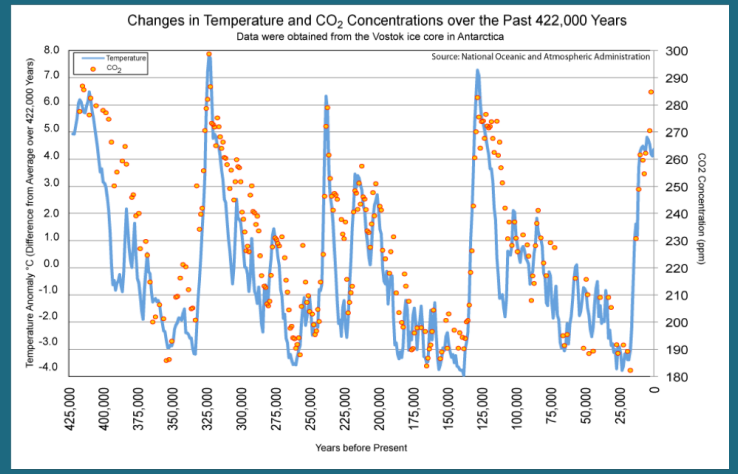
- Scatterplots
- Interpreting coefficients from linear regression
- Making predictions
- Correlation

Polar research

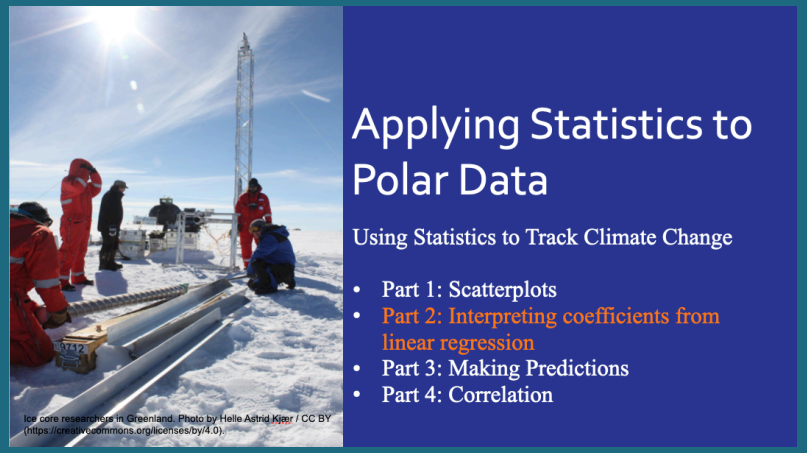
- Polar amplification
- Tracking geologic temperature through ice cores
- Temperature vs. CO2







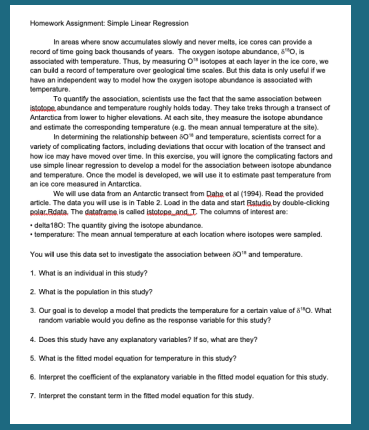
What's in the module?



Presentations & discussions

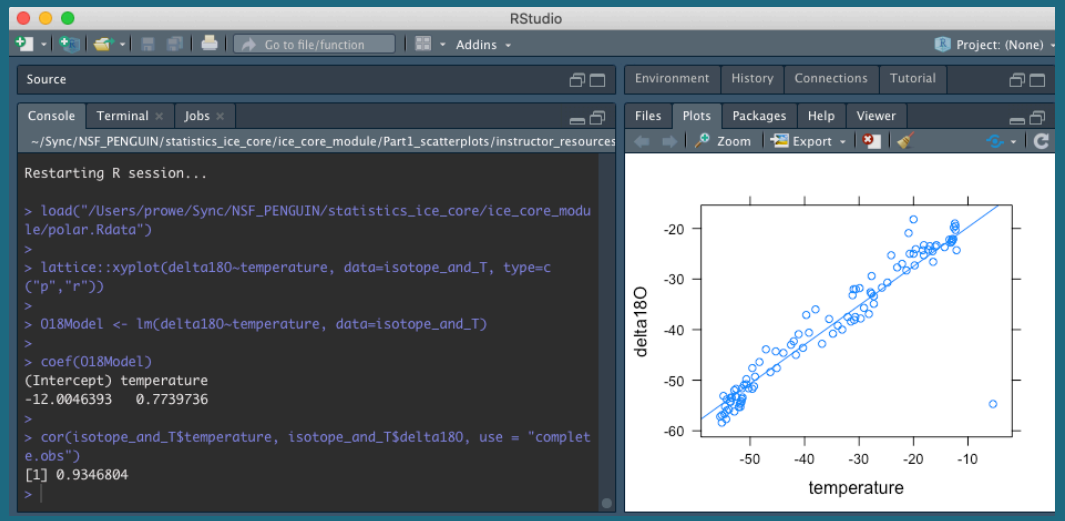

Distribution of stable isotopes in surface snow along the route of the 1990 International Trans-Antarctica Expedition

reading assignment

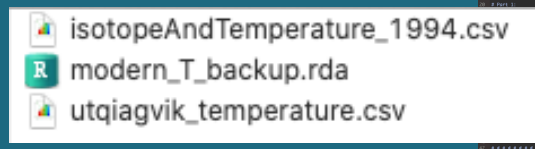

Homework Assignment: Simple Linear Regression

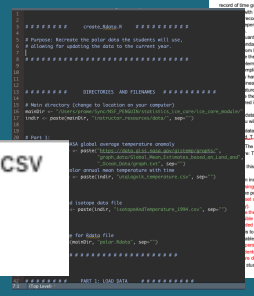
homework assignments

polar data



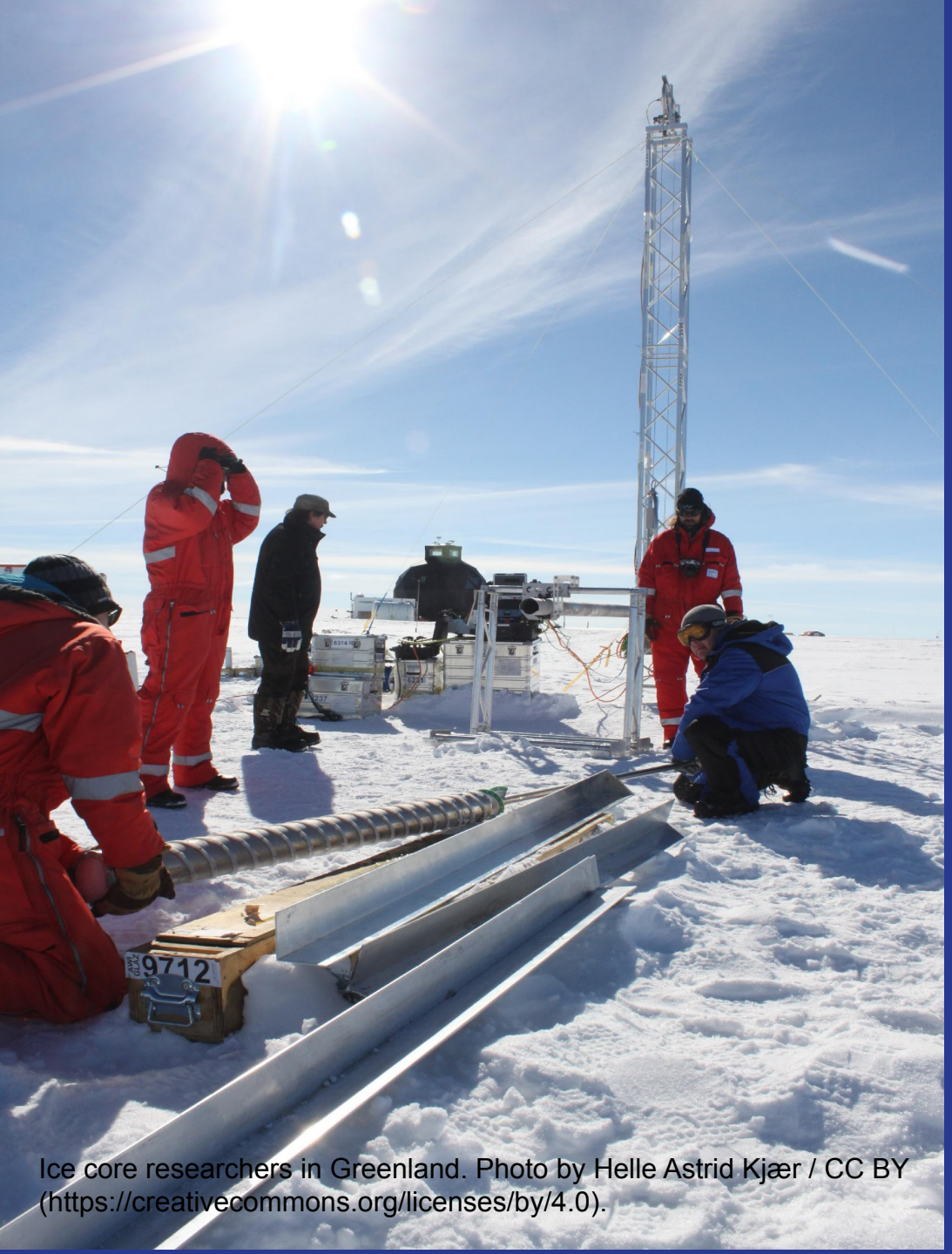
In-class activities





instructor guides, keys, R scripts and backup data

A look at the module

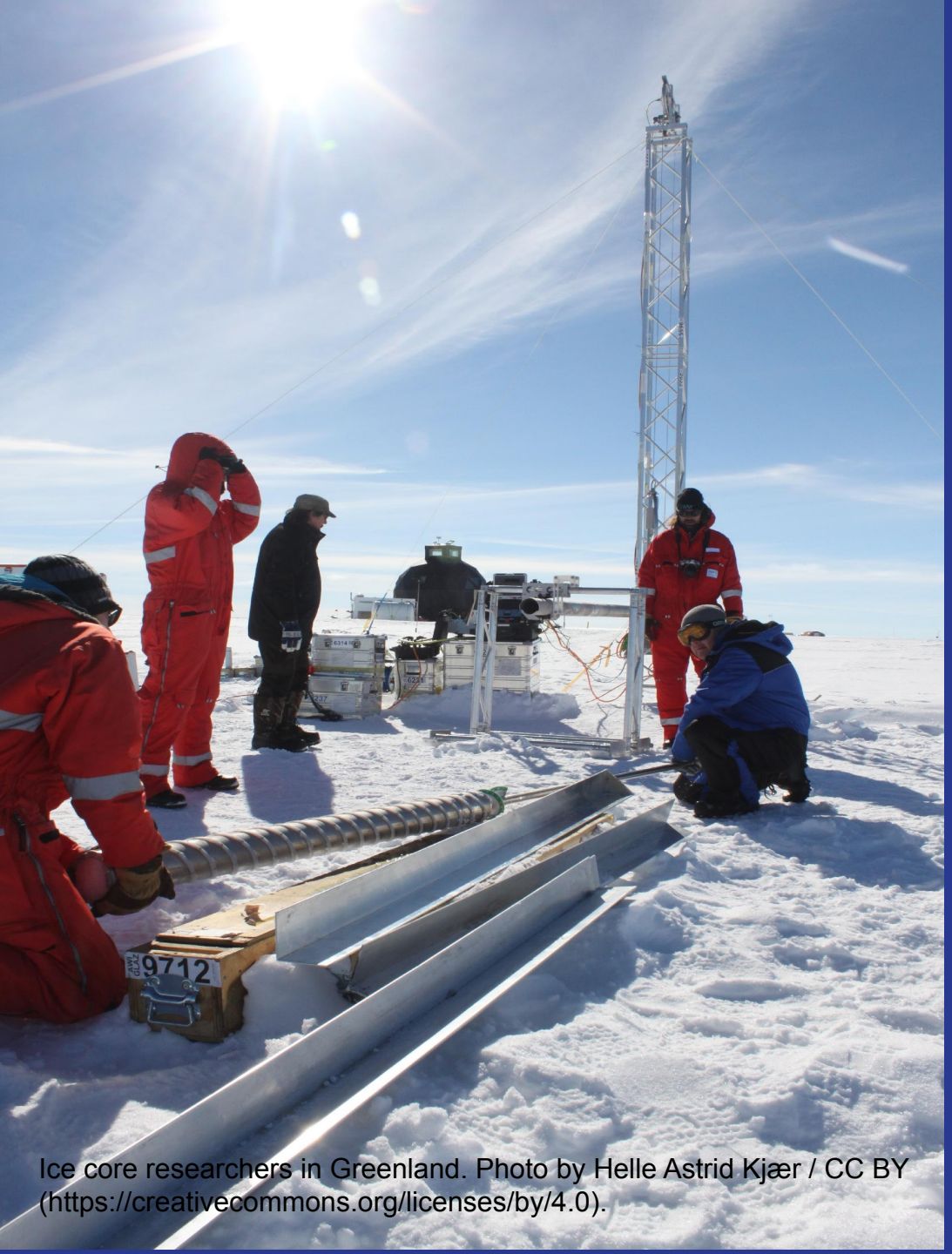


Ice core researchers in Greenland. Photo by Helle Astrid Kjær / CC BY (https://creativecommons.org/licenses/by/4.0).

Applying Statistics to Polar Data

Using Statistics to Track Climate Change

- Part 1: Scatterplots
- Part 2: Interpreting coefficients from linear regression
- Part 3: Making Predictions
- Part 4: Correlation



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What you might think stats is like …

- You get some data.
- You perform linear regression on it.
- Hopefully your answers are right.

What it's really like …

- What's the question? Why should we care about it?
- What data do I need?
- If the data cannot be collected, what useful data *can* be collected?
- How are those data associated with the data I need?
- How/where do I collect the data?
- How do I identify and handle errors and outliers?
- To what extent is this analysis valid?

Building a Mental Model:

How can we track temperatures in the distance past?

What it's really like …

- What's the question? Why should I care about it?
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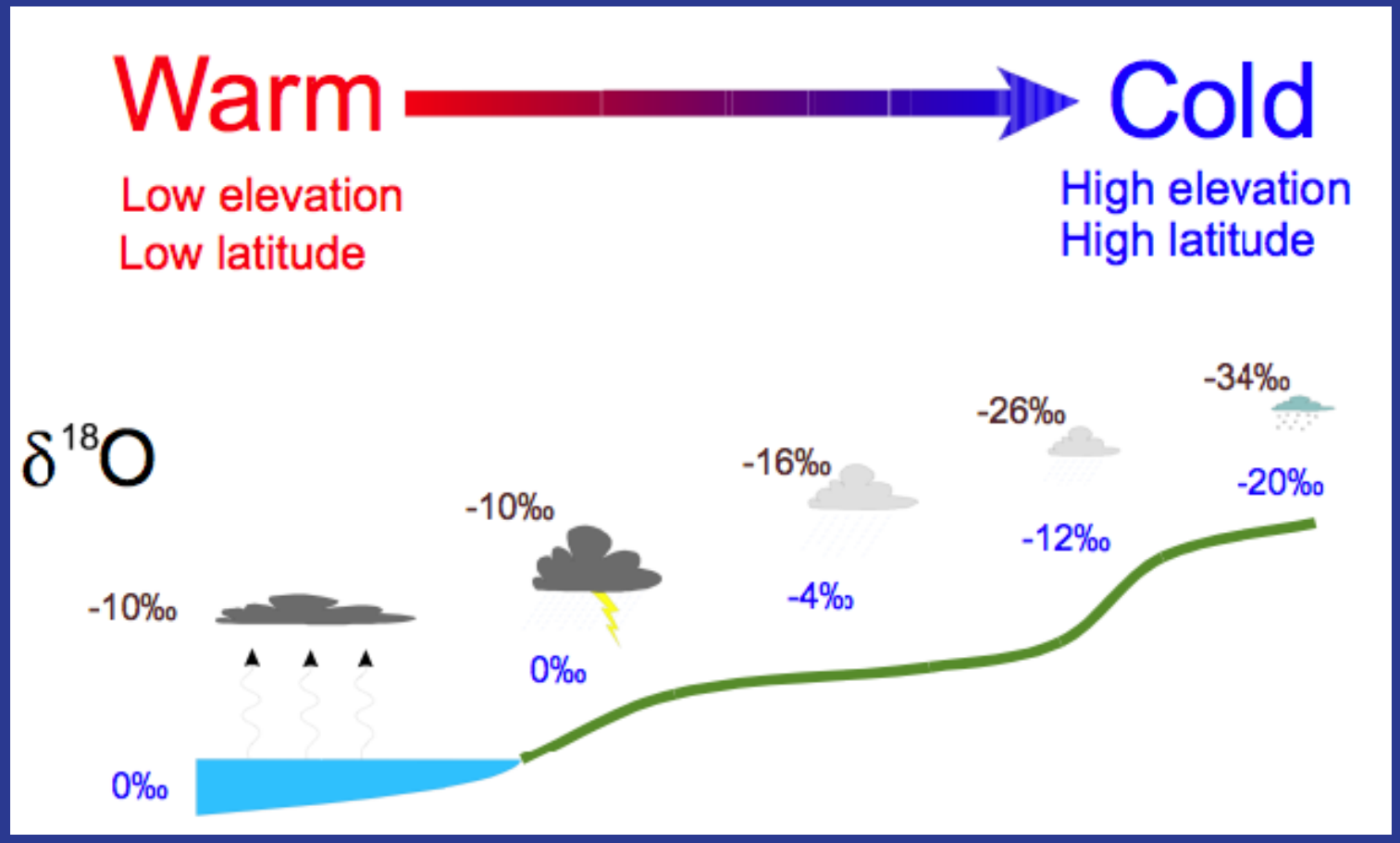
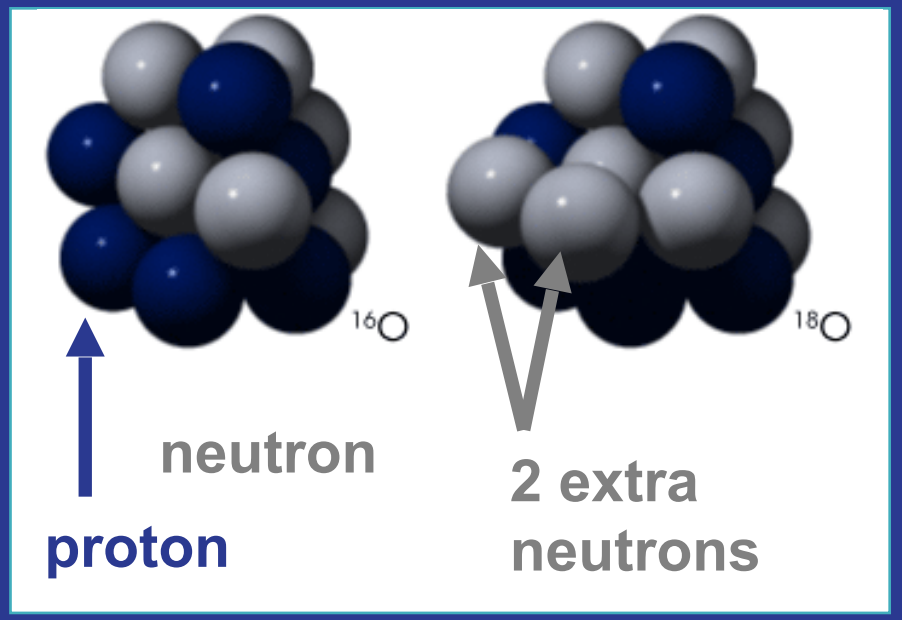
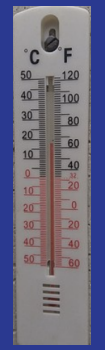
Building a Mental Model:

$\delta^{18}O$ in snow is associated with temperature

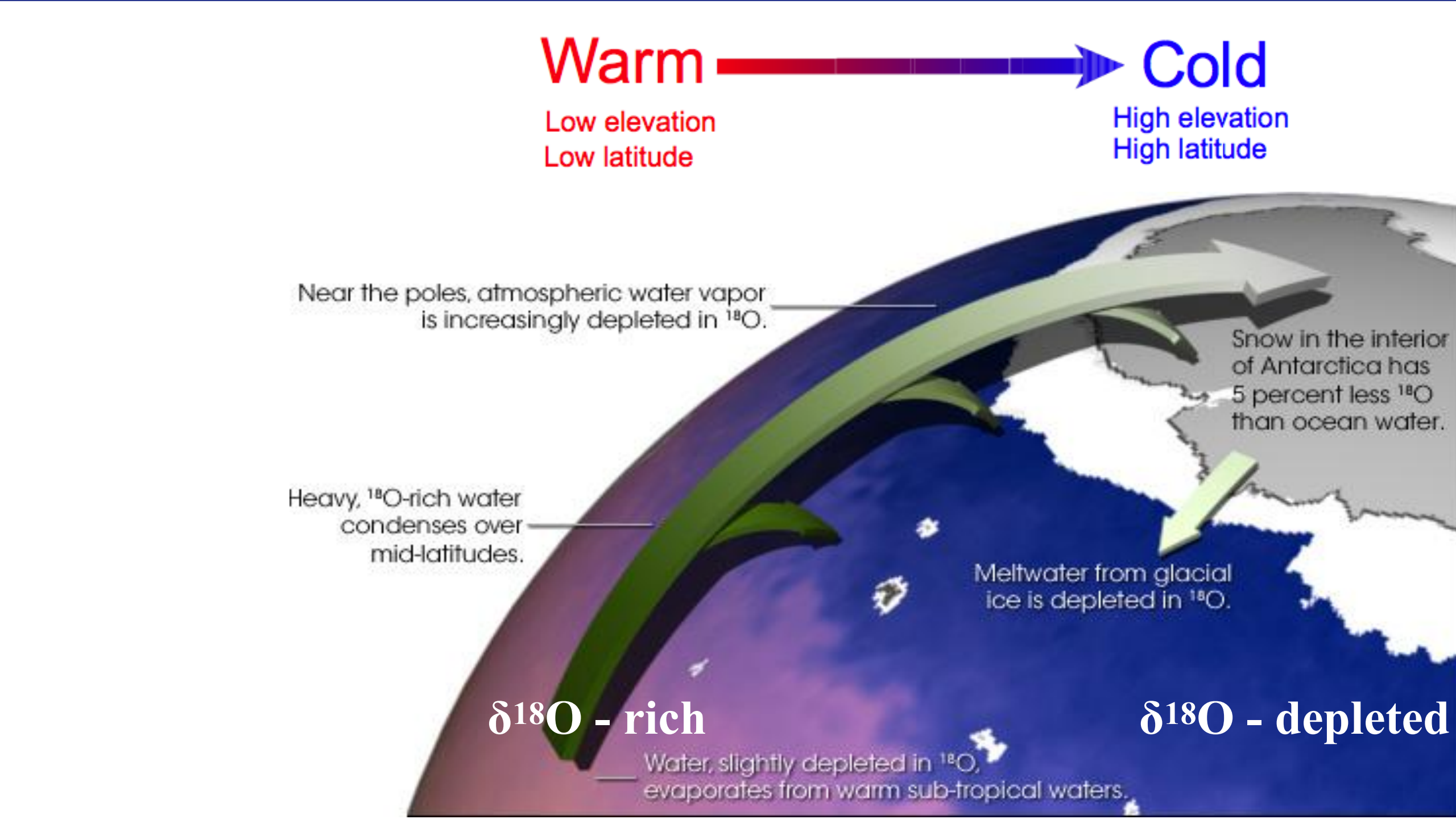




$\delta^{18}O$ can be used as a thermometer



Left image courtesy of Spruce W. Schoenemann, right top image courtesy Robert Simmon, NASA.

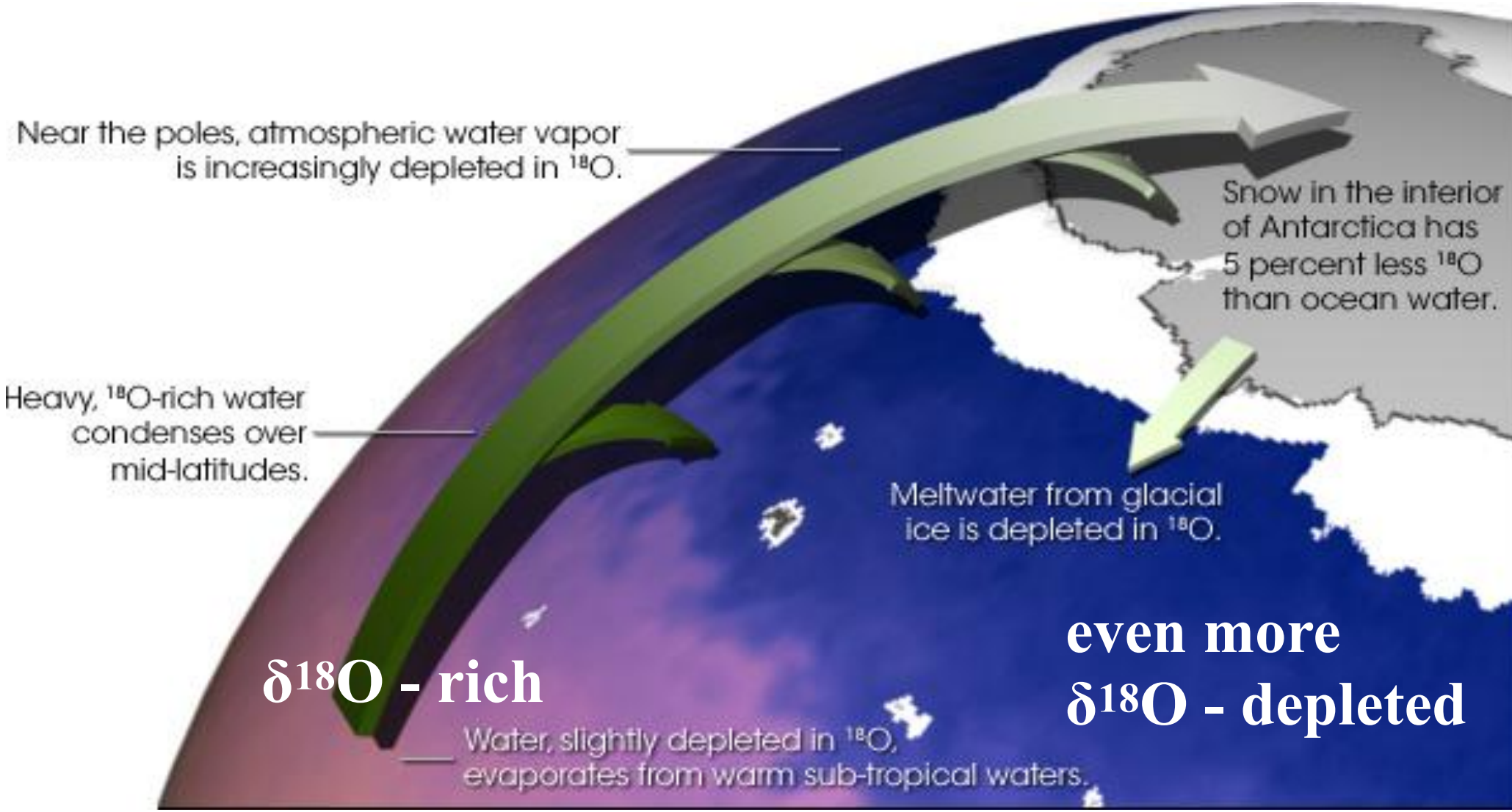

Warm
Cold
Low elevation
Low latitude
High elevation
High latitude
Near the poles, atmospheric water vapor is increasingly depleted in ^{18}O.
Snow in the interior of Antarctica has 5 percent less ^{18}O than ocean water.
Heavy, ^{18}O-rich water condenses over mid-latitudes.
Meltwater from glacial ice is depleted in ^{18}O.
$\delta^{18}O$ - rich
$\delta^{18}O$ - depleted
Water, slightly depleted in ^{18}O, evaporates from warm sub-tropical waters.

Ice Age

Warm → Cold → Colder

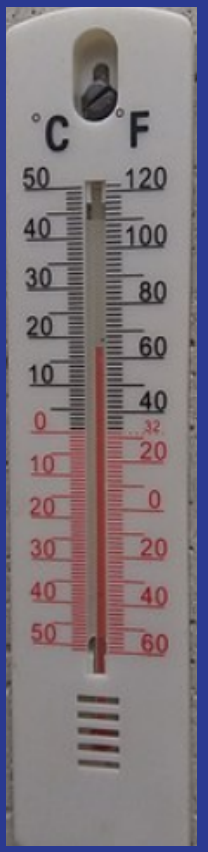
Low elevation
Low latitude

High elevation
High latitude



Tracking past temperatures

- What data do we need?
  Temperature over the geologic record.
- If the data cannot be collected, what useful data *can* be collected?
- How/where do I collect the data?
- How are those data associated with the data I need?



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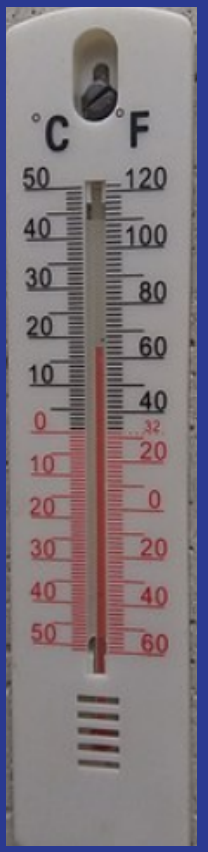
Tracking past temperatures

- What data do we need?
  Temperature over the geologic record.
- If the data cannot be collected, what useful data *can* be collected?
  Isotopes are associated with past temperature.
- How/where do I collect the data?
  Ice cores from polar regions.
- How are those data associated with the data I need?



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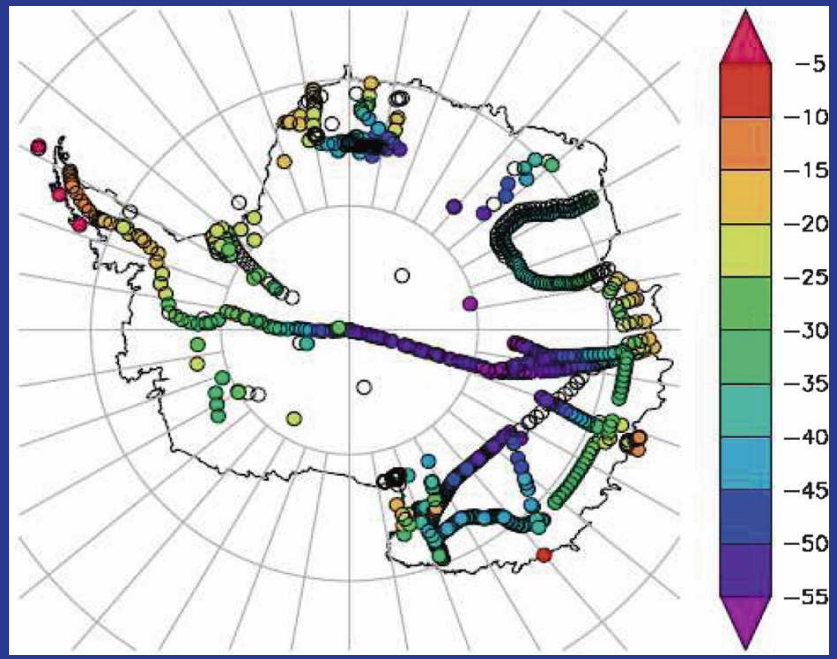

Image courtesy of Spruce W. Schoenemann

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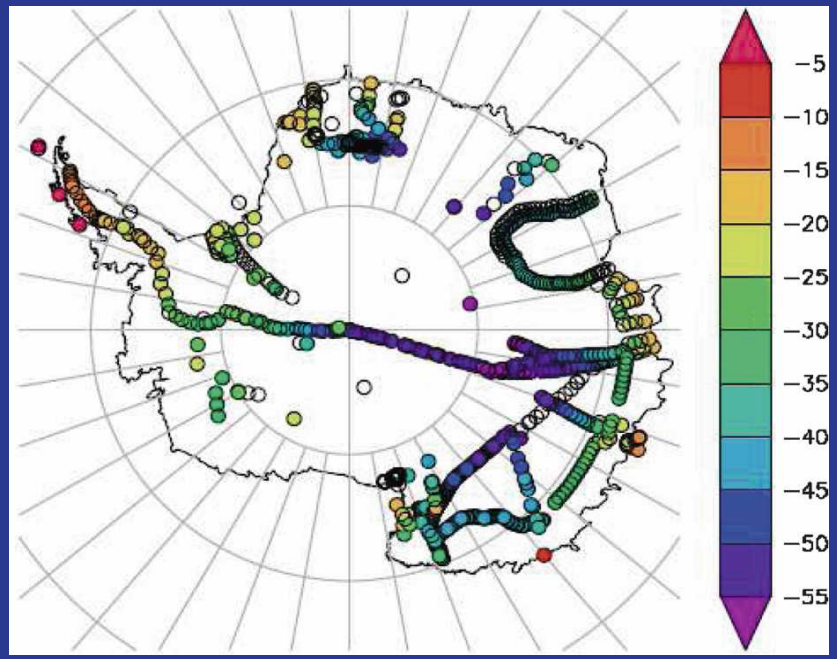
  Ice cores from polar regions.
- How are those data associated with the data I need?
  Determine from measurements of isotopes and temperature over an Antarctic transect.



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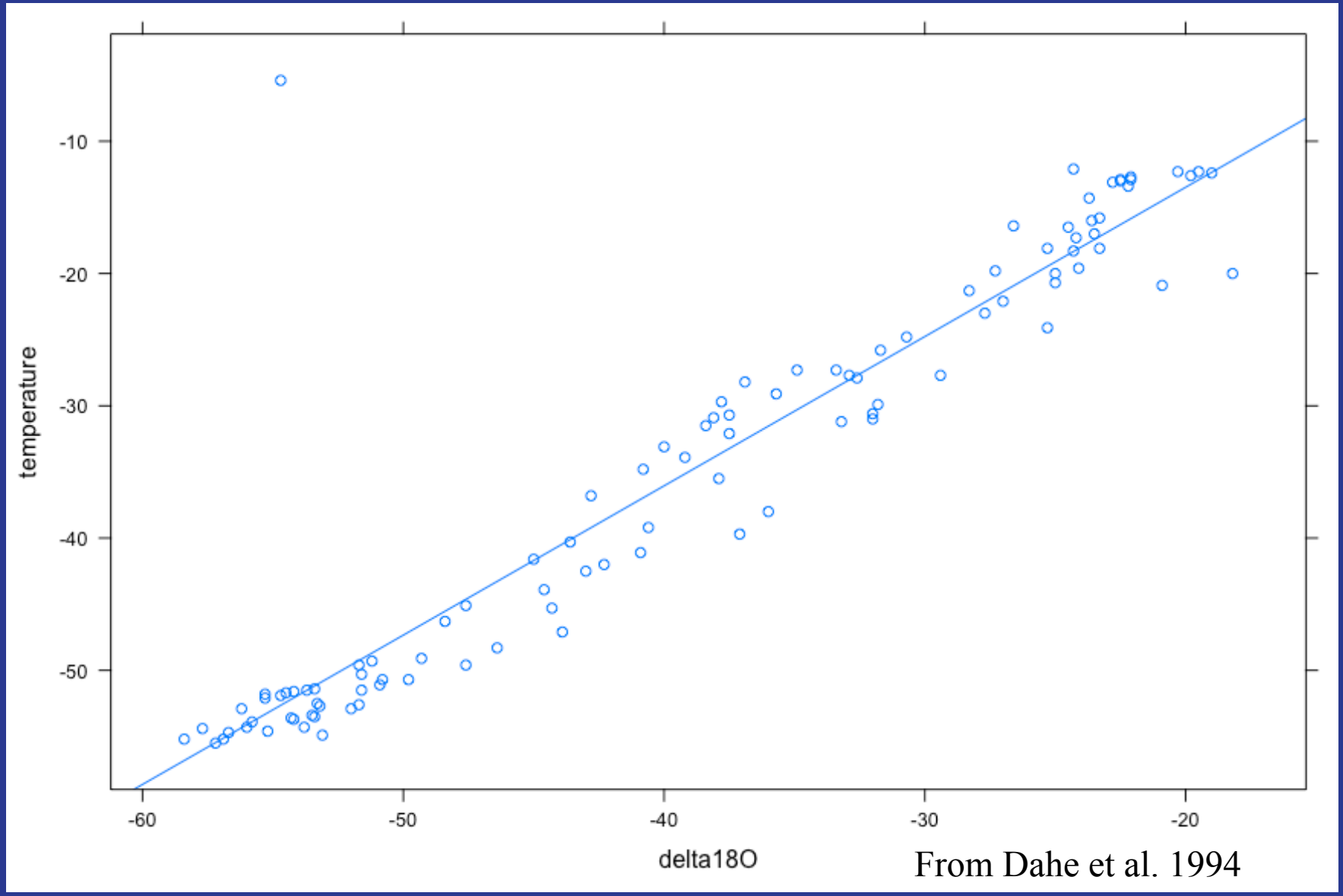
Interpreting Coefficients of Linear Regression



From Dahe et al. 1994

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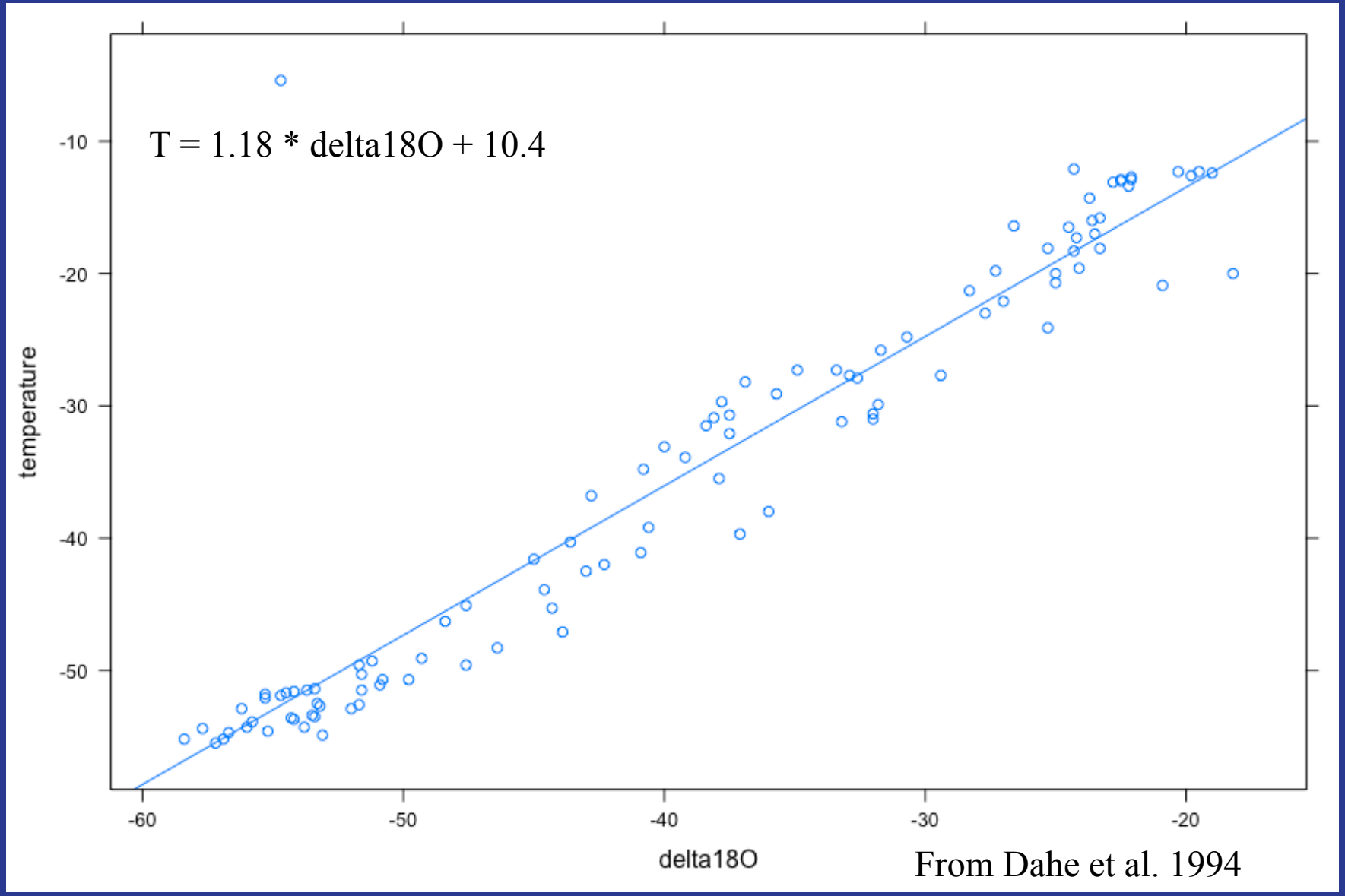

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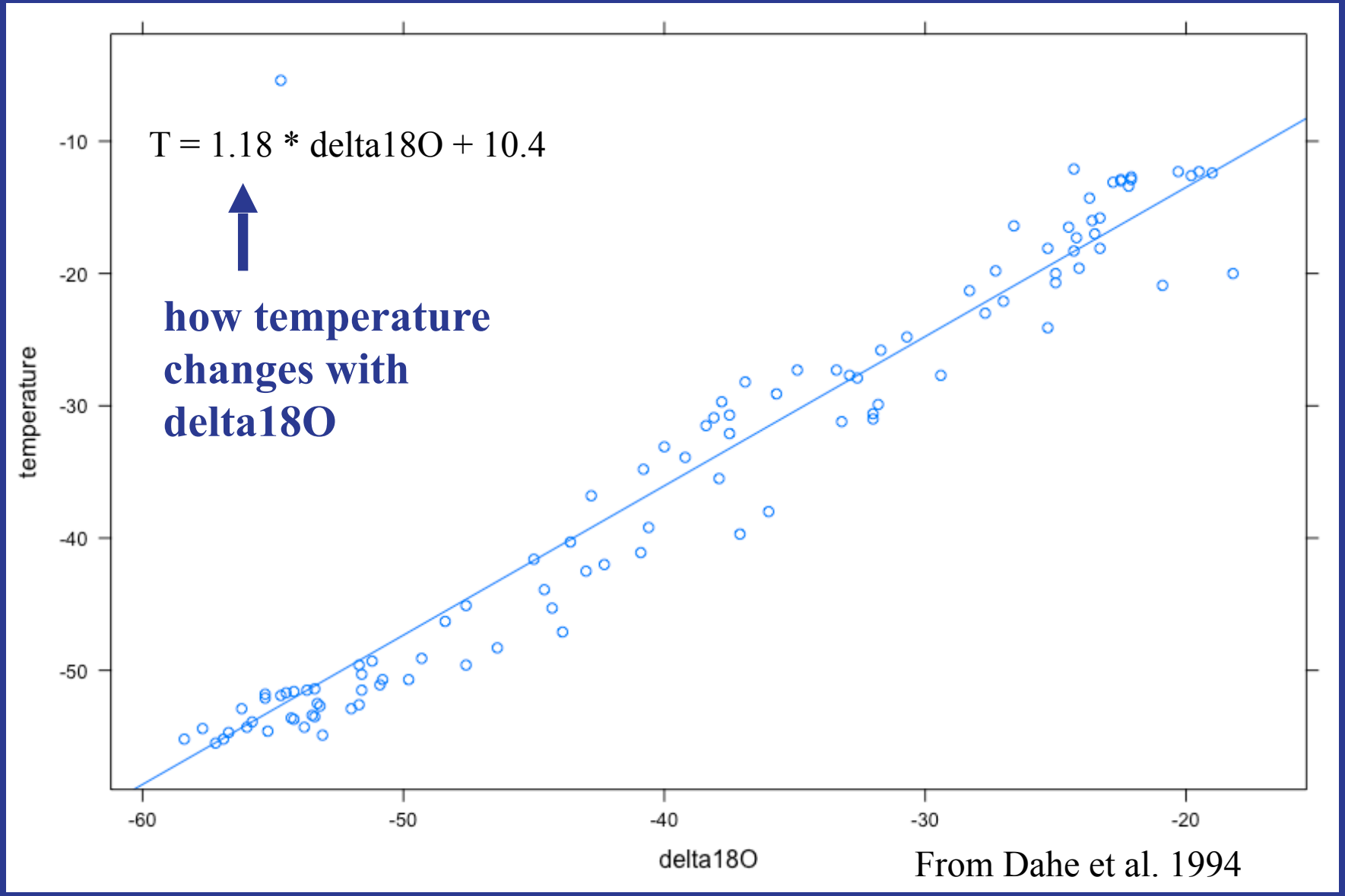

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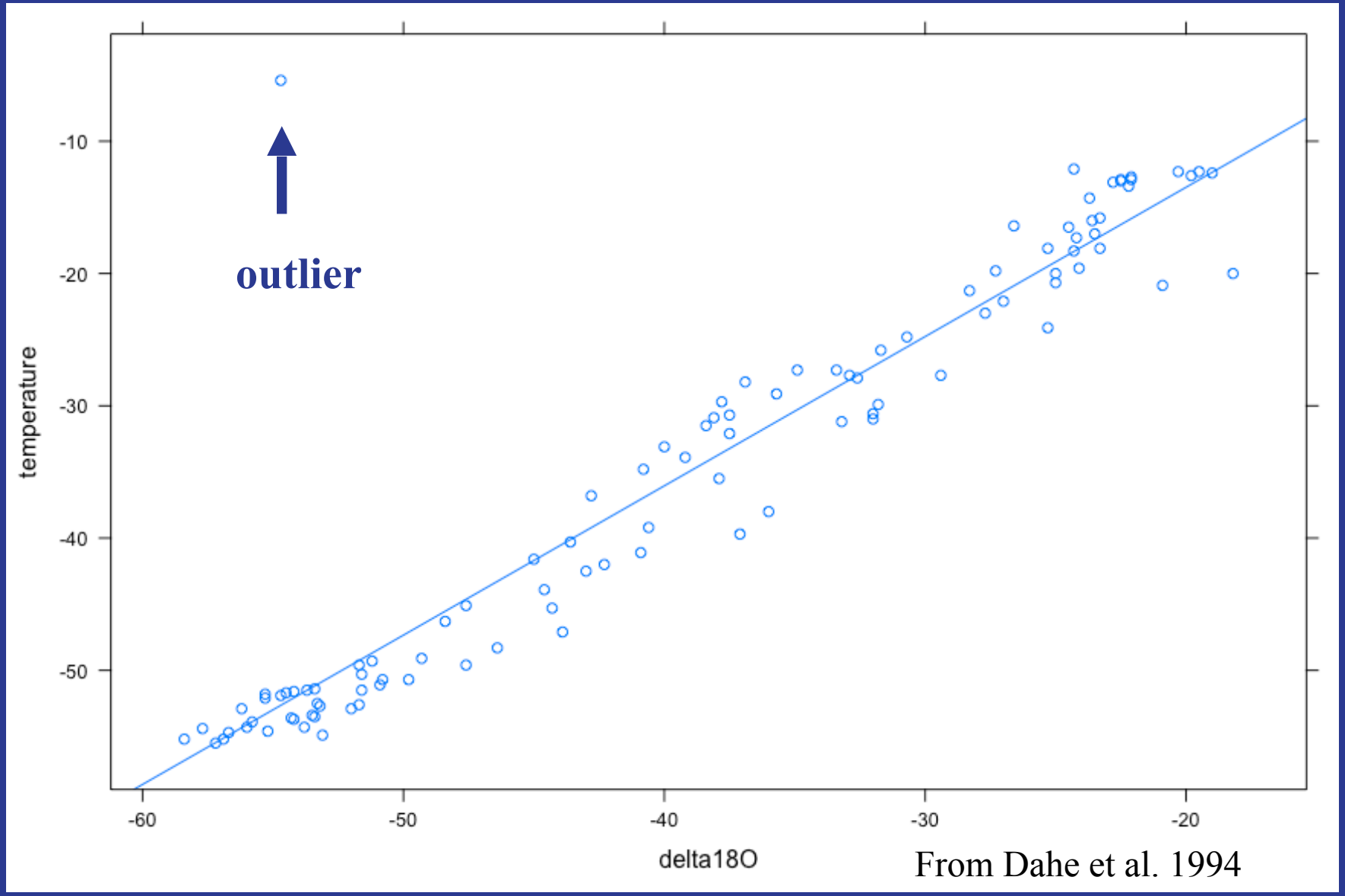

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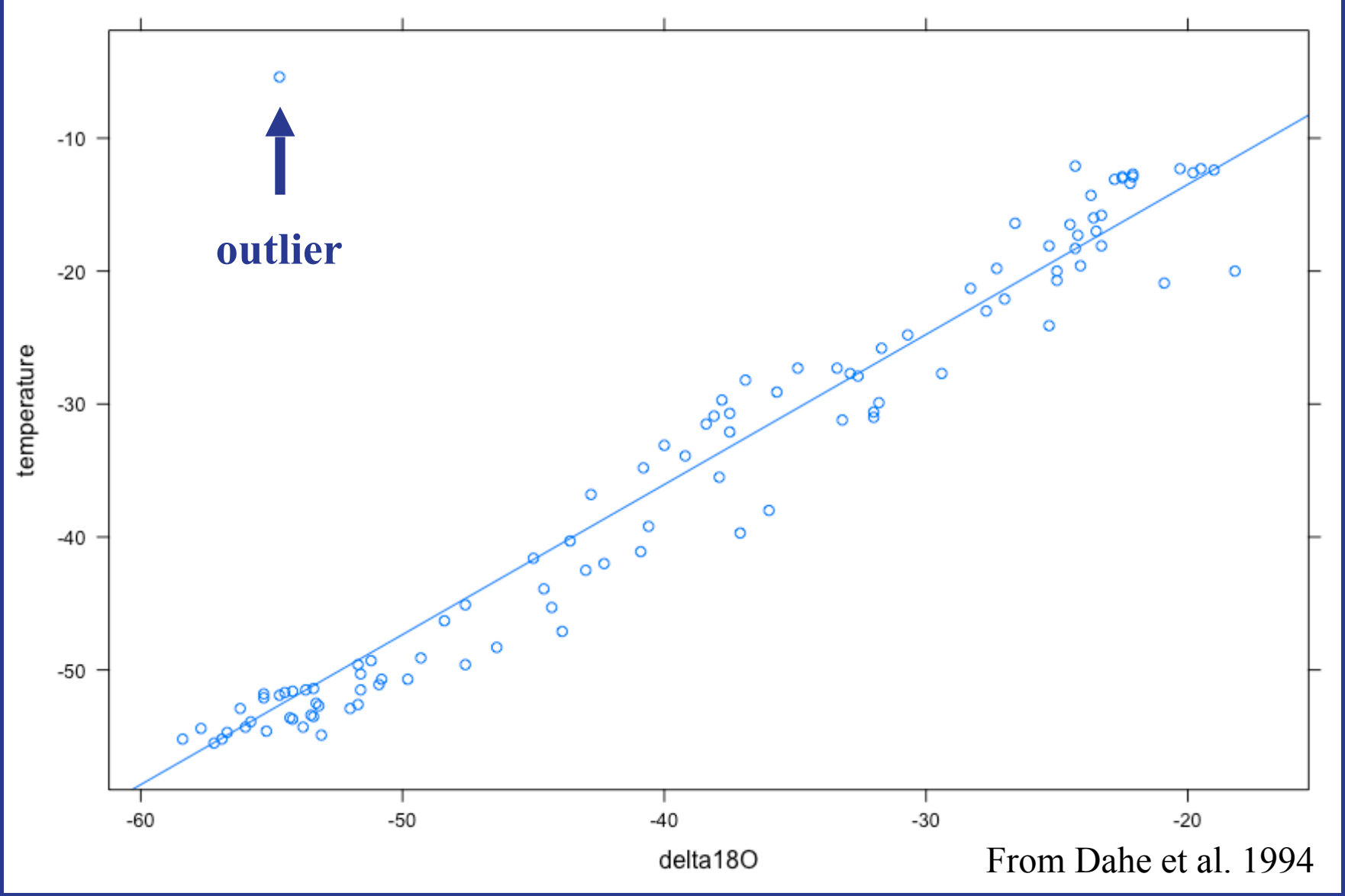
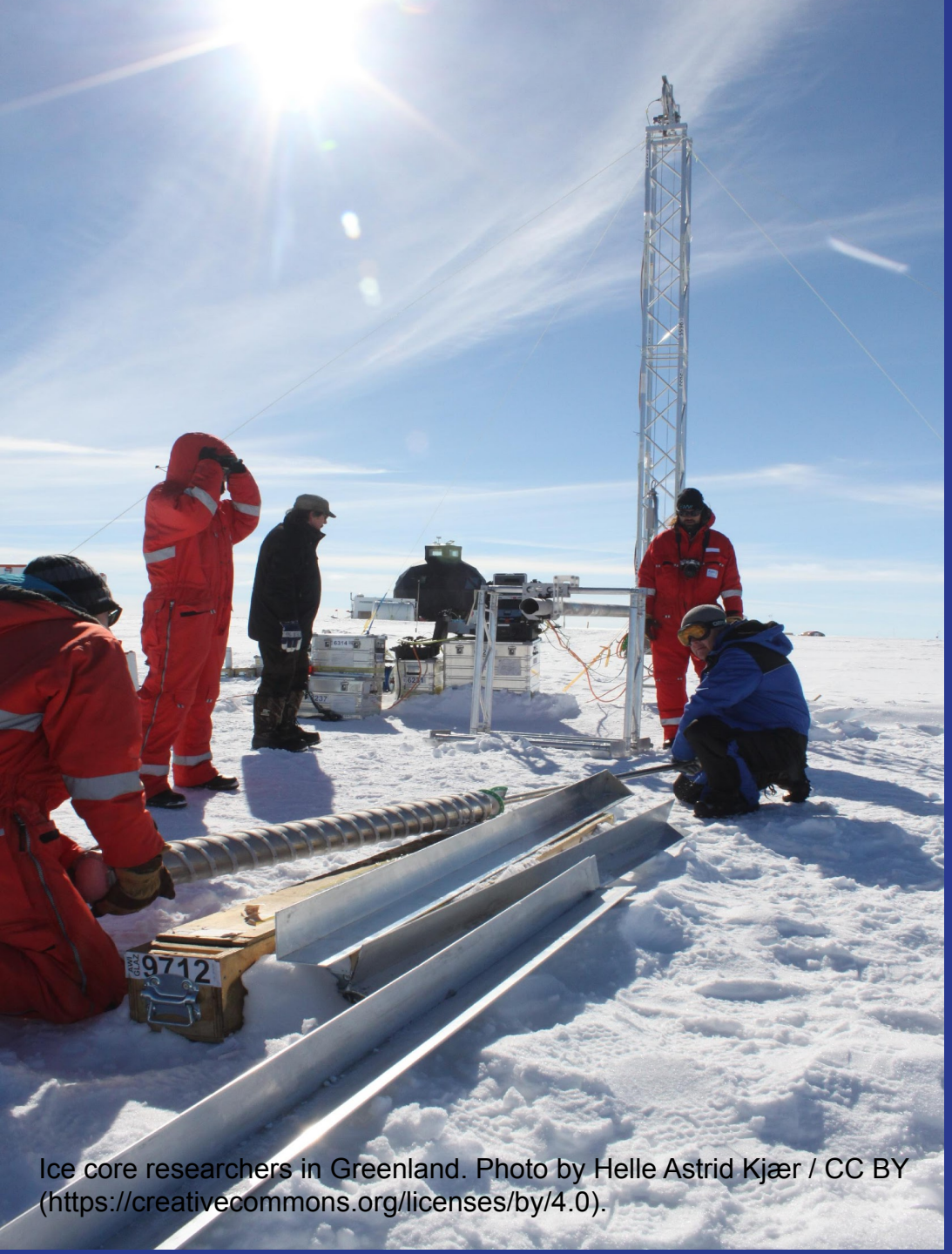


From Dahe et al. 1994

The students can look back at the journal article and see that this outlier is due to a typo in the table of results.



Ice core researchers in Greenland. Photo by Helle Astrid Kjær / CC BY (https://creativecommons.org/licenses/by/4.0).

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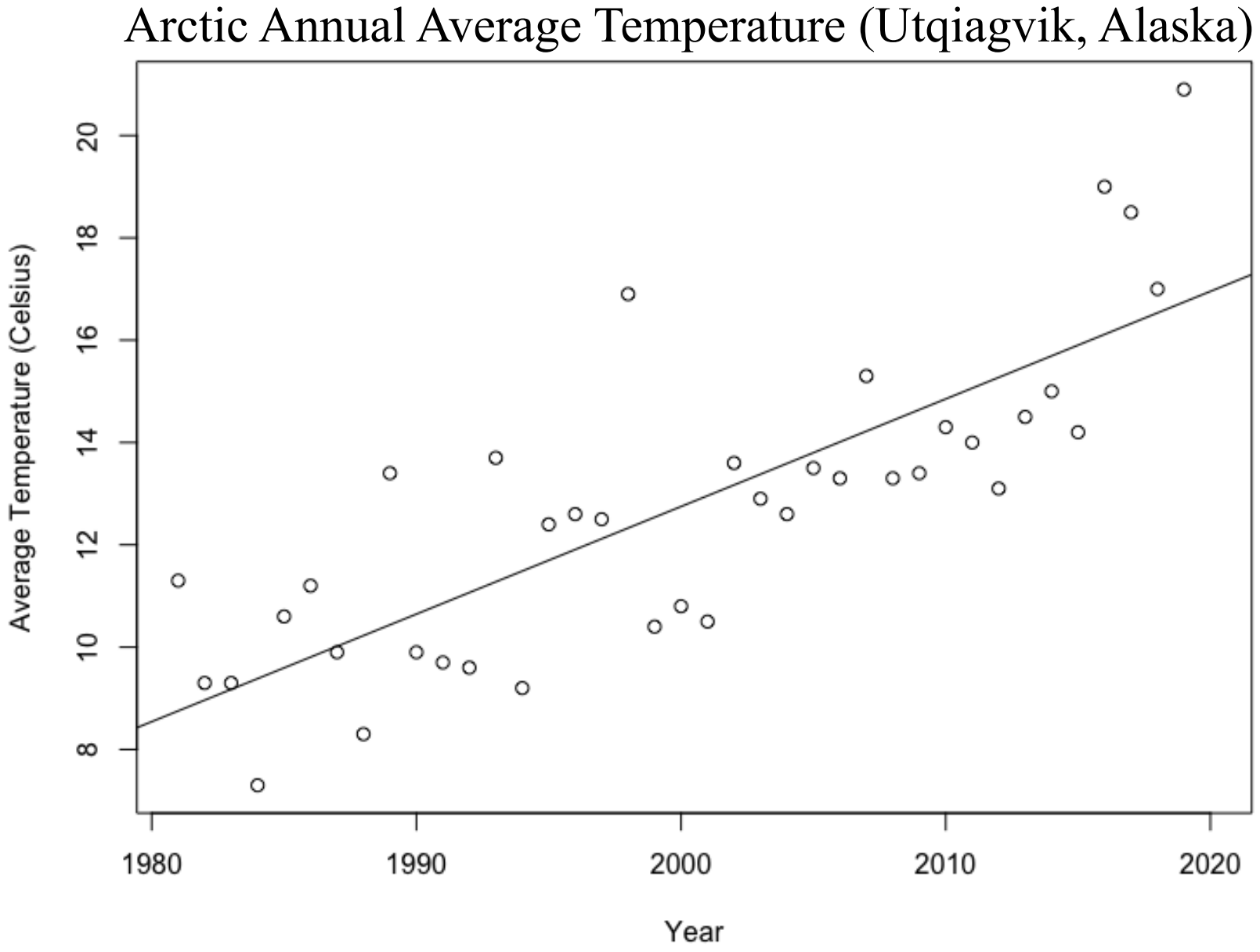


For this scatterplot, what are the:

- explanatory and response variables?
- form, association, and strength of association?
- outliers, if any?

Predict the average temperature in 1900.

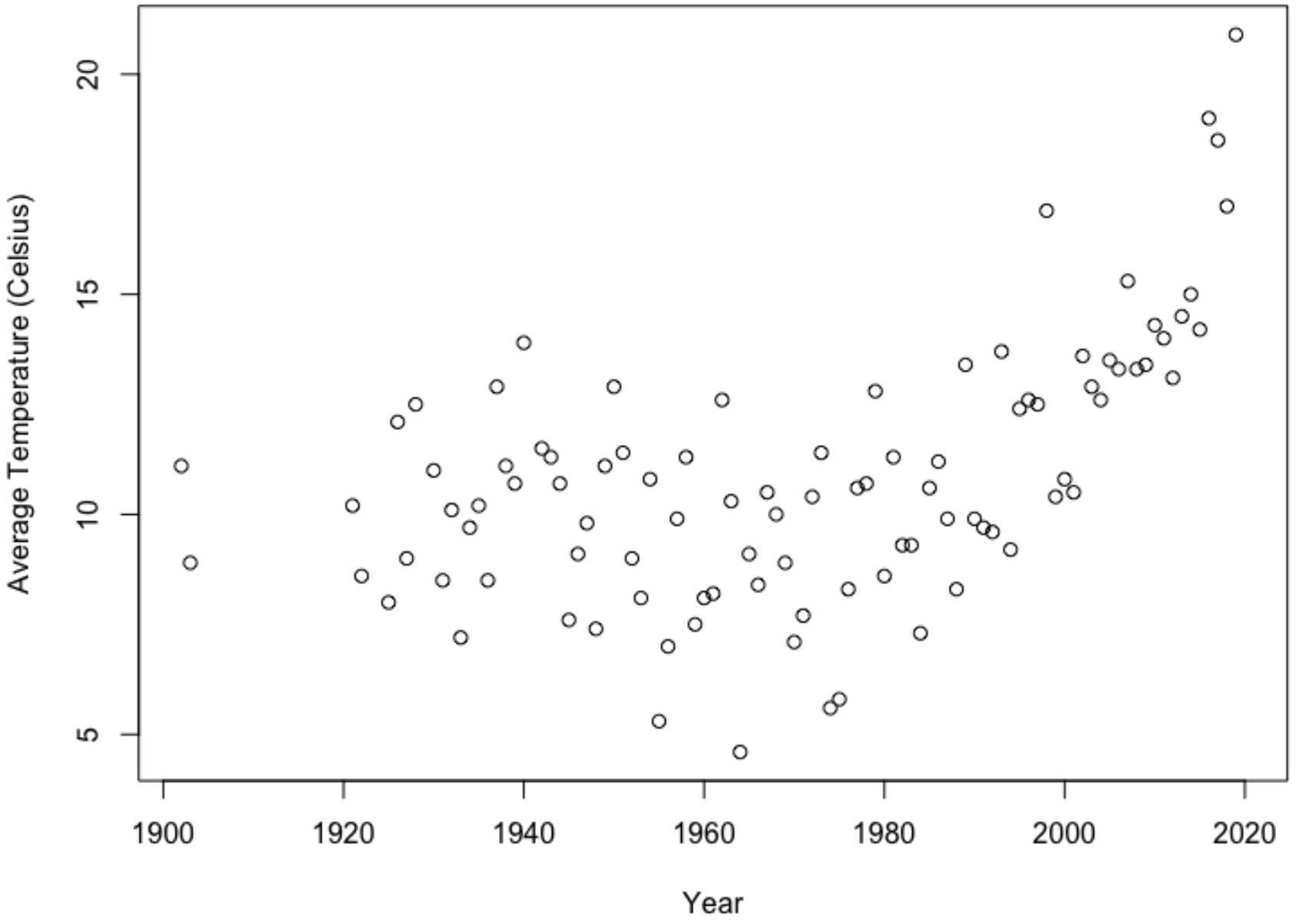
Student in-class activity: Scatterplot of Arctic temperature

- Next we will plot Arctic temperature with time (from Utqiagvik, AK).
- Double-click polar.Rdata to open Rstudio and load in the data.
- The dataframe is called modern_polar_T.
- Plot the average temperature, TAVG, versus the data, DATE.

  Reminder: lattice::xyplot(myY~myX, data=myDataFrame)
- Add an xlabel and ylabel using xlab and ylab:

  lattice::xyplot(myY~myX, data=myDataFrame, xlab = “Year”, ylab = “Temperature (Celsius)”).

Arctic Annual Average Temperature (Utqiagvik, Alaska)



Was your prediction for the average temperature in 1900 correct?

What do you think the temperature will be like in 2030?

What will determine that temperature?

Module Summary

- Statistics and Polar Research
- Designed by polar researchers, statistics and math instructors, research students, & an education researcher.
- Designed for undergraduate students (also High School version about penguins)
- Duration: ~2 weeks of class time + homework.
- Computational tools: Rstudio.

Next steps

- Focus group will work through module and knowledge test survey next week.
- Modify based on feedback.
- Planned to be taught starting in the fall.
- Will be shared soon via our website: https://serc.carleton.edu/penguin/index.html

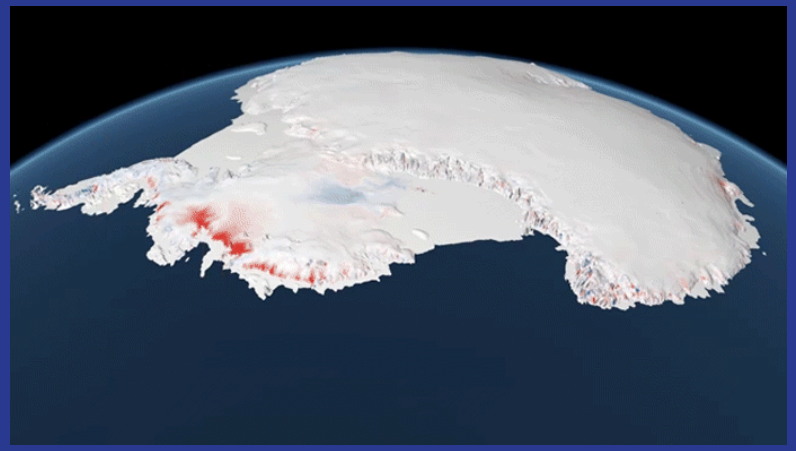
Thank you!

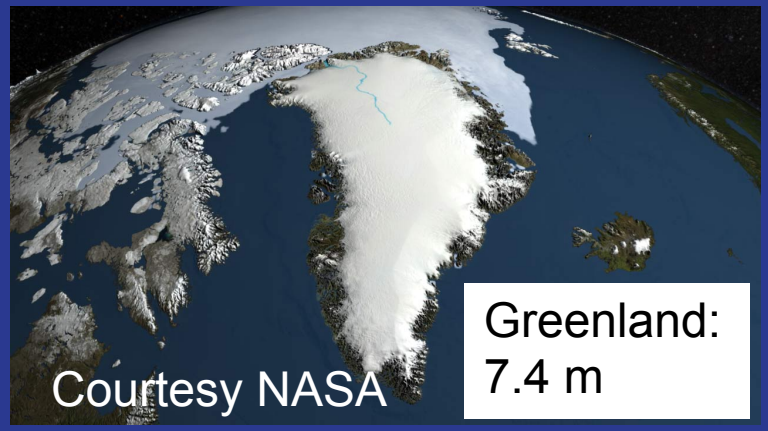
Acknowledgements

Funding for this project was provided by NSF OPP awards 2021429 and 2021213. We are grateful to our external evaluators at the Social and Economic Sciences Research Center at Washington State University, Candiya Mann and Adam McKee; to the Science and Education Resource Center at Carleton College for hosting our materials; and to the students who will be participating in the focus group, Jesus Deloya Garcia, Bela Dunn Dias Ferreira, Charlie Henning, Max Bloom, Cas Almond, Nick Wolff-Gee, and Miranda Roland.

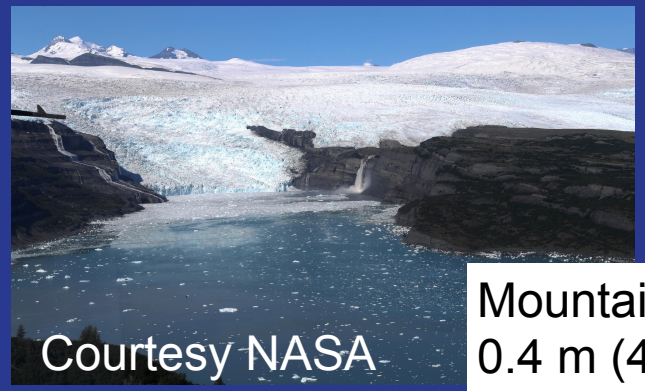
Extra Slides

Future Sea Level Rise Predictions





Greenland:
7.4 m



Mountain glaciers:
0.4 m (40 cm)

Sea level equivalent (SLE) estimates from Davies, 2019

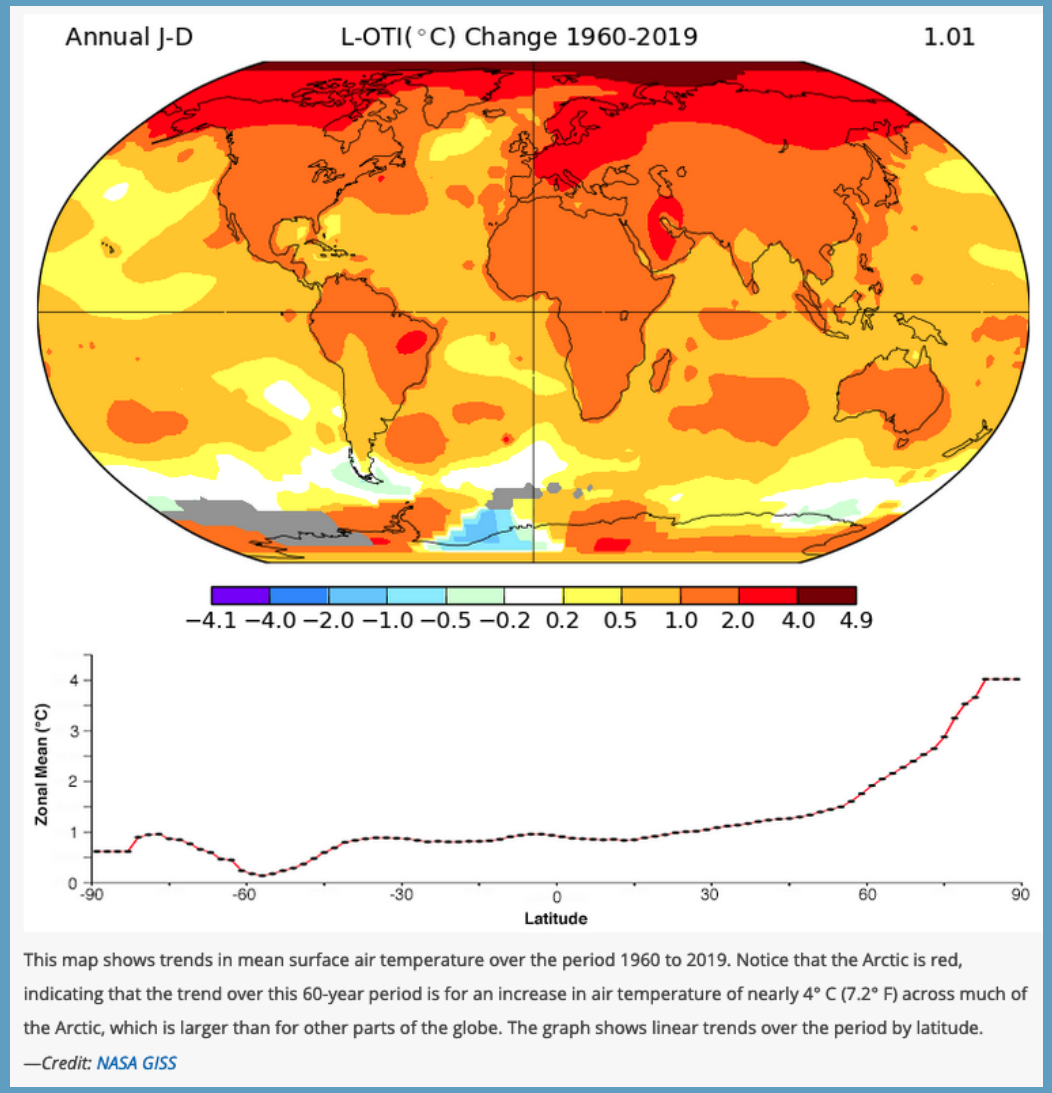
Polar Amplification

Positive feedback:

- Increased greenhouse gases trap heat, leading to melting sea ice.
- Sea ice is very reflective, so less sunlight is reflected and more sunlight is absorbed, and the ocean warms.
- The warming ocean causes more sea ice to melt.

Positive feedback:

- Increased greenhouse gases trap heat.
- The extra heat thaws permanently frozen ground (permafrost).
- Methane is released (also damage to infrastructure).
- Methane is a strong greenhouse gas.



This map shows trends in mean surface air temperature over the period 1960 to 2019. Notice that the Arctic is red, indicating that the trend over this 60-year period is for an increase in air temperature of nearly 4° C (7.2° F) across much of the Arctic, which is larger than for other parts of the globe. The graph shows linear trends over the period by latitude.

—Credit: NASA GISS

Oxygen Isotopes

- **Oxygen 16 (^{16}O)**
  - 8 protons, 8 neutrons
- **Oxygen 18 (^{18}O)**
  - 8 protons, 10 neutrons
- Which one is heavier?

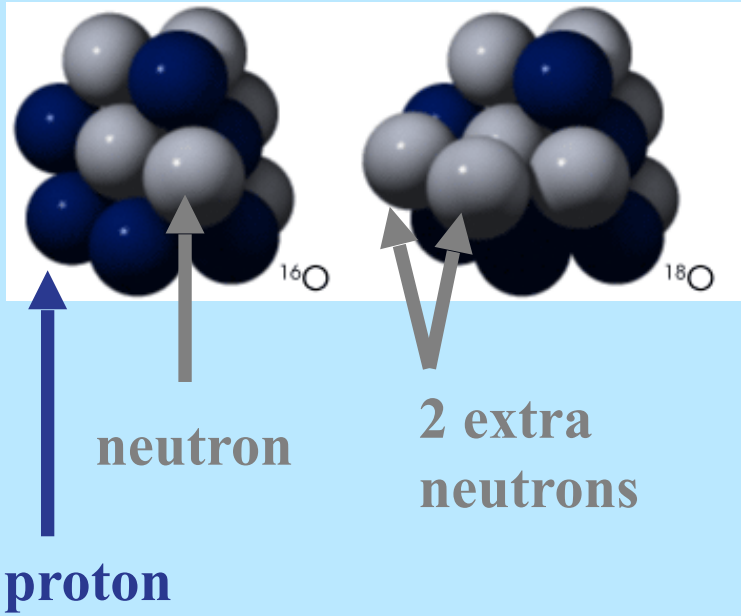


Image courtesy Robert Simmon, NASA