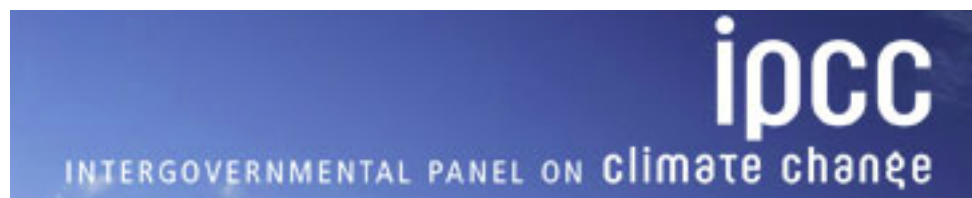


# p-value: an example from climate change

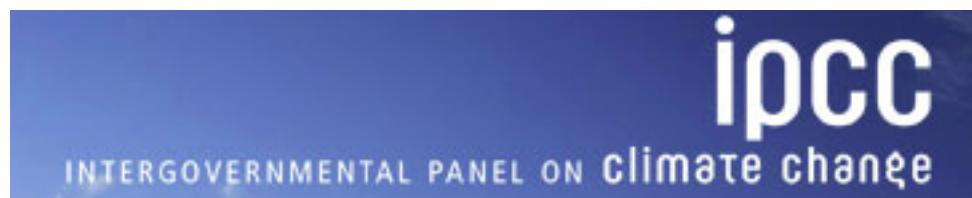


In 2008, “It is certain that Global Mean Surface Temperature has increased since the late 19<sup>th</sup> century. Each of the past three decades has been successively warmer at the Earth’s surface than all previous decades in the instrumental record ...”

Source: Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 2013

# p-value: an example from climate change

CLAIM

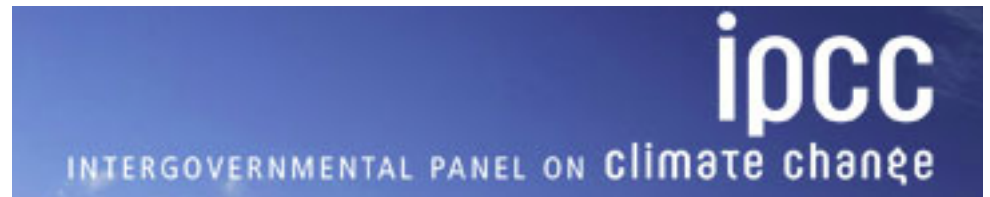


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Source: Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 2013

# p-value: an example from climate change

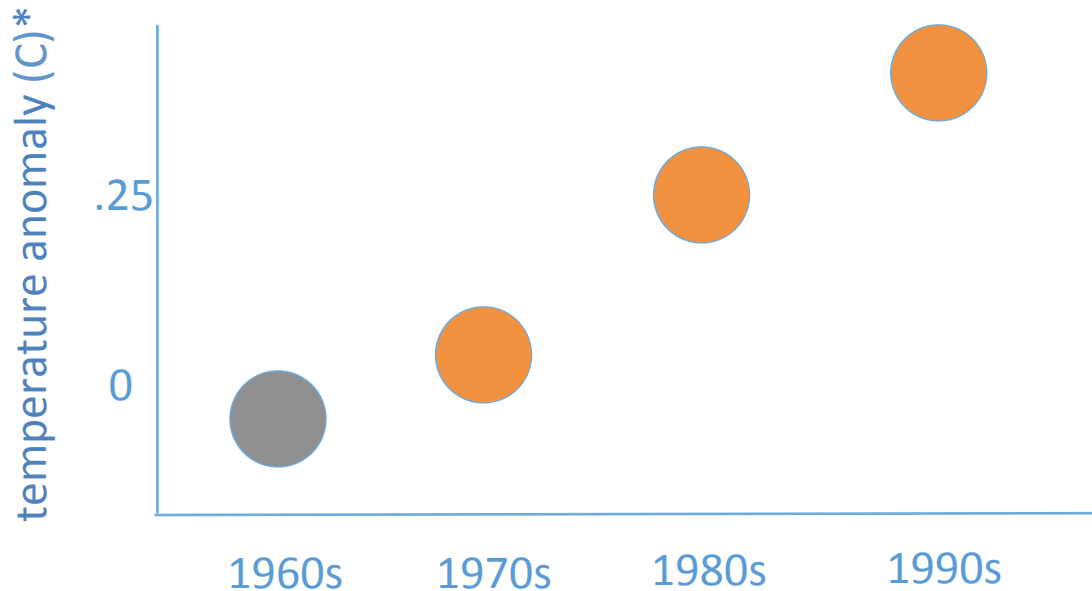
## EVIDENCE



In 2008, “It is certain that Global Mean Surface Temperature has increased since the late 19<sup>th</sup> century. → Each of the past three decades has been successively warmer at the Earth’s surface than all previous decades in the instrumental record ...”

Source: Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 2013

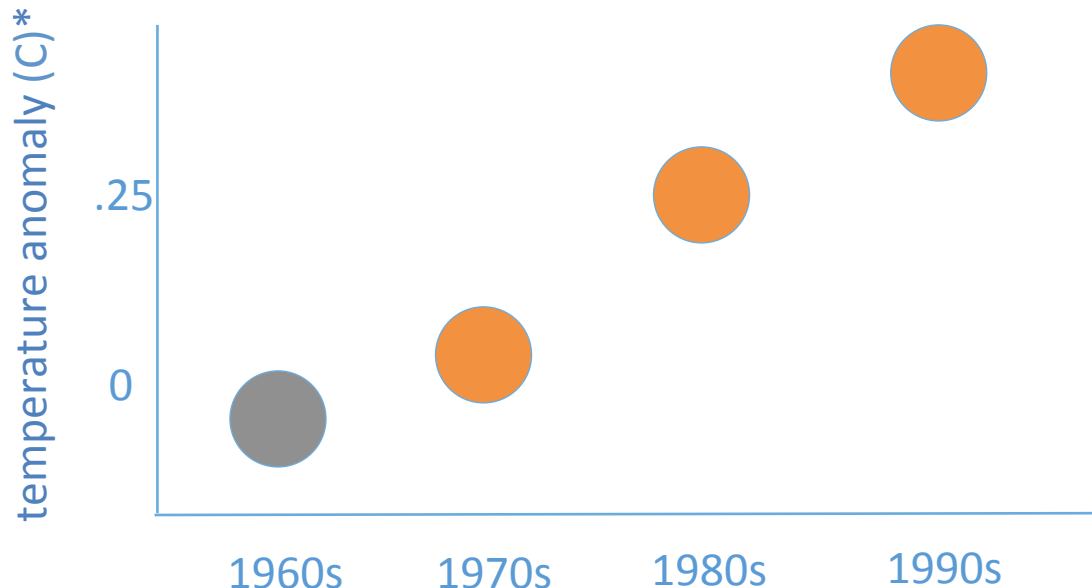
# Simplified graph of findings



What questions would you ask after seeing this graph?

\*difference between annual average and 1951-1980 average

# Simplified graph of findings

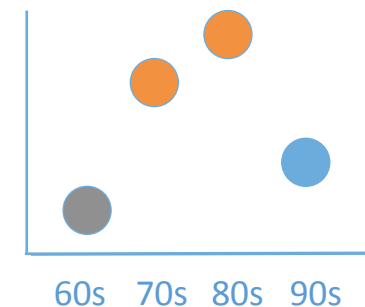
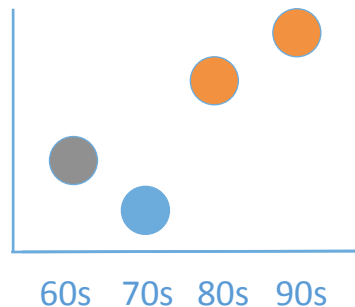
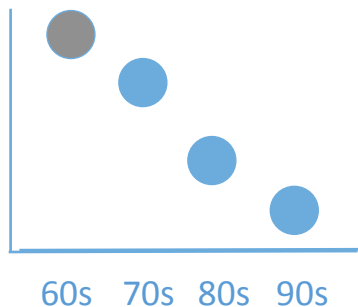
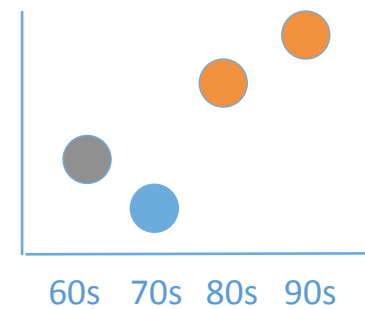
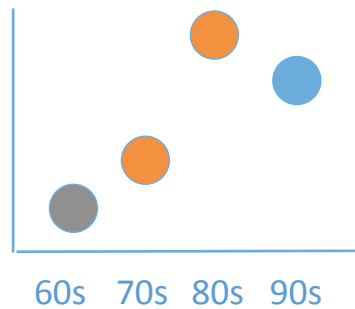
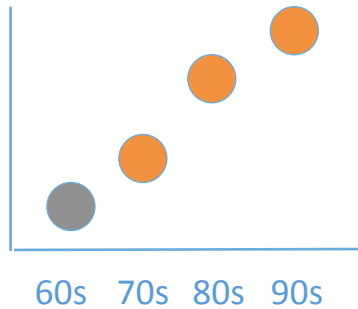


Could the increases in the Global Mean Surface Temperature over the last three decades be due to chance?

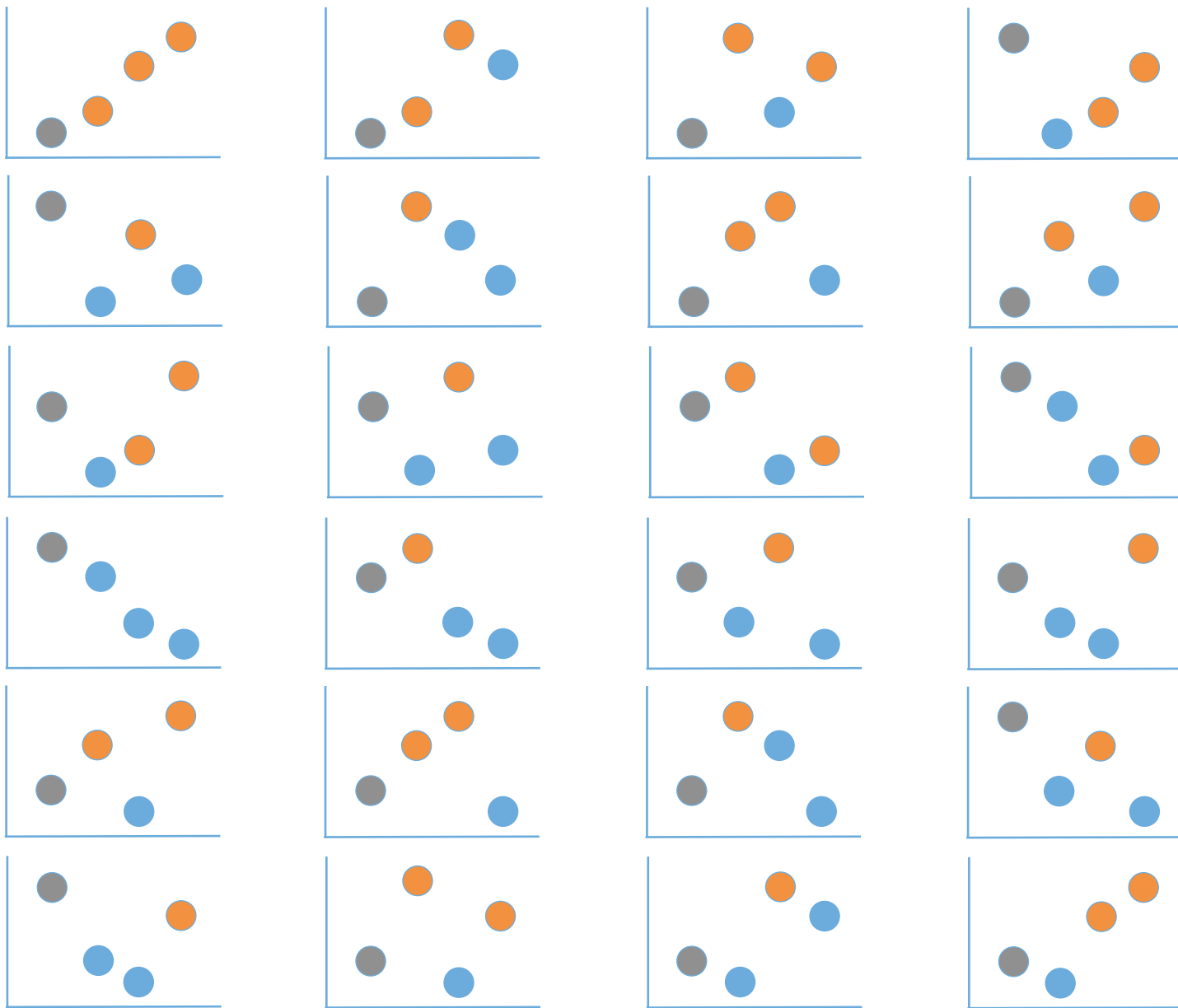
To figure out p-value, we need a **null hypothesis**.  
Our null hypothesis: these increases are due to chance

If the increases really were due to chance, anything COULD have happened.

Each decade could have showed an **increase** or **decrease** at random.



and the data we observe was just as likely as any other trend.



All the possible trends we could have observed

Which trends provide as much or more evidence of global warming?

our universe



All the possible trends we could have observed

Which trends provide as much or more evidence of global warming?



our universe



$$1/24 = .042$$



Is this



“significant”?

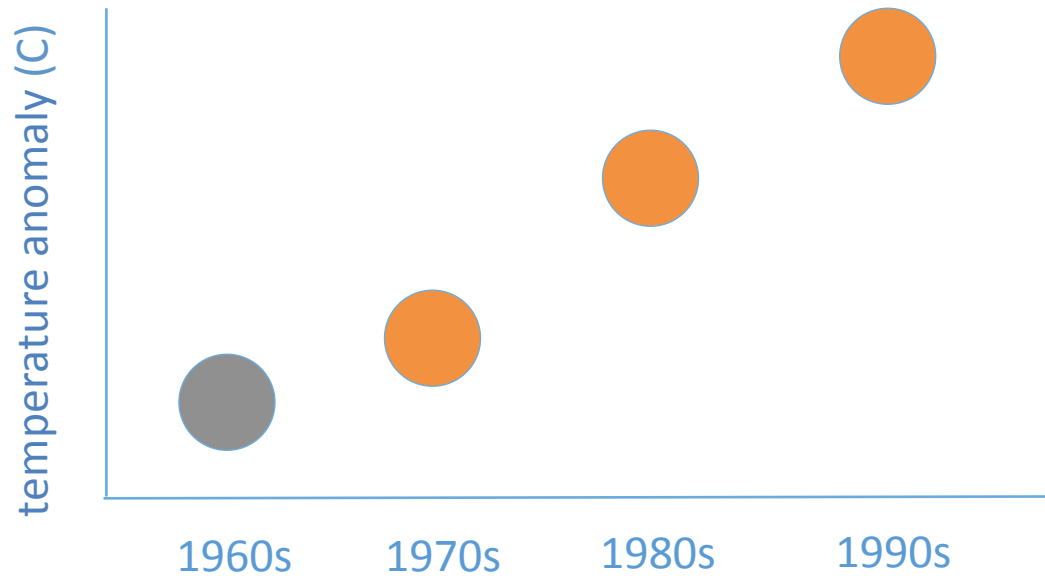


$$0.042 < 0.05$$

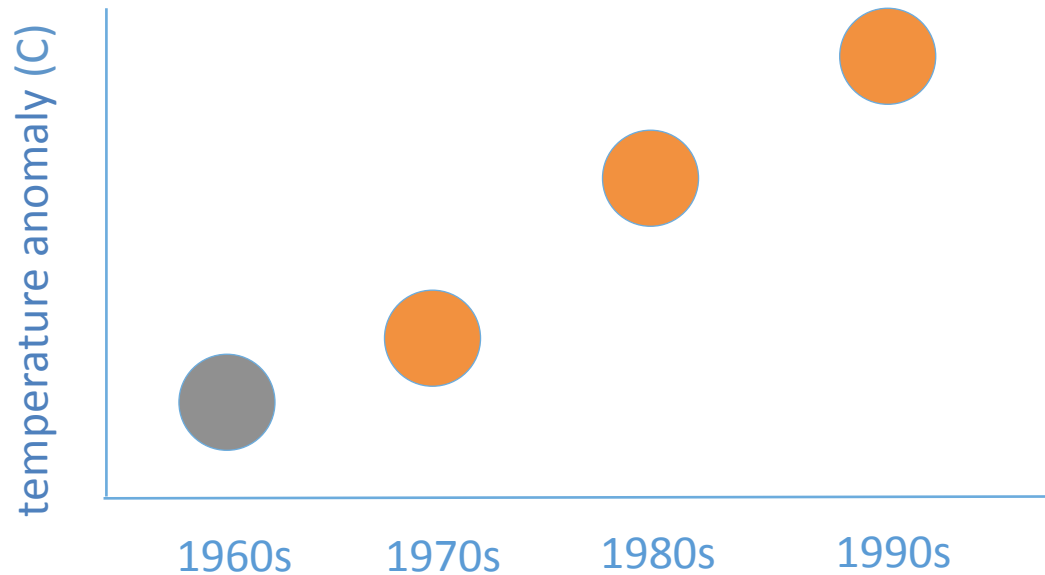


We can now calculate the probability of seeing a trend like the one we observed if the **null hypothesis** is true

So what can we conclude?

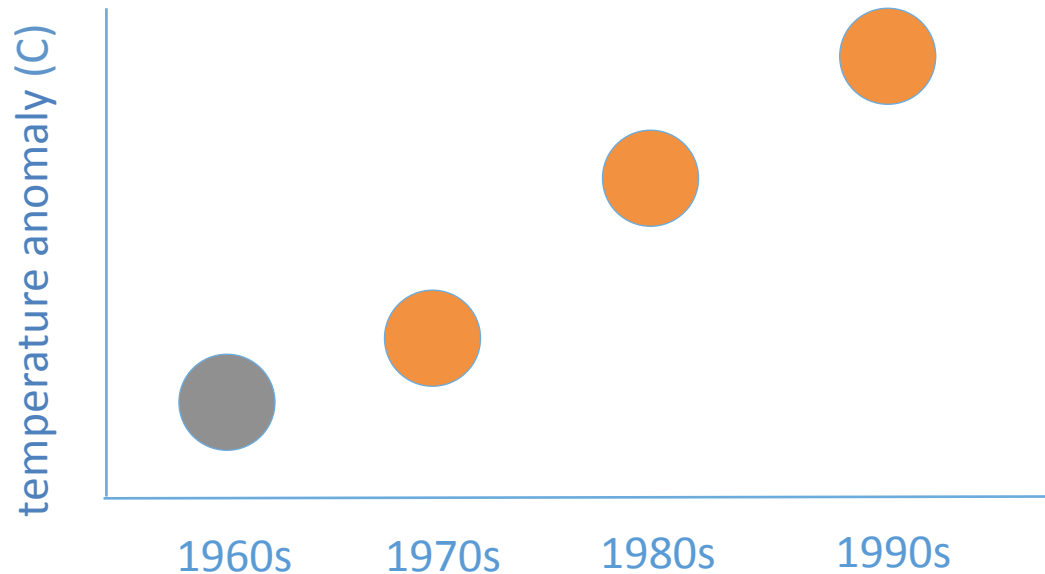


If there's no real trend here, there's only a 4% chance of ending up with this pattern. So either . . .



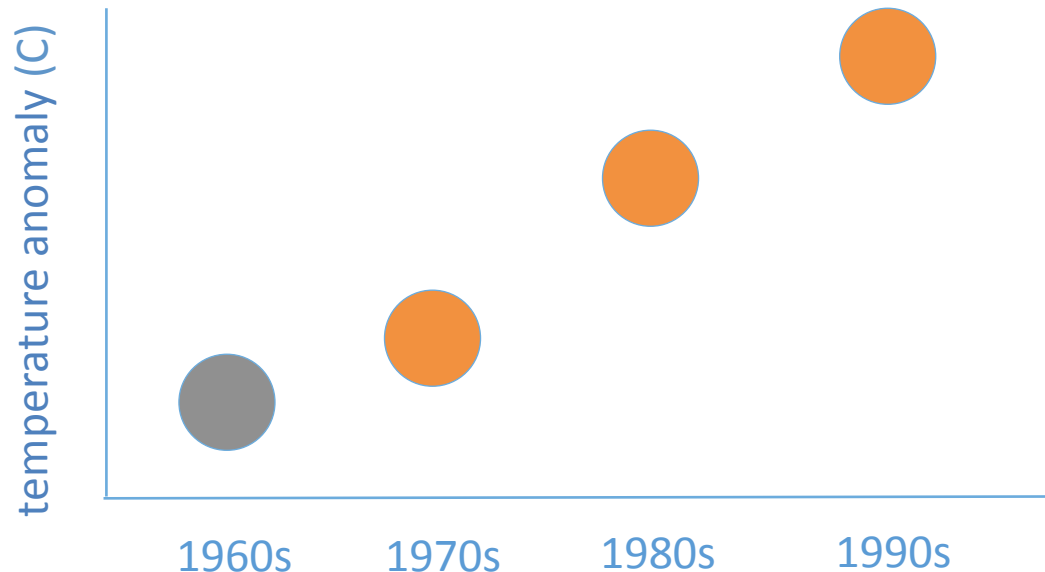
If there's no real trend here, there's only a 4% chance of ending up with this pattern. So either . . .

1. We were wrong, and there is a real trend here.

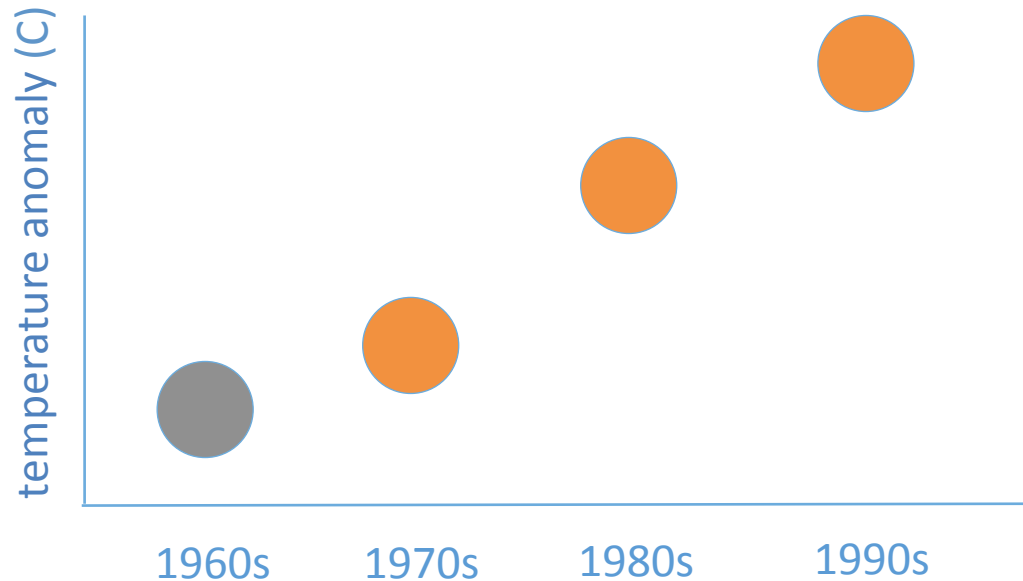


If there's no real trend here, there's only a 4% chance of ending up with this pattern. So either . . .

1. We were wrong, and there is a real trend here.
2. OR we're in that 1 universe out of 24 where this happened by chance.

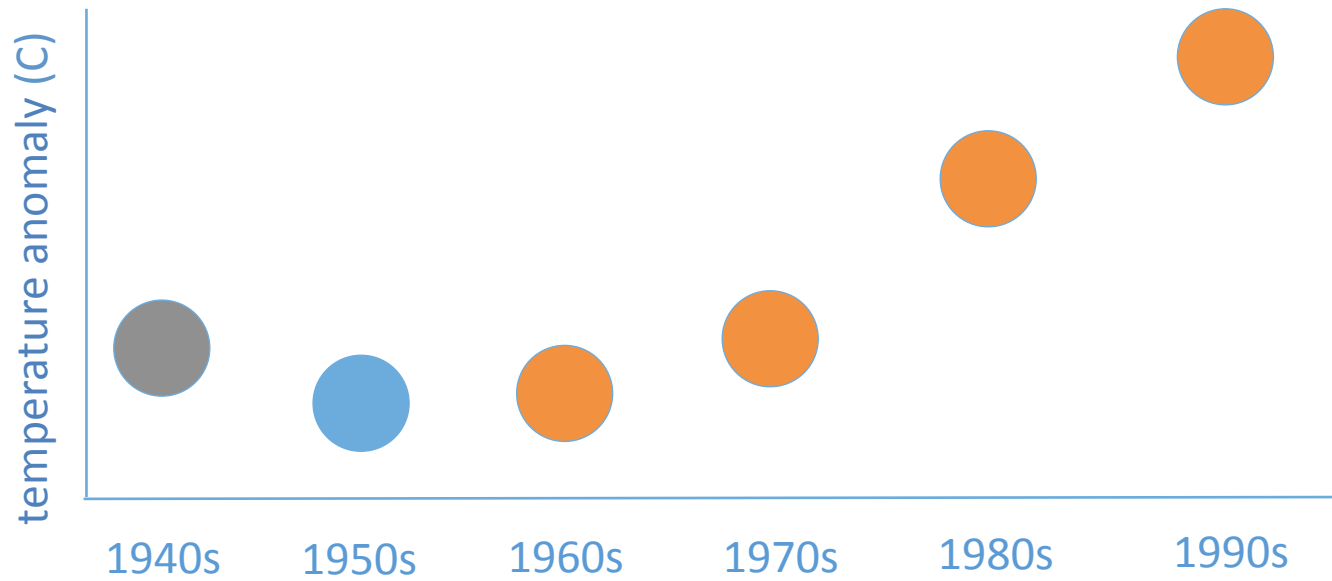


But why just look at the past THREE decades?



What about if we asked, "Could the trend in the past FIVE decades be due to chance?"

Notice we stated this research question after looking at the data.



$$58/720 = 0.08$$

$$0.08 > 0.05$$

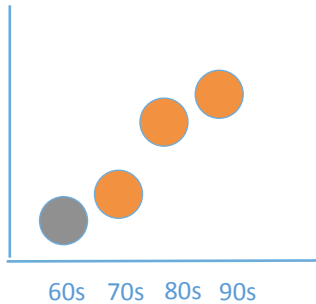
# p-hacking: what's so wrong with this?

- We now have two results: one statistically significant and one statistically insignificant.
- It would be dishonest if we only report the result with the significant p-value.
- We can report both results **or** report one but adjust the cut-off for multiple comparisons.

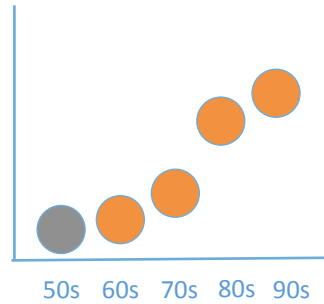


An extreme case of p-hacking would be iteratively adding years until we arrive at a really low p-value.

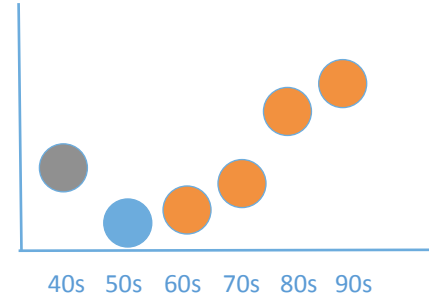
$$1/24 = .042$$



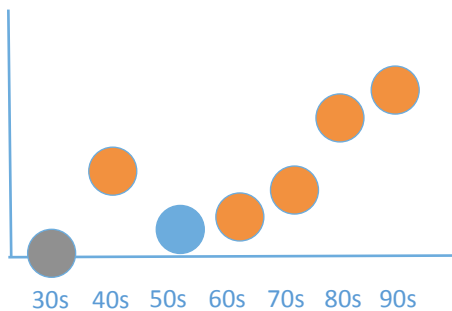
$$1/120 = .008$$



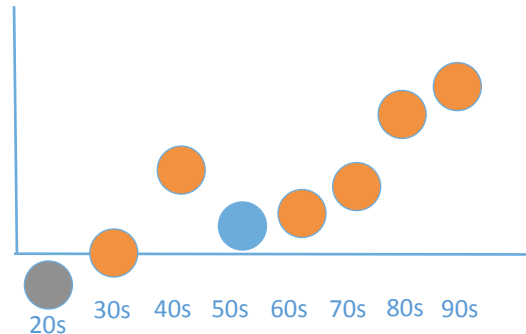
$$58/720 = .081$$



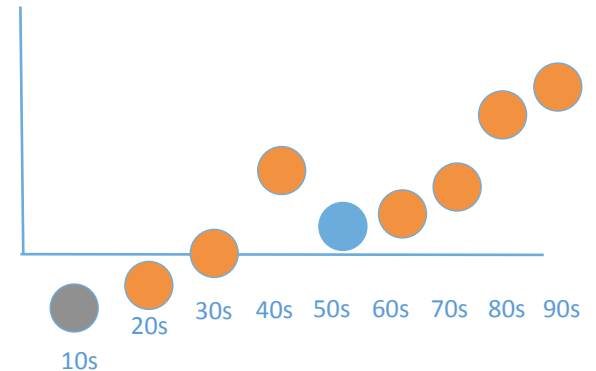
$$121/5040 = .025$$



$$248/40320 = .006$$



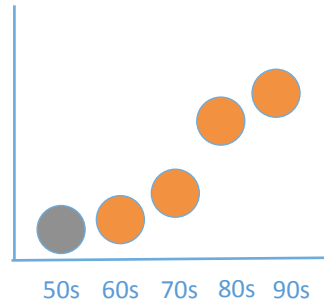
$$503/362880 = .001$$



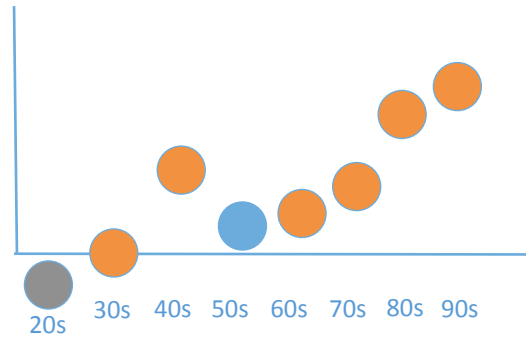
We can report all of these trends.

Or we can pick any trend and report a conservative p-value cutoff.

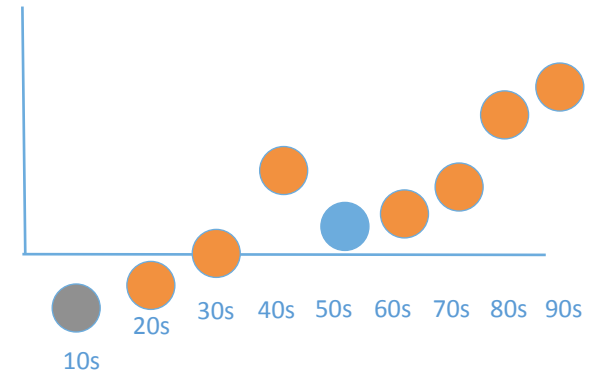
$$1/120 = .008$$



$$248/40320 = .006$$



$$503/362880 = .001$$



These trends are statistically significant at cutoff  $.05/6 = .008$ .

