9/1/2022

Basics of Climate Models

Woodwell Climate Research Center

When you are using climate models it's important that you know how models work.

Importance of Ensembles

Photo by Giuseppe Mondi on Unsplash

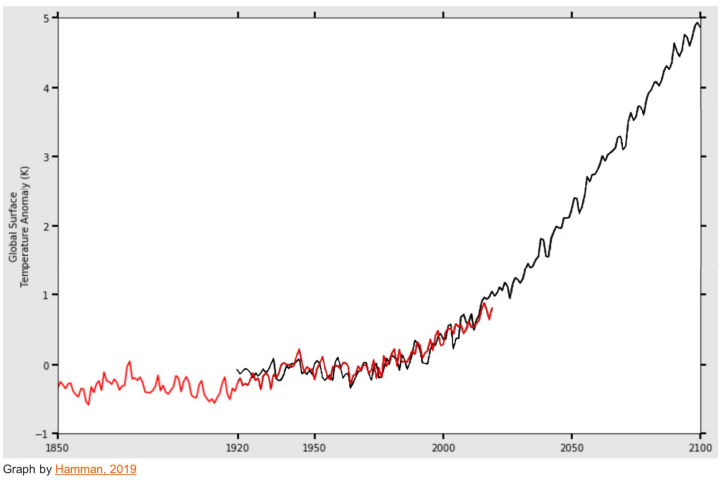
First its important to know that models are not reality.

This is reality.

And models are an approximation of reality. And each model is different from other models. Each model has its own approximations. And so, this is not reality, this is not reality, this is not reality, …

…but when you look at the three together … they form a picture more like reality than any single model.

There are differences between the models together and reality, but it is much better.



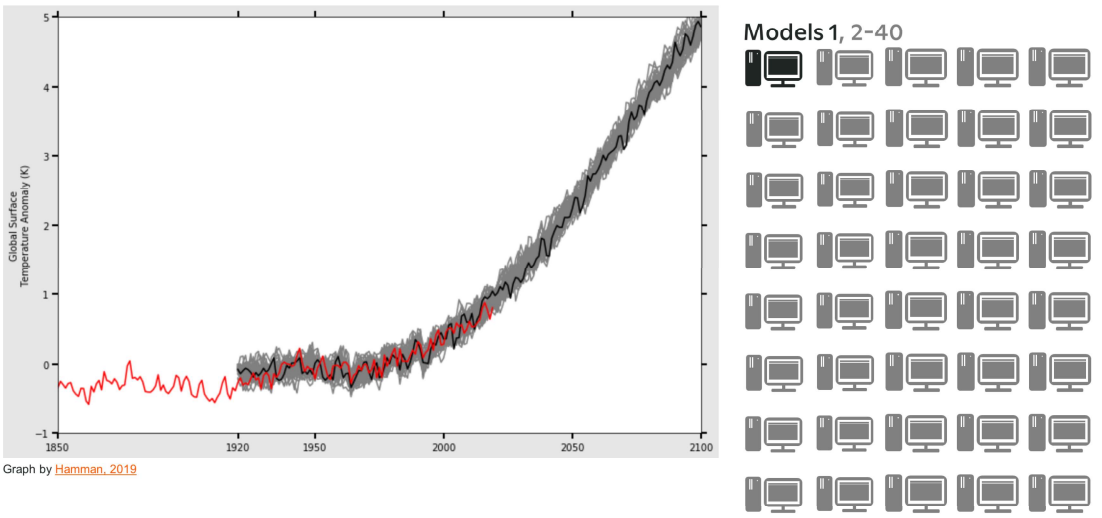
What does this look like with real data?

Here we are looking at the global temperature change.

The observation data in red has many ups and downs. This is normal. There are big oscillations in the climate, like El Niño, which can cause variability.

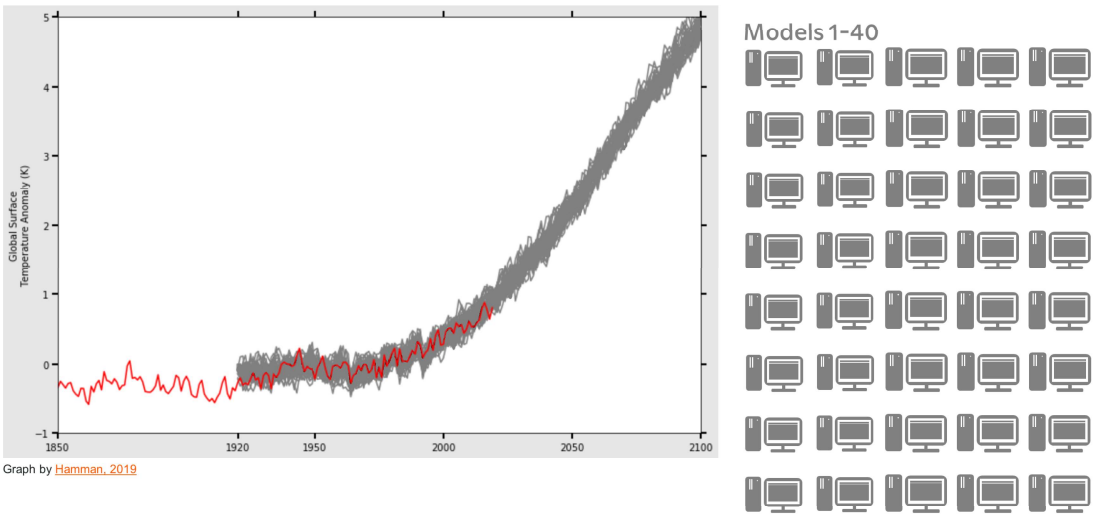
And every models have their own ups and downs. The single model is doing is best to approximate how the real climate acts. It is noisy. It has variability.

Pic: https://miro.medium.com/max/1400/1*x1wkpGTZTRqt5LHvT0e_gA.png
https://medium.com/pangeo/cesm-lens-on-aws-4e2a996397a1



It is much better if you consider multiple models. Here we can see that first model's pathway and 39 other models' pathways.

Pic: https://miro.medium.com/max/1400/1*x1wkpGTZTRqt5LHvT0e_gA.png
https://medium.com/pangeo/cesm-lens-on-aws-4e2a996397a1



And if we look at all 40 models as a group, or ensemble, they form a path. And the observations are following the path pretty well.

The models working together are better than a single model. They are a good approximation.

Pic: https://miro.medium.com/max/1400/1*x1wkpGTZTRqt5LHvT0e_gA.png
https://medium.com/pangeo/cesm-lens-on-aws-4e2a996397a1

Time Periods

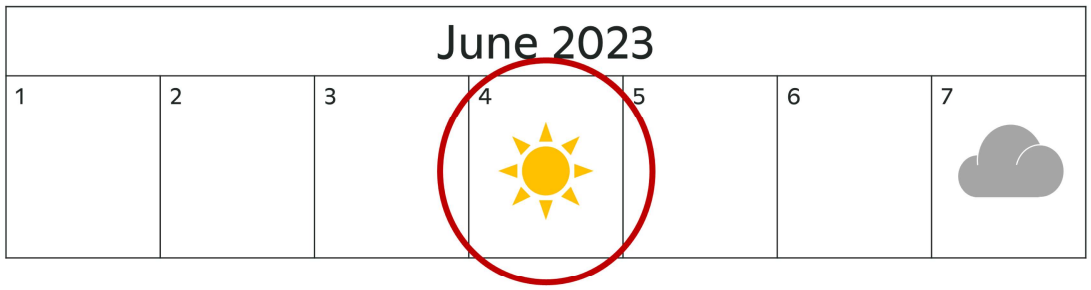
It is important to use the appropriate time period for prediction.

Which day will be hottest next year?

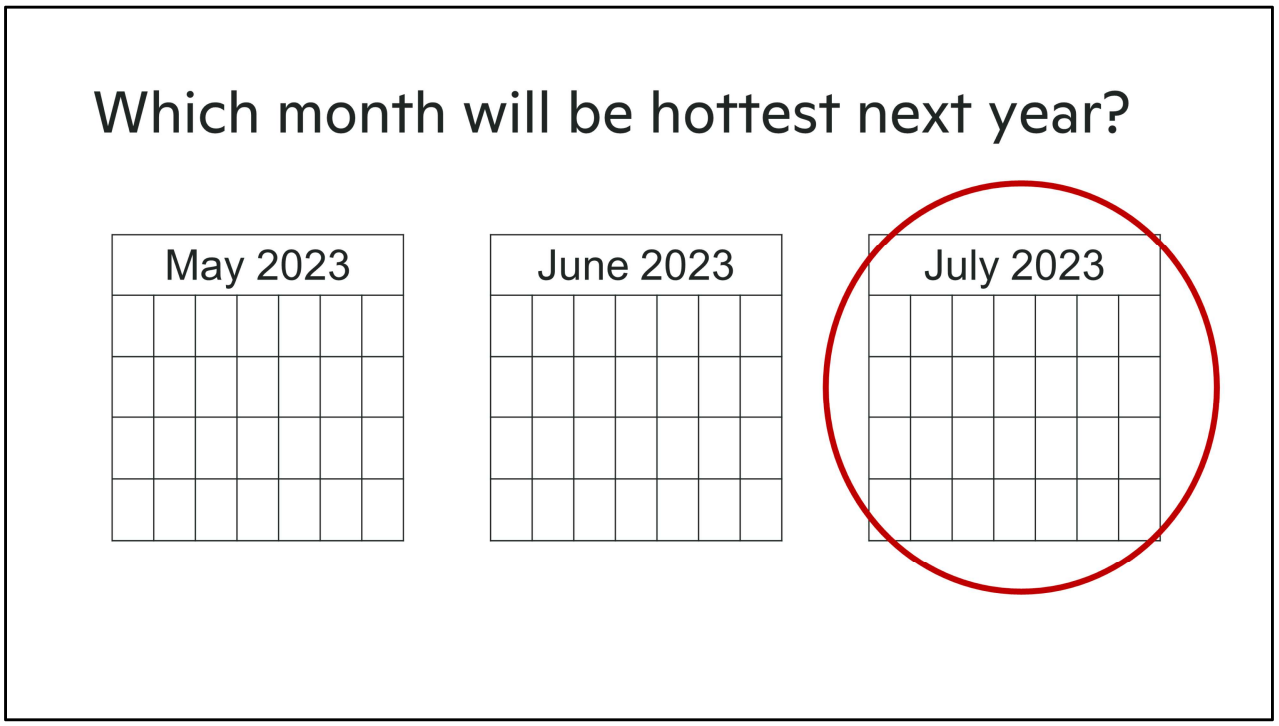
June 2023						
1	2	3	4	5	6	7

If I say, “Which of these days is going to be the hottest next year?” You are going to say, “I don’t know, June 7th?”

Which day will be hottest next year?



But, if it is very sunny on the 4th that day is going to be hotter than the 7th. There is too much variability for you to predict exactly.



However, if I say, “Which month will be the hottest?” You will say, “July!” Because, of course, it’s almost always July. By going from 1 day to 1 month, our guess is going to be better.

And the models have a very similar relationship with time and predictions.

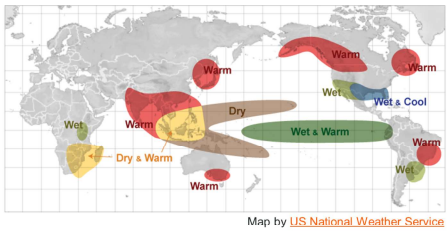
Which year will be hottest?

… 2045, 2046, 2047, 2048, 2049, 2050 …

If I ask the question, “Which year will be the hottest?” and you know about climate change, you are going to say 2050.

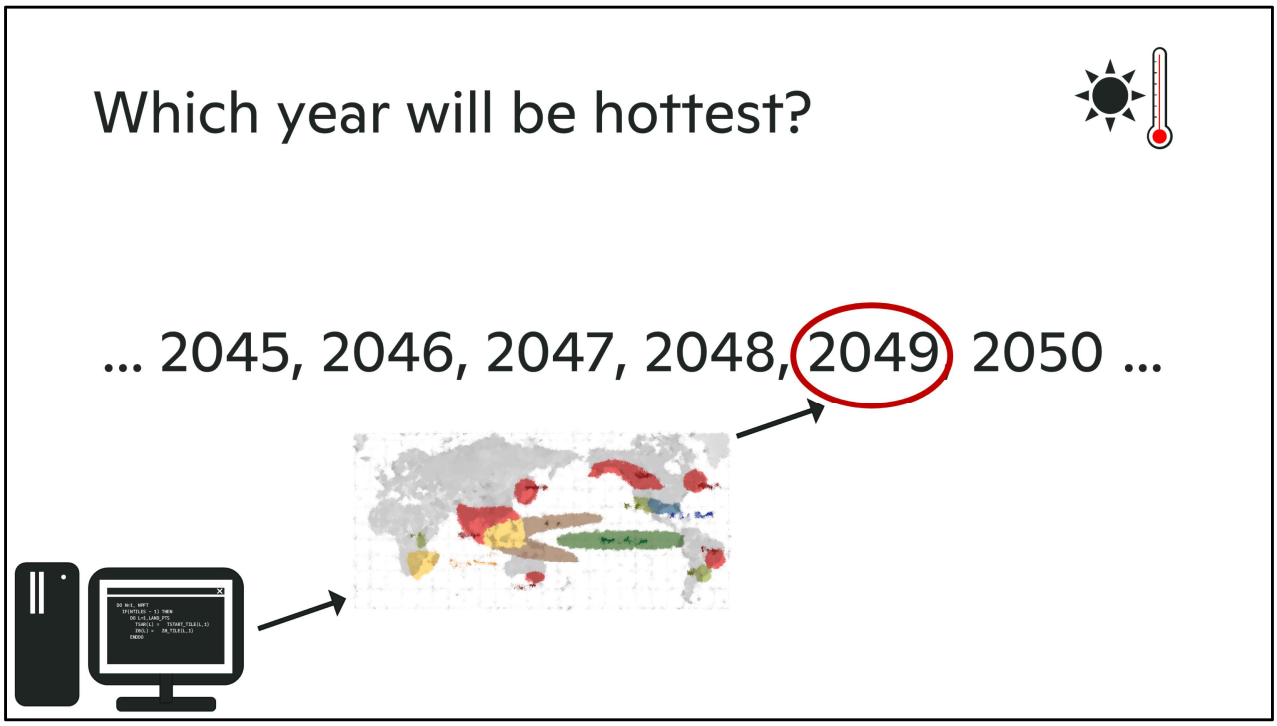
Which year will be hottest?

… 2045, 2046, 2047, 2048, 2049, 2050 …



But, if there is an El Niño, a different year can be hotter. We do not know exactly which years will have El Niños, nature is too random.

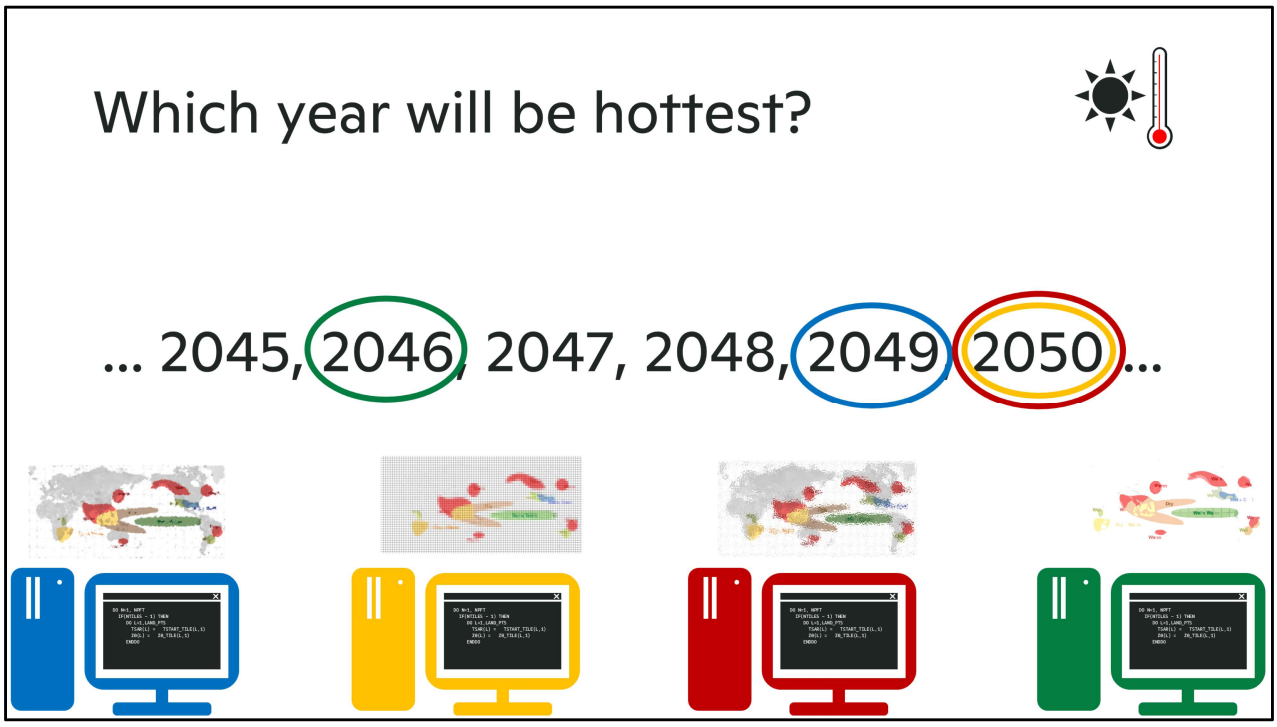
Pic: https://www.weather.gov/jetstream/enso_impacts



But the models can approximate El Niño. It will give them those “ups and downs”, “ups and downs” that we saw in the observations.

But the model’s approximation of El Niño cannot always match the real El Niño. The real El Niño is too random. So it may choose a different hottest year.

https://rmets.onlinelibrary.wiley.com/doi/abs/10.1002/joc.3695

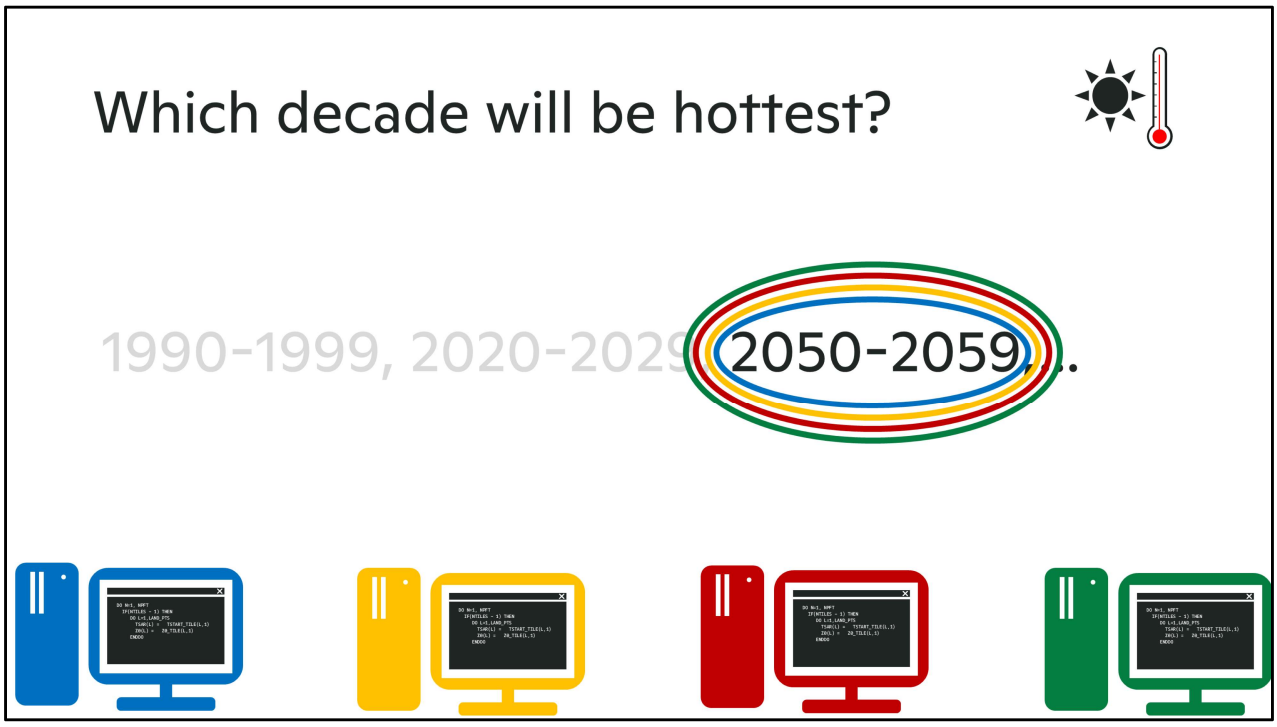


And every model is going to have an approximation of El Niño so they are going to guess different years. This is normal.

Which decade will be hottest?

1990-1999, 2020-2029, 2050-2059,…

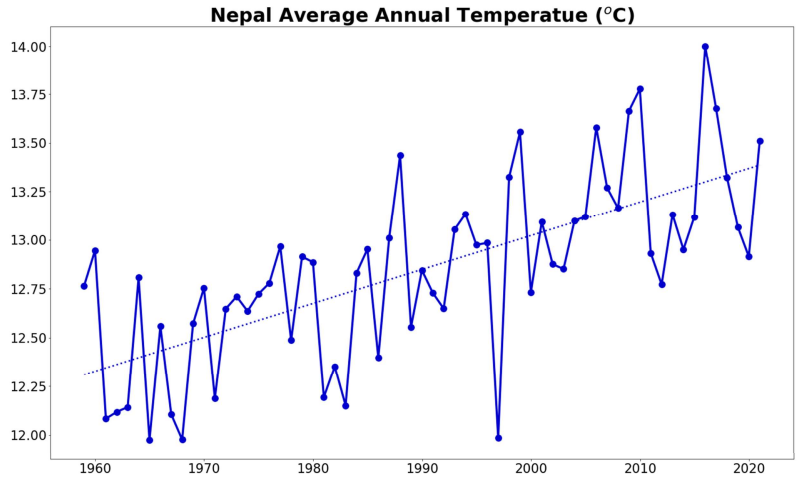
But if we ask the question “which decade is the most hot?” The single computer model is going to say “This decade.”



And all of the other models will agree. They are going to say “This decade will be the hottest.”

But note: There is time between each of these decades because….

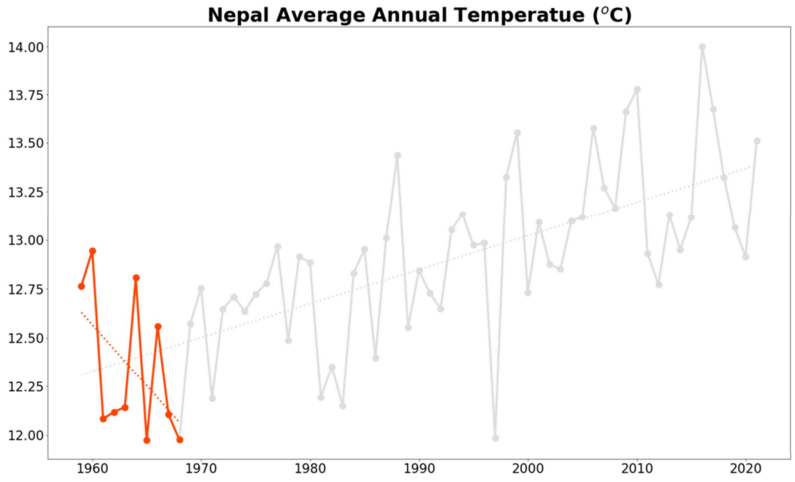
Careful using only decades



…we need to be very careful if we only use a decade.

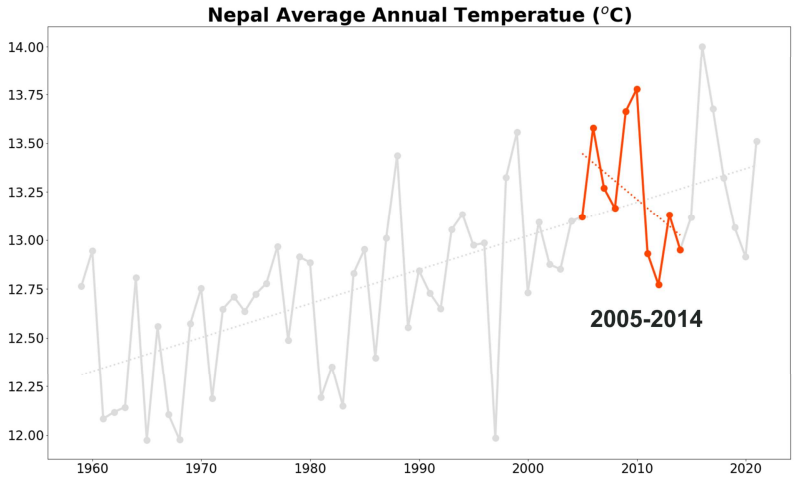
Here is the average temperature in Nepal from 1959 – 2021. In general, it is getting warmer.

Careful using only decades



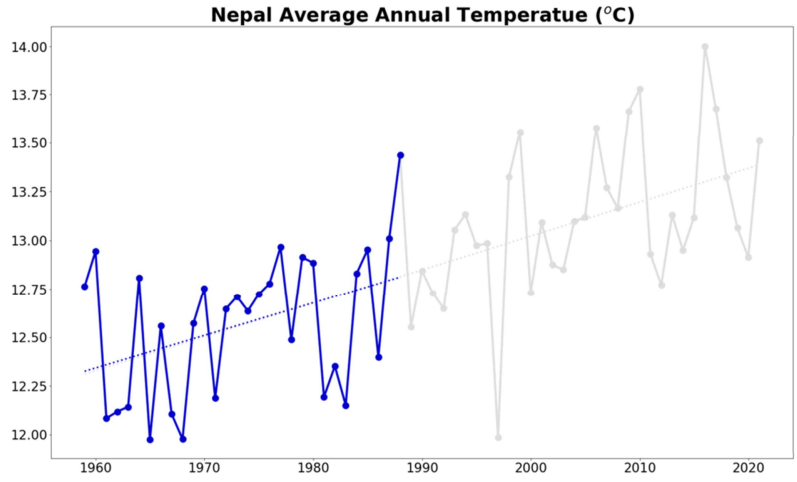
But if we only look at 10 years, or 1 decade, at a time, the trend does not always match the 60-year trend. The 10-year trend is more variable and unstable. Sometimes the 10-year period even makes it look like Nepal is getting cooler.

Careful using only decades



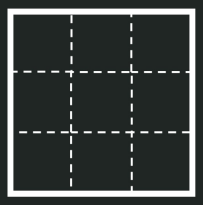
Even recently there was a decade where during that period Nepal seemed to be cooling. But that does not match what we have seen over 60 years. A 10-year period is too short.

30 years is best

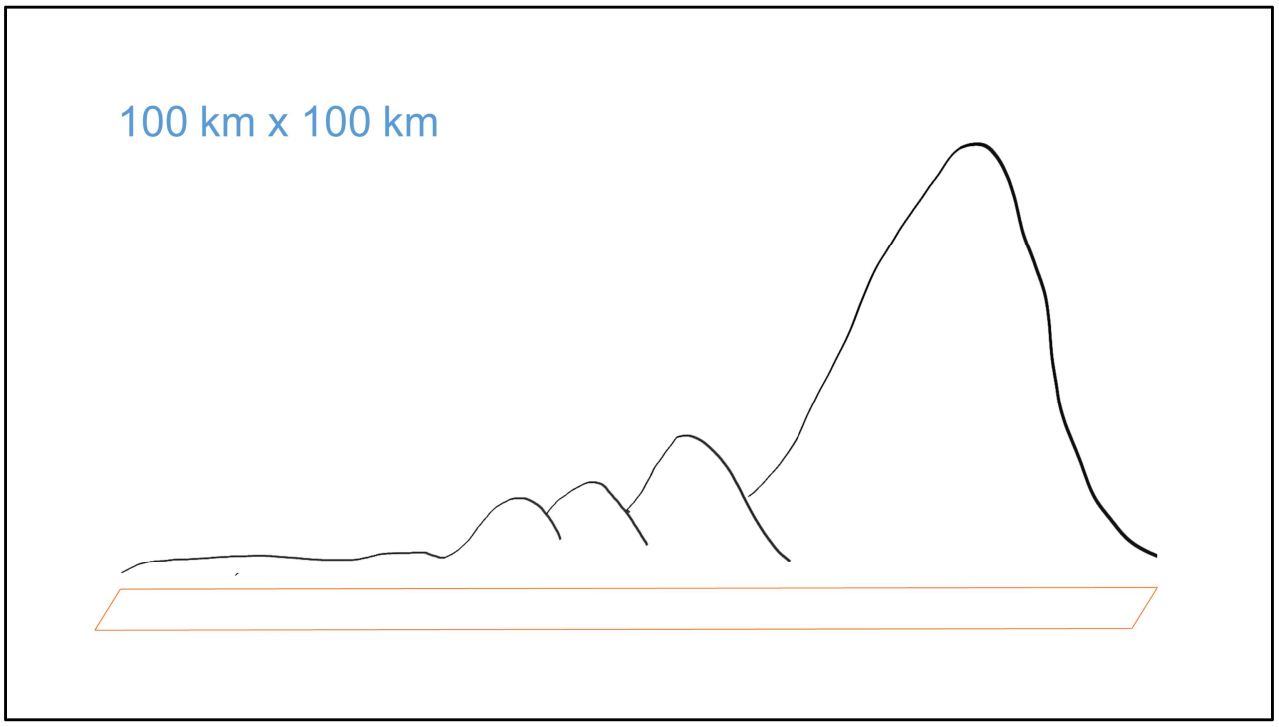


30 years is best. The trend lines for the 30-year periods stay much closer to the 60-year period. And it never shows cooling.

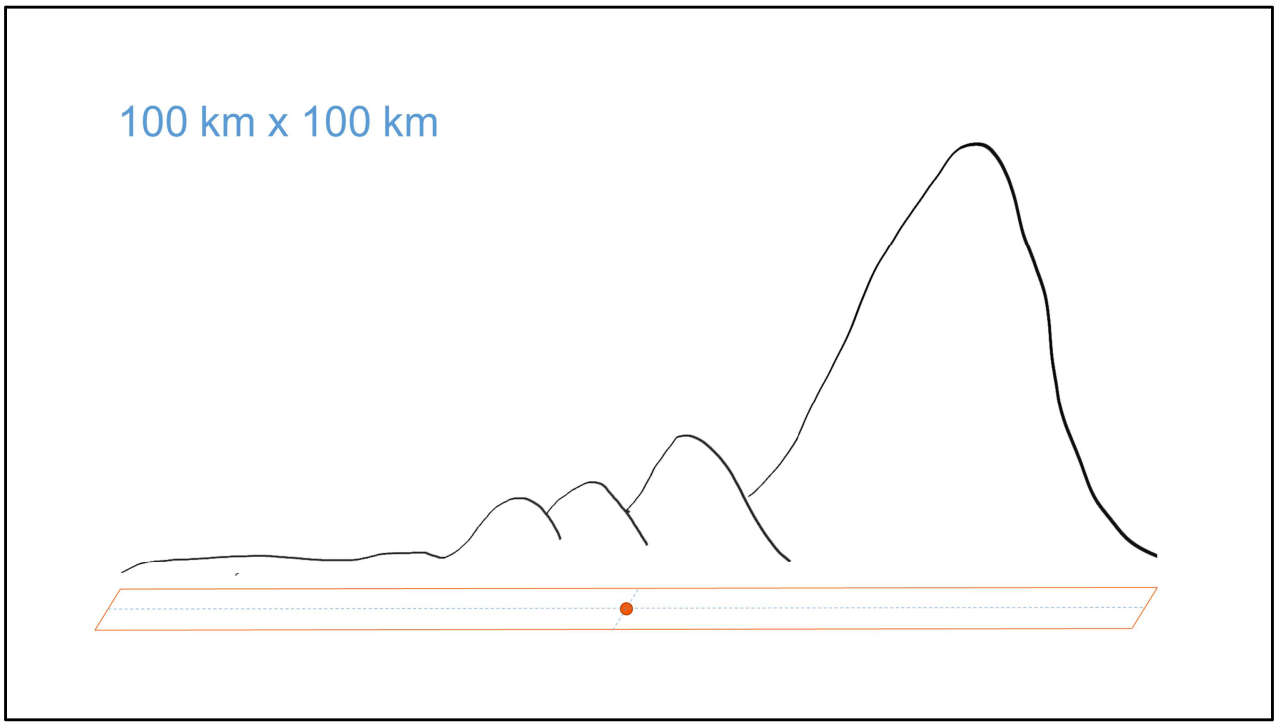
Resolutions



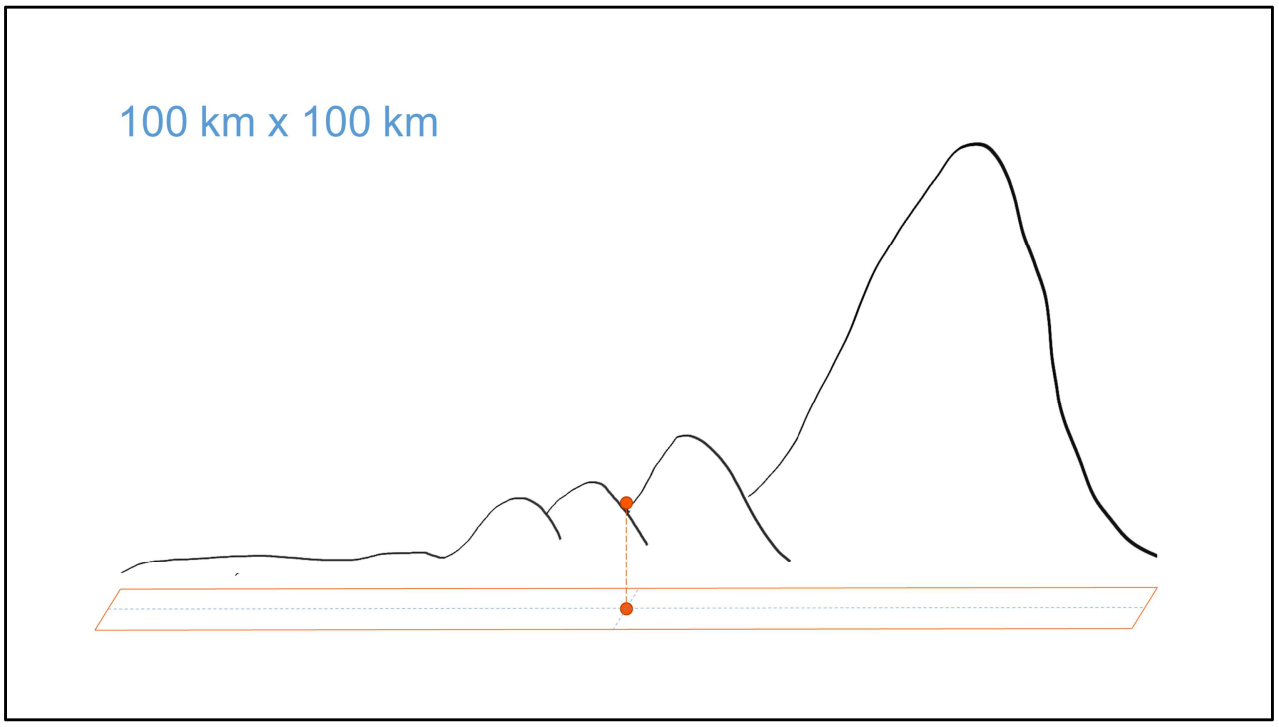
Now we will talk about the resolution of data or the size of the grid.



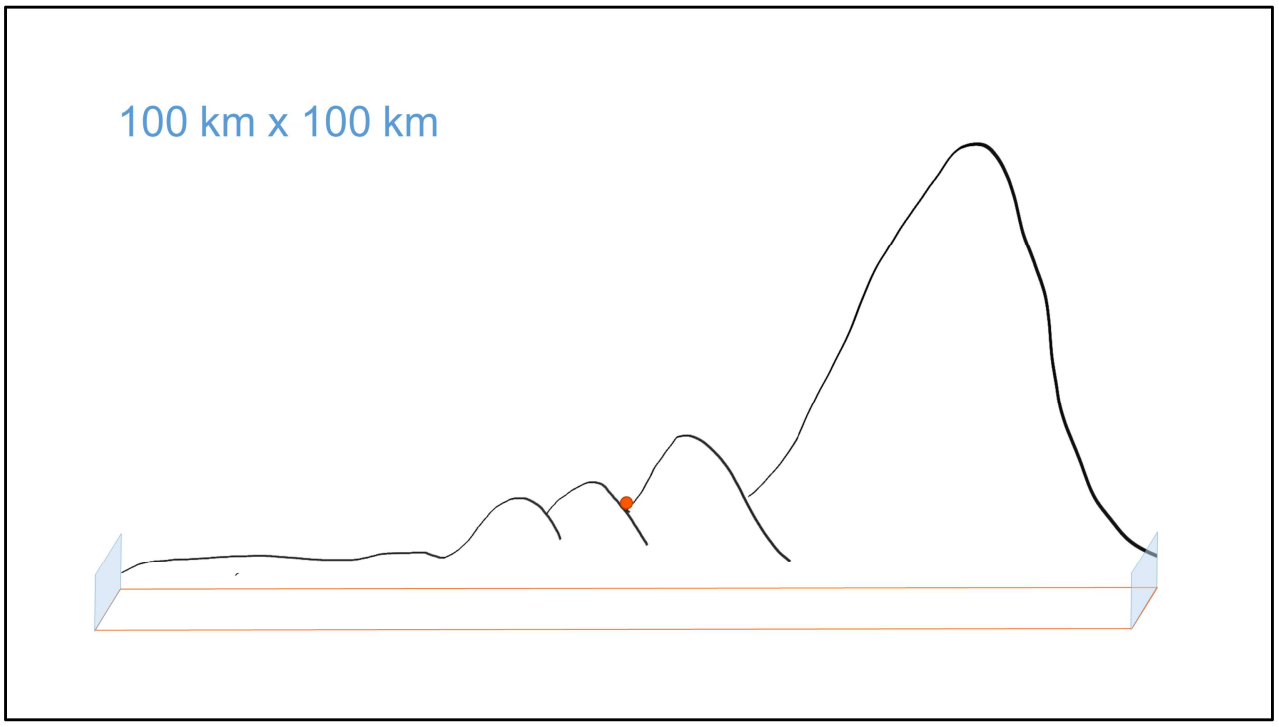
If we have a 100 km by 100 km square there is a lot of land and types of land inside these squares. There are Tarai, hills, and mountains.



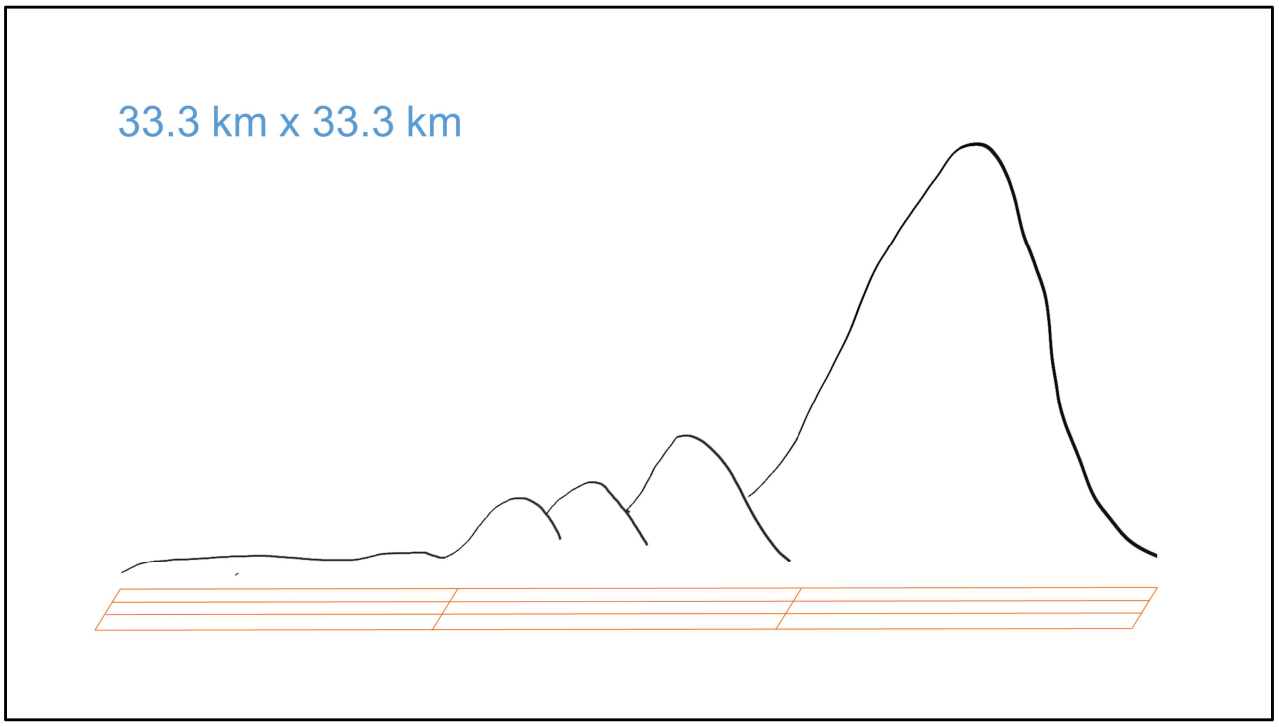
When climate data is gridded we look at the center point and apply it to the entire square.



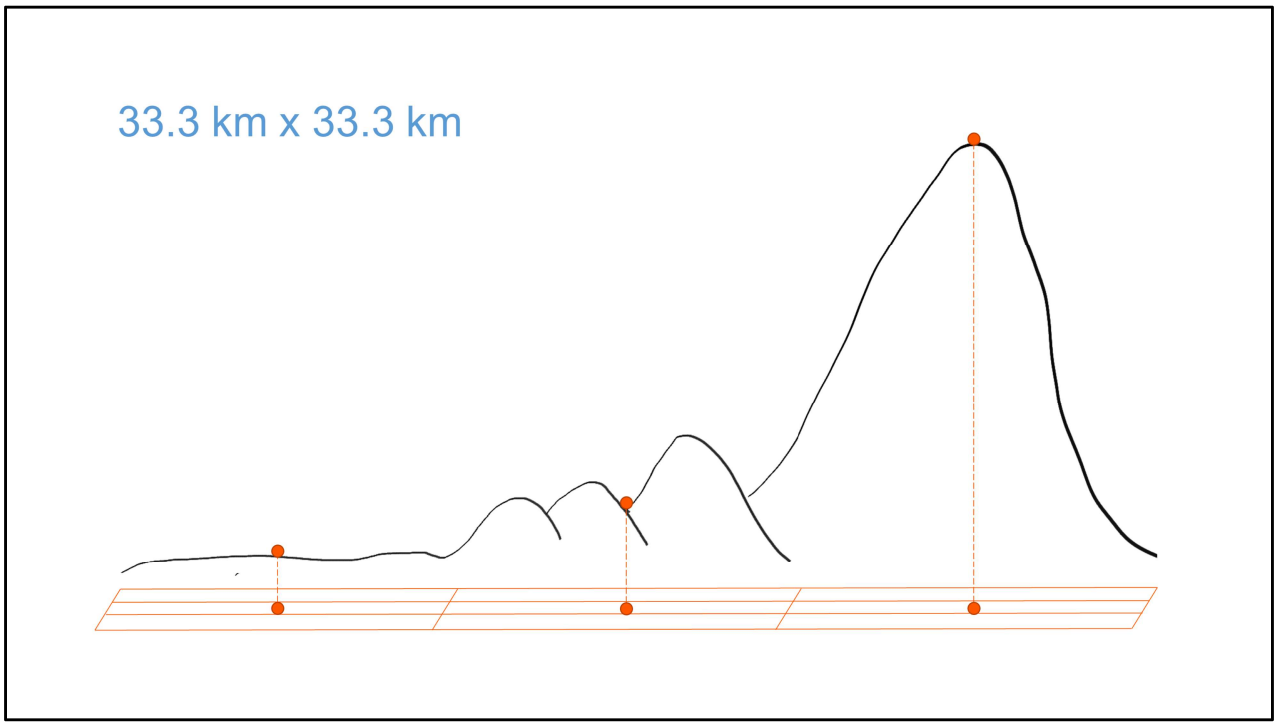
Here the center point would be in the hills.



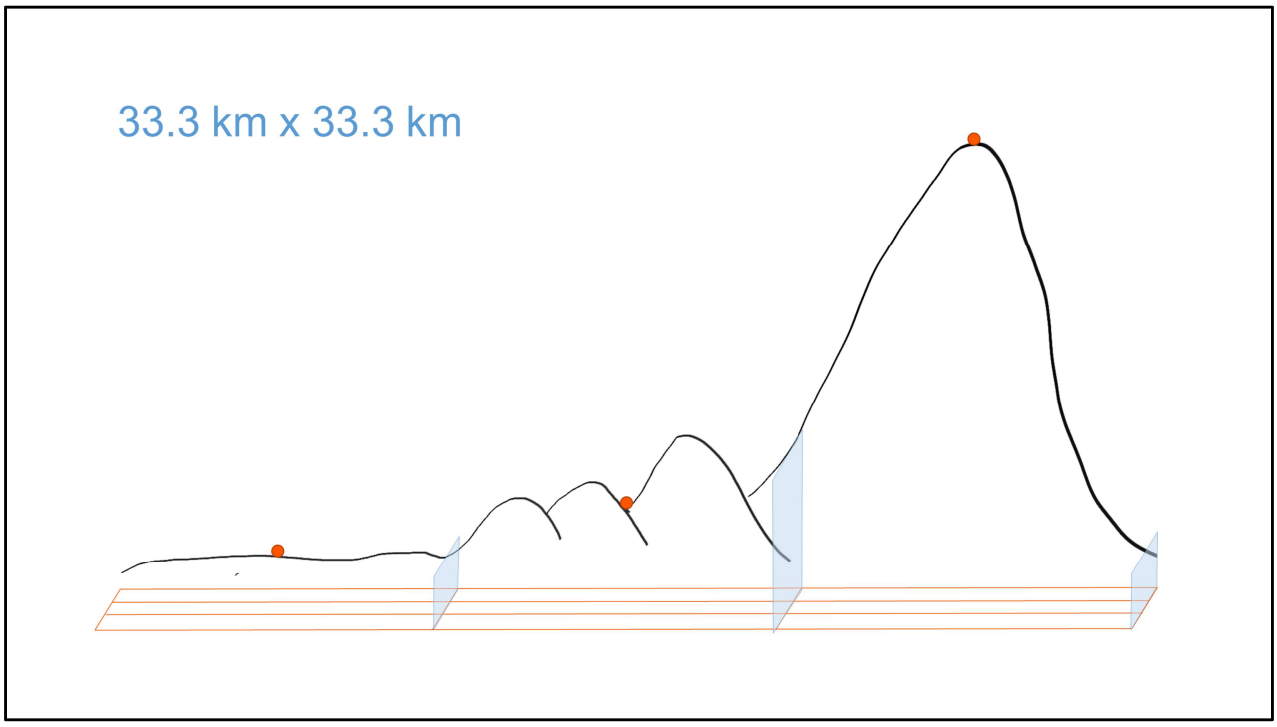
The hills do not represent the Taarai well. And they are very bad at representing the mountains. The top of the mountain is very different from the center point.
But we use one value for everything.



But, if we use a different grid that is 33.3 km by 33.3 km, we can do a lot more.

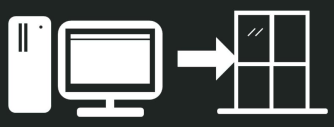


The center is here in the Tarai. This center is here in the hills. And this center is here on the mountain.



Now the grid is so small there is only one land type with a square.

The average of the square is a little better at each location. But the mountains… It's difficult for the mountains. Here on top of the mountain has a very different climate than here at the bottom.



Very good at rates of change

The thing that the models can do best is rates of change.

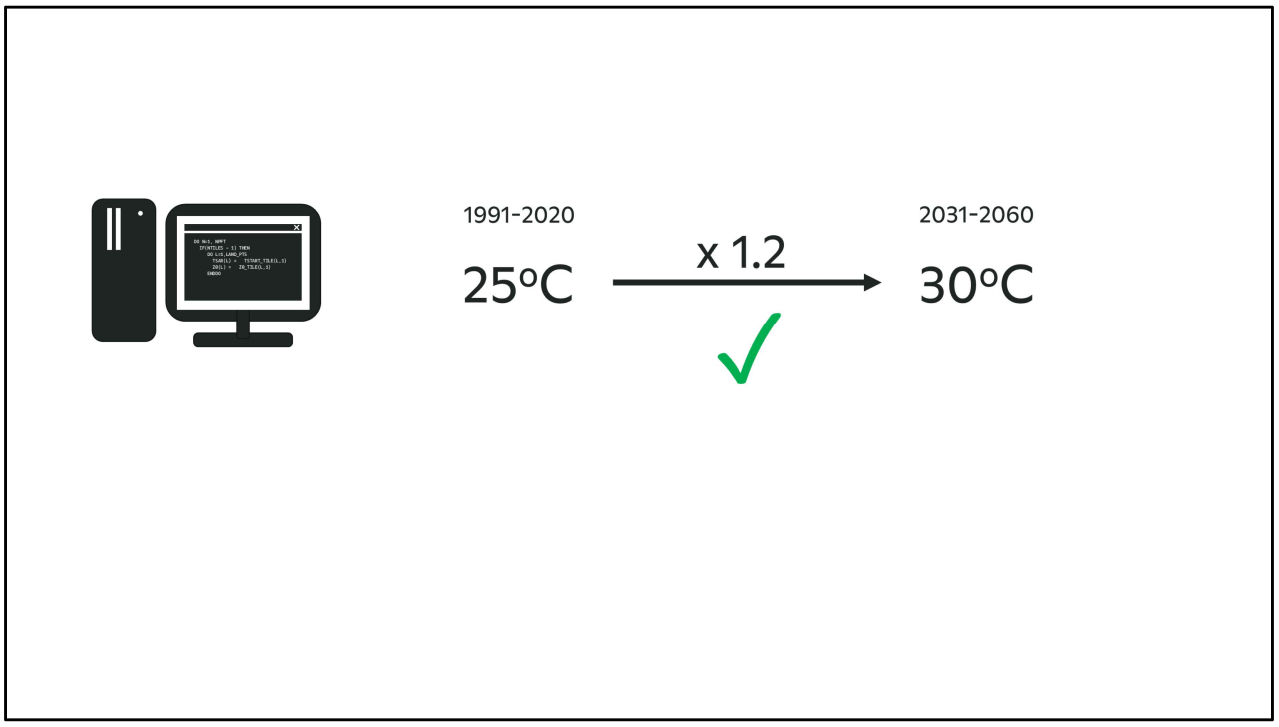
1991-2020

25°C

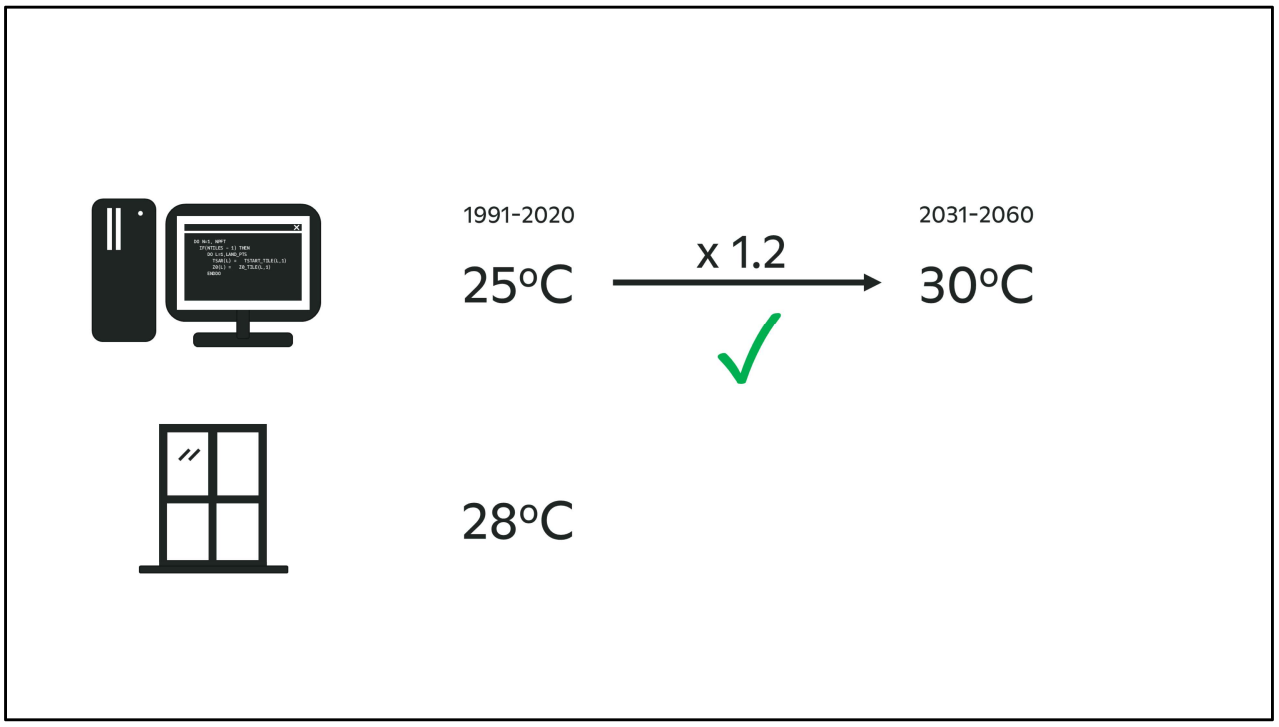
2031-2060

30°C

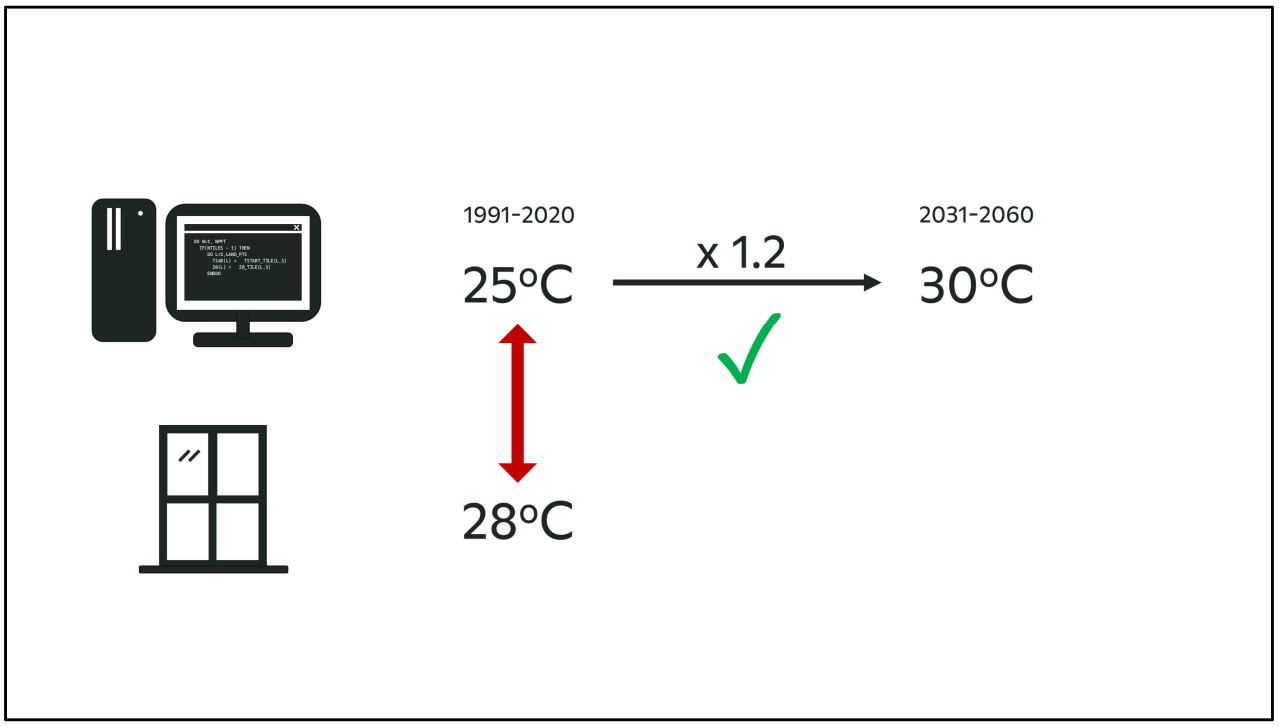
So, the model on the computer is searching for the maximum temperature. The model says, “in these 10 years the maximum temperature is 25°C. And in the future it will be 30°C.”



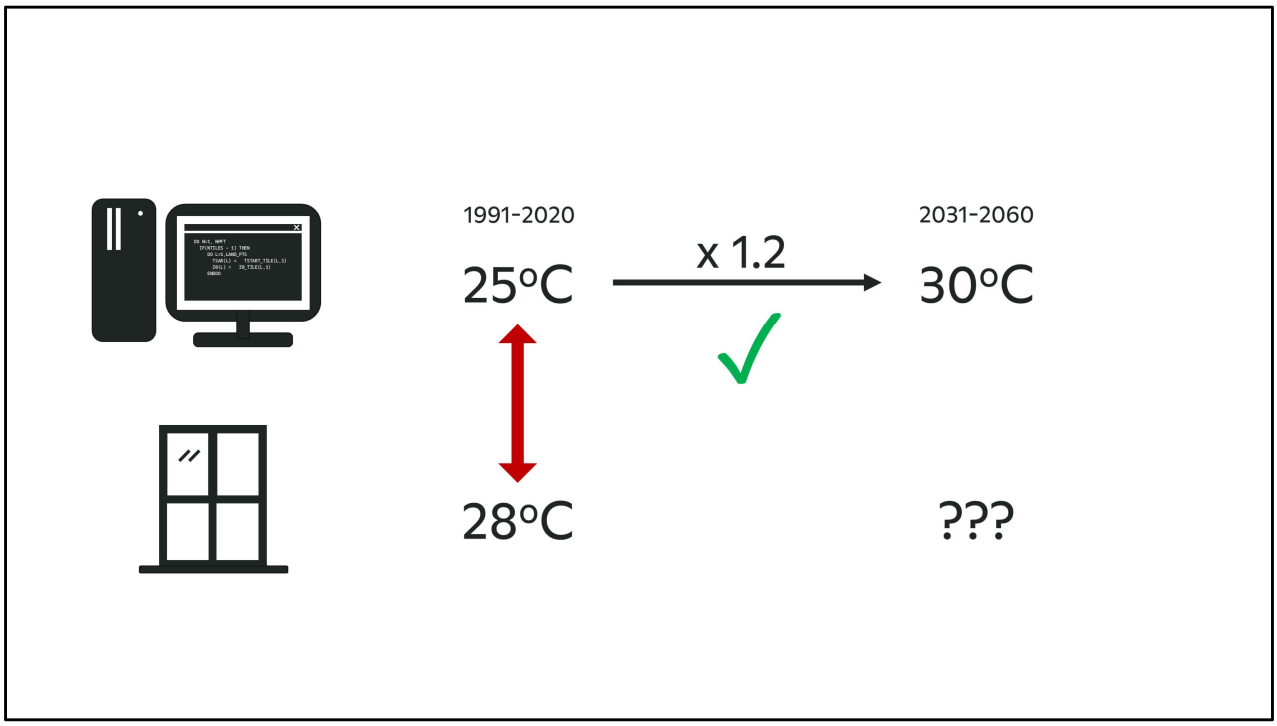
This is a rate of change of 1.2. 25 multiplied by 1.2 is 30. The model is very good at the rate of change.



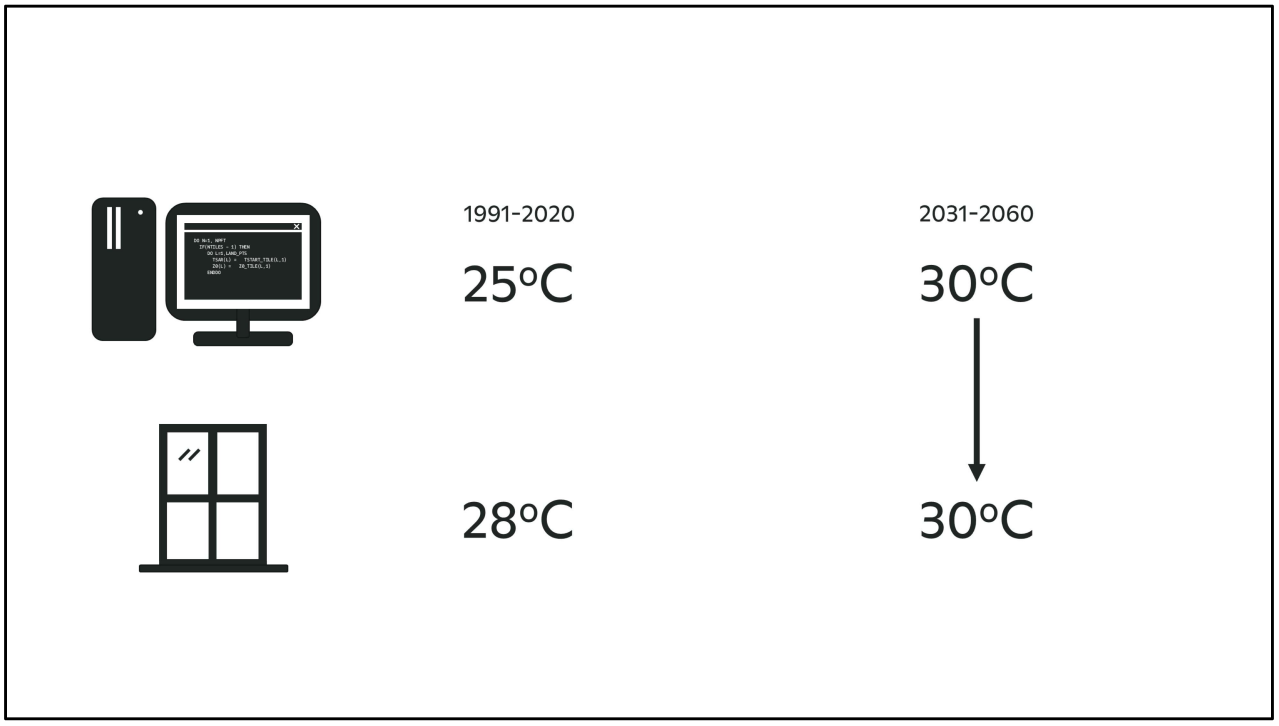
But it is also important to consider real world data, because …



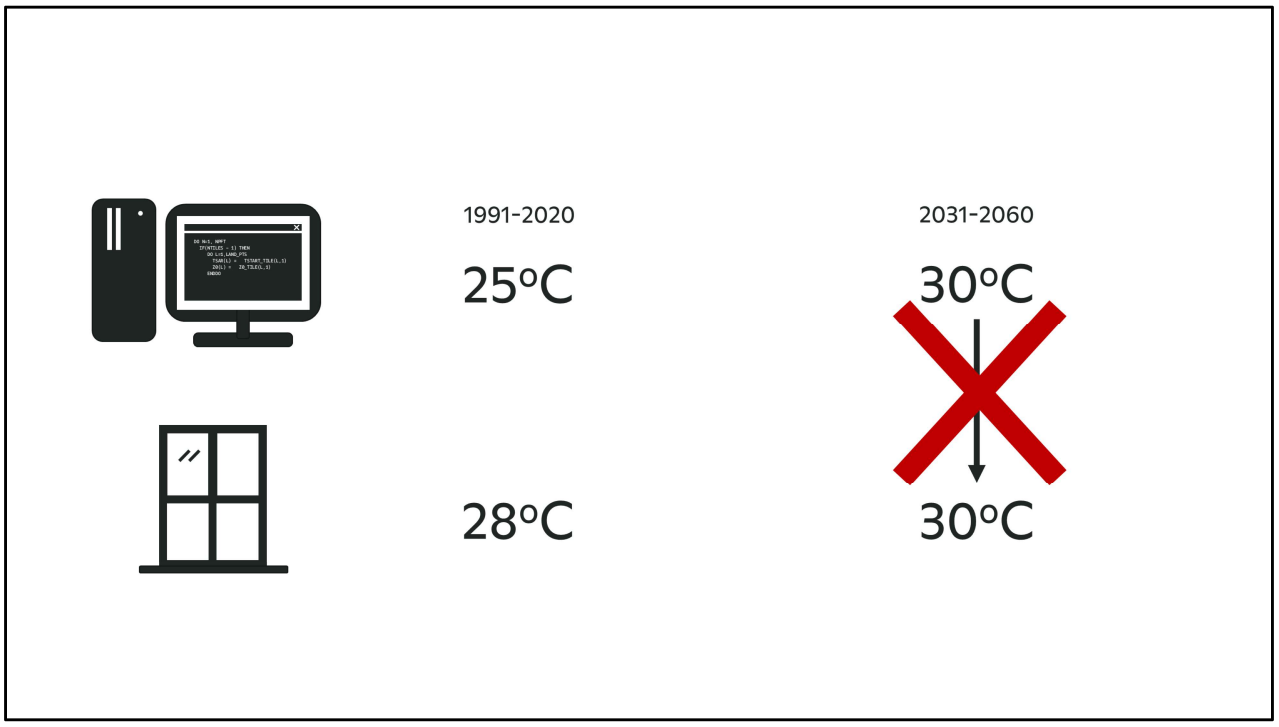
….sometimes the real world data at a specific location does not match the model data. Here it is a little bit hotter



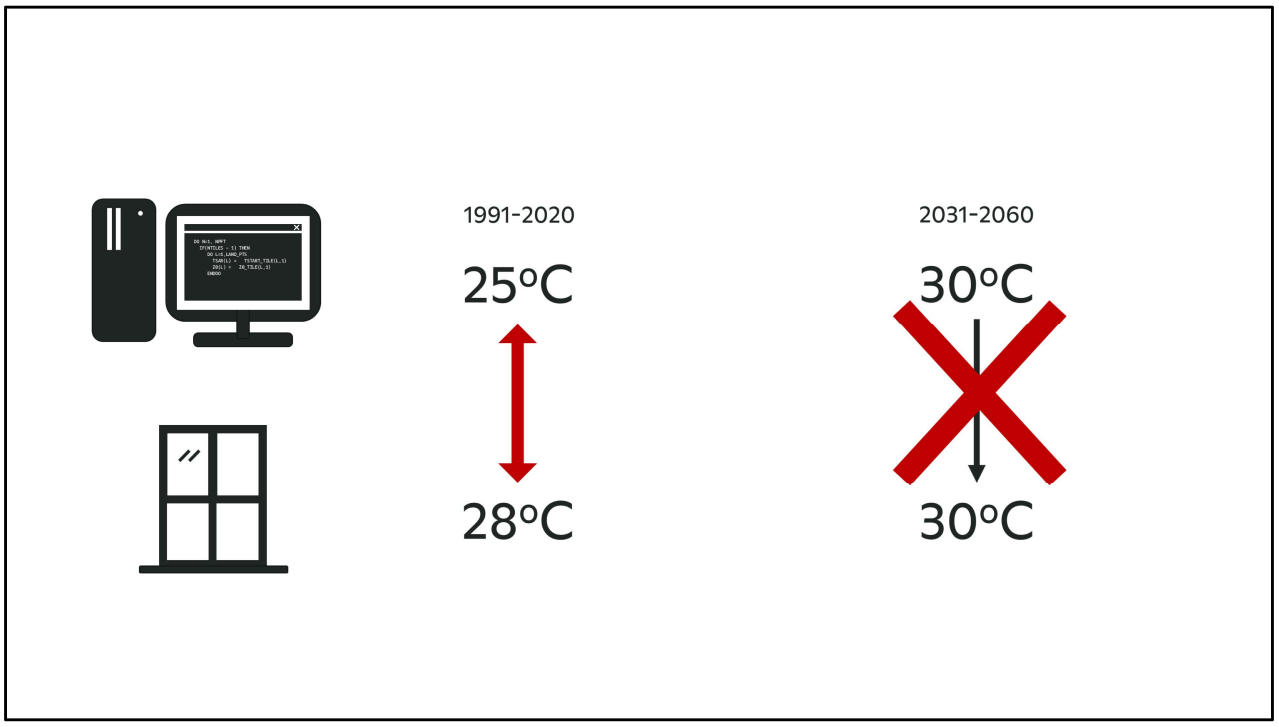
So, how can you predict the real world temperature in the future at this specific location?



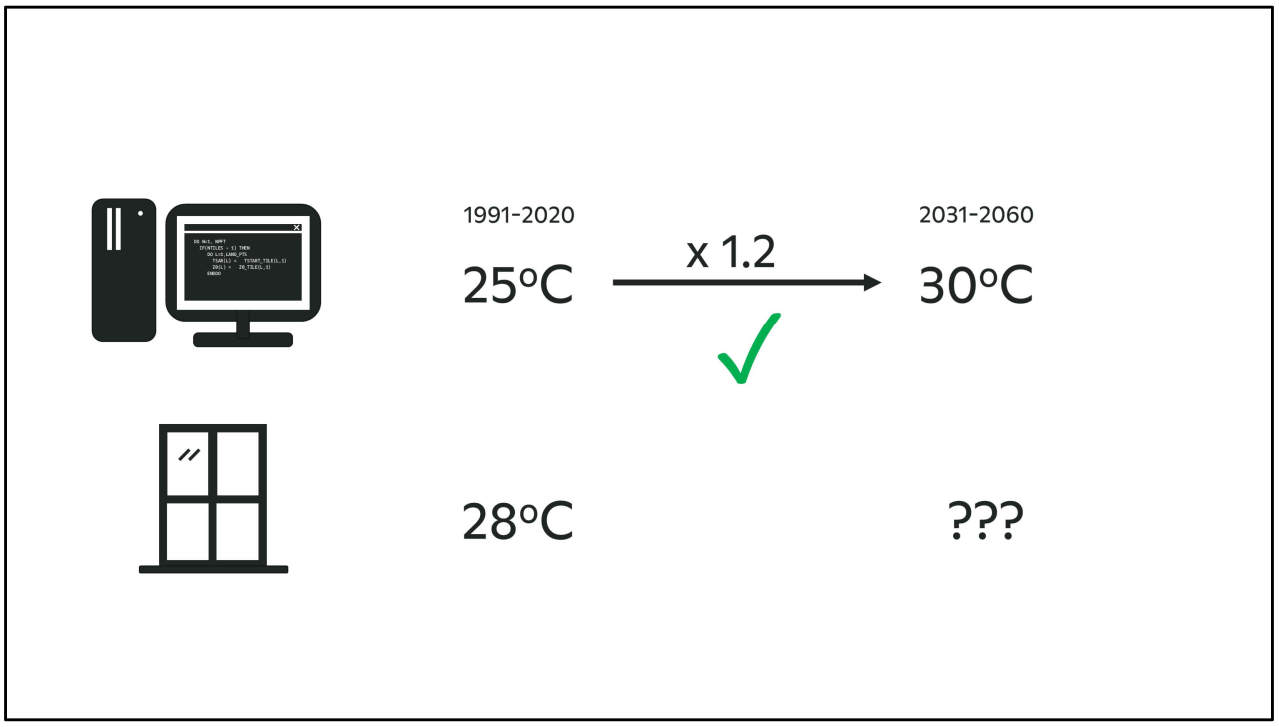
You could just use the model's future value.



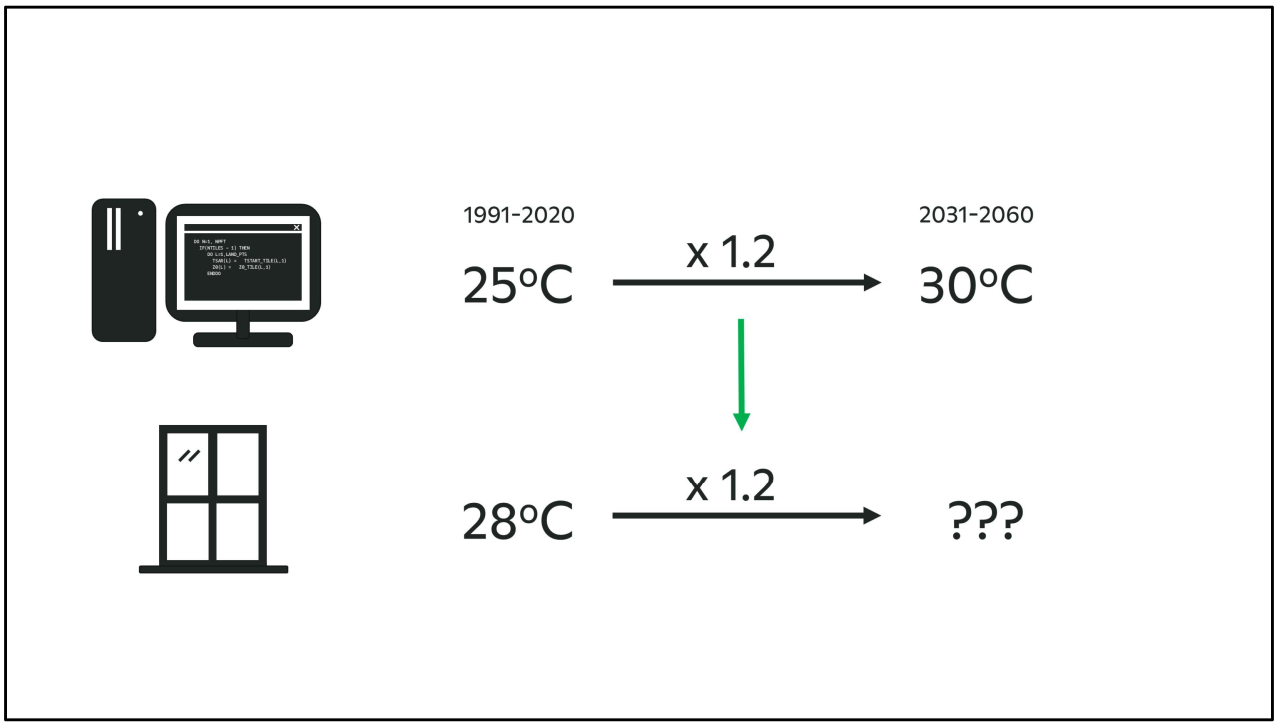
But, that is not a good idea.



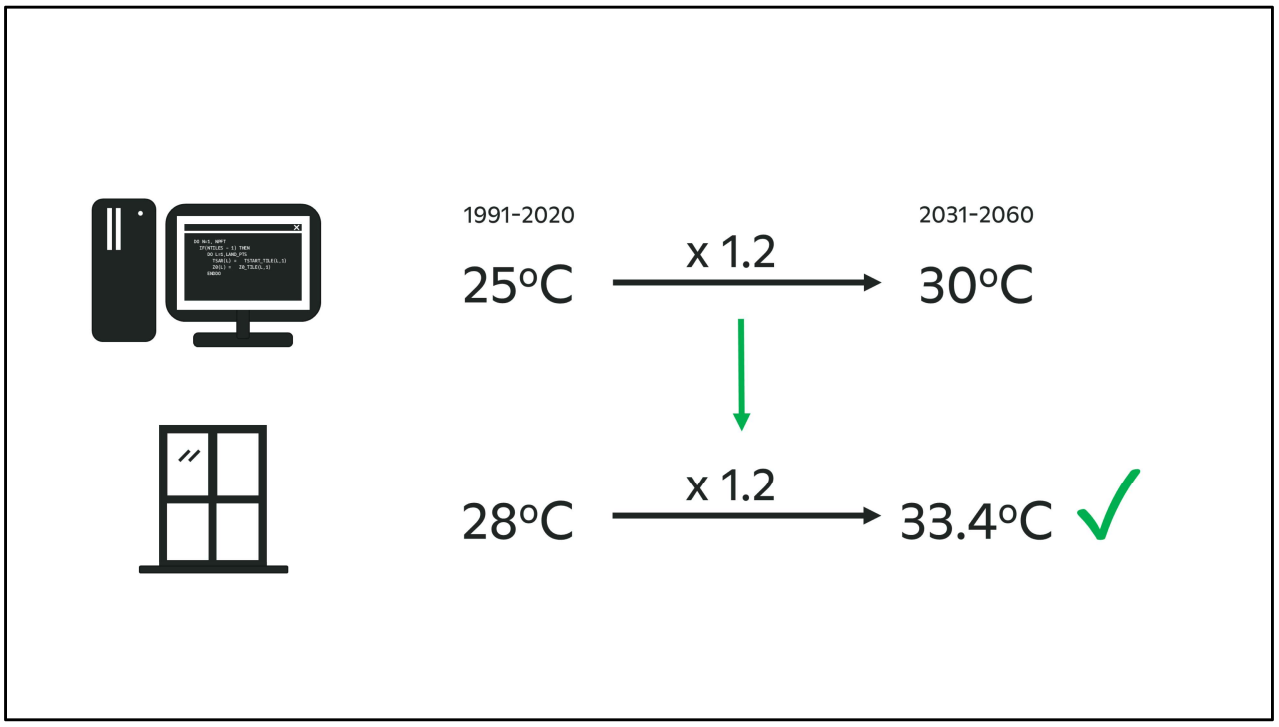
This location was hotter than the model predicted in the past.



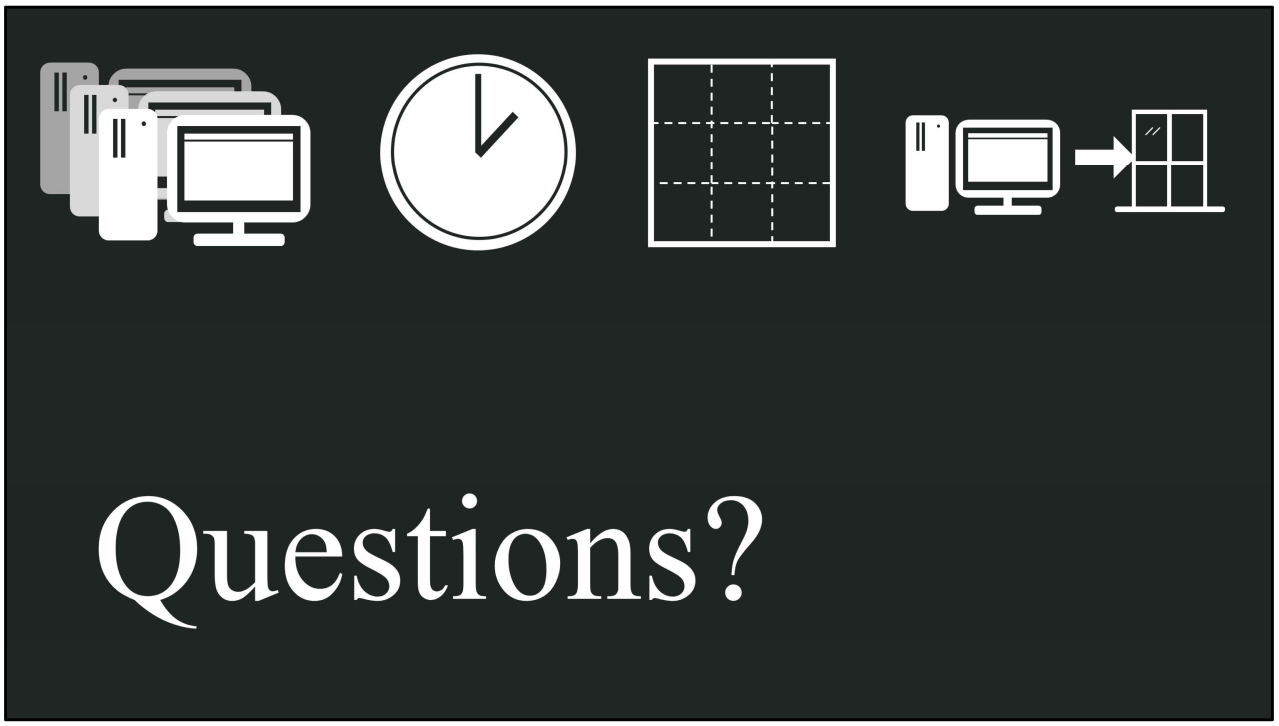
So, you want to use the very good rate of change and



and you want to apply it to the temperature in the observations, the real temperature, ….

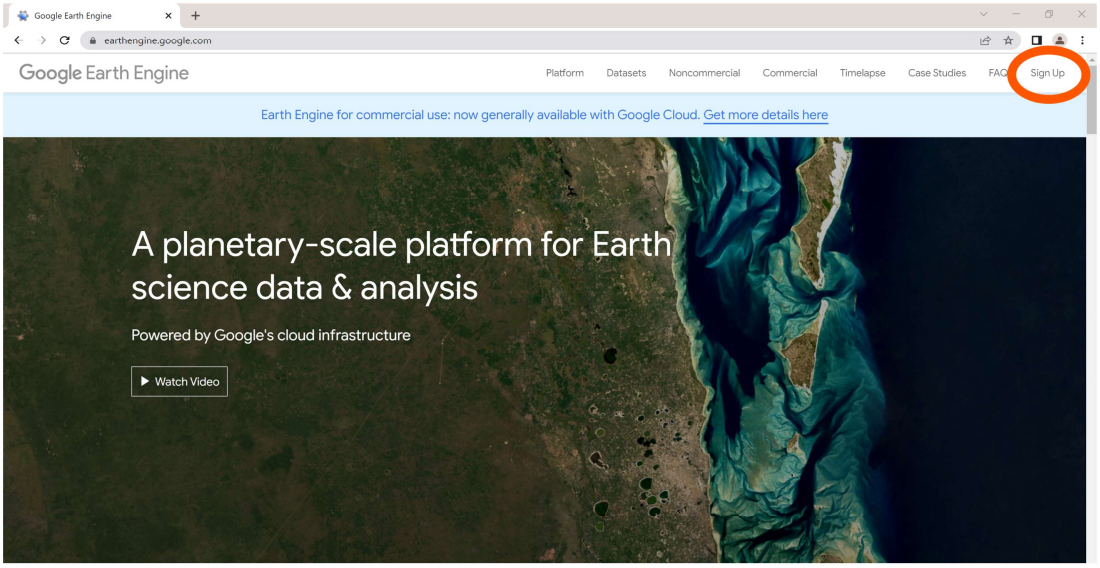


and then you have the real-world temperature in the future for this specific location.

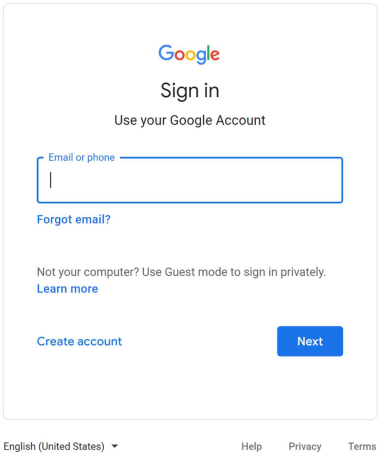

Questions?

Homework:
Technical Sessions ONLY

earthengine.google.com



earthengine.google.com



https://www.linkedin.com/pulse/step-by-step-create-your-google-earth-engine-account-khang-vu-tien