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Why are the Himalayas getting hotter?

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Abstract

Reaching almost nine kilometers (29,000 feet) up into the sky, Mount Everest (Fig.1) is the tallest and most famous mountain in the world. It belongs to a mountain chain called the Himalayas, which sits on the border of several countries in Southeast Asia.

We carried out a study looking at the *climate* of the Himalayas, a neighbouring mountain range (the Karakoram), and the Tibetan Plateau.

We used data from *climate models* to investigate temperature changes, and their relationship to altitude (height above sea level). We found that higher altitudes experienced greater rates of warming, and that the rate of warming is likely to further increase by the end of this century. This could have serious consequences for people around the world.

Figure 1: Mount Everest is so high that its peak is in the Jet Stream! The wind can blow over 160 km/h (100 mph) at the summit. Hold on tight!

Introduction

Mountains are very special environments, providing essential resources such as water for the people that live near them. (See Fig. 2)

But mountains are also particularly sensitive to global climate change, responding faster and more intensely than other regions to climatic and other environmental changes.

We wanted to study a phenomenon called *elevation-dependent warming (EDW)*, where climate warming rates are greater in high-altitude regions. This causes mountains to experience faster and more intense warming compared to the lower-lying areas, or to global averages.

There are lots of different ways to study EDW, all of which are quite tricky! We analyzed a selection of *global climate models* because they are not affected by many of the problems that observations suffer from, especially in high mountains where sometimes there are no measurements at all. A climate model uses lots of math to simulate how different factors affect the Earth's climate. It can look at historical conditions, or make future projections based on certain assumptions (called *scenarios*).

We used the results from these models to find out:

1. **Did the models show EDW in our study region?**
2. **If so, how much?**
3. **What are the main causes – or "driving factors"?**
4. **Which factors are the most important?**

Please, see Figure 2 on Page 2

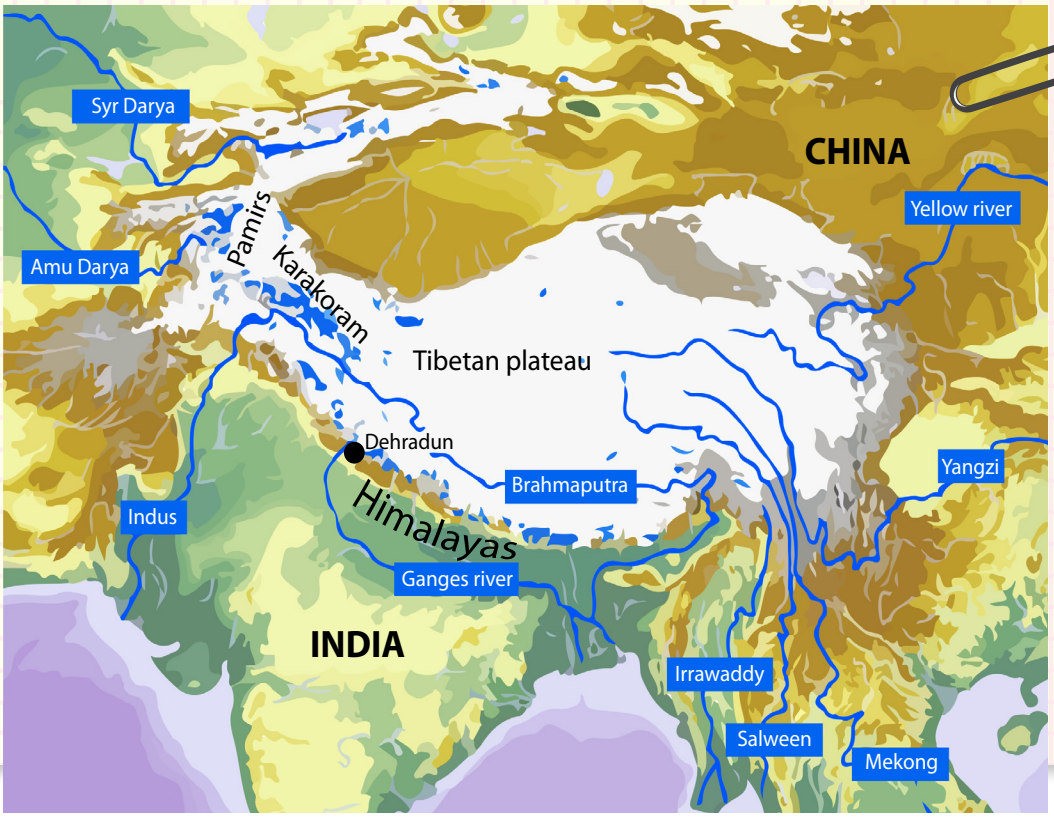


Figure 2: Many people refer to the Himalayas the as "Third Pole" of Earth because they hold the largest amount of snow and ice outside the North and South Poles. This very large reserve of fresh water feeds several of the largest rivers on our planet.

Methods

Our study area covered the Himalayan Mountains, a neighbouring mountain range called the Karakoram, and the Tibetan Plateau (Fig. 2). This was a larger area than in previous studies, and included more lower-lying regions.

We analyzed data from 27 climate models. Each of them provided the right set of *variables* (the changing elements of the models) to allow us to study EDW. The main variables that we focused on were:

- *surface albedo*, which is a measure of how reflective the Earth's surface is to the sun's radiation
- *surface downwelling thermal radiation*
- *near-surface specific humidity* (see Glossary).

We looked at historical simulations (from 1870 to 2005) and future projections (from 2006 to 2100) for one *carbon emissions scenario*.

To measure warming at different altitudes, we calculated the changes in the minimum and maximum temperatures for the following periods:

- 1871–1900 compared to 1971–2000 (historical changes)
- 1971–2000 compared to 2071–2100 (future changes based on the carbon emissions scenario).

We then looked into what was causing EDW in the Tibetan Plateau, Karakoram and Himalayas. We did some math to assess the importance of each of the main variables and of their combined action (the climate system is very complex and everything is interconnected!) in causing temperature changes.

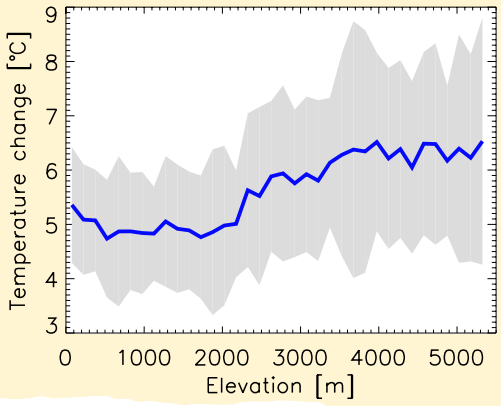
Results

We found increased rates of warming at higher elevations in the region. This was both in historical simulations and in future projections. This EDW was greater in the future simulations. This trend was particularly strong for the minimum temperatures in winter and spring (Fig. 3), and for the maximum temperatures in summer and autumn. All results were *statistically significant*.

In most cases the rate of warming changed sharply from the lower regions, with temperatures above the freezing point of water, to the higher regions, with temperatures below freezing. (As you know, the higher you go on a mountain, the colder the air is.) This means that we found a *non-linear relationship* between the warming rates and the elevation.

Figure 3:
Temperature change between future climate (the 2071-2100 period) and past climate (the 1971-2000 period), in relation to surface elevation (in winter). Different models make different predictions, but they are all within the shaded gray area.
The blue line is the average of all models.

X axis = surface elevation (from low-lying land to high-altitude mountains)
Y axis = temperature change between the two periods
Blue line = average daily minimum near surface air temperature
Grey area = range of model uncertainty



How much greater warming do the models predict at high elevation than at sea level?

Discussion

The non-linear relationship between warming rates and elevation suggests that the *phase of water* and the amount of snow or ice are particularly important in EDW. Snow and ice affect surface albedo. We found that this variable was the leading *driver* of change.

We recommend more research into other possible drivers for EDW, such as aerosol particles (tiny solid or liquid particles suspended in the air) or clouds. We also think that it is important to understand how different drivers work together to affect warming rates.

Mountain regions are very complex, and we need to understand much more about them because of the important local and global impacts that warming in these areas can have.

If the global carbon in the atmosphere continue to increase as in the projections we used, then we predict that the phenomenon of enhanced warming at higher elevations is going to become greater over this century.

This increased rate of warming in the mountains could have serious consequences for high-altitude *ecosystems*. These include melting glaciers and loss of *biodiversity* (the variety of different plants and animals). Reduced glacier water recharge for the major rivers will also have serious consequences for all of human society. What happens in the mountains does not stay in the mountains!

Conclusion

The Himalayas are so far away and so huge in scale that it's hard to imagine how making changes in our own lives could ever make a difference there. But remember that climate change is a global phenomenon! And each of us has a small, but vital part to play.

By choosing to live a greener life, you can help to slow down the rate of global temperature increase. This could include buying less things (as carbon is emitted to make and transport goods to stores), walking more and using the car less, and getting your parents to use renewable energy suppliers for your home electricity.

Glossary of Key Terms

Climate – the collection of weather conditions in a specific region over a long period of time (at least 30 years).

Climate model (aka Global Climate Model) – a mathematical computer simulation of the processes occurring in the atmosphere, oceans, land surface and ice and of their interactions. Models are used to study the dynamics of the climate system and to make projections of future climate.

Carbon emissions scenario – a prediction of the amount of carbon dioxide gas that will be present in our atmosphere by the end of the century, based on estimated future carbon emissions. One global climate model can test multiple carbon emissions scenarios, each based on different assumptions about the future.

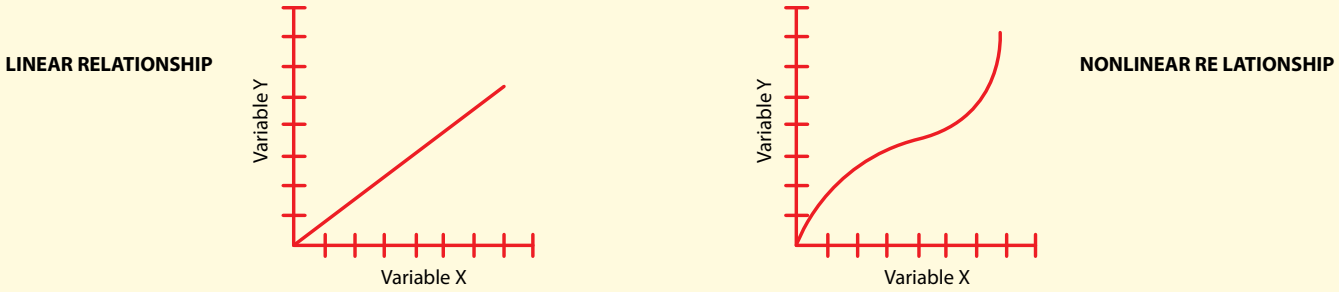
Driver – a factor, or variable that causes the thing that we're studying to change (in our study, this was elevation dependent warming, or EDW).

Ecosystem – a biological community of interacting organisms and their physical environment.

Elevation-dependent warming (EDW) – a tendency of high-altitude regions (e.g. mountains) to experience faster and more intense warming compared to the lower-lying areas, or to the global average.

Near-surface specific humidity – the fraction of the mass of water vapor within a mass of air near to the Earth's surface.

Non-linear relationship between two variables – when a given increase in one variable (*x*, or the independent variable) does not always correspond to a constant increase in the other variable (*y*, or the dependent variable), for all possible values of *x*. The graph of this relationship will be a curve instead of a straight line (as is the case in *linear* relationships).



Phases of water – water can exist in three phases. As a solid (in the form of ice or snow), a liquid (as we know it best!), and a gas (we call this water vapor). It changes from one "phase" to another at different temperatures and pressures.

Scenario - see *Carbon emissions scenario*

Statistically significant – a result that is likely not due to chance, but rather due to a real process. Scientists often define a result as "significant" if it would happen by chance less than 5% of the time (shown as $p < 0.05$). The more significant a result is, the lower its *p* value.

Surface albedo – the fraction of solar energy (shortwave radiation) reflected from the Earth back into space. It is a measure of the reflectivity of the earth's surface. Ice, especially with snow on top of it, has a high albedo: most of the sunlight hitting the surface bounces back towards space. Water, rock, or other dark surfaces have a low albedo: most of the sunlight hitting the surface is absorbed.

Surface downwelling thermal radiation – a measure of the heat radiation emitted by the atmosphere towards the Earth's surface.

Variable – in scientific or mathematical models, a variable is a factor whose value may vary (e.g. average air temperature, amount of solar radiation etc).

Weather – the short-term (up to about one week) atmospheric conditions (temperature, amount of rain or snow, windiness, etc.) in a specific region.

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Check your understanding

1 What effect might the increased temperatures in the high altitudes of the Himalayas have on the surrounding countries?

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2 What are the most important mountain ranges in the US? What possible effects do you think that EDW could have on the US?

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3 In our conclusions, we mentioned some things that you could do to help reduce carbon emissions. Can you think of any others? What's the one thing that you think you could do that would have the biggest impact?

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4 Many children live among the Himalayan Mountains, going to school, playing, and working more than 3 miles above sea level. What do you think life would be like for those children? How do you think it would differ to your own life?