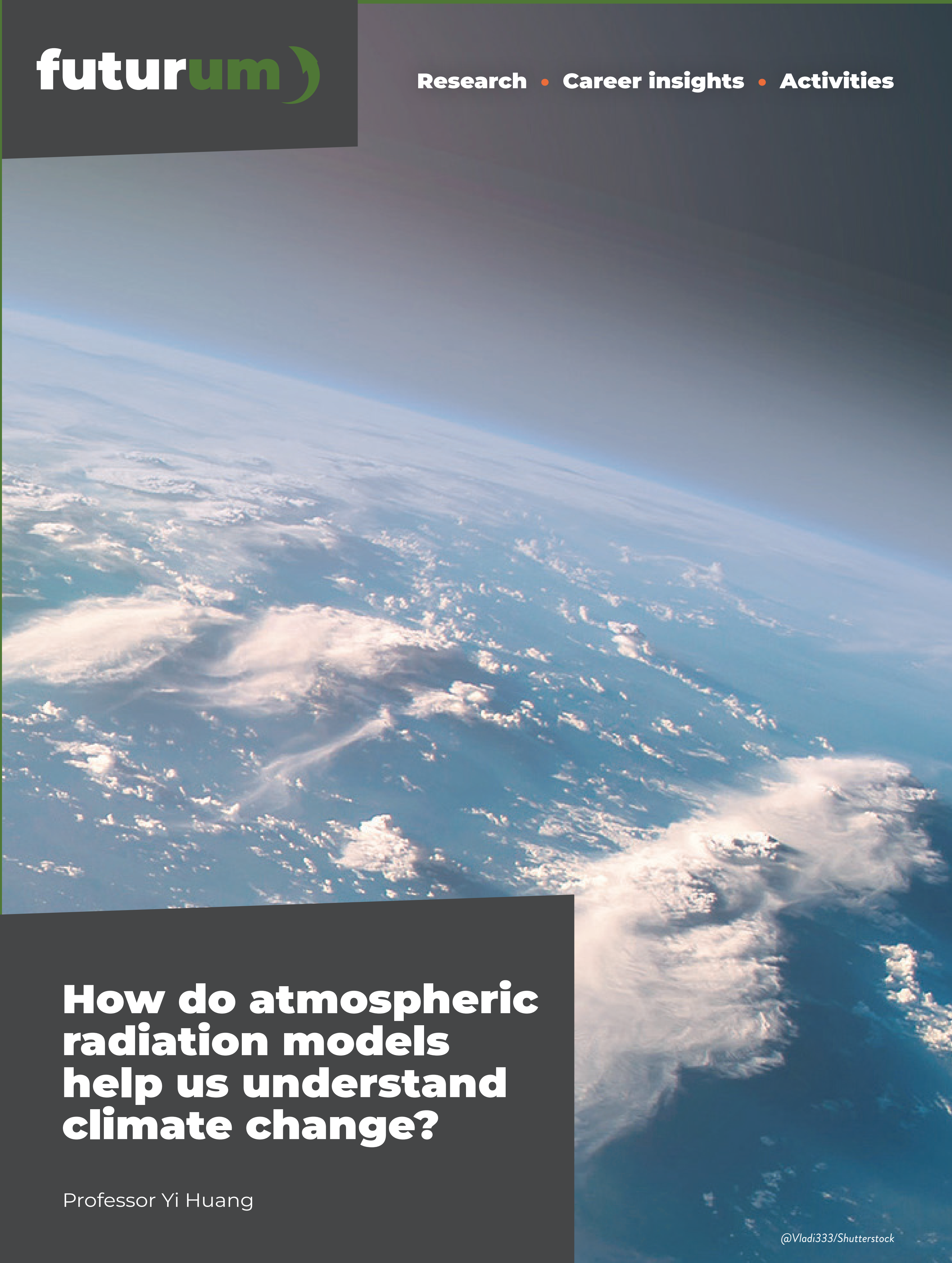

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How do atmospheric radiation models help us understand climate change?

Professor Yi Huang

How do atmospheric radiation models help us understand climate change?

Our atmosphere is dynamic and ever-changing, constantly balancing incoming radiation from the Sun and outgoing thermal radiation emitted by the Earth. The balancing of this atmospheric radiation shapes our climate and impacts global weather patterns. **Professor Yi Huang**, a physical climatologist from **McGill University** in Canada, is studying atmospheric radiation to better understand how changes in our atmosphere contribute to climate change.

Professor Yi Huang

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Fields of research
Physical climatology, atmospheric radiation

Research project
Modelling atmospheric radiation and greenhouse gases to understand their impact on climate change

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Talk like a ...

physical climatologist

Atmospheric emitted radiance interferometer (AERI) — a specialised instrument used to measure the energy emitted from the Earth's atmosphere. It helps scientists collect data on atmospheric radiation, which is crucial for understanding climate patterns

Atmospheric radiation — energy that moves through our atmosphere, originating from both the Sun (in the form of photons) and the Earth (in the form of thermal infrared radiation), and influences the planet's climate and weather systems

Greenhouse gases — gases, including carbon dioxide, methane and water vapor, that trap heat in the Earth's atmosphere and contribute to global warming

Outgoing longwave radiation (OLR) — heat energy emitted by the Earth as infrared radiation

Low-level clouds — clouds that form near the Earth's surface and play a role in regulating temperature by reflecting sunlight and trapping heat

All that separates our planet from the cold expanse of space is a thin strip of air that we call the atmosphere. This blanket of gases protects us from harmful ultraviolet radiation and keeps our planet warm and our climate stable, allowing life to flourish. However, our atmosphere is in constant flux as energy pours down from the Sun and rises up from the Earth.

"This energy, known as atmospheric radiation, plays a key role in shaping our weather and climate," says Professor Yi Huang from McGill University. "It influences everything from daily weather patterns, like afternoon thunderstorms, to larger changes, such as the shifting seasons and global warming."

When the incoming solar radiation and outgoing terrestrial radiation are balanced, Earth remains at a comfortable temperature. "However, too much trapped heat — caused by greenhouse gases — can lead to climate change, affecting our environment and weather patterns," continues Yi. "Understanding atmospheric radiation helps us see how our actions impact the planet and what we can do to protect it."

Cloud control
Clouds help to maintain the balance of atmospheric radiation by reflecting energy from the sun and trapping heat produced by the Earth. However,

A field team launching a weather balloon to take measurements in the atmosphere.

as greenhouse gases continue to warm our climate, cloud formation patterns are beginning to change, with some places experiencing fewer low-level clouds.

"We found that when there are fewer low-level clouds, this can partly cancel out the warming effect caused by more greenhouse gases[1]," explains Yi. By analysing years of data from a specialised instrument called an atmospheric emitted radiance interferometer (AERI), the team observed that as cloud cover decreases, more heat escapes into space, cooling the surrounding air.

Although this 'balancing act' was unexpected, it will not protect our planet from large-scale global warming. However, this discovery will help researchers like Yi improve the accuracy of the climate models and simulations that they use to study climate change. "Most importantly, it highlights the need for continuous, detailed measurements of Earth's atmosphere," says Yi. "This will help us improve our predictions and understand how natural processes interact with human-driven climate change."

An Arctic outlet

"As the Earth absorbs sunlight, it warms up and then 'cools off' by radiating heat back into space," says Yi. "This energy, emitted from the Earth as infrared light, is called outgoing longwave radiation (OLR)." The amount of OLR varies from region to region. "For example, the Arctic has drier air than most regions," explains Yi. "With less moisture to trap the heat, more of the Earth's surface radiation escapes into space here than in other regions[2]."

This outlet of OLR changes how energy is spread around the planet and affects the Earth's energy budget. "The Earth's energy budget is the balance between the energy it gets from the Sun and the energy it sends out into space," explains Yi. "So, when heat escapes from the Arctic, more energy must be moved from the tropics to make up for it, altering atmospheric circulation and impacting global climate patterns."

As global warming continues to heat the planet, the amount of water vapour in Arctic air may increase, preventing as much OLR from being released into space. "If the Arctic continues to warm and its air becomes more moist, its ability to cycle heat out by the means of OLR may be reduced," says Yi. "New satellites, such as the Canadian HAWC (High-altitude Aerosols, Water Vapour and Clouds), are being developed to monitor this important aspect of climate change."

How to study the atmosphere

Yi and his team use computer models to simulate how radiation moves through the atmosphere. "To validate these models, we use observational data acquired from spaceborne satellites and ground-based instruments," says Yi. "For example, we use AERIs to measure atmospheric radiation from the ground, and we collaborate with other researchers to develop and deploy new satellite instruments." To analyse these data, Yi's team uses analytical techniques such as machine learning methods powered by artificial intelligence.

Collecting, analysing and modelling these data is a highly collaborative effort that often involves international collaborations. For example, Yi and his team were recently involved in the WHAFFFERS Campaign. "This was a month-long field study that took place in McGill University's Gault Reserve at the start of 2025," says Yi. "Scientists from Canada, the UK, the US and Italy teamed up to measure atmospheric radiation using some of the most advanced instruments being developed for next-generation satellites." These instruments measure critical factors like cloud cover, air temperature and atmospheric radiation, helping researchers gain deeper insights into the atmosphere's behaviour.

Yi also leads the GHG-Montreal Project, which studies greenhouse gases such as methane and carbon dioxide in Montreal, a city with high greenhouse gas emissions due to human activities. Researchers are mapping the sources of these gases, tracking how their levels change and studying how they move through the atmosphere using sensors on the ground and in the air. "By developing new remote sensing techniques, the project also aims to establish new methods for more complete and efficient monitoring of greenhouse gases at the city level," says Yi.

Both of these projects focus on collecting real-world data to better understand atmospheric processes and the impact of human activities on the climate. "Our team develops new technologies to better observe the greenhouse gases that drive climate change," says Yi. "Understanding how these gases are distributed and changing is indispensable for developing and verifying climate change mitigation methods."

1 doi.org/10.1038/s41586-024-08323-x
2 iopscience.iop.org/article/10.1088/1748-9326/ad3e17

About *physical climatology*

Physical climatology is a branch of atmospheric science that focuses on understanding the physical processes driving the Earth's climate. "Unlike other areas of climatology, which may study climate patterns or social impacts, physical climatology uses physical equations to simulate and predict how our climate changes in a quantitative way," says Yi. More specifically, it combines theories from physics, mathematics and environmental science to tackle real-world problems like global warming, extreme weather events and long-term climate trends.

One of the unique aspects of physical climatology is that it is both abstract and tangible. "The mathematical equations are quite abstract, but they connect to and explain the real world and its practical problems," says Yi. For instance, scientists use these models to understand how changes in atmospheric radiation, cloud cover or greenhouse gas emissions might impact Earth's overall energy balance and climate patterns. This makes the field both intellectually challenging and practically impactful, as it directly contributes to solutions for major global issues.

However, the field isn't without its challenges. "It requires both mathematical skills and physical knowledge to be able to devise and test theories," says Yi. Additionally, the process of developing the instruments used for climate studies is long and requires patience. But the rewards are significant – physical climatologists play a crucial role in understanding the planet's future and helping society prepare for climate change.

Pathway from school to *physical climatology*

"If you are interested in pursuing a career in physical climatology, follow your heart and begin with the basics – mathematics, physics and computer programming," says Yi. "When you're ready, the opportunities will find you."

"A recipe to become a good physical climatologist is to study mathematics and physics in high school and college and then to develop data analytics and instrumentation skills through research projects in graduate school," says Yi. "The best training opportunities are with the research groups that lead exciting projects."

Explore careers in *physical climatology*

To learn more about physical climatology, explore the following organisations, which offer educational resources, careers advice and research opportunities: the Canadian Meteorological and Oceanographic Society (**cmos.ca**), the American Meteorological Society (**ametsoc.org/ams**), the European Geosciences Union (**egu.eu**) and the European Meteorological Society (**emetsoc.org**).

"The Department of Atmospheric and Oceanic Sciences at McGill University hosts annual open house events for high school and college students," says Yi. "The Faculty of Science at McGill also organise such events as **Soup and Science** to introduce cutting-edge research to the general public."

Outside of academia, there are also opportunities in the weather and consulting sectors. Many companies involved in meteorology, environmental consulting and climate prediction are willing to hire people with a strong background in physical climatology, as well as analytical skills in data handling and mathematical modelling.

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Meet *Yi*

I was interested in everything when I was younger, and I tried many different fields, including economics, before focusing on physical climatology. It was a lot of trial and error. Don't be afraid of failure when you're young.

I love that my job allows me to learn new things and constantly interests me.

Every new discovery that we make and every new research paper that we publish is a highlight. They keep my energy and curiosity charged up.

I'm proud of my students graduating with PhDs and growing into competent researchers themselves. I hope they become colleagues in future.

Outside of work, I play tennis and ski with my family.

> ***"Every new discovery that we make and every new research paper that we publish is a highlight"***

Yi's *top tip*

Try to identify something you do well, and develop those skills. The better you are at something, the more you'll enjoy it – that positive feedback usually take you to success.

Physical climatology
with Professor Yi Huang

Talking *points*

Knowledge
1. What is atmospheric radiation, and what are its two main sources?
2. What is outgoing longwave radiation (OLR)?

Comprehension
3. Why does the Arctic lose more heat than other regions?
4. How can clouds both warm and cool the Earth's surface?
5. How is Yi's research improving climate change predictions?

Application
6. Imagine you are a climatologist studying greenhouse gases. What tools or methods would you use to measure atmospheric radiation?
7. How could policymakers use the findings from the GHG-Montreal Project to combat climate change?

Analysis
8. Compare the effects of greenhouse gases and low-level clouds on Earth's temperature. How do they interact with each other?
9. Why do scientists use both computer models and real-world measurements when studying climate change?

Evaluation
10. What are the limitations of using computer models to predict climate change, and how can scientists address these challenges? What real-world factors might be difficult to simulate accurately in a climate model, and why?
11. Climate research requires international collaboration. What are the advantages and potential obstacles of global scientific partnerships in studying atmospheric radiation? How can different countries work together more effectively to tackle climate change?

Activity

As atmospheric concentrations of greenhouse gases continue to rise, more and more heat is being trapped within our atmosphere, leading to changes in our climate and weather systems. A report released by the International Panel on Climate Change (IPCC) in 2021 stated that the human-caused rise in greenhouse gases has increased the frequency and intensity of extreme weather events.

Imagine that you are a climate journalist. Using either a piece of writing (e.g., a magazine article or a news report), a video (e.g., a short documentary or news reel) or audio media (e.g., a podcast or a radio feature), report on an extreme weather event from the last five years and explain the link between greenhouse gases and extreme weather.

Think about what you want to tell or show your audience. For example, you could include:
- Details of the extreme weather event
- Real stories from local people and communities
- Reactions from the international community
- Information from Yi's article about the atmosphere and its effect on climate and weather
- Evidence that supports the links between human-caused climate change and extreme weather events
- A call to action e.g., what can your audience do to help?

Think about your role as a journalist and the responsibilities that you have towards your audience. For example, how will you ensure that you are being accurate and representing the truth to the best of your ability? How will you show respect to your audience and the people in your story? Will you remain objective and impartial, or will you express your own views and opinions? Is your aim to inform or entertain?

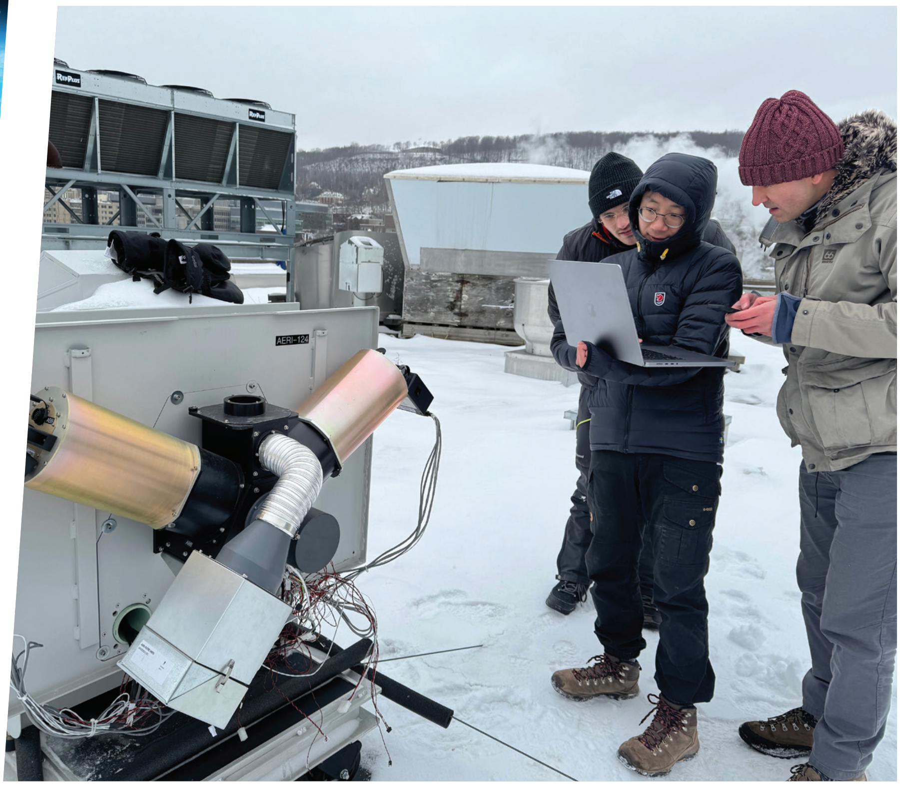
Share your finished piece with your classmates, friends and family, and reflect on how their feedback can help you to become a better journalist.

More *resources*

- Learn more about the WHAFFFERS Campaign (**whafffers.meteo.mcgill.ca**) and the GHG-Montreal Project (**ghg-montreal.meteo.mcgill.ca**)

- Explore NASA's 'vital signs' to see real-life data and annual global trends on greenhouse gas concentrations, global temperature and other climate change effects: **science.nasa.gov/climate-change**

- Watch these TED Talks to learn about some ingenious ways in which scientists are trying to remove greenhouse gases from the atmosphere: **youtube.com/watch?v=T6WSy0FdBdU**, **youtube.com/watch?v=XY_IzonfE3I** and **youtube.com/watch?v=60e6u_1TEls**



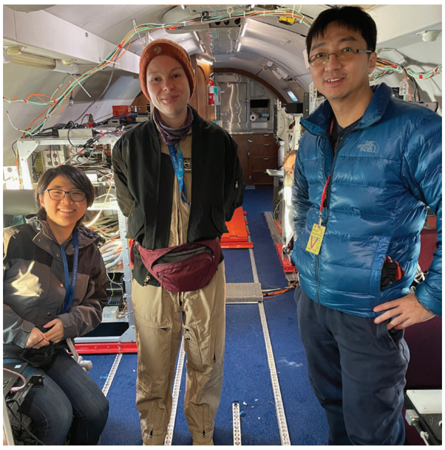


Photo *montage*

Top: *Yi's students working with a collaborator to diagnose an issue with an instrument.*

Middle row: ***Left:*** *A field team launching a weather balloon to take measurements in the atmosphere.*

Centre: *Yi and collaborators on a research flight.*

Right: *Yi and technicians after installing an atmospheric emitted radiance interferometer (AERI).*

Bottom: *Yi and students operating a drone.*

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