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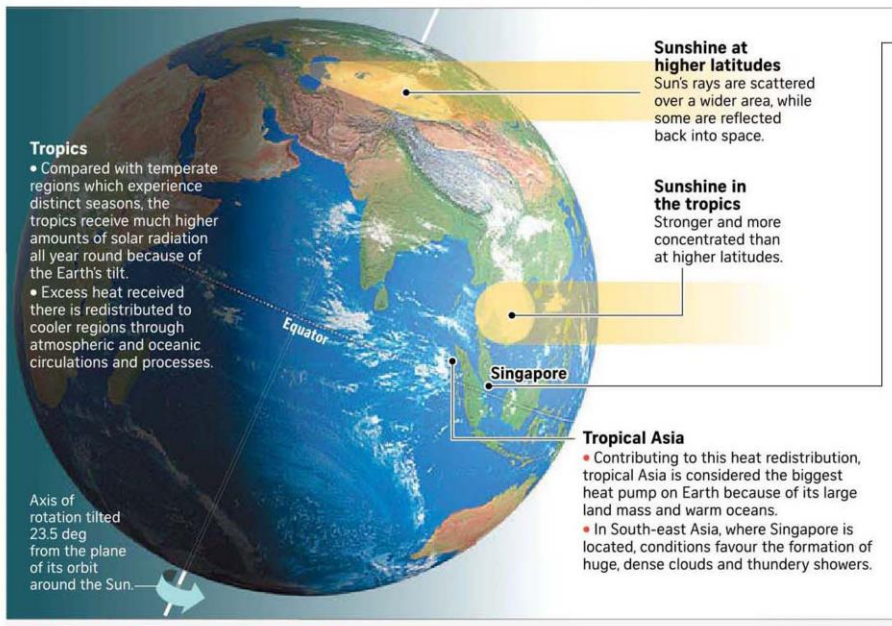
Tropical dilemma

It is sunny all year round in the tropics. But the heat received at the waistline of the planet does not just stay there – it warms up the rest of the planet too. Greenhouse gases are changing the Earth's heat balance. How will the world's heat pump be affected by climate change? **SHABANA BEGUM** delves into the science of tropical weather and the uncertainties that remain.



HOW IS CLIMATE CHANGE AFFECTING SINGAPORE?

Definite indicators

Temperature
- From 1980 to 2020, the annual mean temperature increased from 26.9 deg C to 28 deg C.
- 2010 to 2019 is the hottest decade in Singapore.

Sea-level rise
- Sea levels surrounding the city state are 14cm above pre-1970 levels, the Meteorological Service Singapore assessed last year.

Work in progress

Rainfall
- There is no evidence yet showing how Singapore's rainfall intensity or frequency has been affected by or could be attributed to climate change.
- Rainfall in the tropics is affected by many factors, and scientists are still studying how these could be affected by climate change.
- For instance, on April 17, when flash floods were reported around Singapore, the rain was caused by a Sumatra squall and a typhoon brewing off the Philippines.

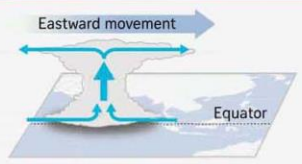

Flash flooding along Boon Lay Way on April 17.

WHAT CAUSES RAIN IN SINGAPORE?

Short-term drivers (hours, days, weeks)

Heating the seas
- Strong sunlight causes seawater to evaporate.
- A lot of moisture is sent to the atmosphere, fuelling rain clouds.

Sumatra squall
- An organised line of thunderstorms that develops over Indonesia's Sumatra island before sweeping eastward over Singapore.



The Madden-Julian Oscillation (MJO)
- A band of rain clouds typically developing in the Indian Ocean that travels eastward around the Equator every 30 to 60 days, like a cyclist pedalling across a stage.
- When it makes an appearance in Singapore (active phase), it brings clouds and rainfall from west to east.
- After it passes by and the MJO is in its dry phase, warmer and drier conditions can occur.

Monsoon surges
- This usually happens when the northern hemisphere is experiencing winter.
- Cold winds from the north sweep over the South China Sea, which heats up the air parcel and feeds it with moisture, leading to the formation of dense rain clouds over the western Pacific equatorial region.
- Singapore experiences two to four monsoon surges each year. Each event can last between one and five days.

Long-term drivers (months)

El Nino Southern Oscillation
- There are three phases to this climate phenomenon: El Nino, which brings drier and hotter weather here, La Nina, which brings rain, and a neutral phase which does not show any preference either way.
- The shifts in these phases are caused by changes in sea surface temperatures and the corresponding atmospheric pressure and winds in the tropical Pacific Ocean.
- Singapore experienced La Nina conditions between the third quarter of last year and May this year.

North-east monsoon
- From November to March.
- There are two phases to this monsoon season. In its wet phase, from November to January, widespread, continuous moderate to heavy rain is expected over Singapore.
- In its dry phase, which extends to March, drier conditions are expected.

South-west monsoon
- From June to September.
- Winds typically blow from the south-east or south for Singapore, and rainfall is generally sporadic.
- Because of drier conditions in South-east Asia, forest fires in the region tend to burn harder and for longer. Singapore usually experiences haze during this season.


The Bukit Panjang area shrouded in haze on Sept 23, 2019.

Sources: DR AUREL MOISE, METEOROLOGICAL SERVICE SINGAPORE, ASSOCIATE PROFESSOR KOH TIEH YONG, THE NATIONAL CLIMATE CHANGE SECRETARIAT, ST FILE PHOTOS: LIANHE ZAOBAO, ST FILE STRAITS TIMES GRAPHICS

S'pore making own 'crystal ball' for climate projection

Global climate models unable to cater to needs of small countries

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Singapore is building up its arsenal of weapons to help it better deal with the effects of climate change.

Other than protecting its coastlines and weather-proofing its food and fresh water production, the Republic is also honing another skill: the ability to see the future.

In broad strokes, the effects of planetary warming are clear.

Global temperatures and sea levels are rising, certain extreme weather events could intensify, and rainfall patterns could become more erratic.

But at a finer resolution, many questions remain about how these changes would manifest in Singapore and South-east Asia.

For instance, how fast would sea levels rise around the city state, and how high could the waters go? If rainfall patterns change, would the country experience more droughts or flash floods?

These are questions that scientists at the Centre for Climate Research Singapore (CCRS) – a division under the National Environment Agency's Meteorological Service Singapore – are looking into.

The aim is to provide some answers to these questions in the Republic's third national climate change study, which is expected to be published at the end of next year, Dr Aurel Moise, head of the climate research department at CCRS, told The Straits Times.

Currently, climate projections used in global reports such as those by the Intergovernmental Panel on Climate Change are made using global climate models – a climate scientist's "crystal ball" to see into the future.

These models simulate the physics, chemistry and biogeochemistry of the atmosphere, land and oceans in great detail, and require supercomputers to generate their climate projections. Mathematical equations are used to characterise how energy and matter interact in different parts of the ocean, atmosphere and land.

This allows scientists to model how the earth system responds to changes in, say, the amount of planet-warming emissions that mankind releases into the atmosphere.

Based on these changes, the models project how parameters such as temperature, rainfall, sea levels or tropical cyclone activity will be affected.

But gazing into this crystal ball is not easy for a tiny country.

For one thing, tiny Singapore is barely on the radar of these global models, so to speak.

In these models, the planet's surface is represented in a three-dimensional set of grid cells.

The size of the grid cells defines the resolution of the model. Similar to how smaller "nano bricks" can build more detailed 3D models than larger Lego bricks, smaller grid cells allow higher levels of detail in the model.

Models with more grid cells need more computing power.

In global models, each grid cell usually spans between 70km and 250km. But Singapore is only about 45km long at its widest.

As a result, Singapore appears as just one grid point or not at all in these models, said Associate Professor Koh Tieh Yong, a weather and climate scientist at the Singapore University of Social Sciences.

With just one grid point or less, it is not possible to model the small-scale storms that develop within the island of Singapore, he said. Yet these storms are responsible for a significant fraction of flash floods or wind damage every year.

Prof Koh said this lack of resolution also means that the coastlines and mountainous terrain of Singapore's surrounding regions in the Malay Peninsula, as well as the Sumatra and Borneo islands, are "poorly resolved".

As terrain and coastlines influence how winds transport moisture across the maritime continent – the region including Singapore and Indonesia – the result could be inaccurate predictions, he noted.

Dr Moise told ST that the purpose of global climate models is to understand global climate and large-scale drivers and processes.

"The next step down is to use these global models and zoom in and run what we call a regional climate model," he added.

CCRS is working with the National Supercomputing Centre to downscale these models to produce grid cells spanning about 2km to 8km.

"With this, Singapore will be covered by a lot of grid cells, showing more features and structures. It will be a dynamic model with a full atmosphere, and can better help with our temperature and rainfall projections," Dr Moise said.

Prof Koh added that this will allow the future wind and humidity conditions in Singapore and its surroundings to be projected more reliably. "This is necessary to detect changes in local wind and rainfall statistics as climate changes, making it possible to prepare against future storm, flood and drought hazards in Singapore."

But building a climate model for Singapore and the South-east Asian region is just one part of the equation.

Observational data – lots and lots of data on rainfall and temperature and sea-level changes – is needed to evaluate and fine-tune the models so they make more accurate predictions.

As Dr Moise put it: "To build a big house, you need a strong foundation."

Once a downscaled climate model is built, researchers can use it to go back in time, introduce changes that have already been seen, and see whether the output from the model corresponds with the observations of today.

"How valid a model is is determined by how well it simulates reality," explained climate scientist Winston Chow, associate professor of science, technology and society at Singapore Management University. "Having an extensive set of baseline data... allows scientists to assess how good a job the model does prior to future attribution research work."

Attribution studies are an emerging science that aims to detect the "fingerprint" of climate change on historical extreme weather events.

A useful analogy to understand this could be as follows: If the weather is a person's mood, then climate is the personality.

This means that the occasional outburst – like a cool spell or a day of heavier-than-usual rain – will not necessarily be enough to establish whether the climate is truly changing.

If an extreme weather event is indeed linked to climate change, then a case can be made for scientists to call on governments to take more preventive measures to reduce emissions, and also to take adaptive steps to reduce a nation's vulnerability to the event.

This area of attribution studies is one that Singapore will look into in the future, said Dr Moise. Now, the priority is to establish the baseline and collect data, he added.

Prof Koh said that in Singapore, more data is needed before the impact of climate change on rainfall – which is highly variable in South-east Asia – can be teased out. Sources of data can include an island-wide network of rain gauges, for example.

"We need to know how frequently storms occurred within the past 30 years before we can determine whether a climate projection over the period 2071 to 2100 yields a higher or lower storm frequency," he said. "Without such a baseline, we cannot estimate how much change there will be and, hence, to what extent we need to make preparations."

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MORE DATA NEEDED

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ASSOCIATE PROFESSOR KOH TIEH YONG, a weather and climate scientist at the Singapore University of Social Sciences, on teasing out the impact of climate change on rainfall.