How the seas stimulate rainfall

Waters of the Earth

The ocean and the atmosphere have a long-lasting relationship. At the global scale, winds give the water its momentum and affect its buoyancy. The waters of the Earth are constantly trading heat and moisture with the atmosphere, and these exchanges have a big impact on where and when rainfall occurs around the world. Recent investigations have revealed just how big this impact is.

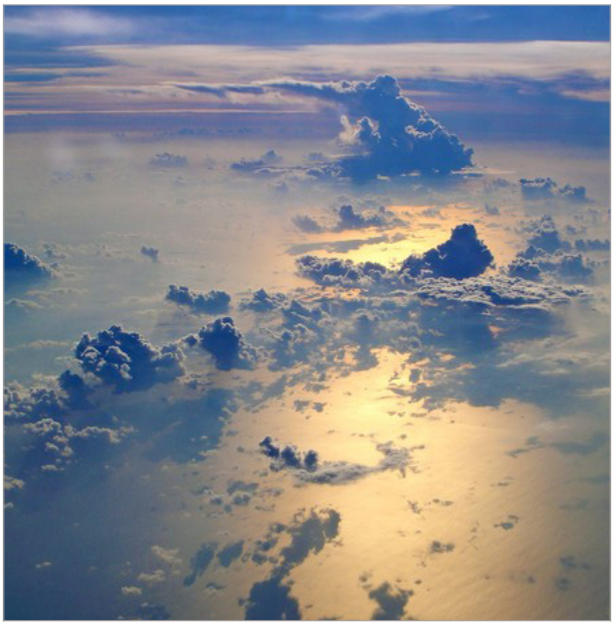
Snatching heat from the Southern Hemisphere

North and south of the equator, the same basic circulation systems are shifting air around the planet, but there are huge differences in tropical weather and climate either side of this line. To the north, it is much wetter and many countries are affected by heavy rains, particularly when the monsoon comes into season. In the past, this difference in rainfall between the Northern and Southern Hemispheres has been attributed to the amount of land vs. the amount of water either side of the equator, but there are other forces at work.

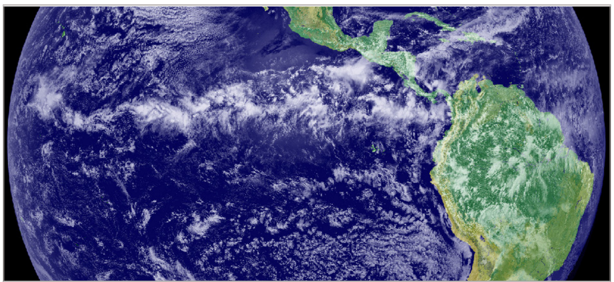
The region where the mass of rainfall forms is the Inter-Tropical Convergence Zone (ITCZ), and its position shifts with the seasons. The ITCZ snakes across the Northern Hemisphere between May and July, forming the hemisphere's wet season. The rain band shifts to the south for the southern wet season from November to February, but throughout the year there's still more rain in the north. Why?

Within the oceans, heat is redistributed via the thermohaline conveyor belt. In the Atlantic, for example, warm surface water flows north, cools, sinks and returns south at depth. This cold, deep water upwells in the Southern Ocean and warms as it flows towards the equator, where the process begins again. A recent study, led by Dargan Frierson, from the University of Washington, has revealed that this circulation system is responsible for shifting the ITCZ further north.

Frierson found that the flux of energy from the ocean to the atmosphere in the north is far higher than its southern equivalent at almost every latitude beyond 20°. The water cycle is more vigorous when there's more energy in the system, so more heat means more rainfall. But because the Southern Hemisphere receives slightly more radiation from the Sun over the course of a year than its northern counterpart, this couldn't explain why there was more heat being exchanged in the north. There had to be some mechanism taking the heat from the south and setting it free in the Northern Hemisphere – ocean circulation. Using a model of a world without continents, Frierson found that small gradients in surface heat flux from the ocean were enough to cause the ITCZ to be displaced northward, dispelling the idea that geography was the cause of the rain band's position.



The amount of moisture the atmosphere picks up over the ocean is strongly influenced by sea surface temperature. Generally, the warmer it is, the more moisture the air picks up from the ocean. This leads to greater cloud cover and an increase in rainfall. (Credit: Jorge Magalhães, distributed via imaggeo.egu.eu)



The Inter-Tropical Convergence Zone (ITCZ) is the region where trade winds from the Northern and Southern Hemispheres converge and create a low pressure area characterised by high rainfall. The location of the ITCZ varies over the course of a year and with extreme weather events, but generally lies just north of the equator. (Credit: NASA Earth Observatory/GOES Project Science Office)

The eddy effect

While it is well-known how the oceans and atmosphere interact at the global scale, what happens at the mesoscale has remained more of a mystery – especially just outside the tropics. Circular currents spanning some 10–100 kilometres in diameter are found all over the ocean. These circling masses are known as mesoscale eddies, and have an effect on the Earth's winds, clouds and rainfall.

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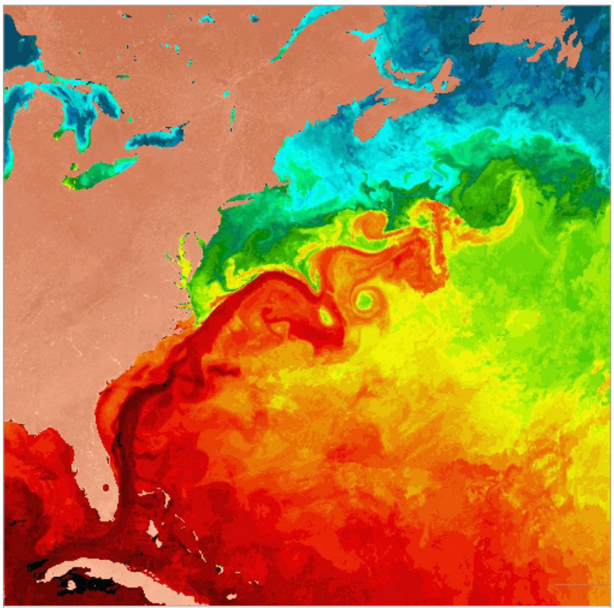

Eddies bud off large ocean currents, like the Gulf Stream, bringing packages of cold water into warmer regions and pockets of warmer water into colder regions. These 10–100 km across masses of water have a big impact on local wind and rainfall patterns. The colour is indicative of relative water temperature. (Credit: National Science Foundation/NOAA)

An eddy can be a package of warm water in an otherwise cold ocean, or a pocket of cold in the warm, and they affect the atmosphere differently, depending on their temperature.

The effect of an eddy on atmospheric circulation has, until now, been rather overlooked, as they were initially thought to be too small to have a significant impact. A group of Swiss scientists set out to solve the mystery of how eddies effect the atmosphere by looking at some 600,000 eddies in the Southern Ocean. Using satellite data, they tracked both eddies and the properties of the surrounding atmosphere, taking into account temperature, cloud cover, wind and rainfall. They found the warmer eddies in the Southern Ocean were typically 0.5°C warmer than their surroundings and the cold ones were 0.5°C colder than the water beyond. Throughout the Southern Ocean, these temperature anomalies correspond to changes in cloud cover and water content, as well as the frequency and probability of rainfall. The reason? They alter the flux of heat between the ocean and the atmosphere.

In the atmosphere, low pressure systems are the ones that generate rainfall. As these systems pass cold-core eddies, which have less heat to release, the cloud cover drops, moisture declines and rainfall reduces by 2-6%. The converse is true for warm-core eddies, which stimulate rainfall in their local vicinity.

As well as providing the fuel for rain-filled clouds, the oceans shape where rain forms and falls around the planet. The heat energy heist undertaken by the Northern Hemisphere as it harvests energy from the south drives the differences in rainfall either side of the equator. And an eddy in the ocean is all that's needed to create a small, but significant, change in the amount of rainfall close to the water mass. Combined, these studies highlight just how wonderfully connected the waters of the Earth are.

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Evolution, extinction and the fossil record

Life of the Earth

Recent research suggests that the Earth is entering a biodiversity crisis and we may be on the brink of our planet's sixth mass extinction. Under these circumstances, an understanding of macroevolutionary patterns in diversification and extinction will be vital to guide conservation strategies. In a recent analysis, Barnosky and colleagues from the University of California showed current extinction rates are highly elevated when compared to background rates in the geological past. If extinctions continue at this pace, we could be seeing an event that qualifies as the Earth's sixth mass extinction (defined by a loss of at least 75% of species) in as little as 300 years from now. Fortunately, the team also discovered that it may not be too late to slow down extinction rates and avoid a catastrophic event. So far we have only lost a few percent of species, and we may be able to reduce extinction rates by targeting conservation where it is most needed, or will be most effective.

Uncertainty remains in these estimates, though. To get a clear picture of which conservation approaches could avoid a mass extinction, it is important to address this uncertainty. A huge amount of information is available on present day extinction patterns and risk factors, but this is only a snapshot of the 3.5 billion years that life has existed on Earth. To map out and truly understand macroevolutionary processes that could help us today, we have to use data from fossils, and the researchers emphasise that integration of palaeontological and present day data will be crucial. Previously, the differences between these types of data have often made it difficult

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