ATMOSPHERIC SCIENCE

Rainfall's oceanic underpinnings

Understanding the processes that govern the complex spatial structure of rainfall is crucial. Idealized numerical simulations reveal the strong influence that ocean heat transport exerts on this structure.

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Narrow bands of intense rainfall in the deep tropics stretch around the globe in close proximity to arid regions where rainfall is scarce. This rainfall-rich zone, termed the intertropical convergence zone (ITCZ; Fig. 1), is neither centred on the Equator, nor symmetric about it. Instead, much of the rainfall is located over the northern tropical oceans. Writing in *Nature Geoscience*, Frierson and colleagues[1] use model simulations and observational data to show that the ocean's overturning circulation and its associated transports of energy are key determinants of rainfall's boreal disposition.

According to conventional understanding, the hemispheric asymmetry of the ITCZ is rooted in geography, resulting from the influence of tropical continental landmasses on ocean currents and temperatures, and associated atmospheric circulation and cloud fields[2]. However, the Southern Hemisphere absorbs, on average, slightly more energy at the top of the atmosphere than the Northern Hemisphere. The ocean's meridional overturning circulation redresses the resultant energetic imbalance by transporting heat northwards across the Equator, and into the boreal extratropics, where it escapes into the atmosphere.

Frierson and colleagues[1] demonstrate the sensitivity of the ITCZ to the redistribution of heat by this meridional overturning circulation in various model simulations. In general, the oceans absorb energy at the surface in the tropics and release it in the extratropics[3]. Using an aquaplanet model (that is, a model set-up devoid of continents), Frierson and colleagues explore perturbations to this mean state by imposing a small inter-hemispheric gradient in extratropical surface heat flux, such that slightly more heat flows out of the Northern Hemisphere oceans into the atmosphere than usual. This asymmetric flux is intended to mimic the ocean's meridional overturning circulation. In this configuration, they are able to induce a hemispheric asymmetry in the ITCZ.

To further test their hypothesis that the meridional overturning circulation, as opposed to geography, determines

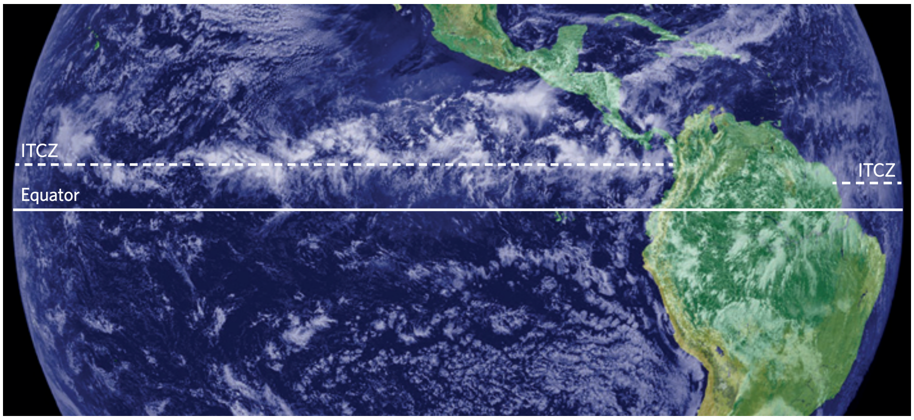

Figure 1 | Tropical rain band. A narrow band of intense rainfall, depicted here by the bright white clouds that cut across the centre of the image, and termed the intertropical convergence zone (ITCZ), stretches from east to west just north of the Equator. As a result, more rain falls to the north of the Equator than the south. Frierson and colleagues[1] show that the redistribution of ocean heat from the Northern to the Southern Hemisphere by the meridional ocean overturning circulation can account for this hemispheric asymmetry in tropical rainfall. Cloud retrievals from NOAA's Geostationary Operational Environmental Satellite (GOES-11); image courtesy of the NASA Earth Observatory.

the ITCZ asymmetry, Frierson *et al.* impose a symmetrical surface heat flux between the tropics and extratropics on both hemispheres, in a model that includes realistic landmasses. They find that the asymmetry in the ITCZ, which is captured well by the model when forced with the observed, lopsided surface heat flux, disappears when the symmetric heat flux is imposed. The findings suggest that hemispheric differences in ocean–atmosphere heat flux in the extratropics associated with the meridional overturning circulation may be a necessary condition for ITCZ asymmetry.

It is worth pointing out that the hemispheric imbalance in the surface heat flux is itself a consequence of continental geometry, which influences the circulations of both the atmosphere and ocean[4]. However, by emphasizing the role of energetics, rather than the location of landmasses, the findings provide new insight into the processes that might dictate changes in the distribution of tropical rainfall. For instance, inter-hemispheric contrasts in aerosol abundance may modulate rainfall not just in their immediate vicinity (for instance by seeding clouds), but also throughout the tropics by modulating the surface radiative budget. As the boreal economies, especially those of India and China, transition to first-world environmental standards, the implications for aerosols, and by extension patterns of tropical rainfall, are substantial. Specifically, a reduction in aerosol levels could increase the amount of sunlight reaching the surface in the Northern Hemisphere, thereby reducing the hemispheric heat contrast and ITCZ asymmetry.

Frierson *et al.*'s conclusion that the ocean overturning circulation influences the location of rainfall in the tropics needs to be explored further, both to test whether it is robust across a range of models, and to determine the relative significance of the meridional overturning circulation compared to other influences — such as land-surface feedbacks and greenhouse gas concentrations — on rainfall distribution[5]. Furthermore, even if verified, the natural variability in tropical rainfall, which spans an enormous range of temporal and spatial scales, continues to pose a challenge for both monitoring rainfall and detecting such an effect in the historical record.

Frierson *et al.*[1] show that the redistribution of ocean heat by the meridional overturning circulation could account for the hemispheric asymmetry in tropical rainfall. The findings challenge the notion that the ITCZ asymmetry is geographically fixed. Continued improvements in our understanding of the processes that govern rainfall's future spatial shifts could prove instrumental in successfully adapting to our changing climate. ❒

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References

1. Frierson, D. M. W. *et al. Nature Geosci.* http://dx.doi.org/10.1038/ngeo1987 (2013).
2. Philander, S. G. H. *et al. J. Clim.* **9,** 2958–2972 (1996).
3. Trenberth, K. E. & Fasullo, J. T. *J. Phys. Oceanogr.* **38,** 984–999 (2008).
4. Rahmstorf, S. in *Encyclopedia of Quarternary Sciences* (ed. Elias, S. A.) (Elsevier, 2006).
5. Xie, S-P. *et al. J. Clim.* **23,** 966–986 (1996).

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