A vital Pacific–Indian link

The Indonesian through-flow — the many passages separating the islands of Indonesia — allows warm water from the Pacific to carry large quantities of heat into the Indian Ocean. Oceanographers know these passages significantly affect world ocean circulation and climate, but it is hard to discern that effect among the array of influences on ocean currents.

Climate models allow scientists to 'experiment' with the oceans and continents, and thereby gain a better understanding of climatic patterns without leaving the computer lab. A global ocean model developed by CSIRO has been used to investigate whether the climatic effects of the Indonesian through-flow may be felt beyond the tropical and eastern areas of the Indian Ocean. The answer, it appears, is yes.

In order to separate the effect of the through-flow from other factors, Dr Anthony Hirst of the Division of Atmospheric Research and Dr Stuart Godfrey of the Division of Oceanography compared two simulations of global circulation by the ocean model — one in the world as we know it and the other in a world in which a land bridge connects Java to Australia, via Irian Jaya and Papua New Guinea, thereby isolating the tropical Pacific and Indian Oceans.

An analysis of the results indicates that the through-flow strengthens the Agulhas Current, which runs southward along Madagasgar and the African continent. The through-flow also influences the Leeuwin Current along the Western Australian coast (see *Ecos* No. 45, 17–18), and Dr Hirst and Dr Godfrey suggest that it is responsible for warmer air over southern Australia and may enhance rainfall over much of the continent. If they are right, it probably follows that the through-flow has a big effect on annual weather patterns — because other studies suggest it varies in intensity from year to year by as much as 60% above or below the mean.

In addition, the model indicates that the Indonesian through-flow is responsible for redirecting circulation in the south-west of the Tasman Sea, where the cooled water from the Indian Ocean re-enters the Pacific. Comparing the simulations with and without the land bridge, the researchers found that it appears to alter the ocean current in the Sea from a strong southward flow, at most depths, to a weak variable one. If true, then it appears the through-flow, which cools the Tasman Sea, gives the south-east coast of Australia a drier, more stable flow of onshore easterly winds than would otherwise occur. That would suggest that it lowers the amount of coastal rainfall in this region.

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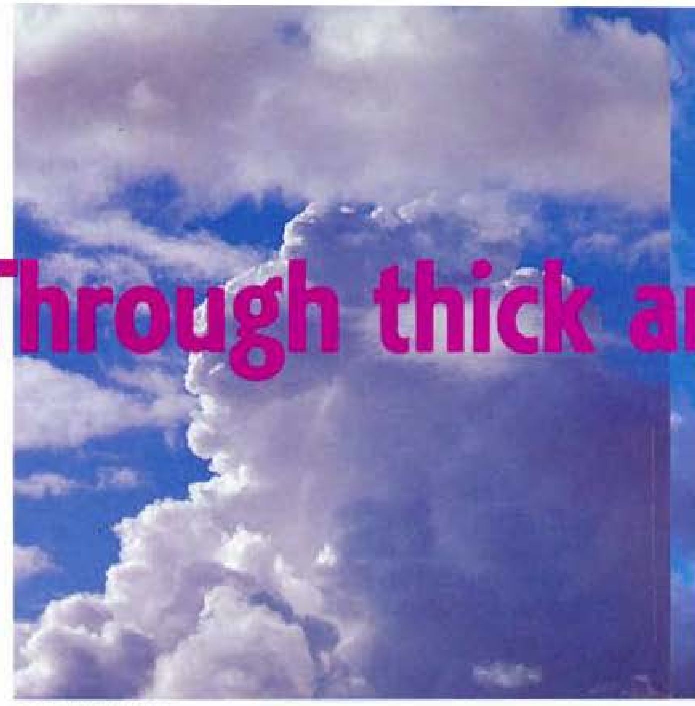

Through thick a

Photos: David Johns

The cloud is an emblem of poetic inspiration and a source of scientific doubt. Clouds reflect 20% of the sunlight entering the atmosphere, making them a crucial factor in the enhanced greenhouse effect. But their role is not simple: they also absorb sunlight and infrared radiation from the surface, release heat when they produce rain, alter their optical properties in response to pollution, emit radiation into space and influence the concentration of a major greenhouse gas, water vapour.

The complexities of clouds and their interactions with land, sea and air are thought to account for most of the variation in estimates of the probable magnitude of greenhouse-induced global warming. The world's best atmosphere models calculate the climatic impact of cloud cover in differing ways — with the result that some models indicate that clouds substantially magnify the enhanced greenhouse effect, while others say they may dampen the effect slightly.

A cloud's ability to reflect light (known as its 'albedo') is related to the average size of the water droplets it contains, which, in turn, depends on the concentration of air-borne particles that can act as nuclei for the formation of droplets. In short, more particles or nuclei mean more and smaller water droplets form. More droplets imply an increase in a cloud's albedo, making it 'whiter' and able to reflect more light from its surface.

Early in 1992, a group of American climatologists, led by Dr Robert Charlson at the University of Washington, calculated that a 30% rise in the droplet concentrations of the world's stratus and stratocumulus clouds (over the oceans only) would reduce greenhouse warming in the atmosphere by 2 watts per sq. m of the Earth's surface. That's about half of the estimated increase in the strength of the greenhouse effect resulting from a doubling of atmospheric carbon dioxide. Dr Charlson and others earlier claimed that air-borne particles of sulfate from the burning of fossil fuels in the Northern Hemisphere may be having a significant cooling effect on the atmosphere — due in part to backscattering, and also because of increased cloud albedo resulting from higher concentrations of cloud condensation nuclei (CCN). In the Southern Hemisphere, the concentration of CCN is largely determined by the natural emission of sulfur-containing gases from the ocean (see *Ecos* 71).

In recent months, however, the debate on clouds has become... somewhat clouded. It is widely accepted that a rise in the number of droplets in a cloud causes an increase

nd thin — the problem of clouds

in its albedo, provided the thickness of the cloud and its liquid-water content stay constant. But in reality those two provisos are never met.

Clouds are imperfect solar reflectors — they also absorb considerable amounts of light energy, a process that alters the thermodynamic and physical structure within them. Although the mechanisms of this internal change are complex and poorly understood, several scientific studies strongly suggest that the absorption of solar radiation 'dries out' clouds of some types and reduces their thickness. One long-term study of stratocumulus clouds over San Nicolas Island, off the Californian coast, found that — during the daytime — their depth and liquid-water content fell to half of the night-time values. These changes reduce cloud albedo markedly. In effect the Sun itself acts to reduce a cloud's ability to reflect sunlight. Drawing on the terminology of electronics, climate scientists call this a negative feedback loop.

Two fundamental questions then arise. Is there also a feedback loop associated with changes in the droplet concentration that would significantly affect a cloud's ability to absorb sunlight and alter its albedo? And, if so, is the feedback negative or positive?

Dr Reinout Boers and Dr Ross Mitchell, at CSIRO's Division of Atmospheric Research, have devised a model that approximately describes the changes in solar absorption for clouds of varying thicknesses. Their preliminary analysis suggests that cloud thickness is the key: thin clouds behave differently from thick clouds.

According to their analysis, a rise in droplet numbers in a thick cloud causes a decline in its ability to absorb solar radiation. That's because the average droplet size is reduced, and a photon of light passing through a cloud has less chance of being absorbed by a small droplet than a big one. But reduced absorptivity also lowers convective mixing within the cloud and is associated with an increase in cloud thickness. Both of these effects tend to raise albedo, so the feedback is positive — it enhances the rise in cloud reflectance resulting from higher droplet concentrations.

With thin clouds, a rise in droplet numbers appears to increase solar absorptivity. More droplets raise the likelihood that a photon entering the cloud will collide repeatedly with water molecules (the collisions are known as 'multiple scatter events') thereby following a longer path through the cloud, and raising its chances of being absorbed. In the thin cloud, this effect more than offsets the opposing tendency due to smaller droplets, and so the feedback is negative — it diminishes the rise in cloud reflectance resulting from higher droplet concentrations.

According to Dr Boers, the thin-cloud regime is dominant for clouds up to about 250 m thick; beyond that, the thick-cloud regime takes over. Stratocumulus clouds straddle the 250-m mark with, he believes, at least 50% of them in the thin-cloud category, especially over the oceans. There is, however, little empirical evidence on the typical thicknesses of marine clouds.

The strengths of these feedback loops globally are not known. Dr Boers and Dr Mitchell estimate roughly that the thin-cloud negative feedback could reduce a rise in cloud albedo by 25%, while the thick-cloud feedback could enhance a rise in albedo by about the same proportion. That makes the feedbacks too important to be ignored in the study of climate change.

In order to find out much more about the internal structure of clouds, three CSIRO climate groups are planning a Southern Ocean cloud experiment, to be conducted off Tasmania's west coast in mid 1993 and early 1994.

Under the proposal, the scientists will use aircraft to fly their instruments through clouds to take measurements of CCN and droplet concentrations, turbulence and the flux of solar radiation. They will match these with ground-based measurements (taken at the Cape Grim baseline monitoring station) of albedo, cloud thickness and liquid-water content. The groups will also investigate the structure of the atmosphere immediately above clouds. The data they gather will enable them to improve the mathematical representations of clouds currently used in global atmosphere models.

The proposed experiment, which is already attracting interest from scientists in the United States, Japan and New Zealand, may change forever how we think about clouds.

Brett Wright

More about the topic

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