View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by University of Southern Queensland ePrints

Ribbe, J (2004) *The Southern Supplier.* Nature, 427. pp.24-25.
This is the author's final draft post-refereeing

The southern supplier

Joachim Ribbe

Abstract: Physical processes in the Southern Ocean largely control nutrient distribution in the global marine environment, a finding that further highlights the influence of this oceanic region on Earth's climate.

To understand how climate change comes about, and what the future may hold, we need to untangle the linkages between ocean circulation and the productivity of phytoplankton. Productivity depends on nutrient availability in the ocean and, as phytoplankton are leading players in the global carbon cycle, they partly determine levels of the greenhouse gas carbon dioxide in the ocean and atmosphere.

On page 56 of this issue, Sarmiento *et al.* (1) argue that the Southern Ocean controls the distribution of nutrients in most of the upper ocean throughout the world. It does so through the formation of nutrient-rich water masses, which spread throughout the Southern Hemisphere and into the North Atlantic. A similar process occurs in the North Pacific, but makes a smaller contribution to nutrient availability.

The formation of water masses within defined geographical regions links the global ocean and the atmosphere, and is a central mechanism of oceanic control of climate. They constitute a repository for heat, fresh water and gases such as carbon dioxide, all of which are exchanged at the ocean–atmosphere interface. On the largest scale, the water masses spread and fill the ocean basins. These huge bodies of water are also the engines of large-scale ocean circulation, one that is primarily driven by so called North Atlantic Deep Water (NADW). As its name suggests, this is water that forms at high latitudes in the North Atlantic, sinks to depth and flows southwards.

Since the initial recognition of this circulation (2), oceanographers have busied themselves with finding out how NADW is resupplied to the Northern Hemisphere. A complex pattern of circulation pathways has become evident, with the Southern Ocean apparently having an important role in the production and interchange of water masses (3, 4). Subantarctic Mode Water (SAMW) is a large water mass created by exchange of heat and fresh water with the atmosphere over much of the Southern Ocean. It sinks below the ocean surface (5, 6) and moves northwards at depths of about 200–600 m. These regions of the Southern Ocean can be thought of as windows to the deep ocean that allow water of particular heat, freshwater and nutrient content to enter the subsurface ocean.

The surface regions where SAMW is formed are characterized by low levels of silicic acid and high concentrations of nitrate. Sarmiento *et al.* (1) apply a newly designed 'conservative' tracer that captures this nutrient signature as a characteristic of SAMW. Their analysis of its distribution shows that SAMW reaches most of the world's upper ocean — that is, much of the global marine environment receives nutrients from the surface of the Southern Ocean. Another water mass, known as North Pacific Intermediate Water, has a subordinate role only: its nutrient delivery is limited to the upper ocean of the North Pacific.

Sarmiento *et al.* (1) also performed several computational experiments. They use a model of the global ocean that couples physical and biological processes, and come up with a reason why diatoms, a major component of the phytoplankton, do not reach their full productive potential in much of the global ocean. By varying the strength of the nutrient source in their models, Sarmiento *et al*. find that the ratio of silicic acid to nitrate in SAMW is less than ideal for diatom growth, and is therefore a primary cause of their widespread low productivity.

The conclusion that a physical process, and one operating in only a tiny part of the world's oceans, has such a huge influence on productivity is startling in itself. But there are more lessons to be learned from the new work (1).

First, use of the new tracer as a diagnostic tool allows further insight into the dynamics of present-day ocean circulation. In particular, it has revealed that Antarctic surface water, driven northwards by the winds, contributes to the characteristics of SAMW. This finding supports earlier studies of this water mass (6, 7) and highlights the more general point that models of the climate system have to capture accurately the physical processes through which water masses form.

Second, the simulations identify a possible deficiency in representing mixing processes in the North Pacific. Models of the climate system may have to include the possible effect of tides on water-mass formation globally, which in turn has implications for the global influence exercised by the outflow characteristics of NADW.

Third, the SAMW pathway does more than provide nutrients for the upper branch of the ocean circulation. In the Southern Hemisphere it also supplies heat and fresh water to the thermocline — the layer of sudden temperature change — which occurs at varying depth below the surface and effectively separates the upper, productive part of the ocean from the deeper waters. The authors do not stress this point, but it is highly topical, given its bearing on our understanding of climate variability in the tropics. At the moment there is vigorous debate over the question of oceanic 'teleconnection' of high and mid-latitudes with low latitudes, which may drive year-to-year climate variability in the tropics (8).

As to the climate connection, the physical processes that lead to water-mass formation in the Southern Ocean are driven by air–sea interactions. The indications are that the Southern Ocean is one of the few regions of the global ocean where the atmospheric consequences of climate change enter the ocean (9). Any perturbation of the formation of SAMW, and subsequently of ocean circulation, is likely to have a dramatic impact on global marine productivity. That will affect the levels of carbon dioxide in the atmosphere, which in turn are linked to global temperature changes (10).The overall conclusion is that the Southern

Ocean has as powerful an influence on climate change as the North Atlantic. Difficult though it may be, it would pay to monitor conditions there.

Joachim Ribbe is in the Department of Biological and Physical Sciences, University of Southern Queensland, Toowoomba, Queensland 4350, Australia. e-mail: Joachim.Ribbe@usq.edu.au

1. Sarmiento, J. L., Gruber, N., Brzezinski, M. A. & Dunne, J. P. *Nature* **427,** 56–60 (2003).
2. Broecker,W. S. *Oceanography* **4,** 79–89 (1991).
3. MacDonald, A. M. & Wunsch, C. *Nature* **382,** 436–439 (1996).
4. Rahmstorf, S. *Nature* **419,** 207–214 (2002).
5. Ribbe, J. *Tellus Ser. A* **51,** 517–525 (1999).
6. Sørensen, J. *et al*. *J. Phys. Oceanogr.* **31,** 3295–3311 (2001).
7. Rintoul, S. R. & England, M. H. *J. Phys. Oceanogr.* **32,** 1308–1321 (2002).
8. Gu, D. & Philander, S. G. H. *Science* **275,** 805–807 (1997).
9. Banks, J. R. *et al. Geophys. Res. Lett.* **27,** 2961–2964 (2000).
10. Petit, J. R. *et al. Nature* **399,** 429–436 (1999).