

Contents in Context

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Investigating the current thinking on the CLAW Hypothesis

Jill M. Cainey

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This issue of *Environmental Chemistry* focuses on the research arising from the publication of the 'CLAW Hypothesis', a paper published over 20 years ago in *Nature*. This paper suggested a potential role for sulfur emissions from phytoplankton in modifying cloud albedo and hence climate.

The CLAW hypothesis: a review of the major developments

Greg P. Ayers and Jill M. Cainey

Environ. Chem. **2007**, 4, 366

Understanding the role of clouds in the warming and the cooling of the planet and how that role alters in a warming world is one of the biggest uncertainties climate change researchers face. Important in this regard is the influence on cloud properties of cloud condensation nuclei, the tiny atmospheric particles necessary for the nucleation of every single cloud droplet. The anthropogenic contribution to cloud condensation nuclei is known to be large in some regions through knowledge of pollutant emissions; however, the natural processes that regulate cloud condensation nuclei over large parts of the globe are less well understood. The CLAW hypothesis provides a mechanism by which plankton may modify climate through the atmospheric sulfur cycle via the provision of sulfate cloud condensation nuclei. The CLAW hypothesis was published over 20 years ago and has stimulated a great deal of research.

Do I believe in CLAW?

Barry Huebert

Environ. Chem. **2007**, 4, 375

In 1987 Charlson, Lovelock, Andreae and Warren revolutionised the way we think about the Earth when they argued that marine algae, atmospheric particulate matter and clouds might be linked in such a way that they could work like a planetary thermostat. This stimulated scientists to work with colleagues outside their traditional disciplines to understand the Earth system. Twenty years later we still can't say whether the CLAW idea is 100% correct, but we have begun to appreciate that the many parts of the Earth are linked into a living whole that cannot be understood by any branch of science working in isolation.

Climate change: the effect of DMS emissions

Peter S. Liss and James E. Lovelock

Environ. Chem. **2007**, 4, 377

The idea that gases produced by plankton living in the oceans can affect cloudiness and regulate climate was given prominence by the promulgation more than 20 years ago by Charlson, Lovelock, Andreae and Warren of the CLAW hypothesis. In the intervening period it has been difficult to prove or disprove the idea, although much research has flowed from its enunciation. Perhaps its lasting legacy is in the way we view the planet and how research is conducted to try to understand how it operates.

A look at the CLAW hypothesis from an atmospheric chemistry point of view

Roland von Glasow

Environ. Chem. **2007**, 4, 379

Feedbacks in the climate system as suggested by, for example, the CLAW hypothesis have often been accepted as fact whereas many open questions remain. In this manuscript some of these uncertainties and their implications are discussed and additional processes that might drastically change the importance of this suggested feedback loop are highlighted.

Do biologically produced aerosols really modulate climate?

Glenn E. Shaw

Environ. Chem. **2007**, 4, 382

In 1983, the author proposed that global climate might be regulated with a machine that uses natural sulfur as its fuel. This climate regulation machine might operate several ways; one is by scattering light back to space from a haze that forms as a consequence of microscopic plant and animal life in the oceans. The idea has evolved, and continues to be pursued as a paradigm.

Re-visiting the CLAW hypothesis

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Environ. Chem. **2007**, 4, 384

Over the last twenty years, large and continued research efforts have been invested in deciphering whether oceanic plankton contribute to the regulation of climate by the production and release of cloud-seeding atmospheric sulfur. Our recent research using globally spread observations and satellite-derived data suggest that biogenic sulfur from the oceans represents a major source of cloud-forming aerosols over much of the pristine southern hemisphere oceans. These climate-cooling sulfur emissions respond positively to incoming solar radiation over seasonal cycles, but show a weak response to anthropogenic global warming foreseen for the current century.

Plankton modelling and CLAW

Roger Cropp and John Norbury

Environ. Chem. **2007**, 4, 388

The prospect of human-induced climate change provides a compelling imperative for an improved understanding of living systems, especially those involving ocean plankton that are proposed to have an important role in regulating climate. Ecosystems are complex,

adaptive systems and mathematical modelling has proved to be a powerful tool in understanding such systems. The present article considers some of the fundamental issues currently constraining such understanding with particular consideration to modelling ecosystems that underpin the CLAW hypothesis and how they might behave in response to global warming.

Sea-salt particles and the CLAW hypothesis

Michael H. Smith

Environ. Chem. 2007, 4, 391

When proposing that dimethyl sulfide (DMS) releases from phytoplankton had a role in regulating the global climate, the potential parallel influences of sea spray aerosols on climate were largely disregarded. Over the intervening 20 years, scientific studies have clearly demonstrated a substantial role for sea spray particles in modifying cloud properties and influencing global sulfur cycling, diminishing the significance of the DMS-based CLAW mechanism.

The iron CLAW

Mike Harvey

Environ. Chem. 2007, 4, 396

A 'climate stabilising' feedback system known as the CLAW hypothesis, which involves the phytoplankton driven influence on cloud reflectivity through the cycling of sulfur was proposed ~20 years ago, and because of its complexity, it remains unproven today. Since the CLAW proposal, experiments that have added iron to the ocean have proven that iron can significantly limit phytoplankton productivity and can also affect the marine sulfur cycle in a complex manner. Because of a range of possible feedbacks between iron, sulfur and climate, it is likely that future advances in understanding the CLAW hypothesis will require a comprehensive process-based description that can be tested in fully coupled earth-system models.

A modified aerosol–cloud–climate feedback hypothesis

Caroline Leck and E. Keith Bigg

Environ. Chem. 2007, 4, 400

Problems with the aerosol–cloud–climate feedback process known as the 'CLAW' hypothesis are discussed and a modified scheme that poses a stronger possible link between marine biology, cloud properties and climate than is provided by dimethylsulfide alone is proposed.

Crucial uncertainties in predicting biological control of DMS emission

Stephen Archer

Environ. Chem. 2007, 4, 404

The CLAW hypothesis, published in *Nature* in 1987, highlighted the important potential role in climate regulation of dimethyl sulfide (DMS) production in the oceans. Since the hypothesis was presented, it has become increasingly apparent that a complex network of biological and physicochemical processes control DMS emissions from the oceans. The present essay discusses several of the crucial biological controls on DMS production that remain major uncertainties in our ability to decipher whether DMS cycling could contribute to the regulation of a warming climate.

Where to now? A synthesis of current views of the CLAW hypothesis

Jill M. Caine, Herman Sievering and Greg P. Ayers

Environ. Chem. 2007, 4, 406

The CLAW hypothesis was published 20 years ago, building on suggestions that the sulfur cycle provided a natural feedback mechanism whereby plankton in the ocean had a role in modifying climate by providing the precursors for cloud condensation nuclei, which leads to the formation of high albedo clouds.

In this issue, the 10 preceding articles represent the opinions of several leading scientists working on various aspects of the CLAW hypothesis and here we synthesise these varied opinions to answer the questions: Does the CLAW hypothesis operate as described in the original 1987 publication? and What steps and advances are needed to better understand CLAW and resolve any outstanding areas of difficulty?

Comparative study of organic Cd and Zn complexation in lake waters – seasonality, depth and pH dependence

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Environ. Chem. 2007, 4, 410

The bioavailability of trace metals such as zinc and cadmium strongly depends on what chemical form they are in, and not simply on the total metal concentration. Zinc is an essential micronutrient, whereas cadmium is extremely toxic, but when they occur in the same environment there is potential for the two metals to compete for the same biological binding sites. In this study we have studied the trends in Cd and Zn complexation in three alpine lakes in New Zealand. We conclude that, although the total concentration of cadmium is much lower than that of zinc and copper, it bears the highest risk of toxicity for organisms.

Colloidal matter in water extracts from forest soils

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Environ. Chem. 2007, 4, 424

Little is known about the proportion of tiny dispersed particles and true solutions in soil water although the distinction has a major influence on transport processes of organic matter, fertiliser and pollutants in soils and thus, e.g., on carbon storage, and its role in global warming. Our study has found a noticeable amount of tiny particles (range 17 nm to 1.0 µm) in filtered soil water, that have a different chemical composition and a lower bioavailability of their organic components in comparison to the soluble part. This significant occurrence and the ecological relevance of colloids for the transport and storage of soil constituents highlights the need to partition soil water content into 'particulate' and 'dissolved' since the access to soil pores determines particle transport.