Arctic 'greenhouse effect'

SIR — Kahl et al.[1] show that the autumn and winter seasons during the past 40 years over the high Arctic have been significantly colder at the sea-ice surface. Moreover, the strength of the surface temperature inversion has increased by 7.8 °C. The authors argue that these results contradict the warming trend predicted by general circulation models. But Walsh in News and Views[2] argued that, when these observations are taken in a broad context, the results are consistent with model simulations of increasing CO_2. Because warming is occurring over land and on the fringe of the Arctic Ocean, the models predict the largest response in ice margins, away from the central region where the data used by Kahl et al. were collected. Nevertheless, the important surface cooling and the significant strengthening of the lapse rate over the Arctic Ocean remains to be explained.

The greenhouse warming effect resulting from water vapour is one of the chief causes of the observed global temperature rise. But the surface of the Arctic would be cooled if the water vapour concentration was reduced. The energy balance of the Arctic is mainly provided by import of moist and mild maritime air. This air mass is transformed by radiative cooling to polar air over a period of about 2 weeks. The process depends on the dehydration rate of the air. If this rate increases then by the greenhouse effect the surface cools at a faster rate. On the other hand, a lower H_2O concentration in the air reduces locally the infrared cooling rate of the air above the surface. The net result is a colder surface and a warmer air temperature aloft. This implies a steeper vertical temperature gradient (see ref. 1).

Almost all natural aerosol particles in the Arctic are coated by anthropogenic sulphuric acid[3,4]. We have shown that acidification of Arctic aerosol (Arctic haze) can result in acceleration of the air-mass dehydration cycle[5]. A detailed and explicit simulation of the aerosol–cloud–precipitation–radiation processes in the Arctic atmosphere shows that an increase in the acid-to-insoluble-particles ratio reduces the number of activated nuclei, accelerates their growth rate, and increases the precipitation flux of atmospheric water. This process has been proposed to enhance precipitation in cloud seeding[6].

Observations of Arctic haze[7] support the idea that aerosol containing sulphuric acid produces fewer ice nuclei and results in fewer ice crystals. Controlled by the cooling rate of the ambient air, the condensation rate of atmospheric water vapour on fewer ice nuclei yields larger ice crystals. This effect substantially increases the total water flux to the surface and the dehydration rate of maritime air that is enriched by excess anthropogenic sulphate during the cold Arctic season.

The Arctic haze is an aged anthropogenic aerosol. The aerosol particles achieve long lifetimes through the minimum removal rate and large static stability of the Arctic air. This process enhances the lifetime of aerosols by reducing their activation rate. To some extent, the aerosol is self-sustained in the Arctic region, prolonging its cumulative effect on the regional climate.

This mechanism provides a possible explanation for the observed trend during the past 40 years in the high Arctic, where the concentration of acid haze has been increasing[8,9] because of long-range transport from industrialized regions.

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Crab hydrostatic pressure sensors

SIR — Adult crabs show locomotor-related responses to pressure pulses and altered rhythmic behaviour in response to pressure cycles[1,2]. Planktonic crustacea show orientation changes with thresholds between 5 and 25 millibar (mb)[1,3]. However, no pressure sensor has been identified and the lack of any obvious, compressible gas-filled partition has been considered a problem in making a sensor work[4–6]. We report here that sensory hair receptors from the balancing organ, or statocyst, of adult crabs respond to step changes in hydrostatic pressure, and propose a mechanism involving mechanoreceptor activation by the alteration of the interior volume of cuticular hairs.

Angular accelerations are sensed by crabs by means of thread hairs and free hook hairs that are displaced by inertial fluid movements in the orthogonal canals of the statocyst[7–9]. Thread hairs are also affected by gravity; their sensitivity is greatly dependent on the resting position of the hair. Individual hairs are sensitive over different ranges[7]: typically, a thread hair responds over a 12–25° displacement range with phasic or tonic activity and maximum sensitivity of about 15 Hz per degree displacement. Each hair is innervated by two bipolar neurons with opposite directional sensitivities[7].

Tonic and phaso-tonic increases and decreases in firing frequency of statocyst thread hair receptors occurred following increasing and decreasing pressure steps of 0.22 to 1.1 bar above ambient (Fig. 1). Significant differences were found between mean spike densities for 40 s before pressure changes compared with spike densities after pressure changes in 50 of 156 mixed units analysed. It was necessary to leave preparations for 15–30 min following a step of pressure to obtain a second full response, and variations in responsiveness or different proportions of positive or negative-going responses made construction of an intensity function inappropriate. Statocyst hairs in crustacea are unusual in that a chitinous chorda links the hair base with the dendrites which are sheathed by scolopale cells[9] (Fig. 2b, c). In the crayfish statolith the chorda inserts on a cuticular spine, the lingula, near the base of the hair. There is evidence that the chorda of the narrower (2–4 µm) thread hair passes up the shaft of the hair and may have a loose hydraulic coupling within the hair (Fig. 2; and P. Dunn, personal communication). Volume changes within the interior fluid, arising from hydrostatic pressure, will lead to displacements of the chorda like the plunger of a syringe. The high hydraulic resistance, caused by the small diameter of the hair and the small opening through which the chorda passes at the base, will also help couple chorda displacement to volume change. The long, thin, cylindrical shape of the hair will help translate volume changes into displacements.

Consider a simple model with chorda coupled to the hair at its midpoint (Fig. 2). A 1° displacement of a 2-µm-diameter hair will lead to a displacement of 0.0175 µm of the chorda, assuming no slippage or elasticity. In the simplest case the effect of pressure on the hair can be modelled in the absence of hoop stress. Consider also the change of volume of contents of a 400-µm-long by 2-µm diameter hair to a 1-bar pressure change. Assume the compressibility of the hair cell interior is similar to that of sea water (43.9×10^{-6} per bar and the cuticle is relatively incompressible)[6]. If the diameter stays the same, then the length change following compression by 1 bar is $43.9 \times 10^{-6} \times 400$ µm = 0.0176 µm.

Considering the similarity of the calculated pressure-evoked displacement of the chorda to that following an above-threshold response, it seems unnecessary to invoke a compressible gas-phase transducer[4,6]. This application of Enright's differential compressibility idea,