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Atmospheric dust increase could lower Earth's temperature

By increasing the dust content of the atmosphere, mankind is risking a significant decrease in the surface temperature of Earth, conceivably sufficient to speed up the onset of the next ice age. So say Ichtiaque Rasool and Stephen Schneider of the Goddard Institute for Space Studies (*Science* **173**, 138, 1971).

At present the atmosphere, which is mainly composed of nitrogen and oxygen, contains small amounts of carbon dioxide, water vapor and dust; nearly all of these last three ingredients is produced naturally. These constituents, though minor, play an important role in determining the temperature of the surface of Earth. Carbon dioxide is produced by biological activity and is consumed by photosynthesis. The biological residence time is a few years. It deposits in the oceans in a few decades and is removed from the ocean into the crusts as carbonates in a few thousand years. Dust is produced by volcanic activity and by winds over desert and land areas. Water vapor enters through evaporation. The abundances of these constituents, previously in natural equilibrium, are now being modified by human activity. The question is, what will happen to the temperature of the Earth's surface as a result?

Rasool and Schneider investigated the effect of adding carbon dioxide and the effect of adding dust. Using a model of the Earth's atmosphere under present conditions, they studied the energy balance of the atmosphere at the surface. Their results agreed with the parameters measured by meteorological satellites. They then increased the amounts of carbon dioxide in the model by a factor of two, four, eight and so on.

This increase in carbon dioxide does not affect the solar radiation reaching the Earth's surface because the planetary albedo (reflectivity) remains un-

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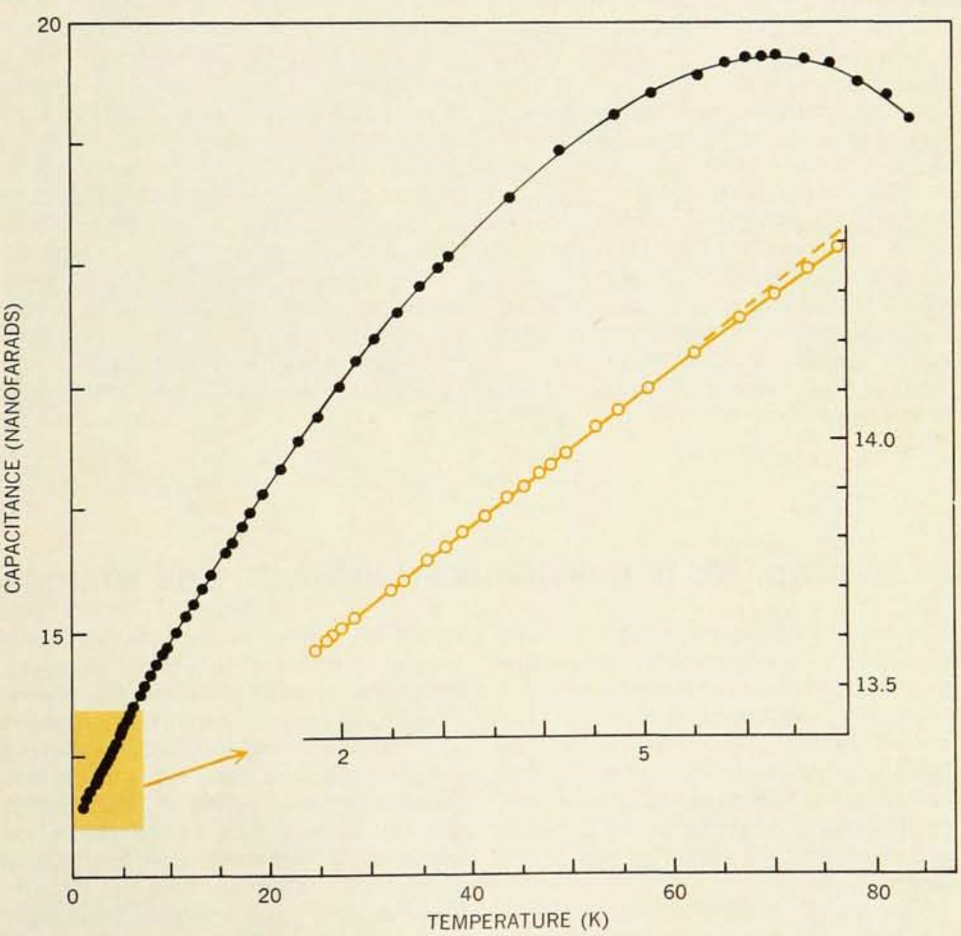
Low-temperature thermometers discussed at symposium

A thermometer can be a glass-ceramic capacitor, a superconducting tunnel junction, the He^3 melting curve or a paramagnetic salt. These approaches were all discussed at the Fifth Symposium on "Temperature—Its Measurement and Control in Science and Industry," which was held in Washington at the end of June. They are attempts to find additional ways of measuring temperatures below the range of the platinum resistance thermometer—below about 14 K.

Capacitance thermometer. A convenient glass-ceramic capacitance thermometer has been developed by W. N. Lawless[1] of Corning Glass Works. Its most remarkable feature is that its thermometric properties do not appear to be affected by magnetic fields as high as 140 kG; that is, the temperature error is less than 1 mK. The device was tested between 1.5 and 4.2 K.

The thermometer is strontium titanate, which has been crystallized *in situ* from alumino-silicate glass. It can easily be made by changing the composition of the material used in a standard capacitor production run. Lawless made multilayer capacitors 1 × 2 × 5 mm^3 and measured their temperature response from 0.025 to 300 K. Their dielectric permittivity was about 200.

He found that the thermometer acts differently over three different temperature regions. From 0.025 to 0.10 K the capacitance C is proportional to T^{-1}.



Capacitance-temperature behavior for glass-ceramic capacitance thermometer, whose thermometric properties are unaffected by magnetic fields as high as 140 kG. Inset shows region of linear behavior below 5.2 K.

From 100 to 300 K, C follows the Curie–Weiss law as a function of temperature. In the range of 0.10 to 72 K, C increases smoothly with T, including a linear region from 1.1 to 5.2 K.

The sensitivity dC/dT is approximately 250 picofarads/K at helium temperatures.

Another kind of capacitance thermometer, which was not reported at the symposium, has been built by R. A. Brand, S. A. Letzring, H. S. Sack and Watt Webb at Cornell University[2] and by A. Fiory[3] (now at Bell Labs). They used potassium chloride doped with Li^+ ions (or various other ions to introduce paraelectric impurity centers) and found that the temperature variation of its dielectric constant was a useful thermometer over the range 1–30 K. In that range the capacitance varied with $1/T$ as expected.

When a magnetic field as high as 100 kG was applied to the Li^+-doped capacitors, the effect on capacitance was immeasurably small, the experimenters say, and definitely less than the absolute temperature uncertainty (about 0.2%) at 4.2 K.

Tunnel-junction thermometer. A group at the Catholic University (Nijmegen, The Netherlands), J. W. Bakker, H. van Kempen and P. Wyder,[4] propose using a superconducting tunnel junction as a primary thermometer. To investigate its thermometric possibilities the experimenters deposited an aluminum–aluminum oxide-silver junction onto ruby that was cooled down below 1 K by adiabatic demagnetization. Because the metal films are about 1000-Å thick, they have a very small heat capacity and consequently a microsecond response to temperature changes.

The experimenters measure the current–voltage characteristic curves, which are strongly temperature dependent. They deduce the temperature by comparing the data with calculations using BCS (Bardeen–Cooper–Schrieffer) theory. Once the calibration is made of tunnel current versus temperature, one has a thermometer. Results were compared with the temperature indicated by a calibrated germanium thermometer. Bakker and his collaborators say that the thermometer has reasonable accuracy, very high resolution and a power dissipation of about 10^{-12} watt.

Although aluminum is only superconducting up to 1.1 K, if one were to use lead junctions instead, the range might be extended to about 7.2 K.

He^3 melting curve. R. A. Scribner (Stevens Institute of Technology) and E. D. Adams (University of Florida)[5] proposed that the measured variation of the melting pressure of He^3 with temperature could be used as a thermometer for temperatures between about 250 and 2 mK. Among the merits of such a thermometer, they say, are its inherent sensitivity and its ease of calibration.

Scribner and Adams cite a number of recent developments that make the He^3 melting pressure a feasible thermometer for T greater than about 2 mK. These developments include refinements in capacitive pressure gauges, which permit pressure changes as small as 10^{-6} atm to be measured; measurements of the melting pressure, which are establishing the functional dependence of the melting curve, and development of the technique of adiabatic compressional cooling of He^3, for which the melting curve would be a "natural" thermometer. With existing *in situ* capacitive pressure-gauge techniques, they say that a temperature resolution of better than 10^{-7} K can be obtained over the range 100–2 mK and better than 10^{-6} K from 250 to 100 mK.

In addition to its use as a secondary thermometer, Scribner and Adams feel that once we have complete knowledge of the behavior of the liquid and solid at melting, He^3 has potential as a primary thermometer.

Magnetic temperature scale. To determine a magnetic temperature scale from 0.9 to 18 K, T. C. Cetas and C. A. Swenson[6] (Iowa State University) used two paramagnetic salts, chromic methylammonium alum and manganous ammonium sulfate. The ac susceptibility of the salt is determined by using a mutual inductance bridge with the salt located at the center of a set of mutual inductance coils. Then the bridge reading X is related to the temperature by

$$X = A + B(T + \Delta + \delta/T)^{-1}$$

A and B depend on coil geometry and salt used: δ and Δ are correction terms, which are usually small.

The experimenters determined A and B by making measurements from 18 to 34 K in terms of temperatures given by a National Bureau of Standards-calibrated platinum resistance thermometer. A self-consistent approach was used to extrapolate this calibration to low temperatures; the procedure had a 0.01% accuracy.

One major conclusion that Cetas and Swenson drew is that the accepted liquid-helium vapor pressure–temperature relation is inconsistent with the higher temperature scales. In other words, the temperature that is assigned to the boiling point of helium, 4.215 K, is too low by somewhere between 7 and 9 mK. The uncertainty in this statement, Cetas and Swenson say, does not arise from the precision of their data, but rather from uncertainties in the NBS-1958 and the International Practical Temperature Scale-68 platinum resistance thermometer scales. —GBL

References

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SLAC proposes to boost energy above 50 GeV without superconductors

The plan to fit Stanford's 20-GeV electron linac with superconducting cavities has been dropped, and a new proposal to upgrade performance has been submitted to the AEC. SLAC director Wolfgang Panofsky told us that at present a complete conversion to superconducting cavities would be noncompetitive, both in terms of time and money.

To turn the 10 000-foot machine from 20 GeV to the proposed 100 GeV would require a gradient of 10 MeV per foot. To achieve such a gradient in a reliably operating superconducting accelerator would require very large extrapolation beyond current experience, Panofsky said. This gradient is about an order of magnitude larger than that obtained in actual accelerating superconducting sections operated thus far. There are still many basic problems standing in the way of large-scale use of microwave superconducting structures for a long linear accelerator, he went on. One of these is that, using current technology, whenever there is any kind of vacuum failure the cavities must be reprocessed at 2000 C, he said.

Many solutions for the problems have been proposed and are actively being pursued in Brookhaven, Karlsruhe, at SLAC and the Stanford High-Energy Physics Laboratory, he noted. Most of the tests have been done with X-band and S-band cavities, whereas the HEPL accelerator is designed to operate with L-band cavities, he said.

Panofsky feels that, in the long run, superconducting microwave techniques are very promising for many applications in high-energy physics, including microwave particle separators as well as accelerator components.

Instead of the superconducting con-