MacCready and Oldham's "Gossamer Condor" on 23 August 1977.

We must end on a footnote. Reay conclusively shows that Icarus could not possibly have flown from Crete to the mainland of Greece. Someone needs to reexamine that legend to see what his real objective might have been or whether he might have been under the influence of hallucinogenic drugs.

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Lightning Discharges

Lightning. R. H. GOLDE, Ed. In two volumes. Vol. 1, Physics of Lightning. xx pp. + pp. 1–496, illus., + index. $41. Vol. 2, Lightning Protection. xx pp. + pp. 497–850, illus., + index. $33.25. Academic Press, New York, 1977.

Modern lightning research began in the early 1900's with C. T. R. Wilson's determination of the cloud charges moved by lightning by measuring the resulting electric field change. Since then, the study of the physical properties of lightning has proceeded at a slow but steady pace, the bulk of the work having been done in South Africa, England, Switzerland, and the United States. Much of the research from the 1920's to the present has been motivated by the problems lightning causes for electric power utilities. Recently the use of vulnerable solid state electronics, both on the ground and in aircraft and space vehicles, has produced renewed interest in (and funding for) lightning research. The field, however, is still a relatively small one. In the last ten years only about 500 journal articles and one monograph (also titled *Lightning*) on lightning physics have been published; there have been considerably fewer journal articles on lightning protection, although monographs have been written on the protection of structures, communication systems, and airplanes.

The two volumes of *Lightning* together comprise chapters by 27 authors. The English is uniform and excellent throughout, despite the disparate national origins of the authors. The two volumes were written, according to the editor, to meet the need for "a comprehensive survey of present knowledge of *all* major aspects of lightning and protection against its effects." The contributors "were requested to start with a brief survey of early work and to present a balanced critical review of present knowledge with clear indications of their own views." The book is largely successful in achieving these goals. The main failings of the book can be laid to a tendency on the part of authors to discussion of their own experience in preference to their appointed subjects and to the use of jargon. One of the shortcomings of almost any collection of this type is that it is difficult for the reader to determine the relative importance of the subjects discussed. For example, in this work there is no consideration of which are the most important unsolved lightning problems and, of these, which are amenable to solution with available technology.

Volume 1, "Physics of Lightning," contains 14 chapters that cover "lightning in history," point discharge, thunderclouds, long laboratory sparks, lightning to earth, lightning in clouds, lightning currents, spectroscopy, radiofrequency radiation, thunder, frequency of lightning discharges, electric-field measuring techniques, and ball lightning. The volume includes more than its subtitle indicates, subjects apparently being relegated to this volume if they are not specifically concerned with protection. Perhaps the best chapter in this volume is "The cloud discharge" by M. Brook and T. Ogawa. It is a balanced, up-to-date review containing a good mix of theory, experiment, results, and appropriately labeled speculation. Most disappointing are the chapter on instrumentation, which does not give the reader what its title implies, and the chapter on ball lightning, which presents an uncritical view of a subject that is badly in need of a critical analysis.

Volume 2, "Lightning Protection," contains 12 chapters covering lightning warning and avoidance, injury and death from lightning, the principles of operation of lightning rods, grounding of lightning, and the protection of structures, underground blasting operations, aircraft, transmission and distribution power systems, telecommunication systems, and trees. The chapters range from equation-filled to equationless, the more technical ones requiring considerable background. One advantage of this volume is that the reader can examine the variety of ways in which engineers concerned with the protection of different types of systems approach similar problems. Perhaps the best chapter in this volume is R. H. Golde's "The lightning conductor," which lives up to the charge he gives his authors. Most of the chapters are quite good; several are disappointing in that the background material necessary to follow the development of ideas is not given.

Lightning will be very important to researchers who are already knowledgeable in the field. Novices will do better to introduce themselves to the subject by first investigating several of the single-author books available on the subject.

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Long-Term Patterns

Climatic Change and Variability. A Southern Perspective. Papers from a conference, Melbourne, Dec. 1975. A. B. PITTOCK, L. A. FRAKES, D. JENSSEN, J. A. PETERSON, and J. W. ZILLMAN, Eds. Cambridge University Press, New York, 1978. xxiv, 456 pp., illus. $37.50.

Climatic Change. JOHN GRIBBIN, Ed. Cambridge University Press, New York, 1978. xii, 280 pp., illus. Cloth, $37.50; paper, $11.95.

That two books on climatic change could be published in the same year by the Cambridge University Press attests to the current high level of interest in the subject. Both books deal with the history of climate over the span of geologic time, as well as with recent and even proximate events. The contributions in both are of generally high quality. Neither compilation is parochial in scope, but the emphasis placed on Australia and the Antarctic Ocean (and to a lesser degree, Antarctica) in the Pittock *et al.* volume is not to be found in Gribbin's book.

The concept of climatic change eludes simple definition, and its diffuseness is parent to the eclectic nature of successful work on the subject. Climate itself must be broadly defined, for to study it involves delineating weather states over a run long enough to characterize the whole assemblage. If climate were stable, then frequencies of given weather types recovered from the world weather record would be repeated with the same frequencies in the future. Although many necessary and useful climate-related works, such as dams for flood control and heating and cooling units for buildings, are based on the assumption of such stability, it is nevertheless true that every year parts of the planet experience weather events not recorded before. Careful examination of the longest series of weather records (the temperature record for Lancashire begins in 1751) fails to reveal one-sided trends of impressive magnitude. What do appear are many irregular variations composed of some variable combination of chance and periodic controls. This state of affairs requires an allowance for drift in climate in terms of a variability factor. Indeed, in 1968 Arnold Court and his co-workers found that the optimum length of record useful in predicting the next year's weather was no greater than ten years.

If climatic variability exists, then why speak of climatic change? To answer that question a great deal more has to be examined than events of the last ten years. Acceptance of the fact that the earth has experienced climatic patterns significantly different from the current pattern was gained with the determination in the last century that massive ice sheets had covered much of northwestern Europe, and especially the northern half of North America, in the relatively recent past. It is now accepted that at least seven ice ages occurred still earlier and that at present we are living in a world far from completely free of ice, at a time that probably represents an interstadial period past its peak of warmth.

Where, then, do we stand with respect to the processes and stages that account for the sequence of events that we term climatic change? It is to that question, directly or indirectly, that most of the pages of these books are devoted. A précis would go something like this.

Glaciation of the polar regions has occurred when large landmasses drifted into high latitudes. At such times, the glacial cycle can be initiated when the orbital elements of the earth combine in such a way as to provide least solar energy to the summer hemisphere. A periodicity of the order of 2×10^4 years is involved, which was first adequately described by Milankovitch in 1938. The pulse provided by orbital (and axial) changes is rapid compared to the pace of continental drift, thus allowing a series of advances and retreats of ice to occur over the same terrains. In the case of Antarctica, ice apparently first reached sea level in middle Oligocene times, 37 million years ago, according to Frakes (in Pittock *et al.*). The Northern Hemisphere ice domes were formed much more recently, perhaps a little more than a million years ago, although Alaskan alpine glaciers were formed earlier than that.

The most recent events of the Pleistocene are dated more accurately than earlier stages, for a variety of reasons. For the past 150,000 years, Mason (in Pittock *et al.*) reports astonishingly good agreement between ice advance and retreat in the Northern Hemisphere and the heat excesses and deficits calculated by the methods of Milankovitch, which Mason has revised on the basis of improved astronomical data. Nevertheless, Flohn (in Gribbin) notes intermediate ice advances that do not fit the periodicities supplied by Milankovitch and attributes them to surges of Antarctic ice sufficient to affect global climate.

Budyko (in Gribbin), as well as Sellers and others, believes that variations in the solar constant are also a causal agent in controlling the ice margin of northern polar ice. Small changes in solar output—differences little larger than those provided by Milankovitch—may be sufficient to shift the ice margin from its present position (72° north latitude) to its average Pleistocene limit (50° north latitude). Lorenz, by very different reasoning, also concludes that the present climate is unstable.

Against this background of historical evidence and theoretical reasoning, we are led to contemplate our present climatic pattern with new appreciation of its geniality and to hope that this amiable state of affairs will last longer. It is known, of course, that humans have altered the climatic system for millennia by changing water tables and vegetation in establishing agriculture and, more recently, by adding to the carbon dioxide content of the atmosphere through combustion of fossil fuels and by increasing the dust veil already provided by volcanic activity. Interesting and possibly significant extrapolations of climatic changes have been made on the basis of inadvertent changes in atmospheric composition caused by humans.

It is the hope of some investigators that computer simulations of atmospheric activity will allow us to predict the effects of both natural and anthropogenic variables on the climatic system. The books under review consider that possibility as promising, but not attainable with present computing capacities. Above all, improved linkage between the atmosphere and the hydrosphere is needed to provide realistic climatic models. It is hardly accidental that two of the great meteorologists of this century, C.-G. Rossby and J. Bjerknes, turned toward the oceans in their later years.

The question of solar effects has always loomed large in studies of climatic change, for however much heat may be stored in the oceans it originated with the sun, and over long spans of time variability in solar activity has the potential of explaining most of the facts of climatic history. Unfortunately, we still do not have a record of insolation accurate to within 1 percent and so cannot verify through observation that the sun is effectively variable.

Both books are signficant collections of information. A useful blend of fact and theory is found in each, though differences in balance exist: climatic change as a problem is cleanly presented in the Gribbin collection, whereas Pittock and his co-workers include more data, and some writing that borders on the didactic. With books of this quality, comparisons are essentially invidious. So ramified is the subject of climactic change that both books can be read with profit.

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Honoring Chandrasekhar

Theoretical Principles in Astrophysics and Relativity. Papers from a symposium, Chicago, May 1975. NORMAN R. LEBOVITZ, WILLIAM H. REID, and PETER O. VANDERVOORT, Eds. University of Chicago Press, Chicago, 1978. viii, 258 pp., illus. $23.

This book contains the papers presented at a symposium held in honor of the 65th birthday of Subrahmanyan Chandrasekhar. The topics of these papers touch on many, but by no means all, of his interests, which are so diverse that it would take another Chandrasekhar to write an adequate review of the book. There being no one like him, I agreed to review the book for the opportunity it gives me to join in honoring him.

Since his first published paper in 1928, entitled "Thermodynamics of the Compton effect with reference to the interior of stars," Chandrasekhar has made a massive and unique contribution to mathematical astronomy. As remarkable as his contribution is his style of work. He takes up a subject for a few years, imposes on it his own mathematical authority, organizes the material in a definitive treatise, and then leaves the subject, rarely to return to it. I can still remember the excitement I felt when he told me in the early '60's that he intended to take up the study of general relativity. His first important paper on this subject was published in 1964 and contained a result typical of him—the instability of a massive sphere in general relativity. Fortunately for relativists he has not yet written his definitive treatise on the subject. Long may it be delayed!

The papers in this book are organized around two main themes, stars (and stellar systems) and relativistic astrophysics. They vary from brief and predominantly verbal accounts to extensive, systematic, mathematically detailed reviews. They all bring out very clearly the great difficulties of modern