opment of the small ICBM. Thus the years of search for an MX basing mode ended only after what had been considered its essential characteristic, survivability, was abandoned.

—David F. Bond

Earth sciences

The effects of the eruption of the Mexican volcano El Chichón and of the unusually strong El Niño in the Pacific Ocean occupied the attention of Earth scientists in many disciplines during the past year. Other subjects of research included the remote sensing of phenomena by satellites, the long-range prediction of earthquakes, and the extinction of species.

Atmospheric sciences

During 1983 four areas of atmospheric science achieved particular advances. These were the monitoring of the atmosphere, the modeling and simulation of the atmosphere, the investigation of inadvertent climate change, and the distribution of weather information to the public.

Monitoring the weather. The Wave Propagation Laboratory of the National Oceanographic and Atmospheric Administration (NOAA) in Boulder, Colo., continued the development and testing of an atmospheric remote profiler system that provides almost continuous measurements of wind and, somewhat less accurately, of moisture and temperature throughout the lowest 10 km (6 mi) of the atmosphere. The winds are estimated by using an upward-looking Doppler radar, while temperature and moisture profiles are evaluated by using a vertically pointing radiometer. Used in conjunction with temperature soundings from satellites, the profilers may make upper-air balloon soundings obsolete.

Also under development was a Doppler radar system referred to as NEXRAD (Next Generation Radar). In contrast to current weather radar systems NEXRAD will monitor the wind flow within the atmospheric boundary layer in addition to estimating the intensity of rain and snowfall. (The atmospheric boundary layer is the thin layer of air near the Earth's surface within which the wind distribution is directly influenced by friction due to the ground.) The prototype NEXRAD system was proposed to be installed at the National Severe Storms Laboratory in Norman, Okla., where much of the U.S. research on severe convective storms has taken place.

During the summer of 1983 an experimental program utilized Doppler radar, profilers, and other meteorological measurement systems in order to determine if improved prediction of severe convective storms could be achieved. Part of an effort called the Program for Regional Observing and Forecasting Services, the investigation was organized by the Environmental Research Laboratories in Boulder. Probability forecasts for severe thunderstorms and tornadoes were made for several sectors of eastern Colorado, with chase teams using vans and automobiles sent out to verify forecasts. Initial evidence suggested that the new monitoring tools did help meteorologists improve their forecasts of severe storms.

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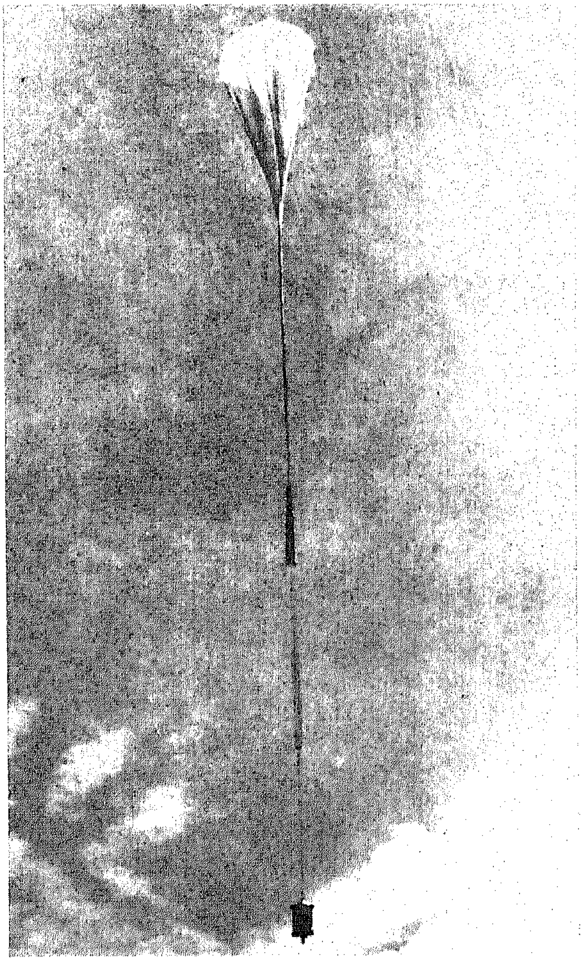


A balloon 135 m (450 ft) in height lifts a gondola containing scientific instruments that will study the ozone layer in the Earth's upper atmosphere.

Imagery from the Geostationary Earth Satellite (GOES) located 35,800 km (22,245 mi) above the Equator showed that during the summer thunderstorms preferentially develop over mountainous terrain in Montana and Colorado and then move out over the Great Plains during the afternoon as a result of the westerly winds which typically blow at that latitude. The composite imagery shows great promise for providing improved weather forecasts.

Modeling and simulation of the atmosphere. The application of computer models to simulate atmospheric flow began in the early 1950s. The current high-speed supercomputers such as the Cray 1 and Cyber 205 permit large and comprehensive model simulations to be made. During the past year a series of comparisons were made using such models at several national centers and research institutes in the U.S., Canada, Europe, and Japan. Forecast accuracy for as many as seven days in the future was achieved with the models, although even after the first day certain aspects of the atmospheric circulation pattern were incorrectly predicted. The source of these errors appeared to be related to the inability of scientists to monitor adequately the initial state of the atmosphere.

On a smaller scale, simulation models of the Earth's planetary boundary layer received heightened attention during 1983. Referred to as large-eddy simulation models, they were designed to resolve the dominant energy-containing turbulent eddies in the lower kilometers of the atmosphere. The understanding of turbulent processes is essential in order to achieve better weather and climate predictions. A working group organized in 1983 by John Wyngaard of the Mesoscale Research Section of the U.S. National Center for Atmospheric Research was leading the effort to expand the use of large-eddy simulation models.

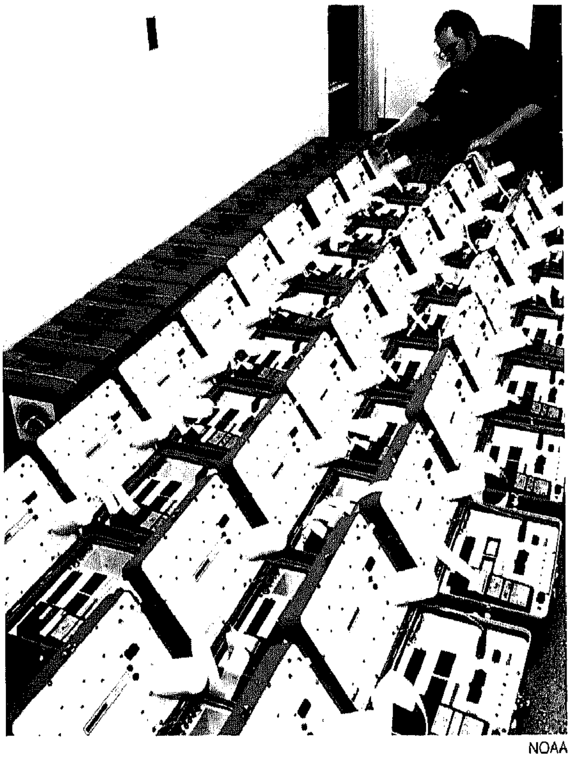
Intermediate between the scales discussed above is a range of atmospheric motions called the mesoscale, which have horizontal scales on the order of ten to several hundred kilometers. In 1983 a U.S. initiative referred to as STORM (for Stormscale Operational and Research Meteorology), organized by George Benton, Rick Anthes, and others working with the University Corporation for Atmospheric Research in Boulder completed reports and meetings designed to focus attention on the nation's mesoscale program. The first major STORM research project, referred to as STORM-Central, was designed to investigate large mesoscale clusters of thunderstorms and rain that frequently develop over the Great Plains of the U.S. during the summer. These features, referred to as mesoscale convective systems, contribute substantially to the total number of severe thunderstorms that occur over that part of the U.S.

Inadvertent climate change. The sensitivity of the Earth's climate to natural and man-made effects continued to receive considerable attention in 1983. As reported by the Climate Analysis Center of NOAA, the major Pacific Ocean anomaly called the El Niño/Southern Oscillation decreased dramatically in both magnitude and extent during the Northern Hemispheric summer of 1983, after being dominant in influencing the unusual atmospheric circulation pattern during the preceding winter and spring. The term El Niño refers to a major warming of the surface water along the South American Pacific coast associated with the reduction or elimination of the large-scale wind flow parallel to the coast. This wind change occurs because of a substantial change in the atmospheric pressure pattern across the tropical Pacific Ocean (hence the name Southern Oscillation).

The effects of the El Niño/Southern Oscillation are worldwide. Bill Gray of Colorado State University, for example, correctly predicted that there would be fewer tropical storms than normal in the Atlantic Ocean in 1983, based on climatological data from previous seasons in which an El Niño preceded the fall Atlantic hurricane season.

The influence on climate of the eruption of the El Chichón volcano in Mexico in 1982 appeared to continue throughout 1983 and into 1984. This volcano ejected into the stratosphere large volumes of the gas sulfur dioxide, which was then converted to sulfuric-acid droplets a few tenths of a micrometer (millionth of a meter) in diameter. These particles act to reduce the solar radiation that reaches the Earth's surface and to warm the stratosphere. Alan Robock of the University of Maryland suggested that an average surface cooling of as much as about 0.4° C could occur over the Northern Hemisphere in 1983 and from 0.4° to 0.5° C in 1984 and 1985. Robock suggested that even after ten years cooling as a result of the volcanic eruption would persist,

Rows of air samplers are inspected. They are to be used to study how the pollutants that may contribute to acid rain are dispersed by winds.



NOAA

although it would be of a smaller magnitude. (For another view and an extended discussion of the effect of volcanic eruptions on climate, *see* Feature Article: PURPLE SKIES AND COOLING SEAS: VOLCANISM AND CLIMATE.)

During 1983 a number of both Soviet and U.S. scientists suggested that a major nuclear exchange between the superpowers would cause even greater climatic change. They postulated that the enormous volumes of dirt and smoke that would be ejected into the upper atmosphere and stratosphere by surface thermonuclear releases and the conflagrations following such an exchange would darken the sky for an extended period, reducing the sunlight reaching the ground and thereby resulting in subfreezing temperatures at the surface throughout much of the world, even in the summer. The protagonists of this view claimed that the massive "human volcano" effect could cause the extinction of human life. This scenario became the subject of considerable debate, with a number of scientists suggesting that the model used to estimate the meteorological impact of a thermonuclear war was much too simplistic.

The subject of acid rain continued to receive widespread attention during the past year. In the U.S. federal legislation to limit sulfur emissions from power plants was urged. Sulfur dioxide from power plants is considered to be one of the major precursors of and contributors to acid rain. A major controversy concerning acid rain, however, focused on the relationship between the sources of the acid material and the eventual receptors. The question that arose was whether all the material is transported over long distances or is some of it recirculated locally. A limited attempt to answer this question was the Cross Appalachian Transport Experiment conducted during the fall of 1983. The tracer material perfluorocarbon was released into the atmosphere in Dayton, Ohio, on five occasions and in Sudbury, Ont., twice. By sampling the atmosphere downwind of the release areas, scientists hoped to determine the trajectories of the acid material.

Concern regarding the impact of the steady increases of carbon dioxide on the Earth's atmosphere continued in 1983. The U.S. Environmental Protection Agency released reports in the fall which suggested that by 2100 the average global temperature could increase by 5° C (9° F) with an associated rise in global sea level of between 144 cm (4.8 ft) and 217 cm (7 ft) as a result of the increased levels of carbon dioxide and other trace gases put into the atmosphere primarily through the burning of fossil fuels. These gases act to reduce the emission of long-wave radiation out into space yet still permit solar radiation to reach the Earth's surface. This mechanism of heat increase is referred to as the "greenhouse effect." At about the same time the U.S. National Research Council (NRC) issued a somewhat more conservative report on the same subject, which emphasized the remaining uncertainties in estimating the effect of carbon dioxide and other trace gases on climate. The report concluded, for instance, that if deforestation has contributed significantly to the increase in carbon dioxide during recent decades, then existing models that project future atmospheric concentrations based on man-made sources may overpredict the fraction of carbon dioxide remaining airborne. The NRC report concluded that existing evidence does not support a change away from fossil fuels but did suggest that some priority be given to the enhancement of long-term energy options that do not involve the combustion of such fuels.

Increased levels of aerosols in the upper atmosphere and lower stratosphere that are associated with high levels of industrial activity could counter the greenhouse effect of high levels of carbon dioxide. This possibility was not adequately examined in either of the studies. These aerosols appear to be ejected into the upper atmosphere and stratosphere via deep cumulus clouds, a process that is referred to as cloud venting.

Weather information. Two major changes in the ways in which weather information is distributed to the public received recognition in 1983. *The Weather Channel*, distributed via cable television, provided continuous 24-hour weather analyses and forecasting to about 11,200,000 subscribers in the U.S. as of December 1983. National Weather Service warnings and watches were relayed routinely as part of the broadcasts. Also, a full one-page discussion of past weather, a national forecast, and specific city forecasts were prepared during the week by *USA Today*, a national daily newspaper. Color graphics were used to make the treatment more effective.

These two mechanisms to distribute weather information represented major deviations from past efforts at public communication. They may herald a new era in the dissemination of meteorological analyses and forecasts.

—Roger A. Pielke

Geological sciences

No major theoretical breakthrough occurred in geology during the past year, which is to say that it was like almost every other year. It has become fashionable since the publication of Thomas Kuhn's *Structure of Scientific Revolutions* in 1962 to call almost any scientific change a revolution. An examination of the history of science will plainly reveal, however, that fundamental conceptual changes of the kind that occupied Kuhn's attention are much rarer than anything likely to be reflected in an annual report. On the other hand, 1983 was a year in which there