A few years ago, I found a book, Climate and Man, published in 1941 by the United States Government. It is a huge book with an incredible amount of information related to weather, especially as weather affects agriculture. I was immediately curious as whether, perhaps, the book contained any information from a 1941 perspective on climate change. I suspected that it did not.

However, I was very pleasantly surprised that it contains an entire sub-chapter on climate change that I find very informative and enlightening. The following are the major excerpts, quoted directly, from that sub-chapter. As I continue my study of climate change, I find the information, despite it being almost eighty years old, to be very useful and beneficial in understanding this most important issue.

Donald Lee Parsons

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Climatic Change Through the Ages

BY RICHARD JOEL RUSSELL

IT WILL be news to many people that man, during his geologically brief existence on earth, has never known a "normal climate. We are now at the tail end of an ice age and living in a period of crustal and climatic violence as great as any the earth has known. This is why we have to think so much about the weather. Such periods of revolution have occurred briefly several times in the history of the earth. Between them have been the far longer periods of crustal peace and a genial climatic uniformity – the "normal" times of the geologist. Here is the story.

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CLIMATE AS A WORLD INFLUENCE

The history of the earth can be traced back some billion and a half years by geologists. Suppose we imagine this vast period as a single year of time-imagine that a billion and a half years ago it was moment is the stroke of midnight on December January 1, the present 31, and the entire history has been telescoped into the 365 days between.

During practically the whole of that year, according to geologic evidence, the climate of the earth was much more genial and uniform than it is today. It was as though the earth were experienceing a long succession of balmy summer days. Toward the end of April (millions of years ago, of course), there was a brief, severe cold snap lasting a matter of hours on our condensed time scale-actually, an ice age. In the latter part of August there was another cold snap; still another around the middle of November; a somewhat less severe one about the middle of December; and finally another severe one beginning along toward this evening, December 31.

In our condensed time scale, man appeared on earth about 6 hours ago, around suppertime on December 31, and he began to keep historical records of his activities about 1 minute and 12 seconds before midnight. Thus he came here in an ice age, and he has never known any other kind of climate. But the fact is that all of the ice ages put together have lasted only about 3 days out of the year on our timescale.

Human beings, then, have seen only the more violent moods of the earth. They were not here during the immense stretches of time when it was comparatively quiet and peaceful.

The long periods of climatic geniality -never known by man – are called "normal" times by the geologist; the brief intervals of comparative violence are called revolutions. Two outstanding features, Russell points out, characterize the revolutions. (1) There is unrest in the crust of the earth-earthquakes, volcanoes, an up thrusting of high mountains, extensive deserts, retreat of the oceans. We are now in a period of as violent crustal unrest as the earth has ever seen. For example, 325 volcanoes are now active. (2) There are ice caps - frozen seas - in the polar regions, and sometimes the ice extends, in the form of glaciers, far down over the normally warmer parts of the earth. Out of these icy regions sweep cold winds; stormy battles occur where cold and warm air masses meet; there are violent changes from day to day and season to season, and the contrast is strong between hot equatorial latitudes and those around the poles. In "normal" times, on the other hand, the earth's crust is quiet, its surface is more level, oceans are more extensive and warmer, and there are open, unfrozen seas around the Poles. Over the earth, the climate is more like that in maritime regions today -not so hot around the Equator, much less cold toward the Poles, much less variable from day to day and season to season.

The key to the climatic difference between normal and revolutionary times, Russell holds, is the existence of the polar ice cap. During all times, normal or revolutionary, climate obeys the same physical laws, set by the nature of the earth as a rotating ball with an inclined axis, moving around the sun and surrounded by an atmosphere. But the difference between polar ice and no polar ice is very great over the whole earth. Yet the balance between the two conditions is delicate. "A rise of 2° F. in the temperature of the earth now would be sufficient to clear polar seas of all ice. We would then be living in a "normal" climate.

WHAT THE RECORDS SHOW

Geochronological climatology demonstrates a gradual amelioration, or lessening, of extreme glacial conditions during the recent epoch and sheds much light on the major oscillations which have at times opposed and at other times accelerated the general trend. Its conclusions are dated only in relative terms toward the beginning but become fixed as to year as the record progresses.

The climatic pattern of the last major glacial advance is the real starting point from which amelioration proceeded; hence a brief summary of those conditions is now in order. The discussion will be confined to the Northern Hemisphere, where records are most completely known. It must always be borne in mind that the Southern Hemisphere approaches being a reverse or mirror of the Northern, with important modifications resulting from more wide-spread development of oceans south of the Equator.

Along the borders of the ice cap there was a strip of tundra, just as now, but in Europe it extended as far south as northern Spain. The evidence is that of arctic plants in peat and the remains of such animals as the arctic fox, reindeer, musk ox, and arctic lemming (a small rodent).A similar belt in North America has been demonstrated by the finding of such animals as the musk ox in Indiana, Illinois, West Virginia, Missouri, and Iowa and reindeer in New Jersey, Connecticut, and Vermont.

Between tundra and true forest climates in Europe was a zone of cold steppe similar in many ways to the treeless plains of southern Siberia today. Here lived the dry-climate jerboa (a jumping rodent), red suslik (a ground squirrel), steppe marmot (related to the wood- chuck), and saiga antelope. The zone appears to have been narrower in North America, where forests approached ice margins more closely as they do today in parts of Alaska and particularly in New Zealand, where luxuriant tree ferns and other plants of tropical aspect almost reach the ice itself. The contrast between European and American steppe climates is readily explained by the difference in trends of mountain systems.

True deserts were more limited in extent than now, partly as the result of greater precipitation but chiefly because lower temperatures reduced the evaporation rates. They were somewhat farther south where topography permitted.

Forest climates in Europe were split into two groups, one confined to narrow strips along the Atlantic seaboard and the other in the highlands toward the southeast. Glaciation so upset pre-Quarternary conditions that most of the Tertiary flora vanished, and Europe today is poor in plant species. The ice crowded plants against mountain ranges they could not cross. In North America the open belt of land south of the ice permitted southward migration of plants, and they again moved northward as the ice retreated. Many plants have remained behind as disjuncts or relics of ice-age distribution.

Tropical climates were somewhat cooler during glacial maxima. The glaciers on Mount Kenya, 8 miles south of the Equator, are now confined to elevations in excess of 15,000 feet. During the Pleistocene they extended down to 10,000 feet. A similar record exists in Mexico. The glaciers on Popocatepetl came down about 4,725 feet below present levels and those on Ixtaccihuatl, 3,860 feet.

Recession of glaciers shifted climatic belts toward existing positions (1, 28). As land formerly covered with ice was exposed, tundra vegetation was established upon it, steppes expanded in continental interiors, deserts grew in size and shifted northward. Forests followed in the path of migrating tundras both northward and upward into mountains as temperatures ameliorated.

It is thought that the last general recession of continental glaciers began about 30,000 to 40,000 years ago. Varves in North

America account for some 28,000 years, but the record is incomplete and has not been tied into the European geochronology. From a climatic standpoint it is convenient to consider this epoch of retreat, the Recent of the geologist, in four parts, differentiated chiefly on the basis of evidence: (1) From about 30,000 to 40,000 years ago to about 12,000 B C., a time of glacial recession, with halts and minor advances indicated by verves and types of evidence that are essentially geologic; (2) from 12,000 to 120 B. C., a time when the record is fairly clear with respect to minor climatic oscillations, the evidence being essentially archeologic or paleontological and the dating depending chiefly on verves; (3) from 120 B. C. to the middle of the nineteenth century, with documental evidence of climatic swings; and (4) since the middle of the nineteenth century, the instrumental period, with precise data. The major events during ice retreat do not coincide with these periods.

In northwestern Europe the Arctic period, characterized by extreme glacial climates, gradually passed into the Subarctic period in about 12,000 B. C. A Baltic ice lake, which did not communicate with the Atlantic Ocean, was then established along the southern and eastern fringe of the melting ice. Accelerated melting occurred in about 8,000 B. C., and the ice retreated far enough northward to permit the entrance of saline Atlantic waters into the Baltic, and a cold-water Yoldia fauna (a group of shelled animals, the most common of which was Yoldia arctica, which today lives only in waters at least as cold as 32° F.) was established. The lands of central Europe then experienced a northern (Boreal) climatic period, the diminishing intensity of which permitted northward migration of forests. After some complications in Baltic history, which are chiefly of geologic interest and need not concern us here, in about the year 5,000 B. C. the Baltic became warm enough to support types of life that demand temperatures warmer than those of today. Geologists speak of this time as the Littorina period, naming it after one of the dominant species of snails living in the Baltic at that time. Men living in western Europe were making kitchen middens, or refuse heaps, which are now being excavated for the purpose of examining their culture, a stage called Epipaleolithic. From the climatic standpoint, warm and moist conditions lasted from about 5,000 to 3,000 B.C., and the time is called the Atlantic period. Temperatures were high enough so that all small mountain glaciers of the Alps and the present United States disappeared completely.

The Atlantic period was followed, about 2,000 B. C., by the dry and warm Subboreal period, which lasted well over a thousand years. Men were leaving curious piles of rock – dolmens - in western Europe and practicing mass burials of their dead. Others, the "lake dwellers, were building houses in marshy places which later became lakes The cultural stage was Neolithic in western Europe. . Some lines of evidence lead us to believe that the actual minimum in precipitation occurred in about 2,200-2,000 B. C., but there was also very dry weather centering about 1,000 B. C. In all probability there were two times of extreme dryness separated by a short period of intense rainfall, for it has been established that the lake villages in Switzerland were destroyed by flood in 1,275 B, C.

Subboreal times were followed by increasing rainfall and cooler weather in western Europe, during a period known as Sub Atlantic, which reached typical development between 850 and 300 B. C. Bronze and iron ages were blended into historic times. The Hallstatt and La Tene cultures of central Europe characterize most of the period. From peat bogs of Sub Atlantic times come not only record of human events but also a detailed botanical record of sequential climatic changes.

The climatic history just sketched is quite definite for western and central Europe. Was it universal? Instrumental records from recent decades plainly tell us that many extreme departures from normal conditions at one place have little or no expression elsewhere. On the other hand, certain sympathetic swings seem to be related even though appearing in observations as widely spaced as different continents or hemispheres. Unfortunately, we know less about the geochronologic period in other continents than Europe. The record from western Asia is in rather close agreement as far as it is known. Anau was occupied during the wet period of about 5,000 B.C. Drought occurred there in about 2,000 B. C., during the European Subboreal period. Western Asia was again wet during the moist Sub Atlantic period of Europe. About 400 B.C. a precipitation maximum is indicated in North America, Africa, western Asia, and Europe. All of these places record very dry conditions about A. D. 700. There is thus considerable evidence in favor of world-wide climatic swings. On the other hand, the records indicate some notable exceptions, particularly between European and Chinese precipitation.

The documental period of European climatic history indicates many swings in climatic conditions. During the first century after Christ precipitation conditions over Europe and southwestern Asia appear to have closely resembled those of today. This fact has been widely used as an argument against climatic change. The evidence is strong, however, that considerable variability has occurred during the interval. Advocates of climatic stability who use first-century vs. twentieth-century comparisons have no stronger case than would a person who might visit Duluth each January and advocate a theory that average annual temperatures there are below freezing.

From about A. D. 180 to 350 Europe experienced a wet period. The fifth century was dry in Europe and western Asia and apparently also in North America. Many of the lakes in the western United States appear to have dried out completely. Europe was both warm and dry in the seventh century. Glaciers retreated to such an extent that a heavy traffic used Alpine passes now closed by ice. Tree rings in the western United States indicate minimum precipitation at this time. Nile floods were low until about A. D. 1000.

The beginning of the ninth century brought heavier precipitation to Europe. The levels of lakes rose, and people living around their borders were pushed upslope. Documental evidence from western Asia and American tree rings give similar testimony. Warm, dry conditions returned during the tenth and eleventh centuries. This was a time of great exploratory activity among northwestern Europeans. The Arctic ice cap may have disappeared entirely. In any event the logs of Greenland voyagers show routes of travel where they would now be impossible because of ice floes. Greenland was settled in 984 and abandoned about 1410. During the eleventh and twelfth centuries it was in rather close touch with Iceland and Europe, even to the point of having its own bishop. The decline of the colony was due to unsatisfactory conditions both in Greenland and in northwestern Europe. The first half of the thirteenth century was a period of great storminess, as shown by documents describing conditions on the North Sea. The early fourteenth century was unusually cold and snowy in Iceland and Denmark. America, too, experienced cold and wet weather during this general period. The Aztecs settled Mexico in 1325, when lakes stood at levels higher than today's levels. Drought and lower levels followed, but in 1550 lakes again reached high stages. Glaciers retreated between 1640 and 1770 and then advanced until the middle of the nineteenth century. Since then they have retreated back to sixteenth-century positions. This appears to be a world-wide condition and suggests that the last century has had higher summer temperatures than the eighteenth century just preceding.

RATE OF CHANGE OF CLIMATE

One normally considers that a flea and an elephant differ greatly in size. In relation to the sun, however, the difference is inconsequential. To a geologist, a long-time trend in climatic change might occupy a million years or so. To a climatologist, especially one who is dealing with the instrumental period, a long-time trend might be a matter of half a century to several centuries. Short-time fluctuations would involve only a small number of years.

The time during which instrumental observations have been made in sufficient quantity and under well enough standardized conditions to permit comparative studies has been so short that climatologists have been severely handicapped in their attempts to find systematic changes in weather conditions. Precise studies can do little more than call attention to short-time fluctuations. Our surest long-time trends are established so far on documental evidence.

A list of more than 50 "climatic cycles," varying in length from a few to nearly 2 centuries, has been compiled by Mascart. Each man who has proposed one or more of these cycles has become convinced that he has found a particular rhythm in which climatic conditions have changed from a minimum, through a maximum, and back to the minimum observational value. It may be possible that there is true significance in some of these cycles, but it is also apparent that the climatic experience resulting from various combinations of cycles is indeed complex.

Though firm advocates of climatic cycles will sharply disagree, such facts as we possess today neither definitely demonstrate nor disprove the existence of any real cycle. Such climatic variability as has been observed may be explained as resulting wholly from random fluctuations.

CLIMACTIC CHANGES FROM YEAR TO YEAR

While the changes in climate over such long ranges of time as geologic epochs or periods are primarily of practical interest only to students of earth history, and such variations as occur during decades are of practical utility only in such fields as long-range economic or cultural planning, the ordinary citizen, especially if he is concerned with agriculture, finds his interests chiefly centered about the question of variation from one year to the next. The problems of long-range forecasting are discussed elsewhere in this volume. Here it need be stated only that new concepts are arising continually in the minds of climatologists and that their testing in the light of increasingly valuable instrumental observation is gradually building a secure footing for the complete understanding of the causes and nature of climatic variations from year to year.

SOME THEORIES OF CLIMATIC CHANGE

CLIMATE AND CHANGES IN THE EARTH'S SURFACE

The close relationship shown in the geological record between times of revolution and glacial climatic patterns leaves slight room for doubt that crustal unrest is responsible for the major breaks in the continuity of normal geologic climates.

At times of revolution continents are most extensive, and their topography is most complex and has greatest relief. These factors make for increased temperature ranges between opposite seasons, increased pressure ranges both between seasons and from place to place, higher wind velocities, and numerous other changes in weather conditions, all of which make for climatic complexity.

The fact that glacial deposits are almost wholly restricted to the formations originating at times of revolutions strongly favors a cause and effect relationship. Most salt layers, the greatest deposits of coarse sediment, and the most extensive deposits of nonmarine sediment also come from these times of crustal unrest. Volcanic activity is most pronounced at such times.

In sharp contrast to the glacial climatic patterns of revolutions is the moderate, uniform, subdued-zonal, "normal" climatic pattern of the long intervals of geologic quiet. These were times of reduced continental area, low relief, diminished volcanic activity, and crustal rest.

No widely accepted theory explains the underlying cause of more or less periodic geologic revolutions. Their occurrence is widely accepted as geologic fact. Their climatic relationships appear to be well established. Their causes may be regarded as matters for the future to decide.

POSSIBLE ASTRONOMIC EFFECTS ON CLIMATE

Several theories of climatic change based on causes not related to the earth's crust or atmosphere are, or have been, held in widespread popular esteem. The more significant will be sketched here.

The annual revolution of the earth around the sun takes place in a plane called the ecliptic. The axis of the earth in inclined toward this plane at an angle of about 23°27’3”. This inclination of the earth’s axis is the principal cause of seasons. It is responsible for the differing lengths of night and day experienced in various latitudes, causes seasonal shifting of wind belts, and in other ways materially affects climatic distribution. If the axis were exactly right angles to the eliptic, days and nights would always have the same length in all latitudes. This would keep winter days from being shorter and reduce cold in higher latitudes.

It is thoroughly established that the angle between the axis and the ecliptic is not constant. It will reach a minimum of about 22°30 some 9,600 years from now. Arguments that climatic changes result from this cause are sound enough in quality but are not impressive from the quantitative standpoint. The variation is altogether too small to account for contrasts indicated by the geologic record. The cycle recurs too often to explain the small number of glacial climatic experiences since the beginning of the

Paleozoic era. It may contribute to certain cycles “long range” in terms of nongeological climatology.

Another astronomic fact is that the axis of the earth does not always point approximately toward the North Star. This means that existing conditions whereby the earth's nearest approach to the sun (the perihelion) occur only a few days after shortest day of the northern winter (winter solstice) will gradually change opposite extreme in which the earth will be closest to the sun in northern midsummer. This cycle occurs each 26,000 years and is called the precession of the equinoxes. Northern hemisphere seasonal contrasts should be somewhat intensified as the perihelion approaches the summer solstice. This effect also may contribute to “long-range” cycles in nongeological climatology.

The sun is a variable star. This means that the amount of radiant energy it emits changes from time to time. Some of the shorter periods of change have been considered to be cyclic, but instrumental observations extend back for only a few decades. Changes in solar radiation have been related to the numbers, positions, and polarity of sunspots. The relation between sunspots and terrestrial magnetism is very close, but no conclusive evidence indicates any simple climatic relationships.

Whether variations in the sun’s radiant energy could cause such contrasts as exist between glacial and normal geologic climates is unknown. Against the idea is the close correlation between glacial conditions and crustal revolutions. If the sun is the underlying cause, some mechanism whereby revolutions and increased volcanic activity result from varying amounts of radiant energy must be found.

CLIMATE AND CHANGES IN THE ATMOSPHERE

One of the most popular explanations of glacial climates relates them to changes in the earth's atmosphere. The ability of the sun’s radiant energy to travel from the outer limits of the atmosphere to the earth's surface may change with changes in the atmosphere itself; on a clear day, the coefficient is higher than on a day with a heavy cloud cover. If the atmosphere had a perpetual cloud layer, a great deal of solar radiation would be reflected back to space and consequently the amount of energy available to the earth's surface in the form of heat would be diminished. A cloud blanket, however, would also cut off a good deal of terrestrial radiation tending to conserve such heat as might exist beneath it. Temperature ranges between day and night, one season and another, and higher and lower latitudes would be reduced. Arguments as to whether the loss in the sun's heat reaching the surface (insolation) exceeds the energy value of heat trapped by a cloud layer are of interest only if it can be demonstrated that such a layer is a possibility. The ascent of air to form cloud in one place must be matched by descent elsewhere. Rotation and equatorial heating are bound to produce an atmospheric circulation in which definite belts of descending air occur. The cloud blanket would be broken at all places where air descends, and it would also be punctured as the result of topographic irregularity such as exists on earth today. An extensive, though not world-wide cloud blanket could best form over an earth of small continents having subdued relief. Tendencies in this direction are most readily realized during normal geologic periods and might have contributed to the minor zonal differences characteristic of normal climatic patterns. They may be regarded as impossible of realization over the earth today or at any other time of geologic revolution. As far as the contrast between normal and glacial climatic patterns is concerned, we may regard crustal stability as the true cause of contrasts, cloud layering as a possible conditioning factor.

Much has been written about varying amounts of carbon dioxide in the atmosphere as a possible cause of glacial periods. The theory received a fatal blow when it was realized that carbon dioxide is very selective as to the wave lengths of radiant energy it will absorb, filtering out only such waves as even very minute quantities of water vapor disposes of anyway. No probable increase in atmospheric carbon dioxide could materially affect either the amount of insolation reaching the surface or the amount of terrestrial radiation lost to space.

VARIATIONS IN THE EARTH'S HEAT

There is a slow radiation into the atmosphere of heat that slowly escapes from the earth's interior. It has been suggested that variations in the rate of escape could produce changes in climates. The rate of escape, however, is too slow to have an appreciable effect upon such things as daily or seasonal temperature ranges today. These are controlled by solar rather than by terrestrial energy.

A possibility exists that cyclic variations in the rates of escape of the earth’s heat have occurred during the course of geological time. If such is the case, they have followed the general history of normal versus revolutionary conditions. The idea is highly speculative, and at most such changes have acted only as conditions modifying climatic patterns determined by crustal behavior.

CLIMATE AND MAN

The world pattern of climates today depends primarily definite facts of atmospheric behavior related to surface conditions such as the relative proportion of oceanic cover, shapes and sizes of continents, their positions with reference to the Poles and Equator, and the distribution of plains, plateaus, and mountains upon land surfaces. The world pattern during any part of the geologic past was, in general, related to exactly the same phenomena. Many of the facts of atmospheric behavior have remained practically constant throughout geologic time. The amount of atmosphere has not changed appreciably nor has its average temperature, viscosity, composition, or other significant physical property. The speed and direction of the earth's rotation, the rate of escape of heat from the earth’s interior, the amount of solar radiation received by the earth, and similar fundamental climatic factors have either remained constant or varied by only inconsequential amounts. The most variable factors affecting climate have been those relating to continental sizes and elevations. It is thus reasonable to regard these as the most probable causes of such climatic change as is indicated by geological evidence. This conclusion finds strong support in numerous divergent, but not wholly unrelated, fields of geological investigation.

For reasons that are today unknown, the earth has experienced several relatively brief periods of crustal unrest, each of which has been accompanied by evidences of glaciation in various parts of the earth's surface and by intense aridity in other parts. Between these revolutionary periods have been vastly longer intervals of quiet and climatic monotony. Such is the general outline of climatic history of geological proportions.

Man appeared on the scene during a revolutionary period and has experienced glacial climates. In the geologically recent portion of his experience, during which he has progressed through a cultural development which has culminated in such scientific advances as the introduction of modern instrumental observation, he has witnessed a slow, and possibly permanent, amelioration of extreme glacial climates, but he has at no time experienced the normal climate indicated by most of the geologic record.

Man has observed that climatic conditions fluctuate rather widely from time to time at a given place, and in seeking to understand such natural phenomena he has been tempted to explain such fluctuations on the basis of recurring cycles. As yet, however, no definite proof has been advanced to contradict the opinion that all such relatively short-term climatic changes are nothing more than matters of chance. The world pattern of climates today is the product of climatic variations, not the expression of recurring mean, or normal, conditions. The extent of desert climate will not be the same next year as this. The humid margin of the desert is the product of an ever-changing distribution of extreme aridity. The time may come when such changes will be well enough understood to be of definite forecast and economic value, but it is likely that such information will be the fruit of long continued and patient research.

Interest in changes of geologic proportions will remain intellectual. There is satisfaction in learning the secrets of earth history, even though our investigations are based almost entirely upon evidence that accumulated long before the appearance of man on the earthly scene and all forecasts relate to a time when he may no longer be present to verify or contradict them.

END OF EXCERPTS

All the text in this tract is quoted directly from, and attributed to the book, Climate and Man, commissioned by the United States Congress, compiled by the United States Department of Agriculture and published by the United States Printing office, 1941

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