amount of gas by an emergency use of base reserves.

It is possible that the allocation of this gas will place, in some localities, an extraordinary burden on pipelines. This situation must be dealt with in the same manner: conservative ratings of pipeline pressure must be carefully raised, for example, so that adeuqate gas, on an emergency basis, can be provided.

2. Any remaining shortfalls between now and March 31 must be covered through increased production from existing wells. Due to technical complications and the already low overall pressure in the national pipeline systems, a lead time of three to four weeks is necessary to realize such increases. However, the technical equipment (compressors, etc.) for more rapid exploitation of wells exists, and given the relatively small added amounts of gas needed, the risk to the wells, with adequate planning, is at a minimum.

3. Canada, Algeria and the Netherlands have offered varying small amounts of gas for import. While these amounts are marginal they could significantly contribute to the alleviation of certain local hardship situations. This import capacity exists now, without further capital investment.

It must at this point be reiterated that the present energy crisis is a direct result of postponement of the development and introduction of more advanced energy technologies. The U.S. Labor Party has already called for a congressional investigation into the causes for such "shortsightedness." Passage of the Schlesinger bill, aside from its most dangerous strategic political implications, would only further obscure the fact that this country at this time has no competent long-term energy policy and would abet those who would prevent its development. Defeat of the Schlesinger bill is an emergency measure on a par with the measures we have identified above.

EXCLUSIVE

The Real Causes Of The Winter's Weather

The abnormal weather afflicting North America this winter — the extreme cold in the East and the extreme warmth and drought in the West — is *not* the result of sunspots, Soviet radio signals, an impending Ice Age or any of a dozen absurd explanations currently being circulated. Its principal cause is the application of the very "energy conservation" policies which the cold wave is being used to justify.

The global disruption of weather over the past year has been triggered by the spreading drought in the Amazon basin, a drought caused by deforestation policies imposed on Brazil by the International Monetary Fund. This deforestation policy is the immediate correlate of the substitution of labor-intensive for energy-intensive methods in industry and agriculture, of the substitution of primitive charcoal for coal in Brazil's steel mills. It is the massive reduction in energy throughput caused by the application of such policies which is responsible for the weather disaster.

It is useless to attempt to understand the actual causes of the weather on the basis of the reductionist approach of most current meteorology. It is therefore scarcely surprising that no meteorologist working with that method has in fact come up with even a plausible reason for the current climatic shifts. What is required is the application of the same consideration of nonlinear effects which has been successfully used in the field of plasma physics.

The earth's atmosphere, as is the case with laboratory-sized plasmas, is dominated by nonlinear effects — self-expanding energy flows (energy flows which themselves contribute to the global process by which those energy flows are created). The dominance in the atmosphere of self-generating processes means that, in general, seemingly marginal initial effects can become rapidly magnified into new self-expanding processes, eventually substantially altering global climate.

How Weather is Produced

To understand how local climatic effects in a single part of the world can affect global climate, it is necessary to understand how the earth's weather is actually produced. Energy coming to earth from the sun is converted to energy of motion through the evaporation and precipitation of water, as in a steam engine. This drives weather patterns. About 15 per cent of all solar energy hitting the earth is absorbed through the evaporation of water. In the normal weather pattern, solar energy is absorbed in the evaporation of ocean water in the large oceanic anticyclones (see Map I and Diagram 1) in a manner analogous to the boiler of a steam engine. The resulting moisture-laden air flows into the major tropical cyclonic regions — the tropical jungles of the Amazon, the Congo, and Southeast Asia. From the centers of these cyclonic regions the moist air is pushed upwards, cooled, and the water precipitated out of it, releasing the energy previously stored. This tremendous release of energy, by warming the upper level air at the level where precipitation occurs, actually drives the motion which continues the circulation. This energy of motion not only drives the cyclonic circulation of the tropics, but is the main engine for driving the entire gobal circulation. The polar cyclonic zones constitute secondary engines of a similar sort, but of lesser overall energy throughput.

The role of the biosphere in this energy flow is dominant, although foolishly ignored by most meteorologists. Plant life, by utilizing solar energy directly to pump water into the atmosphere, contributes greatly to the recycling of rainfall back into the circulation. At least

30 per cent of the overall energy flow in the global circulation is directly attributable to the effect of vegetation. For example, the difference in water throughput between a temperate forest and bare ground is estimated at the equivalent of 40-50 cm (20 in.) of rain. The role of the tropical rain forests, of which the Amazon is by far the most important, is especially significant. The ability of these dense masses of vegetation to recycle water using solar energy is responsible for the intense energy flows in these regions, in excess of ten times the density of energy flows for the globe as a whole. The Amazon region alone accounts for about 10 per cent of overall climatic energy flows.

These energy flow patterns are self-maintaining, or metastable, rather than absolutely stable in any static sense. The cyclonic regions, characterized by the transformation of heat energy into energy of motion, maintains this characteristic flow since the resulting upward flow of air maintains the release of energy through precipitation. The vegetation which contributes to this process is in turn also maintained by the rainfall generated. Conversely, in an anticyclone (on land for the sake of comparison) the absence of moisture and therefore of an energy source for upward motion, maintains a descending, outward air flow, which sustains the lack of moisture and rainfall and the resulting lack of vegetation. The large oceanic regions, which of themselves could support cyclonic activity as well (like hurricanes) are similarly maintained as anticyclones by the driving force of the surrounding land-linked circulation patterns.

This very metastability or self-maintenance of existing circulation patterns (which determines climate) implies that such patterns can evolve rapidly since initial marginal changes will tend to become self-magnifying once a threshold is passed. During periods in which the biosphere is developing greater energy densities and greater amounts of vegetation come into existence, the overall circulation of the atmosphere is intensified — more rainfall and greater cyclonic activity results, leading to still greater increases in biomass. During such periods increased ordering of circulation leads to greater differentiation of climate and a greater difference in polar and equatorial temperature. The greater proportion of energy converted from heat to motion is connected with a general cooling of the earth as a whole, accentuating further the polar-equatorial climate contrast and expanding the polar air mass. In this cooling, the upper portions of cyclonic storms act as gigantic condensors on a refrigerator, radiating part of the heat released by precipitation into outer space. Such a process of energy intensification and cooler and wetter climate has characterized the long-term meteorological trend for the past tens of millions of years, climaxing in the present relatively cool climate and the even colder climate of the recent Ice Ages. The trend of the historic past few thousand years has also been toward colder, wetter climate — in general more and more favorable to human agricultural activity.

In historic times, the very expansion of human agricultural activity, by increasing energy throughput to the biosphere, contributed to the increasingly favorable

DIAGRAM 1

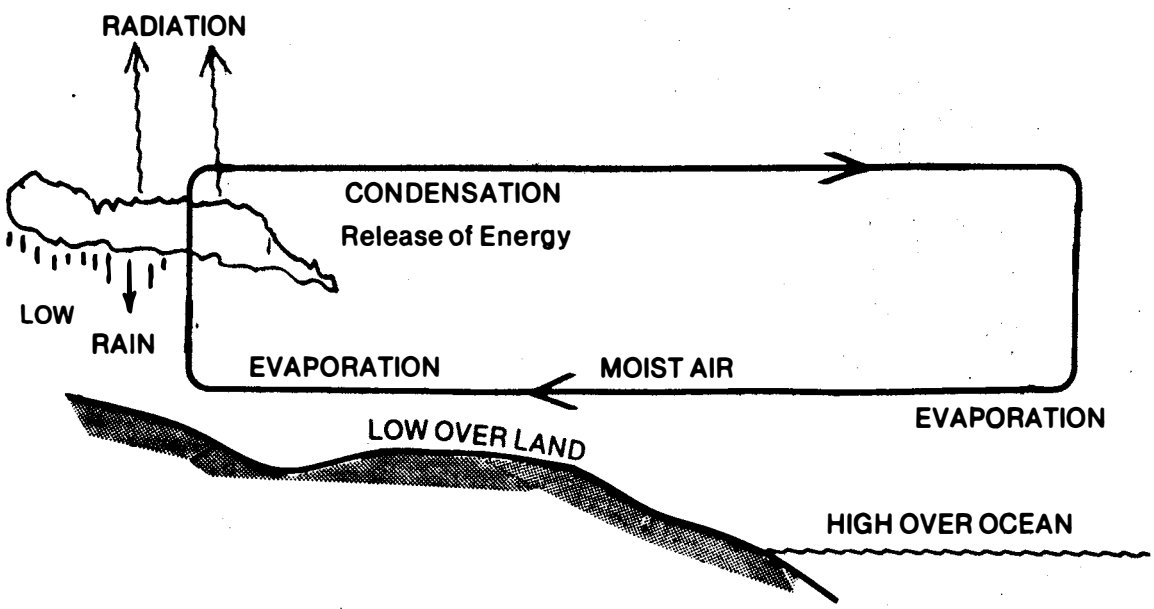
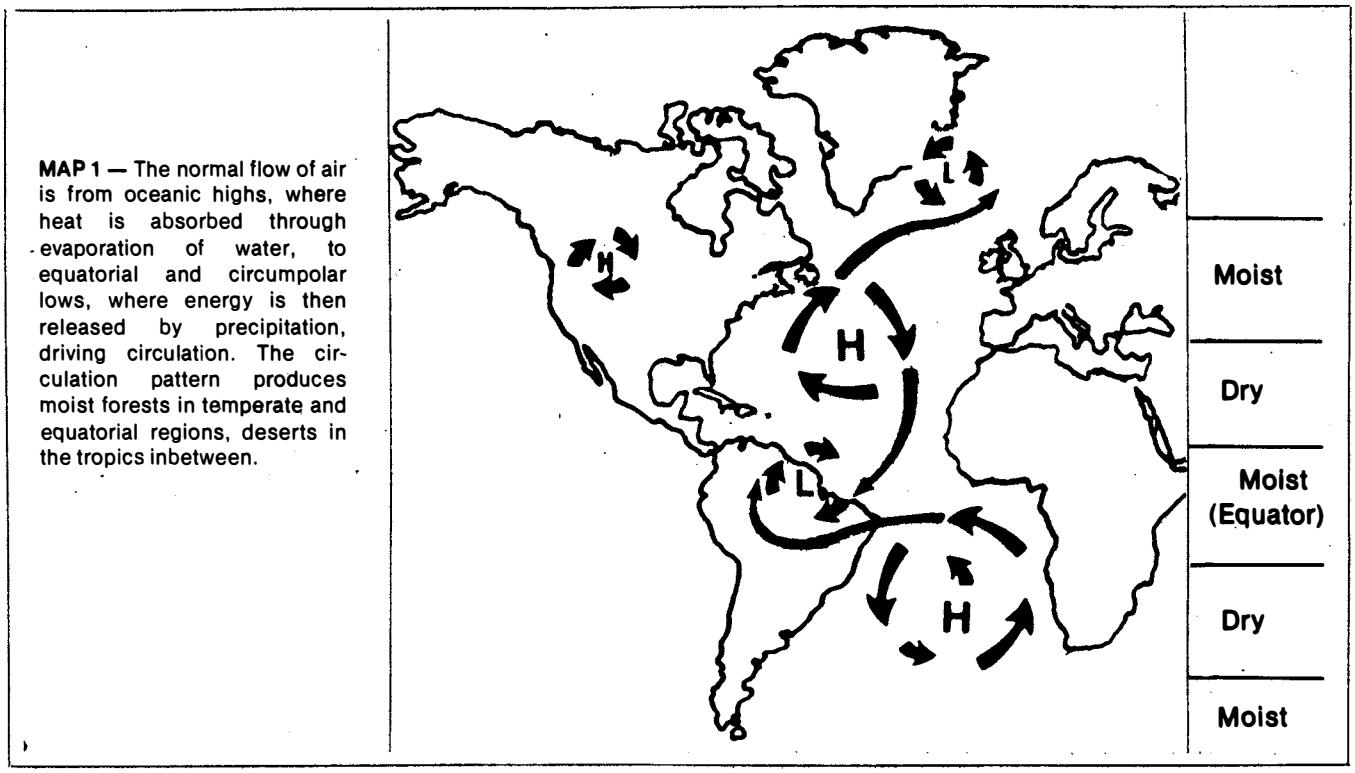


DIAGRAM 1 — Vertical cross section of normal atmospheric flows, such as along the line connecting centers of the North Atlantic High and Amazon Low. Descending air is warmed in the high and absorbs moisture, which it carries to the Low, where it is driven upwards. As air rises, it cools, leading to precipitation. This releases energy, heats the air and drives it further upwards. Precipitation is recycled by vegetation back into the atmosphere, continuing the energy flow.

development of the climate.

However, the opposite process, devolution of energy flows, can occur as well. When vegetation is stripped from the ground, the process of desertification sets in. The energy flow necessary to drive cyclonic storms is lessened, leading to lessening of rainfall, increased loss of vegetation and increasing drought. Pushed sufficiently far on a global scale, this process leads in the direction of the formation of self-sustaining anticyclones over all land areas, general desertification, and tremendous changes in global circulation patterns. In opposition to the pattern during periods of development, the climatic zones become less differentiated, warm dry air expands outwards from the equator, the general circulation is weakened, rainfall decreases, and the average global temperature is slowly increased. On a local scale, such a phenomenon is evident in recent times in the spread of the Sahara Desert, and on a global scale was typified by the early stages of the Age of Dinosaurs 200 million years ago, when the continents were covered by vast interior deserts, no ice existed, and the global climate was warm and dry from the equator to the poles.



MAP 1 — The normal flow of air is from oceanic highs, where heat is absorbed through evaporation of water, to equatorial and circumpolar lows, where energy is then released by precipitation, driving circulation. The circulation pattern produces moist forests in temperate and equatorial regions, deserts in the tropics inbetween.

The Present Situation

It will quickly be seen that the current weather patterns are symptomatic of exactly that later sort of devolution of energy flows, despite the apparent contradiction involved in the abnormally *cold* weather in the East. While the precise details of the mechanics by which the shifts in the Amazon have altered temperate climate remain in doubt, the overall process is completely certain.

The phenomenology of both the summer and winter weather of the past year is widely known and agreed on among meteorologists. In the summer, the principal distortions in circulation in the Northern Hemisphere were the anomalous northerly location of the North American high and the anomalous North-easterly location of the Azores high to a location over West Europe. The result of these two northerly shifts was to divert the polar cyclonic storms northwards, bringing drought to both Western Europe and Western North America. The shift of the Azores high, which normally brings warm air to the East Coast in summer, allowed a greater southwards motion of the Greenland low, making for a considerably cooler than normal summer in the East.

In the fall and winter, this pattern intensified and shifted (Maps 2 through 7). The North American high shifted still further northward, and the anomalous high in the West European area was now located over Iceland. The very strong North American high pushed warm air very far north, bringing 40° weather to Anchorage and even more efficiently diverting rain-bearing air far to the north of the drought-stricken western states. Simultaneously, the "Greenland low," hemmed in on all sides by the anomalous highs, and unable to retreat northwards, was pushed still further south, over Nova Scotia. The combined effects of the strong Western high, bringing frigid air from much further north than usual, and the southerly low has created a powerful funnel, bringing glacial air down over the Great Lakes and into the Mid-Atlantic states.

Since the weather flows are interlinked in a single hydrodynamic pattern, the behavior of the Greenland low can be treated as a mere corollary of the location of the anomalous highs.

Up to this point, all meteorologists would be in essential agreement, as is indicated by statements by Dr. Gilman of the U.S. Weather Bureau Long Range Forecasting, the noted predictor Jerome Namias, and others. The question is — what caused the tremendous, 500-600 mile shifts of the anticyclone circulations? It is

The maps show the development of circulation over the North temperate and North Polar regions in the past year. In addition to indicating average monthly location of the centers of high and low pressure systems, the maps show the mean flow of air around the polar lows, a flow which marks the average boundary of the polar air mass. The paths of winter storms form a band extending somewhat to the south of this flow line. Air flow around the most important highs is also indicated.

The general process clearly portrayed here is the distortions of polar circulation resulting from the northerly motion of the high pressure systems due to Northward shifts in equatorial circulation (south of the area shown in this map) The equatorial circulation shifts are connected with the Amazon drought and are communicated to the subtropic highs.

MAP 2 — The normal winter situation. The normal summer locations are similar, although strengths of systems differ. During summer, the North American high is further to the west, off California.

MAP 3 — January 1976. Note the change already evident. The North Atlantic high has been pushed northward and distorted into a dumbbell shape. This northward motion has put a dent into the polar circulation, separating the normal Greenland low into two components — one Near Novaya Zemlya (just east of Finland) and the other over northern Canada. The effect on weather was to divert winter storms both to the north over the Western United States and Western Europe bringing drought, and to the south over northern New England, bringing extreme cold to New Hampshire and Maine.

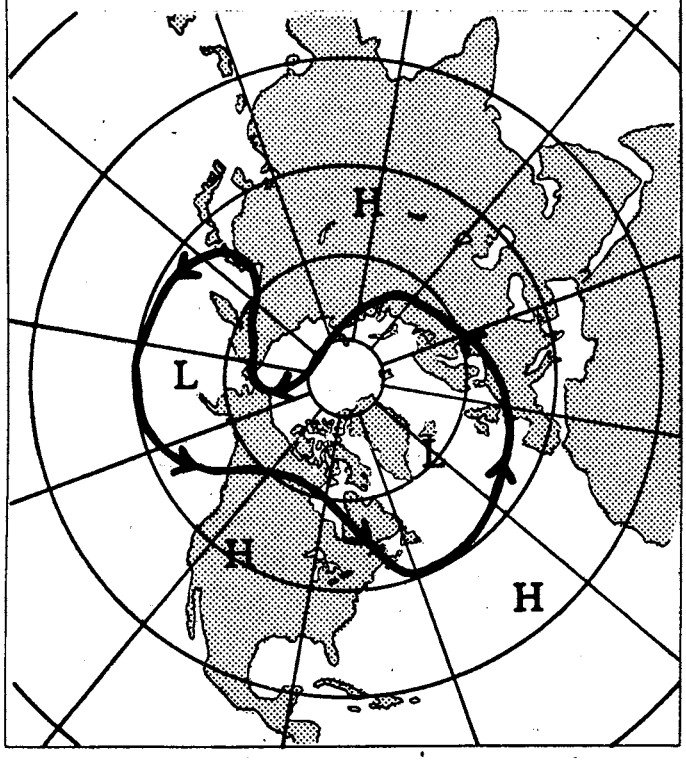
MAP 4 — April 1976. The situation has greatly accentuated. The cross and arrow show the motion of the northern end of the North Atlantic high between January and April. It has travelled much further north, squeezing the entire polar circulation northwards and further distorting it. This intensifies the droughts in the U.S. west and Europe, as rain storms move further North.

MAP 5 — August 1976. The continuous northerly motion of the North Atlantic high is pushing the Novaya Zemlya low towards the pole and closer to the low over northern Canada. A highly unstable situation is set up, since nearby lows tend to merge, one growing stronger at the expense of the other. The continuous movement of the circulation patterns further intensifies the Western European drought.

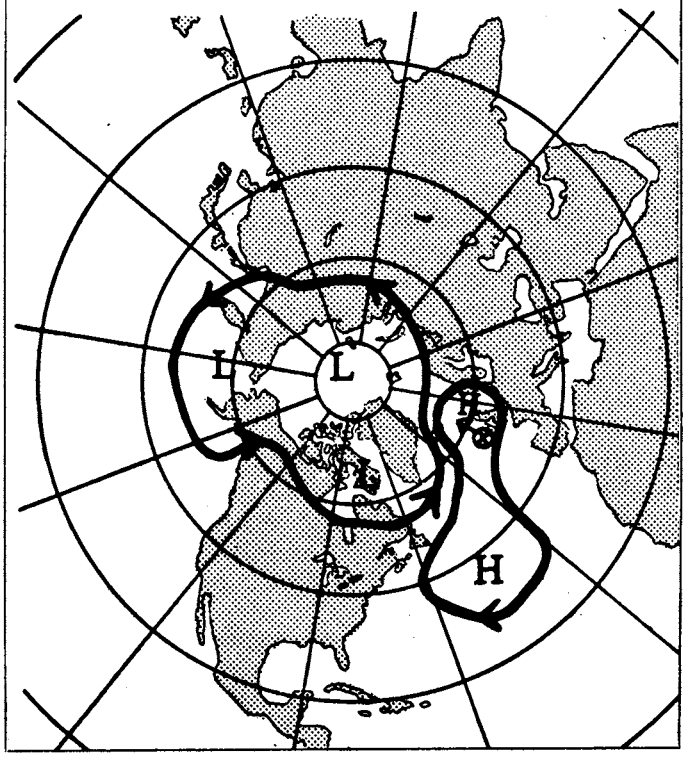
MAP 6 — September 1976. The North Atlantic and North American highs move further, and the instability begins to manifest itself, with the Novaya Zemlya low rapidly weakening and the flow reorganizing itself around the two remaining lows. Note also the southwesterly motion of the northern Canadian high, away from the North Atlantic high which is now located to the northeast of it. The instability continues through the fall as the circulation shifts betweeen the two organizations of flow. Between Oct. and Dec., this instability brings a more variable flow to Western Europe and Scandinavia, temporarily alleviating the drought.

MAP 7 — Jan. 1977. The present situation shows the consolidation of a new metastable circulation system. Compare this with the normal winter situation shown in Map 2, the January 1976 situation in Map 3, and the preceding September map. The highs in North America and the North Atlantic are far to the north of both their normal position and last year's position. The entire circumpolar circulation has been pushed totally off center from the pole, now occupied by the powerful highs. The Novaya Zemlya low has been destroyed. The Canadian low has been forced down to northern New England. This result has forced cold air into the Great Lakes and Mid-Atlantic states, while producing very warm weather in the U.S. West and Alaska and cold again in northern Japan. If this situation remains stable over several months, it will renew the drought in Western Europe.

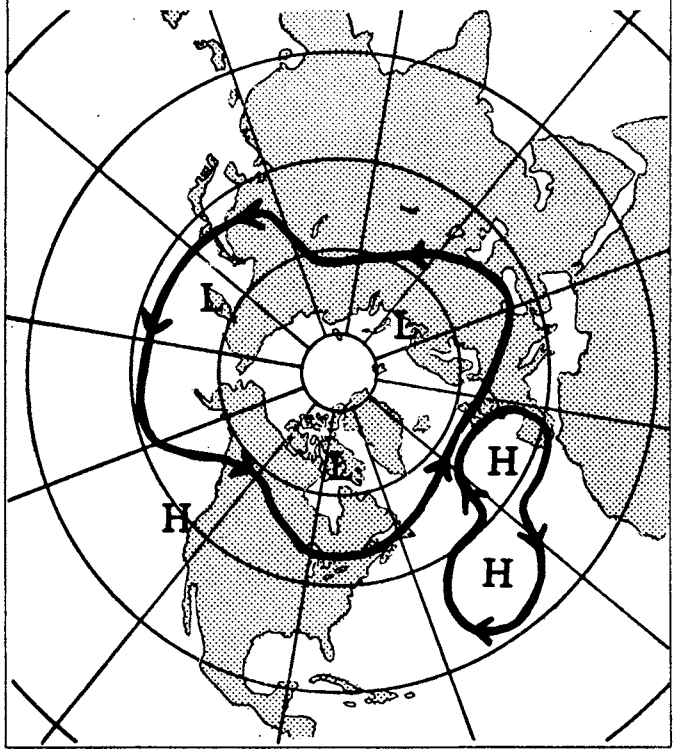
MAP 2 — NORMAL WINTER



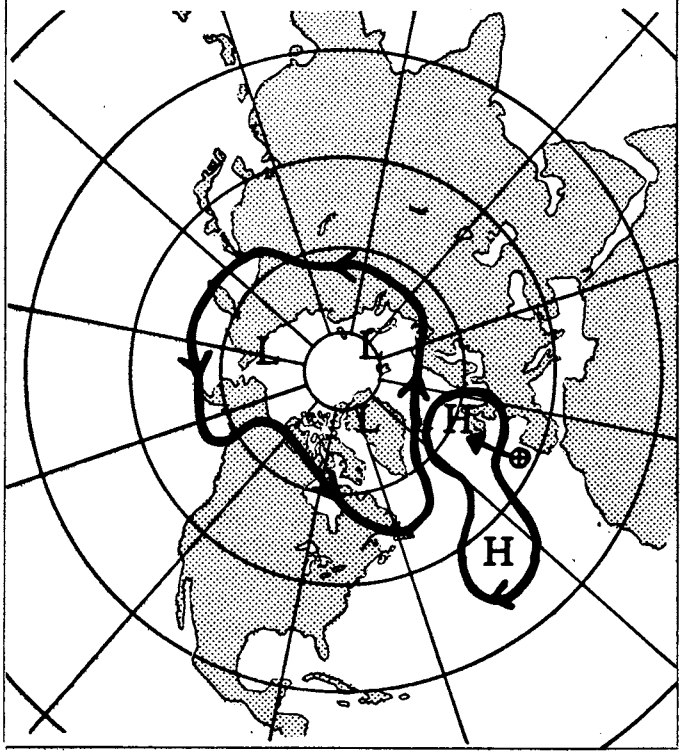
MAP 5 — AUGUST 1976



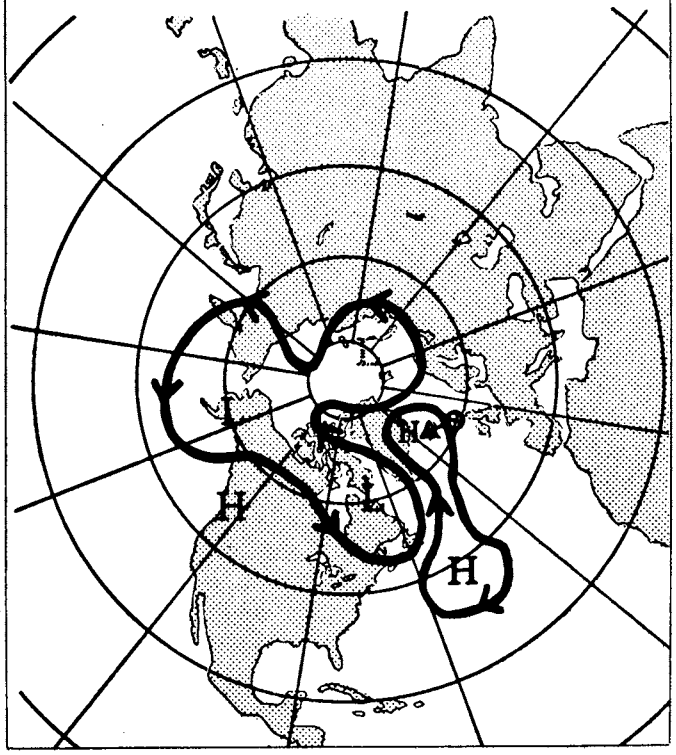
MAP 3 — JANUARY 1976



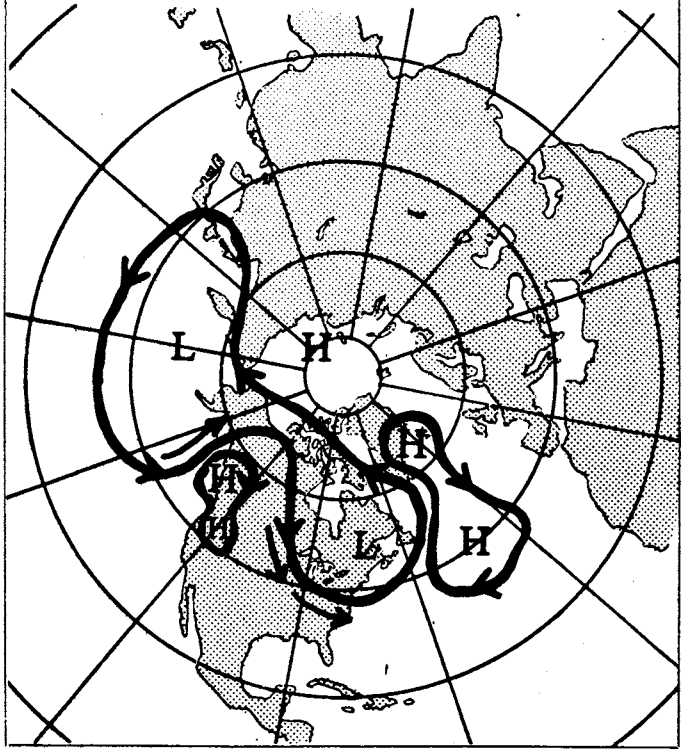
MAP 4 — APRIL 1976



MAP 6 — SEPTEMBER 1976



MAP 7 — JANUARY 1977



evident that this movement can be traced back at least to late 1975 and probably as much as a year earlier. There is no question that once set in motion, this shift too tends to become self-intensifying as both Gilman and Namias have correctly noted. The warm dry air over the western states intensifies the anticyclonic process leading to further warming, while the heavy snow cover over the East radiates the heat away, intensifying the cold. However, these additional self intensifications could only operate on the basis of an already large initial change in circulation, which neither Gilman nor Manias explain.

Before examining the actual explanation it is worthwhile setting up a firm criterion for dealing with the host of spurious causes which have been proposed.

The key criticism is that, even granted the self-intensifying character of climatic phenomena, the energy flow of the proposed cause must be of the same general order of magnitude of the effect. If this were not the case, than any normal small fluctuation would lead to similarly extreme weather. The trigger for such an extreme process must be over a certain threshold, and obviously greater than average fluctuations.

This consideration immediately rules out a number of hypotheses, since the energies involved are tremendous. The total solar energy reaching the earth is roughly 100,000 trillion watts,or 10,000 times present world human energy production. Total climatic flows amount to about 15 per cent of this total, in the sense that they are absorbed in the water cycle, while the rest is absorbed in direct heating.

To determine the approximate change in energy flows involved in the current shifts, we can calculate that roughly 5 million square miles of western North America and the Eastern Pacific have temperatures about 15-20°F above normal. This implies an overall energy flow about 10-12 per cent above normal over one fourtieth of the earth's surface, or about 200-250 trillion watts — still 25 times human energy production. We can consider that, since the extreme cold in the east is essentially a corollary effect of the warmth in the west that this figure is a good overall representation of the size of the effect involved.

Such calculation immediately rules out such fantastic hypotheses as that mooted in the Washington Post that Soviet radio wave experiments, whose total power is a mere 10 megawatts or so could have any effect whatsoever on the phenomenon of the scale required. The Soviets could have a greater effect on the weather by ordering their army to face due North and blow hard.

Other theories which locate the cause extra-terrestrially, or as the CIA does, in "long term trends," are sheer nonsense. Causal connections are required, not mere correlations. The history of the CIA's efforts in long range climatology, as documented in the Jan. 28 issue of *Science* magazine, should be sufficient warning of the pitfalls of such linear projections. In May of last year, the CIA released a report predicting a general cooling trend leading to a new Ice Age. This cold weather, they said, would hurt food production, and in particular hurt the Soviet food crop. The evidence for this was a straight line extrapolation of climatic trends during the period 1950-74. Unfortunately the CIA failed to notice the end of this trend in 1974-75 and therefore was somewhat embarrassed by the extreme heat over Western Europe and parts of Russia which followed in the summer. Undaunted, the CIA commissioned a new study appearing Jan. 7, which extrapolated the more recent 2-year warming trend into a 100 year prediction, concluding that the *contraction* of the polar air mass would lead to dry weather in Russia, hurting the Soviet crop. This report predicting warmer weather came out in the middle of the worst winter in the eastern U.S. in one hundred years. But the CIA has still not learned its lesson, and last week released a statement saying that the current bad weather was an indication of "growing instability of weather," which would hurt the Soviet crop. Evidently *nothing* can help the Soviet crop.

Setting aside such fantastic explanations, the general considerations of meteorology we have just set forth would lead to an examination of changes in the main energy flow regions, starting with the Amazon basin, for possible causes for the circulation shifts observed. In fact such changes in Amazon climate have occurred over the same period as the shifts in Northern Hemisphere circulation. Beginning at the start of 1976, a devastating and still growing drought had afflicted a large and growing part of the Amazon basin and the surrounding region. By mid-year more than .7 million sq. km were affected, mainly in the northeast Brazil area. By year-end, the drought had spread in Brazil and also affected nearly all of Peru and Colombia. Rainfall in the unpopulated Amazon jungle heartland is also substantially affected. Overall, a region of nearly 1.5 million sq. km. has suffered a loss of more than half of a normally heavy rainfall, involving shifts in energy flows in excess of 300 trillion watts. Here we have a phenomenon of the proper scale to effect the circulation changes in the north, which as we have already calculated involve some 200-250 trillion watts. The local circulation has been massively changed in the course of the drought. Early last year, the high pressure region normally confined to the South Atlantic moved far to the north over part of northeast Brazil. By year-end, this motion had continued to the point where the normal low pressure region over the Amazon basin was essentially destroyed and replaced by an anomalous high. This change in circulation is exactly what is to be expected in the course of a self-feeding drought. The lack of moisture recycled to the air as vegetation dies off, decreasing the energy needed to drive the cyclone, leading to its contraction and the expansion of neighboring anticyclones. This decreases rainfall further, increasing the intensity of the drought, until the previous circulation pattern is completely replaced with a stable anticyclone.

By itself, the drought has produced substantial changes in the amount of energy available to drive global circulation — perhaps as much as a quarter of the entire Amazon throughput, or a few per cent of the global total. If this affected global patterns in a linear manner, it would have driven polar circulation northward by a few degrees of latitude, rather than the displacements of 15-20 degrees of latitude both north and south which actually occurred. However, the global nature of weather circulation introduces further nonlinearities. Since circulation occurs on a closed surface — that of the sphere — any shift in circulation in one part of the globe, if it is of

sufficient magnitude, must directly affect similar shifts throughout the globe, as the entire circulation redistributes itself to accomodate the local shift. Thus, relatively localized shifts, by putting a strain on the entire circulation, can precipitate major reorganization of the global pattern into new metastable configurations.

This is clearly what is occurring now. The immediate impact of the decrease in energy flow through the Amazon has been to replace the inward flow of the Amazon cyclone with a general relaxation of circulation — the outward flow from an anticyclone. This has effected a shift of nearly 20° northward of the normal South Atlantic high circulation. This new displaced flow has tended to force the adjoining circulations, normally driven and dominated by the energy flows of Amazon, North Atlantic, and North American highs, much further north.

In the circumpolar regions, where energy flows originating from the equator become compressed, the nonlinear effect of global circulations becomes accentuated. The tendency for the northward circulation shifts to force the polar circulation into a smaller radius is resisted by the still strong polar cyclonic patterns, which have been weakened only slightly by the direct impact of the overall energy reduction. The effect of these circulation shifts in the polar areas is sudden reorganizations of polar air flow and equally sudden resulting climatic changes.

The normal polar air flow is typified by the large Greenland and Aleutian lows, which together with the North American and Siberian highs give (especially in winter) a "two wave" pattern to the air circulations (see Map 2). During the early part of 1976 and through the first two thirds of the year, the northwards movement of the North Atlantic high into Western Europe distorted this flow into a "three wave" or "three lobe" pattern, with an anomalous low over Novaya Zemlya (maps 3-5). With controlled accentuation of the northward movement of both the North American and West European high, now moving into the vicinity of Iceland, the Novaya Zemlya low shifted further north and eventually merged with the Greenland low, reasserting a two lobe pattern in a very distorted fashion. The far northern location of the highs, occupying in fact all of the circumpolar region, has forced the Greenland low far to the south, over New England and has had the same effect on the Aleutian low, bringing frigid weather to Japan.

The Amazon drought is thus fully capable of accounting for both the scale and direction of the climatic changes over the past year. The question of course remains — what caused the Amazon drought? Here the answer can be quite unequivocal — the energy throughput of the Amazon has been massively reduced by deforestation. Since major deforestation began in 1972-73, over 250,000 square kilometers, more than 10 per cent of the total Amazon region has been stripped clean. The main motivations for the deforestation have been the encouragement of labor intensive agriculture and industry — cattle raising above all. The conversion of the Brazilian steel industry increasingly to charcoal derived from wood has added considerably to the main devastation caused by the agricultural projects. The total energy flow loss involved in the total clearing of the forests is of the order of 100 trillion watts by itself, or one third of the total energy involved in the drought. Once the area of devastation passed a critical threshold sometime in 1974 or early 1975, the rapid self intensification of the drought which we have described set in.

In sum, we have a chain of nonlinear events which, once set in motion, built up to the observed climate changes. The deforestation, already of a large magnitude, set in motion a self-feeding drought in the Amazon. This drought intensified to the point that it crossed a threshold and energy flow was no longer sufficient to maintain the Amazon cyclone. Local circulation patterns were thus shifted into an anticyclone, altering flow by nearly 20° of latitude. This local alteration of flow, communicated through the interlocking shifts in global circulation patterns, intensified the overall effect of decreased energy flow — the shift of flow patterns polewards. This polewards shift first distorted the polar air mass during the spring and summer, bringing the European and American droughts, and then, with the intensified shift northwards, totally reorganized the polar air mass, forcing cold air southward over the Northeast U.S., Far Eastern Siberia and Japan, while further intensifying the North American drought. In each step we have a nonlinear "jump" effect, which intensified the change of climate involved. However, the overall magnification from initial cause to final impact is small — a factor of two or three. Although some details are still to be confirmed, this explanation is fully adequate for the main features of the current situation, a criterion not fulfilled by any proposed alternative.

From this analysis, a few things can be said about the probable future course of climatic developments — if the situation in the Amazon is not rapidly reversed.

The general tendency over the medium term, four or five years, will be a further accentuation of the drought conditions over North America as this stable high intensifies and moves northwards. Similar drought conditions could develop in the Soviet grain producing regions as well. The persistence of the extreme cold in the Northeast and the situation in Western Europe is more difficult to predict, because relatively small shifts in longitude of the Greenland low will dramatically alter the climatic effects. Over the longer run however, the extension of the Amazon drought and the further contraction of overall energy throughput will without question lead to a general poleward movement of weather patterns, and a general shrinking of the polar cyclones. This will mean generally warmer and dryer weather for the entire grain producing belt and disastrous consequences for world food production. If this leads to a general melting of the Arctic ocean, irreversible climatic changes of long lasting consequences could be brought about.