Recent Changes of Nature

By

F. F. DAVITAYA*

最近における自然の変化

F. F. ダビターヤ

自然は絶えず変化している。自然のままの状態では気候の変化が最も速やかに行なわれ、植生や地形の変化は何世紀、何十万年という速度で進行する。しかしいつたん人為が加わるとそれぞれ変化の速度が異なってくる。人為の影響を受けやすいのは植生で、気候はいちばん遅れて変化が現われるようになる。気候・植生・土壌などによる地域区分の境界線が一致しないのは、それぞれ変化の速度に違いがある以上当然だといえる。

今世紀になってから人間の活動はますます活発になって、森林の減少、草原の砂漠化、河川の汚染、地氾りの激化などが急速に進んでいるので、このままでは大きな弊害が生ずるであろう。影響を受けるのが遅いはずの気候でさえも人間の影響を無視できなくなってきた。Budyko の計算(1962)によると年々太陽から得ている熱量は49 kcalであるのに対して、世界中の人間が出している熱量は $0.02 \text{ kcal/cm}^2/\text{yr}$ であるが、これが毎年10%ずつ増えているとすると100年以内に太陽からの熱量に匹敵する量になる。また、人間活動によって大気中の炭酸ガスの量が増加して気温が上昇することも考えられる。一方、水蒸気量や雲量や塵埃量の変化がこれらの効果を強めたり弱めたりする。量的な研究はまだ進んでいない。

最近50~100年間に気温の上昇が認められている。1940~50年から再び下降の傾向を示しているが、上昇がもう終わってしまったのか、一時的な変動であるのかは今のところわからない。

気候の温暖化と氷河の後退との関係はなかなか

複雑で一義的には決まらない。気候温暖化の主因は大気大循環にあると考えられているが、地球全体が温暖化することを説明できない。炭酸ガス説も不十分である。人工発熱量も現在までのところ問題にならないくらい小さい。

そこで気候温暖化の一因に大気中の塵埃量の増大が考えられる。ここに逆説的な観測事実が二つある。一つはコーカサスと中央アジア地方の高山で過去50~70年の間に、降水量は同じか増加し、気温は下降の傾向を示しているのに氷河が後退していること、もう一つは融けつつある氷の表面の温度が0度以上であることである。これらは最近大気中の塵埃量が増えてきていることで説明がつきそうである。

大気中の塵埃は宇宙塵、海成の塵埃、火山灰による塵埃、風成の塵埃、工業による塵埃などであるが、最初の三つは少量で変化も小さい。大気中の全塵埃の70~75%を占める風成の塵埃は森林の伐採、耕地の開拓などによって近年急速に増加した。工業による塵埃も相当量にのぼる。ソ連各地の直達日射量の観測結果からも1920年ごろから塵埃量が著しく増加したことがわかる。

このような最近の自然現象の変化の方向や強さを研究するためには、全地球的規模の計画に従って同時観測を実施することが必要である。そしてこのような観測の計画を樹てるためには世界各地の地理学者の協力がなければならない。

(中村和郎 抄訳)

One of the most important features of Nature is her continuous change. Various components of Nature change with an unequal rate. The order of these changes taking place naturally or caused by artificial influence is also different. In the wild nature climate

* Academician.

possesses the greatest changeability. Decades are enough for its essential change; after it the change of land water resources and the sea hydrological regime takes place; then comes fauna. Centuries are required for a natural change of vegetation; soil changes occur during milleniums, while relief is changing for tens and hundreds of thousands of years.

With the emergence of the human society which exerts its influence upon the geographical environment, the order of natural processes development in time has become considerably different. When the influence is artificial, components of Nature occupying tens and hundreds of square kilometres change in the sequence as follows: vegetation—fauna—soils—land hydrological regime—relief—climate.

Economic activity of man is especially mobile. It is the climate only that exerts the most limiting influence on it. After the change of weather conditions or that of water resources of land during several decades, immediately change for example, agricultural methods, which are almost always adjusted to existing conditions.

Not infrequently the climatic zoning of territory does not coincide with its division on geobotanical, pedological and other bases. Thus, for example, according to the available data (G. F. White, 1956) arid territories occupy by climate 36% of the earth's surface, about the same area is marked by interior drainage, by the type of vegetation—35%, while by soils—43%. This is quite natural. One of the causes of such a discrepancy is an asynchronism and an unequal rate of change of the components making up a single nature. Therefore groundless are the attempts of some scientists to adjust to each other the boundaries of geographical zones and areas determined according to isolated natural indices. The analysis of one of nature's components permits to determine the character of a landscape only approximately.

Voluminous literature exists there about the change of nature by man. For some components of nature (vegetation, fauna) these changes appeared to be so profound that geobotanical and zoogeographical maps, for example, are at present made not according to the factual data on plant and animal distribution but according to the ecological conditions of their habitat. Before the beginning of our century man's influence on nature had predominantly a spontaneous character and was relatively limited.

In the current century human activity reinforces with heightened speed and reached already such a stage that if it proceeds in this uncontrolled way it will do harm and not good to the mankind. Before the eyes of one generation the zone of deserts broadens at the expense of steppes while the steppes occupy territories formerly entirely covered by forests, rivers and natural reservoirs are polluted with industrial wastes, modern geomorphological processes proceed much more rapidly than in the past; erosions and slides are developing. Meanwhile the growth of natural processes at the present level of science and technique can be directed not at the deterioration of nature but at the improvement of it, not at the exhaustion but at the enrichment of her resources. As good examples for this may serve territories of the Central Asia, formerly barren but now radically transformed and irrigated, drained areas of the Polesje and Kolchida lowlands in the USSR, completely meliorated regions of the Tennessee valley in the USA and the analogous samples in other developed countries. Now has become real even the problem of change of climate—the most difficult object for an artificial influence. According to M. I. Budyko's calculations (1962) the energy that is produced by men all over the world now, makes up approximately 0.02 kcal/cm^2 yearly while the average of the radiation balance is 49 kcal. If one assumes that the annual increase of the antropogenic energy is 10%, which is quite real, in less than 100 years the energy produced by men can reach the quantity commensurable with

the energy given by the sun. In such a situation the direction of changes of natural processes under the influence of human activity must be controlled on the basis of strict scientific calculations. This will allow to exclude possible mistakes which in future may become incorrigible. Fossil fuel deposited during hundreds of millions of years are now combusted during several decades releasing accumulated solar heat. The unique experiment which the mankind is now performing can have no less important indirect effect than the direct making of energy. The increase of carbon dioxide content in the atmosphere may lead to the degrees of a long-wave radiation of the Earth and, consequently, to the rise of mean temperature of the atmosphere's lower layers. The above-mentioned effect can be compensated or, on the contrary, intensified by the change of the water vapour content, cloudiness or air dusting depending on the possible trend of these changes. However, nobody has done convincing quantitative evaluation of all these influences as yet. There are even no more or less homogenous and representative observations which could serve as a basis for such an estimation. It is known, meanwhile, that during the last 100~50 years, beginning with the twenties of our century especially, intensive warming-up of climate takes place. It began with the high latitudes and spreaded over the greater part of the earth embracing regions situated in the low latitudes too. It is determined for certain that the rise of temperature proceeded up to the latest decades. It is not clear yet whether some decrease of temperature observed from the forties—fifties is the end of the general warming-up or it is a small fluctuation on the background of this continuing warming (Rubinshtein and Polozova, 1966).

With the climate's warming there are connected mountain glaciers degradation, diminution of land glaciation in high latitudes (Greenland, Antarctica), icing of polar seas and a maked eustatic rise of the world ocean's level. These relations, however, are very complex. In some cases the rise of temperature may lead not to the reducing, but on the contrary, to the intensification of glaciation, if this rise is accompanied, for example, by increase of solid precipitations. The principal cause of the modern warming of climate is considered to be the intensification of atmospheric circulation, its meridional constituent—in particular. This satisfactorily explains heat redistribution on the earth surface. The circulation, however, cannot be a single cause of climate warming, for it is not able either increase or decrease the temperature of the atmosphere's lower layers almost of the whole earth. Augmentation of the carbon dioxide content could not, apparently contribute greatly to the change of climate too. This fact is even less essential in high-mountainous regions where land glaciation is so well developed in middle and low latitudes. Heat energy worked out by the mankind till now is too little yet for the appreciable change of the atmospheric processes on a planetary scale. The two latter factors may, however, aquire great importance in the nearest future.

One of the causes of climate's contemporary warming and intensive ice melting according to our hypothesis* (Davitaya, 1965) may be the dusting of the atmosphere. As a result of our investigations conducted on the basis of homogenous instrumental observations there were established two facts that seem paradoxal:

1. During the last 50~70 years in the high mountains of the Caucasus and Central Asia temperature from decade to decade is decreasing. Precipitations remain constant or increase. Nevertheless glaciers recess and their mass decreases owing to intensive melting.
2. The surface temperature of the melting ice or firn is considerably higher than

* O vozmozhnom vlianii zapilennosti vozdukha na umenshenie lednikov i poteplenie klimata, *Izvestia Akademii Nauk SSSR, Seria geograficheskaya*, Tom 2, 1965.

0°C. The both facts can be explained by the following: during the last decades dust content in the atmosphere of the earth increases at a rapid pace. Being accumulated on glaciers surface the dust absorbs greater and greater quantities of solar radiation and decreases albedo. This results in the rise of radiation balance. This may be conducive to glacier degradation even at favourable conditions for their growth and advance. This hypothesis, of course, does not deny other causes of glaciers area and mass variations it only assumes that other conditions being equal, the dynamics of dusting may contribute greatly to glacier regime as well as to the change of climate.

It is known that radiation heating of the air has no essential importance in its heat balance. The earth surface being heated by sun rays gives the warmth to the air layers, while temperature of the atmosphere itself predominantly by means of turbulent change. The presence of dust in the atmosphere brings in considerable changes. Solid particles of dust, absorbing solar radiation, heat the air directly. Besides that, they favour earth's radiation diminution. Dust particles together with the absorbed air molecules, being heated, raise upwards and increase air turbidity. Myriads of invisible "air bubbles" with specks of dust in the center promote the intensive intermixing of the troposphere's lower layer and contribute to its better heating.

The principal cause of the increasing atmosphere dusting is human activity.

The total amount of dust in the atmosphere (D) is composed of the following items: cosmic dust (Dc); volcanic dust (Dv); marine dust in the form of various salts (Dm); aeolian, raised in the atmosphere by air currents from the earth surface (Dae) and industrial dust (Di):

$$D = (Dc + Dv + Dm) + (Dae + Di)$$

Cosmic and volcanic dust reaches at times considerable quantities but during the last two centuries their share in the atmosphere's dusting was very small if one does not take into consideration the Krakatoa eruption in 1883 which was exceptional by its strength. The atmosphere however, was cleared from the effects of this eruption in a few years. In the whole of the atmosphere the permanent quantity of the cosmic dust is averagely about 10^6 tons, that is less than 1% of the total dust content (Fett, 1958).

The dust of marine origin is also insignificant in the atmosphere and its amount does not change considerably during the Holocene, at least. Thus, the sum of the three mentioned components of the atmospheric dust represents an extremely small quantity and for the last centuries remained practically invariable.

The dust of aeolian origin makes up a prevalent part of the atmosphere's dusting—more than 70~75%. The share of the industrial dust (Air pollution, 1962) is also considerable. The sum of these two constituents predominates sharply in the total amount of the atmospheric dust. Both the aeolian and industrial dust have, besides that, a growing trend from decade to decade. Ploughing up of lands, forest felling and expansion of woodless areas, advance of steppes at forest zones and that of deserts of steppes—all this contribute greatly to the increase of aeolian dust, as well as strengthening of the meridional constituent of the atmosphere's total circulation, observed for the last 50 years. Industrial dust also has a marked tendency to increase with a heightened speed owing to the growth of cities, transport, energetics, extractive and manufacturing industries.

Investigation of the secular trend of the annual sums of direct solar radiation (which depends on the atmosphere's dusting) carried out by us (Davitaya, 1965) for the stations of Karadag (the Crimea), Tbilisi (the Caucasus), Tashkent (Central Asia) and Alma-Ata (Kazakhstan), the analysis of dust content deposited in firn layers (the Kazbek, H=4600 m) for the past decades, as well as theoretical calculations, made in 1966 (not published)

pointed to the fact that beginning with the twenties of our century the amount of dust in the atmosphere increases sharply. As a result, it exceeds now 2~4 times the quantity which was 50~100 years ago.

Investigation of the direction and intensity of changes of modern natural processes requires synchronous observations carried out according to a single program on a planetary scale. It is known, that such an observation during the period of the International Geophysical Year and the Quiet Sun Year yielded so important results that these observations will be continued for an indefinitely long term. Now observations are conducted for the Hydrological Decade and the analogous works are planned for the Biological Program. There is no doubt that these observations will give significant materials for the study of regime and dynamics of the nature's separate components. Together with this they pave the way for the organization of regular observations upon the state of the whole nature and for the use of her resources. Creation of a unified program of such observations will require joint efforts of geographers from many countries of the world. Accumulated materials of these observations will allow to determine changes in such a way that the Earth inherited by us from ancestors will become better and richer for our well-being and for generations to come.

この問題について筆者は日本人の意見を求めていますので、ご意見をお持ちのかたは下記あてお知らせください（編集委員）。

Prof. F. F. Davitaya
Institute of Geography
Roukhadze Str. 1
Tbilisi, USSR