CLIMATE AS LIFE-SUPPORT SYSTEMS: A CLIMATOLOGICAL OVERVIEW

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Contents

Summary

In order to review in this article the problems in climate as life-support systems, attention is first paid to its physical representation. Secondly, historical development of terms of acclimatization and adaptation in geography, physiology, and recent global environment sciences are discussed. Thirdly, interactions between climate and human activities are considered. Examples are taken from agriculture, forestry, and fisheries on a macroscale and carbon dioxide (CO_2) by human activity on a small scale.

Important results are as follows: (i) With regard to climatic indices for biological as well as human environment, the opposite conditions are important (e.g. the lowest monthly-

mean air temperature in the tropics, the warmest monthly-mean air temperature in the high latitude zones, or extremely heavy rainfall in arid regions). (ii) To express climate conditions theoretically or empirically, a water budget is important. (iii) Phenology, as an empirical method of observation of biological life, is important and the quantitative information it provides is particularly necessary. (iv) The synoptic climatological approach, using weather patterns for every day, is important for long-range forecasting as well as short-term forecasting for people's lives. (v) The term acclimatization has been changed to "adaptation" through adjustment. Problems such as "management" and "vulnerabilities" have become major subjects in discussions relating to human societies. The term "acclimation" is a purely natural process or state, used mainly in the USA. (vi) It is noteworthy that, through effective countermeasures, forecasting, and information systems, the relationships between climate and human activities are changing. For example, the relationship between severe impacts of tropical cyclones and their effect (in terms of quantity of damage events) has been different from decade to decade. (vii) Agricultural, fishery, and forestry production has been affected by drought, caused by circulation patterns that were different in the El Niño and the La Niña years. (viii) In the small-scale space, a significant relationship between number of visitors and CO_2 amount in a cave, a closed space, was found. Protecting speleological processes and their sustainability should be taken into consideration in relation to suitable development for tourism.

1. Introduction

Climate is one of the most important elements affecting the life-support systems, because climate is one of the main parts of our physical environment, considered in terms of topography, climate, soil, vegetation, water, etc. It should be stressed that biological processes in a broad sense, including human activity, affect climate. A good example is global warming as a result of human-made increases of greenhouse gases. So we should pay attention to both directions of relationships between climate and life: influences of climate upon life, and the effect of biological processes including human activity upon climate.

Historically, these relationships have changed according to space and time, beginning in the archaeological period for human activity. Life in caves or huts is an example of use of microclimatic conduction. Changes in vegetation types or plant life forms have also been observed in accordance with changing climatic conditions.

2. Physical Representation

2.1. Köppen's Classification

Many studies on climate indices representing global distribution of vegetation types have been done since the nineteenth century. Of these, Köppen's classification of climate was empirical but the must useful. After several revisions, in 1931 he came to an established form. There are several important viewpoints on this classification. (i) The climate of the earth was first depicted by dry conditions, as B-climate (desert and steppe climate). The humid regions were classified by temperature conditions. This is the most outstanding point by which to classify the climate, because the arid/humid condition is the most fundamental for vegetation types. (ii) The boundary between tropical climate (A climate) and temperate climate (C climate) is determined by air temperature of the coldest month. On the other hand, the boundary between polar climate (E climate) and cool climate (D climate) is determined by air temperature of the warmest month. This is an excellent point, because tropical vegetation is more sensitive to cold conditions. In contrast, warm conditions are more important for high-latitude vegetation than for tropical vegetation. Therefore, consideration of the opposite climatic conditions is more important for representation of climatic indices.

From the viewpoint not only of climatology, but also of physical and human geography, which are connected closely to the various life-support systems, such an approach should be encouraged.

2.2. Water Budget Approach

One of the best climatic indices for the arid/humid climates—the water balance—was devised in 1948 by Thornthwaite. Water balance is the net difference between precipitation and evapotranspiration on a monthly timescale and its lag effects on the soil moisture in the root layer of vegetation. There are, of course, many problems with this. How many amounts are kept in the root layer in soils? How much depth is suitable for representation of evapotranspiration on a monthly basis? Is suitable depth different for broad areas in the tropical rainforests, the boreal forests, in the deserts, and in swampy lands in the world? However, it should be stressed that, as a first approximation, a generalized approach that is as rational as possible is necessary for the classification of climates of the world in a water budget approach. These can be treated by different time scales and by space scales from spot, local, and regional to global.

In addition to the empirical approach mentioned above, the physical approach to water balance by Penman and climate classification by Budyko should be mentioned. These are more theoretical representations of climates as an element of the physical environment. Their validity, however, changes with various biological/human societies in the various time and space scales. Therefore, problems in empirical and theoretical approaches are similar at least for representation of climates as life-support systems.

2.3. Phenological Approach

Phenological observations as indicators of climatic and seasonal events are important measures. In particular, farmers have been observing the phenological events of plants and animals in the course of seasons in the different times of the year, season, and day. Such observation has been indispensable particularly for farmers in the traditional agricultural regions, where the cultivation calendar depends on the observation of local phenological events occurring earlier or later from year to year.

From the botanical standpoint, the leaf area index (LAI) is a critical variable for the estimation of feedback to the atmosphere, since it influences albedo and thereby the energy flux back to the atmosphere. Seasonal LAI is important for water balance calculations. Recent results of dynamic global vegetation models (simulations, using climate model output) by Walker et al. showed that the general processes of vegetation dynamics, such as replacement of species during changing environmental conditions, are modeled appropriately. Some models simulate a strong reduction in deciduous trees in the tropics due to global warming. Nevertheless, the overall biomass of these types has increased because of enhanced growth in the remaining areas. For these models, quantitative phenological information is necessary for both deciduous and evergreen trees. When we consider not only vegetation types but also the flowering date, fruiting date, colored date, etc. of some plants, empirical phenological approaches should also be stressed strongly. They are important components for gardening or tourism under the influence of future climate change.

In order to estimate the impact of global warming on plant phenology in monsoon Asia, an attempt was made to analyze the flowering dates of cherry blossoms in Japan, Korea, and China in relation to air temperature in March, or as a function of latitude, longitude, and coldness/warmness indices. Using the experimental formula, in the first place one can estimate global warming. In the second place, it shows the effects of urbanization in bringing forward the blooming dates at a rate of one to three days per 1ºC. It has also been shown that the mean flowering dates of cherry blossoms in Japan and Korea are three to four days earlier when the monthly-mean air temperature of March increases 1ºC. Further, the early blooming or flowering dates have more significance in relation to March air temperature. The flowering date is significantly earlier in the El Niño years. The deviations are completely opposite in the La Niña years. This is caused by conditions influenced by developed zonal anticyclones in the subtropics over the North Pacific in the El Niño years, which it is suggested occur because of global warming.

2.4. Synoptic Climatological Study

One of the outstanding events in climatology in the twentieth century was the development of synoptic climatology. This was supported by the technical development of collecting information for daily synoptic weather charts and their introduction to military strategies during World War II, when several days to half-month forecasts were needed based on climatological knowledge. In a broad sense, this was an application of a branch of climatology named synoptic climatology. In the second half of the twentieth century, these study methods were introduced to research into impacts on/by biological activities, including human activities.

Weather patterns at the air layer near the ground are, of course, the most influential as this is the space for the activities of plants and animals. However, the geopotential topography patterns at the 850 hPa (hectopascal) level, the 500 hPa level, etc. in the troposphere were being used for short- to long-term forecasting and climatological research in the second half of the twentieth century. These were particularly helpful for considering the seasonal, monthly, and ten-day-mean life-support systems at ground surface level. Good examples are medical weather forecasting for some diseases, which was developed particularly in Germany, and wildfire occurrences in the boreal forests in Canada and Alaska.

2.5. Historical Viewpoint

It is important to consider past climate conditions for life-support systems faced as we are at the present and future by global warming. Paleoclimatic conditions in Java and its surrounding areas since the last interglacial stage were reconstructed initially using previous studies by various researchers. Summarizing the evidence related to paleoclimate in the various areas made it clear that the paleoclimatic conditions were cooler and drier at the last glacial maximum 18,000 BP than they are today. Formation of dry valleys in Gunung Sewu in Java was conditioned by lowering of sea level, and establishment of a cool and extremely dry climate. Subsequent to the initial reconstruction, the results of the estimated palaeoclimate at 18,000 BP were plotted first at these respective points where the samples were obtained. The maps for northern winter and northern summer were then constructed showing the estimated streamlines of monsoon circulation, polar frontal zones, and intertropical convergence zones in order the better to explain the distribution of the palaeoclimatic conditions of the area.

The conclusions obtained were as follows. During the last interglacial stage evidence for sea-level rise had been reported in Java Island. It was slightly warm and humid. The reconstructed palaeoclimate in the study areas, however, is not clear enough for this period as a whole. During the last glacial stage, a cool and dry climate was common in the study areas. The degree of lowering of annual temperature was larger in highland areas than in the lowlands. The amount of precipitation must have been small in all study areas. In this stage, tropical westerlies in the northern winter over the region were not so active. On the other hand, tropical easterlies were strong in the southern winter (northern summer) as compared with the present.

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Biographical Sketches

Masatoshi Yoshino was born on January 1, 1928, in Tokyo, Japan. He graduated from Tokyo Bunrika University in 1951 and completed a master's at the same university in 1953, gaining his Doctor of Science in 1961. Dr. Yoshino's research fields are geography, climatology, agrometeorolgy, and global environmental sciences. Dr. Yoshino has held the following academic positions: instructor, Tokyo University of Education (1953–1967); Alexander-von-Humboldt research fellow, University of Bonn, Germany (1961–1963); guest professor, University of Heidelberg, Germany (1967–1968); associate professor (1967–1969) and full professor (1969–1974), Hosei University, Tokyo; full professor (1974–1991) and professor emeritus (since 1991), University of Tsukuba, Japan; professor (1991–1998), Aichi University, Toyohashi, Japan; retired 1998. He has also been an adviser for Kokudo-kankyou Ltd. since 2001, and a senior program adviser at the United Nations University since 2001.

Dr. Yoshino continues to be active in learned and other societies, including past president of the Association of Japanese Geographers; past vice-president of International Geographical Union (IGU); present president of Japanese Association of Arid Land Studies; member of Japanese Association of Agricultural Meteorology; member of Japanese Association of Biometeorolgy; past member of Science Council of Japan; and foreign member of Rumanian Academy of Science. He has been awarded the following honors: Fujiwara Prize (Meteorological Society of Japan), Alexander-von-Humboldt Foundation Research Prize (Germany), and Laureat D'Honneur (IGU, 2000).

Dr. Yoshino has published 14 books and monographs in English and 34 in Japanese, and about 165 articles in English/German and 225 in Japanese. He is chief editor of *Global Environmental Research* (Japan) and a member of the editorial boards of *Erdkunde* (Germany), *Polish Geography*, *Acta Geographica Sinica* (China), *Journal of Human Ecology* (India), *Journal of Meteorological Society of Rumania* (Rumania).

Kazuko Urushibara-Yoshino was born in Iwate Prefecture, Japan, on March 26, 1943 and was awarded a B.S. (1965) and an M.S. (1968) in geography from Hosei University, and a Doctor of Science (1983) from the University of Tsukuba, Japan. Dr. Urushibara-Yoshino has held the following positions: instructor (1975–1977), lecturer (1977–1984), and associate professor (1984), Ashikaga Institute of Technology; associate professor of natural sciences (1984–1990) and professor of natural sciences (1990–1999), Komazawa University; and professor of geography, Hosei University (since 1999). She is also active in several learned societies, being a full member of the IGU Commission on Environment Change and Conservation in Karst Areas and a member of societies related to geography, geomorphology, quaternary research, speleology, forest sciences, and environmental sciences in Japan. She has published one book and 30 articles.