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SOME ASPECTS OF CLIMATE MAP CREATION

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Abstract
This article discusses the key aspects of creating climate maps. It highlights the processes of collecting, processing, and analyzing climate data, as well as the main cartographic visualization methods used in climate mapping. The article also addresses the main challenges encountered in creating climate maps and suggests possible solutions. In addition, it provides detailed information about the role of modern GIS technologies and interpolation methods in climate cartography, particularly in enhancing data accuracy and improving the quality of visual information. Furthermore, the article discusses the importance of climate maps in the development of various sectors of the national economy.

Keywords: Continent, sea, weather, climate, genetic climate classification, solar radiation, air masses, monsoon, continental, temperate, atmosphere, climate zone, Arctic, subarctic, temperate, subtropical, tropical, equatorial, Antarctic, interpolation, climate maps, models, cartographic method, localization method.

Introduction
All natural processes, human life, and economic activities are increasingly linked to climate. Climate is defined as the average state of weather phenomena observed over many years in a specific geographic area. It forms under the influence of solar radiation, atmospheric movements, characteristics of the Earth's surface, the effects of oceans and seas, and human factors. Climate changes and regional climate differences significantly impact not only the natural environment but also the economy, agriculture, public health, and infrastructure.
Therefore, in-depth study of climatic conditions and regional analysis through scientific and practical research is gaining particular importance. In this regard, it is essential to use cartographic methods to comprehensively analyze climate changes both quantitatively and qualitatively, and to create thematic climate maps and atlases based on a systematic approach. Today, climate maps are widely used in many fields, including geography, meteorology, ecology, architecture, agriculture, irrigation planning, and urbanization processes.

Especially in recent years, due to global climate change, abnormal warming and cooling, and the increasing frequency of extreme weather events, the demand for climate maps has significantly increased. Climate maps and models help assess and predict regional climate risks (droughts, floods, storms, etc.), develop preventive measures, identify safe zones, and ensure the rational use of resources.

Analysis of the Used Literature

Global, regional, and local-level studies on the creation of modern climate maps have been conducted by scholars such as P. Alisov [1], Ye.A. Bojilina [3,4], A.K. Suyorov [3], M.F. Andreychik [2], S.A. Chupikova [2], R.K. Abdulin [1], A.N. Shikhov [1], S.V. Pyankov [1], I.N. Guseva [7], T.E. Samsonov [8], K.S. Trigub [8], N.O. Telnova [9], and V.V. Bratkov, among others, who have achieved notable results in their research. Below is an overview of the main outcomes of their scientific studies:

B.P. Alisov, a prominent climatologist, developed the genetic climate classification, which is based on identifying the air masses responsible for climate formation. He categorized 7 major climate zones—Arctic, Subarctic, Temperate, Subtropical, Tropical, Equatorial, and Antarctic—as well as 6 transitional zones, which are determined by seasonal changes in dominant air masses. His classification considers both air masses and their frontal regions, emphasizing the role of frontal systems in defining final climate types. Furthermore, he divided climates by continentality and proximity to oceans, differentiating monsoonal, sharply continental, moderately continental, and maritime climates. Based on these classifications, he contributed to climate mapping and the development of relevant cartographic methods. Ye.A. Bojilina, a climate scientist, is one of the key researchers in the methodology of creating climate maps. In her academic works, she analyzed the demand for climate maps in higher education and proposed general approaches and methods for their development. Her contributions also include experiences in creating global climate maps and their educational applications. Notably, she emphasized methods for analyzing climate parameters (e.g., temperature, humidity, precipitation), classifying geographic areas by climatic conditions, employing GIS (Geographic Information Systems) technologies, and forecasting climate change.

Together with A.K. Suyorov, Bojilina developed the "CliWare" system in 2011, designed for collecting, analyzing, and visualizing climate data. This system is widely used in climatology centers and research institutions. M.F. Andreychik and S.A. Chupikova studied the climate of the Tuva mountainous region using remote sensing data and modern GIS technologies. They developed cartographic layers reflecting interpolated values of average annual precipitation and visualized them through electronic precipitation maps.

R.K. Abdulin, A.N. Shikhov, and A.B. Tarasov proposed the structure and content of an electronic climate change atlas for the Ural region. They also provided comprehensive information on climate change, data source integration, extreme climate characteristics, and negative consequences. Their work includes mathematical and cartographic modeling of the spatial-temporal distribution of hazardous weather phenomena.

T.E. Samsonov and K.S. Trigub conducted studies on the spatial and temporal distribution of hazardous weather events using mathematical and cartographic modeling. They mapped the local climate zones of Moscow based on Landsat 8 satellite imagery, analyzed the climatic characteristics of these zones, and conducted evaluations based on the results.

N.O. Telnova investigated the impact of climate change on agricultural regions in Russia for agro-ecosystem purposes using remote sensing data and GIS technologies. Her research involved forecasting and yielded significant findings on land use and climate response.

Research Methodology.

This study employed various methods including historical analysis, geographical comparison, cartographic techniques, scientific observation, and other relevant approaches.

Main Body.

Climate maps depict the spatial characteristics of climate conditions based on long-term observational data. These maps can illustrate the primary features of specific climatic indicators—such as temperature, precipitation, and humidity—as well as the combined characteristics of these elements near the Earth's surface and in the upper layers of the atmosphere. On one hand, climate maps provide a comprehensive and visually accessible overview of a region's climatic properties and enable comparative analysis across different parts of the studied area. On the other hand, they allow for the interpolation of climatic values at specific points based on existing data.

Climate maps describe the patterns and processes of climate formation and include meteorological data intended for practical use. Such data play a critical role in developing various sectors of the national economy—for example, assessing the impact of climate on agricultural development and on the living and working conditions of the population. The diversity and dynamism of climate elements, the indicators used to describe their characteristics, and the density of mapped zones all contribute to the accuracy of the information presented. Long-term climate maps display the distribution of key climate elements expressed as long-term averages and extreme values. These maps are constructed using data from climate and agro-climatic reference sources and are based on regularly collected meteorological observations from state-operated stations and posts.

In climate maps, climatic characteristics are represented using isotherms (curved lines connecting points with equal air temperature), isobars (curved lines connecting points with equal air pressure), and isohyets (curved lines connecting places with the same amount of precipitation). Precipitation is usually shown using a color scale corresponding to average annual precipitation, while wind is depicted using motion symbols or wind roses.

Special climate maps illustrate the climate zoning schemes of a region, showing the boundaries of climate zones and regions. The main elements that define climate are physical phenomena in the atmosphere and their statistical representations. These serve as the primary sources for identifying, characterizing, and cartographically analyzing climate conditions. Proper and scientifically grounded mapping of each climatic element allows for in-depth analysis of climate zones, microclimates, and global climate changes.

The diversity of information that can be obtained from climate maps underscores the relevance of climate mapping in the current context. The method most commonly used in creating climate maps is the method of isolines. This method reflects the continuous distribution of climatic elements (such as atmospheric pressure, temperature, humidity, etc.) and their gradual quantitative changes. Choosing appropriate quantitative indicators is a crucial aspect of climate mapping. Additionally, the accuracy of the materials used for mapping and the practical significance of the selected indicators must be considered. The contour intervals should reflect specific values and align with natural boundaries (e.g., ecological zones or certain tree species distributions). In the process of drawing isolines, linear and geographic interpolation methods are applied.

Linear interpolation assumes that values of indicators change evenly between observation points. Based on this assumption, points are identified for the selected values of isoline scales, determining the position of isolines. Such interpolation is performed using automated methods through various software models (e.g., ArcGIS), spline approximation, minimum curvature, kriging, inverse distance weighting, nearest neighbors, stepwise regression, and others.

Graphical interpolation is based on establishing quantitative relationships between climatic indicators and other natural factors—relief, vegetation, etc. Geographical interpolation, on the other hand, is carried out using high-quality hypsometric bases or digital elevation models and derived maps. Graphs are created to show changes in climate parameters based on slope height and orientation. Initial zoning of the mapped area is performed, differentiating regions based on equal vertical gradients, identical slope directions, and similar relief features. Vegetation maps, landscape maps, and others are also involved. This method ensures accurate geographical representation of spatial data distribution.

In climate mapping, the localization diagrams method is widely used. This approach allows the representation of temporal variability of climatic elements at specific points. For example, diagrams can show annual precipitation levels, temperature, relative humidity, and other climatic elements. These diagrams are presented in polar or Cartesian coordinate systems and vary in graphical and design execution, allowing conclusions about climate types to be drawn. In electronic maps, such diagrams are created using 3D modeling and visualization methods.

To represent the multidimensional nature of climate, several mapping methods are used together. For instance, the isoline method is combined with localization diagrams (a hybrid method). In illustrating wind characteristics, the motion symbol method is employed, such as on wind direction maps. Qualitative color methods are extensively used in general and applied climate zoning maps. Under modern conditions, analytical-synthetic type maps are developed, which depict both integral and analytical indicators through the combination of multiple cartographic representation techniques. Special dynamic symbols are developed for electronic maps and animations.

The point-specific diagrams method is also used in climate mapping. These diagrams show annual temperature variations, monthly precipitation distribution, snow cover dynamics, annual river flow by month, wind direction and strength, etc. Points for diagram placement are selected in locations best representing the characteristics of surrounding areas, such as meteorological stations or specific points along linear features like hydrological posts. It's important to note that diagrams for point-related phenomena are fundamentally different from symbol methods used for linear or continuous phenomena.

Diagrams are constructed in Cartesian or polar coordinate systems in the form of curved distributions or bar charts. The main sources for creating climate maps are long-term observational data processed according to a unified methodology and program within the Hydrometeorology and Environmental Monitoring Service system. Such data is published in regional climate reference books of Uzbekistan. These references provide data on solar radiation, radiation balance and sunshine, air and soil temperature, wind direction and speed, humidity, precipitation, snow cover, cloudiness, atmospheric phenomena, and so on.

To create accurate and comprehensive maps of climate resources for agriculture, reference books titled "Agroclimatic Resources" compiled based on a unified methodology and published for the republic and its regions are used. They contain information on the start and end of the vegetation period of various crops, thermal characteristics of soil in spring and autumn, and moisture reserves in the soil layers of arable lands.

When creating climate maps for small areas, in addition to using reference books, it is recommended to consult higher-scale climate maps of smaller territories to avoid potential interpolation errors. If such maps are unavailable, data from neighboring stations is used to draw isolines accurately. Results of large-scale microclimate studies of specific sub-regions are also valuable for mapping.

Cartographic study of climate plays a crucial role in deepening knowledge about the climate system, identifying risks, and scientifically justifying decision-making. This methodology enables the creation of climate maps that are spatially, temporally, and statistically grounded based on scientific and technical approaches.

Conclusion

Climate is one of the key factors for human life, the balance of nature, and the sustainable development of economic activities. To understand and assess it correctly, not only theoretical knowledge but also practical analysis and precise cartographic tools are required. In this regard, the creation of climate maps plays a crucial role. Through visual representation of climatic conditions, such maps clearly display regional differences, climate zones, and potentially hazardous areas.

The research findings show that the use of modern technologies such as Geographic Information Systems (GIS), digital databases, satellite imagery, and statistical methods ensures the effectiveness, accuracy, and reliability of climate map creation. This approach allows climate data to be widely applied not only in scientific circles but also in practical fields.

In conclusion, climate mapping not only deepens geographical and meteorological understanding but also serves to systematize this information and apply it in real-life scenarios. In the future, the development of more advanced, interactive, dynamic, and digital maps will be of great importance in achieving ecological sustainability and developing climate adaptation strategies.

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