

Recollections

Reflections on the Evolution of Heat Alert Systems into Heat Health Risk Warning Systems

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ABSTRACT

The frequent occurrence of extreme heat events in the context of global warming poses a serious threat to public health. Increasing evidence has highlighted the limitations of China's traditional early heat warning system, including an overemphasis on meteorological factors, the absence of health risk assessments, limited regional adaptability, and a disconnect between observations and public perception. These shortcomings hinder the ability of the system to meet the growing demand for precise health protection warnings and initiatives. Consequently, the development of an early warning system that focuses on the health risks of high temperatures has emerged as a critical strategy for addressing climate change-related health impacts. This study systematically reviews the existing standards and service limitations of heat warning systems in China and analyzes the necessity of advancing research on and applications of health-oriented heat risk warnings. In the future, the broader social scope of such meteorological warning systems is expected to transform them into health risk assessment systems that benefit the entire population.

STANDARDS AND SERVICE LIMITATIONS OF HEAT WARNING SYSTEMS IN CHINA

China's meteorological departments began meteorological disaster warning operations as early as 1951. However, the modern meteorological disaster warning system, which is currently in use, was created according to the *Measures for the Release and Dissemination of Meteorological Disaster Warning Signals* issued by the China Meteorological Administration (CMA) in June 2007. This regulation standardized the release and dissemination procedures for warning signals for 13 types of meteorological disasters, including typhoons, blizzards, and other severe weather events, by meteorological agencies at all

administrative levels. In 2007, the National Meteorological Center formally established a national meteorological disaster warning mechanism encompassing high-temperature warnings. The latest version of the *Measures for the Issuance of Meteorological Disaster Warnings* in 2023 outlines 14 categories of disaster warnings that the CMA currently authorizes, clarifies the responsibilities associated with each warning, and further standardizes the operational protocols for heat alerts and the corresponding national-level response guidelines.

Definitions of Hot Weather According to Meteorological Standards

High temperature weather: daily maximum temperature of $\geq 35^{\circ}\text{C}$ (1).

High temperature weather process: occurrence of two or more consecutive days of hot weather (1).

Heat wave: a weather process with high temperature and an extended period of high humidity that causes discomfort in the human body and may pose a threat to public health and safety, along with increasing energy consumption and affecting social production activities (2).

High-Temperature Warning Criteria of the National Meteorological Center

The National Meteorological Center issues heat alerts according to the following criteria (3):

Red alert: This alert is issued if parts of more than four provinces (including autonomous regions and municipalities) have experienced maximum temperatures $\geq 40^{\circ}\text{C}$ over the past 48 h, with expectations that these areas will continue to experience high temperatures $\geq 40^{\circ}\text{C}$. Alternatively, a red alert is issued if the forecast suggests that most areas in more than four provinces (including autonomous regions and municipalities) will experience daily maximum temperatures $\geq 40^{\circ}\text{C}$ within the next 48 h.

Orange alert: This alert is issued if most areas in more than four provinces (including autonomous

regions and municipalities) have experienced daily maximum temperatures of $\geq 37^{\circ}\text{C}$ and some areas in more than two provinces have reached a temperature of $\geq 40^{\circ}\text{C}$ over the past 48 h, with expectations that these conditions will persist with temperatures remaining $\geq 37^{\circ}\text{C}$ in most areas and reaching $\geq 40^{\circ}\text{C}$ in certain regions. An orange alert is also issued if the forecast predicts that, in the next 48 h, most areas in more than four provinces (including autonomous regions and municipalities) will experience daily maximum temperatures of $\geq 37^{\circ}\text{C}$ and most areas in more than two provinces will continue to reach a temperature of $\geq 40^{\circ}\text{C}$.

Yellow alert: This alert is issued if most areas in more than four provinces (including autonomous regions and municipalities) have experienced a daily maximum temperature of $\geq 37^{\circ}\text{C}$ over the past 24 h, with expectations that the hot weather in these areas will persist. A yellow alert is also issued if it is expected that most areas in more than four provinces (including autonomous regions and municipalities) will experience a daily maximum temperature of $\geq 37^{\circ}\text{C}$ over the next 48 h.

The heat alert system of the National Meteorological Center focuses not only on extreme temperatures but also on their persistence. A red alert event has occurred only once, during a widespread and prolonged heat wave in southern China from June to August 2022, with 22 consecutive warnings issued. This event affected an area of 4.53 million km^2 and impacted approximately 1.05 billion people. The extent of regions experiencing temperatures $\geq 40^{\circ}\text{C}$ was the largest in recorded history.

The heat alerts of the National Meteorological Center differ from those issued by provincial authorities in terms of their specific content. Furthermore, the provinces vary in terms of alert levels, issuance criteria, and regional coverage. Although the levels and wording of the warnings may vary, their primary purpose remains the same: to provide advance notice to the public to ensure that individuals can adopt appropriate precautions to mitigate the impacts of hot weather.

LIMITATIONS OF METEOROLOGICAL HEAT ALERTS

Lack of Health Risk Indicators

Currently, heat alerts focus on meteorological features and have not yet incorporated comprehensive

health risk assessment systems. This shortcoming can be attributed to a lack of technologies that can accurately correlate meteorological conditions with health outcomes. This limitation makes it difficult to implement quantitative health risk warnings based on population characteristics and to provide targeted protection advice for high-risk groups such as older adults, individuals with chronic illnesses, and outdoor workers. This constraint affects the precision and practicality of early warnings, undermining their effectiveness in shaping public risk perceptions and responses.

Lack of Regional Adaptation

The fixed thresholds of the current warning systems cannot be adapted uniformly across regions because they fail to account for the differences in physical fitness and heat adaptation levels among residents in various areas. Therefore, health risks in atypical high-temperature regions are often underestimated. For instance, residents of northeastern China may be highly sensitive to temperatures as low as 30°C , a threshold not adequately captured by current warning systems. Hence, the accuracy of regional adaptation and risk identification must be improved.

Variation Between Meteorological Observations and Real-world Perception

Although temperature observation measures in China follow international norms, temperatures are affected by complex factors in specific environments. In addition, real body temperature often differs significantly from meteorological observations. Thus, these systems do not account for the diversity in human physiological responses and health outcomes.

NEED FOR EARLY WARNING RESEARCH ON HIGH-TEMPERATURE HEALTH RISKS

The significant intensification of global warming and increased frequency, intensity, and duration of extreme heat events pose a significant threat to public health and social security. Heat-related deaths in China reached approximately 50,900 in 2022, representing a 342% increase compared to the historical baseline (1968–2005) (4). High temperatures can trigger heat stroke and pyrexia and significantly increase the risk of acute episodes of cardiovascular and respiratory

diseases. Therefore, establishing a heat health risk warning system is critical for improving public health preparedness and response capacity.

On July 2, 2025, the National Disease Control and Prevention Administration and CMA released the first National High Temperature Health Risk Warning, described as an “across-disciplinary collaboration between China’s public health and meteorological departments in response to the frequent occurrence of extreme weather and climate events and a landmark practice to proactively address the health risks brought about by the current climate change” (5). This warning system integrates meteorological data with epidemiological evidence to enable a refined risk classification and region-specific management. The key features of this heat health risk warning system are as follows:

More precise risk grading: Based on relative temperature thresholds and evidence-based assessments, high-temperature health risks are classified into five levels to accommodate the diverse needs of the northern and southern regions as well as different climate zones.

More comprehensive coverage: The limitations of traditional high-temperature warnings are removed, allowing the system to include potential health risks in non-traditional high-temperature regions. This expansion helps fill the gap in heat protection systems in cold climate zones.

Service-oriented transformation and upgrading: The system has evolved from weather forecasting to issuing health-risk warnings by providing personalized health intervention recommendations for various population groups and industries. This feature marks a qualitative leap from simply “knowing the weather” to “truly knowing the people.”

Health-risk warning systems are not only powerful tools for enhancing evidence-based government decision-making, but also serve as a critical foundation for medical resource allocation, public safety management, vulnerable population protection, and public health interventions. The adoption of such systems results in a significantly stronger health-emergency response capacity and improved societal resilience to climate change. Simultaneously, the widespread implementation of such early warning systems can improve public risk perception and awareness, facilitating a shift from a passive response to proactive prevention and promoting the overall health and safety of society.

PROSPECTIVE APPLICATIONS OF HIGH-TEMPERATURE HEALTH RISK EARLY WARNINGS

In the future, while the national warning network will maintain its core function as the initiator of heat and health risk prevention and control strategies, heat-related health risk warnings will be applied to extend beyond traditional boundaries and expand into a wide range of sectors. At the community level, integrating grid-based risk data with population characteristic databases will allow the system to support the development of a refined health management framework, enabling dynamic assessments of individual heat exposure risks and targeted interventions. In the context of clinical medical institutions, warning technology can be embedded into diagnosis and treatment decision support systems to provide a quantitative basis for risk stratification of heat-related diseases (e.g., hyperthermia and acute cardiovascular and cerebrovascular events), early screening, and optimization of intervention strategies. In the commercial sector, warning systems can offer technical support for the development of high-temperature health insurance products, provide data for demand forecasting models and supply chain optimization in e-commerce pharmaceutical enterprises, and facilitate innovation in the development of climate-adaptive products and service models for recreation and tourism industries. These applications represent a comprehensive functional network of macro-level warnings, meso-level coordination, and micro-level responses. Finally, value transformation across multiple scenarios may enable meteorological early warning technologies to undergo a fundamental transformation into health warning technologies for the entire population to serve as the core infrastructure for the modernization of public health governance under the “Healthy China” initiative.

While challenges persist, such as imperfect data-sharing mechanisms across industries, the need to improve cross-departmental coordinated response efficiency, and the limited adaptability of existing technologies in specific scenarios, public demand for health and safety will drive technological innovation and institutional breakthroughs. Health-weather warning technologies, exemplified by heat health risk warning systems, are expected to evolve into national health protection infrastructure, providing systematic solutions to the health challenges posed by climate

change.

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