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Research on Ultra-Short-Term Prediction Model of High Temperature in Summer

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Abstract. The high temperature weather in summer is one of the extreme meteorological events that frequently occur under the background of global climate change, and high temperature ultra-short-term prediction is of great significance to high temperature disaster prevention and mitigation. Currently, most short-term temperature forecasts are hourly forecasts. This paper proposes a minute-level temperature forecast, which can capture local fluctuations in temperature. This study uses minute-resolution meteorological data and compares and analyzes the prediction results of TimesFM, GRU, LSTM, and MLP. Based on Bayesian optimization for parameter tuning and XGBoost algorithm for feature selection, this study constructs an ultra-short-term prediction model for summer high temperatures, whose performance is comprehensively validated through multiple metrics including R^2, MSE, MAE and ACC. An early stop strategy is added to monitor the loss of the verification set during model training to prevent overfitting during model training. We adopt two strategies to build models: (1) using temperature as input. In the task of predicting the next 60 minutes, the BO-GRU performs the best, with an MSE of 0.4705, and an MAE of 0.4335; In the 120-minute ahead prediction task, the BO-GRU model again shows optimal performance with an R^2 of 0.9262, an MSE of 1.0763, and an MAE of 0.6804. (2) When using temperature, ground surface temperature, grass surface temperature, minute precipitation, and hourly cumulative precipitation as input features for the prediction of 60 minutes ahead, the three models XGBoost-BO-GRU, XGBoost-BO-LSTM and XGBoost-BO-MLP exhibit reduced prediction errors at 12:00 on August 19th. The research results clearly indicate that the BO-GRU model is more suitable for minute-level temperature prediction tasks.

AMS subject classifications: 62M10, 62C10
Key words: Normalization Processing, Time Series, Temperature Prediction, XGBoost, Bayesian Optimization Algorithm.

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1 Introduction

As global temperatures rise, the frequency and intensity of extreme weather events continue to increase, subjecting ecosystems, economic activities, and human health to escalating threats [1, 3]. This is particularly pronounced in rapidly urbanizing areas, where the urban heat island effect exacerbates high-temperature impacts. Consequently, accurate summer high-temperature predictions, especially ultra-short-term forecasting, hold significant practical importance. Recent advances in meteorological observation technology now enable the acquisition of minute-level high-resolution data, offering new opportunities to enhance ultra-short-term high-temperature prediction through improved temporal granularity.

Traditional weather forecasting models are based on numerical simulations derived from physical equations and atmospheric dynamics. Although effective for long-term and mesoscale predictions, they face inherent challenges in ultra-short-term prediction due to computational constraints. In contrast, conventional time-series methods require predefined model structures for parameter estimation. A representative example is Zhao et al. [4], who applied seasonal ARIMA to monthly temperature prediction, whereas Li [5] implemented Holt-Winters triple exponential smoothing to analyze 2021 cargo throughput trends. The accuracy of such methods hinges critically on appropriate model selection.

With the rapid development of deep learning technology, the accuracy of deep learning models in facial recognition and speech recognition applications has surpassed that of human [6]. It is regarded as an effective tool for realizing time series prediction and has also been widely used in meteorological elements prediction. For example, Ye et al. [7] proposed a method to predict temperature based on convolutional neural networks and bidirectional long and short-term memory networks. The spatial characteristics of meteorological factor data are extracted through one-dimensional convolutional neural networks, and then introduced them into the bidirectional long and short-term memory network to learn the context information of meteorological elements, thereby effectively predicting temperature; Jin and Li [8] used the hourly meteorological observation data of Xianju National Basic Meteorological Station from 2017 to 2021 to propose a hourly temperature prediction model based on LSTM neural network, and predict the hourly temperature value of the next 12 hours through historical data of multiple elements. Liu et al. [9] combined CNN with GRU to extract the daily highest and lowest temperature data of eight sites in Yunnan from 1980 to 2019. After processing the highest and lowest temperature data of the past thirty days, they entered the CNN, GRU and GRU-CNN models for training to predict the highest and lowest temperatures of the site in the next three days.

The existing temperature prediction work can be divided into two categories: one is global century-long climate change prediction, which usually considers abnormal changes in the atmosphere, ocean and its coupling systems [10, 11]. The second category is regional short-term climate prediction, but most short-term temperature predictions use