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Research and Analysis of Global Weather Extremes Affecting Civil Engineering Construction Schedules Based on LSTM Algorithm

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Abstract

The occurrence of extreme weather events will cause serious harm to natural ecosystems, human social economy and construction sites. Large-scale construction projects have a long cycle and complex construction environment, and the schedule control is obviously disturbed by meteorological and other factors. Risk control of schedule delays is an important part of project risk management. The study of extreme weather events has become a key focus and hotspot in meteorological and climate science research in the context of global change. This paper proposes a more objective approach to defining extreme climate events from the study of extreme climate event uncertainty. On this basis, the spatial and temporal characteristics of extreme temperature and precipitation in recent decades are analysed. Considering the variability of precipitation and temperature, an idea is proposed to study extreme continuous precipitation events, and the mechanism of extreme precipitation occurrence in the region is explored. Finally, the LSTM model data are used to carry out studies and projections of changes in extreme climate events under different future scenarios.

Keywords: contracting, extreme weather conditions, LSTM, construction risk assessment

1. Background

Project schedule risks are becoming increasingly prominent. The probability that the actual schedule execution time will exceed the planned completion time within the contracted time frame is gradually increasing. This situation is already common internationally. In the face of a rapidly developing society, various engineering and construction projects involve more and more uncertainties, risks are occurring more frequently and the scale of losses is increasing. Scientific researchers and practical managers must attach great importance to this in theory and practice, rather than to causality. Due to the characteristics of open-air operations, construction projects are influenced by the external environment, especially meteorology and geology, which creates unexpected risks during the construction process, resulting in the quality of the project not meeting the requirements, the schedule not being completed on time and the economic benefits not being fully utilised. In addition, this has become a common problem in today's construction engineering industry. In this regard, the majority of project managers should pay great attention to improve the scientific management level and strive to reduce the construction risks of construction projects.

Against the backdrop of global warming, increasingly serious problems of ecological environment, food security, resource crisis and frequent disasters have emerged worldwide in recent years, and the harmonious development of population, resources and environment has become an important issue facing social development. Under the combined influence of human activities and natural forcing, the Earth is experiencing changes characterised mainly by warming. The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) states that the global average surface temperature warming rate from 1951 to 2012 was 0.12 (0.08-0.14) ℃/10a, almost twice the rate of warming since 1880. The resulting frequent occurrence of extreme weather and climate events such as flash floods, droughts and heat waves poses a major threat to human society.

2. Risk Analysis of Construction Schedule Delays Based on Meteorological Factors

2.1 Analysis of Meteorological Disturbance Factors

General contracting projects and other large construction projects have a very large time horizon. They are subject to varying degrees of spatial risk at different locations and times. The impact on some tunnels and indoor works is not significant, but for large infrastructures operating in the open, they are more affected by weather. First of all, according to the analysis and summary of the international weather history, weather hazards have the following main characteristics: many types, wide range, high frequency, long duration, prominent occurrence of groups, significant chain reaction and severe disasters. According to the above characteristics, the project manager must: do a good job of risk identification, analysis and evaluation in the pre-construction stage to provide a scientific approach to the smooth progress of the project construction. According to the United Nations, 10,000 people die in a year from natural disasters worldwide, with meteorological disasters causing the highest number of deaths. Globally, disasters such as floods and typhoons occur every year, with an average of a few floods and a few tropical cyclones per year. And these disasters occur in clusters, with strong convective weather such as thunderstorms, hailstorms, strong winds and tornadoes often occurring in multiple areas within the same period. At the same time, this connection should be significant. Weather and climate conditions often create or cause and exacerbate natural hazards such as floods, mudslides and plant pests and diseases. The distribution of disasters above shows that outdoor operations can be particularly disruptive to construction projects, causing not only delays in the project schedule, but also economic losses, casualties and even devastating disasters.

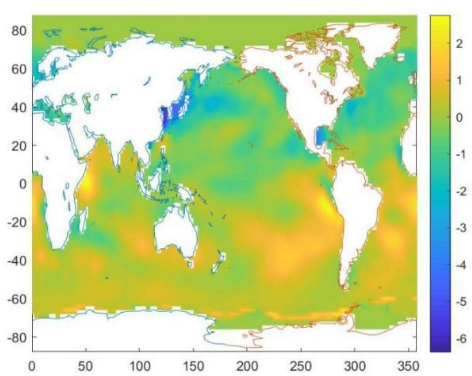
For some productive investment projects, if they are not completed and put into operation on time as planned, they will directly affect the effectiveness of the investment. Therefore, how to effectively manage the project schedule and successfully complete the set targets while ensuring safety, quality and cost is the main monitoring objective of the project management team. The purpose of EPC project schedule control is to align the actual activities with the schedule in a timely manner, to ensure that all engineering activities start and finish on time as planned, and to ensure the completion of the total schedule target, thus ensuring the overall schedule. Effective duration control as an indicator of schedule control in EPC project management can serve the purpose of schedule control. However, the use of schedule control alone can sometimes be misleading and schedule delays can eventually manifest themselves as delays in construction.

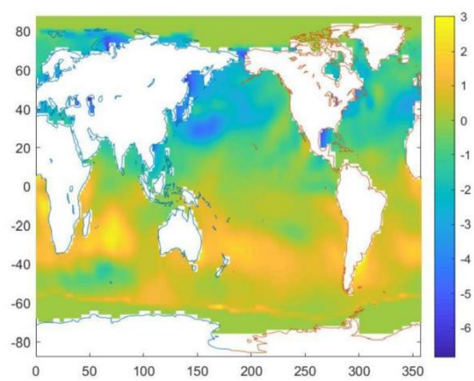
Schedule control, investment control and quality control of EPC projects are all integral components of EPC project management. This paper focuses on how to ensure the progress of the project under the premise of ensuring that the quality of the project and the investment remain unchanged. Reducing the risk of schedule delays in the construction process is an important measure to ensure that construction projects are completed on time, resources are reasonably arranged and project costs are saved.

2.2 Global Climate Overview

2.2.1 Marine Spatial and Temporal Climate Maps

Based on the collection of global ocean climate data and the use of matlab to create global ocean spatial and temporal cloud maps and surface temperature variations, some of the cloud maps are shown in Figures 1 and 2, with the colours in the maps representing the high and low ocean temperatures at a particular time.





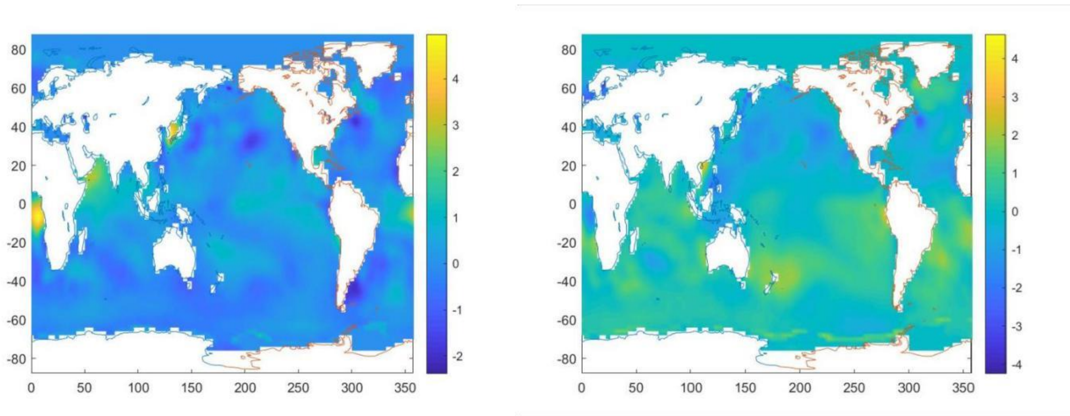


Figure 1. Global ocean spatial and temporal cloud map (partial)

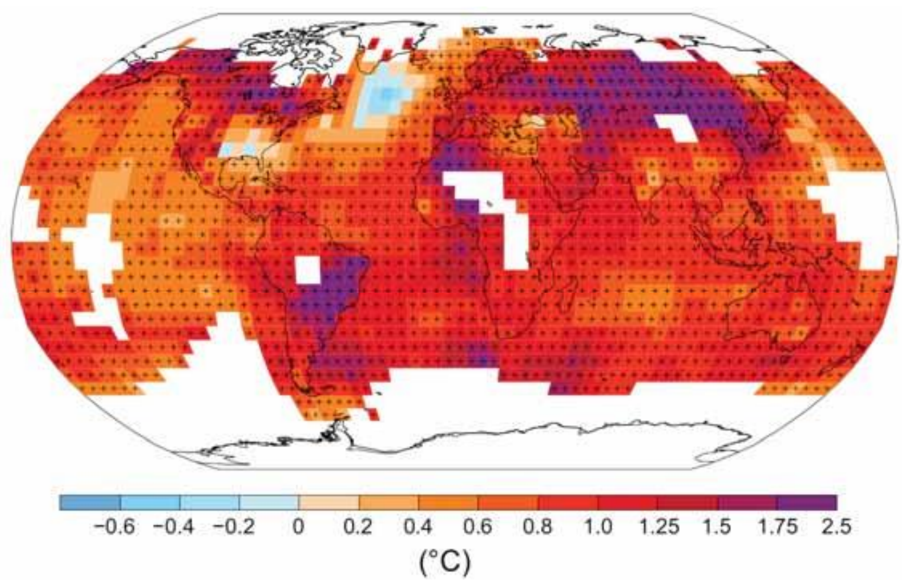


Figure 2. Observed surface temperature change (1901 to 2017) where the "+" sign represents a trend reaching significant levels

2.2.2 Time-Space Input Series Dataset

We use the Canadian temperature data as an example. Both the Canadian temperature and global ocean datasets are strongly correlated with time space, and the above data sets are entered in the following form: T[(u, v), t]. t denotes global ocean or Canadian temperature values; u is longitude; v denotes latitude; and t denotes time.

2.2.3 LSTM Modeling of Spatial and Temporal Climate Trends

The LSTM model replaces the traditional implicit nodes with memory blocks so that the gradients do not disappear or explode when the training unfolds over a relatively long period of time, thus solving the problem that traditional neural network models cannot handle long time sequences The core part of the improved LSTM model based on KNN is the memory block, which consists of input and forgetting gates and output gates. The computation process of a memory block at moment t is as follows.

$$\tilde{c}_t = \tanh(w_{xc}x_t + w_{ch}h_{t-1} + b_c)$$
$$\mathrm{i}_t = \sigma(\mathrm{w}_{xi}\mathrm{x}_t + \mathrm{w}_{hi}\mathrm{h}_{t-1} + \mathrm{w}_{ci}\mathrm{c}_{t-1} + \mathrm{b}_i)$$
$$\mathrm{f}_t = \sigma(\mathrm{w}_{xf}\mathrm{x}_t + \mathrm{w}_{hf}\mathrm{h}_{t-1} + \mathrm{w}_{cf}\mathrm{c}_{t-1} + \mathrm{b}_f)$$
$$\mathrm{o}_t = \sigma(\mathrm{w}_{xo}\mathrm{x}_t + \mathrm{w}_{ho}\mathrm{h}_{t-1} + \mathrm{w}_{co}\mathrm{c}_t + \mathrm{b}_o)$$
$$\mathrm{c}_t = \mathrm{c}_{t-1} \otimes f_t + i_t \otimes \tilde{c}_t$$
$$h_t = o_t \otimes \tanh c_t$$

Figure 3

where: represents the updated state of the memory cell at time t: represents the output of the input gate, the forgetting gate, the output gate, the memory cell and the hidden layer at time t: represents the input at time t: represents the output of the hidden layer and the memory cell at time t-1: represents the matrix of weights of the memory cell and the input and hidden layers respectively; represents the weights of the input gate and the hidden layer, the memory cell, the forgetting gate and the output layer, the memory cell, the memory cell and the output layer, the memory cell respectively; and represents the weights of the memory cell and the output layer, the memory cell.

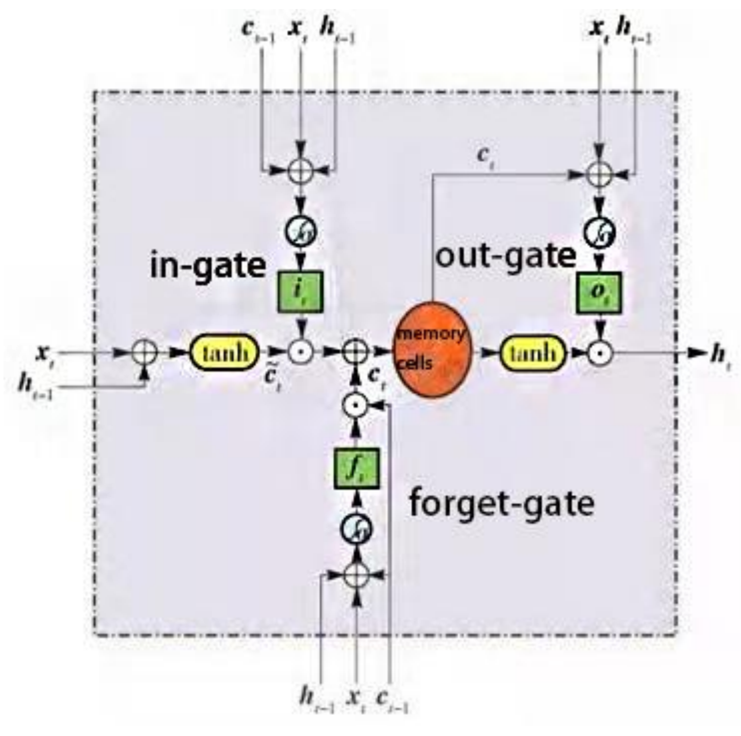


Figure 4. Schematic diagram of the LSTM memory cell structure

2.2.4 Solution and Results of the Model

(1) Solution of the model

The key information extraction and trend analysis model of climate change in LSTM is as follows:

Step1: Raw data input

Enter the collected Canadian temperature spatiotemporal data as well as global marine spatiotemporal data

Step2: Dataset alization

Raw data were input spatiotemporal dataset as input to the program independent variable:

$$T[(u, v)$$

Step3: M-K non-parametric statistics

Output trend inspection indicators are as follows:

$$S=\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\operatorname{sgn}(X_j - x_i)$$

Output mutation trend test is as follows:

$$\sqrt{Var(S_k)}$$

Step4: Dataset input LSTM climate spatiotemporal trend change model:

The spatiotemporal trend model is program implemented by Python and inputs the dataset in Step2 into the program.

Step5: Results output

A: M-K trend test index; B: M-K mutation trend test index

2.2.5 CMIP5 Model Simulation Data Profile

Based on the collection of data from the CMIP5 GCMs, this paper will use the predicted results from three GHG emission scenarios, RCP2.6, RCP4.5 and RCP8.5, while the predicted results from the RCP6.0 scenario will not be analysed. The basic information of the 17 CMIP5 global climate models used in this paper is shown in Table 1, including five Chinese models, namely BCC-CSM1-1, BNU-ESM, FGOALS-g2, FGOALS-s2 and FIO-ESM. It should be noted that in this study, as the scenarios and data termination used in the 21st century estimation tests for each model In comparing the results of the simulations under different scenarios, only the 22 models that completed the prediction tests under the RCP2.6, RCP4.5 and RCP8.5 scenarios with an end-of-21st-century year (2100) were selected, considering that it is best to maintain consistency in the models used and the time period studied.

Model name	Country of affiliation	Mode resolution
BCC–CSM1–1	BCC, China	128×64
BNU–ESM	BNU, China	128×64
CanESM2	CCCMA, Canada	128×64
CCSM4	NCAR, United States	288×192
CNRM–CM5	CERFACS, France	256×128
CSIRO–Mk3–6–0	CSIRO–QCCCE, Australia	192×96
GFDL–ESM2G	NOAA GFDL, United States	144×90
GFDL–ESM2M	NOAA GFDL, United States	144×90
HadGEM2–ES	MOHS, United Kingdom	192×145
IPSL–CM5A–MR	IPSL, France	144×143
MIROC5	MIROC, Japan	256×128
MIROC–ESM	MIROC, Japan	128×64
MIROC–ESM–CHEM	MIROC, Japan	128×64
MPI–ESM–LR	MPI–M, Germany	192×96

MPI–ESM–MR	MPI–M, Germany	192×96
MRI–CGCM3	MRI, Japan	320×160
NorESM1–M	NCC, Norway	144×96

2.3 CMIP5 Assessment of the Ability of Global Climate Models to Simulate Regional Averages of Elements

Taylor plots (Taylor, 2001) are a useful way to assess the ability of model simulations as they provide a combination of the root mean square error, the ratio of standard deviation to observations, and the correlation coefficient between spatial series and observations. The root mean square error (RMSE) is a measure of how similar the spatial pattern is to the observations. The closer the root mean square error is to zero, the better the model simulation performance. The standard deviation ratio characterises the ability of the model to simulate the central amplitude, while the spatial correlation coefficient characterises the ability of the model to describe the location of the principal centres. The Taylor diagram distributions of sea level pressure, 850 hPa meridional wind, 500 hPa geopotential height, 200 hPa latitudinal wind and surface air temperature for the East Asian region (20°-50°N, 100°-144°E) simulated by the CMIP5 model are given in Figure 5.

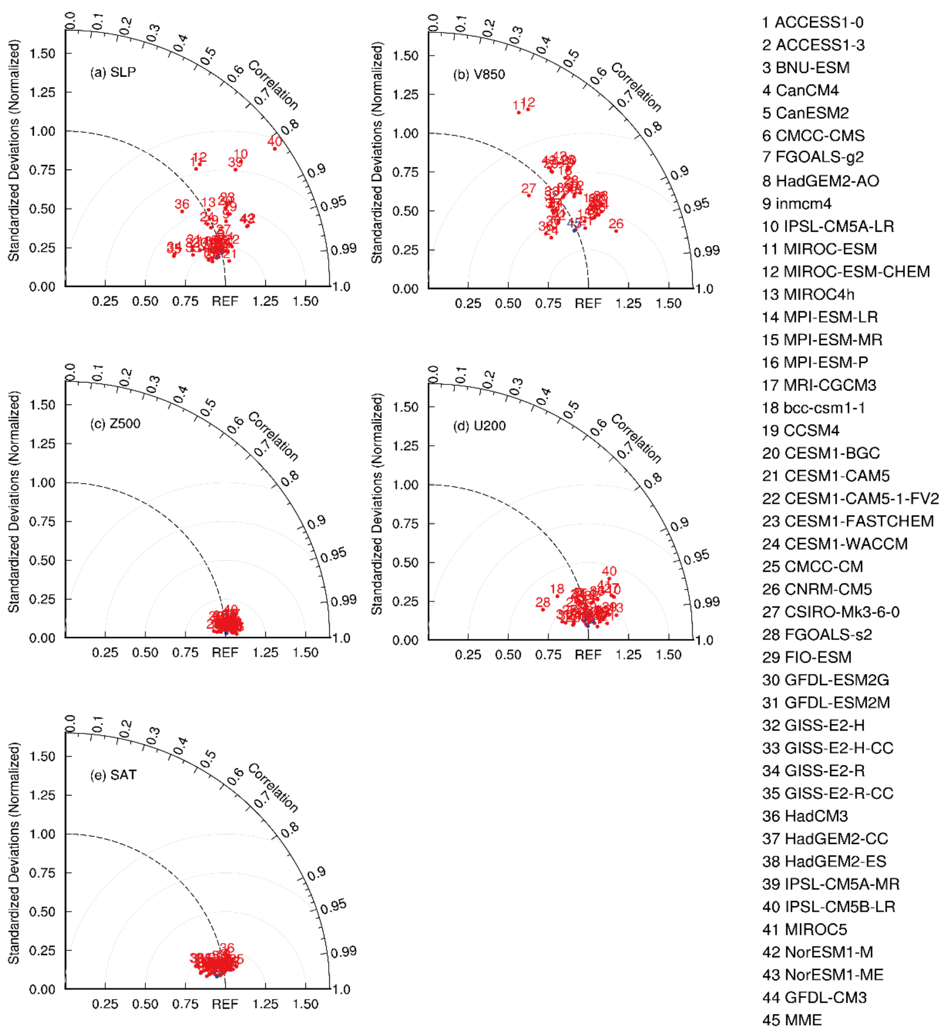


Figure 5. Taylor distribution. The results of the individual CMIP5 models are shown in red, the results of the multi-model ensemble are shown in blue, and REF is the reference point (observation). (a) sea level pressure, (b) 850 hPa meridional wind, (c) 500 hPa geopotential height, (d) 200 hPa latitudinal wind, (e) surface air temperature

As shown in Figure 6, the simulation results of the 44 GCMs are generally good for surface air temperature; the simulation results of the 500 hPa potential height show that the six models FGOALS-g2, IPSL-CM5A-LR, GFDL-ESM2G, IPSL-CM5A-MR, IPSL-CM5B-LR, GFDL-CM3 have relatively large deviations. The simulations of sea level pressure show relatively large deviations for IPSL-CM5A-LR, MIROC-ESM, MIROC-ESM-CHEM, HadCM3, IPSL-CM5A-MRIPSL-CM5B-LR; the simulations of 850 hPa The results for the longitudinal winds show relatively large deviations for the MIROC-ESM and MIROC-ESM-CHEM models, and for the latitudinal winds at 200 hPa, the FGOALS-s2 and IPSL-CM5B-LR models show relatively large deviations. The assessment of the multi-model ensemble shows that the MME is better than most of the individual CMIP5 models for the five climate elements. Therefore, when using the multi-model ensemble data for future predictions, the models with relatively large deviations from the simulation results for each element will be excluded first, and then the models will be averaged together with equal weights.

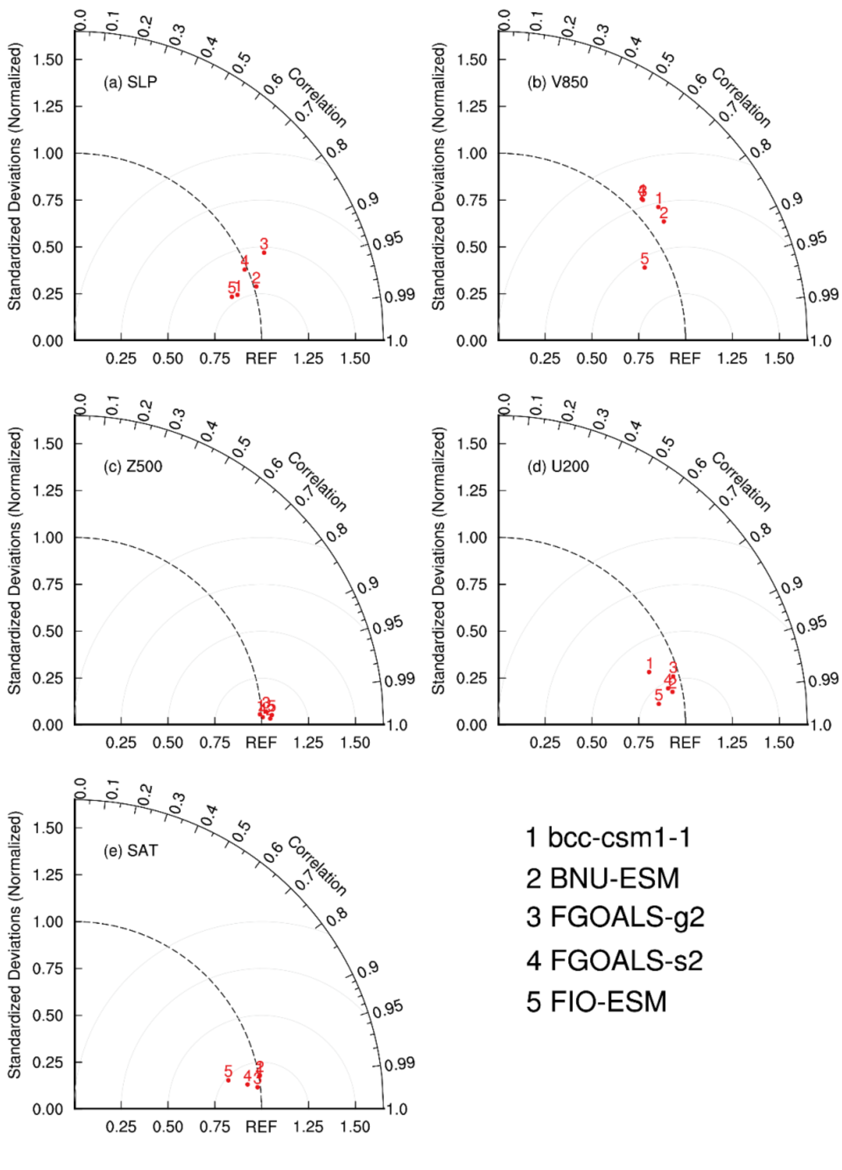


Figure 6. 1-5 represent BCC-CSM1-1, BNU-ESM, FGOALS-g2, FGOALS-s2, FIO-ESM respectively

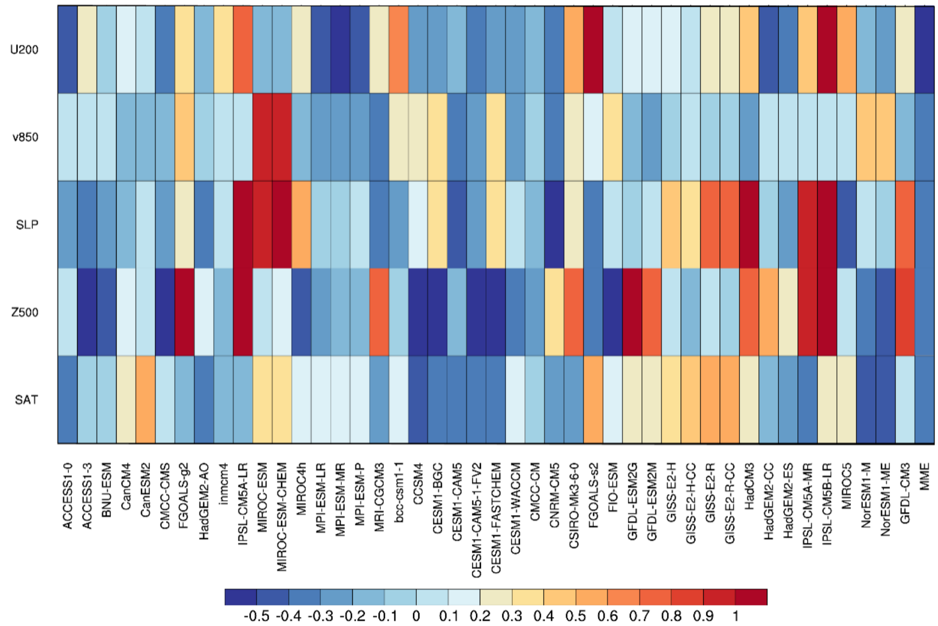


Figure 7. Relative RMS errors of individual CMIP5 models and MME for East Asian winter surface temperature, 500 hPa geopotential height, sea level pressure, 850 hPa meridional wind, 200 hPa latitudinal wind

We can conclude that the climate change experienced by Canada, for example, is a 50-year event and that the average temperature in the region has been increasing over a 26-year period, and that the greater the TK, the greater the range of variation, resulting in delays in civil construction schedules.

3. Spatial and Temporal Patterns of Climate

As can be seen from the graph, the average annual temperature fluctuates over the 26-year period covered by the statistics, but there is an overall upward trend; the positive timeliness-tendency value used to evaluate the temperature trend in the graph also provides a basic indication of the overall trend of increasing temperatures. The difference between the minimum and maximum temperatures is around 2.5 ℃, and the annual average temperature in Canada was low between 1994 and 1996.

The absolute magnitude of the timeliness-tendency value reflects the rate of change of the annual mean temperature in the region over a 26-year period. A negative TK indicates a decreasing trend in the annual mean temperature of the region over a 26-year period. By dividing the range of changes in the evaluation criterion TK into 8 bands, gradually increasing from the cooler bands to the warmer ones, it is possible to quickly see how the rate of temperature increase or decrease over a 26-year period in an area by observing the change in colour in the graph.

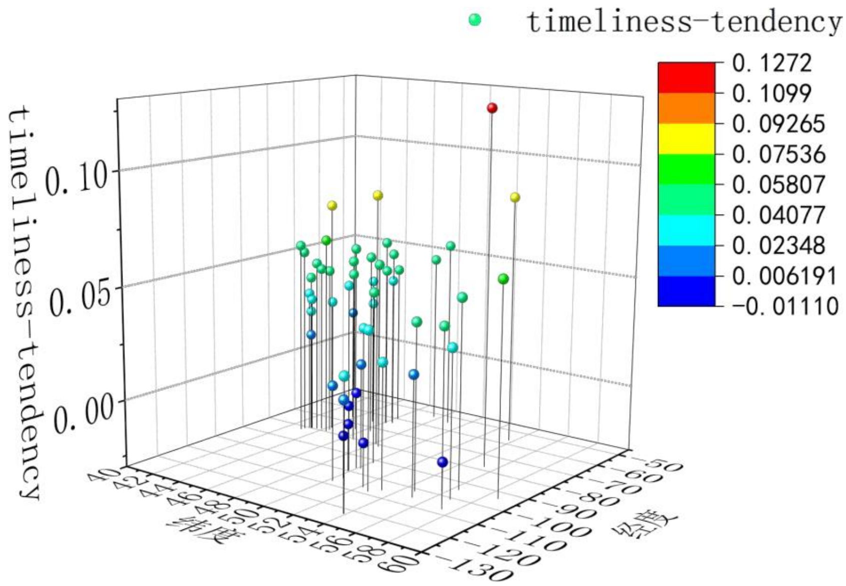


Figure 8

By analyzing data on CO2 concentration, vegetation cover, total population and GDP for 34 countries, a multivariate higher polynomial temperature prediction model based on energy conservation was applied to derive the trend over the next 20 years as shown in the figure above, with global temperatures showing an upward trend and a sudden increase around 1940, taking into account that economic development affects the increase in GDP and thus greenhouse gas emissions. The increase in greenhouse gas emissions will result in a slow but significant global warming over the next century, with predictive models calculating a global average temperature increase of around 0.5 degrees Celsius around 2040.

Recent assessments suggest that global temperatures will rise by just over 4 degrees Celsius by 2100. If economic growth continues and no effective interventions are implemented, pre-industrial levels could be exceeded and the actual temperature rise could be a few degrees larger or smaller, depending on the actual trend in future emissions and the still poorly understood climate response to rising greenhouse gas levels. Our projection of a global temperature rise of 0.5 ℃ by 2040 is thus a reasonable one.

This is shown in Figure 9 below.

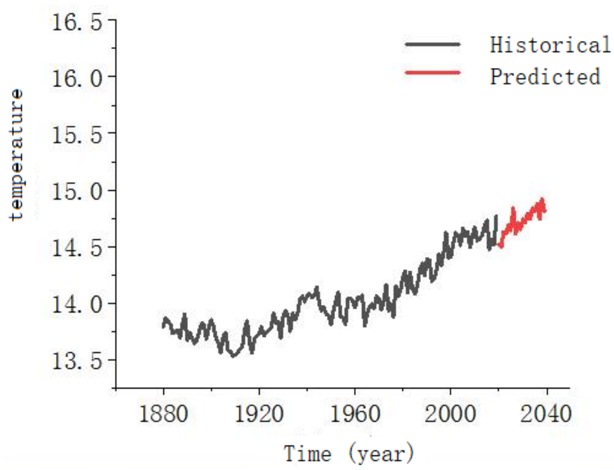


Figure 9. Global 25-year temperature projections

The main reasons for this are global warming, firstly the destruction of forests and other vegetation, and the fact that as society develops, more and more people are cutting down vegetation, resulting in large areas being damaged and unable to grow again. We all know that carbon dioxide is one of the causes of global warming, and the increasing amount of carbon dioxide emitted by such a large population will have a direct impact on the climate change on the earth's surface, which is also a serious threat to the balance of the natural ecosystem. In addition, the atmosphere is now very polluted, with car exhausts and industrial gases being released into the atmosphere without filtering, seriously polluting the atmosphere and causing one of the main factors of warming.

4. Extreme Weather Risk Assessment Report

Extreme weather events are rare events that occur in a particular region and at a particular time, and typically include events such as floods, droughts, heat waves and tropical storms. However, as the climate warms, and as our analysis above shows, the frequency of extreme events is increasing.

Through the research status of related aspects at home and abroad is discussed in detail, for example, there are many scholars on risk analysis, risk management, meteorological risk, construction progress has done a lot of research, the risk factors affecting the project progress are mainly technical risk, human risk, meteorological risk, geological risk and several other aspects, because in the construction progress delay risk meteorological factors are difficult to control, so this paper mainly on the meteorological risk In this paper, meteorological risks are analysed and combined with the climatic characteristics of southern China, rainfall becomes a typical risk factor for construction schedule delays. However, there is very little research on the analysis and monitoring of construction schedule risk when affected by rainfall, and no complete set of risk management implementation plan has been proposed.

Therefore, carbon neutrality and reduction of carbon emissions are now urgent in order to further reduce the occurrence of extreme weather and slow down the trend of global warming!

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