Numerical simulation of sea surface temperature based on big data and calculation of economic effect of import trade

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Abstract

The Arctic Oscillation and the North Atlantic Oscillation are the dominant patterns of the atmospheric circulation except the tropics in the northern region. In winter, the Arctic Oscillation and the North Atlantic Oscillation have a great influence on the climate of most regions except the tropics, and it has an organic integration with the North Atlantic sea surface temperature. It is still used by many departments and institutions to judge and predict atmospheric circulation according to the set sea surface temperature. However, the short-term climate judgment is greatly affected by different sea surface temperatures, and the understanding of the otherness is still lacking. Therefore, it is the main way for China to predict the climate of relevant regions through the prediction experiments of several different sea surface temperatures for atmospheric circulation climate carried out by the National Climate Center and the analysis of relevant data information through the experiments. It is still the main way to strengthen the development of trade, especially the development of import and export trade, by reducing tariffs. But it is inevitable that the reduction of tariffs will also reduce the country’s government revenue. By studying the impact of tariff reduction on finance on the basis of theory, to enhance the level of fiscal revenue of each country. Import trade is the main content of international trade, and its scale and form have a significant impact on the development of a country. Research shows that we should strengthen the import of high-tech products. Improving the import structure of general products and paying attention to the import of consumer goods play a very important role in stabilizing the country’s economic growth level and improving the country’s economic income.

Keywords  Big data · Numerical simulation of sea surface temperature · Import trade · Economic effect

Introduction

The Arctic Oscillation (AO), the main change form of atmospheric circulation in the northern region except the tropics. There are usually very low sea-level pressure and sea-level oscillation in some areas. There are three main active areas of the Arctic Oscillation (Touliabah and Elbassat 2017). The North Atlantic Oscillation is the main change form of the atmospheric circulation outside the tropical region of the North Atlantic. It usually occurs in Iceland and the surrounding high-pressure areas of uneven sea-level pressure. The spatial structures of the Arctic Oscillation and the North Atlantic Oscillation are basically the same, and there is a great consistency between them in time. It mainly affects the natural changes of the atmosphere in some parts of Asia, as well as the sea temperature and the temperature and humidity of the sea ice and soil in the plateau. The forcing of SST plays a very important role in it (Venkatramanan et al. 2014). The thermal distribution of sea surface temperature changes the atmospheric circulation and ocean atmosphere to a certain extent and affects the monsoon, water temperature, and precipitation. Therefore, it is very important to establish a model to predict the temperature, climate, and sea surface temperature in Asia (Wake 2005). Different SST forcings can predict the accuracy of the ocean’s initial value in the model. Therefore, the study of SST frequency has an important influence on the judgment of Asian climate (Hariri and Abu-Zied 2018), and there are differences in the accuracy of this effect (Hedge et al. 2009).
After China’s accession to the WTO, the trade volume with other countries in the world has increased to a great extent. With the continuous strengthening of the process of world economic integration, the competition between countries is also more intense. Now, China has become the world’s top international economic trading power (Shriadah et al. 2004). In recent years, China’s total international trade has decreased to a certain extent. But the phenomenon of Chinese residents’ outbound travel and overseas purchasing is more and more frequent (Sabina et al. 2005). China has become the world’s largest consumer country and a powerful consumer country abroad. Therefore, with the decline of the number of China’s international trade transactions, the consumption ability and level of Chinese residents are rising, mainly through purchasing or outbound tourism to buy foreign products (Zhang et al. 2018). How to transform this part of consumption into domestic consumption is a problem to be studied by many experts and relevant institutions. Therefore, on the theoretical basis of this paper, through the change of tariff income, and through weakening the fiscal effect of tariffs, we can enhance the redistribution of national income and national welfare (Youssef and El-Sorogy 2016).

Materials and methods

Data source

The following monthly observation data were used in this study.

1. The atmospheric field data from the national environmental prediction agency and the National Institute of atmospheric research, including terrain elevation field, horizontal and meridional wind field, and vertical temperature field.
2. The monthly surface heat flux includes the radiation from the downstream of the incoming wave, the surface sensitive heat flux and the total heat flux, and the total capacity data issued by the national environmental prediction agency and the energy agency. Its resolution is T62 Gaussian style.
3. NOAA is the horizontal resolution data.
4. NCEP is the data provided by the ocean data assimilation system all over the world. It includes variables such as oceanic heat flow, sea level, sea temperature, and meridian velocity.
5. In the past 50 years, the data of the Arctic Oscillation and the North Atlantic Oscillation are displayed on the CPA website.

In this paper, winter is defined as December, January, and February, while summer is defined as June, July, and August. The main research time is the last 50 years. During this period, we mainly studied the interannual scale changes. All the indexes and changes were processed by a high-pass wave. The linear trend of all variables in related research and analysis is eliminated.

Numerical simulation of sea surface temperature

Heat budget equation of ocean mixed layer

In this paper, the heat budget equation of mixed sea layer has been calculated to diagnose the influence of oceanic dynamic process and heat exchange between ocean and atmosphere on seawater temperature:

\[
\frac{\partial T'}{\partial t} = -u \frac{\partial T'}{\partial x} - v \frac{\partial T'}{\partial y} - w \frac{\partial T'}{\partial z} + \nabla^2 T' + Q' \rho
\]

(1)

In the formula, \(u, v, w\), and \(T\) represent the sea surface current, meridional current, and turbulence. The horizontal lines and points represent the mean or annual trend of the climate, and \(R\) represents the time remaining due to the interruption of the stroke. In the subnet hybrid layer, it can be expressed as

\[
Q' = \frac{Q'_{\text{net}} \rho}{\rho C_p H}
\]

(2)

where \(Q'_{\text{net}}\), \(\rho\), and \(C_p\) represent the net heat flux of the surface layer, the density, and specific heat capacity of the seawater. \(H\) is the equilibrium degree of the mixing layer.

EOF decomposition

The meteorological field (\(X\)) changes with time and can be expressed as a function of time and geography. If the meteorological area \(m\) has a geographical location and \(N\) observations, the meteorological area can be represented by a matrix:

\[
X = \begin{bmatrix}
X_{11} & X_{12} & \cdots & X_{1n} \\
X_{21} & X_{22} & \cdots & X_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
X_{m1} & X_{m2} & \cdots & X_{mn}
\end{bmatrix}
\]

(3)

The EOF extension consists of dividing the matrix in the product by its own vector (\(V\)) and time factor (\(T\)), i.e. \(X = VT\):

\[
V = \begin{bmatrix}
V_{11} & V_{12} & \cdots & V_{1m} \\
V_{21} & V_{22} & \cdots & V_{2m} \\
\vdots & \vdots & \ddots & \vdots \\
V_{m1} & V_{m2} & \cdots & V_{mm}
\end{bmatrix}
\]

(4)
The formula includes the variable contributions corresponding to each characteristic sector:

$$R_k = \frac{V_k}{\sum_{i=1}^{m} V_i}$$

The greater the contribution of change, the more important the conditions in the meteorological region.

**Research on the economic effect of import trade**

The database used in this paper is the latest version of GTAP, which records the data information of most countries and regions in the world. In addition, there are data of carbon dioxide emissions in various countries in the world, as well as the grouping of different industrial sectors. See Table 1 for details.

**Results**

**Mechanism analysis of ocean SST warming**

In order to study the climate change process of North Atlantic Oscillation in winter in the whole year, the North Atlantic Oscillation in winter is calculated and judged according to the diagnostic method of ocean mixed layer temperature. The details are shown in Fig. 1. It can be seen from Fig. 1a that in the tropical Atlantic region, the sea surface temperature increases significantly, the static heat flux on the north side increases significantly, and the sea surface wind speed and cloud cover decrease to a certain extent.

Through the analysis of the North Atlantic Oscillation in winter, Fig. 1a shows the sea surface temperature; Fig. 1b shows the heat flux in the sea level and the tilt of sea surface temperature caused by shyven; Fig. 1c shows the tilt of sea surface temperature and the wind speed on the surface caused by the thermal quantity at sea level; Fig. 1d shows the tendency of sea surface temperature caused by short wave radiation at sea level; Fig. 1e shows the trend of sea surface temperature caused by the current in the ocean; and Fig. 1f shows a linear regression of SST due to vertical ocean flow.

At the same time, for the SST tendency in the North Atlantic Oscillation, there is a correlation between the obvious increase of temperature in the North Atlantic. The details are shown in Fig. 2.

In order to study the heat flux, short wave radiation, and ocean dynamics, the effect of the heat flux on the tilt of the North Atlantic Ocean temperature is studied. In Fig. 3, the linear regression distribution of the SST tilt in the North Atlantic is continued. From Fig. 3, it can be seen that the most important effect on the SST tilt of the North Atlantic is short wave radiation, followed by heat flux, while marine dynamics play a relatively small role.

It can be seen from the observation that the rise of SST at the north and south ends of the North Atlantic is caused by the abnormal heat flux. The abnormal heat flux will also make the large-scale circulation in the North Atlantic abnormal. See Fig. 4 for details.

**Table 1** Grouping of industrial sectors in GTAP model

| Industry sector       | Included product division                                                                 |
|----------------------|------------------------------------------------------------------------------------------|
| Agriculture          | Rice, flour, grains and others, vegetables, fruits, various fruits, and other crop products |
| Animal husbandry     | Livestock such as pigs, cattle, and sheep, and poultry creatures such as chickens and ducks |
| Extractive industry  | Coal, oil, natural gas, and other products as well as non-ferrous metals and other related products |
| Food                 | Various food products and other related products, rice products, pasta products, and dairy products, and other related products |
| Textile              | Knitting, down and other textiles, clothing, shoes and hats, leather, and other related products |
| High industry        | Tobacco and alcohol, home appliances, furniture, hardware, toys, musical instruments, ceramics, textiles, papermaking, printing, daily necessities, office supplies, stationery, sporting goods, and other industries |
| Heavy industry       | Iron and steel industry, metallurgical industry, machinery, energy (electricity, petroleum, coal, natural gas, etc.), chemical, materials, and other industries |
| Public service       | Water, electricity, natural gas transportation, and sale industries                        |
| Transportation       | Various transportation and other service industries such as road, railway, ocean, and air transportation |
| Other service industries | Various industry sectors such as trade, transportation, banking, communications, healthcare, education, and construction |
With the abnormal temperature phenomenon in the north and south ends of the North Atlantic, the subsidence of the sea area also occurs in the north and south ends. This makes it more convenient to reduce cloud flow and increase of short wave radiation over the North Atlantic. See Fig. 5 for details.

**Numerical simulation of the interannual relationship between ocean atmosphere and sea surface temperature**

Figure 6a shows the time series indices of the winter Arctic Oscillation and the North Atlantic Oscillation over the past 50 years. Figure 6b shows the sea level pressure and linear regression distribution of the winter Arctic Oscillation. Figure 6d shows the SST corresponding to the Arctic Oscillation Index in winter and its linear regression distribution. Figure 6c and e is similar to Fig. 6b and d, showing the variation and linear distribution of North Atlantic Oscillation Index in winter.

Figure 7 shows the variation and distribution of Arctic Oscillation and North Atlantic Oscillation Index and SST at different latitudes in the Atlantic Ocean in winter in recent 50 years. It can be found from Fig. 7 that the Arctic Oscillation and the North Atlantic Oscillation have a very direct relationship with the sea surface temperature changes in the North Atlantic in winter.

Compared with the atmosphere, the climate change of the ocean is relatively slow, so the time of sea surface temperature change caused by Arctic Oscillation and North Atlantic Oscillation...
oscillation is relatively long in winter. Figure 8 shows the variation of Arctic Oscillation and North Atlantic Oscillation Index in winter and SST at different latitudes in the North Atlantic in spring and summer next year. It can be seen from the figure that the variation of the Arctic Oscillation and the North Atlantic Oscillation with the sea surface temperature is obvious in winter, while the influence of the Arctic Oscillation and the North Atlantic Oscillation on the sea surface temperature is relatively small in the next spring and summer.

Analysis of the results of the economic effect of import trade

Changes in fiscal revenue effect of tariff reduction in China

The reduction of the import tariff rate in our country can increase the volume of import transactions, but the change of tax policy is the reduction of a tax rate, which makes the tax revenue change differently, as shown in Table 2.

It can be seen from Table 2 that in the case of tariff reduction, industries with relatively small tax changes are mainly concentrated in the light industry. However, heavy industry and food industry have a great influence on tax revenue. Therefore, we can appropriately reduce the tariff rate of the light industry and other industries so that the fiscal revenue can maintain sustained growth.

The impact of China’s tariff reduction on macroeconomic effect

Through the study of the changes of fiscal revenue caused by the reduction of tariff rate, we can further determine the macro-impact on China’s economy after the reduction of tariff rate. When China’s overall tariff rate drops to a certain extent, China’s social welfare will increase. The overseas consumption of Chinese residents will also change. The details are shown in Table 3.
In order to have a firm foothold and good competitiveness in the international market, most domestic enterprises will adopt the way of price reduction to compete with the same industry. After the price falls, the export of products will increase, the demand for various consumption will increase correspondingly, and finally, the social welfare will increase to a certain extent. There is a positive correlation between the reduction of tariffs and the increase of welfare. Therefore, the reduction of tariff rates can ensure the sustained and stable growth of China’s economy and improve the level of social welfare.

Discussion

Development and processing technology of big data

Since the emergence of big data, after more than 10 years of rapid development, all kinds of science and technology of big data have made great improvements and become more and more perfect. Big data has been widely used in all aspects of social life and all walks of life. There are many new types of business, such as online sales, sharing activities, personalized manufacturing and service-oriented production, adjuvant therapy, and risk control. And big data has become a major driving force to promote the rapid development of China’s economy and society. The relevant scientific and technological information of big data has been effectively integrated with all aspects of society.

Big data technology is different from the traditional, modern information technology and information technology means and methods; big data reflects that the data capacity is very large, and the data structure is more complex, can be processed at any time and efficient analysis operation and other advantages. Through data processing, data collection, data storage and data analysis, and other modern advanced scientific and technological means, the data information can be classified and collected so that the data can more...
objectively and truly reflect the law of social development and people’s social structure (Alharbi and El-Sorogy 2019). A few years ago, our country established a big data research center, which promotes the development of big data to the height of national strategy. Through data sharing and other information, it strengthens the cooperation between different institutions and departments. At the same time, the country is also urging relevant functional departments to formulate laws and regulations on big data.

Fig. 4 Standardized winter NAO index for 2000–2020 × (−1). The sea surface temperature and 925 hPa horizontal wind field from December to January are analyzed.

Fig. 5 Temperature anomalies in the north and south ends of the North Atlantic.
In the process of big data processing, the most important thing is to analyze and sort out the data information, in which the use of a variety of science and technology is also very critical (Batayneh 2010).

1. **Cloud computing and MapReduce.** Cloud computing is a very large-scale distributed data model. Through the network connection, all kinds of data information and service content are transmitted to the user’s terminal devices through the network. Cloud computing is the most important content of big data processing, and it is also the main core component of big data analysis and collation. MapReduce is a way and method of data processing and analysis, deep mining, and deep learning created by

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**Fig. 6** a) Time series index of Arctic fluctuations and North Atlantic fluctuations in winter in recent 50 years. b) Sea level pressure and linear regression distribution corresponding to Arctic fluctuations in winter. c) Sea level pressure and linear regression distribution corresponding to North Atlantic fluctuations in winter. d) SST corresponding to Arctic volatility index in winter and its linear regression distribution. e) SST corresponding to North Atlantic volatility index in winter and its linear regression distribution.
Google. This technology is very mature and important for parallel data processing.

2. **Distributed file system.** Google designed and developed this distributed file system on the basis of its own usage. The file system is distributed, processing and running on the basis of the distributed cluster. This is a technology supported by the upper layer, which can help MapReduce technology to store and analyze data and provide an effective guarantee.

3. **Distributed parallel database.** In order to meet the needs of big data technology, Google has created the BigTable database (Bazzi 2014). Users can enter the database through the data model, query the relevant data information through multidimensional tables and methods, and adjust and set the relevant data information.

4. **Open-source implementation platform Hadoop.** In the era of big data, data analysis and data collation have different requirements, but the original data processing and analysis technology has been unable to meet the requirements of modern data processing technology. In order to make data processing more efficient and accurate, the Hadoop platform is created (Diagomanlin et al. 2004). The platform can be used for Java writing and can be mobile.

**Big data visualization.** To improve and perfect the visualization of big data means to process the image technology through the use of computer graphics and convert the data into images, which can be viewed by others on the screen. This interactive processing mode and method can make data information more intuitive and vivid to be understood by users and help people better understand and analyze all kinds of information in big data (El Sayed 2002).
Since China’s accession to the world trade organization, it has been carrying out the policy of reducing tariffs. At the same time, according to the arrangements and requirements of international organizations, we should improve the quality of products and the level of science and technology in foreign trade so as to strengthen the international competitiveness of Chinese products. With the continuous development of China’s import and export trade, China has become the largest import and export trade country in the world. The details are shown in Table 4.

It can be seen from Table 4 that in the process of China’s import and export trade, there was a slow downward trend in the past few years. And compared with other countries with high import dependence in the world, China’s import dependence is still at the lowest level in the world, which can also show that our country’s import market still has great development space and potential (Ghandour and Haredy 2019).

### Change trend of China’s import trade structure

1. **The main structure of import trade**: From the perspective of import trade, in China’s existing enterprises, foreign-funded enterprises import more and the growth of import is relatively slow. However, the import situation of state-owned enterprises in China fluctuates greatly.
Before the beginning of this century, the import volume of private enterprises was relatively small, but after entering the new century, the import scale of private enterprises increased rapidly and has been maintaining a steady growth trend.

2. **Import trade mode structure.** From the perspective of import trade structure, processing trade and other general commodity trade still occupy a dominant position in import trade. The processing trade also shows a slow-growth trend every year (Guerra et al. 2009).

3. **Product structure of import trade.** From the analysis of the structure of imported products, in the past few years, China’s import of primary agricultural products and industrial products changed little. From a macro perspective, China’s imports are still concentrated in industrial products. This has a lot to do with China’s emphasis on export policy in the past. The import is mainly for some high-tech modernization of key equipment and main parts import, as well as for energy and resources import is relatively large.

**Analysis of economic effect of import trade structure change**

1. **Technology spillover effect.** According to the research data of different countries in the world, import trade can help countries achieve the effect of technological growth and the research of relevant experts and scholars shows that modern advanced science and technology equipment import is the most important way for developing countries to achieve rapid development and reduce the technological differences with developed countries. Count spillover is also the main way of international trade. The import of modern high-tech products and equipment can play a very important role in promoting the economy of importing countries. First, through the introduction of modern high-tech products, the production capacity and production cost of importing countries can be used more scientifically and reasonably, which can improve production efficiency and reduce production cost. Second, by importing modern high-tech products and facilities, the importing countries save a lot of time in digesting, absorbing, and using new products and technologies, thus greatly reducing the R&D costs and R&D expenses of the importing countries for modern new technologies. Therefore, China always pays attention to the proportion of modern high-tech products in imported products. Through the import of some modern high-tech products and equipment, to improve the country’s competitiveness in the international market and promote the development of national economy and trade.

2. **Import competition effect.** The country will expand the import at the same time and will also make the domestic-related industry competition more intense. In the increasingly fierce competition, it will also urge enterprises to improve labor productivity, improve the production and management of enterprises, increase the efficiency of products, and improve the quality of products, so as to make products more competitive in the market and ensure a considerable proportion of profit space (Guieu et al. 1997). And the overall improvement of the industry competition will also make the whole industry’s labor productivity and other aspects get a very good improvement, so that some small-scale, relatively backward equipment enterprises cannot exist and develop in the increasingly fierce competition. To some extent, the capital structure and resources of the country have been more reasonably optimized.

3. **Intermediate input improved.** With the development of information technology and the improvement of transportation, every country in the world is developing its overall strength and economic level. At the same time, as intermediate goods, trade is more and more important in the

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**Table 4** General situation of China’s import trade from 2012 to 2020

| Year | Imports (100 million yuan) | Import growth rate (%) | Proportion of China’s imports in world imports (%) | Import dependence (%) | Trade balance (100 million yuan) |
|------|-----------------------------|------------------------|-------------------------------------------------|----------------------|----------------------------------|
| 2012 | 94,699.6                    | 38.1                   | 7.6                                             | 23.1                 | 12,323.4                         |
| 2013 | 113,161.5                   | 19.6                   | 8.5                                             | 23.3                 | 10,079.3                         |
| 2014 | 114,800.8                   | 1.5                    | 8.9                                             | 21.4                 | 14,558.4                         |
| 2015 | 121,037.6                   | 5.5                    | 9.4                                             | 20.5                 | 16,094.1                         |
| 2016 | 120,358.1                   | -0.7                   | 9.7                                             | 18.9                 | 23,525.8                         |
| 2017 | 104,336.2                   | -13.4                  | 9.7                                             | 15.3                 | 36,882                           |
| 2018 | 104,967.3                   | 0.7                    | 9.6                                             | 14.3                 | 33,452.2                         |
| 2019 | 124,789.9                   | 18.8                   | 9.8                                             | 15.3                 | 28,519.9                         |
| 2020 | 140,873.8                   | 12.8                   | 10.4                                            | 15.7                 | 23,303.1                         |
international market. The import of intermediate inputs can enable the importing countries to obtain more high-quality intermediate inputs with less cost, effectively improve the labor productivity of related enterprises, and promote the development of economic benefits of enterprises. The improvement of intermediate investment can also help import enterprises concentrate their own resources in leading and advantageous industries, which is also conducive to the realization of specialization and precision production in the production process.

4. **The consumption structure has been upgraded.** Since China’s opening up to the outside world, the main imports are advanced modern scientific and technological equipment, key parts, and energy resources. These imported products mainly serve our country’s domestic production and export. At the same time, with the rapid development of China’s economy, people’s consumption ability and living standard have also been greatly improved. The import demand for consumer goods is also growing, and the opening of the consumer goods market by the state also makes our residents freer and freer to choose some high-quality consumer products, so as to improve the consumption ability and level of our residents.

5. **Reduce trade frictions.** Since China’s opening up to the outside world, the main imports are advanced modern scientific and technological equipment, key parts, and energy resources. These imported products mainly serve our country’s domestic production and export. At the same time, with the rapid development of China’s economy, people’s consumption ability and living standard have also been greatly improved. The import demand for consumer goods is also growing, and the opening of the consumer goods market by the state also makes our residents freer and freer to choose some high-quality consumer products, so as to improve the consumption ability and level of our residents.

**Conclusion**

Through the analysis of the Arctic Oscillation and the North Atlantic Oscillation, the effect of the Arctic Oscillation on the sea surface temperature in the North Atlantic region in the past 145 years is discussed. It can be found that the effect of short wave radiation on SST anomaly and SST tilt in the North Atlantic is very obvious. With the development of world economic integration, the trade and trade exchanges between different countries in the world are becoming more and more frequent. The import and export of trade are also one of the main aspects to increase China’s international competitiveness and promote the rapid development of the national economy and society. Through the reduction of tariff rate, China’s fiscal revenue can be sustained and stable growth and increase consumer welfare. Through the original role of reducing tariffs, this paper makes the economic development adapt to the overall requirements of world development and changes to the growth of social welfare.

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**Declarations**

**Conflict of interest**

The authors declare that they have no competing interests.

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