Research on trend of warm-humid climate in Central Asia

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Abstract. Central Asia is a typical arid area, which is sensitive and vulnerable part of climate changes, at the same time, Central Asia is the Silk Road Economic Belt of the core district, the warm-humid climate change will affect the production and economic development of neighboring countries. The average annual precipitation, average annual temperature and evapotranspiration are the important indexes to weigh the climate change. In this paper, the annual precipitation, annual average temperature and evapotranspiration data of every pixel point in Central Asia are analyzed by using long-time series remote sensing data to analyze the trend of warm and humid conditions. Finally, using the model to analyze the distribution of warm-dry trend, the warm-wet trend, the cold-dry trend and the cold-wet trend in Central Asia and Xinjiang area. The results showed that most of the regions of Central Asia were warm-humid and warm-dry trends, but only a small number of regions showed warm-dry and cold-dry trends. It is of great significance to study the climatic change discipline and guarantee the ecological safety and improve the ability to cope with climate change in the region. It also provide scientific basis for the formulation of regional climate change program. The first section in your paper

1. Introduction:
Central Asia is the largest main non-zonal arid regions in the world. It is very sensitive to climate change, researches show that the rate of global warming in Central Asia is more than doubled in recent centuries [13], which making a series of climate security risks in Central Asia, such as poverty increasing, immigrant increasing and cross-border resource conflicts caused by climate change. At the same time, Central Asia is the key area for the implementation of the strategy “One Belt and One Road”. In order to ensure the smooth implementation of this strategic initiative, it is necessary to study the climate change trend of warm and wet climate in Central Asia.

The traditional method of studying the climate change of the warm-humid climate is to use the surface meteorological station data to interpolate and obtain the climatic change status of the whole study area. However, the meteorological stations in Central Asia are sparsely distributed and unevenly

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distributed, the terrain span is large and the underlying surface situation is complex, the traditional methods there is a serious point to surface phenomenon, it is difficult to accurately describe the region's climate trends and the spatiotemporal pattern distribution [5].

The feature of remote sensing data is spatial continuity, which can overcome the limitation of the sparseness site data and the inherent error of spatial interpolation data. It has become an important data source of climate change research in the region (especially in Central Asia, where the climate data is scarce and the terrain is complex). The study of warm-humid climate trends in Central Asia based on remote sensing data can obtain the rich, comprehensive and scientific understanding of the "Silk Road Economic Belt". Thus it also provide scientific advisory and support for the construction of the "Silk Road Economic Belt".

In this paper, the trend of annual mean temperature, precipitation and evapotranspiration in Central Asia is analyzed by using multiple remote sensing data, and using the model to study the trend of warm-humid climate in Central Asia. It is of great significance to respond to climate change to make the appropriate decision-making.

2. The data sources and methods of the warm-humid climate trend

In this paper, the region of Central Asia, including the five Central Asian countries and China's Sinkiang, the latitude and longitude range of 50°~90° E, 35°~55° N, which is defined as the study area. The southeastern terrain is lower than the northwestern part, and it is the typical temperate desert steppe continental climate, where the annual precipitation in 100 ~ 400mm, the Mountain is slightly higher than others, however the height of the desert areas was in 50mm below [4].

The paper mainly uses the NASA's high-resolution evapotranspiration data mod16, the temperature data mod11c3 products and the trmm satellite data. Evapotranspiration and temperature data are monthly collected values. The spatial resolution of original data is 1 km, after resample, we obtain the data that the spatial resolution is 5 km. The trmm data is used on a monthly scale with a spatial resolution of 0.25 degrees for the data product.

In this study, the average annual temperature, precipitation and the annual evapotranspiration of each pixel point in China's Sinkiang and the five central Asian countries were analyzed by using a linear trend analysis method. Then obtain the annual mean temperature trends (temperature_K ), Annual precipitation trends (evapotranspiration_K) and rainfall trends (evapotranspiration_K). Finally, using the method which was named decision tree to establish the warm-humid trend monitoring model on temperature, evapotranspiration and precipitation data, last access to Central Asia warm-wet climate change trend.

3. Temporal and spatial variation of warm-humid climate and conclusions

Temperature, rainfall and evapotranspiration are the important indicators of warm-humid climate. In this study, we analyzed the climatic characteristics of Central Asia using by annual precipitation, annual mean temperature and annual evapotranspiration in Central Asia, so as to have a comprehensive understanding of the trend of warm and humidification in Central Asia.

3.1 The analysis of temporal and spatial variation on temperature

Rapid warming of the global climate is already an indisputable fact. Central Asia is the world's largest non-zonal arid zone, which is the most sensitive to global warming. In recent 30 years, with the global warming in Central Asia, the temperature increased significantly and the rate of temperature is higher than the global average data, which makes the glaciers melt rapidly and the freshwater reserves of the glaciers decrease sharply. This is a great challenge to the fragile ecological environment of arid and semi-arid in Central Asia [5].

Although the general trend of global temperature change is almost the same, the variation trend of temperature in different regions is unequal because of sundry causes which are latitudes, terrain and land-sea distribution. In order to understand the long-term trend of temperature in Central Asia, we
analyzed the trend of pixel-by-pixel variation of the annual mean temperature from 2000 to 2015 in Central Asia and China's Sinkiang based on the MODIS and the MOD11C3 products from 2000 to 2015,

![Image](image1)

**Figure 1.** Annual average temperature trends from 2000 to 2014.

The results As shown in Fig. 1, the regression coefficients of annual mean temperature trends in Central Asia are between -0.2 and 0.2, with the north and central regions of Kazakhstan showing a trend of increasing temperature. But the west and southeast parts show a decreasing trend; The trend of temperature increasing in Turkmenistan, Uzbekistan, Kyrgyzstan, the most area of junction in Tajikistan; The border region and the central region of China's Sinkiang showed the trend of temperature increasing.

3.2 *The analysis of temporal and spatial variation on precipitation*

Rapid Precipitation in Central Asia is characterized by an increasing trend of both sides while decreasing trend of middle sides in space. High-value centers of precipitation appear in Kyrgyzstan, Tajikistan. Western part of Uzbekistan, southern part of Kazakhstan and northern part of Turkmenistan and China's Sinkiang are the low value of precipitation centers, especially in Xinjiang, China's Tarim Basin, the average annual rainfall is insufficient [2].

In order to understand the trend of annual precipitation change in Central Asia, we used the trmm satellite data 3B43 month data to analyze the annual precipitation in China.

![Image](image2)

**Figure 2.** Trends in annual precipitation from 2000 to 2014.

Monitoring results shown in Fig 2, trmm precipitation data cover the range of 50 ° S-50 ° N, so the data of northern region of Kazakhstan would be missing. The regression coefficients in the Central Asia region are in the range of -5 to 10, with the positive data region being the dominant region. The annual precipitation in most parts of Central Asia is increasing, with the increase in the eastern region of Tajikistan, Kyrgyzstan and Kazakhstan. The precipitation in Kazakhstan, Turkmenistan and southwestern part of China's Sinkiang is slightly decreasing.
3.3 Analysis of temporal and spatial variation on evapotranspiration

The arid region of Central Asia is a region where has serious shortage of water resources and very large evaporation [1]. The change of annual evapotranspiration seriously affects the humid climate in Central Asia. In order to understand the trend of annual evapotranspiration in Central Asia, we used MODIS data mod16 which spatial resolution of 1 km of annual evapotranspiration data to monitor the trend of each pixel in Central Asia.

![Figure 3. Trends of annual evapotranspiration from 2000 to 2014](image)

Monitoring results As shown in Fig3, mod16 evapotranspiration data products are severely missing due to the low vegetation coverage in the northwestern parts of Turkmenistan and Uzbekistan and the southwest of China's Sinkiang. The annual evapotranspiration in most parts of Kazakhstan showed an increasing trend, especially in the northern region; The annual evapotranspiration in the northwestern Uzbekistan and Turkmenistan showed an increasing trend, while the southeast part showed a decreasing trend; Kyrgyzstan showed an increasing trend, but Tajikistan showed a decreasing trend; The north of Xinjiang Uygur Autonomous Region showed an increasing trend of increasing and a declining trend in the west.

3.4 Spatial Analysis of Climate Change Trends

The warm-humid climate is the result of the interaction of annual precipitation, annual evapotranspiration and annual mean temperature. In this study, the method of dryness index —— formula (1) , which is used to reflect the dry and wet change in Central Asia.

\[ R = \frac{E}{P} \] (1)

In the formula: \( r \) is the drought index, \( E \) is the annual evaporation, mm; \( P \) is the annual precipitation, mm.

When \( r > 1 \), the annual evaporation is greater than the annual precipitation, the climate is dry, as the \( r \) value larger, reflecting the climate is more dry; when \( r < 1 \), the annual precipitation is greater than the annual evaporation, the climate is wet, as the \( r \) value smaller, reflecting the climate is more wet.

To obtain weather change trend(\( r_K \)) from 2000—2014, we analysis the drought index-\( r \) by unitary linearity regression, then combine with temperature_\( K \), to Draw a scatter diagram to show the trend of warm and wet change in Central Asian.
Results as shown in figure 4 (for temperature_K abscissa and ordinate r_K - 1), on the whole area in central Asia, the change of humidity is bigger, either warm-wet or cold-wet, temperature changing trend is lesser, cold-wet, dry-wet, warm-wet and cold-wet has little difference.

Using the trend of drought index (r_K), combining with the annual temperature trend (temperature_K) to establish a decision tree model (Figure 5) to obtain the spatial distribution of warm-humid climate change trends in Central Asia.

**Figure 4.** Scatter diagram of warm-humid climate change

**Figure 5.** Decision tree model for warm and wet change trends
Figure 6. Trends in warm and humid trends for the Central Asian region, 2000-2014

The results are shown in Figure 5, because of the westerlies and global warming, the western and eastern regions of Kazakhstan were respectively showed cold-wet and warm-wet trends, a small part of the central region showed a dry-cold trend; the southern part of Uzbekistan and Turkmenistan showed warm-humid trend, but appeared cold trends in the middle part; Tajikistan is characterized by a warm-humid trend; the northern part of Kyrgyzstan is shown cold-wet trend, but the southern showed warm-humid trend. The Xinjiang Uygur Autonomous Region has a warming trend at the junction with Kyrgyzstan and Tajikistan.

4. Expectation

Central Asian climate is obviously influenced by westerly circulation which with seasonal characteristics and the North Atlantic Oscillation [2]. Therefore, in order to reveal the climatic change of the warm-humid climate in Central Asia more comprehensively and meticulously, we need to use the temporal resolution of monthly scale to analyze the tendency of warm-wet climate in Central Asia by using remote sensing data.

There is lack of data on the rainfall and evapotranspiration used in the study. We need to find other data resources to replace or build up the model to invert the data of rainfall and evaporation to complement the research.

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