

Research on Applicability Analysis of Drought Index in Liaoning Area

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Abstract. Based on brightness temperature data of AMSR-E (advanced microwave scanning radiometer — earth observing system) in 2009 and 2011, the inversion on 8 brightness temperature ratios is performed as alternative drought indexes in this paper. The correlation analysis is made through the soil moisture extracted from inversion drought index and data itself, and 3 kinds of alternative drought that relatively coincide with soil moisture of AMSR-E data itself are selected. And then on this basis, the analysis on the change situation of 3 kinds of microwave moisture indexes in 10 pixel \times 10 pixel rectangular region of Shenyang and Chaoyang is made, and the evaluation on the monitoring advantages and disadvantages of 3 kinds of indexes on soil moisture is performed, so as to obtain the optimal index PIV6.9 for drought monitoring. In the end, in order to further study PIV6.9 on soil moisture monitoring situation within the range of Liaoning province, four days with relatively large precipitation are selected according to meteorological station data in 2009, the precipitation data of 51 meteorological stations in Liaoning province are interpolated within the range of the whole province by utilizing Kriging method, and the contrastive analysis on the spatial distribution of precipitation and PIV6.9 index is made. The results show that PIV6.9 can best reflect the spatial distribution characteristics of drought status in Liaoning province.

1 Introduction

Drought is a kind of complex natural phenomenon that generally occurs around the world, with wide spread range, long duration, which is one of the most serious natural disasters in agricultural production and human life. It will directly lead to huge economic, social and environmental losses. Liaoning is a province that is seriously influenced by drought disaster. The annual precipitation of the whole province is 600~1100mm. Influenced by geographical location, natural environment and general atmospheric circulation, the precipitation is distributed unevenly in time and space, and arid and semi-arid area is about one half of the whole area of Liaoning province. So it is a province with frequent drought disaster. Drought exerts very large influence on the industrial and agricultural production and human life in the whole area of Liaoning, so the research on spatial and temporal distribution characteristics of drought disaster has important meaning for drought control and disaster reduction of Liaoning province.

With the development of satellite remote sensing technology, the evaluation on soil moisture status is performed from different sides by applying multi-temporal, multi-spectral and multi-dimensional remote sensing data, so as to perform the monitoring, evaluation and early warning on large-area drought severity. It has advantages like rapid, timely, macroscopic and so on. Comparing with optical



remote sensing and active microwave remote sensing, although the spatial resolution of passive remote sensing is lower, it can burst through clouds with merits of all-day observation, higher temporal resolution and relatively simple data processing. Therefore, in recent twenty years, microwave remote sensing was also extensively used for drought monitoring and obtained certain progress: Ya-Qiu Jin (1998) applied brightness temperature data for 7 channel radiation of SSM/I to study the spatial distribution of soil moisture of farmland in northeast and north China, and put forward to use scattering index and polarization index that are generated from microwave data to analyze the microwave radiation characteristics of farmland, so as to monitor the status of crop growth and soil moisture; Feng Gao and so on (2004) applied TMI data and ground-based observation data of Qinghai-Tibet Plateau experimental research on Asian monsoon of global energy water circulation to improve the passive microwave remote sensing inversion on three-dimensional lookup algorithm of earth surface temperature, soil moisture and vegetation water content, and performed the inversion experiment successfully within the mid-scale range of middle part of Qinghai-Tibet Plateau; He-Bin Guo (2009) performed the soil moisture inversion by combining BSM and ANN and utilizing AMSR-E data to still keep certain precision when the priori knowledge is with uncertainty. Based on the above research, the inversion on many kinds of microwave soil moisture indexes is performed by utilizing the calculation of AMSR-E data in 2009 in this paper, and then the correlation analysis on soil moisture value is made according to data itself, and in the end the optimal moisture index for soil moisture monitoring is determined and the demonstration is performed by utilizing data in 2011.

2 General situation of measuring area

Liaoning province is located in the south of northeast China Region, the geographic coordinate lies between 118°53' and 125°46' east longitude, and 38°43' and 43°26' north latitude. It is located in the east coast of Eurasian continent and mid-latitude region, belonging to continental monsoon climate area of temperate zone. Its rainy season and hot season are in the same period, with abundant sunshine, higher accumulated temperature and four distinctive seasons. The annual average temperature is 7-11°C, the highest temperature is +30°C, the extreme highest temperature can reach +40°C, and the lowest temperature is -30°C. Influenced by monsoon climate, the differences of precipitation at various regions are larger, decreasing progressively from southwest to northeast, plain to mountain area. It is wet in the east and dry in the west.

3 Data and methods

3.1 Data

AMSR-E earth surface soil moisture data in four days like September 16 and 17, 2009 and September 22 and 23, 2011 are collected in this paper as analysis objectives, which are used for studying the soil moisture index. In addition, AMSR-E data in four days like January 28, May 4, July 31, and October 28, 2009 are collected for dynamic monitoring of drought all year round. The data are all obtained from NSIDC (National Snow and Ice Data Center) and soil moisture L3 data product is grid point data product of EASE-Grid global 25km resolution ratio. AMSR-E/Aqua L3 Daily soil moisture product is daily product data that is combined by AMSR-E/Aqua L2B earth surface instant soil moisture and EASE-Grid Level-2B TBs produced by projection transformation processing.

3.2 Drought index

The inversion on 8 brightness temperature ratios as alternative drought indexes is performed. These eight drought indexes include: horizontal polarization multi-temporal microwave moisture indexes PIH6.9 and PIH10.7, vertical polarization multi-temporal microwave moisture indexes PIV6.9 and PIV10.7, microwave polarization difference indexes MPDI6.9 and MPDI10.7 and vertical polarization ratio indexes DIV6.9 and DIV10.7.

In which, the calculation formula of microwave polarization difference indexes MPDI6.9 and MPDI10.7 is:

$$MPDI_{6.9} = \frac{T_{B,V}(6.9) - T_{B,H}(6.9)}{T_{B,V}(6.9) + T_{B,H}(6.9)} \quad (1)$$

$$MPDI_{10.7} = \frac{T_{B,V}(10.7) - T_{B,H}(10.7)}{T_{B,V}(10.7) + T_{B,H}(10.7)} \quad (2)$$

Comparing with other microwave moisture indexes, MPDI is not influenced by earth surface temperature, and it is with certain advantages for the monitoring on soil moisture. Many scholars in domestic all adopt this index to study the soil moisture. Comprehensively considering features like earth surface type in this research district and so on, we select brightness temperature data of dual polarization channel of frequency 6.9GHz and 10.7GHz to calculate MPDI. The brightness temperature of microwave radiation quantity is usually expressed by TB. In formula (1), and respectively express vertical polarization brightness temperature and horizontal polarization brightness temperature of 6.9GHz frequency wave band, in formula (2), and respectively express vertical polarization brightness temperature and horizontal polarization brightness temperature of 10.7 GHz frequency wave band.

The calculation formula of horizontal polarization multi-temporal microwave moisture indexes PIH6.9 and PIH10.7 and vertical polarization multi-temporal microwave moisture indexes PIV6.9 and PIV10.7 is:

$$PI_H 6.9 = \frac{T_{B2,H}(6.9) - T_{B1,H}(6.9)}{T_{B2,H}(6.9) + T_{B1,H}(6.9)} \quad (3)$$

$$PI_H 10.7 = \frac{T_{B2,H}(10.7) - T_{B1,H}(10.7)}{T_{B2,H}(10.7) + T_{B1,H}(10.7)} \quad (4)$$

$$PI_V 6.9 = \frac{T_{B2,V}(6.9) - T_{B1,V}(6.9)}{T_{B2,V}(6.9) + T_{B1,V}(6.9)} \quad (5)$$

$$PI_V 10.7 = \frac{T_{B2,V}(10.7) - T_{B1,V}(10.7)}{T_{B2,V}(10.7) + T_{B1,V}(10.7)} \quad (6)$$

Referring to the algorithm of microwave polarization difference index (MPDI), some scholars put forward many kinds of multi-temporal microwave drought indexes (PI). It is calculated that PI eliminates the influence of earth surface temperature to a certain extent by utilizing the brightness temperature data of adjacent 2 days. Horizontal (H) and vertical (V) polarization multi-temporal microwave moisture indexes of 6.9GHz and 10.7GHz of the current ten days () and former ten days () are selected in this research. Low-frequency wave band has certain penetrating power to earth surface cover, which can better reflect the earth surface moisture status. But the drought monitoring results under the condition of different underlying surfaces are different through the difference of interval time of ten days to represent the change of earth surface soil moisture.

The formula of vertical polarization ratio indexes DIV6.9 and DIV10.7 is:

$$DI_V 6.9 = \frac{T_{B,V}(6.9)}{T_{B,V}(36.5)} \quad (7)$$

$$DI_V 10.7 = \frac{T_{B,V}(10.7)}{T_{B,V}(36.5)} \quad (8)$$

We can know from comparative research on 43 kinds of alternative drought indexes in Hebei province that, ratio index (drought index, DI) relatively applies to the monitoring on soil moisture. The vertical polarization ratio indexes of 6.9GHz and 10.7GHz are selected as alternative drought indexes in this paper, so as to study the drought distribution in Liaoning area.

3.3 Correlation analysis

In order to select the index that can be used for expressing soil moisture, we need referential image. As for AMSR—E Level-3 land product, it can not only provide quality evaluation on brightness temperature value and data of 12 channels, but also contain inversion value of earth surface soil moisture of every day, so we adopt the soil moisture inversion value image of data itself as the referential image. First, we separate the soil moisture inversion value wave band of AMSR—E data by using HEG software, and then perform operation like image encryption processing, format conversion, cutting, reclassification and so on to obtain the soil moisture inversion value image of data itself, whose resolution ratio is 1000m after encryption processing. Due to influences of factors like earth surface type, vegetation distribution, precipitation and so on, the inversion moisture index image and moisture value image of AMSR-E data itself are compared only. It is still difficult to judge which inversion moisture index is better, so it is necessary to make correlation analysis. When making the correlation analysis, if directly utilizing earth surface data, on one hand, the resolution ratio of AMSR-E data is lower and the difference of single point value of earth surface and grid point value of satellite data is large, on the other hand, the consistency of time is also difficult to be mastered. Therefore, the discussion on correlation is made by adopting the soil moisture value of AMSR-E product in this paper. First, we convert grid image of inversion soil moisture index and grid image of soil moisture value of data itself to point data by utilizing ArcToolbox tool of ArcGIS software, and then input the point data to SPSS software, and make the correlation analysis by utilizing Pearson method to select three drought indexes with the largest correlation coefficient.

3.4 Selection of optimal drought index

On the basis of the above research, a more intuitive research on the soil moisture monitoring aspect for three drought indexes with the largest correlation coefficient is made, so as to select the optimal index that is suitable for soil moisture monitoring in Liaoning area. A rectangular region including Shenyang and Chaoyang is cut, and the comparative analysis on monitoring results of three indexes on precipitation is made, so as to select the optimal monitoring moisture index of soil moisture. In order to verify the optimal moisture index, the verification is made by adopting Kriging difference value method within the range of Liaoning area with the help of ArcGIS platform.

4 Results and analysis

4.1 Correlation analysis on 8 drought indexes and soil moisture inversion value

First we convert grid image of 8 inversion soil moisture indexes and grid image of soil moisture value of data itself to point data by utilizing ArcToolbox tool of ArcGIS software, and then input the point data to SPSS software, so as to make the correlation analysis and obtain the numerical value of correlation, see Table 1:

Table 1 Correlation analysis results

Correlation coefficient of index	PIH6. 9	PIH10.7	PIV6.9	PIV10.7	MPDI6.9	MPDI10.7	DIV6.9	DIV10.7
	0.191	-0.020	-0.635	0.067	0.01	-0.501	-0.01	-0.581

We can know from Table 1 that, the correlation of moisture indexes PIV6.9, DIV10.7 and MPDI10.7 is higher, which is respectively -0.635, -0.581, -0.501, the correlation type is negative correlation, namely, the more the ratio is, the more dry it is. In order to prevent the deviation brought by data itself,

we also select AMSR-E data on September 22 and 23, 2011 to perform the verification, and adopt the same method for correlation analysis to obtain the correlation of moisture indexes PIV6.9, DVI10.7 and MPDI10.7, which is respectively -0.621, -0.601, -0.485. From this we can know that, the correlation of moisture indexes PIV6.9, DVI10.7 and MPDI10.7 is also higher, which has little difference with 3 moisture indexes in 2009. We can know from the above analysis that, the moisture indexes PIV6.9, DVI10.7 and MPDI10.7 has better correlation with soil moisture, which is more suitable for the research on soil moisture monitoring.

4.2 Selection of optimal drought index

Based on meteorological station point data of Liaoning province, we select index data on May 31, June 5, and June 12, 2011 with precipitation of respectively 9.6mm, 0mm, 11.3mm in Shenyang, cut two rectangular regions including Shenyang and Chaoyang, and compare and analyze the monitoring results of moisture indexes PIV6.9, DVI10.7 and MPDI10.7 on precipitation.

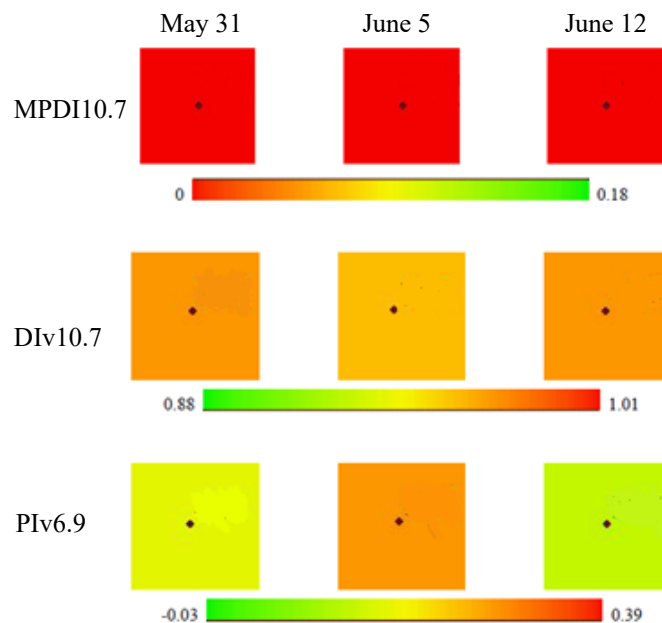


Fig. 1 Comparison of PIV6.9, DVI10.7 and MPDI10.7 on monitoring of precipitation in Shenyang

We can know from Fig. 4-12 that, in pixel “Shenyang”, the change of PIV6.9 is obvious in these three days like May 31, June 5, and June 12, rising first and then reducing, showing that PIV6.9 has obvious negative correlativity with precipitation and reflecting the change of soil moisture content; the frequently-used microwave moisture index MPDI10.7 in former research has almost no change, showing that the relationship of MPDI10.7 and precipitation is not obvious; DVI10.7 and MPDI10.7 has almost no change, showing that the change of these two indexes on precipitation is not obvious, the analysis results of Chaoyang area and Shenyang area are the same, therefore, the correlativity of microwave soil moisture index PIV6.9 and precipitation is obviously superior to that of MPDI10.7 and DVI10.7, showing that the moisture index PIV6.9 on soil moisture monitoring is more excellent.

4.3 Application of soil moisture index in Liaoning area

We can know from former research that, the correlation of moisture index PIV6.9 and soil moisture inversion value is the best, and the result on soil moisture monitoring is the most obvious. In order to further study the moisture index PIV6.9 on soil moisture monitoring condition within the whole range of Liaoning province, we adopt the data of 51 meteorological stations of Liaoning province in 2009, and select 4 days with more precipitation, namely January 28, May 4, July 31, and October 28, 2009. By utilizing ArcGIS software, we convert precipitation data of 51 meteorological stations to point

vector data, and then interpolate the point vector data of precipitation in 51 meteorological stations of Liaoning province within the range of the whole province with Kriging method, and in the end compare and analyze the interpolation diagram of precipitation and distribution diagram of moisture index PIV6.9 of the same day.

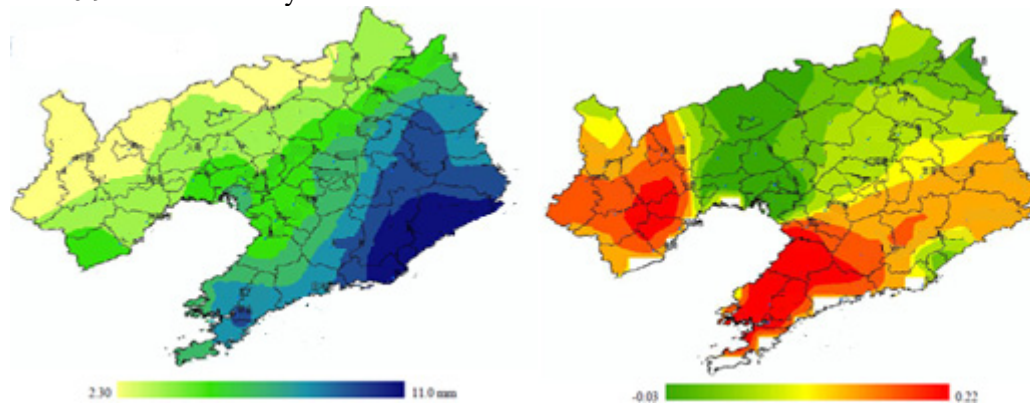


Fig. 2 Interpolation diagram of precipitation and interpolation diagram of index PIV6.9 on July 31, 2009

Through the comparative analysis of image, the inversion soil moisture index PIV6.9 basically conforms to actual drought severity in Liaoning in 2009: PIV6.9 index and precipitation in January 28 have good negative correlativity, and only the value in part of regions like Fuxin, Beizhen, Shenyang, Dalian, Yingkou and etc are higher; except that PIV6.9 value in partial regions of Liaozhong and northeast in May 4 are higher, the soil moisture index and precipitation in other regions also have good negative correlativity; we can see from Fig. 2 that, except for Liaozhong and northern region, the distribution of PIV6.9 is relatively consistent with that of precipitation, having good negative correlativity; except that PIV6.9 value in partial regions of west and regions like Gaizhou, Dalian and so on in October 28 are higher, the soil moisture index and precipitation in other regions also have good negative correlativity. In conclusion, the passive microwave moisture index PIV6.9 can better monitor the soil moisture status in Liaoning, being used for drought monitoring in Liaoning region.

5 Conclusion

Although soil moisture observation and analysis have great development at present, their respective defects are still obvious. Limited by large space rate of change of soil moisture itself and earth surface observation conditions, it is difficult to obtain soil moisture station-observed data with large range, high temporal-spatial resolution and long time sequence at present; and satellite remote sensing data has defects like limitation of inversion algorithm accuracy and failure of inversion of deep soil moisture status. This paper aims at providing an actual inspection index for the earth surface process model to reveal the basic characteristics of soil moisture in Liaoning region. The following is main conclusion of this paper:

(1) The correlation analysis is made firstly on the soil moisture extracted from 8 inversion drought indexes and data itself in this paper, and 3 alternative drought indexes that relatively coincide with soil moisture of AMSR-E data itself are obtained preliminarily, namely, vertical polarization multi-temporal microwave moisture index PIV6.9, ratio index DIV10.7 and microwave polarization difference index MPDI10.7.

(2) And then on this basis, the analysis on the change situation of 3 kinds of microwave moisture indexes in 10 pixel \times 10 pixel rectangular region of Shenyang and Chaoyang is made, and the evaluation on the monitoring advantages and disadvantages of 3 kinds of indexes on soil moisture is performed, so as to obtain the optimal index PIV6.9 for drought monitoring.

(3) In the end, in order to further study PIV6.9 on soil moisture monitoring situation within the range of Liaoning province, four days with relatively large precipitation are selected according to meteorological station data in 2009, the precipitation data of 51 meteorological stations in Liaoning

province are interpolated within the range of the whole province by utilizing Kriging method, and the contrastive analysis on the spatial distribution of precipitation and PIV6.9 index is made. The results show that, the soil moisture index and precipitation have remarkable negative correlativity, which can basically reflect the actual meteorological drought status in Liaoning province in 2009.

In consideration of the difference of complexity of soil moisture itself and spatial distribution pattern of precipitation in Liaoning, the future work focus is further research on monitoring of microwave remote sensing soil moisture under the condition of different underlying surfaces and different climate types, and verification by further utilizing inversion result of optical remote sensing soil moisture and earth surface soil moisture observation data, so as to make the conclusion of this research more perfect.

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