Improvement of the Drought Monitoring Model Based on the Cloud Parameters Method and Remote Sensing Data

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Abstract

Based on the original model, this paper mainly introduces modification to the cloud index in both temporal and spatial dimension, and leads to a new drought monitoring model with a stable performance to the temporal and spatial variation of remote sensing data. In this study, taking into consideration of the temporal and spatial variation, a comprehensive analysis is performed about functions which describe the how the cloud indexes affect the ravage of drought. Afterwards, based on this analysis, a modification function is restricted to a certain format, which is finally settled with the parameters retrieved by the remote sensing data accompanied with the measured date about the humidity of the soil deep to 20cm. This modification function is applied to regulate the 3 cloud impaction functions. Finally, the new drought monitoring model is modified by evaluating different weights to three cloud impaction functions. Meanwhile, this new model is applied to the FY-2C data covering the whole land surface of China. Compared with the traditional monitoring algorithms, the new model is proved to be able to offer a more accurate and reliable result in large scale of time and space.

1. Introduction

Drought is a complex phenomenon which resulted from many factors. Drought intensity is accumulated gradually through a complex progress which involves many natural and artificial aspects, such as climate, hydrology, agriculture, landscape and so on [1-3].

Currently, drought monitoring algorithms could be categorized as two types: drought index algorithms and remote sensing algorithms [4-6]. A common defect for traditional algorithms is the inadequate utilization of RS data contaminated by cloud. Drought monitoring model based on cloud indexes is developed to improve traditional methods, as well as further utilize the RS data. Based on this model, modification function for cloud index is investigated as the change of time and space in this study, and infection functions resulted from each cloud index are also studied and improved in this paper. It is proved to be applicable in spite of the change of time and space, and result in a high accuracy while applied to drought monitoring in China.

E-FORENSICS 2008, January 21-23, Adelaide, Australia

DOI 10.4108/wkdd.2008.2651

2. Drought monitoring model based on the cloud parameters method

2.1. Introduction to the original drought monitoring model

Prerequisites for drought monitoring algorithm based on cloud indexes are listed as follows: （1）No cloud indicates no precipitation, and increased possibility of drought; （2）No cloud indicates strengthened solar radiation at shortwave, more transpiration and increased possibility of drought. These two prerequisites are fundamentally generalized from law of nature.

Three cloud indexes are defined to demonstrate information described by cloud: in a monitoring period, Continuous Cloud-Free Days (CCFD) which refers to the longest days of the study site with no cloud continuously, Cloud Days Ratio (CDR) which refers to the ratio between summary days with cloud and summary days, and Continuous Cloud Days (CCD) which refers to the longest days of the study site covered with cloud continuously.

With three cloud indexes calculated, relationship between these indexes and drought condition could be generalized as functions, which are finally combined to show the Remote Sensing Drought Risk Index (RDRI) as the following formula(1):

$$RDRI = \frac{F_1 \cdot W_1 + F_2 \cdot W_2 + F_3 \cdot W_3}{F_1 + F_2 + F_3} \quad (1)$$

Here, W is the infection function and is F weight.

2.2. Improvement of the drought monitoring model

Temporal and spatial changes will lead to diversity of drought conditions, which has not been taken into consideration in our original model, and might result in bad accuracy in application. Same cloud indexes will result in same RDRI, even in different seasonal conditions, which is obviously incorrect in the real world. So it is required to perform naturalization for these infection functions, which lead to the improved drought monitoring model based on cloud index. Three basic infection functions could be rewritten as formula (2):

$$\begin{aligned} W_1 &= P_1(CCFD, Q_1, R_1) \\ W_2 &= P_2(CCD, Q_2, R_2) \\ W_3 &= P_3(CDR, Q_3, R_3) \end{aligned} \qquad (2)$$

Here: W is the modified (naturalized) infection function, P is the basic function; Q 、 R is the modification function.

2.2.1. Modification functions with temporal changes. Temporal changes will lead to variegates of drought condition contributed by cloud indexes, so this kind of impact is analyzed and described quantitatively, by investigating the temporal modification function and retrieve required parameters with both training RS data and measurements. Firstly, according to historical statistical data reports, larger precipitation occurs in summer and less in winter, so most of droughts happen in winter and spring. Thus, modification function for CCFD shall reach max in winter and min in summer, and mean value in both spring and autumn.

2.2.2. Spatial modification functions. With the same consideration as temporal change, spatial change will also affect the contribution made by cloud indexes for drought condition, so quantitative method is also applied to analysis and modify the infection functions. Low latitude indicates higher possibility of drought, while change in longitude means little. So latitude is the main independent variable. As latitude increases, same cloud index at same time lead to different RDRI, with an increased possibility of serious drought for the same CCFD, a decreased possibility for the same CCD, CDR.

Thus, characteristics of modification function is investigated and generalized, and an improved model which applicable for different RS data independent for time and location could be generalized in the next part.

3. Implementation and validation of the improved the drought monitoring model

3.1. Implementation of the validation of the improved the drought monitoring model

General designation of the improved drought monitoring model could be described as follows: Calculate the cloud indexes due to the definitions, then cloud indexes are assigned to different drought levels according to different locations, modification functions are retrieved, and finally naturalized as standard modification functions.

Relationship between drought level and cloud indexes which is affected by temporal change is simulated firstly, thus temporal modification functions for each drought level could be generalized. Since there is little diversity among functions for different levels, modification functions are unified as one function. The following figures describe how the function is simulated and generalized.

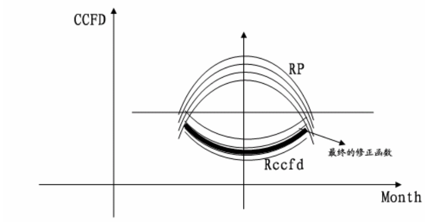


Figure 1. The calculate process of time modification function of CCFD

Curves in Fig1 demonstrate the general variegation tendency for drought levels change with seasons, namely grading drought lines. It is observed that CCFD increase with the drought level for the same season. It is also required to amend the affection to CCFD caused by seasonal change. The function could be generalized as formula (3):

$$R_{CCFD} = \overline{R_{CCFD,D_i}} = \frac{\overline{R_{CCFD}}}{a\sin(\frac{\pi}{6}month + b) + c} = \frac{1}{a'\sin(\frac{\pi}{6}month + b') + c'} \qquad (3)$$

Here , $\overline{R_{CCFD,D_i}}$ donates the common format of modification function for each drought level. Same process is applied to the other two cloud indexes.

Spatial modification function is generalized with the same idea, and with plenty experiments, parabola function is selected to describe the law.

When both temporal and spatial modification functions were generalized, formula (2) could be written as formula (4) (take the CCFD for example):

$$W_{CCFD} = P_{CCFD}(CCFD, Q_{CCFD}, R_{CCFD}) = CCFD * Q_{CCFD} * R_{CCFD} \quad (4)$$

Thus relationship between three basic functions and drought levels could be instructed by weighting functions, and finally lead to the RDRI.

3.2. Comparison of results

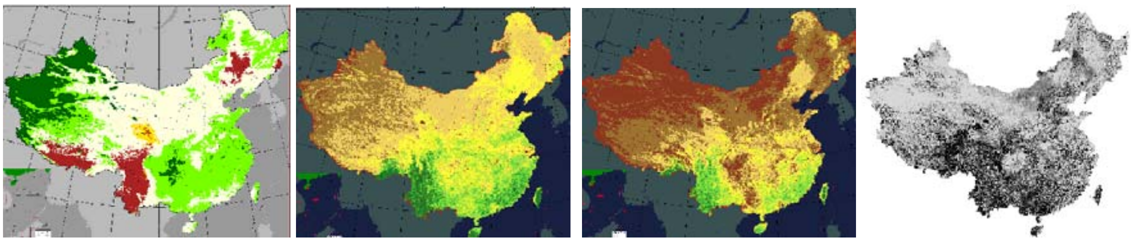
General algorithms such as VCI proposed by Kogan are also implemented in our study, to compare the result of the CI (the drought monitoring based on the cloud parameters method) algorithm.

Kogan[9-10] proposed the idea of VCI firstly in 1990 and define VCI with NDVI data produced with NOAA data from 1984-1987. Applications VCI in China is relatively later, Feng Qiang [11] issued a research about the monitoring of drought condition of China based on vegetation state index, with NDVI data from 1981 to 1994.

FY-2C data from September 2005 to August 2006 is used in our improved model and a measurement of soil moisture deep to 20cm is also involved. NDVI data from January 2002 to September 2007 provided by MODIS satellite ground receiving stations at Wuhan University is selected to perform VCI algorithm. The following table demonstrates the accuracy for users:

Table 1. Precision analysis of drought monitoring results

	CI（%）		VCI（%）	
	acceptable	Usable	acceptable	usable
September of 2005	90.94	65.48	61.16	40.81
October of 2005	85.94	59.55	72.48	54.67
November of 2005	94.18	71.81	58.57	37.96
December of 2005	91.41	66.46	69.85	45.55
January of 2006	97.35	90.27	57.33	43.11
February of 2006	98.57	89.64	76.08	60.87
March of 2006	93.94	78.79	51.37	32.96
April of 2006	92.41	79.33	62.64	37.07
May of 2006	91.92	77.10	56.48	31.24
June of 2006	90.23	77.05	58.86	47.82
July of 2006	89.45	75.34	70.23	60.37
August of 2006	90.65	76.76	72.69	62.14



a b c d

Figure 2. Drought monitoring result of January, 2006

a for CI result ,b for maximum of NDVI result,
c for minimum of NDVI result, d for VCI result.

Acceptable accuracy for users on the table is calculated as the percentage of incorrectly identified drought level within two levels as measured level. Usable accuracy is calculated as the percentage of correctly identified drought level within zero or one level as measured level. Through the analysis of the test results, it could be generalized that: CI method performs better than traditional method because: user acceptable accuracy is more than 90%, and usable accuracy is also very large, which is a great improvement than traditional algorithms. This result was due mainly to the limitation of traditional method that it only considers the vegetation index, and it is built on years of accumulated vegetation index. So if the ground vegetation conditions have changed greatly, errors would be introduced. In addition, this experiment historical NDVI data used in this study is relatively less, which might contributes to the poor performance of traditional method.

4. Conclusion

In this study, FY-2C data from September of 2005 to August of 2006 is utilized to collect the cloud indexes in China. Theoretical derivations are applied to get temporal and spatial modification functions, and drought monitoring model based on cloud indexes is improved. All the experimental results show that this model could detect drought accurately and tell the location, time and drought levels, which will be of great value for decision making in drought controlling and drought resistant. Conclusions could be summarized as:

(1) Drought monitoring model based on cloud indexes performs much better than general algorithms, eliminates temporal and spatial limitation, and greatly improves the accuracy;

(2) This model eliminates the limitation for different solar zenith angles by spatial modification.

(3) For general algorithms, accuracy is limited due to the reason that study area is whole China, while they are mainly applied in regional study. However, our algorithm shows a much better performance within the same study area.

In addition, precipitation and land surface temperature are observed to be closely related to drought condition, so it is very important to measure the precipitation and retrieve LST for drought monitoring. In some months the model performs unsatisfied which might be resulted from the two modification functions. So, further research will be focused on further derivation of the modification functions.

5. Acknowledgements

Thanks to the National Satellite Meteorological Center of China Meteorological Administration for providing the Remote Sensing data. Meanwhile, we thank the Hubei Weather Bureau for providing the data of soil humidity. We also thank staffs of National Disaster Reduction Center of China and MODIS Data Reception Station at Wuhan University. This paper granted by the National Key Base Research and Development Program of China (No.2004CB318206).

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