THE RESEARCH ON APPLICATION OF FY-2C DATA IN DROUGHT MONITORING

YU Fan[①②] LIU Liang-ming[①] WEN Xiong-fei[①]

① School of Information Engineering and Remote Sensing , Wuhan University , Wuhan 430079,china-yufan021@126.com

② Graduate School of the Chinese Academy of Sciences, Beijing 100049, China,-wxfei19@gmail.com

Commission VIII ,WG VIII/2

KEYWORDS: Drought; FY-2C; Cloud Index; Temperature; Drought-monitoring Model;

ABSTRACT:

FY-2C satellite data, with high temporal resolution and vast coverage range, have been applying for long-term and dynamic drought-monitoring, as well as for weather forecast, especially for forecasting disaster weather. Considering that the traditional remote sensing drought-monitoring models are easily influenced by cloud, a cloud index-based drought-monitoring model is presented in this paper. The parameters used in the model are: Max Continuous Cloudy Days (CCD), Max Continuous Cloud-Free Days (CCFD), Cloudy Days Ratio (CDR) and Temperature Difference from Day to Night (TD). As the important improvement, the latitude correction function to the three cloud parameters is introduced to the model. Finally, the 20 cm deep soil moisture data from Oct. 2005 to Sep. 2006 are used to validate the accuracy of this model. The result shows that the improved model is efficacious in the great extent drought detection and forecast.

1. INTRODUCTION

Drought is one of the natural calamities in the world; it influence agricultural produce most in all kinds of the natural calamities. The average disaster area reaches 20,000,000 km^2 for drought in China every year, which makes a loss of 50% of the whole loss in all of the natural disasters(Liu W T,1996). The most serious area affected by drought is major grain-producing region in China. Sustainable drought immediately influences industrial production, lives of the people and ecological environment, and even causes various natural calamities, such as the land desertification, the land subsidence and so on. Drought has become one of the key restricted factors of the sustainable development of the society and economy(Gong,1997).

FY-2C is the first operational GEO meteorological satellite of china successfully launched on Oct. 19 2004 and it was located at 105°E，FY-2C is in good condition with theirs Visible Infrared Spin Scan Radiometer (SVISSR), provides the measurement of the ‘top of atmosphere’ radiance and reflectance with a temporal resolution of 30 min and a spatial resolution of 5 km at the sub-satellite point in 4 infrared bands at 10.8, 12.0, 6.9 and 3.7µm, 1.25 km in 1 visual band at 0.55-0.90µm. Comparing with polar-orbiting satellites, such as NOAA/AVHRR, FY-2C satellite data has high temporal resolution, on every half hour to generate an image. As a geostationary satellite at the same time, the scope of its coverage is very broad, it is very suitable for Large-scale drought-monitoring. There are some preprocessing for the FY-2C data before using it .So a new Drought-monitoring Model based on FY-2C is intrduced.

2. MODEL PROFILE

‘Cloud Index-based Drought-monitoring Model' is based on the following two facts:

(1) Cloud-free means no precipitation, the possibility of drought increases. On the contrary, cloud means precipitation, the possibility of drought decrease.

(2) Cloud-free means receiving more solar short-wave radiation, the ground temperature rises, and there are more evapotranspiration, the possibility of drought increases. On the opposition, cloud can cover the ground, so there is less solar short-wave radiation, and the result is on the opposition.

2.1 The parameters of the model and its processing

2.1.1 Cloud Detection

As the temperature on the top of cloud is much lower than the land surface in the thermal infrared bands, and the reflectivity of cloud is extremely high in the visible band, cloud detection can be completed by simple threshold method with visible bands and thermal infrared bands. In this paper, the reflectivity accounted by visible channel and the bright temperature obtained by an infrared band (10.3 µ m - 11.3 µ m) are used for cloud detection.

2.1.2 Temperature Difference

Land surface temperature is not only a good indicator of energy balance of the earth’s surface, but also a key factor of the physical process in regional or global scale surface. There are strong correlation between the surface soil moisture and the land surface temperature difference between day and night. The greater the temperature difference is, the ability of the surface evapotranspiration is stronger and the possibility of drought increases. Due to five channels only in FY-2C, it is complicated to calculate temperature difference. Bright temperature difference (TD) is used to replace temperature difference gotten directly after calibration. Cloud has low bright temperature in the thermal infrared bands, making it easy for error. So before the calculation of TD, cloud should be masked. But the TD computed can not cover the whole research region after cloud mask. Therefore the average temperature is introduced, which means the TD over a period of time is used to strike an average, to make up for the impact of clouds. Then, by the least square method, the function between TD (average) and the synchronous drought grade is simulated to get the drought index of TD (TD_DI).

2.1.3 Cloud-index extraction

Precipitation is an essential factor in the drought monitoring. As the sole source of precipitation, cloud is very important. Cloud-index consists of three parameters: Max Continuous Cloudy Days (CCD), Max Continuous Cloud-Free Days (CCFD) and Cloudy Days Ratio (CDR). These three are calculated in a definite monitoring cycle, the cycle is a month in this research. The function between CCD and the synchronous drought grade acquired from the field measurements can be founded by the least square method. By this function, CCD in the whole image can be converted to CCD_DI, which is one of the drought-index. The other two drought-index CCFD_DI and CDR_DI can be gained in the same way. These three are called drought index of cloud(Liu,2004).

After drought-index(including CDR_DI, CCFD_DI, CCD_DI, TD_DI) extracted, the integrated drought index (Int_DI) can be calculated by the flow chart. (Figure 1).

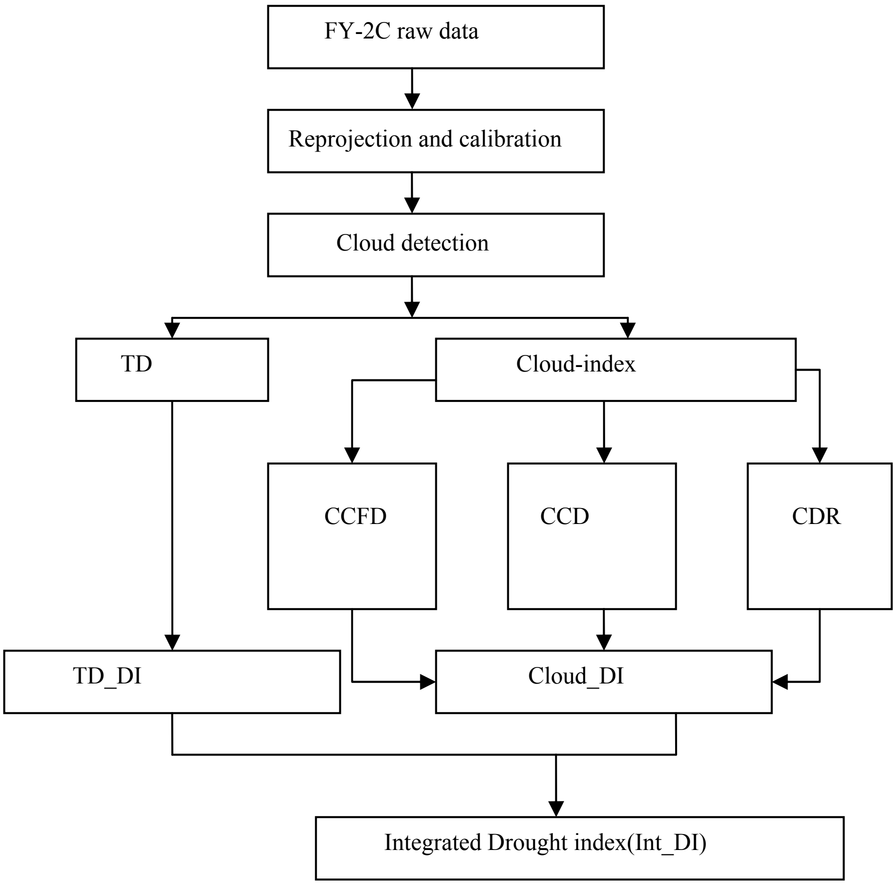


Figure 1. The flow chart of the model

The integrated drought index can be computed by the expression as follow:

$$Int\_DI = (\sum X_i * P_i) \qquad (1)$$

Where Int_DI is the integrated drought index, X_i is the parameters of drought-index (such as CCFD_DI), and P_i is the weight of the drought index.

In the drought monitoring, the monitoring cycle is a month. The Int_DI is divided into six categories: very wet D0(-2.0→-1.5)、wetlands D1(-1.5→-0.5)、normal D2(-0.5→0.5)、slight dry D3（0.5→1）、dry D4(1→1.5)、heavy drought D5（1.5→2.0）(Liu Liangming,2005).

3. MODEL IMPROVEMENTS IN LARGE SPATIAL SCALES

In the large-scale drought-monitoring, even the same drought conditions leads to different results because of the different research areas. For example, within one month, if Max Continuous Cloud-Free Days (CCFD) is 10 in the South of China, it is probably very dry. But towards the north of China, may be the situation is not serious. The different geographical position of the study area influences the result of drought monitoring. The reason mainly is that the ground of different regions receives different solar irradiance (or the total solar radiation energy). In Formula 2, the solar altitude angle and the distance from the sun to the earth cause the diversity.

$$E = \frac{E_0 \cos\theta}{d^2} \qquad (2)$$

Where E is normalized solar radiation, E_0 is normalized solar radiation at the average distance between the earth and sun , θ is solar zenithal angle(complementary angle of solar altitude angle), d is the distance between the earth and sun (astronomical units). In general, E_0 is a constant , θ can be obtained from the raw data, d is a season-related variable。

The change of latitude leads to diversification of θ and d , then makes the solar radiation received by the ground changing. In order to describe the influence to the drought caused by the different geographic location of the study area, the introduction of latitude is necessary in simulating the function between the cloud and the drought.

In the same region and a certain period of time (such as one month), the greater the value of CCFD is, the greater the possibility of drought. Their relationship is positive correlation and the relations function can be thought as a logarithmic function(P_1) approximately, see Figure 2 (a); when it concerns to CCD, the result is reverse. Bigger the CCD is, the less the possibility of drought. Their relationship is negative correlation and an inverse logarithmic function(P_2) can be used to describe their relation, see Figure 2 (b); Also the greater the value of CDR is, the smaller the possibility of drought, and their relationship can be depicted as a linear function (P_3), see Figure 2 (c). In the Figure 2, the longitudinal coordinates DI is a single parameter of integrated drought index (Int_DI), range (-2, +2); the abscissas are respectively corresponding to the value of CCFD, CCD and the CDR in a cycle of 30 days, range(0,30).

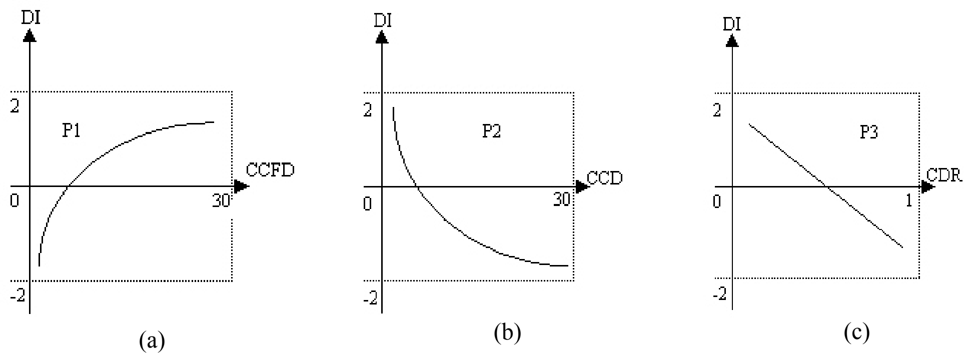
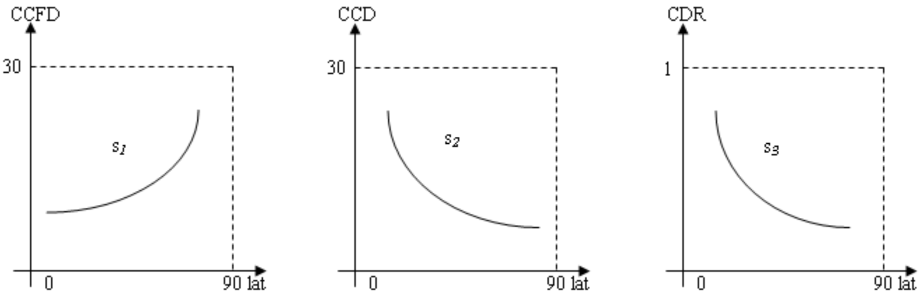


Figure 2. the relation function between DI and the three cloud parameters in the same area

As derived from the research on the small and restricted area, the functions in Figure 2 can not be used in the large area research directly. The introduction of latitude to amend cloud parameters in different area is feasible. when latitude increases in different regions, the sun altitude angle decreases, then the solar radiation energy received by the ground decreases(formula 2). In order to achieve the same Int_DI, the value of CCFD should become bigger, the correction function of CCFD can be describe as monotone increasing function (e.g., exponential function), shown in Figure 3 (a); In the same way, the amend function of CCD can be described as monotone decreasing function, and also monotone decreasing function can describe the correction function of CDR, see Figure 3 (b), Figure 3 (c). In the Figure 3(a), Figure 3 (b) and Figure 3 (c), the longitudinal coordinates is latitude, the abscissas are respectively corresponding to CCFD，CCD and CDR.



(a) (b) (c)

Figure 3. three correction functions

The research after large number of experiments shows that: the cosine of latitude can be better fitted for the three correction functions, which can be seen in Eq 3:

$$\begin{aligned} CCFD' &= P_1(CCFD * S_1(lat)) \\ CCD' &= P_2(CCD * S_2(lat)) \\ CDR' &= P_3(CDR * S_3(lat)) \end{aligned} \quad (3)$$

Where $CCFD'$, CCD' and CDR' are the cloud parameters after correction; $CCFD$, CCD and CDR are the cloud parameters before correction， lat is latitude.

4. CASE ANALYSIS

The research zone focus on the Chinese land area, latitude is from north 18 ° 05 'to north 53 ° 34' , longitude is form east longitude 73 ° 20 'to east 135 ° 05'. The data is the FY-2C data from October 2005 to September 2006.

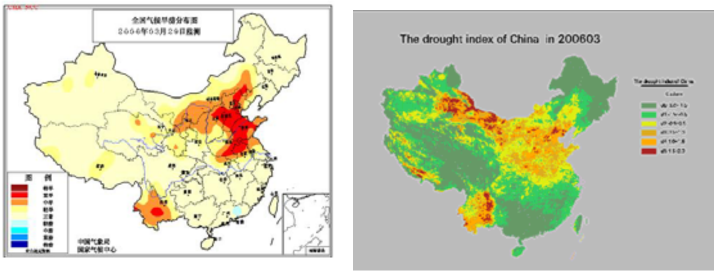
Analysis of the relationship between the parameters and the drought index can determine the relation function. Many experiments show that the relation function between CCD and Int_DI or CCFD and Int_DI is nearly exponential function. The function of CDR or CFDR can be used with the sub-linear function; the function between temperature difference and Int_DI can be described as almost exponential function[11]. Some of the functions are in the Table 1.

CCFD Drought-index	1	2	3	4	5	6	7	8	9	10	≥11
	-2	-1.8	-1.5	-1.2	-0.5	-0.2	0.2	0.8	1.2	1.7	2
CCD Drought-index	1	2	3	4	5	6	7	8	9	10	≥11
	2	1.8	1.2	0.8	0	-0.5	-1.2	-1.2	-1.6	-1.8	-2
CDR Drought-index	≤20		（20 ～ 50）			（50 ～ 70）				≥70	
	2		-（X-40）/10			-（X-50）/20 -1				-2	
TD Drought-index	≤3		（3 ～ 7）			（7 ～ 11）				≥11	
	-2		-（7-X）^{2}/8			（X-7）^{2}/8				2	

Table 1 Functions of all parameters from June to August

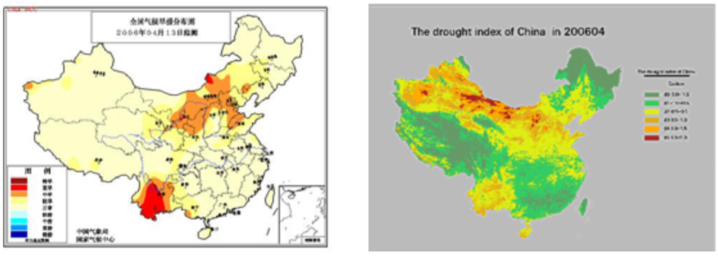
4.1 Qualitative analysis

Comparing the model result(see Appendix) with the synchronous Distribution of Drought Climate (China national drought monitoring business products, in 1995 R & D) from Oct. 2005 to Sep. 2006, the distribution of drought are basically the same. For example, the distribution maps shows severe drought on January, February and May in Yunnan province and terrible long-term drought in Chongqing from July to September. The outcome is proved correct by the Distribution of Drought Climate. Taking some maps for example, the contrasts are as follows (Figure 4, Figure 5):



(a) (b)

Figure 4. The outcome of model and the Distribution of Drought Climate on Mar. 2006



(a) (b)

Figure 5. The outcome of model and the Distribution of Drought Climate on Apr. 2006

There are some differences in the northwest of China in the Figure 4 and Figure 5. Because the northwest of China are desert and hungriness, undoubtedly they are very arid, and there is little field observation station there, so the Distribution of Drought Climate based on field observation shows no drought. Droughts of the other place are nearly the same in both of the maps.

4.2 Quantitative analysis

The verification data provided by the National Satellite Meteorological Center (NSMC) is 20 cm deep soil moisture from Oct. 2005 to Sep. 2006 obtained by 810 field stations in China. The relationship between 20 cm deep soil moisture percentage and drought-grade can be found on the Agro-meteorological Observing Criterion(Qin,2003), the standards is shown in Table 2:

very wet D_0	wetlands D_1	normal D_2	little dry D_3	dry D_4	heavy drought D_5
94～99%	80～93%	61～79%	51～60%	41～50%	≦40%

Table2 The relationship between 20 cm deep soil moisture percentage and drought-grade

So the precision can be quantitatively calculated by the droughty grade obtained by Eq (1) minus the Verification grade gotten by Table5, the distribution table is below (Table 3):

Year	2005 年			2006 年								
Month / Precision	Orc	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
homology	34%	37%	33%	28%	30%	33%	37%	38%	39%	40%	38%	44%
One grade discrepancy	39%	38%	41%	38%	40%	38%	37%	37%	41%	43%	39%	37%
Two grade discrepancy	20%	15%	11%	19%	15%	17%	19%	18%	11%	9%	16%	12%
Three grade discrepancy	6%	6%	10%	12%	10%	9%	6%	7%	9%	8%	5%	7%
>3 grade discrepancy	1%	4%	5%	3%	5%	3%	1%	0%	0%	0%	2%	0%

Table 3 The precision of model from Oct. 2005 to Sep. 2006

Statistics from the accuracy table of the results of the drought monitoring shows that the precision of the grade discrepancy of zero and one can control in 66% -83%. With the exception of 66% on Jan. 2006, accuracy of the other month is more than 70%. The error of two grade discrepancy does not exceed 20% and the three grade discrepancy error and above is no more than 15%. As the study area is the whole inland of China, many factors influence the precision, such as anomalistic topography, intricate climate, different season and so on. Also there are some meteorological stations in the especial location and they can not reflect the drought. The Precision is acceptable because the precision of the grade discrepancy of zero and one can control nearly over 70%. The precision result shows that the model is reliable and stable.

5. CONCLUSION

This is the first time to monitor drought in the whole Chinese inland, the problem of how to monitor drought in the large-scale area and the adaptability of the model has been solved. By the research, the three correction function are set up (Eq (3)), which was proved to be efficient and reliable. From the precision distribution in the Table 6, the Cloud Index-based Drought-monitoring Model can basically meet the application needs.

But there are some shortcomings in the model as follows:
1. The spatial resolution of FY-2Cdata is 5000m*5000m, a pixel represents an area of 25km^2, the verification data from the field station denotes a very small area, nearly a point. It is not very suitable to validate the result of the model by this verification data.
2. The temperature of cloud top is close to the land surface temperature in the place of high latitude in winter. Drought detecting by the threshold method may leads error of the correction function.
3. The precision of the Cloud Index-based Drought-monitoring Model depends on the integrity and continuity of FY-2C. The incomplete FY-2C data can not get the real CCDF and CCD, and can not reflect the real situation of drought.
4. There are many influencing factors in the large-scale drought monitoring, such as artificial rainfall, artificial irrigation, human destruction of the ecological environment, and other activities, which may aggravate or relieve the drought. The difficulty is these factors are unable to control and quantitative analysis.

REFERENCE

[1] Carlson，T . N.， Regional scale estimates of surface moisture availability and thermal inertia using remote thermal measurements ［J］. Remote Sensing Reviews，1986（1）：197 ～ 247 .

[2] Gong Deji, Hao Muling, Hou Qiong. Study on the Complex Index of the Drought Disaster. Meteorological Monthly,1997 ,22 (10) :3～7

[3] Liu W T，Kogan F. Monitoring regional drought using the vegetation condition index[J]. Int J Remote Sense，1996，1 7(14)：2761～2782.

[4] Liu Liangming，The Research of Remote Sensing Drought Prediction Model Based on EOS MODIS Data，A Ph.D. Dissertation of Wuhan University, P.R. China. 20004

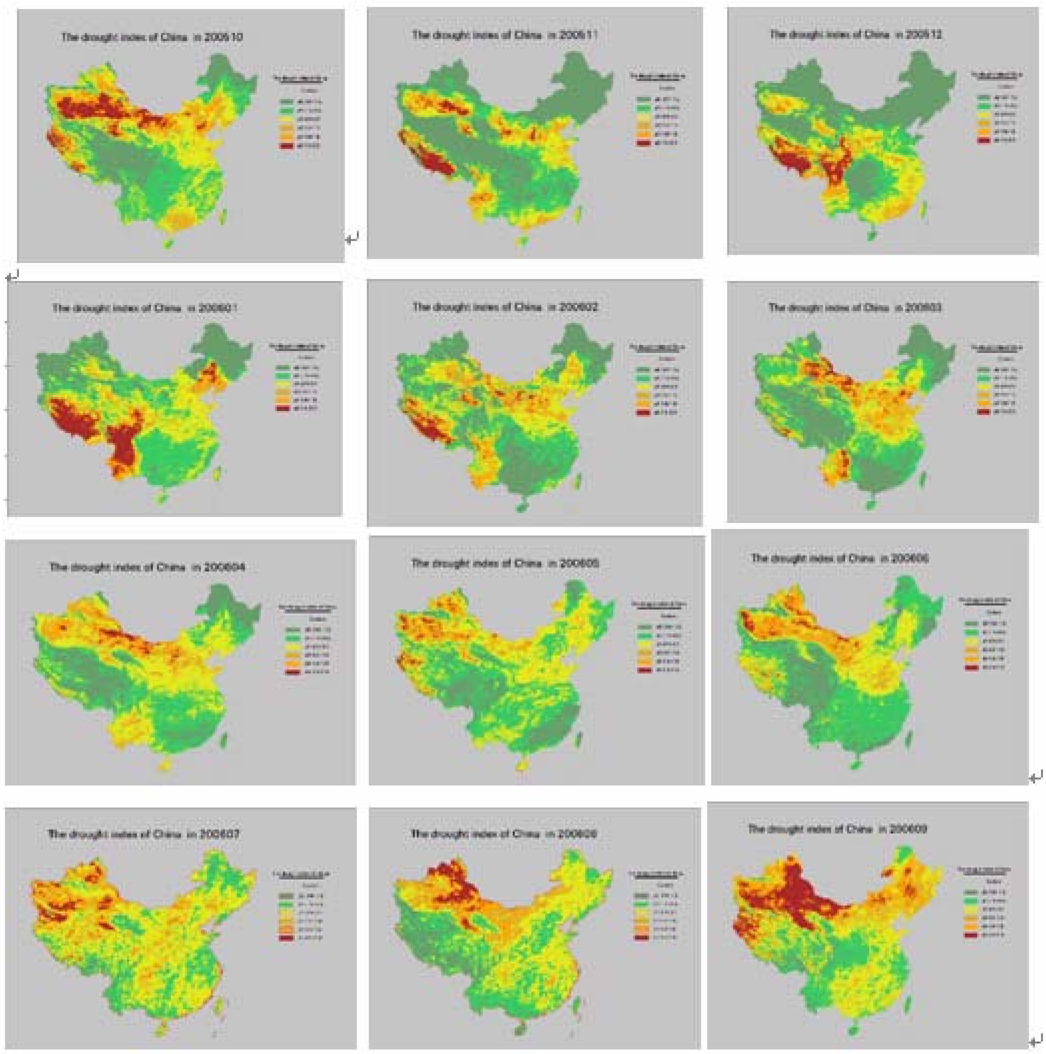
[5] Liu Liangming，Hu Yan. Analysis of Parameters and Their Powers of MODIS Drought Monitoring Model. Geomatics and Information Science of Wuhan University, 2005，30（2）：139～142

[6] Qin Dahe.e.t. Drought[M].weather book concern.2003.

ACKNOWLEDGEMENTS

We thank the National Satellite Meteorological Center for supplying the FY-2C data.

APPENDIX



The distribution maps of drought from Oct. 2005 to Sep. 2006