Satellite Multiangular Remote Sensing for Distinguishing Areas Harmed by Mice and Insects in the Grassland

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Abstract The research on monitoring the prairie harmed by mice and insects in the Ruoergai county with AVHRR data is presented in this paper. It shows that on the basis of application of the multiband spectrum, the application of multiangular remote sensing is more useful and improves the effect on distinguishing the ground objects and the areas harmed by mice and insects.

Key word AVHRR, Multiangular remote sensing, Harmed by mice and insects

It is necessary to distinguish the areas harmed by mice and insects to prevent and control the prairie harmed by mice and insects. The ground surface investigation from Grassland Work General Headquarters of Sichuan Province reported that mice and insects mainly lived in subalpine meadow bog (elevation of 3300—3800m) where drier and mainly sunny hillside with a slight slope was not well covered by high herbage[1]. The factors of its ecological environment include soil, water of soil, herbage and topography. The application of remote sensing for distinguishing the areas harmed by mice and insects firstly need to distinguish the subalpine meadow bog from other kinds of ground objects. This research includes the prairie of Ruoergai county (33. 06°—34. 31°N, 102. 18°—103. 62°E).

The AVHRR data of NOAA—12 and NOAA—14 are used in this paper. The monitoring time is July 8, 1995 and August 2, 3, 4 and 7, 1996, the local data set are the files of equal grid (equal latitude and longitude), Grid length is 0. 01°. The remote sensing data were calculated according to calibration. The data of the visible light band and the near infrared ray band were converted to reflectance and the data of the infrared ray band was converted to brightness temperature. The AVHRR data processing software developed by National Satellite—Meteorological Center of National Meteorological Administration[2] was employed. "The picture of Ruoergai Mice and Insects Harm Distribution"[3] and "The picture of Ruoergai Grassland Utilization"[4] were referenced to determine the basic zone harmed by mice and insects and the actual distribution of the ground objects.

1 DISTINGUISHING THE GROUND OBJECTS BY USING MULTIBAND SPECTRA IN SINGLE TIME

To distinguish ground objects by multiband spectra in single time show prominent advantages that is the little location difference among the several band spectra. We used the AVHRR data of NOAA—12 on July 8, 1995 to distinguish the ground objects in Ruoergai but didn't complete multiangular remote sensing analysis. The satellite azimuth was 281.

88°, the zenith angle was 20. 40°; The sun azimuth was 82. 80°, the zenith angle was 58. 03°. Ruoergai had clear sky at that time. The surface reflectance of the ground objects obtained by NOAA satellite remote sensing in visible light band (abbreviated as CH1R), the surface reflectance of the ground objects obtained by NOAA satellite remote sensing in near infrared ray band (abbreviated as CH2R) and the brightness temperature of the ground objects obtained by NOAA satellite remote sensing in infrared ray band (λ: 3. 55 — 3. 93μm) (abbreviated as CH3BT) were converted into gray scale[2] (0 — 255), CH1R, CH2R and CH3BT were used as three dimensional (3—D) vectors, and the remote sensing data in Ruoergai were classified into 14 categories by the systematic cluster analysis[5]. The classified principles were that the variance of the same categories was no more than 10, or the number of pixels of the same category was no more than 30, or a new category could no longer be obtained by the cluster analysis. The ground objects which each category of the remote sensing data represented were determined according to《Present Situation Diagram of Ruoergai Grassland Utilization》. Some categories included many kinds of ground objects of marsh, marsh meadow bog, subalpine meadow bog and mountain ground objects among which there were many a differences. Hongxin section, for example, one of the seriously harmed subalpine grassland was clustered into the same category with marsh meadow bog because of the spectral features of Hoxing section and marsh meadow bog were similar when the remote sensing zenith angle and azimuth were 20. 40° and 281. 88°. So it was not effective to distinguish areas harmed by mice and insects in the grassland by using single time multiband spectrum data.

Some results of Professor Alan. H. Strahler and Li Xiaowen's research is that the spectral features of ground object include two factors: one is the spectral feature of the material[6], another is the space structure of the ground object. Different ground objects have different BRDF models. According to the theory, the multiangular remote sensing can reflect the ground objects material and their space structure features in some extent, so it can improve the ability of distinguishing the ground object by using remote sensing data.

2 THE FEATURES OF MULTIANGULAR REMOTE SENSING DATA

In this paper, the atmospheric correction of AVHRR data has not been used, because of the remote sensing data to the ground objects at same time in a small scope have been compared, and the atmospheric conditions at a same time among August 2, 3, 4 and 7, 1996 were similar, when Ruoergai county was controlled by Tibetan high without rain and new weather system coming, and the Research result was not affected by atmospheric correction. Assuming that the ground objects had not changed among August 2—7, 1996 and the atmospheric correction were similar at a same time, then the change of CH2 (or CH1) reflectance of ground object was mainly determined by the azimuthes and zenith angles of the satellite and the sun. If the angles of incidence of the sun rays were similar, the CH2 or CH1 vectors obtained from the multiangular remote sensing are approaching to the subset of the bidirectional reflectance of ground object and show the structure and characters of the ground object in some extent. The latitude and the longitude of the satellite remote sensing images have been adjusted to make the errors smaller than 1km. Ground objects in the research include the sections of Reerdaba, Hongxing and Axi (which are seriously harmed by mice and insects), Nenwa and Heihe (which are moderately harmed areas), Huanghe grassland (it is a slightly harmed area), marsh meadow bog (unharmed) and mountains with woodlands in either east or west slope (which are little harmed by mice and insects). Their CH1 and CH2 reflectance have been calculated and indicated by percentage or grey scale. The azimuths and zenith angles of the sun and the satellite were calculated. The results were listed in Table 1. The azimuths and zenith angles of the sun and the satellite to the other ground objects in Ruoergai county were represented by the azimuthes and zenith angles of the sun and the satellite to the

Ruoergai county seat when the satellite scanned the Ruoergai county seat. In this paper we have done correction of the CH1 and CH2 reflectance from NOAA—14's AVHRR according to Professor Sun Yi Yi's research result[7].

The relationship between the differences both the CH2 (or CH1) reflectance with the remote sensing angle

The differences between CH1 (or CH2) reflectance of different ground objects is influenced by the azimuthes and zenith angles of both the satellite and the sun and by atmosphere. The difference between CH2 (or CH1) reflectance of some ground objects is large when the zenith angles of the sun and the satellite are small and the azimuths of them are similar. For example, at noon of August 4, 1996 the difference between the CH2 reflectance of Hongxing section and marsh meadow bog was 14.09%, but in the morning it was 1.22%, the details were listed in Table 2. When the azimuth and zenith angles of satellite were 258.76° and 12.28° respectively, the difference between CH2 reflectance of both the east slope and the west slope with woodlands was 0.6%. When the azimuth and zenith angle of the satellite were 79.87° and 6.6°, it was 6.4%. Analyzed from the theory, when the solar zenith angle decreases, the luminance of the ground objects increase, and the shadow areas of ground objects and the atmospheric affection decrease. On the other hand, when the angles between the direction of satellite remote sensing and the solar incident light decrease, the remote sensing areas of the ground objects' shadow decrease, then their reflective index increases and the differences between surface reflective index of different objects increase correspondingly. The remote sensing data which spectral features have great difference can be selected to improve the effect of distinguishing ground objects.

Table 1 The data of multiangular remote sensing to some ground objects

date	sun azimuth (°)	sun zenith angle (°)	satellite azimuth (°)	satellite zenith angle (°)	band	channel 1 surface reflectance & channel 2 surface reflectance from the AVHRR data									
						Reer grassland	Hongxing grasslang	marsh meadow bog	Nenwa grassland	Xiaman grassland	Axi grassland	West slope woods	East slope woods	Heihe grassland	Huanghe grassland
Aug 4, 1996	234.77	24.95	79.87	6.60	CH1	7.56	6.42	5.04	6.17	—	6.80	5.29	5.54	8.95	6.30
					CH2	32.94	27.71	13.62	26.92	—	33.73	24.53	18.06	31.04	35.62
Aug 3, 1996	239.25	26.67	258.76	12.28	CH1	8.99	8.49	5.88	7.0	11.75	8.38	6.49	6.37	9.50	8.00
					CH2	35.96	33.76	15.70	31.25	30.00	38.48	25.91	26.52	32.83	40.05
Aug 2, 1996	243.26	28.50	261.77	29.32	CH1	9.43	9.55	6.54	10.52	—	—	—	—	10.61	—
					CH2	40.44	34.98	19.92	35.85	—	—	—	—	38.01	—

Note: the surface reflectance of the ground objects are averaged by 3×3 pixels around the ground object.

Table 2 The differences between surface reflectance of Hongxing grassland and marsh meadow bog

date	azimuth (°)		zenith angle (°)		CH1 surface reflectance (%)			CH2 surface reflectance (%)		
	sun	satellite	sun	satellite	Hongxing grassland	marsh meadow dog	difference	Hongxing grassland	marsh meadow bog	difference
Aug. 4, 1996	79.93	96.16	73.49	44.4	2.65	2.47	0.18	8.40	7.18	1.22
Aug. 4, 1996	234.77	79.87	24.95	6.6	6.42	5.04	1.38	27.71	13.62	14.1

The features of multiangular CH2 (or CH1) reflectance

Because the material spectral features and the space structure features of ground objects are different, the CH2 (or CH1) reflectance of some objects obtained from different remote sensing angles has slight difference such as marsh meadow bog, some of that has great difference such as the west and the east

slopes with woodland or grassland. Those are shown in Fig. 1.

3 APPLICATION OF MULTIANGULAR REMOTE SENSING FOR DISTINGUISHING THE AREAS HARMED BY MICE AND INSECTS IN GRASSLAND

To my opinion, the standards for the effect on distinguishing the ground objects by the application of the satellite remote sensing technique should include two aspects. One is what singleness degree of ground objects included in every category after remote sensing data being classified, that is to say, the kinds of the object for every category are fewer and the distinguishing effect is better. The other is what rightness degree it can stands for the objects. As is known that multiseason remote sensing data are usually used to distinguish vegetation. Furthermore, it can improve the effect in distinguishing ground objects by combining multiangular and multispectrum remote sensing after the season being determined.

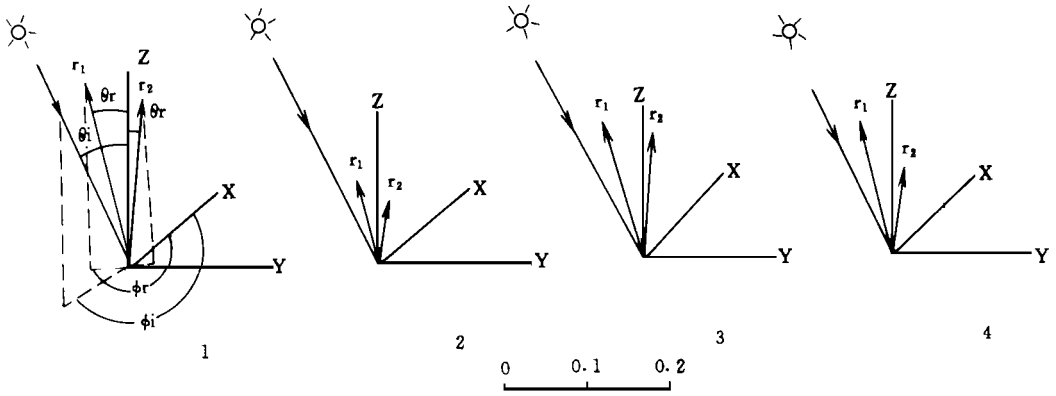

Fig. 1 Channel 2 surface reflectance (%) from the AVHRR data

θ_i, ϕ_i represent solar zenith angle and azimuth, θ_r, ϕ_r represent zenith angle and azimuth of channel 2 surface reflectance

1—Subalpine meadow bog; 2—Marsh meadow bog; 3—woodland in west slope; 4—woodland in east slope

Choosing the most characteristic data for zones harmed by mice and insects from multiangular remote sensing data

To distinguish the areas harmed by mice and insects, it's necessary to choose the data of one angle from the multiangular remote sensing data, so that the spectral features of seriously harmed areas are greatly different from those of unharmed areas.

When the solar azimuth and zenith angle remote sensing on August 4, 1996 were 234.77° and 24.95° respectively and those of the satellite were 79.84° and 6.6°, the CH2 (or CH1) reflectance of ground objects had great difference and there was little cloud in the sky of Ruoergai county. The CH1R, CH2R and CH3BT (expressed Table 3 by grey scale) were used as three dimensional vectors and classified into 14 categories by systematic cluster analysis. Every category spectral features and the kind of ground objects which it stands for were listed in Table 3. It's obvious that every category in Table 3 includes fewer kinds of objects, and the objects it includes have similar features. For example, "3" and "4" in Table 3 only include the mountain objects. "2" includes marsh and marsh meadow bog. "C" and "D" almost

Table 3 Every category spectral features and its represented ground objects (August 4 1996)

category	average value of gray scale			variance			kind number	ground objects
	CH1	CH2	CH3	CH1	CH2	CH3		
1	16	53	32	3	10	5	2	marsh lake, east slop woods
2	19	50	48	4	8	4	2	marsh, marsh meadow bog
3	19	67	42	3	3	7	1	mountain area
4	21	81	47	3	4	6	1	
5	23	53	65	6	10	7	2	marsh, marsh meadow bog
6	26	71	68	7	3	9	2	
7	25	83	61	9	4	3	2	marsh meadow bog, few bush region
8	31	83	77	8	4	9	1	degenerated marsh grassland
9	23	97	54	3	4	5	1	subalpine meadow bog
A	25	113	55	3	7	5	1	
C	28	96	72	3	4	8	1	drier subalpine meadow bog
D	28	109	71	3	5	7	1	
F	39	96	91	4	3	9	2	sand, serious area harmed by mice & insects
其它	—	—	—	—	—	—	2	cloud field

include seriously harmed zones by mice and insects. 27 pixels were chosen at random from "C" and "D", among them, 25 pixels standed for ground objects which were areas harmed by mice and insects seriously or moderately. "9" and "A" standed for slightly harmed zones and a few seriously harmed zones. "1", "2", "3", "4", "5", "6", "7", "8" standed for unharmed zones. On the other hand, Hongxing section was classified as "C" and "D", its spectral features belonged to the same category with drier subalpine meadow bog harmed by mice and insects and Hongxing section was distinguished from marsh meadow bog. It was coincident with the ground surface investigation. So, application of multiangular remote sensing can improve the ability to distinguish the areas harmed by mice and insects.

Distinguishing ground objects by using the similarity of CH2 (or CH1) reflectance of multiangular remote sensing

When the NOAA-14 scanned the Ruoergai county seat on the August 3 and 4, 1996, the solar azimuthes were 239.25° and 234.77° respectively, and the solar zenith angles were 26.67° and 24.95° respectively, and therefore the angles of incidence of the sun were similar. The azimuth and the zenith angle of CH2 (or CH1) reflectance of the ground object were isogonal with the azimuth and the zenith of the Satellite at the same time.

name	date	h	m	s	Azimuth	Zenith
NOAA-14	August 3, 1996	14	50	37	258.76°	12.28°
CH2	August 3, 1996	14	50	37	258.76°	12.28°
CH1	August 3, 1996	14	50	37	258.76°	12.28°
NOAA-14	August 4, 1996	14	39	42	79.87°	6.60°
CH2	August 4, 1996	14	39	42	79.87°	6.60°
CH1	August 4, 1996	14	39	42	79.87°	6.60°
NOAA-14	August 4, 1996	14	39	42	79.87°	6.60°

The CH2 reflectance on August 3 and 4, 1996 were used as two dimensional vectors, them were conducted by the systematical cluster analysis. The remote sensing data were classified as 20 categories. Every category features shown in Fig. 2. In Fig. 2, "2", "3", "4", "5", "6", "7" represented the features of CH2 reflectance of the kinds of subalpine meadow bog which indicated with @ in Fig. 3 where it was not well covered by high herbage, and some areas were harmed by mice and insects. "8" and "9" represented the features of CH2 reflectance of the kinds of the subalpine meadow bog which herbage grows moderate and indicated with * in Fig. 3, and some areas were harmed by mice and insects. "10", "11" and "12"

represented the features of CH2 reflectance of the kinds of the subalpine meadow bog which herbage grows good and indicated with (in Fig. 3, and some areas were slightly harmed. "1" represented the features of CH2 reflectance of the marsh. The character "1" in Fig. 3 represented marsh.

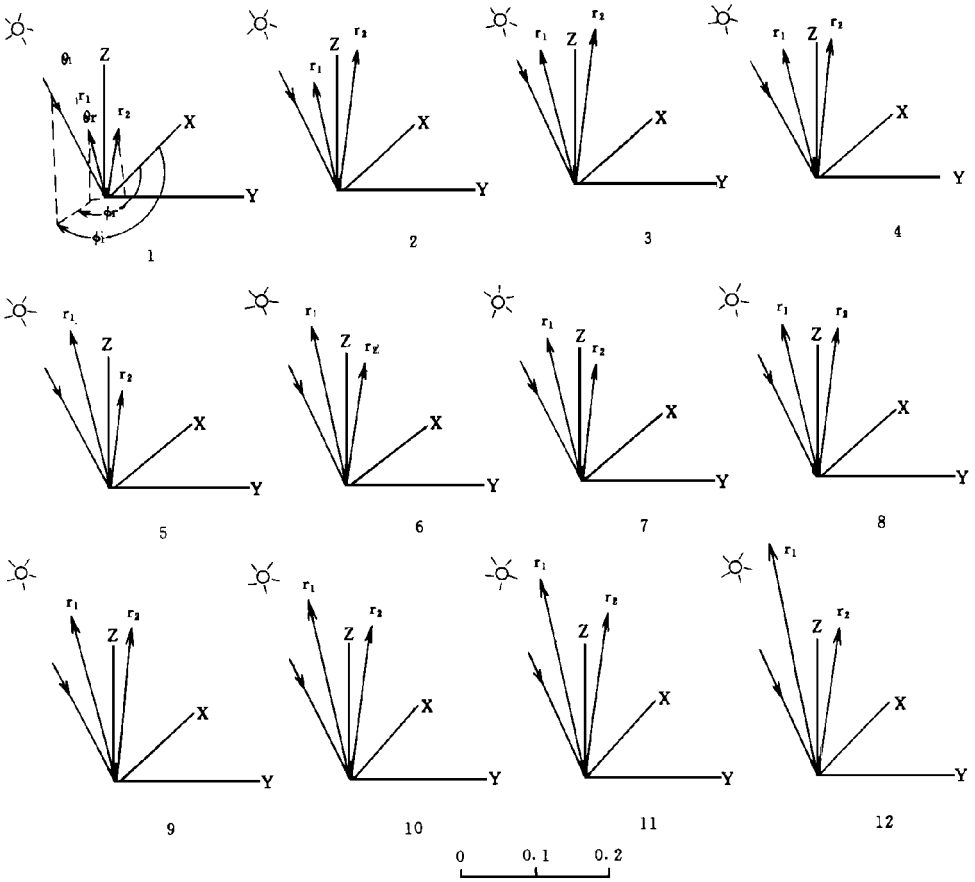

Fig. 2 Channel 2 surface reflectance from the AVHRR data of ground objects. θ_i, Φ_i represent solar zenith angle and azimuth, θ_r, Φ_r represent zenith angle and azimuth of channel 2 surface reflectance on August 3 and 4, 1996. r_1—zenith angle and azimuth of surface reflectance are 12. 28°and 258. 76°; r_2—zenith angle and azimuth of surface reflectance are 6. 6°and 79. 87°; Solar zenith angle azimuth are 25°—27°and 235°—239°.

4 CONCLUSION

The application of AVHRR multiangular remote sensing data has distinguished the subalpine meadow bog and marsh and marsh meadow bog, and improved the ability to monitor the zones harmed by mice and insects in Ruoergai, it will be of great value to us. However, it is necessary to measure bidirectional reflectance data and establish the model to carry out quantitative monitoring of zones of the prairie harmed by mice and insects. A lot of work is still needed to be done.

Note: Marsh, marsh meadow bog described in this paper is on deep cold zone where the sea level elevation is over 3000m.

Fig. 3 Distribution of each category of channel 2 bidirectional reflectance from the AVHRR data on August 3 and 4, 1996 in Ruoergai county

@ corresponds to subalpine meadow bog where it is not well covered by high herbage, some areas are harmed by mice and insects.

* corresponds to subalpine meadow bog which herbage grows moderate, some areas are harmed by mice and insects.

(corresponds to subalpine meadow bog which herbage grows good. 1 corresponds to marsh and marsh meadow bog.)

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应用卫星多角度遥感识别被老鼠和昆虫破坏的草地

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摘　要　该文研究用 AVHRR 数据监测 Ruorgai 县大草原被老鼠、昆虫破坏的情况。鼠虫危害区的光谱特征是：AVHRR 数据的可见光波段（0.58—0.68μm）地面反射率（CH1）较高，近红外波段（0.725—1.1μm）的地面反射率（CH2）较低，红外辐射波段（3.55—3.93μm）的亮度温度（CH3）较高；鼠虫危害区的遥感信息特征在雨季 7 月最为明显；可用比值植被指数 RVI（CH2/CH1）确定鼠虫危害程度；用多角度获得的 RVI 可反映鼠虫危害。结果显示在这方面上，多角度遥感比多波段光谱法能更好地识别老鼠、昆虫破坏的地区。

关键词　AVHRR，多角度遥感，草原鼠虫危害