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Analysis on the Spatial Distributing Rules of the Land-surface Parameters based on SEBS

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Abstract: The land-surface parameters are major components which affect the global climatologic change. Based on the improved SEBS model, a scene cloudless NOAA / AVHRR image spreadsheet model to analyze the distribution and characteristics of the surface parameters in west Jilin province. Temperature, emissivity, Albedo and NDVI were calculated. Then, analysed the spatial distributing rules of the land-surface parameters in study area. Meanwhile, it analysed qualitatively the correlation between the land-surface parameters, which would provide essential information for the study of the eco-environmental problems of western Jilin Province.

Keywords: NOAA/AVHRR, land-surface parameters, distributing rules,western Jilin Province

1. Introduction

Land surface is an entity in which land, ocean, atmosphere, biosphere interact on each other. Virtually, the process of interaction between land surface and atmosphere is the process of exchange between energy, momentum and mass [1, 2]. Because of the variety and diversity of land surface, meanwhilethe characteristics of land surface and the physical property of underlying surfaces in the time and space distribution are different, which influence greatly on the distribution of energy, momentum and mass. Therefore, the energy re-distributes, which influences climatologic change locally and even globally [3]. In order to describe the process of exchange between energy, momentum and mass quantitatively, firstly, we need to retrieve the land-surface parameters (Albedo, emissivity, land-surface temperature, NDVI, soil moisture and thermal inertia and other physical characteristic parameters) precisely.

The land-surface parameters are major components which affect the global climatologic change [4]. They are also important indexes in the study on eco-environmental system. Precise land-surface parameters retrieval plays an important role in the synthetic study and the quantitative prediction of the eco-environmental system [5]. Because of the friability of eco-environment, the problem of land degradation is very serious [6], which has been the primary factor to restrict severely the development of economy in Jilin Province. Therefore, chosing western Jilin Province as the study area is very representative.

2. Data and Study Area

Our focus in this study will be on the NOAA/AVHRR data. The data required for the derivation of the above mentioned land physical parameters are as follows:

1. 1 km digital elevation model (DEM);
2. 1.1 km NOAA/AVHRR data (5 bands from visible to thermal infrared);

Since this study is concerned with retrieval of physical parameters at regional/continentalscales, the practical applicability of the described algorithms are particularly emphasised, in addition to detailed physical considerations. For the purpose of illustration, a data set for western Jilin Province will be used.

Study area is located in the west of Songnen Plain and east of the Horqin prairie. It's low-lying, waterlogged, saline-alkali soil. At the same time, it is a fragile ecological environment ecotone. The ecological and environmental problems is very serious, Especially in land desertification, salinization, grassland degradation.

Western Jilin Province usually refers to the Baicheng and Songyuan two regions, The study area include the Bai-cheng City, Songyuan City, Zhenlai County, Taonan

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County, Tongyu County, Daan County, Qianan County, Guo'erluosi Mongolian Autonomous County, Fuyu County, and Changling County. It has 1433 million population and a total area of 46 879.7 sq km, accounting for 25% of the Jilin Province. The specific geographic coordinates are $E: 121°37'43''-126°11'23''$, $N: 44°22'26''-46°18'5''$.

3. SEBS

The Surface Energy Balance System (SEBS) has been developed by the Satellite Earth Observation-Researches into Water, Climate and Environment (SEO-WaterCliEnt) group of Wageningen University & Research Centre. The details are provided by Su and Jacobs [7, 8] and Su [9]. A brief description is described in the following.

Firstly, the surface energy balance is commonly written as

$$R_n = G_0 + H + \lambda E. \quad (1)$$

Where R_n is the net radiation, $G_0$is the soil heat flux, H is the turbulent sensible heat flux, and λE is the turbulent latent heat flux.

The equation to calculate the net radiation is given by

$$R_n = (1-\alpha)\cdot R_{swd} + \varepsilon \cdot R_{lwd} - \varepsilon\cdot\sigma\cdot T_0^4. \quad (2)$$

where α is the albedo,R_{swd} is the downward solar radiation, $R_{lwd}$is the downward long wave radiation, ε is the emissivity of the surface,σ is the Stefan-Bolzmann constant, and T_0 is the surface temperature.

The equation to calculate soil heat flux is parameterized as

$$G_0 = R_n \cdot [\Gamma_c + (1-f_c)\cdot(\Gamma_s - \Gamma_c)]. \quad (3)$$

in which we assume the ratio of soil heat flux to net radiation $\Gamma_c = 0.05$ for full vegetation canopy [10] and$\Gamma_s = 0.315$ for bare soil [11]. An interpolation is then performed between these limiting cases using the fractional canopy coverage f_c.

Then, decomposition of some specific parameters, and taking into account some of the conditions $[12-14]$,we get the equation as

$$H_{wet} = ((R_n - G_0) - \frac{\rho C_p}{r_{ew}\cdot}\frac{e_s - e}{\gamma})/(1+\frac{\Delta}{\gamma}). \quad (4)$$

$$\lambda E = \frac{\Delta\cdot r_e\cdot(R_n - G_0) + \rho C_p\cdot(e_{sat}-e)}{r_e\cdot(\gamma+\Delta)+\gamma\cdot r_i}. \quad (5)$$

In order to facilitate the implementation of SEBS , embedded SEBS in ENVI. Then, modify the ENVI menu file by "envi.men" file, add the following statement:

0 {SEBS}
1 {Retrieve Data} {} {On_retriever}
1 {Extract DEM}{}{on_exdem}
1 {Globrad} {}{On_globrad}{separator}
1 {ANE} {}{On_ane}
1 {Temperature} {}{On_lst}
1 {Evaporative Fraction} {}{On_evapfrac}{separator}
1 {Daily Evaporation} {}{On_dailyevap}{separator}
1 {Month Evaporation} {}{on_monthevap}{separator}
1 {Month Mean} {}{on_monthmean}{separator}
1 {Annual Evaporation} {}{on_annualevap}{separator}

Based on the improved SEBS model, a scene cloudless NOAA / AVHRR image spreadsheet model to analyze the distribution and characteristics of the surface parameters in west Jilin province.

4. Land-surface Parameters

4.1. Albedo

Based on the observation test, it provide the linear regression relationship between broadband reflectivity (surface albedo) and the narrow-band reflectance (spectral albedo) of NOAA / AVHRR:

$$\alpha = a\cdot r_1 + b\cdot r_2 + c \quad (6)$$

$r_1$and r_2 are the 1^{st} channel and 2^{nd} channel narrow-band reflectance (spectral albedo) of NOAA / AVHRR, and constant a,b and c are different with the any test area. In this study,we use the formula by Valiente [9]:

$$\alpha = 0.545\cdot r_1 + 0.320\cdot r_2 + 0.035 \quad (7)$$

r_1,r_2 can obtained directly from the NOAA / AVHRR data, then, the surface albedo easily strike by the formula 7.

From Figure 1 and Table 1, the surface albedo of the eastern part of the study area was significantly lower than the west, especially,the lowest Fuyu and Songyuan in the

Table.1 Statistics of albedo in western Jilin Province

Area \ statistical	albedo (%) Min	Max	Average	standard deviation
Baicheng	11.7	56.0	38.4	9.9
Songyuan	23.3	35.4	30.1	1.5
Zhenlai	12.6	61.4	37.6	6.1
Taonan	11.8	69.9	42.6	7.9
Tongyu	1.0	81.7	46.2	9.0
Daan	11.9	83.2	42.1	11.3
Qianan	13.0	82.6	41.4	9.4
Guo'erluosi	10.1	64.4	33.2	5.0
Fuyu	17.3	47.2	29.6	3.2
Changling	21.9	82.9	38.2	7.9

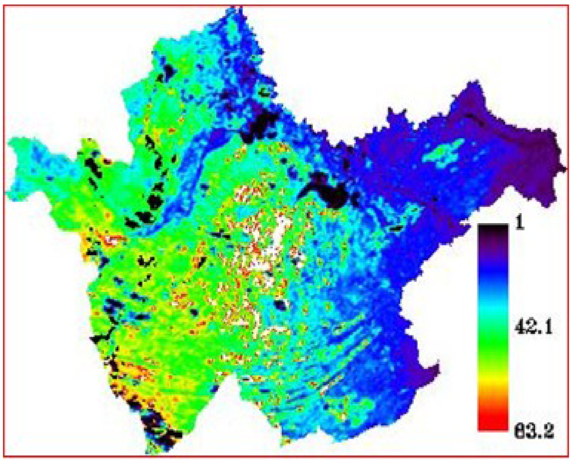

Figure 1 The distribution of albedo in western Jilin Province

eastern part. While, Tongyu, in the western was highest. By data comparison analysis with the 2011 Land-Use and Land-Cover Change (LUCC), we know just arable land is relatively dense of Fuyu and Songyuan, while Tongyu farmland is more dilute.

4.2. Emissivity

According the Vegetation coverage by Caselles and Sobrino [17], εcan be expressed as $[17-19]$

$$\varepsilon = \varepsilon_v \cdot f_v + \varepsilon_g \cdot (1 - f_v) + 4 \cdot \langle d\varepsilon \rangle \cdot f_v \cdot (1 - f_v). \quad (8)$$

In Equation (8), f_v is vegetation coverage, according to the vegetation coverage formula ,which provided by Carlson and Ripley.

$$f_v = \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}. \quad (9)$$

In Equation (9),$NDVI_{max}$, $NDVI_{min}$ are the maximum and minimum NDVI of the study area. Within the spectral range of 10.5 to 12.5$^{\mu m}$, the emissivity of the coverage area of vegetation and bare land are as follows: $\varepsilon_v = 0.0985 \pm 0.007$, $\varepsilon_g = 0.0960 \pm 0.010$; $\langle d\varepsilon \rangle$ for regional eigenvalue (0.00 to 0.02), the above variables are dimensionless unit. Therefore, it can easily calculate the surface emissivity. if derived vegetation cover f_v.

From Figure 2 and Table 2, emissivity of the whole study area are low, especially the the southern(QIAN'AN, Tongyu and Changling) surface reflectance are lowest, while relatively high in the northern(Baicheng,Taonan and Zhenlai). By data comparison analysis with the 2011 LUCC, we corroborate that more waters and paddy fields in the northern part of the entire study area. Especially, in July, there are more paddy fields in the Baicheng Taonan and Zhenlai.

Table.2 Statistics of emissivity in western Jilin Province

statistical / Area	emissivity (%)			standard deviation
	Min	Max	Average	
Baicheng	95.0	98.9	97.1	0.7
Songyuan	95.0	97.5	96.5	0.3
Zhenlai	95.	98.9	96.5	0.5
Taonan	95.0	98.9	96.7	0.6
Tongyu	95.0	99.0	96.6	0.8
Daan	95.0	99.0	96.0	0.5
Qianan	95.0	99.0	95.8	0.5
Guo'erluosi	95.0	98.7	96.4	0.6
Fuyu	95.0	97.6	96.5	0.4
Changling	95.0	99.0	96.4	0.6

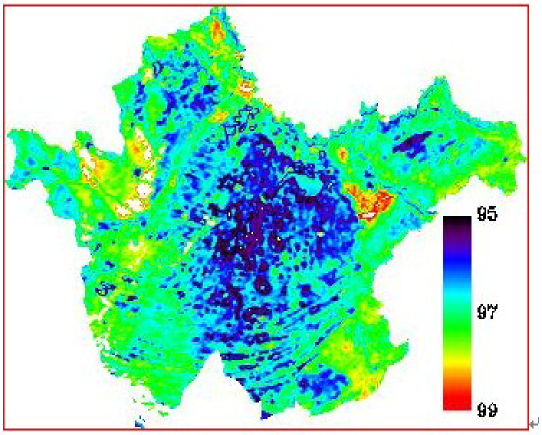

Figure 2 The distribution of emissivity in western Jilin Province

4.3. NDVI

For NOAA /AVHRR, the first and second channel detection purpose is to identify cloud, land / sea border, the snow and ice cover conditions and the growing of crops. So, it often used to determine the surface conditions. In order to eliminate changes in solar elevation angle, the elimination of satellite viewing angle and atmospheric effects, the NDVI (Normalized difference vegetation index) obtained by joint the albedo of first and second channel:

$$NDVI = \frac{r_2 - r_1}{r_2 + r_1} \quad (10)$$

r_1 and r_2 are the 1^{st} channel and 2^{nd} channel narrow-band reflectance (spectral albedo).

Table.3 Statistics of NDVI in western Jilin Province

statistical / Area	NDVI(%)			standard deviation
	Min	Max	Average	
Baicheng	0.9	95.7	47.5	18.9
Songyuan	0.2	55.3	31.9	7.5
Zhenlai	0.5	93.8	33.3	12.7
Taonan	0.7	95.2	37.5	15.5
Tongyu	0.0	97.5	34.3	20.1
Daan	0.0	97.8	21.7	12.1
Qianan	0.0	97.9	17.6	10.0
Guo'erluosi	0.0	90.0	30.1	13.0
Fuyu	0.1	59.8	33.7	9.3
Changling	0.0	97.7	30.7	12.7

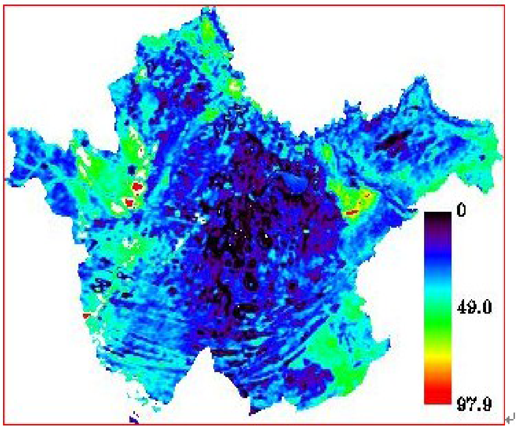

Figure 3 The distribution of NDVI in western Jilin Province

From Figure 3 and Table 3, we know that only scattered a few small areas of vegetation index is relatively high, most of the vegetation index is very low, even zero. In summer, be crops and vegetation lush season, such a situation can be seen in west Jilin Province ecological environment is quite poor.

4.4. Land-surface temperature

The surface temperature of the substance is one of the important parameters on any material surface thermal radiation. There are one of the most commonly used method of satellite retrieval of surface temperature. It is atmospheric correction by two different near-band radiation in the atmospheric window absorption characteristics, which is the famous "split window" method. The general expression of the form of split window algorithm as follows:

$$T_s = A_0 + A_1 T_4 + A_2 T_5 \tag{11}$$

T_s is the surface temperature (K),T_4 and T_5 are brightness temperature (K) for channel 4,5 of AHVRR. A_0,A_1,A_2 are coefficient, which determined by atmospheric conditions, viewing angle and surface emissivity, different coefficient for different algorithms. In this paper, Coll and Caselles [20] proposed a split window algorithm using the following formula,

$$\begin{aligned} T_s &= T_4 + [1.34 + 0.39(T_4 - T_5)](T_4 - T_5) \\ &\quad +\alpha(1-\varepsilon) - \beta\Delta\varepsilon + 0.56 \\ \alpha &= W^3 - 8W^2 + 17W + 40 \\ \beta &= 150(1 - W/4.5) \end{aligned} \tag{12}$$

Table.4 Statistics of land-surface temperature in western Jilin Province

statistical / Area	land-surface temperature (℃)			standard deviation
	Min	Max	Average	
Baicheng	20.3	31.7	26.8	2.3
Songyuan	23.0	32.8	28.9	1.5
Zhenlai	21.1	32.6	26.3	1.7
Taonan	20.4	32.6	27.8	1.9
Tongyu	-13.9	33.0	27.7	3.7
Daan	22.6	32.2	27.8	1.7
Qianan	22.3	34.8	30.3	2.0
Guo'erluosi	22.3	35.6	29.4	2.7
Fuyu	23.4	34.9	29.5	1.8
Changling	23.4	33.5	29.5	1.2

By Figure 4 and Table 4, we can see that the lower temperatures in the western part of the study area and higher temperatures in the eastern. The surface temperature of Qianan, Guo' erluosi south, Fuyu and Changling are the highest. The surface temperature of Zhenlai, Baicheng, Guo'erluosi northern is relatively low. By data comparison analysis with the 2011 LUCC, there are the larger bodies of water and vegetation cover in Zhenlai, Baicheng and Guo'erluosi northern, while less water and vegetation covered in Qianan, Guo'erluosi south, Fuyu and Changling.

Lower temperatures are in the surface of vegetation and water area, and the higher temperature are in the surface of bare soil area. It is exactly in line with the conventional surface temperature distribution law. The "split

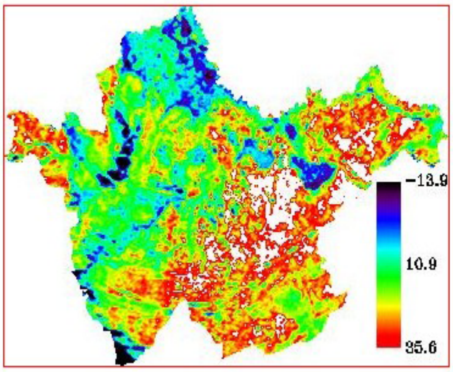

Figure 4 The distribution of land-surface temperature in western Jilin Province

window"method proposed by Coll and Caselles is quite reliable.

4.5. Evapotranspiration

The surface energy balance is the theoretical basis of a variety of evapotranspiration research methods. The surface energy balance equation can be expressed as

$$R_n - \lambda E - H - G + A_n + L_p F_p = \partial w / \partial t \quad (13)$$

In formula(13), R_n is the net radiation flux,H is sensible heat flux,G is soil heat flux,λE is latent heat flux (λ is latent heat of vaporization ($\frac{wm^{-2}}{mm}$);E is evapotranspiration mm),their units are w/m^2,$L_p F_p$ are energy for vegetation photosynthesis and biomass increase,A_n is the underlying surface convective energy flux,$\partial w/\partial t$ is the rate of change of energy. Because the values of $L_p F_p$,A_n,$\partial w/\partial t$ are all very small,in the actual calculations, they can be ignored:

$$\lambda E = R_n - H - G \quad (14)$$

Respectively calculate the R_n,G and H,we can calculate the latent heat flux for evapotranspiration λE, so as to further obtain E_{day},E_{month},E_{year}.

This paper calculated the average evapotranspiration 159.8mm from figure5 and table5, the real evapotranspiration average of 161.4mm, the relative error can be received.

5. Conclusion

By the above analysis, we found that:

• If the surface albedo high , surface emissivity is often lower; particularly surface albedo low, surface emissivity is often higher;

• If surface albedo are high,the surface temperatures tend to be lower, because the high albedo means that the earth reflected off the solar radiation energy more, and absorption of solar radiation is less, resulting in lower temperatures, and vice versa;

• Temperature is one of the conditions of the impact of evapotranspiration, promoting evapotranspiration occurrence of elevated temperatures. So in high temperature area, evapotranspiration is also higher; cooler areas, evapotranspiration and less;

• This also can be inferred albedosame effect on evapotranspiration, albedo higher, evapotranspiration tend to be less and vice versa.

This paper using of NOAA/AVHRR inversion characteristic parameters in west Jilin Province, such as surface albedo, surface emissivity, NDVI, surface temperature, monthly mean evapotranspiration. Through statistical analysis of surface parameters,achieved the rules and char-

Table.5 Statistics of evapotranspiration in western Jilin Province

statistical / Area	evapotranspiration (mm)			standard deviation
	Min	Max	Average	
Baicheng	109.1	250.5	153.0	21.6
Songyuan	131.2	240.2	188.7	15.1
Zhenlai	103.8	252.9	164.4	24.7
Taonan	64.7	217.9	135.2	21.9
Tongyu	93.4	243.1	147.6	21.2
Daan	71.4	254.4	154.4	26.2
Qianan	89.3	258.2	154.3	24.9
Guo'erluosi	85.7	262.9	177.6	27.6
Fuyu	105.4	268.2	184.8	21.3
Changling	95.7	240.3	160.4	25.0

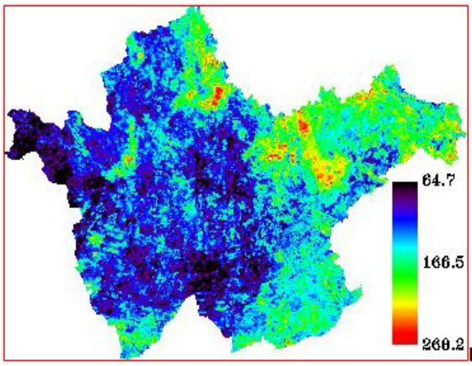

Figure 5 The distribution of monthly mean evapotranspiration in the study area

acters in the spatial distribution of the study area. It proved the rationality of the model, while the qualitative analysis of the relationship between the local characteristic parameters of Table (For quantitative results, further research is needed). It not only promote the goal of sustainable development of west Jilin Province, but also provide a new range of applications for the NOAA / the AVHRR data.

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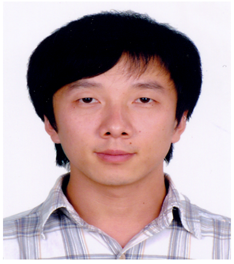

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