Inversion Research on Aerodynamic Roughness of Different Underlying Surfaces in Aral Sea Basin

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Abstract. The study of water and heat flux in Aral Sea Basin is a hot topic in the study of water resources in Central Asia. Aerodynamic roughness is the key parameter of inversion. Z_{om} is retrieved based on NDVI and Albedo simulation and verified by the vegetation height in Central Asia. The results show that the inversion of Z_{om} by this model is basically reasonable. In 2018, the monthly average value of Z_{om} is about 0.056m, the vegetation height in Aral Sea Basin is about 0.44m, and both Z_{om} and vegetation height in space are higher in eastern mountainous areas than in western desert areas.

1 Introduction

Aerodynamic Roughness (Z_{om} , Aerodynamic Roughness Length) refers to the fact that when airflow passes through a certain physical boundary, if the flow velocity near the boundary is zero, then the physical boundary is said to be aerodynamically rough, and its size mainly depends on the surface roughness, that is, the distribution of underlying surface types^[1]. Z_{om} is a key parameter for studying surface water heat flux, and is also a basic parameter for estimating thermodynamic roughness (Z_{oh} Thermal Roughness Length), additional damping of heat transfer ($KB^{(-1)}$), regional sensible heat flux and latent heat flux. Aral Sea Basin is located in the center of Eurasia. It is a typical arid and semi-arid region with a general lack of water resources^[2,3]. The surface type in this region is complex. The accurate estimation and verification analysis of Z_{om} can provide a more accurate parameter basis for regional energy balance and remote sensing simulation of surface energy in this region.

2 Research Area and Z_{om} Inversion Model

2.1 Overview of Research Area

The Aral Sea Basin covers a total area of 1.76 million km², involving five Central Asian countries and Afghanistan and Iran^[2,4]. Its geographical division is shown in Figure 1.

Fig. 1. Aral Sea Basin Geographical Zoning Map

Fig. 1 is a geographic zoning map of the Aral sea basin, including 8 regions and 20 subdistricts, of which 8 regions are: (1) Aral sea; (2) Turan desert area; (3) Central Kazakhstan desert region; (4) Mount South Turkistan region; (5) the high mountain areas of the central Tianshan mountains; (6) Pamir-Tibet high mountain area; (7) Mount Hindu Kush region; (8) Iranian mountainous areas. Aral Sea Basin is a continental climate with typical temperate desert and grassland, with sufficient sunshine and little rain (Han Qifei, 2018; Chen Qichuan, 2012), the annual maximum rainfall is 200mm, and the annual rainfall in consecutive dry years is 65mm, and the spatial distribution is uneven. The rainfall in Turan desert area in the southwest of the basin is less than 100 mm. Based on the analysis of the typical vegetation height of each division based on the vegetation division, as shown in Figure 2 and Table 1, the study area is widely distributed in the Haloxylon ammodendron desert area (702), mainly in the Turan desert area. Its typical trees are Haloxylon ammodendron

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1-7m, shrubs are Calligonum Bai Pu 20-150cm, and typical vegetation in grassland, Gobi and desert is Salix psammophila 14-60 cm. The second is savanna type grass (1012), and the typical vegetation is bulbous barley 70-90 cm; In the desert region of Central Kazakhstan, the vegetation is divided into the central desert Tugailin and meadow (802), with the representative trees being Elaeagnus angustifolia 5-10m, shrubs being Tamarix ramosissima 3-6m, and herbaceous vegetation being Agropyron strobilacea 80cm; In addition, there is also Artemisia desert region (705) in the desert region of central Kazakhstan, where shrubs are 8-30cm in diameter and herbs are 25-35cm in diameter.

Fig. 2. Aral Sea Basin Vegetation Zoning Map [6]

Table 1. Vegetation Zoning in Aral Sea Basin Representing Vegetation Height

Representative plants	Attribute	Vegetation Code	Height	Representative plants	Attribute	Vegetation Code	Height
Halogeton strobilacea	Perennial semi-shrub	401	20-40cm	Stipa caucasica	Perennial herbs	1009	15-30cm
Common Pistache	Small trees	1006,1012,10,13,1101	5-7m	Caragana aurantica Koehne	Shrub	1006,1010,10,11,1012,1013,1101	1m
Festuca coelestis	Perennial dense clump	1004,1006,10,08,1010	4-15cm	Elytrigia trichophora Nevski	perennial	1003,1012,10,13,1101	50-150cm
Seriphidium terrae-albae	Perennial subshrub	705,708,709	8-30cm	hordeum bulbosum	Perennial Gramineae	1012,1013,11,01	70-90cm
Zanthoxylum bungeana	Perennial shrubs	702	20-150cm	Calligonum mongolicum Turcz.	Perennial shrubs	710,711	20-150cm
Haloxylon persicum	Small trees	702	1-7m	Agriophyllum squarrosum	Annual herbs	702	14-60cm
Tamarix chinensis	Shrub	802	3-6m	Elaeagnus angustifolia Linn.	Tree	802	5-10m
Juniperus formosana	Small trees	1005,1011	12m	Prangos Lindl.		1003	60cm
Artemisia terrae-albae	Biennial herb, perennial shrub	717	50-150	Carex spp.	Perennial herbs	401,702,704,705,708,709,710,711,1203	20cm,
Salsola orientalis	Small shrub	710,711	30-35cm	Halogeton strobilacea	Perennial semi-shrub	704,1202,1203	20-40cm
Agropyron crispus	Perennial herbs	802,1005,1011	80cm	Anabasis salsa	Small herb shrub	704,717,719	15-20cm
Oxytropis immersa	Perennial herbs	1005,1011	20cm,	Artemisia Linn.	Perennial herbs or semi-shrubby, small shrubby plants	1006,1008,10,09	70cm
Haloxylon aphyllum	Small trees	708,709	7-8m	Poa pratensis	Annual Grass	716	6-30cm
Betula	Tree	1010	20m	Stipa capillata Linn.	Perennial herbs	1006,1008,10,10	40-80cm
Desert Helictotrichon	Perennial, xerophytic grasses	1004	25-70cm	Salsola collina Pall.	Annual herbs	705	25-35cm
Astragalus propinquus Schischkin	Perennial herbs	719	10-20cm				

2.2 Z_{om} and H Inversion Model

Currently, Z_{om} is estimated in many ways and mostly by empirical formulas. This paper is based on the empirical formula proposed by Liu [5,7], which can estimate Z_{om} and H in a large range using remote sensing data as shown in formula (1) (2). The remote sensing image is the 30-day composite daily mean data of MODIS NDVI and albedo1km in 2018. In the simulation process, using the geographical division and vegetation type division of Central Asia [6] and the land cover of Aral Sea basin, the typical representative vegetation maximum height values of each vegetation division in the study area (as shown in Table 1) are obtained and spatially analyzed. It is proposed to compare the simulated values of H and June, analyzed the applicability and rationality of the empirical formula in Aral Sea region, and revise the inversion results. The vegetation code is shown in Figure 2.

$$Z_{om} = \exp\left(a \frac{NDVI}{\alpha} - b\right) \quad (1)$$

Where, a and b are empirical coefficients, which refers to 0.0553 and 3.64 respectively; α is broad band albedo and NDVI is normalized difference vegetation index.

$$H = Z_{om}/0.136 \quad (2)$$

3 Analysis of Inversion Results

3.1. Rationality Analysis of Simulation Results

The simulated vegetation height in June based on Z_{om} inversion is compared with the spatial distribution map of vegetation height formed by typical vegetation gridding based on vegetation zoning and surface classification, as shown in Table 2, in which the vegetation height is compared and analyzed according to the three conditions of land type, geographical zoning and vegetation zoning respectively, hRe is the height of typical vegetation and hes is the simulated inversion of vegetation height. According to the analysis of land type, the highest simulated result value of forest land for vegetation height is 16.66m, followed by 2.57m for urban land and 2.31 m for rural residential land. Thirdly, the average height of shrub forest is 1.52m, and the height of other land types is between 0.5 and 0.02. Compared with the height of typical vegetation in different regions, the simulated values are smaller in desert, Gobi, saline-alkali land, wetland, dry land, urban land and residential area, while the simulated heights of woodland and shrub are larger. Other simulated values are close to the height of typical vegetation. Based on geographical division, the height of simulated vegetation is higher than that of typical vegetation in Fergana region, Guhrstein region and Gizal-Dalvaz region, while the height of simulated vegetation in other regions is slightly different from that of typical vegetation. The height of simulated vegetation based on vegetation zoning is generally lower than that of typical vegetation

in the region, with the exception of savannah shrub sparse forest and grass and mountain cold xerophytic subshrub grassland. The average height of simulated vegetation is 1.86m and 1.31m respectively, and the height of typical vegetation is 1.08m and 0.92m respectively. By comparing the simulated vegetation height and typical vegetation height of different land types, different geographical divisions and vegetation divisions, the simulated values are generally reasonable.

Table 2. Height Simulation Validation Analysis

Land type	Height /m		Geographical Zoning	Height /m		Vegetation Zone	Height /m	
	$\bar{h}_{18}$	$\bar{h}_{15}$		$\bar{h}_{18}$	$\bar{h}_{15}$		$\bar{h}_{18}$	$\bar{h}_{15}$
paddy field	0.55	0.45	Aral Sea	0.25	0.08	Grassland vegetation in non-river floodplain	0.18	0.08
Irrigated land	0.55	0.45	South Kuitun District	0.55	0.26	White Haloxylon Desert	0.35	0.07
dry land	0.55	0.06	Bahara District	0.49	0.19	Persical halophytic desert	0.14	0.08
Woodland	10.79	16.66	Amu River Basin Area	0.76	0.43	Artemisia desert	0.16	0.04
Shrubwood	1.02	1.52	North Kuitun District	0.33	0.10	Black Haloxylon Desert	0.18	0.11
High coverage grassland	0.74	0.30	Karadaviz District	0.72	0.37	Mixed Haloxylon ammoxendron desert	0.18	0.08
Medium coverage grassland	0.72	0.75	Western Tianshan Mountains	1.79	1.96	Short-lived shrub-like small semi-shrub desert	0.34	0.18
Low coverage grassland	0.70	0.59	Fergana District	0.69	1.15	Short-lived small semi-shrub and semi-shrub desert	0.24	0.11
Urban land use	6.00	2.57	Ancient Helan District	1.26	1.45	Artemisia desert	0.22	0.06
Rural settlements	6.00	2.51	Gusu-Dunhuang District	1.13	2.49	Landy shrub desert	0.79	0.21
Channel	0.00	0.15	Baidah District	0.38	0.13	Blackdesertic grassy desert	0.20	0.02
lake	0.00	0.22	South Tajikistan	0.98	0.84	Control Desert Tugai Forest and Meadow	0.91	0.37
Reservoir pond	0.05	0.22	Southern Grassland of Middle Tianshan	0.49	0.69	Alpine meadow and subalpine cold meadow	0.58	0.21
Permanent glacier and snow	0.05	0.02	Northern Meadow of Middle Tianshan	0.39	0.23	Cold grassland	0.13	0.19
Beach land	0.00	0.03	Eastern High Mountains of Middle Tianshan	0.23	0.15	Mountainous Ice Plateau Vegetation	0.37	0.14
Desert	0.37	0.03	Alai Grassland of the Middle Tianshan	0.43	0.20	Mountain Slope	0.52	0.57
Gobi	0.41	0.05	Northeast of Pamir-Tibet Alpine Region	0.29	0.09	Mountain desert	0.38	0.26
Saline alkali soil	0.41	0.02	Southeast of Pamir-Tibet Alpine Region	0.42	0.17	Mountain Desertification Grassland	0.56	0.33
Wetland	0.68	0.02	Hindu Kush Mountains	0.78	0.29	Mountainous broad-leaved forest	1.70	1.53
Bare land	0.05	0.05	Iran mountain area	0.85	0.52	Cold and xerophytic semi-shrub grassland in mountainous area	0.92	1.31
Bare rock gravel	0.05	0.04	Average Value	0.64	0.47	Savannah-type grassland	0.88	0.45
Average Value	0.64	0.47				Shrubs and grasses of savanna type	1.08	1.86
						Waste hollow and other vegetation-free areas	0.67	0.34
						Southern Halophytic Desert	0.40	0.02
						Halophytic desert in central China	0.11	0.10
						Average Value	0.64	0.47

3.2 The analysis of simulation result

The analysis of the simulation result is based on the change of the monthly mean value of z_{om} 2018 in different geographical areas as shown in Figure 3. According to the value, it is divided into 5 grades. The corresponding land types of 0.002~0.0029m include permanent glacier and snow, beach, saline-alkali land, wetland and desert. The maximum z_{om} of wetland and desert reaches the annual peak value of 0.0028m around April, and the z_{om} of other land types is between 0.0025~0.0028m; The corresponding land types of 0.006~0.013m are dry land, lake, Gobi and bare land, among which z_{om} in dry land rose from 0.0065m to 0.0075 m from March to October. The changes of z_{om} in bare land, Gobi and lake are not big. 0.15~0.45m, bush forest, urban land and rural residential area z_{om} are 0.20m, 0.40m and 0.30m respectively; The z_{om} of paddy field, irrigated land, high coverage grassland, medium coverage grassland, low coverage grassland, canals, reservoir ponds and bare rock gravelly land fluctuates between 0.018 m and 0.080 m. The z_{om} value of forested land fluctuates between 1.86~2.0m, with the highest month being around June.

Fig. 3. z_{om} monthly mean of different land types in 2018

In Aral sea basin in 2018 is shown in fig. 4. since the floating value of z_{om} in each month is small, the spatial distribution of z_{om} is illustrated by taking June 2018 as an example. According to the statistical mean of z_{om} geographical division at 2000 random points in the study area, the z_{om} values in the western mountain area, the Alai grassland area in the central Tianshan Mountains and the Gisar-Dalvaz area are about 0.0562m; Secondly, z_{om} in guhstein area is 0.1628 m; z_{om} is 0.0965 m in southwest Tianshan grassland area. The lowest area of z_{om} is 0.0059m in Aral sea and 0.07 m ~ 0.01 m in other areas. From the spatial distribution map of z_{om} , it can be seen that z_{om} is between 0.001 and 0.003 m in the north Kizilkum region, the south Kizilkum region and the Aral sea region. The z_{om} values in the Hindu Kush and Iranian mountains are between 0.03 and 0.05 m; The z_{om} in the northwestern Amu Darya river basin, the northeastern bukhara region, the southern western Tianshan mountain and the guhstan region is between 0.08 and 0.1m, and the z_{om} in the south Turkistan mountain region and the high mountain region of the central Tianshan mountain is between 0.8 and 5.0m .

Fig. 4. z_{om} spatial distribution of different geographical divisions in June 2018

The spatial distribution of Aral Sea Basin H in June 2018 is shown in Figure 5. The H of North Kizilkum Region, South Kizilkum Region and Aral Sea Region is between 0.0001~0.1m; The eastern Aral Sea Basin includes the South Turkistan Mountains and the high mountain areas of the Central Tianshan Mountains. The vegetation height is between 0.3 and 0.5m. During this period, the vegetation height of some forest lands is scattered between 3 and 3~20m. Based on the analysis of random dotting values in the study area, based on the analysis of land types, the h value of forested land is the highest at 16.66m, followed by the vegetation height of urban land and rural residential areas at 2.6m and 2.3m, the vegetation height of shrubbery is about 1.5m again, the vegetation height of paddy field and irrigated land is about 0.44m, and the vegetation height of other land types is between 0.01 and 0.8 m. According to geographical division analysis, the vegetation height in Aral Sea region varies from 0.04 m to 0.08 m. The vegetation height in Guisard-Dalvaz region is about

2.45m, followed by Guhestan, West Tianshan and Fergana regions, with vegetation heights of 1.45m, 1.35m and 1.13 m respectively. The vegetation height in the grassland area in the southwest of Zhongtian is 0.68m, that in the mountainous area of Iran is 0.50m, and that in the Amu Darya River Basin is 0.43 m on average. The vegetation height in other areas fluctuates between 0.08~0.4m.

Fig. 5. Simulated spatial distribution map of vegetation height h of Aral sea basin in June 2018

4 Conclusion

The results of dynamic roughness of Aral sea basin based on NDVI and Albedo simulation inversion are reasonable. In 2018, the monthly average value of z_{om} is about 0.056m, the eastern part is larger than the western part in space, the mountainous area is higher than the plain desert, and the woodland, grassland and town land are larger than other land types, especially the Gobi and desert areas, z_{om} is about 0.003m m. The vegetation height in Aral Sea Basin is about 0.44m m. According to the comparison of land types, there are woodland H value > urban land > village residential vegetation height > shrub vegetation height > paddy field and irrigated land vegetation height > other land types. According to geographical division comparison, the vegetation height in Guisard-Dalvaz region > Guhstan > west Tianshan region > Fergana region > southwest grassland region of Zhongtian > Iranian mountain region vegetation height is 0.50m > Amu Darya river basin vegetation > other regions, of which the Aral sea region vegetation height changes at the lowest level between 0.04 and 0.08 m.

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