VALIDATION OF SNOW COVERED AREA BASED ON SNOW PRODUCT DERIVED FROM MODIS AND AMSR-E IN THE HEILONGJIANG BASIN

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1. INTRODUCTION

The distribution of snow in space and time is an important parameter for a wide variety of reasons. Knowing the extent of the snow is valuable information in that it provides insight as to the amount of water to be expected from snowmelt available for runoff and water supply. In addition to in situ network of snow cover measurements, various snow cover products are operationally produced from satellite observations by numerous agencies using both optical and passive microwave imagery data [1]. A number of comparisons studied had been conducted on the accuracy of snow maps derived from various sensors on board satellite and meteorological stations observations [2]. These studies have examined relative snow mapping accuracy of various snow cover products or the relationship between snow mapping accuracy and spatial resolution, ruggedness, land cover and snow depth [3]. Due to the large variation of land use/cover from region to region, a great efforts need to be made to assess the snow cover products derived from satellite-borne observations. This study focuses on validation of the snow product performance to MOD10C2 and MOD10A2, and snow covered area derived from snow water equivalent product based on AMSR-E onboard Aqua satellite.

2. MATERIALS AND METHODOLOGY

The HLB is very large, trans-boundary mega ecosystem that includes portions of Northeast China, Russia, Mongolia and North Korea, which locates between Lat. 43 to 57 N and Long.108 to 141 E, with an area of 2,095,000 km^2. HLB is characterized by diverse natural ecosystems and abundant natural resources. Land cover types, ranging from temperate to boreal evergreen conifer-deciduous broad leaf mixed forests, deciduous broad leaf forests, woodlands, and shrublands in the Mountain Ranges to typical steppes and desert steppes in the west parts of the basin where Mongolia and inner Mongolia jointed, with agricultural lands, wetland meadow extensively locate in these alluvial flood plains, meadow and steppes was in the mid part of HLB. The study area is characterized by a temperate continental monsoon climate.

In this study, two types of MODIS snow cover products were utilized, including the 8-day composite

MOD10A2 product and 8-Day L3 Global 0.05Deg CMG (MOD10C2) Snow Cover product. In this study, seven tiles of the MOD10A2 8-daiy snow cover products from 1st October to 1st May of year 2002–2007 were obtained from the National Snow and Ice Data Center (NSIDC) Distributed Data Archive. MOD10AC2 is an 8-day composite product of to meet the CMG criteria. The 5-day level-3 AMSR-E snow water equivalent (SWE) data AE_5DSno (AMSR-E/Aqua 5-Day L3 Global Snow Water Equivalent EASE-Grids) in Northern Hemisphere were obtained from the NSIDC website [4]. SWE value zero indicates a snow-free surface (or land surface); values 1–240 represent the snow-covered surface; and values 248, 252, 253, 254 and 255 represents off-earth, land or snow impossible, ice sheet, water and data missing, respectively.

Daily measurements of snow depth (SD), snow density, minimum, maximum and mean temperature were observed during the snow season from 1st October 2002 to 1st May 2007, and elevations at 87 climate stations were extracted from DEMs (Digital Elevation Models) with spatial resolution of 500 m were derived from SRTM from NASA website with minor modification based on 1:250,000 scale of topographic maps. The climate stations report snow depth based on gauges in centimeters, with a minimum reported value of 1 cm. Snow depths less than 0.5 cm are reported as Zero, and are rounded to the nearest centimeter if snow depth is equal to or great than 0.5 cm according to the rules of observing snow cover by the meteorological bureau of China. To analyze the accuracy of MODIS snow cover maps through MOD10A2, MOD10C2 products in our study area, only ground observations under cloud-free conditions were used during the six snow season years.

All the preprocessed MOD10A2, MOD10C2 and Aqua-AMSR-E SWE snow products were transformed into ArcGIS 9.1 grid format, then the cell values where collocated with 87 climate stations extracted by using ArcGIS 9.1 zonal analysis. To determine the accuracy of the MODIS snow cover mapping algorithm, observations of MODIS snow cover maps were made against 5-day or 8-day combination products with in situ snow depth measurements reported at 87 climate stations throughout the HLB region. A confusion matrix which incorporates both information on agreement and disagreement between remotely sensed images and ground observations (Klein & Barnett, 2003) were used to estimate the accuracy of the MODIS snow mapping algorithm.

3. RESULTS AND DISCUSIONS

Table.1 shows a confusion matrix comparing all valid cloud-free observations between MODIS and climate stations during the winter season of 2002-2007. In this study, 5938 cloud-free pairs of comparisons from ground observations and MOD10A2 data during the snow season of 2002 to 2007 were matched. The snow agreement ranges from 69.4% to 83%, the overall agreement is 75.7%. Similar amount of cloud-free pairs of comparison data were selected for MOD10C2 validation. The accuracy for MOD10C2 product increased significantly, the snow agreement ranges from 84.5% to 91.7%, the overall accuracy is 89.0%. Analysis should be done to look insight into the real reason for this discrepancy.

Table.1. Confusion matrices for MODIS snow cover compared with ground truth from 2002-2007.

Snow product	Study peroid	Satellite snow product				Ground truth				Agreement	
		No snow	(%)	Snow (%)		No snow (%)		Snow (%)		Agreement(%)	
MOD10A2	2002-2003	409	41.0	588	59.0	134	13.4	863	86.6	692	69.4
	2003-2004	267	26.7	733	73.3	133	13.3	867	86.7	830	83
	2004-2005	329	29.0	806	71	172	15.2	963	84.8	896	78.9
	2005-2006	506	40.3	748	59.7	295	23.5	959	76.5	937	77.6
	2006-2007	697	44.9	855	55.1	381	24.6	1171	75.4	1124	72.4
Overall accuracy(%)							75.7				
MOD10C2	2002-2003	194	17.2	937	82.8	83	7.3	1048	92.7	998	88.2
	2003-2004	157	13.6	998	86.4	79	6.8	1076	93.2	1059	91.7
	2004-2005	184	14.6	1080	85.4	126	10.0	1138	90.0	1142	90.3
	2005-2006	259	20.7	994	79.3	225	18.0	1028	82.0	1103	88.0
	2006-2007	340	24.4	1056	75.6	300	24.4	1056	75.6	1180	84.5
Overall accuracy (%)							89.0				

There are 9620 pairs of comparisons from ground observations and AMSR-E 5D-Sno product data during the snow season of 2002 to 2007 were matched (table.2). Taking the overall accuracy as consideration, there is no obvious difference between AMSR-E snow covered area derived from passive remote sensing data and MOD10C2, the snow agreement ranges from 83.2% to 93.3%. However, the non-snow cover area agreement is only 61.86%. The overall accuracy is 88.9%, it can be seen that the AMSR-E product resulted in low omission error (11.11%), which is much lower than the commission error (41.86%), that may explain why passive remote sensing data tend to overestimate snow covered area.

Table.2. Confusion matrices for AMSR-E snow cover compared with ground truth from 2002-2007.

Snow product	Study period	Satellite snow product				Ground truth				Agreement	
		No snow (%)		Snow (%)		No snow (%)		Snow (%)		Agreement (%)	
AMSR-E	2002-2003	71	4.5	1505	95.5	109	6.9	1467	93.1	1450	92
	2003-2004	119	6.2	1790	93.8	119	6.2	1790	93.8	1781	93.3
	2004-2005	149	7.7	1795	92.3	165	8.5	1779	91.5	1774	91.3
	2005-2006	182	8.7	1922	91.3	340	16.2	1764	83.8	1814	86.2
	2006-2007	176	8.4	1911	91.6	411	19.7	1676	80.3	1736	83.2
Overall accuracy(%)							88.9				

It can be seen from fig.1 that there is intimate relationship between land surface, snow covered area and cloud covered area in the sky. Though the MOD10A2 is the 8-day composite of MOD10A1 snow cover product, the snow covered area still affected by the cloud contamination. The maximum cloud contamination can cause 24% of snow covered area underestimation in the study area. So, how to integrate snow cover product derived from both optical remote sensing and microwave remote sensing is a promising way for the realy snow cover monitoring which may serves better for some land surface process modeling.

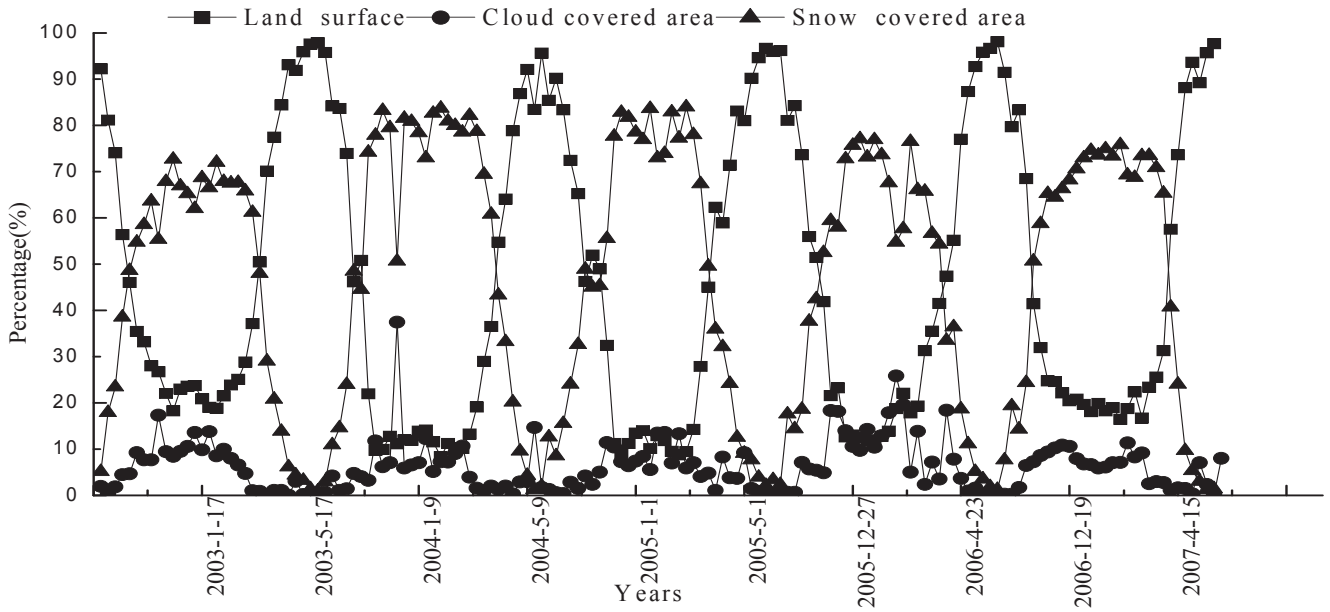

Fig.1 the relationship between snow, non-snow covered surface and cloud from MOD10A2 during the winter season of 2002 and 2007

The absolute validation of snow cover parameters derived both from optical remote and passive remote sensing turned to be a challenge for the research community. Since the most readily available snow ground truth data is snow gauge data from climate stations, point measurements are used as a major validation source[5]. How to redesign a practical strategy to validate the snow cover information is to be expected, and cross validation of different snow products is also turn to be promising approach. In this study, both ground truth data from climate stations and snow cover data from MODIS were applied to validate the snow covered area indirectly derived from AMSR-E 5D-Sno product.

4. REFERENCES

[1] T. G. Liang, X. D. Huang, C. X. Wu, X. Y. Liu, W. L. Li, Z. G. Guo, J. Z. Ren, "An application of MODIS data to snow cover monitoring in a pastoral area:A case study in Northern Xinjiang, China", *Remote Sensing of Environment*, 112, pp.1514–1526, 2008.

[2] D. K. Hall, G. A. Riggs, V. V. Salomonson, et al., "Development of a technique to assess snow-cover mapping accuracy from space", *IEEE Transactions on Geoscience and Remote Sensing*, 39(2), pp.232−238, 2001.

[3] D. K. Hall, G. A. Riggs and V.V. Salomonson, "Updated daily. MODIS/Terra Snow Cover 8-Day L3 Global 0.05deg CMG V005", Boulder, Colorado USA: National Snow and Ice Data Center, Digital media, 2006.

[4] V. V. Salomoson, I. Appel, "Estimation fractional snow cover from MODIS using the Normalized Difference Snow Index", *Remote Sensing of Environment*, 89, pp.351-360, 2004.

[5] R. E. J. Kelly, A. T. C. Chang, J.L. Foster, and M. Tedesco, "Updated every five days. AMSR-E/Aqua 5-day 3 Global Snow Water Equivalent EASE-Grids V002", Boulder, Colorado USA: National Snow and Ice Data Center, Digital media, 2004.