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Time series of snow cover data of Northeast China (2004-2013)

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Abstract: Northeast China is one of three major steady snow cover areas in China. Monitoring spatial-temporal changes of snow cover is very important in water resources management and snow disaster evaluation and prediction. Daily Terra and Aqua MODIS snow cover products are used to produce two basic dataset including Terra/Aqua daily combination (MODISDC) and flexible multiday combination (MODISMC), and the thematic snow cover data including snow cover day (SCD), snow cover onset date (SCOD), and snow cover melting date (SCMD) in the last decade from 2004 to 2013. Compared with in situ observations, the daily and flexible multiday combinations achieve overall accuracy of 47.51% and 76.52 % respectively, more than 34.45% of MODIS Terra and 30.57% of MODIS Aqua under all-sky conditions.
Keywords: snow cover; snow cover day (SCD); snow cover onset days (SCOD); snow cover melting day (SCMD); Northeast China

1 Introduction

Time series of snow cover data covering Northeast China is an important outcome of monitoring snow cover changes by remote sensing from Oct.01, 2003 to Sep.30, 2013 in Northeast China. This dataset plays a crucial role in attenuating the effects of snow disasters and ensuring sustainable development of agriculture in Northeast China. Based on MODIS Terra/Aqua original daily products, the authors produce the products on snow cover dataset, including Terra/Aqua daily combination (MODISDC), flexible multiday combination (MODISMC), snow cover days (SCD), snow cover onset date (SCOD), snow cover melting dates (SCMD).

2 Metadata of the time series of snow cover data covering Northeast of China

The descriptions of the time series of snow cover data of Northeast China (2004-2013) (SnowCoverData_NortheastChina_2004-2013) are recorded. These information include the

Table 1   Summary of the SnowCoverData_NortheastChina_2004-2013 metadata

Data set name	Time series of snow cover data of Northeast China (2004-2013)		
Short name	SnowCoverData_NortheastChina_2004-2013		
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Geographic area	The geographic area covers 38°43′12″N-53°33′28″N and 115°31′38″E-135°5′4″E, which includes provinces of Liaoning, Jilin, Heilongjiang and part of Inner Mongolia.		
Time period	Oct.1, 2003 to Sep.30, 2013		
Spatial resolution	500 m	Frequency	Daily and 8-day
Data format	ARCGIS .tif	Data Size	1.15 GB
Dataset publisher	Global Change Research Data Publishing and Repository DOI:10.3974/		
Data access and services platform	Global Change Research Data Publishing and Repository, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, http://www.geodoi.ac.cn		
	National Data Sharing Infrastructure of Earth System Sciences of China, http://www.geodata.cn		
Academic Editors	LIU Chuang, SHI Ruixiang, XU Xinliang, HE Shujin		
Data Sharing Policy	The authors of the dataset agree to publish the data here according to the Article I of Data Sharing Policy of the Global Change Data Publishing and Repository, which states that the dataset can be used freely for research, education, and decision making; any users for commercial uses should get formal permission from IGSNRR/CAS.		

dataset full name, dataset short name, corresponding author, authors, geographical region of the dataset content, year of the dataset, number of the dataset tiles, dataset spatial and temporal resolution, dataset format and size, data publisher, data sharing platform and contact information, technical editors, foundation and the data sharing policy. Table 1 below summarizes the main metadata elements of the SnowCoverData_NortheastChina_2003-2013 dataset.

3   Methodology

Time series of snow cover data covering Northeast China is conducted from the Terra MOD10A1 and Aqua MYD10A1 snow cover products[1-2]. The dataset include five sub datasets, and the processing methods are described in detail as follows.

3.1   Integrating the MODIS snow cover product

Based on MODIS daily products MOD10A1 (Terra) and MYD10A1 (Aqua), the combination methodology and process includes two steps: daily combination and flexible multiday combination, and the flow chart of processing are shown in Figure 1[3-5]:

(1) MODIS Daily Combination (MODISDC)

MODIS snow products reflect different land cover types by using different numbers[6-7]. First, original MOD10A1 and MYD10A1 are reclassified and the codes are unified to 7 categories covering snow (6), ice (5), water (4), land (3), cloud (2), polar/darkness (1), data missing/no meaning (0). Second, if the code numbers of MOD10A1 is the same as that of MYD10A1 for same pixel, the code number is assigned to the pixel of MODISDC. Third, if not the same, the code with higher priority is assigned to the pixel of MODISDC. The

priority order is "snow>ice>water>cloud> polar/darkness> data missing/no meaning".

　　(2) MODIS Flexible Multiday Combination (MODISMC)

　　Based on MODISDC maps, flexible multi- day combination are controlled by two thresholds, maximum cloud percentage $P \leqslant 10\%$ and maximum composite days $N \leqslant 8$ days. As long as either of the two parameters reaches threshold, the data process stops. The combination scheme is the same as the daily combination.

3.2 Snow cover remote sensing parameters

　　Snow cover pixels (code: 200) of flexible multiday combination is reclassified into No. 1 and others into No.0 Snow cover day (SCD) maps are calculated by overlying all the binary maps of snow cover in each hydrological year, and snow cover onset date (SCOD) and snow cover melting date (SCMD) maps are then generated from SCD. SCOD is defined as the date of first day of snowfall for each pixel using SCD between Oct.1 and Dec.1; SCMD is defined as the date of last day of snowfall for each pixel using SCD between Mar.1 and June 30[8-10].
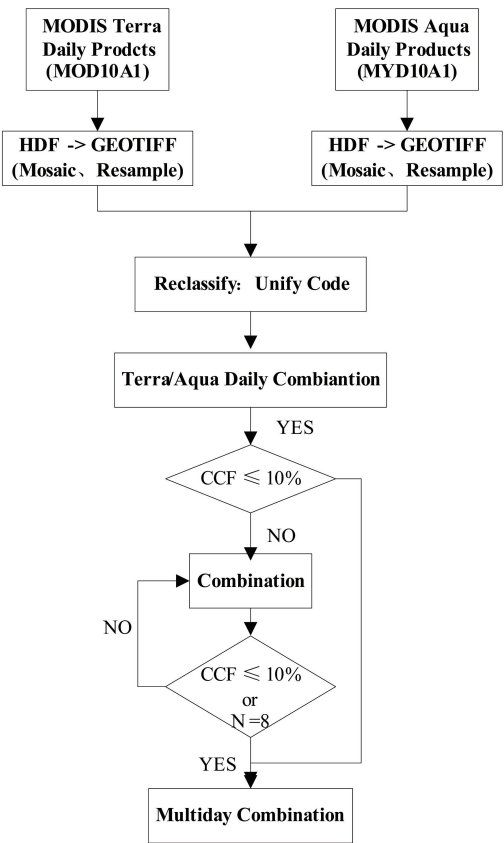

Figure 1　Flowchart of MODIS snow cover products processing (Adapted from [3-5])

4　Output data

4.1 MODIS Terra/Aqua Daily Combination (MODISDC_DByy/mm/dd/.tif)

　　MODIS Terra/Aqua daily combination starts from Oct.1, 2003 to Sep.30, 2013, 500 m in
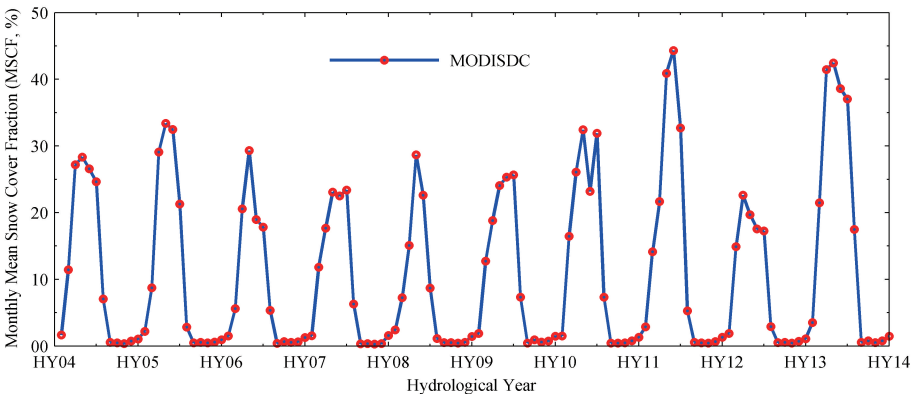

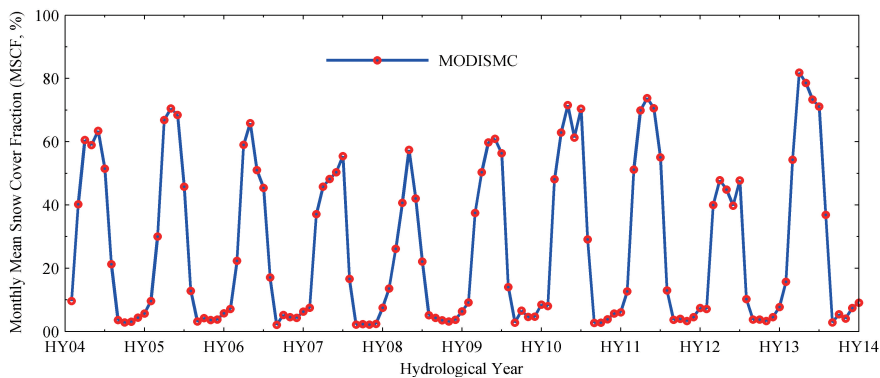Figure 2　Times series of monthly mean snow cover fraction (MSCF, %) of MODIS Terra/Aqua daily combination MODISDC

Figure 3   Times series of monthly mean snow cover fraction (MSCF, %) of MODIS flexible multiday combination MODISMC

spatial resolution, daily data. yy/mm/ dd/ represents the day on which the data observed (year/month/Julian day). The data size is 941MB, consisted of 3636 files. Figure 2 lists the timeseries of monthly mean snow cover fraction of MODISDC.

4.2   MODIS Flexible Multiday Combination (MODISMC_S yy/ mm/dd/.E yy/mm/dd/.Td.tif)

MODIS flexible multiday combination starts from Oct.1, 2003 to Sep.30, 2013, 500 m, daily to 8-day data. S yy/mm/dd/ represents stating day of data fusion (year/month/ Julian day), E yy/mm/dd/ represents ending day of data fusion, T d represents the day coverage involved. The data size is 131 MB, consisted of 528 files. Figure 3 lists the time
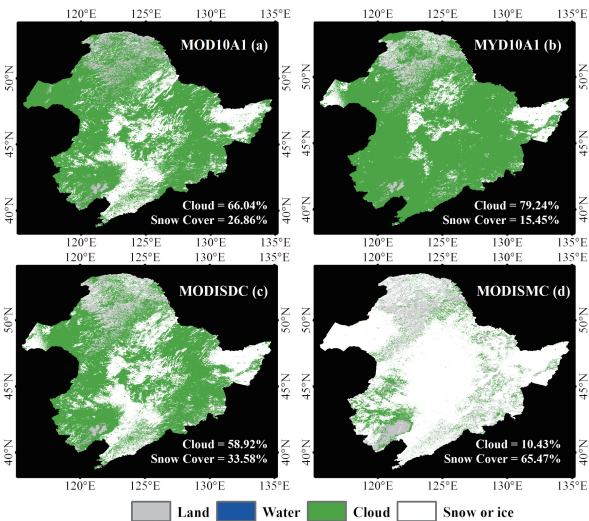

Figure 4   Cloud and snow changes of MODIS products on Jan.2, 2013

(a) Terra daily MOD10A1; (b) Aqua daily MYD10A1; (c) Terra and Aqua daily combination MOIDSDC; (d) flexible multi-day combination MODISMC ranging from December 30th, 2012 to January 6th, 2013[8]

series of monthly mean snow cover fraction of MODISMC. Figure 4 compares snow cover fraction and cloud cover fraction of four snow cover products on Jan.2, 20013.

4.3 Snow Cover Day Products (SCD_DByyyy.tif)

The products are SCD maps in each hydrological year, 500 m in spatial resolution for one year. The data size is 29.7 MB, consisted of 10 datasets. The yyyy represents the hydrological year. It is defined that a hydrological year starts from Oct.1 in the first year to Sep.30 of the next year. For example, HY2004 starts from Oct.1 of 2003 to Sep.30 of 2004. Figure 5 lists the time series of yearly mean SCD. With HY2004 as an example, the spatial distribution of SCD is shown in Figure 6.

4.4 Snow Cover Onset Date Products (SCOD_DByyyy.tif)

The products are SCOD maps in each hydrological year, 500 m in spatial resolution for
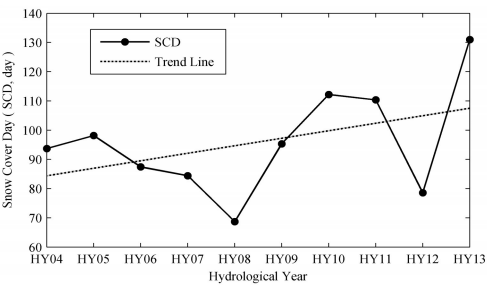
Figure 5 Time series of snow cover days (SCD) in
each hydrological year

Figure 7 Time series of snow cover onset date
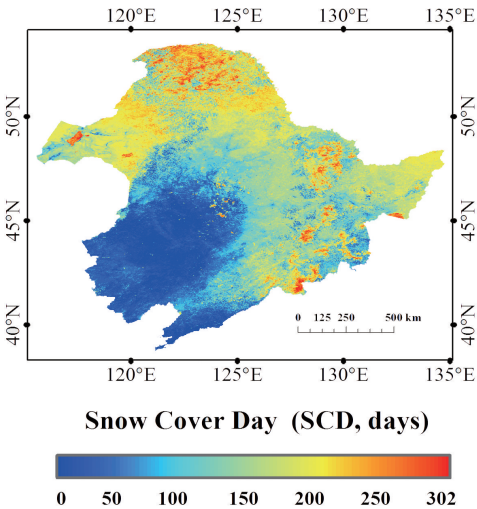(SCOD) in each hydrological year

Snow Cover Day (SCD, days)

0   50   100   150   200   250   302

Figure 6 Spatial distribution map of snow cover
days (SCD) in HY 2004

Snow Cover Onset Day (SCOD)
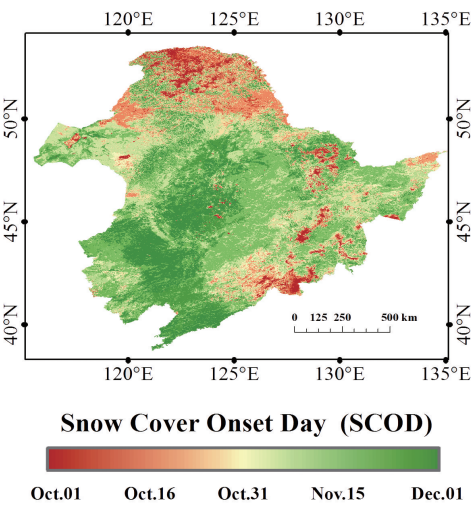

Oct.01   Oct.16   Oct.31   Nov.15   Dec.01

Figure 8 Spatial distribution map of snow cover
onset date (SCOD) in HY 2004

one year. The data size is 11.0 MB, consisted of 10 data. yyyy represents the hydrological year. Figure 7 lists the time series of yearly mean SCOD. With HY2004 as an example, the spatial distribution of SCOD is shown in Figure 8.

4.5 Snow Cover Melting Date Products (SCMD_DByyyy.tif)

The products are SCMD maps in each hydrological year, 500 m, one year data. The data size is 13.0 MB, consisted of 10 datasets. yyyy represents the hydrological year. Figure 9 lists the time series of yearly mean SCMD. With HY2004 as an example, the spatial distribution of SCMD is shown in Figure 10.

5 Data reliability evaluation

The combination algorithm adopted could reduce the influence of the cloud pixels and restore the land cover information under the cloud. The daily mean values of cloud cover fraction (CCF) and snow cover fraction (SCF) between HY2004 to HY2013 are calculated, and the inner annual distributions are shown in Figures 11 and 12, including four MODIS products. As seen in Figure 11, CCFs of MOD10A1 and MYD10A1 are rather high, especially in snowfall seasons. As seen in Figure 12, SCF increases from MYD10A1,
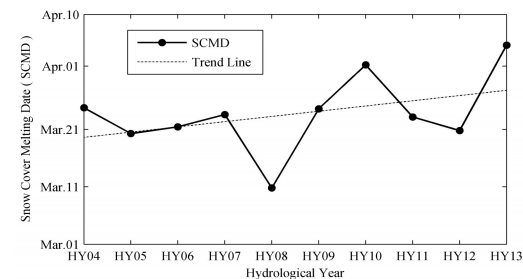
Figure 9 Time series of snow cover melting date (SCMD) in each hydrological year
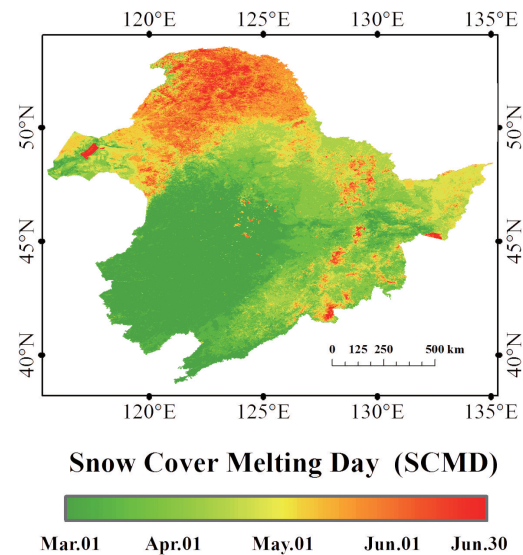

Figure 11 Inner annual means of Cloud Cover Fraction of four MODIS products: MODIS Terra (MOD10A1), MODIS Aqua (MYD10A1), MODIS Terra/Aqua Daily (MODISDC), and MODIS Terra/Aqua Multiday (MODISMC)

Snow Cover Melting Day (SCMD)

Mar.01   Apr.01   May.01   Jun.01   Jun.30

Figure 10 Spatial distribution map of snow cover melting date (SCMD) in HY 2004

Figure 12 Inner annual means of Snow Cover Fraction of four MODIS products: MODIS Terra (MOD10A1), MODIS Aqua (MYD10A1), MODIS Terra/Aqua Daily (MODISDC), and MODIS Terra/Aqua Multiday (MODISMC)

MOD10A1, MODISDC to MODISMC. Compared with in situ observations, the daily and flexible multiday combinations achieve overall accuracy of 47.51% and 76.52 % respectively, larger than 34.45% of MODIS Terra and 30.57% of MODIS Aqua under all-sky conditions[10].

6   Conclusion

This dataset with 500 m spatial resolution improved the algorithm of MODIS TERRA / AQUA original data. Compared with field measurement, the products have a higher accuracy than MODIS original products, which are fundamental data for snow cover monitoring and resource research in Northeast China.

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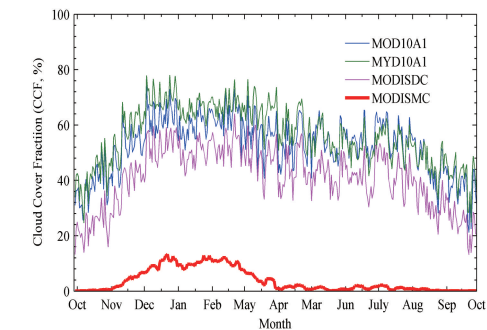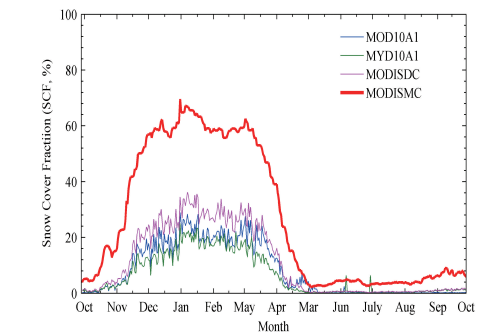[3] Gao Y, Xie H, Lu N et al. Toward advanced daily cloud-free snow cover and snow water equivalent products from

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