Accuracy assessments of MTBS and AFS 30m resolution burned area products

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Abstract

Accurate and complete data on fire locations and burned areas are important for a variety of applications. Imagery collected by the family of Landsat sensors is useful and appropriate for monitoring the extent of area burned, and provide spatial and temporal resolutions ideal for science and management applications. In recent years, the Monitoring Trends in Burn Severity Project (MTBS) provided consistent, 30 meter resolution burn severity and perimeters of fires across the United States from 1984-2015 based on Landsat imagery; Australia released its Fire Scars (AFS) products derived from all available Landsat 5, 7 and 8 images. Both 30 meter burned area products can be freely accessed from the website. However, to date, there currently lacks an independent validation to the MTBS and AFS products. In this paper, a study was performed to validate these two 30 meter burned area products. Validation data covered a range of ecosystems and fire regimes, and the acquisition time of the validation data were in different seasons and spanned from 1980s to 2010s. It was found that the accuracy of the MTBS burned area products ranged from 76.67% to 100%, and the average accuracy was 97.24 %. While the AFS product accuracy ranged from 25.71% to 100%, with average accuracy of 81.75 %.

Keywords: satellite remote sensing, Landsat, burned area.

1. Introduction

Burned area is an important parameter for carbon cycling and global change studies in satellite remote sensing community. Up to now, there is no Landsat based global burned area product yet, however, some regional Landsat burned area products have been publicly released

in recent years. Australia released its Fire Scars (AFS) products derived from all available Landsat 5, 7 and 8 images using time series change detection technique⁽¹⁾. Fire scars are automatically detected and mapped using dense time series of Landsat imagery acquired over the period 1987 – 2015 and the AFS product only covers the state of Queensland, Australia. Monitoring Trends in Burn Severity (MTBS) project, sponsored by the Wildland Fire Leadership Council (WFLC) provided consistent, 30 meter resolution burn severity data and fire perimeters across all lands of the United States from 1984-2015⁽²⁾. MTBS products are generated based on the difference of Normalized Burned Ratio (NBR) calculated from pre-fire and post-fire images; products generation relies on manually mapping. The Burned Area Essential Climate Variable (BAECV), developed by the U.S. Geological Survey (USGS), produced Landsat derived burned area products across the conterminous United States (CONUS) from 1984-2015, and its products have been released in April 2017⁽³⁾. Main differences between the MTBS and BAECV is the BAECV products are automatically generated based on all available Landsat images. Shortly after the release of the BAECV products, Vanderhoof et al.⁽⁴⁾ performed a validation to this product and gave an overall evaluation of its accuracy. However, to date, there currently lacks an independent validation to the MTBS and AFS products. This study is designed to carry out accuracy validation to these two 30 meter burned area products.

2. Methodology description

While Landsat is often used to validate the coarse resolution products (e.g. AVHRR or MODIS), for Landsat science products, no such regularly collected, long-term source of higher resolution satellite imagery exists,

complicating the validation of these products. In this study, accuracy validation were performed in support of random sampling and expert decision. Both the MTBS and AFS products are monthly products. To verify the MTBS and AFS products, 29 and 5 World Reference System, version 2 (WRS2) path/rows were selected across the CONUS and the state of Queensland, Australia, respectively. Path/row locations were spatially distributed in order to capture major ecosystems and differences in their fire regimes, with more path/rows selected in areas where fires more frequently occur (the under-laid burned area distribution map were generated by compositing the monthly MTBS and AFS products). The acquisition time of the path/rows were in different seasons and spanned from 1980s to 2010s. Sample points were collected randomly across the Landsat imagery. One half of the random sampling points locations were located within MTBS/AFS burned area perimeters and attributes from each fire were assigned to the points. The other half sampling points were randomly located outside of the burned area perimeters. Sampling points were interpreted by three independent experts who have abundant experiences in burned area recognition and the points were identified as burned if at least two of the three experts agreed.

Fig.1 selected path/rows for MTBS product

Fig.2 selected path/rows for AFS product

3. Results and discussion

Accuracy validation results of the MTBS and AFS products are displayed in table 1 and table 2, respectively. As table 1 shows, accuracy of the MTBS burned area

products ranged from 76.67% to 100%, with the average accuracy of 97.24 %. We can learn from table 2 that accuracy of the AFS burned area products ranged from 25.71% to 100%, and the average accuracy was 81.75 %. Goodwin and Collett⁽¹⁾ developed the AFS algorithm for mapping fire history captured in Landsat time series across Queensland, Australia, and they also conducted accuracy evaluation to their algorithm. The evaluation results demonstrated an average producer's accuracy of 85% (range of 28 to 100% for individual images) and average user's accuracy of 71% (range of 4 to 99% for individual images). MTBS products were produced based on analysis of the difference of Normalized Burned Ratio (NBR) calculated from pre-fire and post-fire images; the MTBS dataset relies on manually mapping and human intervention, and achieved a high accuracy. Algorithm of the AFS product is fully automatic. Despite the advantages, automation can be expected to introduce errors in burned area generation, which may result to the lower accuracy and wider accuracy range of the AFS product. For automated approach, a possible way to improve its accuracy is using supervised machine learning approach, like the USGS Landsat BAECV burned area product, which achieved a relatively high and stable accuracy⁽⁴⁾. While such approach relies heavily on training samples as the primary source of observed burned and unburned areas to train and evaluate the algorithm, these training samples should have similar spatial resolution with the Landsat data. It is difficult to collect a sufficient number of high-quality training reference samples, especially for a large study area or long temporal studies.

Algorithm of the AFS product is fully automatic and some fixed thresholds were used in the production. When using fixed thresholds method, Landsat DN value must be converted to land surface reflectance or land surface temperature to ensure comparability between Landsat data acquired from different Landsat sensors, different places, and different dates. For AFS product, Landsat time series imagery was converted from DN to a standardised surface reflectance using the method of Flood et al.⁽⁵⁾. In this method, atmospheric effects due to high aerosol loadings were not removed as no operational method was available for accurately estimating aerosol loading/haze/smoke over much of Australia. However, aerosol absorption and scattering exert serious influences in the conversion process from satellite DN to land surface reflectance. Furthermore, for AFS algorithm, the DN stored in thermal infrared band 6 (10.40–12.50 μm) was only converted to

top-of-atmosphere brightness temperature, and no atmospheric correction for the thermal band was applied. Inaccurate preprocessing may be another reason for the relatively low accuracy of the AFS product. When the fixed threshold method is employed to derive large scale and long temporal burned area product, Landsat data must be processed to acquire real land surface reflectance (or land surface temperature) by considering a variety of influencing factors, including atmospheric scattering and absorption, topographic variations (shadow, slope, etc.), and Bi-Directional Reflectance Distribution Function (BRDF) effects. Landsat higher level science data products project launched by USGS aims to provide systematically consistent global scale land surface reflectance product, which may be a better choice as inputs to the threshold based burned area extraction algorithm.

Table 1. Validation results of the MTBS products

Acquisition time	Path/row	Points Number	Accuracy
Aug.1991	016041	50	100.00%
Apr.1992	032038	46	100.00%
Aug.1992	037032	41	100.00%
Aug.1992	044028	42	97.62%
Oct.1992	018034	43	100.00%
Oct.1992	029038	48	100.00%
Oct.1992	032034	47	100.00%
Oct.1992	038029	44	100.00%
Nov.1992	041036	45	100.00%
Aug.1996	040030	50	98%
June 1998	038036	41	100%
Aug.1998	043034	46	93.48%
Aug.1998	045030	50	100%
Sep.1998	024035	49	100%
Sep.1998	040030	47	100%
Sep.1999	041032	50	98%
Sep.1999	042032	50	100%
Sep.1999	029034	30	76.67%
Sep.1999	040032	50	96%
Aug.2000	040029	50	98%
Apr.2007	032038	48	100.00%
June 2007	037032	50	100.00%
Aug.2007	040031	50	94%
Aug.2007	039031	50	98%
Aug.2007	044028	47	100.00%
Aug.2007	018034	46	100.00%
Sep.2007	038029	45	100.00%

Oct.2007	032034	48	100.00%
Oct.2007	029038	48	100.00%
Nov.2007	041036	49	100.00%
Feb.2008	016041	49	98.00%
June 2011	035037	50	94%
June 2011	028034	50	84%
July 2011	039034	30	90%
Mar.2013	038036	50	100%
July 2013	045030	53	100%
Sep.2013	024035	53	100%
Sep.2013	040030	47	100%
Sep.2013	043034	56	100%
May 2014	035028	30	96.7%
May 2014	028033	50	96%
Aug.2014	046031	100	97%
		Average	97.24 %

During the validation process of this study, sampling points were interpreted by three independent experts who have abundant experiences in burned area recognition and the points were identified as burned if at least two of the three experts agreed. A similar method was used by Vanderhoof et al.⁽⁴⁾, and they found that errors could be minimized by using the rendition of the dataset in which pixels were mapped as burned if at least two of the three analysts agreed.

For satellite data product validation, a commonly used method is to employ higher spatial resolution satellite data. For example, in order to validate MODIS derived data product (1KM spatial resolution), Landsat satellite data is commonly used. Considering the long temporal range of Landsat data (1970s-present) and moderate to high spatial resolution, it is impossible to find regularly collected, long-term source of higher resolution satellite imagery to validate Landsat derived burned area product. Although the validation process was conducted by three independent experienced experts with great caution. However, relying on Landsat for both product generation and validation limits our ability to assess inaccuracies imposed by the satellite sensor itself, such as radiometric calibration accuracy, spectral band settings, geolocation and mixed pixels⁽⁶⁾.

4. Conclusions

Accuracy assessments of the MTBS and AFS 30m resolution burned area products were performed in this

study. The MTBS product relies on manually mapping, and achieved a high accuracy, with accuracy ranging from 76.67% to 100% and average accuracy of 97.24%. Algorithm of the AFS product is fully automatic and without human intervention. Despite the advantages, automation can be expected to introduce errors in burned area generation, and accuracy of the AFS product was lower than MTBS, with accuracy ranging from 25.71% to 100% and average accuracy of 81.75 %.

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Table 2. Validation results of the AFS products

Acquisition time	Path/row	Points Number	Accuracy
Sep.1987	091078	50	83.33%
Sep.1987	097074	39	100.00%
Sep.1987	096079	42	100.00%
Oct.1987	098076	38	100.00%
Apr.1988	098069	50	86.00%
Aug.1990	098069	30	76.67%
Oct.1991	098069	41	80.49%
Oct.1993	098069	40	65.00%
June 1994	091078	30	100.00%
Aug.1994	096079	44	100.00%
Aug.1994	097074	37	100.00%
Aug.1994	098076	41	100.00%
July 1995	098069	43	53.49%
Sep.1997	098069	40	50.00%
June 2004	091078	27	96.30%
July 2004	098069	35	25.71%
July 2004	097074	37	100.00%
Aug.2004	096079	31	100.00%
Sep.2004	098076	44	100.00%
Sep.2005	098069	45	68.89%
Sep.2007	098069	39	53.85%
June 2009	098069	38	47.37%
Feb.2011	098069	38	81.58%
June 2011	098069	40	50.00%
Jan.2013	098069	41	85.37%
July 2014	091078	28	100.00%
Aug.2014	098069	40	75.00%

Aug.2014	096079	33	100.00%
Aug.2014	097074	40	100.00%
Aug.2014	098076	41	100.00%
		Average	81.75 %

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