Effects of segment length on burned forest classification with ICESat-2 Data

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1. Introduction

Forests store a huge amount of carbon and play a critical role in controlling global carbon balancing and cycling. However, increased frequency and extent of fires are a growing concern (Cattau et al., 2020; Liu and Yang, 2020) and threaten forest health as well as the sustainability of terrestrial ecosystems. Fires have become more severe and destructive in response to a warming climate with many examples such as the 2018 California wildfire, the 2019 Amazon forest fire, and the 2020 Australia wildfire. These extreme fire events emphasize the necessity of fire occurrence monitoring and forecasting over space and time. Accurately classifying burned forest is critical for the analysis of fire patterns and carbon emissions as well as understanding the effects of climate change on ecosystems.

NASA's Ice Cloud and land Elevation Satellite-2 (ICESat-2) mission provides global photon counting LiDAR data with a 14 m footprint and the along track sampling distance of 0.7 m, which come with three pairs and offer new opportunities for burned forest classification. Each pair contains a strong beam and a weak beam distinguished by a designed energy ratio of 4:1. The ICESat-2 mission provides datasets like the geolocated photon data (ATL03), which comprises precise latitude, longitude and elevation of each photon point where a photon interacts with land surface. By kicking out noises and classifying photons, Neuenschwander and Pitts (2019) produced the Land and Vegetation height product (ATL08), which comprises estimated terrain and canopy height measurements at 100 m segments along tracks. The ATL08 product, with a nominal spatial resolution of 100 m by 14 m, provides various canopy and terrain related metrics in each segment such as mean canopy height and max canopy height. Liu et al. (2020) leveraged ATL08 data to classify burned forest along ICESat-2 tracks with an overall accuracy of up to 83%. However, few studies investigate the effects of segment length on burned forest classification when using ICESat-2 data.

Previous studies were focused on a specific spatial resolution when using LiDAR data in fire analysis. It must be noticed that spatial resolution has significant impacts on land cover classification (Roth et al., 2015) and canopy structure characterization. However, few studies have fully investigated the effects of spatial resolution when classifying burned forest with LiDAR data. In this study, we sought to analyse the effects of spatial resolution on burned forest classification based on ICESat-2 photon counting data.

2. Data and methods

2.1 Study area and data

The Carr fire complex, containing the Carr fire and the Delta fire (Figure 1d), in the temperate forest in northern California was employed. In this study, the ATL03 data whose ground track go through the burned areas were downloaded from the National Snow & Ice Data Center (NSIDC). To avoid interference of regrowth in burned regions, only data collected after fire events and in the same year of the fires were selected. Due to cloud obstructions, only one ground track was available (Figure 1d). ATL08 data corresponding to the selected ATL03 products were also downloaded to provide classification labels (terrain, canopy, and noise). Pre-fire and post-fire Sentinel-2 data (Figure 1a and b) were also downloaded as ancillary data. The forest map (Figure 1c) was obtained from ISODATA classification using pre-fire Sentinel-2 image, with an overall accuracy of 87% and the kappa of 0.74. The fire perimeters were downloaded from the CalFire (https://www.fire.ca.gov/) and rasterized to 10m to produce the burn map (Figure 1d).

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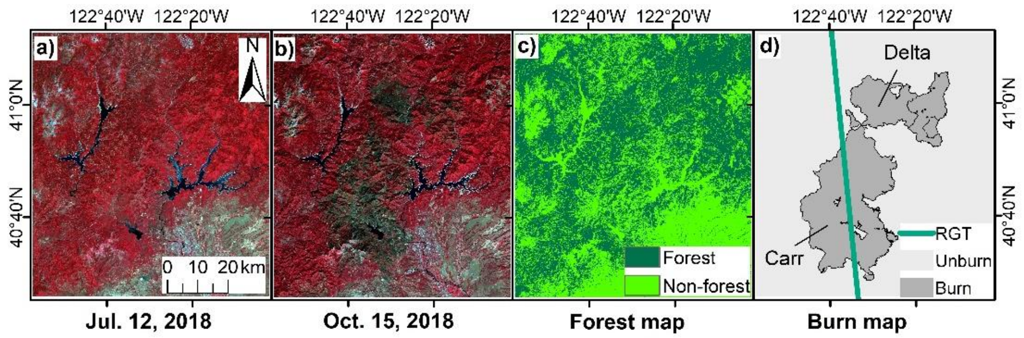

Figure 1. Sentinel-2 data: (a) pre-fire image, (b) post-fire image, (c) forest map and (d) burn map.

2.2 Segments classification

ATL03 photon points were summarized at different segment lengths, i.e. 10m, 30m, 60m, 100m, 200m, and 250m, producing 26 LiDAR metrics (Figure 2). If over 90% of Sentinel-2 pixels within a segment were forest type, this segment would be defined as a forest segment. In the same way, the forest segments were overlaid with the corresponding burn map. If over 90% of pixels within a forest segment were burned, this forest segment would be defined as a burned forest segment. Conversely, if over 90% of pixels were unburned, this forest segment would be labelled as an unburned forest segment. The Random Forest classification method was further employed to classify burned segments of ICESat-2 data from unburned ones. We chose the Random Forest method because it has no assumptions on data distributions (non-parametric) and can process high-dimensional data.

3. Results and Discussion

In Figure 2, average values of canopy metrics are changing along with spatial resolutions in both burned and unburned samples (Figure 2), which means spatial resolutions can influence canopy structures we detected. For instance, the maximum canopy height (max) are increasing when spatial resolutions get coarser, which is due to biomass consumption and sparser canopy after the fire. The average number of canopy photon points (num_cpy) in both burned and unburned samples are also increasing along with spatial resolutions. Furthermore, burned samples have lower numbers of canopy photons than the unburned ones.

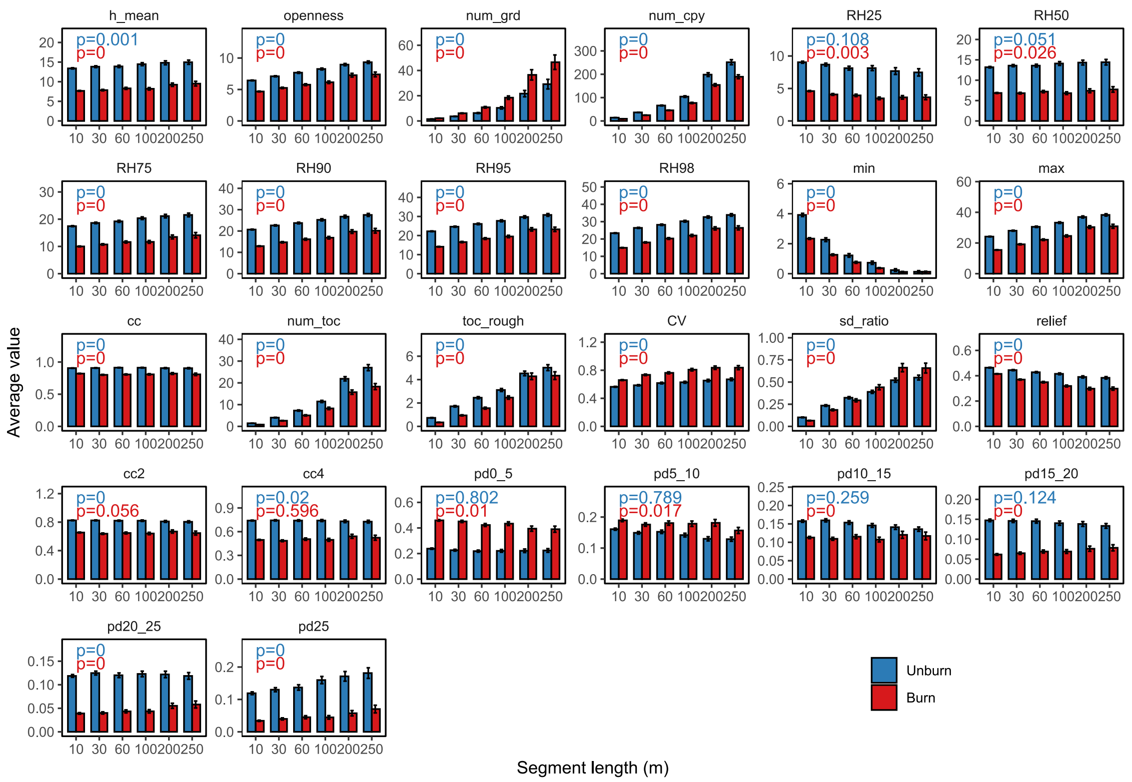

Figure 2. The average value of each canopy related metric in the temperate forest in California using strong beams, where the error bars are standard errors.

The classification accuracies of segments from both strong beams and weak beams are increasing along with spatial resolutions (Figure 3a) and saturate at 100 m segment length. It is worth noting that, samples of weak beams always have lower accuracies than those of strong beams. This is due to lower point density since energy in weak beams is only ¼ of that in strong beams. With lower point density, it is more difficult to distinguish real ground points, canopy points, and noises, causing more errors in metrics calculation and burned forest classification. Figure 3b shows the distribution of burned and unburned forest segments at 100m using strong beams, whose classification accuracy is 81.57%. The distribution of segments are comparable with the reference burn map.

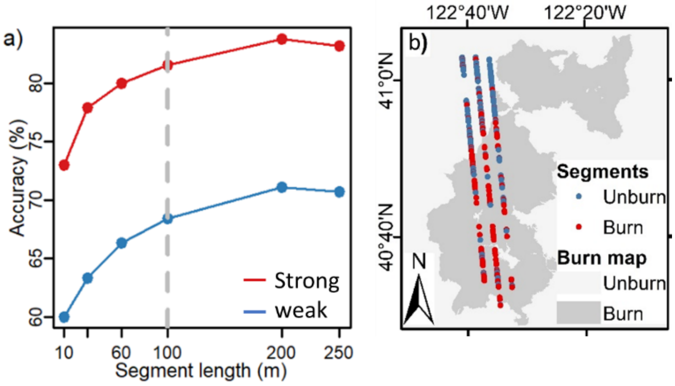

Figure 3. Burned forest classification: (a) classification accuracy at different segment lengths and (b) distribution of classified segments at 100m length using strong beams.

4. Conclusions

This study analyses the effects of segment length (spatial resolution) on burned forest classification using spaceborne LiDAR data. ICESat-2/ATLAS photon counting data were summarized at different segment length, e.g. 10 m, 30 m, 60 m, 100 m, 200 m, and 250 m, to match commonly used spatial resolutions. Results show that canopy structure characterization is significantly influenced by segment length. The classification accuracies of burned forest are increasing along with coarser spatial resolutions and saturate at 100 m segment length. Moreover, accuracies of burned forest classification based on strong beams are higher than those of weak beams. These findings demonstrate that spatial resolution will influence canopy characterization and fire monitoring. As more spaceborne LiDAR data are available and accumulating, e.g. ICESat-2 data and GEDI data, further research can explore more applications of LiDAR data in fire management and extend the use of LiDAR data to applications in ecological recovery and carbon dynamics.

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