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FOREST SERVICE REMOTE SENSING TIPS

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Implementation of a Near Real-Time Burned Area Detection Algorithm Calibrated for VIIRS Imagery

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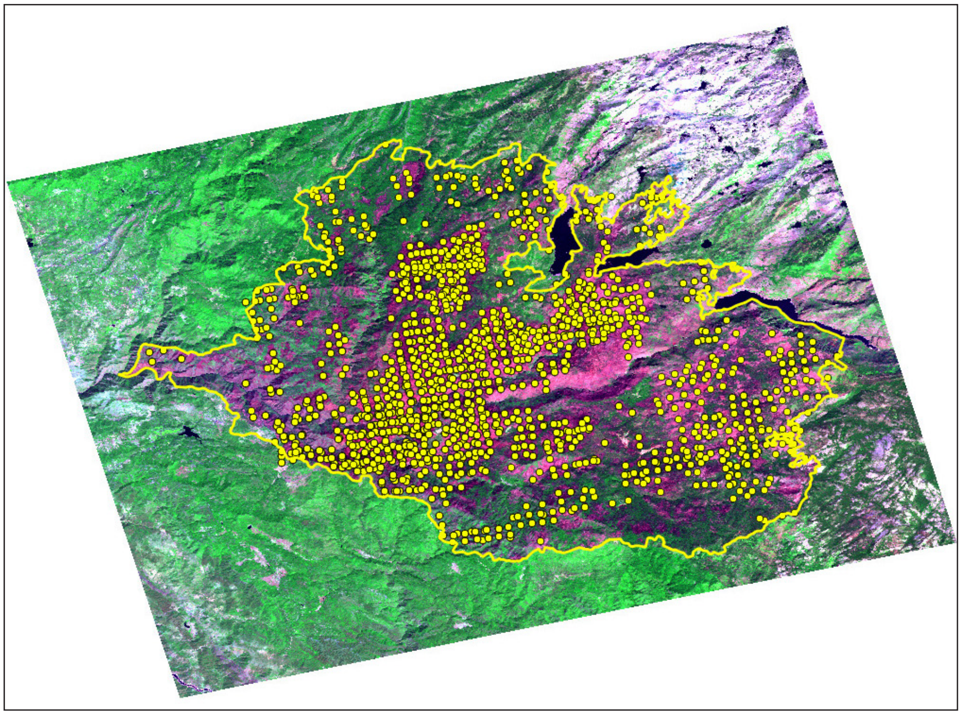

Figure 1— A Landsat shortwave infrared composite showing a burned area in purple. Each yellow dot represents a VIIRS pixel the algorithm classified as burned. For comparison, the yellow perimeter represents the burned area as determined by the Monitoring Trends in Burn Severity (MTBS) program.

Summary

There is a need to implement methods for rapid burned area detection using a suitable replacement for Moderate Resolution Imaging Spectroradiometer (MODIS) imagery to meet future mapping and monitoring needs (Roy and Boschetti 2009, Tucker and Yager 2011). The Visible Infrared Imaging Radiometer Suite (VIIRS) sensor onboard the Suomi-National Polar-orbiting Partnership satellite (S-NPP) presents an alternative raw data source (www.nsof.class.noaa.gov) with resolutions comparable to that of MODIS (Boken and others 2010, Murphy and others 2001, Tucker and Yager 2011), and it has already proven capable of standing in for MODIS in active fire detection work (Schroeder and others 2014). Given the specifications of the sensor, it should be possible to replicate the output from MODIS-based burned area detection models using VIIRS imagery (figure 1). With sponsorship from the Remote Sensing Steering Committee (RSSC) and additional funding from the Missoula Fire Sciences Laboratory (FiSL), we have developed an application that applies a MODIS-based model for burned area detection to VIIRS imagery. Given current data access timelines, a burned area product can be delivered shortly (within a few hours) after the S-NPP/VIIRS afternoon overpass. Using the MODIS algorithm as a foundation, VIIRS-specific thresholds have been calibrated to create VIIRS-derived burned area products. These data will soon be made available on the U.S. Department of Agriculture, Forest Service, Remote Sensing Applications Center Active Fire Mapping website.

Introduction

The burning of biomass emits significant amounts of greenhouse gases, particulate matter, and ozone precursors into the atmosphere (Ito and Penner 2005, Michel and others 2005, van der Werf and others 2006), which has significant negative effects on public health at multiple scales (DeBell 2004, Morris and others 2006, Mühle and others 2007, Phuleria and others 2005, Sapkota and others 2005, Spracklen and others 2007). In order to mitigate these impacts, state agencies require daily air quality forecasts to minimize exposure risk (Urbanski and others 2009b). Air quality analyses are also necessary to identify fire related "exceptional events"—exceedances of National Ambient Air Quality Standards due to smoke. In addition to air quality forecasting, burned area maps are invaluable tools used by emergency response teams consisting of professional biologists and resource staff. These teams effectively quantify and assess threats to life, property, and natural resources in the days and weeks immediately following a fire. Burned area maps can also be used to assess estimates of carbon loss (especially when using burned area products that specify the severity of fire). Furthermore, burned area maps assist field teams, giving them explicit detail regarding areas recently affected by fire and improving efforts to dispatch personnel to the necessary field locations. In general, post-fire efforts are interagency, involving federal and state governments as well as private organizations, and burned area map products are frequently in high demand within the fire community.

The availability of timely, comprehensive, and consistent burned area extent estimates can improve fire and forest management decisions (Giglio and others 2006, Seiler and Crutzen 1980) and lead to better emission estimates and subsequent air quality forecasts (Conard and others 2002, Wiedinmyer and others 2006). While in most cases field-collected burned area data are not readily available for emissions modeling, burned area estimates can be derived from remotely sensed data and used as an interim solution with relative ease (Giglio and others 2006). MODIS imagery can provide robust burned area products (Urbanski and others 2009a); however, due to the aging nature of the MODIS sensors, a suitable alternative is required (Roy and Boschetti 2009, Tucker and Yager 2011). While established methods for a MODIS-derived burned area product exist, a tool is not currently available. Rather than invest in an aging system, this project has developed a VIIRS-based tool to create a burned area product, providing a longer-term solution.

The VIIRS sensor collects data in spectral bands similar to those of MODIS, and many MODIS-based workflows can be adapted to VIIRS imagery (figure 2). Consequently, VIIRS can provide continuity of services and data as well as increase the longevity of a variety of programs.

Through collaboration between the USFS Remote Sensing Applications Center (RSAC) and the Missoula Fire Sciences Laboratory (FiSL) and with funding from both the USFS Remote Sensing Steering Committee and FiSL, a tool has been developed to create a near real-time burned area product using VIIRS data. This tool not only creates a much-needed burned area data product in a timely and efficient manner for monitoring work but also serves as a proof of concept for the viability of VIIRS data as a replacement for MODIS data in burned area mapping workflows.

VIIRS Model

The VIIRS sensor is one of five instruments on the S-NPP platform and collects imagery across 22 bands ranging from 0.412 µm to 12.01 µm at resolutions ranging from 375 m to 750 m. Each ground location is imaged at least once daily. In addition to the 22 spectral bands, VIIRS also provides a thermal-derived active fire detections data product (a standard data product). The algorithm implemented for this project detects burned area extent using a combination of:

- VIIRS spectral data
- VIIRS active fire detections product (375 m and 750 m)

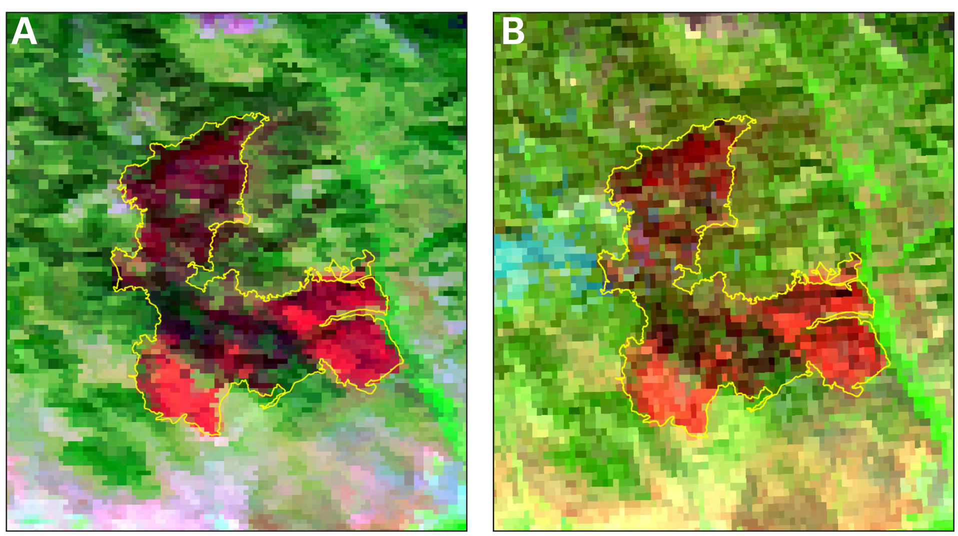

Figure 2—Image *(A)* shows MODIS imagery of the Beaver Creek Fire displayed in a shortwave infrared composite, while *(B)* shows VIIRS imagery of the same fire. MODIS and VIIRS have very similar bands and highlight features similarly in terms of spectral and spatial characteristics, making VIIRS an ideal replacement for MODIS in many existing workflows.

Basic Principles

The goal of the model is to classify pixels in VIIRS reflectance data as either burned or unburned using a combination of spectral thresholding and the VIIRS active fire detections product. Processing of the model is performed by a Python script linked to a PostgreSQL/PostGIS geodatabase. The model is executed by running the Python script and specifying an initialization file, which contains all of the variables necessary to run the model—input data folder, spectral thresholds, temporal and spatial validation parameters, and output data location. The output product is a vector dataset delineating those areas estimated as burned area.

Basic Workflow

Once the initialization file is read, a Python script processes the listed imagery. Each raster is converted to an array, and pixel values are converted to reflectance. Band-specific thresholds are applied to discriminate between burned and unburned pixels. If a pixel meets all threshold criteria, it is considered a candidate burned area, and its location is pushed to an empty geodatabase. VIIRS active fire detections require no candidacy step and are confirmed as burned area by default – they are also added to the geodatabase.

A secondary screening process filters each of the candidate burned area pixels using two additional criteria: spatial and temporal proximity to confirmed fires. Temporal proximity specifies a time window within which a burned area must fall, and the spatial proximity specifies the maximum allowable distance a burned area can be from a confirmed active fire. If a burned pixel falls within the temporal and spatial ranges (which are specified in the initialization file), that pixel is confirmed as a burned area.

The final step groups active fire detections and confirmed thresholded pixels into individual fire events. The data is then exported as a shapefile and is ready for the user to download. Figure 3 provides a flow chart of algorithm execution.

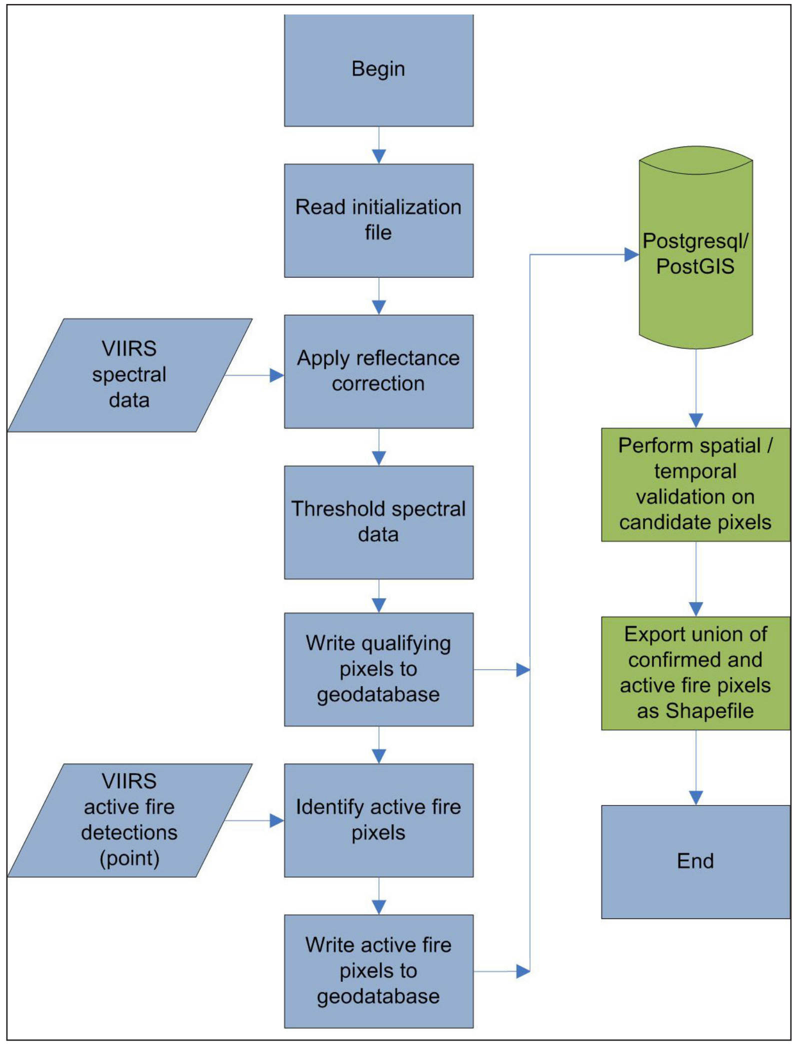

Figure 3—The burned area detection workflow involves reading an initialization file, opening and correcting the imagery, applying spectral thresholds, pushing the burned areas and VIIRS active fire detections to a database, and exporting the fire events to a shapefile. Processes shown in blue are performed in Python, processes shown in green are performed in Postgresql/PostGIS.

Calibration and Evaluation

The algorithm applies nine thresholds to three spectral bands to classify VIIRS imagery as burned areas. Changing the thresholds from the original MODIS values (even slightly) caused dramatic changes (false detection, or commission error) in four of the variables. As a result, these thresholds were left at or close to the values in the original MODIS model. An iterative brute force method was used to determine the optimal reflectance threshold values for the remaining five spectral variables in the VIIRS near real-time burn detection algorithm. To determine the optimal threshold, for every combination of parameter values, the entire test dataset was reprocessed, and the resultant burned areas were evaluated using three figures of merit. Outputs were compared against Monitoring Trends in Burn Severity (MTBS) data, which are derived from higher resolution imagery (Landsat, 30 m resolution) and we are accepting as a truth dataset—figure 4 provides an example of the performance of the model overlaid on the Beaver Creek Fire (2013). Calibration of these model parameters took nine iterations (totaling 2,187 runs).

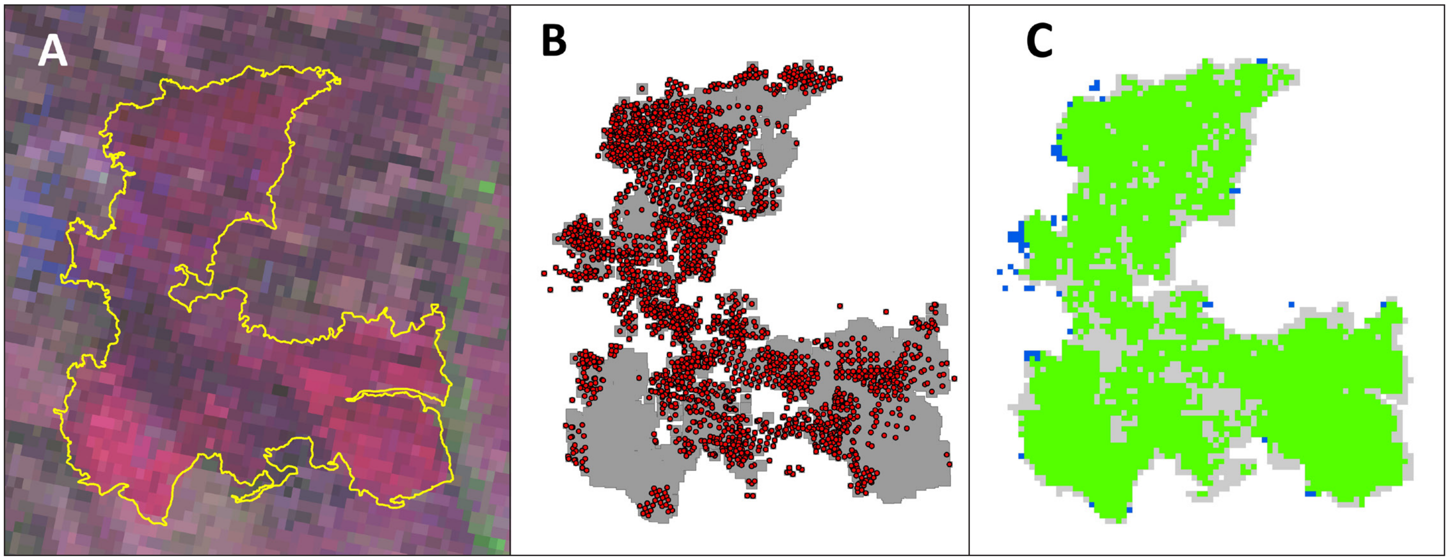

Figure 4—The yellow outline *(A)* shows the extent of the Beaver Creek Fire as mapped by MTBS on top of VIIRS imagery, which is displayed in a shortwave infrared composite. *(B)* shows the coverage of VIIRS pixels thresholded as burned area in gray with VIIRS active fire detections overlaid as red points, and the combination of these two datasets represents all locations that the VIIRS model interprets as burned areas. *(C)* shows a comparison of MTBS and VIIRS-derived outputs, where green pixels represent area estimated as burned by both MTBS and the VIIRS algorithm, gray pixels represent area estimated as burned by MTBS but not by the VIIRS algorithm *(VIIRS algorithm omission)*, and blue pixels represent area estimated as burned area by the VIIRS algorithm but not by MTBS *(VIIRS algorithm commission)*.

The three approaches, or figures of merit, used to evaluate the VIIRS near real-time algorithm were labeled "spatial" (FOM1), "event" (FOM2), and "zone" (FOM3). The "spatial" and "event" approaches were based on the event reference database. For these approaches, the event reference database and VIIRS burned area were resampled to a 375 m grid. VIIRS burned area pixels that were not within 5 km (the spatial proximity threshold) of a reference fire event were excluded from the evaluation. In contrast, the "zone" approach employed the zone reference database and included all valid VIIRS burned areas within the evaluation zones. The figures of merit used in the optimization of the surface reflectance thresholds are described in greater detail in the materials included with the tool documentation.

The model was found to perform best in forest areas and poorest in grassland areas (10% omission versus 16% omission). The higher level of omission in rangeland fires may be attributable to fast moving fires with little post-fire combustion that grow considerably over the 12 hours between VIIRS over passes. In addition to outperforming grasslands in terms of omission error rate, the forest class also had a lower commission rate (20% compared to grasslands' 30%) and a higher FOM1 value (73% compared to grasslands' 60%). Areas with higher severity burns (according to MTBS data) are classified by the model as burned areas more accurately than lower severity burns are. It should be noted that none of the fires missed using the VIIRS algorithm were detected by the MODIS algorithm.

Conclusions

VIIRS data present a robust and viable solution for replacing MODIS data in burned area mapping workflows. VIIRS collects data in similar bandwidths and at similar temporal intervals as compared to MODIS, making it an ideal replacement for the aging sensor. The near real-time burn detection algorithm, modified for use with VIIRS, is a simple, easy-to-implement Python script. At present, the user must set up and run the script on their own—contact surbanski@fs.fed.us for more information. There are plans to operationalize the script, and output burned area products are expected to be hosted at the USFS Active Fire Mapping Program website (https://fsapps.nwcg.gov/afm/) in time for the 2017 fire season.

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