

# Processing Smoke Plume Products from the Moderate Resolution Imaging Spectroradiometer (MODIS) within a Workflows Environment

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**Abstract – A national web-based service is being designed to develop generic software tools to improve access to Australian satellite data. This remote sensing workflow, run in a High Performance Computing (HPC) environment, will allow end-users to easily access, process and analyse satellite data for their individual environmental research needs.**

**Various products will be made available through the workflow including smoke plume products. The impact of smoke plumes on urban areas leads to respiratory problems in the population and, accordingly, building statistics on these events is of interest. Case studies will be presented to showcase the smoke detection methods being used and some of the forms of output available through the remote sensing workflows project.**

**Keywords:** Smoke Detection, Plume, Satellite, Workflow, Remote Sensing, MODIS

## 1. INTRODUCTION

A team comprising satellite remote sensing experts at Curtin University and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) are collaborating with experts at iVEC and the Centre for Comparative Genomics at Murdoch University to devise a remote sensing workflow. RS-YABI (described in Fearn et al., 2011) will access the large existing satellite data archive available for Australia and its surrounding oceans and establish itself as an easily accessible and important tool for users interested in environmental satellite information. Available RS-YABI products currently include dust detection, surface temperatures (land and ocean), vegetation indexes, ocean attenuation coefficients, chlorophyll *a* measurements, and smoke plume detection.

According to a report by the Australasian Fire and Emergency Service Authorities Council (AFAC), there are expected future increases in bushfire frequency and severity in Australia where effects will penetrate further into urban areas. (Hunter and Pearman, 2010). Studying the impacts on population health due to exposure to bushfire smoke is of increasing importance and by determining ways to correctly differentiate bushfire derived particulates from other aerosols and cloud particles in satellite imagery, smoke plume trajectory and intensity can be more accurately monitored.

## 2. SMOKE PLUME DETECTION METHODS

Differentiating smoke plume pixels from surrounding scene elements in a satellite image requires the application of several threshold-based tests. Each test works with specific spectral

bands that are sensitive to the presence of scene elements such as smoke, cloud, bright surface features or water. Xie et al., (2010) outlines various band ratio tests, brightness temperature difference tests and other band tests in the process to achieve a smoke detection image. The tests are based on threshold values that should be individually tailored to different regions.

The types of fuel being burnt in a region will affect the composition of the resultant bushfire smoke plume and the absorbing constituents in the plume will impact its spectral signature. Using hyper-spectral measurements, transmission values through smoke plumes will provide additional information to aid in focusing a regional smoke detection scheme for multi-spectral instruments, such as the Moderate-resolution Imaging Spectroradiometer (MODIS).

## 3. WORKFLOW OUTPUTS

RS-YABI will generate products from satellite data and deliver a variety of outputs to the end user. Imagery of the processed data will be made available along with the function to extract data and create transect plots. Processing multiple sequential files will allow for the generation of time series data plots and movie loops of imagery. Additional output will be incorporated as required based on consultation and requests by end users.

Two case studies have been chosen to showcase the application of our smoke plume detection scheme and the output available from RS-YABI.

Figure 1 shows the smoke plume of a bushfire that began on the 13<sup>th</sup> of December 2009 in a forested area 20km east of Harvey, Western Australia. The fire burnt through approximately 11,000 hectares of state forest over several days. The image used in this study was taken from MODIS on the morning satellite (*Terra*) overpass on the 15<sup>th</sup> of December 2009. In the two days after the commencement of the fire, the smoke plume had drifted in a northerly direction over land before heading offshore. Figure 1a shows a thick central plume emanating from the fire source. As the plume travels further from the ignition point, the plume disperses. After applying the threshold tests for smoke plume detection, the resultant smoke plume mask was generated and is shown in Figure 1b. The smoke plume mask captures most of the smoke plume evident from this event.

The fire in Figure 2 began on the 10<sup>th</sup> of January 2011 in the Lake Clifton area of Western Australia. Burning through approximately 2000 hectares, the fire destroyed 10 properties. The MODIS image used in this study was taken from the afternoon satellite (*Aqua*) overpass on the same day. The smoke plume travelled straight offshore from the seven ignition

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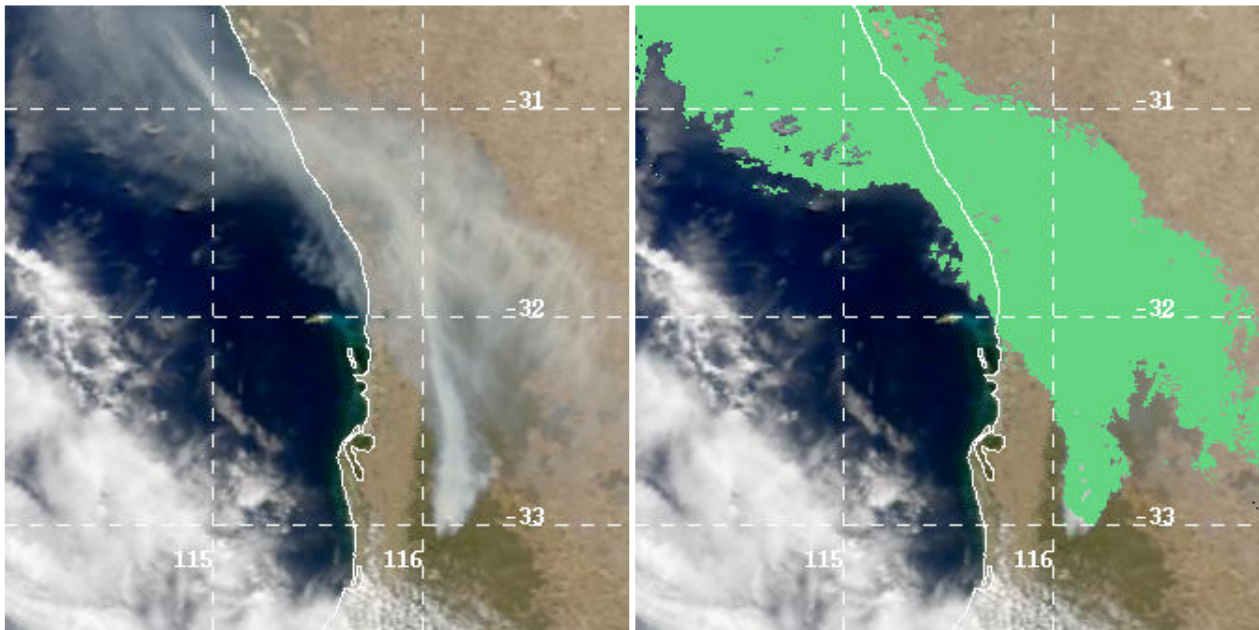


Figure 1. a) A true colour image taken from MODIS *Terra* on the 15<sup>th</sup> of December 2009 (0215 UTC) showing the Harvey bushfire smoke plume drifting north over land before heading over the coastline. b) A true colour image with the multi-threshold tested smoke plume mask overlaid in green.

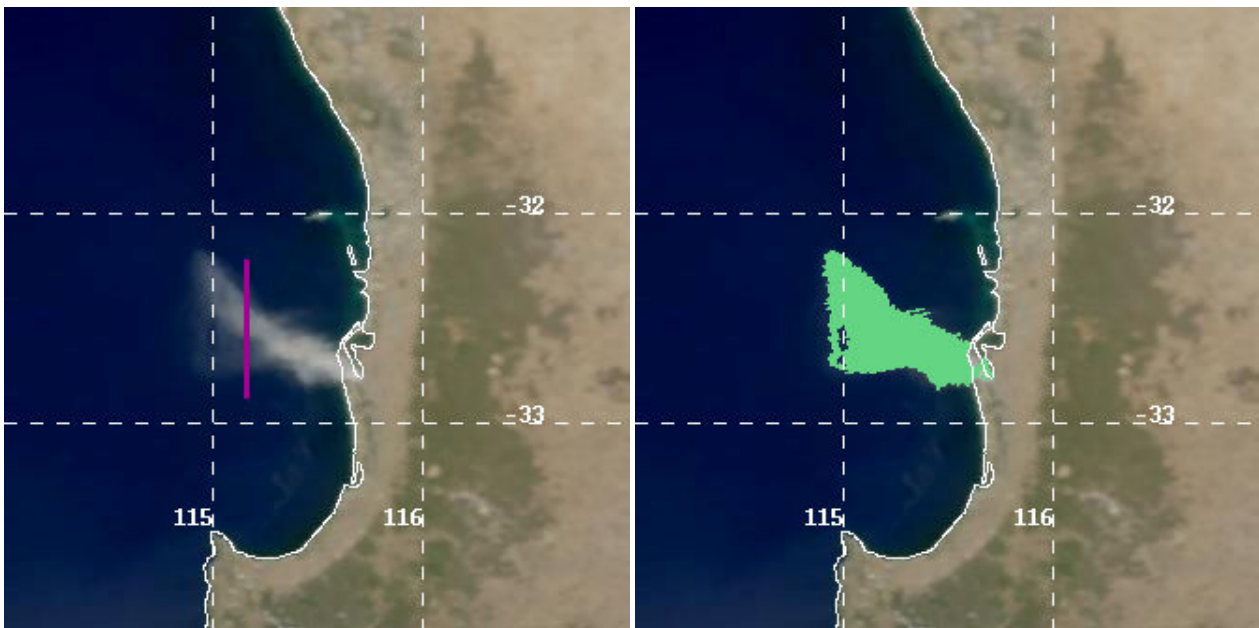


Figure 2. a) A true colour image taken from MODIS *Aqua* on the 10<sup>th</sup> of January 2011 (0640 UTC) shows the Lake Clifton bushfire smoke plume over the Indian Ocean. The North-South transect through the smoke plume is indicated by the magenta line. b) A true colour image with the multi-threshold tested smoke plume mask overlaid in green.

points in the area, as seen in Figure 2a. The main plume drifted in a northwesterly direction with a thinner arm of the smoke plume dispersing due west. In Figure 2b, the smoke mask picks

up the entire dispersing plume. Top-of-atmosphere reflectance values were extracted along the North-South, single pixel transect, indicated in Figure 2a by the magenta line, and plotted

in Figure 3. This profile shows a larger peak that coincides with the thicker part of the smoke plume while the smaller peak corresponds to the thinner, dispersed part of the smoke plume.

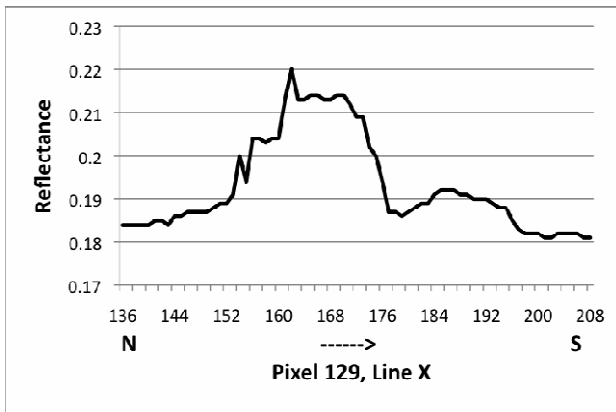


Figure 3. Top-of-atmosphere reflectance values along the North-South transect (indicated in Figure 2a.) through the smoke plume on the 10<sup>th</sup> of January 2011.

#### 4. CONCLUSIONS

The current detection method provides binary results for the presence of a smoke plume. Being able to differentiate between thicknesses of the plume will aid in the monitoring of plume dispersion. The threshold values used in the collection of tests for smoke plume detection are also currently individually

tailored to each scene. Issues such as variability in absorbing constituents in the smoke plume, smoke particle size distributions, time of day and sun position during the satellite overpass all affect the robustness of an automated smoke plume detection process. Further work is being conducted to find a way to work with these variables to best increase the success of an automated smoke plume detection scheme that highlights variation in smoke density.

#### 5. REFERENCES

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