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VIIRS Nightfire Remote Sensing Volcanoes

Grigory M. Trifonov[a,*], Mikhail N. Zhizhin[b,**], Dmitry V. Melnikov[c], Alexey A. Poyda[d]

[a]*Moscow State University, Moscow, Russia*
[b]*CIRES, University of Colorado, Boulder, Colorado, U.S.A.*
[c]*Institute of Volcanology and Seismology, Petropavlovsk-Kamchatsky, Russia*
[d]*National Research Centre "Kurchatov Institute", Moscow, Russia*

Abstract

Satellite based remote sensing of active volcanoes has been performed in various forms since 1965. Compared to "on the ground" observations it lets data to be gathered globally at regular pace for long periods of time without the need for local maintenance. Currently existing publicly available volcanoes thermal activity monitoring systems rely on the detection algorithms narrowly specified for volcanoes temperature ranges and operate using the data from previous generation of sensors, which is supported with non-reserved constellation of two satellites. The presented work proposes pipeline (the sequence of actions) based on the clustering of the data received from the Nightfire thermal anomalies detection algorithm, which is not focused on the specific type of infrared sources. Pipeline has been tested on Kamchatka's region 2016 year dataset and proved to produce sound results corresponding to manual observations.

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Keywords: Nightfire ; VIIRS ; Remote sensing ; clustering ; volcanoes

1. Introduction

History of satellite based volcanic activity observations spans as far as 1965. The advantages of such an approach are obvious: good coverage, including hard to get to areas, regularity, cost-effectiveness (considering the coverage).

The first globally available system focused on continuous volcanic activity monitoring is MODVOLC[4], the system is using data received from the MODIS equipped Terra and Aqua satellites. The both satellites were launched as a part of the NASA EOS program in 1999 and 2002 respectively. MODVOLC has been in action for more than 15 years [10], although it has its shortcomings, it may be considered a classic comparison base for similar systems. A more modern example would be Mirova[1] system similarly based on MODIS data the system capitalizes on MODVOLC experience and addresses some of its flaws.

* Corresponding author.
** Principal corresponding author.
E-mail addresses: trifonov.grigory@gmail.com (Grigory M. Trifonov)., Mikhail.Zhizhin@noaa.gov (Mikhail N. Zhizhin).

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The short-term mission involving MODIS was intended to fill the gap between the two long-term scientific programs DMSP and JPSS. With the arrival of new satellites equipped with sensors of the new generation it is possible to significantly improve quality of the monitoring. For instance new VIIRS sensor launched on board of Suomi-NPP satellite has better resolution and precision than MODIS. The aforementioned characteristics are crucial for building a more precise spectrogram of the observed source, thus making it possible to estimate additional source characteristics, such as temperature.

Nightfire is the first algorithm successfully taking advantage of the new generation sensors. The algorithm uses VIIRS nighttime data to detect and estimate characteristics of subpixel sized infrared sources[2]. Initially algorithm has been developed to monitor volumes of natural gas burning in the locations of hydrocarbons extraction and refining. Nightfire is using multitude of infrared bands (from short-wave up to long-wave) in conjunction with visible spectrum data whilst the majority of previous solutions is using one or two infrared bands in the mid-wave and long-wave parts of the infrared spectrum.

Nomenclature

MODIS	Moderate Resolution Imaging Spectroradiometer
EOS	Earth Observing System
DMSP	Defense Meteorological Satellites Program
JPSS	Joint Polar Satellite System
VIIRS	Visible Infrared Imaging Radiometer Suite
SDR	Sensor Data Record
SNR	Signal to Noise Ratio
IR	Infrared
SWIR	Short Wave Infrared Range
MWIR	Mid Wave Infrared Range

2. VIIRS Nightfire Detecting Temperature Anomalies

To detect and estimate characteristics of “hotsposts” on the night side of the Earth Nightfire is using the whole infrared spectrum in the range of 1 to 12 μm. The algorithm is using the data from the infrared multispectral radiometer VIIRS. VIIRS provides infrared readings with spatial resolution of 750 m in nadir down to 1500 m at the edge of scan. It was noticed [2] that in nighttime “hotsposts” may be seen in short-wave infrared range (SWIR) with the best signal-to-noise ratio (SNR) characteristic. The SNR difference between SWIR (bands M7, M8 and M10) and MWIR (bands M12 and M13) may be clearly seen in Figure 1. In the day imagery in this range signal from “hotspots” is overpowered by the solar radiation, thus “hotspots” are undetectable in SWIR at the average spatial resolutions of $\approx 1kmpp$. Which explains why since the publication of the “classic” Dozier’s method in 1981 [5], which was used with slight modifications in all the remote Earth sensing algorithms [9] except Nightfire, combustion IR sources are searched in MWIR. However MWIR “hotspots” are always observed with the background heat from the earth surface and clouds, which drastically affects the sensitivity for both size and temperature estimations of the detected combustion sources.