Pipeline oil fire detection with MODIS active fire products

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Abstract

We investigate 85 129 MODIS satellite active fire events from 2007 to 2015 in the Niger Delta of Nigeria. The region is the oil base for Nigerian economy and the hub of oil exploration where oil facilities (i.e. flowlines, flow stations, trunklines, oil wells and oil fields) are domiciled, and from where crude oil and refined products are transported to different Nigerian locations through a network of pipeline systems. Pipeline and other oil facilities are consistently susceptible to oil leaks due to operational or maintenance error, and by acts of deliberate sabotage of the pipeline equipment which often result in explosions and fire outbreaks. We used ground oil spill reports obtained from the National Oil Spill Detection and Response Agency (NOSDRA) database (see www.oilspillmonitor.ng) to validate MODIS satellite data. NOSDRA database shows an estimate of 10 000 spill events from 2007 - 2015. The spill events were filtered to include largest spills by volume and events occurring only in the Niger Delta (i.e. 386 spills). By projecting both MODIS fire and spill as 'input vector' layers with 'Points' geometry, and the Nigerian pipeline networks as 'from vector' layers with 'LineString' geometry in a geographical information system, we extracted the nearest MODIS events (i.e. 2192) closed to the pipelines by 1000m distance in spatial vector analysis. The extraction process that defined the nearest distance to the pipelines is based on the global practices of the Right of Way (ROW) in pipeline management that earmarked 30m strip of land to the pipeline. The KML files of the extracted fires in a Google map validated their source origin to be from oil facilities. Land cover mapping confirmed fire anomalies. The aim of the study is to propose a near-real-time monitoring of spill events along pipeline routes using 250 m spatial resolution of MODIS active fire detection sensor when such spills are accompanied by fire events in the study location.

Pipeline oil fire detection with MODIS active fire products

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Introduction & Motivation

The Niger Delta is the oil base for Nigerian economy where oil facilities (i.e. pipelines, flowlines, trunk line, flow station, oil well and oil fields) are domiciled. The pipeline infrastructure transports crude oil and other constituents from this region to other parts of Nigeria and other countries. Unprecedented cases of oil spills from the pipelines have continued to militate the safe delivery of the oil. Spills are caused by operational or maintenance error, old age of oil facilities and by acts of deliberate sabotage of the pipeline equipment which often result in explosions and fire outbreaks [1].
Despite several research efforts, oil spills and the attendant fire outbreaks have continued with persistent environmental damage and in some cases the loss of lives.

Our aim is to investigate if these spills can be detected using earth observations when they are attended by fire scenario. Can earth observation detect oil pipeline spill fires?

Scientific Question

Can the oil pipeline spill fires be detected and monitored using MODIS fire products in near-real time regardless of their cause? How are the oil pipeline fires different from other fires in the study location?

Methods and Background Data

(A) OIL SPILL GROUND DATA

(i) Oil spill reports through the National Oil Spill Detection and Response Agency (2007-2015) (www.oilspillmonitor.ng).
(ii) Filter oil spill (10072) to contain the Niger Delta.

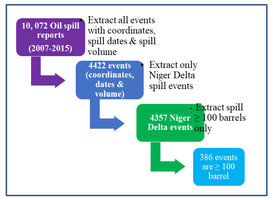


Fig 1: Filtering process of 10072 spills (2007- 2015)

(B) FIRE SATELLITE DATA

We acquired MODIS fire products from NASA focusing on the Niger Delta of Nigeria from 2007 to 2015 (Fig 2).

Fig 2: Area of Interest drawn with a polygon

85129 MODIS fire products Were acquired from 2007-2015 in the Niger Delta (Fig 3).

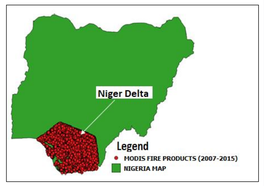


Fig 3: MODIS fires in Niger Delta (2007-2015)

Methods and Data Analysis

(A)
i) By definition, oil spills are along pipeline routes
ii) We spatially plotted spills with coordinates on pipelines from Niger Delta to other parts of Nigeria & its borders (Fig 4).

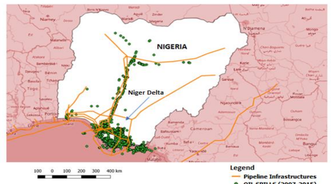


Fig 4: Spatial plot of spills

(C) Vector analysis through Quantum GIS allowed the extraction of all MODIS fires close to the pipelines by 1000m (Fig 7).

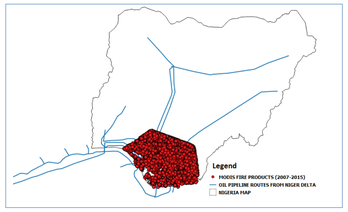
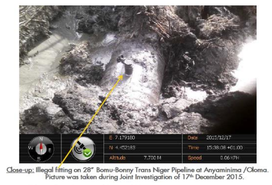


Fig 7: 85129 MODIS fires on pipelines

(B)
Oil pipelines are strictly controlled in the Right of Way (ROW) management to ensure the safety of oil transportation and the environment. Normally, oil spills impact the right of way (see fig 6), and hence contaminate the environment. A significant spill will result in severe environmental damage. Such cases abound in the Niger Delta.

Fig 5: Global oil pipeline right of way management



Close-up; Illegal fitting on 28" Bonny-Bonny Trans Niger Pipeline at Anyanmimo /Okoroa. Picture was taken during Joint Investigation of 17th December 2015.

Fig 6: An oil spill event

Results

(A) 2192 fires were extracted and classified as pipeline fires

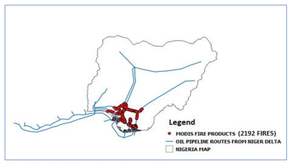


Fig 8: 2192 pipeline fires

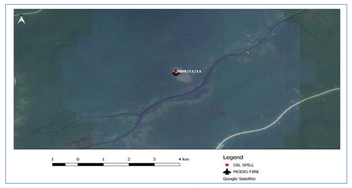


Fig 12: Satellite imagery of a correlated event

(B) In addition to pipeline fires, spatial analysis show four other classes of fires according to their sources. Industrial fire, Built fire, Agricultural fire and Ocean fire. Fig 9 shows the spatial plot of the fires in the Niger Delta

Fig 9: Spatial plot of five sources of fires

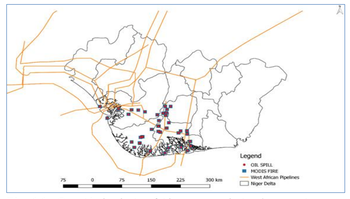


Fig 11: Spatial plot of the correlated events

(C) The spatio-temporal analysis between 386 largest spill events (fig 1) & MODIS fire products show that 43 events were correlated. See fig 10.

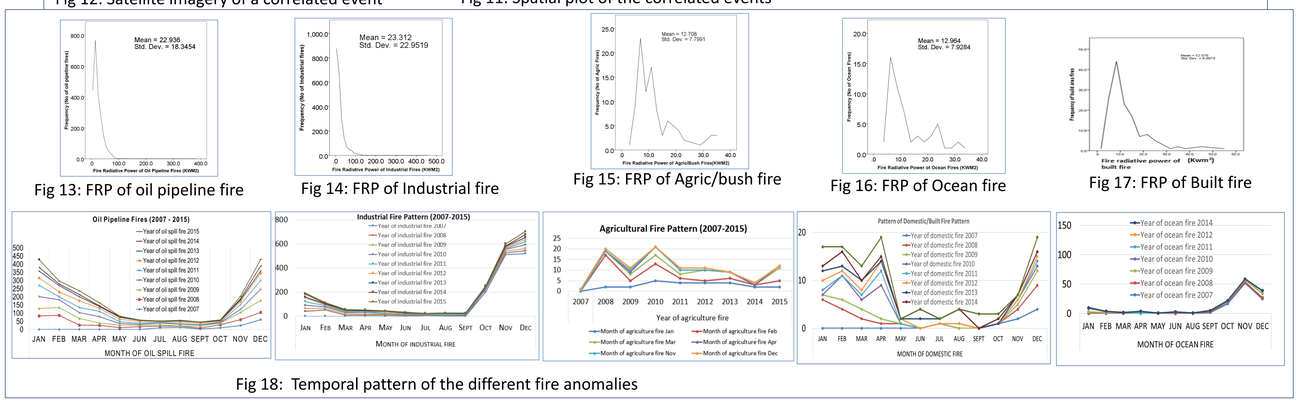


Fig 13: FRP of oil pipeline fire
Fig 14: FRP of Industrial fire
Fig 15: FRP of Agric/bush fire
Fig 16: FRP of Ocean fire
Fig 17: FRP of Built fire
Fig 18: Temporal pattern of the different fire anomalies

Results

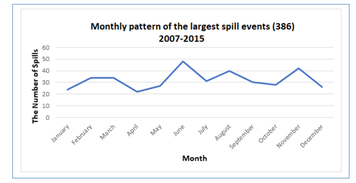


Fig 19: Monthly pattern of the largest spill events

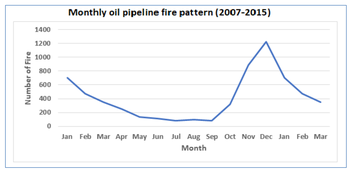


Fig 20: Oil pipeline fires.

Figures 19 & 20 show the temporal comparison between the largest spill events and the oil pipeline fires.

Summary

A) Fires from oil pipeline can be detected and monitored using MODIS instrument in near real time [2].
B) In addition to oil pipeline fires, MODIS instrument can detect other fire anomalies. Hence, irrespective of the cause, MODIS instrument can detect such fire in the study location.
C) In exception to Industrial fires, oil pipeline can be distinguished from other fire anomalies using Fire Radiative Power of MODIS sensor. Oil pipeline fire has higher FRP [3].
D) The fires anomalies have temporal pattern according to the fire situations in the study location [4].
E) The study establishes spatio-temporal correlation between oil spill events and MODIS fire products.
F) All the fire anomalies have similar temporal patterns

Future Direction

Although the study shows that MODIS instrument can effectively detect oil pipeline fires, the future work is to further study the fire radiative power of MODIS and compare with other instruments like VIIRS and SIVIRI. Such study will provide more information about oil fire detection.

Abstract

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References

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