Indonesia peatland fire detection with nighttime Landsat- Preliminary results

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NGDC VIIRS Data Products

• Regional data service covering Indochina (including Vietnam) with many day and night data products in geotiff format: http://ngdc.noaa.gov/eog/viirs/download_thailand.html

• VIIRS low light imaging monthly composites: http://ngdc.noaa.gov/eog/viirs/download_monthly.html

• VIIRS Nightfire (VNF): http://ngdc.noaa.gov/eog/viirs/download_viirs_fire.html

• Regional subset of VNF covering Vietnam is available at: http://ngdc.noaa.gov/eog/viirs/download_thailand.html
Singapore chokes on haze as Sumatran forest fires rage

By Peter Shadbolt, CNN
updated 1:32 PM EDT, Fri June 21, 2013

Students wear masks as haze shrouds Kuala Lumpur on June 23. Many schools in Malaysia were closed on Monday after air pollution caused by forest fires in Indonesia spiked to hazardous levels.

Malaysia chokes on smoke

STORY HIGHLIGHTS

• Singapore enveloped in a thick pall of wood smoke caused by forest fires in Sumatra

• Pollution Index reaches 371 on Wednesday, the worst level since 1997 when it reached 220

(CNN) -- Singapore was shrouded in haze on Wednesday as smoke from forest fires in nearby Sumatra drifted across the Malacca Strait in the city's worst pollution crisis in more than a decade.

Buildings in the city of 5.3 million people have been enveloped in a smoky haze since the beginning of the week as illegal burn off in nearby Indonesia and prevailing winds were causing a smoke crisis.
Fires were detected. But were peat fires detected?
NGDC Indonesia Fire Project

• One year project funded by the U.S. Forest Service.

• Objectives:
  – Explore the remote sensing of peat fires
  – Develop daily and seasonal GHG and particulate daily emission estimates from 2013 & 2014 fires

• Team members:
  – NGDC: remote sensing research & tech transfer
  – LAPAN: field validation
  – NCAR: emission modeling
The Challenges of Peatland Burning

- Peatland fires are a mixture of flaming and smoldering fires. 600 K is considered the break point between flaming (~800 K) and smoldering (~400 K).
- Emissions are distinctly different for flaming versus smoldering peatland fires.
- Satellite detection works reasonably well for detection of flaming fires.
- Detection and characterization of smoldering peat fires from satellites is challenging:
  - Much of the burning is underground – while satellites observe the surface.
  - Detection of low temperature sources requires large source areas to yield sufficient infrared emissions.
  - Some satellite fire detection algorithms rely on a background radiance subtraction derived from analysis of pixels surrounding suspected fire pixels. Undetected smoldering fires can corrupt the background radiance subtraction.
Planck’s Law

- Developed by Max Planck in 1900.
- States that all objects above absolute zero emit radiation and that the emission can be modeled based on temperature and emissivity.
- Clouds, water, and green vegetation behave as blackbodies in mid- and long-wave infrared.

300 K = 26.85°C
Wein’s Displacement Law

Wavelength of peak radiant emissions is calculated based on temperature = 2898 (um.k)/K
Stefan Boltzmann Law – Remember $T^4$

Total radiant power (area under the Planck curve) can be calculated from temperature$^4$.

Stefan-Boltzmann constant ($S$) = $5.67 \times 10^{-8}$ W/m$^2$K$^4$

Radiant power = $S \times K^4$
Measuring the temperature of an object that fills the field-of-view

Can be done with a single spectral band. Why? Because the Planck curves always go up as temperature increases. The lines do not cross each other.
Sub-pixel source look like “graybodies”

Wein’s law provides the temperature. The emission scaling factor (ESF) is the ratio of the observed peak radiance to the full pixel peak radiance for an object at that temperature.
Subpixel fire at 900 K (flaming phase) filling 1/1000 (E-3) of the pixel footprint
Subpixel fire at 800 K filling 1/1000 (E-3) of the pixel footprint

Detect hot spot pixels based on anomalous radiance in SWIR and MWIR
Subpixel smoldering at 500 K filling 1% (E-2) of the pixel footprint

Difficult to detect smoldering in km scale pixel footprints
Subpixel fire at 900 K filling 1/1000 (E-3) plus smoldering at 500K filling 1% of the pixel footprint
Subpixel fire at 900 K filling 1/1000 (E-3) plus smoldering at 388K filling 20% of the pixel footprint.
VIIRS

• The Visible Infrared Imaging Radiometer Suite (VIIRS) is the primary imaging sensor flown on the NASA/NOAA Suomi National Polar Partnership satellite.
• Launched on October 28, 2011, VIIRS began to collect usable data in late-February 2012.
• 22 spectral channels, most with 750 meter pixels at nadir.
• 3000 km swath. Overpasses at ~01:30 and 13:30 daily.
• VIIRS is unique for collecting near and short-wave infrared data at night.
VIIRS Nighttime Bands

Note – B11 nighttime collection is pending

Planck curve for typical gas flare (1800 K)
VIIIRS Nighttime Data Riau June 19, 2013
VIIRS Nightfire has three hot pixel detection algorithm types

1. NIR & SWIR: Detection threshold set based on background noise – mean plus four standard deviations. The detected pixels are then checked for detection in M7 & M8.

2. MWIR: M12-M13 (3.8 and 4 um) scattergram analysis identifies background. Hot pixels are the outliers. M12 sub-pixel saturation detected by M13/M12 ratio.

3. LWIR algorithm sets detection threshold as the maximum M16 radiance found for the M12/M13 background pixel set.
VIIRS Nightfire hot pixel detections for June 19, 2013

Detections are color coded based on temperature. Hot gas flares are red, yellow, or green. Fires are purple or blue. White markers have insufficient signal for Planck curve fitting.
Typical biomass burning
Temperature in the 700-1000 K range
Planck Curve Calculations

• Peak radiance indicates temperature (K) using Wein’s Displacement Law.

• Subpixel sources appear as graybodies. The ratio of the observed curve versus the full field of view curve for that temperature is traditionally referred to as emissivity. We call it emission scaling factor (ESF) to distinguish it from full field of view graybodies. Source area is calculated by multiplying ESF by the size of the pixel footprint.

• Radiant heat (aka heat release) is calculated in MWs using the Stefan-Boltzmann Law.
Typical gas flare

Temperature near 1800 K
Band M12 subpixel saturation is ignored in Planck curve fitting
VNF detection limits versus observed data
Sumatra June 19, 2013

Temperature versus Source Area

Detectable Area (m²) vs Temperature (K)

Fires
Flares
Unseen fires below the sensor detection limits

M10
M13
## Landsat 8

<table>
<thead>
<tr>
<th>Bands</th>
<th>Wavelength (micrometers)</th>
<th>Resolution (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 1 - Coastal aerosol</td>
<td>0.43 - 0.45</td>
<td>30</td>
</tr>
<tr>
<td>Band 2 - Blue</td>
<td>0.45 - 0.51</td>
<td>30</td>
</tr>
<tr>
<td>Band 3 - Green</td>
<td>0.53 - 0.59</td>
<td>30</td>
</tr>
<tr>
<td>Band 4 - Red</td>
<td>0.64 - 0.67</td>
<td>30</td>
</tr>
<tr>
<td>Band 5 - Near Infrared (NIR)</td>
<td>0.85 - 0.88</td>
<td>30</td>
</tr>
<tr>
<td>Band 6 - SWIR 1</td>
<td>1.57 - 1.65</td>
<td>30</td>
</tr>
<tr>
<td>Band 7 - SWIR 2</td>
<td>2.11 - 2.29</td>
<td>30</td>
</tr>
<tr>
<td>Band 8 - Panchromatic</td>
<td>0.50 - 0.68</td>
<td>15</td>
</tr>
<tr>
<td>Band 9 - Cirrus</td>
<td>1.36 - 1.38</td>
<td>30</td>
</tr>
<tr>
<td>Band 10 - Thermal Infrared (TIRS) 1</td>
<td>10.60 - 11.19</td>
<td>100</td>
</tr>
<tr>
<td>Band 11 - Thermal Infrared (TIRS) 2</td>
<td>11.50 - 12.51</td>
<td>100</td>
</tr>
</tbody>
</table>
Night and Day Landsat 8

Nighttime Band 7 (2.2 um)
March 28, 2014

Daytime Band 7,5,4 RGB
March 24, 2014
Full Resolution
Night vs Day

March 28, 2014

April 4, 2014
Nighttime Landsat has fire detection in four spectral bands

<table>
<thead>
<tr>
<th>Band 6 = 1.61 um</th>
<th>Band 7 = 2.2 um</th>
<th>The strongest signal is in band 7.</th>
</tr>
</thead>
</table>
| Band 10 = 10.8 um | Band 11 = 12 um | No signal detected in bands 1,2,3,4 & 9.
|                  |                 | Rare pixel detects in bands 5 & 8. |

Are the LWIR hot pixels sites of peat fire?
Planck curves were modeled with bands 6 & 7. From these we calculated temperature, source size, radiant heat and hot source radiance in band 10.
Nighttime Landsat Fire Detection Limits

Temperature VS Active Fire Area

- Band 6
- Band 7

Detectable Area (m²) vs Temperature (K)
Temperature (K)
Little variation
Most pixels are in the 700-900 K range

Area of Active Fire ($m^2$)

Radiant Heat (KW)

L8 Night Combustion Parameters
Is there residual LWIR emission indicating the detection of smoldering? No.

Band 10

Band 10 hotpixels

Band 10 minus radiance modeled from B6 & B7 Planck curve
Hypothesis: The LWIR detections found in nighttime Landsat are expressions of smoldering phase peat fires

- Take the B6 & B7 Planck curve as a representation of flaming phase burning
- Estimate flaming phase radiance in LWIR with Planck curve
- Subtract the flaming phase LWIR radiance from the observed LWIR radiance
- A positive residual LWIR radiance indicates a second hot source at lower temperature = peat fire
- If there is no positive residual, the LWIR anomalies are attributable to flaming phase burning
Active fire area of LWIR anomalies is generally greater than $1\text{m}^2$
Summary on Nighttime Landsat

- Nighttime Landsat short-wave infrared (SWIR) data readily detects flaming phase peatland fires down to meter sizes.
- The SWIR data are amenable to Planck curve modeling to estimate temperature, source size and radiant heat.
- LWIR anomalies are found in areas with daytime Landsat spectral signatures associated with peat fires.
- Subtracting the flaming phase LWIR radiance, no residual was found, smoldering could not be detected.
- LWIR hot pixels are associated with active fire areas of more than 1m².
- Nighttime Landsat collections are being continued in the coming months when more burning is anticipated.
- Field validation is planned.
Reference