Spectral features of open fires for detection and burn scar

Dr. Stefania Amici - INGV
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Overview

- Problem
- Methodology
- Input data
- Algorithm -> product
- Work in progress
- Impact

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Problem

Economic

- Loss of infrastructure, natural and cultural resources, insurance
- Fire suppression high costs

Scientific

- Transport gas to atmosphere
- Climate change
- Fire regime, biodiversity

Social

- Transport gas to atmosphere
- Climate change

References:
Need for research

- **Pre-fire** Measurements that can be correlated to fire behaviour

- **Active fire** Localization, flame/ smouldering, evaluation of Parameters for modelling, Linking Energy to Emissions and Air Quality

- **Post- fire** burn scar delineation, Vegetation Mortality, Ecosystem Recovery, Land use change
Metodology: detection methods

- Vegetation fires involve **high temperatures**, so thermal remote sensing is suitable to its identification and study.

- Actively burning **fires emit IR** so strongly, especially at MIR (3–5 μm) wavelengths that can be identify by Earth orbit.

- **Fixed –threshold approach** algorithms which provide ‘hotspot’ counts and fire location maps (e.g. MODIS products Justice et al., 2002, Giglio et al., 2003, Denisson et al., 2006.)

Top-of-atmosphere spectral radiance simulated at four different target) using the MODTRAN 5 radiative transfer code.

**Simulations for a savannah surface at 300 K:** the same surface but with a 1,000 K fire covering 0.5 % of the ground field-of-view (FOV), specularly reflected sunglint from a 300 K surface; and solar-heated (320 K) bare soil.

**The pixel containing the sub-pixel fire shows a signal highly elevated in the MIR (3–5μm) spectral region compared to all other targets, equivalent to a brightness temperature of around 400 K.** (Wooster et al. 2012.)
Caratteristiche spettroscopiche dei fuochi: emissione del Potassio

- Fuel biomass is largely composed of **Carbon (~45%)**, **Hydrogen (5.5%)**, **Oxygen (41%)**, and **Nitrogen (3.5%)**, and the molecular combustion products are dominantly CO2, H2O, CO, CH4, and various nitrogenous compounds (Levine, 1991)

✓ In addition ‘trace’ elements: K: up to 7%, Na: 0.1%, P: up to 1%, Ca: up to 5%
✓ When ionized alkalies can make transitions resulting in very strong emission lines.
✓ At high temperatures associated with flaming combustion, trace elements like K are mobilised. This produces a sudden increase in reflectance at **766.5nm** and **7.69.9nm**, which very narrow band (hyperspectral) sensors detect as a sharp emission peak or line. (Vodacek 2002).

**Advantages:**
- being specific to flaming combustion a K emission approach theoretically allows for the separation of smouldering from flaming areas of vegetation and active fire detection.

**Potassium Emission Line (Simulation) Simulated Earth atmosphere.**
Transmission was calculated as viewing the Earth from 100 km elevation at nadir and assuming a US 1976 Standard Atmosphere and a 23 km rural aerosol. Simulation was conducted at 0.1 cm⁻¹ wavenumber resolution using the high spectral resolution mode of MODTRAN 5.2 (Berk et al., 2008)

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Input data: Laboratory scale

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Spatial resolution</th>
<th>Central band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperion</td>
<td>30m</td>
<td>772nm</td>
</tr>
<tr>
<td>HyspIRI</td>
<td>60m</td>
<td>770nm</td>
</tr>
<tr>
<td>PRISMA</td>
<td>30m</td>
<td>770nm</td>
</tr>
</tbody>
</table>

How different sensors see the K emission?

Data courtesy Prof. M. Wooster

S Amici, M.J. Wooster, A. Piscini RSE 2011, Hyper-SiMGA data courtesy Leonardo

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Airborne data: Mediterranean land cover

Advanced K Band Difference (AKBD) = Max|BandJK_i|-BKG

0.7m VIS Hyper

0.7m AKBD Hyper

30m 30m 60m

True colour composite

S Amici, M.J. Wooster, A. Piscini RSE 2011, Hyper-SiMGA data courtesy Leonardo

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Satellite scale: EO1Hyperion: AKBD and CDI

South –California 23October 2007

- True colour composite
- SWIR colour composite

A & B within fire area
C outside of fire area

(lat. 33.0° N, lon. 117.2° W)
Solution: ASI-AGI (flaming location product)

<table>
<thead>
<tr>
<th>Application</th>
<th>FIRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>Active Fire</td>
</tr>
<tr>
<td>PRODUCT</td>
<td>Potassium (K) Emission Detection from Location of flaming combustion</td>
</tr>
<tr>
<td>Instrument</td>
<td>PRISMA</td>
</tr>
</tbody>
</table>

Short Description

Identification of locations of flaming areas via automatic detection of pixels containing sites where a Potassium (K) emission signature is present - for example via Vodacek index (2002) or the AKD metric described in Apici et al. (2011). The sensor to be used will be the PRISMA, and if successful there may be synergy with other products to better discriminate smouldering to flaming which have very different smoke emission strengths and smoke chemistries, so discrimination can make an important contribution to improving smoke emissions estimates and smoke transport forecasts, and also that the detection of fires will be done at a 30 m spatial resolution from PRISMA in contrast to the 1000 m from MODIS.

Level of maturity

Medium level of maturity. This product has been validated at the laboratory, airborne and moderate spatial resolution (30m) satellite scale. For satellites, the limits to production are mainly the specific spectral band position, the spectral and spatial resolution and the signal to noise ratio. PRISMA has comparable spatial resolution to the satellite data already used to deliver information on the K-signature, but has a good position of band and hopefully better SNR.

Innovation brought by ASI-AGI

- Fully automatic processing chain
- Assess suitability/synergy of the existing methodologies, tailored for the specific datasets (PRISMA)
- Generate final map product that localize flaming area.

Level of input products (L1, L2)

L2

Where we see it

This product can be used directly in Emergency Response Core service offered within GMES (see SAFER Service Portfolio V2)

It can be used in EFFIS.

It can be used by National Command and Control service.

Other Input data required

Other Models required

Selected algorithm

Scale of the covered area

T.8.C

Key performance parameters

T.8.C

Output format

FLAMING AREA RASTER, Raster map

Limitations

Cloudiness.

Delivery mode

FTP, WMS, GEOPORTAL, other

Maximum Delivery frequency

After any acquisition and time need to have a L1 calibrated data

Delivery plan

Continuous.

Example of PRODUCT output

Example of Flaming area identified by applying K_{wv} metric.

EO-1 Hyperion southern California Witch Wildfire: a) Visible colour composite, b) SWIR colour composite and c) Pixels showing the K_{wv}/band ratio are marked at the locations marked in A and B, along with a non-fire background pixel [C]. PRISMA has a much better band position than EO-1 Hyperion, thus potentially offering a better change of detection of the K-emission signature, provided fires of sufficient planimetric area are imaged. See figure below for spectra taken from each of the three pixels A, B and C.

Spectral radiance profiles of two EO-1 Hyperion pixels taken from the southern California Witch Wildfire subscene shown in the above figure, along with spectra of the background pixel marked C. The pixels A and B are those showing the strongest K-emission signal in the areas marked in A and B in the above figure. Wavelength locations of the potassium emission feature and the near oxygen absorption feature are marked as “K” and “O” respectively.
Work in progress- **Post fire effect: peatland UK**

Peak District National Park (PDNP) case study

Decorrelation Stretch (DS) applied to L7 to remove highly correlated data, which is commonly found in multi-spectral images.

Amici, S., Millin-Chalabi, G., Danson, M., Mcmorrow, J., & Agnew, C. (2016). *Aerial high resolution hyperspectral data for validation of the Edale upland peat moorland burn scar derived by SAR and Optical satellite imagery*. Poster session presented at ESA Living Planet Symposium, Prague, Czech Republic. Publication link: 2f0b411d-724b-46df-9d58-8c5c080a8495

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First Attempt: Data Fusion

NEXT steps:
- Validate the fusion interpretation by using
  - NERC ARSF, Eagle Hyperspectral data (01/07/08)
  - and in situ data
- Use the hyperspectral data to apply classification methods and validate L7/ SAR classification results

Amici, S., Millin-Chalabi, G., Danson, M., Mcmorrow, J., & Agnew, C. (2016). Aerial high resolution hyperspectral data for validation of the Edale upland peat moorland burn scar derived by SAR and Optical satellite imagery. Poster session presented at ESA Living Planet Symposium, Prague, Czech Republic. Publication link: [link]

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10 Conference contributions
6 inviting talk
6 papers
6 projects contributions
Network and collaborations

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\textsuperscript{1} INGV,
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\textsuperscript{3} Salfornd Univ.

New areas
Peatland
Landuse change
Fire regime
Burn scar
Model propagation
Regrowing map

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Thanks for listening

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