UK Wildfire Conference 2015 10-11 November 2015, Glasgow, UK

Checking the ability of the K-line method to discriminate between smouldering and flaming activity in case of heather dominated vegetation

Stefania Amici [(1)(2)], Julia McMorrow [(2)], Martin Wooster [(3)],

(1)Istituto Nazionale di Geofisica e Vulcanologia, Roma (Italy). stefania.amici@ingv.it (2) University of Manchester, Manchester, UK (3) Kings College London , Greater London, UK

Abstract : Biomass burning affects the land and atmosphere through the combustion of vegetation and organic soils and transferring chemical constituents directly into the lower atmosphere. Understanding the impacts of global biomass burning on the terrestrial biosphere, atmosphere and their change over time are major scientific questions. At local scales, fires are a major security hazard which affect vegetated resources and settlements. Within Europe, Mediterranean countries are the most affected by vegetation fires, with an average of almost 50 000 between 1980 and 2008 and an estimated total cost of around 1% of Domestic Product (WFC 2009). This includes the cost of fire fighting organisations, fire insurance administration and the protection to buildings.

It is important to be able to detect small fires that may be important as precursors to larger burns, and as predictors of fire spread when incorporated into operational fire models. Data collected remotely by sensors on satellites or aircraft at shortwave infrared and thermal infrared wavelengths are traditionally used, although such instruments are often costly and difficult to operate from traditional airborne platforms. Until now, the use of hyperspectral techniques (imaging using many very narrow wavebands) has been limited by the cost and weight of instruments. The recent growth in the unmanned aerial vehicle (UAV) market has led to the development of light and relatively cheap instruments, including hyperspectral sensors in the visible to invisible near infrared (VINIR).

Hyperspectral sensors can be used to detect small active fires, and especially to discriminate between flaming and smouldering combustion. They can also be used to monitor the regeneration of vegetation on burn scars. In this study we investigate the suitability of a technique called Potassium (K)-line emission to distinguish between flaming and smouldering combustion for an experiment fire in heather, with data collected by an airborne hyperspectral sensor.

Climate change and fire regime in the UK

Northern Europe countries experience an increasing number of vegetation fires when more frequent "exceptional" drought seasons occur

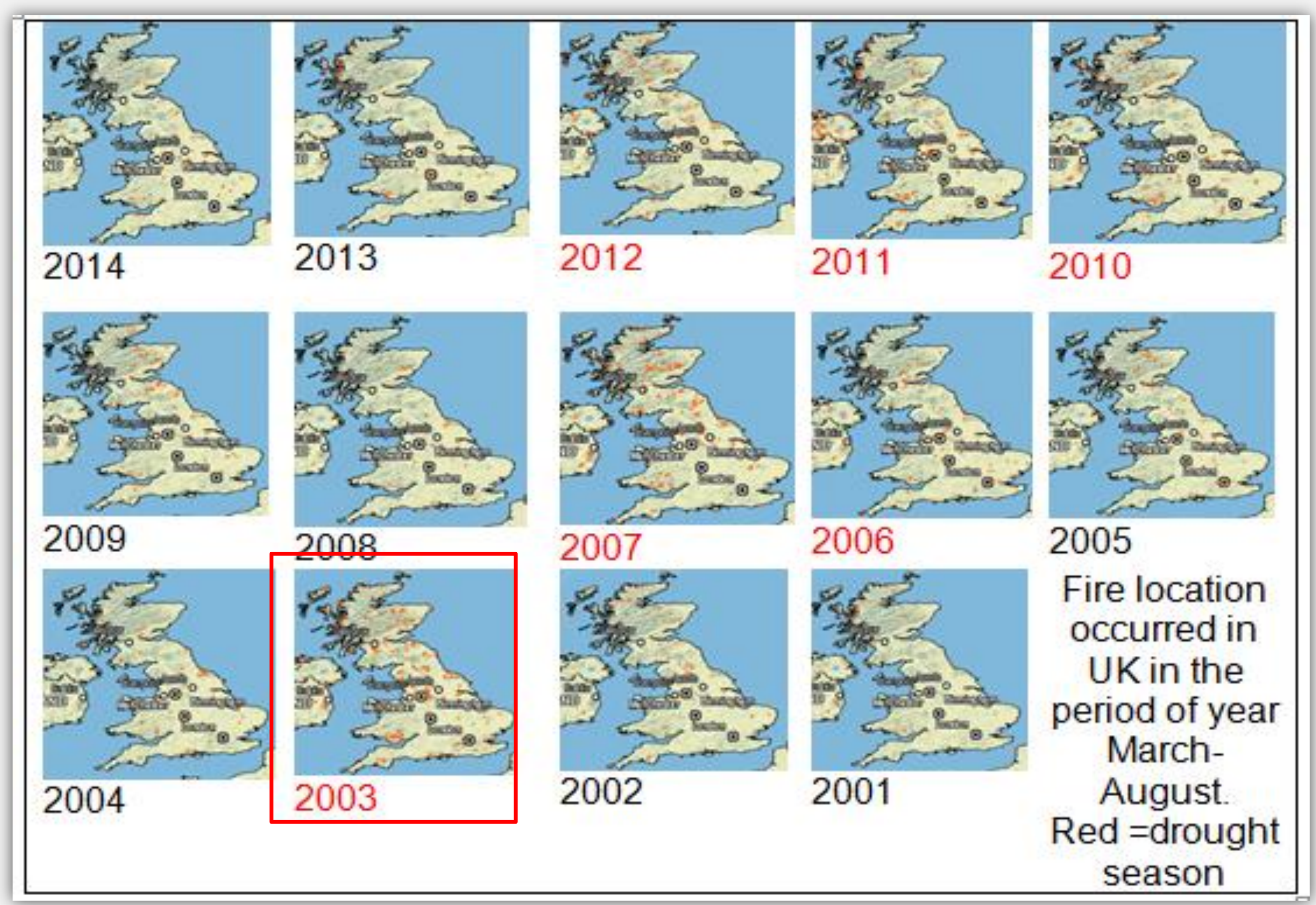
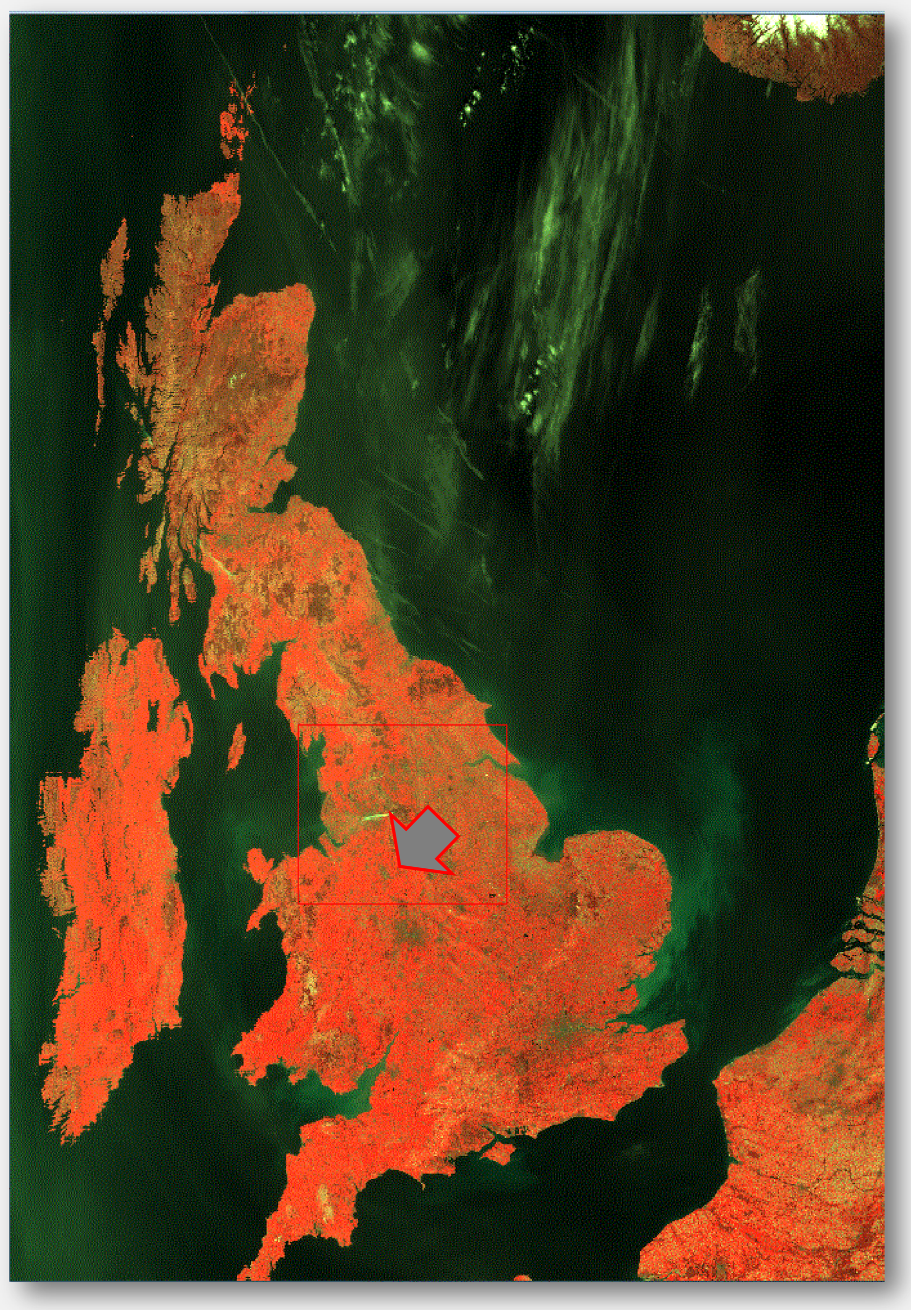


Figure1: Location of hotspots in UK in the last 13 years, many of which are vegetation fires. Some are from industrial chimneys



Satellite remote sensing

Satellite remote sensing at coarse resolution (for instance using the MODIS sensor on Terra and Aqua satellites) are used for detection and monitoring active fires on large scale.

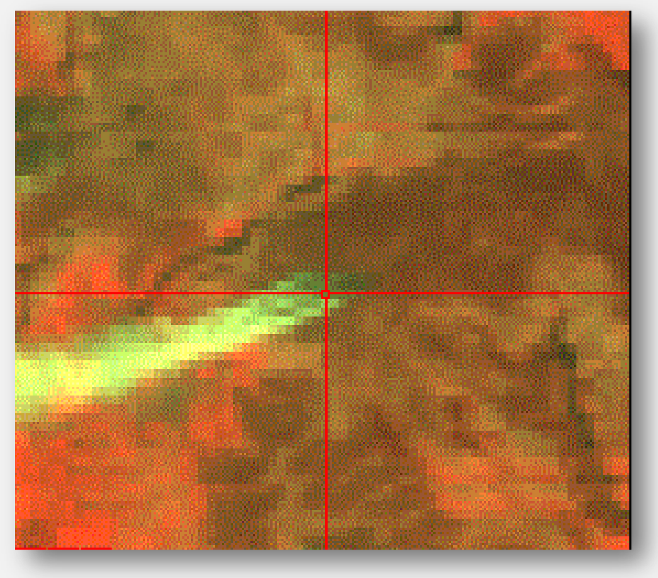


Figure 2: MODIS data on 18 April 2003. False color reflectance at a resolution of 250m/pixel shows vegetation dominated area (in red) and the fire plume (white-greenish)

Airborne hyperspectral data: detecting flaming combustion in heather-dominated vegetation

How the potassium line technique works: When vegetation burns 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**.** The strength of the peak decreases as temperature falls. Smouldering combustion results in a much smaller peak.

Can flaming and smouldering combustion be distinguished in heather? The k-line technique works in Italy and California. It was tested during experimental burns in heather moorland in Northumberland during an airborne campaign funded by NERC-ARSF funded on March 2010.

The strength of K-emission line (Figure 3)

- Eagle spectra (A) can be translated into a **"flaming map"** by calculating a new metric called an Advanced K Band Difference (AKBD) (B)
- Weak signal in AKBD map was confirmed as flame by using super resolution Leika camera (C)

(A) Spectra with K emission line (B) AKBD image (C) Super-resolution LEIKA camera

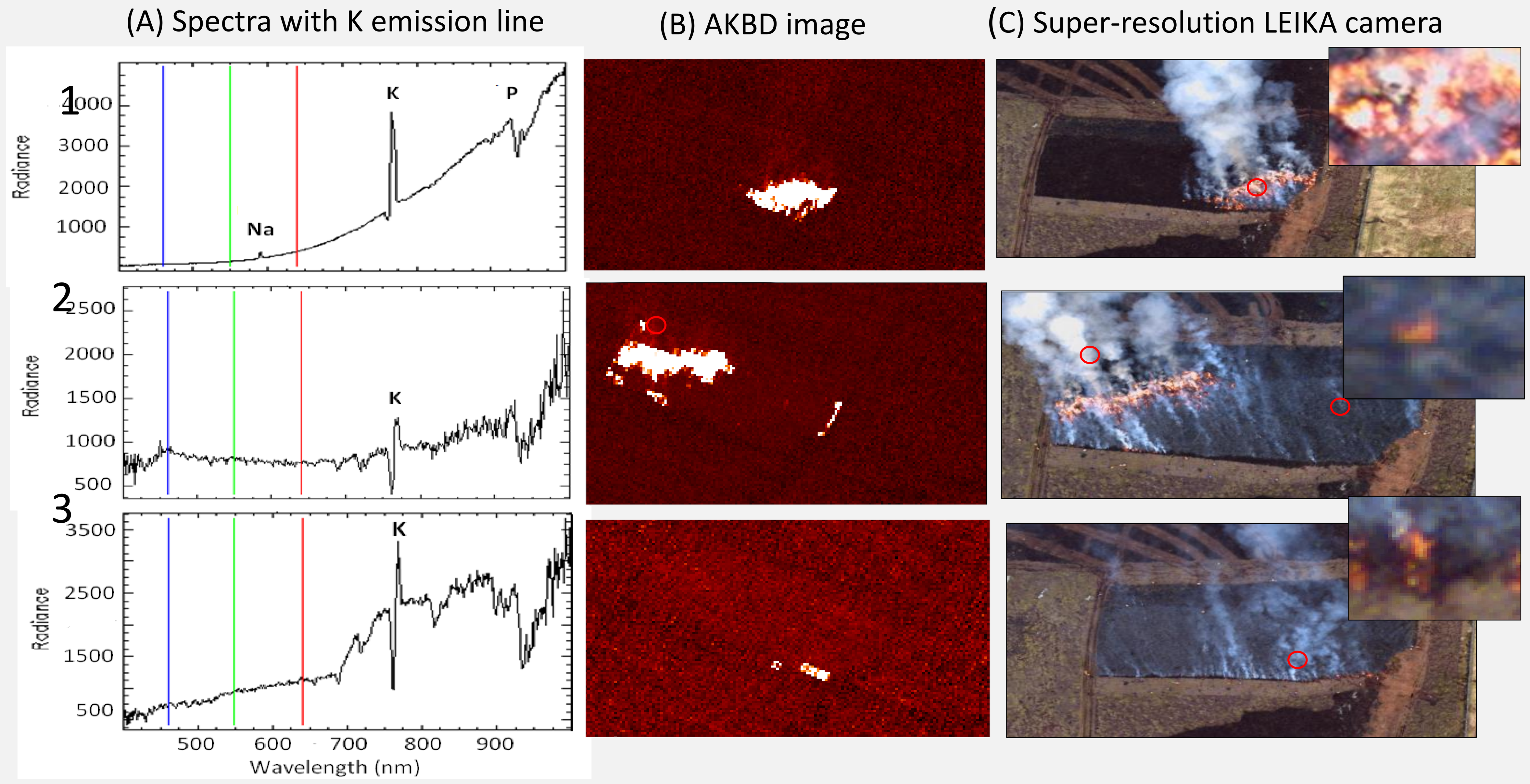


Figure 3 Left to right: (A) Eagle spectra , showing radiance at wavelengths 400 -1000 nm and potassium (K), Na and P emission lines; **(B)** Advanced K-band difference image – intensity of AKBD index shows flame location; **(C)** Super-resolution LEIKA camera photo for validation.

Top to bottom: (1) Flaming combustion produces very strong K emission peak at 766.5 and 769.9 nm, weak Na and P peaks; **(2)** and **(3):** apparently smouldering phases resulting in weak but distinctive K peak.

CONCLUSIONS AND WORK IN PROGESS

- Flaming and smouldering combustion in heather can be distinguished using a hyperspectral airborne sensor
- The flaming signal is still seen through smoke

Future work will:

- Test the correlation between Fire Radiative Power and K emission
- Optimise the spectral index used for burnt area delineation and CO_2 mapping in moorland
- Test the ability of neural networks to recognise actively burning areas

ACKNOWLEDGMENTS

- The study visit and associated project are part of a study funded by Italian Space Agency as part of a work package entitled "Spectral characterization of open fire", ASI-AGI (2011-2015).
- Airborne Research and Survey Facility, Natural Environment Research Council (NERC) for SPECIM Eagle and Hawk images and aerial photographs.
- Professor John Dold (University of Manchester and FireLab Ltd.) for organising the experimental burns at Debdon, Northumberland, March 2010.

REFERENCES

- UAV Thermal Infrared Remote Sensing of an Italian Mud Volcano, S. Amici, M. Turci, S. Giammanco, L. Spampinato, F.Giulietti, Advances in Remote Sensing, Published Online December 2013 (http://www.scirp.org/journal/ars).
- Volcanic environments monitoring by drones mud volcano case study, S. Amici, M. Turci , F. Giulietti, S. Giammanco, M.F Buongiorno, A. La Spina and L. Spampinato, International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-1/W2, 2013, UAV-g2013, 4 – 6 September 2013, Rostock, Germany.
- Chapter in book, ***Thermal Remote Sensing: Sensors, Methods, Applications,*** editors Claudia Kuenzer and Stefan Dech, Springer, May 31 2013, M.J. Wooster, G. Roberts, A. M.S. Smith, J. Johnston, P. Freeborn, **S. Amici** and Andrew Hudak.
- The 2011 Tohoku-Oki (Japan) tsunami inundation and liquefaction investigated by optical, thermal and SAR data, M. Chini, A. Piscini, F.R. Cinti., **S. Amici**, R. Nappi and P.M. Martini, ***Geoscience and Remote Sensing Letters***, NZ and Japan special stream IEEE Geoscience And Remote Sensing Letters, vol. 10, no. 2, March 2013.
- Multi-Resolution Spectral Analysis of Wildfire Potassium Emission Signatures **S. Amici**, M.J. Wooster and A. Piscini, ***Remote Sensing of Environment***, 115, 2011, 1811–1823doi:10.1016/j.rse.2011.02.022