Detecting Moorland Wildfire Scars and their Persistence in the Landscape using Synthetic Aperture Radar (SAR) in the Peak District National Park, UK

Gail Millin-Chalabi, Julia McMorrow and Clive Agnew
School of Environment and Development, The University of Manchester

Introduction

Aim

To assess the ability of SAR to detect moorland wildfire scars and their persistence in the landscape using the case study of the Peak District National Park (PDNP) in the UK.

Objectives

- Determine the ability of a time series of SAR (ASAR, ERS-2 and ALOS PALSAR) images to detect fire scars from 2003 & 2008 in a peat moorland environment
- Understand how scene variables (soil moisture, vegetation, fire behaviour) affect the SAR fire scar signal
- Understand how fire size and fire severity can affect fire scar detectability in a moorland environment

Conceptualising Wildfires

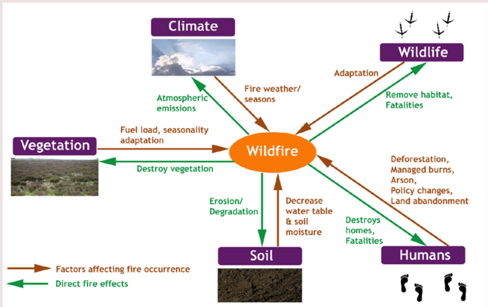

Figure 1 - Conceptualising why wildfires are important?

Methods are needed to record fire scars, and allow calculation of burnt area to provide this information to the PDNP Fire Operations Group (FOG); moorland restoration groups e.g. Moors for the Future (MFF); other land managers (water companies and the National Trust).

Study Area

Bleaklow moor is an area of blanket peat in the PDNP, UK.

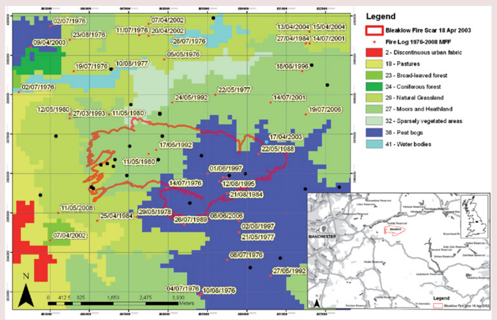

Figure 2 – Bleaklow study area, Peak District National Park, northwest England, showing: GPS outline of the 18 April 2003 fire scar, fire log point data 1976 to 2008 (MFF); CORINE land cover data; and intensity/coherence sampling points (black dots). Kinder is the second study area, the fire occurred 26 May 2008.

Why Use Radar Images?

- Landsat and other optical images detect fire scars but use in the UK is limited by frequent cloud cover.
- SAR can image through cloud and at night
- SAR successfully used to detect fire scars because image brightness (intensity) relates to surface roughness, terrain and soil/fuel moisture properties which are changed by burning (Bourgeau-Chavez et al., 1997).

Methodology

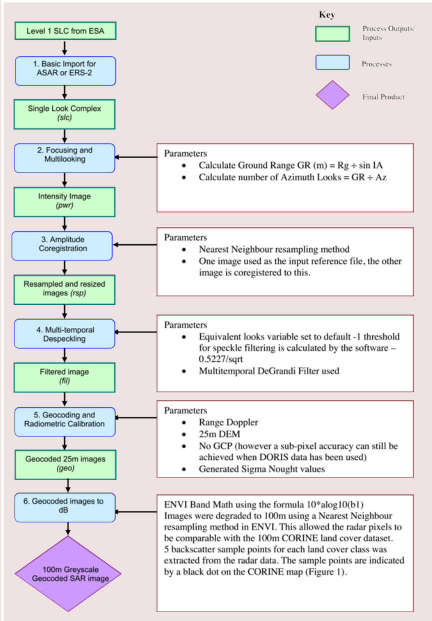

Figure 3 – SAR preprocessing steps in SARScape 4.2 to produce the intensity images adapted from (Kitmitto et al., 2007).

SAR Pre-processing:

All pre-processing was done in SARScape 4.2. The processing chain for producing the intensity images is shown in Fig 3. Intensity values were calculated in ENVI 4.7.

Coherence:

- Coherence image measures the degree of correlation between two SAR images, acquired at different times. Produced during Interferometric SAR (InSAR) pre-processing, using the phase portion of the radar signal. Measured on a scale of 0 - 1 (Rykhus and Lu, 2011).
  - 1 = High coherence (temporal correlation, no change on the ground)
  - 0 = No coherence (no correlation, temporal decorrelation, significant change on the ground

Expect image pair before and after the fire to show low coherence due to biomass loss after the fire. A post fire pair expected to show high coherence within the fire scar prior to recovery of vegetation.

Land Cover:

Data obtained from CORINE 100m dataset; 5 points inside the fire scar and 5 outside for each class: peat bog; moors and heathland and natural grassland (Fig 2) NB. Includes the land cover sampling points.

Soil Moisture

Total daily rainfall data from the Upper North Grain Grain weather station in the PDNP was used as an indicator of soil moisture for the majority of SAR images in the time series (Fig 6).

SAR Intensity Results & Analysis

- Exposed peat bog inside the fire scar had the highest pre-fire intensity created by earlier fires visualised by bright pixels (Fig 4a-e). Peat bog intensity remains consistently high post-fire (0.84 dB JD 144 & -0.86 dB JD 179) (Fig 5).
- SAR images acquired during the dry period JD 72 – 90 (Fig 6) show a downward trend of intensity for all land cover classes except natural grassland and largely intact peat bog outside the fire scar.

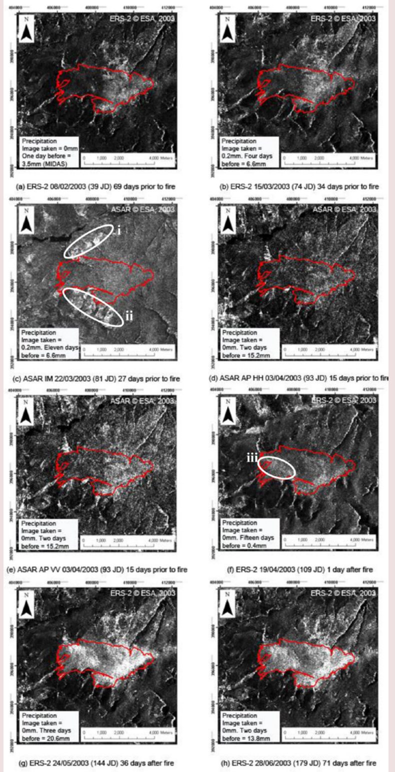

Figure 4 (a-h) – Time series of SAR intensity images of Bleaklow. Wildfire occurred on 18 April 2003 (108 JD, where JD = Julian Day). Key spatial patterns are annotated (i/ii) ascending pass topographic features and (iii) removal of moors and heathland vegetation after the fire.

- A peak in intensity occurs on 03/04/03 (JD 93) (Fig 4e) after 15.2mm of rain on JD 91 (Fig 6).
- JD 109 (1 day after the fire) illustrates a decrease in intensity for all land cover classes (Fig 4f) and (Fig 5).
- The rest of the post-fire period was wet (Fig 6). Peak rainfall of 20.6mm occurred 3 days before 24/05/03 image, JD 144 (Fig 4g). Intensity values post-fire Fig 4(g) and Fig 4(h) increased significantly following rainfall events.
- Amount /timing of rainfall is an important variable affecting detectability of the fire scar in moorlands (Bourgeau-Chavez et al., 1997).
- Colour composites were used to analyse the fire scar further for Bleaklow: area 7km^2 (Fig 7) & the smaller fire scar of Kinder: area 0.1km^2 (Fig 8).

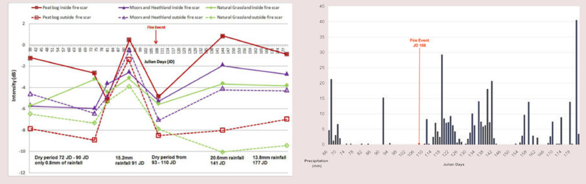

Figure 5 – Average intensity values (dB) inside and outside the Bleaklow fire scar for CORINE land cover classes
Figure 6 – Total Daily Rainfall (mm) from 07/03/03 – 30/06/03 at Upper North Grain, 4km southwest o f the fire scar

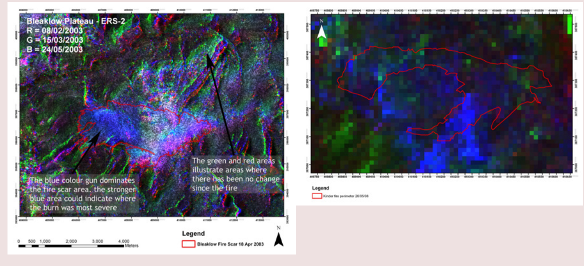

Figure 7 – ERS-2 colour composite of the fire scar at Bleaklow. Red Band = 08/02/2003 image,persistant features in the landscape.Green Band = 15/03/2003 image,unchanged moorland vegetation, Blue Band = 2 4/05/2003 image vegetation destroyed by moorland.

Figure 8 - ALOS PALSAR colour composite of the Kinder fire scar on 26/05/08. Red Band = 12/05/2008 Fine Mode HH; Green Band = 12/05/2008 Fine Mode HV; Blue Band = 10/06/2008 Fine Mode HH.

SAR Coherence Results & Analysis

Unexpectedly there is low coherence for pair 1 (Fig 9) with values ranging from 0.14 – 0.24 depending on the land cover class.

- Coherence increases slightly for all land cover classes for Pair 2 except for natural grassland inside the fire scar.
- Pair 3(Fig 9) is a coherence image produced from two images acquired after the fire (19/04/03 – 24/0503).
- Also greatest variation between land cover classes inside the fire scar, strong increase at the eastern end on peat bog, where already-exposed peat from older fire scars (Fig 9).
- Pair 4 (Fig 9), six and ten days post-fire, shows overall decrease in coherence for all classes. This is likely due to temporal decorrelation and also an initial high baseline of 654 for this InSAR pair. It is also during this time that reseeding began on the east side of the fire scar which would increase temporal decorrelation.

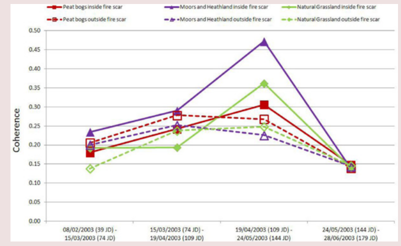

Figure 9 – Trend in average coherence of three CORINE land cover classes, inside and outside Bleaklow fire scar. Fire date 18/04/03

Conclusion & Future Work

- A large fire scar (7 km^2) in a degraded moorland environment can be detected using SAR intensity and coherence for ERS-2 & ASAR. Detection of smaller fire scars (0.1 km^2) such as Kinder appear more challenging after analysing ALOS PALSAR data.
- The occurrence of rainfall is a critical environmental variable affecting the radar intensity signal.
- Within the Bleaklow fire scar, peat bog gave the highest intensity return probably due to its high sensitivity to soil moisture.
- Highest coherence values within the fire scar were obtained from InSAR Pair 3 (Fig 9) for the two images acquired shortly after the fire, probably due to a low baseline of 147 and this result indicates low temporal decorrelation between 19/04/03 – 24/05/03.

Acknowledgements

Many thanks to the School of Environment and Development (SED) and Mimas for funding to support this research. Also many thanks to the European Space Agency (ESA) for allowing access to ERS-2 , ASAR and PALSAR data as part of Cat1 Project 2999 and to MFF for access to fire log and fire scar boundary data.

References

Bourgeau-Chavez, L.L., Harrell, P.A., Kasischke, E.S. & French, N.H.F. (1997) The detection and mapping of Alaskan wildfires using a spaceborne imaging radar system. International Journal of Remote Sensing, 18, 355-373.
Kitmitto, K., Millin, G., and Muller, P. (2007) Promoting the use of Radar data within the UK academic community. Fringe Workshop 26-30 November 2007.
Rykhus, R and Zhong, L. (2011) Monitoring a boreal wildfire using multi-temporal Radarsat-1 intensity and coherence images, Geomatics, Natural Hazards and Risk, 2: 1, 15 – 32.

Email: Gail.Millin-Chalabi@manchester.ac.uk