Using ASAR & ERS-2 to Detect a Moorland Fire Scar in the Peak District National Park

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Gail Millin-Chalabi, Julia McMorrow and Clive Agnew

School of Environment and Development, University of Manchester, Oxford Road, Manchester, M13 9PL

Introduction

Aim

To explore whether Synthetic Aperture Radar (SAR) intensity and coherence images can be used to detect a fire scar in a degraded UK peat moorland environment.

Objectives

- Determine the ability of a time series of SAR (ENVISAT ASAR and ERS-2) intensity and coherence images to detect a fire scar in a peat moorland environment
- Improve understanding of how scene variables (soil moisture, vegetation, fire behaviour) affect the SAR fire scar signal
- Investigate the effect of filtering during pre-processing.

Why is Moorland Fire Scar Monitoring Needed?

- Wildfires which burn into blanket peat contribute to climate change by releasing carbon dioxide into the atmosphere. Can permanently damage protected wildlife habitats and discolour drinking water supplies
- Fire ground location on UK moorlands is poorly recorded. PDNP is unusual in having a fire log (1976 - present) (Fig 1).
- GPS mapping of fire scars is rare because it is costly and operationally difficult, especially on remote moorlands.
- Methods are needed to record fire scars, and allow calculation of burnt area and GIS analysis.
- Important for fire responders e.g. PDNP Fire Operations Group (FOG); moorland restoration groups e.g. Moors for the Future (MFF); other land managers (water companies, the National Trust and gamekeepers).

Study Area

Bleaklow moor, area of blanket peat in the Peak District National Park (PDNP) UK.

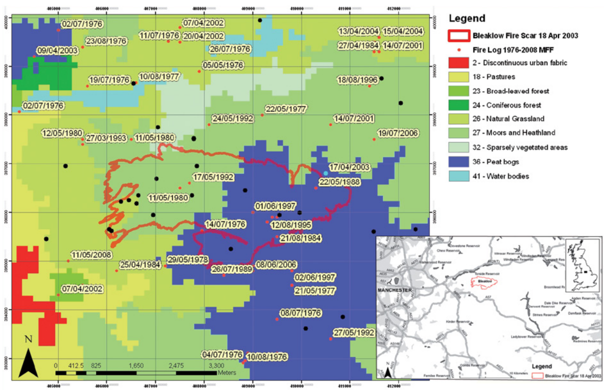


Figure 1 – Bleaklow study area, Peak District National Park, northwest England, showing: GPS outline of the 18 April 2003 fire scar, fire log point data 1976 to 2008 (MFF); CORINE land cover data; and intensity/coherence sampling points (black dots).

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

SAR Pre-processing:

- All pre-processing was done in SARScape 4.2. The processing chain for producing the intensity images is shown in Fig 2. Intensity values were calculated in ENVI 4.7.
- Frost, Lee and Degrandi filtering methods have been used during pre-processing to reduce speckle (noise) (Fig 3).
- Frost filter (Fig 3a & 3d), and Lee filter (Fig 3b & 3e) outputs are similar. Fire scar is high intensity (bright) on both, but could be confused with topographic effects.
- Multitemporal Degrandi filter smoothed speckle more effectively

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

Four InSAR pairs processed:

- 1 before the fire (Fig 7a),
- 1 before and after the fire (Fig 7b)
- 2 after the fire (Fig 7c/d)

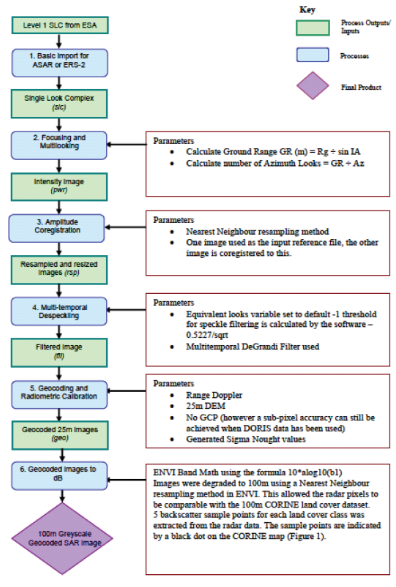


Figure 2 – SAR preprocessing steps in SARScape 4.2 to produce the intensity images adapted from (Kitmitto et al., 2007).

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 1) NB Includes the land cover sampling points.

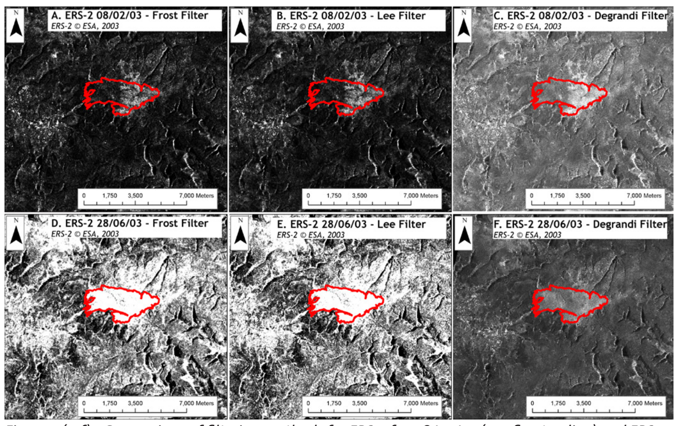
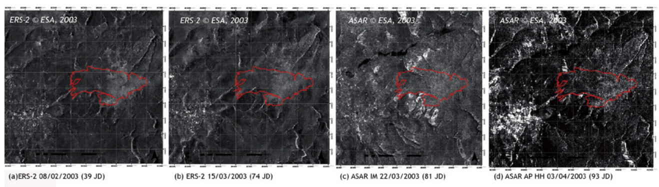


Figure 3 (a-f) - Comparison of filtering methods for ERS-2 for 08/02/03 (pre-fire, top line) and ERS-2 28/06/03 (post fire, bottom line): Frost(a, d), Lee (b, e), multitemporal Degrandi (c, f) methods.

Soil Moisture

Total daily rainfall data from the Upper North Grain weather station in the PDNP was used as an indicator of soil moisture.

SAR Intensity Results & Analysis



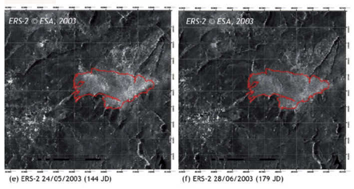
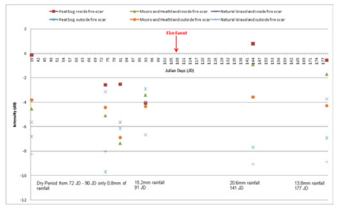


Figure 4 (a-f) – Time series of SAR intensity images of Bleaklow. Fire occurred on 18 April 2003 (108 JD, where JD = Julian Day). Top row, pre-fire. Bottom row, post-fire. It is possible that the difference between sensors may affect intensity.

- Exposed peat bog inside the fire scar had the highest pre-fire intensity at 0.16 dB JD 39 (Fig 4a) created by earlier fires. Peat bog intensity remains consistently high post-fire (0.78 dB JD 144 & -0.57 dB JD 179) (Fig 5).
- Please note CORINE classification does not differentiate between intact and exposed peat, so need to try other land cover classifications in the future.
- 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.
- A peak in intensity occurs on 03/04/03 (JD 93) (Fig 4d) following 15.2mm of rainfall on JD 91 (Fig 5).
- Post-fire period was wet (Fig 6). Peak rainfall of 20.6mm occurred 3 days before 24/05/03 image, JD 144 (Fig 4e).
- Intensity values post-fire Fig 4(e) and 4(f) increased significantly following rainfall events.
- Therefore, amount and timing of rainfall is an important variable affecting detectability of the fire scar in a moorland environment. Bourgeau-Chavez et al., (1997) also found intensity increased after rainfall events just prior to image acquisition.

SAR Coherence Results & Analysis

Unexpectedly there is low coherence for pair 1 (Fig 7a) with values ranging from 0.14 – 0.24 depending on the land cover class.



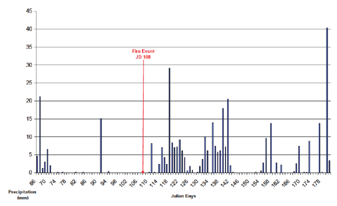


Figure 5 – Average intensity values (dB) inside and outside the Bleaklow fire scar for CORINE land cover classes
Figure 6 – Total Daily Rainfall (mm) from 07/03/03 – 30/06/03 at Upper North Grain, 4km southwest of the fire scar

- Coherence increases slightly for all land cover classes for Pair 2 except for natural grassland inside the fire scar.
- Pair 3 (Fig 7c) 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 7c).
- Outside the fire scar, coherence decreased for all except natural grassland, probably due to seasonal change in vegetation (Fig 8).
- Pair 4 (Fig 7d), six and ten days post-fire, shows overall decrease in coherence for all classes. Illustrates an 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.

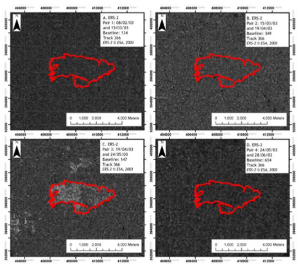


Figure 7(a-d) clockwise – InSAR coherence images for Bleaklow. Each produced from a pair of SAR images: (a) Pair 1, pre-fire, 08/02/03 – 15/03/03; (b) Pair 2, pre- and immediately post-fire, 15/03/03 – 19/04/03; (c) Pair 3, post-fire, 19/04/03 – 24/05/03; (d) Pair 4, post-fire, 24/05/03 – 28/06/03.

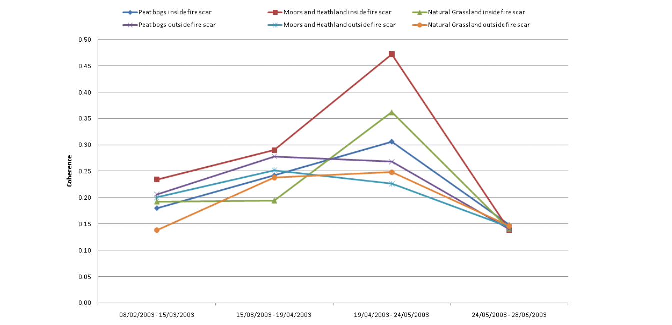


Figure 8 – Trend in average coherence of three CORINE land cover classes, inside and outside Bleaklow fire scar. Fire date 18/04/03

Conclusion & Future Work

- A large fire scar in a degraded moorland environment can be detected using SAR intensity and coherence.
- The occurrence of rainfall is a critical environmental variable affecting the radar intensity signal.
- Within the 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 7c) 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.
- Results are sensitive to filtering methods applied during pre-processing.
- Further investigation is required for fire scars of different sizes, on different land cover types, and critically, with different preceding and post-fire rainfall patterns. Also sensitivity to SAR polarisation and frequency.

Acknowledgements

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