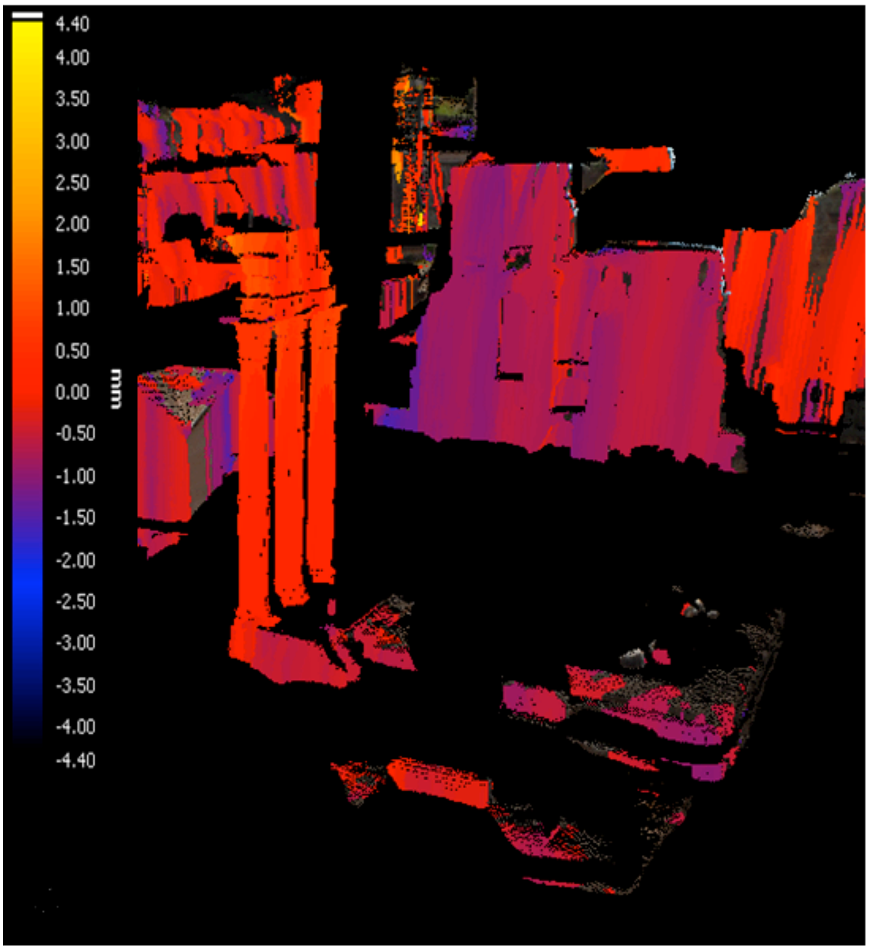
Archaeology Special Interest Group Newsletter

Spring 2013



Cover Image: '3D interferometric radar point cloud' ***Deodato Tapete***

ArchSIG Chair: Chris Brooke (archsig@rspsoc.org)

Editor: Rebecca Bennett

Contents

Welcome note from the Editor

Hello and welcome to the latest edition of the Archaeology Special Interest Group newsletter. First, an apology for the lateness of this issue; 2013 has been a busy year all round and compounded by an Autumnal relocation across the Atlantic for your editor, this newsletter is has been delayed. Many thanks to the contributors for their patience.

The first article in this edition covers an exciting application of radar technology for monitoring change and targeting resources at archaeological sites in Italy. Mark Kincey gives us a summary of work undertaken by English Heritage and partners in the North Pennines Area of Outstanding Natural Beauty using airborne remote sensing survey data to map and understand former industrial heritage and threats to it from erosion and land use change. Our final article is a short reflective piece looking at three recently published comparative papers that have the potential to guide historic environment users to improved choices for lidar data processing.

We end with a summary of upcoming events in 2013, which looks to be an exciting year for conferences and training. Don't forget to let the editor know of any event you are planning for inclusion in the announcements for the next newsletter!

Rebecca Bennett
on behalf of ArchSIG Steering Group
Chris Brooke, Paul Bryan, Keith Challis and Danny Donoghue

Call for contributions

ArchSIG is looking for contributions for the next issue (Summer 2013). These should be introductory articles with text (up to 500 words) and an image which give a flavour of your current research in remote sensing techniques for archaeology and heritage management. We are looking for a diverse range of topics from visualisation to mapping and imagery along with more technical studies, at a scale ranging from landscape to artefact.

The newsletter provides an excellent way to introduce your research to other archaeological remote sensing specialists. The editors welcome all expressions of interest as it is intended to issue the newsletter quarterly.

Contributions should consist of the following:

text (circa 500 words),

images (300dpi in jpeg or png format)

your contact details.

Please send your articles to Rebecca Bennett (rebecca.bennett@duke.edu) for inclusion.

The Remote Sensing and Photogrammetry Society ArchSIG does not claim to have a unified view; this newsletter provides a forum and therefore any views expressed by contributors are not necessarily those of the editor or steering committee.

Using satellite and ground-based radar technologies for strategic condition monitoring: outcomes from research on the archaeological heritage in Rome, Italy

Deodato Tapete,

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In times of funding cuts for cultural heritage preservation, it is increasingly crucial to implement methodologies of preventive diagnosis to identify the key areas of concern for the conservation and consequently prioritize restoration programmes. Satellite and ground-based remote sensing technologies based on Interferometric Synthetic Aperture Radar (InSAR; Rosen et al., 2000) nowadays appear a sustainable solution for strategic condition monitoring, as also testified by the currently routine applications for terrain motions monitoring (e.g., Casagli et al., 2010), civil protection activities and natural hazard management (e.g., Cigna et al., 2011). Both the configurations are highly suitable for multi-temporal detection, mapping and Early-Stage Warning (ESW) of instability mechanisms, with significant perspectives for deterioration and deformation pattern studies on cultural heritage (Tapete et al., 2011; Tapete and Cigna, 2012a).

In the period 2009-2012 InSAR technologies were specifically tested on the archaeological heritage in Rome, Italy, in the framework of co-operation with the Archaeological Superintendence and the Italian Ministry of Cultural Heritage and Activities. Persistent Scatterer Interferometry (PSI) was exploited to zone the unstable sectors of several archaeological areas, among which the Palatino Hill - Roman Forum site and the park of the Oppio Hill, respectively located W and N of the Colosseum. PSI data from ERS-1/2 and RADARSAT-1/2 SAR images processed by means of PSInSAR (Ferretti et al., 2001) and SqueeSAR algorithms (Ferretti et al., 2011) were radar-interpreted according to the methodology proposed by Tapete and Cigna (2012b).

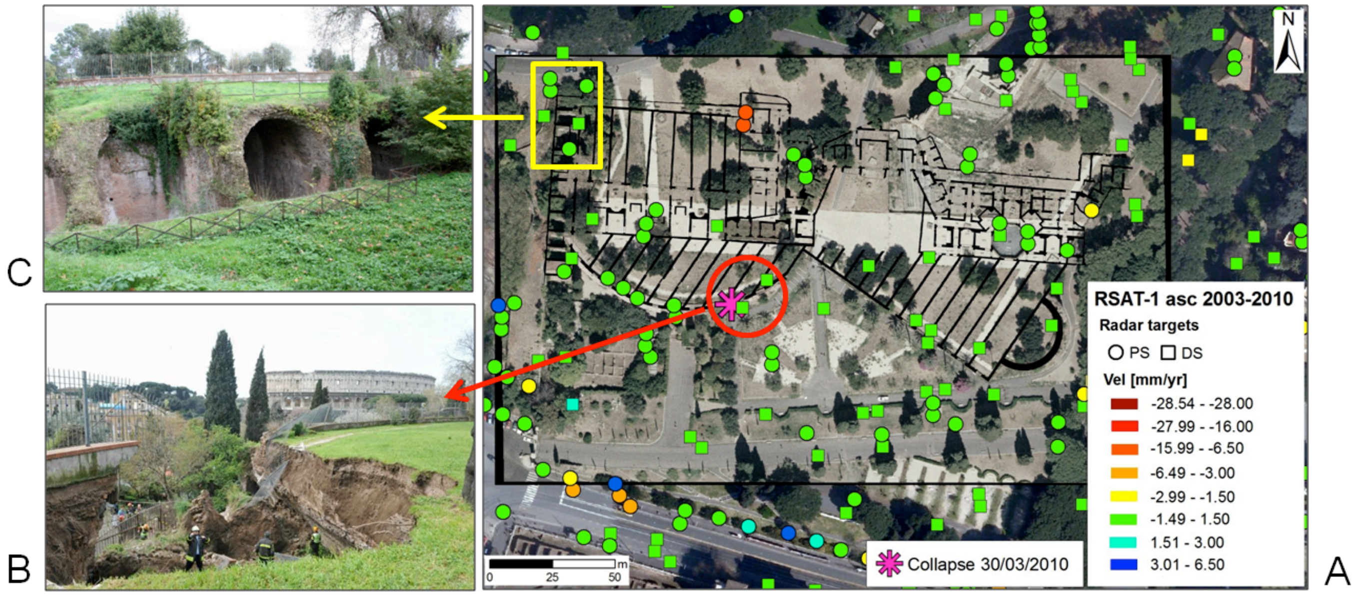

Figure 1 – A) Spatial distribution and LOS velocity field of the PS and DS identified over the terrain covering the Nero's Golden House from SqueeSAR processing of RADARSAT-1 images ascending (2003-2010). Deformation time series analysis allowed the back monitoring of the terrain motions before the collapse of March 2010 (B) and an effective Early-Stage Warning (ESW) of the potential instability affecting the Neronian rooms on the NW corner of the archaeological park (C).

Back monitoring of the deformation patterns confirmed that since 1992 the Palatino Hill was affected by localized deformation rather than a regional-scale land subsidence. Relative stabilization of the movements recorded along the Line-Of-Sight (LOS) of the satellite in 2003-2009 over the N-NW sector of the site suggested beneficial effects of the recent consolidation works. These results contributed to focus the next restoration programmes on the still critical sectors, such as those on the SW corner of the hill.

The improvement brought by the SqueeSAR processing resulted in satisfactory densities of Persistent and Distributed Scatterers (PS and DS) over the Oppio Hill (Figure 1A), overcoming the limits for the identification of stable radar targets in partially/totally vegetated areas of investigation. PSI outcomes included new insights into the collapse of about 60-80 square metres of vault ceiling of a gallery close to the Nero's Golden House occurred in March 2010 (Figure 1B). The event triggering was definitely correlated with the progressive detrimental effects of the tree roots and uncontrolled water seepage into the terrain covering the buried Roman structures.

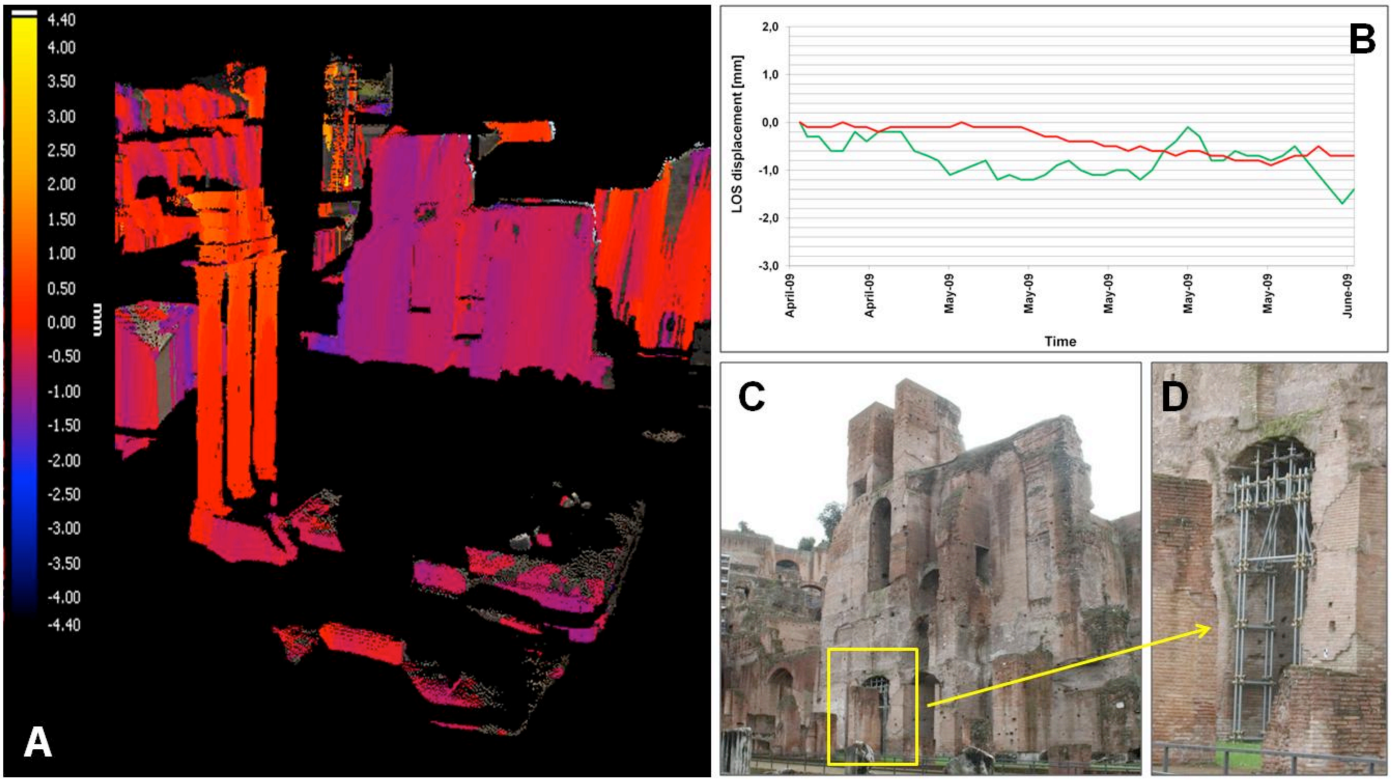

Figure 2 – A) '3D interferometric radar point cloud' allows a precise spatial interpretation of LOS displacement data collected by means of ground-based radar (GBInSAR) directly on the 3D geometry of the monitored monuments reconstructed from TLS point clouds. B) For each point of the view scene deformation time series are extracted and constantly updated. Detection of displacement trends can warn about ongoing instability, especially for those monuments with structural weaknesses (C-D).

Full details of the PSI analysis and the time series-based ESW procedure (Figure 1C) are discussed in Tapete et al. (2012). Passing to activities of structural monitoring at a scale of single monument/artefact, a novel methodology has been recently proposed by Tapete et al. (2013) to integrate terrestrial laser scanning (TLS) and Ground-Based Interferometric Synthetic Aperture Radar (GBInSAR) (Figure 2).

Displacements affecting the monitored structures are estimated along the LOS of a continuous-wave step frequency radar operating with central frequency of 17.3 GHz and moving along a linear rail of certain length, which determines the corresponding synthetic aperture of the SAR images. The latter are acquired with a temporal sampling up to few minutes, and the processed interferometric products are automatically georeferenced onto the TLS data which reproduce the 3D geometry of the monitored objects (Figure 2A). Such method allows a precise spatial interpretation of the constantly updated LOS displacements data, and enables the operators to know which architectural elements are showing suspicious movements or structural behaviour anomalies. Thanks to the high spatial and temporal resolution, an actual 24/7 monitoring can be performed, and deformation time series are extracted and updated for each point of the view scene (Figure 2B). Benefits for surveillance activities are demonstrated by the results obtained during the 1-year long monitoring campaign aimed to assess the stability of the archaeological monuments in the Roman Forum (Figure 2C) and, in particular, of the Domus Tiberiana, which has been chronically affected by ground instability since Roman times (Tapete et al., 2013).

Casagli, N., Catani, F., Del Ventisette, C., Luzi, G. (2010) Monitoring, prediction and early warning using ground-based interferometry, Landslides 7 (3):291–301.

Cigna, F., Del Ventisette, C., Liguori, V., Casagli, N. (2011) Advanced radar-interpretation of InSAR time series for mapping and characterization of geological processes, Natural Hazards and Earth System Sciences 11 (3):865–881.

Ferretti A, Fumagalli A, Novali F, Prati C, Rocca F, Rucci A (2011) A new algorithm for processing interferometric data-stacks: SqueeSAR, IEEE Transactions on Geoscience and Remote Sensing 49(9):3460–3470.

Ferretti A, Prati C, Rocca F (2001) Permanent Scatterers in SAR Interferometry. IEEE Transactions on Geoscience and Remote Sensing 39(1):8-20.

Rosen, P.A., Hensley, S., Joughin, I.R., Li, F.K., Madsen, S.N., Rodriguez, E., Goldstein, R.M. (2000) Synthetic aperture radar interferometry, Proc. I.E.E.E. 88 (3):333–382.

Tapete, D., Casagli, N., Luzi, G., Fanti, R., Gigli, G., Leva, D. (2013) Integrating radar and laser-based remote sensing techniques for monitoring structural deformation of archaeological monuments, Journal of Archaeological Science 40 (1):176–189.

Tapete D., Fanti, R., Cecchi, R., Petrangeli P., Casagli, N. (2012) Satellite radar interferometry for monitoring and early-stage warning of structural instability in archaeological sites, Journal of Geophysics and Engineering 9: S10–S25.

Tapete, D., Casagli, N., Fanti, R. (2011) Diagnosis of deterioration in cultural heritage sites: promising perspectives for monitoring at different scales by radar interferometry techniques. In: Fioravanti M. and Mecca S. (eds), Proceedings of COST Strategic Workshop "The Safeguard of Cultural Heritage: A Challenge from the Past for the Europe of Tomorrow", Florence, Italy, 11-13 July 2011, Firenze University Press, pp. 211–213. ISBN 978-88-6655-058-7

Tapete, D., Cigna, F. (2012a) Site-Specific Analysis of Deformation Patterns on Archaeological Heritage by Satellite Radar Interferometry. In: XX International Materials Research Congress, Symposium 8 Cultural Heritage and Archaeological Issues in Materials Science, Cambridge University Press, MRS Proceedings, 1374, imrc11-1374-s8-o20, doi: 10.1557/opl.2012.1397.

Tapete, D., Cigna, F. (2012b) Rapid mapping and deformation analysis over cultural heritage and rural sites based on Persistent Scatterer Interferometry, International Journal of Geophysics, Volume 2012, Article ID 618609, 19

Multisensor remote sensing of the upland lead mining landscapes of Alston Moor, North Pennines, UK

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In 2008, English Heritage's Research Department initiated a five-year project to investigate the archaeology of the upland landscapes of the North Pennines Area of Outstanding Natural Beauty (AONB) (Ainsworth 2009). Far from being 'England's last wilderness' as they are often described, the North Pennines are actually historically amongst the most heavily exploited and managed upland landscapes in the UK, particularly as a result of the area's extensive mineral deposits and associated lead mining industries. One module of this 'Miner-Farmer Landscapes' project was specifically designed to assess the potential of multisensor remote sensing for understanding the complex interplay between historic land-use practices and the surrounding semi-natural environment.

Airborne lidar, aerial photography (RGB and CIR) and AISA Eagle hyperspectral data were initially used for the rapid mapping of industrial archaeological sites within the study area, in order to establish a baseline archaeological record against which to assess issues of threat. This mapping recorded 1193 features of probable industrial heritage, suggesting an approximate spatial density of c.37 extant surface archaeological sites per square kilometre (Figure 1).

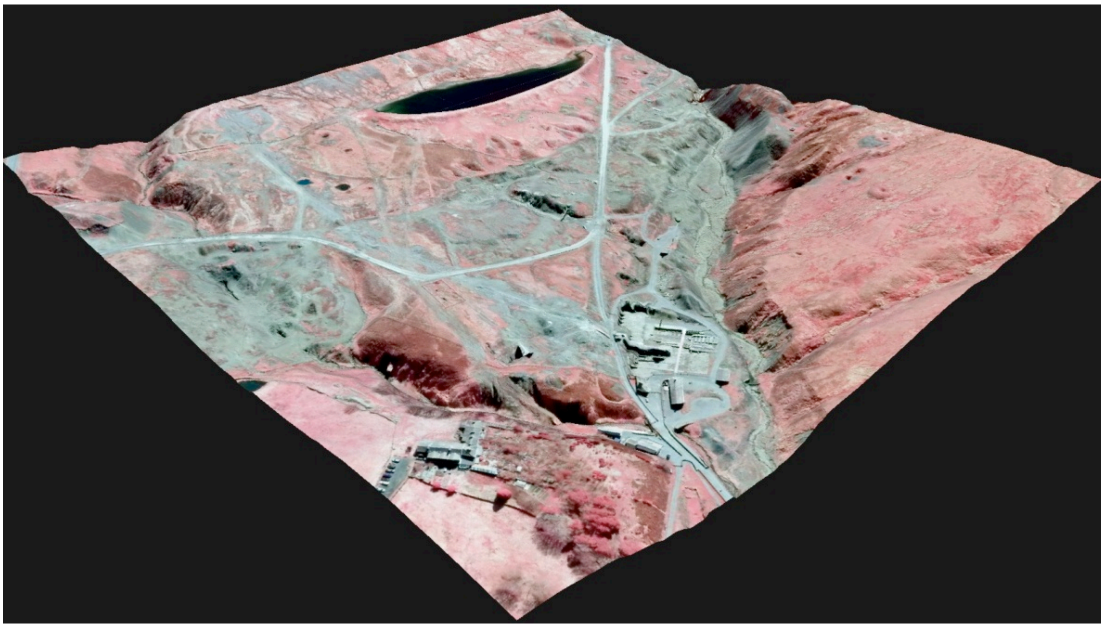

Figure 1:. Colour-infrared aerial photograph draped over 0.5m resolution airborne lidar DEM, showing complex lead mining remains at Nenthead (© English Heritage)

This archaeological record was then supplemented by the mapping of erosion features using the same data sets, with the aim being to better understand the spatial interactions between the two (Fig 2). This analysis recorded a number of regions of severe peat erosion and gullying, although generally in areas distinct from the mapped archaeological sites. However, the large amount of loose, unconsolidated mining waste that is found in non-peat areas throughout the Alston landscape also has huge erosion potential. An assessment of which sites are at risk from this erosion was carried out using land cover characteristics derived from the classification of spectral imagery, slope severity and hydrological flow derivatives from the airborne lidar data and a fieldwork walkover to verify specific conclusions.

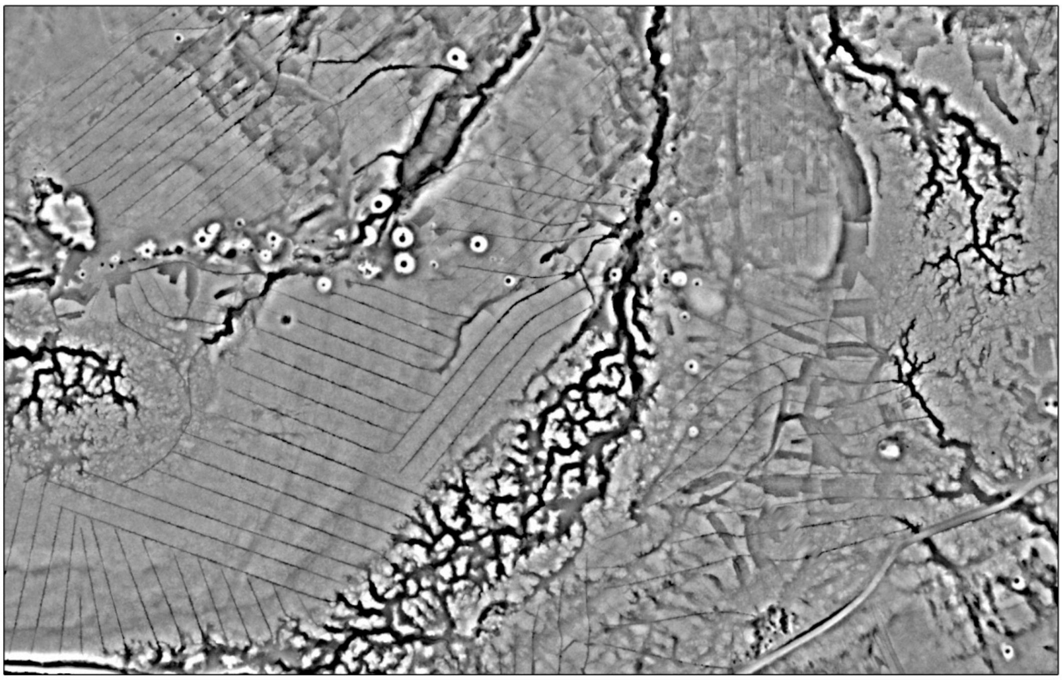

Figure 2:

Airborne lidar image showing extensive gully erosion and lead mining remains on Flinty Fell (© English Heritage)

These analyses provided a useful high spatial resolution point-in-time assessment of the current location and nature of erosion within the study area but it was deemed equally important to consider how the extent and severity of this damage has changed over time. This temporal assessment was accomplished using multispectral Landsat data from five epochs spanning four decades (1977, 1988, 1992, 2000 and 2006). The results highlighted significant variability in patterns of erosion across relatively small distances, with both the visual image analysis and NDVI change detection revealing some areas that appear to have remained relatively stable and others that have experienced a considerable reduction in vegetation health or cover. The Landsat NDVI analysis of the mining remains at Fletcheras Rake, for example, indicated a marked increase in the extent of bare, un-vegetated ground between 1977 and 2006, particularly extending away from the core of the site in a south-westerly direction. Comparison with recent aerial photography indicates that these decreased values correspond with the location of pronounced gullies and it appears likely that this response is due to the redistribution of mining waste from the core of the site and the covering or erosion of the minimal vegetation in the downslope areas. Lead concentrations obtained from soil samples in these locations were extremely high and exceeded all suggested soil guideline values, highlighting the importance of such research for both the heritage management and environmental agendas.

Ainsworth, S. 2009. Miner-Farmer Landscapes of the North Pennines AONB. Research News. No. 11. English Heritage.

Lidar Processing for Archaeology – a short review

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Over the eight years since the publication of Bewley, Crutchley and Shell's "New light on an ancient landscape" (2005), lidar has become a go-to method for feature prospection at a landscape scale for all those who can acquire access. Journals, conference papers and newsletters were quick to broadcast the results of applying these data, clearly indicating the potential of high-resolution topographic survey. During these early days, relatively little attention was given to processing techniques with shaded-relief modelling remaining the ubiquitous visualisation tool. Three years later, the problems of illumination bias and multiple images were beginning to be recognised and in some ways addressed (Devereux et al. 2008) but remained a key issue in the application of lidar data for historic environment research.

As is so often the case, where there is a need there is a solution, and in 2010/2011 the archaeological community was presented two processing techniques that aimed to improve on the shaded-relief technique. Hesse published the Local Relief Model or LRM (2010) a method that allowed the extraction of micro-topography from the landscape highlighting positive and negative features. Swift to follow was Kokalj et al's sky-view factor (SVF or horizon model) (2011), a technique which although reflecting light levels on a feature in a similar user-friendly way to shaded-relief modelling removed directional bias by calculating average light levels from illumination angles across the hemisphere.

While much needed and welcome additions to the toolkit, these techniques understanding how and when to apply these techniques posed a problem for the general archaeological community. Without published comparative data, users could not assess the appropriateness of any technique for their research environment which is where three recent publications come to the fore. Luckily a number of recent publications have addressed just this issue with Challis et al. leading the way in 2011. This paper presents the results of visual analysis from four different locations, covering a range of six processing techniques – colour shading, slope, hill-shading (shaded-relief), PCA (of shaded-relief models), terrain filtering (LRM) and Solar Insolation (SVF). Although the fact that the latter techniques are not referred to by the most recently published names may confuse some readers, the publication provides very useful information regarding processing software and a workflow to guide users through visualisation selection in high and low relief landscapes.

Štular et al. present the results of similar analysis of a range of techniques for an area of known sites in a wooded, mountainous environment (2012). These include colour-ramped DTMs, slope, LRM (termed here as trend removal) SVF and a number of variants of solar-illumination They also incorporate a survey of 12 users with a range of experience in lidar data interpretation and propose a method of quantifying efficiency of the techniques by means of assessing contrast between cells of the image using the median of five different standard deviations. Noise is also calculated using the standard deviations of the standard deviations. As the unique selling point of the article, it is felt that this important step in quantifying contrast and noise warranted further explanation or reference.

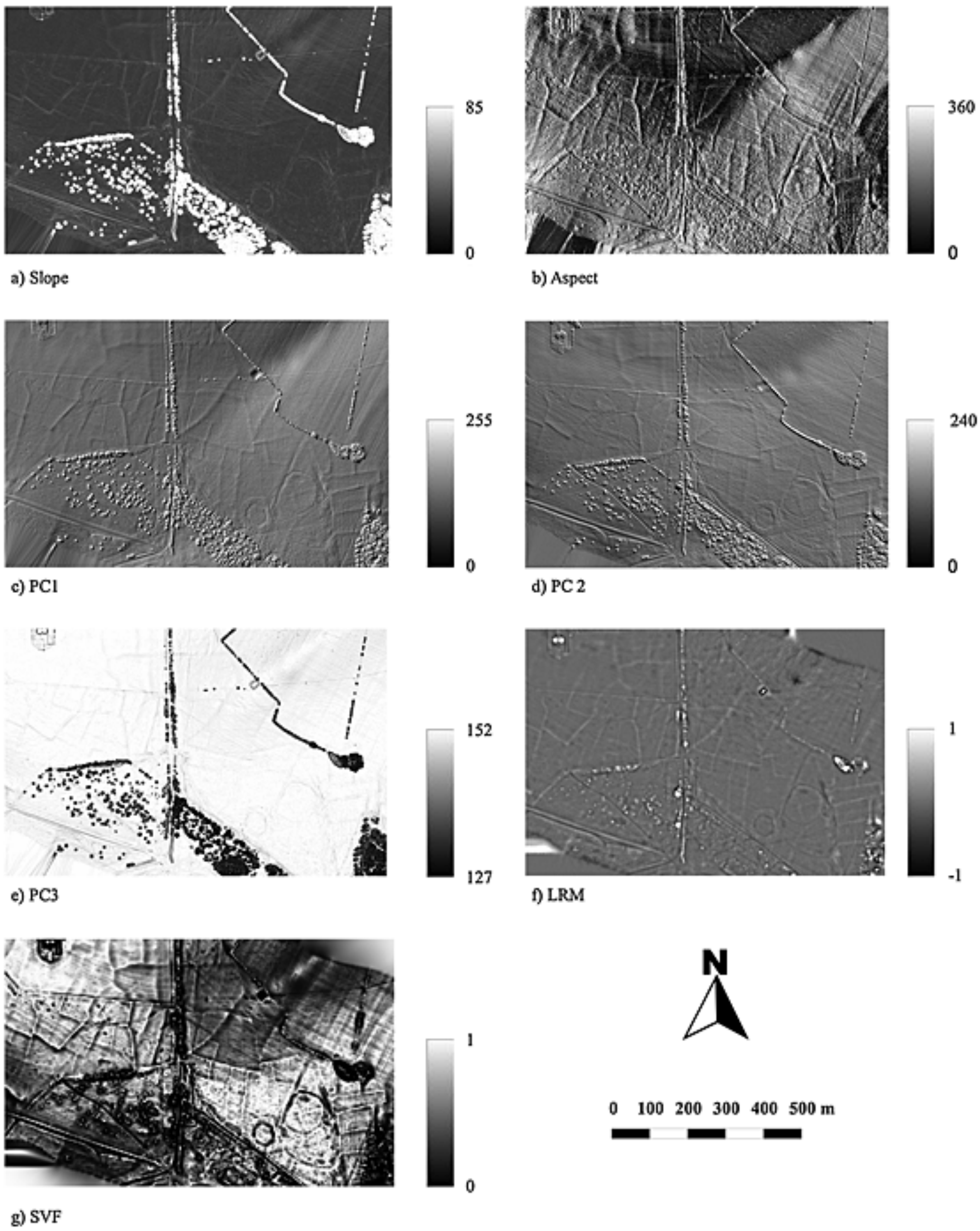

Figure 1: Comparison of visualization techniques used by Bennett et al 2012: (a) slope, (b) aspect, (c) PC1 of shaded relief images, (d) PC2 of shaded relief images, (e) PC3 of shaded relief images, (f) local relief modelling and (g) sky-view factor. Reproduced with permission of Wiley-Blackwell.

Complementary to the analysis of the above-mentioned articles is a short report by Bennett et al (2012). While only one environment, grassland, is assessed by this paper it provides the only quantitative information published to date regarding the varying visibility of individual archaeological features in shaded-relief, slope, PCA, LRM and SVF visualisation. The paper gives details of issues of how various techniques affect position, scale and accuracy of the archaeological features represented along with a brief discussion of the nature of "false positives" or artefact features whose presence was enhanced by certain visualisation techniques.

So what are the conclusions of these comparisons? Well sadly for lidar-users everywhere there is no silver bullet but all the papers agree on the following points:

- Although visually pleasing and the most commonly used visualisation technique shaded-relief modelling is a poor method for identifying and accurately mapping archaeological features
- Multi-method analysis is recommended, with LRM and SVF and slope highly recommended
- Users should try to familiarise themselves with the potential pitfalls of any technique prior to its application
- The most effective and appropriate selection comes from the trial of a number of visualisation techniques for a given environment.

Together the articles mentioned provide a crucial starting point from which to begin to understand the visualisation techniques that are most appropriate for your research although remains to be seen what impact these papers will have on the techniques used by the growing non-academic community of people using lidar for archaeological survey, especially as currently only one of them is available as an open-access document without subscription or one-off payment to an academic journal.

Bennett, R., Welham, K., Hill, R.A., and Ford, A. 2012. A Comparison of Visualization Techniques for Models Created from Airborne Laser Scanned Data. Archaeological Prospection 19: p.41–48.

Bewley, R.H., Crutchley, S.P., and Shell, C.A. 2005. New light on an ancient landscape: Lidar survey in the Stonehenge World Heritage Site. Antiquity 79(305): p.636–647.

Challis, K., Forlin, P., and Kincey, M. 2011. A Generic Toolkit for the Visualization of Archaeological Features on Airborne LiDAR Elevation Data. Archaeological Prospection 18(4). Available at: http://ejournals.ebsco.com/direct.asp?ArticleID=4E2EB94BD0C20BCD6604.

Devereux, B.J., Amable, G.S., and Crow, P. 2008. Visualisation of LiDAR terrain models for archaeological feature detection. Antiquity 82(316): p.470–479.

Hesse, R. 2010. LiDAR-derived Local Relief Models - a new tool for archaeological prospection. Archaeological Prospection 18(2).

Kokalj, Z., Zaksek, K., and Ostir, K. 2011. Application of sky-view factor for the visualisation of historic landscape features in lidar-derived relief models. Antiquity 85(327): p.263–273.

Štular, B., Kokalj, Ž., Oštir, K., and Nuninger, L. 2012. Visualization of lidar-derived relief models for detection of archaeological features. Journal of Archaeological Science 39(11): p.3354–3360.

Announcements / Notices

This section will announce upcoming conferences, meetings, seminars. If you have an item for inclusion in the next issue please send details to the editor.

22nd-23rd February 2013	CAA UK http://www.lparchaeology.com/caauk/call-for-papers/	L-P Archaeology, London
25th-28th March	CAA 2013 http://www.caa2013.org/	Perth, Australia
8th-10th April	First International Conference on Remote Sensing and Geo-information of Environment' http://www.cyprusremotesensing.com/rscy2013/	Pafos, Cyprus
12th-14th April	Rathcroghan Conference "Peeling back the layers: Remote Sensing and Ritual Landscapes" http://www.rathcroghan.ie/rathcroghan-conference-2013/	Rathcroghan Ireland
17-19th April	IFA Annual Conference "Making Waves" http://www.archaeologists.net/2013makingwaves	Birmingham, UK
29th June – 2nd May	10th International Conference on Archaeological Prospection http://ap2013.univie.ac.at/	Vienna, Austria
14th May	Practical Applications of Geographic Information Systems (GIS) in the Historic Environment: Short Course OUDCE http://www.conted.ox.ac.uk/courses/details.php?id=197	Oxford, UK
6th July	Digital Heritage 2013: Interfaces with the Past http://www.york.ac.uk/digital-heritage/events/cdh-2013/	York, UK
4th-6th September	RSPSoc Annual conference "Earth Observation for Problem Solving" http://www.rspsoc.org.uk/index.php/rspsoc-2013.html	Glasgow, UK
26th-28th September	Aerial Archaeology Research Group Annual Conference	Amersfoort, The Netherlands
23rd – 26th September	SPIE Remote Sensing 2012 http://spie.org/remote-sensing-europe.xml?WT.mc_id=RCal-ERSW	Dresden, Germany