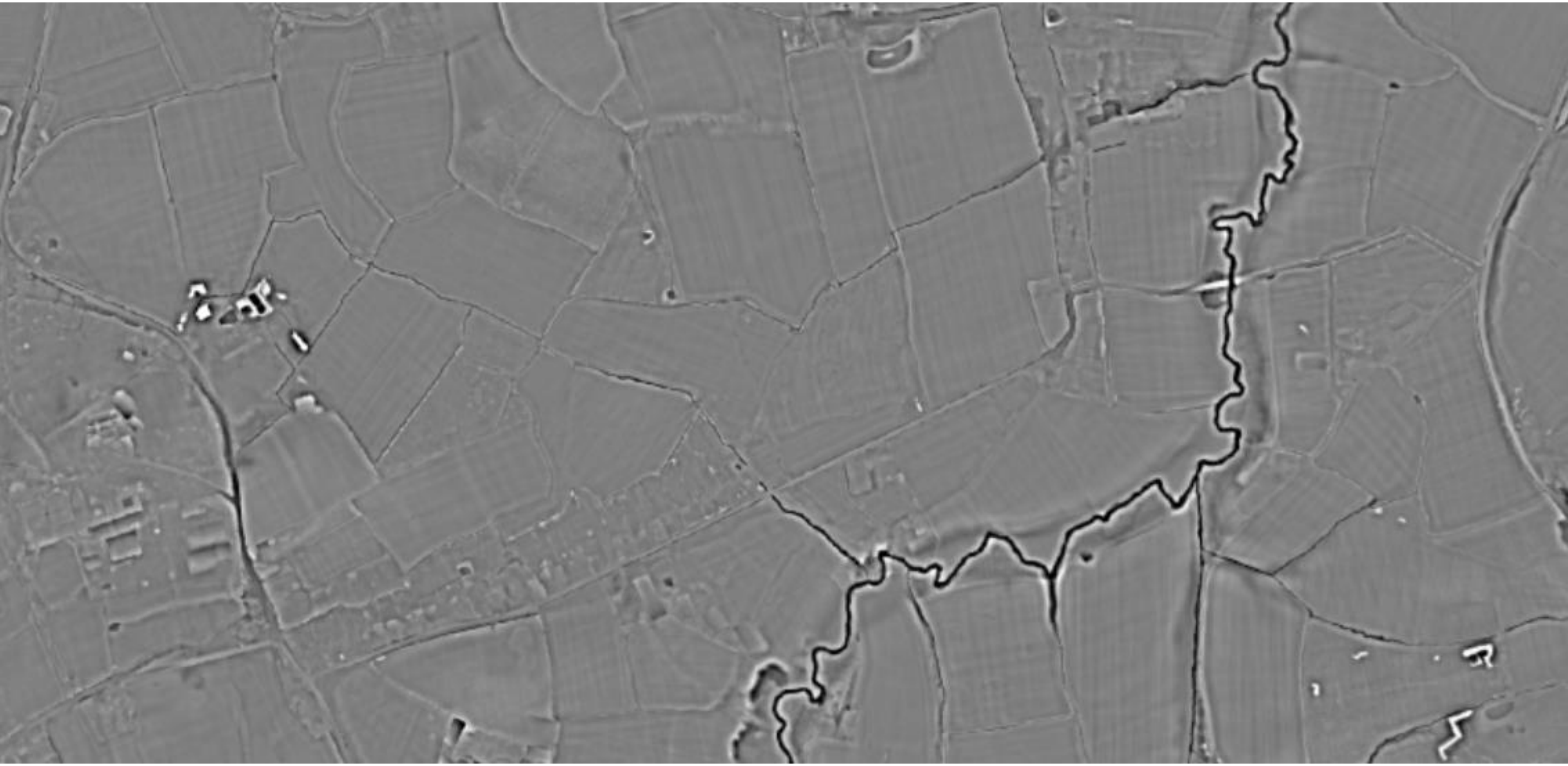
How to Read LiDAR



Surrey LiDAR Portal

How to use this guide

The **Surrey LiDAR Portal** is a citizen science mapping project which relies on volunteer involvement to help enhance the county's historic record through identification of previously unknown archaeological features spotted in LiDAR data. In order for the resulting records to be as informed and accurate as possible, a basic understanding of how to read the imagery itself and interpret some of the apparent oddities is essential.

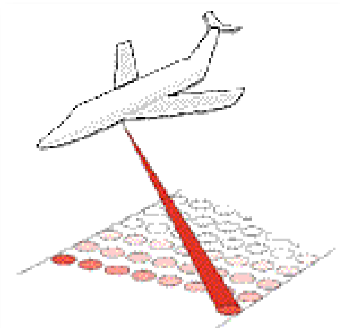
This guide on **How to Read LiDAR** is intended to serve as a helpful supplement to the **Gazetteer of Monument Types**, both of which can help in identifying possible features spotted in the LiDAR data on the online Portal. It is not a definitive resource in how to read and interpret LiDAR, and links to further material and resources are recommended, including Historic England's *Using Airborne LiDAR in Archaeological Survey*. There will also be various workshops and opportunities to consult with others on what a particular feature might mean, so do not worry if you're unsure at first of what you're seeing.

Volunteers interpreting the images with help from other sources

Additional, more detailed tutorial guides are provided which instruct on how to undertake research and fieldwork to aid interpretation, as well as how to digitise features, including a **Guide for Desk-Based Study**, **How to Digitise and Record** and **Guide to Groundtruthing**.

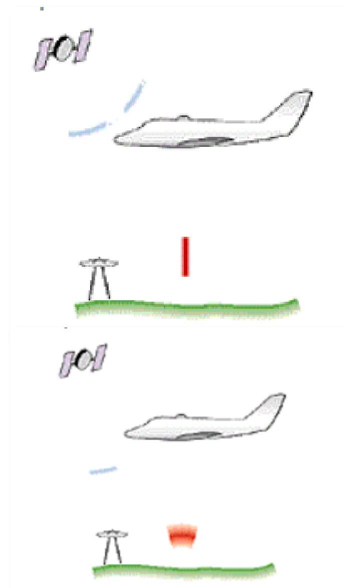
Understanding LiDAR

LiDAR (**Li**ght **D**etection **a**nd **R**anging) is based on the principle of measuring distance through the speed and intensity recorded for a pulse of light to be fired from sensor equipment and reaching a target, before sending a return signal.



Airborne LiDAR systems rely on echo location to measure distance from the sensor to a target, in this case the ground and any features upon it. LiDAR sensors commonly operate by scanning a laser beam from side to side as an aircraft flies over the survey area and recording the reflections. A cloud of height points is created from these reflections which can then be turned into 3D models of the landscape.

Although LiDAR systems were developed in the 1960s, it was the widespread developments in Global Positioning Systems in the late 1980s that allowed for the creation of the highly accurate land surface models which we are familiar with today.



In the UK it was The Environment Agency who instigated the widespread use of topographic LiDAR from 1996 onwards for the production of terrain maps to assess flood risk. Although it is particularly well-known and useful in wooded areas, LiDAR can also assist archaeologists in recognising earthworks and other features otherwise difficult to detect in open ground.

DSM vs DTM

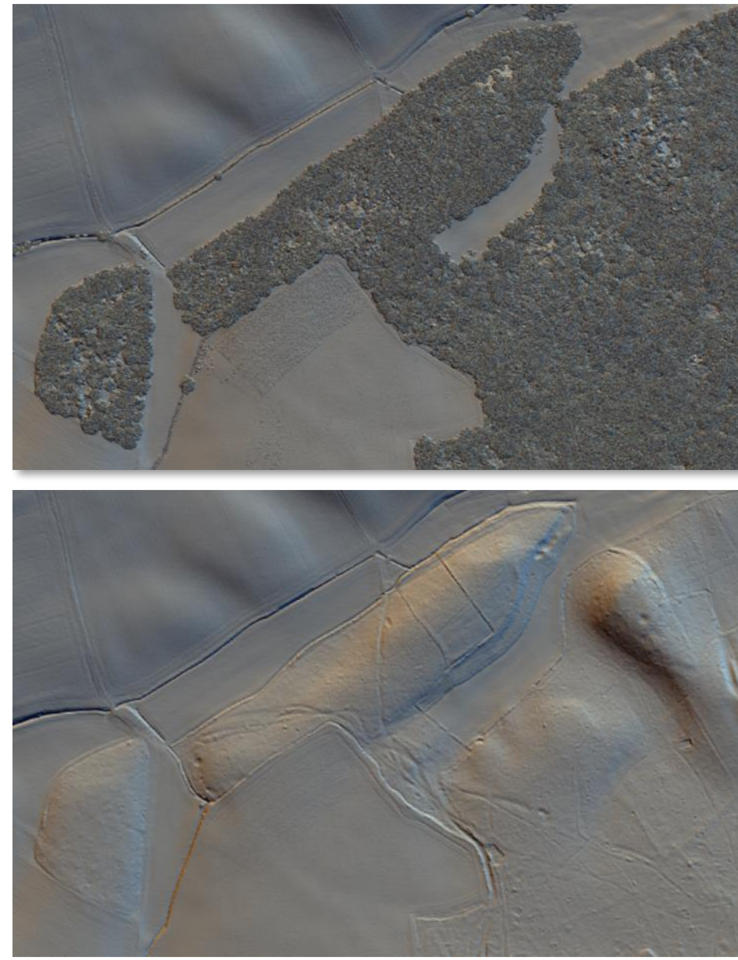
In order to visualise the data easily, a surface is created which can be modelled and shaded as a raster image. The most common raster images differ based on the point at which the pulses are returned to the sensor and the resulting data is processed.

The **Digital Surface Model (DSM)** is the first return or highest point of pulse return, usually showing the whole landscape, including the ground surface in open areas, vegetation, woodland canopy and buildings.

The **Digital Terrain Model (DTM)** is created by filtering the LiDAR dataset to remove all non-ground returns such as those that reflected from vegetation and buildings. This filtering allows features under the vegetation canopy to be visualised.

It needs to be remembered that DTM does not necessarily strip all vegetation away, as some denser canopy still does not allow any light to penetrate.

Generally, if a site is in an open area, it can be better to consult the DSM data and reduce the risk of a smoothing effect on the final visualization, resulting in archaeological features being removed.

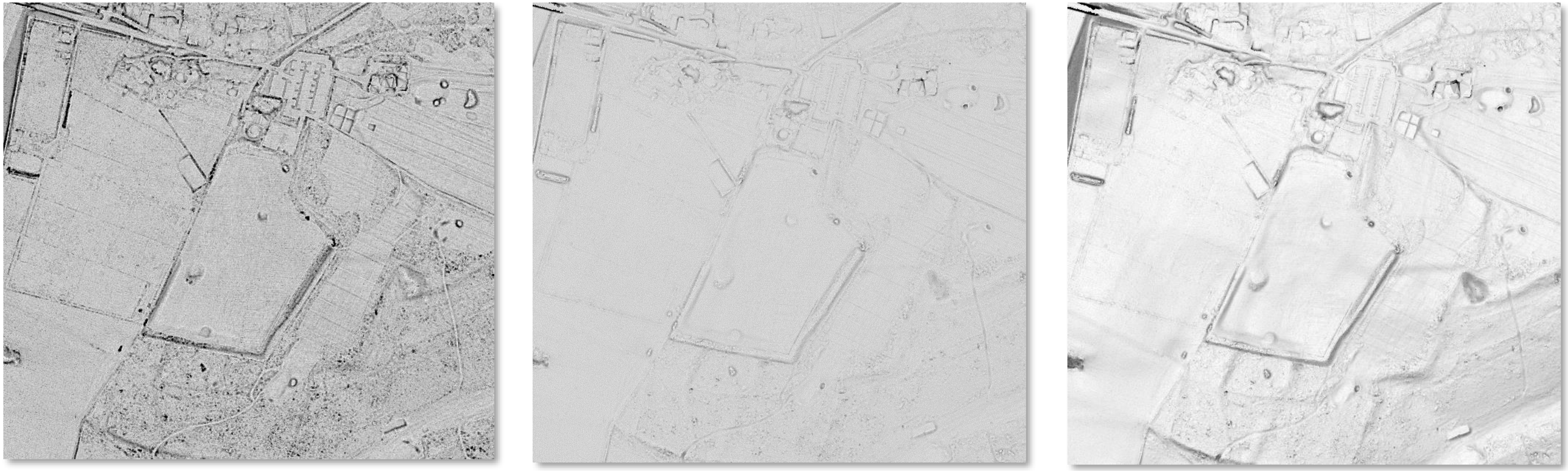


DSM (top) and DSM (bottom) of Watts Hill

Different Visualisations

LiDAR is best viewed through various visualisations, each which have their own advantages and disadvantages, offering different ways of viewing the data to aid in interpretation.

Single lit hillshade images are the standard form commonly made available by the Environment Agency, and though easy to interpret, they can be limited in their display. Others, such as the Openness technique (which accentuates positive and negative features) or Sky View Factor (which produces a shaded image as though illuminated uniformly from above) offer more information, but can be more complex in their interpretation.



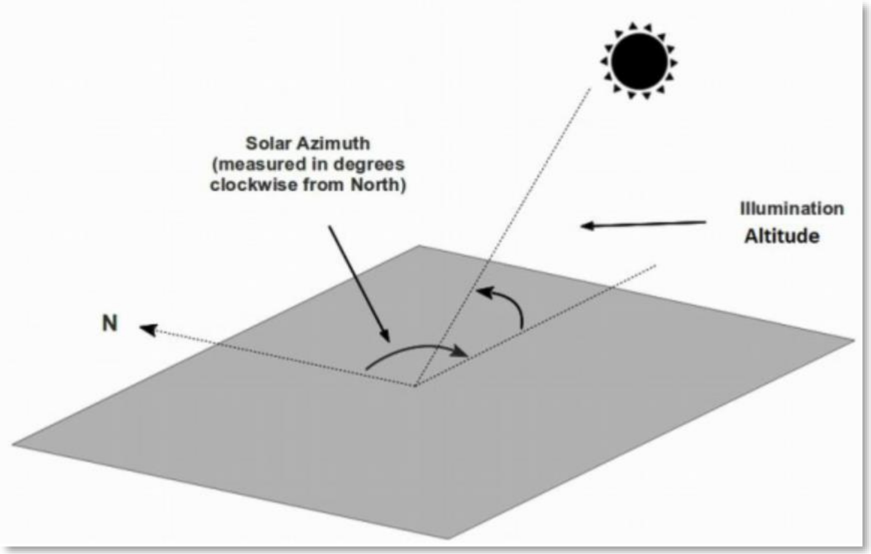
Visualisations showing openness negative, openness positive and sky view factor

For the Surrey LiDAR Portal, only the two most common and (arguably) most useful visualisations have been selected as layers for viewing: **Hillshade** and **Local Relief Modelling**.

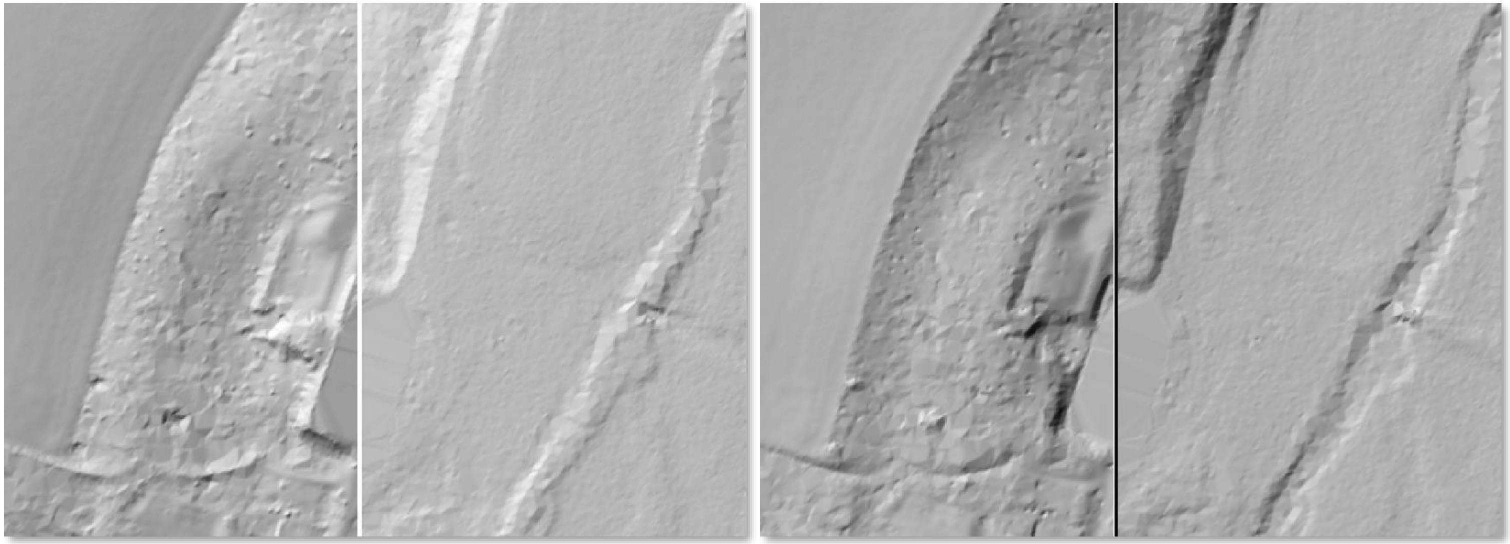
Hillshade

Hillshade, also known as 'shaded relief model', attempts to replicate conditions of 'raking light' to artificially illuminate and highlight landscape features from various angles.

Hillshade can be calculated from a single direction and angle, with the parameters fed into software to create the required visualisation. This includes the solar azimuth (the position of the sun in the sky with 0° as north) and the angle of illumination (the altitude of the sun).



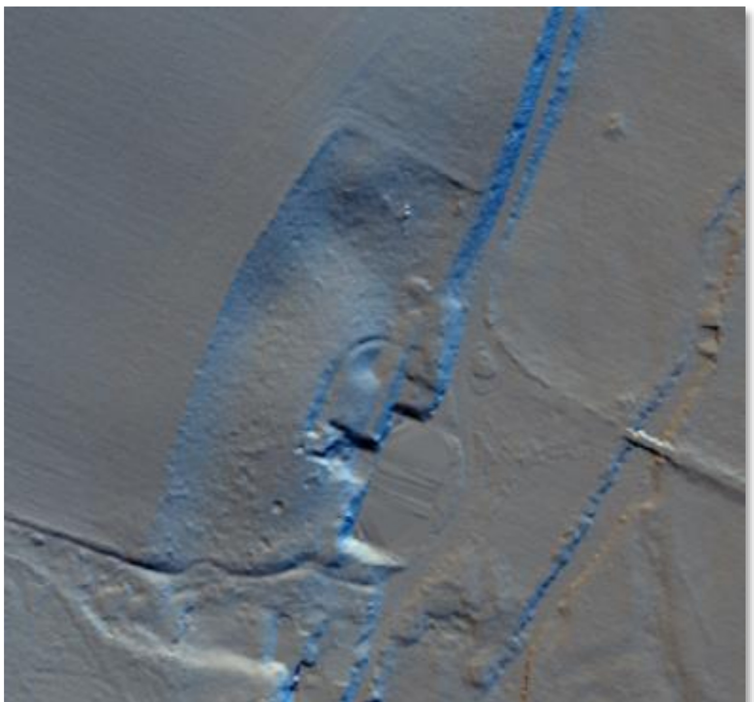
Hillshade diagram (© Rebecca Bennett)



Hillshade of Lullingstone Villa, showing the solar azimuth as 135° and illumination height of 35° (on left) and an azimuth of 315° (on right)

Hillshade

It is more common however for a 'multi-directional hillshade' visualisation to be created, where multiple directions of artificial illumination, taken equally from 0° to 360°, are combined to create a single image. As many as 16 directions are frequently used, though to prevent possible inversion of features, a static image composed of three hillshades (usually with azimuth directions of 0°, 45° and 90°) is usually created.



16-direction shaded relief model of Lullingstone Villa as used on the Portal

Hillshade is one of the most popular visualisations used, as it is considered the most familiar and understandable, particularly for those used to viewing aerial photography.

One disadvantage however is that it can be misleading in the supposed position of a feature, as changing the direction of illumination can make the position on the ground appear different to its actual location. A single-lit hillshade image can also miss features if they are aligned along the source of light.

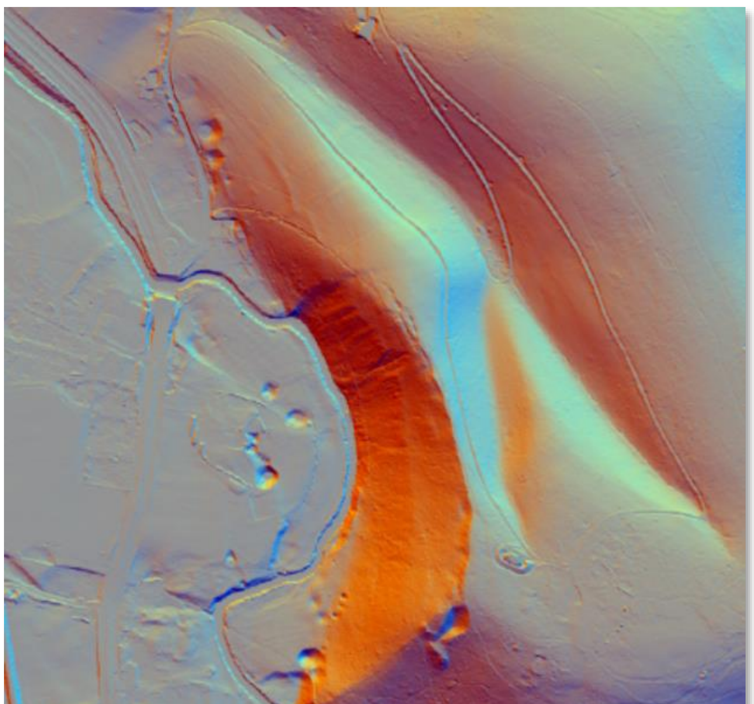
Multi-directional hillshade is often the preferred visualisation and the one which used on the Portal.

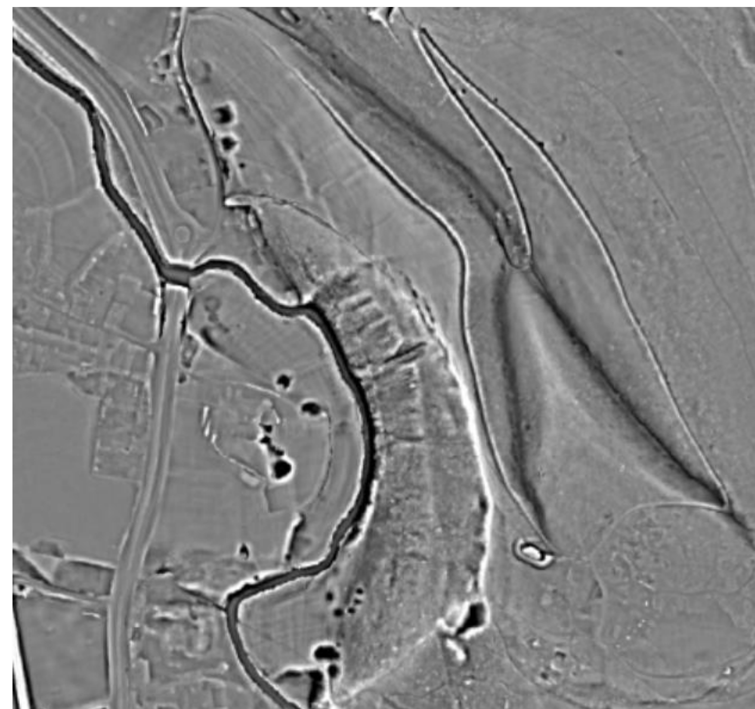
Local Relief Model

Local relief modelling (LRM) is another visualisation which filters out large-scale topographical elements from the data, such as hills and valleys, so that the more subtle, small-scale features remain.

LRM can make archaeological features – whether burial mounds, sunken roads or ridge and furrow – more apparent, though there can be a certain level of distortion to some features.

Hillshade DTM (left) versus Local Relief Model (right)



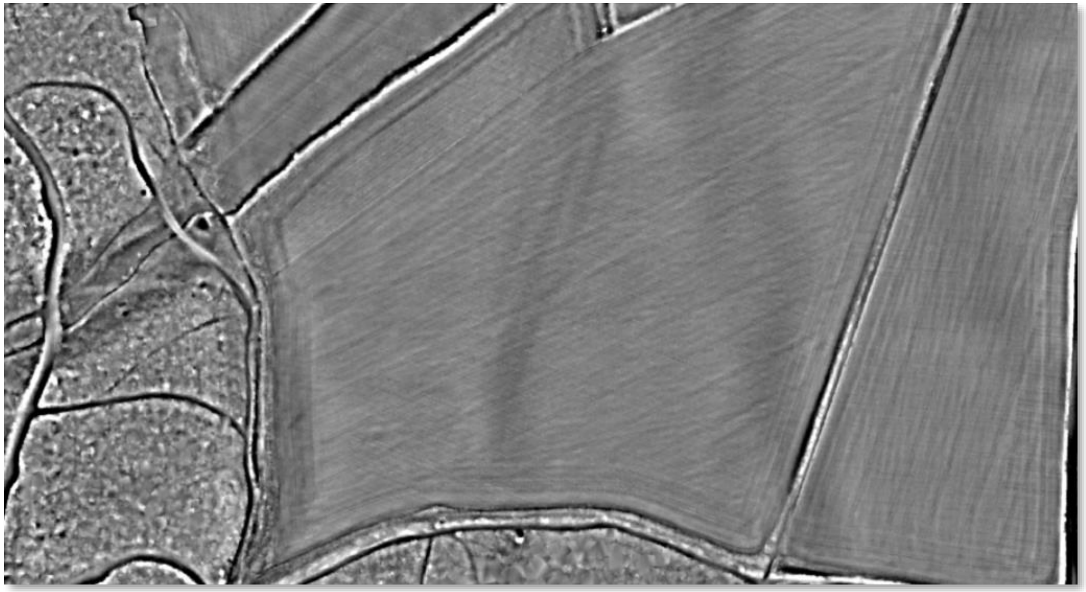


Interpretation issues

Although at first glance, the LiDAR visualisations can appear easy in their interpretation, understanding the various issues which can result from the flight and data-processing afterwards, as well as following up any potential features with groundtruthing, is essential for informed and accurate results.

As with aerial photography, LiDAR interpretation relies on informed recognition of differences in height data, however slight, which appear as subtle shadows and highlights and reveal the various banks, mounds and ditches scattered across the landscape.

This analysis includes filtering out features which, rather than being historical in relevance, are the result of modern agriculture or geology.



Modern plough lines, field boundaries and natural ridges apparent across landscape, though some earthworks and ditches are also apparent in the wooded area

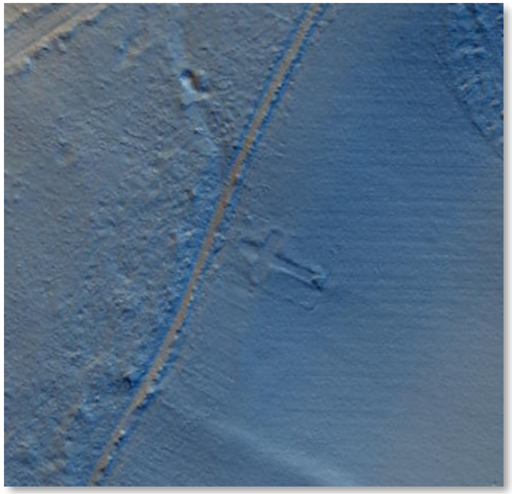
Overall, failure to examine all available data sources at the outset can lead to features and sites being misidentified (see the **Guide to Desk-Based Study** for other resources).

False features

When looking at the LiDAR images in isolation, it is common to automatically interpret features which look to be promising as archaeological. It is essential however to refer to other maps and images for interpretation in case there is another more likely alternative. The Portal makes other layers available for this purpose, which should always be consulted.

Some interesting-looking features will already have an HER record which can quickly identify them.

Aerial photographs are a quick way to check if a feature is actually a more recent structure in the landscape, e.g. swimming pools, pylons, water treatment plants, etc.



'Shoreham Cross' chalk memorial in Kent, which is easily identified from its aerial photo and HER record

Possible extraction pit, which on quick assessment is part of a golf course

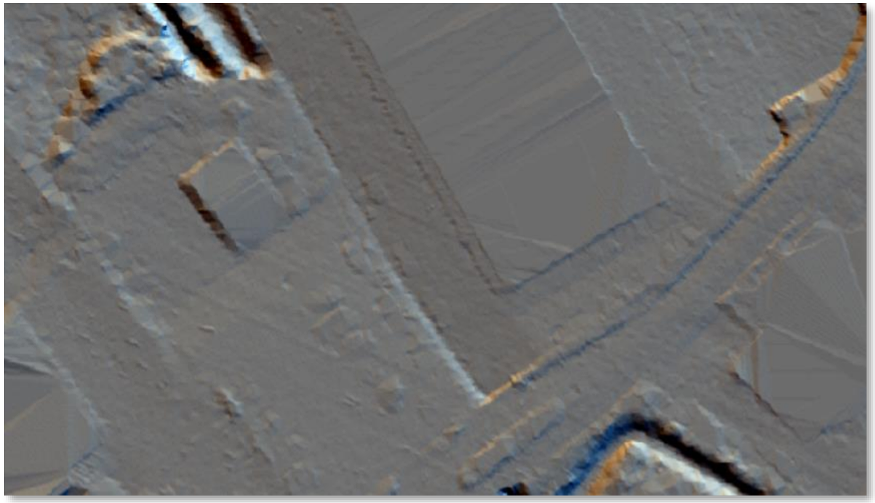
Often, potential features can also be natural hills or patches of low vegetation which have not been filtered out via the applied algorithms.

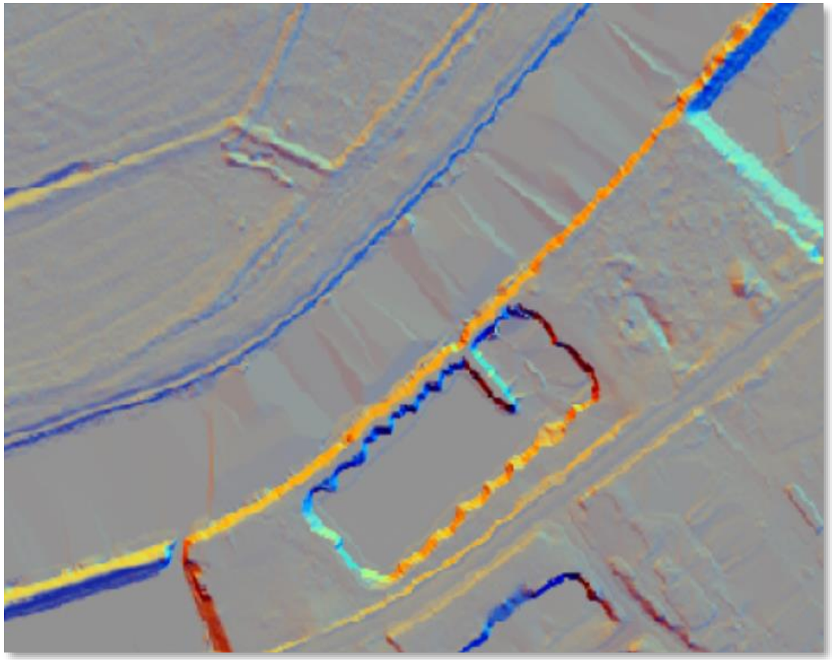
Artefacts from processing

Some features may appear in the LiDAR which are actually a result of the way in which the data was processed or how the aircraft itself was flown, and are known as 'artefacts'. This can particularly happen if there is some drift in flight, resulting in the direction of scan and direction of flight differing, or when two datasets are superimposed.

In order to pick out the artefacts from the authentic features, you need to see how they fit in with the surrounding landscape. For instance, are they aligned with or perpendicular to the line of flight? Do they go over buildings or other features?

Parallel lines running diagonally across landscape at a Dartford business park extend over both roads and land, representing 'artefacts' from the line of flight

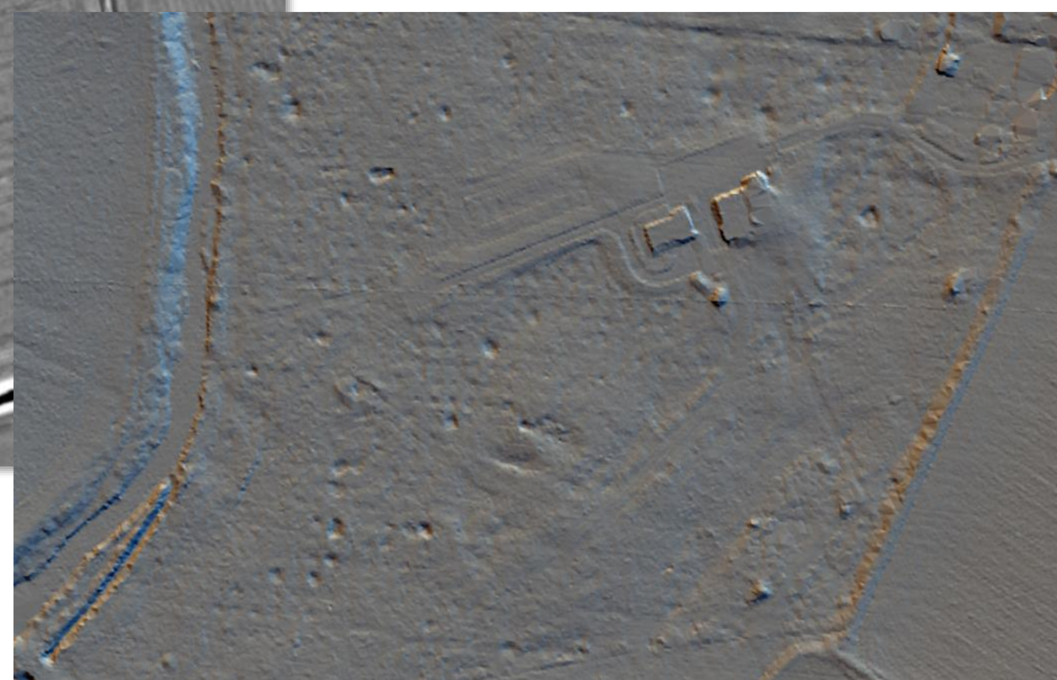




Elongated triangles over water at Hampton Court indicate processing issues

Artefacts from processing

A possible ‘speckling’ or ‘orange peel’ effect near Franks Hall, Horton Kirby, due to slight variances in two datasets



Flightline edge effect, almost stippled in appearance, in field along Westerham Road

Suggested sources for further reading:

Historic England 2018, *Using Airborne Lidar in Archaeological Survey: The Light Fantastic*. Swindon: Historic England.

https://historicengland.org.uk/images-books/publications/using-airborne-lidar-in-archaeological-survey/heag179-using-airborne-lidar-in-archaeological-survey/

For further information on using LiDAR generally, see https://www.historicengland.org.uk/research/approaches/research-methods/airborne-remote-sensing/lidar/ and https://research.historicengland.org.uk/Report.aspx?i=15437

For a guide on how to access freely available Environment Agency tiles, see https://historicengland.org.uk/content/docs/research/using-ea-lidar-data-pdf/

Kokalj, Ž ZRC, Hesse, R, 2017. *Airborne laser scanning raster data visualization. A Guide to Good Practice*. Ljubljana: Založba ZRC

https://omp.zrc-sazu.si/zalozba/catalog/book/824

Various online teaching materials are also available through ‘Pushing the Sensors’ PTS Consultancy, who offer training courses on using LiDAR, tailored to skill level and need (https://www.pushingthesensors.com/teaching-materials/)

This **How to Read LiDAR** guide was produced by the Surrey Archaeological Society for interpretation of the LiDAR data on the **Surrey LiDAR Portal**

It is based on a similar guide produced by the Darent Valley Landscape Partnership Scheme for the **Kent LiDAR Portal**

Written and compiled by Dr Anne Sassin, Community Archaeologist, with image contribution and consultation from Dr Rebecca Bennett

June 2021

Research Centre, Hackhurst Lane,
Abinger Hammer, Surrey RH5 6SE
info@surreyarchaeology.org.uk
www.surreyarchaeology.org.uk
+44 (0)1732 280951

@surreyarch

@surreyarch