Here come the drones

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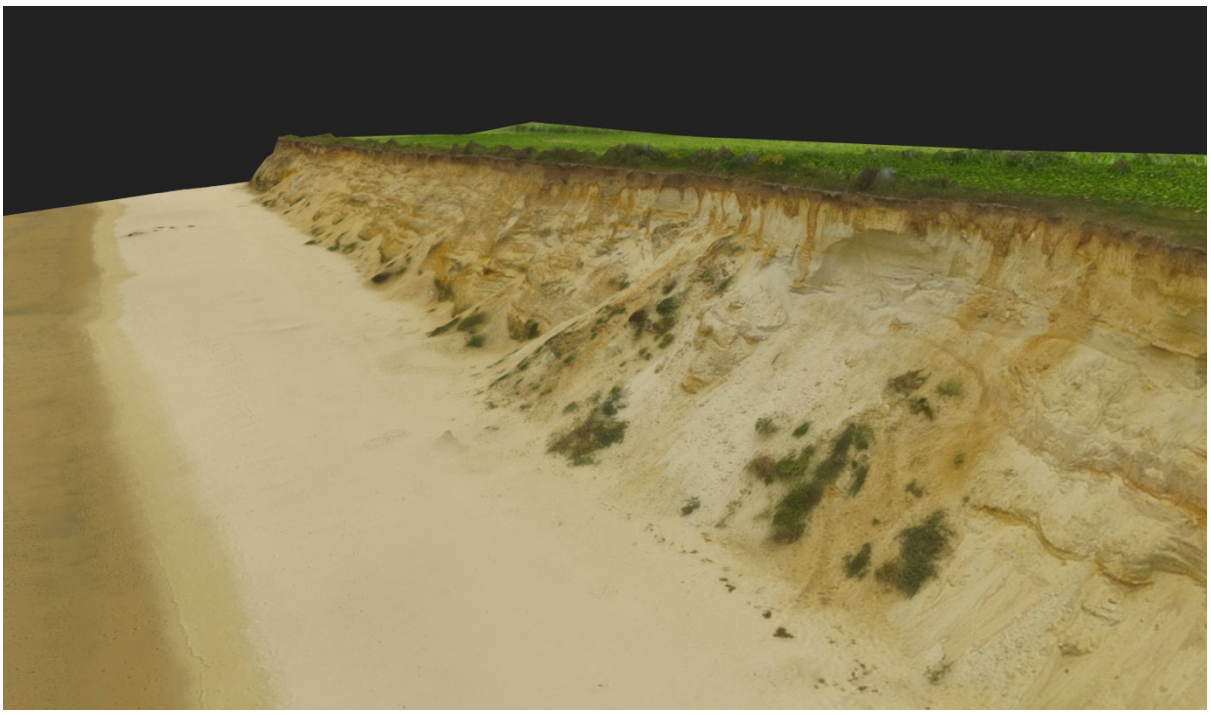


Oblique drone image of Covehithe beach and cliffs

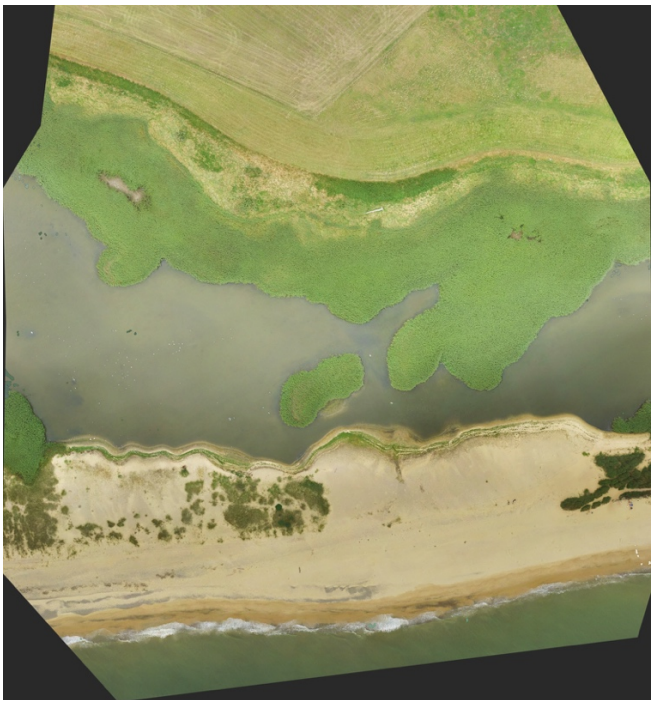
The methods we use to teach physical geography and environmental science are rapidly changing. As a new generation of high-quality affordable drones creates a revolution in the way that schools collect, process and view landscape data, Dr Steve Boreham of the Department of Geography at the University of Cambridge takes us through the ins and outs of flying drones for research

Drones, also known as un-manned aerial vehicles (UAV) have been undergoing a quiet transformation from the crash-prone toys and expensive high-end instruments of five years ago into the fully-featured, reliable and relatively inexpensive survey tools of today.

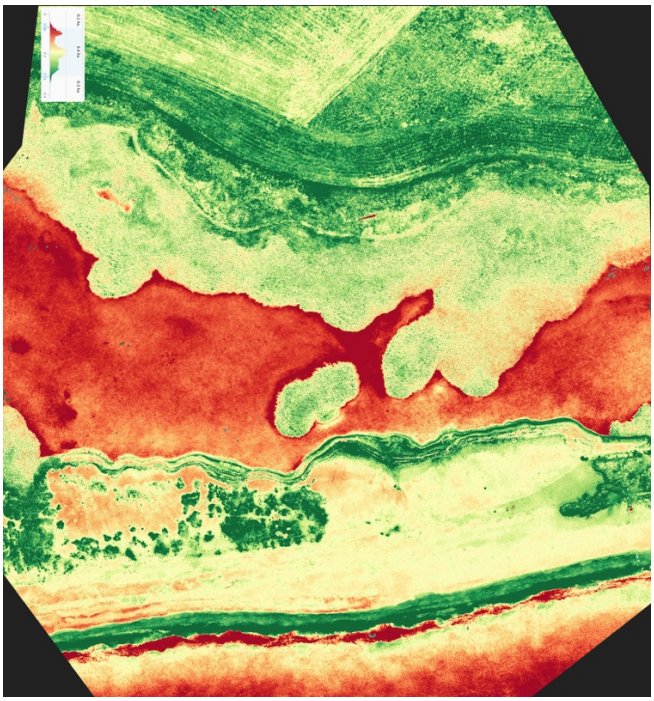
The new drone technology fills a gap between ground-based survey techniques (total stations, laser scanning, GNSS – Global Navigation Satellite System) and airborne systems (traditional aerial photography and LIDAR – Light Detection And Ranging) in both scale and resolution. The ability to quickly and easily execute remote sensing surveys of relatively small areas of landscape is now a reality.

For educational establishments, the use of drones for teaching and research opens up many exciting possibilities. The rapid acquisition of elevation and spectral data allows ecologists and biogeographers to quickly survey the living landscape in a way not possible before. Botanical applications range from mapping seasonal changes in coastal vegetation, plotting the aerial extent of plant communities in grassland and heathland environments, looking for archaeological crop marks in arable fields, and assessing the extent of damage to ash trees in woodland canopies affected by Chalara (ash dieback disease). Using NDVI (Normalized Difference Vegetation Index) as a plant health indicator, agricultural scientists are able to observe problems developing within a growing crop, and are able to take immediate remedial action.

In rapidly changing natural systems such as recurved spits, dune fields, eroding cliffs, rivers and estuaries, repeated drone missions throughout a year or over several years can provide essential information on processes and pacing, informing future management decisions. Inaccessible landforms such as landslips and geological outcrops on coastal promontories or in quarries can now be surveyed remotely in detail. Potential hazards can be evaluated before committing to a field visit, leading to better risk assessment and safer fieldwork. Drones equipped with spectrometers have been used to 'sniff' the composition of gases emanating from volcanic craters. Photogrammetry has been used to model calderas, and the addition of an infrared thermal camera can help locate fumaroles and incipient vents. Fixed wing drones have been used to create 3D models of the Greenland ice sheet where it is calving into the North Atlantic ocean, to help understand the effects of global climate change.



Vertical drone image of Covehithe Broad and beach



False colour NDVI plant health image of Covehithe Broad and beach

DRONE MODELS

The range of drones available is large and rapidly changing. Models range from the high-end Leica Aibot X6 Hexacopter for professional survey work, the DJI S1000+ Octocopter that can carry a DSLR camera for cinematography, the 3DR Solo, the DJI Phantom series, and the robust new DJI Mavic Pro. Smaller drones costing less than £100 are ideal for training and available from manufacturers such as Hubsan and Syma.

For the images accompanying this article we used a DJI Phantom 3 Advanced drone costing less than £1,000. This Quadcopter has a 4k camera mounted on a gimbal, and uses photogrammetry to provide three-dimensional data. The controller uses a handheld device, such as an iPhone or Android phone as the display.

FLYING A DRONE MISSION

We use the DroneDeploy app running on a handheld device linked to the controller to fly our drone missions. Other apps such as Pix4D, Agisoft Photoscan and 123D Catch are also available. DroneDeploy has the benefit of managing the entire mission from start to finish and uses cloud-based storage and processing so that demands on your PC are minimal. The app claims to be compatible with any drone and is free to use for first month with all features and then available by subscription thereafter.

Pre-flight preparations include checking the battery life of the drone, controller and handheld device before take-off, and a GPS-based location check for no-fly zones. Apps such as UAV Forecast, Hover, or No Fly Drones can also be used to check no-fly zones. Take-off and landing are fully automated. You will also need a 3G/4G mobile signal to upload an aerial photograph of the local area to your handheld device, or to have cached this image before you get to the field. Once the survey area is drawn on the aerial photograph and the drone height is set, the flight path and data resolution is automatically calculated. After one last systems check the drone takes off and robotically follows the flight-path for the mission, automatically taking geo-referenced images as it goes. There is an emergency 'return home' command, and the drone can be manoeuvred and landed manually if necessary.

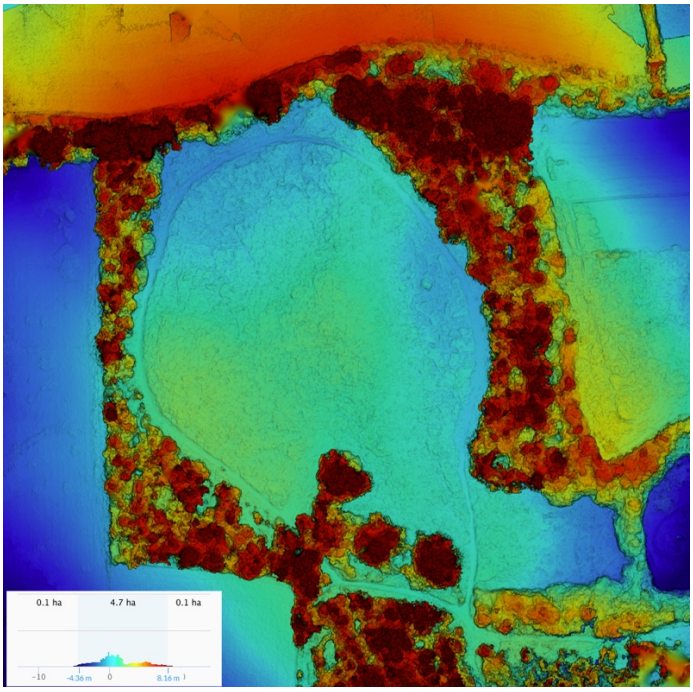
Battery life currently gives flight durations of more than 20 minutes, which allows missions to easily survey c.10 hectares of landscape at moderate resolution. Subsequent missions can be overlapped to provide better coverage in the final data set. Flying heights are typically between 30m and 50m. The trade-off is that higher altitude covers a larger area more quickly but reduces resolution. The drone also needs to comfortably avoid obstructions such as trees.

Most drones can operate in wind speeds up to 15 to 18mph, although you should avoid turbulent or gusty environments. It is also necessary to avoid temperatures below 5ºC, precipitation and foggy conditions. This limits the number of fly-days possible each year, especially in exposed environments. There are also geographical restrictions on where you can fly, with obvious exclusions being near airports and centres of population.

MISSION OUTPUTS

The DroneDeploy website allow you to view your post-processed drone mission data as a two-dimensional detailed (geo-referenced and orthorectified) aerial photograph mosaic, a three-dimensional model, a plant health map using NDVI and an elevation map. Models can be shared online without the need for specialist software. Data can be exported as 3D models (.obj files) or point clouds (.las files). Depending on the licence, image export resolution is between 50cm/pixel and 1cm/pixel as a single image or a set of tiles, using a variety of projections and file formats such as GeoTIFF or jpeg.

Vertical drone image of Reach Wood Meadow



False colour elevation map of Reach Wood Meadow

DIFFICULT LANDSCAPES

Drones have trouble seeing water correctly. This seems to be to do with constantly changing surface imagery, reflections and ripples or waves. The tops of trees also require a bit of extra effort to capture properly, especially if they are moving in the wind. Capturing the horizon in imagery can also confuse the photogrammetry algorithms. Sometimes large expanses of grassland or ploughed fields present problems for the image stitching process because there aren't enough different-looking points. The best way to overcome these challenges is to use a slower flight-speed and a higher image overlap to ensure multiple stitch points and remove motion-blur.

DRONE TRAINING AND SAFETY

As long as you are not using your drone for commercial purposes, you don't generally need a Civil Aviation Authority qualification. However, it is a good idea to take a short course on drone skills, which maybe available locally. Membership of your local model aircraft club could provide a safe place to practice and help with insurance matters. The British Model Flying Association has a good deal of Drone Aware flying guidance.

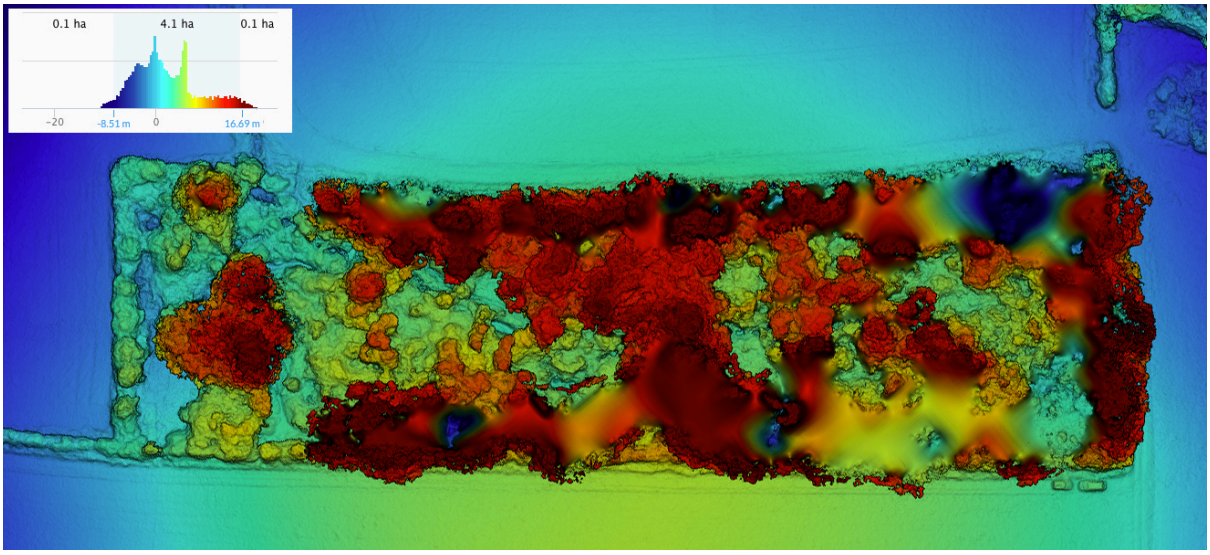
Like any other aircraft, drones must always be flown in a safe manner. The Civil Aviation Authority has produced the CAA Dronecode to help with safe drone operation. Even flying for educational use or fun may require permission, so it is always best to know as much as you can before you go.

THE FUTURE

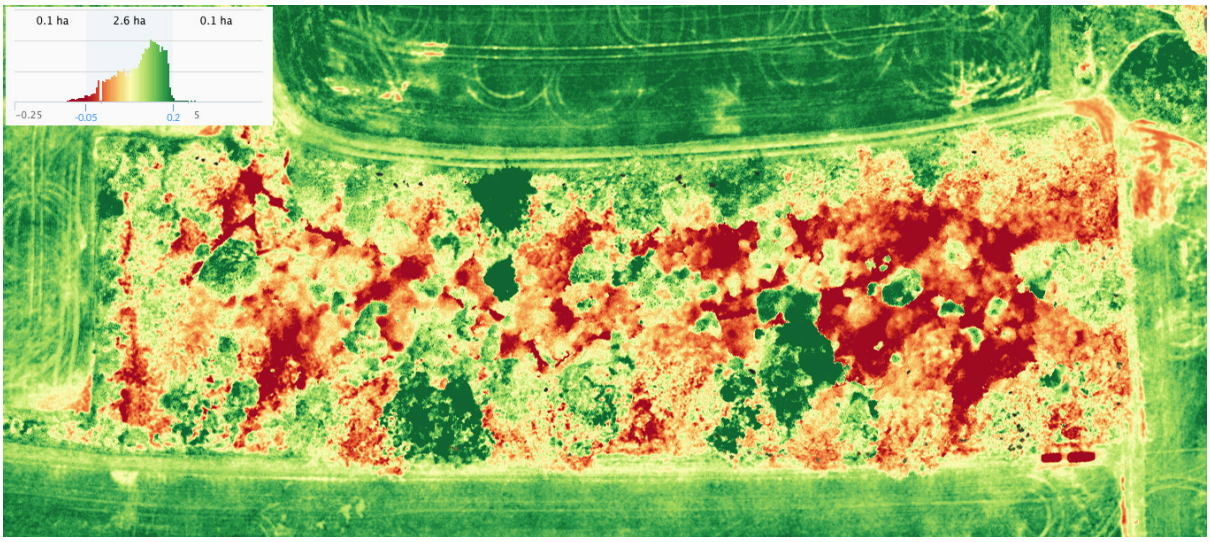
Drone technology is moving fast. Ever-more sophisticated and reliable drones with longer fly-times are becoming the norm. However, it is the output from drone missions that offers some of the most exciting prospects for physical geography teaching now and in the near future. Innovations include enormous improvements in Virtual Reality allowing students to 'explore' their 3D models. Inexpensive VR headsets (such as Google Cardboard and Daydream) use a handheld device as the viewing screen. At the other extreme, purpose-built VR suites with active 3D glasses allow groups of students to move around detailed models of field sites, potentially located anywhere on the Earth. These innovations bring the possibility of mass-participation in virtual fieldtrips, allowing the exploration of a variety of landforms and features never before possible.

An augmented reality 3D projection and modelling set-up called AR Sandbox is capable of guiding you to re-create your 3D landscape and model how it responds to rainfall and rising water levels. Sea walls can be made to fail, floods can be unleashed on river valleys and drainage diversions can be re-enacted, all in real-time 3D. Finally, the advent of 3D printers means that detailed solid landscape models can now be produced from drone missions. The possibilities for making hand-sized models showing the landscape impact of housing developments or mineral extraction can now be easily created. Never before have such rich and diverse options been available to those who teach and study landscapes.

Vertical drone image of Nine Wells spinney



False colour elevation map of Nine Wells spinney



False colour NDVI plant health image of Nine Wells spinney