A Template for Virtual Reality Simulations

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Executive Summary

Virtual reality simulations, from simple panoramas and animations to fully realised 3D buildings and structures in a true 3D environment, are becoming increasingly common as a tool for communication, education and stakeholder interaction. For a simulation to be legitimately termed virtual reality (VR) it must achieve a reasonable level of at least one of the following three factors: dynamism (change over time or in space); interactivity (ability of the viewer to control the position and field of view) and graphic realism (level of similarity to reality).

The tools for constructing VR simulations have been getting steadily more accessible over the past decade. 'Digital globes', such as Microsoft Virtual Earth, NASA World Wind and, by far the most popular, Google Earth, provide free imagery and a free DTM for the entire globe, and their advent has been a huge step in this progress towards increased accessibility to VR. In addition to Google Earth, it has become easier to make animated movies of 2 and 3D images using ubiquitous media players such as Apple Quicktime and RealPlayer. With the exponential increase in digital photography the construction and website display of 360º panoramas has also become increasingly popular.

Until recently VRML (virtual reality markup language) or Java 3D were the most widely used tools for obtaining true 3D scenes with full interactivity. However, Google Earth compares just as well in terms of dynamism and interactivity, and better in terms of 'free' graphic realism, and as such is rapidly superseding both in terms of popularity. However fully interactive subsea 3D scenes are not possible with Google Earth. Only one of the 'digital globes', NASA World Wind, has that capability, as do VRML and Java 3D.

GIS (geographical information systems) is the only software that offers true geographical analytical capability, and as such it is often the 'base' software needed prior to using 'digital globes', media players or VRML. The increased availability of GIS freeware means that it is steadily becoming more popular, though not at the exponential rate of Google Earth.

In conclusion, there are VR options to suit every combination of data availability, finance availability and technical expertise.

Preferred Reference:

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Glossary of Acronyms

DTM: Digital terrain model
DEM: Digital elevation model
ESRI: Environmental Systems Research Institute
GE: Google Earth
GPS: Global positioning system
ICZM: Integrated coastal zone management
KML: Keyhole markup language
KMZ: Keyhole markup zip
NASA: National Aeronautics and Space Administration
SPOT: System Pour l'Observation de la Terre (French satellite imagery)
VR: Virtual Reality
VRML: Virtual reality markup language
XML: Extensible markup language
X3D: XML 3D **(**a proposed standard for representing 3D objects and scenes combining aspects of the VRMLspecification with the XML standard).

1. Introduction

Computer-based visualization is becoming increasingly important in natural resource management, including ICZM (integrated coastal zone management). New techniques permit new ways of viewing and interpreting data that provide viewers with a perspective that was difficult, if not impossible, to obtain in the past (Thurmond *et al* 2005). The use of 360º panoramas, animations and movies have become increasingly common as communication tools on the Internet, and the increasing popularity of Google Earth looks set to continue the trend. Virtual reality is therefore an area of interest to natural resource managers, as a tool to illustrate an environment and to display the effects of physical changes in that environment (Mouatt 2006).

This template and tutorial guide has therefore been written as a basic introductory guide to building one's own Virtual Reality simulation.

There is some confusion as to exactly what the term 'Virtual Reality' means, and so Section 2 describes in some detail the important factors in defining a product as Virtual Reality (hereafter referred to as VR), and their resource implications.

Section 3 goes on to describe the basic principles, strengths and weaknesses of two software approaches, namely Google Earth (GE) and Geographical Information Systems (GIS).

Section 4 then applies this understanding of the two basic systems, together with understanding of the strengths and weaknesses of the software for other 'digital globes', 3D models, animations and panoramas, in order to provide a template for users making the initial choice of VR system.

Section 5 then goes on to look at eight different examples of VR: Three of which are in Google Earth (a basic 'tour', draping satellite imagery and maps over the GE DTM, and creating 3D objects); two of which are in other 'digital globe' software (Microsoft Virtual Earth and NASA World Wind); two of which require some use of GIS before using a second software package (fully interactive VRMLs in ArcView/Cortona, animated time-series in ArcView/Quicktime) and one of which requires neither digital globe nor GIS (360º panoramic VR in Panavue). All of these examples, except for the Virtual Earth and World Wind ones, are held on the Uinversity of Aberdeen CMCZM website where they may be viewed by interested readers.at http://www.abdn.ac.uk/cmczm/about.htm

The final section, Section 6, summarizes the findings of the previous sections. The bibliography which follows includes a list of websites containing useful information on virtual reality, including many where virtual reality simulations may be viewed "in action". The two appendices contain, firstly, a selection of different definitions of Virtual Reality, and secondly the responses of 28 participants at a geospatial technologies workshop to a questions on the usefulness on Virtual Reality tools for decision-making, particularly in the context of coastal zone management.

2. VR Factors & their Resource Implications

2.1 VR Factors

There are four important factors in defining a product as Virtual Reality (hereafter referred to as VR).

1. Level of Immersion - body suit, goggles, and auditory stimulation being full immersion, looking at a computer screen being minimal immersion.
2. Level of Graphic Realism – high resolution photography, with panoramic 360º viewing, being full graphic realism, line structures being minimal graphic realism.
3. Level of Interactivity - physically interacting with structures etc. via a body suit being full interactivity, using a mouse to guide a flythrough with complete control over position, direction and angle of view being medium-high interactivity, using a mouse to guide a panoramic view (no control over position, but some over angle of view) or a time-series slider being medium-low interactivity, passively watching a flythrough or unfolding time-series being minimal interactivity.
4. Level of Dynamism - a long (30 seconds or more), smooth flowing sequence with considerable change either over time or in space is a high level of dynamism, a short (5 seconds or less) sequence is medium dynamism, and the absence of any change sequence (i.e. no movement) is minimal dynamism.

Several definitions are given in detail in Appendix 1. Those definitions supplied by IT professionals emphasize the factors of immersion and interactivity. Definitions supplied by those outside the IT professional world emphasize the factors of graphic realism and dynamism. This is succinctly discussed by Harrison Eiteljorg in his paper on the trend in archaeology for the use of simulations, the first of the definitions in Appendix 1, and he concludes: "*I will take VR to include any system* *that provides interactive, real-time access to a relatively realistic portrayal of some specific physical realities*" (http://www.csanet.org/newsletter/spring02/nls0205.html).

Information resources designed for the general public, rather than IT professionals or academics, provide an even broader interpretation of VR. For example, the Encyclopedia of Educational Technology (http://coe.sdsu.edu/eet/articles/vrk12/index.htm) looks at VR as a tool for education, and on their webpage offer two examples of this – a virtual tour through the Louvre (good graphics therefore good graphic realism, but passive watching so zero interactivity) and a very simple picture exercise on line symmetry (minimal immersion, but the viewer moving the mouse changes the angle of the butterfly's wing, therefore some interactivity). They also provide a list of other websites with what they consider to be VR resources available online. The following four websites represent a typical selection from this list:

- Stanford University (http://www-graphics.stanford.edu/~tolis/toli/research/morph.html) – time series
- US Geological Survey (http://woodshole.er.usgs.gov/operations/modeling/) – time series
- CRS4 (Center for Advanced Studies, Research and Development in Sardinia) (http://www.crs4.it/Animate/) – time series, some flythroughs
- Indiana University (http://astrowww.astro.indiana.edu/animations/) – time series of galaxy clusters

What characterizes these (and other, similar, offerings) as web resource VR is not immersion (usually minimal) or interactivity (usually minimal), or even the levels of graphic realism (highly variable) but the levels of *dynamism*, either in space (3D flythroughs, 360º panoramas) or in time (time series). Immersive VR (body suit, wrap-around helmet etc.) is a highly specialised and to-date extremely costly field, though the emergence of the Nintendo Wii may be the first step to it becoming more accessible. The following discussion of resource use implications will concentrate on the other three factors, namely graphic realism, interactivity and dynamism.

2.2 Resource Implications

High levels of graphic realism, interactivity and dynamism are expensive, in terms of the software needed and, more importantly, in terms of computing and personnel time. For example, NASA has constructed several animations of the International Space Station which are available to view on their website http://www.grc.nasa.gov/WWW/MAELVRSTATION/media/ISS_animation/animation.html . These animations are reasonably dynamic, and they have a very good level of graphic realism, but there is zero interactivity. Nevertheless the cost was high – as explained on the website, "*The NASA ISS animation was produced by creating individual frames of the entire fly-around which when played back, created a movie… If this animation were done on a single home/personal computer (1 processor running at 400 MHZ), this animation would have required 6400 hours of processing time running around-the-clock*." Note that this is just processing time – the time spent for personnel training and on personnel preparing the data prior to processing is not included.

Many other groups or organisations will not have the resources for an equivalent exercise. Therefore a lower standard must be accepted for one or more of the three factors – graphic realism, interactivity and dynamism.

To reprise the conclusions of Section 2.1:

- Dynamism is the factor that is generally agreed as being necessary for VR.
- Interactivity was identified by Eiteljorg (2002) and other academics as being equally important, but appears to be of less importance to the general public, who are the major stakeholders for VR simulations.
- A high degree of graphic realism is always desirable, but is not essential.

Graphic realism is perhaps the factor that can be most easily sacrificed. If enough context is supplied (in terms of legends, written scene descriptions etc.) a surprisingly basic image can be enough – the viewer's experience and imagination can 'fill in the gaps'. This fact is, of course, the basis of successful cartography.

A useful example of a website that has practically zero graphic realism but which provides some degree of both dynamism and interactivity can be found at the UK Met Office http://www.metoffice.gov.uk/weather/charts/index.html . This provides the Europe surface pressure charts for 8 time frames (from 0 to 84 hours ahead). The charts can either be selected by mouse (hence the interactivity) or viewed as an animation (hence the dynamism), which gives a better idea of how the frontal systems are developing. No concession is made to graphic realism, however - it is assumed that the viewer will have a basic understanding of isobar charts. These 8 charts are produced daily, but, because of their simplicity, putting them up on the website every day is no doubt a short, simple task.

A website with a good example of a very high degree of interactivity and dynamism, though a very low level of graphic realism, is http://www-vrl.umich.edu/intro/index.html - look down the page and download the VRML for Escher's Penrose Staircase.[1]

A good example of a website that has good levels of all three factors is the "*Virtual Campus*" found at http://ag.arizona.edu/agnet/icac/vrml/ As it says in the website, VRML stands for "*Virtual Reality Markup Language*" and is currently the most used format for simple VR simulations, although the new standard X3D will eventually supersede it. The process by which this VRML was constructed is also explained on this

[1] One of the VRML freewares at either http://cic.nist.gov/vrml/vbdetect.html, http://freeware.intrastar.net/vrml.htm, http://www.modelpress.com/verml-software.htm, or http://www.xj3d.org must be installed in order to view this. Both Cortona and Flux player should run this. If having problems with one, try downloading the other.

website (and is the same process which will be described in detail in Section 3, Example 3.1).

Of particular note is the ease in which the basic map and wireframe for the buildings were constructed in ArcView, compared with the difficulties of the subsequent texturing (i.e. adding surface detail in order to increase graphic realism):

"*Unfortunately, applying textures to the buildings was a more painstaking process than creating the buildings.....Applying textures to these faces was monotonous, if not easy. Creating the textures from digital images proved to be an interesting task in image processing as well*." http://ag.arizona.edu/agnet/icac/vrml/

Also of interest on this website is the "*simulated walkthrough of 30 images mirrored by 30 images taken in the field from the corresponding locations*." The website author has recognised the fact that most viewers will not have VRML software available, and so has provided an alternative – still dynamic, still with graphic realism (helped by having real photos alongside the VR images), but minimal interactivity (you can only alter the speed at which the images change). There are also 360º panoramas (http://ag.arizona.edu/agnet/icac/pans.html - use the Java version to view them), dynamic and highly realistic graphically, with medium-low interactivity.

Using digital photography of existing scenes is an inexpensive way to generate graphic realism, both in terms of data collection costs and in terms of personnel/processing time. However, generating new textures for planned, but as yet non-existent, structures is often highly demanding of personnel/processing time (cf. the earlier NASA example), unless one has access to a library of textures (Google Earth SketchUp has such a library, but this can only used within SketchUp). It may be better use of resources to use simple wireframes for planned structures, together with some interactivity and dynamism, rather than using all available resources to produce a very realistic, but passive and static, image.

3. Basic principles

3.1 Introduction

This section comprises seven parts including this introduction. The second part describes in detail the basic principles underlying the 'digital globe' Google Earth (GE), which is becoming an increasingly versatile and popular medium for displaying and sharing mapped data. The third describes the basic principles of geographical information systems (GIS), necessary for analysing mapped data. The fourth looks at the limitations of GE, and the fifth at the limitations of GIS. The sixth details how to obtain and get started in GE, and the seventh how to obtain ArcView, one of the most popular and widespread GIS software.

3.2 Google Earth – basic principles

Google Earth (GE) (http://earth.google.com/) is an internet interface that allows the user to 'browse' the Earth. It consists of a virtual globe with satellite imagery, maps and a global DTM (digital terrain model – also known as a DEM or digital elevation model). This is most easily accessed online, so the makers of GE recommend that an internet connection is kept on while using GE. However, a substantial amount of data is cached (held on the user's computer hard drive) each time GE is used, and this cache is available whether online or not.

GE uses a streaming process to move from low resolution imagery and terrain (when looking at large areas of the globe) to high resolution imagery and terrain (when looking at an area of a few square kilometres). The cache will store enough low resolution imagery to cover the whole globe, but obviously there are limits to the amount of high resolution imagery it will hold, so if planning to work offline it is first essential to zoom in to your area of interest while online. You can then close GE, physically disconnect from the internet, and reopen GE (it will display the message "*Google Earth could not contact the authentication server, the application* *will continue to operate but will only display data available in your cache*"), and your cache should be holding enough high resolution imagery and terrain for you to work on your area of interest. This set of cache contents will be maintained until you next use GE online.

The satellite imagery covers the entire globe, and is of excellent quality, even for notoriously difficult areas such as the Arctic regions. However, it should be noted that the satellite imagery is for visualization purposes only – it is not accessible for data analyses such as supervised classification (where the vegetation cover of the image can be determined through spectral analysis), etc.

The satellite imagery becomes less satisfactory at very low altitudes (e g. 500 metres or less) because of the coarse resolution. The imagery is also not clearly pixellated as GE used a filtering process to smooth out the pixels for aesthetic purposes. The GE user guide (http://earth.google.com/userguide/v4/#getting_to_know) does not specify the original resolution. In some locations it appears to be 1 or 2 metres, in others it appears to be in the range 30 to 100 metres.

The maps held on GE (either online or in the user's computer cache) include roads, transportation (rail etc.), and geographic features. However, it should be noted that these are not usually of sufficient detail to be of anything other than general interest. If on-line even more map themes will be available via Google Earth Community. The most useful 'free data' from Google Earth is probably the terrain model – having a working elevation model on hand certainly saves a lot of time, energy and money, because;

a.) Getting digital national survey elevation data or pre-produced DTMs can be very expensive (though UK universities have an agreement on free use for research with the UK national survey organisation, the Ordnance Survey).

b.) Digitising your own elevation data from raster maps runs into copyright issues with the national survey organisation, and is also very time consuming.

c.) Generating rough DTMs is very easy, but it becomes more time consuming if you want a higher quality product.

Having an accurate DTM for the coastline is an important prerequisite in the development of VR simulations for coastal areas. It is relevant, therefore, to examine the quality and accuracy of the GE DTM. This will be discussed further in sub-section 3.4.

3.3 GIS – basic principles

A Geographical Information System (GIS) is a collection of computer hardware, software, and geographic data for capturing, managing, analyzing, and displaying all forms of geographically referenced information.

The following is taken from the ESRI website introducing new users to GIS (http://www.gis.com/), and is a useful starting point.

"*A GIS can be viewed in three ways:*

The Map View: *A GIS is a set of intelligent maps and other views that show features and feature relationships on the earth's surface. Maps of the underlying geographic information can be constructed and used as "windows into the database" to support queries, analysis, and editing of the information. This is called* geovisualization.

The Database View: *A GIS is a unique kind of database of the world—a geographic database (*geodatabase*). It is an "Information System for Geography." Fundamentally, a GIS is based on a structured database that describes the world in geographic terms.*

The Model View: *A GIS is a set of information transformation tools that derive new geographic datasets from existing datasets. These* geoprocessing *functions take information from existing datasets, apply analytic functions, and write results into* *new derived datasets. In other words, by combining data and applying some analytic rules, you can create a model that helps answer the question you have posed."*

One example of GIS software, ArcView 3.3, has the following functions, among others:

1 Changing map projections
2 Dissolving features based on an attribute
3 Merging adjoining themes together
4 Clipping one theme based on another
5 Union of two themes (intersecting polygons and assigning attributes from both original themes)
6 Creating buffers around selected features (a common tool in development planning)
7 Finding the area or perimeter of a polygon, and the length of a line/network.
8 Calculating statistics (histograms etc) for a theme
9 Converting a vector dataset (polygons) to raster (cell grids) and vice versa
10 Converting vector data (e.g. contour lines) to a 3D digital terrain model and vice versa)
11 Deriving slope and aspect from a DTM
12 Calculating hillshade and viewshed from a DTM
13 Model building – applying the cell values of selected raster themes within a rule based algorithm in order to obtain a predictive distribution for a criterion of interest.

All of these functions are dependent on the relational links between the features on the map (the 'theme' in ArcView) and the data held in the database (the 'attribute table' in ArcView). All true GIS have this capability, though terms different to theme and attribute table may be used. Some GIS, particularly freeware, have a fairly basic set of functions, these usually being 1-7 on the above list. ArcView 3.3 is a midrange GIS in terms of both functionality and price. Top end GIS such as ArcGIS have an extremely extensive set of functions and capabilities, and are priced accordingly.

3.4 Google Earth - limitations

A mountainous area was chosen in order to examine the quality of the GE DTM – Loch Hourn, Highland Region, Scotland. When originally examined, in October 2006, there were several serious anomalies noted, including areas of sea given an altitude of 120m. However, on 17th December 2006 GE installed an extensive upgrade of the DTM, and this seems to have resolved many of the problems.

Nevertheless, some anomalies remain. In the most fjord-like part of the loch, Inner Loch Hourn, the loch still appears to be tilted at an angle part way up the opposite hillside (Figures 1 & 2), although the nearer shore and the loch's surface are now acceptably level. DTM errors such as this are not uncommon in particularly complicated terrain like this.

For comparison, Figure 3 shows an equivalent screenshot from Anquet Maps, a commercial product (http://www.anquet.co.uk/ - England, Wales & Scotland coverage. £100 CD gives 1:50,000 maps plus Virtual Landscapes for one-third of Britain). Anquet maps covers a much smaller area (the British Isles rather than the whole globe), and is targeted to the outdoor recreationist, so greater attention has been paid to getting hill features and coastlines correct. Despite the extra quality control in the commercial product, the complexity of the terrain in this area still results in some errors – Figure 3 shows a certain degree of unevenness in the facing coastline (though nothing like as uneven as in the Google Earth DTM in Figures 1 and 2).

Figure 1: Loch Hourn(Oct 2006)

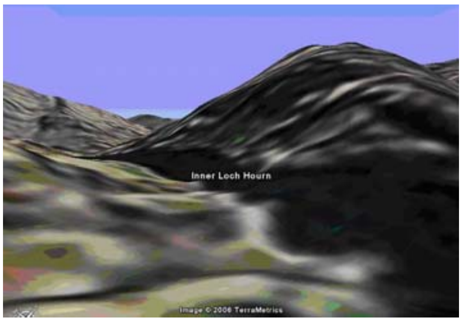


Figure 2: Loch Hourn (Dec 2006)

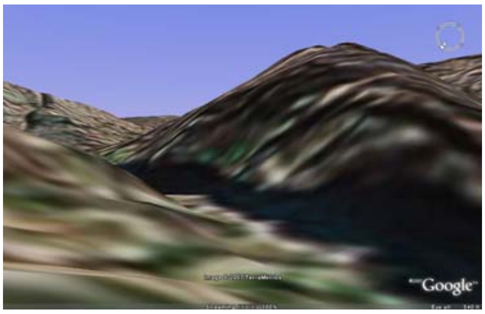


Figure 3: Loch Hourn (© Anquet Maps)

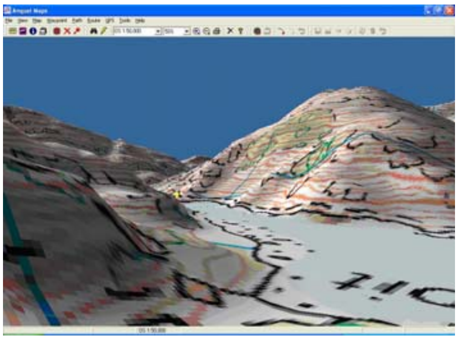


Figure 4: Skye - coastline

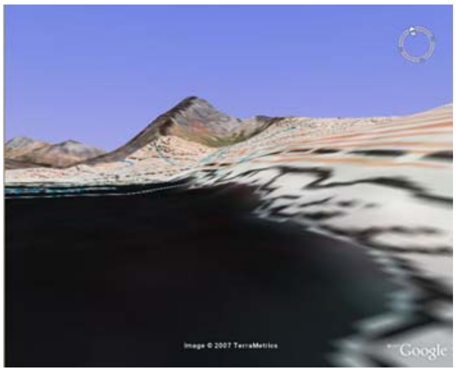
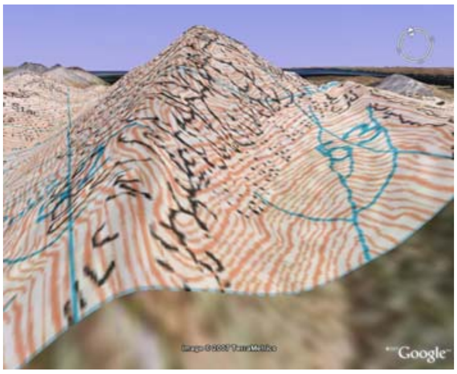


Figure 5: Skye – drape over DTM



The inaccuracies of the DTM are further exacerbated when draping map imagery in GE. Figures 4 and 5 show the example from Section 4.3. Figure 4 shows that the coastline is not even and level, and Figure 5 shows that the contour lines on the drape are nowhere near correctly aligned with the underlying DTM. To a certain extent such problems are typical of most of the DTM viewers, sometimes due to graphic display limitations, at other times due to data limitations. It can certainly be a problem when building one's own DTM in a GIS. However, when building one's own DTM one does have absolute control over the quality of the input and output, and so can eventually build as accurate a DTM as is required.

Unfortunately it is not possible to have an equivalent level of control over the GE DTM. The Google Earth Community Fora were investigated as to whether it would be possible for a user to either correct the GE DTM or to delete it and put in a new, better quality DTM model of one's own. The resultant conclusion is that it is not, as yet, possible to do this.

This conclusion is in agreement with that of Dunne & Sutton (2006b), who state: "*A shortcoming of KML [GE] is the fact that it does not currently support elevation data overlay. While it is possible to overlay imagery, it is not possible to overlay a custom elevation model. Because of this, all the illustrated shaded relief images imported into Google Earth are draped over the primary database elevation model, which is fixed at zero metres for marine areas.*"

The corollary of this conclusion is that 3D bathymetric models cannot be incorporated into the GE DTM, so it is not possible to have a 'subsea' tour. Note that GE does not allow the viewer to go 'below' the surface of the DTM, and that surface has a minimum elevation of 0. Some users have requested that bathymetric data be included in the GE DTM (see Google Community thread "Navigation below Ocean/Lake-level in GE"). This request elicited the response "It's certainly something we're interested in…." from the Google Earth Server Ops (response dated 14th Dec 2006). This possibility may therefore be developed in further releases of GE. It is still possible, of course, to incorporate bathymetric data into GE as a map/shapefile or to construct a 3D model totally separate from GE (see Google Community thread "A possible plane crash?").

This limitation is shared by GE's main competitor in the 'digital globe' field, Microsoft's Virtual Earth. However the third digital globe available, NASA World Wind, does have the capacity for bathymetric DTMs. However this software requires much more processing time and is therefore much slower to run, and is less widespread and popular than the other two digital globes.

A second limitation of GE is that it does not, as yet, support any analytical functionality approaching that of a GIS. Even GE's top-end product, GE Pro, does no more than measuring the area of a polygon or the length of a line/network.

This means that it is not possible, within GE itself, to undertake even the simplest geoprocessing in order to add value to a map or dataset. Such geoprocessing tasks include clipping one theme based on another, union of two themes (intersecting polygons and assigning attributes from both original themes) and creating buffers around selected features. These three simple tasks alone are together the basis of the simplest geographical analysis, and as such the basis of many land management analyses, the most obvious of these being development planning.

Therefore anybody with a wish to either produce their own data or to analyse existing datasets will need to have a GIS in *addition* to GE.

3.5 GIS – limitations

The most obvious limitation of GIS software is the price – as a rough guide, the greater the functionality the more expensive the software. For example, ESRI ArcGIS (ArcView 9.1 plus 3D analyst) is around $4000. However, for the purpose of creating simple themes with perhaps some very basic geoprocessing functionality one of the many GIS freeware will be adequate. This will be discussed further in sub-sections 3.6 and 3.7.

A more serious limitation, vis-à-vis producing *dynamic* and *interactive* graphics that can be considered as being VR, is accessibility. While the results of any GIS can be screen captured and put up on websites as still images, and increasing numbers of GIS software are being designed as webGIS (i.e. are being designed for simple investigation on the web – switching layers on and off, panning around the aerial view etc.), it is not possible in most cases for the VR product of a GIS to be viewed directly on the web unless it has been converted to a format *in widespread use* (which cannot be said to be true for any GIS). On this point GE outscores GIS, as it is so cheap, easy to use, and immediately visually attractive that it has already become a 'standard' software on many home computers.

It would therefore seem, in a reflection of the last statement of the previous sub-section, that anybody with a wish to effectively display and disseminate their data will need to have GE in *addition* to a GIS. However, there are alternatives to GE, notably the use of VRMLs (Virtual Reality Markup Language), Java 3D and of common media players (Apple Quicktime, Realplayer and Windows Media Player). These will be discussed further in sub-section 3.7.

3.6 Google Earth – getting started.

There are three grades of Google Earth: Google Earth, which is free; Google Earth Plus, which has an annual cost of $20 providing GPS device support, the ability to import spreadsheets, drawing tools and improved printing quality, and finally; Google Earth Pro, which has an annual fee of $400 and is aimed towards professional and commercial users providing measurement and additional annotation tools, the ability to overlay many more image types (including shapefiles) and enhanced printing.

The Google Earth interface provides a simple set of navigational controls (at the top right of the screen in GE plus) that allows the user to zoom and pan. Google Earth files are based on an Extensible Markup language (XML) known as Keyhole Markup Language (KML). Projects can be saved as either **kml** or **kmz** files. Kmls are primarily a set of links to large items such as map images and 3D models, although small items such as placemarks are held within the kml file itself. They cannot, therefore, be moved about a PC filing system using Windows Explorer or My Computer, as this will disrupt the links, nor can they be emailed to others, nor put up on a website. Kmzs are compressed kml files, and as such include the map images and 3D Models within the compressed bundle, and so are therefore suitable for emailing or for being put up on a website.

Downloading a GIS freeware would allow use of basic GIS functionality, enabling simple data analyses to be undertaken prior to display in GE. There are several GIS freeware programs available at http://opensourcegis.org/ and at http://www.gislounge.com/ll/opensource.shtml.

However, for most users the optimum combination of software (re. performance and budget) is to download the following:

1. Google Earth Plus (http://earth.google.com/).
2. MapWindow (freeware GIS - http://www.mapwindow.com/).[2]
3. Shape2Earth (This was free until recently. It is currently available for $29.95. (http://bbs.keyhole.com/ubb/showthreaded.php/Cat/0/Number/345508/an/0/page/0). [3]

[2] It is important to download MapWindow and to make sure it is running correctly before the next stage (downloading Shape2Earth). It may be necessary to download dotnetfx.exe (the plug-in for the necessary Microsoft.NET framework upgrade) at the same time as the MapWindow exe. Once downloaded and installed, open MapWindow. Problems opening it will most likely be due to not having installed the dotnetfx, or having installed it incorrectly. If this is the case, un-install both MapWindow and dotnetfx, and start over again. Problems can arise when using Internet Explorer 6 for downloading. Using Mozilla Firefox is likely to be more successful, as it stores the .exe programs as desktop shortcuts prior to installation, so it is easier to check that the dotnetfx.exe is there.

[3] It is essential that MapWindow is correctly installed *prior* to downloading Shape2Earth. Once it is downloaded, it is installed within MapWindow itself – open MapWindow, click on plug-ins and click on Shape2Earth. Click on GIS tools also, as these will also be needed. The MapWindow defaults will now be set up correctly.

In addition to providing some basic GIS functionality, these latter two options enable incorporation of shapefile data within Google Earth without having to purchase Google Earth Pro. This is done via converting ArcView/ArcGIS shapefiles to GE KML files. The sequencing of the installation is important – see footnotes on previous page.

3.7 GIS – getting started

As noted earlier, GIS freeware is available at at http://opensourcegis.org/ and at http://www.gislounge.com/ll/opensource.shtml. Christine http://www.christine-gis.com/ is a good option, and Tatuk GIS http://www.tatukgis.com/products/summary/products.aspx and Idrisi from ClarkLabs http://www.clarklabs.org/ are also cheap and multifunctional. However, it may be preferable to have a GIS with higher functionality, and in the examples in the following section ArcView 3.3 was used for all GIS analysis.

ArcView is probably the world's most widely used solution for desktop mapping and GIS analysis. The more recent versions, ArcView 8.x and 9.x, are the most often used, usually within a total ArcGIS package. ESRI ArcView 9.1 plus 3D analyst is around $4000. The older, but still available, ArcView 3.x is considerably cheaper. If interested in using ArcView 3.x it is worth contacting Rockware and asking for a price http://www.rockware.com/catalog/pages/arcview3x.html. Remember to include spatial analyst and 3D analyst in your price request. If a member of an academic institution it may be possible to obtain an academic discount. Many websites estimate $1200 (=€900) to purchase ArcView 3.x, but with an academic discount at Rockware it may be €300 or even less.

Like GE kmls, ArcView project files (.apr files) are primarily a set of links. These links are to the themes (vector data), grids (raster data) and images (satellite data or aerial photos), as well as to all the associated attribute tables. Like GE kmls, apr files cannot be moved separately about a PC filing system using Windows Explorer or My

Computer, as this will disrupt the links. The apr file is really only a display file – the important files are the shapefiles (a set of three or more files – always name.shp. name.dbf & name.shx, which comprise the map, the attribute table and the positioning data respectively, and often name.prj which contains information on the projection used) for vector data and the grids (an image folder plus an info folder) for raster data.

Notwithstanding the previous statement "that anybody with a wish to effectively display and disseminate their data will need to have GE in *addition* to a GIS", there are two other display software options which can be used with ArcView 3.x.

The first of these is the use of VRML or Java 3D. As noted in Section 2 VRML stands for "Virtual Reality Markup Language" and is currently the most used format for simple VR simulations. This display software scores highly for the first two VR criteria of dynamism and interactivity, and can score highly for graphic realism, depending on the original input. However, it cannot be said to be in widespread use, and it is a possibility that visitors to a website with a VRML may not make the effort to download the necessary freeware in order to view it. It should also be noted that there is much variation in the performance of VRML players, due to the lack of standardisation of this format. Cortona and other free VRML players can be found at http://cic.nist.gov/vrml/vbdetect.html).

It should be noted that, while VRML is itself evolving, there is also increasing attention on Java 3D, which can allow the creation of a virtual environment without the use of plug-ins at all (Huang *et al* 2001). Java 3D can be found at http://java.sun.com/products/java-media/3D/. Some introductory example programs can be found at https://j3d-webstart.dev.java.net/test/, which demonstrate how easy it is to display Java 3D images. A good introductory tutorial can be found at http://www.javacoffeebreak.com/tutorials/gettingstarted/index.html. The main advantage of Java is that it is very stable, so the end product is very easy to view on a website, in comparison to the rather temperamental performance of many VRMLs. However the disadvantage is that developing VR in Java requires much use of code and therefore some dedication to developing real programming skills. Java will not, therefore, be examined in further detail in this template, which aims to examine the simplest and most available VR options for ICZM practitioners.

The other display software which may be of use are standard media players such as Apple Quicktime (http://www.apple.com/quicktime/download/win.html), Realplayer (http://uk.real.com/player/) or Windows media player. These are set up to display a number of media, including movies and animations, which can be interpreted as VR in the sense that they are highly dynamic, and the use of a time-slider allows a small degree of interactivity. Again they can score highly on the level of graphic realism, depending on the original input. Additionally, they score over VRMLs as being in widespread use – almost all home computers will have one if not all of these three media players, and they are all free to download.

The following section describes how to make the initial choice of type of VR.

4. Initial choice of VR option

Table 1 illustrates in brief the strengths and weaknesses of each of the VR options as discussed in the previous section.

Table 1: Evaluation of different VR options

	GoogleEarth	Virtual Earth	World Wind
Cheap	Yes	Yes	Yes
Easy to use	Yes	Yes	No: time consuming
In widespread use	Yes, and increasing	Yes, and increasing	Not yet
Analytical functionality	No	No	No, and difficult to import vector data
Free DTM	Yes	Yes	Yes
Accurate DTM	No	No	Yes
Bathymetric DTM	No	No	Yes
Interactivity	High	High	High
Dynamism	High	High	High
Graphic realism	Depends on resolution for area of interest	Resolution generally better than GE	Not known
Wireframe buildings	Yes	Not known	Not known
Textured buildings	Yes	Not known	Not known
Linear time lines	Yes	Not known	Yes
Area time series	No	Not known	Yes, but details not known

	GIS	VRML
Cheap	Depends on functionality – in general, no	Depends on GIS software chosen
Easy to use	Depends on functionality – in general, no	No
In widespread use	No	No
Analytical functionality	Yes	No
Free DTM	No	No
Accurate DTM	Depends on quality of input data – potentially, yes	Depends on quality of input data – potentially, yes
Bathymetric DTM	Yes	Yes
Interactivity	Low	High
Dynamism	Low	High
Graphic realism	Generally low	Depends on quality of draped imagery – potentially, high
Wireframe buildings	Yes	Yes
Textured buildings	Generally, no	Generally, no
Linear time lines	Generally, no	No
Area time series	Generally, no	No

Table 1 continued: Evaluation of different VR options

	Animation	Panoramic
Cheap	Yes	Yes
Easy to use	Yes	Yes
In widespread use	Yes	Yes
Analytical functionality	No	No
Free DTM	No	No
Accurate DTM	Depends on quality of input data – potentially, yes	No
Bathymetric DTM	No	No
Interactivity	Low	Low to medium – depends on extent of field of view used
Dynamism	Low to medium – depends on number of frames used	Low
Graphic realism	Low	High to very high
Wireframe buildings	Yes	Possible, but not easy
Textured buildings	Generally, No	No
Linear time lines	Yes	No
Area time series	Yes	No

The 14 criteria in the left hand column can be grouped as follows:

1. Accessibility (cheap, easy to use, in widespread use)
2. Functionality (2D analytical capability, 3D buildings capability, time series capability)
3. DTM quality (free, accurate, bathymetric)
4. VR quality (interactivity, dynamism, graphic realism)

It is important, that anyone wishing to build a VR should first identify the answer to the following question; does one have a specific VR output in mind, or does one merely wish to use existing, available, data to produce a simple VR as easily as possible?

If one wishes to produce a specific VR output, one should examine the list of criteria in Table 1 and assign importance values to each of them. This will enable identification of the most suitable VR approach for their project. This selected approach should then be compared with:

a.) Immediately available data
b.) Immediately available software

It may be that further data and software need to be obtained. If this is the case, the difficulty of doing so needs to be assessed. Will the necessary data be expensive, or are they held under stringent copyright conditions that preclude their use? Will the necessary software be expensive, is there any existing expertise in the organisation in using it, if not will it be easy to learn? Sufficient resources (finance for buying software, staff time for learning how to use it) will need to be committed to the project.

Let us say that the important criteria for a VR project are cheapness, ease of use, and ability to produce wireframe and textured buildings. In this case examination of Table 1 leads to the conclusion that GE is the most suitable VR option for this project.

By comparison, if the important criteria are the need for an accurate bathymetric DTM plus a high emphasis on the resulting VR scoring highly for both interactivity and dynamism, then VRML is a more suitable approach, although NASA World Wind may be an alternative option.

If one wishes to use existing, available, data and software to produce a simple VR as easily as possible, say for demonstration and educational purposes, the process is much easier. Simply assess:

a.) Immediately available data
b.) Immediately available software

If one's area of study has a great deal of vertical interest (i.e. tall buildings or structures, high mountains close by), and one already has, or can easily obtain, a set of digital photos for the area, then a panoramic VR is the obvious choice. If one already has GE downloaded, and has digital satellite/aerial/map imagery which can be draped over the GE DTM, then a GE tour can be chosen. If one has a good set of time-related GPS data, then it could be a linear timeline in GE – etc., etc.

The following section details eight examples; three of which are in GE; two are the two digital globes in competition with GE - Virtual Earth and NASA World Wind; two which require some use of GIS before using a second software package; and, finally, one which requires neither a digital globe nor a GIS, panoramic VR in Panavue.

5. Examples

5.1 Introduction

This section will run through 7 examples of virtual reality, with tutorial level details of the commands. These examples are 1. A basic tour in GE; 2. Adding imagery and shapefiles in GE; 3. Creating 3D objects in GE; 4. Virtual Earth; 5. NASA World Wind 6. Fully interactive VRMLs in ArcView; 7. Animated time-series in ArcView/Quicktime and Global Mapper; and 8. Panoramic VR in Panavue. All of these examples, except for examples 4 & 5, are held on the Uinversity of Aberdeen CMCZM website at http://www.abdn.ac.uk/cmczm/about.htm where they may be viewed "in action". Commands are shown as in this example: **{File/Open}** i.e. in Arial, in bold, in brackets.

5.2 Example 1: Basic tour in GE

As a first step in using GE, it is recommended that readers select an area that they know well, zoom in to it, and add a few placemarks. Placemarks allow users to add/highlight points of interest within Google Earth for their personal use or for distribution to the wider Google Earth community. A placemark can be added via the following procedure;

{Add/Placemark/New Placemark}.

A 'push pin' icon will appear, and can be placed anywhere in the field of view using the mouse. Each placemark can be given a name. You will note that the placemarks are stored as a bundle in the My Places folder. Once you have a few of these, you have something which can be saved as a **kml** file. Use drag and drop to move all your placemarks from the 'My Places' folder to the 'Temporary Places' folder. You can use this opportunity to amend the order the placemarks come in, should you so wish. Click on 'Temporary places' in order to select every placemark in that folder, then click;

{File/Save place as/}.

Then choose the name ‘Placemarks1’ and location on your hard drive for the kml file. Make sure kml rather than kmz is selected as the file tag. This bundle of placemarks can also be saved as a **kmz** file, which is a zipped kml file. Click; **{File/Save place as/}.**

Then choose the name ‘Placemarks2’ and location (the same as the one you chose for the kml file) on your hard drive for the kmz file. Again, make sure that the correct file tag is chosen.

Close down and then reopen GE. Despite having just saved your placemarks you will be prompted with “you have unsaved items in your Temporary places folder. Would you like them saved to your My Places folder” – click no.

Click; **{File/Open}**, and navigate to where you saved your kml and kmz files. You will observe that both files are identified by the same GE symbol – this is the reason for giving them slightly different names, in order to identify them more easily. Open the kml file ‘Placemarks1’ first. You will observe that it will be opened up as a set of nested folders and files (click on the +/- sign to reveal or hide the nesting) in ‘Temporary places’, as follows:

{Main folder: Temporary places

Second Folder (GE symbol): Placemarks1

Third folder: Temporary places

Files: P1, P2, P3 etc.}

To avoid confusion in future, one can change the name of the third folder, ‘Temporary places’ to something else via right clicking on the folder name and choosing ‘rename’. The kml must then be saved again to preserve the change.

Right click on ‘Placemarks1’ and delete from GE. Click; **{File/Open}** and open up the kmz ‘Placemarks2’. GE unzips the kmz automatically, and in all respects it will look identical to the kml file. If using Windows explorer or My Computer to look at the kml and kmz file details they will be of different files sizes. In this exercise, because the files contain only a few placemarks, the kml files will be slightly larger than the (compressed) kmz files, although both files will be very small, of the order of a few kilobytes. However, once a user gets to the stage of having large items (draped maps, for example, or 3D models) included in the kml then this position will be reversed, and kmzs will be considerably larger than kmls. Experimentation with a 2048x2048 pixel map image, 3 placemarks and a very simple 3D model of a house gave rise to a kml of 5kb and a kmz of 149kb.

Figure 6 shows an aerial view of the Golfe de Morbihan with several placemarks placed upon it. These placemarks were set at different altitudes and viewing angles, and on pressing the ‘play’ button (outlined in pink on Figure 6) a tour will commence which will go through the placemarks in order, stopping briefly at each placemark at the pre-set altitude and angle. Google Earth automatically calculates a smooth ‘flight’ from one placemark to another. The viewpoint from one of these placemarks is shown in Figure 7. While you have GE running ‘Placemarks2’, click on the folder name ‘Placemarks2’ and then click on the ‘play’ button, and watch a tour of your placemarks. If you put all your placemarks in from the same angle of view this tour will not be very interesting. If this is the case, try adding a few more placemarks with very different angles of view and then play the tour again.

The co-ordinates (degrees, minutes and seconds), description, colour, type of marker (default is the push-pin icon) and altitude of the placemark can be assigned in the properties box that will come up on the screen when you double-click the placemark name. It is also possible to add images and links to other web pages as part of the placemark description, which requires some knowledge of web-authoring languages (e.g. XML) using a simple text editor such as Notepad.

Figure 6: Aerial view of Golfe de Morbihan

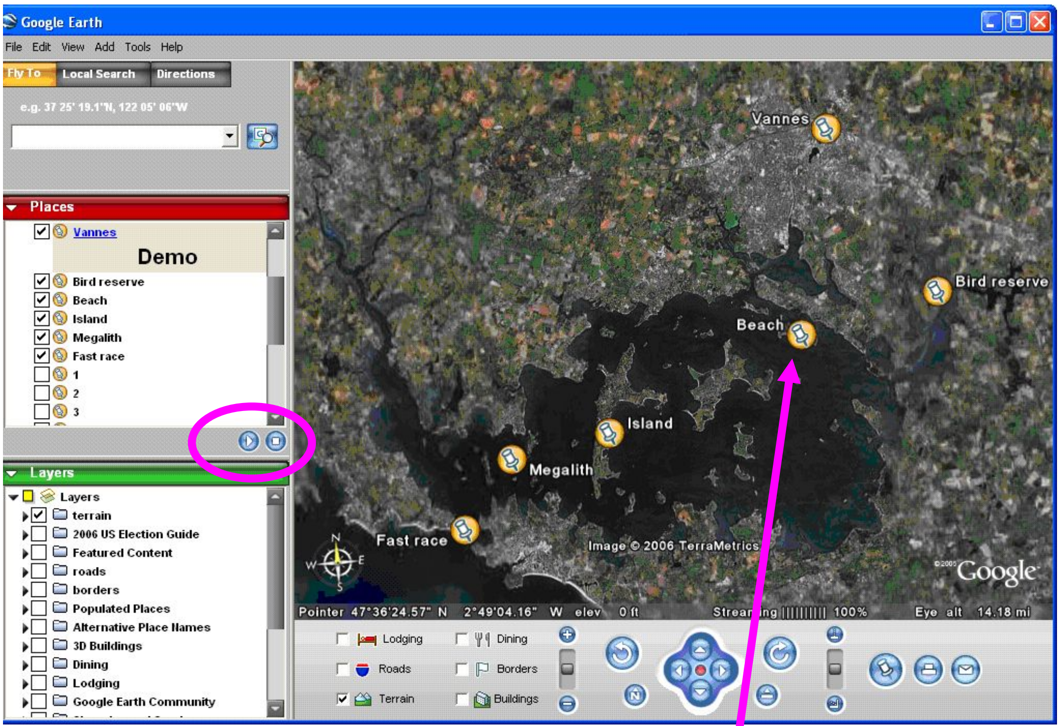
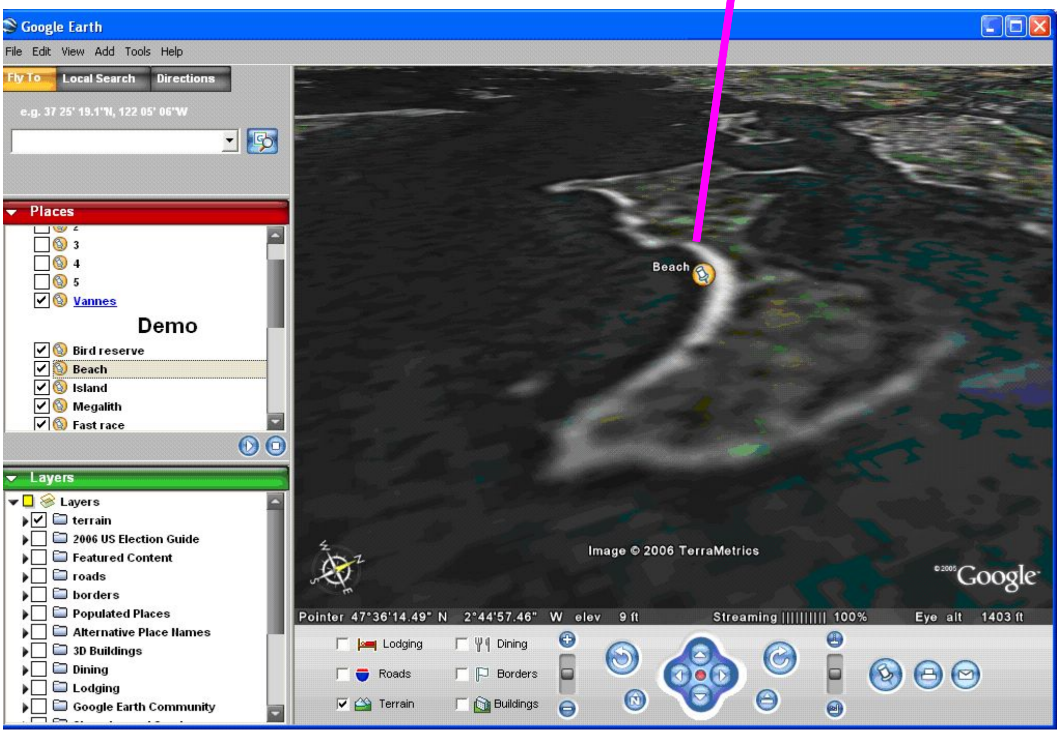


Figure 7: View from tour of Golfe de Morbihan



5.3 Example 2: Adding imagery and shapefiles in GE.

It is possible for users to overlay their own information through the addition of georeferenced images and shapefiles. Imagery such as aerial photographs or high resolution satellite imagery would provide finer resolution and therefore greater graphic realism. Image file types that can be added directly to the standard free version of Google Earth are jpg, tiff, png and gif. Shapefiles can be converted to kmls and opened directly in GE. Both images and shapefiles will be draped over the DTM once the 'terrain' layer is switched on. The GE User's Guide http://earth.google.com/userguide/v4/ has detailed instructions on pasting images into GE in the desired location. The following notes are in addition to the GE User's Guide, not a replacement for it.

If the bounding coordinates of the image are known these can be assigned when adding the image. It should be noted that the bounding co-ordinates must be in Lat-Lon. Many satellite images (e.g. SPOT Quick Looks) will already have their co-ordinates in Lat-Lon, and so these data can be easily assigned at the start.

Most raster map images, and many detailed satellite images, are projected onto the national grid of the given country – and it is not possible to convert images from national grids to Lat-Lon in ArcView or MapWindow (although either will quite happily re-project shapefiles). MapWindow appears to have the facility - **{GIS Tools/Image/Re-project}** - but in fact this tool does not yet appear to be supported. High specification software such as Erdas Imagine can re-project images at the same time as re-sampling them.

Fortunately, it is also possible to manually resize, move and rotate an image in GE using the green 'handles' that appear when the properties box of the file is opened.

Therefore there are two options

a.) Copy and paste the image into the field of view and use the green handles to manoeuvre it manually by eye (this works if you have many clear features to match it up to, like roads, or water bodies).

b.) In ArcView or MapWindow create a rectangular shapefile exactly matching the boundary of the image. This can be re-projected, in either ArcView or MapWindow. It can then be converted to a kml in Shape2Earth, then imported into GE. Copy and paste the image as before, and match up the image to the edges of the shapefile.

With both of these techniques, because your image projection is subtly different from the Lat-Lon globe, you will find that a large image will be impossible to match up exactly. Also note that there is a limit on image size, 2048 x 2048 pixels. Therefore you may need to resample/reclassify your image to a coarser resolution or crop it into a smaller area. The freeware Irfanview (http://www.irfanview.com/) has been found to be suitable for this task.

The following images (Figures 8 and 9) illustrate a UK Ordnance Survey 1:50,000 tif cropped and draped over Elgol and the Southern Cuillin, Skye.

Figure 8: Skye – aerial view of drape

Figure 9: Skye – drape over DTM 2

In MapWindow the shapefile re-projection facility is found in GIS Tools.
{GIS Tools/Vector/Reproject a shapefile}. Browse and select your shapefile (it need not be open in the viewer).

At the request 'Please select the projection to be applied', select:

{Category: Geographic Co-ordinate Systems
Group: World
Name: WGS 1984}

At the request 'Please select the current projection of the file', select:

{Category: Projected Co-ordinate Systems
Group: National Grids
Name: British National Grid (or French, Belgian etc.)}

The file will be saved under a new name, usually containing the term 'reprojected'. Then **{Shape2Earth/Export to kml}**. Browse to required file location, select name and save as kml or open straightaway in GE. This can be done for any shapefile, not just simple ones delineating image boundaries. However, it was found that Shape2Earth tends to time out for medium to large sized shapefiles (more than 1000 polygons). Figure 10 shows a converted shapefile for two of the most important biomes in the Western Isles, the machair (outlined in green) and the vegetated dunes (outlined in yellow).

Figure 10: Baleshare biomes shapefile draped over DTM
(COREPOINT Baleshare project, N. Uist)

5.4 Example 3: Creating 3D objects in GE.

It is also possible to design and create 3D objects (e.g. houses, sea defences etc.) for placement within Google Earth using Google SketchUp, which is freely available at http://sketchup.google.com/. An exciting example of use of SketchUp can be found at http://www.lloydbailey.net/airspace.html (download uk.air.kmz – it should automatically open in Google Earth). Here 3d airspace blocks have been created, and moving through and around them gives a very intuitive sense of the working world of the air traffic controller.

Go to http://download.sketchup.com/sketchuphelp/gsu6_win/gsuwin.html for the SketchUp User's Guide. Familiarization with this detailed guide is recommended if wishing to use SketchUp. When ready to create a SketchUp model in GE, go to http://sketchup.google.com/support/bin/answer.py?answer=36241&topic=9057. This latter guide is extremely clear and easy to follow, and there is no need for further detail to be added here. Figure 11 shows a simple model, sitting on a draped map image in GE.

Figure 11: 3D structure on top of Skye drape

5.5 Example 4: Virtual Earth - Windows Live Search Maps

(Contributor: Tim Stojanovic, MACE Cardiff University)

Windows Live Search Maps (http://local.live.com/) is an internet based free global mapping and search service that lets you view aerial photography of the earth, see bird's eye or 3D views and basic maps. The software has been produced as competition to Google Earth, and the aerial photography is at an even higher resolution and of excellent quality. 3D viewing requires software add-ons, otherwise the tool can be used via Internet Explorer. Like Google Earth, Live Search Maps uses a streaming process to move from low resolution imagery and terrain to high resolution imagery and terrain. An example is the 3D View of Blackpool Tower: http://maps.live.com/default.aspx?v=2&cp=sz2dpcgrbvp2&style=o&lvl=1&tilt=-90&dir=0&alt=-1000&scene=7587299&encType=1

Windows Live Search Maps allows the user to interact with the map base by using pushpins, defining paths or marking areas. These interactions can be saved by the user within a 'Collection' and a registered user can then share the 'Collection' online with other registered users in a similar way to the Google Earth Community.

Cardiff University used Windows Live Search Maps for interactive visualization at a workshop on Coastal Planning in May 2007 in partnership with planners and professionals from some of the 14 Local Authorities around the Severn Estuary. This task was undertaken with a view to developing the Strategic Environmental Assessment for Coastal Planning: Visualising the Developed Coast, Flood Risk Coast, Rural Coast and Future Developments. The VR can be found at: http://local.live.com/?v=2&cid=619154DCE9867002!101&encType= and http://maps.live.com/?v=2&cid=619154DCE9867002!101&encType

The tool was used to give an idea of the scale and types of existing and potential developments in the Severn Estuary. Figures 12 & 13 illustrate the tool.

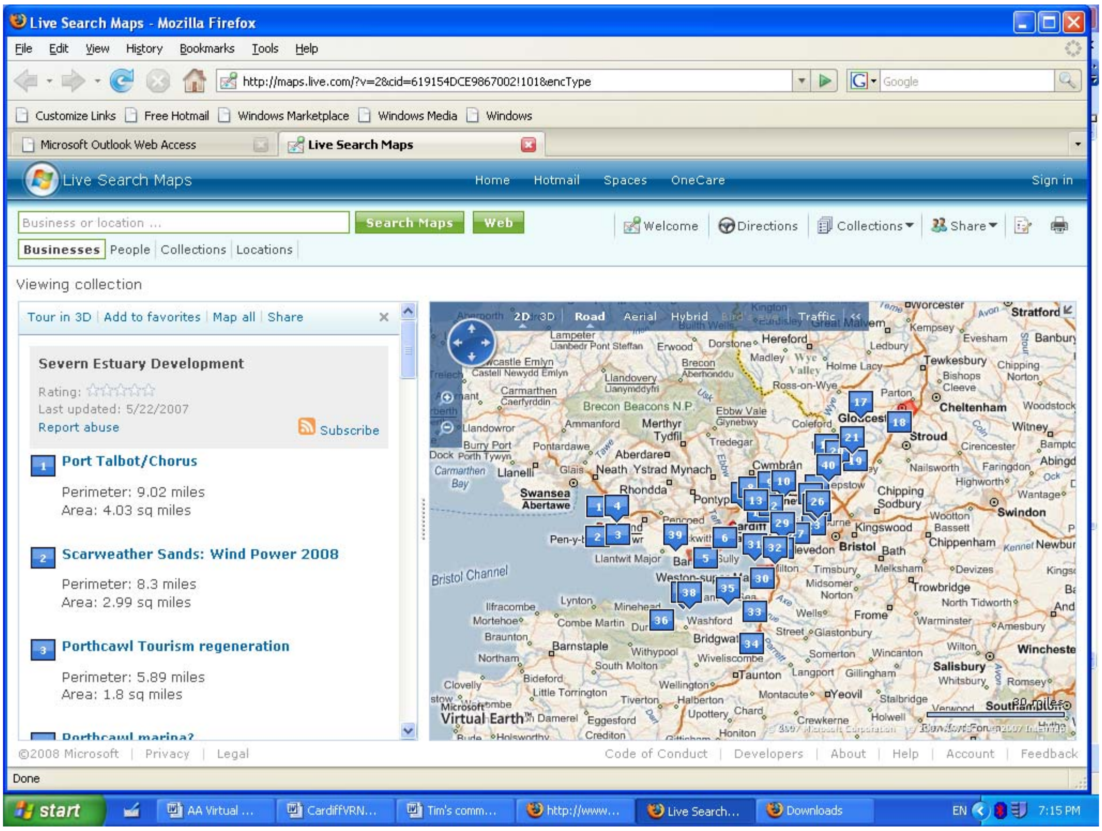


Figure 12: Screenshot of Virtual Earth (2D) for Coastal Planning in the Severn Estuary

Figure 13: Virtual Earth (3D) for Coastal Planning in the Severn Estuary: Offline windows media file 'fly through'

Planning Policy Guidance 20 Coastal Planning (England)(1992) and Technical Advice Note 14 Coastal Planning (Wales)(1998) requires local authority planners to identify areas for development, protection and flood risk in order to have a strategic view of coastal issues. Recent regulations on applying Strategic Environmental Assessment to planning frameworks and documents also suggest that it is good practice for planners to have a strategic view of coastal issues. Linked with this, Planners are having difficulties in providing planning permissions for developments where cumulative and in-combination effects have not been considered. For example, the variety of renewable energy projects around the estuary.

Outputs

The tool has great potential in helping meet the above policy drivers. The intention is that the tool will be used by planners to gain a strategic understanding of development in the estuary which goes beyond their local authority areas, and other versions are under production for flood risk and protection. The Visualization also acts as a 'prompt' to share additional information and reflections about ongoing development around the estuary

Production

The developed areas were marked in Virtual Earth/Windows Live Media by mouse using approximation with streaming aerial photography and validation against planning document maps. This provides a more than adequate representation from altitudes of 2 miles and above, and is a very quick and easy way of providing an overview. Additional information about each coverage, on such as the perimeter, area (automatically calculated) and type of development, can be viewed by dwelling above each marker. The visualization was also recorded in non-interactive form as a windows media file 'fly through' so that it can be viewed offline.

5.6 Example 4: NASA World Wind

(Contributors: Joanna Mouatt, Aberdeen Universit,y & Jeremy Gault, CMRC Cork)

NASA World Wind is the third widely available 'digital globe' software. There is not a Corepoint case study example available to provide a detailed guide to its use, but the following excerpts describe it in outline.

"NASA launched World Wind in 2004, which is a free programme that uses Landsat satellite imagery and Shuttle Radar Topography Mission (SRTM) to create a 3D representation of Earth. World Wind is aimed more towards the scientific community with an open source code that allows users to tailor the application to their own individual needs (Butler, 2006; Kim, 2006). This makes the interface a little less intuitive than Google Earth, for the average user; but, the ability to import shapefiles and KML point files provides similar tools to those explored here within Google Earth. Also, a Virtual Earth plug-in has been developed that enhances World Wind by overlaying Virtual Earth map data, which is in turn enhanced by the 3D terrain of World Wind (Chestnut, 2006). Unfortunately, one drawback of World Wind, at present, is that it is very computer processor intensive, often taking significant time to load images and impeding computer performance. Nevertheless, World Wind provides access to NASA datasets such as Landsat and MODIS satellite imagery and the GLOBE database (scientific observations such as temperature, rainfall and atmospheric pressure measured within schools. This makes World Wind an interesting application and it seems likely that it will also prove to be a useful resource to the remote sensing, GIS and educational communities, for example, in the future." (Mouatt 2006)

"NASA World Wind (http://worldwind.arc.nasa.gov) is an interactive, web-enables 3D-globe viewer. It was first released by NASA's Learning Technologies

project in August 2004 and is similar to the Google Earth viewer, where you can soom in to any place on Earth.

World Wind uses public-domain satellite/aerial imagery…[and] is open-source, allowing developers to modify the source code or develop plug-in or add-on tools. For example, free plug-ins have been developed that can access imagery and maps from the French Géoportail and Microsoft's Virtual Earth, although in these cases data licensing can be more restricted.

World Wind supports 3D visualization of both land and ocean. It is therefore possible to explore … the ocean's continental slopes in 3D.

Support for importing vector data into World Wind is currently limited. For example, vector objects such as polygons are not rendered directly but instead rasterised and rendered as a texture. Basic ESRI shapefile and KML are supported, but these features are still under development.

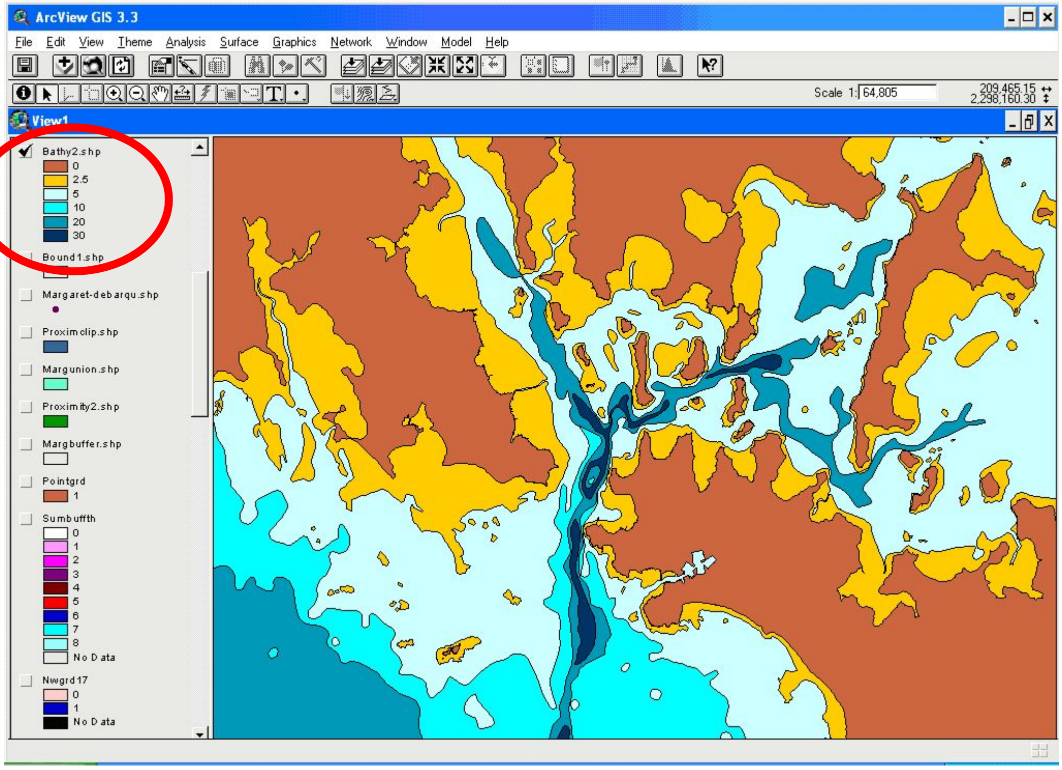
True 3D support is also required. The ocean is not a surface but a volumetric space. For example, to better visualise and interpret a volumetric hydrodynamic model, slicing and profiling tools are needed….. However it is the marketplace that will determine the additional functionality that is actually realised." (Dunne & Sutton 2006a).

To conclude: Of the three 'digital globes' discussed in this report (Google Earth, Virtual Earth and World Wind), NASA World Wind is the only one that offers subsea terrain modelling, and this may make it of particular interest to ICZM practitioners.

5.7 Example 6: Fully interactive VRMLs in ArcView

ArcView 3.3 was used for this example. Figure 14 shows the ArcView shapefile for the bathymetry of the Golfe de Morbihan. The legend (circled in red) shows the median depth for each polygon.

Figure 14: Bathymetry shapefile of Golfe de Morbihan (© CEDEM/UBO/IFREMER 2006)



From the toolbar the commands are as follows:

{Surface/ Create TIN from Features/

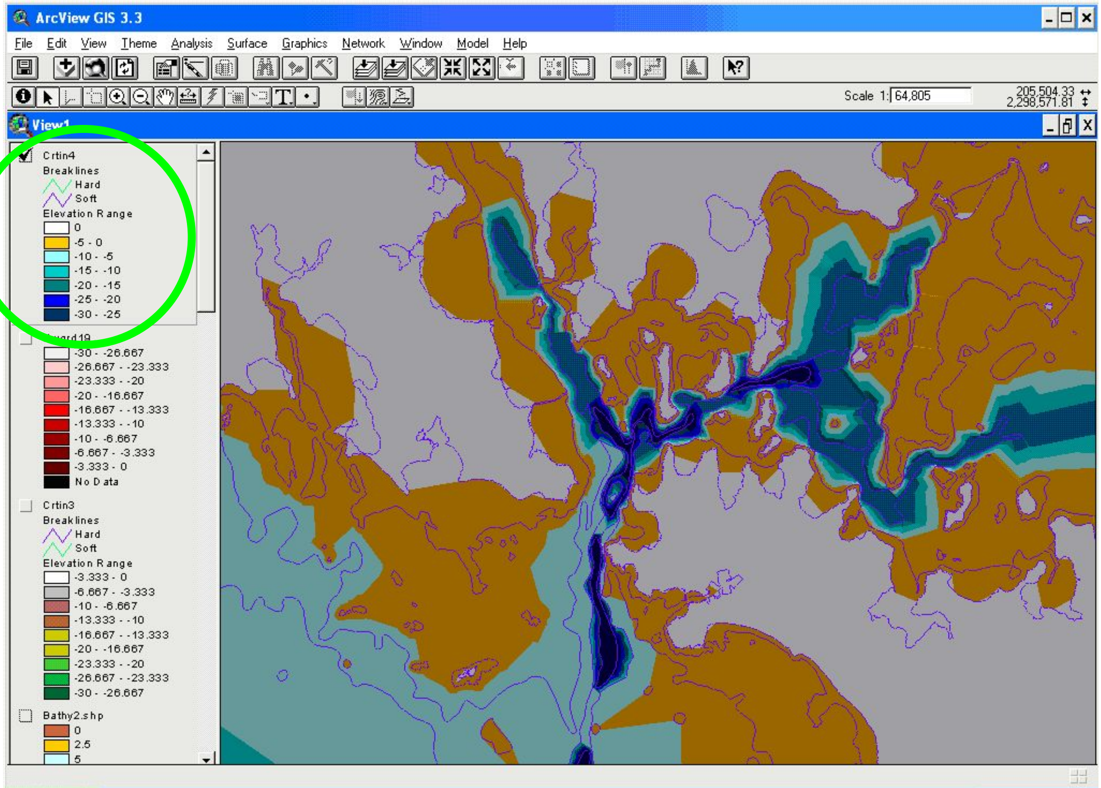
Height source: Z depth (or other relevant attribute)

Input as: Soft Replace Polygons

Value Field: ID}

Make sure you name and save the TIN (triangulated irregular network) to the folder you want (otherwise it will be stored in a temp folder and may take some finding again!). The final result is a TIN as shown in Figure 15 (legend circled in green)

Figure 15: Bathymetry TIN of Golfe de Morbihan (© CEDEM/UBO/IFREMER 2006):

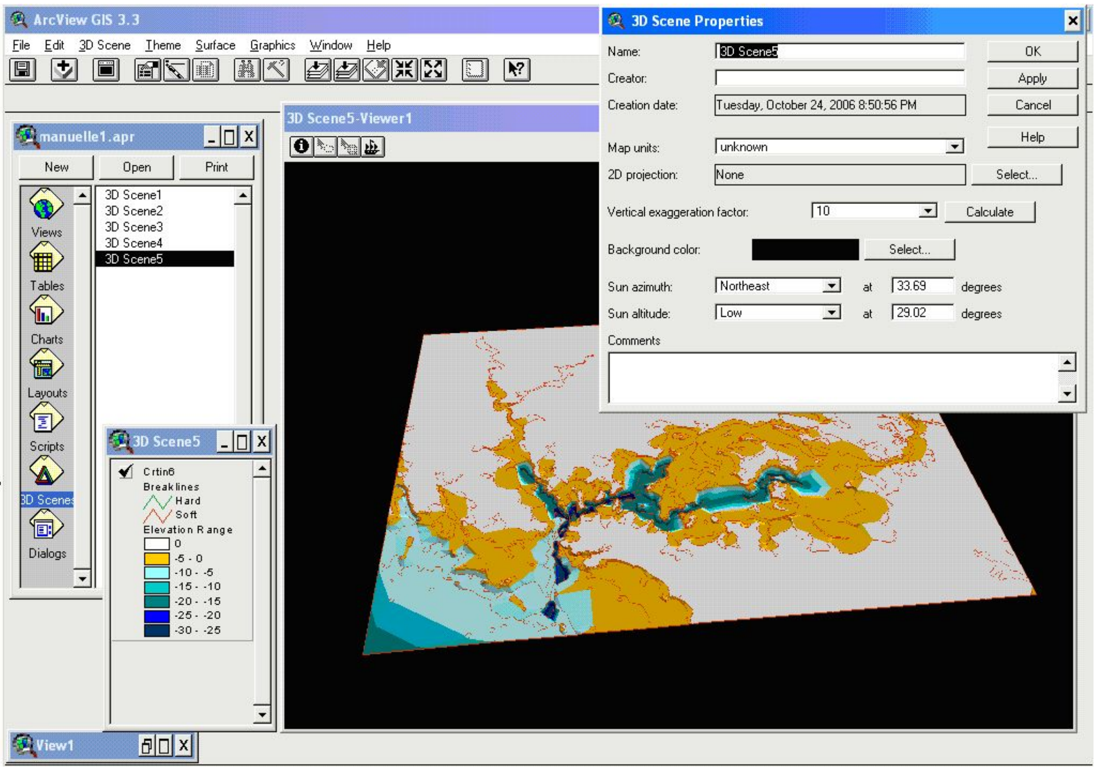


Open a new 3D scene from the project window.

{Add};

Make sure you select TIN data source in Data Source Type. At this point you will need to go back to the folder where you have saved your TIN in order to select it. The result will be as shown in Figure 16.

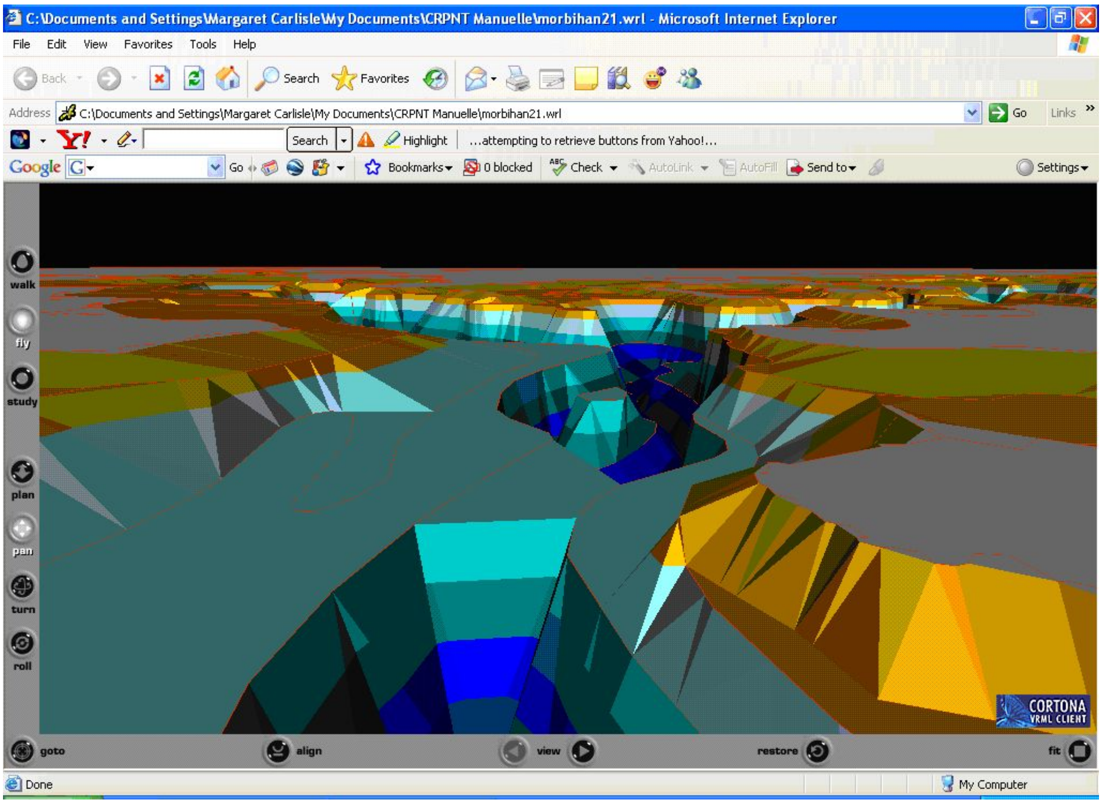
Figure 16: 3D scene of Golfe de Morbihan (© CEDEM/UBO/IFREMER 2006):



In this case, in order to exaggerate the bathymetry, a vertical exaggeration factor of 10 was selected in 3D Scene Properties. Other changes are possible at this stage – for example, in the legend. Once satisfied with how the 3D scene looks, select File/Export to VRML 2.0, ensuring that the name and folder location are as required.

The scene is now ready for opening in a VRML player. In this instance Cortona was found to be effective. Once loaded into a VRML player one can move around the 3D scene at will. Figure 17 shows a close up of the deep water trench at the mouth of the Golfe de Morbihan. Obviously the depth has been deliberately exaggerated (note that this was done in the previous, ArcView stage), but it demonstrates some of the visualization power of even very simple 3D scenes.

Figure 17: VRML screenshot of Golfe de Morbihan (© CEDEM/UBO/IFREMER 2006):



5.8 Example 7: Animated time series in ArcView/Quicktime and Global Mapper

Google Earth has a timeline function which enables linked positional and temporal data to be downloaded from a GPS, and a timeline constructed from these data. One example, at http://www.gearthblog.com/blog/archives/2006/04/ski_snowbird.html shows the real time movements of a skier going up the chairlifts then skiing down the slopes at a US ski resort. Another interesting example is found at http://www.gearthblog.com/blog/archives/2005/09/tracking_a_whal.html, where a GPS tagged whale shark can be followed on its travels around the Indian Ocean. These timelines are equivalent to linear time series.

Google Earth does not, however, allow for animated area time series. ArcGIS does have this function, but, as already noted, this software is not available to all due to price considerations. Additionally, it would appear that ESRI have focused on time series capability within their main product, ArcGIS, rather than their older product ArcView 3.x, as there do not appear to be any ArcView 3.x scripts that would enable animated time series. However, it is possible to produce a very simple animated area time series using ArcView, or indeed MapWindow and other free GIS software, by taking a 'brute force' approach and building the animation frame by frame. An example of this is described below.

The example chosen is the flooding that took place at Baleshare, North Uist, Western Isles in January 2005, where a large area of farmland was inundated by the sea, resulting in the loss of much livestock. The extent of the final flooded area is based on eye witness accounts, and the intermediate flood maps are based on interpretation of the terrain together with the eye witness accounts. The GIS software chosen is ArcView 3.3, but as noted above it would be as easily done in MapWindow or other GIS freeware.

Individual coverages are constructed for each of the 12 flooding levels. Figure 18 shows one of these – Flood level 5 - but note that ALL the flood coverages (outlined in pink) are set up in the project, ready to be switched on or off.

From the toolbar the commands are as follows;
{View/ Layout/ in Template Manager **Landscape / OK}**
Having got a layout, objects such as scale bar, north arrow, legend etc. can be adjusted as desired. In this case the layout is shown in Figure 19.

Figure 18: Project and View for Flood level 5

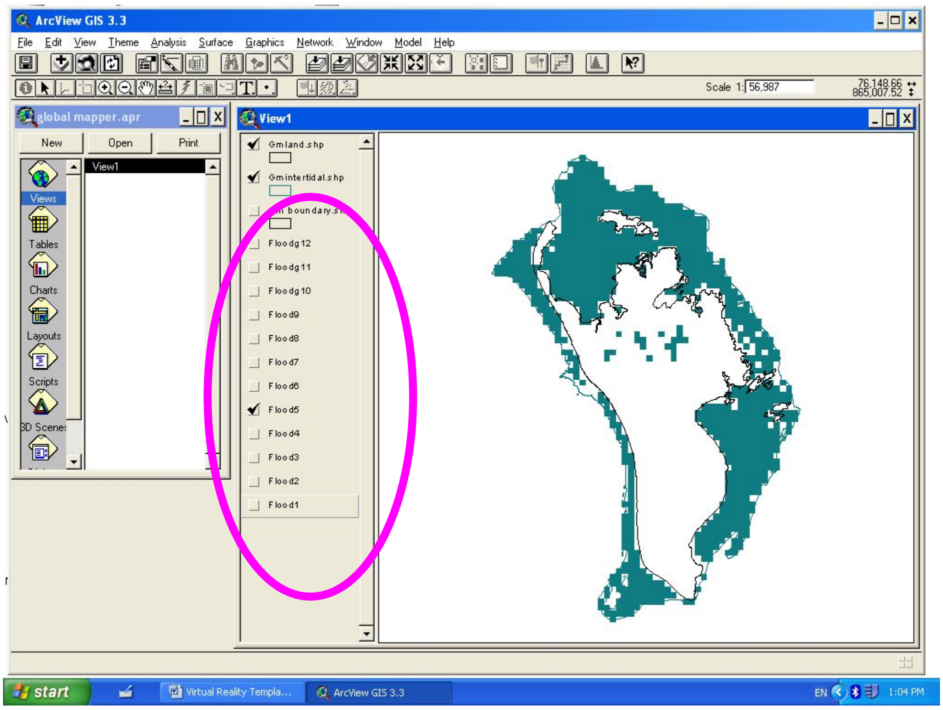
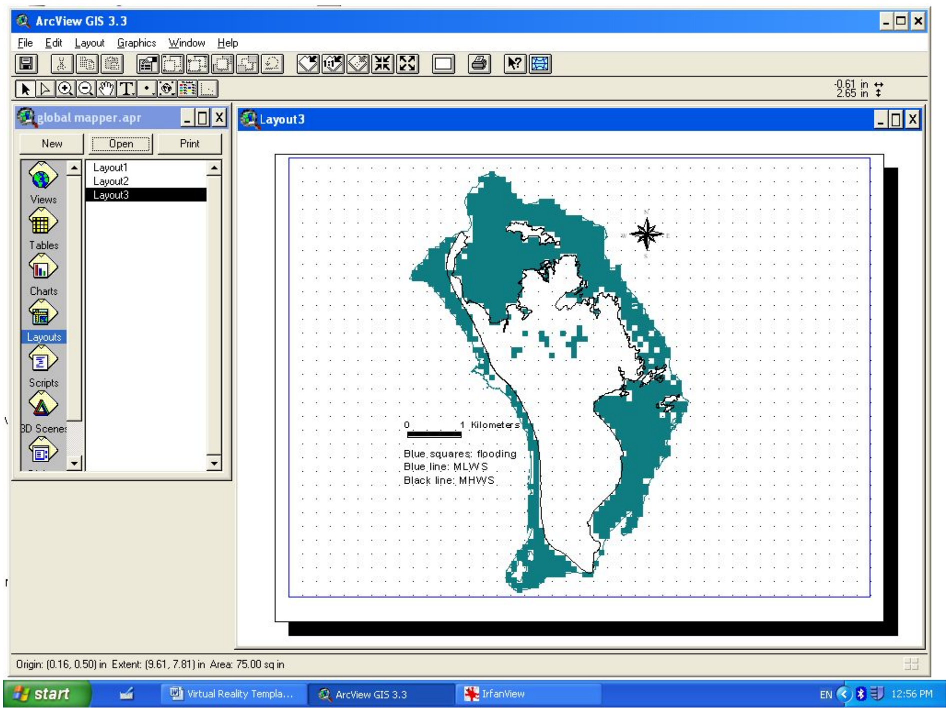


Figure 19: Project and Layout for Flood level 5



All the objects in the view are grouped, selected, and copied, then pasted into Irfanview for cropping and saving as a jpeg (named Flood5.jpg). This process is repeated for all 12 flooding levels by swapping backwards and forwards between view and layout while switching previous Flood coverage off and new Flood coverage on. It is important to maintain exactly the same field of view in the View window, in order for boundaries to match up in the animation.

The results are 12 jpegs, named in order Flood1, Flood2 etc. These jpegs need to be put into a separate folder for the next stage, which is undertaken in Apple Quicktime. The free version can be obtained at http://www.apple.com/quicktime/download/win.html, which enables viewing of Quicktime movies. However, for making animations it is necessary to purchase Quicktime Pro (currently $29.99) from the same website. Having done so, Quicktime is opened, and from the toolbar;

{File / Open Image Sequence / Navigate to folder with Flood jpgs

File name: Choose first in sequence (in this case **Flood1**)

Files of type: Image file

Frame rate: Choose preferred rate (in this case **2 frames per second**)

Then **Open}**

A separate window titled Flood1 is opened. If necessary, {**View / Fit to screen**} to get bottom toolbar into view. Using the buttons and slider on the bottom toolbar enables one to check that the image sequence is in the correct order. However this is not yet an animation, it needs to be saved as such;

{File / Save as/

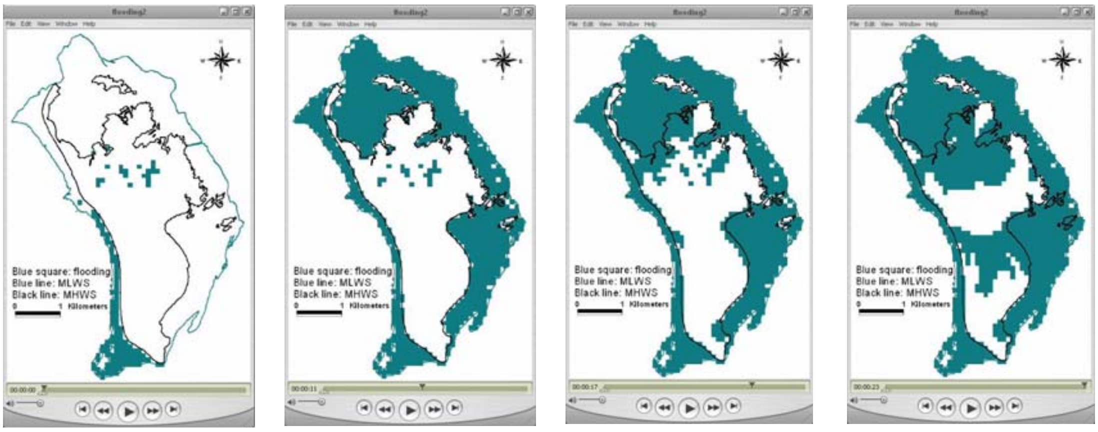
File name: Flooding1 (to avoid confusion with Flood1)

Save as type: Movies

Save as self contained movie}

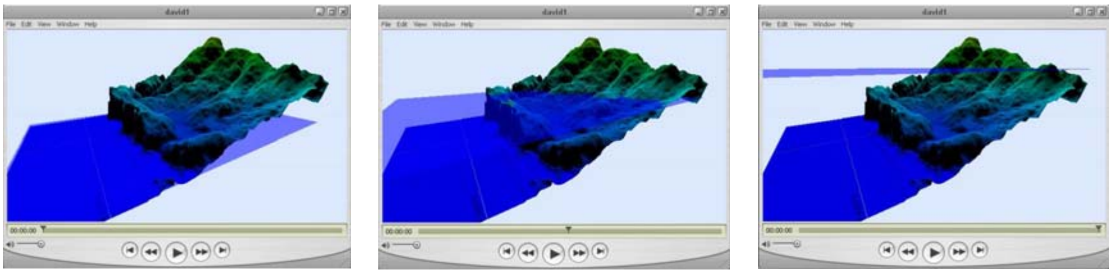
This is now an animated movie, Flooding1.mov, that can be put on a website – website users will be able to play it interactively (i.e. they can stop and start the animation where they wish) in Quicktime and also in Realplayer. Snapshots from the animation are shown in Figure 20.

Figure 20: Snapshots from Flooding1.mov



A similar animation process can be undertaken with other software. A 3D example is shown in Figure 21, created in Global Mapper (currently $228 at http://www.earthscienceagency.com/gis/?gclid=CMSEx8bjyYsCFQUrlAodSEkRBQ).

Figure 21: Sea level rise on a DTM in Global Mapper



5.9 Example 8: Panoramic VR in Panavue

Panoramic VR is the creation of a Virtual Reality by displaying a *Panoramic* image mapped onto a virtual sphere. Panoramic VR is most notably different from traditional 3D implementations of VR by restricting the viewer or the object viewed to one point in space. The viewer cannot 'walk' around in a Panoramic VR space in the way that they might in a 3D environment. The benefit of this approach is that it is possible to produce photographic quality VR at very little cost.

Figure 22 shows a section of a panoramic VR of Ben Nevis and Carn Mor Dearg, taken from the CIC Hut. This section of the panorama was constructed with three standard sized photographs in Panavue software. The whole 360º panorama was constructed with twelve photographs, resulting in a Quicktime movie, nevisorama1.mov, which can be viewed interactively i.e. the person viewing can use the mouse to pan round the panorama, stopping at views of interest.

Figure 22: Part of Ben Nevis panorama

Figure 23: Part of Ythan panorama

Figure 23 shows a more purely coastal panorama, in this case the estuary of the River Ythan. This illustrates that the restriction on viewpoint of Panoramic VR is more of a limitation for flat areas. It is therefore a technique best suited to areas with a great deal of vertical interest i.e. mountainous or built-up areas. Figure 42 shows the same viewpoint as in Figure 22, but was constructed with six original photos, two rows of three each. A free trial download of Panavue can be found at http://www.panavue.com/. The trial has unlimited use time, but all outputs are in B/W and will have the Panavue logo in centre screen. Panavue standard edition currently costs $64.

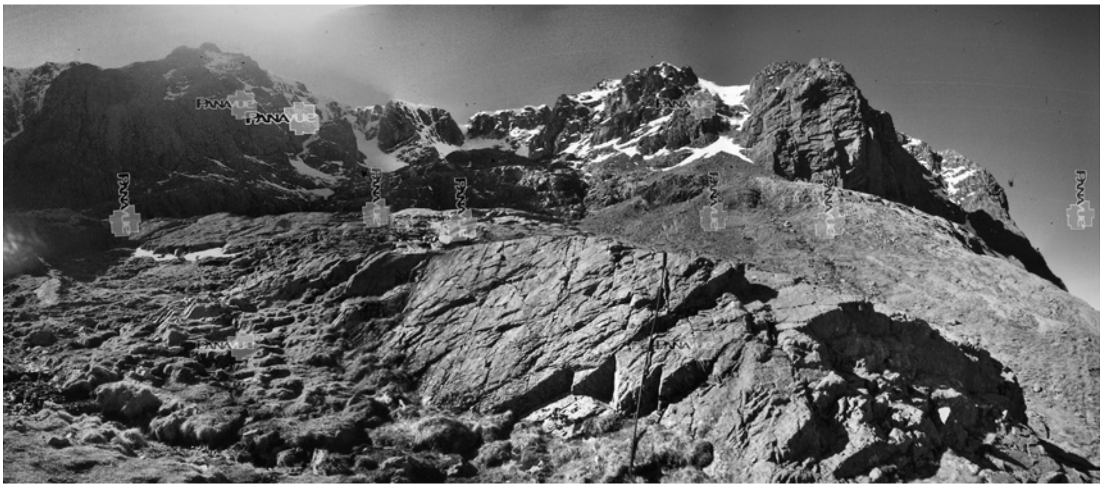


Figure 24: Six photo mosaic of Ben Nevis

On opening Panavue, click on **Help**. A new screen will open, with a set of suggested tutorials. Open **Panorama Stitching Tutorial**. This gives a detailed guide to building a 360º panorama, using a set of digital photos which will have been automatically downloaded with the software. This guide is extremely clear and easy to follow, and there is no need for further detail to be added here. Wireframe or textured buildings can be inserted, but require image software such as Photoshop (currently $649 at http://www.adobe.com/products/photoshop/index.html). Cheaper alternatives to Photoshop do exist, and are reviewed at http://reviews.cnet.com/4520-3513_7-6229928-1.html. The link http://www.abdn.ac.uk/~clt011/PanoramicVR/ provides information and links to a collection of illustrative panoramic VR projects from around the world.

6. Conclusions

Reviewing the definition of VR detailed in Section 2, it can be concluded that the following three factors must be achieved, to a greater or lesser degree, for an output to be legitimately termed virtual reality (VR):

1. *Dynamism* is the factor that is generally agreed as being essential for a product to be perceived as being VR. A long (30 seconds or more), smooth flowing sequence with considerable change either over time or in space is a high level of dynamism, a short (5 seconds or less) sequence is medium dynamism, and the absence of any change sequence (i.e. no movement) is minimal dynamism.
2. The factor *interactivity* is identified by professionals as being equally important, but appears to be of less importance to the general public. Using a mouse to guide a flythrough with complete control over position and angle of view is defined as being medium-high interactivity, using a mouse to guide a panoramic view or a time-series slider is medium-low interactivity, while passively watching a flythrough or unfolding time-series is minimal interactivity.
3. The final relevant factor, *graphic realism*, is the factor with the widest range – high resolution photography, with panoramic 360º viewing, being full graphic realism, line structures being minimal graphic realism. A high degree of graphic realism is always desirable, but is not essential, and in terms of resource use is perhaps the factor that can be most easily sacrificed.

The tools for constructing VR simulations have been getting steadily more accessible (cheaper, easier to use, and more widespread) over the past decade. The advent of Google Earth (GE) has been a huge step in the direction of increased accessibility, providing as it does free imagery and a free DTM for the entire globe. Not surprisingly this has led to an exponential growth in its popularity. This very popularity means that one of the major difficulties in previous use of VR for communication – namely, persuading viewers to download the necessary viewing software – is lessened, as more and more people choose to have GE on their home computers as a permanent download. Microsoft's Virtual Earth and NASA World Wind, the other two 'digital globes' on offer as freely available software, are also becoming increasingly popular, although the latter's usefulness is limited by its high processing requirements.

However, GE and other 'digital globes' are not the only option. Media players such as Apple Quicktime and RealPlayer are also becoming ubiquitous, and it has become increasingly easy to make animated movies using these. With the exponential increase in digital photography Panoramic VR software has also become increasingly widespread and popular, and is easy to display in one of the above mentioned popular media players. GIS is certainly less popular than any of these three tools (digital globes, media players and panoramic software), but because it is the only alternative that offers true geographical analytical capability it is steadily growing in use, particularly with the increased amount of GIS freeware available. The last VR tool, VRML, produces excellent results in terms of true 3D VR. However GE compares just as well in terms of dynamism and interactivity, and better in terms of 'free' graphic realism. Additionally, VRML viewers are highly variable in performance and are not in widespread use. An alternative option to VRML is Java 3D, which provides a much more stable and widespread viewer, but with the demerit that it requires considerably more skill to produce the landscape and object to be viewed. However, until GE incorporates bathymetry into its DTM, the only options for highly interactive 3D bathymetric models remain VRML, Java 3D or the processing-intensive digital globe NASA World Wind.

In conclusion, there are VR options to suit every combination of data availability, finance availability and technical expertise. VR simulations, from simple panoramas and animations to fully realised 3D buildings and structures in a true 3D environment, will become increasingly common as a tool for communication, education and stakeholder interaction.

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http://cic.nist.gov/vrml/vbdetect.html
http://coe.sdsu.edu/eet/articles/vrk12/index.htm
http://download.sketchup.com/sketchuphelp/gsu6_win/gsuwin.html
http://earth.google.com/
http://earth.google.com/userguide/v4/#getting_to_know
http://freeware.intrastar.net/vrml.htm
http://java.sun.com/products/java-media/3D/
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http://sketchup.google.com/
http://sketchup.google.com/support/bin/answer.py?answer=36241&topic=9057
http://uk.real.com/player/
http://woodshole.er.usgs.gov/operations/modeling/
http://www.abdn.ac.uk/~clt011/PanoramicVR/
http://www.adobe.com/products/photoshop/index.html
http://www.anquet.co.uk/
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http://www.gis.com/
http://www.gislounge.com/ll/opensource.shtml
http://www.grc.nasa.gov/WWW/MAELVRSTATION/media/ISS_animation/animation.html
http://www.intuition-eunetwork.net/
http://www.irfanview.com/
http://www.javacoffeebreak.com/tutorials/gettingstarted/index.html
http://www.kartografie.nl/pubs/geovisualization/5-2.html
http://www.lloydbailey.net/airspace.html
http://www.mapwindow.com/
http://www.metoffice.gov.uk/weather/charts/index.html
http://www.modelpress.com/verml-software.htm
http://www.panavue.com/
http://www.rockware.com/catalog/pages/arcview3x.html
http://www.tatukgis.com/products/summary/products.aspx
http://www-graphics.stanford.edu/~tolis/toli/research/morph.html
http://www-vrl.umich.edu/intro/index.html
http://www.xj3d.org
https://j3d-webstart.dev.java.net/test/
www.auridian.com/glossary/HTML/V.htm
www.cem.uvm.edu/util/html/definitions.php
www.saugus.net/Computer/Terms/Letter/V/
www.teladesign.com/ma-thesis/glossary.htm
www.unesco.org/education/educprog/lwf/doc/portfolio/definitions.htm

Appendix 1: Definitions of Virtual Reality

The following bullet points give a selection of definitions of VR found on the Web.

1. "Some would limit the term VR to those systems that put the viewer into an immersive environment of some sort and then allow the viewer to navigate through a virtual world, perhaps through time as well as space. The navigation system must provide real- time interaction, meaning that the interaction between user and computer is continuous and instantaneous. Others would expand the definition to include much simpler viewing systems -- as simple as a standard computer monitor -- and to permit interaction between an operator and the virtual world, with the viewer in only a passive role. Although I would prefer a more limited definition, requiring at least that the viewer be in charge of navigation, I think the broadest definition is better for the purposes of this discussion. Therefore, I will take VR to include any system that provides interactive, real-time access to a relatively realistic portrayal of some specific physical realities. The user, in this broad definition, may be either someone trained to operate the system or a naive user, but the definition is not stretched to include prepared sequences that are, in essence, short movies; real-time interaction is a requirement. The level of realism required is, I acknowledge, vaguely defined. I do not think a good, precise definition can be constructed; this is a moving target because the technology is changing so fast. However, the term is meant to indicate realistic textures and coloring, some shadows or shading, though not necessarily cast shadows, and a general sense of realism strong enough to engage viewers." **Harrison Eiteljorg** http://www.csanet.org/newsletter/spring02/nls0205.html
2. "Virtual reality, sometimes called VR, refers to computer simulations of real-world "environments" that use 3-D graphics and external devices like a dataglove or helmet to allow users to interact with the simulation. Users move through virtual reality environments as though they were navigating in real worlds -

walking through structures and interacting with objects in the environment." http://www.intuition-eunetwork.net/

(**Note: INTUITION is the EU's own VR project**).

3. "An immersive and interactive simulation of either reality-based or imaginary images and scenes." www.unesco.org/education/educprog/lwf/doc/portfolio/definitions.htm
4. "A digital simulation of the real world. Immersed VR is three dimensional giving the feeling that the user is in another world." www.auridian.com/glossary/HTML/V.htm
5. "A computer simulation of a real 3-dimensional world, often supplemented by sound effects. People often associate VR with a body suit and head gear that includes an internal screen. The suit measures your body's movements and displays them on the screen….. making you feel like you're really there." www.cem.uvm.edu/util/html/definitions.php
6. "VR is generally speaking an attempt to provide more natural, human interfaces to software. *It can be as simple as a pseudo 3D interface* [my italics] or as elaborate as an isolated room in which the computer can control the user's sense of vision, hearing , and even smell and touch." www.saugus.net/Computer/Terms/Letter/V/
7. "The proposed construction of artificial realities in a purely digital realm; not yet technically feasible in the strictest sense. By extension any form of simulated reality – textual or graphical – created using computers. Also used as a marketing term to sell *technology that can create two-dimensional representations of three-dimensional space on a computer screen* [my italics]." www.teladesign.com/ma-thesis/glossary.htm
8. Virtual reality (VR) is a technology which allows a user to interact with a computer-simulated environment, be it a real or imagined one. Most virtual reality environments are primarily visual experiences, displayed either on a computer screen or through special stereoscopic displays, but some simulations include additional sensory information, such as sound through speakers or headphones. Some advanced, haptic systems now include tactile information,

generally known as force feedback, in medical and gaming applications. Users can interact with a virtual environment either through the use of standard input devices such as a keyboard and mouse, or through multimodal devices such as a wired glove, the Polhemus boom arm, and/or omnidirectional treadmill. The simulated environment can be similar to the real world, for example, simulations for pilot or combat training, or it can differ significantly from reality, as in VR games. In practice, it is currently very difficult to create a high-fidelity virtual reality experience, due largely to technical limitations on processing power, image resolution and communication bandwidth. However, those limitations are expected to eventually be overcome as processor, imaging and data communication technologies become more powerful and cost-effective over time.
http://en.wikipedia.org/wiki/Virtual_reality

Appendix 2:

Feedback on Virtual Reality tools from Eco-Imagine 2007

Eco-Imagine 2007 was a 6 day training course introducing participants to the role of Geographic Information Systems (GIS) and related geospatial technologies in Integrated Coastal Zone Mangement (ICZM). The course was run by David R. Green of the University of Aberdeen, with assistance from Margaret Carlisle (Corepoint) and Guillaume de la Fons, both also from the University of Aberdeen. Drawing upon a combination of local academic, commercial and government expertise, as well as local stakeholder knowledge, the training course focussed on the use of the geospatial technologies to undertake a practical GIS-based coastal project.

Visualization and VR tools were one important component of the course, and several of the tools as described by this report (GE and GE Sketch-up, ArcView GIS, Quicktime media player) were made described in presentations and made available to the participants for practical workshops. At the end of the course the participants (22 academic researchers, 3 ICZM practitioners and 3 other practitioners) filled in a questionnaire in order to evaluate the usefulness of VR tools for ICZM. The detailed results are shown on the following 5 pages.

All respondents (25) thought that the VR options described and worked through in the course added to their knowledge/experience of VR, despite 42% having had some prior experience of VR before, and in a few cases quite extensive prior experience. Only 1 out of 27 respondents disagreed with the statement that web-based VR tools (particularly the digital globes such as GE) are potentially useful tools for aiding decision-making in ICZM.

The final question asked respondents which they thought were the more useful tools for ICZM decision-making, and which the less useful. The results are shown in the table immediately below – the numbers refer to the number of respondents who specified that tool:

MORE USEFUL		LESS USEFUL	
Google Earth	**10**	Virtual Earth (not as easy to access as GE)	**1**
GE Sketch-up	**3**	VRML (less portable & requires much skill)	**1**
Macaulay Virtual Theatre	**2**	Macaulay Virtual Theatre (because of price)	**1**
Geoserver (also referred to by respondents as Geoportal and WebMap)	**1**	Geoserver (too complex)	**2**
GIS	**1**	GIS (i.e. scientific data without VR)	**1**
ArcView/Quicktime	**1**		
Aquaterra	**1**		

Tools specified here which are not included in this report include:

Macaulay Virtual Theatre: A full size theatre which can give audiences a very immersive experience in a virtual landscape

Geoportal/Geoserver: A webserver for making one's own maps available to others.

Aquaterra: A software suite for the design of canals and river engineering works. http://www.aquaterra-software.com/Default.aspx?tabid=306

It is worthy of note that by far the most positive response was for Google Earth, with GE Sketch-Up being the second most popular tool.

Question 1: Are you a.an academic researcher, b. an ICZM practitioner or c. other (please specify)

Question 2: Have you had experience of VR before? If yes, please give details.

	1a	1b	1c	2yes	2no	2 details
Rsp. 1	1				1	
Rsp. 2	1				1	Not really
Rsp. 3	1				1	
Rsp. 4	1			1		Used GE and tried to use ArcScene
Rsp. 5			1 Govt. researcher	1		Experience of 3D animation of spatio-temporal fields
Rsp. 6	1				1	
Rsp. 7	1				1	
Rsp. 8			1 GIS practitioner		1	
Rsp. 9	1				1	
Rsp. 10		1			1	Not much
Rsp. 11	1			1		Demonstration software/installations similar to the one at Macaulay Inst.
Rsp. 12	1				1	
Rsp. 13	1				1	
Rsp. 14		1		1		Yes, linked with ArcScene projects and datasets
Rsp. 15	1				1	
Rsp. 16	1			1		A little - personnel work (very small applications though!)
Rsp. 17	1			1		A little - just creating some animations with ArcGIS for showing the evolution of an estuary
Rsp. 18			1 Training organisation	1		Not structured, only for personal information
Rsp. 19	1			1		Attended several research meeting in early 2000 and developed some case studies. Previous experience
Rsp. 20	1				1	
Rsp. 21	1				1	
Rsp. 22	1			1		I have developed models for aquaculture development in Sierra Leone using VR/GIS
Rsp. 24	1			1		
Rsp. 25	1				1	
Rsp. 26	1			1		A little, only read papers about it
Rsp. 27	1			1		Yes, it's my work- I want to make a research group in our institute of GIS & VR.
Rsp. 28		1			1	Not much
Rsp. 29	1				1	
No Rsp.23	22	3	3	12	16	

Question 3: Did the VR options described, illustrated and worked through in Eco-Imagine add to your knowledge/experience of VR? If yes, please give details

3yes	3no	3 details
1		Greatly improved my understanding of VR. The objective of VR in public participation was very clear, Macaulay Inst. was a practical experience of VR, using 'Sketch-up' allowed us to practice it as a tool
		They certainly did, it was very enlightening to see the different aspects
1		
1		Especially the field trip to Macaulay Institute, the Google sketchup tool (although I worked on the presentation at that time and I didn't try it out) and setting up a geomap server
1		The course will help me to visualize the results of my research
1		Wide open my knowledge/experience, I could apply on several GI reports on presentation
1		Because it's a brand new theme for me and I think it has been pretty well discussed
1		Shows new perspectives to use and visualize GI....probably the future now!
1		Sketch-up, Aquaterra tools
1		The most important was to learn how can we use very well known tools GE to provide more scientific (less recreational) information to the general public
1		I was surprised with VR options. I'm sure that I will apply it to future work
1		Yes, sure! I was more impressed with the 3D VR for public awareness
1		Absolutely yes! It enlarged my own VR perspective...
1		A new tool to improve results
1		Sketchup + GE, Aquaterra
1		It showed me different software packages for working with VR, as well as give a different way of looking to GE
1		Hints and suggestions about possible use
1		First time I use Sketch-up. Quite interesting & several application opportunities in collaborative/particpatory planning domain
1		Advantage to add VR into GIS projects; teach this tools to Master students
1		I can now use webGIS in combination with the desktop one to develop more detailed VR model
1		Yes, of course as they improve the subject of VR with the GIS, GPS too and know how to integrated with the landscape studies too.
1		
1		Practical use of different tools
1		Some new things in web publishing - practical work about GE & Sketch-up
1		Yes very much so - I can see how it could be of use to a number of stakeholders
1		
25	0	

Question 4: Do you think that the web-based VR tools described in Eco-Imagine are potentially useful tools for aiding decision-making in ICZM? And why?

4yes	4no	4 details
1		Potentially useful but could be too powerful as a tool for the average individual who has no experience with technology
1		They are very visual, meaning they do give a lot of information through images. They can be quite striking and sometimes as seen in the Macaulay Institute can change points of view
1		
	1	Not exactly for decision-making, rather than visualizing the results, in order to show the already made decisions
1		VR is very easy to understand by decision-makers
1		Improve model representation of the reality and help on the spatial planning acts
1		I think it can be very useful especially in the raising awareness phase of a project or a proposal. The results are really effective an deasy to be understood also by non-e1perts
1		Apparently could give a more real perspective of the analysis space
1		I think many of these tools are very useful in the public participation process for informing the public and other stakeholders and receiving active input (e.g. voting at the Macaualy Institute)
1		Because everybody loves VR tools like GE and so we can have people paying attention to issues that usually they tend to discard, ignore or just don't feel in the mood for it.
1		
1		Not decision-making directly and entirely. But rather to promote stakeholers role as an input into decsion-making process
1		They can help you to better imagine future reality from different perspectives and improve people's understanding of the landscape as a whole
1		Better visualization of the final result
1		Yes, but VR alone is NOT enaough. It is necessary to link it with more common representations of the reality (photographs etc.)
1		Because they made available a series of data to be visualized at different scales and also to be queried in a very different way in relation to classic paper maps used in decision-making in ICZM
1		Yes, if they are cleaned by their fascinating effect that induces a positively based evaluation, forgetting details that are maybe not considered and could have a negative effect - i.e. VR should be anticipated by a scheme of all new objects and structures and of how they have been detailed or not in the VR model (e.g. windmills on earth may require a service road)
1		Easy of use, collaborative in nature support discourse
1		Very good tools for decision making and public participation processes
1		Because is more easy for the stakeholders understood the problems and visualization of the old problem
1		Decision making is effective when those making it are well informed and VR is an effective tool in properly and effectively informing the decision makers and planners
1		Of course, because with integrated this VR studies and analysis. It's more help to take decisions-making in ICZM. It helps you to take reality, which give to you clear VISION for the area. So, can help you with right decision and to improve the design wise too.
1		
1		To communicate to the stakeholders and the public
1		It may be so for people without spatial vision
1		Only for big projects as they have the time and money to use VR
1		It gives one quite a good idea of what to expect when the project is done
26	1	

Question 5: If your answer to question 4 was yes, which tool do you think would be more useful, less useful, and why?

5 more useful	5 less useful
Google Earth, access from home/work online. Sketchup allows the user to create a model.	
Visualization software such as GE or microsofts, because they are quite easy to handle	Web Map services, developing maps for the internet, and making them available for the public - because it takes time to actually be able to have to actually be able to have maps available and visualize them in the net.
GE - it's free, easy to use, and widely used	Maybe Virtual Earth. People cannot access it as easily as GE
3D visualization - 3D vis. Provides decision makers with the useful and straightforward tool to support their decisions	
Aquaterra - visualisation is widely applicable	
GE, but they are all useful if well used. In the end, VR is raising the awareness of everybody, specially general public, to what we were used to hear about it or maybe to have a look about it in pictures. Now VR is allowing everybody to know more in a much better and funny way. That's why I think all VR tools (as long as they work properly) are useful.	None is not useful
Tools which could address a wider audience like the one in Macaulay Institute	
3D visualization tools, integration tools, modelling tools. They are nowadays easy to access and easy to use and they can really make a difference on understanding reality. Additionally, this tools are getting free of charge which can provide dissemination of data and information not just to the researchers but also to the general population.	I can't think of any at this point....
Sketch-up & GE	VRML is less portable and you need more skills to develop a model
Sketchup, GoogleEarth, Macaulay Institute VR theatre. Sketchup is easy to use and free software. Tools of Macaulay Institute are of great power as to be well understood by non	
Geoportal, GE - is more easy for the people see the internet	VRT [Macaulay Virtual Reality Theatre] because of PRICE
GIS & VR	Scientific data without VR, because not all decision-makers are technically inclined
The models example was presented with GE. It help to understanding the geomorphologys for the lunch	
GE and AV-Quicktime	
It's not so easy to answer - only good visualisation, its not enough.	
GE it is easy to use	Geoserver is just complex