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The ethics of Google Earth: Crossing thresholds from spatial data to landscape visualisation

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ABSTRACT

'Virtual globe' software systems such as Google Earth are growing rapidly in popularity as a way to visualise and share 3D environmental data. Scientists and environmental professionals, many of whom are new to 3D modeling and visual communications, are beginning routinely to use such techniques in their work. While the appeal of these techniques is evident, with unprecedented opportunities for public access to data and collaborative engagement over the web, are there nonetheless risks in their widespread usage when applied in areas of the public interest such as planning and policy-making?
This paper argues that the Google Earth phenomenon, which features realistic imagery of places, cannot be dealt with only as a question of spatial data and geographic information science. The virtual globe type of visualisation crosses several key thresholds in communicating scientific and environmental information, taking it well beyond the realm of conventional spatial data and geographic information science, and engaging more complex dimensions of human perception and aesthetic preference. The realism, perspective views, and social meanings of the landscape visualisations embedded in virtual globes invoke not only cognition but also emotional and intuitive responses, with associated issues of uncertainty, credibility, and bias in interpreting the imagery. This paper considers the types of risks as well as benefits that may exist with participatory uses of virtual globes by experts and lay-people. It is illustrated with early examples from practice and relevant themes from the literature in landscape visualisation and related disciplines such as environmental psychology and landscape planning. Existing frameworks and principles for the appropriate use of environmental visualisation methods are applied to the special case of widely accessible, realistic 3D and 4D visualisation systems such as Google Earth, in the context of public awareness-building and agency decision-making on environmental issues. Relevant principles are suggested which lend themselves to much-needed evaluation of risks and benefits of virtual globe systems. Possible approaches for balancing these benefits and risks include codes of ethics, software design, and metadata templates.

1. Introduction

'Virtual globe' software is growing rapidly in popularity as a way to visualise and share 3D environmental data. Google Earth "A 3D Interface to the Planet" was publicly released in June 2005 and has attracted widespread public use and attention due to its ability to view landscapes in fairly realistic three dimensions, using a combination of digital elevation models, satellite imagery, and 3D building envelopes (in some selected cities). Google Earth grew to over 100 million users on the Internet within one year of its release (Google Corporation, n.d.). In the United Kingdom, it is reported that "Google Earth" became the eighth most popular search term during the month of January 2006 (Hopkins, 2006). Other programmes are becoming available with some similar capabilities, including World Wind (NASA, 2006) and ESRI's ArcGIS Explorer (Environmental Systems Research Institute, 2006).

Breakthroughs in tiling, data transfer, and caching technology have allowed seamless viewing and real-time exploration of spatial data, including medium to high resolution satellite imagery anywhere in the word. The appeal of these techniques is evident, not only for private users but also for scientists, practitioners, policy-makers, and stakeholders on environmental and planning issues (Butler, 2006). The speed of uptake by the scientific community, for example, can be gauged by the fact that the American Geophysical Union's Conference advertised 38 technical presentations on the use of virtual globes in the earth sciences (AGU, 2006). There would seem to be unprecedented opportunities for greatly increased

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access to, engagement in, and collaborative use of spatial information. Are there, however, risks in this widespread and possibly indiscriminate usage when applied to awareness building and decision-making contexts central to the public interest? If so, how might these risks be balanced with the advantages provided by virtual globe systems?

In considering possible problems stemming from virtual global systems and possible solutions, this paper reviews theoretical frameworks and principles applying particularly to the use of 3D environmental visualisation methods, drawn from relevant disciplines and fields of professional practice. The paper explores how these principles apply to the new subcategory of visualisation known as virtual globes, primarily in the context of social learning and decision-making by government and local communities on issues such as environmental awareness-building, public policy debates, and land use planning. Accordingly, the focus will be primarily on questions of validity (including notions of correctness or appropriateness of the information), not the more obvious aspects of utility in information transfer, usability, and engagement, which are already becoming self-evident. We will argue that it is vital to consider more than the cognitive role of virtual globes, by virtue of their realistic depiction of real places with diverse social meanings to users. Ultimately, it is hoped that a structured identification of observed and potential issues and corresponding principles will encourage much-needed and systematic evaluation of virtual globe use, so we can justify confidence in their use.

Two groups of users are the focus of this paper; in both cases, these have not previously been typical users of or practitioners in visualisation systems. One group comprises scientists and experts from various disciplines, seeking to use these new tools to inform, present and contextualize their work. The other group comprises interested members of the lay-public (here defined as people without particular expertise in science or environmental professions), who can freely access these tools over the Internet and potentially interact in new ways with public processes; this group would include both viewers who primarily browse and navigate through the available information, and more active users who manipulate, add to, and re-post the information, essentially serving as data providers. While it is beyond the scope of this paper to review systematically patterns of current usage of virtual globe systems, we will highlight potential issues by reference to some early examples of Google Earth use. Accordingly, considerable reliance on information from web-sites is unavoidable in this paper, given the recent availability of the virtual globe software.

After reviewing relevant frameworks and principles for evaluating virtual globe systems in the context just described, the paper describe benefits (briefly) and possible risks (in more depth) of using virtual globes. It concludes with suggestions for balancing those benefits and risks on issues of public interest, and for prioritizing further research.

2. Possible frameworks and principles for evaluating virtual globes

The field of computer-based visualisation is still only a couple of decades old and theories, frameworks and principles to guide appropriate usage are still emerging. Two disciplines that have begun to develop frameworks for understanding and evaluating visualisations in ways that are relevant to the focus in this paper comprise cartography/GIS, with particular reference to collaborative GIS and web-GIS applications, and landscape visualisation.

The main discipline in which visual media are used to convey environmental and scientific information has been cartography and allied or derivative forms of geo-visualisation, showing the world in GIS maps, diagrams, or conceptual simulations of 3D forms (Appleyard, 1977; Monmonier, 1996). These media are typically semiotic as they communicate using primarily abstract symbols. MacEachren (2004, p. 355) uses the term "visualisation" in the context of "cartographic visualisation" or "scientific visualisation", which refers to the use of "advanced computer technology to make visible scientific data and concepts". He has proposed one schema for analyzing uses and types of visual media (including maps) that could be applicable to 3D virtual globes, in the form of a conceptual cube (Fig. 1).

MacEachren (2004, p. 257) summarizes the visualisation cube variables as follows:

> The dimensions of the interaction space are defined by three continua: from map use that is private (tailored to an individual) to public (designed for a wide audience); map use that is directed towards revealing unknowns (exploration) versus presenting knowns (presentation); and map use that has high interaction versus low interaction. There are no clear boundaries in this human–map interaction space. All visualisation with maps involves some communication and all communication with maps involves some visualisation. The distinction made is in emphasis. Geographic visualisation is exemplified by map use in the private, exploratory, and high interaction corner. Cartographic communication is exemplified by the opposite corner.

This framework distinguishes between use of visual media for "visualisation" (emphasis on analysis or exploration) and "communication" (emphasis on presentation), with the suggestion that an important role of visualisation is to discover information not previously known from other data sources. The public/private dimension can be related to general use by lay-people (more public) versus scientists or individual experts (more private). Under this framework, virtual globes would seem generically to occupy a space in the cube with high public content and presenting mostly 'knowns', in the sense that the information is not new to science, although presenting perhaps much previously unknown information to the public. This would lean toward an emphasis on communication as represented in the cube, but with quite high levels of interaction in some limited ways, e.g. visual

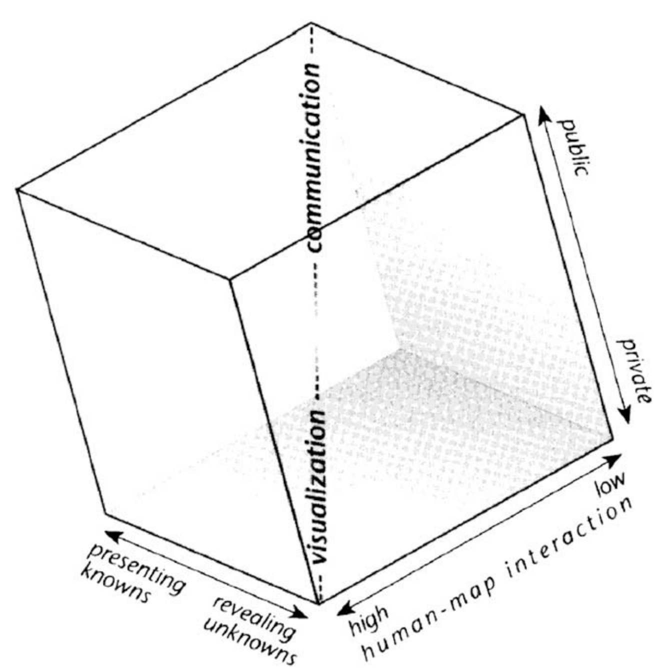


Fig. 1. MacEachren's cube diagram representing key dimensions related to visualisation and communication. Source: MacEachren (2004, p. 358) with permission from The Guilford Press, New York, NY.

exploration and some data creation. Google Earth provides only basic measuring and simple manipulation tools, but ESRI's ArcGIS Explorer will offer more advanced analytical tools. Individual applications of virtual globes might be classified quite differently from this generic application of MacEachren's criteria.

Other relevant GIS frameworks pertain specifically to collaborative GIS and web-GIS. Collaborative GIS is here taken to include a wide range of participatory forms as described, for example, by Sieber (2006), ranging from general use of GIS products in public participatory processes to interactive hands-on GIS exercises among collaborating experts or stakeholders (see MacEachren, 2001). MacEachren (2000) categorizes collaborative uses of GIS using spatial and temporal dimensions, distinguishing same place and different place collaborations, and synchronous and asynchronous collaborations. Virtual globes can be used collaboratively in any of these conditions, though commonly accessed via the web by dispersed single lay-users (asynchronous collaboration) or used by experts in public group settings (co-located and synchronous). The latter situation offers interesting extensions to the more typical participatory planning process, through use of virtual globe systems: (1) as a graphic communication medium where images are pre-prepared for static or animated presentation in the meeting, or where imagery is modified overnight between successive charrette meetings to reflect citizens and expert input (e.g. the AIA Colorado Springs Design Charrette, 2007: http://www.aia150.org/bl150_default.php); or (2) more rarely, in interactive mode where models are altered in real time in the meeting.

Sieber (2006), drawing on the work of Barndt (2002) and others, identifies various goals and criteria for participatory GIS which could be used to evaluate virtual globes (Table 1), though as she points out, the criteria are rather general and difficult to define reliably. They do, however, reflect a concern for ethics and equity in participatory processes which is integral to the history of the collaborative GIS movement, and relevant to validity issues addressed later in the paper.

Web GIS comprises one component of collaborative GIS, with particular relevance to the use of virtual globes delivered at a distance in participatory processes via the Internet. Peng (2001, p. 891) defines web GIS as "a network-centric GIS tool that uses the Internet as primary means of providing access to distributed data and other information, disseminating spatial information, and conducting GIS analysis." Peng (1999, 2001) has developed frameworks for assessing web-based public participation systems, addressing the following criteria: providing a user-friendly means for public exploration of, and interaction with, information; presenting users with planning alternatives and a way to analyze their consequences; enabling users to create, manipulate, and share their own alternative scenarios; and a forum for public discussion and recording preferences. The criteria address levels of public participation but focus mostly on user-friendliness and capability, rather than validity. Mention is made of data standards, though it is not clear how they would be imposed or met by lay-providers of information. Wherrett (1999) identifies several possible validity issues raised by obtaining responses to landscape imagery over the Internet, including display characteristics (such as resolution and screen size), respondent representativeness, and respondent honesty (discussed later).

Table 1
Criteria for evaluating participatory GIS

Ultimate performance goals	Disseminating more information Expanding the number of stakeholders involved in planning Improving articulation and consideration of stakeholder's views Improving collaboration and linkages between parties Improving shared understanding of analyses/data Enabling greater exploration of ideas Capacity building Improving transparency of social processes/decisions Moving towards consensus Better policy-making Social change
Evaluation indicators for technology and data	Appropriateness to issues and relevance to stakeholders/users Accuracy (actual and perceived) Access/availability and ownership Representation Usability

Adapted from Sieber (2006) and Barndt (2002).

The other discipline which pertains strongly to environmental visualisation in a public interest context is the study of landscape visualisation or visual simulation as it used to be called (Appleyard, 1977; Sheppard, 1989; Bishop and Lange, 2005a). There is a significant (though incomplete) body of work here to draw upon, from the planning professions mostly, with some substantive research conducted over the years. Landscape visualisations "attempt to represent actual places and on-the-ground conditions in three-dimensional (3D) perspective views, with varying degrees of realism" (Sheppard and Salter, 2004, p. 487). Appleyard (1977) refers to these as the experiential type of visualisation, with much less abstraction than conceptual visualisations; Zube et al. (1987), citing McKechnie (1977), refer to them as 'perceptual' simulations. These experiential visualisations have historically been used mainly in the fields of urban planning and landscape assessment, to help judge design options or project proposals.

The two categories of conceptual and experiential visualisation are not mutually exclusive, since a range of visualisations exist in a continuum between the extremes of abstraction and realism. Sheppard (1989) has identified three main dimensions by which to evaluate visualisations: understanding, credibility, and fairness (lack of bias) in representing actual or expected conditions. Sheppard (2005a) provides specific criteria for evaluating experiential landscape visualisation explicitly, considering their impact on viewers' responses and incorporating many key concepts provided by Appleyard (1977), McQuillan (1998), Sheppard (1989, 2001), Orland (1992), and Orland et al. (2001), among others. Table 2 presents seven criteria for evaluating landscape visualisation as used in virtual globes, drawing on these sources.

Much of the theory on how people use cartography, GIS and conceptual visualisations refers primarily to cognition of scientific information, often with a focus on expert analysis which is less constrained by highly technical information or symbology (MacEachren, 2004). Landscape visualisation, however, is designed to permit both cognition and judgments of perceived experiential qualities, based in part on affective reactions in observers (Sheppard, 1989). MacEachren's criteria are descriptive, while Sheppard's criteria are explicitly evaluative (more of a dimension is good). While both of these frameworks can be applied to virtual globes, they are designed for somewhat different purposes. The latter framework is used for more in-depth analysis in this paper, given the degree of realism provided by programs such as Google Earth, the focus here on use by lay-people as well as experts, and the broader more evaluative criteria developed to address experiential and affective issues in landscape visualisation. Seiber's (2006) criteria in Table 1 which relate to validity are also addressed in more depth in the landscape visualisation principles.

A third and allied field, addressing human–computer interfaces (HCIs) and virtual reality (Sherman and Judkins, 1992), is also relevant, though often less concerned with broader validity issues in terms of larger environmental contexts; for example, Bishop and Lange (2005b) provide a synthesis of six significant features of virtual reality (immersion, interaction, intensity (apparent realism),

Table 2
Criteria for evaluating landscape visualisation

Accuracy	Visualisations should simulate the actual or expected appearance of the landscape (at least for those landscape factors being judged), without distortion and at an appropriate level of abstraction/realism for the intended purpose.
Representativeness	Visualisations should represent typical or important views/conditions of the landscape.
Visual clarity	The details, components, and overall content of the visualisation should be clearly communicated
Interest	Visualisations should engage and hold the interest of the audience.
Legitimacy	Visualisations should be defensible and their level of accuracy demonstrable.
Access to visual information	Visualisations should be readily accessible to the public via a variety of formats and communication channels.
Framing and presentation	Important contextual and other relevant information (such as labeling, narration, mapping, etc.) should be presented in a clear, neutral fashion, along with the visualisation imagery.

Adapted from Sheppard (2005a).

intelligence, illustration, and intuition), but none of these directly address validity. The cognitive focus of scientific visualisation is reflected in much of the work on HCIs applied to educational psychology (e.g. Winn et al., 2006), where there is considerable emphasis on evaluating a sense of 'presence' through immersive displays as an engagement, and ultimately, a learning device. While such studies and more numerous usability studies on new technologies have demonstrated high levels of engagement and cognition with non-experts, relatively few have addressed affective dimensions relevant to environmental and community decision-making. It is beyond the scope of this paper to integrate a systematic review of this field, desirable though that may be.

3. The benefits of virtual globe systems

The evident and potential benefits of virtual globe systems have been widely noted. An editorial in that most august of scientific journals, "Nature", describes the "ability to model the earth in exquisite three-dimensional detail" and exults that "Millions of people across the world are zooming in from space, flying across continents, and swooping over mountains and through cities, thanks to Google Earth, NASA's World Wind, and other free virtual globes…" (Nature, 2006). As described in Nature (2006), scientists and environmental professionals from many fields not formerly noted for their expertise in 3D rendering are beginning routinely to use such techniques in their work. In the same issue, Michael Goodchild commented that Google Earth represents the realization of former Vice-President Al Gore's vision of a "Digital Earth", where the earth was seen as an organizing metaphor for digital information (Butler, 2006). Virtual globes may also lead to what Goodchild called the "Second Age of Geographic Discovery", prompted by an "immersive environment providing access to the planet at any level of detail, and to invisible as well as visible information." (Goodchild, 1998).

Clearly there are advantages to scientists and other experts in communicating science via these new engaging platforms and making their findings more relevant to people's own experience. Potentially, any such expert messages may be seen and understood by many more people than is currently the norm. Some of the benefits to scientists in enhancing awareness-building are illustrated in the example in Fig. 2, showing the melting of a glacier over time in photographs and a corresponding Google Earth visualisation (Paz, 2006a). Since many glaciers are not easily accessible to the public, the significance of this glacier melting "in full view of

Fig. 2. Chrono-sequence of photographs of a glacier melting, taken from the same viewpoint and replicated in a Google Earth visualisation: reproduced from the web-page "Glaciers and Glacial Warming, Receding Glaciers" (Paz, 2006a). Image created using Google Earth Pro, Glacier Melting© (2006) http://bbs.keyhole.com/ubb/showthreaded.php?Cat=0&Board=EarthNature&Number=289260&fpart=1&PHPSESSID=; http://www.worldviewofglobalwarming.org/pages/glaciers.html.

residents, tourists, and scientists" is emphasized, though the photo-pairs are much clearer than the Google Earth visualisation. In this case, the Google Earth visualisation serves more to lead viewers to compelling information about global warming than to add value via its own imagery. In more participatory applications of virtual globes, experts can benefit from the feedback readily enabled by online chat-lines and preference surveys (Wherrett, 1999).

Other possible benefits to scientists and other experts using such techniques, include increased impact on target communities, enhanced collaboration with other expert users (MacEachren, 2000), increased publicity and recognition, and improved fund-raising for research (Sieber, 2006). The International Society for Digital Earth (ISDE, 2006) cites among its major activities: "Raising awareness and influencing policy decisions by means of media and other communication technologies."

For members of the lay-public, the appeal of virtual globes seems to lie in the realism, the sensation of flying towards or over the earth, the ability to view their own homes or other meaningful locations, and the sense of their own control over the medium and data: through navigation, manipulation of visible data, and even adding their own data for viewing by others (see below). The allure of realism is captured in Google's own advertising (Google Corporation, 2006) for Release 4:

> Seeing buildings in 3D is one of the coolest things about Google Earth. And with this release, this feature is even better. For the first time, we support "textured" 3D buildings, meaning the bricks look like real bricks, the glass like real glass, and overall, the world looks more like, well, the real world.

Benefits to individual viewers or browsers would therefore include: satisfaction and enjoyment of the experience; ease of use; free, convenient, and rapid access to massive amounts of previously proprietary information; the ability to put information into perspective (literally); and improving their grasp of spatial, reference, or scientific information by contextualizing it in the user's local, real world conditions. As with other forms of web-based participatory GIS, there may also be larger benefits to society through sharing of data via an open and accessible platform to a wider audience, the possibility of earlier participation in planning processes (Peng, 2001), possibilities for online feedback and dialogue, and increasing transparency on environmental issues by allowing multiple views of the world to be expressed (again, literally) (Peng, 2001; Sieber, 2006). Quoting Goodchild on the democratization of GIS, Butler (2006) sees the virtual globe as facilitating the communication of spatial information between stakeholders and the government, noting that "environmental groups that have discovered GIS are starting to use it to change the balance of power in public debates". An example of stakeholders without computer expertise making effective use of Google Earth in addressing environmental concerns (Dicum, 2006) is shown in Box 1.

> Box 1. Example of the use of virtual globe products to resolve a potentially contentious issue on water withdrawals from Napa Creek in California (http://www.sfgate.com/cgi-bin/article.cgi?file=/g/a/2006/01/11/gree.DTL&type=tech).
>
> But it's perhaps even more impressive that people without Moore's programming skills can use these same tools to get dramatic results of their own.
>
> John Stephens is one of them. A retired plumber in Napa, Stephens is dedicated to the preservation of the remaining forestlands and watersheds in his county. ''We're alarmed over the loss of native habitat and forest for farming,'' he says.
>
> So when a local landowner applied for a permit last year to withdraw water from a Napa creek, Stephens went to the State Water Resources Control Board. ''We were concerned about insufficient flows of the creek,'' he says.
>
> The meeting took place just a week after the release of Google Earth. Stephens downloaded the program as soon as he heard about it, and immediately saw how useful it could be. He printed out a series of screen shots of the watershed and taped them together. ''It was about three or four feet long,'' he says. ''We rolled it out on the table very dramatically.''
>
> Because of the map, Stephens was able to ask detailed questions of the hydrologist the landowner had hired. ''I asked exactly where the location of the withdrawal was going to take place,'' says Stephens. ''He pointed to a location and I said, 'Oh, right above that is about 300 feet of bare stream bank. Somebody must have cleared that area. Are you willing to re-establish vegetative cover there?'''
>
> ''Well, everybody's sitting around that room,'' continues Stephens. ''Fish and Game is there. The Water Board is there. We're there, and the owner says, 'Well, yeah, I could re-vegetate the area.'''
>
> Stephens says that because the visuals make the abstract obvious, the result was positive for everyone. The stream was re-vegetated, the landowner got the water he needed and the whole thing happened quickly, without the litigation and endless hearings that are so common in land-use disputes.
>
> ''Google Earth is great because you can get a feeling of the valleys and the slope of the hills,'' says Stephens. ''You can go up a creek bed like you're flying. It's very dramatic. People cannot hide anymore…''.
>
> http://www.sfgate.com/cgi-bin/article.cgi?file=/g/a/2006/01/11/gree.DTL&type=tech.

The ability for anyone to add information to the shared database represents both an individual and potentially a shared benefit. While the bulk of place-marks and data-files posted on the "Google Earth Community" relate to places of personal, cultural, or scenic interest, some potentially useful environmental information is emerging from local users; for example, the "Collection of Ecology Posts" lists 47 place-marks or data-files related to global warming, protected areas, wildlife, and toxic sites (Paz, 2006b). Google Corporation (n.d.) obviously seeks to encourage additions to the collective information set through the provision of new data creation tools such as SketchUp:

> It's just one more step on the path of creating a life-like 3D model of the whole planet. There's just one catch – there aren't many photorealistic 3D building models out there. Yet. That's where Google SketchUp comes in. With Google SketchUp, you can now create your own textured 3D models.

In terms of the landscape visualisation evaluation framework described above, the principal benefits expected to result from virtual globe usage include access to visual information, user engagement, and representativeness of viewing situations (see details in Table 3).

Also, virtual globes can provide clarity on important spatial relationships, within the limits of data resolution. Given the detail of the relatively high-resolution orthophotography available in some areas, one might expect accuracy of existing condition visualisations to be an advantage, depending on how up-to-date the imagery is (but see below); texture mapping of 3D forms using ground-based photography should also improve realism (Sheppard, 1989).

Table 3
Key benefits of using virtual globes to provide landscape visualisations

Access to visual information	Open free access for all Internet users with high-speed connections and reasonably up-to-date computers, providing relatively equitable access to information within the "developed" world (especially across remote areas or scattered users), though probably concentrated more on those who are younger, more affluent, with more formal education, and higher levels of computer literacy (Peng, 2001; Wherrett, 1999).
Interest	More meaningful and enjoyable engagement in viewing or manipulating information, plus increased interest with viewing familiar locations. This is consistent with increased engagement observed with other kinds of landscape visualisation (e.g. Al-Kodmany, 2002; Lewis and Sheppard, 2006).
Representativeness	Freedom to view places or features from any angle or height, and from any number of views (except absolute ground-based as the lowest viewing height is often about 20 m), instead of the more conventional limited selection of static views determined by the creator of the visualisations. This is consistent with theorized benefits for representativeness in interactive landscape visualisations (e.g. Bishop et al., 2001; Sheppard, 2005a).

Possible implications of these benefits include:

- Improved understanding of local area attributes (e.g. relative scale, distances, orientation, and, where temporal sequences are available, types and rates of landscape change). Experimental and community-based research has demonstrated that this type of holistic information can enhance cognition as compared with conventional GIS maps (Duerden and Johnson, 1993; Lewis and Sheppard, 2006).
- Improved credibility of the visualisations to lay-users through freedom to explore the information.
- Possibly more accurate and honest work by project proponents where they are pressured to use more sophisticated media and data, and to place their project into a realistic 3D site context, rather than 'hiding' behind a selective artist's rendering or detached computer model (see Box 1).

It is also possible that virtual globes may foster closer identification or empathy with distant groups or societies because equal access to their home conditions has now been granted. Will the ability to "see" other places lead to a cultural paradigm shift like that which arose with the first view of the whole earth from space, further shrinking the world? Conversely, will the novelty of virtual globes dissipate soon after people have used them a few times, leading primarily to a mundane and utilitarian role?

4. Possible risks in using virtual globe systems

Is the enthusiasm for virtual globe software held by users and the editors of Nature fully justified? Acknowledgement of the appeal and likely benefits of the system is no reason to accept its use without constraint or critical thinking about its side-effects. Any powerful new technology has the potential for misuse, and with universally accessible systems, there is much greater potential for errors to be rapidly magnified or persuasion to have major global consequences. What disadvantages might there be that deserve serious consideration? This section addresses conceptual problems drawn from the frameworks discussed above, supporting results from evaluation research, early actual examples of virtual globe use, and precedents from allied technologies, for both scientific/expert users and lay-users. It also considers the special problems associated with projecting future conditions in this medium.

The field of computer visualisation is largely technology-driven; technological improvements such as virtual globe software are often interpreted to mean faster, 'higher-tech', more realistic, more user-friendly, and more widely accessible. However, these traits often relate more to efficiency, convenience, image, entertainment value, popular demand, profit, and persuasion, than to ultimately more important factors when protecting the public interest and invoking science: truth, deeper understanding, improved civil discourse, safer and more informed decisions, and other ethical considerations. Achievement of these social objectives may or may not be correlated with technological performance. In the realm of science, these issues are usually addressed via the concepts of validity and reliability. In our context, validity generally refers to whether an instrument, process, or outcome is sound, defensible, and well-grounded or appropriate to the issue in question; are we measuring or representing what we think we are? (Sheppard, 2005a). With visualisations, for example, if the intent is to predict the attractiveness of a design, it is important that responses to the visualised design are similar to those obtained from the actual design once built (i.e. bias-free); this has been termed "response equivalence" (Craik et al., 1980) or "representational validity" (Daniel and Meitner, 2001). Reliability refers to consistency in repeated applications: "the degree to which an instrument…can retrieve the same answers when applied under similar conditions" (Weller and Romney, 1988, p. 70). For example, if the same software and project data are used by different operators and lead to very different visualisations and responses, this would be considered initially a problem of reliability. Both these concepts are central to the ethical use of landscape visualisations being prepared by diverse users.

Pragmatically, there are a number of dimensions of landscape visualisation (and by extension, virtual globes) which relate to problems with validity and reliability. Realism has been defined in terms of actual realism – response equivalence or lack of bias in responses between simulated and real environments, as described above; and apparent realism – the degree to which the simulation appears to look like the real world when judged on the basis of the image alone (Sheppard, 1989; Lange, 2001). It has often been pointed out that apparent realism is not a safe guide to accuracy or response equivalence of visualisations (Sheppard, 1989; Orland et al., 2001), though visualisation research often seems to focus on it. The seven evaluation criteria for landscape visualisation outlined in Table 2, if met, are intended to minimize threats to validity.

The Nature (2006) editorial on virtual globes notes: "The production of visually appealing, even statistically sound, results that do not reveal anything useful about either pattern or process is perhaps the greatest danger facing newcomers to this powerful technology." However, it is not simply a question of learning to use spatial data or thinking spatially, and therefore not an issue lying wholly within the discipline of geographic information science. The Google Earth type of visualisation crosses several key thresholds in communicating scientific and environmental information, that take it well beyond conventional spatial data. The works of Monmonier (1996) and Tufte (1990) have shown that even cartographic and other 2D/3D diagrammatic information can distort meanings and interpretations. The leap to 3D landscape information, combined with the use of 'realistic' levels of detail and the free choice of the user to select the viewed location, raises still more troubling questions; it transforms what was map data into recognizable local perspective views which are not only more meaningful to many people, but also inevitably more value-laden. We quickly enter the realm of perception and emotional reactions.

Virtual globes take us beyond mere cognition, into an experiential world where we can expect other kinds of response: affective, evaluative, physiological, and potentially behavioural (Zube et al., 1982; Sheppard, 2005b). This is particularly likely when users of virtual globes are viewing familiar local scenes (literally their backyard), to which they are strongly attached (Bott et al., 2003). Psychologists have long argued over the primacy of affect over cognition in people's perceptions (Zajonc, 1984). Thus, in addition to concerns over whether virtual globe imagery is cognitively ineffective or even cognitively misleading (i.e. invalid), there is also the chance that emotional meanings (valid or invalid) may overwhelm valid cognitive responses. For example, many landscape visualisation programs that begin with spatial data infuse additional pictorial information (such as blue skies or building facades) which are not necessarily data-driven, representative, or accurate, in order to create an 'appealing' landscape view.

Some of the potential problems posed by virtual globes are not new, and have been addressed in research and practice in landscape visualisation, itself drawing on other fields such as landscape aesthetics, environmental psychology, sense of place, and the design arts. At the same time, there is still much debate (and inadequate research) on several key issues for landscape visualisation validity (Sheppard, 2001, 2005a). For instance, there is a general belief that the greater the realism, the more similar responses will be to real life (e.g. Bishop and Rohrmann, 2003); there are, however, widespread concerns that highly realistic visualisation can incur greater risk of bias (e.g. MacEachren, 2001; Orland et al., 2001) whether deliberate or not, since it can become harder to remain aware of limitations or uncertainties in the underlying data.

4.1. The risks of scientists and experts using virtual globes

This section addresses the risks of using virtual globe visualisations that are created by experts; these may be used by the experts themselves for analysis or dissemination, by other experts, or by interested lay-people. Computer-based landscape visualisation may be preferred as graphics regardless of scientific content, and can imply greater accuracy or legitimacy than is warranted (Luymes, 2001; Peng, 2001). The medium can thus become the message. Orland et al. (2001) have voiced concern over the sought-after intimacy or 'presence' of virtual reality techniques, which break down the detachment usually associated with professional media such as static visualisations. Web applications, which are less mediated by the scientific or expert presenter, may further add to the risk of misinterpretation. Powerful persuasive media effects may even be justified by some on the grounds that the underlying 'hard' scientific data remains unchanged; anyone who watched on CNN the continuously running, red-coloured animation of the approach of Hurricane Katrina to New Orleans in 2005 can understand the impact that framing and display format (over and above data content) can have on the viewer (see Table 2). There is also the risk of non-deliberate errors by experts, or simply assertions of errors or bias from the audience that cannot be refuted, being enough to damage reputations; this is compounded by the general lack of training and the approach of trial and error (not usual condoned in other scientific endeavours): "Scientists are already *experimenting* with these tools to showcase their research to the public in *visually appealing ways*..." (Nature, 2006; authors' emphasis added). While science is traditionally associated with skepticism about surface appearances, there is the danger that the enthusiasm and hyperbole surrounding virtual globes may overwhelm common-sense rules and precautions in using visual imagery.

Actual problems found with recent scientific or expert use of visual globes, or even with other kinds of landscape visualisations, have been only sporadically documented (Sheppard, 2005a). While it is beyond the scope of this paper to conduct a systematic review of virtual globe examples, Table 4 documents a number of relevant examples of applications found through a quick search (including those shown in the figures), as a precedent for a more comprehensive survey of practice. It addresses both expert and lay-user material, with an initial indication of possible problems relevant to the evaluation criteria laid out above.

One of the more common problems with virtual globes is the low data resolution in low-elevation or on-the ground visualisations (see Fig. 2), affecting clarity, accuracy, and perceived realism (Appleton and Lovett, 2003). The Internet raises technical issues such as mismatch of screen size and image resolution (Wherrett, 1999). Where 3D data is available for buildings in cities, there can be unsettling mis-matches (inaccuracies) between 3D forms and draped satellite or orthophotographic imagery (Fig. 3), although Salter et al. (2009) found semi-realistic visualisations of buildings in 3D to be effective with community members in addressing some broader planning issues. Figs. 4 and 5 provide examples of expert-created future visualisations, illustrating some common problems of labeling with minimal scientific data and uncertainty information to guide the viewer (Fig. 4), and visualisations which lack important 3D context such as vegetation, other existing buildings, and ground level views (Fig. 5).

Table 4
A classification of virtual globe examples from Google Earth, and related validity issues

User Type	Condition shown	Example	Viewing Context	Potential issues[a]
Expert providers	Existing/historic	Glaciers melting (Fig. 2)	Web-site	Low resolution visualisation lacks clarity, compared with high-resolution photography.
		3D city buildings (Fig. 3)	Web-site	Discrepancies between the base photography and 3D models in this urban example may lead to distraction or confusion.
		Greenland (Fig. 9)	Web-site	Photographs demonstrate fairly high level of realism and accuracy.
		UNEP Landscape Change	Web-site	Photographic and remote sensing base provides good scientific credibility
	Future	Sierra Club sea-level rise (Fig. 4)	Web-site	Limited framing data, high level aerial view precludes accurate interpretation of local effects.
		AIA Colorado Springs Design Charrette (Fig. 5)	Public process	Good orientation, but lack of context (trees, other 3D buildings) in some views. Labeling, animation, and music may limit objective responses; few ground level views.
Lay-providers	Existing/historic	Napa Creek water withdrawals (Box 1)	Public process	See Box 1.
		Queen Charlottes logging (Fig. 7)	Web-site	Titling is partisan, limited scientific data provided to support images.
		Appalachian Mountain top removal	Web-site	Photographic and remote sensing base provides good scientific credibility, though some framing is emotive and non-neutral.
	Future	Los Gatos Creek logging (Box 2)	Public process	See Box 2.

[a] Such as accuracy, representativeness, clarity, legitimacy, access, framing/labelling, etc.

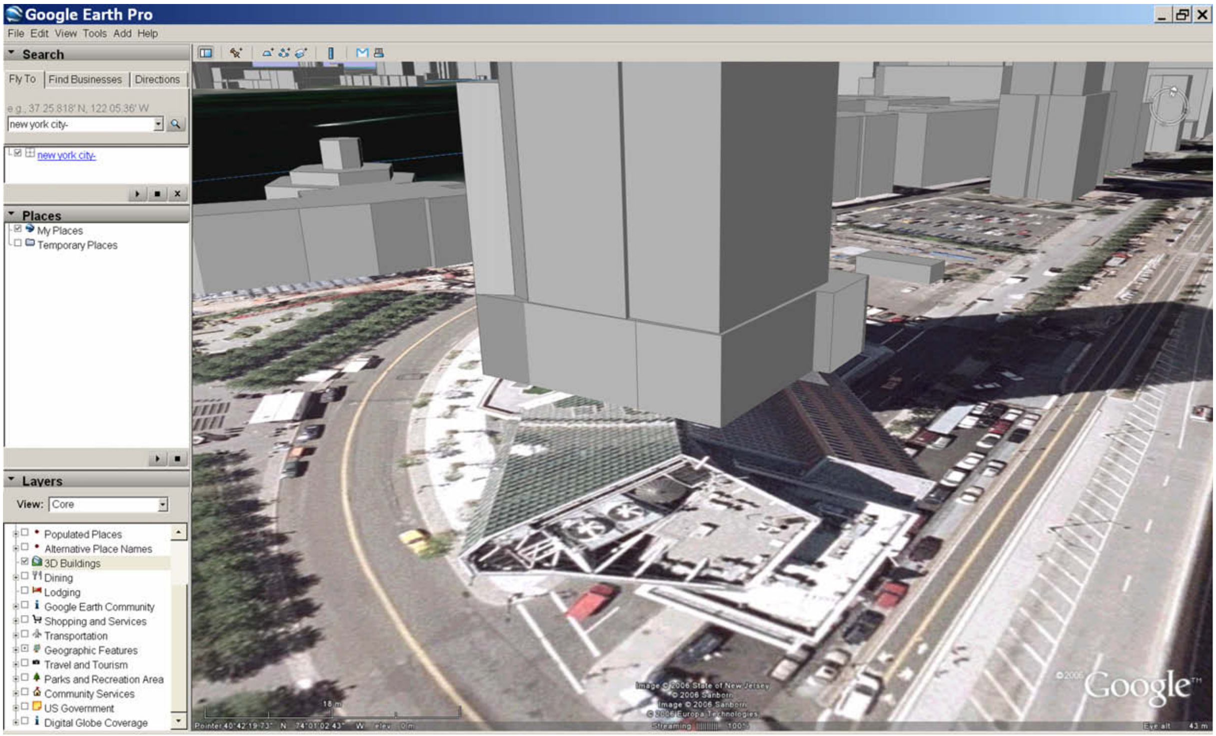


Fig. 3. Close-up of 3D objects in urban setting, showing inaccuracies in matching textures and forms. Image created using Google Earth Pro. Example of 3D Distortion in Matching© (2006).

There are some older documented examples in practice of visualisation inaccuracy, unrepresentativeness, poor clarity, low credibility, and biased responses (e.g. Appleyard, 1977; Sheppard, 1989; Oh, 1994). Examples of dueling databases (Sieber, 2006) and even ‘dueling visualisations’ sometimes occur, as in competing expert visualisations of strip-mining at the Alton Coal field in Utah (Sheppard and Tetherow, 1983). Professional visualisations have on occasion been publicly discredited, as in the incident of the photo-retouched imagery of the Beirut bombing used then rejected by Reuters in 2006 (Associated Press, 2006).

4.2. The risks of lay-members of the public using virtual globes

This section addresses risks primarily from visualisations created by lay-people as visualisation providers. On the one hand, these risks may be seen as less dangerous because such users, if identified as such, carry less authority (Luymes, 2001). However, when such ‘unofficial’ graphics find their way into the public discourse or decision-making (Appleyard, 1977), they can raise difficult issues for society, such as “who has a legitimate voice?” (Sieber, 2006), “whose visualisation is right?” and “which

Fig. 4. Highly publicized aerial visualisations of a far-future flooding scenario in the Lower Mainland of BC under unrestrained climate change, provided with minimal scientific framing or uncertainty information. Source: Sierra Club of British Columbia.

Fig. 5. Typical 3D visualisations of projected development in Colorado Springs affecting the city skyline, with limited 3D contextual information for judging impacts on city character. Image courtesy AIA Colorado South (2006).

visualisations have more legitimacy?'' (see Hansen, 2005, and Fig. 6). According to Google Earth (n.d.): ''With Google SketchUp, you can now create your own textured 3D models,'' which can be stored in an online 'warehouse' and made available to others. The risk of non-experts creating models that are not accurate or verified but become integrated into larger models shared by others, presents serious issues of propagation of error, and possibly even questions of liability.

Fig. 6. 'Before' (photograph) and 'after' visualisation created by a member of the public contesting official information on a proposed highway project at Eagle Ridge Bluffs, BC. Source: Hansen (2005). Reprinted courtesy of CanWest Mediaworks.

The impact of labeling and information context on the legitimacy of visualisation can be seen in the example of the ''Native Forest Council Google Earth Portal,'' maintained by a non-profit organization whose stated mission is to preserve public land. Fig. 7 shows one of many pictures of actual timber harvesting operations, entitled ''Disastrous Logging on Queen Charlotte Islands, BC'' (Native Forest Council, 2005). The titling may provoke emotional reactions among viewers, though the overall credibility of the presentation may be low, since no further information about the logging or the imagery is provided.

The risk of misinformation or biased responses with virtual globes would seem to increase with data creation by those outside of scientific or professional organizations which are bound by their own general codes of practice. Factors contributing to this risk include lack of training or standards, and inadequate metadata providing transparency to others. Untrained users may fail to perceive the limits of the data they are using or creating, and even if the data are correct, visualisations may not be presented correctly. Even the question of who is a visualisation expert is a matter of debate, since there are no recognized training standards; technically adept computer wizards may in fact have little knowledge of psychological effects on environmental or policy perceptions, for example. Additionally, there may be many possible (and largely unconstrained) motivations to shock, mislead or overstretch the truth in order to achieve a political or personal end. How emotions are aroused, and whether or not they are valid emotions to experience, is obviously vulnerable to manipulation by commercial, political, or ideological 'spin', in addition to mistakes or inexperience. The automobile industry, for example, now has access to highly sophisticated expertise in landscape visualisation and 'special effects' through its television advertisements designed to lure new car-buyers.

The original participatory GIS movement seems to advocate a multiplicity of voices and perspectives as the solution to bias in decision-making (Sieber, 2006) but without some agreement on common standards, confidence in the visualisation work of interest groups such as developers, industry, environmental NGOs, or even computer experts may be compromised. In addition, web access raises the concern over who responds and who dominates the online dialogue, relative to the full range of interests and stakeholders (Peng, 2001; Wherrett, 1999).

In summary, non-expert users may be expected to produce less accurate, less credible, and possibly quite biased visualisations, although this may not necessarily be apparent to other users.

4.3. Special issues of projecting future conditions

Ethical issues become more complex still when considering the issue of future conditions being presented in the virtual globe medium as a new form of 'crystal ball' (Sheppard, 2001); examples include modeling forecasts of ecosystems or land-use plans, proposed projects, alternative climate change scenarios, or even imaginary design visions. Visualising future conditions represents another major leap, since the accuracy of the environmental conditions shown cannot be verified at the time by conventional methods (e.g. checking against site photos or actual post-construction visits). Validation of future conditions requires much greater scrutiny of supporting modeling, assumptions or interpretations of land use policies, documented design proposals, etc. Issues of modeling constraints, representing multiple scales, scientific and social uncertainties (Moser, 2005), and the potential to influence decisions inappropriately, need to be very carefully evaluated.

The SketchUp website offers the opportunity for everyone to ''Dream. Design. Communicate.'' (SketchUp from Google, 2006), and Google Earth exhorts users to ''Feel Free To Change Your World''

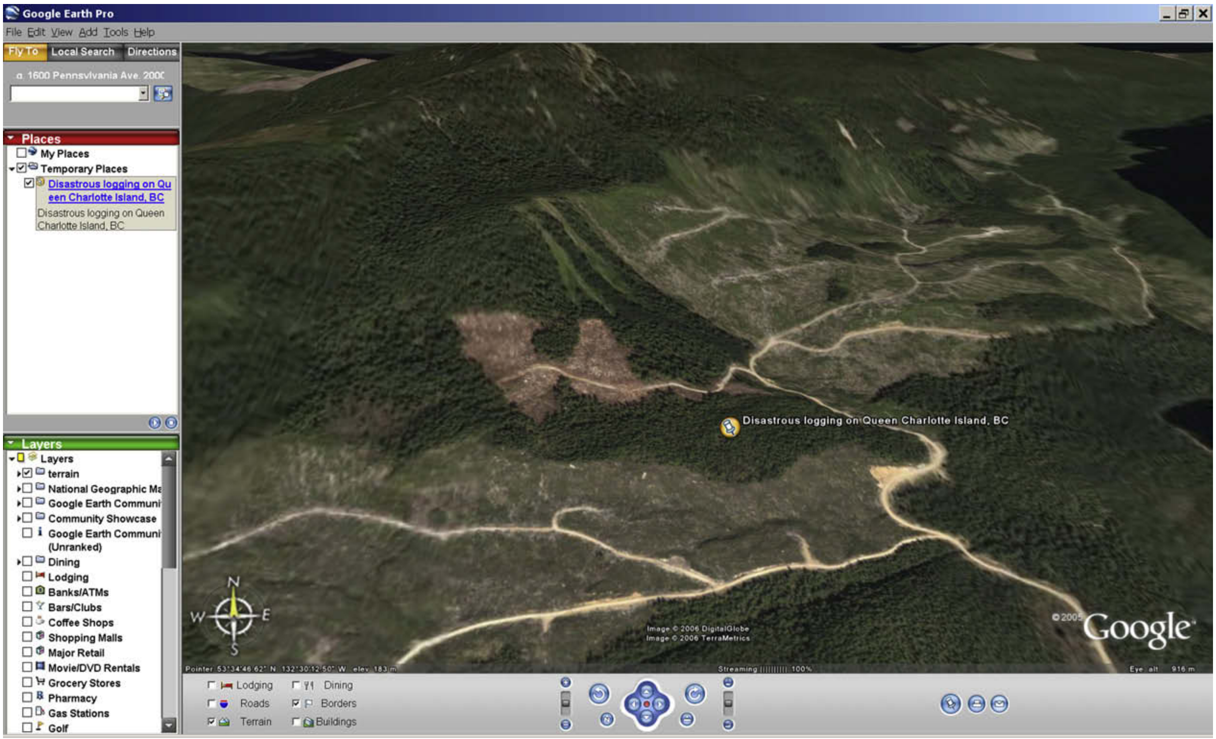


Fig. 7. Google Earth Image of logging operations on Queen Charlotte Islands, BC, labeled as "disastrous logging". Note that remote sensing imagery draped on a digital terrain model can somewhat exaggerate the visibility of forest openings in perspective views, since screening by tree heights is omitted. Image is courtesy of Google Earth Pro. Disastrous Logging© (2006) http://forestcouncil.org/googleearth/learn.html.

(Google Earth, n.d.). The creative possibilities and equity of the public no longer being constrained by the expert or designer's vision of the future is very appealing. However, the risk that 3D "dreams" unfettered by reality or regulations may become indistinguishable from accurate 3D objects based on survey data or careful design/visualisation processes, pose serious questions for those seeking to use such information. One can imagine, for example, misapplications such as the unwitting use of tree species or building designs from the 3D model warehouse that are not viable in other places or climates, i.e. lack ecological validity (Palmer et al., 1999).

At the same time, it is important to recognize that there are different levels of certainty and design detail for specific future man-made conditions depending on the stage in the design or decision-making process. There is a widely held view among professionals that early, more conceptual designs for proposed buildings, for example, should be rendered less definitively than more concrete detailed designs closer to implementation on the ground. Evaluation experiments by Appleton and Lovett (2003) and Salter et al. (2009) provide some evidence that certain types of semi-realistic visualisation may be adequate to make viewers comfortable in using them, and in some cases may even be preferable when addressing large scale broader planning issues, relative to highly detailed models which show design details irrelevant to these issues.

An example of some of the issues which can arise with virtual globe visualisation of future land development proposals is provided in Box 2, which shows excerpts from web-pages documenting a citizens organization's interaction with a logging proposal for Los Gatos Creek (Moore, 2005) in California. Overall, the Los Gatos Logging visualisations present a compelling and effective presentation that uses various tools available in the Google Earth software, including animation and pop-up balloons to access on-the-ground photographs. However, there is a possibility that the logging area polygon shown in red may have been interpreted by some viewers to mean that the whole area would be clear-cut, when the logging proposal was for selection harvesting within the coloured area. This level of abstraction and symbology could have influenced the responses observed and therefore its validity, though providing much clearer spatial orientation than the original information provided to the community by the logging proponents (Moore, 2005).

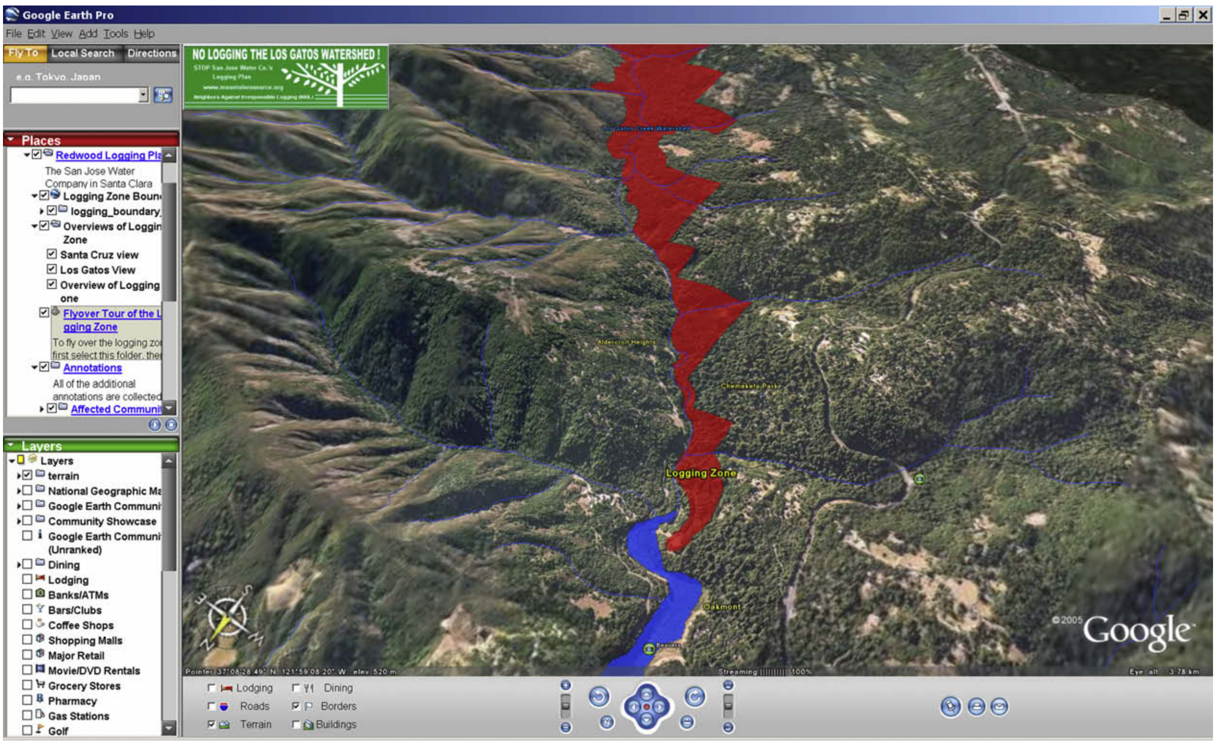
Greater risks may well lie less in the accuracy of data than in the process and framing by which the visualisations are disseminated and mediated with other viewers, especially with forecast or future projections. Lewis (2006) has demonstrated major swings in opinion with different stakeholder groups using visualisations of certain future landscape management scenarios in Northern BC, before and after he explained what the visualisations actually depicted. The limitations or uncertainty contained within underlying models of visualised future scenarios, for example, may be completely ignored when not tied to the presentation or conveyed directly by the visualisation-creator. The effect of collapsing time with future visualisations, and thus the potential to inform or shock the viewer with simple 'build-out' scenarios of official plans (Sheppard, 2005b), deserves to be better understood. It raises the question: is there an 'official future' effectively already agreed to which can be visualised, or are there alternative interpretations of the official plans which deserve to be shown and debated, in addition to alternative policy/planning scenarios. The potential for bias in such presentations to favour a particular option is clear.

5. Possible solutions for protecting the ethics of virtual globes

How can we keep the obvious benefits of virtual globes while avoiding or minimizing harmful effects or mis-use? Two main conceptual approaches to providing safeguards or limits on threats to visualisation quality have been defined (Sheppard, 2005a): (1) more prescriptive approaches which guide or drive the

Box 2. Google Earth visualisations and reactions to them from members of a citizens organization concerned with a logging proposal in California. Image created using Google Earth. Data © (2005), reprinted with permission from Rebecca Moore, Mountain Resource Group.

An animated visualisation of a logging proposal for Los Gatos Creek was created by Rebecca Moore, a member of the ''Mountain Resources Group'' citizens organization and a programmer with the Google Corporation, and presented at a community meeting of over 300 citizens in September, 2005 (Moore, 2005).



''At a public presentation of more than 300 residents, Moore ''flew'' in from outer space to the Santa Cruz Mountains, then turned on the swath of red that represented the proposed logging. 'There was a gasp from the audience,' she recalls. 'It electrified the room.''' (Dicum, 2006).

The flyover movie was also featured in a local San Francisco CBS television broadcast on March 20, 2006:

''A Google Earth virtual fly-over along a 5-mile length of Los Gatos Creek – between Lexington Reservoir and Lake Elsman in the Santa Cruz Mountains – shows the 1000 acres of land the San Jose Water Company wants to log. The map was created by software engineer Rebecca Moore, who lives in the area, and it's being used to galvanize opposition to the company's plans.'' (Russomanno, 2006).

The following feedback indicates that this technology is accessible to novice computer users (Moore, 2005).

I want to tell you that I find your Google presentation of the logging issue awesomely clever and helpful to an understanding the SJWW/Big Creek proposal (expected proposal?). I was stunned by your presentation at the meeting last Sunday, and am much appreciative of your making it available online. As I am only fair in computer competence, it took some attention to get the online version to work, but it works just great and I have used it many times. Each time I have used it, I discover new features and tricks. I hope everybody interested in this matter will avail themselves of your Google work the better to understand the extremely serious issues raised by this logging proposal.

presentation of visualisation material according to shared principles or standards; and (2) more flexible and interactive approaches which give much greater control over visualisation information to the user/viewer. The latter would give the viewer (or reviewers) much more choice and control over what they see, and freedom to roam within the visualisation dataset; any stage in the preparation of visualisation models might be viewed, and visualisations could even be replicated by the reviewer to assess their reliability directly (Sheppard, 2005a). Both approaches provide greater access to and transparency of visual imagery and underlying metadata than is normal with current tools, though in different ways and to differing degrees. A number of possible solutions to enhance visualisation validity and reliability, using one or both of these approaches, are briefly outlined below.

5.1. Software and system design

Virtual globes come close to assuring their own credibility to users by allowing "the user/viewer to manipulate the landscape model itself, re-rendering the landscape or project conditions in real-time as well as choosing their own view path, viewing conditions, or time frames" (Sheppard, 2005a, pp. 94–95). The use of georegistration with standardized map bases, and transparent scaling/measurement tools in programs such as Sketchup (SketchUp from Google, 2006), make some accuracy problems (e.g. 2D placement, existing 3D objects) much less of a concern, especially with the advent of highly accurate 3D LiDAR datasets.

The standard ortho-photo or satellite image base of virtual globes also forces the designer of new object to look at them in the surrounding landscape context. These advances effectively narrow the freedoms of the user to distort reality by accident or design. The option of choosing more sketchy rendering styles to imply uncertainty in the final design outcome, as offered by SketchUp (see Fig. 8), also seems helpful if used at the right stage of planning or design (SketchUp from Google, 2006). Further improvements could be made through provision of standard 3D visualisation templates or 'wizards' that lead the more complex construction and viewing of 3D buildings and landscape for a given level of desired realism.

5.2. Codes and guidelines

Best practices or codes of ethics for preparation of visualisations would be helpful in providing agreed guidelines for various types of user, based on a synthesis of research and practice (see for example an Interim Code of Ethics in Sheppard, 2001, 2005a). For professionals there are adopted visualisation rules in practice in some jurisdictions, such as the City of San Francisco, the California Energy Commission, and the Tahoe Regional Planning Agency (Sheppard, 1989). Such precedents mostly constitute narrower applications to urban design project approval, land use planning, and environmental/visual impact assessment, and pre-date the more advanced technology of virtual globes. Therefore, some adaptation is likely to be needed in addressing broader applications such as public/policy debate over alternative futures, scientific visualisation for awareness building on key environmental issues, and creation of 3D and 4D visualisations by lay-users. A code of ethics, detailed protocols, or presentation templates could improve the documentation and consistent delivery of completed visualisation imagery; examples might include documenting the rationale for viewing conditions selected or recommended, structuring the display of alternative levels of realism, and pointing to metadata. A broader consensus of researchers and practitioners would be desirable before finalizing any such guidelines. Table 5, culled from the literature and recent practice, presents some tips for use of landscape visualisation in virtual globes.

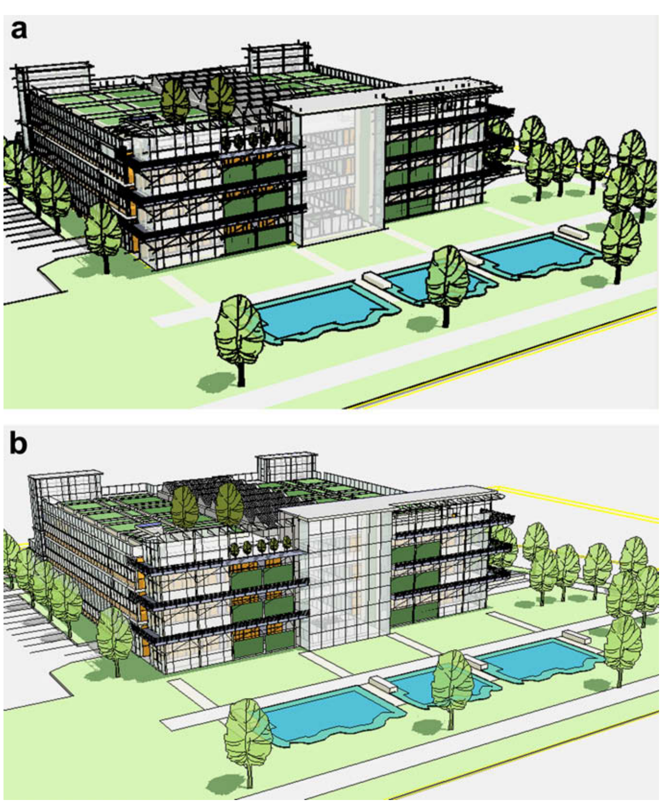


Fig. 8. Alternative rendering styles in Google Sketchup which imply differing degrees of uncertainty in design (though with identical content and data precision). Images created using Google SketchUp© (2006). (a) Less 'certain' design (with profile and extended edges turned on). (b) More 'certain' design (with only edges turned on).

Awareness and use of such guidelines for experts and lay-users could be encouraged by bundling them with the virtual globe software user guide (Google Corporation, 2006), or the license agreement. Professional bodies such as the American Society of Landscape Architects, Canadian Institute of Planners, or the International Society for Digital Earth could champion codes and protocols for landscape visualisation. Special attention should be given to the mediated use of 2D or 3D data within virtual globes as an integral part of official or public collaborative processes for decision-making (Sheppard, 2005c). Recommended processes might require stakeholder participation in the visualisation creation process, to reduce risks of biased responses or surprise when visualisations are used. For example, the Collaborative for Advanced Landscape Planning (CALP, 2006), supported by the GEOIDE National Centre of Excellence, is currently developing decision rules for visualisation as part of a future (4D) visioning process with stakeholders on local climate change awareness building (http://www.geoide.ulaval.ca/files/60_E.jpg).

5.3. Metadata and labeling

Providing key background information on 3D landscape models and visualisation material would be an important step in supporting the legitimacy of virtual globes on public interest issues. Data standards have long existed for 2D mapping databases, such as the Content Standard for Digital Geospatial Metadata (CSDGM) (Federal Geographic Data Committee, 2006), in order to assure quality and facilitate appropriate, efficient, and informed transfer of data among users. However, no such generally applicable standards exist for 3D visualisation models in the environmental or land use arenas, to the authors' knowledge. Google SketchUp provides a limited online form or template for adding model data to its warehouse (Google Earth, n.d.), which could be expanded to require certain data inputs (e.g. data source, data accuracy, texture map image sources, limitations in model applicability, professional qualifications of the creator, etc.), in order that other users may judge the risks in using the model. This may require classification of user types or application types, so as not to discourage non-professional usage with unnecessary requirements.

Equally important is the issue of attaching labels and critical information visibly to the visualisation imagery, to be sure that primary and secondary presenters (e.g. the media) and viewers of the model are forced to acknowledge key limitations or assumptions behind certain imagery; this could be in the form of embedded titles or even watermarks across, for example, hypothetical images of future scenarios, to avoid them being mistaken for actual plans.

Table 5
Some tips for ethical use of 3D landscape visualisation within virtual globe systems

Some visualisation planning considerations:

- Different users may require different visualisation approaches (know your audience).
- The same data can be visualised in many different ways: what are the important messages arising from the data?
- The same visualisation presented to the same types of people can evoke different responses, due to framing, process, accompanying data, presenter, etc.
- Choose the appropriate level of realism/symbolism for the purpose.
- What local or community issues might affect viewpoints and landscape characteristics that might influence the visualisations?
- More than one presentation mode and means of access for the affected public may be safest, to moderate any bias from particular media.
- Provide the viewer with a reasonable choice of viewing conditions (e.g. important lighting or weather conditions) and time frames appropriate to the area being visualised.
- Avoid seeking a particular response from the audience: let the visualisation and supporting data do the talking.
- Record responses to visualisations as feedback for future efforts

Some practical tips:

- Document supporting data available for or used in the visualisation process.
- During the visualisation/model building process, relate the visualisation to actual ground photos and/or site visits (don't rely exclusively on aerial views/plan view data).
- Do not use vertical exaggeration in ground level views; always confirm whether or not any exaggeration has been used.
- Never distort the aspect ratio of photographs or visualisation images: distorted images can be misleading.
- Provide more detailed foreground imagery if possible where higher levels of realism is required.
- Never 'tweak' spatial dimensions of objects (especially heights) in SketchUp unless you are deliberately modifying a dimension accurately.
- Obtain iterative review of developing visualisation material, preferably with both peers and local stakeholders, to assure credibility and avoid surprises, before final presentations.
- Provide information describing how the visualisation process was conducted.
- Disclose assumptions, level of accuracy, and uncertainties inherent in the visualisations; provide labeling or other key data as part of the visualisation if it is to be released for use by others in unmediated settings (e.g. over the web).
- Provide evidence of an appropriate level of qualifications and experience in visualisation work.

5.4. Training

Training programmes and qualifications would be helpful at various levels of user, from the beginner to the advanced communicator of scientific visualisation. Accredited education and training programmes for landscape visualisation were recommended as long ago as 1991 (Orland, 1992), but have not materialized; training programmes are scattered and tend to focus on learning the technology rather than how to use it appropriately. A clear hierarchical training programme identifying different types or levels of at least the professional or scientific user, combined with consistent metadata standards for published or shared visualisation work, would help avoid confusion or misleading responses resulting from false assumptions on the lineage of visualisations.

The engagement of human perception and aesthetic preferences via landscape visualisation requires interaction with disciplines such as environmental psychology, landscape assessment, and human–computer interfaces, to go beyond the norms and methods of the physical sciences, cartography, and even 3D modeling. There is, therefore, a considerable need for specialized training of scientific and other expert users on social science aspects of visualisation where these affect provision of public information, sound policy, and decision-making.

5.5. Review and approval mechanisms

At present, there is no comprehensive filtering mechanism for visualisation material entering virtual globe systems. If a gateway is needed, and assuming that a set of standards or code could be established (as in Section 5.2 above), who should judge? Possibilities for administering a formal programme include the software company running the virtual globe, a professional or certification organization, appointed advisory body, local government, or interested users, though the feasibility of policing an almost universally accessible gateway confounds the imagination. Assuming some recognized system of qualifications, levels of permission could be set for given models, providing different kinds of access to users depending on their credentials or role. This would be crucial for scientists releasing their information into the public domain: the possibility of deliberate or instrumental bias needs to be rigorously tested prior to release, as it would in any other field of scientific endeavour; furthermore, the risk of misinterpretation or manipulation of released data in the hands of others needs to be minimized. Chenoweth (1991) raised the issue of legal status of visualisations, and the need for professional standards in order to gain legitimacy in the courts.

Some cities or other agencies responsible for a given land area already require 2D data from developers to be standardized before integrating with their own area model, and these requirement could be extended to address landscape visualisation more fully. Advanced hubs centered in regions could provide a similar service to multiple agencies and users lacking the manpower or facilities in-house (Sheppard, 2006).

5.6. Monitoring and evaluation research

There is a potential role for monitoring of actual visualisations in use, in order to evaluate quality and impact of the visualisations, and to determine the need for quality controls. This is particularly important in assessing the accuracy and validity of predictive visualisations after the construction of the proposed development project or land use plan. It could be done officially on a sampling or auditing basis by a professional body or by researchers, or it could be done by volunteers and user groups (Fig. 9). Frequent virtual earth users might develop an informal code of conduct through negative feedback and public exposure of inappropriate visualisation material, drawing on the wisdom of crowds (Surowiecki, 2004, cited by Snyder, 2006), and perhaps serving to discourage poor practice in creating visualisation. While there is often a tangible body of knowledge and opinion among users/experts on the quality of work in such areas, it is not clear that web-viewers outside this group would be aware of problems

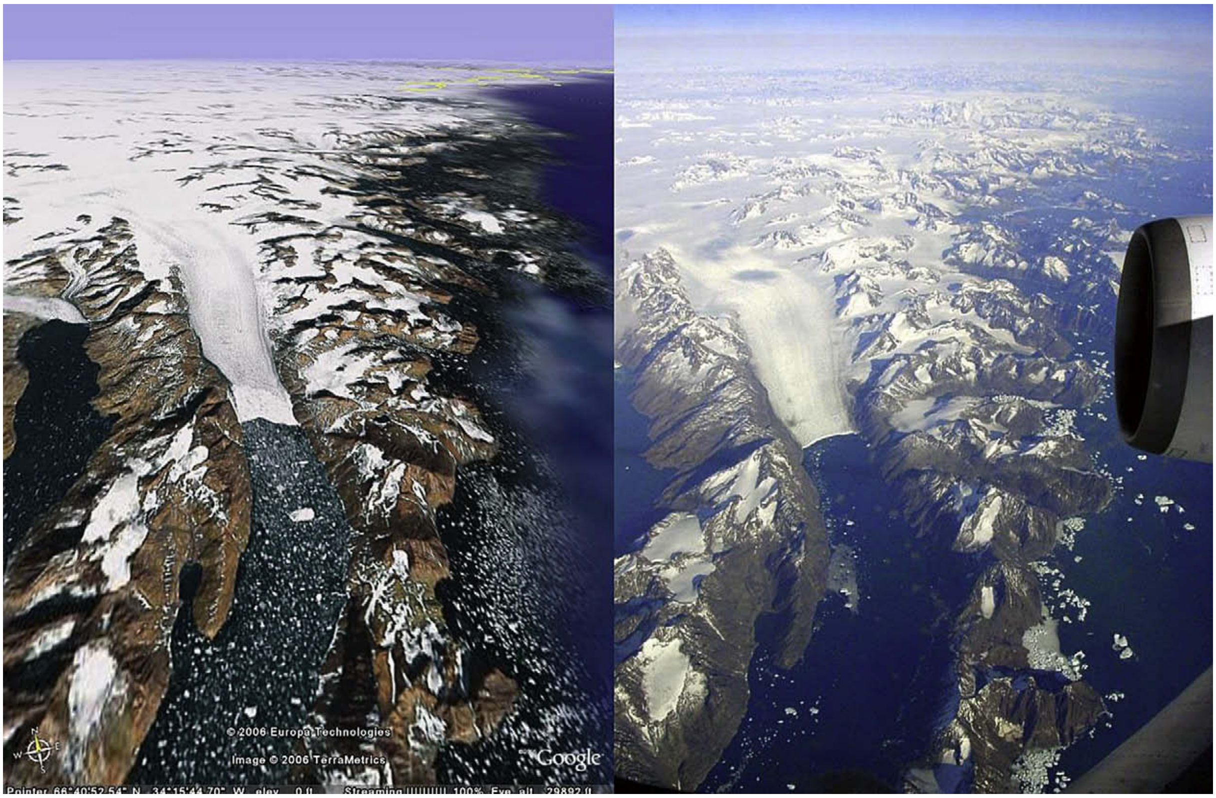


Fig. 9. A simple accuracy test of the Google Earth 3D model of an area in Greenland, conducted by a user, reveals considerable similarity with a real world image taken form a plane. (http://timeclick.blogspot.com/2006/09/checking-google-earths-3d-features.html, Accessed 25 September 2006). Image courtesy of Google Earth© (2006) and reprinted with permission from David Lissmyr.

with a visualisation. The court of public opinion raises the prospect of suspect simulations being tagged or criticized (rightly or wrongly) on the Internet; again, public credibility alone is not necessarily a safe guide to visualisation validity.

Overall, some combination of these potential solutions would seem advisable for public interest projects, involving both the prescriptive and interactive flexibility approaches described earlier. Providing the user with choice and freedom to roam within the virtual globe system reduces the risk of systematic bias from a presenter or preparer, and allows more direct and individualized estimates of (pre-construction) validity. However, there is nothing to say that freedom to choose and roam would automatically lead to the appropriate information being found, and it could lead to more biased or confusing arrays of visualisations for public decision-making. A combination of approaches might ultimately lead to the greatest validity, in providing an ethical structure to evaluate the information while preserving public freedom to explore the visualisation process and design options.

6. Conclusions and recommendations

Virtual globes offer the benefits of accessibility, interactivity, and engagement in landscape visualisation to millions, with the promise of greater representativeness in the views seen by users, improved accuracy of 3D imagery, and accelerated learning. The technology has the potential to democratize the planning process to an unprecedented degree, consistent with the underlying rationale for participatory GIS, to permit multiple voices and interpretations. However, there has as yet been little scientific evaluation of the performance and validity of virtual globe usage; we should not be naive and assume that no problems will arise. They may result not only from limitations in technology (e.g., resolution, accuracy of 3D objects), but also from inexperience, bias, and unforeseen influences arising from the larger process, leading to poor decisions, a misled public, and perhaps reduced trust in the visualisations providers. Caution is advisable: just as the Internet is open to pornography and rampant commercialization, so Google Earth will attract spin, special interests, and amateurism. Relative to previous practice in landscape visualisation, the risks and importance of getting it right are greater, and the likelihood of mistakes by untrained creators far higher. Any problems could mushroom quickly, possibly discrediting individuals, organizations or even the software itself (as is sometimes seen in the public skepticism regarding visual imaging software such as Photoshop). The leap to realistic perspective views (landscape visualisation) carries the user beyond mere cognition and into the realm of emotion and more complex psychological effects associated with place, home, and aesthetic preferences. These should not be ignored, yet there are few guiding frameworks or training programmes to help navigate this odd mix of new technology and strangely familiar digital worlds.

Many of these problems are not completely new, however. Existing principles and emerging codes of ethics, developed primarily for landscape visualisation in the field of urban and land use planning, are relevant to the new generation of web-based GIS and visualisation tools, and could be adapted and integrated into the software delivery systems for virtual globes. Amongst users and visualisation providers, a convergence of scientific/technical expertise, 3D computer modeling skills, and understanding of social responses to landscape imagery is needed. As lay-users increasingly enrich the information in virtual globe datasets, it is important to recognize that visualisation represents an entire language to be learned; knowing how the software works is only part of the issue.

Research can play a crucial role in answering some key questions, such as:

- What are the actual measurable benefits and problems encountered in using virtual globes in public processes? Are the promises delivered or are the fears warranted? These questions may require both controlled evaluation experiments and some real world monitoring.
- What roles do virtual globes play in official processes for decision-making and design, beyond generation of static maps? Does the universality and usability of virtual globes force old-fashioned agencies finally to engage with visualisation technology?
- How do virtual globes affect our ability to perceive and understand scale, as in the cumulative impacts of the massive industrial infrastructure developing across northern Canada, currently unseen by most Canadians (Cizek, 2005)?
- How do aerial versus ground views affect perception and learning on environmental and social issues?
- What codes of practice are emerging autonomously among virtual globe users, and are these supported by research results?

Such research to evaluate virtual globe usage is needed to provide a basis for more defensible 3D/4D communications and collaborative decision-making with virtual globe systems.

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