Tools for the understanding of spatio-temporal climate scenarios in local planning: Kimberley (BC) case study

Authors
Dr. Olaf Schroth
Co-authors: Ellen Pond, Sara Muir-Owen, Cam Campbell, Prof. Dr. Stephen Sheppard

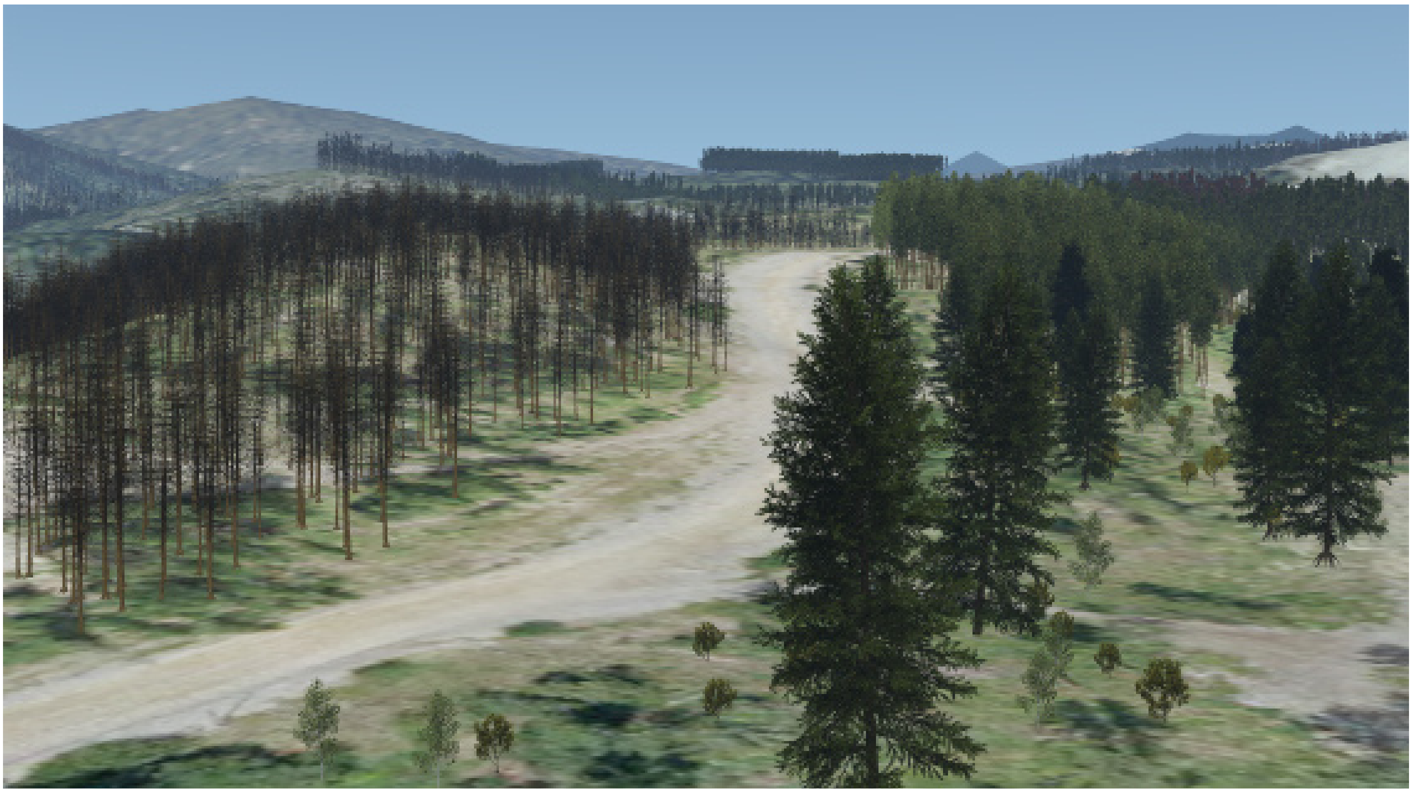
Affiliation
SNF Prospective Researcher Fellowship
Host: Prof. Dr. Stephen Sheppard, Collaborative for Advanced Landscape Planning (CALP), University of British Columbia, Vancouver

Project and reports were funded by the SNSF

CALP

FNSNF
FONDS NATIONAL SUISSE
SCHWEIZERISCHER NATIONALFONDS

Tools for the understanding of spatio-temporal climate scenarios in local planning: Kimberley (BC) case study



Cover images

Possible climate change impacts for Kimberley forest stands in 2100+. The first cover image shows possible species change and mitigation under major adaptation and mitigation management, e.g., thinning. The second image shows possible change under minor adaptation and mitigation management, e.g., succession through forest fire and diseases (Schroth 2009 with thanks to Paar, Schliep and Ernst from the Biosphere3D community).

Keywords

climate change, visioning, scenario method, multi-dimensional navigation, virtual globe, Google Earth, landscape visualization, participatory planning, adaptation, mitigation, decision-support tools

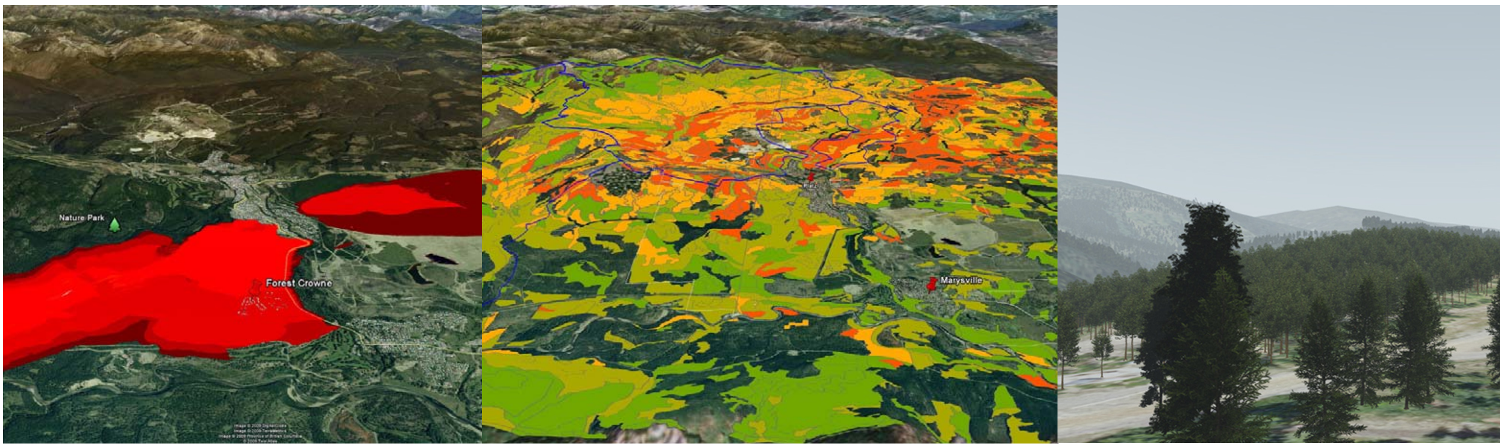
Abstract

The research question of this explorative case study asks how multi-dimensional navigation, defined as the combination of spatial, temporal and thematic navigation, can facilitate the understanding of complex climate change impacts and adaptation and mitigation options. Multi-dimensional navigation was implemented in virtual globes and applied as part of a scenario-based stakeholder engagement in the City of Kimberley (British Columbia). The use of multi-dimensional navigation to understand the spatio-temporal dimensions of climate change risk assessments climate change scenarios was documented in quantitative pre-/post questionnaires, video observations and qualitative in-depth interviews. The analysis included statistical methods as well as the triangulation of multiple sources of evidence.

The results show that multi-dimensional navigation facilitated the spatio-temporal understanding of climate-related scenarios in this case study. Users successfully applied multi-dimensional navigation to select individual perspectives and to compare climate change risks over time. Particularly important was the opportunity to explore alternative scenario options which gave users a scope of action. In contrast, anecdotal evidence indicated that the global to local zoom might alienate some users and that the temporal navigation could add unwanted drama to the user`s perception. In order to address these open questions, recommendations for future research have been formulated. In summary, the study results suggest that the use of multi-dimensional navigation can offer a "way in" to people`s understanding, which is particularly powerful in combination with the scenario method.

Unless otherwise declared, the images were produced by the author.

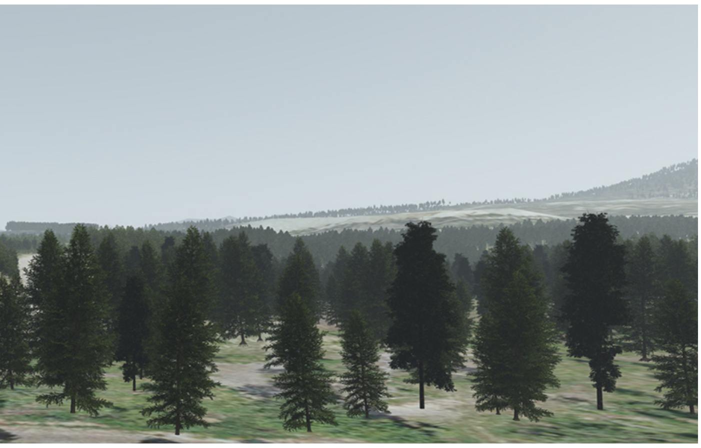
Table of Contents



1. Climate Change in Spatial Planning

Climate change is a global problem with significant impacts on local landscapes. Rising snow lines, decreasing snow cover, melting permafrost, and vanishing glaciers are impacts of climate change that affect mountainous regions in particular (IPCC 2007). According to the synthesis report of the Conference on Global Risks, Challenges and Decisions in Copenhagen 2009 (Richardson et al. 2009), recent observations confirm the worst-case IPCC scenario trajectories or show even worse trends. The Richardson report warns about “dangerous climate change” causing social disruption and calls for immediate action. It is now of high environmental, social and political priority to both mitigate CO2 emissions as a major climate change course, and adapt to the forthcoming unavoidable changes.

It is inevitable that spatial planning has to address climate change in two ways: mitigation and adaptation. Mitigation is needed to drastically reduce greenhouse gas (GHG) emissions in order to slow down and eventually halt global warming. However, mitigation alone will not be sufficient as phenomena such as rising snow lines will require decision-makers to adapt current spatial planning to the new climate change realities. For example, decision-makers in winter tourism have to start discussing alternative strategies for low altitude skiing destinations. However, climate change as yet has rarely been recognized as a driver of landscape change in current planning practice: new planning processes are needed for landscape and urban planning to incorporate the challenges posed by climate change.
The key challenge in the understanding of climate change as a driver of planning is its complex spatio-temporal implications (Blanco et al. 2009). First of all, even climate science is still struggling to spatialize climate change impacts (Nicholson-Cole 2005), with ongoing challenges at downscaled, local scales. This in turn makes it more difficult for non-experts to imagine local spatial climate change impacts and develop suitable adaptation and mitigation measures (O`Neill, Saffron and Hulme 2009). Second, climate change impacts will take place over time spans as long as a hundred years and more whereas human perception seems to be limited to plan 50 years at most (Drottz-Sjöberg 2006). Tonn et al. (2006) show empirical evidence that people‘s ability to image the future already blurs at approximately 15-20 years into the future. Finally, uncertainties in climate change science and difficulties in modelling feedback effects of future adaptation and mitigation measures IPCC (2007) complicate current decision-making for future pathways in local communities.



This paper presents the case study of a spatial planning and community engagement approach in the City of Kimberley that uses scenario-based stakeholder engagement (chapter 1.1) and multi-dimensional visualization tools (chapter 1.2) for decision-support in a community climate change planning process in the small rural municipality Kimberley. In this context, multi-dimensional visualization is defined as interactive visualization that combines spatial navigation (movement and zoom), temporal navigation (time sliders), and thematic navigation (layers). The goal of the visioning process was to develop guidelines for small communities engaged in similar climate change engagement and planning work. The research question (chapter 1.3) asks how multi-dimensional navigation facilitates understanding of the spatio-temporal dimensions of climate change impacts and alternative scenario options. After a description of the case study site in chapter 2, the multiple quantitative and qualitative sources of evidence are analysed through data triangulation in chapter 3. On this basis, recommendations for future research and for the use of multi-dimensional navigation in planning are discussed in chapter 4.

1.1 Tools for participation: Scenario-based stakeholder engagement

Scenario-based stakeholder engagement has been suggested as a promising approach to climate decision-making for two reasons. First, the uncertainty of climate change impacts, i.e., that the location and extent of local climate impacts cannot be predicted with sufficient certainty, makes it more difficult to justify climate-related planning decisions. As well, tensions may arise from climate strategies based on both adaptation and mitigation. Therefore, the participatory construction of alternative scenarios becomes crucial when discussing concepts of vulnerability, resilience, and adaptation (Larsen and Gunnarsson-Östling 2009). Second, participatory scenario building promises to be more efficient than top-down planning decisions in climate change plannning implementation because mitigation and adaptation measures require major public support. As Tompkins et al. (2008) show for two coastal planning case studies in the UK, scenario-based stakeholder engagement, i.e., the combination of stakeholder analysis, climate change management scenarios and participatory techniques, is a useful tool to address the complexities and challenges of climate change. The Economics of Climate Adaptation Working Group recommends the use of the scenario method to decision-makers: “The first is that, despite much uncertainty about the possible effects of global warming on local weather patterns, society knows enough to build plausible scenarios on which to base decision-making” (2009: 11).

Scenario methods were developed in the 1970s as approaches to explore possible futures. The objective of a scenario is to describe a very complex and often unpredictable future pathway as simply as possible in “plausible storylines” (Swart, Robinson and Raskin 2004) or scenario narratives. Such scenario narratives about possible futures not only consider quantitative data, such as demographic data, but they are also based on qualitative data such as local knowledge, cultural values and norms in order to give a range of possible futures from our current present (van‘t Klooster and van Asselt 2006). They provide “images of the future”, neither prediction nor forecast, but rather a systematic framing of uncertainties that scrutinize human and environmental responses under “contrasting future conditions” (Swart, Robinson, Raskin 2004: 139). Scenarios provide the framing for the climate change visioning process and visualization development.

There are many different types of scenario methods and there is no consensus about a standard scenario typology (van Notten et al. 2003). Björeson et al. (2006) provide an overview of the most common scenario types and the principal questions they address. Their classification distinguishes predictive scenarios asking *What will happen?*, explorative scenarios asking *What can happen?*, and normative scenarios asking *How can a specific target be reached?* Predictive scenarios include forecasting techniques and “what-if” analyses that examine the implications of different assumptions. Explorative scenarios usually explore possible developments from diverse perspectives and aim for variety. Normative scenarios start in the future and discuss how an attempted final state can be achieved, e.g., using backcasting techniques. Backcasting assesses the feasibility of desirable futures and the implications of long-term risks which are useful for setting greenhouse gas (GHG) mitigation targets and then working backwards to figure out how to achieve them.

Bishop et al. (2007) provide a generic approach to the scenario method, distinguishing five different steps: Framing, scanning, forecasting, visioning, planning and acting (Table 1). In the Kimberley case study, the CALP Visioning Process included the scanning step, i.e., collecting information; forecasting based on downscaled climate models and local drivers; visioning, e.g. choosing a preferred adaptive and low-carbon future; the planning of actual adaptation and mitigation strategies and options in plan documents; and acting by using public open houses and other media to communicate the results. Further implementation would be undertaken by local communities and planning processes.

Step	Description	Product
Framing	Scoping the project: attitude, audience, work environment, rationale, purpose, objectives, and teams	Project plan
Scanning	Collecting information: the system, history and context of the issue and how to scan for information regarding the future of the issue	Information
Forecasting	Describing baseline and alternative futures: drivers and uncertainties, implications, and outcomes	Baseline and alternative futures (scenarios)
Visioning	Choosing a preferred future: envisioning the best outcomes, goal-setting, performance measures	Preferred future (goals)
Planning	Organizing the resources: strategy, options, and plans	Strategic plan (strategies)

Table 1: *A generic approach to a comprehensive foresight project (Bishop et al. 2007)*

The CALP Visioning Process as visual approach to scenario planning

The Collaborative for Advanced Landscape Planning (CALP) at the University of British Columbia (UBC) has become a knowledge broker in local climate change planning processes by combining participatory scenario-building with 3D landscape visualization. The CALP Visioning process is a multi-scale approach that starts by downscaling global climate change scenarios to the regional and local level, assessing and adding local drivers as well. On this basis, alternative planning scenarios are developed in a local participatory process and visualized for time frames up to 2100 and in 3D views of iconic local places (Shaw et al. 2009). The **visual landscape is the shared platform to synthesize data from diverse stakeholders, impacts issues and mitigation strategies**, **and across multiple**

scales, e.g., global climate models, regional and local data. The visual landscape is also the interface to communicate this data and to discuss future adaptation and mitigation scenarios between diverse stakeholder groups.

To date, the **CALP Visioning** scenarios have been based primarily on the IPCC scenario model, with key drivers being global economic trends (globalization vs localization), population projections, and differing emphases on environmental concerns. These critical drivers determine the range of emissions pathways, which drive the range of climate change impacts. The CALP Visioning process "downscales" scenarios to the local community level with as much robustness as possible, and the Visioning scenarios are linked to local land use and resource planning options (Shaw et al. 2009; Swart et al. 2004). As illustrated in the schematic belowm (Figure 1), visioning processes are iterative – they are undertaken collaboratively with a Local Working Group, and use the best available data and group input to produce materials for planning and climate change work which are continually revised and improved upon. The process alternates between the critical participatory components (black circles above) and the technical and production components (blank circles, filled by each project depending on context and need).

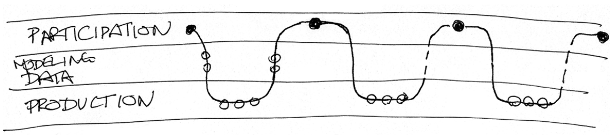


Figure 1: *Conceptual Visioning Process*

Scenario development is undertaken in part as a group process, such as in one or more workshops, that explores and develops a number of plausible alternatives (or scenario storylines) to "book-end" a range of futures by extrapolating uncertain yet influencing trends and driving forces. These alternative storylines with their spatio-temporal implications are organized in a **scenario narrative** (Figure 2). The participatory work may either begin by defining the set of indicators or framing drivers, or begin with a pre-determined set of drivers set by the research team (van t'Kloosters and van Asselt 2006), as was the case with Kimberley. From these, local alternatives are developed.

Spatio-temporal dimensions of scenarios

In comparison to other scenario approaches, the Visioning Process emphasizes the visioning step (Table 1) most. Thus it is of particular importance that the participating stakeholders are enabled to assess alternative spatial options of climate change adaptation and mitigation at different points in time. This is a very complex spatio-temporal task, requiring participants both to think across alternatives and to understand the spatial and temporal interrelations, illustrated in Figure 2. If the previous steps of information scanning and forecasting (Bishop et al. 2007) are supposed to inform this complex task, data has to be aggregated and communicated in a new way. Salter et al. (2009) have shown that interactive landscape visualizations can support such spatio-temporal tasks.

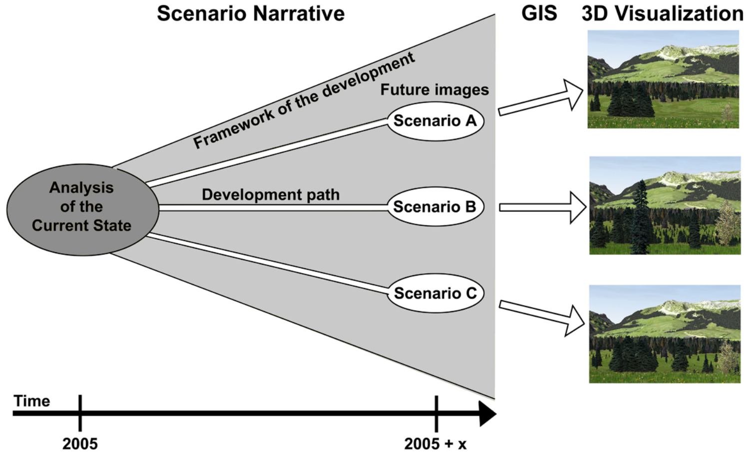


Figure 2: *Multiple spatio-temporal dimensions of alternative scenario narratives*

1.2 Tools for participation: Multi-dimensional visualization of model-driven participatory scenarios in virtual globes

The project is **situated in the context of research about landscape visualizations as tools for participation**, such as Al-Kodmany (1999), Danahy (2001), Ervin (2001), Lange (2001), Hehl-Lange and Lange (2005), Appleton et al. (2002), Schroth (2007), Kwartler (2008), Schroth et al. (2008) and Salter et al. (2009). Special focus is given to climate change which is now acknowledged as a main driver of adaptation and mitigation planning. Recent work by Sheppard (2005), Nicholson-Cole (2005), Shaw et al. (2009) and O`Neill and Hume (2009) address the potential of local landscape visualization as a tool for the improved communication of climate change impacts in planning. These authors have identified the lack of personal concern, which could reduce public support for climate change policies, as a major problem in the public discussion of climate change. There is a need to make the local and individual relevance of climate change clearer because climate change is still seen as a geographically remote problem (Moser and Dilling 2004).

Climate change is also perceived as a long-term problem beyond the individually experienced time-frame (Moser and Dilling 2004, Drottz-Sjöberg 2006, Tonn et al. 2006). Local impacts of climate change are difficult to predict and even more difficult to discuss because they impose such complex spatio-temporal task. At the local level, trade-offs between alternative adaptation options can be difficult to grasp, while the implications of mitigation strategies may still be poorly understood. In combination with the scenario method, landscape visualization provides an important tool to highlight the local relevance of climate change. 3D landscape visualization potentially enables the impacts of long-term global climate change to be localized, spatialized, and visualized in a way that the local relevance becomes clear, building the public support needed for decision-makers to move forward with climate change policy and implementation (Sheppard 2005).
Despite multiple research projects on the scenario method, there is still a lack in visual scenario methods (Fuerst and Scholles 2001).

Therefore, the research refers to the context of cartography to provide the framework for spatio-temporal representations. MacEachren (1995) proposes interactive maps for the comparison of features across different time periods. He is sceptical about static representations of temporal processes because they might communicate a wrong perception. If it was possible to navigate through data by going back and forth in time, it will make it easier to match patterns. However, the navigation imposes additional cognitive costs and needs careful assessment whether the potential benefit outweighs these costs. Often, such navigation that includes spatial, temporal and thematic navigation is called "4D navigation" referring to the three spatial dimensions and the additional "fourth" temporal navigation. In this report, the combination of spatial, temporal and thematic navigation is defined as "**multi-dimensional navigation**" instead (Neumann 2005) because this term is more precise than "4D". Approaches of multi-dimensional navigation were developed by Neumann (2005) and Schroth (2007) and were tested in the proposed research. The following illustration by Neumann (2005) shows a space/time/theme model how items from history of arts could be mapped in a spatio-temporal way.

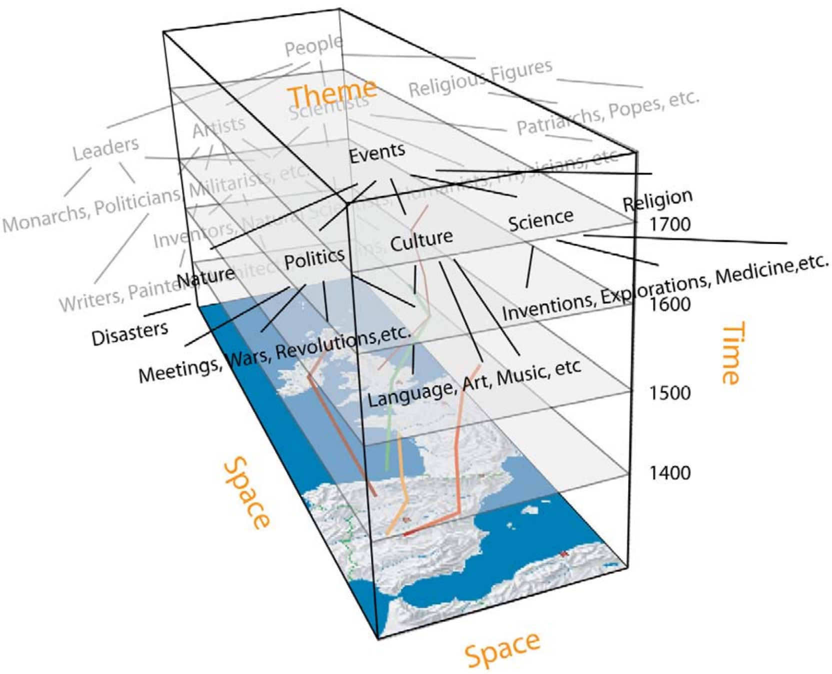


Figure 3: *Space/Time/Theme model by Neumann (2005), in Hurni (2005) showing a multi-dimensional problem.*

Benefits and risks of using virtual globes as multi-dimensional tools

The possibilities for scenario management inside GIS can be extended through plug-ins like CommunityViz (Kwartler 2008) which also provides an interface to export scenarios to virtual globes. The so-called virtual globe is a promising visualization tool that provides multidimensional navigation, a type of geovisualization software that has become widespread over the last years (Nature 2006; Craglia et al. 2009). The basic feature of virtual globes is the globe metaphor that allows users to zoom between global and local scales. Some virtual globes also provide navigation features for time travel and layers for thematic navigation. In this context, the term "**navigation metaphor**" is defined as the common concept used to explain how users interact with the 3D model to navigate, e.g., through the selection of a target point to fly to or through moving the bar of a time slider (for more details, see chapter 2.3).

However, the potential role of virtual globes as tool for the communication of climate change impacts raises a lot of questions. Craglia et al. (2009) set up a research agenda on the use of virtual globes as position paper from the Vespucci Initiative for the Advancement of Geographic Information Science. In this position paper, they identify the questions of "space-time analysis and modeling" and the "visualization of abstract concepts in space" as urgent needs for research. They call for case studies that incorporate up-to-date modelling and indicators defined on basis of observation data to visualize and reason abstract concepts in space such as "quality of life" or "vulnerability". The questions of quality of life, vulnerability and resilience are central to climate change planning as well and this research starts to fill this gap.

Sheppard and Cizek (2009) highlight the need to investigate the ethical implications of virtual globe tools. They identify potential benefits and risks of using virtual globes in planning, distinguished by risks for experts and lay people. This overview of potential benefits and risks provides an important guideline for the application and assessment of virtual globe tools in the Kimberley Climate Adaptation Project (KCAP):
In contrast to the potential benefits, Sheppard and Cizek (2009)

Key benefits of using virtual globes to provide landscape visualizations	
Access to visual information	Within the restrictions of general internet access, virtual globes provide a rather equitable access to information at least in the developed countries.
Interest	Studies by Al-Kodmany (2002), Lewis and Sheppard (2006) and others show that viewing and manipulating information in virtual globes can raise interest and awareness.
Representativeness	In comparison to traditional static visualizations, virtual globes provide the freedom to view spatial information from various and self-selected perspectives (Sheppard 2005).
Identification with distant groups	Sheppard and Cizek (2009) address the common conception that the global metaphor will enable empathy or identification with distant groups. The authors point out that it is still open whether virtual globes really will have this effect.

Table 2: *Key benefits of using virtual globes to provide landscape visualizations (Sheppard and Cizek 2009)*

Possible risks in using virtual globe systems	
Actual vs. Apparent realism	If the representation is more realistic than the accuracy of the underlying data allows, Sheppard (2001) defines it as apparent realism which can be misleading and is not a valid representation.
Affective, evaluative, behavioural responses	Few research has addressed the potential affective, evaluative or behavioural responses to “realistic” representations in virtual globes. It is likely that such visualizations will evoke more emotional and value-laden responses that potentially could overwhelm cognitive responses.
Misinterpretation because the medium is not mediated	If virtual globes are used online without any further face-to-face explanation from the authors, the risk of misinterpretation may increase.
Low data resolution, inaccuracy, unrepresentativeness, poor clarity, low credibility)	Especially Google Earth still has some problems with regard to the resolution of underlying data, inaccuracy, unrepresentativeness, clarity and credibility of the underlying data. The issue is partly linked to the issue of user-generated content as discussed in more detail by Sheppard and Cizek (2009).
Validation of future conditions requires more scrutiny of modeling, assumptions or interpretations	The complex issues of future conditions, also addressed in this report, are subject to modeling constraints, issues of scale and uncertainties (Moser and Dilling 2004). These issues are directly relevant for the understanding of spatio-temporal implications: • Different levels of scale • Different levels of certainty • Different levels of detail • Possibly shocking effects of collapsing time

Table 3: *Possible risks in using virtual globe systems (based on Sheppard and Cizek 2009)*

list many possible risks that rarely have been addressed and need further research. Issues related to projecting future conditions are particularly relevant for this project: The field is largely technology-driven and therefore more focused on the evaluation of technical performance and realistic rendering rather than validity and reliability in a scientific sense. Instead, Sheppard and Cizek argue, validity and reliability should be crucial criteria for the ethical use of landscape visualizations. Sheppard and Cizek (2008) identify the above benefits and risks for virtual globes in general and Google Earth in particular. The list of benefits and risks guides the critical analysis of multi-dimensional navigation and is addressed in “Research Objective 4: Analyse possible bias and risks”.

1.3 Research question

Need for research on multi-dimensional navigation as a tool for the communication of climate change

With the SNSF post-doc fellowship, the benefits and risks of multi-dimensional navigation for the understanding of climate change impacts and adaptation and mitigation options in stakeholder participation were researched. Multi-dimensional navigation, i.e. the extension of spatial navigation through the dimensions time and theme (Hurni 2005), is a particularly promising concept in combination with the scenario method because it allows navigating through the scenario narratives on global, regional and local scales without losing the spatial context. Multi-dimensional navigation provides the potential to communicate the long-term dimension of climate change more comprehensibly than traditional means of visualization. Third, multi-dimensional navigation enables the comparison of alternative scenarios and links alternative scenarios with indicators.

However, current modelling and visualization techniques in GIS and virtual globes are still limited in their multi-dimensional functionality. Most important, it is unclear whether the benefits of multi-dimensional approaches to complex spatio-temporal climate issues outweigh the additional cognitive costs and the potential risks of misinterpretation etc. Therefore, there is an urgent need for research on understanding of spatio-temporal issues and scenarios using multi-dimensional navigation tools.

Research objectives

The research objectives address the effectiveness of multi-dimensional navigation as a tool for understanding (Objective 1), methodological (Objectives 2-3) and ethical issues (Objective 4).

1. Evaluate how multi-dimensional navigation can facilitate the understanding of local impacts of climate change and adaptation and mitigation scenarios in planning.
2. Develop suitable navigation metaphors to facilitate the understanding of adaptation and mitigation scenarios at different geographical scales and at different points in time.
3. Develop suitable representations to facilitate understanding of climate related indicators (greenhouse gas GHG, risk factors, etc.) on a local scale.
4. Analyse possible bias and risks of the use of multi-dimensional landscape visualizations (Sheppard and Cizek 2008; Sheppard 2005; Nicholson-Cole 2005).

Research question

Multi-dimensional navigation through landscape visualization is applied as a tool to improve the understanding of climate change. Basically, the overall research project is interdisciplinary, having links to issues on climate change, spatial planning, cartography, computer graphics, forestry, ecology, sociology and other fields. However, the core perspective of the research question is the planning perspective. The complexity of climate change, including its spatial, temporal and thematic dimensions, needs to be understood by stakeholders in the planning process in order to enhance local climate change planning, both for adaptation and mitigation.

How can multi-dimensional landscape visualization facilitate the understanding of the spatio-temporal dimensions of alternative climate change scenarios in planning?

Research hypotheses

Multi-dimensional navigation is the most potentially interactive method to be tested from a planning perspective. In this context, multi-dimensional navigation is defined as the combination of spatial, temporal and thematic navigation. With regard to previous case studies, the hypothesis puts forward that it will facilitate the understanding of climate change:

Multi-dimensional navigation, defined as the combination of spatial, temporal and thematic navigation, facilitates the understanding of spatio-temporal climate change impacts and alternative adaptation and mitigation scenario options in planning.

In contrast, the rival hypothesis assumes that the additional cognitive costs and risks of multi-dimensional navigation outweigh the benefits. Thus:

Multi-dimensional navigation imposes cognitive costs and risks of misinterpretation that inhibit the understanding of spatio-temporal climate change impacts and alternative adaptation and mitigation scenario options in planning.

1.4 Research design: Deductive mixed methods approach

The study was exploratory and its basic approach used the case study method according to Yin (2003) with the Kimberley Climate Adaptation Project (KCAP) as case study. The benefit of the case study method is that it allows for testing of multi-dimensional navigation in a real planning context. On the other hand, control over the research environment and the variables in the case study setting is limited. For a more controlled research design such as an experimental design (Yin 2003: 8), the baseline would be a "business-as-usual" climate change workshop without the opportunity for models with multi-dimensional 3d navigation. However, given the multiple variables affecting real planning processes – and the research question that requires real-world planning conditions – a controlled comparative study was not deemed possible in the first year of the SNSF funding. A multiple-case study that will allow the comparison with other planning processes and will increase the replicability of the results (Yin 2003) is proposed as follow-up project.

Rather, in order to provide robust results within the case study methodology, mixed quantitative and qualitative methods were applied in a deductive way, starting with quantitative analyses of general questionnaires and going into detail through investigating individual understanding in qualitative in-depth interviews. For the study, the independent variables being changed by the researchers included:

Independent variables:

- Spatial navigation
- Temporal navigation
- Thematic navigation

The dependant variables, or observed results from the changing independent variables, included:

Dependant variables:

- Spatial understanding of climate change impacts
- Temporal understanding of climate change impacts
- Understanding of alternative adaptation and mitigation scenario options

Controlled variables:

- Scenario process
- Setting
- Presentation and use of different media

During the scenario development and visualization review workshops, qualitative data was collected in form of meeting minutes, transcriptions of audio records from the workshop groups and transcriptions of expert interviews with the facilitators. The data from the workshops was mainly analysed in order to monitor the controlled variables and to document the scenario process. On the basis of the expert workshops, various presentation media and an interactive multi-dimensional 3d model in a virtual globe were prepared for the final public open house.

Data set	Type of data
Audio recordings and transcriptions of workshop groups	Group discussions
Audio recordings and transcriptions of in-depth interviews	Qualitative expert interviews
Questionnaires	Quantitative survey data
Screenshots, meeting minutes	Documentary data
Photos, observation protocols	Observation data

Table 4: *Collecting multiple sources of evidence (cf. Yin 2003: 86)*

Deductive mix of quantitative and qualitative methods during public open house

The overall research was exploratory and aimed to identify the nature of the relationship between multi-dimensional navigation and understanding of spatio-temporal phenomena. On this basis, first recommendations for future use of multi-dimensional navigation in scenario planning and questions for future research can be formulated.

1st Research step: Comparison of pre-/post questionnaires – Analyse changes in awareness and understanding

Pre-/post questionnaires are an appropriate method to analyse changes in awareness and understanding through workshops (Shaw et al. 2009). Before the start of the public open house, a quantitative questionnaire was handed out to every participant, asking them to first rate their awareness and second their understanding of climate change impacts and adaptation and mitigation options. The same questionnaire was handed out after the workshop as well. The comparative analysis of pre-/post questionnaires shows whether the respondents assessed their understanding as having changed throughout the public open house.

2nd Research step: Rating of visualization benefits and ranking of different visualization media in the post questionnaire – Determine the role of the visualizations in the process

In the post questionnaire, respondents were additionally asked to rate the benefits of the visualizations in general and then, to rank a) slide presentation, b) 2D maps, c) posters and d) the mediated multi-dimensional presentation in a virtual globe. The ranking provided self-assessed data showing which percentage of participants favoured which media and how the multi-dimensional navigation was ranked in comparison to non-interactive presentation media.

3rd Research step: In-depth user interviews with participants interacting directly with spatio-temporal scenarios in a virtual globe – Investigate how multi-dimensional navigation facilitates understanding

In-depth interviews and video recordings documented the user experience for the user‘s interaction with the virtual globe model. Extensive qualitative data was collected on how people experienced the multi-dimensional navigation through spatio-temporal climate change impacts and adaptation and mitigation options. The researcher conducted guided interviews with the participants while they explored the model, asking them to report their understanding of the experienced information.

Analytical strategy for the in-depth interviews

In addition, the post questionnaire contained open questions where respondents could provide further details how the visualizations facilitated their understanding of climate change issues. 25 out of 38 respondents used this opportunity and offered additional insights. Finally, the KCAP facilitator had added a feedback section to the questionnaire which also referred to the visualizations. Both, open comments and the KCAP feedback form, provided very detailed evidence and were included in the analysis:

The transcripts of the video and interview protocols were analysed through data triangulation (Yin 2003: 97) with video-recorded observations and qualitative comments from the post questionnaire and the KCAP feedback form. Pattern-matching (Yin 2003: 116-120) was chosen as analytic technique to match evidence of understanding spatial and temporal phenomena or understanding scenario alternatives to spatial, temporal, and thematic navigation steps. In addition, hints for cognitive load, bias and other risks according to chapter 1.4

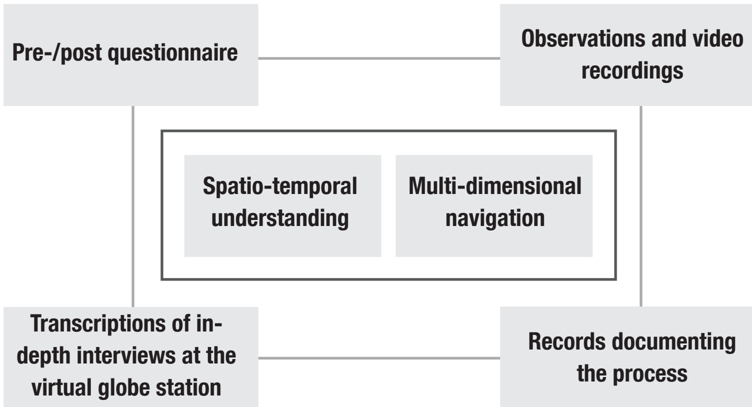


Figure 4: *Data triangulation*

2. Case Study Site: Kimberley

The Visioning Process was first developed by CALP under GEOIDE funding (Project SII) for two municipalities in Metro Vancouver in 2004-2007. A version of the process was then tested again in the smaller (population approx. 6000), less urban municipality of Kimberley, British Columbia in 2008-2009. The next larger city is Cranbrook, where a large proportion of Kimberley's residents are commuting. Kimberley typifies smaller communities that need to plan for a range of climate change related issues and impacts, including rising snowlines with its ski resort, forest pest infestations and species shifts, and an increasing fire season length.

Kimberley's pilot Climate Adaptation Project (KCAP, or the Kimberley Climate Adaptation Project) was funded by the Columbia Basin Trust, with a volunteer Steering Committee and issue-focused Working Groups of local experts and community members. It had the full support of Mayor and Council, and the local city planner. Funded by the Real Estate Foundation and the Provincial Ministry of Community Development/City of Kimberley, CALP joined the KCAP team, bringing adaptation and mitigation scenario-building as well as spatial data synthesis and mapping, alternatives land use planning, and 3D visualizations to the project.

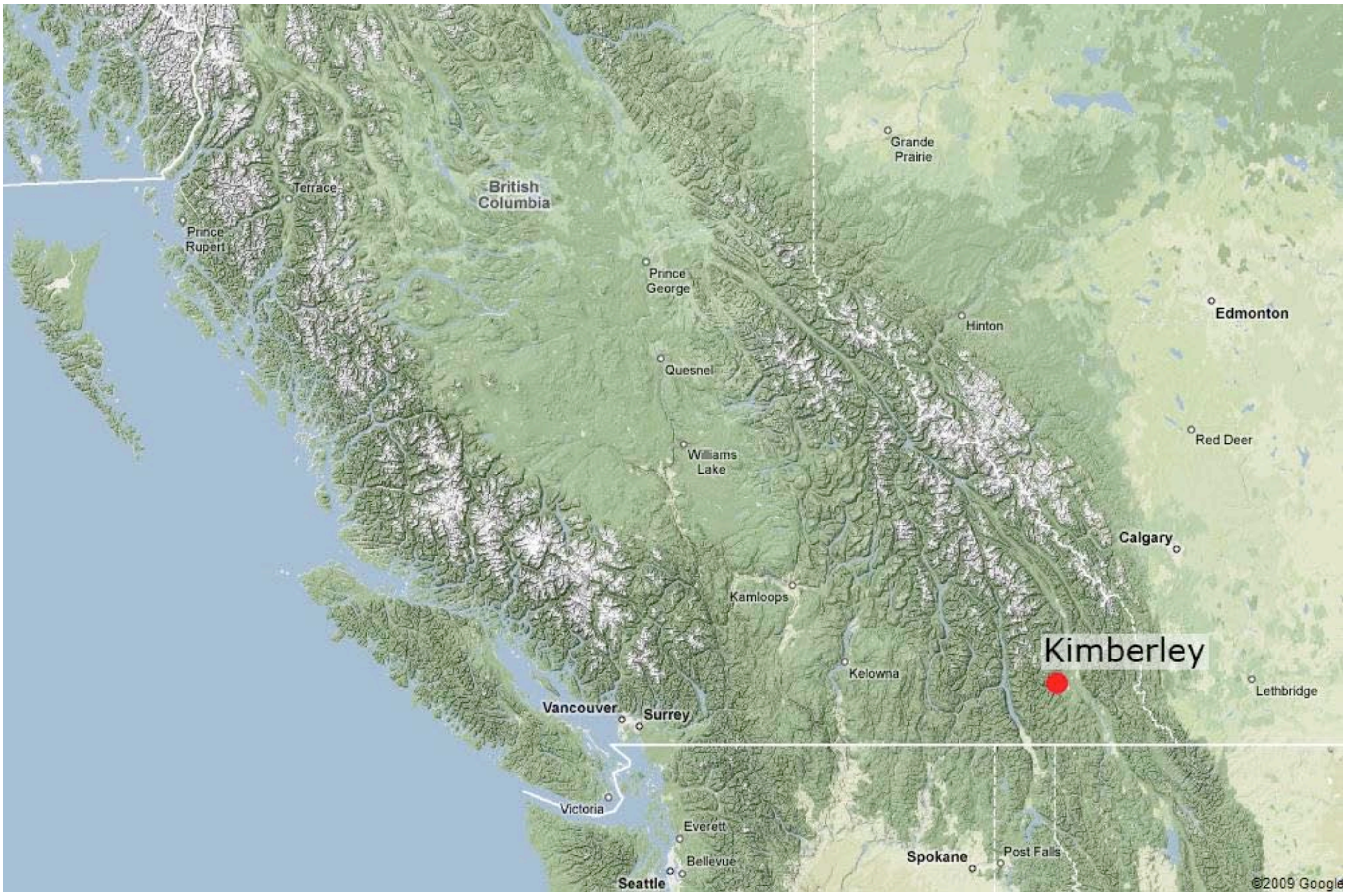


***Figure 5**: Location of Kimberley, British Columbia (Google Maps 2009)*

2.1 Outcomes of the KCAP scenario process

Kimberley's scenarios were developed over the period of several months in an iterative process that involved local Steering Committee members, City staff, councillors, as well as several other community stakeholders in the latter stages. The process began with a collaborative workshop, after which local KCAP members refined and revisited the plausibility of the alternatives (Table 1). The scenarios considered the interactions of the following factors at both a global and local level out to 2100.

Starting from the IPCC SRES scenarios (Figure 6), a group of 21 local stakeholders and experts identified the following ten climate-related themes as most important for Kimberley`s future:

- Energy use
- Economy
- Land use and development trends
- Transportation
- Levels of greenhouse gas emissions
- Projected climate impacts based on greenhouse gas emissions measures
- Population trends, including climate-related migration
- Food security
- Ecosystems and water
- Governance and policy

As impacts and adaptation responses were assessed through the KCAP process, and mitigation strategies explored with the CALP team and the Scenarios Working Group, increasing levels of local detail and complexity were added to the scenarios. Key steps in this process were the workshops listed in table 5:

SRES Scenarios

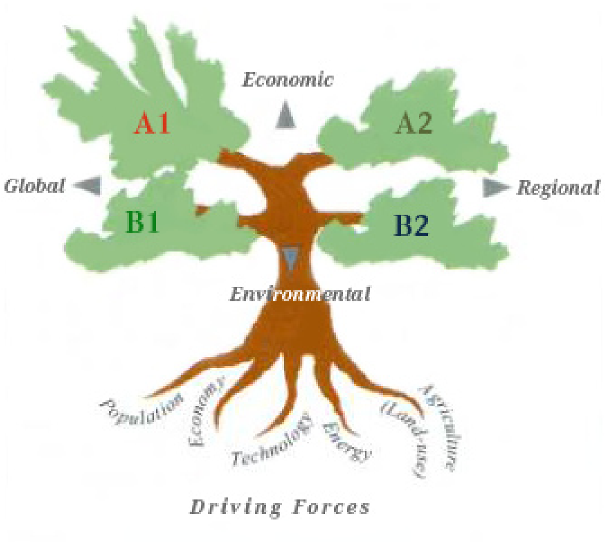


Figure 6: *Schematic illustration of the four "Special Report on Emissions Scenarios" SRES storylines (IPCC 2009)*

2.2 Modeling data

In order to facilitate spatially-based impacts' assessments and scenario development, the CALP team had the role of integrating and producing 2D and 3D data. Large amounts of City CAD data, provincial geodata, development plans, a 3D city model and modelling results had to be integrated and prepared for the participatory workshops. Guiding principle for the selection of data were the scenario narrati-

Workshop	Place and time	Participants	Topics	Records
Scenario preparation workshop	UBC / CALP Dec 11 2008	KCAP facilitator, city planner, community representative, CALP team	Scenario building Visualization methods	Group discussion protocols
KCAP "Kick Off" Meeting	Kimberley Feb 2 2009	CALP team and 21 local experts and stakeholders	Scenario building Visualization methods	Meeting minutes, Screenshots
"Big Viz" expert workshop with three thematic working groups	Kimberley Mar 25 2009	CALP team and 30 local experts and stakeholders from City staff, local and regional government agencies, private consultancies, KCAP Steering Committee, Councillors and the Mayor	Discussion of the scenarios and underlying data	Group discussion protocols, Facilitator interviews, Observation protocols, Screenshots
Public open house and exhibition with presentation, posters and computer station	Kimberley Jun 9 2009	46 members of the public and City of Kimberley staff and Council members	Presentation and public discussion of the workshop outcomes	Before-/after questionnaires, Qualitative interviews, Video documentation of computer station
Selkirk workshop	UBC / CALP Sep 28-29 2009	CALP team and the Selkirk geospatial unit	Future dissemination of the project data and visualizations	Meeting minutes

Table 5: *Overview of participatory workshop meetings*

ves. In general, the scenario narratives included the following three elements (ECA 2009: 22):

1. “The threat already posed to society from today‘s climate.”
In history, Kimberley has already suffered from forest fire and flooding events. Mapping location and time of these historic events provides a starting point for the scenario discussion. As well, Kimberley is the epicentre of the Kootenay region’s Mountain Pine Beetle epidemic – a first wave of current climate change impacts that threatens to exacerbate historic threats such as forest fire and flooding.

2. “Development paths that might put greater population and value at risk.”
Current development proposals such as Forest Crowne and Taylor‘s Mill are located in highly vulnerable places. By overlapping build-out and risk map the increasing risk is ‚put on the map‘.

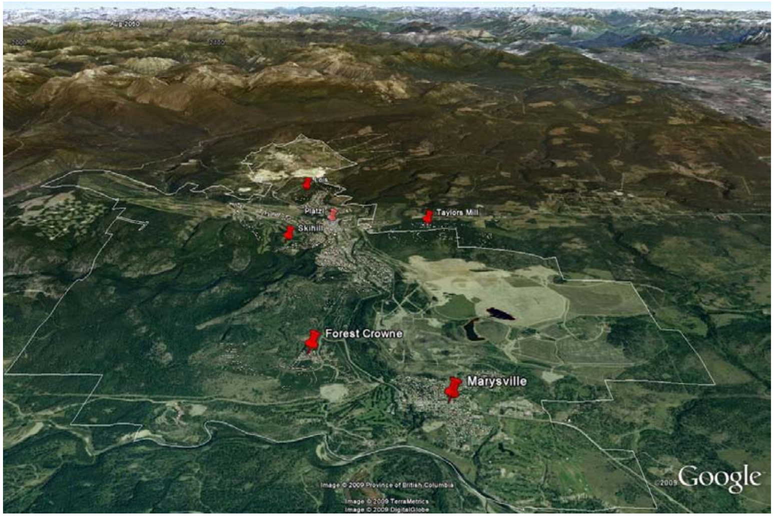


Figure 7: *Kimberley 3d city model showing the city boundaries and the proposed future build-out*

3. “The potentially devastating but still largely uncertain additional risks presented by climate change. “
Spatial models provide projections for future risks by climate change. Events such as Mountain Pine Beetle infestation and forest fires are likely to become more frequent and appear in longer seasons because of climate change (ECA 2009). In order to acknowledge the uncertainties of these projections, alternative scenarios are discussed.

It was necessary to request data from various different sources and in different formats because the basic data was rather limited – as it is quite common for small towns like Kimberley. As a consequence, for some of the data, georeferences had to be added while for other data, it was necessary to transform the original projection into the shared projection of the project geodatabase. A key step in the iterative process of mapping impacts and future projected impacts was the expert workshop on March 25, where the working groups selected the most important data and identified data gaps (Table 5).

Spatial data was also generated within CALP. For example, a figure-ground was prepared in GIS by drawing the building footprints for all existing building within the community, to show the current development and land use patterns (see Figure 7). Proposed development plans for roads and lots were digitized in GIS, and then CommunityViz was used to generate future build-out maps that show how current land use and development plans will alter the community’s form and carbon emissions, barring adaptive or mitigative changes. For this purpose, CommunityViz provides the building wizard, which helps calculating the number of houses according to given density numbers and floor area ratios (Kwartler 2008). Based on the parameters from current zoning maps and development proposals, plausible build-out designs were created. The build-out maps also show the potential future community that will need to adapt to climate change impacts, and allowed for calculation of potential future GHG emissions, barring any mitigative actions. Thus, the build-out maps allow questions to be asked about the community’s future adaptation needs and potential risks, as well as questions about how to develop in a way that mitigates, rather than contributes to, GHG emissions.

Modelling results came either from external models specific to the project, such as the hydrological modeling projecting future snowpack conditions that was converted into geodata, or from existing models, such as geodata of Mountain Pine Beetle Susceptibility (Shore and Safranyik 1992, updated by ILMB 2006) and the Farsite fire area simulator (Missoula Fire Sciences Laboratory 2009).

2.3 Multi-dimensional navigation metaphors

The visualization workflow was supposed to be kept as simple and accessible as possible to make it replicable for other small communities and for the Geoide IV-32 follow-up project, as testing replicability was one of the CALP team’s research objectives. The desire for replicability, along with the research objectives with regards to spatio-temporal navigation described below in 2.3, led to the project team decision that virtual globes, i.e., geo-browsers that use the globe metaphor for representation, were to be used for the final presentation. The virtual globe type of software provides fly-throughs, zooming from global to local levels, navigation through time, and layers to facilitate the comparison of alternative storylines (Craglia et al. 2008). Google Earth was chosen as one presentation medium because it is widely accessible already, making it potentially replicable in the future for other smaller communities. In addition, the virtual globe Biosphere3D (B3D) was chosen as a second presentation medium because it is specialized in the representation of vegetation and provides an open-source alternative to Google Earth. In this visualization environment, the following visualization types were distinguished with regard to Salter and Sheppard (2004):

Visualization types
- 2D GIS maps
- Cartographic 3D maps (Häberling 2003)
- Realistic 3D landscape visualizations (Schroth 2007)
- Indicator charts (Figure 9; Wissen et al.2008)

Scales

- The spatial scale ranges from global climate change data on temperature increases to regional vegetation data and to downscaled local climate change data and city inventory.
- Time scales range from 8 hours for the fire spread model to 100 years for urban development and species change.
- Two scenario alternatives are developed through the scenario-building process: 1) Kimberley Adapts and 2) Low-Carbon Kimberley

Research objective 2: Metaphors for multi-dimensional navigation

Navigation metaphors in landscape visualization (Schroth 2007), atlas cartography (Hurni 2005) and 3D city models (Döllner 2005) were reviewed to identify suitable navigation metaphors. Levels of abstraction, different representation forms, e.g., a fly-through for the introduction, and suitable navigation metaphors were selected together with key stakeholders during the scenario preparation workshop on December 11 (Table 5).

a) Spatial Navigation: Move

In a virtual globe, the user can move in six directions, i.e., forwards, backwards, left, right, up and down. Especially for the up and down movement, additional interfaces such as a 3D mouse are very helpful.

b) Spatial navigation: Click-&-Fly

The viewer navigates by clicking a visual target and the computer will move towards this point. This navigation metaphor is useful for approaching a specific location quickly.

c) Spatial navigation: Zoom navigation

The distance to a focus point can be decreased or increased interactively. Zoom is a standard function of most real-time applications and makes it possible to zoom into an area of interest, e.g., the property of a stakeholder, and to zoom back to the overview of the spatial context. In the context of the global IPCC scenarios, visualized for Google Earth by the Met Office Hadley Centre UK (2009), the globe metaphor should make it possible to link global climate change impacts with local impacts on the landscape scale.

e) Temporal navigation: Time-slider

In the representation of temporal processes, alternate models of time can be distinguished (Edsall and Sidney 2005). Navigation through linear time is best supported through a "time slider" metaphor, which helps exploring trends over time, going forwards and backwards or pausing at specific points in time (Figure 8).

f) Thematic navigation: Layers

The layer concept goes back to cartography and is well-known in GIS: Related spatial themes are combined in so-called layers. The layer concept makes it possible to organize theme sets according to the scenario narratives.

d) Navigation support: Bookmarks and tours

The user can define points-of-interests and specific views as so-

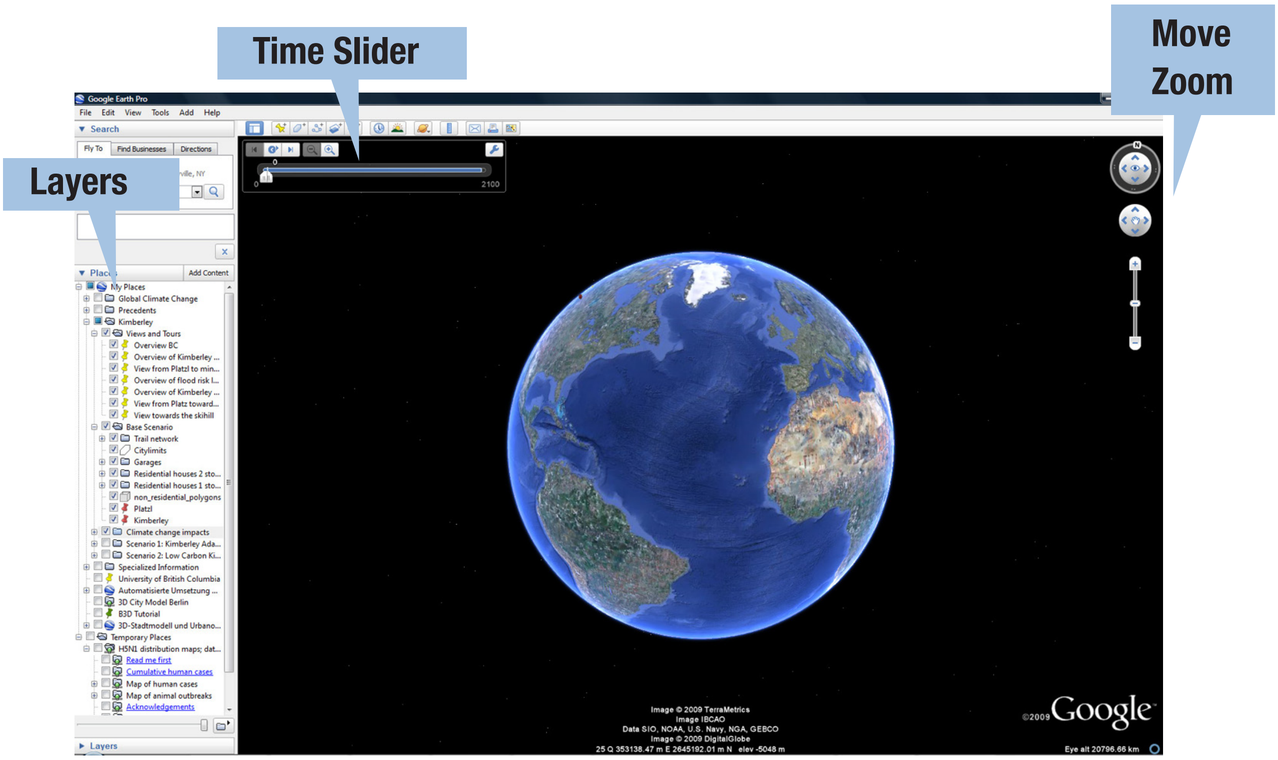


Figure 8: *Spatial (move, zoom), temporal (time-slider) and thematic (layers) navigation in a virtual globe (here: GoogleEarth).*

called "bookmarks." Bookmarks and tours, i.e. a series of bookmarks, can be used to visualize a scenario narrative by showing a sequence of locations and themes.

Research objective 3: Representation of indicators

Within the scope of the project, it was not possible to implement a fully linked model and visualization of GHG emissions as an indicator, but GHG emissions were modelled for the proposed future build-out in ArcGIS and CommunityViz (Pond 2009). The outcomes were visualized as indicator charts (Figure 9) and shown together with the realistic 3D visualizations of the future build-out. The further development of integrated GHG and land use modeling and visualization systems is strongly suggested for future research.

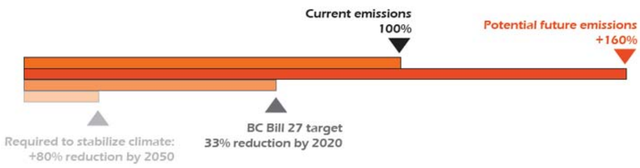


Figure 9: *Indicator chart showing current GHG emissions, target emissions and projected emissions for the proposed future development. This chart was shown in combination with the realistic 3D visualization of the build-out.*

Visualization workflow

Figure 10 illustrates the overall visualization workflow. ArcGIS as well as the ArcGIS plug-in CommunityViz were used for the export to Google Earth while Sketchup was used for the urban design component. A prototype visualization was set up in Google Earth and tested in a first workshop in December 2008, including CALP experts and the workshop facilitator, city planner and a community representative from the City of Kimberley. The feedback was an important consideration for the next visualization steps. A second workshop with interactive Google Earth as well as 2D maps was run with the KCAP Working Groups in March 2009. Feedback from this session led to a final round of data gathering, modeling, analysis, and synthesis, and improved 3D visualizations for a final Public Open House in June 2009.

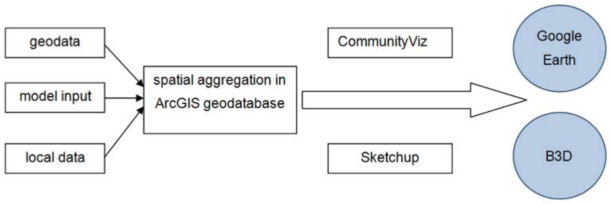


Figure 10: *Visualization workflow*

In summary, the novelty of this approach in comparison to previous visioning workshops is that visualizations of drivers and scenario narratives are aggregated in an interactive, multi-dimensional and comprehensive 3D landscape model as shared communication platform.

3. Results: Spatio-Temporal Understanding of the Kimberley Adapts and Low-Carbon Kimberley Scenarios

Two scenarios were developed for Kimberley, including one impacts scenario, where current land use policies and development plans are carried into the future, and climate impacts are assumed to be high. This impacts scenario was bundled with the KCAP findings, including over 75 possible adaptation actions for the community to take, which produced an **adaptation-only scenario**, named "Kimberley Adapts". At the other end of the scenario spectrum, a **low-carbon alternative future** proposed a suite of mitigation and adaptation strategies to achieve a resilient, low GHG emissions future, or "Low-Carbon Kimberley". The benefits and risks of multi-dimensional navigation were tested with regard to the user's spatio-temporal understanding of these two scenarios.

3.1 Outcomes of the Visioning Process

Starting points for both scenarios were the global World 2 (IPCC A2) and World 4 (IPCC B1 or better) CALP (2007) scenarios. Kimberley Adapts is based on the assumption that global demographic and economic growth continue as before and only minor mitigation will take place. In contrast, Low-Carbon Kimberley is based on a global shift towards a new sustainability. It is assumed that global change will take place parallel to describe local scenarios. The two scenarios that were developed are used to illustrate "extremes", understanding that a range of possible options and pathways lie between them, including pathways with synergies between adaptation and mitigation options.

Carbon emissions were one indicator used to distinguish the scenarios. Preliminary carbon emissions for the current City of Kimberley and the full build-out pathway (Kimberley Adapts) were initially calculated using a spatial methodology in order to assess the potential GHG implications of current development plans, barring any GHG mitigation actions. The carbon emissions numbers in the CALP posters used a combination of the British Columbia Community Energy and Emissions Inventory (CEEI) material and CALP projections to give preliminary assessments of potential emissions under the "Kimberley Adapts" scenario; emissions for "Low-Carbon Kimberley" were not calculated, but low emissions were assumed to be attainable based on existing research (Miller and Cavens 2008) and the scenario development.

A. Kimberley Adapts

This scenario is based on a high energy use, fossil fuel-based economy which continues current development pathways, including a full build-out of Kimberley's current and proposed land use development plans. Global and local climate change impacts are at the extreme end and considerable adaptation is required, with a local emphasis on flood and forest fire protection. Landscape-scale fuel management continues within the City's boundaries, while fuel management beyond the City's boundaries is also implemented. Most of the KCAP Working Groups' findings and their adaptation recommendations fit within this scenario.

Figure 11: *Expert workshop group*

B. Low-Carbon Kimberley

This scenario is based on sharply reduced energy usage and greenhouse gas emissions. A move to renewable energy includes solar thermal for hot water, and local biomass energy that helps to drive the local economy. Other elements include a steadystate local population with the capacity to double if necessary (depending on the number of "climate refugees" or climate migrants), electric vehicle and rail-based transportation, and development patterns based on rebuild and infill within the existing walkable nodes in Kimberley. Alternative green building technologies such as strawbale housing (fire resistant and thus an adaptation as well) are implemented. Local food production (regional) is greatly enhanced. The KCAP Working Group recommendation to pursue local energy planning fits within this scenario.

CALP produced a series of 2D technical posters giving the background for the visualizations along with the data sources; a preliminary downtown Sketchup model with adaptations (Green Infrastructure) and low-carbon infill development (Figure 23), based on a conceptual landscape architecture plan for the downtown area; a Biosphere 3D model of the forest stands around Kimberley to illustrate potential fire, MPB, and species change possibilities (Figure 21); and an interactive Google Earth visualization for a "virtual tour" (e.g., Figure 15). All of these helped to build an overall narrative around Kimberley's climate issues and opportunities for adaptation as well as mitigation. All the materials were presented to the community at a Public Open House in June, 2009.

The order of topics and visualizations represents the underlying storyline of both scenarios. First, under current conditions and planned developments, GHG emissions are increasing, so that Kimberley is contributing to climate change. Posters and virtual globes were used to highlight the interrelated impacts of decreasing forest health, wildfire and changes in precipitation/snowpack. Under climate change, further stress on the forests could result in an increase in forest susceptibility to pests and diseases. Furthermore, the fire seasons will become even longer. As well, the forest, fire, and precipitation/snowpack changes could have qualitative and quantitative impacts on Kimberley's drinking water, and flood risk in the downtown area. Lastly, after considering the climate change impacts, the adaptation and low-carbon scenarios were presented and discussed.

The presentation of the virtual tour and posters, covered the material, i.e., land use, suitability, susceptibility and risk maps as well as future visions, in the following order, thus telling the overall scenario narrative:

- Baseline of Kimberley now, showing land use patterns and GHG emissions (3d map + indicator chart)
- Kimberley at full build-out given current development plans until 2050, with possible GHG emissions (3d landscape visualization)
- Mountain Pine Beetle susceptibility maps for the area around Kimberley (3d map)
- 3D visualization of possible Mountain Pine Beetle long-term infestation cycles (2010-2090) depending on chosen adaptations to the current epidemic (3d map)
- Wildfire risk maps showing locations of historic wildfires (1919-2000), predicted susceptibility to fire risk based on current forest composition, forest fire spread modeling, as well as the potential fire season extension under a high emissions climate change scenario (3d map)
- Snowpack depth for April 1st, from 1965 to 2100, which was limited to preliminary, uncalibrated modeling for the local area including the Mark and Matthew Creek watersheds. (3d map)
- Flood risk maps associated with Mark Creek, and upstream deforestation (3d map)
- Scenario 1: Kimberley Adapts -- using Green Infrastructure to meet multiple working group recommendations for Kimberley's Platzl or downtown area (3d landscape visualization)
- Scenario 2: Low-Carbon Kimberley options for renewable energy, transportation, and intensification through mixed-use infill development (3d landscape visualization)
- Alternative options of long-term forest management and climate change impacts such as species change (3d landscape visualization)
- A "Green Ribbon Vision" for Kimberley shows one possible way to build the low-carbon options into the community, along with the necessary adaptations for unavoidable climate change impacts, by using Kimberley's considerable assets as a starting point. In the Green Ribbon Vision, Kimberley is surrounded by a firesmart, biomass-producing community landscape, with a network of trails, called "green ribbon", linking compact residential and mixed-use nodes along the Mark Creek corridor. The trails also connect to economically important recreational amenities. The concept shows how low-carbon scenarios can be integrated into land-use and planning decisions for community development. (3d map)

Most of the CALP material was integrated into a Google Earth (virtual globe) platform, and presented as a live "virtual tour" of Kimberley at the June Public Open House. The database set includes a 3D model of the town with all of the current houses and public buildings. 2D maps, 3D maps, realistic landscape visualizations and indicator charts (see chapter 2.3) were used as indicated in the above list.

The spatial, temporal and thematic dimensions of the scenarios were addressed: Development plans are shown in "4D" -- they include a time-phased build-out sequence that can be viewed with a time slider in Google Earth. Forest fire modeling was also shown with time phasing – in hours for the fire spread model, and in years (out to the 2080s) for projected fire season extensions under climate change. By turning layer sets on and off, it was possible to navigate through the different themes and to create the scenario narrative.

3.2 Changes in understanding and the role of multi-dimensional visualization in the public open house

Records from the scenario development process suggest that virtual globes still need the context of the presentation and expert assistance to fulfill their potential benefit. The full "visioning package" (Shaw et al. 2009) needs to include data, narratives and visualizations. The Kimberley process was testing how multi-dimensional visualization can facilitate the understanding of spatio-temporal climate change impacts and adaptation and mitigation options. Qualitative feedback and observations provided information on the context in which multi-dimensional navigation through virtual globes works. In comparison to research by Schroth (2007), where all workshop settings had been mediated through a visualization expert navigating on demand for the participants, here the participants could also engage directly with the virtual globe model at the computer station (Figure 12).

1st research step: Quantitative rating of changes in awareness and understanding in the pre-/post questionnaire

The quantitative analysis of the pre-/post questionnaires handed out at the beginning of the public open house tested the levels of awareness and understanding of climate change impacts, adaptation, and mitigation with regard to self-assessed ratings. The response rate was rather high: 38 out of 46 participants filled in the questionnaires. Awareness was assessed by asking for different types of concern in the question: "*How concerned are you about the effects of climate change/global warming? (Please circle the number corresponding to your level of concern, from 1-5)*" In the corresponding matrix, five

***Figure 12:** Public house with posters and virtual globe computer station*

types of effects were distinguished with regard to the previous Geoide SII project (Shaw et al. 2009): Global and local effects, effects to local ecosystems, to the respondent`s family, to future generations.

Understanding was assessed in the question: "*How strongly do you think the link is between climate change and future land use development?*" The Wilcoxon Signed Ranks Test shows a significant increase in the awareness of climate change impacts for the local area in general, local ecosystems and future generations as well as an increase in the understanding of the link between climate change and land use decisions (Table 6). Only the awareness of climate change at a global level did not show a significant change. However, it should be considered that the level of awareness was already very high among respondents (average 4.89 out of 5 maximum), and there were no global examples in this particular public open house. Nevertheless, the level of concern about global impacts still outweighs the concern about local impacts – before and after the workshop (Table 6).

The quantitative questionnaire proves a significant increase in awareness and understanding of local climate change effects for the public open house. Only on basis of this rating, it is difficult to distinguish the specific influences of the scenario method, nor of the different media used in the process. For that purpose, the perceived benefits of the visualizations were rated and different media types were ranked in the second research step.

2nd research step: Quantitative rating of visualization benefits and ranking of visualization media types in the post questionnaire

The question is still open: Within the overall process, how helpful were the visualizations in general and the multi-dimensional visualization in the virtual globe in particular? For that purpose, the post questionnaire adds the following question: "If you were asked for your opinion on mitigation and adaptation strategies for climate change in Kimberley, would the visualizations you have seen help you?"

Ranking of different visualization media

The questionnaire also asked respondents to rank the different visualization media, i.e. 2D maps, posters, presentation and the virtual globe (Table 7). Respondents were asked to compare 2D maps, posters, Powerpoint presentation, and the virtual globe with the Kimberley 3D model as it was used in combination with the presentation by ranking them in the order from 1 (best) to 4 (last): "*During the open house, you saw various forms of visualizations. Please rank those visualizations, you have seen, in order of importance to you if you were involved in making a comment on a planning proposal.*" The ranking included n=38 responses including 2 invalid responses.

Descriptive Statistics	N	Min	Max	Mean	Std. Dev.	z (b)	Asymp. Sig. (b)
Changes in awareness							
Pre concern globally	36	4	5	**4.89**	.319		
Post concern globally	38	4	5	**4.89**	.311	-1.000a	.317
Pre concern locally	36	4	5	**4.56**	.504		
Post concern locally	38	4	5	**4.74**	.446	-2.449a	.014
Pre concern local ecosystems	36	4	5	**4.61**	.494		
Post concern local ecosystems	38	4	5	**4.79**	.413	-2.449a	.014
Pre concern family	36	2	5	**4.22**	.760		
Post concern family	38	2	5	**4.47**	.647	-3.532a	.000
Pre concern future generations	36	3	5	**4.69**	.624		
Post concern future generations	38	3	5	4.84	.437	-2.449a	.014
	38	na	5	3.84	2.188		
Changes in understanding							
Pre understanding of the link to land use	36	na	5	3.42	2.310		
Post understanding the link to land use	38	na	5	3.84	2.188	-2.345a	.019

a. Based on negative ranks. b. Wilcoxon Signed Ranks Test
***Table 6:** Self-assessed ratings of awareness and understanding of climate change before and after the workshop (pre-/post questionnaire)*

	Frequency (n=38)	Valid Percent
1. Of no help	2	5.3
2. Not of much help	1	2.6
3. Neither helpful, nor unhelpful	1	2.6
4. Helped me a little	11	28.9
5. Helped a lot	23	60.5
Total	38	100.0
Mean	4.370	
Std. Dev.	1.051	

***Table 7:** Rating of the visualization benefits*

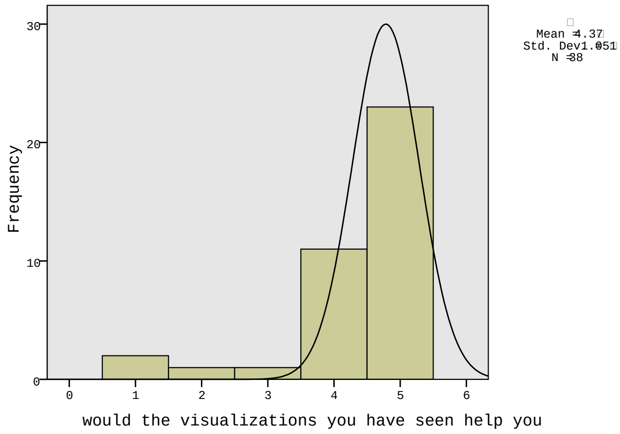


***Figure 13:** Rating of visualization benefits (1= of no help, 2= not of much help, 3=neither helpful, nor unhelpful, 4= helped a little, 5=helped a lot)*

Most interestingly, the virtual globe was ranked first 16 times and ranked last 11 times, showing a bimodal distribution. The posters were ranked first 12 times and only once ranked last. Therefore, they achieve a higher mean overall. However, the median is more meaningful for ordinal rankings and both posters and virtual globe achieve medians of 2. Interestingly, the 12 respondents who ranked the posters first, in average ranked the virtual globe fourth (mean of their globe rankings = 3.083, median = 4, std. dev. = 1.165). This result implies that respondents, who liked the posters, reject the virtual globe. In contrast, respondents, who liked the virtual globe, also like the posters: Posters achieve a mean of 2.125 and a median of 2 with std. dev. of 0.5. Considering that the posters presented more information at once whereas virtual globe users had to explore the information through interaction, a possible explanation could be that respondents who like the posters have a non-interactive learning style. On the other hand, virtual globe users who preferred to explore the information interactively also liked the poster in average. Unfortunately, the valid sample (n=38) is not big enough to distinguish these group differences and possible distinctions with regard to age, gender or profession in further detail.

	N (valid)	Min. rank	Max. rank	**Median rank**	Mean	Std. Dev.
Posters	38 (36)	1	4	**2**	1.94	0.826
Virtual globe	38 (36)	1	4	**2**	2.19	1.305
Presentation	38 (36)	1	4	**3**	2.83	0.775
2d maps	38 (35)	1	4	**3**	2.86	1.167

Table 8: *Medians and means of ordinal rankings of different media, n=38.*

The graph in Figure 14 shows the bimodal distribution for the virtual globe, indicating that people either liked it most or they did not like it least. Therefore, although a virtual globe was favoured by a large proportion of respondents, an additional presentation form is needed to meet the learning styles of all respondents. In comparison, the average ranking of the posters was very good, making them a suitable complement to the virtual globe.

Ranking of navigation metaphors

The comparative ranking of different visualization media shows that the multi-dimensional virtual globe did have a significant role for a particular group of respondents. With regard to the mediated virtual globe presentation, respondents were also asked to rank the different navigation types: "In Google Earth, you had the opportunity to use various features of interaction. Please rank the features in order of importance to you if you were involved in making a comment on a planning proposal." The question was illustrated with sample pictures of the navigation type. The results show the following distribution:

The ranking gives a first impression how respondents assessed the importance of the multi-dimensional navigation metaphors in comparison to each other. Please note that these values are not absolute, i.e., the popup information that is ranked last, could still achieve high absolute ratings. However, it is seen as less important than the other navigation metaphors which is consistent to previous findings in Schroth (2007). Again, the significance of mean values is limited, but the median ranks of all fly-through, layer and time slider features are all rather high which indicates that multi-dimensional navigation does have an impact.

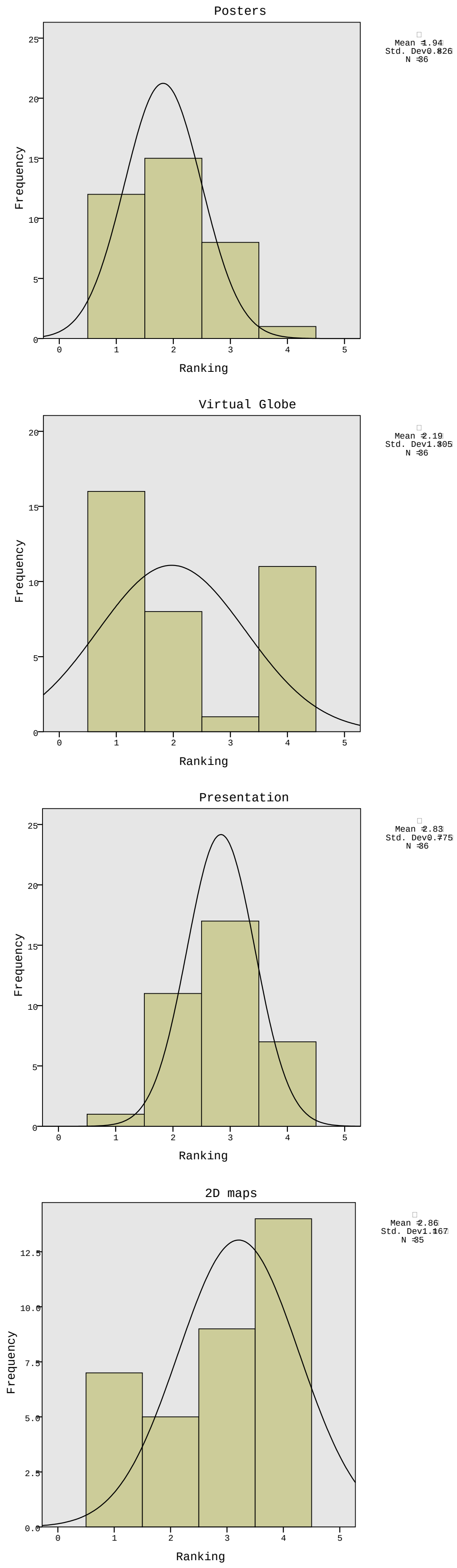


Figure 14: *Ranking of different visualization media*

	N (valid)	Min	Max		Mean	Std. Dev.
Fly-through (spatial nav)	38 (32)	1	4	**2**	2.09	1.027
Layers (thematic nav)	38 (31)	1	4	**2**	2.26	1.210
Time slider (temporal nav)	38 (33)	1	4	**2**	2.39	1.088
Pop-up (indicator charts)	38 (30)	1	4	**3**	3.03	0.964

Table: 9: *Medians and means of ordinal rankings for different navigation metaphors, n=38.*

summary, the findings that respondents self-assess an increase in understanding and that they rate the visualization benefit as rather high and that they rank the virtual globe as an important medium indicate that the virtual globe does have an impact on understanding. The comparison of different navigation metaphors indicates how effective which metaphor is in comparison but a more detailed qualitative analysis is required to build explanations. After these quantitative rankings, the detailed relationship between multi-dimensional navigation and understanding is now analysed qualitatively in the third step.

3rd research step: In-depth qualitative interviews with virtual globe users

In the following chapter, the results from the content analysis are presented. These results are based on the coding of the open questions in the post questionnaire (n=25; 25 out of 38 respondents added comments in the open question sections) and the qualitative in-depth interviews (n=17) with virtual globe users. For this purpose, both KCAP and CALP parts of the questionnaire are included in the analysis. First, the controlled variables are summarized, discussed and interpreted. The focus is on the second part: The verification of the hypothesis on spatio-temporal understanding through multi-dimensional navigation. The analysis is done through pattern-matching for the independent variables (multi-dimensional navigation) and the dependant variables (understanding of spatio-temporal climate change options).

The following terms are introduced: “Respondents” refers to people quoted from the questionnaire and “users” to people quoted from the in-depth interviews at the virtual globe station. Sources of evidence are coded by giving the number of the document and the line(s) with the referred quote. Example: 4:108 refers to line 108 in document 4 (document 3: presentation and public discussion; 4 and 5: virtual globe interviews / observations; 13 KCAP debrief meeting; 14 open questionnaire comments).

Controlled variables:
Scenario process, setting and presentation

- Accessibility
- Scenario process
- Setting
- Presentation and use of different media

Previous case studies of 3D visualization use in planning settings have shown that the effectiveness of the visualization input depends on both visualization as well as context (Schroth 2007). Although the real planning situation does not allow controlling the variables as strictly as it would be possible in a laboratory experiment, controlled variables can be tracked for the context by coding transcripts and questionnaires. The controlled variables describe the context of the visioning setting and process. The overall participant feedback from the open questions in the post questionnaire and the qualitative in-depth interviews with virtual globe users are consistent in the description of the controlled variables:

Accessibility

It has to be considered that most participating users were mainly stakeholders with an above average computer literacy and three stated that they have used Google Earth or a GIS before. After a facilitated introduction, only one out of 13 users directly interacting did not feel confident navigating in the virtual globe. Anecdotal evidence seems to support an interest of people in using the Kimberley 3D model in virtual globes online.

Scenario process and setting

25 out of 25 respondents found the information presented useful. Asked in an open question, which aspects they liked in particular, 18 respondents referred to the presentation and visualizations, 5 to the interactive dialogue, three to the balance of future scenario options and two to the overall atmosphere of the setting. The feedback shows that the visualizations do have an important impact in comparison to other context factors – which is consistent to the quantitative ranking of different media in research step 2. However, when asked for suggestions for improvement, four respondents criticized the public open house format and wished a more interactive participation setting.

Presentation and use of different media

In general, respondents acknowledged the high amount and variety of information. For example, one respondent wrote that he particularly liked the ”amount and quality of information“ (respondent 14:27). The feedback indicates that the presentation of the information and visualization, i.e., the mix of presentation, scientific posters and virtual globe station, the verbal explanations and the overall setting and atmosphere, is very important for enhanced understanding – which is consistent with standard learning literature (Issing and Klimsa 2002).

Data

The transcripts show that respondents asked about data sources and underlying assumptions of the visualizations to verify their plausibility. Again the use of technical posters, rather than the more limited pop-ups, can ameliorate the data source and assumptions limitations within virtual globes. These findings are supported in the literature: Sheppard and Cizek (2009) define validity and reliability as key criteria for data.

3.3 Multi-dimensional navigation and understanding of spatio-temporal climate change impacts and alternative adaptation and mitigation options

In the following chapter, the research hypothesis that "multi-dimensional navigation, defined as the combination of spatial, temporal and thematic navigation, facilitates the understanding of spatio-temporal climate change impacts and alternative adaptation and mitigation scenario options in planning" is verified through pattern-matching for independent and dependent variables.

Independent variables

Multi-dimensional navigation was implemented through movement, fly-through, zoom, time-slider and layers as navigation metaphors. They are part of the following independent variables:

1. Spatial navigation (move, fly-through, zoom)
2. Temporal navigation (time slider)
3. Thematic navigation (layers)

Dependant variable

Spatio-temporal understanding of climate change is divided into:

1. Spatio-temporal understanding of climate change impacts and risks
2. Spatio-temporal understanding of future climate change projections
3. Understanding of alternative adaptation and mitigation options (scenarios)

Spatial navigation and orientation

In order to choose different views, **orientation** is crucial. Various landmarks are mentioned in the transcriptions. It is particularly interesting that two stakeholders orientated with regard to the non-visible (in the real world) administrative features such as the city boundaries and watershed boundaries. It should be noted that both stakeholders work with planning documents and therefore are familiar with these administrative features. After summarizing and abstracting all landmarks identified by users, the following types of landmarks (Figure 15) can be distinguished:

- Topographic features (creeks, mountains, ski hill)
- Built structures (city districts)
- Linear built structures (roads, trails)
- Administrative boundaries (city boundary, watershed boundary)

Twice, users as well as CALP team members got lost in 3D space because the handling is sometimes cumbersome and there are few navigation constraints embedded. Therefore, the navigation usability of the used virtual globe could still be improved through smart navigation (cf. Döllner 2005). However, the virtual globe provides bookmarks which could enable re-orientation within the virtual globe when a user 'gets lost'.

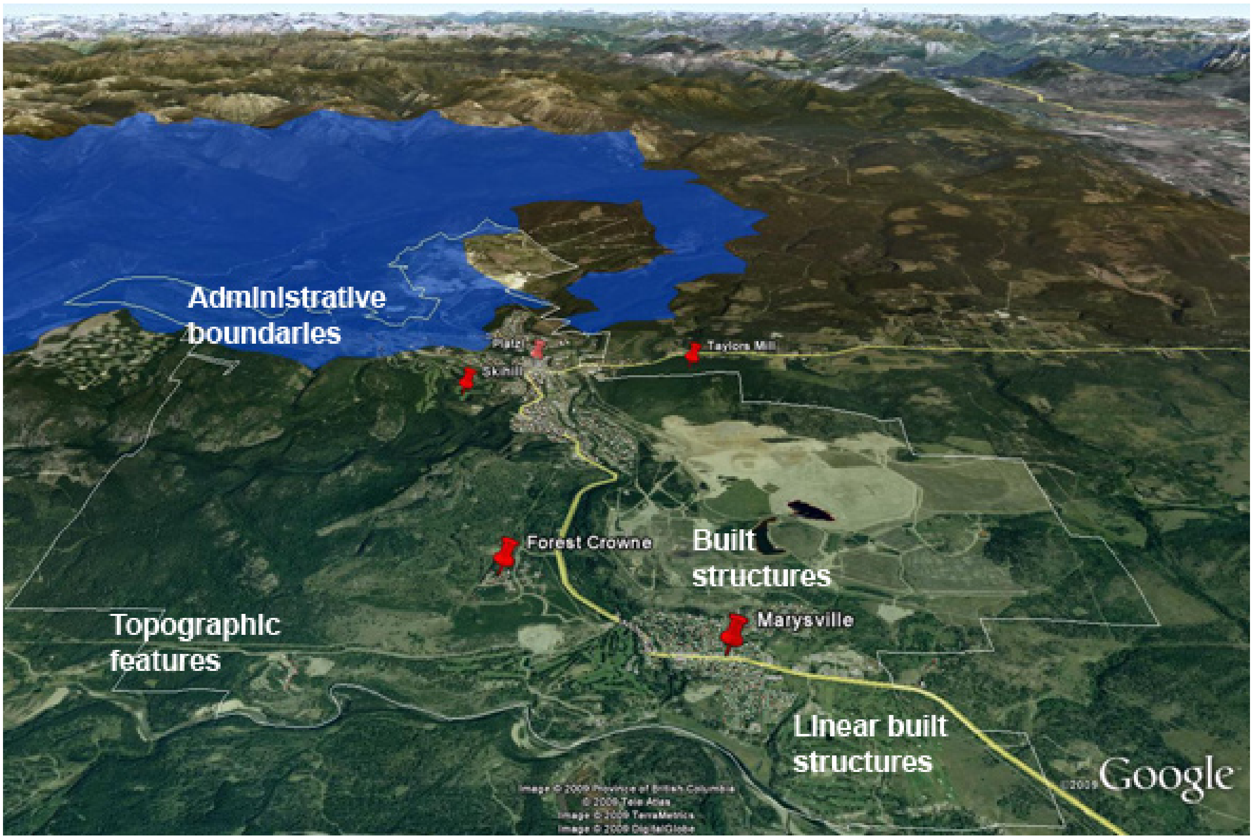


Figure 15: Orientation landmarks

Understanding and taking a new perspective

In the post questionnaire, 25 out of 25 respondents approved that they found the presented information useful. In the open comments, 11 comments were related to the understanding of climate change impacts („Helped me understand impacts regarding things like pine beetle, forests [...]“ (respondent 14:73)). Three comments particularly referred to climate change risk assessment.

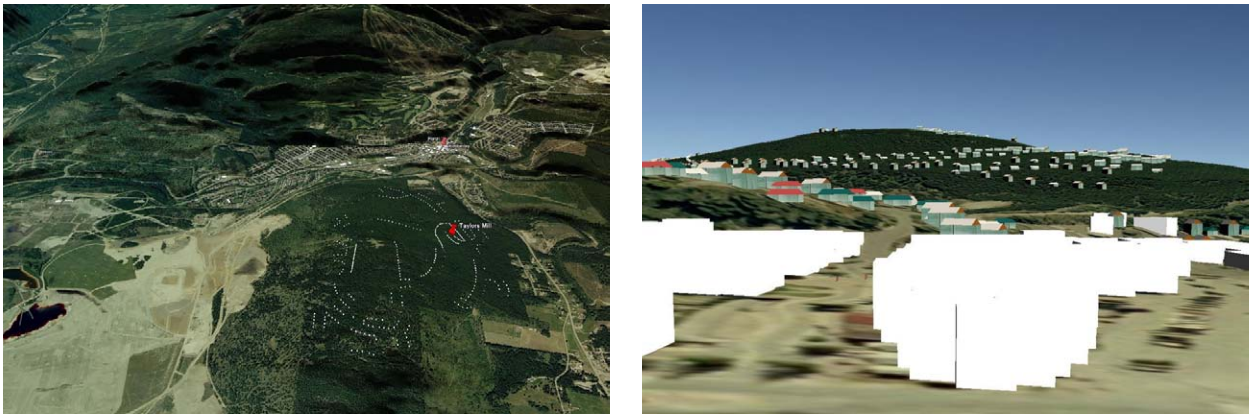


Figure 16: Different perspectives of the Taylor`s Mill development – overview (left) and perspective from the Platzl (right)

The content analysis of video and audio transcriptions provides multiple evidence how users navigate: Spatial navigation (move, fly-through, zoom) is used to select specific perspective views, e.g., the view of the watersheds north of Kimberley, seen from the town centre, the view of the proposed future development on Taylor‘s Mill (Figure 16), or to zoom into the details of the adaptation plan. One user described the use of spatial navigation: „coming at it from different angles from that birds-eye view, you know. It would be so helpful sometimes. Just to understand how it fits into the larger picture“ (user 4:741).

The in-depth interviews with the virtual globe users support the assumption that the multi-dimensional visualization helped users in understanding climate change impacts and risks. Some users who used the virtual globe, referred to topographic features and estimated area size on basis of the model. Two users said that the visualizations provided them with a „different perspective“ (user 4:767), which makes them a helpful tool for locals who know the area very well.

Expectations were high that the globe metaphor could also link the global perspective of climate change with the local (Craglia et al. 2008). In contrast, qualitative feedback indicated that the globe metaphor and the zoom from global to local scale might even alienate and disempower people. People might end up feeling small in the face of global climate change: “We maybe just a little speck on Google Earth but we can’t wait for the rest of the world to catch up” (respondent 14:187). On the other hand, this quote could also be interpreted in a proactive way that the user does not feel disempowered but instead he wants to act locally so that his community becomes a global best practice precedent. The validity of the findings about the impact of global to local zoom is rather low and the findings are open to interpretation. However, it is seen as very important to investigate such a possible bias. Therefore, a quantitative experiment focussing on the global to local zoom is recommended.

Spatio-temporal understanding of climate change risk assessment

Flood mapping based on the 1999 Flood Risk Assessment Study for the City of Kimberley was digitized in GIS, and exported to Google Earth. The thematic navigation through layers and overlay of different layers allows the Mountain Pine Beetle susceptibility to be visible at the same time. Viewers can thus understand potential risks, such as increased downstream flooding, from climate-related deforestation in the watershed. The zoom function (spatial navigation) highlighted certain areas of interest such as the Kimberley downtown area in Figure 17.

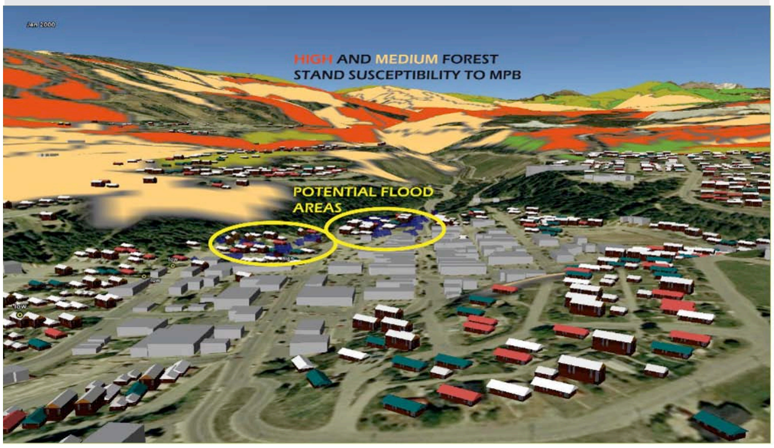


Figure 17: The zoom function and overlay of climate change related mountain pine beetle (MPB) susceptibility on flood risk areas.

The video recordings and transcriptions show that the users started asking detailed questions about the represented risks - which indicates that they understand the risks in the first place. For example, one user wanted to know if there were a fire in the watershed, how quickly it would spread, how that would affect the town's water supply and how serious that risk might be. However, another user might have misunderstood the model because he saw a decreasing risk in flooding due to climate change - an assumption that is not deliberately included in the model.

Thus, the multi-dimensional representation seems to facilitate the understanding of risks (see the later analysis of risk assessment over time) but is limited by the underlying models and open to misinterpretation. It will be a task for further research to improve the links between models and visualization in climate change risk assessment. The possibility that users will misinterpret the data being represented suggests that public use without guided facilitation and data contextualization, may not be desirable.

Spatio-temporal understanding of density, greenhouse gas emissions and resilience

The spatio-temporal interrelations between the proposed future urban development (visualized as current buildings and future residential build-out), increasing GHG emissions (visualized as an indicator pie chart) and resilience (visualized as overlay with 3d risk maps) are worth a closer look. The CALP team anticipated that the large scale of the proposed development, mainly consisting of large single-family homes with high GHG emissions and in potentially vulnerable areas, would draw major attention. In contrast, the stakeholders in the previous workshop showed surprisingly low interest in the topic, despite the clearly articulated link between such developments and strong increases in community GHG emissions. One key stakeholder didn't see any links between land use, density, GHG emissions, climate change and resilience. Kimberley currently is using land use development as a key economic driver locally, and this may be partially responsible for the blinkered vision about sprawling developments and GHG emissions; as well, other immediate risks and climate impacts presented in the Open House were clearly resonant with the public (see fire discussion below), and seemingly of more immediate concern to users.

On the other hand, during the in-depth interviews at the virtual globe station, the users did refer to land use, urban form and density, indicating that these users did see the connections. The users successfully compared different densities of the existing rather dense community and the proposed low-density future build-out of Taylor's Mill (shown in Figure 16), they overlayed risk maps and development zones, looked at the open space and vegetation and assessed the (lack of) walkability in the new development areas. In summary, the transcriptions indicate that the multi-dimensional representation can facilitate the assessment of different development patterns and density, GHG emissions and resilience indicators, but is limited through other conflicts of interest.

Spatio-temporal understanding of future climate change projections

In the post questionnaire, 11 out of 25 respondents refer to future phenomena. The post questionnaire also shows that the time slider navigation metaphor was well received and seen as influential. These findings are consistent with the observations that time animations of the fire spread model and the fire seasons changing over time caused considerable emotional and verbal response when they were presented during the public open house. The time slider was mainly used in combination with the fire spread model and, to a lesser degree, with the development plans for Forest Crowne and Taylor's Mill, and the mountain pine beetle susceptibility cycle (Figure 20). These themes have very different time scales: 8 hours for the fire spread model and up to 100 years for urban development and mountain pine beetle cycle.

Time sequencing was used for the development plans as well as the fire mapping. A FarSite fire model developed by the City's fire consultant was exported from GIS to Google Earth, and then had a time slider applied in order to show time sequences in hours for a potential fire threat. Using the animation during the virtual tour resulted in a visible and audible reaction from the users at the Open House. When the current regional MPB susceptibility layer is added, the potential fire risk to the community, barring adaptive actions, becomes very clear.

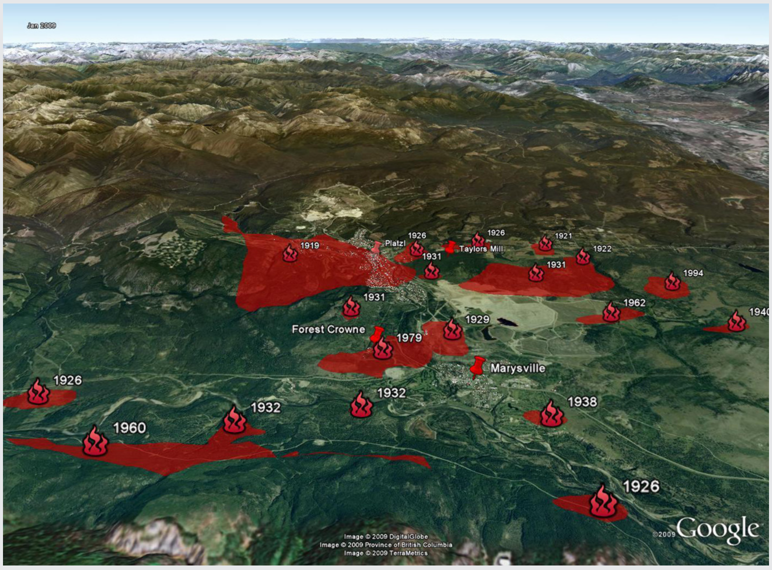
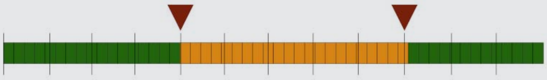
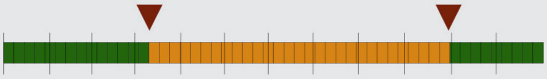


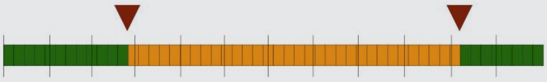
Figure 18: *Historic fire maps (Gray 2009) were exported from GIS into Google Earth as part of the "virtual tour".*



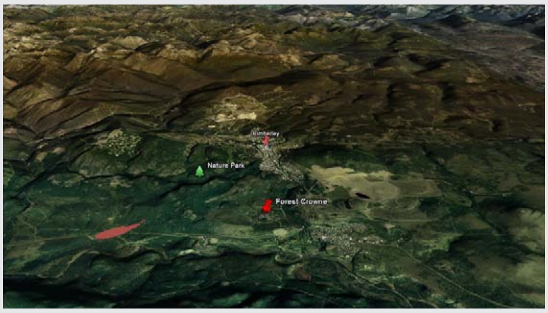
Fire Seasons 2009



Fire Seasons 2040

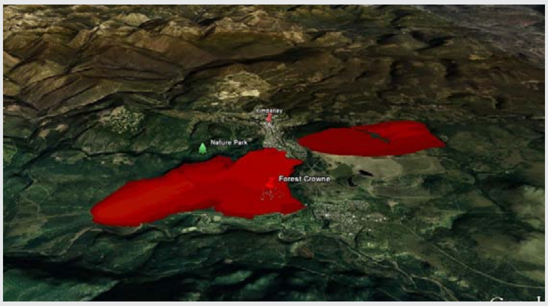


Fire Seasons 2080



1 hour after ignition

3 hours: First evacuation exit is cut off



8 hours: Second evacuation exit is cut off

Figure 19: *The progression of the Farsite fire spread model showed how fast a possible forest fire with an ignition point southeast of Kimberley will spread. The animation was accompanied by an animated graph showing how the fire seasons will extend because of climate change.*

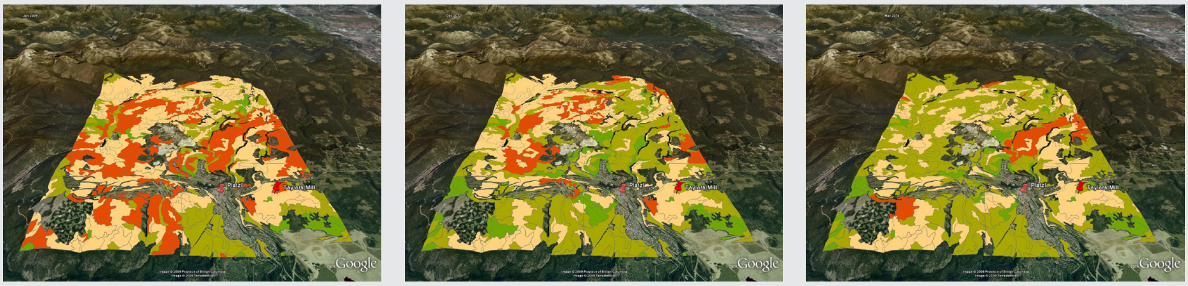
User quotes support the observation that the time slider can be very powerful. As one stakeholder expresses it, „... around this time because I mean even myself will be very old (laughing). You know it definitely provides more dramatic effect. [...] you know there's probably going to be way more development" (user 4:107). Overall, observations and respondent feedback both suggest that the time collapsing animation of the forest fire spread model was a **key moment** in the public open house and had the highest impact. Several respondents referred to the fire spread animation and exemplary, one councillor reported in personal communication that: "Fire viz was most powerful – could feel it in the room"(councillor: 13:087). The time collapsing animation of the fire spread model was the moment with most **emotional impact** and the audio record indicates major unrest in the audience for that moment.

For future research, the **link between models and visualization** appears to be of specific importance. Basing visualizations in scientific modeling means that the visualizations not only gain in information value but also that they are better able to communicate scientific data. In two cases, the data presented in the visualizations had already been presented to the City Council and other publics by scientists: the fire season extension under climate change, and the fire spread model. Neither case led to emotional and cognitive responses, nor to changes in planning practice, – indeed, the data (in the case of fire season extension) seems to have been forgotten, while anecdotal evidence from multiple sources suggests that the fire model was not being taken seriously within the local community. In contrast, the CALP fire visualizations have already been incorporated into local and regional fire planning processes, and are being used as an extension tool for fire smart education. Lastly, the link between models and visualization has a very critical component: visualizations can provide a powerful validation of the models.

However, according to Sheppard and Cizek (2009), the use of **drama** requires very careful handling. In this case, the visualization was based on a well-situated fire spread model and it was accredited by the chief fire consultant of the city. The feedback of the virtual globe users was very positive as well: "The forest fire one I thought was really great"(user 4:151). However, the following quote shows that it did have a high emotional impact that might easily evoke fear: "Ya´cause I mean the fire models have my house destroyed in like 8 hours"(user 4:001). Further fire material in the form of a second technical poster has since been prepared for the City and the Fire Chief that illustrates the City's fuel management plan and firesmart solutions for homeowners, as the dangers of showing risk and vulnerability alone, without solutions, was determined to be unethical by the CALP team (the posters are attached to this report).

Understanding of different temporal phenomena and time scales

It has been noted that **different temporal phenomena** and **different time scales** need to be distinguished. "Many risk assessments require a simple method for evaluating the frequency of events as an essential part of the quantification" (Calow 1998: 106). **Frequency** (historic forest fires) is one temporal phenomenon, another one is **progression** (fire spread model, urban development). While fre-



2009 2030 2070

Figure 20: *GIS mapping was moved into a virtual globe to enable 3D interactive visualizations with zoom function, time slider and layers. These images show current and future Mountain Pine Beetle susceptibility maps for the forests surrounding Kimberley. The dark orange shows high susceptibility, while the light orange shows medium susceptibility. The green areas are low or very low susceptibility. Because pine stands older than 80 years show the highest level of susceptibility, infestation is likely to take place as a cycle as shown in the time series. Susceptibility was modelled based on the amount of pine in the stand, the age of the pine, the density of the stand, and the stand's location (Shore and Safranyik 1992, updated by ILMB 2006); GIS data supplied by the BC Forest Service.*

quency was visualized in a static map (Figure 18), progression was interactively animated with the time slider function (Figure 19). Both visualizations were understood correctly as the transcriptions show, although the time slider animations were more dramatic. In summary, the time slider navigation is a very powerful tool that supports the understanding of climate change impacts while adding drama in comparison to maps.

More research is needed how different spatio-temporal phenoma such as progression and frequency of events require different visualization approaches. Another future research question is to ask whether the collapsing of a long-term time scale such as 100 years evokes as much response as collapsing a short-term time scale. The literature such as Moser and Dilling (2004) suggests not; however, such detailed differences require further testing.

On the other hand, the use of an extremely long-term time scale (2001+) for the visualization of species change in forest landscape helped coping with the embedded uncertainties. Although the representation is photo-realistic (Figure 21), users realized that the scenarios are only possible futures with many uncertainties: "Somewhere in the far future. [...] No one knows, ya" (user 5:47-59).

Understanding of alternative adaptation and mitigation scenarios

It is a key part of CALP's Visioning Process that adaptation and mitigation options are examined together. For that reason, understanding is analysed for both options together as well. The post questionnaire shows that 13 out of 25 respondents comment to the adaptation and mitigation options. All comments about the visualization of
It may be suggested that there is a link to the scenarios which incorporate both not only negative impacts but also adaptation and mitigation options. Again, distinguishing between the impact of scenarios, and the impact of visualizations, is difficult. The emotive reaction of hope to visualizations, as well as its potential to generate action (implicit in Moser and Dilling 2004) remains a further research question. Another respondent stated that what he liked about the

Figure 21
The open source virtual globe Biosphere 3D was used to show realistic renderings of potential climate change impacts on forested lands northwest of the community, along the main drinking water creek. As the Biosphere3D software specializes in realistic representations of forest stands based on GIS vegetation data, it was used to illustrate plausible climate change impacts on the visual landscape. This scene shows what projected fire damage, species changes, the shift to grasslands, and the return of pests and diseases might look like by 2100 and beyond (Kimmel 2009, Gray 2009). The first image shows forest stands with high densities and no beetle infestation or forest fire as it looked like over the past years. Due to already severe beetle infestation and high risk of forest fires, both enhanced through climate change, major changes are predicted. The second image shows a possible landscape if only minor adaptation and mitigation measures are taken. The third image shows a possible future in the case of major adaptation and mitigation measures.

adaptation and mitigation options were positive and assessed as "helpful". This result is even more significant as adaptation and mitigation options took only 35% of the presentation time. Particularly popular (4 positive comments) was the location of a solar farm on an industrial brownfield site (Figure 22). Feedback from key stakeholders (participating experts 13:33, 13:49) indicates that the level of complexity was rather high – which was one goal not to oversimplify the climate change issues and options. On the other hand, some users might have felt overwhelmed by the options and the necessary decisions: "maybe people were overloaded with content" (expert 13:31).

Four people specifically pointed out that having positive choices is important for them. The visualizations seem to have communicated the adaptation and mitigation options in a comprehensible way. Even **hope** - a positive emotion which is not documented in the literature on visualization impact yet - was expressed by two users.

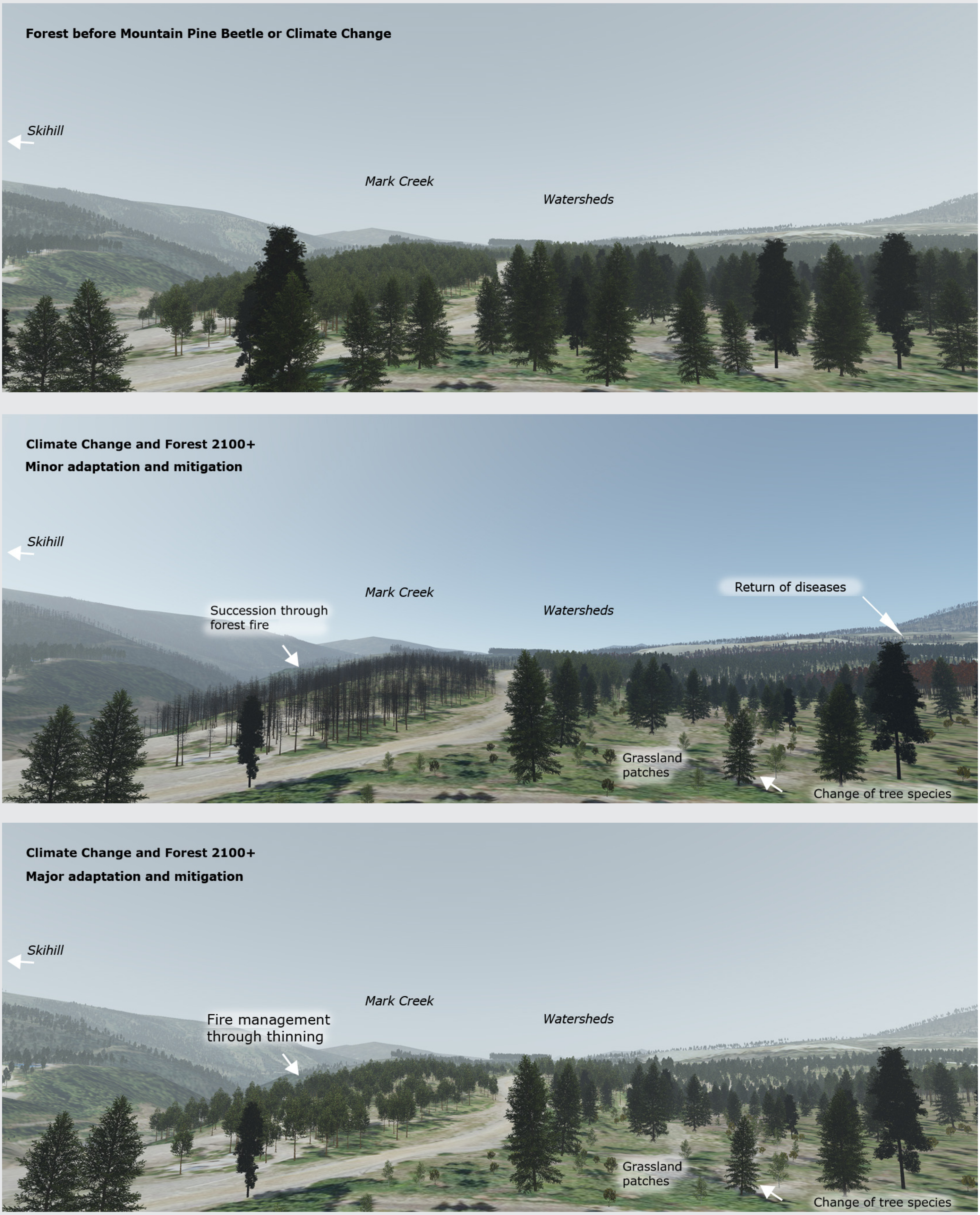


Figure 21*: Possible climate change impacts for Kimberley forests in 2100+ (Schroth 2009 with thanks to Paar, Schliep and Ernst from the Biosphere3D community)*

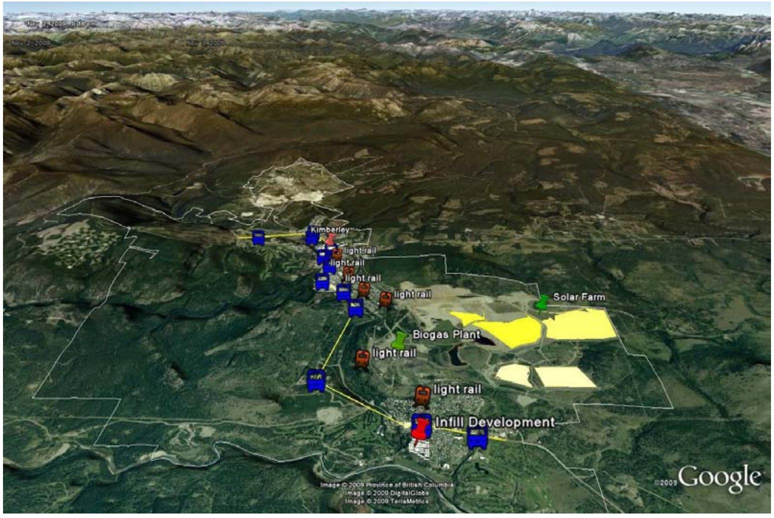


Figure 22: *Low-carbon Kimberley scenario – Solar farm (yellow area)*

Figure 23: *Low-carbon Kimberley scenario – Green Ribbon Vision, zoom into details of the build-out (Miller 2009)*

workshop was that "it was positive and not full of gloom and doom," (respondent 14:47) suggesting both that users expect climate change workshops to be negative, and that generating hope for the future may be a useful outcome of climate change visioning that incorporates scenarios and visualizations.

It may be suggested that such a process, including the multi-dimensional visualizations as key element, can initiate a change of behaviour. Two respondents declare their intent to change behaviour as a consequence of this workshop: "That I need to be part of the change, not only locally but globally. 'Do my part.' Use more solar energy"(respondent 14:105). "It helps me understand future impact of climate change and ideas for mitigation. Will also help me change behaviour to mitigate / change where I can"(respondent 14:79). Declarations of intent were also given by two City councillors who said that the Council will address climate change in its policy (councillor in the public discussion 3:54; councillor 13:106). However, it will require a long-term study such as GEOIDE IV-32 to verify the hypothesis that 3D landscape visualization can initiate a change of behaviour.

3.4 Dissemination materials

The GIS database, posters and digital images have been made available to the City of Kimberley staff. The GIS database in particular represents a strong planning tool for the City moving forward, as it has not had GIS planning support prior to CALP and SNSF involvement. On September 28 and 29, 2009, CALP hosted a workshop where all spatial data as well as analyses of the process and visualization tools were passed to Selkirk College, which is located in the Kootenays and is the GIS educational partner for the local communities. CALP will be producing a report for the Real Estate Foundation on the Visioning Process for Small Communities, as well as an extension Guidance Manual for Local Communities, which will cover the visioning and visualization methods used, and research findings, available in early 2010.

CALP collaboration with the City of Kimberley, whose Mayor, Councillors, staff and residents have demonstrated a strong commitment to climate change and progressive City planning, will continue. Next-step projects could work on integrating landscape-scale forest fire fuel management options with mountain pine beetle responses and biomass-fuel production in order to plan and visualize integrated landscape responses. Joint planning across jurisdictions (Municipal, Crown Land) may enhance community adaptation options. The presentation material is also going to be used in the next set of local climate adaptation projects funded through the Columbia Basin Trust, and contribute to the toolkit for climate change visualization used by the BC Ministry of Community Development. The City of Kimberley will be using the material to further public awareness of and support for climate change initiatives, as well as in local planning initiatives such as the Integrated Forest and Fuel Management Committee, and possibly the OCP (Official Community Plan) review process in 2010/2011. In the Kootenays and beyond, the City of Kimberley may become a best-practice precedent in climate change adaptation and mitigation, facilitating other small peri-urban or rural communities to plan for climate change as well.

Products from the Kimberley project include:

- an annotated Powerpoint presentation for use in other communities
- a set of 10 posters
- a set of animations, including stand-alone short movies illustrating different impacts or response options
- a Google Earth model
- GIS inventory for the City of Kimberley
- a chapter in the Kimberley Climate Adaptation Project's Final Report and Recommendations to the City of Kimberley, July 2009
- a September update report for provincial funders and stakeholders
- Real Estate Foundation Report (still to come)
- Guidance Manual (still to come)
- SNSF report
- Publication in journal papers (still to come)

3.5 Knowledge transfer to communities in Switzerland

Although some of the themes in the Kimberley Climate Adaptation Project are similar to current issues in Switzerland, e.g., mountain pine beetle infection, crisis of winter tourism in the face of climate change, the transferability of thematic details is limited. The planning law is different, geo-climatic zones are different and even the local mountain pine beetle species is different from the one in Switzerland. However, it was noted that showing examples in Kimberley of how a Swiss community has dealt with climate change impacts gave the community a sense that it is not alone in facing ongoing climate challenges – and networking across international boundaries by small communities may enhance their climate change planning and implementation over time.

In contrast to the themes, the visioning method and multi-dimensional navigation are transferable to climate change related planning in Switzerland. The scenario method is becoming increasingly popular in European and Swiss spatial planning, and the European Environment Agency EEA (2009) suggests to use it in combination with climate change scenarios as well. Virtual globes are universally accessible tools and the visualization methods are transferable, too. It would be preferable to have comparable case studies in Switzerland to increase the overall replicability of this study. The dissemination materials of this project (see the list in the previous paragraph 3.4) will be provided to the SNSF and through the institute website so that interested communities can benefit from the knowledge transfer.

3.6 Technical limitations

Some technical limitations of the virtual globe, in this case Google Earth, have been identified: First, views are incomplete because of the lack of vegetation. This becomes particularly acute when attempting to show impacts that change vegetation, particularly in small, relatively rural, forest interface communities. Second, spatial navigation could be improved by incorporating smart navigation constraints. However, the bottleneck is not the visualization frontend but the underlying data and models. For that purpose, new research proposals addressing the downscaling of climate models are planned together with PCIC.

3.7 Limitations of the visioning process

It should be noted that the virtual globe tool is part of the overall visioning process and its benefit depends on the topic, on the selection of participants, how people can participate, and how well the local planning process is run, etc. In this case study, the collaboration between external experts, who synthesize global and regional climate models, and local working groups, who assess local impacts and adaptations, was fruitful and led to better local and regional data on current conditions and impacts such as fire and mountain pine beetle. It proved practical to develop visualizations in a participatory process and to incorporate iterative feedback to fine tune the different pieces for the final presentation. Without the local stakeholder feedback, the final results would have been less robust, and likely less accepted by the public, city officials, and city staff. Finally, the scenario narrative is crucial: It is on basis of the multi-dimensional scenario narratives (Figure 2) that the data can be structured in a way it can be explored through multi-dimensional navigation tools.

3.8 Limitations of the research method

The study is subject to the typical limitations of exploratory research and its limitations in validity and replicability. On the other hand, only an exploratory approach made it possible to gain insights into a real planning process in a rural mountain community in British Columbia. Only on this basis, it was possible to formulate research questions for further explanatory research. Three research steps were conducted to increase the validity of the case study:

1. Comparison of pre-/post questionnaires – Analyse changes in awareness and understanding
2. Rating of visualization benefits and ranking of different visualization media in the post questionnaire – Determine the role of the visualizations in the process
3. In-depth user interviews with participants interacting directly with spatio-temporal scenarios in a virtual globe – Investigate how multi-dimensional navigation facilitates understanding

Validity

The first two research steps are quantitative and provided some statistically significant results on changes in understanding in general and rankings of the different media. In the quantitative part, the ranking of different visualization media could be improved in an experimental setting through a clearer distinction between the different media. In this case, the participation process required that the presentation contained some visualization as well and the posters also included some 2D maps and static 3D images.

The qualitative third part was important to explore the underlying causal chains between multi-dimensional navigation and spatio-temporal understanding. The validity was ensured through a deductive research design starting with a quantitative survey preparing the detailed investigation in qualitative interviews. Furthermore, multiple sources of evidence were collected and triangulated in the analysis (data triangulation).

Replicability

Each community is unique and the context of the participation process and the selection of participating stakeholders is also influential on planning process outcomes. However, the findings are consistent with other literature findings on visualization and participatory processes, such as Tress and Tress (2003); Nicholson-Cole (2005), Hehl-Lange and Lange (2005), Dockerty et al. (2006), and Salter and Campbell (2009). Therefore, it is suggested that a similar setup in a different geographic context is likely to have similar outcomes – 4D visualization using multi-dimensional navigation in virtual globes to overcome spatio-temporal issues in communicating climate change impacts and planning options can enhance participant understanding of issues and options facing their local community. The next research step will be to test whether outcomes can be replicated in a multiple-case study and the CALP Geoide PIV-32 project offers an opportunity to implement such a multiple-case study.

4. Discussion

The results verify the hypothesis that multi-dimensional navigation facilitated spatio-temporal understanding of climate change scenarios in the Kimberley case study. Multi-dimensional navigation was particularly helpful in combination with climate change risk assessment and as part of the scenario method. On this basis, recommendations for planning practice and open questions for future research are formulated.

The Kimberley case study shows that real opportunities exist to explore and plan for a future, resilient community in the face of climate change. If the interrelations between climate change impacts, mitigation and adaptation scenarios are communicated within a participatory process, the stakeholders can become aware of and deepen their understanding of climate change impacts, adaptation and mitigation options, and the opportunities for synergies across adaptation and mitigation.

The results from the quantitative questionnaires support evidence that multi-dimensional navigation facilitates public awareness of local climate change impacts and increases the understanding of links between climate change impacts and resilience, particularly for people who respond positively to virtual globes. This indication is confirmed and explicated through the qualitative in-depth interviews with virtual globe users. All sources of evidence together, that is, both quantitative questionnaires and qualitative interviews, verify the hypothesis that multi-dimensional navigation can facilitate the understanding of spatio-temporal climate change impacts and alternative adaptation and mitigation options in planning. There is also evidence supporting the rival hypothesis: Some technical limitations are reported and the bimodal ranking of the virtual globe indicates that some user groups assess multi-dimensional navigation as less beneficial than others. In summary, there is more support for the hypothesis that multi-dimensional navigation facilitates understanding; however, such tools should be used in a learning context that facilitates all learners, including those who respond negatively to virtual globes and multi-dimensional navigation, by including other media to communicate impacts and planning options.

The key findings from the research are that: First, multi-dimensional navigation **makes the complexity of climate change comprehensible** to many users, provided that spatio-temporal systems are communicated in an integrative way with a scenario narrative (cf. chapter 1.1 and Figure 2).

Second, spatial navigation is used by stakeholders to select **individual perspectives**. In this, the results are consistent with the literature (Danahy 2001, Orland et al. 2001). However, there are indications that **the globe metaphor can also alienate users**. If users are exposed to the global level of climate change, they may feel disempowered and helpless. It is strongly suggested to further investigate these negative implications of the globe metaphor and its related zoom navigation.

Third, and in comparison to previous visioning processes with static 3D-visualizations, multi-dimensional navigation adds the possibility to create different time-lapses. The study shows that temporal navigation **facilitates the understanding of spatio-temporal processes although it adds drama**. In the Kimberley case study, the wildfire spread had an important (short-term) time factor whereas build-out, mountain pine beetle cycles and snow level rise cover very long time spans. These processes of change became more apparent through the time slider feature.

Fourth, the layer concept made it possible to **distinguish alternative scenario pathways** or to overlay diverse climate change impacts and development patterns. The data supports that planning stakeholders appreciate having choices and they assessed the multi-dimensional visualization of adaptation and mitigation options as very positive. In two cases, there is evidence that positive emotions such as hope were evoked. On the other hand, too many choices and options may impose cognitive costs. Therefore, it is suggested to apply the technology as part of a wider scenario building process only.

4.1 Future Research

This is an exploratory study of the benefits of multi-dimensional navigation for the understanding of complex climate-related issues in a real-world planning setting. The findings give evidence for benefits and limitations for the use of multi-dimensional navigation in climate change risk assessment. However, due to the explorative nature of the study many new research questions were raised and it is suggested to address these questions in follow-up multiple-case studies and more detailed quantitative experiments. Here, the Geoide IV-32 project and the SNF Fellowship for Advanced Researchers provide great opportunities to increase the replicability of the study results and to investigate the open questions:

Does multi-dimensional navigation have a long-term impact on decision-making and change of behaviour?
Although the results indicate that multi-dimensional visualization fa-

cilitates understanding, it is still open as to whether it might also have an impact on long-term decision-making and changes in behaviour. The questionnaires and interview data provide quotes from respondents who declared they will change their personal behaviour, and two declarations of intent by public councillors to address the learnings from the public open house in planning policy. It is suggested to further monitor the Kimberley case study in order to analyse how far these declarations of intent will be put into practice.

How do group differences affect the use of virtual globes as a tool for climate change understanding?

It is further suggested to explore the bimodal distribution of the virtual globe ranking as part of an experiment. With regard to Schroth (2007), it may be suggested that map knowledge is the variable that distinct the two user groups who like (lay map users) and dislike (expert map users) virtual globes. Such an experiment will provide recommendations on how to address different target groups in planning.

How should climate models and visualizations be linked, so that the visualizations represent the complex spatio-temporal dimensions of the underlying models and model outcomes can be verified?

The interrelation between models and multi-dimensional visualizations was identified as an issue of major interest. In the case study, all model visualizations, i.e., fire spread model, snow model and mountain pine beetle projections, revealed errors in the modeling or in the previous mapping. In this case, the localization of snowpack data through PCIC, and 3D-visualization of the data through CALP provided important feedback for the future downscaling and calibration of regional climate models. Therefore, it is suggested to address not only the downscaling of climate change models in further detail (Nicholson-Cole 2005), but also the relation between models and visualization in general as addressed by Jordanova (2004).

4.2 Recommendations for planning practice: Application of multi-dimensional navigation in combination with scenario method and climate change risk assessment

In summary, responses showed that using multi-dimensional navigation such as time sliders and layers enhances public understanding of climate change risks such as forest fire threats to the City. Layering the different data into one representation medium allowed for comparisons across impacts. Users combined risk and zoning maps, exploring the change of risk over time and comparing it to future development patterns with regard to vulnerability and resilience. Such tools can be useful in climate change risk assessment in general.

The combination of multi-dimensional navigation with the scenario method is particularly promising and proved to be successful in this case study: The empirical evidence shows that multi-dimensional navigation helped to facilitate the understanding of the multi-dimensional scenario narratives. Vice versa multi-dimensional visualization, e.g., in a virtual globe, requires a scenario narrative in order to become meaningful for the users. Thus, multi-dimensional navigation as one visualization concept seems to offer a “way in” to people’s understanding.

Acknowledgement

in no particular order:
CALP team including Sara Muir-Owen (Project Manager), Ellen Pond, Duncan Cavens, Cam Campbell, Stephen Sheppard, Kristi Tatebe, Nicole Miller and Courtney Miller; Swiss National Science Foundation, particularly Sonja Negovetic; Dagmar Wandinger; Selkirk College GeoSpatial Unit, particularly Paul Sneed; Pacific Climate Impacts Consortium, particularly Trevor Murdock; Columbia Basin Trust and their Climate Advisory Committee, particularly Stewart Cohen; the City of Kimberley including Mayor Jim Ogilvie, all the Councillors, and the staff, particularly Operations staff and Troy Pollock in Planning; the Kimberley Climate Adaptation Project team: Ingrid Liepa, Project Coordinator, Kent Goodwin and the Steering Committee, and all the members of the Working Groups; Art Stock, Entomologist, BC Forest Service; Bob Gray, Fire Consultant with the City of Kimberley; The British Columbia Ministry of Community Development, particularly Cathy LeBlanc; the Real Estate Foundation; and all the residents of Kimberley who participated in workshops and public open houses.

References

Al-Kodmany, K. (1999). Using visualization techniques for enhancing public participation in planning and design: process, implementation and evaluation. Landscape and Urban Planning 45, 37-45.

Appleton, K., A. Lovett, G. Sünnenberg, and T. Dockerty (2002). "Rural landscape visualisation from GIS databases : a comparison of approaches, options and problems." Computers, Environment and Urban Systems 26 (2002): 141-162.

Bishop, P., Hines, A., Collins, T. (2007). The current state of scenario development: an overview of techniques. Foresight 9, 1, 5-25.

Blanco, H., M. Alberti, A. Forsyth, K.J. Krizek, D.A. Rodríguez, E. Talen, and C. Ellis (2009). "Hot, congested, crowded and diverse: Emerging research agendas in planning." Progress in Planning 71, no. 4: 153-205.

Börjeson, L., Höjer, M, Dreborg, K.-H., Ekvall, T., Finnveden, G. (2006). Scenario types and techniques: Towards a user's guide. Futures 38, no. 7, 723-739.

Calow, P. (1998). Handbook of environmental risk assessment and management. Oxford: Blackwell.

Craglia, M., Goodchild, M. F., Annoni, A., Camara, G., Gould, M., Kuhn, W., Mark, D., Masser, I., Maguire, D., Liang, S., & Parsons, E. (2008). Next-Generation Digital Earth. A position paper from the Vespucci Initiative for the Advancement of Geographic Information Science. International Journal of Spatial Data Infrastructures Research 3, 146-167.

Danahy, J.W. "Technology for dynamic viewing and peripheral vision in landscape visualization." Landscape and Urban Planning 54 (2001): 125-137.

Dockerty, T., A. Lovett, et al (2006). „Developing scenarios and visualisations to illustrate potential policy and climatic influences on future agricultural landscapes." Agriculture, Ecosystems & Environment 114(1): 103-120.

Döllner, J. (2005). "Constraints as Means of Controlling Usage of Geovirtual Environments," Cartography and Geographic Information Science 32, no. 2, 69-79.

Drottz-Sjöberg, B.-M. (2006). "Perceptions of time and long time intervals." presented at the VALDOR Conference: Values in Decisions of Risk, Stockholm, Sweden, 2006.

Economics of Climate Adaptation Working Group (2009). Shaping Climate-Resilient Development. A framework for decision-making. Report.

Ervin, S.M. (2001). Digital landscape modeling and visualization: a research agenda. Landscape and Urban Planning 54, no. 1-4, 49-62.

European Environment Agency EEA (2009). Regional climate change and adaptation, EEA Report: Copenhagen.

Fürst, D., and F. Scholles (2001). Handbuch Theorien + Methoden der Raum- und Umweltplanung. Dortmund: Dortmunder Verlag für Bau- und Planungsliteratung.

Gray, Bob. (2009). GIS fire maps. City of Kimberley Fire Consultant. Pers. and email communication.

Häberling, C. (2003): Topografische 3D-Karten. Thesen für kartografische Gestaltungsgrundsätze. Dissertation am Kartografischen Institut, ETH Zürich 2003.

Hehl-Lange, S., Lange, E. (2005). Ein partizipativer Planungsansatz für ein Windenergieprojekt mit Hilfe eines virtuellen Landschaftsmodells. Natur und Landschaft 80, no. 4 (2005): 148-153.

Hurni, L. (2005) "Anwendung kartographischer Medien im Rahmen aktueller I+K-Technologien," Kartographische Nachrichten (KN) 5 (2005): 244-249.

Integrated Land Management Bureau ILMB (2006). Mountain Pine Beetle Hazard Rating Documentation version 1.2" ILMB Project #: P07-0199, Southern Interior Forest Region, last update, Dec.20, 2006.

Intergovernmental Panel on Climate Change IPCC (2007). Climate Change 2007: The Physical Science Basis, Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: WMO, UNEP.

Intergovernmental Panel on Climate Change IPCC (2009). The SRES emissions scenarios, website, http://sedac.ciesin.columbia.edu/ddc/sres/.

Issing, J., P. Klimsa (2002). Information und Lernen mit Multimedia und Internet: Lehrbuch für Studium und Praxis. Weinheim: Beltz.

Jordanova, L. (2004). "Material Models as Visual Culture," in Models: The Third Dimension of Science, Stanford: Stanford University Press, 443-451.

Kimmel, R. (2009): Climate Change Adaptation and Biodiversity. Workshop proceedings, Simon-Fraser University.

Kwartler, M. (2008). Visioning and Visualization: People, Pixels, and Plans: Lincoln Institute of Land Policy.

Lange, E. (2001). The limits of realism: perceptions of virtual landscapes. Landscape and Urban Planning 54, 163-182.

Larsen, K., Gunnarsson-Östling, U. (2009). Climate change scenarios and citizen-participation: Mitigation and adaptation perspectives in constructing sustainable futures. Habitat International 33(3): 260-266.

Lewis, J.L., Sheppard, S.R.J. (2006). Culture and Communication: Can Landscape Visualisation Improve Forest Management Consultation with Indigenous Communities? Landscape and Urban Planning 77, 219-313.

MacEachren, A.M. (1995). How maps work: representation, visualization, and design. New York [etc.]: Guilford.

Met Office Hadley Centre (2009): Met Office Hadley, Website, http://www.metoffice.gov.uk/climatechange/science/hadleycentre/.

Miller, N., Cavens, D. (2008). City of North Vancouver 100 year Sustainability Vision: GHG Measurement and Mapping. CEEI Technical Paper.

Missoula Fire Sciences Laboratory (2009). Fire Behaviour and Fire Danger Software, FireModels.org, 2009, http://www.firemodels.org.

Moser, S., Dilling L. (2004). Making Climate Hot: Communicating the Urgency and Challenge of Global Climate Change. Environment 46(10): 32-46.

Nature, editorial (2006). Think global. Nature 439, no. 7078, 763.

Neumann, A. (2005) "Thematic Navigation in Space and Time, Interdependencies of Spatial, Temporal and Thematic Navigation for Cartographic Visualization.," in 4th SVG Open developers conference (Enschede NL, 2005).

Nicholson-Cole, S. A. (2005). Representing climate change futures: a critique on the use of images for visual communication. Computers, Environment and Urban Systems 29, 255-273.

O'Neill, Saffron J., Hulme, M. (2009). An iconic approach for representing climate change." Global Environmental Change 19, no. 4, 402-410.

Orland, B., Budthimedhee, K, Uusitalo, J. (2001). Considering virtual worlds as representations of landscape realities and as tools for landscape planning. Landscape and Urban Planning 54, 139-148.

Pond, E. (2009): Kimberley, Planning Expansion. Poster for the Kimberley Climate Adaptation Project, Vancouver: CALP.

Richardson, K., Steffen, W. (2009). The IARU International Scientific Congress on Climate Change: Global Risks, Challenges and Decisions (12 March, Copenhagen, Denmark). IOP Conference Series: Earth and Environmental Science.

Salter, J., Campbell, C., Journeay, M., & Sheppard, S. R. J. (2009). The Digital Workshop: Exploring the use of interactive and immersive visualisation tools in participatory planning. Journal of Environmental Management 90 (6), 2090-101.

Schroth, O. (2007). From Information to Participation - Interactive Landscape Visualization as a Tool for Collaborative Planning, Dissertation No. 17409, ETH Zurich.

Schroth, O., Sheppard, S.R.J. , Lange, E., Schmid, W.A. (2008). Transferring Control to the User - Interactivity as an Approach Towards Participatory Visualization Processes. In Digital Design in Landscape Architecture 2008. Heidelberg: Wichmann, 203-213.

Shaw, A., Sheppard, S., Burch, S., Flanders, D., Wiek, A., Carmichael, J., Robinson, J., & Cohen, S. (2009). Synthesizing, downscaling, and visualizing climate change scenarios for participatory capacity building. Global Environmental Change. 19: 447-463.

Sheppard, S. R. J. (2001). Guidance for crystal ball gazers: developing a code of ethics for landscape visualization. Landscape and Urban Planning 54, 183-199.

Sheppard, S. R. J. (2005). Landscape visualisation and climate change: the potential for influencing perceptions and behaviour. Environmental Science & Policy 8, 637-654.

Sheppard, S.R.J., Cizek, P. (2009). The ethics of Google Earth: Crossing thresholds from spatial data to landscape visualization. Journal of Environmental Management, 6, 2012-2017.

Sheppard, S.R.J., Salter, J. (2004). The Role of Visualization in Forest Planning. In Landscape and Planning Section, Encyclopedia of Forest Sciences, London, Oxford, Wisconsin: Elsevier, 486-498.

Shore, T. L., & Safranyik, L. (1992). Susceptibility and risk rating systems for the mountain pine beetle in lodgepole pine stands. Ministry of Supply and Services Canada (Ed.). Victoria: Pacific Forestry Centre.

Swart, R.J., Robinson, J., Raskin, P. (2004). The Problem of the Future: sustainability science and scenario analysis. Global Environmental Change 14,137-146.

Tompkins, E. L., Few, R. (2008). Scenario-based stakeholder engagement: Incorporating stakeholders preferences into coastal planning for climate change. Journal of Environmental Management 88(4): 1580-1592.

Tonn, Bruce, Angela Hemrick, and Fred Conrad. Cognitive representations of the future: Survey results. Futures 38, no. 7 (September 2006): 810-829.

Tress, B., Tress, G. (2003). Scenario visualisation for participatory landscape planning - a study from Denmark. Landscape and Urban Planning 64, 161-178.

van Notten, P. W. F., Rotmans, J., van Asselt, M., & Rothman, D. (2003). An updated scenario typology. Futures, 35, 423-443.
van ,t Klooster, S. A., & van Asselt, M. (2006). Practising the scenario-axes technique. Futures, 38, 15-30.

Wissen, U., Schroth O., Lange, E., Schmid, W. A. (2008): Integration of 3D visualisations and non-visual indicators as an instrument for participation. Journal of Environmental Management 89 (3), 184-196.

Yin, R. K. (2003). Case Study Research. Design and Methods. Thousands Oaks, London, New Delhi: Sage.