Visualization and simulation of impacts and strategies

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1 Description work package

1.1 Problem definition, aim and central research questions

The objective of the project is to facilitate the use of knowledge on climate change in planning and decision making processes through visualization. Knowledge use in municipalities, provinces and hotspots can be facilitated by visualization techniques. This work package refines communication by (geo-)visualization strategies and evaluates how these strategies improve a more effective knowledge transfer about climate change to different target groups.

Geo-visualization is a loosely bounded domain that addresses the visual exploration, analysis, synthesis and presentation of geospatial data by integrating approaches from cartography with those from other information representation and analysis disciplines (Dykes et al, 2005). Since climate change impacts are surrounded by uncertainties, and occur on the long term, visualizations are an important means to communicate this state of knowledge. Latest scientific discussion show concern about the persuasive character some forms of visualization may have, deliberately engaging the emotions of target users (Stephan et al, 2009)

The main objective of the work package is to develop and test various types of target group directed visualization strategies (including tools and procedures) within a participative planning procedure. For that the project identifies target groups (the general public, stakeholders, policy makers at different institutional levels). This work package specifies for three hotspots regarding their target groups a specific visualization strategy to be developed, aiming at an effective communication of climate change impacts and adaptation options, taking into consideration supplies and demands of the other work packages. Various applied innovative visualization techniques (Google Earth and Google Street plug-inns, 3D interactive scenes; visual analytics, multimedia visualizations and GIS-services) and related scientific discourses will be analyzed, out of it the best practices and lessons learned will be selected and used for the definition of visualization strategies. These strategies will be applied, tested and discussed. The sequence of outcomes form case study literature desk study, workshop applications, discourse and tested strategies will lead to practitioners guidelines.

1.2 Interdisciplinarity and coherence between the projects

The projects within the work package are interlinked, but the work package also has important links with other work packages within the overall thematic proposal. There are also connections to other thematic projects (the other KvK themes), and with research and assessment activities outside the 2nd tranche of the Knowledge for Climate program.

Links between the projects within WP4:

- The 3D visualizations and water simulations developed by the TU Delft for the Haaglanden hotspot (projects 2 and 3) will be evaluated in the „Development, application and testing visualizations for knowledge transfer in adaptation planning" project (project 1). The effectiveness of the 3D visualizations will be evaluated and it serves as an important case study in this work package.

Links within the overall project

- Links with WP3 (interactive design): WP3 develops an approach for interactive development of adaptation strategies. Maps are used to communicate and exchange knowledge among policy-makers and stakeholders. WP 4 will develop visualizations that will be used in the interactive design process. The series of interconnected workshops of WP 3 will be used as test cases to measure the effectiveness of the visualizations.
- Links with WP 7 (Indicators): Visualization can be used to communicate the performance of adaptation strategies on vulnerability and adaptation indicators. Hence close collaboration with WP7 on indicators will be ensured.

Links with other KvK projects

- Visualizations are in theory relevant to all of the KvK themes and research projects. The Climate Effect Atlas is a KvK project which attempts to capture and disclose relevant knowledge form the various projects (within and outside the KvK program). The Climate Effect atlas will play a central role in both work package 3 and 4 and will safeguard a close connection to ongoing KvK research.

Links with other research

- In the domain of GeoVisualisation there are links with the VISCOM project [10], visualization of aerosols [4] ,previous experiences within the PSPE project [5], making use of the PEER-METIER network on geo-visualization [6] and on both ICA networks on visual analytics and on usability [7]. In the domain of user impacts there are relations with studies on understanding user groups and their perception of environmental changes [8] and their perception of maps/3D scenes in relation to spatial awareness [9], [10]
- There is also a link with the research project “the role of visualization in environmental impact assessment, Kenia”

1.3 Stakeholders

An important target group for the visualizations are the local and regional governments (provinces, municipalities) involved in the development of local and regional adaptation strategies. This workpackage will focus specifically on the Haaglanden region. The relevant stakeholders are water boards, municipalities and consulting companies. To facilitate their involvement, a User Group will be formed and two case studies will be conducted. The user group will meet twice a year. In the initial stage of the project the user group will formulate their demands and special needs. Besides Haaglanden, other case studies are related to the Hotspot Fen Meadows and Shallow Lakes in which stakeholder workshops are planned in the three case studies planned in this hotspot: 1. Zegveld, 2.Zevenblokken and 3. Tjeukemeer, in close collaboration with WP 3 (see WP3 description). Finally the Hotspot Dry Rural Areas will be supported in the case study of the Peel Region.

The tools to be developed in the projects 2 and 3 of this work package are (ultimately) to be used by the stakeholders. The relevant stakeholders are water boards, municipalities and consulting companies. To facilitate their involvement, a User Group will be formed and two case studies will be conducted.

In this user group the following institutes will participate (in brackets the contact persons):

- *Waterboard: Hoogheemraadschap Delfland* http://www.hhdelfland.nl/ (Rob Ammerlaan)
- *Waterboard: Hoogheemraadschap Hollands Noorderkwartier* http://www.hhnk.nl/ (Jan Strijker)
- *Municipalities: Waterkader Haaglanden* http://www.waterkaderhaaglanden.nl (Ben van de Ven)
- *Research institute: Deltares* http://www.deltares.nl (Eric Ruijgh)
- *Consulting company: Nelen & Schuurmans*, http://www.nelen-schuurmans.nl/ (Wytze Schuurmans)

The user group will meet twice a year. In the initial stage of the project the user group will formulate their demands and special needs. In the later stage the user group will comment on the (prototype) versions of the tools developed. In addition to the user group meetings, close contact will be maintained with Deltares and Nelen & Schuurmans to explore the further development of the tools and to explore the international potentials.

The case study areas are already selected and are located near Delft University. The first case study is the Oranjepolder and the second case is the Plaspoelpolder. In these densely populated areas significant spatial developments are foreseen, while coping with urgent water problems from both heavy rainfall and potential dike bursts. The case studies are selected after consultation with the , and will be used to demonstrate the practical benefits and potentials of the tools developed by the TU Delft. Furthermore, the case studies will provide the developers with relevant datasets, like the original Flimap data (3D) and relevant (GIS) data like GBKN, AHN2, top10 and LGN.

Other case studies and evaluation studies will be performed in collaboration with Work Package 4, Project 1: Development, application and testing visualizations for knowledge transfer in adaptation planning, and with Work Package 3, Project 1: Interactive development of spatial adaptation strategies. Social and psychological aspects in these cases will be group communication, generation and exchange of ideas, getting detailed insights about climate change consequences and protective measures, policy development, and decision making. These aspects will be studied using group sessions where the role and effectiveness of interactive simulation and 3D visualization is analysed evaluated.

2 Project 4.1 Development, application and testing visualizations for knowledge transfer in adaptation planning

Project leader: dr. Hasse Goosen, prof.dr.ir. A. Bregt, prof.dr.ir. P. Vellinga, dr. R. Janssen, dr. R. Van Lammeren

2.1 Problem definition, aim and central research questions

The development of an adaptation strategy is not a straightforward policy activity. Adaptation planning typically includes a multitude of aspects and affects a wide variety of stakeholders. Moreover, it requires dealing with uncertainties and impacts that occur over the middle long term (>20 years) and long term (> 50 years). Decision support tools can aid decision makers in their complex task of developing adaptation strategies. Within the Knowledge for Climate program tools are developed to bridge the spatial gap between knowledge and policy makers on assessing the impacts of climate changes. This research project develops and analyses visualizations to improve the usability of the Climate Adaptation Atlas. This Atlas is translates scenario‟s from climate models into more local impacts. The tool delivers spatial data and knowledge, and is being used in interactive and participatory ways, exploring impacts and possible solutions and strategies, and more importantly, reaching better understanding of common interests and concerns and facilitating the creation of joint gains. If properly developed, decision support tools have a great potential in the complex process of implementing the national adaptation strategy. However, the achievements of decision support tools have repeatedly being reported as modest. Various discussions on the possible pitfalls of decision support efforts have been reported recently (Goosen, 2006, Walker, 2002, Uran and Janssen, 2003). Often a mismatch occurs between the capabilities of the decision support tools and the requirements of decision makers and end-users. This mismatch has repeatedly been identified as an important bottleneck for decision support.

The goal of this project is to investigate how visualization techniques can improve the effectiveness of decision support tools in bridging the gap between science and policy in adaptation planning at the local/regional level. The research aims at improving the Climate Adaptation Atlas through the development of new visualizations and analyses, tests and evaluates both new and existing visualizations. The goal is to measure their effectiveness in different decision making and problem context. Therefore the following research questions are answered:

Research questions:

- Which forms of visualizations are likely to contribute to the Climate Adaptation Atlas, and how are these effective in different decision making settings? The following variables will be distinguished:
    - Which types of visualization are suitable for better communication of the impacts of climate changes?
    - Which types of visualization are effective in different phases of the policy making process?
    - Which types of visualization are preferred by different target groups?
    - Which types of visualization are equipped for different scale levels?
    - How can visualization techniques be used to express uncertainties?
- How can efficiency and usability be measured? Usability is defined as the perception of the target user of the effectiveness (fit for purpose) and efficiency (work or time required to use) of the tools.
- How to develop an experimental setup for measuring usability?

2.2 Approach and methodology

The research will be performed in four distinct phases.

- Phase 1: inventory of visualization tools and methods through literature review;
- Phase 2: elaboration of the decision making strategies in which the tools are to be used and analysis of demands related to particular target groups;
- Phase 3: develop, apply and evaluate of visualization tools and methods in case study applications;
- Phase 4: develop different strategies for applying visualization tools as a part of the policy and decision making process.

The first two phases are performed in year 1 after which a go-no-go decision is made. Phase 3 will cover a period of three years and is performed by a PhD candidate supported by senior researchers and technical developeds at Atlerra-Wageningen UR and IVM. Phase 4 will cover the final year of the project and is aimed at analysing and integrating the results of the various case studies in which visualizations have been applied. Each phase delivers clear scientific and societal deliverables (see under D and F)

Phase ***1: inventory of existing visualization tools, methods and experiences.*** In this phase tools and methods and experiences will be identified that can be used for visualizing the climate impacts and adaptation strategies. The impacts of visualization on awareness, attitudes, and behaviour in relation to climate change will be explored. In the context of motivating behavioural change at the policy level, the potential content of visualization imagery need not be limited to the direct impacts of climate change on the local environment and community. (Sheppard, 2005; Brink, 2007). An overview of existing visualization techniques is provided. Specific attention is given to the communication of the uncertainties in climate changing effects through visualization techniques. A key question is how to communicate uncertainties without increasing the complexity of the information offered. If a map or any means of visualization becomes too complex, the user will not be able to grasp the information offered. On the other hand, ignoring the uncertainties for simplicity‟s sake, will increase the chances of misinterpretation of information.

Phase ***2: inventory of the decision making process and elaborate of the decision making strategies.*** A good understanding of the decision making process and the role of visualizations in this process is a crucial factor. This phase therefore involves a process of identifying end-user needs and requirements rather than offering „standard‟ research products via a standard project approach. The visualization tools to be developed and applied in phase 3 have to be sufficiently flexible and robust to include new insights/data/information (Basic, 2006, Boer, 2009; Brink, 2007). Through a literature review, an analytical framework is developed identifying different decision making contexts based on the type of problem and the specific aims of the target groups. Next, a method for the assessment of the efficiency and credibility of visualizations is developed based on insights and experiences from recent usability studies (see for instance Sheppard, 2009, Brink, 2007).

Phase ***3: develop, apply and evaluate visualizations in case study applications.*** In this phase, a set of visualization tools will be developed and tested in the case study areas. The climate impact atlas (a tool developed within the KfC project Building Blocks NAS) will used to identify the impacts of climate change in various case study areas. The research focuses on estimating the effectiveness/usability of the climate impact atlas: which types of visualization can contribute to transfer the knowledge from the atlas to the different type of end-users? The Climate Impact Atlas and it's visualizations will facilitate the design process of regional adaptation strategies in interactive sessions in at least four case study areas with different decision making settings. Existing tools are improved and new tools are developed and adjusted. New tools will be developed and applied in collaboration with the Wageningen UR - Centre of Geo Information and Alterra. An experimental set-up is developed and applied to various case studies in the hotspots as mentioned under D. A key innovation of the project is to address the specific visualization characteristics in specific decision making context with specific target groups. The visualizations are developed, applied and evaluated in a number of iteration steps. Intermediate results will be provided to improve both the visualizations as the applicability and usage of scientific information developed in more fundamental research projects, in terms of process and contents. The project uses state-of-the-art Geo-ICT techniques, visualisation techniques and innovative interfaces (Maptable, MS Surface). The tools and interfaces will be tested in interactive workshops with stakeholders. To measure the effectiveness and usability of the tools and interfaces an experimental method based on literature review of phase 2.

Phase ***4: develop different strategies for applying visualization tools.*** In the final phase of the project, the lessons learned will be used to develop different strategies for applying visualization tools. Based on the outcomes of the various case studies practitioner guidelines are developed for applying visualization tools. The research will analyze, develop and test the suitability of visualization techniques in these four typical decision making contexts. The research will investigate both new and available visualizations within Knowledge for Climate are relevant for the different strategies. The results will underpin the appropriateness of specific visualizations in specific decision-making contexts. These different decision making settings are characterised through an analytical framework derived from sociological psychology literature (De Boer, 2009). De Boer distinguishes four different decision-making strategies based on the two basic dimensions of decision (Thompson & Tuden, 1959; Thompson, 2003). The first dimension refers to beliefs about the cause/effect relations that are instrumental for what the decision might actually accomplish; the second refers to preferences regarding the possible outcomes of the decision.

Beliefs about cause/effect relations	Preferences regarding possible outcomes: Certain	Preferences regarding possible outcomes: Uncertain
Certain	Causation and outcome preferences are certain – data are voluminous **Computational strategy**	Uncertain due to - opposing preferences - external constraints **Compromise strategy**
Uncertain	Uncertain due to - incomplete knowledge - inherent uncertainty - competition with rival decision-makers **Judgmental strategy**	Uncertain due to - a combination of reasons **Inspirational strategy**

If there is certainty regarding both causation and outcome preferences, decision making is relatively straightforward. Tools like multi criteria and cost-benefits analysis can support the decision. If outcome preferences are clearly known and shared but cause/effect relations are uncertain or disputed, the decision unit must rely on a judgmental strategy to find a solution. In contrast, if cause/effect relations are certain but outcome preferences are uncertain or disputed, a compromise strategy seems most suitable to identify a common preference. Finally, if both causation and outcome preferences are uncertain or disputed, the most likely action of the decision unit is to avoid any decision on the issue, unless an inspirational strategy can be introduced to create a new vision or belief. This analytical framework will be applied and tested in three case study areas selected by the Hotspots Haaglanden, Fen Medows and Dry Rural area‟s.

In the Haaglanden Hotspot, a User Group will be formed and two case studies will be conducted. In this user group the following institutes will participate:

- *Waterboard: Hoogheemraadschap Delfland* http://www.hhdelfland.nl/ (Rob Ammerlaan)
- *Waterboard: Hoogheemraadschap Hollands Noorderkwartier* http://www.hhnk.nl/ (Jan Strijker)
- *Municipalities: Waterkader Haaglanden* http://www.waterkaderhaaglanden.nl (Ben van de Ven)
- *Research institute: Deltares* http://www.deltares.nl (Eric Ruijgh)
- *Consulting company: Nelen & Schuurmans*, http://www.nelen-schuurmans.nl/ (Wytze Schuurmans)

The user group will meet twice a year. In the initial stage of the project the user group will formulate their demands and special needs. In the later stage the user group will comment on the (prototype) versions of the tools developed.

To support the Fen Meadows hotspot, stakeholder workshops are planned in collaboration with WP3. in three case studies: 1. Zegveld, 2.Zevenblokken and 3. Tjeukemeer. Stakeholders input is very important in preparation of these workshops and stakeholder interaction is central to the workshops themselves.

4. The case study Zegveld is policy oriented. Stakeholders involved in this case study are the Province of Utrecht and Waterboard Stichtse Rijnlanden (HDSR). Stakeholders will be participate in one workshop that combines various policy plans for this polder with predictions on ground water levels and soil subsidence. This workshop is planned for 2010.

5. Within the case study Zevenblokken stakeholders are the Waterboard Noorderzijlvest, The Province of Drenthe, Natuurmonumenten and local farmers and their organization (LTO). Two or three workshops will be conducted with these stakeholders as part of a process to develop water management plan (Integraal Peilbesluitplan Smilde). Stakeholders are consulted in preparation of these workshops and will be asked to participate. Workshops are planned in 2010 and 2011.

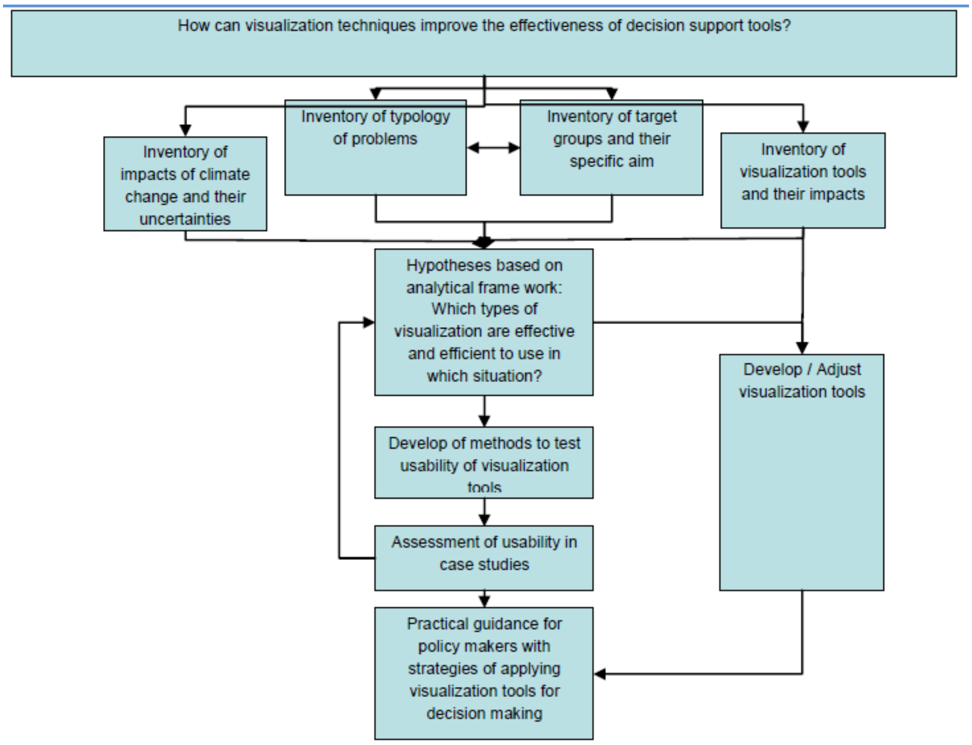
The case study Tjeukemeer includes both the lake and the fen meadow polders to the south of the lake. Stakeholders are the Wetterskip Fryslân, the Province of Fryslân, the municipality of Lemsterland, farmers and their organization (LTO Noord), Nature NGO‟s (Staatsbosbeheer and It Fryske Gea), organizations of local residents. Three workshops are planned involving these stakeholders in the years 2011 and 2012.

The Hotspot Dry Rural Areas is supported in a case study for the Peel region. A series of three workshops are planned in 2010 within the ongoing project of Building Blocks NAS (Bouwstenen NAS). These stakeholder workshops will be used to specify end user requirements regarding visualizations. Important stakeholders are the Waterschap Aa en Maas, the Province of Noord Brabant. A forth stakeholder workshop will be planned in 2011 to apply and test the developed visualization tools.

The scientific underpinning will be described in a scientific report or dissertation, and complemented by more practical guidance for policy makers (Boer, 2009,; Sheppard, 2009; Brink, 2007)

The research will be performed by a PhD supported by professional staff at Alterra-Wageningen UR in collaboration with IVM. Intermediate and final results will be presented at (inter-)national scientific meetings, in scientific papers, and, in parallel, discussed with policymakers and other stakeholders during workshops and other meetings, some of which may be specifically organized for this project, while the project will make use of opportunities provided by ongoing KvK events.

The approach to address the research questions as marked above is pointed out in the scheme below.



2.3 Scientific deliverables and results

As a part of the research the methods and tools to visualize and communicate the impact of climate change will be improved. The (intermediate) results and recommendations of the project will be published in at least four scientific papers. Scientific deliverables are:

D1 A the theoretical framework addressing the relations between visualizations and the transfer of knowledge on climate change in different type of phase in the adaptation planning process;
D2 A method developed to measure the effectiveness of the different type of visualization tools;
D3 development and application of visualizations in the case study areas (Haaglanden: plaspoelpolder and Oranjepolder; Fen Meadows: Zegveld, Zevenblokken, Tjeukemeer and Dry Rural Areas: Peel Region).

D4 Analysis of the empirical results of the (non)effectiveness of the various visualization tools applied in the case study areas;
D5 Visualization strategy for applying visualizations in different decision making contexts of adaptation planning.

The project delivers at least four peer reviewed papers (d6), a practical guide for stakeholders (d7) and a website / blogspot (d8) is set up to communicate (intermediate) case study oriented results. The project will also result in a dissertation (d9).

2.4 Integration of general research questions with hotspot-specific questions

The research questions in this Work Package primarily address questions posed to the KvK program by the Adaptation, Space and Climate interdepartmental group (ARK) in the context of the development and implementation of the National Adaptation Strategy (NAS). Within the KvK "NAS Building blocks" project applications are foreseen at the national (evaluation framework, PBL), provincial (*structuurvisies, plan-MER*) and municipal level (*structuurvisies, bestemmingsplannen*, *Natura 2000 beheersplannen,* etc.).

Four hotspots (dry rural areas, major rivers, Haaglanden region and shallow waters and peat meadow areas) and several provinces and municipalities have expressed interest in support from the theme 8 project.

2.5 Societal deliverables and results

The case study areas used for the development and assessment of the visualization tools will be directly supported in their ongoing policy and decision making processes. Intermediate results will be used to improve and complement the toolbox to in the KvK "NAS Building blocks" project.

As a result of the project a practical guideline for policy makers with strategies of applying visualization tools for decision making will be written.

2.6 Most important references

1. Bacic, U., D. Rossiter, A. Bregt (2006) Using spatial information to improve collective understanding of shared environmental problems at watershed level; Landscape and Urban Planning 77 (2006) 54–66
2. Boer, J. de (2009)."Frame-based guide tot situated decision-making on climate change."IOP Conf.Series: Earth and Enviromental Science **6** (39).
3. Brink, A. van den , R. van Lammeren, R. van de Velde, S. Däne (2007) Geo-vizualisation for participatory planning in Europe, Mansholt publication series – vol 3; 199 pp
4. Dykes. J, A. MAceachren, MJ Kraak (2005) "Exploring geovisualization", Elsevier
5. Rijn, N. v. (2009). Validating the use of the Isovist tool as a means to assess landscape openness in the Netherlands Centre for Geo Information. Wageningen, Wageningen University. PhD.

6. Sheppard, S.R.J. (2005). “Landscape visualization and climate change: the potential for influencing perceptions and behaviour.”Environmental Science & policy **8** (6): 637-654.
7. Stephen, S. R.J. Sheppard, P. Cizek (2009) The ethics of Google Earth: Crossing thresholds from spatial data to landscape visualization. “Journal of Environmental Management 90 (2009) 2102-2117
8. Thresholds to the future: visualizing regime shifts in socio-ecosystems - PhD research
9. Vervoort, J.K. Kok, R. van Lammeren, T. Veldkamp Stepping into futures: exploring the potential of interactive media for participatory scenarios on social-ecological systems**”**, in Futures (2010, accepted)

3 Project 4.2 Simulating flows and flood flows in rural and urban areas

Project leader: prof.dr.ir. G.S. Stelling, TU Delft CiTG

3.1 Problem definition, aim and central research questions

Climate change will have a large influence on flood risks and subsequently on our drainage and water management systems. One might expect a major rearrangement of our rural and urban infrastructure in which water will play an important and perhaps more dynamic role. More dynamic for instance due to retention basins, dry ponds, etc. All these drastic changes of our infrastructure are to be designed and planned carefully. Reliable predictions of the feasibility and communication with stakeholders representing a variety of interests will pay a crucial role in planning of infrastructural adaptations to climate change. Also a careful and reliable analysis of flooding events, to support disaster management, does play an important role in future water management.

Related important innovative developments are:

1. **Very accurate and detailed data collection**, containing: (i) digital terrain models, with data for instance collected from remote sensing technology such as laser altimetry data (the resolution could be of the order of magnitude of 10 cm), (ii) GIS data with general, also non geometric, information, (iii) data bases with 1d line oriented information such as sewer systems (e.g. SUF-HYD), drainage channels, .dikes etc.
2. **3Dimensional visualization systems**. The best method for the inspection huge data sets is by visualization in 3 dimensions. Now a day‟s many ways are available to visualize 3d data in a 3D virtual world. If driven by high resolution input a very realistic image of reality can be produced. Fast graphical processors of every increasing speed and other equipment is the technology push to realize this development.

The aim of this project is to develop a flow and flooding model, directly based on the very detailed digital terrain and drainage system input data and directly coupled to modern high speed 3D visualization systems

Two research questions play an important role:

1. From the physical point of view: How can rainfall/runoff, including street/sewer or land/channel interaction, be improved, based on a more deterministic approach. All this in such a way that in particular the effect of heavy local rainstorms can be predicted in a reliable way.
2. From the numerical point of view: How is it possible to make use of extreme high resolution input data in such a way that the computational speed remains fast while the flow results, with optimal accuracy, fit exactly in the detailed geometrical data. This will yield very realistic results in combination with a 3D visualization system.

3.2 Approach and methodology

It is not intended to start from scratch. The starting point will be DelftFLS and SOBEK1D/2D. Presently these models are applied for a lot of flooding and drainage simulations by important stakeholders. Verification of these models, in the context of very different applications, is described by Hesselink(2002) ,Hesselink et al(2003), Stelling and Duinmeyer(2003), Alkema(2007) At present only limited research is known in the literature on the accurate modelling of floods in urban areas. A physical model, including subways, is described by Ishigaki(2003)

The dynamics flood flow depends upon the area where the flood takes place. For this purpose we make a distinction between *rural* areas and *urban* areas. In rural areas interaction between land and drainage (or flooding) by ditches and channels has to be improved in SOBEK. In cities street/sewer interaction, or even interaction with tunnels and subway systems, has to be improved.

To improve the rainfall/runoff simulation of severe rainstorms a more deterministic approach will be followed, similar to Rientjes 2004. Important issues here are the formulations of overland/over street flow, discharges to sewers via man holes etc. From the computational point of view two components are important:

1. Massive computations on parallel platforms
2. Sub grid modelling

Ad 1: Land with roads, buildings, trees, etc, has a much more inhomogeneous character than sea bottoms. To model floods accurately many details are important which will require a relatively small grid size. With present inundation models a million grid points is no exception. For a reasonable computing time per simulation, implementation on parallel clusters is imperative. In addition the development of graphical processors is of interest. The question arises to what extent graphical processor can be applied also for the implementation of numerical algorithms. This would enable perhaps a fast and cheap parallel platform for simulations that are integrated with visualization.

Ad 2: An interesting and new development is found in a paper by Casulli(2009). Rather than having just one depth value per computational cell he shows that having a detailed sub grid with very high resolution depth values can greatly improve the flooding and drying characteristics of a computational model. This technique forms a very interesting starting point for the numerical integration of high resolution depths and elevation data with relative lower resolution computational cells. In this way the high resolution land data is used by the simulation system without the computational impossibility of billions of computational cells.

3.3 Scientific deliverables and results

Deliverables of this project:

Project 2: Simulating flows and flood flows in rural and urban areas
d1 Year 1: Implementation of an unstructured 1D-2D grid model in a massive multiprocessor environment.

d2 Year 2: Implementation of additional features such as street/sewer interaction and buildings for large scale urban flooding simulations(year 2)
d3 Year 3: Implementation of the sub grid approach for full integration with the high resolution elevation data.(year 3)
d4 Year 4: Documentation, publication and the completion of a doctoral dissertation.
Scientific results:

1. Validated 1D/2D coupling algorithms for the interaction of 1D drainage channel flow with 2D overland runoff/ flood flow. Automatic capturing of hydraulic jumps, dam break bores and other locally rapidly flow phenomena will be part of these algorithms.

2. New approach to rainfall runoff with severe local rainstorms, both in rural and urban areas. Aspects such as infiltration and pond formation are to be taken into account as well.

3. Parallel algorithm for the sub grid approach. This algorithm exploits and integrates very fine grid data, with large local variation of the surface in terms of pavement, vegetation, land height, etc. The fine sub grid will be covered by a variable coarse grid such that the accuracy is hardly less than the fine grid while the computational time is largely reduced. This is similar to the Casulli 2009 approach, but with important improvements with respect to the integrated friction effect of an inhomogeneous bottom.

Of course a number of scientific journal papers will be written. A PhD dissertation is the final closure of the scientific results.

3.4 Integration of general research questions with hotspot-specific questions

The tools to be developed in this project aim at local applications by stake holders, such as local water authorities, to support their specific decisions in view of climate proof water management. See also the general description of stakeholder involvement in the WP description.

3.5 Societal deliverables and results

First of all this project will contribute to a better understanding of the effects of climate change on local water issues. It can be used to optimise water management with respect to several objectives, such as safety, attractive living environment, etc. The result of this project will be integrated in a virtual reality system. It will look like a large dynamic virtual scale model. This will also greatly improve communication with non-experts. What climate change implies locally, in your own city, can be explained and almost experienced, with the virtual reality system that we envisage. In particular for local water authorities this can be of great help as a communication tool with the society. Water projects for instance with young children, to create awareness, can be intensively supported with such a system, that is not only spectacular to look at but also reliable in its predictions.

3.6 Most important references

1. V. Casulli, A high-resolution wetting and drying algorithm for free-surface hydrodynamics**,** International Journal for Numerical Methods in Fluids, Volume 60, Issue 4, Date: 10 June 2009, Pages: 391-408
2. D. Alkema, Simulating floods. On the application of a 2D-hydraulic model for flood hazard and risk assessment, University of Utrecht, 2007, Dissertation
3. T.H.M. Rientjes, (2004) Inverse modelling of the rainfall - runoff relation : a multi objective model calibration approach. Delft, Delft University Press, 2004. 371 p. ISBN: 90-407-2491-1.
4. Q. Liang Q, A.G.L. Borthwick, G. Stelling**,** Simulation of dam- and dyke-break hydrodynamics on dynamically adaptive quadtree grids, International Journal For Numerical Methods In Fluids 46 (2): 127-162 SEP 20 2004
5. T. Ishigaki, T. Keichii and I. Kazuya, Hydraulic model tests of urban area in underground space, proceedings XXX IAHR congress, pp 487-493, 2003
6. G.S. Stelling and S.P.A. Duinmeyer, A staggered conservative scheme for every Froude number in rapidly varied shallow water flows, Int. J. for Num. Meth. in Fluids,.43;1329-1354, 2003.
7. A.W. Hesselink, G.S. Stelling, J.C.J. Kwadijk and H. Middelkoop, Inundation of a Dutch river polder, sensitivity analysis of a physically based model with historic data, Water Resources, 39 (9): art. no. 1234 SEP 4 2003
8. A.W. Hesselink, History makes a river. Morphological changes and human interference in the river Rhine, University of Utrecht, 2002, dissertation
9. J.F. Dhondia and G.S. Stelling, Application of one dimensional – two dimensional integrated hydraulic model for flood simulation and damage assessment, Proceedings of fifth international conference of hydroinformatics, edited by R.A. Falconer, B. Lin, E.L. Harris and C.A.M.E Wilson, 2002
10. F.H.L.R. Clemens, Hydrodynamic models in urban drainage, application and calibration. TU Delft, 2001, 365 pp., dissertation.

4 Project 4.3 Interactive simulation and 3D visualization for water protection policy development

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4.1 Problem definition, aim and central research questions

Many groups of people are involved in policy development and decision making on climate change adaptation. These groups range from the various researchers and consultants in water management (technical, societal, economic, environmental, etc.) through policy developers, decision makers, and the general public. To get insight in climate change consequences and the effectiveness of adaptation strategies and protective measures, process simulations and design studies will have to be performed. In this project we will intensify and open up this process for collaboration between all parties involved.

Visualization, interactive modelling and simulation are important tools for this purpose, acting as a communication medium. *Our aim is the investigation of new techniques for interactive 3D visualization of climate change and adaptation scenarios, usable by policy developers and decision makers*. The visualization will be directly linked with policy scenario simulations, and embedded in a collaborative policy development environment, which allows interactive visual evaluation and comparison of design variants. This will include the use of high resolution GIS data, such as the new AHN2 (Actueel Hoogtebestand van Nederland), to provide an accurate and intuitive context for visualization of climate change consequences and adaptation scenarios.

Central research questions

Which type of visualization is most suitable for the given task? In general, for both expert and public audiences, in intuitive visualization can be based on a realistic landscape visualization as can be directly generated from the AHN2 data (De Haan 2009b). Water simulations, such as flooding, can be visualized in the context of the landscape, resulting in a broadly understandable and realistic image (see Figure 1). This can even be more effective if a stereoscopic projection can be used, on a large VR-screen (Koutek, 2003; De Haan, 2009a).

1. But other visualization modes are also important, including more abstract representations, such as water depth, quality, or flow visualizations. In general, the interface for a collaborative scenario study session should show multiple linked visualizations, for different aspects of the task. The effectiveness of different types will be investigated in Project 1.

2. *How can very large amounts of data be represented and processed so they are suitable for interactive visualization?* Data sets resulting from acquisition and simulation will have to be used together, and efficient data structures will be used to maintain interactive frame rates.

3. How can large-scale geo-data (such as the AHN2 or bathymetric data), be used in constructing models and representations suitable for visualization and simulation? Many computational simulations will use mesh models (such as in finite-element analysis), and techniques will be developed to improve the interface between the point clouds and the geometric representations used for simulation.

4. How can a 3D visualization and a numerical simulation be integrated in a single interactive system? In project 2, techniques will be investigated for increased performance of grid-based numerical simulations, while using the highest available resolution data describing the simulation domain. Another improvement of the performance is the application of a graphics processor (GPU) or other massively parallel systems for fast simulations. We have done very promising preliminary work on this, indicating that similar performance as a remote supercomputer can be achieved on the desktop (Griffith et al., 2009).

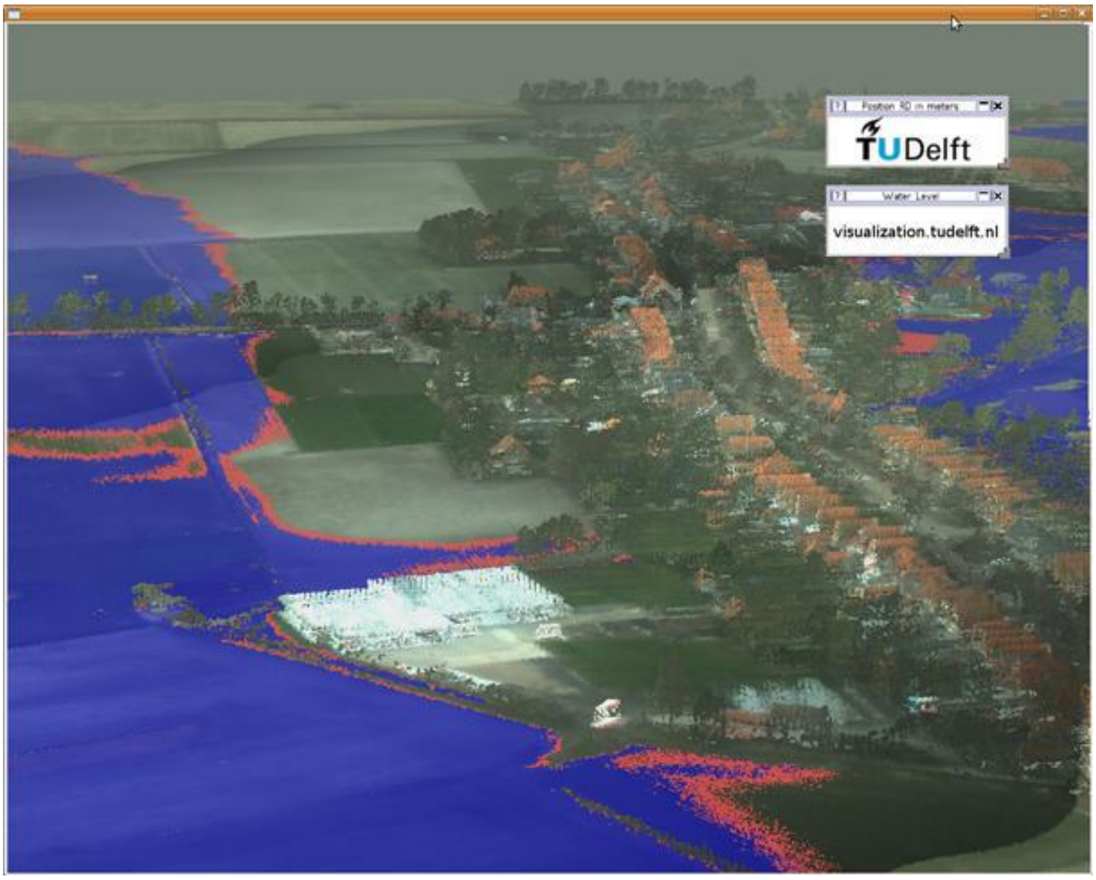

Figure 1: screenshot of AHN2 point cloud rendering, with flooding (image by Gerwin de Haan)

The goal is to design and build a single integrated system that offers a flexible user interface and allows interactive set-up and steering of numerical simulations, with direct visualization of the results. This tool is very suitable for use in collaborative scenario studies, as fast simulations can be set up and executed in an interactive session, and show results in a form usable for policy development for water protection.

4.2 Approach and methodology

NB. The numbering corresponds with the research questions in section A above

1. Massive point-cloud rendering with level-of-detail techniques; colour correction and improved shading; particle advection and animated visualization (Dussel et al., 2009); interactive navigation techniques; virtual reality (in cooperation with Project 1)
2. Techniques for large data handling, efficiency and scalability: adaptive levels of detail, adaptive mesh refinement, data compression, streaming, out-of-core algorithms.
3. Fusion of several types of GIS and simulation data, boundary reconstruction for use in computational grids (in cooperation with Project 2)
4. 3D interaction and computational steering; virtual reality and collaborative scenario evaluation environment, session management for access of historical cases and recording of decision processes and results. Advanced tools and techniques have been developed for fast prototyping of interaction techniques (De Haan et al., 2007a,b; De Haan 2009a)

4.3 Scientific deliverables and results

Results will be presented in technical reports and publications in scientific journals and conferences. The techniques will be implemented in research prototypes and extensively tested, including performance with very large data, and human usability. Annually, a demonstrator will be developed and shown at a suitable project event.

Deliverables and demo‟s:
d1 *March 2010:* Demo of interactive 3D landscape visualization (AHN2 point cloud data, with colour information if available), variable water level (horizontal plane, no physical simulation), with interactive navigation and level-of-detail rendering. Different colour scales for landscapes and water levels. Also usable with large screen stereo viewing (Virtual Reality).
d2 *End 2010:* Stand-alone 3D visualization application: using landscape data (AHN2), other GIS-data (eg. bathymetry data or river/canal beddings), and registered simulation output data (eg. Sobek, see Project 2). We will show water levels and also other simulation parameters such as water flow patterns.
d3 *End 2011:* Stand-alone application for linked fast simulation and 3D visualization. Similar visualization functionality as in Year 1, but equipped with a user interface for interactive set-up and steering of flooding simulations. Facilities for stereo-large-screen viewing and navigation.
d4 *End 2012:* Extended steering of the interactive simulations, with interactive modification of models (eg. dike breaks) and conditions (eg. wind force). Support of case studies and session management eg. archiving and communication of session results). Case study, evaluation and usability research (in cooperation with Project 1).
d5 *End 2013:* Integrated simulation/3D visualization application, suitable for integration in an existing water management information system.

Final result (prototype) is suitable for use door/with water experts, policy developers, and the general public.

4.4 Integration of general research questions with hotspot-specific questions

The ideas for this project have been deloped in close cooperation with water management organizations such as Deltares and Hoogheemraadschap Delfland. This project is based on the concept of an interactive visualization and simulation environment for scenario exploration and decision making, and the fundamental research questions underlying it closely correspond with the research questions formulated by hotspot Haaglanden in their research agenda[1], especially related with their project „Climate in Spatial Choices‟.

1) Programmabureau Waterkader Haaglanden: *Onderzoeks- en innovatieagenda*, Ruimte voor water en economie in Haaglanden, Hotspot Haaglanden – Kennis voor Klimaat, mei 2009

See also the general description of the WP.

4.5 Societal deliverables and results

d6The societal deliverables will be software tools that can be integrated with existing information systems used by water management institutions, and will be provided as a public web service. This will allow conducting collaborative policy development and evaluation conferences in the framework of decision support for climate change adaptation. Visualization will play the role of easing communication between different specialists, policy makers, decision makers, and the public at large, allowing a mixture of qualitative and quantitative criteria to be used.

d7 By interactive simulation on the spot, and 3D multi-view visualization, more alternatives can be evaluated, from more different viewpoints, and this will hopefully lead to better decisions on climate change adaptation strategies.

4.6 Most important references

1. M. Koutek (2003), Scientific Visualization in Virtual Reality: Interaction Techniques and Application Development, PhD Thesis, Delft University of Technology, May 2003
2. G. de Haan, M. Koutek, F.H. Post (2007), Flexible Abstraction Layers for VR Application Development, Proc. IEEE Virtual Reality 2007, IEEE Computer Society Press, pp. 239-242
3. E.J. Griffith, M. Koutek, F.H. Post (2007), Fast Normal Vector Compression with Bounded Error, SGP 2007 – 5th Symposium on Geometry Processing, 2007, pp. 263-272
4. Gerwin de Haan, René Molenaar, Michal Koutek, Frits H. Post (2007), Consistent Viewing and Interaction for Multiple Users in Projection-Based VR Systems, Computer Graphics Forum 26(3), September 2007, pp. 605-704
5. Gerwin de Haan, Michal Koutek, Frits H. Post (2008), Flexible Architecture for the Development of Real-time Interaction Behavior, IEEE VR 2008 Workshop Software Engineering and Architectures for Real-time Interactive Systems (SEARIS), Shaker Verlag, Aachen 2008, pp. 71-75
6. Tony McLoughlin, Robert S. Laramee, Ronald Peikert, Frits H. Post, and Min Chen (2009), Over Two Decades of Integration-Based, Geometric Flow Visualization, Eurographics 2009 State of the Art Reports, in Eurographics 2009 Annex, pp. 73-92
7. Gerwin de Haan, Frits H. Post (2009), StateStream: An Integrated Software Model and Architecture for Development of Dynamic Interaction, Proceedings of ACM SIGCHI Symposium on Engineering Interactive Computing Systems EICS 2009, pp. 13-22
8. Gerwin de Haan (2009a), Techniques and Architectures for 3D Interaction, PhD thesis, Delft University of Technology, September 2009
9. Dylan Dussel, Eric J. Griffith, Michal Koutek, Frits H. Post (2009), Interactive Particle Tracing for Visualizing Large, Time-Varying Flow Fields, Technical Report TU Delft Data Visualization Group, June, 2009

10. Gerwin de Haan (2009b), Scalable Visualization of Massive Point Clouds, Presented at the NCG seminar Management of massive point cloud data: wet and dry, De Meern, The Netherlands, 26 November, 2009
11. E.J. Griffith, T. Heus, F.H. Post, H.J.J. Jonker (2009), Interactive Simulation and Visualization of Atmospheric Large-Eddy Simulations, Technical Report TU Delft Data Visualization Group, June 2009