Using virtual reality to visualize extreme rainfall events derived from climate simulations

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Introduction

Virtual Reality is a powerful tool for scientific visualization and science communication. Utilizing all three spatial dimensions as well as intuitive interaction methods allows us to present large sets of data in immersive ways.
We present a VR visualization of precipitation data pertaining to the hydrological area of Bavaria.

Data originating from the ClimEx Project[1]:

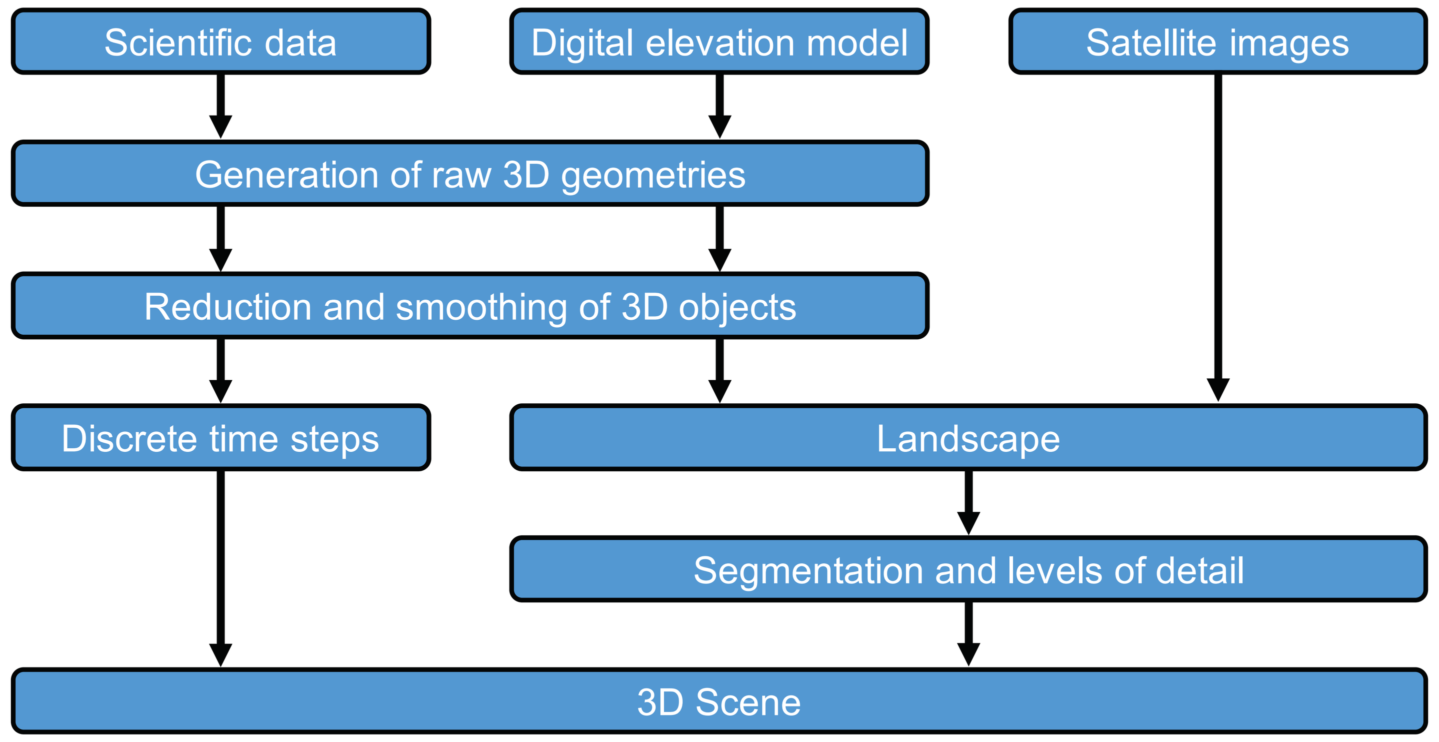
- Climate change simulation for 1950-2100
- RCP 8.5 scenario using the Canadian Regional Climate Model (CRCM5)
- 50-member ensemble run on the SuperMUC
- Numerous climatological and hydrological variables, e.g. temperature, pressure, soil humidity and rainfall

Our goal is a scientific visualization that is:

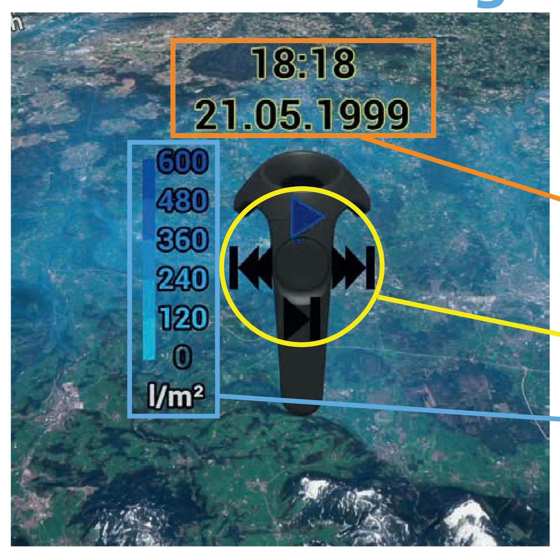
- Able to display various events of 60 hours of accumulated rainfall each
- Immersive and engaging
- Easy to control and understand, especially for non-experts
- Open to exploration
- Able to render 90+ frames per second per eye on commercial hardware

Method

We use the feature-rich Unreal Engine 4 to design the 3D scene as well as the VR interaction. For this we create a 3D surface from the grid of data values. The z-value of the surface corresponds to the aggregated amount of rainfall since the beginning of each respective event.



Interaction design

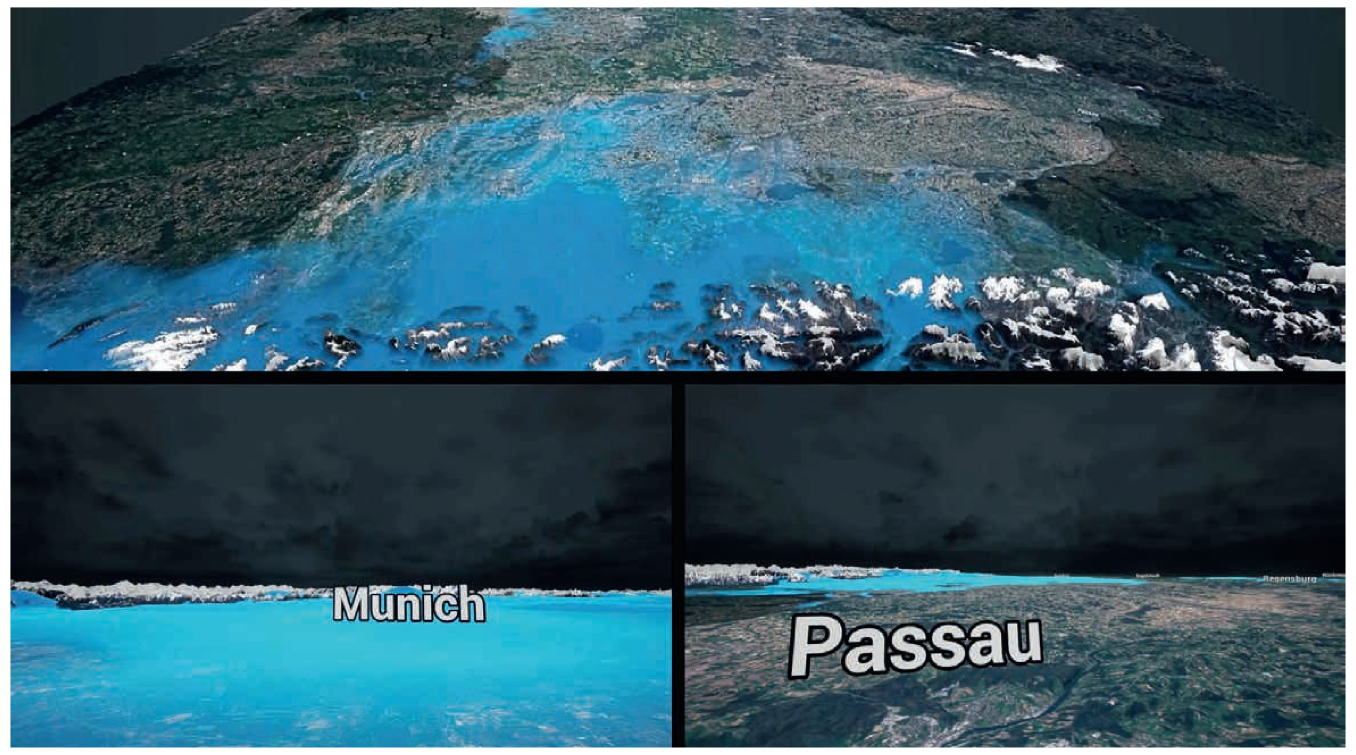


Virtual representation of the controller

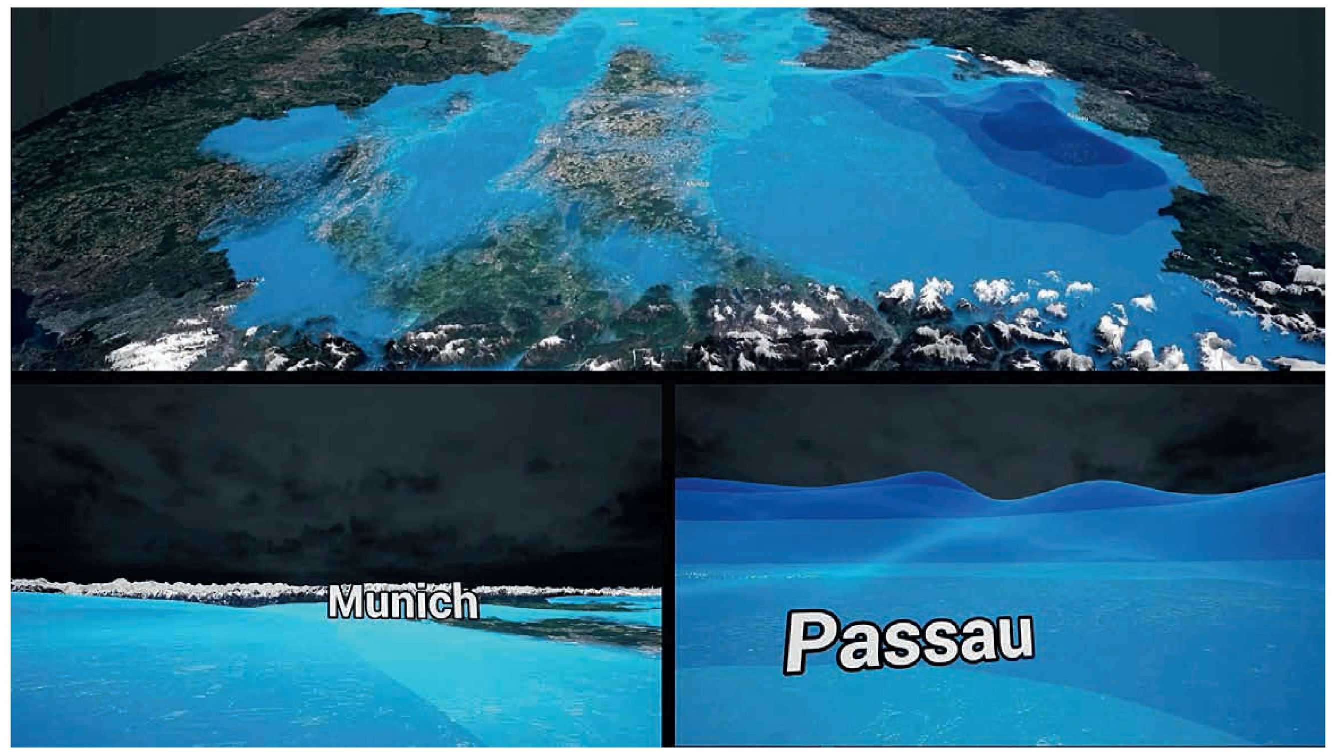
- Coloring along a discrete gradient to ease visual comparability
- User-facing name plates for major cities
- Single controller as input device with
  - a date and time indicator for the current time step
  - Icons for the button assignment
  - a legend for the color mapping
- Controls for flight and steering of the visualization

Results

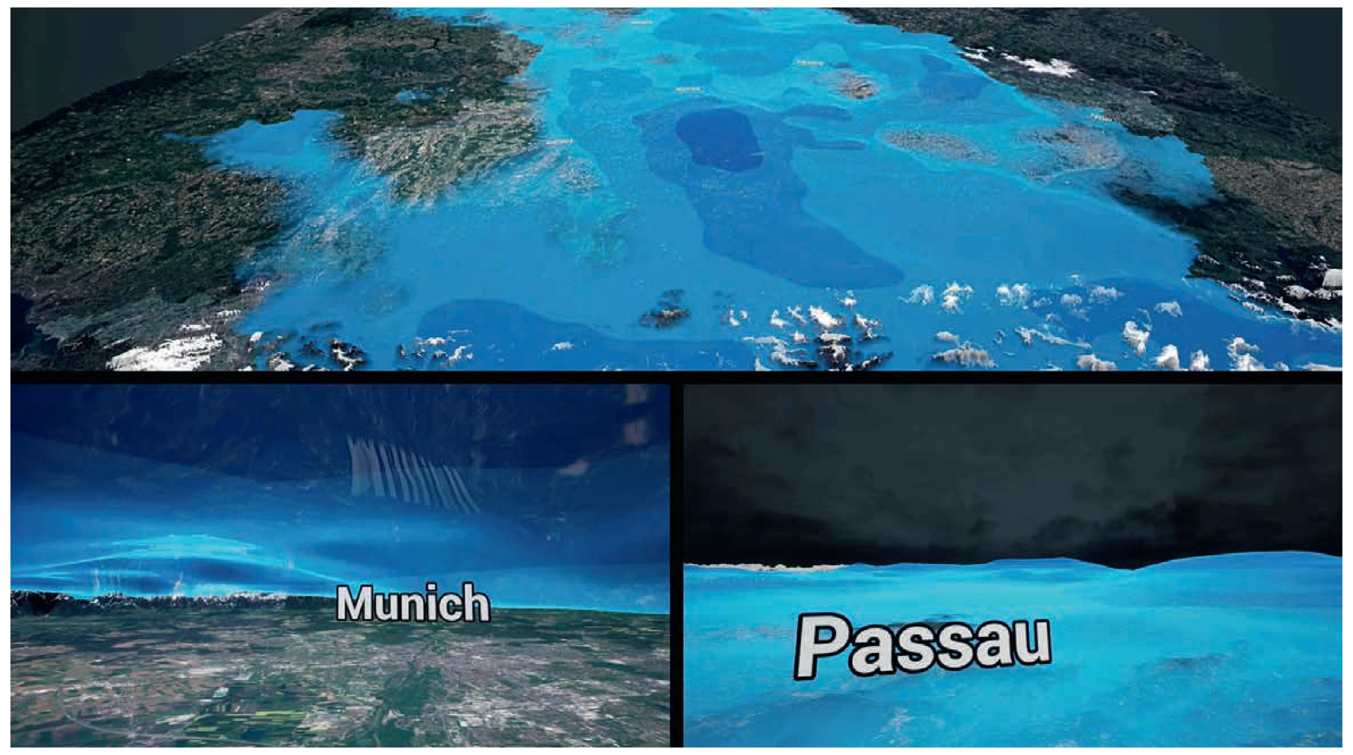
We were able to present our VR visualization to a wide field of interested people in varied settings. The users included prospective secondary school graduates evaluating branches of study, climate scientists, non-climate scientists, politicians, elder citizens and other decision makers. While different groups focused on different aspects of the visualization, all were able to independently control and explore the VR application with minimal introduction and guidance.



Three points of view of the historical rainfall event of 1999



Three points of view of the 2040-2070 event



Three points of view of the 2070-2100 event

The use of a commercial game engine and a straightforward interaction design allowed us to expand the application to further teaching settings with limited effort.

Currently available exploration options:

- Small co-operating groups in a CAVE automatic virtual environment
- Lectures to larger groups using a 3D-capable powerwall
- Autonomous exploration with a head-mounted display (HMD)

Conclusion

We have developed a way to present data results from climate computations in an immersive and accessible manner.

Challenges:

1. Boundaries imposed by hardware:
   - Rendering time
   - Memory usage
2. Technological barrier to exploring the virtual world:
   - Powerful, yet concise controls
   - Meaningful, yet unhindering displays
   - Comprehensibility of the presentation

Solutions:

1. Optimization of the 3D meshes:
   - Polygon count reduction
   - Laplace Smoothing
   - Level of detail system
2. Application of familiar design patterns and principles:
   - Contour lines
   - Established UI designs
   - Flat interaction hierarchy
   - Feedback on current status
   - Visible input options

Acknowledgement

We would like to thank our colleagues, Elisabeth Mayer, Lea Weil and Kristian Weinand, for their support with the processing of 3D objects as well as their helpful feedback on design choices. We also gratefully acknowledge funding of the project ClimEx by the Bavarian State Ministry of the Environment and Consumer Protection.

References

[1]Leduc, Martin, et al. „ClimEx project: a 50-member ensemble of climate change projections at 12-km resolution over Europe and northeastern North America with the Canadian Regional Climate Model (CRCM5).“ Journal of Applied Meteorology and Climatology 2019.

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