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Atlas of Switzerland Goes Online and 3D – Concept, Architecture and Visualization Methods

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Abstract. Interactive atlas systems are products of high cartographic quality and user-targeted functionality. The main challenge for future digital atlases will be to incorporate the new trends of 3D mapping, online and mobile applications into atlas design. The Atlas of Switzerland, an example of a mature digital atlas, tries to advance these trends together with existing atlas functions in its next version. Starting with the concept of an online 3D atlas, this article explains the architectural implications of an atlas based on a virtual globe engine. By embedding the globe in a modern graphical user interface and implementing cartographic 3D visualizations, it is intended to strengthen the position of the atlas against other online mapping services.

Keywords. National Atlas, Web Cartography, 3D Visualization

[*] This version is the reviewed and accepted version of the manuscript before it was copyedited by the publisher.

1. Introduction

During the last two decades, numerous interactive atlas and mapping systems have been developed. With the rise of high-speed Internet connections, online atlases appeared (e.g. Atlas of the USA, Atlas of Canada, ÖROK Atlas, Atlas of Belgium) facing the challenge of streaming map data with good performance. One trend goes towards service-oriented online atlases (e.g. National Atlas of the Netherlands, WebAtlasDE), which act as visualization front-ends of the National Spatial Data Infrastructure. In parallel, gesture-driven online atlases for mobile devices have been created (e.g. National Geographic World Atlas, Barefoot World Atlas, Statistical Atlas of Switzerland). All these systems offer mainly statistical 2D map types like choropleths, point symbols and charts, and partly some 3D map types like panoramic views and block diagrams (e.g. Swiss World Atlas). They also include a bundle of atlas functionalities for spatial and temporal navigation, map visualization, and layer handling. Nevertheless, all kinds of online atlases have to compete with freely available map services (e.g. OpenStreetMap, Google Maps), geoportals (e.g. INSPIRE, geo.admin.ch), and virtual globes (e.g. Google Earth, AGI Cesium). At the same time, the popularity of geodata and geo-related applications enables digital atlas products to activate new user groups and to animate them for collaboration. Thus, also the development of atlases has to strive for new horizons.

A detailed survey on current geovisualization products points out that the majority of up-to-date applications are dedicated and conceived for 2D web and mobile use (Hurni et al. 2011). Web-based applications are rather heterogeneous concerning content handling and cartographic quality. The attractiveness of these applications is primarily based on the immediate benefit in everyday life and on the actuality of the data. In addition, the survey reveals that 3D maps in atlases are nearly inexistent. However, applications using 3D concepts and virtual globes are persuading users by their intuitive navigation and their spatial clarity (Bodum 2002). Regarding atlas cartography, map and atlas authors should be engaged in the 3D application discussion to determine and establish viable visualization rules (White 2012). They have to know the weaknesses of 3D symbolization and interpretation, but first of all, they have to investigate in and demonstrate possible solutions for 3D maps. Although there is a tendency towards 3D representations in cartography, many questions on their effectiveness (e.g. of 3D charts) and their usefulness (e.g. of extruded polygons) remain unsolved and disputed (Harrower 2009, Bleisch et al. 2008). Scientific research has proven that 2D overrules 3D symbolization in terms of accuracy estimation of chart sectors and height, or in comparing different charts (e.g. White 2012, Wilkening and Fabrikant 2013). Attempts have been made to improve 3D symbolization, for instance the cartography-oriented design of 3D visualization (Semmo et al. 2015), the evaluation of graphic variables for 3D use

(Häberling et al. 2008) or the definition of the appropriate levels of abstraction depending on viewing distance (Pasewald 2012). For quantitative interpretation of 3D symbols, there are already approaches to use tools like reference grids or scale bars (Bleisch 2011).

To summarize, the main challenge for future digital atlases will be to merge the big trends of *online mapping*, *mobile mapping* and *3D mapping* with cartographic design and atlas-specific functionality. Thus, research and development should focus on cartographic 3D visualization and interactivity for different user groups and applications. In the upcoming version of the *Atlas of Switzerland*, we try to follow the proposed strategies.

2. Project Background

The *Atlas of Switzerland (AoS)* is mandated by law by the Swiss Federation to visualize themes from different fields, such as socio-economy, ecology, traffic, and energy, in an ongoing long-term project (Hurni et al. 2015). Since its beginning in 1961, the Swiss national atlas offered cartographically sound maps in combination with additional information to the general public in order to visualize visible and hidden structures and processes.

A first printed version with over 600 maps has been produced and published until 1997. These maps show the whole range of thematic cartography, including various kinds of charts, and even 3D symbolization (www.atlasofswitzerland.ch/portfolio). From 2000 to 2010, three interactive versions of AoS were published on CD-ROM / DVD (*Figures 1, 2*).

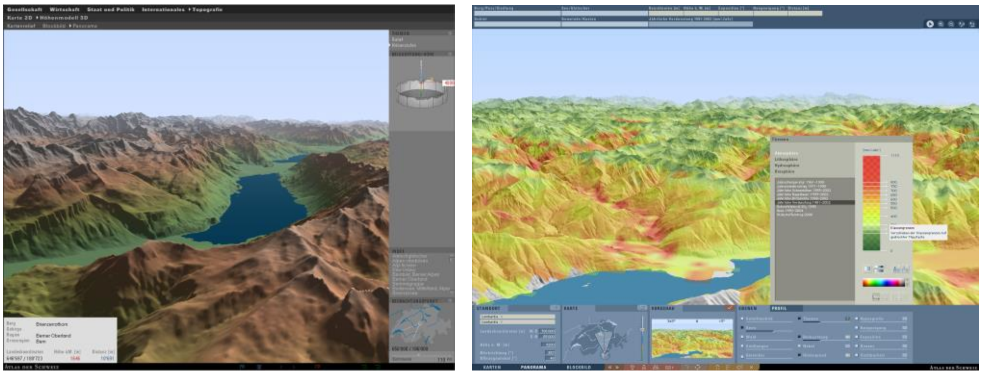

Figure 1. Atlas of Switzerland – interactive series: AoS 1 (2000; left), AoS 2 (2004; right).

The last edition, AoS 3, contains about 2000 maps with additional time series in 2D maps and 3D mode (block diagrams, prism maps, and panoramic views). It offers a multitude of tools and map functions, including a sky tool, terrain analysis tools, data and map comparison tools, smart legends, and many more (Sieber et al. 2009).

The series of interactive AoS was a big success: overall, more than 23.000 copies were distributed during this decade. The interactive AoS versions can be characterized as stand-alone GIS in a Multimedia approach (Bär and Sieber 2007), where map visualization, atlas tools and GUI are fully developed in-house by the AoS team. Main achievements were the integration of various map types (point symbols, charts, lines, choropleths, and grids), a graphically appealing map design, adaptive map layers, and tailor-made functionality. The drawbacks of this approach were that the atlas was developed as a closed single application with proprietary data formats, too many tools and features, no smooth transition between 2D and 3D map mode, and nearly no online connection.

To sum up, the AoS product cycle has reached the stadium of a mature desktop-based atlas system, and only a total conceptual rethinking would push the project to meet current user needs.

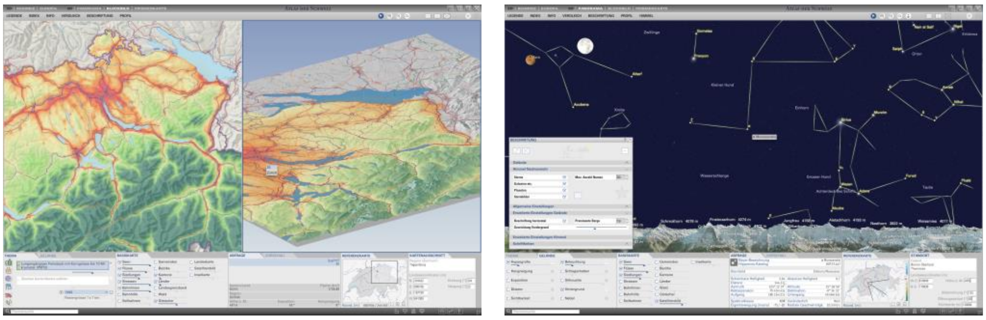

Figure 2. Atlas of Switzerland 3 (2010): 2D map/block diagram (left), Starry sky with settings panel (right).

3. New Concepts

The next generation of the Atlas of Switzerland focuses on online cartography with real-time 3D visualization of geographic data. Thus, the concept of a *3D-based cartography* will be pursued, where a 2D map is considered as a special case of a 3D map setting (Sieber et al. 2013). The basic idea is to combine 2D and 3D by allowing the user to choose a conventional 2D map view, but also to detect additional information in a 3D map view. Within this 3D environment, new rules, interactive methods and user-friendly tools for 3D navigation in space and time, map graphics and layer handling, and explorative analysis will be developed.

The 3D atlas should stand for a *world of experience and discovery*, inviting people to explore its thematic content, and interrelations (Vozenilek 2015). Hence, the functionality of the atlas has to start with basic functions of navigation and information retrieval (Häberling et al. 2007). In detail, the 3D atlas functionality consists of *spatial navigation* (3D navigation, place search, geolocation, home extent), *temporal navigation* (time points and periods), *thematic navigation* (map search/menu; related/popular maps), *information* (query, legend, theme description, multimedia elements), *visualization* (2D/3D mode; layer interaction), *import* (WMS, GPX) and *export* (PDF, permalink). The functionality will be augmented stepwise according to user needs, that is, the user's vote is essential to develop new tools and actions.

Map themes of the new AoS will be grouped into ten thematic categories: Portrait of Switzerland, History & Future, Nature & Environment, Landscape & Space, Tourism & Leisure time, Society & Culture, State & Politics, Economy & Energy, Traffic & Communication, and finally, Switzerland International. In the first edition, each category will contain only a few maps. These maps are selected according to the following principles: popularity (e.g. Swiss records, beer map) as a door opener for other more serious topics, "classical" themes (like geology, population) as a must-have in every national atlas, and data suitability for 3D representation (*c.f. chapter 6*). It will also be forced to present well-known themes in a new way, for example by approaching the historical origination of Switzerland on the commune level. Although the main part of the thematic content spatially focuses on Switzerland, the use of a virtual globe also allows integration of European and worldwide map themes (e.g. international flights).

Conceptual considerations are also dedicated to the *Graphical User Interface (GUI)* of the 3D atlas (Sieber et al. 2015): the GUI should work for desktop and mobile applications, and consider reduced feature and layout complexity as well as responsive design. Further graphic-oriented concepts and techniques concerning the GUI are described in the next chapter.

4. Atlas System Architecture

As a basic framework for future AoS products and affiliated atlases, the *AtlasPlatformSwitzerland (APS)* has been propagated and prototypically implemented (*Figure 3*).

On the back-end, map-editors can import attribute, vector, and raster data to a PostGIS database with the *APS Editor*, a plug-in for QGIS. The *APS Editor* facilitates composing map layers, adding multimedia elements (e.g. images in MongoDB), and annotating map metadata (e.g. text sources in Zotero). In addition, tile caches (TFS for vector data, TMS for raster data) can be created which split maps into smaller parts at different levels of generalization. Once a map is ready to be published, metadata is exported from the database to JSON documents, which are – together with the map tiles – hosted on a scalable web server (nginx). A load balancer (HAProxy) mediates the HTTPS requests for map tiles and metadata.

The APS front-end architecture consists of a desktop application, at which the Chromium Embedded Framework (CEF) combines the web-based atlas user interface with the *APS Globe*. The *APS Globe* extends the 3D visualization engine osgEarth whose dedicated virtual globe offers near real-time rendering and navigation, high geodetic quality, dynamic streaming of large data sets, and a multi-resolution terrain representation. It also supports overlaying custom imagery, manifold GIS formats and web services. This enables, amongst others, the interactive data exploration in AoS, such as combination of a base map and thematic maps, interactive adjustment of transparency of thematic maps, and query of the map elements.

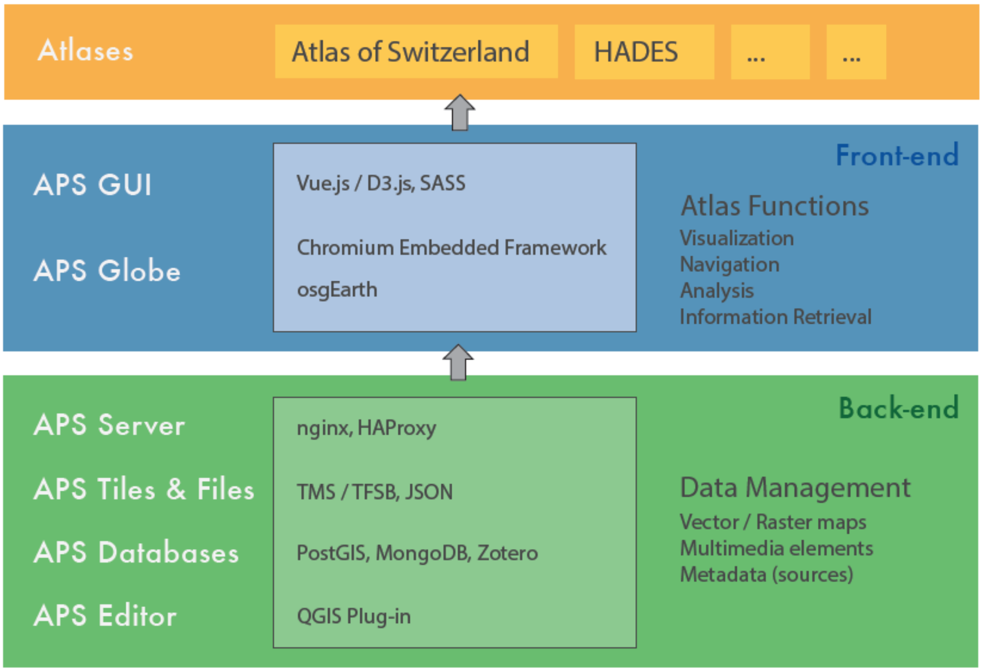

Figure 3. System architecture of the AtlasPlatformSwitzerland (APS).

Currently, the APS is in use for two thematic atlas products, the *Atlas of Switzerland – online* and the *Hydrological Atlas of Switzerland (HADES)*.

The GUI for the atlas platform has been established with methods of interaction design (IxD) in the four following steps (Sieber et al. 2015): 1) investigation phase, 2) rough design phase, 3) detailed design phase, and 4) implementation phase.

After investigating existing atlas GUIs, use cases, and possible GUI layouts, interaction designers deepened into sketching the appearance of the atlas. At the rough design stage, they used wireframe techniques to create a storyboard, whereas moodboards set the main design direction of the GUI.

During the detailed design phase, interaction designers created and specified all layouts, icons, tools, and actions. Finally, web application engineers implemented the GUI with JavaScript frameworks (e.g. Vue.js, D3.js) and a CSS preprocessor (SASS).

Figure 4. GUI design of the 3D Atlas of Switzerland: Start screen with main categories (left) and map screen with layer and tool bar (right).

The final GUI consists of two main screens: the start screen and the map screen *(Figure 4)*. A transition between the two screens is initiated by clicking on a map tile, a search result, or an icon at the top left corner. It is possible to combine up to three thematic atlas maps and three external maps atop of a base map. Controls for spatial 3D navigation, a time slider for animating map layers, and elements for thematic navigation (i.e. a quick and an advanced search for places and themes, a hierarchical menu, and panels for related and combinable maps) help users to explore the atlas contents. Following Shneiderman's (1996) information seeking mantra – overview first, zoom and filter, then details on demand – user may obtain additional information on maps by displaying multimedia elements, inspecting metadata, and measuring distances and areas in separate panels. The GUI is designed to be responsive for tablets, laptops, and desktop PCs as well as to be extensible for new functions.

5. Cartographic 3D Visualization

The APS aims to provide eye-catching and well-readable 3D visualizations to raise the interest of the public. The third dimension has the advantage to depict an additional variable, but at the same time, it has the disadvantage that depth cues lead to misinterpretation of size. Furthermore, although we perceive the world in three dimensions, reading a map may be puzzling when trying to interpret 3D visualizations with too many graphical variables. This information overload can be partly avoided by using generalization methods like selection, decluttering, etc.

Depending on the source data type, the APS includes cartographic 3D representation techniques like solid charts and billboards for point data, curved lines for trajectories, extrusion for areas, and terrain modelling for volumes. Considering the interaction of thematic layers with terrain, the LOD behavior, the performance, as well as possible occlusions need to be taken into account. The challenging part is to make an intuitive visualization both in 2D and in 3D: Map-readers should get an overview from the birds-eye perspective and more details when tilting the globe.

Cartographic 3D visualizations are driven, but sometimes also restricted by the underlying technology. In the *APS Globe*, the terrain surface is generated by a uniform triangle mesh (regular grid), which is simpler to store and manipulate than an irregular triangle mesh (Luebke et al. 2003). Terrain and maps are stored in tiles and loaded in a quad-tree graph so that data sets can be transferred in little chunks and at a convenient resolution. Maps are either draped as textures on the terrain or tessellated in case of vector data. During the rendering process, the virtual globe engine has to solve tasks like intersections, ordering of map features, avoiding artefacts from projections and at tile borders, shading of 3D features, and opacity of different layers (Cozzi & Ring 2011).

Below are examples of the 3D visualization methods that have been implemented in the new version of the Atlas of Switzerland.

5.1. Point Features

Basic visualization methods used in AoS for point features are translation, billboards, 3D solid charts, 3D symbols, and labels.

Translation can be applied to the point data, as it was done to represent the population of Switzerland (Sieber et al. 2013). The result of such a combination is a point cloud map (*Figure 5*). From an orthogonal view, the point cloud densifies to a choropleth-like map; population peaks are visible from a tilted view. As height-depending scaling of features is quite cost-intensive, the behavior of the map when zooming in remains an open issue. The initial loading time of the map, on the other hand, was reduced by creating tiles with a limited number of point features.

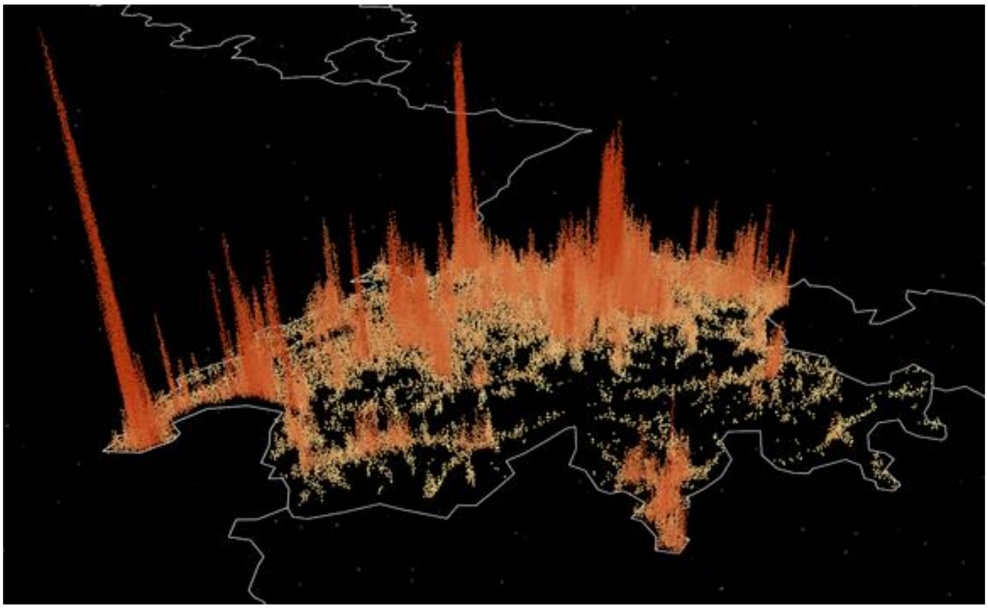

Figure 5. Point cloud map: Population distribution in Switzerland.

A common representation of point data is a *billboard*. In a 3D space, a billboard rotates always to the direction of the camera, as draping 2D symbols on the terrain would distort them. Billboards can contain both images (e.g. PNG) and vector data (e.g. SVG), the latter however are rendered into a texture due to performance reasons. This technique was used, for instance, to visualize different types of mountain cableways (Schnürer et al. 2014), such as cable railways, funiculars, or shuttle cableways (*Figure 6, left*).

Another example of using a billboard, implemented by Schnürer et al. (2014), is a 2D wing chart showing how many passengers travel at the airport at certain time slots (*Figure 6, right*). Wing colors represent the time of day, and the radius of each sector the number of passengers. The angle stays the same to enable users to compare the areas of different sectors correctly. 2D wing charts can be used with absolute values. A still open cartographic question concerns the display order when billboards intersect each other: Shall the nearest, the smallest or the most important feature be displayed the foremost? In our map, the nearest feature to the camera is visible, whereas intersecting features are minified and faded.

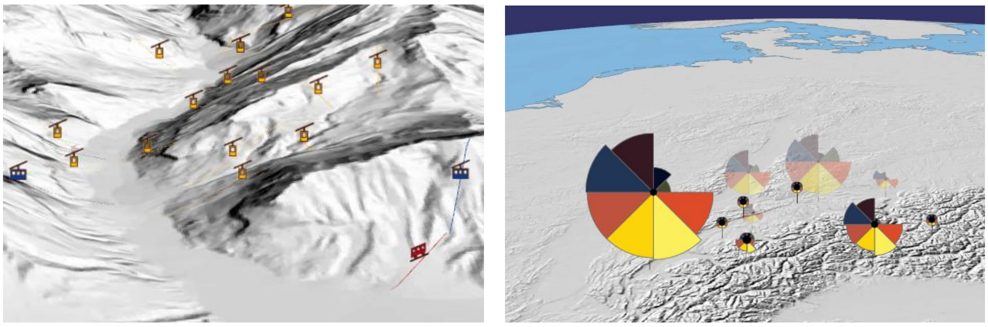

Figure 6. Billboards: Mountain cableways (left). 2D wing charts: Number of airport passengers at different times of day (right).

The atlas also contains maps with *3D charts*, for example stacked pyramid frustums (*Figure 7*). The frustums show population counts of European countries from 1960 (bottom layer) to 2010 (top layer) with changes over decades, displayed by differences in square of upper and lower planes of every single frustum. Thus, top and bottom surface areas represent thematic variables at sequent points in time. From an orthogonal view, however, this kind of visualization hides the temporal dimension and displays only one variable at a point in time. Compared to 2D bar charts, which are also suitable for population counts, stacked pyramid frustums imply the metaphor of a population pyramid. As charts are 3D features, it is possible to query individual chart parts. Yet, the rendering of edges and line joins needs to be further improved so that outlines are visible from all distances (Schnürer et al. 2015).

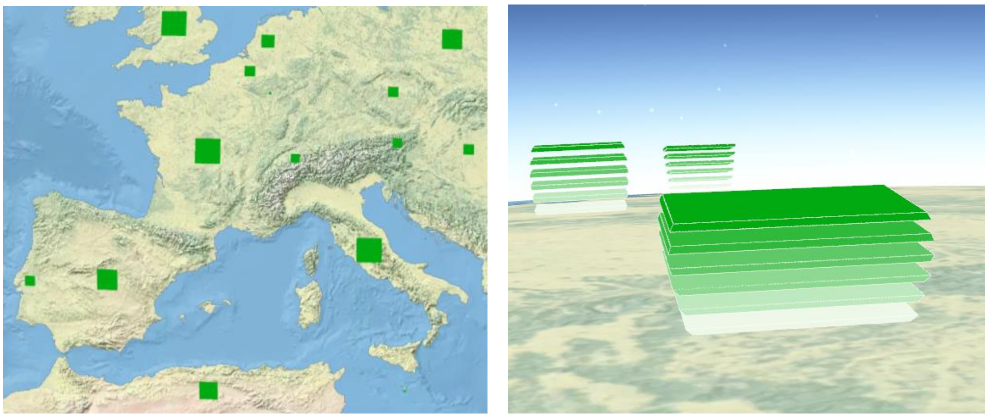

Figure 7. Stacked pyramid frustums: Population in European countries. Orthogonal view (left) and tilted view (right).

Point features can be depicted on a more realistic level by *3D symbols,* such as castles, airports, volcanoes, and types of houses. Those may replace billboards on some maps in future since they may serve as landmarks for the map-reader.

Beyond, point information can be conveyed as *labels*. An example of this representation type is a map of worldwide appearances of the term 'Schweiz' (German for Switzerland), because some names of small mountain chains and regions in different countries contain this word fragment.

5.2. Line Features

3D curved lines are a technique to visualize paths between a starting point and an end point. With this kind of visualization, a "focus" effect can be achieved by setting a common starting point. It is much easier to identify the destination points. An additional attribute can be mapped to the height of the path, for instance the approximate flight height, and parameters for a finer or coarser line tessellation can be set. An addition would be the implementation of arrows at the line endings to indicate directions. This type of visualization is applied for the flight routes of the main airports in Switzerland (Sieber et al. 2013, *Figure 8*). Darker shades of pink represent a bigger number of passengers, and lighter shades indicate a lower number.

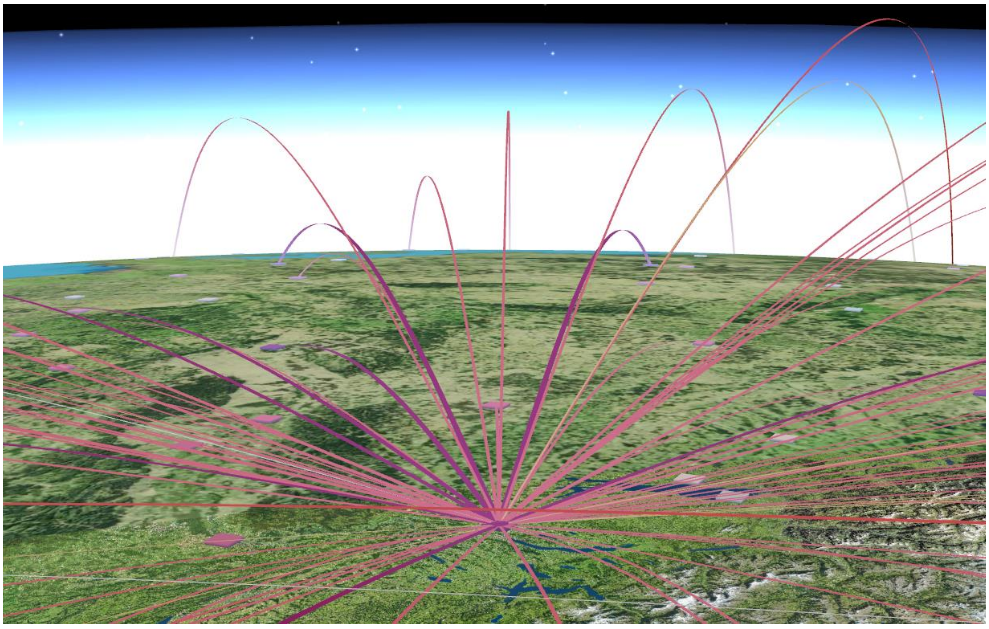

Figure 8. Curved lines: Direct flights from Zurich airport.

Linear objects bound to the ground in AoS are usually rendered by means of *GPU clamping* mechanism, which is fast, generally well suited to lines and causes no jags at the edges, as if it would happen when draping linear features (Pelican Mapping 2013). In the atlas, natural gas pipelines are displayed with the GPU clamping technique. To avoid the problem of Z-fighting of intersecting lines, altitude offsets have been introduced for pipelines with different diameters.

5.3. Area Features

Vertically extruded polygons are implemented in AoS to assist in visualizing quantitative data or to simply embed them appealingly into 3D space. Challenges for this technique are intersections of larger extruded polygons with the terrain, that can be avoided by a finer tessellation. Extruded grid cells were applied, for example, in a precipitation map, where the third dimension demonstrates the amount of rain. Another example is the conversion of building footprints into 3D building areas in the settlement development map (*Figure 9*), where extrusion intensifies the built-up area connotation (Chesnokova et al. 2015). Together with the color-coded time component – the darker the older – the user gets a vivid impression of the urban development.

In contrast to lines, polygons can easily follow the terrain by means of *draping*, which is the process of rendering features into a texture and projecting them onto the surface of the terrain (Pelican Mapping 2013). Despite possible jagged artifacts (which are mostly visible when tilting the globe), areal features benefit from draping, as they fully match the terrain, and the resolution is preserved. Since draped polygons are always displayed at the bottom level, thematic choropleth maps will not cover all base map elements (e.g. rivers), what is not desirable from a cartographic perspective.

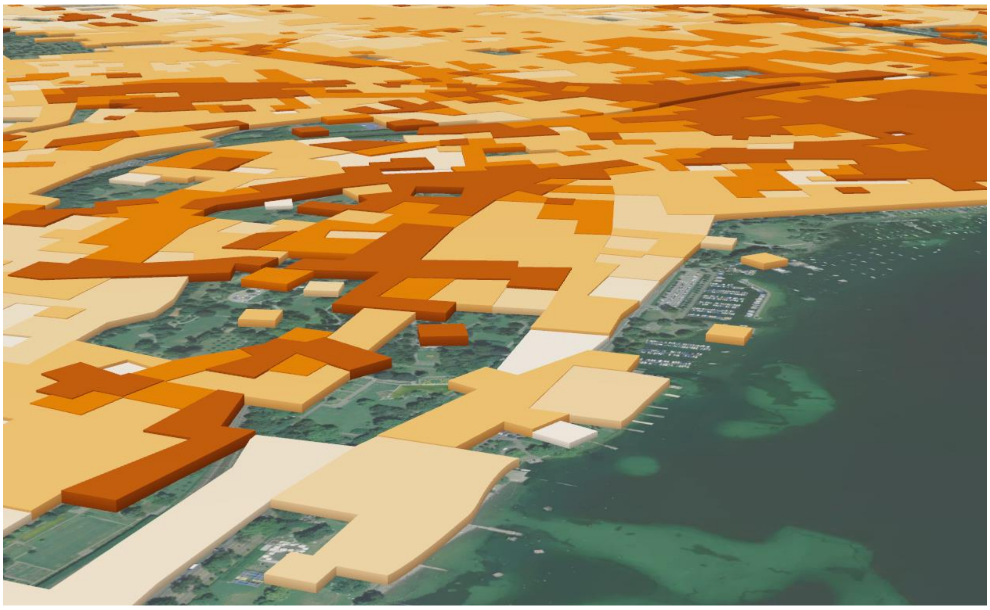

Figure 9. Extruded polygons: Settlement development.

5.4. Volume Features

To depict volumes in 3D, two techniques were applied. The first type is represented by *terrain volumes* and is used, for instance, in the Swiss last glacial maximum map (*Figure 10*). The DEM appears here as a variable that represents the height of an ice shield. When applying this technique, it is possible to combine the former ice shield with the situation today. Thus, the user can locate different known places and compare the thickness of the ice.

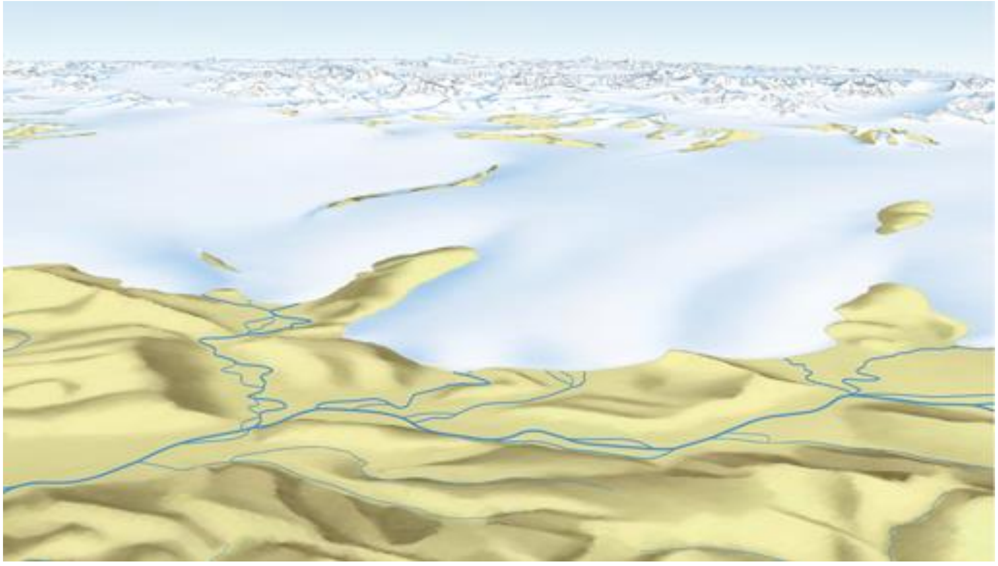

Figure 10. Terrain volumes: Last glacial maximum in Switzerland.

The other type of volume visualization implemented in AoS is *polyhedral surfaces* like airways, airspaces and geological layers. Map-readers can fully explore the dimensions of those 3D volumes in a virtual globe, what would not be possible on a 2D map, where height information is lost. In a 3D environment, however, it is likely that the map-reader loses orientation when diving into a transparent 3D volume. Therefore, the atlas needs to provide additional aids, for example an overview map including the current altitude.

6. Outlook

The launch of the new product line *Atlas of Switzerland – online* is scheduled in spring 2016 as a desktop version for Windows. In the upcoming years, the functionality and content of *AoS – online* will be enriched and completed with an OS X Mac version. A version for tablets, *AoS – mobile*, is also planned. Both versions will offer a broad range of thematic maps, visualized with 3D techniques, giving professionals and inexperienced users the opportunity to combine different geospatial phenomena in a modern atlas user interface.

Conceptually, more storytelling aspects will be included in the next versions to deliver the atlas contents to users easier. Accompanying usability studies will evaluate the user experience and may reveal further user needs for the GUI and globe. To ensure a good performance for many users, a private Cloud infrastructure is currently being developed, as the speed of rendering 3D maps is a crucial factor for user satisfaction. Internal workflows for creating new maps and for updating existing maps in the atlas are continuously optimized and automated by geoprocessing scripts and GIS tools. Lastly, it is planned to make map metadata available for search engines and to introduce some animated 3D visualizations.

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