

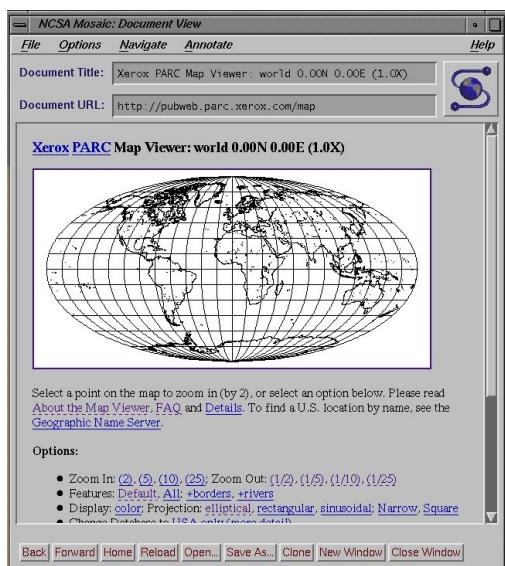
Web map printing solutions

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2018-03-08

Abstracts

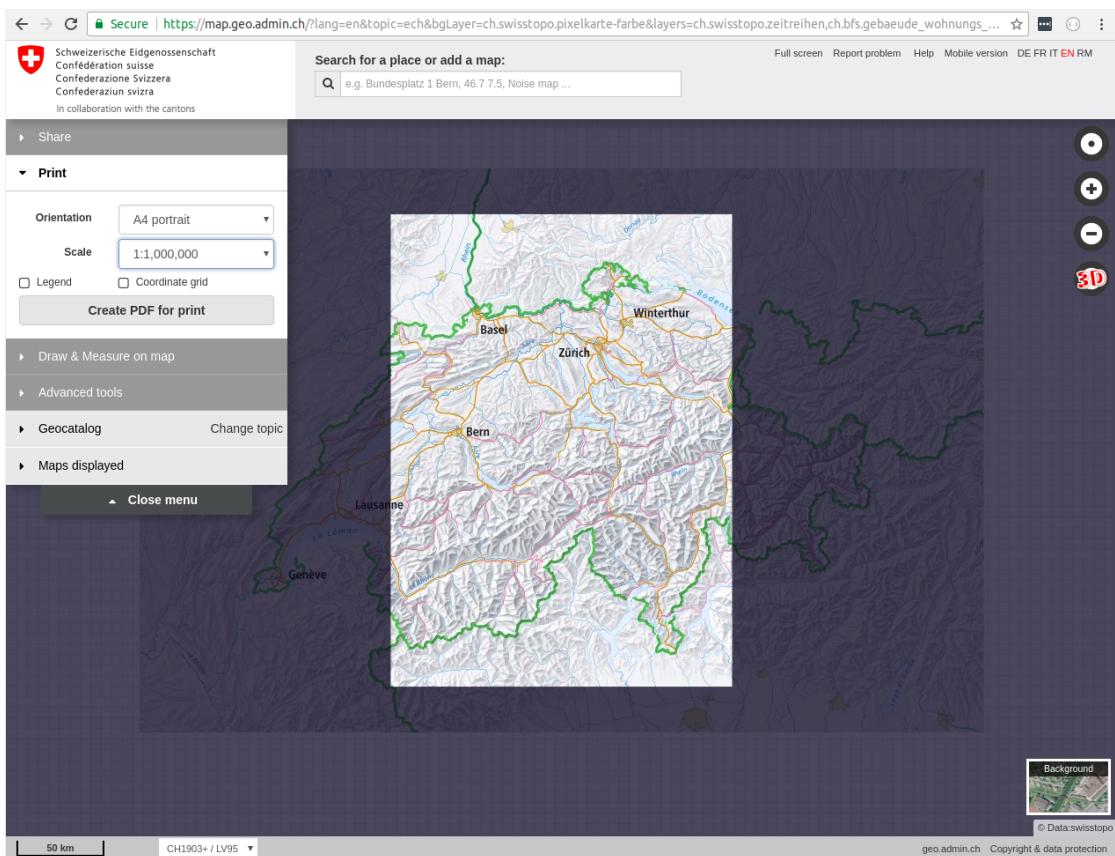
This document explores various alternatives for generating suitable document for printing to be used in a web mapping application.



1 Current situation

The swiss federal geoportal map.geo.admin.ch uses a customed developed server-side printing application ([service-print](#)) based on a [forked of MapFish Print v2](#) and a [Python Flask](#) application to allow for multiserver use and multipage PDF document generation. Currently, it runs in a Docker auto-scaling group, with one server at night and two during the day.

Print dialog and print extent as implemented in map.geo.admin.ch:



1.1 Capabilities

- Printing all 2D layers from map.geo.admin.ch, including import GPX/KML and most WMTS/WMS
- Selecting a predefined scale (from 1:500 to 1:2'500'000)
- Generating an A4/A3 PDF 1.3 at 150 DPI (not a technical limitation), portrait or landscape orientation.
- Generating a multipage PDF for Zeitreise (one year per page, about 20 pages)
- Synchronous print for single page, asynchronous for multipage
- 247'198 PDF page generated the last 90 days (500-5'000 per day) and 1'383 multipage print (0 to 50 per day)
- Dockerized application running on a auto-scaling cluster (time-based, two containers during the day, one at night)
- Using an extend version of the standard [Mapfish print protocol](#) used by GeoMapFish/GeoExt/GeoServer
- Printing legends, if needed (classes)
- Printing a *LV95* and *WSG1984* grid if need (the grid is generated by Mapserver)
- Merging legends of complex layers (geology) to the end of the PDF document.

1.2 Shortcomings

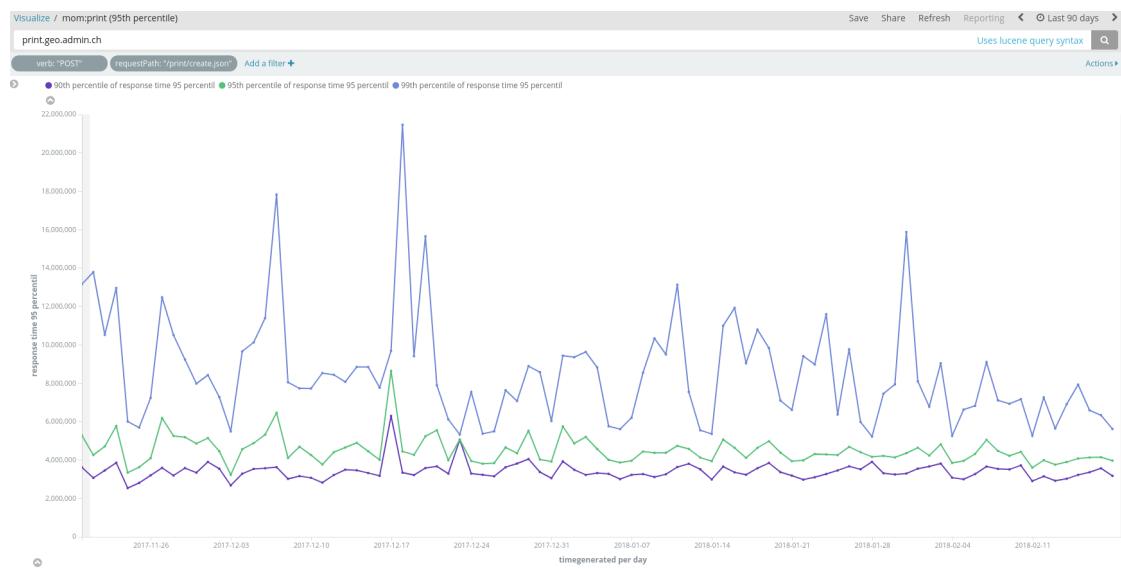
- Print only 2D map

- Imported WMS and WMTS layers won't be printed if remote server do not support LV95 projection (EPSG:2056). These layers may be still displayed in the application
- WMTS layers are added as individual tiles to PDF, for every layer (way too much information if some layer are fully opaque) 232 MB for Zeitreise only, 376MB (25 pages)
- Very limited support for Vector. Luckily, imported vector do not support many styles.
- Symbols size for Raster layer (Vector symbol are adapted to print resolution)
- MapFish v2 is not developed anymore. swisstopo is patching a fork.
- Support for retry and multiserver is sub-optimal.
- Not 100% WYSIWIG. The print extent is always correct, but some people are confused because both the *ch.swisstopo.pixelkarte-farbe* and the *ch.swisstopo.pixelkarte-grau* are combination of maps of various scales which are not necessarily printed.

1.3 Performances

1.3.1 Overall print jobs

The 95th percentile for all print jobs are between 3.7 and 5.0 s (only time for generation, without download)



<https://kibana.bgdi.ch/goto/3566fae450682eea244826f2ec49e477>

Error rate: last month 1'082 errors for 97'988 success (about 1.09%)

1.3.2 Simple print job (cron)

Printing a standard A4 landscape page at 1:25'000

Generation time (POST to json response): 1.21 ? 0.05 s (n=4578, every 5 minutes)

Errors: 22 out of 4578 jobs (0.48%)

1.3.3 Pingdom

Same spec file as above sent every 5 minutes from Pingdom

692 ms average response time (time to get JSON response) 1.17 s max response time 7 outages totalising 35 minutes uptime 99.83%

1.3.4 Testing

Many spec file examples are available on github at [mapfish-print-examples](#)

1.3.5 Examples

Some PDF output from [print.geo.admin.ch](#)

[A4 1:25'000 150 dpi](#)

Non standard print, for comparison:

[A4 1:25'000 96 dpi](#)

[A4 1:25'000 300 dpi](#)

2 What is printing?

In the context of web mapping application, printing is generally seen as a way to generate a file, like an image or a PDF, suitable to be sent to an office printer. But even in this context, some people may primarily interested in the PDF file, for instance for archiving or offfile use, not a paper impression.

The advent of 3D data and 3D capable application as well as the generalisation of vector data also brings new possibilities and challenges for printing.

3 What should be printed?

Since their inception, maps have been decorated with more or less useful features.



3.1 Map data

In the GIS world, two things are almost infinite, the number of map projections and the number of data formats.

3.1.1 2D

3.1.1.1 Raster

Source are generally satellite/aerial imagery, and scan of legacy (printed) maps (historical maps). Vector data are rasterized with [Mapserver](#) Served usually served as [OGC WMS](#) and [WMPS](#)

3.1.1.2 Vector

In [map.geo.admin.ch](#), there are now about 22 vector layers (for 465 WMPS/WMS layers), loaded as GeoJSON (e.g. [Water temperature river](#)). Vector files like GPX and KML may also be imported.

Question: rasterize data to print seems obvious, but it is definitely a loss of information and a waste of size.

3.1.2 3D

- To convert to 2D or not? If so, rasterize or not?
- Render as 3D (export ?) for use with 3D printer or anything else (virtual world, KML, etc.)

3.1.3 Time (4th dimension)

- Data changing over time (Zeitreise)
- Position changing over time (fly path)

How to render: multipage, movie?

Another challenge: mixing data with different rate of change and/or lacking data.

3.2 Non map data

Non-map data generally added to a document intented for printing.

3.2.1 Logo and corporate identity

Important or not, it gives a professional look and always generated the most heated discussion.

3.2.2 Disclaimer/copyright

Providing a clear delimitation between which geodatas are from the geoportal and which data are 3rd party.
Some reminder of copyright use.

3.2.3 Date

Time of document generation

3.2.4 Title, note by user

Provide the user to give its work a title and notes

3.2.5 Legend to the map

Some data are more complexe, and need an explanation. It could be as *simple* as displaying the classification or add a complexe and lengthy explanation in the case of a geological map to the generated PDF.

3.2.6 Scale, scalebar, north arrow

Useful information for the orientation, and when hiking.

3.2.7 QRcode, shortlink

Useful to recreate the map in the application online

3.2.8 Table data (reporting)

Some information be easier to display as table. Not used in [map.geo.admin.ch](#), but proposed by some printing application (

3.2.9 File metadata (if applicable)

Metadata are something useful for search engine if the main goal is to store the PDF.

3.2.10 Grid

Various geographical grids, for orientation and use with GPS.

3.2.11 Information on elements displayed

Could be the location of a search term in the simplest form (Google Map-like marker) or additional information on a highlighted object (tooltips,etc.)

4 Tools, building bricks

4.1 Browser

4.1.1 @media print

4.1.2 Rasterizing

HTML5, `toBlob()`, `toDataURL()`

4.1.3 Export canvas to a vector format

As SVG or PDF (what libraries?)

4.2 Server-side rendering of GIS data

Either vector or raster.

4.2.1 Rasterizing of canvas

Challenges:

- Pretty slow
- How do you know the map is fully loaded and rendered?

4.2.1.1 SlimerJS (Firefox based)

- WebGL support
- Not truly headless (?)

4.2.1.2 PhantomJS (WebKit based)

- No WebGL support

4.2.1.3 Print services

Several commercial services are able to generate PDF from web pages:

- [PDFreactor](#)
- [PrinceXML](#)
- [Antennahouse CSS Formatter](#)
- [DocRaport](#)

4.2.2 Rasterizing/exporting data

Several tools are able to rasterize vector data or export them to another vector format (PDF, SVG). Some of them may deal both with vector and raster geodata, others not.

4.2.2.1 Mapserver

The grand-mother of all cartographic server: [Mapserver](#).

[Cartographical Symbol Construction with MapServer](#)

Mapserver is now able to render to vector format like SVG and PDF (when using [PDFlib](#))

4.2.2.2 Mapnik

Map Markup Language file) is a YAML or JSON Mapnik XML, Cascadenik MML, Carto MML [Mapnik](#) was the original tool to generate OSM tiles for the so-called slippy map. Mapnik is also able to generate PDF when compiled with [Cairo](#).

It uses [Mapnik XML](#) as configuration, also for styles. [Cascading Sheets Of Style for Mapnik](#) aka [Cascadenik](#) is a preprocessor for Mapnik, using cascading style sheet for map definition.

[CartoCSS](#) is a language for map design. It is similar in syntax to CSS, but builds upon it with specific abilities to filter map data and by providing things like variables. It targets the Mapnik renderer and is able to generate Mapnik XML or a JSON variant of Mapnik XML.

It is now deprecated ([The end of CartoCSS](#)) by its parent company, [Mapbox](#).

4.2.2.3 Tileserver GL

A [Mapbox Style Specification](#) is a document that defines the visual appearance of a map: what data to draw, the order to draw it in, and how to style the data when drawing it. A style document is a JSON object with specific root level and nested properties. This specification defines and describes these properties.

Vector and raster maps with GL styles. Server side rendering by Mapbox GL Native. Map tile server for Mapbox GL JS, Android, iOS, Leaflet, OpenLayers, GIS via WMTS, [Tileserver GL](#)

4.2.3 Other tools

4.2.3.1 GDAL/Rasterio

4.2.3.2 OWSlib

4.3 Print server

4.3.1 Mapfish print

The purpose of [Mapfish Print 3](#) is to create reports that contain maps (and map related components) within them. The project is a Java based servlet/library/application based on the mature [Jasper Reports Library](#).

4.3.2 Geoserver print

The [Geoserver Printing Module](#) allows easy hosting of the Mapfish printing service within a GeoServer instance. The Mapfish printing module provides an HTTP API for printing that is useful within JavaScript mapping applications. User interface components for interacting with the print service are available from the Mapfish and GeoExt projects.

4.4 Integrated print tools

Need more testing...

4.4.1 QGIS print

4.4.2 ArcGis print

ArcGIS Enterprise includes a geoprocessing service called PrintingTools. Web applications invoke the PrintingTools service and get a printable document in return (see [Printing in Web application](#)):

5 Other considerations

5.1 Scale and resolution

Are scale and print quality of the result important? Difference in resolution may be important between screen and paper.

5.2 WebGL

5.3 Vectors in PDF

Must vector layers rendered as vector or must be rasterized?

5.4 Need for User defined style

With vector data, it is easy to apply user defined style, though defining styles for complexes dataset is a daring undertaking.

5.5 PDF standard

What PDF version? Support of PDF/2 or PDF/A? No, open source library available. See [PDFlib](#). Most client-side libraries are PDF 1.3 (Acrobat 4.x) capable.

5.6 Legacy client

For some legacy client, we must eventually also provide raster tiles (from vector layer)?

5.7 Vector style definition

How are the styles for vector layer defined? Where? And how it is applied?

Currently, all style are defined in Mapserver's [Mapfile definition](#).

5.8 Complexe symbols

Especially complexe labels placement is hard (what to render, at what scale, collision avoidance)

5.9 Mashup

Maps should be mashed up with other sorts of infos (diagram, plot, data tables)

5.10 Movie

Zeitreise, Fly along path, etc.

5.11 Compute power

Externalize compute power on client or not?

5.12 Performance

Synchronous or asynchronous printing

5.13 WYSIWIG

Symbol scaling, which LK to use, grid display, etc.

5.14 Grid

Grid for various projection system

5.15 Projection issue

One selling point of vector tiles and 3D is that 2D is only a special case when pitch is 0 (or 90?). But the 3D world is a WGS1984 only world, which translates in the infamous [Equirectangular \(or plate carré\) projection](#). Using the same projection for printing as in the browser (projection of the data, target projection). When using a Webmercator, deformation, scale, with LK

5.16 Rasterize as a data protection tool

Rasterizing vector data was also a way to *protect* the more valuable original vector datasets ([e.g.](#) WMS).

5.17 Export to other format

Only PDF, or other format as well (SVG, GeoTIFF)

5.18 Use on smartphone and tablet

Client only printing on small scale and/or less powerful devices is challenging to get nice printed results.

5.19 Printing API

Providing an API for 3rd party

5.20 Multiserver use, autoscaling, etc.

Most print server are meant to run on a single machine.

5.21 KMZ with local file

5.22 GeoPDF

6 Approaches

6.1 CSS: @media print

[@media in MDN web docs](#)

The @media CSS at-rule associates a set of nested statements, in a CSS block that is delimited by curly braces, with a condition defined by a media query. The @media at-rule may be used

6.1.1 Browser print function

Easiest solution, used by Google Map, Bing Map. WYSIWIG

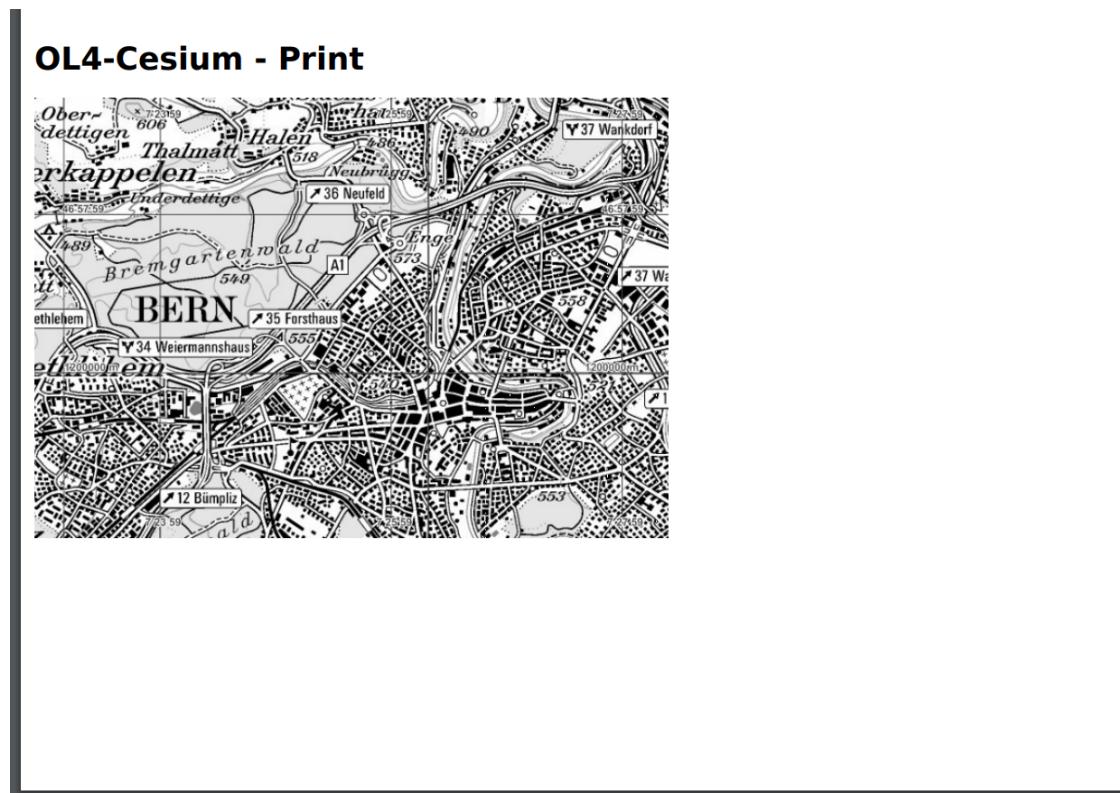
All it takes is to define a CSS stylesheed for print (for inspiration [Paper CSS](#)).

A CSS at-rule `@page` to define page-specific rules when printing web pages, such as margin per page and page dimensions. Not supported by Safari (all versions).

```
page[size="A4"][layout="landscape"] {  
    width: 21cm;  
    height: 29.7cm;  
}
```

But, as we do not have any influence on the size of the image generated in the browser, we have to make trade off in term of scale, print resolution and image aspect ratio. To print at 150dpi on A4, we need an image of 1750x1250 pixel approximatly, which is OK on a desktop computer, but probably not on a laptop or tablet.

Canvas of 650x450px not fitting an A4 page



Canvas of 1050x750px fitting an A4 page

OL4-Cesium - Print



A bigger display will be cropped

With a map covering the whole screen (`width: 100%; height: 100%`), the challenge is to get an absolute width and height, to be fitted in the print page.

Challenges

- Print to many different paper sizes and orientations
- Make browser recognize size and orientation
- Print quality, on smaller display e.g. Laptop with 14" screen

Works well on Chrome, Firefox and Opera (only 2D for the latter), when preview is activated.

[Live demo](#)

6.1.2 PDF generation in client

[PDF.js](#) (Open Source) and [jsPDF](#) (commercial), [PSPDFKit](#) (commercial)

6.1.3 Rendering PDF on a server

[Generating PDF from XML/HTML and CSS - A tutorial and showcase for CSS Paged Media](#)

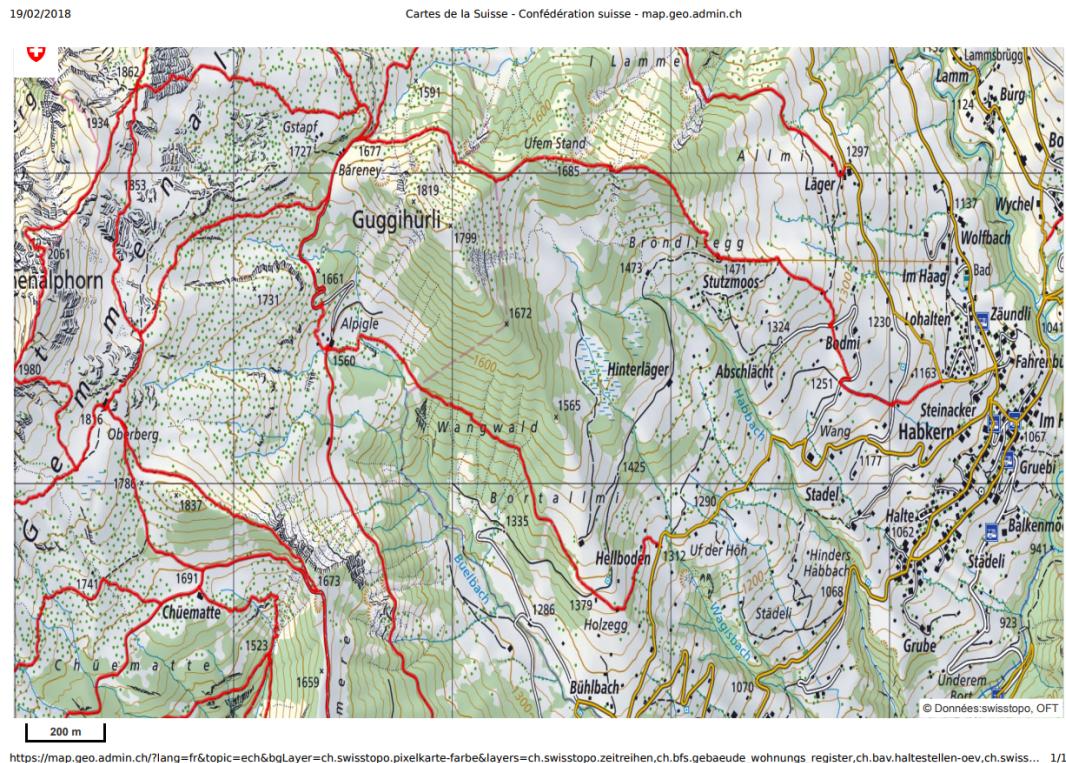
[Print CSS rocks](#)

Rendering HTML page to PDF using the full CSS Page media standard with commercial tool like [PDFreactor](#), [PrinceXML](#), [Antennahouse CSS Formatter](#) or [DocRaport](#). Some are based on [XSL-FO](#) other on [Webkit](#).

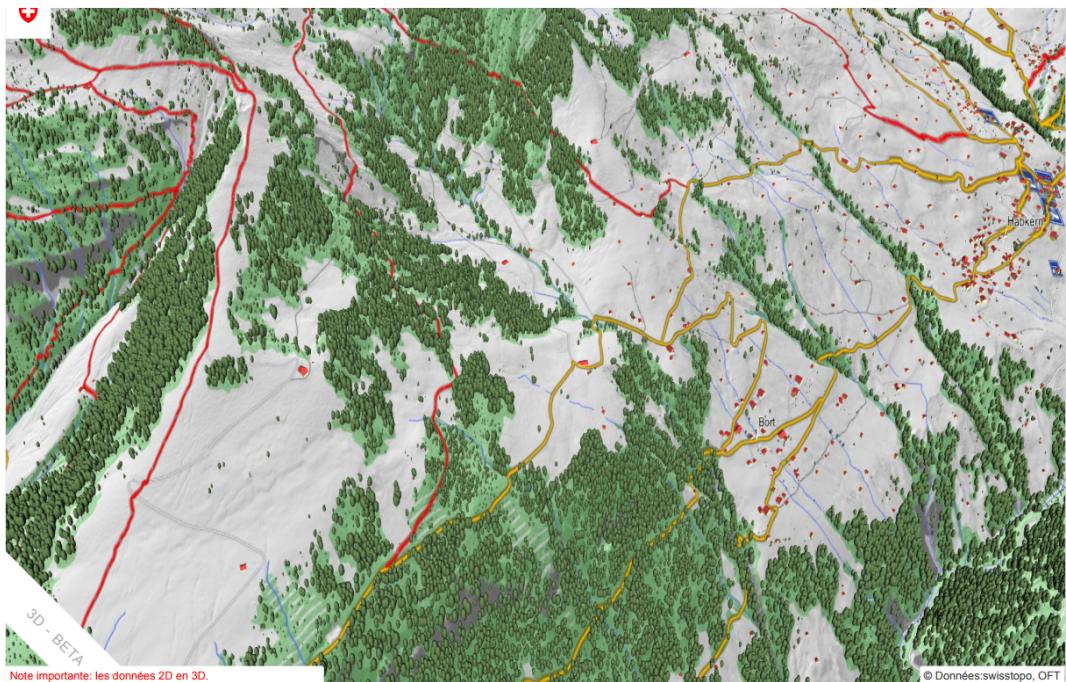
6.2 Export canvas as image

6.2.1 Export canvas as image

Printing in 2D



Printing in 3D



https://map.geo.admin.ch/?lang=fr&topic=ech&bgLayer=ch.swisstopo.pixelkarte-farbe&layers=ch.swisstopo.zeitreihen,ch.bfs.gebaeude_wohnungs_register,ch.bav.haltestellen-oev,ch.swiss... 1/2

Live demo. This is [OL-Cesium](#), you may toggle 2D/3D.

6.2.2 Export image + popup

Create a simple page in a new popup window, with additional elements, and copy the map as an image HTML template for printing

6.2.3 Better resolution

An approach to gain control over the generated image is to recreate a hidden canvas to generate an image that suit the need. This is the approach of the “High DPI print” for Mapbox ([print-maps](#)).

Maybe OK, for simple 2D applications, more difficult for complexe 3D applications with user defined content. What about performance ?

6.2.4 Examples

[Browser print](#)

[Browser print](#)

[Mapbox GL using print-maps](#) by Matthew Petroff.

Cesium and swisstopo terrain

OL-Cesium in 2D and 3D mode

OL4-Cesium - Print



Leaflet Easy Print Demo

6.2.5 Discussions

6.2.5.1 Shortlinks

May be useful to recreate the application elsewhere, when needed.

6.2.5.2 Browser support

But 3D and WebGL is forcing to use modern browsers.

6.2.5.3 Workload is offloaded to clients

No more server

6.2.5.4 Raster only

Raster only, but smaller images

6.2.5.5 WYSIWIG

Especially in Chrome with the print preview function, the user sees exactly what is going to be printed. A print preview may also be implemented for other browser.

6.2.5.6 No special code for rendering

If we consider CSS is no code, yes...

6.2.5.7 Resolution, aspect ratio, screen size, pixel density

Basically, you get the canvas at disposition and try to fit in an A4 page. A small screen means a poor print quality, while a large screen means a decent or good print quality.

Some are trying to get a larger image by recreating a large hidden map canvas. It may work in 2D, but will consume much resource in 2D. Remember, A4 at 150 dpi is 1750x 1250px, and A3 at 150 DPI is 1750x2480px.

Pixel density

A paper map is read at 25cm, screen at 50-70cm 14" and 75 - 105 cm for 20/21". The maximal resolution is about 300 dpi at 25cm, 152 dpi at 50cm and 76 dpi at 100cm. So while a resolution of about 100dpi is acceptable on a desktop, it makes no sense to print above 300dpi for instance.

Table 1: Relation between paper size (mm) and image size (pixels). *dpi* (dot per inch)

Paper	96 dpi	150 dpi	300 dpi
A5 (210x148mm)	793x563	1240x880	2408x1760
A4 (297x210mm)	1112x793	1753x1240	3507x2408
A3 (420x297mm)	1587x1112	2408x1753	4360x3507

Table 2: PPI for some smartphone and tablets

Device	Screen (in)	Resolution (px)	PPI
galaxy S8 (2017)	6.2	2960x1440	530
galaxy S9 (2018)	5.8	2960x1440	567
ipad (2017)	9.7	2048x1536	263
ipad pro (2017)	12.9	2732x2048	264
iphone 5S (2013)	4.0	1136x640	325
iphone 6 (2014)	4.7	1334x750	325
iphone 6s (2014)	4.7	1334x750	325
iphone 7 (2016)	4.7	1334x750	325
iphone 8 (2017)	5.5	1920x1080	400
iphone X (2017)	5.8	2436x1125	462

6.2.5.7.1 Conserving the scale

The next three images have the same spatial extent (2500 meters wide), but have different sizes. If we want to keep the scale, here 1:25'000, we have to print the image of 100mm, regardless of the pixels of the image. The result is a low quality for smaller images.

Image of 377x188 pixels, printed @96 dpi (100x50mm)

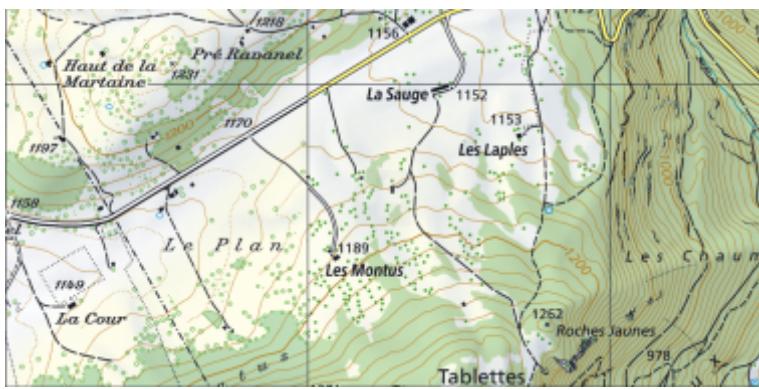


Image of 590x295 pixels, printed @150 dpi (100x50mm)

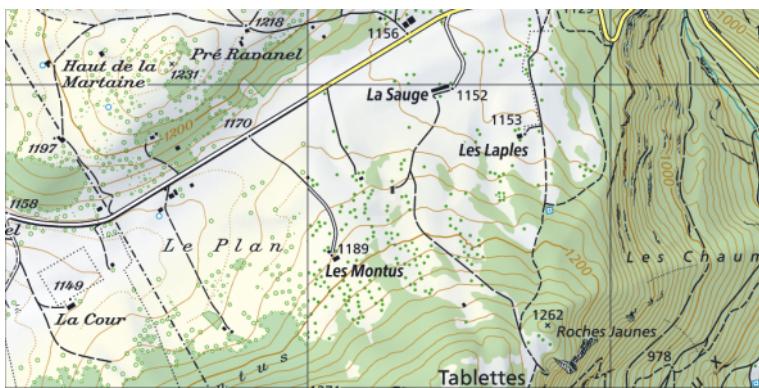
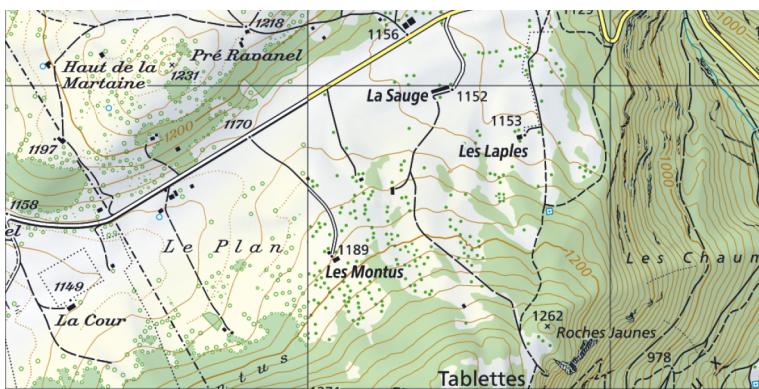


Image of 1181x590 pixels, printed @300 dpi (100x50mm)



6.2.5.7.2 Conserving the print resolution

The next three images have the same spatial extent (2500 meters wide), but have different sizes. In this example, we want to keep a good print quality (300 dpi), so we have to decrease the size of the final printed image. The result is loosing the original map scale of 1:25'000.

Image of 377x188 pixels, printed @300 dpi (32x16 mm), print scale is about 1:78'125



Image of 590x295 pixels, printed @300 dpi dpi (50x25 mm), print scale is 1:50'000

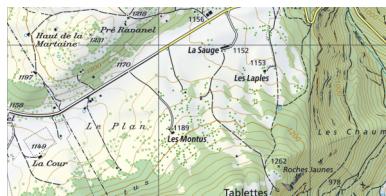
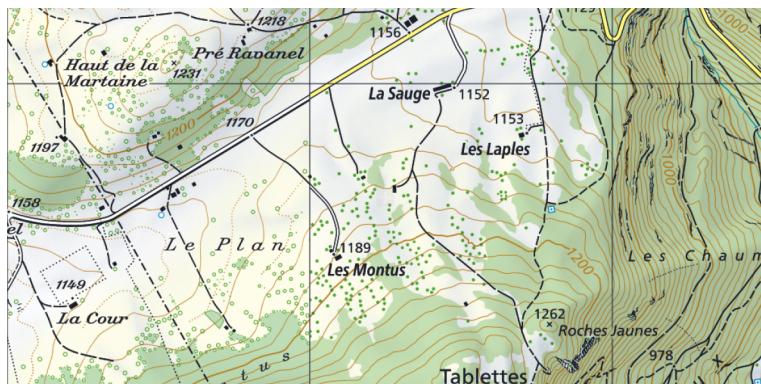


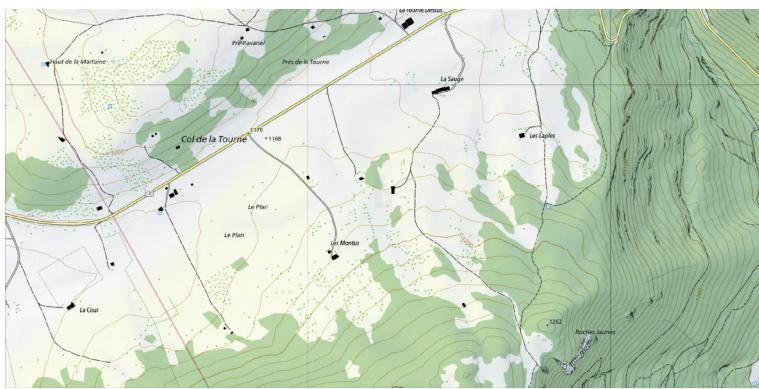
Image of 1181x590 pixels, printed @300 dpi (100x50mm), print scale is 1:25'000



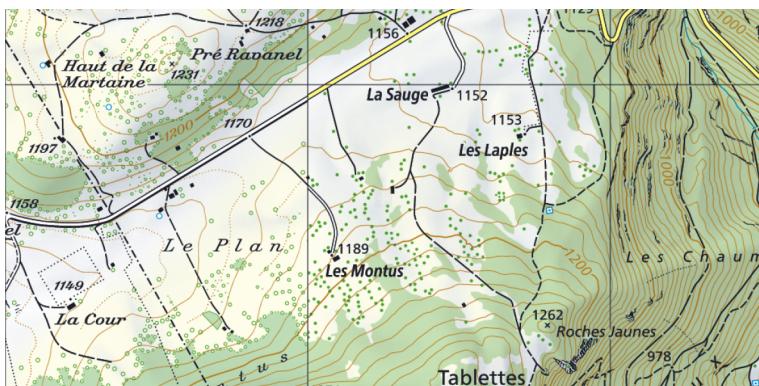
6.2.5.7.3 Effect of style

In this example we use the *Landeskarte/Pixelkarte* because their style is targeted for a very specific scale: 1:10'000, 1:25'000 and 1:50'000. The three following picture are printed at 300dpi for a scale of 1:25'000.

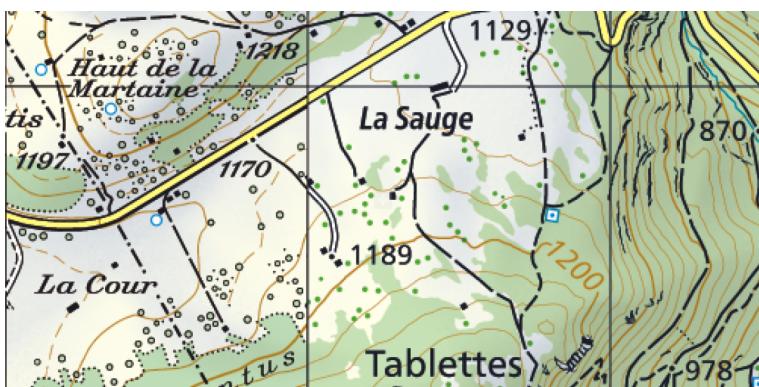
LK10, designed for 1:10'000 Labels and features are very small, hard to read.



PK25, designed for 1:25'000 Labels and features are easily readable, making a joyful impression.



PK50, designed for 1:50'000 Features and labels are big. You may clearly have more information.



6.2.6 PDF compression

Compression with jsPDF of an A4 PDF page containing a single image of 12'236'896 bytes (pk25.noscale-3271-2244-@300.png)

The following compressions are tested: **NONE**, **FAST**, **MEDIUM** and **SLOW**. For comparison, the uncompressed PDF file has been compressed with **ps2pdf**. Five repetitions for each methods.

Compression	Time (s)	PDF (bytes)	Size (%)
NONE	6.99 ? 0.10	29363689	100.0
FAST	8.84 ? 0.08	11978739	40.8
MEDIUM	11.61 ? 0.41	11282507	38.4
SLOW	67.91 ? 2.37	10469602	35.6
ps2pdf	< 0.5	1227882	4.18

Another example with an image targeted for 150 dpi 3'609'601 bytes(pk25.noscale-1635-1122-@150.png)

Compression	Time (s)	PDF (bytes)	Size (%)
NONE	2.01 ? 0.07	7341071	100.0
FAST	2.91 ? 0.20	3554307	48.4
MEDIUM	3.69 ? 0.35	3465019	47.2
SLOW	12.33 ? 2.24	3290648	44.8
ps2pdf	< 0.25	400244	5.4

6.2.6.1 Templating

6.2.6.2 Performance

Hard to find when the page is fully rendered...

6.2.6.3 Security

Cross-Origin Resource Sharing (CORS) and Content-Security-Policy (CSP)

6.2.7 Conclusion

If the added value is not much more than what a screenshot offers, there not point to provide this functionality

6.3 Server side

6.4 Mixed approach

Some elements are rendered client-side and then sent to the server, or only some operation are done server-side.

6.5 Integrated approach

Tools like QGis and ArcGIS used to configure the layers. Configuration files, including styles, are used in the web application. As both client and server are using the same configuration, printing may be done server-side.

[QGis Print Composer](#)

7 Discussion

8 Conclusion

Colophon

This document was created with [pandoc](#), with the following commands:

```
$ pandoc -f markdown --latex-engine=xelatex --number-sections \
--variable mainfont="Gentium" -V fontsize=10pt "README.md" \
--toc -o "web-map-printing.pdf"
```