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CERTIFICAT COMPLÉMENTAIRE EN GÉOMATIQUE

Testing the Swiss Data Cube and development of a Snow Detection Tool

By

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Summary

To complete my Geomatics Certificate at the University of Geneva, I chose to take an internship of three months and a half at the Global Resource Information Database (GRID) Geneva. The internship itself was built around the exploration of the Swiss Data Cube (SDC), a newly created data storage and analysis system that gives users access to a large quantity of analysis-ready satellite data, as well as a suite of tools developed to provide a variety of useful outputs (such as water detection, fractional cover…).

The internship was divided into two parts: initially the web interface of the SDC was tested for bugs and user friendliness. The second phase was to develop a unique SDC tool based on the knowledge gleaned from the testing phase.

The internship objectives were all successfully reached and the following tasks were completed:

- Gain a working knowledge of the SDC
- Test the SDC's user friendliness and the large suite of tools it provides
- Compile a report detailing the bugs and issues pertaining to the SDC's performance
- Become acquainted with the SDC's Jupyter Notebook environment and gain knowledge pertaining to the Python construction of the SDC tools
- Develop a Snow Detection Tool for the SDC, based on the C Function of Mask
- Co-Author a scientific article for the International Geoscience and Remote Sensing Symposium

The tasks completed during the internship were a first step in the direction of a more detailed development of both the SDC and the Snow Detection tool. For both of these elements to reach their true potential a variety of factors need to be taken into consideration and problems resolved.
The internship at GRID-Geneva was an immensely enrichening experience that gave me a new outlook on the microcosm that is geomatics, as well as introducing me to a new environment of office work, that in the case of GRID is dynamic fun and highly instructive.

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List of Acronyms

6S	Second Simulation of the Satellite Signal in the Solar Spectrum
ARD	Analysis Ready Data
BS	Bare Soil
CEOS	Committee on Earth Observation Satellites
CFMASK	C Function of Mask
DEM	Digital Elevation Model
EOS	Earth Observing System
FOEN	Federal Office for the Environment
GRID	Global Resource Information Database
IGARSS	International Geoscience and Remote Sensing Symposium
MAP-X	Mapping and Assessing the Performance of Extractive Industries

NDBI	Normalized Difference Built Index
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NG	Non-Governmental
NIR	Near Infrared
NPV	Non-Photosynthetic Vegetation
PV	Photosynthetic Vegetation
SDC	Swiss Data Cube
SOfS	Snow Observations from Space
SWIR	Short Wave Infrared
TSM	Total Suspended Matter
UNEP	United Nations Environment Program
USGS EROS	United States Geological Survey Earth Resources Observation and Science

1. Introduction

Among its proposed formations, the University of Geneva offers the Complementary Certificate in Geomatics. To obtain the certificate itself, students must follow a certain number of courses, hand in projects and finally write a memoir. This memoir can be either an academic production such as a master's thesis or an internship report. This document is the latter.

To complete my complementary geomatics certificate, I was offered an internship of three and a half months at the Global Resource Information Database (GRID) of Geneva, an organism that is part of the United Nations Environment Program's (UNEP) global group of information centres. During these three months, I worked on the Swiss Data Cube (SDC) a project that uses Open Data Cube technology to organize and analyse satellite data of a given space for a certain time period. The internship was supervised by of Dr. Gregory Giuliani and Mr. Bruno Chatenoux.

This report will initially present GRID-GENEVA, the Swiss Data Cube and the internship objectives and tasks. It will then detail the methods used to fulfil the same tasks, the results obtained and finally the conclusions drawn from them.

1.1. UNEP-GRID

The Global Resource Information Database (GRID) of Geneva is part of a large global GRID network, composed of 15 centres under the direction of UNEP's Division of Early Warning and Assessment (DEWA) which is located in Nairobi [1]. Of the fifteen global sites, Geneva and Nairobi were the first, as they were launched in the program's genesis in 1985.

GRID-Geneva is based in in the International Environment House in Chatelaine, Geneva which houses both UN and NG organizations whose mission pertains to environmental protection and sustainable development. GRID shares partnerships and is supported by a variety of institutions both local and international, such as the United Nations Environment Program (UNEP), the Federal Office for the Environment (FOEN) and the University of Geneva [1]. Much like the rest of the organizations present in the International Environment House, GRID-Geneva is bilingual (spoken and written French and English).

In general, GRID-Geneva is a unique organization that specializes in providing high quality environment-related data and information to aid in decision-making processes. The data in question comes in a variety of geo-spatial formats; GRID uses a combination of remote sensing, geographic systems and statistical analysis to provide information and solution for a large amount of environment-related problems [1]. These efforts have now been

furthered by the development of the Swiss Data Cube and MAP-X projects, two web platforms that aim to provide high quality Analysis Ready Data (ARD).
GRID's mission is to take raw data and transform it into accurate scientific information that may be used to aid in supporting environmental early warnings and assessments for sustainable development from local to global scales[1].

1.2. The Swiss Data Cube (SDC)

The Swiss Data Cube (or SDC) is a project currently being developed by UNEP/GRID-Geneva and he University of Geneva with support from the Federal Office for the Environment (FOEN) [2].
The SDC is based on a new form of technology for storing and organizing geospatial data called the Open Data Cube [3]. This project was initially developed by Geoscience Australia along with CEOS to address the problem of increasingly larger EOS satellite data [3]. It originated when Geoscience Australia initiated the ULA (Unlocking the Landsat Archive) project, transferring countless Landsat datasets to new High Performance Data facility which permitted access to an enormous volume of previously inaccessible EOS satellite images [4].
Following this upgrade in data storage and accessibility, it was possible to develop the Open Data Cube, a new system of storage that due to its structure makes it possible to easily develop systems that provide Analysis Ready Data (ARD) [5]. The Open Data Cube now also provides a variety of open source tools and application that are compatible with data cube format and may be used to analyse query and exploit the available data.
The SDC currently contains a wide variety of open access datasets, [5] including Landsat 5-7-8 as well as the newly ingested Sentinel 2. It has also developed both a web interface and a series of Jupyter notebooks that can be used to query the Swiss territory-related ARD data to answer question pertaining to cloud cover, water detection and much more [6].

1.2.1. Presentation of the SDC web interface

In the following portion of the paragraph the web interface of the Swiss Data Cube will be explored and illustrated, as it is an important component of the internship and requires explaining. It is important to note that to use and benefit from the SDC's various functions, it is necessary to be logged into the system.

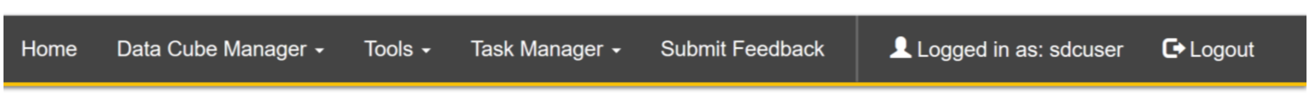


Figure 1: Main SDC drop-down menu

In Figure 1 we can observe the main drop down menu on the SDC web interface website (SDC - http://sdc.unepgrid.ch/) .The first tag on the banner is marked "Data Cube Manager". In this section the user can access all the areas of the interface pertaining to the management of the data cube. The options are as follows:

- Data Cube Visualization: permits to view the ingested data cubes on a world map
- Dataset Types: permits the user to become acquainted with the various datasets within the data cube (such as Landsat and Sentinel data). This page also links to the Dataset Viewer and to a Dataset Definition page that provides further details
- Dataset Viewer: gives a more precise idea of the data available in the cube
- Ingestion Configuration Builder: allows the user to create a new data ingestion configuration
- Ingestion on Demand: allows the user to create a sample Data Cube for analysis

The second menu, "Tools" gives access to the various tool that may be used to analyse the SDC. They are described in more detail in paragraph 2.1. The third menu, marked "Task Manager" is where users may recover results obtained through the use of the tools. Once the user chooses a given tool, the interface produces a list of recent tasks the tool was applied to. The user then chooses his task and finds himself/herself on page specific to that task which provides information regarding the outputs, its statistics and possible download formats.

The final menu is tagged "Submit Feedback" and is self-explanatory. Throughout the internship at GRID-Geneva, the SDC was accessed with the username "sdcuser".

1.3. Objectives and Tasks

The internship at GRID-Geneva revolved around the completion of two separate sets of objectives. Initially, it was necessary to test the SDC web interface, identify the problems and compile a report. The second phase of the internship was devoted to the development of a snow detection tool for the SDC and the preparation of an article relating to its implementation for the International Geoscience and Remote Sensing Symposium (IGARSS).

The tasks relating to the testing of the SDC were as follows:

- Test the general features of the SDC web interface [6] such as connection between pages, links and user friendliness
- Test the various SDC tools to verify performance issues, interpretation errors and accessibility
- Test the SDC tools on different terrain types (where required) to check accuracy of results

- Preparation of a report detailing all of the above

The tasks relating to the development of the snow detection tool were as follows:

- Become acquainted with Jupyter Notebooks and their Python structure
- Test the SDC tools in the Jupyter Notebook environment, to understand their construction
- Develop a Snow Detection tool capable of discerning snow cover from water or cloud cover
- Co-author a paper for the IGARSS at Valencia in 2018

Given the objectives and tasks detailed above, here follow the methods used to complete them.

2. Methodology

In this section of the report, the methodology used to advance each of the internship objectives will be illustrated.

2.1. SDC Testing Methodology

The first step in verifying the overall performance of the SDC was testing the various tools it made available on its web interface. By doing this it was subsequently possible to also remark the issues relating to the more general features of the interface.

At the time of testing the SDC considered the following data sources as input for its interface tools [7]:

- The Landsat 5 satellite: launched in March 1, 1984 and decommissioned in January 2013.
- Landsat 7 satellite: launched April 15, 1999, still operating
- Landsat 8 satellite: launched February 11, 2013, still operating

The tools tested were as follows:

- Cloud Coverage: this tool performs a time series analysis that detects the average cloud cover percentage within a time period. This is useful because it gives the users an idea whether the area in question may be considered for further analysis: if there is too much cloud cover, other tools won't produce a viable result.
- Coastal Change: this tool performs a time analysis on coastlines to determine if and how much they are receding.
- Custom Mosaic: this application presents the user with various options relating to the creation of images of chosen areas. In other words, the tool considers the extent and time frame chosen and produces an

image based on the users' choice of pixel treatment option. These options are: most recent, least recent, median, and minimum maximum NDVI value pixel.[6]

- Fractional Cover: this tool analyses the considered extent and classifies its pixels in three categories: percentage of photosynthetic vegetation, non-photosynthetic vegetation and bare soil. This gives the user an idea of the type of vegetation cover present within the target area[6].
- NDVI Anomaly: this feature of the SDC calculates the NDVI change between a single detection (scene) and baseline time frame preceding it defined by the user. In other words, it would be used to understand whether the NDVI of a given area at a given time has varied compared to a preceding time period [6].
- Slip: this tool combines both satellite and DEM data to propose possible locations for landsides within the selected time frame [6].
- Urbanization: this tool performs a time series analysis to classify various pixels into three categories: NDVI, NDWI, and NDBI. In other words, the algorithm produces images that represent areas covered by vegetation, water and buildings [6].
- Water Detection: this tools uses the WOfS algorithm [8] to detect water for a given area and time frame [6].
- Water Quality TSM: this SDC application allows users to verify the average amount of suspended matter in a given water body for a given time frame [6].

2.1.1. General Tests

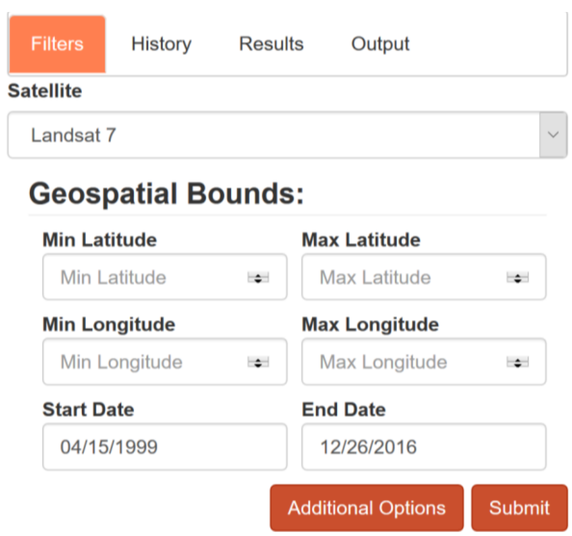


Figure 2: SDC main tool interface

To test the SDC, its features and its various tools, the following method was employed:

1. Choose the tool in question to test (from the list above)
2. Once the tool is opened (as in Figure 2) choose the satellite data to query. The options were as follows:
    a. Landsat 5
    b. Landsat 7
    c. Landsat 8
    d. Landsat 5/7/8
    e. Landsat 7/8
    f. Landsat 7 collection 1
3. The next step is to determine the area on which to run the tool. This can be done in two ways: by dragging the cursor on the map and selecting the desired extent or by typing latitude and longitude values into the interface (Figure 2). For the purpose of these tests, the tools were applied to two principal areas: that of the Grimselsee, due to its many different types of terrain (such as snow, mountains, forests etc.) and that of Lake Ceresio (in the Lugano region) for contrast (this area being more urban and flat). A third area was considered for the Coastal Change tool (that of the Lake of Neuchatel) so as to test it on one of the few areas in Switzerland that has actually experienced a coastal change [9].
4. At this point, the time period for the tool was selected. Given the different durations of the various Landsat missions (2.1) it was important to choose dates that were compatible with the initial choice of satellite data.
5. Once these steps had been completed, the various options for each tool needed to be selected and specified. These different option will be presented in the results section to avoid repetitions.
6. Finally, the “Additional Options” button was selected (Figure 2), and a title was added along with a description to be able to find the results in the “Task Manager” [6] later.
7. The results were then retrieved from the “Task Manager” [6], analysed and commented.
8. This process was repeated according to the obtained results, errors and peculiarities remarked after each run

In general, each tool was tested for most of the satellite inputs available and for the majority of the different tool-specific options. The tools were tested on different regions when this was relevant (such as for the Urbanization tool).

2.2. Snow Detection Tool development: Methodology

The Snow Detection Tool was developed for the SDC in the Jupyter Notebooks environment. This form of development is very practical for a series of reasons. It permits a user who is acquainted to Python to develop a tool by dividing code into manageable blocks that can be run subsequently or independently and that save variables in the background to facilitate the development process. Another advantage is that the results are immediately visible (the outputs for each section of code are immediately produced under that code's block). This enables a user to immediately identify potential problems and to swiftly test potential solutions.

This section of the internship report details the theoretical ideas that support the Snow Detection Tool and explains each section of the its code.

2.2.1 Theoretical Framework

The idea behind the Snow Detection Tool, named SOfS (Snow Observation from Space) was first proposed by Mr. Bruno Chatenoux and consists in using a feature present in satellite datasets to accurately detect snow separately from water.

The feature in question is called the C Function of Mask. It is an algorithm developed by Boston University (originally as the Function of Mask) and later adapted to C programming language by USGS EROS [10]. This algorithm takes satellite data as input and runs it through a decision tree system that labels each pixel according to different categories. The classification is then validated by comparing the pixel's label to the general statistics of the considered scene [10].

The values of CFMASK used for this internship were obtained from the Second Simulation of the Satellite Signal in the Solar Spectrum (6S) algorithm, which considers five distinct pixel classes: clear, water, cloud shadow, snow and cloud pixels [11].

The general idea of the Snow Detection tool was to extract the snow pixels classified through CFMASK to obtain snow detections for a specified extent and time. This would be done through the initial extraction of the pixels and subsequent analysis of the considered time series.

Here follows a step by step description of the base code of the SOfS tool. The entirety of the code can be found in Annex 3.

2.2.2 SOfS code

Initially, the code is instructed to import all the necessary scripts and libraries necessary for the successful execution of the program.

```
In [1]: %matplotlib inline

        from datetime import datetime
        import numpy as np

        import datacube
        from utils.dc_snow_classifier_test_LJF import wofs_classify
        from utils.dc_utilities import perform_timeseries_analysis, create_cfmask_clean_mask
        import dc_au_colormaps

        from utils.dc_notebook_utilitiesLF import *
```

Figure 3: Code detailing the importation of libraries and dependencies

In Figure 3, we can see the many libraries imported by the code. At the time of writing, some of these have become redundant in the code and will be removed in future versions. Of those imported however, the two most important are the dc_utilities library (which contains the CFMASK extraction code as well as the time series analysis code) and the data cube itself.

```
In [2]: dc = datacube.Datacube(app='dc-water-analysis')
        api = datacube.api.API(datacube=dc)
```

Figure 4: Code querying the contents of the data cube and its metadata

In Figure 4, the data cube itself is queried and connected to the Jupyter script, along with its general metadata.

```
In [3]: # Get available products
        products = dc.list_products()
        platform_names = list(set(products.platform))
        product_names = list(products.name)
```

Figure 5: Code for obtaining the platforms and products present within the cube.

In Figure 5, we find the importation of the various platforms and products contained within the cube. In this case, the word “platforms” is a synonym of the different satellite systems (such as Landsat 5, 7 and so on) while the “products” are the specific suites of data pertaining to each platform.

```
In [4]: product_values = create_platform_product_gui(platform_names, product_names)
```

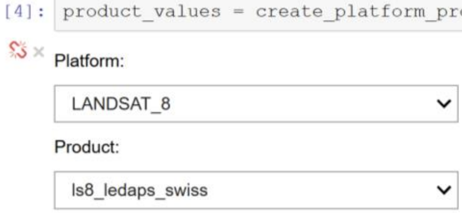


Figure 6: Code that generates a form to choose the desired platform and product

Here (Figure 6) we can observe the creation of a form that enables the user to easily select the desired platform and product from a handy drop-down menu.

```
In [5]: # Save the form values
platform = product_values[0].value
product = product_values[1].value

# Get the pixel resolution of the selected product
resolution = products.resolution[products.name == product]
lat_dist = resolution.values[0][0]
lon_dist = resolution.values[0][1]

# Get the extents of the cube
descriptor = api.get_descriptor({'platform': platform})[product]

min_date = descriptor['result_min'][0]
min_lat = descriptor['result_min'][1]
min_lon = descriptor['result_min'][2]

min_date_str = str(min_date.year) + '-' + str(min_date.month) + '-' + str(min_date.day)

min_lat_rounded = round(min_lat, 3)
min_lon_rounded =  round(min_lon, 3)

max_date = descriptor['result_max'][0]
max_lat = descriptor['result_max'][1]
max_lon = descriptor['result_max'][2]

max_date_str = str(max_date.year) + '-' + str(max_date.month) + '-' + str(max_date.day)

max_lat_rounded = round(max_lat, 3) #calculates latitude of the pixel's center
max_lon_rounded = round(max_lon, 3) #calculates longitude of the pixel's center

# Display metadata
generate_metadata_report(min_date_str, max_date_str,
                         min_lon_rounded, max_lon_rounded, lon_dist,
                         min_lat_rounded, max_lat_rounded, lat_dist)

show_map_extents(min_lon_rounded, max_lon_rounded, min_lat_rounded, max_lat_rounded)
```

Figure 7: Code that saves the above form values and obtains the metadata specific to them

The above (Figure 7) large portion of code is used to save the users selection from Figure 6 and then to subsequently extract and present its metadata. This enables users to get to know their dataset and to understand what extents and timeframes they can consider in their calculations.

```
In [7]: extent_values = create_extents_gui(min_date_str, max_date_str,
                                           min_lon_rounded, max_lon_rounded,
                                           min_lat_rounded, max_lat_rounded)
```

Start date:

2017-1-1

End date:

2017-7-31

Min lon:

7.82

Max lon:

8.24

Min lat:

46.25

Max lat:

46.62

Figure 8: Code that generates a form to choose the spatial and temporal extents of the data

Much as in Figure 6, Figure 8 enables the user to specify his or her desired spatial and temporal extents.

```
In [8]: # Save form values
        start_date = datetime.strptime(extent_values[0].value, '%Y-%m-%d')
        end_date = datetime.strptime(extent_values[1].value, '%Y-%m-%d')
        min_lon = extent_values[2].value
        max_lon = extent_values[3].value
        min_lat = extent_values[4].value
        max_lat = extent_values[5].value

        # Query the Data Cube
        dataset_in = dc.load(platform=platform,
                             product=product,
                             time=(start_date, end_date),
                             lon=(min_lon, max_lon),
                             lat=(min_lat, max_lat))

In [9]: #Winter Months
        def is_winter(month):
            return (month >= 12) | (month <= 2)

        dataset_in = dataset_in.sel(time=is_winter(dataset_in['time.month']))
```

Type *Markdown* and LaTeX: α^2

```
In [10]: snow = dataset_in.cf_mask == 3
         snow
         #so far, works
```

Figure 9: Code that saves the form values queries the data cube, and begins the preparation of snow data

In Figure 9, the parameters specified in Figure 8 are saved and then used to query the data cube. This produces a dataset composed of the desired platform, product and extents. This data is then subsequently filtered to only consider the winter months; the reason for this filter is because that is the period in which snow is most abundant in Switzerland. The filter should thus remove any smoothing effect on the output data created by the inclusion of other seasons.

After this, the data pertaining to CFMASK class 3 (snow) is extracted.

```
In [11]: snow_dataset = snow.astype(np.int16).to_dataset(name = "snow")
         snow_dataset
         #works

Out[11]: <xarray.Dataset>
         Dimensions:    (latitude: 1364, longitude: 1549, time: 17)
         Coordinates:
           * time       (time) datetime64[ns] 2017-01-07T10:16:42 2017-01-07T10:17:05 ...
           * latitude   (latitude) float64 46.62 46.62 46.62 46.62 46.62 46.62 46.62 ...
           * longitude  (longitude) float64 7.82 7.82 7.82 7.821 7.821 7.821 7.822 ...
         Data variables:
             snow       (time, latitude, longitude) int16 1 1 1 1 1 1 1 1 1 1 1 1 1 1 ...

In [12]: no_data = dataset_in.cf_mask == 255
         no_data = no_data.values
         snow_dataset.snow.values[no_data] = 255
         #works

In [13]: #perform_timeseries_analysis(snow_dataset, "snow", no_data = 255)

In [14]: ts = perform_timeseries_analysis(snow_dataset, "snow", no_data = 255)

In [15]: ts

Out[15]: <xarray.Dataset>
         Dimensions:          (latitude: 1364, longitude: 1549)
         Coordinates:
           * latitude         (latitude) float64 46.62 46.62 46.62 46.62 46.62 46.62 ...
           * longitude        (longitude) float64 7.82 7.82 7.82 7.821 7.821 7.821 ...
         Data variables:
             total_clean      (latitude, longitude) int64 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 ...
             normalized_data  (latitude, longitude) float64 0.125 0.125 0.125 0.125 ...
             total_data       (latitude, longitude) float64 1.0 1.0 1.0 1.0 1.0 1.0 ...

In [16]: ts.total_clean.plot()
```

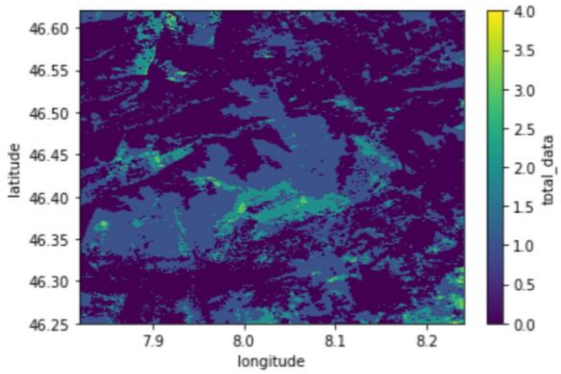
Figure 10: Code that continues the preparation and analysis of the snow data

The data is then defined as an int16 dataset (Figure 10) and the modified to recognize no data values as the CFMASK value of 255.

After this operation, the dataset is considered ready to analyse. It is the submitted to a time series analysis that produces three outputs: a plot detailing the number of clear detections, a plot detailing the number of snow observations and a normalized plot that represents a number of normalized snow observations (this last plot is obtained by dividing the number of total snow observations by the number of clear observations).

```
In [17]: ts.total_data.plot()

Out[17]: <matplotlib.collections.QuadMesh at 0x7f0360877fd0>
```




```
In [18]: ts.normalized_data.plot()
```

Figure 11: Code that concludes the snow data analysis

In this last portion of code Figure 11, the two final plots are produced.

2.2.3 Testing the code

After having completed the development code, the code was tested to verify its accuracy and functionality. It was tested on three separate regions:

- The Grimselsee (in the same manner as the SDC testing)
- The Ferpècle glacier (due to the carefully kept records of its shrinking)
- The Bernese Alps

The results of SOfS tests are detailed in the following section, as well as in Annex 1.

3. Results

This section of the report will illustrate the results pertaining to the different stages of the internship. The SDC testing is further explored in Annex 4, and the final Snow Detection Tool is presented in Annex 1 of this report.

3.1. SDC Testing

In this first part of the results, the outcome of the various tests conducted on the various SDC tools will be illustrated and explained.

3.1.1. Cloud Coverage

The first tool to be tested was the Cloud Coverage tool. The testing began with this specific tool because it was important to understand whether the considered region was ideal for testing other tools as well.

The first test was executed in the Grimselsee region from 1984 to 2016 and ran successfully for the separate Landsat 5, 7 and 8 datasets. The tool was also applied to the lake Ceresio region (Lugano) as well as the canton of Fribourg. This was done to have an example of a sunny region (Lugano) as well as a cloudy region (Fribourg), to verify the tool's accuracy.

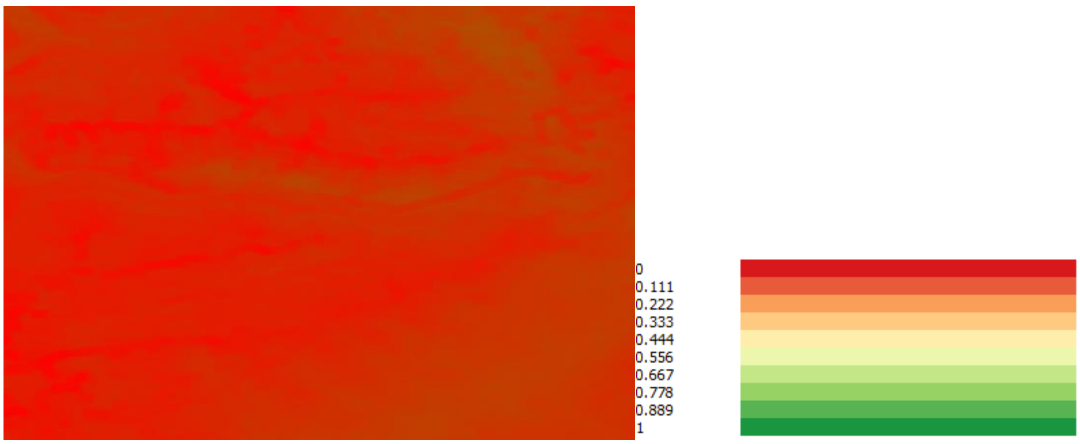


Figure 12: Custom Mosaic Image Landsat 7 (1999-2016) Grimselsee region with colour scale (found on SDC Grid [6])

As we can see in Figure 12, the tool indicates that the Grimselsee region has a low average cloud coverage, meaning there are a good number of "clean" observations to analyse.

The two ulterior tests run for Lake Ceresio and Fribourg confirmed the quality and accuracy of these results: the Lugano region was mostly devoid of clouds, while Fribourg had considerably more.

3.1.2. Coastal Change

The testing continued with the Coastal Change tool. The chosen region was the Cheseaux-Noreaux region on the Lake of Neuchatel. This region was chosen because it is one of the only lakeside areas in Switzerland which has seen its coast change, due to erosion and subsequent restoration efforts [9]. The satellite data used for this test came from Landsat 7 and the tool was run for the lakeside restoration period (that is to say from 1999 to 2003). Ideally, the tool would also have been tested for the period in which the lake was plagued by erosion (prior to 1999) but unfortunately, the Landsat 5 time frame was stuck between 1999 and 2016.

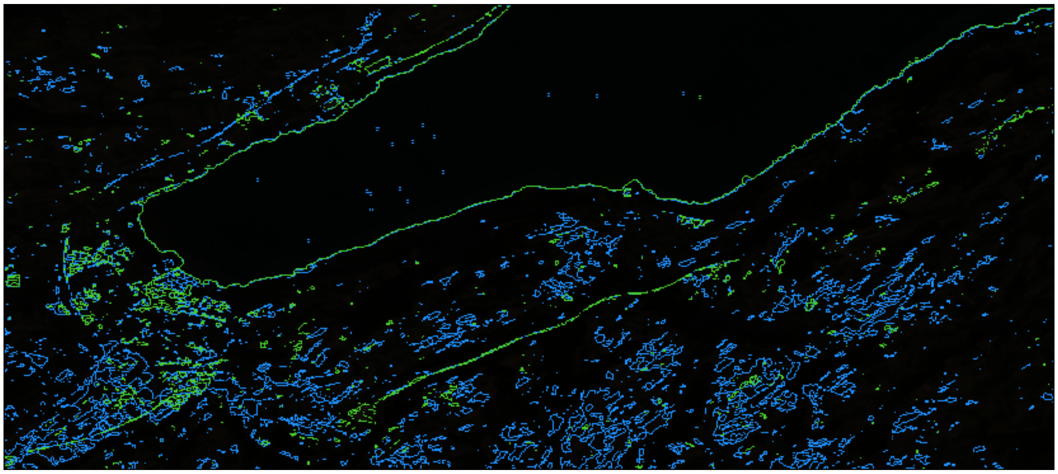


Figure 13: Coastal Boundaries for 1999-2003

In Figure 13 we can observe the results of the Coastal Change tool. The lines in green represent the old coast while the lines in blue the new. It appears clear that the results are not extremely accurate. Although the coast marked in green seems to be an accurate representation of the current lakeside, the lines in blue appear on dry land as well as in the middle of the lake. Upon a closer examination however, it appeared that by increasing the image it was possible to detect a slight change in the Cheseaux-Noreaux area.

3.1.3. Custom Mosaic

The next tool tested was the Custom Mosaic tool. As specified earlier, this tool allows users to create true or false colour images of their selected area [6]. The following tests were all executed in the Grimselsee region for the Landsat 7 dataset, for the period between 1999 and 2016. Given the wide variety of possible combinations to explore with this tool, only the most pertinent were considered for this report.

The three parameters that the tool permits the user to calibrate are as follows:

- Result type: this parameter lets the user choose between different combinations of satellite bands to render the final image. Examples of the possible choices are True color, NIR, SWIR, Green, Blue and Red [6]
- Compositing method: this parameter defines the way in which the algorithm chooses the pixels to be rendered in the final image. The options for this parameter are [6]:
    - Least and Most Recent Pixel
    - Minimum and Maximum NDVI Pixel

    - Median NDVI Pixel
- Generate time Series Animation: this option enables the user to create an animation based on the time frame defined in the initial parameters. The options for this tool are Cumulative or Scene [6]. These options are not explained on the SDC site, however it can be assumed that a cumulative series animation renders a video showing the augmentation of the pixel values through time, whereas a scene option renders an animation of each individual detection.

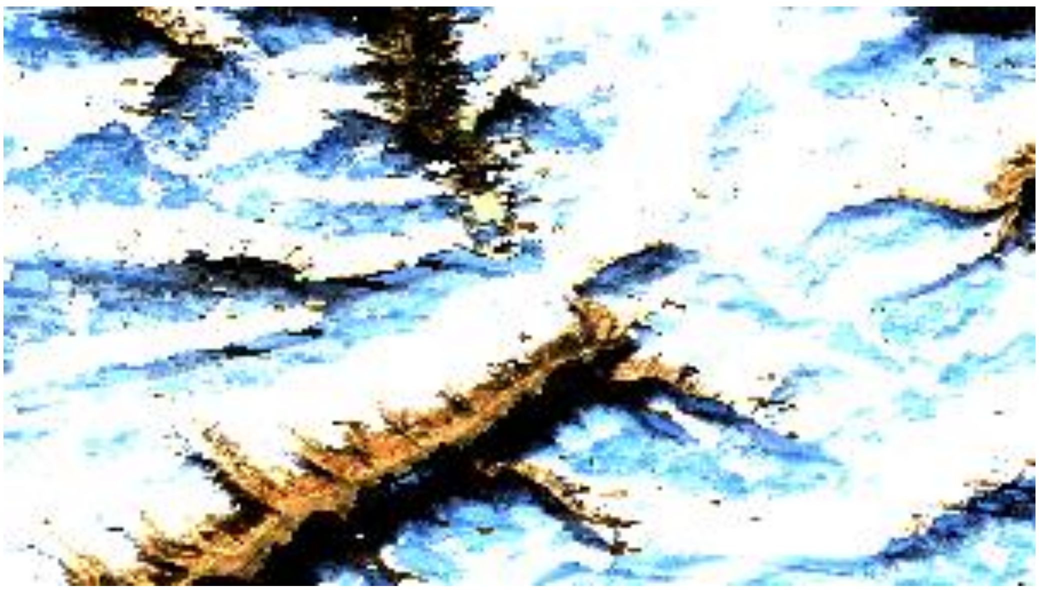


Figure 14: Custom Mosaic, true color, least recent pixel, 1999-2016

The first test (Figure 14) was executed with the True Color and least Recent Pixel options. Figure 14 appears to be a good example of a true colour image: the Grimselsee region s fairly recognizable and the image is of good quality. However the rendering appears to have some difficulty detailing the lower altitudes.

Figure 15: Custom Mosaic, True Color, Max NDVI, 1999-2016

The second test (Figure 15) used True Color with a maximum NDVI pixel selection. This choice produces an image that accurately details the vegetation present in the region (as plant life is more easily detected through the use of the NDVI index). Consequentially areas that are devoid of colour must lack vegetation (in this case the tops of mountains and the Grimselsee itself).

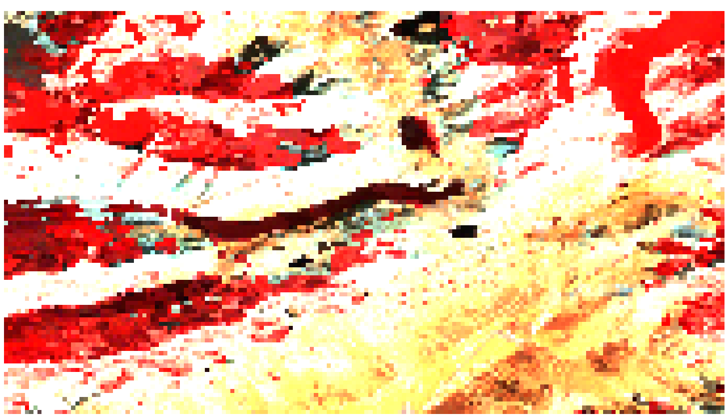


Figure 16: Custom Mosaic, NIR/SWIR1/SWIR2, least recent pixel, 1999-2016

The third test (Figure 16) considered the NIR/SWIR1/SWIR2 satellite bands (so exclusively infrared bands) coupled with the Least Recent Pixel method. This selection still provides a high quality result, with the various features (valleys, mountains, lake) still recognizable.

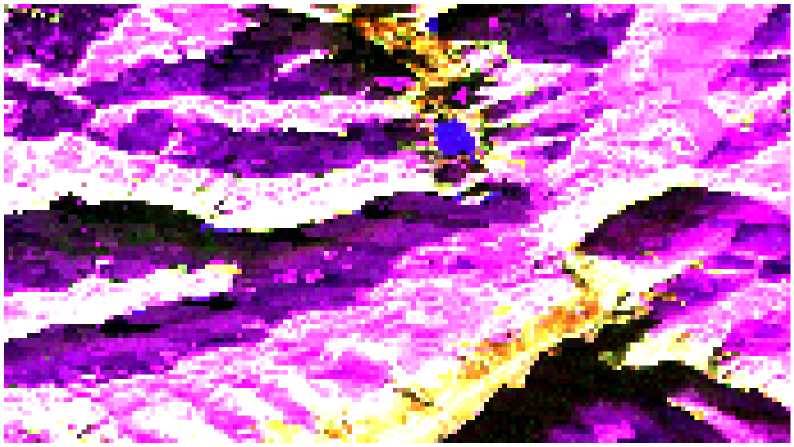


Figure 17: Custom Mosaic, NIR/SWIR1/RED, most recent pixel, 1999-2016

The fourth test (Figure 17) was execute using a NIR/SWIR1/RED band combination along with a Most Recent Pixel method. The features of the region remain still quite recognizable. It is interesting to note that the difference in altitude has a great influence on the resulting images. Depending on the direction of the inclines of the valleys in Figure 17, vegetation, water bodies and other features are detected differently.

3.1.4. Fractional Cover

The next tool tested was the Fractional Cover tool. The tool was tested on the Grimselsee region for Landsat 7 and the combination of Landsat 5-7-8 during the period between 1984 and 2016. This tool also presents the user with a Compositing Method option (identical to that in 3.1.3).

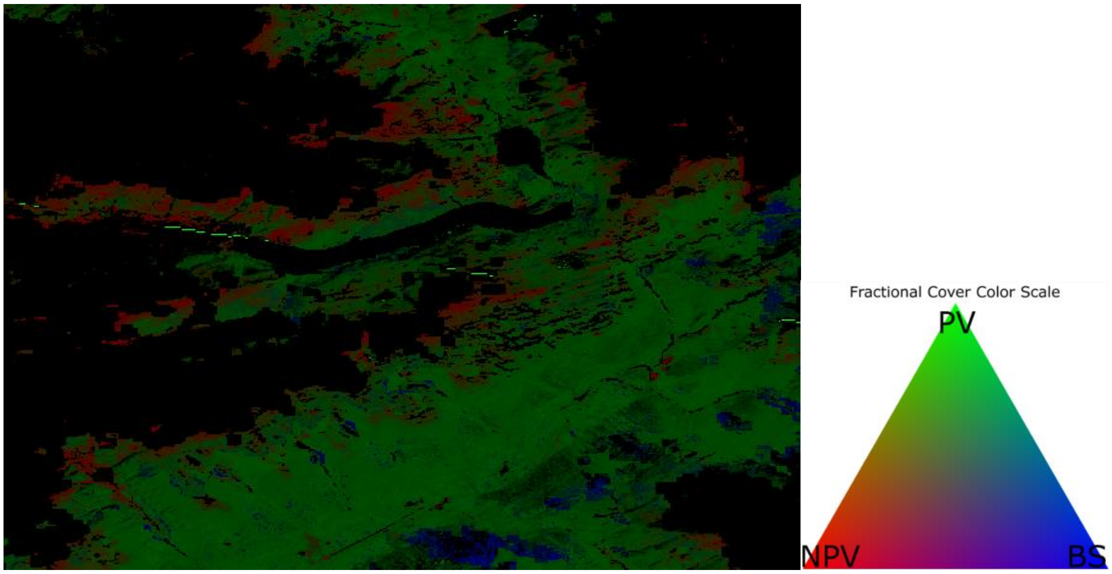


Figure 18: Fractional Cover, least recent pixel, 1999-2016 with Fractional Cover Scale

The first test (Figure 18) was executed for the Landsat 7 dataset with the Least Recent pixel compositing method. The image appears fairly precise, as the algorithm appears to clearly differentiate between photosynthetic vegetation (PV), non-photosynthetic vegetation (NPV) and bare soil (BS). PV is concentrated on the slopes of mountains, while NPV appears to be nearer to the summits. BS appears in patches here and there. As noted in Figure 17, the difference in altitude appears to play a significant role in the distortion of accurate detection. The patches of dark colour in Figure 18 seem to be directly related to the higher portions of the territory.

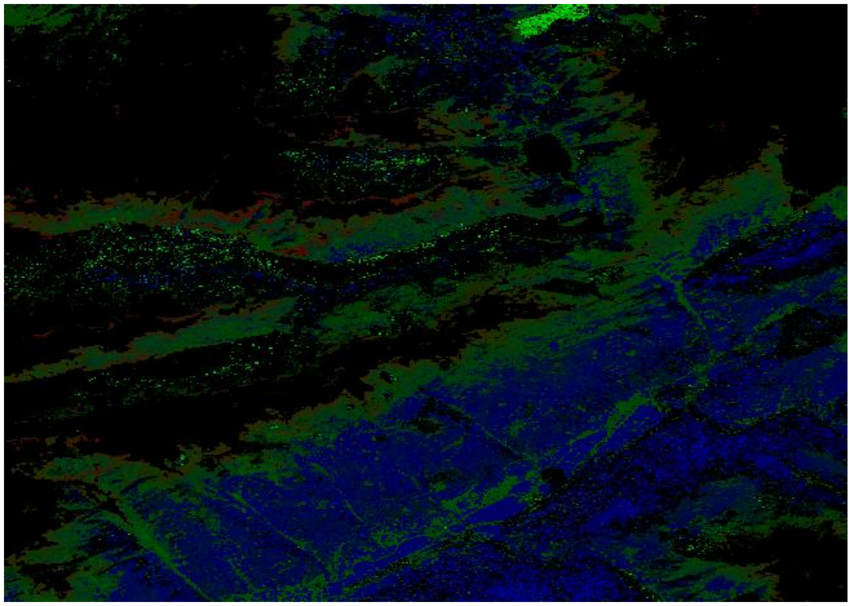


Figure 19: Fractional Cover, Max NDVI, 1999-2016

The second test (Figure 19) was executed for the Landsat 7 dataset with the Maximum NDVI compositing option. Much as in Figure 18, this image gives a detailed representation of the conditions of vegetation in the Grimselsee region. What is interesting to note is that due to the different compositing method, Figure 19 presents a much more extreme picture than Figure 18 (there is much more Bare soil in the lower portion of the image and there is little to no non-photosynthetic vegetation).

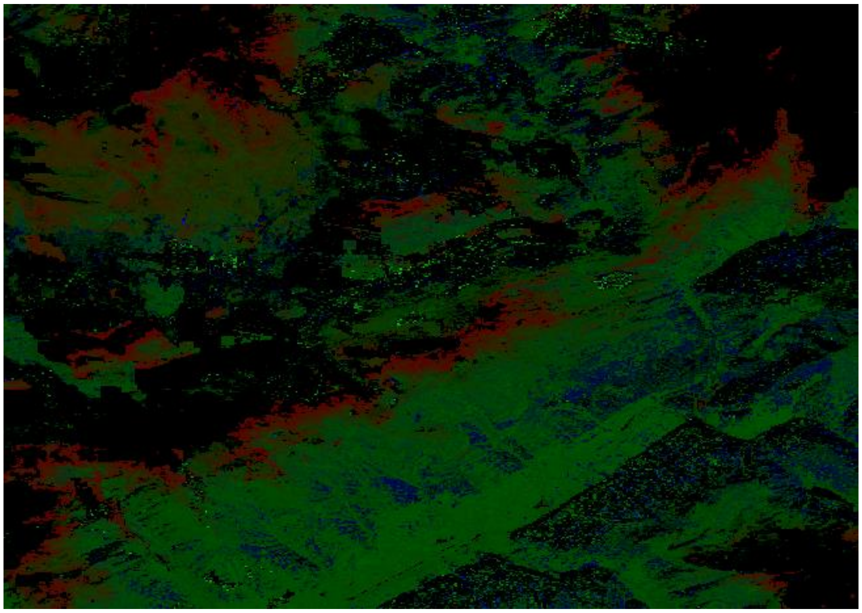


Figure 20: Fractional Cover, Max NDVI, Landsat 5-7-8, 1984 to 2016

The last Fractional Cover test (Figure 20) was run using the combined Landsat 5-7-8 datasets and the maximum NDVI pixel compositing method. Due to the fact that this test takes into account a larger detection period (1984 to 2016), the Fractional Cover values are once again different from the other two tests (Figure 18 and Figure 19).In general this rendering appears to consider the best possible vegetation condition option (due to the compositing method and the larger time frame).

3.1.5. NDVI Anomaly

The next tool tested was the NDVI Anomaly tool. This tool was one of the most complex to test due to the fact that it is poorly explained in the interface. In general the tool requires the user to define a baseline period on which to base the calculations. According to the explanation, it then compares this baseline to a single detection or "scene". In the interface it was however unclear as to which date (start date or end date in Figure 2) would be considered for the scene.

The first test did not work at all on account of the considered dates being unspecific and not compatible with the baseline.

The second test ran Landsat 5 data on a baseline period from June to August for the years 1987 to 1999. The considered start date was the first of June 1987.

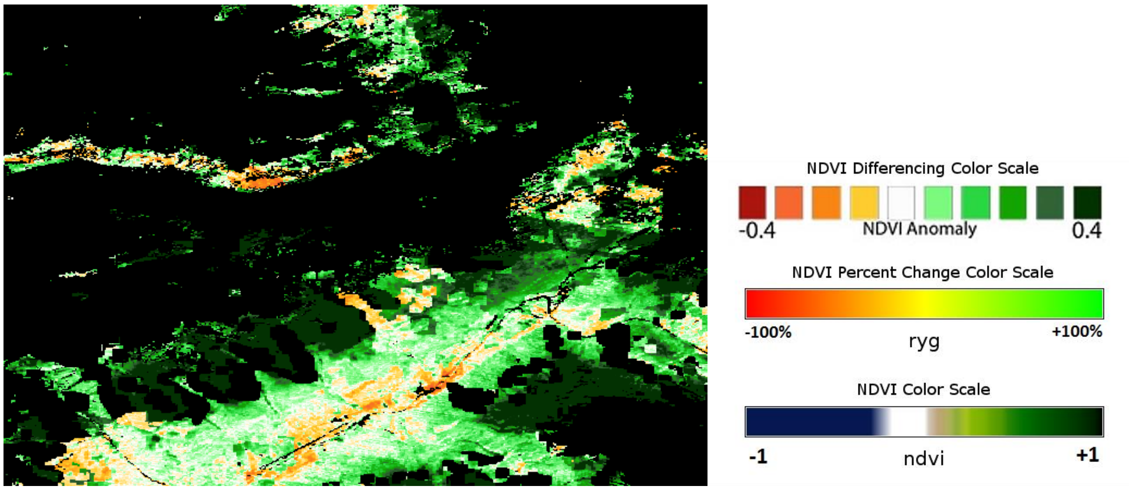


Figure 21: NDVI Anomaly 1987-1999 and NDVI Differencing Color Scale [6]

Figure 21 represents the NDVI anomaly for the chosen time period of the first test. The results are quite promising, as the algorithm appears to have detected a variation of the NDVI index on the valley floor. This may be in part due to urbanization activities that happened between 1987 and 1999 (although to be sure it would be necessary to conduct further research).

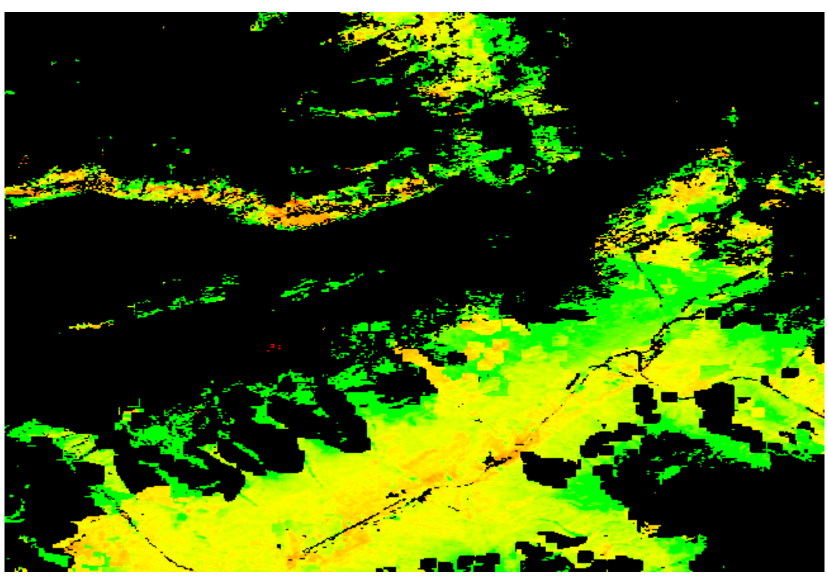


Figure 22: NDVI Anomaly Percentage

Figure 22 represents the NDVI Anomaly percentage. The scale for this image can be found in Figure 21 . This image is quite similar to Figure 21 .

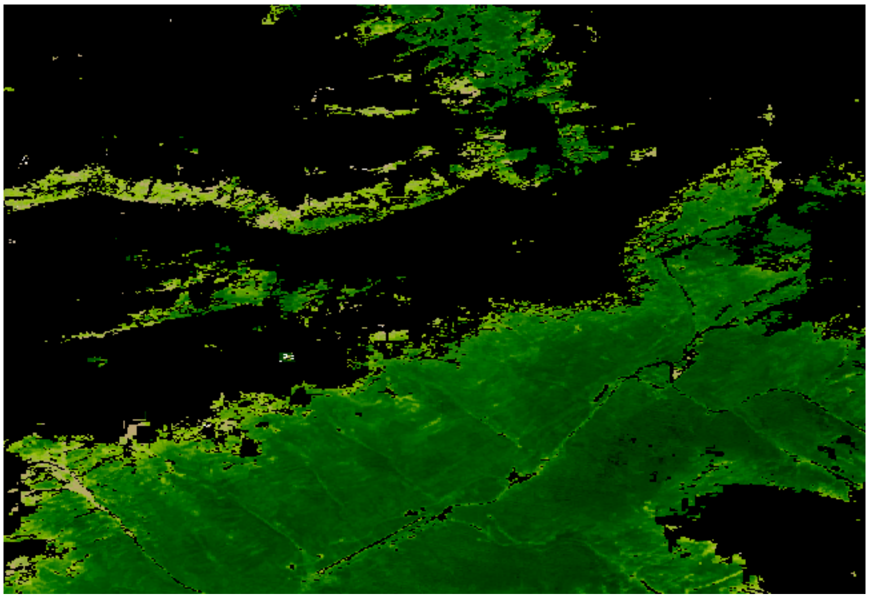


Figure 23: NDVI Anomaly Scene

Figure 23 can be assumed to represent the specific NDVI for the considered scene date (in this case either the start date or end date of the test).

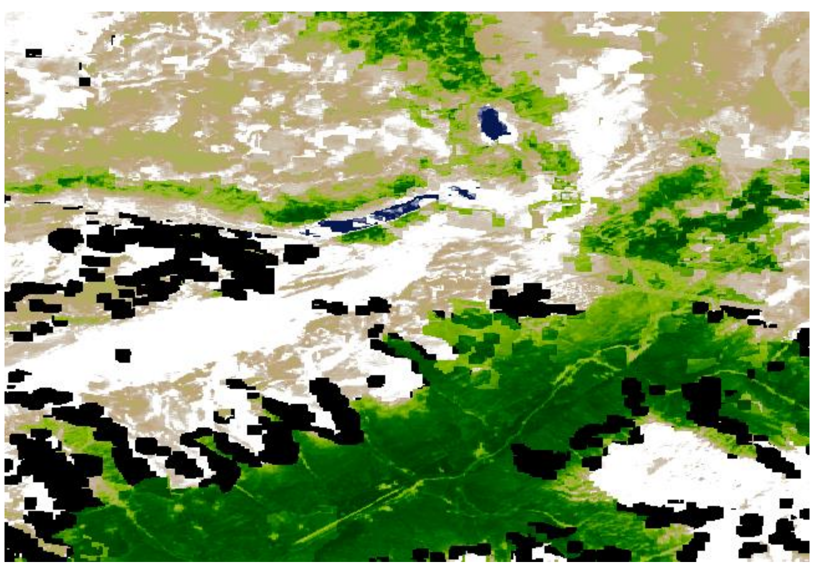


Figure 24: NDVI Anomaly Baseline

Figure 24 is a rendering of the NDVI Anomaly Baseline, that is to say the NDVI values for the period between June and August 1987.

The second test of the NDVI Anomaly tool used the Landsat 8 dataset for a time frame between 2014 and 2016 (start date 30th of June 2014) and a baseline period of June to August.

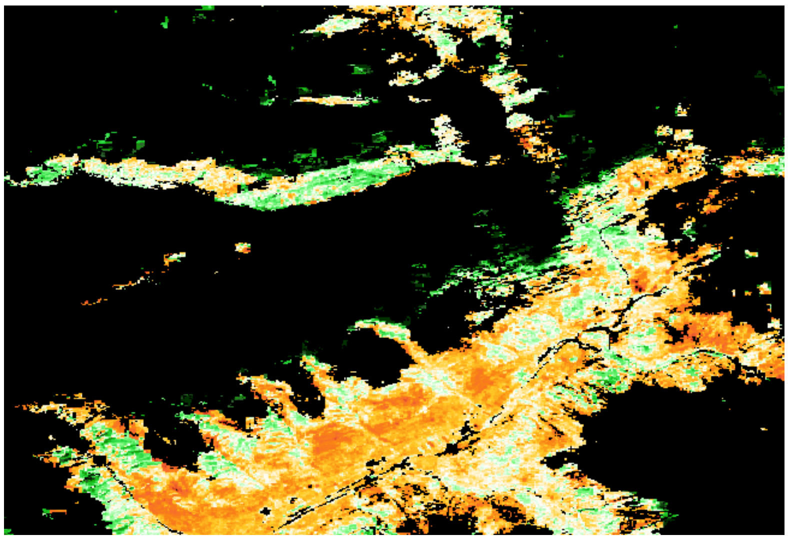


Figure 25: NDVI Anomaly 2014-2016

Figure 25 represents the NDVI Anomaly for the second test. This test appears to render a considerably different result from the first (Figure 21). The results remain clear and the features of the region recognizable. There appears however to be a considerable variation in NDVI, but this largely depends on the scene chosen and the baseline.

Overall, this tool was complicated to test and the results difficult to interpret due to the lack of instructions and explanations.

3.1.6. Slip

It was, unfortunately, not possible to test the Slip tool. This tool uses satellite data as well as a DEM. The latter was not ingested into the SDC at the time of testing, making it unusable.

3.1.7. Urbanization

The next tool tested was the Urbanization tool. It was tested for a variety of Landsat datasets on the regions of the Grimselsee and Lake Ceresio. It was calibrated with a variety of Compositing Method options.

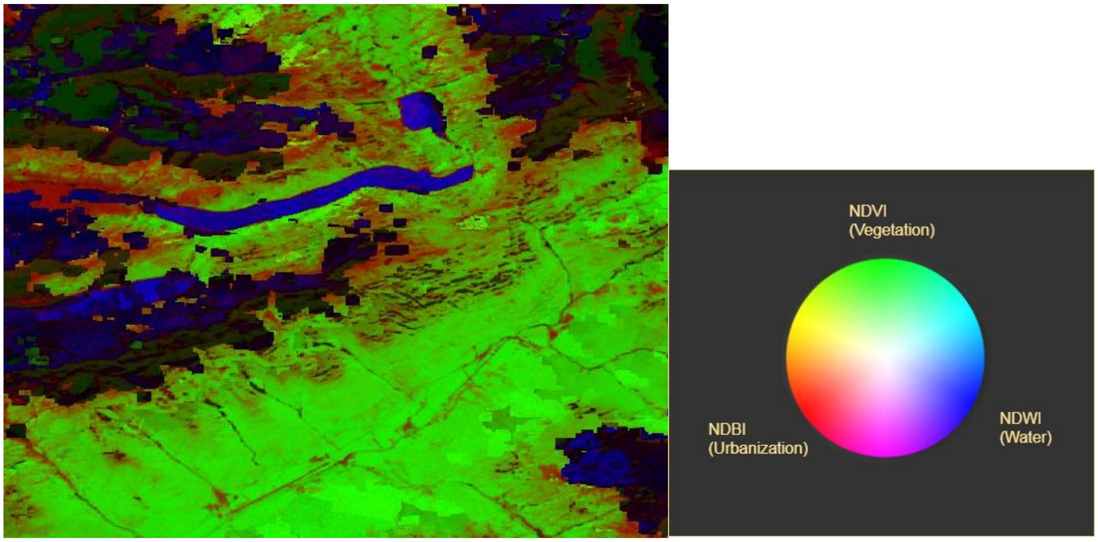


Figure 26: Urbanization Tool, least recent pixel, 1999-2016 and legend for Urbanization algorithm[6]

The first test (Figure 26) ran for Landsat 7 data and the Least Recent Pixel compositing method. This tool appears to clearly detect and represent the three different classes considered in its legend. It represents vegetation, water and patches of urbanized territory fairly accurately. As usual, the difference in altitude appears to distort a part of the detection.

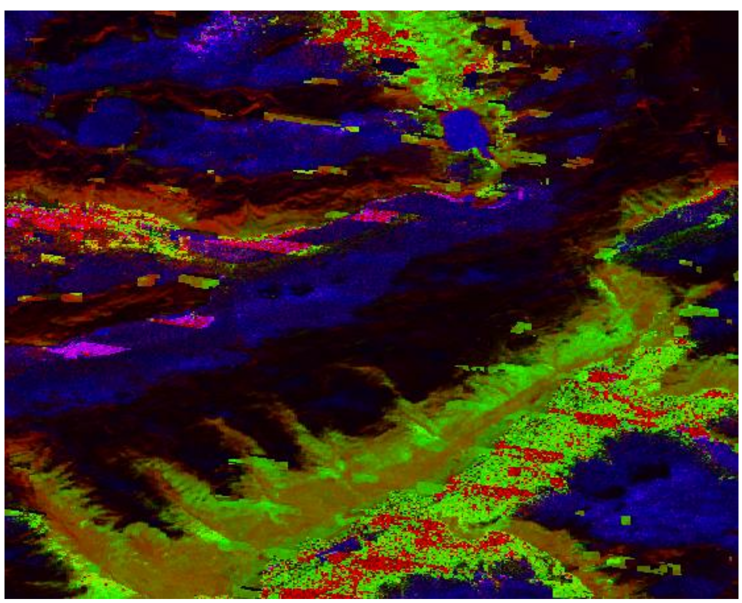


Figure 27: Urbanization tool, most recent pixel, 1999-2016

Test number 2 (Figure 27) used the same parameters as in Figure 26 but with a different compositing method (Most Recent Pixel). The final image is considerably less accurate and more confused than in the first test.

The third test was considered a failure due to the fact that the interface failed to interrupt the process when the user selected dates not compatible with the Landsat 5 mission duration. This is explained in detail in Annex 4.

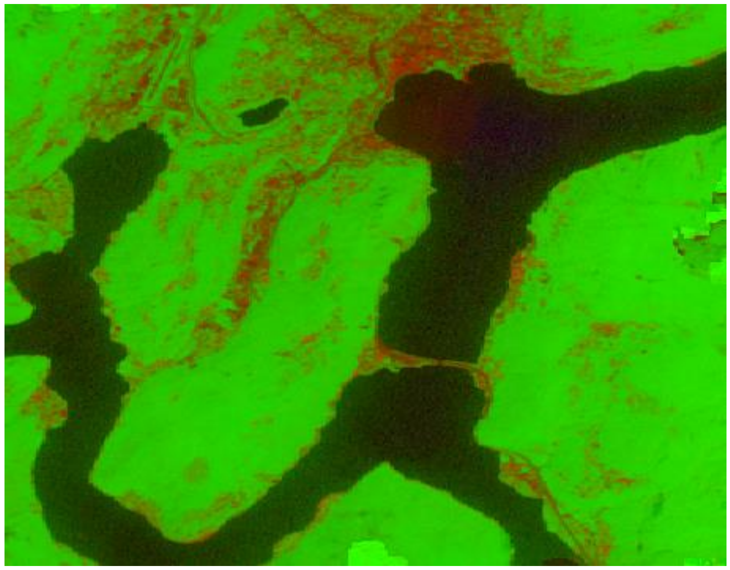


Figure 28: Urbanization tool for Lake Lugano

Test 4 (Figure 28) used the same parameters as in the first test, only that it was executed for the Lugano region. The tool accurately detected the urbanized portions of the region as well as the more vegetated spots. It was unable to detect water as such, but this may be due to the highly eutrophic nature of the lake.

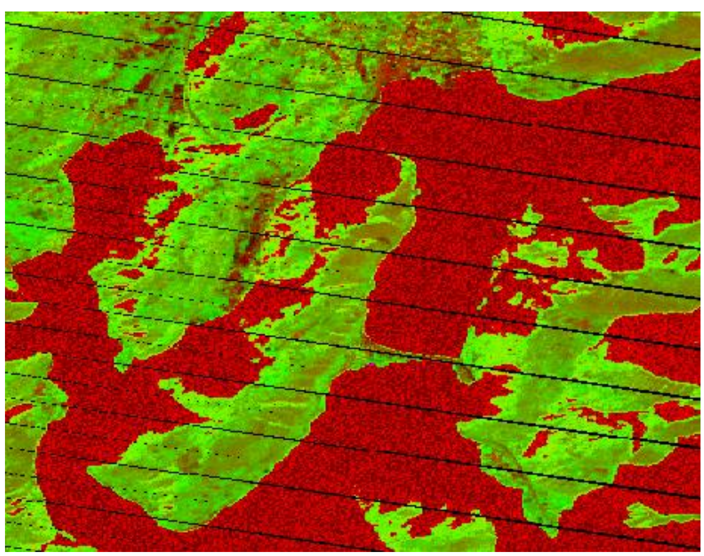


Figure 29: Urbanization tool for Lake Lugano, Most Recent Pixel method

The fifth test (Figure 29) used the same parameters for the second test applied to the Lugano region. Much like in the case of Figure 27, the results are confused with water and urbanization being undistinguishable.

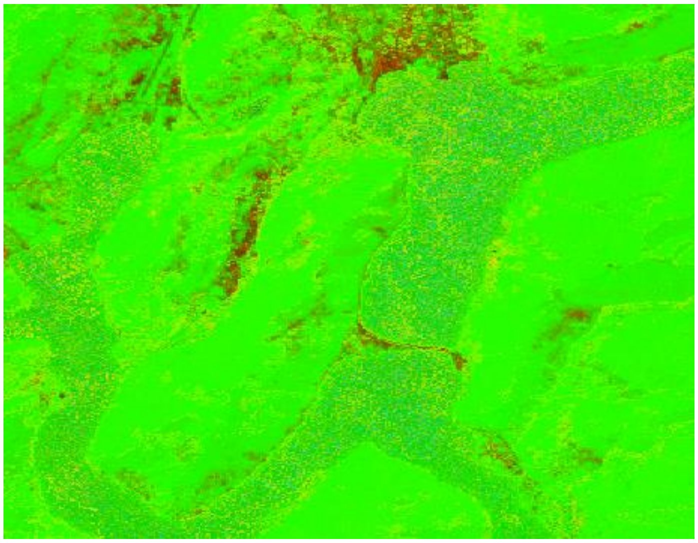


Figure 30: Urbanization tool for Lake Lugano, Max NDVI compositing method

The last test for this tool (Figure 30) used the same parameters, save for the compositing method (which was change to Max NDVI). Although vegetation and urban areas are still recognizable, there is less distinction between the two and the problems with water detection persist.

3.1.8. Water Detection

The next tool tested was the Water Detection algorithm. It was tested on the Grimselsee region for Landsat 7 data (from 1999 to 2016) and the combined Landsat 5-7-8 datasets (from 1984 to 2016).

The first test was executed with the Landsat 7 dataset.

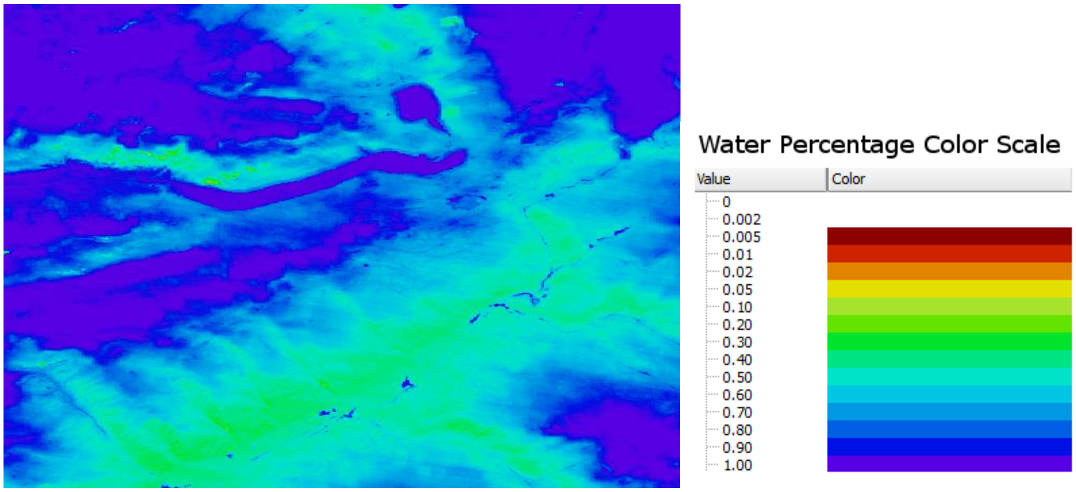


Figure 31: Water Detection tool, 1999-2016 with Water Percentage Color Scale[6]

Figure 31 represents the water percentage detected in the Grimselsee region. The results seem accurate, although the tool is incapable of distinguishing between different types of water (ice, snow…).

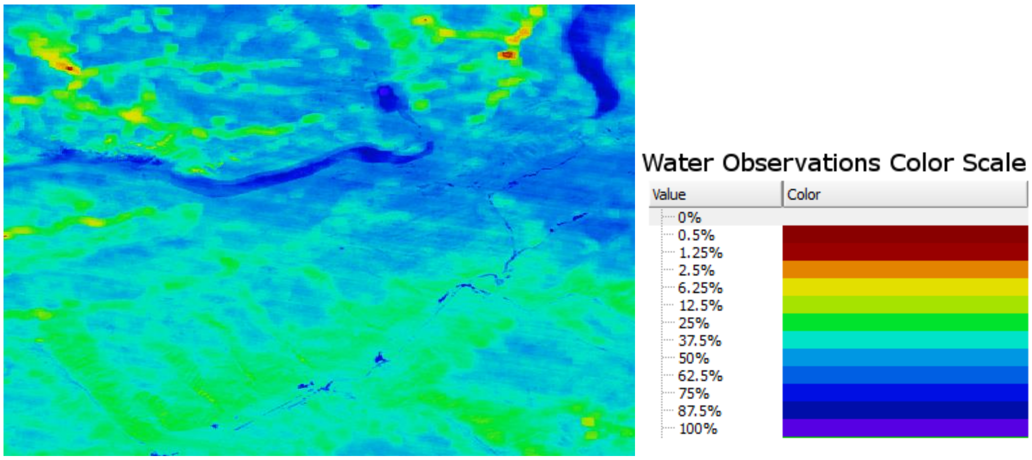


Figure 32: Water Observations, 1999-2016 with Water Observations Color Scale [6]

Figure 32 appears to provide a more detailed overview of the water in the region. The Grimselsee is clearly recognizable as well as the Räterichsbodensee, the Rhonegletscher and the various small rivers. There also appears to be a differentiation between water and snow (this is probably due to the fact that snow is not observed during the summer months).

The last image provided by the Water Detection tool details the Clear Observations. It is explained in greater detail in Annex 4.

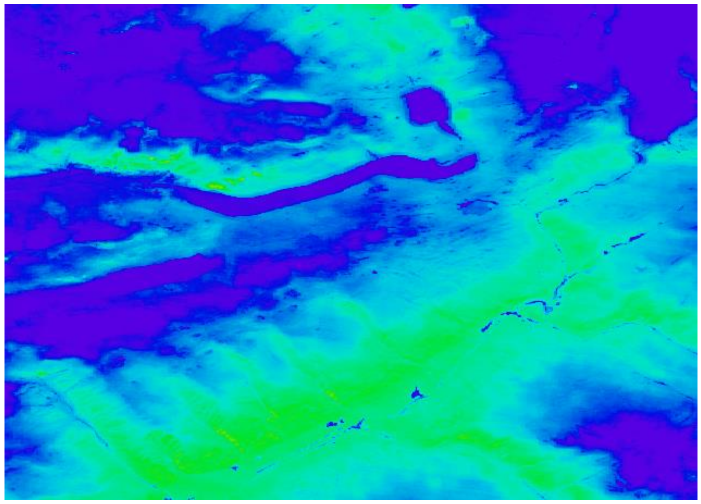


Figure 33. Water Detection tool, 1984-2016

The second test (Figure 31) was run for the combined Landsat datasets. There appear to be some differences between this image and Figure 31, however they appear to be minimal.

In general the tool appears to accurately detect water, although it struggles to differentiate its different forms and suffers from the same altitude-related problems as many of the other SDC tools.

3.1.9. Water Quality (TSM)

The last tool tested was the Water Quality TSM tool. Given the objective of this tool (to determine the average suspended matter in a given area [6]), the tool was tested on lake Ceresio (Lugano) with the Landsat 7 dataset for the period between 1999 and 2016.

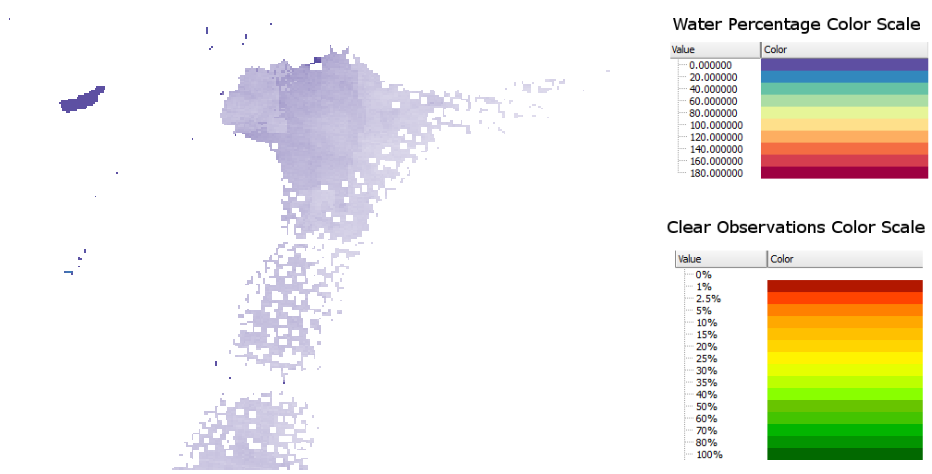


Figure 34: Average TSM for Lake Lugano, 1999-2016 with the legends for Water Quality

This tool produced results that were difficult to interpret. Figure 34 appears to show the average suspended matter in Lake Lugano; however there is no scale associated to this image. It is possible that the Water percentage scale is mislabelled, but that would require further research to determine.

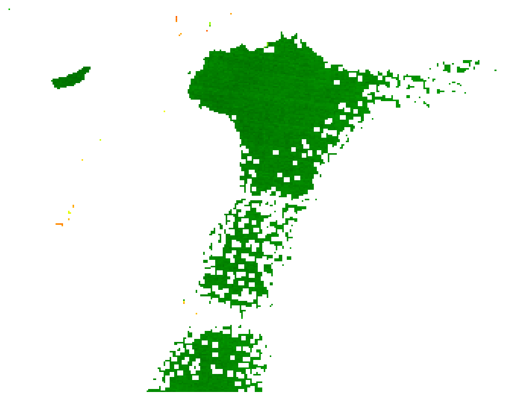


Figure 35: Clear Observations for Lake Lugano

Figure 35 represents the clear observations calculated by the tool, of which Lake Lugano appears to have very few.

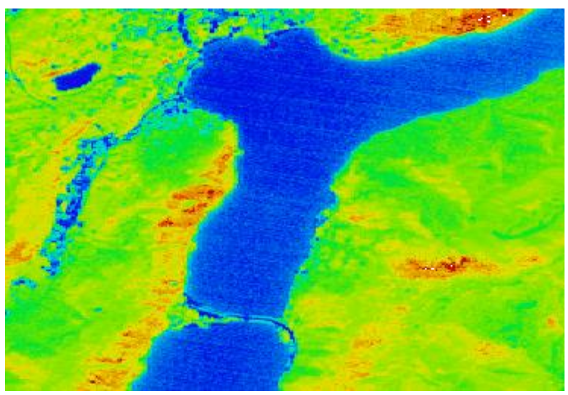


Figure 36: Water percentage for Lake Lugano

The last image (Figure 36) produced by the tool is a water percentage map. It appears to be quite detailed, and although it does not represent any form of particle suspension, it seems to be detect water bodies quite effectively.

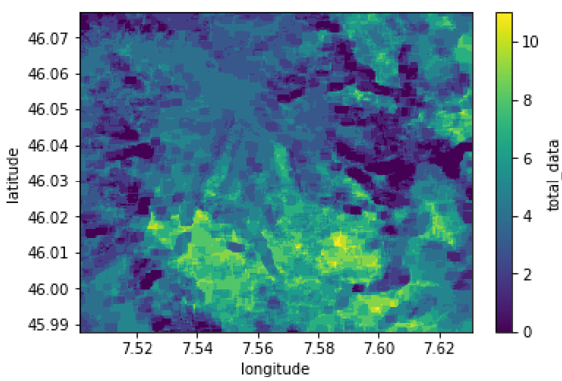
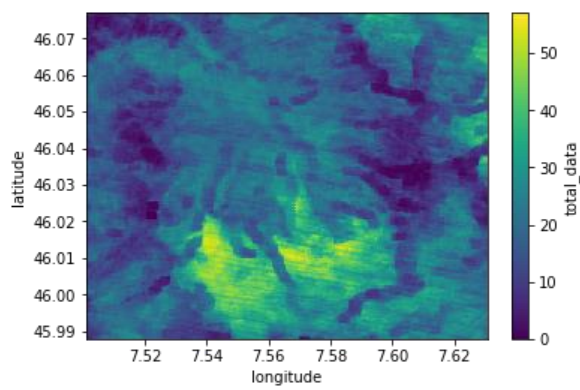
This concludes the section relating to the results obtained from the testing phase of the SDC. The conclusions and proposed modifications will be discussed in par 4.1.

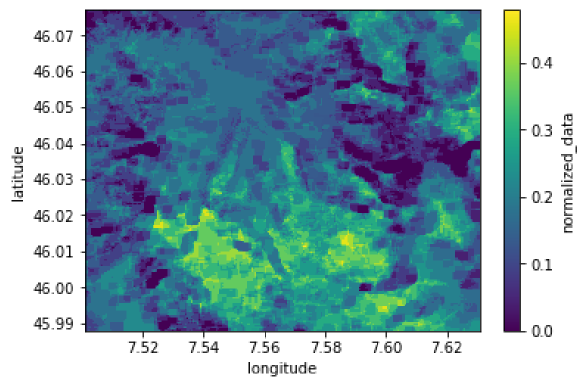
3.2. Snow Detection Tool

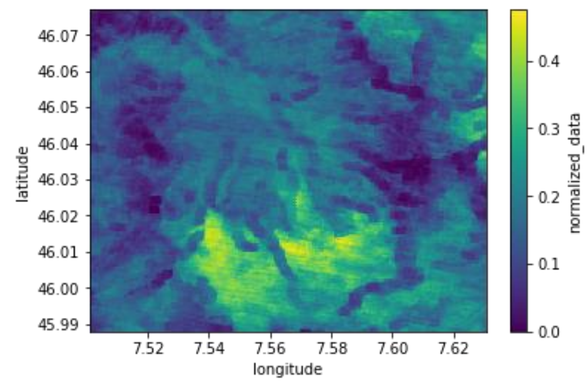
This section of the internship report will detail the results of the SOfS testing. As expressed in paragraph 2.2.3, the tool was tested on three regions. It was also tested for two different time periods: the first from 1985 to 1995 (using the Landsat 5 dataset) and the second from 2005 to 2015 (using Landsat 7). The reason for comparing these two time periods is that according to data relating to climate change [12], snow cover is due to decrease as time goes by. Logically, this tendency should be observable through the use of the Snow Detection tool. For the tool to be deemed accurate it should be able to detect a decrease in snow cover between the two selected periods.

For the purpose of this report only two of the three plots produced by the tool will be illustrated in this section. The third, the clean observations plot is not critical to the purpose of this report: it represents the number of "clean" detections calculated by the algorithm and is roughly similar for all the tests run on the SOfS tool. An example of the clean observation plot can be found in Annex 2.

Table 1: Ferpècle Snow Detection Results

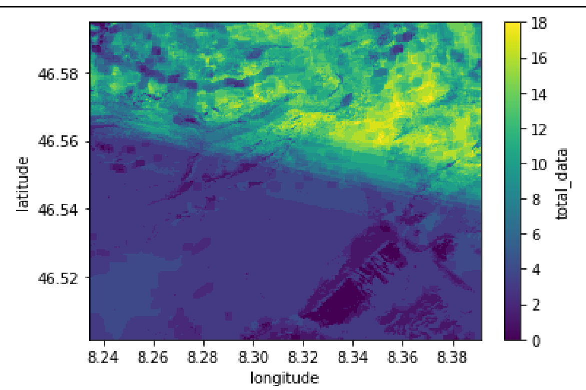
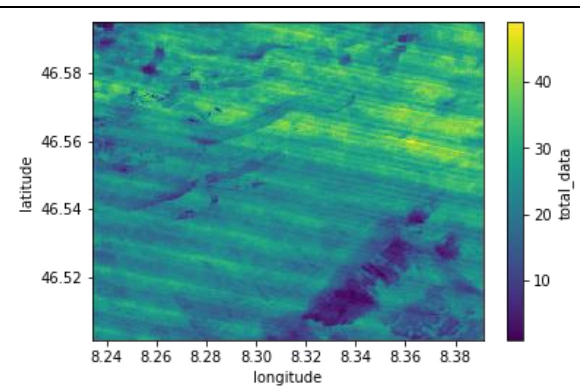
<table>
<tr><td>Ferpècle 1985-1995 Total Snow Observation</td><td>Ferpècle 2005-2015 Total Snow Observation</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Ferpècle 1985-1995 Normalized Snow Observation</td><td>Ferpècle 2005-2015 Normalized Snow Observation</td></tr>
</table>

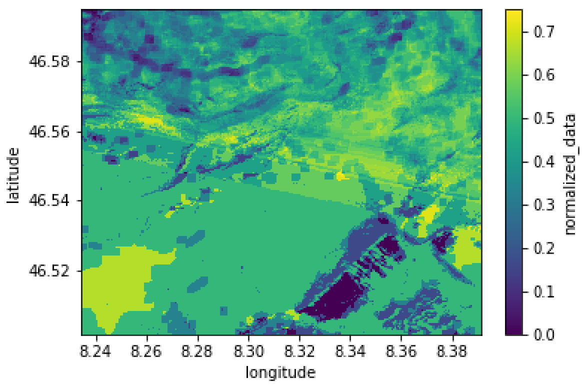
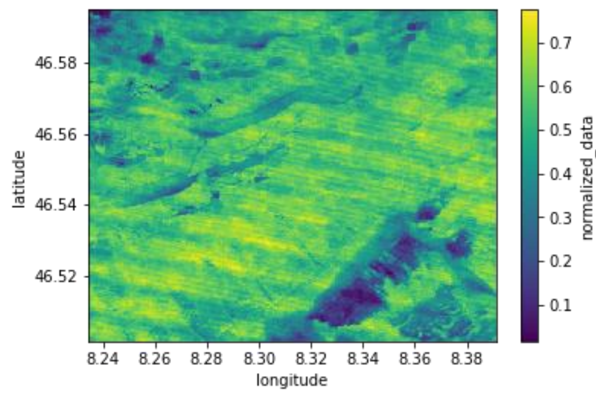




The first region tested was that of the Ferpècle glacier. This first test was executed when the tool did not yet differentiate between winter and other seasons. The idea in testing the tool on the glacier was to verify whether it could detect the latter’s progressive shrinking. As we can see in the first row of Table 1, there appears to be a larger number of snow observations in the period between 2005 and 2015 (this can be easily note by observing the scales of the two time periods). Once we take into account the number of clear observations however, it become clear that the difference is not as great as it seems. In the second row of the table in fact, the normalized snow observations appear to be very similar, and are within the same order of magnitude. It is interesting to note that the snow detections appear to be spatially more concentrated in the 2005 to 2015 period. More precise observations would require further research however.

Table 2: Grimselsee Snow Detection Results

Grimselsee 1985-1995 Total Snow Observations	Grimselsee 2005-2015 Total Snow Observations
	

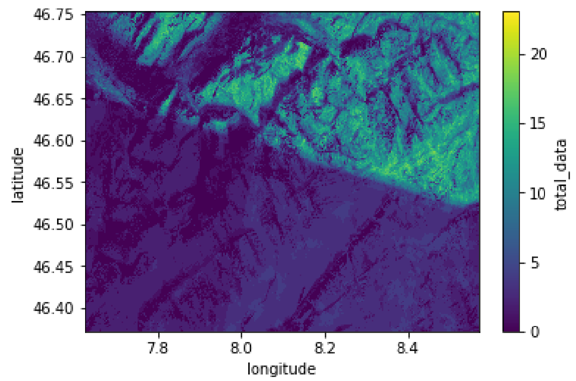
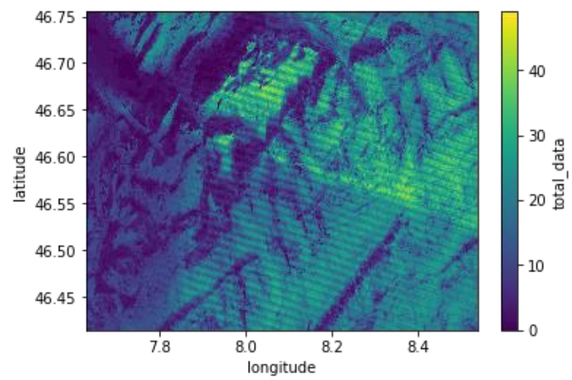
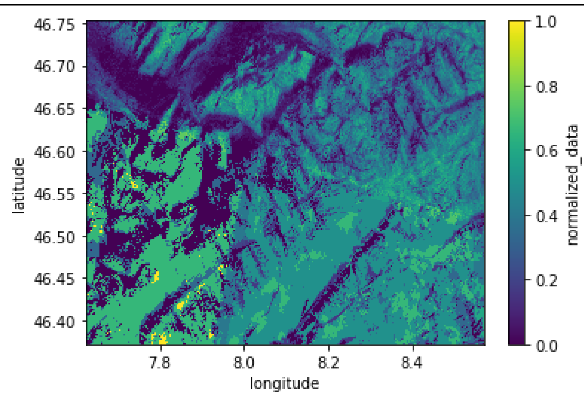
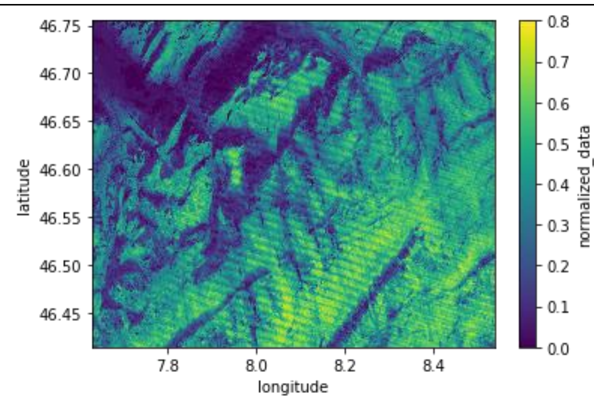
Grimselsee 1985-1995 Normalized Snow Observations	Grimselsee 2005-2015 Normalized Snow Observations
	

Starting from the Grimselsee test, the script was calibrated to only consider the winter months, so as to prevent smoothing of data.

In Table 2, we can observe a similar effect to that of Table 1: there is a great difference in the number of total observations, due to the amount of available clear observation data. Once the data is normalized however, the results seem to be quite similar, albeit that the period between 1985 and 1995 seems to be less defined.

The similarity exhibited between the two time periods in the second row of Table 2 are contrary to the hypothesis that supposes that snow cover should decrease between the periods of 1985 to 1995 and 2005 to 2015. To verify whether this result was a product of the tool's inaccuracy or of the chosen location, a larger area was selected, that of the Bernese Alps.

Table 3: Bernese Alps Snow detection Results

Bern Alps 1985-1995 Total Snow Observations	Bern Alps 2005-2015 Total Snow Observations
	
Bern Alps 1985-1995 Normalized Snow Observations	Bern Alps 2005-2015 Normalized Snow Observations
	

In the first row of Table 3 we can once again observe the “Clear Observation” effect. After having removed it in row two, we can observe the first real difference between the two temporal extents. By observing the two scales of the images representing the normalized snow detection for the Bernese Alps, we can see that the one representing the period between 1985 and 1995 considers a 0.2 fractional amount more of snow of normalized snow observations than the other period. This seems to indicate that there is in fact a considerable difference in snow cover between the two periods.

In general, the SOfS tool has proven to be a good first step in the direction of an accurate means of detecting snow from space. To perfect it however it requires more research and a series of modifications that will be detailed in the discussion portion of this report.

4. Conclusions and critiques

In this last portion of the internship report, the conclusions and critiques of the two projects developed at GRID-Geneva will be illustrated. The closing remarks pertaining to the general experience of the internship will be addressed in paragraph 5.

4.1. SDC Testing

After having tested the SDC, the results were compiled in a report that was subsequently sent to CEOS to help in the perfecting of the SDC interface. The remarks and suggestions for improvement are carefully detailed in Annex 4, which is the integral report.

In general, the web version of the SDC mostly requires an overhaul for all that concerns user friendliness: the tools should provide more information on their use and outputs as well as the algorithms that they are based on. The interface itself, although intuitive, could benefit from a site map or possibly a brief tutorial. Another aspect that requires some work is the animation creation option of some tools: although it has high potential, it should be reworked to render the frames more pertinent (by adding a timestamp for example) and to exclude empty scenes.

The tests conducted on the SDC were conceived to identify the more pressing and important problems relating to the web interface. Although testing was conducted over a period of a month, it was not able to verify the performance of each tool for each satellite dataset. Ideally, every single application in the SDC should be tested for every dataset, for different spatial and temporal extents and for every available option.

The limits encountered in this phase of the internship were mostly time related: a more detailed testing of the SDC would have required a significantly larger portion of time. Also, the testing was limited by the lack of knowledge concerning the inner workings of the tools themselves; this limit was later overcome once the internship turned towards the analysis of the tools in the Jupyter environment.

The final report could have also benefited from considering a larger portion of spatial extent, as well as possibly comparing smaller portions of time to understand the sensitivity of the SDC tools.

After the Swiss Data Cube has been updated, future interns or SDC developers should concentrate their efforts on perfecting the Slip tool and testing Landsat data as detailed above, as well as the newly ingested Sentinel data.

4.2. Snow Detection Tool

The development of the Snow Detection Tool was explained and presented along with its test results in an article co-authored with Mr. Syed R. Rizvi, Dr. Gregory Giuliani, Mr. Bruno Chatenoux and Mr. Jean-Philippe Richard. The article was then submitted for publication for the IGARSS symposium in July 2018 in Valencia and is contained within Annex 1 of this document.

In general, the Snow Detection Tool or SOfS, is a good first step in the accurate detection of snow cover in Switzerland. To the knowledge of those involved, it is also the first example of snow detection implemented within a data Cube environment. However, before it can be considered highly accurate, the SOfS has to overcome a series of limitations.

Firstly, the results need to be presented with a uniform scale so as to see the real variation over the course of time. Results like those found in Table 3 can be easily interpreted however they lack an immediate form of clarity. A second limitation is that this tool, like all the others in the SDC still suffers from the problem relating to variations in altitude. Although compared to the other tools the distortions appear to be less, it is still a key stage in the further development of the tool.

Once these two major issues have been corrected, the tool can be added to the SDC interface, adapted to the new Sentinel data and can be used to detect snow on a national scale.

Concerning this stage of the internship, the limitations were mostly related to the initial lack of knowledge relating to the Python structure of SDC tools. This limitation was rapidly overcome thanks to the continued support of the staff at GRID-Geneva.

According to this report, future interns and SDC developers should ideally focus on perfecting the SOfS tool as well as potentially try and develop new CFMASK based tools for water and ice

5. Closing remarks

If we consider the initial objectives set for this internship, it can be stated that they have been fulfilled. The SDC was in fact tested extensively and a report was compiled to further its development and perfect its performance. By researching the SDC and its tools more carefully, it became possible to begin the development of an original tool for the Data Cube, capable of detecting snow. This last phase finally brought to the writing of an article which will potentially be published for the IGARSS symposium. Although the tool is still in its early stages it shows much potential, and the results it provides are already of high quality.

Throughout the internship, a variety of skills were perfected, such as the development of a methodology to test a web interface, getting acquainted with a data cube infrastructure and Python coding to name a few.

During the three and a half months of internship at GRID-Geneva, I was fortunate to work on two connected yet quite different issues pertaining to the Swiss Data Cube. It was an immensely enrichening experience both professionally and personally. It permitted me to become acquainted with a fairly specific aspect of geomatics that before was unfamiliar to me. The time at GRID-Geneva also gave me the possibility to participate in an office environment, through staff meetings and team work. Finally, this internship also introduced me to the aspects of writing a (small) scientific article and the procedure of submitting it to be reviewed.

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7. Annex 1: IGRASS Article

Snow observations from Space: an approach to map snow cover from three decades of landsat imagery across Switzerland

[1]*Lorenzo Frau*, [2]*Syed R Rizvi*, [1]*Bruno Chatenoux*, [1]*Jean-Philippe Richard*, [1]*Gregory Giuliani*

[1]University of Geneva, Institute for Environmental Sciences, GRID-Geneva
[1]Analytical Mechanics Associates, Hampton, VA

ABSTRACT

Snow accumulation is one of the most important forms of water storage. The natural cycle of water is being increasingly influenced by climate change and will continue to change in the future. To understand the evolution of snow cover and to perfect its accurate detection UN Environment/GRID-Geneva and the University of Geneva have developed a Snow Detection tool called "Snow Observations from Space" for the Swiss Data Cube. The Snow Detection tool uses the C Function of Mask to identify snow pixels and then subsequently produces a normalized detection raster.
Through further development, this tool will reach its full potential as an accurate method of detecting snow cover change for Switzerland.

Index Terms— Landsat, Snow, Open Data Cube, Switzerland, CF Mask, Jupyter

1. INTRODUCTION

Switzerland in known internationally for its tall mountains and verdant pastures. This reputation however could never come to be without the copious amounts of water that flow from the "water castle of Europe" [1].
Although its territory is many times smaller than the rest of Europe, Switzerland is the repository for 6% of Europe's water reserves [1].
Of these water reserves, 40% of all running waters in Switzerland comes from snowmelt [2]. Snow is consequentially a critical part of the water cycle in Switzerland as well as the rest of Europe.
Unfortunately due to climate change, the portion of snow contributing to water bodies is set to diminish to 25% by 2085. This will have serious consequences on many major rivers that are born in Switzerland, such as the Rhone, Rhine and Danube [2].
To better understand the distribution of snow cover, as well as its evolution over time, the UN Environment/GRID-Geneva and the University of Geneva have developed a Snow Detection tool that uses the data present in the newly created Swiss Data Cube.
In recent years, satellite-based snow detection strongly relied on the NDSI (Normalized Difference Snow Index) to map snow cover [3]. However this method has one drawback: it cannot distinguish between water bodies and snow, making it necessary to use a mask to remove the former from calculations.
The aim of this paper is to present the preliminary results obtained with the Swiss Data Cube Snow Detection tool.
These results were obtained using Landsat imagery and are to our knowledge, the first examples of a snow detection tool used in a Data Cube environment. They illustrate the application Snow Detection on three distinct regions of Switzerland for two separate time periods.

2. THE SWISS DATA CUBE

To help monitor pressures on Swiss natural resources in support of land planning for various environmental issues such as climate change, biodiversity loss, urbanisation, or water quality, UN Environment/GRID-Geneva and the University of Geneva, supported by the Federal Office for the Environment (FOEN) are currently building the Swiss Data Cube (SDC – http://www.swissdatacube.org).
Based on the Open Data Cube (ODC – http://www.opendatacube.org) technology, an open source project initiated and developed by Geoscience Australia, the Commonwealth Scientific and Industrial Research Organization (CSIRO), the United States Geological Survey (USGS), the National Aeronautics and Space Administration (NASA) and the Committee on Earth Observations Satellites (CEOS), the "Open Data Cube" is a new way for organizing Earth Observations geospatial data (especially satellite data) by gathering all satellite images from selected sensors (e.g. Landsat, Sentinel) through space and time for a given period over a dedicated region. While a data cube is just a data storage format, the Open Data Cube also provides a common analytical framework for

processing satellite data. This is a change of paradigm in the way that remote sensing data are being organized for delivering it to end-users. In the recent years, the development of Open Data Cube has involved API development, big data, cloud integration, data analysis and collection, user interface development, analytics and reporting, visualization, and verification and validation. It is a sophisticated software with multiple services designed for better satellite data collaboration, automation and governance across platforms.

The SDC makes use of a number of freely and openly accessible data repositories. Currently, the SDC contains 33 years of Landsat 5,7,8 Analysis Ready Data (1984-2017) corresponding to approximately 4000 scenes for a total volume of 1TB and more than 35 billion observations over the entire country [4], [5]. A prototype platform is running and allows testing and applying several algorithms to extract useful information country-wide. Sentinel-2 data have been recently ingested in the SDC adding more than 2300 scenes for a total size of 3.5TB over the period 2015-2017. Soon Sentinel-1 will be also added.

This is constituting a unique collection of data which are analysis ready, meaning all corrections (spatial, atmospheric corrections) are already applied.

The Swiss Data Cube is a new paradigm aiming to realise the full potential of EO data by lowering the barriers caused by Big data challenges (e.g., Volume, Velocity, Variety) and providing access to large spatio-temporal data in an analysis ready format making it faster and easier to provide information on issues that can affect the country.

The main objectives of the Swiss Data Cube (SDC) are to support the Swiss government and the Cantons for environmental monitoring and reporting and enable Swiss scientific institutions (e.g., Universities) to facilitate new insights and research using the SDC and to improve the knowledge on the Swiss environment using EO data.

3. SNOW DETECTION ALGORITHM: THE METHOD AND TOOLS

Among the objectives set for the Swiss Data Cube (SDC), is the development of tools to facilitate the analysis and understanding of the great wealth of data available. The Python programming language is greatly suited for research in scientific computing, remote sensing, Earth science, and machine learning due to its extensive standard library and selection of add-on packages, its readability, and its ease of programming compared to other languages, and the great quantity of help resources easily found online. It has been widely adopted by the scientific community both for internal analysis and for published material. The tools in question are initially constructed in Jupyter Notebooks (.ipynb format) and subsequently implemented in the online interface. These notebooks act as interactive Python development environments which allow developers to divide their code into blocks which can be run independently of each other, with variables stored in the background and the environment persisted between blocks.

All the tools are constructed in approximately the same manner: initially, the program is instructed to connect to the Data Cube. Subsequently the desired extent values are chosen (according to the area considered for analysis) and the Data Cube is queried. At this point, the tools differ, as each distinct analysis requires a specific algorithm.

As stated in the introduction, this paper regards the development of a Snow Detection algorithm.

This tool uses the C Function of Mask to run its analysis, an algorithm applied to Landsat data, initially developed by Boston University as Function of Mask and the translated to C by USGS EROS [6]. This algorithm executes multiple runs through a decision tree system that labels pixels according to different categories. It then validates this choice by comparing the labels to the general statistics of the considered scene [6].

The CF Mask values the Swiss Data Cube uses were obtained from the Second Simulation of the Satellite Signal in the Solar Spectrum (6S) algorithm available in the Atmospheric and Radiometric Correction of Satellite Imagery (ARCSI - http://rsgislib.org/arcsi/) software and take into consideration five main classifications for pixels: clear pixels, water, cloud shadow, snow and cloud [7].

The idea behind the Snow Detection algorithm was to use the CF Mask snow pixels to obtain the snow cover for a given time period and spatial extent. Through close collaboration with CEOS, it was possible to extract the relevant pixels and perform a time series analysis on them.

To test the Snow Detection algorithm, the tool was applied to three different alpine regions of Switzerland:

- The Grimselsee Region, that presents a wide variety of terrain types (a lake, glacier, forests and urban areas) as well as a wide variation in altitude (it is a very mountainous region)
- The Ferpècle Glacier in Valais. The idea behind this choice was to verify whether the tool could potentially detect the well documented [8] retreat of the glacier.
- The Bernese Alps.

4. RESULTS AND DISCUSSION

The tool was applied to the regions of the Grimselsee and the Ferpècle glacier for two separate time periods (1985 to 195 and 2005 to 2015) to facilitate comparison.

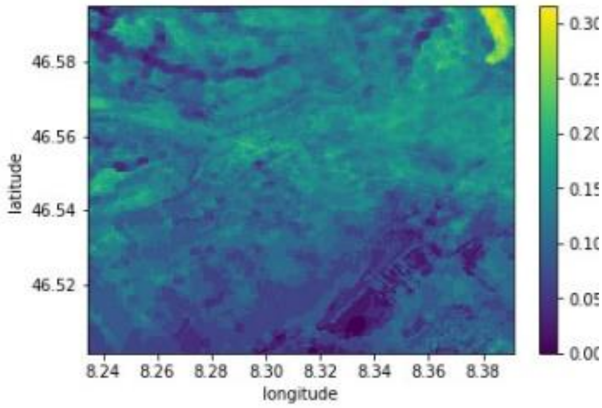

Figure 1: Grimselsee normalized Snow Detection for 1985 to 1995

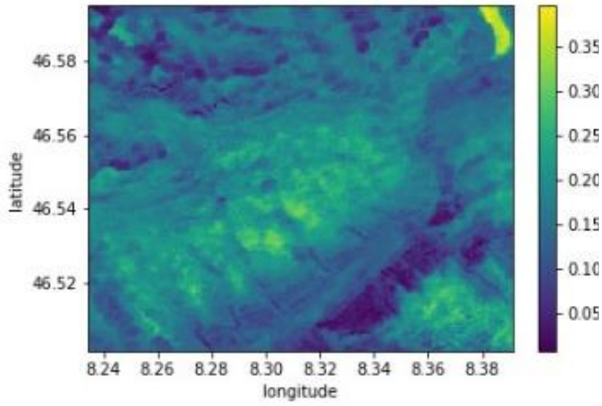

Figure 2: Grimselsee normalized Snow Detection for 2005 to 2015

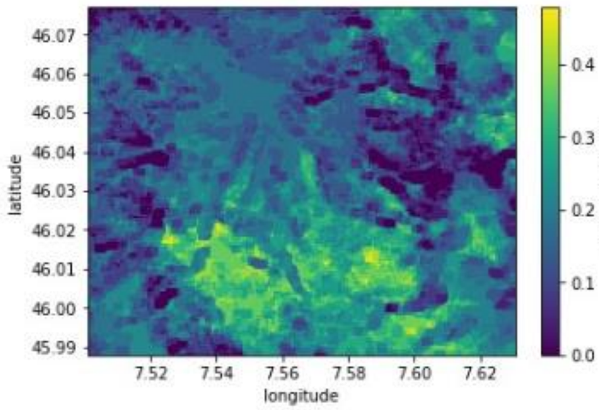

Figure 3: Ferpècle Glacier normalized Snow Detection for 1985 to 1995

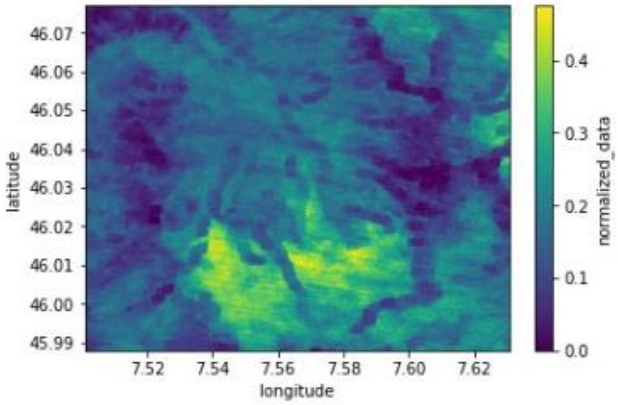

Figure 4: Ferpècle Glacier normalized Snow Detection for 2005 to 2015

The figures above (Figure-4) represent the normalized snow detection (that is to say the total snow observations divided by the number of clear observations) for the two considered areas. The images show clear differences between each other, although it would currently be difficult to establish a relationship between the two time periods.

We can observe however that the small glacier in the higher right corner from Figure 1 to 2 appears to have become somewhat smaller between the two considered time periods. A similar tendency can be noticed in 3-4, although the details are difficult to make out.

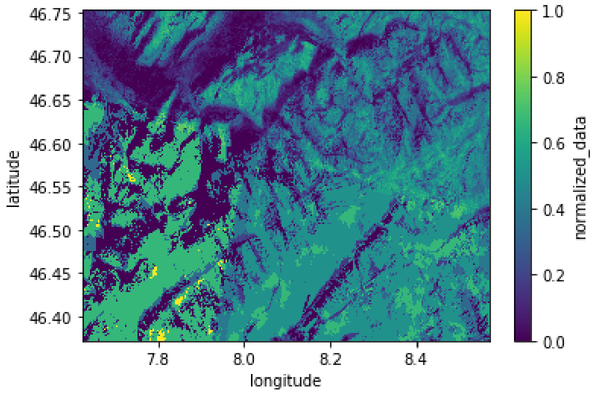

Figure 5: Bernese Alps normalized Snow Detection for 1985 to 1995 (winter months)

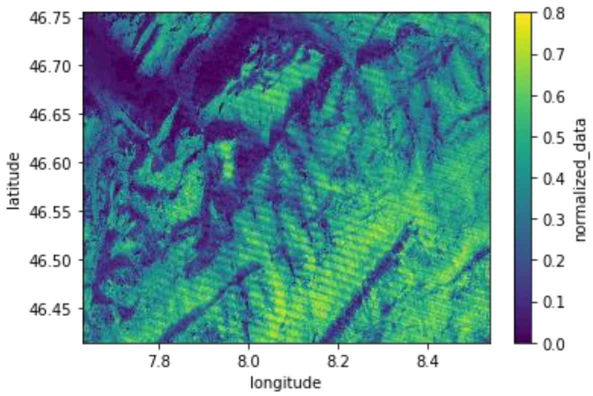

Figure 6: Bernese Alps normalized Snow Detection for 2005 to 2015 (winter months)

Figures 5 and 6 represent normalized snow detection that only takes into consideration winter months (December to February). This filter was recently added to the Snow Detection tool to avoid smoothing of final results. We can observe that although there may not be a very large difference visually, scale-wise there are regions in Figure 5 that present a higher number of snow observations than in Figure 6.

This new tool is the first step in the accurate detection of snow cover and potentially, glacier evolution. This tool is the first of its kind which can detect snow independently from water. This is great step ahead both for future snow detection tools as well as for more accurate water detection. By detecting the change in snow cover for different time periods, it will become possible to better understand the effects of climate change on both a national scale, as well as a local one. Also, the possibility of using this tool for developing a more accurate ice detection algorithm could prove invaluable to accurately detailing glacier evolution through the use of satellite data.

The tool presents a series of limitations. The current version takes into account scale variations, but it presents them individually with the same color scheme. Ideally, the program should be configured on a unique scale to better emphasize the difference between time periods. This would be very useful in better understanding snow cover change through time.

Another limitation is that the tool does not take currently take into consideration the variation in altitude. At the current stage of testing, this appears to cause only minor distortions in snow detection, but it remains an issue to be solved. A possible solution could be to implement a stage in the algorithm that corrects the total snow observations according to a digital elevation model.

As stated previously, the tool is still in the process of being developed and will undergo a series of modifications before it can be considered to accurately detect snow.

Initially, the tool should correct for altitude distortion. After this has been implemented, the program should be calibrated to use a unique scale and color scheme.

Once these two issues are resolved, the tool can be tested on the totality of Switzerland. This should provide us with a better understanding of the general snow cover.

Finally, the tool will be implemented in the Swiss Data Cube Interface and will be tested to verify its effectiveness and accuracy.

5. CONCLUSIONS

In this article, we have illustrated the development and application of a Snow Detection algorithm called “Snow Observations from Space” to the Swiss Data Cube.

If we consider the future projections concerning climate change [9] and water availability [2], we can conclude that snow detection can be an invaluable asset to water management practices.

In “Europe’s Water Castle” [1], snow is and will remain an important water source; how it changes and is managed will affect the future of Switzerland as well as its neighboring countries.

Satellite data can greatly contribute to the accurate detection of snow. By using the data provided by the Landsat and Sentinel programs ingested in the Swiss Data Cube, it is now possible to run a variety of algorithms for the whole of Switzerland as well as monitor the evolution of certain environmental factors (such as Forest Cover or Water Detection).

The Swiss Data Cube’s Snow Detection algorithm is the latest step towards a better understanding of snow cover and its evolution through time in Switzerland. There is still much to do to fully exploit the available data’s potential, but the preliminary results demonstrate that this algorithm can prove to be a powerful asset for past, present and future snow detection.

ACKNOWLEDGMENTS

The authors would like to thank the Swiss Federal Office for the Environment (FOEN) for their financial support to the Swiss Data Cube. We would like also to acknowledge Dr. Brian Killough (NASA), Otto Wagner (Analytical Mechanics Associates), and the Open Data Cube community for their valuable support in implementing and developing the Swiss Data Cube. The views expressed in the paper are those of the authors and do not necessarily reflect the views of the institutions they belong to.

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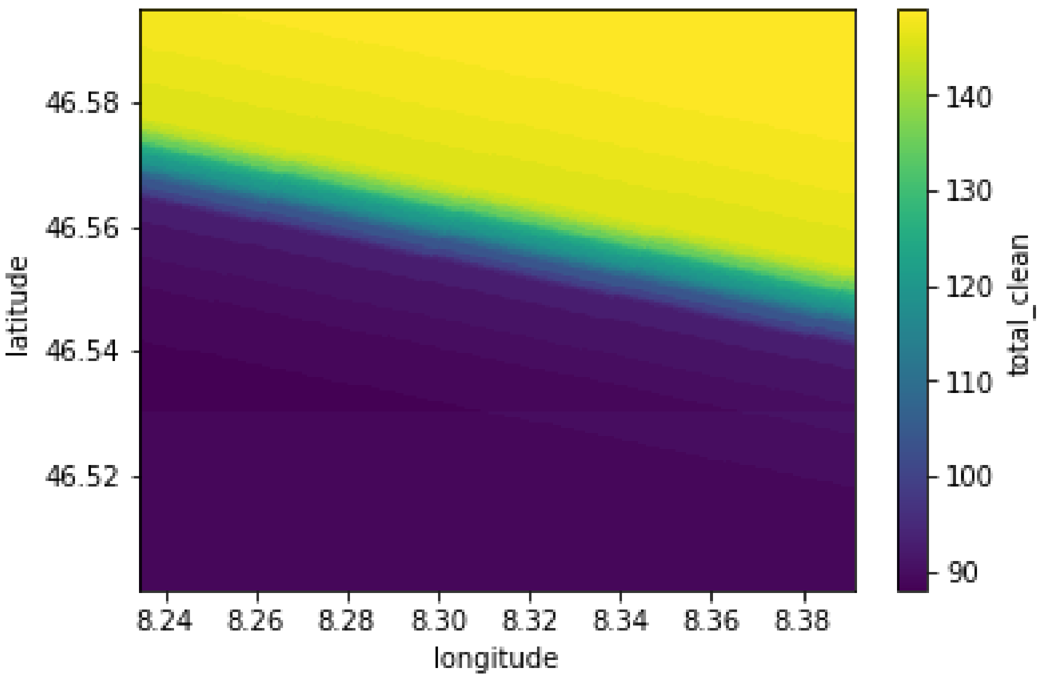
8. Annex 2: Miscellaneous Images



Annex 1: Example of clean observation plot

9. Annex 3: Complete Snow and Water Detection Python Code

Here follows the complete Python code required to run the SDC SOfS tool in a Jupyter Notebook environment:

```
%matplotlib inline

from datetime import datetime
import numpy as np

import datacube
from utils.dc_snow_classifier_test_LJF import wofs_classify
from utils.dc_utilities import perform_timeseries_analysis, create_cfmask_clean_mask
import dc_au_colormaps

from utils.dc_notebook_utilitiesLF import *

dc = datacube.Datacube(app='dc-water-analysis')
api = datacube.api.API(datacube=dc)

# Get available products
products = dc.list_products()
platform_names = list(set(products.platform))
product_names = list(products.name)

product_values = create_platform_product_gui(platform_names, product_names)

# Save the form values
platform = product_values[0].value
product = product_values[1].value

# Get the pixel resolution of the selected product
resolution = products.resolution[products.name == product]
lat_dist = resolution.values[0][0]
lon_dist = resolution.values[0][1]
```

```
# Get the extents of the cube
descriptor = api.get_descriptor({'platform': platform})[product]

min_date = descriptor['result_min'][0]
min_lat = descriptor['result_min'][1]
min_lon = descriptor['result_min'][2]

min_date_str = str(min_date.year) + '-' + str(min_date.month) + '-' + str(min_date.day)

min_lat_rounded = round(min_lat, 3)
min_lon_rounded =  round(min_lon, 3)

max_date = descriptor['result_max'][0]
max_lat = descriptor['result_max'][1]
max_lon = descriptor['result_max'][2]

max_date_str = str(max_date.year) + '-' + str(max_date.month) + '-' + str(max_date.day)

max_lat_rounded = round(max_lat, 3) #calculates latitude of the pixel's center
max_lon_rounded = round(max_lon, 3) #calculates longitude of the pixel's center

# Display metadata
generate_metadata_report(min_date_str, max_date_str,
                min_lon_rounded, max_lon_rounded, lon_dist,
                min_lat_rounded, max_lat_rounded, lat_dist)

show_map_extents(min_lon_rounded, max_lon_rounded, min_lat_rounded, max_lat_rounded)

extent_values = create_extents_gui(min_date_str, max_date_str,
                    min_lon_rounded, max_lon_rounded,
                    min_lat_rounded, max_lat_rounded)

# Save form values
```

```
start_date = datetime.strptime(extent_values[0].value, '%Y-%m-%d')
end_date = datetime.strptime(extent_values[1].value, '%Y-%m-%d')
min_lon = extent_values[2].value
max_lon = extent_values[3].value
min_lat = extent_values[4].value
max_lat = extent_values[5].value

# Query the Data Cube
dataset_in = dc.load(platform=platform,
                product=product,
                time=(start_date, end_date),
                lon=(min_lon, max_lon),
                lat=(min_lat, max_lat))

#Winter Months
def is_winter(month):
   return (month >= 12) | (month <= 2)

dataset_in = dataset_in.sel(time=is_winter(dataset_in['time.month']))

snow = dataset_in.cf_mask == 3
snow

snow_dataset = snow.astype(np.int16).to_dataset(name = "snow")
snow_dataset

no_data = dataset_in.cf_mask == 255
no_data = no_data.values
snow_dataset.snow.values[no_data] = 255

ts = perform_timeseries_analysis(snow_dataset, "snow", no_data = 255)

ts
```

```
ts.total_clean.plot()

ts.total_data.plot()

ts.normalized_data.plot()
```

At the same time as the SOfS tool was developed, a Water related tool based on CFMASK was also tested. Here is the code (which should follow the code above):

```
water = dataset_in.cf_mask == 1
water

water_dataset = water.astype(np.int16).to_dataset(name = "water")
water_dataset

no_data = dataset_in.cf_mask == 255
no_data = no_data.values
water_dataset.water.values[no_data] = 255

tw = perform_timeseries_analysis(water_dataset, "water", no_data = 255)

tw.total_clean.plot()

tw.total_data.plot()

tw.normalized_data.plot()
```

10.Annex 4: SDC Test Report

Swiss Data Cube Testing

A report

Lorenzo Joseph Frau, Intern at GRID UNEP

Table of Contents

List Of Figures

1. Introduction

The following document describes the testing of the Swiss Data Cube and the results obtained. The objective of this report was to extensively test the SDC to identify problems and bugs.

Initially, the report will address the more general issues encountered in the user interface. For each issue, the report will also present some suggestions. The report will then analyze the different algorithms currently implemented in the SDC and provide feedback relating to their performance.

The tests were for the most part executed in the area of the Grimselsee in the Canton of Bern. This region was chosen due to its great variety of terrain (ice, snow, water, vegetation and altitude variation). Other tests were run near Lake Lugano for comparison (a more urban area by the lakeside).

The different data sources for this report are (USGS, 2017):

- Landsat 5: **March 1, 1984 – January 2013**; Landsat 5 Thematic Mapper (TM) operational imaging ended in November 2011. Landsat 5 Multispectral Scanner (MSS) was powered back on in 2012 and collected data until January 2013. The satellite was decommissioned June 5, 2013.
- Landsat 7: **April 15, 1999 - present**
- Landsat 8: **February 11, 2013 - present**

The final purpose of this report is to identify bugs, areas of improvement and propose solutions.

2. General observations and bugs

The observations in this section pertain to the main portion of the website and are not specific to any algorithm.

1. There is no indication of length in the map interface. If someone, for example, were to want to select an area of one square kilometer, they would have no way of telling how much they were selecting. Ideally, the distances could be displayed on each of the lines of the square the user would "drag", or alternatively in a box similar to the latitude and longitude in the far right corner.
2. To download the final products of an algorithm, the user must go into the outputs sections, scroll to the bottom of the appropriate window and select the output desired. This should be more visible; it isn't immediately apparent to users where they can correctly download the outputs. The risk is that they click "Download" which produces an html file that leads back to the SDC.
3. Often the tool submission dates and times are wrong. This would appear to be a server issue.
4. Currently, to identify a given tool run, the user can attribute a title and description to it. This makes it simpler to in in the task manager portion of the SDC. However, the title and description options are "hidden" in the "Additional Options" section. This parameter should be more visible (potentially one of the first parameters users fill in).
5. It would be interesting to add a transparency option or slider to the SDC. There is currently a similar option for the Water Quality TSM tool; however it is only a fixed value. Ideally this option should be implemented for the whole SDC, in the map screen proper and with the possibility of defining the degree of transparency.

6. Date selection is a little laborious; unless the user goes through a double verification process (selecting the date and then clicking done) the date switches back. Also, changing one date (to extend the time frame of study for example) can also change the other to give a full year period. This is more cumbersome than helpful.
7. The Landsat 5 data sometimes starts from 1987 instead of 1984
8. The "More Information" button is hidden (bottom of the "Outputs" section") and is not currently very useful. It only works for the NDVI Anomaly tool. All the others either link to a very general webpage or back to the Data Cube (in the case of the Coastline tool)
9. There appear to be a number of spelling mistakes in various portions of the SDC interface
10. The "Show/Hide" button is also a little hidden (In the "Results" "Completed Tasks" Section). It might be better to move it to the map dashboard.
11. The Landsat 5-7-8 option only works for the "Custom Mosaic" tool, the "Fractional Tool" and the "Water Detection" tool.
12. The SDC offer the possibility of creating an animation (in GIF format). Although this option is intriguing it requires at least two modifications:
    - 12.1. The final animation presents a large number of unusable images (completely white or insufficiently detailed). Although the user can always use editing software to remove these undesired results, it would be ideal to eliminate in the final product (through a filter perhaps?)
    - 12.2. It would be ideal to add a timestamp to each frame of the animation. Without this, the user has no idea at which point of the temporal progression they find themselves.
13. It would be a good idea to implement an image-switching option on the main dashboard. Currently users need to scroll through the "Completed Tasks" section to even be aware that different images have been produced by a tool (for example in the "Water Detection" tool).
14. In the "Task Manager: Details" section, various images are presented to the user. They may be downloaded or simply perused. In the lower left section of the screen a title appears for each image. This title is unstable, and changes if the images are switched back and forth too much. An image of Water Percentage will for example be labeled as Clear Observations once and Water Observations shortly after.

3. SDC Tests

In this section, the various results obtained from testing the SDC tools will be presented.

3.1.Cloud Coverage

We begin with the Cloud Coverage application. The idea behind this algorithm is to run a time series analysis that produces the average cloud percentage over a given time period. This enables the user to determine whether the area is suitable for other forms of analysis.

Test 1

- Grimselsee area
- Starting with all Landsat data (5-7-8)
- Date: 03.01.1984; 12.26.2016 → there are no acquisitions for this parameter set
    - Tried only Landsat 7
    - 04/15/1999 to12.26.2016

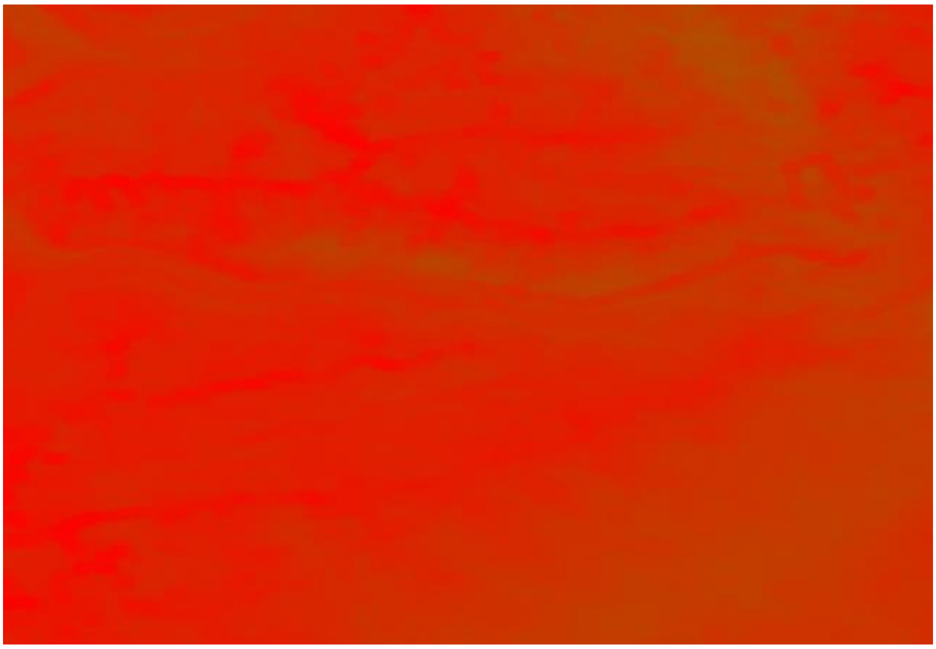


Figure 1: Custom Mosaic Image Landsat 7 (1999-2016) Grimselsee region

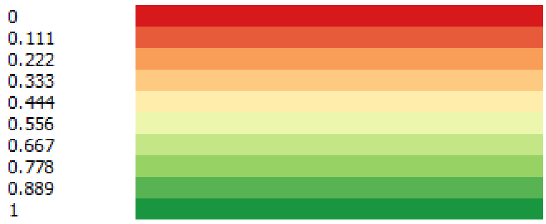


Figure 2: scale found on SDC Grid (GRID-Geneva, 2017)

The results appear to be of good quality and pertinent to the considered area. The same test was run for Landsat 8 and Landsat 5. The same test was run for a known sunny area (Lake Lugano) and a known cloudy area (Fribourg region). In both instances the results were pertinent and of high quality.

3.2.Coastal Change

This tool computes the area covered by receding coastline over a user defined period.

The chosen area for this test was the Cheseaux-Noreax region. This is due to the fact that the lakeside in this area has been modified in past years because of erosion and the efforts to fight it (Entreprise de Correction Fluviale ECF-RSLN, 2004).

Test 1

- Cheseaux-Noreax region
- Landsat data 7
- Date: 1999-2003 (restoration period)

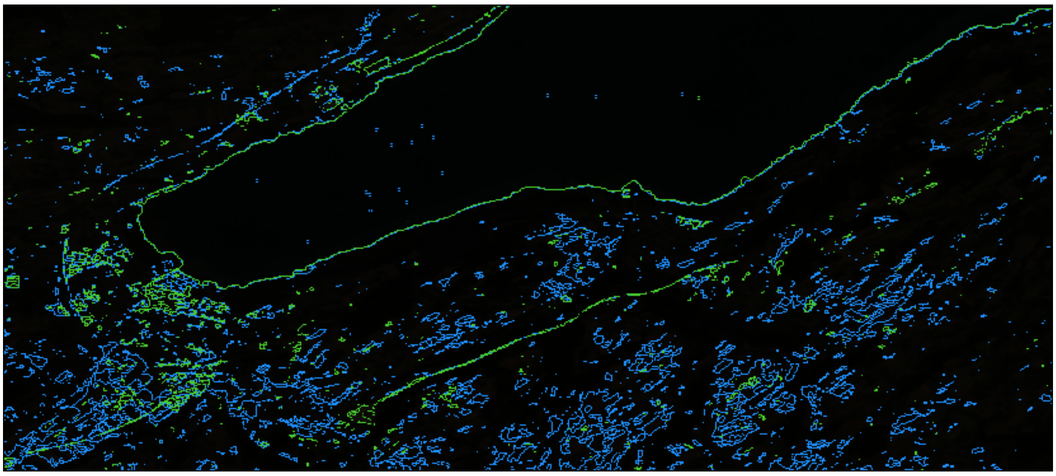


Figure 3: Coastal Boundaries for 1999-2003

The results are questionable. In general the tool notices odd changes in the middle of the lake as well as on dry land. By zooming in however, in the areas where restoration was implemented, it appears a change was detected.

Ideally, the period of lakeside erosion should have been tested, however for this tool, the Landsat 5 data is set to dates between 1999 and 2016 and it is not possible for the user to change them.

3.3.Custom Mosaic

"The Custom Mosaic Tool allows users to create detailed true or false color images of given areas using optical data from various Landsat satellites. Choose how the 'best' pixel will be chosen: Most recent, least recent, median, or min/max NDVI value pixel."(GRID-Geneva, 2017)

Test 1:

- Grimselsee
- Landsat 7
- True color
- Least recent pixel mode
- Time series animation: scene
- Date 1999-2016

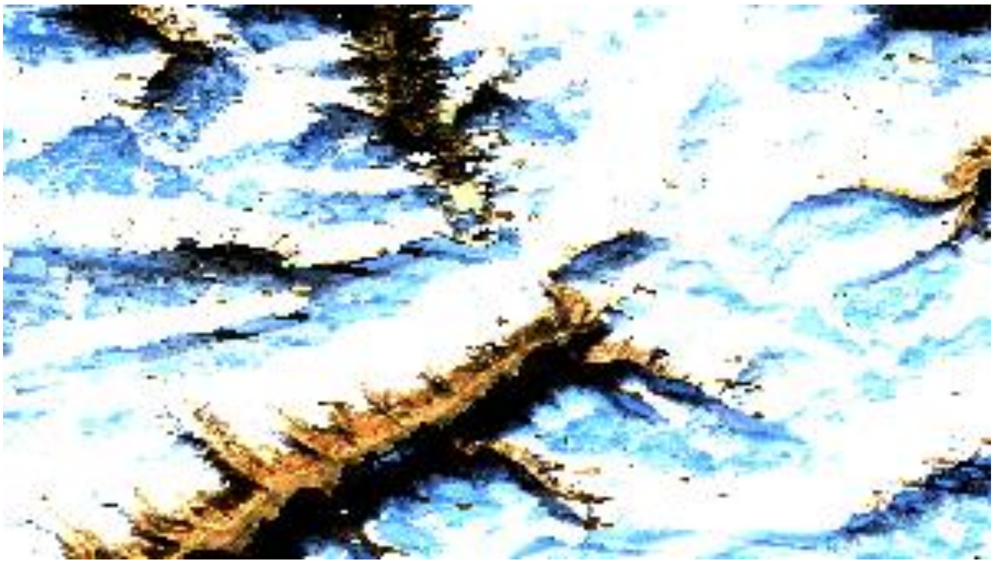


Figure 4: Custom Mosaic, true color, least recent pixel, 1999-2016

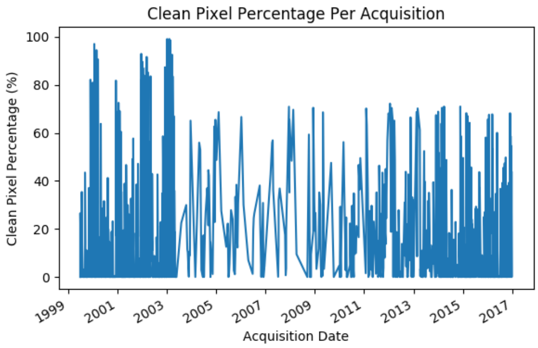


Figure 5: Clean Pixel Percentage graph (GRID-Geneva, 2017)

This part of the test was an apparent success.

Test 2

- Grimselsee
- Landsat 7
- True color
- Max NDVI
- Time series animation: scene
- Date 1999-2016

Figure 6: Custom Mosaic, true color, max ndvi, 1999-2016

We can clearly see the NDVI index in play here. The vegetation cover is quite visible. Areas in white appear to be those that are not in the NDVI range.

Test 3

- Grimselsee
- Landsat 7
- NIR, SWIR1, SWIR2
- Least Recent pixel
- Time series animation: none
- Date 1999-2016

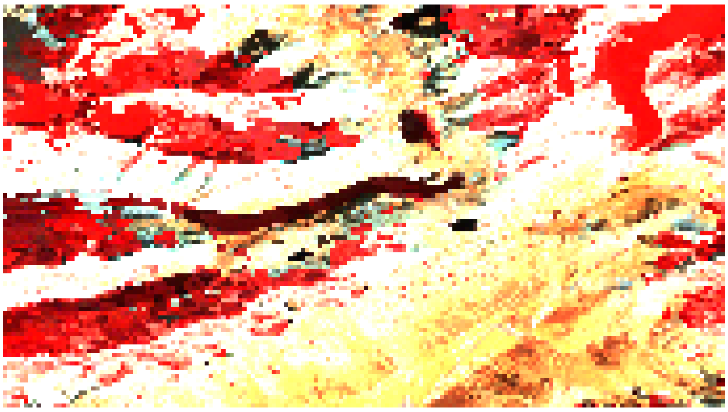


Figure 7: Custom Mosaic, NIR/SWIR1/SWIR2, least recent pixel, 1999-2016

Considering different Landsat bands still produces a viable and high quality result.

Test 4

- Grimselsee
- Landsat 7
- NIR, SWIR1, RED
- Most Recent Pixel

- Time series animation: none
- Date 1999-2016

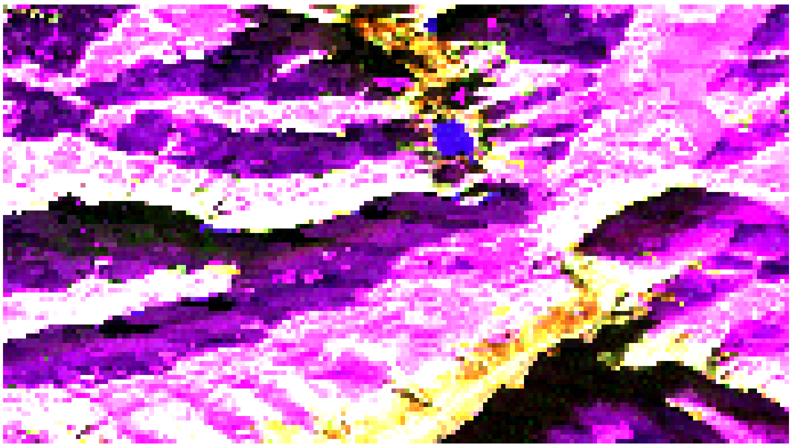


Figure 8: Custom Mosaic, NIR/SWIR1/RED, most recent pixel, 1999-2016

The results remain quite promising. It is interesting to note that water bodies in the shade of the mountains (the Grimselsee for example in Figure 8) are not detected as such with this combination of Landsat bands.

3.4.Fractional Cover

"The Fractional Coverage tool allows users to create a three band output product used to visualize the sub pixel composition of selected areas. Pixels are classified as a percentage of photosynthetic vegetation, non-photosynthetic vegetation, and bare soil." (GRID-Geneva, 2017)

Test 1

- Grimselsee
- Landsat 7
- Least recent pixel
- Date 1999-2016

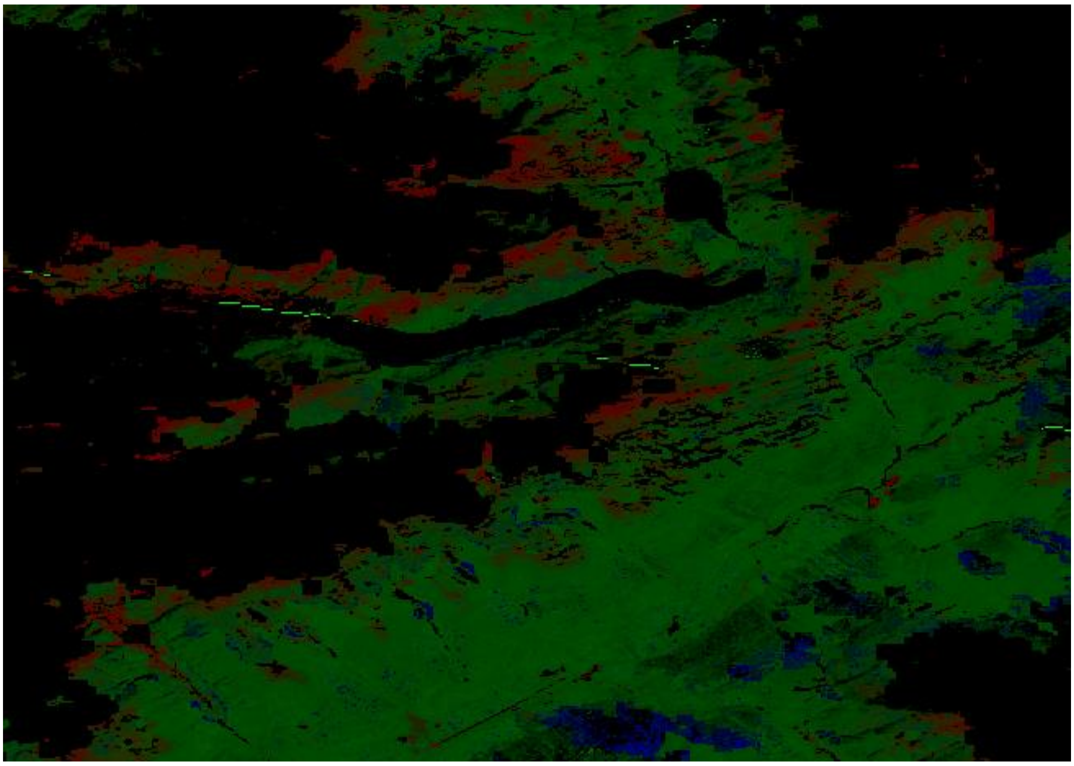


Figure 9: fractional cover, least recent pixel, 1999-2016

The striations in the picture are a typical result of using Landsat 7 input.

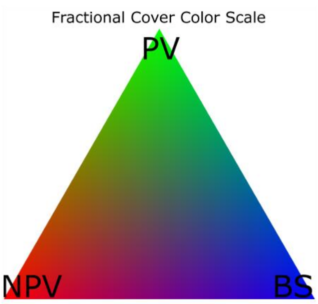


Figure 10: Fractional Cover Color Scale (GRID-Geneva, 2017)

Test 2

- Grimselsee
- Landsat 7
- Max NDVI Pixel
- Date 1999-2016

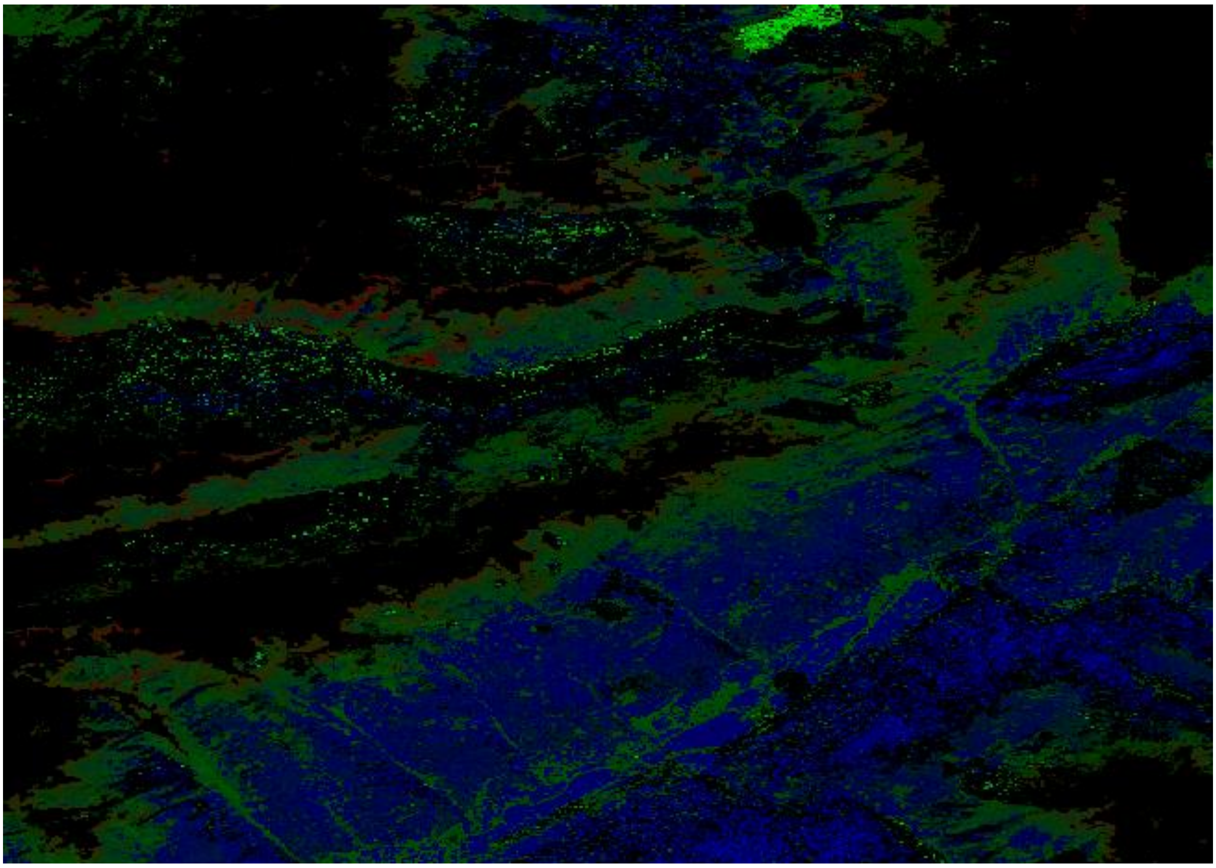


Figure 11: Fractional Cover, Max NDVI, 1999-2016

Figure 11 is the Band math .png output for the above Fractional Cover test. The results are impressive, in that they well-represent the different variations of both photosynthetic and non-photosynthetic vegetation and bare soil (see Figure 10).

Test 3

- Grimselsee
- Landsat 5-7-8
- Max NDVI Pixel
- Date 1984-2016

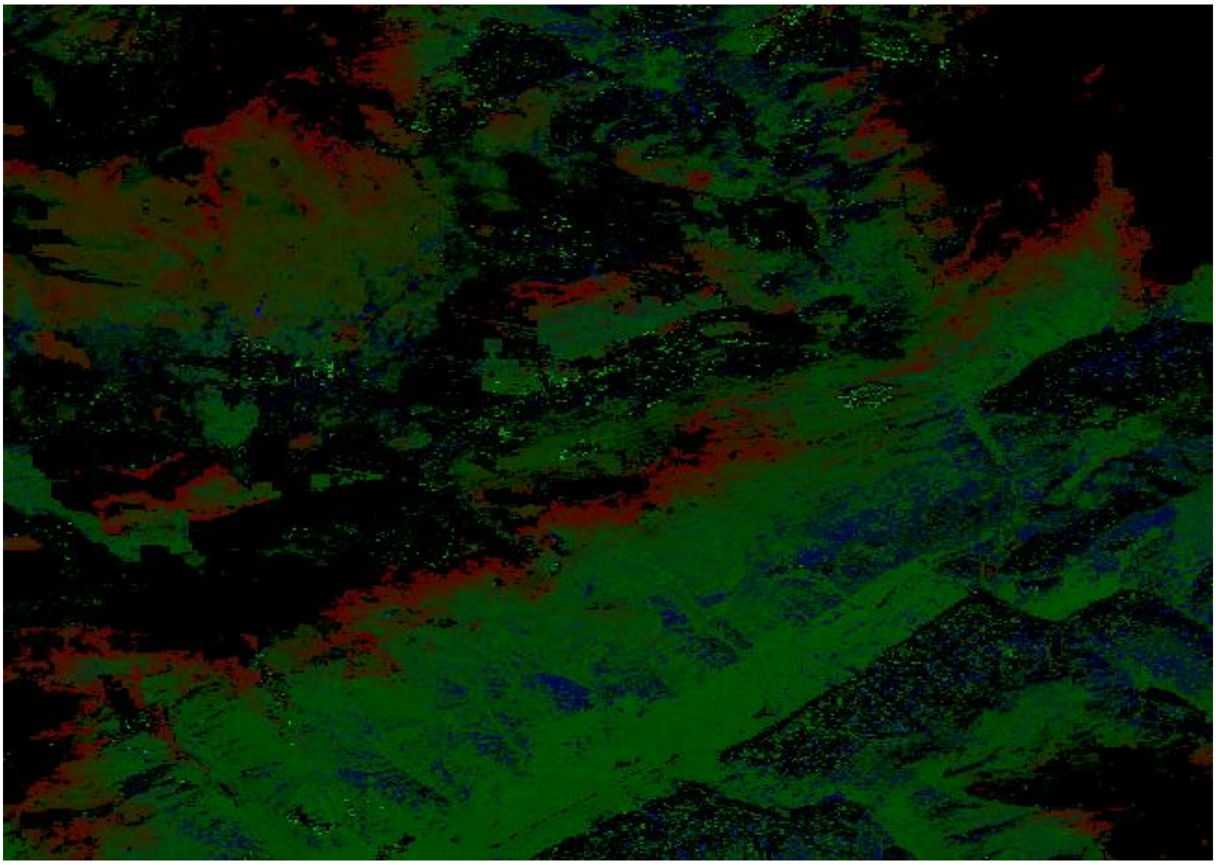


Figure 12: Fractional Cover, Max NDVI, Landsat 5-7-8, 1984 to 2016

Figure 12 is a perfect example of the use of all three Landsat datasets. The results appear to be good for the Max NDVI option. Photosynthetic vegetation is clearly visible, as is the non-photosynthetic and bare soil. The only peculiar aspect is the portions of black in the picture, which are likely caused by the difference in altitude and the slope. Also, waterbodies are not entirely evident.

3.5.NDVI anomaly

"The NDVI Anomaly tool allows users to calculate and visualize the NDVI change between a single scene and a user defined baseline composite of scenes preceding it."(GRID-Geneva, 2017)

Test 1

- Grimselsee
- Landsat 7
- Baseline period: June
- Date 1999-2016

After this first test, it became apparent that this tool requires some work.

It is not at all clear how users are supposed to interact with the tool: it requires an initial scene and a baseline composed out of a selection of months. The peculiarity is that unless a very specific combination of "scene dates" and baseline months are chosen, the tool refuses to work. It is also unclear which date is the "scene" date: the beginning or the end date?

Test 2

- Grimselsee
- Landsat 5
- Baseline period: June, July, August
- Date 1987-1999
- Start date: 01 June 1987

This combination of start dates and baseline period worked. It is however difficult to understand why.

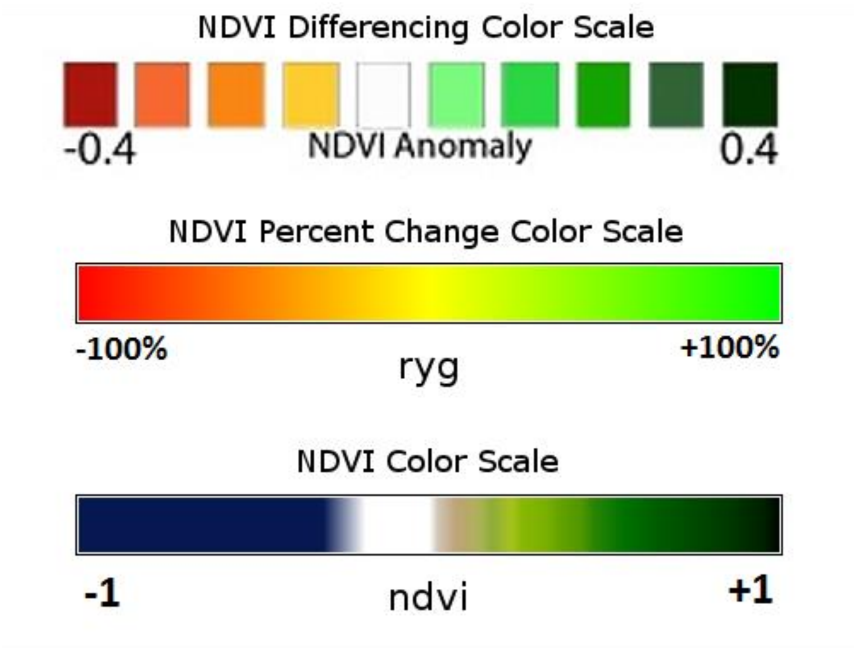


Figure 13: NDVI Differencing Color Scale (GRID-Geneva, 2017)

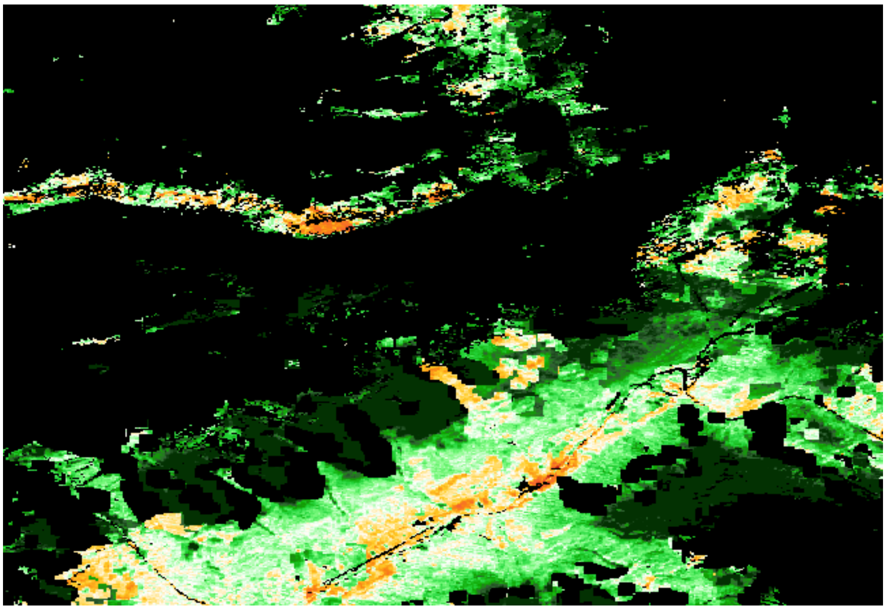


Figure 14: NDVI Anomaly 1987-1999

This image (Figure 14) gives a good feel for NDVI anomaly. We can clearly see that between the years 1987 and 1999, there was a strong variation in NDVI on the valley floor (possibly due to urbanization?), and less variations on the sides of the mountains.

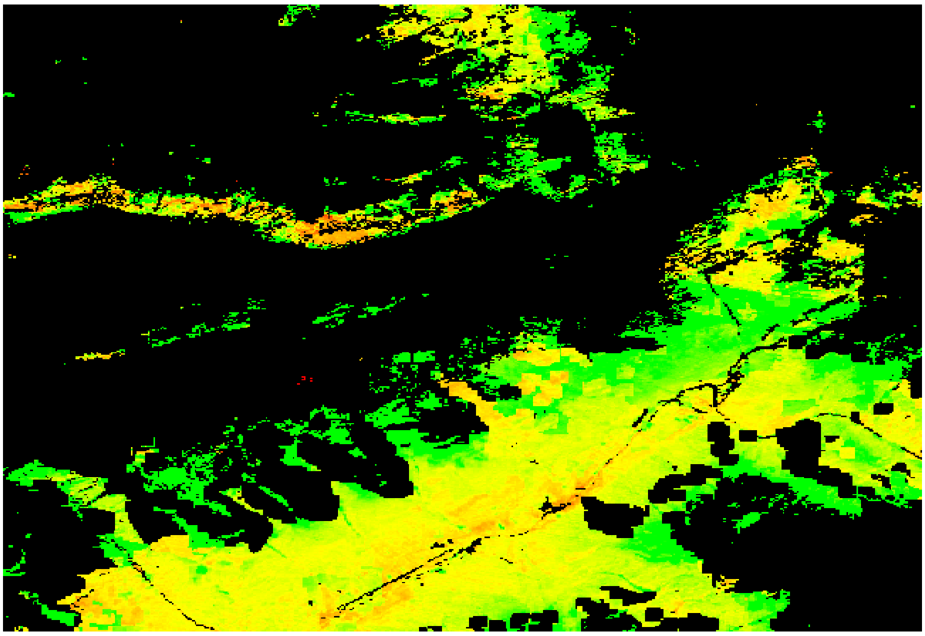


Figure 15: NDVI Anomaly Percentage

Figure 15 gives an even better feel for the variation in NDVI, as it shows the increase or decrease of NDVI in percentage. An interesting feature of this map is the mountain side just adjacent to the Grimselsee (in the central right portion of the figure), which shows a considerable variation.

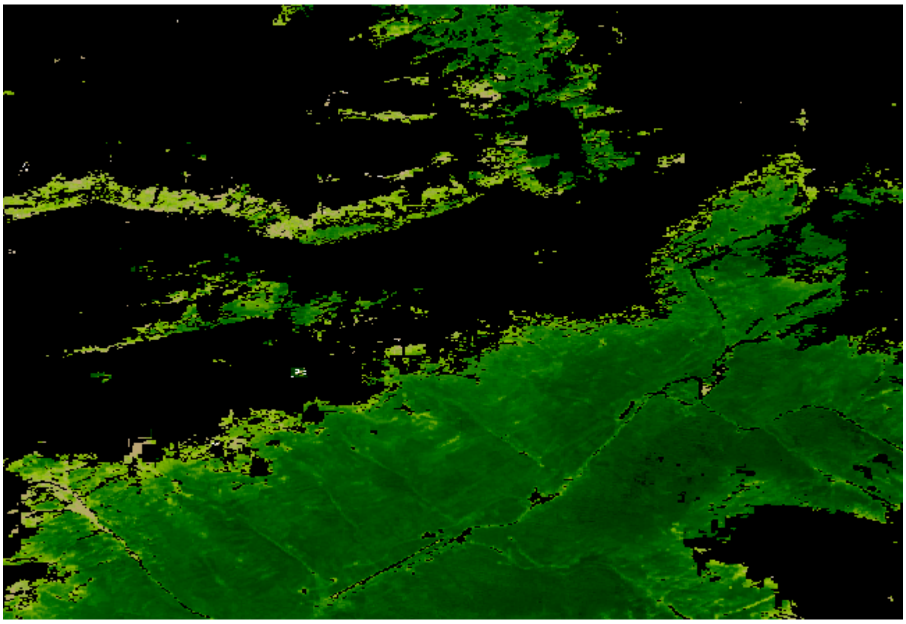


Figure 16: NDVI Anomaly Scene

This image (Figure 16) is defined by the SDC as the NDVI Scene. Given that it is not clarified by a description, we can assume that it portrays the NDVI for the date of the 01st June 1987. This should be clarified to prevent user confusion.

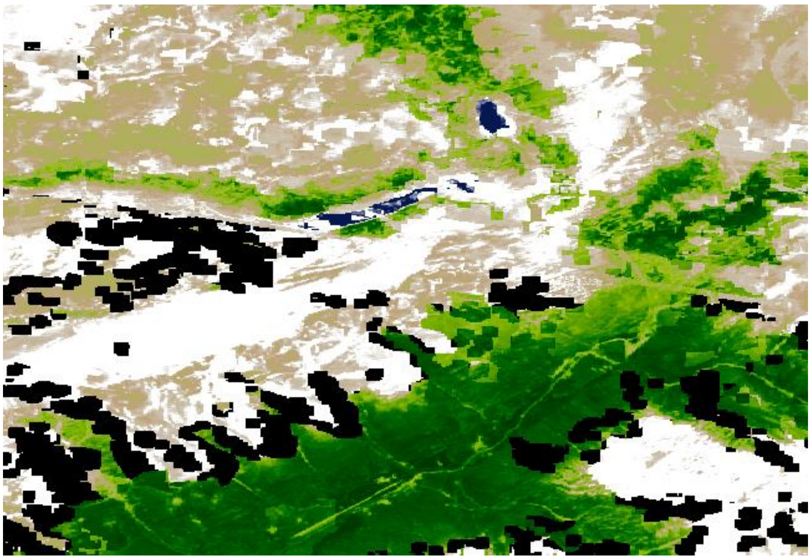


Figure 17: NDVI Anomaly Baseline

This image (Figure 17) is defined by the SDC as the NDVI Anomaly Baseline. Given that it is not clarified by a description, we can assume that it portrays the NDVI for the period ranging between June and August 1987. This should be clarified to prevent user confusion.

Test 3

- Grimselsee
- Landsat 8
- Baseline period: June, July, August
- Date 2014-2016
- Start date: 30th June 2016

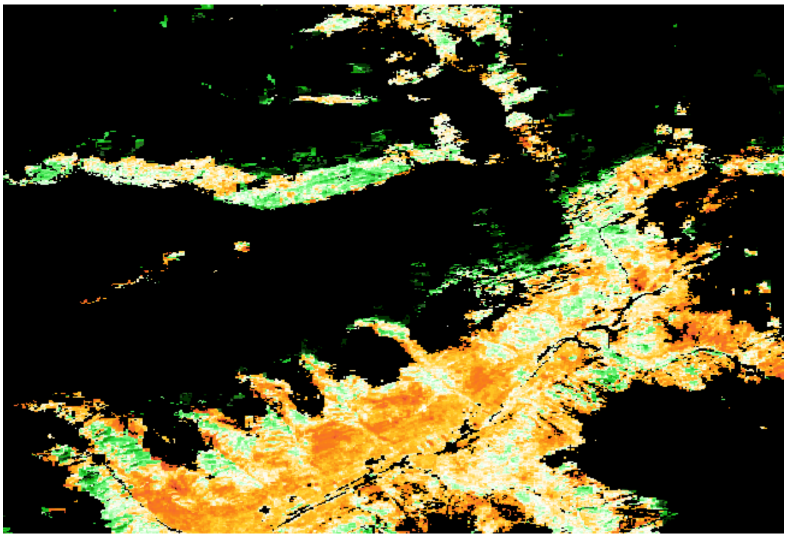


Figure 18: NDVI Anomaly 2014-2016

This NDVI Anomaly image (Figure 18), portrays a very different situation than in Figure 14. This is probably due to the different Landsat datasets. It is possible that these results show such a large variation due to the baseline and scene used. However, due to the fact that the latter is difficult to identify, this tool remains still unclear.

3.6.Slip

"The SLIP tool uses algorithms to combine optical and elevation data to determine possible locations for recent landslides. Set the baseline thresholds to expand or narrow results of possible landslide data."(GRID-Geneva, 2017)

Test 1

- Area of Bellinzona (Canton Ticino), where a landslide occurred in May of 2012 (Preonzo)
- Landsat 7
- Baseline length: 1 (needs more explaining)
- Baseline method: average
- Date 1999-2016

The results for this tool are always the same: the interface indicates that elevation data is missing. Until this is remedied, the tool can undergo no further testing.

3.7.Urbanization

"Create a filtered mosaic before analysis to increase accuracy and reduce execution time. Visualize area contents with the use of well-known remote sensing indices."(GRID-Geneva, 2017)

Test 1

- Grimelsee
- Landsat 7
- Compositing Method: least recent pixel
- Date 1999-2016

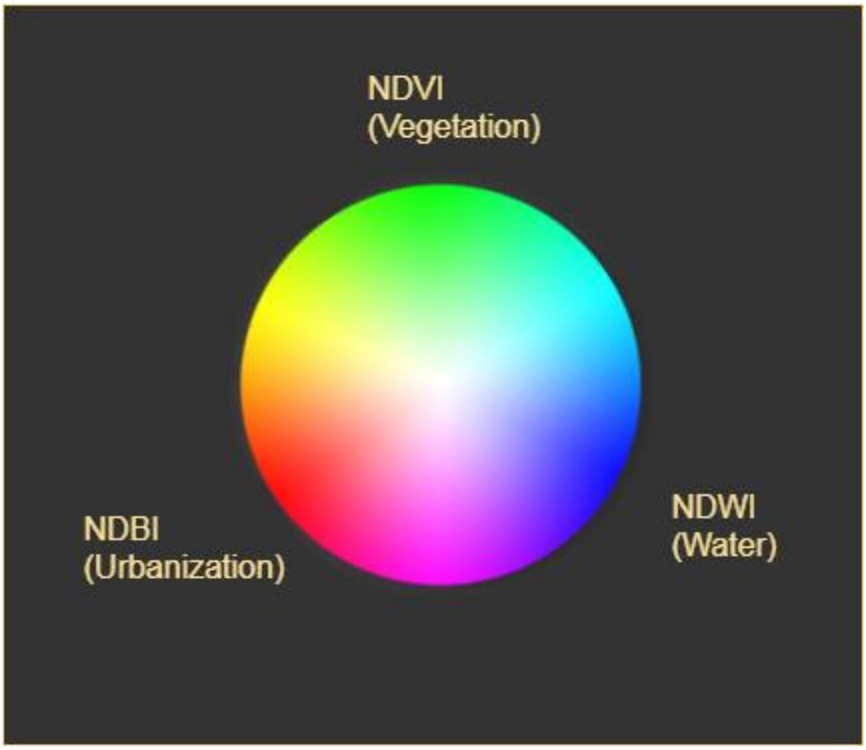


Figure 19: Reference legend for Urbanization algorithm(GRID-Geneva, 2017)

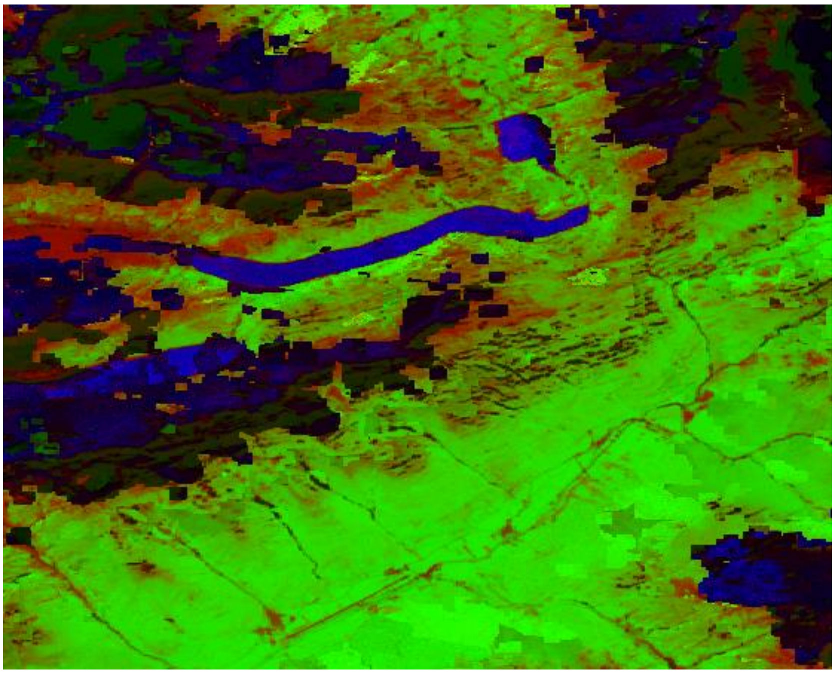


Figure 20: Urbanization Tool, least recent pixel, 1999-2016

Figure 20 appears to faithfully depict the different indices considered in Figure 19: water, vegetation and even some specks of urbanization are quite clearly distinguishable. However, altitude still presents a problem, as the tool detects “urban” areas at higher altitudes. Also, at the highest points in the area, the tool develops black spots.

Test 2

- Grimelsee
- Landsat 7
- Compositing Method: most recent pixel
- Date 1999-2016

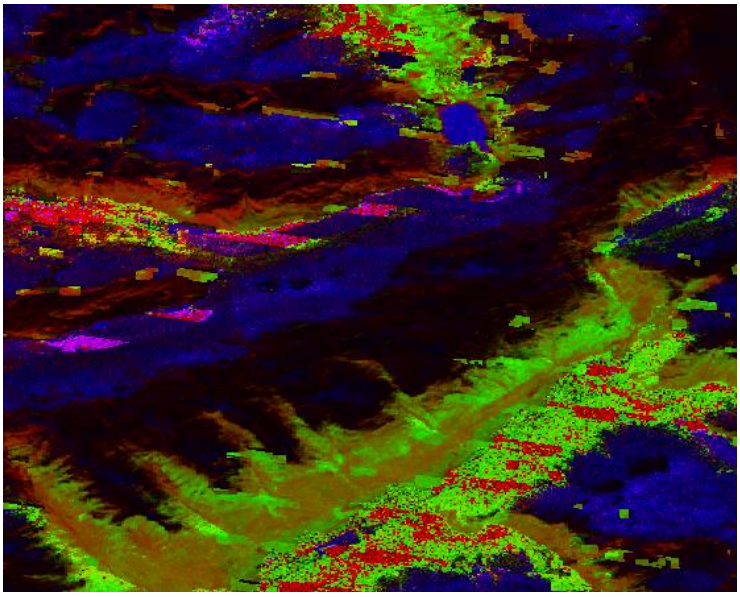


Figure 21: Urbanization tool, most recent pixel, 1999-2016

Considering that the tested surface is identical, this method (Figure 21) appears to have more problems than the first: water is almost undetected (probably due to the mountains in the area). Also, although some portions of urbanization are clearly correct, others are not.

Test 3

- Grimelsee
- Landsat 5-7-8
- Compositing Method: least recent pixel
- Date 1984-2016

Initially this test failed to work and the message "There are no acquisitions for this parameter set" appeared. To continue testing, the Landsat parameter was changed to only comprehend Landsat 5. By mistake the dates were not changed. However the program launched any way and produced the following results.

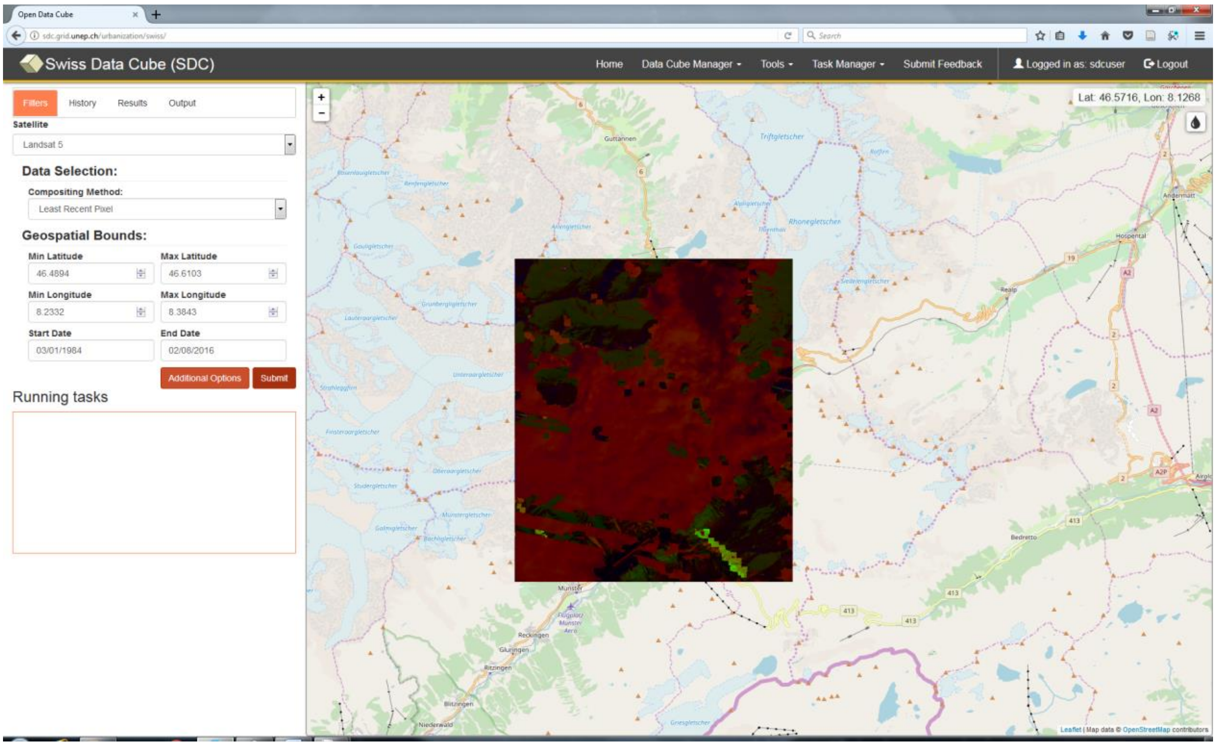


Figure 22: Launch of Urbanization tool for Landsat 5, dates 1984-2016

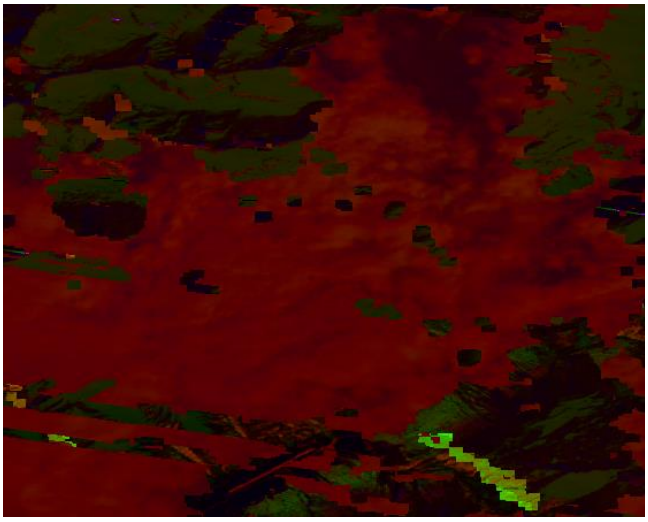


Figure 23: Final result of Landsat 5 Urbanization tool error run

Given that Landsat 5 stopped Thematic Mapping in 2011 and was decommissioned in 2013, the program ought to have considered the request an error and produced nothing.

Test 4

- Lake Lugano
- Landsat 7
- Compositing Method: least recent pixel
- Date 1999-2016

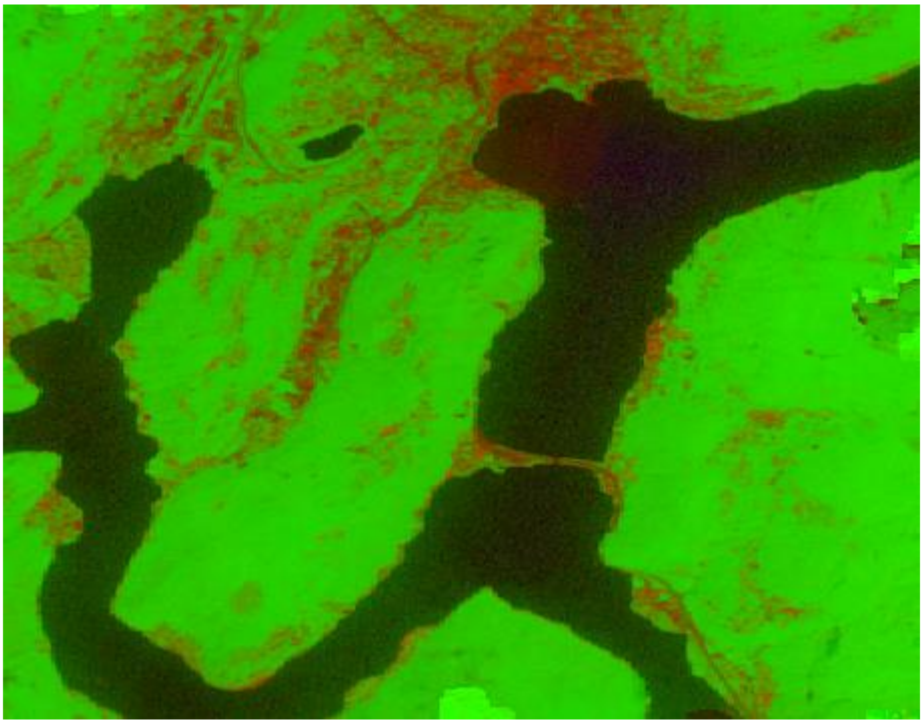


Figure 24: Urbanization tool for Lake Lugano

The tool does a good job of detecting urbanization. If we compare Figure 24 with Figure 20, we notice that water however is not well detected. This could be due to the highly polluted state of the lake, in which case, the tool could hypothetically repurposed and exploited for other uses (such as pollution detection?).

Test 5

- Lake Lugano
- Landsat 7
- Compositing Method: most recent pixel
- Date 1999-2016

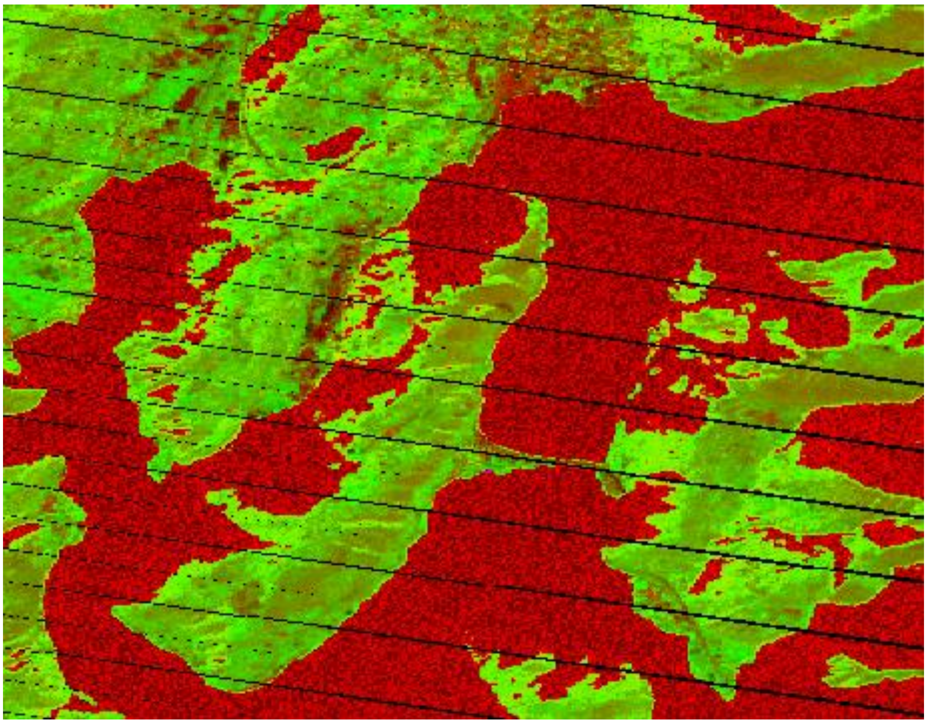


Figure 25: Urbanization tool for Lake Lugano, most recent pixel method

The result here (Figure 25) are quite different than in Figure 24; urbanization and water are clearly confused. The only thing that changed was the compositing method. The reason behind this difference is not clear.

Test 6

- Lake Lugano
- Landsat 7
- Compositing Method: Max NDVI
- Date 1999-2016

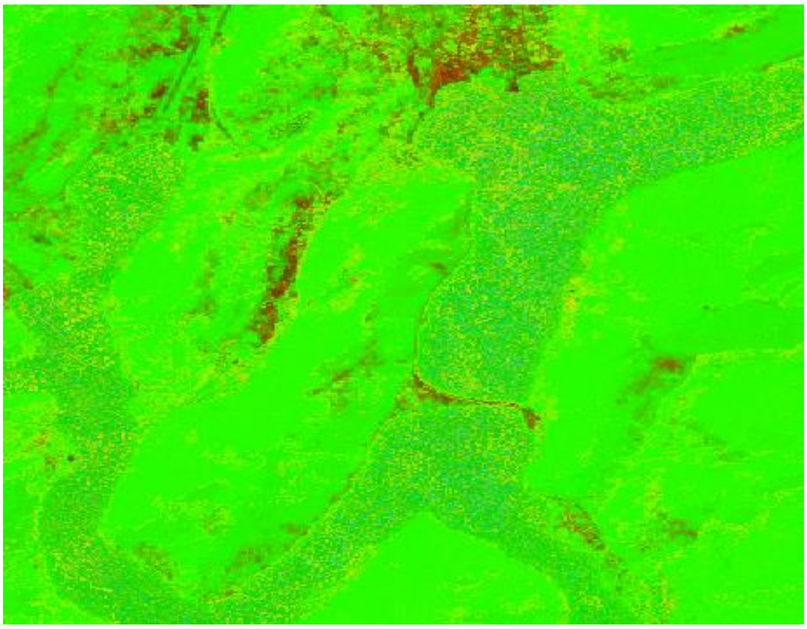


Figure 26: Urbanization tool for Lake Lugano, Max NDVI compositing method

The result (Figure 26) is still peculiar: urbanization is present; however there is little distinction between water and land.

3.8. Water Detection

"The Water Detection tool allows users to determine a per pixel analysis of water vs not-water for a given scene over many acquisitions."(GRID-Geneva, 2017)

Test 1

- Grimselsee
- Landsat 7
- Image Background color: black
- Generate Time series animation: none
- Date 1999-2016

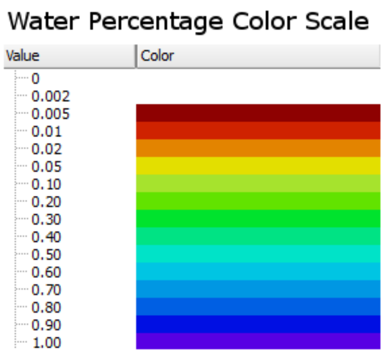


Figure 27: Water Percentage Color Scale(GRID-Geneva, 2017)

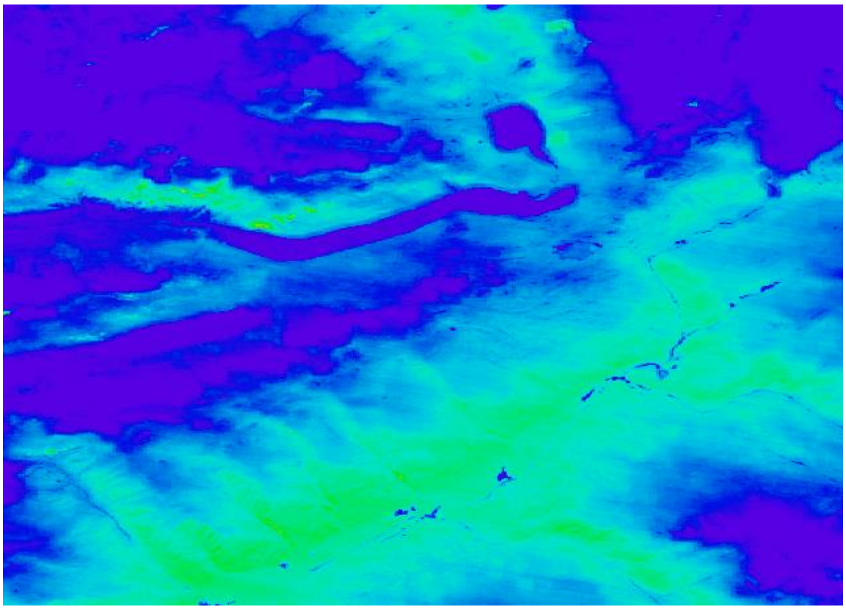


Figure 28: Water Detection tool, 1999-2016

The water percentage seems to be accurate in Figure 28, with the caveat that snow and water are undistinguishable. It may be possible to remedy this by modifying the Water Detection Algorithm.

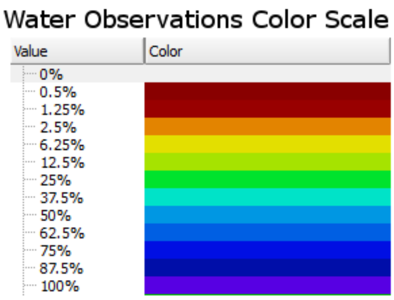


Figure 29: Water Observations Color Scale (GRID-Geneva, 2017)

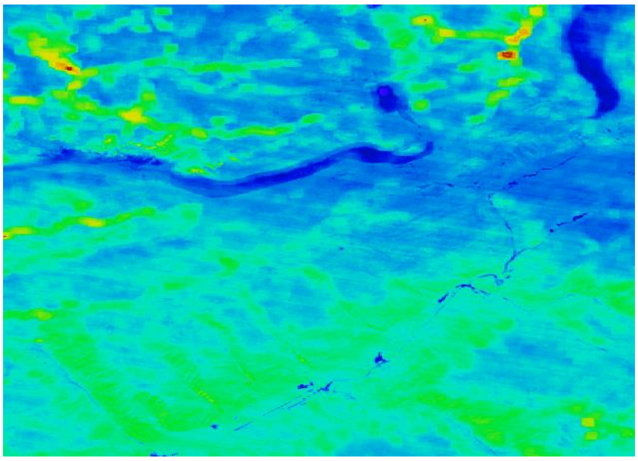


Figure 30: Water Observations, 1999-2016

The water observation seem to be more precise: the main water bodies are mostly distinguishable, and appear to be differentiated from snow.

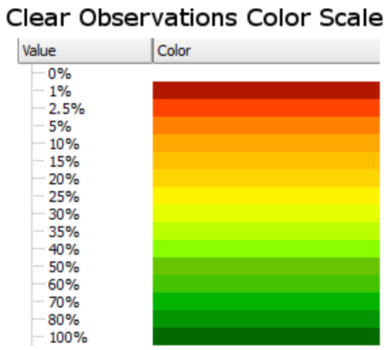


Figure 31: Clear Observations Color Scale (GRID-Geneva, 2017)

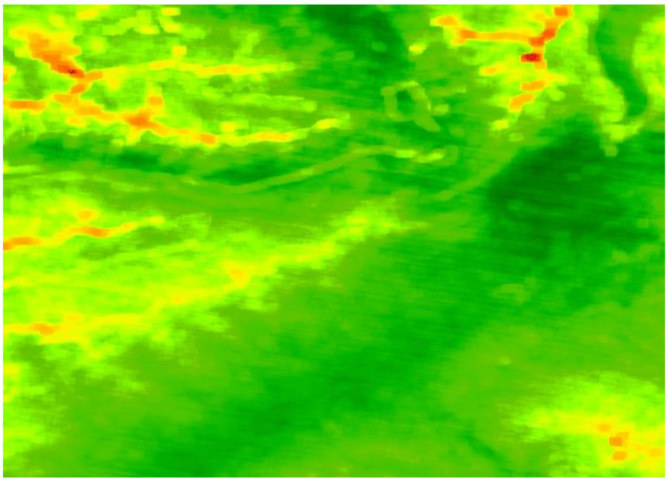


Figure 32: Clear Observations, 1999-2016

There is no explanation on the SDC website detailing what exactly “Clear Observations” are. This requires clarification, much in the same way as the “More Information” button (par 2).

It does however appear that observations are less clear at higher altitudes.

Test 2

- Grimselsee
- Landsat 5-7-8
- Image Background color: black
- Generate Time series animation: none
- Date 1984-2016

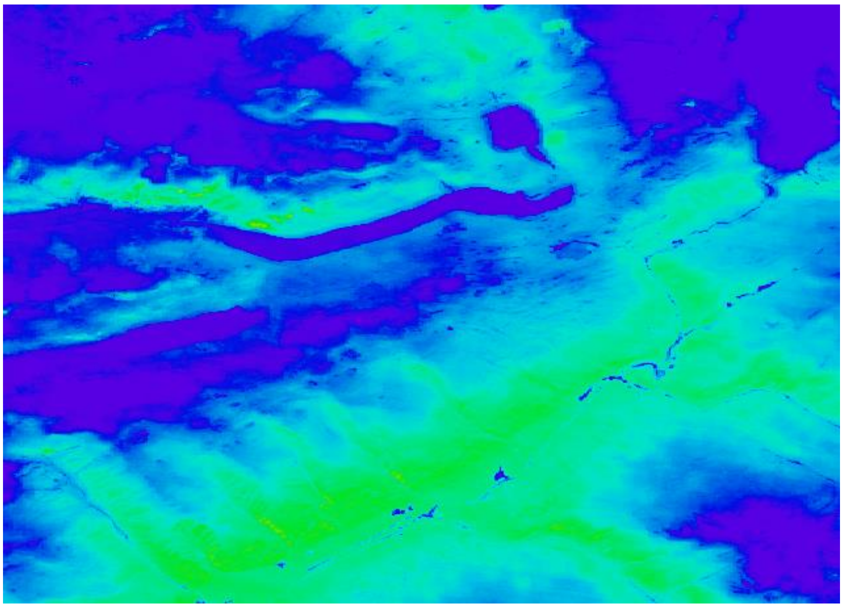


Figure 33. Water Detection tool, 1984-2016

Differences between the two runs of the Water Detection tool are difficult to observe; however they are present. Also, the suite of Landsat data works quite well.

This tool mostly requires a theoretical clarification, as well as a possible refinement result-wise (to distinguish snow from water and integrated altitude in its calculations).

3.9.Water Quality (TSM)

"The TSM tool allows users to run an algorithm to determine the average amount of suspended matter in a given area."(GRID-Geneva, 2017)

Test 1

- Lake Lugano
- Landsat 7
- Result type: transparent
- Generate Time series animation: scene
- Date 1999-2016

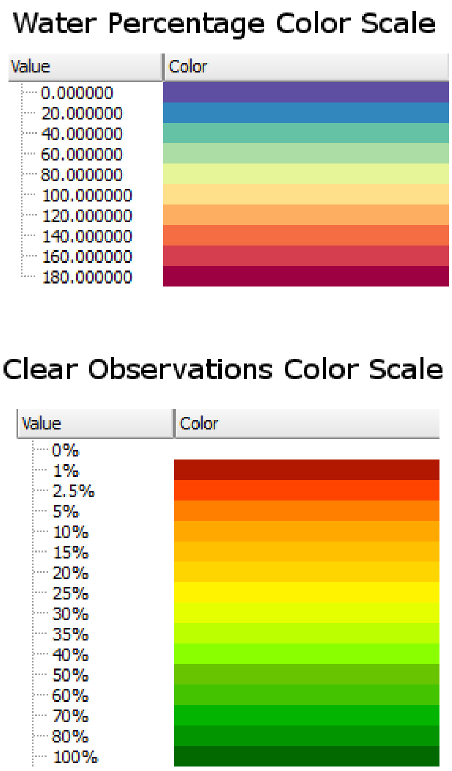


Figure 34: Legends for Water Quality

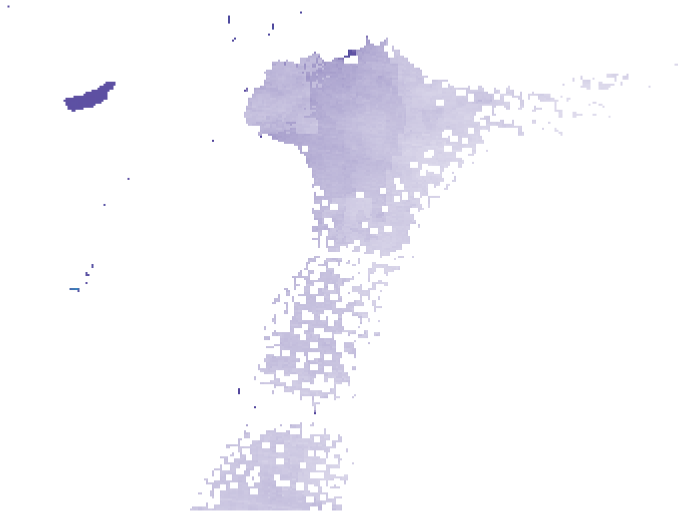


Figure 35: Average TSM for Lake Lugano, 1999-2016

There are no explanations provided for the values provided in Figure 35: Not only is the theoretical explanation missing, but the first scale in Figure 34 is mislabeled: by observing the colors we can clearly tell that it is connected to the Average TSM and not to Water Percentage (Figure 37).

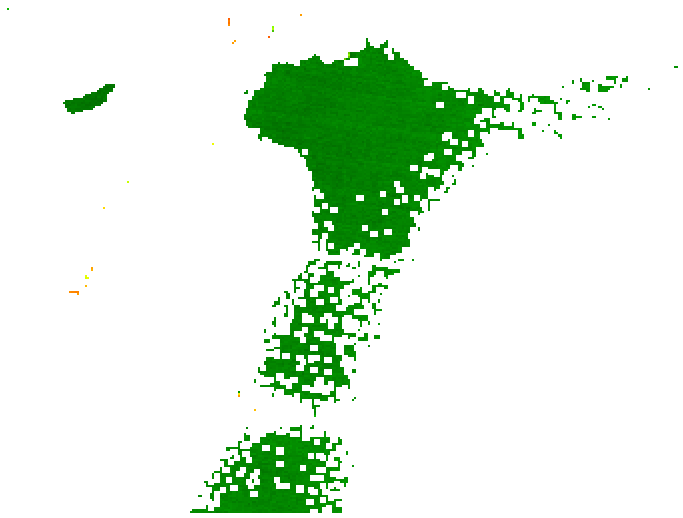


Figure 36: Clear Observations for Lake Lugano

Figure 36 shows that there are apparently very few clear observations for Lake Lugano.

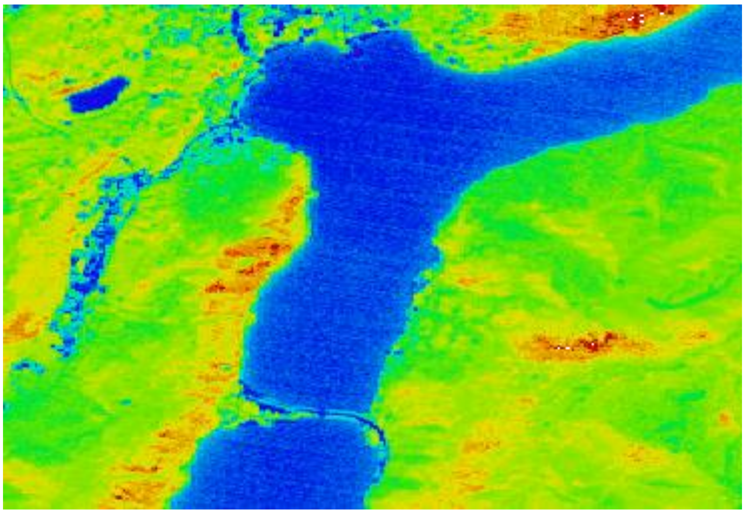


Figure 37: Water percentage for Lake Lugano

The water percentage image is of high quality and clearly shows a difference between different aspects of the territory. It is however a little odd that a "Total Suspended Matter" should produce a water percentage image detailing different components of the surrounding territory. It is possible that it is simply a by-product of the tools' algorithm.

4. Bibliography

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USGS. (2017). Landsat Missions |. Retrieved October 16, 2017, from https://landsat.usgs.gov/