Surface Water Mapping Tool - User Guide

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Introduction

The manual describes the user interface of the Surface Water Mapping Tool (SWMT) as well as a number of use cases in which maps for specific purposes are created with the tool. This tool calculates past patterns of surface water extent from multiple layers of Landsat imagery. The tool consists of a Google Earth Engine application and a user friendly web interface, which allows the user to specify the period evaluated and other calculation parameters that are then executed in a cloud service. Results are displayed on screen and can be downloaded for specified areas. The Surface Water Tool is a collaborative effort between its developers and its community of users. We welcome suggestions for improvements (e.g. through the feedback form, described in another section of this document). A background manual describes the used procedure in more detail and a scientific description of the method used can be found in Donchyts et al. (2016).

Using the tool

Starting and requirements

The entry page for the surface water mapping tool (SWMT) can be found from the SERVIR homepage (servir.adpc.net/) at servir.adpc.net/tools/surface-water-mapping-tool From there, the actual tool can be started (at surface-water-servir.adpc.net/). This will present the home screen depicted in Figure 1. The tool should run with any modern browser.

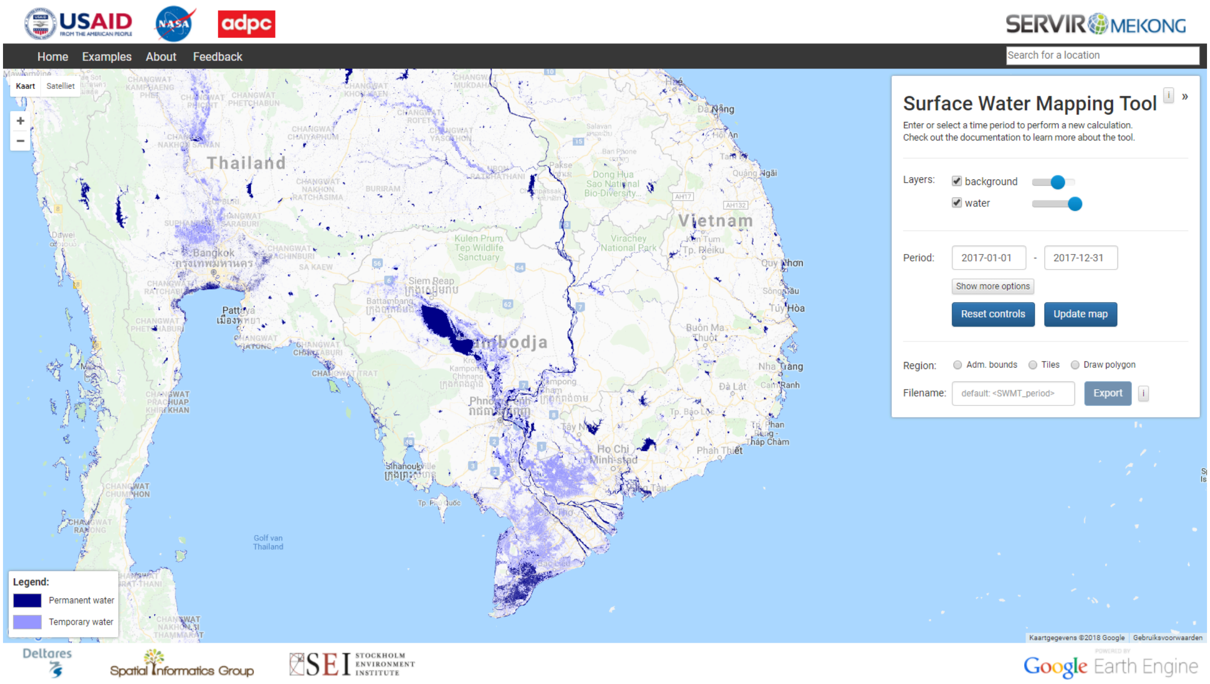


Figure 1: User interface of the Surface Water Mapping Tool

The overall user interface consists of:

- A white bar at the top and bottom displaying the logos of the institutes that form the SERVIR-MEKONG consortium and which were involved in the creation of this tool. Each logo links to the webpage of the respective institute.
- A black bar at the top with buttons to navigate to the different screens of the tool (Home, Examples and About, as well as a link to a Feedback form).

The rest of the user interface depends on which screen is currently active. These are described in more detail below.

Home screen

The home screen is the default screen of the application. This is loaded when the user first navigates to the tool. The user interface consists of the following main areas:

- A Google Maps background that can be interacted with and that displays the surface water layer calculated by the tool.
- A panel on the top right that can be used to specify options for the tool, control map layers, (re)calculate the maps and download data. In addition to this there are a number of info buttons that explain the various features. The panel can be collapsed to expose more of the map.
- A legend on the bottom left, indicating the colours used to display the map layers.

Additionally, the black bar on the top will display a location search box at the very right. All of these items are shown in Figure 2.

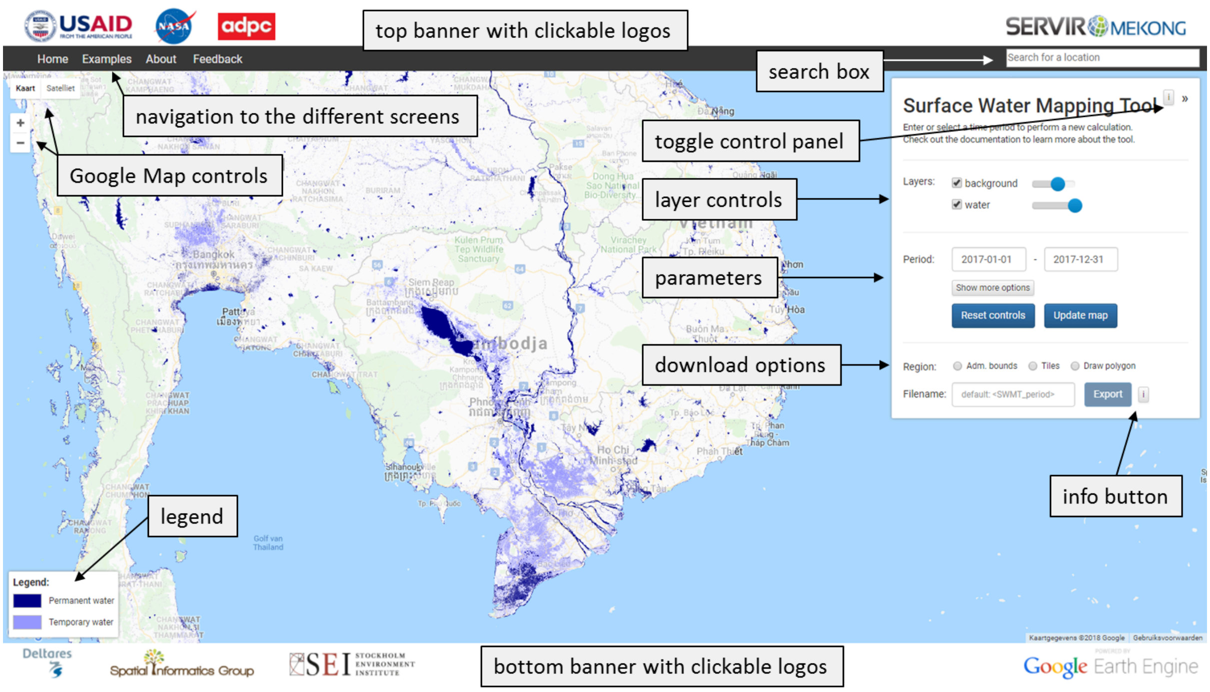


Figure 2: User interface elements of the home screen.

Info buttons

Buttons with relevant information about the section of the UI that they are located at are placed at various locations. Figure 2 shows one next to the Export button, which, when clicked, reveals a panel that displays information about exporting/downloading data from the application. Another one can be seen at the top right of the control panel, which displays general information about the tool. It is advised to check out this information if you haven't already. Finally, each parameter that can be adjusted by the user (explained further down) has its own info button.

Updating the map

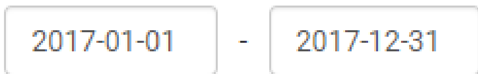
As most options should work fine with their default values the basic workflow when using the tool is as follows:

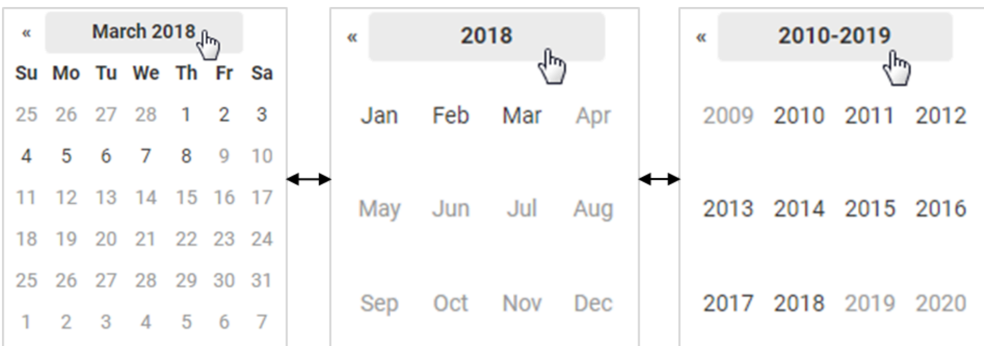
1. Zoom in to an area of interest using the main map functionality
2. Set a time period of interest (see next section)
3. Update the map using the 'Update map' button

In the paragraphs below the different options of the tool are described in more detail. After options have been changed the map should be updated using the update map button.

Time period for calculations

The user can select the time period for which results should be calculated. This can be done by manually entering the start and end date or by clicking one of the boxes and selecting the date using the interface that then pops up. The format of the dates is YYYY-MM-DD (year-month-day). The selecting interface allows quick switches between dates, months and years by clicking on the top field, while navigation to an adjacent month, year or period can be done with the arrows on the top left/right:





The selection for the time period for calculations has a significant effect on the results. In the Landsat 8 era the SWMT has one image available every 8 days (Landsat 7 and 8, see Figure 3). For the method of the tool to work a significant number of cloud-free pixels must be available. For most of the Mekong basin 6 months is probably the minimum period required. However, for the higher percentile (permanent water) smaller time periods may be possible. Therefore, the following limits have been imposed on the time period selection:

- 90 days (~ 3 months) for regular use
- 1095 days (~ 3 years) for when the 'show months' option is activated (explained in more detail further down)

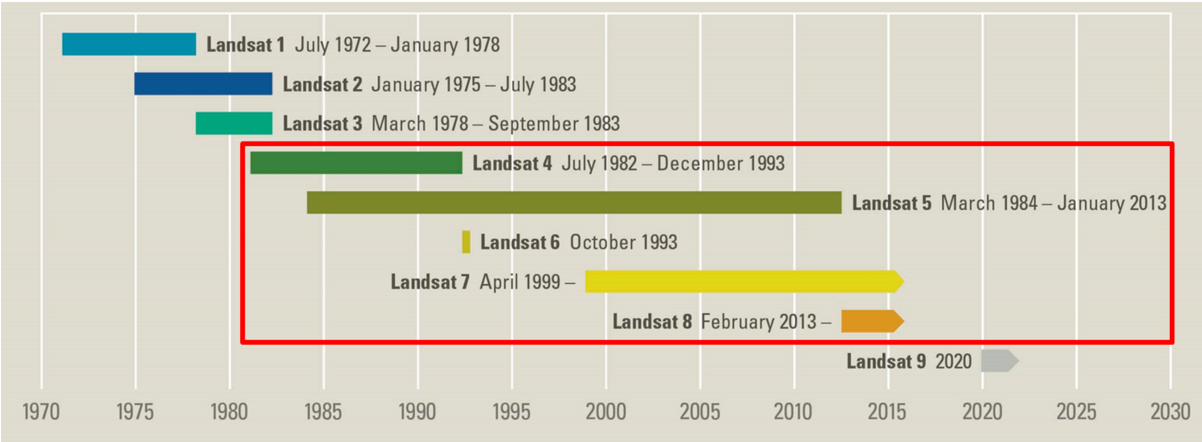


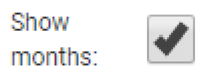
Figure 3: Landsat missions (with those included in the tool enclosed in the red rectangle) [source: landsat.usgs.gov/landsat-missions-timeline]

Adjusting parameters

While the time period is the most important parameter, there are other parameters that can be adjusted by the user. These are hidden by default, but can be shown by clicking the 'Show more options' button.

Show months

With this option enabled, the tool will perform the calculations for all individual months separately. A slider bar will be displayed below the map layer controls, to allow the user to view each month. By default January is loaded, but other months will be calculated when the slider is updated.



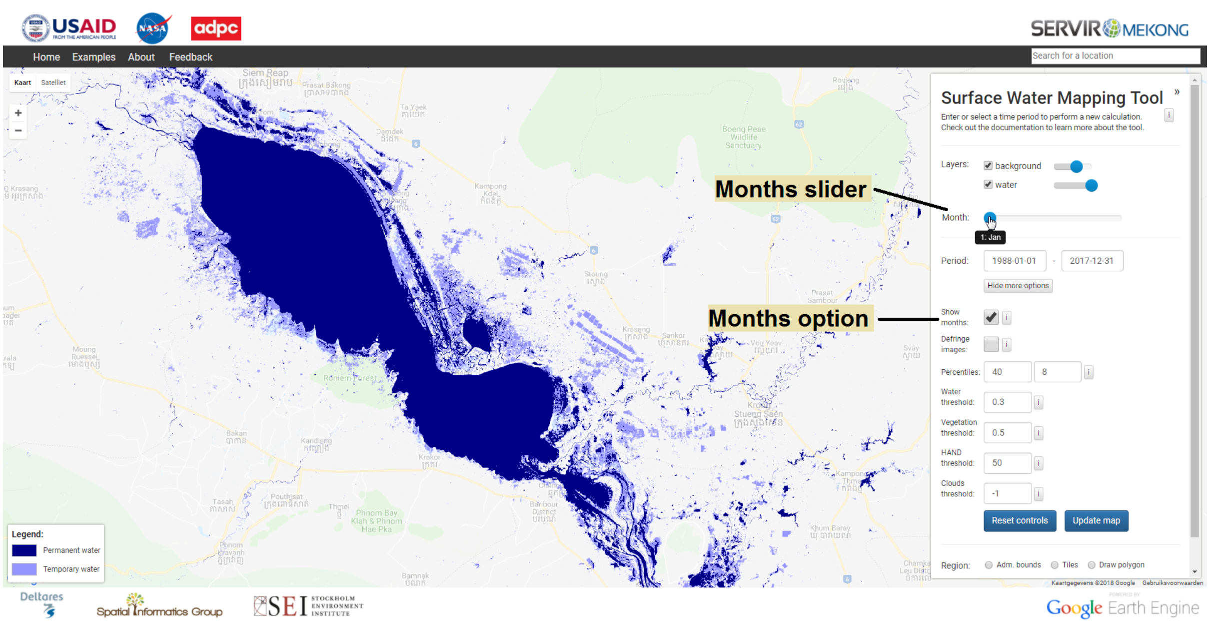


Figure 4: Controls for monthly data

Defringe images

Landsat 7 suffered a failure of Scan Line Corrector (SLC) in the ETM+ instrument as of May 31, 2003. As a result images show striping. If this option in enabled the tool tries to filter these out (as they have a predictable pattern). This result in cleaner image with no visible banding but it also means that less data is available for processing and as such less water may be detected. See Figure 5 on the next page for an example.

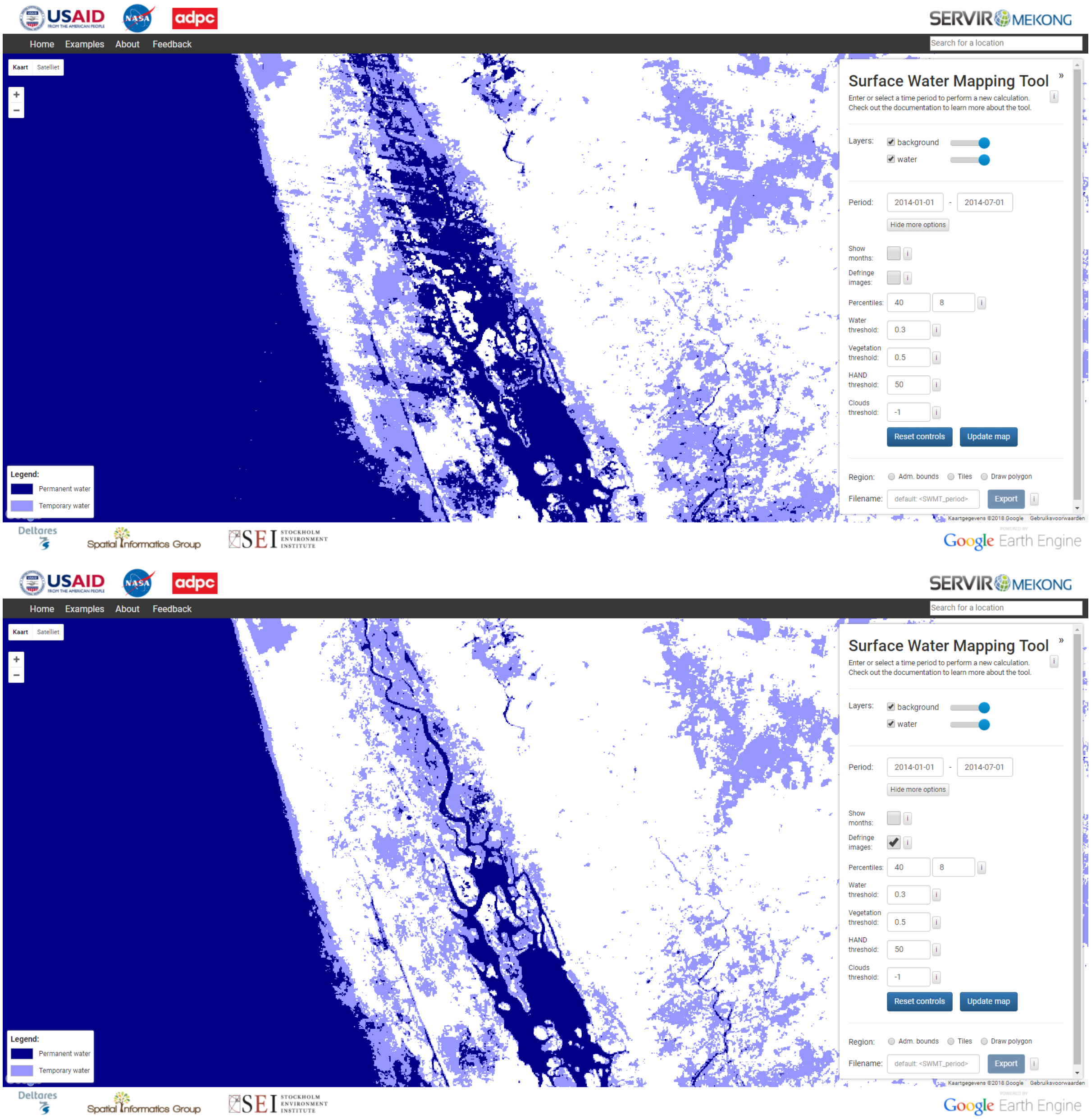


Figure 5: Effect of the defringing option. By enabling this option the striping pattern in Landsat 7 is masked out, as can be seen by comparing the two images. However, this also results in less pixels available for processing and as such can result in less water being detected.

Percentiles

The default values for the permanent and temporary water are 40 and 8%, respectively. The percentiles in the SWMT relate to the percentile in the frequency distribution of the original landsat bands used in the calculation of the Modified Normalized Difference Water Index

(MNDWI) over the selected period. In this case the 40th percentile indicates a value below which 40% of the values of a specific Landsat band[1] fall. Given the way MNDWI is calculated (see the background documentation) a lower percentile will result in a higher MNDWI value compared to a higher percentile. As such, a lower percentile will detect more water compared to a higher percentile. Figure 6 shows the effect of entering different percentiles for temporary water over the same area.

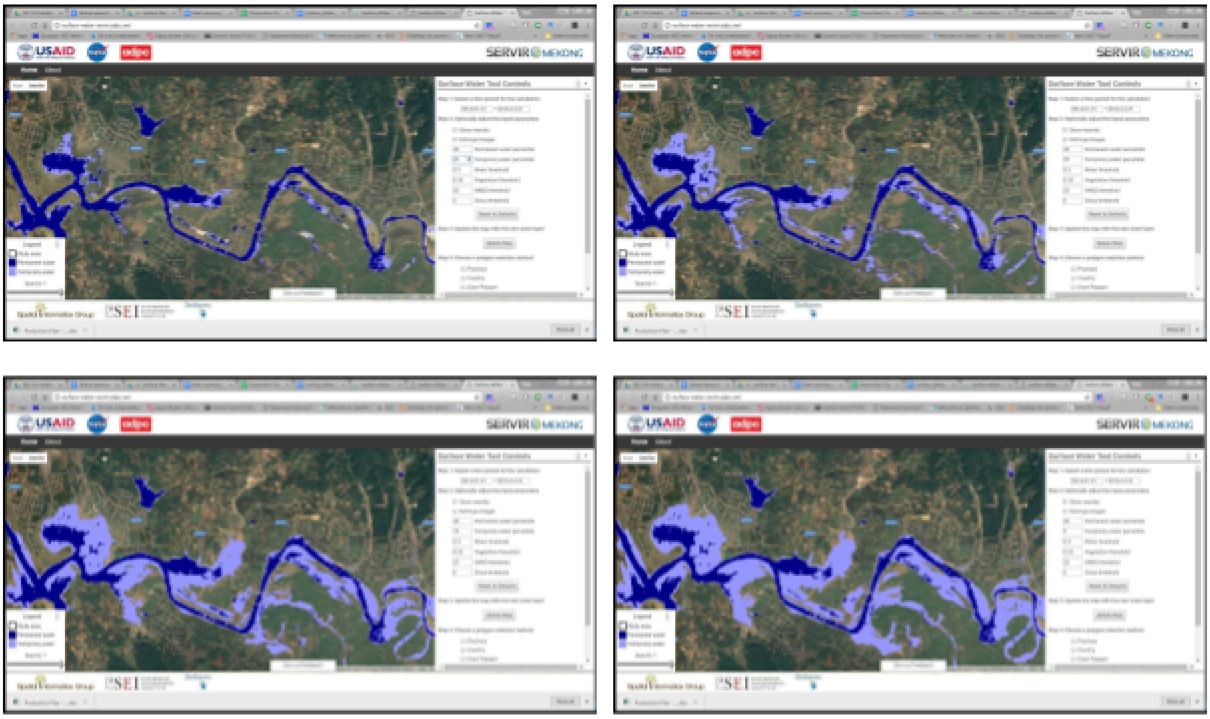


Figure 6: Different values for the temporary water percentile (permanent percentile is kept constant at 40). Top left: 35, top right: 25, bottom left: 15 and bottom right: 5. The percentiles have been calculated using one year of data (2014). The screenshots are from an earlier version of the user interface.

For permanent water, it is recommended to stay within the range of 15 - 60. For temporary water, it is recommended to stay within the range of 5 - 15.

Water threshold

The default value for the water threshold is 0.3. This threshold is applied to the calculated MNDWI to detect water (see Figure 7). In general the value of 0.3 works fine for most regions but lower values can be used in area with a low number of clouds and/or dark vegetation. When lowering the value false positives may be detected and visual inspection is required. Similarly, when increasing the value the algorithm may miss water and inspection of the results for known water bodies is suggested. Figure 8 shows the effect of changing the threshold from 0.3 to 0.1.

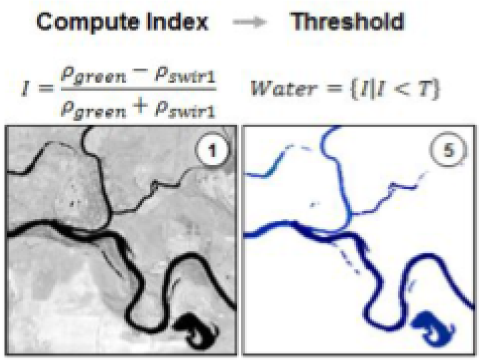


Figure 7: Applying a threshold to the MNDWI

[1] We use the bands green, NIR and SWIR1.

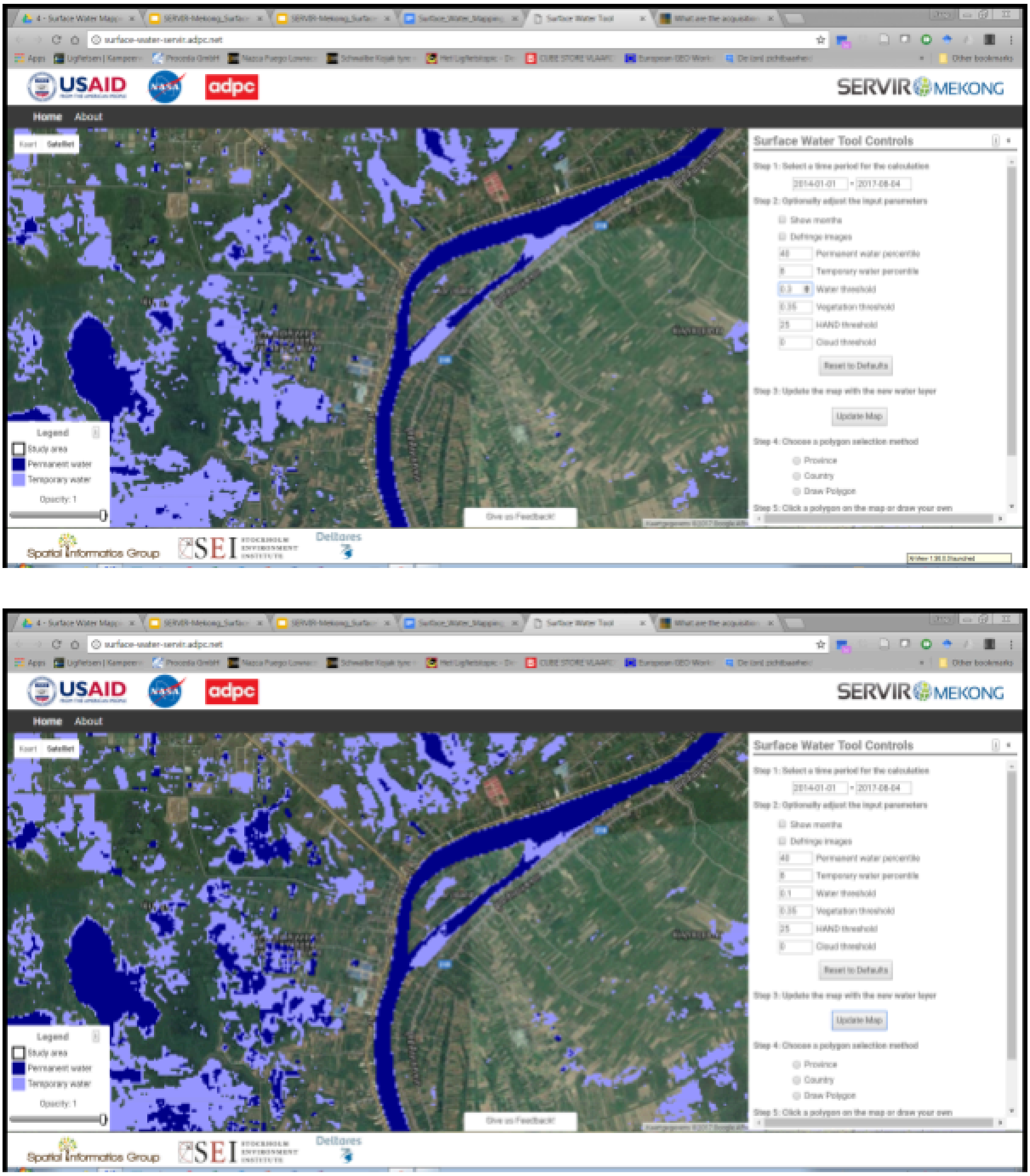


Figure 8: Two different MNDWI water thresholds (top 0.3, bottom 0.1). The screenshots are from an earlier version of the user interface.

Vegetation threshold

The default value for the vegetation threshold is set to 0.5. This value is used with a Normalized Difference Vegetation Index (NDVI) map to find dark vegetation and mask it in order to decrease false positives in the water detection. Lower values will include more vegetation, higher values less (dark) vegetation. Just like the MNDWI map, the NDVI map is calculated from the percentile map and as such depends on the time period, and whether defringing, cloud masking and/or monthly images have been activated.

HAND threshold

Height Above Nearest Drainage (HAND) [Rennó et al., 2008] is a measure of the height of each pixel in a map above the nearest stream or river (drain). By filtering out pixels with a high HAND value (which are unlikely to hold surface water), false positives are being filtered out. This is especially important in mountainous areas, where hill shadows can lead to the incorrect detection of water. Figure 9 shows an example of this situation; hill shadows are present in the percentile image and these cannot be distinguished from water by using the MNDWI alone. However, by using the HAND mask this error can be fixed and the final water map no longer has incorrectly classified water.

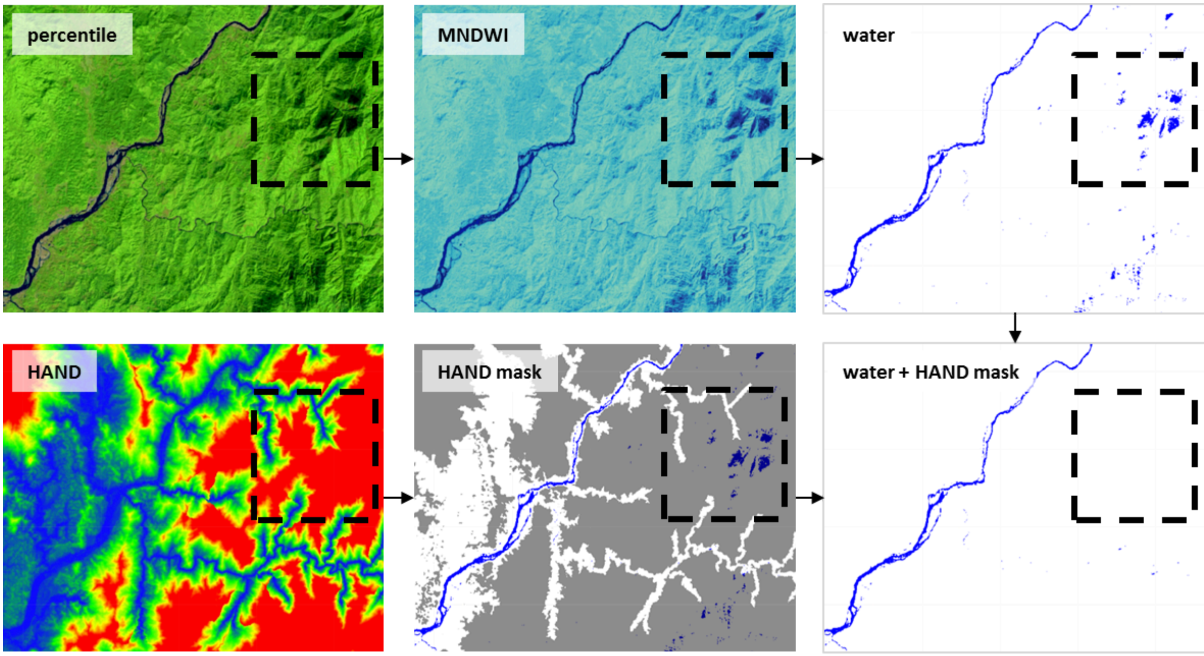


Figure 9: Example of HAND masking. Without HAND masking there are false positives within the area marked by the square box. With HAND masking these errors are removed.

One possible scenario in which the HAND mask can filter out genuine surface water is for reservoirs constructed after the generation of the digital elevation model used in the HAND map. So use this with caution in an area with recent reservoir construction.

Cloud threshold

While the percentile-based approach already produces a cloud free composite for most of the study area, there are some heavily clouded areas (such as northern Vietnam) where the percentile approach might not be sufficient to filter out clouds. For these areas, cloud masking (or ‘busting’) on an image-by-image basis might be a necessity. The algorithm uses a Google Earth Engine function that computes a simple cloud-likelihood score in the range of 0-100, using a combination of different indices. This option is switched on in the app if you specify a value between 0 and 100 (with the default -1 the option is switched off), with lower values masking out more potential clouds. A good value to start with is probably 80. See the figure below for an example of different thresholds.

From the figure the effect of the cloud masking threshold can be seen. It is important to understand that this masking occurs on all individual images, which can significantly reduce the number of valid pixels that are used to create the percentile image. For this reason, it might be necessary to adjust the percentile values as well, as the default values are based on a situation without cloud masking.

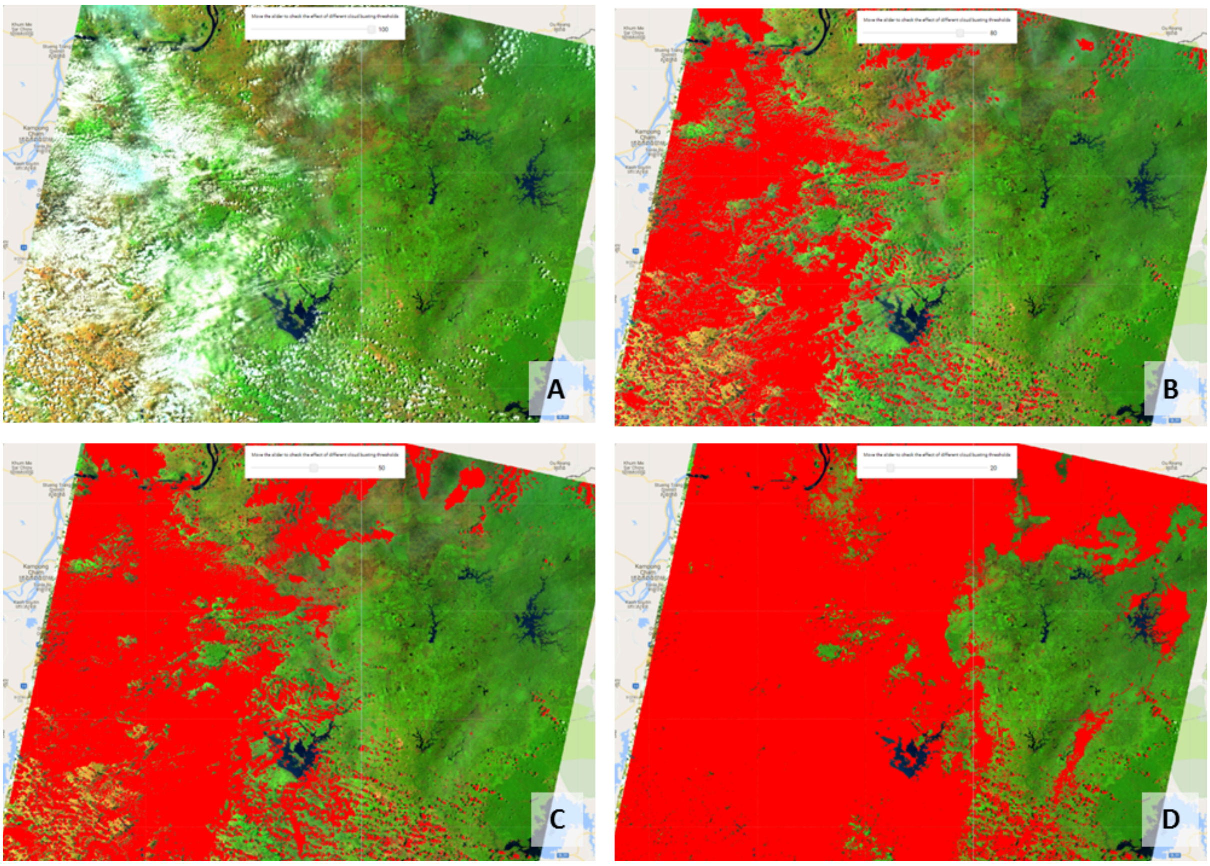


Figure 10: Example of cloud masking with different thresholds on a single test image. A: image with no cloud masking (visualization with bands SWIR 1, NIR, GREEN). B: the same image with cloud masking activated, using a threshold value of 80. C: threshold of 50. D: threshold of 20.

Exporting/Downloading maps

Please note that this feature is still under development!

It is possible to download the surface water data shown on the map by following these steps:

1. Activate a region selection layer (either administrative bounds, regular tiles or the option to draw a polygon on the map yourself)
2. Select a region or draw the polygon on the map (this will enable the Export button)
3. Click the Export button.

Clicking the Export button will queue a download task on Google Earth Engine and a download panel will appear on the top left of the screen. The text *"Preparing download links"* is shown, indicating that the download task is still running. When finished, this will be replaced by *"Click here to download water layer"*. These features are shown in Figure 11.

The water layer is downloaded as a GeoTIFF file. By default, a filename is constructed automatically based on the chosen time period. For example, if this is 2017-01-01 to 2017-12-31, the filename will be SWMT_20170101_20171231. Optionally, the user can enter his own filename. It is also possible to download a metadata file in CSV format from the download panel, this contains all parameter settings used to create the map.

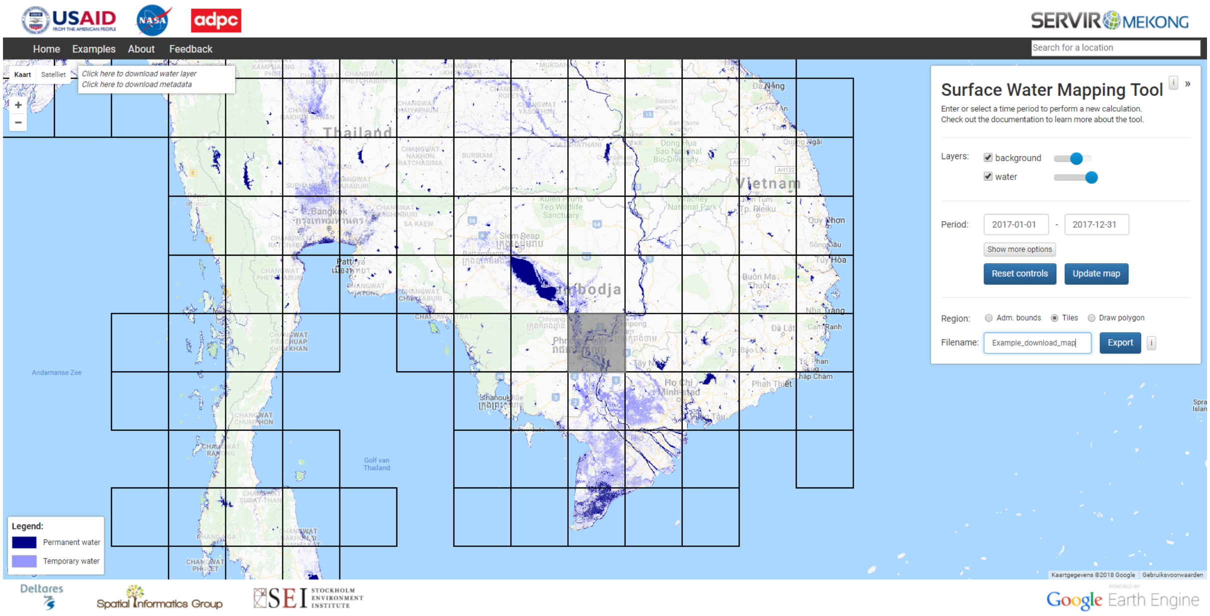


Figure 11: Downloading data from the tool. Tiles are chosen as region selection, with the selected tile highlighted in grey. The Export button has been enabled and the download panel on the top left is active, showing two download links.

Examples

This page shows a few potential applications for which the Surface Water Mapping Tool could be used, by loading a pre-calculated map in the tool. These maps only cover the area of interest of each specific example to keep storage and loading times to a minimum. The input parameters are also updated to match those used to create the example map. This gives the users a quick look at what is possible, from within the user interface of the tool itself. The examples are loaded by clicking on the relevant image and include:

1. A general example on permanent and temporary water
2. Reservoirs
3. Floods
4. River morphology
5. Seasonal inundation

About

The About screen gives a brief description of the tool and the methods behind it. It also contains links to the documentation and acknowledgements of involved studies and efforts.

Feedback

The Feedback button in the black top bar links to a Google Docs feedback form. Here you can submit your feedback, which will be used by the developers to improve the tool.

Example Use cases

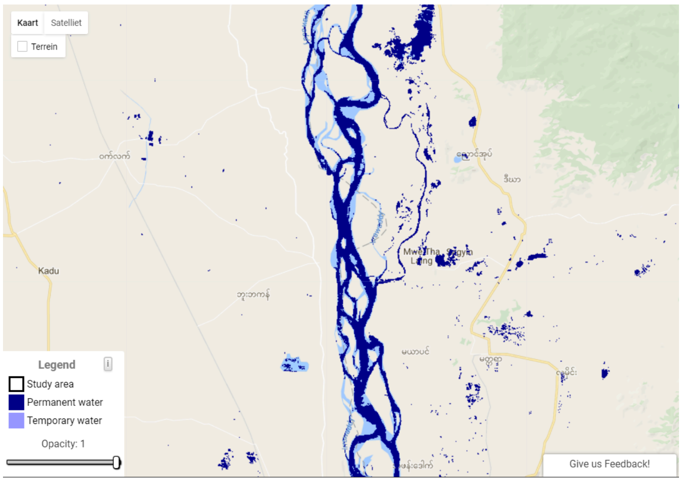
The sections below briefly describe a number of use cases of the tool and how the results can be obtained. Some of these might overlap with the examples listed in the online tool itself.

River morphology (*"dancing rivers"*)

Because the tool can run of the whole Landsat archive available in GEE it is possible to make maps of the course of a river for each year and thus investigate if and how the river's course changes over time and where the erosion and sedimentation areas are located.

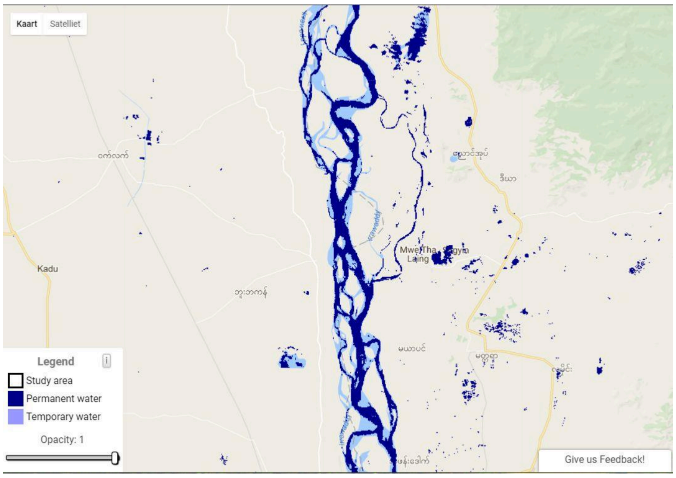
The following list of steps explains how this can be done:

1. Zoom in to the area of interest.
2. In the example below the Irrawaddy river in Myanmar is shown. We have set the temporary water percentile to 40 (same as the permanent water) to make the map less cluttered
3. Set the time range to the first year you want to investigate. In this case we have used 2013 and updated the map



4. Now use the download functionality to save this map and rename it to 2013.tif

5. Now set the time to 2014 and update the map



6. Save this map (2014.tif) and repeat the steps until you have all the years you want.

The figure below shows 5 years of surface water as an animation made using the steps above (with an earlier version of the user interface).

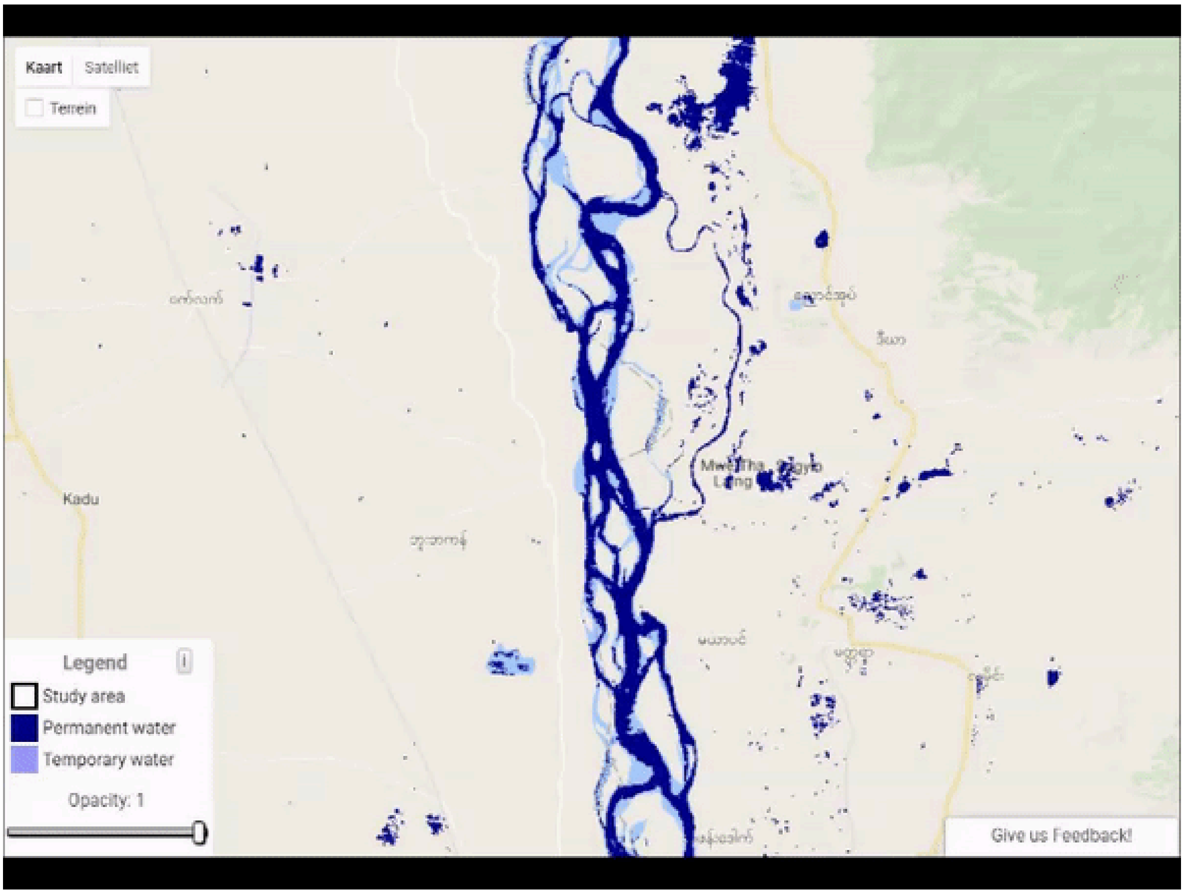


Figure 12: Animation of 5 years of river course (2013-3017) of the Irrawaddy in Myanmar using the SWMT. Areas of erosion and sedimentation can be identified.

Surface water climatology

By setting the time period to a relatively long period (minimal three years but preferably longer) the tool can be used to calculate the surface water for the individual months in that period. In essence, this will construct a climatology for each month during that period. You will get 12 maps, one for each month where each map is constructed of all the months in the selected period.

1. Zoom in to the area of interest and select a sufficiently long period[2]
2. Make sure to select thon months option in the panel on the right and select the month you are interested in using the slider (see section Show months). After selecting the month use the update map button to update the map.
3. Use the download functionality to download the selected month and repeat this for the other months.
4. Post-process the downloaded maps in a GIS program

In Figure 12 below we have made screenshots of each month and merged these into a small animation that displays the seasonal surface water dynamics.

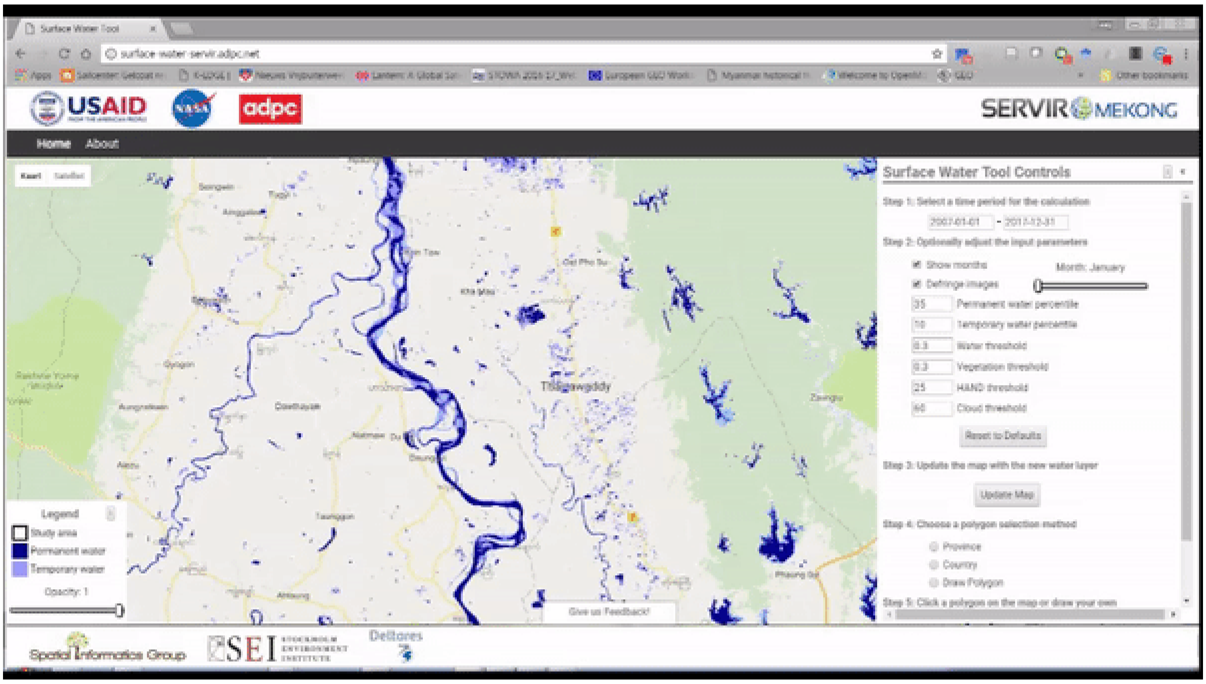


Figure 13: Animation of the seasonality of a stretch of the Irrawaddy river determined over the period 2007 - 2017, using an earlier version of the user interface.

[2] The tool will give a warning if the selected period is shorter than 3 years when using the months option.

Flooded areas

Although the tool is not designed to be able to identify individual floods it can be used -- depending on atmospheric circumstances -- to estimate flooded area by running it for a relatively short period around a flood and comparing this to a (longer) reference period in which no or little floods occurred. The procedure to do this is as follows:

1. Select and are of interest and zoom to that area
2. Now set a time period around the flood (with a three months minimum).
3. Fine tune the parameters
4. Download the map for further processing.
5. See Figure 14 below where we have zoomed to the Minbya region in Myanmar where a flood was recorded in June 2016
6. Now select a long (reference period) in which little of now floods have been recorded and repeat the above steps (cf Figure 15)

The downloaded files can be used to estimate the flooded areas. Flooded area can be calculated by overlaying the permanent water of the reference period over the permanent and temporary water of the flood period. All detected water not masked by the permanent water of the reference period is most probably flooded.

The flood in the Minbya region of Myanmar was also mapped by the Dartmouth Flood Observatory (http://floodobservatory.colorado.edu/). In the Background and Verification document of the SWMT this is compared against results obtained with this example.

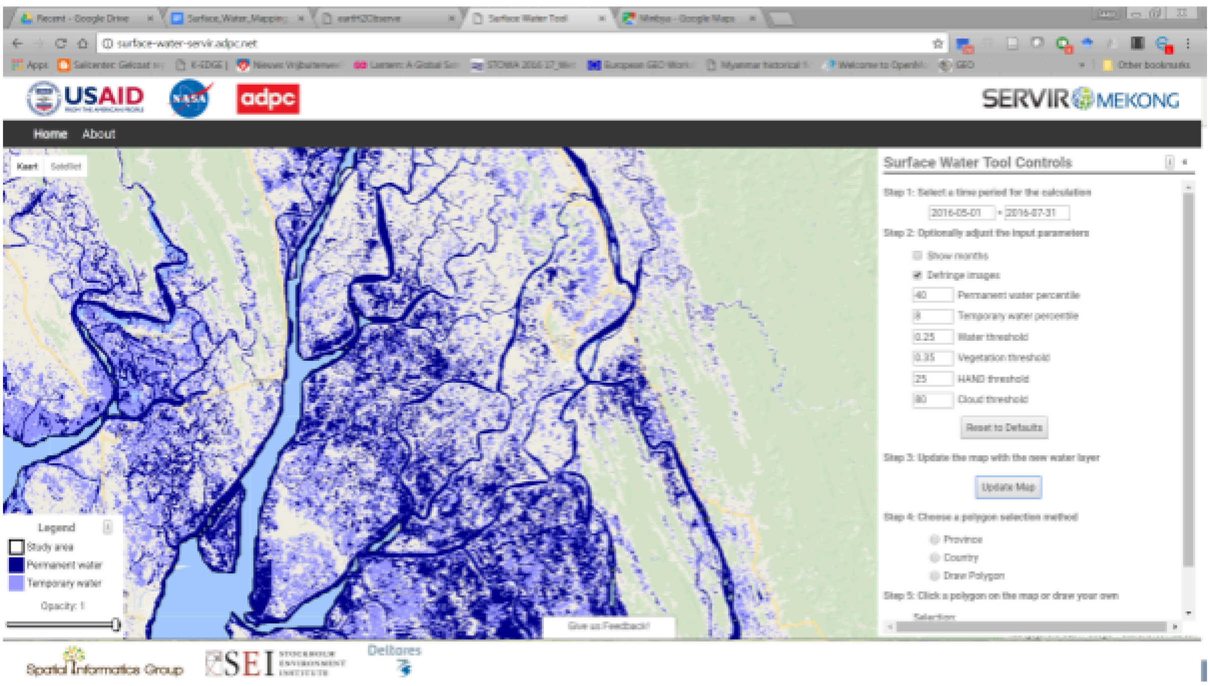


Figure 14: Surface water in the Minbya region determined during a period of recorded flooding (June 2016). Screenshot from an earlier version of the user interface.

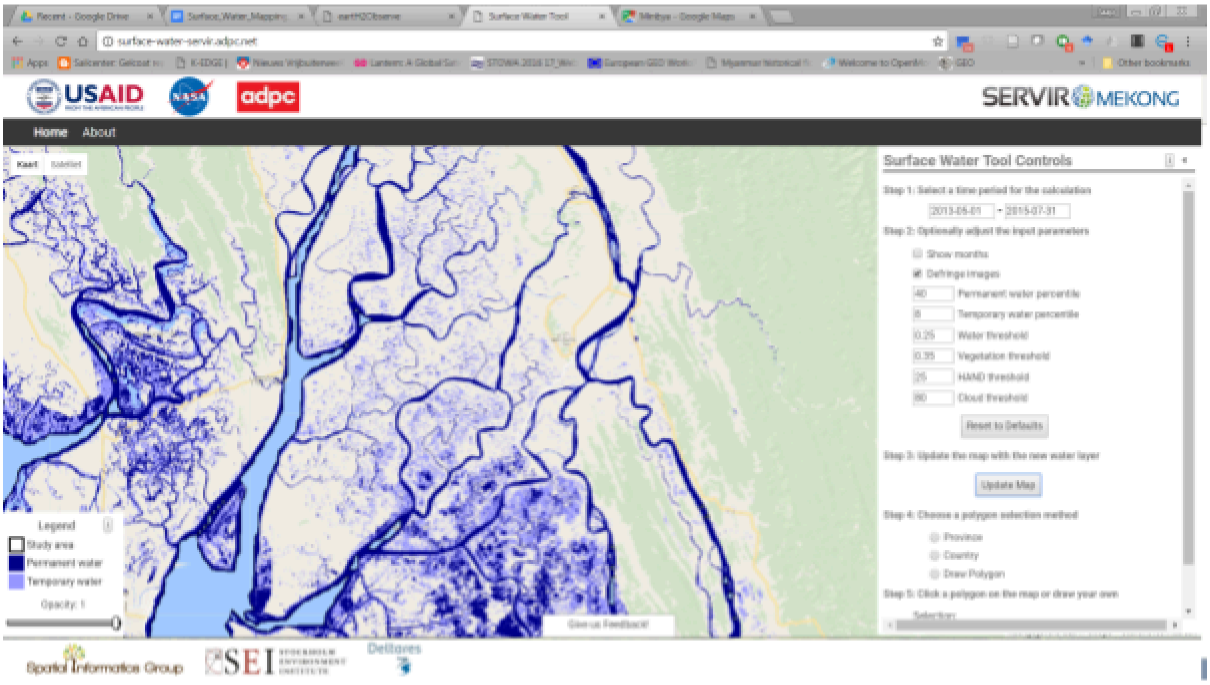


Figure 15: Surface water in the Minbya region determined for a reference period (2013-2015). Screenshot from an earlier version of the user interface.

Land cover mapping input

The tool can be used to make a map of water as part of a full land-cover map. In general, this tool can provide a relatively high quality classification of water and non-water that can be merged with other maps. The procedure to make these maps is as follows:

- Define the period of interest to derive the map from (last year, last five years, whole range etc)
- Fine tune the parameters
  - If you are only interested in permanent water set the percentile for temporary water the same as permanent water. This will give you a map with only permanent water. (see Percentiles)
- Run the tool
- Download/export the map using the download functionality (Exporting/Downloading maps)

The exported map is a GeoTIFF that can be loaded into most GIS programs

References

Donchyts, G., Schellekens, J., Winsemius, H., Eisemann, E. and van de Giesen, N.: A 30 m Resolution Surface Water Mask Including Estimation of Positional and Thematic Differences Using Landsat 8, SRTM and OpenStreetMap: A Case Study in the Murray-Darling Basin, Australia, Remote Sensing, 8(5), doi:10.3390/rs8050386, 2016.

Rennó, C.D., Nobre, A.D., Cuartas, L.A., Soares, J.V., Hodnett, M.G., Tomasella, J., Waterloo, M.J., 2008. HAND, a new terrain descriptor using SRTM-DEM: Mapping terra-firme rainforest environments in Amazonia. Remote. Sens. Environ. 112. doi:10.1016/j.rse.2008.03.018