Water Observations from Space: accurate maps of surface water through time for the continent of Africa

Meghan Halabisky[1], Kenneth Mubea[1], Fatou Mar[2], Fang Yuan[1], Chad Burton[1], Eloise Birchall[1], Negin Fouladi Moghaddam[1], Ghislain Adimou[3], Bako Mamane[4], David Ongo[5], Edward Boamah[1], Ee-Faye Chong[1], Nikita Gandhi[1], Alex Leith[1], Lisa Hall[1], and Adam Lewis[1]

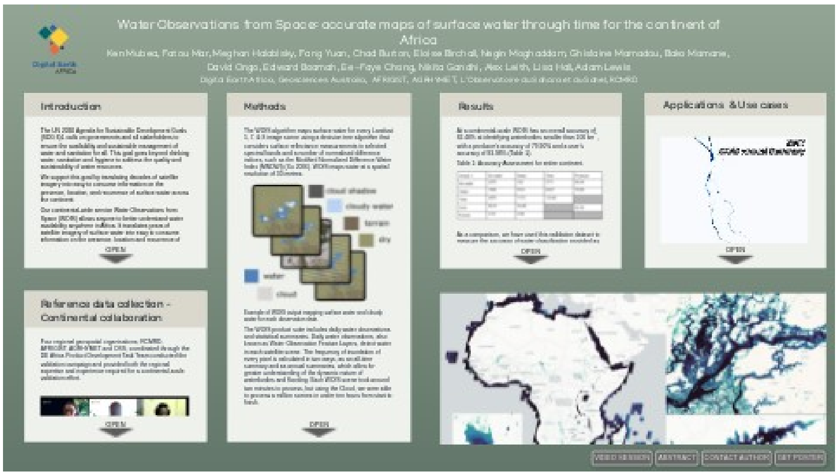
[1]Digital Earth Africa
[2]L'Observatoire du Sahara et du Sahel
[3]AFRIGIST
[4]AGRHYMET
[5]RCMRD

November 24, 2022

Abstract

Earth observation of waterbodies through time is a powerful tool in understanding both the location of waterbodies and their temporal dynamics. Water Observations from Space (WOfS), developed and well-tested in Australia, is a service providing historical surface water observations derived from Landsat satellite imagery from 1987 to present day. WOfS provides better understanding of where water is usually present; where it is seldom observed; and where inundation of the surface has been occasionally observed by satellite. We applied the WOfS algorithm to Africa and validated its accuracy through image interpretation of satellite and aerial imagery using an online tool created by the NASA Servir program, Collect Earth Online. The Digital Earth Africa Product Development Task Team, composed of four regional geospatial organisations RCMRD, AfriGIST, AGRHYMET and OSS, conducted the validation campaign and provided both the regional expertise and experience required for a continental-scale validation effort. In order to understand the accuracy and bias of the WOfS algorithm in Africa at both the continental-scale and regional zones, we generated 2900 sample points covering the continent including the main islands and distributed them into 7 Agro-ecological zones. We assessed whether the point was flooded, dry, or cloud covered, for 12 months in 2018, resulting in 34,800 assessed observations. As water information is available through WOfS in near real-time, it can be used for environmental monitoring, flood mapping, monitoring planned water releases, and management of water resources in highly regulated systems. WOfS is expected to be used by ministries and state departments of agriculture and water management in countries, international organizations, academia and the private sector.

Water Observations from Space: accurate maps of surface water through time for the continent of Africa



Ken Mubea, Fatou Mar, Meghan Halabisky, Fang Yuan, Chad Burton, Eloise Birchall, Negin Moghaddam, Ghislain Adimou, Bako Mamane, David Ongo, Edward Boamah, Ee-Faye Chong, Nikita Gandhi, Alex Leith, Lisa Hall, Adam Lewis

Digital Earth Africa, Geosciences Australia, AFRIGIST, AGRHYMET, L'Observatoire du Sahara et du Sahel, RCMRD

PRESENTED AT:

INTRODUCTION

The UN 2030 Agenda for Sustainable Development Goals (SDG 6)1 calls on governments and all stakeholders to ensure the availability and sustaina management of water and sanitation for all. This goal goes beyond drinking water, sanitation and hygiene to address the quality and sustainability of w resources.

We support this goal by translating decades of satellite imagery into easy to consume information on the presence, location, and recurrence of surface water across the continent.

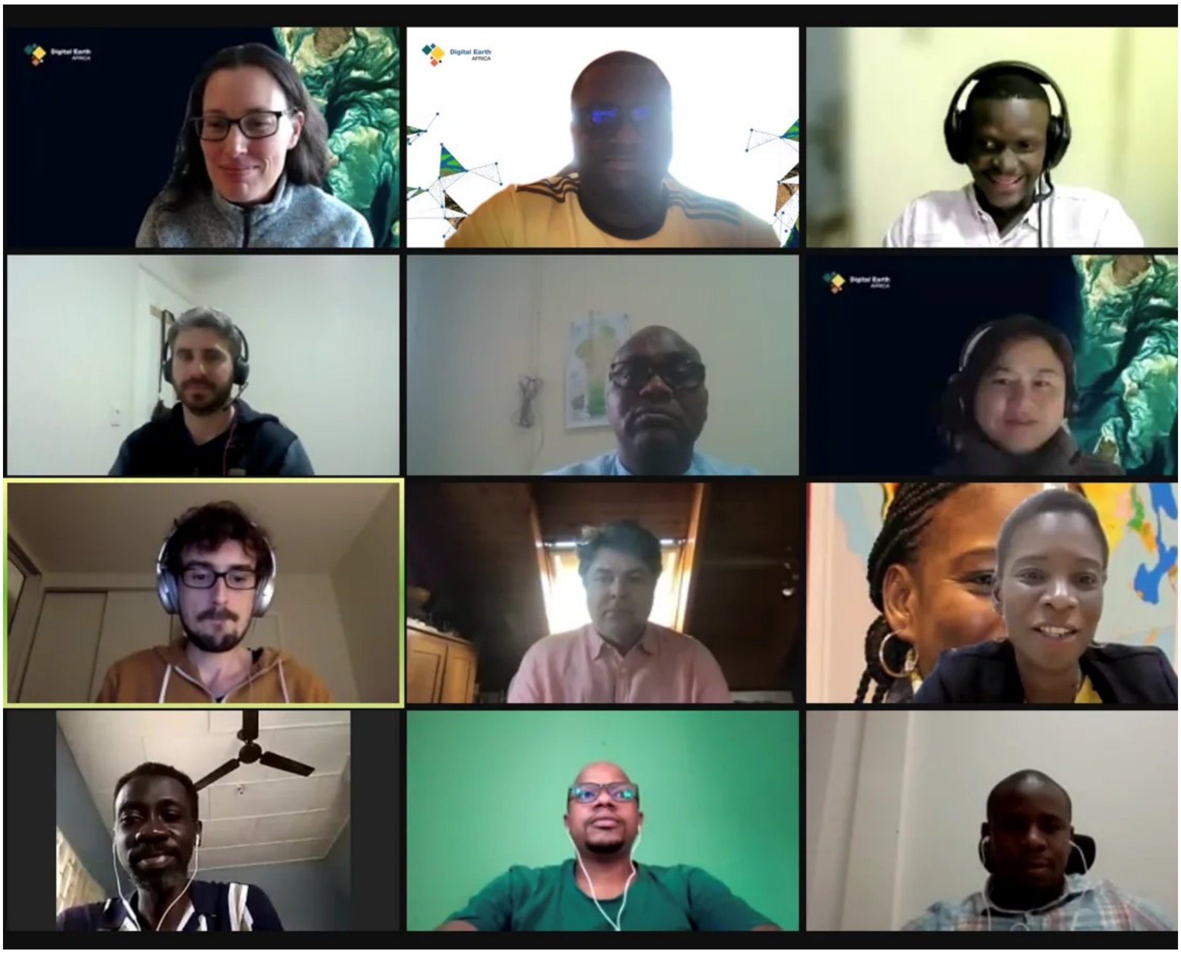
Our continental-wide service Water Observations from Space (WOfS) allows anyone to better understand water availability anywhere in Africa. It trans years of satellite imagery of surface water into easy to consume information on the presence, location and recurrence of water within Africa. This allov users across Africa to map, assess, visualise, and manage water resources and understand trends over time.

The Water Observation from Space (WOfS) service for Africa was created using an algorithm that has been developed and well-tested in Australia (M 2016). Development of complex algorithms for dynamic mapping requires the use of training data that captures the variability of features across space and time. Transferring and extending algorithms trained in one location to a new location with a different range of temporal and spatial variability across target features can res poor results. However, we believed that due to the similar climate and geography between Australia and Africa and the use of analysis ready data that it would be pos to extend the WOfS algorithm to Africa without the necessary process of re-training the algorithm from the beginning.

Applying WOfS to the continent of Africa would allow for an initial deployment of a surface water map service without the need for a lengthy research and developr phase. While the two continents may have some similar climate and geographies we realized that there are still many differences. Any effort to test the accuracy of th WOfS product would require local and regional expertise. Moreover, DE Africa is guided by the principle of fostering national and regional co-production to develop ownership of both the DE Africa program and all products and services.

REFERENCE DATA COLLECTION – CONTINENTAL COLLABORATION

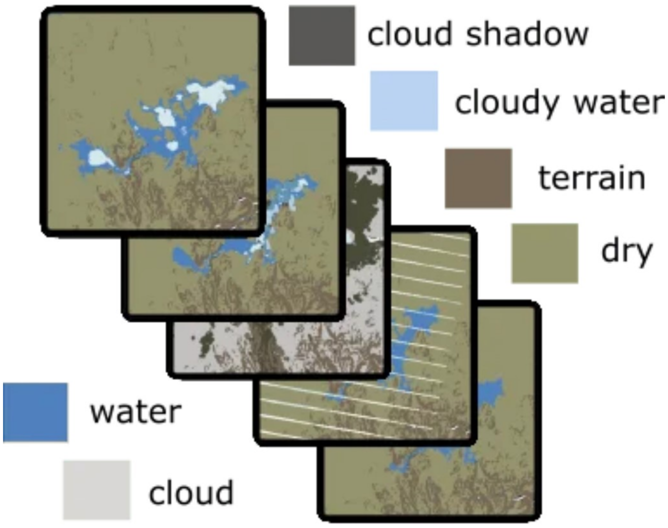
Four regional geospatial organisations; RCMRD, AFRIGIST, AGRHYMET and OSS, coordinated through the DE Africa Product Development Task Te
conducted the validation campaign and provided both the regional expertise and experience required for a continental-scale validation effort.



The Product Development Task Team (PDTT) is a working group of Digital Earth Africa composed of implementing partner members representing sev
African-based, regional and national geospatial organizations. The PDTT works together to identify shared needs and data gaps for the continent of A
and selects, designs, plans, develops, and validates DE Africa's continental-scale services and products. The PDTT also provides support in the use a
application of DE Africa data products by stakeholders and end users within their networks (e.g. National Statistics offices). At the time this project wa
carried out the PDTT consisted of the following organizations; L'Observatoire du Sahara et du Sahel (OSS, Tunisia), Regional Centre for Mapping of
Resources for Development (RCMRD, Kenya), African Regional Institute for Geospatial Science and Technology (AFRIGIST, Nigeria), and AGRHYMI
(Niger).

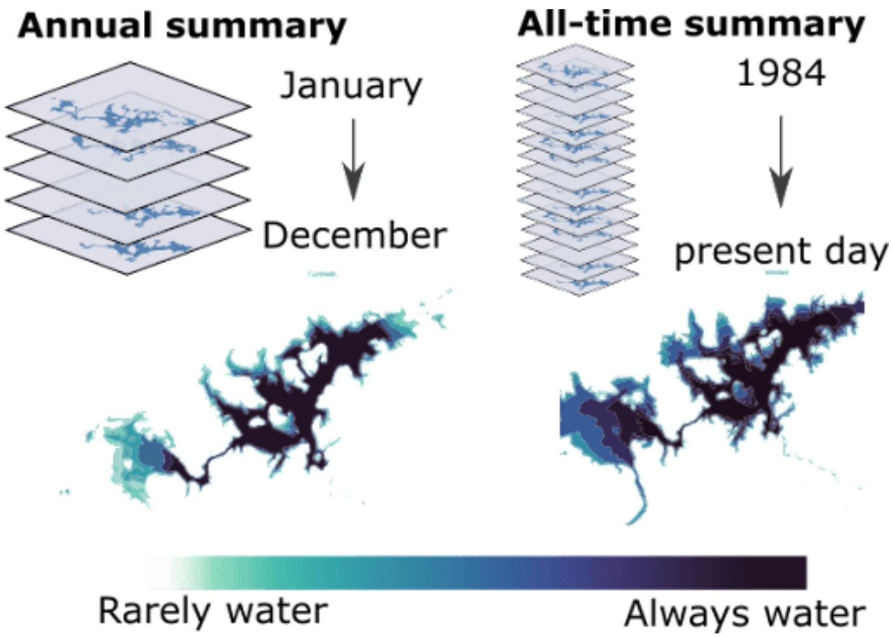
METHODS

The WOfS algorithm maps surface water for every Landsat 5, 7, & 8 image scene using a decision tree algorithm that considers surface reflectance measurements in selected spectral bands and a number of normalised difference indices, such as the Modified Normalized Difference Water Index (MNDWI) (Xu 2006). WOfS maps water at a spatial resolution of 30 metres.



Example of WOfS output mapping surface water and cloudy water for each observation date.

The WOfS product suite includes daily water observations and statistical summaries. Daily water observations, also known as Water Observation Fea Layers, detect water in each satellite scene. The frequency of inundation of every pixel is calculated in two ways, as an all-time summary and as annu summaries, which allow for greater understanding of the dynamic nature of waterbodies and flooding. Each WOfS scene took around two minutes to process, but using the Cloud, we were able to process a million scenes in under ten hours from start to finish.



Example of WofS annual and all-time summaries.

The goal of this project was to test out the transferability of the WOfS algorithm to the African continent.

Our objectives were as follows:

1. Determine the accuracy across the continent in each of seven simplified Agro-Ecological Zones (AEZ).
2. Understand how accuracy varies temporally across both wet and dry seasons.
3. Compare the accuracy of WOfS to the Sentinel-2 water mask in the Scene Classification Layer.

4. Create a reference dataset that could be used as a benchmark for future updates and improvements on surface water extent map services in Africa.

To meet our project objectives, we selected a validation approach that provided insights on both the spatial and temporal accuracy of WOfS. We used a stratified ranc sampling scheme and assessed points as 'truth' through interpretation of imagery. Because of the large effort required to create a continental-scale, multi-temporal reference dataset we selected a sampling design that is independent of the WOfS classification so that it can be used to compare future versions of WOfS (new algori new products i.e. Sentinel-2) and other existing surface water maps.

One of our aims was to create a reference dataset that would be sensitive to differences between water classifiers and source imagery (Landsat v. Sentinel-2). Water classifiers typically do a good job mapping large open waterbodies, which was not the focus of this map service. Therefore, we mas out large water features with an area of more than 100 square km (sourced from the Food and Agriculture Organization (FAO) of the United Nations) f the sample frame. This focused validation on areas that are more challenging to map such as small waterbodies with different colors, depths and surrounding environments, and edges of waterbodies that often contain mixed pixels. By focusing our sample on the more difficult-to-map areas, this sample scheme allows us to both understand the limitations of WOfS and compare WOfS to other datasets that are available with higher sensitivity th we had chosen a purely random sample. However, the downside of selecting a sampling scheme focused on the more difficult-to-detect areas and nc the large waterbodies will result in lower accuracies if compared to other sample schemes that did not do large waterbody masking or stratified sampli

Not all observations could be labelled as water or not water due to cloud cover, lack of imagery, or uncertainty about class due to poor resolution and r pixels. Of the 3,000 points 2,814 had one or more clear observations within the 12 months. In total, 24,349 observations had a label, with 29.5% label water (7,186) and ~70.5% labelled as not water (17,163).

RESULTS

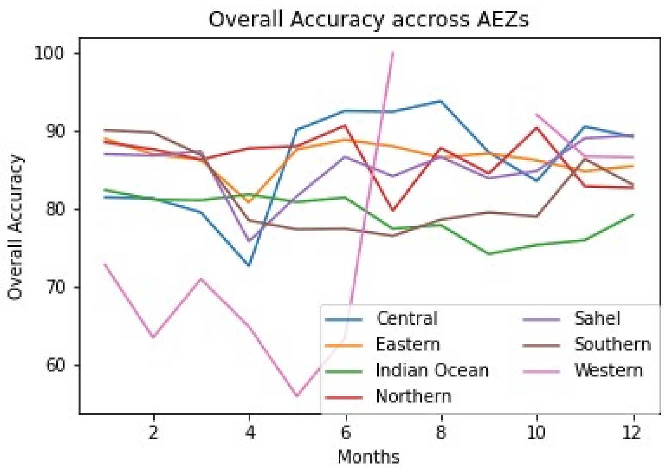
At a continental-scale WOfS has an overall accuracy of 82.48% at identifying waterbodies smaller than 100 km^2, with a producer's accuracy of 79.90% a user's accuracy of 93.98% (Table 1).

Table 1: Accuracy Assessment for entire continent.

Actual ->	No water	Water	Total	Producer
No water	3279	432	3711	88.36
Water	1696	6741	8437	79.90
Total	4975	7173	12148	
User	65.91	93.98		82.48
f-score	0.76	0.86		

As a comparison, we have used this validation dataset to measure the accuracy of water classification provided as part of the Sentinel-2 analysis reac data (in a scene classification layer). The Sentinel-2 dataset is able to detect less than 60% of the labeled water features.

There is considerable variability in the accuracy across each AEZ. At the AEZ level, WOfS performs well in Eastern, Sahel and Northern AEZs with ar overall accuracy of more than 85% and less than 15% errors of omission and errors of commission (85% producer's and user's accuracy). This mear 85% or more of the labelled reference water features in these zones have been identified correctly as water using the WOfS algorithm. The classificati accuracy was highest for the Eastern AEZ and lowest in the Western AEZ. The Western AEZ has an overall accuracy of 71.3% and errors of omissior errors of commission.



APPLICATIONS & USE CASES

[VIDEO] https://res.cloudinary.com/amuze-interactive/image/upload/f_auto,q_auto/v1639180415/agu-fm2021/e9-af-34-fe-69-38-18-49-15-e89-21-74-c0-29/image/bui_ghana_wofs_annual_t00moa.mp4

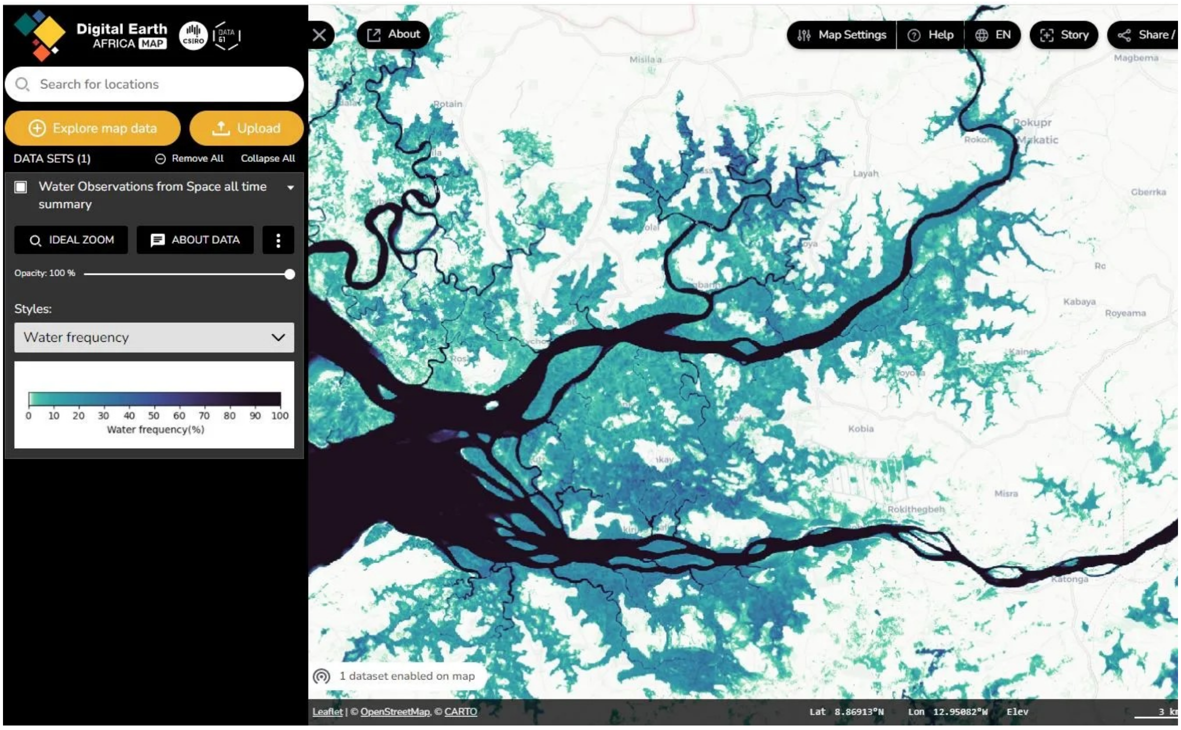
Example: Annual WOfS summary from 2004 - 2021

WOfS is expected to be used by ministries and state departments of agriculture and water management in countries, international organizations, acad and the private sector. A large-scale collaborative effort, which included regional and technical skills spanning two continents was required to create a service that is regionally accurate and has African ownership.

Currently, WOfS has been applied to several use cases. See links to a few examples below:

- Lake Baringo - link (https://www.digitalearthafrica.org/media-center/blog/eo-conservation-rehoming-giraffes-lake-baringo-kenya)
- Wetland Insight Tool - link (https://docs.digitalearthafrica.org/en/latest/sandbox/notebooks/Real_world_examples/Wetlands_insight_tool.html)
- Water changes in Ghana - link (https://www.digitalearthafrica.org/media-center/blog/monitoring-water-extent-using-earth-observation-data)

How to use the data:



To get started using WOfS and other DE Africa map oproducts and services go the the DE Africa website.

- Platform Resources - link (https://www.digitalearthafrica.org/platform-resources/platform)
- Tutorials & trainings - link (https://www.digitalearthafrica.org/platform-resources/training-and-help)
- More information on WOfS and how to access the data - link (https://www.digitalearthafrica.org/platform-resources/services/water-observations-from-space)

Limitations

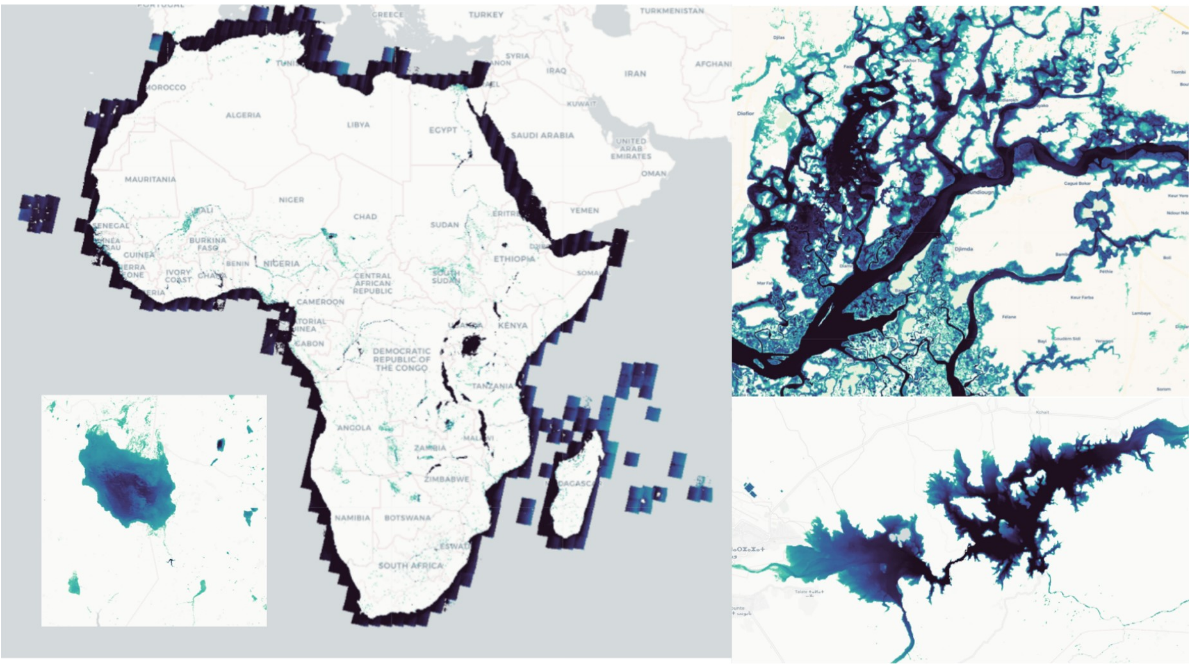
During this assessment, we have also discovered a few types of issues associated with input data, validation method and the WOfS algorithm. The validation results should be interpreted with the following caveats:

Spatial Resolution: The WOfS product is based on 30 m resolution Landsat imagery while the validation data is produced using 10m resolution Sent imagery. WOfS has trouble in areas with mixed pixels (where a pixel covers both water and upland). These areas tend to be on edges of lakes and in wetlands where there is a mix of water and vegetation. The Sentinel-2 imagery can identify these edges at a higher resolution than the current WOfS product.

Environmental factors: There are some errors that are hard to correct for. Sediment, floating vegetation etc. are potentially contributing factors in thi of error by changing the color of water and making detection hard.

Temporal Resolution: Reference locations may have been observed on different dates by the Sentinel-2 and the Landsat satellites. If the water exter changed between the dates, a mis-match in the classification is expected.

To learn more about Digital Earth Africa go https://www.digitalearthafrica.org/ (https://www.digitalearthafrica.org/)



ABSTRACT

Earth observation of waterbodies through time is a powerful tool in understanding both the location of waterbodies and their temporal dynamics. Water Observations from Space (WOfS), developed and well-tested in Australia, is a service providing historical surface water observations derived from Landsat satellite imagery from 1987 to present day. WOfS provides better understanding of where water is usually present; where it is seldom observed; and where inundation of the surface has been occasionally observed by satellite. We applied the WOfS algorithm to Africa and validated its accuracy through image interpretation of satellite and aerial imagery using an online tool created by the NASA Servir program, Collect Earth Online. The Digital Earth Africa Product Development Task Team, composed of four regional geospatial organisations RCMRD, AfriGIST, AGRHYMET and OSS, conducted the validation campaign and provided both the regional expertise and experience required for a continental-scale validation effort. In order to understand the accuracy and bias of the WOfS algorithm in Africa at both the continental-scale and regional zones, we generated 2900 sample points covering the continent including the main islands and distributed them into 7 Agro-ecological zones. We assessed whether the point was flooded, dry, or cloud covered, for 12 months in 2018, resulting in 34,800 assessed observations. As water information is available through WOfS in near real-time, it can be used for environmental monitoring, flood mapping, monitoring planned water releases, and management of water resources in highly regulated systems. WOfS is expected to be used by ministries and state departments of agriculture and water management in countries, international organizations, academia and the private sector.