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TAKING THE PULSE OF OUR PLANET FROM SPACE

The WorldWater project – advancing the mapping of surface water dynamics from space

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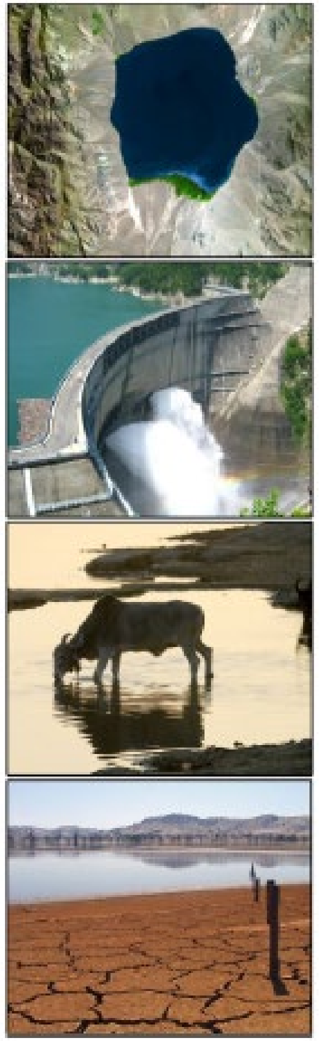
Background

- Inland water resources are affected by climate change as well as increasing demands for food production, energy, and water
- There is a need to monitor water resources at national, regional, and global levels to understand their vulnerability to change and ensure sustainable management
- The last decades have seen a steady decline in in-situ hydrological monitoring, and satellite Earth Observation is now being recognized as an essential tool for large-scale monitoring of water resources



Water is at the core of 3 main global agendas

Climate Action

Paris Agreement

Monitoring Climate Change & Understanding

Sustainable Development

2030 Agenda

Managing progress on sustainable development in all its facets

Disaster Risk Reduction

Sendai Framework

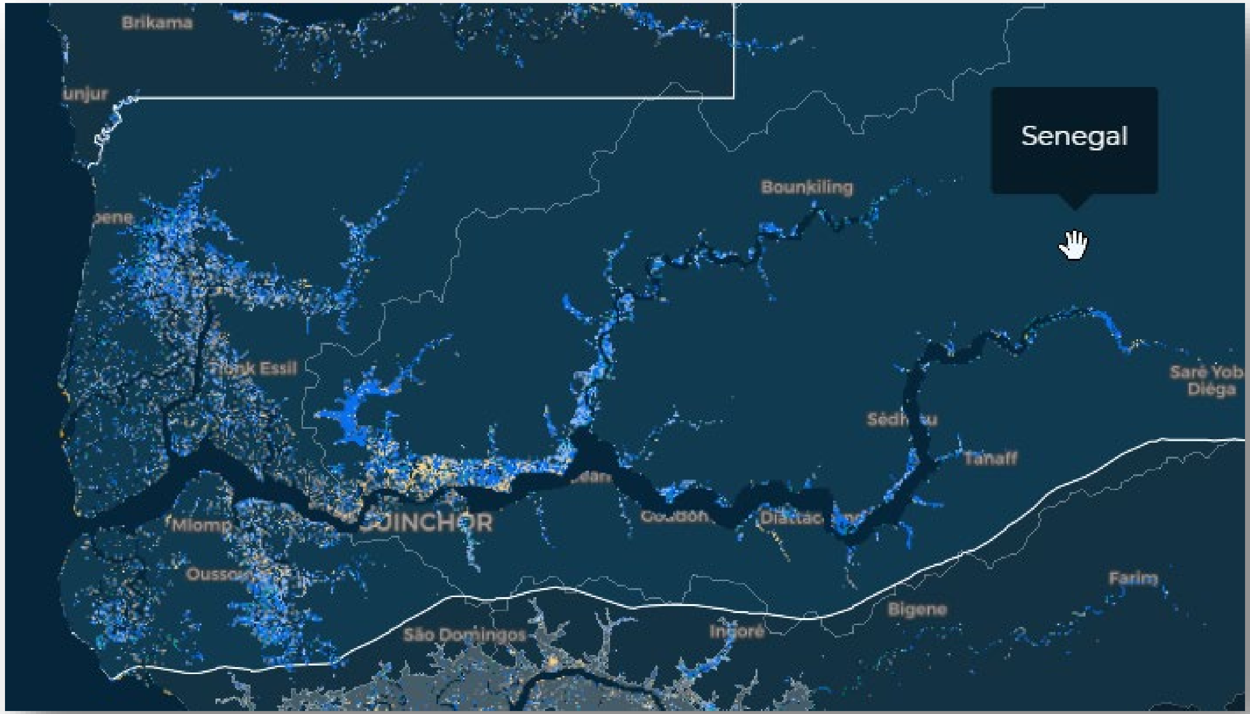
Supporting Disaster Resilient Societies

Global EO products in support of SDG indicators

Global Surface Water Extent for SDG 6.6.1 (water-related ecosystems)

6 CLEAN WATER AND SANITATION

- The SDG661 indicator is designed to measure changes in the extent (and quality) of different types of freshwater ecosystems over time
- UNEP has the custodian responsibility for SDG 661
- The Freshwater Ecosystem Explorer was developed to fill a global data gap as many countries don't have this information available
  - Benchmark product*:
    - 30 m spatial resolution and monthly temporal resolution 1984-2020

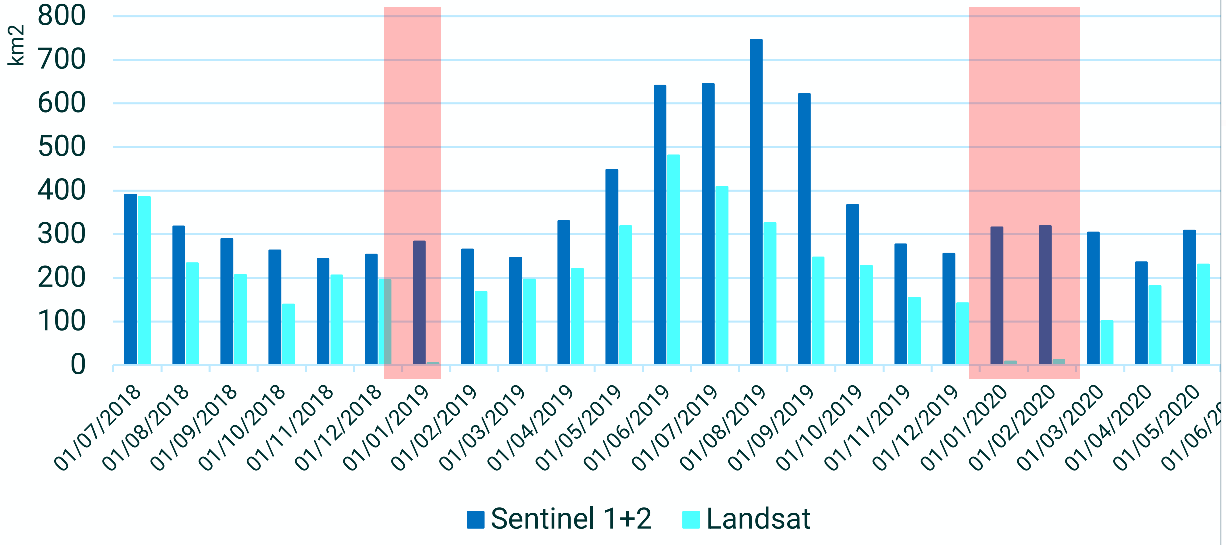


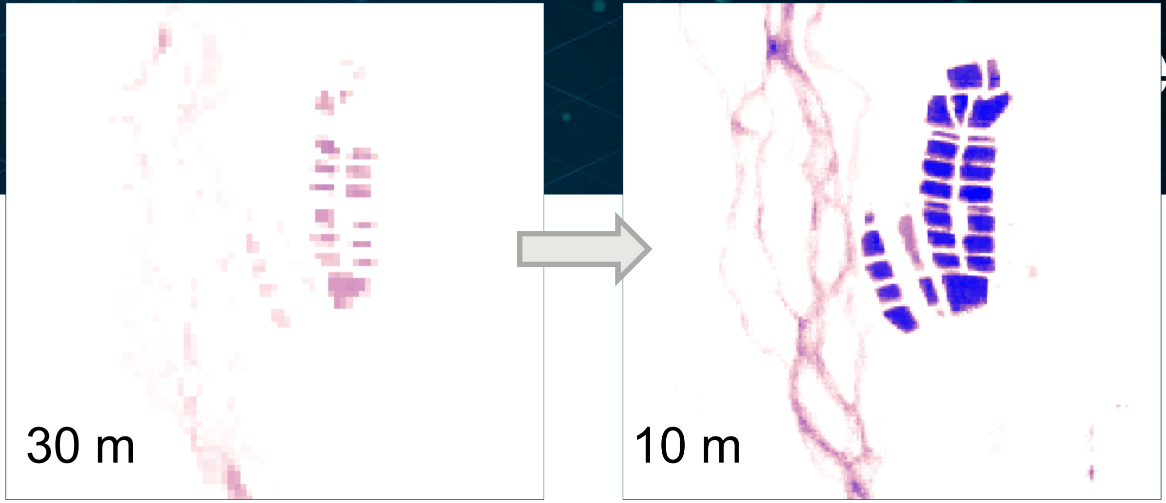
https://map.sdg661.app/#

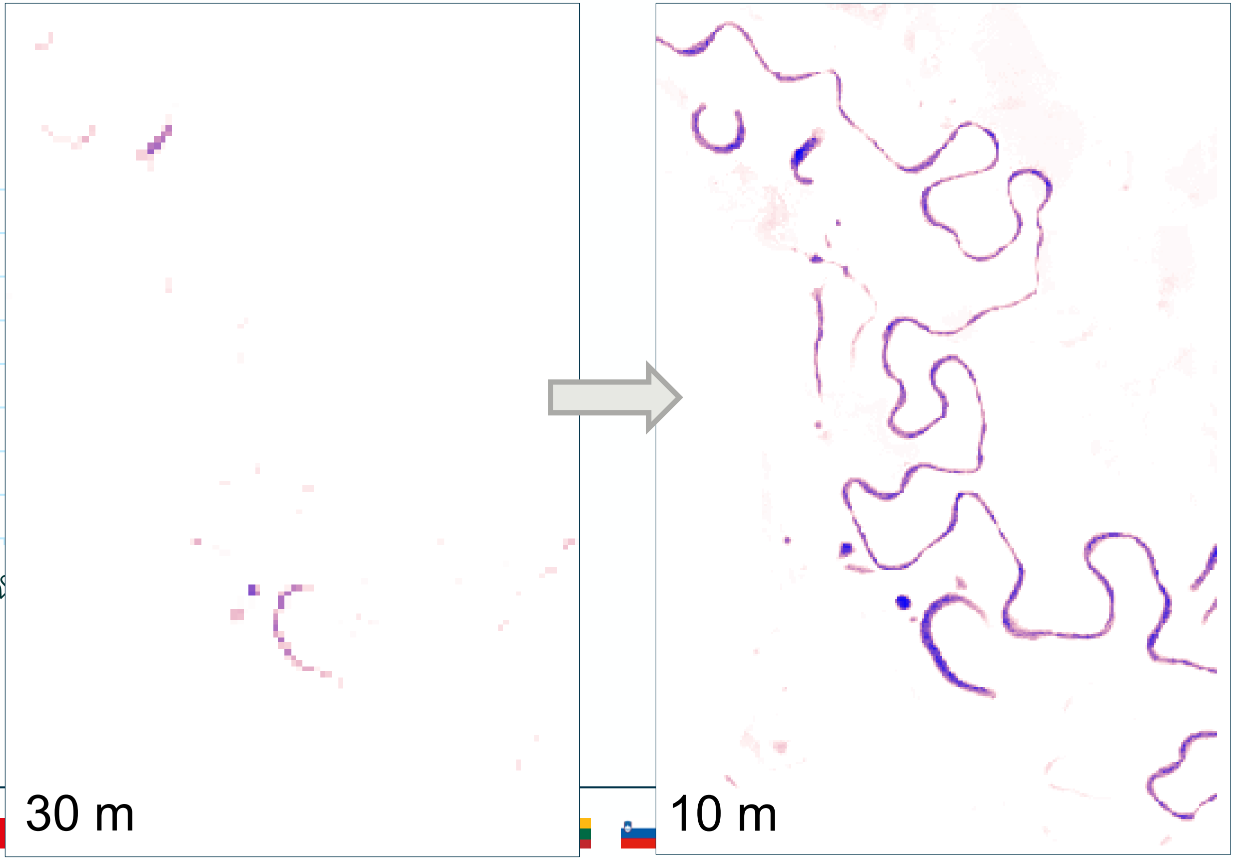
* *Jean-Francois Pekel, Andrew Cottam, Noel Gorelick, Alan S. Belward, High-resolution mapping of global surface water and its long-term changes. Nature 540, 418-422 (2016). (doi:10.1038/nature20584)*

Next generation mapping

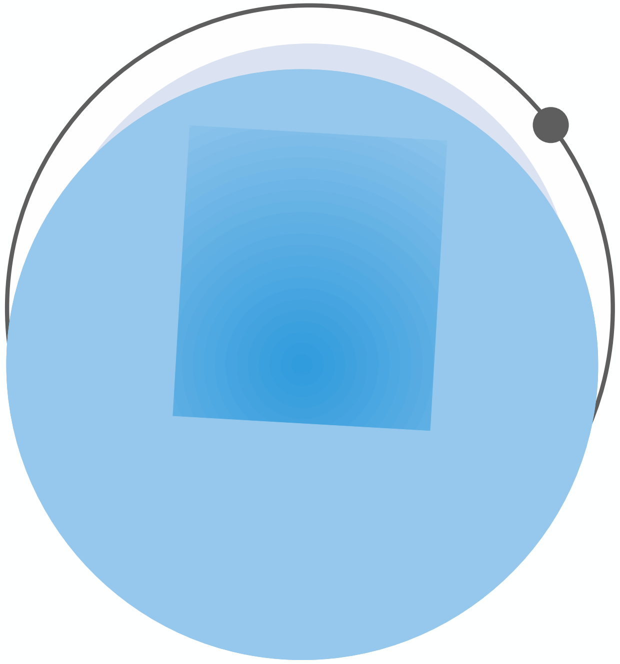
- A dual sensor approach based on Sentinel-1 and Sentinel-2
  - Capture more details
  - More consistent seasonal variations







Enabling EO based national monitoring



Empower national and regional stakeholders with EO data and tools
to better monitor their water resources and report on the global water agenda.

Project objectives

- **DEVELOP** innovative and scientifically robust EO methods and tools on data streams of free satellite imagery at high spatial & temporal resolution (S1, S2, L8) and inland water level observations from RA, for the monitoring of the intra-annual and inter-annual variations of surface waters, in extent and volume.
- **DEMONSTRATE** the robustness and scalability of the EO algorithmic approaches and software tools for large scale water monitoring systems.
- **SHOWCASE** the utility of the WorldWater products by conducting a number of use case studies related to sustainable water management;
- **INTEGRATE** the WorldWater tools and products in web-based Surface Water Data Analytics Portals with data visualisation, statistical and analytics tools;
- **SUPPORT** countries developing / strengthening their technical capacities to monitor the extent and changes of surface waters

A Round Robin intercomparison

- To compare robustness of approaches, assess EO best practices, and identify shortfalls and areas of further research ultimately the RR will help to underpin the credibility of the final SWE algorithm and hence user acceptance
- Round Robin set-up
  - Open to all 3rd party developers of SWE mapping algorithms
  - 5-test sites - only surface water extent
  - Same datasets for everybody (S1, S2 and Landsat)
  - Independent accuracy assessment

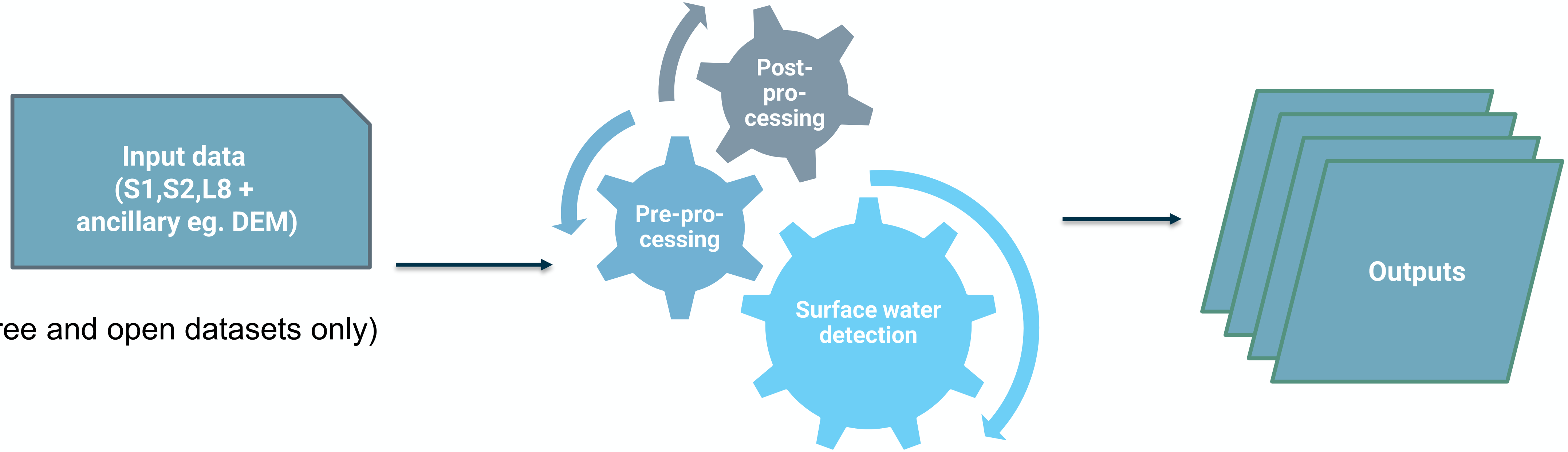
Test sites

Key challenges

- Topography
- Clouds
- Canopy shading
- Burn scars
- Urban areas
- Regions with permanent low backscatter
- Diverse waterbodies
  - Large Waterbodies (wind and wave effects)
  - Permanent and seasonal water, impacted by water constituents and shallow waters influenced by bottom reflectance

Expected outputs

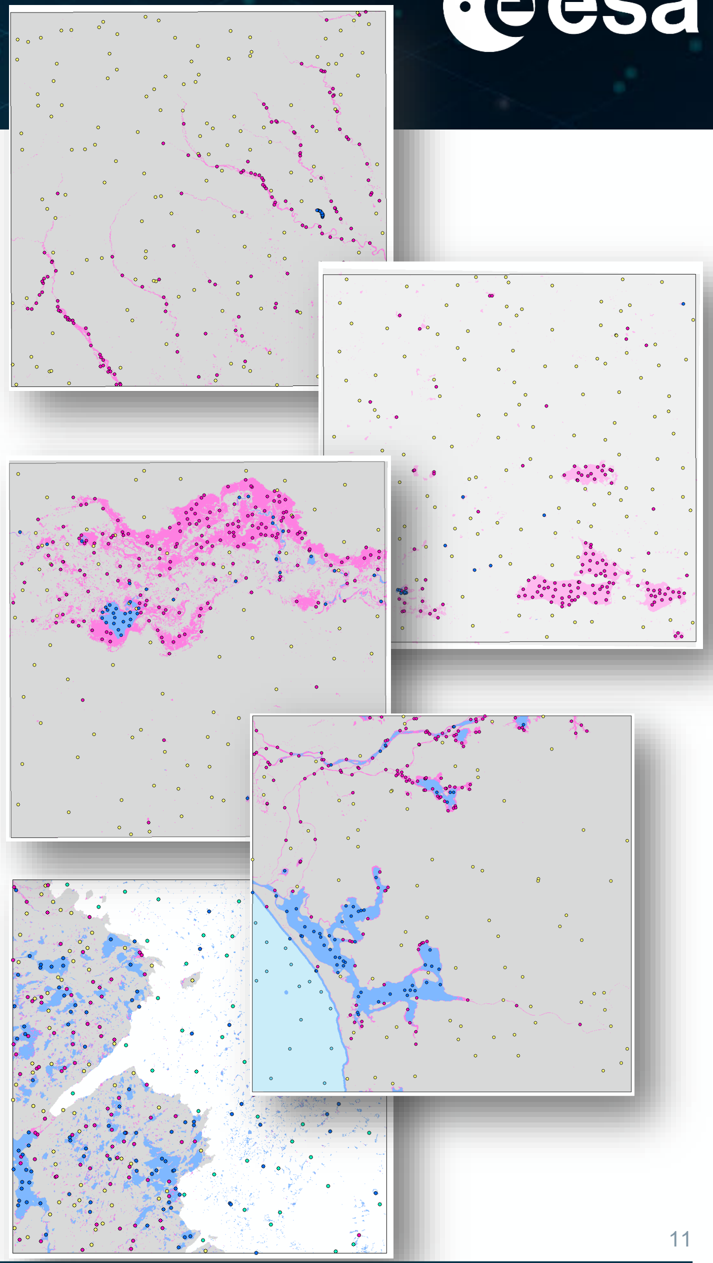
- Maps of **monthly** surface water presence **(water/non-water)** at **10-meter** spatial resolution for 2 years **(July 2018 to June 2020)**
- Full freedom to come from input data to requested output



(free and open datasets only)

Validation (sample based)

- Stratified random sampling to ensure sampling across the continuum from permanent water to non-water
- Samples collected every 2. month (2019)
- Sample sizes adjusted within sites and strata:
  - bigger strata –> more samples
  - the higher expected variance in the strata –> more samples
- Accuracy assessments using standard metrics
  - Overall accuracy (OA), producers' accuracy (PA) and users' accuracy (UA);
- Nearly 10.000 samples in total



Object extraction accuracy

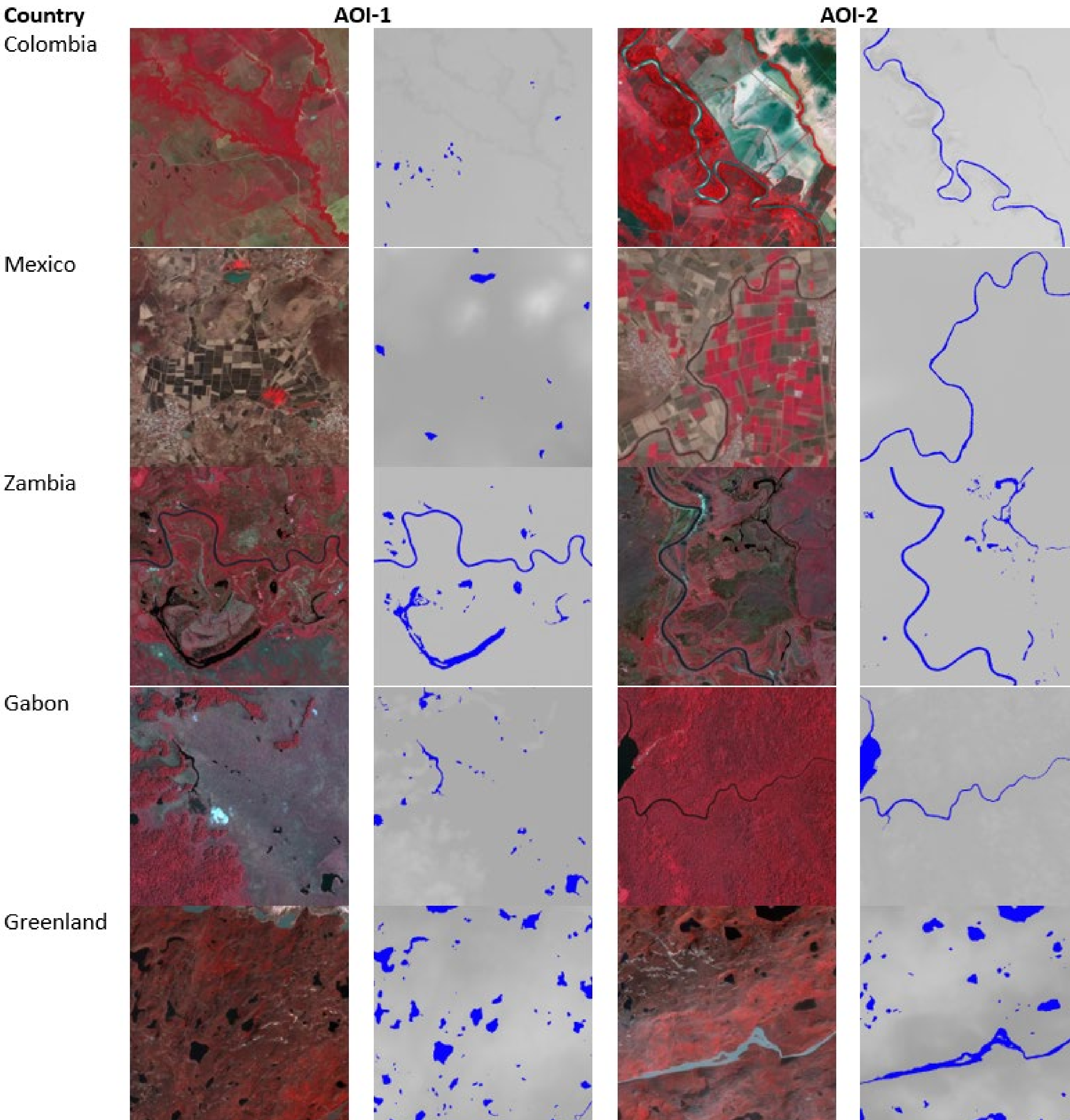
- The conventional sample-based validation was complemented with an evaluation of object extraction accuracy
- Based on the combined measure of Maximum overlap area:

$$A_{max} = \frac{1}{2}\left(\frac{A_{C,i} \cap A_{R,j}}{A_{C,i}} + \frac{A_{C,i} \cap A_{R,j}}{A_{R,j}}\right)$$

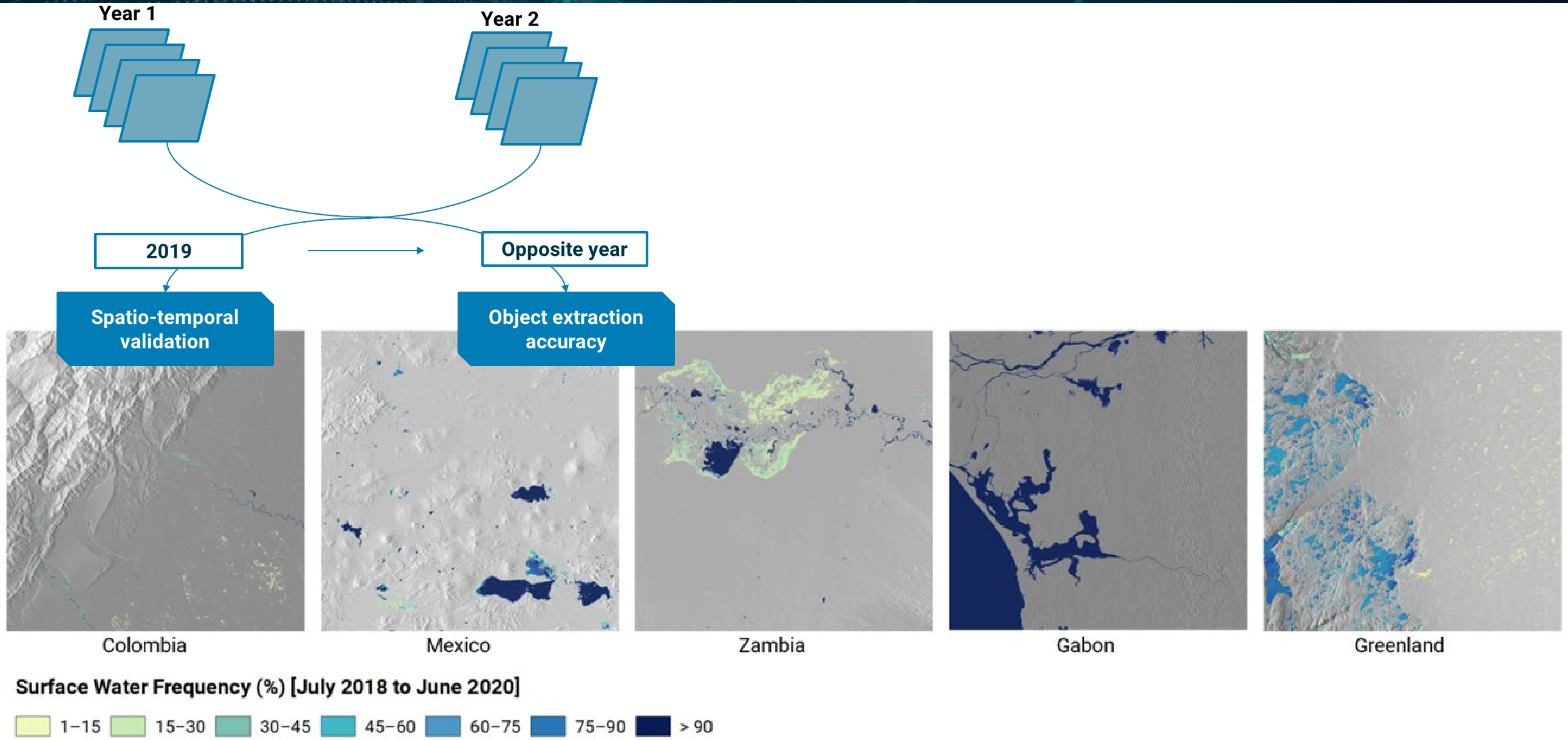
and the Area quality match:

$$A_{qual} = \frac{A_C}{A_{DC} + A_{RC} - A_C}$$

- The range of overlap/quality is 0 to 1.



Evaluating two-years of data

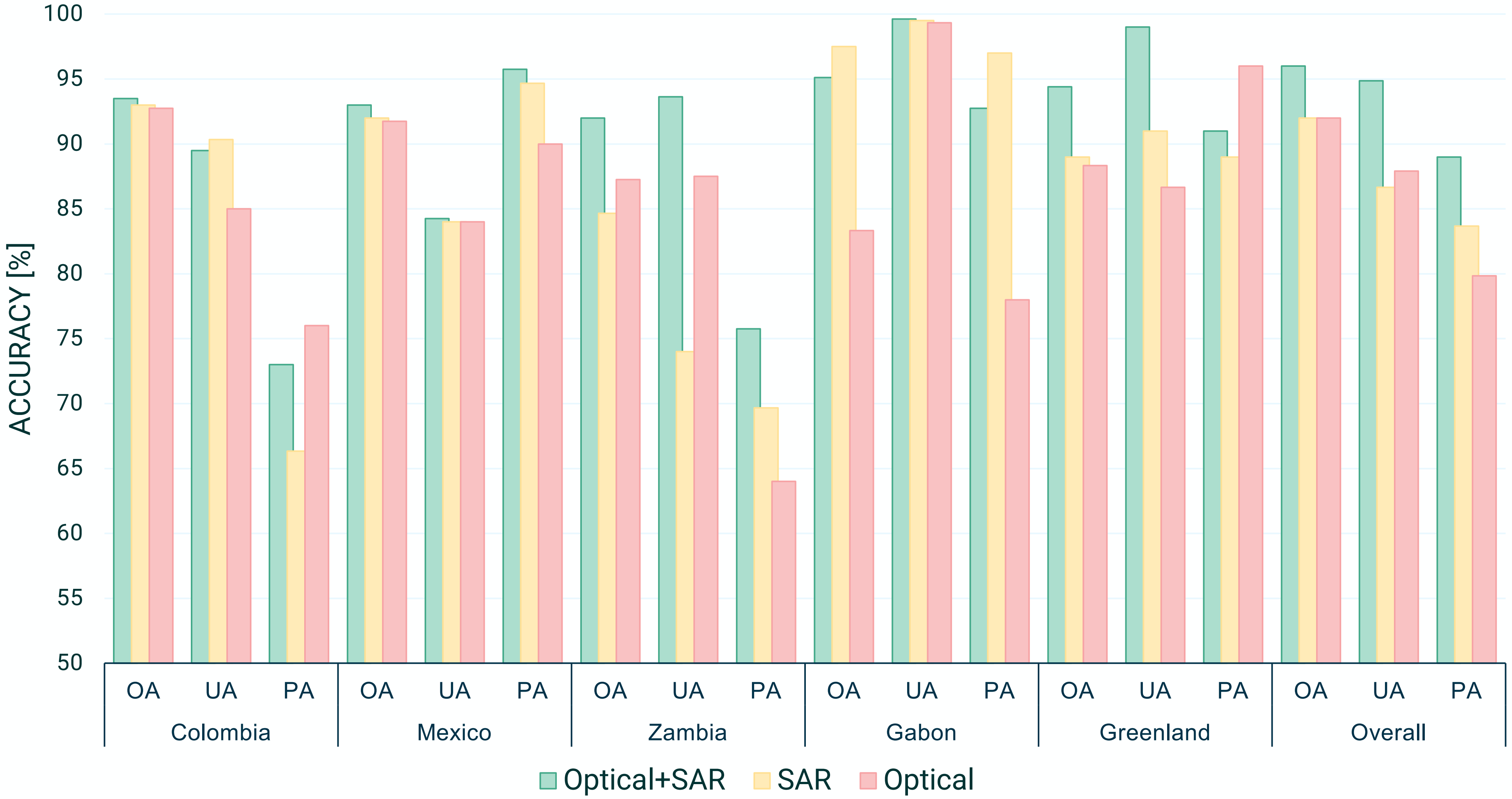


Results (sample based)

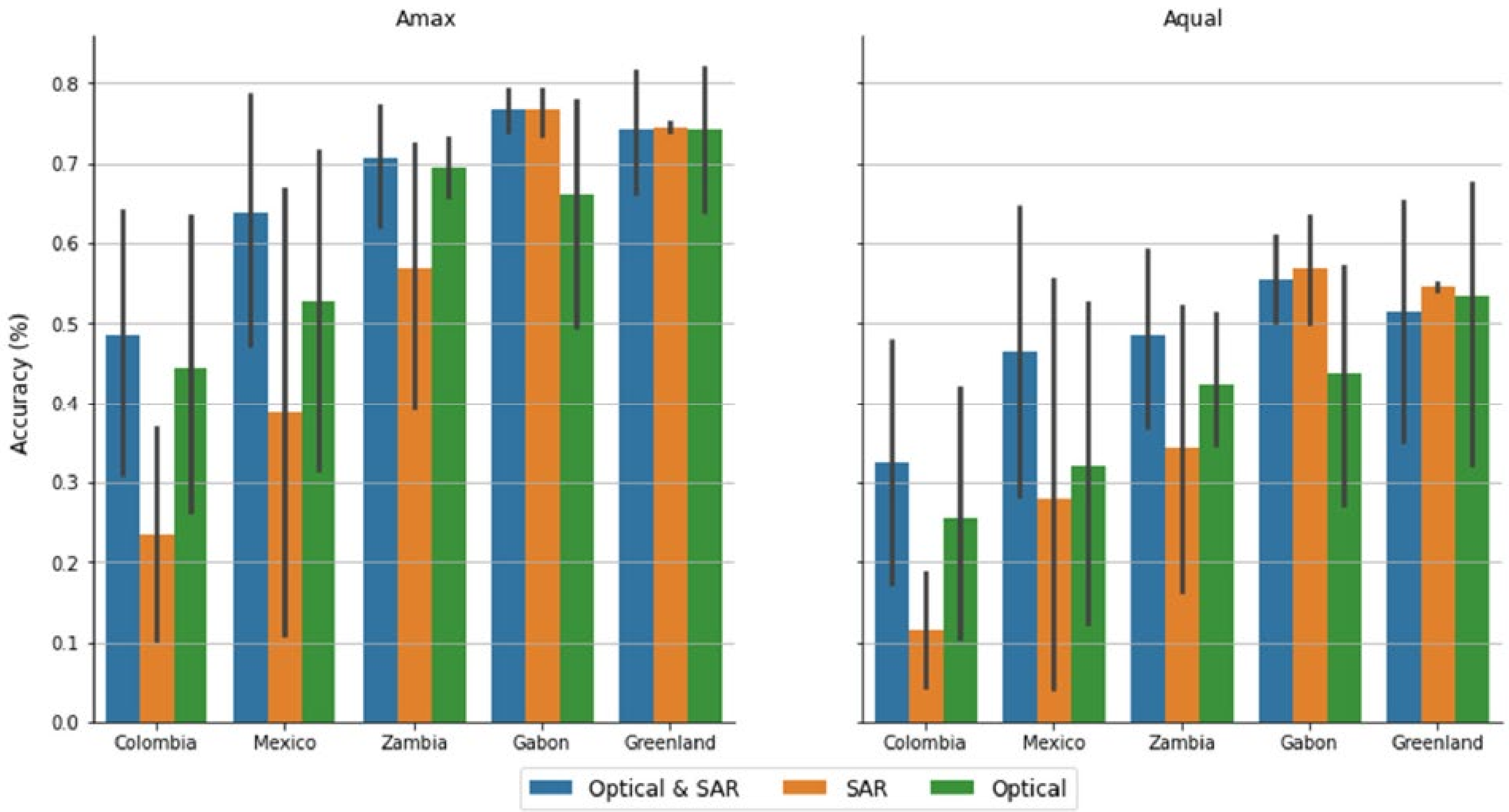
esa

model	Colombia			Mexico			Zambia			Overall (mandatory sites)			Gabon			Greenland		
Model	OA	UA	PA	OA	UA	PA	OA	UA	PA	OA	UA	PA	OA	UA	PA	OA	UA	PA
A [o+s]	94	81	85	94	85	99	92	99	71	97	95	93	99	99	98	-	-	-
B [o+s]	94	95	71	94	84	98	84	68	75	94	85	90	95	100	93	-	-	-
C [o+s]	90	98	43	93	84	95	91	97	68	95	98	81	91	98	87	89	100	81
D [o+s]	91	93	58	93	84	98	92	99	71	96	98	85	90	100	85	-	-	-
E [s]	93	90	65	93	82	99	77	54	70	90	77	88	97	100	96	-	-	-
F [o+s]	93	76	85	90	86	80	91	96	70	94	92	83	98	100	98	94	100	90
G [s]	92	94	58	90	87	87	89	86	69	93	93	80	-	-	-	-	-	-
H [o]	95	98	74	94	85	98	90	100	62	97	100	87	-	-	-	-	-	-
I [o]	94	95	71	94	85	97	91	100	67	95	97	85	82	100	74	95	99	92
J [s]	94	87	76	93	83	98	88	82	70	93	90	83	98	99	98	89	91	89
K [o+s]	92	92	57	88	81	80	85	71	73	91	84	77	-	-	-	-	-	-
L [o]	92	83	68	91	82	90	75	53	53	89	77	78	75	99	69	85	81	98
M [o]	90	64	91	88	84	75	93	97	74	93	87	85	93	99	91	85	80	98
N [o+s]	96	95	84	94	83	100	96	96	87	98	97	96	98	100	97	97	97	98
O [o+s]	96	89	84	93	84	98	95	97	82	97	97	92	95	100	92	96	99	93

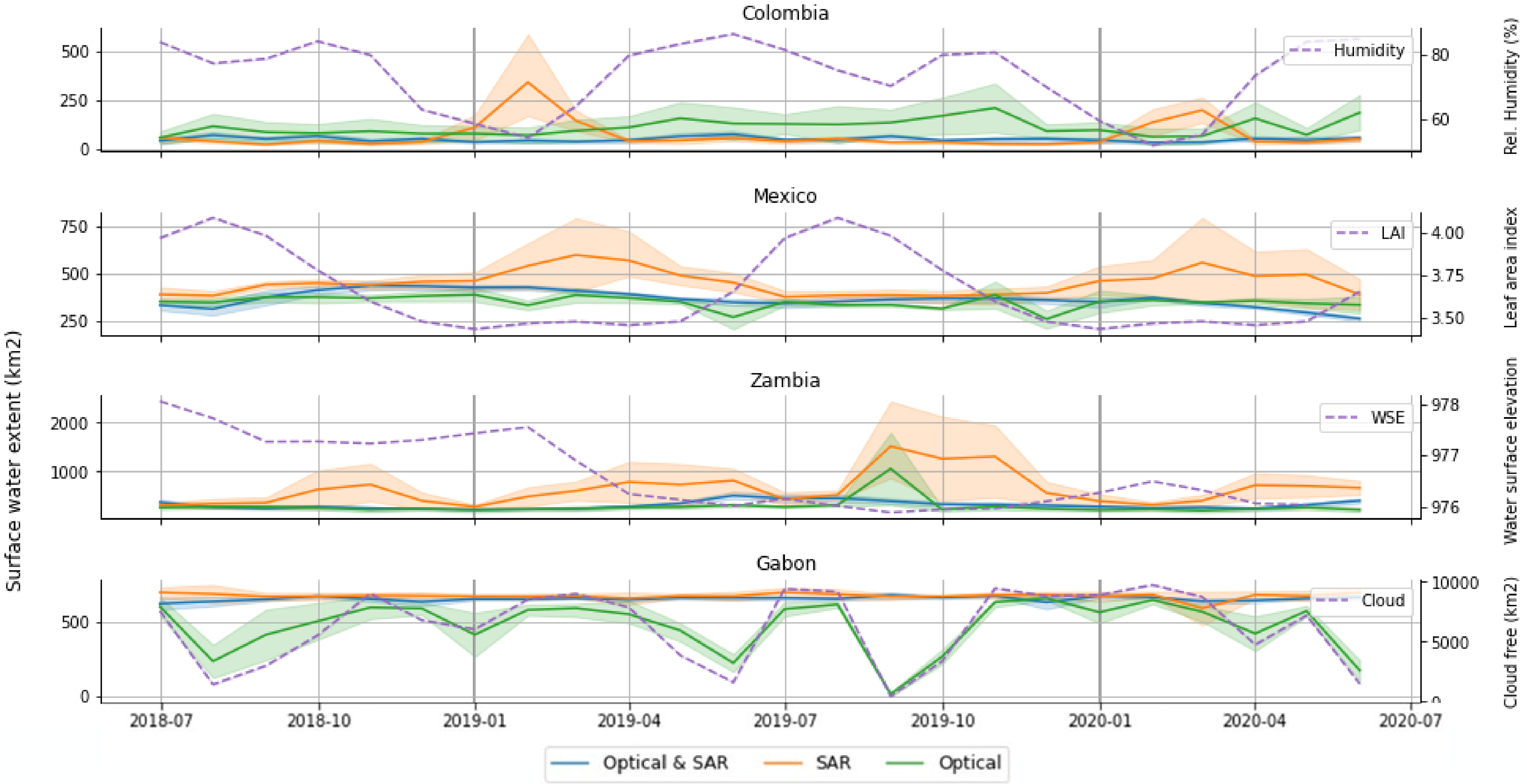
Accuracy by model type

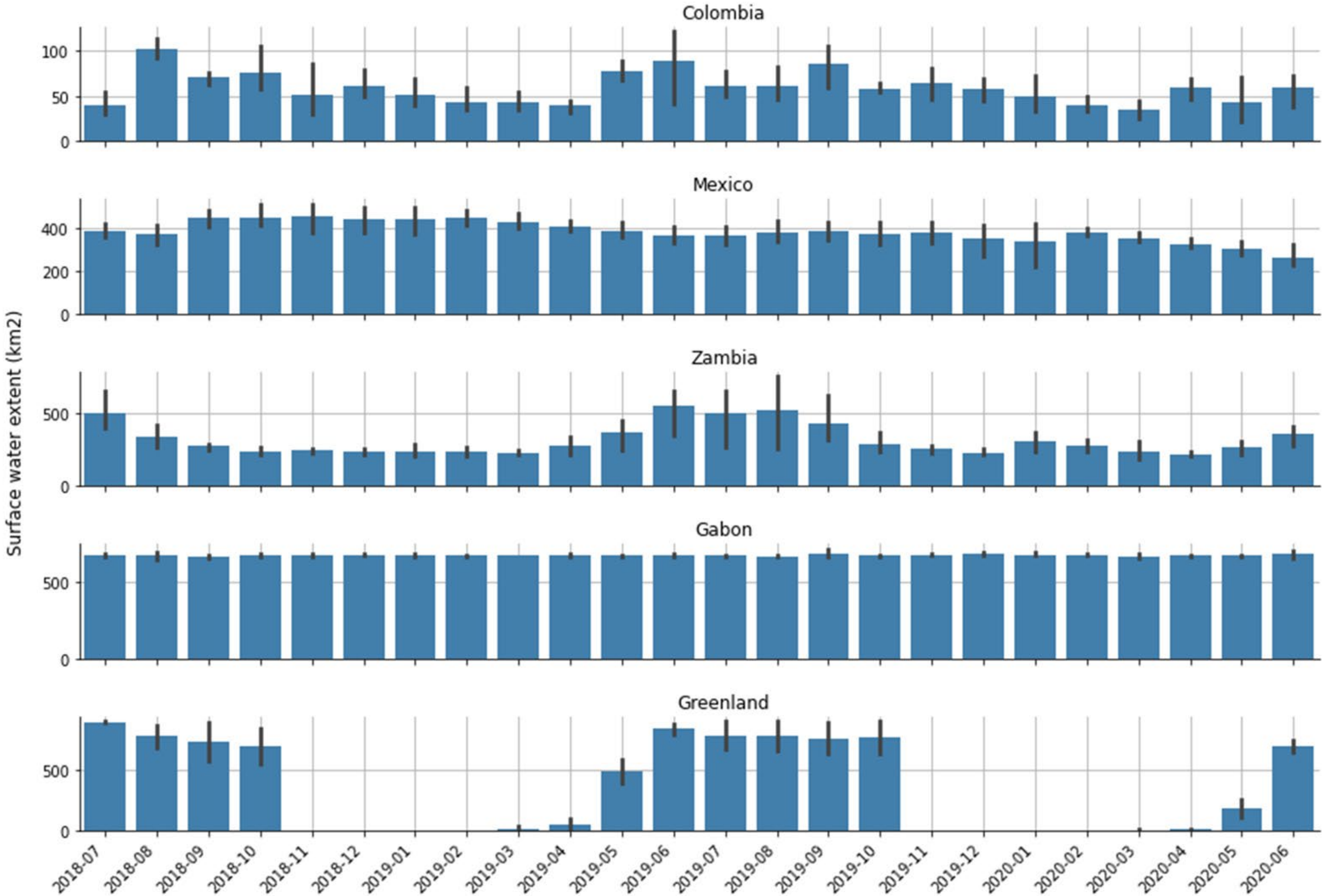


Object accuracy evaluation



Results (sample based)



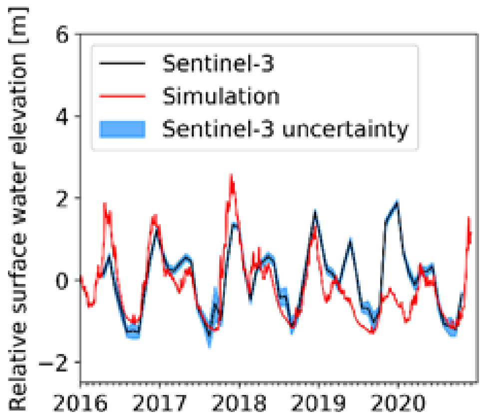

Colombia
Mexico
Zambia
Gabon
Greenland
Surface water extent (km2)
100
50
0
400
200
500
2018-07
2018-08
2018-09
2018-10
2018-11
2018-12
2019-01
2019-02
2019-03
2019-04
2019-05
2019-06
2019-07
2019-08
2019-09
2019-10
2019-11
2019-12
2020-01
2020-02
2020-03
2020-04
2020-05
2020-06

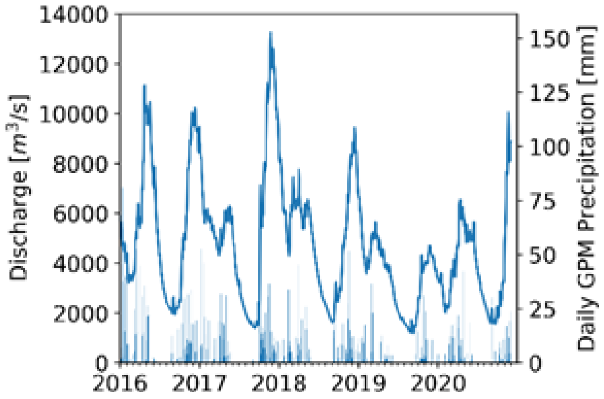
Conclusion & Outlook

- Regular and systematic EO data acquisitions provides an efficient tool for monitoring, and statistical reporting on surface water dynamics:
  - A dual sensor approach should be preferred, at larger scales across diverse ecological gradient
  - Yet, SAR data may be preferred for the effective and timely monitoring of water extent and potential emerging floods during cloudy periods
  - and similar optical data may be preferred to monitor the status of farm dams and smaller waterbodies during drought periods and when clouds are not an issue.
- Combined with the advances in technical infrastructures for big data analysis, it is now within the realm of countries to implement satellite-based surface water monitoring systems

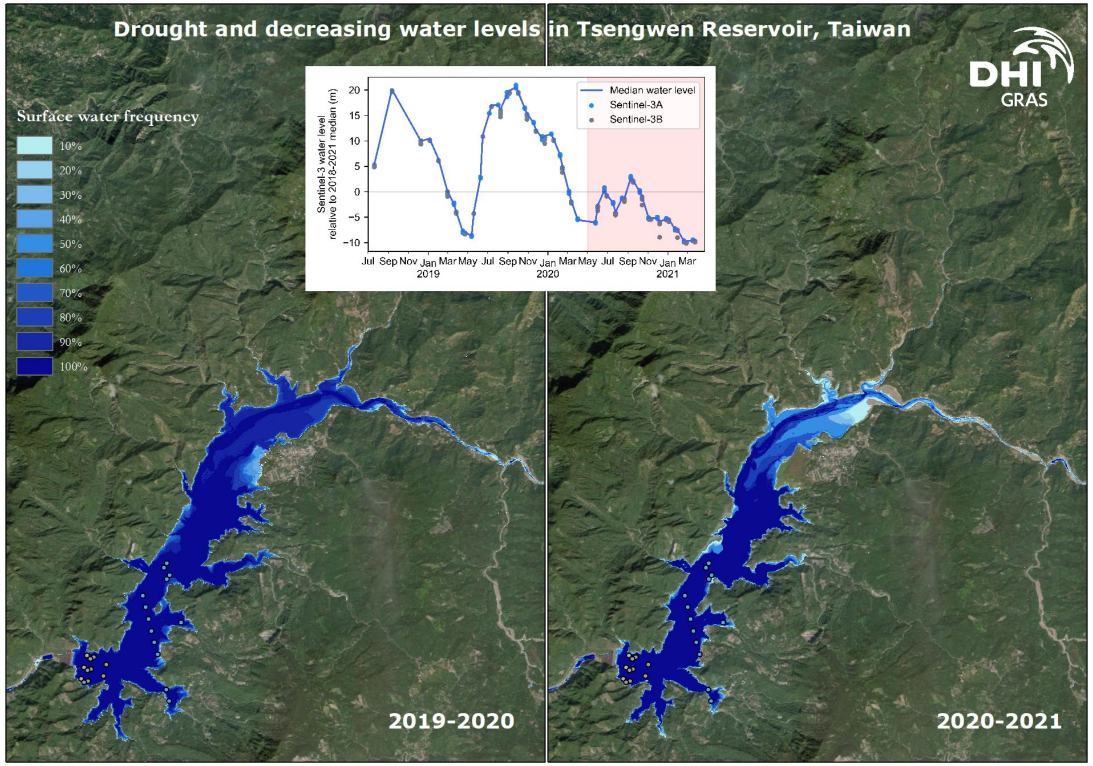
From water extent to quantity

- Satellite altimetry missions monitor river & lake level changes globally
- Surface water extent maps can be used to optimize altimetry target selection for inland water bodies





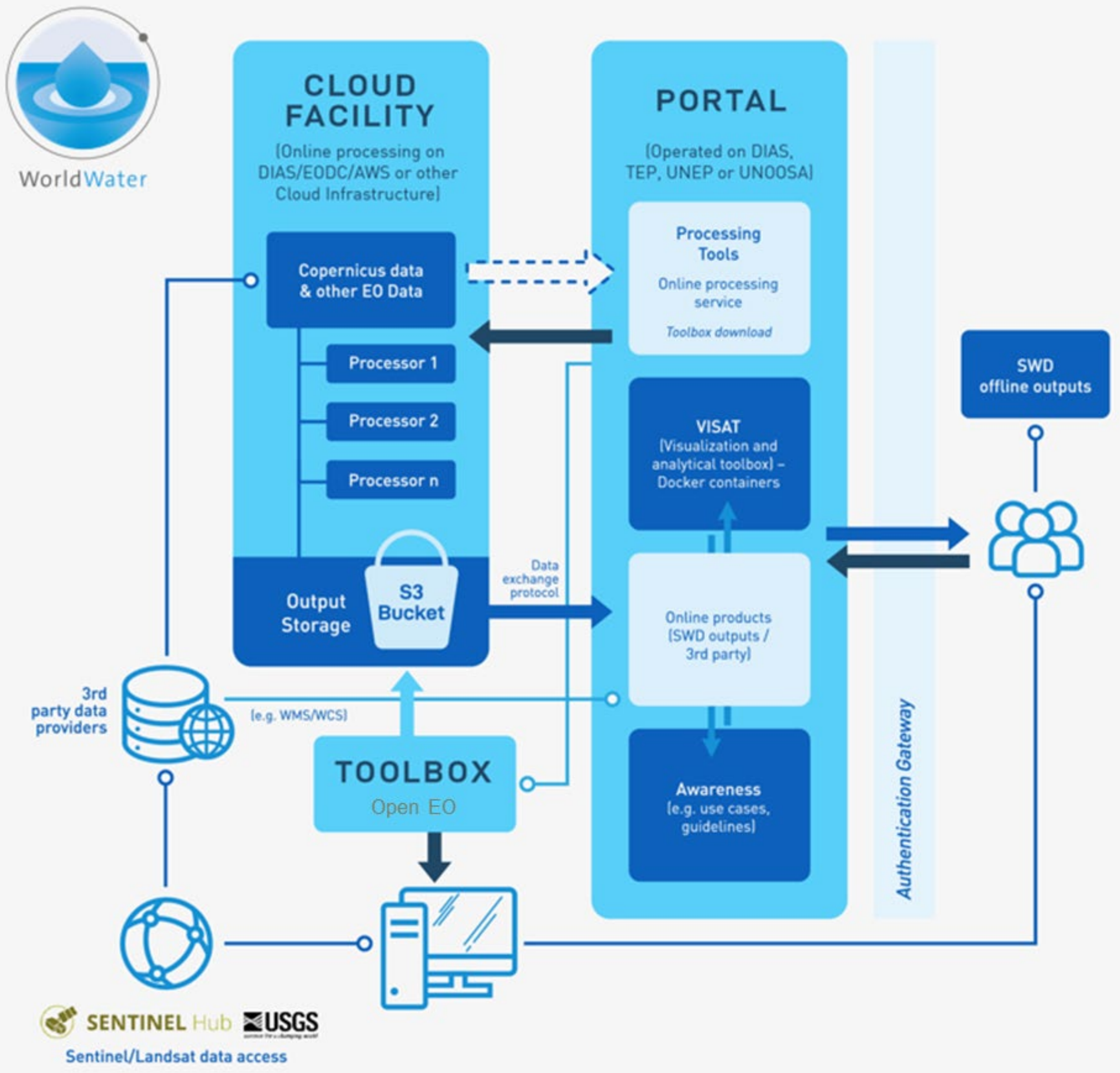
- Synergy with hydrologic and hydraulic modelling to produce discharge



Water extent dynamics and water level time series can track water storage changes in reservoirs

Enabling EO based national monitoring

- Member States own SDG monitoring and there is a need to recognize the critical importance of supporting countries in strengthening the capacity of national statistical offices, line ministries and data systems to ensure access to high quality, timely and reliable and data
- Flexible methodologies to enter monitoring in line with national capacity and resource availability



Acknowledgement

Round Robin paper availble at:https://www.mdpi.com/2072-4292/14/10/2410

WorldWater consortium

DHI gisat GeoVille GRID ARENDAL A Centre Collaborating with UNEP DTU

The validation data samples used in this study are openly available in Zenodo at https://doi.org/10.5281/zenodo.6539508

remote sensing MDPI

Article

Surface Water Dynamics from Space: A Round Robin Intercomparison of Using Optical and SAR High-Resolution Satellite Observations for Regional Surface Water Detection

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