

# Prospects and Challenges in the Field of Geospatial Data and its Applications

## to **Overcome Data Deficiency** for Evidence-Based Decision-Making in the Water and Agriculture sectors

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Giuseppe Ottavianelli<sup>2</sup>, Benjamin Koetz<sup>2</sup>, Zoltán Szántói<sup>2</sup>,  
and many other ESA colleagues  
Presented by: Zoltán Vekerdy<sup>1</sup>,  
<sup>1</sup>ESA EO AFRICA R&D Facility  
<sup>2</sup>ESA - ESRIN

Fourth Meeting of the High-Level Joint Water-Agriculture Technical  
Committee of the League of Arab States,  
Cairo, Egypt

18. October 2022.

## EUROPE'S GATEWAY TO SPACE

### WHAT

22 Member States, 4 associate members,  
5000 employees

### WHY

Exploration and use of space for  
exclusively peaceful purposes

### WHERE

HQ in Paris, 7 sites across Europe  
and a spaceport in French Guiana

### HOW MUCH

€6.68 billion = €12 per European per year





## • Building on a long-term cooperation

- Project based – e.g. GlobCover 2005, TropForest 2010, Sen2Agri 2013, Sen4Stat 2018
- FAO engaged as key user driving requirements

## • FAO ESRIN visit 2020

- Identification of priority thematic areas

## • Setup of FAO-ESA MoU

- Design of common Activity Plan (MoU Annex)
- Formalization of the MoU – signature in April 2021



## FAO & ESA MoU COOPERATION ON THE USE OF EARTH OBSERVATION FOR FOOD AND AGRICULTURE

FAO and the European Space Agency unite to support countries in achieving the SDGs

A new Memorandum of Understanding enhances the use of Earth observation data for food and agriculture statistics

**Objective:** “to improve the exchange of expertise between the Parties, to facilitate the development of Earth Observation applications and exchange of relevant data, to enhance the understanding of agricultural processes and food systems [...]”

- **Main benefits (Article 2):**

- Identification and understanding of the requirements;
- Facilitation of sharing of field data sets
- Support of access to open Earth Observation data sets
- Development of innovative Earth Observation algorithms, products and applications using cloud computing;
- Demonstration and validation of Earth Observation capabilities
- Support of capacity development of Earth Observation skills for FAO

- **6 thematic priorities (MoU Annex):**

- Agriculture, water productivity, forestry, land cover, early warning, SDG reporting

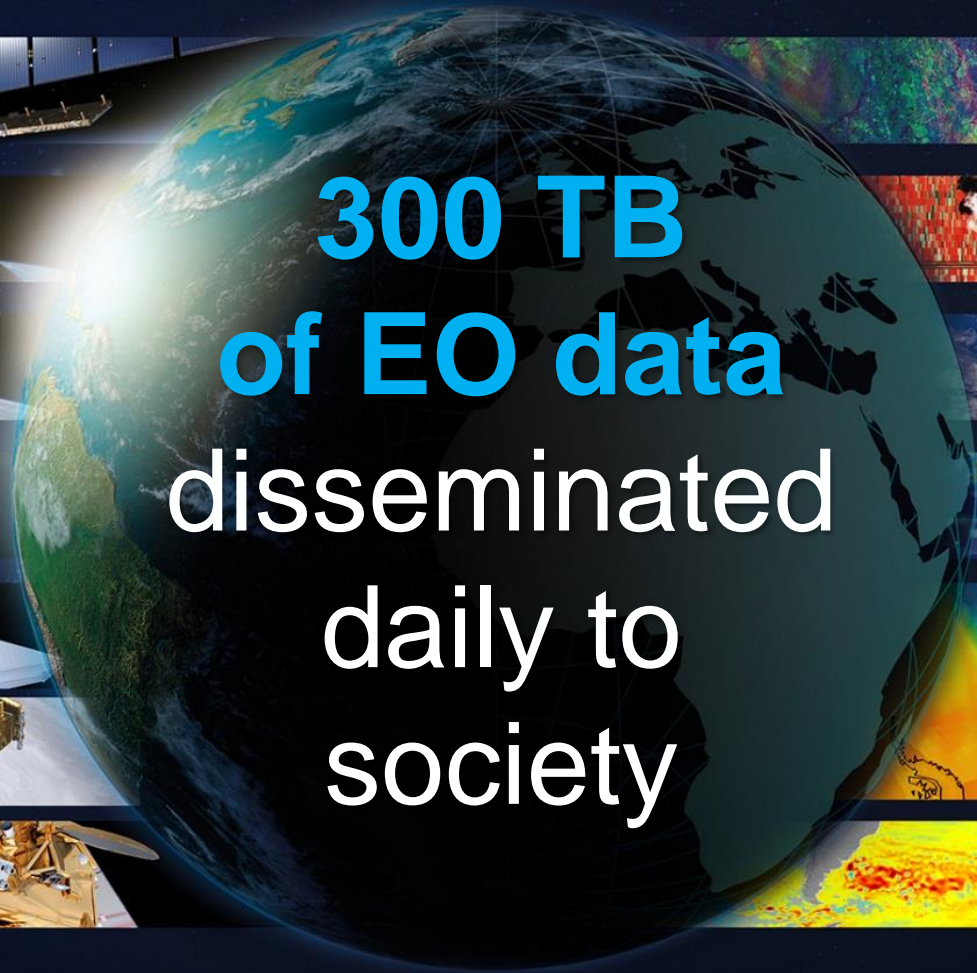
- **Activity plan** for the next 3 years by thematic, progress to be reviewed annually







# Copernicus Sentinels (First Generation)



**300 TB**  
**of EO data**  
disseminated  
daily to  
society

sentinel-1

→ RADAR VISION

sentinel-2

→ COLOUR VISION

sentinel-3

→ A BIGGER PICTURE

sentinel-4

→ EUROPEAN AIR MONITORING

sentinel-5p | sentinel-5

→ GLOBAL AIR MONITORING

sentinel-6

→ CHARTING SEA LEVEL



*Monitoring the State of the Earth System Environment ...*

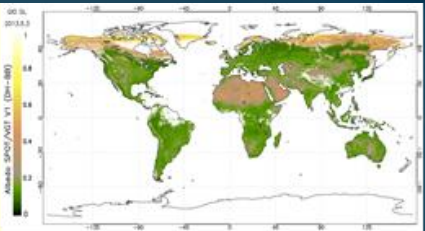


*... Six cross-cutting Thematic Services*





Global Systematic Monitoring



Global Hot Spot



Pan-European land cover mapping

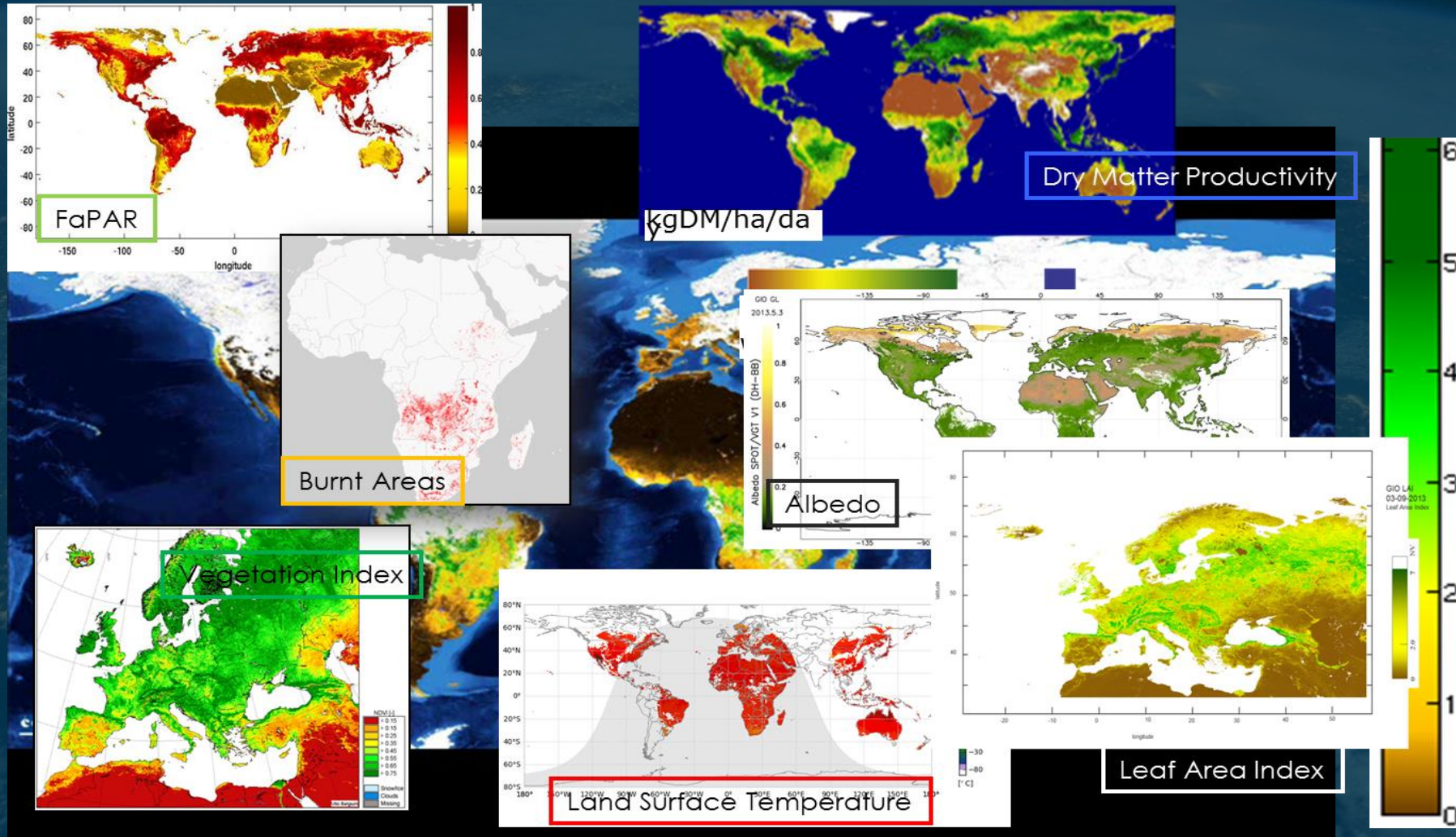


EU Local component





# Land Service: Global portfolio





# Land services: variables

Products (vegetation - energy - water) providing a picture of the world :

- Ten daily frequency / Delivery timeliness 3 days
- Resolution from 1km to 300m and 100m
- Current Portfolio of 27 products

Product Family	Product (Variable)	
	Full name	Acronym
Vegetation	Leaf Area Index	LAI
	Fraction of absorbed photosynthetically active radiation	FAPAR
	Fraction of vegetation cover	Fcover
	Normalized Difference Vegetation Index	NDVI
	Vegetation Condition Index	VCI
	Vegetation Productivity Index	VPI
	Greenness Evolution Index	GEI
	Dry Matter Productivity	DMP
	Phenology metrics	PHENO
	Evapotranspiration	ET
	Radiation fluxes	
	Global Land Cover	GLC
	Active Fires	AF
	Burnt Areas	BA
Energy Budget	Top Of Canopy Reflectance	Toc-R
	Surface Albedo	SA
	Land Surface Temperature	LST

Product Family	Product (Variable)	
	Full name	Acronym
Water	Surface Soil Moisture	SSM
	Soil Water Index	SWI
	Water Bodies	WB
Snow	Snow water extend	SE
	Snow water equivalent	SWE
Lake	Lake ice coverage	
	Lake surface water temperature	
	Lake and river water level	
	Lake surface reflectance	
	Lake turbidity	
	Lake trophic state	
Coastal	Erosion	



# Activities and results

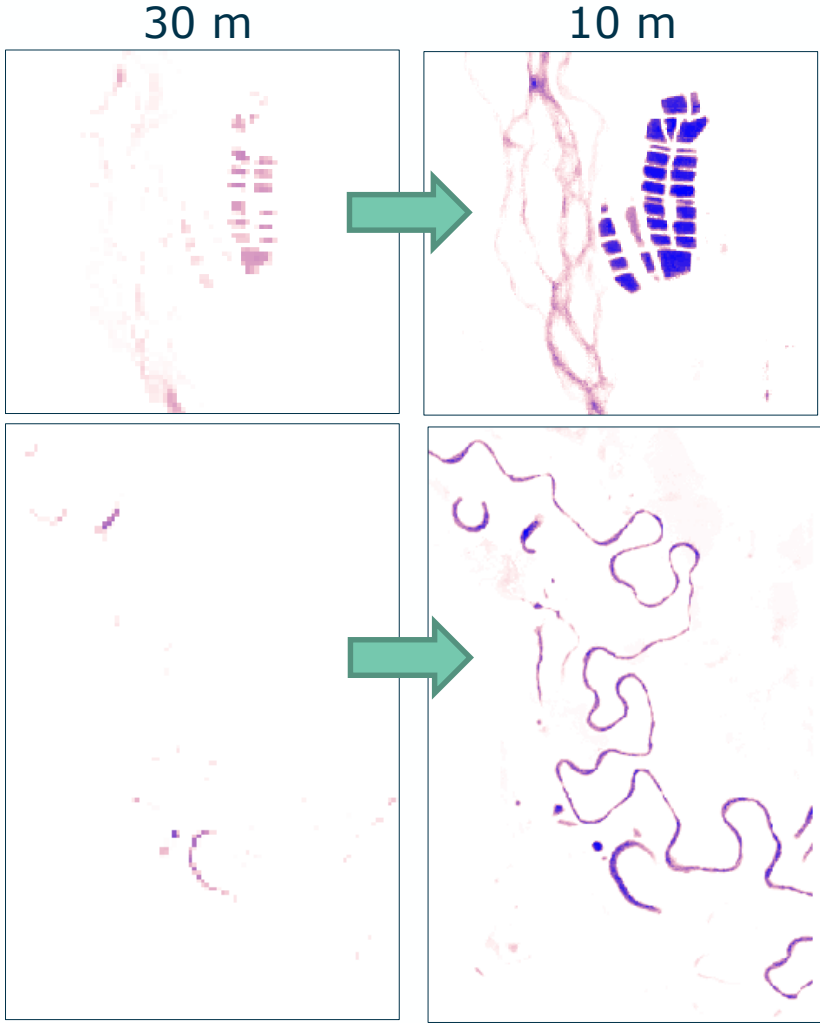
# Water Resources Management





# Surface Waters examples

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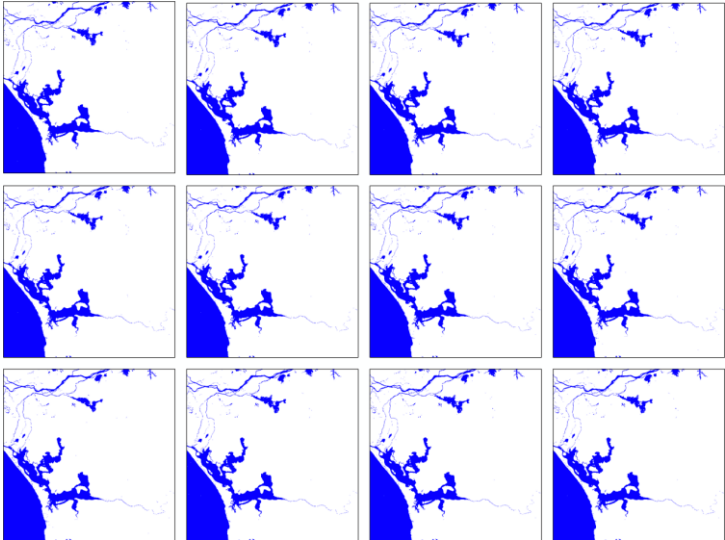


**WorldWater**  
SURFACE WATER DYNAMICS FROM SPACE

New advanced algorithms.  
Methods intercomparisons.

WATER EXTENT AND VOLUME.

Monthly water masks: (S1+S2)

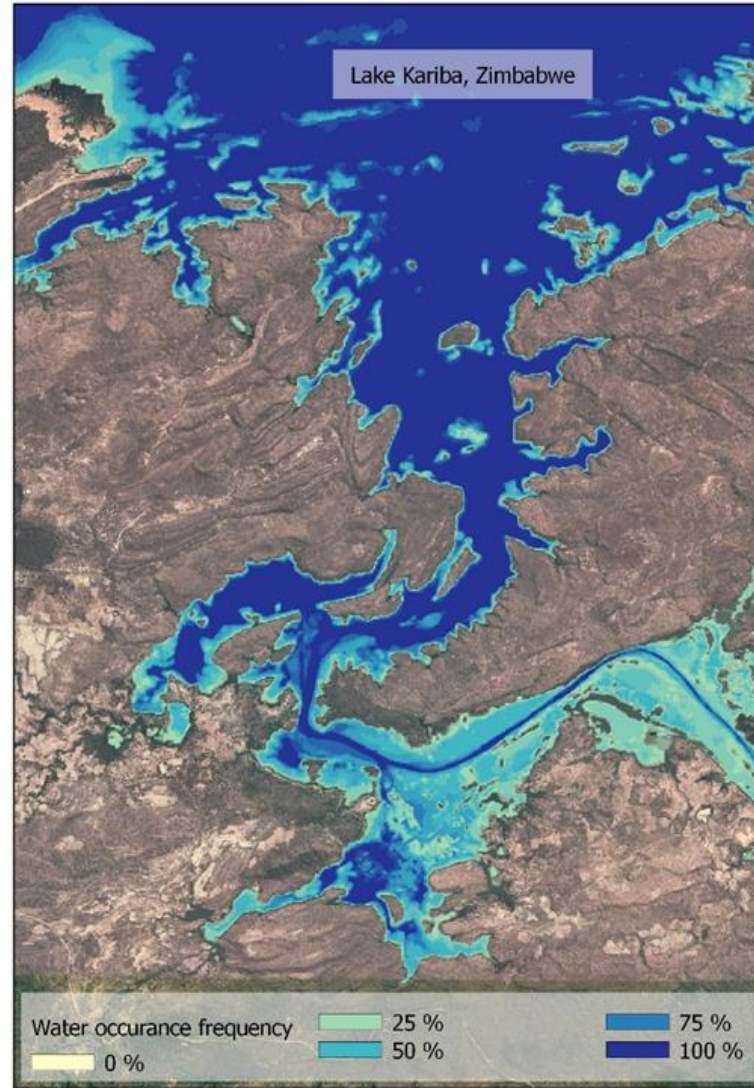
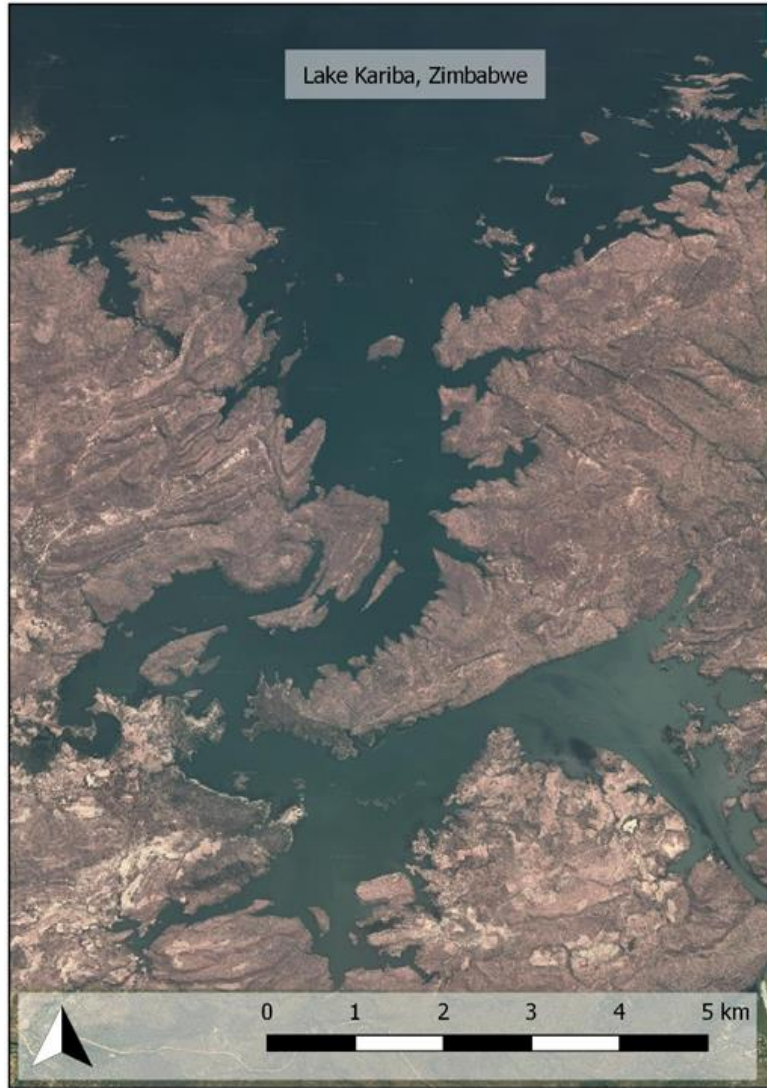


Involved stakeholders

National Water Management Agencies, River Basin Authorities





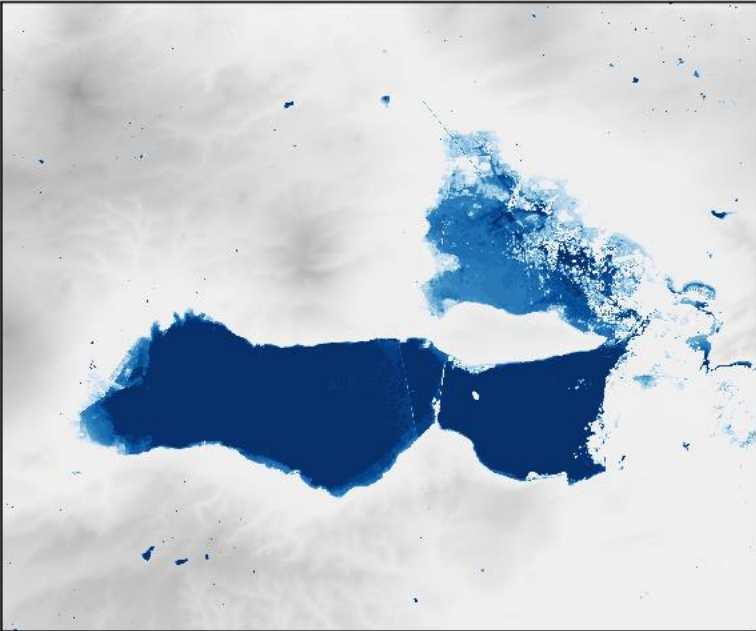


## Changes in surface water extent *Lake Kariba, Zimbabwe*

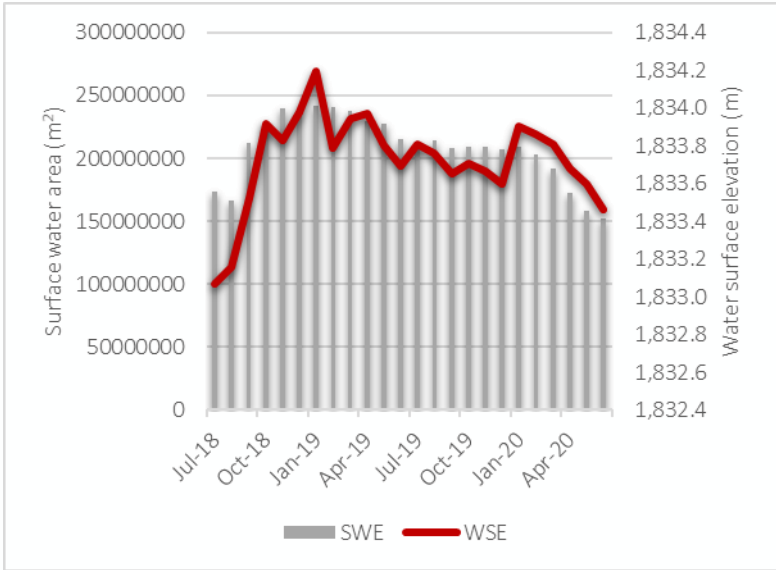
Southern shore of Lake Kariba, Zimbabwe, 12-month **water occurrence frequency map** synergistic use of Sentinel -1 and -2

# Changes in Lake volume

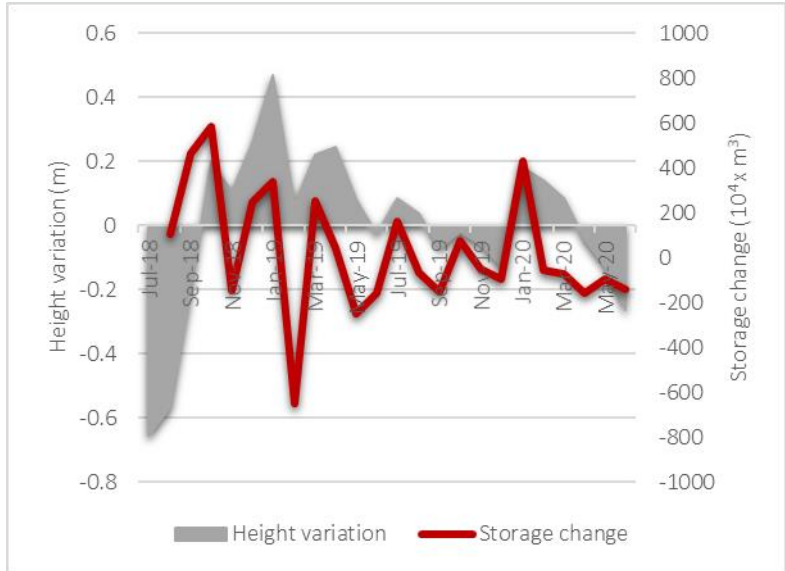
## Lake Cuitzeo, Mexico



**Multi-annual surface water frequency**  
From Sentinel-1 and -2.



**Monthly water surface elevation (WSE) timeseries from Sentinel-3**  
**Monthly surface water extent (SWE) timeseries**  
From Sentinel-1 and Sentinel-2

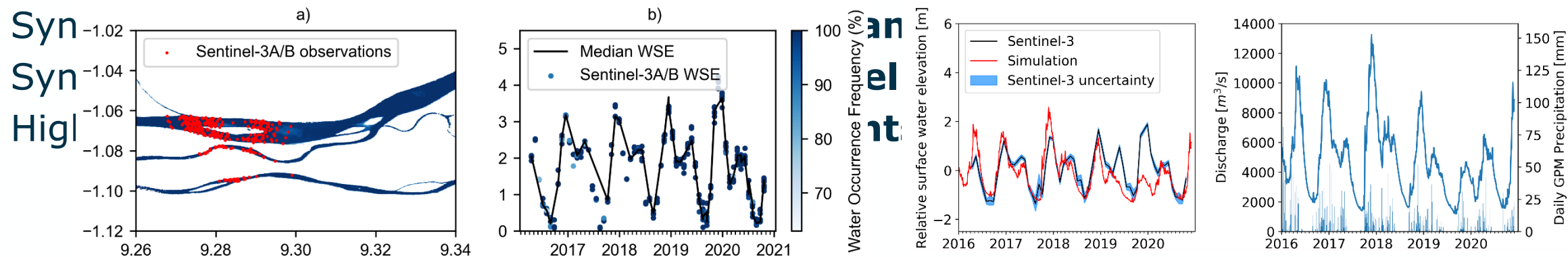


**Water level variations and Lake storage changes**

# Changes in river discharge

## From river water level to river discharge

Satellite altimetry missions monitor river level changes globally  
Fleet of satellites carrying altimeters growing





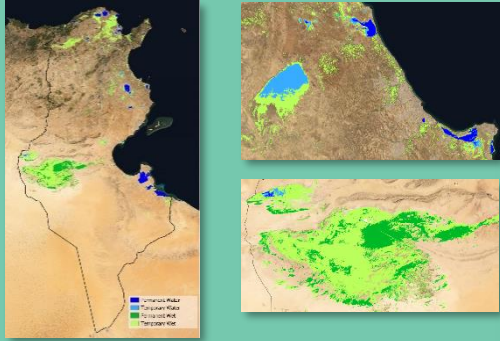
# Wetlands, Soil Moisture and Evapotranspiration examples

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## → WETLAND INVENTORY

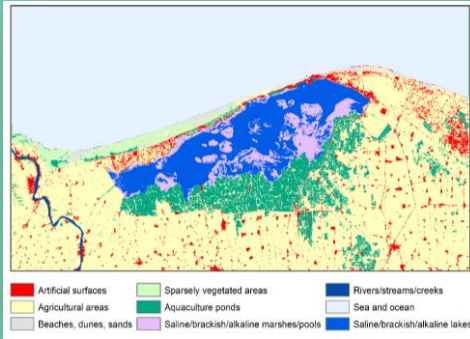
The wetland inventory product serves the needs of national/regional agencies interested in exploring the possibilities to reduce costs associated with doing large wetland inventories, and with a particular relevance for the monitoring requirements under the sustainable development goals (cf. indicator 6.6.1 "change in extent of water-related ecosystems").



Level of maturity

## → WETLAND HABITAT MAPPING

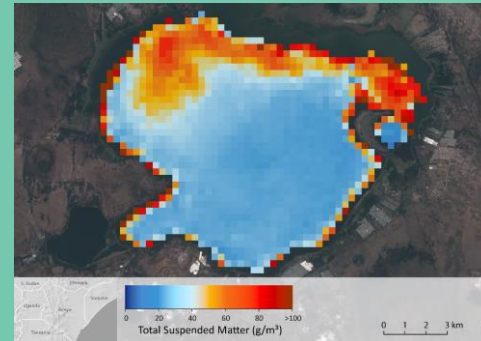
The wetland habitat mapping provides users with a detailed map of wetlands and their surrounding areas. From historic EO data, information on land use changes can be obtained and from which wetland threats (e.g. agriculture or urban pressures) and their impacts over time can be assessed.



Level of maturity

## → WATER QUALITY

Earth Observation derived water quality parameters such as chlorophyll-a concentrations and total suspended sediments allow users to monitor wetland ecosystem contamination such as water body eutrophication due to excessive nutrients from urban and industrial waste discharge or increased levels of suspended sediments caused by deforestation and soil erosion.



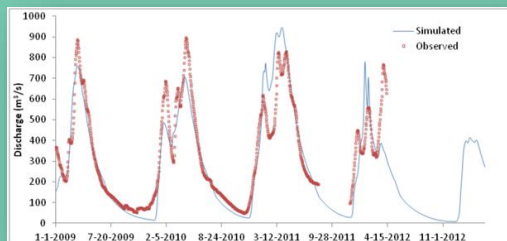
Level of maturity

## Sentinels for wetland inventory, assessment and monitoring

- **Multi-sensor information (S1+S2+S3)** allow to overcome limitations of single sensor approaches.
- **10m spatial resolution** allow to have more spatial details for capturing the variety of small habitats in wetlands and for detecting small water bodies.
- **Short repeat cycle** allow to capture the flooding regimes of wetlands (permanent and seasonal waters) that are important indicators of wetland healthy conditions, and to detect decreases in water availability (due to misuse, abstraction & climate change).
- **Systematic global acquisitions** allow to improve wetland inventories globally, which are still largely lacking.

## → RIVER BASIN HYDROLOGY

The River Basin Hydrology is a hydrological modelling framework using Earth Observation data and in-situ observations for assessing the water balance and analysing the changes in the inflow hydrographs to selected wetlands in response to e.g. climate change, land use changes, and hydropower.



Level of maturity

## → MANGROVES MAPPING

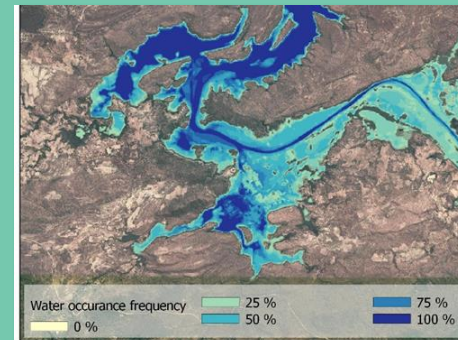
This product supports full inventorying of mangrove areas i.e. mapping of the mangrove extents and the characterization of the spatial distribution and the geometrical/structural arrangements of mangroves.



Level of maturity

## → INUNDATION REGIME

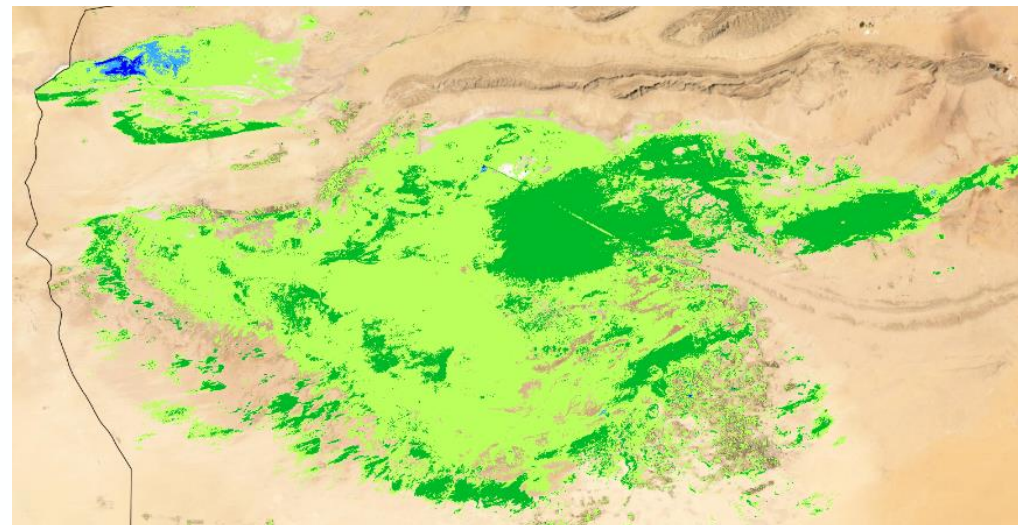
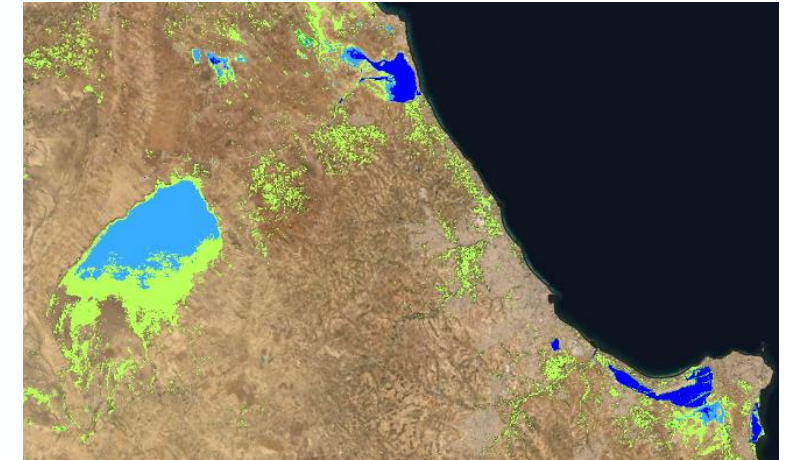
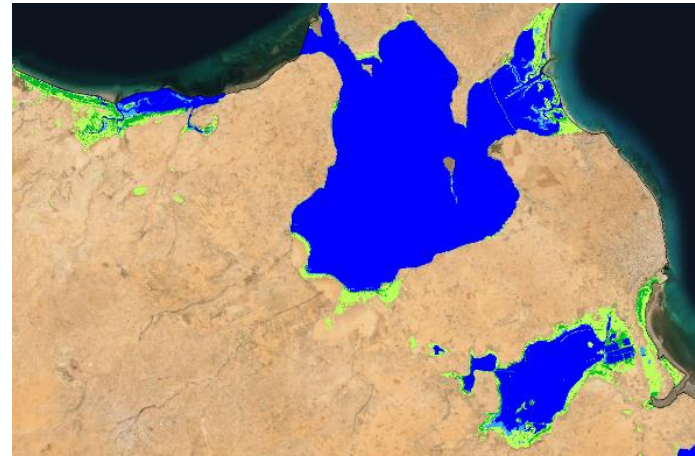
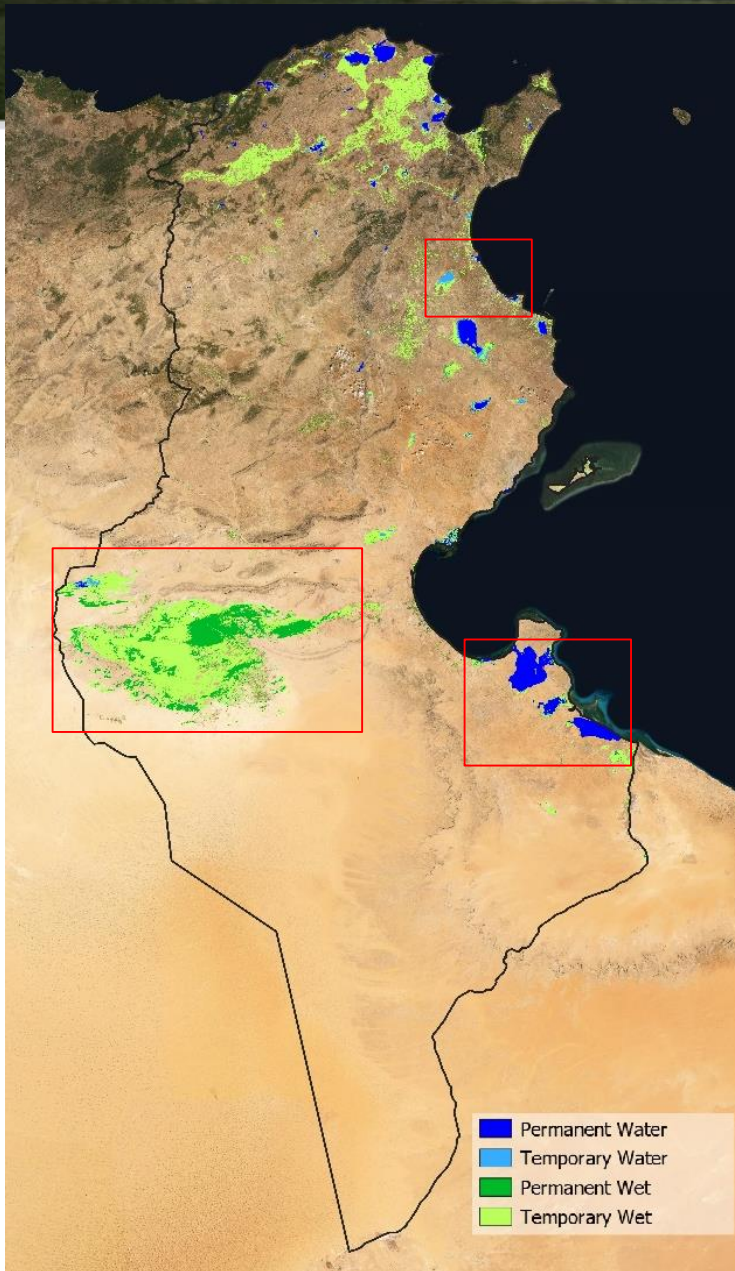
Time-series of EO data allow for the characterization of the inter- and intra-annual variations of the water tables, to monitor the dynamics of water retention and flow and to assess how these changes in the inundation regime may affect the overall wetland ecosystem.



Level of maturity



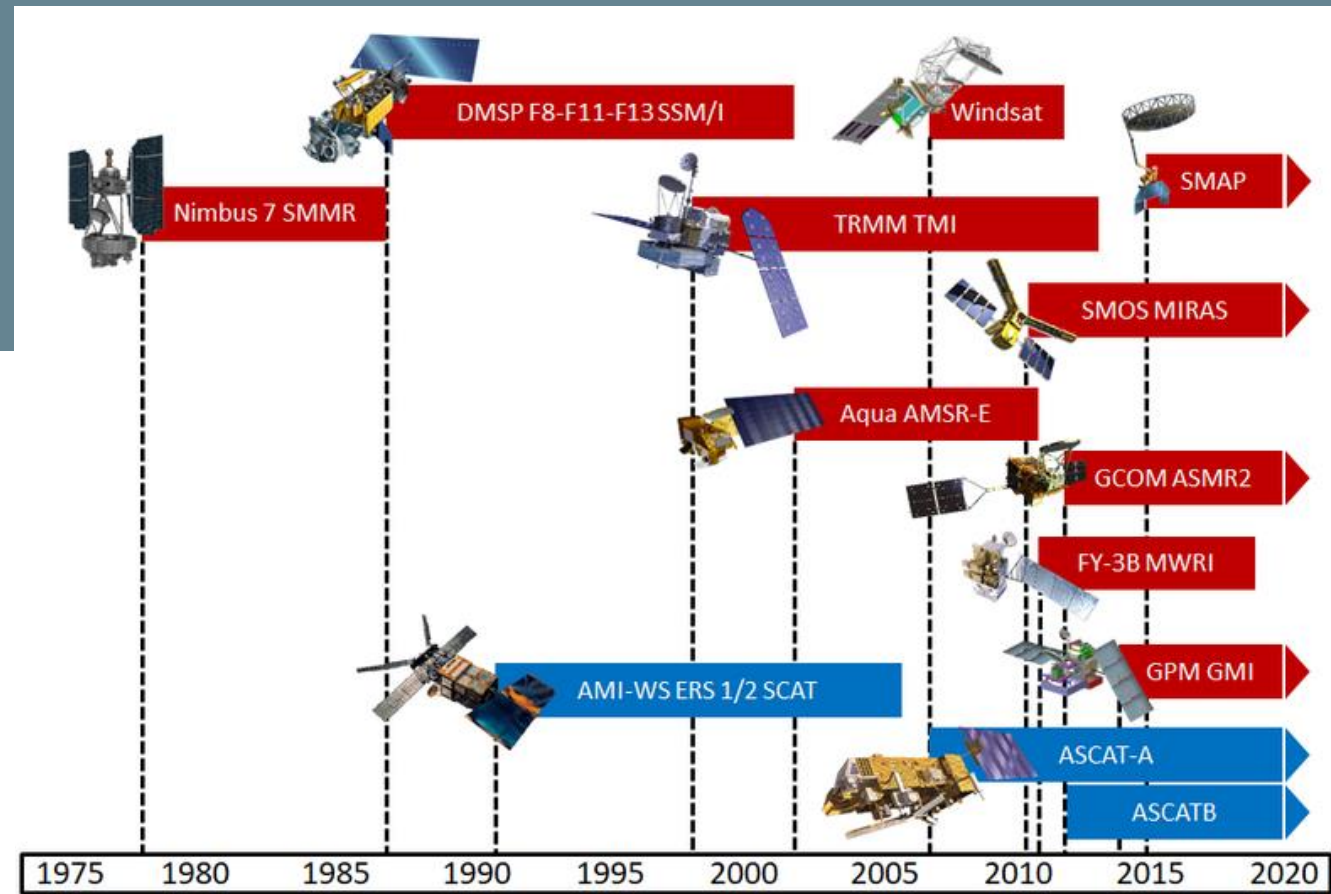
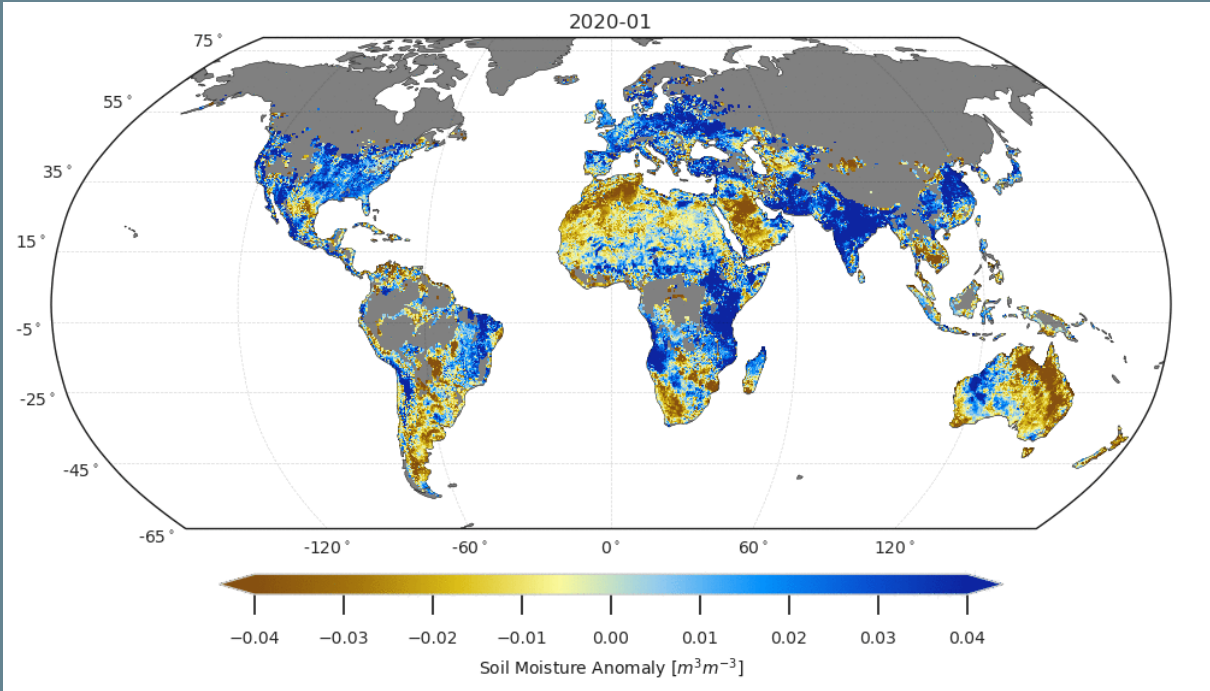
# GlobWetland Africa Wetland Pre-inventories: Tunisia





# Climate Change Initiative: Soil Moisture

- Annually algorithmically updated global climate data record of soil moisture spanning > 40-yr
- 3 separate soil moisture products derived from active, passive and combined (active + passive) sensors
- 12 public releases to date

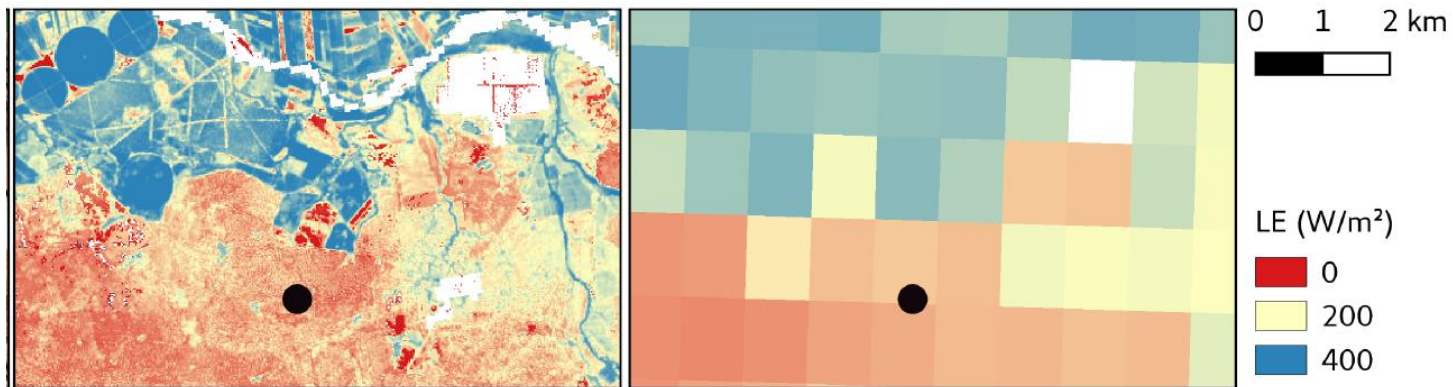


ESA CCI soil moisture v06.1 products utilize 4 active and 10 passive microwave sensors



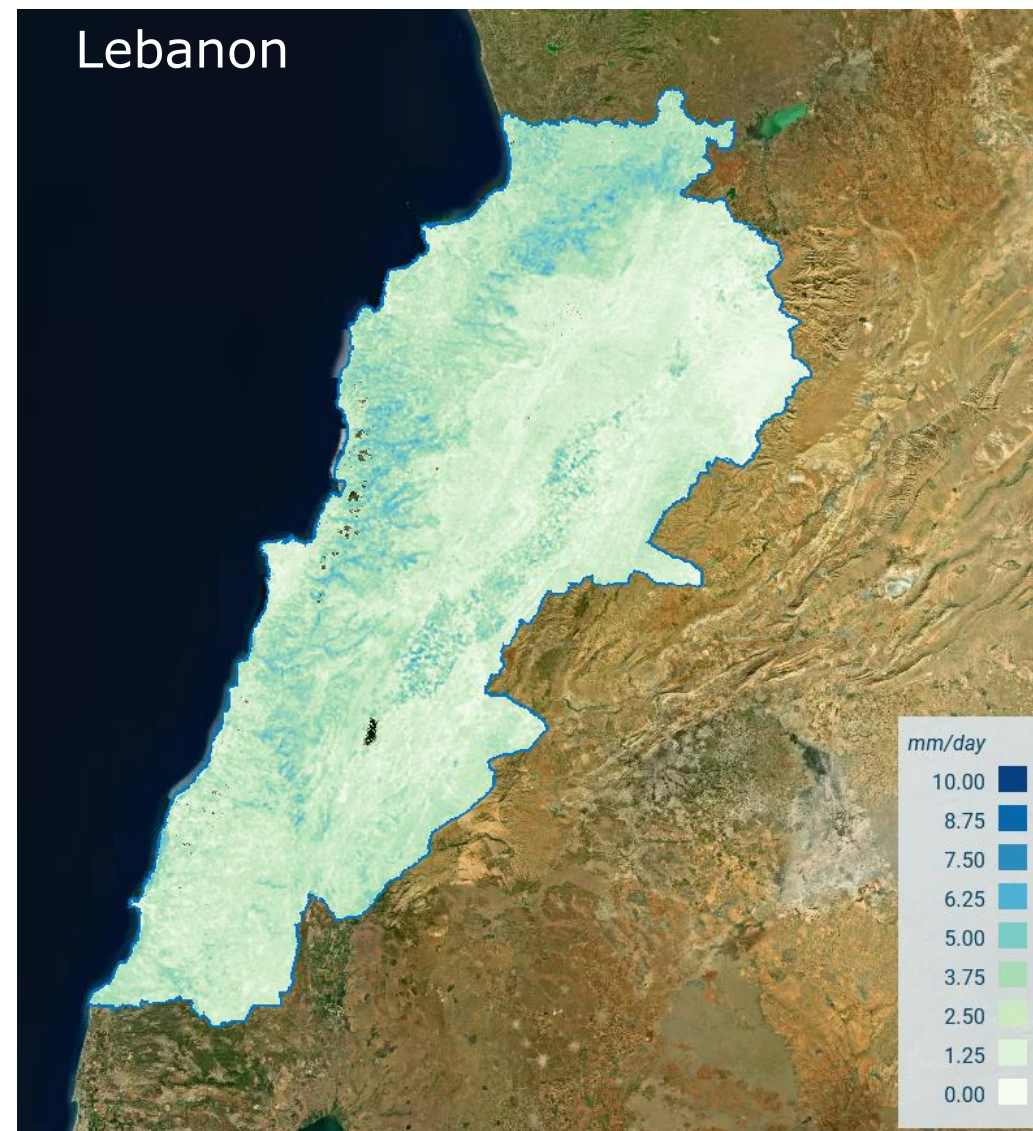
# High resolution Evapotranspiration

- Use of Machine Learning for EO sharpening (1km to 20 m)
  - Combination of Sentinel-2 & -3
  - ET Modelling based on open-source algorithms
  - **ET4FAO** – demonstration for SDG 6.3
- <https://et4fao.dhigroup.com/#/>



Fine resolution ET  
(20 m - S2 & S3)

Coarse resolution ET  
(1 km - S3)





# Water use, pollution and the Blue Economy examples

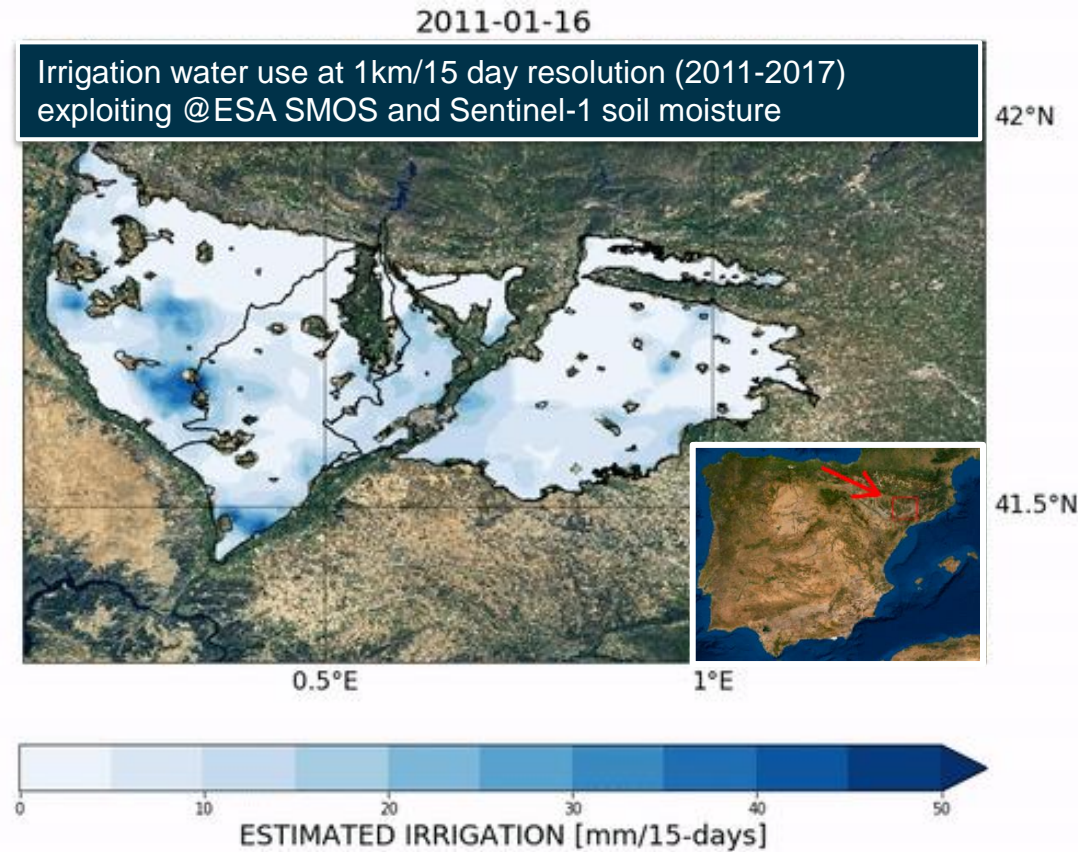
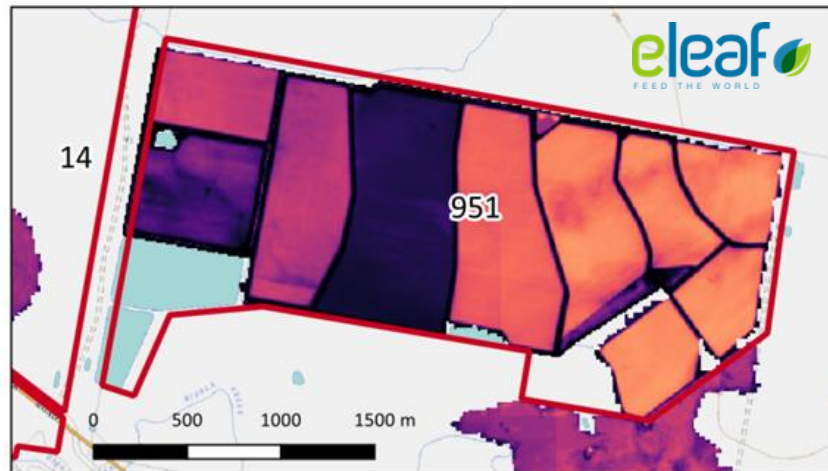
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# HOW MUCH WATER IS USED FOR IRRIGATION?

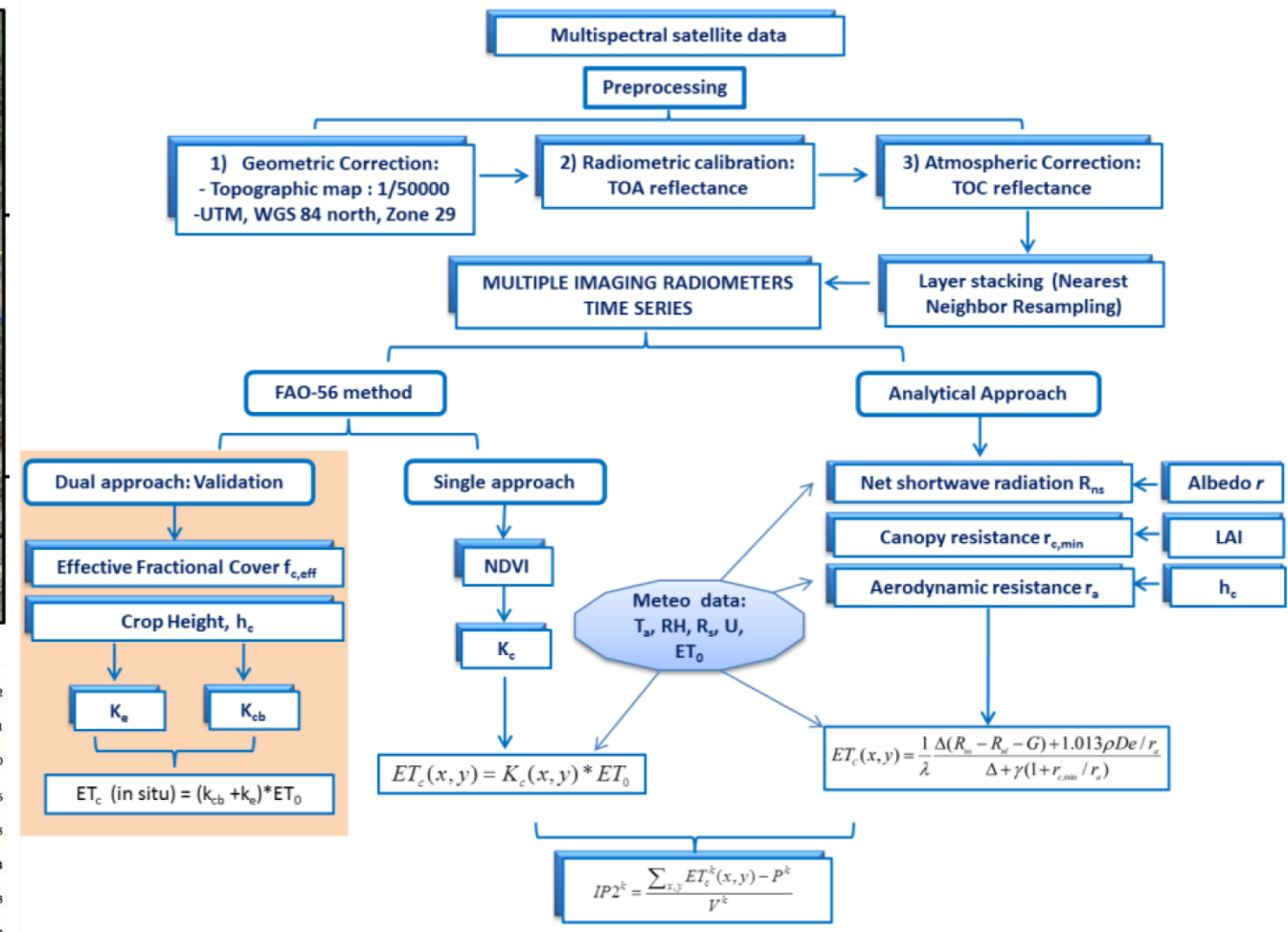
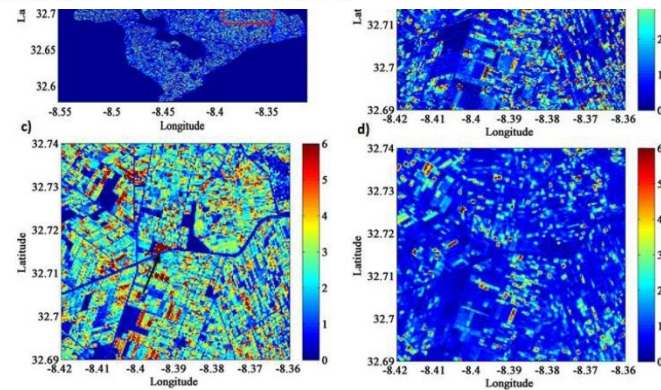
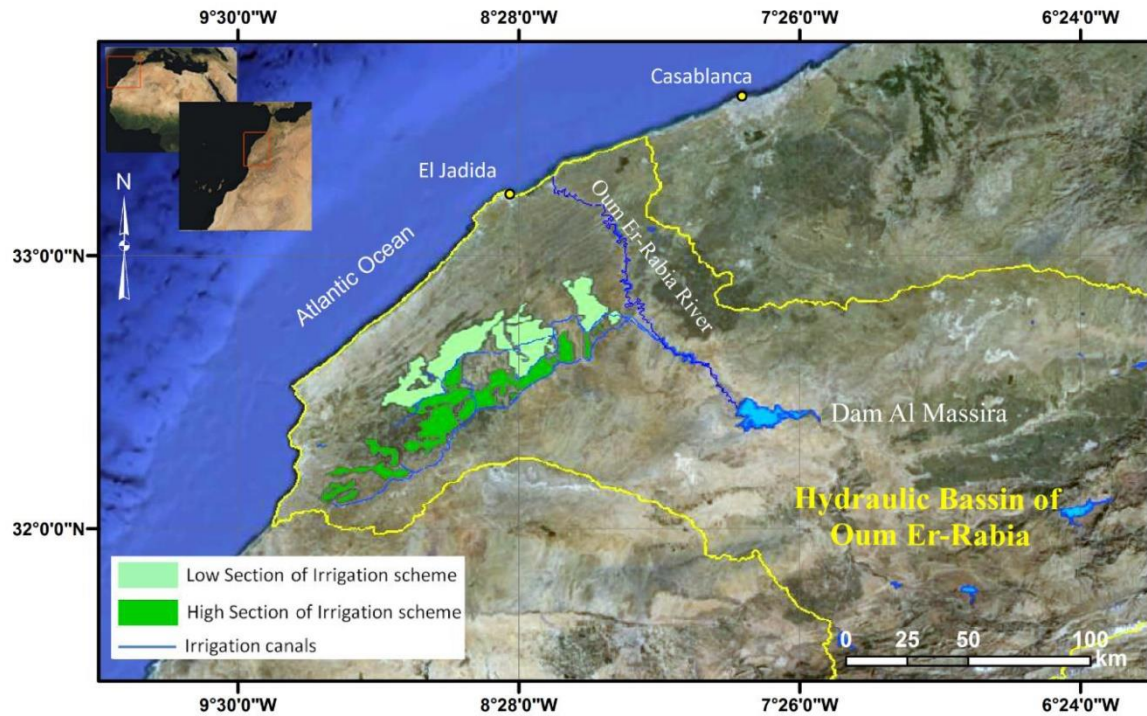
Irrigation is the major water consumer of our planet (70%), and it has a tremendous impact on the water cycle in our times

**IRRIGATION+** aims to explore, develop and validate advanced EO-based algorithms and techniques for irrigation mapping, quantification and detection of seasonal timing of irrigation from field to regional/global scale





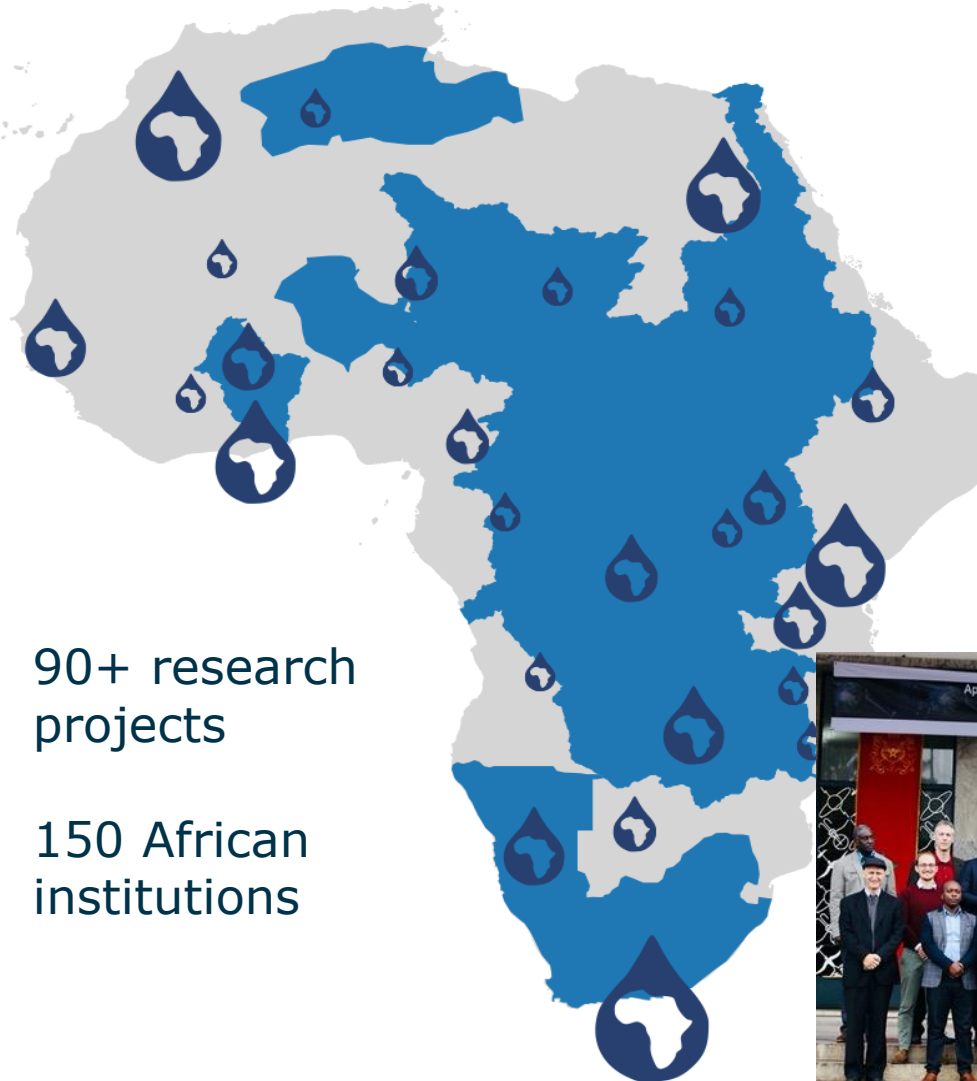
# Optimization of irrigation water distribution in Morocco







# Past TIGER Initiative: Water in Africa



90+ research projects

150 African institutions

## → NEAR REAL TIME FLOOD ASSESSMENT

SENTINEL-1 FLOOD



## → SMALL WATER BODIES (RESERVOIRS) MONITORING

CHANGE DRY/WET SEASON 2011, VOLTA BASIN AUTHORITY



## → HISTORICAL FLOOD ASSESSMENT

NILE BASIN INITIATIVE - HISTORICAL FLOOD MAPPING



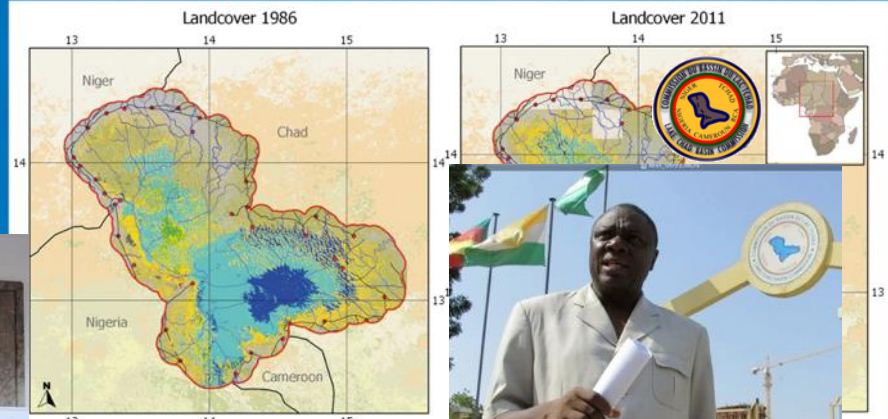
## → TOWARDS SATELLITE-BASED WATER BALANCE MONITORING

WATER DEMAND - MOKOLO, SOUTH AFRICA



## → SUPPORTING THE FULFILMENT OF REPORTING OBLIGATIONS

HIGH RESOLUTION LANDCOVER 1986 / 2011, LAKE CHAD BASIN COMMISSION



Description: This map shows the Landcover in the year 1986 and 2011 of the Lake Chad Basin catchment for Commission. The product provides a monitoring service for high-resolution basin characterization including a recent land cover inventory as well as land cover change, providing information on processes, such as affects of climate change or overexploitation (e.g. disappearance of vegetation, change of cropland area). In the Lake Chad catchment is serves as basis for an assessment of the seasonal water demand by water management related land cover classes.



Cloud Computing Training



EO African Framework for Research, Innovation, Communities & Applications



Fostering  
Partnership



Facilitating  
R&D



Leveraging  
Digital Tools



Reinforcing  
Capacity



Enhancing  
Data Accessibility



# African-European EO Partnership: ESA's contribution



## FutureEO

Earth Science for Society



## EO AFRICA

EO African Framework for Research, Innovation, Communities & Applications



EO AFRICA

## GDA

Global Development Assistance



GDA

## CCI

Climate Change Initiative



from EO R&D activities to EO mainstreaming  
in partnership with AUC, EC, African stakeholders



Marine Environment & Blue Economy

KO Jun'22



Fragility, Conflict & Security

KO Jan'22



Climate Resilience

KO Dec'21



Urban Sustainability

KO Feb'22



Disaster Resilience

KO Sep'21

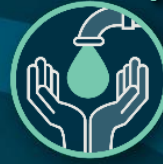


Agriculture

KO Sep'22



Water Resources



Clean Energy



**GDA**

Global Development Assistance

**GDA AID**

Agile EO Information Development





# EO AFRICA: Partners and Contributors

## Strategic Partners

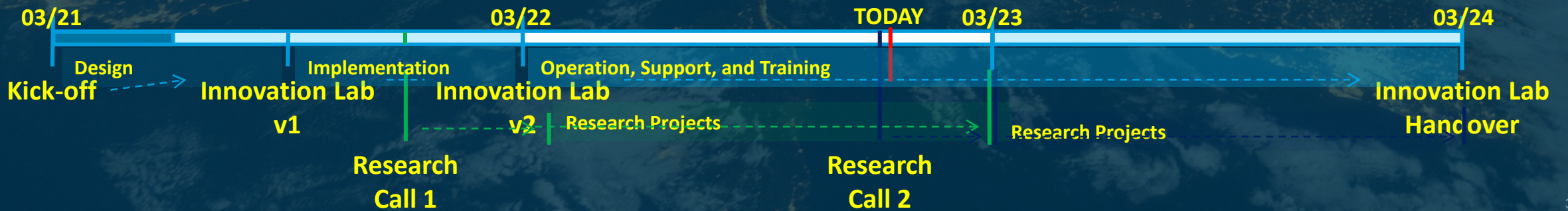


## R&D Facility – Advisory Board



# 1<sup>st</sup> Call for Research Projects: Selected Proposals

Title	Countries	Co-PIs
A workflow for forecasting primary productivity and its determining climatic factors using remote sensing in the eastern Sahel region	South Africa-Hungary	Adam-Toth
Applying innovative cloud computing technology for the effective management of Groundwater resources to promote SUSTainable food security within the Sokoto Basin, Nigeria	Nigeria-U.K.	Oladeji-Novellino
Crop Stress Monitoring in the semi-arid context of Doukkala, Morocco	<b>Morocco-Italy</b>	<b>El Ghandour-Corbari</b>
Drought impACT on the vegeTation of South African semlarid mosaiC landscapes: Implications on grass-crop-lands primary production	South Africa-Spain	Dube-Andreu
Fusion of EO data for crop yield forecast in Benin and Morocco	<b>Morocco-Germany</b>	<b>Brouziyne-Lehnert</b>
Improvement of Agricultural Statistics in the cotton zone of Mali thanks to the synergy of the Sentinel-1 and 2 time series	Mali-Belgium	Traore-Defourny
Integration of open-source solutions with deep learning for estimating crop production in data-scarce smallholder farming areas	Ethiopia-Austria	Mengistu-Lang
Mapping and Monitoring Artisanal Mining from Space	Ghana-Germany	Forkuor-Ullmann
Monitoring by optical and radar satellite imagery of the level and volume of water in the lakes Buyo and Kossou dams in Côte d'Ivoire	Côte d'Ivoire-France	Kouame-Mertens
Quantifying Soil Moisture from Space-based Synthetic Aperture Radar (SAR) and Ground-based Geophysical and Hydrological Measurements	Senegal-Spain	Djanni-Gao
Rising with temperature! Reconstructing the hydroclimatic record of Lake Naivasha with Earth Observation	Kenya-Netherlands	Ongo-Salama
Sentinel-1 and -2 data fusion for mapping smallholder cropping areas in southern Africa to support crop monitoring and yield forecasting	Namibia-Germany	Hamunyela-Herold
SENTINELs for Cape Verde Water & Food Security Monitoring	Cabo Verde-Netherlands	Tavares-Mannaerts
Towards daily maps of water hyacinth cover: exploiting synergies between Sentinel-2 and 3	South Africa-Netherlands	Shoko-de Vries
West Africa Lake Monitoring System	Benin-Netherlands	Belfrid-van der Kwast





# EO AFRICA – 2<sup>nd</sup> call for R&D Research Projects



EO AFRICA



Theme: EO for managing water scarcity and safeguarding food security in Africa in collaboration with African Union Commission

Who can apply: African-European research tandems

- call for 12-month projects
- EUR 25,000 research budget + ICT infrastructure + technical/scientific support

Deadline for proposal submission **15 November 2022.**

With the research period starting from March 2023.

<https://www.eoafrika-rd.org/research/call-for-research-proposals-2022-2023/>

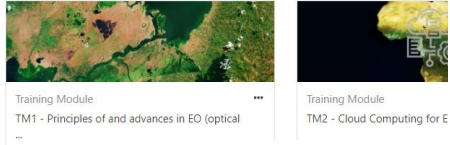


Establishing a **digital capacity development platform** to provide domain-specific training (**SPACE ACADEMY**)

Moodle: Open-source learning management system

Provide:

- 8 Training modules
- MOOC
- Webinars
- Online and face to face courses
- Support for hackathons
- The next one: AARSE2022



	Online course TOPIC	Lead		Participants
1	Cloud Computing for EO analyses	UT	March	60
2	Principles of and advances in EO	SERCO	March	60
3	Water and Energy budgets from EO	UT	April	64

	Project Year	Event	Course organiser	Topic	REMARKS		Participants
1	1	17-19 November: 2021 AfriGEO symposium (RCMRD) Kenya (possibly in distance mode)	SERCO	Advances in EO	PROVIDED ONLINE	September	30
2	2	with CRASTE_LF Morocco	VITO	Agriculture/ Vegetation	Postponed	September 2022	
3	2	May 15-19 Following 5th International conference on the use of space technology for water resources management, Ghana	UT	Water Resources		January 2023	
4	2	November 7 -11 jointly with RCMRD	SERCO	Advances in EO	RCMRD sponsor candidates	February 2023	
5	2	October 18-22 AARSE conference, Kigali, Rwanda	UT	Mapping and Performance Monitoring of Agroecosystems from Space		April 2023	
6	2	tbd	UT	Vegetation		October 2023	
7	3	November 2023 GMES	SERCO			November 2023	
8	3	November 2023 AfriGEO	UT	Agriculture			
9	3	tbd	VITO				
10	3	October WaterNet symposium	UT	Water Resources			



casting from space



# EO AFRICA – Accessibility and Data Services

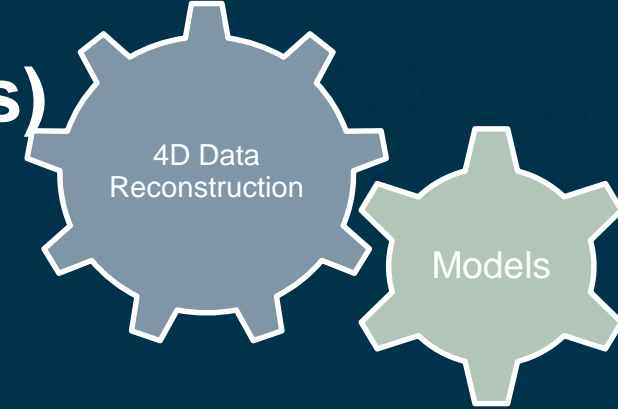


**Brief description:** This procurement focuses on complementary data services provision and cloud resources collocated with the Copernicus Sentinels data over Africa. An environment to share additional value-adding resources and services tailored for Africa with protocols adapted to low bandwidth and fast data exploitation. Resources provision will also be included.

**Status:** ITT launch in the second half of 2022. Budget: 3.6MEuros



# Destination Earth (digital twin of the Earth precursors)



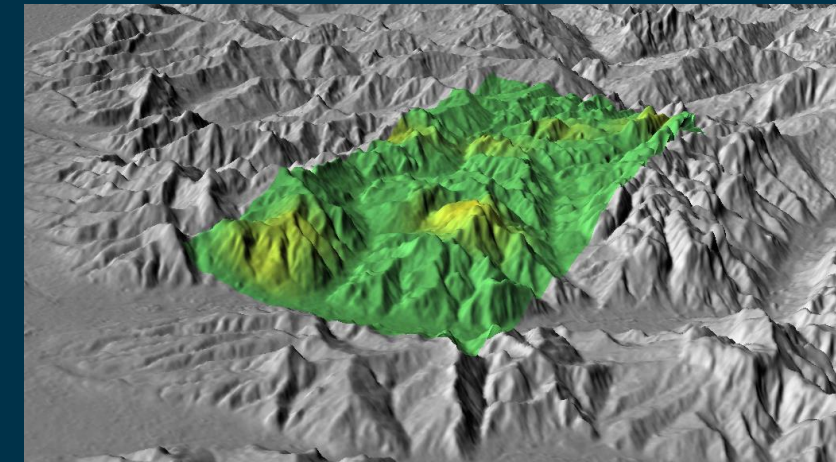
- Encourage and support open science practices (open software, open data, open papers, and open methods) to accelerate development and facilitate broader adoption of remote sensing methods into the operational practices and systems of institutional stakeholders.



**Water management:** New 1Km Datasets and model results are used together for *water resources management at basin scales, drought risk and agriculture.*



**Flood Risk:** Modelled river discharge is used as input for *flood modelling* and hence for *flood risk*. Satellite river discharge (and flooded areas) are used for calibration and testing *flood modelling*.



**Landslide risk:** Modelled soil moisture together with satellite **soil moisture** and **precipitation** are used for *landslide modelling* and hence *landslide risk*.



<http://www.eoafrika-rd.org>



[@EOAfricaRD1](https://twitter.com/EOAfricaRD1)



[info@eoafrika-rd.org](mailto:info@eoafrika-rd.org)



Prof. Dr. Zoltán Vekerdy (Project Leader, ITC)

[z.vekerdy@utwente.nl](mailto:z.vekerdy@utwente.nl)



**EO AFRICA**  
R&D Facility

- Land cover statistics

FAO: Francesco N. Tubiello and Lorenzo De Simone (FAO ESS/OCS)  
ESA: Olivier Arino and Marc Paganini

- Agricultural statistics

FAO: Carola Fabi, Yakob Seid, Lorenzo De Simone (FAO ESS/OCS)  
ESA: Benjamin Koetz, Zoltan Szantoi

- Agricultural water productivity

FAO: Jippe Hoogeveen and Livia Peiser (FAO NSL)  
ESA: Benjamin Koetz

- SDG Statistics

FAO: Lorenzo De Simone, Yakob Seid, and Aida Khalil (FAO OCS)  
ESA: Marc Paganini

- Forestry Statistics

FAO: Anssi Pekkarinen (FAO NFO)  
ESA: Frank Martin Seifert

## Agricultural Stress Index system

FAO: Monika Tothova (FAO EST)

ESA: Benjamin Koetz, Zoltan Szantoi

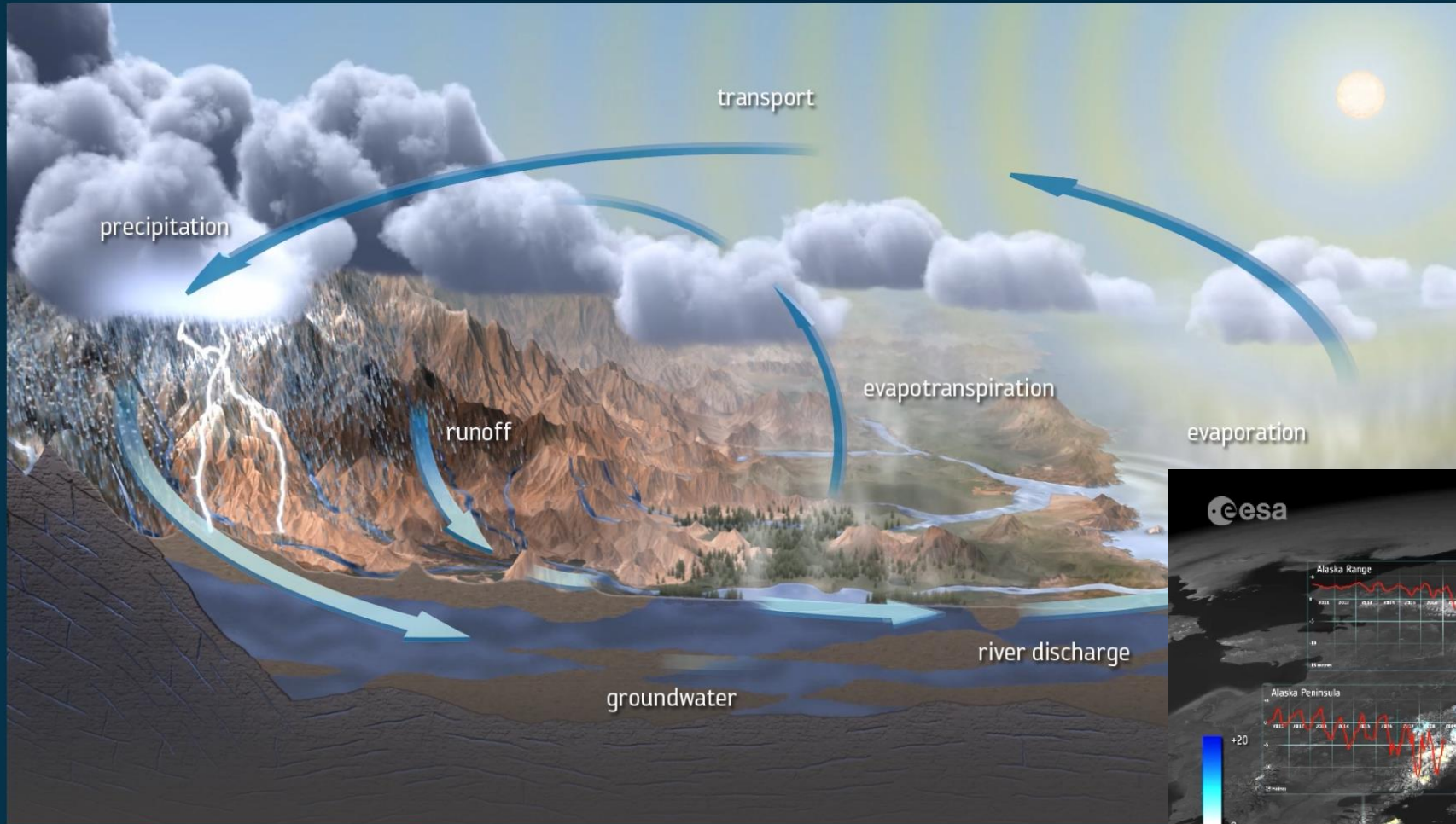
## Coordination activities of the program and with other programs

FAO: Yakob Seid (FAO OCS)

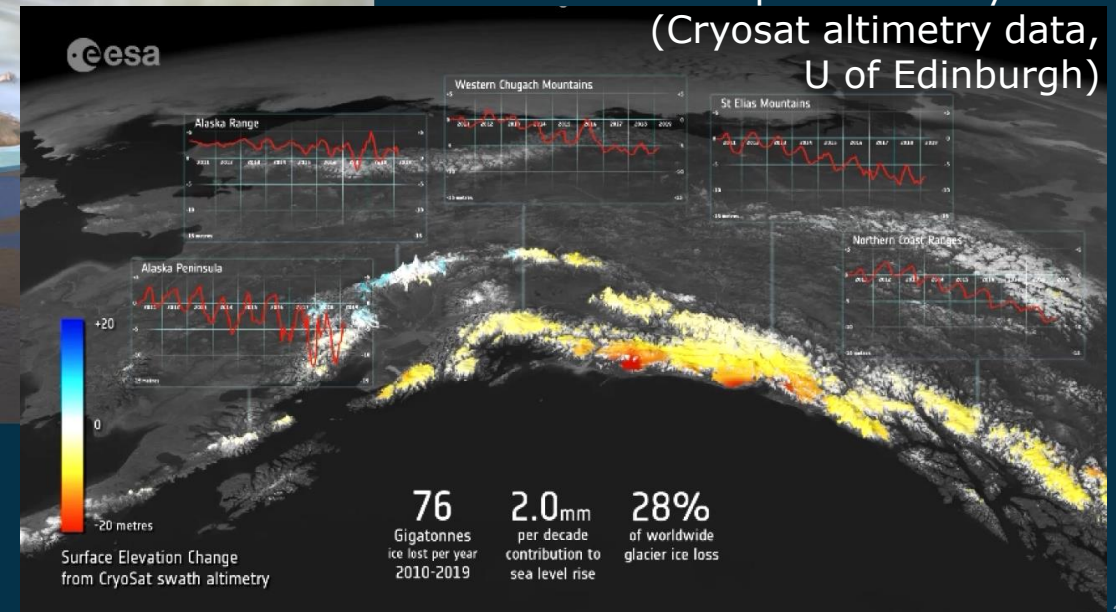
ESA: Benjamin Koetz, Patrick Griffith



# An Earth system approach



Glaciers and snow cover also part of the system (CryoSat altimetry data, U of Edinburgh)



Source: ESTELLUS (FR) WACMOS-MED, In close collaboration with HYMEX