



User Experiences in Earth Observation for Water Management

25 OCTOBER 2023

AGENDA

- Welcome & icebreaker (5 mins)
Erin Jordan, IWA
- Presentations (45 mins)
Karin Schenk, EOMAP
 - Using SAR for Smarter Water Planning and Disaster Risk Reduction – *Brian Eyster, Stimson/Mekong Dam Monitor*
 - Flood And Drought Forecasting And Warning Systems Of The Mekong River Commission Based On Satellite Data – *Sothea Khem, Mekong River Commission Secretariat*
 - Potential and Uptake of Earth Observation for Inland Water Quality Monitoring and Reporting – *Ils Reusen, VITO/ WaterForCE Water Quality Continuum*
 - Leveraging a range of Earth observing satellites for aquatic applications – *Megan Coffer, NOAA/GST*
- Q&A Panel Discussion (30 mins)
Karin Schenk, EOMAP
- SeBS Project Presentation (5 mins)
Geoff Sawyer, EARSC
- Wrap Up and Close (5 mins)
Karin Schenk, EOMAP & Erin Jordan, IWA

EO4WAT COMMUNITY OF PRACTICE

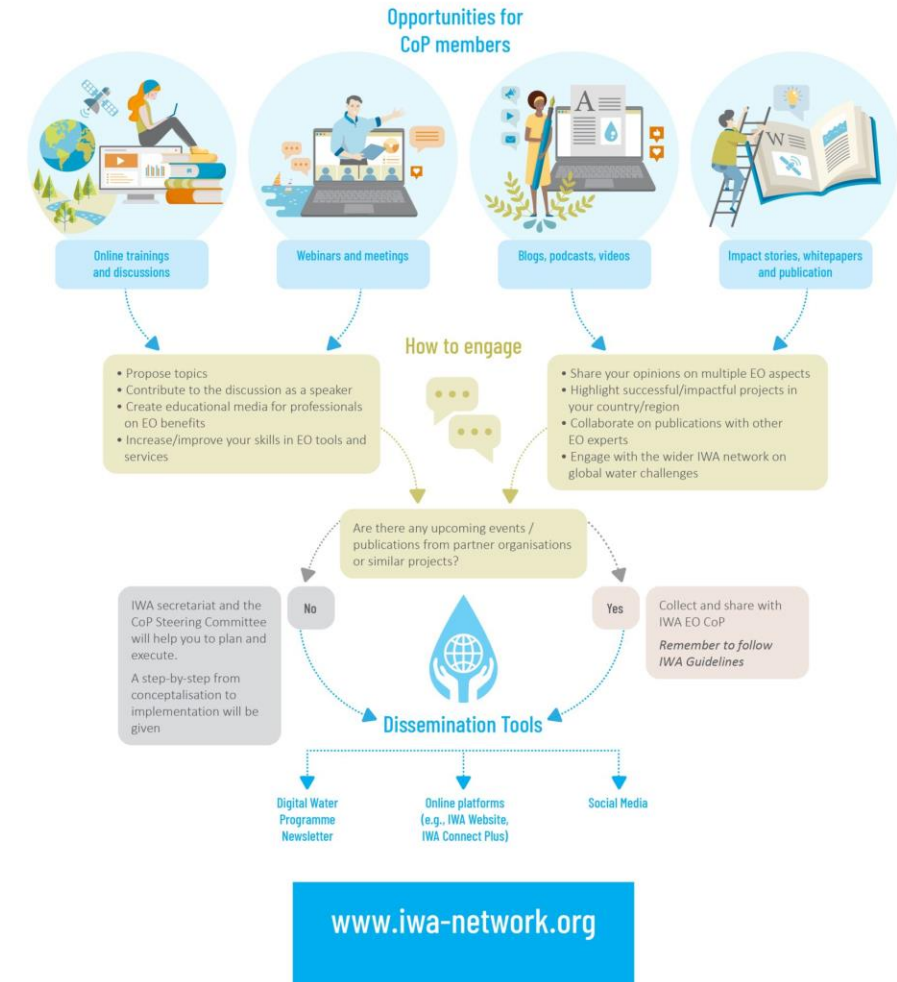
The CoP aims to:

- Provide a platform to share approaches on the application of EO technologies for water management for different end-users.
- Enable linkages between cross-cutting scientific communities and end-users to attain a better understanding of how EO technology can be best used, and what are needs of end-users
- Identify gaps and how these can be addressed in the understanding and use of EO technology in managing water.

The IWA Earth Observation for Water Management Community of Practice (CoP) brings together experts from different sectors of the water industry interested in the use of Earth observation technologies for improved water quality and quantity management.



As a member of the CoP, you have access to numerous capacity building and collaboration opportunities. This infographic shows you in a snapshot all the avenues for you to get involved in the Cop, get recognised as an EO expert and expand your network!



MODERATOR & PANELLISTS



Karin Schenk

Head of Water Quality
Department, EOMAP,
Germany



Brian Eyler

Senior Fellow and
Director Energy,
Water, and
Sustainability, The
Stimson Center, USA



Sothea Khem

River Flood
Forecasting Specialist
at Mekong River
Commission
Secretariat, Cambodia



Ils Reusen

Project Manager at
VITO Remote
Sensing, Belgium



Megan Coffey

NOAA/Global
Science &
Technology, Inc.,
USA

Using SAR for Smarter Water Planning and Disaster Risk Reduction

Brian Eyler
Stimson Center
Southeast Asia Program
Energy, Water, and Sustainability Program

The screenshot displays the Stimson Center 'Eyes on Earth' website interface. At the top, the navigation bar includes 'HOME', 'VIRTUAL GAUGES', 'CASCADE ANALYSIS', 'NATURAL RIVER FLOW MODELS', 'COMPARE MAPS AND DATA', 'BASIN-WIDE DAMS & CONNECTIVITY', 'METHODS', 'ALERTS & ADVISORIES', and 'ABOUT'. The 'English' language dropdown is set to 'English'. Below the navigation is a 'Menu' and 'Profile' section.

The main content area features a map of Southeast Asia with a network of blue lines representing rivers and dams. The map includes labels for 'Gobi Desert', 'CHINA', 'MYANMAR (BURMA)', 'THAILAND', 'VIETNAM', and 'MALAYSIA'. Major cities like Xining, Lanzhou, Xi'an, Chengdu, Chongqing, Kunming, Linzhi, Nanning, Hanoi, Da Nang, Bangkok, Phnom Penh, Ho Chi Minh City, George Town, Medan, Singapore, Padang, Palembang, and Bactou are marked. A scale bar at the bottom left indicates 0 to 400 km.

Below the map is the 'Virtual Gauges Summary' table:

Category	# of Dams	Est. Current Active Storage	Est. Total Active Storage	Est. Current Active Storage %	Increase/Decrease	Flow Change From Last Week	Volume Change From Last Week
MDM Mainstream Dams	13	14.110 km ³	24.803 km ³	56.9%	↑	-190.34 cumecs	0.115 km ³
MDM Tributary Dams	15	5.202 km ³	13.085 km ³	39.8%	↓	-205.73 cumecs	0.124 km ³
EDL Wholly-Owned Dams	10	4.634 km ³	5.444 km ³	85.1%	↑	-352.67 cumecs	0.213 km ³
EGAT Dams	7	2.334 km ³	3.299 km ³	70.7%	↓	-995.21 cumecs	0.601 km ³
Total	45	26.280 km³	46.631 km³	56.4%	↑	-1743.96 cumecs	1.053 km³

Below the summary table is the 'Dams & Reservoirs' section, which includes a table with the following data:

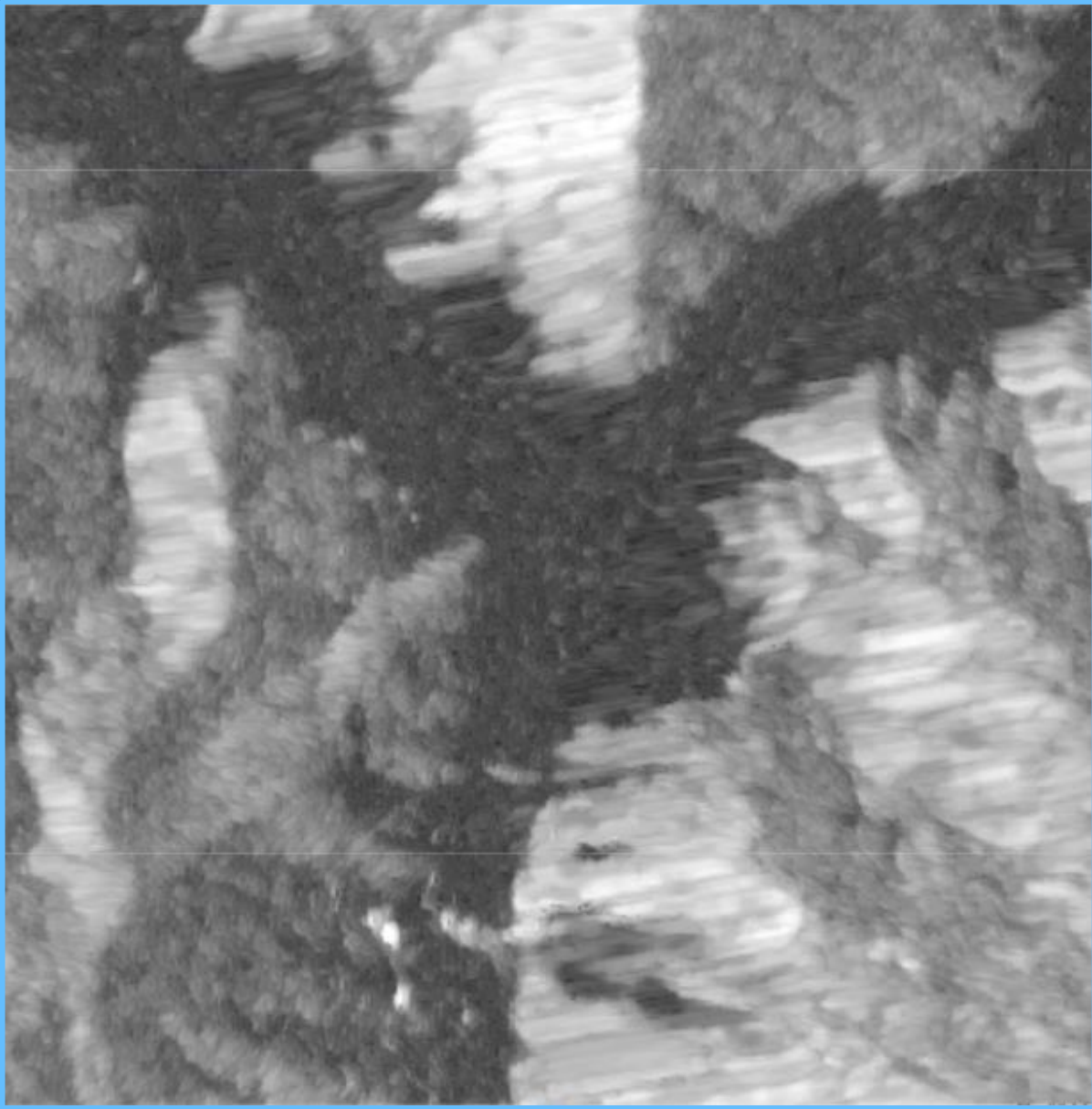
Dam/Reservoir	Location	Est. Current Active Storage	Est. Total Active Storage	Est. Current Active Storage %	Increase/Decrease	Flow Change From Last Week	Level Change From Last Week	Vol Ch Fr L W
Wunonglong Reservoir	China	0.036 km ³	0.106 km ³	33.4%	□	0.00 cumecs	0.00 m	0. k
Lidi Reservoir	China	0.016 km ³	0.024 km ³	65.4%	□	0.00 cumecs	0.00 m	0. k
Huangdeng Reservoir*	China	0.036 km ³	0.792 km ³	4.6%	□	0.00 cumecs	0.00 m	0. k
Dahuaqiao Reservoir	China	0.121 km ³	0.103 km ³	100.0%	□	0.00 cumecs	0.00 m	0. k
Miaowei Reservoir	China	0.000 km ³	0.177 km ³	0.0%	□	0.00 cumecs	0.00 m	0. k
Gongguoqiao Reservoir	China	0.095 km ³	0.179 km ³	53.2%	□	0.00 cumecs	0.00 m	0. k
Xiaowan Reservoir*	China	4.760 km ³	11.178 km ³	42.6%	↑	-125.49 cumecs	0.53 m	0. k
Manwan Reservoir	China	0.058 km ³	0.088 km ³	66.0%	□	0.00 cumecs	0.00 m	0. k
Dachaoshan Reservoir	China	0.024 km ³	0.124 km ³	19.1%	□	0.00 cumecs	0.00 m	0. k
Nuozhadu Reservoir*	China	8.380 km ³	11.193 km ³	74.9%	□	0.00 cumecs	0.00 m	0. k

2022-2023 Mekong Dam Monitor Highlights

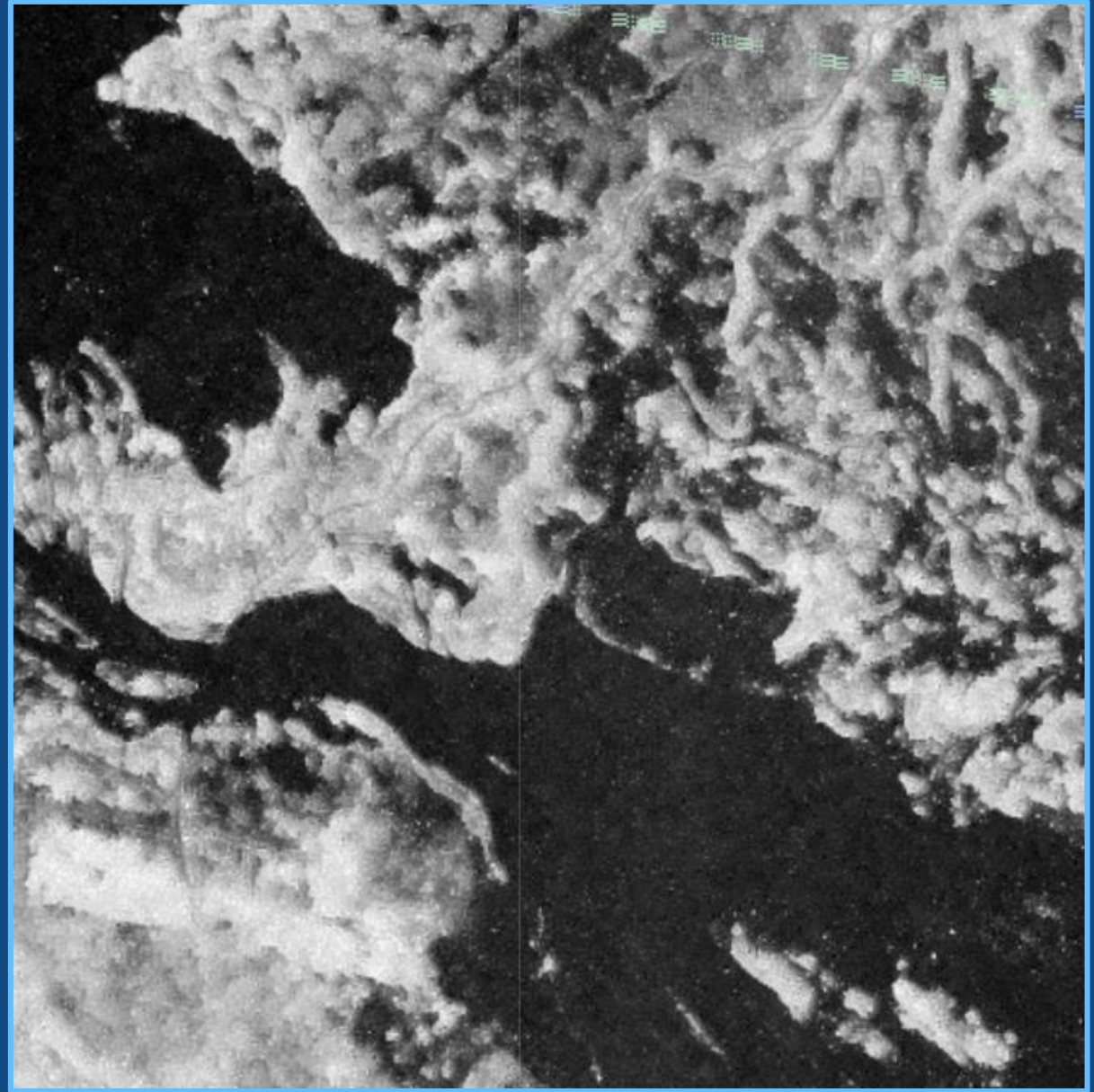
- Confirmed use cases by MRC, govts & NGOs in Vietnam, Cambodia, Thailand, Laos
- 50 Early Warning Alerts issued
- ~35 million social media accounts in 7 languages

Mekong Dam Monitor

Sharing Data, Empowering People.



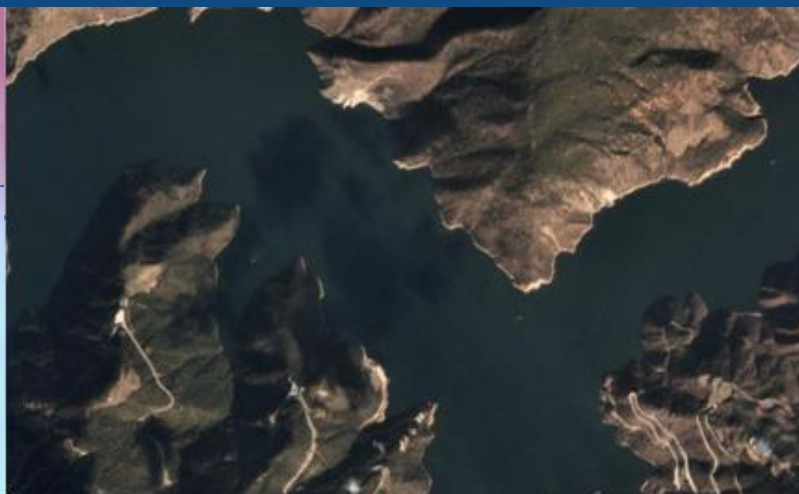
Xiaowan Dam



Tonle Sap Lake bottleneck

What is a Virtual Gauge?

```
S1 step 2*
134 var sliced0 = yearMonth.slice(6,9);
135
136 Map.centerObject(image, 17);
137 Map.addLayer(image);
138
139 // Classify the image
140 var classifiedData = classifier.radarClassifier(image, region, 10, 'clusters', 20);
141
142 // Plot clusters by backscatter mean values to inspect water classes.
143 /*
144 chartClusters.plotClustersByBackscatter(
145   image,
146   classifiedData,
```



Identify level shape of reservoir

1. Import Sentinel 1-2 imagery (10 meter resolution) via Google Earth Engine
2. Process image to identify water
 - Filter
 - Cluster
 - Modify code
3. Export to ArcGIS

*Sentinel 1 imagery preferred because it can see through clouds.



Determine raw altimetry data (masl)

1. Remove extraneous shapes from reservoir shape
 2. Generate a line circumference of shape
 3. Select reliable areas of shoreline (white boxes above)
 4. Generate mean shoreline elevation using 30-meter ALOS digital elevation model (remove outliers with filters)
- Error: +/- 2.5 meters



Check altimetry data vs satellite images

1. Outlier check (is raw data outside known range of maximum and minimum)
 2. Fluctuation check (if raw data shows major fluctuation, does image also show this?)
 3. Adjust identified outliers & erroneous fluctuations using proxy known data
- Error: +/-1 meter

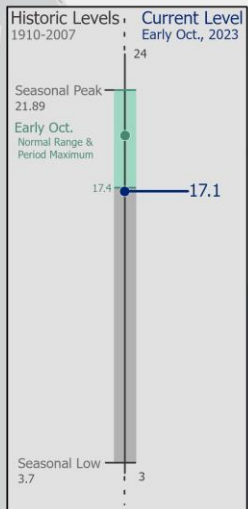
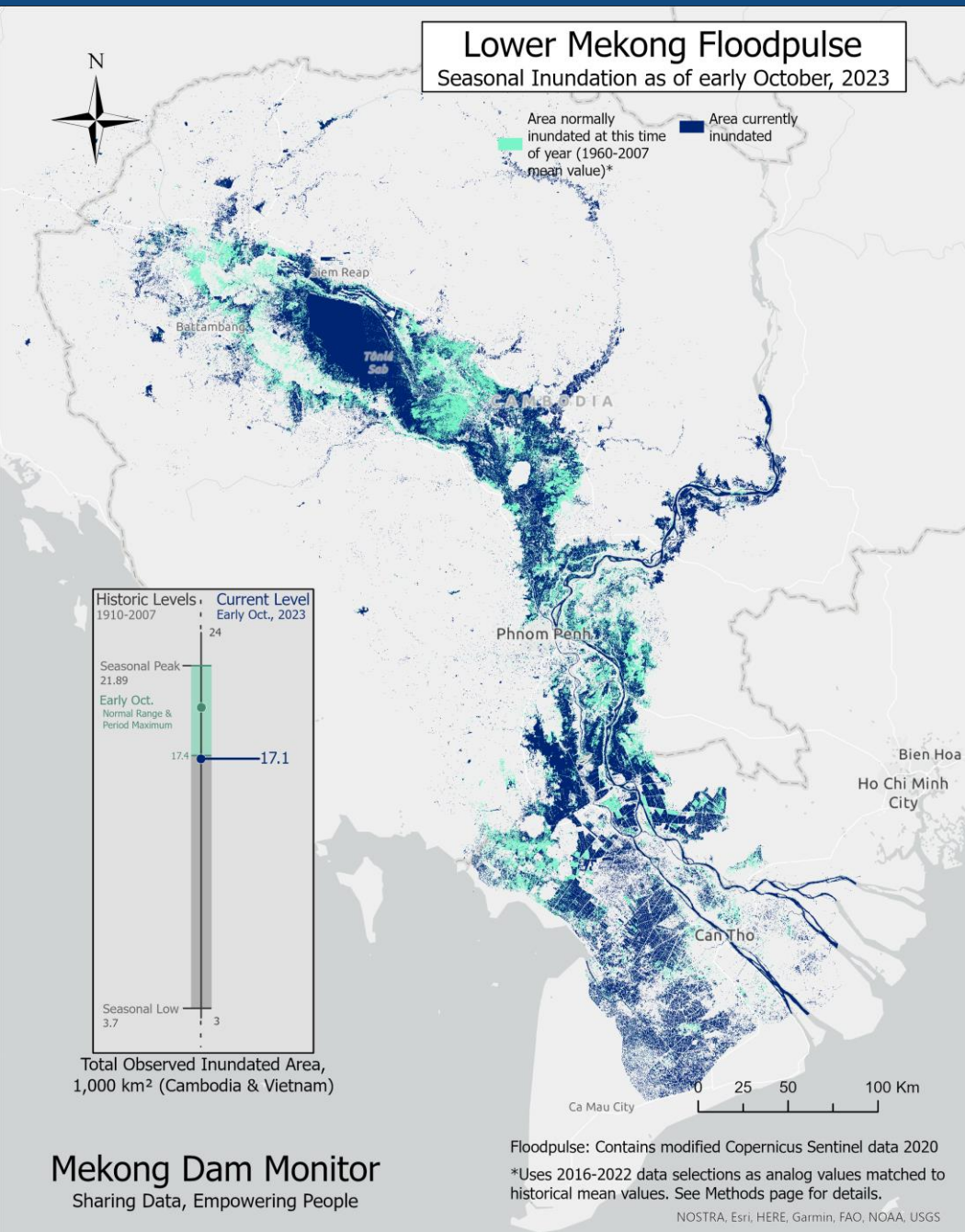
Lower Mekong Floodpulse

Seasonal Inundation as of early October, 2023



Area normally inundated at this time of year (1960-2007 mean value)*

Area currently inundated



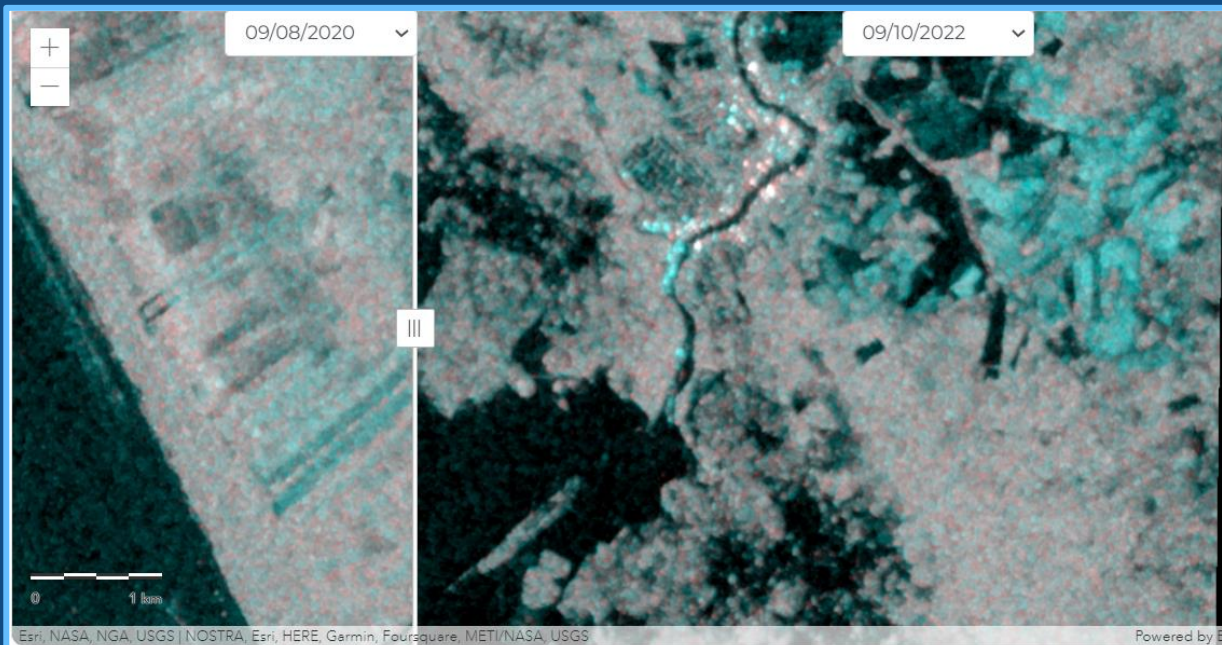
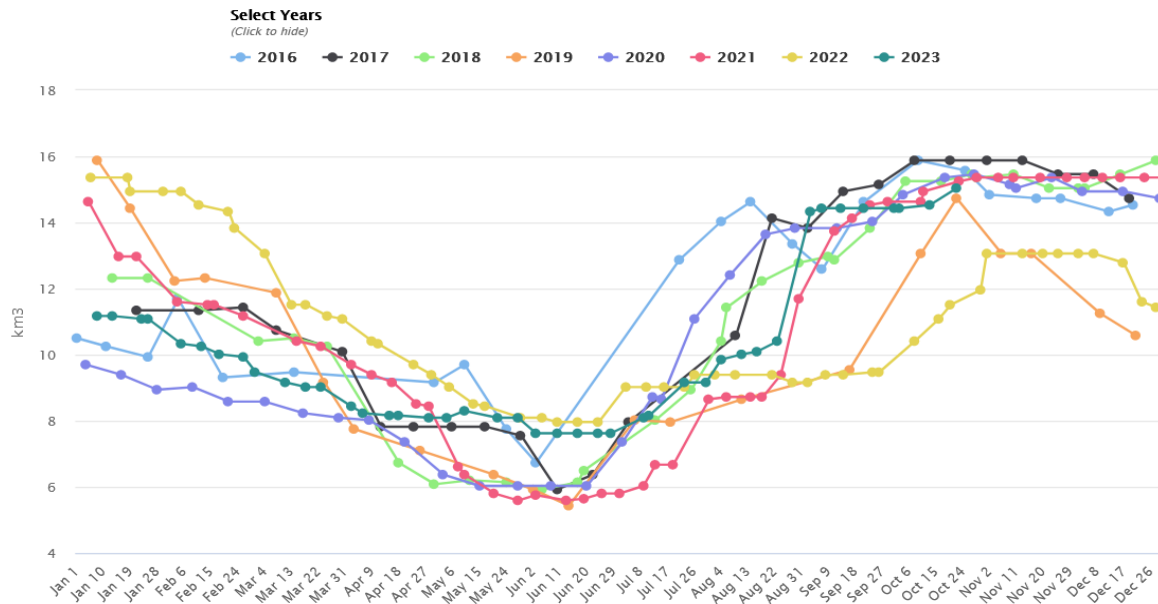
Total Observed Inundated Area, 1,000 km² (Cambodia & Vietnam)

Mekong Dam Monitor
Sharing Data, Empowering People

Floodpulse: Contains modified Copernicus Sentinel data 2020
*Uses 2016-2022 data selections as analog values matched to historical mean values. See Methods page for details.

NOSTRA, Esri, HERE, Garmin, FAO, NOAA, USGS

Xiaowan Reservoir Operating Curves (km³)

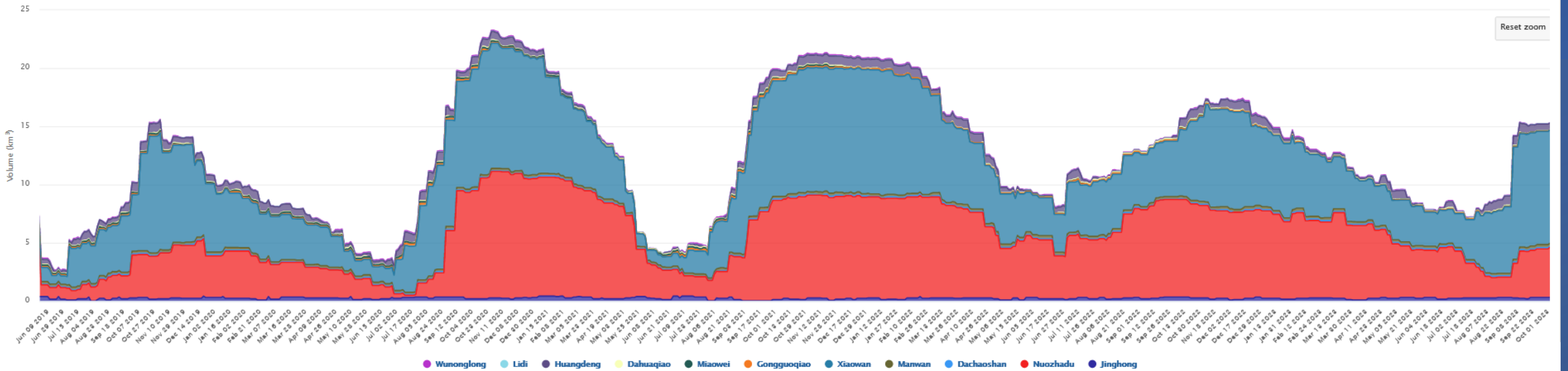


Esri, NASA, NGA, USGS | NOSTRA, Esri, HERE, Garmin, Foursquare, METI/NASA, USGS

Powered by Esri

Lancang (PRC) 3S Basin Sekong Basin Sesan Basin Srepok Basin

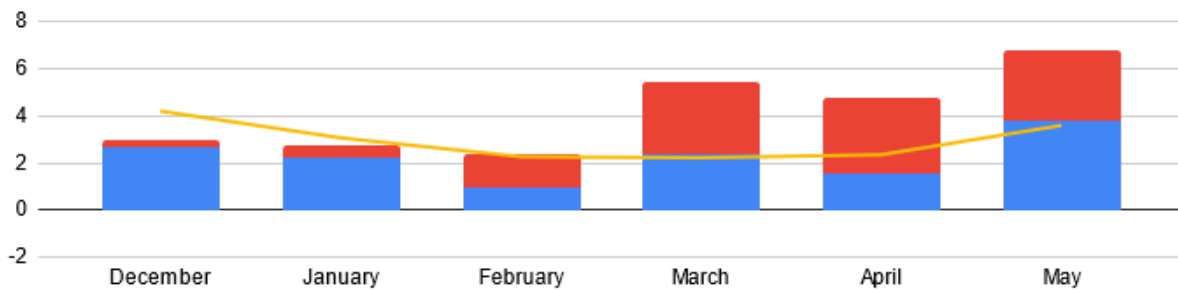
Active Storage in the Lancang Cascade 2016–2023



Download Data

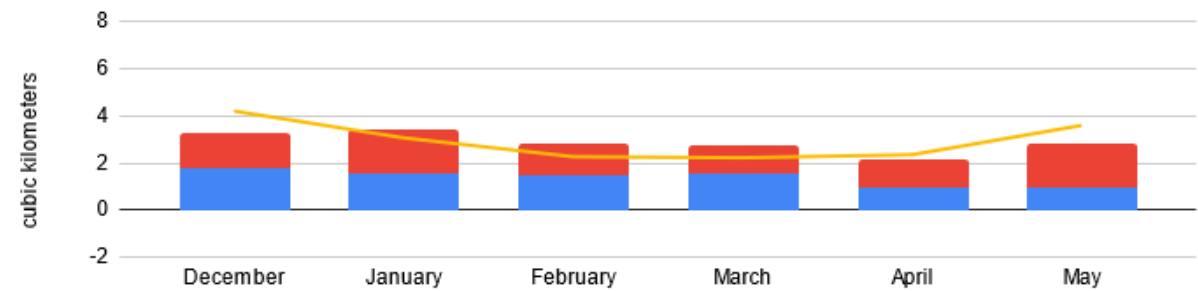
Chiang Saen Dry Season 2022

Pre-dam Mean Flow PRC releases Flow without releases

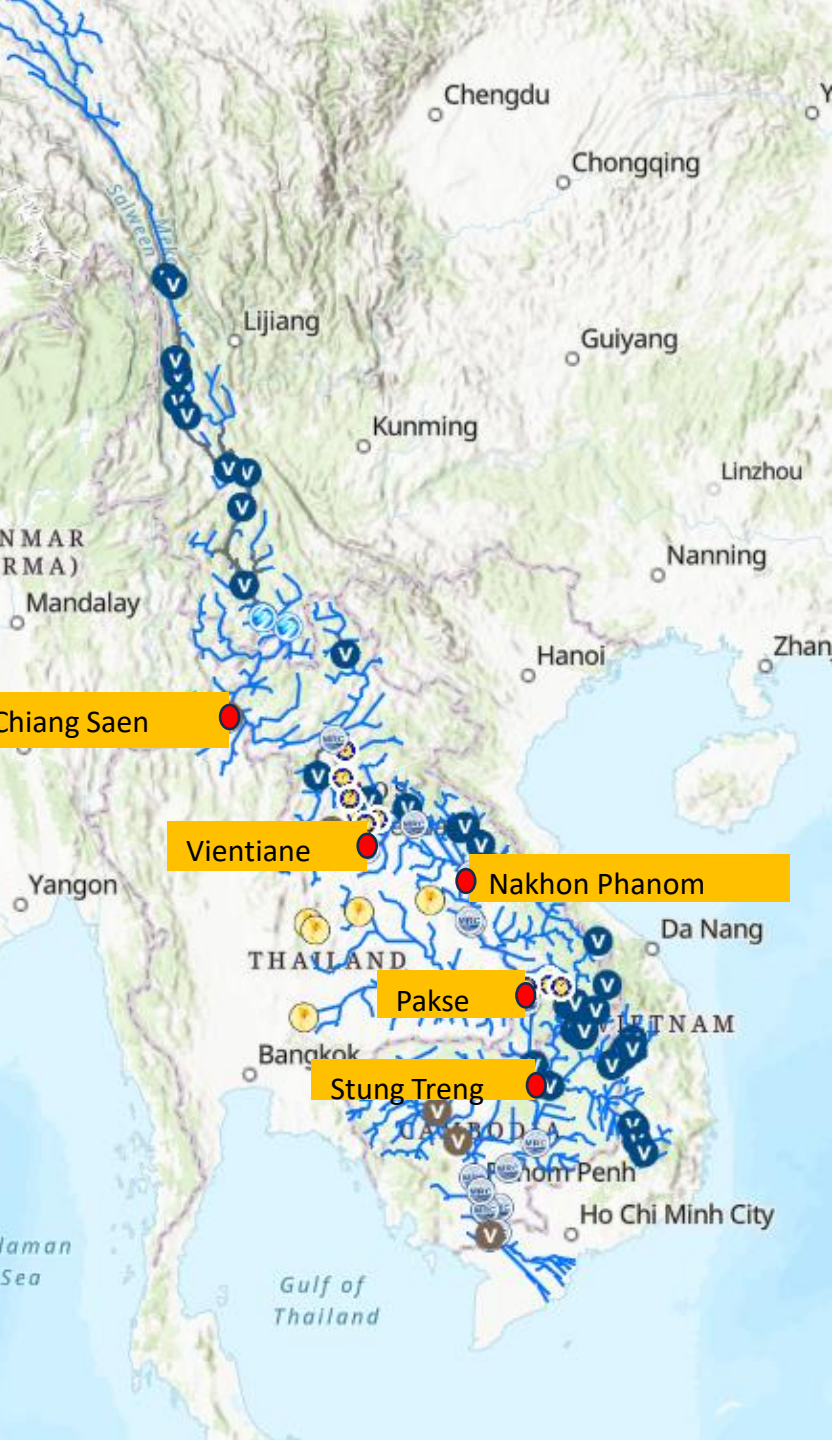


Chiang Saen Dry Season 2023

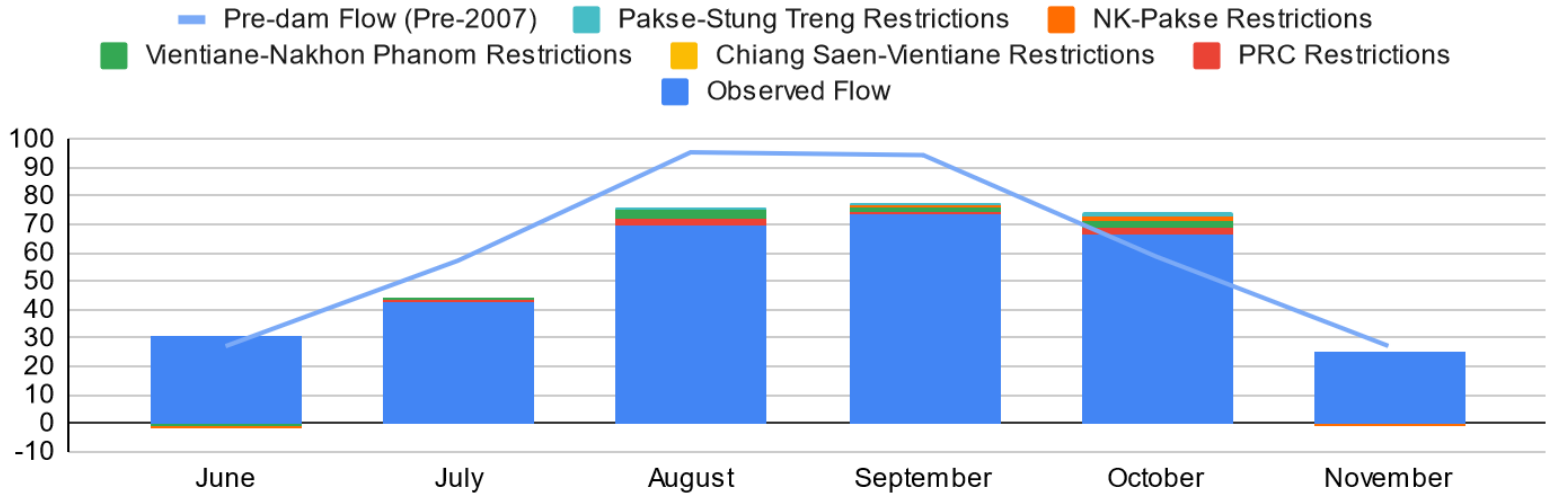
Pre-dam Mean Flow PRC releases Flow without releases



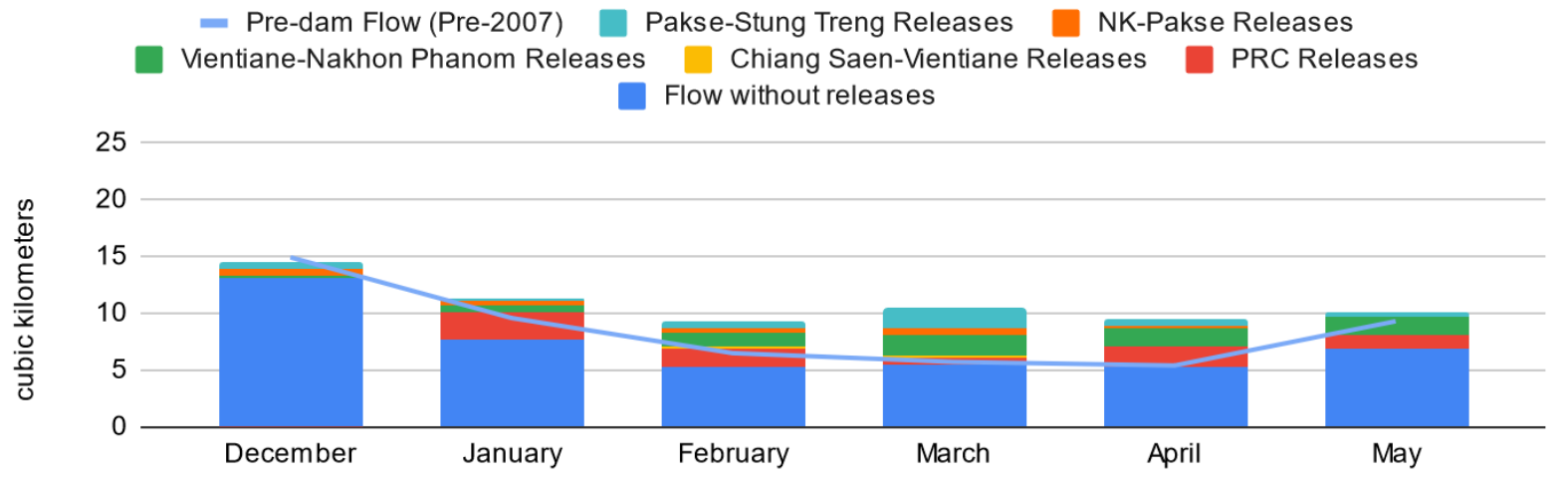


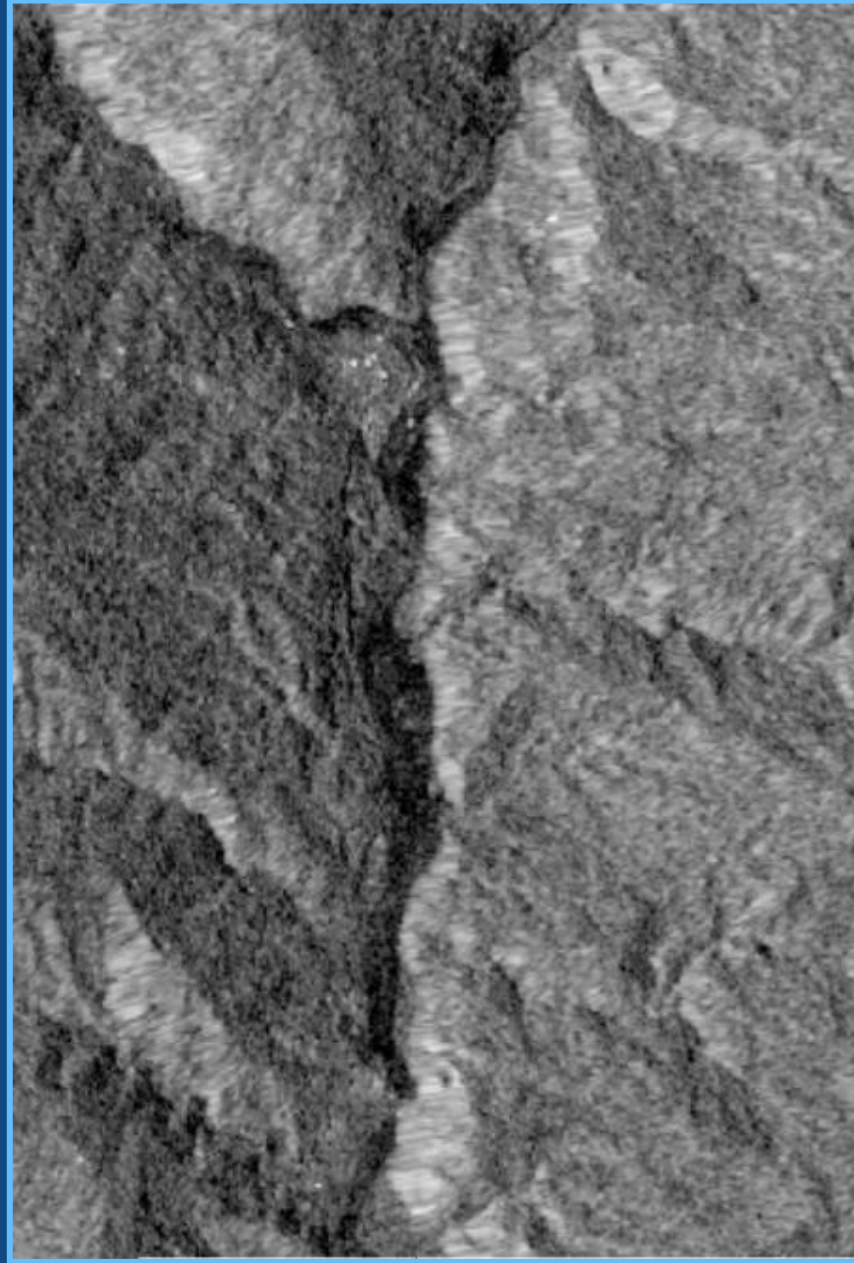
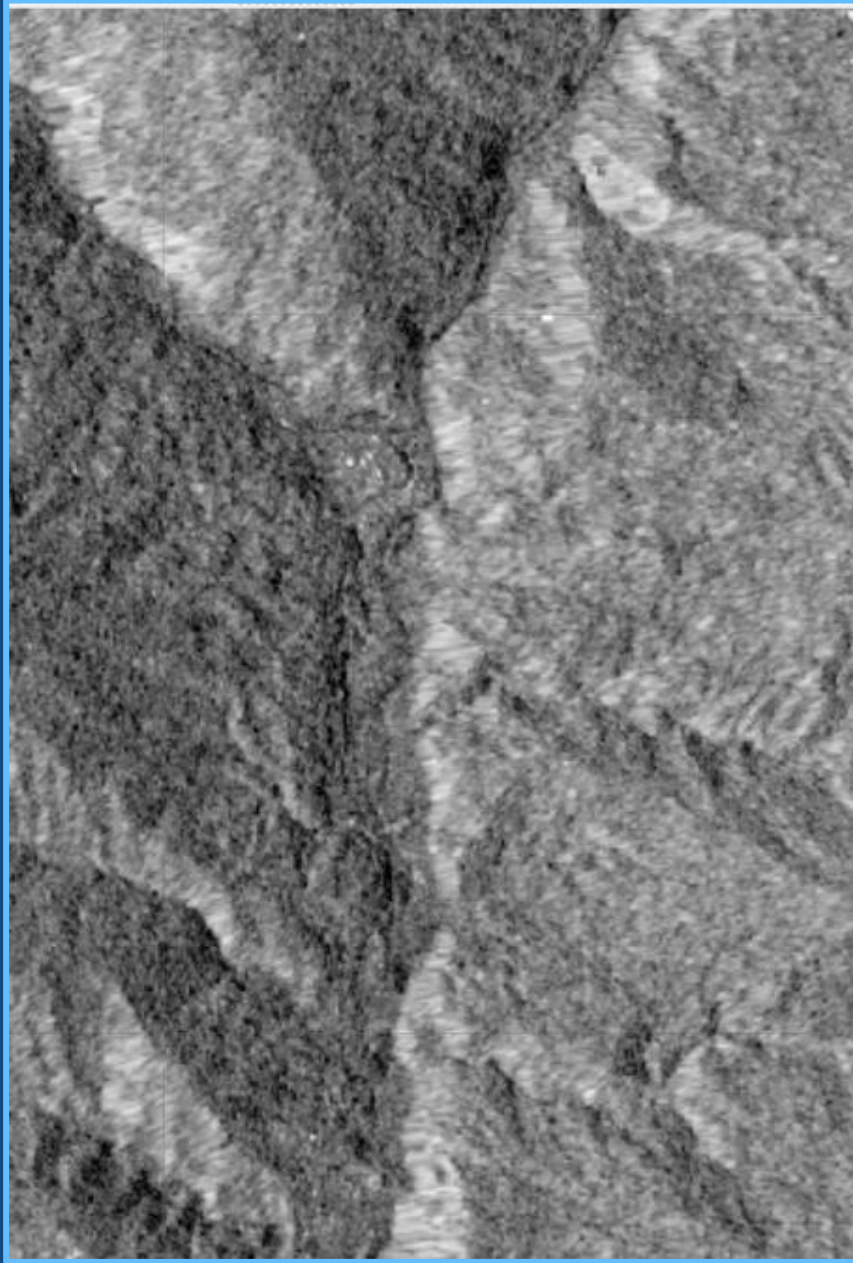


Stung Treng Wet Season 2022



Stung Treng Dry Season 2023





Cascading hazards disaster at Melamchi, Nepal (June 15, 2021)



Thank you!

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Brian Eyler

Southeast Asia Program Director

Energy, Water, Sustainability Program Director

Stimson Center

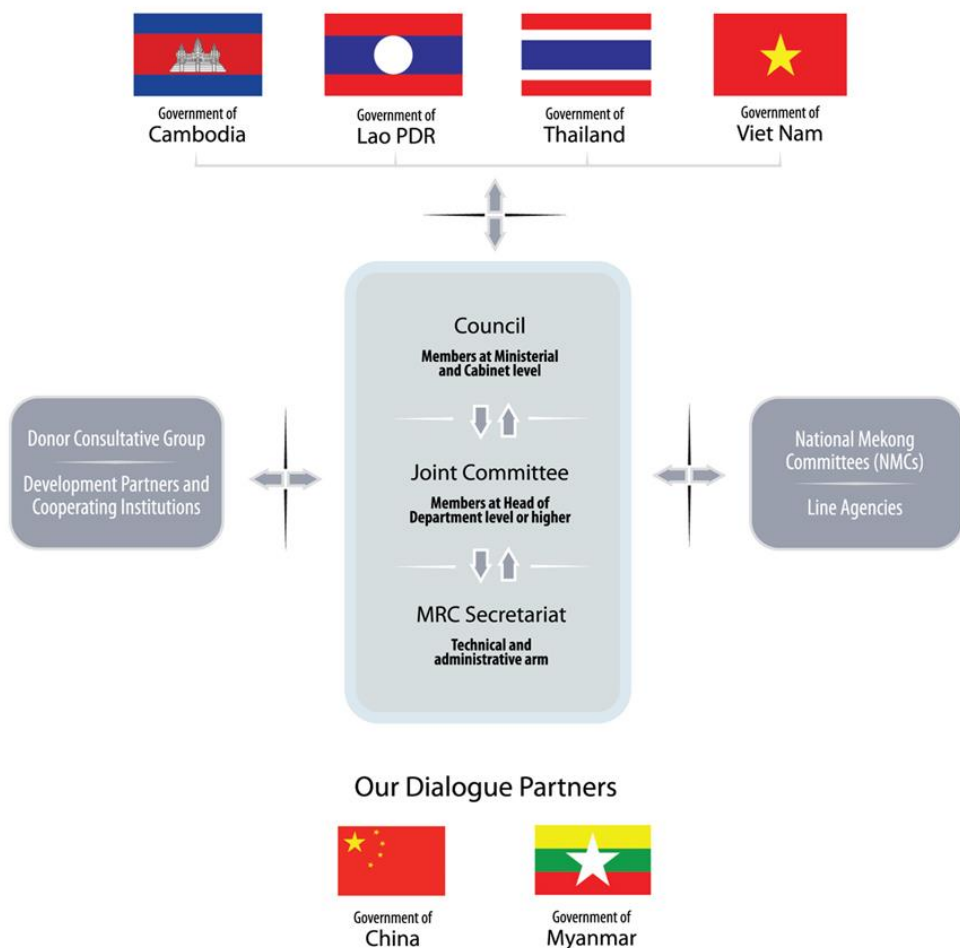
FLOOD AND DROUGHT FORECASTING AND WARNING SYSTEMS OF the MEKONG RIVER COMMISSION BASED ON SATELLITE DATA

DR. KHEM SOTHEA,
RFDMC/MRCS
25 OCTOBER 2023

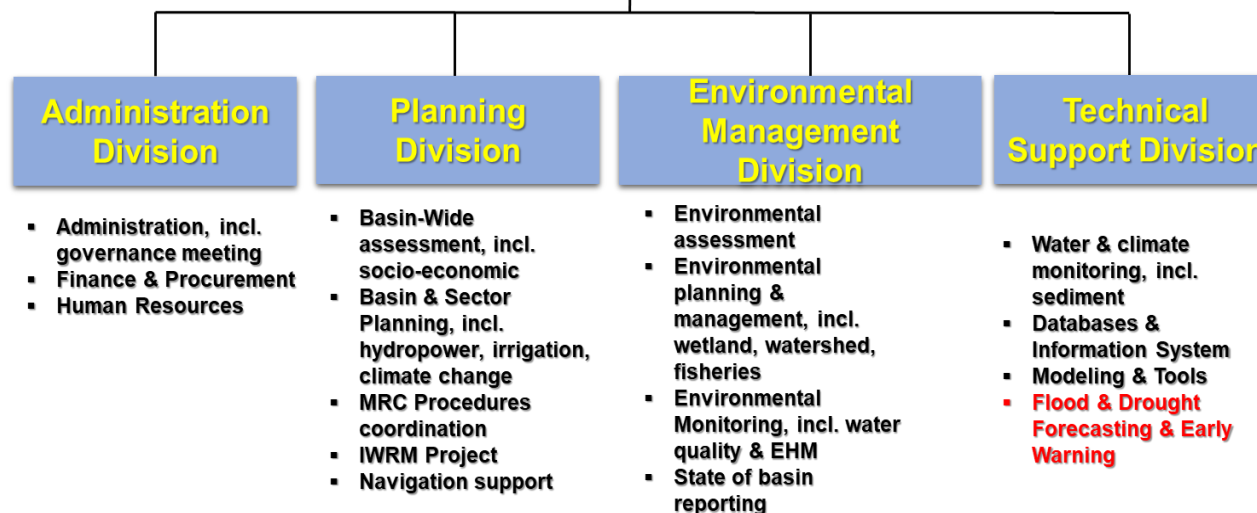


1. Background about MRC

Mekong River Commission Governance Structure



Office of CEO

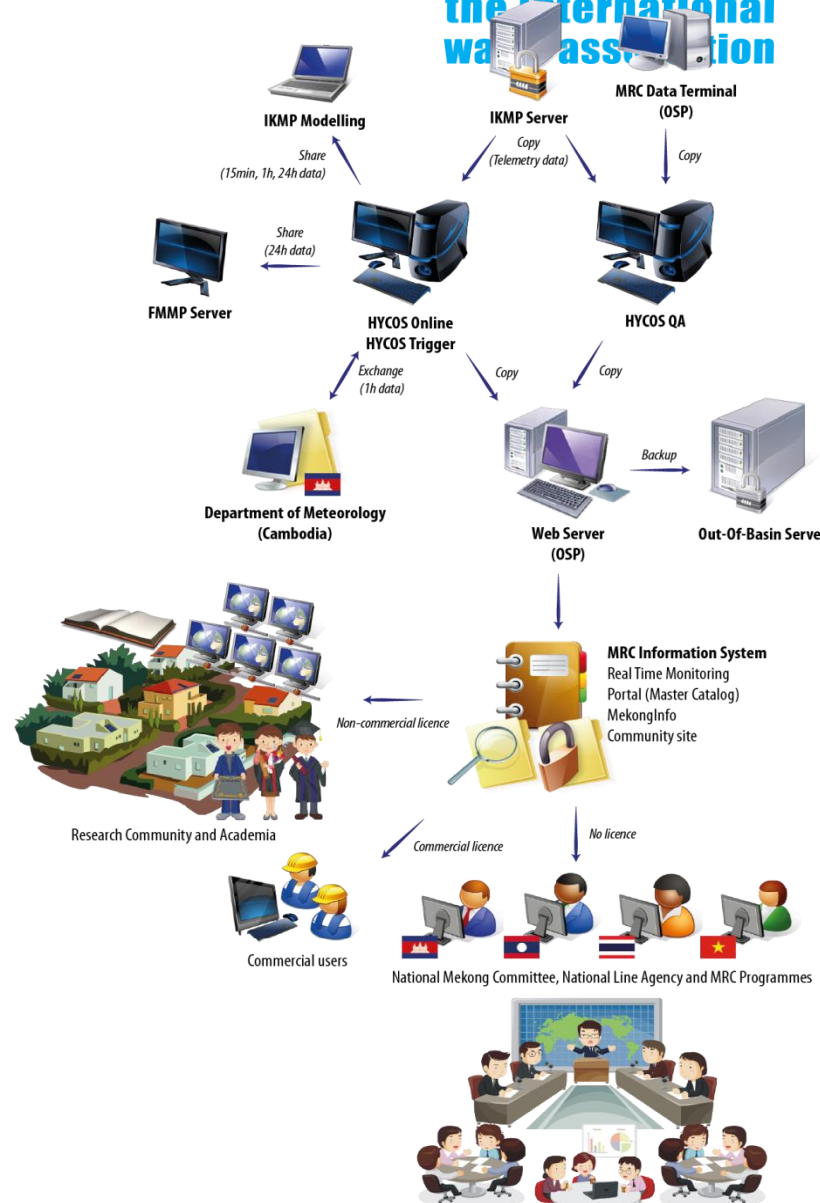
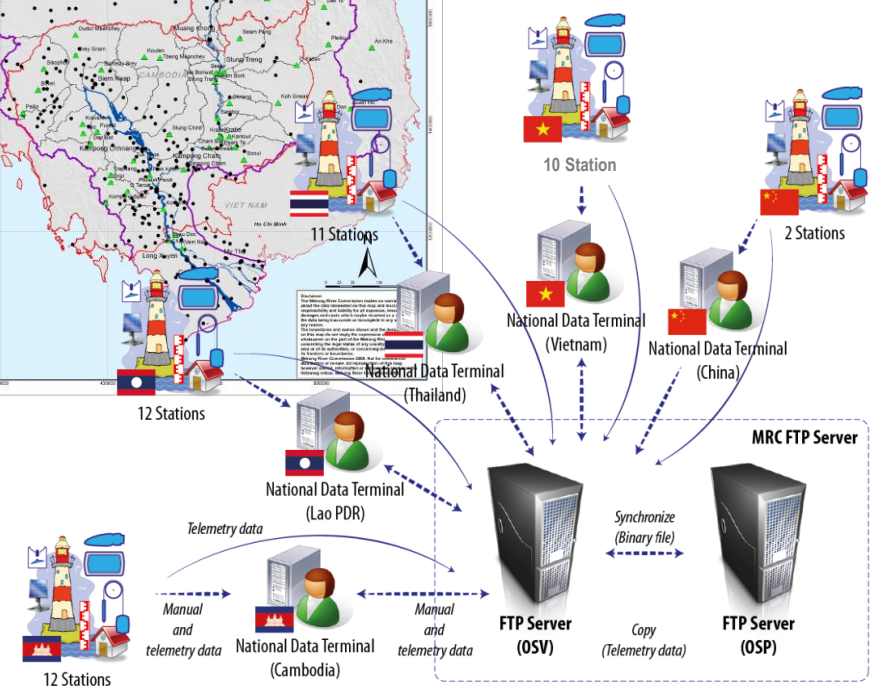
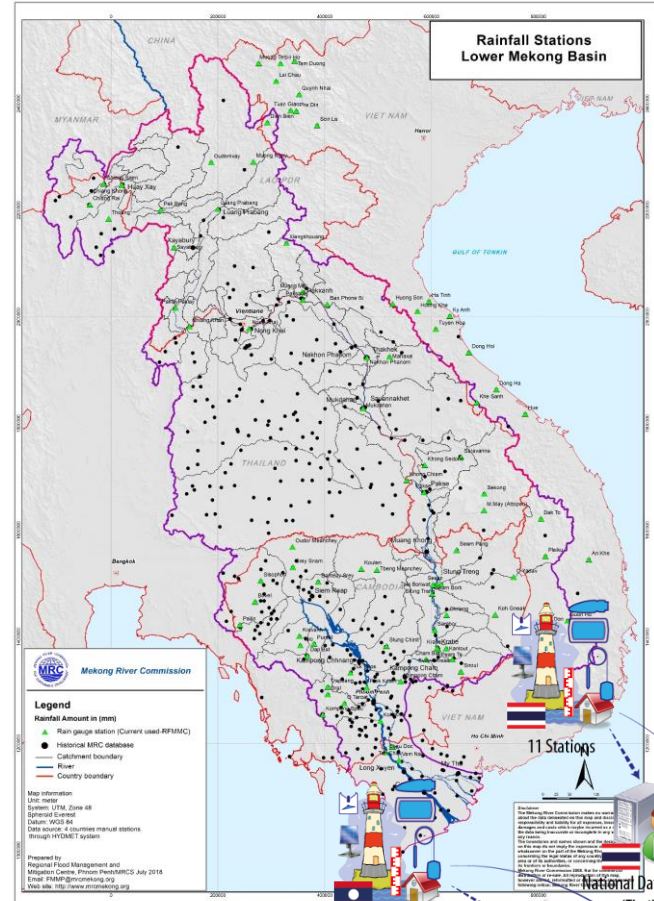
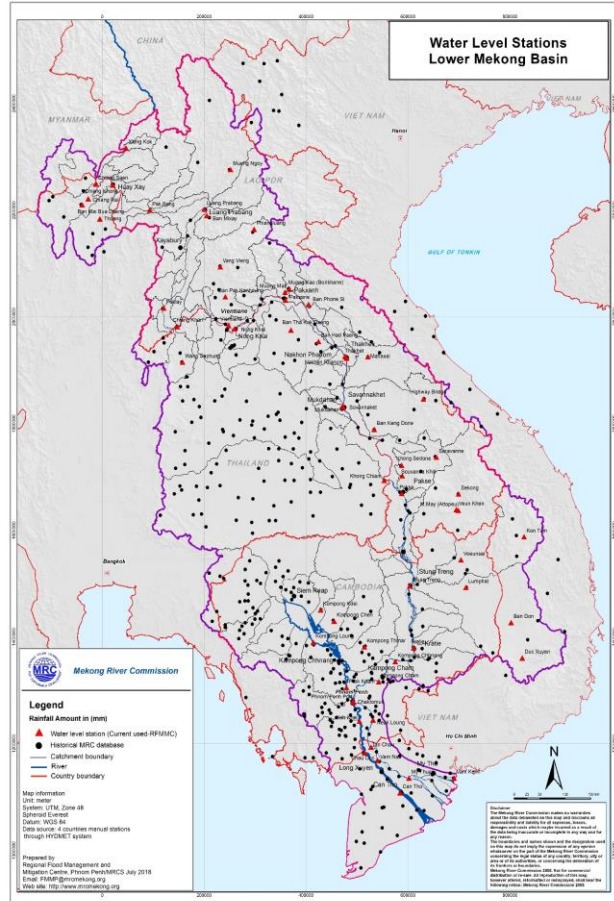


MRCs building in Vientiane, Lao PDR



Regional Flood and Drought Management Centre in Phnom Penh, Cambodia

2. Data sharing information within the LMB via MRCS



3. The MRC's Regional Flood & Drought Management Center

- 1. Daily (once/twice) flood forecasting & warning during flood season, Weekly monitoring WL in dry season, for Mekong mainstream.

- 2. Flash Flood Guidance (1-3-6-24 hourly updates) & Flash Flood Alerts during critical weather situations.

- 3. Drought forecasting & monitoring (3 months, updated monthly/2-month depend on NASA' data)

MRC FLOOD FORECASTING SYSTEM

Forecasting Platform

Models

Data

The Dotted River Basin Simulator (DRBS) is a hydrologic conceptual rainfall routing model that enables the simulation of catchment storage and runoff response in the river and stream network. The system consists a set of 31 DRBS models, covering over 140,000 km² of the entire Mekong River basin.

DRBS Subwatershed for Lower Mekong River Basin

Data Availability in the RYMRC: RYMRC, RYOM, RYOM, RYOM, RYOM, RYOM (Other real time rainfall & water levels)

The additional information please contact Regional Flood Management and Mitigation Centre (RFMMC), as a part of the MRC's Decision Support Framework (DSF), as a general CD model for the simulation of 'nearby flow' it channel network. The model within the RFMMC environment runs in 'Flow' through the extent of downstream boundaries of the model to beyond the influence of the flood flow capacity to the estuary at the mouth of the Mekong.

The new Mekong Flood Forecasting System offers an increased ability to provide satisfactory and more accurate forecasts of some locations within the basin and offers the possibility for longer lead times

MRC FLASH FLOOD GUIDANCE SYSTEM

Basin Delineation

MRCFFG System Design Overview

FFG System User Interface

BACKGROUND

The implementation of the MRC Flash Flood Guidance (MRCFFG) System for the Lower Mekong Basin is funded by the USAID Office of U.S. Foreign Disaster Assistance (OFDA), partnered with National Oceanic & Atmospheric Administration (NOAA), and Hydrologic Research Center (HRC) under the Asia Flood Network Program.

Development, implementation and testing of system models (base correction, soil moisture, flash flood guidance)

Development, implementation and testing of input procedures for acquiring satellite and in situ precipitation data

Regional and national training for operators on hydrologic basin of stream components, on the use and maintenance of FFG software systems, on product retrieval, and the interpretation, use and validation of system products.

BENEFITS OF THE SYSTEM

- Addresses all flash flood prone basins over large areas
- Early awareness of impending local flash flood threats for all potentially vulnerable areas
- Provide rapid assessments of the potential of flash floods allowing improvement of the early warnings for the occurrence of a flash flood
- Allow for the more rapid mobilization of response agencies (rather than a system that provides detailed forecasts of the magnitude - which add complexity and uncertainty to warning development)
- Responsive national/line agencies can establish criteria for issuing warnings alerts based on flash flood guidance and flash flood threat
- System is a diagnostic tool used to indicate the likelihood of flooding of small streams over large regions
- System uses bias-corrected satellite-based and in-situ gauge precipitation estimates and real-time soil moisture estimates to produce flash flood threat

Basin Delineation

- 1,377 sub-basins
- Mean basin area 182 km²
- Sub-Div. Basin area 140 km²
- Mean channel length 33 km

Example One-hour Flash Flood Guidance (Kantana Storm on 25/08/2008)

Example Six-hour Flash Flood Guidance (Kantana Storm on 25/08/2008)

Example Regional Flash Flood Threat Product (Kantana Storm on 25/08/2008)

RFMMC Hydrologic Research Center
USAID FROM THE AMERICAN PEOPLE

Drought Early Warning Lower Mekong Basin

Date: 09-02-2020

Weekly Forecast

Combined Drought Index (CDI)

- D4 (Exceptional Drought)
- D3 (Extremely Drought)
- D2 (Severely Drought)
- D1 (Moderate Drought)
- D0 (Normal Condition)

Mekong River
Country Boundary
Catchment Boundary
Lower Mekong Basin Boundary

The drought monitor focus on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

RFMMC USAID FROM THE AMERICAN PEOPLE NASA adpc

Disclaimer: This drought monitoring and forecasting map is calculated based on the satellite imageries with no ground verification. MRC does not guarantee the values and accuracy of the products nor be responsible for any risks of using the products.

4. Improving Flood Forecasting based on Satellite Data

SRE/GFAS (NOAA) 

- CHIRPS-GEFS (5km x 5km)
- GPM-BICO (10km x 10 km)

PROPOSED DATA USE

Existing FEWS

New FEWS

FLOODS FORECASTING

NEAR REAL TIME OF SATELLITE DATA

- SRE

SATELLITE FORECASTING RAINFALL

- GFAS

MANUAL DATA

- Water levels and Rainfall

FEWS

NEAR REAL TIME OF SATELLITE DATA

- GMP (GLOBAL MEASUREMENTS PRECIPITATION)

SATELLITE FORECASTING RAINFALL

- CHIRPS-GEFS (Global Ensemble Forecast System)

MANUAL DATA

- Water levels and Rainfall

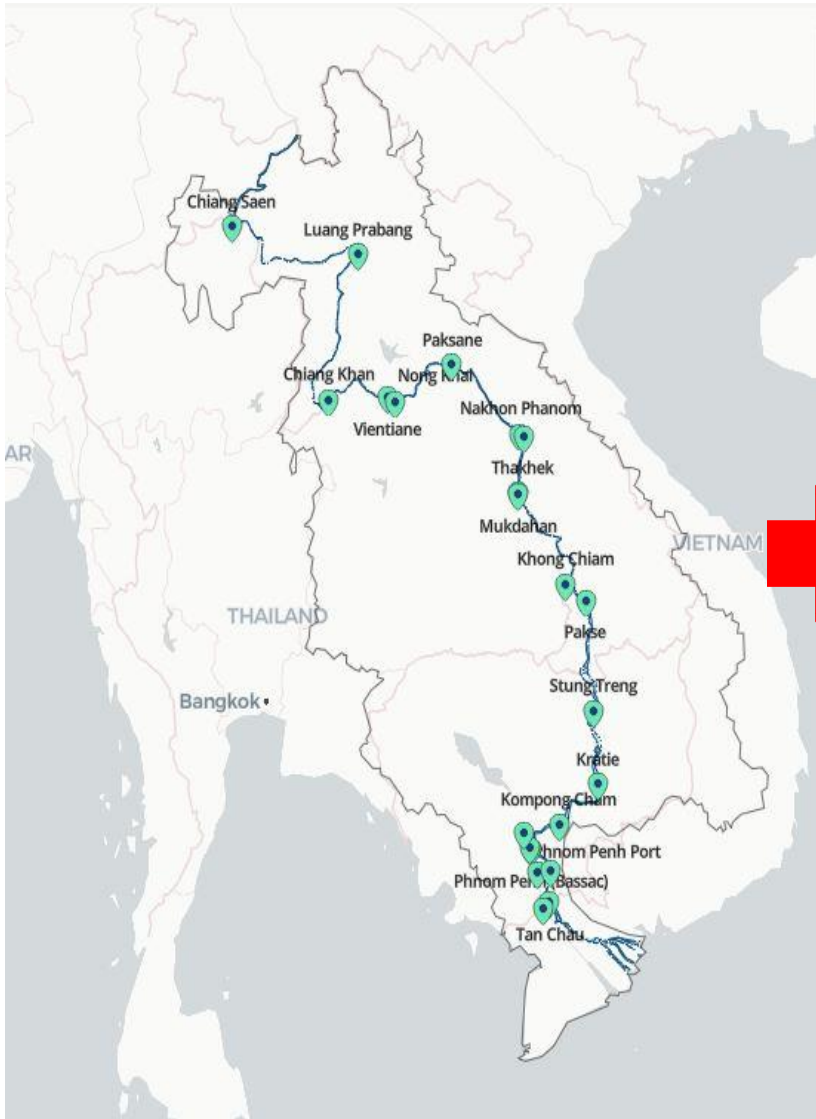
GMP-BICO

FLOOD MITIGATION AND DATA SHARING

UNDER TESTING AND EVALUATION



A. Riverine flood forecasting



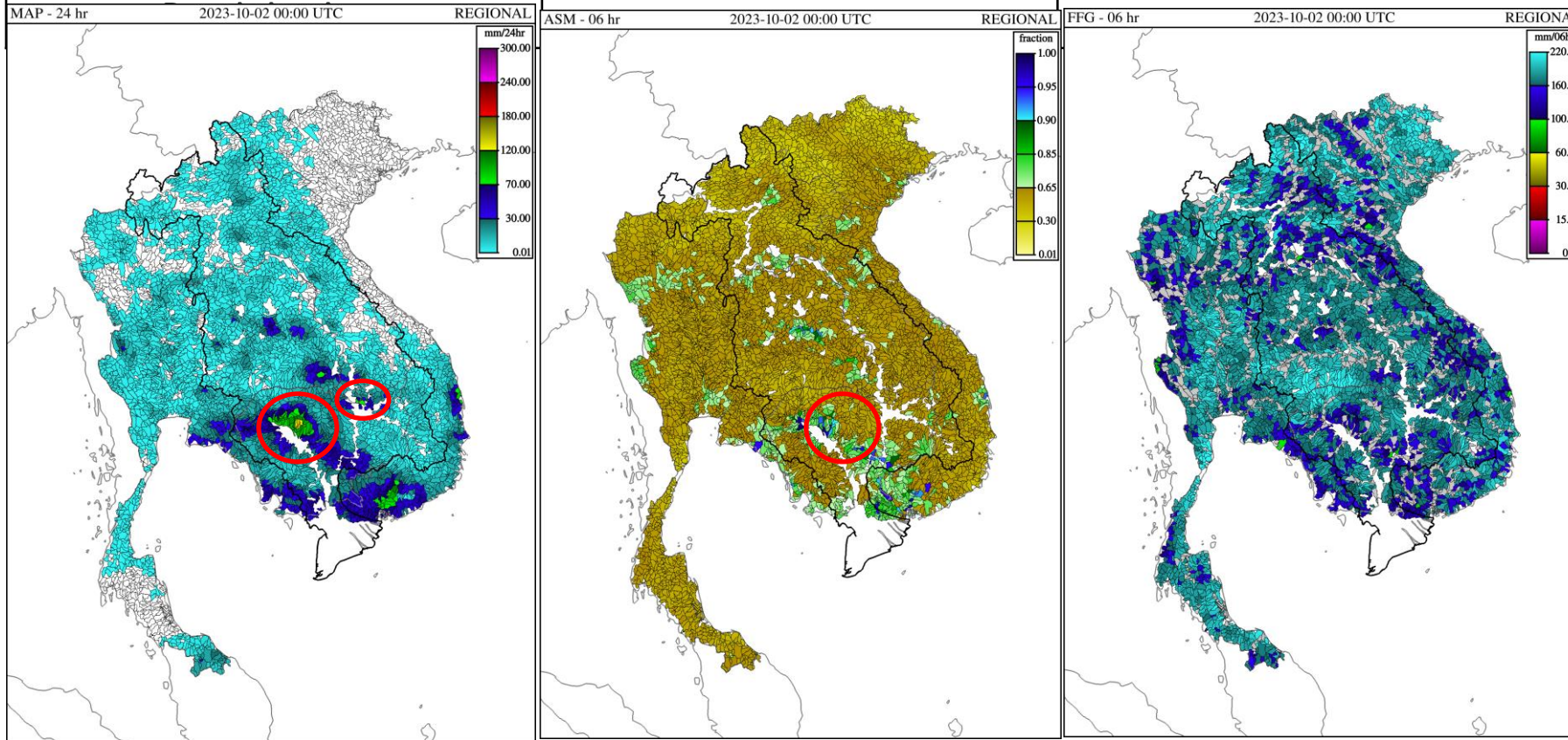
Forecasting Station	24h Observed Rainfall (mm)	Zero gauge above M.S.L (m)	Alarm Level (m)	Flood Level (m)	Observed W. level against zero gauge (m)		Forecasted Water Levels (m)					Forecasted Water Levels change in 5 days (m)	Max Water Levels change within next 5 days (m)	Min distance to alarm level within next 5 days (m)	Min distance to flood level within next 5 days (m)	
	1 Oct				1 Oct	2 Oct	3 Oct	4 Oct	5 Oct	6 Oct	7 Oct					
Jinghong	0.5	-	-	-	536.38	536.08	-	-	-	-	-	-	-	-	-	-
Chiang Saen	16.0	357.110	11.50	12.80	3.96	→ 3.94	→ 3.87	↓ 3.75	→ 3.80	→ 3.89	↑ 4.01	0.07	0.07	7.49	8.79	
Luang Prabang	4.4	267.195	17.50	18.00	10.80	→ 10.82	→ 10.87	→ 10.85	→ 10.77	→ 10.84	→ 10.94	0.12	0.12	6.56	7.06	
Chiang Khan	0.6	194.118	14.50	16.00	9.06	↑ 9.25	→ 9.30	→ 9.35	→ 9.36	→ 9.30	→ 9.35	0.10	0.11	5.14	6.64	
Vientiane	0.0	158.040	11.50	12.50	7.32	→ 7.39	↑ 7.61	→ 7.69	→ 7.77	→ 7.80	→ 7.74	0.35	0.41	3.70	4.70	
Nong Khai	0.0	153.648	11.40	12.20	7.00	→ 7.05	↑ 7.25	→ 7.31	→ 7.36	→ 7.39	→ 7.35	0.30	0.34	4.01	4.81	
Paksane	8.2	142.125	13.50	14.50	8.51	→ 8.58	→ 8.63	↑ 8.75	→ 8.78	→ 8.81	→ 8.83	0.25	0.25	4.67	5.67	
Nakhon Phanom	0.0	130.961	11.50	12.00	8.10	↓ 7.90	↓ 7.75	→ 7.72	→ 7.80	→ 7.84	→ 7.87	-0.03	-0.03	3.63	4.13	
Thakhek	0.0	129.629	13.00	14.00	9.13	↓ 8.95	↓ 8.81	→ 8.77	→ 8.86	→ 8.90	→ 8.94	-0.01	-0.01	4.06	5.06	
Mukdahan	0.0	124.219	12.00	12.50	8.34	↓ 8.15	↓ 7.95	↓ 7.80	→ 7.75	→ 7.83	→ 7.87	-0.28	-0.20	4.05	4.55	
Savannakhet	0.0	125.410	12.00	13.00	6.78	↓ 6.50	↓ 6.25	↓ 6.08	→ 6.03	→ 6.08	→ 6.11	-0.39	-0.25	5.75	6.75	
Khong Chiam	7.0	89.030	13.50	14.50	10.87	↓ 10.81	↓ 10.57	↓ 10.32	↓ 10.12	↓ 10.05	→ 10.10	-0.71	-0.24	2.93	3.93	
Pakse	5.2	86.490	11.00	12.00	8.90	→ 8.90	↓ 8.70	↓ 8.55	↓ 8.42	→ 8.38	→ 8.41	-0.49	-0.20	2.30	3.30	
Stung Treng	20.0	36.790	10.70	12.00	8.09	↑ 8.18	→ 8.21	↓ 8.04	↓ 7.92	↓ 7.80	→ 7.77	-0.41	0.03	2.49	3.79	
Kratie	18.8	-0.101	22.00	23.00	18.85	→ 18.83	↑ 18.90	↑ 18.93	↓ 18.74	↓ 18.60	↓ 18.46	-0.37	0.10	3.07	4.07	
Kompong Cham	2.2	-0.930	15.20	16.20	12.40	↑ 12.46	→ 12.48	↑ 12.52	→ 12.50	↓ 12.36	↓ 12.24	-0.22	0.06	2.68	3.68	
Phnom Penh (Bassac)	1.4	-1.020	10.50	12.00	7.95	↑ 8.02	↑ 8.06	→ 8.08	→ 8.07	↓ 8.00	↓ 7.95	-0.07	0.06	2.42	3.92	
Phnom Penh Port	-	0.070	9.50	11.00	6.67	→ 6.69	→ 6.72	→ 6.74	→ 6.74	↓ 6.70	↓ 6.67	-0.02	0.05	2.76	4.26	
Koh Khel (Bassac)	32.6	-1.000	7.90	8.40	6.98	↑ 7.02	↑ 7.05	→ 7.07	→ 7.08	↓ 7.05	↓ 7.02	0.00	0.06	0.82	1.32	
Neak Luong	nr	-0.330	7.50	8.00	5.72	↑ 5.80	↑ 5.83	→ 5.85	→ 5.87	→ 5.85	↓ 5.80	0.00	0.07	1.63	2.13	
Prek Kdam	7.2	0.080	9.50	10.00	6.97	↑ 7.05	↑ 7.12	↑ 7.15	→ 7.17	→ 7.16	↓ 7.13	0.08	0.12	2.33	2.83	
Tan Chau	46.6	0.000	3.50	4.50	2.80	↓ 2.75	↓ 2.70	→ 2.68	→ 2.66	→ 2.69	→ 2.71	-0.04	-0.04	0.79	1.79	
Chau Doc	12.0	0.000	3.00	4.00	2.55	↓ 2.47	↓ 2.40	→ 2.38	→ 2.36	↑ 2.40	↑ 2.44	-0.03	-0.03	0.56	1.56	

B. Flash flood guidance system (FFGS)

Figure 1: Mean Areal

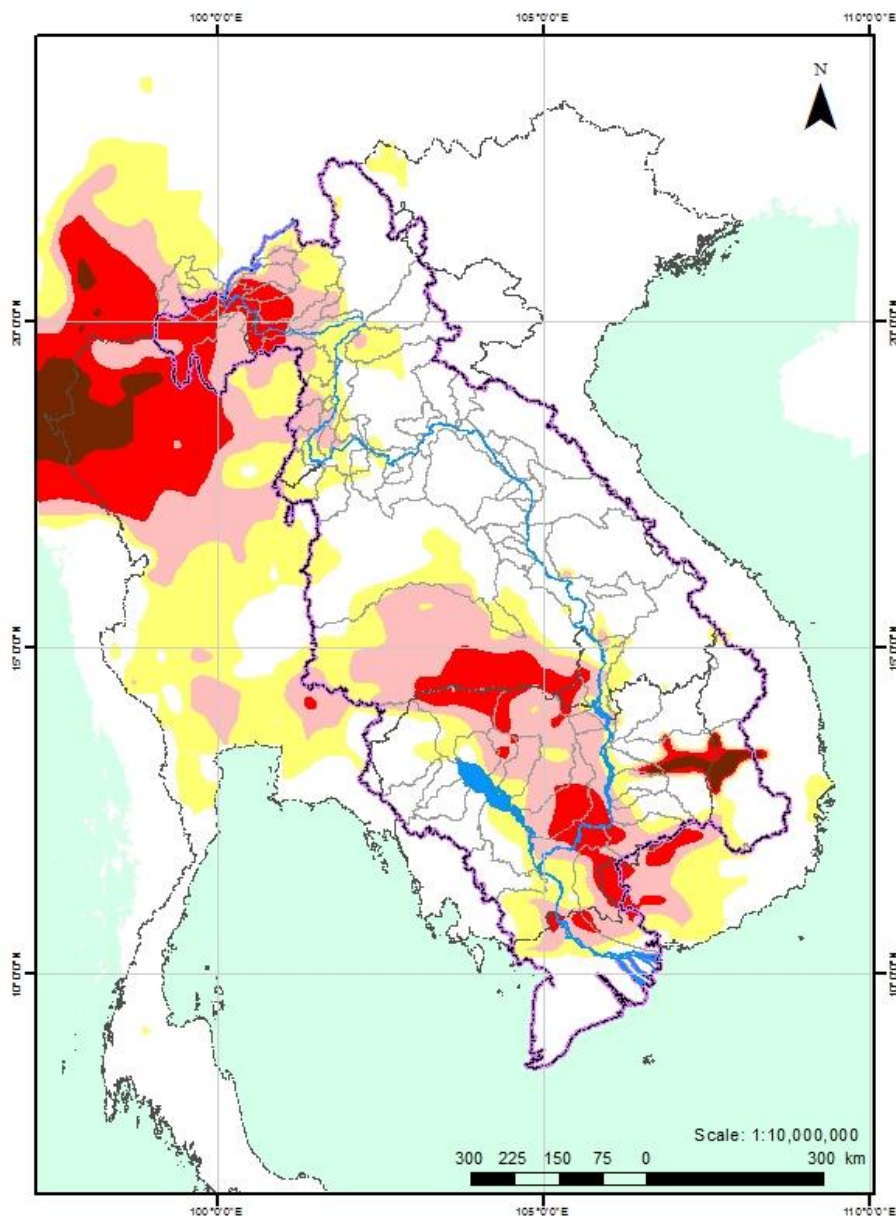
Figure 2: Average Soil Moisture

Figure 3: Flash Flood Guidance



- Very heavy rain occurred in Kompong Kdei area of Cambodia in the past 24 hours.
- Soil moisture in some areas in Siem Riep province were nearly saturated state
- In the next 6 hours, the flash flood will likely be detected in some areas of Siem Riep.

C. Drought Forecasting

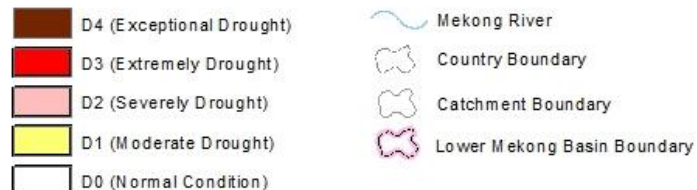


Drought Early Warning Lower Mekong Basin

Date: 09-02-2020

Weekly Forecast

Combined Drought Index (CDI)



The drought monitor focus on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.



Disclaimer: This drought monitoring and forecasting map is calculated based on the satellite imageries with no ground verification. MRC does not guarantee the values and accuracy of the products nor be responsible for any risks of using the products.

Provides 3-month forecast (updated weekly).

Main indicators:

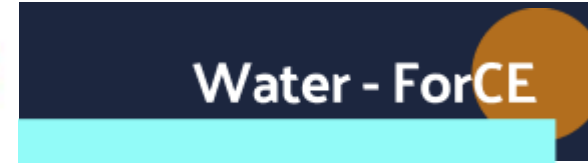
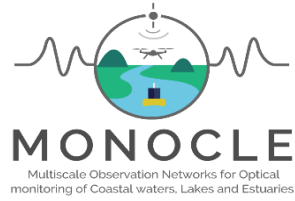
- ❖ **Meteorological drought indices**
 - Rainfall anomalies
 - **Standardize Precipitation Index (SPI)**
 - Moisture Availability Index
 - **Dry Spells, Drought Condition, RD**
- ❖ **Hydrological drought indices**
 - Stream flow
 - Water level
 - **Standardized Runoff Index (SRI)**
 - Groundwater level
 - Reservoir storage
- ❖ **Agricultural drought indices**
 - Normalized Difference Vegetation Index
 - Normalized Difference Water Index
 - Soil Moisture Anomalies
 - **Soil Moisture Deficit Index (SMDI)**
 - Temperature Anomalies
 - Evapotranspiration deficit

Note: Those highlighted in red are the used indices by MRC

5. Actual Plan for Flood Season 2023

- Improving quality of both hydro-meteorological (water level & rainfall) data as inputs for models based on QA/QC.
- Applying GPM-BICO application (cooperating with ADPC...) for improving riverine flood forecasting, FFGS and Drought prediction.
- Updating Rating-Curves for all key-stations to improve flood forecasting outputs.
- Input dam/reservoir operations information for FEWS, if data is available.
- Provide capacity building on flood forecasting for National Levels.
- Integrating medium and long-ranges forecasting of the floods and drought on webpage.
- Addressing the needs in a more effective and efficient manner in proper cooperating with MCs and other technical partners (ADPC, DHI, eWater.....)





POTENTIAL AND UPTAKE OF EARTH OBSERVATION FOR INLAND WATER QUALITY MONITORING AND REPORTING

ILS REUSEN (VITO; ILS.REUSEN@VITO.BE), STEFAN SIMIS (PML), STEEF PETERS (WI), ANNELIES HOMMERSOM (WI), CLAUDIA GIARDINO (CNR), GARY FREE (JRC) + CO-AUTHORS WHITE PAPER

inspiring change

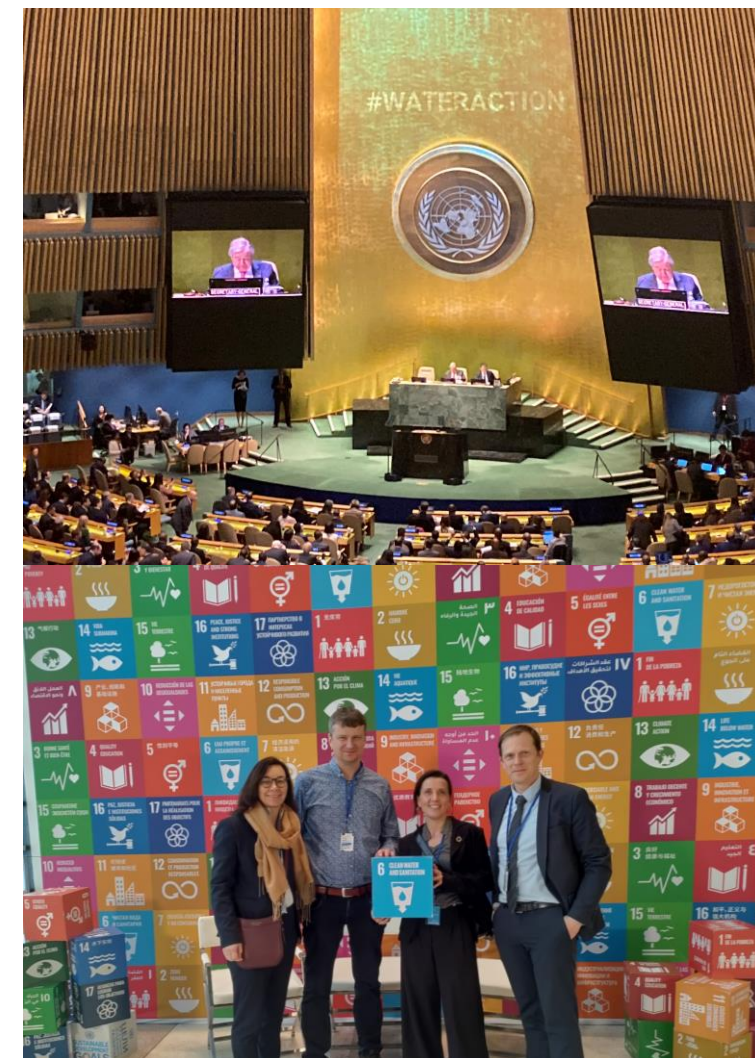


UN WATER 2023 CONFERENCE, NY

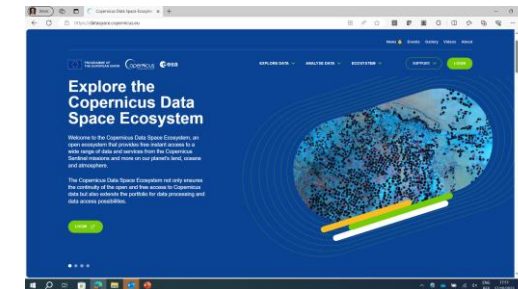
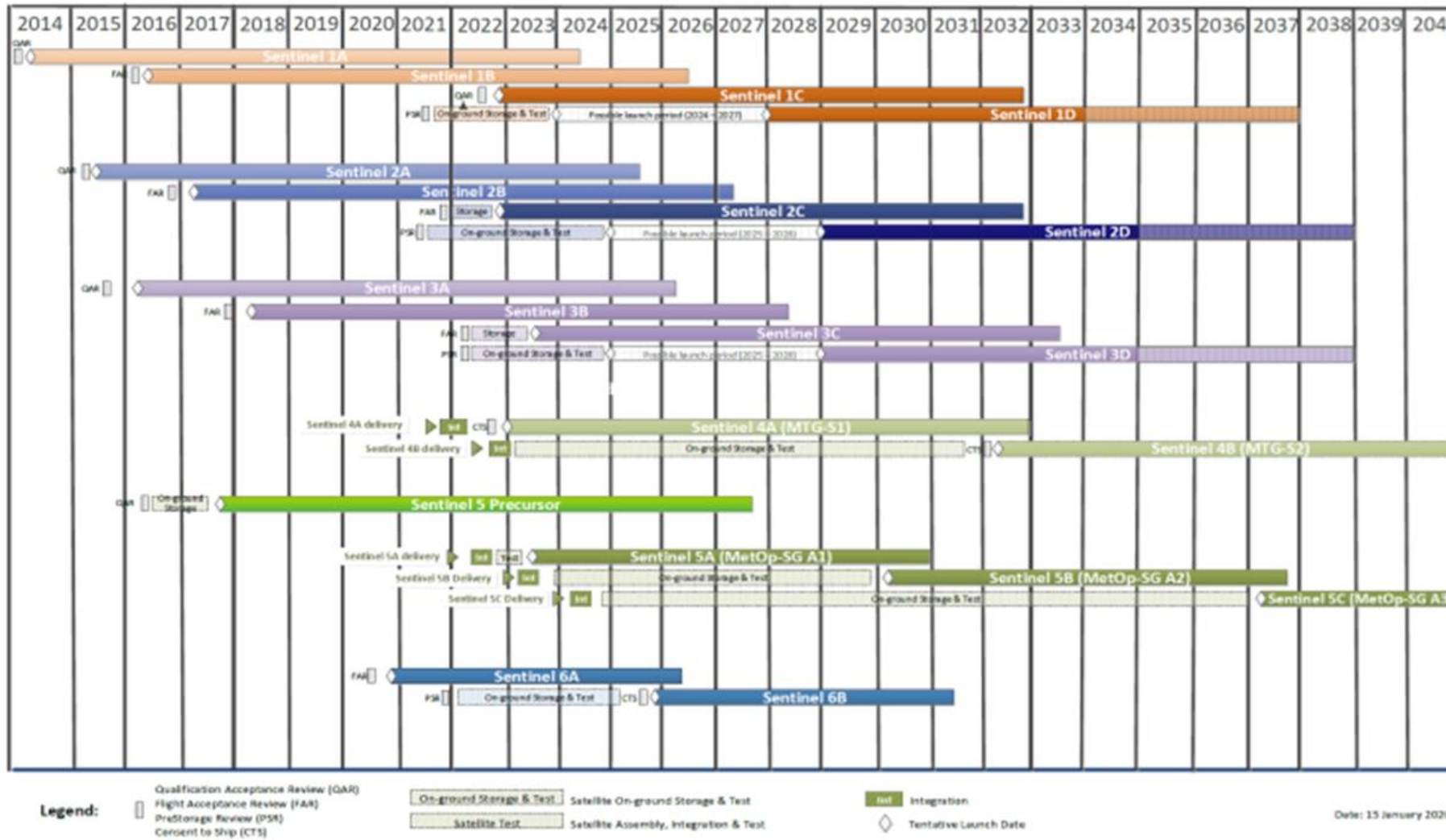
Concept Paper Interactive dialogue 3: Water for climate, resilience and environment – source to sea, biodiversity, climate, resilience and disaster risk reduction

“The power of Earth observation. Accelerating digital transformation, through remote sensing and satellite imagery data, holds great potential for transforming how data and information are generated and accessed and used for monitoring and reporting on water bodies.

Earth observation increasingly enables innovative water and decision information systems across scales. **This will offer more opportunities for neutral, reliable and transparent data and information-gathering and sharing, essential for ensuring sustainable water management and to close data and information gaps. Field observation, however, will remain essential to “ground-truth” Earth observation data”**



THE EUROPEAN SATELLITE OBSERVATION INFRASTRUCTURE IS FULLY OPERATIONAL (OPEN AND FREE)



WHAT?
A constellation of two identical satellites in the same orbit, Copernicus Sentinel-2 images land and coastal areas at high spatial resolution in the optical domain

WHERE?
Designed and built by a group of around 60 companies led by Airbus Defence and Space for the space segment and Thales Alenia Space for the ground segment

WHICH?
Main applications include agriculture; land ecosystems monitoring; forests management; inland and coastal water quality monitoring; disasters mapping and civil security

WHEN?
Sentinel-2A was launched on 23 June 2015; Sentinel-2B on 7 March 2017, both on a Vega rocket from Kourou, French Guiana

DATA AND USERS
As of July 2020, about 20 million products have been generated and made available for download, culminating a total of 10 Petabytes

DATA ACCESS
<https://scihub.copernicus.eu>

WHO?
Services include CLMS (Copernicus Land Monitoring Service); CMEMS (Copernicus Marine Environment Monitoring Service); CEMS (Copernicus Emergency Management Service) and Copernicus Security Service, among others

WHATS NEXT?
Continuity over the coming years will be ensured by the launch of additional satellites (Sentinel-2C and Sentinel-2D). Furthermore, a new generation of Sentinel-2 satellites is being prepared, to take up the relay from the first generation

10 metre spatial resolution:

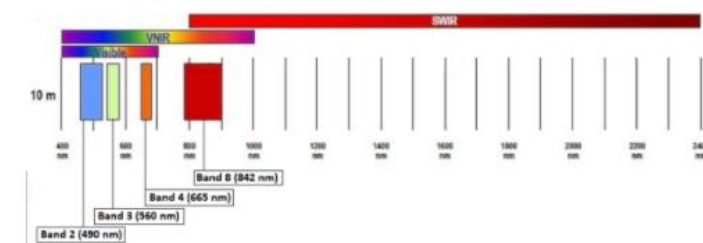


Figure 1: SENTINEL-2 10 m spatial resolution bands: B2 (490 nm), B3 (560 nm), B4 (665 nm) and B8 (842 nm)

20 metre spatial resolution:

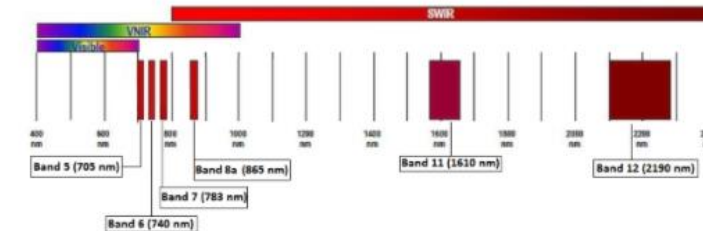


Figure 2: SENTINEL-2 20 m spatial resolution bands: B5 (705 nm), B6 (740 nm), B7 (783 nm), B8a (865 nm), B11 (1610 nm) and B12 (2190 nm)

60 metre spatial resolution:

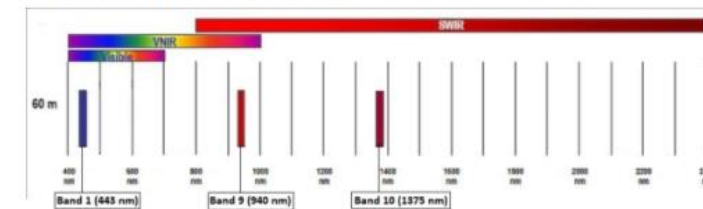


Figure 3: SENTINEL-2 60 m spatial resolution bands: B1 (443 nm), B9 (940 nm) and B10 (1375 nm)

- Swath width: 290 km
- Revisit time: 5 days with two satellites (Sentinel-2A and B)
- 13 spectral bands in VNIR and SWIR wavelength region
- Spatial resolution dependent on the spectral band

COMPLEMENTARITY

There is complementary value in **optical water quality observations from satellite sensors** and this is relevant to the goals of the **EU Water Framework Directive (WFD)** wrt surface waters to achieve good ecological status by 2027

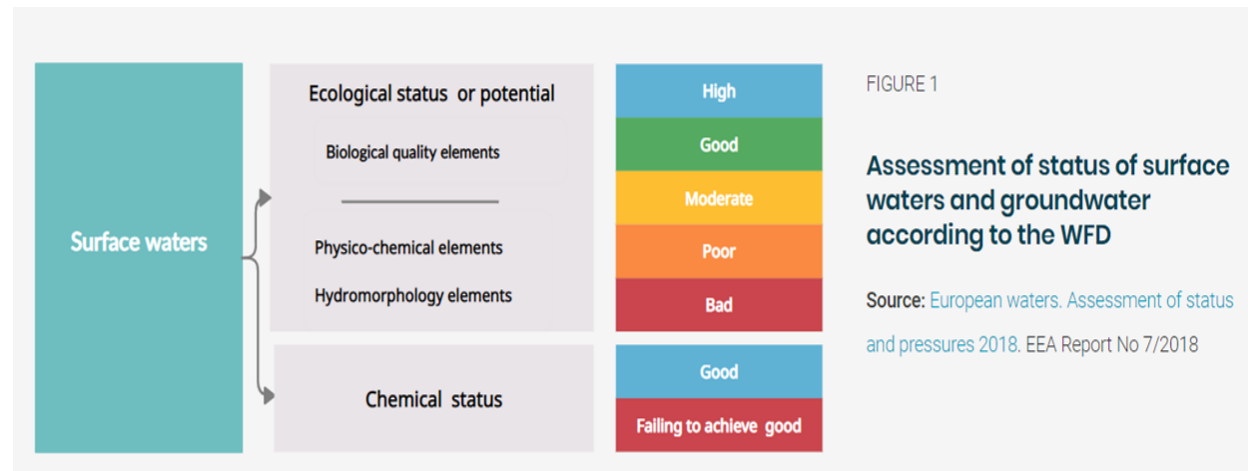
2022/0344 (COD)

Proposal for a

DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

amending Directive 2000/60/EC establishing a framework for Community action in the field of water policy, Directive 2006/118/EC on the protection of groundwater against pollution and deterioration and Directive 2008/105/EC on environmental quality standards in the field of water policy

- (31) It is necessary to take into account scientific and technical progress in the area of monitoring of the status of water bodies in accordance with the monitoring requirements set out in Annex V to Directive 2000/60/EC. Therefore, Member States should be allowed to use of data and services from remote sensing technologies, earth observation (Copernicus services), in-situ sensors and devices, or citizen science data, leveraging the opportunities offered by artificial intelligence, advanced data analysis and processing.



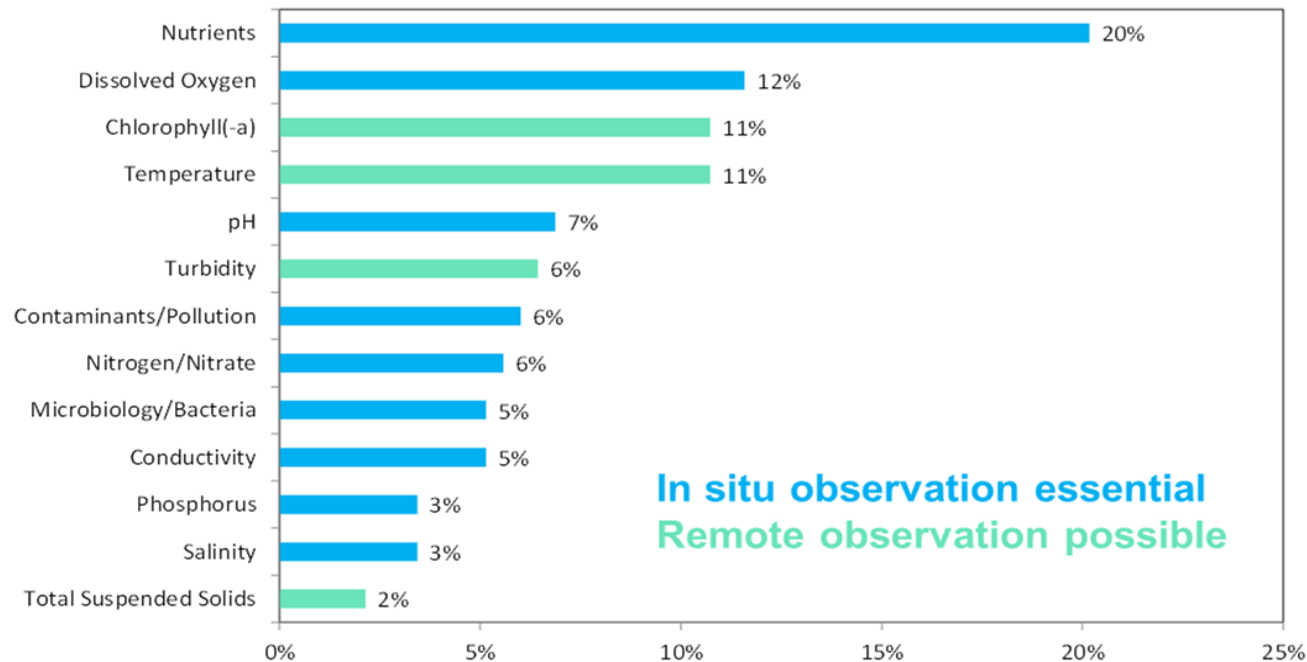
But need to:

- align in situ and satellite remote sensing strategies to achieve the best complementary value
- integrate satellite and in situ observations into policy frameworks

COMPLEMENTARITY

Optical water quality satellite observation can complement (and does not replace) *in situ* sampling efforts

“Which of the water quality variables sampled in your region do you consider to be the most relevant?”



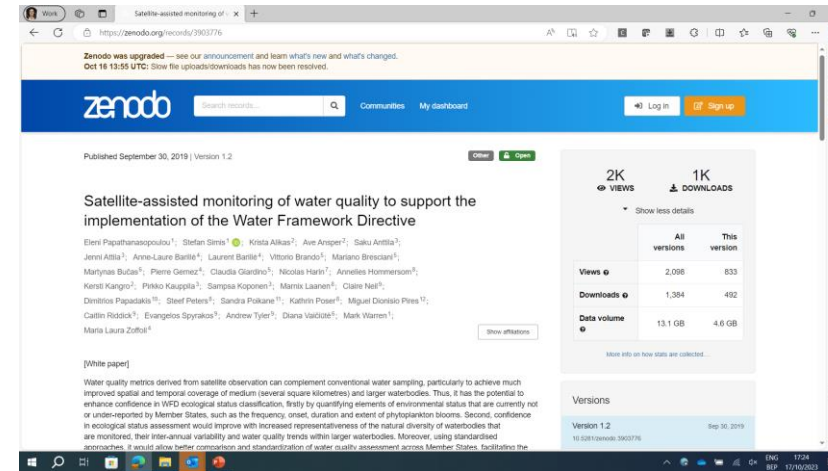
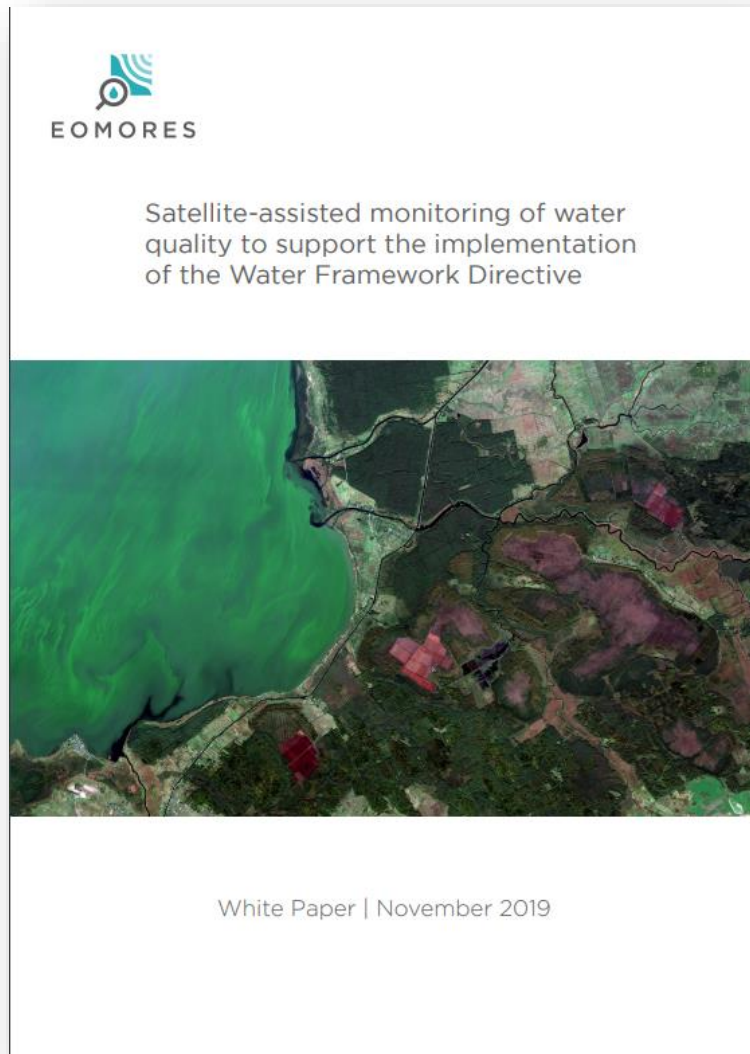
In situ observation essential
Remote observation possible



MONOCLE

Multiscale Observation Networks for Optical monitoring of Coastal waters, Lakes and Estuaries

<https://monocle-h2020.eu/Resources>
2018. CC-BY-NC-SA 4.0 License



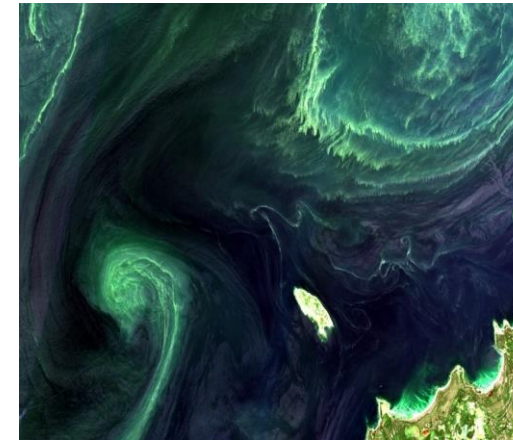
E Papatouanopoulos, S Simis, K Alikas, A Anspes, S Anttila, J Attila, ... M L Zoffoli. (2019, September 30). Satellite-assisted monitoring of water quality to support the implementation of the Water Framework Directive (Version 1.2). Zenodo. <http://doi.org/10.5281/zenodo.3903776>

The white paper looks at current satellite-based opportunities through a WFD lens

COMPLEMENTARY VALUE-BIOLOGICAL ELEMENTS

Table 1: Current in situ metrics and corresponding satellite-derived quality metrics to be considered

WFD requirements	National Systems	Satellite-derived proxies to be considered
QE1 Biological elements		
QE1-1. Phytoplankton		
Abundance and biomass	Extracted chlorophyll-a concentration ¹ Biovolume of phytoplankton ¹	Chlorophyll-a concentration from in vivo pigment absorption ^{ii,iii} Trophic State Index derived from Chlorophyll-a
Composition	Biovolume of cyanobacteria ¹ % of cyanobacteria of total biovolume ¹ Various other metrics, trophic indices	Phycocyanin (cyanobacterial pigment) concentration ^v Functional size classes (only in oceanic waters) ^{vi}
Frequency and intensity of planktonic blooms	Not reported / not possible using conventional monitoring	Chlorophyll-a concentration ^{ii,iii} Phycocyanin (cyanobacterial pigment) concentration ^v Surface accumulations of cyanobacteria ^{vi}
QE1-2 Other aquatic flora		
Macrophyte abundance	Various trophic indices; Submerged vegetation cover ¹ Total areal coverage ¹	Areal cover of floating vegetation
Macrophyte composition	Proportion of taxa	Not from current satellite sensors, but from airborne surveys ⁱⁱ
Macroalgal cover and angiosperm abundance	Combination of spatial extent and relative abundance (measured as density) of macrophytes Abundance of macrophytes ^{iii,ix}	Spatial extent In intertidal areas ^{x,xi,xii} ; spatial distribution of seagrass density of sea grass, total surface area of seagrass beds
QE3. Chemical and physico-chemical elements		
QE3-1. General		
QE3-1-1. Transparency	Secchi disk depth (Dissolved organic carbon also used to characterise lake typology)	Satellite backscatter as turbidity, suspended particulate matter weight or vertical transparency (extinction or Secchi depth) ^{xiii,xiv}
QE3-1-2. Thermal conditions	Mean water temperature Water temperature range Air temperature	Surface water temperature ^{xv} (in open water > 2 km from land)

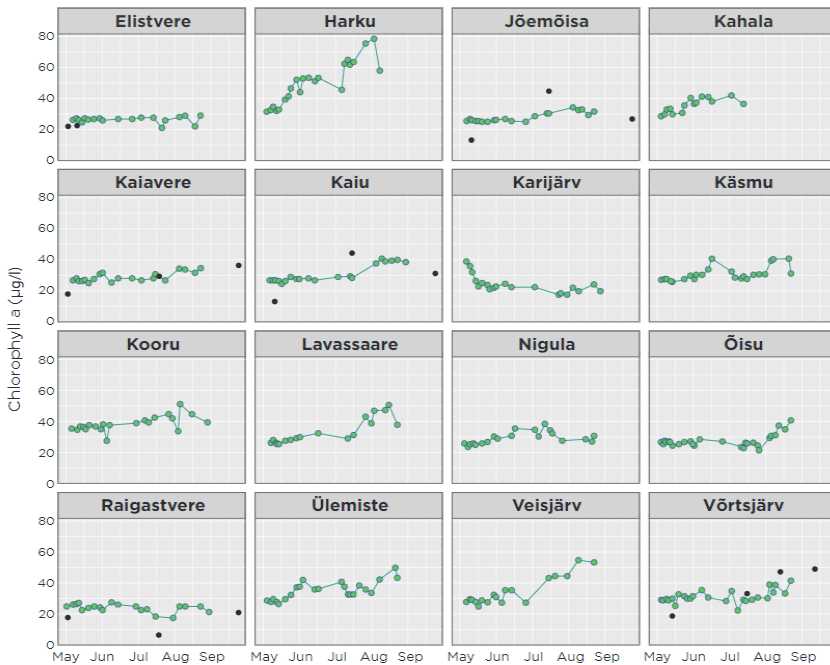


Optical satellite observation can be considered in seven biological and physico-chemical elements.

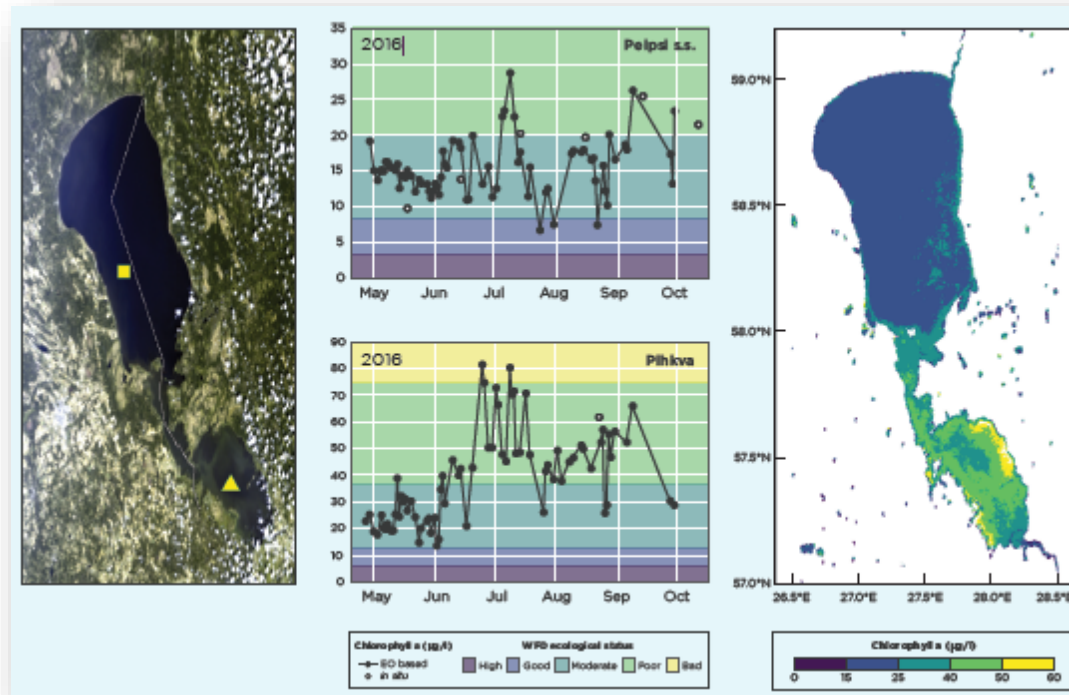
Major improvements possible for *frequency of blooms* because this requires high spatio-temporal coverage.

E Papatathanasopoulou, S Simis, K Alikas, A Ansper, S Anttila, J Attila, ... M L Zoffoli. (2019, September 30). Satellite-assisted monitoring of water quality to support the implementation of the Water Framework Directive (Version 1.2). Zenodo. <http://doi.org/10.5281/zenodo.3903776>

Analysing satellite observations of lakes and coastal waterbodies



Seasonal dynamics of chlorophyll-a in selected Estonian lakes under WFD reporting obligations from Sentinel-2 satellite during 2018. Black dots denote spectrophotometrically measured (in situ) chlorophyll-a.

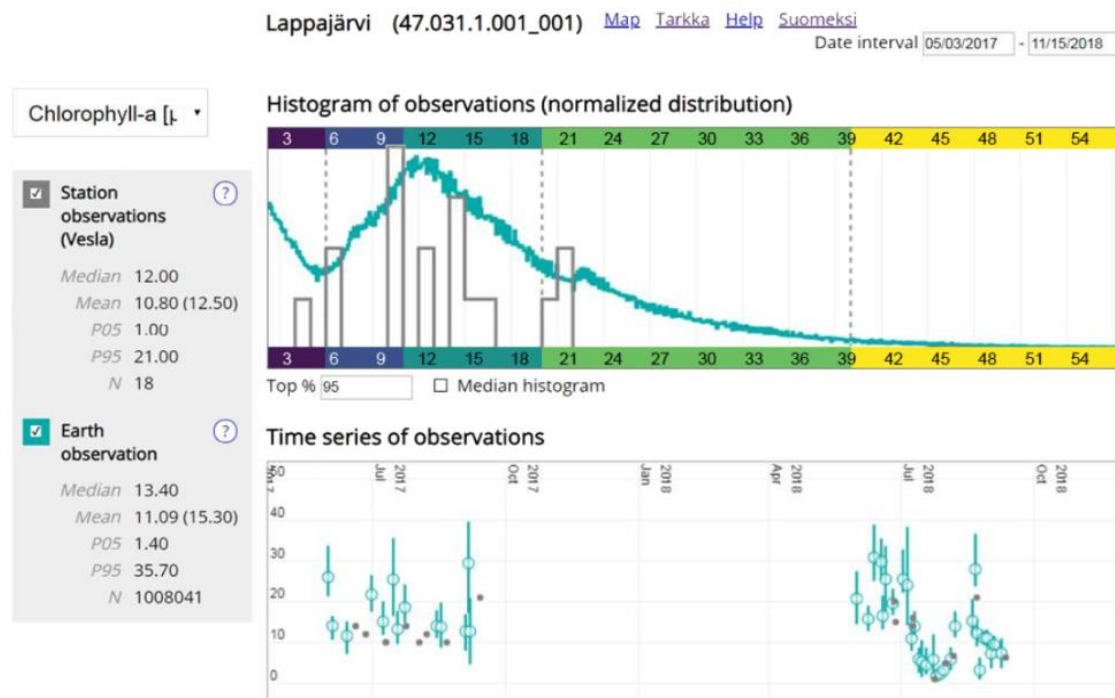


Using medium and high-resolution sensors, temporal data coverage is > 10x improved. Validation is good on the basis of WFD classes

FINLAND

Satellite products provide complementary information on 87% of the area of Finnish WFD lakes and nearly all coastal waterbodies (4,617 lakes and 276 coastal in the WFD). **Satellite products were already included in the last two reporting periods**

Classification accuracy was within 23% (cf. $\pm 20\%$ uncertainty for laboratory-based Chl-a)



A view of the web application showing statistics, data distributions (histograms) and time series of station and satellite-derived chlorophyll-a of a coastal WFD region. In the histogram, WFD status classes are indicated by colours (purple: excellent, blue: good, teal: moderate, green: poor, yellow: bad).

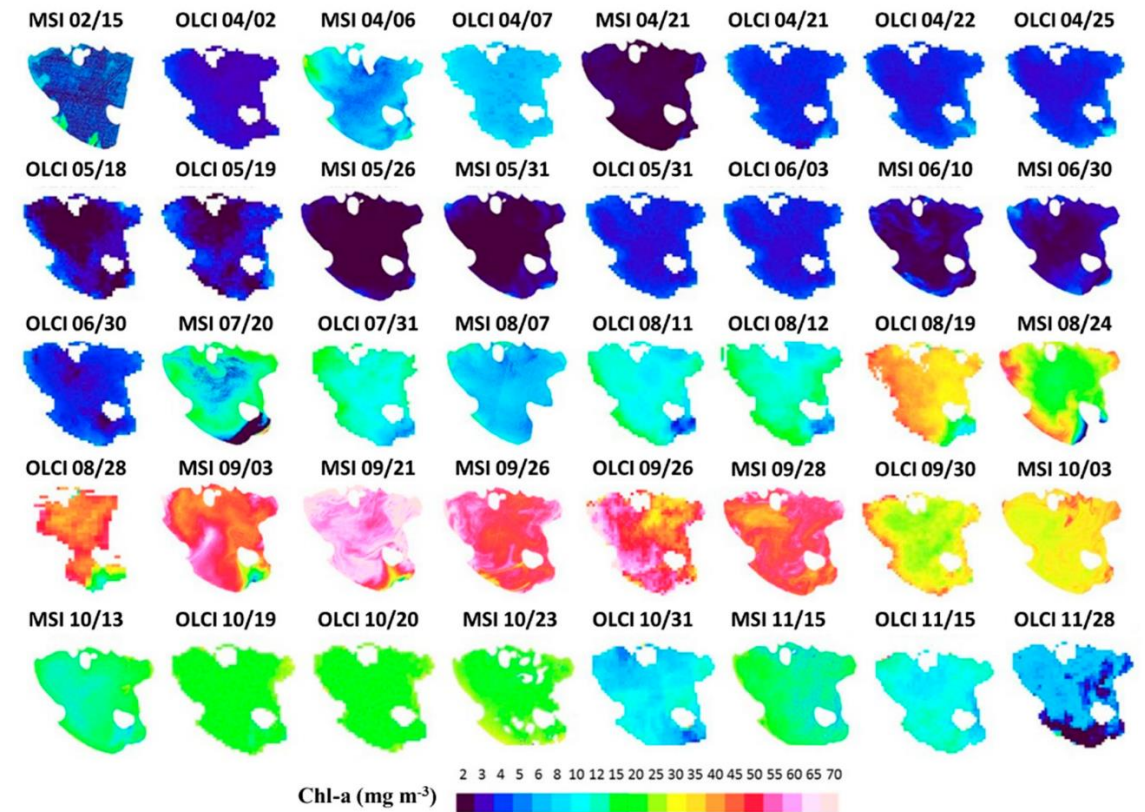
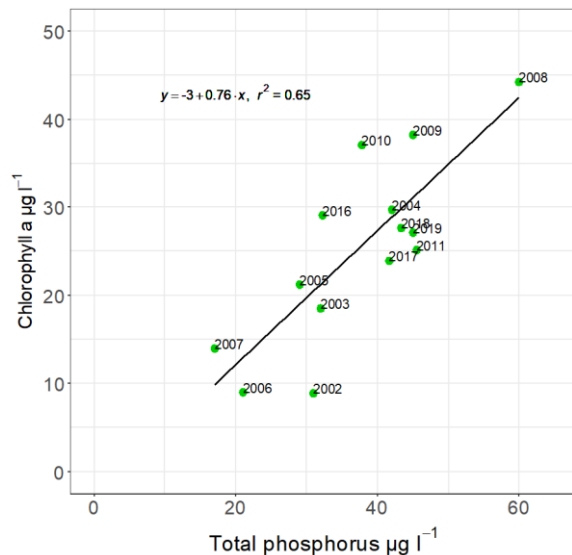
Waterbody statistics include each individual observation in the classification:
N = 18 samples in situ versus >1M from satellite

ITALY

Chlorophyll *a* in Lake Trasimeno (data from Lakes CCI)

Seasonal monitoring is possible, here combining results from high and medium resolution sensors

Results compare well to Total Phosphorus:

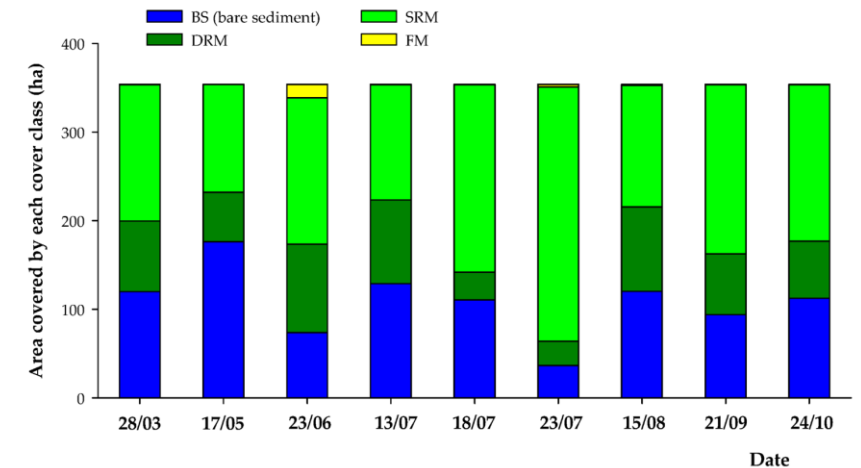
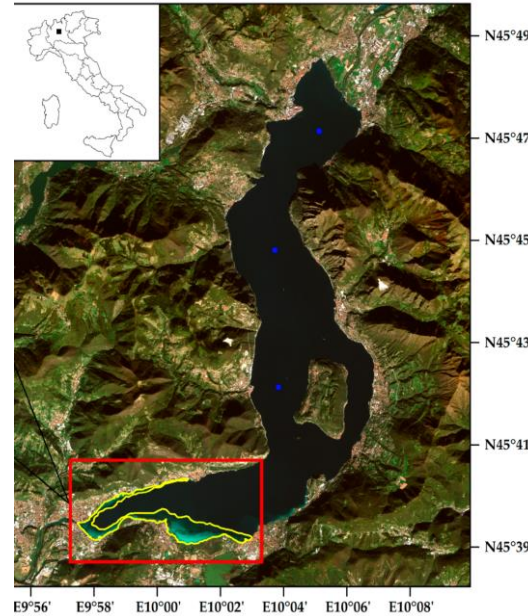
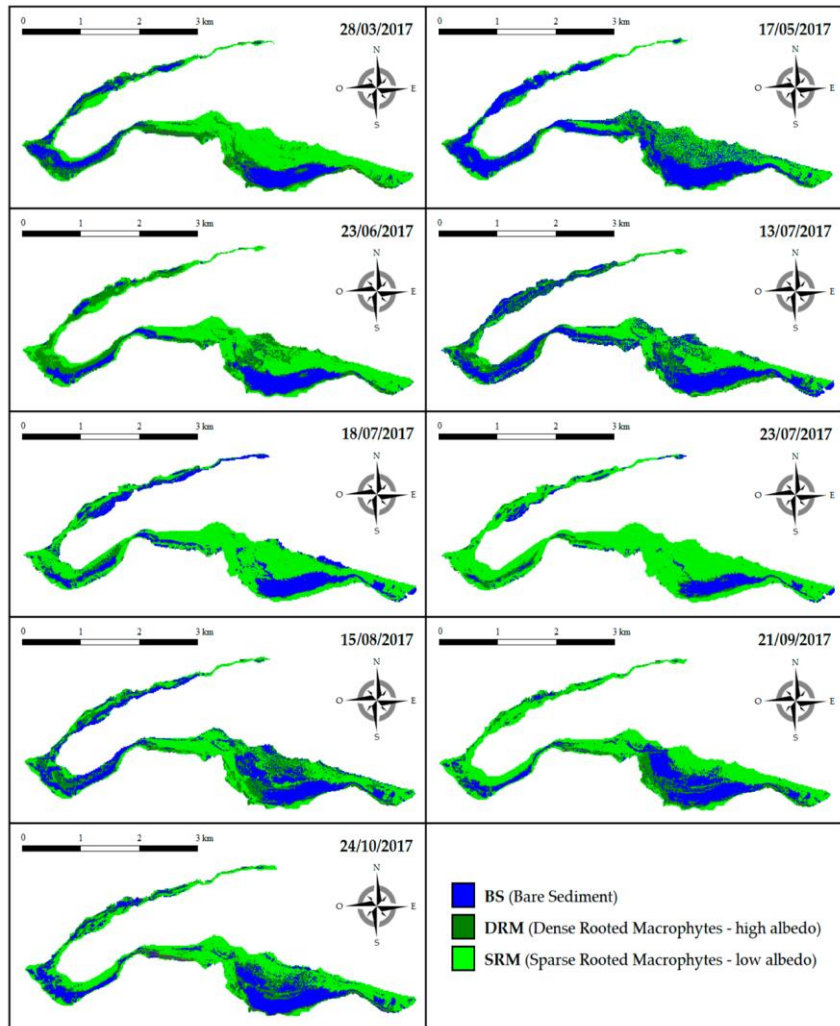


Bresciani *et al.*, 2020 <https://doi.org/10.3390/w12010284>

ITALY

Macrophytes: submerged

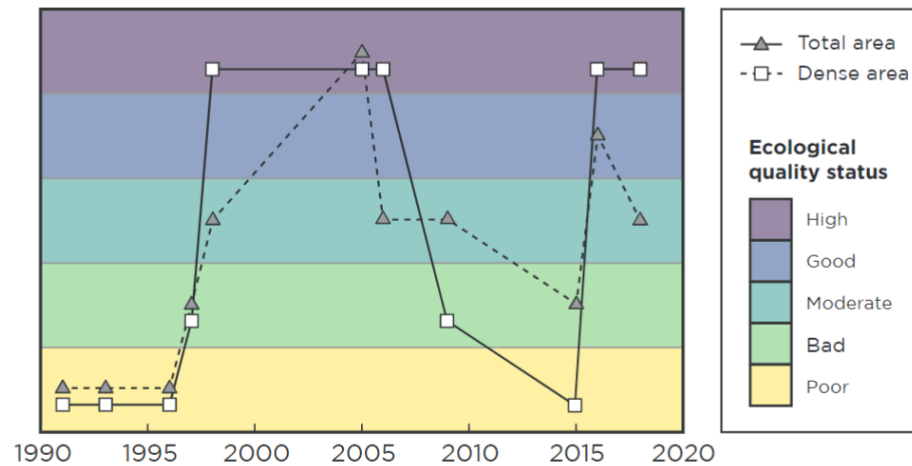
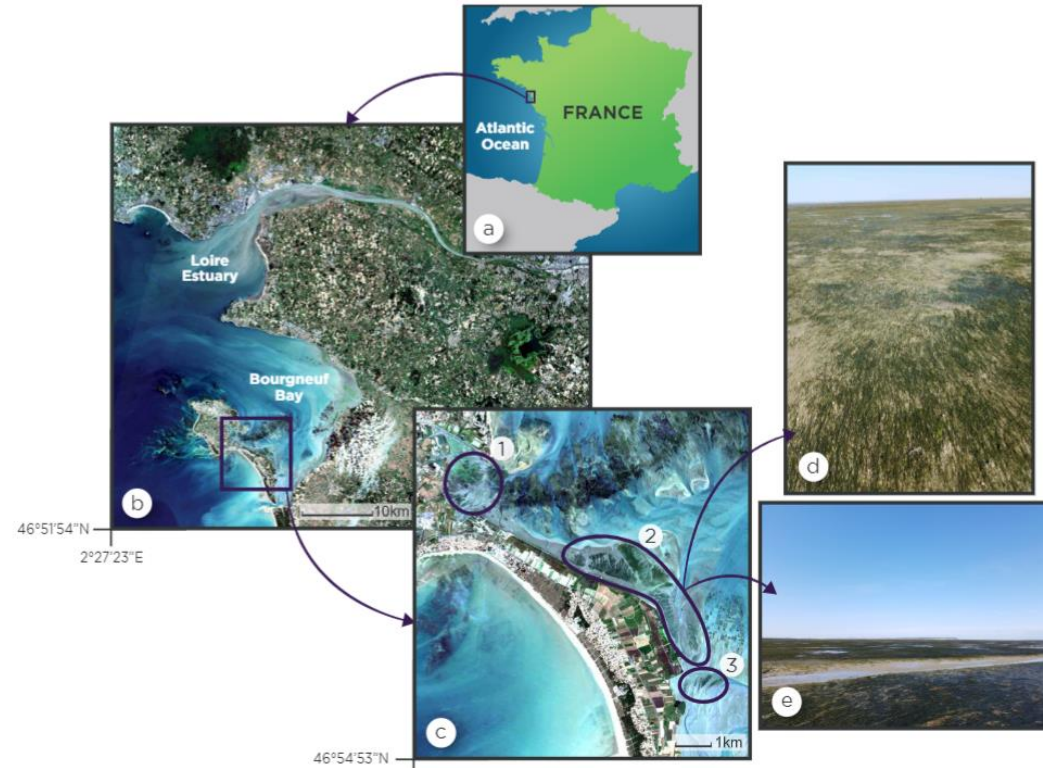
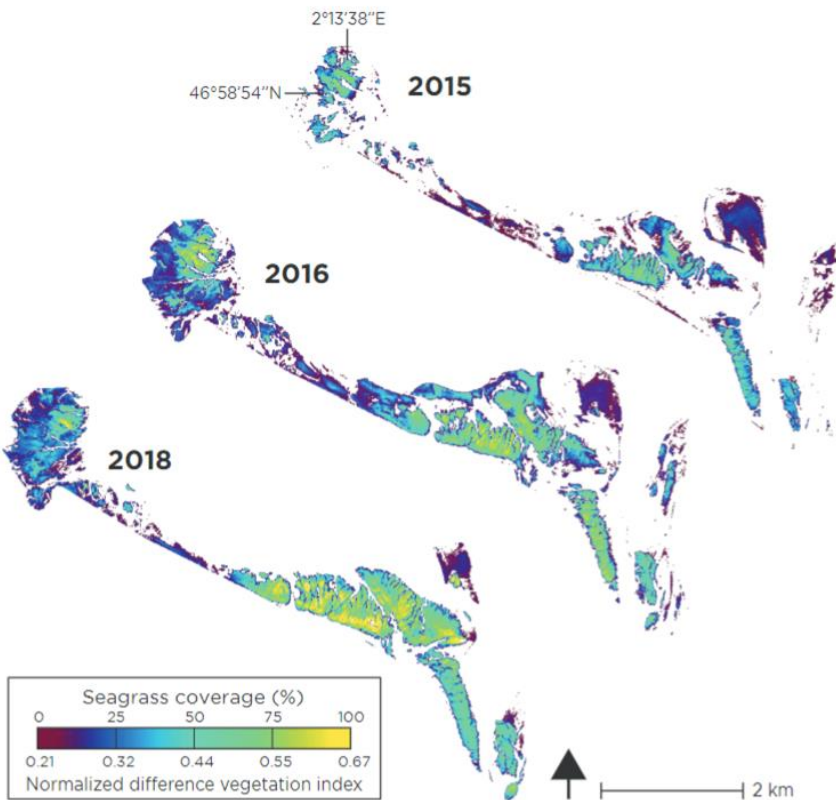
Mapping lakes substrates colonised by submerged macrophyte communities



Ghirardi et al. (2020). <https://www.mdpi.com/2073-4441/11/3/563>

FRANCE

Seagrass mapping from high-resolution satellite provides **seasonal dynamics**. The total area is observed rather than average %cover in quadrats -> different approach (do WFD targets need adjustment?) but more robust



IRELAND

THE IRISH TIMES

LATEST NEWS MOST READ MEDIA IRELAND WORLD SPORT

Pollution police look to space to monitor over 800 Irish lakes

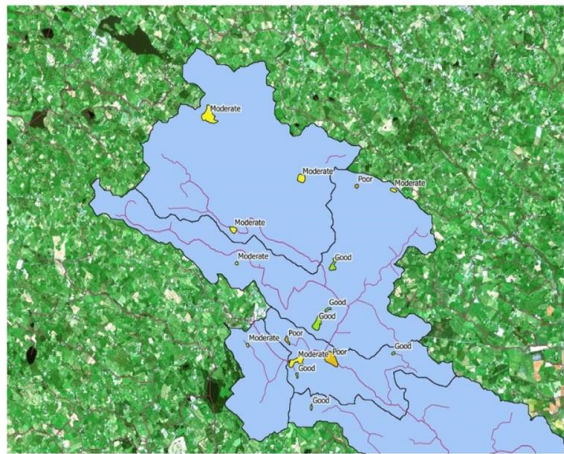
Environmental body says use of satellites a major step forward when checking water quality



Lough Ree, one of 812 Irish lakes now being monitored from space.

Brian Hutton

Mon, Nov 19, 2018, 01:00



Ecological status predicted from Sentinel-2 for the Glyde-Proules catchment



Assessing ecological status

Until now, only about a quarter of these have been actively monitored

Gary Free, an aquatic environment expert with the EPA, said the new technology would not entirely replace the traditional testing methods, but should help them **monitor many lakes which currently go unchecked because of cost constraints.**

“It is fascinating the images you get back,” he said of the real-time pictures beamed down every time the satellites pass over the State.

“The main thing for us is the layers and layers of information – all the different wavelengths – are reported back by the satellites. It is not a simple snapshot, there are layers of data within it. It can tell you an awful lot about the environment.”

<https://blog.vito.be/remotesensing/an-eye-on-european-waters>

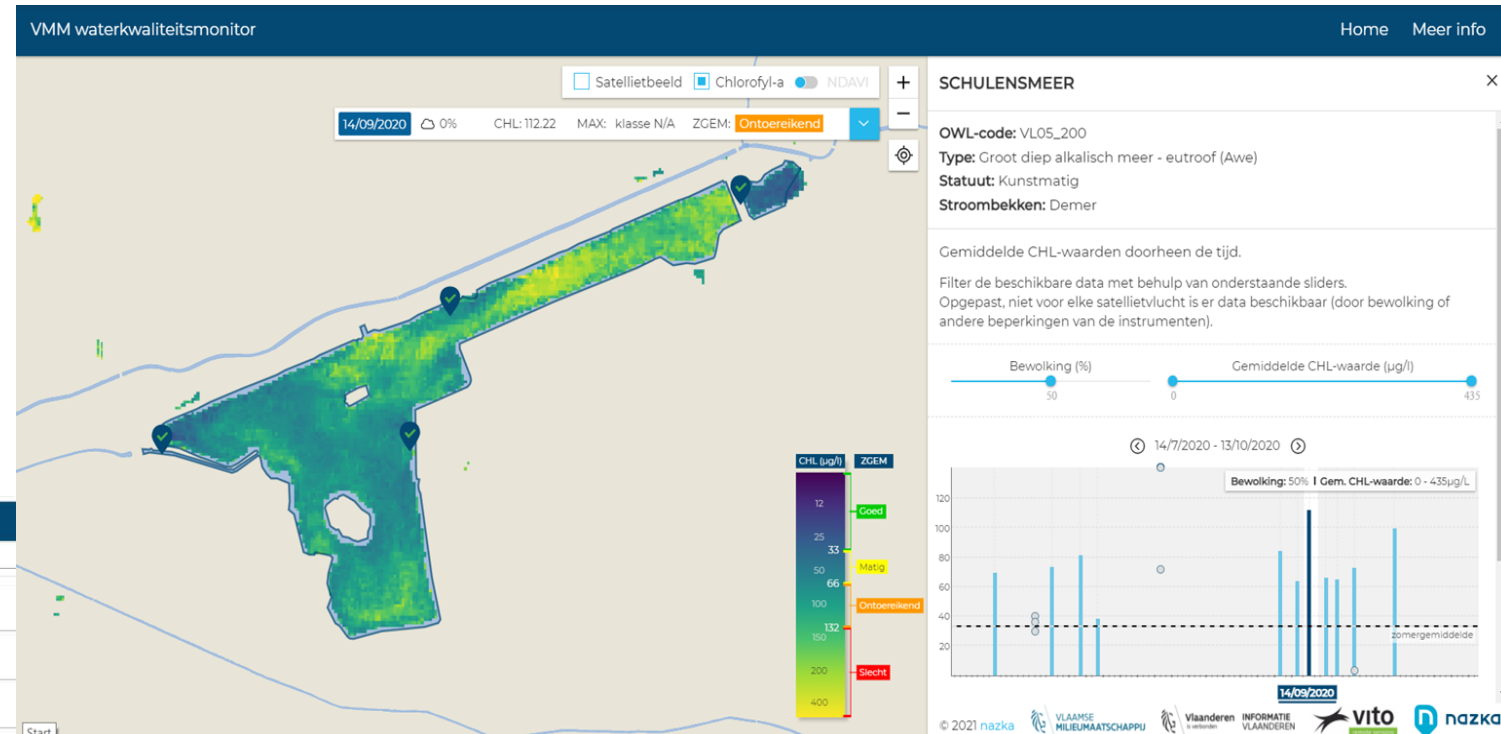
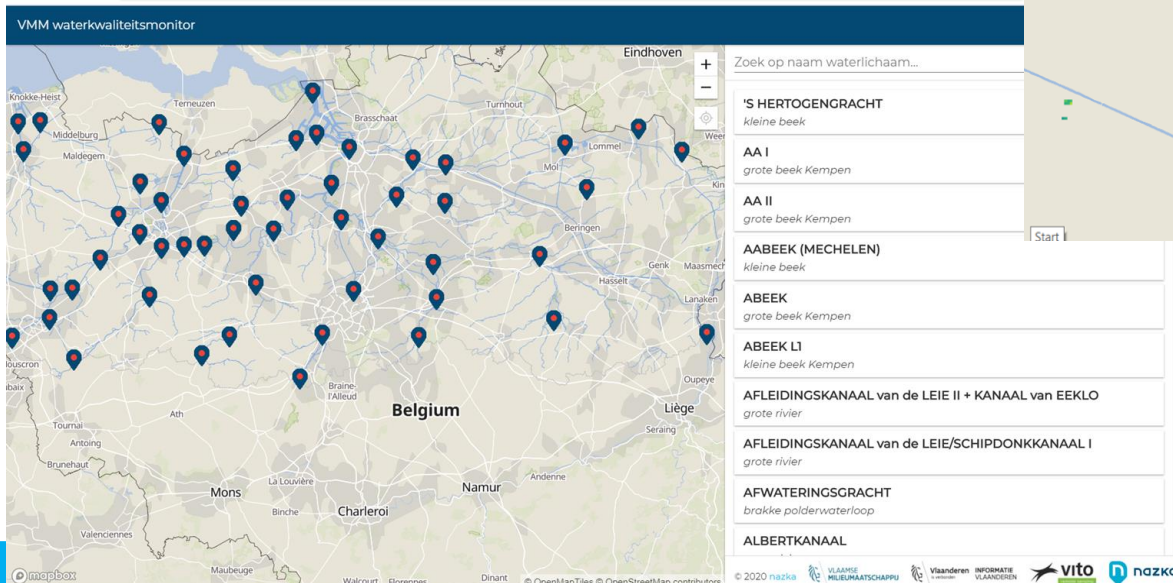
BELGIUM/FLANDERS

Watermonitor for Flanders Environment Agency (VMM)

Demo (2020-2021) NRT Sentinel-2 based Chla + in situ Chl-a

WFD classes/colour code (max Chl-a and summer average Chl-a)

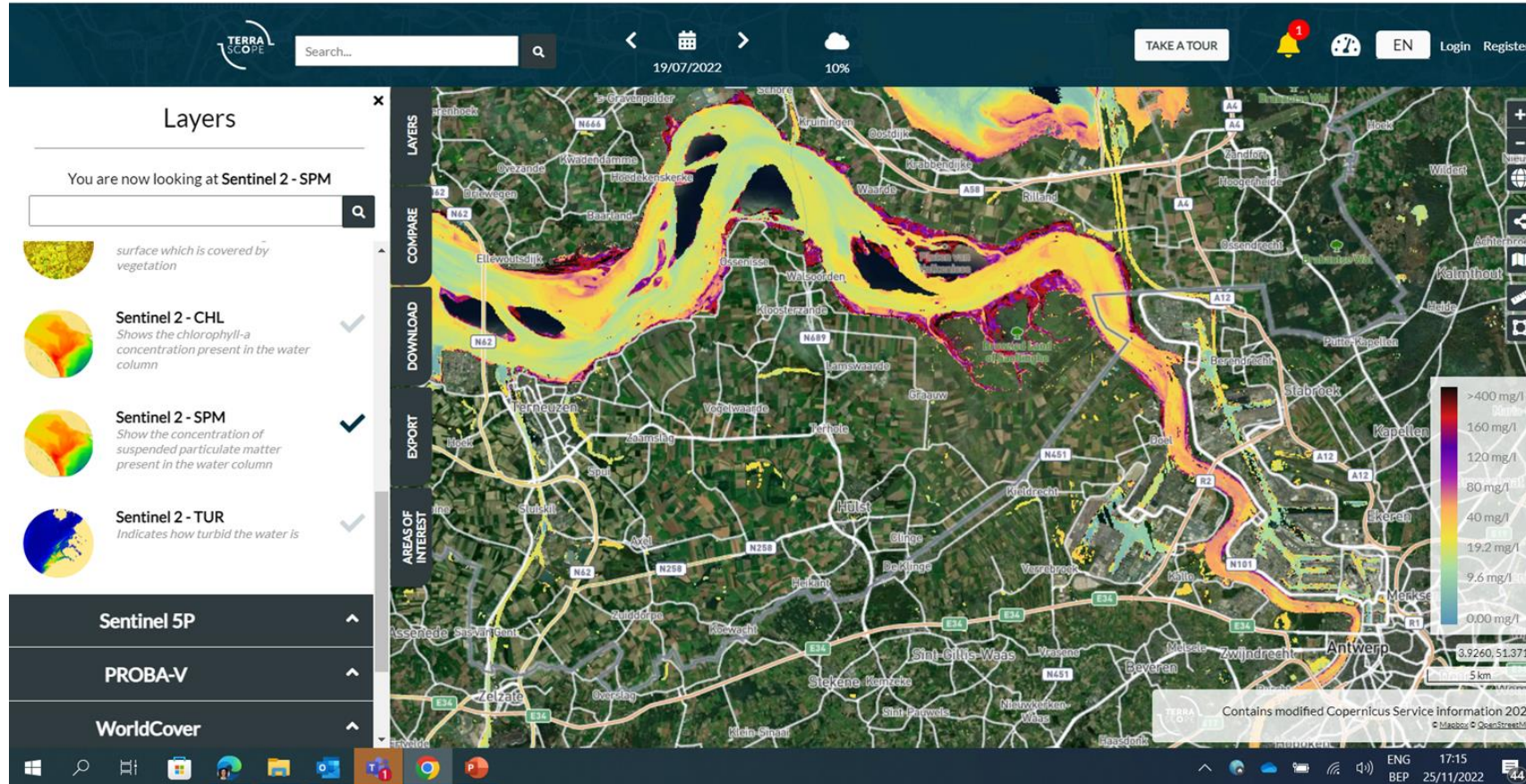
Exceedance alert



<https://remotesensing.vito.be/case/watermonitor>

BELGIUM/FLANDERS

Suspended Particulate Matter and Turbidity-NRT



<https://viewer.terrascope.be/>

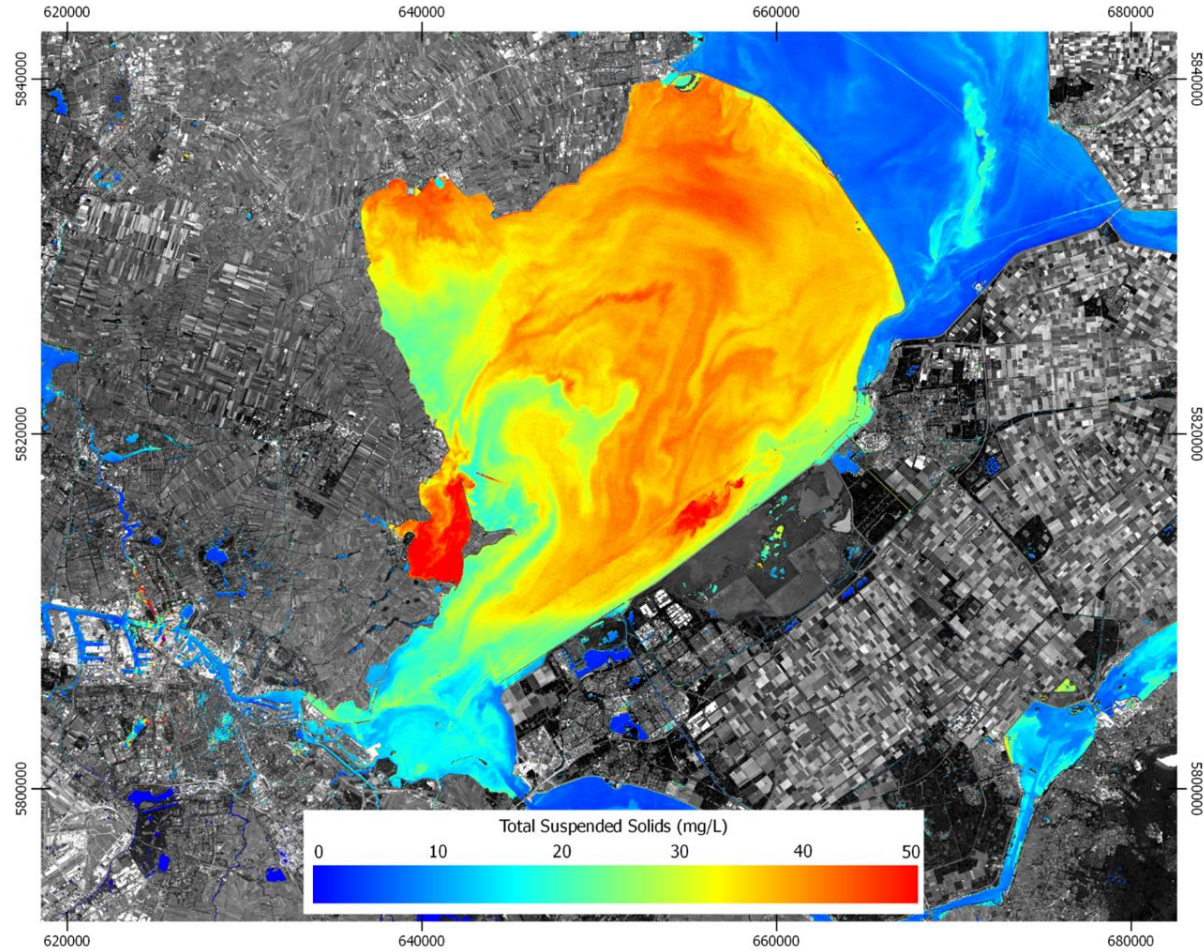
THE NETHERLANDS

Lake Marken

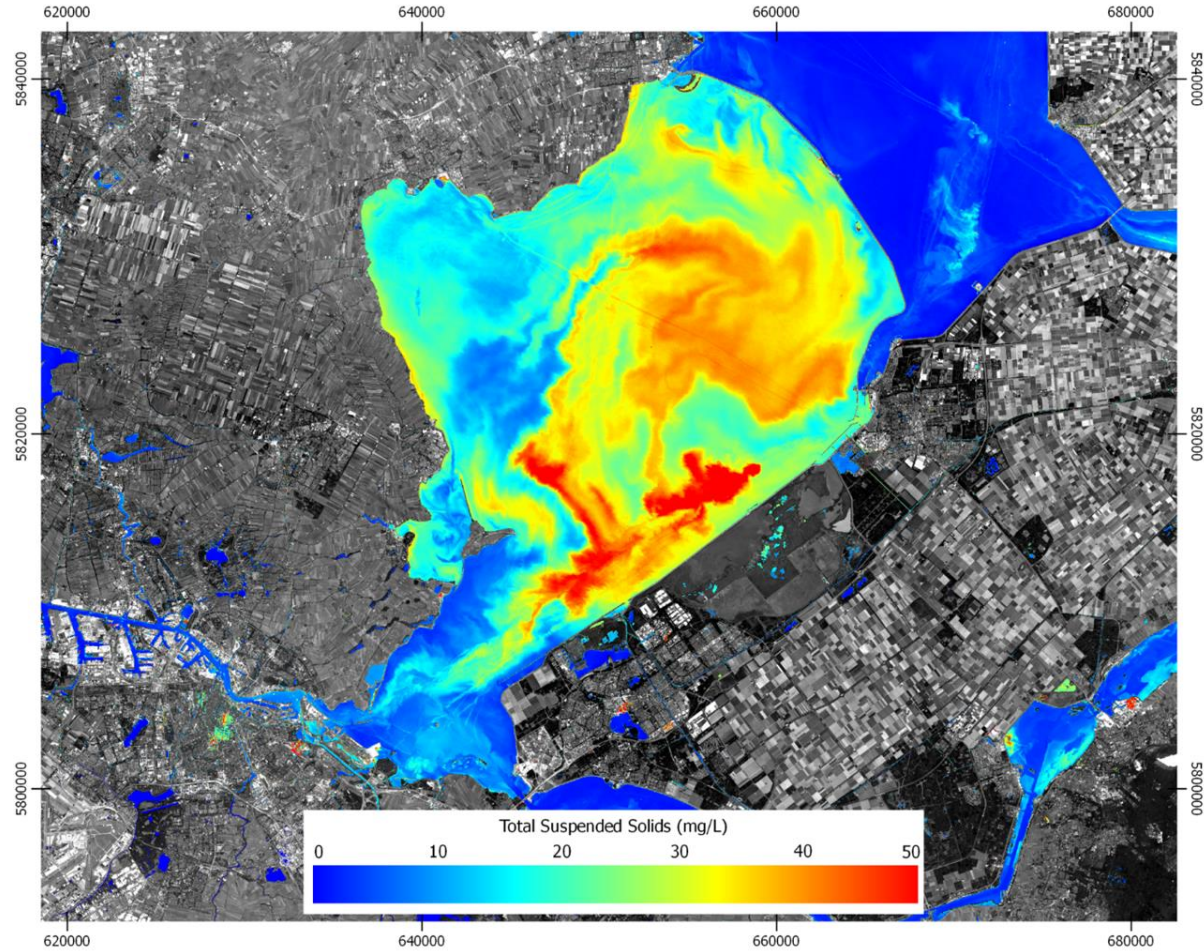
2016: Because of silt dynamics growth of plants and Zebra mussel population decreased (less food for birds)

Silt used to create Marken Wadden islands

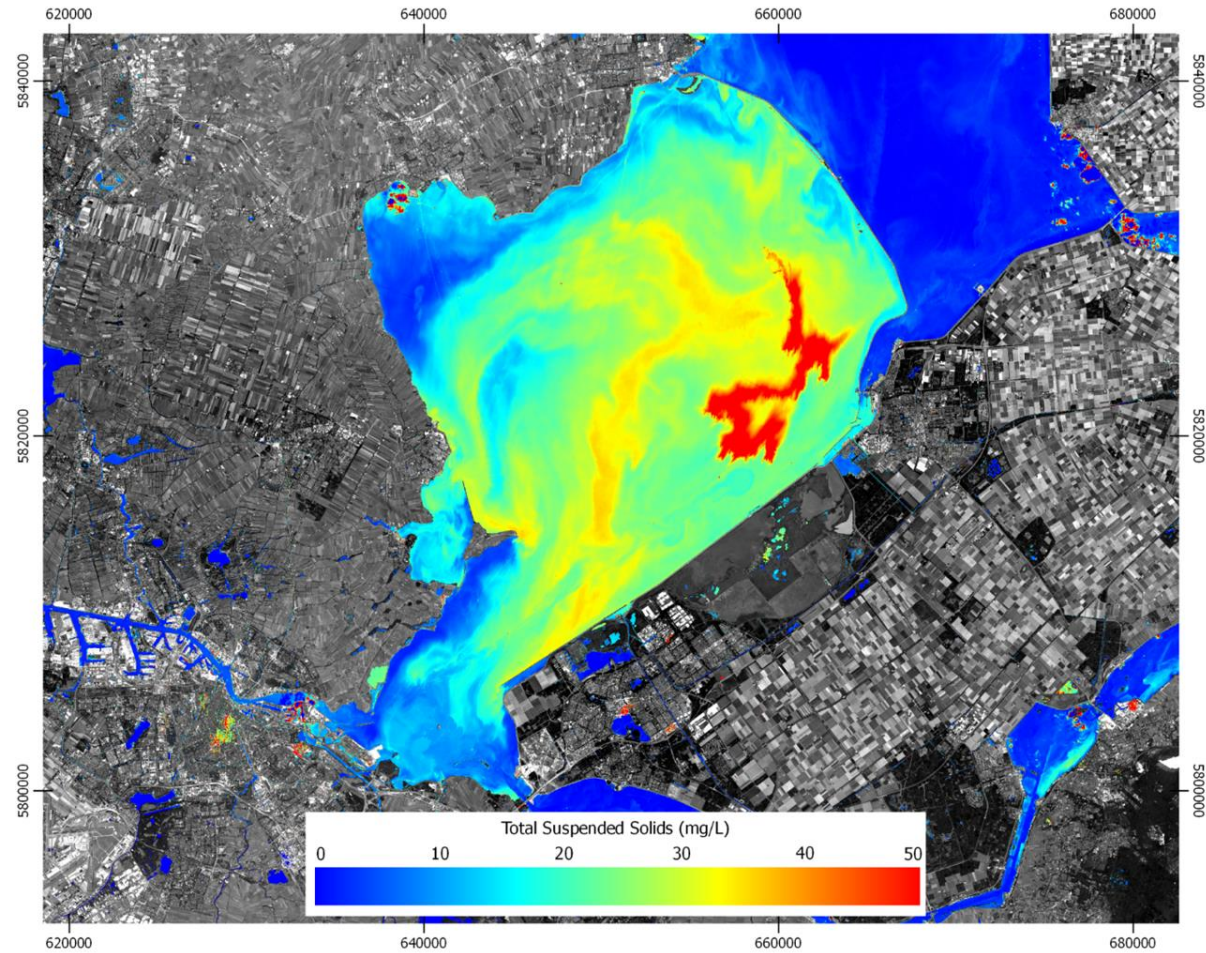




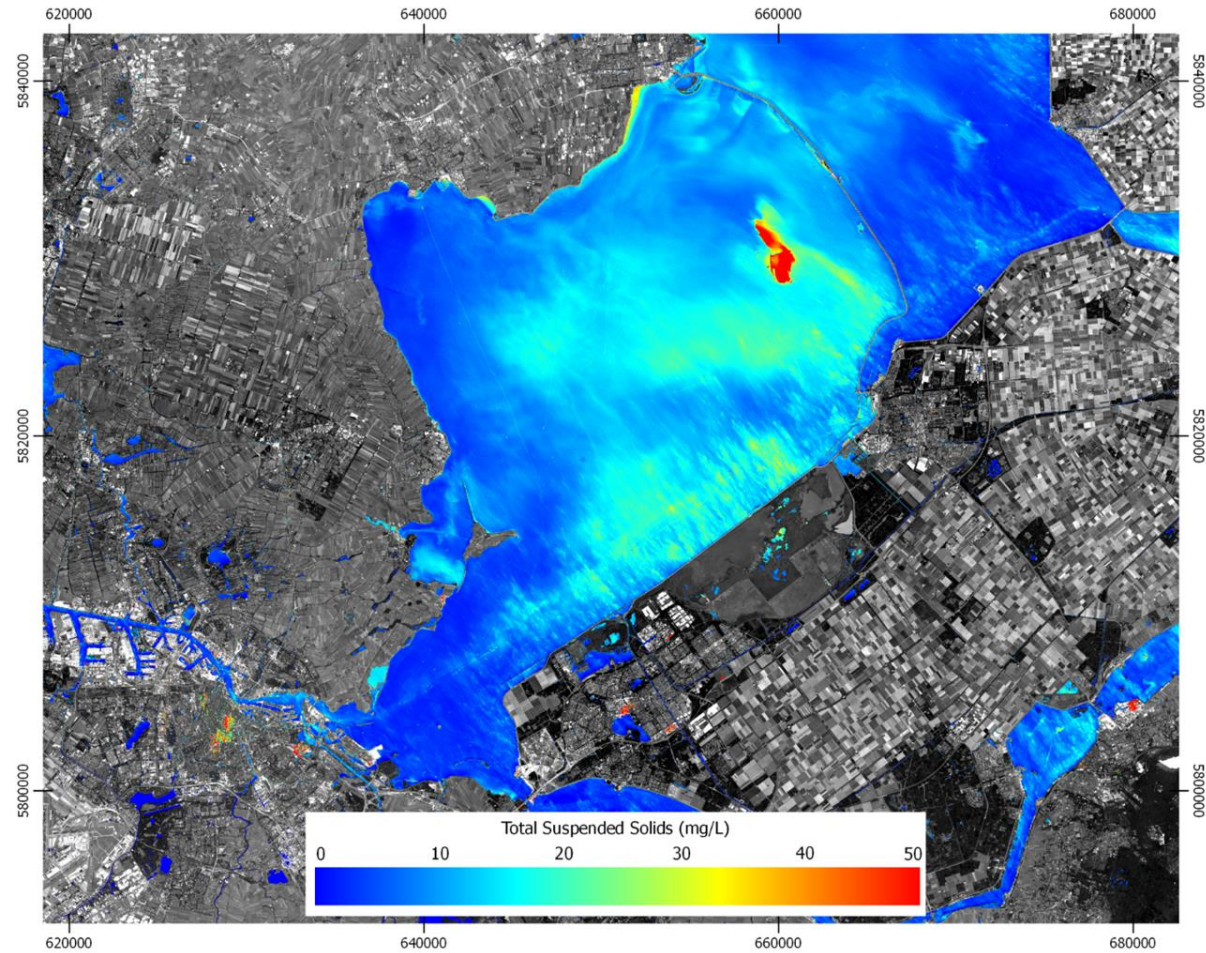
Total Suspended Solids map for Lake Marken, the Netherlands (Landsat-8, 7 January 2015) processed by VITO



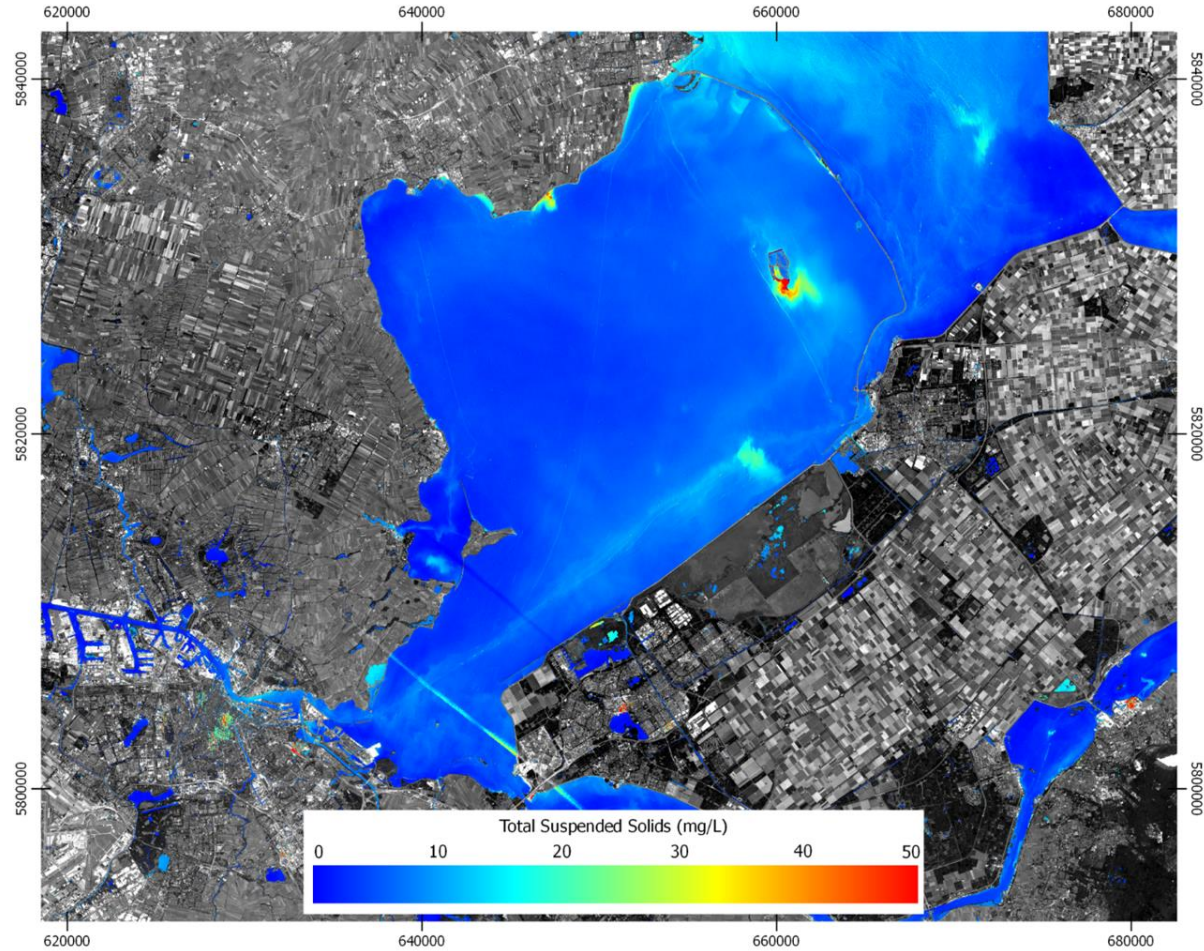
Total Suspended Solids map for Lake Marken, the Netherlands (Landsat-8, 12 March 2015) processed by VITO



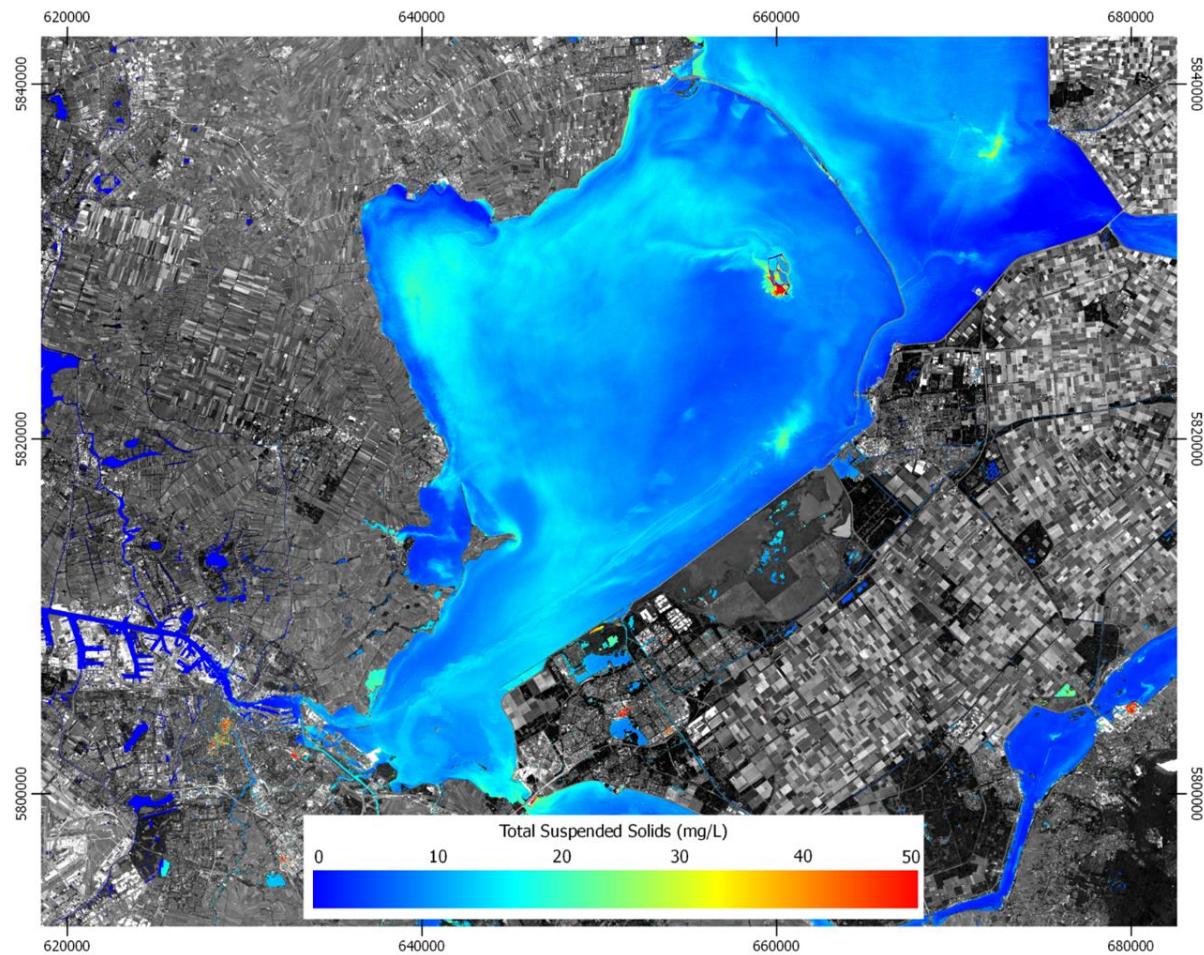
Total Suspended Solids map for Lake Marken, the Netherlands (Landsat-8, 1 May 2016) processed by VITO



Total Suspended Solids map for Lake Marken, the Netherlands (Landsat-8, 20 July 2016) processed by VITO



Total Suspended Solids map for Lake Marken, the Netherlands (Sentinel-2A, 8 September 2016) processed by VITO



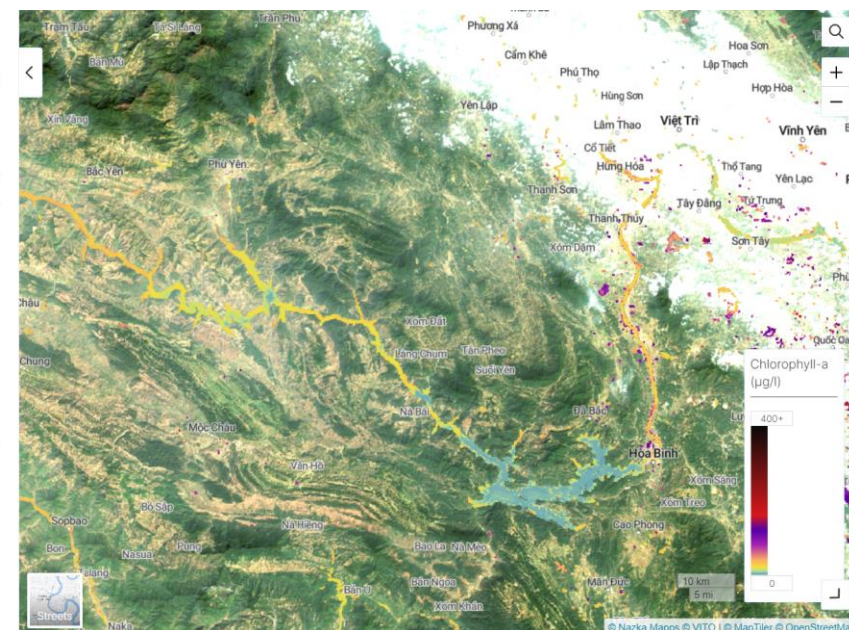
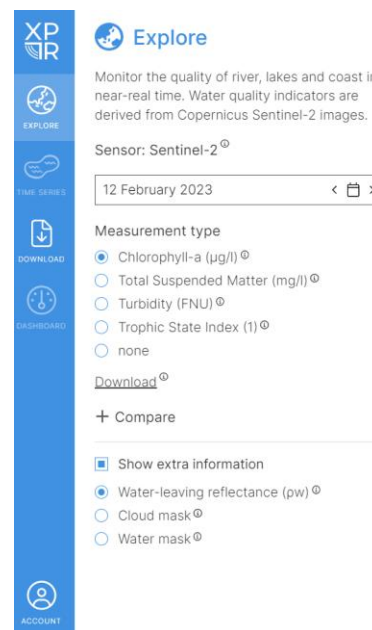
Total Suspended Solids map for Lake Marken, the Netherlands (Sentinel-2A, 15 September 2016) processed by VITO

VIETNAM

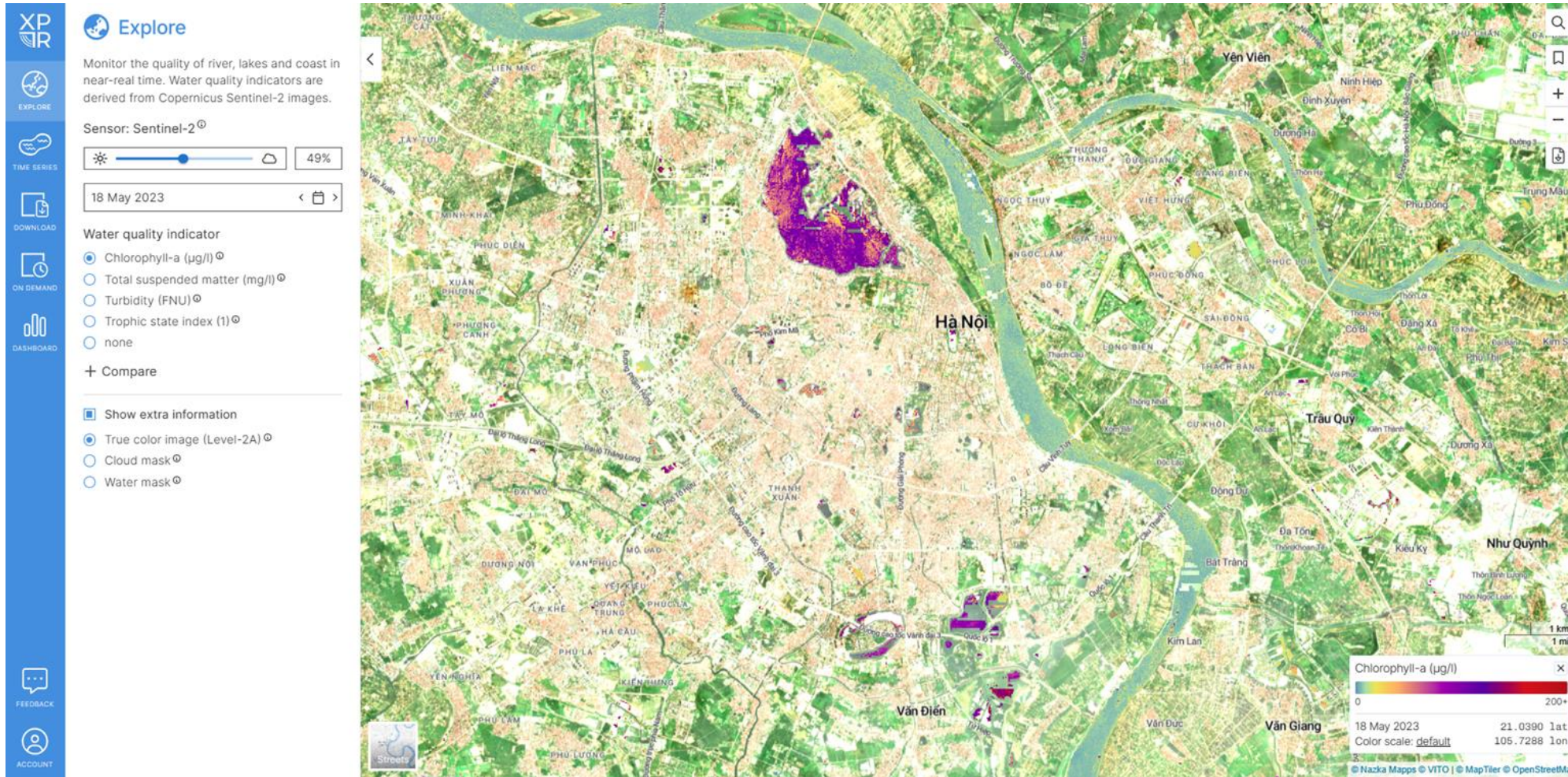
EXPLORE-VN

MONITORING EARTH FROM SPACE IN NEAR REAL-TIME

- An **operational** environment monitoring solution specifically designed for **VAST-IG Vietnam** based on Earth Observation satellite imagery
- The products are made accessible through a **user-friendly web application**, making it easy to access and interpret the information
- Client management (Credit system for **resource accounting**)
- All **data can be downloaded** for further processing and analysis in own software environment



EXPLORE-VN: EXPLORE



EXPLORE-VN: TIME SERIES

XP Time Series

Analyze the state of a waterbody over time.

Waterbody +

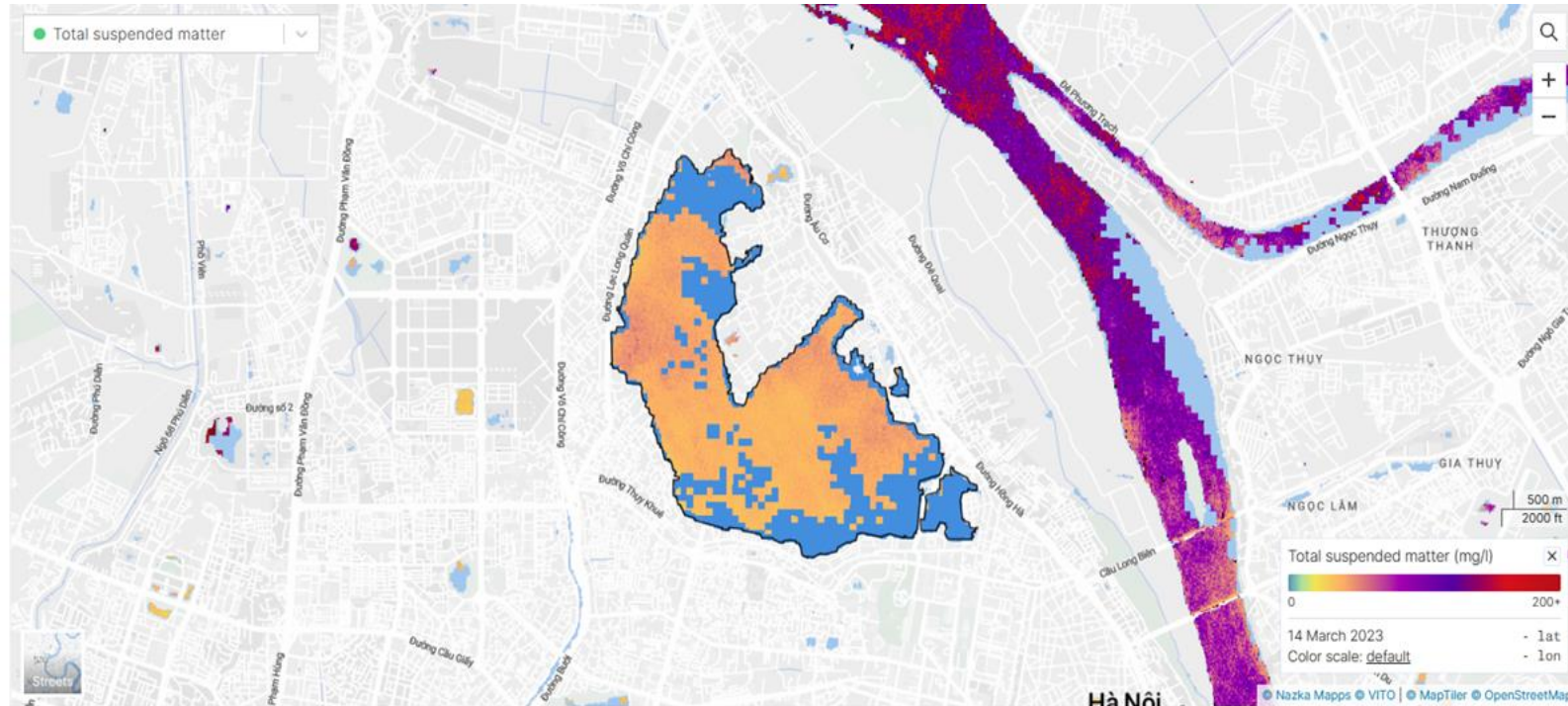
Statistic

Water quality indicator

- Chlorophyll-a
- Total suspended matter
- Turbidity
- Trophic state index

Ratio of valid-to-total pixels

Show extra information



EXPLORE-VN: DOWNLOAD

Download

Choose your product. You can download full tiles or smaller areas.

Water quality indicator

- True color image (Level-2A) ©
- Chlorophyll-a ©
- Total suspended matter ©
- Turbidity ©
- Trophic state index ©

75%

Tile selection

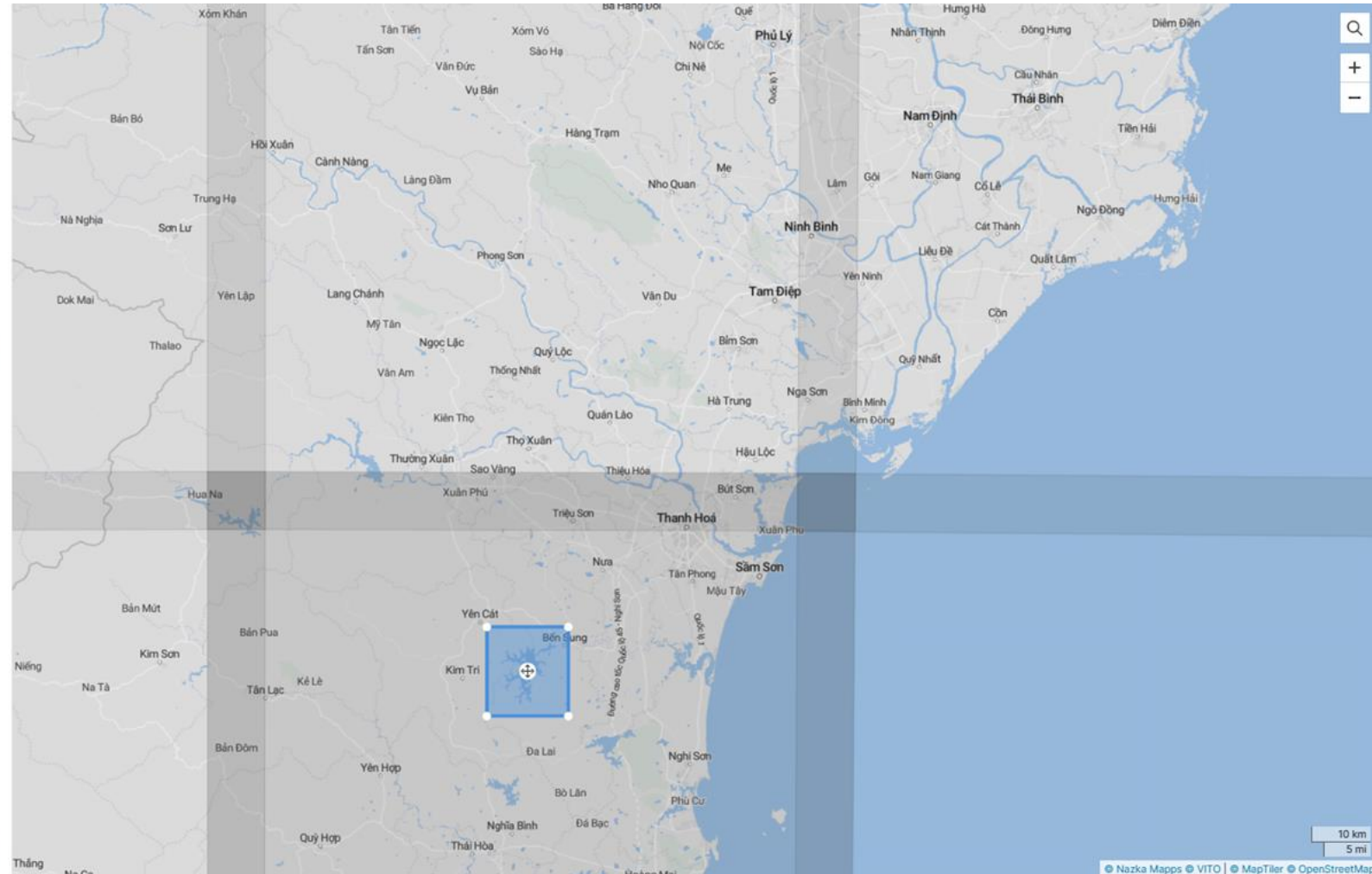
Tiles

48QWG

- 12 June 2023 < > X
- 07 June 2023 < > X
- 04 June 2023 < > X
- 02 June 2023 < > X

+ Add date

Clip © Clip and merge © **Proceed**



EXPLORE-VN: ON DEMAND

XP
R

EXPLORE

TIME SERIES

DOWNLOAD

ON DEMAND

DASHBOARD

FEEDBACK

ACCOUNT

On demand

Process tiles that are not in the standard set, are older than one year, or have a high cloud cover.

☀️ ☁️ 75%

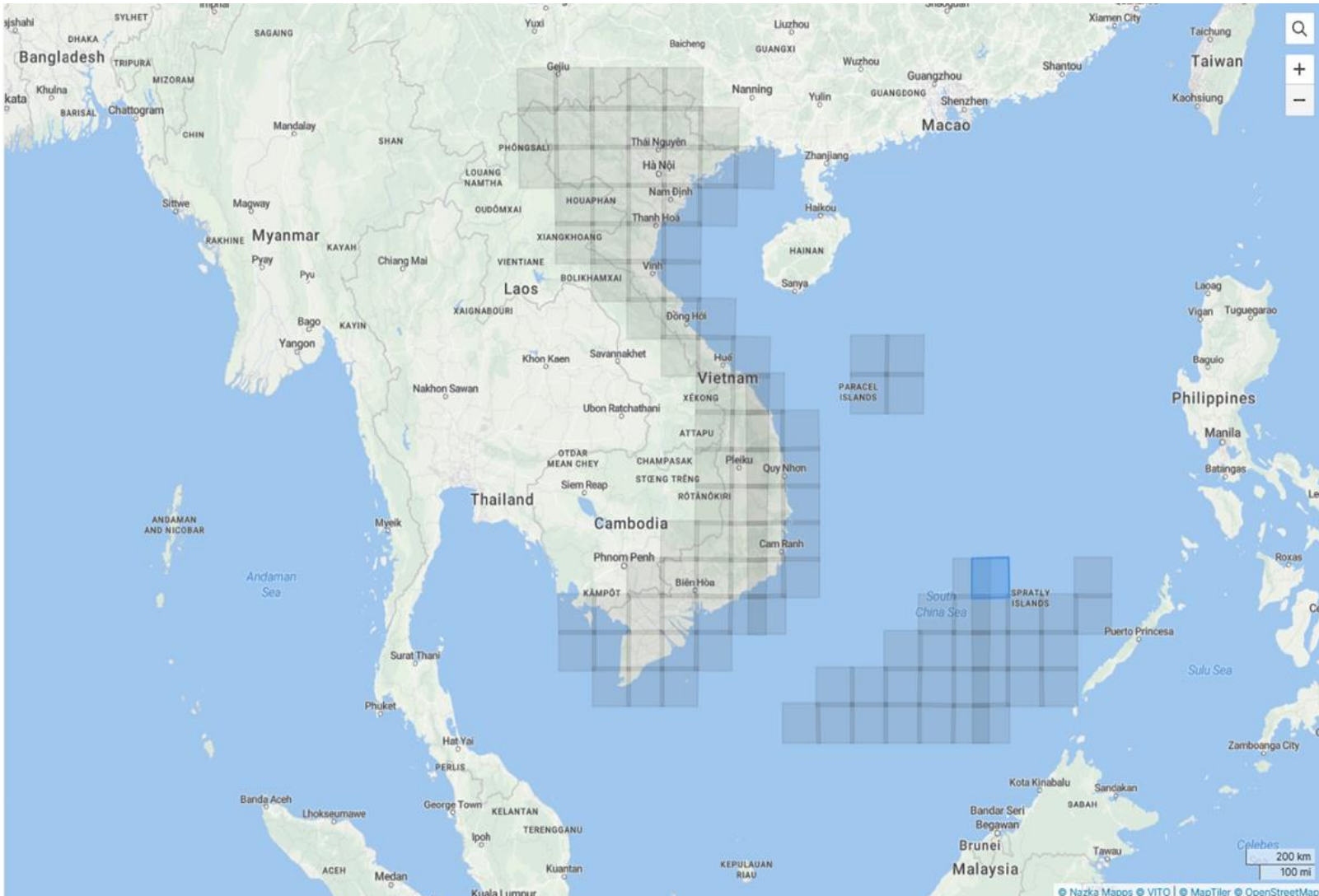
Tiles

50PKT

17 June 2023

+ Add date

Proceed



Map showing the region of Southeast Asia, including Vietnam, Laos, Cambodia, Thailand, Myanmar, and parts of the Philippines and Malaysia. The map displays a grid overlay, likely representing the 'On Demand' data tiles mentioned in the interface. Key cities and geographical features are labeled, such as Hanoi, Vientiane, Phnom Penh, Bangkok, and the Andaman Sea. The map also shows the South China Sea and the Spratly Islands.

Roadmap for the Copernicus services

Water-ForCE

Developing a Roadmap for Copernicus Water Services



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004186

Introduction

Inland and coastal waters play a crucial role in human health and wellbeing, in the global carbon and nutrient cycles, as well as supporting high levels of biodiversity. The **Copernicus Programme** is an European contribution improving our understanding of the Earth system, including water quantity and quality at regional and global scale.



Scope

The Horizon 2020 project "Water scenarios For Copernicus Exploitation", **Water-ForCE**, will analyse the needs of different users from policy makers, researchers and industry to businesses, NGOs and general public, determine gaps in current Copernicus WATER portfolio, evaluate technical capabilities of present and future Copernicus sensors in providing the necessary information about water quantity and quality. The recommendations on the evolution of water services will be summarised in a **Roadmap**.

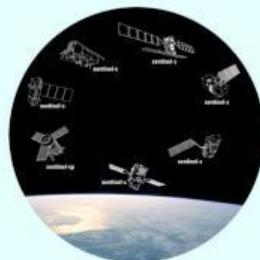
Want to contribute to how the future Copernicus water services will look?

Go to our web page waterforce.eu, register in one of the relevant international working groups and participate in the development of the **Roadmap**

Six **Copernicus Services** (Atmosphere, Marine, Land, Climate Change, Security, Energy) deliver water and hydrology related services from Earth Observation, in situ and modelled data.

However, the current Services have some shortcomings:

- difficulties in getting comprehensive understanding of the global water cycle (water products provided by different Services)
- gaps in water related products
- unclear which Service should fill which gap
- duplication aspects
- finding relevant Copernicus products not easy for users



The main outcome: Roadmap for Copernicus Water Services

- Optimal long-term strategy taking into account existing water related products
- List of higher-level biogeochemical products
- Technical requirements for future Copernicus sensors
- Analysis on how Copernicus Water services can support policy development
- Proposal for organizing *in situ* measurement networks to best validate EO products
- Proposal for defining the relationships between Core Services and Downstream Services
- Recommendations on the evolution of Water Services



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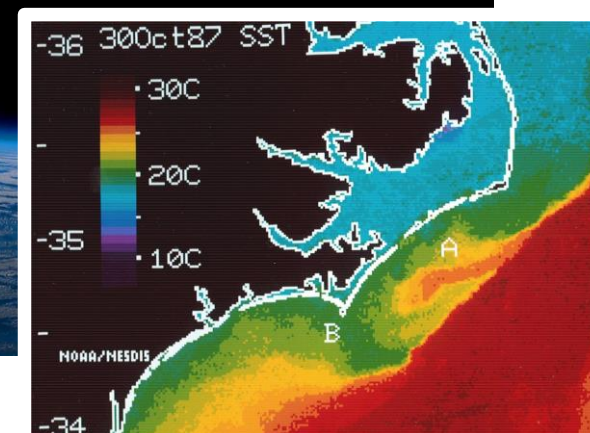


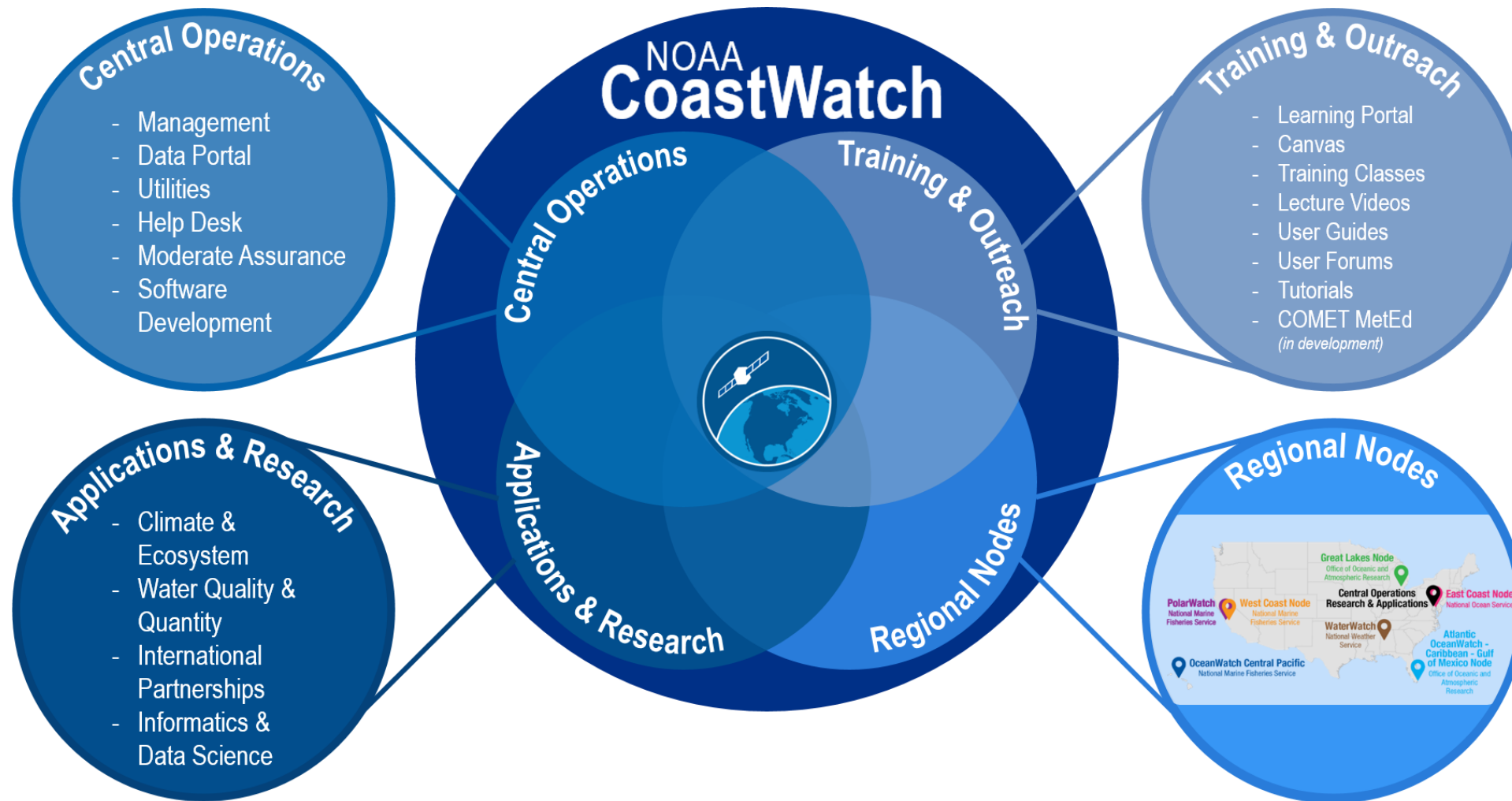
Leveraging a range of Earth observing satellites for aquatic applications

MEGAN COFFER, NOAA/GST



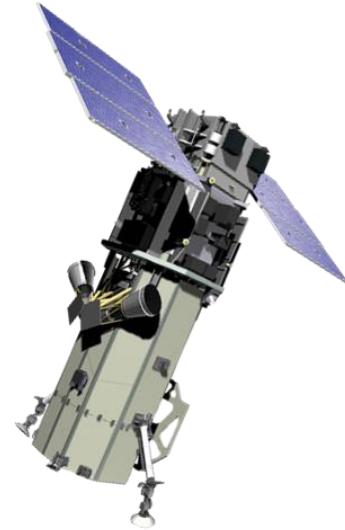
inspiring change





NOAA uses Earth observation data to study water quality and provide satellite-based tools for water quality monitoring and management

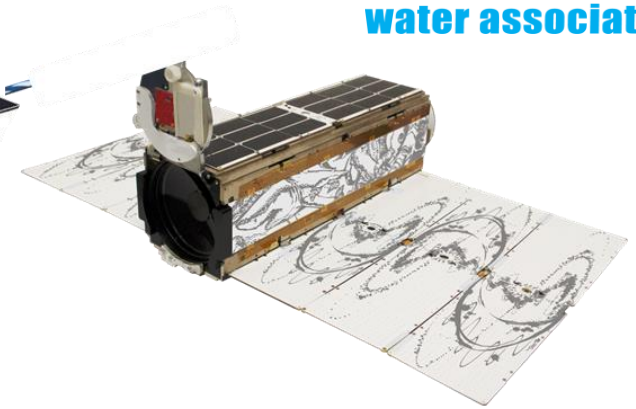
Commercial, high
spatial resolution
satellite platforms



WorldView-2 (2 m)

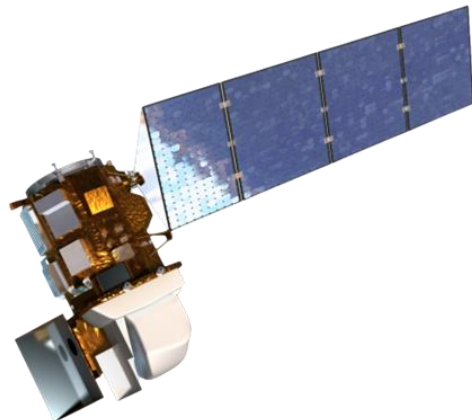


WorldView-3 (2 m)



PlanetScope (5 m)

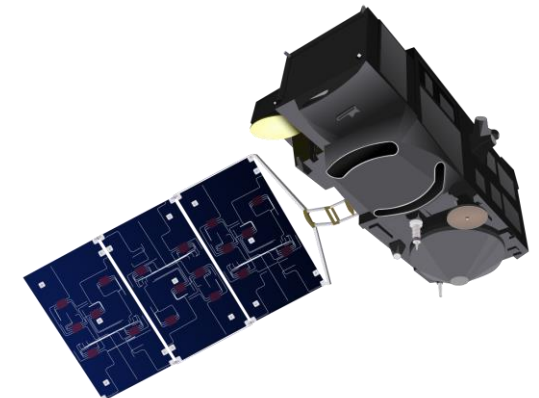
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satellite platforms



Landsat 8 (30 m)

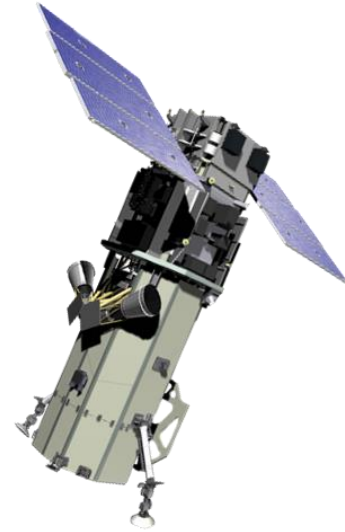


Sentinel-2 (20 m)



Sentinel-3 (300 m)

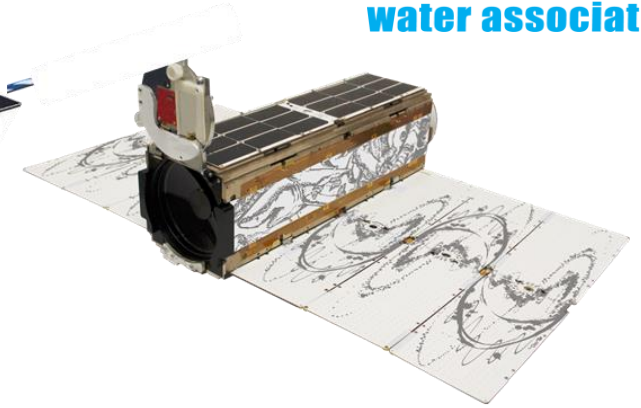
Commercial, high
spatial resolution
satellite platforms



WorldView-2 (2 m)

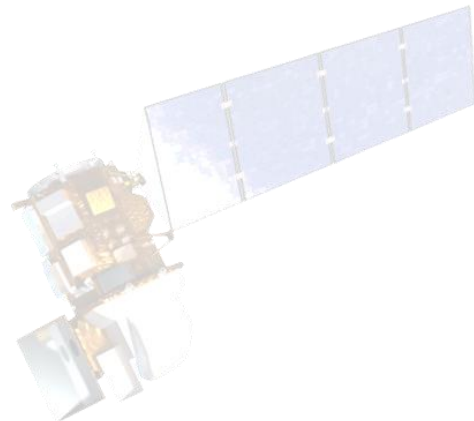


WorldView-3 (2 m)

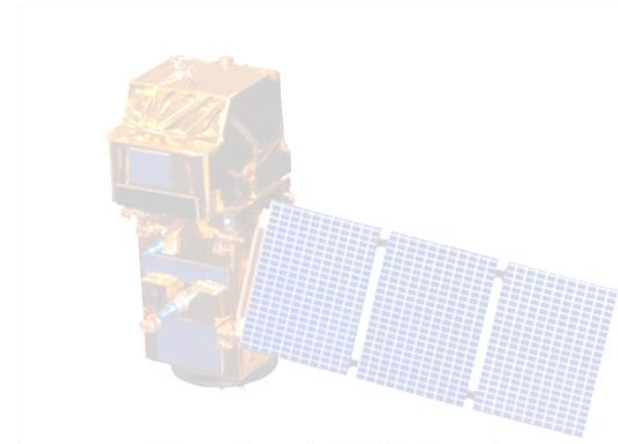


PlanetScope (5 m)

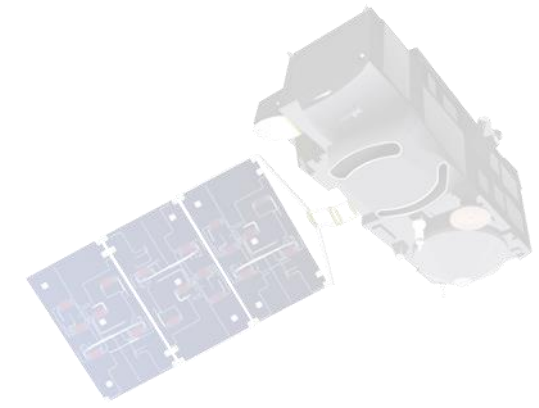
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satellite platforms



Landsat 8 (30 m)



Sentinel-2 (20 m)



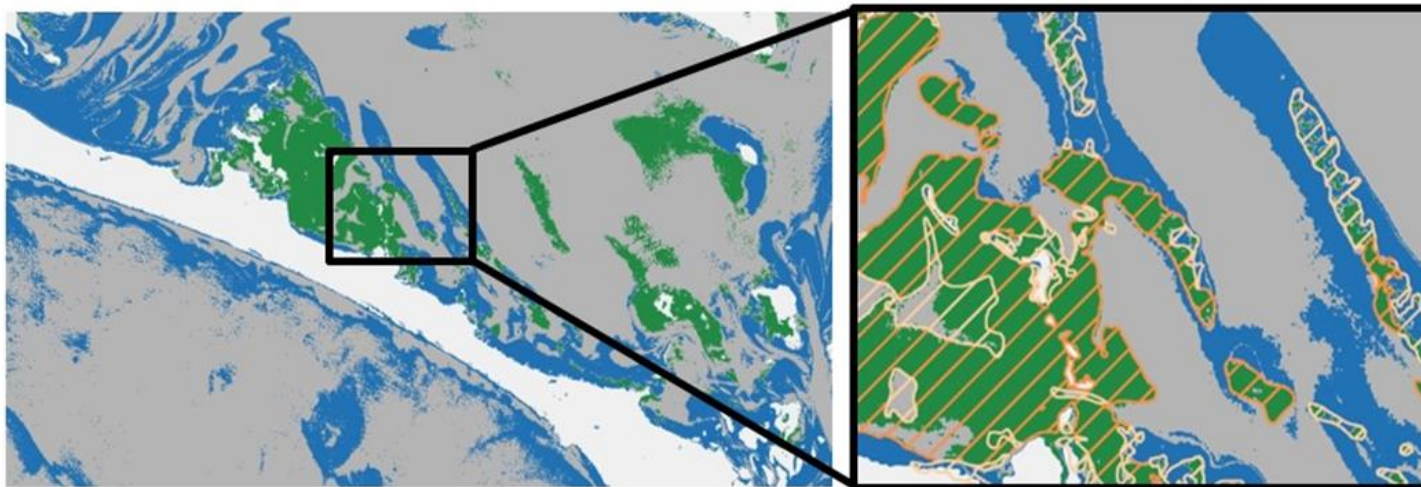
Sentinel-3 (300 m)

Back Sound, NC

(a) WorldView-2 image with field data



(b) WorldView-2 image classification



Satellite image classification

- Land
- No data
- Seagrass
- No seagrass

Reference data

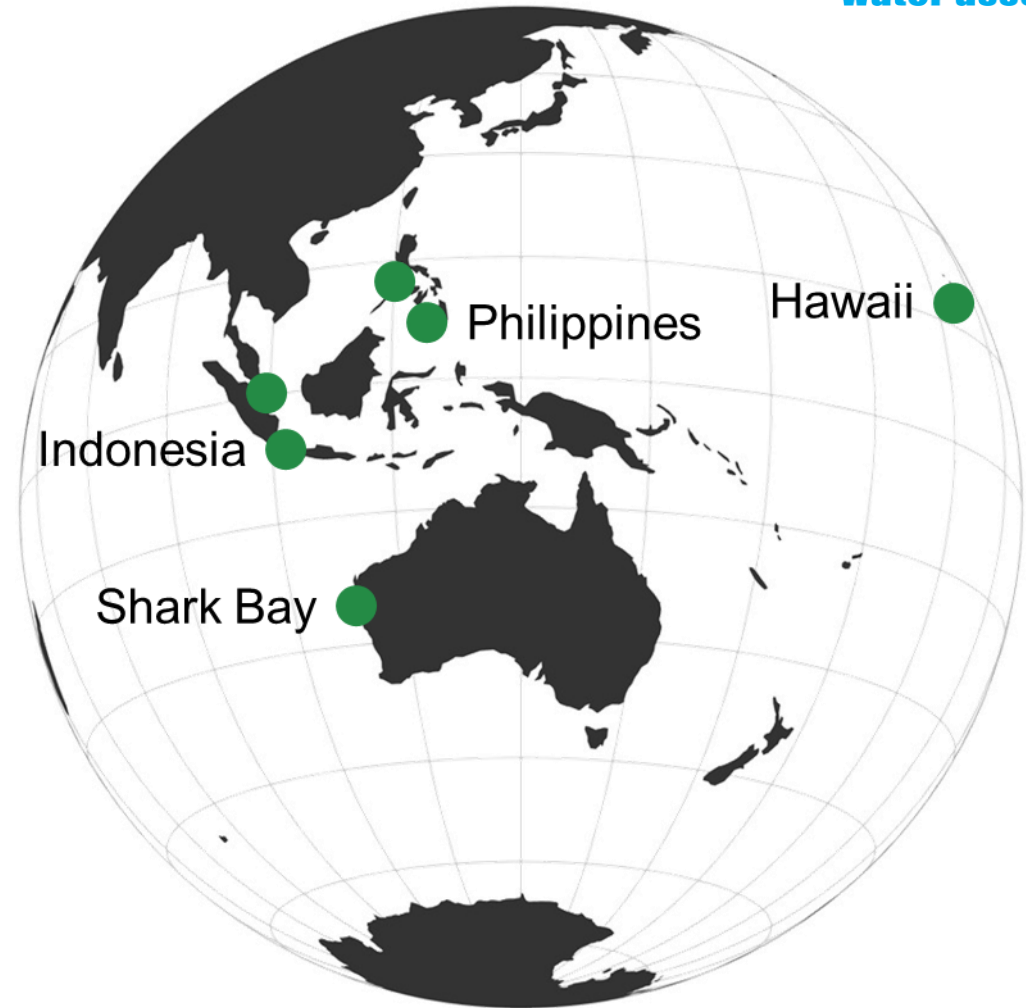
- Patchy
- Continuous

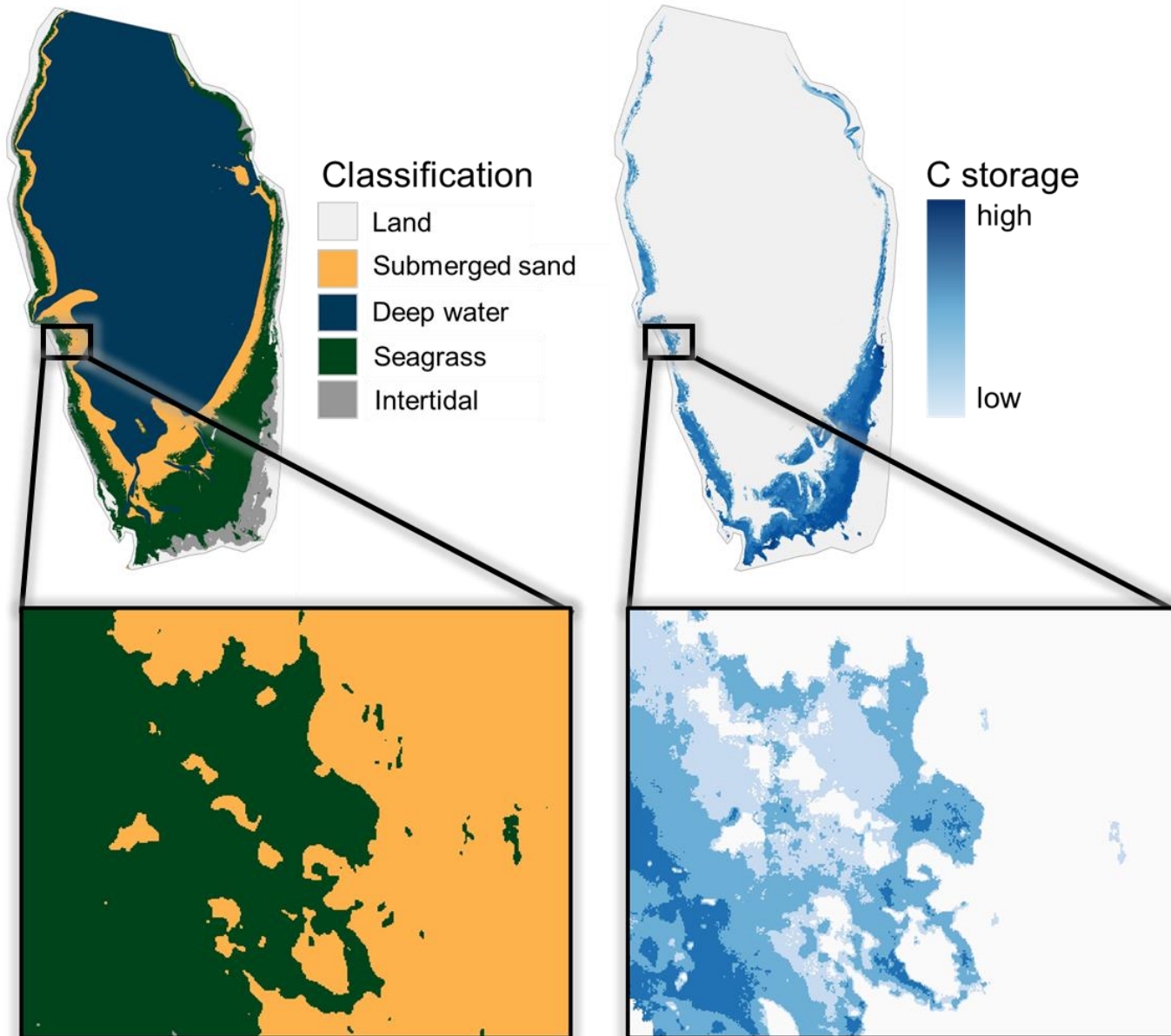
Reproducible and semi-automated workflows developed to process commercial satellite data for aquatic applications and classify seagrass extent.

Where we've been



Where we're going

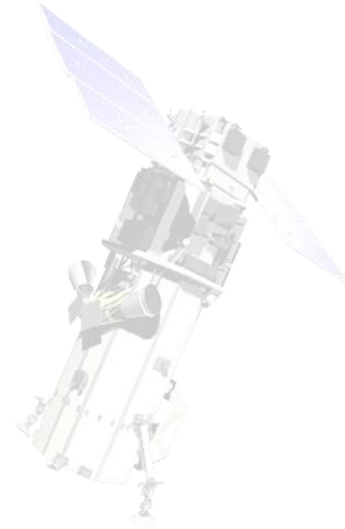




Commercial Earth observing satellites are used by NOAA to retrieve carbon storage estimates from seagrass classification.

In 2010, seagrasses in St. Joseph Bay, Florida, held 1,600 metric tons of carbon, equivalent to CO₂ emissions generated from 4 million gallons of gasoline.

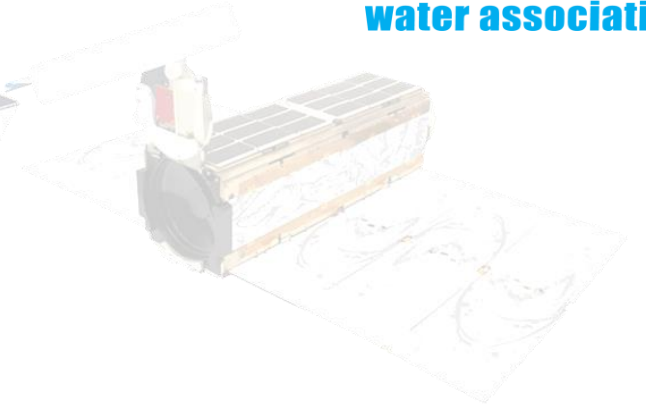
Commercial, high
spatial resolution
satellite platforms



WorldView-2 (2 m)

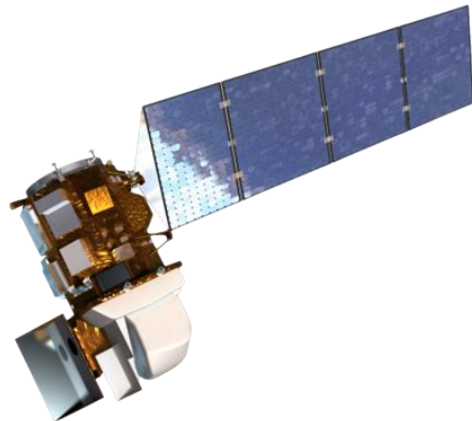


WorldView-3 (2 m)



PlanetScope (5 m)

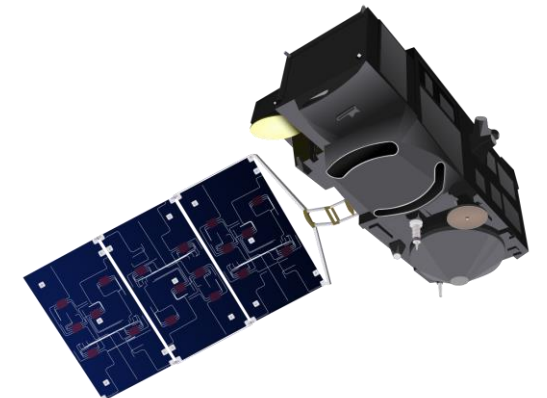
Freely available,
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satellite platforms



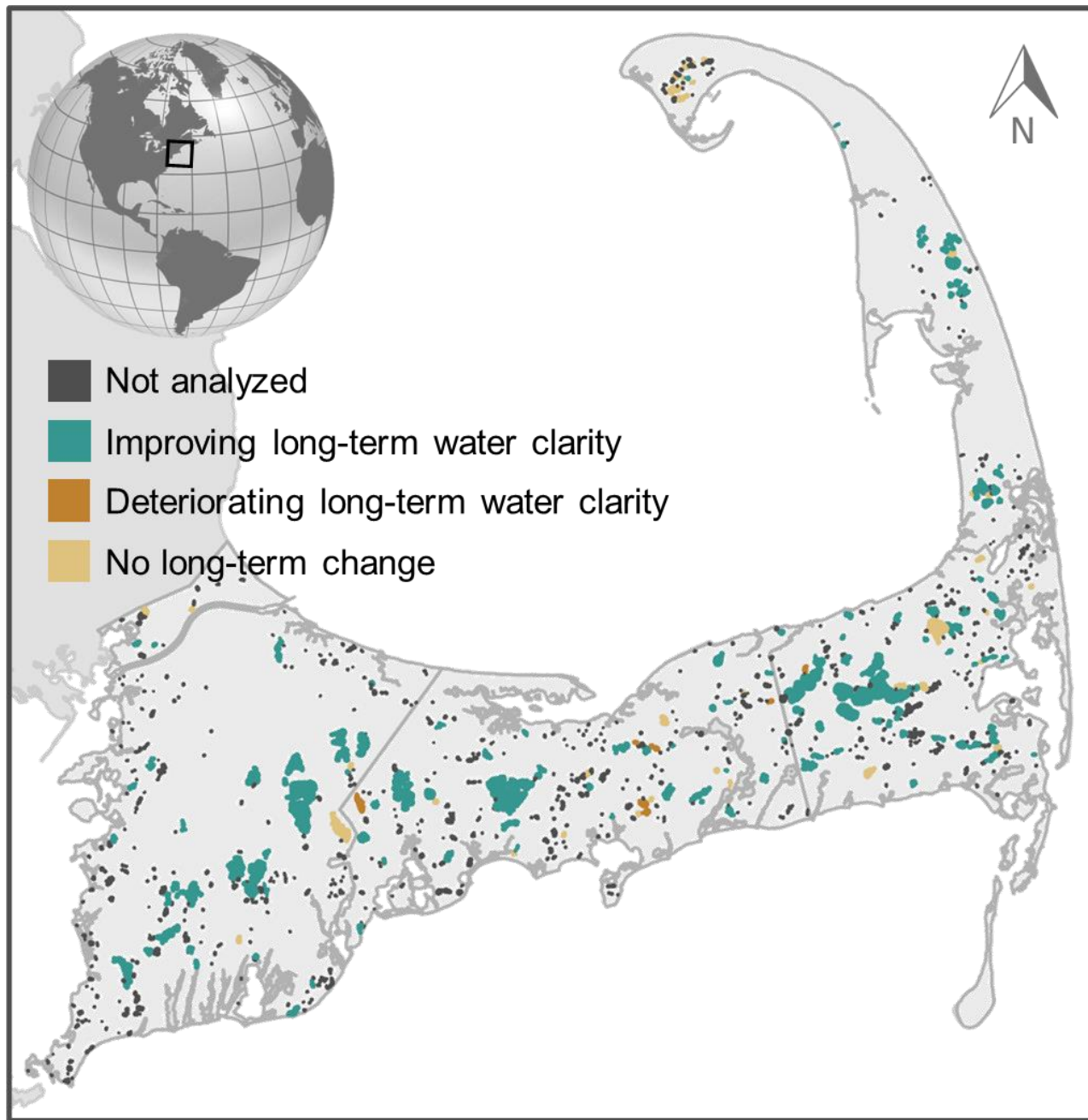
Landsat 8 (30 m)



Sentinel-2 (20 m)



Sentinel-3 (300 m)



Satellite data from the Sentinel-2 mission and the Landsat legacy were used to estimate water clarity across a nearly 40-year time period at Cape Cod, Massachusetts

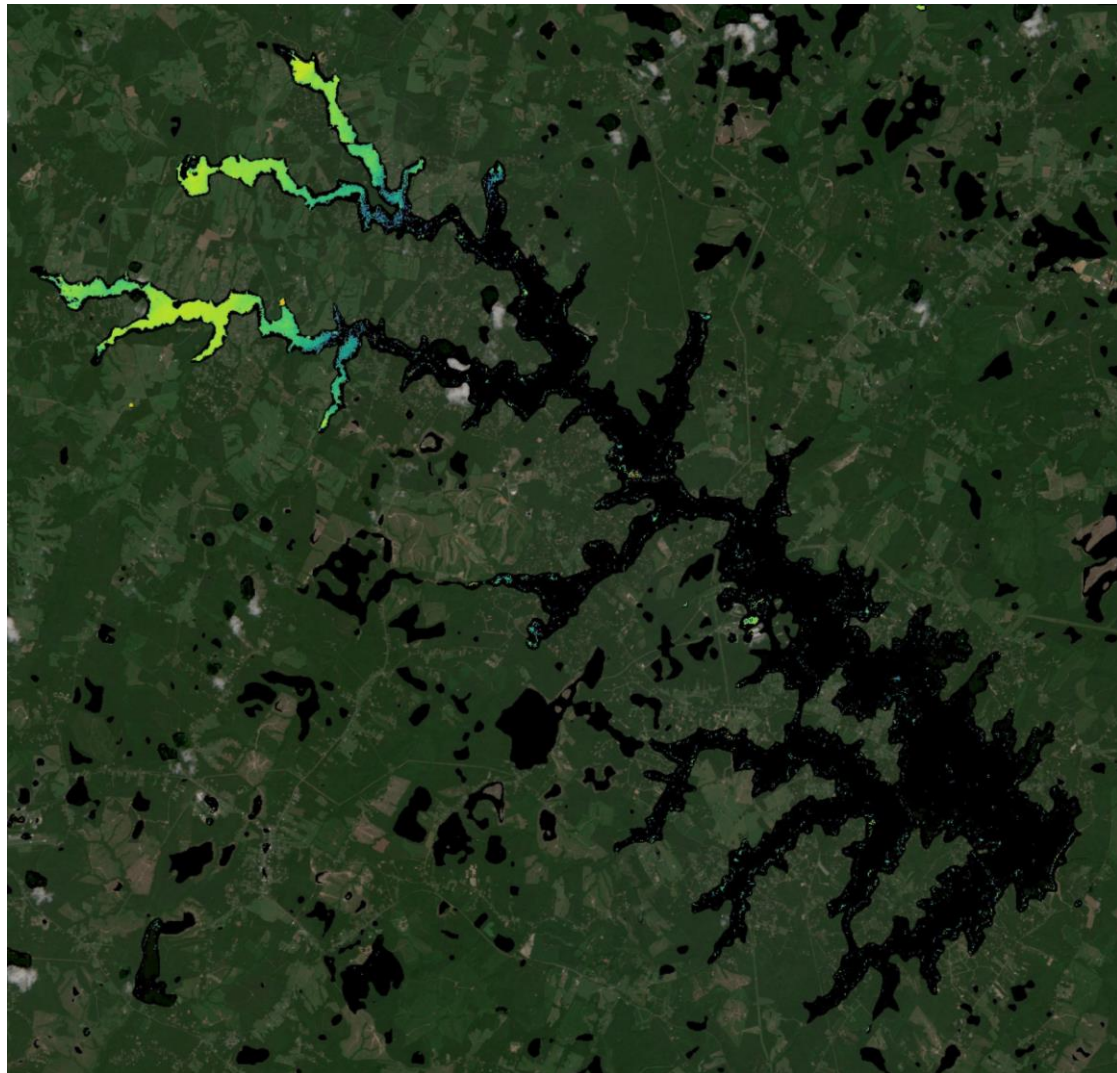
2019 cyanobacterial bloom frequency



Temporal frequency of cyanobacterial blooms computed for over 2,000 lakes across the United States from 2016 to present

Coffer et al., 2021. *Ecol. Indic.*

Lake Anna, Virginia

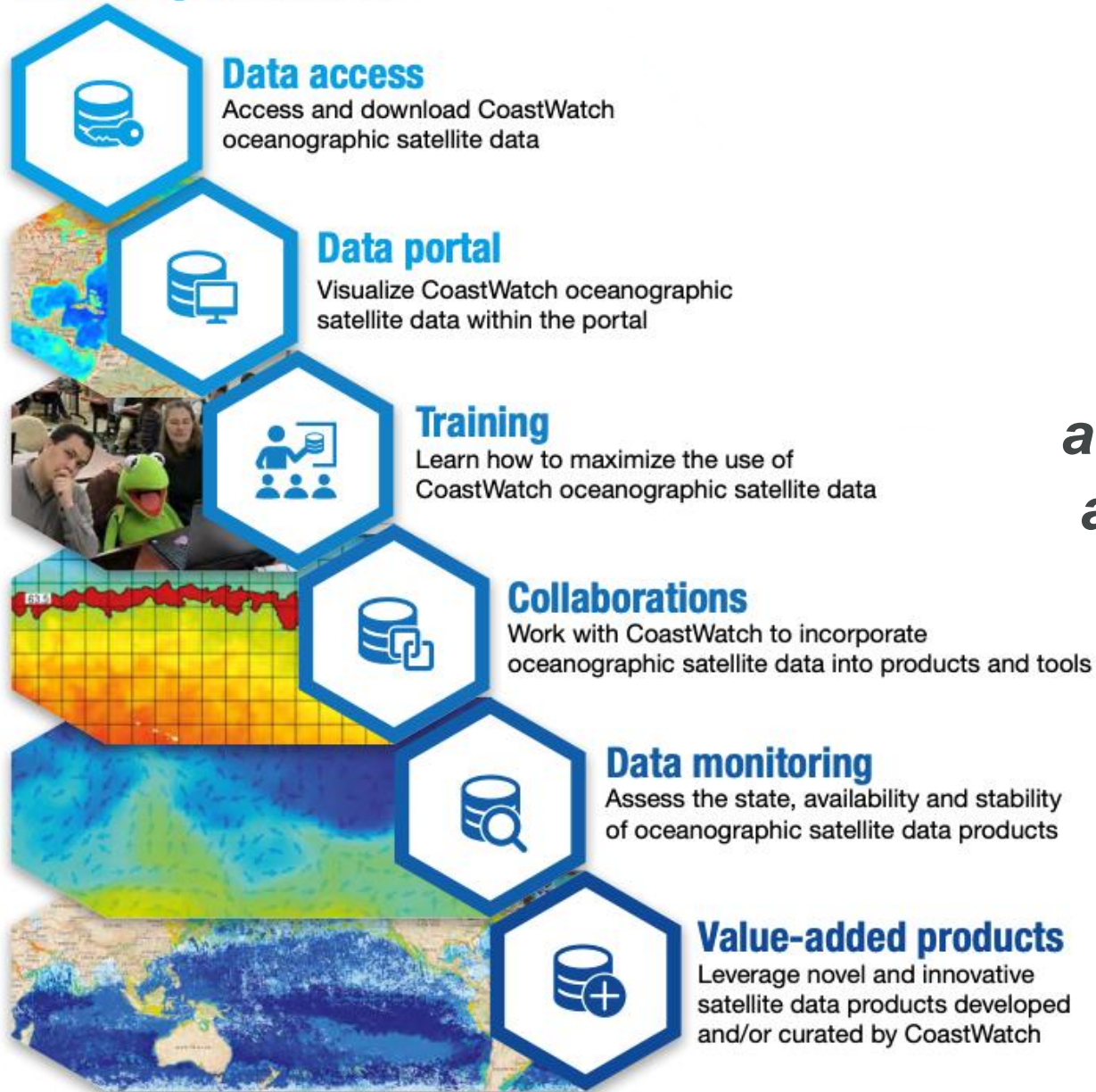


Maximum
chlorophyll
index (MCI)



*Currently developing methods
to use higher resolution,
Sentinel-2 imagery to generate
operational chlorophyll-a
products across over 150,000
lakes and reservoirs across the
United States*

Our capabilities



Within NOAA CoastWatch, we mostly uptake Earth observations through automated routes, and attempt to provide a streamlined source for users to access and interpret satellite data for use in coastal and ocean applications

Q&A Discussion

MODERATOR: KARIN SCHENK

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