the international
water association

User Experiences in Earth Observation for Water Management

25 OCTOBER 2023

inspiring change

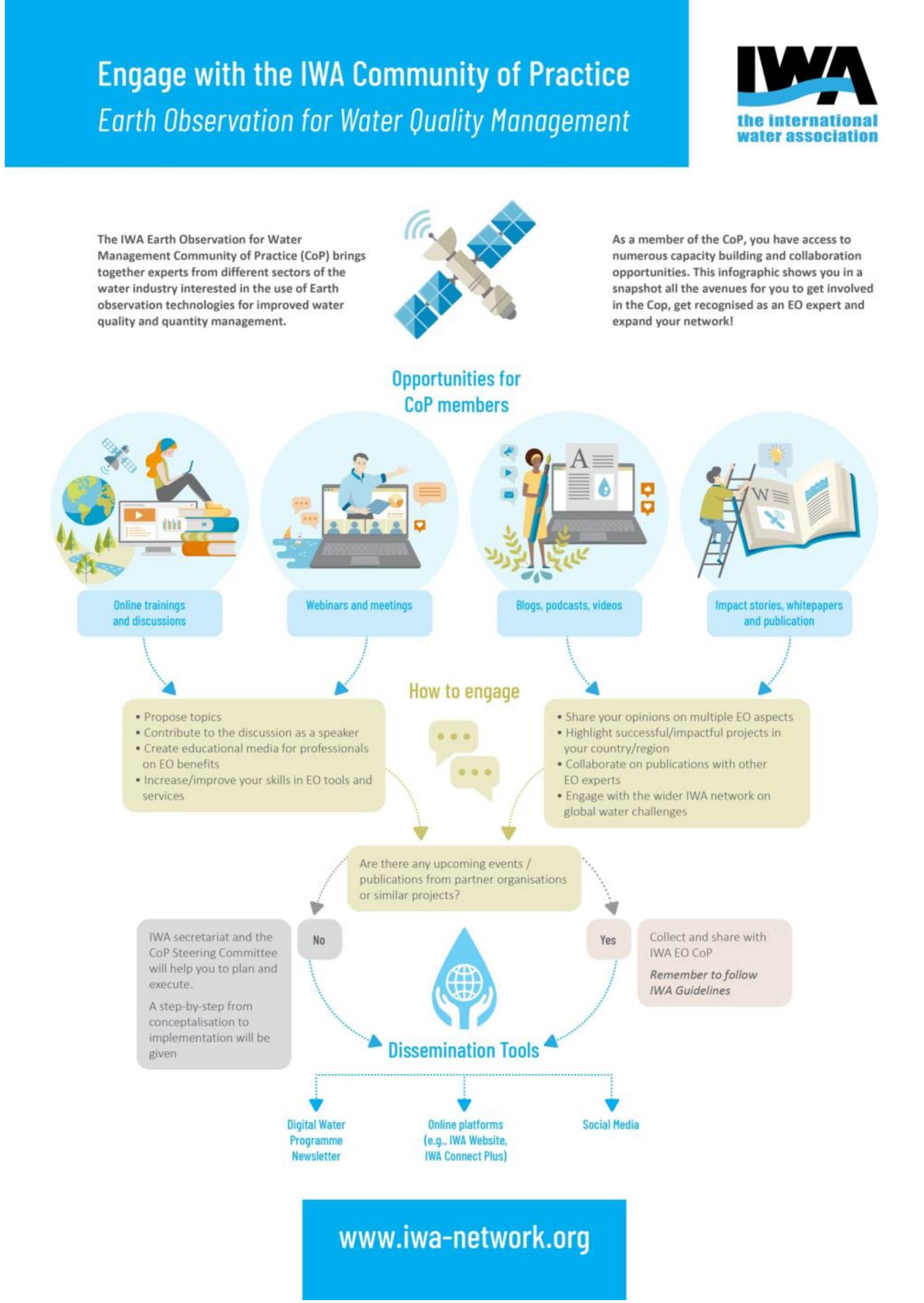
AGENDA

- Welcome & icebreaker (5 mins)
  Erin Jordan, IWA
- Presentations (45 mins)
  Karin Schenk, EOMAP
  - Using SAR for Smarter Water Planning and Disaster Risk Reduction – *Brian Eyler, 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.



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

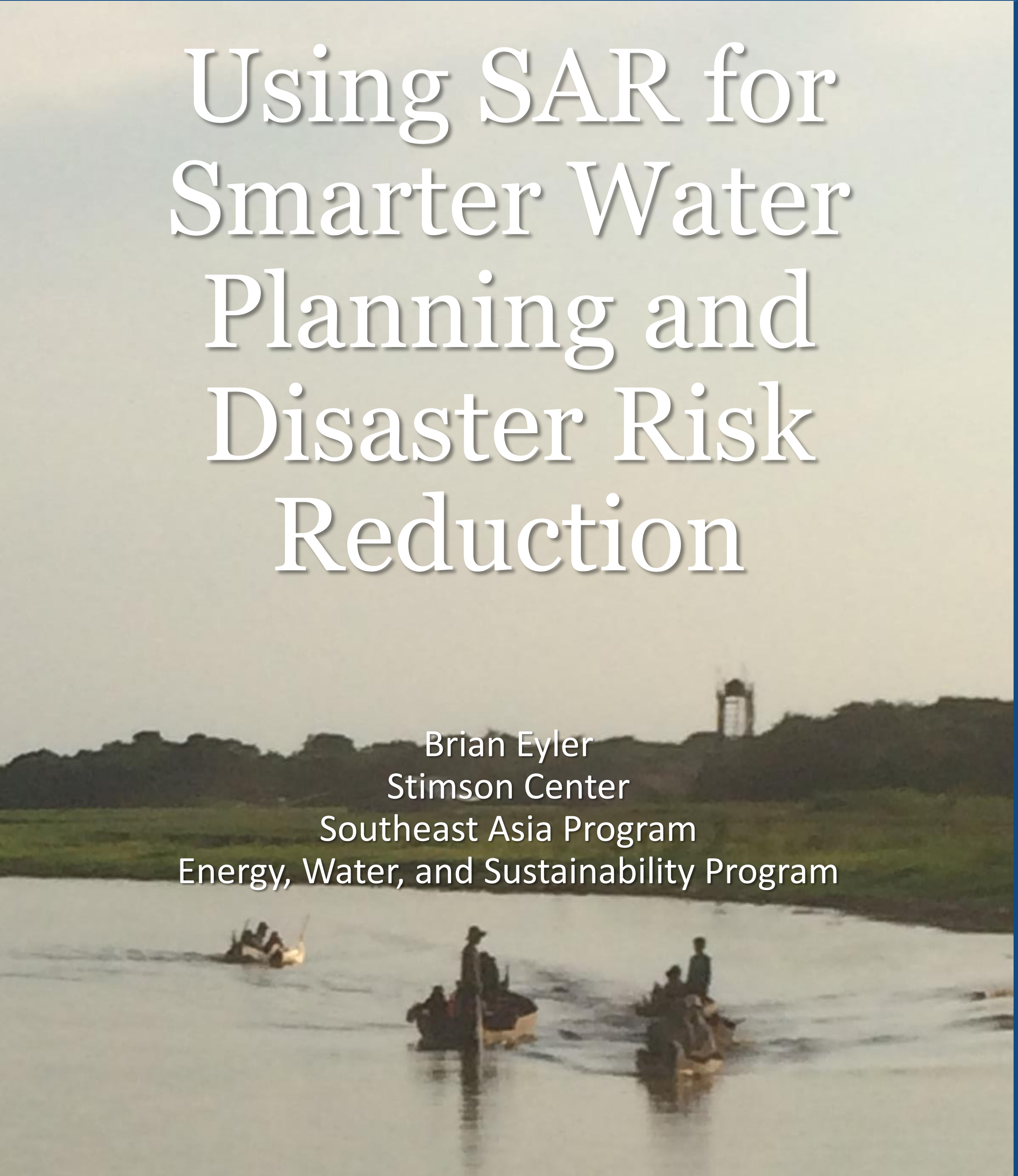
Sothea Khem
River Flood Forecasting Specialist at Mekong River Commission Secretariat, Cambodia

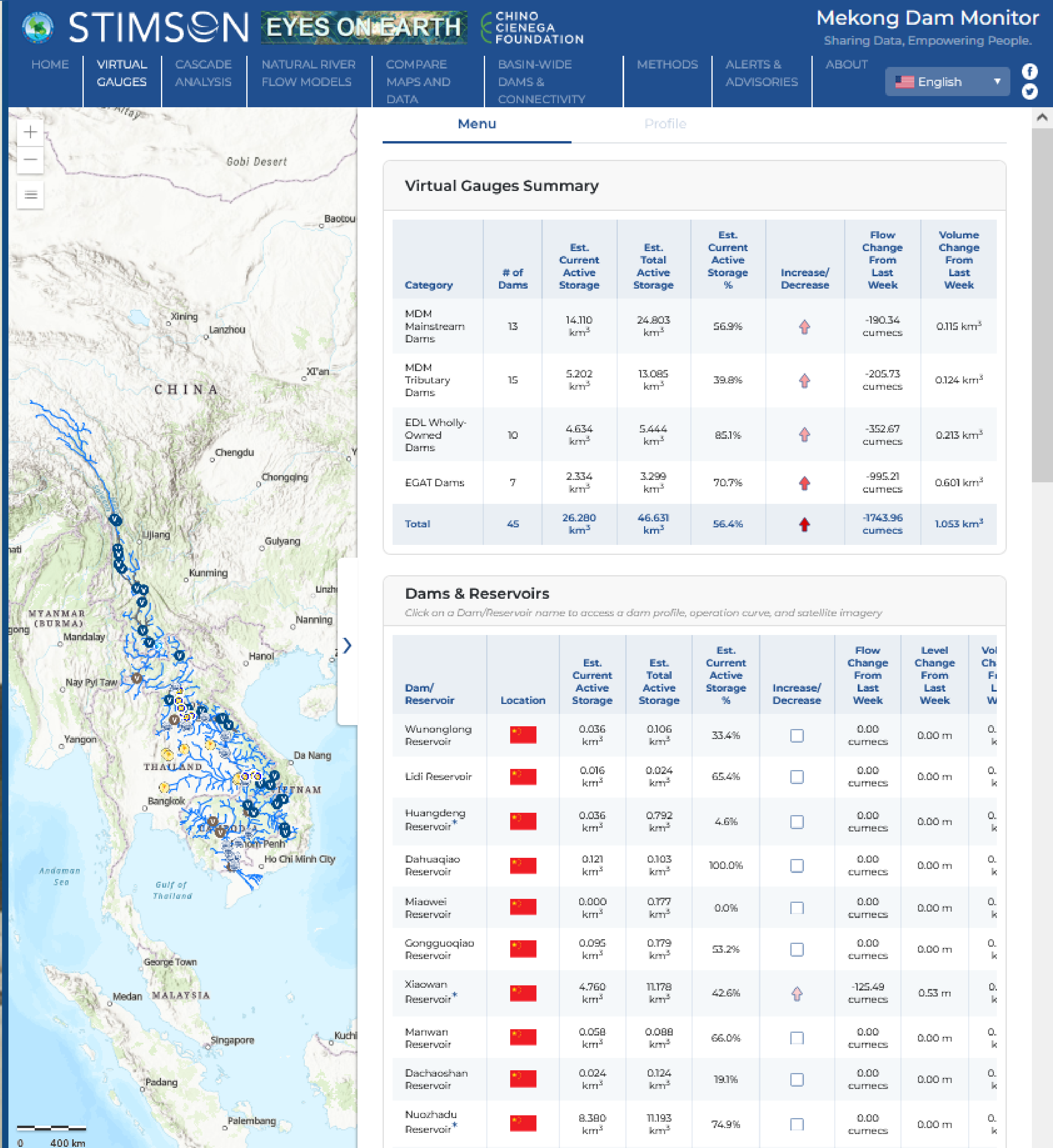
Ils Reusen
Project Manager at VITO Remote Sensing, Belgium

Megan Coffer
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





STIMSON

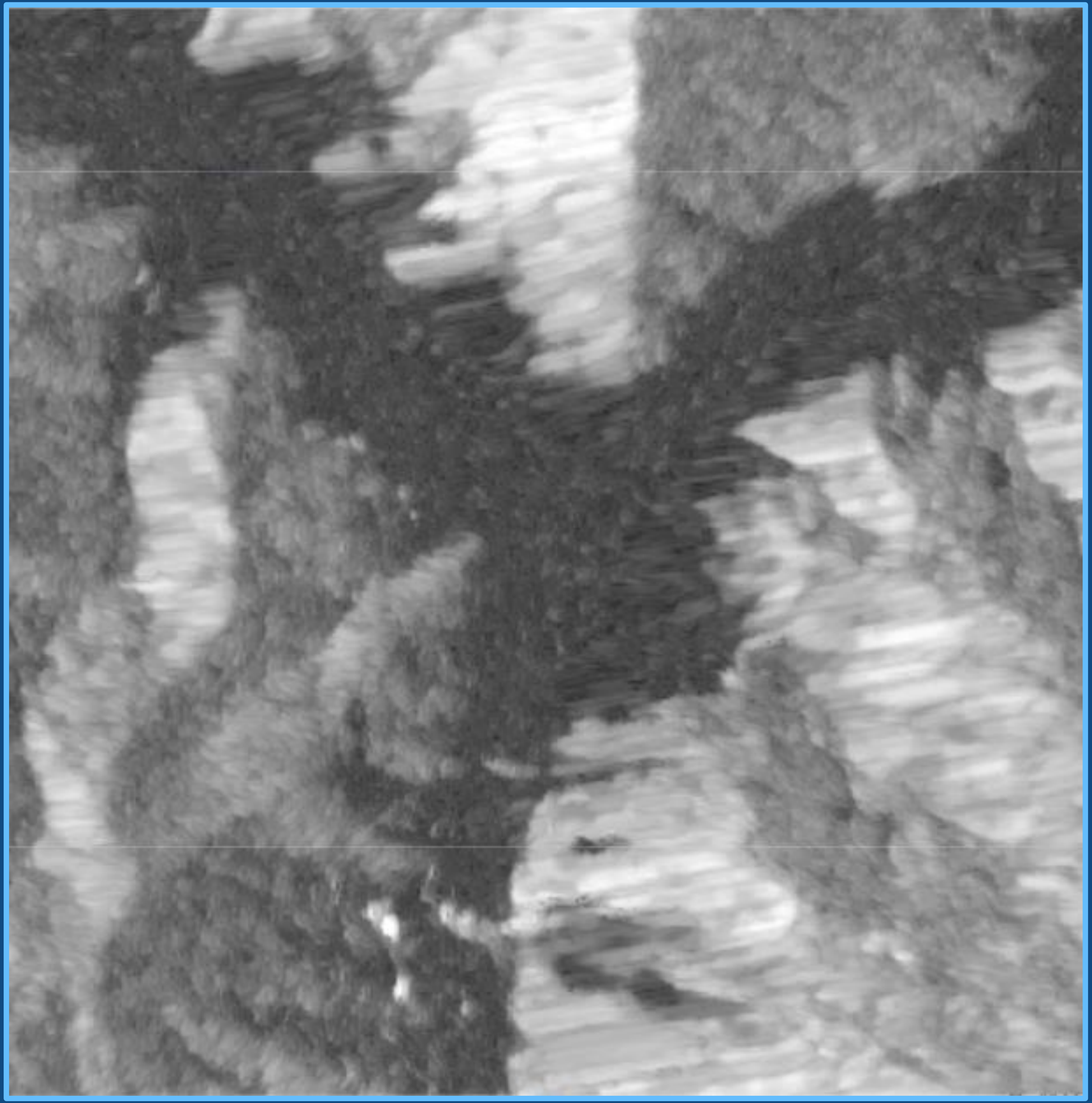
EYES ON EARTH

2022-2023 Mekong Dam Monitor Highlights

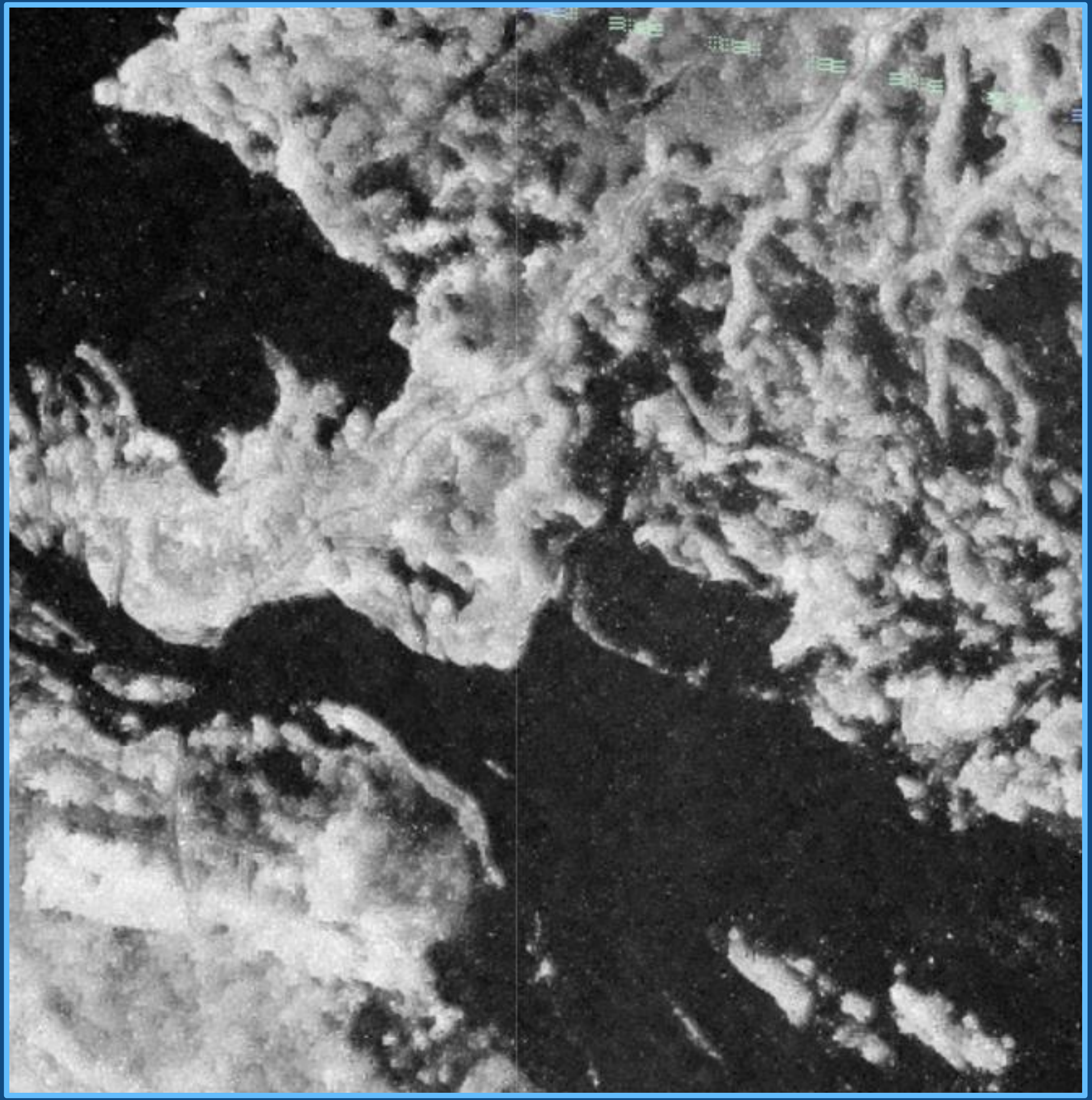
- Confirmed use cases by MRC, govts & NGOs in Vietnam, Cambodia, Thailand, Laos
- 50 Early Warning Alerts issued
- ~35 million social media accounts in 7 languages

Mekong Dam Monitor

Sharing Data, Empowering People.

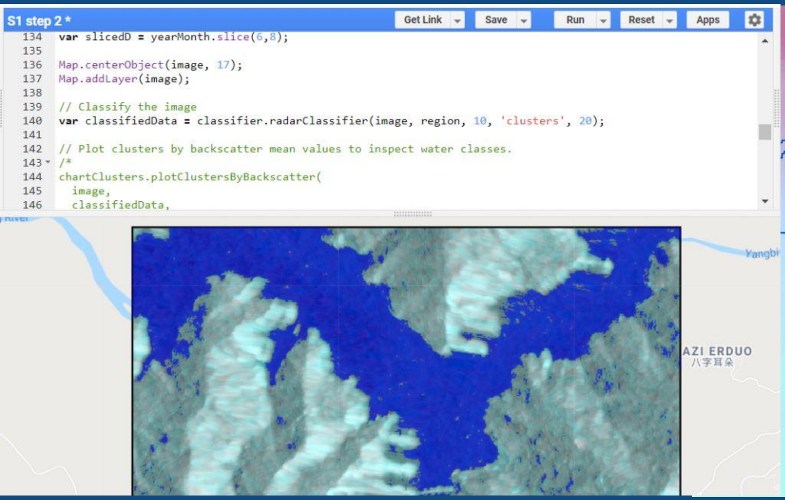


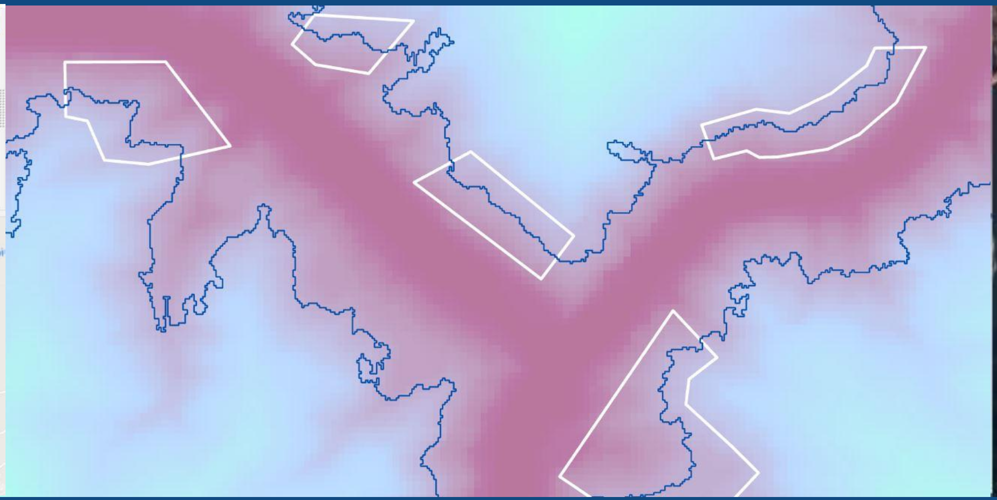
Xiaowan Dam



Tonle Sap Lake bottleneck

What is a Virtual Gauge?





<u>Identify level shape of reservoir</u>

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.

<u>Determine raw altimetry data (masl)</u>

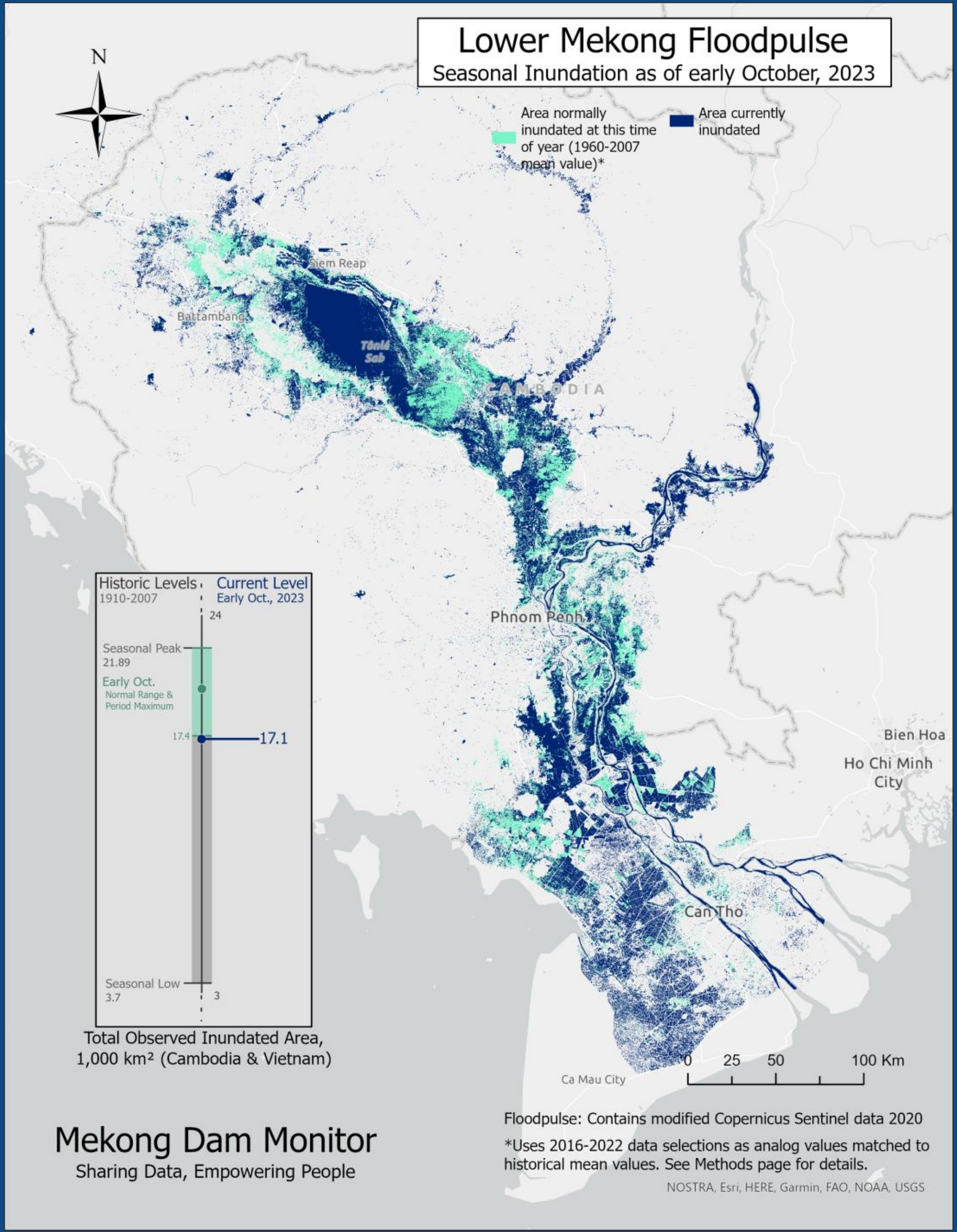
1. Remove extraneous shapes from reservoir shape
2. Generate a line circumference of shape
3. Select reliable areas of shoreline (white boxes above)
4. Generate mean shoreline elevation using 30-meter ALOS digital elevation model (remove outliers with filters)

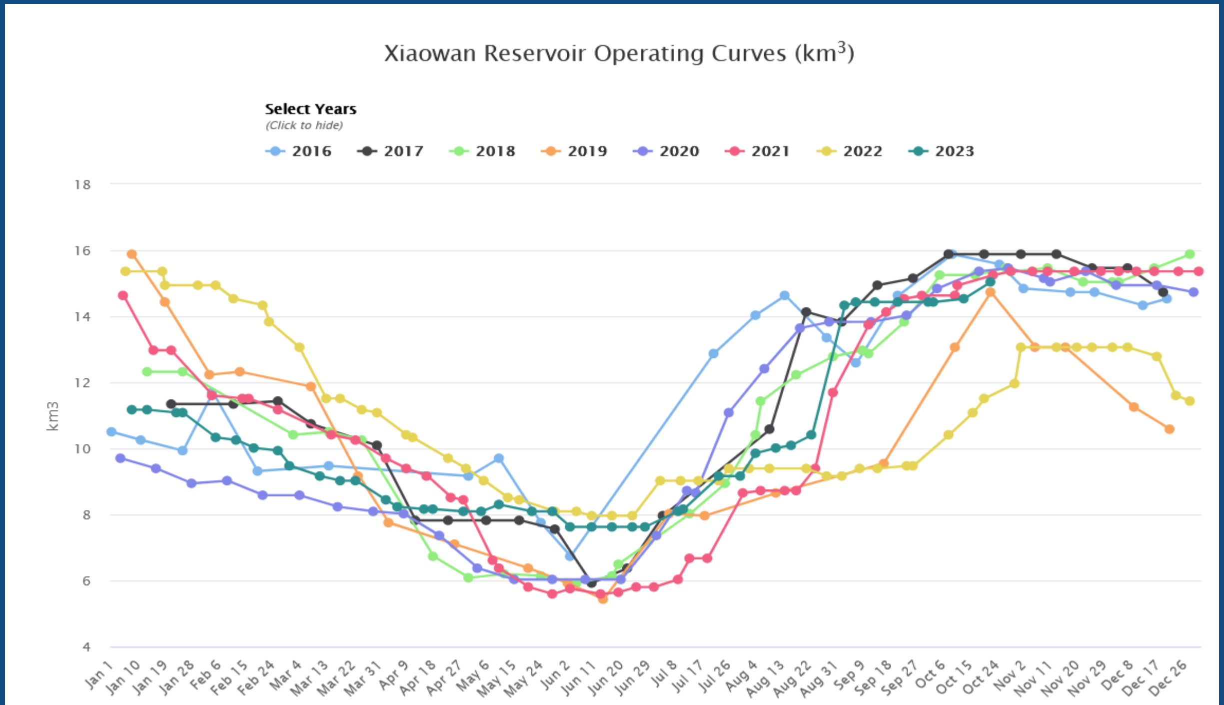
Error: +/- 2.5 meters

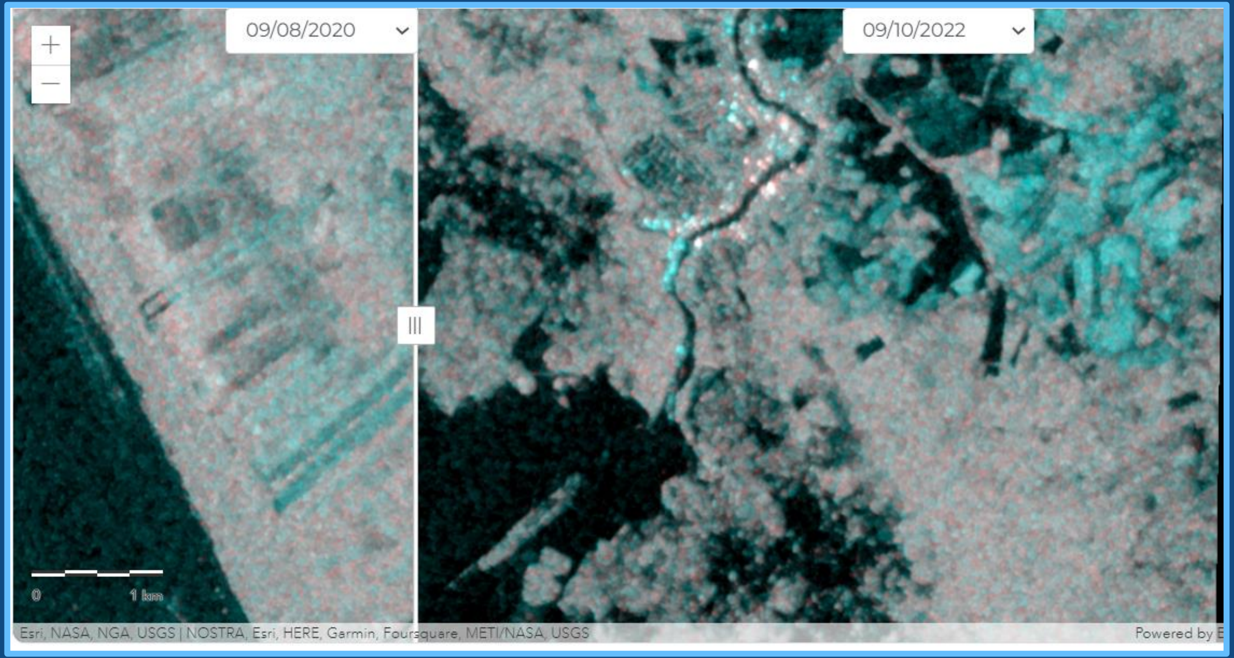
<u>Check altimetry data vs satellite images</u>

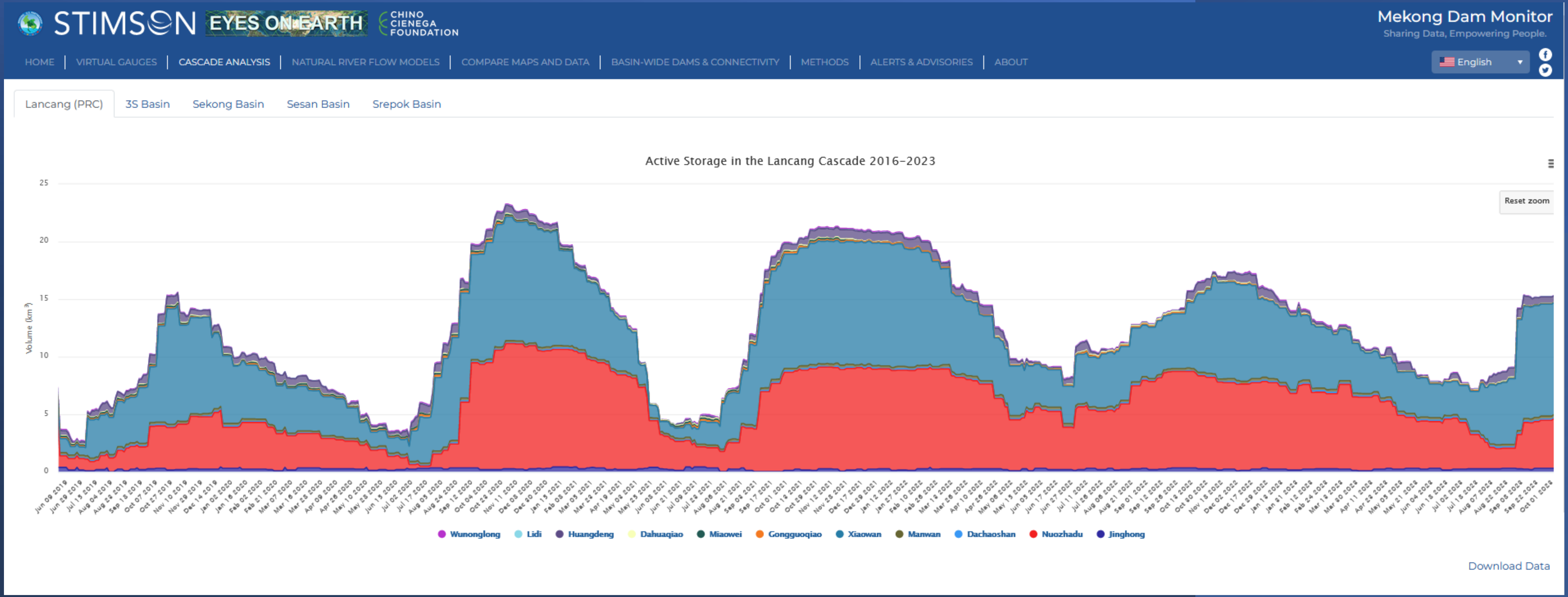
1. Outlier check (is raw data outside known range of maximum and minimum)
2. Fluctuation check (if raw data shows major fluctuation, does image also show this?)
3. Adjust identified outliers & erroneous fluctuations using proxy known data

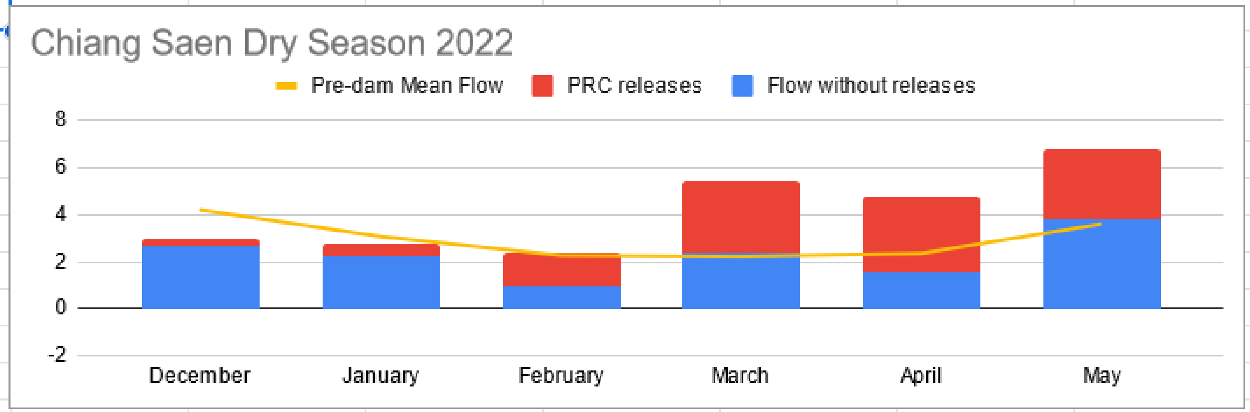
Error: +/-1 meter

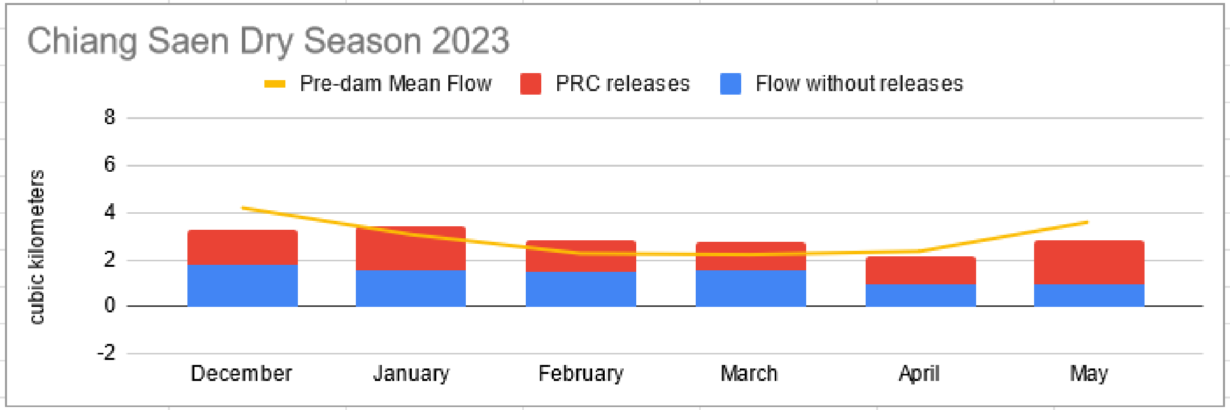

Lower Mekong Floodpulse
Seasonal Inundation as of early October, 2023
N
Area normally inundated at this time of year (1960-2007 mean value)*
Area currently inundated
Siem Reap
Battambang
Tonlé Sab
CAMBODIA
Phnom Penh
Bien Hoa
Ho Chi Minh City
Can Tho
Ca Mau City
Historic Levels 1910-2007
Current Level Early Oct., 2023
24
Seasonal Peak 21.89
Early Oct. Normal Range & Period Maximum
17.4
17.1
Seasonal Low 3.7
3
Total Observed Inundated Area, 1,000 km² (Cambodia & Vietnam)
0 25 50 100 Km
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

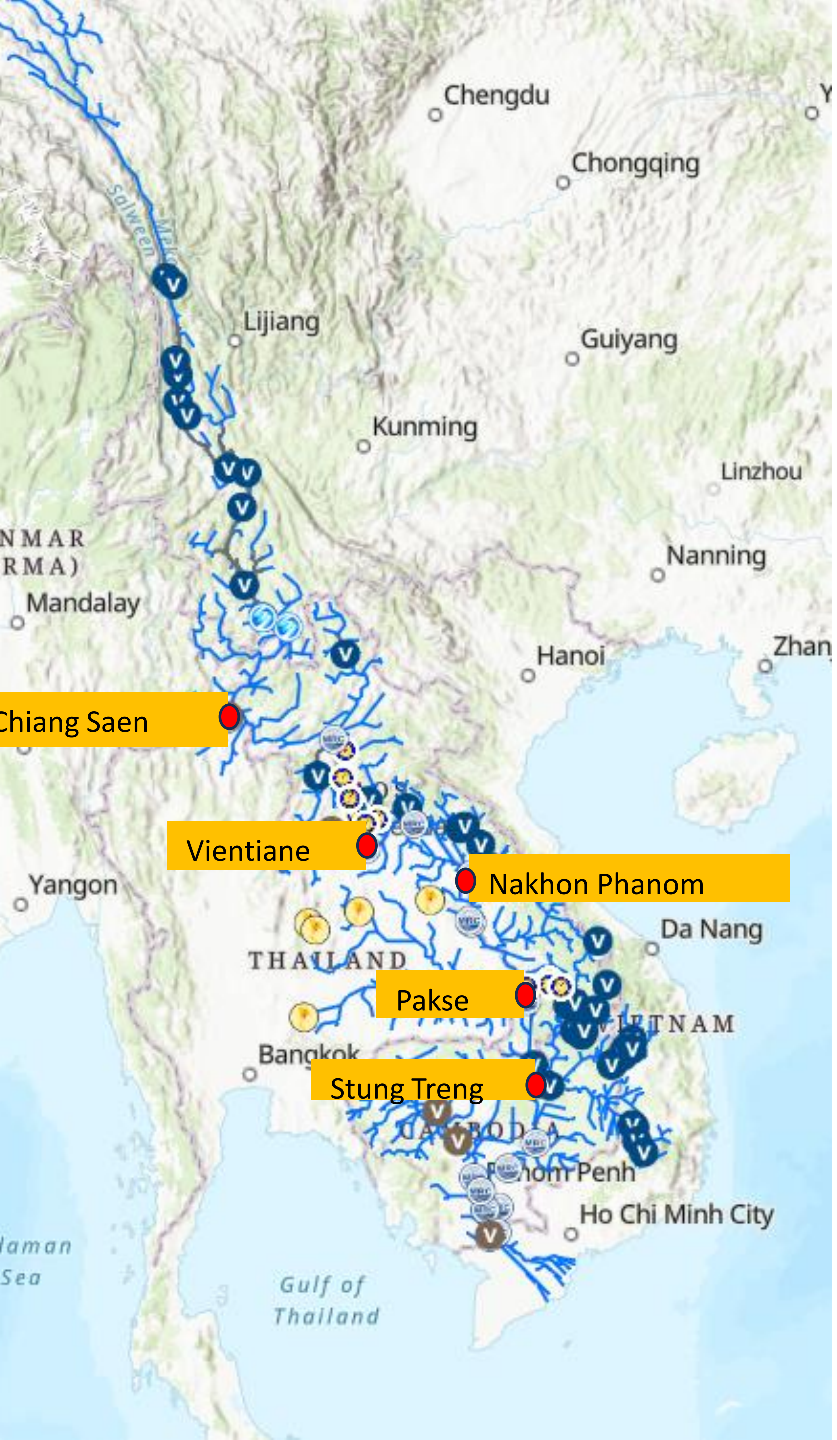

Xiaowan Reservoir Operating Curves (km³)
Select Years
(Click to hide)
2016
2017
2018
2019
2020
2021
2022
2023
km3
18
16
14
12
10
8
6
4
Jan 1
Jan 10
Jan 19
Jan 28
Feb 6
Feb 15
Feb 24
Mar 4
Mar 13
Mar 22
Mar 31
Apr 9
Apr 18
Apr 27
May 6
May 15
May 24
Jun 2
Jun 11
Jun 20
Jun 29
Jul 8
Jul 17
Jul 26
Aug 4
Aug 13
Aug 22
Aug 31
Sep 9
Sep 18
Sep 27
Oct 6
Oct 15
Oct 24
Nov 2
Nov 11
Nov 20
Nov 29
Dec 8
Dec 17
Dec 26


09/08/2020
09/10/2022
0
1 km
Esri, NASA, NGA, USGS | NOSTRA, Esri, HERE, Garmin, Foursquare, METI/NASA, USGS

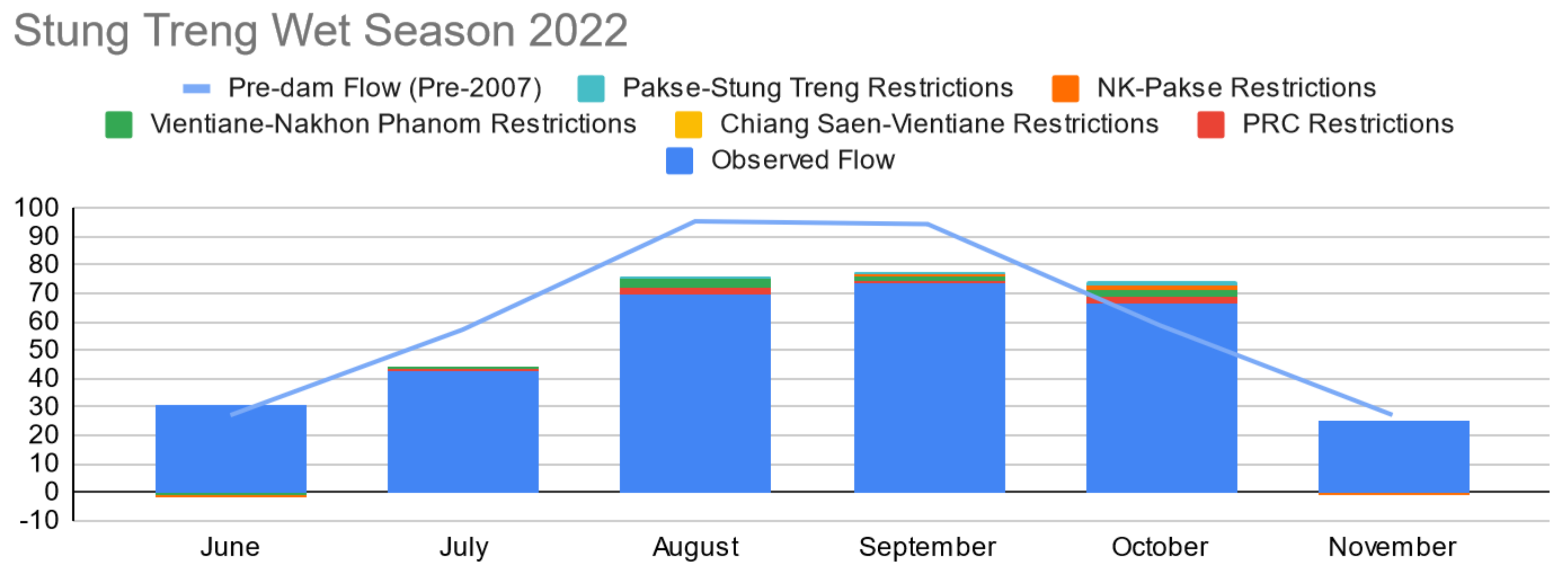

STIMSON
EYES ON EARTH
CHINO CIENEGA FOUNDATION
Mekong Dam Monitor
Sharing Data, Empowering People.
HOME | VIRTUAL GAUGES | CASCADE ANALYSIS | NATURAL RIVER FLOW MODELS | COMPARE MAPS AND DATA | BASIN-WIDE DAMS & CONNECTIVITY | METHODS | ALERTS & ADVISORIES | ABOUT
English
Lancang (PRC)
3S Basin
Sekong Basin
Sesan Basin
Srepok Basin
Active Storage in the Lancang Cascade 2016-2023
Reset zoom
Volume (km³)
25
20
15
10
5
0
Wunonglong
Lidi
Huangdeng
Dahuaqiao
Miaowei
Gongguoqiao
Xiaowan
Manwan
Dachaoshan
Nuozhadu
Jinghong
Download Data


Chiang Saen Dry Season 2022
Pre-dam Mean Flow
PRC releases
Flow without releases
8
6
4
2
0
-2
December
January
February
March
April
May

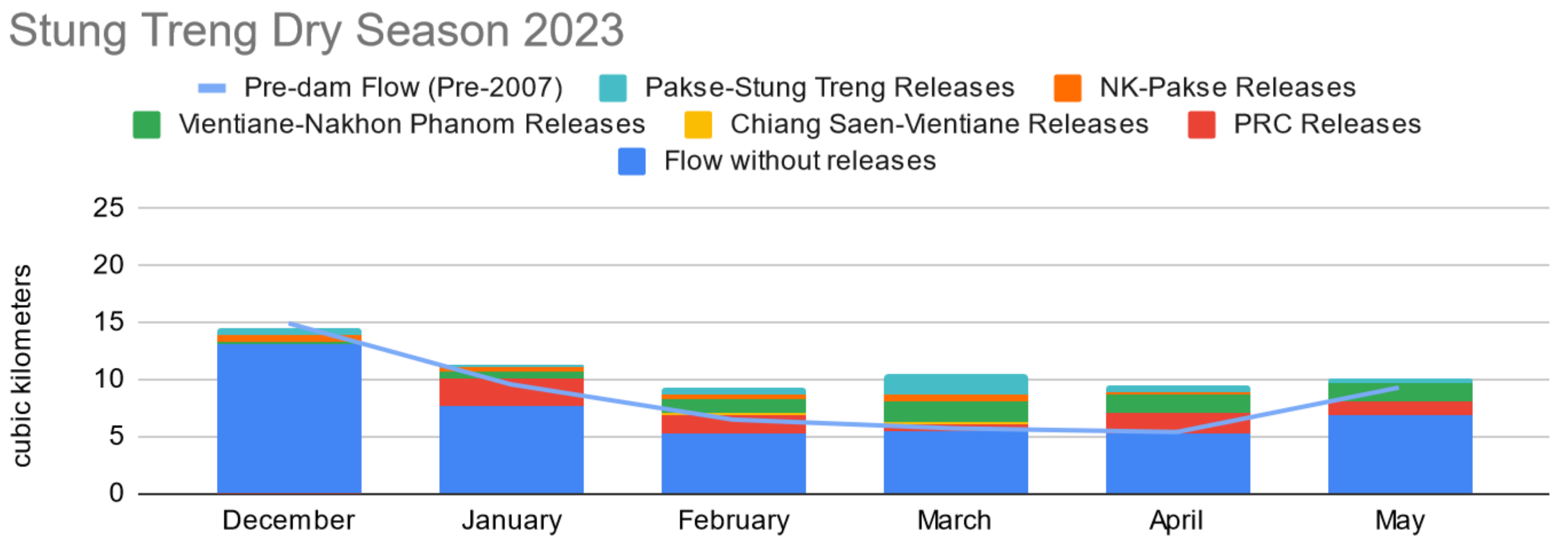

Chiang Saen Dry Season 2023
Pre-dam Mean Flow
PRC releases
Flow without releases
cubic kilometers
8
6
4
2
0
-2
December
January
February
March
April
May



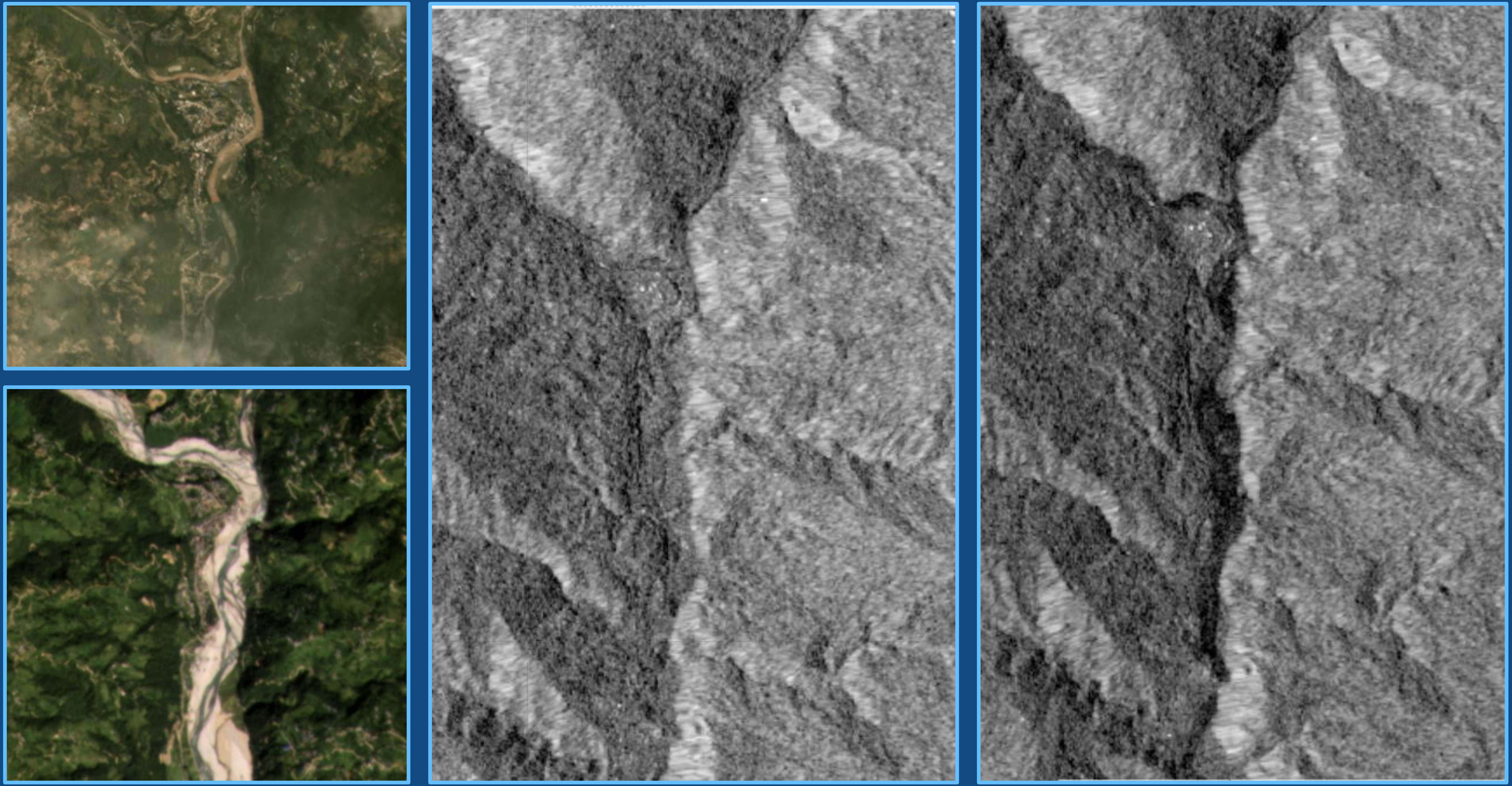
Chengdu
Chongqing
Lijiang
Guiyang
Kunming
Linzhou
Nanning
Mandalay
Hanoi
Chiang Saen
Vientiane
Nakhon Phanom
Yangon
Da Nang
THAILAND
Pakse
Bangkok
Stung Treng
Ho Chi Minh City
Gulf of Thailand



Stung Treng Wet Season 2022
Pre-dam Flow (Pre-2007)
Pakse-Stung Treng Restrictions
NK-Pakse Restrictions
Vientiane-Nakhon Phanom Restrictions
Chiang Saen-Vientiane Restrictions
PRC Restrictions
Observed Flow
100
90
80
70
60
50
40
30
20
10
0
-10
June
July
August
September
October
November



Stung Treng Dry Season 2023
Pre-dam Flow (Pre-2007)
Pakse-Stung Treng Releases
NK-Pakse Releases
Vientiane-Nakhon Phanom Releases
Chiang Saen-Vientiane Releases
PRC Releases
Flow without releases
cubic kilometers
25
20
15
10
5
0
December
January
February
March
April
May



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

STIMSON

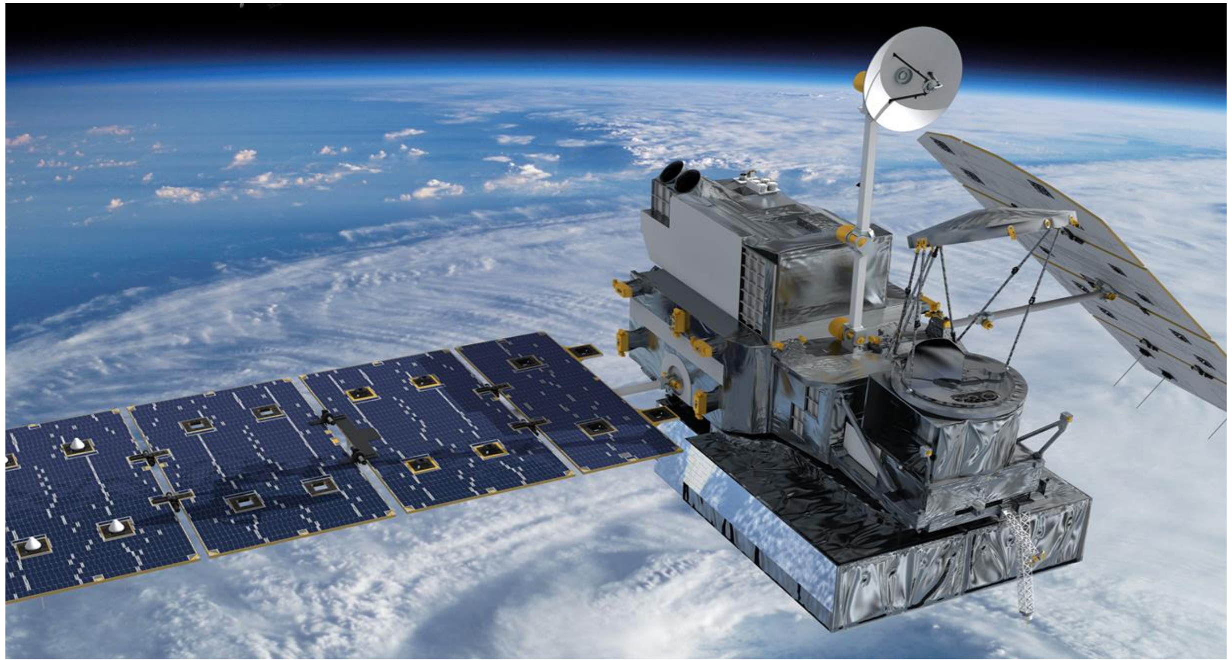
Thank you!

beyler@stimson.org
Twitter: @aikunming

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



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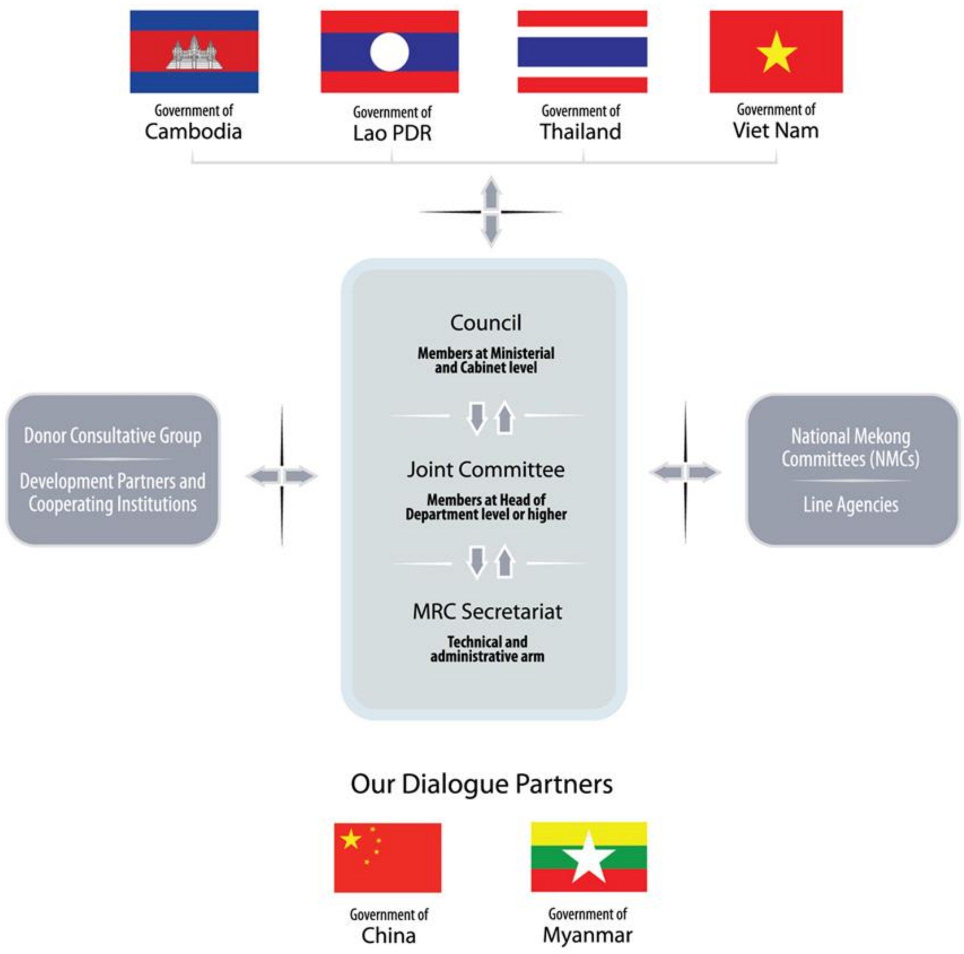
1. Background about MRC

Mekong River Commission Governance Structure



Office of CEO

Administration Division

- Administration, incl. governance meeting
- Finance & Procurement
- Human Resources

Planning Division

- Basin-Wide assessment, incl. socio-economic
- Basin & Sector Planning, incl. hydropower, irrigation, climate change
- MRC Procedures coordination
- IWRM Project
- Navigation support

Environmental Management Division

- Environmental assessment
- Environmental planning & management, incl. wetland, watershed, fisheries
- Environmental Monitoring, incl. water quality & EHM
- State of basin reporting

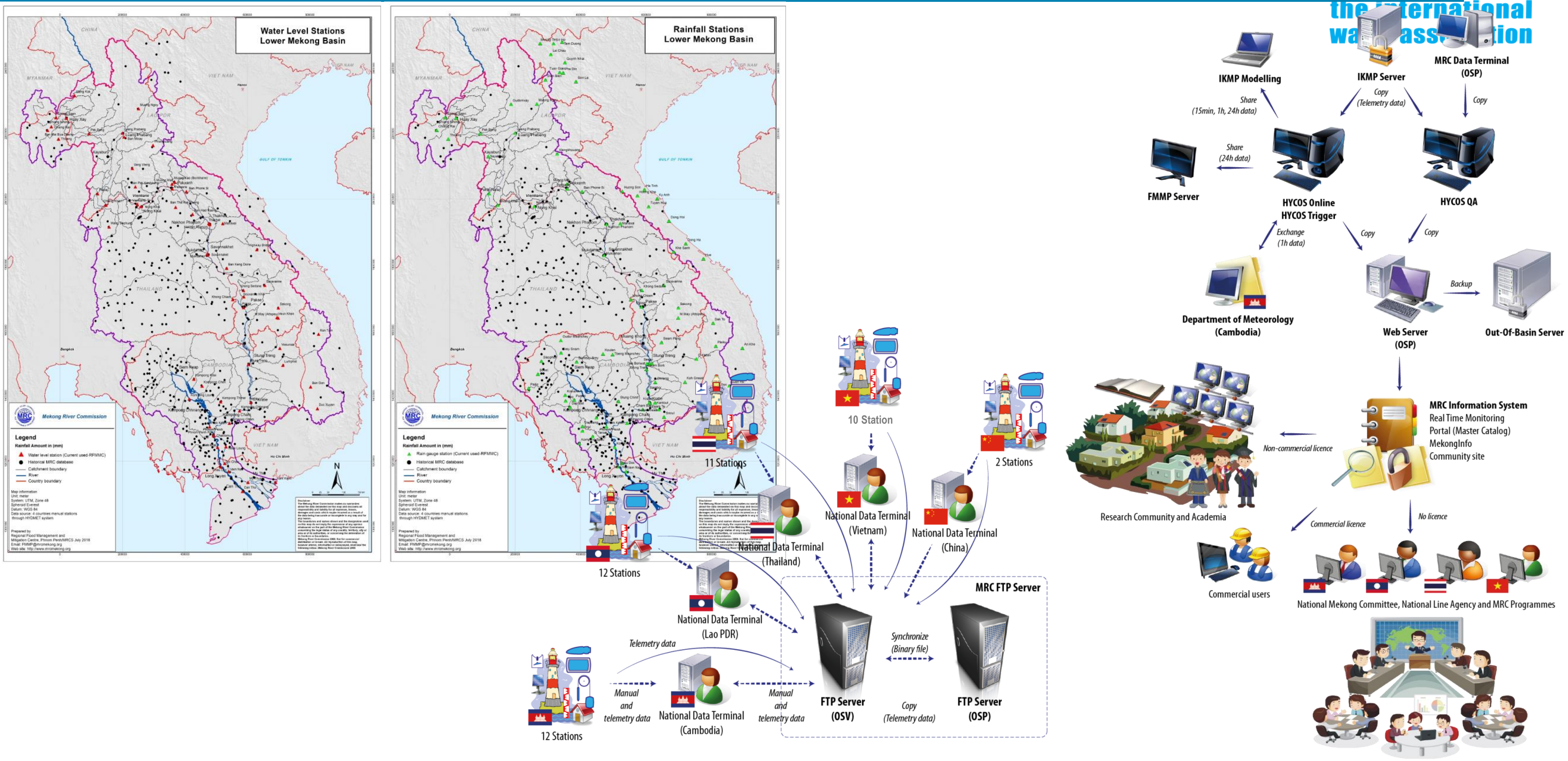
Technical Support Division

- Water & climate monitoring, incl. sediment
- Databases & Information System
- Modeling & Tools
- Flood & Drought Forecasting & Early Warning

MRCS building in Vientiane, Lao PDR

Regional Flood and Drought Management Centre in Phnom Penh, Cambodia

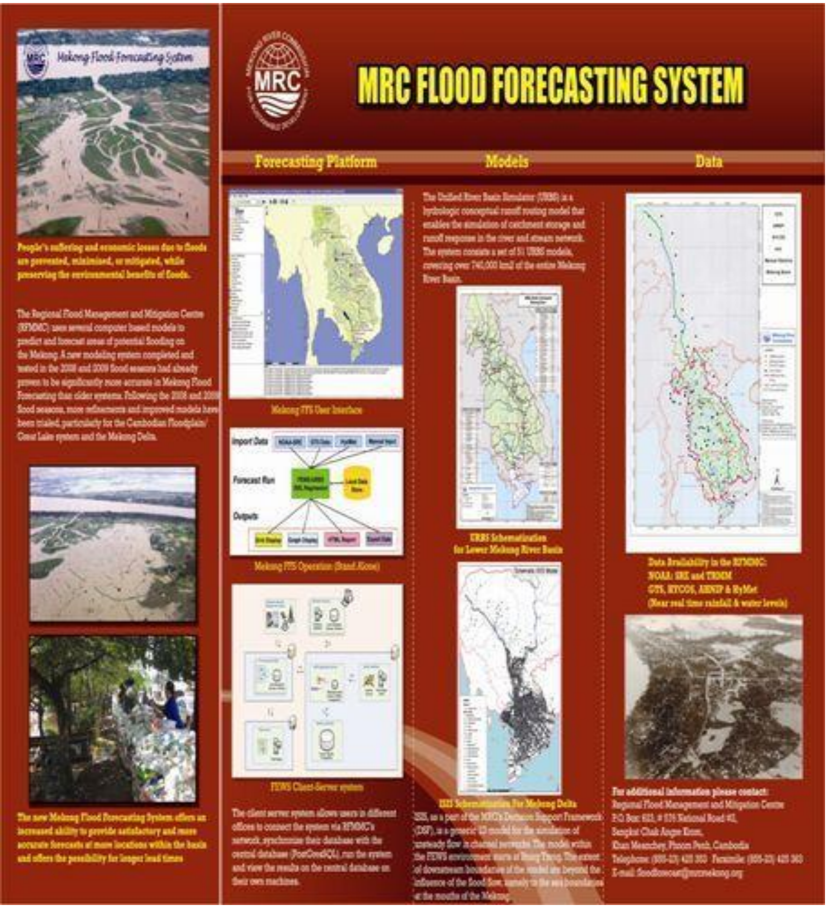
2. Data sharing information within the LMB via MRCS

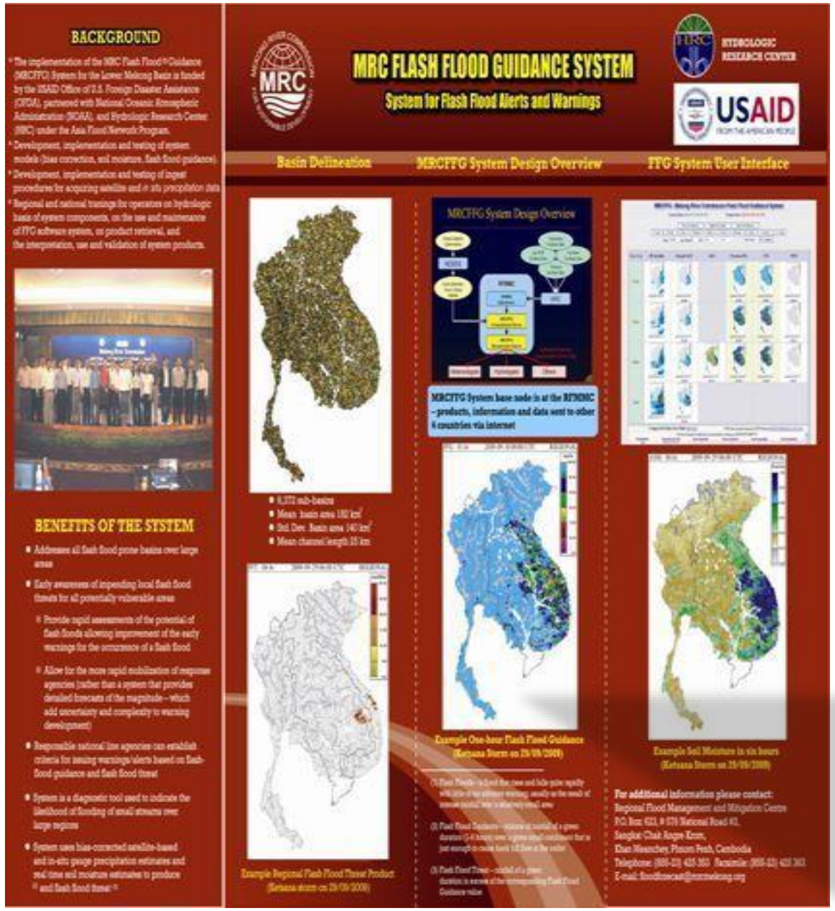


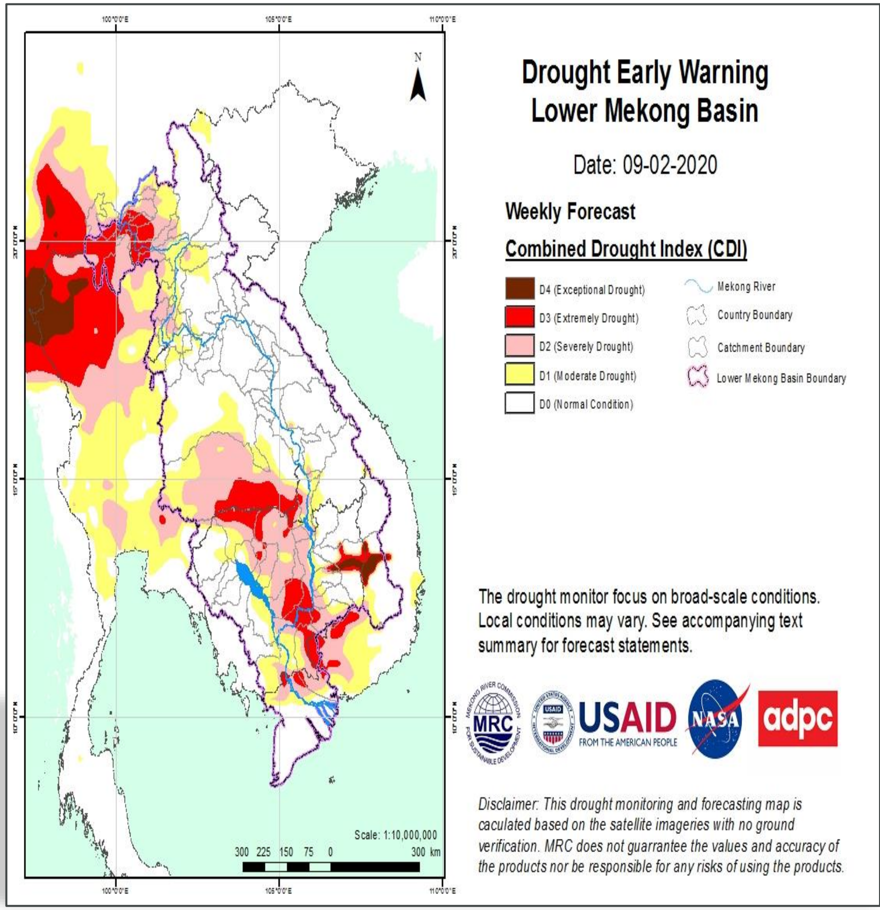
3. The MRC’s Regional Flood & Drought Management Center

- 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)







4. Improving Flood Forecasting based on Satellite Data

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SRE/GFAS (NOAA) →

PROPOSED DATA USE
- CHIRPS-GEFS (5km x 5km)
- GPM-BICO (10km x 10 km)

FLOODS FORECASTING

Existing FEWS

NEAR REAL TIME OF SATELLITE DATA
- SRE

SATELLITE FORECASTING RAINFALL
- GFAS

MANUAL DATA
- Water levels and Rainfall

FEWS

New FEWS

NEAR REAL TIME OF SATELLITE DATA
- GMP (GLOBAL MEASUREMETNS PRECIPITATION)

SATELLITE FORECASTING RAINFALL
- CHIRPS-GEFS (Global Ensemble Forecast System)

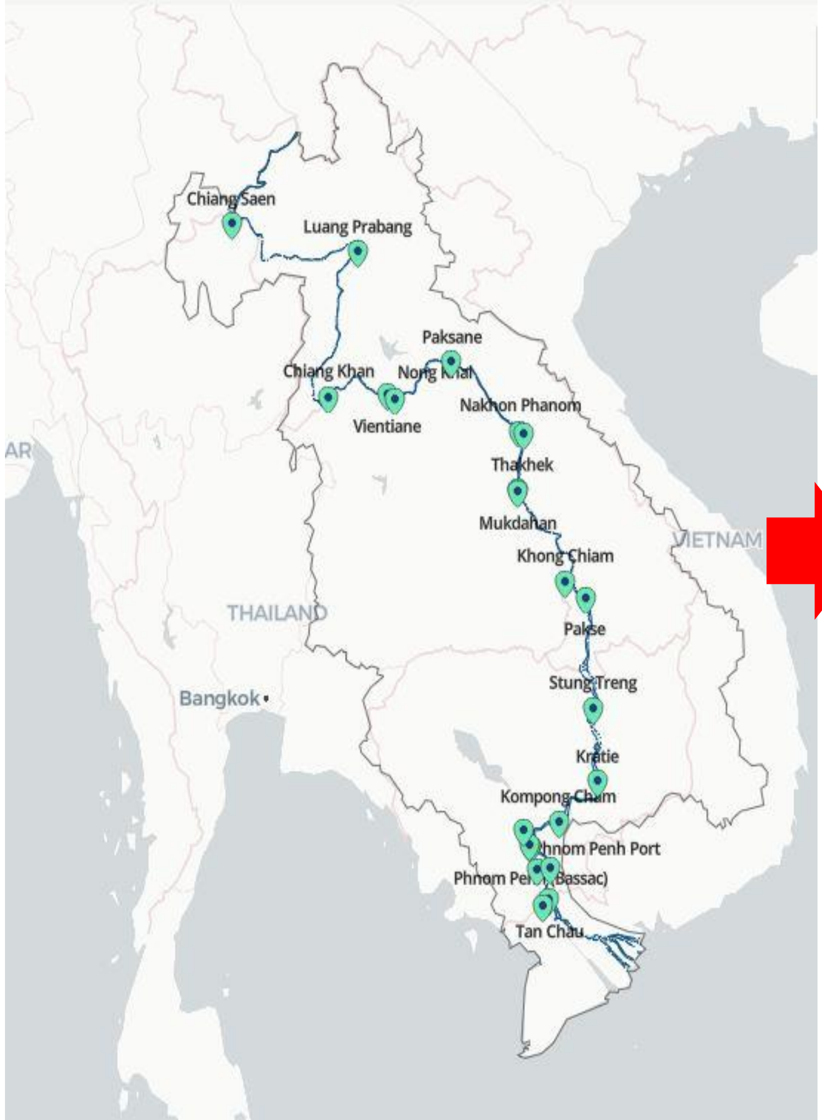
MANUAL DATA
- Water levels and Rainfall

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 againt 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

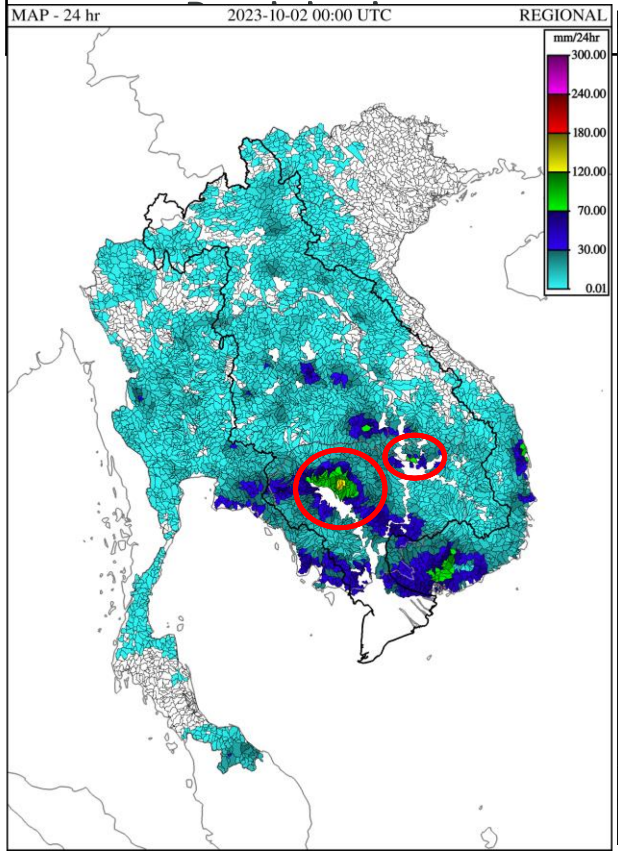


Figure 2: Average Soil Moisture

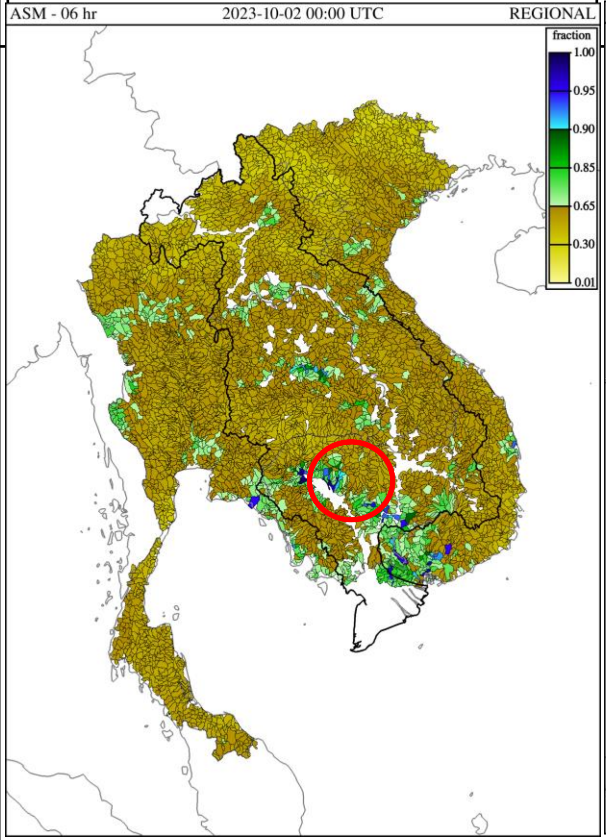
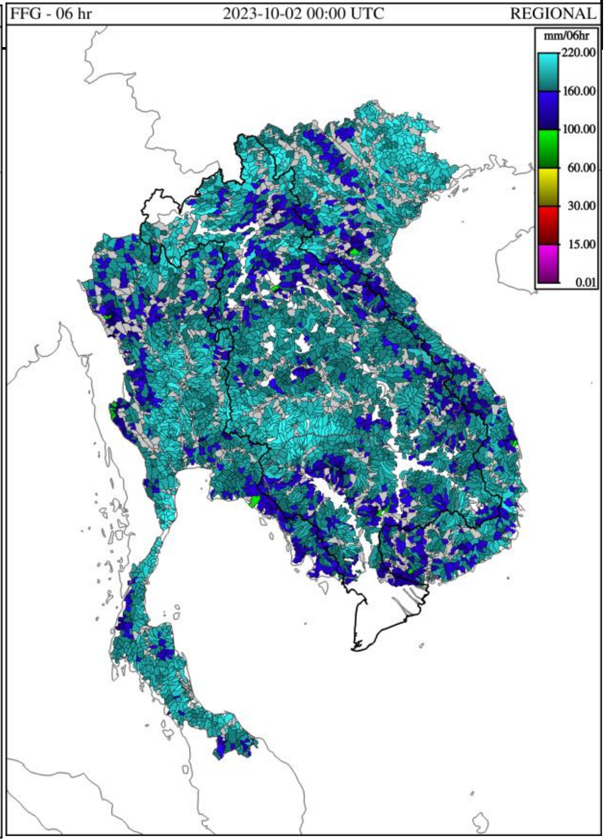
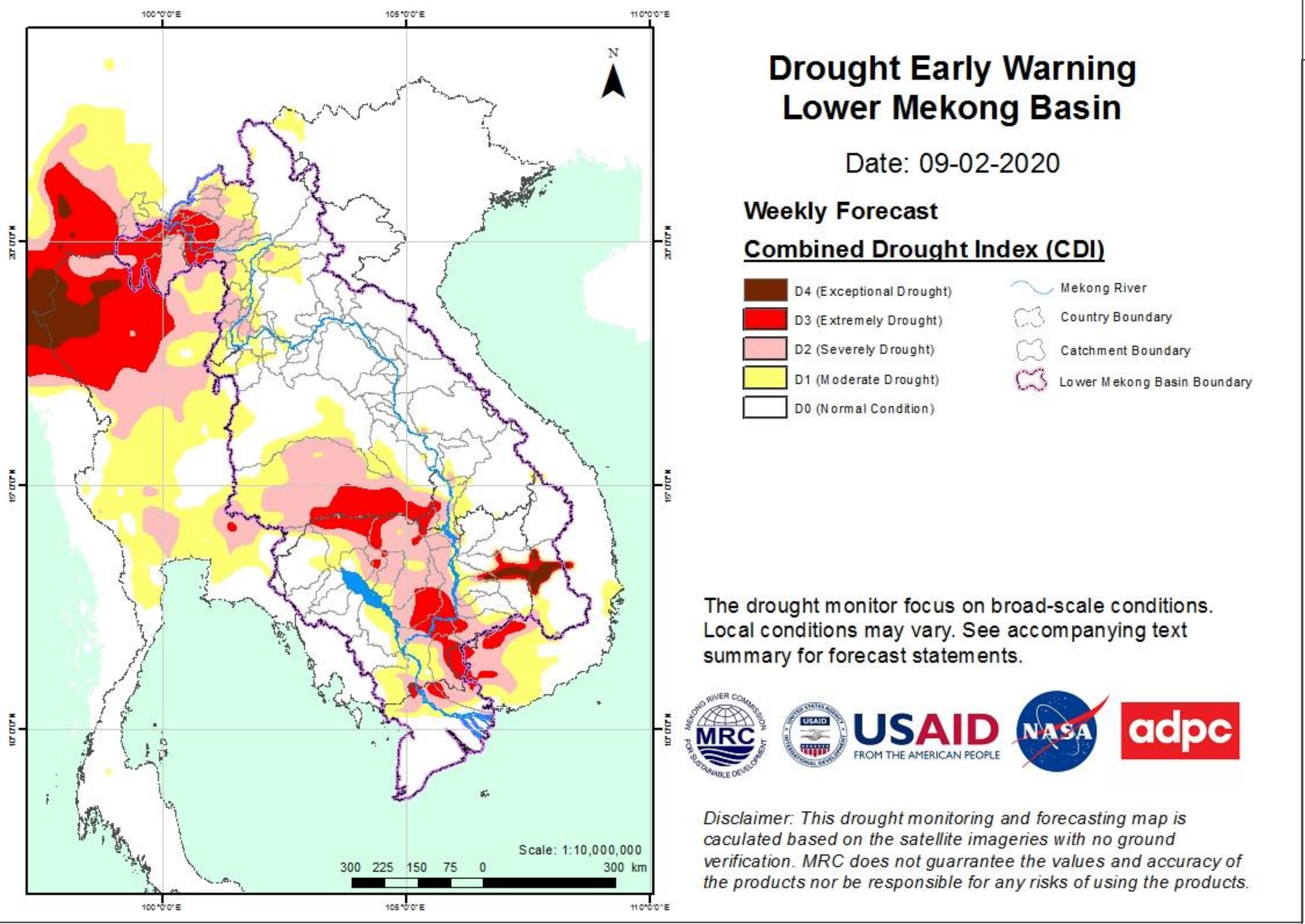


Figure 3: Flash Flood Guidance



- 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



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

the international water association

- 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…..)

THANK YOU

One Mekong. One Spirit.

MEKONG RIVER COMMISSION FOR SUSTAINABLE DEVELOPMENT

the international water association

EOMORES

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

lakes cci

Water - ForCE

IWA
the international water association

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

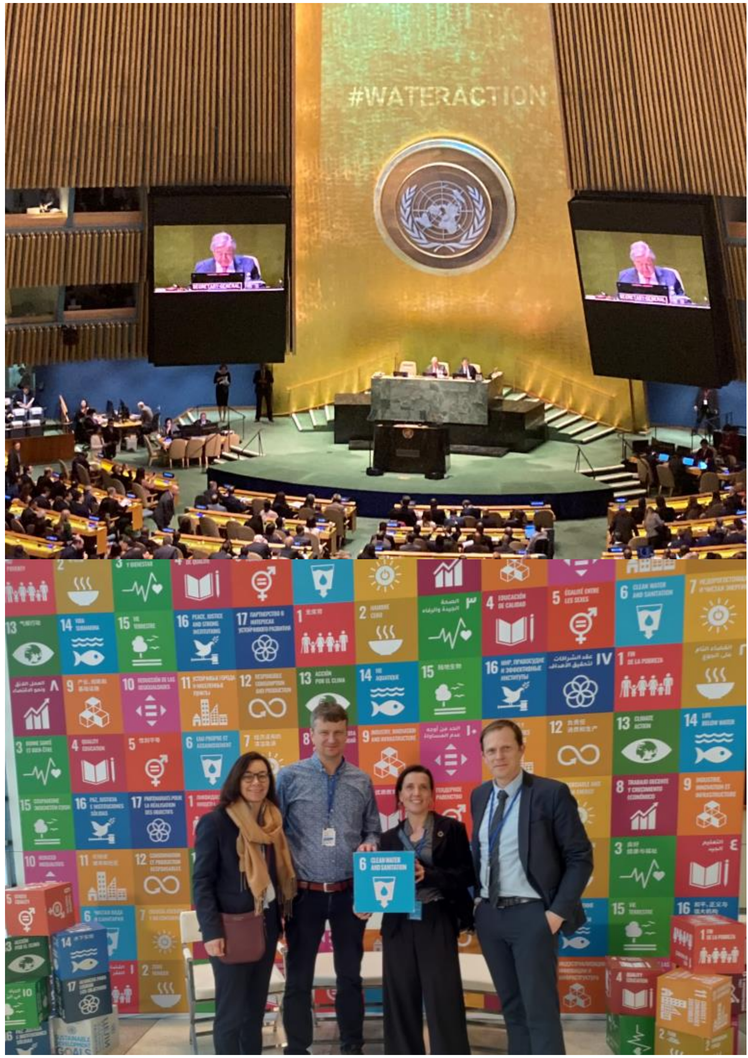
inspiring change

UN WATER 2023 CONFERENCE, NY

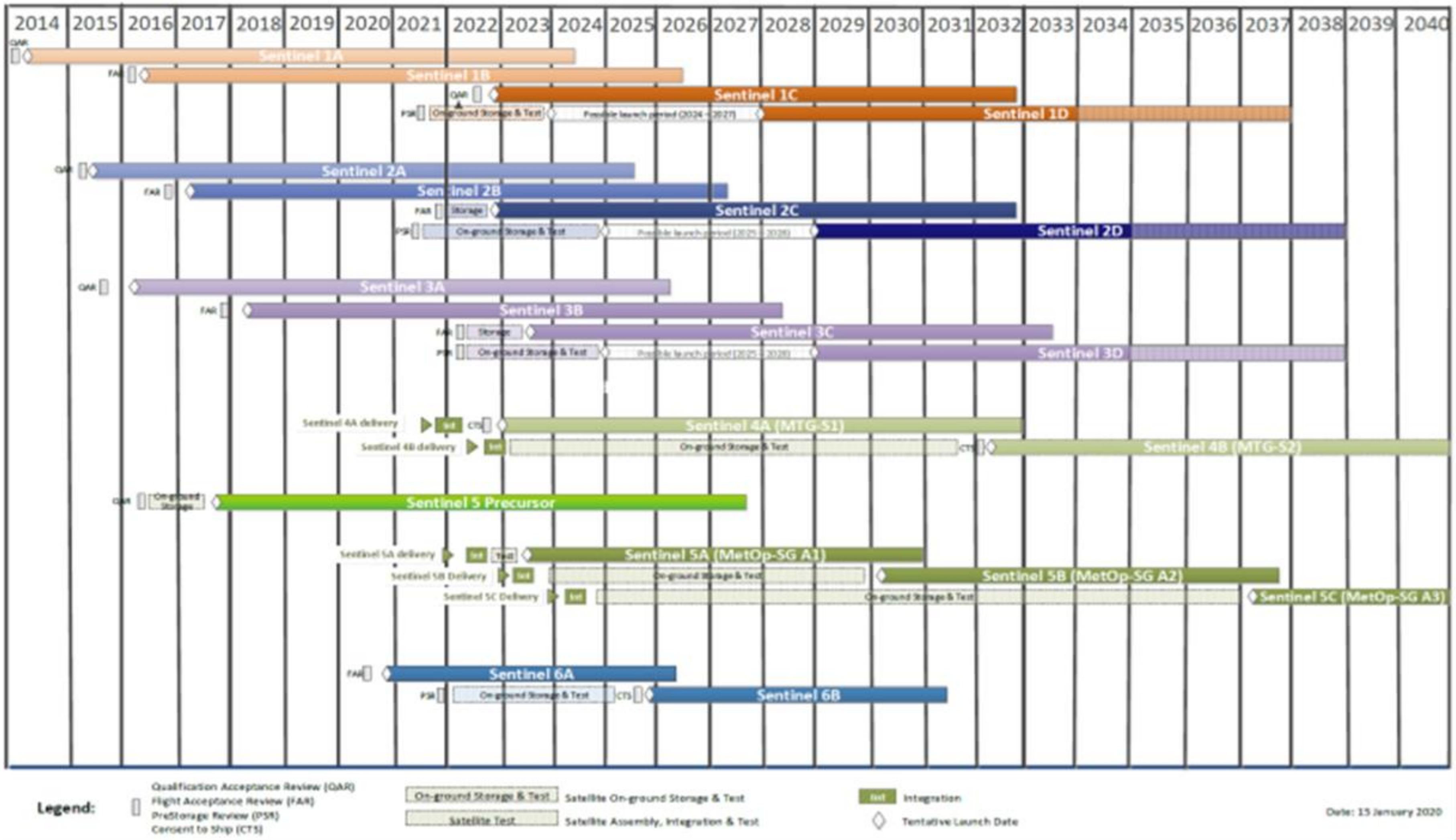
Concept Paper Interactive dialogue 3: Water for climate, resilience and environment – source to sea, biodiversity, climate, resilience and disaster risk reduction

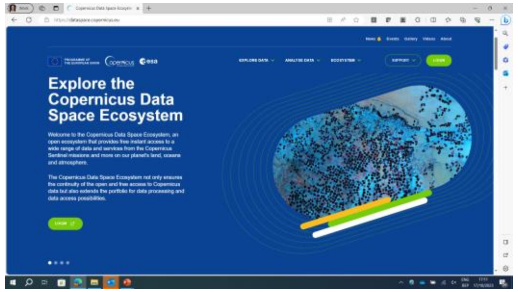
“**The power of Earth observation**. **Accelerating digital transformation, through remote sensing and satellite imagery data, holds great potential for transforming how data and information are generated and accessed and used for monitoring and reporting on water bodies.**

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”

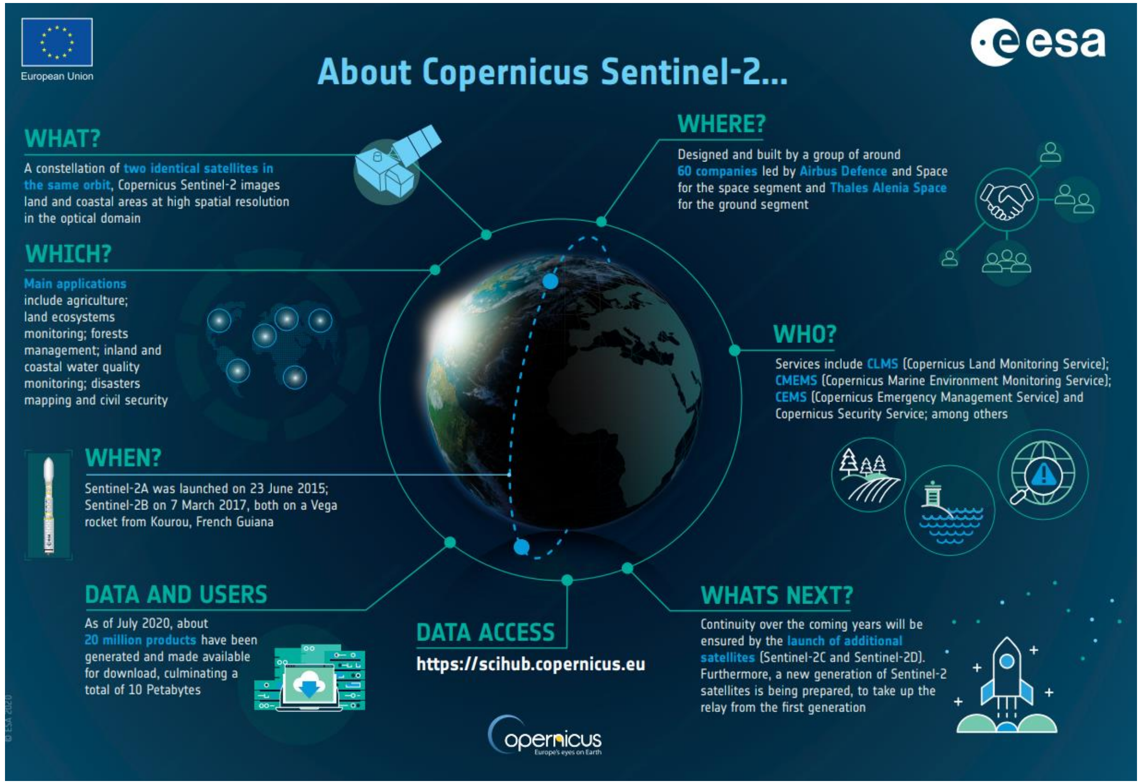


THE EUROPEAN SATELLITE OBSERVATION INFRASTRUCTURE IS FULLY OPERATIONAL (OPEN AND FREE)





the international water association



- 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

10 metre spatial resolution:

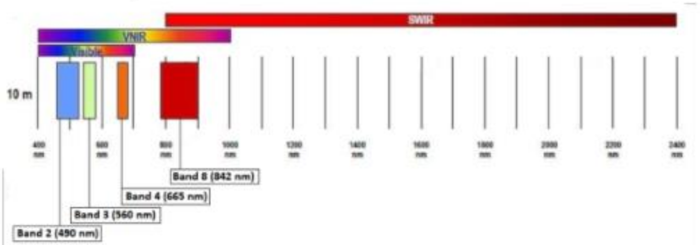


Figure 1: SENTINEL-2 10 m spatial resolution bands: B2 (490 nm), B3 (560 nm), B4 (665 nm) and B8 (842 nm)

20 metre spatial resolution:

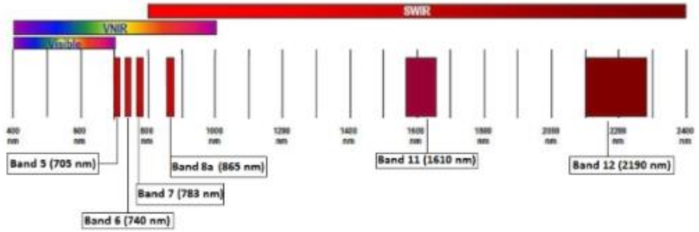


Figure 2: SENTINEL-2 20 m spatial resolution bands: B5 (705 nm), B6 (740 nm), B7 (783 nm), B8a (865 nm), B11 (1610 nm) and B12 (2190 nm)

60 metre spatial resolution:

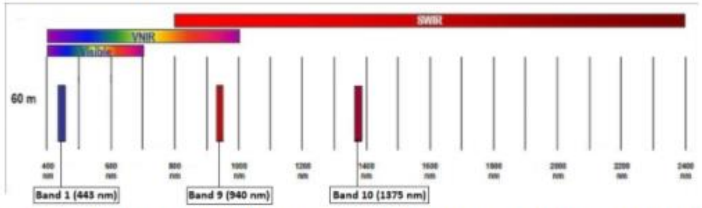


Figure 3: SENTINEL-2 60 m spatial resolution bands: B1 (443 nm), B9 (940 nm) and B10 (1375 nm)

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

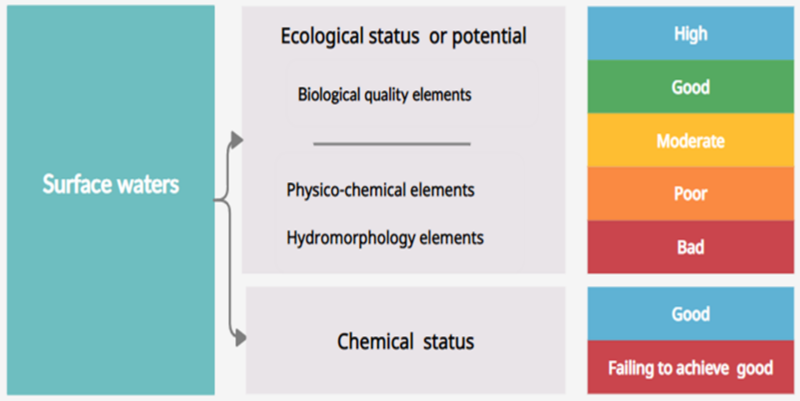


FIGURE 1

Assessment of status of surface waters and groundwater according to the WFD

Source: European waters. Assessment of status and pressures 2018. EEA Report No 7/2018

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.

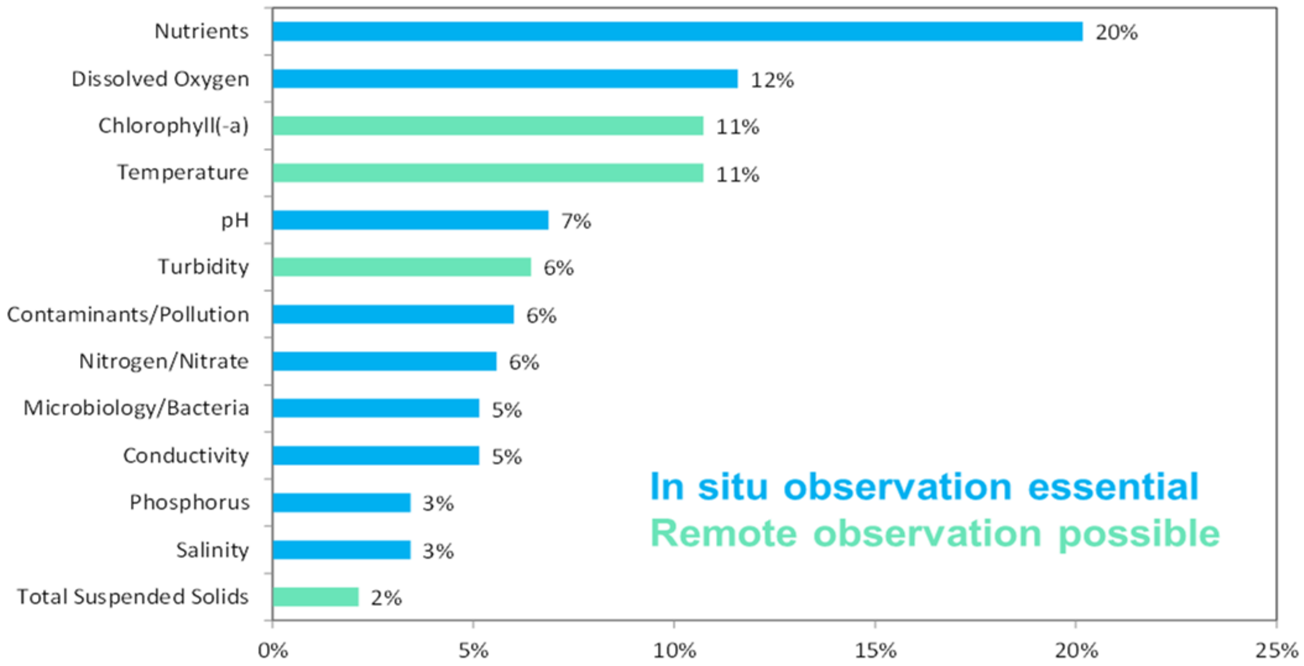
But need to:

- 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

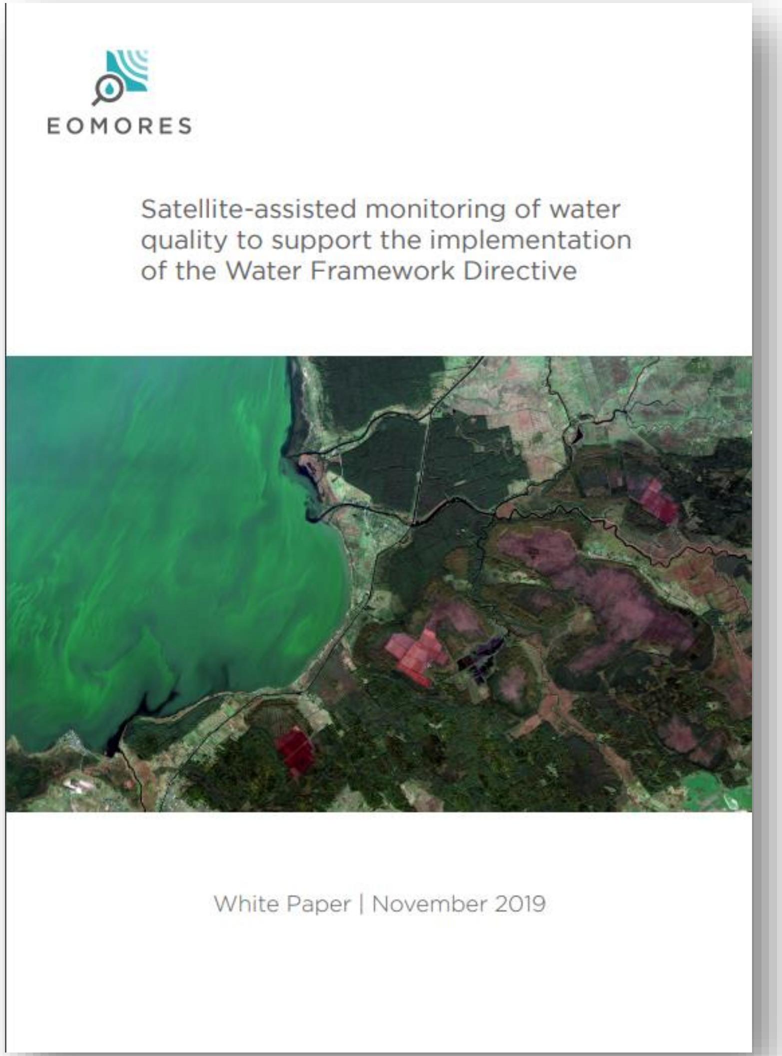
"Which of the water quality variables sampled in your region do you consider to be the most relevant?"

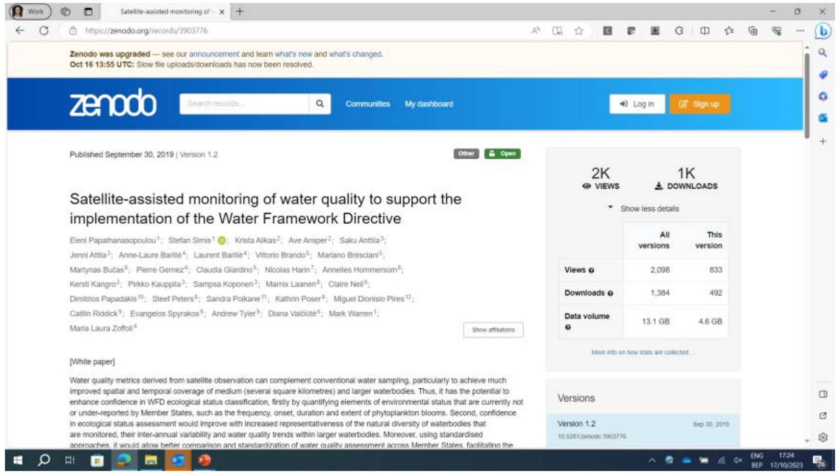


MONOCLE
Multiscale Observation Networks for Optical monitoring of Coastal waters, Lakes and Estuaries

https://monocle-h2020.eu/Resources

WHITE PAPER 2019





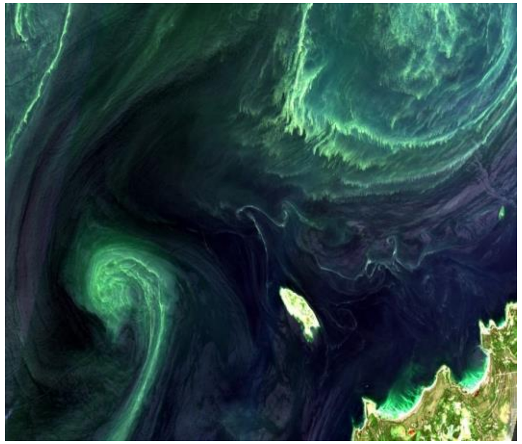
E Papathanasopoulou, S Simis, K Alikas, A Ansper, S Anttila, J Attila, … M L Zoffoli. (2019, September 30). Satellite-assisted monitoring of water quality to support the implementation of the Water Framework Directive (Version 1.2). Zenodo. http://doi.org/10.5281/zenodo.3903776

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[i] Biovolume of phytoplankton[i]	Chlorophyll-a concentration from in vivo pigment absorption[ii,iii] Trophic State Index derived from Chlorophyll-a
Composition	Biovolume of cyanobacteria[i] % of cyanobacteria of total biovolume[i] Various other metrics, trophic indices	Phycocyanin (cyanobacterial pigment) concentration[v] Functional size classes (only in oceanic waters)[iv]
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[i] Total areal coverage[i]	Areal cover of floating vegetation
Macrophyte composition	Proportion of taxa	Not from current satellite sensors, but from airborne surveys[vii]
Macroalgal cover and angiosperm abundance	Combination of spatial extent and relative abundance (measured as density) of macrophytes Abundance of macrophytes[viii,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)



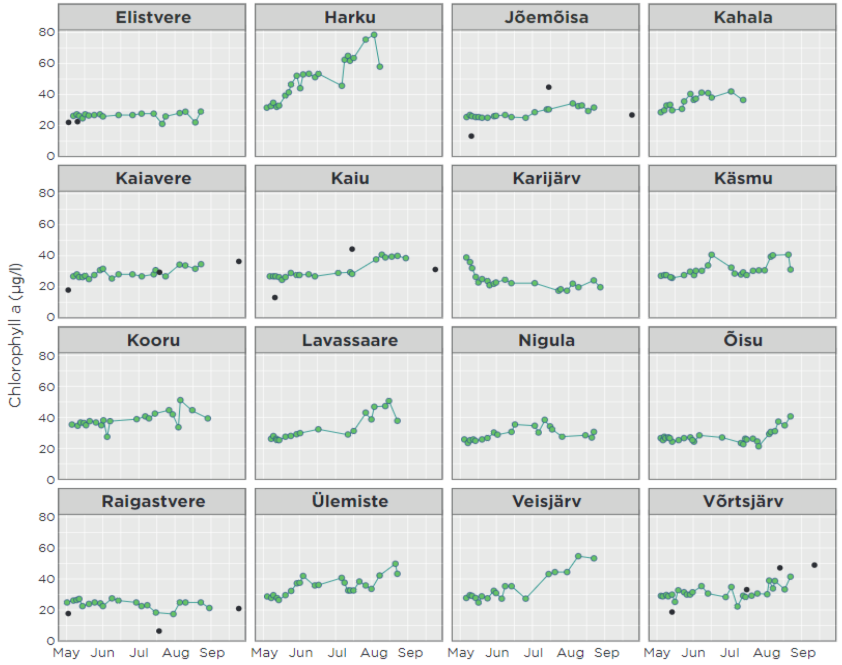
Optical satellite observation can be considered in seven biological and physico-chemical elements.

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

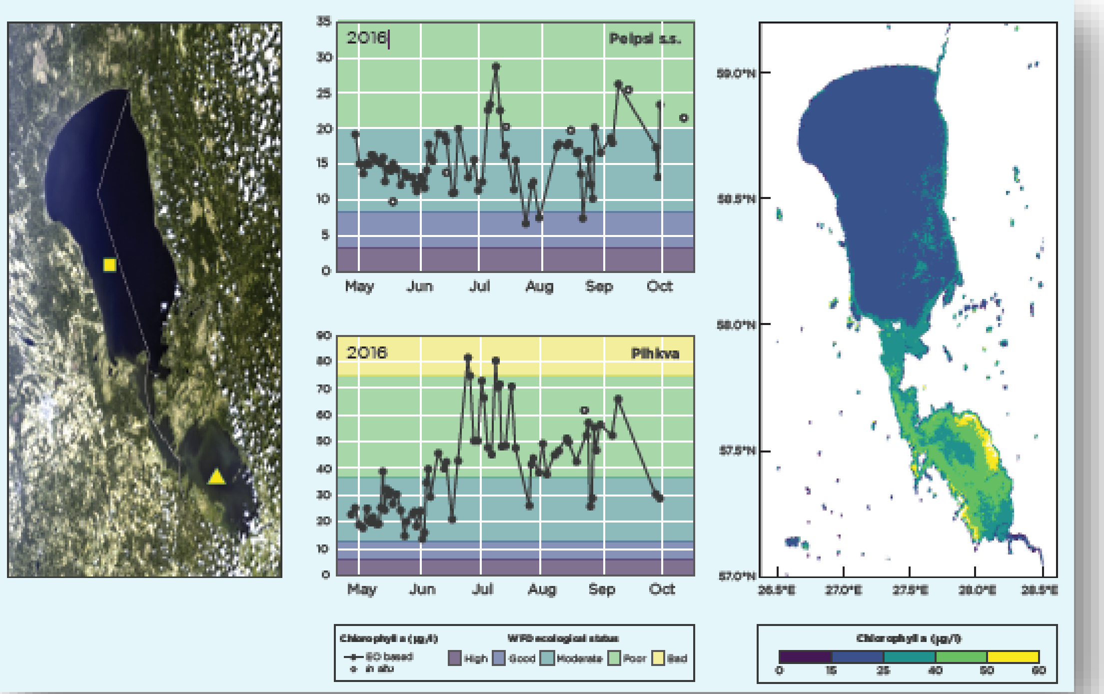
E Papathanasopoulou, S Simis, K Alikas, A Ansper, S Anttila, J Attila, … M L Zoffoli. (2019, September 30). Satellite-assisted monitoring of water quality to support the implementation of the Water Framework Directive (Version 1.2). Zenodo. http://doi.org/10.5281/zenodo.3903776

ESTONIA

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.

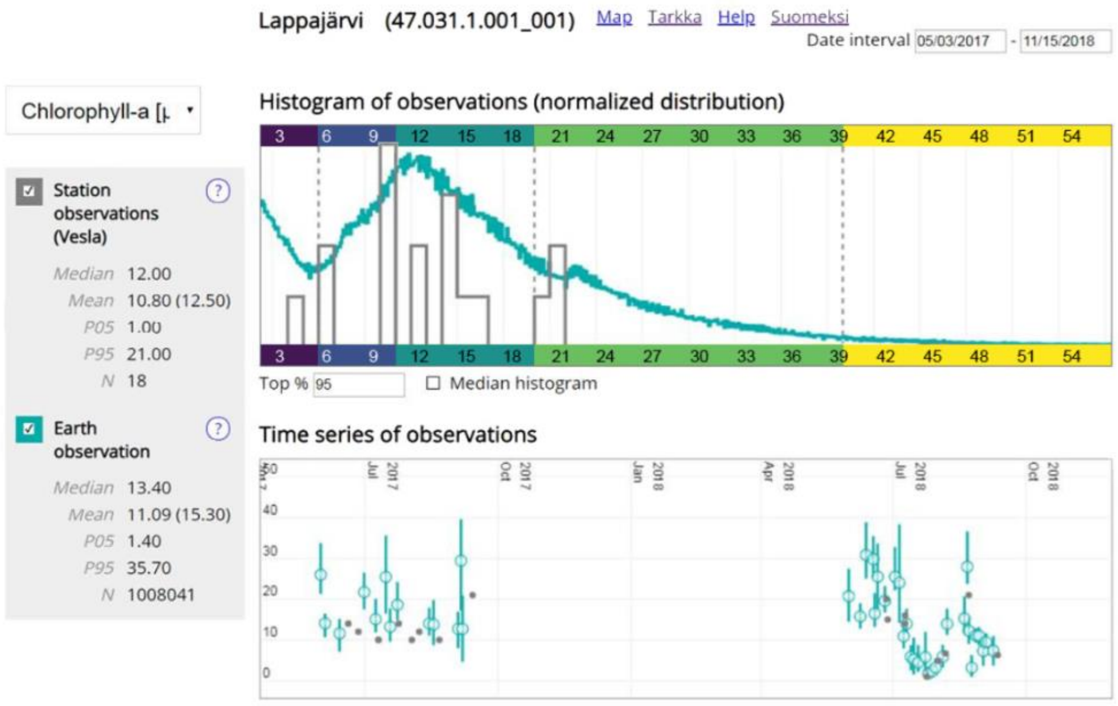


Using medium and high-resolution sensors, temporal data coverage is > 10x improved. Validation is good on the basis of WFD classes

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. ±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).

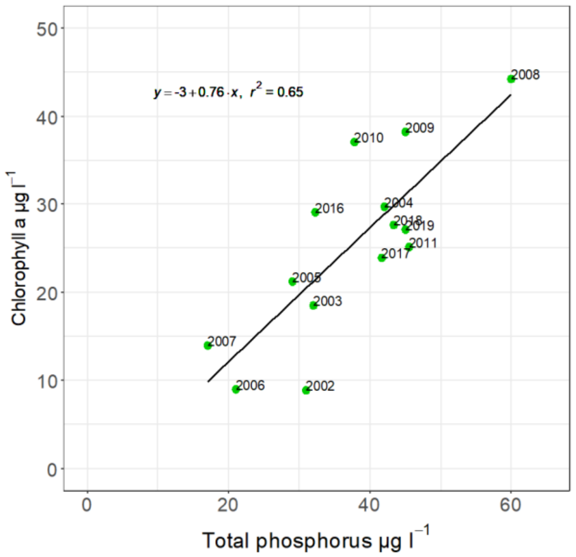
Waterbody statistics include each individual observation in the classification:
N = 18 samples in situ versus >1M from satellite

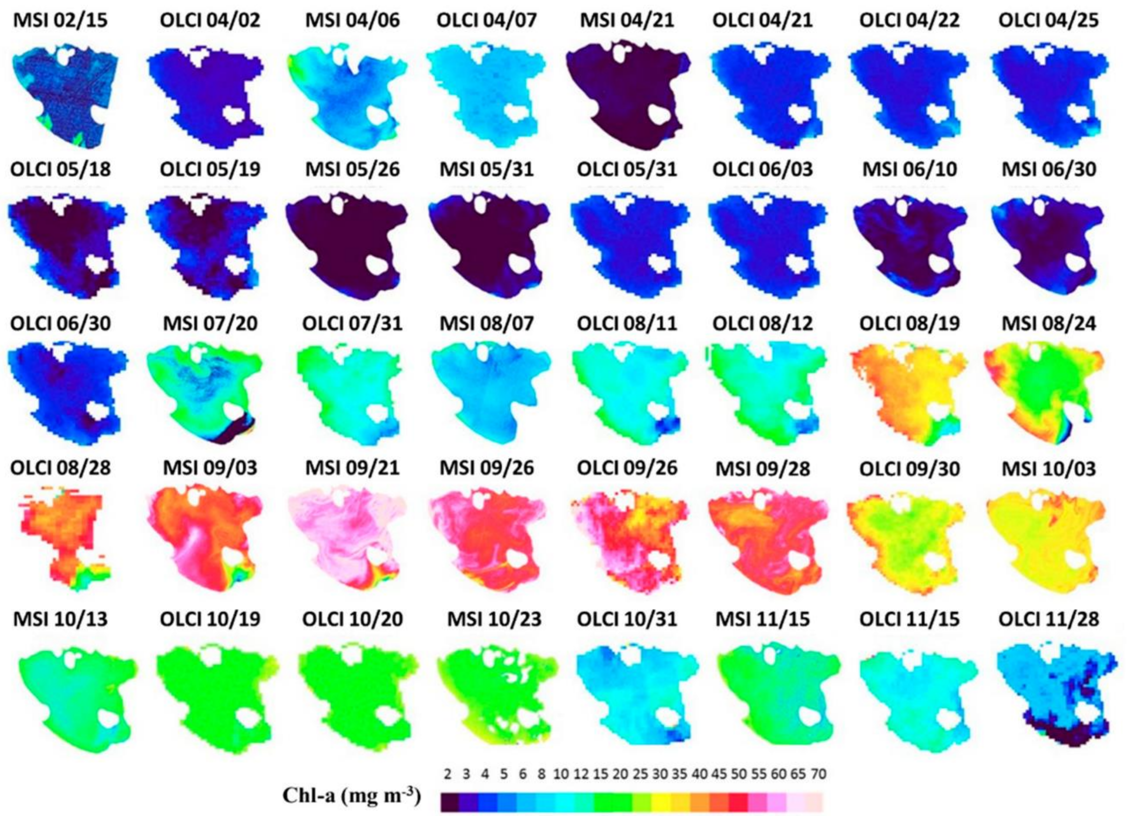
ITALY

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:



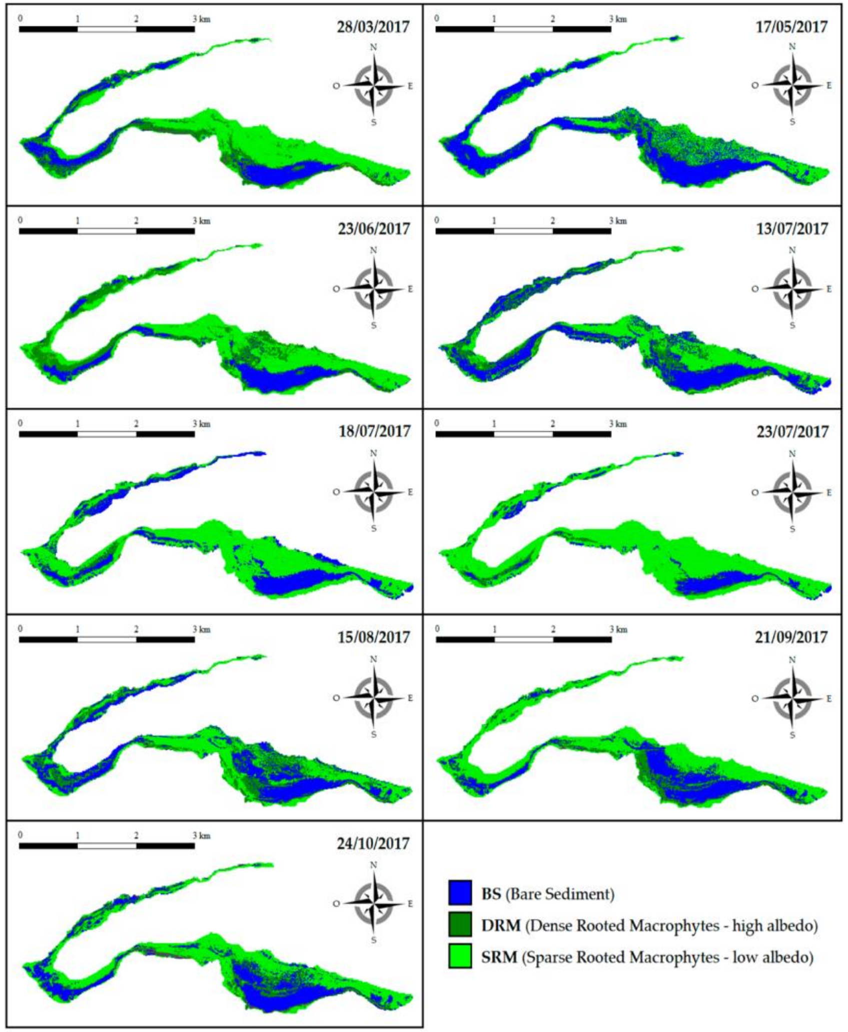


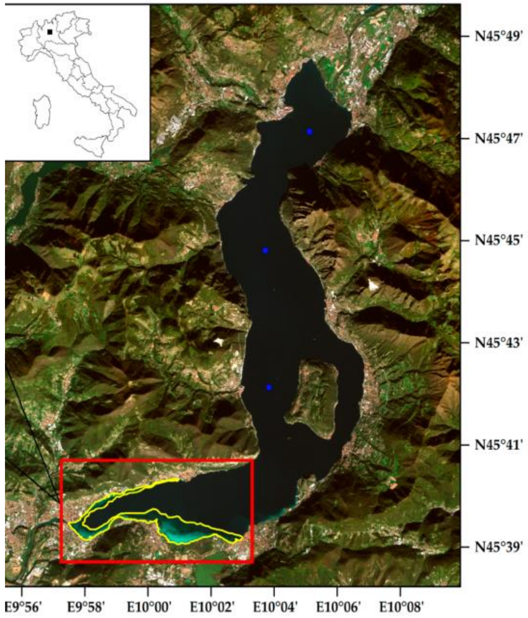
Bresciani *et al.*, 2020 **https://doi.org/10.3390/w12010284**

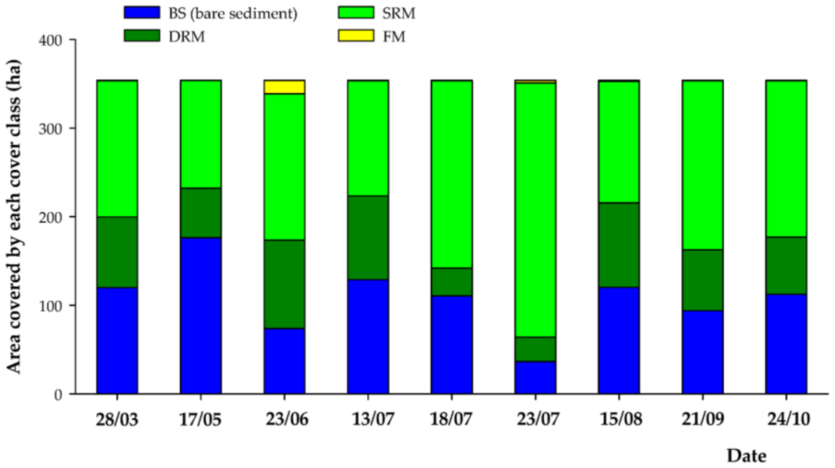
ITALY

Macrophytes: submerged

Mapping lakes substrates colonised by submerged macrophyte communities



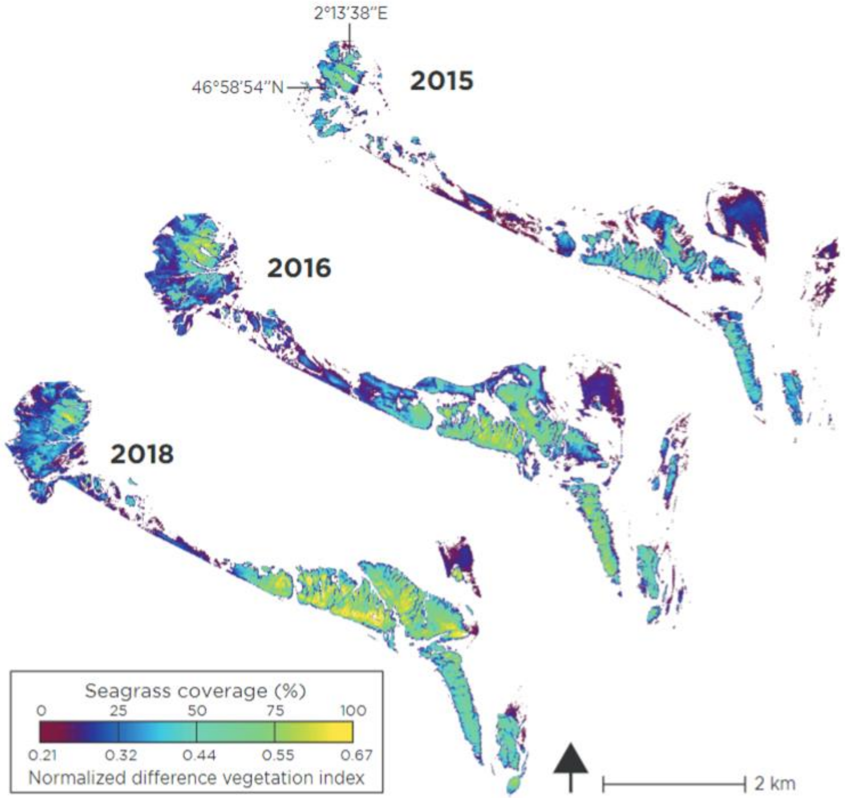


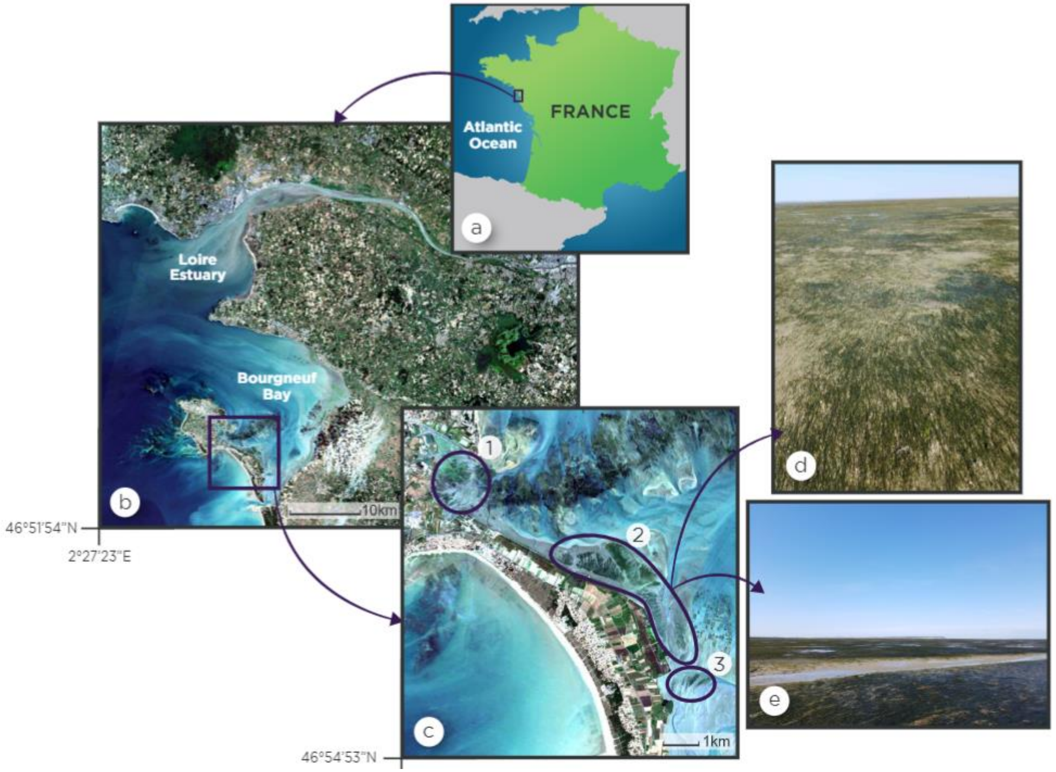


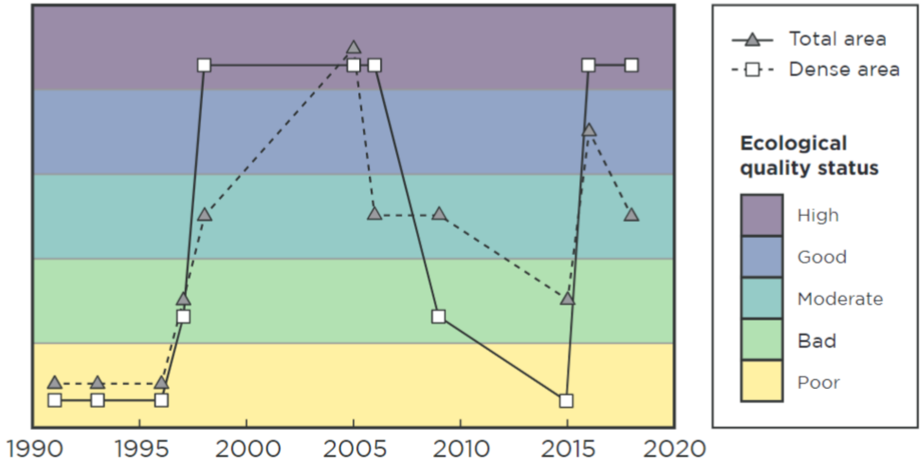
Ghirardi et al. (2020). https://www.mdpi.com/2073-4441/11/3/563

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

the international water association

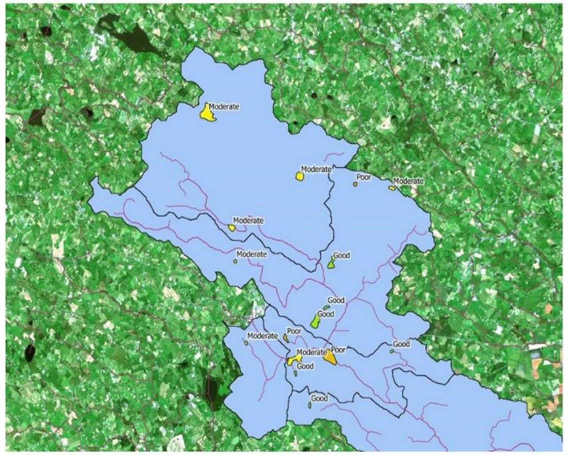
Assessing ecological status

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.”



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

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

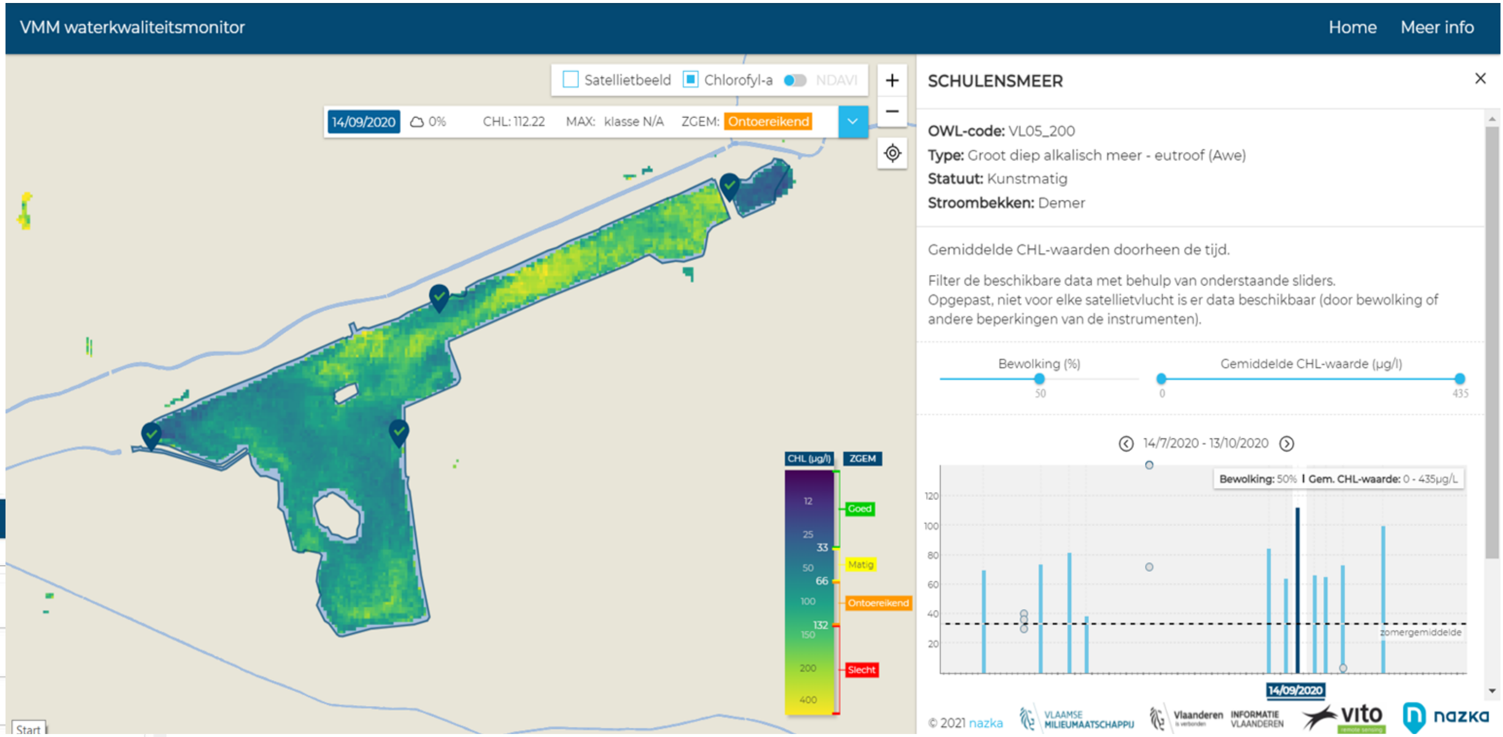
BELGIUM/FLANDERS

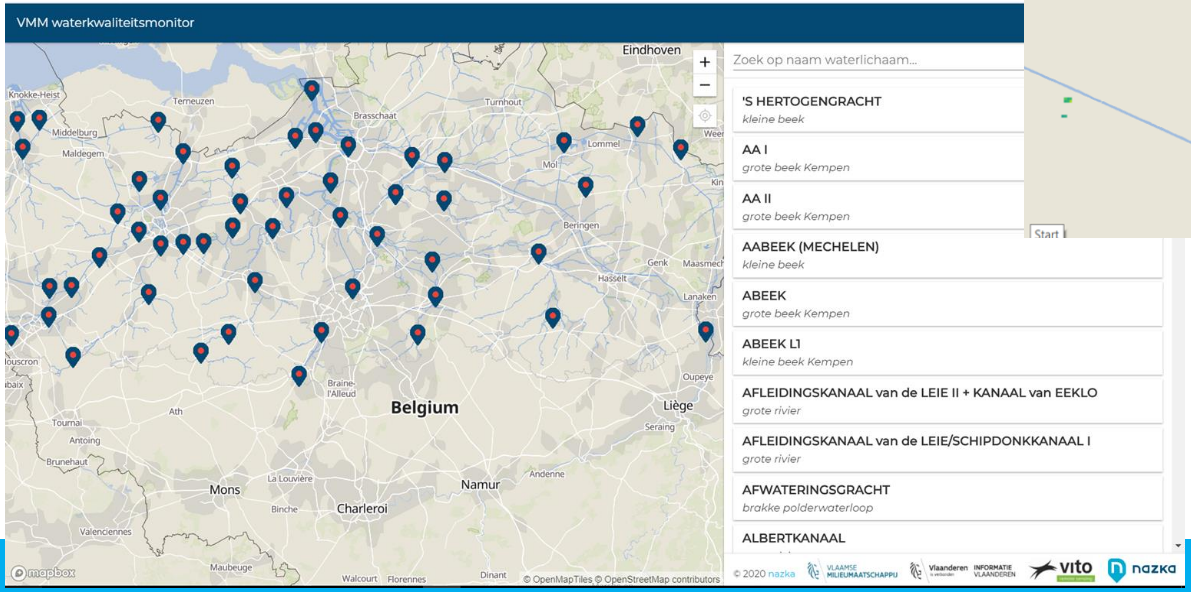
Watermonitor for Flanders Environment Agency (VMM)

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





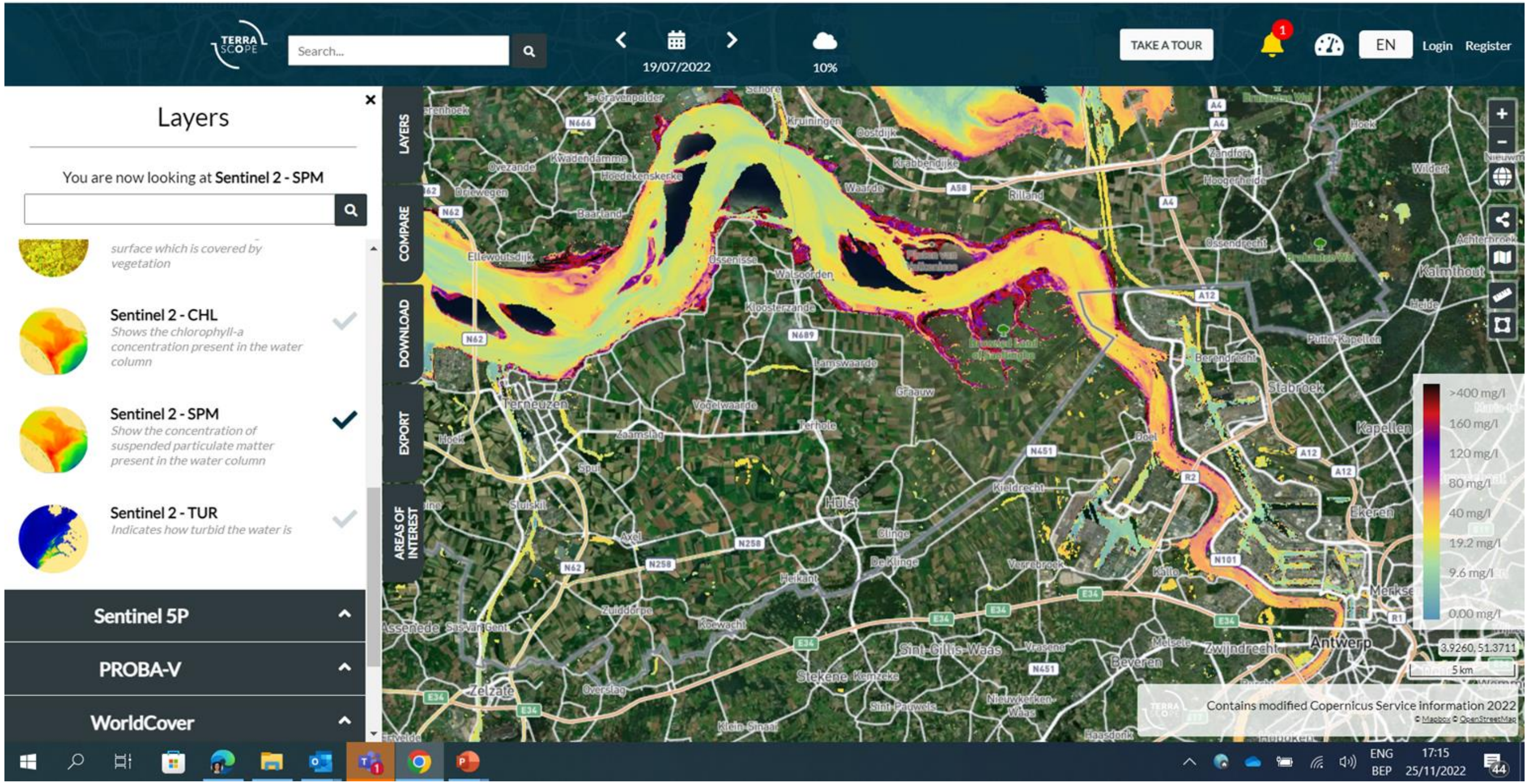
https://remotesensing.vito.be/case/watermonitor

GEO.INFORMED

BELGIUM/FLANDERS

the international water association

Suspended Particulate Matter and Turbidity-NRT



belspo sentinel-2 vito remote sensing

TERRA SCOPE

https://viewer.terrascope.be/

THE NETHERLANDS

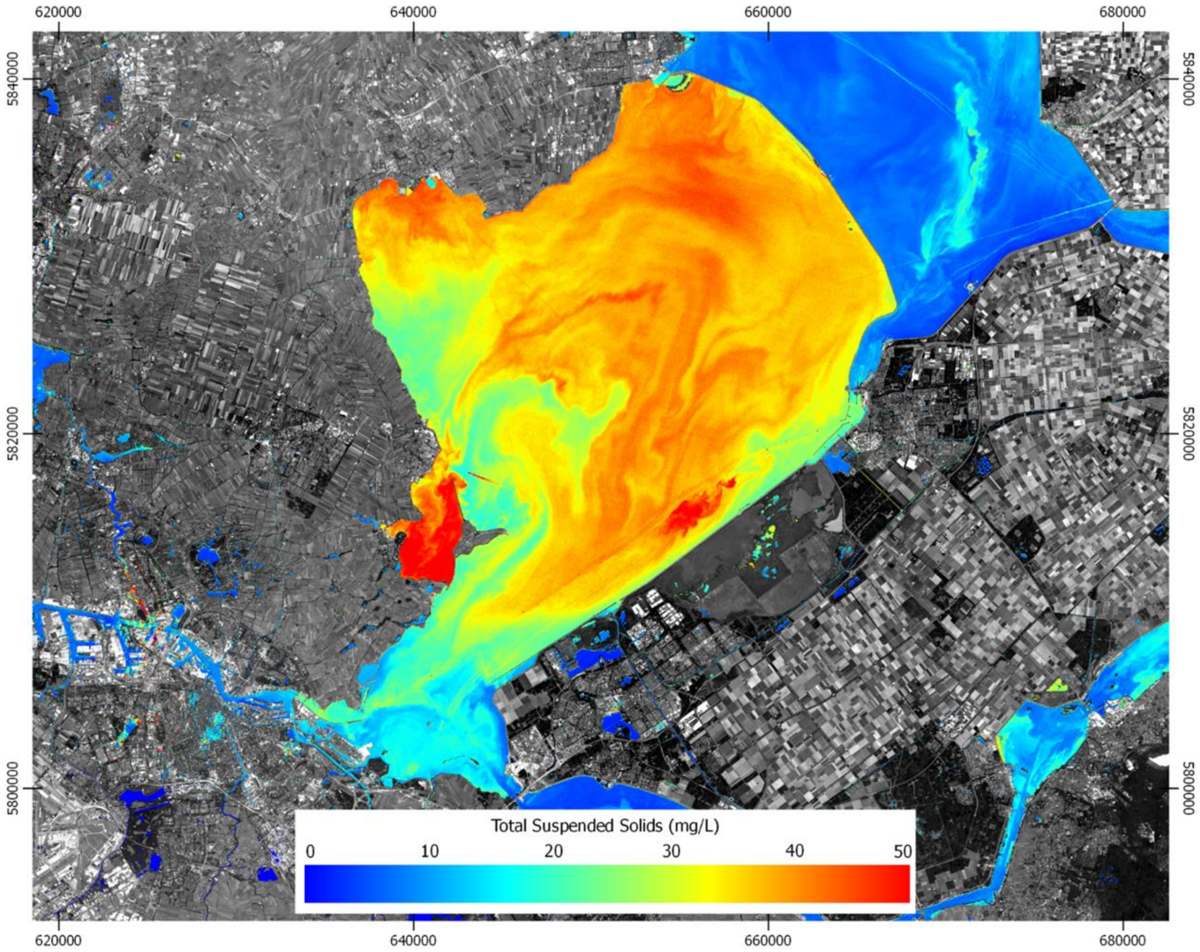
Lake Marken

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

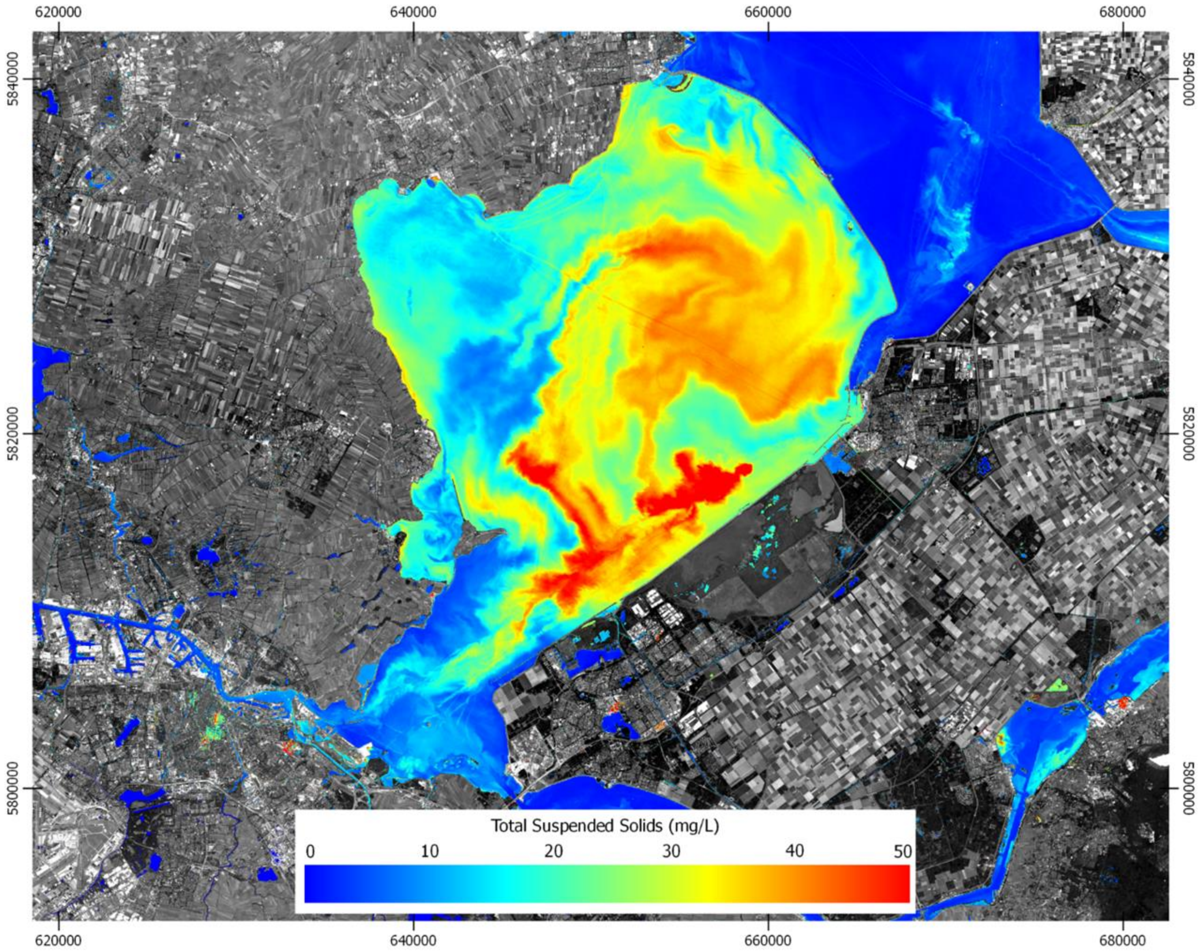
Silt used to create Marken Wadden islands

De ingenieur: eerste eiland

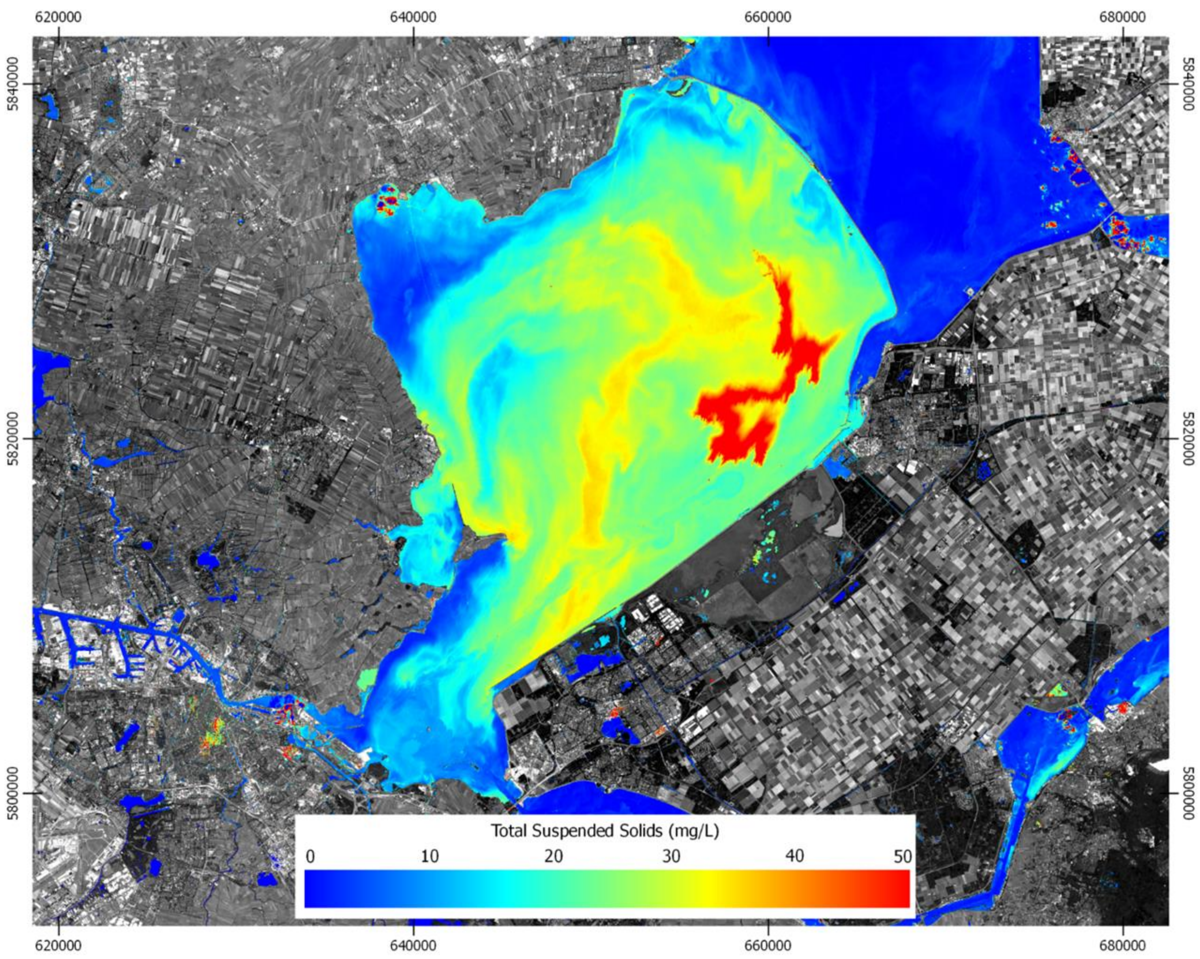
Sentinel-2 image Copernicus Sentinel data (2016)



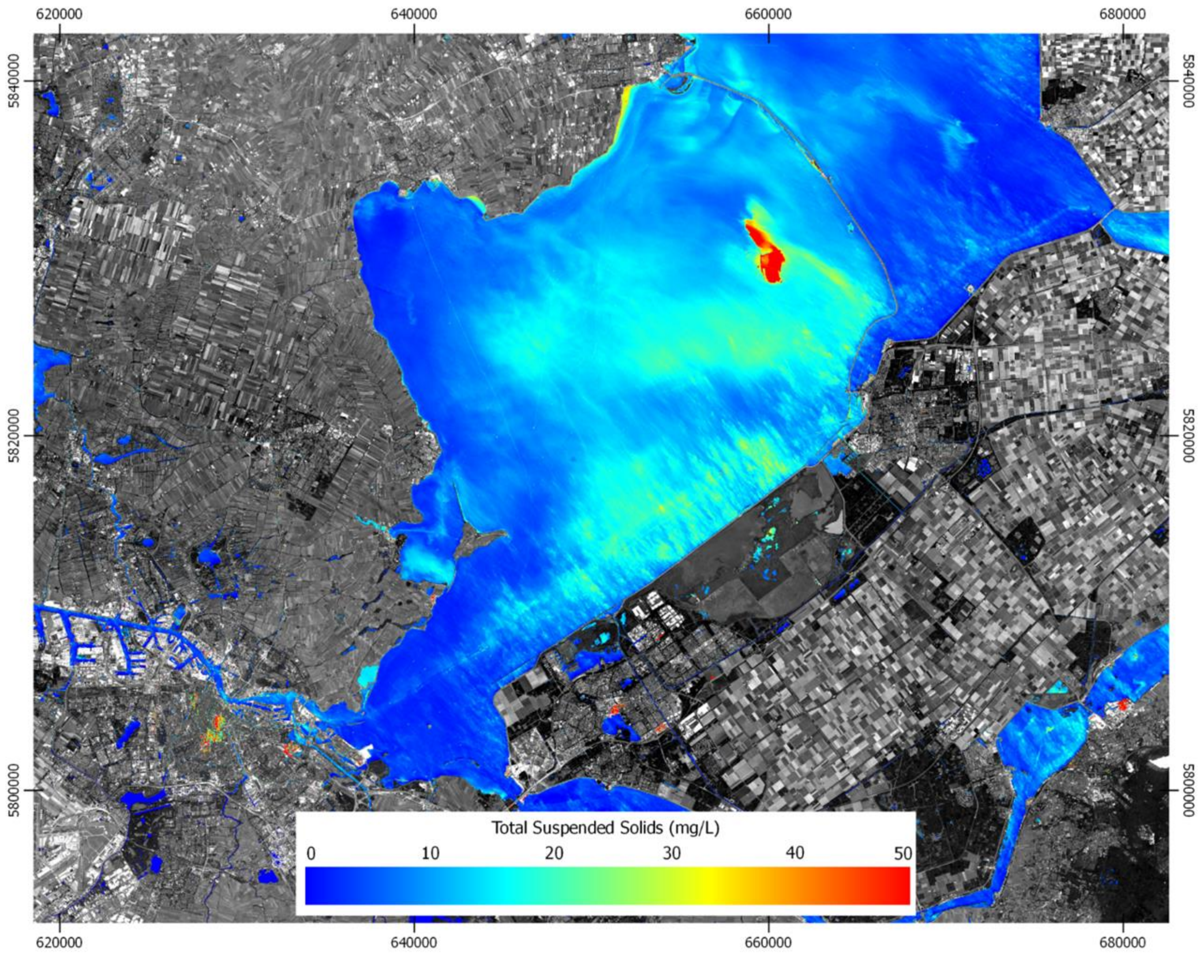
Total Suspended Solids map for Lake Marken, the Netherlands (Landsat-8, 7 January 2015) processed by VITO



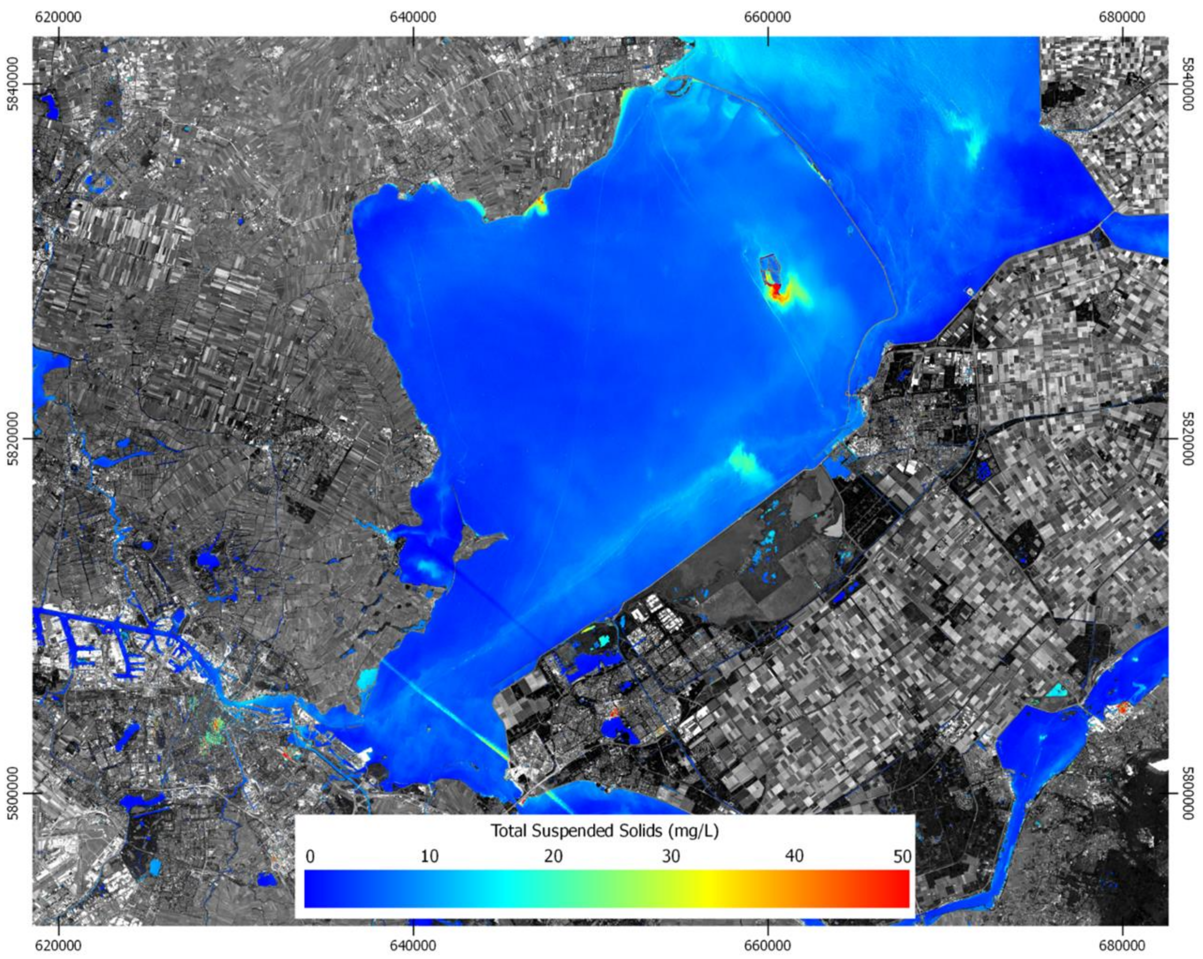
Total Suspended Solids map for Lake Marken, the Netherlands (Landsat-8, 12 March 2015) processed by VITO



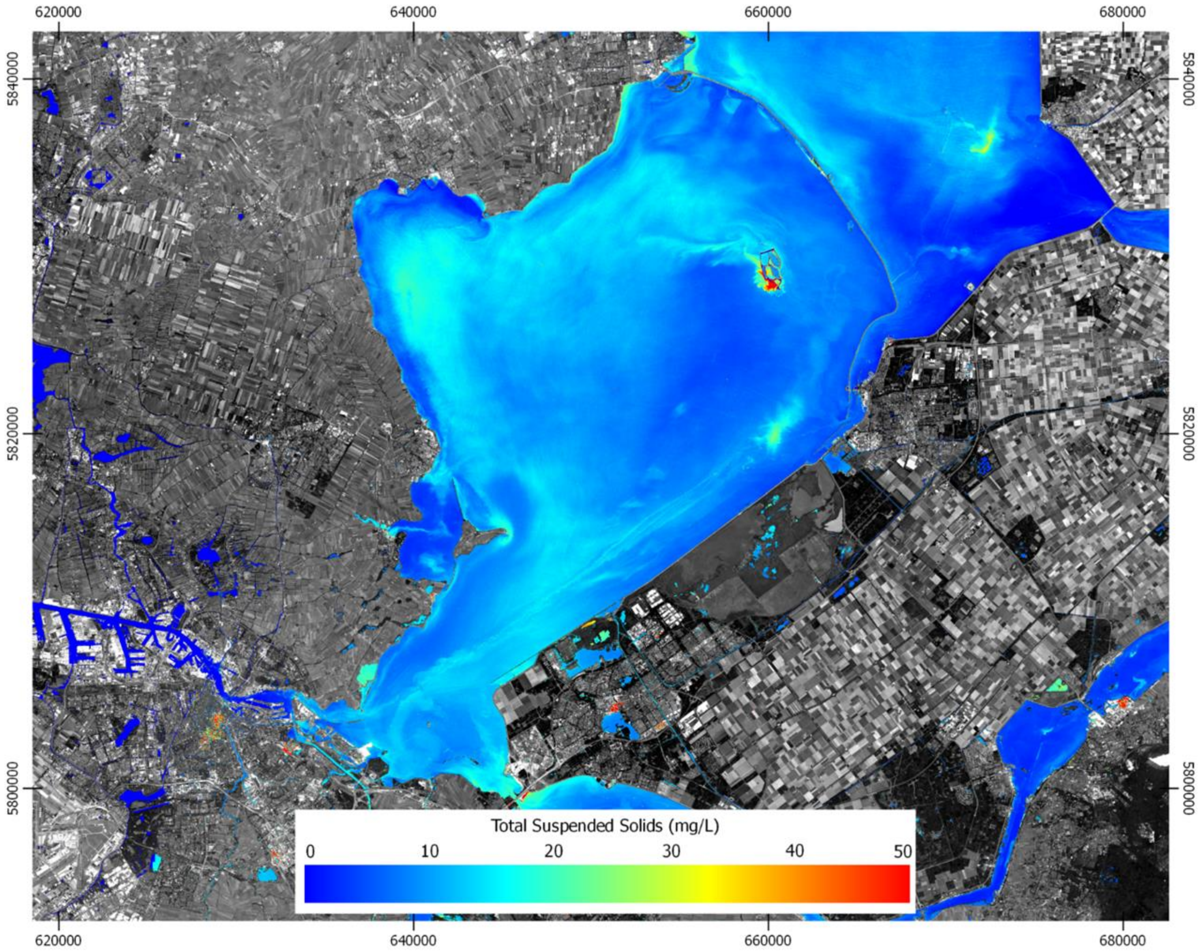
Total Suspended Solids map for Lake Marken, the Netherlands (Landsat-8, 1 May 2016) processed by VITO



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



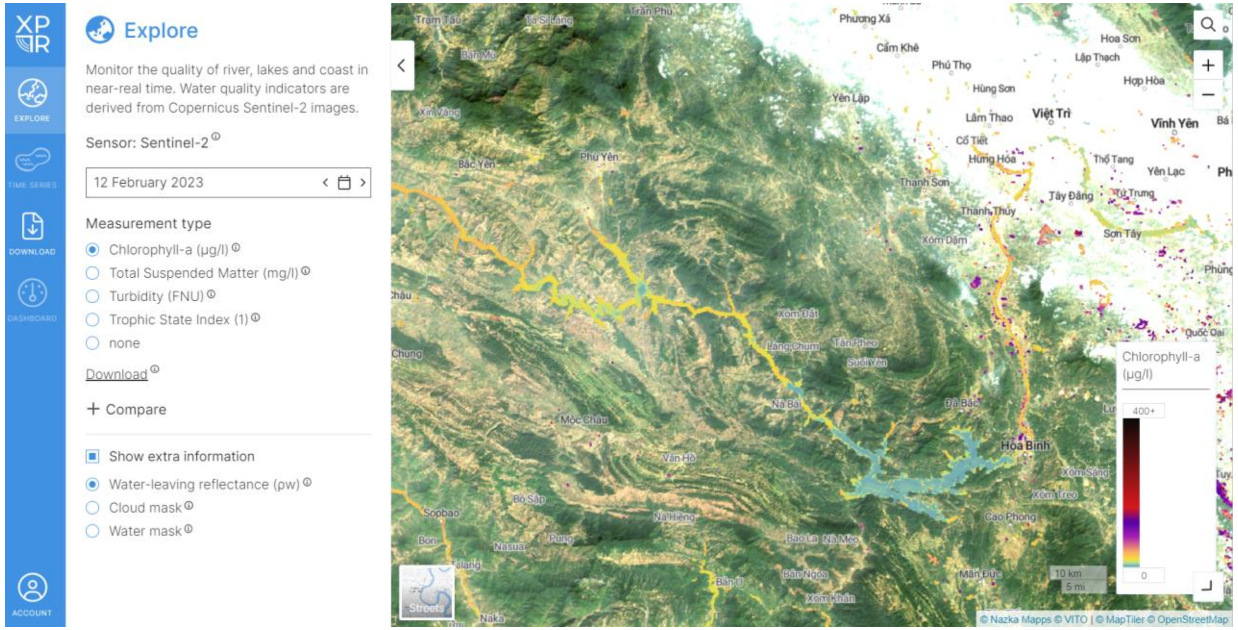
Total Suspended Solids map for Lake Marken, the Netherlands (Sentinel-2A, 15 September 2016) processed by VITO

VIETNAM

EXPLORE-VN

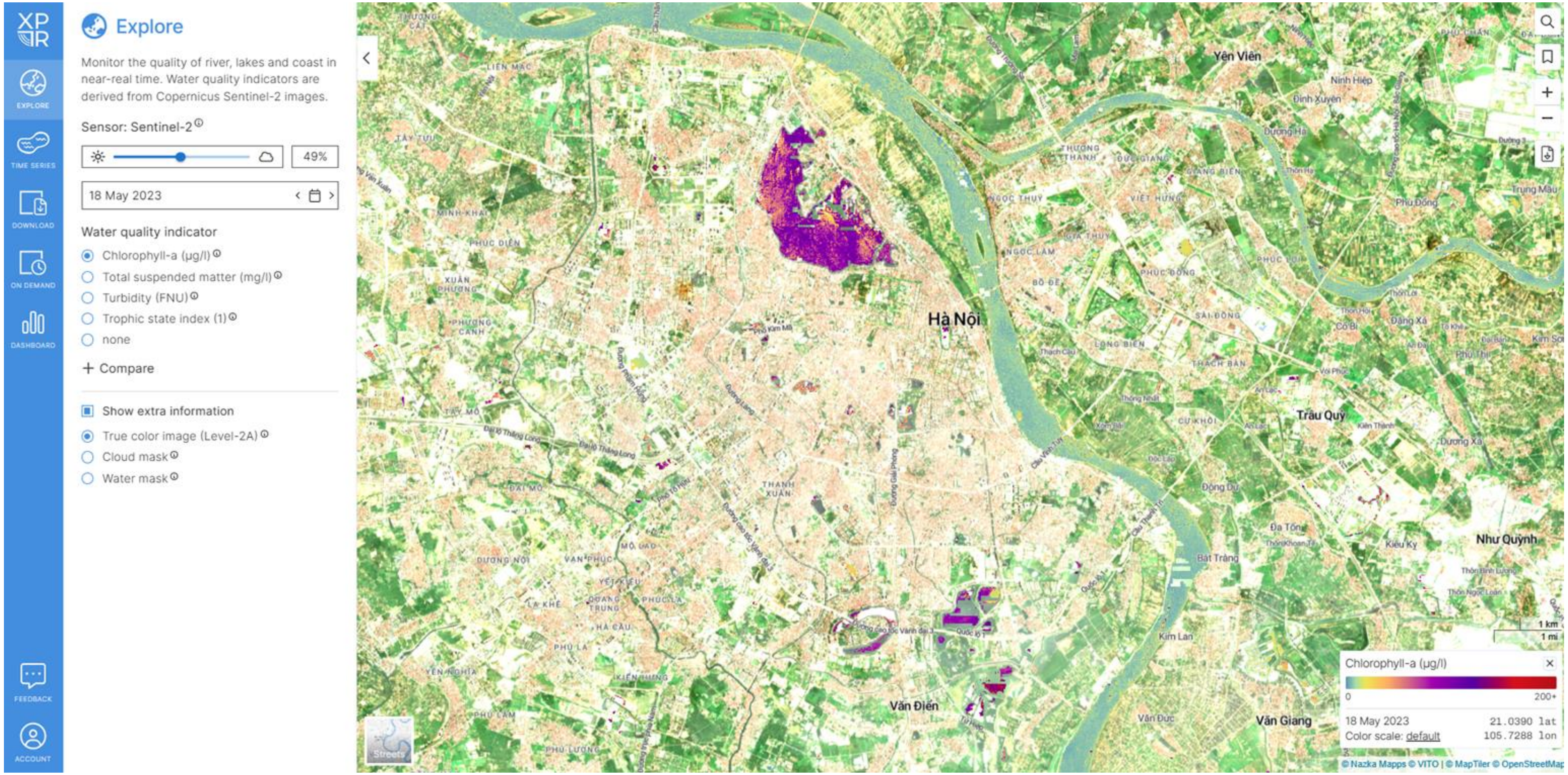
MONITORING EARTH FROM SPACE IN NEAR REAL-TIME

- 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

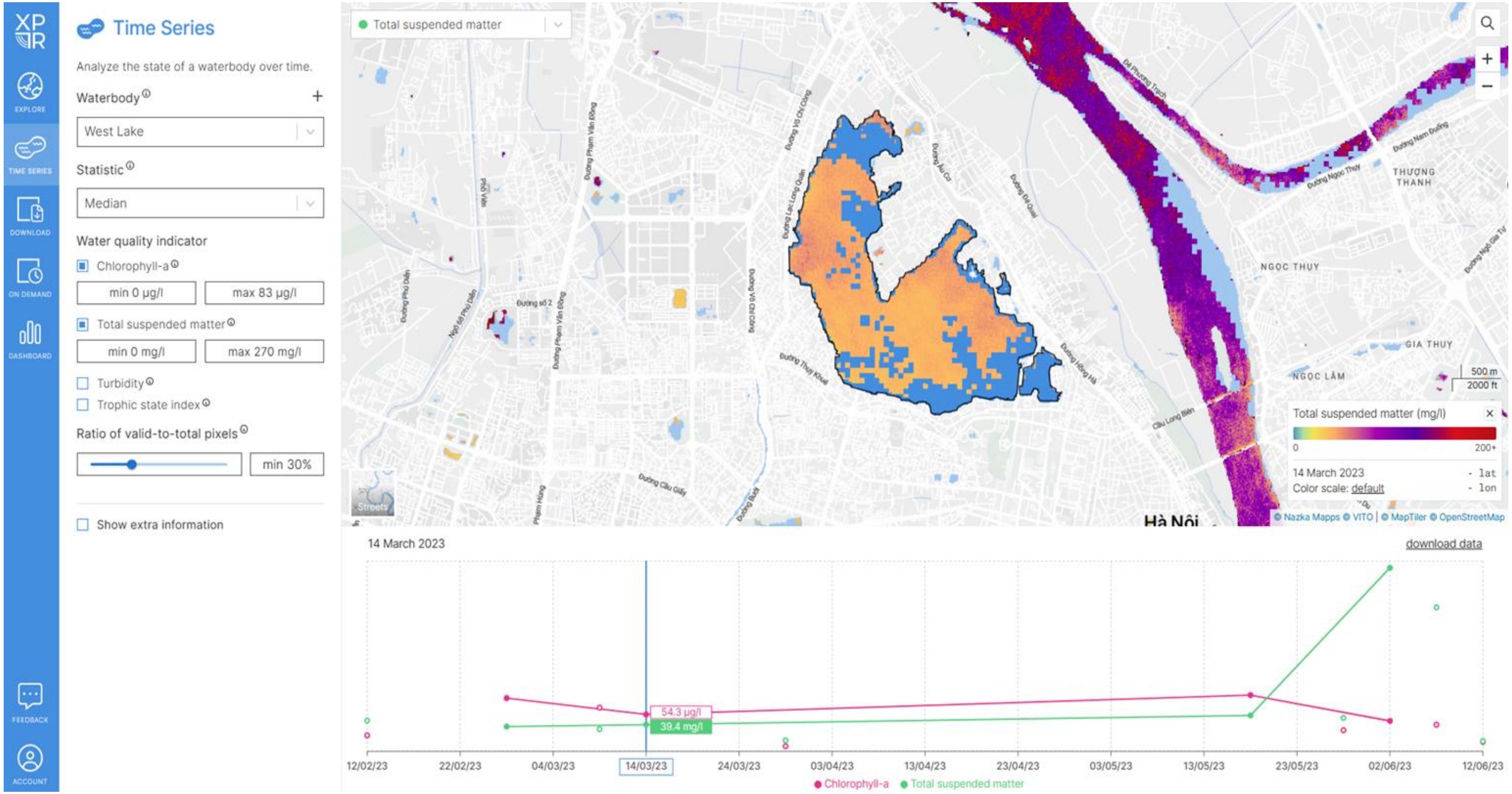


VAST nazka vito remote sensing

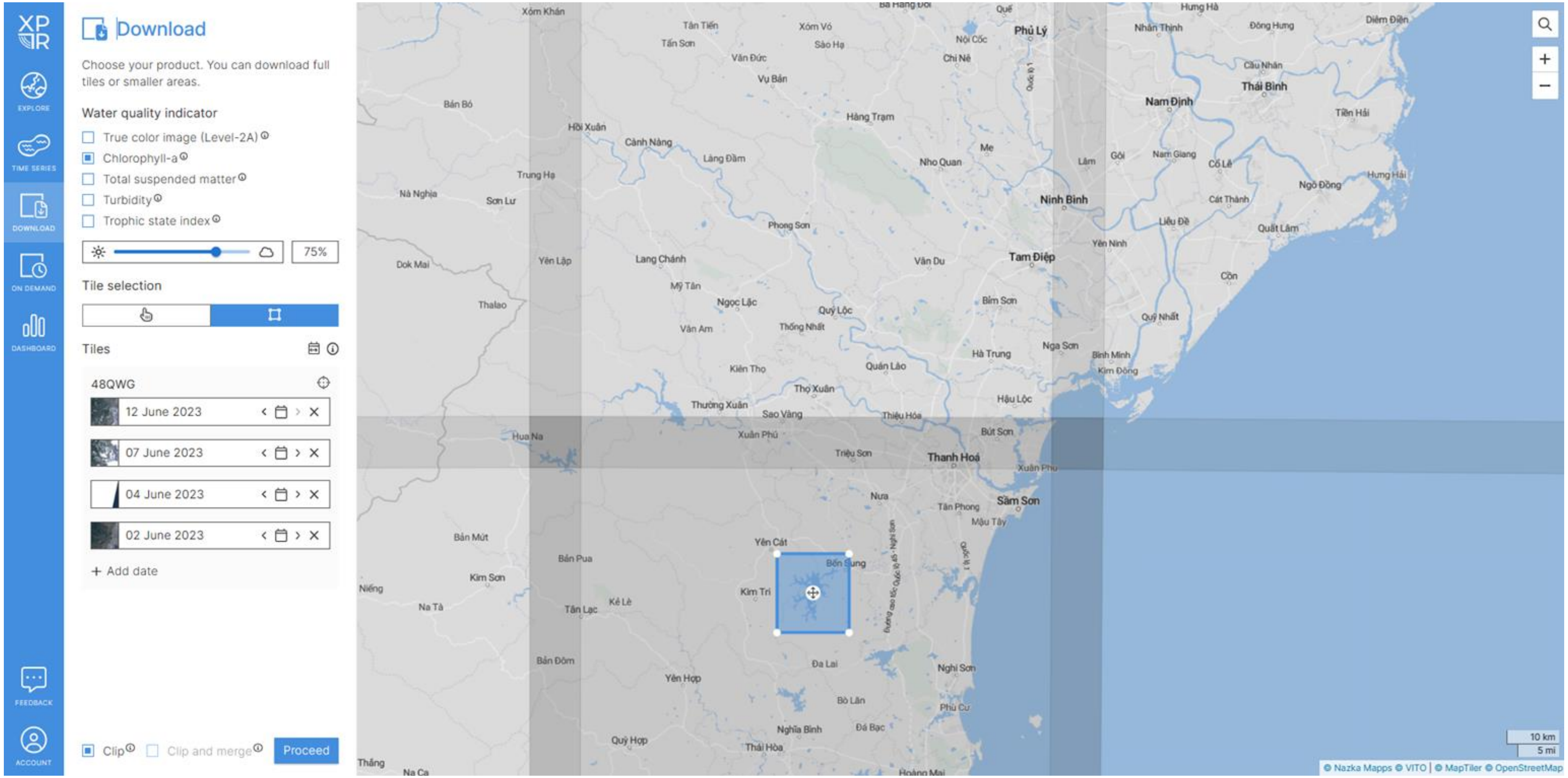
EXPLORE-VN: EXPLORE



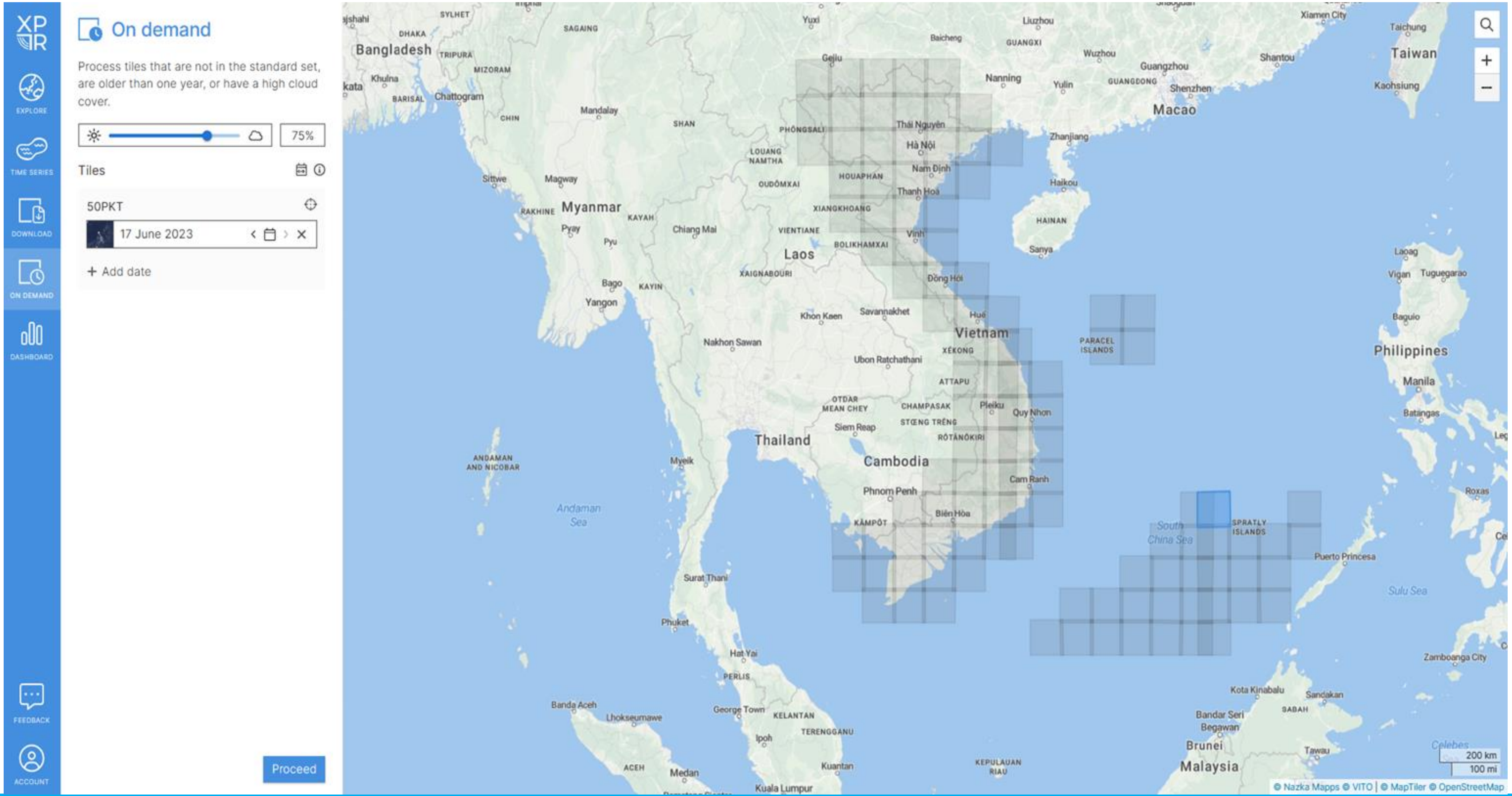
EXPLORE-VN: TIME SERIES



EXPLORE-VN: DOWNLOAD



EXPLORE-VN: ON DEMAND



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

vito
remote sensing

the international water association

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remotesensing.vito.be

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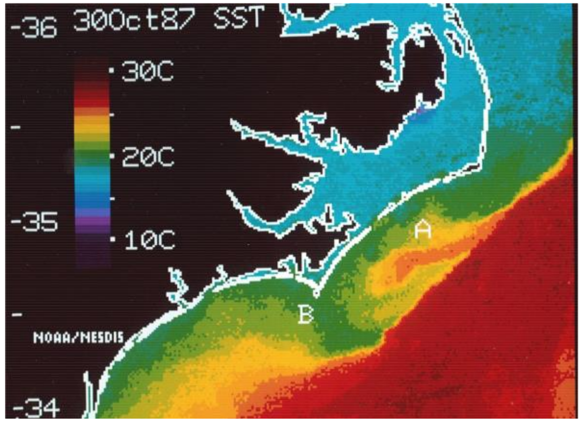
Copernicus Academy

Copernicus Relays

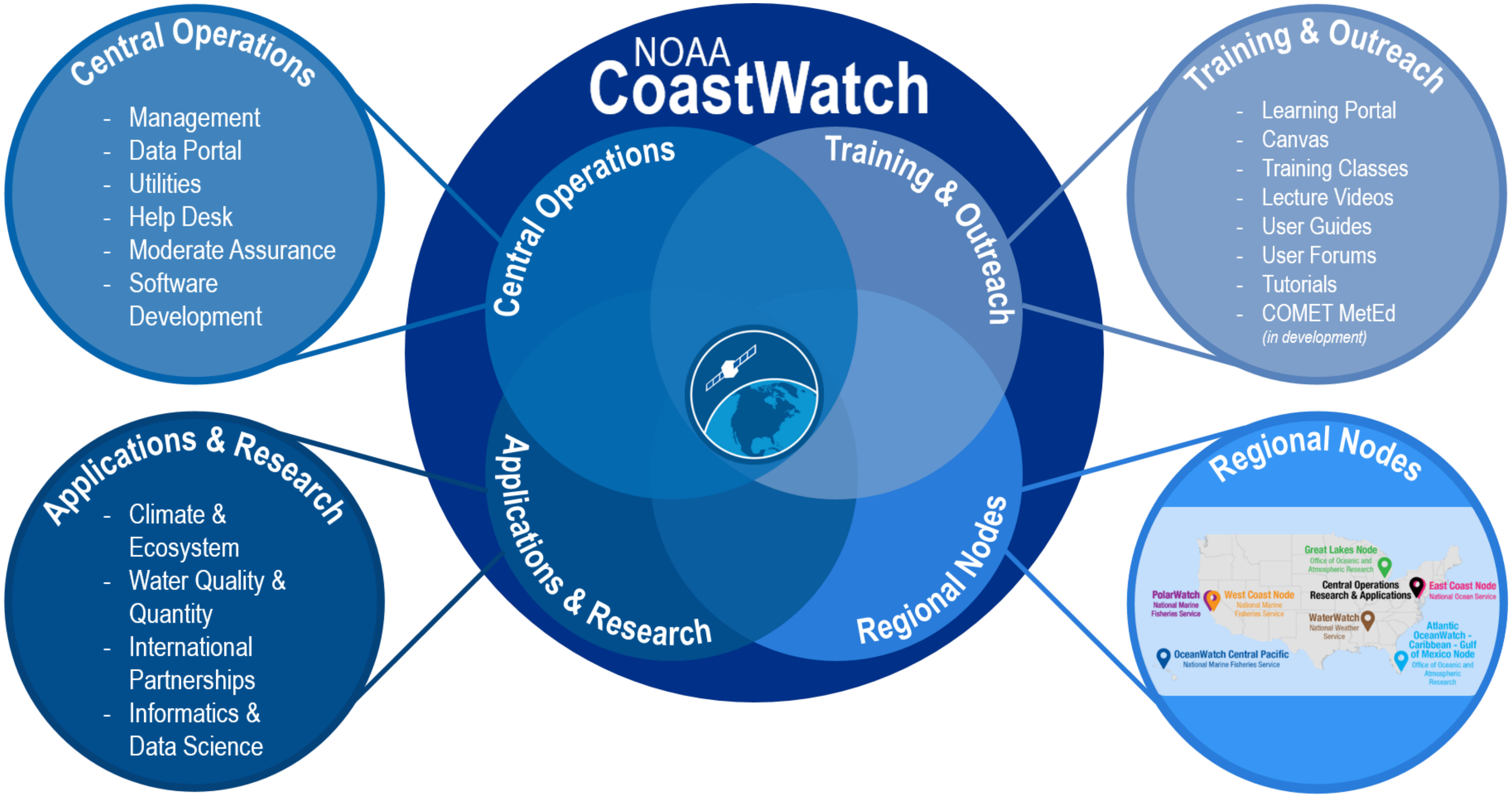
Leveraging a range of Earth observing satellites for aquatic applications

MEGAN COFFER, NOAA/GST



the international water association

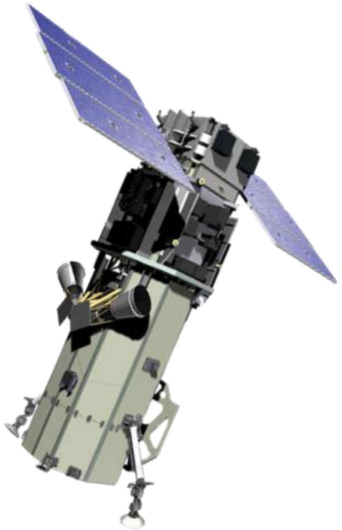
inspiring change



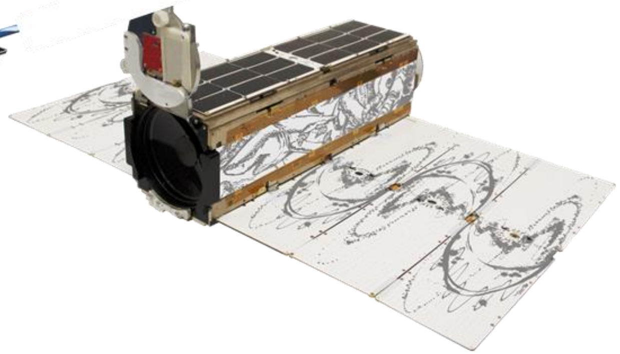
the international water association

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

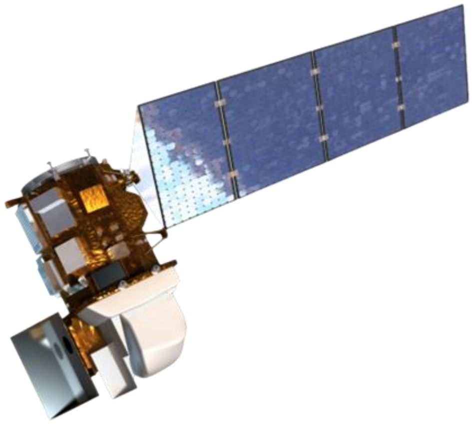
Commercial, high spatial resolution satellite platforms


WorldView-2 (2 m)

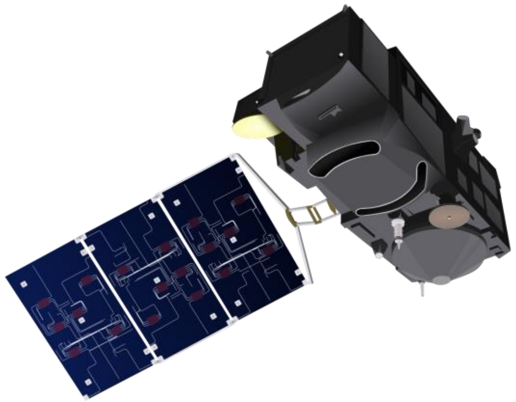

WorldView-3 (2 m)


PlanetScope (5 m)

Freely available, open access satellite platforms


Landsat 8 (30 m)


Sentinel-2 (20 m)


Sentinel-3 (300 m)

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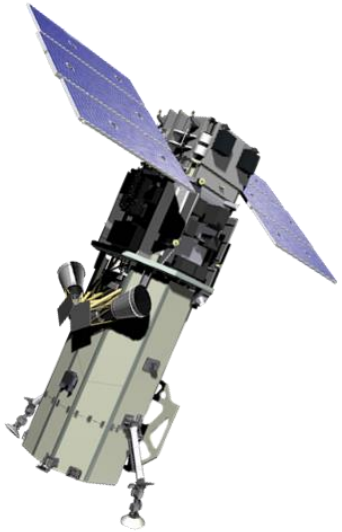
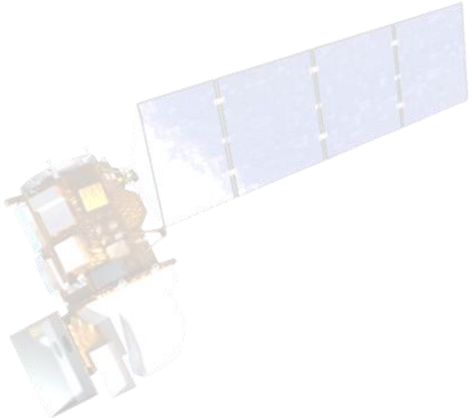
Commercial, high spatial resolution satellite platforms


WorldView-2 (2 m)

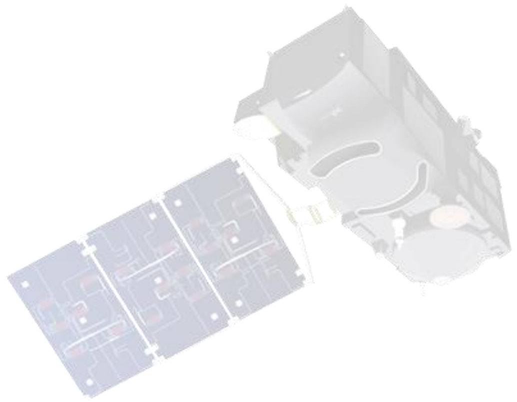

WorldView-3 (2 m)


PlanetScope (5 m)

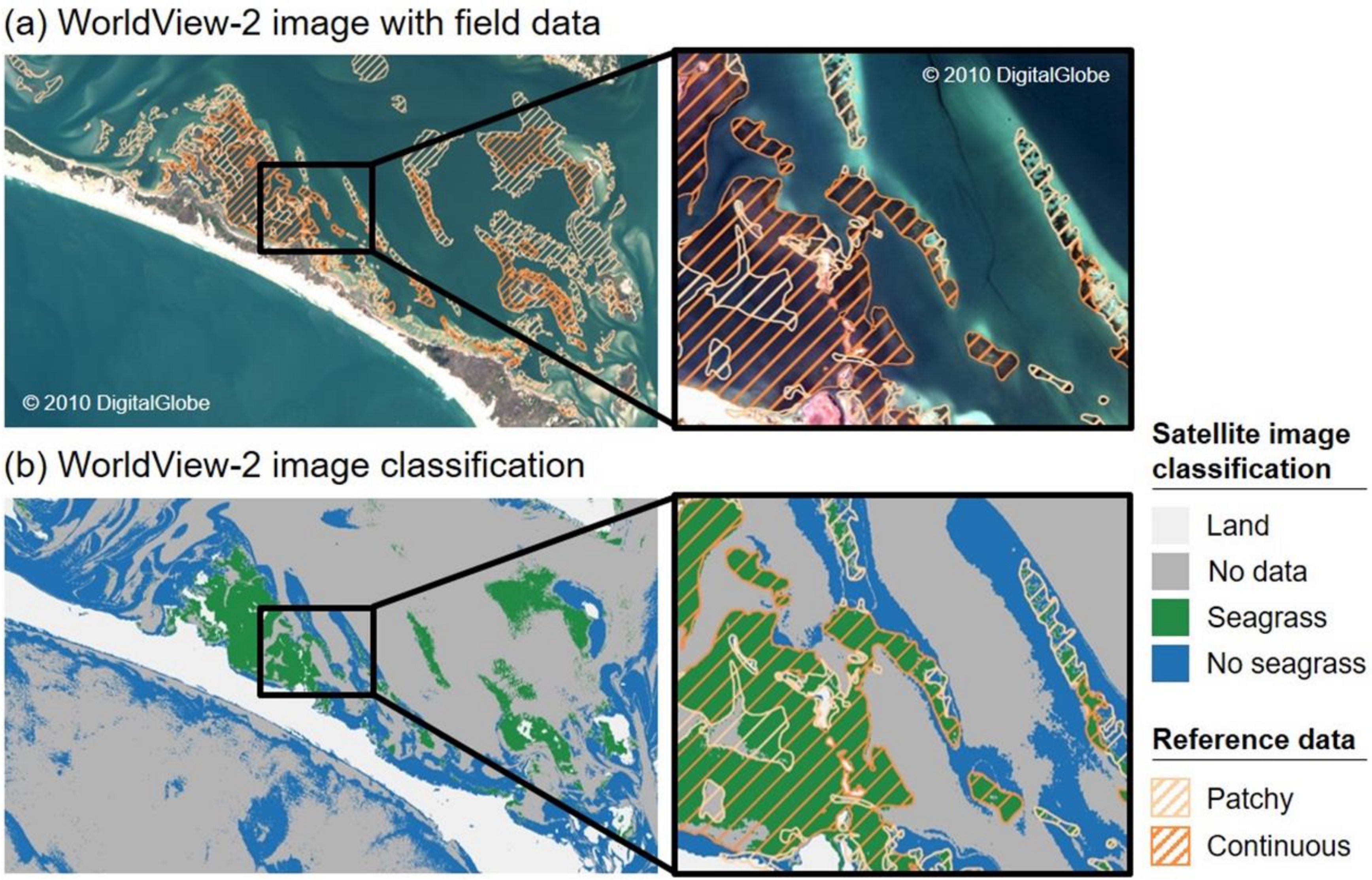
Freely available, open access satellite platforms


Landsat 8 (30 m)

Sentinel-2 (20 m)


Sentinel-3 (300 m)

Back Sound, NC

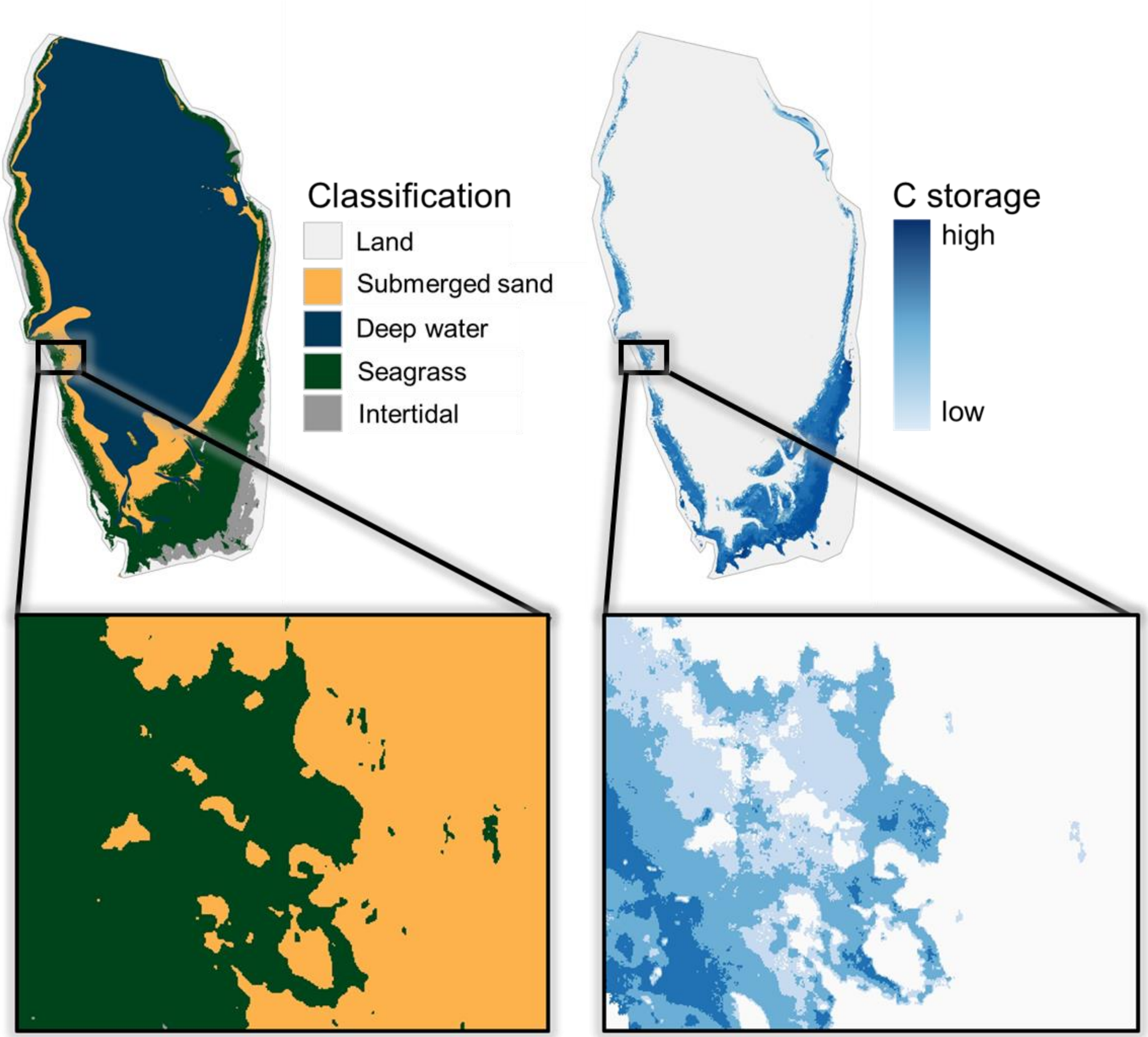


Reproducible and semi-automated workflows developed to process commercial satellite data for aquatic applications and classify seagrass extent.

Coffer et al., 2023. *J. Environ. Manag.*

Where we've been

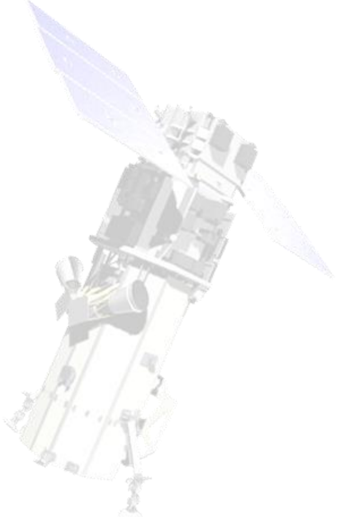
Where we're going

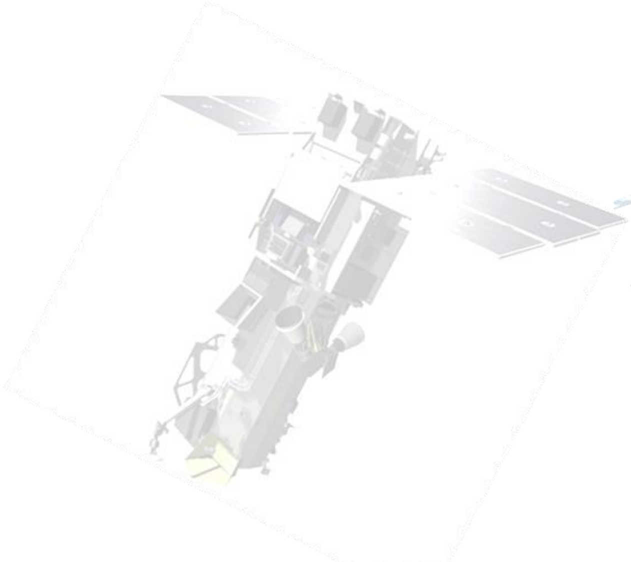


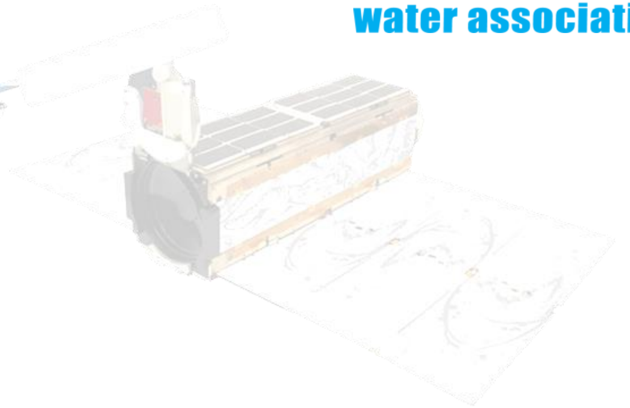
Commercial Earth observing satellites are used by NOAA to retrieve carbon storage estimates from seagrass classification.

In 2010, seagrasses in St. Joseph Bay, Florida, held 1,600 metric tons of carbon, equivalent to CO_2 emissions generated from 4 million gallons of gasoline.

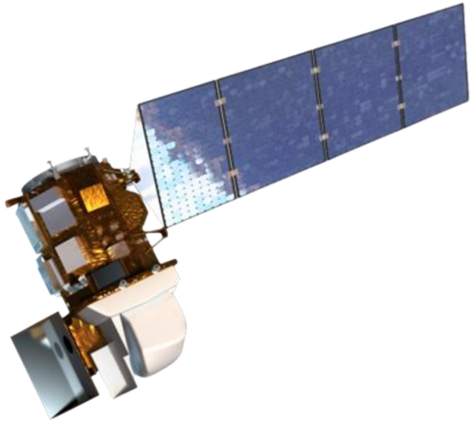
Commercial, high spatial resolution satellite platforms


WorldView-2 (2 m)

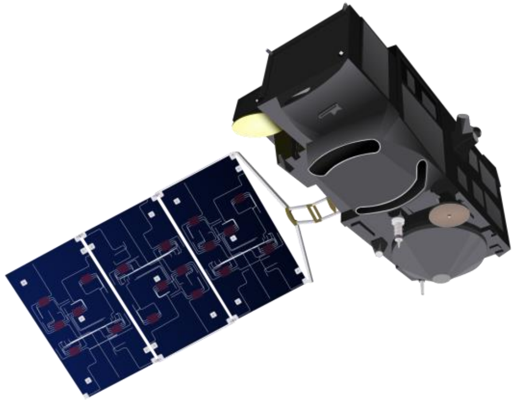

WorldView-3 (2 m)

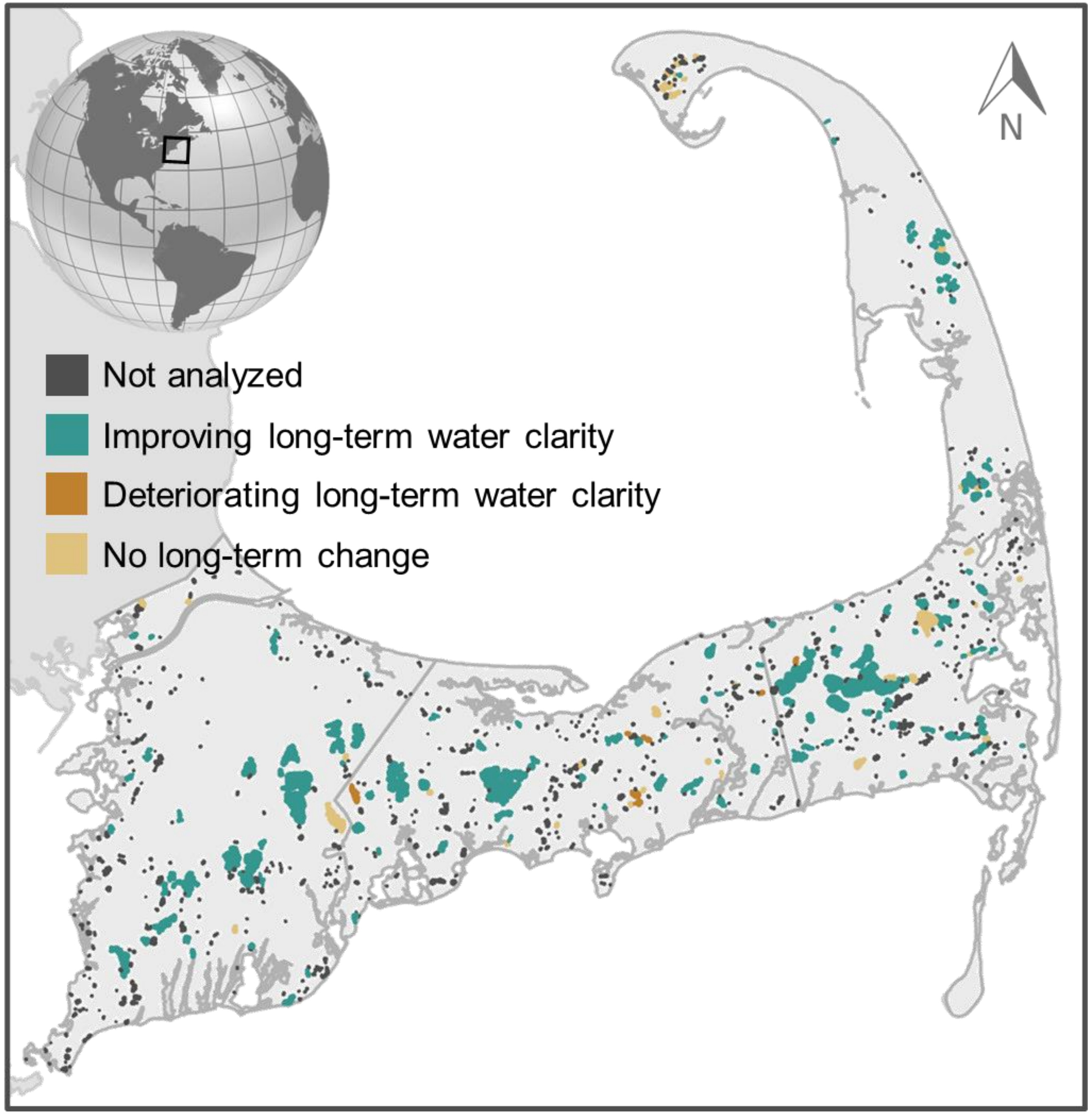

PlanetScope (5 m)

Freely available, open access satellite platforms


Landsat 8 (30 m)


Sentinel-2 (20 m)

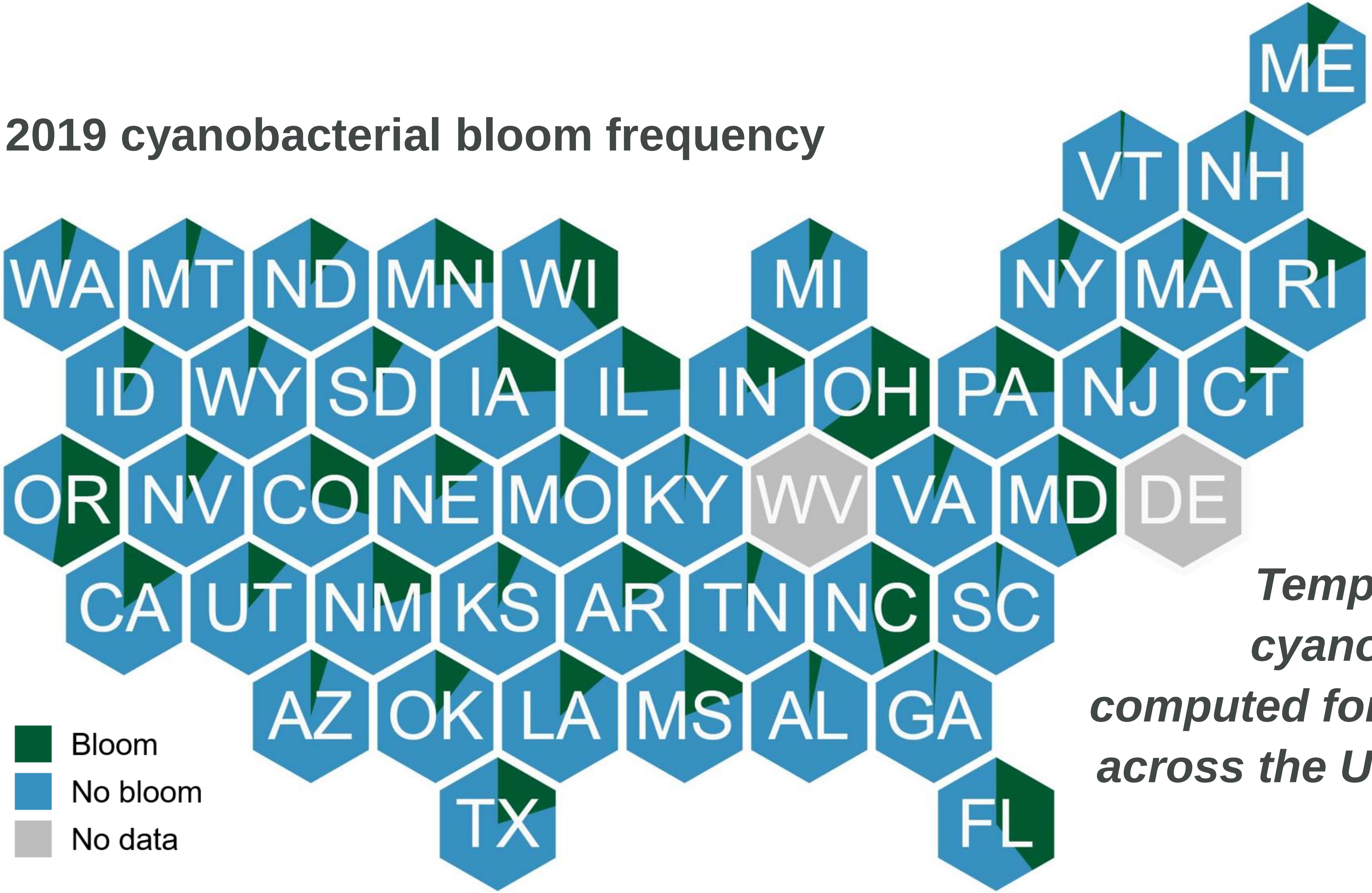

Sentinel-3 (300 m)



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

Coffer et al., *In prep. J. Environ. Manag.*

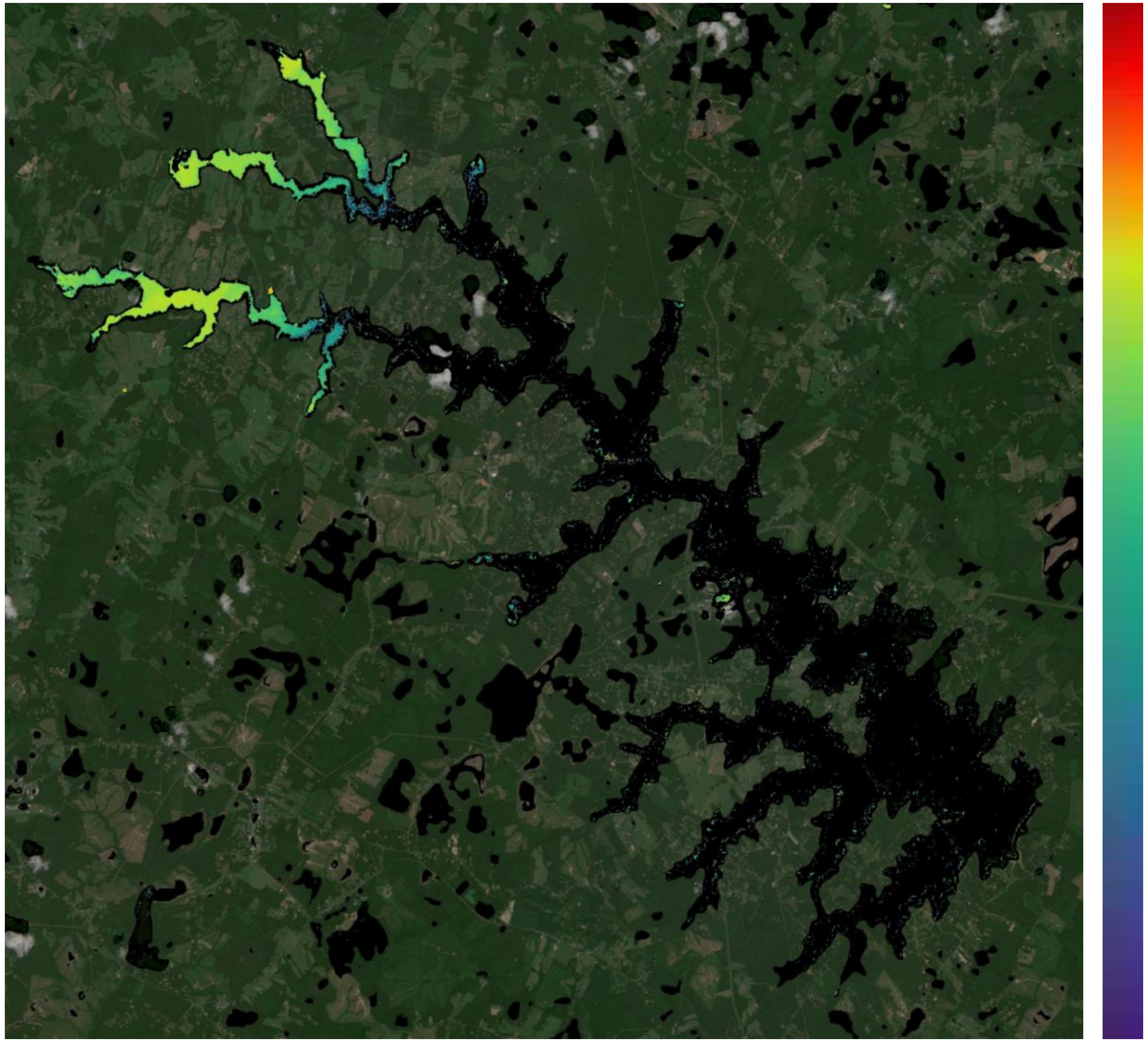
2019 cyanobacterial bloom frequency



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

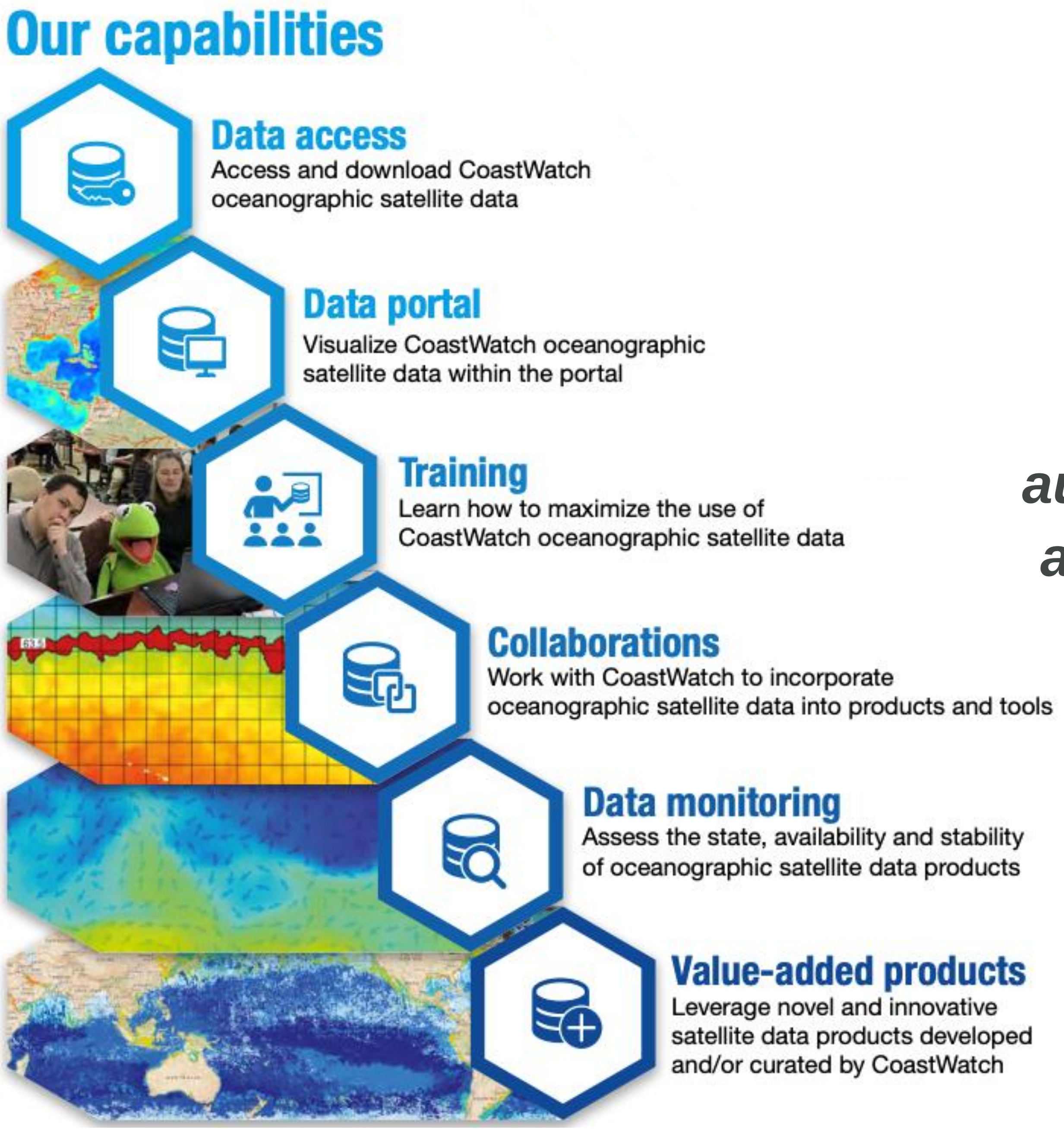
Coffer et al., 2021. *Ecol. Indic.*

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



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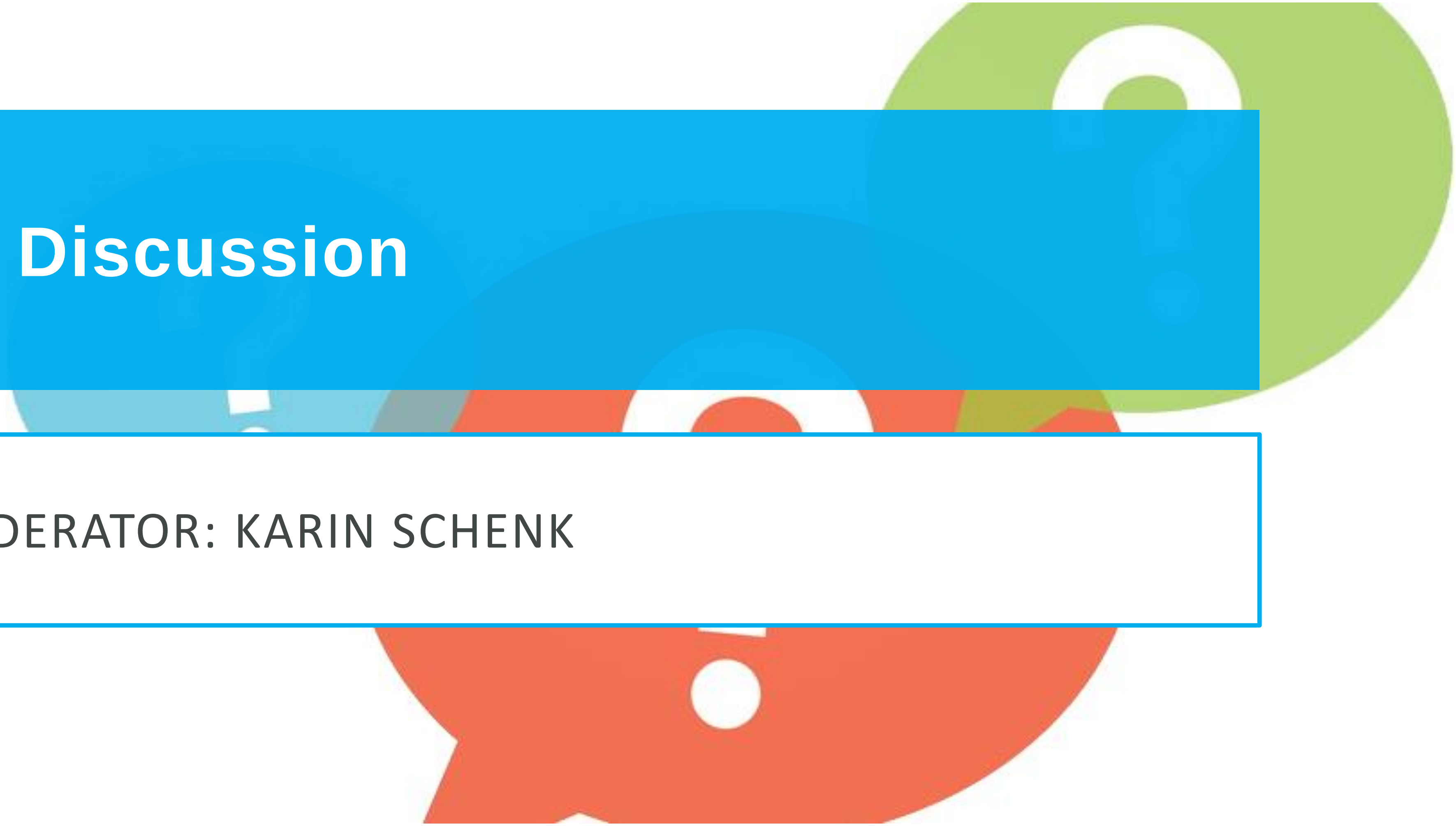
Within NOAA CoastWatch, we mostly uptake Earth observations through automated routes, and attempt to provide a streamlined source for users to access and interpret satellite data for use in coastal and ocean applications



Q&A Discussion

MODERATOR: KARIN SCHENK

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