



JNCC Workshop - Earth Observation for Water Quality Monitoring  
13-14<sup>th</sup> October 2020

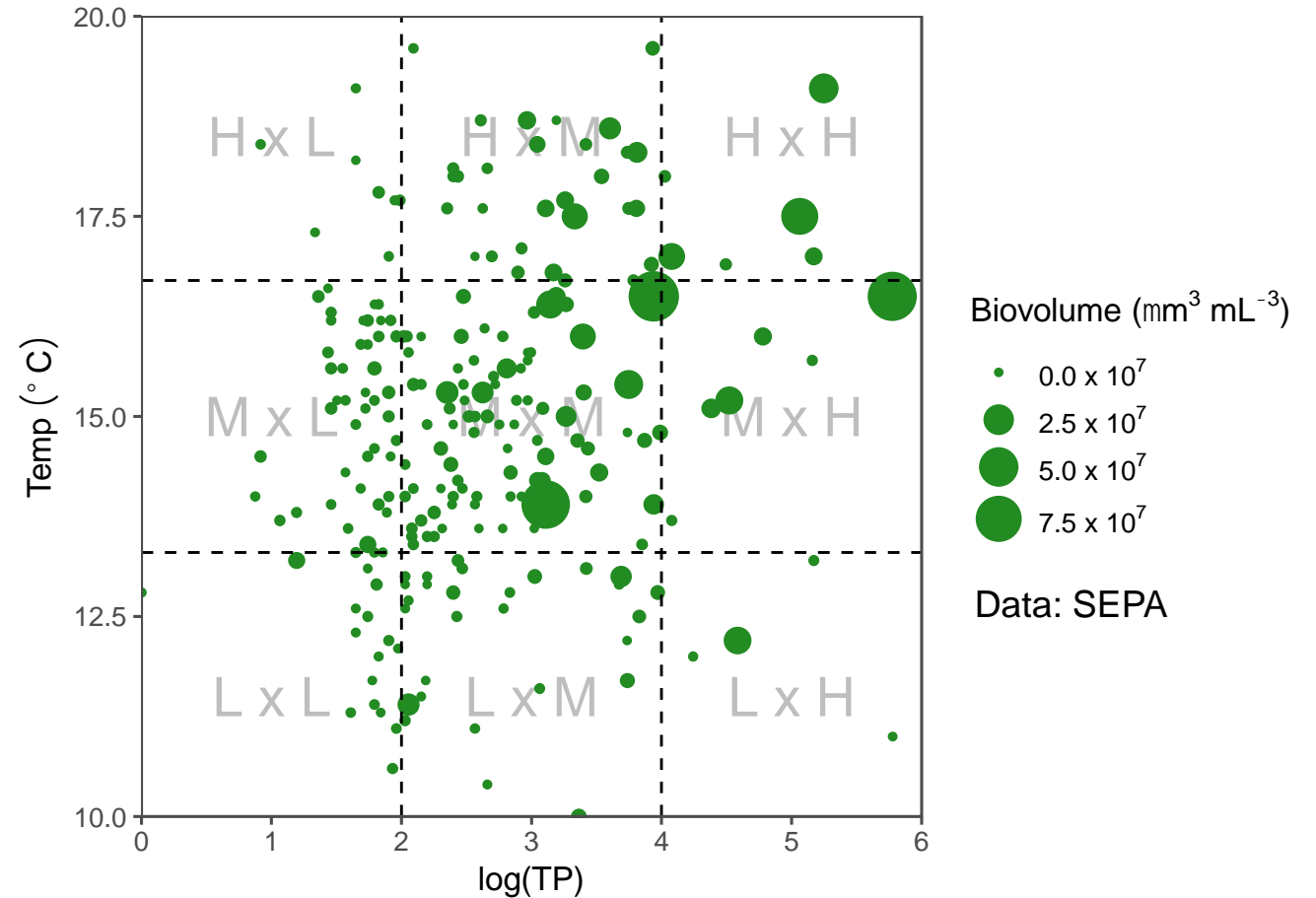
# Using Earth observation for national-scale monitoring of cyanobacterial blooms in the UK

Peter Hunter, **Vagelis Spyarakos**, Caitlin Riddick, Adam Varley & Andrew Tyler | University of Stirling  
Laurence Carvalho | UK Centre for Ecology & Hydrology  
Marion Scott & Claire Miller | University of Glasgow  
Team 3DEO| 3DEO

# Cyanobacteria, nutrients & climate change



- Cyanobacterial blooms occur annually throughout the UK
- Blooms pose risks to water security and human and animal health
- Main drivers of blooms are nutrients and climate (temperature and drought)

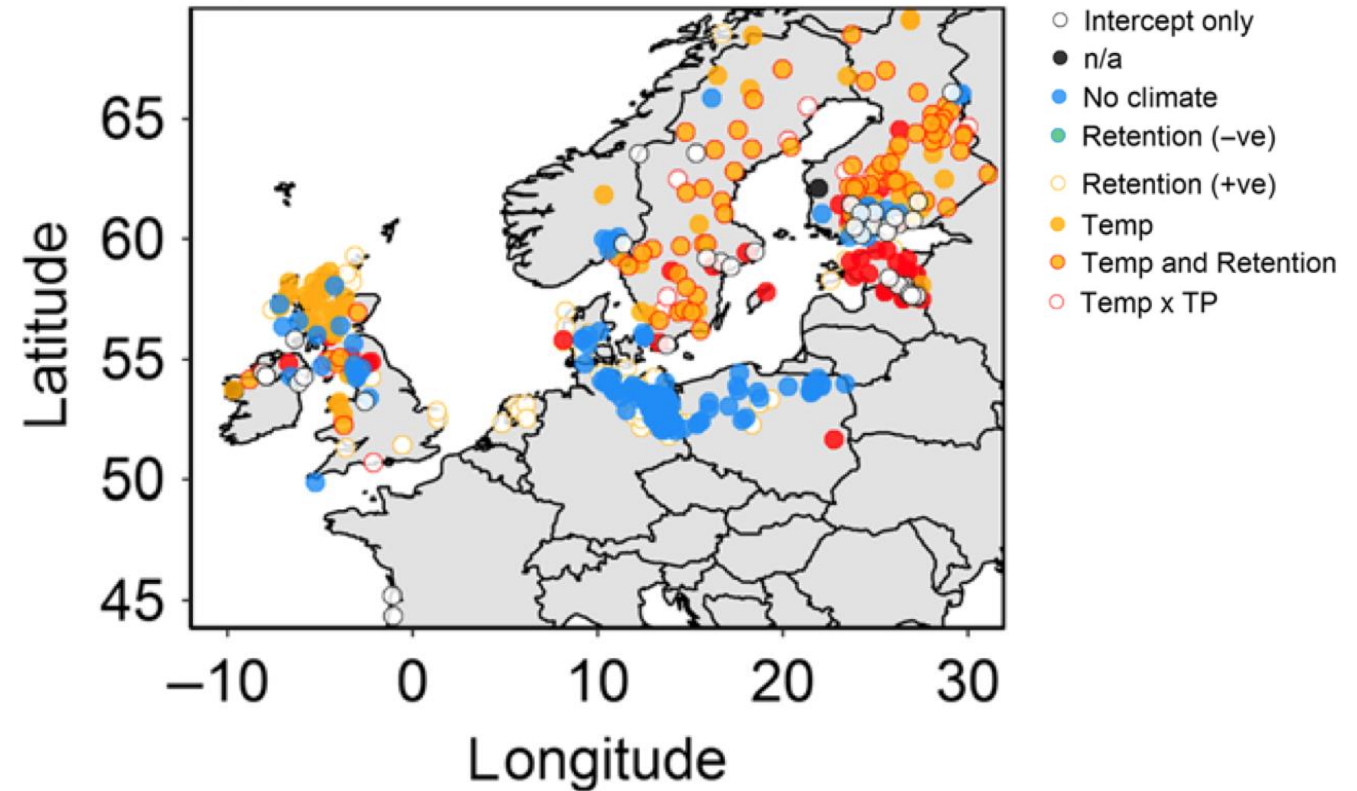


**Effect of phosphorus and temperature on cyanobacterial biovolume in Scotland [Hunter, unpublished]**



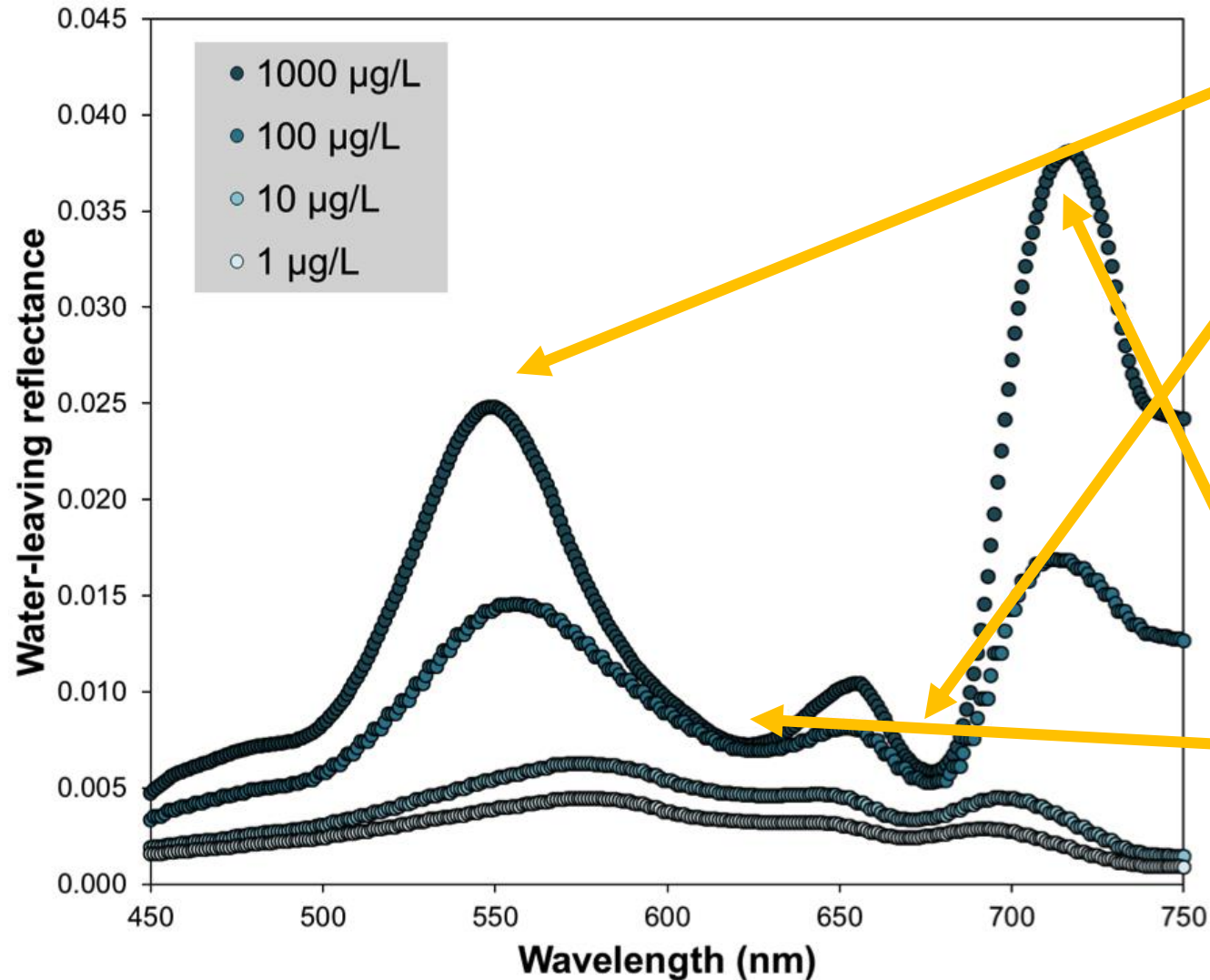
# Cyanobacteria, nutrients & climate change

- UK lakes and reservoirs susceptible to increases in blooms due to warming and drought (>55°N latitude)
- But lack of systematic monitoring to track changes in risk to protect water security and human health



**Effect of temperature and lake retention time on the occurrence of cyanobacterial blooms in European lakes** [Richardson, Hunter & Carvalho et al. 2018. *Global Change Biology*, 24(11)]

# How can we detect blooms with EO?



## 1. Detection of greening

- peak in green

## 2. Quantification of chlorophyll

- absorption at ~ 665 nm

## 3. Detection of surface scums

- peak in NIR/SWIR

- e.g. Ho et al. 2019

## 4. Quantification of phycocyanin

- absorption at ~ 620 nm

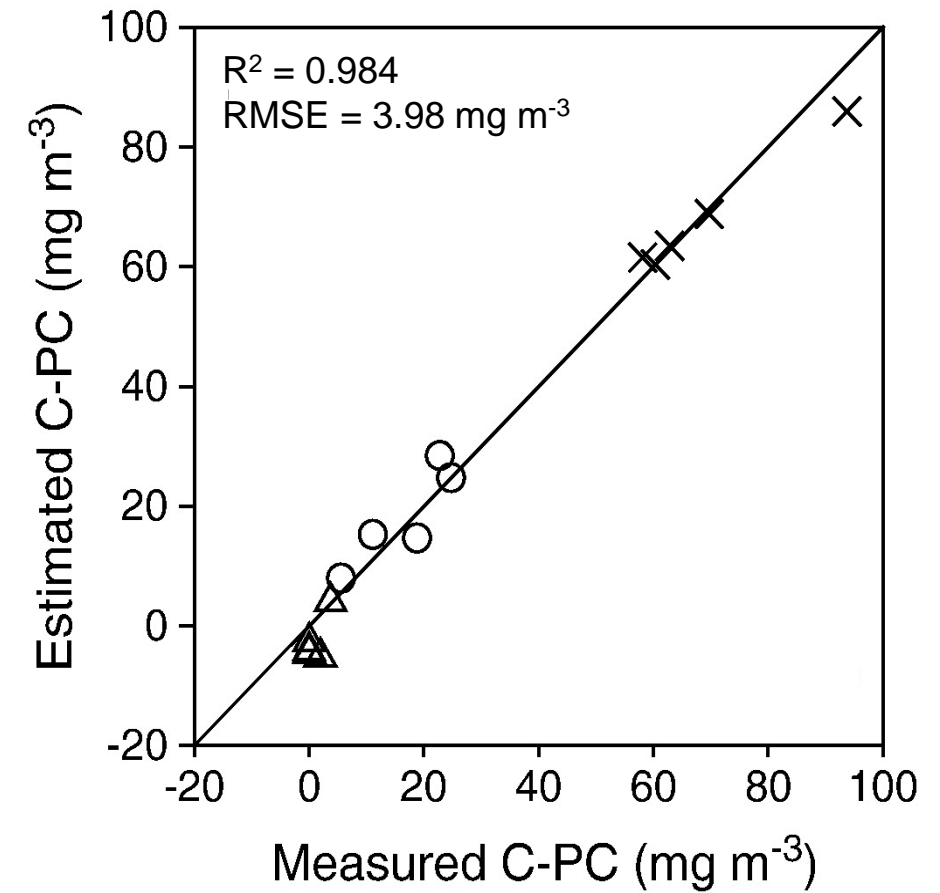
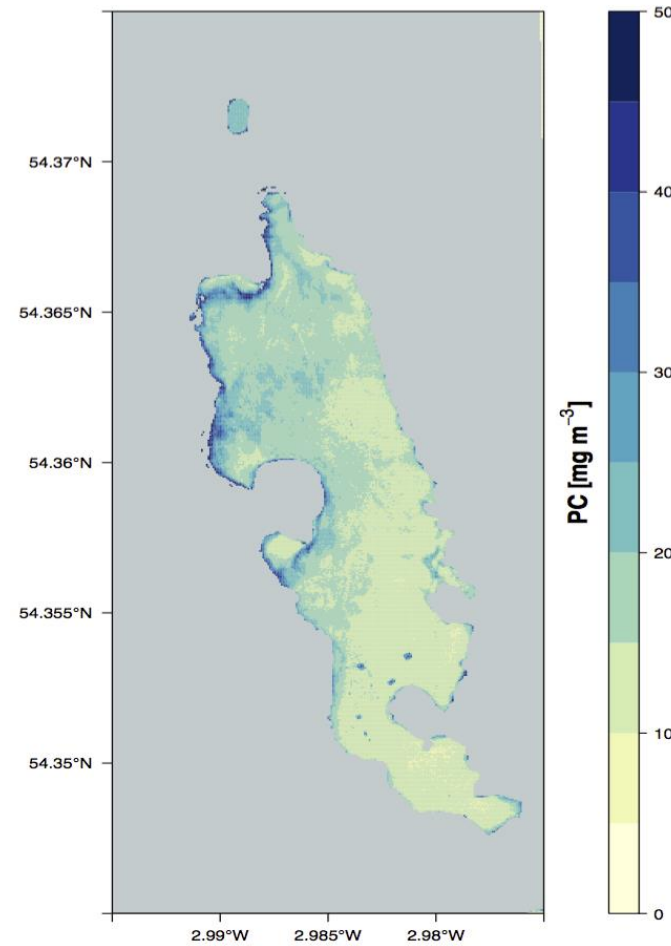
- fluorescence at ~ 650 nm

- e.g. Hunter et al. 2010

Applicability

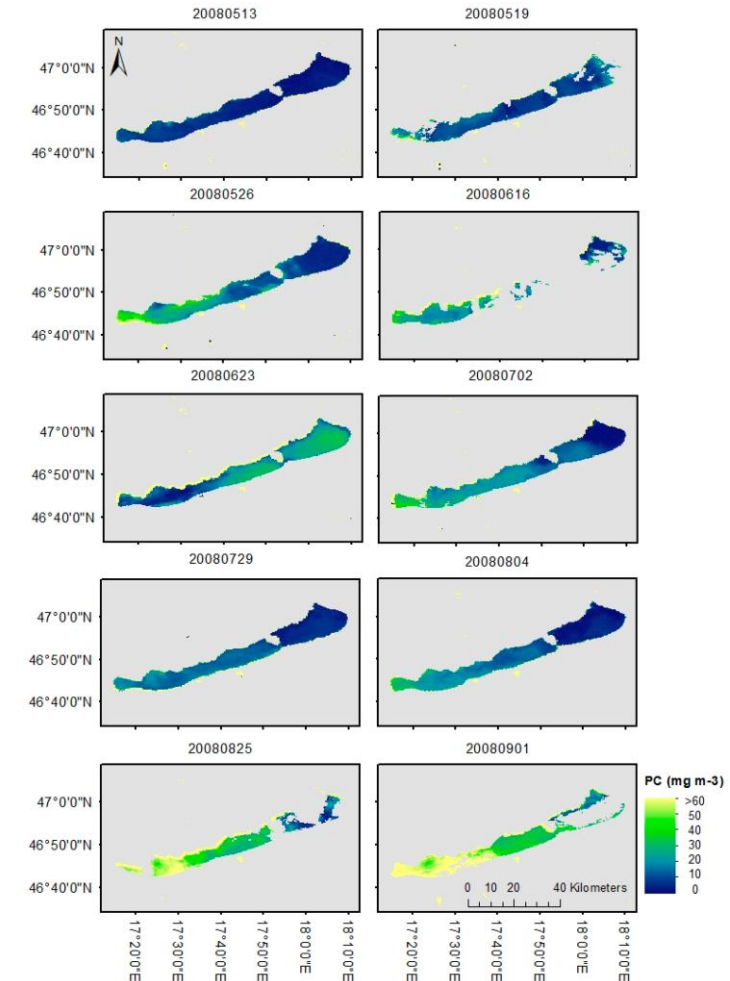
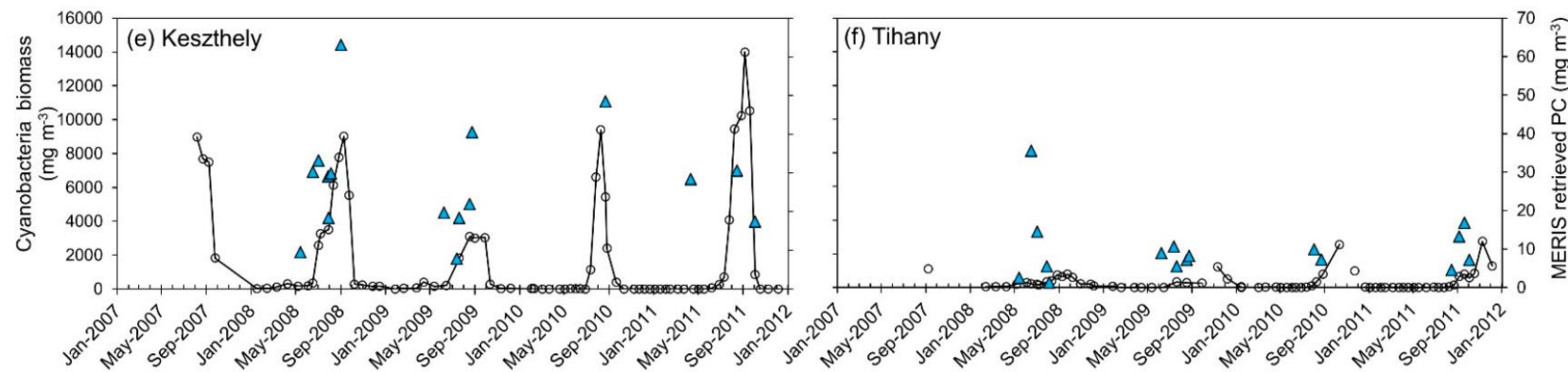
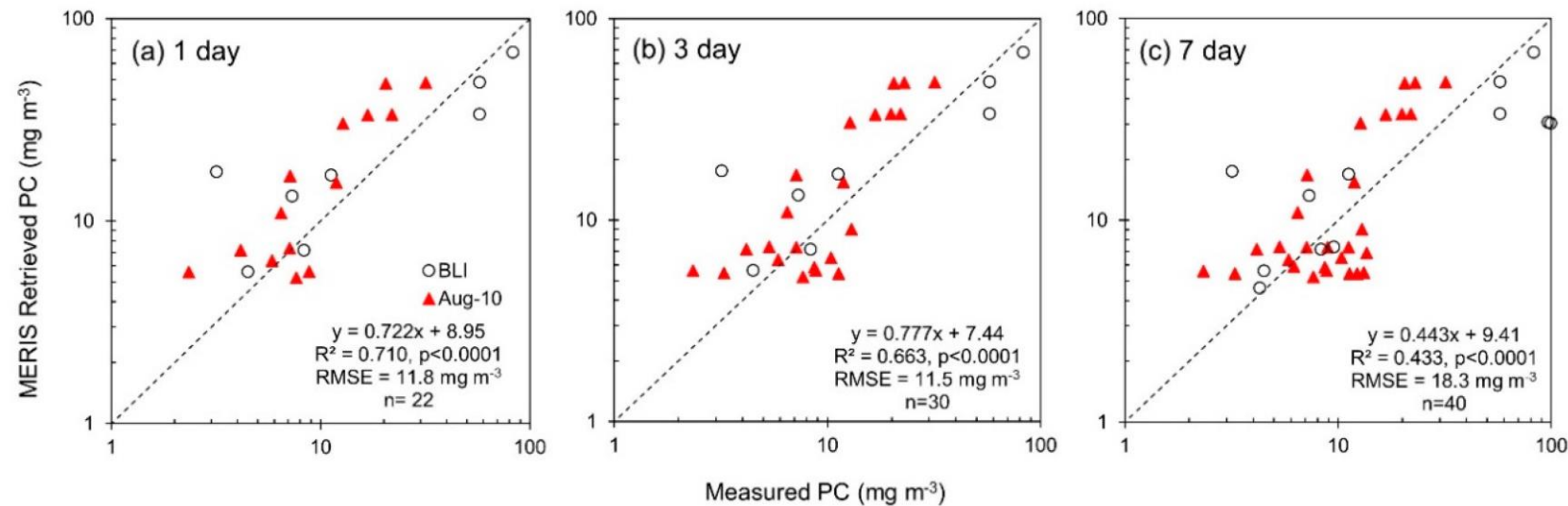
Specify

# Phycocyanin retrieval from airborne imagery



**Retrieval of phycocyanin concentrations from hyperspectral AISA Eagle data in Esthwaite Water, UK [Hunter et al. (2010) Remote Sensing of Environment, 114(11), 2705-2718.]**

# Phycocyanin retrieval from Envisat MERIS



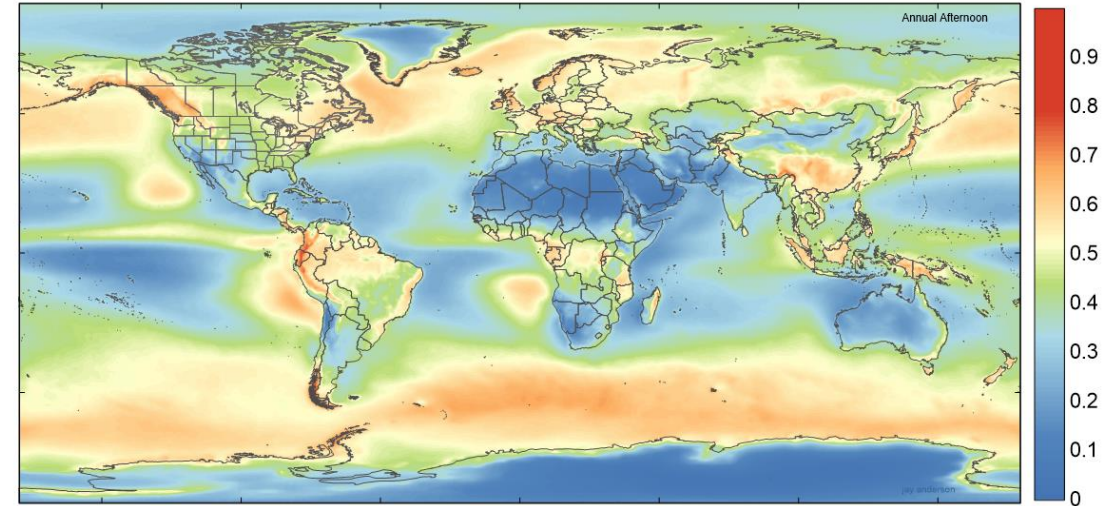
Retrieval of phycocyanin concentrations from hyperspectral AISA Eagle data in Esthwaite Water, UK [Riddick, C. A. L., Hunter, P. D., Domínguez Gómez, J. A., et al. (2019). Remote Sensing, 11(13)]



# Challenges for bloom monitoring in UK



- Vast majority of UK waterbodies cannot be observed at 300 m (e.g. MERIS / OLCI) resolution
- Higher spatial resolution sensors lack 620 nm band needed for PC detection
- Less frequent revisit cycles reduce temporal coverage and increase gaps due to cloud cover



Global annual cloudiness derived from observations from Aqua-MODIS satellite. Data: NASA.



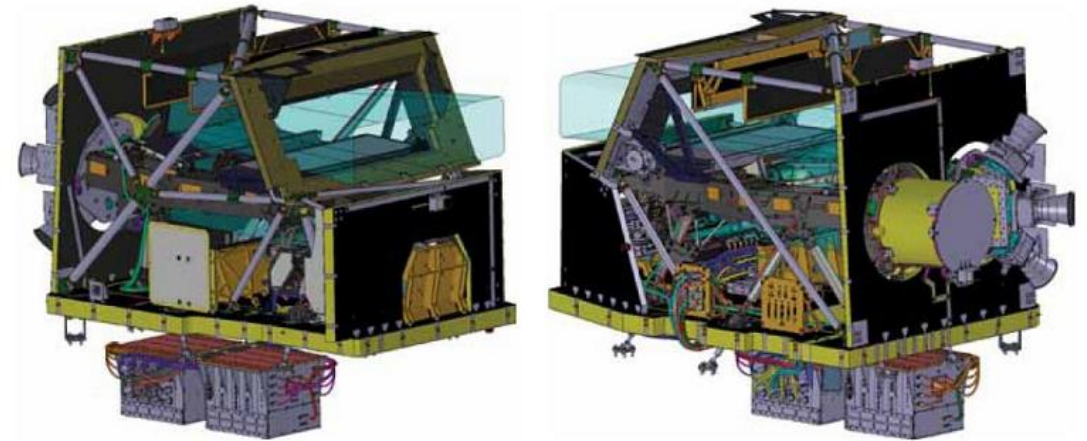
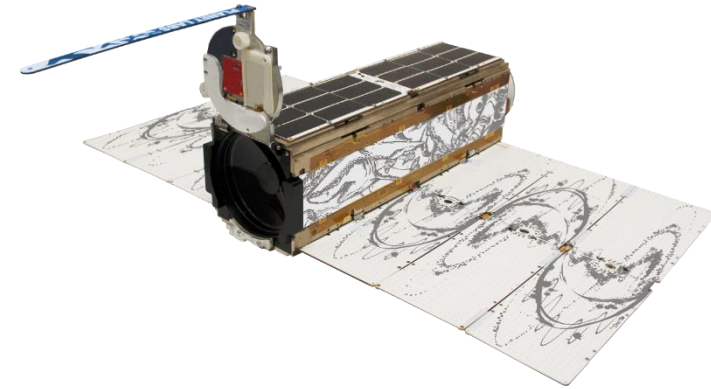
	Operator	Satellite	Sensor	Bands (n)	Spatial resolution (m)	Temporal revisit (equator)	Mission duration	Chl-a quantification	Phycocyanin quantification	Scum detection	Data access
Decommissioned	ESA	Envisat	MERIS	15	300 / 1000	3 days	2002-2012	Highly suitable	Highly suitable	No	Free
	NOAA	Suomi-NPP	VIIRS	22	750	1 day	2011-2017	Highly suitable	Unproven	No	Free
	USGS	Landsat-5/-7	ETM+	8	30	16 days	1984-2020	Suitable	No	Yes	Free
Operational	NASA	Aqua / Terra	MODIS	36	250 / 500 / 1000	2 days	2000-present	Highly suitable	No	No	Free
	ESA	Sentinel-3a/b	OLCI	21	300 / 1200	<2 days	2016-present	Highly suitable	Yes	No	Free
	ESA	Sentinel-2a/b	MSI	12	10-60	<5 days	2015-present	Suitable	No	Yes	Free
	USGS	Landsat-8/-9	OLI / OLI-2	9	30	16 days	2013-present	Suitable	No	Yes	Free
	PlanetLabs	Dove	PlanetScope	4	3	1 day	2014-present	Unproven	No	Yes	Free for R&D \$1.28/km <sup>2</sup>
Forthcoming	PlanetLabs	SuperDove	PlanetScope	8	3	1 day	2020-	Unproven	Unproven	Yes	Free for R&D \$????/km <sup>2</sup>
	NASA	PACE	OCI	117	1000	2 day	2022-	Highly suitable	Highly suitable	No	Free
	ASI	Prisma	n/a	238	30	29 days	2020-	Highly suitable	Highly suitable	Yes	On application





# Solutions for bloom monitoring in the UK?

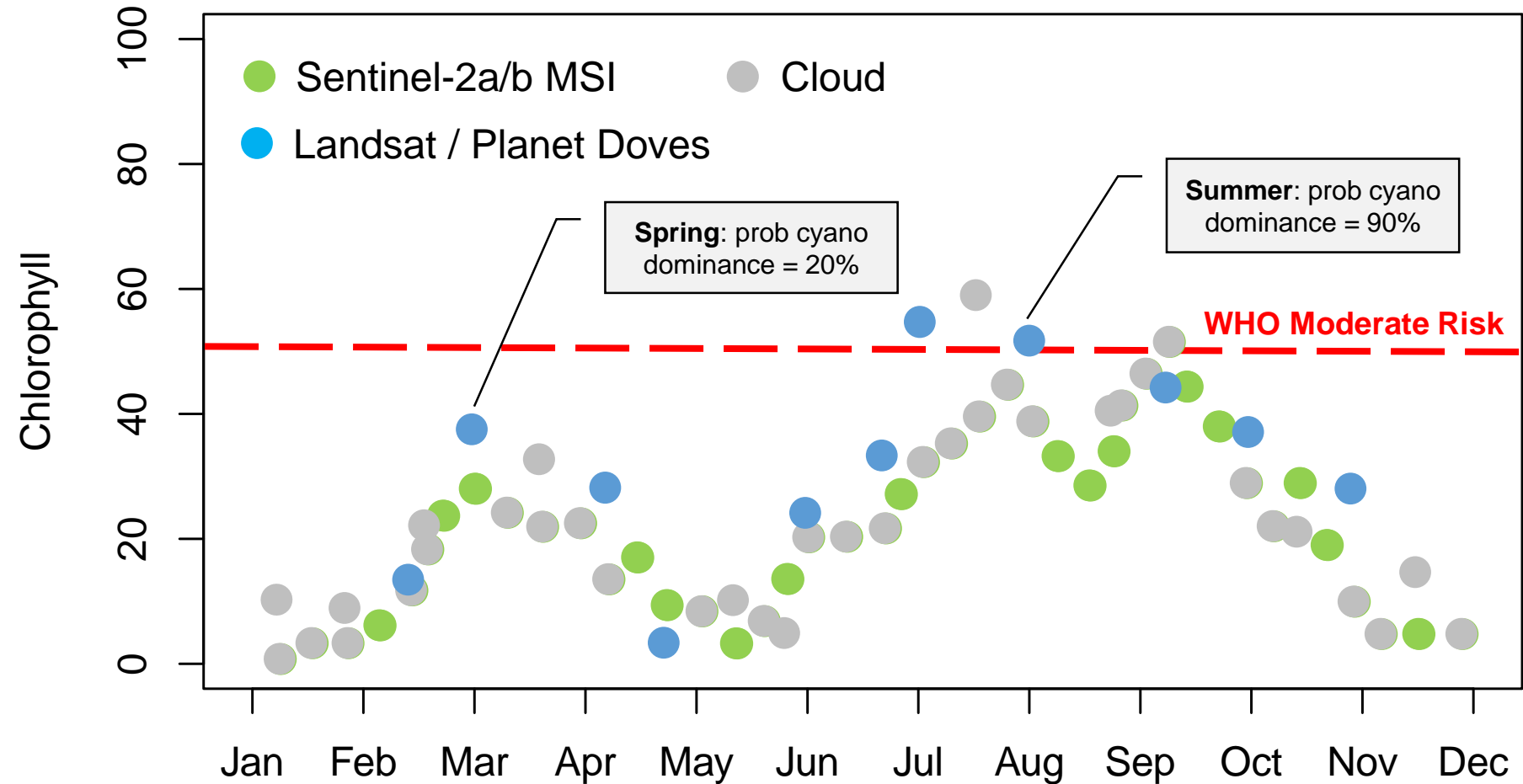
- **NOW:** Develop multi-sensor chlorophyll products to identify blooms and predict likelihood of cyanobacteria dominance based on a priori knowledge (e.g., lake type & date)
- **FUTURE:** Develop improved methods for phycocyanin detection/retrieval from future missions with high-res orange bands (e.g. Planet Labs Super Doves)



# Solutions for bloom monitoring in the UK?

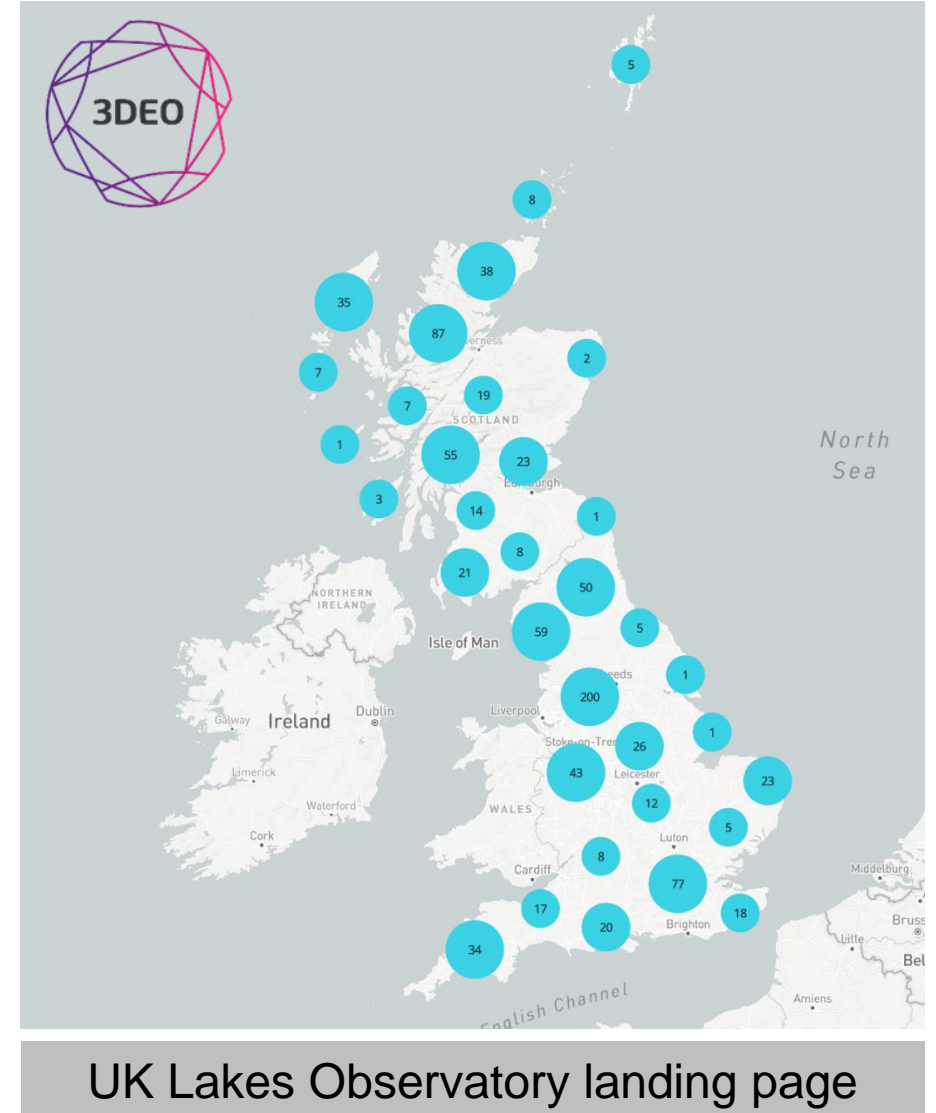


- Virtual constellation of sensors
- Probabilistic modelling of cyanobacteria dominance
- Integrate with data from automated *in-situ* sensors and citizens



# UK Lakes Observatory: A satellite-based climate service

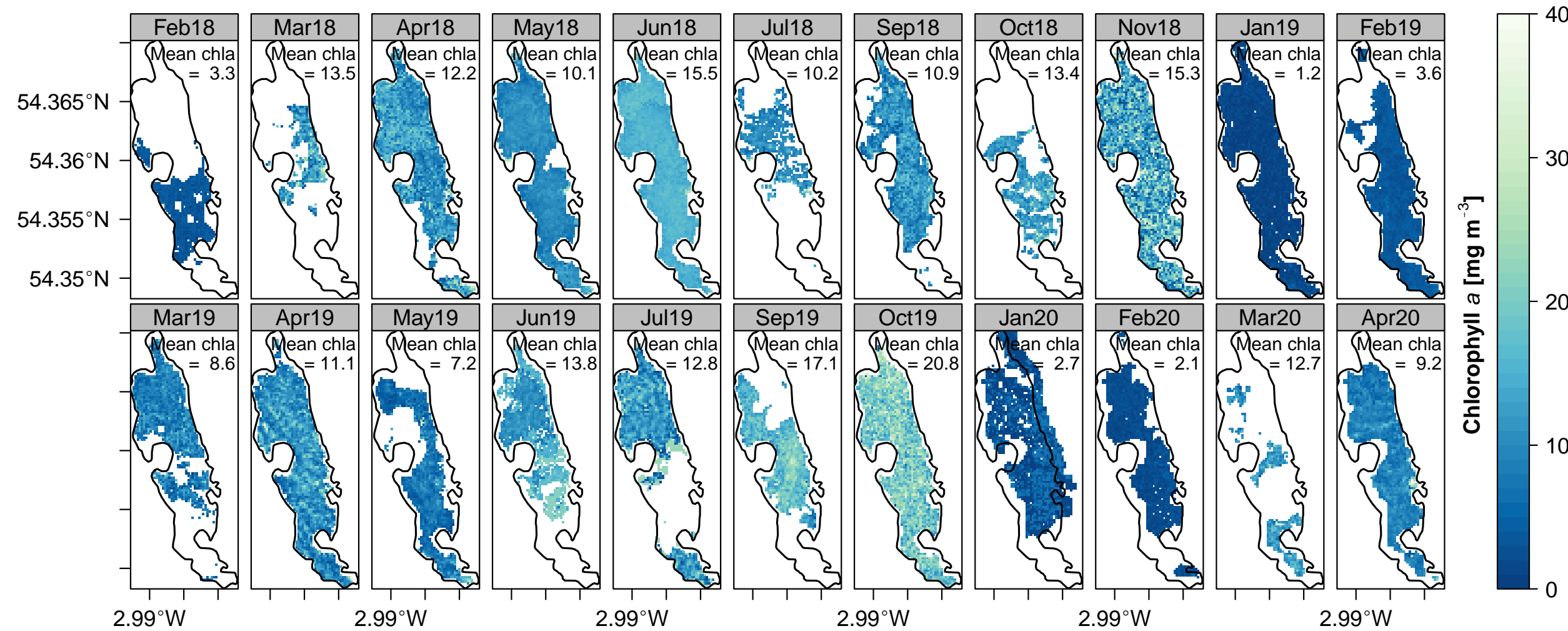
- Pilot service developed with funding from NERC Climate Resilience programme
- Chlorophyll products produced weekly for **933 UK lakes** at 20 m resolution using dynamic selection of algorithms based on lake optical water types
- Data delivered to end-users via open web-based platform built by 3DEO
- [www.eo4ukwater.stir.ac.uk](http://www.eo4ukwater.stir.ac.uk) ← not currently live





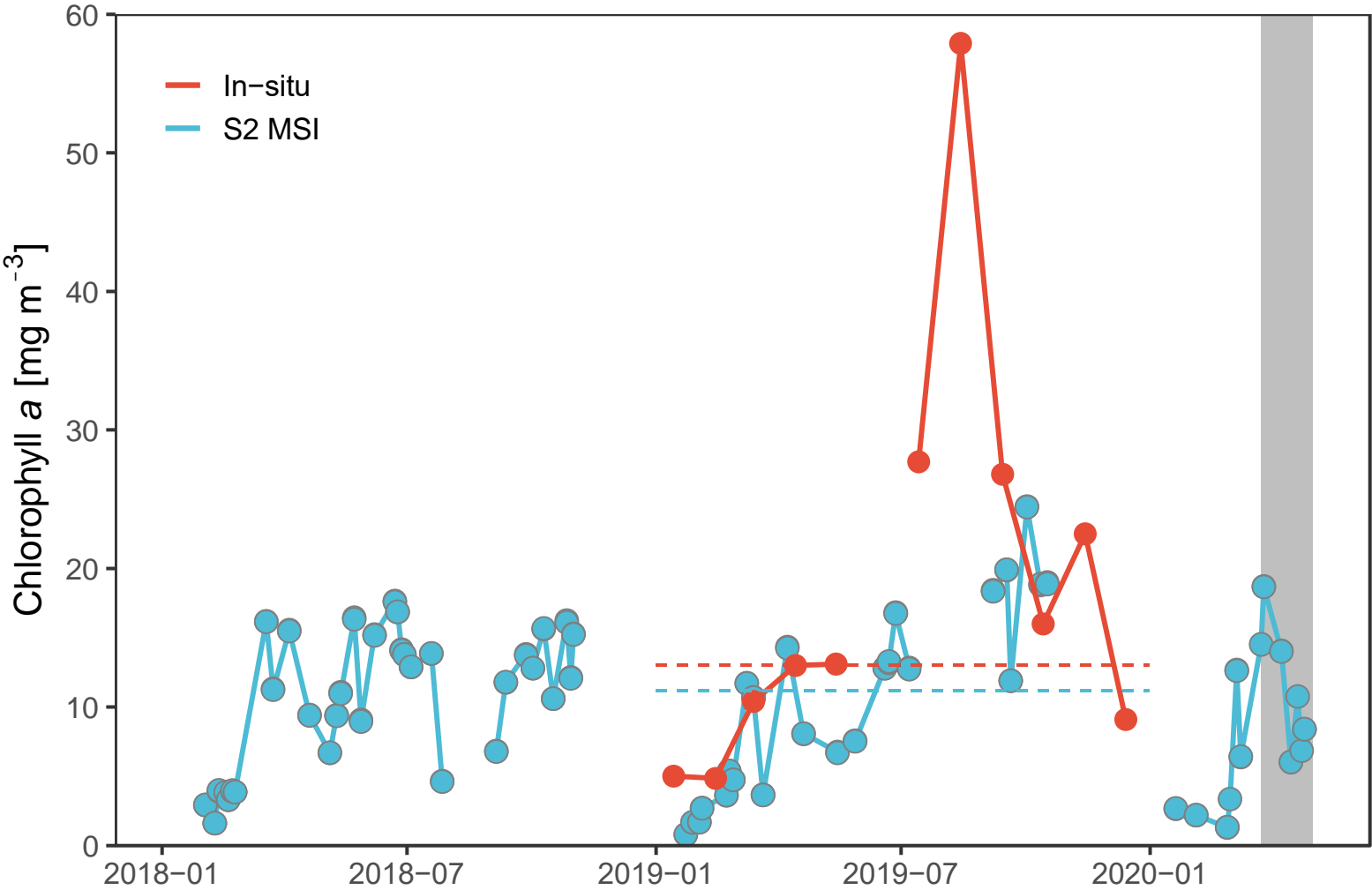
# UK Lakes Observatory: A satellite-based climate service

## Esthwaite Water Sentinel-2a/b MSI monthly mean chlorophyll



# UK Lakes Observatory: A satellite-based climate service

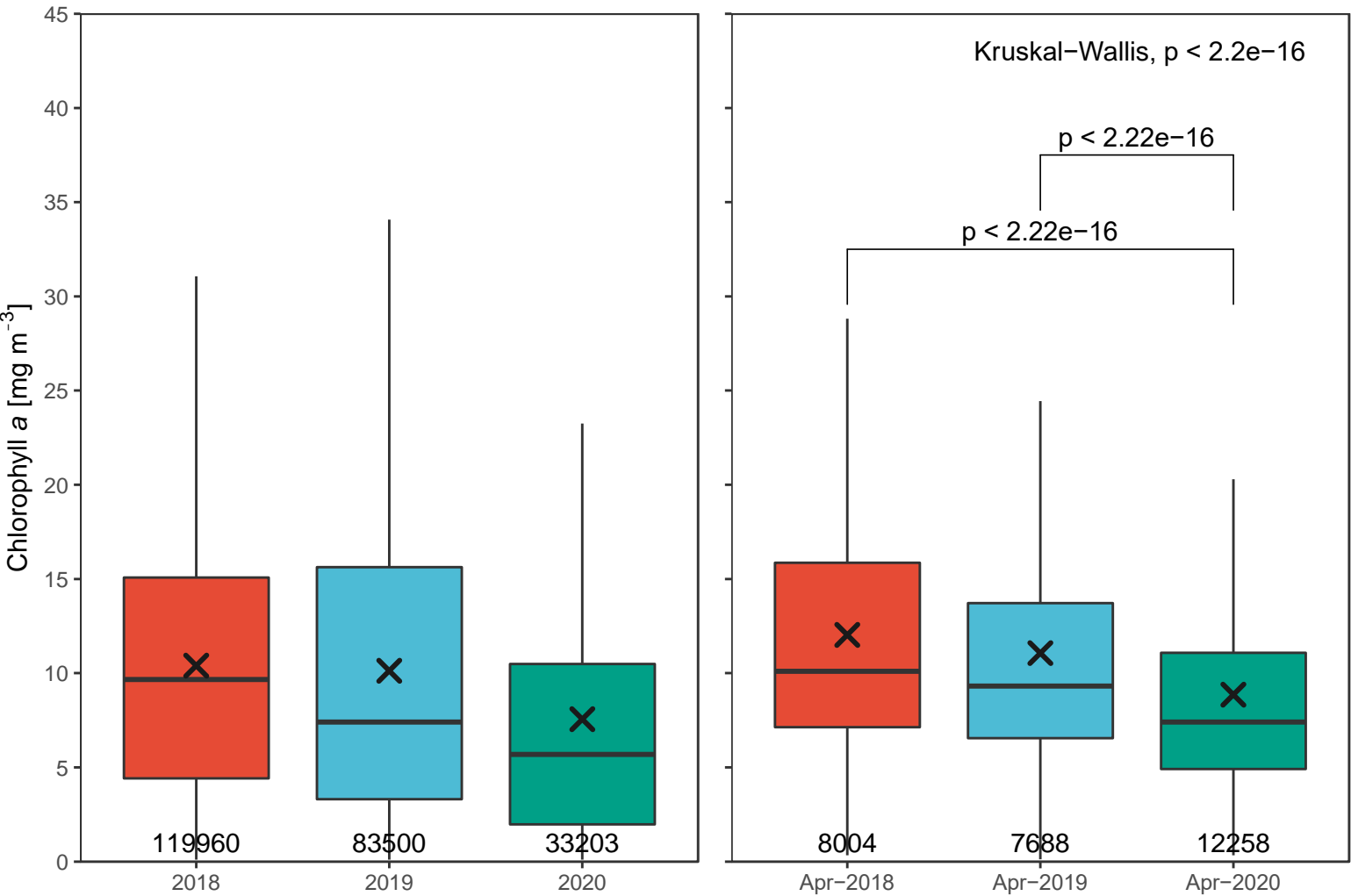
Esthwaite Water  
Sentinel-2a/b MSI versus in-situ chlorophyll



Comparison between Sentinel-2 MSI lake mean chlorophyll and in-situ monitoring data from UK CEH mean in Esthwaite Water (dashed lines show annual means for 2019)

## Esthwaite Water

Chlorophyll-a retrieved from Sentinel-2a/b MSI images (n=136)



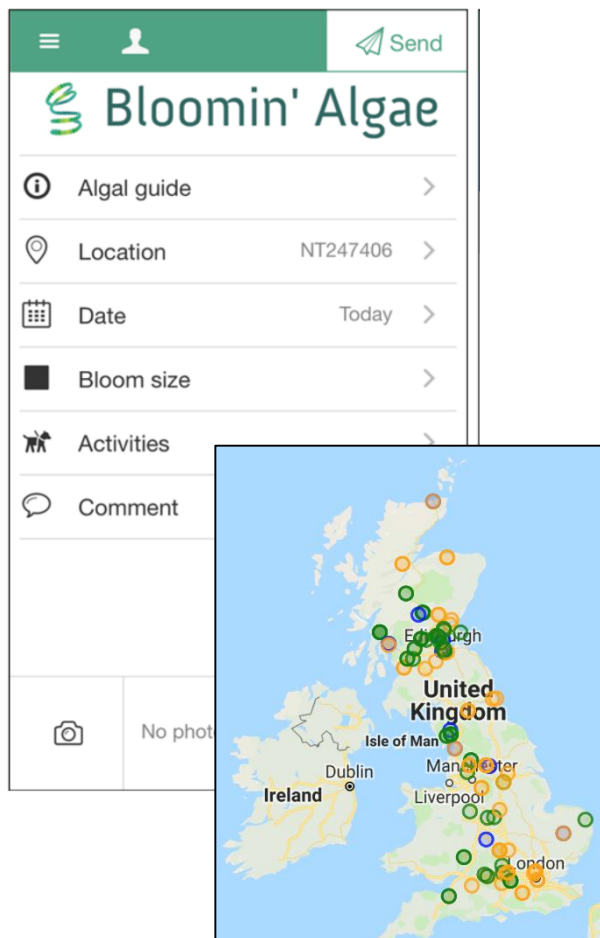
Sentinel-2 MSI mean annual chlorophyll and mean April chlorophyll for Esthwaite Water showing possible effect of Covid-19 lockdown on water quality



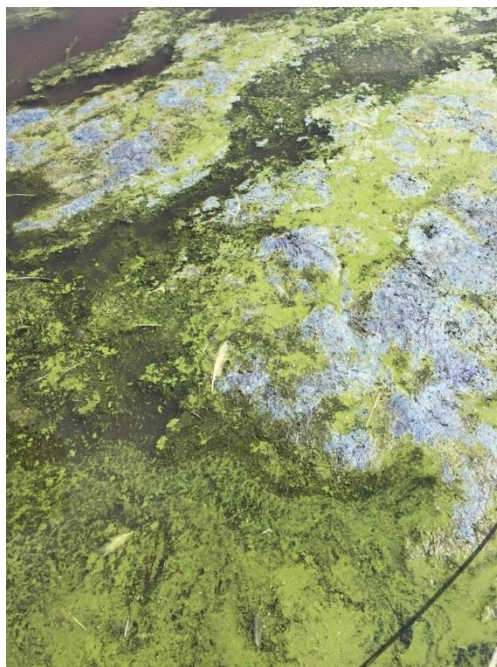


# Integrating in-situ observations

- Citizen science monitoring

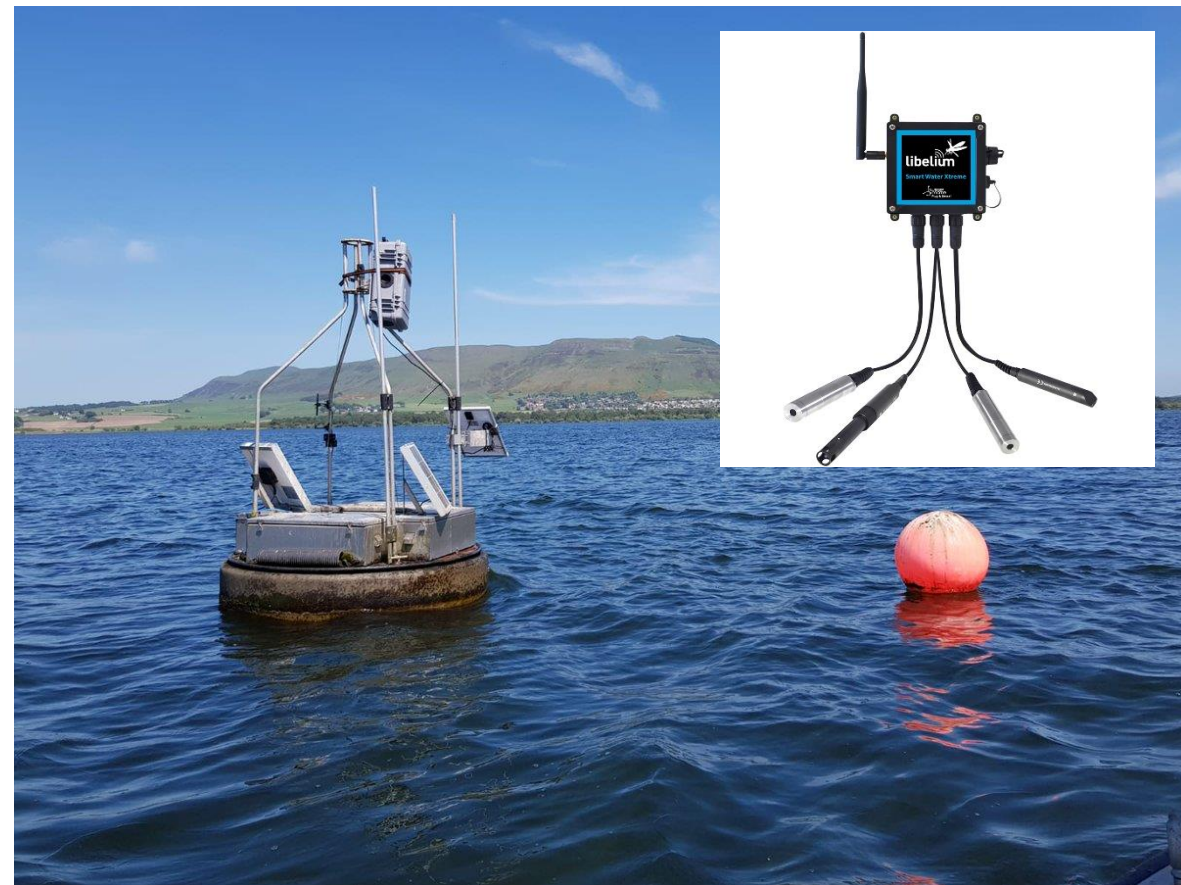


Citizen Science: UKCEH “Bloomin’ Algae” app



**ID:** 7233755  
**Date:** 14/07/2018  
**Location:** Loch Leven north shore  
**Recorder:**  
**Status:** Accepted: correct

- Wireless sensor networks (e.g. Forth-ERA)



Forth-ERA monitoring buoy (with LoRaWAN Libelium Smart Water Extreme sensors for chl / PC)

# Summary & next steps

- UK Lakes Observatory will launch in November / December for 12-month pilot phase
- Satellite lake chlorophyll data will be distributed via UK CEH Lakes Portal: <https://eip.ceh.ac.uk/apps/lakes/>
- Improvements to current algorithms for chlorophyll retrieval to be implemented by end of 2020 → better performance in low chlorophyll waters
- Bayesian models for predicting probability of cyanobacteria dominance being developed for selected case studies