Canopy Height Estimation including Calibrated Uncertainty - spatioTempCHM -

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Canopy height mapping is an important tool for ecosystem monitoring and sustainable forest management.
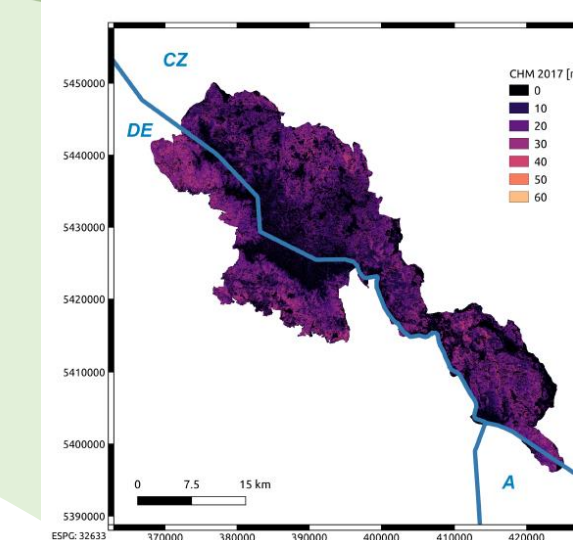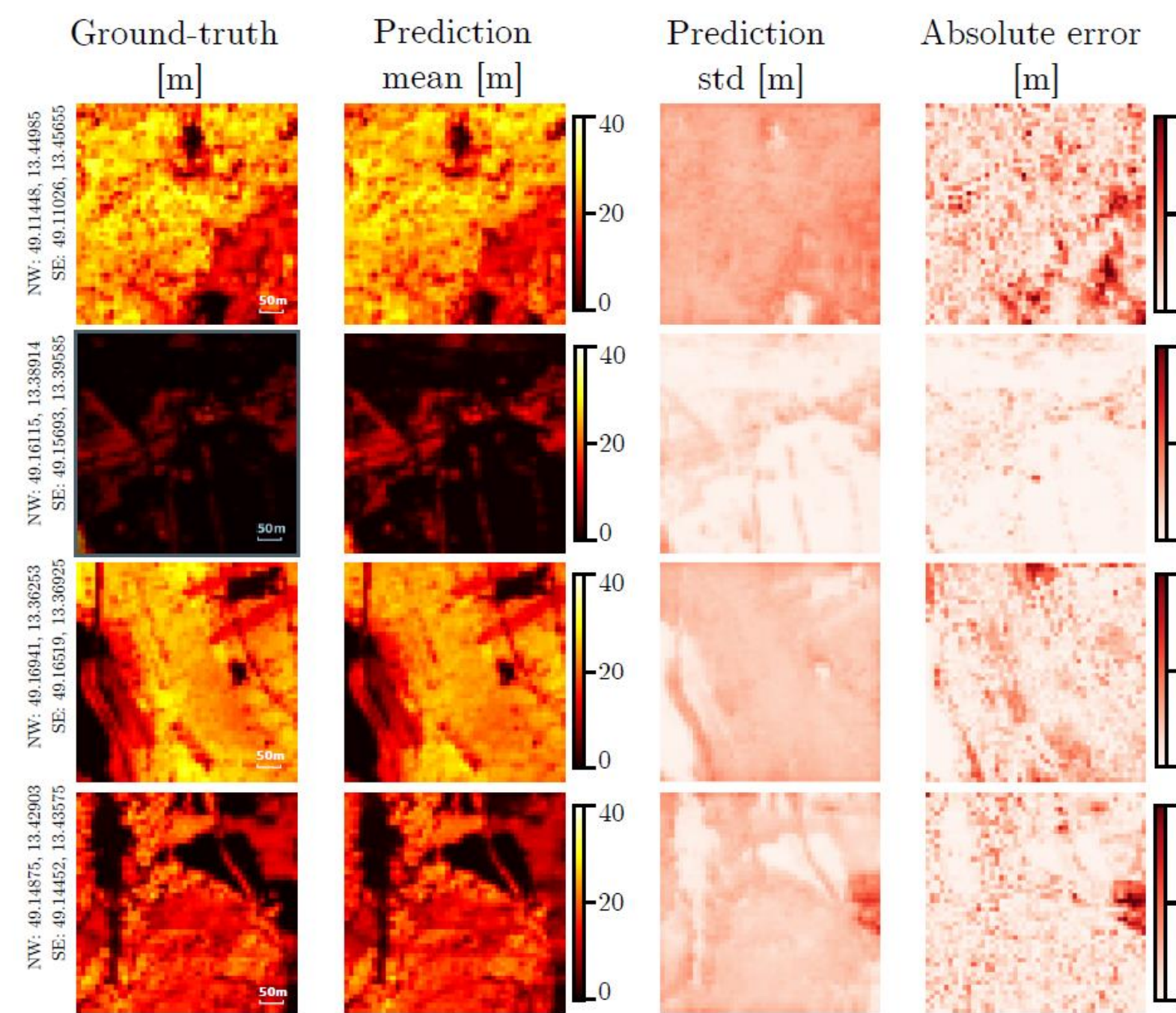
We adopt a convolutional variant of a long short-term memory (LSTM) model for canopy height estimation from multi-temporal instances of Sentinel-2 products.

We utilize deep ensembles technique for meaningful uncertainty estimation on the predictions and post-processing isotonic regression model for calibrating them.

Our lightweight model (320k trainable parameters) achieves mean absolute error (MAE) of 1,29m in the Bohemian forest (an area of 79km^2).

It outperforms state-of-the-art methods based on single-shot spaceborne images as well as costly airborne images, while providing additional confidence maps that are shown to be well calibrated.
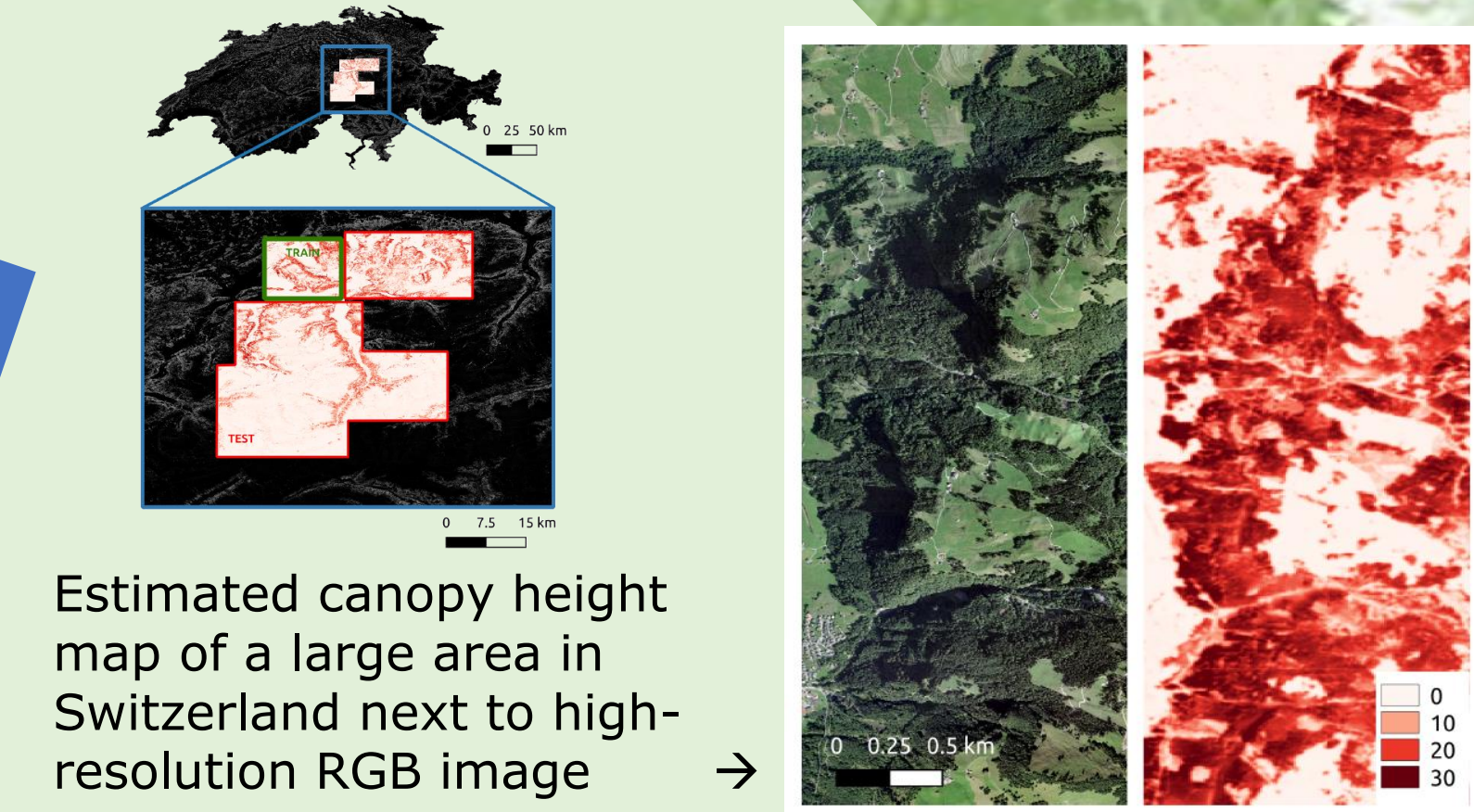
The trained model is transferable in Switzerland using a fine-tuning area of as low as 2km^2 with MAE = 1,94m.

Annual Canopy Height Estimation 10x10 m^2 pixel size

Predicted mean and standard deviation of canopy height alongside with LiDAR measured ground-truth and absolute error.

Pixel-wise comparison of `spatiotempCHM` model with state-of-the-art results.

Method	Location	Area	MAE [m]	RMSE [m]
Lang et al. [1]	Switzerland	91Mpx	1.7	3.4
Lang et al. [1]	Gabon	25Mpx	4.3	5.6
ConvEnc-Dec [2]	BF	9.4Mpx	2.29	3.15
ConvEnc-Dec-mean40	BF	9.4Mpx	2.04	3.05
spatioTempCHM	BF	9.4Mpx	**1.29**	**1.87**

[1] Lang, N., et al., (2019). Country-wide high-resolution vegetation height mapping with Sentinel-2. Remote Sensing of Environment, 233, 111347.
[2] Alagialoglou, L. et al.,(2021). Canopy Height Estimation from Spaceborne Imagery Using Convolutional Encoder-Decoder. In MultiMedia Modeling: 27th International Conference, MMM 2021, Prague, Czech Republic, June 22–24, 2021, Proceedings, Part II 27 (pp. 307-317). Springer International Publishing.
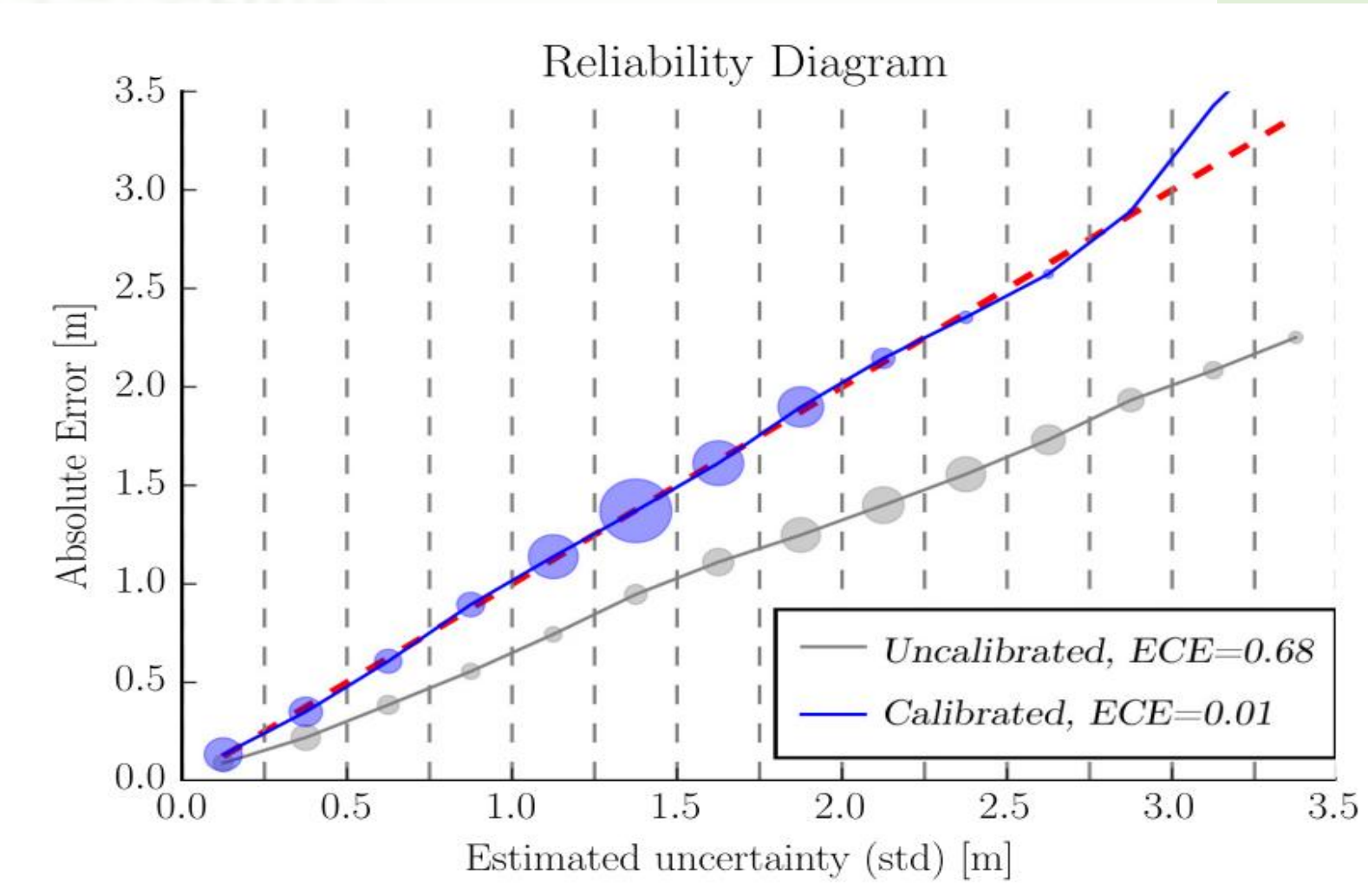
State of the art

Transferability

Estimated canopy height map of a large area in Switzerland next to high-resolution RGB image →
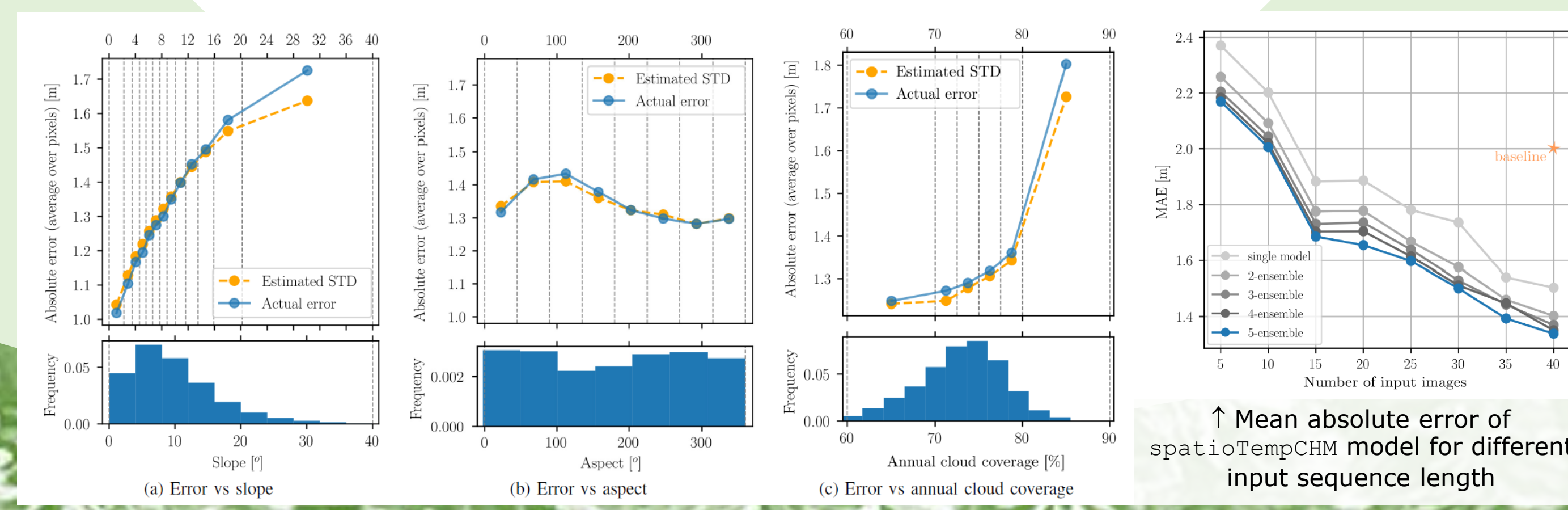

Calibrated Uncertainty Quantification

Robustness

Reliability diagram using 6-ensemble spatioTempCHM model, before (uncalibrated) and after (calibrated) isotonic regression calibration technique.
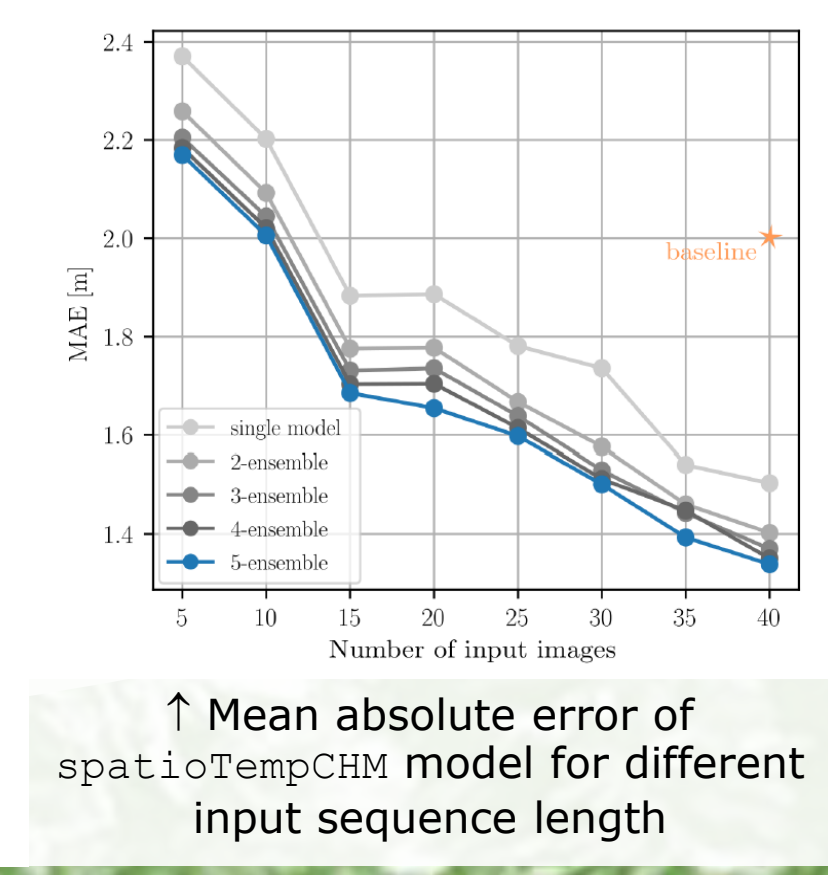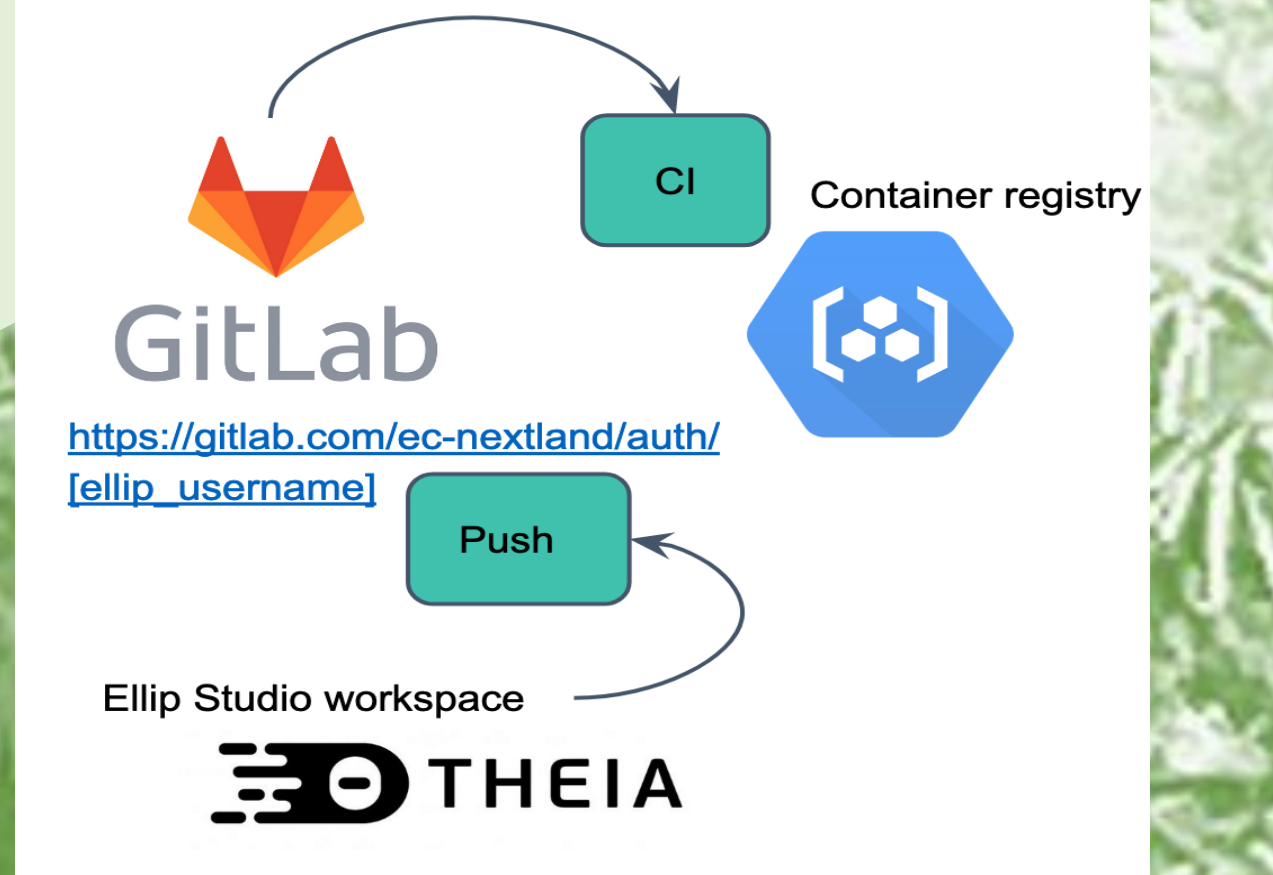

Reliability Diagram
- Uncalibrated, ECE=0.68
- Calibrated, ECE=0.01

Service integration

Integrated and compatible with operational service platforms

OGC Best Practice for Earth Observation Application Package

https://gitlab.com/ec-nextland/auth/[ellip_username]

Ellip Studio workspace

Influence of topography & cloudiness factors

(a) Error vs slope

(b) Error vs aspect

(c) Error vs annual cloud coverage

↑ Mean absolute error of spatioTempCHM model for different input sequence length

The WQeMS Platform For Inland Surface Water Quality Monitoring: A Collaborative Tool For Drinking Water Managers And Innovators

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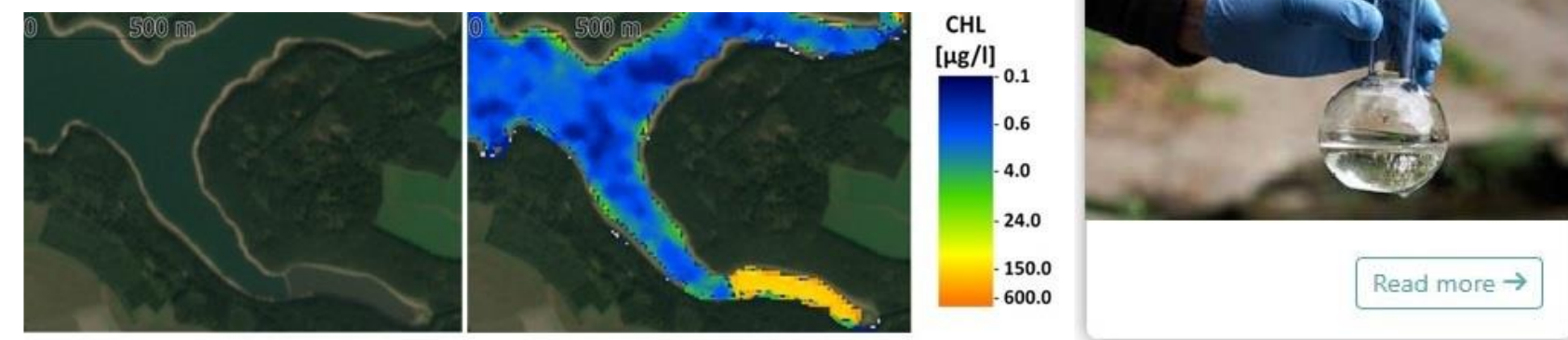imanakos@iti.gr | http://eos.iti.gr
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On behalf of the Consortium

Service Line 1: Water Quality Features

CHL [μg/l]
0.1
0.6
4.0
24.0
150.0
600.0

True Colour Image and **Chlorophyll-a** WQeMS service product, derived from Sentinel-2 data (19-09-2018). The pre-reservoir with the high Chlorophyll values is easily identified, consistently with its collector function; thus, reducing the Chlorophyll content in the actual reservoir (Saidenbach area in Germany).
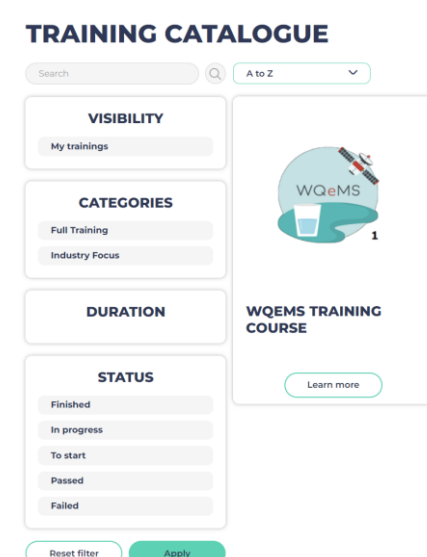
Service Line 3: Land Water transition zone change detection
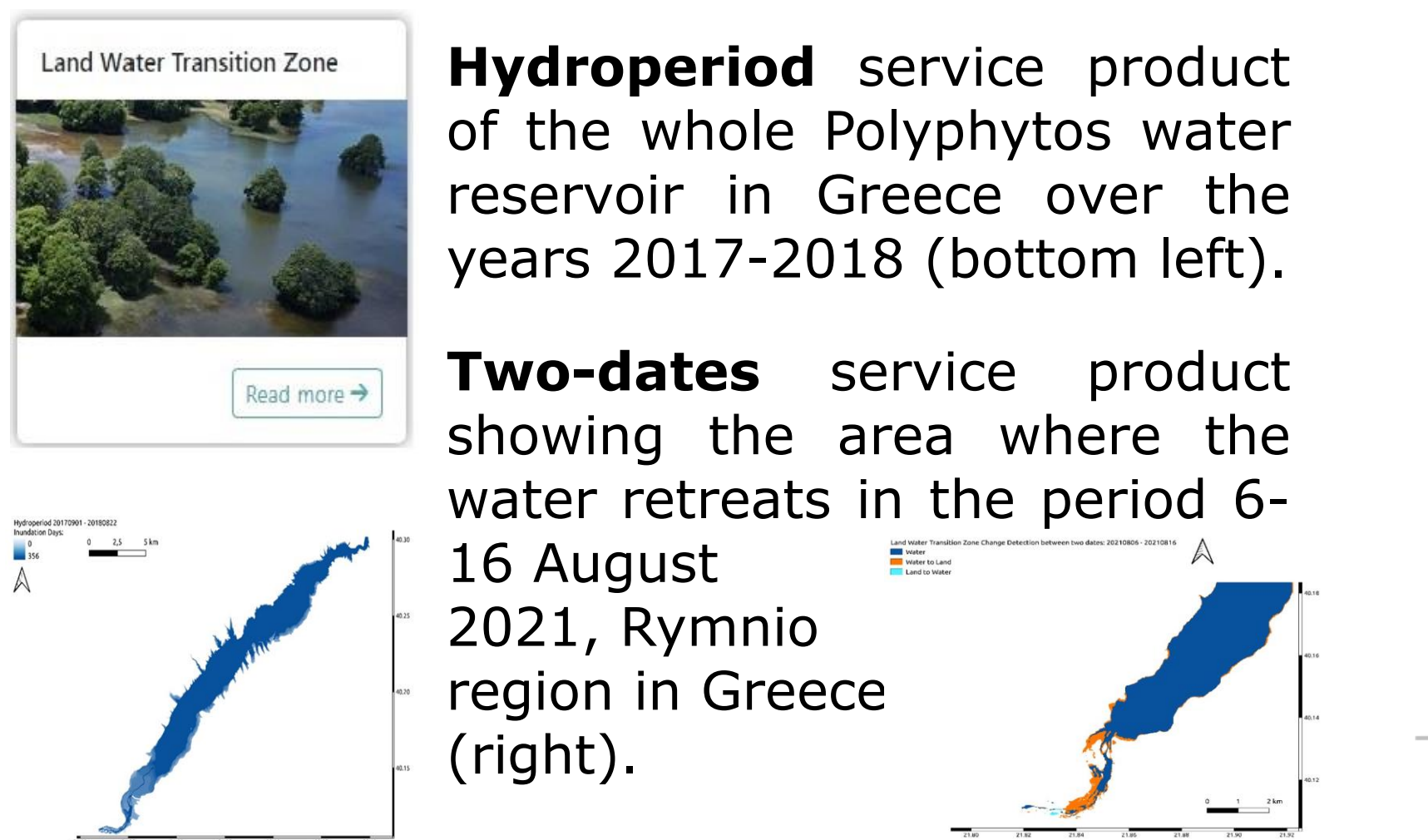
Hydroperiod service product of the whole Polyphytos water reservoir in Greece over the years 2017-2018 (bottom left).
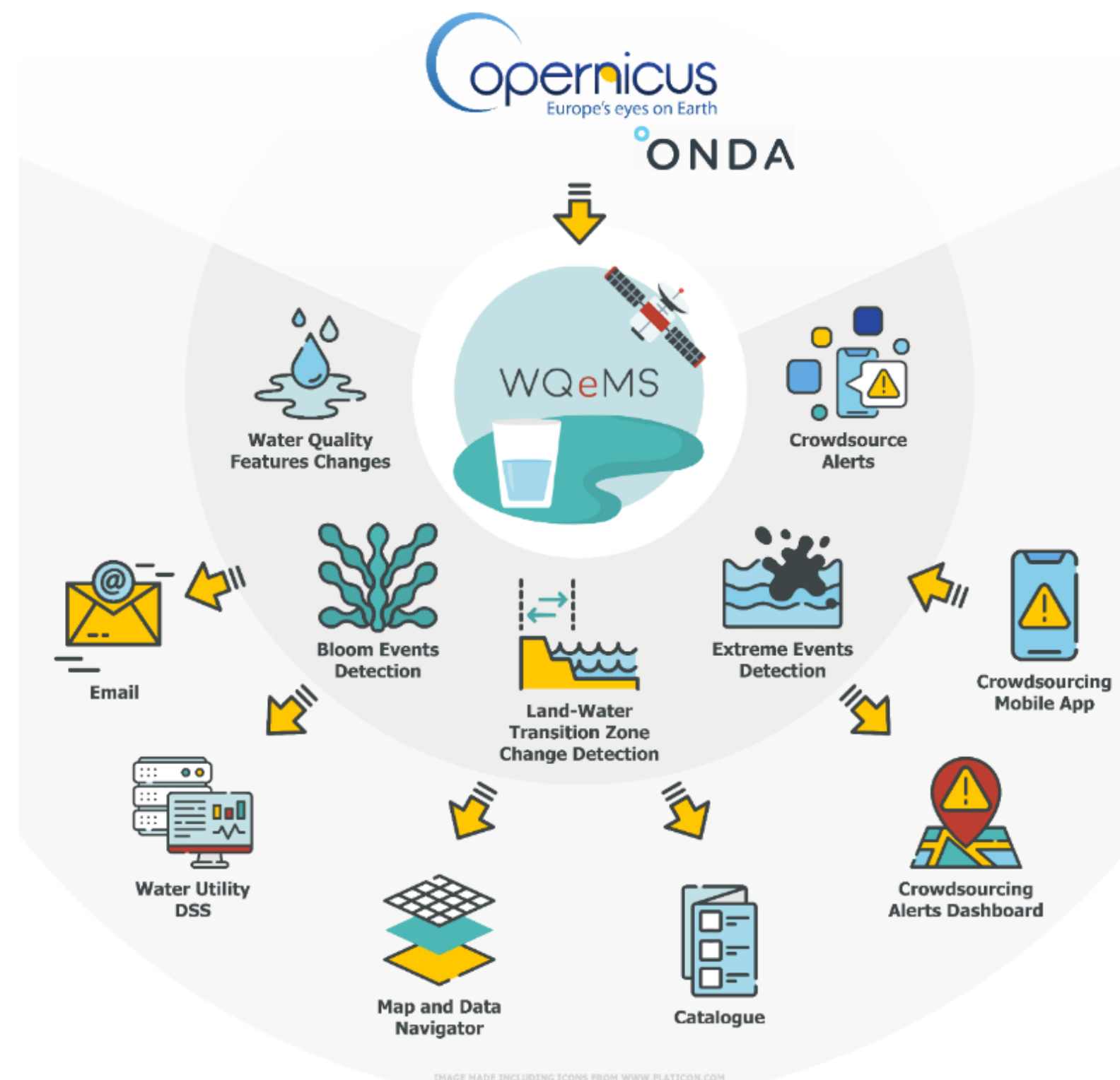
Two-dates service product showing the area where the water retreats in the period 6-16 August 2021, Rymnio region in Greece (right).
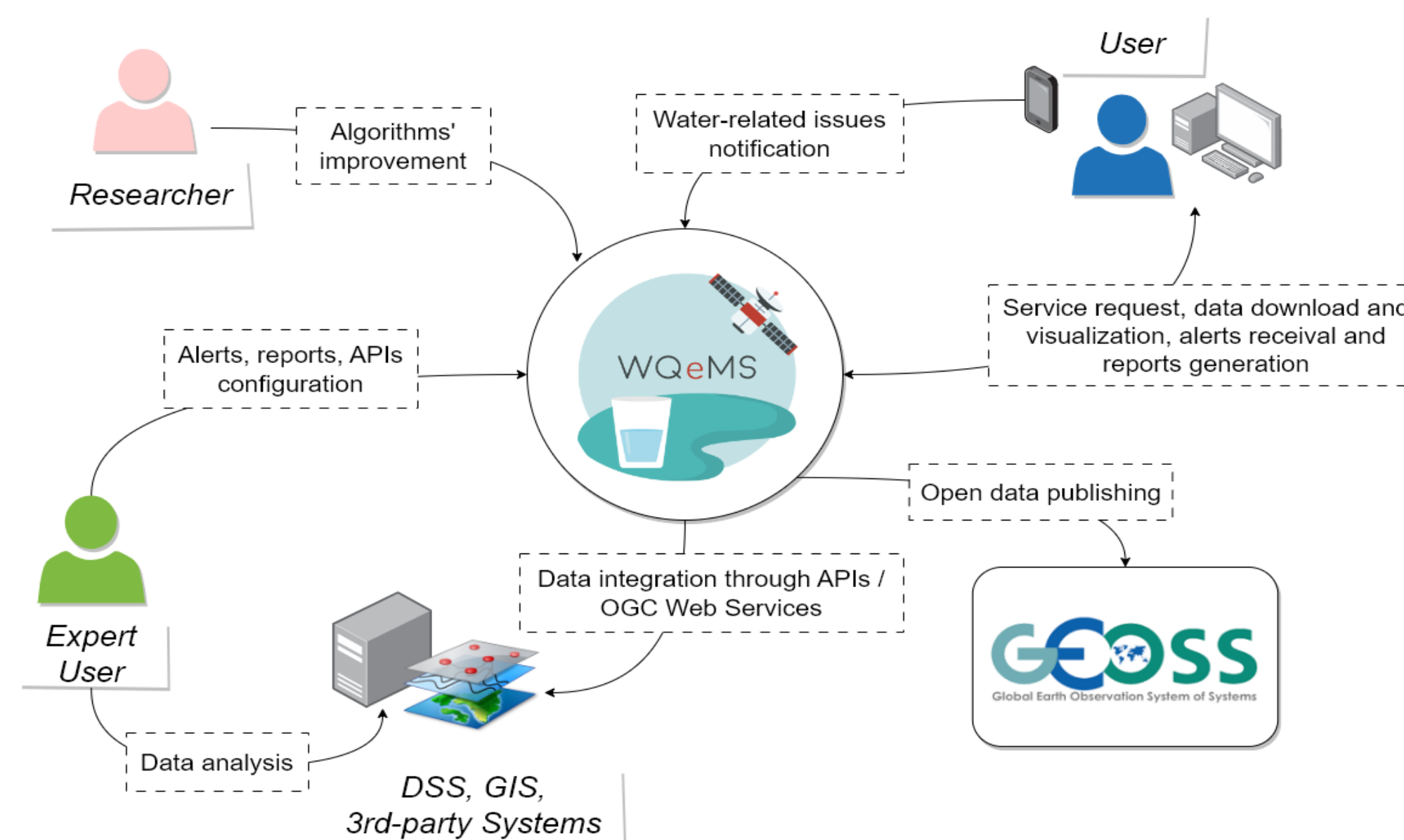
Capacity Building

Water professionals and water utilities can acquire the necessary skills and competencies related to the operation and content interpretation of the developed WQeMS services.

WQeMS provides an inland open surface Water Quality Emergency Monitoring Service (WQeMS) to the water utilities' industry leveraging on the Copernicus products and services.

WQeMS Concept & Actors

Service Line 2: Bloom events detection

Azud de Ojós, Spain
2020-08-28, Sentinel-2 ESA 2021
2020-08-26, WorldView-3 MAXAR Technologies 2021
2020-08-26, WorldView-3 MAXAR Technologies 2021

HAB indicator
no HAB (prob. 0%)
HAB unlikely (prob. 20%)
HAB likely (prob. 50%)
HAB very likely (prob. >50%)

Comparison of the **Harmful Algal Bloom** (HAB) **Indicator**, derived from Sentinel-2 data (left) and WorldView-3 imagery, Azud de Ojós area in Spain (right).
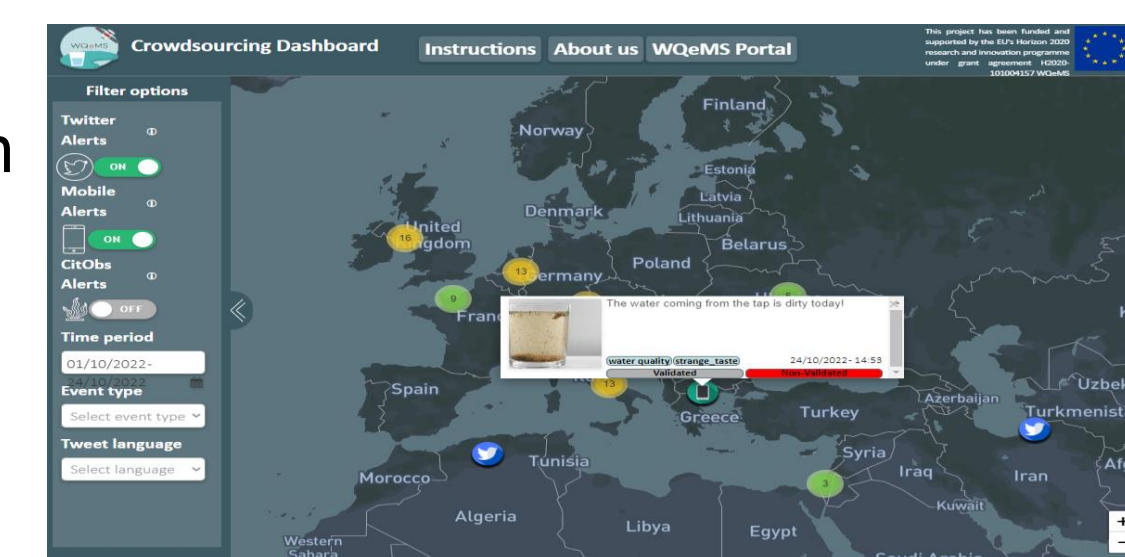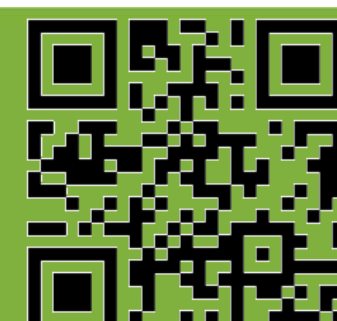
Service Line 4: Extreme events detection
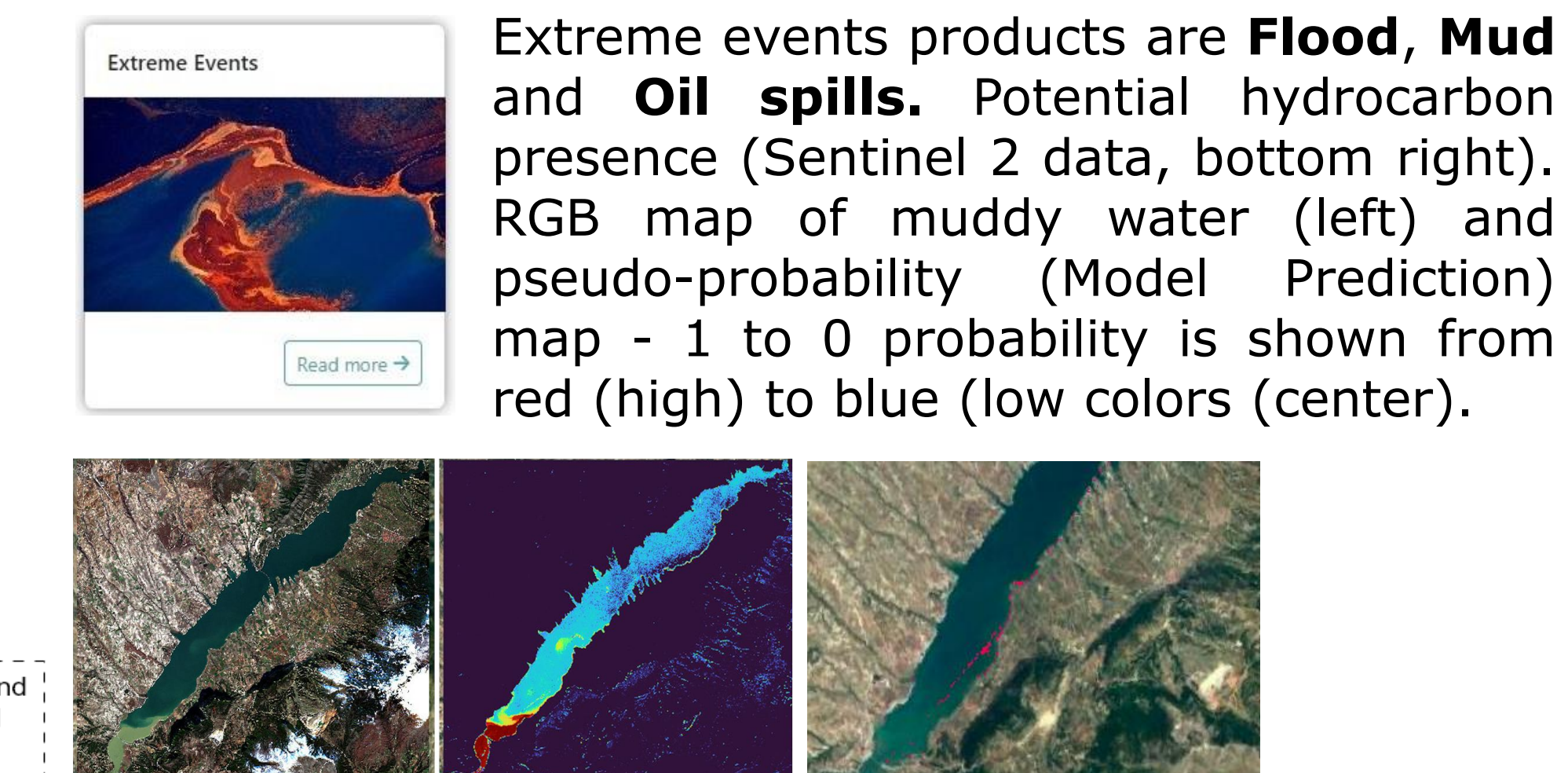
Extreme events products are **Flood**, **Mud** and **Oil spills.** Potential hydrocarbon presence (Sentinel 2 data, bottom right). RGB map of muddy water (left) and pseudo-probability (Model Prediction) map - 1 to 0 probability is shown from red (high) to blue (low colors (center).
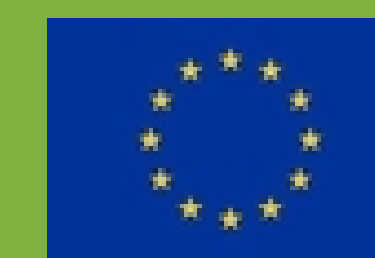
Crowdsourced Data Dashboard

Alerts are retrieved from the alerting module and visualized in the dashboard map as popups (right).

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https://wqems.eu/