On the synergistic use of SAR and optical imagery to monitor cyanobacteria scum in inland waters

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Rationale:

Global warming and anthropogenic pressures have increased the frequency of algal blooms occurrence in inland water bodies [1]. The algal blooms are an unpleasant sight and hinder various recreational and economic activities. In particular, the increase in the anthropogenic load of nutrients (eutrophication) has led to an increase in the presence of cyanobacteria in the coastal and internal water bodies [2]. A mature flowering of cyanobacteria often emerges on the top of the water surface like a layer of foam, called scum, containing high concentrations of toxins. Contact with these toxins poses a direct health risk for both humans and animals. Therefore, monitoring the concentration of algae and the occurrence of scum in lakes from remote has become a topic of interest for management and science.

Problem:

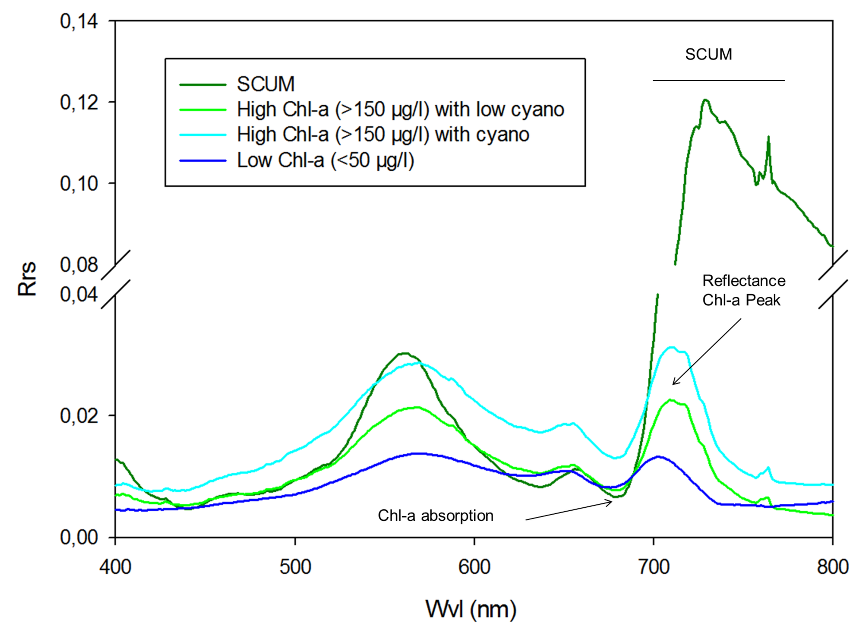
Optical remote sensing is a validated tool for detecting, monitoring and developing methodologies aimed at a better understanding of the state of lakes. However, it is highly hindered by clouds. For regions with frequent cloud cover, this means loss of data, which derails the purpose of sensing. This makes difficult to spatially and temporally characterize scum area for a comprehensive ecological analysis. Combining data obtained using different types of sensors can be an option worth investigating, and a good candidate for this purpose is the synthetic aperture radar (SAR), due to its capacity to collect data independent of cloudy cover [3].

Method:

We use a synergistic approach involving optical and SAR images together with meteorological parameters to monitor algal cyanobacteria blooms in lakes. The satellite images are provided by the Sentinel 1 and 2 satellites. Meteorological parameters come from in situ stations or from the European Centre for Medium-Range Weather Forecasts (ECMWF) database.

With respect to optical data, the scum index was developed using ratio of TOA reflectances in NIR and RED bands exploiting the high difference in backscattering and absorption between water with and without scum.

For S1 imagery, a polarimetric index has been considered because of its ability to identify anomalies on the lakes surface.



$$I_{S1} = \frac{VV - VH}{VV + VH}$$

$$I_{S2} = \frac{b6}{b5}$$

$I_{S2}>1$ ⟶ **SCUM**

$I_{S1}>-0.1$ ⟶ **Anomalies at the water surface**

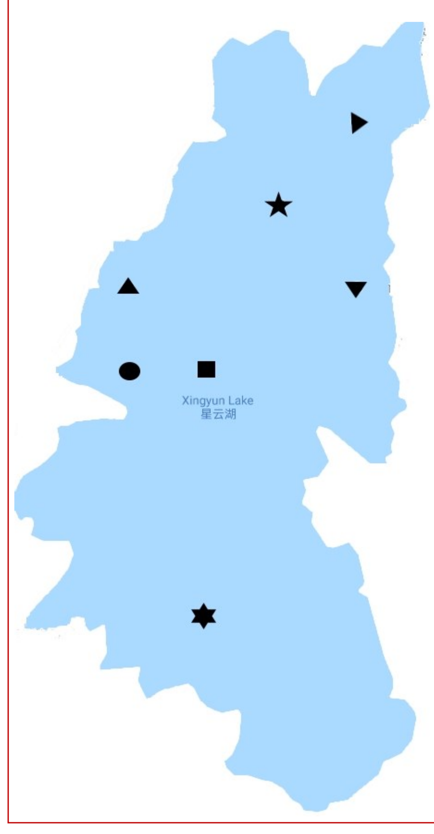
Can I_{S1} be used to detect SCUM?

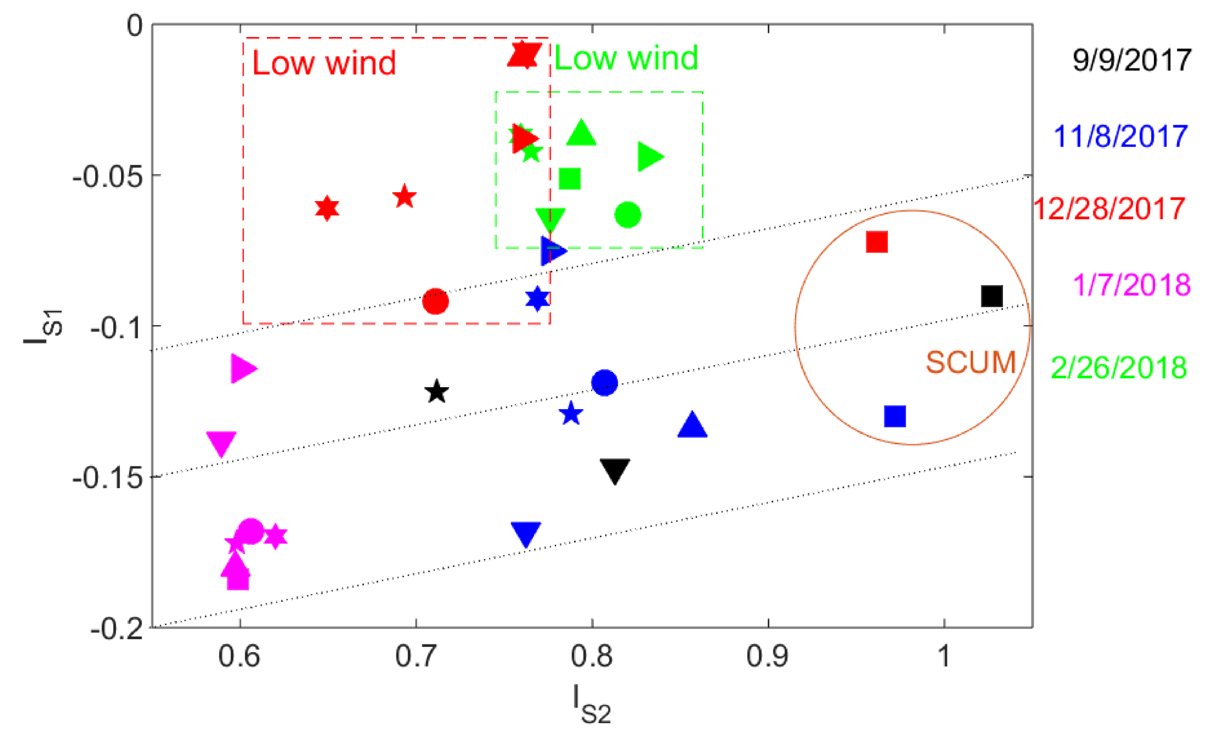
Google Earth Engine tool:

Google Earth Engine is an advanced cloud-based geospatial processing platform, which allows to run algorithms on georeferenced satellite imagery and vectors stored on the Google's infrastructure.

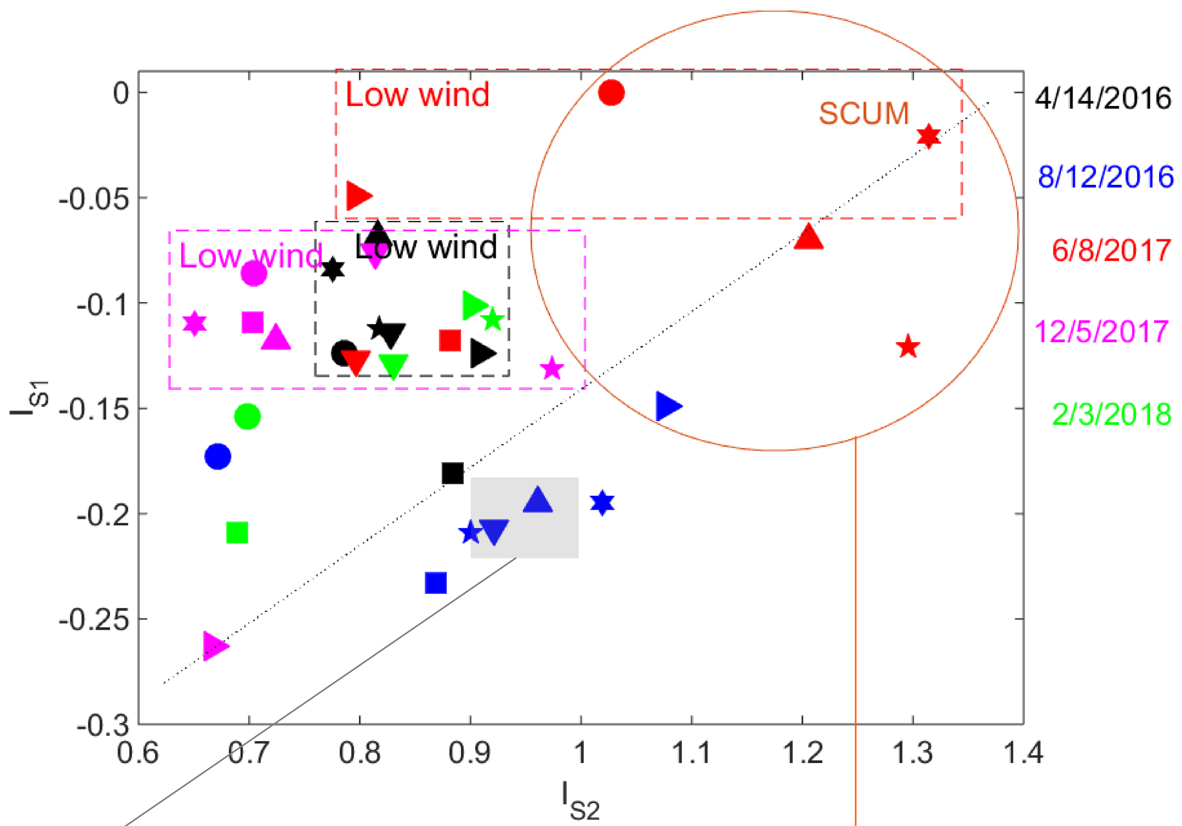
In particular, we have used it to easily perform a time series analysis of the two indexes in order to investigate if some correlation exists.

Xingyun Lake (102.78 E 24.33 N)





Tai Hu Lake



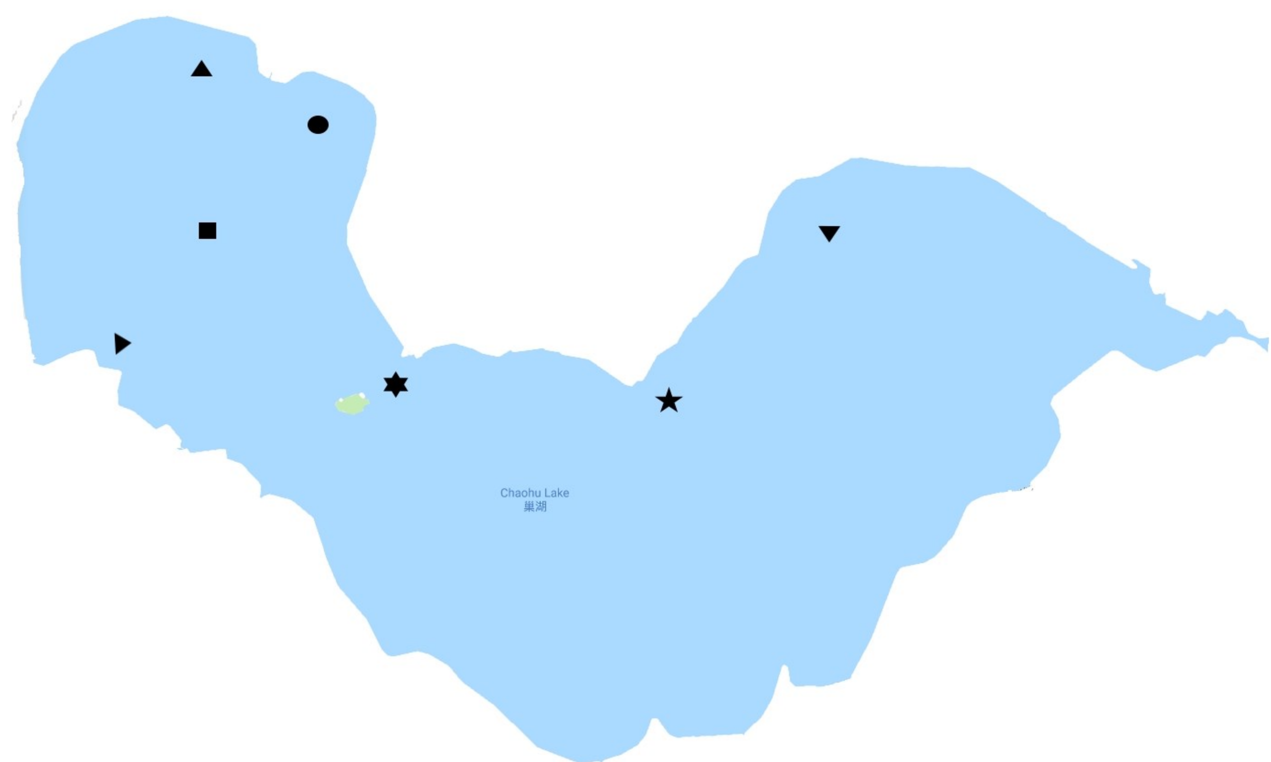
Spatio-Temporal analysis:

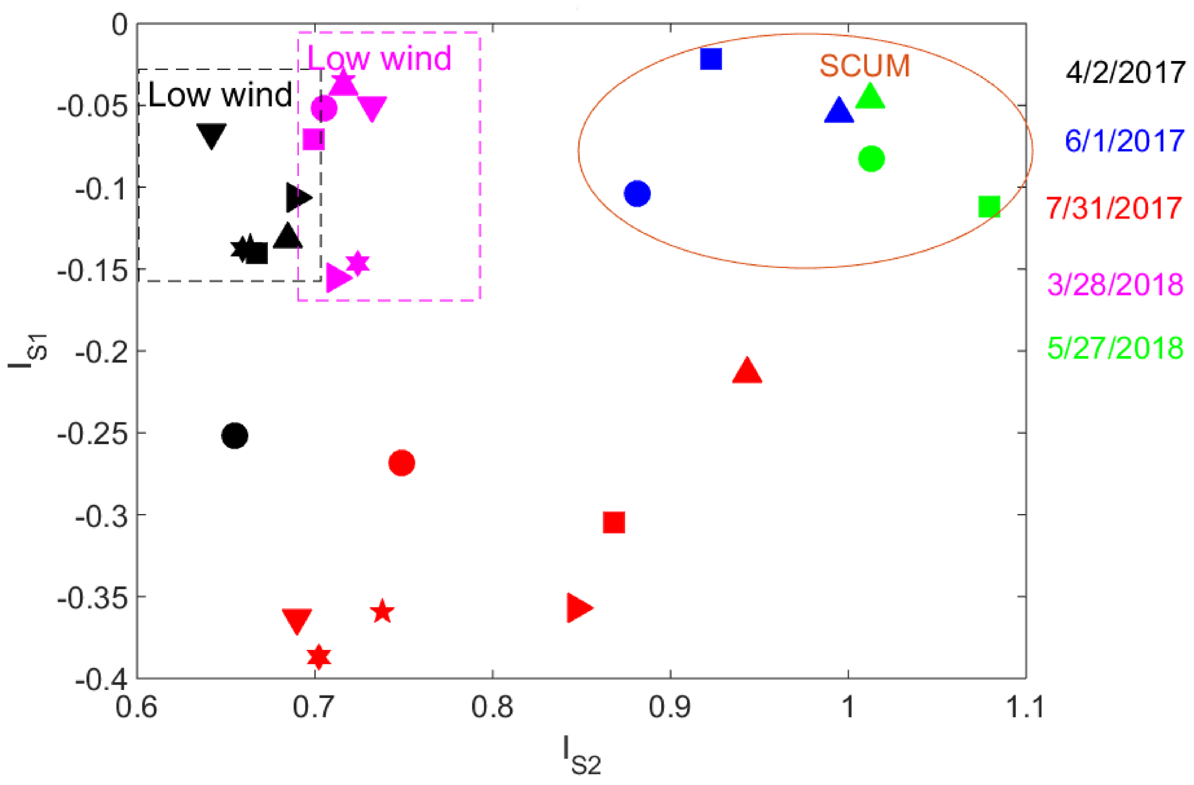
Correlation between the time series of the indices in the neighborhood of a single point.

We consider here only those days in which images from Sentinel 2 and Sentinel 1 are both available. Among these matches we have to exclude the case in which the Sentinel 2 image is cloud cover.

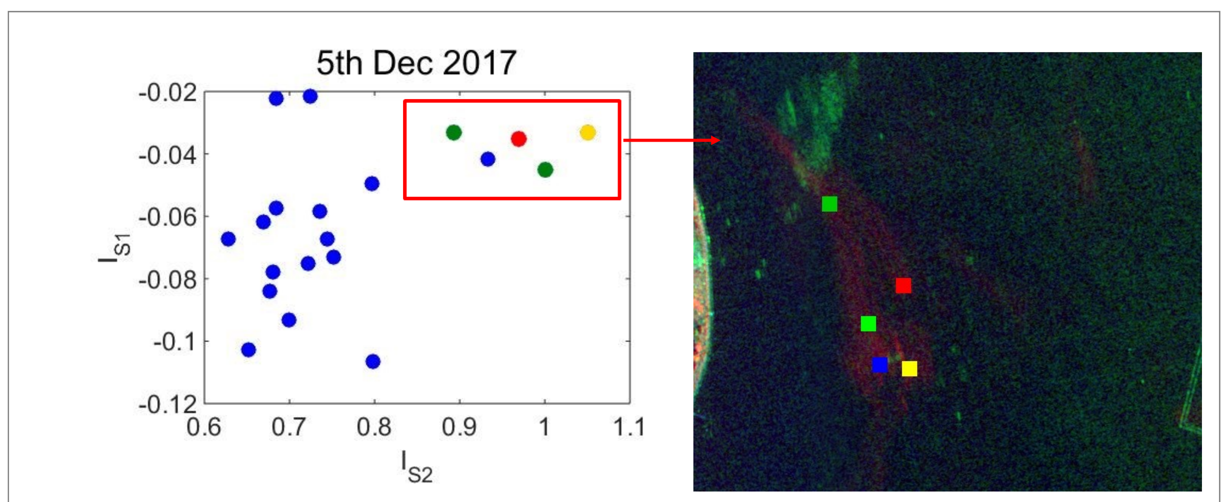
The different coordinates are indicated with different markers. Same dates are signaled with same color.

Chaohu Lake



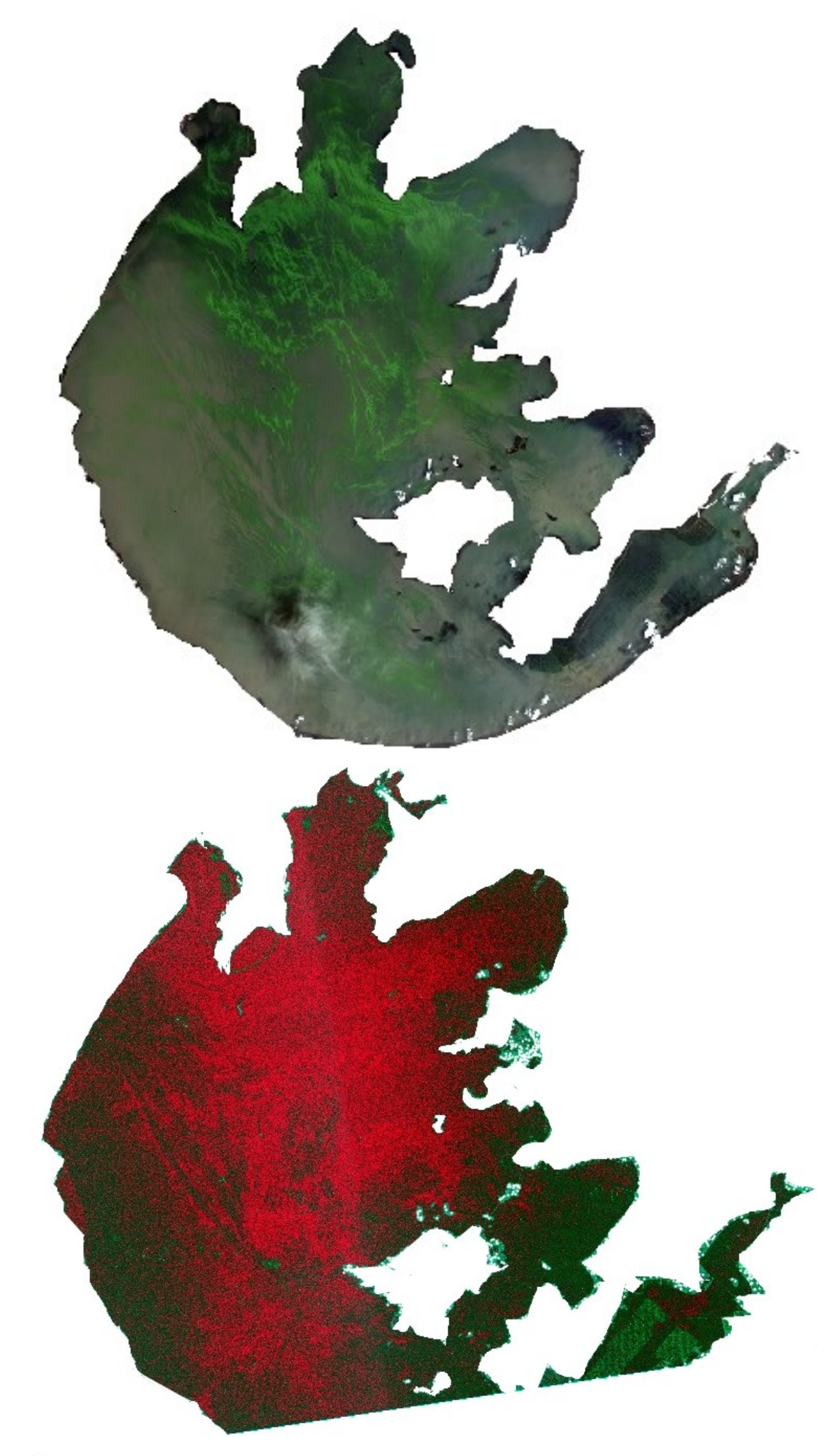


Spatial correlation:



Correlation between I_{S1} and I_{S2} for twenty different regions of interest (ROI) of 400 pixel each. Right panel zoom of the SCUM area (R:I_{S2}, G:VV, B:VH).

Qualitative comparison of Sentinel 2 (true color) and Sentinel 1 (R:I_{S1}, G:VV, B:VH) image of the 8th of June 2017



Concluding remarks:

This preliminary study suggests that the polarimetric index combined with the knowledge of wheatear variables, such as wind speed and the air temperature at 2m height, might reliably detect the occurrences of algal blooms.

A full validation of the method proposed is not trivial: Sentinel 2 and Sentinel 1 are non-synchronous and SCUM phenomena can last only few hours.

We need to find an algorithm to distinguish the other possible causes for the smallness of I_{S1}, such as the presence of ice or oil at the lake surface. In particular, we have shown that low wind condition and presence of SCUM give similar values for I_{S1}. As low wind generally enhances the occurrence of SCUM, it is crucial to find some non-optical information that might help to discriminate such cases.

References:

[1] Paerl & Huisman, Science, 320 (2008)

[2] Sellner et al., J Ind Microbiol Biotechnol, 30 (2003)

[3] Bresciani et al., Remote sensing of environment 146 (2014)

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