Characterising and monitoring phytoplankton properties from satellite data

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Abstract

Harmful Algal Blooms (HABs) pose a great threat to human and animal health, their occurrence also has a significant impact on a variety of socio-economic and environmental factors. HAB events are now a global problem and is expected that the occurrence of HABs is likely to grow significantly with the increase in human population coupled with climate change. This study will draw on satellite sensors which differ in spatial, spectral, and temporal resolution: Sentinel-2 MSI, Sentinel-3 OLCI. The objectives of this study are to develop and validate HAB detection algorithms for near-shore and coastal waters, with better generalisation capability and lower computational overload that could improve the identification of the optical characteristics directly associated with phytoplankton properties. This research will be focused on four optically diverse regions of interest; The Danube Delta and Black Sea Coastline (Romania), Galician Coast (NW Spain), Shandong Peninsula Coast (China) and the Northern-South China Sea (China). Here, we will present results from the Galician coast. We used in-situ data such as hyperspectral Remote Sensing Reflectance, Chlorophyll-a concentration, phytoplankton abundance and taxonomy, along with fractionated chlorophyll-a and particle absorption properties to gain an understanding of the optical properties directly associated with *Alexandrium minutm*. We focus on the detection of *Alexandrium minutum* from Sentinel-2 MSI and Sentinel-3 OLCI data. We tested different atmospheric correction models against in-situ hyperspectral data and evaluated their performance over coastal waters. We will present results on the optical characteristics of A. *minutum* and the potential of MSI and OLCI for their remote detection.

Atmospheric correction (AC)

- Tested and validated 3 open-source AC algorithms (C2RCC, Polymer and Acolite) (Fig 1)
- Hyperspectral R_{rs} obtained in Vigo during 3 campaigns during 2016, 2018 and 2019 were used to validate the 3 models (Fig 3).
- A total of n = 40 match-ups were obtained (3x3 widow all valid pixels)
- C2RCC has the lowest MAPD and bias across all bands followed by Polymer and then Acolite (Fig 1)
- All AC models had trouble correcting in areas near the shoreline (Fig 2), likely due to the adjacency effect

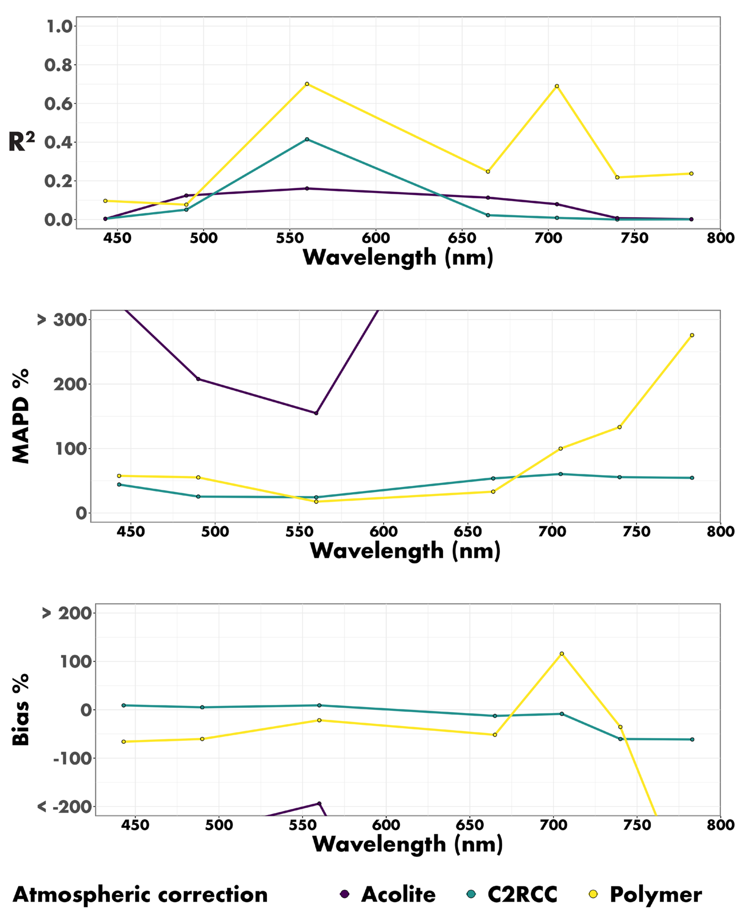


Fig 1. Performance metrics of the 3 AC models across each band

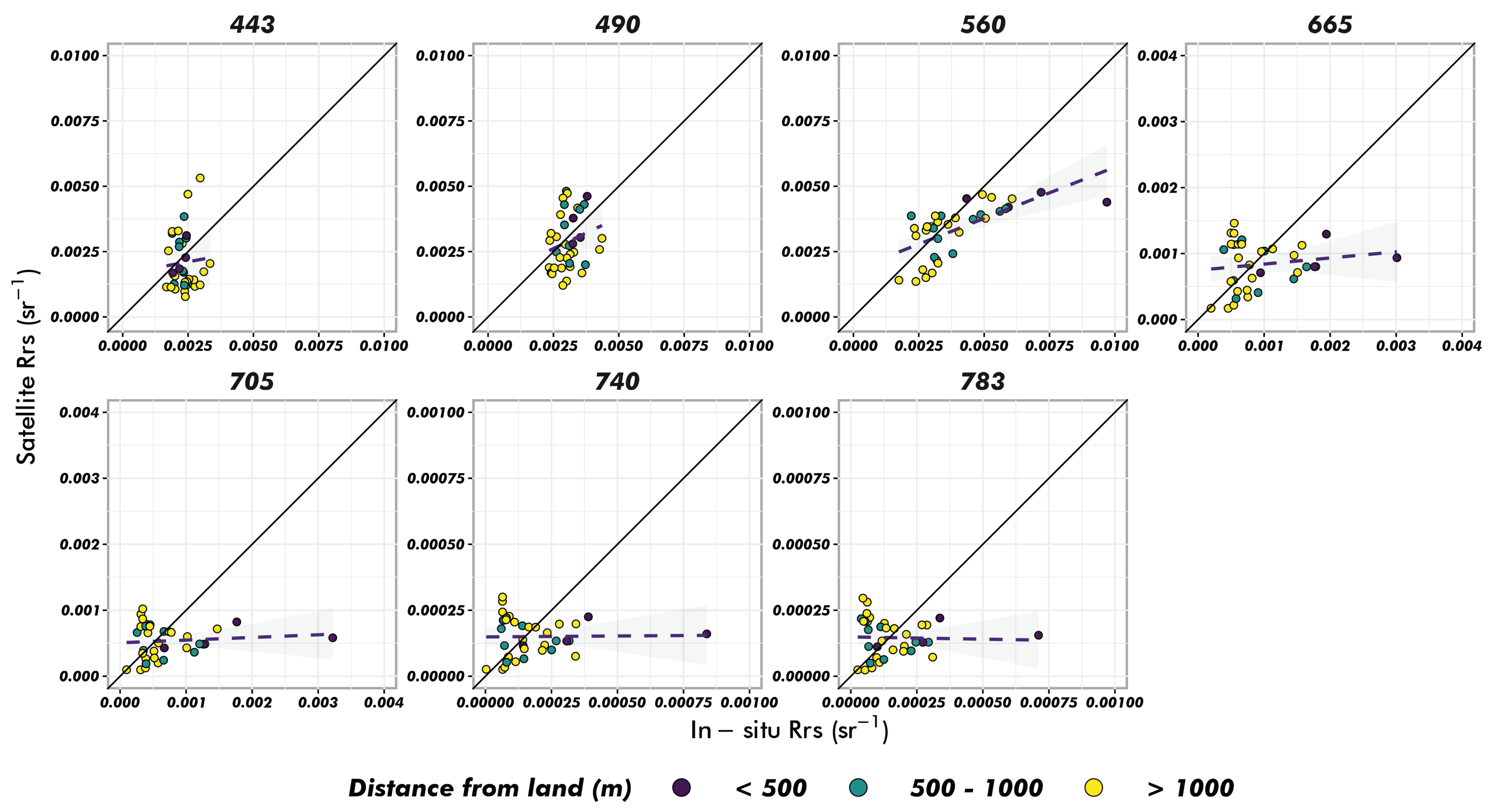


Fig 2. Scatter plots showing matchup points between in-situ and C2RCC AC model

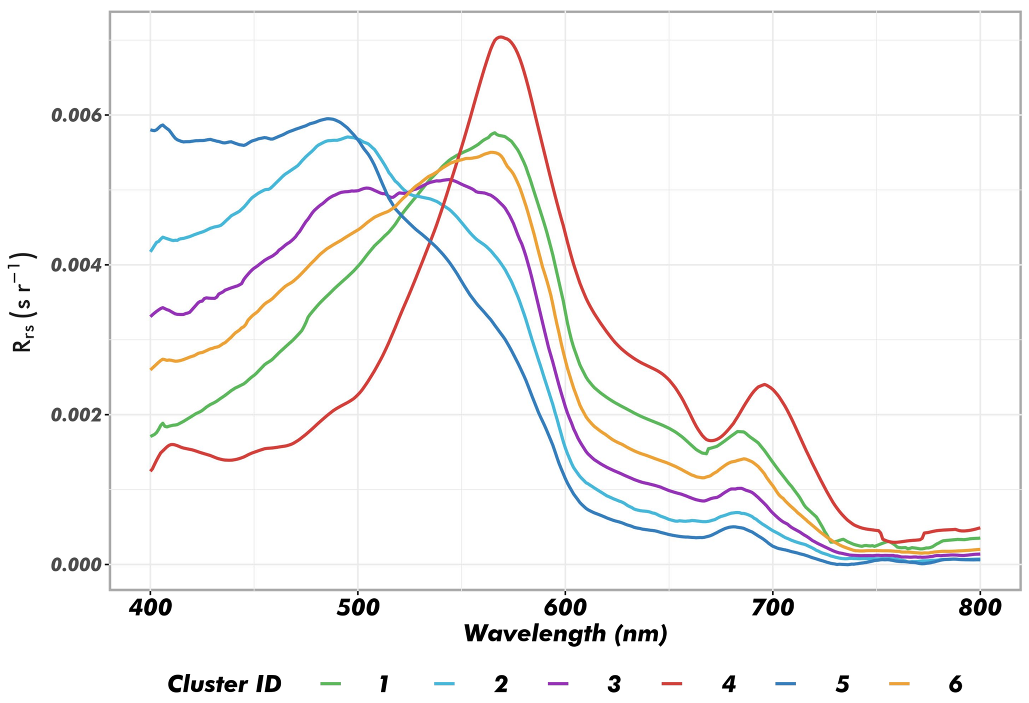


Fig 4. Cluster medians of the in-situ R_{rs}

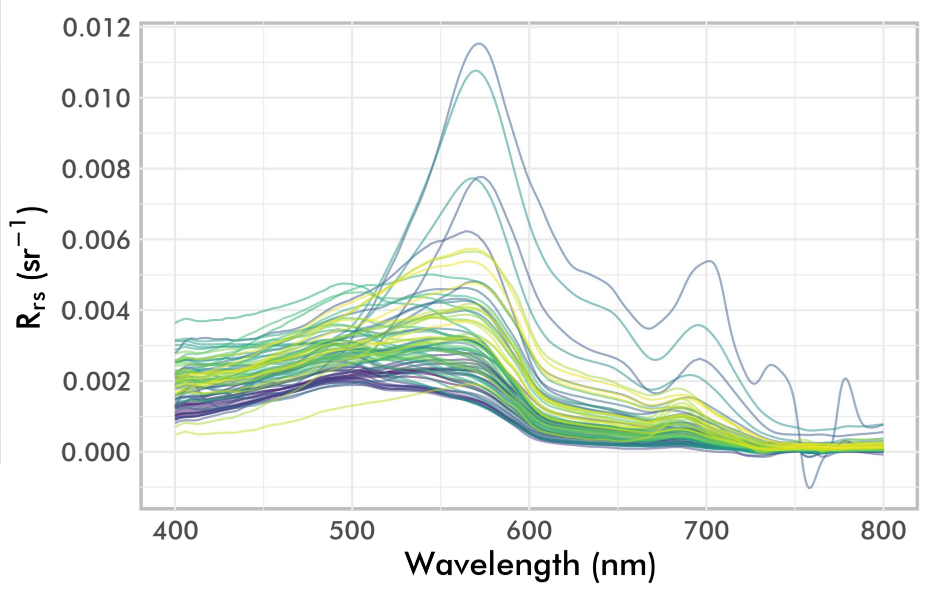


Fig 3. In-situ R_{rs} used in clustering

Proposed methodology

- The Reflectance signature of *A.minutum* is highly dependent on many factors, e.g., Cell abundance and other in-water constituents. Thus, it is difficult for algorithms to capture the full dynamic range that it may present.
- We used an unsupervised clustering algorithm (c-means) to cluster hyperspectral R_{rs} in to 6 optically distinct clusters (Fig 4), k = 6 was determined to be the optimal number of clusters (results not shown).
- Proposed method will be a 2 step approach:
  - Classify pixels based on the spectral means of the 6 clusters
  - Develop further algorithms to separate *A.minutum* from diatom/ mixed waters in other clusters

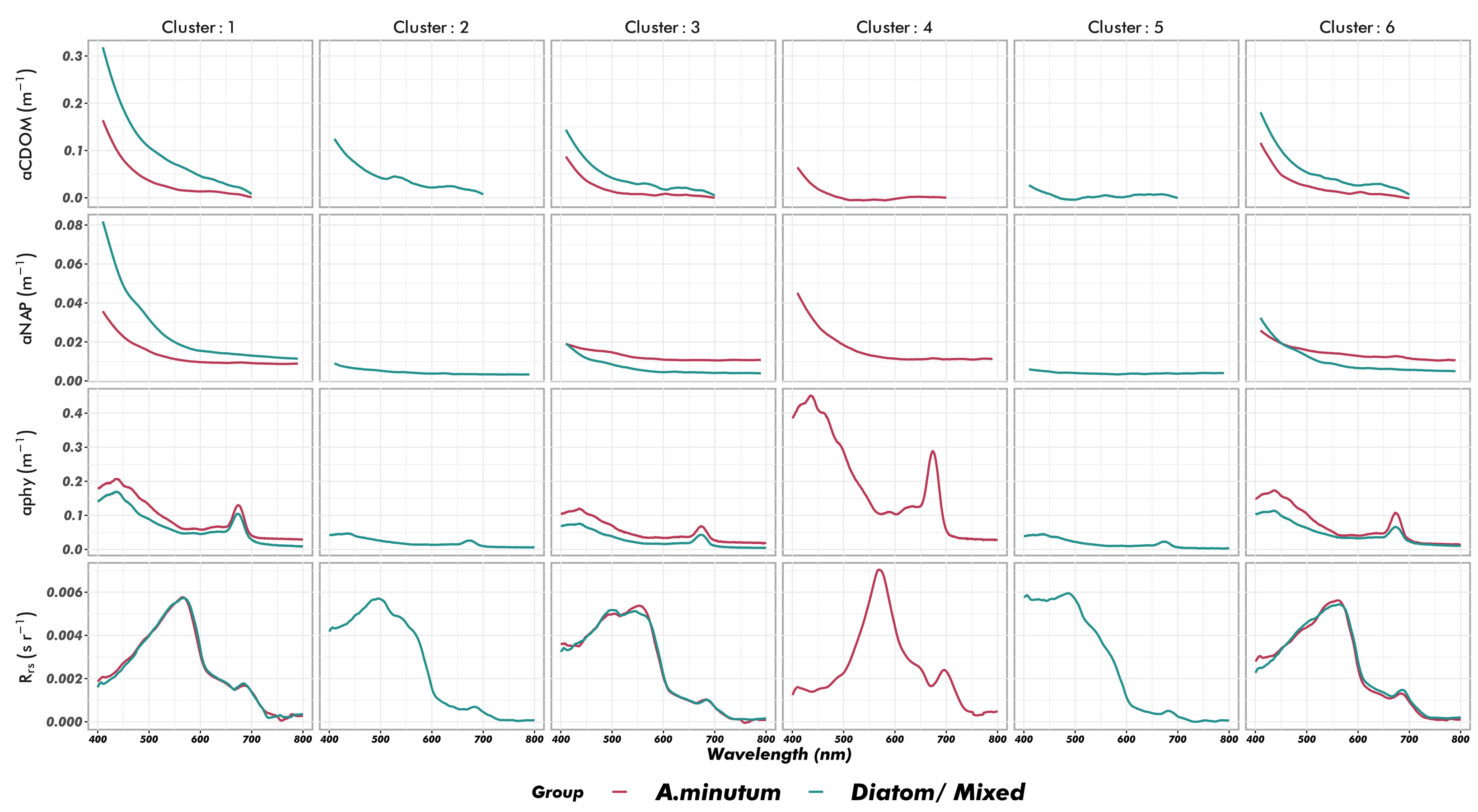


Fig 5. Cluster medians by group of the AOPs and IOPs

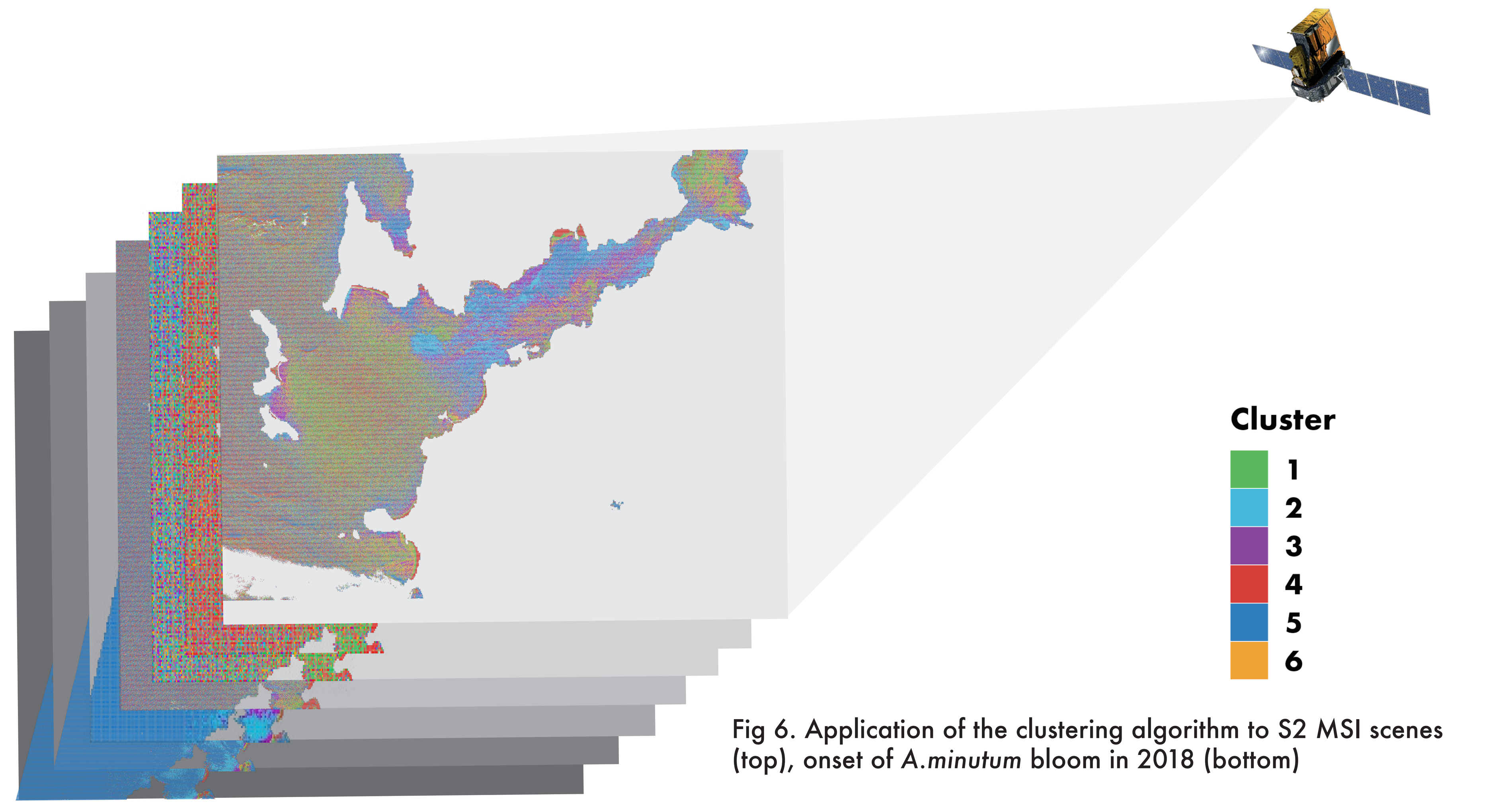
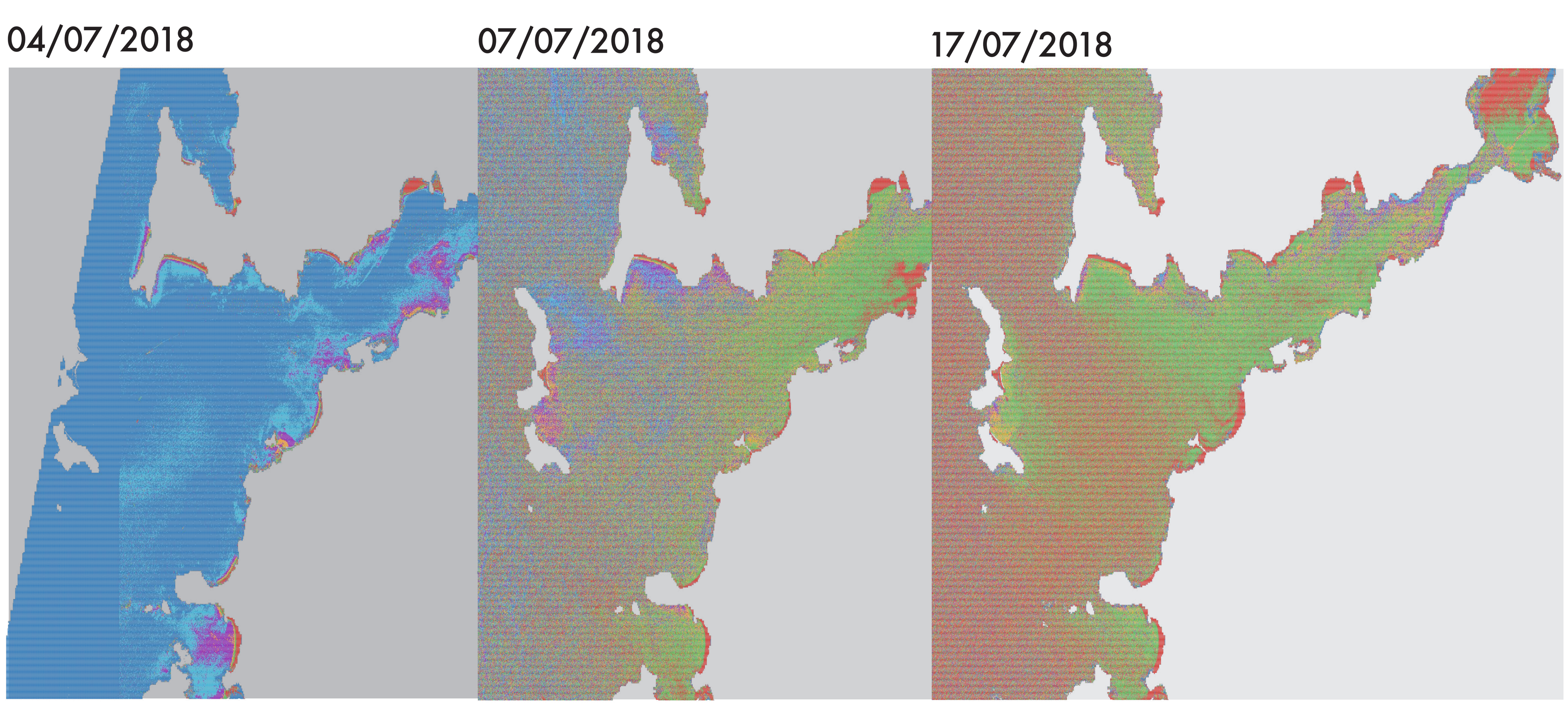


Fig 6. Application of the clustering algorithm to S2 MSI scenes (top), onset of *A.minutum* bloom in 2018 (bottom)

Preliminary results and application

- Cluster 4 was separated well from the other water types, this cluster has extremely high concentrations of *A.minutum* (10^5 – 10^7 cells/ L)
- Clusters 1 and 3 have *A.minutum* counts > 10^4 (considered a bloom) but occur along with diatom/ mixed waters with similar Chla/ TSM (data not shown)
- Cluster 6 contains high concentrations of *A.minutm* (10^5 cells/ L) but it is not the dominant algae present, therefore not dominating the optical signal (data not shown)
- Fig 6 highlights the potential onset of a major *A.minutum* bloom which occurred in July 2018, which is consistent with in-situ cell count data (not shown here), with cell counts reaching 10^7 cells/ L



Next steps

- Development of new *A. minutum* detection algorithms (within clusters)
- Explore the potential use of Sentinel-3 OLCI to detect *A.minutum* blooms in Vigo
- Validate results with in-situ measurements and apply to new study area(s) with similar IOPs