Vertical distributions of blooming cyanobacteria populations in a freshwater lake from LIDAR observations

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Abstract

In August of 2014, we measured the vertical profiles of environmental and optical properties, and cyanobacteria cell counts from digital holographic imaging in western Lake Erie. An aircraft-borne LIDAR system was also flown over the region during the same time period. These combined data provide a unique view into the natural variations in distribution patterns of cyanobacteria and resulting impacts on the light field critical to remote sensing detection and associated interpretations.

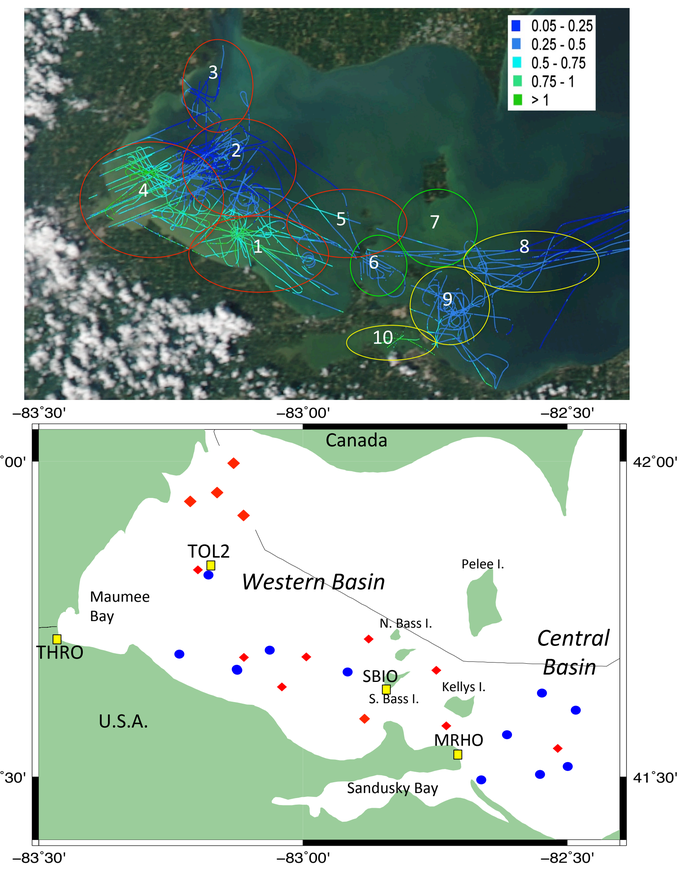
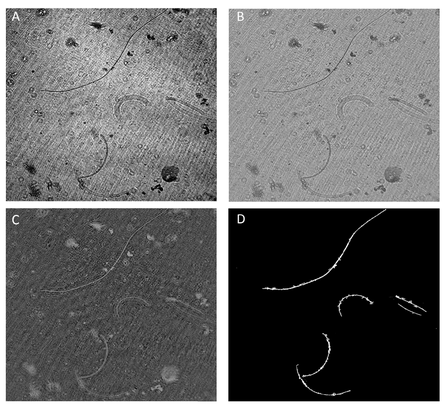


Figure 1. Top: Map of LIDAR flight tracks in August, 2014. Sub-regions 1 − 10 identified based on geography/hydrography; colors indicate basin: red - western basin; green - transition region; yellow - central basin. Bottom: locations of discrete stations; blue points contain above-water R_{rs} and IOP profiles; red points also include HOLOCAM profiles; yellow squares: wind stations.

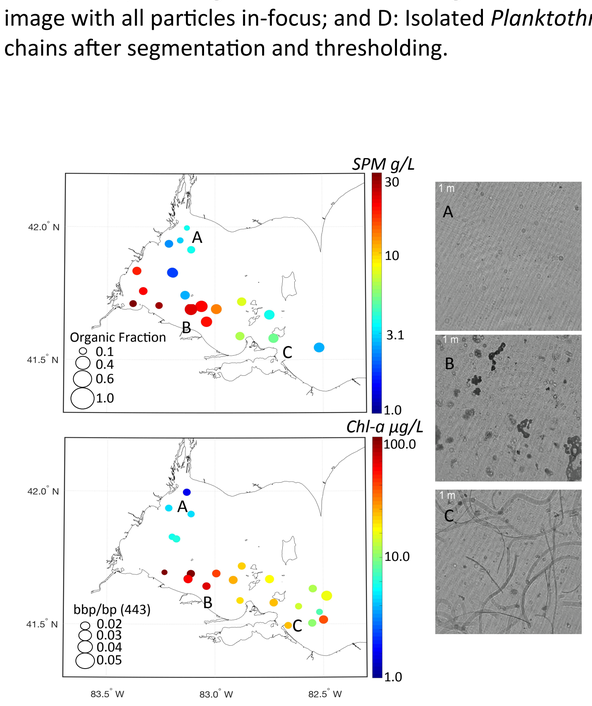
Data

- Over 50 LIDAR tracks flown between Aug. 17-28, 2014 (Figure 1).
- 23 stations were measured for profiles of IOPs using Wet Labs ac-9,bb-3, and Seabird CTD.
- 13 stations co-measured with profiling digital holographic system (HOLOCAM).
- 13 stations measured for HPLC pigments.
- Above-water radiometry measured with an ASD.

Holography



Identifying and Counting cells: A: sample raw hologram with *Planktothrix*; B: Background-subtracted hologram; C: Post-recon image with all particles in-focus; and D: Isolated *Planktothrix* chains after segmentation and thresholding.



Discrete surface SPM and *Chl-a* across the study area. Size of circles in top left proportional to organic fraction of SPM; Right panels show HOLOCAM frame shots from three different areas.

Area 1 – Western Basin

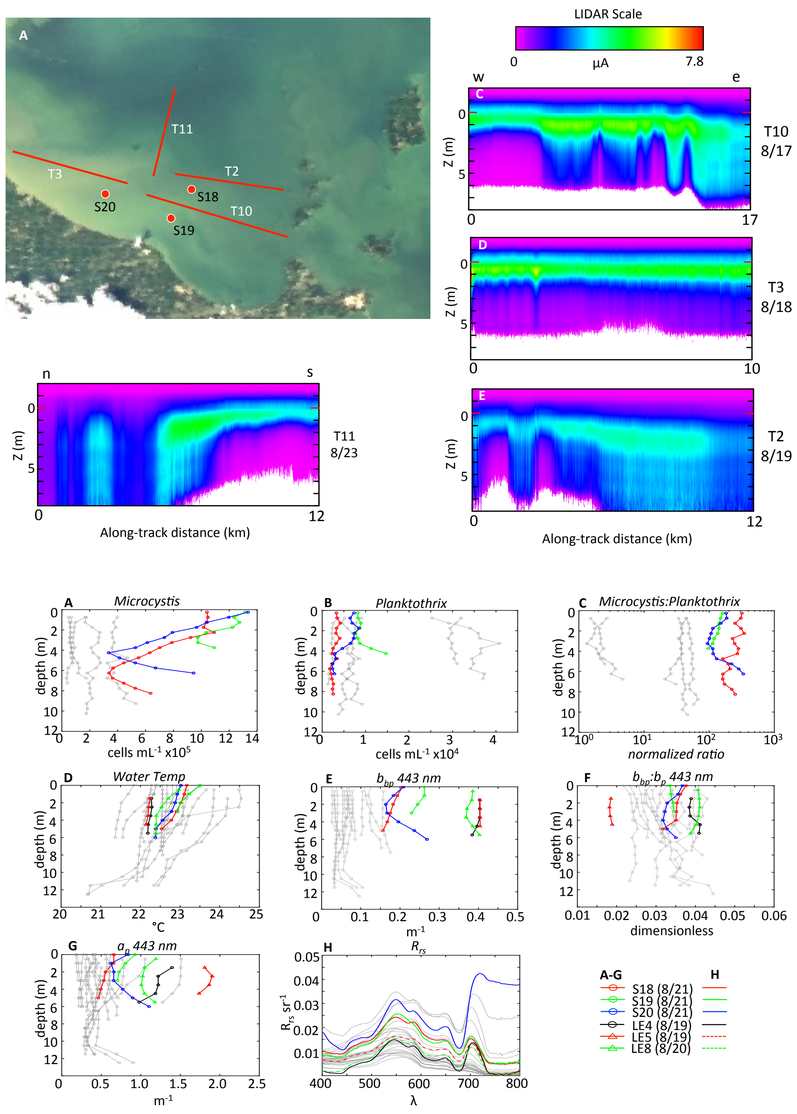
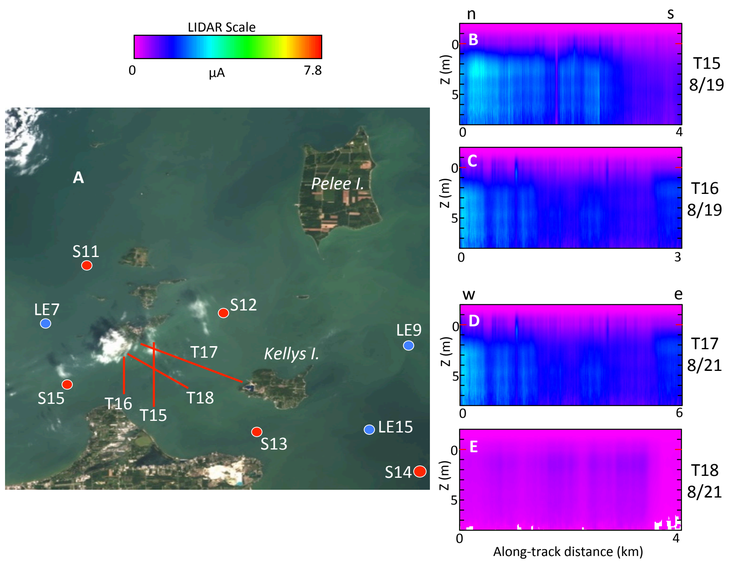


Figure 2. Top: Echograms from LIDAR tracks in the western basin. Colors indicate intensity of particle concentration. Bottom: vertical profiles of IOPs and cell counts from the HOLCOCAM. This region was dominated by dense, *Microcystis* populations in the near surface waters with pronounced Rrs features.

Some Results

- *Microcystis* populations dominated the western basin, concentrated in the upper 2-3 m near the surface (Figure 2).
- *Planktothrix* were dominant in the central basin and the island region, and were lower in concentration and more distributed vertically (Figures 3 and 4).
- Zeaxanthin:*Chl-a* higher in *Planktothrix*-dominated waters, indicating more photoprotection (Figure 5).
- Depth of *Planktothrix* maxima varied with light attenuation: maxima was deeper in water with lower attenuation (clearer waters) (Figure 5).
- In mixed populations, depth of *Planktothrix* maxima was closer to the surface, shielded from light in part by surface *Microcystis* populations.
- These distributions drive IOP variations and associated R_{rs} (Figures 2-4).

Area 6 – Southern Island Region



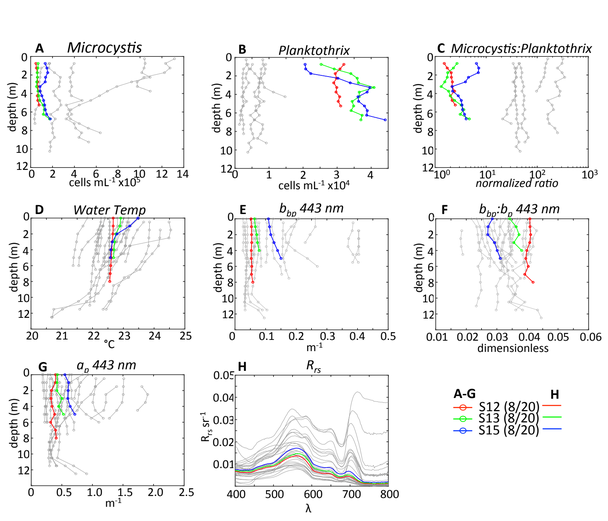
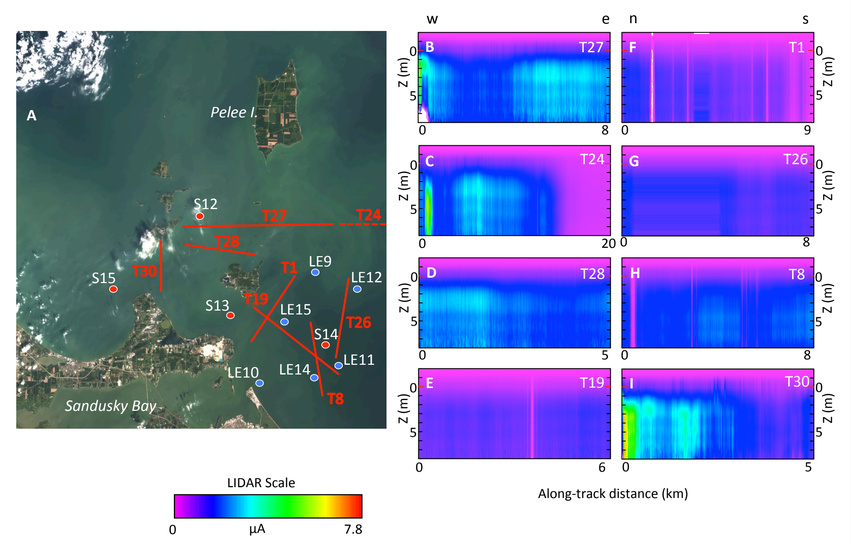


Figure 3. Top: Echograms from LIDAR tracks in the island region. Colors indicate intensity of particle concentration. Bottom: vertical profiles of IOPs and cell counts from the HOLCOCAM. This region was transitional with depth variations between *Planktothrix* and *Microcystis* populations, with moderate R_{rs} features.

Area 9 – Central Basin



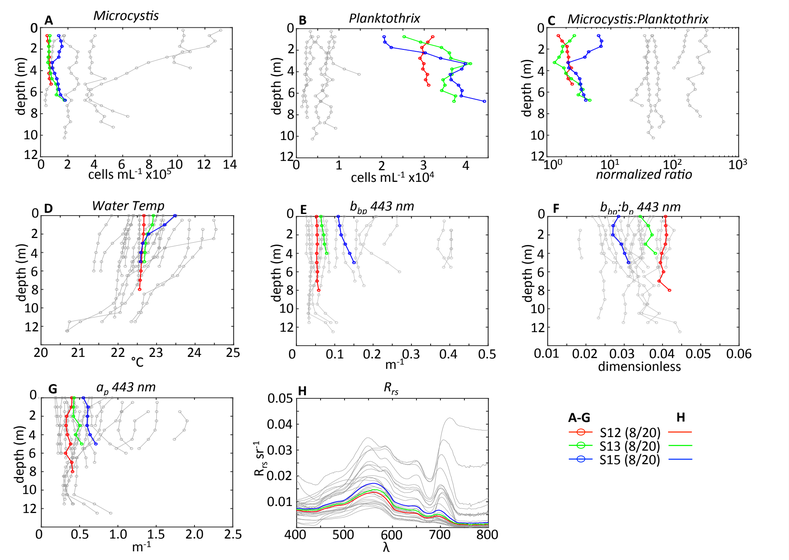
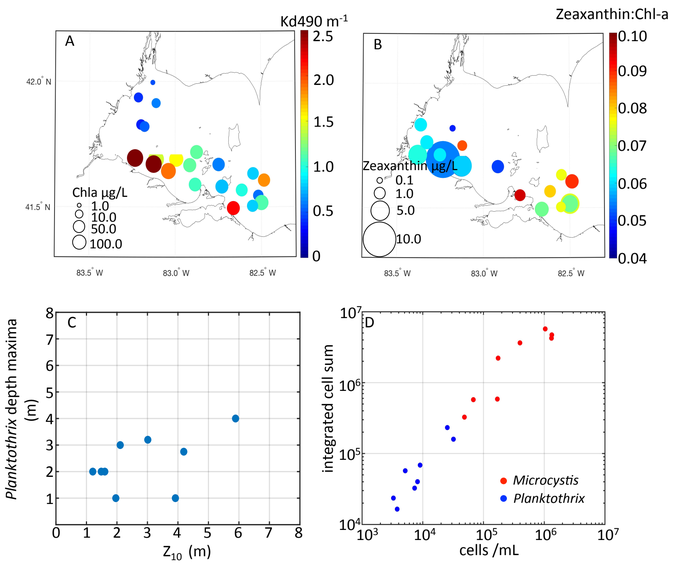


Figure 4. Top: Echograms from LIDAR tracks in the central basin. Colors indicate intensity of particle concentration. Bottom: vertical profiles of IOPs and cell counts from the HOLCOCAM. This region was dominated by distributed, *Planktothrix* populations in the near surface waters with weak R_{rs} features.



A: Map of *Chl-a* (circle size) color-coded by the attenuation coefficient at 490 nm (Kd490); B: Map of zeaxanthin (circle size) color-coded by the ratio of zeaxanthin to *Chl-a*; C: depth of *Planktothrix* maximum cell count versus optical depth; D: column-integrated cell counts for *Microcystis* and *Planktothrix* versus surface cell count.

Conclusions

- *Microcystis* populations were consistently nearer to the surface relative to *Planktothrix*, when either both are present or separate.
- These distributions were related to light intensity in the water column and known tolerances and/or preferences for each genus.
- Differential buoyancy regulation of vertical position permitted co-existence through niche partitioning.
- Remote sensing reflectance is strongly impacted (enhanced) by the backscatter efficiency of the gas vacuoles in cells, but ultimately is governed by the vertical distributions of cells/ colonies associated with ecological preferences.

If you get confused listen to the music play

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