

# Life Under the Ice

## Complex Patterns of Microbial Colonies in Antarctica



Allison Peng, Caden Williams, and David Gee

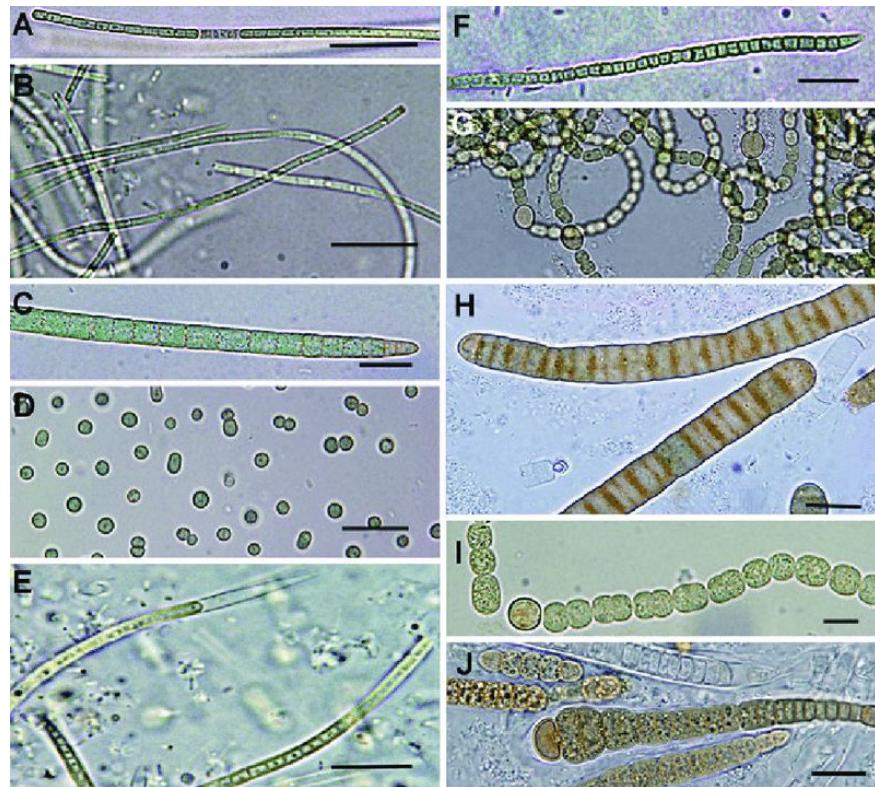
# Context: Why Microbes?

- Microbes are the oldest life on Earth and some of the most successful
- Dominant life for billions of years before larger organisms evolved
- Simple, relatively easy to study
- Cyanobacteria were the first oxygenic photosynthesizers, shaped our atmosphere and environments
- Important to planetary history



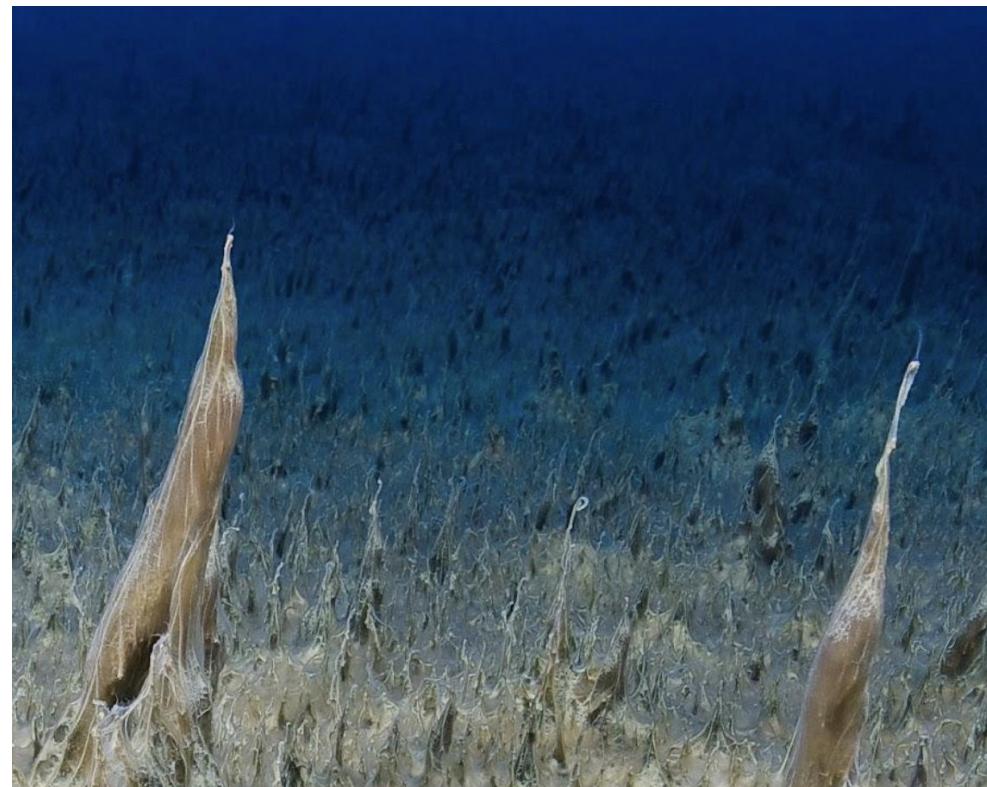
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# Context: Microbial Mats



Ian Hawes

Microscopic photos of various Antarctic cyanobacteria



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Microbial pinnacles in our study site

# Mat formation

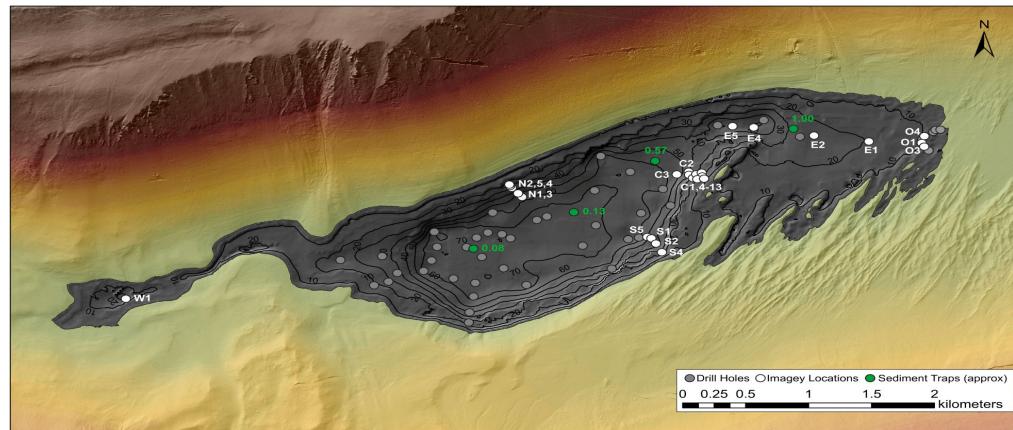
- These cyanobacteria like each other, want to stick together
- Extrapolymeric substances (EPS)
  - Stick together
  - Trap sediments, dust
- Layers build up
- Tend to grow upwards in our study site, but not always
- We don't fully understand why they grow in the directions they do



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# What influences microbial mat growth and morphology?

- Individual, patch, and community level interactions
- Pinnacle growth affected by environmental conditions and the microbes themselves
- We know why the pinnacles grow, but we do not know how they spatially distribute themselves



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# Turing and Spatial Pattern Introduction

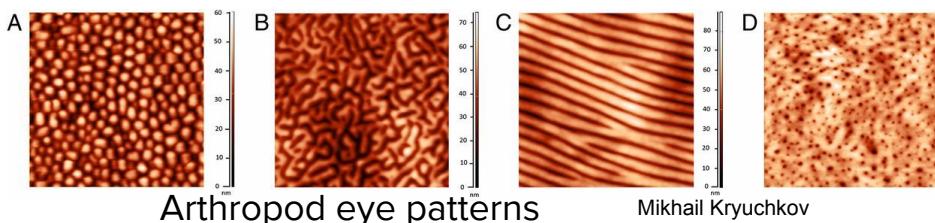
- Alan Turing: Mathematician and computer scientist
- Developed a mathematical equation to describe the formation of patterns in biology, i.e. tiger stripes, cow spots
- **Generalized idea:** What controls how organisms space themselves in an environment?



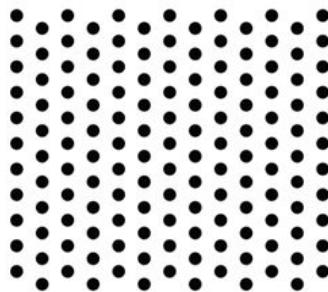
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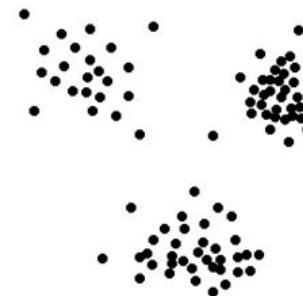
# What controls how organisms space themselves in an environment?



Competition for nutrients  
(long distance)



Mutualistic behaviors  
(short distance)



Spatial patterning



Wikimedia Commons

# Feedbacks Forming Patterns

- Negative = discouraging clustering
- Positive = encouraging clustering
- Long-distance negative feedback would be e.g., nutrient competition
- Range of possibilities: perfectly spaced, randomly spaced, clustered
- Our goal: use statistical methods to analyze the spatial patterns that form from the pinnacles



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# Questions

- Spatial ecology of cyanobacteria communities, pinnacle morphology, and modeling
- Why are the microbial mats shaped the way they are?
- How can we use 3D modeling to detect patterns in the mats?
- What types of patterns can we find in the microbial mats and what does this tell us about how the organisms interact?



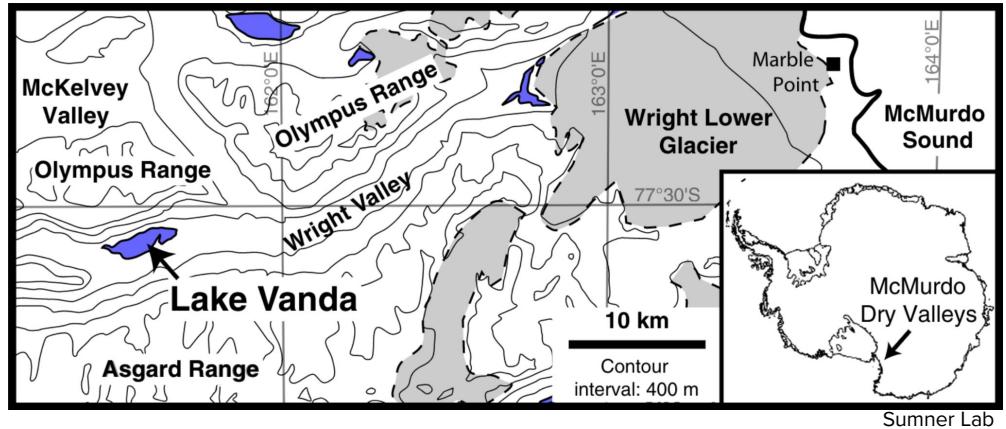
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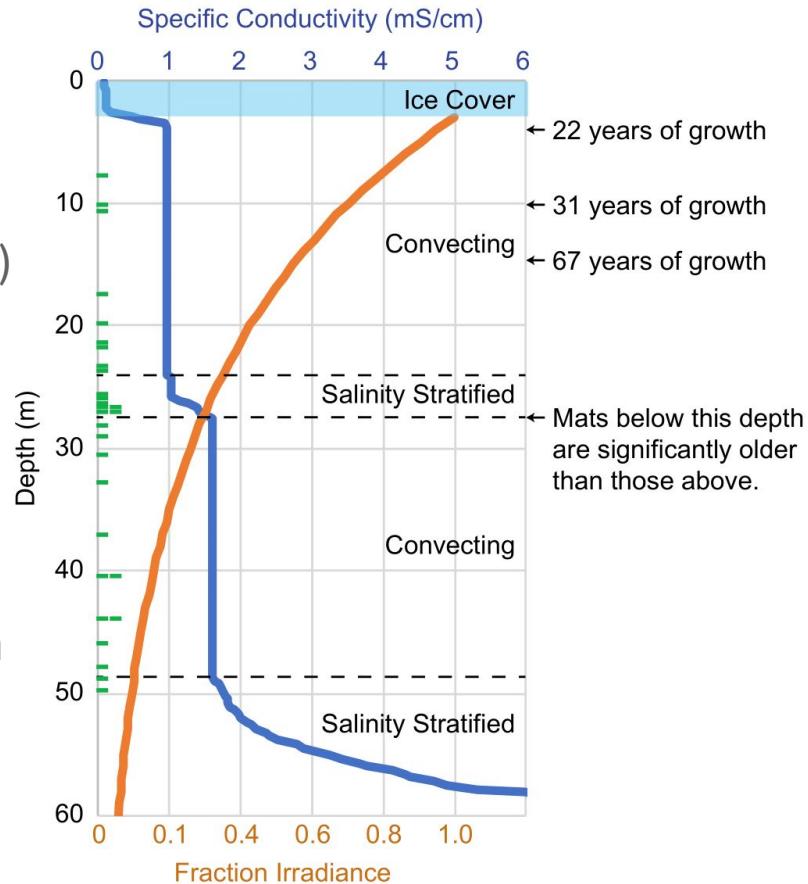
# Setting

- Microbial communities live along the bottom of Antarctic lakes
- Lake Vanda as our case study
- Despite being covered with ice year-round, microbial communities are still able to survive and photosynthesize, creating microenvironments and changing local geochemistry



# Lake Conditions

- Naturally stratified on environmental variables (light, sulfide, salinity, oxygen etc.)
- Importantly, light declines with depth (orange)
- At some depths, nutrients are brought in through diffusion only, while other depths have some slow currents to aid distribution
- Uniform salinity curves = water mixing



# Video - 2023 Field Season

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# Fieldwork

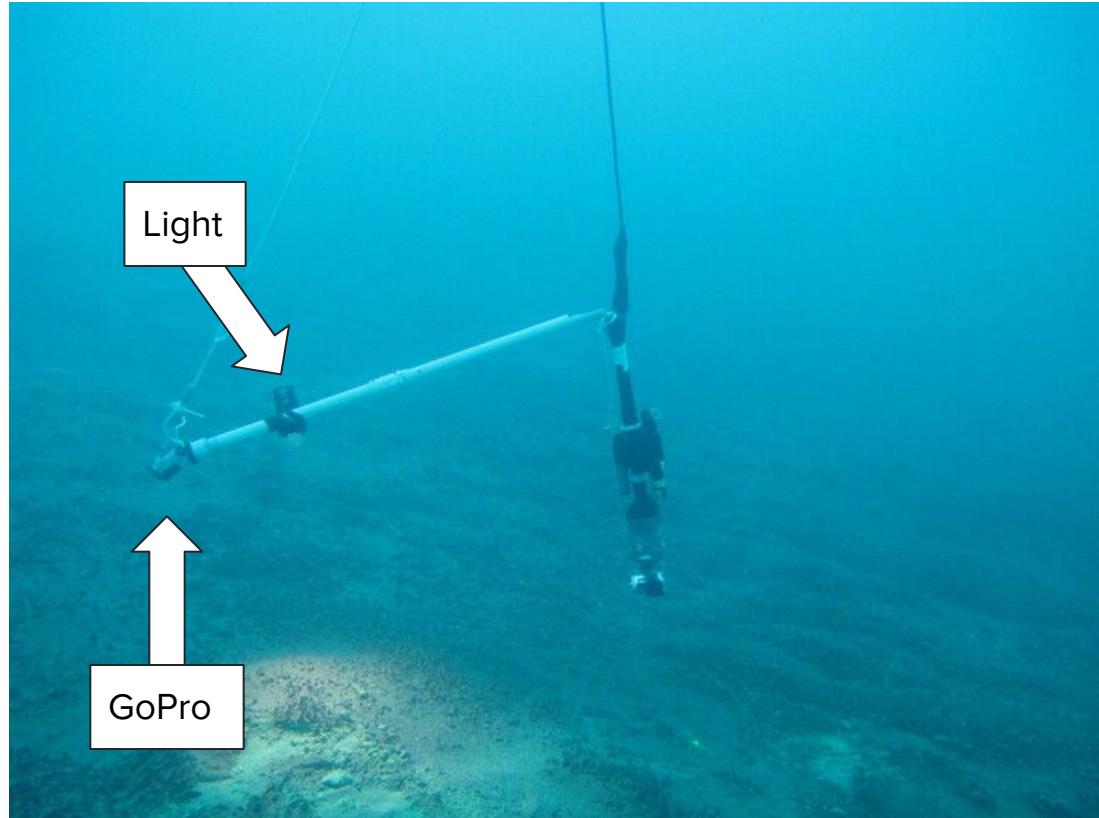
- Our video data is from the 2013-2014 field season
- Members of the Sumner Lab visited Antarctica to collect video data of Lake Vanda
- Scientific divers collect samples and footage



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# Fieldwork cont.

- Drill holes, camera rig equipped with a GoPro and parallel lasers for scale
- Once within range of the lake floor, the camera rotated 360° to capture a video of the benthic topography.
- Total of 37 locations in Lake Vanda



# Video - 2013 Drop Camera

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# Photogrammetry: What is it?

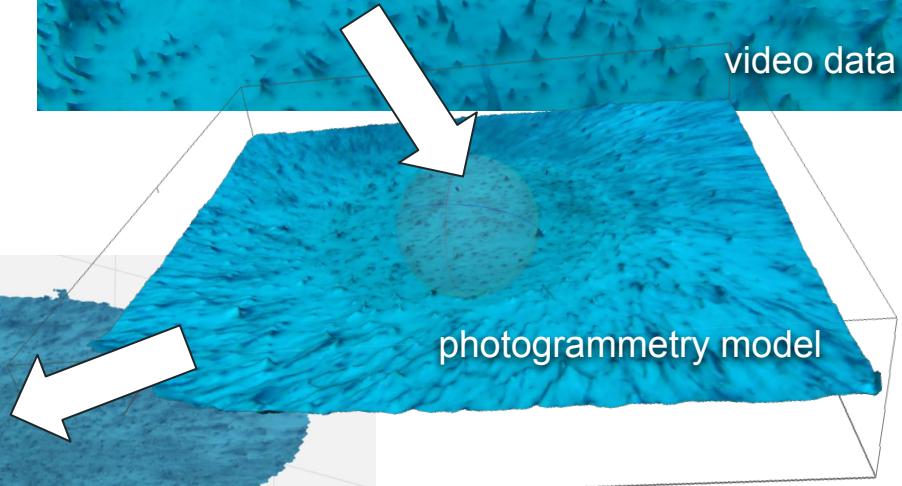
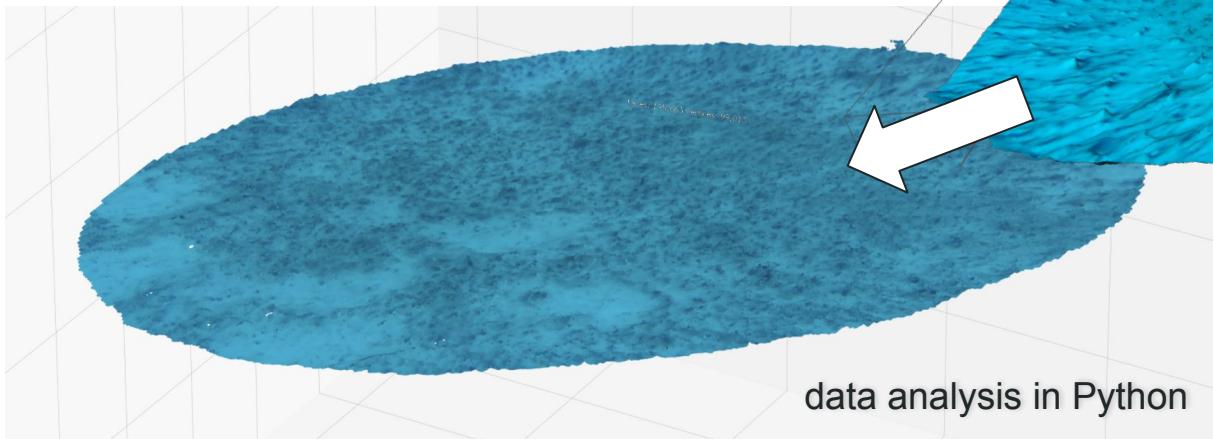
- Visual data (photos or video) surrounding an object or location
- Software transforms into three-dimensional model by analyzing differences between similar photos



Maria Alfonso

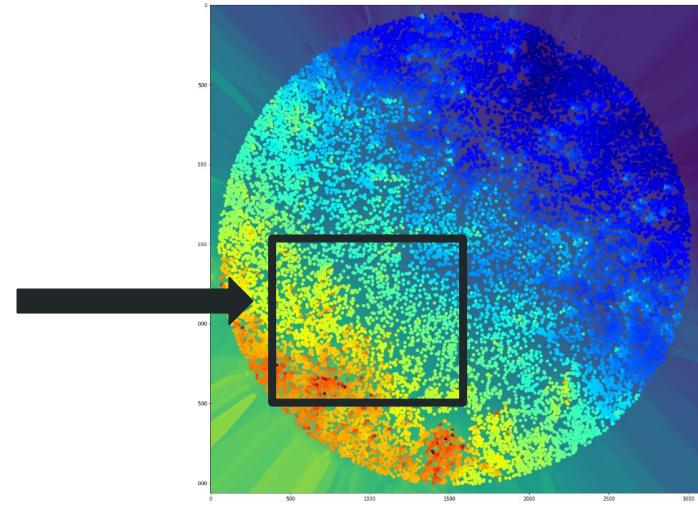
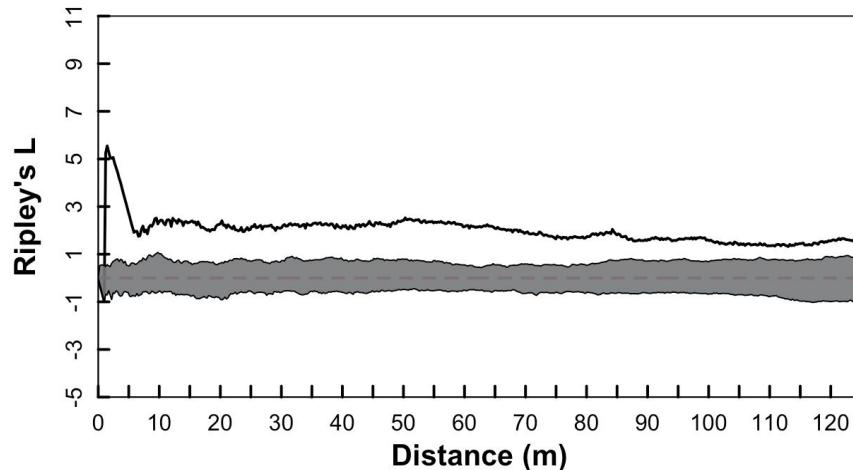
# Methods - Making Models

- Cameras and drill holes (fieldwork)
- 3D models → Python, VR
- Why model?

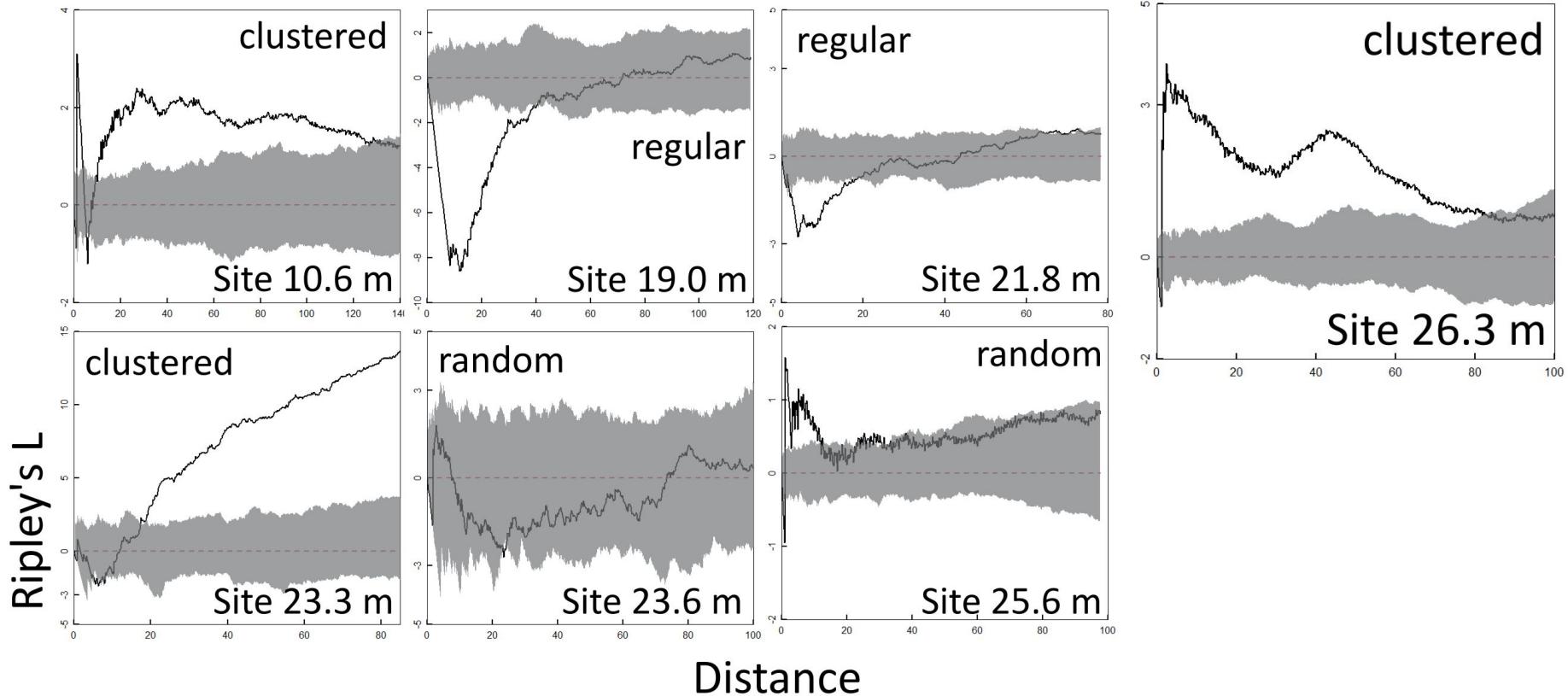


# Data Analysis

- Identify local maxima (peaks) of pinnacles
- Statistical Methods:
  - Test for clustering using a statistical function
  - The grey envelope is created from simulations that represent randomized points



# Methods - Data Analysis



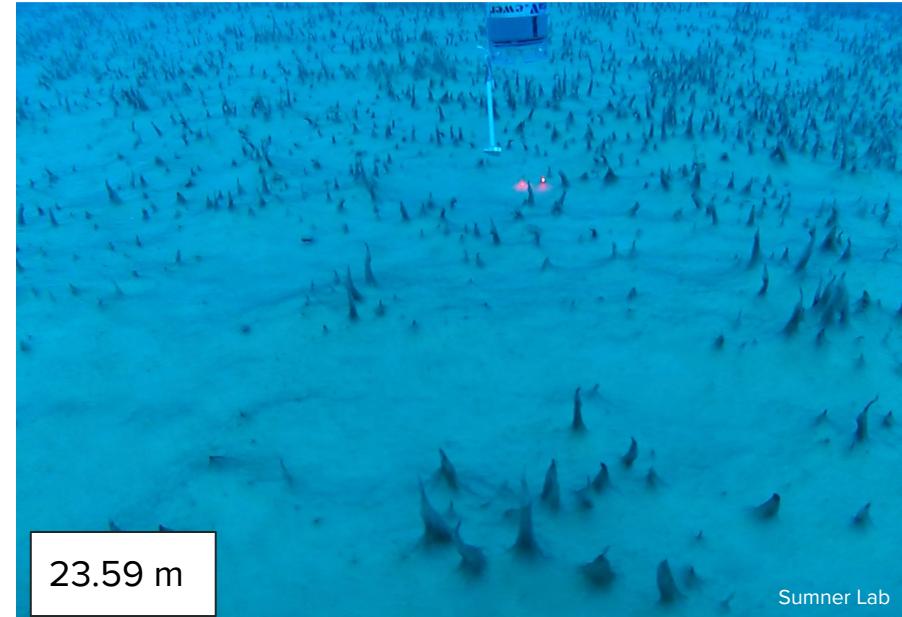
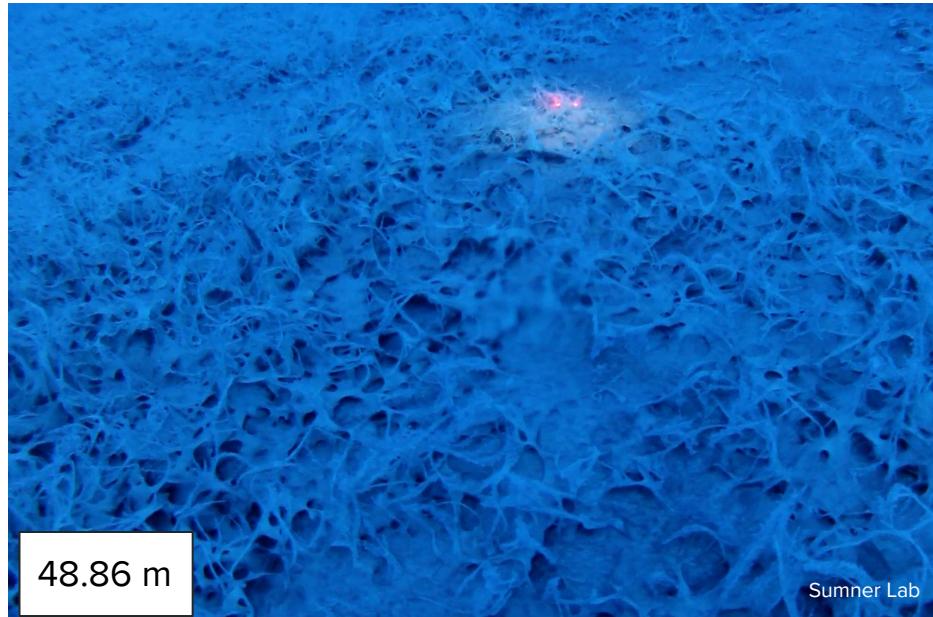
# Virtual Reality for Research

- No distortion in VR
- 3D data is represented as 3D
- Can interact with your model
- Collaborative analysis
- “Seeing creates insights” - Dawn Sumner
- “Looking at an image is like looking at a forest from the top, but VR lets you work in the forest and fly around.”
  - Graduate student Lucy Lu



# What our data tells us - Results

- Mutualism vs competitive influences on mat/pinnacle distribution
- Varying mat morphologies with depth and location in the lake
- Limitations to 3D modeling?



# Significance

- Geobiology – interplay of physical, chemical, biological factors on each other
- Key piece to planetary history
- Climatic information
- Extreme environment biology, ecology
  - Important to astrobiology as a model for early Earth and proxy for other (cold) worlds

= record of our past, tool for our future on Earth (climate change) and exploring other worlds

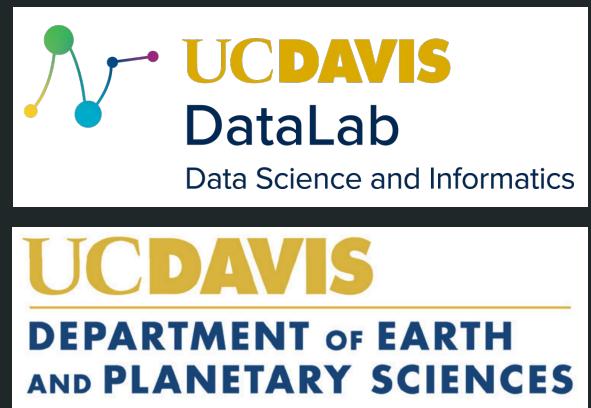
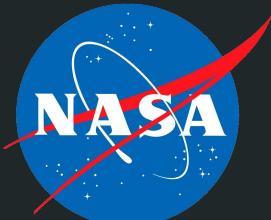


# Acknowledgements

- Dr. Dawn Sumner
- Sarah King
- Everyone in Sumner Lab
- Oliver Kreylos (DataLab)
- Lucy Lu
- All of you for listening!



Antarctica  
New Zealand



Nice work guys

<3 Sarah