In situ detection of microbial and non-cellular organic matter hotspots in subsurface glacial ice: field testing at Summit Station, Greenland as an analog to the icy crusts of the Ocean Worlds.

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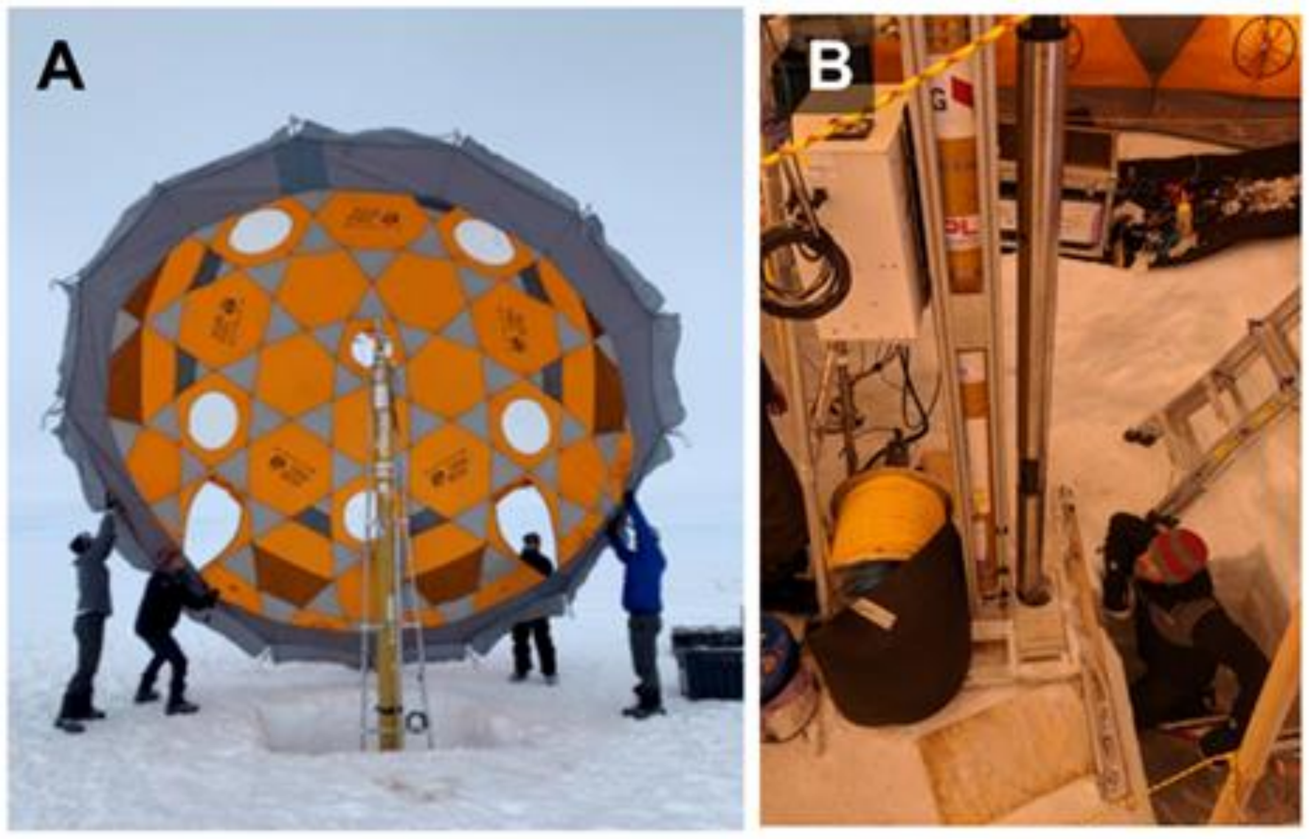
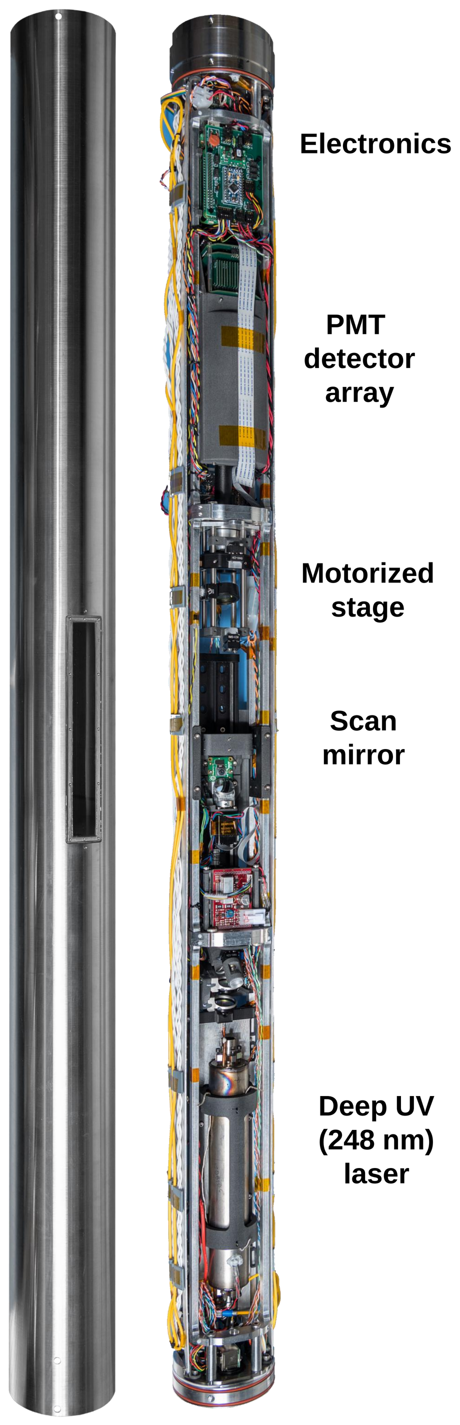
Introduction

With a 3 km thick ice cap, Summit Station, Greenland can serve as a terrestrial analog for icy habitats in the deep crusts of the Ocean Worlds.

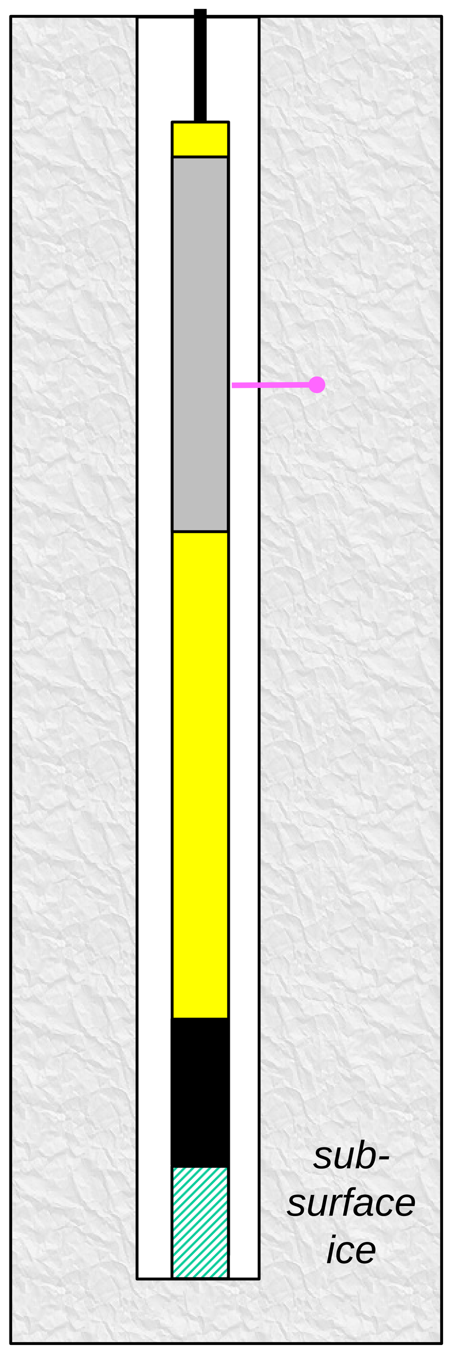


A. Raising the drill tent at the remote Drill Camp 7 km away from Summit Station . B) inside the drill tent. WATSON instrument at center.

We coupled a Deep UV fluorescence mapping spectrometer with a wireline robotic drill system to create a down-borehole instrument-drill combination (WATSON, Wireline Analysis Tool for the Subsurface Observation of Northern ice sheets) to explore 100 m deep inside the Greenland Ice Sheet.



Detail of the WATSON instrument tube (left), internal view (right)

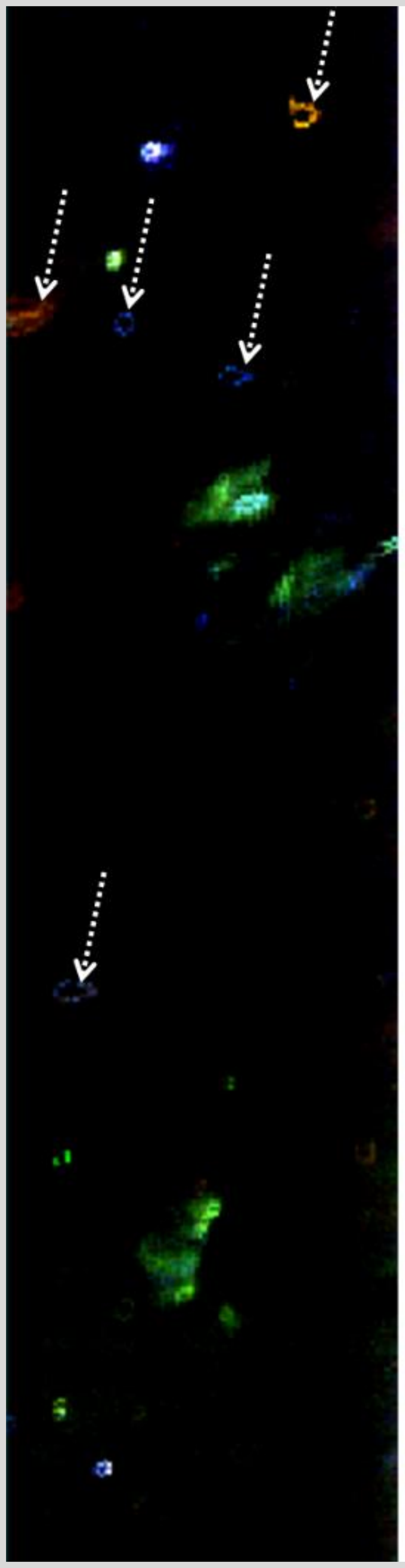


In ice borehole fluorescence scanning Deep UV laser excitation at 248 nm.

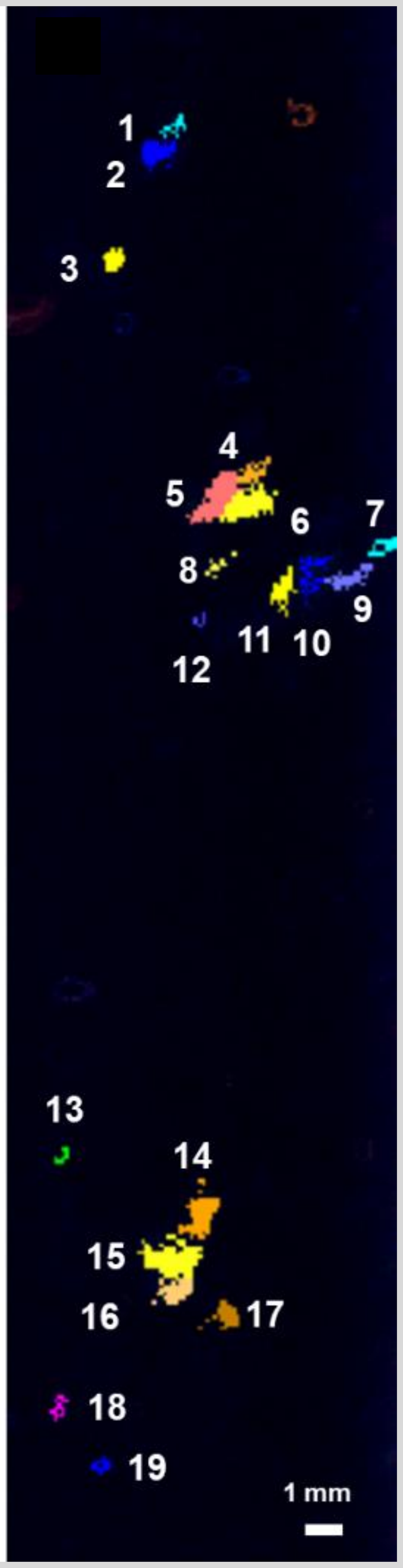
Mapped features in glacial ice

We completed successful down-borehole scanning using line scans and raster mapping from 3 to 105 m depths in both firn and glacial ice.

We found that most fluorescent signals were present in discrete hotspots – roughly 2 mm in size. There was a wide a diversity of spectral types. Spectral analysis of the hotspots showed that they were spectrally uniform across the hotspot.

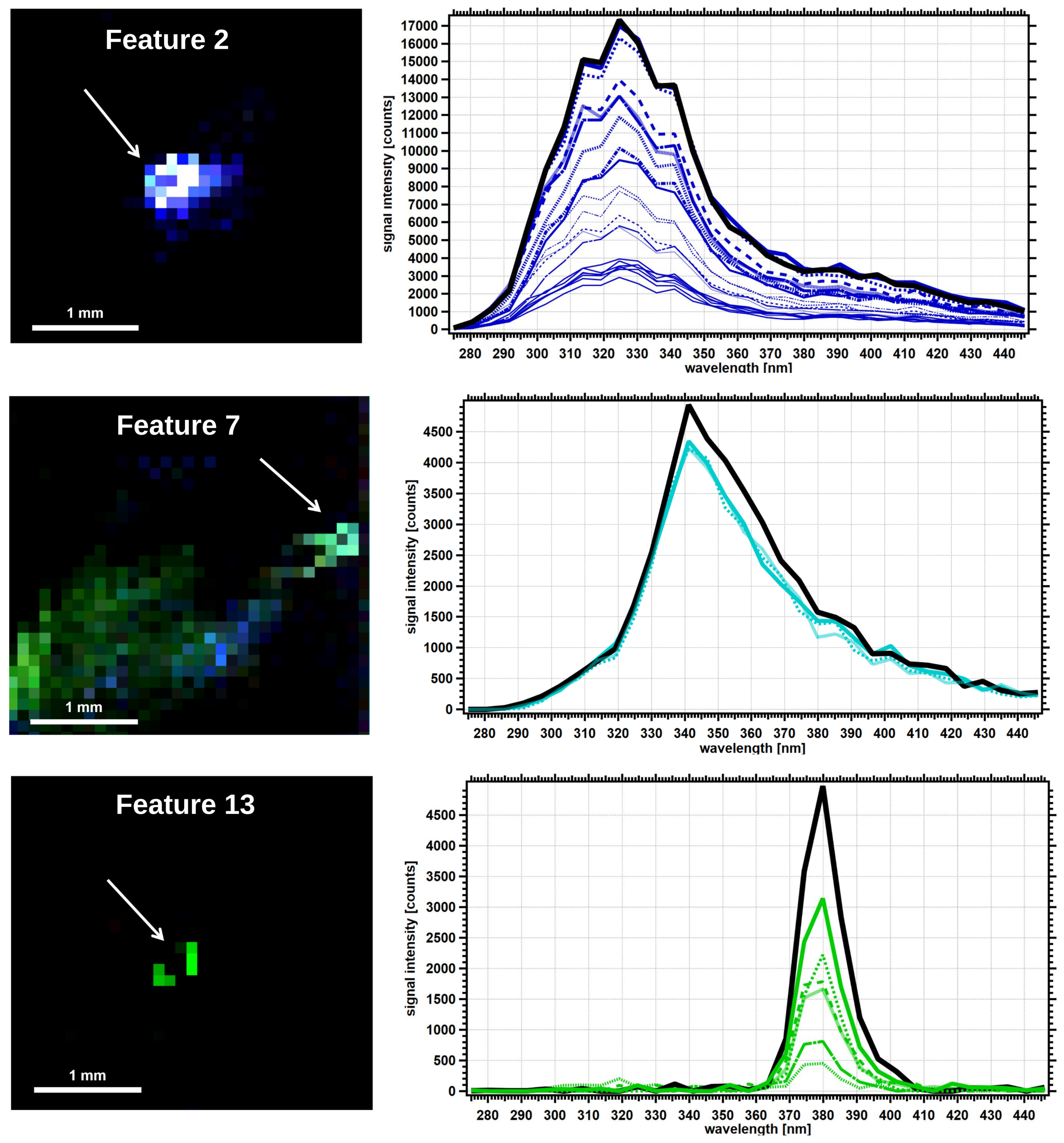


Raster map (Map 1) of fluorescent features detected at 93.8 m depth in glacial ice. Arrows indicate artifacts. RGB = 413 nm, 385 nm, 314 nm.



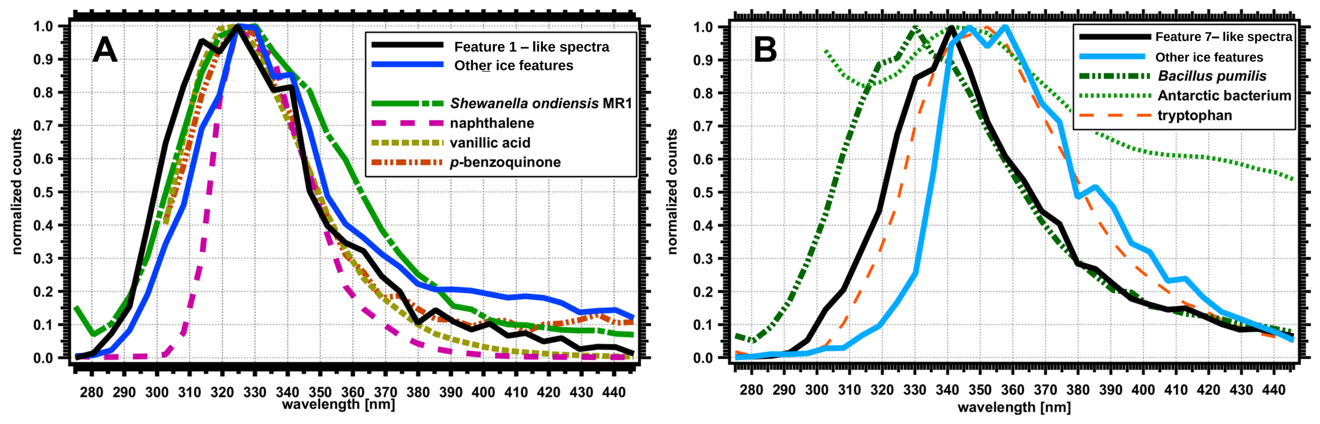
Annotated Map 1 image showing identified spectral features. Cold tones have a shorter wavelength lambda max, warm tones longer.

Images and spectra from 93.8 m deep ice



Isolated feature images and spectra for the annotated features in Map 1.

Hotspot signals similar to microbial and organic matter fluorescent signatures



Comparison spectra of laboratory acquired spectra of features detected in Map 1 and other points along the Summit borehole (solid lines) compared with laboratory spectra of microbial isolates and organics of biological-derivation. Vanillic acid is a type of phenol derived from lignin degradation.

Conclusions

Our expedition detected a diverse array of features embedded in glacial ice. These features are consistent with microbial and biologically-derived organic signatures.

We demonstrated the ability to drill and detect biological hotspot signatures in both firn and glacial ice. This technique may enable detection of microbial and organic hotspots in terrestrial icy environments or on future missions to the Ocean Worlds of the Solar System.

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