Multispectral Imaging of the Coastal Zone Near Tampa, Florida

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ABSTRACT

An aerial survey crew was in Florida as part of a multi-spectral imaging project, permitting them to offer acquisition of additional imagery with a Compact Airborne Spectrographic Imager (CASI) at reduced rate because of shared mobilization costs. The Florida Department of Environmental Protection (FDEP) used the opportunity to acquire CASI imagery of the Tampa area on April 30, 2000. Target areas selected were as follows: Two target areas in Tampa Bay (Terra Ceia Bay and Apollo Beach), one target area in St. Joseph Sound (where Rhodamine dye was injected into adjacent industrial and domestic wastewater discharges) and Anclote Anchorage. An overview of data acquisition, processing, and classification of submersed vegetation is provided here. The CASI was flown over the designated areas at several altitudes (10,800 feet for 4 m resolution, 6,000 feet for 2 m resolution and 3,000 feet for 1m resolution). Raw image data were calibrated to radiance units (nW/cm2/sr/nm) measured at the sensor. The imagery was first corrected for aircraft roll, pitch, yaw and partially for atmospheric interference; then projected into UTM WGS 84 coordinates and re-sampled to square pixels. A multispectral classification of submersed vegetation and bottom types for the Apollo Bay area was performed. Data for the targeted areas were delivered as Band InterLeaved (BIL) files and as 3-band tiff files for input into a GIS database.

BACKGROUND

Cost effective remote sensing of resources is an important management tool. Currently, the Tampa Bay Estuary Program (TBEP) utilizes seagrass coverage distribution change as one surrogate for overall health of the Tampa Bay ecosystem. The Southwest Florida Water Management District (SWFWMD) similarly monitors additional geographical areas on the southwest coast of Florida for the same purpose. Recent development in remote sensing technology and availability has led to evaluations of the cost effectiveness of various tools for resource management purposes.

Mumby *et al.* (2000), include a comparison of cost effectiveness of CASI and aerial photograph interpretation (API). The authors conclude that as the area that needs to be assessed increases, the cost of API is likely to rise faster than the cost of digital airborne scanner surveys (e.g., CASI), making API progressively less cost effective. Virnstein *et al.* (1998), describe a comparison of digital multispectral imagery versus API for mapping seagrasses in Indian River Lagoon, Florida. Because of contractual problems a cost comparison was not completed, but the authors commented favorably on advantages of multispectral imagery over API, including classification capabilities and the utility provided by a digitally acquired product. The present project was implemented by the Southwest District of FDEP as a further evaluation of the utility of digital multispectral imagery for resource.

OBJECTIVES

The main objective of the data acquisition was to acquire aerial multispectral imagery in the Tampa area that could be used to assess and demonstrate the capability of these data. A detailed project plan was developed that included standard operating protocols, instrument bandset and planned flight lines. Borstad Associates were responsible for mission planning, instrument bandset configuration, flight line planning, data collection, image geocorrection, registration and preliminary processing as reported here.

THE COMPACT AIRBORNE SPECTROGRAPHIC IMAGER (CASI)

The *CASI* is a push-broom imager built by Itres Instruments Ltd. of Calgary, Alberta. The Borstad *CASI* [s/n 101 manufactured in 1990 by Itres Instruments Inc. and modified in 1995 to improve the blue sensitivity] was flown in spatial mode, configured to acquire 11 spectral channels (**Table 1**) for the high altitude flights (MRT1.CCF). The eleven-channel band set was developed specifically for coral reef mapping and used previously for reefs in Mauritius, Reunion (Borstad *et al.* 1997), Puerto Rico and the Bahamas.

Table 1. MRT1 bandset used for the Tampa survey

Band No.	Wavelength range (nm)	Mean wavelength (nm)
1	421.9 - 453.6	437.75
2	461.9 - 490.4	476.15
3	493.4 - 516.7	505.05
4	526.8 - 544.9	535.85
5	569.2 - 587.4	578.30
6	610.0 - 626.5	618.25
7	640.3 - 653.2	646.75
8	665.3 - 685.3	675.30
9	704.6 - 715.7	710.15
10	745.8 - 762.3	754.05
11	774.5 - 801.8	788.15

With the airplane at 10,800 feet altitude, the cross-track pixel size was 4 m and the image swath was 2 km wide. At an integration time of 75 msec and a ground speed of 104 knots, the along-track pixel size was also 4 m. The imagery was captured with the instrument fore-optics at f8 (or occasionally 5.6) and a narrow angle (35°) lens. Slight variations in speed or altitude will somewhat expand or contract pixels; however, during processing all pixels are re-mapped using a nearest neighbor approach to the desired pixel spacing.

The Borstad *CASI* also records aircraft roll and pitch from a separate mechanical gyro and latitude and longitude from a GPS receiver to provide data for subsequent geo-correction of the imagery. These flights were staged on April 30, 2000 just before Selective Availability was turned off. However a GPS base station was not used on this mission due to its short duration.

The base station would require a minimum of 72 hours operation at an un-surveyed location (within 50km of the target location) to derive an accurate reference position. As a result, the navigation data were not differentially corrected. However during second stage rectification of the data, ground control points collected from well navigated reference imagery were used to improve the rectification of the airborne imagery.

Twenty-two flight transects were acquired in just over 2.5 hours of flight time. Two target areas in Tampa Bay (Terra Ceia Bay and Apollo Beach), one target area in St. Joseph Sound (where Rhodamine dye was injected into adjacent industrial and domestic wastewater discharges) and Anclote Anchorage were all imaged several times. Some targets were imaged at several altitudes to obtain different spatial resolutions. Only a small portion of one flight line over Apollo Bay is discussed here. The Apollo Bay transect (**Figs. 1** and **2**) was flown 4 times.

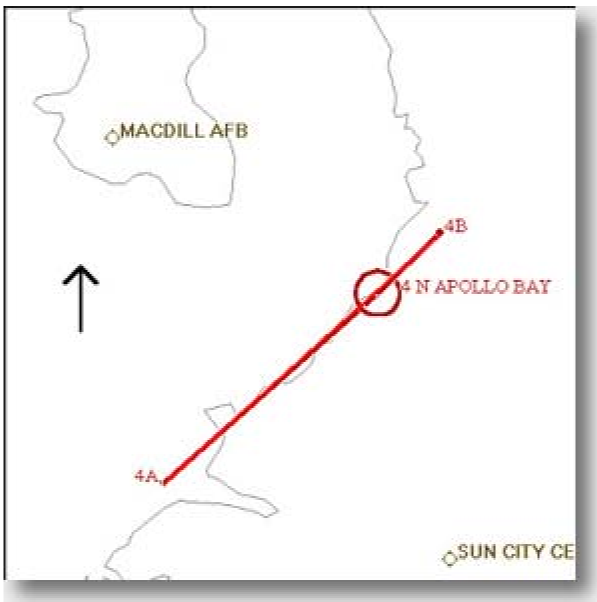


Figure 1. Flight path for Apollo transect (VISTA™)

Figure 2. of the Apollo Bay target area used for CASI rectification

DATA PROCESSING

Radiometric calibration

During radiometric calibration raw image data are read from tape the raw radiance values are converted into upwelling radiance units (nW/cm2/sr/nm), using a responsivity function obtained during laboratory calibration of the instrument. After removing dark and electrical offset signals from each scan line of the data, the responsivity of each individual array element from the calibration is averaged according to the bands used for the flight data collection, and applied to the image data to produce a radiance for each band. The values calculated represent radiance at the sensor, that includes the effect of the atmosphere below the aircraft as well as the extra path radiance at the edge of the swath. The imagery can be viewed at this stage but because no corrections have been applied for aircraft motion it can be difficult to interpret.

Geometric and geographic correction

During acquisition, the roll and pitch of the aircraft are recorded by the gyro for each scan line while the CASI image is being acquired. As part of the first order geo-correction process the roll, pitch, and GPS data for each image scan line are used to re-map the imagery to remove aircraft motion, using a nearest neighbor approach. Aircraft yaw is not recorded by the gyro but instead was compensated for by re-orienting the camera on each flight line using the photo-camera mount. Data processed to this stage is in 16-bit signed format, in units of radiance (nW/cm2/sr/nm) at the sensor altitude, each file representing an individual flight line, mapped north up to WGS 84 UTM co-ordinates and corrected for aircraft motion. Such first order geo-corrections should be accurate to within 10 - 25 meters over flat terrain.

Second stage rectification, which forces a fit at the GCP and interpolates the regions between the GCPs allows improvement of absolute positioning of image data. This rectification generally reduces position error to within 2 to 3 pixels relative to the reference imagery. The geo-referenced data used for the collection of ground control points for the Apollo Bay area was a USGS digital orthophoto retrieved from the USGS website. The original map projection for these maps was NAD27, UTM zone 17. The 1-meter resolution orthophotos for the Apollo Bay area were converted to NAD83 and resampled at 4-meter resolution to match the acquired *CASI* imagery.

During all transformations the data were re-sampled using a nearest neighbor technique, ensuring that no spectral distortion was introduced. This is an important consideration for subsequent classification.

Classification

The classification of a resampled and georectified subscene of the Apollo Bay area (**Fig. 3**) was performed using ENVI's Spectral Angle Mapper (SAM) and PCI's Imageworks spectral tools. The process involved 5 SAM analyses using various angles and modeling algorithms in PCI. The classification thematic channel was filtered in several steps to merge small classification polygons (**Fig. 4**)

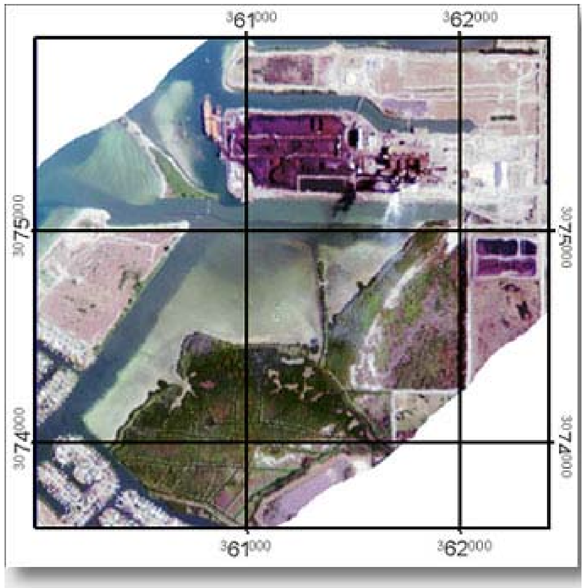


Figure 3. Near true color scene of the Apollo Bay target area, composite of bands 8 (675 nm), 5 (578 nm) and 2 (476 nm)

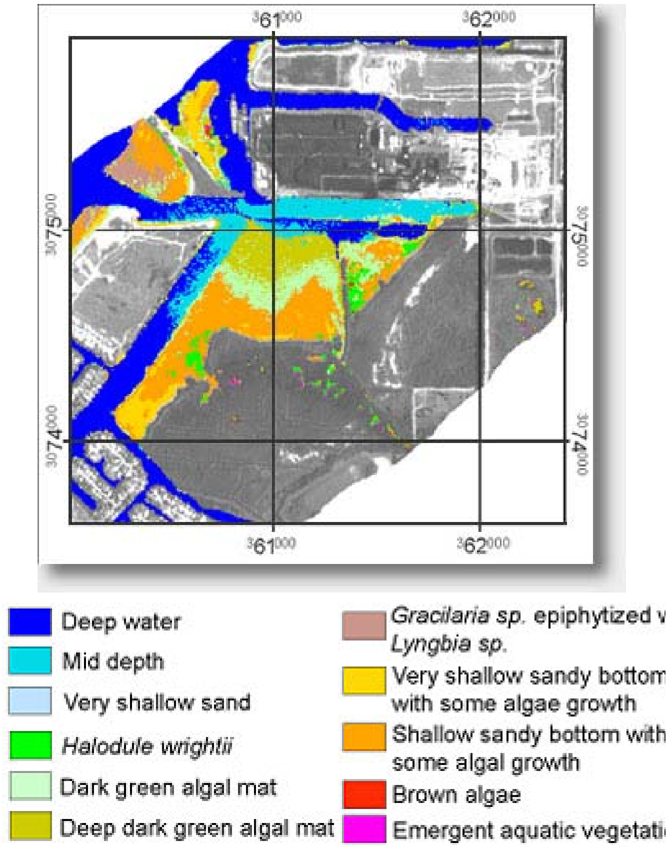


Figure 4. CASI multispectral classification and legend for Apollo Bay

Each class was assigned a color code that was saved into a pseudo-color table. A report on the filtered channel was produced (**Table 2**) containing areas and percentages for each thematic class. The "null" class referred to the land pixels not included in this classification and zero data. Eleven spectral classes were separated according to spectral similarities and RGB appearance.

Table 2. PCI's Maximum Likelihood Report on the filtered thematic channel

Seq Name	Code	Pixels	Hectares	%Image	Subtotals
Submerged aquatic vegetation					
Very shallow sandy bottom & algae	8	4,950	0.49	5.09	
Shallow sandy bottom & algae	9	18,378	1.84	18.9	**23.99**
Dark green algal mats	6	8,521	0.85	8.76	
Deep dark green algal mats	11	9,954	1.00	10.24	**19.00**
Gracilaria & Lyngbia	7	2,942	0.29	3.03	
Halodule wrightii	5	2,223	0.22	2.29	
Brown algae	10	218	0.02	0.22	
Emergent Aquatic Veg.	16	290	0.03	**0.3**	
Total aquatic vegetation				**48.83**	
Others					
Deep water	1	38,039	3.8	39.12	
Mid depth	2	11,145	1.11	11.46	
Shallow sand	15	539	0.05	0.55	**51.13**
Image total		97,477	9.75	100	

Class Descriptions

The classes described in this section were grouped according to spectral similarities, RGB appearance and identified classes from previous classifications of similar targets from other projects done by Borstad Associates' analysts. Some ground truth observations were performed (Mr. C. Kovach, and Jim Culter, Mote Marine Laboratory; personal communications and photos), however, further ground-truthing would be necessary to confirm and identify the species present in each class.

Throughout this section the "Blue peak" refers to a radiance maximum near 476 nm, the "Green peak" to a radiance maximum near 536 nm, the "Orange peak" to a radiance maximum near 578 nm. The "710 peak" refers to a local radiance maximum near 710nm caused by an interaction between strong infra-red reflectance of plants and strong absorption of water. "NTC color" refers to the color of a class in a "near true color" scene composite of the MRT1 bands 8 (675.3 nm), 5 (578.3 nm) and 2 (476.15 nm).

AQUATIC VEGETATION

The vegetation group accounted for 48.83% of the total classification. The "submersed" class was the most abundant with the "Sandy bottom with algae growth" group presenting the highest occurrence (23.99%), followed by the "Dark green algal mats" (19%), the "*Gracilaria* & *Lyngbia*" patches (3.03%), the "*Halodule wrighti*i" patches (2.29%), the "Brown algae" (0.22%) and finally the "Emergent" class (0.3%).

Submersed vegetation: All the submersed vegetation exhibited low NIR radiance values spectra but strong/apparent 710 peak. Several classes were obtained:

Sandy bottom with algal growth (Classes 8 & 9) The spectra were characterized by a high "orange peak" (578 nm) and variable but clear 710 peaks (**Graph 1**). This class was identified by ground-truthing as "very shallow bare sandy bottom", however, the 710 and "orange" peaks indicate algal growth. Perhaps diatomaceous mats (Paterson *et al.*, 1998) or algal turfs. Two subclasses were separated based on the spectral values:

Very shallow sandy bottom with algae growth (class 8). The spectra had peak radiance values at 578 nm ("orange peak") higher than 3500 DN, with radiance values decreasing towards both ends of the spectral range (Graph 1, green spectrum). The NTC was almost white. This class accounted for 5.09% of the image.

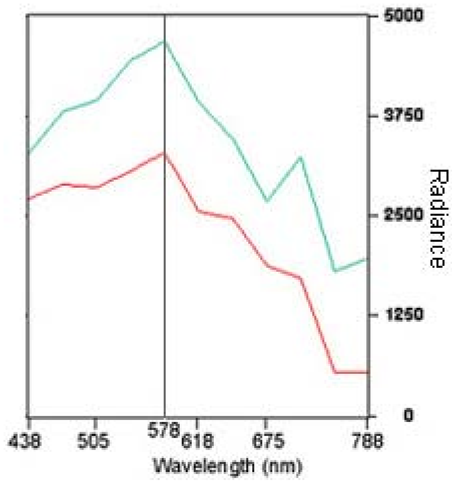
Shallow sandy bottom with algae growth (class 9). The most abundant of this group (18.9 % of the total classification), spectrally similar to the previous class except that the values of the "orange peak" were lower than 3500 DN, a subtle "blue peak" was present but never higher than "green peak" (**Graph 1**, red spectrum). The NTC was light pink.

Green algal mats (classes 6 and 11). This class was recorded from field ground-truthing observations as algal mats (dark green coloration, species unidentified). It was the second most abundant submersed group (19%) and was spectrally similar to the seagrass (**Graph 2**, blue spectrum) with the presence of a variable "double hump" (strong blue and green peaks) but with lower 710 radiance peaks . Two subclasses were separated based on the spectral values:

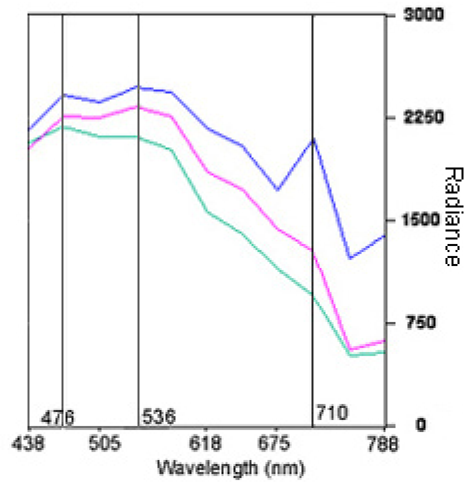
Dark green algal mat (class 6). Spectra showed the presence of subtle a 710 peak and a 'double hump' with the radiance peak at 536 nm lower than that at 47 nm (**Graph 2**, light green spectra). The NTC ranged from light green, yellow-green to dark green.

Deep dark green algal mat (class 11). The most abundant of the two subclasses and the second most abundant class within the submersed group (10.24%). Spectrally similar to the previous class, but with a more defined 'double hump' with the green peak values higher than those of the blue peak. The NTC was light red-green.

Seagrass beds:*Halodule wrightii* (class 5). This class was easily separated from the other submersed vegetation classes by the 'double hump' spectra composite of strong blue and green peaks and for the high 710 peak values (**Graph 2**, blue spectrum). The NTC was dark green. NTC was dark green. The identification of the *Halodule* patches in the classification was confirmed by field observation and compared favorably with historical records and aerial photos (J.Culter, *personal communication*) of the seagrass beds in the area.



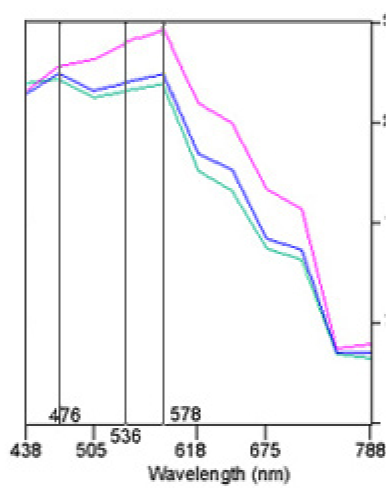
Graph 1. Spectra of “sandy bottom with algal growth”.



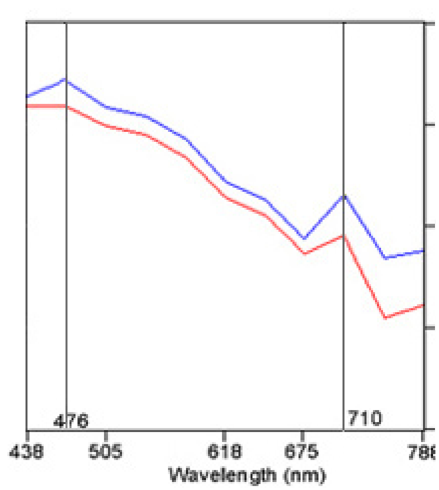
Graph 2. Spectra of“green algae” (green and pink) and “seagrass” (blue)

***Gracilaria sp*. & *Lyngbia sp.* (class 7).** This class was identified by field observation as the red algae *Gracilaria sp*. epiphytized with the blue green algae *Lyngbia sp*. Spectrally similar to the shallow sandy bottom with algal growth classes (**Graph 3**) in presenting a clear "orange peak" but differing from those classes in the strong "blue peak" (which values never exceeded those of the "green peak". The NTC was green-brown-reddish. It was found mainly in the northwest of the mosaic and accounted for 3.032% of the classification

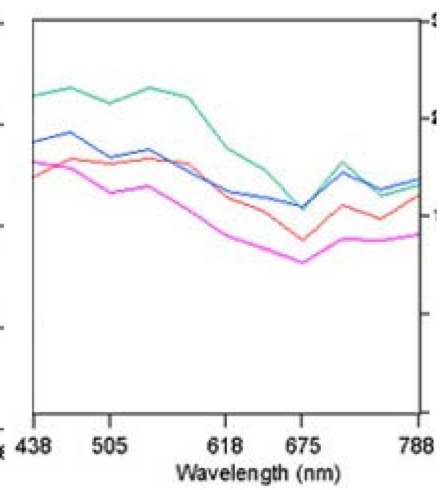
Brown algae (class 10). Least abundant of the submersed vegetation classes (0.22%) The spectra (**Graph 4**) exhibited a strong 710 peak and blue peak values higher than any other class. The NTC was dark green-brown.



Graph 3. Spectral comparison of ”*Gracilaria/Lyngbia*” (blue and green) and “sandy bottom/algae” (pink) classes.



Graph 4. “Brown algae” spectra.



Graph 5. Example of “emergent vegetation” spectra

Emergent aquatic vegetation (class 16): This class was not very abundant (0.3 %) and included all spectra with strong 710 peak and high NIR values (**Graph 5**). It was found along the shoreline, and it might represent exposed aquatic vegetation, partially submersed land vegetation, or mixed pixels (vegetation and land spectra).

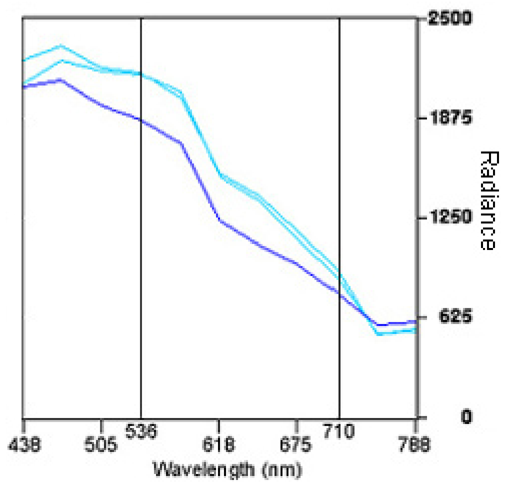
OTHERS

This group includes three no-vegetation aquatic classes, which together accounted for 51.3% of the total classification.

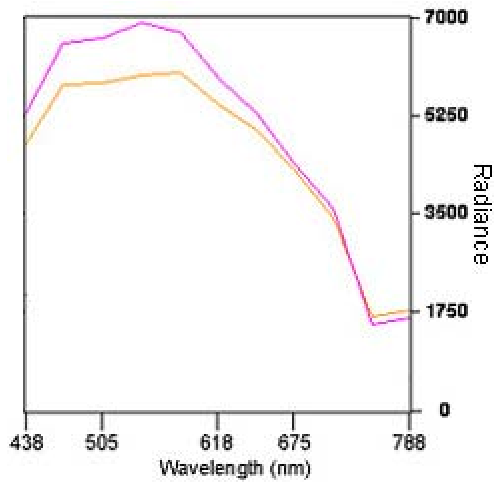
Deep water (class 1). Most abundant in the classification (39.12%) and it was separated by the low spectra with blue peak and radiance values decreasing steadily towards the NIR bands (**Graph 6**). No 710 peak was present. The NTC was dark blue.

Mid depth(class 2). Spectrally similar to the deep water class but with higher radiance values at 536nm and 710nm (**Graph 6**). The NTC was blue-green and light blue. This class accounted for 11.46 % of the classification.

Shallow sand(class 15). Spectra for this class presented very high radiance values (>4000 DN) at the low wavelength bands (476-578 nm) values decreasing rapidly towards the NIR and a subtle 710 peak was present, indicating possible/sparse growth of vegetation over very shallow/shallow sand/rubble (**Graph 7**). This class was found along the shoreline and was not very abundant (0.55%).



Graph 6. Example of deep water (blue) and mid depth (cyan) spectra



Graph 7. Example of "shallow sand" spectra

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