Environmental case studies as monitored by Imaging Spectroscopy technology in Israel

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ABSTRACT

Imaging spectroscopy (IS) activity in Israel began fifteen years ago with the data acquisition of the first commercial IS airborne sensor (GER-63) over several sites in Israel. Since then, several other sensors have covered the country from north to south, in projects which mainly focus on environmental issues. The sensors included airborne such as GER-63, CASI, DAIS-7915 and AISA and spaceborne such as CHRIS-PROBA. The data were processed to provide new insight on different aspects of the environmental, previously unattainable from the traditional multispectral remote sensors. In this regard, the first GER-63 flight in 1989 demonstrated that it is possible for the IS technology to generate a mineralogical distribution map of Makhtesh Ramon, Israel, as accurate as those produced by traditional field mapping methods. From that point further, many interdisciplinary subjects have been examined using this technology. In this direction, marketing strategy in Israel has developed to allow any consumer to purchase IS data at reasonable cost using easily operate VIS-NIR-SWIR airborne IS sensor. The sensor is operated by a commercial company (*Bar-Kal Systems Engineering Ltd*) that provides professional services to the customer, ushering in a new era of Israeli IS activity. The environmental case studies that were investigated by the IS technology in Israel over the past ten years were: urban studies, limnology, salinity mapping, soil degradation mapping, geomorphology mapping, geology mapping, vegetation mapping and air quality assessment. The following article will briefly review these case studies, and will discuss how the IS activity in Israel can be world wide beneficial.

Keywords: Imaging Spectroscopy, Environment case studies, Israel

1 INTRODUCTION

The IS activity in Israel started in June 1989, when the first commercial airborne sensor GER-63 was brought to Israel for a short campaign by Prof. Kaufmann (presently the head of the Remote Sensing Section in GFZ Potsdam Germany), Dr. Frank Lehman (Grmany), Prof. Emanuel Mazor (Israel) and Dr. Michael Byth (Israel). During that campaign, the GER-63 airborne sensor flew over selected areas in Israel. Apparently, the acquired data were shelved for more than four years, due to a lack of experience in image processing of IS technology at that time (mainly because atmospheric removal techniques were not developed then). The first study to process the data, was that of Kaufmann in 1991 (1), which despite not being properly corrected for the atmospheric attenuation, gave remarkable results for the most famous mineralogical site in Israel, Makhtesh Ramon. Later, Ben-Dor et al (2,3,4,5) further processed the data at the Center for the Study of Earth from Space (CSES) at the University of Colorado at Boulder, and together with Dr. Kruse, were able to atmospherically correct the data, and process it to yield geology, geomorphology and gas maps of Makhtesh Ramon, in the Israel's Negev desert area. This pioneer work was a precursor for work to come, and most significantly, to recommend the area as a global calibration site for future IS sensors (airborne or orbital) as well as for other optical sensors. Makhtesh Ramon is a cloud free area, with many spectrally active minerals, dark and bright flat targets (sand dune and basalt), well known geology and a detailed spectral library. The area has no vegetation coverage and is characterized by two flat terrains at distinct elevations separated by 500 m vertically. Based on these characteristics and on the experience gained over the area, Makhtesh Ramon is used by us as a calibration target as well as being proposed to serve the international community for that purpose.

Since the above mentioned historical flight of 1989, the IS activity in Israel has grown to such prominence, that many workers and authorities have recognized its potential that prompted independent capability to acquire IS data in Israel. Today, a new airborne sensor, operated by a private company, and available to users world wide at a reasonable cost, is available in Israel. The sensor, termed AISA-ES, covers the entire spectral region from 0.4-2.45μm, and is operated by *Bar-Kal Systems Engineering Ltd.*, with full chain service from mission planning and data acquisition, to radiometric calibration (by *El-OP Ltd*.) and atmospherically rectification.

As mentioned earlier, the main core of the IS projects that were gathered over the years, was aimed at studying the environment. The results of these activities were used to further prompt other activities, such as precision agriculture and geomorphological surface mapping. These activities were started (and are still carried out) by the academia (education and pure scientific research) and recently also by the industry (service to consumers) sectors. The Remote Sensing and GIS laboratory, in the Department of Geography and Human Environment at Tel-Aviv University (IRSL), is the leading academic unit in Israel for the IS technology which collaborates closely with the commercial and (other) scientific sectors.

Over the years several projects have emerged to cover four main categories as follows: pure spectroscopy, simulation, developing algorithms for automated classification, and conducting flight campaigns. The first three categories were aimed at building a foundation for the fourth category, and at preparing steps and routines for launching airborne IS missions. In the first category, pure spectroscopy, we study quantitative approaches to assess several soil properties solely from the soil reflectance information, and also to account for the BRDF effect that found to significantly affect quantitative spectral analyses. The second category, simulation, was aimed at simulating both the atmosphere and ground variation, in order to develop ways to better remove the atmospheric attenuation from real IS data, as well as to simulate extreme scenarios in different environments. The third category, developing algorithms, is aimed at developing statistical-mathematical ways to classify IS data in a real time mode, and to provide reasonable maps to consumers automatically and rapidly (in almost near real time). The fourth category, flight campaigns, is aimed at planning and launching airborne IS campaigns to analyze diverse aspects of the environment. This paper provides a brief summary of some selected case studies, from the above four categories, over the past ten years.

2 THE *IS* ACTIVITY IN ISRAEL

The selected case studies are presented herein on a category by category basis:

2.1 Pure Spectroscopy

Mapping of soil properties using reflectance spectroscopy is a very important issue. It can provide rapid and cost effective ways to assess properties in a real time mode. This information is important to farmers and environmental supervisors that need high temporal resolution data with which to make correct decisions. During the last five years, we developed and established the NIRA (Near Infra Red Analysis) concept for determination of soil properties, which is today used worldwide (6). NIRA is a statistical based model that combines spectral and chemical information, and uses the specific absorption features of each property in question to assess its concentration. This concept was developed under optimal laboratory conditions, demonstrating that even with monotonous spectral behavior, it is possible to account for several soil properties solely from the reflectance data, such as: clay content, free iron oxides, organic matter, carbonate, specific surface area, particle size distribution and more (see ref 7,8,9,10). Besides the quantitative approach previously described, spectral libraries of soil, urban targets, and artificial materials were created for potential utilization in IS applications (see (http://www.tau.ac.il~geograph/RSL). This activity has received significant attention from us, as we realized that a comprehensive spectral library will be a key factor in any IS activity to come.

2. 2 Simulation

In this category, we studied how changes in the atmosphere can render the retrieval of ground reflectance properties inappropriate. Using a simulated AVIRIS scene, we were able to pin-point the most effective method to correct the atmospheric attenuation under complex conditions (11). Also using this simulated data, we were able to develop an innovative approach to account for the aerosol loading on a pixel by pixel basis (12). This was done by using the oxygen peak at 760nm, which is (spectrally) situated on a Mie effective spectral region. Based on the idea that oxygen is a well mixed gas, any variation from homogeneity in the oxygen image may be directly related to the scattering effect. The method enabled us to extract the proper physical relationship between the optical thickness of a given scene and the corresponding oxygen image. Another project in the simulation category was to generate an IS simulation of an urban environment, in order to study a complex environment in which diverse and extreme conditions can be created. Figure 1(a,b) shows an example of AVIRIS spectral ratios using six methods to remove the atmospheric attenuations (the spectral ratio was created using the corrected versus the real ground spectra of the target in question with any divergence from unity indicates poor correction). In Figure 2, a simulated scene of a selected neighborhood in Tel-Aviv is given, side by side with a real corresponding area that was acquired by the CASI sensor. This example shows a significant similarity, which indicates that the present simulator can aide in the study of IS technology without flying an aircraft (13). In summary, it can be concluded that the simulation category indeed provides new insight for the IS discipline and make it study to be more convenient and friendly used.

2.3 Developing Algorithms for Automated Classification

One of the most important priorities in the IS processing chain, is the ability to automatically and rapidly (preferably in real time) obtain the spectral endmembers which compose the scene's spectral variations. Generating a classified image from raw IS data set may solve problems posed by transferring data from the sensor to the ground, and posed by employing sufficiently skilled personnel to process the data. Broadcasting IS data from afar results in operative bottlenecking for orbiting IS technology. Large amounts of data are difficult to electronically broadcast to the ground station. Consequently, much IS technology still leans on onboard data archiving and not on the traditional data broadcasting system that current orbital sensors offer. Performing automatic on board classification may solve the problem of IS data in orbit, as a (classified) single three bands image is easier to transfer to the ground than any IS data that is composed of hundreds of bands. For these reasons, we focused on developing new automatic ways to classify the IS images onboard the platform. Several papers have been published in this regard (14,15,16); they demonstrate promising results, without using the long classic IS analytical chain (e.g. Kruse and Boardman (17).

2.4 *IS* Data Acquisition

Based on the three previous categories, and after establishing the infrastructure for IS interpretation technology, we moved to the next step: field campaigns and data acquisition with airborne IS sensors.

Soil salinity:. The first study was aimed at mapping the soil salinity distribution over Beqat Zvaim Israel, using NIRA technology and IS data base that was acquired by the DAIS-7915 sensor. In this project, several ground locations were sampled during the overpass, and sent to the laboratory for soil properties determination (organic matter, electrical conductivity (EC), moisture content). A spectral based model to describe each property from the soil reflectance was generated, and was applied to the reflectance image on a pixel by pixel basis. The study demonstrated a feasible IS based method to map a soil salinity problem long before it is visible to the farmer's eye (18).

Soil erosion: Soil erosion is one of the properties which attract the attention of many environmental supervisors, farmers, and governmental authorities. Soil erosion is an important phenomenon that affects soil degradation, and plays a major role in soil management and conservation. We proposed to use the spectral properties of the physical crust (rearrangement of small particles on the soil surface based on the rainstorm energy), in order to track soil erosion status. The physical crust is one of the phenomenon that significantly reduces the hydraulic permeability of the soil, and accordingly increases run off and soil erosion. Based on a comprehensive laboratory study using a rain simulator and field spectrometer, we were able to establish a set of models (for each examined soil) that correlate spectroscopic properties and the soil's water infiltration properties (19,20). Applying this model to a real IS data revealed an infiltration/erosion map, that can be used by farmers prior to the next rain-storm event. In hazardous areas, gentile tillage of the soil in question (provided by the IS based map), may dramatically reduce the soil's erosion potential (21)

Soil formation: Sand dune transform into a real soil body via a pedogenesis processes that are governed by environmental factors such as time, climate, topography, parent material and organic matter. Formation of free iron oxide is one of the processes which occurs during the weathering of sand dune into a typical red soil. The question whether it is possible to account for the soil formation process via the free iron oxide content, remained unknown in a spatial domain and was the driving force for the current IS based study. In this study, we suggested the use of reflectance spectroscopy and traditional chemical analysis, to find a model that permits such detection. After finding that this strategy does indeed work in the laboratory domain, we applied it to airborne IS data using the CASI sensor. The processed map was then examined in the field, and was compared to the dune stability measurements. A very good agreement was found between the IS based map and the field stability measurements, suggesting that the pedogenesis process can be sensed remotely, even in its very early stages (22,23).

Urban mapping: To the best of our knowledge, the urban application of IS technology was first used in 1999 over Tel-Aviv (24). This was done after discovering that the spectral signatures of urban targets do indeed hold discreet information. It was shown that IS over urban environments can produce new information, which has never been obtained before. A single area in the city could be precisely mapped based on the chemical-physical characteristics obtained from the IS technology. Since this pioneer study, many workers have entered into the urban IS field, demonstrating that this discipline is promising. Figure 3 provides a set of classification maps, based on the spectral information of the cities targets, and generated from the CASI sensor (25).

Aerosol assessment on a pixel by pixel basis: The advantages of the IS technology, lie in its ability to catch small and narrow spectral features of both terrestrial and atmospheric components. Whereas the terrestrial application has gained much attention, and has progressed due to the involvement of many workers; utilization of the atmospheric signals is underdeveloped (except in the assessment of water vapor content). This is mainly due to the limited information that the available IS scanners can provide on other gases, while maintaining reasonable signal to noise ratio quality of the data. In all other atmospheric models, all atmospheric attenuation (except water vapor content) are considered to be constant, as long as the terrain is flat. While this consideration is mostly true for well mixed gases such as O_2, CO_2 and 0_3; it may not be the case for the aerosol load. Smoke, local dust, or point particle emissions, may hamper correct reflectance data retrieval for the area in question. Determining the aerosol content with a pixel by pixel approach, using only the airborne data (as done with the water vapor estimation), is still unavailable to the best of our knowledge. In this study, we propose a method to estimate the Mie scattering effect of a given IS scene, by using the O_2 peak at 760 nm. To do so, we first generated a synthetic AVIRIS scene, composed of a constant water vapor content, and varying aerosol load ranging from 0 to 100 km visibility, over vegetated and urban terrain (and their mixtures). Based on this data we developed a parameter to account for the aerosol effect, using the oxygen peak from the radiance data. We generated look-up-tables for different objects over a selected urban environment, and incorporated this information with authentic AVIRIS data, acquired over Santa Monica US in 2001. The aerosol load, was then calculated on a pixel by pixel basis for further atmospheric correction. It was shown that in a clear skies scenario (20 km < visibility), the aerosol content does not hamper the results, and an visibility estimation by the pilot is more than sufficient. In dusty skies scenario however (10 km > visibility), the proposed correction provides sharper reflectance data for the contaminated pixels. Based on the same idea, the oxygen band was also used to detect and correct for thin cirrus clouds contamination on a pixel by pixel basis (26). Later, Ben-Dor et al. (5) showed that is also possible to account for the topography, using the CO_2 absorption band at 2005 nm, with the water vapor slope between 1.8/2.95. Figure 4 shows the Santa Monica image with its corresponding aerosol image, created using the proposed method.

Atmospheric correction : Special attention was recently given to the examination of the wide variety of atmospheric correction methods used to remove the atmosphere attenuation (27). In practice, this is the bottle neck of the IS discipline. If not properly removed, atmospheric chromospheres can produce signals that may bias ground classification. On the market, there are several methods to correct for the atmospheric effects, each of which have draw backs and limitations. We generated a simulated AVIRIS image (ground + atmosphere), and reconstructed the reflectance after applying the available methods. The product of this study is a look-up-table for soil and vegetation targets (and their mixtures) that indicates which method is appropriate for what target, under what atmosphere condition (11). We found that there is no a single method that can accomplish the correction job completely; and generally there is a need to merge several methods for a given scene. Table 1 provides the look-up-table created in the above study.

Current work: In the pure spectroscopy category, we are studying the BRDF effect on several surfaces, and trying to define the anisotropy function that will make it possible to correct this effect as much as possible. In the modeling category, a project is being conducted to assess the spectral effect of sediment dust on surfaces (28). In the methods developing category, we are attempting to develop a methodology to assess change detection, in the thermal region, for quantification of relatively small scale environmental contamination (16). In the IS acquisition category, the current work is focused on operating the AISA-ES sensor over areas with agricultural green houses in order to determine their transparencies to light, in various locations across the country. Currently, we are also checking the performance of the AISA-ES instrument in scenarios of various flight conditions. High and low altitude flights, and flights that pass over light and dark targets simultaneously, are some examples of these scenarios. Additionally, radiometric calibration of the instrument is scheduled for the next working year.

3 SUMMARY AND CONCLUSIONS

The IS technology in Israel is well developed and recognized. The activity is composed of pure spectral studies, laboratory modeling of the environment, and developing new rapid methods for IS classification. Based on these foundations, airborne campaigns using several sensors have been conducted over the country, focusing mainly on environmental issues. In this instance, it was shown that the IS technology is able to provide additional information that can not be obtained from the traditional methods, while demonstrating in general, the great potential of the IS technology. Due to these recent activities, an IS sensor, has been purchased in Israel by the industrial sector, and is ready and available for utilization by any potential consumer overseas by *the Bar-Kal Systems Engineering Ltd* company. In the near future, this capability will push the IS activity in Israel further, as the exposure of this technology to both the scientific and the applicative sectors in Israel becomes extensive.

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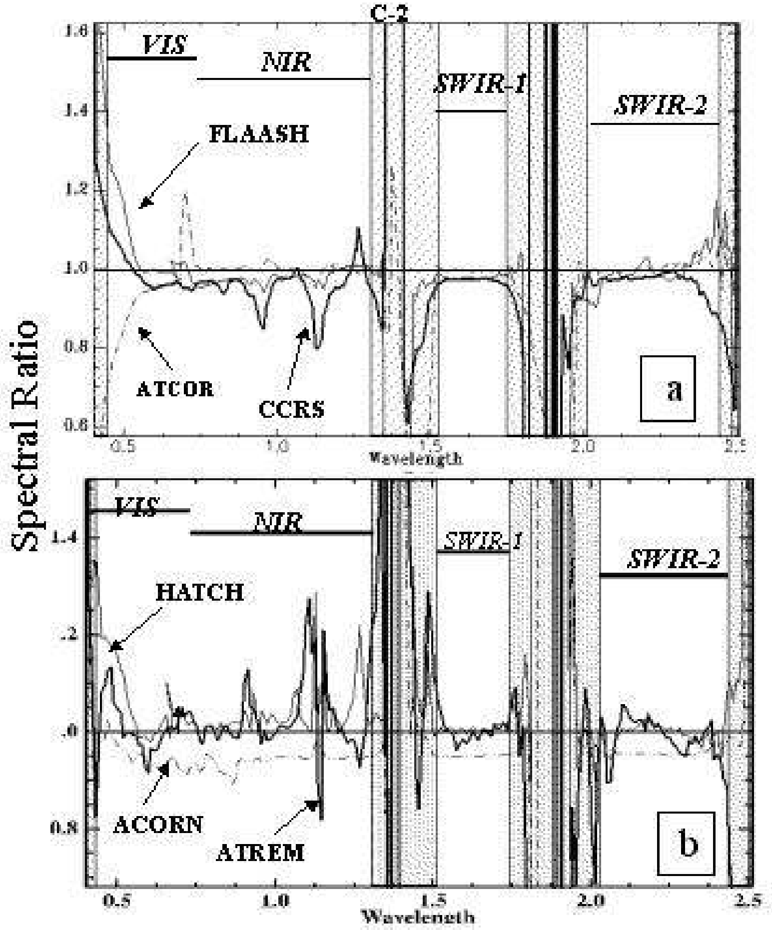

Figure 1: The ratio spectra of 50% soil and 50% vegetation target spectra (true versus reconstructed) after applying six different method to remove the atmosphere attenuations (ATCOR, CCRS, FLAASH, HATCH, ACORN, ATREM).

Figure 2: A simulated scene of Tel-Aviv generated by the IS simulator (left) versus the same area as acquired from the CASI sensor (right).

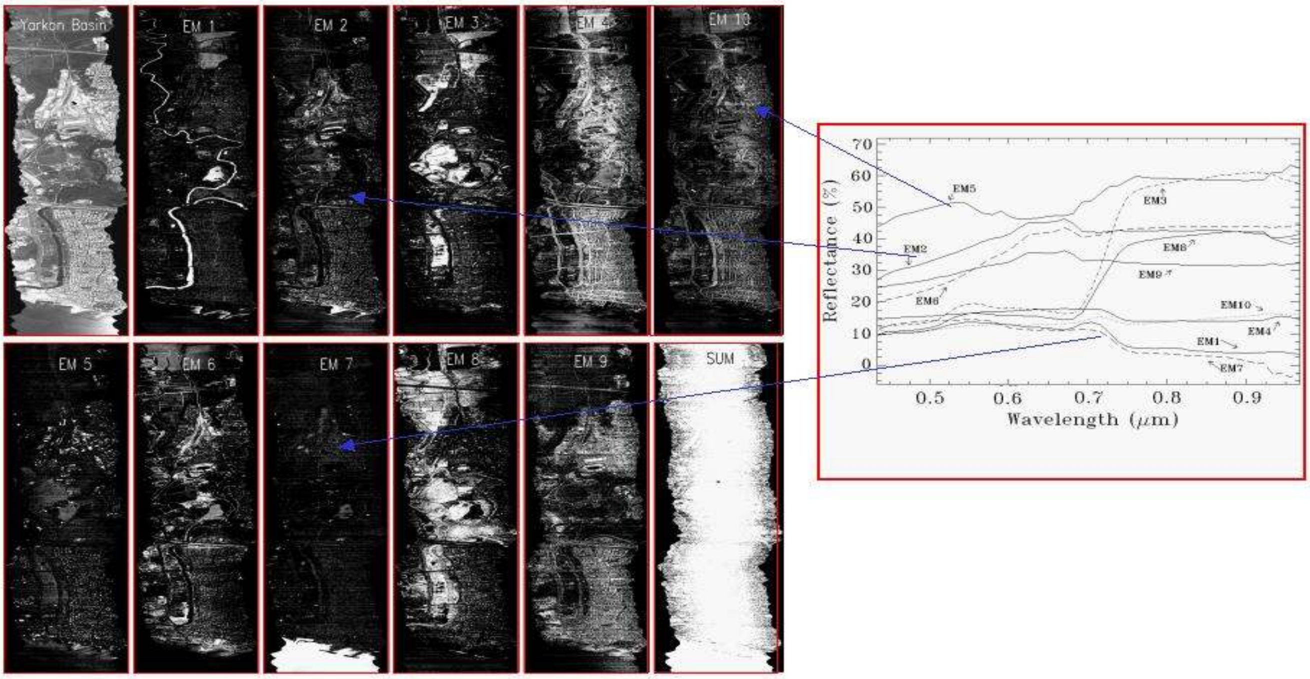

Figure 3: The classification map of selected neighborhood in Tel-Aviv as obtained by SAM method using 10 end members best represent the surface characteristics of the city.

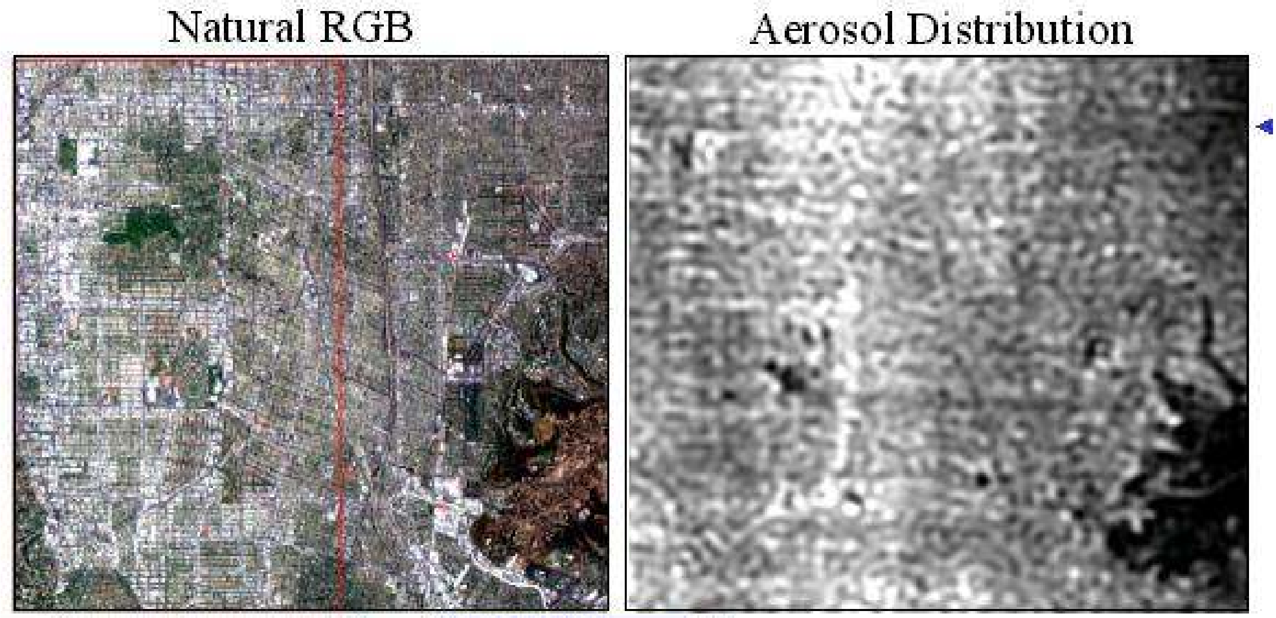

Figure 4: A true color composite image of Santa Monica US (left) and a corresponding “dust” image as generated from the oxygen absorption band method.

Table 1: A *look-up-table* that summarized the best methods to remove atmosphere attenuations on each spectra segments (VIS, NIR, SWIR1, SWIR2) and targets (Vegetation, Vegetation and Soil, Soil) under varying of water vapor environment.

		Water Vapor					
		0.5cm	1.5cm	2.5cm	3.5cm	4.5cm	
	veg	Acron	Acorn	Acorn	CCRS	Acorn	
	veg+soil	Aterm	Atrem	Acron	Atrem	Atrem	VIS
	soil	Atrem	Atrem	Atrem	Atrem	Atrem	
	veg	Flash	Flash	Flash	CCRS	CCRS	
Target	veg+soil	Flash	Flash	Flash	Atcor	CCRS	NIR
	soil	Atcor	Atcor	Atcor	Atcor	Atcor	
	veg	Atcor	Atcor	Atcor	Atcor	Atcor	
	veg+soil	Atcor	Atcor	Atcor	Atcor	Atcor	SWIR-1
	soil	Atcor	Atcor	Atcor	Atcor	Atrem	
	veg	Atcor	Atcor	Atcor	Atcor	CCRS	
	veg+soil	Atcor	Atcor	Atcor	Atcor	CCRS	SWIR-2
	soil	Atcor	Atcor	Atcor	Atcor	CCRS	