USING EO-1 HYPERION IMAGES TO PROTOTYPE ENVIRONMENTAL PRODUCTS FOR HYSPIRI

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1. INTRODUCTION

The Earth Observing One (EO-1) Mission, launched in November, 2000 as part of NASA's New Millennium Program, is completing a decade of operation at the end of 2010. EO-1 has served its original purpose to demonstrate new technologies in support of Earth Science studies from space, but the mission has also developed new technologies. In the first several years of the mission, the EO-1 Science Validation Team conducted a range of investigations to ascertain how well the new EO-1 technologies and image acquisition strategies enhanced the provision of scientifically viable information, resulting in a special IEEE technical issue in 2003 [1]. These new technologies included acquisition from space of visible to shortwave infrared (VSWIR) hysperspectral spectra in 10 nm contiguous bands (400-2500 nm) from the EO-1 Hyperion sensor, lunar (Fig. 1) and solar calibrations, and a off-nadir pointing capability to capture disasters and extreme events. Investigators engaged in NASA's Terrestrial Ecology, Carbon Cycle Science, Land Cover and Land Use Change (LCLUC), as well as international investigators, have used the EO-1 Hyperion imagery in their research projects, and have achieved results for land-based classification maps for a variety of applications with accuracies exceeding those reached with contemporaneous space borne multispectral sensors.

2. CURRENT STATUS

EO-1 is participating in a broad range of investigations, demonstrating the utility of imaging spectroscopy in applications relating to forestry, agriculture, species discrimination, invasive species, desertification, land-use, vulcanization, fire management, homeland security, natural and anthropogenic hazards and disaster assessments, and has provided sensor information to support characterization for a number of instruments on existing and future orbital platforms (e.g., MODIS on Terra and Aqua, Landsats 5 & 7, LDCM, and HyspIRI). To date more than 45,000 images have been acquired, 34% to support the mid-decadal Global Land Surveys (GLS2005 and GLS2010), 46% to support the EO-1 Mission Science Office (MSO) for science support and disaster monitoring, and 20% to support other user requests. Since 2007, the MSO has made systematic collections for current field

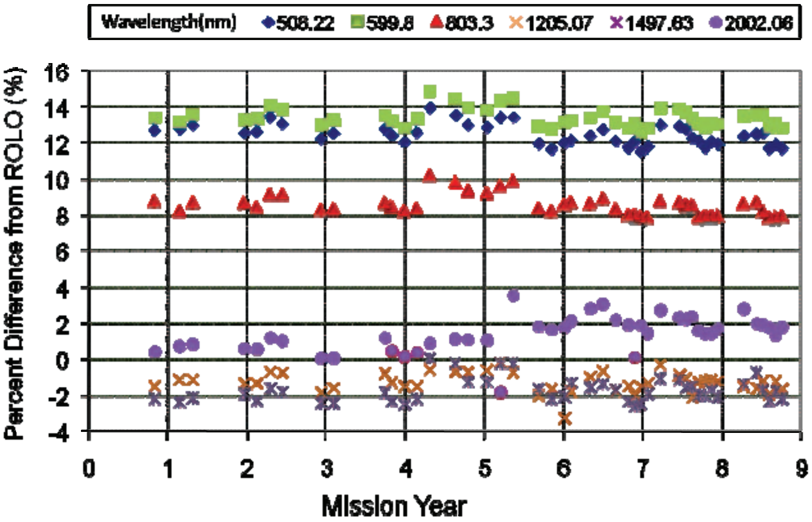
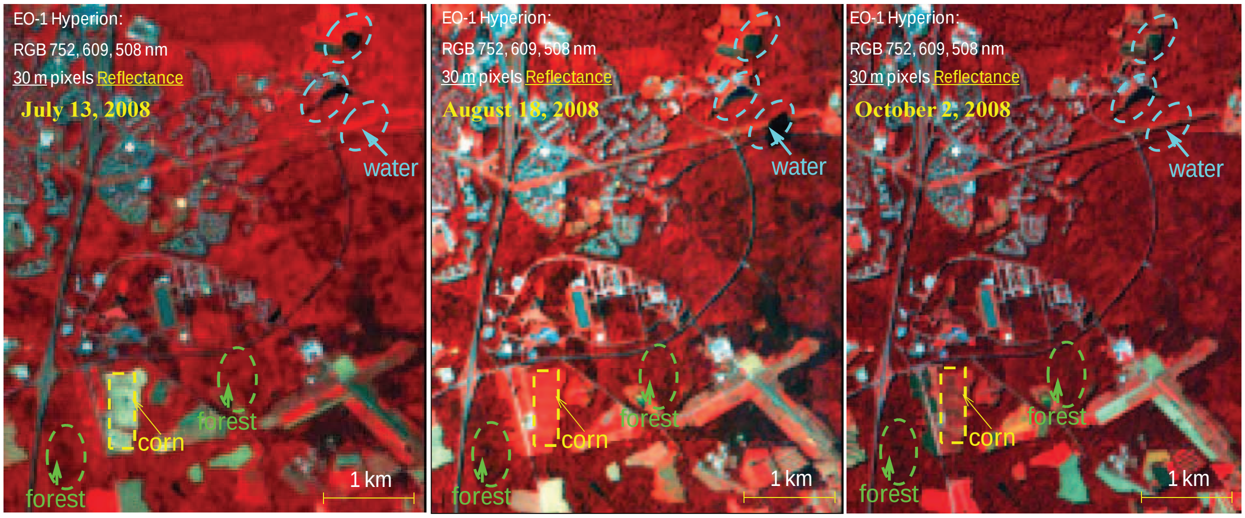
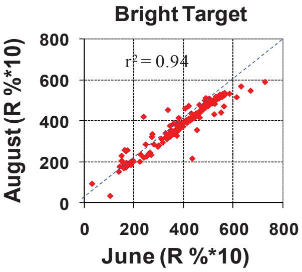


Figure 1. EO-1 Hyperion lunar calibration trends for selected bands. A comparison of integrated radiance values of a few selected bands from the Hyperion images, along with those provided by the Robotic Lunar Observatory (ROLO) lunar model, shows that the sensor's performance is within ± 1.0 -1.5 % and that Hyperion has remained stable over the last eight years.





Cover Type	Hyperion, 2008	V1	PRI	REIP	Dmax	WBI	Albedo
Corn	13-Jun	1.03	-0.04	712	0.36	0.96	0.461
	18-Aug	1.81	-0.06	722	0.75	1.09	0.197
	3-Oct	1.15	0.04	721	0.51	0.98	0.155
Forest	13-Jun	1.12	-0.06	712	0.89	1.00	0.257
	18-Aug	1.56	-0.03	722	0.51	1.01	0.140
	3-Oct	1.61	-0.10	712	0.42	0.94	0.127
Water	13-Jun	0.15	0.01	712	0.16	1.23	0.058
	18-Aug	0.52	0.02	712	0.10	1.46	0.031
	3-Oct	0.62	-0.07	712	0.08	0.93	0.036

Figure 2. Seasonal dynamics of major land cover types. EO-1 Hyperion data were acquired in the Beltsville/Greenbelt, MD area during three months of 2008. Atmospherically corrected image subsets are shown for July 13, August 18, and October 2, on which the occurrence of three surface classes are outlined (forest in green, corn in yellow, and water in blue) and used to produce the average values for spectral indices in the table. Atmospheric correction was accomplished using ATREM [2], with similar bright target retrievals throughout the year. Spectral indices provided in the table include: V1, a band ratio between reflectance at 740 nm and 720 nm [4]; the PRI is the Photochemical Reflectance Index [5], a normalized difference index using 531 and 570 nm; the Red-Edge Inflection Point (REIP) is the wavelength for the first derivative's maximum value (Dmax) between 680-740 nm [4, 6]; the water band index WBI (ratio of reflectance at 900 and 970 nm) [7] reflects the water status in vegetation; and albedo, calculated as the reflected fraction of incoming shortwave radiation over the full spectrum of Hyperion [9].

investigations and future time-series studies, for which a seasonal database (Fig. 2) of repeated observations for selected instrumented sites (e.g., EOS, flux towers) is being compiled, and to support scientific calibration/validation activities. Atmospheric correction methods for hyperspectral data have been evaluated and applied [2, 3], as shown in Fig 2. The MSO is also collaborating with the USGS/EROS to facilitate the distribution of existing images to users and to assist with data acquisitions, since both services became available at no cost through USGS in the summer of 2009.

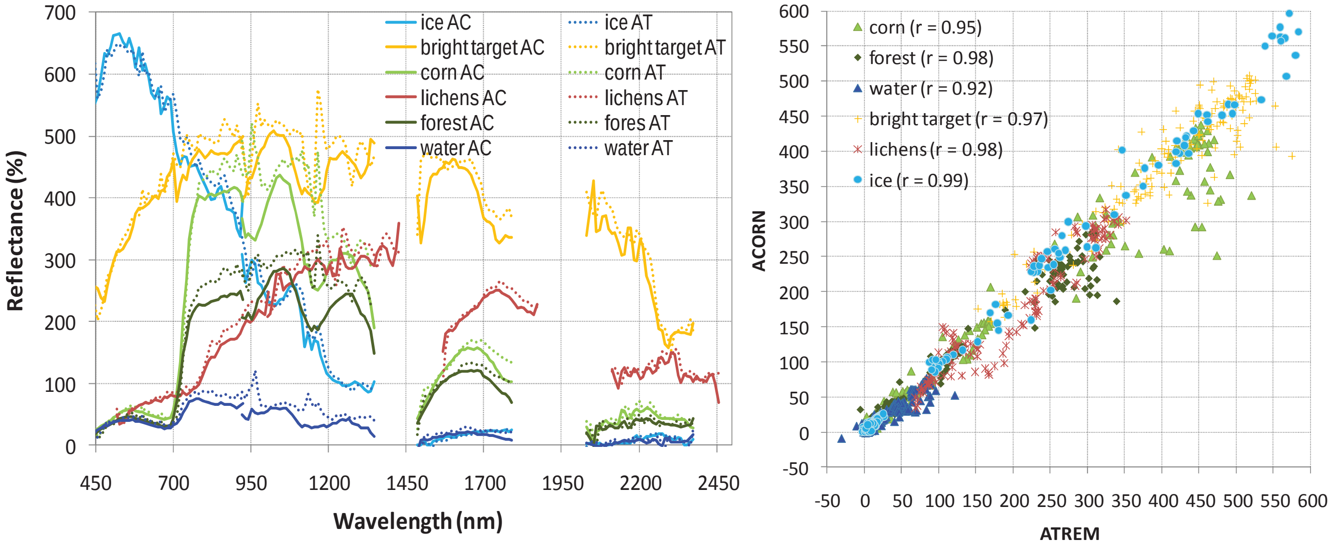


Figure 3. Atmospherically corrected spectra for six surface types (ice, bright target, cornfield, lichens, deciduous forest, and water) are shown in the left panel (A). Two different atmospheric correction programs were used, the ATmosphere REMoval algorithm (ATREM) [2]) and the Atmosphere CORrection Now (ACORN) [3], designated by AT and AC, respectively. The values retrieved for the six surface types by ATREM and ACORN, are compared in the right panel (B). A high overall correlation (r>0.98) was obtained for ACORN vs. ATREM spectra, with correlations for individual categories ranging between 0.92-0.99.

1. PREPARING FOR HYSPIRI

EO-1 Level 2 tools are being developed and tested by the MSO (for which an EO-1 toolkit and atmospheric correction server is available at http://eo1.geobliki.com/) and reflectance prototypes (Fig. 3) for new science products are being developed to provide biophysical parameters such as LAI and fAPAR at <100 m spatial resolution for selected EOS validation sites. Variables produced include spectral indicators of chlorophyll, water content, albedo, fAPAR, LAI, etc. (see Table in Fig. 2), and new, experimental variables such as APARchl obtained by model inversion (Fig. 4, [10]). These will be used to resolve seasonal trends and variability in heterogeneous areas (e.g. agriculture, narrow shapes, urban and developed lands) and for managed ecosystems less than 10 km^2. EO-1 is leading the international collaboration for coordinated tasking of multiple satellites, with special emphasis on disaster management. In future 2009-2012 efforts, more uniform tasking interfaces on other satellites will draw upon the full autonomy approach now employed by EO-1. A set of invariable reference targets (e.g. sun, moon, deserts, Antarctica) are being characterised to allow cross-calibration of EO sensors, comparison of land products generated by multiple sensors and retroactive processing of time series data.

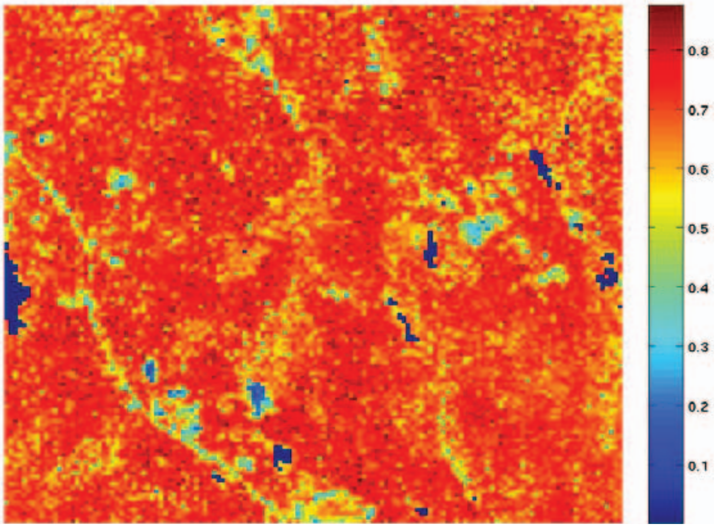


Figure 4. The is an fAPAR$_{\mathrm{chl}}$ map for the Harvard Forest in Massachusetts, USA for a mid-summer day (DOY 159 in 2008), computed from spectral information and model inversion using an atmospherically corrected (by ATREM, [2]) EO-1 Hyperion image, scaled between 0 and 1 (water bodies are set to 0).

Such products are needed to develop Science Requirements for the next generation of hyperspectral satellite sensors and to address global societal needs.

2. SUMMARY

By generating a high spectral and spatial resolution, seasonally repeated data set for numerous terrestrial ecosystems and for the coral reefs and islands, EO-1 is contributing toward realizing the goals of the National Research Council's Decadal Survey and provides an excellent platform for testing strategies to be employed in the HyspIRI mission.

3. REFERENCES

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