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

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ABSTRACT

In November 2010, the Earth Observing One (EO-1) Satellite Mission will successfully complete a decade of Earth imaging by its two unique instruments, the Hyperion and the Advanced Land Imager (ALI). Both instruments are serving as prototypes for new orbital sensors, and the EO-1 is a heritage platform for the upcoming German mission, EnMAP. We provide an overview of the mission's lifetime. We briefly describe calibration & validation activities and overview the technical and scientific accomplishments of this mission. Some examples of the Mission Science Office (MSO) products are provided, as is an example of a image collected for disaster monitoring.

Index terms - EO-1, Hyperion, spectrometry, bio-physical variables, HyspIRI

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 well-served its original purpose to demonstrate new technologies in support of Earth Science studies from space, and also expanded its role to develop new technologies. During 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) hyperspectral spectra in 10 nm contiguous bands (400-2500 nm) from the EO-1 Hyperion sensor, lunar (Fig. 1) and solar calibrations, and an 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) programs, as well as international investigators,

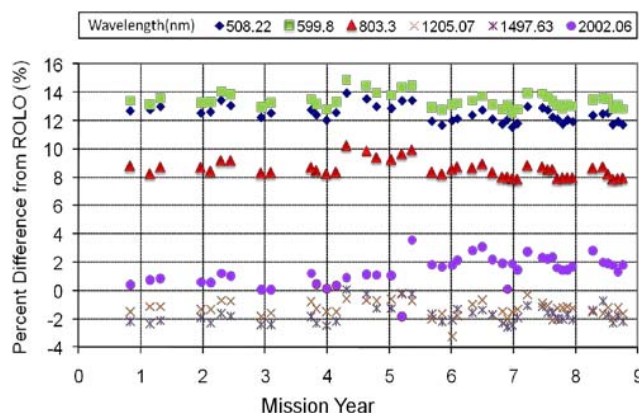


Figure 1. EO-1 Hyperion lunar calibration trends. A comparison of integrated radiance values of a few selected bands from the Hyperion images, along with those provided by the Robotic Lunar Observatory (ROLO) lunar model, shows that the sensor's performance is within ± 1.0 -1.5 % and that Hyperion has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

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]. The EO-1 Advanced Land Imager (ALI) is invaluable to the international community for disaster observations, and the mission participates in key disaster programs such as SERVIR and the UN SPIDER, and others.

The EO-1 is currently the only satellite that simultaneously acquires high spatial resolution (30 m) data for terrestrial and aquatic monitoring with two unique spectral instruments - the Hyperion and the ALI. It also has a 10 m pan-sharpening capability. As the only civilian satellite sensor now acquiring continuous spectrum hyperspectral imagery, Hyperion is greatly assisting investigators with the identification of ecosystem components and enabling the separation of various vegetated land covers.

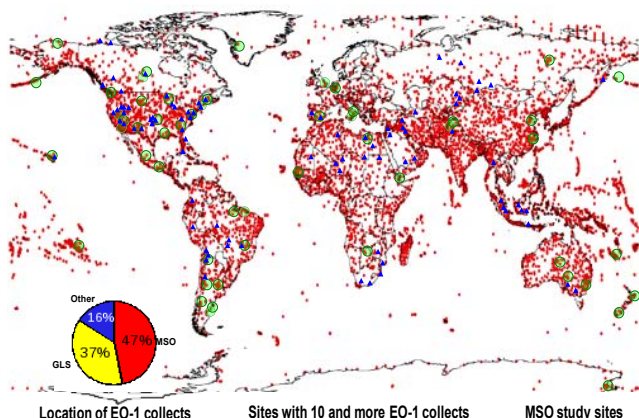


Figure 2. The EO-1 image acquisitions from 2001-2010 around the world total in excess of 49,000 (in red). Regions where more than ten cloud-free collections have occurred, capturing the seasonal dynamics in ground cover, are indicated by green circles.

Because of this range of capabilities, the Hyperion has become the primary data source for numerous investigations which have demonstrated the utility of imaging spectroscopy for a broad range of ecological and geophysical studies around the world. These include examinations of the benefit of spectroscopy in applications relating to forestry, agriculture, species discrimination, invasive species, desertification, land-use, vulcanization, fire management, homeland security, as well as natural and anthropogenic hazards and disaster assessments. In addition, EO-1 has provided sensor information to support characterization for a number of instruments on existing orbital platforms (e.g., MODIS on Terra and Aqua, Landsats 5 & 7), and on future platforms (e.g., LDCM for Landsat-8; EnMAP, and HypSIPI). The EO-1 participates in numerous activities of the Committee on Earth Observation Satellites (CEOS) designed to characterize calibration/validation of ground targets.

2. CURRENT STATUS

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 (**Fig. 2**) [3]. The EO-1 mission has a vital and active role in disaster monitoring activities and in continuing technology developments. Recent examples of disaster observations by EO-1 include images of Haiti before/after the January 2010 earthquake, images of Iceland's Eyjafjallajökull volcanic eruption (one acquired on 14 April 2010 was featured as the back cover of *Physics Today*, June 2010), and a series of images have been acquired for the Gulf of Mexico oil spill (one shown, **Fig. 3**).



Figure 3. The EO-1 Advanced Land Imager (ALI) observed the BP oil spill in the Gulf of Mexico on 26 June 2010. Captured in this pan-sharpened RGB image are streams and ribbons of oil impacting the Mississippi barrier islands of Horn Island (left) and Petit Bois (right).

Since 2007, the MSO has made systematic collections to support field investigations and to make time-series collections at established calibration/validation sites.

A seasonal database of repeated observations (e.g., **Fig. 4**) for selected instrumented sites (e.g., EOS, flux towers) is being compiled to support scientific calibration/validation activities. Atmospheric correction methods for hyperspectral data have been evaluated and applied [4, 5], as shown in **Fig. 4**. 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.

3. 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://eol.geobliti.com/>). Reflectance prototypes (**Fig. 5**) 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. 4**), and new, experimental variables such as APARchl obtained by model inversion (**Fig. 6**, [12, 13]). These will be used to resolve seasonal trends and variability in heterogeneous areas (e.g. agriculture, urban and developed lands) and for managed ecosystems less than 10 km². 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.

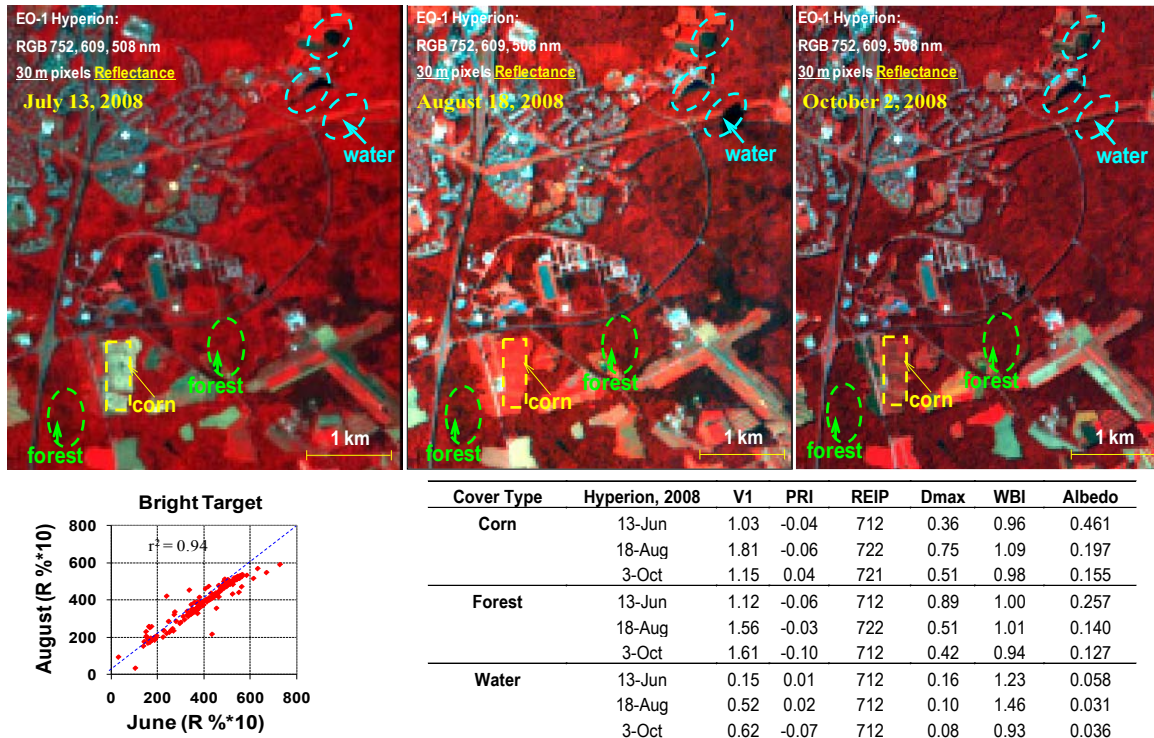


Figure 4. Seasonal dynamics of major land cover types. EO-1 Hyperion data were acquired in the Beltsville/Greenbelt, MD USA area during three months of 2008. Atmospherically corrected image subsets are shown for July 13, August 18, and October 2, for which the occurrence of three surface classes are 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 [4], 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 [6]; the PRI is the Photochemical Reflectance Index [7], 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 [6, 8, 9]; the water band index WBI (ratio of reflectance at 900 and 970 nm) [10] reflects the water status in vegetation; and albedo, calculated as the reflected fraction of incoming shortwave radiation over the full spectrum of Hyperion.

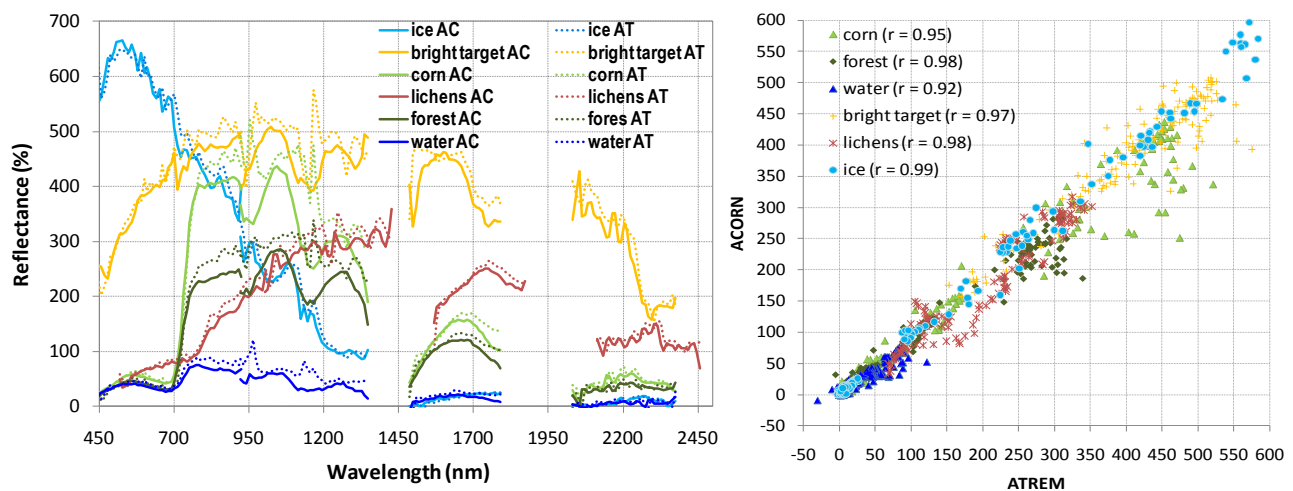


Figure 5. Atmospherically corrected spectra for six surface types (ice, bright target, cornfield, lichens, deciduous forest, and water) are shown in the left panel. Two different atmospheric correction programs were used, the ATmosphere REMoval algorithm (ATREM) [4]) and the Atmosphere CORrection Now (ACORN) [5], designated by AT and AC, respectively. The values retrieved for the six surface types by ATREM and ACORN, are compared in the right panel. 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.

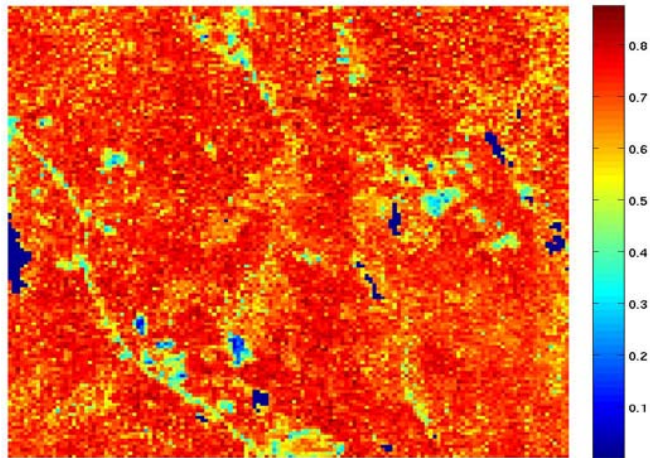


Figure 6. The is an $fAPAR_{chl}$ map for the Harvard Forest in Massachusetts, USA for a mid-summer day (DOY 159 in 2008), computed from spectral information and model inversion using an EO-1 Hyperion image that was atmospherically corrected by ATREM, [4], scaled between 0 and 1 (water bodies are set to 0) [12]. $fAPAR_{chl}$ = the fraction of absorbed photosynthetically active radiation (PAR) by the chlorophyll containing canopy.

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

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