EO-1 Hyperion Time Series for Remote Sensing of Vegetation Carbon Flux Dynamics

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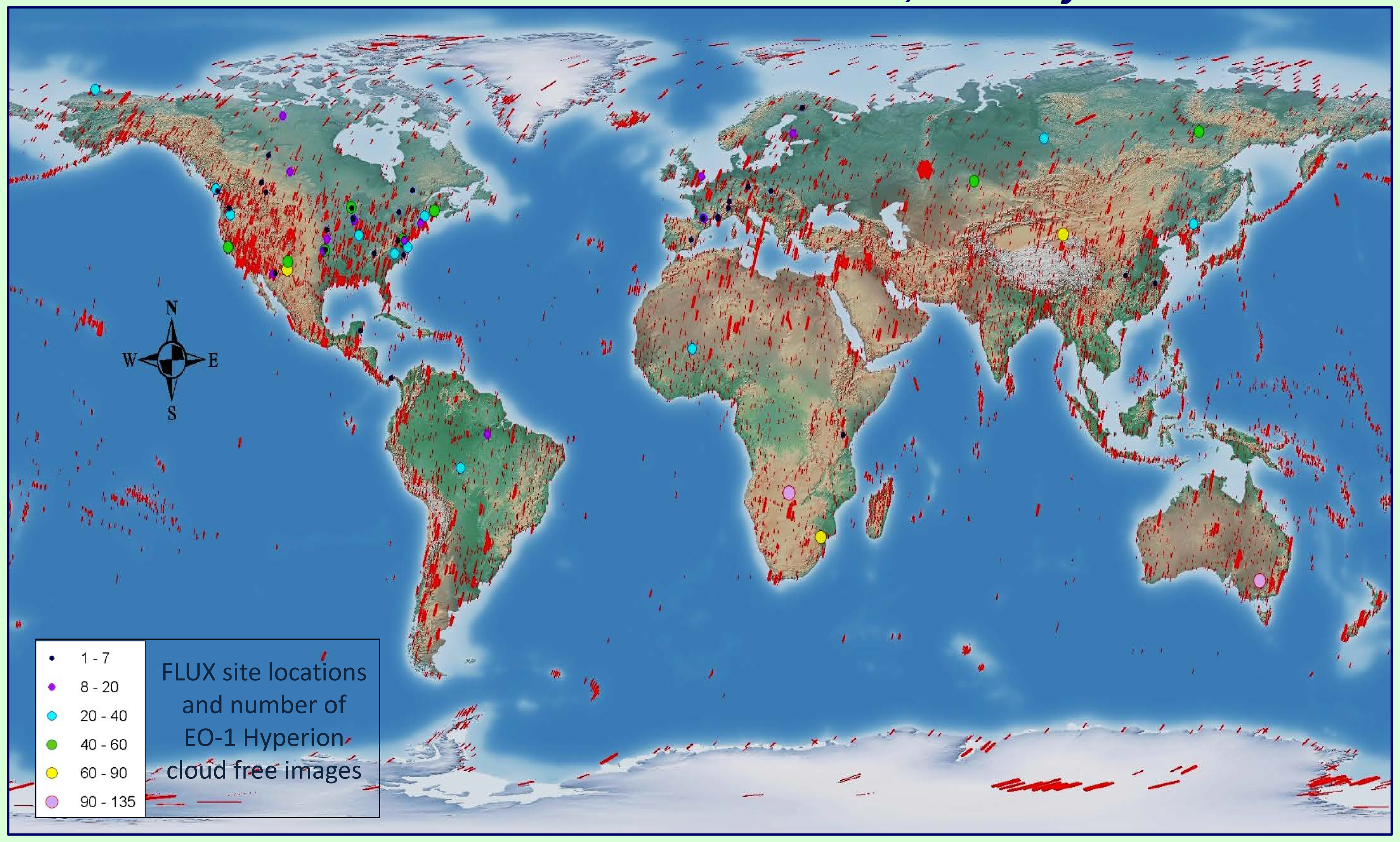
Summary

Spatial heterogeneity and seasonal dynamics in vegetation physiology contribute significantly to the uncertainties in regional and global CO_2 budgets. High spectral resolution imaging spectroscopy (~10 nm, 400-2500 nm) provide an efficient tool for synoptic evaluation of many of the factors significantly affecting the ability of the vegetation to sequester carbon and to reflect radiation, due to changes in vegetation chemical and structural composition. Since 2008 the EO-1 mission has targeted the collection of time series for vegetation studies [1], and currently time series of hyperspectral images are available for studies of vegetation carbon dynamics at a number of FLUX sites, as demonstrated by the table below.

EO-1 Hyperion [1] seasonal composites were assembled and the radiance data were corrected for atmospheric effects and converted to surface reflectance using the Atmosphere CORrection Now (ACORN) model [2]. Spectral differences and seasonal trends were evaluated for each vegetation type and site specific phenology. Spectral bio-indicators were computed from surface reflectance spectra collected in the flux tower footprints and compared to field flux tower measurements (e.g., CO_2 flux, μmol m^{-2} s^{-1}). Comparing spectral parameters in these very different ecosystems, continuous reflectance data and a set of spectral parameters were correlated well to CO_2 flux parameters (e.g., NEP, GEP, etc.) [2]. These spectral parameters traced well the dynamics in vegetation carbon flux induced by the variations in temperature, nutrient and moisture availability. Imaging spectrometry provided high spatial resolution maps of CO_2 fluxes absorbed by vegetation, and proved to be efficient in tracing seasonal flux dynamics.

The study illustrates the ability of Earth Observing-1 (EO-1) Hyperion images to map CO_2 flux dynamics, using examples for Mongu, Zambia but similar results have been obtained for Duke forest and Konza Prairie [2]. The research is being expanded further to include northern hardwood forest, evergreen coniferous forest, savanna, woodland and rain forest at additional sites with available FLUXNET data and EO-1 Hyperion time series.

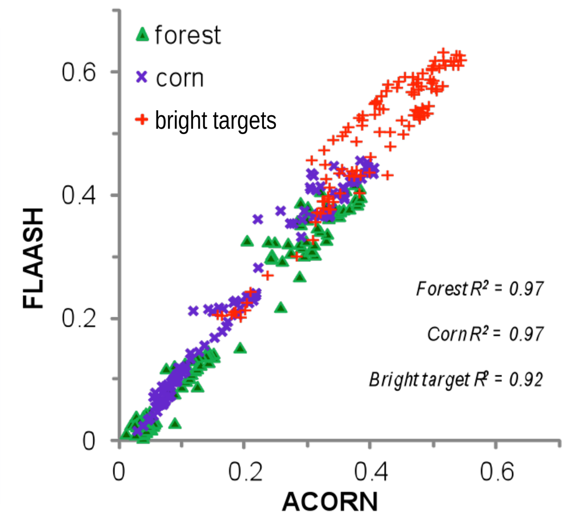
The EO-1 Time Series at FLUX Sites, January 2015

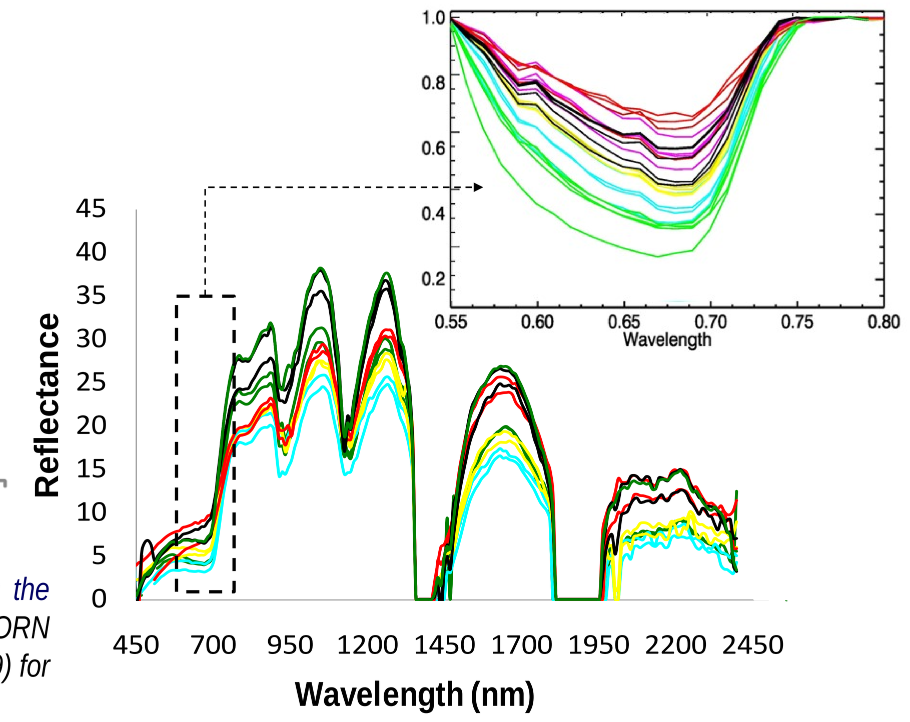


The Earth Observing One (EO-1) was launched in November 2000. As of January 2015 more than 77,960 Hyperion images have been collected. Numerous time series have been produced for selected FLUX sites, which are freely available for download from USGS (http://earthexplorer.usgs.gov/). Hyperion has demonstrated the utility of satellite imaging spectroscopy for vegetation monitoring in applications relating to forestry, agriculture, land-use change, biodiversity, natural and anthropogenic hazards and disaster assessments.

Site Description and Spectral Characteristics

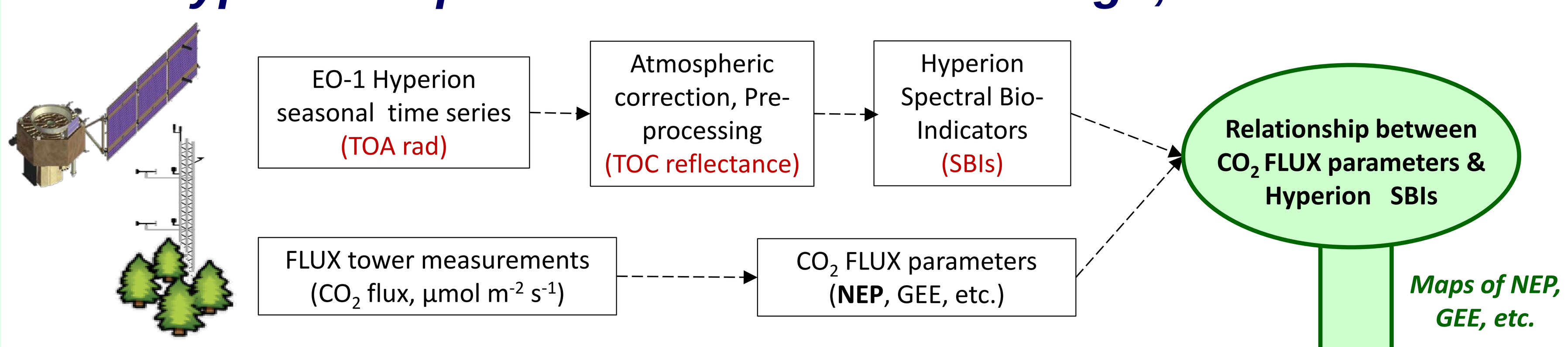
FLUX Site, Location	Mongu, Zambia
Climate	Temperate, warm summer
Vegetation type	Kalahari, Miombo Woodland
Hyperion images	Displayed 11 images from 2009
Image acquisition date [DOY]	4, 22, 40, 145, 171, 199, 225, 256, 284, 302, 315

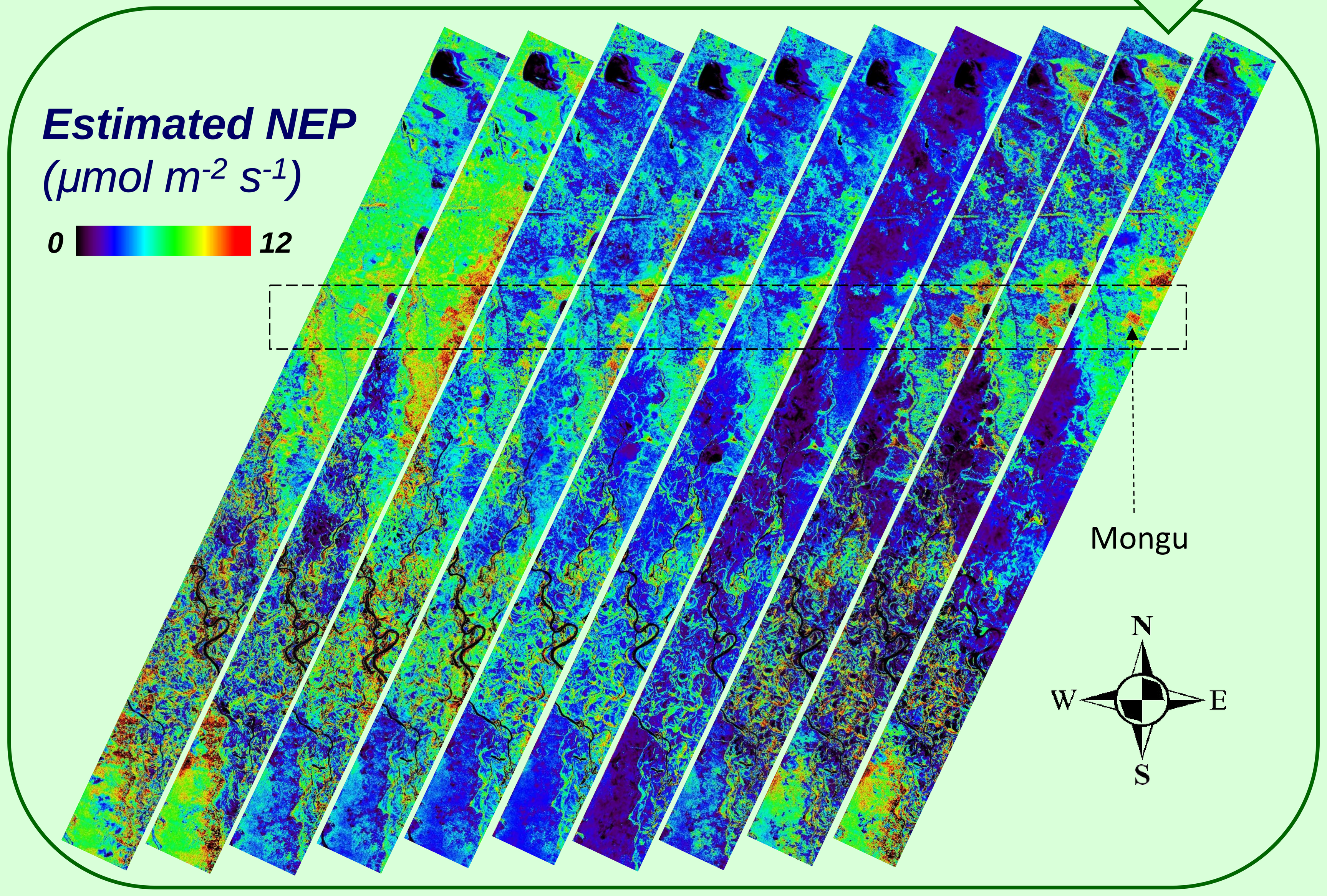




Hyperion radiance images are corrected for atmospheric effects to surface reflectance using the Atmosphere CORrection Now, ACORN software [3]. A comparison of images corrected with ACORN and FLAASH (available at http://eo1.geobliki.com) reveals relatively similar results (r^2 ~ 0.92--0.99) for different geographical areas and covers. The axes indicate the relative reflectance value (0-1).

EO-1 Hyperion: Spectral Time Series for Mongu, Zambia

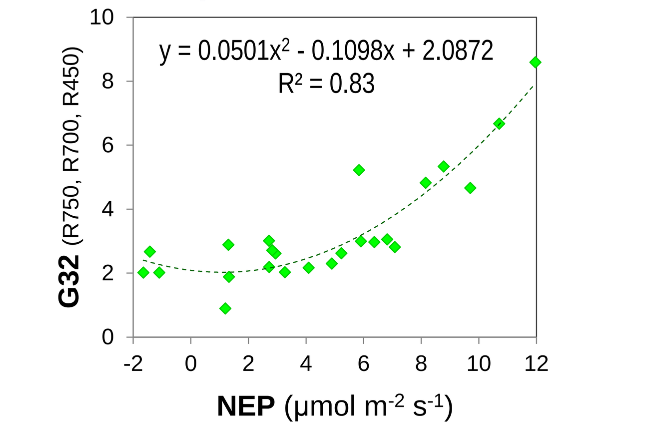




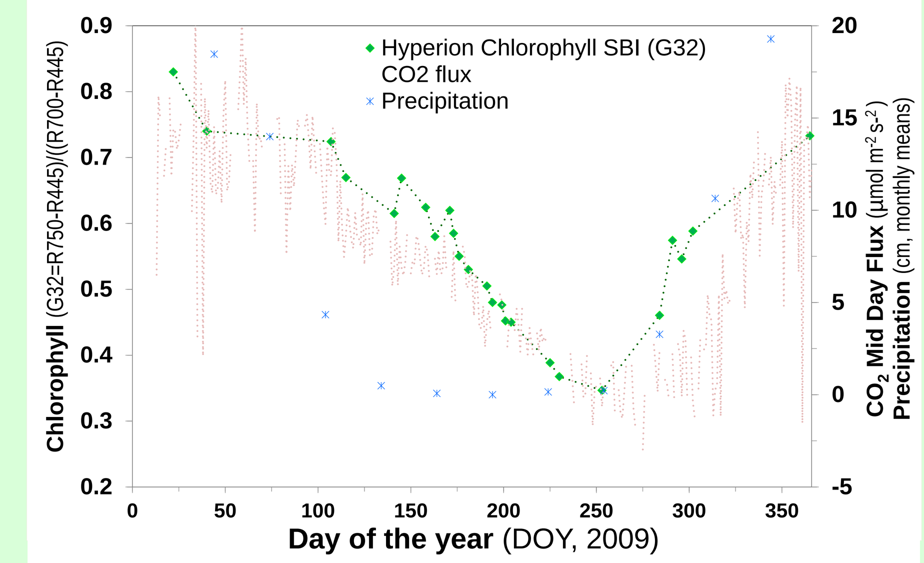
Hyperion's Spectral Bio-indicators (SBIs)

Bio-indicator	Bands (nm)	R^2 [NEP (GEP)]
G32	R750, 700, 450	0.83 (0.81) NL
Dmax	D max (650…750 nm)	0.77 (0.87) NL
Dmax / D704	D(690-730)	0.79 (0.80) NL
mND705	R750, 704, 450	0.75 (0.79) NL
RE1	Av. R 675…705	0.71 (0.56) NL
EVI	R (NIR, Red, Blue)	0.73 (0.88) L
NDVI	Av. R760-900, R620-690	0.52 (0.60) NL

Relationship between G32 & NEP

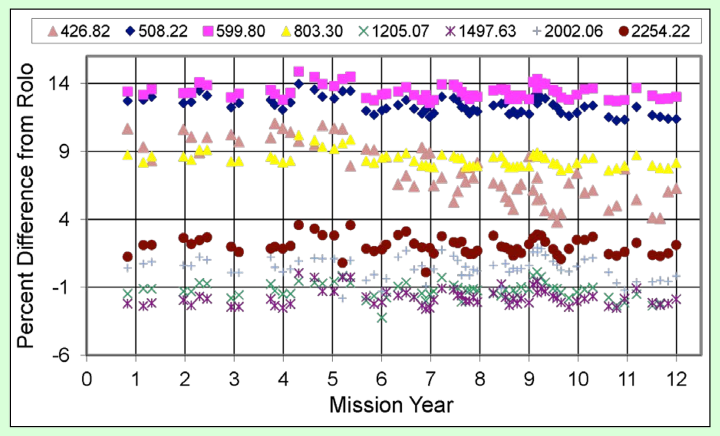


Seasonal Dynamics in G32 (Chlorophyll) Tracing Vegetation Phenology



Hyperion Description

Nominal Data Specifications	
Spatial Resolution	30 m
Swath Width	7.5 km
Spectral Range	400 - 2400 nm
Spectral Resolution	~10 nm



Comparison of the Hyperion integrated lunar responses with the USGS Robotic Lunar Observatory (ROLO) Lunar model, demonstrates the stability of the spectral observations

FLUX Sites and Available Hyperion Images

Site	Images		Site	Images		Site	Images	
	Total	Clear		Total	Clear		Total	Clear
Tapajos (LBA: Santarem)	267	21	Metolius/Cascades, OR	101	37	Bily Kriz Beskidy (spruce)	22	5
Skukuza	258	91	Jasper Ridge	98	44	BCI	17	0
Uardry	238	132	Bartlett	91	24	Audubon	12	8
Mongu	227	135	Duke forest, HW	89	34	Milk river, Rangeland	11	5
Prk Falls, WI LTER	224	55	Hyytiala	87	15	Walnut Gulch /Kendall	9	7
BC DF49, Campbell River	180	38	Virginia coastal reserve	84	36	Santa Rita Grassland	9	7
Barrow	176	31	Hackett River	82	18	Dyn_Agra_(Crop_land)	8	2
Howland forest	171	42	Madison WI	51	15	Wind River Crane, WAS	8	1
Zotino	166	33	Arlington_BF	49	14	ARM/CART SGP	6	8
Changbaishan	165	40	French agri, site 3	44	15	NC Loblolly plantation	6	3
JI-Parana(Jaru-LBA)	163	39	BERMS_SSA	42	13	BC Young, Campbell River	6	2
Dunhuang	158	78	French savanna, Mali	36	26	Baraboo Hills	6	1
BARC (USDA corn N)	130	48	Konza prairie	36	13	Oil sands	6	1
ARM/CART Ponca City	123	47	French agri, site 1	36	10	Mead US-Ne1	5	4
Jornada	115	72	Sian Kaan	36	1	Mead US-Ne2	5	4
Shortandy, Kazhstan	115	42	SERC	34	9	ARM/CART Shider	5	3
Barton Bendish	112	17	Sodankyla	30	4	Barrax	5	2
Bondville	111	32	Thor, IT (Micol1)	28	0	Oak Ridge, Tennessee	5	2
Sevilleta	103	57	Micol2	28	0	Blackhawk island	5	1
Yakitsk Larch	101	49	Harvard Forest	25	13	Mead US-Ne3	4	3

Conclusions and Future Work

Our results suggest a strong correlation between CO_2 flux and Hyperion's spectral bio-indicators associated with chlorophyll content. The bio-indicators with strongest relationships to NEP were derived using continuous spectra or numerous wavelengths associated with chlorophyll content. We verified the feasibility of a common (global) hyperspectral strategy to monitor vegetation processes, including the vegetation ability to uptake CO2. The approach requires a diverse spectral coverage, representative of major ecosystem types, as well as time series of spectra representing the internal dynamics of cover types. These findings are directly relevant to the forthcoming HyspIRI (NASA, USA) and EnMAP (DLR, Germany) hyperspectral missions. In future work we will assess the relevance of the results to the Sustainable Land Imaging initiative (NASA, USA), the long term time series of Landsat 8 and the forthcoming Sentinel-2 (ESA) and VENμS (France/Israel) missions.

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[1] Middleton, E. M., S. G. Ungar, D. J. Mandl, L. Ong, P. E. Campbell, D. R. Landis, J. P. Young, N. H. Pollack (2013). The Earth Observing One (EO-1) Satellite Mission: Over a Decade in Space. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* 04/2013; 6(2):243.

[2] Atmosphere CORrection Now (ACORN v. 6.1b), ImSpec LLC. Analytical Imaging and Geophysics LLC (AIG), (2001), ACORN User's Guide, Stand Alone Version, 64 p.

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