# EO-1 Hyperion capturing seasonal dynamics in vegetation phenology and spectral properties associated with $CO_2$ uptake


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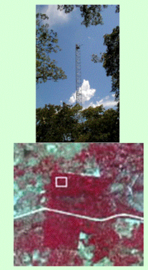
## Abstract

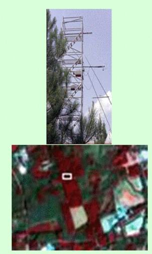

Spatial heterogeneity and seasonal dynamics in vegetation physiology contribute significantly to the uncertainties in regional and global $CO_2$ budgets. Satellite remote sensing is essential for monitoring vegetation physiology, phenology and spatial variation, to assess the impact of terrestrial ecosystems on the dynamics of carbon fluxes and improve our understanding of the underlying factors. High spectral resolution measurements (≤10 nm, 400-2500 nm) provide the optimal 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 pigment and water content, structural and chemical composition. Invariant ground targets are commonly used to monitor the long-term radiometric stability of remote sensing sensors, while core Earth Observing Sites provide key data to monitor the properties of major ecosystem types.

This study focuses on the analysis of EO-1 Hyperion data in comparison to $CO_2$ flux estimates at three vastly different vegetative sites (Mongu, Duke and Konza), representing major vegetation types (e.g. hardwood forest, grassland, evergreen forest, savanna). Our goal is to assess the temporal dynamics in vegetation spectra at these sites, seeking common spectral trends (spectral bio-indicators) associated with vegetation function, induced by the seasonal effects/variation of temperature, moisture and humidity. EO-1 Hyperion seasonal composites were assembled and the radiance data was corrected for atmospheric effects to surface reflectance using the Atmosphere CORrection Now (ACORN) model. Reflectance spectra were collected in the flux towers footprints, and utility of spectral indicators of vegetation physiology were computed and compared to field flux tower measurements (e.g. $CO_2$ flux, μmol $m^{-2}$ $s^{-1}$).

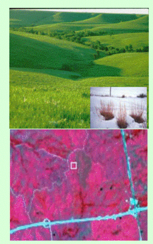
Spectral signatures significantly differed based on vegetation type and site specific phenology. Our preliminary results suggest a strong correlation between $CO_2$ flux and a number of bio-indicators associated with pigment content (r=0.77--0.86; using 670-790 nm region), regardless of vegetation type and site. This study will further be expanded to other vegetation types and sites (FLUX and LTER) to test the ability of the established spectral indicators of vegetation function to capture the dynamics in vegetation phenology and estimate $CO_2$ fluxes.

1. Mongu, ZA

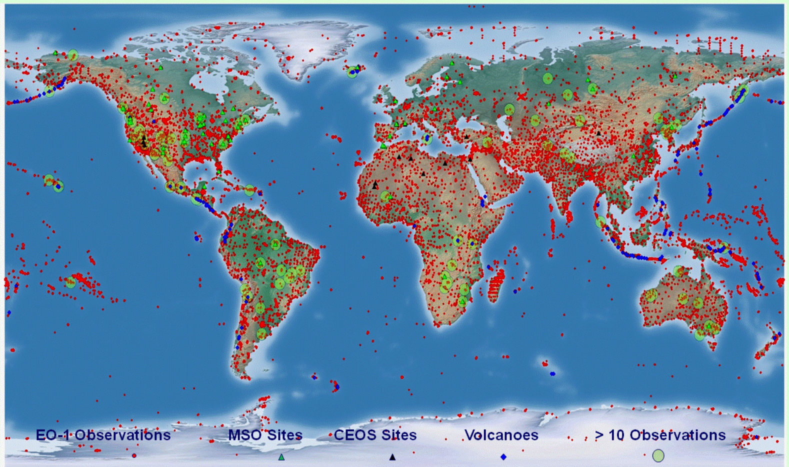


2. Duke, NC

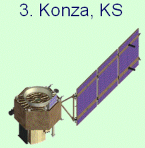


3. Konza, KS

## The EO-1 Time Series



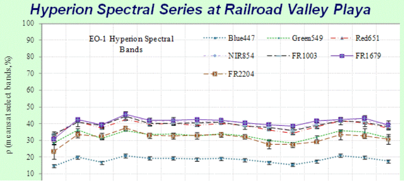

*The Earth Observing One (EO-1), launched in November 2000, is in it's tenth year of operation. EO-1 Hyperion has demonstrated the utility of space borne imaging spectroscopy in applications relating to forestry, agriculture, geology, plant species discrimination, desertification, land-use, vulcanization, fire management, homeland security, natural and anthropogenic hazards and disaster assessments.*



## Hyperion Description

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

### Hyperion Spectral Series at Railroad Valley Playa

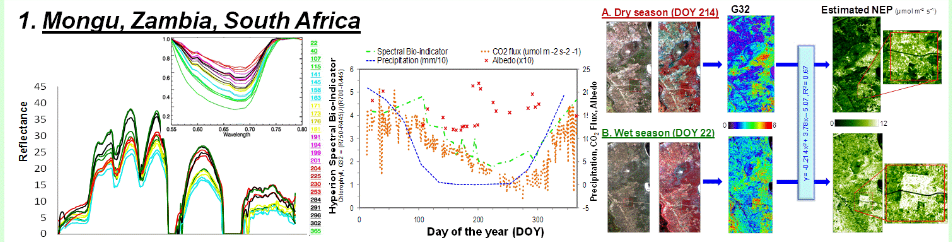



## Study Sites and Data

| FLUX Site | 1. Mongu | 2. Duke | 3. Konza Prairie |
|---|---|---|---|
| Location | *Zambia* | *North Carolina, US* | *Kansas, US* |
| Climate | *Tropical, dry warm summer* | *Temperate, hot summer* | *Cold/ no dry season/ hot summer* |
| Vegetation type | *Kalahari/ Miombo Woodland* | *Loblolly Pine/ Evergreen* | *Grassland* |
| Hyperion data | *25 images (2008)* | *7 (2008-2009)* | *7 (2008-2009)* |
| Hyperion images by acquisition date *[DOY]* | *22, 40, 107, 115, 141, 145, 158, 163, 171, 173, 176, 181, 191, 194, 199, 201, 204, 225, 230, 253,* | *6/2009, 34/2009, 162/2008, 180/2008, 203/2008, 290/2008, 300/2008* | *13/2009, 28/2009, 202/2008, 205/2008, 261/2008, 266/2008, 302/2008* |

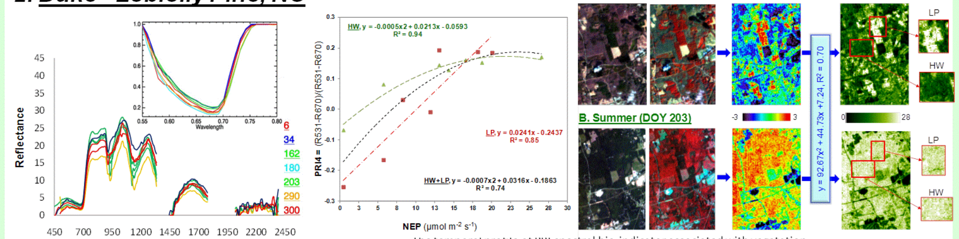
## Corresponding Changes in Spectral and Physiological Parameters

### 1. Mongu, Zambia, South Africa



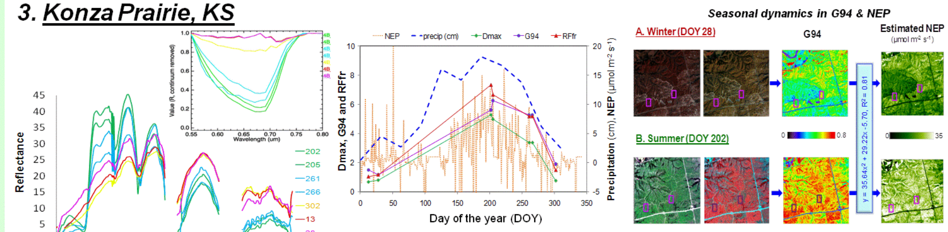

The temporal profile of a spectral bio-indicator associated with chlorophyll content (G32, green line) captured the dynamics in vegetation phenology at the flux site Mongu, Zambia.

### 2. Duke - Loblolly Pine, NC




The temporal profile of PRI spectral bio-indicator associated with vegetation function (LUE) captured the dynamics in vegetation phenology at Duke, NC.

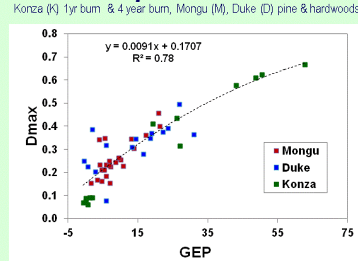
### 3. Konza Prairie, KS




The temporal profile of Dmax, spectral bio-indicator associated with vegetation physiology captured the dynamics in vegetation phenology at Konza, KS.

## Multiple Flux Sites

Konza (K) 1yr burn & 4 year burn, Mongu (M), Duke (D) pine & hardwoods




At a number of sites with vastly different vegetation type, the derivative spectral bio-indicator (Dmax) reflected vegetation dynamics and was negatively correlated with $CO_2$ flux.

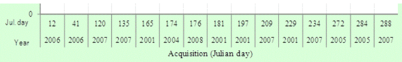
## All Flux Sites -- Top Performing Bio-indicators ($R^2$)

| Spectral indicator | Formula | NEP | GEP | LUE |
|---|---|---|---|---|
| **Dmax** | Max D in the 650-750 nm | 0.73 L+ | **0.77** L+ | 0.75 L+ |
| DP22 | Dmax/D(max + 12) | 0.65 L+ | 0.74 NL+ | 0.71 L+ |
| G34 | Chlorophyll, R bands at 750, 800, 520, and 450 nm | 0.55 NL- | 0.52 NL- | -0.65 NL- |
| NDWI | R(870-1240)/R(870-1240) | **0.74** NL + | 0.67 NL+ | 0.63 L+ |
| MCARIa | Chlorophyll, R bands at 700, 670, and 550 | 0.41 L+ | 0.75 L+ | **0.77** L+ |

In addition, $CO_2$ flux, and *G* had the highest correlations, respiration had low correlations. Dmax was positively correlated with *G* and negatively with $CO_2$. This is potentially because higher $CO_2$ results in greater biomass, that shades the soil and protects the soil from heating.

## Conclusions and Future Directions

• Spectral bio-indicators correlated well with $CO_2$ flux parameters in 3 unrelated ecosystems. Reflectance seasonal dynamics captured each

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|---|---|---|---|
| | ***284, 291, 296, 302, 365*** | | |

***Acknowledgments:*** *Our collaborators include Bruce Cook (NASA/GSFC, Greenbelt, MD), Hank Margolis (Laval University , Quebec, Canada), Jose F. Moreno (University of Valencia, Spain), Nicholas Coops (University of British Columbia, Vancouver, CA), Caroline J Nichol (School of GeoSciences, University of Edinburgh, Edinburgh, UK), Frederic Baret (CNES, Avignon, France). We would like to acknowledge Dr. Brunsell and the KNZ-LTER supplied flux data for the Konza Prairie. The School of the Environment at Duke University supplied flux data for the Duke Forest sites. The project provides research experience for graduate and undergraduate students.*

• Spectral bio-indicators correlated well with $CO_2$ flux parameters in 3 unrelated ecosystems. Reflectance seasonal dynamics captured each site's specific phenology. Spectral bio-indicators with strongest relationships were calculated using wavelengths associated with chlorophyll content and required continuous spectra. Hyperion spectral data were useful for detecting parameters related to NEP, GEP, LUE and other canopy physiological parameters.

• We plan to expand the tests over additional ecosystem types (rain forest, temperate and sub-arctic vegetation types), extend analyses at the mentioned sites as new observations become available, and confirm/validate the findings and assess the accuracy of the produced maps.

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