Alphabetical Order (Presenter's Last Name)

1. Modeling Carbon and Water Fluxes Across Ecosystems: the Land Core Information Service of Geoland

Manuela Balzarolo[1], Gianpaolo Balsamo[2], Alina Barbu[3], Souhail Boussett[2], Jean-Christophe Calvet[3], Alessandro Cescatti[4], Frederic Chevallier[5], Sebastien Lafont[3], Fabienne Maignan[5], John de Vries[6], Laszlo Kullman[7], and Dario Papale[1]

[1]*University of Tuscia, Italy*
[2]*ECMWF, United Kingdom*
[3]*Météo-France, France*
[4]*JRC, IES, Ispra, Italy*
[5]*LSCE, France*
[6]*KNMI, The Netherlands*
[7]*OMSZ, Hungary*
manuela.balzarolo@unitus.it

Even if ecological models based on remotely sensed data show good results in predicting carbon and water fluxes they need to be tested at global scale in order to evaluate goodness of their simulations across and within the ecosystems. The existing global eddy covariance (EC) network (FLUXNET [1]), where CO2 and water exchange is continuously measured [2], make it possible for most of world regions.

This study reports the results of the verification activities of the Land Carbon Core Information Service (LC-CIS) of the Geoland2 European project [3]. Carbon and water fluxes were simulated over Europe using three land surface models: C-TESSEL from ECMWF [4, 5] SURFEX from CNRM [6] and ORCHIDEE from IPSL [7]. These models differ in their hypotheses used to describe processes and the interactions between plant-soil-atmosphere system, climate and environmental conditions. The estimation of carbon fluxes (NEE, GPP and Reco) and water fluxes (H and LE) simulated by models are verified against FLUXNET eddy covariance data for the most important worldwide Plant Functional Types (PFTs: forest, grassland and cropland). Quality of the EC data is verified using the CarboEurope database methodology [8, 9] and accuracy is evaluated by u* threshold value uncertainty. Verification methodology includes the statistical analysis (R2, RMSEabs, E, MAPE, BE) of the fluxes magnitude, daily and annual cycles, inter-annual anomalies for all PTFs and for each PFT.

References

[1] www.fluxdata.org
[2] D. Baldocchi et al., 2001, Bull. Amer. Meteorol. Soc., 82, 2415-2434.
[3] www.gmes-geoland.info
[4] S. Boussetta et al., in preparation
[5] http://www.ecmwf.int/research/EU_projects/GEOLAND/CTESSEL/index.html
[6] http://www.cnrm.meteo.fr/surfex/
[7] G. Krinner et al., 2005, Global Biogeochem. Cycles, 19, GB1015.
[8] D. Papale et al., 2006, Biogeosciences, 3, 1-13.
[9] M. Reichstein et al., 2005, Global Change Biol., 11, 1424-1439.

2. Estimation of Carbon Fluxes by Broadband Vegetation Indices for Mediterranean Mountain Grassland

Manuela Balzarolo and Dario Papale

University of Tuscia, Via S.C. de Lellis, S.nc., 01100 Viterbo - Italy
manuela.balzarolo@unitus.it

This study investigates the possibility of monitoring carbon dioxide fluxes of grassland by broadband broadband Normalised Difference Vegetation Index (bNDVI) and Simple Ratio (bSR) derived from reflectance measurements of photosynthetically active and short-wave radiation. These low cost radiometers allow continuous high temporal reflectance optical measurements (half-hourly or higher) improving the knowledge of biophysical parameters of the ecosystems (e.g. LAI and biomass). Optical and eddy covariance fluxes measurements were continuously carried out at a Mediterranean mountain grassland in Italy from the 2005 to 2008, years with constraint meteorological conditions. Estimations of CO2 fluxes from optical data base on Artificial Neural Network model (ANN) trained using as input variables meteorological data (global radiation, air temperature, soil temperature, vapor pressure deficit, soil water content, potential radiation, Top of Atmosphere radiation transformations (ToA)), bNDVI and bSR. Results show that use of broad band vegetation indices get better prediciton of NEE and GPP of grassland providing helpful information on seasonal and interannual variability of ecosystems parameters. Therefore broadband vegetation indices can provide helpful information in flux data simulations and gap-filling.

3. Mapping Pigment Concentration and Leaf Area Index from High Spatial Resolution LiDAR and Hyperspectral Airborne Data: Applications in Land Surface Modeling

J.A.J. Berni[1], E. Van Gorsel[1], N. Kljun[2], L. Chasmer[3],V. Haverd[1], A. Cabello-Leblic[1], J. Hacker[4], C. Hopkinson[3,5], A. Held[1], and R. Leuning[1]

[1]*CSIRO Marine and Atmospheric Research, Canberra, Australia (jose.jimenez-berni,eva.vangorsel,vanessa.haverd,arancha.cabello,alex.held,ray.leuning@csiro.au)*
[2]*Department of Geography, Swansea University, Swansea, United Kingdom (n.kljun@swansea.ac.uk)*
[3]*Cold Regions Research Centre, Wilfrid Laurier University, Waterloo, ON, Canada (lechasme@yahoo.ca)*
[4]*Airborne Research Australia, Flinders University of South Australia, Australia – (jorg.hacker@flinders.edu.au)*
[5]*Applied Geomatics Research Group, Lawrencetown NS, Canada (chris.hopkinson@nscc.ca)*

Quantitative remote sensing using hyperspectral and LiDAR sensors provide spatially extensive information about biophysical parameters which are linked directly to physiological processes that control carbon and water exchanges in vegetation. The high spatial resolution of these sensors can deliver maps of these driving factors and appropriately account for disturbance effects or heterogeneity.

Active sensors like the LiDAR allow the extraction of the 3D structure of the vegetation and ultimately parameters related with radiation interception like leaf area index (LAI) or fractional cover (*fCover*). LiDAR-derived canopy fractional cover (*fCover*) was determined by counting the total number of returns within each cumulative bin (in 2m intervals) divided by the total number of returns. *fCover* from LiDAR was then used to estimate effective LAI (LAI_e) calibrating it with digital hemispheric photographs (DHP). The LAI map for the canopy was modelled using the scaled LAI_e at a cumulative bin height of 8 – 44 m. This was determined based on the equation from Chen et al. (2006, AgForMet, 140 pp 257-268)**.**

Multispectral or hyperspectral sensors can be used to estimate the biochemical properties of the vegetation, such as the chlorophyll leaf concentration (*Chl*) and ultimately the photosynthetic capacity in the form of the maximum carboxylation rate ($Vc_{max,0}$, where 0 stands for “normalized to standard temperature”) and the potential rate of electron transport ($J_{max,0}$). Care must be taken when upscaling vegetation indexes (VI) related with pigment concentration as such indexes are influenced by structural effects at canopy scale. We have used PROSPECT5, a leaf level radiative transfer model (RTM), coupled to the 3D canopy RTM (FLIGHT) to take these structural effects into account. Inputs for FLIGHT like tree dimensions and distribution were derived from the LiDAR data. Simulations for a range of chlorophyll concentration and LAI values were conducted resulting in synthetic spectra that were related with the input Chl and LAI. As result a new vegetation index for *Chl* that combines the canopy reflectance in the red edge region (750 and 710nm) and LAI derived from the LiDAR has been developed. $Vc_{max,0}$ and

$J_{max,0}$ have been derived from *Chl* using leaf level measurements of photosynthesis for different levels of *Chl* concentrations.

To test the VI we use data from a hyperspectral sensor and a full waveform LiDAR flown over a temperate forest in Australia which is the location of the Tumbarumba Ozflux site. Maps of LAI, $V_{cmax,0}$ and $J_{max,0}$ at 25m grid size were subsequently used to derive parameters to run surface atmosphere transfer models (CABLE-SLI) and generate a map of net ecosystem exchange (NEE). Flux data is used to validate the footprint weighted NEE estimates.

4. Vegetation stress detection using a micro-hyperspectral airborne sensor on board an Unmanned Aerial Vehicle (UAV)

J.A.J Berni[1] and P.J. Zarco-Tejada[2]

[1]CSIRO Marine and Atmospheric Research, Canberra, Australia (Jose.Jimenez-Berni@csiro.au)
[2]Instituto de Agricultura Sostenible (IAS), Consejo Superior de Investigaciones Científicas (CSIC), Córdoba, Spain (pzarco@ias.csic.es)

Topic: Hyperspectral remote sensing, new technologies

This work presents new advances on vegetation stress detection methods using a micro-hyperspectral imager on board an Unmanned Aerial Vehicle (UAV) flying over natural vegetation and crop canopies with varying levels of nutrient and water stress condition. A 5-m wingspan platform was used to fly autonomously at altitudes ranging 150-500 m and 75 km/h with endurance time to cover up to 3.500 ha per flight. A micro-hyperspectral imager was installed on board the UAV platform to acquire a range between 260-360 spectral bands and 3 to 6 nm FWHM imagery depending on the acquisition mode used, obtaining 40 cm spatial resolution in the 400-1.000 nm spectral range. Radiometric calibration, atmospheric correction and imagery ortho-rectification were conducted using commercial solutions and software developed at QuantaLab – IAS – CSIC laboratory. Indices related to xanthophyll, carotenoids, anthocyanins, and chlorophyll *a+b* were extracted using optical indices such as PRI, TCARI/OSAVI and new indices related to carotenoid and anthocyanin pigments from study areas flown that comprised a gradient in stress conditions due to varying water and nutrient stress levels. The retrieval of chlorophyll fluorescence using the fluorescence *in-filling* FLD3 method through the O_2 band at 760 nm was conducted from pure crowns due to the high spatial resolution acquired (less than 40 cm pixel size for 260 bands at 6.4 FWHM bandwidth). Automatic object-based image analysis methods were applied to the hyperspectral imagery acquired with the UAV platform, obtaining thematic maps of stress at the crow level. The study demonstrates the feasibility for hyperspectral imagery acquisition on board UAVs using lightweight micro-hyperspectral imagers synchronized with low cost IMU systems. Hyperspectral imagers onboard UAV platforms enable flexible airborne campaigns for the validation of biochemical and biophysical parameter retrievals for stress detection over relatively large areas exceeding 3.000 ha per flight.

5. Narrow waveband sensor for continuous canopy NDVI, PRI, and NWI measurement

Ross Bricklemyer[1], Gaylon Campell[2], Doug Cobos[2]

[1] *Dept. of Crop and Soil Sciences, Washington State University, Pullman, WA*
[2] *Decagon Devices Inc., Pullman, WA*

As concerns over rising atmospheric carbon dioxide (CO_2) levels continue, it is critical to understand the mechanisms of mass and energy balance between the atmosphere and the biosphere for monitoring current and estimating future fluxes. Networks of environmental monitoring sensors are increasingly being used to continuously collect data important to understanding the interaction between plant canopies and the atmosphere. While spectral data are critical to scaling CO_2 and water flux estimates, the number of flux towers currently equipped with continuous spectral data collection is few. A low-cost, low-maintenance, high data-quality option is needed to outfit a significant number of flux tower locations with continuous spectral measurements that could lead to better representation of flux tower footprints. Building on a simple photodiode sensor (QuadPod) designed by Garrity et al. (2010) to continuously collect NDVI (675 and 800 nm) and PRI (532 and 570 nm) data, we added a spectral index related to plant water status (880 and 970 nm) to our Triple Vegetation Index Radiometer (TVIR). Preliminary TVIR testing results suggest that this sensor is capable of providing high quality, high temporal resolution canopy reflectance data. TVIR wavebands were highly correlated ($r^2 > 0.96$) with similar bandwidths collected using a UniSpec DC. Short-term repeatability of the TVIR was found to be 0.0002% of the total signal and initial field testing found the TVIR insensitive to shading yet responsive to reflectance from differing ground covers. While these results are encouraging, further testing is required to better ascertain the long-term durability and stability of the sensors under field conditions.

6. A case study for integrating optical remote sensing and carbon flux measurements over an alfalfa crop field

Saulo Castro-Contreras and John A. Gamon

Departments of Earth & Atmospheric Sciences, University of Alberta, Edmonton, Canada.

The integration of optical remote sensing with–carbon flux measurements has the potential to provide better quantification of ecosystem productivity and health by providing novel methods for gap filling and respiration calculations and improving our understanding of disturbance events. Furthermore, remote sensing provides the ability to study carbon exchange over a wide variety of spatial scales, ranging for leaf to global scales. The light use efficiency model (LUE) has provided an operational model that allows the assessment of productivity through remote sensing. For our study, optical measurements gathered over an alfalfa crop, and matching the scale of the flux tower footprint, have been used to develop a LUE model driven entirely from optical measurements. The resulting modeled productivity can be directly compared to productivity derived from flux measurements collected at the same site. The modeled carbon fluxes accurately track the seasonal dynamics in fluxes and provide continuous time series that provide a novel approach for gap filling missing eddy covariance data. Moreover, the significantly better correlation between respiration and NDVI, compared to that of temperature, displays the potential for using optical remote sensing for estimating ecosystem respiration and deriving Gross Ecosystem Exchange (GEE) from Net Ecosystem Exchange (NEE).

Having the optical and flux measurements at the same location and time scale as the eddy covariance allows for up-scaling flux measurements, and allow a direct comparison to aircraft and satellite measurements. By integrating remote sensing and flux measurement approaches, we can achieve a more comprehensive understanding of the dynamics involving the biospheric carbon budget.

7. Using a Flux Footprint Model and Airborne LiDAR to Characterize Vegetation Structure and Topography Frequently Sampled by Eddy Covariance: Implications for MODIS Product Validation

L. Chasmer[1], N. Kljun[2], C. Hopkinson[3], S. Brown[1], T. Milne[3], K. Giroux[1], A. Barr[4], K. Devito[5], I. Creed[6], and R. Petrone[1]

[1]*Cold Regions Research Centre, Wilfrid Laurier University, Waterloo, ON, Canada*
[2]*Dept. of Geography, College of Science, University of Swansea, Swansea, Wales, UK*
[3]*Applied Geomatics Research Group, NSCC, Middleton, NS, Canada*
[4]*Environment Canada, National Water Research Institute, Saskatoon, SK, Canada*
[5]*Dept. of Biological Sciences, University of Alberta, Edmonton, AB, Canada*
[6]*Dept. of Biology, University of Western Ontario, London, ON, Canada*

lechasme@yahoo.ca

Exchanges of CO_2 transported to eddy covariance instruments are often assumed to be representative of site average characteristics, regardless of the frequency with which vegetation, understory and ground surface characteristics have been sampled. All sites have some degree of heterogeneity (e.g. an upland area, bog, area of dense understory, etc.), which could influence CO_2 exchanges if scalar fluxes from prevailing wind directions frequently sample these parts more than others. This could have implications for site representation, model evaluation, and remote sensing product validation and scaling.

The use of flux footprint models has improved our understanding of the spatial and temporal distribution of source/sink areas measured within the field of view of eddy covariance instrumentation. Combining footprints with high resolution spatially continuous remote sensing data from airborne LiDAR, hyperspectral or spectral imagery provides a powerful tool for characterizing the areas sampled most frequently by eddy covariance. In this study, we use a 3D classification methodology to characterize vegetation structural and topographic attributes most frequently sampled by eddy covariance within 1) a homogeneous mature boreal aspen stand; and 2) a heterogeneous upland aspen/wetland complex using airborne LiDAR. The vegetation and topographic characteristics found within the areas most sampled at each site were then used to classify the larger region for evaluation of the MODIS gross primary production (GPP) product, i.e. choosing MODIS pixels that have similar attributes to those found within footprint most frequently sampled by eddy covariance. The correspondence between MODIS GPP and GPP estimated using eddy covariance and meteorological methods improved by 13% when using LiDAR ‘classified’ pixels as opposed to those pixels most proximal to the tower.

8. Spatial and Temporal Variability of CO_2 Exchanges along a Fen-Plateau-Bog Transect within the Discontinuous Permafrost Zone: Implications for Change Using Historic Remote Sensing

A. Kenward, L. Chasmer, R. Petrone, and W. Quinton

Cold Regions Research Centre, Wilfrid Laurier University, Waterloo ON N2L 3C5

lechasme@yahoo.ca

The southern boundary of the discontinuous permafrost zone of north-western Canada is dominated by a mosaic of channel fens, ombrotrophic flat bogs, and tree-covered permafrost plateaus that rise 0.5 to 2 m above the surfaces of bogs and fens. Peatlands, which contain approximately one-third of the global soil C pool, are particularly sensitive to changes in soil moisture and air temperature. Therefore, the conversion of plateaus to fen or bog ecosystems has unknown but potentially significant implications for net CO_2 exchange. In this study, net ecosystem exchange (NEE) and total soil/ground cover respiration (R_{tot}) were measured during the snowmelt to spring leaf-flush period (April 26 - June 6 2008) within bog, plateau, and fen land cover types using nine soil chambers. The objectives are to: 1) quantify soil CO_2 exchanges and associated drivers within these land cover types; and 2) determine the impact of land cover change on aerially weighted fluxes from 1947 to 2008.

During the time of study, NEE measured at the bog sites were found to be the greatest sources of CO_2 to the atmosphere, followed by plateau, and fen (which switched from a source of CO_2 to a sink by late May). All sites were a slight source of CO_2 to the atmosphere during the snow-melt period. R_{tot} (and net losses) increased rapidly within one to two days following complete snow melt. Soil temperature was the primary (positive) control of R_{tot} at the plateau and fen chamber sites, while the depth to the water table was negatively related to R_{tot} at plateau sites. Analysis of historical aerial photography and satellite imagery of the basin from 1947 to 2008 indicate that plateaus are converting more rapidly into bogs than channel fen. These rapid land cover changes could have important implications for northern C exchanges during the spring shoulder period within the discontinuous permafrost zone.

9. Wavelets: a useful tool to derive vegetation properties from hyperspectral data

Tao Cheng[1,4], Benoit Rivard[2], Arturo Sánchez-Azofeifa[2], and Stephane Jacquemoud[3]

[1]*Center for Spatial Technologies and Remote Sensing, Department of Land, Air and Water Resources, University of California, Davis, CA, 95616, USA*
[2]*Earth Observation Systems Laboratory, Department of Earth and Atmospheric Sciences University of Alberta, Edmonton, Alberta, Canada, T6G 2E3*
[3]*Universite Paris Diderot, Institut de Physique du Globe de Paris, 35 rue Helene Brion, 75013 Paris, France*
[4]*qtcheng@gmail.com*

One of the goals of collecting hyperspectral measurements of vegetation is to derive accurate remote sensing products of biophysical properties. Many studies have investigated spectral indices to model various vegetation properties. However, established spectral indices use only a limited number of wavebands out of hundreds or thousands of wavebands available for hyperspectral data. This study evaluates a useful tool, continuous wavelet analysis (CWA), to derive accurate estimates of leaf gravimetric water content (GWC) from hyperspectral reflectance spectra. CWA enables the multi-scale analysis of absorption features in reflectance spectra and provides the potential to capture the shape information over spectral regions of various widths. Three data sets, two measured and one simulated, were used to assess the predictive capabilities of CWA and test the robustness of CWA for a wide range of leaf GWC values and species from different ecosystems. Of the measured data sets one was collected for tropical forests in Panama (PANAMA) and the other for Mediterranean ecosystems in Italy (LOPEX). The radiative transfer model PROSPECT was used to generate the simulated data set (PROSPECT) by reconstructing spectral variations in the PANAMA data set. For each data set, reflectance spectra were transformed to the wavelet domain. Subsequently, the transformed data as a function of wavelength and scale were correlated with leaf GWC across samples to identify the wavelet features that are most sensitive to changes in leaf GWC.

Results demonstrated that five of eight features derived from the PANAMA data set matched five of seven features from the LOPEX data set. The recurrence of wavelet features between the two measured data sets confirmed the applicability of CWA for the estimation of leaf GWC for a broad variety of species or for data sets with a wide range of GWC values. The spectral variations caused by changes in leaf GWC were captured by wavelet features at various scales. High-scale features captured variations in the overall amplitude and low-scale features captured variations in dry matter absorption regions. The PROSPECT data set did not well reconstruct the spectral variations in the PANAMA data set and had only one wavelet feature closely corresponding to recurrent features from the PANAMA and LOPEX data sets. The wavelet-based spectral analysis tool adds a new dimension to modeling vegetation biophysical properties with hyperspectral reflectance data.

10. Unattended field spectrometric systems for continuous measurements of hyperspectral reflectance and fluorescence

S. Cogliati[1], M. Rossini[1], M. Meroni[1, 2], A. Barducci[3], M. Migliavacca[1, 4], F. Castagnoli[3], T. Iulitta[1], L. Busetto[1], E. Cremonese[5], M. Galvagno[1,5], U. Morra di Cella[5], R. Colombo[1]

[1]Remote Sensing of Environmental Dynamics Lab., DISAT, University of Milan-Bicocca, P.zza della Scienza 1, 20126, Milan, Italy
[2]EC, DG-JRC, IES-MARS Unit, Ispra, VA, Italy
[3]NATIONAL RESEARCH COUNCIL, Istituto di Fisica Applicata "Nello Carrara", Florence, Italy
[4]EC, DG-JRC, IES-CC Unit, Ispra, VA, Italy
[5]ARPA Valle d'Aosta, Aosta, Italy

Keywords: Field spectroscopy; calibration, fluorescence; PRI

Current Earth observing systems generally provide information of plant status derived from structural or biochemical properties (eg. *Leaf Area Index* (LAI), chlorophyll content) which can be used to model the potential photosynthetic rates of plants. Recent *Remote Sensing* (RS) techniques have encouraged the investigation of the actual photosynthetic rate through the *Photochemical Reflectance Index* (PRI) and the analysis of *sun-induced chlorophyll Fluorescence* (F) in the Fraunhofer lines (Meroni et al., 2009). Despite of the growing number of studies that have recently focused on the collection of large datasets of repeated field hyperspectral measurements in the sampling area of *Eddy Covariance* (EC) flux towers, only a small number of automatic tower based hyperspectral instruments are available nowadays. Overall, most of these instruments are based on reflectance measurement at "*fine*" (1 nm of Full Width at Half Maximum, FWHM) spectral resolution. Only the system recently proposed by Daumard et al. (2010) provides continuous measurements at "*ultra-fine*" resolution (0.1 nm of FWHM) in the spectral region interested by F. Several international initiatives (eg. SpecNet, Eurospec - COST ES0903) intended to promote continuous and long term spectral sampling at EC tower sites. Furthermore, recently (27 November 2010), the satellite mission FLEX (FLuorescence EXplorer) by the European Space Agency (ESA) has been selected for further development to 'Phase-A/B1'.

Object of the present contribution is the development of automatic spectrometric systems capable of collecting unattended, continuous, long-term spectral measurements of vegetation. Two different automatic spectrometric systems have been developed: the *HyperSpectral Irradiometer* (HSI) (Meroni et al., 2011) and the *Multiplexer Radiometer Irradiometer* (MRI) (Cogliati, 2011). Both instruments are able to routinely and autonomously measure: sun incoming irradiance (downwelling irradiance, E^{TOT}) and the irradiance (E^S)/radiance (L^S) upwelling from the investigated Earth surface (HSI measures E^S, MRI measures L^S). These systems are able to simultaneously collect "*fine*" and "*ultra-fine*" spectrums, in particular the instruments employ two Ocean Optics® High Resolution Spectrometers HR4000 sharing the same optical signal. The "*fine*" resolution spectrometer covers the VNIR range 400-1000 nm, the "*ultra-fine*" spectrometer provides an higher resolution (0.1 nm FWHM) within the 700-800 nm interval. The collected spectral data allow to estimate: i) vegetation biochemical and structural parameters using optical Vegetation Indices (e.g. NDVI); ii) the energy dissipation pathways exploiting the PRI and F at O_2-A band at 760 nm (F@760).

The development of such systems includes the optical design, the development of the data acquisition (*Auto3S*) and processing software as well as the definition of the calibration procedures.

Radiometric and spectral calibration is essential in order to get reliable hyperspectral data by these automatic systems that are continuously exposed to varying environmental factors (e.g. temperature, rain, humidity etc.) which affect instrument performances. For such reasons a "laboratory calibration" carried out yearly before installing the instrument in the field and an "in-situ calibration" (Meroni et al., 2010) performed regularly during instrument field operations to check and keep upgraded the instrument calibration coefficients have been developed.

Finally, the automatic instruments proposed were tested in field in the last years (from 2008 on), in particular the HSI was installed and operated during two consecutive years (2009-2010) in an abandoned pasture of the subalpine belt in the framework of the Interreg project *PhenoAlp* (www.phenoalp.eu), while the MRI was employed in 2009 in the context of the *Sentinel-3 Experiment* field survey promoted by the European Space Agency (www.esa.int/esaLP/SEMTST4KXMF_LPgmes-_0.html) as consolidation study to the future mission Sentinel-3.

Results show that the proposed automatic spectrometric systems (HSI and MRI) succeeded in collecting unattended and long-term hyperspectral data. Reliable time series of optical properties (incident irradiance, radiance upwelling from the earth surface, resulting reflectance factors and vegetation indices) were obtained with both instruments, in different experimental conditions (i.e. extreme environmental conditions) and on different vegetated canopies. The seasonal trends obtained in this research are consistent to previous works. NDVI is strongly related to the canopy greenness and thus to its potential photosynthetic capacity. PRI and F@760 are instead related to excess energy dissipation pathways and thus to the canopy actual photosynthesis.

The development of two different automatic systems addresses the need of study the best optical equipment and measurement configuration (e.g. upwelling radiance, L^S; upwelling irradiance, E^S) to quantify local scale vegetation properties and actual photosynthetic rate.

References

S. Cogliati, 2011. Development of automatic spectrometric systems for proximal sensing of photosynthetic activity of vegetation. (Tesi di dottorato, Università degli Studi di Milano-Bicocca, 2011). http://boa.unimib.it/handle/10281/19798

Daumard, F. et al., 2010. A Field Platform for Continuous Measurement of Canopy Fluorescence. Ieee Transactions on Geoscience and Remote Sensing, 48(9): 3358-3368.

M. Meroni, A. Barducci, S. Cogliati, F. Castagnoli, M. Rossini, L. Busetto, M. Migliavacca, E. Cremonese, M. Galvagno, R. Colombo, and U. Morra di Cella. 2011. The hyperspectral irradiometer, a new instrument for long-term and unattended field spectroscopy measurements. Rev. Sci. Instrum. 82, 043106 (2011), DOI:10.1063/1.3574360

Meroni M., Busetto L, Guanter L., Cogliati S., Crosta G.F., Migliavacca M., Panigada C., Rossini M., Colombo R., 2010. Characterization of fine resolution field spectrometers using solar Fraunhofer lines and atmospheric absorption features. Applied Optics, 49(15): 2858-2871.

Meroni, M., Rossini, M., Guanter, L., Alonso, L., Rascher, U., Colombo, R. and Moreno, J., 2009. Remote sensing of solar induced chlorophyll fluorescence: review of methods and applications. Remote Sensing of Environment, 113(10): 2037-2051.

11. Measuring CO_2 from Space: The NASA Orbiting Carbon Observatory-2 (OCO-2)

David Crisp

Jet Propulsion Laboratory/California Institute of Technology, Pasadena, CA, U.S.A. for the OCO-2 Team

The Orbiting Carbon Observatory was the first NASA mission designed to measure atmospheric carbon dioxide (CO_2) with the sensitivity, coverage, and resolution needed to quantify CO_2 sources and sinks on regional scales and characterize their variability over the seasonal cycle. This project suffered a major setback in February 2009, when its launch vehicle failed to reach orbit. In early 2010, NASA authorized a "carbon copy" of OCO, called OCO-2, which is currently on track for launch in 2013. The OCO-2 instrument will collect high-resolution, co-boresited spectra of reflected sunlight in the CO_2 bands centered near 1610 and 2060 nm, and in the molecular oxygen (O_2) A-band centered near 764 nm. It will record 12 to 24 soundings/second, yielding 200 to 400 soundings per degree of latitude over the sunlit portion of the orbit. Between 5 and 30% of these soundings are expected to be sufficiently cloud and aerosol free to retrieve full-column estimates of the column-averaged CO_2 dry air mole fraction, X_{CO2}, which accuracies of ~0.3% (1 ppm out of the ambient 390 ppm background). CO_2 and O_2 measurements currently being collected by the Japanese Greenhouse Gases Observing Satellite, GOSAT, are being analyzed to improve the retrieval algorithms, calibration methods, and validation techniques for OCO-2. These data are also being used to asses methods for integrating these space based measurements with surface measurements of CO_2 concentrations and fluxes in source-sink inversion models.

12. Combining tower mixing ratio and community model data to estimate regional-scale net ecosystem carbon exchange by boundary layer inversion over 4 flux towers in the U.S.A.

Xuerui Dang[1, 2], Chun-Ta Lai[2*], David Y. Hollinger[3], Andrew J. Schauer[4], Jingfeng Xiao[5], J. William Munger[6], Clenton Owensby[7], James R. Ehleringer[8]

We evaluated an idealized boundary layer (BL) model with simple parameterization using the vertical transport information from community model outputs (NCAR/NCEP Reanalysis and ECMWF Interim Analysis) to estimate regional-scale net CO_2 fluxes from 2002 to 2007 at 3 forest and 1 grassland flux sites in the U.S. The BL modeling approach builds on a mixed-layer model to infer monthly average net CO_2 fluxes using high-precision mixing ratio measurements taken on flux towers. We compared BL model NEE with estimates from two independent approaches. First we compared modeled NEE with tower eddy covariance (EC) measurements. The second approach (EC-MOD) was a data-driven method that upscaled EC fluxes from towers to regions using MODIS data streams. Comparisons between modeled CO_2 and tower NEE fluxes suggested two interesting general patterns. First, modeled regional CO_2 fluxes display inter- and intra-annual variations similar to the tower NEE fluxes observed in the Rannells Prairie and Wind River Forest was, whereas model predictions were frequently different from NEE observations at the Harvard Forest and Howland Forest. Second, model predictions showed distinct temporal patterns between the two northeastern U.S. forests. At the Howland Forest site, modeled CO_2 fluxes showed a lag in the onset of growing-season uptake by two months behind that of tower measurements. At the Harvard Forest, modeled CO_2 fluxes agreed with the timing of growing season uptake but underestimated the magnitude of observed NEE seasonal fluctuation. This modeling inconsistency among sites can be partially attributed to the likely misrepresentation of atmospheric transport and/or CO_2 gradients between ABL and the free troposphere in the boundary layer model. EC-MOD fluxes showed that spatial heterogeneity in land use and cover very likely explained the majority of the data model inconsistency. We show site-dependent atmospheric rectifier effect that appears to have had the largest impact on ABL CO_2 inversion in the North American Great Plains. We conclude that a systematic BL modeling approach provided new insights when employed in multi-year, cross-site synthesis studies. These results can be used to develop diagnostic upscaling tools, improving our understanding of the seasonal and interannual variability of surface CO_2 fluxes.

13. Biochemical constrains limit the potential of the photochemical reflectance index as a predictor of effective quantum efficiency of photosynthesis during the winter spring transition in Jack pine seedlings

Ingo Ensminger[1,4], Florian Busch[2], and Norman P. A. Hüner[3]

[1] *Department of Biology, University of Toronto, Mississauga, ON L6J 1C6, Canada*
[2] *Department of Ecology and Evolutionary Biology, University of Toronto, Toronto, ON M5S 3B2, Canada.*
[3] *Department of Biology and The BIOTRON, University of Western Ontario, London, ON N6A 5B7, Canada.*
[4] *Corresponding author. Email: ingo.ensminger@utoronto.ca*

Keywords: chlorophyll a fluorescence, dehardening, PRI, xanthophyll cycle, zeaxanthin

Leaf reflectance spectral measurements are now widely used to derive the photochemical reflectance index (PRI) to assess the physiological state of plants from leaf to ecosystem level. Changes in PRI are associated with changes in the xanthophyll cycle activity and provide an estimate of changes in the effective photochemical quantum efficiency (Φ_{II}) during the growing season. However, we hypothesised that the correlation between PRI and Φ_{II} might be poor when the xanthophyll cycle is primed for sustained thermal dissipation of the light energy absorbed. To test our hypothesis, we studied the recovery of winter acclimated Jack pine (*Pinus banksiana* Lamb.) seedlings that were exposed to different simulated spring recovery treatments in controlled environments. Different growth temperatures and light intensities were used to dissect the effect of these two factors on chlorophyll fluorescence, pigment composition and leaf reflectance. Φ_{II} showed a clear response to temperature whereas PRI was mostly affected by light intensity. In contrast, the de-epoxidation state of the xanthophyll cycle pigments was both temperature and light dependent. This indicates that zeaxanthin-independent non-photochemical quenching is employed to various degrees in the different treatments. As a result, within the limits of our experimental setup, PRI could not explain the variation in Φ_{II}. We therefore conclude that an improved understanding of the different energy quenching mechanisms is critical to accurately interpret the PRI signal under environmental conditions where the predominant mode of excess energy dissipation does not involve a dynamic operation of the xanthophyll cycle, but a sustained mechanism of energy dissipation.

14. Fluxes of BVOC and tropospheric ozone from a *Citrus* orchard in the California Central Valley

Silvano Fares[1,2], Jeong-Hoo Park[1], Robin Weber[1], Drew Gentner[3], John Karlik[4], and Allen H. Goldstein[1,3]

[1]*University of California, Berkeley, Division of Ecosystem Sciences, Department of Environmental Science, Policy, and Management*
[2]*Agricultural Research Council (CRA), Research Centre for the Soil Plant System, Rome, Italy. CNR (National Research Council) – Istituto di Biologia Agroambientale e Forestale, Via Salaria km. 29,300, 00016 Monterotondo Scalo (Rome), Italy*
[3]*University of California, Berkeley, Department of Civil and Environmental Engineering*
[4]*University of California Cooperative Extension*

Citrus plants, especially oranges, are widely cultivated in many countries experiencing Mediterranean climates. In many of these areas, orchards are often exposed to high levels of tropospheric ozone (O_3) due to their location in polluted airsheds. *Citrus* take up O_3 through their stomata and emit biogenic volatile organic compounds (BVOC), which can contribute to non-stomatal O_3 removal through fast gas-phase reactions with O_3. The study was performed in a valencia orange orchard in Exeter, California. From fall 2009 to winter 2010, CO_2 & water fluxes, together with O_3 uptake and BVOC emissions were measured continuously *in situ* with specific sensors (e.g. fast ozone analyzer and Proton Transfer Reaction Mass Spectrometer) using the eddy covariance techniques. Vertical concentration gradients of these compounds were also measured at 4 heights from the orchard floor to above the canopy. We observed high levels (up to 60 ppb) of volatile organic compounds including methanol, isoprene, monoterpenes, sesquiterpenes, and some additional oxygenated BVOC. Methanol dominated BVOC emissions (up to 7 nmol m^{-2} s^{-1}) followed by acetone. Monoterpenes fluxes were also recorded during the all vegetative period, with the highest emissions taking place during flowering periods, and in general highly temperature dependent. The orchard represented a sink for ozone, with uptake rates on the order of 10 nmol m^{-2} s^{-1} during the central hours of the day. We found that BVOC played a major role in removing ozone through chemical reactions in the gas-phase, while only up to 40 % of ozone was removed via stomatal uptake. The current research aimed at investigating the fate of BVOC emitted from orange trees will help understanding the role of *Citrus* orchards in the complex oxidation mechanisms taking place in the polluted atmosphere of the San Joaquin Valley (California).

15. Interacting controls on productivity in a northern Great Plains grassland and implications for response to ENSO events

Lawrence B. Flanagan and Angela C. Adkinson

Department of Biological Sciences, Water & Environmental Sciences Building, University of Lethbridge, 4401 University Drive, Lethbridge, AB, T1K 3M4, Canada
larry.flanagan@uleth.ca

In this study we investigated the causes of annual variability in peak aboveground biomass production, net ecosystem productivity (NEP) and gross ecosystem productivity (GEP) during an eight-year period (1999-2006) in a northern Great Plains grassland near Lethbridge, Alberta, Canada. In particular, we tested for a significant relationship between growing season precipitation and productivity and determined whether soil moisture carry-over from the previous fall-winter could alter this relationship. We also investigated the interaction between soil moisture availability and temperature in controlling grassland productivity. There was a very strong correlation between total precipitation input and average soil moisture content during the May-October growing season. However, the growing season average soil moisture contents in 2003 and 2006 were very similar to those recorded in 1999, despite lower than normal precipitation occurring in these two years. This resulted from a positive difference between precipitation and evapo-transpiration that allowed significant soil moisture to be carried-over from the previous fall-winter during both 2003 and 2006. Strong logistic relationships were observed between soil moisture and annual productivity based on data from all years except 2003 and 2006, years which had higher productivity than was predicted from the logistic regression. Interaction between temperature and soil moisture explained this difference. Productivity values in 2003 and 2006 were high compared to 1999, a year with approximately the same soil moisture content, and this resulted from the higher average growing season temperatures that were apparent in 2003 and 2006. Analysis of weather records indicated that precipitation in the month of June was significantly higher during El Niño years than during La Niña years in Lethbridge. During the study period, aboveground biomass, NEP and GEP were generally higher in El Niño years and lower in La Niña years because of associated variation in summer precipitation.

16. Development of a data assimilation system to estimate ecosystem exchange of carbon at the continental scale using data from the National Ecological Observatory Network

Andrew Fox[1,2], Williams Sacks[1,2], David Moore[1], Steve Berukoff[1], Tim Hoar[2] and David Schimel[1]

[1] *National Ecological Observatory Network, USA*
[2] *National Center for Atmospheric Research, USA*

afox@neoninc.org

Ecosystem exchange of carbon is a key measure of productivity and ecosystem health. Eddy covariance flux towers provide direct measurements of this exchange at small spatial scales but estimates of these fluxes at the regional and continental scale are required to diagnose the global carbon cycle where the present rate of carbon uptake is uncertain and future rates are difficult to predict. The National Ecological Observatory Network (NEON) is a continental scale facility that will collect ecological data, including eddy covariance flux observations and airborne hyperspectral and LIDAR remote sensing data, from 60 sites in the continental US, Alaska, Hawaii, and Puerto Rico over 30 years.

The data products group at NEON is tasked with producing high resolution, gridded, daily estimates of ecosystem carbon exchange over the continental US which, along with all NEON data, will be available to researchers, educators, planners, policy makers and the public. This will require both spatial extrapolation from flux tower sites and temporal forecasting on decadal timescales.

Here we describe the approach we are taking in developing a model-data fusion framework in which a wide range of ecological data collected by NEON and other institutions, including products derived from hyperspectral remote sensing, can be combined with the Community Land Model (CLM). We are using a Bayesian approach to produce optimal solutions for model states and fluxes and parameter values, with their associated uncertainties, at a continental scale. We have developed the Community Earth System Model (CESM) infrastructure to allow an ensemble of multiple instances of CLM to work simultaneously. This is allowing us to couple CLM with the National Center for Atmospheric Research’s Data Assimilation Research Testbed (DART) ensemble Kalman filter and begin an observing system simulation experiment in which we are attempting to optimize a limited subset of CLM parameters that a sensitivity analysis has shown strongly affect vegetation dynamics and land-atmosphere fluxes.

17. Deriving Biophysical Constraints from MODIS Sensor to Estimate Evapotranspiration in Semiarid Regions

Monica Garcia[1], Inge Sandholt[1], Pietro Ceccato[2], Marc Ridler[1], Rasmus Fensholt[1], Eric Mougin[3], Franck Timouk[3]

[1]*Institute of Geography, University of Copenhagen, Øster Voldgade 10, DK-1350 Copenhagen, Denmark.*
Mg@geo.ku.dk. Phone: +45- 35322500
[2]*International Research Institute for Climate & Society, The Earth Institute at Columbia University, Lamont Campus, Palisades, New York 10964-8000, USA*
[3]*CESBIO (UPS-CNRS-CNES-IRD) 18 Avenue Edouard Belin 31401 Toulouse Cedex 9, France Toulouse, France*

There is a need to estimate spatially evapotranspiration over semiarid ecosystems and to capture the quick vegetation responses to rainfall pulses characteristic of these areas. The model proposed by Fisher *et al.*, (2008) estimates evapotranspiration at monthly time scales based on the Priestley-Taylor equation adjusted to down regulate for multiple constraints. Fisher model has proven to be successful over 16 Fluxnet sites, ranging from boreal to temperate and tropical ecosystems, but none of those sites included semiarid vegetation. In this work, we evaluated the validity of the model in the Sahelian semiarid grasslands at a daily time scales. The model was tested at a measurement site in Agoufou (Mali) using a micrometeorological dataset from the African Monsoon Multidisciplinary Analyses (AMMA) and MODIS (Terra and Aqua) satellite products during the 2007 growing season. First, a global sensitivity analysis was performed using EFAST (Extended Fourier Amplitude Sensitivity Test) to identify the relative importance, in terms of contribution to the output variance, of each parameter required by the model. We run Fisher model using different estimates of some of the most critical parameters found with EFAST analyses. Thus, f_{APAR} and *LAI* were derived using (a) a linear function of NDVI and k_{PAR} (the extinction coefficient of visible radiation) as in the original model or (b) an average of MODIS Terra and Aqua products of *LAI* and f_{PAR}. The soil moisture constraint f_{SM} was estimated using (a) as $f_{SM} = RH^{VPD/}$ being *RH* the Relative Humidity, *VPD* (vapor pressure deficit) and =1.0 kPa as in the original model or (b) using measured SWC (Soil Water Content) to evaluate the validity of the model formulation.

We compared eddy covariance measurements in Agoufou with the model outputs. The best results were obtained when using *LAI* and f_{APAR} from *NDVI* and k_{PAR} and f_{SM} from measured SWC with R^2 =0.87 and mean absolute error (MAE) of 13.5 Wm^{-2}. We also obtained satisfactory results (R^2=0.83 and MAE=15.54 Wm^{-2}) when estimating $f_{SM} = RH^{VPD/}$. When using $f_{SM} = RH^{VPD/}$ and MODIS f_{APAR} and *LAI* the R^2 decreased to 0.77 and the error increased to 19.13 Wm^{-2}. These preliminary results show the validity of the formulation in the Fisher model to capture daily evapotranspiration dynamics in semiarid conditions. It is possible to estimate f_{SM} in relation with the atmospheric water deficit avoiding the need of SWC data but future improvements are focused on estimating f_{SM} from satellite surface temperature and albedo to reduce the need of climatic data and spatialize the model.

18. Up-scaling Carbon Fluxes from the Canopy to the Landscape Level at Wytham Woods, Oxfordshire, UK - a Preliminary Study

Charles George

Accurate assessment of regional- and global-scale fluxes of carbon (CO_2, CH_4, and CO) depends upon a combination of field measurements, remote sensing, and ecological modelling. Flux towers measure the exchange of carbon between the land and the atmosphere using the eddy-flux measurement approach, which involves the short-term measurement of flux densities (vertical transport of mass, momentum and energy per unit area and time) at scales of a few hectares or km^2, but are in reality point measurements. The usefulness of remote sensing on the other hand is that it can be used to map inferred carbon fluxes over much larger spatial scales. At present, bridging the gap between these two scales is a major challenge facing the research community.

Towards this end the Centre for Ecology and Hydrology (CEH), UK has set up a preliminary study based around a 400ha broadleaved wood in Oxfordshire. Measurements include CO_2 fluxes from a 30m tower, multispectral radiometry from several radiometers and vegetation phenology from 2 webcams. Hyper-spectral airborne (2m resolution) and satellite imagery (Landsat ETM, SPOT and MODIS) of the site have also been collected. The airborne data will provide a species map of the woodland which, together with the integration of the flux data, radiometry and phenology data, will allow an investigation into the issues of up-scaling carbon fluxes from the canopy level to the wider landscape. If successful, it is planned to expand the radiometry measurements to a further 11 flux sites over various land cover types across the UK.

19. Five Years of Land Surface Phenology in a Large Scale Hydrological Manipulation Experiment in an Arctic Tundra Landscape

Santonu Goswami[1], John A. Gamon[2], and Craig E. Tweedie[3]

[1]*Dept. of Environmental Science and Engineering, University of Texas at El Paso, El Paso, TX, USA*
[2]*Dept. of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Canada*

Climate change appears to be most pronounced at high northern latitudes. Many of the observed and modeled climate change responses in arctic tundra ecosystems have profound effects on surface energy budgets, land-atmosphere carbon exchange, plant phenology, and geomorphic processes. Detecting biotic responses to a changing environment is essential for understanding the consequences of global change. Plants can work as very effective indicators of changing conditions and, depending on the nature of the change, respond by increasing or decreasing amounts of green-leaf biomass, chlorophyll, and water content. Shifts in the composition and abundance of plant species have important effects on ecosystem processes such as net primary production and nutrient cycling. Vegetation is expected to be responsive to arctic warming, although there is some uncertainty as to how the interplay between geomorphic, hydrologic, climatic and other biotic will manifest over a range of spatial scales. The NSF-supported Biocomplexity project in Barrow, Alaska, involves experimental manipulation of water table (drained, flooded, and control treatments) in a vegetated arctic thaw lake basin to investigate the effects of altered hydrology on land-atmosphere carbon balance. In each experimental treatment, hyperspectral reflectance data were collected in the visible and near IR range of the spectrum using a robotic tram system that operated along a 300m tramline during the snow free growing period between June and August 2005-09. Water table depths and soil volumetric water content was also collected along these transects. The years 2005-2007 were control or unmanipulated experimental years and 2008 and 2009 were experimental years where water table was raised (+10cm) and lowered (-10cm) in flooding and draining experiments respectively. This presentation will document the change in phenology (NDVI) between years, treatments, and land cover types. Findings from this research have implications for remote sensing, ecosystem modeling, terrestrial ecology and the Arctic Observing Network.

20. Interpreting Trace Gas Fluxes through Eddy Covariance from Different Land Management Types in the Sacramento-San Joaquin Delta

Jaclyn Hatala

University of California, Berkeley

During the past two years, we analyzed the energy, CO2, CH4, and H2O fluxes in tandem from a rice paddy and cow pasture, which share the same basic meteorology due to their spatial proximity. Interpretation of the quasi-continuous CO2, H2O, and CH4 fluxes reveals different biological controls on the net balance trace gas fluxes for the different land-use types. Trace gas fluxes from the cow pasture are dominated by large, sporadic fluxes from cow metabolism throughout the year, water-logged soils near canals during the wet season, and invasive plant productivity during the dry season. The rice paddy fluxes are controlled by the high productivity of rice during the growing season and reflect slowly increasing levels of methane flux since land-use conversion. By analyzing the differences among the trace gas fluxes in these different land-use types, we gain insight into controls of water level, plant productivity, seasonality, and alteration of carbon pools upon wetland restoration.

21. A data assimilation method for using low-resolution Earth Observation data in heterogeneous ecosystems

Timothy Hill

The University of Edinburgh, The Crew Building, The Kings Buildings, West Mains Road, Edinburgh EH9 3JN
(0)131 6507721

Satellite Earth Observations can extend site specific ecosystem knowledge to wider regions. However, the use of coarse scale observations is complicated by the spatial heterogeneity and non-linearity of natural ecosystems. Unaccounted for, these characteristics bias predictions. We describe a ?disaggregation? approach that allows the unbiased combination of multi-resolution EO. This approach is particularly useful in data assimilation studies.

22. Upscaling Carbon Fluxes over the Great Plains Grasslands: Sinks and Sources

Li Zhang[1,2], Bruce K. Wylie[3], Lei Ji[4], Tagir G. Gilmanov[5], Larry L. Tieszen[3], and Daniel M. Howard[6]*

[1]Key Laboratory of Digital Earth, Center for Earth Observation and Digital Earth, Chinese Academy of Sciences, Beijing 100101, China, lizhang@ceode.ac.cn
[2]State Key Laboratory of Earth Surface Processes and Resource Ecology, Academy of Disaster Reduction and Emergency Management, Beijing Normal University, Beijing 100875, China
[3]U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center, Sioux Falls, SD 57198, USA, wylie@usgs.gov, tieszen@usgs.gov
[4]ASRC Research and Technology Solutions, contractor to USGS EROS Center, Sioux Falls, SD 57198, USA, work performed under USGS contract 08HQCN0007, lji@usgs.gov
[5]Department of Biology and Microbiology, South Dakota State University, Brookings, SD 57007, USA,
tagir.gilmanov@sdstate.edu
[6]Stinger Ghaffarian Technologies (SGT), contractor to USGS EROS Center, Sioux Falls, SD 57198, USA, work performed under USGS contract 08HQCN0005, dhoward@usgs.gov
**presenting author*

Previous studies suggested that the grasslands may be carbon sinks or near equilibrium, and they often shift between carbon sources in drought years and carbon sinks in other years. It is important to understand the responses of net ecosystem production (NEP) to various climatic conditions across the U.S. Great Plains grasslands. Based on 15 grassland flux towers, we developed a piecewise regression model and mapped the grassland NEP at 250-m spatial resolution over the Great Plains from 2000 to 2008. The results showed that the Great Plains was a net sink with an averaged annual NEP of 24 ± 14 g C · m−2 · yr−1, ranging from a low value of 0.3 g C · m−2 · yr−1 in 2002 to a high value of 47.7 g C · m−2 · yr−1 in 2005. The regional averaged NEP for the entire Great Plains grasslands was estimated to be 336 Tg C yr-1 from 2000 to 2008. In the 9 year period including 4 dry years, the annual NEP was very variable in both space and time. It appeared that the carbon gains for the Great Plains were more sensitive to droughts in the west than the east. The droughts in 2000, 2002, 2006, and 2008 resulted in increased carbon losses over drought-affected areas, and the Great Plains grasslands turned to a relatively low sink with NEP values of 15.8, 0.3, 20.1, and 10.2 g C · m−2 · yr−1 for the four years, respectively.

23. Optical sensing of Temporal and Spatial Patterns of GEP

Karl F. Huemmrich, Lawrence A. Corp, Andrew L. Russ, Elizabeth M. Middleton, William P. Kustas, John H. Prueger, Yen-Ben Cheng Petya K.E. Campbell, and Qingyuan Zhang

Understanding the dynamics of ecosystem carbon cycling requires an accurate determination of the spatial and temporal distribution of photosynthetic CO_2 uptake by vegetation. Optical sampling using spectral reflectance can provide the observations required for this type of analysis without physical contact with the vegetation, to supply inputs to a light use efficiency (LUE) model. LUE models have been used to estimate productivity for a number of ecosystems, and take this form:

$$G = \varepsilon \text{ fAPAR Qin}$$

where: G is gross ecosystem production (GEP); the uptake of carbon through photosynthesis; Qin is the incoming photosynthetically active radiation (PAR); fAPAR is the fraction of PAR absorbed by green vegetation; and ε is the LUE.

This study examined the use of spectral reflectance to determine inputs to the LUE model, utilizing narrow band spectral indices to calculate fAPAR and ε, and examined the remotely determined ecosystem GEP over diurnal periods and throughout the growing season. fAPAR was calculated using the Normalized Difference Vegetation Index (NDVI, using red and near-infrared wavelengths) and ε was estimated using the Photosynthetic Reflectance Index (PRI). PRI detects changes in Xanthophyll cycle pigments using reflectance at 531 nm compared to a reference band at 570 nm.

Data were collected at the Optimizing Production Inputs for Economic and Environmental Enhancement (OPE3) fields (39.03°N, 76.85°W) at USDA Beltsville Agricultural Research Center. Agricultural Research Service researchers grew corn (Zea mays L., 'Pioneer 33A14') and measured CO2 fluxes using eddy covariance methods throughout the 2007, 2008, and 2009 growing seasons. Over daylight periods on multiple days, which spanned the growing seasons, hyperspectral reflectance measurements were made using an ASD FieldSpec spectroradiometer along a fixed transect in the cornfield. A sensor mounted on the flux tower measured incoming PAR. The net CO2 fluxes were partitioned into gross ecosystem production (GEP) and ecosystem respiration.

The LUE model driven by optical measurements provided a good description of GEP, both for diurnal trends within days and for trends over weeks and months, and when sampled over multiple growing seasons. GEP calculated from spectral information was strongly related to GEP from tower measurements, with R2=0.76 for 130 observations and a standard error of 0.29 mg m-2 s-1. Based on these results, data from the Airborne Imaging Spectrometer for Applications (AISA) were used to create images of GEP variation over the entire cornfield. This approach and our results highlight the importance of narrow spectral band data for detecting physiological changes in vegetation.

24. Scaling photosynthesis in Amazonian ecosystems: from forest to savanna, from seasons to extreme events

Huete, A.R. [1], Dye, D. [2], Saleska, S.R. [3], Restrepo-Coupe, N. [1,3], Didan, K. [4], Wu, J. [3], Marostica, S. [5], Shimabukuro, Y. [6], Nelson, B. [5], da Rocha, H. [7], Manzi, A. [8], Kobayashi, H. [9], and Araújo A. [10]

[1]*Plant Functional Biology & Climate Change, University of Technology Sydney, Australia*
[2] *U.S Geological Survey, Flagstaff, Arizona USA*
[3]*Dept. Ecology & Evolutionary Biology, University of Arizona, Tucson, U.S.A.*
[4]*Dept. Electrical & Computer Engineering, University of Arizona, Tucson, U.S.A.*
[5]*National Institute for Amazon Research (INPA), Manaus, Brazil*
[6]*Instituto Nacional de Pesquisas Espaciais (INPE), São José dos Campos, Brazil*
[7]*Universidade de Sao Paulo, Sao Paulo, Brazil*
[8]*National Institute for Amazon Research (INPA), Manaus, Brazil*
[9]*Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Japan*

Remote sensing methods offer potentially powerful insight into the response of vegetation to climatic variability, a particularly pressing question in Amazonian forests in light of recently observed contrasting responses to two widespread droughts in 2005 and 2010. While widespread increases in MODIS Enhanced Vegetation Index (EVI) (a photosynthetic "green-up") of forests were observed during the intense drought of July, August, September 2005, the pattern was reversed in 2010 when there were widespread EVI declines during a similarly intense drought in the same months. However, remote sensing approaches to studying Amazonian drought have also been criticized as vulnerable to atmospheric aerosol and cloud artifacts, calling into question the reliability of these results. To simultaneously address the scientific question of vegetation response to climate, and the quality and reliability issues of remote sensing methods, we are integrating long-term *in-situ* and remote sensing observations of Amazonian ecosystems. These observations integrate daily satellite remote sensing from above the atmosphere with super-sampled, half-hourly "local" remote sensing (multiband and hyperspectral) images of vegetation and full-sky radiometer images of incoming radiation fields), mounted on towers along with direct measurements of ecosystem fluxes by eddy covariance in forests and savanna. An initial complete year of half-hourly images of the forest canopy in three spectral regions (red, green, and near infrared) from an eddy flux tower in old-growth primary forest near Santarem, Brazil (the km67 site), suggest that tower based spectral and EVI reproduces the same basic dry-season "green-up" pattern observed from space. Diurnal observations are further separated into direct and diffuse canopy reflectances and direct and diffuse irradiances onto a panel reference and provide initial insights into the nature of light interactions on canopy greening. Our results will further be integrated into a parameterized and sophisticated 3-D canopy photosynthesis model (FLiES) in order to scale up tropical forest characteristics and radiation components (including aerosol-, cloud-, and subcanopy-influenced effects of diffuse radiation fraction and angular distribution). These initial results suggest that integrating imagery from satellites and towers, and linking these to ecosystem fluxes will provide

a powerful tool for understanding the dynamics of vegetation-climate interactions in tropical Amazônia.

25. Role of different regional flux networks to constrain spatial GPP estimation by empirical upscaling

Kazuhito Ichii and Masayuki Kondo

Faculty of Symbiotic Systems Science, Fukushima University
1, Kanayagawa, Fukushima, 960-1296, Japan

Nowadays, eddy flux data cover wider ranges of geographic regions, and several studies have extrapolated these observations to estimate spatial variations in terrestrial carbon and water cycles at from continental to global scales. In the next step, we need to assess the potential applicability and limitations of these methods and further requirement of observations to constrain carbon cycle estimations. In this study, we examined the role of regional flux networks to constrain spatial GPP estimation with empirical upscaling. We adopted Support Vector Machine (SVM) regression (e.g. Yang et al., 2006; 2007) to empirically extrapolate eddy flux observations. Among regional flux networks, we used Ameriflux, CarboEurope, and CarboEastAsia data. We conducted four different SVM model tuning using (1) All three network data, (2) Ameriflux data, (3) CarboEurope data, and (4) CarboEastAsia data for 2000-2004 period data, and SVM model run for all available data for 2005-present. We quantified the effect of different regional coverage on spatial GPP estimation, and the results will be presented in the workshop.

26. Use of near-ground spectral measurement to observe vegetation phenology and productivity in the Fennoscandian region

Hongxiao Jin[1], Per Schubert[2] and Lars Eklundh[3]

Department of Earth and Ecosystem Sciences, Lund University, Sölvegatan 12, SE-223 62 Lund, Sweden
[1]*Hongxiao.Jin@nateko.lu.se*
[2]*Per.Schubert@nateko.lu.se*
[3]*Lars.Eklundh@nateko.lu.se*

We have installed optical sensors for spectral measurement at five sites across the Fennoscandian region from 56°N to 69°N, to observe vegetation phenology and productivity. These sites encompass different ecosystems, from Ombrotrophic bog in the south, coniferous forests in the middle, to tundra mire and mountain birch forest in the north. We used 55°-off-nadir multi-spectral sensors with large field-of-view (FOV, 60°) to look obliquely downward at the land surface along east-west directions. Such viewing geometry with large FOV and large off-nadir angle has advantages for sensing subtle transitions of land surface phenophases in weak light situations at the high latitude region. In this poster, we first analyse this viewing geometry by modelling hemispherical-conical reflectance factors (HCRF) from our ground tower observations. This is realized by using a forest reflectance and transmittance (FRT) model and the Monte-Carlo integration, with a Gibbs sampler to sample a truncated bivariate Cauchy distribution of ground points. We then present the first year's results of NDVI measurement, with comparisons to the NDVI from MODIS Terra and Aqua satellites, as well as gross primary productivity (GPP) derived from eddy covariance flux measurements. Our previous work has demonstrated strong correlations of the observed GPP to the modelled one from MODIS vegetation index (VI) data. However, during spring period the vegetation index results are disturbed by snow, bare soil, and other factors, and it is difficult to use satellite data to infer vegetation productivity and phenophases changes. Our spectral tower measurements disclosed accurate NDVI trajectories in this special transition period. They will be useful both for developing VI-driven GPP models further, and for calibration of satellite-derived estimates of vegetation phenology in the Fennoscandian region.

The research was supported by grants from the Swedish National Space Board and Nordregio of the Nordic Council of Ministers.

27. FluxPro: Real Time Monitoring and Simulation System for Eddy Covariance Flux Measurement

Wonsik Kim[1], Hyeong-Ho Seo[2], Daisuke Komori[3], Keisuke Ono[1], Masayoshi Mano[1] and Akira Miyata[1]

[1]*National Institute for Agro-Environmental Sciences, Tsukuba, Japan*
[2]*Agricultural Research Center for Climate Change, Jeju, Korea*
[3]*The University of Tokyo, Tokyo, Japan*

To cope with unusual weather changes on crop cultivation in a field level, prompt and precise monitoring of photosynthesis and evapotranspiration, and those fast and reliable forecasting are indispensable. So we have developed FluxPro which is simultaneous operating system of the monitoring and the forecasting.

The monitoring subsystem provides vapor and CO2 fluxes with uncertainty to understand the live condition of photosynthesis and evapotranspiration by open-path eddy covariance flux measurement (EC) system and self-developed EC tolerance analysis scheme. The forecasting subsystem serves the predicted fluxes with anomaly based on model parameter assimilation to estimate the hourly or daily water consumption and carbon assimilation during a week by multi-simulation package consisting of various models from simple to complicate.

FluxPro is helpful not only to detect a critical condition of growing crop in terms of photosynthesis and evapotranspiration but also to decide time and amount of launching control for keeping those optimization condition when an unusual weather event is arisen.

28. Predicting carbon dioxide fluxes from the newly flooded black spruce forest and peatland in Quebec, Canada

Youngil Kim[1,*], Nigel T. Roulet[1], Changsheng Li[2], Steve E. Frolking[2], Ian B. Strachan[1,3], Changhui Peng[4], Yves T. Prairie[4], Cristian R. Teodoru[4], and Alain Tremblay[5]

[1]*Department of Geography, McGill University, Montreal, QC H3A 2K6, Canada*
[2]*Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, Durham, NH 03824, USA*
[3]*Department of Natural Resource Sciences, Macdonald Campus, McGill University, Ste Anne de Bellevue, QC H9X 3V9, Canada*
[4]*Département des sciences biologiques, Université du Québec à Montréal, Montreal, QC H3C 3P8, Canada*
[5]*Unité Environnement, Direction Barrages et Environnement, Hydro-Québec Production, Montreal, QC H2Z 1A4, Canada*

We developed a process-based reservoir model (FF-DNDC) to project carbon fluxes from inundated black spruce forests and peatlands over the life-time of a hydroelectric reservoir located in the boreal biome. The reservoir model was used to examine the changes of carbon dioxide (CO_2) fluxes during the first four years after inundation and to evaluate the effects of the impoundments on CO_2 fluxes from the Eastmain-1 reservoir in northern Quebec, Canada. The framework for the reservoir model was Forest-DNDC, a process-based terrestrial biogeochemistry model, which supports detailed soil carbon processes from considering redox chemistry and oxygen diffusion in flooded ecosystems. We modified this terrestrial model to represent the alteration of soil and vegetation carbon processes when they are located under a water column: soil decomposition parameters were adjusted for difference rates and temperatures due to submergence and the addition of new carbon via sedimentation. Using the measured environmental conditions from 2006 to 2009, modeled daily CO_2 emissions from the flooded forest averaged 0.60 g C m^{-2} d^{-1} (ranging from 0.43 to 1.07 g C m^{-2} d^{-1}), and those from the flooded peatland averaged 0.63 g C m^{-2} d^{-1} (ranging from 0.49 to 0.86 g C m^{-2} d^{-1}). The simulated CO_2 emissions decrease with the duration of flooded condition. Our simulations resulted in smaller values than those in CO_2 flux measurements by the eddy-covariance system at the surface of the reservoir, but the changing pattern over time were similar. The disagreements would stem from the model structure and measurement method: the developed model certainly lacks some processes occurring in the open water portion of the reservoir, and the measured fluxes are a function of the turbulent transfer and are therefore somewhat removed in time and space from the actual production of CO_2.

29. Airborne LiDAR and Hyperspectral Data for Flux Tower Sites

N. Kljun[1], L. Chasmer[2], C. Hopkinson[3], E. van Gorsel[4], J.A.J. Berni[4], A.G. Barr[5], C. Bernhofer[6], T.A. Black[7], R. Leuning[4], A. Lindroth[8], H. McCaughey[9], E. Moors[10], and R. Petrone[2]

[1]Dept. of Geography, College of Science, Swansea University, Swansea, United Kingdom (n.kljun@swansea.ac.uk)
[2]Cold Regions Research Centre, Wilfrid Laurier University, Waterloo, Canada
[3]Applied Geomatics Research Group, NSCC, Middleton, Canada
[4]CSIRO Marine and Atmospheric Research, Canberra, Australia
[5]Environment Canada, Saskatoon, Canada
[6]Technische Universität Dresden, Forst-, Geo-, Hydrowissenschaften, Dresden, Germany
[7]University of British Columbia, Faculty of Land and Food Systems, Vancouver, Canada
[8]Lund University, Dept. of Physical Geography and Ecosystems Analysis, Lund, Sweden
[9]Queens University, Dept. of Geography, Kingston, Canada
[10]Wageningen University, Centre for Water and Climate, Wageningen, The Netherlands

We present a methodology to combine flux-tower data, footprint model results, airborne LiDAR (Light Detection And Ranging) and airborne hyperspectral data. The airborne remote sensing data is collected using an aircraft flown at low altitude (250 m to 2500 m above ground level) using LiDAR instruments (in our case Optech ALTM 3100, Riegl Q560, and Leica ALS50), and hyperspectral instruments (AISA Eagle and Hawk), and typically covers an area of around 4 km x 4 km centred at the flux tower. These data yield site and forest stand characteristics such as elevation, topographic derivatives (e.g., slope, aspect), tree height, canopy depth, canopy fractional cover, leaf area index, and biomass at very high, three-dimensional spatial resolution (0.35 m to 2 m). In addition, chlorophyll leaf concentration and the maximum carboxylation rate can be derived.

For each flux-data point of a selected study period, the footprint area can be calculated taking into account atmospheric turbulence, prevailing wind direction and site characteristics. The input data is given from the usual instrumentation of an eddy-covariance tower. We use the footprint model of Kljun et al. (2002, 2004) to derive a footprint climatology, providing spatial information on the actual sources/sinks distribution surrounding the tower at very high temporal resolution. The footprint climatology in combination with the unique three-dimensional dataset of vegetation structure and elevation surrounding the towers opens up new opportunities for interpreting and understanding ecosystem processes and for determining the sensitivity of measured carbon dioxide and water vapour tower fluxes to site heterogeneity.

The approach is applied to several trans-continental flux-tower sites, namely i) the three Boreal Ecosystem Research and Monitoring Sites (BERMS) and the Jack Pine Chronosequence sites located in the southern boreal forest, Saskatchewan, Canada; ii) the three European flux-tower sites Loobos (The Netherlands), Tharandt (Germany), Norunda (Sweden) and iii) the Tumbarumba site in New South Wales, Australia. At these sites, airborne LiDAR, airborne hyperspectral data (with the exception of the Canadian sites), and digital aerial photography have been collected during the growing season 2005 (CA), 2008 (CA), 2009 (AUS), and 2010 (NL and D). At Norunda, an airborne mission is planned for 2011. The flux towers are located within forests of differing levels of heterogeneity; conifer, deciduous to mixed forest stands, different ages of regeneration, forest stands of varying impact of disturbances (e.g., selective harvesting, storm felling), and sites varying from predominantly flat to undulating terrain.

First results show that even for relatively homogeneous flux tower sites (BERMS), heterogeneity in vegetation structure and small changes in elevation may impact net fluxes (e.g., Chasmer et al. 2008). Results of the above approach can be used as input for land surface atmosphere exchange models to generate, for example, regional maps of net ecosystem exchange. It is suggested that upscaling approaches may be improved by weighting of fluxes and thus by accounting for within-site variability (Chasmer et al. 2011). The results highlight the importance of a tool taking into account within-site heterogeneity when linking flux-tower observations to regional or even global estimates of net ecosystem exchange and productivity from satellite remote sensing products.

References

Chasmer, L., N. Kljun, C. Hopkinson, et al., 2011: Characterizing vegetation structural and topographic characteristics sampled by EC within two mature aspen stands using LiDAR and a flux footprint model: Scaling to MODIS. J Geophys. Res. G., in press.

Chasmer, L., N. Kljun, A.G. Barr, et al., 2008: Vegetation Structural and Elevation Influences on CO2 Uptake within a Mature Jack Pine Forest in Saskatchewan, Canada. Can. J. Forest Res. 38, 2746-2761.

Kljun, N., P. Calanca, M.W. Rotach, et al., 2004: A Simple Parameterisation for Flux Footprint Predictions. Boundary-Layer Meteorol. 112, 503-523.

Kljun, N., M.W. Rotach, H.P. Schmid, 2002: A 3D Backward Lagrangian Footprint Model for a Wide Range of Boundary Layer Stratifications. Boundary-Layer Meteorol. 103, 205-226.

30. Using hyperspectral imaging and eddy covariance measurements to quantify yellow star thistle invasion of California grassland

Steve Klosterman

The Jasper Ridge Biological Preserve, located near Stanford University in San Mateo County, California, is situated on roughly 500 ha of mixed vegetation types including riparian, grassland, chaparral, deciduous, and evergreen woodland. Eddy covariance instrumentation is installed at the site including a CSAT3 and LI-7500. Previously, the species composition of the eddy covariance site was dominated by European grasses including wild oats (Avena fatua and Avena barbata) and soft and ripgut brome (Bromus hordeaceus and Bromus diandru). Hyperspectral images from the Carnegie Airborne Observatory can be used to provide an estimate of the extent of a recent invasion by yellow star thistle (Centaurea solstitialis) at the site. It is proposed to investigate the effect of the invasive specie on ecosystem function using eddy covariance measurements.

31. Coupling 3D Radiative transfer models with soil vegetation transfer models for sparse vegetation and Validating with Hyperspectral Remote Sensing and Eddy Covariance Flux Data

Hideki Kobayashi[1], Dennis Baldocchi[2], Youngryel Ryu[3], Qi Chen[4], Siyan Ma[2], Jessica Osuna[2], and Susan Ustin[5]

[1]*koba.hidekin@gmail.com, JAMSTEC, 3173-25, Showa-machi, Kanazawa-ku, Yokohama, 236-0001, Japan*
[2]*University of California, Berkeley*
[3]*Harvard University*
[4]*University of Hawai'i*
[5]*University of California, Davis*

Many land surface and ecosystem models use one dimensional (1D) turbid medium layer when computing mass, energy, and carbon exchange. However, the 1D approaches fail to simulate radiation environments with heterogeneous landscapes, and thus it can cause the errors in simulating energy and carbon fluxes. We coupled a spatially explicit three-dimensional (3D) radiative transfer model with a soil vegetation model to understand the role of heterogeneous structure on the energy and carbon fluxes. The 3D approach requires more computation time and canopy structural variables than 1D turbid medium models, but is expected to provide more reliable energy and carbon fluxes when the reliable canopy structural variables are available. Recent improvement of the airborne remote sensing techniques such as Light Detection and Ranging (LiDAR) and hyper-spectral imagers enables us to obtain canopy structural and optical parameters that can be used as inputs or for validation of 3D models. The 3D model we developed was compared with a wide variety of field and remote sensing data (e.g., hyper-spectral remote sensing images, overstory and understory radiation, soil properties, and tower-based energy and CO_2 fluxes) in a woody oak savanna in California. The 3D approach worked better than the 1D approach across the various weather conditions while the relative importance of the 3D approach depends on climate and canopy physiological conditions. The 3D model has the potential to serve as a useful tool for analyzing the spatio-temporal variability of radiation and energy fluxes in evaluating footprints of radiation sensors and eddy covariance fluxes, and serve as a standard in evaluating the performance of a hierarchy of simpler land surface models to compute mass and energy exchange of heterogeneous landscapes.

32. The characteristics of fractional uncertainty on eddy covariance measurement and its application to data quality control

Daisuke Komori[1], Wonsik Kim[2], and Jaeil Cho[3]

[1]*Institute of Industrial Science, The University of Tokyo, d-komori@rainbow.iis.u-tokyo.ac.jp*
[2]*National Institute for Agro-Environmental Sciences, wonsik@affrc.go.jp*
[3]*Kasuya Research Forest, Kyushu University Sasaguri, Fukuoka 811-2415, Japan*

Keywords: Eddy covariance measurement, Error analysis, Fractional uncertainty, Quality control and quality assurance

Micrometeorological heat, water, and CO_2 fluxes have been widely monitored with eddy covariance (EC) method. Its uncertainty information should be as important as the flux measurement itself and indispensable to studies addressing site intercomparison, model validation, and model-data synthesis. Therefore, we estimated the fractional uncertainty (φ) using EC data collected over various types of land cover and at different instrumental heights, and also investigated φ characteristics according to spatiotemporal scale and flux averaging interval (τ).

As results, we demonstrate that the least median of squares method should be applied to estimate φ because the frequency distribution of φ has more significant kurtosis and skewness than Gaussian. Furthermore, we suggest that if φ is estimated under the EC measurement condition satisfying stationarity, it is stable and uniform regardless of land cover, spatiotemporal scale, and kind of flux. Based on the constancy of φ, we determined the baseline as a function of τ for a stationarity or a heterogeneity index of EC measurement.

In addition, these results suggest that φ and τ can be a general threshold to support data quality control and assurance (QCQA), φ analysis is adequate to estimate not only uncertainty magnitude but also whose sources, and τ analysis is helpful to explore ecosystem intercomparison, model development, and model-data synthesis with EC measurement.

33. Model based analysis of biomass growth curve using eddy covariance observation and biometric observation

Masayuki Kondo and Kazuhito Ichii

Migrating environmental changes have been drawing attention due to its potential influence on carbon cycle. A number of studies reported that human disturbance might be a key factor to explain current terrestrial carbon sink. Previous model based studies primarily focused on the effect on carbon cycle with the implementation of disturbance simulation. With a slight change of a viewpoint, it would be realized that the same simulation scheme can be adapted to the study of the potential relationship between carbon exchange and forest age or biomass growth rate, which is often neglected in model based analysis. As a step toward the verification of this relationship this analysis aims toward (1) estimation of the suitable forest growth function by treating the simulation output as data, and (2) assessment of its associated properties: potential maximum biomass, the year that reaches to it, and forest growth efficiency and clarification of its sensitivity, and (3) derivation of time dependent NEP function by a conjunction with the biomass growth function. To validate derived equations an adequate amount of data is required for curve fitting. To compensate the qualitative limitation in observation, model outputs were treated as data. Among accessible terrestrial models Biome-BGC ecosystem model was chosen for the study due to the following reasons: disturbance routine for the model, including clear-cut, replanting, fire, etc, have been introduced and well examined (Thornton et al., 2002), and observation-basis eco-physiological parameters for each vegetation type are available (White et al., 2000). The gap-filled and flux-partitioned eddy-covariance observation data were prepared at multiple sites from the AsiaFlux network including Takayama (TKY), Tomakomai (TMK), Fujiyoshida (FJY), and Laoshan (LSH). Those sites are known for either a large scale disturbance occurred in the last several decades or the well understood stand age. Knowing the year in which the current forest ecosystem emerged, the model is able to simulate the forest growth curve. Toward further sophistication of the model simulation a parameter optimization routine was developed to fit not only with the carbon flux but also with the biomass inventory data from the observation.

34. A cyberinfrastructure for integrating data from an eddy covariance tower, robotic tram system, and a network of phenostations and phenocams at a Chihuahuan Desert research site

Christine Laney, Ryan Cody, Irbis Gallegos, John Gamon, Ann Gates, Libia Gonzalez, Jose Herrera, Aline Jaimes, Ari Kassan,Vladik Kreinovich, Paulo Pinheiro da Silva, Gesuri Ramirez, Leonardo Salayandia, and Craig Tweedie

The Systems Ecology Lab at the University of Texas, El Paso, is studying land-atmosphere carbon, water, and energy fluxes at a mixed creosote (Larrea tridentata) - mesquite (Prosopisglandulosa) shrubland in the northern Chihuahuan Desert on the USDA ARS Jornada Experimental Range. The site includes an eddy covariance tower built to Ameriflux and FLUXNETspecifications, a robotic cart mounted on a 110m fixed rail system that measures hyperspectral reflectance, an 8-node network of SpecNet phenostations and other sensors, phenology cameras, and transects where the phenology of key plant species are monitored. After more than a year in operation, the lab has started to analyze the annual pattern of productivity from each of these data sources and to compare data between the sources. Currently, researchers (i.e. five graduate students) mostly follow a traditional mode of data management: each researcher manages his/her own datasets independently and manually produces processed data products as need dictates. In order to make data more easily accessible for processing, visualization, and sharing, much of this work can be automated. Here, we present a novel local cyberinfrastructure (CI) to helpdocument, manage, visualize, and integrate high temporal and spatial resolution data from the multiple sensing platforms at the site. This CI is currently under development but presentlyincludes 1) a common PostgreSQL database, 2) common metadata standards, 3) data quality checking and flagging toolsand machine learning algorithms, 4) semantic web tools for documenting and sharing information provenance, 5) an interactive web mapping application built in the Flex framework 6) a custom data-handler that provides database querying, and web-service generation for interfacing with other CI, including. This poster presentation will provide an overview of this CI and will be coupled with live demonstrations of the various tools that comprise it.

35. Application of Lidar Remote Sensing in Forestry

Wenkai Li

University of California, Merced

Light Detection and Ranging (lidar) is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant object. Due to its ability to generate 3-dimensional data with high spatial resolution and accuracy, lidar technology is being increasingly used in ecology, geography, geology, geomorphology, seismology, remote sensing, and atmospheric physics. In this project we acquire airborne lidar data for the study of hydrologic, geomorphologic, and geochemical processes at six CZOs: Southern Sierra, Boulder Creek, Shale Hills, Luquillo, Jemez, and Christina River Basin. Each site will have two lidar flights (leaf on/off, or snow on/off). Based on lidar data, we derive various products, including high resolution Digital Elevation Model (DEM), Digital Surface Model (DSM), Canopy Height Model (CHM), canopy cover & closure, tree height, DBH, canopy base height, canopy bulk density, biomass, LAI, etc. Individual tree mapping and forest visualization are also provided.

36. Comparison of Quantum Sensors with Different Spectral Sensitivities

X. Lin, D. K. McDermitt, R. Garcia, and T. Demetriades-Shah

LI-COR Biosciences, Inc. Lincoln, NE 68504

Lights absorbed by vegetation in the canopy are often used for estimating the light use efficiency in modeling the net carbon dioxide uptake. A better understanding of the photosynthetically active radiation (PAR) measurements would be helpful for accurately estimating the PAR incident on canopy and perhaps the PAR absorbed by canopy. We tested three different PAR sensors in terms of spectral sensitivities. The results indicated that all three PAR sensors are reasonably accurate under open sky conditions but, when measuring reflected lights and any artificial light sources, their measurements should be cautious to be interpreted in applications.

37. Modeling Tundra Net Ecosystem CO_2 Exchange with Satellite Remote Sensing Data

Michael M. Loranty[1], Scott J. Goetz[1], Elyn R. Humphreys[3], Peter M. Lafleur[4], Edward B. Rastetter[2], Adrian V. Rocha[2], and Gaius R. Shaver[2]

[1]*The Woods Hole Research Center*
[2]*The Ecosystems Center, Marine Biological Laboratory*
[3]*Department of Geography and Environmental Studies, Carleton University*
[4]*Department of Geography, Trent University*

Tundra ecosystems are experiencing amplified climate warming, and satellite observations of vegetation productivity suggest concurrent acceleration of the carbon cycle. Understanding the spatial variability, direction and magnitude of these changes is essential to quantify the contribution of tundra ecosystems to the global carbon cycle and associated climate feedbacks. Here we present predictions of net ecosystem CO_2 exchange for North American tundra ecosystems derived using a model scaled from field observations and moderate resolution satellite remote sensing data. Here we show results from several sites throughout the North American Arctic. Modeled NEE shows good agreement with flux tower observations over several growing seasons. Additionally we explore predictions outside of the growing season as a means to resolve annual carbon budgets for tundra ecosystems.

38. NEON's Physical and Information Infrastructure: From Site Design to Spatial Data Products

Hongyan Luo[1,2] and Henry Loescher[1,2]

[1]*NEON, Inc. 1685 38th Street, Suite 100, Boulder, CO 80301 www.neoninc.org*
[2]*Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO 80309*
hluo@neoninc.org

The US National Ecological Observatory Network (NEON) is a large facility project funded by the National Science Foundation. NEON's goal is to contribute to global understanding and decisions in a changing environment using scientific information about national scale ecology obtained through integrated observations and experiments. NEON will create a new national observatory network to collect ecological and climatic observations across the continental U.S., Alaska, Hawaii and Puerto Rico. The observatory network will be the first of its kind designed to detect and enable forecasting of ecological change at national scales over multiple decades. NEON has partitioned the U. S. into 20 ecoclimatic domains, each of which represents different regions of vegetation, landforms, climate, and ecosystem performance. Data will be collected from strategically selected sites within each domain and synthesized into information products that can be used to describe changes in the nation's ecosystem through space and time. The data NEON collects and provides to all users without restrictions will focus on how land use, climate change and invasive species affect biodiversity, disease ecology, and ecosystem services. Obtaining integrated data on these relationships over a long term period is crucial to improving forecast models and resource management to prepare for environmental changes. These data and information products will be readily available to scientists, educators, students, decision makers, and the public. This will allow a wide audience, including members of underserved communities, to use NEON tools to understand and address ecological questions and issues. The general tower site layout, the temporal and spatial data products that relevant to flux community and spectral community will be presented.

39. Understanding Seasonal and Inter-annual Variablilty in Ecosystem CO2 Exchange from Temporal Variations of Leaf Traits

Siyan Ma[1]*, Dennis D. Baldocchi[1], Stefania Mambelli[2], and Todd Dawson[1]

[1]Department of Environmental Science, Policy and Management, University of California, Berkeley, CA 94720, USA
[2]Department of Integrative Biology and Center for Stable Isotope Biogeochemistry, University of California, Berkeley, CA 94720, USA

Ecosystem CO 2 exchange is highly variable in seasons and across years. Such seasonal and inter-annual variability in ecosystem CO2 exchange is mainly attributed to numerous climate drivers. However, ecological functions and processes behind climate drivers are keys to understand mechanisms of temporally fluctuated ecosystem productivity in natural ecosystems. In this study, we sampled grass and oak leaves in a woody savanna and open grassland in California, USA. Sample were collected at weekly to monthly intervals from 2001 - 2007, including leaf nitrogen concentration (N), leaf mass per unit area (LMA), leaf carbon concentration (C), and leaf carbon stable isotope discrimination (Δ). We also measured ecosystem-level photosynthetic rates of annual grasses and oak tree canopy were deduced from eddy covariance towers over the 7-year study period. Ecosystem-level photosynthetic rates were compared at the same canopy/community age under various combinations of climatic variables. We discussed possible biological and ecological processes involved in regulating seasonal and inter-annual variability in ecosystem-level photosynthesis. Clearly, seasonal and inter-annual variation in ecosystem photosynthesis was strongly associated with the dynamics of leaf traits.

(Notice: This topic has been published: Ma et al. 2011. Are temporal variations of leaf traits responsible for seasonal and inter-annual variability in ecosystem CO 2 exchange. Functional Ecology 2011, 25, 258–270)

40. Dry season leaf flush in a Central Amazon *terra firme* forest via optical methods

Marostica, S.F.[1].; Nelson, B.W[1]; Wu, J.[2] and Saleska, S.R.[2]

[1]*National Institute for Amazon Research (INPA), Manaus, Brazil*
[2]*Ecology & Evolutioinary Biology, University of Arizona, Tucson, U.S.A.*

There is an ongoing debate about the response of Amazon forests to climate anomalies, including both routine seasonal variations and extreme drought. Satellite observed Amazon green-up during the 2005 drought remains controversial, with green-up attributed by some to cloud/aerosol contamination. Satellite detection of seasonal dry-season green-up in years of normal rainfall is also confounded by seasonal BRDF effects. In-situ studies of canopy leaf phenology may resolve these issues. To address these concerns, we used a high-resolution 3-band video camera*, mounted 54 m above the forest floor on an eddy covariance tower 60 km north of Manaus, to more directly assess changes in the forest canopy. We selected one frame per day (23 Sept, 2010 to 03 Feb, 2011) captured under diffuse solar illumination near local noon. Camera aim was perpendicular to the solar transit with an oblique downward view. We measured leaf flush and changes in greenness/woodiness using three approaches: (1) visual classification of transition types for all trees that underwent marked full-crown changes; (2) relative green channel brightness averaged over the entire frame -- ratio of green band DN to DN total of all three bands; and (3) Principal Component Analysis of the entire frame to remove spatial variations in illumination and estimate area of exposed bark. In order to avoid artifacts, we also examined the influence of variation in incident PAR on indicators 2 and 3 above. Of eleven trees that underwent full-crown transitions in the first month, nine were experiencing some stage of leaf flush. Relative brightness of the green channel showed that this flush of new leaves was already taking place at the beginning of the study and continued at least into October, when leaf maturation caused changes in leaf colors, limiting the usefulness of this indicator. The area of exposed bark decreased steeply during the mid-dry season leaf flush and further suggested that leafing-out continued at a slower pace into the rainy season. In the next step we will attempt to link camera-based vegetation greenness with environmental variables. The results of this study contribute an understanding of what actually controls seasonality of vegetation greenness in Amazon and its photosynthesis response.

**Stardot Netcam XL 3MP RGB bands (1024x768 native resolution) with zoom lens LEN-MV4510CS set to wide angle, following PhenoCam network specifications*

41. Using FLUXNET Data to Improve Predictive Models of Vegetation Phenology

Eli Melaas[1], Andrew Richardson[2], and Mark Friedl[1]

[1]*Boston University*
[2]*Harvard University*

Time series of CO_2 and H_2O exchanges obtained by eddy covariance measurements are a valuable resource for evaluating and improving model representation of seasonal vegetation dynamics. Despite recent efforts, accurate representation of phenology in ecosystem models has been elusive, and current models exhibit unrealistic levels of variability and errors in predictions for both leaf phenology and canopy fluxes. Using micrometeorological and eddy covariance data provided by the FLUXNET 'La Thuile' community database, we evaluated 11 different models driven by air temperature and photoperiod to simulate spatial and temporal variability in phenology. To do this, we used a subset of sites in the La Thuile database in ecosystems with distinct seasons and where air temperature is a primary driver of phenology. We then compared the results from these models with other prediction schemes, including phenology sub-routines currently implemented in land surface parameterizations used in global climate models. The root mean square errors produced by the modified growing degree-day models range from 7-14 days and provide substantial (14-35 days) improvement over current phenology schemes. Results from this study demonstrate that relatively simple variants of widely used phenology models can be used to simulate seasonal dynamics in ecosystem processes with good realism, and by extension, may provide a basis for improved models and predictions of how the phenology and carbon budgets of temperature-sensitive ecosystems will change in the coming decades.

42. The Swiss Fluxnet Initiative

Lutz Merbold and the Grassland Sciences Group, ETH Zurich, Switzerland

The Swiss FluxNet initiative combines all ecosystem-scale CO2 and H2O vapour (at some sites also CH4 and N2O) flux measurement sites in Switzerland. It currently encompasses eight long-term sites, covering the major land-use types in Switzerland: forest, cropland, grassland (differing management intensities) and urban area. Further sites with short-term measurements, specifically winter measurements, provide additional information. The sites are equipped with highest quality infrared gas analyzers and laser spectroscopy (CH4/N2O) to resolve turbulent shorter, fluctuations in the trace gas mixing ratio. The fluxtowers are accompanied by auxilliary instrumentation to measure variables such as soil CH4 and N2O fluxes, soil/stem/leaf respiration, phenology (phenocams), leaf area index, meteorologey and others. Besides the Grassland Sciences Group (ETH Zurich), the Institute of Atmospheric Sciences (ETH Zürich), the Research Station Agroscope Reckenholz-Tänikon (ART) and the Climate and Remote Sensing Group of the University of Basel are involved.

33. Phenological Eyes Network (PEN) -Connecting Satellite Remote Sensing to the Ground-Level Ecosystems

Shin Nagai[1], Kenlo Nishida Nasahara[2], Satoshi Tsuchida[3], Takeshi Motohka[4], Hiroyuki Muraoka[5] and PEN members

[1]*Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 3173-25 Showa-machi Kanazawa-ku, Yokohama 236-0001, Japan*
[2]*Graduate School of Life and Environmental Sciences, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, 305-8572, Japan*
[3]*National Institute of Advanced Industrial Science and Technology (AIST), 1-1-1 Umezono, Tsukuba 305-8568, Japan*
[4]*Earth Observation Research Center, Japan Aerospace Exploration Agency (JAXA), 2-1-1 Sengen, Tsukuba, 305-8505, Japan*
[5]*River Basin Research Center, Gifu University, 1-1 Yanagido, Gifu 501-1193, Japan*

nagais@jamstec.go.jp

Satellite remote-sensing (S-RS) is an useful tool to evaluate the ecosystem structure and functioning with various spatio-temporal resolutions. However, from the in situ ecological research viewpoint, the S-RS approach has not been tested or validated by ground-truthing observations. This may be due to the following three reasons. (1) Field or S-RS scientists did not collect the long-term continuous in situ data to validate S-RS. (2) We have not yet understood the sufficient ecophysiological interpretations for S-RS. (3) Collaboration and communication between field and S-RS scientists were poor. To solve three problems, we need an interdespliminary and multidespliminary field observation approach to validate S-RS on super sites. In this case, we should construct a stable, robust, general, continuous, and long-term ground observation network system for multiple ecosystems. We also should positively collaborate with the field scientists' networks and communities such as flux net and ILTER. For the sake of it, Japanese scientists have started "Phenological Eyes Network" (PEN; http://www.pheno-eye.org) since 2003, which consists of Automatic-capturing Digital Fish-eye Camera (ADFC), Hemi-Spherical Spectro-Radiometer (HSSR), and SunPhotometer (SP) systems. PEN sites have been set up various terrestrial ecosystem sites in Japan, South Korea, China, Malaysia, United Kingdom, Germany, and USA. For instance, we identified that the previously reported criterion for the timing of leaf expansion and defoliation by using satellite-observed NDVI (the maximum rate of growth or reduction of vegetation indices and a value midway between the year's maximum and minimum values) are misleading in a deciduous broad-leaved forest (Nagai *et al*. 2010). GRVI (= (R_{green} – R_{red}) / (R_{green} + R_{red}), where R_{green} and R_{red} are the reflectance bands of green and red, respectively) is a promising new vegetation index that we can detect specific responses to subtle disturbance and the difference of ecosystem types (Motohka *et al*. 2010). In this presentation, we will present the design, consept, philosophy, challenge and some recent activities of PEN.

44. Forest carbon balance over its production cycle

Asko Noormets[1], Steve G. McNulty[2], Jean-Christophe Domec[1], Michael Gavazzi[2], Ge Sun[2], Emrys Treasure[2], Guofang Miao[1], Siyao Zhang[1], Jiquan Chen[3], and John S. King[1]

[1]*North Carolina State University*
[2]*USDA Forest Service, Eastern Forest Environmental Threat Assessment Center* - Raleigh
[3]*University of Toledo*
anoorme@ncsu.edu

An increasing number of studies have looked at carbon fluxes in forest chronosequences and evaluated the effects of natural and anthropogenic disturbances on net CO2 balance and its major components.

However, integrative estimates over the entire natural or commercial lifecycle of a forest are rare because in open systems like those exposed to commercial harvests or natural fires, it is difficult to account for all carbon pools, and the upscaling inevitably relies on significant assumptions and broad generalizations. However, such integrated assess-ments must be made in order to understand the role of a particular ecosystem in the global carbon cycle. Here we attempt such integration using 5 years of data from two adjacent loblolly pine plantations in the coastal plain of NC and compare the findings to other pine harvest chronosequences in North America. The cumulative CO2 losses during the post-disturbance source phase are proportional to the amount of harvest residue but not climate, whereas the duration of the source phase varies with mean annual temperature. Validation of these stand lifetime carbon balance estimates requires independent estimates of harvested biomass, the decomposition dynamics of roots and aboveground slash, including coarse woody debris. The rates of incorporation of each of these fractions to soil carbon pool are highly uncertain and in some systems may determine even the sign of stand lifetime carbon balance.

45. Temporal variation in bulk stomatal conductance and leaf nitrogen in a rice paddy

Keisuke Ono[1], Masayoshi Mano[1], Atsushi Maruyama[2], Tsuneo Kuwagata[1], Kentaro Hayashi[1], Akira Miyata[1]

[1]*National Institute for Agro-Environmental Sciences, Tsukuba, Japan*
[2]*National Agricultural Research Center for Kyushu Okinawa Region, Kumamoto, Japan*

Bulk stomatal conductance, g_s, that represents stomatal behavior at canopy scales is generally independent from LAI development and thus more representative of crop physiological condition than the surface conductance in big-leaf approaches. Recently, Maruyama and Kuwagata (2008) assessed diurnal and seasonal variations in g_s of rice canopy and their environmental controls. In their results, g_s showed a typical seasonal variation in accord with the rice growth and relatively symmetric diurnal patterns. At another paddy site, Mase, in Japan, however, the surface conductance as determined by PM equations largely decreased in the afternoon corresponding vapor pressure deficit and wind velocity increasing (Ono, 2008). In this study, we calculated g_s by the technique presented by Maruyama and Kuwagata (2008) using the three-year dataset collected at the Mase paddy site and further investigated diurnal and seasonal variations in g_s and their dependence on leaf nitrogen concentration. Rice seedlings were transplanted on 2nd May for the three seasons and matured rice was harvested in early to middle September depending on weather conditions. This study focused on the stages with LAI > 1 to avoid errors in g_s calculation.

Surface energy imbalance was obvious in the dataset and corrected using the Bowen ratio every half hour, which enabled us to compare the results with those in Maruyama and Kuwagata (2008). The Ball-Berry parameters that relate stomatal conductance with the assimilation rate were also explored at canopy scale using CO2 flux data. Bulk stomatal conductance, g_s, at the Mase site showed a seasonal variation where g_s was the highest in the early vegetative stage and decreased with crop growth. The seasonal variation in g_s was generally similar to that in leaf nitrogen concentration. At a diurnal scale, g_s showed a diurnal hysteresis in particular subperiods. The depletion in g_s was related to vapor pressure deficit and wind enhanced in the afternoon. Net canopy assimilation scaled by LAI was generally correlated with g_s. Finally a set of the Ball-Berry parameters was obtained for the three-year data, which were not much changed among years.

46. Linking spectral information at different spatial scales with biophysical parameters of Mediterranean vegetation in the context of global change (BIOSPEC)

M. P. Martín[1], J. Pacheco-Labrador[2*], A. Carrara[5], M. P. Echavarría[2], J. Gajardo[3], M. Gallardo[2], C. Gimeno[5], I. Gómez[2], R. González[4], F. J. Martínez[2], G. Mendiguren[2], H. Nieto[6], F. Pérez[7], D. Riaño[2] and J. Salas[3]

[1]*Centro de Ciencias Humanas y Sociales (CCHS), Consejo Superior de Investigaciones Científicas (CSIC), C/ Albasanz 26-28, CP 28003, Madrid, España. E-mail: mpilar.martin@cchs.csic.es*
[2]*Centro de Ciencias Humanas y Sociales (CCHS), Consejo Superior de Investigaciones Científicas (CSIC)*
[3]*Departamento de Geografía, Universidad de Alcalá (UAH)*
[4]*Departamento de Medio Ambiente, Instituto Nacional de Investigación de Tecnología Agraria y Alimentaria (INIA)*
[5]*Fundación Centro de Estudios Avanzados del Mediterráneo (CEAM)*
[6]*Institute of Geology and Geography, University of Copenhagen*
[7]*Departamento de Geografía y Ordenación del Territorio, Universidad de Zaragoza*
**presenting*

Several studies have demonstrated the potential of satellite imagery for global estimates of vegetation parameters such as leaf area index (LAI), moisture content, fraction of light intercepted by photosynthetically active vegetation (FPAR), etc. Proper characterization/estimation of these parameters are a key issue to understand the exchange of flows in the global biosphere. However, these estimates have not been validated globally, at least in a consistent manner, especially in complex ecosystems like Mediterranean ones. The project Biospec (http://www.lineas.cchs.csic.es/biospec) tries to contribute to the generation and improvement of remote sensing products for estimating biophysical parameters of vegetation in the context of global change studies establishing relationships between biophysical variables (LAI, water content, nitrogen, etc...) measured in the field, carbon and water fluxes, and spectral measurements obtained at various scales (from leaf to canopy).

The estimation of carbon budget on a global scale is currently based on direct measurement of CO_2 and H_2O fluxes using the eddy covariance (EC) technique. However, this technique has shown important limitations mainly related to the low spatial representativeness of the measurements. Remote sensing offers a unique opportunity to overcome these limitations due to its synoptic vision at temporal and spatial scales which are appropriated to estimate variables directly related to carbon and water fluxes.

Biospec propose a multi-source approach to combine remote sensing products of various spectral and spatial scales (field spectroscopy, airborne and satellite images) in order to analyze and quantify the potential uncertainties in the estimation of relevant vegetation parameters such as LAI, water and nitrogen content, etc. The dataset underlying the study include various spaceborne (Landsat and MODIS) as well as airborne (AHS and CASI) reflectance datasets with different spatial and spectral resolutions. Ground information have been simultaneously obtained including spectral measurements using field spectroradiometers, measurements of biophysical vegetation parameters, meteorological variables and CO_2, H_2O and energy fluxes. Figure 1 shows a flowchart outlining Biospec main activities.

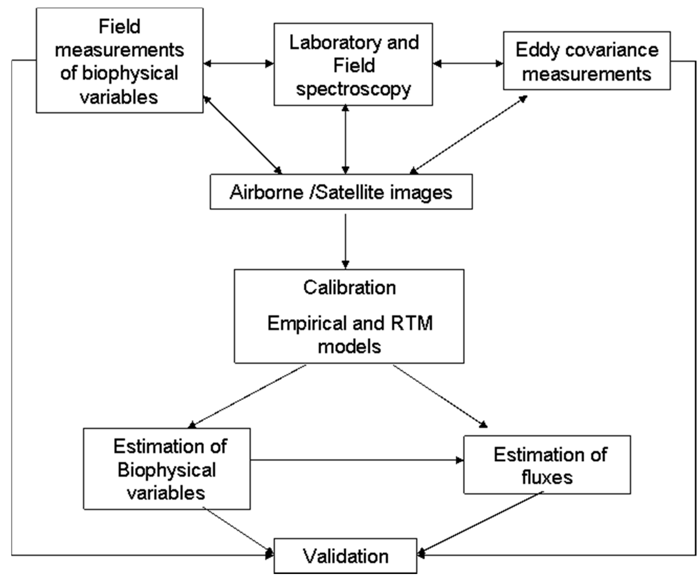

Figure 1. Biospec main activities

Biospec study area is located in a grazed pasture in northeastern province of Cáceres (Spain). The site is representative of the typically Iberian ecosystem "dehesa", a managed savanna ecosystem type that covers large areas in Western Spain and Portugal. The terrain is quite flat with an average altitude of 258 m. The climate is Mediterranean, with hot and dry summers, annual average temperature of 16.7 º C and an average annual rainfall of 572 mm. The ecosystem is composed by and herbaceous layer covered by a sparse tree layer (20% canopy cover fraction) where the Holm oak (*Quercus ilex L.*) is the predominant species. In this area an eddy-covariance flux tower included in the Fluxnet network (http://www.fluxnet.ornl.gov/fluxnet/sitepage.cfm?SITEID=440) has been operating since 2003 by Fundación Centro de Estudios Ambientales del Mediterráneo (CEAM).

Field sampling has been carried out at the study site every 16 days from April 2009 to May 2011 in order to measure vegetation parameters (LAI, biomass, chlorophyll, water, nitrogen and carbon content). Additionally, field spectroscopy measurements has been acquired simultaneously to vegetation sampling using an ASD FieldSpec® FR3 spectroradiometer that measures reflectance from 350 nm to 2500 nm. Finally, all available Landsat TM and MODIS images have been collected for the whole study period.

So far empirical models have been applied to the estimation of biophysical variables. Preliminary results have shown consistent relationships between spectral indices (calculated from field spectra and MODIS images) and variables related with vegetation water content (Mendiguren et al. 2010) and the nitrogen content of oak leaves (Pacheco-Labrador et al. 2011). In the first case, the sampling design allowed to calculate three variables related to the moisture content of vegetation: Fuel Moisture Content (FMC), Equivalent Water Thickness (EWT) and Canopy Water Content (CWC) so we could compare their temporal and spatial evolution and determine their degree of fit with the spectral measurements taken in the field and from satellite images. The CWC variable always shows the highest correlations with spectral indices, both obtained from field radiometry and from MODIS images ($r^2 = 0.85$ and 0.79 respectively).

Empirical models have been also applied to the estimation of the oak leaf nitrogen from hyperspectral data recorded in the field with the ASD spectroradiometer (Pacheco-

Labrador et al. 2011). Linear regressions were established between the data of the oak leaf nitrogen measured in the field and a) reflectance at each 1nm-width bands obtained with the ASD FieldSpec® FR3 between 400nm to 2500nm, b) 66 spectral indices proposed in the literature to estimate chlorophyll and nitrogen content from remote sensing and c) normalized spectral indices obtained from all possible combinations of 210 bands (using one of every ten bands available originally provided by the ASD spectroradiometer). The results show that temporal dimension is critical to establish a robust empirical relationship between leaf nitrogen content (LNC) and optical measurements. The analysis of complete phenological years allows characterizing optical response and biophysical variables behavior, and achieving acceptable estimations when independent data are used. Red edge bands are highly correlated with LCN, but this relation is only partially controlled by some nitrogen compounds such as chlorophylls, which show an influence on this region. No high correlations have been found in bands related to nitrogen bounds and molecules. In agreement with other authors we have demonstrated that LNC can be indirectly estimated through chlorophylls optical response. However, this research demonstrates that this approach may not be sufficient when temporal dimension is taken in account.

Further research will include the use of Radiative Transfer Models for the estimation of vegetation parameters as well as the estimation of fluxes from remote sensing data.

References

MENDIGUREN, G., MARTÍN, M.P., RIAÑO, D., MARTINEZ, F.J., PACHECO, J. and VILAR L., *Multi-scale estimation of vegetation and soil moisture in a Mediterranean wooded grassland (dehesa) using optical sensors*. 2010. Proc. Third Int. Symposium on Recent Advances in Quantitative Remote Sensing, Torrent, Spain. Ed. Sobrino, J.A., pag. 483-485.

PACHECO-LABRADOR, J., GONZÁLEZ, M.R., RIAÑO, D. and MARTÍN M.P. 2011. *Nitrogen estimation in a Mediterranean wooded grassland ecosystem from hyperspectral normalized ratio indexes*. Proc. EARSEL 7th imaging spectroscopy workshop. Edinburgh, Scotland.

47. A metadata oriented model for integration and exploration of optical and flux data

Gilberto Z. Pastorello and John A. Gamon

University of Alberta

Carbon flux monitoring integrating optical and eddy covariance data involves multiple data dimensions. In addition to spatial and temporal dimensions, spectral scales and metadata themselves become key dimensions for a full comprehension of carbon flux. Besides the usual field metadata, choices made in data processing also become relevant metadata and need to be tracked for full data transparency. For example, gap filling, filtering, integration methods, and aggregation methods can all affect the outcome and subsequent analyses of flux data. Similarly, spectral calibration, methods of atmospheric correction, and correction for irradiance or sensor view angle all influence the conclusions for optical remote sensing. To achieve a more complete understanding of carbon flux, all these dimensions should be an integral part of data analysis and visualization, guiding changes of perspective and (re-)shaping of data sets. This is essential in isolating and understanding the factors that affect upscaling of field optical sensors and eddy covariance measurements. Our proposal is to embody this multi-dimensional approach into an information system capable of answering queries over multiple data dimensions. This system could help with understanding and comparing the effects of different metadata values, particularly processing choices, on any final conclusions. We are creating a prototype to test this approach with eddy covariance and optical data from a variety of Canadian sites. Our goal is for this approach and associated software to be made available to the FLUXNET/SpecNet communities, contributing towards scalable data analysis and visualization.

48. Toward assimilation of hyperspectral reflectance data into field crop models: case of Monteith (RUE) and STICS models

Elizabeth Pattey[1*],Jiangui Liu[1], Guillaume Jégo[1], John R. Miller[2], and Baoxin Hu[2]

[1]*Agriculture and Agri-Food Canada, 960 Carling Avenue, Ottawa, Ontario, Canada, K1A 0C6*
[2]*Department of Physics and Astronomy, York University, Toronto, ON, M3J 1P3, Canada*
[*]*Corresponding author*

Crop descriptors, such as leaf area index (LAI), crop cover fraction, and leaf chlorophyll content, can be successfully estimated using appropriate spectral indices from the visible and near infrared spectral region. However, these indices do not provide estimates of dry biomass, an important indicator of crop productivity. In this study, we tested two approaches for estimating dry biomass and yield. The first one consists in integrating crop descriptors and abiotic stressors derived from optical remote sensing data into the Monteith radiation use efficiency model. The second approach consists in optimizing unknown input parameters of a process-based crop model (STICS developed by INRA, Avignon, France) using multiple LAI images extracted from remote sensing. Multi-temporal remote sensing data were acquired by the Compact Airborne Spectrographic Imager and the Landsat-5/7 Thematic Mapper/Enhanced Thematic Mapper Plus (TM/ETM+) sensors to monitor the growth conditions. The modified triangular vegetation index (MTVI2) derived from the remote sensing data was used to estimate the fraction of absorbed photosynthetically active radiation (f_{APAR}) and LAI. A canopy structure dynamics model was then used to simulate the seasonal variation of f_{APAR}. For Monteith RUE model, corn water stress was estimated from the near and shortwave infrared reflectance of the Landsat images for a dry period in the 2001 growing season. By estimating leaf chlorophyll content using the Transformed Chlorophyll Absorption in Reflectance Index (TCARI) in combination with the Optimized Soil Adjusted Vegetation Index (OSAVI), different levels of nitrogen content could be identified. For the 2001 and 2006 corn growing seasons, the shoot dry biomass and yield were linearly related with the cumulative absorbed photosynthetically active radiation (APAR) using the Monteith radiation use efficiency model. The cumulative APAR accounted for 96% of the corn shoot dry biomass variability and 72% of the yield variability. Biomass and yield variability were partly explained by the variations in crop water stress intensity, which was dependent on soil texture. The seasonal radiation use efficiency was stable over the 2 years and was about 3.9 g MJ^{-1}, with a confidence interval of 0.6 g MJ^{-1} at the 95% confidence level. For the second approach, generic cultivars of spring wheat, corn and soybean were calibrated and verified in STICS model for Eastern Canada. Prediction of daily total dry biomass and evapotranspiration were successfully compared with those derived from eddy covariance fluxes for several seasons. By assimilating LAI, seeding date and soil moisture at field capacity could be re-initialized in STICS. Prediction of biomass and yield were greatly improved compared to using recommended practices.

49. Seasonality and inter-annual variability of transpiration and soil evaporation in a semi-arid oak-savanna forest: what can modeled results tell us on how well we understand ecosystem behavior?

Raz-Yaseef, N.[1], Sonnentag, O.[1,2], Kobayashi, H.[1,3], Baldocchi, D.D.[1]

[1]*Department of Environmental Science, Policy and Management, UC Berkeley, Berkeley, CA, USA*
[2]*Department of Organismic and Evolutionary Biology, Harvard University, Cambridge, MA, USA*
[3] *Japan Agency for Marine-Earth Science and Technology*

Semi-arid climates experience large seasonal and inter-annual variability in radiation and precipitation, creating natural conditions adequate to study how year-to-year changes affect atmosphere-biosphere fluxes. We used a 10-year flux database collected at a semi-arid savanna site in order to: (1) define seasonal and inter-annual variability of climatic inputs; (2) investigate how changes in precipitation, mainly on annual scales, affect the ecohydrology of the forest and its components, and (3) evaluate model capability to predict seasonality and inter-annual variability of carbon and water fluxes above and below the canopy. This is based on the perception that the capability of process-oriented models to construct the deviation, and not the average, is important in order to correctly predict ecosystem sensitivity to climate change.

Our research site is a low density and low LAI (0.8) semi-arid (precipitation $=523\pm180$ mm yr^{-1}) savanna (oaks and grass), located at Tonzi ranch, Northern California. Measurements of carbon and water fluxes above and below the tree canopy using eddy covariance and supplementary measurements have been made since 2001. Measured fluxes were compared to modeled based on two bio-meteorological process-oriented ecosystem models: BEPS and 3D-CAONAK.

Measured precipitation at the research site presented a large inter-annual variability, and standard deviation between years was 38% of the average. Accordingly, the wet soil period (measured volumetric water content > 8%) varied between 156 days in dry years to 301 days in wet years. Inter-annual variability of the vapor fluxes were lower than that of precipitation (standard deviation was 17% for the trees and 23% for the floor components), suggesting on ecosystem buffering to changes in precipitation. On average, models simulated annual fluxes well ($R^2>0.93$), but inter-annual variability of the tree fluxes was higher than measured (24%), mostly due to model underestimation during dry years. A threshold at P~500 mm yr^{-1} was observed, above which tree transpiration barely increased. The high inter-annual variability of the floor component was not replicated in the models (standard deviation =5%), although this flux accounted for 55% of total ET. Based on our study we conclude that trees in this semi-arid ecosystem have developed adaptive mechanisms that buffer themselves from the year-to-year variations in precipitation.

50. Assessing uncertainties in ground-based vegetation indices derived from radiation instrumentation: comparison with MODIS data

Adrian V. Rocha, Verity Salmon, John Gamon, and Gus Shaver

Ground-based radiation fluxes of PAR and shortwave radiation may provide valuable information on vegetation phenology and a way to validate remotely sensed vegetation indices such as NDVI or EVI. Measurement uncertainties or biases in these radiation fluxes may influence the derivation of Ground Based Vegetation Indices (GBVI), but an assessment of these uncertainties has yet to be undertaken. We used incoming and reflected radiation fluxes from 23 Ameriflux sites for a total of 133 site years of data to derive GBVIs and assess their performance with corresponding MODIS reflectances and vegetation indices (i.e. NDVI and the two band EVI (EVI2)). Ground based EVI2 exhibited closer correspondence with MODIS EVI2 than NDVI across all sites and years, but both GBVIs were underestimated for most of the growing season due to a lower than expected ground-based Near Infrared and Red reflectance. The seasonal cycles of NIR, RED, NDVI and EVI2 were less pronounced for ground-based measures than for MODIS. Improvements to the derivation of GBVIs are critical for incorporating GBVIs into coupled surface greenness-CO_2 and H_2O flux models.

51. Estimation of gross ecosystem production by means of hyperspectral reflectance and fluorescence measurements in terrestrial ecosystems

M. Rossini[1], S. Cogliati[1], M. Meroni[1,2], M. Migliavacca[1,3], L. Busetto[1], E. Cremonese[4], M. Galvagno[1,4], U. Morra di Cella[4], B. Gioli[5], F. Miglietta[5], and R. Colombo[1]

[1]*Remote Sensing of Environmental Dynamics Lab., DISAT, University of Milan-Bicocca, P.zza della Scienza 1, 20126, Milan, Italy*
[2]*EC, DG-JRC, IES-MARS Unit, Ispra, VA, Italy*
[3]*EC, DG-JRC, IES-CC Unit, Ispra, VA, Italy*
[4]*ARPA Valle d'Aosta, Aosta, Italy*
[5]*IBIMET CNR, Florence, Italy*

Keywords: Field spectroscopy; eddy covariance; fluorescence; PRI

In recent years, a growing number of studies has recognized the importance of collecting field spectroscopy observations at flux towers for a better understanding of the relation between photosynthesis and optical signals. Such data are intended to "bridge the gap" between the flux tower and satellite observations, enabling the latter to be used for scaling up carbon estimates to regional and global level. The SpecNet (Spectral Network) project (Gamon et al., 2006) and the "Spectral Sampling Tools for Vegetation Biophysical Parameters and Flux Measurements in Europe" EU COST action (Eurospec action, ES0903 http://cost-es0903.fem-environment.eu/) have been recently established to promote these activities.

The present contribution investigates the possibility of monitoring Gross Primary Productivity (GPP) of two terrestrial ecosystems (i.e. alfalfa crop and alpine grassland in Italy) from high spectral resolution field spectroscopy measurements. Canopy radiance spectra were collected in the footprint of eddy covariance flux towers using unattended spectral systems developed for the automatic collection of high-frequency long-term high spectral resolution radiometric measurements. These systems host a couple of HR4000 spectrometers (OceanOptics, USA). The first one covers the 400-1000 nm range with a full width at half maximum (FWHM) of 1 nm and allows the computation of vegetation indexes including the Photochemical Reflectance Index (PRI, Gamon et al., 1992). The second spectrometer covers a restricted spectral range (700-800 nm) with a finer resolution (FWHM = 0.1 nm) to allow the estimation of sun-induced chlorophyll fluorescence at the oxygen absorption band O_2-A located at 760 nm (F_{760}) (for a review see Meroni et al., 2009). Hyperspectral data were used to test different versions of the light use efficiency (LUE) model. We started using a LUE model in which ε is held constant and remote sensing data are used to estimate the photosynthetically active radiation absorbed by vegetation (APAR). We then investigated the improvements in GPP modeling provided by the use of the apparent fluorescence yield (Fy^*_{760}) and the scaled Photochemical Reflectance Index (sPRI) to estimate ε. Afterwards, we tested the use of F_{760} as a proxy of photosynthetic canopy APAR. Preliminary results of this analysis will be summarized in the present contribution.

References

Gamon, J.A., Penuelas, J. and Field, C.B., 1992. A Narrow-Waveband Spectral Index That Tracks Diurnal Changes in Photosynthetic Efficiency. Remote Sensing of Environment, 41(1): 35-44.

Gamon, J.A., Rahman, A.F., Dungan, J.L., Schildhauer, M. and Huemmrich, K.F., 2006. Spectral Network (SpecNet) - What is it and why do we need it? Remote Sensing of Environment, 103(3): 227-235.

Meroni, M., Rossini, M., Guanter, L., Alonso, L., Rascher, U., Colombo, R. and Moreno, J., 2009. Remote sensing of solar induced chlorophyll fluorescence: review of methods and applications. Remote Sensing of Environment, 113(10): 2037-2051.

52. Role of ground observation networks with phonological monitoring for long-term and continental scale carbon budget estimations in East Asia

Nobuko Saigusa

Center for Global Environmental Research, National Institute for Environmental Studies (Onogawa 16-2, Tsukuba 305-8506, Japan; Phone +81 29-850-2517; Fax: +81 29-858-2645; E-mail n.saigusa@nies.go.jp)

Recent studies using flux measurement networks in Asia have shown that the year-to-year changes in annual net ecosystem CO_2 exchanges are controlled by different key factors in different biomes. In humid temperate forests, the key factors are the temperature and solar radiation during the growing season, which vary year-to-year in response to the timing of the early summer rainy seasons. In tropical forests in Southeast Asia, the keys are the length and strength of the dry season, and the El Niño/Southern Oscillation (ENSO)-related dry weather and smoke from fires.

In order to improve future climate change predictions, more synthetic knowledge of how ecosystem functions on carbon and water cycles respond to large-scale meteorological phenomena, such as year-to-year changes in Asian monsoon circulations would be desirable. This is because ongoing global warming has the potential to increase the frequency and magnitude of many extreme climatic events, including floods, droughts, storms, and anomalous temperatures in the global scale as well as in the Asian monsoon region. Another reason is that any of the recent climate prediction models needs to incorporate the biological feedback of terrestrial ecosystems that may play important roles in the global carbon and water cycles. However, we still do not understand the magnitude of the feedback, and the models have enormous uncertainties in the estimation of that feedback.

Since there is a potential that the frequency of anomalous weather conditions increases in the future affecting productivity in the Asian forests, further studies are necessary to gain a more accurate understanding of the response of Asian ecosystems to the meteorological patterns. Responses of East Asian forest productivity to large-scale meteorological anomalous and to disturbances caused by severe storms will be discussed based on ground networks including phonological monitoring as well as satellite observations. The results lead to an understanding of the spatial distribution of ecosystem responses to large-scale meteorological phenomena and serve as a verification dataset for the development of forest carbon monitoring, accounting and reporting system.

53. Utilizing Spatially Representative Flux Tower Albedo Data to Assess Moderate Resolution Satellite Products

Crystal Schaaf, Miguel Román, Xiaoyuan Yang, Jihyun Kim, Alessandro Cescatti, and Bev Law

Establishing realistic ground truth validation data remains a perennial problem facing all producers of satellite products. The difference in spatial scale between what can be measured at the surface and what can be retrieved by satellite sensors is very difficult to reconcile. Tower mounted albedometers provide the best possible measurements of land surface albedo and the albedometers deployed as part of the Baseline Surface Radiation Network (and the US components provided by Surfrad and ARM) are monitored and calibrated and provide the highest quality measurements (Schaaf et al., 2009). However even these albedometers are deployed on fairly short towers providing a small field of view. Therefore it is important to rely on tower sites that are representative of the larger surrounding region so that the quantities being sensed from space at resolutions of 300m to 1km are similar to those being sensed from the tower. High resolution satellite data can be used to provide an interim measure of the spatial heterogeneity of a locality and assess the representativeness of tower measurements. High resolution thermal brightness temperature imagery can be used in a similar fashion to assess the representativeness of surface temperature measurements. A geostatistical framework to provide these assessments has been developed by Román et al. (2009). A number of geostatistical attributes that describe the overall variability, spatial variability, spatial extent, strength, and temporal structure of the surface albedo (temperature) patterns are generated from the high resolution imagery. This new validation framework allows us to determine whether the tower measurements are properly capturing the albedo over a large enough area to be suitable for use in direct "point-to-pixel" comparisons with satellite data or instead the sites are so spatially unrepresentative of the surrounding landscape that they should not be included in validation exercises involving moderate resolution satellite products unless a full scale effort to scale up through higher resolution imagery is employed. These measures of spatial representativeness have recently been extended to the LaThuile data set and examples will be described.

54. Retrieval of Vegetation Structural Parameters and 3-D Reconstruction of Forest Canopies Using Ground-Based EchidnaR Lidar

Alan H. Strahler[1], Tian Yao[1,2], Feng Zhao[1], Xiaoyuan Yang[1], Crystal Schaaf[1], Curtis E. Woodcock[1], David L.B. Jupp[3], Darius Culvenor[4], Glenn Newnham[4], and Jenny Lovell[3]

[1]*Geography and Environment, Boston University, Boston, MA, United States*
[2]*School of Geography, Beijing Normal University, Beijing, China*
[3]*Marine and Atmospheric Resources, CSIRO, Canberra, ACT, Australia*
[4]*Sustainable Ecosystems, CSIRO, Clayton South, VIC, Australia*

A ground-based, scanning, near-infrared lidar, the EchidnaR validation instrument (EVI), built by CSIRO Australia, retrieves structural parameters of forest stands rapidly and accurately, and by merging multiple scans into a single point cloud, the lidar also provides 3-D stand reconstructions. Echidna lidar technology scans with pulses of light at 1064 nm wavelength and digitizes the full return waveform sufficiently finely to recover and distinguish the differing shapes of return pulses as they are scattered by leaves, trunks, and branches.

Deployments in New England in 2007 and the southern Sierra Nevada of California in 2008 tested the ability of the instrument to retrieve mean tree diameter, stem count density (stems/ha), basal area, and above-ground woody biomass from single scans at points beneath the forest canopy. Parameters retrieved from five scans located within six 1-ha stand sites matched manually-measured parameters with values of R2 = 0.94-0.99 in New England and 0.92-0.95 in the Sierra Nevada.

Retrieved leaf area index (LAI) values were similar to those of LAI-2000 and hemispherical photography. In New England, an analysis of variance showed that EVI-retrieved values were not significantly different from other methods (power = 0.84 or higher). In the Sierra, R2 = 0.96 and 0.81 for hemispherical photos and LAI-2000, respectively. Foliage profiles, which measure leaf area with canopy height, showed distinctly different shapes for the stands, depending on species composition and age structure. New England stand heights, obtained from foliage profiles, were not significantly different (power = 0.91) from RH100 values observed by LVIS in 2003.

Three-dimensional stand reconstruction identifies one or more "hits" along the pulse path coupled with the peak return of each hit expressed as apparent reflectance. Returns are classified as trunk, leaf, or ground returns based on the shape of the return pulse and its location. These data provide a point cloud of hit locations, intensities, and object classes within a three-axis coordinate system centered at the instrument. Merging point clouds from overlapping scans produces the 3-D reconstruction, which can be used to measure individual DBH (R2 = 0.97, 0.99, n = 20, 15 trees, two Sierra Nevada sites) and tree height (R2 = 0.98, 0.98, n = 18, 16 trees, compared to LVIS RH100 values). The point clouds should also allow more realistic measurements of green and woody biomass as well as crown size and shape. They point the way toward measurements of directional gap probability for applications in radiative transfer modeling. A second-generation instrument, the Dual-Wavelength Echidna Lidar (DWEL), is currently under development by the Echidna Lidar Team at Boston

University with NSF support. Supported by NASA grants NNG06GI92G and NNX08AE94A and NSF grant DBI-0923389.

55. Can We Have a Universal Light Use Efficiency of Vegetations?

Ramesh K. Singh, Ph.D[1], Shuguang Liu, Ph.D[2], and Larry L. Tieszen, Ph.D[2]

[1]*ASRC Research and Technology Solutions, contractor to the USGS Earth Resources Observation and Science (EROS) Center, 47914 252nd Street, Sioux Falls, SD 57198. Work performed under USGS contract G08PC91508*
[2]*USGS Earth Resources Observation and Science (EROS) Center, 47914 252nd Street, Sioux Falls, SD 57198*

rsingh@usgs.gov
sliu@usgs.gov
ltieszen@usgs.gov

Models based on light use efficiency are often used to estimate gross primary production (GPP), a key indicator of ecosystem performance. Information on spatiotemporal distribution of GPP helps in many ecological decision making processes. We evaluated the eddy covariance–light use efficiency (EC–LUE) model for estimating GPP in the Great Plains, United States. Photosynthetically active radiation (PAR) and fraction of absorbed PAR were computed using net radiation and the normalized difference vegetation index (NDVI), respectively. A strong correlation was found between daily PAR and Landsat-based midday instantaneous net radiation ((R^2 =0.94, N=24) as well as Moderate Resolution Spectroradiometer (MODIS) based instantaneous net radiation (R^2 =0.98, N=24). The EC–LUE model validation has shown that the potential light use efficiency varies with vegetation species (e.g., C_3 and C_4 plants). Interannual comparison of model outputs has also indicated the temporal changes in potential light use efficiency. Our results suggest that the universal potential light use efficiency in the EC–LUE model should be replaced with species-dependent potential light use efficiency.

56. Digital repeat photography for phenological research

Oliver Sonnentag[1], Koen Hufken[2], Cory Teshera-Sterne[1], Adam M. Young[3], Mirco Migliavacca[4], Andrew D. Richardson[1], and PheoCam/FLUXNET Collaborators

[1]*Harvard University, Cambridge, MA*
[2]*Boston University, Boston, MA*
[3]*State University New York*
[4]*European Commission, DG-JRC, Ispra, Italy*

Phenological research is increasingly based on the continuous and automated monitoring of vegetation canopies with digital repeat photography. Red-green-blue (RGB) color channel information can be separately extracted as digital numbers and summarized through color indices such as excess green (*ExG*: 2G-(R+B)) or through transformations to chromatic coordinates (e.g., green chromatic coordinate, g_{cc}: G/(R+G+B)). Several previous studies have demonstrated especially the use of digital *landscape* image archives for tracking ecosystem-scale canopy development with *ExG* or g_{cc} at temporal and spatial scales that can bridge the gap between field observations by humans and satellite remote sensing. With our contribution we present results from several recent studies from a range of different ecosystems (deciduous- and coniferous-dominated forests in New England, invasive plant infestation in California, subalpine grassland in Italy) using digital landscape image archives. We propose a processing method to extract *ExG* and g_{cc} time series that minimizes the effects of changes in scene illumination, assess the role of digital camera and image file format choice, and highlight the potentials, limitations and also challenges of long-term digital landscape image archives for phenological research.

57. Is the biosphere losing carbon (and hence value)? An analysis of NPP, NDVI, and productivity at Flux-Net sites around the world

Donnette Thayer, Global Carbon Index; John Gamon, University of Alberta

New tools are needed for visualizing the changing productivity of the terrestrial biosphere. Emerging carbon markets could benefit from this kind of information. The MODIS ASCII subsets provide a unique opportunity to explore trends in productivity for over 1000 sites around the world, including hundreds of FLUXNET sites. We examined regional and global trends using NPP and NDVI data from MODIS ASCII subsets as proxies for vegetation productivity and value.

Carbon sequestration values based on NPP were calculated for all sites listed in ORNL DAAC's Collection 5 MODIS Land Products, a dataset including 1052 sites, valuing carbon sequestration at $10/metric ton. Sequestration values using GPP-derived NPP data ranged from a low of $0.22 per hectare (Solar Village, Saudi Arabia, 2008) to a high of $673.22 per hectare (Concepcion (VALERI), Chile, 2003). We also developed a calculator that allows users to enter terrestrial extent, latitude and longitude data to determine carbon sequestration value for selected locations based on sequestration values for the nearest field site. NDVI data was collected as a reference. Annualized NDVI results did not always parallel NPP values, and we scrutinized global and regional NDVI trends, finding NDVI declines in certain regions of the world (e.g. N. America and Europe), implying a loss in productivity and biospheric carbon storage. On the other hand, other regions (e.g. Africa) seem to be gaining value. This analysis, while limited by the choice of sites available in the MODIS ASCII subset, provides a way of visualizing these changes for different regions of the globe. By making carbon sequestration (productivity) data simple, accessibly framed in a recognizable financial time-series format, with transparent calculations and source data, a biospheric solution for carbon sequestration becomes viable. A remaining task will be to examine if flux data show the same trends.

58. Use of High Resolution Lidar and Hyperspectral Data to Detect Changes in Energy Balance and Water Use Caused by Heterogeneity in Forest Structure

E. van Gorsel[1], N. Kljun[2], J.A.J. Berni[1], L. Chasmer[3], A. Cabello-Leblic[1], H. Cleugh[1], A. Held[1], V. Haverd[1], J. Lovell[1], D. Jupp[1], J. Hacker[4], Ch. Hopkinson[3,5], and R. Leuning[1]

[1]*CSIRO, Marine and Atmospheric Research, Canberra, Australia - (eva.vangorsel, jose.jimenez-berni, arancha.cabello-leblic, helen.cleugh, alex.held, vanessa.haverd, jenny.lovell, david.jupp, ray.leuning@csiro.au)*
[2]*Swansea University, Dept. of Geography, Swansea, United Kingdom – (n.kljun@swansea.ac.uk)*
[3]*Cold Regions Research Centre, Wilfrid Laurier University, Waterloo, ON, Canada – (lechasme@yahoo.ca)*
[4]*Airborne Research Australia, Flinders University of South Australia, Australia – (jorg.hacker@flinders.edu.au)*
[5]*Applied Geomatics Research Group, Lawrencetown NS, Canada – (chris.hopkinson@nscc.ca)*

Afforestation has been proposed to counteract anthropogenic climate change via sequestration of carbon. However forest ecosystems also modulate the climate through alterations of the surface roughness and the albedo which lead to changes in the energy and water balance. The energy balance and the exchanges of heat and water vapour depend on the source strength and the turbulence through which the scalars are transported and exchanged between forest canopy and the atmosphere. Spatial variability in plant physiological and biochemical properties and stand structure has an influence on both source strength and turbulence characteristics. Thus knowledge of these distributions is likely to improve our ability to upscale energy fluxes to landscape scale.

To test this hypothesis, we analysed airborne LiDAR data (to derive stand structural characteristics) and high resolution hyperspectral data (to derive plant spectral properties) and created parameter maps (LAI and albedo) that were subsequently gridded (25 m x 25 m). We used the Penman-Monteith model to estimate land surface evaporation because it combines the main drivers of evaporation in a theoretically sound way and provides an energy constraint on the evaporation rate (Cleugh et al. Remote Sensing of environment, 106, 2007). The model output is footprint weighted and compared to flux tower measurements of the latent heat flux (slope=0.99, r=0.73, fractional bias=0.06 and nmse=0.13). The estimates of the Penman Monteith model are then cumulated and the influence of heterogeneity in forest structure on the energy balance and the water use are discussed.

59. Towards the creation of a regional flux network in Mexico (MexFlux): opportunities for collaboration

Rodrigo Vargas[1], Enrico Yépez[2], Jose Luis Andrade[3], Gregorio Angeles[4], Tulio Arredondo[5], Alejandro E. Castellanos[6], Josue Delgado[5], Jaime Garatuza-Payan[2], Eugenia González del Castillo[7], Walter Oechel[8], Arturo Sánchez-Azofeifa[9], Enrique R. Vivoni[10], and Christopher Watts[7]

[1]*Centro de Investigación Científica y de Educación Superior de Ensenada, Baja California, México*
[2]*Instituto Tecnológico de Sonora, Sonora, México*
[3] *Centro de Investigación Científica de Yucatán, Mérida, México.*
[4]*Colegio de Postgraduados, Tlaxcala, México*
[5] *Instituto Potosino de Investigación Científica y Tecnológica, San Luis Potosí, México*
[6]*Universidad de Sonora, Sonora, México*
[7]*University of California-Davis, California, USA*
[8]*San Diego State University, California, USA*
[9]*University of Alberta, Alberta, Canada*
[10]*Arizona State University, Arizona, USA*

The global consortium of eddy covariance measurements (FLUXNET) has provided invaluable information to understand how climate variability influences terrestrial carbon and water fluxes. However, this global network is not well distributed in the Earth as sites in temperate regions of the northern hemisphere dominate it. Mexico has been one region that has not been represented within FLUXNET, but presents great opportunities for model validations and improvements as new flux measurements become available. Mexico has high beta diversity and is subject to important anthropogenic disturbances (i.e., land use change), and natural disturbances (e.g., droughts, hurricanes, fires) that may become more frequent under climate change. Thus, Mexico presents opportunities and challenges to the scientific community for validation of models and testing of current theories. Here we present the sites that form the Mexican consortium of eddy covariance measurements (MexFlux) and bring attention to potential opportunities for collaboration. At present the consortium is represented by 8 sites in arid and semi-arid regions with shrublands, forests, grasslands and a tropical dry forest, but is planning to expand to other tropical and managed ecosystems. We seek for collaborations to expand the network and to answer scientific questions that will improve our understanding on how climate variability influence carbon and water fluxes across Latin America.

60. Spectral sampling tools for vegetation Biophysical Parameters and flux measurements in Europe: the European ES0903 COST Action EUROSPEC

L. Vescovo and D. Gianelle

Fondazione E. Mach, CRI, Trento (Italy), vescovo@cealp.it

Key words: optical sampling, carbon fluxes, remote sensing, biophysical parameters, scaling up,
spectroradiometers

The estimate of carbon sequestration by terrestrial ecosystems and the prediction of the global change impact on the ecosystem carbon balance are becoming urgent needs required by international agreements. To support the development of this knowledge, a deep insight into processes that regulate carbon exchanges between terrestrial ecosystems and the atmosphere is fundamental.

Flux towers remain a primary tool for understanding ecosystem carbon fluxes within the global flux networks. International initiatives such as SpecNet are developing to fill the temporal and spatial gap between ecosystem measurements and remote sensing by means of scale-appropriate optical measurements. In this framework, a new EU COST Action project has started in Europe (http://cost-es0903.fem-environment.eu/). Up to now, 16 countries are participating to the Action. The COST Action project is open to researchers from European Cost Countries, but also from Near-Neighbour and non-COST countries can participate to the Action and, in some cases, can obtain some specific national funding (e.g. Australia, New Zealand, South Africa). Remote sensing plays a fundamental role in scaling up both fluxes and biophysical parameters and is generally done by satellite, aircraft-borne sensors, or ground optical sampling. The linkage of ecosystem fluxes measured with the eddy covariance technique, biophysical parameters measurements and remotely sensed information can be considered as the most promising method for scaling up ground observations.

At present, a full integration of remote sensing information and ecosystem level carbon fluxes has not been achieved, although several international initiatives have been developing in the last years with this objective (e.g. SpecNet organization, http://spectralnetwork.net/).

According to the highlighted scientific questions and problems, the objectives of ES0903 are i) to analyse the state of the art of the optical sampling research in Europe, ii) to standardize tools and methods in the optical sampling measurements, iii) to focus on the fluxes and biomass estimation problems as an input to the technological world for development of new sensors and iv) to involve the scientific instruments industries in designing and testing a common multi-band reflectance sensor for ground optical measurements in the European flux network.

Thanks to the Action, the use of standardised protocols will be encouraged within a spectral measurements network, across site comparisons will be enabled and the use of new instruments and sensors will be promoted and tested.

Some of the most common issues of the proximal sampling research, performed at ecosystem level, are: i) methods, protocols and investigated ecosystems are heterogeneous ii) advanced spectroscopic instrumentation is expensive, with high demands on accuracy iii) research is carried out under different conditions and at diverse spatial and temporal scales iv) research groups are scattered and not interconnected. One of the main aims is to focus on these issues, promoting operational contacts between the scientific communities to facilitate integration between optical measurements and other ecosystem observations.

The COST Action ES0903 is focusing on 4 main Working Groups: Networking, Intercomparison, New Instruments and Upscaling. This paper illustrates the Action objectives, focusing on the Action main activities, and giving some examples of the COST spectral optical sampling approach.

61. Quantifying Uncertainties Associated with Light Use Efficiency Model Estimates of Global GPP Using New Information from Eddy Covariance and Satellite Datasets

Y. Wang, Y Jin, M.L. Goulden, and J.T. Randerson

GPP represents the primary inflow of carbon (and thus energy) into ecosystems and is closely coupled with the hydrologic cycle and surface energy fluxes. Obtaining robust estimates of contemporary GPP at regional and global scales is an important first step towards developing realistic prognostic models that can be used to understand the effects of climate change on terrestrial ecosystems and feedbacks between climate and the carbon cycle. Here we evaluated sources of uncertainties in global estimates of GPP derived using light use efficiency models. We examined uncertainty in several major components of the model, including satellite derived estimates of photosynthetic active radiation (PAR), fraction of PAR absorbed by plant canopy (fAPAR), and the distribution of fAPAR absorbed by C4 vegetation. We also evaluated uncertainty arising from the formulation of the light use efficiency (LUE) term, including regulation by temperature and moisture stress, the representation of C4 grasslands and crops, and the GPP observations used to optimize these models. Key driver of uncertainty included: 1) fAPAR derived from vegetation indices; 2) difference in LUE between C3 and C4 plants; 3) the GPP observations used for model calibration; and 4) potential uncertainties in eddy covariance derived estimates of GPP. We derived an optimal model from these different components. Then we present three scenarios of global GPP that take into account different treatment of the major uncertainty sources.

62. Carbon Fluxes in a Managed Landscape: Identifying the Drivers of Temporal and Spatial Variability Across the Cascade Mountains

Sonia Wharton[1], Laura Chasmer[2], Matthias Falk[3], Ken Bible[4] and Kyaw Tha Paw U[3]

[1]*Lawrence Livermore National Laboratory, Livermore, California*
[2]*Wilfrid Laurier University, Waterloo, Ontario*
[3]*University of California, Davis, California*
[4]*University of Washington, Seattle, Washington*

Our research focuses on scaling-up carbon fluxes in the southern Cascade Mountains; a region where clear-cut logging over the past 100 years has created a fragmented landscape of coniferous forests that range in age from 0 to 500 years. In this study, we integrate several datasets to identify the environmental drivers of carbon exchange across time and space in this region. These data sources include: (1) a network of flux towers across a disturbance chronosequence, (2) the MODIS Enhanced Vegetation Index, (3) aboveground net primary production (ANPP) from forest inventories , and (4) Pacific Ocean oscillation indices. Lastly, we use the coupled WRF-Advanced Canopy-Atmosphere-Soil Algorithm (WRF-ACASA) model to see if climatic drivers can be linked to regional vegetation anomalies.

Net ecosystem exchange of carbon (NEE) has been measured at the Wind River Canopy Crane AmeriFlux site since 1998. The canopy crane is located in an old-growth forest composed of late seral Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*). Two flux towers were erected in early seral Douglas-fir stands (< 15 years old) to study the effects of silviculture on net ecosystem exchange. CO_2 uptake at the old-growth stand is highest in the spring before bud break when air and soil temperatures and vapor pressure deficit are relatively low, and soil moisture and light levels are favorable for photosynthesis, while maximum CO_2 uptake is observed two to three months later at the early seral stands and coincides with peak leaf area index. This CO_2 pattern is driven in part by different water conserving strategies. A reduction in carbon exchange is observed at the old-growth forest when moisture becomes limiting and canopy conductance rates drop sharply after mid-morning in the summer. In contrast, inhibition in canopy conductance rates and CO_2 exchange is not observed at the early seral stands until soil moisture levels become critically low at the very end of the summer.

Interannual CO2 flux variability at the old-growth forest is relatively high over the last decade and is linked to climatic changes associated with Pacific Ocean oscillations. The fifty-year record of ANPP also shows high interannual variability and association with teleconnections. Strongest carbon sink years occur during cool phases of the El Nino-Southern Oscillation, Pacific Decadal Oscillation, and the Pacific North American Oscillation. EVI and forest inventory data also show teleconnection links. The 2000-2008 tower-centered MODIS pixel correlates well with annual NEE at the AmeriFlux site and show promise for scaling sparse flux tower observations, even over old-growth forests. The regional MODIS data (200 km X 200 km area) from 2000-2008 show that annual variability in the Enhanced Vegetation Index (EVI) can also be linked to annual changes in precipitation and temperature across the Cascade Mountains. Regional changes in MODIS EVI are correlated with Pacific teleconnections in grasslands and shrublands but forest regions are harder to assess due to varying age classes. Forest age-effects need to be isolated in the MODIS data as the flux towers show age specific patterns in CO2 exchange. Lastly, the WRF-ACASA fluxes at 4 km X 4 km resolution capture spatial CO2 variability across ecoregions (grassland versus forest) but miss landscape-scale variability due to coarse land cover and LAI data. Next steps are to use MOD13Q1 (250 m) and run WRF-ACASA at 1 km with MODIS LAI and high resolution land use data to tease out small-scale variability in highly fragmented forests.

63. Wireless monitoring of microclimate and leaf physiology in single crowns of diverse species: bridging a gap between forest inventory and tower-based flux observations.

Adam Wolf

Princeton University

For 20 years, improved characterization of biological regulation of the carbon and water cycles has been closely linked to observations of large-scale fluxes measured by flux towers. However, theoretical and empirical studies show that biotic turnover - the replacement of some species by others - is a larger control of fluxes than over long timescales and to large climatic perturbations, because the range of response to environmental drivers is larger across species than within species. Recently, a number of innovative research efforts have incorporated parameterizations of plant demography, i.e. the size-structured growth, fecundity, and mortality of plant populations, to improve multi-decadal predictions of the terrestrial carbon cycle. These demographic efforts tend to rely heavily on forest inventory measurements, which in contrast to flux towers are demographically rich but temporally and spatially sparse. It can be argued that while gaining insight into long-term processes, such models have a weaker ability to represent instantaneous fluxes that are the currency of climate and weather models.

This submission will describe an inexpensive wireless observation system for measuring fluxes and microclimate of individual crowns. This system has the potential to connect forest demography, particularly growth rate in response to environmental drivers, to the large scale fluxes that are observed by towers. We anticipate that this system can be link to biogeographic studies that attempt to understand diverse responses of different species to climate change; to phenological studies monitoring changes in the timing of events within seasons in response to climate change, as well as ecological studies that try to understand how climate change will favor some species at the expense of others, leading to differential growth, recruitment, and mortality.

64. Measuring Forest Element Clumping Index in Sierra Forest Stands Using a Full-waveform Ground-Based Lidar

Feng Zhao

Echidna Validation Instrument (EVI), a ground-based, near-infrared (1064nm) scanning lidar, provides statistically similar gap fraction measurements, clumping index measurements, effective plant area index (LAI_e) and plant area index (LAI) measurements to those from hemispherical photos. In this research, a new method integrating the range dimension is proposed for retrieving clumping index with a unique Pgap image series from EVI. These results demonstrate the potential to quantify forest stand clumped conditions comparable to those from gap-size distribution theory using hemispherical photos. We conducted trials at 30 plots within six conifer stands of varying height and stocking densities in the Sierra National Forest, CA, in August 2008. The clumping index measurements retrieved from EVI Pgap image series for the hinge angle region are highly consistent (R^2=0.866) with those from hemispherical photos. Furthermore, the information contained in gap blob size profiles does account for the difference between our method and gap-size distribution theory based method, and therefore further exploration is required for better characterization of clumped condition from EVI Pgap image series.

65. Towards a multiscale approach to link climate, NEE and optical properties from a flux tower, robotic tram system that measures hyperspectral reflectance, phenocams, phenostations and a sensor network in desert a shrubland

Jaimes, Aline[1,2] Herrera, José [1] González, Libia [1] Ramírez, Gesuri [1], Christine Laney[1,2], Dawn Browning[3], Peters Deborah[3], Litvak, Marcy [4] Tweedie, Craig[1,2]

[1]Systems Ecology Lab, Biological Science Department, The University of Texas at El Paso; [2] CYBER-ShARE Center of Excellence, The University of Texas at El Paso; [3]USDA-ARS Jornada Experimental Range / Jornada Basin LTER; [4] Biological Science Department, University of New Mexico

ajaimes@utep.edu, or ctweedie@utep.edu

Over the past century arid and semiarid ecosystems have experience **shrub encroachment,** a process that consequently leads to desertification (Schlesinger et al. 1990, Grover and Musick, 1990; Bahre and Shelton 1993). The drivers of desertification are not well understood, however the process is linked to increased temperature and atmospheric CO2 concentrations, since woody plants usually possess the C3 photosynthetic pathway that confer an advantage under elevated CO2, compared to C4 grasses (Mayeux et al 1991:Johnson et al 1993; Polley et al, 1996).

In our study we present a multiscale approach aimed at improving the capacity for studying ecosystem dynamics at different scales of space and time in a pulse driven desert shrubland ecosystem. **Our multiscale approach follows guidelines of national and international networks** to assure usability and transferability of data to larger networks.

However, the complexity of designing, implementing, and maintaining a multiscale ecological station such as this, brings a range of challenges as either small labs or larger scale networks strive to use the same technology. Therefore, there is a **growing need to develop infrastructure that is able to provide tools** to help document, manage, visualize, and integrate high temporal and spatial resolution data from the multiple sensing platforms **(See Laney, C. et al poster for more details on Cyberinfrastructure).**

The intention is to highlight key time series from various sensor systems and observations, examine relationships between spectral indices typically used for measuring greenness from different sensor platforms, then determine which of these best correlates with fluxes. More robust models for integrating spectral measurements and fluxes are needed. In the near future we plan to expand correlations to include other spectral indices, and light use efficiency models.