Project Title: AmeriFlux Measurement Network: Science Team Research
Project ID: 0010758
Program Manager: James M. Kuperberg Phone: 301-903-4902 Division: SC-23.1
PI: Beverly E. Law
Institution: Oregon State University
Award Register#: ER63911
Institution URL: http://terraweb.forestry.oregonstate.edu
DE-FG02-04ER63911 Mod. 7

KEYWORDS: AmeriFlux, carbon dioxide exchange, NEE, water vapor exchange, terrestrial carbon processes

GOAL: Build a cohesive network of research sites to quantify and understand carbon sources and sinks and the response of terrestrial ecosystems to climate and disturbance.

AWARDS: World Meteorological Organization 2004 Award for Meteorology Paper of the Year (Norbert Gerbier MUMM Award)

OBJECTIVE:
Research involves analysis and field direction of AmeriFlux operations, and the PI provides scientific leadership of the AmeriFlux network. Activities include the coordination and quality assurance of measurements across AmeriFlux network sites, synthesis of results across the network, organizing and supporting the annual Science Team Meeting, and communicating AmeriFlux results to the scientific community and other users. Objectives of measurement research include (i) coordination of flux and biometric measurement protocols (ii) timely data delivery to the Carbon Dioxide Information and Analysis Center (CDIAC); and (iii) assurance of data quality of flux and ecosystem measurements contributed by AmeriFlux sites. Objectives of integration and synthesis activities include (i) integration of site data into network-wide synthesis products; and (ii) participation in the analysis, modeling and interpretation of network data products. Communications objectives include (i) organizing an annual meeting of AmeriFlux investigators for reporting annual flux measurements and exchanging scientific information on ecosystem carbon budgets; (ii) developing focused topics for analysis and publication; and (iii) developing data reporting protocols in support of AmeriFlux network goals.

APPROACH:
A strategic plan guides AmeriFlux research, and the PI is responsible for coordinating priority activities across the network. The approaches to these investigations include the following: Integrating micrometeorological and biological measurements to quantify and understand the carbon balance of terrestrial ecosystems; reduce uncertainties in flux measurements, improve data QA/QC and archiving standards, and require AmeriFlux sites to adhere to consistent measurement and data delivery standards; continue cross-site calibration of measurements using the "gold standard" roving instruments and software; conduct multiple measurements at AmeriFlux sites on CO_2 flux variation, biometrics and carbon storage; measure atmospheric CO_2 concentrations at selected sites, and use of the

data for modeling atmospheric CO_2 exchange; conduct intensive measurements of CO_2 exchange and biomass carbon along with physiological parameters for use in calculating NEP and NPP at AmeriFlux sites; improve knowledge of how processes regulate CO_2 and water vapor exchange, and improve the representations of respiration, phenology and disturbance in ecosystem carbon models; encourage expansion of flux sites as needed to fill critical gaps in biomes, disturbance gradients and climate space; conduct collaborative studies of scaling and integration of AmeriFlux results that include combinations of flux site data, cluster sites, remote sensing and modeling; organize the annual AmeriFlux Science Team meeting.

RESULTS TO DATE:

2012

The AmeriFlux project was involved in several synthesis papers in support of the North American Carbon Program objectives. Highlights are listed below.

We conducted an NACP synthesis on disturbance processes that modify ecosystem carbon dynamics that influence larger landscape-level dynamics. The synthesis highlighted case studies on characteristics of different types of disturbance, including the Pacific Northwest Metolius chronosequence of flux sites and landscape level ancillary plots. The synthesis identified disturbance severity and history as key factors driving post-disturbance carbon source-sink dynamics across all disturbance types (drought, insects, fire, harvest). To further improve understanding and prediction of carbon dynamics in disturbance-prone forests, the study recommended analyses that use multiple lines of evidence, increased measurement capabilities, shared models and online data sets, and innovative numerical algorithms (Goetz et al. 2012).

We evaluated 26 models and the uncertainty in simulated GPP using data from 39 flux towers in the US and Canada. None of the models simulated GPP within the observed uncertainty. In general, seasonality of GPP was not simulated well. The models overestimated GPP in autumn through spring and underestimated GPP in summer. The models also overestimated GPP under dry conditions and for temperatures below 0 C. The study suggested that improvements in simulated soil moisture and ecosystem response to drought or VPD stress would improve simulated GPP under dry conditions, and that adding a low-temperature response of GPP to temperature would reduce the overestimation of GPP in autumn through spring (and thus seasonal phenology). Comparisons of modeled and observed light-use efficiency (LUE; GPP per unit light absorbed)) indicated that the underestimation of GPP in summer was due to LUE.
The study suggested that modeling should use better parameter values for predicting potential GPP (Vcmax, LUE) (Schaefer et al. 2012).

CLM4 calculates Vcmax from several input parameters including foliage nitrogen, specific leaf area, temperature, soil water, nitrogen availability, and daylength. In a separate study using CLM4 at flux sites in Oregon and Canada, we hypothesized that CLM4 uses nitrogen incorrectly to estimate N in Rubisco and thus Vcmax, and

ultimately, maximum potential GPP. We used site-specific foliage nitrogen content values and specific leaf area parameterize the model and we ran sensitivity tests with soil nitrogen availability at the mesic site. Increase in N availability improved summer GPP estimates, but reduced model fidelity for the remainder of the months suggesting N availability alone does not improve GPP seasonality (Hudiburg et al. 2012). Improvement to Vcmax seasonality in CLM4 will require adjustment to other factors such as response to temperature and soil water in order to improve summer GPP.

A study was conducted to guide development of CO2 atmospheric inversion modeling systems. Using ORCHIDEE simulations as an example of prior information in combination with observations from 156 FLUXNET sites globally, we determined the mean, variances, and correlations of the prior errors at the site scale. Spatial correlations were confined to within the first few hundred kilometers, and separating out the plant functional types did not increase the spatial correlations, except for the deciduous broad-leaved forests. Using the statistics of the flux measurements as a proxy for the statistics of the prior flux errors was shown not to be a viable approach. This study showed that as long as the biases of the prior fluxes are much smaller than their error standard deviations, there is no advantage to tune the prior correlations, and biases can be neglected in the inversion design (Chevallier et al. 2012).

Surface albedo is a key parameter in the Earth's energy balance. Previously, we showed how different disturbances affect albedo and thus radiative forcing at flux sites (O'Halloran et al. 2011). Remote sensing of albedo can be used to determine implications of disturbance to radiative forcing at larger scales, however, the data products need to be evaluated with in situ observations. To evaluate MODIS albedo, we use data from 53 FLUXNET sites that met strict conditions of land cover homogeneity (large area with canopy closure) to deal with scale mismatch (1 km pixels vs flux tower point measurement). A good agreement between mean yearly MODIS albedo and in situ measurements was found ($r2 = 0.82$). The mismatch is correlated with spatial heterogeneity of surface albedo. Seasonal changes in MODIS albedo for different plant functional types showed extremely good correlations at the forest sites, but underestimated albedo at non-forested sites (grasslands, savannas, croplands) across seasons. The mismatch observed at grassland and cropland sites is likely due to the extreme fragmentation of these landscapes, as confirmed by geostatistical attributes derived from high resolution scenes (Cescatti et al. 2012).

Other activities:

Dr. Law updated DOE investigators on AmeriFlux activities, including the overall network strategy, organizational structure, steering committee composition, quality assurance and data management goals, synthesis activities, and thoughts on future directions.

Dr. Law worked with LBNL on the transition of AmeriFlux management and science lead from OSU to LBNL, including vision for core sites, producing synthesis-ready data,

improvements in data acquisition and reporting by core sites to LBNL, and QA transition (training, instrument package development for roving system, etc).

2010-2011

Noteworthy activities:

To ensure international consistency of methods and integration of results, Dr. Law serves on: (1) The Global Terrestrial Observing System – Terrestrial Carbon Observtions (GTOS-TCO panel chair); (2) The Advisory Panel for the Integrated Carbon Observation System (ICOS) of Europe (2009-); (3) the Advisory Board of Carbon and Greenhouse Gas management in Europe (GHG-Europe, 2009-). Law also testified before the House on AmeriFlux measurements (2009).

Data management and FLUXNET synthesis – Law continues to serve on the steering group of FLUXNET, which determined Fair Use Policies for open access to all FLUXNET data for modelers and the greater scientific community, and reviews individual proposals for using the data to minimize redundant analyses. The data of interest are the Level 4 data that are gap-filled and additional quantities are computed (gross photosynthesis, ecosystem respiration). These data are on the AmeriFlux website, but we still rely on Europeans to process the Level 4 data. FLUXNET is a Research Coordination Network project funded by NSF; it ends in 2012 and there are no plans to continue processing AmeriFlux data beyond that point. Dr. Law encouraged AmeriFlux sites to submit the next round of data for the past year to be processed by the Europeans. She continues to work with CDIAC in discussing improvements to the AmeriFlux web site and data issues.

Law participated in several AmeriFlux and Fluxnet synthesis activities that resulted in many high-profile publications (see 'Research Synthesis Results' and publications list below). Additional papers are in review.

Annual AmeriFlux meeting – Law and O'Halloran planned the AmeriFlux meeting in DC with help of session chairs (2009). This was a joint meeting with the NACP, in which Law served on the planning committee to ensure the two meetings were complementary. This was the final AmeriFlux meeting with Dr. Law as the Science Chair of AmeriFlux.

2010

National Research Council Committee on Verifying Greenhouse Gas Emissions: Methods to Support International Climate Agreements (2009-10). A key recommendation relevant to AmeriFlux is: 'An interagency group, with broad participation from the research community, should undertake a comprehensive review of existing information and design a research program to improve and, where appropriate, implement U.S. estimates of AFOLU emissions of CO2, N2O, and CH4. Key elements are likely to include continued research on the biogeochemical cycles of these gases, supported by observations from eddy covariance towers, other flux measurements for N2O and CH4,

and ecosystem inventories of all of the major carbon pools and their trends in the United States. These observation systems will be necessary in a modeling framework (e.g., ecosystem biogeochemistry process modeling) to provide the accuracy needed for annual, spatially explicit assessments within countries.

Law contributed to the GEO-Carbon Report and presented an overview at the ministry level meeting of the Group on Earth Observations (Washington, DC, 2009). The strategy in the report is integrated observation systems that include flux networks for model and remote sensing calibrations.

Law serves on the Fluxnet Steering Committee that reviews proposals to use the Fluxnet data to ensure minimum overlap in synthesis efforts.

Research Synthesis Results 2010-2011.

Recent decline in the global land evapotranspiration trend due to limited moisture supply. The soils in large areas of the Southern Hemisphere, including major portions of Australia, Africa and South America, have been drying up in the past decade. These are findings from a Fluxnet synthesis on global evapotranspiration measured by investigators at AmeriFlux sites, and sites in other regional flux networks. Most climate models have suggested that evapotranspiration, which is the movement of water from the land to the atmosphere, would increase with global warming. The new research, published in Nature, found that's exactly what was happening from 1982 to the late 1990s. But in 1998, this significant increase in evapotranspiration – which had been seven millimeters per year – slowed dramatically or stopped. In large portions of the world, soils are now becoming drier than they used to be, releasing less water and offsetting some moisture increases elsewhere. Due to the limited number of decades for which data are available, we can't be sure whether this is a natural variability or part of a longer-lasting global change. But one possibility is that on a global level, a limit to the acceleration of the hydrological cycle on land has already been reached. Consequences could include reduced terrestrial vegetation growth, less carbon absorption, a loss of the natural cooling mechanism provided by evapotranspiration, more heating of the land surface, more intense heat waves and a "feedback loop" that could intensify global warming (Jung et al. 2010).

Forest sector carbon accounting needs improvement. A synthesis of data from flux sites and inventories, and literature review aimed to provide ecologists, land managers and policy makers with a better understanding of important issues related to forest sector carbon management, measurement and verification, and policy related to mitigation and adaptation of forests to climate change. The focus was on carbon sequestration processes, appropriate measurements for international, regional and local scale assessment of net ecosystem carbon balance, and life cycle analysis (LCA) with special attention to the concept of substitution of fossil fuel with bioenergy from forests. Given the slow dynamic of forest carbon, LCA needs to account for preexisting forest conditions, as carbon neutrality (i.e. net ecosystem carbon balance of forests is zero) can take at least a century to achieve in many cases. The substitution of wood for more energy intensive materials has likely been overestimated compared to when additionality,

permanence, and saturation of wood building stores are considered. Greenhouse gas (GHG) emission policies will need to account for emissions associated with bioenergy, which is currently not considered internationally. Thus, GHG emissions resulting from substitution for fossil fuels will have to be more accurately represented if their true impact is to be understood (Law & Harmon 2011).

Recommendation of improvements in Earth System Models on the effects of drought on terrestrial ecosystems. Drought as an intermittent disturbance of the water cycle interacts with the carbon cycle differently than the 'gradual' climate change. During drought plants respond physiologically and structurally to prevent excessive water loss according to species specific water use strategies. This has consequences for carbon uptake by photosynthesis and release by total ecosystem respiration. After a drought, disturbances in moisture availability, organic matter and nutrients in the soil, and carbohydrates in plants lead to longer-term effects in plant carbon cycling, and potentially mortality. Direct and carry-over effects, mortality and consequently species competition in response to drought are strongly related to the survival strategies of species. The paper reviewed the state of the art of the understanding of the relation between water drought and the ecosystem carbon cycle interactions and argued that plant strategies must be given an adequate role in global vegetation models if the effects of drought on the carbon cycle are to be described in a way that justifies the interacting processes (van der Molen et al. 2011).

Nitrogen deposition reduces forest soil respiration. A synthesis of data from NitroEurope and flux data from AmeriFlux, CarboEurope, and ChinaFlux found that low to moderate levels of nitrogen deposition to terrestrial ecosystems lead to enhanced uptake of CO2 from the atmosphere and reduced organic matter decomposition. In an earlier study, we found increased net carbon uptake across a set of sites, but the mechanisms were unclear. Here, we had ancillary data on soil processes to find that soil respiration was reduced with N deposition. The results were published in Nature Geoscience (Janssens et al. 2010), and the results were highlighted on Nature's home page.

New methods are recommended for computing photosynthesis parameters for model inputs. Gu et al. (2010) compiled A-Ci (assimilation) curves from AmeriFlux sites and used the data to develop and demonstrate a model for computing Vcmax and Jmax from the data in a consistent manner. The paper also recommends methods for improved measurements of assimilation rates. The code for processing the A-ci curves is posted on the AmeriFlux web site.

Albedo effects are significant relative to CO2 emission from forest disturbances. The change to albedo from disturbing forest causes a radiative forcing that either enhances or reduces the net heating caused by CO2 release. These findings result from a synthesis of AmeriFlux towers that have witnessed disturbances, including mortality of mangrove forest from hurricane damage in the Everglades and wildfire in boreal forests. MODIS albedo data were also used to develop a case study of mountain pine beetle attack in western North America. In the case of boreal fire, recovery of albedo took 100 years, while the forest was still a net carbon sink at 160 years. This shows how the trajectory of

recovery in albedo and carbon stocks after disturbance are not exactly coupled, which will complicate representing these processes in climate models. Neglecting either the carbon or albedo component of the disturbance would lead to gross errors in representing the net climate effect of these processes. (O'Halloran et al. 2011)

DELIVERABLES:

Publications (pdf files: www.fsl.orst.edu/terra)

2012:

Barr, A., A. Richardson, D. Hollinger, D. Papale, A. Arain, T.A. Black, G. Bohrer, D. Drangoni, M. Fischer, L. Gu, B.E. Law, H. Margolis, H. McCaughey, W. Munger, W. Oehel, K. Schaeffer. 2012. Use of change-point detection for friction velocity threshold evaluation in eddy covariance studies. Agric. For. Meteorol. In press.

Cescatti, A., B. Marcolla, S.K. Santhana Vannan, J.Y. Pan, M.O. Roman, X. Yang, P. Ciais, R.B. Cook, B.E. Law, G. Matteucci, M. Migliavacca, E. Moors, A. Richardson, G. Seufert, C.B. Schaaf. 2012. Intercomparison of MODIS albedo retrievals and in situ measurements across the global FLUXNET network. Remote Sensing of Environment 121:323-334.

Chevallier, F., T. Wang, P. Ciais, F. Maignan, M. Bocquet, A. Arain, A. Cescatti, J. Chen, H. Dolman, B.E. Law, H.A. Margolis, L. Montagnani, E.J. Moors. 2012. What eddy-covariance measurements tell us about prior land flux errors in CO_2-flux inversion schemes. Global Biogeochemical Cycles 26 (GB1021), doi:10.1029/2010GB003974.

Goetz, S., B. Bond-Lamberty, B.E. Law, J.A. Hicke, C. Huang, R.A. Houghton, S. McNulty, T. O'Halloran, M. Harmon, A.J.H. Meddens, E.M. Pfeifer, D. Mildrexler, E.S. Kasischke. 2012. Observations and assessment of forest carbon dynamics following disturbance in North America. J. Geophys. Res.-Biogeosciences 117, G02022, doi:10.1029/2011JG001733.

Hudiburg, T.W., Law, B.E., Thornton, P.E., 2012. Evaluation and improvement of the Community Land Model (CLM 4.0) in Oregon forests. *Biogeosciences Discussions* 9, 12757-12802.

Law, B.E., T. Hudiburg, S. Luyssaert. 2012. Thinning effects on forest productivity: Consequences of preserving old forests and mitigating impacts of fire and drought. Plant Ecology & Diversity, doi: 10.1080/17550874.2012.679013.

Nui, S., Y. Luo, S. Fei, W. Yuan, D. Schimel, C. Ammann, M. Altaf Arain, A. Arneth, M. Aubinet, A. Barr, et al. 2012. Thermal optimality of net ecosystem exchange of carbon dioxide and underlying mechanisms. New Phytologist. doi: 10.1111/j.1469-8137.2012.04095.x.

Schaefer, K., C. Schwalm, C. Williams, M.A. Arain, A. Barr, J. Chen, K.J. Davis, D. Dimitrovs, T.W. Hilton, D.Y. Hollinger, E. Humphreys, B. Poulter, B.M. Racska, A.D. Richardson, A. Sahoo, P. Thornton, R. Vargas, H. Verbeeck, R. Anderson, I. Baker, T.A. Black, P. Bolstad, J. Chen, P. Curtis, A.R. Desai, M. Dietze, D. Dragoni, C. Gough, R.F. Grant, L. Gu, A. Jain, C. Kucharik, B.E. Law, S. Liu, E. Lokipitiya, H.A. Margolis, R. Matamala, J.H. McCaughey, R. Monson, J.W. Munger, W. Oechel, C. Peng, D.T. Price, D. Ricciuto, W.J. Riley, N. Roulet, H. Tian, C. Tonitto, M. Torn, E. Weng, X. Zhou. 2012. A Model-Data Comparison of Gross Primary Productivity: Results from the North American Carbon Program Site Synthesis. J. Geophys. Res.-Biogeosciences 117, G03010, doi:10.1029/2012JG001960.

Schmidt, A., B.E. Law, C. Hanson, O. Krumm. 2012. Distinct global patterns of strong positive and negative shifts of seasons over the last 6 decades. Atmospheric and Climate Sciences 2:76-88.

Schmidt, A., C. Hanson, S. W. Chan, and B. E. Law. 2012. Empirical assessment of uncertainties of meteorological parameters and turbulent fluxes in the AmeriFlux network. J. Geophys. Res., doi:10.1029/2012JG002100.

Schwalm, C.R., C.A. Williams, K. Schaefer, D. Baldocchi, A. Black, A.H. Goldstein, B.E. Law, W.C. Oechel, K.T. Paw U, R. Scott. 2012. Loss of carbon uptake during the turn of the century drought in western North America. Nature Geoscience, 5: 551-556, doi: 10.1038/NGEO1529.

Vicca, S., S. Luyssaert, J. Peñuelas, M. Campioli, F.S. Chapin III, P. Ciais, A. Heinemeyer, P. Högberg, W.L. Kutsch, B.E. Law, Y. Malhi, D. Papale, S.L. Piao, M. Reichstein, E.-D. Schulze, I.A. Janssens. 2012. Fertile forests produce biomass more efficiently. Ecology Letters 15:520-526. doi: 10.1111/j.1461-0248.2012.01775.x.

2011:

O'Halloran, T.L., Law, B.E., Wang, Z., Barr, J.G., Schaaf, C., Brown, M., Goulden, M.L., Fuentes, J.D., Göckede, M., Black, A., Engel, V. Radiative forcing from hurricanes, insects and fire. Global Change Biology 18: 555-565, doi: 10.1111/j.1365-2486.2011.02577.x.

Law, B.E. and M. Harmon. 2011. Forest sector carbon management, measurement and verification, and discussion of policy related to climate change. Carbon Management 2 (1):73-84. *Invited.*

Ryu, Y., D.D. Baldocchi, T.A. Black, M. Detto, B.E. Law, R. Leuning, A. Miyata, M. Reichstein, R. Vargas, C. Ammann, J. Beringer, L.G. Flannigan, L. Gu, L. Hutley, J. Kim, H. McCaughey, E. Moors, S. Rambal, A.D. Richardson, T. Vesala. 2011. On the temporal upscaling of evapotranspiration from instantaneous remote sensing measurements to 8-day mean daily-sums. Agric. For. Meteorol. 52:212–222, doi:10.1016/j.agrformet.2011.09.010.

Van der Molen, M., H. Dolman, P. Ciais, T. Eglin, N. Gobron, B.E. Law, P. Meir, W. Peters, O. Phillips, M. Reichstein, T. Chen, S. Dekker, M. Doubková, M. Friedl, M. Jung, B. van den Hurk, R. de Jeu, B. Kruijt, T. Ohta, K. Rebel, S. Plummer, S. Seneviratne, S. Sitch, R. Teuling, G. van der Werf, G. Wang. 2011. Drought and ecosystem carbon cycling. Agric. For. Meteorol. 151: 765-773.

Masek, J.G., W. Cohen, D. Leckie, M. Wulder, R. Vargas, B. de Jong, S. Healey, B.E. Law, R. Birdsey, R.A. Houghton, D. Mildrexler, S. Goward, W.B. Smith. 2011. Recent rates of forest harvest and conversion in North America. J. Geophys. Res. 11, G00K03, doi:10.1029/2010JG001471.

2010:

Jung, M., M. Reichstein, P. Ciais, S.I. Seneviratne, J. Sheffield, M.L. Goulden, G. Bonan, A. Cescatti, J. Chen, R. de Jeu, A.J. Dolman, W. Eugster, D. Gerten, D. Gianelle, N. Gobron, J. Heinke, J. Kimball, B.E. Law, L. Montagnani, Q. Mu, B. Mueller, K. Oleson, D. Papale, A.D. Richardson, O. Roupsard, S.W. Running, E. Tomelleri, N. Viovy, U. Weber, C. Williams, E. Wood, S. Zaehle, K. Zhang. 2010. A recent decline in the global land evapotranspiration trend due to limited moisture supply. Nature DOI 10.1038/nature09396.

Schwalm, C.R., C.A. Williams, K. Schaefer, A. Arneth, D. Bonal, N. Buchmann, J.Q. Chen, B.E. Law, A. Lindroth, S. Luyssaert, M. Reichstein, A.D. Richardson. 2010. Assimilation exceeds respiration sensitivity to drought: A FLUXNET synthesis. Global Change Biology 16: 657-670.

Xiao, J., Q. Zhuang, B.E. Law, D.D. Baldocchi, J. Chen, A.D. Richardson, J. Melillo, K.J. Davis, D.Y. Hollinger, S. Wharton, R. Oren, A. Noormets, M.L. Fischer, S. Verma, D.R. Cook, G. Sun, S. McNulty, S.C. Wofsy, P.V. Bolstad, S.P. Burns, P.S. Curtis, B.G. Drake, M. Falk, D.R. Foster, L. Gu, J.L. Hadley, G.G. Katul, M. Litvak, S. Ma, T.A. Martin, R. Matamala, T.P. Meyers, R.K. Monson, J.W. Munger, W.C. Oechel, K.T. Paw U, H.P. Schmid, R.L.Scott, G. Starr, A.E. Suyker, M.S. Torn. 2011. Assessing net ecosystem carbon exchange of U.S. terrestrial ecosystems by integrating eddy covariance flux measurements and satellite observations. Agric. For. Meteorol. 151: 60-69.

Anderson, R.G., J.G. Canadell, J.T Randerson, R.B. Jackson, B.A. Hungate, D.D. Baldocchi, G.A. Ban-Weiss, G.B. Bonan, K. Caldeira, L. Cao, N.S. Diffenbaugh, K.R. Gurney, L.M. Kueppers, B.E. Law, S. Luyssaert, T.L. O'Halloran. 2010. Biophysical considerations in forestry for climate protection. Frontiers in Ecology doi:10.1890/090179.

Gu, L., S.G. Pallardy, K. Tu, B.E. Law, S.D. Wullschleger. 2010. Reliable estimation of biochemical parameters from C3 leaf photosynthesis- intercellular carbon dioxide response curves. Plant, Cell and Environment 33:1852-1874. Doi:10.1111/j.1365-3040.2010.02192.x.

Janssens, I.A., W. Dieleman, S. Luyssaert, J.-A. Subke, M. Reichstein, R. Ceulemans, P. Ciais, A.J. Dolman, J. Grace, G. Matteucci, D. Papale, S.L. Piao, E.-D. Schulze, J. Tang, B.E. Law. 2010. Reduction of forest soil respiration in response to nitrogen deposition. Nature Geoscience 3: 315-322. Doi: 10.1038/NGEO844.

National Research Council. 2010. Verifying Greenhouse Gas Emissions: Methods to Support International Climate Agreements. National Academies Press, Washington, DC. ISBN: 0-309-15212-7, 124 pages.

2009:

Cias, P., H. Dolman, R. Dargaville, L. Barrie, T. Battin, A. Bombelli, A.B.H. Boversmann, F.-M. Bréon, M. Bushwitz, J. Butler, P. Canadell, R. Cook, N. Gobron, C. Heinze, M. Heimann, A. Held, M. Henry, E. Kasischke, B.E. Law, S. Luyssaert G. Marland, J. Miller ,T. Moriyama, R. Munro, D. Ojima, Y. Pan, S. Plummer, S. Quegan, P. Rayner, C. Sabine,D. Schimel, O. Tarasova, R. Valentini, A. Watson, G. van der Werf, C. Zehner. 2009. GEO Carbon Strategy. Group on Earth Observations. 61 pp.

Beer, C., P. Ciais, M. Reichstein, D. Baldocchi, B.E. Law, D. Papale, J.-F. Soussana, C. Ammann, N. Buchmann, D. Frank, D. Gianelle, I.A. Janssens, A. Knohl, B. Köstner, E. Moors, O. Roupsard, H. Verbeeck, T. Vesala, C.A. Williams, G. Wohlfahrt. 2009. Temporal and among-site variability of inherent water-use efficiency at the ecosystem level. Global Biogeochemical Cycles, 23:GB2018, doi:10.1029/2008GB003233.

Bombelli, A., V. Avitabile, H. Balzter, L.B. Marchesini, M. Bernoux, M. Brady, R. Hall, M. Hansen, M. Henry, M. Herold, A. Janetos, B.E. Law, R. Manlay, L.G. Marklund, H. Olsson, D. Pandey, M. Saket, C. Schmullius, R. Sessa, Y.E. Shimabukoro, R. Valentini, M. Wulder. 2009. Assessment of the Status of the Development of the Standards for the Terrestrial Essential Climate Variables. Report 67, Global Terrestrial Observing System. FAO, Rome. 18 pp.

Law, B.E., T. Arkebauer, J.L. Campbell, J. Chen, O. Sun, M. Schwartz, C. van Ingen, S. Verma. 2009. Terrestrial Carbon Observations: Protocols for Vegetation Sampling and Data Submission. Report 55, Global Terrestrial Observing System. FAO, Rome. 87 pp.

Invited Presentations (2009-2011)

Law, B.E. The Role of Forests and Forestry in the Terrestrial Carbon Cycle: Considerations for a Changing Climate. April 18-20, 2011. John Grace Symposium, Bologna, Italy.

Law, B.E. Enhancing Global Forest Observations in a Changing Climate. Global Climate Observation System Panel, COP 16, United Nations Framework Convention on Climate Change. November 30, 2010, Cancun, MX.

Law, B.E. Integration of observations and modeling to quantify forest carbon stocks and fluxes. IPCC Expert Meeting on Uncertainty and Validation of Emission Inventories. March 23-25, 2010. Utrecht, The Netherlands.

Law, B.E., A. Linn. Verifying Greenhouse Gas Emissions. American Geophysical Union. Dec 11-17, 2010. San Francisco, CA.

Law, B.E. 2009. Testimony before the U.S. Senate Committee on Energy and Natural Resources Subcommittee on Public Lands and Forests. "Managing Federal Forests in Response to Climate Change, Including for Natural Resource Adaptation and Carbon Sequestration."

Law, B.E. 2009. Testimony before the U.S. House of Representatives, Committee on Energy & Environment on "Monitoring, Measurement, and Verification of Greenhouse Gas Emissions: The Role of Federal and Academic Research and Monitoring Programs."

Law, B.E. A Global Carbon Observation System. Group on Earth Observations (GOP VI) Carbon Community of Practice. November 19, 2009. Washington, DC.

Law, B.E. Can tower flux measurements constrain forest uptake of CO_2? American Association for the Advancement of Science. February 13-15, 2009. Chicago, IL.

Law, B.E. Drought effects on forest carbon processes. COCOS meeting, Model Parameters for Ecosystem Condition. October 19-20, 2009, Amsterdam.

Baldocchi, D.D., and B.E. Law. Carbon Cycle at Global, Ecosystem and Regional Scales. Interagency Forestry Working Group, California Air Resources Board, Oct 19, 2009, Sacramento, California.

Student Training

Two post-doctoral research associates (Tom O'Halloran, Ajit Govind).