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FLUXNET: Unifying a global array of tower flux networks for validating EOS Terrestrial carbon, water and energy budgets.
05118 NASA Goddard Space Flight Center.

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Overview:

FLUXNET is a global network of micrometeorological flux measurement sites, which measure the exchanges of carbon dioxide, water vapor and energy between the biosphere and atmosphere. At present over 140 sites are operating on a long-term and continuous basis. Vegetation under study includes temperate conifer and broadleaved (deciduous and evergreen) forests, tropical and boreal forests, crops, grasslands, chaparral, wetlands and tundra. Sites exist on five continents and their latitudinal distribution ranges from 70 degrees north to 30 degrees south.

FLUXNET has several primary functions. First, it provides infrastructure for compiling, archiving and distributing carbon, water and energy flux measurement, meteorological, plant and soil data to the science community. Data and site information are available from the FLUXNET website, <http://www-eosdis.ornl.gov/FLUXNET>. Second, the project supports calibration and flux inter-comparison activities. This activity ensures that data from the regional networks are inter-comparable. And thirdly, FLUXNET supports the synthesis, discussion and communication of ideas and data by supporting project scientists, workshops and visiting scientists. The overarching goal is to provide information for validating computations of net primary productivity, evaporation and energy absorption that are being generated by sensors mounted on the NASA TERRA satellite.

Data being compile by FLUXNET are being used to quantify and compare magnitudes and dynamics of annual ecosystem carbon and water balances, to quantify the response of stand-scale carbon dioxide and water vapor flux densities to controlling biotic and abiotic factors, and to validate a hierarchy of soil-plant-atmosphere trace gas exchange models. Findings so far include: 1) net CO₂ exchange of temperate broadleaved forests increases by about 5.7 gC m⁻² day⁻¹ for each additional day that the growing season is extended; 2) the sensitivity of net ecosystem CO₂ exchange to sunlight doubles if the sky is cloudy rather than clear; 3) the spectrum of CO₂ flux density exhibits peaks at time scales of days, weeks and year and a spectral gap at the month time scale; 4) the optimal temperature of net CO₂ exchange varies with mean summer temperature; and 5) stand age affects carbon dioxide and water vapor flux densities.

Postdoctoral Research Associates

The FLUXNET Office supported the salary of a postdoctoral research associates. During the course of the FLUXNET project two individuals worked on analysis and synthesis of FLUXNET data. The fellows were:

Dr. Eva Falge, June 1998 to Oct. 1999.

Dr. Lianhong Gu, Feb 2000 to present.

FLUXNET Extended Visitors:

The Fluxnet Office sponsored extended visits by two members of the FLUXNET community to conduct additional synthesis analyses. The visitors were:

Dr. Peter Levy, Centre for Ecology and Hydrology, Bush Estate, Penicuik, Midlothian, July, 2001 Effects of spatial heterogeneity on sampling errors in CO₂ flux measurements over uneven-aged forests

Dr. Kai Morgenstern, University of British Columbia. Vancouver, Canada. Sept, 2001 Investigation of spectral characteristics of surface layer turbulence above site of varying surface structure derived from long-term monitoring data

Calibration Field Studies

The FLUXNET Project Office contracted Dr. David Hollinger and Mr. Robert Evans to conduct flux system intercomparison studies at research sites within regional networks of the FLUXNET Community. Over the duration of this project seven sites were visited. Table 1 compiles the site information.

Table 1.

Site	Location	Functional Type	Regional Network
Norunda	Norunda, Sweden	coniferous	Euroflux
Castelportizano	Italy	macchia	Euroflux
Tumbarumba	Tumbarumba, Australia	Eucalyptus forest	OzFlux
Twizel	Twizel, New Zealand	grassland	OzFlux
Sertaozinho	Sao Paulo Brazil	Sugar cane	LBA
Tomakomai	Hokkaido, Japan	Larch	Asiaflux
Sapporo	Hokkaido, Japan	Deciduous forest	AsiaFlux

Workshops Convened:

One major activity of the FLUXNET Office was the convening of workshops. Below is a list of workshops that were supported by the FLUXNET Project.

Water, Energy, and Carbon Cycles in Terrestrial Systems: Local-Scale Observations Through Fluxnet and Other Micrometeorological Tower Sites II, American

Geophysical Union. San Francisco. Dec 13-14,
2001. Convenors, L Gu, D Baldocchi, S Running.

Fluxnet workshop. Dec. 7, 2001. University of California
Berkeley. Convenors. L Gu, D. Baldocchi

Fluxnet 2000 Synthesis Workshop, Marshall, CA June 2000. Convenor, D
Baldocchi

Second FLUXNET Workshop, Polson, MT, June 3-5, 1998. Convenors, S.
Running, D. Baldocchi

In addition, the Fluxnet office participated in the organization of several regional
meetings, including:

Steering Committee, Workshop for Unaccounted Flux in Long-Term Studies of
Carbon and Energy Exchanges. Boulder, CO. May 30-31, 2000.

Advisory Committee, International Workshop for Advanced Flux Network and
Flux Evaluation. Sept 27-29, 2000, Hokkaido University, Japan.

Travel Support

The Fluxnet office supported travel of several scientists to regional workshops.
European scientists were invited to several AmeriFlux meetings and
several American Scientists were sent to the Euroflux meetings.

Publications: Special Issue

The key product of the Marconi FLUXNET 2000 Workshop is a
special issue in Agricultural and Forest Meteorology. Submitted
papers include:

Massman and Lee	Eddy covariance flux corrections and energy exchange
Schmid, HP	Footprint Modeling for Vegetation Atmosphere Exchange: A Review and Perspective
Curtis et al	Biometric and eddy-covariance based estimates of net ecosystem carbon exchange in five eastern No
Davidson et al	Minimizing artifacts and biases in chamber-based measurements of soil respiration
Falge et al	Seasonality of ecosystem Respiration and Gross Primary production as derived from FLUXNET mea
Falge et al	Phase And Amplitude Of Ecosystem Carbon Release And Uptake Potentials As Derived From Flu
Katul et al	Complexity and Disorder in Scalar Fluxes Measured at Four Tower Sites: A Thermodynamic Analog
Law et al	Carbon Dioxide and Water Vapor Exchange of Terrestrial Vegetation in Response to Environment
Wilson et al	Using the FLUXNET spectrum of canopy structure and topography to examine energy balance closu
Thornton et al	Carbon storage and fluxes in evergreen coniferous forests: influences of climate, stand development ;
Davidson et al.	Belowground carbon allocation in forests estimated from litterfall and IRGA-based soil respiration m
Pattey et al	Measuring nighttime CO ₂ flux over forests and agricultural crops using eddy covariance and nocturn

Publications: Papers Produced

Numerous publications were produced through the FLUXNET Office and the workshops it convened. Below is a list of published and submitted papers that were produced with support of the FLUXNET project.

Baldocchi DD. 2002. Assessing ecosystem carbon balance: problems and prospects of the eddy covariance technique. *Annual Review of Ecology and Systematics* (submitted Dec 28, 2001).

Baldocchi, DD. Wilson, KB, Gu, L. 2001. Influences of structural and functional complexity on carbon, water and energy fluxes of temperate broadleaved deciduous forest. *Tree Physiology*. (submitted August, 2001).

Sanderman J, Amundson R. Baldocchi DD. 2002. The effect of temperature on the residence time of soil organic carbon: a comparative analysis. *Global Biogeochemical Cycles*. (submitted, Nov 2001).

Wilson KB, Baldocchi DD, Aubinet M, Berbigier P, Bernhofer Ch, Dolman H, Falge E, Field C, Goldstein H, Granier A, Grelle A, Halldor T., Hollinger D, Katul G, Law BE, Lindroth A, Meyers T, Moncrieff J, Monson R, Oechel W, Tenhunen J, Valentini R, Verma S, Vesala T, Wofsy S. 2002. Surface energy partitioning between latent and sensible heat flux at FLUXNET sites. *Water Resources Research* (submitted, Oct 1, 2001; accepted Nov 28, 2001).

Wilson KB, Baldocchi DD, Falge E, Aubinet M, Berbigier P, Bernhofer Ch, Dolman H, Field C, Goldstein H, Granier A, Hollinger D, Katul G, Law BE, Meyers T, Moncrieff J, Monson R, Tenhunen J, Valentini R, Verma S, Wofsy S. 2002. The diurnal centroid of ecosystem energy and carbon fluxes at FLUXNET sites. *Journal of Geophysical Research* (submitted, Oct 1, 2001).

Falge, E., Baldocchi, D., Tenhunen, J., Aubinet, M., Bakwin, P., Bernhofer, P., Bernhofer, Ch., Burba, G., Clement, R., Davis, K.J., Elbers, J.A., Goldstein, A.H., Grelle, A., Granier, A., Gu_mundsson, J., Hollinger, D., Kowalski, A., Katul,G., Law,B, Malhi,Y., Meyers,T., Monson,R., Mungler,JW, Oechel,W., Paw U,KT., Pilegaard,K, Rannik,U, Rebmann, C, Suyker,A, Valentini, R., Wilson,K, and Wofsy, S. 2001. Seasonality of ecosystem respiration and gross primary production as derived from FLUXNET measurements. *Agricultural and Forest Meteorology*. (submitted May, 2001).

- Katul, G., Baldocchi, D., Bernhofer, Ch and Munger, W. 2001. Complexity and disorder in Scalar Fluxes Measured at Four Tower Sites: A Thermodynamic Analogy. *Agricultural and Forest Meteorology*. (submitted May, 2001).
- Law, B.E., Falge, E., Gu, L., Baldocchi, D., Bakwin, P., Berbigier, P., Davis, K.J., Dolman, H., Falk, M., Fuentes, J., Goldstein, A.H., Granier, A, Grelle, A., Hollinger, D., Janssens, I., Jarvis, P., Jensen, N.O. Katul,G., Malhi,Y., Matteucci, G., Monson,R., Munger, JW, Oechel,W., Olson, R., Pilegaard, K, Paw U, KT, Thorgeirsson, H, Valentini, R., Verma, S. Vesala, T., Wilson,K, and Wofsy,S. 2001. Environmental controls over carbon dioxide and water vapor exchange of terrestrial vegetation. *Agricultural and Forest Meteorology* (submitted, April, 2001).
- Wilson, K.B., Goldstein, A.H., Falge, E., Aubinet, M., Baldocchi, D., Berbigier, P., Bernhofer, Ch., Ceulemans, R., Dolman, H., Field, C., Grelle, A., Law,B., Meyers,T., Moncrieff, J., Monson, R., Oechel,W., Tenhunen, J., Valentini, R. and Verma, S. 2001. Energy balance closure at FLUXNET sites. *Agricultural and Forest Meteorology* (submitted, April, 2001).
- Falge, E., Tenhunen, J., Baldocchi, D. Aubinet, M., Bakwin, P., Berbigier, P., Bernhofer, Ch., Bonnefond, J-M, Burba, G., Clement, R., Davis, K.J., Elbers, J.A., Falk, M., Goldstein, A.H., Grelle, A, Granier, A, Grünwald, T, Gu_mundsson, J., Hollinger, D., Janssens, I., Keronen,P., Kowalski,A, Katul,G., Law,B, Malhi,Y., Meyers,T., Monson,R., Moors,E., Munger,JW, Oechel,W., Paw U,KT., Pilegaard,K, Rannik,U, Rebmann,R, Suyker,A, Thorgeirsson,H, Tirone,G, Turnipseed,A, Wilson,K, and Wofsy,S. 2001. Phase and amplitude of ecosystem carbon release and uptake potential as derived from FLUXNET measurements. *Agricultural and Forest Meteorology*. (submitted 4/2001).
- Gu, L., D.D. Baldocchi, S. B. Verma, T. A. Black, T. Vesala, E. M. Falge, P.R. Dowty. 2001. Superiority of diffuse radiation for terrestrial ecosystem productivity. *Journal of Geophysical Research* (submitted, 12/2000; revised 6/2001; accepted).
- Baldocchi, DD, Falge, E, Gu, L., R. Olson, D. Hollinger, S. Running, P. Anthoni, Ch. Bernhofer, K. Davis, J. Fuentes, A. Goldstein, G. Katul, B. Law, X. Lee, Y. Malhi, T. Meyers, J.W. Munger, W. Oechel, KT Paw U, K. Pilegaard, H.P. Schmid, R. Valentini, S. Verma, T. Vesala, K. Wilson and S. Wofsy. 2001. FLUXNET: A New Tool to Study the Temporal and Spatial Variability of Ecosystem-Scale Carbon Dioxide, Water Vapor and Energy Flux Densities *Bulletin of the American Meteorological Society* 82: 2415-2434.

- Falge E., Baldocchi, D.D., Olson, R.J., P Anthoni, M Aubinet, Ch Bernhofer, G Burba, R Ceulemans, R Clement, H Dolman, A Granier, P Gross, Th Grünwald, D Hollinger, N-O Jensen, G Katul, P Keronen, A Kowalski, Chun Ta Lai, B E. Law, T Meyers, J Moncrieff, E Moors, J. W Munger, K Pilegaard, Ü Rannik, C Rebmann, A Suyker, J Tenhunen, K Tu, S Verma, T Vesala, K Wilson, Steve Wofsy. 2001. Gap filling strategies for long term energy flux data sets. *Agricultural and Forest Meteorology*. 107, 71-77.
- Falge, E., D. Baldocchi, R. Olson, P. Anthoni, M. Aubinet, Ch. Bernhofer, G. Burba, R. Ceulemans, R. Clement, H. Dolman, A. Granier, P. Gross, T. Grünwald, D. Hollinger, N-O Jensen, G. Katul, P. Keronen, A. Kowalski, CT Lai, B. Law, T. Meyers, J. Moncrief, E.J. Moors, W. Munger, K. Pilegaard, U. Rannik, C. Rebmann, A. Sukyer, J. Tenhunen, K. Tu, S. Verma, T. Vesala, K. Wilson, S. Wofsy. 2001. Gap filling strategies for defensible annual sums of net ecosystem exchange. *Agricultural and Forest Meteorology*. 107, 43-69.
- Baldocchi, D.D., E. Falge and K. Wilson. 2001. A spectral analysis of biosphere-atmosphere trace gas flux densities and meteorological variables across hour to multi-year time scales. *Agricultural and Forest Meteorology*. 107, 1-27.
- Baldocchi, D.D., F.M. Kelliher, T.A. Black and P.G. Jarvis. 2000. Climate and vegetation controls on boreal zone energy exchange. *Global Change Biology*. 6, 69-83.
- Canadell, J., H. Mooney, D. Baldocchi, J. Berry, J. Ehleringer, C.B. Field, T. Gower, D. Hollinger, J. Hunt, R. Jackson, S. Running, G. Shaver, S. Trumbore, R. Valentini and B. Yoder. 2000. Carbon metabolism of the terrestrial biosphere. *Ecosystems* 3, 115-130.
- Running, S.W., D.D. Baldocchi, D. Turner S.T. Gower, P. Bakwin and K. Hibbard. 1999. A global terrestrial monitoring network, scaling tower fluxes with ecosystem modeling and EOS satellite data. *Remote Sensing of the Environment*. 70, 108-127.
- Malhi, Y., D.D. Baldocchi and P.G. Jarvis. 1999. The carbon balance of tropical, temperate and boreal forests. *Plant, Cell and Environment*. 22, 715-740.
- Steffen, W., I. Noble, J. Canadell, M. Apps, d. Schulze, P. Jarvis, D. Baldocchi, P. Ciais, W. Cramer, J. Ehleringer, G. Farquhar, C. Field, A. Ghazi, R. Gifford, M. Heimann, R. Houghton, P. Kabat, C. Korner, E. Lambin, S. Linder, J. Lloyd, H. Mooney, D. Murdiyarso, W. Post, C. Prentice, M. Raupach, D. Schimel, A. Shvidenko, R. Valentini. 1998. The terrestrial

carbon cycle: implications for the Kyoto protocol. *Science*. 280: 1393-1394

Invited lectures:

Baldocchi DD. *Fluxnet, a new tool to study the temporal and spatial variability of ecosystem-scale carbon dioxide, water vapor and energy flux densities*. Atmospheric Science Program. Department of Land, Air And Water Resources University of California, Davis. Nov. 6, 2001.

Baldocchi DD FLUXNET: 2001 Status Report. Ameriflux Annual Meeting, Oct. 2001. Argonne, IL.

Baldocchi DD *FLUXNET, A global network of long term carbon dioxide, water vapor and energy measurement towers*. University of Utah, Department of Biology. June 10, 2001.

Baldocchi DD *FLUXNET, A global network of long term carbon dioxide, water vapor and energy measurement towers*. University of Innsbruck, May, 2001

Baldocchi DD *Using a Network of Micrometeorological Flux Measurement Towers--FLUXNET--to Assess Ecosystem Scale Carbon Dioxide and Water Vapor Fluxes Across Multiple Time and Space Scales*, Colorado State University. April 4, 2001.

Baldocchi DD *FLUXNET, A global network of long term carbon dioxide, water vapor and energy measurement towers*, Indiana University. Environmental Science Seminar, School of Public and Environmental Affairs. March 8, 2001.

Baldocchi DD *FLUXNET Overview*. CarboEurope Workshop Hyytiala Finland. Jan, 2001.

Baldocchi DD FLUXNET: 2000 Status Report. Ameriflux Annual Meeting, Oct. 2000. Atlanta, GA.

Baldocchi DD *Flux Measurements and Flux Networks*. Workshop on Northern Hemisphere Sink. Princeton University, March 2-3, 1999.

Baldocchi DD *On Measuring Carbon Dioxide Fluxes over Complex Terrain*. FLUXNET Workshop. Polson, MT, June, 3-5, 1998.

Baldocchi DD *FLUXNET Overview*. ISLSCP/BAHC Workshop, Paris, France, April 28-30, 1998.

Baldocchi DD *Eddy covariance measurements and long-term flux networks*.
GTCE/BASIN (Biosphere Atmosphere Stable Isotope Network)
Workshop. Snowbird, UT. Dec. 7-10, 1997.

Contributed Talks and Posters

Levy, PE, Baldocchi DD. Effects of spatial heterogeneity on sampling errors in CO₂ flux measurements over uneven-aged forests. American Geophysical Union, San Francisco, December, 2001

Falge, E, Baldocchi DD, Tenhunen, J. Seasonality Of Ecosystem Respiration And Gross Primary Production As Derived From Fluxnet Measurements
American Geophysical Union, San Francisco, December, 2001

Gu, L, Baldocchi, D. Roles of volcanic eruptions, aerosols and clouds in global carbon cycle American Geophysical Union, San Francisco, December, 2001

Debiase, T, Qi, Y, Fischer J, Baldocchi D, Goldstein A, Xu M., Liang X.
Comparison of Potential Evapotranspiration Methods Based on Results from FLUXNET Sites in the United States American Geophysical Union, San Francisco, December, 2001.

Gu, L. and D. D. Baldocchi, MODLAND Fluxnet Synthesis - 2001, MODIS Science Team Meeting, Baltimore, Dec. 17, 2001.

Gu, L., Cloud influences on carbon dioxide fluxes, Ameriflux Meeting, Oct.31 - Nov. 1, 2001, Argonne National Laboratory, Illinois.

Gu, L., Report on the International Workshop on Phenology and CO₂ and Water and Energy, Hyytiälä, Finland, Ameriflux Meeting, Oct. 31 - Nov. 1, 2001, Argonne National Laboratory, Illinois.

Gu, L. and D. D. Baldocchi, Roles of clouds, aerosols and volcanoes in global carbon cycle, Dept. of Energy Carbon Science Team Meeting, Oct. 29 -31, 2001, Argonne National Laboratory, Illinois.

Gu, L., L. Xu, M. Xu, D. D. Baldocchi, Springtime photosynthesis and respiration, International Workshop on Phenology and CO₂ and H₂O Fluxes, 3 -5 September 2001, Hyytiälä Forestry Field Station, Hyytiälä, Finland.

Olson, R.J., Falge, E., Baldocchi, D., Gu, L., Holladay, S, Cook, R.B. A Global Network of Eddy-Covariance Flux Towers to Study Ecosystem Dynamics, Enhance Models, and Validate Remote Sensing Products. IGBP Open Science Meeting, Amsterdam, July, 2001.

Olson, R.J., Falge, E., Baldocchi, D., Gu, L., Holladay, S,. A Global Network of Eddy-Covariance Flux Towers to Study Ecosystem Dynamics, Enhance

Models, and Validate Remote Sensing Products. American Geophysical Union, Boston, May, 29, June 2, 2001.

Gu, L. Too much CO₂ in the atmosphere: can volcanoes help? Berkeley Atmospheric Science Center (BASC), 14 March 2001, University of California at Berkeley, CA, USA.

Gu, L., Baldocchi, D.D., Falge, E.M. and R.J. Olson. Fluxnet: providing foundations for remote sensing studies of global primary production, MODIS Land Validation Annual Review Meeting, 22-23 January 2001, Columbia, Maryland.

Gu, L. Baldocchi, D.D. Impacts of clouds on tower-observed carbon dioxide, water vapor and energy exchanges of terrestrial ecosystems with the atmosphere. American Geophysical Union, San Francisco, December, 2000.

Gu, L, Baldocchi, D. Black, TA, Verma, SB, Vesala, T, Falge, E. A Multiple Response Scheme for Synthesizing Tower Carbon Dioxide Flux Measurements. International workshop for advanced flux network and flux evaluation . Sept 27-29 Hokkaido University, Japan.

Gu, L, Baldocchi, D.D., Falge, E., Fuentes, J. Impacts of clouds in ecosystem carbon dioxide exchange over a spectrum of climates. 24th Conference on Agricultural and Forest Meteorology. Davis, CA. August, 13-18, 2000.

Gu, L. A PDF analysis of tower carbon dioxide flux measurements. Fluxnet 2000 Synthesis Workshop, 11-14 June 2000, Marconi Conference Center, Marshall, CA, USA.

Falge, E., D.D. Baldocchi, R. Valentini, D. Hollinger, R. Olson. Ecosystem Comparison by means of Carbon Exchange Models Parameterized from FLUXNET Data. American Geophysical Union, Dec. 1999, San Francisco.