RESEARCH SCIENTIST POSITION DESCRIPTION

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METEOROLOGIST GS-1340

FACTOR 1 - RESEARCH ASSIGNMENT

A. Research Teams

Until early 2007 the scientist was a research meteorologist in the Rocky Mountain Research Station Research Unit FS-RM-RWU-4451 (Sustaining Alpine and Forest Ecosystems under Atmospheric and Terrestrial Disturbances), located in Fort Collins, Colorado. Since that time the scientist has been a research meteorologist in the Rocky Mountain Research Station Research Program FS-RMRS-4157 (Forest and Woodland Ecosystems: FWE). The scientist is still located in Fort Collins, Colorado.

The former unit's [**RWU-4451**] team mission was to develop and refine the knowledge and technology needed to understand, model, and manage vegetation dynamics and ecosystem processes for the long-term sustainability of alpine, forest and woodland ecosystems of the Rocky Mountains. This RWU was first chartered in December 1997. The five problem areas assigned to this team were (1) improve the understanding of the ecological response to vegetation manipulation, including the physiological mechanisms for regeneration and early stand dynamics and with this knowledge, improve the ability to develop new silvicultural treatments that will sustain and maintain a broader spectrum of ecological conditions; (2) improve the understanding of: (a) the ecology of disturbances such as climate change, atmospheric deposition, insect outbreaks, disease outbreaks, and the ecology of their interactions and (b) the role of silviculture in managing vegetation under these disturbances; (3) improve our understanding of the ecological response of riparian zones to insects and disease, to alternative silvicultural practices, and to atmospheric deposition; (4) improve the ability to measure and predict landscape dynamics under atmospheric and terrestrial disturbances; and (5) improve the ability to model the ecological response of vegetation to the disturbances caused by atmospheric deposition, insects, diseases, and silvicultural practices using empirical and process based models. In FY 2001 problem 2 was expanded when the RWU was awarded funding from the National Fire Plan (under 01.RMS.C.4) to develop management alternatives for fire-prone and fire-dependent ecosystems in Colorado and the Black Hills.

The scientist's current research program [**RMRS-4157**] discovers, develops, and delivers scientific knowledge and innovative technologies to conserve, manage, sustain, and enhance health and productivity of Interior West forest and woodland ecosystems. The scope of the program includes subalpine, aspen, mixed-conifer, and ponderosa pine forests, and pinyon-juniper and oak woodlands as well as ecotones with shrublands, grasslands, and deserts. Increasingly these forests and woodlands are being impacted by large scale urbanization and human developments, uncharacteristically large and severe wildfires, insect and disease outbreaks, exotic species

invasions, drought, and interactions of multiple stressors at local, landscape, and regional scales. These forests and woodlands are the critical source of water, natural resources, genetic diversity, esthetic and recreation amenities, and wildlife habitat in the Interior West. The research program addresses the basic ecology of forest and woodland vegetation and soils and related ecosystem biota and processes as the basis for understanding the function, composition, and structure of these complex ecosystems. The program further develops vegetation and fuels management and restoration strategies as well as quantitative tools to guide management and restoration planning and treatment implementation. The program provides understanding of the complex interactions of management treatments and other ecosystem disturbance processes temporally and spatially. Disturbance mechanisms include resource management and use; wildland fire; complexes of native bark beetles, defoliating insects and disease outbreaks; invasive plants, insects, and diseases; drought; and climate change. Researchers in the program are located at laboratories in Idaho, Montana, Utah, Colorado, and Arizona, and collaborate with scientists in other agencies, academic institutions, public organizations, and land and resource managers throughout the Station territory, nationally, and internationally. The FWE Program has four focus areas:
(1) Knowledge of ecological and physical processes of forest and woodland ecosystems in relationship to disturbance processes and interactions provides the basis for management options;
(2) Knowledge of the adaptive capacity of forest and woodland species, populations, communities, and ecosystems to new and variable climate conditions provides predictive capability;
(3) Mitigation of elevated atmospheric greenhouse gases requires knowledge of carbon dynamics;
(4) Management of complex landscapes under changing environmental conditions and societal values requires modified or new management approaches.

In many ways RMRS-4157 and RWU-4451 are very similar because both focus on research motivated by how human activities alter the ability of indigenous ecological systems of the interior western US to maintain their structure and function in response to terrestrial disturbances such as fire, insects, disease, and pollutant deposition. Furthermore, humans will continue to influence these landscapes at ever accelerating rates through climate change, air pollution, fire suppression, encroachment of urban development into wildland areas, prescribed burning, and other disturbances that cross ownership boundaries and that disperse insects, disease, and pollutants. If western forest and woodland ecosystems are to be sustainable under a changing climate and a continuing regime of disturbances, then the research information provided by this RMRS-4157 is necessary for creating new management strategies in response to these changing conditions.

Eddy covariance related teams

The scientist leads a FS team composed of the scientist and one FS electronics engineer whose mission is to develop and use eddy covariance technology to study the exchange of trace gases (H_2O, CO_2, CH_4 and pollutants such as O_3, NO, NH_3, etc.) between the atmosphere and the earth's surface (the terrestrial biosphere: plant canopies, the soil, and snowpacks). This team, which works primarily on focus area (3) of RMRS-4157, is also part of the larger AmeriFlux and (global) FLUXNET teams. In particular, the scientist is a leading member of the national AmeriFlux team composed of many university and government scientists from around the US who are attempting to measure the annual carbon balance at more than a hundred independent research sites in North America. This is a multidisciplinary effort comprised of atmospheric scientists, ecologists, atmospheric chemists, plant physiologists, physicists, and mathematicians. The scientific goal of AmeriFlux (and FLUXNET) is to better quantify the global terrestrial sources and sinks of carbon, using the eddy covariance approach for long term studies of the annual carbon balance. AmeriFlux, supported in part by the US Department of Energy (DOE), is a multi-source-funded group that attempts to coordinate and standardize all AmeriFlux-related scientific efforts and measurements.

Soil and snowpack trace gas transport teams

Trace gas transport in soils and snowpacks (or any permeable media) is nominally controlled by molecular diffusion. But temporal variations in atmospheric pressure at the surface of a snowpack or soil are capable of inducing advective flows that ventilate the media and thereby transport trace gases in, out, and through that media. This phenomenon is often termed pressure pumping.

The scientist is a member of an informal team examining the influence of diffusion and pressure pumping on the exchange of CO_2 between the atmosphere and the earth's surface. The team is composed of the scientist, a scientist from the University of Utah, and scientists and colleagues from the Institute for Arctic and Alpine Research (INSTAAR; the University of Colorado-Boulder). Results of ongoing studies by this scientific team have implications for biogeochemical cycling, wintertime production of $^{12}CO_2$ and $^{13}CO_2$ in snow-covered ecosystems, trace gas transport through soils and snowpacks, and photochemical production of ozone. Although not always easily quantified, diffusional fluxes of trace gases through porous media are fairly well understood. On the other hand, it is not known at present what role turbulent pressure pumping plays in the release and uptake of gases by soils and plants. Nevertheless, there are several studies indicating that it may be quite important.

Fire (soil and landscape) effects teams

The scientist leads an informal team investigating changes to soil physical and thermal properties caused by fire. At present the team is composed of the scientist, a soil physicist (Colorado State University [CSU]), a soil pedologist (University of Nottingham, UK), and a soil mineralogist (Alabama A&M University). The scientist began developing the current team in early 2007 in order to continue investigating fire/soil interactions that the scientist began in 2000. The previous team formally ended in early 2008, but it still remains active as needed during any follow-up work or publishing. The original team was composed of the scientist, the FS electronics engineer (above), a soil ecologist (CSU, Assistant Professor), an FS silvicultural scientist, and several technicians (as needed) to (*i*) develop and perform experiments to determine the influence that fuel geometry of prescribed slash-pile fires can have on soil physical and thermophysical properties and on soil microbial populations and (*ii*) develop and perform experiments to determine the impact that mastication and dispersal of slash (depth of wood chips) can have on soil temperature, moisture, and CO_2 and on soil microbial populations. The goal of this research effort is to provide management with a better understanding of the consequences of prescribed fires and other methods of fuel reduction to soil health and to the regeneration of vegetation.

Since 2007 the scientist has also been a member of the FS Core Fire Sciences Caucus (CFSC) and has been working with members of the CFSC to improve the process-based models of first-order wildland fire effects.

The scientist is also a member of a team composed of two FS scientists (the scientist and a plant pathologist) and a mathematician (CSU, Professor) who are investigating the utility of wavelet analysis for detecting and characterizing landscape-scale patterns of forest disturbance. This research effort seeks to develop tools for remotely sensing the effects of diseases, insects, and other disturbances on the incidence and spread of wildfire.

These fire related teams were formed in support of the National Fire Plan.

NCAR's BEACHON Project

The scientist leads an FS team participating in BEACHON (= Bio-hydro-atmosphere interactions of Energy, Aerosols, Carbon, H_2O, Organics, & Nitrogen), which is an NCAR project that conducts experimental and numerical research studies to enhance understanding of the roles of biogenic aerosols, nitrogen trace gases and oxidants in linking and regulating the carbon and water cycles. It was initiated in 2006 under the leadership of Dr Alex Guenther and began deployment at Manitou Experimental Forest in summer of 2008 (for further details see http://www.tiimes.ucar.edu/beachon/).

BEACHON seeks to address four key questions (repeated here to highlight the similarities with the five focus areas of FWE): (1) How do whole ecosystem exchanges regulate and link the terrestrial biogeochemical and water cycles, and how will they respond to changes in chemical, physical and biological variables?; (2) How does biosphere-atmosphere exchange impact the intensity, frequency, and duration of precipitation, and how does changing precipitation drive gas and particle fluxes?; (3) How do atmospheric oxidant and reactive carbon and nitrogen interactions influence biogeochemical cycling in a water-limited ecosystem?; (4) To what degree do land-use change and eco-disturbance affect biosphere-atmosphere exchange?

B. Personal Research Assignments

The scientist plans and conducts research to quantify the fundamental processes that govern the exchange of momentum, heat, and atmospheric trace gases (pollutants, CO_2, water vapor, etc.) between the atmosphere and the biosphere with a particular focus on the couplings and responses of ecosystems to changes in the climate and the chemical composition of the atmosphere. [Note here that for the purposes of this PD the scientist intends the word biosphere to include both the soil and the vegetation.] In general, the scientist uses physical principles and mathematical descriptions of the atmosphere and the biosphere to formulate hypotheses (usually expressed in the form of a mathematical or numerical model) which can then be tested using data collected in experimental studies. More specifically, the scientist develops and uses physically-based models and experimental data to gain insights into the nature of energy and trace gas exchange between the biosphere and the atmosphere. The scientist works primarily on RMRS-4157 focus area (3), but the scientist contributes to any research involving atmospheric pollutant deposition, modeling, or energy and trace gas exchange. In the broadest terms the scientist's personal research objectives include: (*i*) to quantify and model the physical processes that govern the exchange of trace gases and energy between the atmosphere, soil, and plant canopies; (*ii*) to quantify and model how canopy structure and atmospheric turbulence interact to affect these processes and exchanges; (*iii*) to quantify and model how diffusion and atmospheric pressure pumping influences trace gas exchange between plants, soils, and the atmosphere; (*iv*) to quantify the uptake of ozone, nitrogen oxides and other pollutants to plants and soils; and (*v*) to determine if plant damage or plant response to ozone deposition, variations in climate, or other disturbances can be assessed from measurements obtained by eddy covariance technology or some other micrometeorologically based method.

In the broadest terms the scientist's research focuses on the atmospheric surface layer, where much of the human influence on the biosphere and the associated exchange processes take place. This is an extremely complex and broad area of science, combining elements of several disciplines, including fluid dynamics, atmospheric turbulence, soil physics, plant physiology, and instrumentation physics. Knowledge exists in all of these areas, but to make progress in understanding the processes governing surface layer exchange requires both synthesizing and extending existing knowledge from one discipline to another and developing entirely new concepts. For example, canopy generated turbulence is the most difficult type of turbulence to study because it is inhomogeneous and non-isotropic. The coupling between the atmosphere and soils is not well understood. In particular the fundamental laws governing pressure pumping and advective fluid flow through permeable media (soils and snowpacks) have yet to be definitively formulated. This may be an important limitation in the ability of current models to account for soil water vapor loss during prescribed burns. Consequently, modeling descriptions of the processes governing the exchange of O_3, CO_2, and other trace gases require a better understanding of canopy turbulence and the coupling between the soils and the atmosphere. Further complications are introduced when considering biotic response and interactions with these abiotic processes. Plant defensive responses to ozone uptake are not understood because the fundamental chemical reactions and chemical kinetics governing the interactions of plant biochemistry/plant physiology and ozone are unknown. Nor are the dynamics of soil microbial response and recovery from fire known. Finally, studying the processes that control these interactions requires data and an appropriate measurement technology, which for the atmospheric surface layer usually involves eddy covariance instrumentation and the measurement of fluxes. While eddy covariance technology has been evolving for the past twenty-five years, using this technology remains complicated and can literally take years to learn and perfect. Nevertheless, recent work in the theory of eddy covariance has challenged many previous assumptions about how to make eddy covariance measurements, what conditions are paramount for obtaining reliable data, and how to interpret the data given site difficulties and atmospheric complexities.

Within the FWE, scientists collaborate to develop appropriate interdisciplinary studies with each scientist's individual expertise being an integral part. The scientist's efforts for these studies are directed toward defining an overall strategy for hypothesis testing, which is usually defined within the context of a physically-based model, and obtaining the relevant micrometeorological flux data and other supporting environmental data. The scientist designs, establishes and supervises or conducts individual studies, as necessary, to fill knowledge gaps. The scientist interprets the studies' results and disseminates the findings and conclusions in peer-reviewed journals and books and by participation in symposiums, workshops, and conferences.

Eddy covariance related teams

The scientist is participating in AmeriFlux as a leading expert on theory and practice of eddy covariance. The scientist's particular area of research has involved the development of methods for spectral corrections to flux data and the application of the Webb-Pearman-Leuning terms to closed- and open-path sensors. Because the scientist has been involved with the development of eddy covariance technology for the last 22 years, the scientist is also a leading member of the micrometeorological flux community. The goal of much of the scientist's recent efforts has been to document and quantify the uncertainties associated with long-term eddy covariance measurements. This issue is of critical importance when making cross site (cross ecosystem) comparisons and network syntheses of net ecosystem gas and energy exchange. More recently the scientist and his team member (FS electronics engineer) have been intensively engaged in preparing 10 years of FS eddy covariance data (from the Glacier Lakes Ecosystems Experiments Site: GLEES) for publication and submission to the AmeriFlux data base. As the FS eddy covariance team leader the scientist has full responsibility for committing available resources necessary to achieve the FS and related AmeriFlux goals. The scientist also has the major responsibility for interpreting all eddy covariance flux data obtained at the GLEES, establishing their credibility, and publishing the results as appropriate. But, all team members participate in carbon balance comparisons and the full interpretive synthesis of the data.

Recently the GLEES eddy covariance team has become an integral part of a larger team, which also includes a FS entomologist and a range of U of Wyoming scientists, that formed more or less spontaneously to study and monitor the impact of a beetle outbreak at GLEES. This team is still in the formative stages and coalesced in response to this major (and potentially devastating) disturbance to this high elevation forest. Repeat photography at the site has suggested that the beetle outbreak may have started about 3 years ago. To the scientist's knowledge this is the first and only long-term eddy covariance site to suffer a beetle epidemic of such magnitude.

Soil and snowpack trace gas transport teams

The scientist is participating in INSTAAR and U of Utah team as the leading expert on the process of pressure pumping. The field site is located at Niwot Ridge, Colorado. The scientist was invited to participate in ongoing undersnow CO_2 experiments and to help plan and implement a first-of-its-kind undersnow high-frequency CO_2 isotope experiment. The scientist's role in these two teams is to provide his expertise in interpreting and analyzing snowpack CO_2 data and to contribute directly and significantly to any publications that result. At present little is known about the possible effects turbulence-driven pressure pumping may have on trace gas exchange and it is still an open question as to whether the current physical and mathematical formulations for pressure pumping are correct. Consequently, results from these undersnow CO_2 studies also have application to pressure pumping effects on soil CO_2 dynamics and CO_2 fluxes.

Fire (soil and landscape) effects teams

Beginning in 2000 the scientist has been and continues to be the team leader and the principal soil physicist on the project. The scientist conceived and designed all studies to examine fire's effects on the soil physical and thermophysical properties and helped to implement other experiments designed to assess the response of soil microbes to fire. The scientist also designed the original team's experiments for assessing the impact wood chips have on soil temperature, moisture, and CO_2 and soil microbial response. Except for the soil microbial work, the scientist has full responsibility for analyzing and interpreting the data and publishing results in the appropriate venues. The scientist was one of two FS scientists on a Research Joint Venture (to CSU, Department of Soil and Crop Sciences), which funded the soil microbial portion of the study. For the CFSC team the scientist is the lead soil physicist working on investigating first-order effects on soils.

These fire-related studies are significant because knowledge is needed on (*i*) the ecological and environmental consequences of management alternatives for treating the current high fuel levels in fire-prone ecosystems, (*ii*) the climate-vegetation conditions under which these management alternatives would be effective, (*iii*) the interactions of fire and fuel treatment management with other disturbance processes such as insects and disease, (*iv*) how to improve current first-order fire effects modeling capabilities, particularly in regard to the transport of water vapor and other trace gases during fires, and (*v*) the long-term impacts of fire (soil heating) on soil CO_2 generation and fluxes.

For the landscape study the scientist acts primarily as a bridge between the pathologist and the mathematician. The scientist's participation in this team results from familiarity with the mathematics of wavelets and physical insights into interpreting the study's results. The scientist was also one of the two FS scientists on the Research Joint Venture (to CSU, Department of Mathematics) that funded the mathematical analysis. There is no available literature on this subject because this is the first attempt to use wavelet analysis for this type of study.

NCAR's BEACHON Project

The scientist is leading a team of two FS employees (the scientist and an electronics engineer) who are investigating (*i*) new methods for estimating the soil surface heat flux, in support of energy balance closure studies at the BEACHON site, and (*ii*) the possible influence that temporal variations in atmospheric pressure and soil heating may have on trace gas transport to and from soils – this is an expansion of the scientist's work on pressure pumping. To date the scientist has worked most closely with Dr David Gochis, an NCAR hydrometeorologist who is studying and measuring soil moisture and precipitation at the site. Otherwise the scientist is the only scientist (from any of the 50 or so institutions and agencies that are participating in BEACHON) who is contributing to studies of soil physical processes and related energy and trace gas fluxes. In addition the scientist has also contributed to the atmospheric sciences component of BEACHON through his cooperative studies with Drs Steve Oncley and Ned Patton on measuring atmospheric pressure fluctuations during CHATS (see 4.D.1 #102, #110, #111, and the BEACHON website).

C. Research-related Assignments

None.

D. Supervisory Responsibilities and Administrative Assignments

The scientist exercises the full range of supervisory duties for a GS-0856-11 Electronics Engineer. Plans unit work, establishes work schedules and priorities, and assigns and reviews work. Communicates with subordinate on the progress of work and problem areas as they arise. Recommends employee status changes, such as promotions, reassignments, and other personnel changes. Approves leave. Sets performance standards and evaluates performance. Identifies training needed by subordinate, and ensures that training opportunities are provided. Has the authority to resolve complaints and informal and first-level grievances, and the responsibility to advise employee of unsatisfactory performance and the obligation to assist such employee to improve performance to satisfactory levels. Keeps employee informed of management policies, procedures, and goals. Conducts periodic safety briefings and assures good laboratory and field work procedures are followed to provide a work environment safe from unacceptable hazards.

Provides leadership, allocates resources, and implements activities to accomplish multicultural organization direction and Equal Opportunity and Civil Rights requirements, goals, policies, and objectives. Supports and participates in the Work Environment Continuous Improvement Process. Ensures all communications – written, oral, visual, signed – is nondiscriminatory and sensitive to all employees and publics. Creates a work environment which respects, appreciates, and accepts the contributions and perspectives of all employees. Acts for the Program Manager and Station Director as assigned.

Supervisory and administrative responsibilities constitute 10% of the scientist's time.

FACTOR 2 - SUPERVISORY CONTROLS

The scientist's supervisor is the Program Manager of RMRS-4157, who provides general administrative supervision, budgetary guidelines and broad research directions designed to integrate the various project disciplines. The scientist develops the appropriate problem analyses and within these analyses the scientist is free to define and initiate studies, to formulate study plans, to define the studies' objectives, to conduct the research and to interpret and report results in peer-reviewed journals, papers at scientific meetings or similar outlets. The scientist also guides or contributes to the development of appropriate collaborative cross-disciplinary problem analyses and studies. But, any research undertaken by the scientist is subject to available resources and agency policies. The program manager provides no technical supervision to the scientist. The scientist works nationally and internationally with scientific peers and colleagues outside and within the Forest Service for technical consultations and comments upon the scientist's research.

The scientist's technical judgment, based on the scientist's experience and assessment of the research needs and efforts of the broader scientific community, is used as a basis for initiating or discontinuing research programs within and outside the Forest Service. The scientist can speak both within and outside the Forest Service as an internationally recognized authority on the eddy covariance technology, surface energy balance, ozone deposition, the measurement and modeling of trace gas exchange between the atmosphere and the biosphere, and the impacts of fire on soil thermo-physical properties and physical modeling of soil heat flow and moisture evaporation and transport during fires.

FACTOR 3 - GUIDELINES AND ORIGINALITY

A. Available Literature

The scientist's personal research objectives comprise five related areas that include modeling and observational studies of the physical, chemical and physiological aspects of trace gas exchange between plant canopies, the soil, and the atmosphere with somewhat greater emphasis on CO_2, H_2O, and O_3. Because of the complexity and interconnectedness of these areas of physics and biology, the scientist develops models and designs experiments synergistically to study the governing processes. Toward this end, the scientist has directed field research to obtain new results which the scientist then uses to develop, test and improve models of the exchange processes. Because eddy covariance data is the main source of data for these modeling studies, the scientist has also developed methods to quantitatively evaluate how instrument design and performance and data processing impact long term eddy covariance flux measurements.

Much of our understanding of the physical processes that govern atmosphere-biosphere interactions is represented in the literature by Soil-Vegetation-Atmosphere Transfer (SVAT) models. But none of the current SVATs is definitive in its fundamental description of the coupling between the soil, plants and the atmosphere. In general there are two types of SVATs: those based on a multi-layered canopy/soil formulation, such as Lagrangian and Eulerian (or closure) models, or a bulk plant/soil formulation, such as single- and dual-source Penman-Monteith models. Lagrangian-based models are useful for depicting trace gas transfer, but they do not model momentum transfer within the soil/plant/atmosphere system. On the other hand, Eulerian models do couple momentum and mass transfer into a single model. Nevertheless, neither modeling approach necessarily reproduces observed within-canopy profiles of trace gas concentrations very well. Furthermore, all Eulerian closure models from first order closure (K-theory) to any higher order closure model suffer from the inherent and inescapable weakness of the closure assumption which to date remains the most significant unsolved problem of fluid dynamics. Dual-source models are simpler than Lagrangian and higher order models, but defining and evaluating the soil and canopy conductances to trace gas exchange is somewhat problematical (e.g., 4.D.1 #40, #67). Aside from the inherent lack of fundamental knowledge for correctly formulating SVATs, applying SVAT concepts to include ozone and nitrogen oxides is made more difficult because to do so requires modeling the chemical kinetics, photochemical reactions and the plant physiological responses to these pollutants. Full photochemical SVATs have been described in the recent literature, but they are relatively rare. Virtually nothing is known at the process level for formulating a model of plant responses to pollution, although empirical approaches have been suggested (4.D.1 #71, #81). To make any progress toward quantitative predictions of plant response to pollutants these SVAT deficiencies must be addressed. Multilayered approaches will need to be further developed because they do simulate within-canopy profiles of trace gases, which may be important if there is a differential response to pollutants within a canopy. A significant advance in multilayer modeling could be made by combining the strengths of the Lagrangian and higher order closure models. Here, the efforts of Massman and Weil (4.D.1 #51, #52, #56, #66, #70) are the first steps at such a combination. Similarly, dual-source (Penman-Monteith) modeling has been significantly advanced by Massman

(4.D.1 #27, #31, #36), who has developed a physically-based in situ approach for estimating soil and plant conductances to water vapor and ozone. This dual-source modeling approach is intended as a diagnostic tool for partitioning trace gases between the plant canopy and the soil by deriving in situ estimates of bulk conductances to water vapor exchange. Otherwise, the partitioning predicted by prognostic models cannot be verified at present. This approach has been directly verified for water vapor by Massman and Ham (4.D.1 #36) and indirectly verified for ozone by Massman and Grantz (4.D.1 #45). Finally, the use of eddy covariance flux data to assess plant response or ozone injury is largely untried. Two studies reported in the literature indicate the importance of ozone fluxes to the health and functioning of individual plant leaves and there are many empirical studies using measured ozone concentration (or ozone exposure) to infer ozone plant damage. Nevertheless, except for exploratory studies of Massman and Grantz (4.D.1 #45) and Massman and colleagues (4.D.1 #63, #71, #81, #89, #92), there are virtually no guidelines in the literature on interpreting ozone eddy covariance flux data at the plant scale in terms of plant level processes or plant defensive responses to ozone uptake.

Unlike SVATs, studies of trace gas movement in permeable media resulting from pressure pumping (i.e., advective flows) are relatively recent and most are based on the linearized version of the equation that describes the pressure forcing, rather than the coupled advective-diffusive equation, which is required to fully model the movement of trace gas in permeable media. Massman's studies (4.D.1 #59, #95, #96) are a major exception to this limitation. Nevertheless, to date no study has explored the consequences of the non-linear formulation for the pressure forcing, nor do current linear models account for some aspects of the observed wintertime variations in the undersnow CO_2 (4.D.1 #95, #96, #104). Additionally, advective flows can also be induced by expansion/contraction of gases when permeable media are heated (e.g., daily heating of soils). There are only two studies that look at this last phenomenon and neither address the fundamental equations necessary to describe it. The present state of knowledge of the physical basis for advective flows in permeable media suggest a reformulation of advective flows using more fundamental approaches (e.g., the Stefan-Maxwell equations: The Dusty gas model, the Binary Friction model, or the recent work of Altevogt). But, to the scientist's knowledge, nothing exists in the literature that correctly couples the pressure, temperature, and momentum fields to describe the influence of turbulent atmospheric structures and daily cycles of pressure and temperature on trace gas exchange at the earth's surface. Similarly, nothing is known about the influence of pressure pumping on the uptake and release of trace gases by plants.

Although eddy covariance technology is extremely complicated and detailed, a considerable amount of information on the theory and practice of eddy covariance is available from the literature (e.g., 4.D.1 #76, #83). Nevertheless, the analytical approach developed by Massman (4.D.1 #72, #74) was the first study to point out the need to include the low frequency portion of the turbulence cospectra when calculating and correcting the spectral attenuation associated with instrument sampling and performance. Furthermore, except for the work of Massman and Clement (4.D.1 #84) there is nothing in the literature on the uncertainties in eddy covariance flux data resulting from issues involving spectral corrections. Another issue that is critical to accurate accounting of ecosystem carbon exchange with eddy covariance systems is the proper form of the WPL or density terms. The original (1980) Webb-Pearman-Leuning (WPL) study has generally been accepted as the authoritative paper on atmospheric density effects on open- and closed-path eddy covariance systems. But until the 2000 paper of Paw U *et al.* and the 2002 paper of Massman and Lee (4.D.1 #76) 3-D WPL effects had never been included in eddy covariance-based calculations of the carbon balance and in 4.B.4.a #39 Massman developed a quantitative estimate of the importance of these 3-D effects to stand level estimates of the carbon budget derived from eddy covariance data. In 4.D.1 #77 and #85 Massman and coworkers suggest that traditional use of the WPL terms have to date likely been misapplied to closed-path sensors. In 4.D.1 #94 Massman and Tuovinen further clarify the physical processes responsible for the density effects (WPL terms). Although progress has been made regarding these issues it is still being debated throughout the literature.

The scientist's personal objectives in fire research, as might be expected from above, are to use physically-based models to study the influence fire has on the soil environment, the soil properties, and the soil biota with the ultimate goal of being able to evaluate and recommend strategies and techniques for minimizing the impacts of prescribed burns on the soil health and recovery from fire. There is considerable literature on some aspects of this type of effort. But there is considerably less literature available on modeling the soil heat pulse and, in particular, the soil heat flux. A key parameter in these fire models is the soil moisture. But to date, no model has been able to correctly predict the evaporation and movement of soil moisture during fires. Advective motions induced in the soil by the fire could be responsible for this failure. These motions are related to the pressure pumping effects the scientist is already investigating. But there is no literature on this subject during fires. Nevertheless, the scientist and coworkers have been able to obtain some of the first in situ measurements of soil heat flux and soil moisture dynamics during fires (4.D.1 #79, #80, #97, #98), as well as observational evidence of advective flows in soils during prescribed burns (4.D.1 #106).

B. Originality Required

The researcher must develop and use processed-based models to create new knowledge and to adapt and synthesize knowledge from one area of research to another. The scientist must also be knowledgeable about eddy covariance technique and devise new approaches to use that technology. The scientist must also be able to apply physical principles to new experimental techniques in order to describe and quantify soil heat and trace gas movement during fires. Successful completion of the research assignments requires extensive interdisciplinary knowledge of instrumentation physics, eddy covariance technology, environmental physics, soil physics, atmospheric turbulence, biological responses, and mathematical and numerical modeling techniques. Lack of fundamental knowledge regarding the couplings and interactions between atmospheric turbulence and vegetation canopies and the processes governing plant response to increasing CO_2 and to O_3 and other pollutants are critical obstacles to progress toward protecting and managing vegetation against damage resulting from a changing physical and chemical climate. Similarly, a lack of fundamental knowledge concerning the short- and long-term impacts of prescribed fires on the soil environment and soil biota are also significant hindrances to our ability to develop management alternatives to fire-prone and fire-dependent ecosystems. Further difficulties arise from the interplay and subtle feedbacks between a variety of physical and biochemical processes operating over many levels of complexity ranging from that of a molecule to that of an ecosystem. For example, delivery of pollutants to ecosystems is controlled by atmospheric motions as mediated by local topography and the architecture and morphology of the plant cover; whereas gas movement through plant stomata and soil pores is governed by molecular diffusion and slow advective motions induced by larger atmospheric turbulence or convective motions. The need for fundamental knowledge over such a broad range of scales is so great that any advance in any of these related areas have the potential for a substantial impact on a variety of disciplines.

C. Demonstrated Originality

Dr Massman's research on the coupling between canopies and the atmosphere (4.D.1 #66, #70) has led to a new method for parameterizing surface processes in global modeling and remote sensing studies (4.D.1 #75). This result is a significant advance for quantifying the remotely-sensed surface energy balance and latent and sensible heat fluxes. Dr Massman's ozone research has focused on the development of models and concepts to incorporate plant defenses into ozone deposition models and effective dose-based ozone standards (4.B.4.a #26, #31, #32; 4.B.4.b #60; and 4.D.1 #81, #89, #90, #91, #92). Results from these studies have demonstrated (*a*) methods of modeling plant defenses to ozone uptake and (*b*) that satellite-retrieved Leaf Area Index can be used as a scaling variable in conjunction with a modern (coupled photosynthesis evapotranspiration) SVAT model to accurately estimate surface conductance to ozone and surface ozone uptake rates, as well as, help set ozone standards to protect vegetation. Dr Massman's previous work on turbulent pressure pumping in snowpacks (4.D.1 #42, #59) was the first of its kind to address winter trace gas exchange. More recently he has focused on observing and modeling the influence pressure pumping has on temporal and spatial variations of CO_2 under snowpacks and within snow covered soils. His observational studies are the first to document significant pressure pumping influence on undersnow CO_2 concentrations. He has also formulated the first analytical model of the snowpack flux associated with pressure pumping (4.D.1 #95, #96) and he has contributed to some of the first wintertime soil respiration $\delta^{13}CO_2$ observations (4.D.1 #104). Dr Massman's eddy covariance work (4.D.1 #72, #74, #76, #77, #83, #84, #85, #94, #103) represents significant advances in the theory and practice of eddy covariance. In particular, he has (*i*) developed simple techniques of applying spectral corrections which include turbulent low frequency effects, (*ii*) quantified the importance of the pressure covariance term to the WPL for open-path sensors, and (*iii*) clarified the application of the original formulation of the WPL to open- and closed-path sensors. These eddy covariance results along with the wintertime gas exchange studies should improve quantitative estimates of the terrestrial CO_2 budget currently being investigated by international CO_2 flux networks. Finally, Dr Massman and coworkers have made some of the first in situ measurements of soil heat flux and soil moisture dynamics during prescribed burns (4.D.1 #79, #80, #97, #98, #106). They are also the first to document long-term changes in (*a*) the thermal conductivity of soil following a prescribed burn and the impact these changes can have on the soil's thermal regime (4.D.1 #101) and (*b*) the soil's pore structure using 3-D X-ray tomographic images (4.D.1 #106). These studies are essential for fuels reduction strategies, for modeling soil heat flow during fires, and for developing and assessing remediation strategies for fire affected soils.

FACTOR 4 - CONTRIBUTIONS, IMPACT, and STATURE

A. Personal Data

1. Name: William J. Massman

2. Educational Background:

Ph.D. - University of Wisconsin, Madison (1978) Meteorology
M.S. - University of Wisconsin, Madison (1973) Meteorology
M.S. - University of Wisconsin, Madison (1970) Physics
B.S. - University of Missouri, Columbia (1969) Physics

Course equivalent of M.S. degree in Applied Mathematics
29 credit hours of graduate mathematics
University of Wisconsin, Madison (1970 - 1974)

Successful completion of Control Data Corporation's vector programming course for the Cyber 205 (Super-Computer) - 75 hours of classroom and lab work -
NASA/Goddard Space Flight Center, Greenbelt, MD (1984)

Successful completion of Introduction to C++ Programming -
Computer Science Department, Colorado State University, Fort Collins, CO (1997)

Successful completion of Fortran 90 Features and Differences -
Seminar presented at the USDA/Forest Service, Fort Collins, CO (1997)

3. Date of last Promotion: August 1998

4. Professional Experience:

01/07 - present: GS-1340-15 Research Meteorologist, RM-4157, Fort Collins, CO
09/98 - 12/06: GS-1340-15 Research Meteorologist, RM-4451, Fort Collins, CO
03/93 - 08/98: GS-1340-14 Research Meteorologist, RM-2, Fort Collins, CO
11/88 - 03/93: GS-1340-13 Research Meteorologist, RM-4452, Fort Collins, CO
09/86 - 11/88: GS-1340-12 Research Meteorologist, RM-4452, Fort Collins, CO
04/85 - 08/86: National Research Council Senior Postdoctoral Fellow,
NASA/Goddard Space Flight Center, Greenbelt, MD
12/82 - 03/85: Assistant Scientist/Senior Systems Analyst,
Applied Research Corporation, Landover, MD
08/78 - 06/82: Research Associate, University of Oregon, Eugene, OR
02/78 - 07/78: Visiting Scientist, NCAR, Boulder, CO
09/72 - 01/78: Research Assistant/Project Assistant, University of Wisconsin,
Department of Meteorology, Madison, WI
09/69 - 08/72: Research Assistant/Teaching Assistant, University of Wisconsin,
Department of Physics, Madison, WI

B. Professional activities and recognition

1. Honors and Awards:

1969 Phi Beta Kappa [Scholastic Achievement]

1969 Pi Mu Epsilon [National Mathematics Honor Society]

1985-86 National Research Council Senior Postdoctoral Fellowship

1995 USDA Certificate of Merit: *For significant contribution to the understanding and quantification of ozone deposition and its interaction with the plant surface*

1995 USDA Certificate of Appreciation: *For contributions to the 1993 RPA assessment update*

2004 USDA Certificate of Merit: *For significant efforts to continue fire ecology research on soils and to initiate new studies in the National Fire Plan Ecology Research Project in FY04*

2007 USDA Certificate of Merit: *For careful and diligent efforts to remove the obsolescent tower at the GLEES research site*

2011 Rocky Mountain Research Station Best Scientific Publication of the Year 2010:
Advancing investigation and modeling of first-order fire effects on soils
Fire Ecology **6**: 36-54 – see D.1 #106 for further details.

2012 UN WMO Norbert Gerbier-MUMM International Award 2012:
Climate control of terrestrial carbon exchange across biomes and continents
Environmental Research Letters **5** 034007 by Yi *et al.* – see D.1 #108 for further details.
The citation noted that "The authors came from 116 academic institutes in six continents. The paper examines relationships between climate and the carbon exchange of land-based ecosystems to predict future levels of atmospheric carbon dioxide".

2. Society and professional activities:

a. Membership

American Meteorological Society (AMS), 1978 - present
American Geophysical Union (AGU), 1988 - present
American Society of Agronomy (ASA), 1992-1993
Air and Waste Management Association (AWMA), 1994
Association of Fire Ecology (AFE), 2007
European Geophysical Union (EGU), 2008

b. Service

AMS Committee on Mountain Meteorology, 1987-1989
AMS Committee on Agricultural and Forest Meteorology, 2002-2005
Associate Editor: Journal of Geophysical Research (JGR)-Atmospheres, 2005-2008

c. Professional Registration

None

3. University Involvement:

01 From 1989 to 2000 I was an Affiliate Faculty Member (AFM) of the Department of Mathematics at Colorado State University (CSU). At present I am an AFM of the Department of Civil and Environmental Engineering at CSU. I have presented invited lectures on surface energy balance to a graduate class in Range Ecology (CSU) and on measurement physics and eddy covariance technology to a graduate class in Range Ecology (University of Wyoming, UWYO). I have served on four CSU graduate committees: three PhDs (two Atmospheric Sciences and one Civil Engineering) and one MS (Civil Engineering). Furthermore, I was very strongly involved in mentoring 3 other CSU graduate students: one Civil Engineering PhD, one Mathematics MS, and one Forest Science PhD. At present I am informally advising one MS/PhD student in the Graduate Degree Program in Ecology at CSU and have been mentoring one MS graduate student in the Department of Civil and Environmental Engineering at Colorado School of Mines (Golden, CO). The most significant publications arising from my work with US graduate students are D.1 #41 and #122. Further details and discussion on my university involvement are included in sections **B.6. Significant consultations, C. Scientific Accomplishments and Contributions, and E. Other Significant Information**.

02 I was very strongly involved in mentoring 3 international graduate students: one Meteorology and Air Pollution MS (Agricultural University of Wageningen, The Netherlands), one Hydrology PhD (Technical University of Denmark), and one Natural Resources Science PhD (McGill University, Montreal, Canada). The most significant publication arising from my work with these international graduate students are D.1 #17, #57, and #65. Further details and discussion on my university involvement are included in sections **B.6. Significant consultations, C. Scientific Accomplishments and Contributions, and E. Other Significant Information**.

03 <u>Special Seminar on Hydrologic Sciences</u>

I was invited by Dr John Selker (Biological & Ecological Engineering, Oregon State University, Corvallis, OR) to present a seminar on my (2006) studies on pressure pumping in snowpacks and soils (D.1 #95, #96) to interested faculty and staff at OSU. During May 2008 I presented the seminar, which was entitled *Snowpack CO_2 dynamics and what they say about pressure pumping*. After the seminar I was the guest speaker at a meeting of the OSU journal club, where I fielded questions and discussed these two 2006 papers. Dr Selker's intention with this invitation (in his words) was that I share and expand upon my "significant synthetic insights from basic physical concepts and mathematical solutions to the issue [of gas exchange at air-snow interfaces]. The propagation of air in snow and soil from atmospheric turbulence are important to soil respiration, snow melt, and the composition of trapped glacial gas."

While on campus at OSU I also gave an informal seminar, entitled *Impact of prescribed fire on soil CO_2 and CO_2 fluxes: some preliminary thoughts* to the Global Change Forest Science (Dr Bev Law's) group of the Dept of Forest Science. I fielded questions and discussed my results and ideas on the impact that prescribed fire can have on soil respiration and CO_2 flux.

04 Advanced seminars on exchange processes between the atmosphere and the land surface – Instrumentation, Observation, and Data Analysis.

I was invited by Dr Z (Bob) Su, Chairman of the Dept of Water Resources at ITC, [http://www.itc.nl/about_itc/whoiswho/viewone.asp?Bob%20Su] to present five lectures for the above seminar at the International Institute for Geo-Information Science and Earth Observation (ITC). ITC (located in Enschede, The Netherlands) is one of the associated institutions of the United Nations University (see http://www.itc.nl for further details concerning ITC). The lectures were delivered during May of 2007 and I was the sole presenter at this seminar series.

The purpose of the lecture series was to introduce an international group of graduate students and faculty to modern eddy covariance technology for quantifying mass (H_2O/CO_2) and energy exchange between the atmosphere and terrestrial ecosystems.
I presented the following lectures:
(1) *Eddy Covariance Webb-Pearman-Leuning Terms or 'What is this fuss all about?'*,
(2) *Eddy Covariance Data Analysis Techniques: Ambient Meteorological Data*,
(3) *Eddy Covariance Data Analysis Techniques: Despiking Raw Turbulence Data*,
(4) *Micrometeorology, the Surface Energy (Im)Balance, Soil Heat Flux, and Fire*, and
(5) *Instrumentation Physics for Eddy Covariance*.
During these lectures I reviewed the state-of-the-science and my own contributions and current research in the surface energy balance (with some additional emphasis on my personal soil heat flux related research: D.1 #87, #101, #106), eddy covariance instrumentation, and eddy covariance data interpretation and analysis techniques. I fielded questions, offered suggestions and guidance on research and thesis efforts, and attempted to assist the participants as they developed their understanding of the many aspects related to eddy covariance and modern micrometeorological science.

05 Summer course on Flux Measurements and Advanced Modeling

I was invited by Dr R Monson (University of Colorado-Boulder) to participate in this two-week summer course, held at the Mountain Research Station, Niwot Ridge, during July 2008. I presented a lecture entitled *Spectral Analysis for Eddy Covariance Data* and assisted John Frank (FS Electrical Engineer) with the associated computer lab session on *Flux Spectral Analysis*. [John Frank's invitation to this summer course was at my request.] During this session of the summer course I introduced the international audience (of students, scientists, and other interested attendees) to the principles of Fourier decomposition, sampling theory, and other topics related to spectral analysis of eddy covariance fluxes. My [Power Point] presentation is available at URL = ftp://ftp2.fs.fed.us/incoming/rmrs/wmassman/.

06 I was invited by Dr John Pomeroy [Canada Research Chair in Water Resources and Climate Change; Director of the Centre for Hydrology, Department of Geography, University of Saskatchewan, Saskatoon, Canada] to be the external examiner for Warren Helgason's PhD thesis defense. Dr Helgason's thesis, entitled *Energy Fluxes at the Air-Snow Interface*, details his research on the measurement and modeling of energy and turbulent heat and mass exchange between the atmosphere and a porous snowpack in complex terrain using eddy covariance methods. The thesis defense was held October 20, 2009. I read and commented on all aspects of the thesis, including scientific content, many aspects of data analysis, writing style, organization, etc, and in general assisted Dr Helgason advance his understanding and contribution to the science of turbulent energy and mass exchange over snow covered surfaces by eddy covariance. As part of my visit to the University of Saskatchewan I also gave an invited talk (B.4.a #45) on a subject of my own choosing.

07 During November 2009 I gave an invited lecture on climate change (using a discussion format) to a class-room course (of the Department of Communication, University of Colorado-Denver), entitled, "Communicating Climate Change". I was invited by the instructor, Dr Larry Erbert, and I led the class of 12-15 undergraduate students for just over an hour. During this face-to-face time I tried to give the students some background into the physics of climate change and to provide them with tools for discussing and keeping abreast of climate change science and ongoing developments.

08 As a consequence of my standing within the international flux community and my eddy covariance research at GLEES, I was invited in 2010 to become a committee member for two University of Wyoming graduate students: John Frank (Dept of Botany; FS advanced training) and David Reed (Dept of Atmospheric Science, PhD). [John Frank, who is a FS employee I have supervised since 1999, is the GLEES electronics engineer and eddy covariance specialist.] At present I am actively engaged in mentoring both students. To facilitate my advising of students I was unanimously elected in early 2011 as an AFM of the University of Wyoming's Program in Ecology.

4. Presentations:

N.B. † denotes location if presented more than once; **[AP]** denotes Abstract Published; **[APE–CD]** denotes Abstract Published Electronically on CD; and **[AMS–W]** denotes that the presentation was recorded and is available on the AMS website; all presentations are oral unless specifically denoted by **[P]** for poster.

a. Invited papers and posters

01 Massman, WJ. 1975.
Preliminary scientific results from the TWERLE energy conversion.
NASA/Goddard Space Flight Center, Greenbelt, MD

02 Massman, WJ. 1976.
The TWERLE energy conversion experiment.
NASA/Goddard Space Flight Center, Greenbelt, MD

03 Massman, WJ. 1982.
Old-growth Douglas fir canopies: an aerial aquatic ecosystem.
† University of Virginia, Dept of Environmental Sciences, Charlottesville, VA
† Smithsonian Institute, Chesapeake Bay Center for Environmental Studies, Edgewater, MD

04 Massman, WJ. 1985, 1986.
Plant-Atmosphere interaction: bulk transfer coefficients for heat and momentum exchange. (D.1 #14)
† NASA/Goddard Space Flight Center, Earth Sciences Division, Hydrological Sciences Branch, Greenbelt, MD [1985]
† USDA FS, Rocky Mountain Research Station, Fort Collins, CO [1986]

05 Zeller, KF, DG Fox and WJ Massman. 1987.
USFS Pawnee dry deposition eddy correlation measurements.
NADP Technical Committee, Minneapolis, MN

06 Massman, WJ, and DG Fox. 1989.
Energy balance methods as a means of verifying eddy correlation measurements of dry deposition at the Pawnee National Grasslands. (D.1 #19)
Front Range Chapter AGU Annual Meeting, Golden, CO

07 Massman, WJ. 1989.
Dry deposition and evapotranspiration by eddy covariance at the Pawnee Grasslands.
EPA Environmental Research Laboratory, Corvallis, OR

08 Massman, WJ, and MR Kaufmann. 1989.
Modeling stomatal conductance of subalpine trees in the central Rocky Mountains. (D.1 #18)
Workshop on stomatal resistance formulation and its application to modeling transpiration, The Pennsylvania State University, University Park, PA

09 Massman, WJ. 1990.
Land surface parameterizations for GCMs.
Workshop on forest/climate interactions: scale transition from individual leaves to the global, USDA Forest Service and NCAR, Boulder, CO

10 Massman, WJ. 1991.
A discussion of the physical processes governing interception and evapotranspiration.
Workshop on climate sensitivity of US forests, Illinois State Water Survey, Champaign, IL

11 Massman, WJ. 1992.
Air quality modeling treatments of dry deposition.
California Air Resources Board, San Francisco, CA

12 Massman, WJ. 1992.
An objective method for partitioning evapotranspiration and ozone from the surface energy balance measurements at a site with partial canopy cover. (D.1 #27)
† USDA ARS, Great Plains Systems Research Group, Fort Collins, CO
† FS, Rocky Mountain Research Station, Fort Collins, CO

13 Aiken, R, D Nielsen, and WJ Massman. 1993.
Quantifying residue effects on transport phenomena.
Meeting of the North-Central Region 160 Committee, Lincoln, NE

14 Massman, WJ. 1993.
Deposition measurements by the eddy covariance method.
USDA Forest Service Air Resources Symposium, Fort Collins, CO

15 Massman, WJ. 1993.
Estimating canopy conductance to trace gas exchange by eddy covariance and leaf scaling methods. (D.1 #45)
† U of Wyoming Botany and Atmospheric Sciences Joint Seminar, Laramie, WY
† FS, Rocky Mountain Research Station, Fort Collins, CO

16 Massman, WJ. 1994.
Interpreting ozone eddy covariance data.
National Forest Systems Air Quality Modeling Course, Fort Collins, CO

17 Musselman, R, WJ Massman and L Joyce. 1994.
Integrating global climate models into forest response assessment.
AWMA 87^{th} Annual Meeting, Cincinnati, OH

18 Massman, WJ. 1995.
CO_2 flux through a Wyoming seasonal snowpack: diffusional effects, atmospheric pressure pumping effects and eddy covariance measurements.
Argonne National Laboratories, Argonne, IL

19 Massman, WJ, and NT Nikolov. 1998.
Estimating ozone deposition rates for areas of central California. (D.1 #55)
California Air Resources Board, Sacramento, CA

20 Massman, WJ. 1998.
Planetary waves of the Jovian atmosphere.
Northern Colorado Astronomical Society, Fort Collins, CO

21 Massman, WJ. 1999.
Modeling and measurement of trace gas movement in snowpack and soils. (D.1 #59)
Workshop on the influences of atmospheric pressure fluctuations on fluxes of trace gases from soils, Lincoln, NE

22 Massman, WJ. 1999.
Frequency response corrections for eddy covariance systems. (D.1 #72)
3^{rd} Annual AmeriFlux meeting, Denver, CO

23 Massman, WJ. 1999. [**AP**]
A model study of kB_H^{-1} for vegetated surfaces using 'Localized near-field' Lagrangian theory. (D.1 #70)
AGU Fall Meeting, San Francisco, CA

24 Massman, WJ. 2000.
A review of AmeriFlux and personal contributions to AmeriFlux.
FS Meteorologist's meeting, Athens, GA

25 Massman, WJ. 2000.
A brief summary of the AmeriFlux workshop on unaccounted flux in long-term studies of carbon and energy. (D.1 #76)
4^{th} Annual AmeriFlux meeting, Atlanta, GA

26 Massman, WJ. 2001.
On the possibility of using remote sensing for ozone uptake and ozone standards to protect vegetation. (50% overlap with D.1 #55)
33^{rd} Annual Air Pollution Workshop, Riverside, CA

27 Massman, WJ. 2001.
Personal research highlights May 2000 - May 2001.
FS Meteorologist's meeting, Roseville, MN

28 Massman, WJ. 2001.
Uncertainties and corrections to eddy covariance CO_2 budget measurements. (D.1 #76)
FS Rocky Mountain Research Station All Scientists Meeting, Salt Lake City, UT

29 Massman, WJ. 2001.
Eddy covariance flux corrections and uncertainties. (with X Lee and KT Paw U; summarizes and extends D.1 #76)
5^{th} Annual AmeriFlux meeting, Argonne National Laboratory, Chicago, IL

30 Massman, WJ. 2002.
Fire effects on soil and soil ecology. (D.1 #79)
FS Meteorologist's meeting, Washington, DC

31 Massman, WJ. 2002. [**AP**]
Application of flux-based standards using remotely sensed data. (about a 60% overlap with #26 above and some overlap with D.1 #55)
AGU Spring Meeting, Washington, DC

32 Massman, WJ. 2002.
Flux Modelling - A US perspective. (about a 90% overlap with #31 above and some overlap with D.1 #55. The scientist was invited to present a talk with this provisional title. The talk presented included N Nikolov as second author and had a similar title to #26 above. The scientist published a sole-authored paper, D.1 #81, as his contribution to the conference proceedings.)
UN/ECE Ad-hoc Expert Panel Meeting on Modelling and Mapping Ozone Flux and Deposition to Vegetation, Harrogate, UK

33 Massman, WJ. 2002.
High frequency corrections to eddy covariance fluxes. (40% overlap with D.1 #72, #74)
AmeriFlux Workshop on Standardization of Flux Analysis and Diagnostics, Corvallis, OR

34 Massman, WJ. 2002.
AmeriFlux Workshop on Standardization of Flux Analysis and Diagnostics – Summary and Discussion of Recommendations. (D.1 #77)
6^{th} Annual AmeriFlux meeting, Atlanta, GA

35 Massman, WJ. 2003.
Winter CO_2 fluxes at a subalpine site in the Rocky Mountains USA: Combining biological activity and atmospheric turbulence. (about a 40% overlap with Offered Papers **b.**#46 and **b.**#48 below; about a 20% overlap with **b.**#56 and D.1 #95 below)
† Stockholm Environment Institute at York, Dept of Biology, University of York, York, UK
† The University of Edinburgh, Department of Ecology and Resource Management, Edinburgh, Scotland, UK

36 Massman, WJ. 2003.
The influence of pressure pumping on CO_2 concentrations and fluxes in snowpacks and soils. (about a 70% overlap with invited paper #35 above and Offered Papers **b.**#46 and **b.**#48 below; about a 40% overlap with **b.**#56 and D.1 #95 below)
Workshop on Measurement and Analysis of Soil CO_2 Fluxes, Boulder, CO

37 Massman, WJ. 2003.
The WPL terms, spectral corrections, and open- and closed-path systems. (D.1 #85)
7^{th} Annual AmeriFlux meeting, Boulder, CO

38 Goldstein, A, R Holzinger, A Lee, M McKay, M Lunden, R Rasmussen, A Steiner, S Cieslik, and B Massman. 2004. **[APE–CD]**
Emissions of very reactive BVOCs are an order of magnitude larger than above canopy terpene flux.
AGU Fall Meeting, San Francisco, CA

39 Massman, WJ. 2005. **[Keynote Speaker] [AP]**
The eddy covariance flux equation. (40% overlap with D.1 #76)
The ACCENT-BIAFLUX Workshop, Risø National Laboratory, Roskilde, Denmark

40 Massman, WJ. 2005. **[APE–CD]**
Impacts of controlled burns on the heating and ecology of soils. (90% overlap with D.1 #87)
ESA/INTECOL Joint Conference (fire ecology session), Montreal, Canada

41 Pampaloni, P, S Paloscia, G Macelloni, M Karam, and W Massman. 2005. **[AP]**
Progress in passive microwave remote sensing of vegetation.
28^{th} General Assembly of International Union of Radio Science (URSI), New Delhi, India

42 Massman, WJ. 2006. **[P]**
Advective transport of CO_2 in permeable media induced by atmospheric pressure fluctuations. (D.1 #95 and #96; also see Offered Papers and Posters **b.**#57 below)
AGU Fall Meeting, San Francisco, CA

43 Massman, WJ, and DR Bowling. 2008.
New results for wintertime soil $\delta^{13}C$ from Niwot Ridge.
(Outlines Massman's perspective on D.1 #104.)
Niwot Ridge Field Site Review (held jointly by CU-Boulder and NEON), Boulder, CO

44 Frank, JM, and WJ Massman. 2008.
An introduction to eddy-covariance and flux measurements at the GLEES-AmeriFlux site.
† Soil & Crop Sciences Weekly Seminar, Colorado State University, Fort Collins, CO
Massman's contribution: I was invited by Dr Greg Butters (soil physicist, CSU) to speak at the seminar series and I offered this speaking opportunity to J Frank, whom I supervise, and he accepted. The presentation covered much of our GLEES eddy covariance research.
† Wyoming BLM Air Quality Team monthly conference call, Cheyenne, WY
J Frank was offered the invitation to present from Dr J Zachariassen of the BLM/WYSO.

45 Massman, WJ [with contributions from JM Frank, S Mooney, G Butters, K Laird, and MM Nobles]. 2009.
Impacts of slash-pile burns on soils: A Manitou Experimental Forest Mystery.
(About a 95% overlap with Invited Presentation #45a and Offered Presentation #84)
Hydrology Seminar, Centre for Hydrology, University of Saskatchewan, Saskatoon, Canada

46 Massman, WJ and JM Frank. 2009. [**AP**]
Three issues concerning open- and closed-path sensors: self-heating, pressure effects, and tube wall adsorption.
AsiaFlux Workshop 2009: *Integrating Cross-scale Ecosystem Knowledge: Bridges and Barriers*, Sapporo, Japan
Presentation available through 2009 on the web at https://fxp.nies.go.jp/

45a Massman, WJ [with contributions from JM Frank, S Mooney, G Butters, K Laird, and MM Nobles]. 2010.
Impacts of slash-pile burns on soils: A Manitou Experimental Forest Mystery.
(About a 95% overlap with #45 above; similar to Offered Presentation #84 below)
CSIRO Marine and Atmospheric Research seminar, Pye Laboratory, Canberra, Australia
Note: Presented while the scientist was a CSIRO Distinguished Visiting Scientist;
see **7. Scientific Exchanges #02** below.

47 Massman, WJ. 2010.
Eddy Covariance Fluxes, Mass Conservation, and the WPL Density 'Corrections': A Synthesis. (Outlines the scientist's contribution to D.1 #112)
University of Wyoming Atmospheric Science Seminar, Laramie, WY

48 Mackay, DS, J Frank, D Reed, F Whitehouse, BE Ewers, E Pendall, WJ Massman, and JS Sperry. 2012. *Modeling evapotranspiration based on plant hydraulic theory can predict spatial variability across an elevation gradient and link to biogeochemical fluxes.*
EGU General Assembly, Vienna, Austria

49 Ham, J, K Shonkwiler-Arnold, WJ Massman, and C Williams. 2012. [**AMS-W**]
Measuring methane fluxes from confined livestock operations using open-path eddy covariance: a challenging opportunity.
AMS 1st Conference on Atmospheric Biogeosciences, Boston, MA

50 Frank, JM, WJ Massman, and BE Ewers. 2012.
Linking bark beetle caused hydraulic failure to declining ecosystem fluxes in a high elevation Rocky Mountain (Wyoming, USA) forest. (D.1 #121)
(Same as Offered Presentation #112 below)
CMMAP Student Colloquium, Fort Collins, CO
NOTE: CMMAP = Center for Multiscale Modeling of Atmospheric Processes,
see http://www.cmmap.org/

b. Offered Papers and Posters

01 Massman, WJ. 1980.
Modeling rainfall storage by old-growth Douglas fir crowns.
AAAS, Pacific Division 62nd Annual Meeting, Eugene, OR

02 Massman, WJ. 1980.
Studying the microclimate inside an old-growth Douglas fir crown.
AAAS, Pacific Division 62nd Annual Meeting, Eugene, OR

03 Stocker, DW, D Stedman, WJ Massman, K Zeller, and D Fox. 1989.
Measurements of the dry deposition of nitrogen oxides to a prairie ecosystem by eddy covariance.
AWMA 82^{nd} Annual meeting, Anaheim, CA

04 Zeller, K, WJ Massman, and D Fox. 1989.
NO_x measurements at Pawnee.
University of Denver Rocky Mountain Conference, Denver, CO

05 Stocker, D, K Zeller, WJ Massman, D Fox, D Lukens, and D Stedman. 1989.
Flux measurements over a prairie grassland in northern Colorado.
5^{th} European Symposium on Phyisco-Chemical Behavior of Atmospheric Pollutants, Varese, Italy

06 Massman, WJ. 1989. [**AP**]
The surface energy balance and the soil and plant resistances to the transfer of heat and moisture at a Colorado short grass steppe site.
AGU Fall Meeting, San Francisco, CA

07 Zeller, K, D Fox, R Sommerfeld, and WJ Massman. 1990.
Measurements of deposition to prairie and alpine ecosystems in the Rocky Mountains.
NAPAP 1990 International Conference, Hilton Head Island, SC

08 Zeller, K, D Fox, and WJ Massman. 1990.
Simultaneous measurements of the eddy diffusivities and gradients of ozone, sensible heat momentum. (D.1 #21)
AMS 9^{th} Symposium on Turbulence and Diffusion, Roskilde, Denmark

09 Massman, WJ. 1991.
The attenuation of concentration fluctuations in turbulent flow through a tube. (D.1 #23)
Front Range Chapter AGU Annual Meeting, Boulder, CO

10 Massman, WJ. 1991.
Improving estimates of soil heat flux and deriving estimates from volumetric soil specific heat capacity from soil temperature and soil heat flow measurements. (D.1 #24)
AMS 20^{th} Conference on Agricultural and Forest Meteorology, Salt Lake City, UT

11 Wooldridge, G, B Connell, R Musselman, and WJ Massman. 1991.
Advective contributions to boundary layer moisture profiles in mountainous terrain. (D.1 #25)
AMS 20th Conference on Agricultural and Forest Meteorology, Salt Lake City, UT

12 Massman, WJ. 1992. [**AP**]
Partitioning dry deposition flux of ozone into soil and plant components: inferring the transfer resistances from eddy correlation flux measurements at a site with partial canopy cover. (D.1 #31)
AGU Spring Meeting, Montreal, Canada

13 Zeller, K, and WJ Massman. 1992. [**AP**] [Presented by WJ Massman]
Flux divergence of ozone in the atmospheric surface layer measured over a shortgrass steppe site.
AGU Spring Meeting, Montreal, Canada

14 Pederson, J, WJ Massman, A Delany, T Horst, G den Hartog, H Neumann, R Desjardins, D Grantz, J MacPherson, L Mahrt, R Pearson, and P Schuepp. 1992. [**AP**] [Presented by WJ Massman]
The California Ozone Deposition Experiment: CODE.
AGU Spring Meeting, Montreal, Canada

15 Nikolov, N, DG Fox, and WJ Massman. 1992.
Sensitivity of coniferous forests ecosystems to simultaneous changes in atmospheric CO_2 *concentration and climate conditions.*
Global Climate Change Conference: Impact on terrestrial ecosystems, Bad Durkheim, Germany

16 Wooldridge, G, WJ Massman, and R Musselman. 1992.
Advective contributions to atmospheric boundary layer development in an alpine ecosystem.
22nd International Conference on Alpine Meteorology, Toulousse, France

17 Aiken, R, D Nielsen, and WJ Massman. 1993.
Quantifying residue effects on transport phenomena.
NRC meeting of the ARS, Lincoln, NE

18 Wooldridge, G, R Musselman, and WJ Massman. 1993.
Windthrow and airflow in a subalpine forest. (D.1 #44)
IUFRO Conference on Wind-related Damage to Trees, Edinburgh, Scotland

19 Massman, WJ, J Pederson, A Delany, G den Hartog, HH Neumann, D Grantz, SP Oncley, and R Pearson Jr. 1993.
A comparison of independent determinations of the canopy conductance for carbon dioxide, water vapor and ozone exchange at selected sites in the San Joaquin Valley of California. (D.1 #28)
AMS Conference on Hydroclimatology, Anaheim, CA

20 Massman, WJ, and J Ham. 1993. [Presented by J Ham]
An evaluation of a surface energy balance method for partitioning ET data into soil and plant components for a surface with partial canopy cover. (D.1 #36)
ASA-CSSA-SSSA Annual Meetings, Cincinnati, OH
N.B. ASA-CSSA-SSSA = Agronomy Society of America - Crop Science Society of America - Soil Science Society of America

21 Massman, WJ, JI MacPherson, A Delany, G den Hartog, HH Neumann, SP Oncley, R Pearson Jr, J Pederson, and RH Shaw. 1993.
Surface conductance for ozone uptake derived from aircraft eddy covariance data. (D.1 #49)
AWMA International Specialty Conference: Regional Photochemical Measurement and Modeling Studies, San Diego, CA

22 Grantz, DA, WJ Massman, JR Pederson, A Delany, S Oncley, G den Hartog, HH Neumann, RH Shaw, and X Zhang. 1993.
Measurements of surface wetness during the California ozone deposition experiment: effect of leaf wetness and stomatal conductance on ozone deposition. (D.1 #50)
AWMA International Specialty Conference: Regional Photochemical Measurement and Modeling Studies, San Diego, CA

23 Pederson, JR, A Delany, G den Hartog, R Desjardins, DA Grantz, LJ Mahrt, JI MacPherson, WJ Massman, HH Neumann, SP Oncley, R Pearson Jr, PR Roth, PH Schuepp, and RH Shaw. 1993.
California ozone deposition experiment: methods, results and opportunities. (D.1 #48)
AWMA International Specialty Conference: Regional Photochemical Measurement and Modeling Studies, San Diego, CA

24 Zeller, KF and WJ Massman. 1994.
Sub-alpine wet meadow diurnal CO_2 fluxes: further evidence of net CO_2 emissions during winter.
Front Range Chapter AGU Annual Meeting, Boulder, CO

25 Massman, WJ. 1994.
Estimating canopy conductance to ozone uptake from canopy scale evapotranspiration observations or by scaling leaf stomatal conductance measurements: Does either method work? (D.1 #35)
AMS 21^{st} Conference on Agricultural and Forest Meteorology, San Diego, CA

26 Grantz, DA, XJ Zhang, JR Pederson, WJ Massman, A Delany, and S Oncley. 1994.
Role of leaf wetness and stomatal conductance in determining ozone flux to cotton in the San Joaquin Valley. (D.1 #34)
AMS 21^{st} Conference on Agricultural and Forest Meteorology, San Diego, CA

27 Aiken, RM, GN Flerchinger, and WJ Massman. 1994.
Penman and gradient energy balance formulations: a sensitivity analysis.
ASA-CSSA-SSSA Annual Meetings, Seattle, WA

28 Massman, WJ, K Zeller, T Hehn, and R Sommerfeld. 1995. [**AP**] [**P**]
Winter eddy covariance carbon dioxide fluxes at a forested mountain site in southern Wyoming, USA.
IAHS Symposium H3: Biogeochemistry of seasonally snow-covered catchments, Boulder, CO

29 Massman, WJ, R Sommerfeld, K Zeller, T Hehn, L Hudnell, and S. Rochelle. 1995. [**AP**]
Carbon dioxide flux through a Wyoming seasonal snowpack: diffusional and pressure pumping effects. (D.1 #42)
IAHS Symposium H3: Biogeochemistry of seasonally snow-covered catchments, Boulder, CO

30 Musselman, RC, GL Wooldridge, WJ Massman, and RA Sommerfeld. 1995.
Wind and ecosystem response at the GLEES.
Interior West Global Change Workshop, Fort Collins, CO

31 Padro, J, I Zhang, WJ Massman, and DW Stocker. 1995.
An application of a dry deposition model including the chemical reactions of NO-NO_2-O_3.
(D.1 #46)
Wessex Institute Third International Conference Air Pollution 95, Porto Carras, Greece

32 Massman, WJ, and J Weil. 1996.
An analytical second-order closure model of turbulent statistics within and above plant canopies. (D.1 #52)
AMS 22^{nd} Conference on Agricultural and Forest Meteorology, San Diego, CA

33 Weil, JC, and WJ Massman. 1996.
Lagrangian stochastic modeling of scalar transport within and above plant canopies.
(D.1 #51)
AMS 22^{nd} Conference on Agricultural and Forest Meteorology, Atlanta, GA

34 Mitic, CM, WJ Massman, and PH Schuepp. 1996. [**AP**]
Time series analysis of structures transporting heat, moisture, CO_2 *and ozone during stable and unstable conditions over California agricultural land.*
30^{th} Canadian Meteorological and Oceanographic Society Congress, Toronto, Canada

35 Massman, WJ, RA Sommerfeld, and AR Mosier. 1996.
Winter N_2O *fluxes at a forested subalpine site in southern Wyoming, USA: Diffusion and pressure pumping effects.*
AGU Chapman Conference on Nitrogen Cycling in Forested Catchments, Sun River, OR

36 Massman, WJ, RA Sommerfeld, AR Mosier, KF Zeller, TJ Hehn, and S Rochelle. 1997.
A model investigation of turbulence-driven pressure pumping effects on the rate of diffusion of carbon dioxide and nitrous oxide through layered snowpacks. (D.1 #59)
AMS 12^{th} Symposium on Boundary Layers and Turbulence, Vancouver, Canada

37 Sun, J, and WJ Massman. 1997.
Bulk formula and aerodynamic quantities. (D.1 #60 and D.1 #67)
AMS 12^{th} Symposium on Boundary Layers and Turbulence, Vancouver, Canada

38 Massman, WJ, KF Zeller, and TJ Hehn. 1998. [**P**]
Eddy covariance heat, moisture and CO_2 fluxes from a subalpine ecosystem site in southern Wyoming, USA.
FLUXNET Workshop, Polson, MT

39 Massman, WJ. 1998.
The bulk canopy boundary layer resistance from 'localized' near-field' Lagrangian theory.
(related to, but not identical to D.1 #70)
AMS 23^{rd} Conference on Agricultural and Forest Meteorology, Albuquerque, NM

40 Sun, J, and WJ Massman. 1999.
Ozone transport in the California ozone deposition experiment. (D.1 #68)
AMS 13^{th} Symposium on Boundary Layers and Turbulence, Dallas, TX

41 Musselman, RC, LA Joyce, AW Schoettle, WJ Massman, and RA Sommerfeld. 1999.
The Glacier Lakes Ecosystem Experiments Site – GLEES, a high elevation alpine/subalpine research study area in SE Wyoming.
Ecological Society of America (ESA) Annual Meeting, Spokane, WA

42 Joyce, LA, J Lundquist, J Negron, WJ Massman, R Musselman, A Schoettle, W Shepperd, and KF Zeller. 1999.
Removing the do not disturb sign: Using silviculture to manage vegetation.
National Silviculture Workshop, Kalispell, MT

43 Massman, WJ, and JM Frank. 2000.
The influence of the pressure-velocity covariance term, $\overline{p'w'}$, on eddy covariance CO_2 fluxes at a high elevation site in southern Wyoming.
† AMS 14^{th} Symposium on Boundary Layers and Turbulence, Aspen, CO
† AMS 24^{th} Conference on Agricultural and Forest Meteorology, Davis, CA

44 Takle, ES, JR Brandle, RA Schmidt, R Garcia, IV Litvina, G Doyle, X Zhou, Q Hou, CW Rice, and WJ Massman. 2000.
Pressure pumping of carbon dioxide from soil. (D.1 #73)
AMS 24^{th} Conference on Agricultural and Forest Meteorology, Davis, CA

45 Massman, WJ. 2001. [**P**]
Measuring and modeling ozone fluxes and ozone deposition.
33^{rd} Annual Air Pollution Workshop, Riverside, CA

46 Massman, WJ, JM Frank, RA Musselman, and J Welker. 2001, 2002.
Pressure pumping effects on fluxes and the release of trace gases from soils.
† AGU Fall Meeting, San Francisco, CA [**AP**] [**P**]
† 6^{th} Annual AmeriFlux Meeting, Boulder, CO
Second presentation is an update of the first – about 75% overlap with the first

47 Massman, WJ, JM Frank, WD Shepperd, and MJ Platten. 2002.
(i) *In situ soil temperature and heat flux measurements during controlled burns at a southern Colorado forest site.* (ii) *In situ soil temperature and heat flux measurements during a controlled burn of a forest understory.* (D.1 #79)
† (i) Conference on fire, fuel treatments, and ecological restoration, Ft Collins, CO [**AP**] [**P**]
† (ii) AMS 25^{th} Conference on Agricultural and Forest Meteorology, Norfolk, VA

48 Massman, WJ. 2002.
Influence of turbulent pressure pumping on fluxes and movement of CO_2 from soils and snowpacks. (about 90% overlap with the second presentation of #46 above)
AMS 25^{th} Conference on Agricultural and Forest Meteorology, Norfolk, VA

49 Joyce, LA, B Kent, JE Lundquist, WJ Massman, JF Negron, WD Shepperd, and AW Schoettle. 2002. [**P**]
Fire plan research in Colorado: From the biophysical to the socio-economic.
2002 National Fire Plan Conference, Madison, WI

50 Musselman, RC, LA Joyce, AW Schoettle, WJ Massman, AC Ellsworth, and KF Zeller. 2002. [**P**]
The Glacier Lakes Ecosystem Experiment Site.
Experimental Forests and Ranges National Workshop, HJ Andrews Exp Forest, OR

51 Massman, WJ, JM Frank, WD Shepperd, MJ Platten, and LA Joyce. 2003. [**P**]
[presented by LA Joyce]
In situ soil temperature and heat flux measurements during controlled burns at a southern Colorado forest site. (about 70% overlap with #47 above and D.1 #79)
2003 National Fire Plan Conference, New Orleans, LA

52 Massman, WJ, JM Frank, SM Massman, and WD Shepperd. 2003. [**AP**]
Performance of high temperature heat flux plates and soil moisture probes during controlled surface fires. (D.1 #80; about a 20% overlap with #47, #49 above, and D.1 #79)
Second International Wildland Fire Ecology and Fire Management Congress, Orlando, FL

53 Massman, WJ, and JM Frank. 2004.
An in situ investigation of the influence of a controlled burn on the thermophysical properties of a dry soil. (D.1 #86, a shortened version of D.1 #87)
AMS 26^{th} Conference on Agricultural and Forest Meteorology, Vancouver, Canada

54 Joyce, LA, WD Shepperd, JF Negron, and WJ Massman. 2004.
Management alternatives for fire dependent ecosystems in Colorado and the Black Hills.
2004 National Fire Plan Conference, Reno, NV

55 Jiménez Esquilin, AE, ME Stromberger, W Massman, and F Frank. 2004. [**P**]
Effects of slash pile burning on microbial community structure and function.
Soil Science Society of America (SSSA) Annual Meeting, Seattle, WA

56 Massman, WJ. 2005. [Presented by LA Joyce]
Advective transport of CO_2 *in permeable media induced by atmospheric pressure fluctuations.* (D.1 #95; about 60% overlap with #48 above)
Annual Meeting of the Association of American Geographers, Denver, CO

57 Massman, WJ. 2005. [**P**]
Advective transport of CO_2 *in permeable media induced by atmospheric pressure fluctuations.* (D.1 #95, #96; about 60% overlap with #56 above)
† Seventh International Carbon Dioxide Conference, Boulder, CO [**APE–CD**]
† 9^{th} Annual AmeriFlux Meeting, Boulder, CO
Presentation available on the AmeriFlux website at:
http://public.ornl.gov/ameriflux/posters_2005.shtml
† AGU Fall Meeting, San Francisco, CA [**APE–CD**] [Presented by L Misson]
† Also see Invited Papers and Posters **a.**#42 above.

58 Paloscia, S, P Pampaloni, MA Karam, and WJ Massman. 2005. [**AP**]
Analysis of brightness temperature data from corn canopy with vertical temperature gradient and leaf stress.
Progress in Electromagnetics Research Symposium (PIERS), Hangzhou, China

59 Emberson, LD, WJ Massman, P Büker, G Soja, I van de Sand, I Mills, and C Jacobs. 2005. [**P**]
The development, evaluation, and application of O_3 *flux and flux-response models for additional agricultural crops.* (D.1 #89)
UNECE – Workshop "Critical Levels of Ozone: Further applying and developing the flux-based concept", Obergurgl, Austria

60 Büker, P, LD Emberson, MR Ashmore, G Gerosa, C Jacobs, WJ Massman, J Müller, N Nikolov, K Novak, E Oksanen, D de la Torre, and J-P Tuovinen. 2005.
Comparison of different stomatal conductance algorithms for ozone flux modelling. (D.1 #90, D.1 #99)
UNECE – Workshop "Critical Levels of Ozone: Further applying and developing the flux-based concept", Obergurgl, Austria

61 Massman, WJ, JM Frank, Jiménez Esquilin, AE, and ME Stromberger. 2006.
Long term consequences of a controlled slash burn and slash mastication to soil moisture and CO_2 *at a southern Colorado site.* (D.1 #97)
† AMS 27^{th} Conference on Agricultural and Forest Meteorology, San Diego, CA [**AMS–W**]
† 3^{rd} International Fire Ecology and Management Congress, San Diego, CA [**AP**] [**P**]
Second presentation updates and expands on the first.

62 Massman, WJ, and JM Frank. 2006. [**AMS–W**]
Effects of controlled burns on the bulk density and thermal conductivity of soils at a southern Colorado site. (D.1 #98)
AMS 27^{th} Conference on Agricultural and Forest Meteorology, San Diego, CA

63 Frank, JM, and Massman, WJ. 2006. [**P**]
Effects of controlled burns on the bulk density, thermal conductivity, and soil temperature of soils at a southern Colorado site. (about a 30% overlap with #62 above)
3^{rd} International Fire Ecology and Management Congress, San Diego, CA

64 Tu, KP, WJ Massman, and JM Ham. 2006. [**P**]
Partitioning ET between plant and soil components using surface temperature and fractional vegetation cover.
10^{th} Annual AmeriFlux Meeting, Boulder, CO

65 Dickinson, MB, AS Bova, BW Butler, TR Engstrom, K Kavanagh, R Kremens, WJ Massman, E Reinhardt, A Smith, and K Stephan. 2007.
First order fire effects: process-based knowledge and models. [Massman's personal research (see D.1 #106) underpinned the soil physics related content of the presentation.]
† 2^{nd} Fire Behavior and Fuels Conference, Destin, FL
† EastFire Conference 2007, Fairfax, VA

57a Massman, WJ. 2007. [**P**] [repeat of #57 above]
Advective transport of CO_2 in permeable media induced by atmospheric pressure fluctuations. (Same as #57 above)
1^{st} FS RMRS Forest and Woodlands Ecosystems Program Meeting, Salt Lake City, UT

66 Frank, JM, and WJ Massman. 2007. [**P**]
Application of running-median filtering for ambient meteorological and eddy-covariance data.
† 1^{st} FS RMRS Forest and Woodlands Ecosystems Program Meeting, Salt Lake City, UT
† 11^{th} Annual AmeriFlux Meeting, Boulder, CO (About 80% overlap with the previous presentation)
Poster and abstract available on the AmeriFlux website at:
http://public.ornl.gov/ameriflux/posters_2007.shtml
† AGU Fall Meeting, San Francisco, CA
Updates previous presentation – about a 75% overlap with it

67 Massman, WJ. 2007.
Boundary conditions for soil heating: Inputs from fire models. (related to #65 above and D.1 #106)
Core Fire Science Caucus Meeting, Madison, WI.

68 Stromberger, M, K Coffin, and WJ Massman. 2007. [**APE–CD**] [**P**]
Forest fuel chipping effects on soil microbial communities and carbon pools.
ASA-CSSA-SSSA International Annual Meetings, New Orleans, LA

69 Bowling, DR, SM Schaeffer, WJ Massman, RK Monson, and MW Williams. 2007.
CO_2 and carbon isotopes of CO_2 within a subalpine forest snowpack. (D.1 #104)
AGU Fall Meeting, San Francisco, CA

70 Massman, WJ, A Ibrom, and L Kristensen. 2007. [**P**]
Attenuation of trace gas fluctuations associated with turbulent flow in tubes: application to closed-path eddy covariance systems. (about a 60% overlap with D.1 #103)
AGU Fall Meeting, San Francisco, CA

71 Massman, WJ and JM Frank. 2007, 2008.
Long term impacts of prescribed burns on soil thermal conductivity and soil heating at a Colorado Rocky Mountain site. (D.1 #101; about a 70% overlap with #63 above)
† AGU Fall Meeting, San Francisco, CA [**P**] [12/2007]
† EGU General Assembly, Vienna, Austria [**APE-CD**] [4/2008]

72 Massman, WJ, and A Ibrom. 2008.
Attenuation of trace gas fluctuations associated with turbulent flow in tubes: application to sampling water vapor with closed-path eddy covariance systems. (about a 75% overlap with previous presentation, #70 above, and about a 85% overlap with D.1 #103)
† EGU General Assembly, Vienna, Austria [**APE-CD**] [**P**]
† AMS 28^{th} Conference on Agricultural and Forest Meteorology, Orlando, FL [**AMS–W**]

61a Massman, W, J Frank, and M Stromberger. 2008. [**APE-CD**] [repeat of #61 above]
Long term consequences of a controlled slash burn and slash mastication to soil moisture and CO_2. (D.1 #97) (slightly different abstract than #61 above)
EGU General Assembly, Vienna, Austria

73 Stromberger, M, and W Massman. 2008. [**APE-CD**] [**P**]
Forest Fuel Chipping Effects on Soil Microbial Communities. (40% overlap with #68 above)
EGU General Assembly, Vienna, Austria

74 Ibrom, A, and WJ Massman. 2008. [**APE-CD**]
Consideration of the Webb-Pearman-Leuning theory for closed-path measurements: What should be done?
EGU General Assembly, Vienna, Austria

75 Oncley, SP, WJ Massman, and EG Patton. 2008. [**AMS–W**]
Turbulent Pressure Fluctuations Measured During CHATS. (D.1 #102)
AMS 18^{th} Symposium on Boundary Layers and Turbulence, Stockholm, Sweden

76 Frank, JM, WJ Massman, and JF Negrón. 2008, 2009. [**P**]
Eddy-covariance flux response to a bark beetle epidemic at the GLEES-AmeriFlux site (WY, USA).
† 12^{th} Annual AmeriFlux Meeting, Boulder, CO [10/08]
Poster and abstract available on the AmeriFlux website at:
http://public.ornl.gov/ameriflux/Site_Info/siteInfo.cfm?KEYID=us.glacierlake.01
† 1^{st} Forest and Plains Research Symposium, Laramie, WY [03/09]
Updates previous presentation – about an 80% overlap with it

77 Musselman, RC, WJ Massman, JL Korfmacher, and JM Frank. 2009. **[AP]** [Presented by WJ Massman]
The Glacier Lakes Ecosystem Experiments Site, a long-term monitoring site in the Snowy Range of Wyoming, USA.
LWF Conference on 'Long-term ecosystem research: Understanding the present to shape the future', Zurich, Switzerland
Available online at http://www.wsl.ch/lwf/anniversary/ppt_presentations/index_EN

78 Frank, JM, and WJ Massman. 2009. **[AP]** **[P]** [Presented by WJ Massman]
A median based data screening procedure. (About a 50% overlap with #66 above)
LWF Conference on 'Long-term ecosystem research: Understanding the present to shape the future', Zurich, Switzerland
3-slide abstract available online at
http://www.wsl.ch/lwf/anniversary/ppt_presentations/index_EN

79 Massman, WJ and Frank, JM. 2009. **[APE-CD]** **[P]**
Response of high elevation Rocky Mountain (Wyoming, USA) forest carbon dioxide and water vapor fluxes to a bark-beetle epidemic. (About a 50% overlap with #76 above)
8^{th} International Carbon Dioxide Conference, Jena, Germany

80 Williams, D, B Ewers, J Angstmann, B Massman, and J Frank. 2009. **[P]**
The isotopic signature of leaf water and transpiration in mixed conifer forest.
AGU Chapman Conference on Examining Feedbacks of Landscape Change along Elevation Gradients in Semiarid Regions, Sun Valley, ID

81 Nobles, MM, WJ Massman, M Mbila, and G Butters. 2009/2010.
Mineralogical and micromorphological modifications in soil affected by slash pile burn. (D.1 #109)
† ASA-CSSA-SSSA Annual Meeting, Pittsburgh, PA **[P]** [11/2009]
† VI International Conference on Forest Fire Research, Coimbra, Portugal **[AP]** [11/2010] [Presented by WJ Massman]

82 Massman, WJ, MM Nobles, G Butters, and S Mooney. 2009/2010.
Transport of CO_2 and other combustion products in soils during slash-pile burns. (D.1 #110)
† 4^{th} International Fire Ecology and Mgmt. Congress, Savannah, GA **[APE-CD]** [11/2009]
† VI International Conf. on Forest Fire Research, Coimbra, Portugal **[AP]** **[P]** [11/2010]

83 Oncley, SP, WJ Massman, and EG Patton. 2010.
Direct observations of turbulence kinetic energy budgets within an orchard canopy. (D.1 #124)
† NCAR EOL Seminar, Boulder, CO [03/2010]
† AMS 19^{th} Symposium on Boundary Layers and Turbulence, Keystone, CO [08/2010]

84 Massman, WJ [with contributions from JM Frank, S Mooney, G Butters, K Laird, and MM Nobles]. 2010.
Impacts of slash-pile burns on soils: A Manitou Experimental Forest Mystery.

(95% overlap with Invited Presentation #45, similar to Invited Presentation #45a)
USGS Water Resources Discipline National Research Program, Boulder, CO

85 Massman, WJ and JM Frank. 2010. [**AP**] [**P**]
Water vapor, CO_2, and energy exchange between the atmosphere, vegetation, and soils.
RMRS All Scientist Meeting, Fort Collins, CO

86 Barnard HR, JL Angstmann, TL Aston, PD Brooks, BE Ewers, JM Frank, A Harpold, WJ Massman, U Norton, E Pendall, D Reed, DG Williams. 2010.
Response of Rocky Mountain forest evapotranspiration and greenhouse gases to bark beetles and blue stain fungi epidemic.
CU-NOAA Western Water Assessment (MOUNTAIN PINE BEETLE SCIENCE SYMPOSIUM: Impacts on the Hydrologic Cycle and Water Quality), NCAR, Boulder, CO
Abstract and presentation available online at
http://wwa.colorado.edu/ecology/beetle/mpb-water-apr2010.html

87 Miles, B, MG Ryan, WJ Massman, and JM Frank. 2010. [**AP**] [**P**]
Impacts of a spruce and fir beetle outbreak on carbon balance in a subalpine spruce-fir forest.
IUFRO Canopy Processes Working Group: Canopy processes in changing climate,
South East Australia; Falls Creek, Victoria & Tarraleah, Tasmania

88 Frank, JM, and WJ Massman. 2010.
Introduction to GLEES and recent carbon and water fluxes.
Mountain Pine Beetle Project Meeting, University of Wyoming, Laramie, WY

89 Bowling, D, and WJ Massman. 2010.
The competing roles of diffusion and advection in CO_2 transport within a mountain snowpack. (About a 90% overlap with presentation #91 below) (D.1 #113)
University of Utah, Department of Geology and Geophysics Seminar, Salt Lake City, UT

90 Ewers, BE, E Pendall, U Norton, D Reed, J Frank, T Aston, F Whitehouse, H Barnard, JL Angstmann, W Massman, D Williams, A Harpold, D Gochis, and P Brooks. 2010. [**AP**] [**P**]
The Rocky Mountain epidemic of bark beetles and blue stain fungi cause cascading effects on coupled water, C and N cycles.
AGU Fall Meeting, San Francisco, CA

91 Bowling, DR, and WJ Massman. 2010. [**AP**] [**P**]
Persistent wind-induced enhancement of diffusive CO_2 fluxes in a mountain forest snowpack. (D.1 #113)
AGU Fall Meeting, San Francisco, CA

92 Yi, C, D Ricciuto, and 150 co-authors. 2010. [**AP**]
Climate control of terrestrial carbon sequestration (D.1 #108)
(Presentation available at http://qcpages.qc.cuny.edu/~cyi/; about a 90% overlap with presentation #89 above)
AGU Fall Meeting, San Francisco, CA

93 Frank, JM, WJ Massman, and BE Ewers. 2010/2011. **[AP]** **[P]**
Response of high elevation rocky mountain (Wyoming, USA) forest carbon dioxide and water vapor fluxes to a bark beetle epidemic.
† AGU Fall Meeting, San Francisco, CA [12/2010]
† 14^{th} AmeriFlux Science Meeting & 3^{rd} NACP All-Investigators Meeting, New Orleans, LA [01-02/2011]
For poster see: ftp://cdiac.ornl.gov/pub/ameriflux/data/Level1/Sites_ByName/GLEES/

94 Frank, JM, and WJ Massman. 2011. **[AP]** **[P]**
Discrepancies in measured sensible heat flux from two different sonic anemometers.
14^{th} AmeriFlux Science Meeting & 3^{rd} NACP All-Investigators Meeting, New Orleans, LA
For poster see: ftp://cdiac.ornl.gov/pub/ameriflux/data/Level1/Sites_ByName/GLEES/

95 Hollinger, DY, C-T Lai, WJ Massman, JM Frank, KL Clark, K Bible, J Vose, K Novick, AR Desai, R Kolka, AD Richardson, JL Hom, and R Evans. 2011. **[P]**
Forest Service climate change network
14^{th} AmeriFlux Science Meeting & 3^{rd} NACP All-Investigators Meeting, New Orleans, LA

96 Frank, JM, WJ Massman, and BE Ewers. 2011.
Evapotranspiration response of a high elevation Rocky Mountain (Wyoming, USA) forest to a bark beetle epidemic. (about 90% overlap with #93 above)
† 31^{st} Annual AGU Hydrology Days, Fort Collins, CO (3/2011) **[APE-CD]**
† Mountain Pine Beetle Science Symposium – Impacts on the Hydrologic Cycle and Water Quality: What have we learned?, Boulder, CO (4/2011) **[AP]** — Presentation available at http://wwa.colorado.edu/ecology/beetle/mpb_symposiumApr2011.html

97 Gochis, D, E Gutmann, T Duhl, P Brooks, A Harpold, J Beiderman, E Pendall, B Ewers, D Reed, F Whitehouse, J Hicke, S Edburg, A Meddens, J Frank, W Massman, N Molotch, and S Burns. 2011. **[AP]**
Quantifying the effects of large-scale vegetation change of coupled water, carbon and nutrient cycles: Beetle kill in western montane forest.
Mountain Pine Beetle Science Symposium – Impacts on the Hydrologic Cycle and Water Quality: What have we learned?, Boulder, CO — Presentation available at http://wwa.colorado.edu/ecology/beetle/mpb_symposiumApr2011.html

98 Gochis, D, E Gutmann, P Brooks, A Harpold, J Beiderman, E Pendall, B Ewers, D Reed, F Whitehouse, J Hicke, S Edburg, A Meddens, J Frank, W Massman, N Molotch, and S Burns. 2011. **[AP]**
Modeling ecohydrologic impacts of mountain pine beetle infestation.
Mountain Pine Beetle Science Symposium – Impacts on the Hydrologic Cycle and Water Quality: What have we learned?, Boulder, CO — Presentation available at http://wwa.colorado.edu/ecology/beetle/mpb_symposiumApr2011.html

99 Kochendorfer, J, T Meyers, M Heuer, J Frank, and W Massman. 2011. **[AP]**
Field estimates of sonic angle of attack errors.
45^{th} Canadian Meteorological and Oceanographic Society Congress, Victoria, Canada

100 Kochendorfer, J, T Meyers, M Heuer, J Frank, and W Massman. 2011. [**AP**]
How well can we measure the vertical the wind speed? Implications for fluxes of energy and mass. (D.1 #116) (Presentation overlaps #98 above by 60%)
AGU Fall Meeting, San Francisco, CA

101 Massman, WJ. 2011.
† *Modeling soil heating and moisture transport under extreme conditions: Forest fires and slash pile burns.* (D.1 #117) FS Missoula FireLab Seminars, Missoula, MT (10/11)
† *Soil heating and evaporation under extreme conditions: Forest fires and slash pile burns.* AGU Fall Meeting, San Francisco, CA [**AP**] (12/11)

102 Frank, J, WJ Massman, and BE Ewers. 2011. [**AP**]
Net ecosystem exchange of carbon dioxide and evapotranspiration response of a high elevation Rocky Mountain (Wyoming, USA) forest to a bark beetle epidemic.
AGU Fall Meeting, San Francisco, CA

103 Mackay, DS, BE Ewers, DE Roberts, N McDowell, E Pendall, J Frank, D Reed, WJ Massman, and B Mitra. 2011. [**AP**]
A coupled carbon and plant hydraulic model to predict ecosystem carbon and water flux responses to disturbance and environmental change.
AGU Fall Meeting, San Francisco, CA

104 Ewers, BE, E Pendall, D Reed, H Barnard, F Whitehouse, J Frank, W Massman, P Brooks, J Biederman, K Naithani, B Mitra, DS Mackay, and A Harpold. 2011. [**AP**]
Use of plant hydraulic theory to predict ecosystem fluxes across mountainous gradients in environmental controls and insect disturbances.
AGU Fall Meeting, San Francisco, CA

105 Lai, C-T, DY Hollinger, WJ Massman, KL Clark, K Bible, J Vose, AR Desai, R Kolka, AD Richardson, JL Hom, and R Evans. 2011. [**AP**]
Half-hourly atmospheric $\delta^{13}CO_2$ observed by cavity ring-down spectroscopy analyzer in the USDA Forest Service Climate Tower Network.
AGU Fall Meeting, San Francisco, CA

106 Frank, JM, WJ Massman, and BE Ewers. 2012.
Net ecosystem exchange of carbon dioxide and evapotranspiration response of a high elevation Rocky Mountain (Wyoming, USA) forest to a bark beetle epidemic.
University of Wyoming Program in Ecology Symposium, Laramie, WY

107 Frank, JM, WJ Massman, and BE Ewers. 2012.
Errors in measured sensible heat flux due to vertical velocity measurements in non-orthogonal sonic anemometers.
18^{th} Annual Front Range Student Ecology Symposium, Fort Collins, CO

108 Kirby, EA, KM Smits, and WJ Massman. 2012. [**APE-CD**]
The effect of fire on the thermal properties of soils. (D.1 #122)
32^{nd} Annual AGU Hydrology Days, Fort Collins, CO

109 Leuning, R, E van Gorsel, and WJ Massman. 2012. [**AP**]
The surface energy balance closure problem. (D.1 #115)
† EGU General Assembly, Vienna, Austria
† AMS 30^{th} Conference on Agricultural and Forest Meteorology, Boston, MA [**AMS-W**] [Presented by WJ Massman]
† Annual OzFlux Meeting, Methven, New Zealand [Presented by P Issac]

110 Massman, WJ. 2012. [**AMS-W**]
Modeling soil heating and moisture transport under extreme conditions: Forest fires and slash pile burns. (About a 70% overlap with #100 above) (D.1 #117)
AMS 30^{th} Conference on Agricultural and Forest Meteorology, Boston, MA

111 Hollinger, DY, CT Lai, WJ Massman, KL Clark, K Novick, F Meinzer, and K Bible. 2012. [**AMS-W**]
Environmental control of forest ecosystem $\delta^{13}CO_2$ discrimination.
AMS 30^{th} Conference on Agricultural and Forest Meteorology, Boston, MA

112 Frank, JM, WJ Massman, and BE Ewers. 2012.
Linking bark beetle caused hydraulic failure to declining ecosystem fluxes in a high elevation Rocky Mountain (Wyoming, USA) forest. (D.1 #121) (Same as Invited Presentation #50)
97^{th} Annual ESA Meeting, Portland, OR

104a Ewers, BE, DS Mackay, E Pendall, J Frank, D Reed, WJ Massman, T Aston, J Angstmann, K Nathani, B Mitra, and U Norton. 2012.
Use of plant hydraulic theory to predict plant controls over mass and energy fluxes in response to changes in soils, elevation and mortality. (90%-95% overlap with #103 above)
† 97^{th} Annual ESA Meeting, Portland, OR
† American Society of Plant Biologists, Austin, TX

113 Bronson, DR, X Song, ML Goulden, K Clark, P Bolstad, T Meyers, J Chen, A Noormets, D Dragoni, D Hollinger, JW Munger, S Wofsy, T Martin, R Monson, D Baldocchi, A Desai, E Euskirchen, W Massman, and B Helliker. 2012.
Forest canopy temperature: a comparison between an isotopic approach and photosynthesis-weighted air temperature.
97^{th} Annual ESA Meeting, Portland, OR

114 Scott, HN, WJ Massman, JM Frank, BL Miles, and MG Ryan. 2012.
Comparing chamber and eddy covariance estimates of ecosystem respiration during bark beetle mortality in a subalpine spruce-fir forest.
† CMMAP Student Colloquium, Fort Collins, CO
† 97^{th} Annual ESA Meeting, Portland, OR

95a Hollinger, DY, C-T Lai, WJ Massman, JM Frank, KL Clark, K Bible, J Vose, K Novick, AR Desai, R Kolka, AD Richardson, JL Hom, and R Evans. 2012. [**P**]
Forest Service climate change network. (about 95% overlap with presentation #95 above)
Front Range Isotope Day Symposium 2012, Laramie, WY [Presented by JM Frank]

115 Rafkin, S, D Banfield, R Dissly, J Silver, A Stanton, E Wilkinson, W Massman, and J Ham. 2012.
An instrument to measure turbulent eddy fluxes in the atmosphere of Mars. (D.1 #118)
International Workshop on Instrumentation for Planetary Missions (IPM-2012), NASA Goddard Space Flight Center, Greenbelt, MD

116 Ewers, BE, DS Mackay, CR Guadagno, S Peckham, E Pendall, B Borkhuu, T Aston, F Whitehouse, J Frank, W Massman, D Reed, Y Yarkhunova, and C Weinig. 2012.
Nonstructural carbon dynamics are best predicted by the combination of photosynthesis and plant hydraulics in both bark beetle induced mortality and herbaceous plant response to drought. AGU Fall Meeting, San Francisco, CA

117 Peckham, SD, BE Ewers, DS Mackay, J Frank, WJ Massman, MG Ryan, H Scott, and EG Pendall. 2012.
Modeling net ecosystem exchange of carbon dioxide in a beetle-attacked subalpine forest using a data-constrained ecosystem model. AGU Fall Meeting, San Francisco, CA

118 Speckman, HN, B Miles, JM Frank, WJ Massman, and MG Ryan. 2013.
Forest respiration from eddy covariance and chamber measurements under high turbulence and 85% overstory mortality.
19^{th} Annual Front Range Student Ecology Symposium, Fort Collins, CO

119 Peckham, SD, BE Ewers, DS Mackay, E Pendall, H Scott, J Frank, WJ Massman, and M Ryan. 2013.
Bayesian analysis of a carbon cycle model: implications for parameter estimation, model selection, and simulation of beetle mortality.
98^{th} Annual ESA Meeting, Minneapolis, MN

5. Participation in technical conferences and workshops:

01 Workshop on Influences of Atmospheric Pressure Fluctuations on Fluxes of Trace Gases from Soils.
April 1999, Lincoln, NE; sponsored by U of Nebraska.
Dr Massman presented B.4.a #21, helped design an experiment to test for the effects of turbulent atmospheric pressure pumping, and helped write a successful proposal to fund such an experiment. The research results of the pilot experiment are reported in B.4.b #44, D.1 #73, #78, and #82.

02 Workshop on Unaccounted Flux in Long-term Studies of Carbon and Energy Exchanges.
May 2000, Boulder, CO; sponsored by DOE and NIGEC and funded by a grant to Yale U.
This workshop was held as a result of Dr Massman's presentation on spectral corrections to eddy covariance flux measurements at the 3^{rd} annual AmeriFlux meeting (see B.4.a #22, D.1 #72). Dr Massman co-organized and co-chaired the workshop with Dr X Lee, led all sessions on methods of spectral corrections, co-ordinate rotation, and the workshop summary. Dr Massman was first author of a published paper, D.1 #76, summarizing and extending the discussions at workshop.

03 4^{th} Annual AmeriFlux meeting.
October 2000, Atlanta, GA; sponsored by DOE and NIGEC.
Dr Massman presented B.4.a #25 and led a discussion session on open path CO_2 sensors and the application of the Webb-Pearman-Leuning terms to the CO_2 fluxes measured with open-path trace gas sensors.

04 Ad hoc Expert Panel Meeting on Modelling of Ozone Flux and Deposition to Vegetation.
June 2002, Harrogate, UK; sponsored by UN/ECE Convention on Long-range Transboundary Air Pollution.
Attendance at this workshop was by invitation only. Dr Massman was invited to present a paper (B.4.a #32), summarizing his research and views on using measured and modeled ozone depositional fluxes and remote sensing for setting ozone standards to protect vegetation. Dr Massman's counsel was sought because he is one of five or fewer people in the US who are developing and testing the concepts for use in this area of research (D.1 #55, #63, #71, B.4.a #26, #31). A published paper (D.1 #81) outlines portions of his workshop presentation. During the meeting Dr Massman also contributed his advice on several aspects of ozone deposition modeling and subsequent to the meeting he has been sharing some of the CODE data for further analysis and model development. His ideas are being applied by the European Community for use in their model development (see page 18 of *Air Pollution and Vegetation*, UN/ECE ICP Vegetation Annual Report 2001/2002, Center for Ecology and Hydrology, University of Wales, Bangor, UK).

05 Workshop on Standardization of Flux Diagnostics and Analysis Guidelines.
August 2002, Corvallis, OR; sponsored by DOE and NIGEC and funded by a grant to Oregon State University.
This workshop was a direct result of the interest and success generated by the first workshop. Dr Massman co-organized the workshop with Drs X Lee and B Law and chaired the workshop. The workshop covered 8 different topics related to current issues regarding theory and practice of eddy covariance. Dr Massman and Mr R Clement were the invited speakers for the session on methods of spectral corrections. Dr Massman presented B.4.a #33. He is also the principal author of the workshop summary, D.1 #77, and contributed two chapters to the workshop book (D.1 #84, #85). One book chapter expands upon his presentation and the other covers some new ideas he developed as a result of issues raised at the workshop. Drs Lee, Massman, and Law edited the workshop book (D.1 #83).

06 6^{th} Annual AmeriFlux meeting.
October 2002, Boulder, CO; sponsored by DOE and NIGEC.
Dr Massman presented some of his new ideas about the application of spectral corrections and the Webb-Pearman-Leuning terms for open- and closed-path CO_2 sensors that were developed after, but as a result of, the second AmeriFlux workshop (#05 above). The workshop summary, D.1 #77, and a book chapter, D.1 #85, discuss his ideas. He also presented a separate paper (B.4.a #34) at the workshop.

07 Workshop on Measurement and Analysis of Soil CO_2 Fluxes.
October 2003, Boulder, CO; sponsored by DOE and NIGEC.
Dr Massman co-lead (with Dr Gene Takle) the discussion devoted to the effects of pressure pumping on CO_2 fluxes. He also presented B.4.a #36 above.

08 Measuring and modeling turbulent fluxes of heat, water, and carbon over snow.
December 2006, San Francisco, CA; Session C12A, AGU Annual Fall Meeting.
Dr Massman co-convened and co-chaired this session with Ms. Michele Reba. The session consisted of eight (2 Invited and 6 Offered) oral presentations.

09 Interaction between water vapor and tube walls for closed-path eddy covariance systems.
June 2007, Risø National Laboratory (Roskilde, Denmark), now part of the Technical University of Denmark; Dr Massman's participation was supported by ACCENT = Atmospheric Composition Change - The European Network of Excellence [http://www.accent-network.org].
(***i***) Dr Massman was invited by Dr Andreas Ibrom to visit the flux groups at Risø National Laboratory to discuss and jointly prepare a theoretical paper for publication on the interaction between water vapor molecules and the inside tube surface of closed-path eddy covariance sampling systems [CPECS] during turbulent tube flow. The inspiration for this joint effort came from Dr Massman's 1991 study of turbulent tube flow (D.1 #23) and from Dr Ibrom's observational study on the attenuation of water vapor fluctuations during turbulent tube flow [Ibrom *et al.* 2007: *Agricultural and Forest Meteorology* **147**, 140-156]. The workshop was called primarily on Dr Massman's behalf so as to take advantage of his proximity to Risø. Dr Massman participated in and contributed to all aspects of the

meeting. The team's efforts resulted in a mathematical model and physically realistic boundary conditions describing adsorption/desorption of water vapor molecules on the inside surface of a tube during turbulent tube flow. This study and the resulting paper (D.1 #103) are intended specifically to improve the utility of CPECS ET measurements.
(***ii***) Dr Massman was also invited to speak about his work with median filters, which he and John Frank (FS RMRS) have been applying to the processing of eddy covariance data and the supporting meteorological data. See seminars (2) and (3) above under **Professional activities and recognition: University Involvement**, B.3.b #02.

6. Significant Consultations and Collaborations:

N.B. Unless otherwise noted all consultations were face-to-face and lasted several hours or days.

01 Eddy covariance technology, instrumentation, and related CO_2 and H_2O flux issues

Dr J Moncrieff and Mr R Clement (now Dr R Clement)
Dept of Ecology and Resource Management, U of Edinburgh, Scotland, UK [6/02]
Consultations primarily involved methods of analyzing eddy covariance spectra and cospectra and Massman's method for spectral corrections of flux data (D.1 #72, #74). Also discussed were Dr Moncrieff's visual aides for his course on eddy covariance instrumentation and the goal and the presentations of the August 2002 AmeriFlux workshop (OSU, Corvallis, OR). Dr Massman's recommendations for analyzing cospectral data were followed and are included in a manuscript (D.1 #84). Dr Moncrieff included Dr Massman's suggestion in his course presentation. Dr Massman also reviewed R Clement's workshop talk to insure that their talks were coordinated and he also reviewed Dr Moncrieff's talk.

Dr J Ham
Professor, Kansas State University, Manhattan, KS [9/03: email and phone]
Presently: Professor, Colorado State University, Fort Collins, CO
Consultations involved questions concerning post-processing (QA/QC, noise detection, coordinate rotation, etc.) of high frequency eddy covariance data and spectral corrections to eddy covariance data in particular. The scientist supplied Dr Ham with some of his own computer code and guided Dr Ham toward other available software packages and discussed their merits with him. As a result of this consultation Dr Ham's understanding of these issues improved, he was able to satisfy his software needs and to implement the spectral corrections algorithms, and ultimately he was able to supply the final fluxes (for 5 Kansas prairie sites and 1 Kansas cedar forest site) to the AmeriFlux data base.

Dr D McDermitt (and micrometeorological and engineering staff)
Vice President LI-COR Corp, Lincoln, NE [1/97; 7/04-10/08: phone, email, and as an invited member of LI-COR's science advisory panel for the design of a prototype eddy covariance CH_4 sensor]
The first consultation concerned condensation of water vapor inside sampling tubes used for eddy covariance measurements of CO_2 fluxes. Dr Massman provided a synopsis of his Pawnee research experience with sampling tubes which ultimately was incorporated into a

report (and recommendations) by Dr McDermitt to the AmeriFlux group. The second consultation was a result of Dr Massman's experience with modeling, design, and performance of eddy covariance systems and instrumentation (see his presentations at the AmeriFlux workshops: B.5 #02, #03, #05, #06, and #07 above). As much as possible Dr Massman's advice on the measurement specifications and operating characteristics of such a sensor, particularly in regards to the importance of water vapor and the WPL terms, have to been incorporated in the final design of the instrument. Other consultations involved attenuation of temperature effects for closed-path eddy covariance systems and methods for reducing the contamination of the LI-COR 7500 signal by self-heating effects. Dr Massman provided data sources for testing hypotheses, literature citations, and insights into the relevant scientific issues involved. The instrument's self-heating effects were satisfactorily resolved and Dr Massman is acknowledged for his contributions by Burba *et al.* (2008; *Global Change Biology* **14**: 1854-1876).

Dr J Prueger
Soil Scientist, USDA National Soil Tilth Lab, Ames, IA [8/04, 1/06, 1/07: in person, email, and phone]
Consultations involved Fast-Fourier Transform techniques, the interpretation of the eddy covariance spectra and cospectra (including the WPL effects), and how to separate and assess atmospheric dynamical effects from sensor performance problems contained within eddy covariance spectra and cospectra. Dr Massman clarified many of these issues for Dr Prueger, outlined the appropriate next steps for his data analysis, and enhanced Dr Prueger's knowledge and usage of atmospheric spectral and cospectral techniques.

Dr R Dahlman
Program Manager, Carbon Cycle Research, DOE, Washington, DC [3 days during 5-6/06]
Dr Massman was invited to the DOE's Terrestrial Carbon Processes Review, where he participated in the discussion and evaluation of about 120 proposals for the DOE's funding program for many AmeriFlux projects and sites. The scientist's comments proved critical for several difficult decisions.

Dr H Loescher
NEON Sensor Systems Scientist, NEON Inc, Boulder, CO [3 days during 8-10/08]
Dr Massman was invited by CU-Boulder and the RMRS director's executive team to participate in NEON's field site visit to Niwot Ridge (also see invited talk B.4.a #43). The scientist's opinion was sought concerning the placement of an eddy covariance flux tower at the Niwot Ridge LTER site and the best instrumentation for measuring high-frequency static atmospheric pressure fluctuations. The scientist did assist in identifying a suitable site and arranged a meeting at NCAR to examine the recommended pressure sensor. The pressure sensor is expected to become part of NEON's eddy covariance instrumentation package. [N.B. The National Ecological Observatory Network (NEON) is a continental-scale research platform for discovering and understanding the impacts of climate change, land-use change, and invasive species on ecology. See http://neoninc.org/about-neon/overview.html for further details concerning NEON.]

02 Modeling evapotranspiration

Dr K Tu
Dept of Integrative Biology, U of California, Berkeley, CA [10/06, 5/07: email and phone]
Dr Tu requested advice for developing a dual-source ET model fashioned after the scientist's own dual-source model (see D.1 #27, #36 and C. Scientific Accomplishments and Contributions **#04**) as well as possible data sources for validating such a model. (Such data are rare because they must include independent and concurrent estimates of both soil evaporation and plant transpiration). Dr Massman supplied the cotton data he used with D.1 #36 and suggested other possible data sources based on isotopic fractionation of water vapor to partition E and T. This consultation is ongoing and has resulted in a remote sensing version of a dual-source ET model and an accompanying presentation, B.4.b #64.

Dr L Joyce
FS RMRS, Range Scientist, Fort Collins, CO [7/07]
Consultations concerned methods of estimating Potential Evapotranspiration (PET) and application and utility of PET to climate modeling. Dr Massman assisted in identifying and locating climatologically-derived maps of PET for the continental US and discussed how they might be used for climate modeling.

03 Measuring and modeling dry deposition of ozone

Mr J Pederson
California Air Resources Board, Sacramento, CA [5/91 - 6/98: by phone, email, in person; occasionally by phone since 1998]
In May of 1991 Dr Massman was invited by J Pederson of the California Air Resources Board (CARB) to be the Technical Principal Investigator for CODE, a significant component of the San Joaquin Valley Air Quality Study (SJVAQS). Dr Massman's role was to lead the (international) science team in obtaining and analyzing ozone deposition measurements and to make recommendations for modeling ozone deposition for an air quality model being developed at that time by the CARB. In addition to these technical duties Dr Massman was also instrumental in expanding the science team to include a vegetation researcher (Dr D Grantz, plant physiologist, UC-Riverside) and an aircraft eddy covariance specialist (Dr L Mahrt, atmospheric scientist, OSU, Corvallis). The scientist also assisted with the installation of the three eddy covariance flux tower sites. Dr Massman's efforts and recommendations helped insure that the SJVAQS was one of the most widely published and successful ozone deposition experiments in the history of ozone research (see Section E. Special Circumstances for more details on Dr Massman's role in the CODE and the SJVAQS and his resulting publications). Since the completion of the CODE in 1998 Dr Massman has also been contacted by J Pederson on many occasions concerning possible measurements and modeling approaches for estimating ozone deposition. Where possible Dr Massman's suggestions have been used by J Pederson in his research efforts at the CARB.

Dr JS Touma
US EPA, Research Triangle Park, NC [5 days during 5/01 - 9/01: phone and email]
Dr Massman was requested by EPA to participate in the scientific review of the document *Deposition Parameterization for the Industrial Source Complex (ISC3) Model*, a report developed for EPA by Argonne National Labs to describe and update the improvements of algorithms used to estimate wet and dry deposition in the ISC3 model system. Dr Massman provided his expertise, insights, and pertinent comments on the document and the supporting computer code. Model merits and deficiencies were documented. Dr Massman's recommendations were incorporated into the model.

Dr Jay Garner
US EPA, Research Triangle Park, NC [3/03-9/03: email, phone, and a 2 day workshop in Durham, NC during 4/03]
EPA (Dr Garner) invited the scientist to participate in the writing and reviewing of EPA's *Ambient Ozone Air Quality Criteria Document*, which EPA is required by law to produce every 5 years. This document is intended to summarize, synthesize, and update the state of scientific knowledge on all key issues involving national air quality. Dr Massman was consulted as a result of his ideas and his modeling of plant defense to ozone uptake (D.1 #81). The scientist co-authored the section of the *Ambient Ozone Air Quality Criteria Document* on effects-based air quality exposure- and dose-response indices (D.6 a) and a related peer reviewed paper (D.1 #92).

Dr L Emberson
Stockholm Environment Institute, York, UK [7/03-8/04: email and working 1 week in York, UK with Dr Emberson and colleagues during 9/03 and again in 7/04]
Dr Massman was invited to collaborate with Dr Emberson on the development of an ozone deposition model for use in the United Nations Economic Commission for Europe convention on Long-Range Transboundary Air Pollution (UN/ECE LRTAP). The immediate goal of Dr Emberson's research, which was partly inspired by Dr Massman's work, is to evaluate a number of stomatal conductance models for their suitability in regional scale modeling of ozone deposition. Dr Massman provided his expertise and knowledge of ozone deposition. He made the CODE data (see E. Special Circumstances) available for parameterizing the stomatal conductance of vineyards and for model validation studies. He assisted in the interpretation of the CODE data and proposed a new model to describe stomatal response to light, which was tested by Dr Emberson and colleagues at SEI with the CODE vineyard stomatal conductance data and other leaf-level gas exchange data obtained from the published literature. The new model was shown to be superior to more commonly used models. The new light response function is discussed in *Development and application of methods for modeling and mapping ozone deposition and stomatal flux*, EPG/1/3/173 (Emberson, 2004: the Final Report to the UK's Department of Environment, Food, and Regional Affairs). Dr Massman was helpful in identifying and obtaining other ozone flux and stomatal data sets for testing new model parameterizations of ozone stomatal uptake. He also provided, interpreted, and coded some of the Fortran code of the LEAFC3 model, a photosynthetic-based stomatal conductance model (see D.1 #41), for

comparison testing. This consultation is a result of the association begun with his invited talk, B.4.a #32, given in 2002 at the UN/ECE Ad-hoc Expert Panel Meeting on Modelling and Mapping Ozone Flux and Deposition to Vegetation, and has so far resulted in two presentations (B.4.b #59, #60) and three published papers (D.1 #89, #90, #99).

Dr D Helmig
Research Faculty, INSTAAR, U of Colorado, Boulder, CO [2/06, 10/07]
(***i***) [2/06] Dr Helmig sought the scientist's opinion concerning pressure pumping and snow chemistry effects on observations of snowpack interstitial ozone at Niwot Ridge, Colorado [Bocquet *et al.* 2007: *Arctic, Antarctic, and Alpine Research* **39**, 375-387].
(***ii***) [10/07] Dr Helmig invited the scientist to review of the Boulder/Front Range Ozone Monitoring System. Dr Massman participated in the review and suggested improvements to the monitoring system and explored ways that the Forest Service and CU-Boulder might cooperate in monitoring ozone along the Front Range of Colorado. He also outlined how his pressure pumping model (D.1 #95 and #96) could be used to assess the influence of pressure pumping on the snowpack trace gas observations.

04 Concerning soils: heat flow, trace gas transport, and fire related effects

Prof E Takle
Iowa State U, International Inst of Theor and Appl Physics, Ames, IA [8/97 and 10/97]
Consultations involved discussions of pressure pumping effects caused by shelter belts. Dr Massman suggested that shelter belts could produce standing pressure waves which would influence gas exchange. After the initial meeting Dr Massman was asked to check calculations of the magnitude of the induced Darcian pressure velocity and to advise Prof Takle concerning the basic physics of pressure pumping. These consultations have led to an invitation to a workshop (B.5 #01), a successfully funded pressure pumping experiment, and several collaborative papers (B.4.b #44, D.1 #73, #78, #82).

Dr W Reiners, P Polzer, and K Driese
U of Wyoming, Laramie, WY [5/00 and 1/01: phone and email]
Consultations basically involved permission and use of Dr Massman's snow diffusion transport model (D.1 #42, #53, #59) as part of the book *Propagation of Ecological Influences across Landscapes*. Dr Massman provided the model, discussed the basic underlying physics of the model, and reviewed the book chapter that discussed his model. The model has been successfully incorporated into the book and can be used interactively as a study guide on molecular diffusion.

Dr D Bowling
U of Utah, Salt Lake City, UT [2/07-present: in person and email]
Consultations involved designing and implementing an undersnow CO_2 experiment focused on $^{12}CO_2$ and $^{13}CO_2$ using a tunable diode laser and interpreting the data from this experiment, particularly in regards to pressure pumping effects and the isotopic fractionation due to the combined effects of pressure pumping and diffusion. Dr Massman developed an analytical approach (model) specifically designed to address this question.

This collaborative effort is ongoing and to date has resulted in one talk (B.4.b #69) and an associated paper (D.1 #104).

Dr M Williams (and CU-Boulder PhD student Brian Seok)
Professor, INSTAAR, U of Colorado, Boulder, CO [1/08-present: in person and email]
(By invitation) Dr Massman toured the Soddie site subnivean shelter at Niwot Ridge and commented on the undersnow CO_2 sampling system at this site. He presently is guiding Brian Seok in the analysis and interpretation of the undersnow CO_2 data from this site and from a similar site in Michigan, which uses a similar sampling system.

05 Concerning one or more related areas of expertise

Prof S Verma (and students)
U of Nebraska, Lincoln, NE [several occasions 8/90 through 4/91]
Consultations were a direct result of Dr Massman's work on attenuation of concentration fluctuations by turbulent tube flow (D.1 #23). Dr Massman's advice was sought on the design and implementation of an closed path eddy covariance system for CO_2 flux measurements. Dr Massman was also requested to review a manuscript (1993; *Boundary-Layer Meteorology* **64**: 391-407) prepared by Prof Verma and his students where some of Dr Massman's modeling work was tested. Subsequent consultations have taken place with Prof Verma's students and post-doctoral associates concerning Dr Massman's physically-based methods of partitioning eddy covariance ET measurements into plant and soil components (D.1 #27, #36).

Dr Z (Bob) Su
Wageningen U and Research Centre, Wageningen, The Netherlands [12/99]
Consultations involved adapting Dr Massman's model of bulk boundary layer effects (B.4.a #23, D.1 #70) to large scale global models. Dr Massman shared all his personal notes detailing model development and helped re-parameterize his model as necessary for implementing into the surface submodel of the global model. This collaboration resulted in a jointly authored publication (D.1 #75), which documents to adapted model's development and performance.

Dr G Wohlfahrt
University of Innsbruck, Innsbruck, Austria [most recent 3/07: email and in person]
Over the past 5 years or so, Dr Wohlfahrt has sought the scientist's advice on subjects ranging from Fourier Transforms and cospectra, pressure pumping effects on CO_2 fluxes, and open- and closed-path eddy covariance (EC) systems. Most recently Dr Massman's insights were sought concerning nighttime CO_2 fluxes from the Mojave desert obtained with both types of EC systems. The measured fluxes were quite small and indicated CO_2 uptake at night, which was not possible at this particular site (because there were no CAM plants). Dr Massman suggested several issues that could influence the sign of the fluxes, which Dr Wohlfahrt explored.

Dr A Guenther (and colleagues)
National Center for Atmospheric Research, Atmospheric Chemistry Division, Boulder, CO
[10/06, 9/07-present: email, phone, and in person]
In 2006 a group of university and NCAR scientists began developing the BEACHON project to study the impact of biogenic aerosols on clouds and precipitation, focusing especially on the links and feedbacks to the carbon, nitrogen, and water cycles (see Factor 1.B for more details). The scientist's input was sought by Dr Guenther and colleagues both as a representative of Mantiou Experimental Forest (MEF), considered a possible BEACHON site at the time, and as a scientist who could contribute to the BEACHON scientific effort. The scientist and Dr W Shepperd lead a field trip of a group NCAR scientists on a scoping visit to MEF in October of 2006. About a year later the scientist was invited to the first BEACHON workshop for which he was requested to write (and wrote) a two page response to the draft BEACHON white paper, which included (*i*) his ideas of how the overall project might move the white paper concepts toward a feasible research plan and (*ii*) outlined a research program defining how the scientist could uniquely contribution to the BEACHON project. The scientist's response is available on NCAR's BEACHON wiki site. In 2008 MEF was chosen as the BEACHON site. This collaboration is ongoing and has developed into an cooperative research effort between the scientists and other NCAR scientists, which so far is focused on improving measurements of soil heat flux and investigating trace gas transport in soils.

7. Scientific Exchanges:

01 Dr Massman (with the support of the RMRS) hosted Dr David Bowling [Dept of Biology, U of Utah; Salt Lake City, Utah] for a month of sabbatical leave for the month November 2009. The sabbatical was competitive within the University of Utah and awarded in February 2009. The sabbatical was used to further the collaboration with Dr Massman on transport of trace gases through snowpacks using wintertime CO_2 isotope data (D.1 #104) to test and enhance Dr Massman's pressure pumping model (D.1 #95, #96). Results of this collaboration are documented in two presentations (B.4.b #89 and #91) and a peer-reviewed publication (D.1 #113). This joint research is the first to unambiguously document and quantify that variations in atmospheric wind and pressure systematically and perpetually enhance diffusional CO_2 fluxes (by about 10%). This implies there is a need to reconsider current model formulations of soil respiration and carbon cycling to include this abiotic forcing of soil CO_2 fluxes.

02 Dr Massman was awarded a Distinguished Visiting Scientist position with the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia's national science agency and one of the largest and most diverse research agencies in the world. This award, which is made annually and is competitive across all scientific disciplines within CSIRO, provides support for five distinguished scientists for up to a year to work collaboratively with CSIRO scientists. Dr Massman's award was predicated on "His great expertise in the physics of transport processes in the atmosphere as applied to instrumentation and measurements". During his tenure (late May through early September 2010) Dr Massman worked with the Land-Atmosphere Interactions team of CSIRO's Marine and Atmospheric Research Division in Canberra on micrometeorological issues involving, soil heat flow, surface energy balance, application of the WPL to eddy covariance data, and numerical methods for global climate models. This collaboration was primarily with Dr Ray Leuning and resulted in co-authorship with Dr Leuning on two papers (D.1 #114 and #115). In addition, Dr Massman also gave an invited talk (B.4.a #45a above) on his fire and soils research, continued preparation of a peer-reviewed publication (D.1 #112), wrote one extended abstract (D.1 #110), and co-authored another extended abstract (D.1 #109).

03 Dr Massman (with the support of the RMRS) hosted Dr Ray Leuning (Chief Research Scientist, CSIRO Marine and Atmospheric Research, Canberra Australia) for a one week visit during July 2011 to continue some of their work that had begun when Dr Massman was at CSIRO in 2010, which included issues involving surface energy balance and sonic anemometry for application to eddy covariance measurements of heat, moisture, and CO_2 fluxes and the application of the WPL to eddy covariance data. Publications D.1 #114 and #115 and the related presentations B.4a #47 (invited) and B.4b #109 (offered) document Massman and Leuning's joint efforts.

C. Scientific Accomplishments and Contributions

N.B. All accomplishments in scientific areas in which the scientist is not presently working are denoted by **I** (Inactive). Otherwise they are active. All accomplishments before the last promotion (i.e., above the double line) have been expanded and updated (as of September 2012) with any new material since the last promotion. Accomplishments since last promotion (below the double line) are (a) new accomplishments (#**08**), (b) references to previous discussion above the double line (#**01**, #**02**), or (c) elaborations on the emerging aspects of the scientist's current or previous research (#**03**, #**04**, #**05**, #**06**, #**07**).

01 ***Atmospheric Gravity Waves*** [**I**]: Atmospheric gravity waves (which can be thought of as similar to ocean waves or ripples on the surface of ponds or lakes) are an important component of stratospheric dynamics and the scientist's pioneered the study of stratospheric gravity waves using instrumented constant level balloons. This work, not only demonstrated the potential that instrumented constant level balloons have as research tools for global investigations of atmospheric gravity waves, but (within just the past 5 years or so) has also helped (*i*) clarify the role of atmospheric gravity waves in polar stratospheric ozone chemistry, (*ii*) improve model parameterizations of the structure of the winter jets and horizontal temperature gradients near the tropopause, and (*iii*) improve simulations of surface wind distributions in weather-forecasting models. Scientific users of this research (25+ years ago) included Dr O Talagrand, Laboratoire de Météorologie Dynamique Du CNRS, Ecole Supérieure, Paris, France and Dr D Cadet, Dept of Meteorology, Florida State University, Tallahassee, FL. Dr Massman's research results, documented in his thesis (D.1 #03), a final technical report (D.1 #04), an NCAR Technical Note (D.1 #07) and six peer-reviewed papers (D.1 #01, #02, #05, #06, #09, #10), have assisted in the design of subsequent balloon-borne instrument packages and the interpretation of data from subsequent atmospheric balloon experiments. This research, completed in 1981, continues to be cited: e.g., Vincent *et al.* (2007; Geophysical Research Letters **34**: paper no. L19804); Boccara *et al.* (2008; Journal Atmospheric Sciences **65**: 3042-3055); Alexander *et al.* (2010; Quarterly Journal Royal Meteorological Society **136**: 1103-1124). **Knowledge Discovery**

02 ***Rainfall Interception*** [**I**]: Interception of rainfall by foliage is an important component of the hydrological balance of forests and the scientist's work in this area better defined the physical principles involved in this process. Dr Massman derived a physically-based model of the interception loss to forests which contained essentially no empirical constants (D.1 #12, in particular, and D.1 #08). This work on interception was a major reason why the scientist was awarded a National Research Council Senior Postdoctoral Fellowship at NASA/Goddard Space Flight Center. His work on interception also formed the basis of a 1996 MS thesis (CSU, Civil Engineering, under Dr J Ramirez, 970-491-7621), in which a statistical model of rainfall interception by plant canopies was developed. This more recent model, discussed by Ramirez and Sunrath (2000; *Journal of Climate* **13**: 4050-4063), was a significant advance in the ability of Global Circulation Models to represent rainfall interception by plant canopies and should have wide applicability in interception studies of all types. Dr N Nikolov (USDA Forest Service, Rocky Mountain Research Station, 970-980-3303) has used Dr Massman's interception model for parameterizing interception in his own atmosphere/biosphere modeling efforts. The scientist's work in this area has been cited 118 publications, 15 of which have occurred since 2008. **Knowledge Discovery**

3** ***Canopy Turbulence and Canopy Structure: Canopy structure is a key determinant in many aspects of the interactions between the atmosphere and the biosphere and has been a continuing theme in Dr Massman's research. His contributions in this area of research include the development of simple, realistic models of (vertical) foliage structure (D.1 #11) and its influence on the canopy roughness length (D.1 #13, #56), canopy-generated turbulence (D.1 #66), and bulk boundary-layer resistance to heat and mass transfer (D.1 #14, #17, #51, #52, #70, #75). Ultimately, these studies continue to be motivated by a need to find simple, practical and realistic methods to parameterize within-canopy turbulence, to parameterize plant/atmosphere exchange, and to scale this information from the leaf level to the level of a canopy or stand. To date Dr Massman's physically-based modeling efforts have shown that foliage structure is important to surface roughness, heat and mass exchange, and canopy turbulence, but in general this is an open-ended problem that the scientist is still investigating. The first 1982 foliage distribution paper, D.1 #11, has been cited 47 times since publication, about half of which have occurred in the last 6 years. It has found application in studies of sound propagation through plant canopies, statistics, forest ecology, and the plant-atmosphere exchange. Dr T Meyers (NOAA/ATDD, Oak Ridge, TN 423-576-1245) has used the some of the models of plant foliage distribution developed in D.1 #11 (1998; *Journal Geophysical Research- Atmospheres* **103**: 22645-22661). Dr J Norman (U of Wisconsin-Madison, 608-262-4576) has used Dr Massman's research (D.1 #52, #56) on this subject for his own modeling efforts. Dr G Wohlfahrt (U Innsbruck, ++43/512/507/5917, Georg.Wohlfahrt@uibk.ac.at) has directly implemented Dr Massman's analytical momentum transfer model (D.1 #56) for his own studies of a mountain meadow canopy (2002; *Boundary-Layer Meteorology* **103**: 391-407). **Knowledge Discovery**

04 ***Evapotranspiration (ET): Partitioning E and T and Canopy Conductance*** [**I**]: For Penman-Monteith-like bulk canopy exchange models the state-of-the-science in modeling ET and the exchange of the heat and trace gases is the dual source model which models soil and plant components separately. Dr Massman's work in this area is a major advance in the development of the dual source model and its ability to provide insight into the nature of the exchange processes. The value of Dr Massman's modeling approach is that it can be used diagnostically to partition ET into plant and soil components and to provide in situ estimates of the canopy and soil conductances to water vapor, ozone and other gases. As such Dr Massman's approach can be used to study both plant and soil components as a coupled system. His work in this area is documented in three peer-reviewed publications (D.1 #27, #31, #36). Dr Massman's dual-source ozone paper (D.1 #31) has been cited 27 times since it publication and 11 times during the last 6 years. His dual-source ET papers (D.1 #27, #36) have been cited 19 times during the last 6 years by scientists working in ET and partial canopy studies. D.1 #27 has been cited 52 times since its publication in 1992. Some of the ideas developed in these studies have inspired other researchers (e.g., Dr J

Ham, Kansas State University, 913-532-5731; Dr AFG Jacobs, Agricultural University, Wageningen, The Netherlands) and have been applied to a variety of different ecosystems (e.g., Dr J Kim, Yonsei University, Seoul, South Korea; Dr S Verma, U of Nebraska, 402-472-6702; Dr T Meyers, NOAA/ATDD, Oak Ridge, TN 423-576-1245). Dr S Cieslik (Joint Research Centre, Ispra, Italy, +39/332/789/567, stanislaw.cieslik@jrc.it) in 2002 commented to Dr Massman that his method for partitioning ozone fluxes into plant and soil components is the only method available for diagnostically performing this partitioning and that Dr Cieslik has used the method himself (Cieslik and Labatut 1997; *Atmospheric Environment* **31**: 177-184). **Knowledge Discovery**

5** ***Eddy Covariance Technology, Surface Energy Balance: The energy balance of the earth's surface has been and remains one of the key focus areas of micrometeorology. This is a very broad cross-disciplinary research area requiring specialized knowledge of (among others) eddy covariance instrumentation and technology, turbulent atmospheric transport, instrumentation for measuring soil heat flux and soil temperatures, and knowledge of soil physics. In the area of soil heat flux/soil physics, Dr Massman has three peer-reviewed papers on soil properties and the measurement of soil heat flux (D.1 #26, #30, #33). In the last of these papers he discusses a previously unidentified problem with the measurement of soil heat flux. Combined these three papers have been cited 14 times in the past 6 years. Most recently Dr Massman has made some significant contributions to soil physics and the science of soil heat flux with his investigations of the impact fires can have on soils (see #**08**). Dr Massman has also contributed significantly to the development of eddy covariance technology, which is the gold-standard method for measuring the exchange rates (fluxes) of momentum, energy and trace gases between the atmosphere and the biosphere. In D.1 #15 the scientist proposed a simple, but novel, method for correcting the non-cosine response to the Gill propeller anemometer for use with eddy covariance flux measurements. He has also developed other novel analytical/computational methods for correcting for eddy covariance sensor design and separation effects (D.1 #16, #19, #72, #74). Dr Massman's work on the attenuation of concentration fluctuations in tubes (D.1 #23) and his ideas concerning the application of the Webb-Pearman-Leuning term and spectral corrections (D.1 #77) are significant advances in the theory and application of closed path sensors used for some eddy covariance trace gas flux measurements. His tube flow paper, D.1 #23, has been cited 48 times since it publication and 21 times in the last 6 years. His standing within the eddy covariance scientific community led to his being asked to lead two international AmeriFlux workshops (2000 and 2004) and to the development of new analyses and insights into the theory of eddy covariance and their implications to CO_2 fluxes measured with eddy covariance (D.1 #76, #77). Users of these various results include many of the AmeriFlux and the global FLUXNET communities, including Dr S Verma, U of Nebraska, 402-472-6702; Dr D Hollinger USDA FS NE Station, Durham, NH, 603-868-7673; Dr J Moncrieff, U of Edinburgh, j.moncrieff@ed.ac.uk; Dr A Black, U of British Columbia, 604-822-2730, ablack@unixg.ubc.ca; Dr L Mahrt, OSU, 541-737-5691, mahrt@oce.orst.edu). **Knowledge Discovery/Knowledge Development**

6** ***Ozone Deposition **[I]**: The scientist's work on modeling and measurement of ozone deposition is recognized nationally and internationally. As an Associate Technical Principal Investigator for the largest and most complex ozone deposition experiment ever attempted (CODE, 1991), Dr Massman made significant advances in the interpretation of ozone flux data and the quantifying and modeling of ozone uptake by plants and soils. His contributions in the area of ozone deposition include quantifying wetness effects on ozone uptake by plant and soil surfaces (D.1 #37, #50, #55, #58), development of new model parameterizations of canopy stomatal uptake of ozone (D.1 #22, #31, #35, #41, #54), the development and testing of new models of ozone deposition (D.1 #37, #38, #40), the first-of-its-kind application of aircraft observations to the estimation of surface conductance to ozone (D.1 #49), the development and evaluation of NO-NO_2-O_3 photochemical models and their supporting data (D.1 #32, #46, #62), the first-of-its-kind study to use eddy covariance ozone flux data to diagnose possible ozone stress in a field-grown crops (D.1 #45), and studies of the influence of turbulent structures within the surface layer on ozone fluxes and ozone deposition (D.1 #65, #68, #69). Just prior to his last promotion, Dr Massman had begun to develop concepts and models for defining ozone standards to protect vegetation that are based on ozone flux or dose rather than on ozone concentration or exposure (D.1 #63), which has continued since his last promotion (see the continuation of this discussion, #**06**, below). His work in the area of ozone standards coupled with his experience in the measurement and modeling of ozone deposition has so far culminated in three invited papers on protecting vegetation from ozone using a combination of models, flux based ozone standards, and remote sensing techniques (B.4.a #26, #31, #32). The scientist's recommendations for modeling ozone deposition have been incorporated into a state-of-the-science regional-scale photochemical model developed for application to California (Mr J Pederson, California Air Resources Board, 916-322-7221). Dr Massman has also contributed to the development of the European Union's model of ozone deposition (Dr L Emberson, University of York, +44/1904/432/925, lde1@york.ac.uk). The scientist has also advised Dr J Padro (Atmospheric Environment Service, Canada, retired) and Dr K Pilegaard (Risø National Laboratory, +45/4677/4175, k.pilegaard@risoe.dk) about parameterization of resistances to ozone deposition. Dr Massman's 12 peer reviewed publications on ozone (D.1 #31, #32, #37, #38, #40, #45, #48, #49, #50, #58, #62, #63) have been cited 271 times in total and 130 in the past 6 years. His ozone related stomatal conductance papers (D.1 #22, #41) have been cited 76 times in total and 36 times in the last 6 years. **Knowledge Discovery/Knowledge Development/Modeling and Systems Integration**

07 ***Gas Transport through Soils and Snowpacks***: The movement of trace gases between soils and snowpacks and the atmosphere is largely controlled by molecular diffusion and by advective air currents that are forced in and out of these porous media by variations in pressure at the top surface. This second phenomena is termed pressure pumping. The scientist's studies relating to molecular diffusion (D.1 #53, #61, #64) have helped quantify the diffusional fluxes of trace gases through snowpacks, soils, and even stomatal openings. The scientist's contributions to pressure pumping (D.1 #42, #59) include the measurements of high frequency turbulent atmospheric pressure fluctuations in complex terrain, quantitative assessment of the importance of pressure pumping through snowpacks, verification of simpler techniques for estimating rates of diffusion through snowpacks, outlining importance of snow physical properties to the quantitative estimation of soil CO_2 production in soils in winter. The main findings of these pressure pumping studies is that turbulent atmospheric pressure pumping can have a short term effect on the exchange of trace gases by soil or snowpacks, but may be relatively small in the long term. But as the second paper (D.1 #59) points out, the modeling formulations for virtually all pressure pumping studies to date may actually be incorrect. Consequently the scientist is actively continuing to his research to develop appropriate model equations to describe the effects of pressure pumping (see post-promotion discussion #**07** below). His three papers on the transport of CO_2 through snowpacks (D.1 #42, #53, #59) have been cited 104 times in total and 63 times in the past 6 years. His molecular diffusivity papers (D.1 #61, #64) have been cited 87 times in total and 70 times during the past 6 years. Some of the users of Dr Massman's researches include Dr P Brooks, U of Arizona, 520-621-3424; Dr J Fahnestock, North Wind Inc, 208-557-7887; Dr M Jones, U of Wyoming, 307-766-5470; Dr E Takle, Iowa State U, 515-294-9871; Dr T Gilmanov, South Dakota State U, 605-688-4295. **Knowledge Discovery**

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00 ***Brief statement concerning the impact of the scientist's publications***:
The scientist has 39 peer-reviewed journal publications that have received more than 20 citations each, which according to *Essential Science Indicators*^{SM} puts each of them within the top 1% of papers cited in the scientist's discipline of micrometeorology. The total number of citations these 39 papers have received now exceeds 2800, most of which occurring in the past 5 years. To date the total number of citations the scientist's first 72 (of 77) peer-reviewed publications and 5 book chapters have received exceeds 3200. The scientist's h-index is 29, which is extremely high for micrometeorologist, making the scientist one of the most (if not the most) cited micrometeorologists in the world. [Note: These enumerations were obtained primarily from Google Scholar, and secondarily from Scopus and the Science Citation Index (Web of Science).]

01 ***Atmospheric Gravity Waves***: Dr Massman's studies are still being cited (see #**01** above the double line).

02 ***Rainfall Interception***: Dr Massman's studies are still being cited and used (see #**02** above the double line).

3** ***Canopy Turbulence and Canopy Structure: The scientist's work here prior to his last promotion (8/98) was the basis of a model developed by Dr G Wohlfahrt (referenced above). Since 8/98 the scientist has concentrated on three different applications of his canopy-atmosphere interaction research.

(***i***) Developing methods of scaling bulk (aerodynamic and turbulence) transfer quantities between bare soil on one hand and full canopy cover on the other (D.1 #66, B.4.a #23, D.1 #70). This problem is of great importance to surface energy balance and heat flux parameterizations for use in global circulation models because of the difficulty in dealing with surfaces of partial canopy cover. In general terms, this difficulty arises because turbulence driving the transfer between the atmosphere and the surface is strongly influenced by the canopy structure (foliage distribution), foliage density (leaf area index), and soil heating. Consequently, the intermediate case of partial canopy cover combines aspects of soil as the dominant heat source with the canopy as the main source of turbulence. Dr Massman's work on this scientific problem (D.1 #70, Eqn 24) is the first relatively simple model to capture the full variation of the bulk transfer quantities between bare soil and complete canopy cover. The scientist's models have been adapted by Dr R Su (D.1 #75) for possible application to remote sensing and global modeling studies. In addition, Dr Massman's 1997 turbulence model (D.1 #56, #66) has found significant application to dispersion modeling (e.g., spore dispersal in forest canopies) and Lagrangian canopies models (for inferring the distribution of sources and sinks of CO_2 and water vapor from mass concentration profiles within the canopy). Combined these two papers have been cited 102 times since publication and 91 times in the past 6 years. **Knowledge Development/Modeling and Systems Integration**

(***ii***) Participating in the development of an integrated microwave radiometry-turbulence model for sparse vegetation (B.4.a #41 and B.4.b #58) with Dr Mostafa Karam (Northrop Grumman, Woodland Hills, CA; mostafa.karam@ngc.com) and researchers at CNR-Institute of Applied Physics (Firenze, Italy). This is a very unusual and unique application of Dr Massman's turbulence model that has the promise of being a major advance in microwave radiometry science. The new integrated model can address (heretofore unapproachable) issues concerning how microwave radiometer data and sensor performance are influenced by sparse vegetation, canopy turbulence, and atmospheric forcing (surface heat flux). Ultimately this research is expected to lead to entirely new remote sensing products such as vegetation water stress and vapor pressure deficit. **Knowledge Discovery/Knowledge Development/Modeling and Systems Integration**

(***iii***) Assisting Ryan Knox (graduate student, MIT) implement my 1997/1999 canopy turbulence model (D.1 #56 and #66) into the Ecosystem Demography Model 2 [see Medvigy, D, SC Wofsy, JW Munger, DY Hollinger, and PR Moorcroft. 2009. *Mechanistic scaling of ecosystem function and dynamics in space and time: Ecosystem Demography model version 2.* J Geophysical Research **114**, G01002, doi:10.1029/2008JG000812.] **Knowledge Discovery/Knowledge Development/Modeling and Systems Integration**

04 ***Evapotranspiration (ET): Partitioning E and T and Canopy Conductance***: As noted in #**04** above the double line, Dr Massman's studies continue to be cited and used. But in 2006 Dr Massman was asked to assist Dr Kevin Tu (UC-Berkeley) to develop a dual-source model for partitioning ET between plants and soils along the lines of Dr Massman's model (D.1 #27, #36) for application to remote sensing (B.4.b #64).

Furthermore very recent developments in the use of isotopes of water also appear to make it possible to partition ET flux data between plants and soils, thereby creating renewed interest in (and ability to validate) Massman-type (surface energy balance) dual-source ET models.

5** ***Eddy Covariance Technology, Surface Energy Balance: Between 8/98 and 2004 the scientist worked with the AmeriFlux network to develop guidelines for measuring and evaluating the quality of CO_2 fluxes with eddy covariance technology. This effort began in 1999 with the 3^{rd} annual AmeriFlux meeting (B.4.a #22 and D.1 #72) at which the scientist spoke on his analytical method for making spectral corrections to eddy covariance flux data. The ensuing discussions then surfaced more general concerns about how uniformly eddy covariance methods were applied across the network and what are the uncertainties inherent in making cross site (and worldwide) comparisons of CO_2 fluxes. These issues must be addressed in order to accurately determine the magnitudes of the terrestrial carbon sink. As a result of the 1999 AmeriFlux meeting the scientist has contributed significant leadership and scientific insights to the AmeriFlux and the (worldwide) FLUXNET communities, including co-organizing and chairing two workshops addressing the site comparison issues (B.5 #02, #05), co-editing *Handbook of Micrometeorology: A Guide to Surface Flux Measurement and Analysis* (D.1 #83), writing 5 papers (D.1 #76, #77, #84, #85, #94), two of which (D.1 # 84, #85) appear in the *Handbook of Micrometeorology: ...*, and contributing to a sixth (D.1 #93), giving the keynote address at the European ACCENT-BIAFLUX workshop (B.4.a #39), and delivering a series of 5 lectures to an international audience on eddy covariance and surface energy balance (B.3.b #02). Dr Massman's personal scientific efforts have contributed to: (a) the fundamental theory and practice of eddy covariance, (b) correction methods for spectral attenuation caused by signal processing, instrument design and finite response times, (c) the development of fundamental principles of closed-path eddy covariance systems (B.5 #09, D.1 #103), and (d) the theory of the Webb-Pearman-Leuning (density-related) terms for open- and closed-path eddy covariance instruments. This last effort yielded a particularly significant result to the theory and practice of eddy covariance (D.1 #77, #85). To date Dr Massman's spectral corrections papers (D.1 #72, #74) have received 82 citations, of which 64 were in the last 6 years. His 2002 paper on the fundamentals of eddy covariance (D.1 #76) has been cited 149 times to date, and the *Handbook of Micrometeorology: A Guide to Surface Flux Measurement and Analysis* sold about 1100 copies between 2004 and 2011 (more recent sales information is not currently available). **Knowledge Discovery/Knowledge Development**

6** ***Ozone Deposition: Since 8/98 Dr Massman has expanded his ozone research to include issues involving ozone standards for protecting vegetation based on effective dose, measured ozone fluxes, and remote sensing (D.1 #63, #71, #81, #91, #92) and collaboration with Drs Lisa Emberson and Patrick Büker (both at Stockholm Environment Institute; York, UK) on comparing different models of plant ozone uptake (D.1 #89, #90, #99). Much of the scientist's efforts in this area evolved from his work for the California Air Resources Board (see D.1 #55 and the second paragraph under E. Special Circumstances). This issue is important scientifically because the current exposure-based standards are known to be inappropriate measures for estimating ozone injury to plants. Regulatory agencies within the US and Europe are aware of this issue and the European Community has been investigating issues relevant to estimating ozone damage (and risk) based on ozone flux rather measured concentrations (exposure). To date very little quantitative research has actually be done in this area and at present Dr Massman is one of fewer than five researchers in the US working on this issue. Dr Massman's research in this area has largely focused on developing and testing relevant concepts as they apply to measured ozone fluxes. His model of effective dose and plant ozone defense, outlined in D.1 #81, is the first model of its kind. His efforts have been recognized by (*i*) three invited talks (B.4.a #26, #31, #32), the most recent of which was delivered at a UN/ECE sponsored (2002) workshop in Harrogate, UK and is documented in D.1 #81 and (*ii*) an invitation from Dr Jay Garner (US EPA, Washington DC) to contribute to the US EPA Air Quality Criteria Document (see D.4.6 #a for a discussion of Dr Massman's contribution). Of Dr Massman's contribution to ozone flux modeling, Dr Emberson says that since the scientist's last visit with her in 2004, she and colleagues have continued "the flux modelling work in the EU but also in South and South East Asia. The flux modelling methods are accepted for crops and forest trees now for regional scale risk assessment (details can be found in the Mapping Manual (2004); revised in 2007 http://www.icpmapping.org/). I would say that the work we did with you was an important step along achieving this goal through evaluation, comparison and development of the flux modelling methods." Finally, it is worth noting that after more than a decade the CODE data are still of interest and useful to researchers (see invited talk B.4.a #38). **Knowledge Discovery/Knowledge Development/Modeling and Systems Integration**

07 ***Gas Transport through Soils and Snowpacks***: Since 8/98 the scientist has continued to work on pressure pumping. His work previous to that time resulted in an invited talk at a 1999 workshop on pressure pumping (B.5 #01) and collaborative work on the influence of pressure pumping on measurement of soil CO_2 flux from chambers (B.4.b44 #25, D.1 #73, #78, #82), which indicated that pressure pumping does not influence the fluxes measured with that particular chamber used for the study. In 2001 the scientist helped design and conduct a 2-year undersnow CO_2 study at GLEES (D.1 #88). The need for such an experiment was first identified in by the scientist in D.1 #59. This 2001/02 experiment demonstrated that undersnow CO_2 can quite dynamic (even when the depth of the snowpack is relatively constant) and that is likely to be responding to pressure pumping (D.1 #95, #96). But the real impact of this experiment probably lies in the pressure pumping model (D.1 #95, #96) the scientist developed for the analysis of the experimental data. This model was developed and used to illuminate the physical principles and atmospheric forcing mechanisms underlying effects advective flows can have on CO_2 fluxes in snow covered ecosystems and in summertime soils as well. The modeling results indicate that ignoring the effects of pressure pumping will result in underestimates of soil CO_2 fluxes from any ecosystem. This recent work on pressure pumping has resulted in two invited talks (B.4.a #36, #42), four offered presentations (B.4.b #46, #48, #56, #57), and an invitation to collaborative work with Dr David Bowling (U of Utah, 801-581-2130, bowling@biology.utah.edu) on a undersnow CO_2 experiment involving isotopes of CO_2

(B.4.b #69, D.1 #104). This isotope experiment is the first of its kind and should provide quantitative estimates of pressure-pumping related CO_2 fluxes. **Knowledge Discovery**

08 ***Impact of fire on soils*** [**AC**]: Since the fall of 2000 Dr Massman has been investigating the influence of fire on soil physical properties and soil ecology. In general, fire influences a variety of biotic and abiotic factors that affect the rate of forest regeneration after fire. Dr Massman designed and helped carry out two major slash pile burn experiments to investigate how different fuel loadings and geometrical arrangements for prescribed burns may influence these aspects of the soil physical and biological environment. An important outcome of the first experiment (documented in D.1 #79, #86, #87; B.4.b #47, #51, #52, #53; B.4.a #30) was to obtain some of the first in situ measurements of soil heat flux during a prescribed fire. Dr Massman's work on soil heat flow during fires, which was part of this first experiment, resulted in an invited talk (B.4.a #40). The second experiment is unique in all of fire/soil science. It is the only experiment to obtain in situ measurements of soil temperatures, heat flux, CO_2, and moisture before, during, and for several years after a prescribed burn (D.1 #97, #98 and several offered talks) and the only experiment to document that soil heating during a prescribed burn can produce long-term changes in the soil's thermal conductivity and its thermal climate (D.1 #101). Dr Massman's fire/soil research should contribute significantly to modeling of the soil thermal pulse and advective flows and trace gas transport in soils during prescribed burns (D.1 #106) and to provide management with a better understanding of the impact that prescribed fire can have on soil health and its ability to recover after fire (D.1 #100). **Knowledge Discovery**

D. Disseminating Research Results

1. Publications:

01 Levanon, N, RA Oehlkers, SD Ellington, WJ Massman, and VE Suomi. 1974.
On the behavior of superpressure balloons at 150 mb.
Journal Applied Meteorology **13**: 494-504. (refereed)
Massman's contribution: analysis of superpressure balloon's neutrally buoyant oscillation as described in the Appendix.

02 TWERLE Team. (Written text and scientific content provided by PR Julian, WJ Massman, and N Levanon.) 1977.
The TWERL Experiment. Bull. Amer. Meteorol. Soc. **58**: 936-948. (refereed)
Massman's contribution: description and discussion of the TWERLE gravity wave experiment.

03 Massman, WJ. 1978.
Hemispheric determinations of vertical fluxes of energy and horizontal momentum by gravity waves using free floating constant density balloons.
Ph.D. Thesis. University of Wisconsin-Madison, 165p.

04 Massman, WJ, B Hinton, and J Afanasjevs. 1978.
Scientific investigation of the tropical wind, energy conversion and reference level experiment (TWERLE).
Final Technical Report NASA Grant NSG-5126, University of Wisconsin-Madison, 43p.
Massman's contribution: analysis and interpretation of all scientific data.

05 Massman, WJ. 1978.
On the nature of vertical oscillations of constant volume balloons.
Journal Applied Meteorology **17**: 1351-1356. (refereed)

06 Afanasjevs, J, WJ Massman, RA Oehlkers, B Hinton, and VE Suomi. 1979.
Extended record length of atmospheric data gathered via Nimbus-6.
IEEE Transactions on Geoscience Electronics **GE-17**: 308-313. (refereed)
Massman's contribution: development of the design criteria used in the electronic circuitry for data retrieval.

07 Levanon, N, PR Julian, VE Suomi, and WJ Massman. 1979.
Daily high-latitude 150 mb pressure maps from TWERLE and radiosondes part I: 16 November 1975 - 31 January 1976. National Center for Atmospheric Research Technical Note NCAR-TN-141+STR, NCAR, Boulder, CO, 89p.
Massman's contribution: team member, assisted in data analysis.

08 Massman, WJ. 1980.
Water storage on forest foliage: a general model.
Water Resources Research **16**: 210-216. (refereed)

09 Massman, WJ. 1981.
An investigation of gravity waves on a global scale using TWERLE data.
Journal Geophysical Research **86**: 4072-4082. (refereed)

10 Massman, WJ. 1981.
Comments on 'The response of superpressure balloons to gravity waves'.
Journal Applied Meteorology **20**: 1089-1090. (refereed)

11 Massman, WJ. 1982.
Foliage distribution in old-growth coniferous tree canopies.
Canadian Journal Forest Research **12**: 10-17. (refereed)

12 Massman, WJ. 1983.
The derivation and validation of a new model for the interception of rainfall by forests.
Agricultural Meteorology **28**: 261-286. (refereed)

13 Massman, WJ. 1987.
A comparative study of some mathematical models of the mean wind structure and aerodynamic drag of plant canopies. Boundary-Layer Meteorology **40**: 179-197. (refereed)

14 Massman, WJ. 1987.
Heat transfer to and from vegetated surfaces: an analytical method for the bulk exchange coefficients. Boundary-Layer Meteorology **40**: 269-281. (refereed)

15 Massman, WJ, and KF Zeller. 1988.
Rapid method of correcting the non-cosine response errors of the Gill propeller anemometer.
Journal Atmospheric Oceanic Technology **5**: 862-869. (refereed)
Massman's contribution: conceptual and numerical development of the algorithm, most of its testing, implementation, and assessment and all of the written text.

16 Zeller, KF, WJ Massman, D Stocker, DG Fox, D Stedman, and D Hazlett. 1989.
Initial results from the Pawnee eddy correlation system for dry acid deposition research.
US Forest Service Research Paper, RM-282, 30p. (peer reviewed)
Massman's contribution: ($\geq$ 95%) specifically all the results and all the written text for the chapters entitled: *Eddy Correlation System Errors* and *Data Results and Analysis* as well as all of the results and written text for Appendices B and C. Also provided editorial coordination between the other authors.

17 Massman, WJ, and A van Dijken. 1989.
Water vapor transfer from a vegetated surface: a numerical study of bulk transfer coefficients and canopy resistances. Boundary-Layer Meteorology **49**: 295-307. (refereed)
Massman's contribution: development of the conceptual and numerical approach detailed in the manuscript and all of the written text. This study is an extension of Massman's two earlier papers, D.1 #13 and D.1 #14 above. The second author was a student cooperator who assisted in the implementation and testing of the computer code.

18 Massman, WJ, and M Kaufmann. 1989.
Modeling stomatal conductance of subalpine trees in the central Rocky Mountains.
In: (Ed. J. Price) Proceedings of the workshop on stomatal resistance formulation and its application to modeling of transpiration, The University of Pennsylvania, 101-103.
Massman's contribution: most ($\geq$ 90%) of the scientific content. The second author supplied the data used in the paper and provided consultations as needed by Massman.

19 Massman, WJ, DG Fox, KF Zeller, and D Lukens. 1990.
Verifying eddy correlation measurements of dry deposition: a study of the surface energy balance components of the Pawnee Grasslands.
US Forest Service Research Paper, RM-288, 14p. (peer reviewed)
Massman's contribution: all of the scientific results and all of the written text. The other authors contributed to the data gathering system and without their efforts this paper would not exist.

20 Zeller, KF, WJ Massman, DG Fox, D Stocker, R McKinney, and D Lukens. 1990.
USFS Pawnee eddy correlation research site (western core site) final report.
Final Report: Interagency Agreement DW 12933093-01-0, 52p.
Massman's contribution: all scientific results and figures relating to the surface energy balance and the surface resistance to transpiration.

21 Zeller, K, DG Fox, and WJ Massman. 1990.
Simultaneous measurements of the eddy diffusivities and gradients of ozone, sensible heat and momentum. In: 9^{th} Symposium on Turbulence and Diffusion, AMS, Boston, 110-114.
Massman's contribution: suggested the idea of the research to the first author as a Ph.D. research topic.

22 Massman, WJ, and M Kaufmann. 1991.
Stomatal response to certain environmental factors: a comparison of models for subalpine trees in the Rocky Mountains. Agricultural Forest Meteorology **54**: 155-167. (refereed)
Massman's contribution: most ($\geq$ 98%) of the scientific content and virtually all of the written text. The second author supplied the data used in the paper, consulted with the first author as requested, and supplied editorial comments on all drafts of the paper.

23 Massman, WJ. 1991.
The attenuation of concentration fluctuations in turbulent flow through a tube.
Journal Geophysical Research **96**: 15269-15273. (refereed)

24 Massman, WJ. 1991.
Improving estimates of soil heat flux and deriving estimates for volumetric soil heat capacity from temperature and soil heat flow data.
In: 20^{th} Conference on Agricultural and Forest Meteorology, AMS, Boston, 34-37.

25 Wooldridge, G, B Connell, R Musselman, and WJ Massman. 1991.
Advective contributions to boundary layer moisture profiles in mountainous terrain.
In: 20^{th} Conference on Agricultural and Forest Meteorology, AMS, Boston, 123-126.
Massman's contribution: assisted in obtaining and interpreting the data.

26 Massman, WJ. 1992.
Correcting errors associated with soil heat flux measurements and estimating soil thermal properties from soil temperature and heat flux plate data.
Agricultural Forest Meteorology **59**: 249-266. (refereed)

27 Massman, WJ. 1992.
A surface energy balance method for partitioning evapotranspiration data into plant and soil components for a surface with partial canopy cover.
Water Resources Research **28**: 1723-1732. (refereed)

28 Massman, WJ, J Pederson, A Delany, G den Hartog, HH Neumann, D Grantz, SP Oncley, and R Pearson Jr. 1993.
A comparison of independent determinations of the canopy conductance for carbon dioxide, water vapor and ozone exchange at selected sites in the San Joaquin Valley of California.
In: Conference on Hydroclimatology, AMS, Boston, 112-117.
Massman's contribution: all of the scientific content, which covered some aspects of the data analysis for the California Ozone Deposition Experiment (CODE). All other authors were part of the CODE team.

29 Delany, T, S Semmer, T Horst, S Oncley, C Martin, and WJ Massman. 1993.
The ASTER deployment at the cotton site during the California Ozone Deposition Experiment, 1991 CODE of the San Joaquin Valley air quality study.
NCAR report to the California Air Resources Board.
Massman's contribution: CODE technical principal investigator. Oversaw report preparation, provided editorial and formatting guidance for the final version.

30 Massman, WJ. 1993.
Periodic temperature variations in an inhomogeneous soil: a comparison of approximate and analytical expressions. Soil Science **155**: 331-338. (refereed)

31 Massman, WJ. 1993.
Partitioning ozone fluxes to sparse grass and soil and the inferred resistances to dry deposition. Atmospheric Environment **27A**: 167-174. (refereed)

32 Stocker, DW, DH Stedman, KF Zeller, WJ Massman, and DG Fox. 1993.
Fluxes of nitrogen oxides and ozone measured by eddy correlation over a shortgrass prairie.
Journal Geophysical Research **98**: 12619-12630. (refereed)
Massman's contribution: provided the computer code for the initial data analysis and significant amounts of editorial effort to the final version.

33 Massman, WJ. 1993.
Errors associated with the combination method for estimating soil heat flux.
Soil Science Society of America Journal **57**: 1198-1202. (refereed)

34 Grantz, DA, XJ Zhang, WJ Massman, A Delany, S Oncley, and JR Pederson. 1994.
Role of leaf wetness and stomatal conductance in determining ozone flux to cotton in the San Joaquin Valley.
In: 21^{st} Conference on Agricultural and Forest Meteorology, AMS, Boston, 263-266.
Massman's contribution: technical principal investigator for the CODE 91. Encouraged first author to present paper and provided guidance and some background to first author concerning aerodynamic resistance calculations. Assisted as requested concerning scientific interpretation of results.

35 Massman, WJ. 1994.
Estimating canopy conductance to ozone uptake from canopy scale evapotranspiration observations or by scaling up leaf stomatal conductance measurements: Does either method work? In: 21^{st} Conference on Agricultural and Forest Meteorology, AMS, Boston, 261-262.

36 Massman, WJ, and JM Ham. 1994.
An evaluation of a surface energy balance method for partitioning ET data into soil and plant components for a surface with partial canopy cover.
Agricultural Forest Meteorology **67**: 253-267. (refereed)
Massman's contribution: most ($\geq$ 99%) of the scientific content and virtually all of the written text. This work continues the development and refinement of Massman's earlier paper D.1 #27 above. The second author supplied the data used in the paper, consulted with the first author as requested, and supplied editorial comments on all drafts of the paper.

37 Massman, WJ, J Pederson, A Delany, D Grantz, G den Hartog, HH Neumann, SP Oncley, R Pearson Jr, and RH Shaw. 1994.
An evaluation of the RADM surface module for ozone uptake at three sites in the San Joaquin Valley. Journal Geophysical Research **99**: 8281-8294. (refereed)
Massman's contribution: most ($\geq$ 99%) of the scientific content and virtually all of the written text. The other authors were decisive in obtaining the data used in the paper, they consulted with the first author as needed, and supplied editorial comments on drafts of the paper.

38 Padro, J, WJ Massman, G den Hartog, and HH Neumann. 1994.
Dry deposition velocity of O_3 over a vineyard obtained from models and observations: the California ozone deposition experiment.
Water, Air and Soil Pollution **75**: 307-323. (refereed)
Massman's contribution: supplied the appropriate data to the first author, checked model results for consistency with data and performed data quality control, reviewed manuscript before submission.

39 Grantz, D, JI MacPherson, WJ Massman, and J Pederson. 1994.
Study demonstrates ozone uptake by SJV crops. California Agriculture **48**: 9-12. (refereed)
Massman's contribution: supplied results and data interpretation from Massman's previous CODE 91 studies. Reviewed manuscript before submission.

40 Padro, J, WJ Massman, RH Shaw, A Delany, and SP Oncley. 1994.
A comparison of aerodynamic resistance methods using measurements over cotton and grass from the 1991 California ozone deposition experiment.
Boundary-Layer Meteorology **71**: 327-339. (refereed)
Massman's contribution: suggested the need for the paper and suggested the aerodynamic resistance formulation to be compared, supplied the appropriate data to the first author, checked model results for consistency with data and performed data quality control, reviewed manuscript before submission.

41 Nikolov, NT, WJ Massman, and AW Schoettle. 1995.
Coupling biochemical and biophysical processes at a leaf level: an equilibrium photosynthesis model for C_3 plants. Ecological Modeling **80**: 205-235. (refereed)
Massman's contribution: directed the first author's efforts during initial phases of the modeling development, guided the first author to the available photosynthesis literature and provided all relevant information for the mathematical and numerical procedures needed to implement the model.

42 Massman, WJ, R Sommerfeld, K Zeller, T Hehn, L Hudnell, and S Rochelle. 1995.
CO_2 flux through a Wyoming seasonal snowpack: diffusional and pressure pumping effects. In: (Eds. Tonnessen, KA, MW Williams, and M Trantor) Biogeochemistry of seasonally snow-covered catchments. IAHS publication no. 228, 71-79. (refereed)
Massman's contribution: conceived and organized the pressure pumping experiment, all of the data analysis, most ($\geq$ 99%) of the scientific content and virtually all of the written text. The other authors were consulted as needed by Massman and assisted in all phases of the data gathering.

43 Musselman, RC, GL Wooldridge, WJ Massman, and RA Sommerfeld. 1995.
Wind and ecosystem response at the GLEES. In: (Ed. Tinus, RW) Interior West Global Change Workshop, USDA/Forest Service General Technical Report RM-GTR-262, 5-8.
Massman's contribution: assisted in gathering the data and reviewed final manuscript.

44 Wooldridge, G, R Musselman, and WJ Massman. 1995.
Windthrow and airflow in a subalpine forest. In: (Eds. Coutts, MP, and J Grace) Wind and Trees, Cambridge University Press, Cambridge, 358-375. (refereed)
Massman's contribution: assisted in gathering the data, provided first author with possible explanations as to why trees do not necessarily fall parallel to the wind direction.

45 Massman, WJ, and D Grantz. 1995.
Estimating canopy conductance to ozone uptake from observations of evapotranspiration at the canopy scale and at the leaf scale. Global Change Biology **1**: 183-198. (refereed)
Massman's contribution: most ($\geq$ 98%) of the scientific content and most of the written text. The second author provided significant editorial guidance for the final draft of the manuscript.

46 Padro, J, I Zhang, WJ Massman, and DW Stocker. 1995.
An application of a dry deposition model including the chemical reactions of NO-NO_2-O_3.
In: (Eds. Power, H, N Moussiopoulos, and CA Brebbia) Air Pollution Engineering and Management, Computational Mechanics Publications, Boston, 93-100. (refereed)
Massman's contribution: supplied appropriate data to first author, checked model results for consistency with data and performed data quality control.

47 Massman, WJ. 1995.
Climate and climate modeling.
In: (Ed. Joyce, LA) Productivity of American forests and climate change, USDA/Forest Service General Technical Report RM-GTR-271, 3-8. (peer reviewed)

48 Pederson, JR, WJ Massman, A Delany, G den Hartog, R Desjardins, DA Grantz, JI MacPherson, LJ Mahrt, HH Neumann, S Oncley, KT Paw U, R Pearson Jr, PR Roth, PH Schuepp, and RH Shaw. 1995.
California ozone deposition experiment: method results and opportunities.
Atmospheric Environment **29**: 3115-3132. (refereed)
Massman's contribution: suggested the need for the paper, provided first author with editorial guidance on structuring the paper. About 30% - 50% of the material covered by this paper is taken from Massman's research efforts for the CODE 91.

49 Massman, WJ, JI MacPherson, A Delany, G den Hartog, HH Neumann, SP Oncley, R Pearson Jr, and RH Shaw. 1995.
Surface conductance for ozone uptake derived from aircraft eddy correlation data.
Atmospheric Environment **29**: 3181-3188. (refereed)
Massman's contribution: most ($\geq$ 99%) of the scientific content and virtually all of the written text. The other authors were decisive in obtaining the data used in the paper, they consulted with the first author as needed, and supplied editorial comments on drafts of the paper.

50 Grantz, DA, XJ Zhang, WJ Massman, G den Hartog, HH Neumann, and JR Pederson. 1995.
Effects of stomatal conductance and surface wetness on ozone deposition in field-grown grape. Atmospheric Environment **29**: 3189-3198. (refereed)
Massman's contribution: provided the first author with appropriate data and assisted in its interpretation and provided general insights into results of data analysis.

51 Weil, JC, and WJ Massman. 1996.
Lagrangian stochastic modeling of scalar transport within and above plant canopies.
In: 22^{nd} Conference on Agricultural and Forest Meteorology, AMS, Boston, J53-J57.
Massman's contribution: suggested the need for this study and provided guidance and motivation for this study. The first author is an expert in Lagrangian models, but not in canopy processes. Massman suggested the application of the Lagrangian model to study canopy processes.

52 Massman, WJ, and JC Weil. 1996.
An analytical second-order closure model of turbulent statistics within and above plant canopies.
In: 22^{nd} Conference on Agricultural and Forest Meteorology, AMS, Boston, J60-J65.
Massman's contribution: most ($\geq$ 80%) of the scientific content and all of the written text. The second author provided a solution of the differential equation for turbulent energy within and above plant canopies for constant foliage distribution. Massman generalized the solution to arbitrary foliage distribution and developed a new model for the canopy roughness length and displacement height.

53 Sommerfeld, RA, WJ Massman, RC Musselman, and AR Mosier. 1996.
Diffusional flux of CO_2 through snow: spatial and temporal variability among alpine-subalpine sites. Global Biogeochemical Cycles **10**: 473-482. (refereed)
Massman's contribution: all modeling estimates of the diffusional flux also assisted the first author with analysis and interpretation of the data. The idea of estimating diffusional fluxes came directly from Massman's earlier work on pressure pumping, see D.1 #42 above.

54 Massman, WJ. 1996.
The California Ozone Deposition Experiment (CODE 91).
Final Report to the California Air Resources Board (CARB).
N.B. This report is included here because some the scientific content is unique to this report and because all scientific content has been reviewed by several of the scientist's peers and colleagues and by the technical staff of the CARB. This work has also been revised according to all appropriate recommendations. To the CARB, who do not directly fund peer-reviewed journal articles, this report represents a scientifically-reviewed document and has been used for their decision making processes. More discussion of this project is included under E.Special Circumstances below.

55 Massman, WJ. 1997.
Estimating ozone deposition rates for areas of central California.
Final Report to the California Air Resources Board.
N.B. This report is included here because some of the scientific content is unique to this report and because at present it documents the scientific efforts of a team of scientists lead by the author who were investigating the possibilities of extrapolating CODE 91 results to areas outside the original CODE domain. More discussion of this project is included under E.Special Circumstances below. This work has been technically reviewed by the scientific staff of the CARB. To the CARB, who do not directly fund peer-reviewed journal articles,

this report represents a scientifically-reviewed document and is being used for their decision making processes.

56 Massman, WJ. 1997.
An analytical one-dimensional model of momentum transfer by vegetation with arbitrary foliage distribution. Boundary-Layer Meteorology **83**: 407-421. (refereed)

57 Schelde, K, FM Kelliher, WJ Massman, and KH Jensen. 1997.
Estimating sensible and latent heat fluxes from a temperate broad-leaf forest using the Simple Biosphere (SiB) model. Agricultural Forest Meteorology **84**: 285-295. (refereed)
Massman's contribution: mentored the first author, who was a student at the time, in the physical principles underlying the model and in the modeling application. Assisted in obtaining the appropriate data and in evaluating model performance and data quality. Reviewed all versions of the manuscript.

58 Grantz, DA, XJ Zhang, WJ Massman, A Delany, and JR Pederson. 1997.
Ozone deposition in a cotton (Gossypium hirsutum L.) field: stomatal and surface wetness effects during the California ozone deposition experiment.
Agricultural Forest Meteorology **85**: 19-31. (refereed)
Massman's contribution: provided the first author with appropriate data and assisted in its interpretation and provided general insights into results of data analysis.

59 Massman, WJ, R Sommerfeld, AR Mosier, KF Zeller, TJ Hehn, and S Rochelle. 1997.
A model investigation of turbulence-driven pressure pumping effects on the rate of diffusion of CO_2, N_2O and CH_4 through layered snowpacks.
Journal Geophysical Research **102**: 18851-18863. (refereed)
Massman's contribution: conceived and organized the pressure pumping experiment, all of the data analysis, most ($\geq$ 99%) of the scientific content and virtually all of the written text. The other authors were consulted as needed by Massman and assisted in all phases of the data gathering. This paper is a further development of Massman's work on pressure pumping, see D.1 #42 above.

60 Sun, J, and WJ Massman. 1997.
Bulk formula and aerodynamic quantities.
In: 12^{th} Symposium on Boundary Layers and Turbulence, AMS, Boston, 544-545.
Massman's contribution: funded the first author's research through a grant from the California Air Resources Board, supplied appropriate data to first author, checked model results for consistency with data, performed data quality control, suggested much of the line of research on which the study is based, reviewed manuscript.

61 Massman, WJ. 1998.
A review of the molecular diffusivities of H_2O, CO_2, CH_4, CO, O_3, SO_2, NH_3, N_2O, NO and NO_2 in air, O_2 and N_2 near STP. Atmospheric Environment **32A**: 1111-1127. (refereed)

62 Padro, J, I Zhang and, WJ Massman. 1998.
An analysis of measurements and modeling of air-surface exchange of investigation of NO-NO_2-O_3 *over grass.* Atmospheric Environment **32A**: 1365-1375. (refereed)
Massman's contribution: supplied appropriate data to first author, checked model results for consistency with data, performed data quality control, reviewed and revised portions of the manuscript, provided critically important information for revisions.

63 Musselman, R, and WJ Massman. 1999.
Ozone flux to vegetation and its relationship to plant responses and ambient air quality standards. Atmospheric Environment **33**: 65-73. (refereed)
Massman's contribution: provided much of the motivation and overall content and organization of the paper, 35% - 40% of the written material, guided the first author in formulating ideas for the paper.

64 Massman, WJ. 1999.
Molecular diffusivities of Hg vapor in air, O_2 *and* N_2 *near STP and the kinematic viscosity and thermal diffusivity of air near STP.* Atmospheric Environment **33**: 453-457. (refereed)

65 Mitic, CM, WJ Massman, PH Schuepp, and JL Collett Jr. 1999.
Structural analysis and flux associations of CO_2, H_2O*, heat and ozone over cotton and grape canopies.* Atmospheric Environment **33**: 1159-1173. (refereed)
Massman's contribution: FS technical representative on RJV that supported the first author while working on the data analysis, assisted in obtaining, evaluating and defining the data set used in the analysis, evaluated and assisted in interpretation of the results, provided editorial review and comments on all versions of the manuscript.

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66 Massman, WJ, and JC Weil. 1999.
An analytical one-dimensional second order closure model of turbulence statistics and the Lagrangian time scale within and above plant canopies of arbitrary structure.
Boundary-Layer Meteorology **91**: 81-107. (refereed)
Massman's contribution: most ($\geq$ 85%) of the scientific content and all of the written text. With Dr Massman's assistance, the second author developed an approximate solution to the appropriate differential equation for constant foliage distribution. Dr Massman developed the exact solution and generalized it to arbitrary foliage distribution, evaluated the model against observed data, and extended his original description for momentum transfer (see D.1 #56 above) to include the within canopy velocity variances and quantities that can be derived from them.

67 Sun, J, WJ Massman, and DA Grantz. 1999.
Aerodynamic variables in the bulk formulation of turbulence fluxes.
Boundary-Layer Meteorology **91**: 109-125. (refereed)
Massman's contribution: funded the first author's research through a grant from the California Air Resources Board, supplied appropriate data to first author, checked model results for consistency with data, performed data quality control, suggested much of the line of research on which the study is based, reviewed manuscript.

68 Sun, J, and WJ Massman. 1999.
Ozone transport in the California ozone deposition experiment.
In: 13^{th} Symposium on Boundary Layers and Turbulence, AMS, Boston, 167-170.
Massman's contribution: funded the first author's research through a grant from the California Air Resources Board, supplied appropriate data to first author, checked model results for consistency with data, performed data quality control, suggested much of the line of research on which the study is based, reviewed manuscript.

69 Sun, J, and WJ Massman. 1999.
Ozone transport during the California ozone deposition experiment.
Journal Geophysical Research **104**: 11,939-11,948. (refereed)
Massman's contribution: funded the first author's research through a grant from the California Air Resources Board, supplied appropriate data to first author, checked model results for consistency with data, performed data quality control, suggested much of the line of research on which the study is based, reviewed manuscript.

70 Massman, WJ. 1999.
A model study of kB_H^{-1} for vegetated surfaces using 'localized near-field' Lagrangian theory.
Journal of Hydrology **223**: 27-43. (refereed)

71 Massman, WJ, RC Musselman, and AS Lefohn. 2000.
A conceptual ozone dose-response model to develop a standard to protect vegetation.
Atmospheric Environment **34**: 745-759. (refereed)
Massman's contribution: most ($\geq$ 75%) of the scientific content and text. The ideas expressed in this paper largely reflect Massman's thoughts on how to develop a flux-based ozone standard to protect vegetation.

72 Massman, WJ. 2000.
A simple method for estimating frequency response corrections for eddy covariance systems.
Agricultural Forest Meteorology **104**: 185-198. (refereed)

73 Takle, ES, JR Brandle, RA Schmidt, R Garcia, IV Litvina, G Doyle, X Zhou, Q Hou, CW Rice, and WJ Massman. 2000.
Pressure pumping of carbon dioxide from soil.
In: 24^{th} Conference on Agricultural and Forest Meteorology, AMS, Boston, 190-191.
Massman's contribution: provided first author with theoretical background for data analysis.

74 Massman, WJ. 2001.
Reply to comment by Rannik on 'A simple method for estimating frequency response corrections for eddy covariance systems'. Agricultural Forest Meteorology, **107**: 247-251. (refereed) [Extends, corrects, and clarifies D.1 #72 above].

75 Su, Z, T Schmugge, WP Kustas, and WJ Massman. 2001.
An evaluation of two models for estimation of the roughness height for heat transfer between the land surface and the atmosphere.
Journal Applied Meteorology **40**: 1933-1951. (refereed)
Massman's contribution: provided first author with inspiration for this study [D.1 #70 and B.4.a #23 above], provided guidance and scientific input for model development and in writing the manuscript, reviewed manuscript.

76 Massman, WJ, and X Lee. 2002.
Eddy covariance flux corrections and uncertainties in long term studies of carbon and energy exchanges. Agricultural Forest Meteorology **113**: 121-144. (refereed)
Massman's contribution: provided inspiration to NIGEC for the study, assisted second author in securing money to fund workshop on which study is based, authored most ($\geq$ 80%) of the paper and scientific content. Dr Massman's specific scientific contributions include all of sections 2, 3, and Appendix B, and part of section 4. Rewrote all of second author's portion to assure consistency in style.

77 Massman, WJ, J Finnigan, D Billesbach, S Miller, A Black, B Amiro, B Law, X Lee, L Mahrt, R Dahlman, and T Foken. 2003.
Summary and synthesis of recommendations of the AmeriFlux workshop on standardization of flux analysis and diagnostics, Corvallis, Oregon, 2002.
Massman's contribution: ($\geq$ 95%), principal author and architect. This summary also documents Massman's new approach to applying spectral corrections and WPL terms to eddy covariance systems. Contributions by other authors are mostly editorial in nature and included some rewording and some clarifying text. The summary is available on the AmeriFlux website: http://public.ornl.gov/ameriflux, navigate to events, then workshops.

78 Takle, ES, JR Brandle, RA Schmidt, R Garcia, IV Litvina, WJ Massman, X Zhou, G Doyle, and CW Rice. 2003.
High-frequency pressure variations in the vicinity of a surface CO_2 flux chamber.
Agricultural Forest Meteorology **114**: 245-250. (refereed)
Massman's contribution: provided theoretical background for the paper, reviewed and edited the paper.

79 Massman, WJ, JM Frank, WD Shepperd, and MJ Platten. 2003.
In situ soil temperature and heat flux measurements during controlled burns at a southern Colorado forest site. In: (Eds. Omi, PN, and LA Joyce) Fire, fuel treatments, and ecological restoration: Conference proceedings; 2002 16-18 April; Fort Collins, CO. USDA Forest Service Proceedings RMRS-P-29, 69-87. (peer reviewed)
Available at URL = http://www.fs.fed.us/rm/pubs/rmrs_p029/rmrs_p029_069_088.pdf

Massman's contribution: ($\geq$ 95%), wrote study plan, designed the experiment, identified the appropriate heat flux sensor for in situ observations, helped install the instruments, coordinated data compilation, analyzed the data, and wrote the paper. The other authors assisted in site preparation, installation of the sensors, electronic data recording, and reviewing and editing earlier drafts of the paper.

80 Massman,WJ, FM Frank, SM Massman, and WD Shepperd. 2003.
Performance of high temperature heat flux plates and soil moisture probes during controlled surface fires. In: Second International Wildland Fire Ecology and Fire Management Congress and Fifth Symposium on Fire and Forest Meteorology, AMS, Boston.
(Manuscript available on CD, paper 1.8)
Massman's contribution: ($\geq$ 98%), wrote study plan, designed the experiment, helped install the instruments, coordinated data compilation, analyzed the data, and wrote the paper. The other authors assisted in site preparation, installation of the sensors, electronic data recording, preparation of the figures, and reviewing and editing earlier drafts of the paper. Some overlap with D.1 #79 above.

*** 81** Massman, WJ. 2004. **Exhibit 1; Accomplishment 6**
Toward and ozone standard to protect vegetation based on effective dose: A review of deposition resistances and a possible metric.
Atmospheric Environment **38**: 2323-2337. (refereed)

82 Takle, ES, WJ Massman, JR Brandle, RA Schmidt, X Zhou, IV Litvina, R Garcia, G Doyle, and CW Rice. 2004.
Influence of high-frequency ambient pressure pumping on carbon dioxide efflux from soil.
Agricultural Forest Meteorology **124**: 193-206. (refereed)
Massman's contribution: apprised the first author on the appropriate theory and supporting references for data interpretation, performed and interpreted results of the spectral analysis reported in the paper (which basically has to do with the attenuation of pressure fluctuations in a porous media), reviewed and edited all earlier versions of the manuscript.

83 Lee, X, WJ Massman, and BE Law (Editors). 2004.
Handbook of Micrometeorology: A Guide to Surface Flux Measurements. Springer, Dordrecht, The Netherlands. 250 pp.
Massman's contribution: chair of the workshop that produced the book (see B.5 #05); wrote two of the ten chapters (see #84 and #85 below); reviewed and edited the Preface, the Introduction, and three other chapters of the book; assisted with typesetting, which was done using LaTex; worked with all authors to ensure timely submission of their assigned chapters.

*** 84** Massman, WJ, and R Clement. 2004. **Exhibit 2, Accomplishment 5**
Uncertainty in eddy covariance flux estimates resulting from spectral attenuation.
In: (Eds. Lee, X, WJ Massman, and BE Law) Handbook of Micrometeorology: A Guide to Surface Flux Measurements, Springer, Dordrecht, The Netherlands, 67-99. (peer reviewed)
Massman's contribution: ($\geq$ 90%) conceived and wrote the paper, invited the second author

to participate and provided the template for the second author's data analysis, edited and rewrote the second author's section (section 3.3) to insure uniformity of style. The second author reviewed all versions of the manuscript for scientific content and editorial purposes.

*** 85** Massman, WJ. 2004. **Exhibit 3, Accomplishment 5**
Concerning the measurement of atmospheric trace gas fluxes with open- and closed-path eddy covariance systems: The WPL terms and spectral attenuation. In: (Eds. Lee, X, WJ Massman, and BE Law) Handbook of Micrometeorology: A Guide to Surface Flux Measurements, Springer, Dordrecht, The Netherlands, 133-160. (peer reviewed)

86 Massman, WJ, and JM Frank. 2004.
An in situ investigation of the influence of a controlled burn on the thermophysical properties of a dry soil. In: 26^{th} Conference on Agricultural and Forest Meteorology, AMS, Boston. (Manuscript [Paper 1.8] available on CD from the AMS and at URL = http://ams.confex.com/ams/AFAPURBBIO/techprogram/programexpanded_220.htm)
[Note this paper is a shortened version of D.1 #87 below]
Massman's contribution: ($\geq$ 95%) wrote study plan, designed the experiment, identified the appropriate heat flux sensor for in situ observations, helped install the instruments, coordinated data compilation, analyzed the data, developed the new model of soil heat flow, and wrote the paper. The second author assisted in site preparation, installation of the sensors, electronic data recording, preliminary data screening, and preparation of the figures.

87 Massman, WJ, and JM Frank. 2004.
The effect of a controlled burn on the thermophysical properties of a dry soil using a new model of soil heat flow and a new high temperature heat flux sensor.
International Journal of Wildland Fire **13**: 427-442. (refereed)
Massman's contribution: ($\geq$ 95%) wrote study plan, designed the experiment, identified the appropriate heat flux sensor for in situ observations, helped install the instruments, coordinated data compilation, analyzed the data, developed the new model of soil heat flow, and wrote the paper. The second author assisted in site preparation, installation of the sensors, electronic data recording, preliminary data screening, and preparation of the figures.

88 Musselman, RC, WJ Massman, JM Frank, and JL Korfmacher. 2005.
The temporal dynamics of carbon dioxide under snow in a high elevation Rocky Mountain subalpine forest and meadow. Arctic, Antarctic, and Alpine Research **37**: 527-538. (refereed)
Massman's contribution: provided motivation, encouragement, and scientific advice, wrote the appendix and portions of the text, reviewed and edited all versions of the manuscript.

89 Emberson, LD, WJ Massman, P Büker, G Soja, I van de Sand, I Mills, and C Jacobs. 2006.
The development, evaluation, and application of O_3 flux and flux-response models for additional agricultural crops. In: (Eds. Wieser, G, and M Tausz) Critical Levels of Ozone: Further applying and developing the flux-based concept. Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW), 219-225.
Massman's contribution: provided the CODE91 data for parameterizing Dr Emberson's DO_3SE model, helped to familiarize the first author with the CODE91 data, assisted in

obtaining other ozone deposition/stomatal conductance data sets for extending and developing models of flux-based standards for protecting vegetation, assisted in evaluating the utility and quality of all data sets, wrote some of the paper, and provided editorial comments on all versions of the paper and the presentation from which it is derived.
N.B. This publication is a result of the consultation and collaboration with Dr Emberson and the UNECE ozone deposition modeling effort. A more complete description of this consultation is provided in section 4.B.6.03-Emberson.

90 Büker, P, LD Emberson, MR Ashmore, G Gerosa, C Jacobs, WJ Massman, J Müller, N Nikolov, K Novak, E Oksanen, D de la Torre, and J-P Tuovinen. 2006.
Comparison of different stomatal conductance algorithms for ozone flux modelling.
In: (Eds. Wieser, G, and M Tausz) Critical Levels of Ozone: Further applying and developing the flux-based concept. Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW), 133-139.
Massman's contribution: helped identify and obtain other ozone flux and stomatal data sets for testing new model parameterizations of ozone stomatal uptake; provided, interpreted, and coded some of the Fortran code of the LEAFC3 model (a photosynthetic-based stomatal conductance model the scientist helped develop, see D.1 #41 above) for comparison with the DO_3SE model; helped guide and familiarize the first author with LEAFC3 and the scientific principles on which it is based; provided editorial comments on all versions of the paper and the presentation from which it is derived.
N.B. This publication is a result of the consultation and collaboration with Dr Emberson and the UNECE ozone deposition modeling effort. A more complete description of this consultation is provided in section 4.B.6.03-Emberson. For the related peer-reviewed publication see D.1 #95 below.

91 Wieser, G, R Matyssek, RC Musselman, AS Lefohn, and WJ Massman. 2006.
Glossary: Definitions of relevancy for the 'flux concept' in ozone risk assessment.
In: (Eds. Wieser, G, and M Tausz) Critical Levels of Ozone: Further applying and developing the flux-based concept. Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW), 385-386.
Massman's contribution: provided text for about 10-20% of the manuscript, reviewed and edited all draft versions, contributed significantly to final definitions presented in the glossary.

*** 92** Musselman, RC, AS Lefohn, WJ Massman, and RL Heath. 2006. **Exhibit 4; Accomplishment 6**
A critical review and analysis of the use of exposure- and flux-based indices for predicting vegetation effects. Atmospheric Environment **40**: 1869-1888. (refereed)
Massman's contribution: Dr Massman's previous work on formulating a flux-based standard to protect vegetation (from ozone) (#71 and #81 above) provided much of the motivation for this new study. The portions of the text that discuss the flux-based indices extend Dr Massman's previous analyses. Reviewed and edited all versions of the manuscript.

93 Liu, H, JT Randerson, J Lindfors, WJ Massman, and T Foken. 2006.
Consequences of incomplete surface energy balance closure for CO_2 *fluxes from open-path* CO_2/H_2O *infrared gas analyzers.* Boundary-Layer Meteorology **120**: 65-85. (refereed)
Massman's contribution: invited by the first author to participate in the study, reviewed the original draft and critiqued the mathematical analysis, helped first author highlight the scientific contribution of this work, and provided editorial and stylistic comments on all versions of the manuscript.

94 Massman, WJ, and J-P Tuovinen. 2006.
An analysis and implications of alternative methods of deriving the density (WPL) terms for eddy covariance flux measurements. Boundary-Layer Meteorology **121**: 221-227. (refereed)
Massman's contribution: ($\geq$ 90%) The scientist developed the scientific content of the paper and wrote virtually all of the manuscript. The second author provided motivation for the study as well as detailed and careful reviews of all draft versions.

*** 95** Massman, WJ. 2006. **Exhibit 5a; Accomplishment 7**
Advective transport of CO_2 *in permeable media induced by atmospheric pressure fluctuations: 1. An analytical model.*
Journal Geophysical Research **111** (G3): G03004, doi:10.1029/2006JG000163. (refereed)

*** 96** Massman, WJ, and JM Frank. 2006. **Exhibit 5b; Accomplishment 7**
Advective transport of CO_2 *in permeable media induced by atmospheric pressure fluctuations: 2. Observational evidence under snowpacks.*
Journal Geophysical Research **111** (G3): G03005, doi:10.1029/2006JG000164. (refereed)
Massman's contribution: ($\geq$ 95%) conceived the pressure pumping study, helped install the instruments, analyzed the data, developed conclusions, and wrote the paper. The second author assisted with sensor installation, maintained the instruments during the experiment, provided quality control for the data, and prepared the figures.

97 Massman, WJ, JM Frank, AE Jiménez Esquilin, ME Stromberger, and WD Shepperd. 2006.
Long term consequences of a controlled slash burn and slash mastication to soil moisture and CO_2 *at a southern Colorado site.* In: 27^{th} Conference on Agricultural and Forest Meteorology, AMS, Boston. (Manuscript [Paper 2.2] available on CD from the AMS and at URL=http://ams.confex.com/ams/BLTAgFBioA/techprogram/programexpanded_352.htm)
Massman's contribution: ($\geq$ 80%) developed and wrote the supporting study plan, helped install the instrumentation, assisted with data QA/QC, conceived and wrote the paper. The other authors contributed their comments on the interpretation of the data and on the scientific content of the paper, obtained the data, performed data QA/QC, prepared and provided the figures, reviewed and edited all versions of the manuscript.

98 Massman, WJ, and JM Frank. 2006.
Effects of controlled burns on the bulk density and thermal conductivity of soils at a southern Colorado site. In: 27^{th} Conference on Agricultural and Forest Meteorology, AMS, Boston. (Manuscript [Paper 2.4] available on CD from the AMS and at URL = http://ams.confex.com/ams/BLTAgFBioA/techprogram/programexpanded_352.htm)

Massman's contribution: ($\geq$ 75%) developed and wrote the supporting study plan, helped obtain the data, assisted with the data QA/QC, guided the statistical analysis of the data, conceived and wrote the paper. The second author largely designed the data gathering approach, obtained the data, and performed the subsequent statistical analysis on the data; he also assisted with the interpretation of the data, performed the data QA/QC, prepared the figures, and reviewed and edited all versions of the paper.

99 Büker, P, LD Emberson, MR Ashmore, C Jacobs, WJ Massman, J Müller, N Nikolov, K Novak, E Oksanen, M Schaub, and D de la Torre. 2007.
Comparison of different stomatal conductance algorithms for ozone flux modelling.
Environmental Pollution **146**: 726-735. (refereed)
Massman's contribution: helped identify and obtain other ozone flux and stomatal data sets for testing new model parameterizations of ozone stomatal uptake; provided, interpreted, and coded some of the Fortran code of the LEAFC3 model (a photosynthetic-based stomatal conductance model the scientist helped develop, see D.1 #41 above) for comparison with the DO_3SE model; helped guide and familiarize the first author with LEAFC3 and the scientific principles on which it is based; provided editorial comments on all versions of the manuscript.

100 Jiménez Esquilin, AE, ME Stromberger, WJ Massman, JM Frank, and WD Shepperd. 2007.
Microbial community structure and activity in a Colorado Rocky Mountain forest soil scarred by slash pile burning. Soil Biology and Biochemistry **39**: 1111-1120. (refereed)
And *Erratum.* Soil Biology and Biochemistry **39**: 2700.
Massman's contribution: FS technical representative on the research joint venture that funded the research (which is part of the first author's Ph.D. project), wrote portions of the text, reviewed and edited all versions of the manuscript, suggested responses to some of the reviewers' comments, suggested one of the hypothesis reported in the paper, assisted in obtaining, analyzing, and interpreting soil temperature and other soil data presented in the paper.

***101** Massman, WJ, JM Frank, and NB Reisch. 2008. **Exhibit 6; Accomplishment 8**
Long term impacts of prescribed burns on soil thermal conductivity and soil heating at a Colorado Rocky Mountain site: a data/model fusion study.
International Journal of Wildland Fire **17**: 131-146. (refereed)
Massman's contribution: ($\geq$ 90%) developed and wrote the supporting study plan, helped obtain the data, assisted with the data QA/QC, guided the statistical and analytical analysis of the data, conceived and wrote the paper. The second author largely designed the data gathering approach, obtained the data, and performed the subsequent statistical analysis on the data; he also assisted with the interpretation of the data, performed the data QA/QC, prepared the figures, and reviewed and edited all versions of the paper. The third author assisted in the data analysis and model algorithm development.

102 Oncley, SP, WJ Massman, and EG Patton. 2008.
Turbulent Pressure Fluctuations Measured During CHATS.
In: AMS 18^{th} Symposium on Boundary Layers and Turbulence, AMS, Boston.
(Manuscript [Paper 18A.3] available from the AMS at URL =
http://ams.confex.com/ams/18BLT/techprogram/programexpanded_505.htm)
Massman's contribution: provided a fast-response static pressure sensor to CHATS, participated in laboratory calibrations and performance evaluations of the fast-response pressure sensors, participated in the CHATS field experiment, assisted in the analysis and interpretation of the data, reviewed manuscript.

103 Massman, WJ, and A Ibrom. 2008.
Attenuation of concentration fluctuations of water vapor and other trace gases in turbulent tube flow. Atmospheric Chemistry Physics **8**: 6245-6259. (refereed)
N.B. This journal (ACP) has a two stage review process. The first stage consists of publication in the online journal ACP-Discussions (ACP-D), where the manuscript is available for public viewing and comment. The referees also submit their comments to the online journal. If the paper is found acceptable, it is then revised and published in the hard-copy print journal ACP. The original version of this paper was accepted for ACP-D in March 2008 and it along with any comments has been archived as a citable reference in ACP-D at http://www.atmos-chem-phys-discuss.net/8/9819/2008/acpd-8-9819-2008.html.
Massman's contribution: ($\geq$ 80%) all original research in the paper, conceived and wrote the paper. The second author (and his Danish colleagues) obtained support for the first author to attend the workshop that initiated this study (B.5 #09), supplied some of the data used in the analysis, helped with background literature searches, and edited the paper.

104 Bowling, DR, WJ Massman, SM Schaeffer, SP Burns, RK Monson, and M Williams. 2009.
Biological and physical influences on the carbon isotope content of CO_2 in a subalpine forest snow pack, Niwot Ridge, Colorado. Biogeochemistry **95**: 37-59. (refereed)
Massman's contribution: assisted in site selection, reviewed data and offered insights into distinguishing possible pressure pumping effects from diffusional effects, provided first author with the basic physical insights for estimating the isotopic fractionation associated with wintertime soil respiration, reviewed and edited manuscript.

105 Wilson, JD, WJ Massman, and GE Swaters. 2009.
Dynamic response of the thermometric net radiometer.
Agricultural Forest Meteorology **149**: 1358-1364. (refereed)
Massman's contribution: Invited by the first author to participate in this study, provided literature citations and resources, investigated temperature effects on the calibration curves and sensor performance, which are small but not well documented, reviewed and edited all versions of the paper.

106 Massman, WJ, JM Frank, and SJ Mooney. 2010. [SEE AWARDS SECTION 4.B.1]
Advancing investigation and modeling of first-order fire effects on soils.
Fire Ecology **6**: 36-54 (plus pages A1-A2 for the Appendix). (refereed)

Massman's contribution: ($\geq$ 95%) principal author of the paper. This paper describes the scientist's perspective on the state-of-the-science concerning fire's impacts on soils and outlines his recommendations for advancing the science in this area. The second author assisted with design, installation, and maintenance of experimental system, with preparation of the figures, and calibration of the high-temperature soil moisture probe (see section entitled *"Mass transport within soils during fires"* and the appendix). The third author performed the x-ray tomographic analysis of the soil samples discussed in section entitled *"Effects of heating on soil structural and physical properties: dynamic feedbacks"*. Both the second and third authors read and edited the manuscript.

107 Pendall, E, B Ewers, U Norton, P Brooks, WJ Massman, H Barnard, D Reed, T Aston, and J Frank. 2010.
Impacts of beetle-induced forest mortality on carbon, water and nutrient cycling in the Rocky Mountains. FluxLetter (The Newsletter of FLUXNET) **3** (no.1): 17-21. (invited)
Available at http://www.fluxnet.ornl.gov/fluxnet/newsletters.cfm
Massman's contribution: Scientist in charge of the GLEES AmeriFlux site. Made the GLEES AmeriFlux data available.

108 Yi, C, D Ricciuto, R Li, J Wolbeck, X Xu, M Nilsson, and 145 other authors, including WJ Massman, listed in alphabetical order. 2010. [SEE AWARDS SECTION 4.B.1]
Climate control of terrestrial carbon exchange across biomes and continents†.
Environmental Research Letters **5** 034007 (refereed)
*** Available online at http://iopscience.iop.org/1748-9326/5/3/034007.
Massman's contribution: Provided the GLEES-AmeriFlux data to the first author and read and edited all versions of the manuscript.

109 Nobles, MM, WJ Massman, M Mbila, and G Butters. 2010.
Mineralogical and micromorphological modifications in soil affected by slash pile burn.
In: (Ed. Viegas, DX) VI International Conference on Forest Fire Research (Abstracts Volume and accompanying CD), ADAI/CEIF, Coimbra (Portugal), Submission 288.
Massman's contribution: Encouraged the first author to get involved with his own fire and soil related research (at Manitou Experimental Forest) and to write the paper; read and edited the paper.

110 Massman, WJ, MM Nobles, G Butters, and S Mooney. 2010.
Transport of CO_2 and other combustion products in soils during slash-pile burns.
In: (Ed. Viegas, DX) VI International Conference on Forest Fire Research (Abstracts Volume and accompanying CD), ADAI/CEIF, Coimbra (Portugal), Submission 086.
Massman's contribution: ($\geq$ 80%) Developed the hypothesis outlined in the text; encouraged and facilitated the research of all co-authors; conceived and wrote the paper.

111 Patton, EG, TW Horst, PP Sullivan, DH Lenschow, SP Oncley, WOJ Brown, SP Burns, AB Gunther, A Held, T Karl, SD Mayor, LV Rizzo, SM Spuler, J Sun, AA Turnipseed, EJ Allwine, SL Edburg, BK Lamb, R Avissar, R Calhoun, J Kleissel, WJ Massman, KT Paw U, and JC Weil. 2011.

The canopy horizontal array turbulence study.
Bulletin American Meteorological Society **92**: 593-611. (refereed)
Massman's contribution: Inspiration for and participant in the CHATS sub-study on atmospheric pressure fluctuations (see publication #124 below). Read, reviewed, and commented on all versions and sections of the manuscript.

112 Lee, X, and WJ Massman. 2011.
A perspective on thirty years of the Webb, Pearman and Leuning density corrections.
Boundary-Layer Meteorology **139**: 37-59. (refereed)
Massman's contribution: responsible for about 80% of the scientific content of the paper; provided motivation for and virtually all of Appendix C *"WPL theory in non-steady state and inhomogeneous flows"* and Appendix D *"Measuring the surface flux of a trace gas"*, which outline the scientist's personal approach and interpretation of the origin and nature of the eddy covariance (flux) WPL terms; provided much of the text for section 5 of the paper, which is supported by Appendix C. Reviewed and commented on the science and content of all sections of the paper.

113 Bowling, DR, and WJ Massman. 2011.
Persistent wind-induced enhancement of diffusive CO_2 fluxes in a mountain forest snowpack.
Journal Geophysical Research **116**: G04006, doi:10.1029/2011JG001722. (refereed)
Massman's contribution: suggested the research and provided inspiration to the first author; developed the basic physical/modeling concepts for the mathematical analysis of the data; read, reviewed, edited and otherwise participated in all aspects of manuscript preparation. Further details can be found item #01 under **Scientific Exchanges** (section B.7).

114 Gu, L, WJ Massman, R Leuning, SG Pallardy, T Meyers, PJ Hanson, J Riggs, KP Hosman, and B Yang. 2012.
The fundamental equation of eddy covariance and its application in flux measurements.
Agricultural and Forest Meteorology **152**: 135-148. (refereed)
Massman's contribution: provided significant inspiration to the first author; provided much of the theoretical background for the paper, which is contained in the Appendix and was essentially written by Dr Massman; suggested the simple one-level approximation to the multi-level storage term; involved in numerous and lengthy discussions with the first author on content and language of the paper.

115 Leuning, R, E van Gorsel, WJ Massman, and PR Isaac. 2012.
The surface energy balance closure problem.
Boundary-Layer Meteorology **156**: 65-74. (refereed)
Massman's contribution: hosted first author's week long visit to the Rocky Mountain Research Station [see items #02 and #03 under **Scientific Exchanges** (section B.7) for further details]. Worked with the first author to develop the ideas and the 'solution' to the energy balance closure problem as presented in the manuscript. Provided GLEES eddy covariance data to the first author. Read, reviewed, and commented on all versions and sections of the manuscript.

116 Kochendorfer, J, TP Meyers, J Frank, WJ Massman, and MW Heuer. 2012. *How well can we measure the vertical wind speed? Implications for fluxes of energy and mass.* Boundary-Layer Meteorology **145**: 383-398. (refereed)
Massman's contribution: suggested the use of the FS's ATI sonic anemometer, which was critical to the paper because it was used as the non-biased standard of comparison with other sonics anemometers. Oversaw and provided advice for John Frank's important statistical contributions to the paper. Provided guidance to the first author and reviewed and commented on all versions of the manuscript.

117 Massman, WJ. 2012.
Modeling soil heating and moisture transport under extreme conditions: Forest fires and slash pile burns.
Water Resources Research **48**: W10548, doi:10.1029/2011WR011710 (refereed)

118 Rafkin, S, D Banfield, R Dissly, J Silver, A Stanton, E Wilkinson, W Massman, and J Ham. 2012. *An instrument to measure turbulent eddy fluxes in the atmosphere of Mars.* International Workshop on Instrumentation for Planetary Missions (IPM-2012), NASA Goddard Space Flight Center, Greenbelt, MD
[Extended Abstract available online at http://ssed.gsfc.nasa.gov/IPM/]
Massman's contribution: invited to participate in NASA funded research project to develop an eddy covariance instrument for Mars, which is described in this (electronically-available) publication. The scientist's contribution to date has involved providing guidance on design and performance of sonic anemometers, with the ultimate intent to ensure that the true surface exchange fluxes are correctly determined from the eddy covariance instrumentation. Reviewed and commented on the paper.

119 Frank, JM, WJ Massman, and BE Ewers. 2013.
Underestimates of sensible heat flux due to vertical velocity measurement errors in non-orthogonal sonic anemometers.
Agricultural and Forest Meteorology **171-172**: 72-81 (refereed)
Massman's contribution: inspired and fostered the first author's creative and intellectual growth by encouraging him to pursue this line of research for his PhD and by guiding him through the science and literature relevant to sonic anemometers; supervised the first author through the design and implementation of the sonic anemometer experiment discussed in paper; assisted the first author with the data analysis; suggested the reviewers of the manuscript; read, reviewed, edited, and commented on throughout all stages of the manuscript.

120 Kochendorfer, J, TP Meyers, John Frank, WJ Massman, MW Heuer. 2013. *Reply to comment by Mauder on "How well can we measure the vertical wind speed? implications for fluxes of energy and mass".* Boundary-Layer Meteorology: IN PRESS
Massman's contribution: Oversaw and advised John Frank's contributions to the paper. Reviewed and commented on all versions of the manuscript. Also see Massman's contribution to publication #116 above.

***** Manuscripts under consideration:**

121 Frank, JM, WJ Massman, and BE Ewers. 2013.
Linking bark beetle and their associated fungi to declining ecosystem fluxes in a high elevation Rocky Mountain (Wyoming, USA) forest.
Global Change Biology: Proposed (refereed)
Massman's contribution: inspired and fostered the first author's creative and intellectual growth by encouraging him to pursue this eddy covariance related research for his PhD; supervised and assisted the first author with the data analysis; read, reviewed, edited, and commented on throughout all stages of the manuscript.

122 Kirby, EA, WJ Massman, and KM Smits. 2013.
The effect of fire on the thermal properties of soils.
Vadose Zone Journal: Submitted 3/2013 (refereed)
Massman's contribution: suggested the line of research to both the first and third authors; obtained the soil samples for the analysis; mentored and guided the first author through the basic science behind the research; and read, reviewed, edited, and commented on all versions and sections of the manuscript.

123 Chen, F, G Zhang, M Barlage, Y Zhang, C Wiedinmeyer, J Hicke, A Meddens, G Zhou, W Massman, and J Frank. 2013.
An observational and modeling study of impacts of beetle-kill on surface energy and hydrological cycles.
Geophysical Research Letters: Proposed (refereed)
Massman's contribution: Provided the GLEES-AmeriFlux data to the first author and read and edited all versions of the manuscript.

***** Manuscripts in preparation:**

124 Oncley, SP, WJ Massman, and EG Patton. 2013.
Measurement of the turbulent kinetic energy in a canopy, including pressure transport.
Agricultural and Forest Meteorology: Proposed (refereed)
Massman's contribution: probably made this part of the CHATS (see #111 above) possible by directly encouraging the NCAR CHATS scientists, as well as providing some of the equipment for measuring atmospheric pressure transport. Participated in the CHATS field program and the data analysis and interpretation. Read, reviewed, and commented on all versions and sections of the manuscript.

2. **Patents:** None

3. **Documents, archived databases:**

   a The Manitou Experimental Forest prescribed burn data (soil temperatures, heat fluxes, moisture, and CO_2 amounts) and all supporting soil data and metafiles are archived in the RMRS database and are available at URL = http://www.fs.fed.us/rm/data_archive/dataaccess/ManitouEF_SoilTemp_HF_WC_CO2.shtml. These data are described or used in publications D.1 #79, #80, #87, #96, #97, #98, #100, #101, #106.

   b The GLEES eddy covariance flux data, all supporting meteorological data, and the associated metafiles are archived in the FS/RMRS and AmeriFlux databases. These data will be available at the RMRS website [URL = ftp://ftp2.fs.fed.us/incoming/rmrs/jfrank/GLEES/] and are (in part) available at present at AmeriFlux web site [URL = ftp://cdiac.ornl.gov/pub/ameriflux/data/Level1/Sites_ByName/GLEES/] and are described or used in publications D.1 #76, #84, #108 and the presentation, B.4.b #76.

4. **Electronic and audio-visual outputs:**

   a Dr Massman's computer model of trace gas diffusion through snowpacks (D.1 #53, #59 above) has been incorporated into an ecological text, *Propagation of Ecological Influences across Landscapes.* For further discussion see consultation with Reiners, Polzer, and Driese (third entry under B.6 #04 above).

   b Dr Massman's method for calculating eddy covariance spectral corrections (D.1 #72, #74, #76 above) has been implemented into a Windows Excel spreadsheet by Dr David Hollinger (see www.fs.fed.us/ne/durham/4104/products/spectralcorrections.shtml).

   c The eddy covariance QA/QC algorithm [C++ computer code] designed by J Frank and Dr Massman for despiking raw eddy covariance data (see University seminar series, 4.B.3.b #02) was requested by and sent to Dr. Fred C. Bosveld of the Royal Netherlands Meteorological Institute (KNMI; De Bilt, The Netherlands) for testing and possible use with his eddy covariance data.

5. **Demonstrations and short-courses:**

   a Manitou Experimental Forest 70th Anniversary Open House. (2006)
   Dr Massman led tours of and lectured on two experimental fire research sites (see D.1 #97 and #98 above) and co-authored a poster:
   Frank, JM and WJ Massman. 2006.
   Measuring the effects of controlled slash-pile burns on the soil.

   b Manitou Experimental Forest 2007 Open House.
   Dr Massman and Dr Stromberger (Soil Microbial Ecologist at CSU) summarized their

research on the impact that different fuels treatments (prescribed burning and chipping) can have on the soils at the Manitou Experimental Forest (Massman's contribution is covered in D.1 #101 above). Their presentation was entitled:
Fire alters long-term soil thermal and microbial dynamics.

6. Assessments, land management plans, and other policy related products:

U.S. EPA. Air Quality Criteria for Ozone and Related Photochemical Oxidants (Final). 2006. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-05/004aF-cF. Available at the web site http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=149923. The scientist is listed as one of 15 Principal Authors of Chapter 9, 'Environmental Effects on Vegetation and Ecosystems' and Chapter 9 Annex, 'Environmental Effects'.
All portions of the Criteria Document were peer reviewed and the final version was edited by EPA designated peers.
Massman's contribution: One of three authors: {AS Lefohn, RC Musselman, and WJ Massman} of *Ozone exposure-plant response relationships* (Section 9.6, pp. 9-15 – 9-18 of Volume I of the Criteria Document) and *Effects-based air quality exposure indices* (Section AX9.4, pp. AX9-159 – AX9-187 of Volume III of the Criteria Document). The scientist's ideas (see D.1 #63, #71, #81, #92) were the inspiration for all discussions of flux-based standards and related vegetation defense concepts. Specifically, the scientist provided ideas and insights regarding his model of plant defense to ozone, provided supporting citations as needed, provided ideas and insights on the use of a flux-based standard to protect vegetation, reviewed and edited the written material.

E. Other Significant Information

<u>N.B.</u> Total number of scientific reviews denoted as (before last promotion, after last promotion)

<u>Journal Reviews</u>

Agricultural and Forest Meteorology (3,31)
Agronomie: Agriculture and Environment (0,1)
Agronomy Journal (0,1)
American Journal of Botany (1,0)
Arid Land Management and Research (0,1)
Atmospheric Chemistry and Physics (0,1) [2 page review published on the journal's web site]
Atmospheric Environment (8,15)
Australian Journal of Agricultural Research (0,1)
Biogeochemistry (0,1)
Biogeosciences (0,3) [1 page review published on the journal's web site]
Boundary-Layer Meteorology (3,21)
Bulletin of the American Meteorological Society (0,1)
Canadian Journal of Soil Science (1,0)
Earth and Planetary Sciences (0,1)
Ecological Applications (0,1)
Ecological Informatics (0,1)
Ecological Modeling (1,0)
Ecology (1,0)
Environmental Modelling and Software (0,1)
Environmental Pollution (1,3)
Forest Science (0,1)
Geoderma (0,1)
Geophysical Research Letters (0,6)
Global Change Biology (2,1)
Human and Ecological Risk Assessment (0,1)
Hydrology and Earth System Sciences (0,1) [1 page review published on the journal's web site]
Hydrology Research (0,1)
International Journal of Climatology (0,1)
International Journal of Environment and Waste Management (0,1)
International Journal of Wildland Fire (0,3)
Journal of Air and Waste Management Association (1,1)
Journal of Applied Meteorology (4,5)
Journal of Arboriculture (1,0)
Journal of Atmospheric and Oceanic Technology (0,6)
Journal of Contaminant Hydrology (0,3)
Journal of Climate and Applied Meteorology (1,0)
Journal of Environmental Quality (2,0)
Journal of Geophysical Research (3,18)

Journal of Hydrologic Engineering (1,0)
Journal of Hydrology (3,1)
Journal of Hydrometeorology (0,2)
Journal of the Atmospheric Sciences (4,1)
Journal of the Meteorological Society of Japan (1,0)
Monthly Weather Review (1,0)
Polar Research (0,1)
Quarterly Journal of the Royal Meteorological Society (0,3)
Remote Sensing Reviews (1,0)
Soil Science Society of America Journal (5,1)
Tellus B (0,2)
Vadose Zone Journal (0,2)
Water Resources Research (7,9)
Wetlands (0,1)

<u>Reviews requested by RMRS Annual Publications Awards Committee</u> (0,19)

<u>Reviews requested by editors and authors of books or proceedings</u> (3,5)

<u>Reviews requested by peers</u> (14,37)

<u>Reviews requested by granting agencies</u>

*** *State Universities* ***

University of Montana: Montanans On a New Trac for Science (2,0)
Professional Staff Congress-City University of New York [PSC-CUNY] (0,1)

*** *US Federal Agencies* ***

EPA Office of Research and Development: Investigator-Initiated Internal Grants Program (1,0)
National Science Foundation: Division of Earth Sciences (1,2)
National Science Foundation: Division of Ecological and Evolutionary Physiology (0,1)
National Science Foundation: Division of Atmospheric Sciences (0,2)
National Science Foundation: Division of Atmospheric Chemistry (0,1)
National Institutes for Global Environmental Change (0,1)
US DOE Terrestrial Carbon Processes Research (0,13)

*** *Foreign Organizations* ***

National Sciences and Engineering Research Council of Canada (0,1)
Israel Science Foundation (0,1)

*** *International Organizations* ***

IPCC Working Group III (0,2)

Special Circumstances

1. The California Ozone Deposition Experiment (1991-1997)

In May of 1991 the scientist was invited to participate as one of two Associate Technical Principal Investigators for the San Joaquin Valley Air Quality Study (SJVAQS), a (several million dollar) field measurement and computer modeling study of the air quality of the San Joaquin Valley of California. The SJVAQS, a major international effort at the forefront of ozone deposition research, was sponsored by federal, state and local governments agencies, as well as private industries and their organizations. The California Ozone Deposition Experiment (CODE), the major field measurement campaign of the SJVAQS, was designed to improve understanding of the causes of high ozone concentrations in the San Joaquin Valley and to develop and evaluate a comprehensive state-of-the-science model for ozone, acid deposition, visibility and secondary aerosols. CODE was performed during the summer of 1991 with aircraft and several ground-based eddy covariance tower systems. The scientist's participation in the SJVAQS was supported by an award of $68,000 from EPA Air and Toxics Division. The award, implemented as an Interagency Agreement, was titled *Dry Deposition Monitoring and Modeling for SARMAP* and lasted for 2.5 years (roughly from 6/91 through 12/93). The scientist was the technical team leader of an international team of scientists from the National Research Council of Canada, the Flight Research Center of the Atmospheric Environment Service of Environment Canada, the National Center for Atmospheric Research (NCAR), the University of California-Davis, McGill University, Agriculture Canada and NASA. The scientist's technical responsibilities included: (a) reviewing all scientific plans for the CODE and recommending appropriate augmentations and extensions to the CODE, (b) overseeing all tower-based eddy covariance flux and surface energy balance measurements, (c) assessing data quality and evaluating data errors and uncertainties, (d) data analysis, and (e) using CODE tower and aircraft data, assess dry deposition model performance and make recommendations for any changes and improvements to the model. The scientist has reported his findings in several conference presentations, two reports to the California Air Resources Board [D.1 #29, #54] and ten peer reviewed publications [three as lead author: D.1 #37 #45, #49; three as second author: D.1 #38, #40, #48; and four as contributing author: D.1 #39, #50, #58, #62].

In part because of his success with the CODE 91, the scientist was awarded $124,000 by the California Air Resources Board (CARB) in late 1994. The award, implemented as a collection agreement between the Forest Service and the CARB, was entitled *Estimating ozone deposition rates for areas of central California beyond the CODE 91 areas.* The grant covered the 2.5 year period between January 1995 through June 1997. The scientist assembled and lead a team consisting of himself, two pre-doctoral students (1 CSU, 1 McGill University) and one NCAR scientist to address the question of how to extrapolate the information on ozone deposition gathered during the CODE to areas outside the CODE area, but within the modeling domain of central California. Three methods of scaling and/or aggregating eddy covariance fluxes from a small area to a larger area were investigated. These include: (a) remote sensing approaches using high resolution EOSAT data and lower resolution AVHRR data in conjunction with a state-of-the-science SVAT to estimate LAI and the associated fluxes of CO_2, water vapor, heat and ozone, (b) structure analysis of the CODE fluxes to determine dominant scale sizes associated with the turbulence atmosphere/canopy surface layer and (c) a bulk aerodynamic approach to determine which processes dominate the surface/atmosphere exchanges. Results have been reported in the final report [D.1 #55], three peer reviewed publications [D.1 #65, #67, #69], one Ph.D. thesis (CSU, Forest Science Department), three invited talks [B.4.a #26, #31, #32], several conference papers, and one refereed paper [D.1 #81].

2. Kids in the Woods Program (2008)

On 10/07/2008 Dr Massman lead a group of six FS scientists and technicians, six [4^{th} - 7^{th} grade] students of the Liberty Common robotics team, and three team leaders (parents of the robotics team members) on a field trip to the GLEES to discuss and educate the students about the connections between climate change and the beetle epidemic at GLEES. (My personal goal was to excite the students about climate science and how physical sciences contribute to environmental research.) This trip was organized by Rita Brown (RMRS-HCM) and the scientist in response to a request of Dr Massman from a parent of one of the student team members. Student feedback about the trip included: "The field trip was incredible! In one day we learned biology, geology, and climatology. The only thing that would have made it better would have been to ride in the snow cat." A parent/team leader commented that "The field trip was such a wonderful experience for the students! Not only did they learn of ton of information specifically related to their research project, they also learned a lot about careers as research scientists. All of the scientists who spent the day with the students did an amazing job of interacting with the students and conveying a huge amount of information, which the students quickly absorbed. There is just no substitute for seeing and experiencing things in person. We feel very fortunate to have had that opportunity."

F. Contact List

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G. Privacy Act Information

I have received a copy of the Privacy Act Notice for the Preparation of Factor 4, Contributions, Impact, and Stature Research Scientist Position Description.

William J Massman	October 26, 2010
(Signature of scientist	Date)