J3.7 COMPARING MODELED AND MEASURED SCALAR CONCENTRATION PROFILES IN A NORTHERN HARDWOOD FOREST

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1. INTRODUCTION

One of the most significant research issues in the measurement and modeling of the trace gas exchange within and above forest canopies has been the relationship between canopy scalar sources and observed scalar concentration profiles (e.g. Raupach 1987; Warland and Thurtell 2000, henceforth WT2000). This issue has become especially important with respect to isoprene, vegetative emissions of which are the largest source of reactive carbon to the atmosphere (Guenther *et al.* 1995). Research of the last two decades has led to the development of reliable empirical models of canopy emissions and fairly good quantitative understanding of the chemical fate of this compound (Atkinson and Arey 1998). However, present models of atmospheric chemistry and transport are unable to account for observations of rapid nocturnal decay of isoprene concentrations. Current research by Hurst *et al.* (2000) and others is attempting to address this problem.

The objective of this research is to use the analytical Lagrangian model proposed by WT2000 to relate measured and interpolated turbulence profiles and scalar source strength to concentration profiles of both non-reactive and reactive carbon. This is a first critical step toward a long-term goal of integrating this canopy turbulence model with chemical and source models to quantify the respective roles of turbulent transport and chemistry on observed isoprene concentration profiles, particularly during the transition to nighttime.

2. MEASUREMENTS

Measurements were collected from May to October in 2000 and 2001 at University of Michigan Biological Station (UMBS) research forest. The UMBS forest is a roughly 90-year-old northern hardwood forest located at 45° 35' N and 84° 42' W. Mean canopy height is 22 m and dominant species include; bigtooth and trembling aspen, red oak, sugar maple, white pine and eastern hemlock Schmid *et al.* (2002) This site has a 46 m AmeriFlux tower instrumented with a fast isoprene analyzer along with canopy flux measurements throughout the growing seasons. Additionally a 22 m canopy tower is used to obtain in-canopy vertical profiles of turbulence, temperature, PAR, isoprene, CO2 and water vapor. Water vapor and CO_2 concentration profiles (8 levels) are continuously collected and aggregated to hourly averages while isoprene concentration profiles (6 levels), which require collection of ambient air over 30 minute periods, followed by chromatographic analysis are limited to about 80 profiles over the course of the summers of 2000 and 2001.

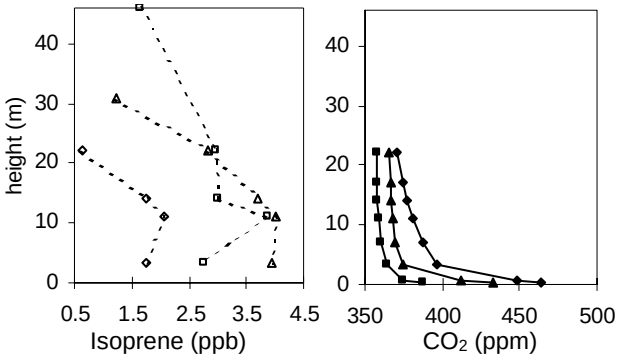

Figure 1: Profiles of CO_2 (on right with solid lines) and isoprene (on left with dashed lines) from 19:00 (squares), 21:00 (triangles), and 22:00 (diamonds) on July 25, 2000. CO2 profiles exhibit the expected pattern for nighttime when soil respiration is the dominant source. Isoprene profiles are more variable although generally the highest concentrations are observed between 11 and 14 m where vegetation density is greatest.

3. MODEL

For a complete explanation of the development of the dispersion matrix designed to account for both near-field and far-field effects the reader is referred to WT2000. In this case a simplified form of the model (WT2000 eq. 28) was used to derive nighttime concentration profiles of CO_2. For a surface source the model is fully described by the following equations where F_{CO_2} is CO_2 efflux from the forest floor:

$$\left.\frac{dc}{dz}\right|_i = \frac{F_{CO_2}}{-\sigma_{w_i} L_{L_i}} \quad , \tag{1}$$

where i refers to discrete layers and the product of the vertical velocity standard deviation (σ_w) and the Lagrangian (L_{Li}) is equivalent to an eddy diffusivity. With concentration specified for one height the resulting concentration profile is given by a simple trapezoid integration:

$$c_{i+1} = c_i + \frac{1}{2}\left(\left.\frac{dc}{dz}\right|_i + \left.\frac{dc}{dz}\right|_{i+1}\right)\left(z_{i+1} - z_i\right) \quad . \tag{2}$$

The Lagrangian length scale was inferred from its Eulerian equivalent, assuming $T_L \approx T_E$, by $L_L = \sigma_w T_L$. Here the Eulerian time scale was assumed to be $0.3h_c$ as indicated by Raupach (1987). Finally, due to data limitations at this time model runs were conducted with measured and

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interpolated σ_w with various source strengths and using an averaged profile of nighttime σ_w/u_* to examine model sensitivity to these parameters.

4. RESULTS

Turbulence data collected on July 29, 2000 (z/L ≈ 0.88) were used to conduct model runs with varying CO_2 flux. The best agreement is found closest to the surface (Figure 2). A bulge between 10 and 14 meters in the measured profile indicates that either respiration within the canopy is important, σ_w varies more strongly than a linear interpolation allows for (Figure 3), or that T_E is variable within the canopy .

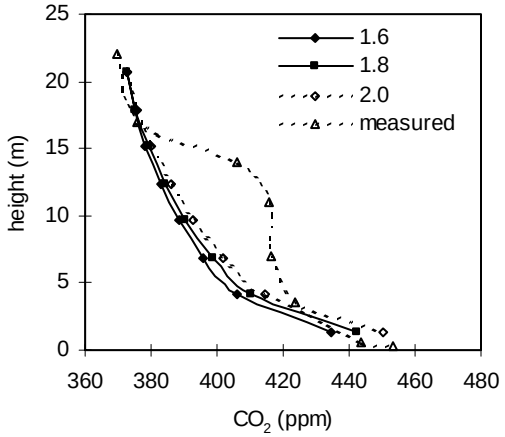

Figure 2: Model runs with varying source strengths (μmol $m^{-2}s^{-1}$) show the model's direct dependence on the specification of surface flux. The initial concentration supplied for these runs was (370ppm). The measured concentration profile for this time (22:00 July 29, 2000) is shown with open triangles.

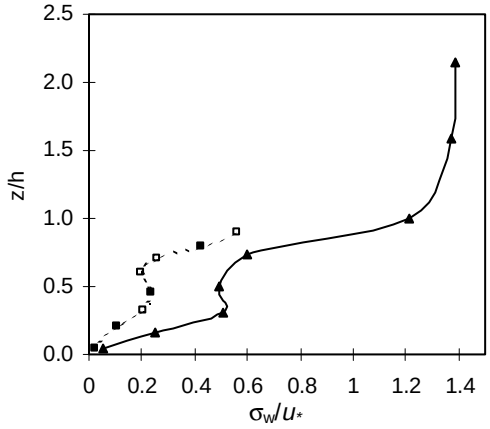

Figure 3: Ensemble profile of nighttime σ_w/u_* (filled triangles summer 1999-zero forcing at surface). This profile was used to conduct model runs while varying u_* to calculate concentration profiles shown in Figure 4. The measured (open squares) and linearly interpolated (filled squares) σ_w/u_* profile is from 22:00-July 29,2000 (u_* = 0.33 m s^{-1}) and was used to calculate the profiles in Figure 2.

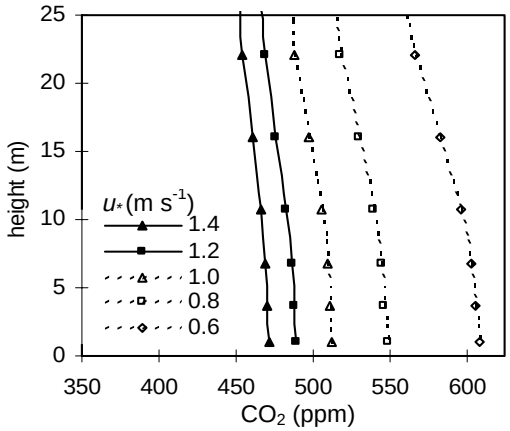

Figure 4: A comparison of CO_2 profiles resulting from variations in friction velocity (u_*), using the σ_w profile plotted as a solid line in Figure 3.

The sensitivity of this model to its turbulence input is illustrated by comparing Figures 2 and 4. Although the shape of the σ_w-profiles used is similar for both simulations (Figure 3), the shapes of the resulting concentration profiles are completely different. These results highlight the importance of accurately specifying the details of turbulence structure within the canopy.

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