Ecological Archives **A018-049-A1**

Chuixiang Yi, Dean E. Anderson, Andrew A. Turnipseed, Sean P. Burns, Jed P. Sparks, David L. Stannard, and Russell K. Monson. 2008. The contribution of advective fluxes to net ecosystem exchange in a high-elevation, subalpine forest. *Ecological Applications* 18:1379–1390.

Appendix A. Comparison of horizontal advection calculated by the cosine-referenced technique and consideration of two-dimensional wind flows.

APPENDIX

Comparison of horizontal advection calculated by the cosine-referenced technique and consideration of two-dimensional wind flows

In this appendix, we present a validation that a true two-dimensional resolution of horizontal advection can be well described by the cosine-referenced, one-dimensional method we use in this study. To accomplish this validation, we used wind data collected at four levels from the WT and CO_2 data measured from three towers (WT, ET, and ST) in 2001. A complete description of the horizontal advection of CO_2 can be written as:

$$\mathbf{U} \cdot \nabla \overline{c} = (U\vec{i} + V\vec{j}) \cdot (\frac{\partial \overline{c}}{\partial x}\vec{i} + \frac{\partial \overline{c}}{\partial y}\vec{j}) = U\frac{\partial \overline{c}}{\partial x} + V\frac{\partial \overline{c}}{\partial y}, \qquad \text{(A1)}$$

where $\vec{i}$ and $\vec{j}$ are unit vectors along x (southward) and y (westward), U and V are half-hourly mean values of velocity components, while $\partial \overline{c} / \partial x$ and $\partial \overline{c} / \partial y$ are CO_2 gradient components, respectively. Equation (A1) can be viewed as the expression of horizontal advection of CO_2 before the coordinate system is aligned with the horizontal mean wind direction. Equation (A1) also can be written in another form:

$$\mathbf{U} \cdot \nabla \overline{c} = \overline{u}\frac{\partial \overline{c}}{\partial r}\bigg|_{iT} \cos(\theta_{iT}), \qquad \text{(A2)}$$

where $\overline{u}$ is the mean horizontal wind speed (mean wind direction is determined by $\text{tg}(\alpha)=\text{V/U}$), r is an axis aligned with the horizontal mean wind direction, $(\partial \overline{c} / \partial r)_{iT}$ is the horizontal CO_2 gradient along the direction from WT to *i*T, and θ_{iT} is the angle between the mean wind direction and the primary axis of the CO_2 gradient measured from WT and iT, i = E, S (see

Equation (4) in the text). Thus, $(\partial\overline{c}/\partial r)_{iT}\cos(\theta_{iT})$ is the projection of the CO_2 gradient measured from the pair towers in the mean wind direction, i. e. $(\partial\overline{c}/\partial r)_{iT}\cos(\theta_{iT})$ is equal to $\partial\overline{c}/\partial x$ in Equation (1) in the main text. Theoretically, (A1) and (A2) are different expressions of the same dot production of two vectors (velocity and CO_2 gradient). Actually, some differences in calculating the advection from the two formulas might be caused by data processing, instrumentation problems, complex terrain, vegetation structure, and atmospheric stability.

We used four months of nighttime half-hourly data (July, August, September, and October in 2001) to test the consistency between these two approaches. The agreement between these two approaches was almost perfect at 10 m (Figure A1a). However, a slight inconsistency was observed between them when the advection terms were small at low vertical levels (Figure Ac-f). These inconsistencies may be attributed to the differences in methods used to calculate half-hourly wind speed. The half-hourly wind speed ($\overline{u}$) was calculated by two steps. In the first, the high-frequency wind speed ($\underset{\sim}{u}$) was first calculated by the formula $\underset{\sim}{u}=\sqrt{\underset{\sim}{U}^2+\underset{\sim}{V}^2}$ where $\underset{\sim}{U}$ and $\underset{\sim}{V}$ are *x*-component and *y*-component of velocity measured from sonic anemometers, respectively, and then mean wind speed was obtained by averaging $\underset{\sim}{u}$ data over a 30-minutes period. This method is different from a second method used to calculate the mean wind speed by $\overline{u}=\sqrt{U^2+V^2}$ where U and V are the half-hourly mean values of $\underset{\sim}{U}$ and $\underset{\sim}{V}$, respectively. Mean wind speed calculated from the second method may be less than the first because some *x*-components (or *y*-components) of velocity were canceled during the averaging process (due to their opposite signs). This is the reason why we used the first method. The inconsistencies shown in Figure A1c-d may also be caused by instrumentation artifacts because wind direction from the Handar 2-D anemometers had significant errors when wind speed was below 0.1m/s.

Nonetheless, we note that there is excellent agreement between the overall estimates of advection using the cosine-referenced approach, versus direct observation of 2-D wind flows referenced to the x and y spatial coordinates.

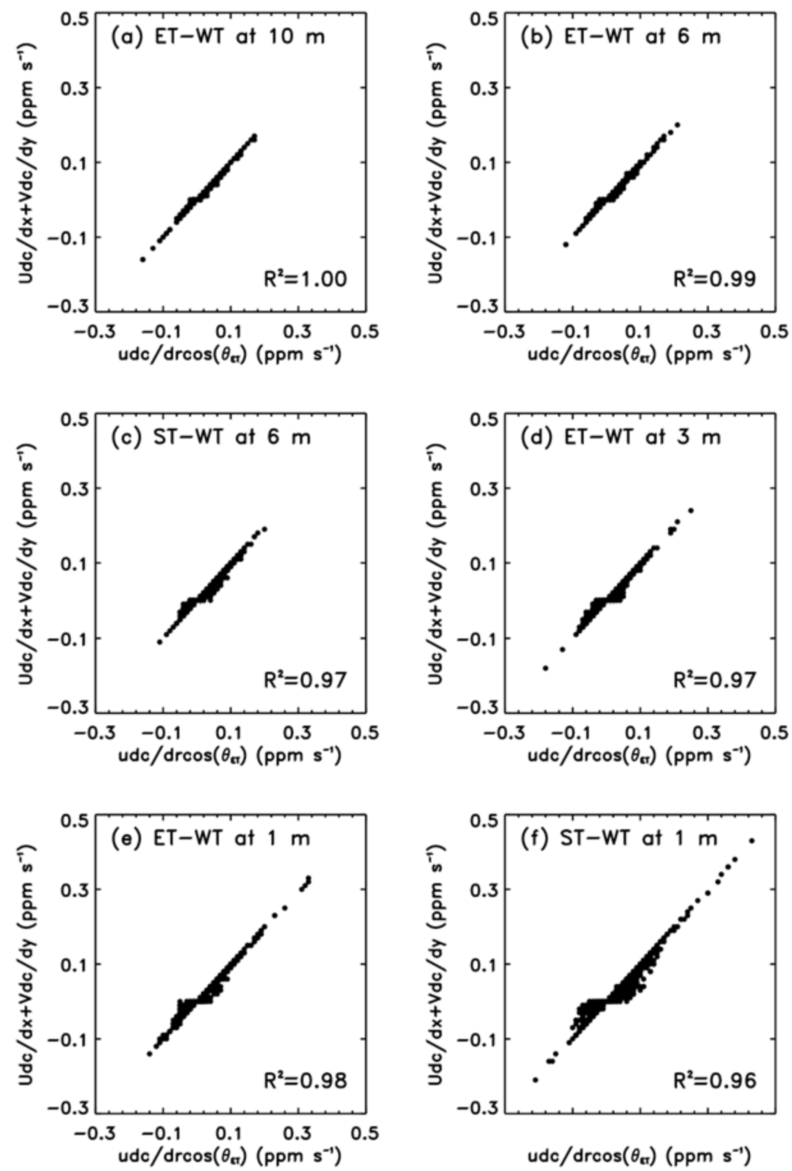

Figure A1. Comparison of calculations of the horizontal advection of CO_2 from Equations (A1) and (A2). The calculation from Equation A1 (the direct 2-D observation) is presented as the ordinate, and the calculation from Equation A2 (the cosine-referenced method) is presented as the abscissa. Data were limited to nighttime in July, August, September, and October of 2001 when data at all levels (1, 3, 6, and 10 m) from three towers (WT, ET, and ST) were available. *U* and *V* are half-hourly mean values of *x*-components and *y*-components of velocity measured by sonic anemometers, respectively; u is the mean wind speed (i.e. $\overline{u}$ in the text). The number of half-hourly data at each level was N=2,322.