

Review of “Modeling moisture fluxes using artificial neural networks: can information extraction overcome data loss?” by Neal, Gupta, Kurc, and Brooks (HESsd -7-6525-2010).

1. **General comment:** The manuscript explores the use of artificial neural networks (ANNs) employed along with a normalization method used by Mishra and Desai (2006) to gap-fill 3-years of ET eddy-covariance (EC) fluxes collected from a mesquite woodland site in Southeastern Arizona. Naturally, any analysis on such long-term records is of value, and identifying optimal gap-filling approaches remains a priority to address questions of long-term nature in hydrology. Seasonal and annual ET fluxes from EC systems certainly fall into this important category.

I do have a number of inquiries and suggested revisions (largely two) for the authors that should be addressed prior to final acceptance of this manuscript.

## 2. Specific comments:

- 2.1 *Critical times and dawn ET fluxes.* The authors do state that “... variation between gap-filling models complicates the application of their output as consistent data sets for land surface modeling, and points to the need for improved data and models to address flux behavior at critical times.”

This was the main conclusion of the study – so addressing the flux behavior at critical times is of important to formulating this conclusion. Logically, it is imperative to commence the manuscript by rigorously establishing these ‘critical times’. Statements such as “...valid data from periods of low turbulence, that is just above the filter threshold, are particularly valuable as a result (validity often established by a criterion such as friction velocity...)” actually miss a number of crucial issues pertinent to the interpretation of a turbulent flux as an ET value. Implicit here is the use of ‘weak turbulence mixing’ as the indicator of critical times. The authors then report that some hours during the day appear more problematic and critical. Perhaps a more rigorous definition of what *should be* labeled as ‘critical times’ (abstract, discussion, conclusion) can benefit from the derivation below.

The mean continuity equation for water vapor is given as

$$\frac{\partial \bar{q}}{\partial t} + \bar{U}_j \frac{\partial \bar{q}}{\partial x_j} = - \frac{\partial}{\partial x_j} \left( K_m \frac{\partial \bar{q}}{\partial x_j} + \overline{u'_j q'} \right), \quad (1)$$

where  $\bar{q}$  is the mean water vapor concentration,  $U_j$  are the three components of the velocity,  $K_m$  is the molecular diffusion coefficient of water vapor in air, and  $\overline{u'_j q'}$  are the turbulent fluxes in all three directions. Let us explore under what conditions the vertical turbulent flux in the atmosphere, as measured by an EC system, represents ET.

[1] In stationary conditions,  $\partial(\cdot)/\partial t = 0$ .

[2] In planar-homogeneous flows  $\partial(\cdot)/\partial x_1 = \partial(\cdot)/\partial x_2 = 0$ .

[3] In conditions with no mean subsidence,  $\overline{W} = \overline{U_3} = 0$ .

[4] Strong turbulence mixing -  $\left| K_m \frac{\partial \overline{q}}{\partial x_j} \right| \ll \left| \overline{u'_j q'} \right|$ .

For those 4 assumptions, the budget equation in (1) reduces to

$$\frac{\partial}{\partial x_3} (\overline{u'_3 q'}) \approx 0, \quad (2)$$

where upon integration with respect to height ( $x_3$  or  $z$ ) yields:

$$\overline{w'q'} = \text{const} = ET. \quad (3)$$

Condition [1] is likely to be violated precisely during 'transition times' such as during sunrise and sunset even if the friction velocity is large. Also, condition (1) is likely to be violated when the forcing variables (e.g. solar or net radiation) is changing rapidly in time – at least on time scales commensurate with the averaging times of the EC system.

Condition [2] is difficult to test – but if the footprint is fluctuating significantly – and the source of water vapor is not uniform (soil-vegetation), then there are good reasons to suspect this condition is violated (or exhibit a 'directional' ET based on the prevailing wind even if the meteorological and soil moisture conditions are the same). Exploring whether ET inference is sensitive to wind direction for the same mean meteorological and edaphic conditions is needed here to demonstrate that this is not an issue.

Condition [3] is likely to be violated when the ABL initially grows (i.e. dawn). Perhaps looking at the pdf( $\overline{w}$ ) around dawn may provide clues about how important the subsidence is, with the usual caveat that sonic anemometry cannot resolve mean velocity smaller than  $0.05 \text{ m s}^{-1}$ . However, if the authors find that around dawn,  $\overline{w}$  is more like  $0.1$  or  $0.2 \text{ m s}^{-1}$ , then this unquestionably indicates that EC based measurements are basically unrepresentative of ET.

High friction velocity alone does not guarantee that assumptions [1]—[4] are satisfied. So, defining critical times as conditions in which assumptions [1]—[4] are violated makes sense. Recall that ANN is inferring ET from meteorological data – and these critical times are times that EC measurements are not appropriate approximations for ET. ANN modeled ET in gap-filling is being convolved with conditions that may be correct for inferring ET from EC measurements and may be wrong at other times.

**2.2 Energy balance closure at critical times:** The authors may want to discuss the energy-balance closure at those critical times. How off was it compared to more

'micro meteorologically ideal times'? This is important given that net radiation is a key driver for the ANN model as well.

**2.3** Also, if the gap-filled ET is used to estimate sensible heat flux, how well does the approach work?

**2.4** *ANN and conclusions:*

After reading this manuscript, I am left with the desire to know how well the two ANN approaches here differ from standard approaches to ET gap-filling. Novick et al. (2010) already presented 5 approaches to gap-filling ET and compared their performances – these approaches can be readily employed here and compared to the two ANN approaches. How different are the results on annual ET estimates? This is essential to illustrating whether ANN is effective over other approaches or not, especially for such types of ecosystems. A summary table (as Table 3 in Novick et al., 2010) can be most helpful.