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Hydrology and Earth System Sciences Discussions

Interactive comment on "Measurement and modelling of evaporation from a coastal wetland in Maputaland, South Africa" *by* A. D. Clulow et al.

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Additions and corrections in response to Anonymous Referee #1 (mainly points 1 and 3). Point 3 was most challenging but we hope to have addressed the valid comments. It was difficult to avoid too much review in order to place the new results in context.

Page 1747 Line 1. The vegetation in the vicinity of the site had an average height of 0.76 m. The canopy cover was full, homogenous and with no areas of exposed peat or water. The leaf area index (LAI) was between ∼1.7 in winter and ∼2.8 in summer. The plant roots had permanent access to the water table at this site.

Page 1756 Lines 15 – 24. Remove detailed description of FAO-56 Penman-Monteith model.

Page 1756 line 25. Remove: ‘Thus, the FAO-56 Penman-Monteith model’ and replace with: ‘The FAO-56 Penman-Monteith model’. . .. . .

Page 1757 line 25. Remove: ‘Priestley-Taylor: the Priestley-Taylor model’ and replace with: ‘The Priestley-Taylor model’. . .. .

Page 1758 Line 3 - 14. Remove Priestley-Taylor equations and replace with ‘The Priestley-Taylor model is therefore commonly used to estimate evaporation from wetlands (Price, 1992; Souch et al., 1996; Mao et al., 2002) and was applied in this study in the form described by Savage et al. (1997).’

Page 1757 Line 3. Renumber equation to (4) due to removal of equations above.

Page 1757 Line 25. The aerodynamic terms of the Penman model are replaced by an empirical and constant α known as the advective term.

Page 1759 Line 16. Insert. The SR method, used to estimate H in this study, was found to be reliable for long-term, unattended use over the Mfabeni Mire with periodic calibration using eddy covariance. Once determined, a re-calibration is only required if there are significant changes in the vegetation canopy (Snyder et al., 1996; Spano et al., 2000; Paw U et al., 2005). Further advantages found to be significant in this study include the relatively low cost of the system, the low power use and the simple and basic maintenance requirements in comparison to alternative methods available for estimating H. This was particularly important as it reduced the cost and time resources required for field visits as the site was remote and the study was long-term. In addition, Drexler et al., (2004) comment that the SR method is less dependent on fetch than other methods (eddy covariance). Therefore, in wetlands with complex surfaces with areas of open water, soil and vegetation, the number of measurements can be replicated at a low cost by including additional fine-wire thermocouples offering a better spatial representation of ET.

The site specific calibration required by the SR method is however a disadvantage as an independent measure of H is required over a suitable calibration period. In addition, the SR method was introduced by Paw U and Brunet (1991) and is still relatively new in terms of measurement systems. As a result there are no complete SR systems available commercially as there are with other methods (eddy covariance). This introduces a significant barrier to entry for wetland hydrologists or ecologist as expertise in logger programming, data processing and an understanding of micrometeorological measurement is required. The fine-wire thermocouples (76 μm diameter), although not prohibitively expensive, are fragile and breakage can result in data loss if backup thermocouples are not installed.

Page 1761 Line 1. Remove (Eq. 6)

Page 1762 Line 15. Remove (Eq. 7)

Page 1762 Line 17. Change (Eq. 8) to (Eq. 4)

Page 1763 Line 8... Correction.......... the available energy in the Mfabeni Mire.

Page 1763 Line 6 – Page 1764 Line 19. The SR method was successfully used to estimate H and was found to be suitable for long-term, unattended use over a subtropical wetland with periodic calibration using eddy covariance. It therefore has the potential to become more accessible to wetland researchers but the method is still relatively new and complete SR systems are not commercially available. Due to system complexity it therefore currently remains the domain of micrometeorologist.

Despite plentiful water and a subtropical environment, wetlands are not necessarily the high water users they are frequently perceived to be (Bullock and Acreman, 2003). Even high windspeeds characteristic of the site did not raise the ET due to the low evaporative demand (or VPD) of the air. Despite maximum ET rates of up to 6.0 mm day-1, the average summer (October to March) ETSR was lower (3.2 mm day-1) due to intermittent cloud cover which reduced the available energy. In winter (May to September), there was less cloud but the average ETSR was only 1.8 mm day-1 due to plant senescence and the accumulated ETSR over 12 months was 900 mm. The results compared well with studies in similar subtropical wetlands of the northern hemisphere although are slightly lower due to lower leaf areas.

The Embomveni Dune (dry grassland) measurements of ETSR provided a useful contrast to the Mfabeni Mire (wetland). The ETSR was seasonal at both sites yet the total ETSR at the Embomveni Dunes was limited by soil water availability and was only 478 mm over 12 months. The drought conditions (650 mm of rainfall versus a mean annual precipitation of 1200 mm yr-1) therefore contributed to the low summer ETSR at the Embomveni Dunes which are expected to be higher in a normal to high rainfall year.

A comparison of ETSR with ETr suggests that the crop factor approach was not suited to estimating ETSR for the Mfabeni Mire. The Priestley-Taylor model however, closely reflected the daily changes in ETSR at the Mfabeni Mire and α = 1 (intercept of -0.3) can be used with confidence to estimate daily ET (R2=0.96) throughout the year. This relationship between ETSR and ETEQ showed that ET from the Mfabeni Mire was largely dependent on energy and was at the equilibrium (or potential) rate. Including the mass transfer term, as is the case in the FAO-56 Penman-Monteith model, was of no benefit due to the complexity of the high windspeed and low VPD at the site.

The significant advantage of the Priestley-Taylor method for use by wetland hydrologists and ecologists is the low data requirement. If Rn and G are measured or estimated (Drexler et al., 2004) from a nearby weather station then only Tmax and Tmin are required to estimate the wetland daily ET. In addition, the Priestley-Taylor model has been internationally accepted and tested since 1972 although the extent to which it can be applied beyond the Mfabeni Mire to other South African wetlands under equilibrium conditions requires further investigation.

The ET measurements and modelling guidelines for the Mfabeni Mire and Embomveni Dunes will assist in determining a more accurate water-balance which was previously

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impossible without reliable estimates of ET. This will not only reduce uncertainty in water-balance studies and environmental flow determinations but provide better insight into the resilience of the system to droughts and the pressures of climate change.

Page 1761 Line 1. Insert new paragraph. Internationally, there are no comparable ET studies in the southern hemisphere to those at the Mfabeni Mire. In Australia, the subtropical wetland studies focus on water treatment wetlands where the 'clothesline effect' is noted (Headley et al., 2012) and in South America the focus is forest wetlands (Fujieda et al., 1998). In the northern hemisphere however, the Florida (USA) Everglades wetland region has been studied intensively and the results at Mfabeni Mire can be compared with studies by Mao et al. (2002) and Abtew et al. (1996) who found ET rates slightly higher than those measured at the Mfabeni Mire over cattail and saw-grass vegetation. Abtew et al. (1996) found average rates of ET over mixed marsh of 3.5 mm day-1 (Mfabeni = 2.5 mm day-1). Mao et al. (2002) measured growing season rates for cattail and saw-grass of 4.1 and 5.9 mm day-1 (Mfabeni = 3.2 mm day-1) and non-growing season rates of 2.2 and 2.0 mm day-1 (Mfabeni = 1.8 mm day -1). These higher rates are likely due to higher leaf areas and a higher net irradiance which was suppressed at the Mfabeni Mire due to prevailing cloudy conditions especially during the summer (Fig. 5).

Page 1761 Line 13. Replace 'between 0.65 and 0.99' with '1.12 and 0.9 respectively'

Page 1761 Line 19 - 24. The α estimate of 1.0 (with an offset of -0.3 mm) calculated for the Mfabeni Mire is low in comparison with results from much of the international literature. However, it agrees well with those of Moa et al. (2002), Gemen et al. (2000) and Abtew et al. (1996) derived from the Florida (USA) Everglade wetlands, and very well with the estimate of 1.035 of Souch et al. (1996) during the warm summer climate of the Indiana Dunes National Lakeshore. In this study it was also noted that a flow of humid air off the nearby Lake Michigan suppressed evaporation. Equilibrium evaporation clearly describes the evaporation rate in the Mfabeni Mire and other wetlands of subtropical climates.

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Page 1755 Line 16. Replace -150 kPa with -800 kPa.

Page 1760 Line 4. Replace -150 kPa with -800 kPa.

Pg 1762 Line 27. In comparison, the LAI of the Mfabeni Mire was lower, between ~1.7 in winter and ~2.8 in summer due to the narrow leaves of the vegetation.

Page 1763 Line 2. Knowles (1996) for example, applied a correction to α based on LAI.

Page 1766 Line 28. Add following references.

German, E. R.: Regional evaluation of evapotranspiration in the Everglades. USGS, Water-Resources Investigations Report 00-4217, Tallahassee, Florida, United States of America, 2000.

Knowles, Leel, Jr.: Estimation of evapotranspiration in the Rainbow Springs and Silver Springs Basins in north-central Florida, U.S. Geological Survey Water-Resources Investigations Report 96-4024, United States of America, 1996.

Abtew, W.: Evapotranspiration measurements and modeling for three wetland systems in south Florida. J. Am. Water Resour. As., 32, 465-473, 1996.

Fujieda, M., Kudoh, T., de Cicco, V. and de Calvarcho, J. L.: Hydrological processes at two subtropical forest catchments: the Serra do Mar, São Paulo, Brazil. J. Hydrol., 196, 26-46, 1997.

Headley, T. R., Davison, I., Huett, D. O. and Müller, R.: Evapotranspiration from subsurface horizontal flow wetlands planted with Phragmites australis in sub-tropical Australia. Water Res., 46, 345-354, 2012.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 1741, 2012.