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First results of energy and mass exchange in a salt marsh on southeastern South America

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ABSTRACT

Salt marshes are vulnerable ecosystems since they are found in locations often preferred for urban development. They produce a great amount of biomass, and also are of great interest because of the ecosystem services they provide from which carbon storage stands out. This work aims to study the energy and mass exchanged by a salt marsh located in southeastern Buenos Aires province (Argentina) and to characterize its net ecosystem production. A field campaign was carried out from February 2014 to March 2015. Sensible heat, water vapor (H_2O) and carbon dioxide (CO_2) fluxes were measured with eddy covariance technique at 6 m height over a *Spartina densiflora* canopy. Fifty five percent of the data were lost and 15% more were discarded due to low turbulence conditions. This gaps were filled with a combination of techniques (look-up tables and mean diurnal variations), which allowed the estimation of monthly mean net ecosystem exchange, gross primary production and ecosystem respiration. As in other marshes, the latent heat flux consumed more than 55% of the available energy of the system, reaching up to 85% after a large flood event. This flux systematically exceeds the values of sensible heat measured throughout the study period. Unlike other environments, this southern salt marsh behaved as a CO_2 sink throughout the year. The net ecosystem production from March 2014 to February 2015 was approximately -10.5 t of $CO_2\,ha^{-1}\,yr^{-1}$ which is greater than reported results for other wetlands. These preliminary results for a southern *S. densiflora* salt marsh are encouraging, although new field studies are under way to confirm their accuracy.

1. Introduction

Distributed all over the world from polar to tropical regions, marshes are one of the most productive ecosystems compared to lands or deep-seas (Mistch and Gosselink, 2007). Due to their proximity to urban settlements, salt marshes are prone to be used as effluent collector or treated as waste disposal sites which make them vulnerable to environmental degradation with the consequent loss of biodiversity. According to Bromberg Gedan et al. (2009), marshes provide ecosystem services of great importance: they are highly productive areas for numerous plant species, provide food, shelter, nesting and breeding sites for animal species and retain water sediments and pollutants that arrive by runoff from the surroundings. Sediment deposition favors the capture and entrapment of organic matter making marshes important carbon sinks. Moreover, they are negligible sources of methane (CH_4) due to the presence of sulfates that inhibits its production (Stumm and Morgan, 1981). According to Chmura et al. (2003) salt marshes carbon sequestration is up to an order of magnitude greater than in peatlands which make them one of the most efficient continental surfaces removing CO_2 from the atmosphere. This combination of factors has drawn attention to their importance for climate change and global warming, reinforced by the fact that marshes and coastal areas net primary production (NPP) has slowly increased in the last decades (Choi and Wang, 2004).

Salt marshes are also important elements of the water cycle. Their sediments and topographical location lead to high soil water contents and raised water tables which in some cases produce higher evaporation than open water bodies (Stan et al., 2016). As a result, their latent heat flux is the largest component of the surface energy balance (Siedlecki et al., 2016). Evapotranspiration (ET) and the raised water table also play an important role in soil and groundwater nutrient and salt concentrations (Hillel, 1998, Chapter 9; Wang et al., 2007).

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The most widely used technique for studying surface energy and mass exchange is the Eddy Covariance (EC) methodology (Baldocchi, 2003; Goulden et al., 1996; Jarvis et al., 1997; Loubet et al., 2013; Reichstein et al., 2014; Ryan and Law, 2005; Shao et al., 2014). Most studies have been carried out in the Northern Hemisphere on different surfaces such as rain forests, tundra, agricultural areas; some of them on wetlands, particularly salt marshes (Artigas et al., 2015; Bonneville et al., 2008; Chmura et al., 2003; Houghton and Woodwell, 1980; Xiao et al., 2013). In the Southern Hemisphere measurements of net ecosystem exchange (NEE) and ET are scarce with practically none for marshes. Goodrich et al. (2015) studied the CH_4 biogeochemistry of peatlands from bogs in New Zealand. They found that CH_4 annual flux was 29.1 g $CH_4\,m^{-2}yr^{-1}$ in 2012 which decreased to 20.6 g $CH_4\,m^{-2}yr^{-1}$ in 2013 due to a severe drought. Campbell et al. (2014) found that in a remnant New Zealand raised peat bog the NEP for two particular years was −7.96 t of $CO_2\,ha^{-1}\,yr^{-1}$ and −9.18 t of $CO_2\,ha^{-1}\,yr^{-1}$ showing a substantially larger uptake than other peatlands in the Northern Hemisphere. Also for three different New Zealand bogs, evapotranspiration showed values from 1,51 to 3.01 mm d^{-1} during summer(Campbell and Williamson, 1997; Thompson et al., 1999). On the other hand, Beer et al. (2010) used an ecophysiological model to study the variability of CO_2 sequestration (mean gross primary production – GPP) at global scale. Their results for the Argentinean Pampa plains predict a vegetation carbon gain of 15 t $CO_2\,ha^{-1}yr^{-1}$. However, there are no measurements to validate these predictions for the region. Different bibliographical collections, such as the Blue Carbon Initiative ("The Blue Carbon Initiative", 2017) show that there is a great information gap in southern South America on these topics.

At regional and global scales there are different measurement networks such as AmeriFlux, Fluxnet and others, based on the EC technique. One of the aims is to generate insight of the role of terrestrial ecosystems in the equilibrium of the carbon cycle under changing CO_2 atmospheric content. Measurements allow researchers to advance both in the understanding of the sequestration dynamics of several ecosystems around the world (Burns et al., 2016; Ma et al., 2016; Meyers, 2001; Valentini et al., 2000; Wilson and Baldocchi, 2000) and the validation of tools developed with satellite information which provide regional insight (Nakano and Shinoda, 2015; Zscheischler et al., 2014). Argentina is starting to produce results on this topic (Posse et al., 2012), although the role of South American salt marshes in carbon sequestration is still unknown. This work was aimed to get the first quantification of the energy, mass exchange and the net ecosystem productivity of a mid-latitude salt marsh ecosystem in southern South America. In order to understand synergic processes between the marsh vegetation and the atmosphere, the main terms of the energy and CO_2 balance equations were analyzed.

2. Materials and methods

2.1. Site description

South Atlantic salt marshes are found between 30° and 50°S. This study was carried out at Mar Chiquita coastal lagoon, located in the southeast of Buenos Aires province, Argentina (Fig. 1). The lagoon is connected to the sea by an elongated outlet channel. The area shows a flat topography with three main landforms: the coastal barrier of sandy dunes and adjacent beaches, the marginal flats whose sediment deposition gives rise to the Mar Chiquita lagoon and associated salt marsh, and the Pampa plain with numerous deflation basins occupied by freshwater bodies. The water body shows two hydrographic areas with marine and inland influence regulated by the sea tides and rainfall respectively (Marcovecchio et al., 2006). The tidal wave amplitude is reduced 78% compared to the lagoon outlet tidal wave due to a bridge located 3 km from the lagoon outlet (Lanfredi et al., 1987). Vegetation has been described and classified by many authors (Cabrera, 1968, 1976; León, 1991; Pérez et al., 2009; Stutz, 2001; Vervoorst, 1967). Sandy dunes are occupied by open vegetation composed of grasses and herb species. On the marginal flat surrounding Mar Chiquita lagoon, *Spartina densiflora* (austral cordgrass, C4 metabolism) and *Sarcocornia ambigua* (perennial glasswort, C4 metabolism) are the main components of an extended salt marsh community with scattered tussocks of *Juncus acutus* (sharp rush) on the highest zones. Surrounding the marginal flat, grasses like *Distichlis spicata* and *D. scoparia* are the main constituents of a grass steppe modified by agriculture and cattle raising during the twentieth century.

Measurements were carried out in an agricultural establishment ("Antonio Romano S. A."), whose main activity is cattle production. A flux tower was settled within the raised high marsh approximately 6 km from the sea and 2 km from the lagoon. Physiognomy surrounding the measurement site is the characteristic evergreen grassy landscape with an average canopy height of 0.7 m and little phenological variation throughout the year (Tonti, 2016). Main species cover at the site were *Spartina densiflora* (51%), *Sarcocornia ambigua* (10%), *Distichlis scoparia* (9%), *Stenotaphrum secundatum* (1%) followed by minor percentages of: *Juncus acutus*, *Coniza floribunda*, several sedges and weeds (22%) and 7% of bare soil (Tonti, 2016).

2.2. Instrumentation and flux measurements

A 3D sonic anemometer (Young 81000, RM Young, Traverse City, MI, USA) and an open path gas analyzer (LI 7500A, LI-COR Inc., Lincoln, NE, USA), sampling at a rate of 20 Hz were used to measure CO_2 and H_2O fluxes. The sensors were mounted in a triangular lattice tower with a face width of 0.18 m (37°33′3.05″S–57°17′50.05″W, 0 m.a.s.l.) at 6 m height pointing to the prevailing wind direction (WNW). The distance between the sensors and the tower was 1.3 m. Horizontal homogeneity was guaranteed for several kilometers round and the slope of the terrain is less than 0.01%.

Additional low-frequency measurements were recorded at 30-s intervals, and 15-min averages saved in a datalogger (CR1000, Campbell Scientific Inc., Logan, UT, USA). Temperature, relative humidity, wind speed and direction were measured at 5 m height (HMP45C, Vaisala, Vantaa, Finland and Wind monitor 05103, RM Young, Traverse City, MI, USA), soil heat flux at 0.1 m depth (HFT3, Hukseflux) and soil temperature at 0.05 m depth (Hukseflux, thermocouples type K, Hukseflux Thermal Sensors, Delft, The Netherlands). Global radiation (LI-200, LI-COR Inc., Lincoln, NE, USA), net radiation (REBS-Q7.1, Radiation and Energy Balance, Inc., Seattle, WA, USA) and photosynthetic active radiation (Li-190, LI-COR Inc., Lincoln, NE, USA) were measured at 2 m height on a mast far apart from the tower to avoid shading by the tower. The extremely horizontally homogeneous surface allowed them to be place below the eddy covariance sensors without loss of representativeness. Global radiation is the total shortwave radiation intercepted by a horizontal surface which includes direct and the diffuse solar radiation. Daily precipitation was recorded and provided by the staff of the ranch. Water table depth was measured monthly on a drilling-hole near the flux tower.

2.3. Data handling and processing

Observations lasted from 14th February 2014 to 9th March 2015. In order to avoid the shadow effect of the tower, observations with wind directions between 60° and 150° were discarded (Wyngaard, 1986). Heavy precipitation, the malfunction of some sensors, power breakups and the lack of accessibility due to a prolonged freshwater flood produce some data losses from April to July and September to November 2014. Fluxes were calculated every 15 min using the TK3 post-processing software (Mauder and Foken, 2015). Calculations included several corrections like the WPL to remove density fluctuation effects (Webb et al., 1980), a spike detection algorithm (Vickers and Mahrt, 1997) with a standard cut-off of 7 standard deviations in a window of 15 observations, the double rotation method for errors related to the