A new approach to quantify evaporative water loss in tropical wetlands

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1 MOTIVATION

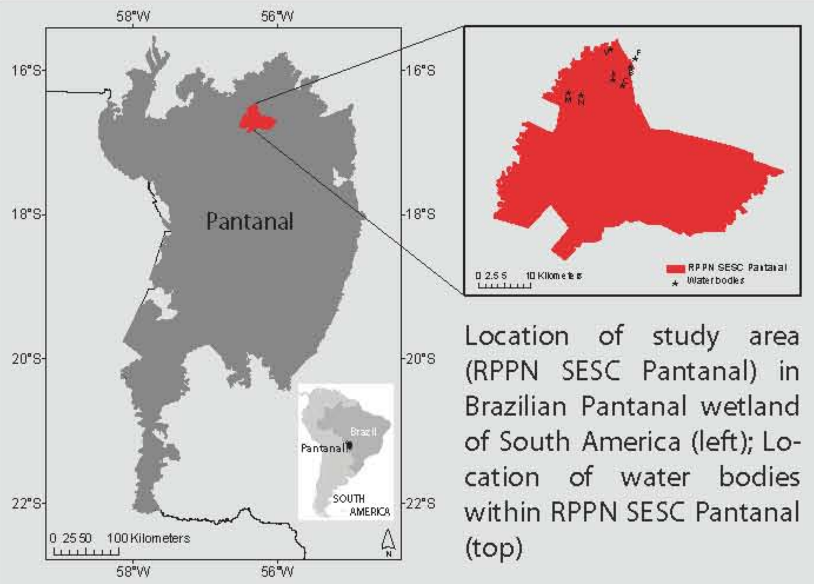
Tropical wetlands are challenging research environments. Their high complexity and heterogeneity make the characterization of hydrological processes very difficult. In particular, large uncertainties complicate estimations of water loss by evaporation (E). One of the largest freshwater wetlands in the world is the Pantanal located in central South America. Data availability is scarce and its remoteness makes direct measurements of E even more challenging. Due to the variability and the complexity of this unique ecosystem, no adequate method for determining E exists.

2 OBJECTIVES

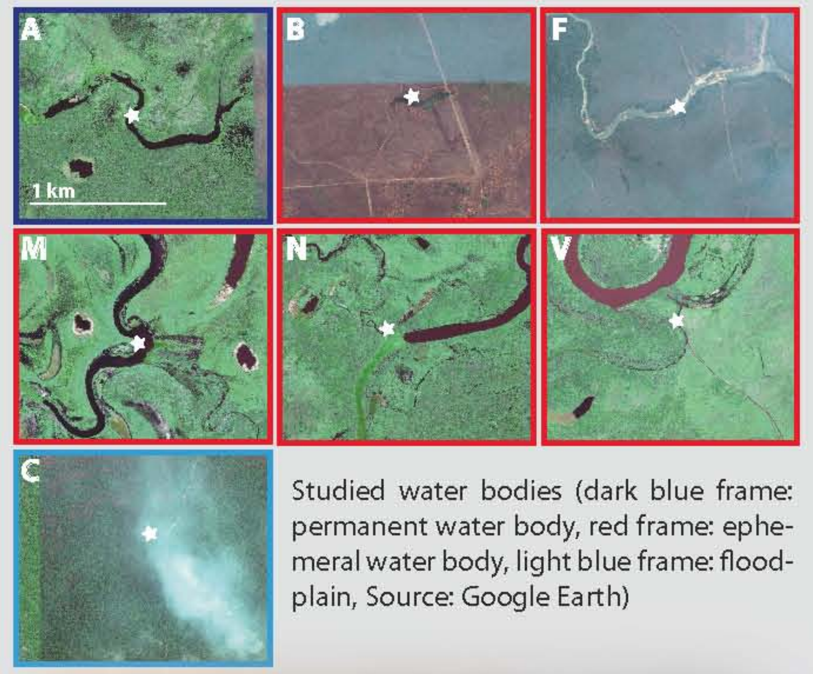
Develop a process-based model to simulate E that accounts for inundation dynamics of seasonal wetlands

Quantify E losses of different types of water bodies for dry and wet years

3 STUDY AREA



Location of study area (RPPN SESC Pantanal) in Brazilian Pantanal wetland of South America (left); Location of water bodies within RPPN SESC Pantanal (top)



Studied water bodies (dark blue frame: permanent water body, red frame: ephemeral water body, light blue frame: floodplain, Source: Google Earth)

4 METHODOLOGY

a) Choice and performance of PET models

A set of seven empirical models with varying complexity was selected to calculate ensembles of potential evaporation (PET) based on different assumptions and available datasets. The parametrization was adjusted to prior successful application in the tropics based on a detailed literature review.

Abbreviation	PET model
PEN	Penman open water
PRT	Pristley-Taylor
HAR	Hargreaves
MAK	Makkink
ABT	Simple Abtew
TUR	Turc
PMO	Penman-Monteith

On the basis of 38 months (Feb 2010 - Apr 2013) of observations we calculated the fit between PET model results and class A pan measurements using five different objective functions. The best PET model for our study area was chosen by ranking the PET models according to the best objective function results.

Abbreviation	Objective function
RMSE	Root mean square error
NSE	Nash-Sutcliffe efficiency
KGE	Kling-Gupta efficiency
SRCC	Spearman's rank correlation coefficient
PCC	Pearson's correlation coefficient

b) Water availability

To account for seasonal inundation in the dry and the rainy season we use high-resolution measurements of surface and groundwater to define water available for E. Groundwater (GW) evapotranspiration (ET) functions predict the actual evaporation (AET) based on the relation between GW ET rate and GW depth. The approach after Stoll & Weiler (2010) serves to derive AET by constraining modeled PET based on available water.

Calibration

Two parameters d_1 and d_2 were derived by Monte Carlo (MC) sampling with 100 steps within predefined ranges:

- d_1: depth until no reduction of PET takes place — range: between -1500 and 0 mm
- d_2: extinction depth — range: between -5000 and -2000 mm

Validation

Results of GW ET function were validated by local measurements of AET with the Bowen ratio method at water body C for the year 2007.

Reference: Stoll & Weiler 2010. Explicit simulations of stream networks to guide hydrological modelling in ungauged basins. Hydrol. Earth Syst. Sci., 14(8): 1435-1448

c) Application to different locations

The best ranked PET model was used to simulate E losses from April 2012 until April 2013 at different locations.

The calibration results of d_1 and d_2 from water body C served to define the water availability for different types of water bodies, such as permanent and ephemeral lakes and rivers as well as the floodplain.

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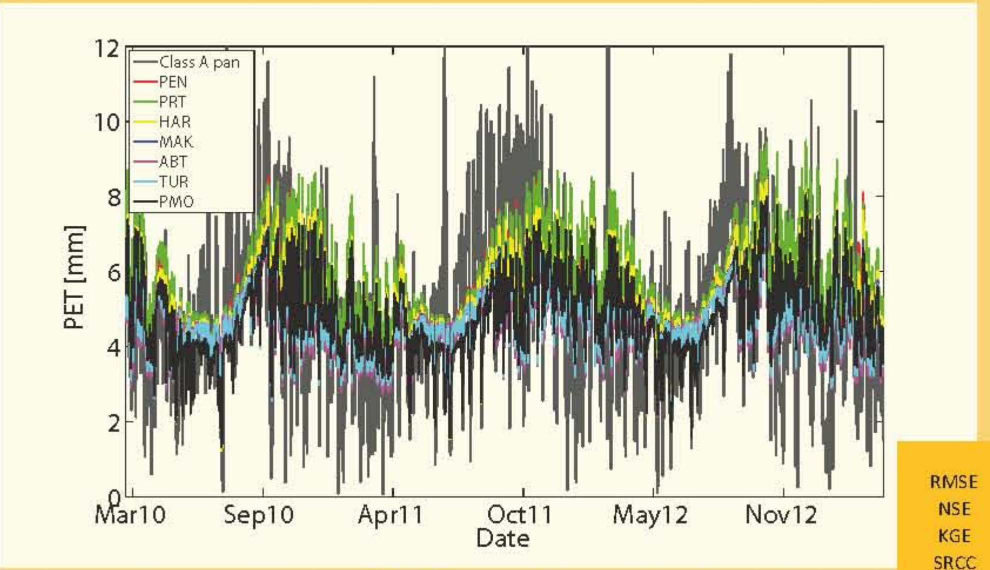
5 RESULTS

a) Performance of PET models

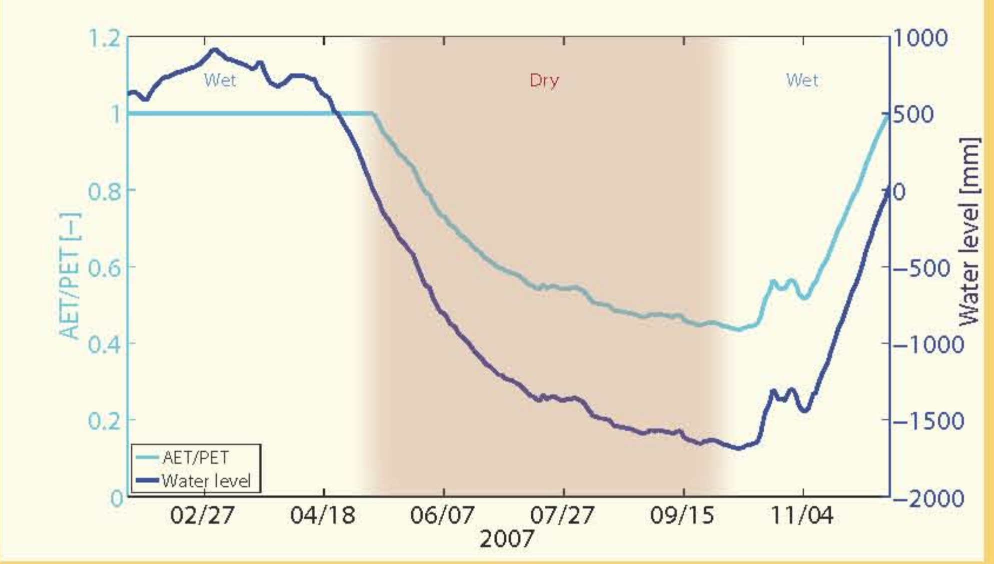


Comparison of PET models with class A pan

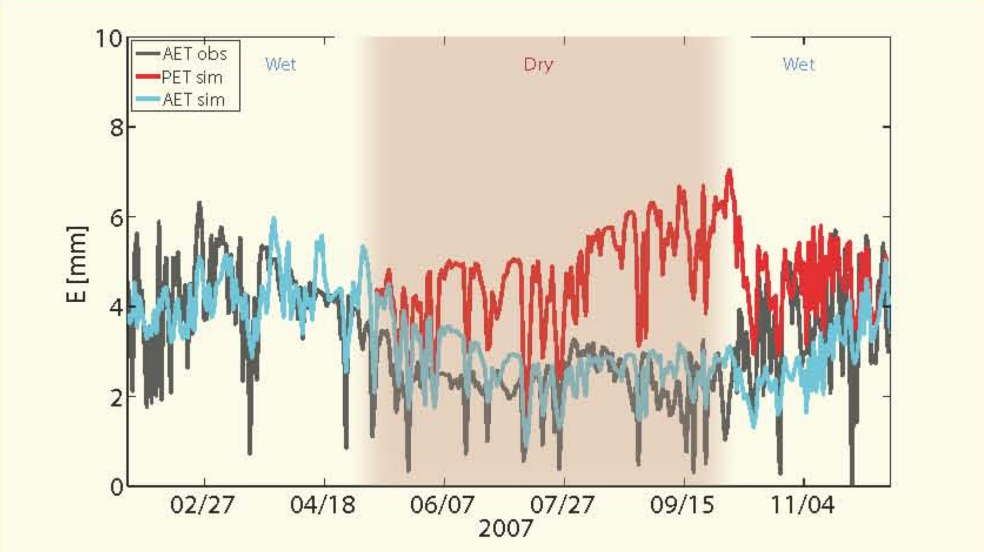
TUR modified for humid subtropical regions was best ranked PET model

	TUR	ABT	MAK	HAR	PEN	PMO	PRT
RMSE	0.99	0.99	1.02	1.16	1.47	1.16	1.69
NSE	0.44	0.45	0.40	0.24	-0.23	0.23	-0.63
KGE	0.45	0.42	0.46	0.50	0.49	0.45	0.44
SRCC	0.75	0.73	0.71	0.68	0.65	0.59	0.59
PCC	0.73	0.72	0.70	0.68	0.65	0.58	0.58
Mean rank	2.2	2.6	3	3.4	4.8	5.2	6.8
Final rank	1	2	3	4	5	6	7

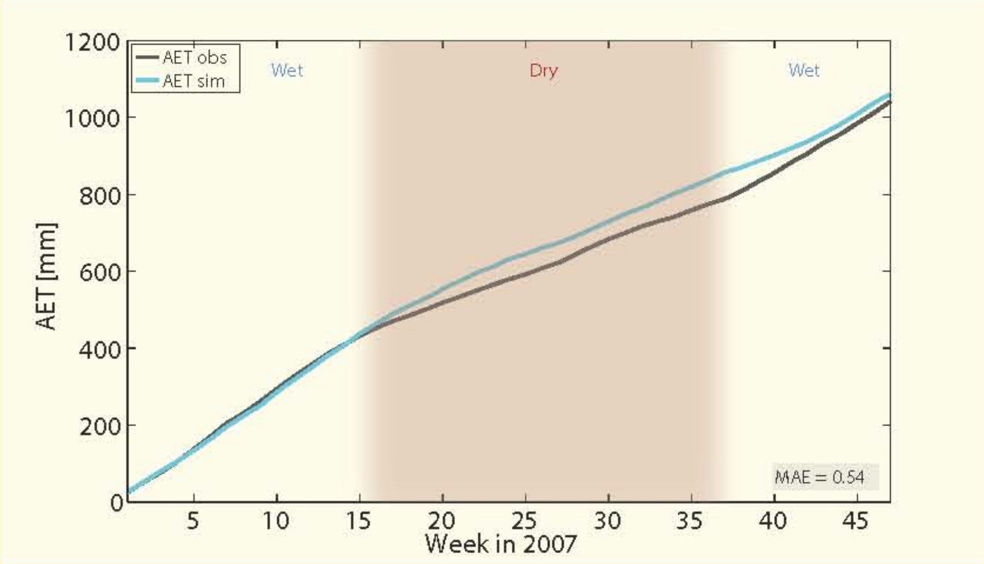
b) Water availability



Relative AET sim to PET sim as well as measured water level at water body C for the wet and the dry season of 2007 (sim = simulated)



Comparison of AET sim with PET sim and AET obs (obs = observed)



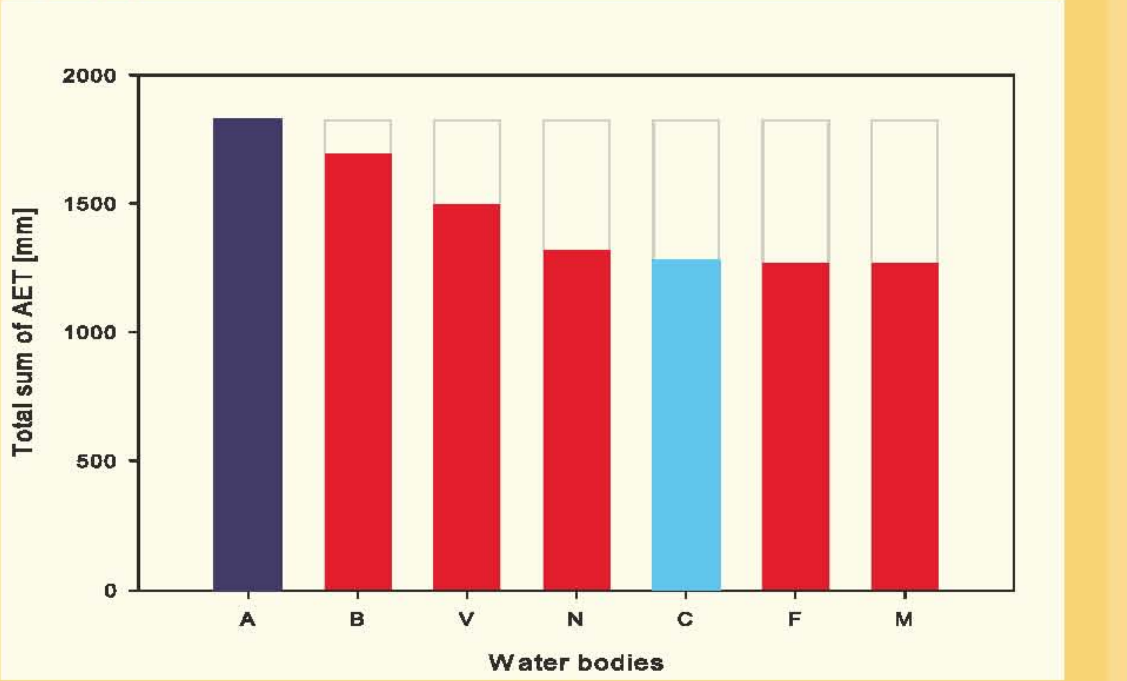
Cumulative sums of AET obs and AET sim on weekly mean basis. Our new model is able to simulate AET total sums [mm]:

AET obs = 1041.8

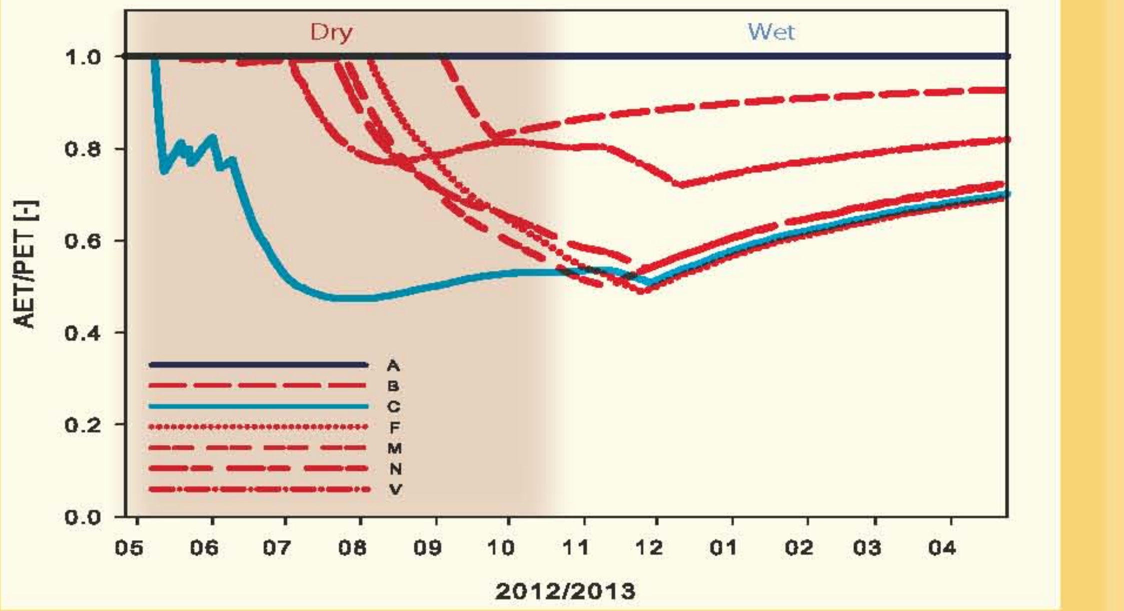
AET sim = 1061.6

(MAE = mean absolute error)

c) Application to different locations



Total sums of AET (Apr 2012 - Apr 2013, colors and letters refer to studied water bodies indicated in the location map) for different types of water bodies in relation to PET (grey columns).



Relative AET sim to PET sim for all water bodies. Constraining modeled PET by available water results in an earlier dry out of the floodplain compared to ephemeral water bodies.

6 CONCLUSION

The Turc model modified for humid subtropical regions best represents PET in our study area.

Inundation dynamics of seasonal wetlands largely influence PET by water availability and can be addressed with implementing a GW ET function.

Considering water availability our new model is capable of simulating AET of different types of water bodies for the dry and the rainy season. The reduction of AET compared to PET accounts for up to 28 %.

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