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RESEARCH AND OBSERVATORY CATCHMENTS: THE LEGACY AND THE FUTURE

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Observing the critical zone on a critical budget: The Peri Lake experimental catchment

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Abstract

The Peri Lake Experimental Catchment, in Southern Brazil, is a small coastal lake (5 km^2, 7 m depth) with a total catchment area of 20 km^2. The catchment is mainly covered by subtropical Atlantic Forest. Peri Lake is a recreational destination, an important ecosystem for biodiversity preservation, and a major water supply source. Even though there is a clear social and economic relevance, the information on this ecosystem is scarce, especially regarding the dynamics of water balance and water quality. We built this observatory using a low-cost, low-technology monitoring system to estimate the major components of the water budget on what we called a critical budget. We monitor meteorology, rainfall interception in two plots, overland flow and groundwater connectivity in a representative hillslope; and streamflow and velocity are measured in several small headwater rivers mostly starting during 2015. Geographic information on topography, land cover, geology, soil characteristics and the location of all the equipment installed in the field are also provided. The data set can be used to understand rainfall interception in Atlantic forests, catchment connectivity and streamflow permanence in coastal areas, spatial patterns of baseflow, and the modelling of complex processes in the critical zone involving the interaction between surface and groundwater, that are important in coastal lake ecosystems. Besides being used for research and education, we hope this observatory built on a shoestring budget will encourage fieldwork particularly in underrepresented and underfunded regions of the world.

KEYWORDS
Brazil, coastal lake, connectivity, critical zone, headwater, subtropical Atlantic forest

1 | INTRODUCTION

Most of the hydrological processes sustaining life take place in the critical zone (CZ) (Brooks et al., 2015; Grant & Dietrich, 2017). To advance hydrological understanding and address critical societal challenges related to water resources there is a need to expand fieldwork in the CZ (Blume et al., 2018; Bogena et al., 2018; Burt & McDonnell, 2015; Grant & Dietrich, 2017). While there is a clear blueprint for the ideal experimental setting (e.g., Long Term Ecological Research LTER, Critical Zone Observatory network CZO, and the Terrestrial Environmental Observatories TERENO), it is unrealistic to expect most research groups to install or maintain such infrastructure (Tauro et al., 2018). Reconciling low-cost equipment, low technology and non-conventional sources of data can be an alternative to expand

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hydrological observation (Tauro et al., 2018), particularly in developing countries, where long-term records are scarce and pressure on water resources is growing (Burt & McDonnell, 2015; Wohl et al., 2012). In Brazil, for example, a vast country extending 10 climatic zones and 6 natural biomes, there are few experimental sites and most of the observations continuity has been hindered by decreasing fund availability (Melo et al., 2020).

In this paper, we present the Peri Lake Experimental Catchment Data Set. The Peri Lake Experimental Catchment is located in Santa Catarina Island, Southern Brazil in a transition between tropical and subtropical climate (27°S, Figure 1), a latitude that lacks experimental catchments (Wohl et al., 2012). This coastal 5-km^2 lake is surrounded by headwaters covered by Subtropical Atlantic Forest with a total catchment area of 20-km^2. Our objective was to install a low-cost monitoring system that would allow us to gather information about the major components of the water budget in a short period. This implementation on a shoestring budget will serve as the base of a long term experimental observatory. We use low-cost and low technology measurements combined with hydrological and hydrodynamic modelling to clarify complex processes in the CZ.

Peri Lake is a recreational destination, an important ecosystem for biodiversity preservation, and a major water supply source. The main concern, however, is that drinking water might be contaminated with trihalomethanes that can be formed due to the combination of organic matter, *Filamentous cyanobacterium*, and the water treatment with chlorine. The flushing of organic matter associated with rainfall-runoff has the potential to affect lake water quality and favour the development of cyanobacteria. Even though there is a clear social and economic

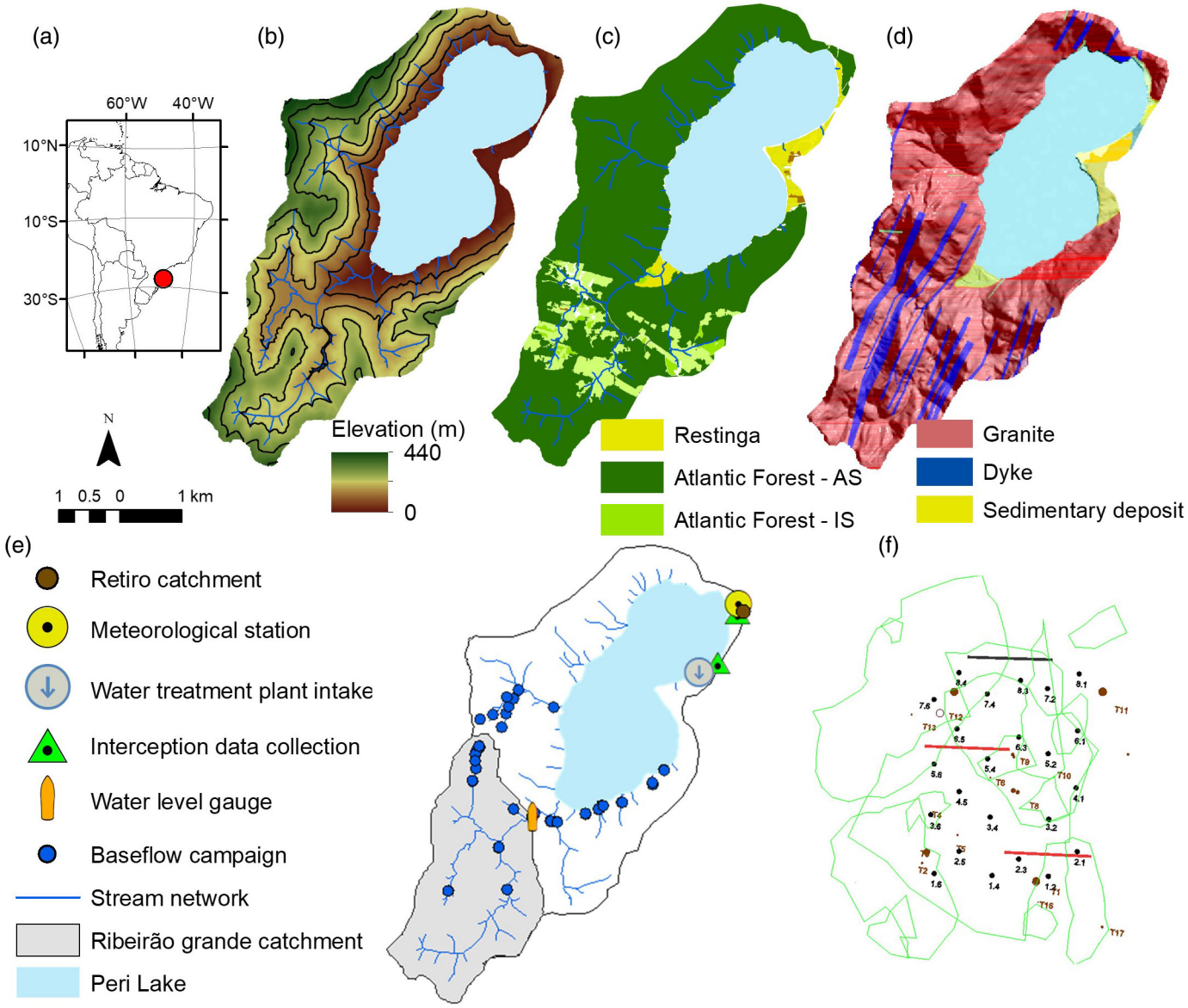

FIGURE 1 The Peri Lake experimental catchment. (a) Location in South America; (b) digital elevation map, contours are shown at 70 m intervals; (c) land cover; (d) geology (Federal University of Santa Catarina, 2014); (e) experimental design map; and (f) plan view of the interception monitoring plot, in green canopy areas, brown dots are the trunk positions, black dots are throughfall gauges, and bars are troughs

relevance, the information on this ecosystem is scarce, especially regarding the dynamics of water balance and water quality. The data set can be used to understand rainfall interception in Atlantic forests, catchment connectivity and streamflow permanence in coastal areas, spatial patterns of baseflow, and the modelling of complex processes in the CZ involving the interaction between surface and groundwater, that are important in lake ecosystems. Furthermore, these productive yet vulnerable coastal habitats can provide a base for studying local coupled water-human systems (i.e., Montanari et al., 2013) and can be used for research and environmental education.

2 | SITE DESCRIPTION AND INSTRUMENTATION

Peri Lake is a freshwater lake with an average depth of 7.0 m and only one outflow to the Atlantic Ocean via the Sangradouro stream. Mean annual precipitation is 1500 mm. The lake is classified as oligotrophic for nutrients concentrations and meso-eutrophic for transparency and chlorophylla, which can be explained by the high densities and monodominance of the cyanobacteria (Hennemann & Petrucio, 2011). The soil is characterized as Alic Podzolic Red-Yellow, with medium and clayey texture, moderately drained with rocky areas and strong undulation (EMBRAPA, 2004). The bedrock is characterized by plutonic and volcanic igneous rocks of Precambrian age (Neoproterozoic), mainly granite interspersed with diabase dykes. The right margin of the lake and the outlet of the Ribeirão catchment are characterized by alluvial deposits (Figure 1(d)). The stream channels are mostly characterized by colluvial cross-sections near the springs and cascade and step-pool turned into riffle near the lake.

We began the installation of the monitoring system in 2015 and approached the monitoring of this catchment from several spatial and temporal scales using both handmade and commercial equipment. We have measured rainfall interception in two plots, overland flow connectivity in a hillslope and streamflow in several small headwater rivers (0.01–5.33 km^2). The data are categorized by measurement type (i.e., meteorology, rainfall, interception, overland flow, streamflow, groundwater, geographic information system) and can be downloaded independently. Each data set contains a "readme" file and that documentation includes a table listing the equipment (Table 1), photos of installations, and graphs of the data. Below we describe the main attributes of the data set.

TABLE 1 Period and instrumentation of each measurement type

Data	Instrumentation	Period of data collection
Meteorology	Temperature (T): Thermistor Temperature Probe H377[a] Wind speed and direction: S2 Sonic Anemometer[b] Solar radiation: CMP3-L Pyranometer[c] Relative Humidity (RH): HygroClip S3[d]	Solar radiation, relative humidity and air temperature: 20 October 2016 to 30 April 2020. Wind speed and wind direction: 06 November 2018 to 30 April 2020.
Rainfall - Peri Lake Park headquarters	Tipping Bucket Rain Gauge - H340[a]	13 October 2015 to 27 February 2020
Rainfall - Retiro	Tipping Bucket Rain Gauge - 260-2501-A[e]	17 June 2016 to 03 March 2020
Interception	Handmade sensors, Tipping Bucket Rain Gauge - H340[a]	22 October 2015 to 21 December 2018
Overland flow	Handmade sensors	27 July 2018 to 09 October 2019
Streamflow	Mechanical current meter - OTT C2[f] Conductivity probe - Orion 4 Star[g]	14 March 2017 to 18 June 2020
Groundwater	Handmade sensors	31 July 2018 to 10 March 2020

[a]Manufactured by WaterLog, Yellow Springs, Ohio, United States of America.
[b]Manufactured by Climatronics, Hamilton, Ohio, United States of America.
[c]Manufactured by Campbell Scientific, Logan, Utah, United States of America.
[d]Manufactured by Rotronic, Grindelstrasse, Bassersdorf, Schweiz.
[e]Manufactured by Nova Lynx Corporation, Grass Valley, California, United States of America.
[f]Manufactured by OTT HydroMet, Ludwigstrasse, Munich, Germany.
[g]Manufactured by Thermo Scientific, Beverly, Massachusetts, United States of America.

2.1 | Meteorological and rainfall interception data

We provide meteorological data (i.e., wind velocity, wind direction, total radiation, relative humidity and temperature) starting from October 2016. There are two sets of rainfall data that are provided, one measured at the Headquarters of the Peri Lake Park starting from October 2015, and the other measured starting from June 2016 near the Retiro hillslope. Rainfall interception process can be estimated using throughfall and stemflow data that have been monitored at two 49-m^2 plots with different vegetation covers starting in October 2015. Those plots consist of 47 handmade pluviometers to measure throughfall and 28 stemflow gauges at each plot. Throughfall is also monitored using a plastic troughs connected to a tipping bucket. Automatic stemflow gauges are composed of a collar connected to a tipping bucket rainfall sensor. Figure 1(f) details canopy cover and the distribution of rainfall gauges and troughs.

2.2 | Overland flow and groundwater level detectors

The ephemeral and intermittent drainage network in the Retiro hillslope (2.65 ha, Figures 1(e) and 2) was monitored from 2018. Twenty-three

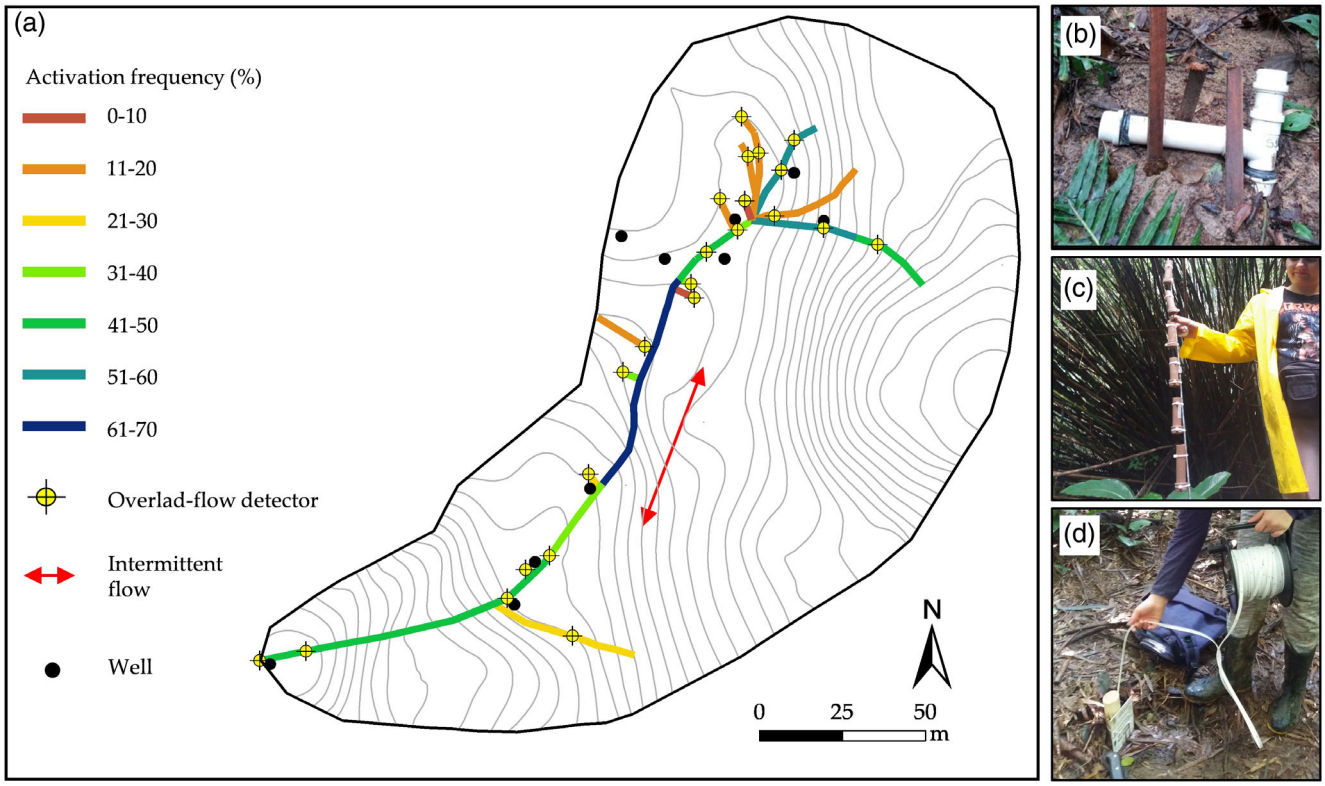

FIGURE 2 The Retiro hillslope. (a) Median channel activation frequency of the Retiro hillslope. (b) Overland flow detector. (c) Plastic reservoirs for groundwater level detection. (c) Tape measurement of groundwater level. Adapted from: Perez et al., 2020

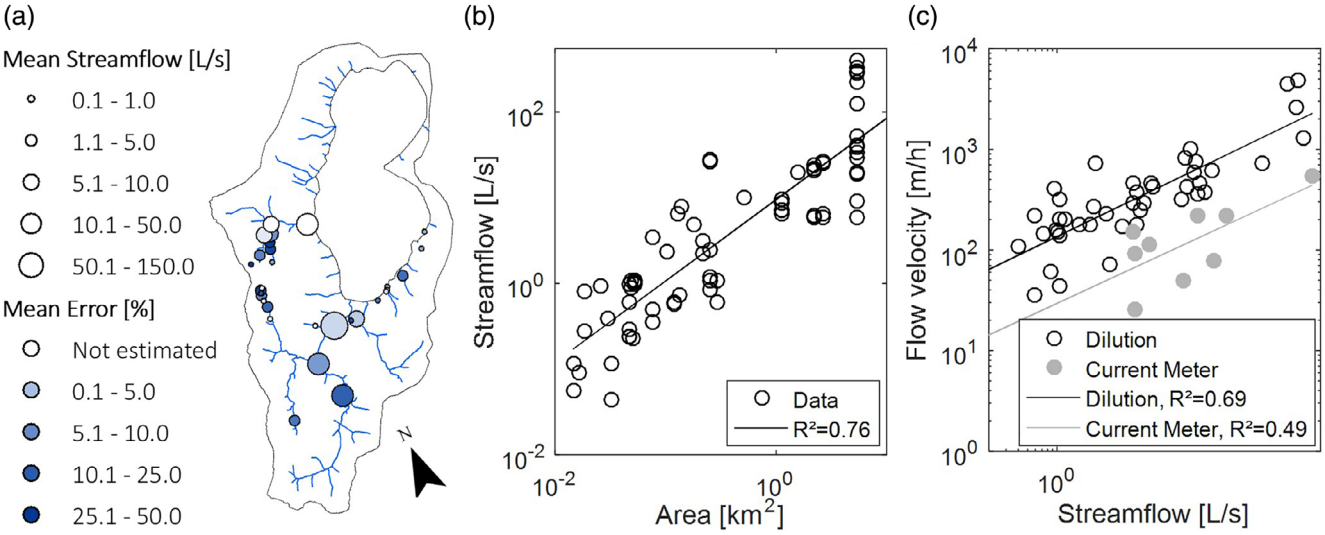

FIGURE 3 Streamflow measured during baseflow campaigns. (a) Spatial distribution of mean streamflow and estimated measurement precision. (b) Relationship between streamflow and area. (c) Relationship between streamflow and velocity using the dilution and current meter methods

manual overland-flow detectors were installed – as developed by Kirkby et al. (1976) and described by Vertessy and Elsenbeer (2000) and Zimmermann et al. (2014) – and provide binary data about presence or absence of flow in temporary streams (Figure 2(b)). The groundwater level has been measured in 10 wells distributed along the hillslope (Figure 2(d)). Inside each well there is a rod containing small plastic reservoirs that register the maximum water level for the precipitation event, with an error equal to the distance between two reservoirs (Figure 2(c)). Forty-eight precipitation events were recorded, with at least 24 h without rain between events. We also measured

infiltration capacity using a double-ring infiltrometer, and saturated hydraulic conductivity using the inverse auger hole method in locations with different landscape features. These data can be used to understand runoff generation mechanisms, the variation in drainage density (Figure 2(a)) and how the precipitation event controls the hydrological connectivity (e.g., Perez et al., 2020).

2.3 | Streamflow measurements

Streamflow and flow velocity measured in 14 campaigns to characterize baseflow conditions across 31 stream cross-sections is provided. Streamflow was measured using three different methods depending on the cross-section characteristics: volumetric, current meter (e.g., Cohn et al., 2013), and salt dilution (e.g., Day, 1976). There are 78 streamflow measurements (Figure 3(a)), 9 measurements with the current meter, 12 measurements with the volumetric method, and 57 measurements with the salt dilution method. The flow velocity was calculated for each mixing length using the median of the salt break-through curve (e.g., Bergstrom et al., 2016). The data follows a power-law relation between flow velocity and streamflow (Figure 3(c)) and more details on the accuracy of the measurements are provided in Innocente dos Santos et al. (2021).

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DATA SET CONTRIBUTORS

Several people have been involved in the field campaigns for the collection of these data including the authors. These include Pedro F. Arienti, Gabriel Anzolin, Daniel Bartiko, Alena G. Bevacqua, Tássia M. Brighenti, Vinícius B. P. Chagas, Paula C. David, Júlia M. Massing, Maria F. R. Pereima, Debora Y. Oliveira, José V. B. Souza, Gustavo A. Speckhann, and staff of the Fundação Municipal do Meio Ambiente de Florianópolis (FLORAM) that operate Peri Lake Park office.

DATA AVAILABILITY STATEMENT

The Peri Lake Experimental Catchment Data Set has no licensing restrictions and is available at http://doi.org/10.5281/zenodo.4445367. For more information on the data set and collaborations, please communicate with the lead author pedro.chaffe@ufsc.br (www.labhidro.ufsc.br).

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