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DATA PAPER

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Regional meteoric water line of the Yucatan Peninsula, Mexico

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Abstract

The data set represents the Regional Meteoric Water Line (RMWL) for the Yucatan Peninsula (Mexico), a region with karstic aquifers but little knowledge of the isotopic composition of meteoric water. This data paper comprises the isotopic composition of meteoric water collected from November 2018 to November 2019 as monthly composite samples expressed as weighted monthly mean precipitation from 16 locations across the Yucatan Peninsula. The RMWL was $\delta^2H = 7.803\ \delta^{18}O + 12.075$, with a slope and intercept suggesting precipitation from air that has undergone condensation, air masses with variable moisture or recycled moisture. The average $\delta^{18}O$ is −2.57‰ (−12.23 to 1.2‰) and δ^2H is −7.94‰ (−83.39 to 18.32‰). This data set was collected by the implementation of an isotopic monitoring network, gathering information useful as a tool for better understanding of the hydrology and hydrogeochemistry of karstic aquifers, and to develop proxies for paleohydrology, ecohydrology, climate change and paleoclimate studies in the Gulf of Mexico and the Great Caribbean Area.

KEYWORDS
precipitation, stable isotopes, water cycle

Dataset

Data set for the Regional Meteoric Water Line of the Yucatan Peninsula (Mexico). We are unable to provide DOI information until after publication.

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Creator: Cejudo E., Leal-Bautista R.M. and Acosta-González G.

Dataset correspondence: eduardo.cejudo@cicy.mx

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1 | INTRODUCTION

The environmental isotopes of water δ²H and δ¹⁸O are essential for estimating groundwater recharge and water balances (Adomako et al, 2015; Clark & Fritz, 1997; Gat, 2010). The isotopic composition of meteoric water at a given location or region is represented in a scatter plot in which the δ^2H and δ^{18}O distribute along a line named Meteoric Water Line. Worldwide, the pattern line is called Global Meteoric Water Line (GMWL) defined by the equation $\delta^2 H = 8.17 \bullet \delta^{18} O + 10.35$ (Rozanski et al., 1993). Local and Regional Meteoric Water Lines are necessary to identify the amplitude of the input parameters, that is, the rainwater throughout the time (Darling et al., 2003; Gat, 2005; Hao et al., 2019). In the particular case of karstic aquifers, the information has assisted in several cases for improving estimates of available renewable water (Al Charideh & Kattaa, 2016; Katz et al., 1997; Wang et al., 2018) because the isotopic composition of groundwater might respond faster to precipitation in such aquifers (Sappa et al., 2018). Hereby, we present the Regional Meteoric Water Line of the Yucatan Peninsula (Mexico) with data from November 2018 to December 2019 from 16 locations in the three Mexican states of the Peninsula (Campeche, Quintana Roo and Yucatan).

2 | DATA DESCRIPTION AND DEVELOPMENT

Meteoric water was collected from direct interception following conventional precipitation monitoring programmes for isotopic studies (Clark & Aravena, 2005). Meteoric water was collected and analysed for isotopic composition integrating all the precipitation for the month into monthly composite samples, expressed as weighted monthly mean precipitation. We aim to represent the territory of the Yucatan Peninsula by establishing meteoric water collection sites in nine regions (Table S1). When possible, we established two collection sites in fixed locations with individual trained and provided with sampling collection kits and manuals for proper sampling, storage and preservation of the water samples (Figure 1). We have 16 sampling stations, all of them operated by the same personal. Each sampling kit is comprised of a container called collector, consisting of a 1.5 L wide mouth plastic container with a plastic funnel (r = 7.5 cm), where meteoric water is collected during the rain events. In very few cases, when rain exceeded 1 L, the collector has a snap plastic tap used a relief valve, where excess water will flow out when more than one litre of water was collected; yet, precipitation still entered and mixed inside the collector.

This method considered the collection of precipitation from events of more than 20 min of duration or 5 mm of precipitation measured in the collector (≈20 mL). The collector was deployed directly to an open area just before the rain event and retrieved after the rain ceased. The water was transferred immediately into a 4 L or 10 L jerry can that stores all the meteoric water representing the calendar month. After each rain event in which precipitation was collected, information about the rain event is registered in into field book containing date, time and duration of the event, as well as important notes or observations about the rain event (i.e. windy, hail, thunderstorm, frontal event and tropical depression).

On the last day of the month, smaller volumes of water from the monthly container are transferred to two 30 ml high-density polyethylene (HDPE) bottles, following the environmental isotope sampling protocol suggested by Clark and Aravena (2005). The 30 ml bottle is filled to the top of the bottle and closed without air bubbles, forming a

FIGURE 1 Sampling collection kits and manuals for sampling, storage and preservation of the water samples

water seal. In this manner, it can be stored indefinitely because samples do not experience evaporation (Spangenberg, 2012). Each bottle is labelled with the sampling location, month, year and name of collector. The establishment of temporary collectors in remote areas or mist collectors was not considered since frequent sample collection cannot be ensured.

2.1 | Stable isotope analyses (δ^2H and δ^{18}O)

Analyses for water stable isotopic were done at the University of Waterloo-Environmental Isotope Laboratory (UW-EIL). The ^{2}H/^{1}H and ^{18}O/^{16}O ratios of the meteoric water samples were measured using a Los Gatos Research (LGR), Liquid Water Isotope Analyser (LWIA), model T-LWIA-45-EP instrument with precisions of δ^2H = ±0.3‰ and δ^{18}O = ±0.1‰. All samples are pre-filtered to 0.45 micron into 12 × 32 mm septum vials. Approximately 1,000 nl of water is injected into the heated septum port by a LEAP Technology (CTC) PAL liquid auto-sampler. Upon injection, the water rapidly vaporizes and is expanded into the laser cell of the LWIA. Each sample is injected eight times. The first two are discarded as conditioning, and the remaining six averaged for reporting. Approximately one in five samples repeated. Water molecules are measured directly by Off-Axis Integrated-Cavity Output Spectroscopy (ICOS) Laser System. Quality control is maintained by running a suite of water standards throughout of the batch. Duplicates are run at a minimum of every tenth sample. Each run also includes an in house check standard of each individual sample batch. All results are expressed in per mil notation (‰) and entered into a spreadsheet.

2.2 | Meteorological data

The monthly precipitation and land surface temperature data for our area of interest were calculated using the NASA application https://giovanni.gsfc.nasa.gov/giovanni/, selecting the precipitation data in a 0.1° × 0.1° pixel resolution and land surface temperature data in a 0.05° × 0.05° pixel resolution. Values were retrieved in millimetres per month (mm/month) for precipitation (Huffman et al., 2019) and Kelvin for land surface temperature (MOD11C3v006) from January 2018 to December 2019. The precipitation and land surface temperature images were entered and edited in a Geographic Information System (QGIS V.3.8.3-Zanzibar). The pixels from the 16 sampling sites were converted into a vector layer extracting the precipitation and land surface temperature information per sampling site. The results are showed in Figure 2a and b. By using this method, the minimum value of precipitation was measured in April 2019 at UNACAR CAMPUS 3 (Campeche, 9.95 mm), during the dry season. The maximum value was observed early in the rainy season, in June 2019 at Champotón (Campeche, 340 mm). Both stations are located by the Gulf of Mexico. Maximum land surface temperature was recorded in Merida in April (38.3°C) and May 2019 (38.8°C), whereas minimum temperatures correspond to Bacalar in December 2018 (23.1°C).

2.3 | Results description

There are 142 data entries, and some of them replicates of the sample as reported by the Laboratory (Table S1). It represents the isotopic composition of meteoric water of the Yucatan Peninsula from November 2018 to November 2019. It is organized with a consecutive number, sampling location, date (*mmm/yy*), Region, Decimal degrees coordinates (longitude west, latitude north), δ^{18}O, δ^2H, *d*-excess and mean monthly precipitation (in mm). There are two samples from a single precipitation event, Sample 18 (Cancun 9 April 2019, 32.5 mm precipitation) corresponding to a frontal system (North event) and a trough in the Gulf of Mexico; sample 112 represents a low-pressure system (Xoy 10 June 2019, ≈25 mm precipitation).

The RMWL of the Peninsula of Yucatan is showed in Figure 3, it was calculated by least square fit of the data points and the equation is

$$\delta^2 H = 7.803 \bullet \delta^{18} O + 12.075 \quad (1)$$

At the regional scale (Yucatan Peninsula), the average δ^{18}O is −2.57‰ (±2.22) and δ^2H is −7.94‰ (±17.76). The dispersion of isotope composition on meteoric water is large. δ^{18}O varies from −12.23 to 1.2‰, whereas δ^2H was measured from −83.39 to 18.32‰. Seasonally, the most depleted δ^{18}O water was measured in May and June 2019. June 2019 was the month with the largest variability in precipitation and δ^{18}O (Figure 4). The same trend applies to δ^2H. Spatially, the most depleted δ^{18}O and δ^2H and the largest data dispersion were observed in the Central Gulf (−90.7 W, 19.3 N), concurrent with the greatest mean monthly precipitation (173.2 mm, Figure 5). We explore the amount effect by region, but we did not find strong correlation ($r^2 = -0.57$). The amount effect obtained by date is described by Equation 2

$$\delta^{18} O = -0.209 \times \text{precipitation} - 0.3257\, (n = 13,\ r^2 = -0.73) \quad (2)$$

With the data, we produced seasonal meteoric water isoscapes (Figure 6).

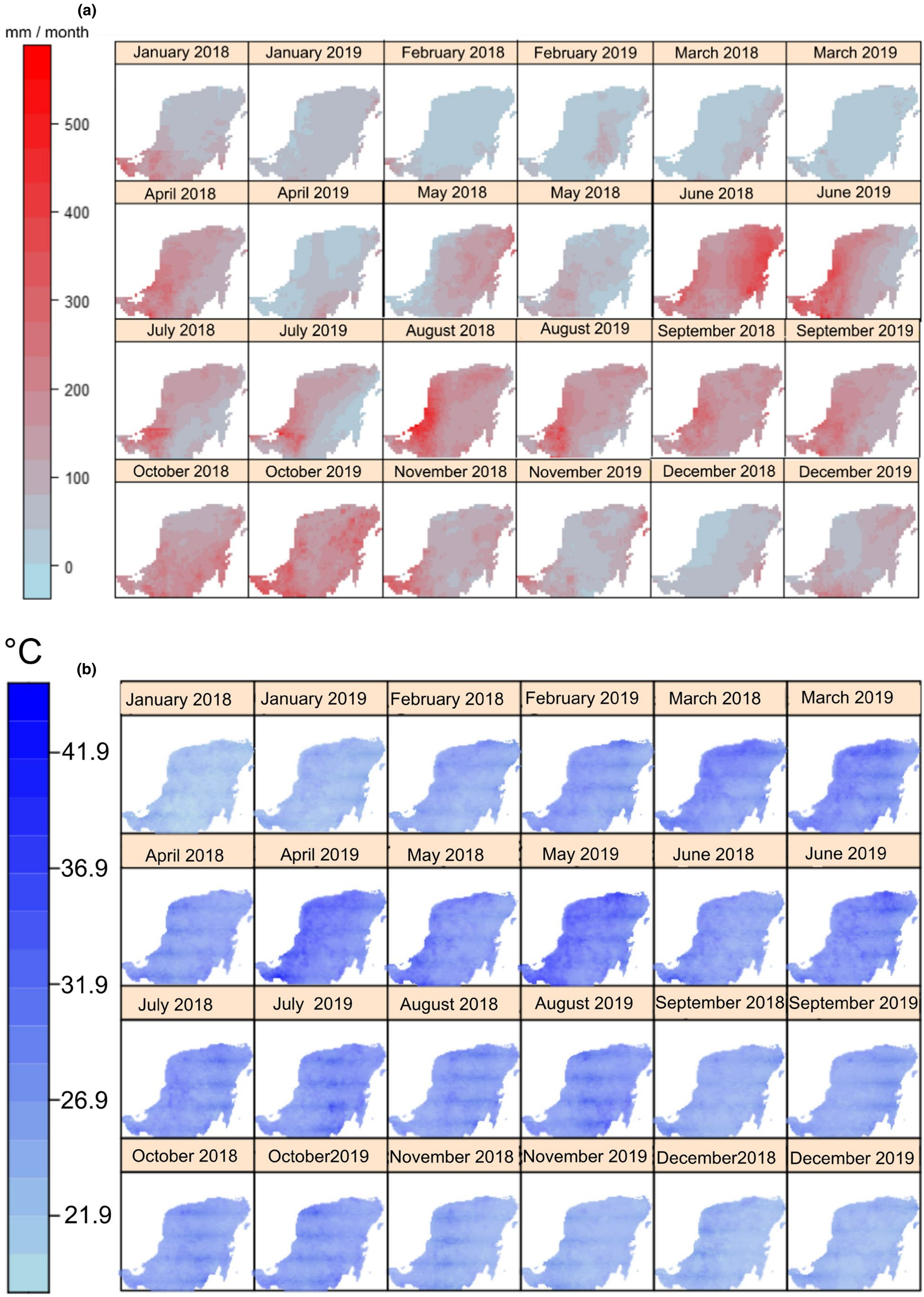

(a)
mm / month
500
400
300
200
100
0
January 2018
January 2019
February 2018
February 2019
March 2018
March 2019
April 2018
April 2019
May 2018
May 2018
June 2018
June 2019
July 2018
July 2019
August 2018
August 2019
September 2018
September 2019
October 2018
October 2019
November 2018
November 2019
December 2018
December 2019
°C
(b)
41.9
36.9
31.9
26.9
21.9
January 2018
January 2019
February 2018
February 2019
March 2018
March 2019
April 2018
April 2019
May 2018
May 2019
June 2018
June 2019
July 2018
July 2019
August 2018
August 2019
September 2018
September 2019
October 2018
October2019
November 2018
November 2019
December2018
December 2019

FIGURE 2 (a) Precipitation (mm/month) of the 16 sampling sites from January 2018 to December 2019 as reported in a 0.1° × 0.1° resolution by NASA. Data retrieved from https://giovanni.gsfc.nasa.gov/giovanni/. (b) Land surface temperature (mm/month) of the 16 sampling sites from January 2018 to December 2019 as reported in a 0.05° × 0.05° resolution by NASA. Data retrieved from https://giovanni.gsfc.nasa.gov/giovanni/

2.4 | Limitations of the data set

Our data set represents one calendar year, from November 2018 to November 2019. Due to scarce population in the central-south area of the Yucatan Peninsula, it was difficult to recruit volunteers at that area and we have few inland stations (3). The sampling design relies on the trained people, volunteering for collecting and storing the precipitation after the event; thus, labour, personal commitments or health issues prevented sampling all the events.

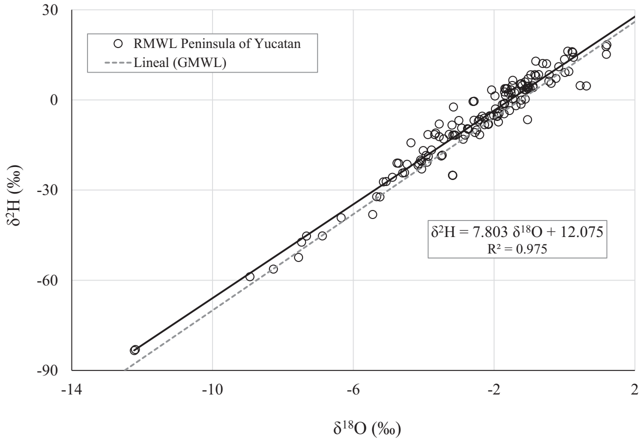


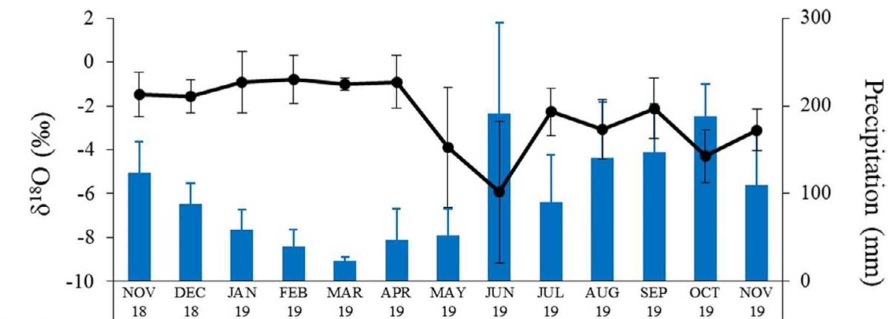
FIGURE 3 Regional Meteoric Water line of the 2018 Peninsula of Yucatan. Data from November 2018 to November 2019

3 | DATASET ACCESS

Data available at http://cicy.repositorioinstitucional.mx/jspui/handle/1003/1812.

4 | POTENTIAL DATASET USE AND REUSE

This is the first report of a Regional Meteoric Water in the Yucatán Peninsula, a groundwater dependant region. The immediate scientific goal of this data set is to obtain and to map the isotopic composition of precipitation throughout the region, as the main input of water into the karstic aquifers of the region. This knowledge is useful for updating and refining water budgets and regional water balances, and it is



	NOV 18	DEC 18	JAN 19	FEB 19	MAR 19	APR 19	MAY 19	JUN 19	JUL 19	AUG 19	SEP 19	OCT 19	NOV 19
PP (mm)	123	88	59	40	24	48	53	191	90	141	147	188	109
δ18O	-1.47	-1.58	-0.91	-0.79	-1.03	-0.91	-3.90	-5.94	-2.28	-3.08	-2.11	-4.29	-3.10

FIGURE 4 Mean monthly precipitation (mm) and volume weighted average $\delta^{18}O$ from November 2018 to November 2019 in the Yucatan Peninsula. Bars represent 1 s.d

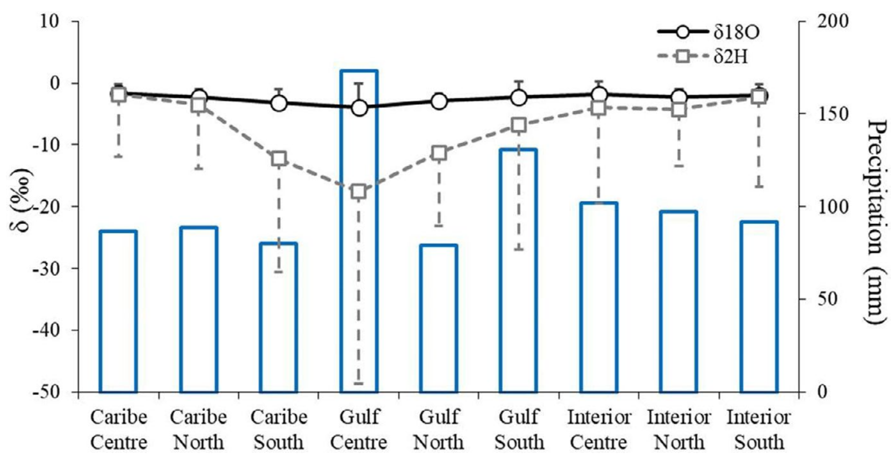


FIGURE 5 Regional mean monthly precipitation (mm); weighted average $\delta^{18}O$ (black) and δ^2H (grey) from November 2018 to November 2019. Bars represent 1 s.d. Regions as described in Table S1

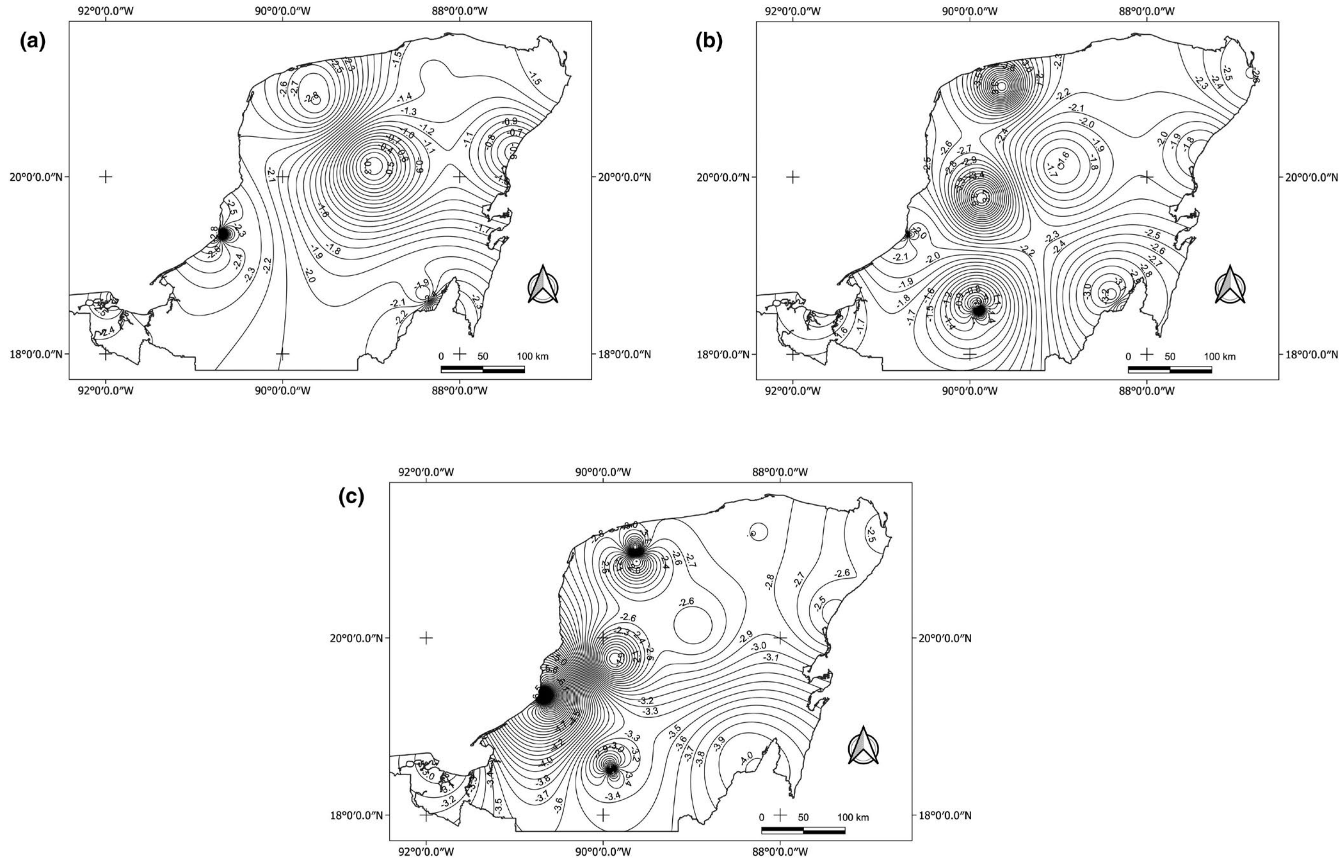


FIGURE 6 Seasonal meteoric water isoscapes ($\delta^{18}O$) of the Yucatan Peninsula. Seasonal volume weighted average $\delta^{18}O$ from November 2018 to November 2019. Winter season from October to January, dry season from February until May, and a summer rainy season from June to September

essential knowledge to understand what happens to the water within the aquifer systems. The difference in isotopic composition allows for differentiation of precipitation sources and consequently of recharge mechanisms. Moreover, there can be differences due to how recently recharge occurred. Extreme meteorological events such as Tropical storms and Hurricanes pass frequently over the Peninsula of Yucatan, such precipitation has a distinctive isotopic signature. The obtained average value for $\delta^{18}O$ in rain is −2.5‰ and −7.7‰ for $\delta^{2}H$, whereas tropical storms passing over the Peninsula have been measured to have an isotopic signature of approximately −9‰ for $\delta^{18}O$ and −60‰ for $\delta^{2}H$ (Perry et al., 2003). Because of this large difference, the isotopic composition of groundwater recharge from hurricanes can be used as a groundwater tracer to better understand the hydrodynamics of the aquifers. This information can also be used with additional experimental approaches involving tracers and implementing 3- or 4-component mixing models, in order to develop mathematical mass balances that will provide greater understanding and the development of conceptual models and identify areas of susceptibility to contamination and priority recharge regions in the aquifer systems of the Yucatan Peninsula. It is also useful in paleohydrology, hydrogeochemistry, ecohydrology, and for developing proxies for climate change and paleoclimate studies in the Gulf of Mexico and the Greater Caribbean Area.

Besides the scientific benefit of this research, we established a collector's network with the help of the same volunteers all the time, allowing coverage of the area at a significantly more detailed level than would otherwise be possible with the current available human and financial resources. Exposing the local population to the acquisition and evaluation of quantitative data, and inform them about locally important aspects of hydrology, hydrogeology and meteorology in their communities, is an asset for all parties as the knowledge acquired is generated with strict scientific basis, allowing them to increase their skillset and producing high-quality data with a citizen science network.

5 | CONCLUSIONS

We produced for the first time a regional meteoric water line for the Yucatan Peninsula, an area relying completely on groundwater, which water balances and budgets had not been produced using isotopic data. We established 16 meteoric water-sampling stations in three states of the Peninsula, gathering 142 data entries comprising precipitation from

November 2018 to November 2019. This information is useful in hydrology, paleohydrology, hydrogeochemistry, ecohydrology, climate change and paleoclimate studies in the Gulf of Mexico and the Great Caribbean Area.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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