**Water isotope characteristics of a flood: Brisbane River,
Australia**

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Water isotope characteristics of a flood: Brisbane River, Australia

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Abstract

Flooding associated with tropical storms can cause extreme perturbations in riverine and coastal ecosystems. Measuring isotope variability of tropical storm events can help investigate the impacts of flooding. We measured the water isotope composition (δD and $\delta^{18}O$) of rain and associated floodwater collected during two storms and subsequent major and minor flooding events in the subtropical coast of eastern Australia. Compared to baseline regional rainfall isotope values of $-15.0 \pm 1.9\text{‰}$ for δD and $-3.3 \pm 0.2\text{‰}$ for $\delta^{18}O$, floodwater had lower values with $-33.8 \pm 2.5\text{‰}$ δD and $-5.1 \pm 0.4\text{‰}$ $\delta^{18}O$ for the major flood and $-29.4 \pm 1.0\text{‰}$ δD and $-4.6 \pm 0.1\text{‰}$ $\delta^{18}O$ for the minor flood. The low isotope composition of the floodwater was associated with the transport of large quantities of suspended sediments, with sediment loads 30 to 70 times larger than during base flow conditions. Floods carried up to 35% of the annual phosphorus and up to 208% of the currently calculated average annual nitrogen load of the Brisbane River. The dramatic changes caused by a rapid increase in discharge from 2 to 2,015 $m^3 s^{-1}$ over two days in the major flood would have major consequences in riverine and coastal ecosystems of the region. These changes could potentially be traced using the isotope composition of the floodwaters.

Keywords: deuterium; $\delta^{18}O$; storm; nutrients; suspended sediment; floodwater

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1 Introduction

2 The hydrogen and oxygen isotope compositions of water (δD , deuterium, and $\delta^{18}O$)
3 have long been used to study hydrological and climatological processes (Gat, 1996). More
4 recently, the use of δD and $\delta^{18}O$ has expanded in many areas. For instance, water isotopes
5 have been used to assess sources of water for plants (Dawson *et al.*, 2002) and to detect
6 migration patterns of birds in North America (Hobson and Wassenaar, 1997). Water isotopes
7 have also been used in forensics to uncover, for example, the place of origin of illegally hunted
8 wildlife (Bowen *et al.*, 2005), or to trace the place of origin of a commercial product, such as
9 milk (Ehtesham *et al.*, 2013). There is great potential for future use of δD and $\delta^{18}O$ in the many
10 fields where water is the underlying driver of change.

12 Hydrological, ecological and forensic studies have benefited from long-term programs
13 that monitor isotope variation in precipitation around the world (e.g. Global Network for
14 Isotopes in Precipitation, GNIP) and produce gridded datasets (Bowen, 2014). However, in
15 some locations, the isotope datasets have low spatial resolution, and the temporal sampling is
16 too coarse (e.g. monthly sampling) to detect isotope variations that occur within a relatively
17 short period of time (e.g. days), such as during storms (Araguás-Araguás *et al.*, 2000). Storms
18 have been recognized as the most important factor affecting isotope variability within
19 precipitation of tropical regions (Kurita *et al.*, 2009; Lachniet and Patterson 2009). Therefore, it
20 is of strong interest to measure isotope variability during short-lasting, but powerful storm
21 events that could explain the long-term rainfall isotope variability within the tropics.

23 The atmospheric moisture during tropical storms has a specific isotope composition with
24 very low δD and $\delta^{18}O$ values that cannot be fully explained by usual assumptions of
25 precipitation and temperature (Gat, 1996). The distinctive isotope composition of tropical

1 storms causes deviations of the seasonal isotope composition of rainfall. For example, in
2 southwest Australia, aseasonal strong rainfall events have an isotope composition significantly
3 lower than the annual minimum (Turner *et al.*, 1987). Tropical storms in Central Amazon have
4 $\delta^{18}\text{O}$ values approaching -10‰ (Matsui *et al.*, 1983), much lower than the annual range of
5 values of -2 to 2‰ . Similarly, water isotope values near -6.5‰ for $\delta^{18}\text{O}$ have been measured
6 during tropical storms and low-pressure systems in Puerto Rico; these values are lower than
7 the annual range of 0 to -3‰ (Scholl *et al.*, 2009). These low values have been explained by
8 the so-called “amount effect” with lower values associated with higher rainfall amounts
9 (Dansgaard, 1964), and more recently, by cloud altitude and atmospheric condensation
10 temperature (Scholl *et al.*, 2009). The characteristic isotope composition of rainfall during
11 storms generates an almost immediate response in the isotope composition of the river flow
12 (Turner *et al.*, 1987). However, there are only a handful of published studies that provide
13 values of water isotopes of rainfall during tropical storms and none, as far as we know, for
14 floodwaters. In this study, we provide the water isotope composition (δD and $\delta^{18}\text{O}$) of rain and
15 associated floodwater collected during two storms and subsequent floods in the subtropical
16 coast of eastern Australia.

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18 Floods can move large amount of nutrients and sediments into riverine and coastal
19 ecosystems (Mitchell *et al.*, 1997). Large nutrient and sediment loads can cause cyanobacterial
20 blooms, hypoxia, seagrass loss and coral reef degradation (Hallock and Schlager, 1996;
21 Campbell and McKenzie, 2004; Paerl, 2008). In this study, we augment information about the
22 isotope values of rain and floodwater with the physicochemical measurements of the
23 floodwater, including nutrient and sediment loads. This information could be used in ecological
24 studies in riverine and coastal ecosystems that use the isotopic composition of water to trace
25 the impacts of flooding.

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5 2 **Methods**
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7 3 *Study Area*
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10 4 Samples were collected in the Brisbane River catchment in Southeast Queensland,
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12 5 Australia (Fig. 1). The region is classified as subtropical, experiencing moderate temperatures
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14 6 year round, with a mean annual maximum temperature of 25.4°C and a mean annual minimum
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16 7 of 15.7 °C (Australian Bureau of Meteorology, ABM 1951– 2000). The climate is characterized
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18 8 by a moderately cold and dry winter with an average total rainfall of 64 mm and monthly mean
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20 9 temperature of 22.3°C (June to August), and a hot and wet summer with a total rainfall of 597
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22 10 mm and a monthly mean temperature of 30.0°C (December to February). The hottest month is
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24 11 January with a monthly mean of 30.2°C and the coldest months are June and July, both with a
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26 12 monthly mean of 21.9 °C. The average total annual rainfall for the region is 1,186 mm (ABM,
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28 13 Brisbane Station, 1999–2015 for temperature and 1951–2000 for rainfall).
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34 15 The Brisbane River is 344 km long with a catchment area of 12,643 km² (Ozcoasts,
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36 16 2015). The mean, minimum and maximum monthly discharge rates from the Brisbane River
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38 17 are 26, 7 and 122 m³ s⁻¹, respectively (State of Queensland, Department of Natural Resources
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40 18 and Mines, DERM, Station 143001C, Brisbane River at Savages Crossing, 1958-2015). The
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42 19 River has a 100-year recurrence interval flood (Q₁₀₀) of 16,437 m³ s⁻¹ (Shellberg and Brooks,
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44 20 2007). The Brisbane River can be classified as hydrologically extreme with extreme flash flood
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46 21 behaviour and large annual variability in peak discharge (coefficient of variation of annual
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48 22 volume = 113%; Shellberg and Brooks, 2007). The Brisbane River is dammed by the
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50 23 Wivenhoe Dam, forming Lake Wivenhoe, which is connected and managed conjunctively with
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52 24 Somerset lake, formed by the damming of Stanley River (Fig. 1). The Brisbane River has eight
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54 25 main tributaries: Stanley River, Breakfast Creek, Moggil Creek, Bulimba Creek, Norman
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Creek, Oxley Creek, Bremer River and Lockyer Creek, with the Lockyer Creek joining the Brisbane River downstream of the dam (Fig. 1).

The catchment of the Brisbane River is considered to be in poor health due to agriculture, grazing, water storage and urban development (Healthy Waterways, 2014). Fine suspended sediment load in the Brisbane River is estimated to be around 247 kilotonnes yr^{-1} (Ozcoasts, 2015). Nutrient loads are estimated at 314 tonnes yr^{-1} for dissolved phosphorus (P), 1,687 tonnes yr^{-1} for fine sediment P, 1,686 for dissolved nitrogen (N) and 1,473 tonnes yr^{-1} for fine sediment N (Ozcoasts, 2015).

Methods

On the 24th of January 2013, tropical storm Oswald crossed the eastern coast of Australia and caused intense rainfall in a short period. In some locations, rainfall in excess of 1,000 mm was measured in 96 hours resulting in moderate to major flooding (ABM, 2013). A historical peak flood of 9 m was reached in the Lockyer Valley at Laidley; the flood wave moved towards the Brisbane River reaching 15 m in the Lockyer Creek (station 143207A, O'Reilleys Weir, Fig. 1) just before discharging into the Brisbane River. The resulting flood wave peaked at 12 m north of Brisbane City (Savages Crossing, Brisbane River station 143001C, Fig. 1), making the flood the 24th highest on record (ABM 2013; DERM). Between February 23th and March 4th, a second strong rainfall event (124 mm in one week) caused some minor flooding. During both floods, stream discharge increased considerably with peaks of 2,405 and 1,880 $\text{m}^3 \text{s}^{-1}$ for the first and second flood, respectively (DERM, station 143001C) (Fig. 2B). As part of the flood management, water from Somerset and Wivenhoe dam was systematically released during the flooding episodes (Fig. 2B, Seqwater).

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1 Sampling was conducted within the mid Brisbane River (-27.4929'S, 153.0184'E) from a
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3 pontoon (Fig. 1). Rainwater was collected with a two-litre open container on the 27th and 28th
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5 of January, 2013. These were the days with the highest recorded rainfall in Brisbane during
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7 our sampling with 55 and 145 mm, respectively (ABM, 2013). The container was left 4-5 hours
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9 and the water was collected while the rain was falling in order to avoid evaporation. Rainwater
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11 was poured in 50 mL plastic containers and kept cool until analysis. Floodwater was collected
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13 every 2-3 hours from the river for the first three days of the first flood, then three times a day
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15 until the 1st of February. Afterwards, weekly samples were collected until the 19th of February,
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17 when daily sampling was resumed for the second flood event (total n = 29). River water was
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19 collected in clean 500 mL polyethylene terephthalate (PET) bottles, which were rinsed with
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21 surface water twice before sample collection at 20 cm below the water surface.
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13 Conductivity and pH were recorded for each sample using an YSI-meter (Xylem Inc.
14 Ohio, USA). Mean daily conductivity, water temperature, rainfall and river discharge were
15 obtained from DERM (station 143001C, Fig. 1). Additionally, we included information on
16 rainfall and river discharge from sampling stations 143203C and 143207A on Lockyer Creek,
17 the tributary which contributed most to the flooding. Water samples were analysed for total
18 suspended solids, dissolved nutrients (P as orthophosphates, N as nitrous oxides, N-NO_x⁻, and
19 ammonium, NH₄⁺), δD and δ¹⁸O. Total suspended solids (TSS) were calculated by filtering a
20 known volume of water through pre-weighed 47 mm glass microfibre GF/C Whatman filters of
21 1.2 µm pore size. Nutrients were analysed with EPA methods: 353.2 for NO_x, 350.1 for NH₄⁺,
22 and OP5A for P (SM-4500). Nutrient analysis detection limits were 0.005 µmol L⁻¹ for P and N-
23 NO_x⁻, and 0.01 µmol L⁻¹ for NH₄⁺. Nutrient loads were estimated from nutrient concentrations
24 and mean river discharge during the flood wave.
25

For δD and $\delta^{18}O$ analyses, rain and floodwater samples were kept in clean plastic bottles with minimum air space and in cool conditions to avoid evaporation before analysis. The water samples were analysed using a laser-based isotope analyser (LGR, Los Gatos Research, CA, USA). Measurements were calibrated with international standards SMOW, GISP, and SLAP, as well as five manufacture-supplied standards LGR1-LGR5 (Ahmad *et al.* 2012). The isotope values had errors (SD) < 2.0 ‰ for δD and < 0.3 ‰ for $\delta^{18}O$. Conductivity was measured for each sample prior to analyses to avoid erratic results due to high salinity. Conductivity readings for all samples were below $1000 \mu S cm^{-1}$ with the majority below $250 \mu S cm^{-1}$, and were thus considered freshwater. Particulate organic matter was filtered out before analyses with nylon syringe filters of $0.22 \mu m$ pore size (Livingstone Int., NSW Australia). Liquid organic contamination was possible, although likely to be minor as most of the floodwater is derived from rain (Turner *et al.*, 1987), most pollution from the Brisbane catchment derives from agriculture, not industrial sources (Healthy Waterways, 2014), and the sampling site was upstream of most of metropolitan Brisbane and its waste water discharges. Deuterium excess (d excess) was calculated as: $d \text{ excess (‰)} = \delta D - 8 * \delta^{18}O$ (Dansgaard, 1964). The d excess is an index of variation from the global meteoric water line (GMWL) and can be used to understand the prevailing conditions during the evolution of air masses as precipitation forms (Froehlich *et al.*, 2002). Averages are reported as mean with standard errors, unless otherwise stated.

Long-term precipitation data for the Brisbane region was obtained from the International Atomic Energy Agency/ Water Resource Program, the Global Network of Isotopes in Precipitation (Brisbane Station, IAEA/WMO, GNIP database 1962-2002, at: <http://www.iaea.org/water>). From this dataset we calculated the local meteoric water line

(LMWL). Seasonal predictions of the isotopic composition of precipitation were obtained from Bowen et al. (2014).

Results

The physicochemical characteristics of the water changed during the floods. During the first and major flood, water temperature decreased from 27.4°C to 23.4°C, after which it stabilized at $24.7 \pm 0.1^{\circ}\text{C}$ (Fig 2C). During this flood, conductivity was low reaching a minimum of $203 \mu\text{S cm}^{-1}$, after which it stabilised at $976 \pm 30 \mu\text{S cm}^{-1}$ (Fig. 2C). Water pH was low in both flooding events, decreasing from ~ 7.70 during pre-flood conditions to a minimum of 6.24 at the peak of the major flood and to 6.77 at the peak of the minor flood (Fig. 2D).

Floodwater had large amounts of TSS, especially during the major flood when values reached 1.5 g L^{-1} (pre-flood conditions were $< 0.1 \text{ g L}^{-1}$, Ozcoast, 2015). During the minor flood, TSS reached a maximum value of 0.3 g L^{-1} (Fig. 2E). Total sediment loads were more than double in the major flood with 481,266 tonnes or $28,148 \pm 10,689 \text{ tonnes d}^{-1}$ compared to the minor flood, which had 208,795 tonnes or $13,938 \pm 3,120 \text{ tonnes d}^{-1}$. The suspended sediment carried by the river during floods was 30 to 70 times larger than during base flow conditions, which is $407 \text{ tonnes d}^{-1}$. The large amount of TSS transported during floods was equivalent to 85-195% of the mean annual discharge estimated for the Brisbane River, which has been estimated to be 247,200 tonnes (Ozcoast, 2015).

Floodwater had high dissolved nutrient concentrations. During the major flood, floodwater had maximum concentrations of $9 \mu\text{mol L}^{-1}$ for P, $42 \mu\text{mol L}^{-1}$ for N-NO_x^- and $16 \mu\text{mol L}^{-1}$ for N-NH_4^+ (Fig 2F). These concentrations are equivalent to $9 \pm 2 \text{ tonnes d}^{-1}$ of P, $288 \pm 62 \text{ tonnes d}^{-1}$ of N-NO_x^- and $21 \pm 5 \text{ tonnes d}^{-1}$ of N-NH_4^+ . During the minor flood, only N-NO_x^-

increased to $28 \mu\text{mol L}^{-1}$ (Fig. 2F) with a load of 276 ± 65 tonnes d^{-1} of N-NO_x^- . Nutrient loads during floods, especially during the major flood, were more than 10 times larger than base flow conditions for P and N-NO_x^- , and almost 50 times larger for N-NH_4^+ ; base flow values for P, N-NO_x^- and N-NH_4^+ are 0.7 ± 0.3 , 28.3 ± 10.2 tonnes d^{-1} , and 0.4 ± 0.1 tonnes d^{-1} , respectively. Thus every flood transports about 110 ± 3 tonnes of P, $3,245 \pm 210$ tonnes of N-NO_x^- and 269 ± 19 tonnes of N-NH_3^+ . This represents about 35% of the annual P and 208% of the annual N estimated for the Brisbane River (Ozcoasts, 2015).

The water isotope composition varied significantly as floodwater moved through the river (Fig. 2G,H, Table 1). Mean values for the major flood were $-33.8 \pm 2.5\text{‰}$ for δD and $-5.1 \pm 0.4\text{‰}$ for $\delta^{18}\text{O}$. Minimum and maximum values at this time were -43.7‰ and -20.3‰ for δD and -6.7‰ and -3.1‰ for $\delta^{18}\text{O}$. There were high δD and $\delta^{18}\text{O}$ values at the beginning of the flood and a few days after the flood peak, probably due to water release from the Wivenhoe-Somerset dam (Seqwater, 2013; Fig. 2B). Prior to the flood, lake water in this large reservoir probably had increased δD and $\delta^{18}\text{O}$ values due to evaporation as this data fell off the GMWL and the LMWL (black circles, Fig. 3), as expected for evaporated waters. During the minor flood, water isotopic composition was also low, but less than during the major flood. Mean values during the minor flood were $-29.4 \pm 1.0\text{‰}$ for δD and $-4.6 \pm 0.1\text{‰}$ for $\delta^{18}\text{O}$, with minimum and maximum values of -33.6 and -27.0‰ for δD , and -5.3‰ and -4.3‰ for $\delta^{18}\text{O}$. For comparison, mean values for precipitation in Brisbane during January and February are $-15.0 \pm 1.9\text{‰}$ for δD and $-3.3 \pm 0.2\text{‰}$ for $\delta^{18}\text{O}$ (Brisbane Station, IAEA/WMO, GNIP 1962-2002).

In a dual isotope diagram, the data collected during this study had a wide range of values (range of 36‰ for δD and 6‰ for $\delta^{18}\text{O}$) and some of the data points from the first day of the major flood deviated from the GMWL and LMWL (grey circles, Fig. 4). The lowest and

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3 1 highest d excess values were measured during the peak of the major flood and had respective
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5 2 values of 1.6 and 14.5‰ (Fig. 2I). For comparison, mean d excess values for precipitation in
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7 3 Brisbane during January and February are $12.2 \pm 0.5\text{‰}$ (Brisbane Station, IAEA/WMO, GNIP
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9 4 1962-2002)
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14 6 The isotope composition of rainfall was different between flooding events. During the
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16 7 major flood accompanying the tropical storm, rainfall had a mean δD value of $-36.1 \pm 6.3\text{‰}$
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18 8 and a mean $\delta^{18}O$ value of $-5.6 \pm 0.7\text{‰}$; during the minor flood, mean rainfall δD values were -
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20 9 18‰ and rainfall $\delta^{18}O$ values were -3.8‰ (Table 1). River values followed the isotope
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22 10 composition of floodwater, indicating that most of the water during the peak flood was rain. The
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24 11 values from the rainfall during the major flood were 20‰ lower for δD and 2.3‰ lower for $\delta^{18}O$
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26 12 compared to the long-term mean values for January and February. The isotopic value of
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28 13 rainfall during the minor flood was similar to the long-term monthly mean.
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35 15 The historical data (1962-2002, IAEA/WMO, GNIP) shows that most flooding events in
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37 16 the Brisbane region, some of them resulting from tropical storms, are associated to rainfall with
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39 17 low isotope composition (Fig. 4A). Therefore, tropical storms in the region could partly explain
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41 18 the high variability of monthly values of long-term data that has standard deviations of 14.3 for
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43 19 δD and 1.7 for $\delta^{18}O$ (Fig. 4B). Overall, there was a long-term trend of low water isotopic
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45 20 composition accompanying high rainfall amounts (Fig. 4C).
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51 **Discussion**

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53 23 Floods throughout southeast Australia are major disruptions to riverine and coastal
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55 24 ecosystems (Olds *et al.*, 2014). In this study, we have shown that tropical storms in Brisbane
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57 25 Australia have distinctly low isotope compositions, twice as low as the long-term mean for the
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1 region. The distinct isotope value of the rain was traced in the floodwater as it moved through
2 the river towards the coastal zone. The low isotope composition of the floodwater was
3 associated with the transport of large quantities of suspended sediments, with sediment loads
4 30 to 70 times larger than during base flow conditions. The floods also carried up to 35% of the
5 annual P and up to 208% of the calculated mean annual N load of the Brisbane River. These
6 dramatic changes were caused by a rapid flow increase, from 2 to 2,015 m³ s⁻¹ in two days
7 during the onset of the major flood in the Lockyer Valley. These changes would have major
8 consequences in riverine and coastal ecosystems of the region and could be traced using the
9 specific water isotopic composition of floodwaters.

11 Measuring the isotope composition of floodwater could help trace flood effects on
12 riverine and coastal ecosystems. For example, during a tropical storm, mangroves can rapidly
13 take up floodwater and nutrients that can be traced in the plant tissues (Feakins and Sessions
14 2010; Lovelock 2011). Similarly, aquatic molluscs can acquire the isotope composition of
15 floodwater within days (Bortolotti *et al.*, 2013), so that the subsidy effect of floods to aquatic
16 foodwebs could be estimated. The effects of flooding could also be used to estimate fish
17 growth and movement using high-resolution analyses of 3-5 days of $\delta^{18}\text{O}$ in fish otoliths
18 (Patterson, 1998; Walther and Thorrold, 2009). Additionally, seasonal variations in $\delta^{18}\text{O}$ in
19 cave speleothems have been associated with the frequency of intense rainfall events (Treble
20 *et al.*, 2005). Thus, summers of intense activity, such as the austral summer of 1976 (Fig 4A)
21 could produce significant changes in the seasonal $\delta^{18}\text{O}$ mean of palaeoecological records
22 (Treble *et al.*, 2005).

24 The water isotope composition of rainfall during other tropical storms also has been
25 reported to be low. For example, during the passage of Hurricane Sandy, a category-three

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hurricane in the eastern United States, rivers and rainfalls had low δD values of -40‰ and -50‰ , respectively (Higgins, 2012). These values were 20-25 ‰ lower than the regional background values (Higgins, 2012). The floodwater from our study had a wide range of isotopic values, 23‰ for δD and of 3.6‰ for $\delta^{18}O$ during the major flood. This suggests large variations in water source and/or precipitation mechanisms (Bowen, 2012). Datasets from tropical storms, including ours, show a large range in d excess values with many points lying well below and above the GMWL (Bowen, 2012).

After the flood peak, the isotopic composition of floodwater was influenced by the water released as part of flood management of the dams upstream of our sampling point, resulting in an increase in the isotopic composition of floodwater. Without the influence of the dam, the curve of change of the isotopic composition of the floodwater likely would have remained low for longer. The influence of water releases from dams is likely to dilute the flood signal in dammed rivers. Nevertheless, during the flood peak, the isotopic composition of floodwater was very close to that of rain, indicating that the composition of the flood during its peak is representative of floodwater from the tropical storm.

In conclusion we found that during a tropical storm in Brisbane Australia and the floods that followed it, rain and floodwater were characterized by low water δD and $\delta^{18}O$ isotopes compared to regional mean values. The distinct isotopic value of the rainfall could be followed into the river and floodwater as the flood moved to the coastal zone carrying large quantities of suspended sediments, and dissolved nutrients. The increased knowledge of δD and $\delta^{18}O$ values during tropical storms and flooding may lead to better understandings of hydrological oscillations and the ecological consequences of extreme weather events.

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For Peer Review

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Tables

Table 1. δD , $\delta^{18}O$ (‰) and d excess values of floodwater and rain during two flood events in the Brisbane River in 2013. Values are mean $\pm$ standard deviations of replicates within the same sample.

Date	Sampling time	δD (‰)	$\delta^{18}O$ (‰)	d excess
Floodwater				
<i>1st flood</i>				
27-Jan	11:00	-7.8 ± 1.3	-1.3 ± 0.2	2.5
	15:00	-7.2 ± 0.5	-1.2 ± 0.1	2.2
	19:15	-13.9 ± 0.3	-2.2 ± 0.0	3.4
	21:45	-17.0 ± 0.4	-3.9 ± 0.2	14.5
28-Jan	9:30	-27.2 ± 2.2	-4.3 ± 0.3	7.3
	15:00	-30.6 ± 0.2	-4.9 ± 0.0	8.3
	18:00	-33.4 ± 1.0	-5.2 ± 0.2	8.5
	21:00	-41.4 ± 0.9	-5.6 ± 0.0	3.8
29-Jan	7:30	-41.4 ± 1.1	-6.5 ± 0.1	10.6
	12:30	-42.8 ± 1.0	-6.7 ± 0.2	10.6
	18:15	-43.7 ± 0.7	-6.4 ± 0.1	7.9
30-Jan	7:30	-33.0 ± 2.3	-4.3 ± 0.3	1.6
	18:00	-20.3 ± 1.1	-3.1 ± 0.1	4.4
31-Jan	18:00	-21.8 ± 1.4	-3.4 ± 0.2	5.3
1-Feb	7:45	-36.1 ± 1.1	-5.5 ± 0.2	7.6
<i>Inter floods</i>				
9-Feb	10:00	-17.5 ± 0.5	-3.8 ± 0.1	13.3
15-Feb	8:10	-24.6 ± 0.3	-4.4 ± 0.2	10.4
19-Feb	18:00	-22.1 ± 0.5	-4.1 ± 0.1	10.5
20-Feb	19:20	-20.9 ± 0.4	-3.5 ± 0.1	7.5
<i>2nd flood</i>				
23-Feb	14:45	-24.1 ± 0.6	-4.1 ± 0.1	8.7
24-Feb	10:45	-22.3 ± 0.3	-3.9 ± 0.3	8.5
	15:30	-25.7 ± 1.2	-4.2 ± 0.3	7.6
	18:20	-24.7 ± 0.5	-3.9 ± 0.3	6.6
26-Feb	7:50	-27.9 ± 0.4	-4.5 ± 0.1	8.0
27-Feb	19:20	-27.0 ± 0.9	-4.3 ± 0.3	7.3
	7:50	-33.6 ± 0.5	-5.3 ± 0.3	8.4
	18:30	-31.1 ± 0.6	-4.8 ± 0.2	7.4
28-Feb	8:20	-28.5 ± 0.7	-4.6 ± 0.2	8.2
	16:50	-28.1 ± 0.7	-4.4 ± 0.3	7.2
Rain				
<i>1st flood</i>				
27-Jan	13:00	-32.3 ± 0.8	-5.1 ± 0.2	8.7
	17:00	-47.4 ± 1.3	-6.9 ± 0.2	8.0
	21:45	-33.2 ± 1.1	-5.4 ± 0.2	10.1
28-Jan	9:30	-15.9 ± 1.8	-3.2 ± 0.2	9.3
	21:00	-51.6 ± 0.5	-7.2 ± 0.2	6.2
<i>2nd flood</i>				
26-Feb	7:50	-18.9 ± 0.6	-3.8 ± 0.5	11.7

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Figure legends

Figure 1. Sampling location within the Brisbane River (cross), long-term GNIP station (Brisbane City station, IAEA/WMO), and sampling stations for rainfall, river discharge, conductivity, pH and water temperature (DERM, State of Queensland).

Figure 2. (A) Daily rainfall (mm) in the upper Brisbane River (station 143001C) and in the Lockyer Creek (station 143203C), (B) river discharge ($\text{m}^3 \text{s}^{-1}$, stations 143001C and 143207A) and releases from Wivenhoe-Somerset dam, (C) daily mean conductivity ($\mu\text{S cm}^{-1}$), temperature ($^{\circ}\text{C}$) at station 143001C, (D) pH; (E) total suspended solids (TSS; g L^{-1}); (F) dissolved nutrients: orthophosphates, P, nitrogen as nitrogen oxides, N-NO_x^- , and nitrogen as ammonium, N-NH_4^+ ($\mu\text{mol L}^{-1}$), and DIN:DIP, (G) $\delta\text{D}_{\text{‰}}$, (H) $\delta^{18}\text{O}_{\text{‰}}$ (vs. V-SMOW) of floodwater collected from the Brisbane River and rain, and (I) d excess. Dashed lines represent expected TSS, dissolved nutrients and isotopic composition baselines as predicted by Ozcoasts, Healthy Waterways and Bowen et al. (2014). Data for rainfall, river discharge, temperature and conductivity was obtained from the Department of Natural Resources and Mines, Brisbane River stations. Data from dam Wivenhoe-Somerset dam releases were obtained from Seqwater. Ph, TSS, nutrients and isotope values were measured by the authors from the Brisbane River sampling point (see Fig. 1).

Figure 3. Floodwater δD and $\delta^{18}\text{O}$ (‰ vs. V-SMOW) plotted against the global meteoric water line (GMWL) and the local meteoric water line (LMWL) calculated from the GNIP database (Brisbane Station 1967-2002, IAEA/WMO). Black circles are values of floodwater during release of water from the upstream dam (Wivenhoe-Somerset dam); grey circles are values from the beginning of the major flood.

Figure 4. (A) Long-term monthly δD values of precipitation from 1972-2002 for the Brisbane River, light grey bars represent moderate and minor floods, dark grey bars represent major floods (ABM, 2015); (B) monthly mean from 1962-2002 and predicted values (dashed line, Bowen 2014) of precipitation for Brisbane; (C) precipitation amount (log mm) against δD values for Brisbane for 1962-2002. Data are from Brisbane Station, GNIP, IAEA/WMO.

Figure 1. Sampling location within the Brisbane River (cross), long-term GNIP station (Brisbane City station, IAEA/WMO), and sampling stations for rainfall, river discharge, conductivity, pH and water temperature (DERM, State of Queensland).
210x296mm (300 x 300 DPI)

Hydrological Processes

B

Log10 precipitation (mm)

C