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| 1 | Supporting Information for |
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| 2 | "Constraining 20th-century sea-level rise in the South Atlantic Ocean" |
| | |
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20 Additional Supporting Information

- 1. Table S1. Swan Inlet diatoms.
- 22 2. Table S3. ¹⁴C measurements.

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²³ Text S1: reconstructing sea-level changes at Swan Inlet, Falklands

| 24 | This supplementary document includes methods and data that underpin the proxy- |
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| 25 | based relative sea-level reconstruction for the Falkland Islands. The reconstruction was es- |
| 26 | tablished by Newton [2017] from microfossils preserved in salt-sediments at Swan Inlet |
| 27 | (51°49'34"S, 58°35'47"W) in East Falkland. The sea-level reconstruction involved three |
| 28 | steps: (1) collecting modern micro-organisms from salt-marsh surface sediments to establish |
| 29 | sea-level transfer functions; (2) establishing a chronology for a sediment core; (3) applying |
| 30 | the sea-level transfer function to microfossils preserved in the core to reconstruct relative sea- |
| 31 | level changes. Step 1 is described in full in a separate paper [Newton et al., 2020]. |

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Sea-level transfer functions

We established three surface transects to investigate the vertical distributions of micro-33 organisms (diatoms) which are known to be reliable sea-level indicators [Barlow et al., 2013; 34 Shennan et al., 2015]. For height control a survey benchmark was established at the edge of 35 the salt marsh from which relative elevations for all sample points were measured. We re-36 fer to this benchmark as Swan Inlet Datum (SID). Using a differential Global Positioning 37 System (dGPS) we determined that SID is 14.35 m above the reference WGS84 ellipsoid. A 38 total of 39 surficial (0-1 cm) sediment samples were collected at ~4 cm vertical increments 39 across an elevational range of 1.27 m. From these samples, diatoms were extracted, counted 40 and identified. The distribution of modern diatoms is shown in Figure S1 The data sets of 41 modern diatoms, with their elevations, were subjected to regression analyses in the software 42 package C2 [Juggins, 2003] to establish sea-level transfer function models following Newton 43 et al. [2020]. Figure S2 depicts the performance of the selected transfer function by com-44 paring elevations of our surface samples predicted by the transfer functions with their actual 45 (surveyed) elevations. The regressions indicate that the diatom sea-level transfer function is 46 capable of reconstructing past sea levels with an average precision of ± 0.06 m (2 sigma). 47

48 Chronology

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Following an extensive reconnaissance of the salt-marsh stratigraphy of Swan Inlet, a core from Swan Inlet (core SI-2, 51°49'33.759"S, 58°35'46.654"W) was selected for the

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| 51 | sea-level reconstruction. The chronology for core SI-2 combines age determinations from |
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| 52 | $^{137}\mathrm{Cs}$ radionuclide activity in the upper 15 cm of the core (Figure S3) and 12 AMS $^{14}\mathrm{C}$ age |
| 53 | determinations (Table S3) on individual horizontally embedded plant fragments down to a |
| 54 | core depth of 0.9 m. The 137 Cs profile in core SI-2 reveals a peak between 6-8 cm that is |
| 55 | related to the maximum deposition (1963 CE) of 137 Cs produced by atmospheric nuclear |
| 56 | weapons testing. Below the maximum, ¹³⁷ Cs is present at reduced levels, down to a depth of |
| 57 | 15 cm. Background ¹³⁷ Cs levels are first exceeded at 10 cm, indicating the onset of nuclear |
| 58 | bomb testing, and we assigned an age of 1954 CE to this level. Due to possible mobility of |
| 59 | Cs, we also subjected several plant fragments to radiocarbon bomb-spike analysis. We anal- |
| 60 | ysed the core for ²¹⁰ Pb, but activity was generally low or below the minimum detection limit |
| 61 | to provide reliable age determinations. An age-depth chronology with 95% confidence lim- |
| 62 | its (Figure S4) was derived from a Bayesian modelling approach using Bacon in R [Blaauw |
| 63 | and Christen, 2011]. The sea-level reconstruction presented here is based on the upper 15 |
| 64 | cm of the core (dated to 1908-2013 CE). Bacon could not fit all age measurements into the |
| 65 | age-depth model, because three samples returned 'modern ages' (Figure S4); two of these |
| 66 | (61889 and 61891) are in the top 15 cm of the core. The dated material in these sample may |
| 67 | have included root or rhizome material of modern plants. Our age model for the top 15 cm of |
| 68 | the core is controlled by the two 137 Cs markers and the radiocarbon measurements at 6.5 cm |
| 69 | (61829), 7.5 cm (61887), 10 cm (61888) and 21 cm (61897). Age uncertainties are lowest |
| 70 | between 1954 and 1963 and increase lower in the core (Figure S4, Table S2). |

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Sea-level reconstruction

Past sea levels were calculated by the transfer function for every centimeter in core 72 SI-2 based on the fossil diatom assemblages (Figure S5, Table S1). All samples have good 73 or close modern analogues, except for one sample (2 cm) which is marginally across the 74 close/poor boundary as defined by Watcham et al. [2013]. Kemp and Telford [2015] rec-75 ommend for diatom datasets a lower cut-off for acceptable analogues, which implies that 76 we should treat the 5 'close' analogue samples (Figure S5) with caution. We have tested the 77 effect of removing these proxy data by removing these samples and using the sea-level ob-78 servations from Port Louis [Woodworth et al., 2010] instead. For this experiment, we tied 79

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the 2006 index point to the Stanley tide gauge data and subsequently tied the Stanley and Port Louis observations using the levelling data as described in [*Woodworth et al.*, 2010]. This test setup gives a 20th-century sea-level trend (without any corrections) at the Falklands of 1.84 [0.92 2.89] mm yr⁻¹ versus 1.63 [1.10 2.77] mm yr⁻¹. Given these relatively small changes and the comparison to tide-gauge observations (Figure 2h), which does not suggest reliability issues with these samples, we have retained these index points in our sea-level reconstruction.

The age for each level, including its uncertainty, was determined by the age-depth modelling (Figure S4, Table S2). The vertical uncertainty of each data point combines several potential sources of error related to sampling processes and regression model uncertainties, expressed as:

$$E = \sqrt{E_{\text{thick}}^2 + E_{\text{surv}}^2 + E_{\text{tfun}}^2} \tag{1}$$

where E is the total vertical error and E_{thick} , E_{surv} , and E_{tfun} are component errors. Compo-91 nent errors are defined as follows. Thickness error (E_{thick}) relates to potential sub-sampling 92 errors associated with measuring the thickness of samples. Here this is defined as half of the 93 measured thickness, following [Shennan, 1986], and thus amounts to 0.005 m for 1 cm slices. 94 Levelling errors are negligible, because all proxy sea-level data are from the same core which 95 required only a single surveying measurement. The uncertainties associated with transfer 96 function estimates of sample elevation (E_{tfun}) use the sample-specific root mean squared 97 errors of prediction (RMSEP) calculated by the C2 software package [Juggins, 2003] us-98 ing bootstrapping [Birks, 1995]. Component errors are assumed to be the mean values with 99 normally distributed uncertainty and are multiplied by 1.96 to obtain the 95% confidence 100 intervals. Vertical errors associated with post-depositional lowering as a result of sediment 101 compaction are considered to be negligible for the upper section of the core [Brain et al., 102 2011]. 103

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- Table S2. Proxy sea-level data for Swan Inlet (Falkland Islands). Age and vertical uncertainties denote the
- ¹⁴¹ 95% confidence interval.

| Depth (m) | Age (CE) | Age uncertainty (+) | Age uncertainty (-) | Sea level (m) | Sea level uncertainty (m) |
|-----------|----------|---------------------|---------------------|---------------|---------------------------|
| 0.01 | 2006 | 2012 | 1994 | 0.015 | 0.115 |
| 0.02 | 1999 | 2010 | 1985 | 0.038 | 0.128 |
| 0.03 | 1992 | 2005 | 1978 | 0.004 | 0.122 |
| 0.04 | 1985 | 2000 | 1972 | -0.073 | 0.149 |
| 0.05 | 1978 | 1992 | 1967 | 0.062 | 0.109 |
| 0.06 | 1972 | 1985 | 1964 | 0.020 | 0.146 |
| 0.07 | 1964 | 1967 | 1961 | -0.125 | 0.124 |
| 0.08 | 1961 | 1965 | 1956 | -0.145 | 0.129 |
| 0.09 | 1957 | 1962 | 1953 | -0.068 | 0.115 |
| 0.10 | 1954 | 1956 | 1951 | -0.086 | 0.113 |
| 0.11 | 1945 | 1954 | 1928 | -0.095 | 0.109 |
| 0.12 | 1936 | 1950 | 1913 | -0.106 | 0.107 |
| 0.13 | 1926 | 1944 | 1901 | -0.116 | 0.113 |
| 0.14 | 1917 | 1938 | 1889 | -0.111 | 0.113 |
| 0.15 | 1908 | 1931 | 1876 | -0.192 | 0.125 |

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| submitted to JGR-Ocean | |

| Region | No corrections | | GIA correction | | GIA + PD | | Residual VLM | | All corrections | |
|----------------|----------------|-------------|----------------|-------------|----------|-------------|--------------|-------------|-----------------|-------------|
| Buenos Aires | 1.53 | [1.42 1.63] | 2.15 | [1.93 2.37] | 2.21 | [1.99 2.44] | 1.79 | [1.11 2.49] | 2.48 | [1.86 3.12] |
| Montevideo | 1.55 | [1.35 1.76] | 2.11 | [1.82 2.40] | 2.12 | [1.83 2.42] | 1.25 | [0.34 2.17] | 1.82 | [0.94 2.72] |
| Mar del Plata | 1.23 | [1.08 1.27] | 1.66 | [1.34 1.81] | 1.76 | [1.43 1.91] | 0.74 | [0.09 1.47] | 1.26 | [0.45 1.95] |
| Puerto Madryn | 1.94 | [1.68 2.29] | 2.50 | [2.18 2.91] | 2.56 | [2.21 3.00] | 2.23 | [0.81 3.84] | 2.85 | [1.43 4.43] |
| Dakar | 1.13 | [1.07 1.24] | 1.19 | [0.99 1.47] | 1.35 | [1.15 1.64] | 1.17 | [0.11 2.26] | 1.38 | [0.41 2.42] |
| South Africa | 1.38 | [1.24 1.52] | 1.53 | [1.38 1.67] | 1.49 | [1.35 1.64] | 1.94 | [1.69 2.15] | 2.06 | [1.78 2.27] |
| Kerguelen | 1.10 | [0.04 2.28] | 0.94 | [0.23 2.13] | 0.93 | [0.24 2.12] | 2.19 | [0.91 3.47] | 2.02 | [0.80 3.26] |
| Falklands | 1.63 | [1.10 2.77] | 1.98 | [1.43 3.14] | 2.25 | [1.63 3.33] | 0.84 | [0.06 2.31] | 1.45 | [0.52 2.81] |
| South Atlantic | 1.48 | [1.14 1.88] | 1.78 | [1.42 2.22] | 1.93 | [1.57 2.36] | 1.13 | [0.59 1.75] | 1.61 | [1.07 2.21] |

Table S4. Trends and uncertainties in mm yr⁻¹ for each individual region and for the South Atlantic basin.

tervals.

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Figure S1. Distribution of modern diatoms in Swan Inlet. SID – Swan Inlet Datum. HAT - Highest Astronomical Tide. MHHW - Mean Higher High Water. MTL - Mean Tide Level. Samples were collected from three transects (as colour coded). Top panel shows the dominant plant species along the transects. From *Newton et al.* [2020].



Figure S2. Scatterplot of observed versus predicted height (a) and observed height against prediction residuals (b) for the diatom transfer function using a Weighted Averaging Partial Least Squares (WA-PLS) model component 3. SID - Swan Inlet Datum. RMSEP - root mean squared error of prediction. From *Newton et al.* [2020].



Figure S3. Profile of ¹³⁷Cs in core SI-2, showing the 1965 nuclear bomb testing maximum at 6-8 cm, and

the 1954 onset of bomb testing at 9-11 cm.



Figure S4. Age-depth chronology for core SI-2 (0-87cm) modelled by R-package Bacon [*Blaauw and Christen*, 2011], showing calibrated ¹⁴C probability distributions (dark blue) and surface and ¹³⁷Cs ages (light blue). Darker greys indicate more likely calendar ages; grey dotted lines show 95% confidence intervals; red dotted line shows the single 'best' model based on the weighted mean age for each depth. For this paper, only the ages for the top 14 cm of the core were used. Laboratory codes correspond with Table S3.



Figure S5. Fossil diatom assemblages, age markers and modelled ages in the top 15 cm of core SI-2 used for the sea-level reconstruction. Diatoms shown for species greater than 5% of the total valves counted.

MinDC - minimum dissimilarity coefficient; definitions of 'good', 'close' and 'poor' follow *Watcham et al.*

¹⁶⁴ [2013]. PSME - palaeomarsh surface elevation. SID – Swan Inlet Datum.