

Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our [Editorial Policies](#) and the [Editorial Policy Checklist](#).

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a Confirmed

- ☒ ☐ The exact sample size (n) for each experimental group/condition, given as a discrete number and unit of measurement
- ☒ ☐ A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
- ☒ ☐ The statistical test(s) used AND whether they are one- or two-sided
Only common tests should be described solely by name; describe more complex techniques in the Methods section.
- ☒ ☐ A description of all covariates tested
- ☒ ☐ A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
- ☒ ☐ A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
- ☒ ☐ For null hypothesis testing, the test statistic (e.g. F , t , r) with confidence intervals, effect sizes, degrees of freedom and P value noted
Give P values as exact values whenever suitable.
- ☒ ☐ For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
- ☒ ☐ For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
- ☒ ☐ Estimates of effect sizes (e.g. Cohen's d , Pearson's r), indicating how they were calculated

Our web collection on [statistics for biologists](#) contains articles on many of the points above.

Software and code

Policy information about [availability of computer code](#)

Data collection No data collection was performed with code in this study.

Data analysis QGIS version 2.14.3 for generating the topographic map (Fig. 2a); ItraxPlot program for producing optical and radiograph profiles of the Bulusan sediments (Fig. 2d); Bacon version 2.2 in R version 3.2.4 for building age-depth modeling; ggplot2 package in R versions 3.2.4 and 3.5.2. for plotting data; nlme 3.1-128 package in R version 3.2.4 and 3.5.2. for Generalized Least Squares (GLS) modeling; Sequential T-test Analysis of Regime-Shifts (STARS) algorithm coded in R version 3.2.4 (Seddon et al. 2014, Ecology 95, 3046–3055); Matlab version R2022b, and the Grid Analysis and Display System (GrADS) version 2.2.1.oqa.1 for plotting climate fields.

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio [guidelines for submitting code & software](#) for further information.

Data

Policy information about [availability of data](#)

All manuscripts must include a [data availability statement](#). This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our [policy](#)

All data needed to appraise the conclusions in the paper are given in the Main Text and/ or the Supplementary Information. The CRU TSv4 dataset is available at <https://crudata.uea.ac.uk/cru/data/hrg/>, and monthly mean isoGSM2 model data, isotopic measurements and composite pollen counts data used in this study can be found at: <https://dataservices.gfz-potsdam.de/panmetaworks/review/0399cc5cfc6f318fb934b73b62f7b4e205380e309b66b24657d6eaf23e3cecc7/>. The Nino3.4 index was taken from NOAA Physical Sciences Laboratory (NOAA PSL): <https://psl.noaa.gov/data/climateindices/list/>. Any additional data related to this paper may be requested from the authors.

Research involving human participants, their data, or biological material

Policy information about studies with [human participants or human data](#). See also policy information about [sex, gender \(identity/presentation\), and sexual orientation](#) and [race, ethnicity and racism](#).

Reporting on sex and gender The study did not include human participants, their data, or biological material.

Reporting on race, ethnicity, or other socially relevant groupings The study did not include human participants, their data, or biological material.

Population characteristics The study did not include human participants, their data, or biological material.

Recruitment The study did not include human participants, their data, or biological material.

Ethics oversight The study did not include human participants, their data, or biological material.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☐ Behavioural & social sciences ☒ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Ecological, evolutionary & environmental sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	Study generated a new high-resolution paleohydrological record using the stable-hydrogen-isotopic composition of terrestrial-lipid biomarkers from a 1,400-year-old lake sedimentary sequence to examine changes in the Pacific climate mean state over the last millennium.
Research sample	Lake sediments were collected in from a single lake site in the northern Philippines using a Livingstone Piston corer on an anchored platform. The geographic location of the lake site was suitable for addressing the question of past climate dynamics in the tropical Pacific.
Sampling strategy	Sediment samples (n = 75) were sampled as a continuous series of 4 cm long slices (i.e., 2-6 g dry weight per sample) from a 300 cm long sequence.
Data collection	One these sediment samples we measured the stable-hydrogen-isotopic composition of terrestrial-lipid biomarkers to reconstruct past hydrological conditions (Ana Prohaska and Bern Meese), pollen data to reconstruct past vegetation dynamics (Ana Prohaska), and radiocarbon dating of plant macrofossils to generate chronology (subsampling by Ana Prohaska and analysis by the NERC Radiocarbon Facility in East Kilbride). This is complemented with isoGSM version 2 data to provide modern hydrological constraint to the paleodata (John Chiang).
Timing and spatial scale	Sediment samples were collected in March 2013 over a course of a single week.
Data exclusions	No data were excluded from the analysis.

Reproducibility	The samples were measured in triplicates, with the exception of top six samples which were measured in duplicates due to low compound concentrations.
Randomization	Randomization was not relevant to the study.
Blinding	Blinding was not relevant to the study.
Did the study involve field work?	☒ Yes ☐ No

Field work, collection and transport

Field conditions	The fieldwork took place in March, specific parameters such as rainfall and temperature were not logged at the time of the fieldwork.
Location	Bulusan Lake (N 12°45', E 124°6') in the Northern Philippines.
Access & import/export	We have obtained permission to (1) collect and export the sediments from the Philippine Bureau of Fisheries and Aquatic Resources and the Philippine Department of Environment and Natural Resources, as well as the Bulusan Volcano Natural Park, and (2) to import the sediments to UK from the Department for Environment, Food & Rural Affairs (licence holder: Kathy Willis).
Disturbance	To the best of our knowledge, no disturbance to the site nor its surroundings was caused by the fieldwork.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☐	☒ Palaeontology and archaeology
☒	☐ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern
☐	☒ Plants

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Palaeontology and Archaeology

Specimen provenance	No paleontological or archaeological specimens have been used in this study.
Specimen deposition	No paleontological or archaeological specimens have been used in this study.
Dating methods	Identified terrestrial plant macrofossils (e.g., leaves, twigs) were used for the radiocarbon analysis of the Bulusan sediment core. The macrofossil samples were washed with Type 1 water and dried in sterile petri dishes prior to shipping to the radiocarbon facility. Radiocarbon analysis was performed at the NERC Radiocarbon Facility, East Kilbride. The age-depth model of the Bulusan core was generated using a Bayesian statistics approach with the Bacon 2.2 package in R and the IntCal13 radiocarbon calibration curve for the Northern Hemisphere.
☒ Tick this box to confirm that the raw and calibrated dates are available in the paper or in Supplementary Information.	
Ethics oversight	No ethical approval or guidance was required for this protocol since it did not include samples from archaeological and paleontological sites.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Dual use research of concern

Policy information about [dual use research of concern](#)

Hazards

Could the accidental, deliberate or reckless misuse of agents or technologies generated in the work, or the application of information presented in the manuscript, pose a threat to:

No	Yes
☒	☐ Public health
☒	☐ National security
☒	☐ Crops and/or livestock
☒	☐ Ecosystems
☒	☐ Any other significant area

Experiments of concern

Does the work involve any of these experiments of concern:

No	Yes
☒	☐ Demonstrate how to render a vaccine ineffective
☒	☐ Confer resistance to therapeutically useful antibiotics or antiviral agents
☒	☐ Enhance the virulence of a pathogen or render a nonpathogen virulent
☒	☐ Increase transmissibility of a pathogen
☒	☐ Alter the host range of a pathogen
☒	☐ Enable evasion of diagnostic/detection modalities
☒	☐ Enable the weaponization of a biological agent or toxin
☒	☐ Any other potentially harmful combination of experiments and agents