Corrected analyses show that moralizing gods precede complex societies but serious data concerns remain

In reply to "Complex societies precede moralizing gods throughout world history"

Bret Beheim, Department of Human Behavior, Ecology and Culture, Max Planck Institute for Evolutionary Anthropology
Quentin Atkinson, School of Psychology, University of Auckland
Joseph Bulbulia, School of Humanities, University of Auckland
Will Gervais, Department of Psychology, University of Kentucky
Russell D. Gray, Max Planck Institute for the Science of Human History, School of Psychology, University of Auckland
Joseph Henrich, Department of Human Evolutionary Biology, Harvard University
Martin Lang, LEVYNA: Laboratory for the Experimental Research of Religion, Masaryk University
M. Willis Monroe, Department of Asian Studies, University of British Columbia
Michael Muthukrishna, Department of Psychological and Behavioural Science, London School of Economics
Ara Norenzayan, Department of Psychology, University of British Columbia
Benjamin Grant Purzycki, Department of Human Behavior, Ecology and Culture, Max Planck Institute for Evolutionary Anthropology
Azim Shariff, Department of Psychology, University of British Columbia
Edward Slingerland, Department of Asian Studies, University of British Columbia
Rachel Spicer, Department of Psychological and Behavioural Science, London School of Economics
Aiyana K. Willard, Centre for Culture and Evolution, Brunel University London

Whitehouse, et al.'s[1] creation of the Seshat open archaeo-historical databank[2] is laudable. However, the authors' analysis methods, treatment of missing data, and source quality undermine the paper's key conclusion that moralizing deities appear only after rapid increases in social complexity. First, their report fails to address the inherent 'forward' biases in first appearance dates of moralizing gods in the archaeo-historical record. When we minimally correct for this, the paper's major finding reverses: moralizing gods precede the dramatic rises in social complexity. Second, the authors handle missing observations on moralizing gods by re-coding them as known absences. These values make up 61% of all outcome data. When missing data are handled appropriately, their result again reverses. Finally, inspections of the Seshat coding reveal systematic inaccuracies, inadequate vetting, and misleading claims.

Whitehouse, et al. analyze the appearance of moralizing gods and forces (MGs) in world history relative to increases in social complexity. Unlike proxies of social complexity such as polity size and population density, their definition of MG requires written evidence in order for MGs to be detected. Yet, as one proceeds back through the archeo-historical record, both literacy and written materials become less common. Thus, the earliest surviving documentary evidence of MGs will likely be much later than their actual emergence and differentially ‘forward biased’ relative to the physical evidence of social complexity (Supplemental S1). For example, Hawaii’s population history is well-documented archaeologically, but MGs only appear in the Hawaiian Seshat records upon the arrival of Europeans with quills. In light of Pacific ethnography[3], MGs likely existed in Hawaii far earlier than post-contact accounts. Indeed, moralizing supernatural punishment appears in the ethnographic descriptions of non-literate, small-scale societies[4–8] around the world, suggesting MGs may have been more prevalent among early societies than the written record indicates (Supplemental S1).

Table 1 illustrates this forward bias across Sehsat’s 12 focal NGAs (Natural Geographic Areas) leading up to the first recorded appearance of MGs. In each case, MGs appear simultaneously with, or after, the appearance of writing or literate observers (Extended Data Figure 1). To test the sensitivity of Whitehouse, et al.’s analysis to differential forward biases, not considered in the authors’ dating-uncertainty checks (which mostly correct for potential backward biases), we re-analyzed the data by moving the date of first appearance of MGs back by one century–the smallest time unit. Using the authors’ analysis code, this minimal correction entirely reverses their main result (Extended Data Fig. 3): MGs *precede* the dramatic rises in SC and the rate of increase in complexity is almost two times larger *after* MGs arrive than before (Supplemental S2.1). In other words, if MGs emerged even just one century earlier than the first recorded appearance in Seshat, the paper's main conclusion is overturned. A correction of three centuries amplifies the reversal and a more appropriate statistical approach confirms its robustness (Supplemental S2.2, Table S1).

years until first appearance of moralizing god

	-1000	-900	-800	-700	-600	-500	-400	-300	-200	-100	0	100
Deccan	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	NA
Kachi Plain	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1
Kansai		NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1
Konya Plain	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1
Latium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1
Middle Yellow River Valley	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	1	1
Niger Inland Delta	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1
Orkhon Valley	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1
Paris Basin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1
Sogdiana	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1
Susiana	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	NA
Upper Egypt	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1

Table 1 | Moralizing gods across 12 key regions. Here, a ‘1’ indicates MGs are known to be present in the century-by-century data, ‘0’ that they are known to be absent. An ‘NA’ refers to missing MG data in the authors’ dataset. Generally, MGs appear in Seshat simultaneously with or after the appearance of writing (green), contra ethnographic records of MGs in non-literate societies (also see Extended Data Figure 1). Only one of the 30 world regions includes a known absence preceding an MG presence (Middle Yellow River Valley, red), data we dispute as miscoded based on expert-generated data (Supplemental S4).

Even more worrying is that the alleged ‘first appearance’ of MGs in Seshat is almost always preceded by unknown values (‘NA’s), indicating no actual evidence that moralizing gods were absent (Table 1). Only one observation in the entire database--China's Middle Yellow River Valley--reports a known absence of MGs in an NGA before their first appearance, and this lone '0' is disputed by other historians (Supplemental S4). Surprisingly, the authors handled this problem by re-coding all cases of missing data ('NA') to known absences ('0') before proceeding with the analysis (Supplemental S1.2). This puzzling decision goes unmentioned in their methods and, in total, 61% (n = 490) of all outcome observations, and 98% of alleged cases of 'moralizing gods absent', were originally unknown values in Seshat. The resulting correlation between 'having any outcome data at all' (not 'NA') and recording 'moralizing gods present' is r = 0.97, suggesting that the study is essentially an analysis of the missingness patterns in Seshat.

Because of the forward bias problem, NGAs with 'known' MG outcomes tend to be very large, on average 3.9 million people, and almost always literate, while regions with missing values have, on average, only about 7,000 people and lack writing. As outcome missingness thus strongly correlates with lower social complexity, converting all unknown values to known absences is an extremely favorable assumption for the authors' main conclusion (Extended Data Fig. 2, Fig. S1). We re-ran the authors' logistic regressions with more conservative approaches for missing data[9] and used these estimates to predict the probable first appearance of MGs (Table S2, S3). Once again, the results predict the emergence of MGs before both writing and major increases in social complexity (Fig. 1A), describing an average forward bias of between 600 and 1400 years (Fig. 1B, Fig. S3).

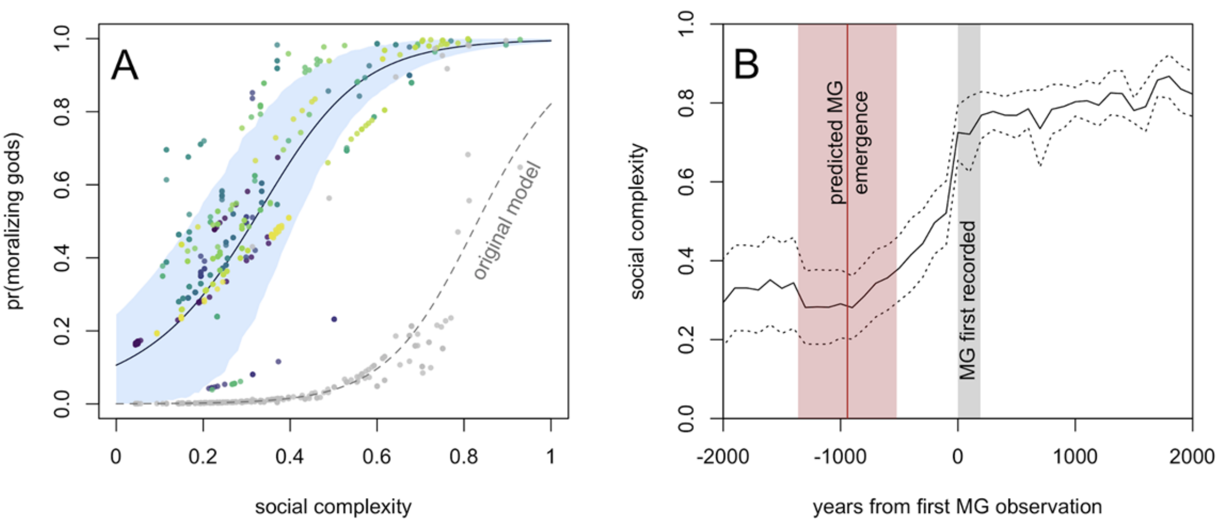

Figure 1 | Comparison of Whitehouse, et al.'s model, where missing outcome data ('NA') was coded as absent ('0') and a reanalysis removing unknown outcomes. Panel (A) Estimated relationship between the probability of MGs being observed and social complexity, held at average distance and language similarity, fit on original dataset ('NA's recoded as '0's; grey dashed line) and reduced dataset that removed missing values (black line with blue 89% HPDI shading). Mean probabilities of "moralizing gods present" for the 490 historical observations with "unknown" outcome values are given as points: from the original model (grey) and grouped by NGA in revised model (each NGA is assigned a different color). **Panel (B)** Recreation of Whitehouse, et al.'s Fig. 2a, estimating forward bias only from known (non-'NA') observations, now showing mean and 95% confidence interval for the predicted first emergence of moralizing gods, approximately 958 (SE: 210) years prior to their first observations in the Seshat database.

While our new analyses indicate that MGs precede complex societies, we caution against strong inferences from these results, because of irregularities found with Seshat's historical coding and expert vetting. While the authors state that all of the crucial religion and ritual variables were vetted, in fact only a small proportion appears to have been, and an alarming amount of key data is attributed to general introductory books or personal communications with area specialists (Supplemental S4). Unlike standard historical sources, this latter evidence is not readily available for verification by the scholarly community. To assess coding accuracy, we compared Seshat's five religion and ritual variables for the Middle Yellow River Valley, from the Late Shang to the Late Tang, to fully expert-generated/vetted codes from the Database of Religious History (DRH; religiondatabase.org). Over two-thirds of Seshat's data did not match equivalent entries in the DRH (Table S4).

Further, Seshat sources referring to specific points in time are often used to 'data fill' broad swaths of spatial and temporal entries outside the scope of the original citation. Of Seshat's 110 data points associated with the religion and ritual variables in the Middle Yellow River Valley, for instance, only 16 represent independent observations. The other 94 carry forward from previous observations, with no new references or expert sources specific to the time and place in question. In one case, a personal communication about a Shang Dynasty ritual was cited as a source for 3,000 years of Chinese ritual data (Supplemental S4). Data on religious practices and social complexity in some NGAs are even filled in from *other NGAs*; if a polity in one NGA (e.g. Kachi Plain, population: 18 million) conquers another NGA (e.g. Deccan, population: 20,000), the conquered NGA's population size, social complexity, and religious practices are immediately replaced by the values in conquering NGA's time series. This curious accounting, rather than actual evidence of population change, is responsible for the sharp discontinuities in social complexity associated with the appearance of MGs that Seshat records through time (Figure S2).

Taken together, these problems cast serious doubt on the authors' reported conclusion. Once either forward bias is accounted for or missing data properly handled, we infer MGs precede - not follow - dramatic rises in social complexity, though it is not clear what the data can tell us in its current state. That said, Seshat continues to evolve, inadequate vetting is correctable, and none of this detracts from the authors' larger enterprise of developing an open archaeo-historical databank.

Author Contributions

Designed reanalysis: JH, ML, RS, BB, BP, MM, QA, RG
Audited Seshat records: ES, WM
Performed re-analyses: BB, RS, ML, BP
Code review: RS, ML, BP
Wrote manuscript: all authors

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Conflict of Interest

The authors declare no conflicts of interest.

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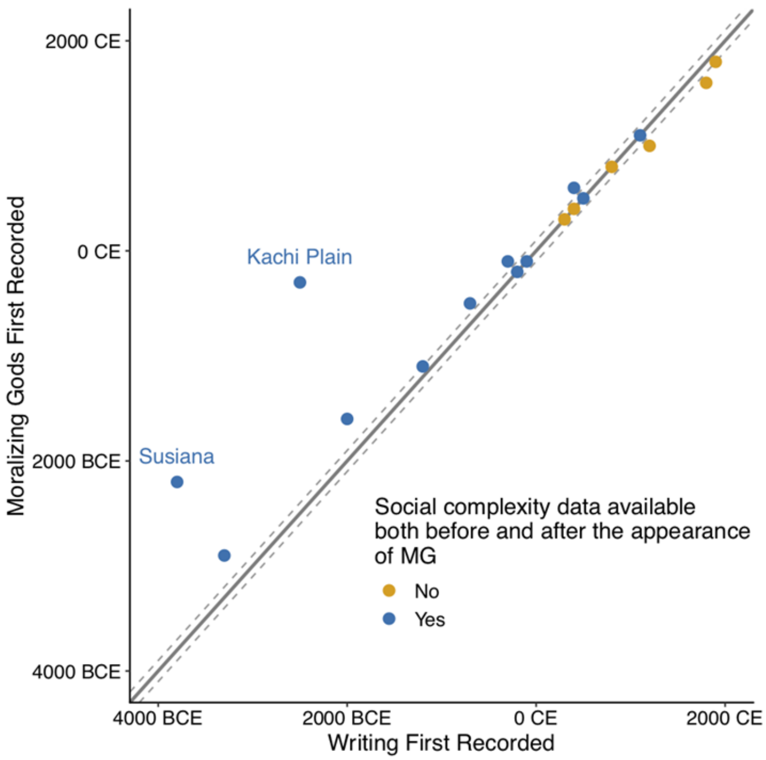
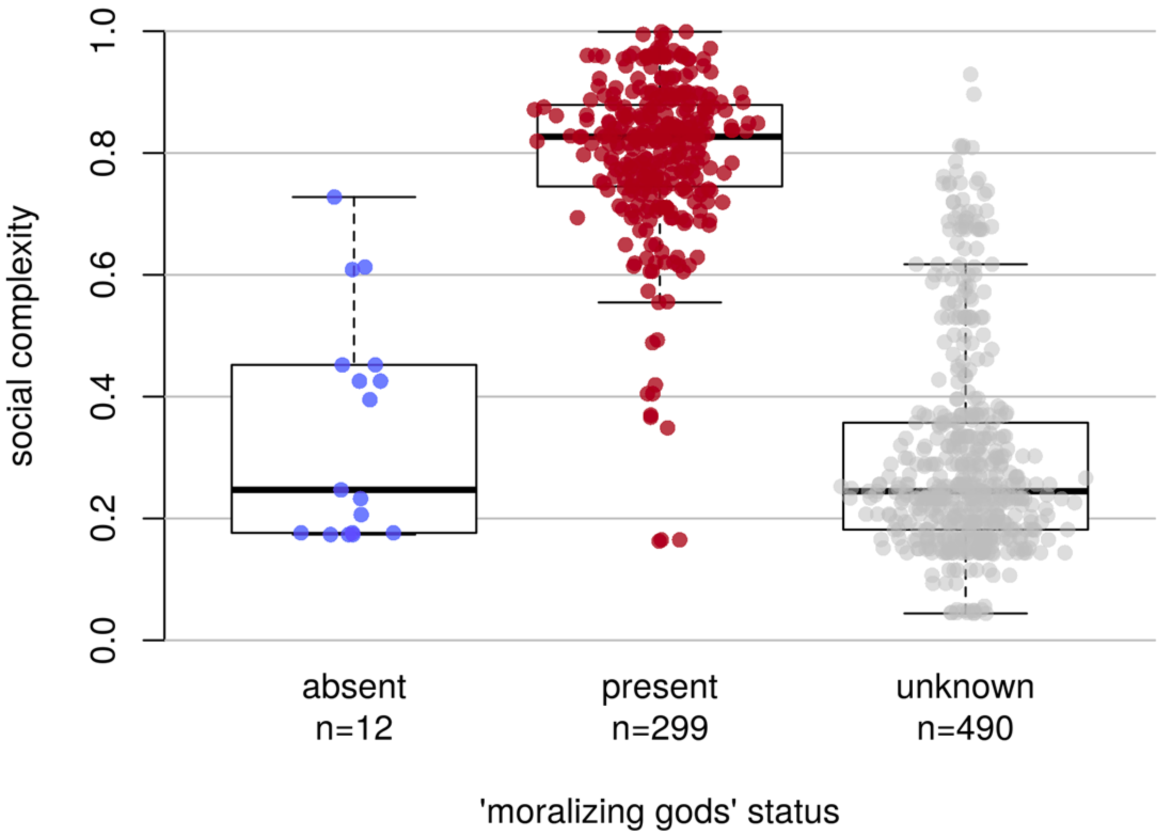
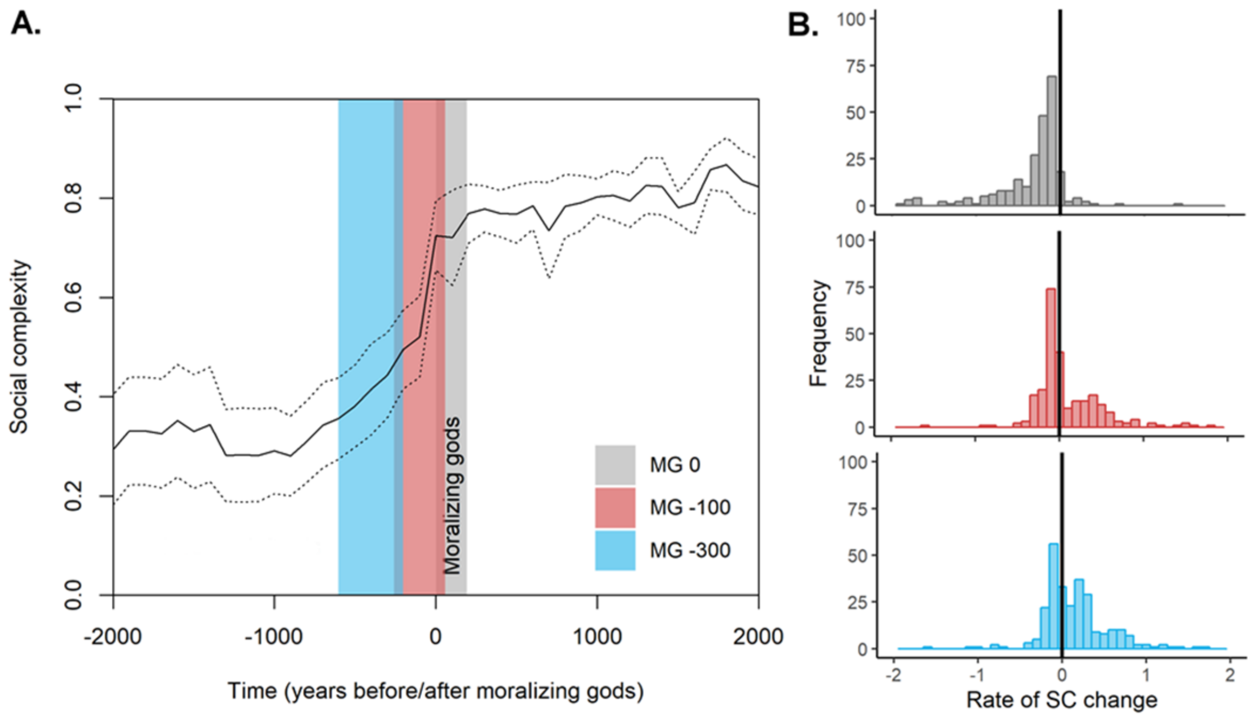
Extended data figures



Extended Data Figure 1 | The first appearance of writing and moralizing gods across NGAs. The solid line indicates when writing and moralizing gods are first recorded in the same century, and the dashed lines show when writing appeared 100 years before moralizing gods and when moralizing gods appeared 100 years before writing. NGAs are colored by whether social complexity data are available both before and after the appearance of moralizing gods or not. Only NGAs with social complexity data available both before and after the appearance of moralizing gods were included in the analysis (and only these NGAs are shown in Table 1). It must be noted that while writing first appears at 2500 BCE in the Kachi Plain, it is absent for the subsequent two polities in the dataset, and does not reappear until 300 BCE - the same time as the first appearance of moralizing gods.



Extended Data Figure 2 | Boxplots & distributions of "social complexity" score for N = 801 observations, by 'moralizing gods' outcome status. Before the regression analysis, the authors re-coded the 490 "unknown" cases as "absent" without explicitly documenting this decision. Because societies with "known" and "unknown" outcome data differ dramatically in social complexity, population size and the presence of writing, this choice is responsible for their key findings.



Extended Data Figure 3 | Effect of small corrections to forward bias. Panel (A) Social complexity (SC) before and after the appearance of moralizing gods. Zero on the x-axis represents a standardized appearance of moralizing gods at each NGA per original Whitehouse, et al. paper. The grey column illustrates that moralizing gods arrived just after the main rise of SC while the red column illustrates that shifting the arrival of moralizing gods just 100 years (the smallest time unit possible in their coding) earlier would imply that moralizing gods preceded the main SC increase. The blue column displays the first appearance of moralizing gods shifted 300 years earlier. Column width illustrates uncertainty around the time of MG appearance and corresponds to the mean duration of the polity in which MG appeared (after correcting for forward bias). **Panel (B)** Histograms of the differences in the rates of change in SC Pre-MG minus Post-MG (multiplied by 1000). Y-axes are the number of centuries with a specific rate of SC change (collapsed across the 12 NGAs). The grey histogram is from the original Whitehouse, et al. data, while the red and blue histograms shift the first appearance of moralizing gods 100 and 300 years earlier, leading to more positive change in SC *after* MGs appearance.

Supplemental Materials

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Bret Beheim, Department of Human Behavior, Ecology and Culture, Max Planck Institute for Evolutionary Anthropology
Quentin Atkinson, School of Psychology, University of Auckland
Joseph Bulbulia, School of Humanities, University of Auckland
Will Gervais, Department of Psychology, University of Kentucky
Russell D. Gray, Max Planck Institute for the Science of Human History, School of Psychology, University of Auckland
Joseph Henrich, Department of Human Evolutionary Biology, Harvard University
Martin Lang, LEVYNA: Laboratory for the Experimental Research of Religion, Masaryk University
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Rachel Spicer, Department of Psychological and Behavioural Science, London School of Economics
Aiyana K. Willard, Centre for Culture and Evolution, Brunel University London

Table of Contents

Introduction

In this supplement, we elaborate on the points made in the main text by critiquing and re-assessing three aspects of Whitehouse, et al.'s study[1]. In Section S1, we assess the authors operational construct of "moralizing gods" in light of the field, data sources and ethnographic record. We also identify the major coding decision that drove the results. In Sections S2 and S3, we examine their statistical analyses, identify serious issues, and provide more appropriate analyses. These analyses support opposite conclusions. Finally, in Section S4, we inspect and assess their coding procedures, vetting process and data quality.

The authors' original code and history of subsequent edits can be found here: https://github.com/pesavage/moralizing-gods. Code and data for a full reproduction of the original analyses, all analyses contained in this response, and an html walkthrough of the analyses can be found here: https://github.com/babeheim/moralizing-gods-reanalysis.

S1. The problems of forward bias, missing data, and the ethnographic record

In this section, we discuss the problematic nature of Whitehouse, et al. assumptions concerning first appearance of crucial variables such as moralizing gods (MGs), as well as how these flawed assumptions drive one of the more dramatic errors we uncovered in their analysis, the widespread conversion of missing data to evidence of absence.

S1.1 The problem of forward bias

The central outcome variable of the analysis is the first appearance of "Moralizing Gods" (MG) within the polities of a particular Natural Geographic Area (NGA). Here, MG include both the traditional concept of "Moralizing High Gods" (MHG) used in the Standard Cross-Cultural Survey and the Ethnographic Atlas, or the more inclusive category of "Broad Supernatural Punishment" (BSP). An MHG is a creator deity who is "specifically supportive of human morality", such as in Judeo-Christian tradition. As many non-creator spirits are punitive and morally concerned, the authors have followed a more general trend towards inclusive concept of BSP in the literature, though they require that BSP monitor behavior related specifically to fairness, reciprocity, and in-group loyalty. Effectively (and somewhat awkwardly), MG thus either refer to creator gods who care about morality in general, or non-creator spirits who specifically monitor three domains of human cooperation.

Any analysis of the archeo-historical record that considers "first appearances," especially when comparing first appearance dates, must consider the problem of inherent forward biases. To understand why the first recorded dates of most cultural traits will be forward biased, consider what it takes for evidence of MGs to make it into the Seshat database:

1. A community must come to believe in a god or supernatural process that reliably monitors and punishes some moral transgressions. This is the true first appearance date.
2. Those transgressions must be related to (1) fairness, (2) in-group loyalty or (3) reciprocity but not other moral domains. Notably, Seshat also codes for six other moral domains, including murder

and property crimes, but the authors ignored moralizing gods associated with these domains[a]. Here, first appearance dates will be pushed forward in time if the authors' three preferred domains happened to emerge after other domains, like murder.

3. These gods and their characteristics must have been accurately written down in sufficient detail for coding. This means that societies either have to first invent or otherwise acquire writing and then use it to express their beliefs about their gods punishing powers and moral concerns, or be described by missionaries, explorers or anthropologists motivated to accurately document these beliefs. The need for writing pushes first appearance dates forward until at least the invention/arrival of writing and the inclination to record supernatural beliefs (Extended Data Figure 1).
4. These possibly ancient written records have to survive to the present day. Such records need to be rediscovered, decoded and accurately described in secondary sources. The older an ancient record the less likely it is to both survive until the present day and be understood by modern scholars. This again biases first appearance dates forward in time.
5. Scholarly analyses of these writings have to be located by Seshat researchers and be accurately entered into Seshat. If early evidence is missed, unlike missed later evidence, the first appearance dates are moved forward in time. See below for distinct cases in which Seshat researchers missed evidence of MGs earlier in history.

These and additional steps in the journey from a historical community's belief in an MG to the Seshat database can each contribute to pushing the first appearance dates in Seshat forward in time. This influences first appearance dates in both absolute and relative terms, compared to the authors' measures of ritual and social complexity (which can often be inferred from non-written sources). This problem is further compounded by the authors' unjustifiable treatment of missing values in the historical record, described below.

S1.2 Replacing missing values with known absences

Another central problem in authors' argument is the treatment of unknown values ('NA') for MG in the analysis dataset. If Seshat's source files simply have no information regarding on supernatural beliefs, entries appear as "unknown" (after expert review) or "suspected unknown" (coded, but lacking expert review). If either BSP or MHG are missing data for a particular time and place, MG will correspondingly be 'NA' in the Whitehouse, et al. dataset, even if the other variable is absent ('0'). The requirements to code MG as absent ("0") are, in contrast, relatively strict: descriptions of a society's supernatural beliefs must exist, but both an MHG and all of the three required features for BSP must be absent as well ('0'). This outcome is correspondingly rare, as MG are known to be absent in only 12 observations, versus 490 observations categorized as unknown.

[a] In other words, some punishing supernatural agents or forces may have been coded as 'absent' (MG = 0) because they were concerned about harming others (e.g., murder), being brave (e.g., in battle), violating property rights (e.g., stealing), and/or respecting local structures (e.g., "obedient to those above you in a hierarchy") but not the authors' three focal domains. This is even more worrisome in light of the historical record that suggests these coded-but-ignored features of moralizing gods are among the earliest documented supernatural concerns[2–6]. In Mesopotamia, for example, the earliest evidence of divine concerns we have identified comes from law codes that point to murder (harm) as the earliest concern in Ur-Nammu (2100 BCE)[47].

Surprisingly, before their logistic regression analysis, Whitehouse, et al. recoded these 490 missing data points from missing (‘NA’) to absent (‘0’), conflating situations in which surviving records of supernatural beliefs exist but do not clearly describe MG, with situations in which no historical records exist, and we simply know nothing about the presence or absence of MGs either way.

In correspondence on this matter, Whitehouse, et al. have advanced the following assertion to justify this decision: “[G]iven the nature of the historical and archaeological record, if there was no evidence of moralizing gods we can treat them as being absent.” Because there are only 12 known absences and 490 missing values, mostly in small populations, this assumption is tantamount to assuming what the analysis seeks to test. As we demonstrate below, the paper’s primary conclusion, that moralizing gods are only present in large, complex societies, is entirely driven by this decision to replace all missing values with 0’s.

The result of this extraordinary decision is extreme overconfidence in our knowledge concerning small, pre-literate historical populations. Of the 390 observations in populations with at a social complexity score less than 0.4, only 8 have any data concerning MGs, so the remaining 382 data points are simply assumed to be absent MGs. By this analysis decision, no human population in the Americas of any size ever possessed moralizing deities before the arrival of European missionaries. Similarly, the authors’ logistic regression estimates (Extended Data Table 2 of the authors’ original report) describe an implausible scarcity of MGs among small-scale societies. The reported logistic regression estimates imply that in observed societies with SC scores less than the median of 0.42 moralizing gods will appear in only about 2% of cases (SE: 1%, Fig. 1A) each century. Because social complexity closely tracks population size (Fig. S1), a practical interpretation is that the model predicts an *extremely low* chance of finding moralizing gods in any human populations with less than 50,000 people. As we can show, however, ethnographic descriptions from small-scale populations regularly contradict this prediction.

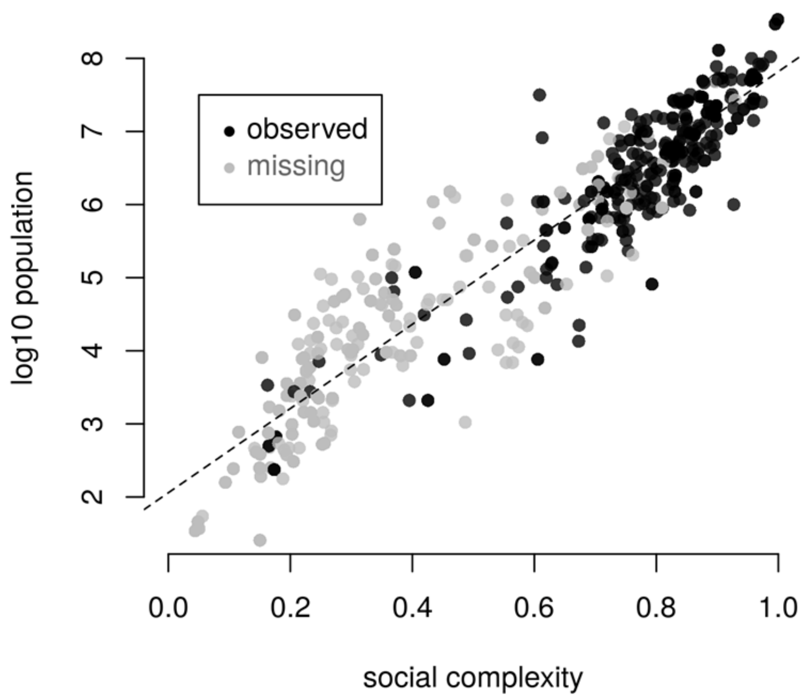

Figure S1 | Social complexity scores for *n* = 864 observations in the full Seshat dataset plotted against log-population sizes, with best-fit line (Pearson's $r = 0.94$) and shading indicating whether the MG outcome variable has known or missing values.

S1.3 Ethnographic evidence of moralizing gods

The fact that Whitehouse, et al.'s alleged first appearance dates for MGs depend heavily on the presence of writing (Extended Data Figure 1) presents a serious problem in light of the ethnographic record. The authors maintain that it is a "fact that evidence for moralizing gods is lacking in the majority of non-literate societies". Elsewhere[7], they claim that "Social scientists have long known that small-scale traditional societies–the kind missionaries used to dismiss as 'pagan'–envisaged a spirit world that cared little about the morality of human behaviour".

Contrary to these claims (which inappropriately cite Bellah[8]), all quantitative anthropological analyses reveal non-trivial frequencies of supernatural punishment in small-scale and non-literate societies. For example, in Boehm's review[9] of 43 hunter-gatherer ethnographies covering 18 societies, there are instances of supernatural punishment of at least one behavior construed as "antisocial" and "predatory on fellow band members" in all groups. In Swanson's classic study[10] of 50 societies (78% of which had populations of 10,000 or more people and 78% of the sample had three or fewer "sovereign organizations"), only 6 (12%) report instances of having a "moralizing high god", yet 11 (22%) are counted as "uncertain". However, 11 have indicators of "active ancestral spirits" that "aid or punish living humans" and 28% (p. 14) "are invoked by the living to assist in earthly affairs". Moreover, *all* of the 50 sampled populations have some documented form of "supernatural sanctions for morality", that is, "behaviors that helped or harmed other people" (p. 212) In Watts et al.'s Pulotu data set[11], 27 of the 74 (36%) Austronesian societies coded as "low political complexity" (acephalous or simple chiefdoms) had MGs. If we expand Whitehouse, et al.'s targeted "moral" behaviors to include breaches of sexual mores, Brown's study[12] suggests that over a quarter of the sample (110 societies' from the HRAF) includes some reference to supernatural punishment. The bottom line is that Whitehouse, et al.'s analysis—driven by their decision to recode all 'NA's as '0'—is strikingly inconsistent with much ethnographic evidence.

Another biasing problem with data used in analyses of human religions in non-literate societies is that much of it comes from early reports by missionaries and colonial administrators. Often, these individuals are evidently biased against seeing any elements that 'look Christian' in pagan religions[b] To see the challenges take, for instance, the case of the Orokaiva, that Seshat[28] codes as having no BSP or MHG (MG = 0) at any point in time. Whitehouse, et al. cite a source by Schwimmer[29], which contains the following:

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[b] Consider this missionary report[27] of the Abipón Indians of Paraguay, a source in the Standard Cross-cultural Sample (SCCS) and the Ethnographic Atlas (EA). The missionary describes his flock as follows, "the American savages are slow, dull, and stupid in the apprehension of things not present to their outward senses. Reasoning is a process troublesome and almost unknown to them. It is, therefore, no wonder that the contemplation of terrestrial or celestial objects should inspire them with *no idea of the creative Deity, nor indeed of any thing heavenly*" (p. 58; emphasis ours). These "slow, dull, and stupid" natives are nevertheless capable of conversion "when the good sense of the teacher compensates for the stupidity of his pupils" (p. 62). Based on this and two other sources, the SCCS and the EA code the Abipón as lacking a high god of any sort.

> If the Orokaiva, by and large, order their lives by the same moral principles, they would explain this by their common belief in certain demigods whom they all regard as their ancestors and as sources of authority, and who created certain institutions embodying moral norms to which they all subscribe. Not only do they obey the precepts of these demi-gods, they also re-enact their feats in ritual and identify with them during ceremonies, and in many of their regular expressive activities (p. 51).

These demi-gods "created certain institutions embodying moral norms to which they all subscribe." The Orokaiva themselves appeared to attribute their moral order to these gods. In Swanson's[10] dataset, the Orokaiva are coded as having no high god, but they do have ancestor spirits that "are invoked by the living to assist in earthly affairs" and have one coded instance of moralistic supernatural sanctions. Despite variation across sources, this example seems like a candidate for evidence of a MG.

This does not imply that the gods of small-scale societies were no different from those of complex societies. Instead, as Norenzayan et. al[30] argue, the differences are often quantitative and related to the size of the sphere of supernatural punishment (from clan members to all humans), the particular domains of punishment (more of those supporting larger scale cooperation) and size of the supernatural incentives (e.g., contingent afterlives). Because of their own source biases, these quantitative anthropological studies only provide a kind of lower bound on the percentage of societies with MGs and leave the question of the ubiquity of MGs unresolved[10,13–26]. Nevertheless, the ethnographic record provides no justification for recoding missing data as 'MG absence' ('0') in less-complex, non-literate societies.

Given the strong evidence of MGs in non-literate societies and the authors' heavy reliance on written historical records for evidence of MGs, there is good reason to suspect a substantial forward bias, both in absolute terms and relative to measures of social complexity and doctrinal rituals. Below, we re-analyze the authors' data while taking seriously the challenge of forward bias and handling of missing data.

S2. Reanalysis of the pre/post-appearance comparison

In this section, we examine the implications of forward bias on the results found by Whitehouse, et al., then we show why their analytical approach was inappropriate, and finally we provide a more appropriate alternative analysis. Even the smallest correction for the problem of forward bias produces the opposite result to that claimed by Whitehouse, et al.

S2.1 Correcting for forward bias in the statistical approach of Whitehouse, et al.

As discussed in the main text, one of the underlying factors that likely influences the appearance of MGs is the presence of writing (Table 1 in the main text). Whitehouse, et al. suggest that the appearance of writing preceded megasocieties (SC > 0.6), and therefore the absence of MGs before megasocieties cannot be explained by the absence of writing. However, there is a suspiciously tight connection between the first appearance of writing and the first appearance of MGs in the Seshat dataset, illustrated in Extended Data Figure 1. While the authors point out that on average writing precedes MGs by 400 years, Extended Data Figure 1 reveals that this average is strongly biased by two outlying NGAs: Susiana and

Kachi Plain[c]. For the remaining 10 NGAs, the appearance of MGs tightly follows the appearance of writing; hence, in our view, the correlation between the appearance of writing and MGs *predict* researchers' ability to detect MGs from written records rather than actual appearance of these beliefs in the historical populations.

Importantly, the dependence of MG detection in the archaeo-historical record on written records naturally biases the first MG appearance toward more recent dates. This problem can be illustrated by one simple historical case. The Mesopotamian sun god Shamash is coded by the Seshat team as an "active" god when he first appears in writing (2250 BCE). Shamash, however, appears in iconography at least half a millennium (2750 BCE) before he appears in writing[46]. Not coding Shamash as "active" in 2750 BCE requires assuming that people did not think of Shamash as an active god, participating in their lives, until he happened to enter the preserved written record—a rather unlikely assumption, especially considering the fact that some sort of organized and widespread belief in Shamash and his power must have motivated the creation of iconography in the first place. Furthermore, even without such pre-existing material evidence, it is reasonable to assume a time-lag between the spread of religious beliefs and their first appearance in writing.

To examine the effect of such a time-lag, we moved the first appearance of MG at each NGA 100 years back, the smallest possible correction given the resolution of the original data. Using the same analytical techniques as in the original paper (which we consider inappropriate, see below), the paired *t*-test now shows that MGs positively predict the *rise* in the rate of SC ($t = 4.04$, $df = 201$, $P < 0.001$) -- not a drop in the rate of SC as Whitehouse, et al. find (see Extended Figure 3 in the main text). This reanalysis demonstrates that, for their causal proposition to hold, researchers would have to be able to detect the first appearance of MG beliefs in the archaeo-historical records with a precision of +/- 50 years and assume that people started to write about religious beliefs immediately after their appearance. We regard this as unlikely. Furthermore, moving the first MGs appearance 300 years back (still a very conservative estimate, see Fig. 1B), the rise in the rate of SC change after the appearance of MGs is even stronger ($t = 5.48$, $df = 199$, $P < 0.001$; see also Extended Figure 3).

Note that Whitehouse, et al. tested their results for robustness against dating uncertainty by randomly placing MG appearance within the time-span of the polity in which MG first appeared.[d] However, for 11 out of 12 NGAs, MGs were always detected in Seshat during the first century of the polity's existence, so any random placing of MGs within the polity time-span would always make the first appearance of MG more recent, i.e. only worsening the forward bias. In other words, in Whitehouse, et al.'s robustness check, there was almost no possibility that MGs might have appeared earlier, only a possibility that they appeared more recently.

Further investigating the reasons for the sensitivity of causal analysis toward such small changes as moving MG 100 years backwards, we found that the appearance of MGs in the archaeo-historical record usually occurs simultaneously with a sudden jump in SC. As illustrated in Fig. S2A, societies increased their complexity on average by 39% within the 100 years just before the appearance of MGs

[c] Note that the estimate for Kachi Plain obfuscates that after the first appearance of writing, writing disappears, and is absent from multiple polities, only to reappear at the same time as MGs.

[d] While the analysis code for this robustness check was not part of the code made available by the authors, we infer on this robustness check from the Methods section in the original manuscript: "Our primary analysis treated moralizing gods as being present from the beginning of the polity in which they appeared. To ensure that our analyses were not affected by dating uncertainty, we reran the analyses randomly resampling to treat moralizing gods as appearing at some point from within the full date range of this polity (for example, 2900–2700 BCE for Egypt)."

while the average between-century increase in SC for the preceding 700 years was approximately 7%. Whitehouse, et al. proposed that the correlation between an increase in SC and the appearance of MGs is an indication that a society has to pass a certain threshold of SC (> 0.6, which they call "megasociety") to evolve a religious system with moralizing gods. However, it is not clear why the appearance of MGs would require such a dramatic change in SC within a single century (Fig. S2A). The fact that MGs can be detected in the archaeo-historical record just after a sudden and unprecedented jump in SC is troubling and points to potentially hidden underlying factors that may have influenced both the measures of SC and researcher's ability to detect MGs presence.

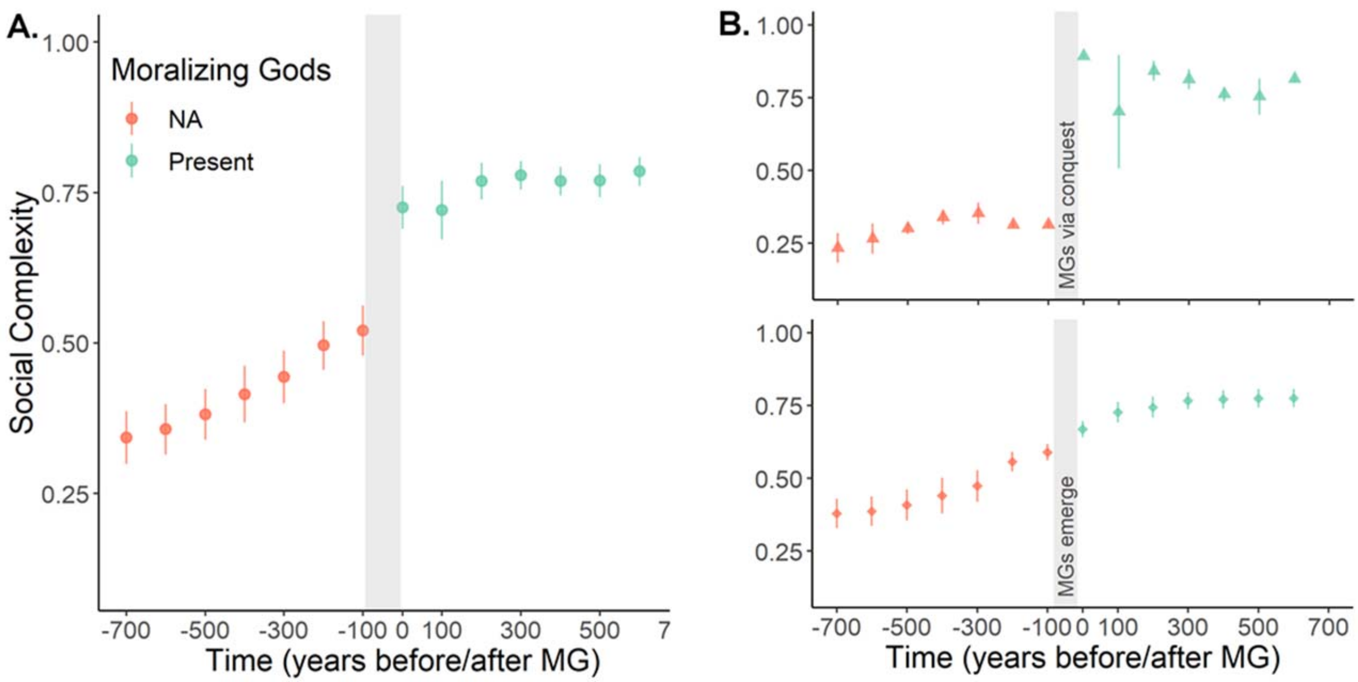

Figure S2 | Social complexity before and after the appearance of moralizing gods. Dots represent mean social complexity (SC) collapsed across NGAs. Bars represent +/- SE. The x-axis represents centered time before/after the presumed appearance of MGs at each NGA. Note that 0 on this axis represents widely disparate times, ranging from 2900 BCE to 1100 CE. **A.** The plot shows that MGs can be detected in the archaeo-historical records just after a sudden jump in social complexity that represents the smallest temporal unit in Whitehouse, et al.'s analysis (one century). **B.** The sudden jump in social complexity just before the appearance of MGs may be partially explained by the fact that 3 NGAs (Deccan, Kachi Plain, Sogdiana) were coded as having MGs only after these NGAs were integrated into larger empires with millions of inhabitants that already had MGs (upper figure in Panel B). The remaining NGAs (*n* = 9) that did not explicitly acquire MGs through being conquered by a larger empire (lower figure in Panel B) show a steady rise in social complexity.

We surmise that one of the explaining factors relates to the treatment of historical conquest by Whitehouse, et al.: at Deccan, Kachi Plain, and Sogdiana NGAs, the apparent rapid increases in social complexity and the appearance of MGs are a direct consequence of conquest by large empires (Fig. S2B). For instance, Deccan has a population of 20,000 in 400 BCE with no MGs and no writing; yet next century, the same NGA has a population of 18 million with MGs and writing, and then a century later reverts back to 20,000 people with no MGs and no writing. This dramatic change is caused by the fact that Whitehouse, et al. assign Deccan the population size, social complexity, and religious beliefs of another NGA, Kachi Plain during a century of Kachi Plain's imperial rule. Likewise, Kachi Plain acquires their MG when conquered by Susiana, suddenly increasing their SC from 0.33 to 0.90 within a single century. Sogdiana rises from a population of 10,000 in 500 BCE to 22 million in next century when Susiana takes over their territory and imports MG. Such a treatment of conquest results in the appearance of "sharp increases" in population size, SC and moralizing gods at the Deccan, Kachi Plain and Sogdiana NGAs. Given the analytical technique employed by Whitehouse, et al. (paired t-test), it looks as if these three NGAs spontaneously increased their SC within a century and only afterwards developed belief in MGs. In other words, the paired t-test treats the three-fold increase in SC for the conquered NGAs as coming before MGs (increase from year -100 to 0 in Fig. S2B) while, as a matter of fact, MGs arrived together with increase in SC due to conquest.

The remaining nine NGAs that did not acquire MGs through conquest show rather a steady increase in the rate of SC change (Fig. S2B). To test the robustness of Whitehouse, et al.'s results, we also performed the same paired t-test analysis on the reduced sample of nine NGAs that did not acquire MGs via conquest. The results revealed that the five-fold higher rates of SC change between Pre- and Post-MGs reported by Whitehouse, et al. decreased only to a two-fold higher rate of SC change (t = -5.28, df = 141, P < 0.001). Furthermore, correcting the forward bias by 100 years indicates that this result is no longer significant at the conventional alpha levels (t = -0.68, df = 142, P = 0.498) and the correction for 300 years again reverses Whitehouse, et al.'s main claim; the Post-MGs rate of SC change is 1.8 the size of the Pre-MG rate of SC change (t = 4.16, df = 143, P < 0.001).[e]

These analyses suggest that the extreme sensitivity of Whitehouse, et al.'s results to forward bias was partially caused by the treatment of historical conquest. When the authors assigned the one-century SC difference caused by conquest as Pre-MG, the t-test analysis produced significant results that favored their hypothesis. When we shifted MG appearance 100 years backwards, the SC difference caused by conquest moved to the Post-MG category and reversed the original results. However, even after we excluded the NGAs with problematic treatment of conquest, correcting for forward bias again reversed the original results.

S2.2 Growth curve models of social complexity

Putting the problems of forward bias aside, we also found their analytical approach inadequate to assess the complex causality between MGs and SC. Treating MGs as an exogenous intervention that begins to influence SC at some year "0" and did not exist before disregards the likely possibility that MGs co-evolved with SC through a complex feedback-loop relationship. However, even if we would assume that MGs suddenly appeared at a specific point in time without prior interaction with SC, the paired t-test employed by Whitehouse, et al. remains inadequate for the nature of the analyzed data. The computed rates of SC change analyzed with the t-test include 400 data points (i.e., 200 Pre-MG time-points and 200 Post-MG time-points), but ignore the fact that these data points are nested within 12 focal NGAs. Additionally, some NGAs have more observations than others (ranging from 0 to 13 missing centuries per NGA). This data structure warrants a model that is flexible enough to handle repeated measures through space (polities within NGAs) and time. When comparing the rates of change for specific time windows

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[e] Note that the degrees of freedom for the t-test analyses in this paragraph differ due to differential rates of available data across the nine NGAs outside the original +/- 2000 years interval (see Supplementary R code).

(e.g., 100 years Pre/-Post-MG), however, the paired t-test analysis treats each pair of data-points as an independent observation. In other words, it only considers one time-window (e.g., 100 years Pre/-Post-MG in Susiana) to be a repeated measure, while the other time-windows (e.g., 200 years Pre/-Post-MG in Susiana) are considered to be from a different "individual" (while actually being from the same NGA and likely very similar to the 100-year time-window). This approach severely violates the assumption of independence[31] and artificially inflates the degrees of freedom for the t-test. In our view, the data have at least two hierarchical levels corresponding to their nesting within NGAs and their further nesting within world regions. We built a linear mixed model accounting for this nesting structure; however, the goodness-of-fit assessment of this model revealed severe deviation from the normality assumption (see Supplementary R code for diagnostic checks and plots).

To account for the violation of the independence and normality assumptions, we used a multilevel growth-curve model that accounts for data-nesting and affords flexibility in modeling the distributional assumptions. While this model is still too crude for modeling complex causal relationships (e.g., it cannot model continuous feedback between the growth of MGs and SC), it produces precise estimates based on the assumed data-generation process[32,33] rather than a simple test of difference. To fit the growth curve model of differences in SC Pre- and Post-MG, we used raw social complexity as the outcome variable (rather than already pre-calculated rates of SC change); time, MG presence, and their interaction as predictor variables; NGA and world region as nesting factors for fitting varying intercepts; and a varying effect of time for each NGA to account for the NGA-specific rate of SC change[f]. Finally, to account for the fact that the SC data were scaled between 0 and 1, we used a beta distribution that allows the model to estimate the mean and dispersion of scaled SC data, which are typically heteroscedastic and skewed[34].

This model allows us to examine the change in SC before and after the assumed MG arrival (for the period of +/- 2000 years) while adjusting the model for the various nestings presented in the data as well as for the assumed beta distribution. Indeed, goodness-of-fit measures indicated that this full model fits the data reasonably well (see Supplementary R code). Table S1, Model 1 displays the results of the full model: Time is the estimated increase in SC over one millennium before the arrival of MGs (we chose one millennium rather than century to improve interpretability); MG [Pre vs. Post] is the difference in intercepts for the Pre-MG and Post-MG regression lines, i.e., SC 2000 years Pre-MG vs. SC at the time of the supposed MG appearance; and Time by MG interaction is the difference in linear slopes for the Pre- and Post-MG periods[g]. The intercept indicates that the mean SC 2000 years before MGs was around 0.24 and with each millennium, it increased by 0.12 SC points (on a scale 0-1). Likewise, the average SC during the first MG century was approximately 0.3 SC points higher compared to 2000 years before. The

[f] The full model is defined below, where g is the logit link for beta regression; Y_{ijk} is social complexity at time-point i within NGA j and world region k. β_0 is a fixed intercept, u_{0j} is a varying intercept for NGA j, and u_{0k} is a varying intercept for world region k. β_1 is the parameter for the fixed effect of time, u_{1j} is the parameter for varying effects of time across NGA j, and X_{1ijk} is the value of the time-point i for NGA j and world region k. Analogically, β_2 is the parameter for the effect of Pre-/Post-MG and X_{2ijk} the value of Pre-/Post-MG. β_3 is the parameter for the interaction of Time*Pre-/Post-MG, and ε represents the error term for the assumed beta distribution with parameters μ representing location and ϕ representing dispersion:

$$g(Y_{ijk})=((\beta_0+u_{0j}+u_{0k})+(\beta_1+u_{1j})X_{1ijk}+\beta_2X_{2ijk}+\beta_3X_{1ijk}X_{2ijk}+\varepsilon_{ijk})\sim \mathrm{Beta}(\mu,\phi)$$

[g] Note that our regression approach does not analyze the 100-year period between the last time-point without MG and the first time-point with MG. While the t-test analysis Whitehouse, et al. performed treats these 100 years as 'Pre-MG', such a step has to assume that MG appeared suddenly and *ex nihilo*. We allow MGs to arise within the 100 years, still an unreasonable assumption but necessary to remain consistent with the original analyses.

interaction coefficient indicates that while the Pre-MG growth was indeed steeper compared to the Post-MG growth, this difference was only small and not significant at the conventional levels ($P < 0.05$). The model estimates the Post-MG increase per millennium was 0.10 SC points (compared to 0.12 Pre-MG).

	Model 1 (MG 0)	**Model 2** (MG - 300)
Intercept	0.238***	0.267***
	(0.174, 0.316)	(0.196, 0.352)
Time	0.120***	0.067*
	(0.075, 0.162)	(0.011, 0.122)
MG [Pre vs. Post]	0.304***	0.015
	(0.224, 0.366)	(-0.079, 0.109)
Time*MG	-0.023	0.125***
	(-0.072, 0.026)	(0.073, 0.175)
Observations	429	429
NGAs	12	12
World Regions	6	6

Table S1 | Estimates with 95% CI from the models of social complexity. Estimates from beta regressions were back-transformed from the logit link. Time is SC change per millennium. Model "MG 0" is a growth curve model with the appearance of MGs assumed by Whitehouse, et al., Model "MG - 300" (MG minus 300) is a growth curve model with shifted MGs' appearance 300 years back. *$P < 0.05$; ***$P < 0.001$.

The results of the multilevel growth curve model reveal that by using a more appropriate statistical approach, the original t-test result presented by Whitehouse, et al. simply does not hold. While the SC growth before MG appearance is steeper compared to the SC growth after MG, this difference is negligible. However, when running the same model only for the +/- 700 period (analogous to Whitehouse, et al. robustness checks), we found that the Post-MG growth was indeed significantly lower [estimated slope difference per century = -0.0002, 95% CI = [-0.0004, -0.00003]), a result that qualitatively corresponds to the paired t-test Whitehouse, et al. reported. The difference between the 2000 years and 700 years models possibly corresponds to the rapid SC change around the supposed MG appearance discussed in the section S2.1, which is tracked only by the latter model.

To further demonstrate the importance of considering forward bias, we also examined the impact of small corrections for forward bias using our more appropriate growth curve modeling approach. Specifically, we built the same model as in Tab. S1, Model 1, but shifted MGs first appearance at each NGA 300 years back (see Tab. S1, Model 2). While the estimated intercept is similar to that of Model 1, the Pre-MG time effect is only half of the original effect (c.f. Model 1 and Model 2). Importantly, the difference in Pre-/Post-MG intercepts is no longer significant while the slope of Post-MG SC growth is now substantially higher compared to the Pre-MG growth (0.19 vs. 0.07). This result again demonstrates that even slight shifts of MGs back in time within a more appropriate modeling framework predicts the SC growth Post-MG is larger compared to Pre-MG, effectively reversing Whitehouse, et al.'s main claim[h].

[h] We observed a similar interaction trend for MGs shifted only 100 years back, albeit the 95% CI crosses zero [estimated slope difference per millenium = 0.032, 95% CI = [-0.019, 0.082]).

In summary, we believe that given the data structure used by Whitehouse, et al., the growth curve model represents a more appropriate and nuanced analytical approach. If the original data were of higher quality (see below), this model could provide more reliable estimates compared to the paired t-test while respecting the test's assumptions. The growth curve model also allows for further investigation of non-linearity in growth curves (and their Pre-/Post-MG difference), which we omitted from the current analysis for the sake of simplicity[i].

S3. Reanalysis of the logistic regression model

Here we examine Whitehouse, et al.'s use of logistic regression to predict the appearance of moralizing gods (their Extended Data Table 2). First, we reproduced Whitehouse's essential results using the materials made public by the authors, including their figures, regression estimates, and data sample sizes. We then examined the sensitivity of their key results to the assumption that missing values (NA's) in their outcome variable could be converted to the absence of moralizing gods' (rewritten as '0's). Because missingness in the Whitehouse, et al. data strongly correlates with smaller population sizes and lower social complexity (Extended Data Figure 2; Section S1.2), their conversion of all missing values to 0's is an extremely favorable assumption for the authors' preferred conclusion. Indeed, we find that one of their main results - that increases in social complexity precede moralizing gods - entirely hinges on this assumption, and for each reasonable alternative we see the opposite pattern.

We here consider the pattern of missingness as a "missing at random" scenario[45], for which the most principled approach is to simply drop the missing values. Despite the authors concerns that outcome missingness is clearly a function of a population's social complexity[43], estimates of the regression intercept and effect of social complexity will be unbiased so long as the model conditions on social complexity as a predictor variable.

The resulting analysis excludes 490 observations with missing values on the outcome variable. Because there are two lag terms in the published model, which use the binary outcome values from the two previous time periods within each NGA, two additional complications appear. First, for the earliest observations where the outcome value is known, we will have missing values in the lagged terms we must deal with. Second, because no world region shows any within-region variance in the outcome value without the "NA to 0" imputation (except one observation in Middle Yellow River Valley, disputed in Section S4), the lag terms become perfectly correlated with the outcome, which no longer allows for a logistic regression time-series approach. To maintain comparability, we removed the lag terms and re-estimated the probability of moralizing gods' appearance as a logistic regression on social complexity, distance, and language similarity as calculated in the original analysis. To account for non-independence across observations by region, we added varying-effect intercept terms for each region, with mildly regularizing priors on each parameter. Specifically, each logistic coefficient is given a Gaussian prior with mean 0 and $\sigma = 4$ log-odds units, with a Gaussian centered intercept prior of 0 with σ of 1 log-odds unit fit by Hamiltonian MCMC with the rstan package[j].

These changes alter the estimates of covariates like spatial proximity, but when fit on the full dataset preserve the essential pattern of rapid increase in the probability of moralizing gods around a social complexity score of 0.6 (Table S2). When judged solely on the MG data that is not missing,

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[i] The analyses presented in this section were conducted using R, version 5.3.5[35] and packages DHARMa[36], dplyr[37], glmmADMB[38], glmmTMB[39], lme4[40], reshape[41]. The figures were plotted with the help of ggplot2[42] package.
[j] Stan Development Team (2018). RStan: the R interface to Stan. R package version 2.18.2. http://mc-stan.org/.

however, this revised model finds that the relationship between social complexity and moralizing gods is far weaker. The estimated frequencies of moralizing gods predicted by this model, particularly in smaller-scale societies with lower levels of social complexity, are much more consistent with the ethnographic record. For example, the contrast in Figure 1A is striking for low and intermediate levels of social complexity: societies with an SC of 0.4 are predicted to have essentially no moralizing gods when 'NA's are recoded as zeros (per Whitehouse, et al.) but over half are expected to have moralizing gods when 'NA's are removed.

	Reduced Dataset *All 'NA' removed*		Full Dataset *All 'NA' to 0*	
	Est. (SE)	P(sign)	Est. (SE)	P(sign)
Intercept	1.05 (0.65)	0.05	-1.48 (0.58)	0.01
Social Complexity	8.64 (2.33)	<0.01	15.11 (1.56)	<0.01
Phylogeny	1.40 (3.88)	0.37	5.08 (2.98)	0.04
Space	6.82 (2.55)	<0.01	3.22 (1.32)	0.01
NGA Varying Effect	2.31 (1.03)	-	2.57 (0.68)	-
N	336		801	
Deviance	104.7		281.2	

Table S2 | Revised logistic regression estimates for the presence or absence of moralizing gods in the reduced dataset and full dataset, with means, standard errors, and probability each effect is null or negative (the Type-S sign error)[44]. Outcome values coded as "unknown" or "suspected unknown" in the Seshat database and 'NA' in the analysis dataset were removed, and to account for within-region non-independence, a varying-effects intercept was added for each NGA. Without NA values converted to 0, lag terms in the original model become linearly dependent with the outcome variable and are removed as well. Social complexity is centered on 0.5 to aid intercept interpretability.

With this revised model, we can then infer the "first emergence" of MGs for each NGA here defined probabilistically as the earliest point at which 80% of the posterior probability mass is above P = 0.5 on the outcome probability scale, which indicates reasonable certainty that moralizing gods are present conditional on available information (Figure S3). Combining these estimates as in the original analysis provides an average emergence point of approx. 1000 years before first observation in Fig. 2B. For comparison, Fig. S4 shows similar posterior probability calculations drawn from Whitehouse, et al.'s model fit on the original dataset including all NA as known 0's. Consistent with the corresponding counterfactual predictions in Figure 1A, this model estimates the probability of MG emergence to be close to 0 for every focal NGA until moralizing gods are actually observed.

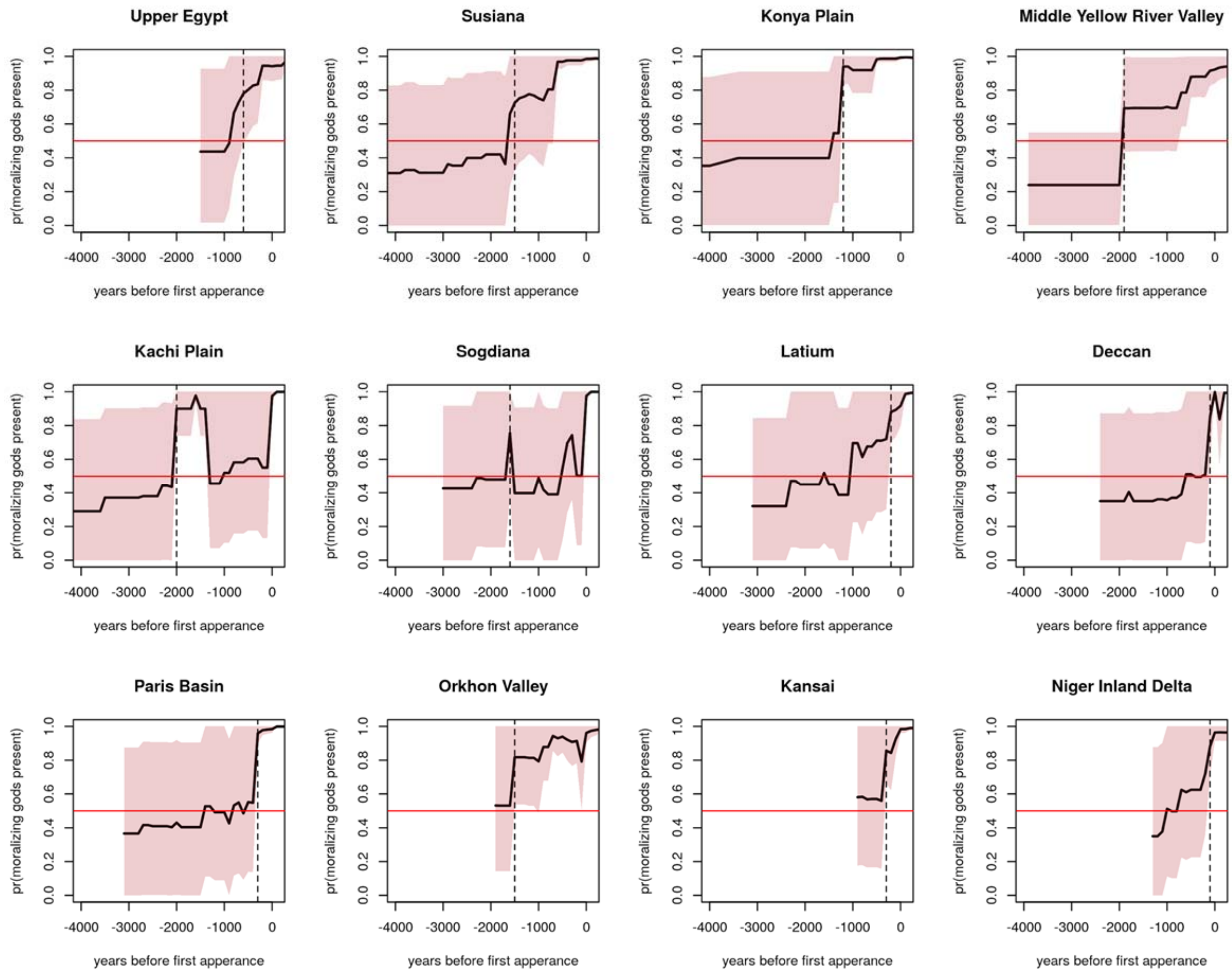

Figure S3 | Posterior predictions for the probability of moralizing gods present by year for Whitehouse, et al.'s main 12 NGAs in their analysis, drawn from the model described in Fig. 1A and Table S2 measured in years before their first documented appearance in the Seshat database. Posterior mean probability (black line) accompanied by 89% HPDI (red shading) indicates a high chance of MG presence in every site several centuries before recorded first appearance. Dashed lines indicate the first year at which 80% of posterior mass is above a probability of 0.5 (coin flip), used as a rough estimate of the "first emergence" of moralizing gods in Fig. 1B.

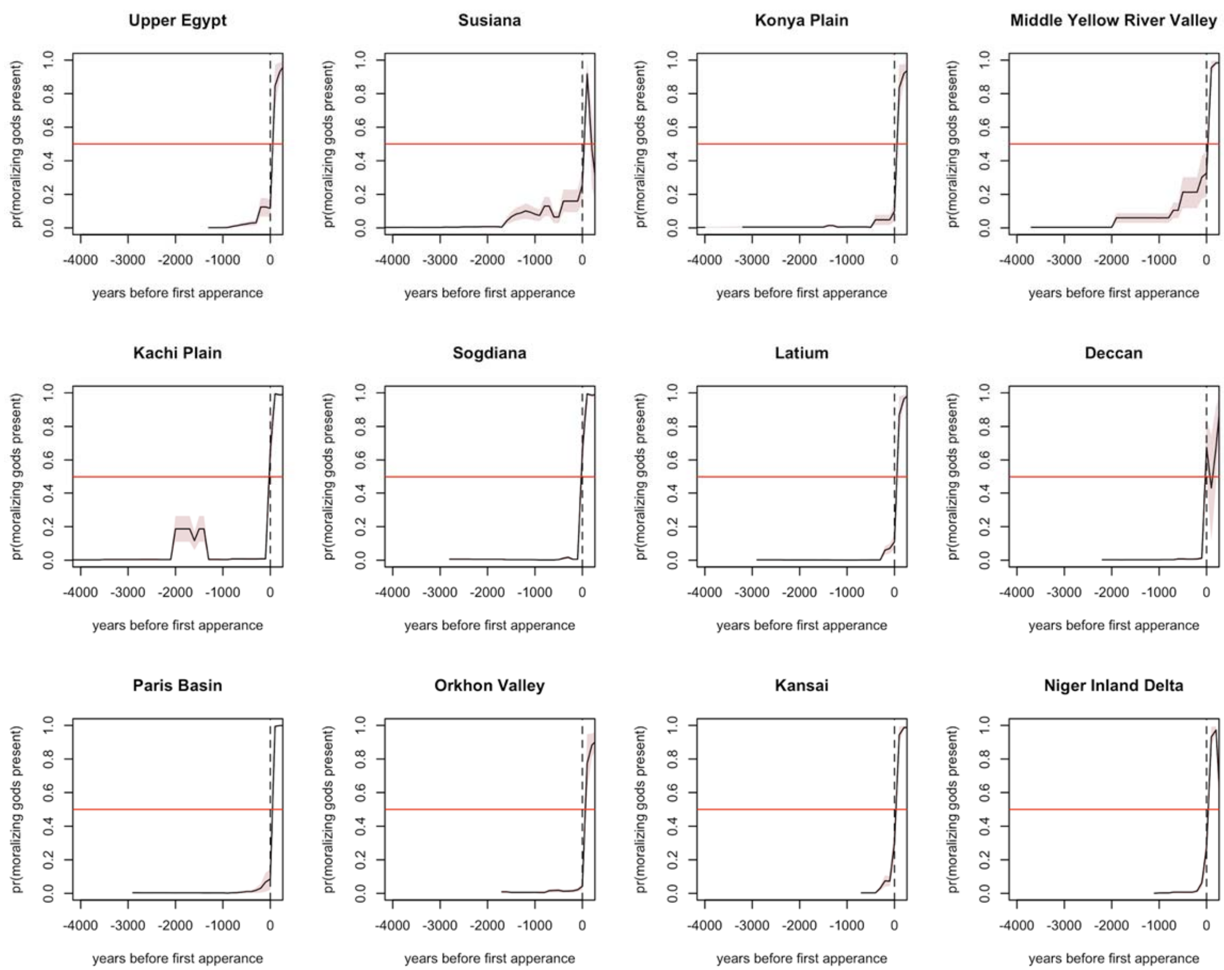

Figure S4 | Posterior predictions for the probability of moralizing gods present by year for Whitehouse, et al.'s main 12 NGAs in their analysis, drawn from their original regression model, measured in years before their first documented appearance in the Seshat database (dashed lines). Posterior mean probability (black line) accompanied by 89% HPDI (red shading) predicts almost no chance of moralizing gods, in contrast to Figure S3.

While reducing to complete cases (i.e., removing outcome 'NAs') is a standard solution in this situation, it is important to consider alternative imputation methods that are more conservative against the hypothesis favored by Whitehouse, et al. For example, they may have instead assumed that moralizing gods appear just as often in small, non-complex populations as in large, complex ones, implying an imputation rule of randomly assigning 1's to missing values at the same rate of occurrence (96%) as in observed values[31]. Or, citing Laplace's "Principle of Indifference", they might have considered how, absent any knowledge of the features of a non-literate society's cosmology, we are equally ignorant of their presence or absence, and assign 50% of missing values "1", and 50% "0". The resulting regression coefficients by these missingness models are presented in Table S3. In both alternative cases, shown in Table S3 and Figure S5, we do not see the rapid increase in the probability of MG appearing after societies have become large and complex megasocieties.

	Original Model		Alternative 1		Alternative 2	
	All 'NA' to 0		*96% 'NA' to '1'*		*50% 'NA' to '1'/'0'*	
	Est. (SE)	P(sign)	Est. (SE)	P(sign)	Est. (SE)	P(sign)
Intercept	-3.09 (0.36)	<0.01	1.30 (0.48)	<0.01	0.12 (0.20)	0.27
Social Complexity	9.78 (1.42)	<0.01	1.08 (0.89)	0.11	2.81 (0.46)	<0.01
Lag1	3.86 (0.67)	<0.01	1.51 (0.47)	<0.01	0.25 (0.18)	0.09
Lag2	0.83 (0.66)	0.11	0.56 (0.50)	0.13	0.85 (0.19)	<0.01
Phylogeny	7.92 (3.97)	0.02	8.25 (5.15)	0.05	6.60 (3.44)	0.02
Space	-2.03 (1.15)	0.04	0.26 (1.23)	0.42	0.85 (0.66)	0.10
N	801		801		801	
Deviance	169.0		267.8		778.4	

Table S3 | Regression estimates for the presence/absence of moralizing gods under three "missingness regimes" for the 490 missing values: means, standard errors, and posterior probability each effect is null or negative (the Type-S sign error)[44]. The "Original model" treats all missing values (`NA') as 0, corresponding to the estimates in Whitehouse, et al. Two alternatives using the same regression model, but different imputation methods for missing values: (1) 96% of NA's assigned randomly to `1' (the frequency of occurrence in the observed data), and (2) 50% of NA's randomly assigned to `1', 50% to `0'. Social complexity is centered on 0.5 to aid intercept interpretability.

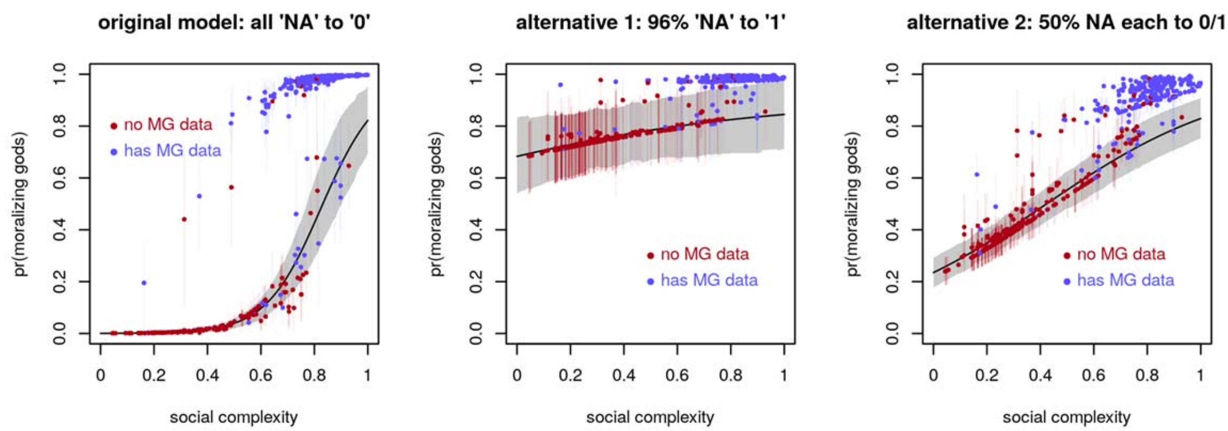

Figure S5 | Estimated relationship between the probability of moralizing gods being observed and social complexity, for original model and two alternatives described in Table S3. Trend lines (black) are all held at average distance and language similarity, with 89% HPDI shading. Mean probabilities of "moralizing gods present", for both "known" and "unknown" outcome values, are given as colored points with 89% HPDI intervals.

Though we prefer the missing-at-random (MAR) approach (removing the cases with NAs) to either of our Alternatives 1 or 2, these other approaches to dealing with missing data nevertheless illustrate how difficult it is to arrive at Whitehouse, et al.'s preferred result--moralizing gods post-date the rise of complex societies--using Seshat data. To summarize, as with our robustness checks in section 2, the only way that we have found to obtain the authors' results is to assume, unjustifiably in our opinion, that the first documented appearance of moralizing gods is in fact the same time as their emergence; more reasonable alternative approaches yield opposite results.

S4. Data vetting and coding quality concerns

This section summarizes our concerns with the vetting process used in Seshat, the reporting of that vetting by Whitehouse, et al. and the overall quality of the data used in the paper. These concerns are detailed at greater length in an invited response accepted and forthcoming at the *Journal of Cognitive Historiography*, Slingerland et al. Historians Respond to Whitehouse, et al., "Complex societies precede moralizing gods throughout world history", available, along with supporting materials JCH.S1-S4 in that paper, mentioned below, at https://hecc.ubc.ca/historians-respond-to-whitehouse-et-al/.

In the Methods section of their paper, Whitehouse, et al. describe their data vetting procedure as follows:

> Data collection for the religion and ritual variables involved matching each fully trained research assistant with one or more Seshat experts. Seshat experts provided guidance on how to delineate the temporal and geographical boundaries of the polity, assembled an initial reading list and, where necessary, helped to interpret some of the key historiographical debates associated with the variables. Research assistants then populated the variables with data and presented this to the Seshat experts for review. The comments and suggestions made by the experts were then implemented by the research assistants. The next stage required a second team of fully trained research assistants to go over the gathered data and to conduct a series of quality checks, including vetting of the footnotes and the use of correct syntax for the machine-readable part of the data. Finally, this checked dataset was given to the Seshat experts for review. **The coding of religion and ritual data required the input of experts every step of the way, given the frequent need for complex and nuanced interpretation of the evidence**. By contrast, the data required for the social complexity variables frequently consisted of facts that research assistants could procure with less supervision, allowing expert input and review to occur at a later stage of the process (emphasis ours).

This description does not match the vetting documented on the version of the Seshat site (http://seshatdatabank.info/nature/) at the time of publication: only 13% of polities reportedly had both sets of variables checked, 24% had only one checked, and 63% had no reported expert vetting at all (JCH.S2). Following publication, a large number of changes were made to both the main site and "/nature" version, including adding new expert vetting attributions and changing many vetting claims. The original attributions, which read "[Expert name], Religion or Normative Ideology System" and/or "Ritual Variables," implies (according to the Methods section) that the expert vetted all of the named set of variables for that particular polity. Many of these attributions have been changed since publication to read "verified key data regarding earliest appearance of moralizing gods/doctrinal rituals." This suggests that the experts only verified two particular variables in one polity—whichever was characterized by this earliest appearance. However, this phrase was added to *all* polities in the NGA (rather than the polity of first appearance, where these two variables would have been checked), inflating the reported percentage of vetted polities.

Personal communication with attributed expert vetters also reveal that even the reported degree of expert vetting is exaggerated: one of Seshat's more prolific scholars (Dr. Vesna Wallace), originally credited with having vetted the religion and ritual variables for 49 polities in 7 NGAs, in fact reports having played no role whatsoever in supervising coding or vetting any portion of the site.

It is worth noting that in the Methods section, the authors, in the process of describing their methods for producing codes and coding justifications, state:

> All data are linked to scholarly sources, including peer-reviewed publications and personal communications from established authorities. On occasions when Seshat experts disagree on a particular coding, we kept a record of disagreements so that analyses could be run taking into account contrasting interpretations. Once used for the purposes of data analysis and publication, that version of the dataset was 'frozen' so that it could be inspected by others and used for the purposes of replication. Nevertheless, the data in Seshat continually evolves, as new sources are discovered and as new Seshat experts contribute additional layers of interpretation.

This statement strongly implies that, while the main Seshat site would continue to be updated, expanded and revised, the version of the codes and coding justifications (with references consulted, personal communications from experts, etc.) actually used in the analysis—the mirror of the site at http://seshatdatabank.info/nature/ provided to referees and the press prior to publication—would be frozen so that outside experts could assess its reliability and draw upon it for purposes of replication. This is not the case: the nature-tagged version of the site has been altered considerably since publication. Dated screenshots from the nature-tagged version of Seshat are available at JCH.S4.

Although the vetting and reporting procedures are problematic, their impact on the quality of the data itself could have been limited. This is not the case. As an example, JCH.S1 and JCH.S3 provide a representative list of specific sourcing problems and coding errors along with full results of Middle Yellow River Valley (MYVR) data check on the religion and ritual variables for the 12 polities in this region, respectively. Approximately 70% of these data contradict the fully expert-generated or expert-vetted data available in the Database of Religious History (DRH; religiondatabase.org) as summarized in Table S4 below. These contradictions are not simply a matter of scholarly disagreement. All of the DRH data can be traced to an expert scholarly opinion, while only 16 of the 110 data points associated with the religion and ritual variables in the MYRV region in Seshat are independent observations with a reference or expert source specific to the time and place in question, as we discuss below.

Seshat NGA	Date	DRH Entries	Agreement
Late Shang	1250 - 1045 BCE	3	6.67%
Western Zhou	1122 - 771 BCE	2	30%
Jin	794 - 489 BCE	1	40%
Wei	488 - 223 BCE	6	25%
Imperial Qin	338 - 207 BCE	6	25%
Western Han	202 BCE - 9 CE	5	45%
Eastern Han	25 - 220 CE	5	31%
Western Jin	263 - 317 CE	2	0%
Northern Wei	386 - 534 CE	3	40%
Sui	581 - 618 CE	1	40%
Early Tang Dynasty	617 - 763 CE	3	40%
Late Tang Dynasty	763 - 907 CE	2	40%
		Total	30.22%

Table S4 | Comparison of Seshat coding of religion and ritual variables in early MYRV with expert-generated or expert-vetted codes from the Database of Religious History (DRH; religiondatabase.org). The specific contradictions can be found here at JCH.S3 at https://hecc.ubc.ca/response-to-whitehouse-et-al/.

Even if the assumption of missingness to absence or the analysis were appropriate, these data quality issues undermine Whitehouse, et al.'s conclusions. In the case of MYVR, for example, the first appearance of a moralizing deity is coded in Seshat as Western Zhou (1122-795 BCE), because they code this variable as 0 in the Late Shang (1250-1123 BCE), based upon a publication by Robert Eno, an expert in the field. However, Eno's position is a minority one. Entries in the DRH indicate that Eno's negative appraisal runs counter to two positive codings by the scholars Lothar von Falkenhausen and David Keightley. Coding the Late Shang moralizing god as "1" based on majority opinion, or weighting it as .66, would make the appearance of moralizing gods and writing in the MYRV contemporaneous. This is significant because this NGA is the sole example Seshat can provide of positive evidence of absence (a coded "0," rather than an "NA" converted to a "0") of moralizing gods after the advent of writing.

Beyond presence and absence data without appropriate expert sourcing, another concerning data quality decision is "data pasting" a single observation about a specific time and place to code a variable, and then copying this coding justification and code value into a string of later polities, or even to polities from other NGAs. In the MYVR the justifications for the religion and ritual variables shows that only 16 independent observations underlie 110 data points (5 variables x 22 polities). In other words, all of the coding of the religion and ritual variables for 5000 years of Chinese history, analyzed by the Seshat team as separate data points, is in fact based on a few (mostly out of context) personal communications from experts and 5-6 citations of (mostly inappropriate) secondary literature. A personal communication from Connie Cook, an early China expert, about Shang ritual practice is used in the coding justification for the crucial ritual frequency variable for every Polity from the Western Zhou (1122 BCE) to the Ming (1643 CE), a span of close to 3,000 years. Similarly, only 50 unique observations underlie the coding of the high god variable across 298 different polities (Fig. S6).

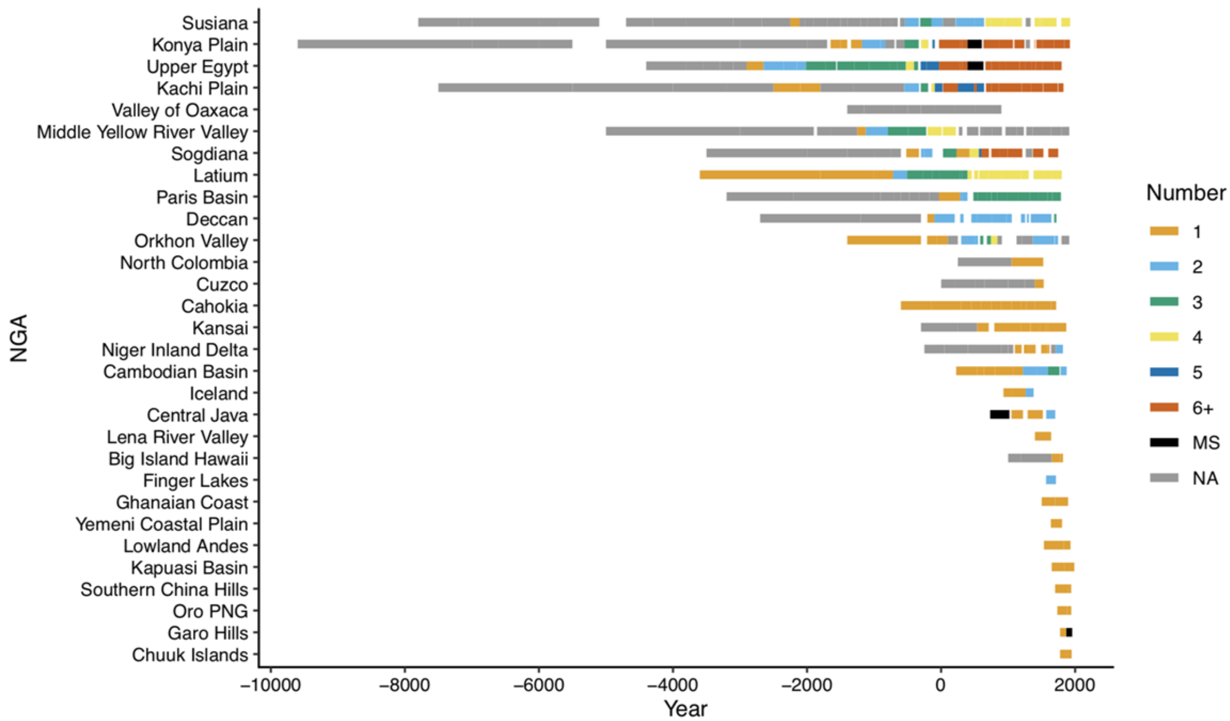

Figure S6 | Number of sources cited for coding justifications, by time period, for the variable high gods (creator gods) per natural geographic area (NGA). For some polities the presence/absence of high gods (creator gods) was categorized as "suspected unknown" or "unknown" and had no coding justification. As these variables are treated as missing values during analysis conducted by Whitehouse, et al., they were categorized as NA (although later converted to 0, as noted above). Some variables with classifications of "moralizing", "active" and "inactive" were missing source attributions and are labelled as MS.

In addition to this "data pasting", highly generic sources are commonly used to "data fill" a broad swath of discrete spatial and temporal points of data that, in fact, have little to do with the citation. For instance, a single quotation from Rupert Gethin (1998, The Foundations of Buddhism. Oxford: Oxford University Press, p. 136) concerning "supernatural enforcement of reciprocity" is used to code this variable in 38 polities in 9 NGAs, spanning from the Kachi Plain/Mauryan Empire (303-194 BCE) to Orkhon Valley/Late Qing (1796 - 1912 CE); the same quotation is used as a coding source a total of 108 times, as it appears in the justifications for multiple variables. Given the nature of historical change and regional variation in Buddhist belief and practice, such imputation is inappropriate without supporting research on these other polities. It also artificially inflates the number of data points. General introductions to Pali Buddhism in South and Southeast Asia are similarly used to code all of the Orkhon Valley (Mongolia); a basic textbook about Indian Hinduism is used to code the Cambodian Basin. This practice, not surprisingly, leads to widespread errors documented by our historian colleagues (see Slingerland et al, accepted, cited above).

These specifically-identifiable errors understate the unreliability of the Seshat data. Data pasting and data filling combined with coding decisions being made by RAs who are not trained in a relevant field lead to irrelevant historical sources or observations. This, in turn, means that there is no way to know how much of the data, at least when it comes to the crucial religion and ritual variables, is reliable as a source of history, raising concerns about any analysis based on these data.

History, as the authors caution, requires nuanced interpretation, and the goal of an archaeo-historical database is to be a central source of accurate historical information based on the best available sources and scholarship. There can be disagreement about the relative merits of an RA- versus expert-based approach to coding the historical record, or the importance or necessity of expert vetting. There should, however, be less disagreement that research teams must be clear about which strategy they are adopting, and that any vetting procedures need to be transparently reported and easily verified.

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