

Peer Review Information

Journal: Nature Human Behaviour

Manuscript Title: Origins and spread of formal ceremonial complexes in the Olmec and Maya regions revealed by airborne lidar

Corresponding author name(s): Takeshi Inomata

Editorial Notes:

Transferred manuscripts This manuscript has been previously reviewed at another journal that is not operating a transparent peer review scheme. This document only contains reviewer comments, rebuttal and decision letters for versions considered at Nature Human Behaviour.

Reviewer Comments & Decisions:

Decision Letter, initial version:
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16th March 2021

Dear Dr Inomata,

Thank you once again for your manuscript, entitled "Origins and spread of formal ceremonial complexes in the Olmec and Maya regions revealed by airborne lidar," and for your patience during the peer review process. I apologise again for our delay in reaching a decision on your work.

Your manuscript has now been evaluated by 3 reviewers, whose comments are included at the end of this letter. Reviewers 1 and 2 also evaluated previous versions of this manuscript, while Reviewer 3 is new to this round of review. Although the reviewers find your work to be of interest, they also raise some important concerns. We are very interested in the possibility of publishing your study in Nature Human Behaviour, but would like to consider your response to these concerns in the form of a revised manuscript before we make a decision on publication.

In particular, Reviewer 2 highlights significant concerns regarding the reliability of your dating and therefore the strength of your models. We consulted with Reviewer 3 regarding these comments (please find their comments pasted verbatim below), and we agree with their recommendation: to address these concerns, we ask that you please remove these five assays and rerun your modelling.

Finally, your revised manuscript must comply fully with our editorial policies and formatting requirements. Failure to do so will result in your manuscript being returned to you, which will delay its

consideration. To assist you in this process, I have attached a checklist that lists all of our requirements. If you have any questions about any of our policies or formatting, please don't hesitate to contact me.

In sum, we invite you to revise your manuscript taking into account all reviewer and editor comments. We are committed to providing a fair and constructive peer-review process. Do not hesitate to contact us if there are specific requests from the reviewers that you believe are technically impossible or unlikely to yield a meaningful outcome.

We hope to receive your revised manuscript within four to eight weeks. We understand that the COVID-19 pandemic is causing significant disruption for many of our authors and reviewers. If you cannot send your revised manuscript within this time, please let us know - we will be happy to extend the submission date to enable you to complete your work on the revision.

With your revision, please:

- Include a "Response to the editors and reviewers" document detailing, point-by-point, how you addressed each editor and referee comment. If no action was taken to address a point, you must provide a compelling argument. This response will be used by the editors to evaluate your revision and sent back to the reviewers along with the revised manuscript.
- Highlight all changes made to your manuscript or provide us with a version that tracks changes.

Please use the link below to submit your revised manuscript and related files:

[REDACTED]

Note: This URL links to your confidential home page and associated information about manuscripts you may have submitted, or that you are reviewing for us. If you wish to forward this email to co-authors, please delete the link to your homepage.

We look forward to seeing the revised manuscript and thank you for the opportunity to review your work. Please do not hesitate to contact me if you have any questions or would like to discuss these revisions further.

Sincerely,

Charlotte Payne
Editor
Nature Human Behaviour

REVIEWER COMMENTS:

Reviewer #1:

Remarks to the Author:

I have reviewed this manuscript for a third time, in light of the second set of responses from the authors. I see they have labelled their outlying data using an extra column in Supplementary Table 8. This is sufficient for the purposes at hand. Overall, I believe the authors have done their best to ensure the radiocarbon side of this study is both reliable and thorough, as well as being transparent and reproducible.

Reviewer #2:

Remarks to the Author:

As with my previous review, I have not evaluated their work on the emergence of Mesoamerican civilization and have concentrated on the radiocarbon data and methods. Although the authors have addressed my previous remarks, which were largely designed to assist with their modeling approach, they failed to take on board that low carbon dates do not date anything related to the event. The high proportion of dates with low %C (36%) in the 2020 analysis, combined with inbuilt age in the charcoal and storage age, means the 5 dated sites are extremely poorly dated.

Consequently, comparison of charcoal outlier models with general outlier models will result in bad models because the data is poor. Comparison between the model results doesn't help in this instance. They have attempted to use the span command to constrain the dates assuming a short time span. This prior information is arbitrary and needs additional support from the archaeological evidence to use effectively. More high quality dates and more thought about potential prior constraints are required.

Reviewer #3:

Remarks to the Author:

For efficiency of organization, the review below employs the heading used by NHB editor in their letter requesting this review. My response to each category appears under a heading that follow this magazine's terms. After this, I provide what I would consider a normal review of archaeological article. Because the editor asked, no part of this manuscript is outside the scope of my expertise.

Key results

Inomata and colleagues process 84,516 sq km of publically available lidar data from Mexico's Gulf Coast to document 463 ancient architectural complexes. Then, based on archaeological excavation of a subset of these sites, date different architectural patterns to different time periods. The most interesting result of this paper is the definition of the "horizontal monumentality" of architectural patterns at San Lorenzo and contemporary Early Formative period sites on Mexico's Gulf Coast. Also significant is the relationship of this early site planning to subsequent Middle Formative period site planning that then was adopted on the Gulf Coast and beyond.

Validity

There are no flaws that prohibit publication of this manuscript, but a number of suggested changes are detailed below.

Originality and significance

In the terms NHB has asked for an evaluation, the submitted paper provides an “evidence-based advance” that will be of interest to all Mesoamerican archaeologists interested in the origins of complex societies as well as anthropological archaeologists working in other areas of the world who study the origins of civilisations comparatively.

Data & Methods

The methodology of processing lidar data outlined in the paper, supplementary materials and discussed in the response to the last set of reviewers demonstrate that the best was made of these admittedly imperfect data. The lidar results are reliable and weaknesses explicitly acknowledged. Inferences made based on these data are reliable: these are ancient architectural features and the different architectural arrangements very likely dated to the time periods as suggested by the authors.

Methodological issues of radiocarbon dating and interpretations are also solid and clearly meets the standards for this dating method is employed by archaeologists.

Preregistration

This category is an issue irrelevant to archaeology or other social sciences.

Appropriate use of statistics and treatment of uncertainties

Yes, both lidar data processing and radiocarbon dating methodologies and associated statistical checks and interpretation demonstrate that appropriate standards have been followed.

Custom code

Irrelevant so not addressed.

Conclusions

Yes, conclusions are reasonable but I provide some suggestions below.

Suggested improvements

I have no suggestion for additional analyses, experiments of data to strengthen this paper. Instead, I have numerous suggestions to improve the interpretation of these data that I detail below.

References

Yes, appropriate literature has been cited.

Clarity and context

Abstract, introduction and conclusions are clear for the most part. There is, however, a problem with the mixed use of the terms “Formative” and “Preclassic” that introduce confusion for the uninitiated and carry an implicit interpretation.

Further, the introductory paragraph is a bit odd as the first half focuses on architectural plans of Middle Formative period sites and the second half of the paragraph focuses specifically on the Early Formative site of San Lorenzo. The two issues are linked but a better indication of the main purpose of the paper could be more clearly laid out in this paragraph.

My Review

With those formalities dispensed with, here is my assessment of the manuscript. This manuscript was extensively evaluated for Nature magazine by five reviewers who focused largely on methodological issues. Inomata and colleagues responses to these issues, has resulted in a methodologically sound article. The authors are to be commended for their diligence and explicitness in grappling with the problems of using relatively low-quality lidar data that is publically available through Mexico's INEGI. Access to such large quantities of low quality but extensive data is also the primary strength of the results presented in this paper. Processing 84,516 sq km of lidar data is a major undertaking and definition of 463 ancient architectural complexes a significant accomplishment. I recommend that the article be published once the following issues are dealt with.

First, for a generalist science magazine such as NHB, the mixing of terms "Formative" and "Preclassic" that both refer to the same time period is needlessly confusing. The former is used in reference to the Middle Formative Chiapas (MFC) pattern, the Middle Formative Gulf (MFG) pattern and the various other patterns of architectural organization. However, these authors then use the term "Preclassic" when refereeing to the very same time periods of occupations at what they consider to be Maya sites. The terms are seen as synonymous by Maya archaeologists who use them interchangeably. In reality, "Preclassic" is only used by Maya archaeologists who generally also assume there to have been long-lasting ethnic and linguistic continuity between contemporary peoples speaking Maya languages and the supposed ancestors extending deep into prehistory. The term "Formative" is used by just about all other archaeologists in all other areas of Mesoamerica. Therefore, the term "Preclassic" implicitly signifies Maya peoples in the distant past. So, the mixing of the two terms in this paper is confusing for the generalist audience and also carries an implicit ethnic signifier for the expert audience. Both shortcoming could be easily solved by only using the term Formative throughout the manuscript.

The second issues, related to the first, is one of implicit "paleo-ethnicity" in the discussion of an Olmec area and a Maya area next to each other on the Gulf Coast of Mexico. For example, on lines 121-122 they say that the 463 site were: "distributed across the entire study area, including the western Maya lowlands and the Olmec region." There is no geographic reason to make this distinction and the data these authors present also indicate that in terms of architectural conventions (which can reasonably be tied to identity) there is also no reason to divide the area during the Formative period. This distinction is reiterated on lines 169-170: "This pattern suggests that the inhabitants of the Gulf Olmec region and the western Maya lowlands maintained close interaction during the Middle Preclassic period." Why assume interaction between two regions rather than within one region? The implicit assumption is that it is between two ethnic/linguistic groups. Other examples of this are found on lines 124-132, lines 148-149 and lines 385-386. Each of these instances should be rephrased to avoid the implicit ethnic divide. In the final line of their response to the previous Reviewer #5, the authors assert that they "do not call Aguada Fenix and nearby Preclassic sites ethnically or linguistically Maya." A statement such as this should be included in the main text of this article to make the authors position clear. However, beyond a statement to this effect, and as suggested above, dispensing with the term "Preclassic" is a more effective way to avoid implicit ethnic attributions in the distant past.

Another related point, on lines 368-370 the authors claim that "ceramics of 1200 to 750 BC in the Middle Usumacinta region closely resemble those of the central and southwestern Maya lowlands and lack characteristic vessels of the Olmec region." This claim is followed by a citation to their own 2020 paper in Nature. In that paper, they make the same assertion but provide no evidence beyond their impression from looking at the ceramic sherds. This is the author's most explicit claim for paleo-ethnic attribution of Olmec and Maya peoples based on different sets of shared characteristics of clay pots.

There is a long-standing critique among archaeologists of the problems with assuming that different styles of pottery are indicators of different ethnic/linguistic groups of past peoples and the authors should avoid it here.

Other points

On lines 163-166 the authors equate residential mounds with residences. However, there could be many residences that did not form mounds which make the statement invalid. It could be true but lidar data are not able to rule out the existence of residences. With these extensive low-resolution lidar data, it would be best to stay away from speculation about the residential mobility of peoples in the area. This point is also irrelevant to the larger arguments made in the paper. Same comment for similar claim on line 371. Both assertions can be removed without altering the important findings presented in this paper.

Line 407-408: The publication of a site map from a site where the authors do not work raises ethical issues that archaeologist will need to grapple with. The authors generated a new map of San Lorenzo and say they have asked Ann Cyphers to collaborate and were rebuffed. They have therefore continued on to reinterpret the layout of the site that Dr. Cyphers has spent the greater part of her professional life labouring at. She is likely annoyed by this intrusion and this is not unreasonable. On the other hand, Inomata et al. are employing publically available data that they have every right to access and use. Such uses are precisely why INEGI have made the data publically available. There are currently no professional standards or consensus on this issue. To be clear, I am NOT claiming that Inomata et al. have done anything wrong in publishing these publically available data but that Dr. Cyphers apparent annoyance is likewise not unreasonable.

Reviewer #3's response to the concerns of Reviewer #2:

The concerns of reviewer 2 do not change my assessment. Ultimately, if Inomata et al were to remove the five dates in question nothing would change in terms of the contribution of the paper. In fact, I would deem this a valuable contribution even if no C14 dating was included! As reviewer 2 notes, the quality of the dates has a bigger impact on the 2020 article that has already been published in Nature (but its too late now). I would suggest that Inomata et al be asked to remove the 5 assays in question and rerun their modeling.

Author Rebuttal to Initial comments

Response to the reviewers

We thank the reviewers for taking the time to give us thoughtful comments.

In addition to the revisions discussed below, we change the number of formal complexes to the Formative period from 463 to 478. The count of 463 in the previous manuscript represented rectangular and square complexes, such as MFUs and VCs, but we decided that it is better to include MFC and MFG complexes as well and present an overall count of all formal complexes.

Reviewer 1 (radiocarbon dating)

The reviewer noted:

I have reviewed this manuscript for a third time, in light of the second set of responses from the authors. I see they have labelled their outlying data using an extra column in Supplementary Table 8. This is sufficient for the purposes at hand. Overall, I believe the authors have done their best to ensure the radiocarbon side of this study is both reliable and thorough, as well as being transparent and reproducible.

Thank you for the positive review.

Reviewer 2 (radiocarbon dating)

The reviewer commented:

As with my previous review, I have not evaluated their work on the emergence of Mesoamerican civilization and have concentrated on the radiocarbon data and methods. Although the authors have addressed my previous remarks, which were largely designed to assist with their modeling approach, they failed to take on board that low carbon dates do not date anything related to the event. The high proportion of dates with low %C (36%) in the 2020 analysis, combined with inbuilt age in the charcoal and storage age, means the 5 dated sites are extremely poorly dated. Consequently, comparison of charcoal outlier models with general outlier models will result in bad models because the data is poor. Comparison between the model results doesn't help in this instance. They have attempted to use the span command to constrain the dates assuming a short time span. This prior information is arbitrary and needs additional support from the archaeological evidence to use effectively. More high quality dates and more thought about potential prior constraints are required.

We appreciate the reviewer's continuing assessment of our manuscript. However, we respectfully disagree with the reviewer's comment on the low carbon content samples. We think that the low carbon content resulted, in most cases, from the mixing of soil minerals with the anthropogenic charcoal that we target. In addition, the humic acid, which the reviewer mentioned in the previous comment, should have been mostly removed with the base pretreatment of the samples.

Dr. Gregory Hodgins, the director of the University of Arizona AMS laboratory that analyzed those samples, has agreed to join us as a coauthor. The following discussions are based on our examination of the samples in the field and the AMS lab.

2.1. Humic acid

In the earlier review, the referee stated that "Values below this must be treated with caution as it could be from a wide variety of sources, including highly mobile humic acids." However, all 2020 samples went

through the ABA pretreatment. Humic acids should have been removed during the base pretreatment. Minuscule amounts of ^{14}C rich humic acids that remain after base pretreatment can be a problem for extremely old samples, like those from Neanderthal sites discussed in Higham et al. (2012), which the referee cited in the previous review. Nonetheless, the large effects of trace contaminants on radiocarbon dates near the limit of detection is a very different circumstance than dating organic remains that range in age from approximately 1200 BC to AD 900. The effect of residual humic acids remaining after ABA treatment in this situation would be negligible.

2.2. Cause of low carbon content

We think that the samples in question, AA-114514, AA-114516, AA-114517, and AA-114537, contain charcoal but are mixed with soil minerals. This mixture results in anomalously low weight percent carbon for these samples. We disagree with the reviewer's assessment that those samples "do not date anything related to the event." The carbon content within those samples can date the event of interest if it is derived from traces of anthropogenic charcoal. The presence of inorganic particles within the sample obscures the identity of the carbon source, and this decreases confidence in the measurement, but it doesn't necessarily invalidate it. The solution is to corroborate the result through other measurements.

Because of the tropical environment, the charcoal samples from our sites are often in poor preservation conditions. This is because of the high temperature, active biological processes, and the cycle of wet and dry conditions during the rainy and dry seasons. In addition, many samples from the 2020 season were taken from artificial construction fills, which tend to degrade charcoal more severely. Many samples from the 2019 season were taken from middens and other better contexts, and the charcoal pieces were generally in better conditions.

Many of the poorly preserved charcoal pieces easily fall apart and become powdery charcoal fragments. When they are mixed with sand and other fine particles, it is difficult to separate them. In the field, excavators collected what they interpreted as charcoal pieces, and at the Arizona AMS lab, lab technicians treated them as charcoal. However, during treatment it became clear that inorganic particles were components in some samples and co-purified with charcoal particles during the ABA treatments. This is a commonly encountered scenario. The contaminants are often visible to the naked eye, and in such cases the mass of material to be combusted is increased to account for the likelihood of smaller carbon yields.

In Supplementary Table 8, we added the combusted sample mass for the 2020 samples. Those with combusted sample masses larger than 10 mg (AA-114515, AA-114521, AA-114528, AA-114532, and AA-114540) contained substantial amounts of inorganic particulates after the ABA treatment. The inclusion of soil particles was less clear but suspected in samples with combusted sample masses under 10 mg, but for some samples (AA114516, AA114517, and AA114537).

2.3. Effects of low carbon content

The analysis conducted by Timothy Beach at his University of Texas Austin soil lab shows that yellow-coloured soils used in construction fills at Aguada Fénix usually contain 0.6% or less organic carbon, to which humin may contribute roughly 30 % (Tonneijck et al. 2006). The rest of the organic carbon consists of humic and fulvic acids, which should be mostly removed by the ABA treatment. The mineral components that remain after the ABA treatment are inorganic and inert, and do not affect radiocarbon dates.

In the previous manuscript, we accepted 4 samples with low carbon content (AA-114514, AA-114516, AA-114517, and AA-114537) as potentially valid dates. We suspected that the quantities of exogenous humins included in these samples were small, and the effect of soil carbon is relatively limited. For example, we can draw a hypothetical estimate of soil contamination on AA-114514 (combusted mass = 4.75 mg, carbon content = 16.3 %, carbon mass = 0.77 mg), assuming that the sample contained anthropogenic charcoal with a carbon content of 50 %, its mixed soil contained 0.5% organic carbon, to which humin contributed 30 % (0.15 % of the total soil mass), and the 50 % of the original soil mass, including mineral components, were dissolved and removed in the ABA treatment (the carbon content in the soil elements that remained after the ABA treatment was 0.3 %):

$$M_c + M_s = 0.77$$

$$M_c/0.5 + M_s/0.003 = 4.75$$

$$M_c = 0.760 \text{ mg (98.7 \%)}, M_s = 0.010 \text{ mg (1.3 \%)}$$

Where M_c = carbon mass derived from charcoal after ABA treatment

M_s = carbon mass derived from soil after ABA treatment

The radiocarbon measurement of AA-114514 was 2514 ± 26 bp (95.4% calibrated date 780-540 BC). For different hypothetical radiocarbon dates for the exogenous humins in the mixed soil, we can estimate the radiocarbon date of the anthropogenic charcoal (Caughley 1988; Gupta and Polach 1985):

Hypothetical radiocarbon date of exogenous humin (bp)	Estimated radiocarbon date of anthropogenic charcoal (bp)	Estimated calibrated date of charcoal with a standard deviation of 26 (95.4%)
2000	2520	790-540 BC
3000	2510	780-540 BC
5000	2490	775-515 BC
10000	2450	755-410 BC

These estimated radiocarbon dates of the anthropogenic charcoal within the sample largely overlap with the measured radiocarbon date of the sample, which suggests that the effect of soil contamination on this radiocarbon date is fairly small. We should also note that some humins possibly result from the

degrading charcoal (Cohen-Ofri et al. 2006). These humins originated from charcoal should not affect the radiocarbon date of the sample.

Of course, we do not know the real exogenous humin content in the mixed soils and the dates of the humin of the individual samples. However, these hypothetical estimates suggest that the possible effects of soil contamination may be in similar ranges as other factors of uncertainty that apply to any radiocarbon samples, including counting errors, old wood, stratigraphic mixing and other potential contaminations. Thus, the best approach to those samples should be to evaluate them in terms of stratigraphy and associated ceramics rather than throw them away outright.

In this regard, AA-114516, AA-1145117, and AA-1145119, found in the same stratigraphic context, showed different carbon content (9.7 %, 1.5 %, and 60.9 %, respectively) but yielded very similar radiocarbon dates. These results suggest that soil particles mixed in those samples were mostly inorganic and did not affect the radiocarbon dates significantly. Those radiocarbon dates likely derived mostly from the anthropogenic charcoal contained in the sample.



2.4. Evaluation of samples with low carbon content

Higham et al (2012), cited by the reviewer in the previous comment, take a similar approach. They discuss samples with low carbon content (OxA-7857, OxA-7979, and OxA-10295) and note that those samples “ought to be viewed with caution” rather than rejecting them outright. They included those samples in the Bayesian model and rejected one (OxA-7979) as an outlier because it is out of sequence. They accepted the other two (OxA-7857 and OxA-10295) as consistent with the stratigraphic sequence and associated lithic artifacts.

Reasoning along similar lines, we evaluate samples with low carbon content by comparing them with the stratigraphic sequence and the dates of associated ceramics. We reject six samples with low carbon content as outliers as they diverge from their stratigraphic positions and associated ceramics (AA-114515, AA-114520, AA-114521, AA-114528, AA-114532, and AA-114540). The remaining four samples with low carbon content (AA-114514, AA-114516, AA-114517, and AA-114537) are consistent with their contexts. We think that the effects of soil organic matters on those samples are small to minimal, and we tentatively accept those dates. At the same time, we acknowledge that those samples are less than ideal, and we caution that these results need to be evaluated with more data in the future.

2.5. Samples with low graphite mass

Another issue that we considered is the low graphite mass of some samples. The measurement effects of small graphite samples have been well documented (Brown and Southon 1997; Cherkinsky et al. 2013; Donahue et al. 1990). These studies show that graphite masses lower than 0.2 mg begin to show size-dependent deviations in their radiocarbon content. The effects depend upon the ^{14}C content of the sample, the ^{14}C content of the laboratory contamination, and also on the relative size of the sample and the standards during measurement. The deviations become increasingly significant as graphite size decreases, but between 0.2 and 0.1 mg their effects are similar in size to the counting statistics uncertainties.

Two small graphite samples are presented in Supplementary Table 8: AA114517 (0.13 mg) and AA114520 (0.18 mg). These were interpreted differently. AA114520 generated the most recent radiocarbon date of the entire suite, and its radiocarbon content differed from AA114519, an associated sample, by 18 standard deviations. Its outlier status is clear. On the other hand, AA114517 had a ^{14}C content within one standard deviation of both AA114516, and AA114514. As we previously said, this suggests that it is reasonable to at least tentatively accept it until it is tested by future measurements.

2.6. Outlier model

We originally used a Charcoal outlier model for the following reasons. First, as we discussed in our previous reply to reviewers, the inclusions of repositied charcoal pieces in construction fills are common in our study. Second, when charcoal is mixed with soils, we expect that the resulting dates tend to be older than the deposition dates because the dates of humin, if present, tend to be older (Martin and Johnson 1995; Pessenda et al. 2001).

After receiving the reviewer's previous comments, we decided to use a General outlier model for samples with low carbon content, while using a Charcoal outlier model for samples with high carbon content. For the reason discussed above, it is unlikely that there is a significant amount of humic acid after the ABA treatment, and we still think that humins tends to give older dates than the deposition dates. However, there can be cases in which younger insoluble organic matters are mixed through biological activities of roots and other organisms after the deposition of soils (Tonneijck et al. 2006). In addition, as discussed above, samples with small graphite mass may have errors that make the dates younger.

2.7. Context of radiocarbon dating

We fully acknowledge that our 2020 collection of radiocarbon samples is less than ideal, and those dates need to be further examined in future studies. At the same time, we would like to argue that these results still fulfill the purpose of our current study within the context of our study area. This study covers an extensive area of 85,000 km². Our radiocarbon dating represents the first step toward establishing a chronology for thousands of sites discovered in this study. Our strategy for the 2020 collection was to

give an initial chronological assessment of multiple sites through small excavations instead of building a detailed chronology of a single site through the intensive excavation of one location.

As discussed above, some challenges in radiocarbon dating derive from the specific conditions of this study area, including the tropical environment and the common practice of rebuilding in the same locations. As our 2020 excavations consisted mostly of small test excavations at multiple locations, good contexts for charcoal sample collection, such as middens, were rare. We collected most samples from construction fills. Thus, the high ratio of outliers and the poor preservation quality of charcoal were expected.

Given this scope of the 2020 operations, radiocarbon dating is a small part of this article. Thus, it is only included in Supplementary Information. However, for the development of a better chronology in the future, it is important to report these data and to evaluate those dates as best we can.

At the same time, the interpretation of the 2020 samples is strengthened through the comparison with our previous results and earlier studies by other scholars through ceramic dating. Our 2019 samples published in our previous article came from more intensive excavations at a single site (Aguada Fénix). There we could choose samples from better contexts, such as middens, caches, canals, etc. Thus, the ratio of outliers was lower, and the qualities of charcoal samples were better. We could build a more robust chronology for this site. We should emphasize ceramic cross-dating is a critical process in tying these results from various sites. The known dates of associated ceramics provide important bases for identifying outliers.

References

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Reviewer 3 (archaeology)

We thank the reviewer for the supportive review.

The reviewer provided the following general comments.

Remarks to the Author:

For efficiency of organization, the review below employs the heading used by NHB editor in their letter requesting this review. My response to each category appears under a heading that follow this

magazine's terms. After this, I provide what I would consider a normal review of archaeological article. Because the editor asked, no part of this manuscript is outside the scope of my expertise.

Key results

Inomata and colleagues process 84,516 sq km of publically available lidar data from Mexico's Gulf Coast to document 463 ancient architectural complexes. Then, based on archaeological excavation of a subset of these sites, date different architectural patterns to different time periods. The most interesting result of this paper is the definition of the "horizontal monumentality" of architectural patterns at San Lorenzo and contemporary Early Formative period sites on Mexico's Gulf Coast. Also significant is the relationship of this early site planning to subsequent Middle Formative period site planning that then was adopted on the Gulf Coast and beyond.

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Data & Methods

The methodology of processing lidar data outlined in the paper, supplementary materials and discussed in the response to the last set of reviewers demonstrate that the best was made of these admittedly imperfect data. The lidar results are reliable and weaknesses explicitly acknowledged. Inferences made based on these data are reliable: these are ancient architectural features and the different architectural arrangements very likely dated to the time periods as suggested by the authors. Methodological issues of radiocarbon dating and interpretations are also solid and clearly meets the standards for this dating method is employed by archaeologists.

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Appropriateness of statistics and treatment of uncertainties

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Custom code

Irrelevant so not addressed.

Conclusions

Yes, conclusions are reasonable but I provide some suggestions below.

Suggested improvements

I have no suggestion for additional analyses, experiments of data to strengthen this paper. Instead, I have numerous suggestions to improve the interpretation of these data that I detail below.

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3.1. Introduction

The reviewer stated that:

Further, the introductory paragraph is a bit odd as the first half focuses on architectural plans of Middle Formative period sites and the second half of the paragraph focuses specifically on the Early Formative site of San Lorenzo. The two issues are linked but a better indication of the main purpose of the paper could be more clearly laid out in this paragraph.

Thank you for the suggestion. The earlier manuscript followed the structure of Nature, in which the first paragraph serves both as an abstract and an introductory paragraph. We revised the introductory paragraphs so that they give a standalone introduction to our study.

3.2. Formative

The reviewer suggested that:

My Review

With those formalities dispensed with, here is my assessment of the manuscript. This manuscript was extensively evaluated for Nature magazine by five reviewers who focused largely on methodological issues. Inomata and colleagues responses to these issues, has resulted in a methodologically sound article. The authors are to be commended for their diligence and explicitness in grappling with the problems of using relatively low-quality lidar data that is publically available through Mexico’s INEGI. Access to such large quantities of low quality but extensive data is also the primary strength of the results presented in this paper. Processing 84,516 sq km of lidar data is a major undertaking and

definition of 463 ancient architectural complexes a significant accomplishment. I recommend that the article be published once the following issues are dealt with.

First, for a generalist science magazine such as NHB, the mixing of terms “Formative” and “Preclassic” that both refer to the same time period is needlessly confusing. The former is used in reference to the Middle Formative Chiapas (MFC) pattern, the Middle Formative Gulf (MFG) pattern and the various other patterns of architectural organization. However, these authors then use the term “Preclassic” when refereeing to the very same time periods of occupations at what they consider to be Maya sites. The terms are seen as synonymous by Maya archaeologists who use them interchangeably. In reality, Preclassic is only used by Maya archaeologists who generally also assume there to have been long-stating ethnic and linguistic continuity between contemporary peoples speaking Maya languages and the supposed ancestors extending deep into prehistory. The term “Formative” is used by just about all other archaeologists in all other areas of Mesoamerica. Therefore, the term “Preclassic” implicitly signifies Maya peoples in the distant past. So, the mixing of the two terms in this paper is confusing for the generalist audience and also carries an implicit ethnic signifier for the expert audience. Both shortcoming could be easily solved by only using the term Formative throughout the manuscript.

Following the reviewer’s suggestion, we changed all instances of Preclassic to Formative.

3.3. Ethnicity

Regarding the issue of ethnicity, the reviewer commented:

The second issues, related to the first, is one of implicit “paleo-ethnicity” in the discussion of an Olmec area and a Maya area next to each other on the Gulf Coast of Mexico. For example, on lines 121-122 they say that the 463 site were: “distributed across the entire study area, including the western Maya lowlands and the Olmec region.” There is no geographic reason to make this distinction and the data these authors present also indicate that in terms of architectural conventions (which can reasonably be tied to identity) there is also no reason to divide the area during the Formative period. This distinction is reiterated on lines 169-170: “This pattern suggests that the inhabitants of the Gulf Olmec region and the western Maya lowlands maintained close interaction during the Middle Preclassic period.” Why assume interaction between two regions rather than within one region? The implicit assumption is that it is between two ethnic/linguistic groups. Other examples of this are found on lines 124-132, lines 148-149 and lines 385-386. Each of these instances should be rephrased to avoid the implicit ethnic divide. In the final line of their response to the previous Reviewer #5, the authors assert that they “do not call Aguada Fenix and nearby Preclassic sites ethnically or linguistically Maya.” A statement such as this should be included in the main text of this article to make the authors position clear. However, beyond a statement to this effect, and as suggested above, dispensing with the term “Preclassic” is a more effective way to avoid implicit ethnic attributions in the distant past.

Another related point, on lines 368-370 the authors claim that “ceramics of 1200 to 750 BC in the Middle Usumacinta region closely resemble those of the central and southwestern Maya lowlands and lack

characteristic vessels of the Olmec region.” This claim is followed by a citation to their own 2020 paper in Nature. In that paper, they make the same assertion but provide no evidence beyond their impression from looking at the ceramic sherds. This is the author’s most explicit claim for paleo-ethnic attribution of Olmec and Maya peoples based on different sets of shared characteristics of clay pots. There is a long-standing critique among archaeologists of the problems with assuming that different styles of pottery are indicators of different ethnic/linguistic groups of past peoples and the authors should avoid it here.

Following the reviewer’s suggestion, in the discussion section we added the explicit statement that by referring to the similarity in ceramics we are not suggesting that the inhabitants of the region are Mayan language speakers.

However, we decided to keep the use of the Olmec region and the Maya lowlands. Those are common terms used both by scholars and the general audience, and we think that these terms help the understanding by readers, particularly those who are not familiar with this area. In the introduction, we added the statement that we use these terms to refer to geographic regions and we do not imply the ethnic or linguistic identities of the inhabitants. In particular, the Maya lowlands are commonly used as a geographic name. The term Olmec is, as the reviewer is well aware of, a loose term that conflates cultural identities, material styles, and a geographic region. Unlike the cases of the Classic and Postclassic Maya, the linguistic identity of the Olmec is still debated

As to the reviewer’s comment “in terms of architectural conventions (which can reasonably be tied to identity) Why assume interaction between two regions rather than within one region?,” we think that architecture styles, particularly those of ceremonial buildings, can be easily adopted by different cultural or linguistic groups as seen in the spread of various religious and administrative building styles in diverse time periods around the world. We do not think that there are any better data to suggest that our study area represents a single cultural region than two regions. In terms of ceramics and obsidian, which are more closely tied to the daily life of people, we see at least two spheres of cultural preference and economic exchange. Again, we do not assume that such spheres necessarily correspond with linguistic identities. But the distributions of those objects tied to daily life are still meaningful. This paper is not a place to present extensive ceramic data, but we plan to discuss these issues and present ceramic data in future publications.

3.4. Residential structures

The reviewer stated that:

Other points On lines 163-166 the authors equate residential mounds with residences. However, there could be many residences that did not form mounds which make the statement invalid. It could be true but lidar data are not able to rule out the existence of residences. With these extensive low-resolution lidar data, it would be best to stay away from speculation about the residential mobility of peoples in the area. This point is also irrelevant to the larger arguments made in the paper. Same comment for similar

claim on line 371. Both assertions can be removed without altering the important findings presented in this paper.

Following the reviewer's suggestion, we rephrased the first instance to specify that lidar does not show substantial buildings with basal platforms. For the second instance, however, we decided to keep our original discussion. The absence of substantial residential structures around some MFU complexes is not only based on low-resolution lidar but also confirmed in the MFU sites in the Middle Usumacinta region, such as La Carmelita and Buenavista, where we analyzed high-resolution lidar and conducted ground surveys. The lack of recognizable residential remains on the surface and other topographic modifications outside the ceremonial complexes is striking. Lidar data alone does not prove or disprove the mobility of people, but these patterns are consistent with the lack of durable buildings and probable mobilities suggested at other contemporaneous sites.

We mention this possibility because it presents important theoretical implications and should be a critical focus of future studies for the following reason. First, in the discussion section, we present the possibility that MFU and similar spatial patterns were adopted by diverse groups with significantly different political organization and life styles. On one hand, San Lorenzo presents a large centre with a certain amount of permanent residents. On the other hand, some MFUs may have been vacant centres where mobile groups may have gathered only in certain times of the year. Second, given the increasing evidence of monumental constructions made by hunter-gatherers or mobile horticulturalists around the world, this possibility presents significant anthropological implications beyond Mesoamerica.

3.5. The publication of a site map

The reviewer also notes:

Line 407-408: The publication of a site map from a site where the authors do not work raises ethical issues that archaeologist will need to grapple with. The authors generated a new map of San Lorenzo and say they have asked Ann Cyphers to collaborate and were rebuffed. They have therefore continued on to reinterpret the layout of the site that Dr. Cyphers has spent the greater paper of her professional life labouring at. She is likely annoyed by this intrusion and this is not unreasonable. On the other hand, Inomata et al. are employing publically available data that they have every right to access and use. Such uses are precisely why INEGI have made the data publically available. There are currently no professional standards or consensus on this issue. To be clear, I am NOT claiming that Inomata et al. have done anything wrong in publishing these publically available data but that Dr. Cyphers apparent annoyance is likewise not unreasonable.

We appreciate the reviewer's comment on this point. We tried to follow professional courtesy and contacted Dr. Cyphers after the publication of the earlier Nature article and during the preparation of this manuscript. We have enormous respect for Dr. Cyphers' work, but we also think that other scholars should be able to present interpretations different from hers along with supporting evidence.

3.6. Radiocarbon dates

The reviewer commented on the issue of radiocarbon dates:

Reviewer #3's response to the concerns of Reviewer #2:

The concerns of reviewer 2 do not change my assessment. Ultimately, if Inomata et al were to remove the five dates in question nothing would change in terms of the contribution of the paper. In fact, I would deem this a valuable contribution even if no C14 dating was included! As reviewer 2 notes, the quality of the dates has a bigger impact on the 2020 article that has already been published in Nature (but its too late now). I would suggest that Inomata et al be asked to remove the 5 assays in question and rerun their modeling.

We thank the reviewer for the supportive comment. We agree with the reviewer's suggestion that radiocarbon dates are a rather small part of this paper, and the removal of those dates does not affect our main argument. At the same time, we think that it is important to express our position regarding these data. Please see the response to Reviewer 2.

The reviewer also mentioned the 2019 data published in the 2020 article. We would like to note that the 2019 data set had 6 samples with low carbon contents, but they all had anomalous dates and were excluded from the models. Whereas the 2020 samples mostly came from construction fills found in small test pits, the 2019 data set contained a substantial number of samples from better contexts, such as middens, on floor, caches, or canals. In addition, more than half of the 2019 samples were examined by a paleobotanist before radiocarbon dating. (We could not send the 2020 samples to the paleobotanist's lab in Japan because of the pandemic). We are confident that the models for the 2019 samples are robust.

Decision Letter, first revision:

Our ref: NATHUMBEHAV-210114082B

25th May 2021

Dear Dr. Inomata,

Thank you for submitting your revised manuscript "Origins and spread of formal ceremonial complexes in the Olmec and Maya regions revealed by airborne lidar" (NATHUMBEHAV-210114082B). It has now been seen by the referee from the previous round and their comments are below. As you can see, they find that the paper has improved in revision. We will therefore be happy in principle to publish it in Nature Human Behaviour, pending minor revisions to comply with our editorial and formatting guidelines.

We are now performing detailed checks on your paper and will send you a checklist detailing our editorial and formatting requirements in about a week. Please do not upload the final materials and make any revisions until you receive this additional information from us.

Please do not hesitate to contact me if you have any questions.

Sincerely,

Charlotte Payne
Editor
Nature Human Behaviour

Reviewer #3 (Remarks to the Author):

This is the second time I have been sent this paper to review and the third time it has been reviewed by NHB. The authors have made many of the changes I suggested last time around and the paper is stronger for it. There are two remaining points of disagreement but that is fine and the field would be a lot less fun if we all agreed on everything. There positions are clear and explicit and, while different than mine, they are not unreasonable.

I do not undertake radiometric dating myself however, as with most archaeologists, I use the resulting data regularly and am well aware of the strengths and weaknesses of this technique. As I stated previously, the paper is a valuable contribution even if all of the dates are removed. The supplemental materials now contain an extremely detailed discussion of these data making all weaknesses explicit for anyone who wishes to evaluate them.

The data presented by Inomata and colleagues, and the patterns that result from their analyses, are important and significant and I unhesitatingly recommend that they be published.

Robert Rosenswig

Decision letter, final requests:

** Please ensure you delete the link to your author homepage in this e-mail if you wish to forward it to your co-authors. **

Our ref: NATHUMBEHAV-210114082B

11th June 2021

Dear Dr. Inomata,

Thank you for your patience as we've prepared the guidelines for final submission of your Nature Human Behaviour manuscript, "Origins and spread of formal ceremonial complexes in the Olmec and Maya regions revealed by airborne lidar" (NATHUMBEHAV-210114082B). Please carefully follow the step-by-step instructions provided in the attached file, and add a response in each row of the table to indicate the changes that you have made. Please also check and comment on any additional marked-up edits we have proposed within the text. Ensuring that each point is addressed will help to ensure

that your revised manuscript can be swiftly handed over to our production team.

We would like to start working on your revised paper, with all of the requested files and forms, as soon as possible (preferably within two weeks). Please get in contact with us if you anticipate delays.

When you upload your final materials, please include a point-by-point response to any remaining reviewer comments.

If you have not done so already, please alert us to any related manuscripts from your group that are under consideration or in press at other journals, or are being written up for submission to other journals (see: <https://www.nature.com/nature-research/editorial-policies/plagiarism#policy-on-duplicate-publication> for details).

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In recognition of the time and expertise our reviewers provide to Nature Human Behaviour's editorial process, we would like to formally acknowledge their contribution to the external peer review of your manuscript entitled "Origins and spread of formal ceremonial complexes in the Olmec and Maya regions revealed by airborne lidar". For those reviewers who give their assent, we will be publishing their names alongside the published article.

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If you have any further questions, please feel free to contact me.

Best regards,
Adam Battishill
Editorial Assistant
Nature Human Behaviour

On behalf of

Charlotte Payne

Charlotte Payne, PhD
Editor
Nature Human Behaviour

Reviewer #3:

Remarks to the Author:

This is the second time I have been sent this paper to review and the third time it has been reviewed by NHB. The authors have made many of the changes I suggested last time around and the paper is stronger for it. There are two remaining points of disagreement but that is fine and the field would be a lot less fun if we all agreed on everything. There positions are clear and explicit and, while different than mine, they are not unreasonable.

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The data presented by Inomata and colleagues, and the patterns that result from their analyses, are important and significant and I unhesitatingly recommend that they be published.

Robert Rosenswig

Author Rebuttal, first revision:

Response to Reviewers

Reviewer #3:

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The data presented by Inomata and colleagues, and the patterns that result from their analyses, are important and significant and I unhesitatingly recommend that they be published.

Robert Rosenswig

Response

Thank you for the positive comments. We look forward to continuing discussions on our different opinions.

Final Decision Letter:

Dear Dr Inomata,

We are pleased to inform you that your Article "Origins and spread of formal ceremonial complexes in the Olmec and Maya regions revealed by airborne lidar", has now been accepted for publication in Nature Human Behaviour.

Please note that *Nature Human Behaviour* is a Transformative Journal (TJ). Authors whose manuscript was submitted on or after January 1st, 2021, may publish their research with us through the traditional subscription access route or make their paper immediately open access through payment of an article-processing charge (APC). Authors will not be required to make a final decision about access to their article until it has been accepted. IMPORTANT NOTE: Articles submitted before January 1st, 2021, are not eligible for Open Access publication. [Find out more about Transformative Journals](https://www.springernature.com/gp/open-research/transformative-journals)

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With best regards,

Charlotte Payne

Charlotte Payne, PhD
Senior Editor
Nature Human Behaviour

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