Overview of changes to Drury et al., "Climate, cryosphere and carbon cycle controls on Southeast Atlantic orbital-scale carbonate deposition since the Oligocene (30-0 Ma)"

Dear Luc Beaufort,

We have completed the requested revisions to our manuscript, as outlined in our author comments in response to the two reviewer comments during the interactive discussion.

The revisions included carefully revisiting the manuscript language, and as such there are numerous small revisions to improve the overall clarity of the manuscript. We have summarised the main revisions to the scientific content here. We have also provided a full list of line-by-line insertions and deletions at the end of this document, and a word track changes file.

The original outcome of the manuscript remains largely unchanged, but we have clarified a few methodological reviewer questions, and expanded our discussed to incorporate some insightful suggestions from the reviewers.

Best wishes,
Anna Joy Drury
Submitted on behalf of all co-authors.

Summary of main changes:

1) **Overall manuscript clarity:**
We have thoroughly proofread through the manuscript to correct previous issues with grammar and spelling. We have also made several revisions to improve the overall clarity of the manuscript. Several relevant publications came out since we submitted the original manuscript (Westerhold et al., 2020, Science; De Vleeschouwer et al., 2020, Nature Communications; Tanner et al., 2020, Paleoceanography and Paleoclimatology), and where relevant, we have included these in our discussion.

2) **Carbonate calibration, calibration uncertainty and treatment of outliers:**
We found a small error in our initial calibration, so we have corrected this. This has resulted in a small change to the calibration; however, this only changes our absolute $CaCO_3$ by less than 0.07% and does not affect our interpretations.

Following a helpful suggestion from the reviewer, we also clarified our outlier treatment process and discussed the uncertainty associated with the calibration and the MARs. The calibration uncertainty is ±2.2% at 2σ. This uncertainty only pertains to the absolute %$CaCO_3$ values. The trends and cyclicity we observe in the calibrated $CaCO_3$ data are independent of this uncertainty, as these patterns are present in the raw ln(Ca/Fe) timeseries. Our interpretations are therefore not affected by this uncertainty.

3) **Improved presentation of the age model and cyclicity observed in the $CaCO_3$ data:**
The reviewers raised concerns that they could not see the cyclicity we were referring to. We have now provided better wavelet figures in the main text and the manuscript, which we feel

highlight the cyclicity better. We have also added a new figure (new figure 6), where we highlight examples of the three main cyclicities discussed in the manuscript.

4) **Expanded discussion to consider winnowing and the processes that may drive the cyclicity we observe in our $CaCO_3$ data:**
We have strengthened our discussion to address reviewers' concerns that to our discussion did not sufficiently consider winnowing or the processes that might drive Site 1264 carbonate.

We now introduce sedimentary processes like winnowing and dilution in the introduction and consider the influence that these processes may have at 1264 throughout the discussion. We conclude that dilution is minimal, and that winnowing may have had some effect, but was likely not the main driver of the trends and cycles we see, with the exception of the last 3.3 Ma.

We also have expanded our discussion in several places to discuss which mechanisms may explain the trends and patterns in carbonate deposition that we observe. We especially focus the discussion on the changes in the previously unstudied interval between 17 and 5.3 Ma. Where appropriate, we have also referred to the original publications dealing with the Oligocene-early Miocene (Liebrand et al., 2016, 2017, 2018) and Plio-Pleistocene (Bell et al., 2014, 2015), as there is already very detailed discussion of these time periods there.

5) **Figures:**
We have made all the revisions requested by reviewers concerning the figures, in addition to the following changes:
- We merged Figures 3 and 4, especially improving the presentation of the wavelets.
- We added the K intensity data to new Figure 3 and Figure 5 (previously Figure 6). Both the Si and K are now also described in the results.
- We present a new figure (new Figure 6) to highlight how the three distinctly different cyclicities in carbonate deposition observed at Site 1264
- We have redone all wavelets presented in the main & supplementary figures to use a more colour-blind friendly scheme.
- We have added epoch and stages to Figures 7 and 8
- We have improved the annotations of Figures 3, 5, 7 and 8.
- Made sedimentation rates m/Myr to be consistent with the main text.
- We have added two supplementary figures:
    - one showing all calibrated XRF data now available at Site 1264
    - 4-part oversized figure showing the age-depth ties for the astrochronology in greater detail.

Main document changes and comments

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At Site 1264, the onset of the LMBB roughly coincides with appearance of strong obliquity pacing of %$CaCO_3$ reflecting increased high latitude forcing.

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The evolution of orbital-scale climate and carbon cycle dynamics across this interval remains relatively unscrutinised (Turner, 2014; De Vleeschouwer et al., 2017).

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Understanding past changes in surface water productivity and deep-sea dissolution can inform about past climate development, and vice versa, how global processes affected regional production and deposition of biogenic carbonates.

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Changes in deep-sea currents can alter the composition of the sediment through processes like winnowing or dilution, which respectively remove fine-grained material or increase certain sedimentary components relative to others (e.g., increased dilution with terrigenous material).

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Understanding past changes in carbonate deposition surface water productivity and deep-sea dissolution can inform about past climate development by helping to disentangle , and vice versa, how global processes affected regional production and deposition of biogenic carbonates.

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We investigate how widespread Miocene warmth followed by Antarctic glaciation influenced the pacing and preservation of Southeast Atlantic carbonate deposition. Finally, we establish the relative timing of the late Miocene-early Pliocene Biogenic Bloom (LMBB; acronym from Lyle et al., 2019) in the Southeast Atlantic versus Pacific Oceans and explore what this reveals about the global and regional driving forces of this multi-million-year productivity event.

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The individual core-box/line-scan core images were then combined into a single composite image along the revised Site 1264 splice using the “SpliceImages” function.

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to form a continuous composite core image spanning the early Oligocene to present day

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This resulted in a continuous spliced image of the sedimentary succession at Site 1264-1265 spanning the early Oligocene to present day.

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All data were inspected directly following collection and outliers were removed if they were clearly associated with cracks and/or uneven sediment surface. Following this, the ln(Ca/Fe) data were additionally despiked using the CODD editing functions.

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is within the 2σ uncertainty of the new %$CaCO_3$ calibration, which equates to ±2.2% in the calibrated %$CaCO_3$ dataset.

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The uncertainty in the calibration likely originates from the scatter of the shipboard coulometry-derived %$CaCO_3$ data that were used in the calibration. This uncertainty only pertains to the absolute %$CaCO_3$ values. The trends and cyclicity observed in the calibrated $CaCO_3$ data are independent of this uncertainty, as these patterns are present in the raw ln(Ca/Fe) timeseries.

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Page 5: Inserted Anna Joy Drury 29/05/2021 14:27:00
7

Page 5: Inserted Anna Joy Drury 17/03/2021 15:31:00
The uncertainty in the MARs is difficult to quantify. The largest uncertainties affecting bulk, $CaCO_3$ and detrital MARs arise from uncertainties in the ρ_{dry}, which was calculated using shipboard GRA and discrete dry density data, and the LSR, both of which are difficult to estimate. $CaCO_3$ MARs additionally have ±2.2% 2σ calibration uncertainty. However, as %$CaCO_3$ is so high at Site 1264, the %$CaCO_3$ calibration uncertainty will have a smaller affect compared with the changes in LSR. Because detrital MARs are low and calculated using the difference between bulk and $CaCO_3$ MARs, changes in detrital MARs should be treated cautiously.

Page 6: Deleted Anna Joy Drury 17/03/2021 15:33:00
composite

Page 6: Inserted Anna Joy Drury 17/03/2021 15:33:00
core

Page 6: Inserted Anna Joy Drury 17/03/2021 15:33:00
, leading to duplicated and/or missing intervals in the shipboard

Page 6: Deleted Anna Joy Drury 17/03/2021 15:33:00
and

Page 6: Inserted Anna Joy Drury 17/03/2021 15:34:00
ese misalignments

Page 6: Deleted Anna Joy Drury 17/03/2021 15:34:00
is

Page 6: Inserted Anna Joy Drury 17/03/2021 15:34:00
are

Page 6: Deleted Anna Joy Drury 17/03/2021 15:34:00
is

Page 6: Deleted Anna Joy Drury 17/03/2021 15:35:00
Using

Page 6: Inserted Anna Joy Drury 17/03/2021 15:36:00
Predominantly

Page 6: Inserted Anna Joy Drury 17/03/2021 15:36:00
using

Page 6: Deleted Anna Joy Drury 18/03/2021 13:59:00
196.13

Page 6: Inserted Anna Joy Drury 18/03/2021 13:59:00
205

Page 6: Deleted Anna Joy Drury 29/05/2021 14:27:00
2

Page 6: Inserted Anna Joy Drury 29/05/2021 14:27:00
3

Page 6: Deleted Anna Joy Drury 29/05/2021 17:34:00
was

Page 6: Inserted Anna Joy Drury 29/05/2021 17:34:00

were

Page 6: Deleted Anna Joy Drury 29/05/2021 14:27:00
2

Page 6: Inserted Anna Joy Drury 29/05/2021 14:27:00
3

Page 6: Deleted Anna Joy Drury 17/03/2021 15:36:00
and splice

Page 6: Deleted Anna Joy Drury 24/05/2021 16:16:00
Hole

Page 6: Inserted Anna Joy Drury 24/05/2021 16:16:00
Core

Page 6: Inserted Anna Joy Drury 24/05/2021 16:16:00
H

Page 6: Deleted Anna Joy Drury 24/05/2021 16:16:00
Hole

Page 6: Inserted Anna Joy Drury 24/05/2021 16:16:00
Core

Page 6: Inserted Anna Joy Drury 24/05/2021 16:16:00
H

Page 6: Deleted Anna Joy Drury 17/03/2021 15:37:00
in order

Page 6: Deleted Anna Joy Drury 17/03/2021 15:37:00
composite

Page 6: Deleted Anna Joy Drury 17/03/2021 15:37:00
and

Page 6: Inserted Anna Joy Drury 17/03/2021 15:37:00
new

Page 6: Inserted Anna Joy Drury 17/03/2021 15:37:00
and

Page 6: Deleted Anna Joy Drury 17/03/2021 15:37:00
, together with the

Page 6: Deleted Anna Joy Drury 17/03/2021 15:37:00
composite

Page 6: Inserted Anna Joy Drury 17/03/2021 15:37:00
stratigraphic

Page 6: Inserted Anna Joy Drury 17/03/2021 15:40:00
ary

Page 6: Deleted Anna Joy Drury 17/03/2021 15:40:00
column

Page 6: Inserted Anna Joy Drury 17/03/2021 15:40:00
succession (0-205 rmcd)

Page 6: Inserted Anna Joy Drury 17/03/2021 15:41:00
Site 1264

Page 6: Inserted Anna Joy Drury 17/03/2021 15:41:00
, stratigraphic

Page 6: Deleted Anna Joy Drury 17/03/2021 15:41:00
/

Page 6: Deleted Anna Joy Drury 29/05/2021 14:27:00
3

Page 6: Inserted Anna Joy Drury 29/05/2021 14:27:00
4

Page 6: Inserted Anna Joy Drury 11/05/2021 14:39:00
, which were

Page 6: Deleted Anna Joy Drury 11/05/2021 14:39:00
.

Page 6: Inserted Anna Joy Drury 17/03/2021 15:44:00
filled with new isotope data (Westerhold et al., 2020).

Page 6: Inserted Anna Joy Drury 12/05/2021 11:51:00
XRF intensities,

Page 6: Deleted Anna Joy Drury 11/05/2021 13:15:00

Page 6: Inserted Anna Joy Drury 18/03/2021 13:22:00
The range of observed %$CaCO_3$ variability is close to the 2.2% uncertainty associated with the calibration. However, we are confident that both the long-term trends and short-term variability discussed below represent true changes in carbonate content, as these patterns originate in the original ln(Ca/Fe) ratio. The calibration uncertainty is most relevant to the absolute carbonate content.

Page 7: Inserted Anna Joy Drury 18/03/2021 13:39:00
span 93-96%

Page 7: Deleted Anna Joy Drury 18/03/2021 13:39:00
span 93-96%

Page 7: Deleted Anna Joy Drury 18/03/2021 13:39:00
is

Page 7: Inserted Anna Joy Drury 18/03/2021 13:39:00
agrees

Page 7: Deleted Anna Joy Drury 18/03/2021 13:39:00
of

Page 7: Inserted Anna Joy Drury 18/03/2021 13:39:00
with

Page 7: Inserted Anna Joy Drury 18/03/2021 13:39:00
s

Page 7: Deleted Anna Joy Drury 18/03/2021 13:40:00
especially

Page 7: Inserted Anna Joy Drury 18/03/2021 13:40:00
especially

Page 7: Inserted Anna Joy Drury 18/03/2021 13:40:00
s

Page 7: Inserted Anna Joy Drury 18/03/2021 13:41:00
s

Page 7: Inserted Anna Joy Drury 18/03/2021 13:41:00
s

Page 7: Inserted Anna Joy Drury 24/05/2021 17:53:00
(mid Miocene)

Page 7: Inserted Anna Joy Drury 18/03/2021 13:42:00
then

Page 7: Inserted Anna Joy Drury 18/03/2021 13:42:00
es

Page 7: Inserted Anna Joy Drury 24/05/2021 17:54:00
0

Page 7: Deleted Anna Joy Drury 18/03/2021 13:42:00
%

Page 7: Inserted Anna Joy Drury 18/03/2021 13:42:00
the

Page 7: Inserted Anna Joy Drury 18/03/2021 13:42:00
content

Page 7: Deleted Anna Joy Drury 18/03/2021 13:42:00
remains

Page 7: Inserted Anna Joy Drury 18/03/2021 13:42:00
decreases slightly to

Page 7: Inserted Anna Joy Drury 24/05/2021 17:54:00
(early Pliocene)

Page 7: Inserted Anna Joy Drury 24/05/2021 17:54:00
-early Pliocene

Page 7: Deleted Anna Joy Drury 29/05/2021 17:35:00
,

Page 7: Inserted Anna Joy Drury 24/05/2021 17:58:00
s

Page 7: Inserted Anna Joy Drury 24/05/2021 17:54:00
(Pleistocene)

Page 7: Inserted Anna Joy Drury 12/05/2021 11:52:00
The Si and K intensities are comparable throughout the record, although Si is generally slightly higher than K (Fig 3). Both elements, together with Fe and Ti intensities, display the same short-term variability and long-term trends (Fig 3 and Supplementary Figure 2), indicating that these elements reflect changes in aluminosilicates. As the trends of Si and K are inverse to those seen in the $CaCO_3$ content, this supports that Site 1264 is predominantly composed of carbonate and clay, with minimal influence of biogenic silica. The amplitude of changes in Si and K becomes much smaller relative to $CaCO_3$ content changes between ~115-0 rmcd compared to ~315-115 rmcd.

Page 7: Inserted Anna Joy Drury 18/03/2021 13:50:00
Because

Page 7: Deleted Anna Joy Drury 18/03/2021 13:50:00
. As a result

Page 7: Deleted Anna Joy Drury 11/05/2021 14:00:00
sedimentation rates

Page 7: Inserted Anna Joy Drury 11/05/2021 14:00:00
LSR

Page 7: Inserted Anna Joy Drury 11/05/2021 14:00:00
LSR also strongly affect detrital MARs; however, these remain low throughout at Site 1264 (0.01-0.2 g/cm^2/kyr).

Page 7: Inserted Anna Joy Drury 18/03/2021 13:52:00
$CaCO_3$

Page 7: Deleted Anna Joy Drury 11/05/2021 14:07:00
variability

Page 7: Inserted Anna Joy Drury 11/05/2021 14:07:00
changes

Page 7: Inserted Anna Joy Drury 11/05/2021 14:06:00
; however, this variability is smaller than that variability

Page 7: Deleted Anna Joy Drury 11/05/2021 14:07:00
superimposed upon variability

Page 7: Inserted Anna Joy Drury 11/05/2021 14:07:00
(see section 4.2)

Page 7: Inserted Anna Joy Drury 29/05/2021 14:36:00
(Fig 3)

Page 7: Deleted Anna Joy Drury 18/03/2021 14:00:00
record

Page 7: Deleted Anna Joy Drury 18/03/2021 14:00:00
sequence recovered

Page 7: Inserted Anna Joy Drury 18/03/2021 14:00:00
succession

Page 7: Inserted Anna Joy Drury 18/03/2021 14:00:00
1

Page 7: Deleted Anna Joy Drury 18/03/2021 14:00:00
3

Page 8: Deleted Anna Joy Drury 29/05/2021 17:35:00
.

Page 8: Inserted Anna Joy Drury 18/03/2021 14:01:00
u

Page 8: Deleted Anna Joy Drury 29/05/2021 17:36:00
.

Page 8: Deleted Anna Joy Drury 29/05/2021 17:36:00
.

Page 8: Deleted Anna Joy Drury 29/05/2021 14:28:00
7

Page 8: Inserted Anna Joy Drury 29/05/2021 14:28:00
8

Page 8: Deleted Anna Joy Drury 29/05/2021 14:28:00
8

Page 8: Inserted Anna Joy Drury 29/05/2021 14:28:00
9

Page 8: Inserted Anna Joy Drury 29/05/2021 14:37:00
; Fig 4 and Supplementary Figure 10

Page 8: Deleted Anna Joy Drury 29/05/2021 17:36:00
.

Page 8: Deleted Anna Joy Drury 18/03/2021 14:02:00
Lithological cycles broadly varying around 2 and 0.5 m length are present in the

Page 8: Inserted Anna Joy Drury 18/03/2021 14:02:00
The depth-domain

Page 8: Inserted Anna Joy Drury 18/03/2021 14:25:00
between 205 and 190 rmcd highlights the lithological cycles in %$CaCO_3$, which broadly varies around 2 and 0.5 m in length

Page 8: Deleted Anna Joy Drury 18/03/2021 14:03:00
for the interval

Page 8: Deleted Anna Joy Drury 18/03/2021 14:25:00
between 205 and 190 rmcd

Page 8: Deleted Anna Joy Drury 24/05/2021 20:44:00
4

Page 8: Inserted Anna Joy Drury 24/05/2021 20:44:00
3

Page 8: Deleted Anna Joy Drury 18/03/2021 14:04:00
decreases to low values that

Page 8: Deleted Anna Joy Drury 24/05/2021 18:17:00
0.

Page 8: Deleted Anna Joy Drury 24/05/2021 18:18:00
c

Page 8: Deleted Anna Joy Drury 24/05/2021 18:18:00
kyr

Page 8: Inserted Anna Joy Drury 24/05/2021 18:18:00
Myr

Page 8: Deleted Anna Joy Drury 29/05/2021 17:36:00
125

Page 8: Inserted Anna Joy Drury 29/05/2021 17:36:00
110

Page 8: Deleted Anna Joy Drury 12/05/2021 17:18:00
cyclicity

Page 8: Inserted Anna Joy Drury 12/05/2021 17:18:00
variability

Page 8: Deleted Anna Joy Drury 18/03/2021 14:05:00
e.g.,

Page 8: Inserted Anna Joy Drury 18/03/2021 14:05:00
which shows

Page 8: Inserted Anna Joy Drury 21/03/2021 14:36:00
~

Page 8: Inserted Anna Joy Drury 21/03/2021 14:36:00
(e.g. the ~95 and ~125 kyr cycles) with

Page 8: Inserted Anna Joy Drury 18/03/2021 14:06:00
longer

Page 8: Deleted Anna Joy Drury 24/05/2021 20:45:00
, 4

Page 8: Deleted Anna Joy Drury 24/05/2021 20:46:00
5

Page 8: Inserted Anna Joy Drury 24/05/2021 20:46:00
4

Page 8: Deleted Anna Joy Drury 29/05/2021 17:36:00
.

Page 8: Inserted Anna Joy Drury 18/03/2021 14:26:00
respectively

Page 8: Inserted Anna Joy Drury 18/03/2021 14:06:00
~

Page 8: Deleted Anna Joy Drury 18/03/2021 14:06:00
about

Page 8: Deleted Anna Joy Drury 18/03/2021 14:06:00
approximately

Page 8: Inserted Anna Joy Drury 18/03/2021 14:06:00
~

Page 8: Deleted Anna Joy Drury 18/03/2021 14:07:00
in the range of

Page 8: Inserted Anna Joy Drury 18/03/2021 14:07:00
from ~

Page 8: Inserted Anna Joy Drury 18/03/2021 14:07:00
~

Page 8: Inserted Anna Joy Drury 18/03/2021 14:26:00
in the depth-domain wavelet analysis of the $CaCO_3$ data

Page 8: Deleted Anna Joy Drury 24/05/2021 20:45:00
4

Page 8: Inserted Anna Joy Drury 24/05/2021 20:45:00
3

Page 8: Inserted Anna Joy Drury 18/03/2021 14:27:00
gradually shifting,

Page 8: Deleted Anna Joy Drury 18/03/2021 14:07:00
are resultant from

Page 8: Inserted Anna Joy Drury 18/03/2021 14:07:00
reflect

Page 8: Deleted Anna Joy Drury 18/03/2021 14:07:00
, that vary

Page 8: Inserted Anna Joy Drury 24/05/2021 18:18:00
0

Page 8: Deleted Anna Joy Drury 24/05/2021 18:18:00
c

Page 8: Inserted Anna Joy Drury 24/05/2021 18:18:00
M

Page 8: Deleted Anna Joy Drury 24/05/2021 18:18:00

k

Page 8: Deleted Anna Joy Drury 24/05/2021 18:18:00
.

Page 8: Deleted Anna Joy Drury 24/05/2021 18:18:00
c

Page 8: Inserted Anna Joy Drury 24/05/2021 18:18:00
M

Page 8: Deleted Anna Joy Drury 24/05/2021 18:18:00
k

Page 8: Inserted Anna Joy Drury 18/03/2021 14:27:00
,

Page 8: Deleted Anna Joy Drury 18/03/2021 14:08:00
can

Page 8: Inserted Anna Joy Drury 18/03/2021 14:08:00
~

Page 8: Inserted Anna Joy Drury 18/03/2021 14:08:00
~

Page 8: Inserted Anna Joy Drury 18/03/2021 14:08:00
~

Page 8: Inserted Anna Joy Drury 18/03/2021 14:08:00
~

Page 8: Deleted Anna Joy Drury 29/05/2021 14:29:00
8

Page 8: Inserted Anna Joy Drury 29/05/2021 14:29:00
9

Page 8: Deleted Anna Joy Drury 18/03/2021 14:27:00
cycle

Page 8: Inserted Anna Joy Drury 24/05/2021 18:01:00
of these cycles

Page 8: Inserted Anna Joy Drury 18/03/2021 14:08:00
,

Page 8: Deleted Anna Joy Drury 18/03/2021 14:08:00
is still

Page 8: Inserted Anna Joy Drury 18/03/2021 14:08:00
remains the

Page 8: Inserted Anna Joy Drury 18/03/2021 14:09:00
cycle

Page 8: Inserted Anna Joy Drury 18/03/2021 14:10:00
in line with the strong ~110-kyr eccentricity cycles observed

Page 8: Deleted Anna Joy Drury 18/03/2021 14:10:00
similar to the older interval

Page 8: Inserted Anna Joy Drury 18/03/2021 14:10:00
~110-kyr

Page 9: Deleted Anna Joy Drury 29/05/2021 17:36:00
,

Page 9: Inserted Anna Joy Drury 18/03/2021 14:12:00
Because of several splice revisions in the upper 55 rmcd of Site 1264 (see Section 3.1.),

Page 9: Deleted Anna Joy Drury 18/03/2021 14:13:00
Although detailed depth and age models are available for upper 55 rmcd of Site 1264 (Bell et al., 2014), resulting from several splice revisions (see Section 3.1.)

Page 9: Inserted Anna Joy Drury 18/03/2021 14:13:00
, even though detailed investigations were previously made (Bell et al., 2014)

Page 9: Inserted Anna Joy Drury 18/03/2021 14:32:00
Visible inspection of the $CaCO_3$ content data and t

Page 9: Deleted Anna Joy Drury 18/03/2021 14:28:00
T

Page 9: Inserted Anna Joy Drury 18/03/2021 14:28:00
associated

Page 9: Inserted Anna Joy Drury 18/03/2021 14:21:00
depth-domain

Page 9: Inserted Anna Joy Drury 18/03/2021 14:32:00
both

Page 9: Deleted Anna Joy Drury 18/03/2021 14:29:00
of the $CaCO_3$ data in the stratigraphic depth domain between 115 and 35 rmcd

Page 9: Inserted Anna Joy Drury 18/03/2021 14:30:00
that there is

Page 9: Deleted Anna Joy Drury 18/03/2021 14:30:00
clear

Page 9: Inserted Anna Joy Drury 18/03/2021 14:30:00
short-term

Page 9: Inserted Anna Joy Drury 18/03/2021 14:30:00
present in the data between 115 and 35 rmcd

Page 9: Deleted Anna Joy Drury 24/05/2021 20:45:00
4

Page 9: Inserted Anna Joy Drury 24/05/2021 20:45:00
3

Page 9: Deleted Anna Joy Drury 18/03/2021 14:33:00
in comparison to the previous depth intervals

Page 9: Inserted Anna Joy Drury 18/03/2021 14:33:00
in comparison to the previous depth intervals

Page 9: Deleted Anna Joy Drury 18/03/2021 14:30:00
and

Page 9: Inserted Anna Joy Drury 18/03/2021 14:30:00
which means that

Page 9: Deleted Anna Joy Drury 18/03/2021 14:33:00
none of

Page 9: Inserted Anna Joy Drury 18/03/2021 14:33:00
not

Page 9: Inserted Anna Joy Drury 18/03/2021 14:30:00
above the 95% level

Page 9: Inserted Anna Joy Drury 18/03/2021 14:30:00
-

Page 9: Deleted Anna Joy Drury 18/03/2021 14:30:00

Page 9: Inserted Anna Joy Drury 18/03/2021 14:30:00
wavelet analyses

Page 9: Deleted Anna Joy Drury 18/03/2021 14:30:00
above the 95% level

Page 9: Inserted Anna Joy Drury 18/03/2021 14:34:00
~

Page 9: Inserted Anna Joy Drury 18/03/2021 14:34:00
-

Page 9: Deleted Anna Joy Drury 18/03/2021 14:34:00
to

Page 9: Inserted Anna Joy Drury 18/03/2021 14:34:00
-

Page 9: Deleted Anna Joy Drury 18/03/2021 14:34:00
to

Page 9: Deleted Anna Joy Drury 18/03/2021 14:34:00
From the bio-/magnetostratigraphic ages w

Page 9: Inserted Anna Joy Drury 18/03/2021 14:34:00
W

Page 9: Deleted Anna Joy Drury 24/05/2021 18:17:00
0

Page 9: Inserted Anna Joy Drury 24/05/2021 18:17:00
0

Page 9: Deleted Anna Joy Drury 24/05/2021 18:17:00
cm

Page 9: Inserted Anna Joy Drury 24/05/2021 18:17:00
m

Page 9: Deleted Anna Joy Drury 24/05/2021 18:17:00
kyr

Page 9: Inserted Anna Joy Drury 24/05/2021 18:17:00
Myr based on the bio-/magnetostratigraphic ages

Page 9: Deleted Anna Joy Drury 18/03/2021 14:34:00
periodicities

Page 9: Inserted Anna Joy Drury 18/03/2021 14:34:00
depth cycles

Page 9: Deleted Anna Joy Drury 18/03/2021 14:34:00
in the depth domain

Page 9: Inserted Anna Joy Drury 18/03/2021 14:35:00
respectively

Page 9: Inserted Anna Joy Drury 18/03/2021 14:34:00

(~0.5 m)

Page 9: Inserted Anna Joy Drury 18/03/2021 14:35:00
(~1 m)

Page 9: Inserted Anna Joy Drury 18/03/2021 14:36:00
(~3-4 and ~10-12 m)

Page 9: Deleted Anna Joy Drury 18/03/2021 14:36:00
,

Page 9: Deleted Anna Joy Drury 18/03/2021 14:35:00
respectively

Page 9: Inserted Anna Joy Drury 29/05/2021 14:31:00
Fig 3;

Page 9: Deleted Anna Joy Drury 29/05/2021 14:31:00
6

Page 9: Inserted Anna Joy Drury 29/05/2021 14:31:00
8

Page 9: Deleted Anna Joy Drury 29/05/2021 14:31:00
8

Page 9: Inserted Anna Joy Drury 29/05/2021 14:31:00
9

Page 9: Inserted Anna Joy Drury 18/03/2021 14:40:00
B

Page 9: Deleted Anna Joy Drury 18/03/2021 14:39:00
For part of this depth interval (55-35 rmcd), both $CaCO_3$ estimate data and benthic foraminiferal $\delta^{18}O$ data is available

Page 9: Inserted Anna Joy Drury 18/03/2021 14:39:00
etween 55 and 35 rmcd

Page 9: Inserted Anna Joy Drury 18/03/2021 14:40:00
w

Page 9: Deleted Anna Joy Drury 18/03/2021 14:40:00
and w

Page 9: Inserted Anna Joy Drury 18/03/2021 14:39:00
$CaCO_3$ content data and benthic foraminiferal $\delta^{18}O$ data

Page 9: Deleted Anna Joy Drury 18/03/2021 14:41:00
these two proxy records

Page 9: Deleted Anna Joy Drury 29/05/2021 14:29:00
9

Page 9: Inserted Anna Joy Drury 29/05/2021 14:29:00
11

Page 9: Deleted Anna Joy Drury 29/05/2021 17:36:00
.

Page 9: Deleted Anna Joy Drury 29/05/2021 17:36:00
.

Page 9: Deleted Anna Joy Drury 18/03/2021 14:41:00
In general, clear

Page 9: Inserted Anna Joy Drury 18/03/2021 14:42:00
At Site 1264, clear

Page 9: Inserted Anna Joy Drury 18/03/2021 14:41:00
generally

Page 9: Inserted Anna Joy Drury 18/03/2021 14:42:00
depth-domain $CaCO_3$ content

Page 9: Deleted Anna Joy Drury 18/03/2021 14:42:00
of the Site 1264 $CaCO_3$ content

Page 9: Deleted Anna Joy Drury 18/03/2021 14:42:00
apart from

Page 9: Inserted Anna Joy Drury 18/03/2021 14:42:00
except for

Page 9: Deleted Anna Joy Drury 18/03/2021 14:42:00
somewhat

Page 9: Inserted Anna Joy Drury 18/03/2021 14:42:00
occasional

Page 9: Inserted Anna Joy Drury 18/03/2021 14:43:00
~1.0-1.5 m

Page 9: Deleted Anna Joy Drury 18/03/2021 14:43:00
with periodicities of 1.0 to 1.5 m

Page 9: Deleted Anna Joy Drury 18/03/2021 14:43:00
are able to

Page 9: Inserted Anna Joy Drury 18/03/2021 14:43:00
can

Page 9: Deleted Anna Joy Drury 18/03/2021 14:43:00
se

Page 9: Inserted Anna Joy Drury 18/03/2021 14:43:00
$CaCO_3$ content

Page 9: Deleted Anna Joy Drury 18/03/2021 14:43:00
ir

Page 9: Inserted Anna Joy Drury 18/03/2021 14:43:00
of these cycles

Page 9: Deleted Anna Joy Drury 18/03/2021 14:44:00
not as pronounced

Page 9: Inserted Anna Joy Drury 18/03/2021 14:44:00
muted

Page 9: Deleted Anna Joy Drury 18/03/2021 14:44:00
interval

Page 9: Inserted Anna Joy Drury 18/03/2021 14:44:00
cycles observed

Page 9: Moved to page 9 (Move #1) Anna Joy Drury 18/03/2021 14:51:00
We derive averaged LSR of <1 cm/kyr for this interval based on the initial bio-/magnetostratigraphic age model.

Page 9: Inserted Anna Joy Drury 18/03/2021 14:51:00
appear to

Page 9: Inserted Anna Joy Drury 18/03/2021 14:51:00
in the upper 35 m

Page 9: Moved to page 9 (Move #2) Anna Joy Drury 18/03/2021 14:53:00
Based on the initial age model we note absence of clear precession and obliquity paced cyclicity in both benthic foraminiferal $\delta^{18}O$ and $CaCO_3$ content records during the last 2.5 Ma (Supplementary Figure 8).

Page 9: Moved from page 9 (Move #1) Anna Joy Drury 18/03/2021 14:51:00
We derive averaged LSR of <10 cm/Mkyr for this0-35 rmcd interval based on the initial bio-/magnetostratigraphic age model.

Page 9: Inserted Anna Joy Drury 24/05/2021 18:19:00
0

Page 9: Deleted Anna Joy Drury 24/05/2021 18:19:00
c

Page 9: Inserted Anna Joy Drury 24/05/2021 18:19:00
M

Page 9: Deleted Anna Joy Drury 24/05/2021 18:19:00
k

Page 9: Deleted Anna Joy Drury 18/03/2021 14:52:00
this

Page 9: Inserted Anna Joy Drury 18/03/2021 14:52:00
0-35 rmcd

Page 9: Deleted Anna Joy Drury 18/03/2021 14:52:00
interval

Page 9: Inserted Anna Joy Drury 18/03/2021 14:52:00
observed

Page 9: Deleted Anna Joy Drury 18/03/2021 14:52:00
periodicity

Page 9: Inserted Anna Joy Drury 18/03/2021 14:52:00
cycles

Page 9: Deleted Anna Joy Drury 18/03/2021 14:52:00
is

Page 9: Inserted Anna Joy Drury 18/03/2021 14:52:00
are

Page 9: Deleted Anna Joy Drury 18/03/2021 14:52:00
either

Page 9: Inserted Anna Joy Drury 24/05/2021 18:28:00
(Bailey et al., 2013)

Page 9: Moved from page 9 (Move #2) Anna Joy Drury 18/03/2021 14:53:00
Based on the initial age model we note absence of clear precession and obliquity paced cyclicity in both benthic foraminiferal $\delta^{18}O$ and $CaCO_3$ content records during the last 2.5 Ma (Supplementary Figure 89).

Page 9: Deleted Anna Joy Drury 29/05/2021 14:32:00
8

Page 9: Inserted Anna Joy Drury 29/05/2021 14:32:00
9

Page 9: Deleted Anna Joy Drury 29/05/2021 17:37:00
.

Page 9: Inserted Anna Joy Drury 21/03/2021 14:23:00
(

Page 9: Deleted Anna Joy Drury 21/03/2021 14:23:00
between

Page 9: Deleted Anna Joy Drury 21/03/2021 14:23:00
and

Page 9: Inserted Anna Joy Drury 21/03/2021 14:23:00
to

Page 9: Inserted Anna Joy Drury 21/03/2021 14:23:00
)

Page 9: Deleted Anna Joy Drury 21/03/2021 14:22:00
%

Page 9: Inserted Anna Joy Drury 21/03/2021 14:22:00
content

Page 9: Deleted Anna Joy Drury 21/03/2021 14:23:00
spanning

Page 9: Inserted Anna Joy Drury 21/03/2021 14:23:00
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Page 9: Inserted Anna Joy Drury 21/03/2021 14:23:00
)

Page 9: Inserted Anna Joy Drury 21/03/2021 14:23:00
a

Page 9: Inserted Anna Joy Drury 24/05/2021 18:26:00
on

Page 9: Deleted Anna Joy Drury 24/05/2021 18:26:00
ng

Page 9: Inserted Anna Joy Drury 21/03/2021 14:23:00
between

Page 10: Inserted Anna Joy Drury 21/03/2021 14:24:00
Because of the splice revisions between 27 and 149 rmcd at Site 1264, we re-evaluated t

Page 10: Deleted Anna Joy Drury 21/03/2021 14:24:00
T

Page 10: Deleted Anna Joy Drury 21/03/2021 14:26:00
has to be re-evaluated

Page 10: Deleted Anna Joy Drury 21/03/2021 14:26:00
, especially

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/

Page 10: Deleted Anna Joy Drury 21/03/2021 14:26:00
(

Page 10: Deleted Anna Joy Drury 21/03/2021 14:26:00
), resulting from the splice revisions between 27 and 149 rmcd at Site 1264

Page 10: Inserted Anna Joy Drury 21/03/2021 14:28:00
we updated

Page 10: Deleted Anna Joy Drury 21/03/2021 14:28:00
were updated

Page 10: Inserted Anna Joy Drury 21/03/2021 14:28:00
cumulative

Page 10: Inserted Anna Joy Drury 21/03/2021 14:28:00
shift in the revised

Page 10: Deleted Anna Joy Drury 21/03/2021 14:28:00
cumulative

Page 10: Inserted Anna Joy Drury 21/03/2021 14:28:00
composite

Page 10: Deleted Anna Joy Drury 21/03/2021 14:29:00
shift due to depth model/splice revisions in

Page 10: Inserted Anna Joy Drury 21/03/2021 14:29:00
of

Page 10: Inserted Anna Joy Drury 21/03/2021 14:30:00
in the depth-domain

Page 10: Deleted Anna Joy Drury 21/03/2021 14:29:00
%

Page 10: Deleted Anna Joy Drury 21/03/2021 14:29:00
record

Page 10: Inserted Anna Joy Drury 21/03/2021 14:29:00
content record

Page 10: Inserted Anna Joy Drury 11/05/2021 14:32:00
using the flexible best-practice guidelines outlined in Sinnesael et al. (2019)

Page 10: Deleted Anna Joy Drury 21/03/2021 14:30:00
However,

Page 10: Inserted Anna Joy Drury 21/03/2021 14:30:00
B

Page 10: Deleted Anna Joy Drury 21/03/2021 14:30:00
b

Page 10: Deleted Anna Joy Drury 21/03/2021 14:34:00
orbital forcing

Page 10: Inserted Anna Joy Drury 21/03/2021 14:34:00
of eccentricity (E), obliquity (T) and precession (P)

Page 10: Deleted Anna Joy Drury 21/03/2021 14:30:00
single and

Page 10: Deleted Anna Joy Drury 21/03/2021 14:30:00
to

Page 10: Inserted Anna Joy Drury 21/03/2021 14:30:00
for

Page 10: Inserted Anna Joy Drury 21/03/2021 14:31:00
we employed

Page 10: Deleted Anna Joy Drury 21/03/2021 14:31:00
were employed

Page 10: Inserted Anna Joy Drury 29/05/2021 14:33:00
and Figure 10

Page 10: Inserted Anna Joy Drury 21/03/2021 14:31:00
tuned

Page 10: Inserted Anna Joy Drury 21/03/2021 14:33:00
;

Page 10: Deleted Anna Joy Drury 21/03/2021 14:33:00
, with o

Page 10: Inserted Anna Joy Drury 21/03/2021 14:33:00
o

Page 10: Inserted Anna Joy Drury 21/03/2021 14:33:00

Page 10: Deleted Anna Joy Drury 21/03/2021 14:35:00

Page 10: Inserted Anna Joy Drury 21/03/2021 14:33:00
is

Page 10: Inserted Anna Joy Drury 21/03/2021 14:32:00
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Page 10: Inserted Anna Joy Drury 21/03/2021 14:32:00
)

Page 10: Inserted Anna Joy Drury 24/05/2021 18:29:00
tuned

Page 10: Deleted Anna Joy Drury 21/03/2021 14:33:00
eccentricity

Page 10: Inserted Anna Joy Drury 21/03/2021 14:33:00
E

Page 10: Inserted Anna Joy Drury 24/05/2021 18:29:00
tuned

Page 10: Deleted Anna Joy Drury 21/03/2021 14:32:00
(/benthic $\delta^{18}O$)

Page 10: Inserted Anna Joy Drury 24/05/2021 18:29:00
tuned

Page 10: Inserted Anna Joy Drury 21/03/2021 14:32:00
(visually aided by $\delta^{18}O$, where available)

Page 10: Inserted Anna Joy Drury 24/05/2021 18:29:00
tuned

Page 10: Inserted Anna Joy Drury 21/03/2021 14:35:00
Between 30-17 Ma,

Page 10: Deleted Anna Joy Drury 21/03/2021 14:35:00
between 30-17 Ma

Page 10: Inserted Anna Joy Drury 21/03/2021 14:36:00
are both antiphase

Page 10: Deleted Anna Joy Drury 21/03/2021 14:36:00
in turn have an inverse relationship

Page 10: Deleted Anna Joy Drury 21/03/2021 14:36:00
(e.g. the ~95 and ~125 kyr cycles)

Page 10: Inserted Anna Joy Drury 21/03/2021 14:39:00

As

Page 10: Deleted Anna Joy Drury 21/03/2021 14:39:00
T

Page 10: Inserted Anna Joy Drury 21/03/2021 14:39:00
t

Page 10: Inserted Anna Joy Drury 21/03/2021 14:39:00
,

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Page 10: Inserted Anna Joy Drury 21/03/2021 14:39:00
w

Page 10: Deleted Anna Joy Drury 21/03/2021 14:39:00
W

Page 10: Deleted Anna Joy Drury 21/03/2021 14:39:00
therefore

Page 10: Deleted Anna Joy Drury 21/03/2021 14:44:00
across the

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between

Page 10: Inserted Anna Joy Drury 21/03/2021 14:40:00
.

Page 10: Deleted Anna Joy Drury 21/03/2021 14:40:00
interval and

Page 10: Inserted Anna Joy Drury 21/03/2021 14:40:00
We therefore also employ the Liebrand et al. (2016)

Page 10: Inserted Anna Joy Drury 21/03/2021 14:40:00
ing strategy of

Page 10: Deleted Anna Joy Drury 21/03/2021 14:40:00
e

Page 10: Inserted Anna Joy Drury 29/05/2021 17:37:00
e

Page 10: Deleted Anna Joy Drury 29/05/2021 17:37:00
E

Page 10: Inserted Anna Joy Drury 21/03/2021 14:45:00
between 17-8 Ma

Page 10: Deleted Anna Joy Drury 21/03/2021 14:42:00
(La2004)

Page 10: Deleted Anna Joy Drury 24/05/2021 20:46:00
5

Page 10: Inserted Anna Joy Drury 24/05/2021 20:46:00
4

Page 10: Inserted Anna Joy Drury 24/05/2021 18:31:00
When benthic foraminiferal stable isotope records become available for the interval between 17-8 Ma,

Page 10: Deleted Anna Joy Drury 24/05/2021 18:31:00
Future work can independently test whether

Page 10: Inserted Anna Joy Drury 24/05/2021 18:32:00
stability of the

Page 10: Deleted Anna Joy Drury 24/05/2021 18:30:00
early

Page 10: Inserted Anna Joy Drury 24/05/2021 18:30:00
late

Page 10: Deleted Anna Joy Drury 24/05/2021 18:30:00
derived

Page 10: Inserted Anna Joy Drury 24/05/2021 18:31:00
can be tested.

Page 10: Deleted Anna Joy Drury 24/05/2021 18:31:00
remains stable until 8 Ma,

Page 10: Deleted Anna Joy Drury 21/03/2021 14:55:00
Our

Page 10: Inserted Anna Joy Drury 21/03/2021 14:55:00
The $CaCO_3$ content to eccentricity

Page 10: Inserted Anna Joy Drury 21/03/2021 14:56:00
is

Page 10: Deleted Anna Joy Drury 21/03/2021 14:56:00
e

Page 10: Deleted Anna Joy Drury 21/03/2021 14:56:00
of the ~110 kyr eccentricity cycles are

Page 10: Inserted Anna Joy Drury 21/03/2021 14:56:00
is

Page 10: Deleted Anna Joy Drury 21/03/2021 14:56:00
more

Page 10: Inserted Anna Joy Drury 21/03/2021 14:56:00
The imprint of

Page 10: Deleted Anna Joy Drury 21/03/2021 14:56:00
O

Page 10: Inserted Anna Joy Drury 21/03/2021 14:56:00
o

Page 10: Deleted Anna Joy Drury 21/03/2021 14:58:00
becomes

Page 10: Inserted Anna Joy Drury 21/03/2021 14:58:00
is apparent

Page 10: Deleted Anna Joy Drury 21/03/2021 14:56:00
more prevalent

Page 10: Deleted Anna Joy Drury 21/03/2021 15:03:00
prior to

Page 10: Inserted Anna Joy Drury 21/03/2021 15:03:00
before

Page 10: Inserted Anna Joy Drury 24/05/2021 20:46:00
4

Page 10: Deleted Anna Joy Drury 24/05/2021 20:46:00
5

Page 11: Inserted Anna Joy Drury 24/05/2021 20:46:00
4

Page 11: Deleted Anna Joy Drury 24/05/2021 20:46:00
5

Page 11: Inserted Anna Joy Drury 21/03/2021 15:01:00
the obliquity solution used in I.b) approach is currently

Page 11: Inserted Anna Joy Drury 21/03/2021 15:01:00
available in the

Page 11: Deleted Anna Joy Drury 21/03/2021 15:01:00

the

Page 11: Deleted Anna Joy Drury 21/03/2021 15:01:00
has the obliquity solution used in I.b) approach

Page 11: Inserted Anna Joy Drury 24/05/2021 18:33:00
solution

Page 11: Deleted Anna Joy Drury 21/03/2021 15:01:00
has the obliquity solution used in I.b) approach

Page 11: Inserted Anna Joy Drury 21/03/2021 15:01:00

There was potential to develop an astrochronology at precession-level, as

Page 11: Deleted Anna Joy Drury 21/03/2021 15:02:00
T

Page 11: Inserted Anna Joy Drury 21/03/2021 15:02:00
t

Page 11: Deleted Anna Joy Drury 21/03/2021 15:03:00
record

Page 11: Inserted Anna Joy Drury 21/03/2021 15:03:00
$CaCO_3$ content

Page 11: Inserted Anna Joy Drury 21/03/2021 15:01:00
(see Section 4.1)

Page 11: Deleted Anna Joy Drury 21/03/2021 15:03:00
, so there was potential to develop an astrochronology at precession-level

Page 11: Deleted Anna Joy Drury 21/03/2021 15:03:00
older than

Page 11: Inserted Anna Joy Drury 21/03/2021 15:03:00
before

Page 11: Inserted Anna Joy Drury 21/03/2021 15:04:00
chose a

Page 11: Deleted Anna Joy Drury 21/03/2021 15:04:00
were

Page 11: Inserted Anna Joy Drury 21/03/2021 15:04:00
strategy of

Page 11: Deleted Anna Joy Drury 21/03/2021 15:04:00
in

Page 11: Inserted Anna Joy Drury 21/03/2021 15:04:00
only

Page 11: Deleted Anna Joy Drury 21/03/2021 15:04:00
only

Page 11: Inserted Anna Joy Drury 21/03/2021 15:05:00
After 8 Ma, t

Page 11: Deleted Anna Joy Drury 21/03/2021 15:05:00
T

Page 11: Deleted Anna Joy Drury 21/03/2021 15:08:00
strong

Page 11: Deleted Anna Joy Drury 21/03/2021 15:06:00
the %

Page 11: Deleted Anna Joy Drury 21/03/2021 15:06:00
record

Page 11: Inserted Anna Joy Drury 21/03/2021 15:06:00
content

Page 11: Deleted Anna Joy Drury 21/03/2021 15:05:00
is

Page 11: Inserted Anna Joy Drury 21/03/2021 15:05:00
decreases

Page 11: Inserted Anna Joy Drury 21/03/2021 15:06:00
, whilst the imprint of

Page 11: Deleted Anna Joy Drury 21/03/2021 15:05:00
reduced after 8 Ma. Spectral analyses show that

Page 11: Deleted Anna Joy Drury 21/03/2021 15:06:00
are

Page 11: Inserted Anna Joy Drury 21/03/2021 15:06:00
is

Page 11: Deleted Anna Joy Drury 21/03/2021 15:06:00
after 8 Ma until around

Page 11: Inserted Anna Joy Drury 21/03/2021 15:06:00
between 8 and

Page 11: Inserted Anna Joy Drury 21/03/2021 15:07:00
therefore

Page 11: Inserted Anna Joy Drury 21/03/2021 15:08:00
and

Page 11: Deleted Anna Joy Drury 21/03/2021 15:08:00
-

Page 11: Inserted Anna Joy Drury 21/03/2021 15:07:00
to accommodate the change in

Page 11: Deleted Anna Joy Drury 21/03/2021 15:07:00
, because the

Page 11: Deleted Anna Joy Drury 21/03/2021 15:07:00
%

Page 11: Deleted Anna Joy Drury 21/03/2021 15:07:00
data

Page 11: Inserted Anna Joy Drury 21/03/2021 15:07:00
content

Page 11: Deleted Anna Joy Drury 21/03/2021 15:07:00
changes

Page 11: Deleted Anna Joy Drury 21/03/2021 15:10:00
A change in the relationship between t

Page 11: Inserted Anna Joy Drury 21/03/2021 15:10:00
T

Page 11: Inserted Anna Joy Drury 21/03/2021 15:11:00
contrasting relationship between

Page 11: Deleted Anna Joy Drury 21/03/2021 15:10:00
%

Page 11: Deleted Anna Joy Drury 21/03/2021 15:10:00
data

Page 11: Inserted Anna Joy Drury 21/03/2021 15:10:00
content

Page 11: Deleted Anna Joy Drury 21/03/2021 15:12:00
Plio

Page 11: Inserted Anna Joy Drury 21/03/2021 15:12:00
latest Miocene

Page 11: Deleted Anna Joy Drury 21/03/2021 15:11:00
a change in

Page 11: Inserted Anna Joy Drury 21/03/2021 15:11:00
different

Page 11: Inserted Anna Joy Drury 21/03/2021 15:11:00
es

Page 11: Deleted Anna Joy Drury 21/03/2021 15:11:00
is

Page 11: Inserted Anna Joy Drury 21/03/2021 15:12:00
are

Page 11: Inserted Anna Joy Drury 21/03/2021 15:13:00
(6.0-3.3 Ma;

Page 11: Inserted Anna Joy Drury 21/03/2021 15:18:00
latest Miocene-Pleistocene

Page 11: Deleted Anna Joy Drury 21/03/2021 15:17:00
overlapping

Page 11: Deleted Anna Joy Drury 21/03/2021 15:12:00
%

Page 11: Inserted Anna Joy Drury 21/03/2021 15:12:00
content

Page 11: Deleted Anna Joy Drury 21/03/2021 15:18:00
is

Page 11: Inserted Anna Joy Drury 21/03/2021 15:18:00
are both

Page 11: Inserted Anna Joy Drury 21/03/2021 15:15:00
6.0

Page 11: Deleted Anna Joy Drury 21/03/2021 15:15:00
5.3

Page 11: Deleted Anna Joy Drury 21/03/2021 15:17:00
(

Page 11: Deleted Anna Joy Drury 21/03/2021 15:19:00
positive

Page 11: Inserted Anna Joy Drury 21/03/2021 15:19:00
Oligocene-early Miocene

Page 11: Inserted Anna Joy Drury 21/03/2021 15:19:00
between

Page 11: Deleted Anna Joy Drury 21/03/2021 15:19:00
display in the Oligocene-early Miocene

Page 11: Inserted Anna Joy Drury 21/03/2021 15:19:00
late Miocene-Pleistocene

Page 11: Deleted Anna Joy Drury 21/03/2021 15:22:00
for this time interval

Page 11: Deleted Anna Joy Drury 21/03/2021 15:31:00
tuned

Page 11: Inserted Anna Joy Drury 21/03/2021 15:31:00
coinciding with

Page 11: Deleted Anna Joy Drury 21/03/2021 15:31:00
to

Page 11: Inserted Anna Joy Drury 21/03/2021 15:32:00
As

Page 11: Deleted Anna Joy Drury 21/03/2021 15:32:00
Considering

Page 11: Inserted Anna Joy Drury 21/03/2021 15:32:00
relationship between

Page 11: Deleted Anna Joy Drury 21/03/2021 15:32:00
inverse

Page 11: Deleted Anna Joy Drury 21/03/2021 15:32:00
-

Page 11: Inserted Anna Joy Drury 21/03/2021 15:32:00
and

Page 11: Deleted Anna Joy Drury 21/03/2021 15:34:00
relationship

Page 11: Inserted Anna Joy Drury 21/03/2021 15:32:00
is inverse

Page 11: Deleted Anna Joy Drury 21/03/2021 15:32:00
5.3

Page 11: Inserted Anna Joy Drury 21/03/2021 15:32:00

6.0

Page 11: Deleted Anna Joy Drury 21/03/2021 15:33:00
interval

Page 11: Inserted Anna Joy Drury 21/03/2021 15:33:00
interval

Page 11: Inserted Anna Joy Drury 21/03/2021 15:34:00
benthic $\delta^{18}O$ and $CaCO_3$ content

Page 11: Deleted Anna Joy Drury 21/03/2021 15:34:00
datasets

Page 11: Deleted Anna Joy Drury 21/03/2021 15:34:00
As such, we

Page 11: Inserted Anna Joy Drury 21/03/2021 15:34:00
We therefore

Page 11: Deleted Anna Joy Drury 11/05/2021 14:35:00
(i.e., Southern Hemisphere insolation minima) (uncertainty up to ±10 kyr),

Page 11: Inserted Anna Joy Drury 21/03/2021 15:35:00
uncertainty up to ±10 kyr;

Page 11: Inserted Anna Joy Drury 24/05/2021 20:46:00
4

Page 11: Deleted Anna Joy Drury 24/05/2021 20:46:00
5

Page 11: Inserted Anna Joy Drury 24/05/2021 20:46:00
4

Page 11: Deleted Anna Joy Drury 24/05/2021 20:46:00
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Page 12: Deleted Anna Joy Drury 29/05/2021 17:37:00
1

Page 12: Inserted Anna Joy Drury 29/05/2021 17:37:00
3

Page 12: Deleted Anna Joy Drury 21/03/2021 15:35:00
Because no changes were made to the shipboard splice in the upper 27 rmcd (3.5 Myr), w

Page 12: Inserted Anna Joy Drury 21/03/2021 15:35:00
W

Page 12: Deleted Anna Joy Drury 21/03/2021 15:35:00
could use

Page 12: Inserted Anna Joy Drury 21/03/2021 15:35:00
used

Page 12: Deleted Anna Joy Drury 21/03/2021 15:36:00
in this interval

Page 12: Inserted Anna Joy Drury 21/03/2021 15:36:00
between 3.3 and 0 Ma, because no changes were made to the shipboard splice in the upper 27 rmcd (3.5 Myr)

Page 12: Deleted Anna Joy Drury 21/03/2021 15:36:00
confirmed

Page 12: Inserted Anna Joy Drury 21/03/2021 15:36:00
validated

Page 12: Deleted Anna Joy Drury 21/03/2021 15:36:00
two

Page 12: Inserted Anna Joy Drury 21/03/2021 15:36:00
1264 and CR

Page 12: Inserted Anna Joy Drury 24/05/2021 20:47:00
4

Page 12: Deleted Anna Joy Drury 24/05/2021 20:47:00
5

Page 12: Deleted Anna Joy Drury 12/05/2021 11:17:00

5 Discussion

Page 12: Inserted Anna Joy Drury 17/01/2021 17:07:00

Page 12: Deleted Anna Joy Drury 10/05/2021 13:50:00

Page 12: Deleted Anna Joy Drury 21/03/2021 15:39:00
are an excellent

Page 12: Inserted Anna Joy Drury 21/03/2021 15:39:00

the orbital climate variability

Page 12: Deleted Anna Joy Drury 21/03/2021 15:39:00
er

Page 12: Inserted Anna Joy Drury 21/03/2021 15:39:00
the

Page 12: Deleted Anna Joy Drury 21/03/2021 15:39:00
orbital climate variability

Page 12: Deleted Anna Joy Drury 12/05/2021 12:29:00
ed

Page 12: Deleted Anna Joy Drury 11/05/2021 14:37:00
icehouse

Page 12: Inserted Anna Joy Drury 11/05/2021 14:37:00
Coolhouse

Page 12: Inserted Anna Joy Drury 21/03/2021 15:40:00
for full discussion, see

Page 12: Inserted Anna Joy Drury 21/03/2021 15:41:00
Atlantic benthic $\delta^{13}C$ gradients indicate that North Atlantic Deep Water (NADW) heavily influenced

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the

Page 12: Inserted Anna Joy Drury 21/03/2021 15:42:00
S

Page 12: Deleted Anna Joy Drury 21/03/2021 15:42:00
s

Page 12: Inserted Anna Joy Drury 21/03/2021 15:42:00
east

Page 12: Deleted Anna Joy Drury 21/03/2021 15:42:00
was heavily influenced by North Atlantic Deep Water (NADW)

Page 12: Inserted Anna Joy Drury 21/03/2021 15:41:00
for full discussion, see

Page 12: Inserted Anna Joy Drury 21/03/2021 16:03:00
complete and

Page 12: Inserted Anna Joy Drury 24/05/2021 20:55:00
; Fig 3

Page 12: Inserted Anna Joy Drury 24/05/2021 20:55:00
; Fig 4

Page 12: Deleted Anna Joy Drury 12/05/2021 12:29:00
for the entirety of Site 1264

Page 12: Inserted Anna Joy Drury 12/05/2021 12:29:00
at Site 1264

Page 12: Deleted Anna Joy Drury 24/05/2021 20:55:00
6

Page 12: Inserted Anna Joy Drury 24/05/2021 20:55:00
5

Page 12: Deleted Anna Joy Drury 12/05/2021 12:31:00
allows for the unprecedented

Page 12: Inserted Anna Joy Drury 12/05/2021 12:31:00
enable

Page 12: Deleted Anna Joy Drury 21/03/2021 15:44:00
have

Page 12: Deleted Anna Joy Drury 21/03/2021 15:44:00
for the interval

Page 12: Deleted Anna Joy Drury 21/03/2021 16:07:00
remains

Page 12: Inserted Anna Joy Drury 21/03/2021 16:07:00
is

Page 12: Deleted Anna Joy Drury 24/05/2021 20:56:00
6

Page 12: Inserted Anna Joy Drury 24/05/2021 20:56:00
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Carbonate content varies between about 92-96% during the Oligocene to early late Miocene (30-8 Ma).

Page 12: Inserted Anna Joy Drury 12/05/2021 15:52:00
$CaCO_3$ content varied between 94-96% during the Oligocene-early Miocene (30-18.5 Ma), with MARs of ~1-2.5 $g/cm^2/kyr$ and are discussed in greater detail in Liebrand et al. (2016).

Page 12: Deleted Anna Joy Drury 21/03/2021 16:07:00
Carbonate varied between 94-96% during the Oligocene-early Miocene (30-18.5 Ma; Liebrand et al., 2016)

Page 12: Inserted Anna Joy Drury 28/05/2021 17:20:00
Broadly concurrent with cooling in the lead up to the mid Miocene climate Transition (mMCT; ~13.9 Ma), $CaCO_3$ content increases and remains between 94-96% during

Page 12: Deleted Anna Joy Drury 12/05/2021 15:58:00
and

Page 12: Inserted Anna Joy Drury 28/05/2021 17:21:00
(see Section 5.2 for discussion)

Page 12: Deleted Anna Joy Drury 21/03/2021 16:08:00
are found

Page 12: Inserted Anna Joy Drury 21/03/2021 16:08:00
occur

Page 12: Deleted Anna Joy Drury 24/05/2021 20:56:00
6

Page 12: Inserted Anna Joy Drury 24/05/2021 20:56:00
5

Page 12: Inserted Anna Joy Drury 21/03/2021 16:22:00
potentially

Page 12: Inserted Anna Joy Drury 24/05/2021 18:37:00
-early Pliocene

Page 12: Inserted Anna Joy Drury 24/05/2021 18:37:00
acronym from

Page 12: Inserted Anna Joy Drury 05/05/2021 14:45:00
further

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Carbonate deposition is strongly affected by the balance between biogenic carbonate productivity (mostly in the surface water) and carbonate dissolution in the water column/at the sea floor. Sedimentary processes, such as dilution with terrigenous material and/or the removal of fine-grained material through winnowing, can affect both the amount and composition of the carbonate preserved. The relative importance of biogenic productivity versus dissolution is discussed in detail in Liebrand et al. (2016) for the Oligocene to early Miocene, in Section 5.2 for the early-mid Miocene, and in Section 5.3 for the late Miocene-early Pliocene. Over the last 30 Myr, detrital MARs are low, indicating that dilution with terrigenous material was not a major contributing factor in controlling carbonate deposition at Site 1264. Winnowing may have removed fine fraction material, including coccolith carbonate, thereby reducing carbonate deposition at Site 1264. By comparing MARs between nearby sites recovered during DSDP Leg 74, Shackleton et al. (1984) suggested that winnowing may have affected parts of the Walvis Ridge. They suggested that winnowing was especially pronounced at DSDP Site 526 (1054 m water depth) since the late Oligocene. Site 1264 is situated on a very gentle slope above the lysocline and carbonate compensation depth (palaeowater depths: 2-2.5 km). Winnowing likely had less effect on Site 1264 compared to Site 526, as Site 1264 is not positioned on the shallowest parts of the Walvis Ridge bathymetry. Nonetheless, Shackleton et al. (1984) also found some indication of winnowing at DSDP Site 525 (2467 m water depth) since the late Pliocene. Independent constraints on winnowing are not available for the entire 30 Myr interval; however, detailed fine fraction weights are available between 30 and 17 Ma (Liebrand et al., 2016; their Fig. 2). If these data are interpreted as a proxy for winnowing, this would suggest that winnowing is modest during the "mid" Oligocene, increasing during late Oligocene warming and relatively high across the Oligocene-Miocene Transition (Fig 5). During the early Miocene (post OMT, pre-mid Miocene) winnowing is comparable to late Oligocene values (Fig 5). There is evidence for winnowing to have increased towards the condensed middle Miocene part of the Site 1264 record, as there is an increase in both high-resolution and low-resolution percent >63 μm coarse fraction (%CF) (Liebrand et al., 2016; Keating-Bitonti and Peters, 2019) (Fig 5). However, between 18.5 and 8 Ma, the Site 1264 %CF varies within a 5% range, suggesting the amount of winnowing remained stable (Fig 5; Keating-Bitonti and Peters, 2019). After ~3 Ma, %CF gradually increases from 20 to 40% (Fig 5), which is the largest increase seen in the entire record and could indicate that Site 1264 is affected by winnowing at this time. The presence of winnowing is also supported by the fact that deeper Walvis Ridge Sites 1266 and 1267 both have higher sedimentation rates than Site 1264 in the last 3 Ma, whereas the opposite would be expected if deep-sea dissolution alone was considered (productivity should affect all sites similarly).

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Liebrand et al. (2016) could not observe a uniform imprint of t

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(Liebrand et al., 2016)

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For periodicities shorter than 405 kyr,

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variability in

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5; Fig 6

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prevails as the dominant forcing

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is the dominant driver

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(Fig 6.A)

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(Fig 6.C)

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see

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in imprinted cyclicity

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that the shifts

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over the last 30 Myr

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parallels

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5 and Fig 6.A

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e prevalence of ~110kyr eccentricity pacing at Site 1264

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The strong ~110-kyr cyclicity observed in marine archives is attributed to eccentricity-driven changes in ice volume and/or deep-sea temperature, likely associated with changes in atmospheric CO_2 (Pälike et al., 2006; Holbourn et al., 2015; Liebrand et al., 2017; Greenop et al., 2019).

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These precession cycles remain the main driver of carbonate deposition until ~8 Ma, although obliquity cycles are visible

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Dduring the 2.4 Myr eccentricity minima from ~12.6- to 12.2 Ma and ~9.7- to 9.3 Ma, when the imprint of precession and ~110 kyr eccentricity imprint is muted (Fig 5 and 6.B), and obliquity paces $\%CaCO_3$ variability.

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and ~110 kyr eccentricity

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(Fig 5 and 6.B)

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, and obliquity paces $\%CaCO_3$ variability

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Strong obliquity was also observed in benthic $\delta^{18}O$ data from the South China Sea during the ~9.7-9.3 Ma node (Holbourn et al., 2013). The strong obliquity intervals observed across multiple marine archives support that obliquity exerts greater control on the climate system as a whole when the orbital configuration is characterised by long-term eccentricity minima coincident with long-term obliquity maxima

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(Holbourn et al., 2013, 2018; Drury et al., 2017; Levy et al., 2019).

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superimposed on larger ~110 kyr eccentricity cycles,

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superimposed on larger ~110 kyr eccentricity cycles

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relative amplitude of eccentricity and precession is different in the mid-late Miocene compared to the Oligocene-early Miocene. In the Oligocene-early Miocene, the amplitude of the

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concurrent with the increase in precession power in the $\%CaCO_3$ data after 14 Ma,

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concurrent with the strong precession-pacing of the $CaCO_3$ content between 14 and 8 Ma

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The influence of early-mid Miocene climate evolution on Southeast Atlantic carbonate deposition is discussed further in Section 5.2.

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During the 2.4 Myr eccentricity minima from ~12.6-12.2 Ma and ~9.7-9.3 Ma, the precession imprint is muted, and obliquity paces $\%CaCO_3$ variability.

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of %$CaCO_3$

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, such as enhanced glacial activity and high-latitude cooling

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at nearby Site 1267, where it is

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Alternatively, winnowing may have obscured some of the cyclicity at Site 1264, considering the indication that both Sites 1264 and 525 (both ~2.4-2.5 km water depth) were affected by winnowing in the late Pliocene-early Pleistocene.

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late Miocene

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on ~110 kyr periodicities

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Considering the three phases with distinctly different orbital controls on $CaCO_3$ deposition at Site 1264,

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, with Northern hemisphere high-latitude processes steadily growing in importance in the latest Miocene

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; De Vleeschouwer et al., 2020

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, which display strong ~110 kyr eccentricity pacing,

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$CaCO_3$

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Low

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The low detrital MARs at Site 1264 (average 0.09 g/cm^2/kyr) are comparable to the non-carbonate MARs of nearby sites drilled during Leg 74, particularly DSDP Site 525 (Shackleton et al., 1984). Dilution was therefore not the main driving factor of

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early-mid Miocene

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Winnowing could have removed the <63 µm fraction at Site 1264 (Fig 5); however, such winnowing also tends to remove both small $CaCO_3$ and detrital particles, ultimately raising the overall $CaCO_3$ content but lowering the $CaCO_3$ MAR (Marcantonio et al., 2014). A 10% increase in the percent >63 µm coarse fraction (%CF) after ~18.5 Ma (Fig 5;

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Liebrand et al., 2016) indicates some winnowing occurred. However, between 18.5 and 8 Ma, the Site 1264 %CF varies within a 5% range, but never increases to the high %CF values seen in the Plio-Pleistocene (Fig 5; Keating-Bitonti and Peters, 2019). This

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likely also drove the early-mid Miocene low $CaCO_3$ content

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, rather than dilution

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An increase of B/Ca concentration at Sites 1264 and 1266 after 15.5 Ma (Kender et al., 2014) indicates that dissolution influenced the early-mid Miocene low $CaCO_3$ content at Site 1264.

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(DSDP 574; IODP U1335-U1338)

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; DSDP Site 574; IODP Sites U1335-U1338

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This dissolution horizon has been traced regionally across the equatorial Pacific as the “Lavender” seismic unconformity, with the dissolution potentially linked to the intensification of proto-NADW formation leading to increased corrosive Antarctic Bottom Water (AABW) reaching the Pacific (Mayer et al., 1985). This hypothesis could not be tested at the time due to the absence of any comparable Atlantic carbonate records. However, the new evidence of low %$CaCO_3$ and $CaCO_3$ MARs at Site 1264 in the Southeast Atlantic indicates that dissolution occurred in the Atlantic and the Pacific during the early to mid-Miocene. Increased dissolution across ocean basins indicates a global forcing, supporting suggestions that t

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seen in the Pacific

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is dissolution driven (e.g., see also (Kender et al., 2014), rather than reflecting a decrease

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also reflect increased carbonate dissolution rather than a reduction

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may

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6A, B and

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towards strong precession-pacing

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as carbonate content recovers

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, which is characterised at

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likely experienced increased carbonate deposition during the MCO as indicated

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between 18.5-14.4 Ma

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that may also be indicative of increased carbonate dissolution

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If dissolution is the dominant control on $CaCO_3$ content at Site 1264,

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which is supported by the increase in B/Ca at Sites 1264 and 1266 (Kender et al., 2014). This deep-water change would have enabled

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allowing for the

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after the mMCT compared to

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during

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early-

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sedimentary and geochemical

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event is referred to as the

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as defined by

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and

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s

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6

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Page 18: Deleted Anna Joy Drury 12/05/2021 11:26:00
which means

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so

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at this time

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between 7.2-6.6 Ma

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6

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During the latest Miocene-early Pliocene (~8-3 Ma), t

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T

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has

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displays

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during the late Miocene-early Pliocene

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Specifically,

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T

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t

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specifically

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Through the mid-late Miocene and early Pliocene, the LSR at Site 1264 are either similar or higher at Site 1264 (2505 m) relative to deeper Site 1266 (3806 m). The available %CF and %$CaCO_3$ from Site 1264 also do not display a strong relationship prior to 8 Ma. This suggests that any winnowing at Site 1264 was minimal and stable for the mid-late Miocene to early Pliocene.

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The

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%CF-%$CaCO_3$

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therefore could

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s

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Conversely,

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There is evidence for dynamic ice sheet activity, although

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relative to those seen mid Miocene and Pleistocene, indicating

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suggesting

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long-term

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large

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; Tanner et al., 2020

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in the Southeast Atlantic

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at Site 1264

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shortly after 8 Ma

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climate

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, such as increased glacial activity and high-latitude cooling

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shortly after 8 Ma

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This increased high-latitude influence may be caused by

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There is widespread evidence that

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, which

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The growing importance of the high-latitudes in the latest Miocene is further supported by evidence that deep-sea stable $\delta^{13}C$ and $\delta^{18}O$ switched from in-phase to anti-phase on eccentricity timescales (Kirtland Turner, 2014; De Vleeschouwer et al., 2020), as a result of continental carbon reservoirs shrinking during cold periods due to increased extent of low-carbon Arctic biomes, such as ice sheets, polar deserts and tundra (De Vleeschouwer et al., 2020).

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,

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in the latest Miocene

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in explaining

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to explain

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will be

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is

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achieve

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aim

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framework

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the

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beginning of the

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s

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cooler,

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leading to

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ation of

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content

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, which suggests a link between the onset of the LMBB and the increased influence of high-latitude processes, such as enhanced glacial activity and high-latitude cooling

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Further work will be needed to disentangle global versus regional productivity patterns and explore causal links in greater detail.

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LL,

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, DK, DB

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LL's part of the research was carried out under the program of the Netherlands Earth System Science Centre (NESSC), financially supported by the Dutch Ministry of Education, Culture and Science (OCW).

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(tables marked with an * are also archived on PANGAEA)

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1) Downcore intercalibrated XRF data from Site 1264, including ln(Ca/Fe), Si, Fe, K, Ti, and Mn

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1) Oversized panels showing depth to age tie points and age model generation

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magnetic susceptibility (

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)

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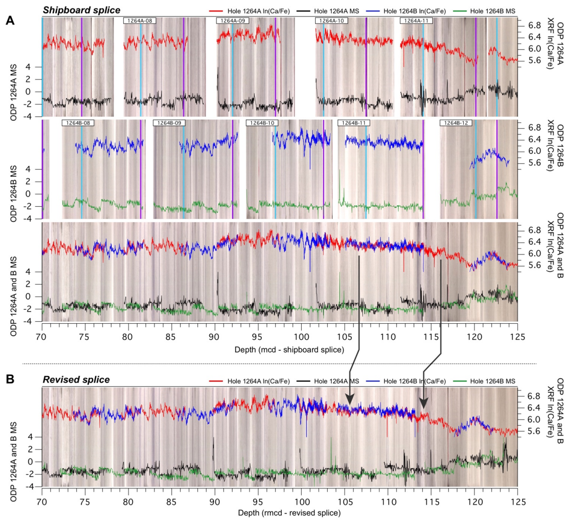

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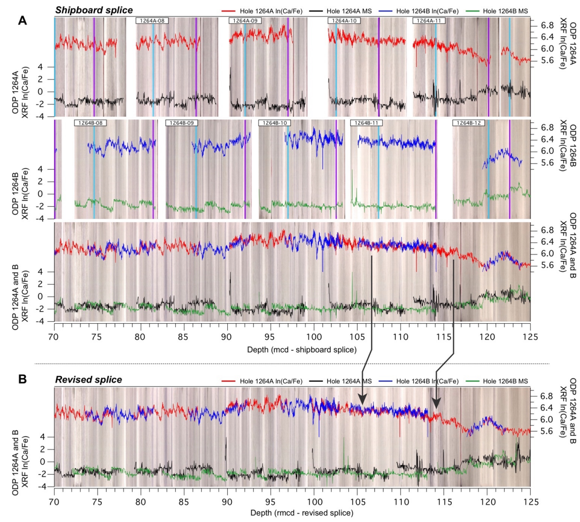

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intensity

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and K (teal) intensities

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bulk =

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blue; $CaCO_3$

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and

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=

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, respectively

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bulk =

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and

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; $CaCO_3$ = dark

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, respectively

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c

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M

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k

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light

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The depth-domain wavelet spectra are shown for the %$CaCO_3$ data after it was detrended to remove all cycles greater than 2 m (G) or greater than 40 m (H). The periods are highlighted in m. The wavelets were generated using the code from Torrence and Compo (1998) and Grinsted et al. (2004). The approximate stratigraphic location of the MCO and the LMBB are highlighted by shaded grey areas.

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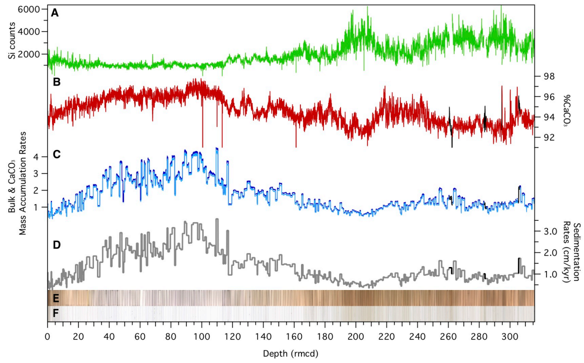

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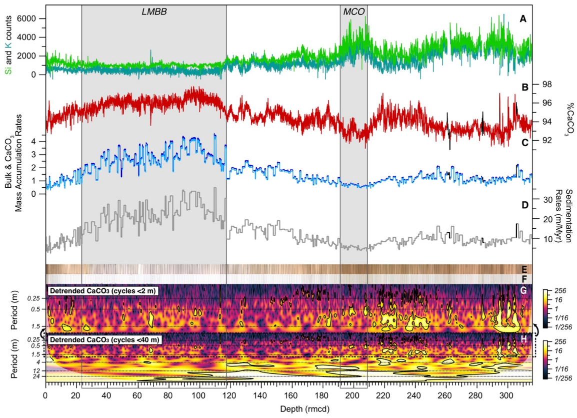

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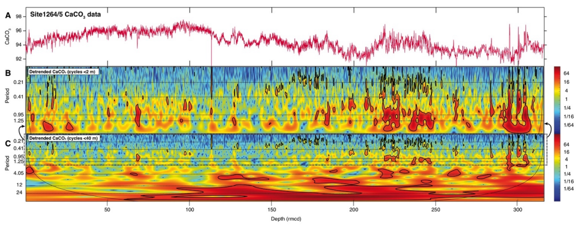
Figure 4: Wavelet spectra in the depth domain of (A) the XRF-derived %$CaCO_3$ data for Sites 1264 and 1265. The %$CaCO_3$ data has been detrended to remove all cycles (B) greater than 2 m or (C) greater than 40 m. The wavelets were generated using the code from Torrence and Compo (1998) and Grinsted et al. (2004).



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Zoomed in figures showing the exact depth-age tie points are shown in Supplementary Information Figure 10.

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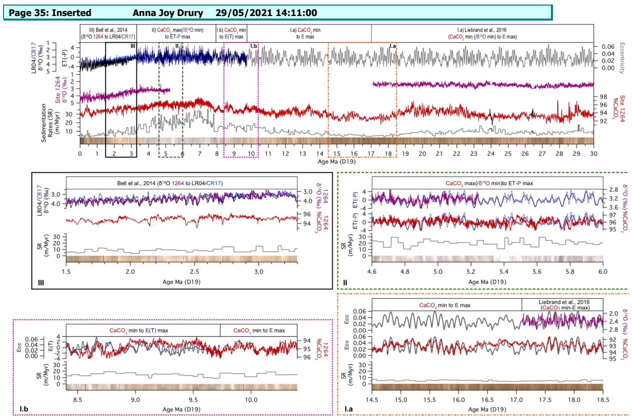

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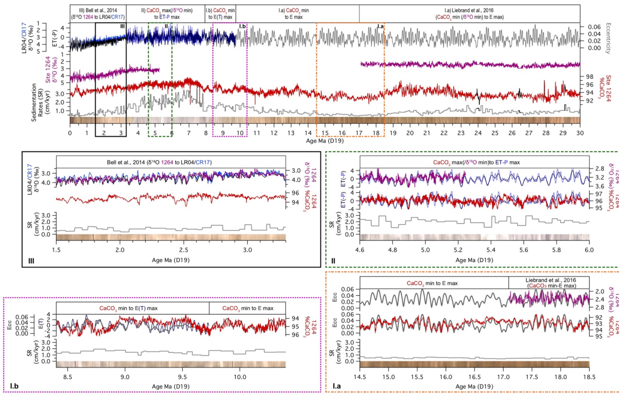

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The MCO, mMCT and the LMBB are annotated.

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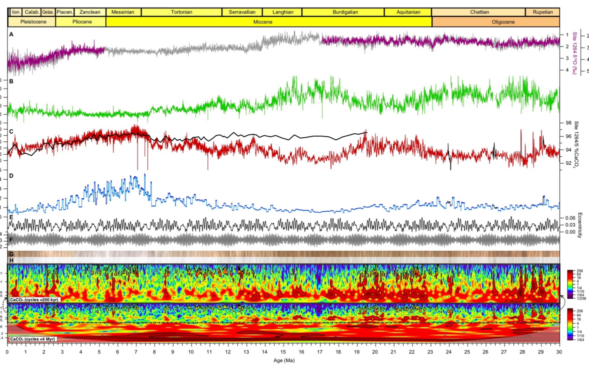

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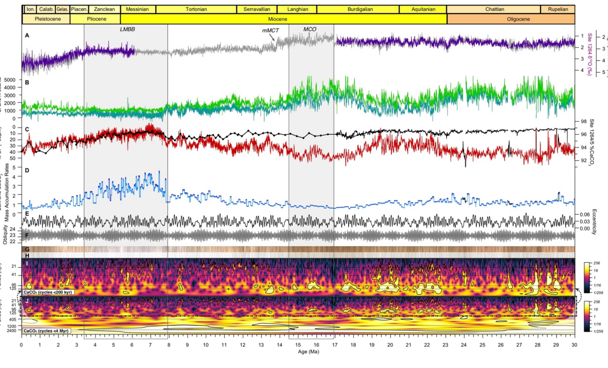
Figure 6: Zoomed in panels highlighting the three distinctly different orbital controls on Southeast Atlantic $CaCO_3$ deposition. A) Example of strong eccentricity (E) pacing present between 30 and 13 Ma; B) Example of the prevalent eccentricity-modulated precession pacing present between 14 and 8 Ma; C) Example of the pervasive obliquity forcing present between 8 and ~3.3 Ma. An example of stronger obliquity appearing in a 2.4 Myr eccentricity minimum, when eccentricity-modulated precession is muted, is also shown in B. $CaCO_3$ minima correlate with eccentricity maxima between 30 and 8 Ma (A and B). Between 8 and 0 Ma, $CaCO_3$ maxima correlate with obliquity maxima (C).



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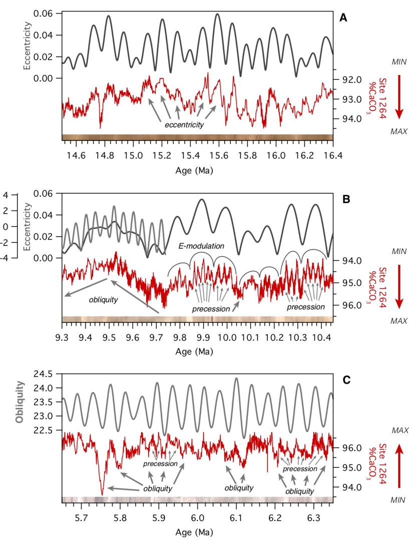

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The approximate location of the MCO and the mMCT are also shown.

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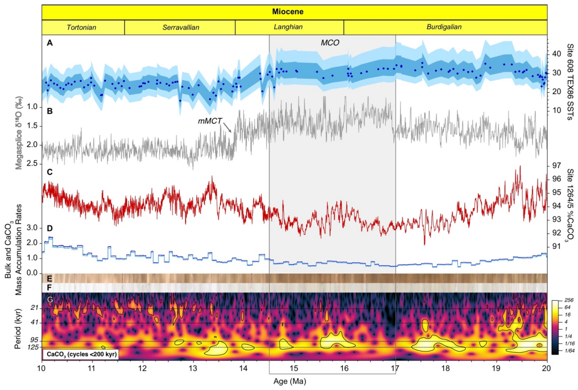

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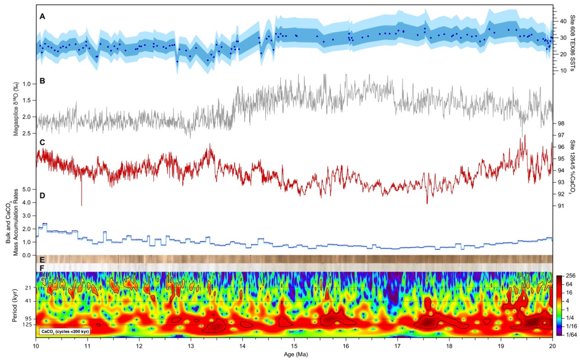

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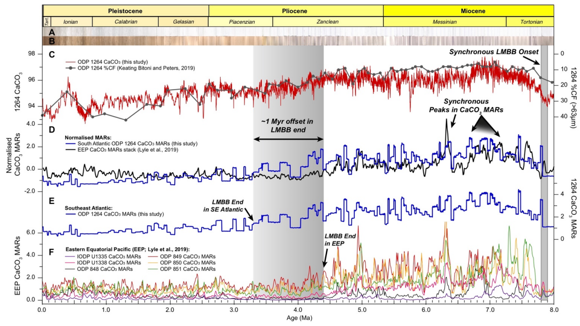

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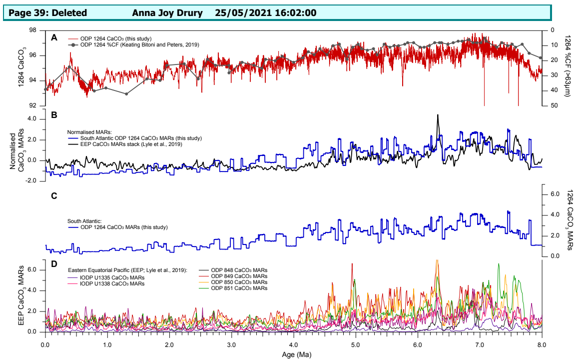

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