

**This PDF file includes:**

Supplementary Text  
Figures and captions S1-S4  
Captions for Tables S1-S2  
Supplementary references

**S1. Data set compilation**

All data compiled are provided in an Excel file, with one sheet per site or paper (Table S1) for a total of 3895 data points across 79 sites or papers. The compiled sites are:

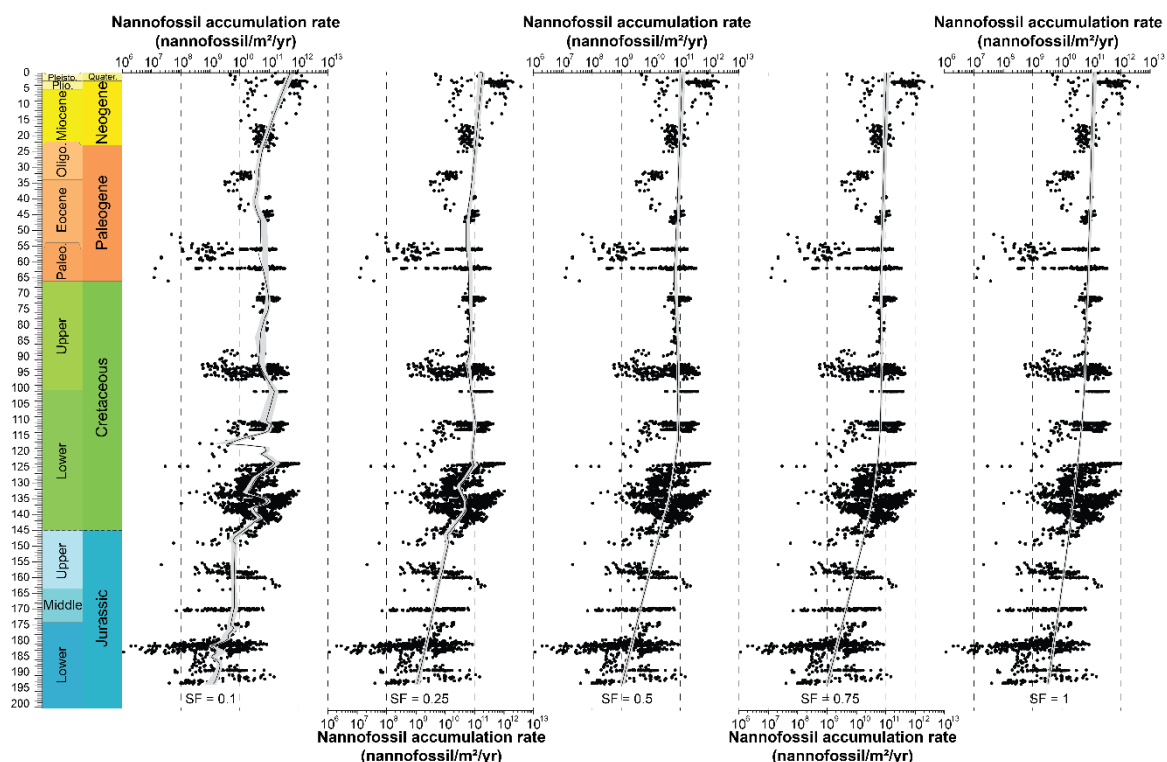
- 1 - Sao Pedro de Moel, Portugal, Late Sinemurian–Lower Pliensbachian (Plancq et al., 2016)
- 2 - Peniche, Portugal, Early Pliensbachian (Mattioli, unpublished data)
- 3 - Peniche, Portugal, Late Pliensbachian (Reggiani et al., 2010)
- 4 - La Cerradura, Spain, Late Pliensbachian–Early Toarcian (Reolid et al., 2014)
- 5 - Peniche, Portugal, Early Toarcian (Mattioli et al., 2009; Suan et al., 2008)
- 6 - Tournadous, France, Late Pliensbachian–Early Toarcian (Mailliot et al., 2009; Suan et al., 2008)
- 7 - Saint-Paul-des-Fonts, France, Late Pliensbachian–Early Toarcian (Mailliot et al., 2009; Suan et al., 2008)
- 8 - Somma, Italy, Late Pliensbachian–Early Toarcian (Mattioli et al., 2009)
- 9 - Dotternhausen, Germany, Early Toarcian (Mattioli et al., 2009)
- 10 - Yorkshire, UK, Early Toarcian (Plancq, 2009)
- 11 - Réka Valley, Hungary, Early Toarcian (Plancq, 2009)
- 12 - Chionistra, Greece, Early Toarcian (Kafousia et al., 2014)
- 13 - HTM-102, France, Early Toarcian (Mattioli et al., 2009)
- 14 - K2-5, France, Early Toarcian (Plancq, 2009)
- 15 - Rabaçal, Portugal, Late Pliensbachian–Late Toarcian (Kenjo, 2010)
- 16 - Cabo Mondego, Portugal, Late Aalenian–Early Bajocian (Suchéras-Marx et al., 2013; Suchéras-Marx et al., 2012)
- 17 - Chaudon-Norante, France, Late Aalenian–Early Bajocian (Suchéras-Marx et al., 2013; Suchéras-Marx et al., 2014)
- 18 - La Voulte, France, Middle Callovian–Early Oxfordian (Giraud, unpublished data)
- 19 - La Voulte, France, Middle Oxfordian (Excoffier, 2001; Pittet, 2006)
- 20 - Meussia, France, Middle Oxfordian (Excoffier, 2001; Pittet, 2006)
- 21 - Balingen–Tieringen, Germany, Late Oxfordian (Mattioli, unpublished data; Pittet, 2006)
- 22 - Plettenberg, Germany, Late Oxfordian (Olivier et al., 2004; Pittet, 2006)
- 23 - Le Pas de l'Assassin, France, Late Oxfordian–Early Kimmeridgian (Carcel, 2009; Carcel et al., 2010)
- 24 - DSDP105, North Atlantic, Tithonian–Valanginian (Bornemann et al., 2003)

- 25 - DSDP534A, North Atlantic, Tithonian–Valanginian (Bornemann et al., 2003)
- 26 - DSDP367, North Atlantic, Tithonian–Valanginian (Bornemann et al., 2003; Lancelot and Seibold, 1978)
- 27 - Perisphinctes Ravine, Greenland, Late Ryazanian–Late Hauterivian (Pauly et al., 2012)
- 28 - Rødryggen, Greenland, Late Ryazanian–Late Hauterivian (Pauly et al., 2012)
- 29 - Polaveno, Italy, Late Berriasian–Early Hauterivian (Erba and Tremolada, 2004; Gréselle and Pittet, 2010)
- 30 - DSDP534A, North Atlantic, Late Berriasian–Early Hauterivian (Bornemann et al., 2005; Gréselle and Pittet, 2010)
- 31 - DSDP603B, North Atlantic, Late Berriasian–Late Valanginian (Bornemann et al., 2005; Gréselle and Pittet, 2010)
- 32 - Vergol–La Charce, France, Valanginian (Gréselle and Pittet, 2010; Gréselle et al., 2011)
- 33 - Carajuan, France, Early Valanginian (Gréselle and Pittet, 2010; Riquier, 2002)
- 34 - DSDP535, Mexico Gulf, Early Valanginian–Early Hauterivian (Kessels et al., 2006)
- 35 - ODP638, North Atlantic, Early Valanginian–Early Hauterivian (Kessels et al., 2006)
- 36 - BGS81/43, North Atlantic, Early Valanginian–Early Hauterivian (Kessels et al., 2006)
- 37 - BGS81/43, North Sea, Late Valanginian–Late Hauterivian (Williams and Bralower, 1995)
- 38 - Speeton, UK, Early Hauterivian–Barremian (Williams and Bralower, 1995)
- 39 - Otto Gott, Germany, Barremian (Mutterlose, 1998; Williams and Bralower, 1995)
- 40 - Nora-1, Denmark, Barremian (Mutterlose and Bottini, 2013)
- 41 - North Jens-1, Denmark, Late Barremian–Early Aptian (Mutterlose and Bottini, 2013)
- 42 - A39-Braunschweig, Germany, Early Barremian–Early Aptian (Pauly et al., 2013)
- 43 - Takal Kuh, Iran, Early Aptian (Mahanipour et al., 2011)
- 44 - Notre-Dame-de-Rosans, France, Aptian (Giraud et al., 2018)
- 45 - Pré-Guittard, France, Late Aptian (Herrle, 2002; Herrle et al., 2003)
- 46 - Alma, Morocco, Late Aptian–Early Albian (Peybernes et al., 2013)
- 47 - Addar, Morocco, Late Aptian–Early Albian (Peybernes et al., 2013)
- 48 - Tamzergout, Morocco, Late Aptian–Early Albian (Peybernes et al., 2013)
- 49 - Hyèges, France, Late Aptian (Giraud, unpublished data; Herrle, 2002)
- 50 - L'Arboudeysse, France, Early Albian (Herrle, 2002)
- 51 - DSDP545, North Atlantic, Early Albian (Herrle, 2002)
- 52 - Col de Palluel, France, Late Albian (Bornemann et al., 2005)
- 53 - Blieux, France, Early Cenomanian–Middle Cenomanian (Giraud et al., 2013; Reboulet et al., 2013)
- 54 - Wunstorf, Germany, Middle Cenomanian–Middle Turonian (Linnert et al., 2010; Voigt et al., 2008)

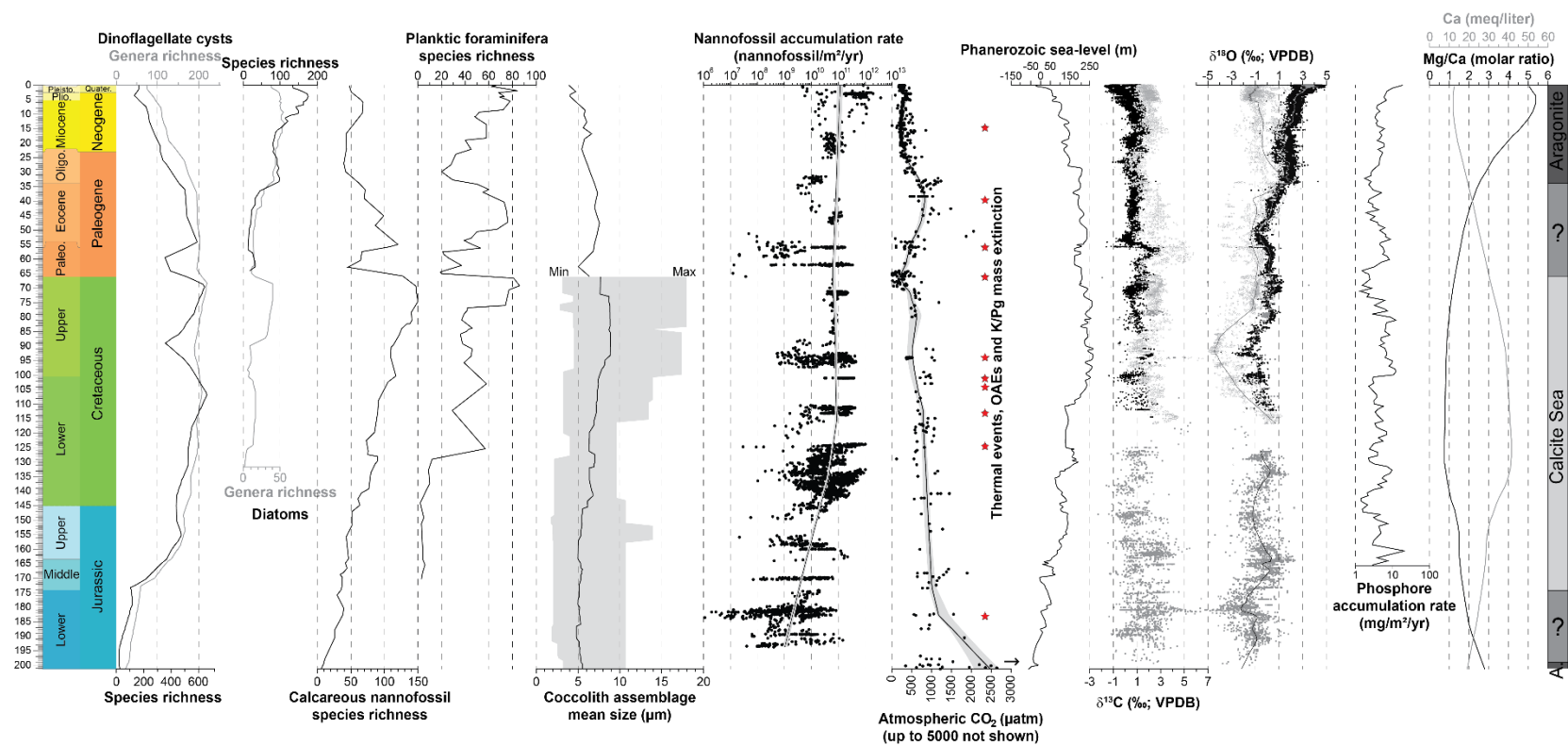
- 55 - ODP1258, Central Atlantic, Early Cenomanian–Middle Turonian (Hardas and Mutterlose, 2007; Shipboard Scientific Party, 1985)
- 56 - ODP1260, Central Atlantic, Early Cenomanian–Early Turonian (Hardas and Mutterlose, 2007; Shipboard Scientific Party, 1985)
- 57 - Holywell Pinnacles, UK, Late Cenomanian–Early Turonian (Linnert et al., 2011b; Voigt et al., 2008)
- 58 - DSDP549-551, North Atlantic, Middle Cenomanian–Late Maastrichtian (Linnert et al., 2011a; Shipboard Scientific Party, 1985)
- 59 - Krons Moor, Germany, Late Campanian–Early Maastrichtian (Linnert et al., 2016)
- 60 - Qreiya 1, Egypt, Danian–Selandian (Youssef Ali, 2009)
- 61 - Qreiya 3, Egypt, Danian–Selandian (Sprong et al., 2011)
- 62 - Araas, Egypt, Danian (Youssef Ali, 2009)
- 63 - Duwi, Egypt, Danian (Youssef Ali, 2009)
- 64 - ODP1260B, Central Atlantic, Late Paleocene–Early Eocene (Mutterlose et al., 2007; Youssef Ali and Mutterlose, 2004)
- 65 - Wadi Abu Ghurra, Egypt, Late Maastrichtian–Early Eocene (Youssef Ali and Mutterlose, 2004)
- 66 - Kurkur Naqb Dungul, Egypt, Late Paleocene–Early Eocene (Youssef Ali and Mutterlose, 2004)
- 67 - ODP1263, South Atlantic, Late Paleocene–Early Eocene (Zuzlewski, 2014)
- 68 - ODP1209A, North Pacific, Eocene (Salaviale, 2013)
- 69 - DSDP511, South Atlantic, Rupelian–Priabonian (Plancq et al., 2014)
- 70 - DSDP516, South Atlantic, Oligocene–Miocene (Plancq et al., 2012; Plancq et al., 2013)
- 71 - DSDP608, North Atlantic, Oligocene–Miocene (Plancq et al., 2013)
- 72 - DSDP588C, North Atlantic, Oligocene–Miocene (Plancq et al., 2013)
- 73 - ODP752A, Indian Ocean, Miocene–Pleistocene (Suchéras-Marx and Henderiks, 2012)
- 74 - DSDP525, South Atlantic, Miocene–Pleistocene (Suchéras-Marx and Henderiks, 2012)
- 75 - ODP806B, East Pacific, Miocene–Pleistocene (Suchéras-Marx and Henderiks, 2012)
- 76 - ODP707A, Indian Ocean, Miocene–Pleistocene (Suchéras-Marx and Henderiks, 2012)
- 77 - ODP982B, North Atlantic, Miocene–Pleistocene (Suchéras-Marx and Henderiks, 2012)
- 78 - Punta di Maiata, Italy, Zanclean (Mattioli, unpublished data)
- 79 - Punta Grande/Punta Piccola, Italy, Pliocene (Plancq et al., 2015)

**S2. Impact of LOESS smoothing factor on the long-term trend of nannofossil accumulation rate.** Interpretation of the long-term trend can be arguably linked to the smoothing factor (SF) selected for the LOESS (LOcally WEighted Scatterplot Smoothing). In Fig. S1 we present the nannofossil accumulation rate for SF = 0.1, 0.25, 0.5, 0.75, and 1. The smaller the smoothing factor, the rougher and less marked the smoothing is. Whereas the smoothed curve at SF 0.1 is clearly influenced by the sampling resolution along the analyzed

time series, from SF 0.25 to SF 1 the same long-term trend is observed without short-term artifact. Accordingly, the discussed trend appears to be a reliable long-term pattern unrelated to the selected SF-value.



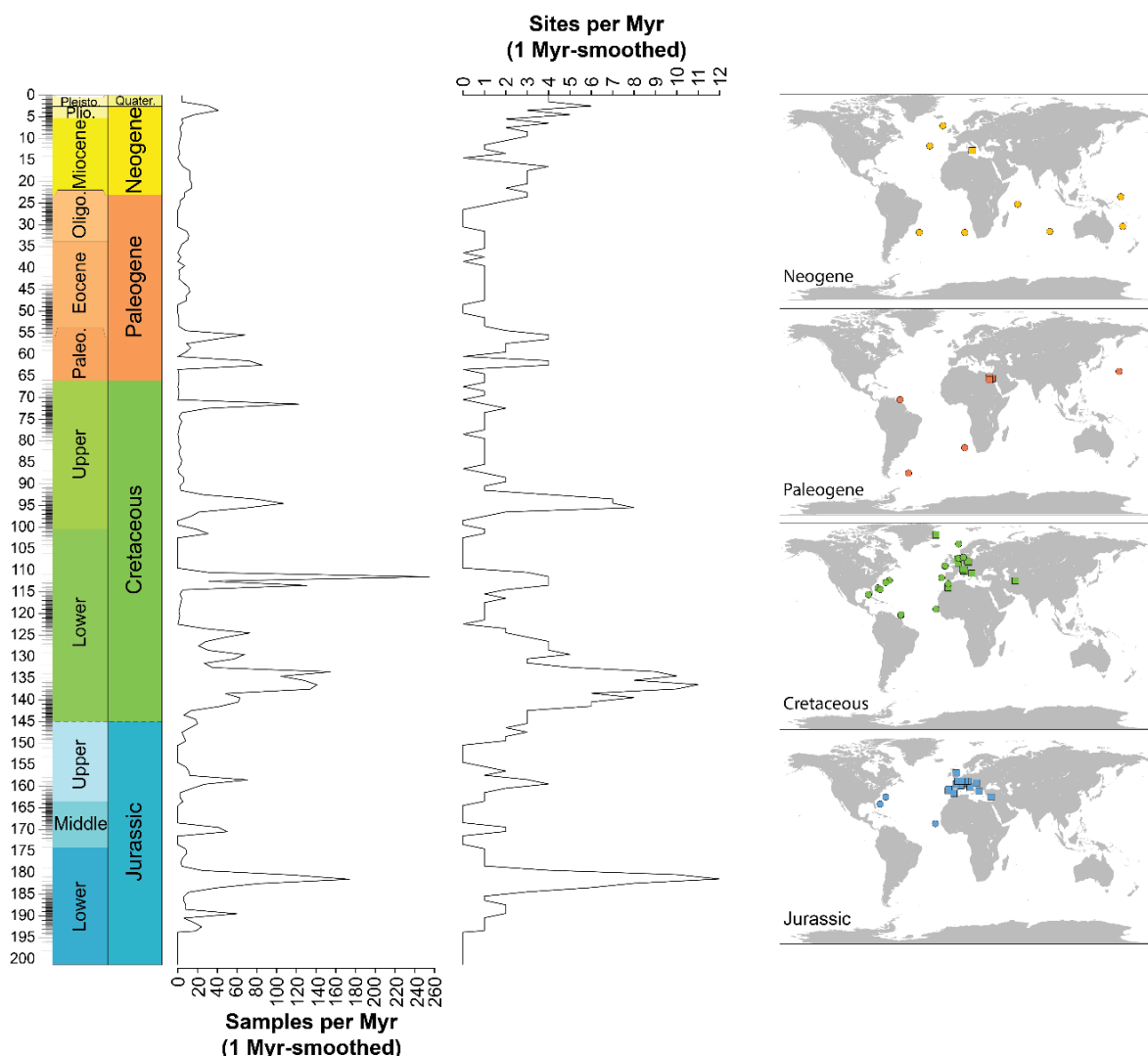
**Fig. S1.** Comparison of the LOESS smoothing for nannofossil accumulation rates (nannofossil/m<sup>2</sup>/yr) with five different smoothing factor values (from left to right): SF 0.1, SF 0.25, SF 0.5, SF 0.75, and SF 1. SF 0.5 is the one discussed in the main text.



**Fig. S2.** Comparison of microplankton evolution and environmental/climatic changes through time. Dinoflagellate cyst richness (number of species in black and genera in grey) (Kooistra et al., 2007; Stover et al., 1996); diatoms richness (number of species in black and genera in grey) (Spencer-Cervato, 1999), nannoplankton species richness (Bown, 2005); planktic foraminifera species richness (Peters et al., 2013); coccolith mean size at the assemblage level ( $\mu\text{m}$ , Mesozoic (Aubry et al., 2005) and Cenozoic (Herrmann and Thierstein, 2012)); nannofossil accumulation rate (this study); atmospheric  $\text{CO}_2$  ( $\mu\text{atm}$ ) (Hönisch et al., 2012); compilation of OAEs, thermal events and K/Pg mass extinction; Phanerozoic sea-level (m) (Hardenbol et al., 1998);  $\delta^{13}\text{C}$  (‰, VPDB; square: belemnite; open circle: planktic foraminifera; black circle: benthic foraminifera) (Friedrich et al., 2005; Prokoph et al., 2008);  $\delta^{18}\text{O}$  (‰, VPDB; square: belemnite; open circle: planktic foraminifera; black circle: benthic foraminifera) (Friedrich et al., 2005; Prokoph et al., 2008); phosphorus accumulation rate ( $\text{mg}/\text{m}^2/\text{yr}$ ) (Föllmi, 1995); Mg/Ca (molar ratio), Ca (mEq/L), calcite vs. aragonite seas (Stanley, 2008). The dinoflagellate species richness presents the same broad pattern as calcareous nannofossil species richness with an increase up to the Early Cretaceous and a decrease from the end of the Paleocene up to Holocene (Falkowski et al., 2004). This long-term pattern is interrupted by a two-phase decrease: one during the early Late Cretaceous and another during the K/Pg crisis. The long-term variations of diatoms species and genera richness are completely different from those observed for both calcareous nannofossils and dinoflagellates cysts. Unfortunately, the lack of literature data on diatoms and dinoflagellate accumulation rates hampers further comparisons with the evolutionary pattern discussed for calcareous nannoplankton. The record of  $\delta^{13}\text{C}$  and phosphorus accumulation rates is not discussed in the main text. They do not show long-term changes, but rather shorter cyclic variations intimately related to climate changes which are tuned by orbital cycles. On the long-term scale, there is no relationship between calcareous nannoplankton evolution and  $\delta^{13}\text{C}$  or phosphorus accumulation rates, but there are likely relationships on the short-term scale (e.g. Mattioli et al., 2009) which are not captured in the present record.

**S3. Disparity of sampling through time and space.** The database presented in this study gathered 3895 samples from 79 sites over the last 193 Myr. This large amount of data is not evenly distributed through time. Figure S3 presents the number of sample per Myr and the number of sites per Myr. Usually, the more sites compiled, the more samples there are in the database, although this is not observed for the Neogene. This figure also highlights the discrete sampling pattern, with some time intervals being more densely studied than others. Three time-intervals are highly documented: the early Toarcian (Early Jurassic), the Valanginian (Early Cretaceous), and the Cenomanian/Turonian transition (Late Cretaceous). To a lesser extent, we can also cite the Aptian-Albian transition (Early Cretaceous) and the Paleogene.

The maps in Fig. S3 present the sites studied for the four geological Periods considered (Quaternary excluded). The Jurassic samples are mainly represented by European sites and are all located in the Northern Hemisphere. The Cretaceous samples are equably distributed between European and Atlantic deep-sea drilling sites, all of them being from the Northern Hemisphere. The Paleogene samples are from Egyptian sites and four deep-sea drilling sites, three from the Central-South Atlantic and one from the North Pacific. Finally, the Neogene samples are dominated by deep-sea drilling sites from the Southern Hemisphere.

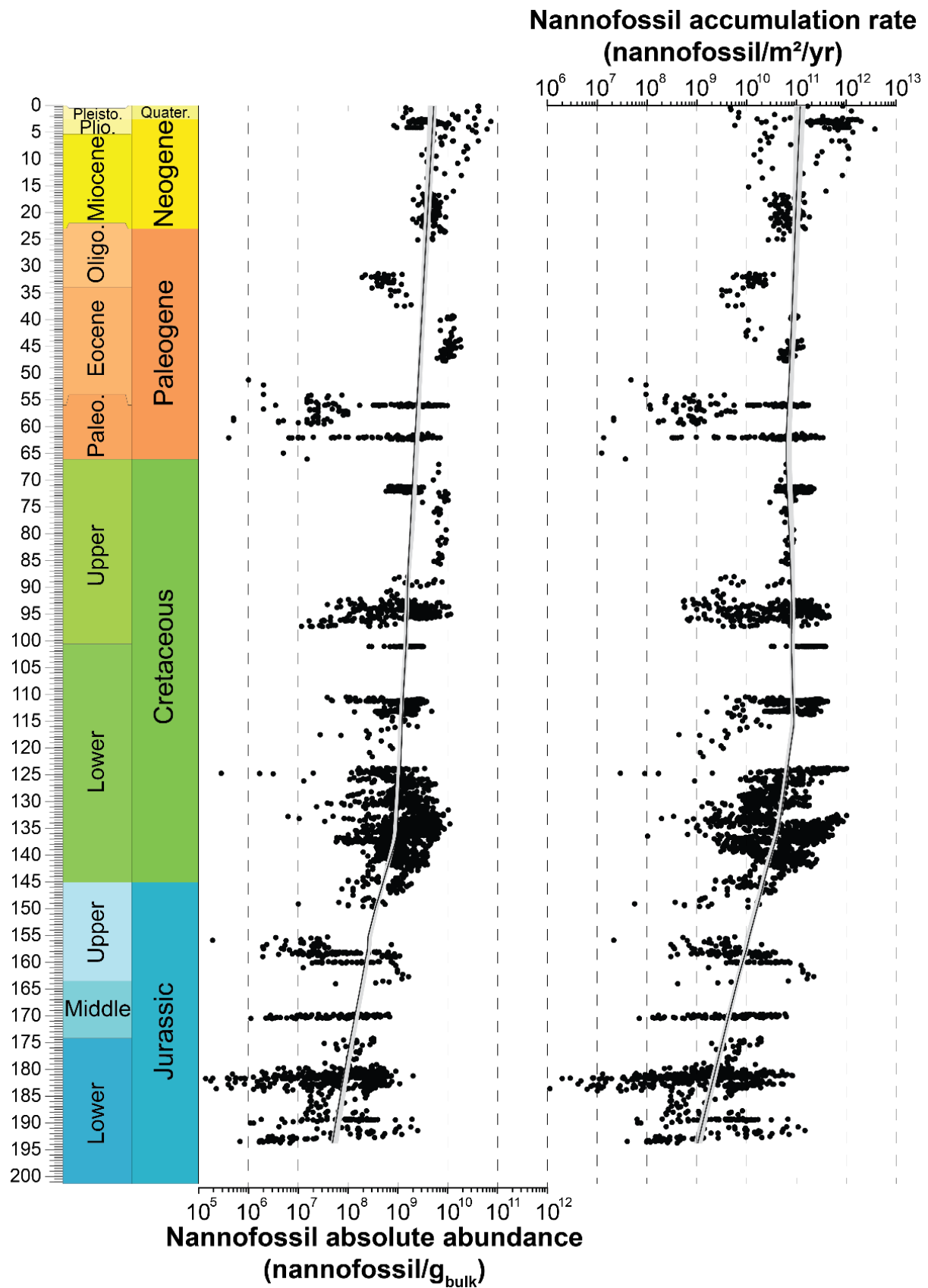


**Fig. S3.** Number of samples and sites per Myr and sites location for the four Periods studied.

#### **S4. Impact of sedimentary rates on the computation of nannofossil accumulation rate.**

This study discusses nannofossil accumulation rate which is derived from nannofossil absolute abundance and sedimentary rates (see Methods). All absolute abundance data compiled but one paper (Erba and Tremolada, 2004) have been obtained using the same method; methodological biases are thus negligible at this level. Conversely, the sedimentary rates used to calculate nannofossil accumulation rates derive from the International Chronostratigraphic Chart 2012 (Gradstein et al., 2012) or from cyclostratigraphy-based estimated durations. These two different methods used to calculate nannofossil accumulation rates might impact the short-term fluctuations observed, but they are not likely to affect the long-term trends discussed here. Figure S4 compares the long-term trends (LOESS SF 0.5) for nannofossil absolute abundance (nannofossil/g<sub>bulk</sub>) and nannofossil accumulation rate (nannofossil/m<sup>2</sup>/yr). The comparison of these two plots highlights some differences due to local sedimentary patterns influencing the nannofossil accumulation rate (e.g., during the Early Cretaceous); nevertheless, the overall long-term trend discussed in the article is the same between nannofossil absolute abundance and accumulation rate. This observation allows us to rule out a bias effect of sedimentary rate calculation on the resulting long-term trend.





**Fig. S4.** Comparison between the compiled nannofossil absolute abundances (nannofossil/g<sub>bulk</sub>) and nannofossil accumulation rates (nannofossil/m<sup>2</sup>/yr) computed in this study.

**Table S1.** Dataset of nannofossil accumulation rate in the different settings studied in this work, sorted in chronological order. Each sheet presents the location of the site, the age (relative and absolute), the nannofossil absolute abundance, the sedimentation rate, the nannofossil accumulation rate, and other information such as the sample name, height in the section and the published reference.

**Table S2.** Dataset of nannofossil accumulation rate used to construct Fig. 3. The table presents for both considered geological stages (i.e., Toarcian and Valanginian) the location of each site, their mean nannofossil absolute abundance and mean nannofossil accumulation rate, and the number of sample per site.

**S5. Supplementary references for nannofossil absolute abundance, nannofossil accumulation rate and sedimentation rate calculation compiled in this study, and supplementary references in Fig. S2 (by alphabetical order)**

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