Paleolatitudinal distribution of lithologic indicators of climate in a paleogeographic framework

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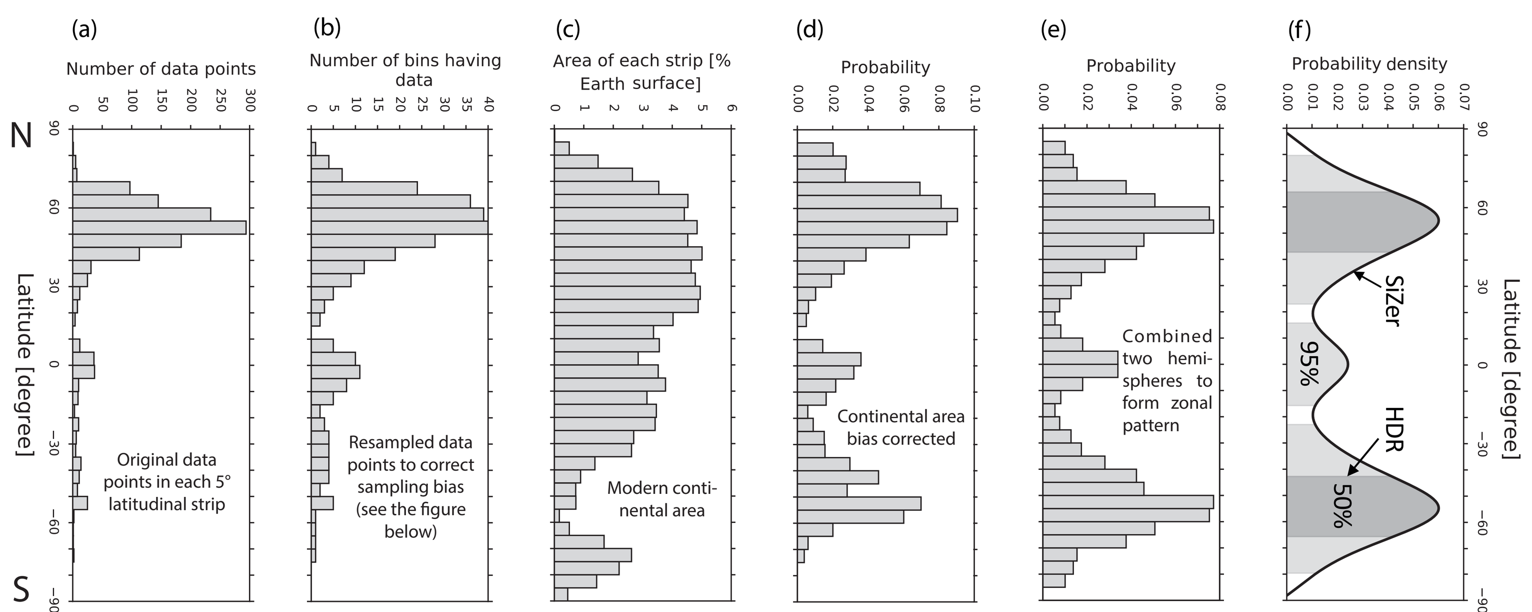
1. Introduction and aims

Whether the latitudinal distribution of climate-sensitive lithologies is stable through greenhouse and icehouse regimes remains unclear. Previous studies suggest that the palaeolatitudinal distribution of palaeoclimate indicators, including coals, evaporites, reefs and carbonates, has remained broadly similar since the Permian period, leading to the conclusion that atmospheric and oceanic circulation control their distribution rather than the latitudinal temperature gradient.

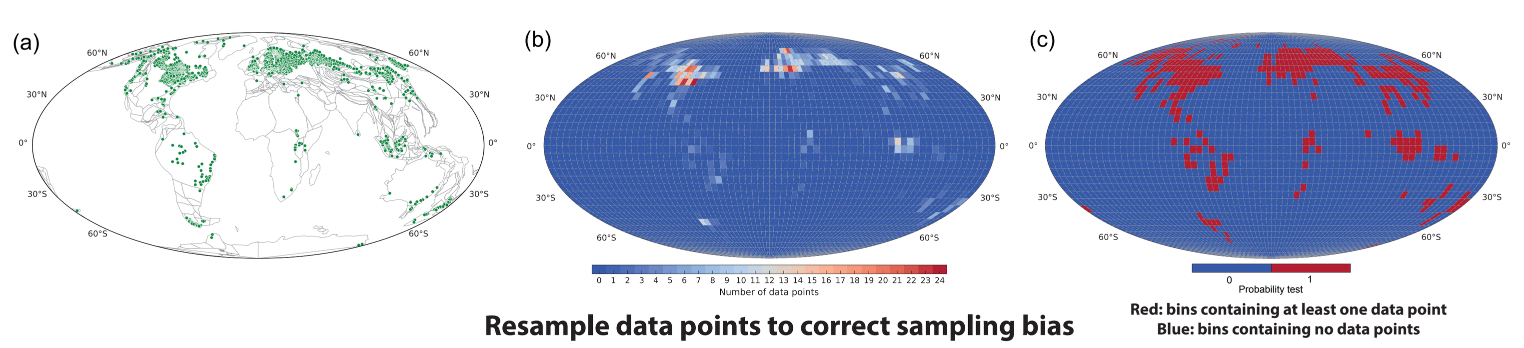
In order to better understand the latitudinal distribution patterns of climate-sensitive lithologies and the associated climate change, we analyzed a global-scale compilation of lithologic indicators of climate, including coals, evaporites and glacial deposits, back to the Devonian period using novel statistical methods. We discuss how the distribution patterns change through time in response to plate motion, orography, evolution and greenhouse/icehouse conditions.

2. Methods



Sample dataset: modern peat points from Ziegler et al. (2003)

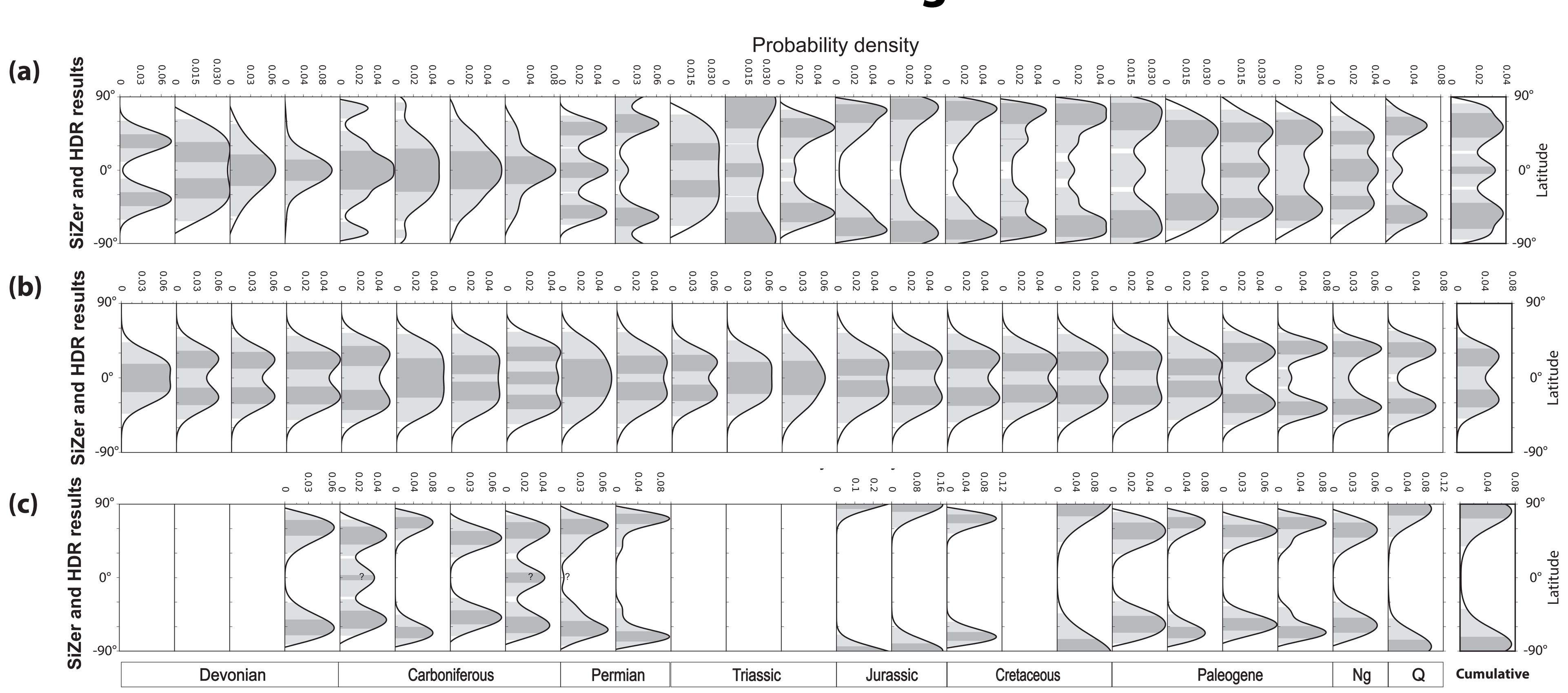
(f) Fitted probability density function (black line) using the method of SiZer from Chaudhuri & Marron (1999). High-density latitude ranges at confidence intervals of 50 % (grey area) and 95 % (light grey area) using the HDR method of Hyndman (1996).



Resample data points to correct sampling bias

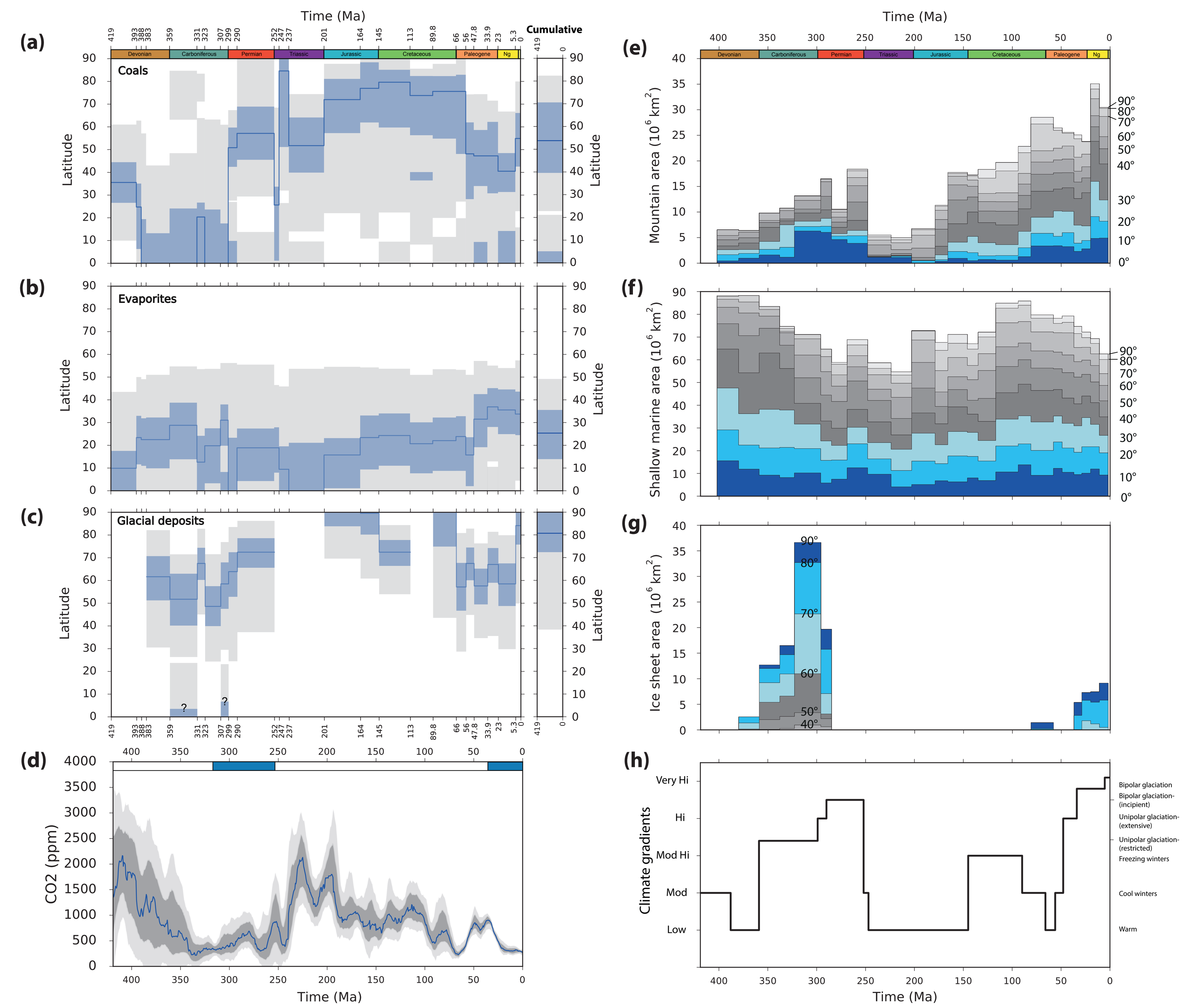
(a) Present-day locations of modern global peats (green points) from Ziegler et al. (2003). Grey polygons are modern terrane geometries. (b) Distribution of modern peat points binned using a 5°×5° mesh of the global surface. (c) Distribution of resampled modern peat points .

3. Paleolatitudinal distribution of lithologies



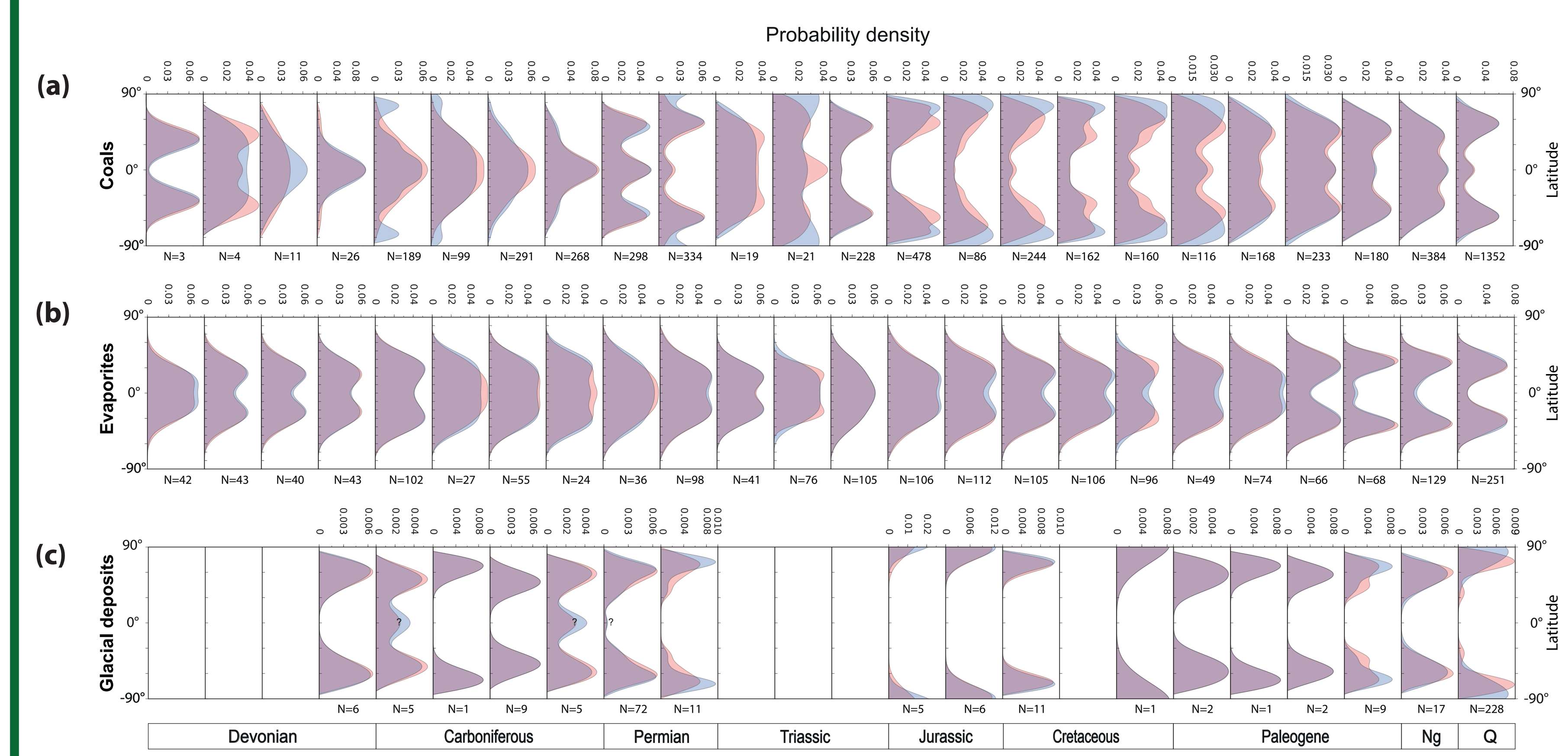
Probability density function (black lines) of symmetric zonal patterns of coals (a), evaporites (b) and glacial depostis (c) from Boucot et al. (2013) and Ziegler et al. (2003) using the SiZer method. High-density latitude ranges at confidence intervals of 50 % (grey area) and 95 % (light grey area) using the HDR method. The cumulative results for all times are presented on the rightmost side with bold borders.

4. Paleolatitudinal distribution patterns of lithologies and Contributors to them



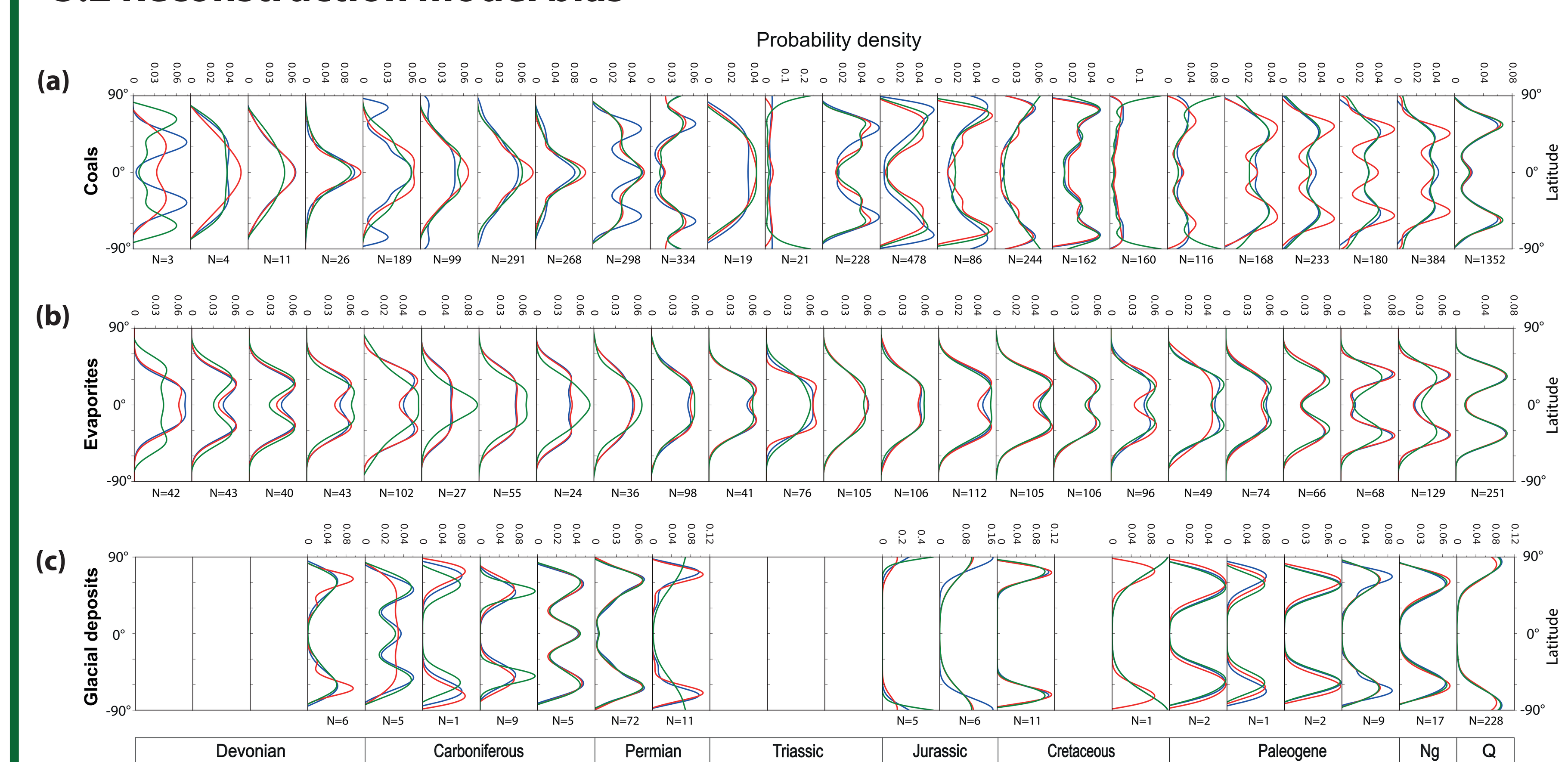
(a, b, c) High-density latitudinal belts of coals, evaporites and glacial deposits, with 50 % (blue area) and 95 % (light grey area) confidence intervals for each time interval since the Devonian period. The blue lines are the most significant peaks of latitudinal distribution. Cumulative high-density probabilities are presented on the rightmost side with bold borders. (d) Atmospheric CO_2 concentration curve since the Devonian period, derived from Foster et al. (2017), with 68 % (dark grey) and 95 % (light grey) confidence intervals. Icehouse intervals and greenhouse intervals (Hay, 2016) are indicated by a blue band and a white band, respectively, at the top of the panel. (e, f, g) Global palaeolatitudinal distribution of mountain ranges, shallow marine environments and ice sheets since the Devonian period calculated from the set of palaeogeographic maps (Golonka et al. 2006; Cao et al. 2017). (h) Climate temperature gradients since the Early Devonian derived from Boucot et al. (2013).

5. Sensitivity tests on - 5.1 Continental area bias



Red: without continental area bias correction; Blue: with continental area bias correction

5.2 Reconstruction model bias



Three reconstruction models - blue: Matthews et al. (2016); Red: Scotese (2008); Green: Golonka (2007)

6. Conclusions

1. Palaeolatitudinal distributions of lithologies have changed through deep geological time, notably a pronounced poleward shift in the distribution of coals at the beginning of the Permian.
2. The distribution of evaporites indicates a clearly bimodal distribution over most of the past ~400 Ma.
3. These climate indicators are sensitive to the correction of continental areas and do not show strong sensitivity to the reconstruction model.
4. There is no single factor that dominates the changing distributions from the Early Devonian to the present. Care should be taken when using the latitudinal distribution of these lithologies to constrain both past global climate and the past positions of continents.
5. This study highlights that combining tectonic reconstructions with a comprehensive lithologic database and novel data analysis approaches provide insights into the nature and causes of shifting climatic zones through deep time.

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