The Caribbean conundrum of Holocene sea level

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

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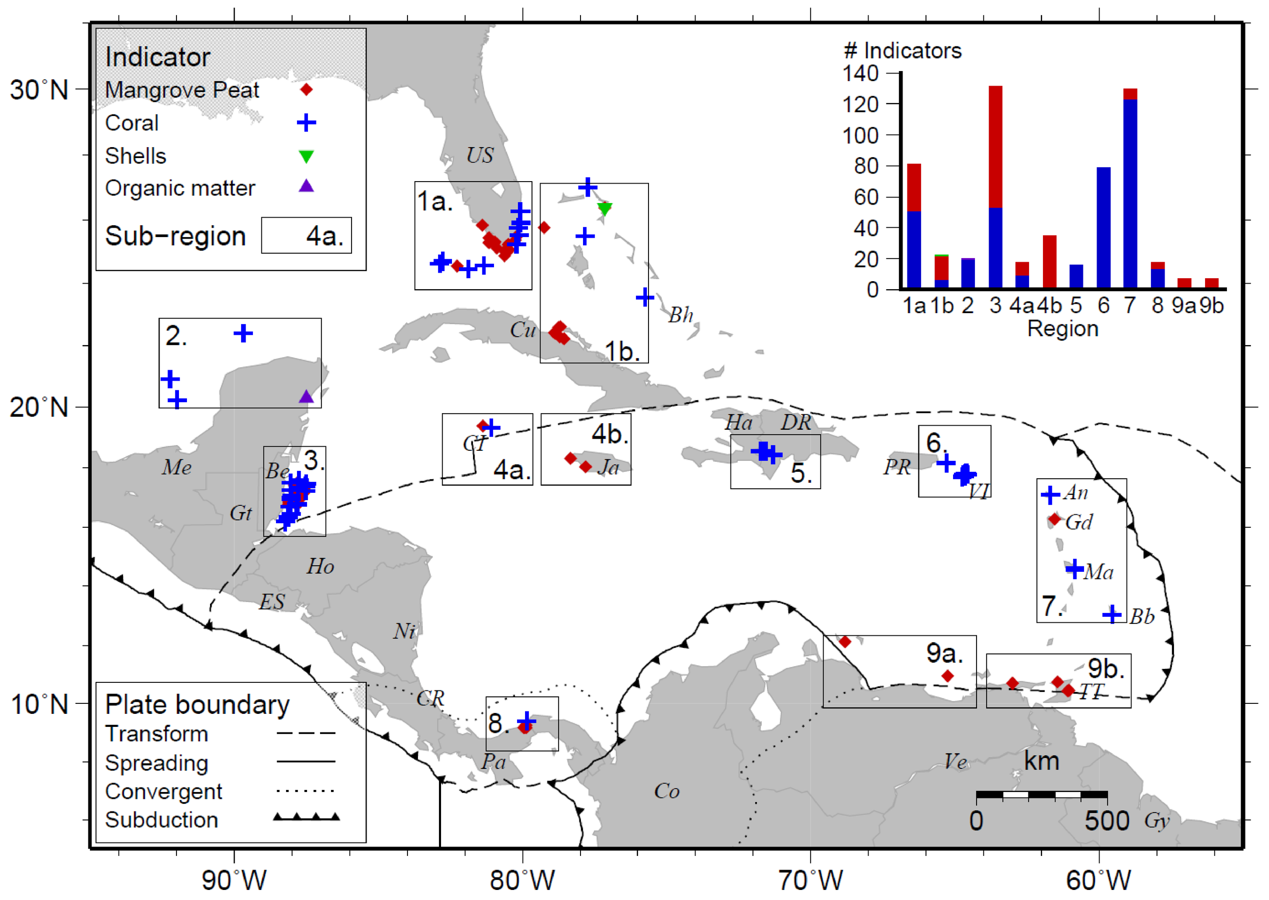
Introduction

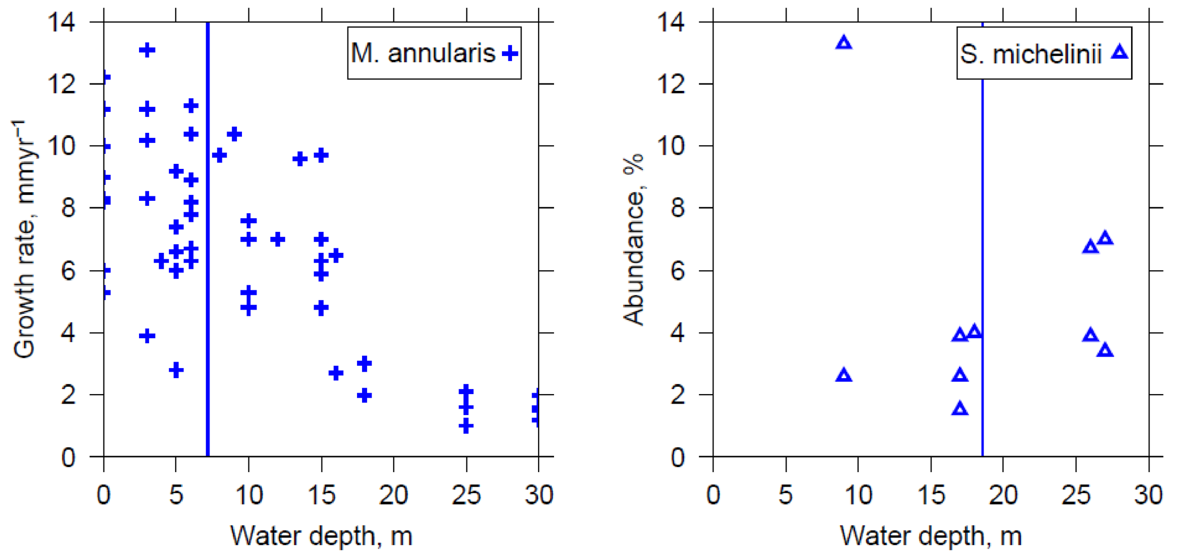
Modern sea-level rise is a hotly debated subject and is of pressing societal concern. A fuller understanding of prehistoric sea-level rise will add valuable insight to this discussion. We consider Holocene sea-level change in the Caribbean guided by three questions about data treatment, resolution and model representation. First though, the data.

Two Data sets: One Past, One Present

There are two main types of palaeo-sea-level indicator in the Caribbean: mangrove peat and fossil coral. Our 'past' catalogue of 565 published sea-level indicators has wide spatial coverage and most sub-regional sub-sets extend in time across the Holocene (12000 cal yr BP - present).



Our 'present' catalogue contains published growth rate-depth and abundance-depth information of 15 modern coral species. Sampling is discontinuous, so we calculate a normalised median depth (z_{med}) and an optimum range (σ).



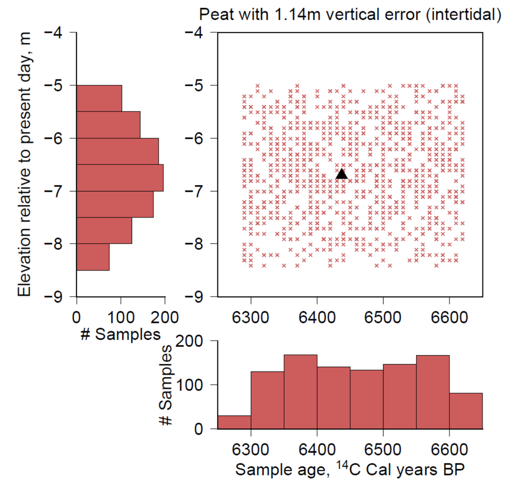
Can we improve Holocene sea-level reconstructions using existing data?

The habitable range of a certain species can be a proxy for sea-level position. Previously, this range hasn't included natural variability. We use our 'present' catalogue to describe the probability of a mangrove or coral species occurring at some position (z) relative to sea level. We use these distributions for each indicator in our 'past' catalogue to make 1000 'sea-level points'.

Normal Distribution (Mangrove)

$$P_n = \frac{e^{-(z-\sigma)^2/2\sigma^2}}{\sigma\sqrt{2\pi}}$$

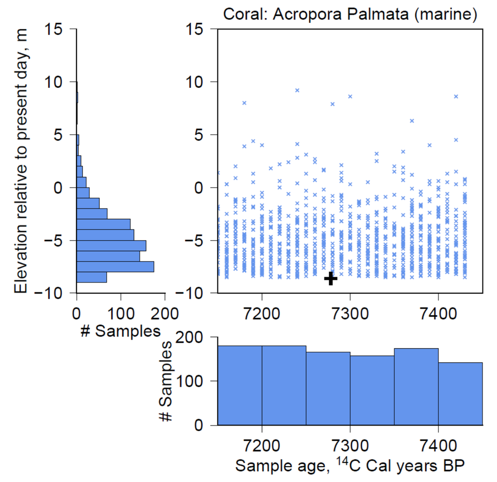
Mangroves lie within a narrower range around sea level. Tidal range is a strong control, hence Gaussian distribution.



Scaled Growth Distribution (Coral)

$$P_g = \tanh 8e^{-2z/z_{med}}$$

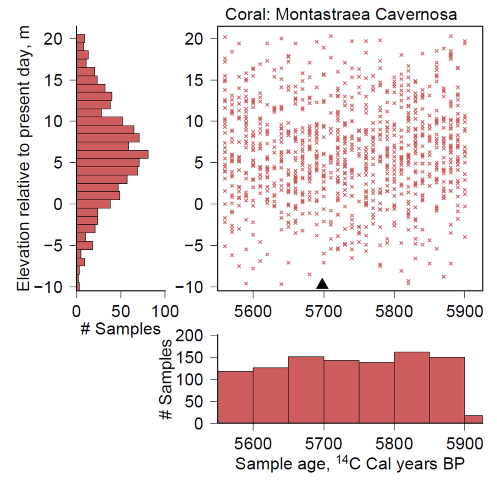
Adapted from Chalker (1981), which relates growth rate to light intensity (i.e.. depth). Good for corals that dominate breaker to fore-reef environments.

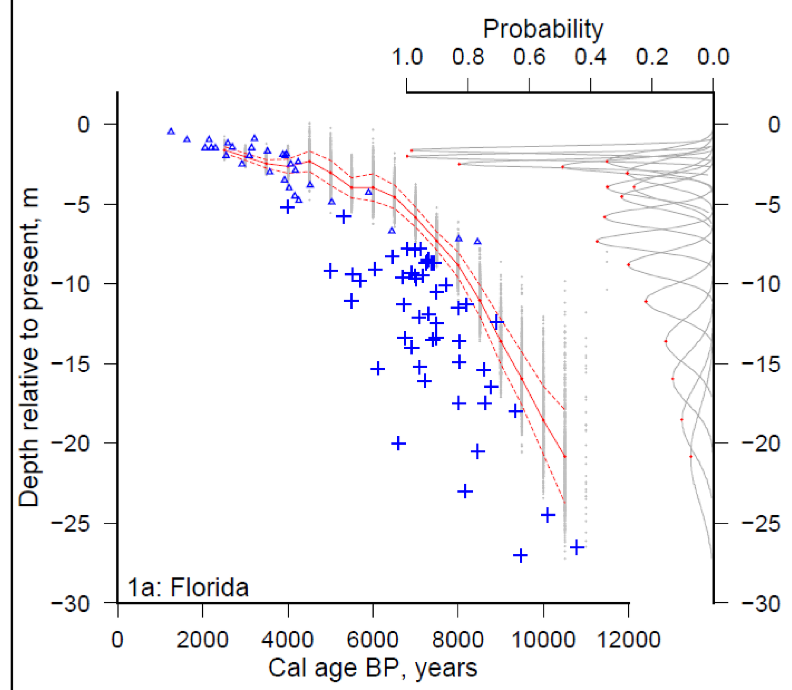


Logistical Distribution (Coral)

$$P_l = \frac{e^{z-z_{med}/\sigma}}{\sigma(1+e^{z-z_{med}/\sigma})^2}$$

Designed to account for corals with preference down fore-reef slope.

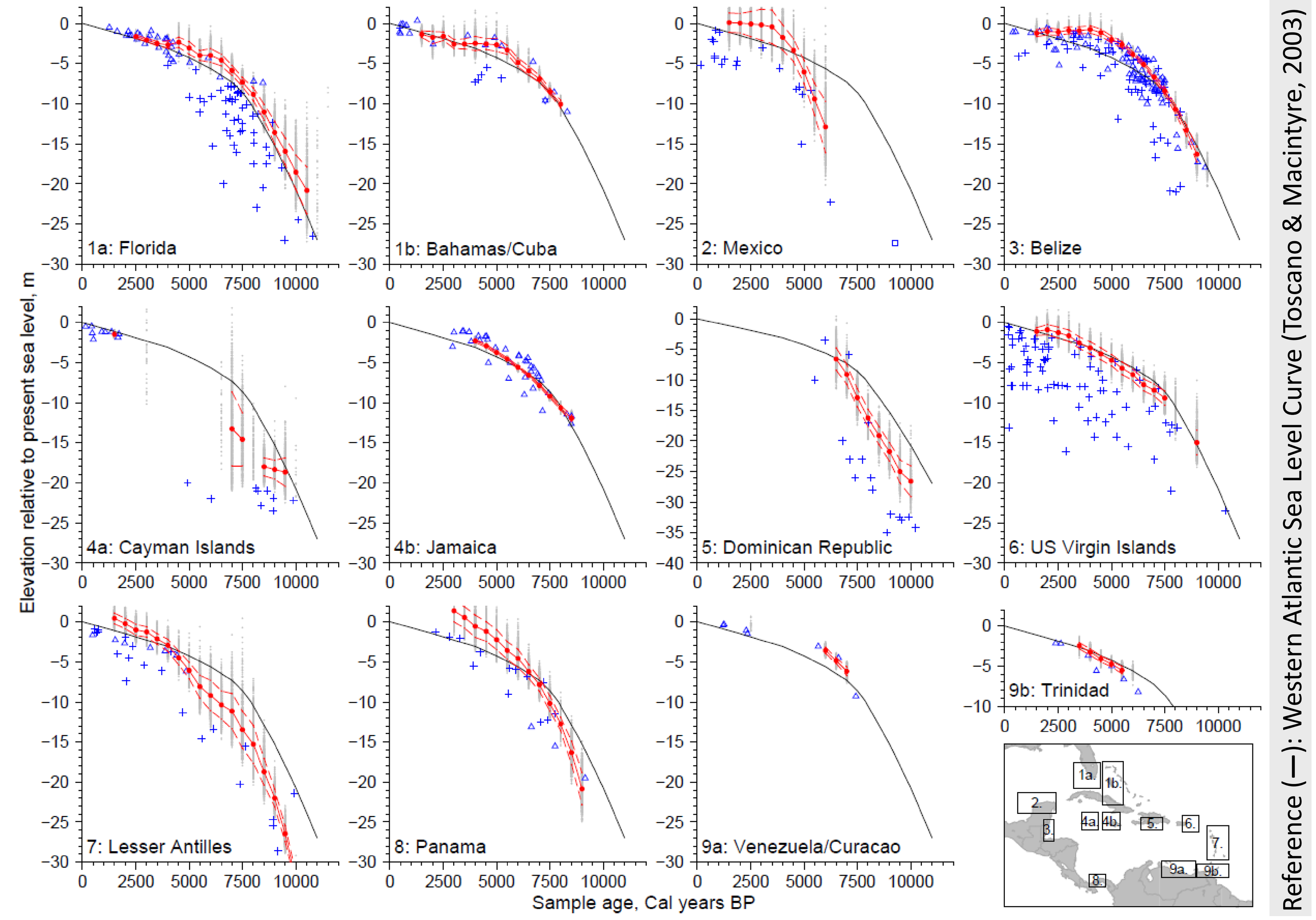




In each sub-region there are 1000 'sea-level realisations'. For each realisation, we derive positions (•) within successive, overlapping, 3000 year time windows. We calculate the mean (•) and standard deviation (- -) to give a probabilistic, *relative* palaeo sea-level curve.

Do the reconstructions show valid changes across the Caribbean?

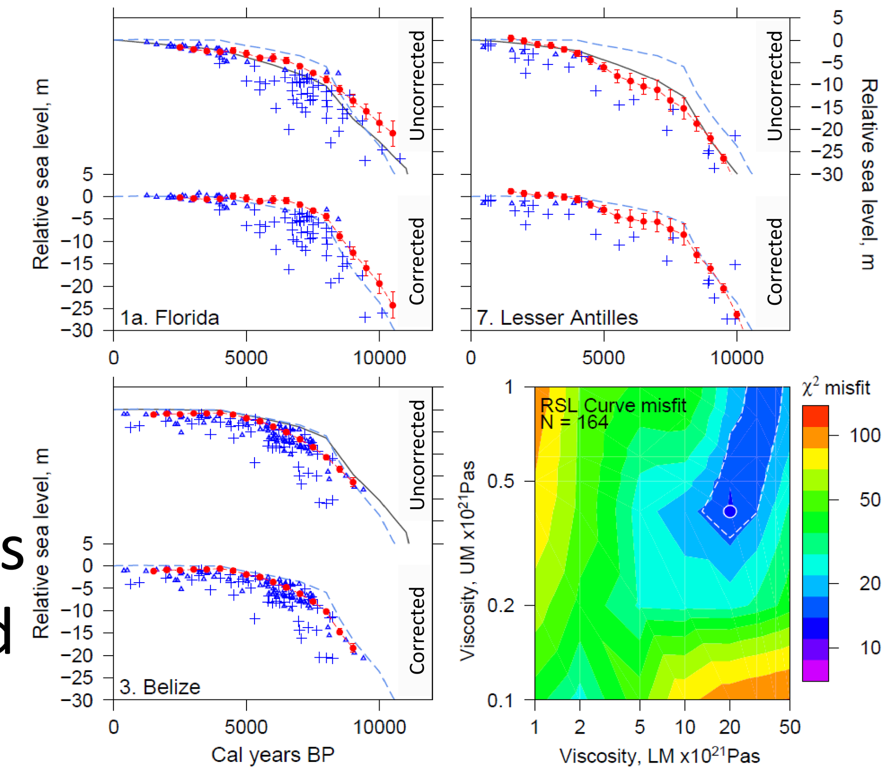
Yes, the curves show distinct spatio-temporal variability. For example, relative sea level was up to 10 m higher in Florida compared to the Lesser Antilles around 9000 cal yr BP, yet sea-level in the Lesser Antilles reached present day levels at least 500 years earlier than Florida, around 2000 cal yr BP.



What causes the sea-level rise?

We correct the reconstructed curves (-•-) for the difference between the optimum glacial isostatic adjustment model (Mitrovica & Milne, 2003; Peltier, 2004) derived sea-level curves (—) and the eustatic rise (- -).

Despite the variable tectonic setting in the Caribbean, the Holocene sea-level rise is largely explained by melt-water from the last deglaciation, loading the ocean basins causing subsidence, in accord with Milne & Peros (2013).



References

Chalker, B. E. (1981), Simulating light-saturation curves for photosynthesis and calcification by reef-building corals, Mar Biol, 63, 135-141.

Milne, G. A., and M. Peros (2013), Data-model comparison of Holocene sea-level change in the circum-Caribbean region, Global Planet Change, 107, 119-131.

Mitrovica, J. X., and G. A. Milne (2003), On post-glacial sea level: I. General Theory, Geophys J Int, 154 (2), 253-267.

Peltier, W. R. (2004), Global Glacial Isostacy and the Surface of the Ice-age Earth: The ICE-5G (VM2) Model and GRACE, Annu Rev Earth Pl Sc, 32, 111-149.

Toscano, M. A., and I. G. Macintyre (2003), Corrected western Atlantic sea-level curve for the last 11,000 years based on calibrated 14C dates from Acropora palmata framework and intertidal mangrove peat, Coral Reefs, 22, 257-270.

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