

# Silicon isotopes in an EMIC's ocean: sensitivity to runoff, iron supply and climate

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## Abstract

The isotopic composition of Si in biogenic silica (BSi), such as opal buried in the oceans' sediments, has changed over time. Paleo records suggest that the isotopic composition, described in terms of  $\delta^{30}\text{Si}$ , was generally much lower during glacial times than today. There is consensus that this variability is attributable to differing environmental conditions at the respective time of BSi production and sedimentation. The detailed links between environmental conditions and the isotopic composition of BSi in the sediments are, however, controversially discussed in the literature. In this study, we explore the effects of a suite of offset boundary conditions during the LGM on the isotopic composition of BSi archived in sediments in an Earth System Model of intermediate complexity. Our model results suggest that a change in the isotopic composition of Si supply to the glacial ocean is sufficient to explain the observed overall low(er) glacial  $\delta^{30}\text{Si}$  in BSi. All other processes explored triggered model responses of either wrong sign or magnitude, or are inconsistent with a recent estimate of bottom water oxygenation in the Atlantic Sector of the Southern Ocean. Caveats, mainly associated with generic uncertainties in today's pelagic biogeochemical modules, remain.

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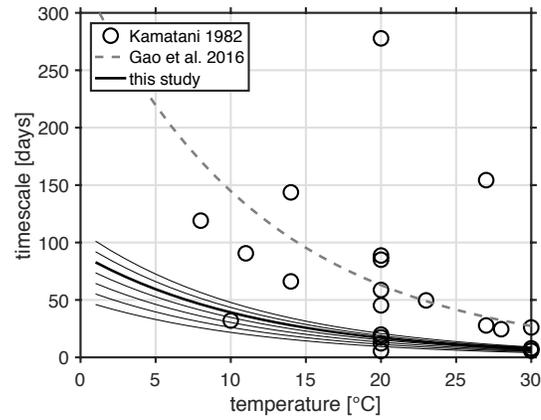
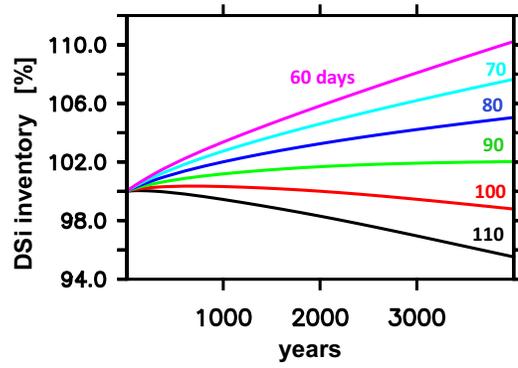
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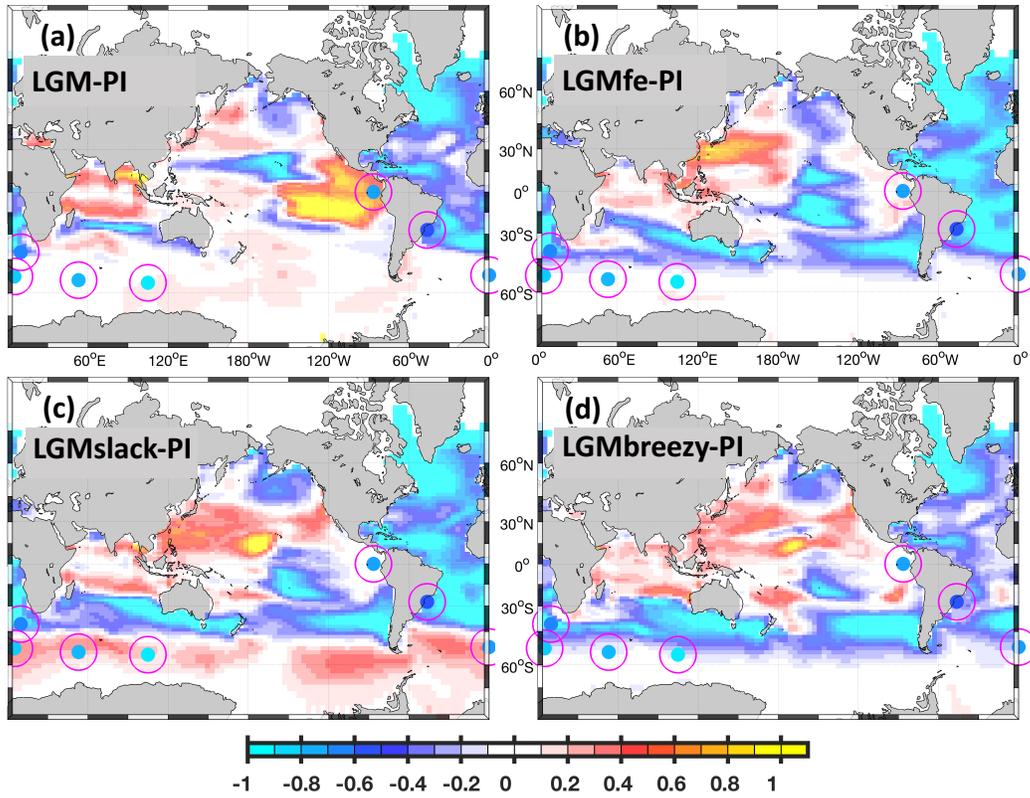
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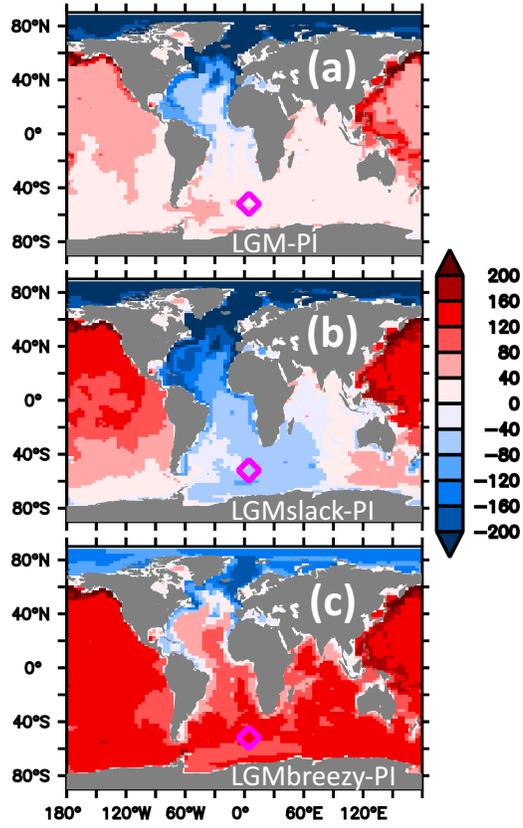
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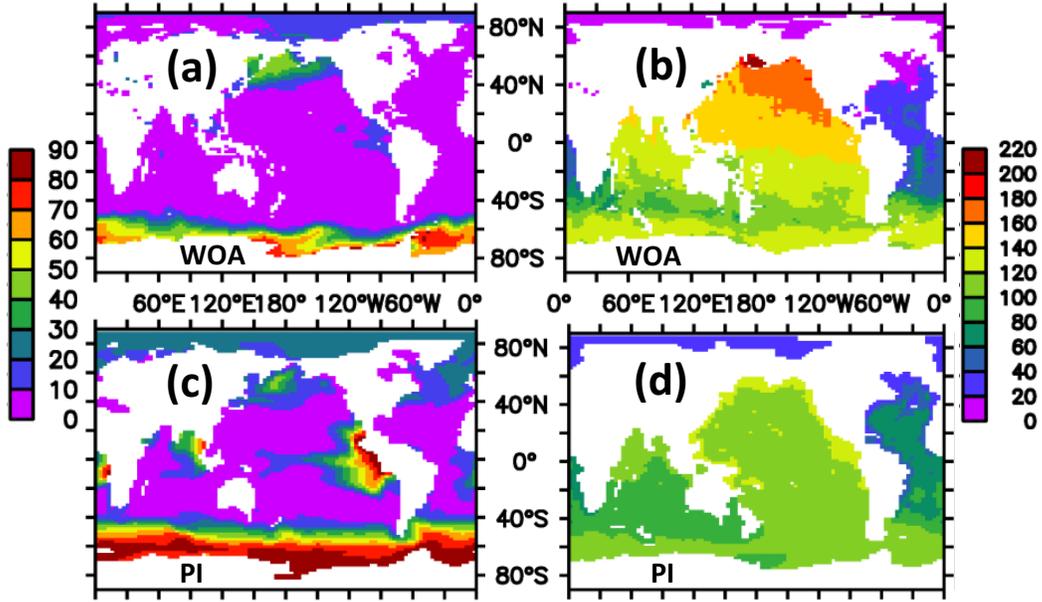
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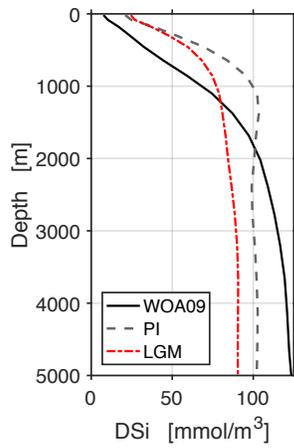
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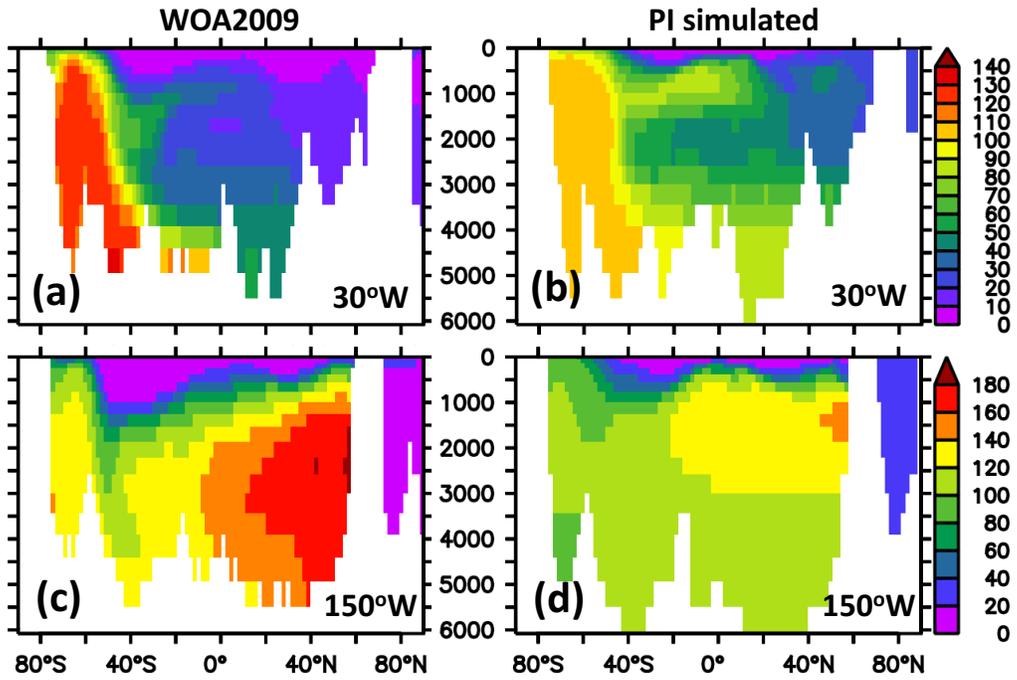
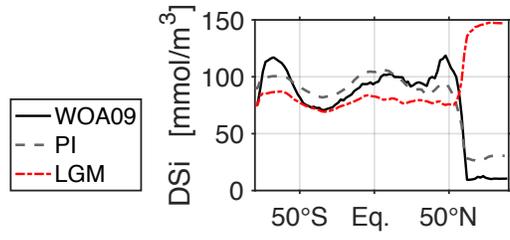


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Figure A.5. Meridional sections over depth (in m) of  $\text{PO}_4$  in units  $\text{mmol Si m}^{-3}$ . Panel (a) and (c) refer to observations (Garcia et al., 2010) and panel (b) and (d) to the preindustrial simulation.

651 nutrient biased low it seems unlikely that a deficient circulation is the cause for these  
 652 biases (although this can not be ruled out). This suggests that the SO nutrient trapping  
 653 relates strongly to the biogeochemical model parameters. One conclusion from this may  
 654 be that the biogeochemical model is better tuned with respect to phosphate than to DSi.  
 655 This is to be expected because of the wider use of the phosphate-based biogeochemical  
 656 model and the much shorter equilibration time scales for phosphate which facilitate the  
 657 respective tuning to observations. In the Pacific, however, the situation differs, and sub-  
 658 surface maxima in the northern hemisphere (except the Arctic) are too low for both phos-  
 659 phosphate and DSi. Following our reasoning above this may be indicative for flaws in the ocean  
 660 circulation module. Please note, however, that the attribution of flaws in model behav-  
 661 ior to respective processes is challenging and may even be impossible given the current  
 662 set of observations (e.g. Loptien and Dietze, 2019).

663 Table A.1 provides a quantitative estimate of how our DSi/BSi module compares  
 664 against the underlying biogeochemical and ocean circulation module of Brennan et al.  
 665 (2012). The simulated temperature variance is overestimated by 3% and the tempera-  
 666 ture bias is 0.6 K, corresponding to 9% relative to the standard deviation in the obser-  
 667 vations. The respective bias to standard deviation of salinity is with 0.03 even smaller  
 668 (5% relative to the standard deviation in the observations). Simulated phosphate con-  
 669 centrations are, surprisingly, even closer to observations than simulated salinities: the  
 670 bias to standard deviation ratio is smaller (4%) and the simulated variance covers 86%  
 671 of observed levels (versus 70% for salinity). Given that the salinity distribution directly  
 672 affects ocean circulation via density driven pressure gradients, it is remarkable that the mis-  
 673 t in this active physical property can be much larger than the misfit of the rather  
 674 passive (in terms of their effect on circulation) phosphate whose distribution is directly  
 675 shaped by oceanic circulation. This may be an indication that the biogeochemical mod-

References

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