Simulating the distribution of stable silicon isotopes in the Last Glacial Maximum

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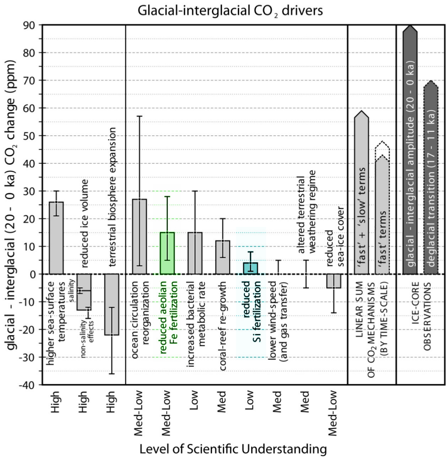
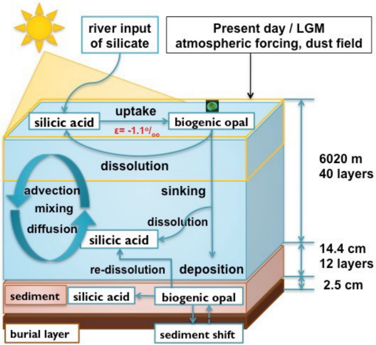
MOTIVATION



Kohfeld et al. (2012)

- changes in Southern Ocean Fe fertilization and Si drawdown are one hypothesized contribution to lower glacial pCO_2
- ultimate test: Si accumulation rates and δ^{30}Si from sediment cores
- but these need interpretation: models can help to check assumptions, and extrapolate to carbon fluxes

MODEL / MODEL RUNS



biogeochemical model: HAMOCC 5.1, with ocean & sediment, weathering fluxes prescribed

added to that: ^{30}Si cycle, with constant fractionation by diatoms (Gao et al, 2016)

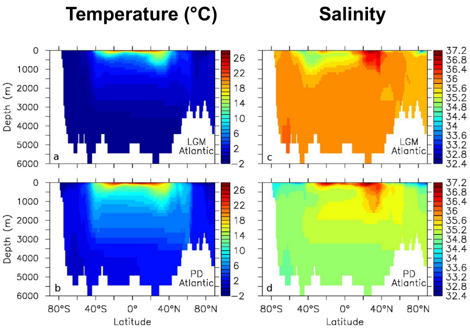
forced by atmospheric fields from coupled climate model for LGM and pre-industrial (Zhang et al. 2013)

integrated for 10000 years with climatological forcing

LGM sea-level lowered by 116 m, ocean inventories of S and nutrients preserved

stronger dust deposition in LGM

LGM OCEAN VS. PRE-INDUSTRIAL



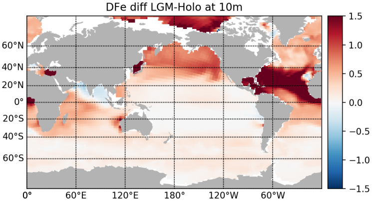
temperature and salinity in Atlantic for LGM and PI

Prominent changes:

- SO winter sea ice area ≈2 times larger
- saltier AABW, filling a larger fraction of the ocean
- weaker and somewhat shallower Atlantic meridional overturning

DUST BRINGS IN MORE FE IN LGM

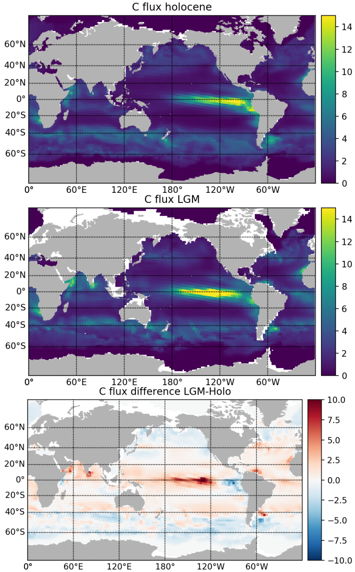
- glacial increase in dust deposition drives higher dissolved iron concentrations
- increase is modest in Southern Ocean: despite large fractional change in dust deposition it still is small compared to upwelling
- caveat: The model only takes into account dust as iron source: changes in sedimentary iron fluxes are absent



change in sea surface dissolved iron, driven by changes in dust deposition

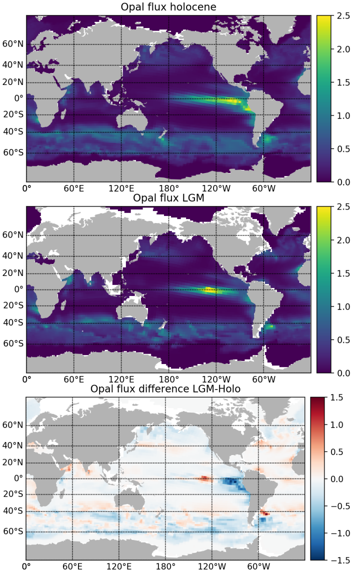
CHANGES IN EXPORT PRODUCTION

- equatorward shift in SO productivity in LGM, due to extended sea-ice cover
- increased productivity in most of the equatorial Pacific
- is this due to more diatom growth, driven by silicic acid leakage from the Southern Ocean, transported in SMPW and AAIW?



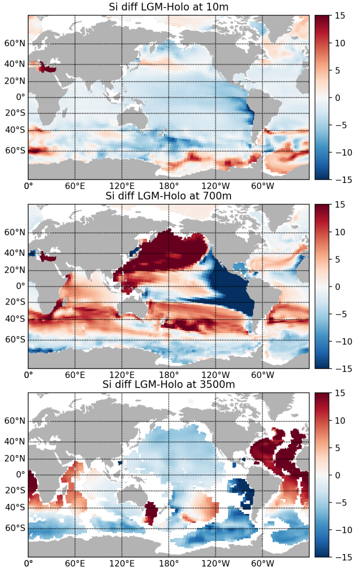
AND IN OPAL EXPORT

- general pattern is similar for opal export
- but: contrary to the expectations of the Silicic Acid Leakage Hypothesis, there is no increase but a decrease of diatom export in the eastern tropical Pacific!
- and an increase in the tropical Atlantic
- this agrees with sediment core findings by Bradtmiller et al. (2006, 2007)

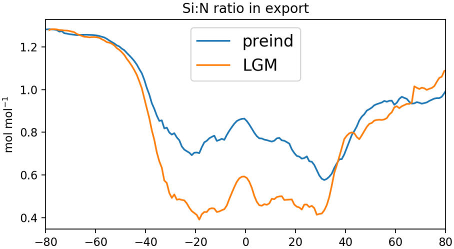


$Si(OH)_4$ DISTRIBUTION CHANGES

- surface $Si(OH)_4$ is reduced thoughtout tropical and subtropical oceans, but most in eastern tropical Pacific
- $Si(OH)_4$ increases in Antarctic Intermediate and Subpolar Mode Waters, *except in the eastern tropical Pacific*
- basin shift in diatom productivity leads to decrease in deep Pacific $Si(OH)_4$, and to increase in deep Atlantic $Si(OH)_4$



A CAVEAT



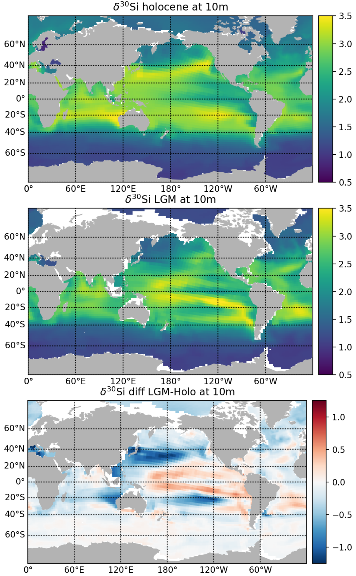
Si:N ratio in 100m sinking flux from the model

A central element of the Silicic Acid Leakage Hypothesis is missing in the model: Si:N ratio in diatoms varies as a function of Fe limitation, leading to higher Si:N drawdown ratio in the Southern Ocean (e.g. Dunne et al. 2007)

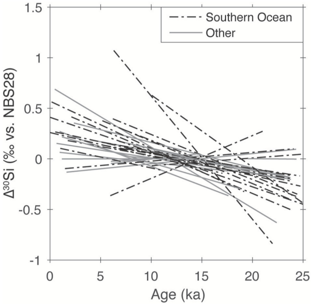
But: very similar results also found in a model that includes this effect: See poster BN34A-1144:
Ye et al. "Modelled changes in the Southern Ocean Si:N drawdown ratio in the glacial ocean, and their biogeochemical consequences"

CHANGES IN δ30SI

- both in pre-industrial and in LGM, the distribution sea surface δ30Si is consistent with fractionation models: low δ30S in regions of abundant $Si(OH)_4$, high in $Si(OH)_4$-depleted regions
- but the *change* in δ30Si is neither clearly related to changes in surface $Si(OH)_4$, nor to changes in diatom productivity

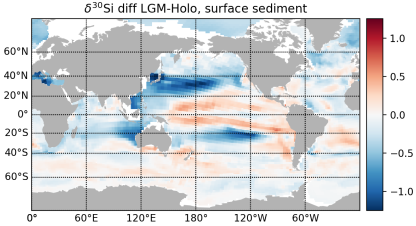


CHANGES IN SEDIMENTARY δ30SI



Sutton et al. (2018)

Many (not all) δ^{30}Si glacial-interglacial records from marine sediment cores show lower glacial δ^{30}Si, higher interglacial δ^{30}Si

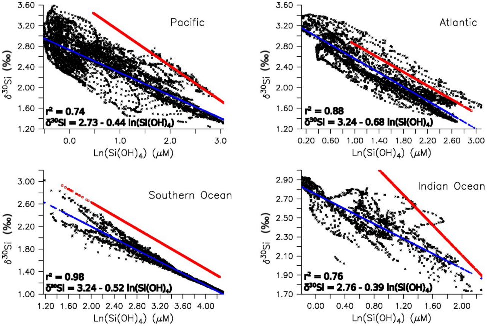


model shows a more mixed pattern: higher δ^{30}S in eastern equatorial Pacific

the pattern is not the same as that in diatom productivity change!

caveat: unchanged δ^{30}S in weathering fluxes!

HOW TO INTERPRETE δ^{30}SI?



blue: best fit for LGM state, red: best fit for PI state

- surface δ^{30}Si values show increased values at low ln(Si(OH)$_4$), consistent with Raleigh fractionation
- slope of δ^{30}Si vs. ln(Si(OH)$_4$) varies between ocean basins, despite constant diatom fractionation
- δ^{30}Si vs. ln(Si(OH)$_4$) relation is different in LGM and PI climate states!

CONCLUSIONS & THANK YOU FOR LISTENING!

- modeled LGM has less diatom production in eastern tropical Pacific, more in tropical Atlantic
- agrees with some sediment core recostructions but not with SALH
- drives some shift of Si from deep Pacific to deep Atlantic
- glacial δ^{30}Si at surface generally lower in LGM, except in tropical Pacific
- fractionation-like relation between δ^{30}Si and Si differs between ocean basins and between climate states

Also go and see poster BN34A-1144: *Ye et al. "Modelled changes in the Southern Ocean Si:N drawdown ratio in the glacial ocean, and their biogeochemical consequences"!*