ALFRED-WEGENER-INSTITUT
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Marine radiocarbon simulations carried out with a global multi-resolution ocean model

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Prior to the Holocene, Marine Reservoir Ages (MRAs, i.e. the ^{14}C ages of marine surface waters) are poorly constrained through reconstructions. Moreover, the entire database of marine ^{14}C records gets increasingly patchy and sparse the further one steps backwards in time. Model simulations provide a valuable interpretation tool and can help to fill spatial and temporal gaps. However, ^{14}C paleorecords typically originate from continental margins, marginal seas, or tropical lagoons. These regions are not properly resolved by default coarse-resolution ocean models, which may result in regional model and hence interpretation biases.

PAL MOD GERMAN CLIMATE MODELING INITIATIVE

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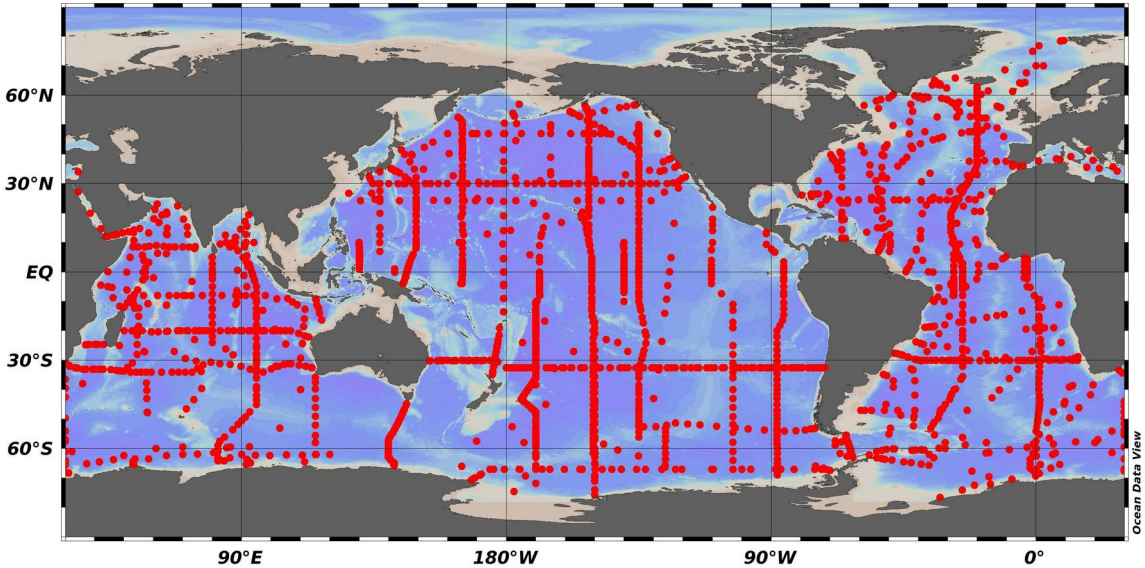
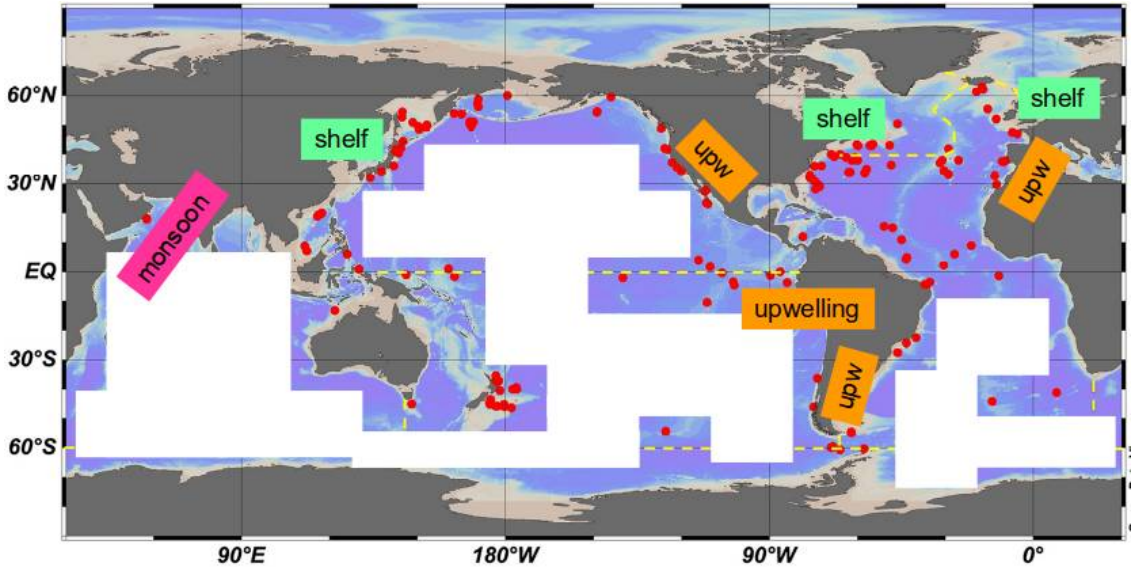
Present and past ^{14}C records



1972 – 2012

GLODAP v2 database
(doi: 10.5194/essd-8-297-2016)



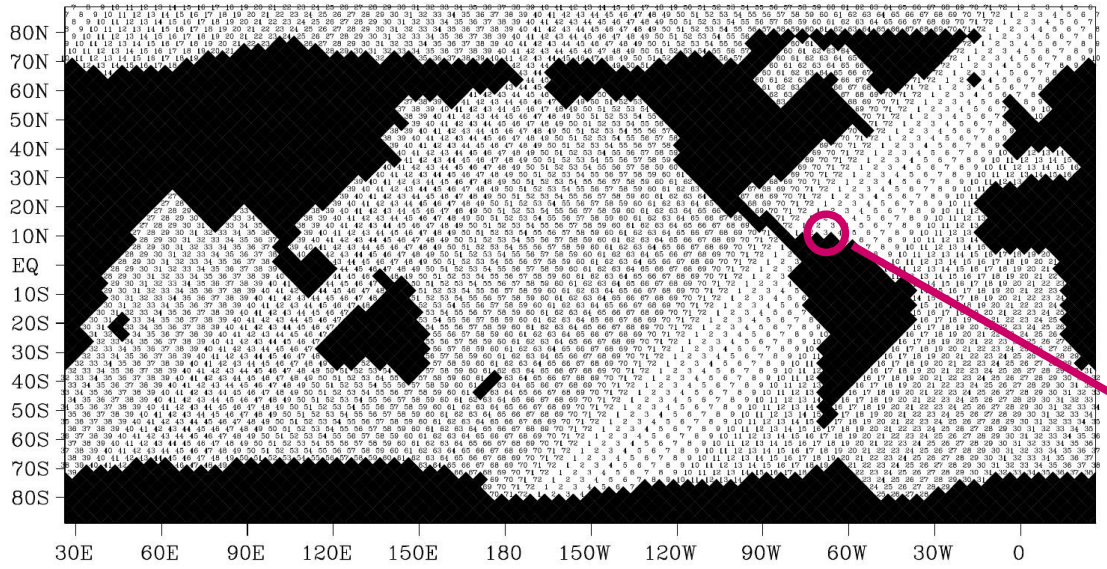
Past 40 kyrs

Sites may not be representative for the global ocean circulation

Compilation by Zhao et al., 2018
(doi:10.1002/2017PA003174,
figure modified)

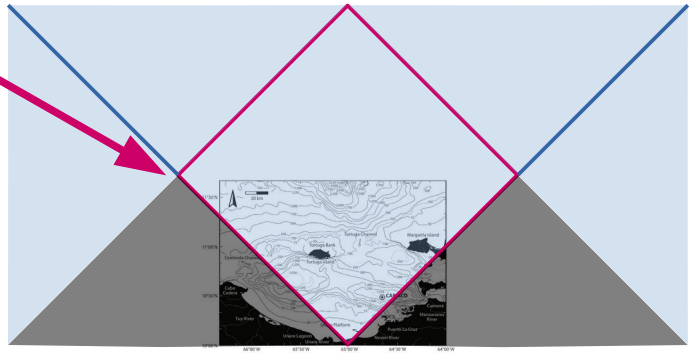
The resolution problem of ^{14}C models

Mesh of the LSG OGCM, applied for IntCal20 & Marine20



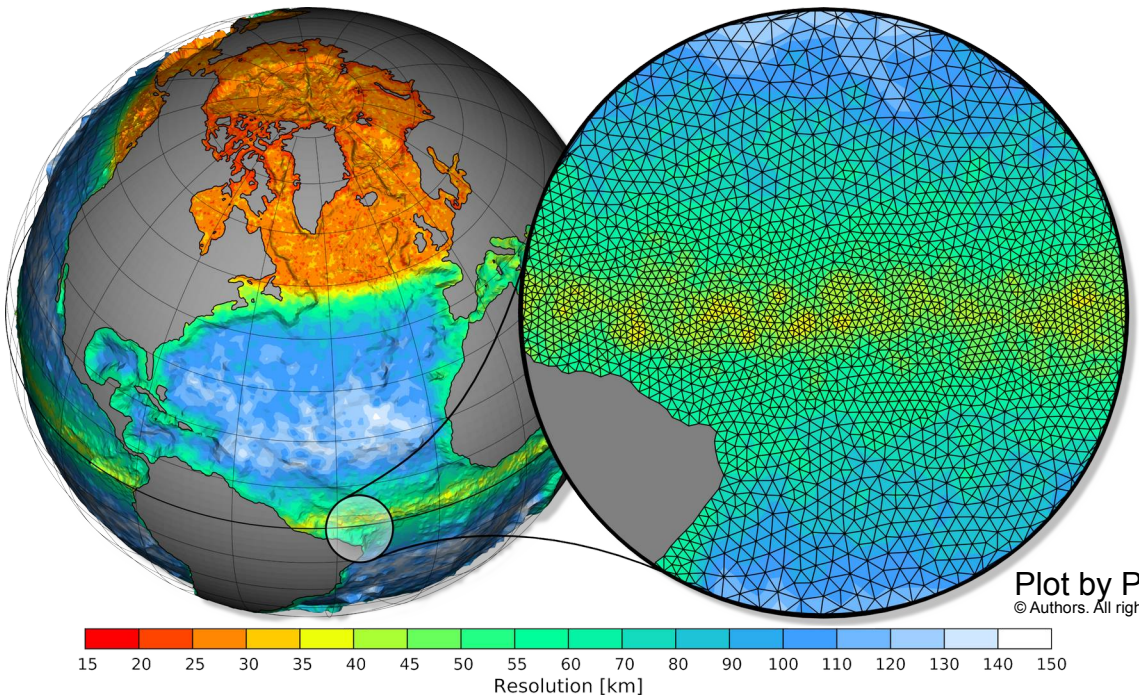
~5000 horizontal grid points,
3.5° horizontal resolution,
22 levels in the vertical

Unresolved Cariaco Basin



If we increase the horizontal resolution, the conventional approach involving uniform meshes results in computational costs which are prohibitive in most cases. To overcome these issues, we have implemented ^{14}C into the state-of-the-art ocean model **FESOM2** which employs unstructured meshes with variable resolution.

FESOM2 multi-resolution mesh



127,000 2-D vertices,
rectangular analog 0.7°,
47 levels in the vertical

Plot by P. Scholz

FESOM2 employs unstructured meshes with variable horizontal resolution. This approach permits zooming into certain regions of interest while keeping the model resolution in other areas sufficiently moderate.

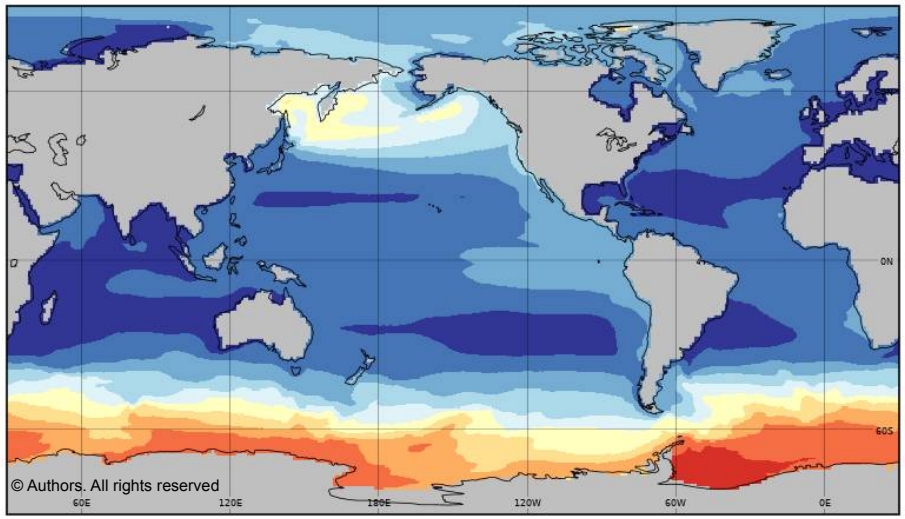
FESOM2 simulation setup

- Global multiresolution approach with unstructured meshes
- Present-day simulation: CORE-II climate forcing
- Glacial simulation: Climate forcing for the Last Glacial Maximum from coupled climate simulations (Shi, pers. comm.)
- Radiocarbon is simulated as $F^{14}R_{\text{oce-atm}}$
- Integration period 7000 – 10,000 years so far – the interior of the Pacific Ocean is not equilibrated yet
- No model calibration with bomb ^{14}C so far – **at the current stage, all results are preliminary and should only be considered as proof of concept**

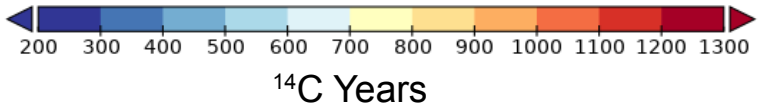
Model description papers:

Danilov et al., 2017, doi:10.5194/gmd-10-765-2017
Koldunov et al., 2019, doi:10.5194/gmd-12-3991-2019
Scholz et al., 2019, doi:10.5194/gmd-12-4875-2019

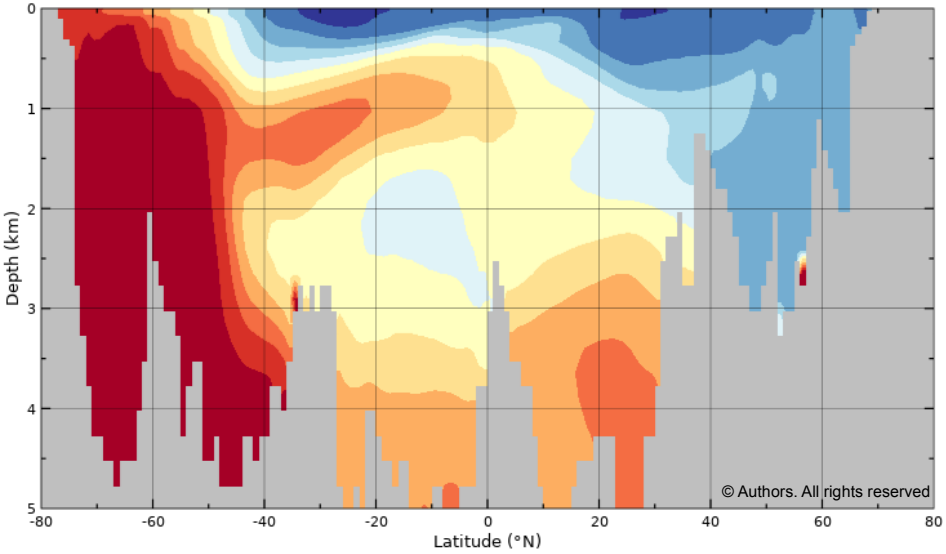
^{14}C Ages: Pre-Nuclear Present Day (PNPD)



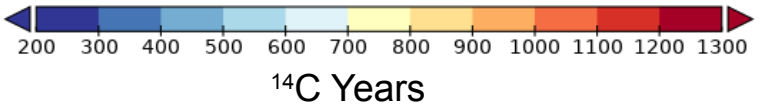
Marine Reservoir Age



^{14}C Years



^{14}C Age along 30°W (Atlantic)



^{14}C Years

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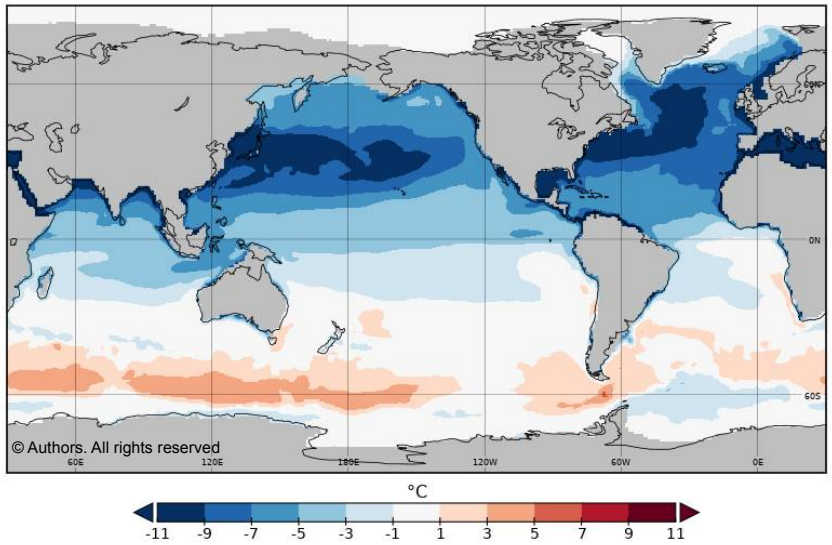
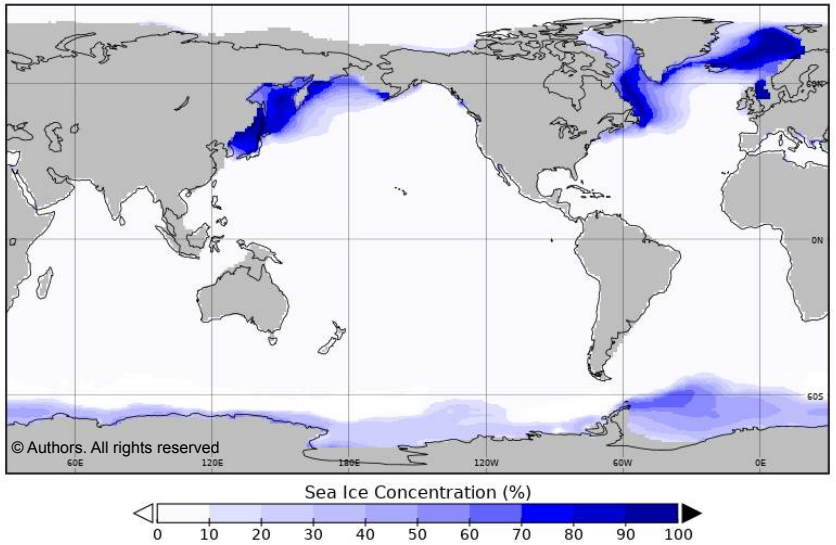
Glacial simulation: Ocean climate changes

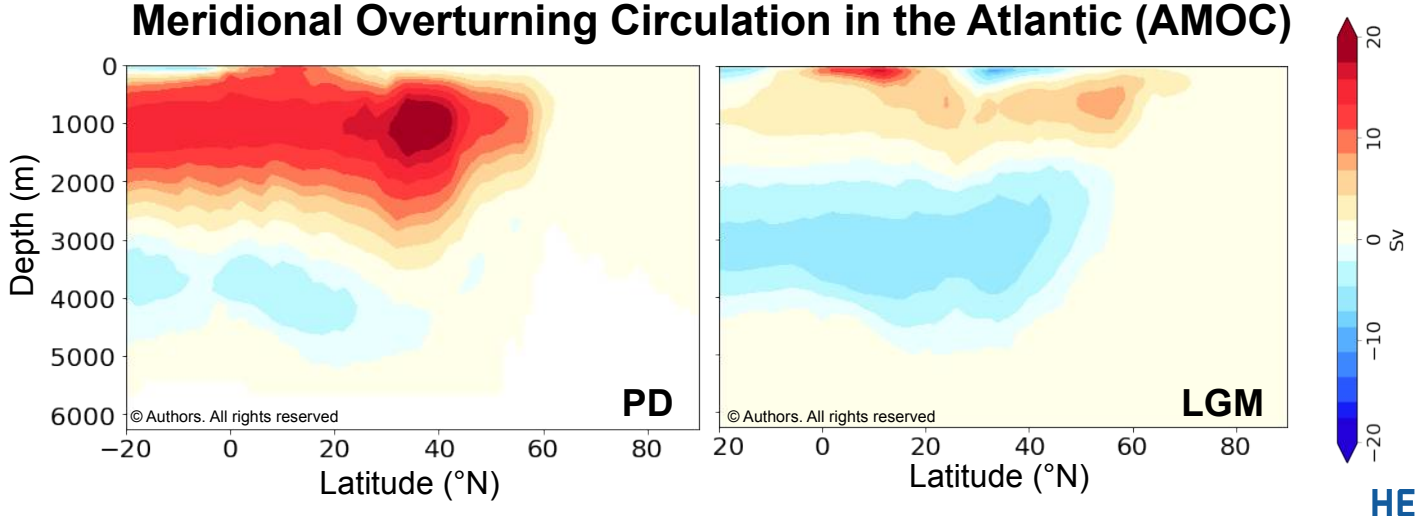
SST Difference



Sea Ice Difference



Meridional Overturning Circulation in the Atlantic (AMOC)



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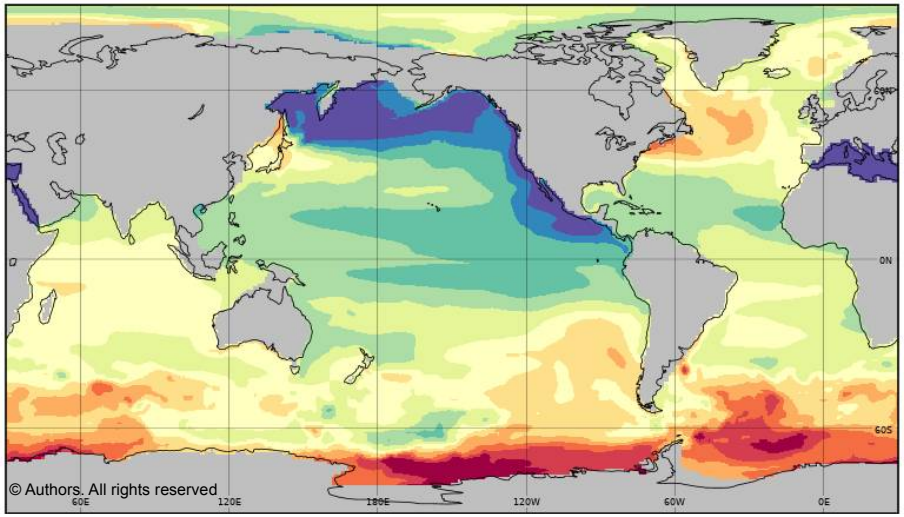
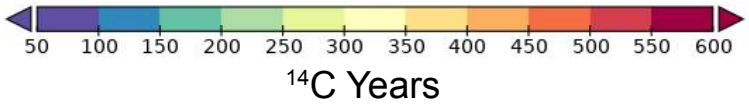
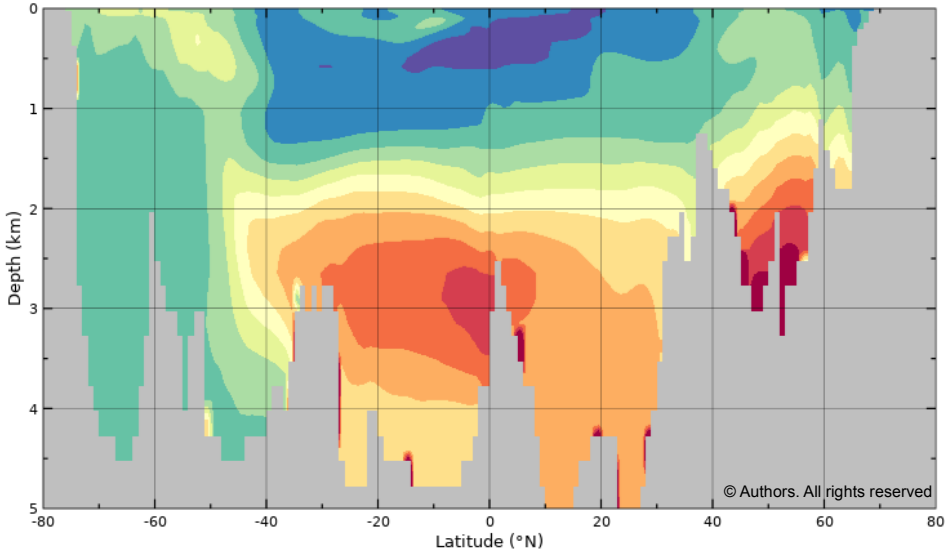
^{14}C Ages: Last Glacial Maximum

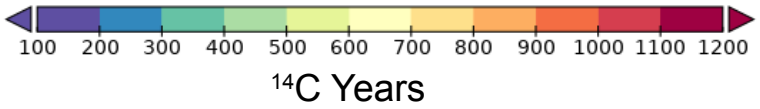


MRA Difference LGM - PNPD





^{14}C Age Difference @30°W (Atlantic)



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Take Home Messages

- The global multiresolution approach overcomes the resolution problem of the current generation of ^{14}C-equipped ocean general circulation models.
- FESOM2 is integral part of the coupled AWI Earth System Model which permits to study climate – ^{14}C cycle interactions in a consistent way.
- First test simulations show promising results.