Last Glacial Maximum Data Assimilation (`lgmDA`) version 2.1

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Overview: `lgmDA` v2.1 is an update to the data assimilation product published in Tierney et al., (2020). It uses the same proxies and DA parameters as v1.0 but incorporates a wider range of priors, drawn from the model simulations described in Osman et al. (2021). Output now includes monthly SST, sea ice, and SAT as well as mean annual precipitation. We encourage caution in the interpretation of monthly quantities as they have not been validated with independent, monthly-resolved proxies.

v2.1 reverts to using preindustrial priors without prognostic phenology, as done in the original Tierney et al., (2020) paper. The reason for this change is that v2.0 had a very cold Late Holocene solution with unrealistic sea ice patterns. The LGM timeslice remains unchanged from v2.0.

Description of model priors: As in Tierney et al., (2020), all model prior states are 50-yr average values. For the LGM timeslice, model priors ($N = 66$) include:

- iCESM1.2 21ka (included in v1)
- iCESM1.3 21ka (included in v1)
- iCESM1.2 18ka (included in v1)
- iCESM1.2 16ka (new for v2)

For the Late Holocene timeslice, model priors ($N = 42$) include:

- iCESM1.2 PI (included in v1)
- iCESM1.3 PI (included in v1)
- iCESM1.2 3ka (included in v1)

Description of proxy data and forward models: Proxy data and forward models used are identical to Tierney et al. (2020) ($N = 956$ proxies for the LGM, $N = 879$ proxies for the Late Holocene).

Description of data assimilation parameters: Data assimilation parameters are identical to Tierney et al. (2020), with localization set at 12,000 km, proxy R set at $R_g/5$. 25 iterations

were conducted, withholding 25% of the proxies in each iteration for validation. Non-linear variables (precipitation and sea ice) were transformed prior to assimilation to ensure that the posterior was properly bounded. Annual precipitation was transformed using the natural log, and sea ice fraction was transformed using the logit function.

Validation: Validation with independent ice core and speleothem proxies for δ^{18}O of precipitation is $R^2 = 0.64$, which is generally comparable to v1.0 ($R^2 = 0.67$).

LGM cooling: The change in global mean surface temperature (GMST; LGM − Late Holocene) in `lgmDA` v2.1 is −5.9°C (−6.4 to −5.5°C, 95% CI). similar to v1 (−6.1°C, −6.5 to −5.7°C, 95% CI).

Patterns in LGM cooling: The figure below shows changes in SST and SAT for version 1.0 and 2.0 of the `lgmDA`, respectively. Patterns of change are generally similar although version 2 has less cooling in the central Pacific, the eastern Pacific cold tongue, and the southern Indian Ocean. v2.1 has elevated cooling off of Baja California.

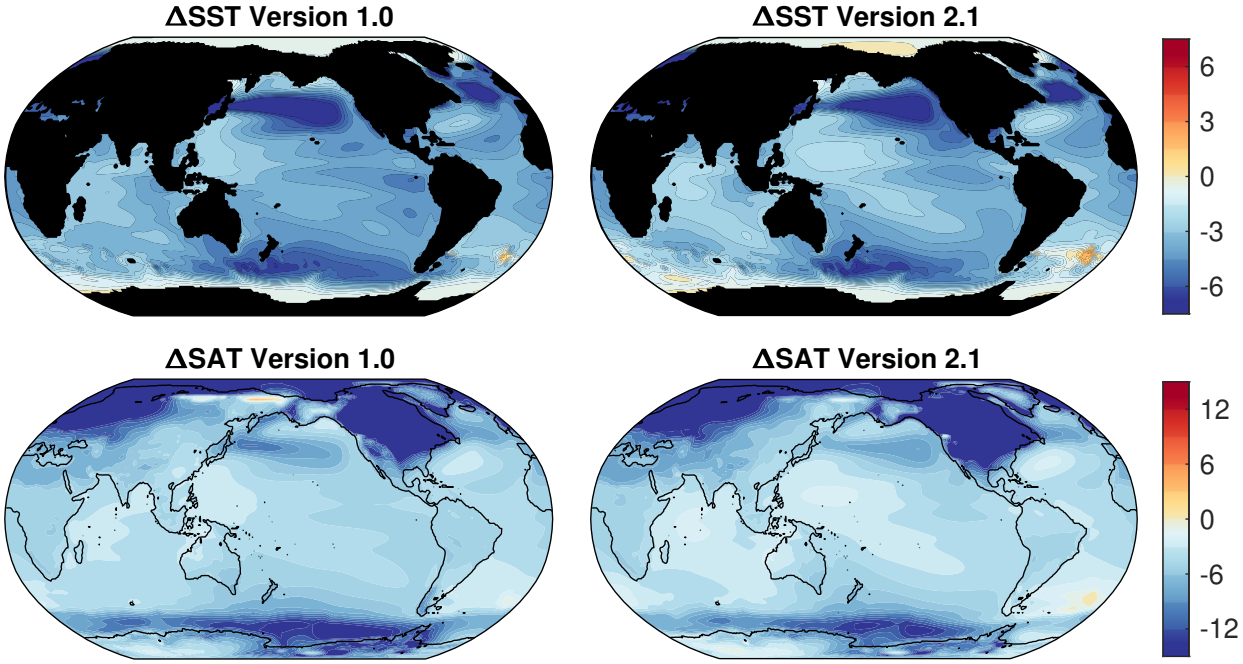

Figure 1: Comparison of changes in SST and SAT (LGM − Late Holocene) between versions 1.0 and 2.1 of `lgmDA`.

Monthly Output: v2.0 includes monthly climatologies for SAT, SST, and sea ice fraction. The annual mean of the posterior monthly SST and SAT values matches the posterior annual mean within machine precision. This is not the case for sea ice fraction, however, because this variable was transformed with a logit function prior to data assimilation to preserve the 0−1 fractional scale, then converted back after the assimilation. Hence, updates to the annual mean sea ice cover and monthly sea cover scale in transformed units but not in the untransformed units, and the mean of monthly sea ice will not match the posterior annual mean.

A further note about sea ice: Because sea ice fraction is a highly non-linear climatic variable, it can be pushed from low (0) to high (1) values dramatically by the proxies. Without external

validation, we cannot ascertain how reliable the sea ice posteriors are. In v2.0 and v2.1, the sea ice posterior for the Late Holocene shows extensive cover in the Atlantic sector of the Southern Ocean in austral summer that seems climatologically difficult to explain. We therefore suggest that the sea ice posteriors be treated with extreme caution.

Citation: When using v2.1, please cite the original `lgmDA` paper:

Tierney, J.E., Zhu, J., King, J., Malevich, S.B., Hakim, G.J., Poulsen, C.J. (2020). Glacial cooling and climate sensitivity revisited. *Nature*, 584, 569–573. `https://doi.org/10.1038/s41586-020-2617-x`.

And ALSO reference the Zenodo data doi for `lgmDA`, which covers v2.1:

`https://doi.org/10.5281/zenodo.5171432`