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Global heat uptake by inland waters

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Heat uptake is a key variable for understanding Earth system response to greenhouse gas forcing. Recent assessments highlighted that most of the excess energy is stored in the oceans, whereas the land, atmosphere and ice melt take up smaller amounts. However, despite the importance of this heat budget, heat uptake by inland waters has so far not been quantified. Here we use a unique combination of global-scale lake models, global hydrological models and Earth system models to, for the first time, quantify global heat uptake by lakes, reservoirs and rivers over the industrial period (1900-2020).

We use a total of 16 different simulations of global-scale lake models and global hydrological models driven by the same bias-corrected climate forcing from four different global climate models, conducted within the framework of the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP). The model output is combined with reservoir and lake data from the Global Reservoir and Dam (GRanD) database and HydroLAKES.

Total inland water heat uptake in the industrial period amounts to 2.8 ± 4.3x1020 J by the end of the period, with the largest uptake realised after 1990. The overall uptake is dominated by warming of natural lakes (2.9 ± 2.0x1020 J, the multi-model mean and standard deviation; 103% of total inland water heat uptake), followed by reservoir warming (5.9 ± 2.7x1018 J; 2.1%). The multi-model mean heat uptake by rivers contributes negatively to the total heat uptake (-0.15 ± 4.3x1020 J; -5.3%), but encompasses a large uncertainty originating from the river storage term, simulated by the global hydrological models. The global picture of positive heat uptake by natural lakes is confirmed at the regional scale in the major lake regions by all global-scale lake model and global climate model combinations. The heat uptake by inland waters makes up ~3.2% of continental heat uptake reported in the IPCC AR5 (2013). The rapid increase in dam construction and resulting reservoir expansion in the second half of the 20th century causes a heat redistribution from ocean to land by storing extra water on land. Remarkably, this heat redistribution exceeds the anthropogenic heat uptake by inland waters by a factor of ~ 9.6, adding up to 27 ± 2.1x1020 J.

Our results overall underline the importance of inland waters for buffering atmospheric warming through enhanced anthropogenic greenhouse gas concentrations.