EGU24-13528, updated on 26 Jan 2025
https://doi.org/10.5194/egusphere-egu24-13528
EGU General Assembly 2024

A MAGICC Arctic Sea Ice Emulator

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CMIP6 models present our best understanding of the Earth system, yet they currently fail to simulate a plausible evolution of sea ice area to changes in the global-mean temperature. We aim to assess whether correcting the temperature and Arctic Amplification biases between CMIP6 models and observations can simulate a sensitivity of sea ice loss to global warming that is within the plausible range. To do this, we develop an emulator that is calibrated to physically-based CMIP6 models and then constrained to observations. Such a tool efficiently translates the global-mean temperature of a specific year into a physically-based and observationally constrained probabilistic ensemble of SIA in each month. This setup allows our emulator to capture the core physical processes of CMIP6 projections, while capturing the observed sensitivity of sea ice loss to global warming through the observational constraint of Arctic Amplification. While there are many application possibilities of our emulator, we use our model here to probabilistically diagnose the timing of an ice-free Arctic Ocean. We find that under a high (SSP5-8.5), medium (SSP2-4.5) and low (SSP1-2.6) emission scenario, an ice-free September Ocean is 'likely' at 1.73 of global warming above the pre-industrial level, however we note that the probability in the lower emission scenario reduces to 'unlikely' in the late 21st century as the global temperature partially recovers. Our projections suggest that the probability of an ice-free summer ocean rises rapidly from 'unlikely' at 1.5 of global warming to 'likely' at 2 of global warming, stressing the importance of preventing global temperatures rising above 1.5, as the probability of losing sea ice coverage in September rises sharply thereafter. For March, we also find that the observational constraints increase the probability of an ice-free ocean under SSP5-8.5, becoming 'likely' in early 2200, while the probability remains very low under SSP2-4.5 and SSP1-2.6 as less than 5% of models reach ice-free conditions. Our projections suggest an ice-free summer ocean could occur at 0.5 cooler levels than the CMIP6 multi-model ensemble mean implies. Likewise, our approach suggests the probability of an ice-free Arctic Ocean year-round is increased when constraining the Arctic Amplification to observations.