Underestimated future Arctic warming due to unresolved marine heatwaves

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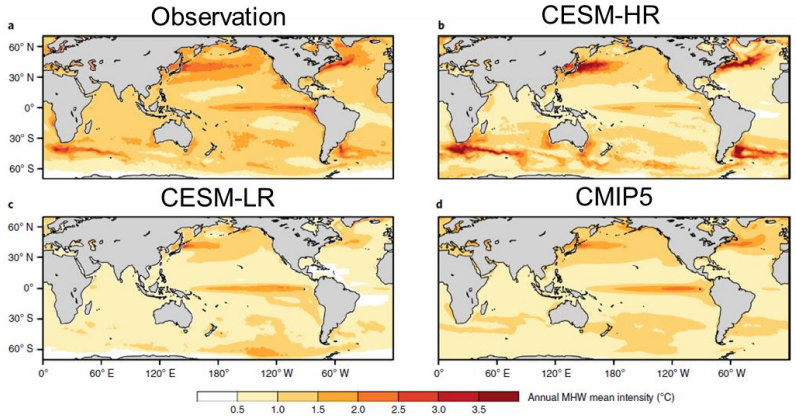
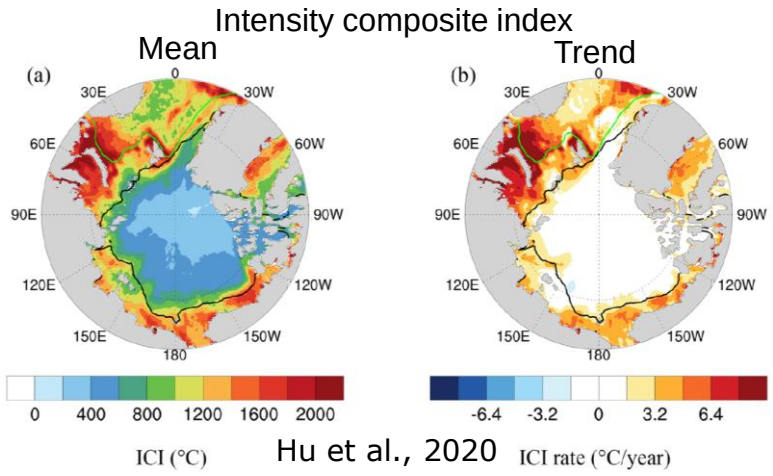
Introduction

Marine heatwaves in high-resolution models

- Marine heatwave (MHW): extreme surface warming episodes that lasts more than 5 days
- **Eddies** and **small-scale air-sea interactions** generate more MHWs (Holbrook et al., 2019; Bian et al., 2023) .
- MHW intensity is **stronger and more realistic** in high-resolution models (Pilo et al.,2019; Guo et al., 2022)

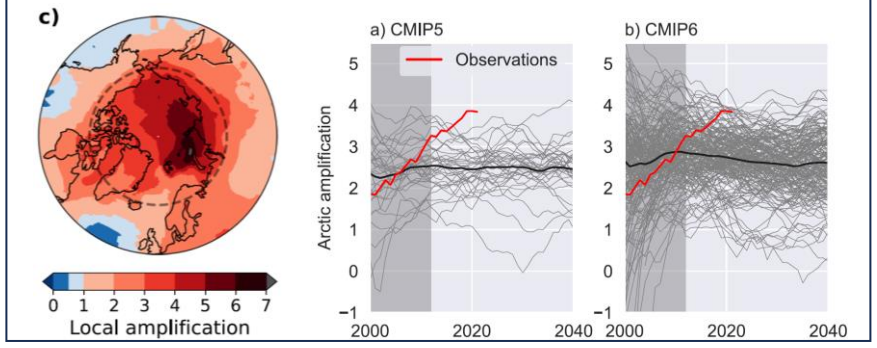


Historical observations show the **Arctic MHWs are getting more intense with sea ice retreating**



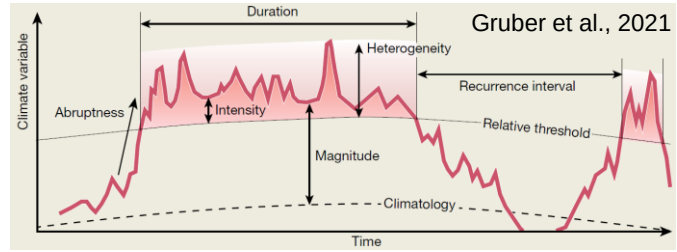
Hu et al., 2020

Arctic amplification is underestimated in CMIP models (Rantanen et al., 2022)



Method

MHW definition: 90% threshold within a 31-year **moving baseline**, to remove the impact from warming trend and just keep the **extreme variability**



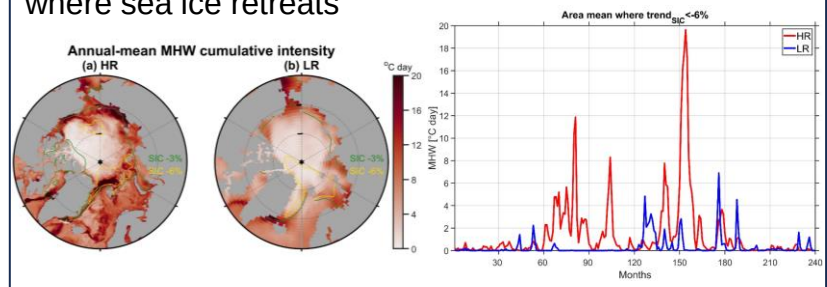
Model (Chang et al., 2020)

- CESM-HR – 0.1° ocean, 0.25° atmosphere
- CESM-LR – 1° ocean and atmosphere

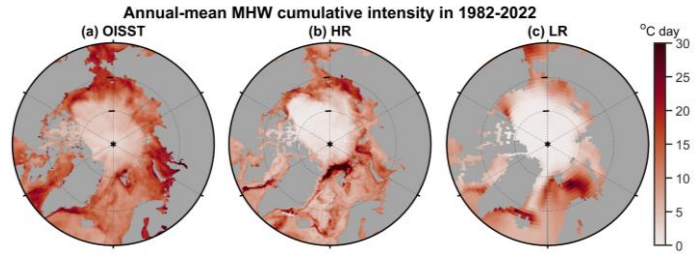
Time span: 1950-2100 (historical and RCP8.5 run)

Arctic MHWs

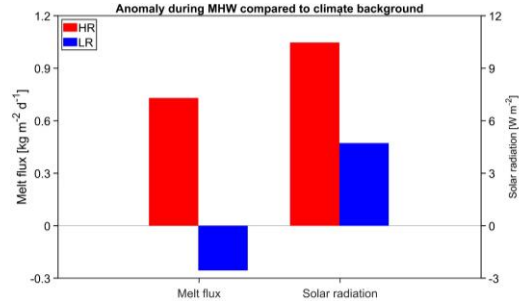
In **HR, much stronger local-scale MHWs** emerge at where sea ice retreats



Although underestimating the MHW intensity, HR shows generally closer magnitude to observations



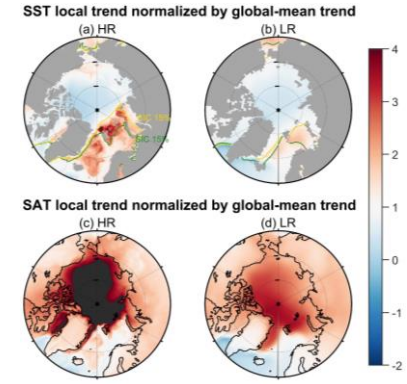
Compared to background climate state (31-year mean of MHW dates), **melt flux and solar radiation during MHWs is a lot stronger in HR than LR**



Arctic warming

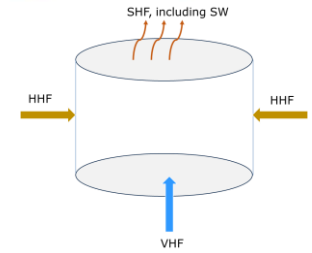
Based on periods when area-mean SIC decreases from 50% to 30%

Enlarged SST trend in HR at where sea ice edge retreats



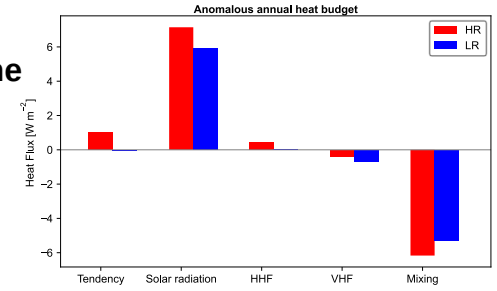
Heat budget analysis

If the MHWs amplify Arctic warming, solar radiation term should be more dominant in HR

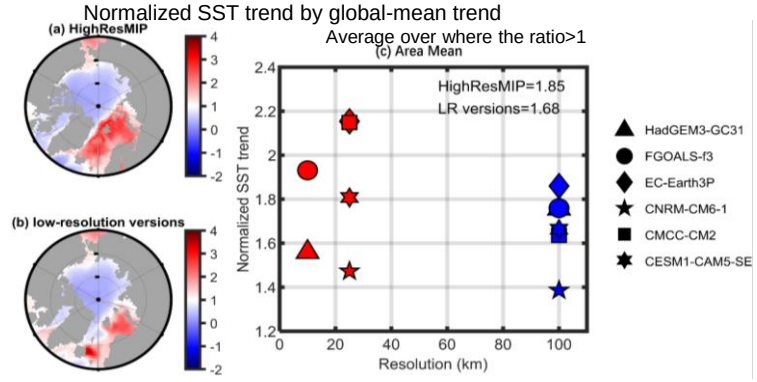


Second half minus the first half of period (SIC 50-30%)

Solar radiation is the main contributor to the further amplified warming in HR



Ocean surface warming in HighResMIP and LR models



Conclusions

The resolved Arctic MHWs in high-resolution model increase the melting of sea ice and thus the ocean absorption of solar radiation in the short term, thereby reinforcing a stronger long-term trend of Arctic warming.

Extremes/(sub)mesoscales ⇨ **Climate transition**

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Changed nature of polar warming in high-resolution climate models

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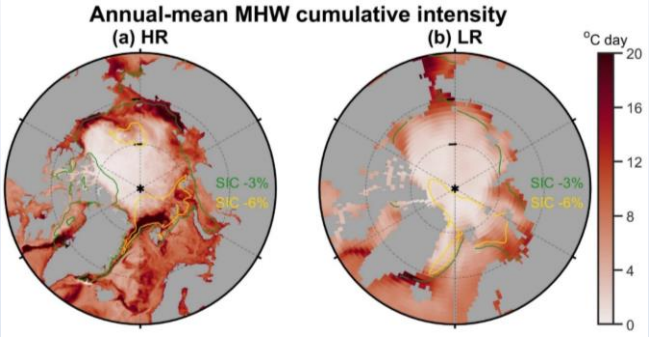
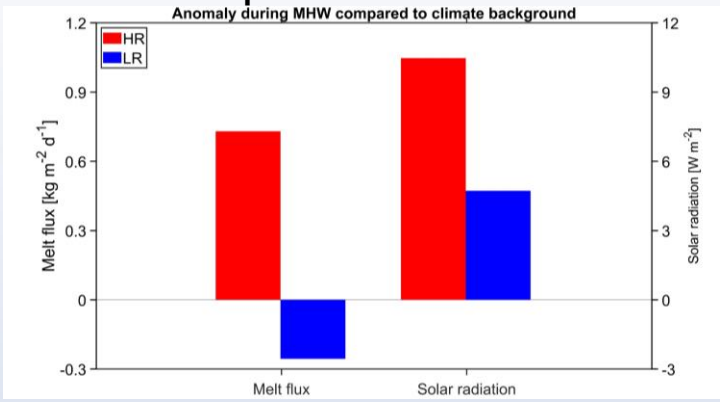
1. Underestimated future Arctic warming due to unresolved marine heatwaves and mesoscale eddies

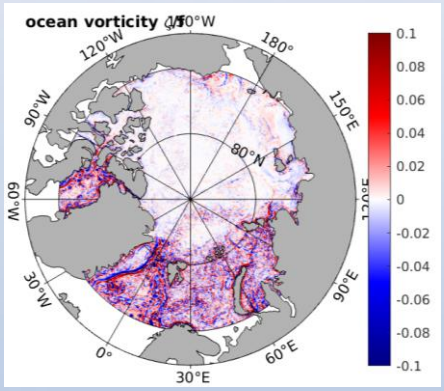
Resolving localized MHWs
(extreme ocean surface warming)

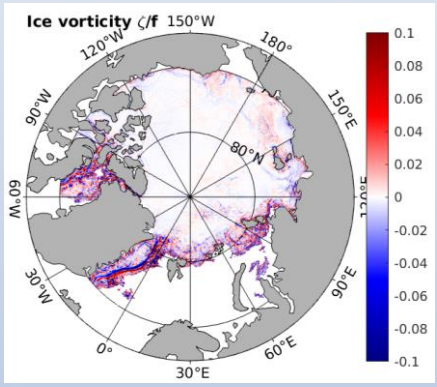


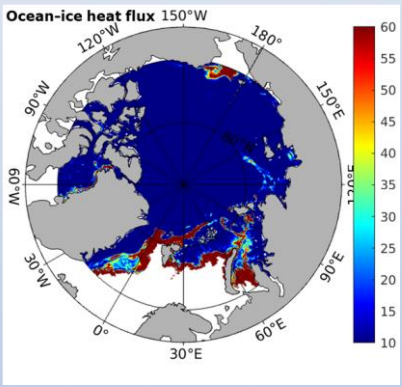
MHWs cause stronger sea ice melt and solar radiation absorption in the short-term



Ocean-ice heat flux induced by ocean eddies increases under global warming

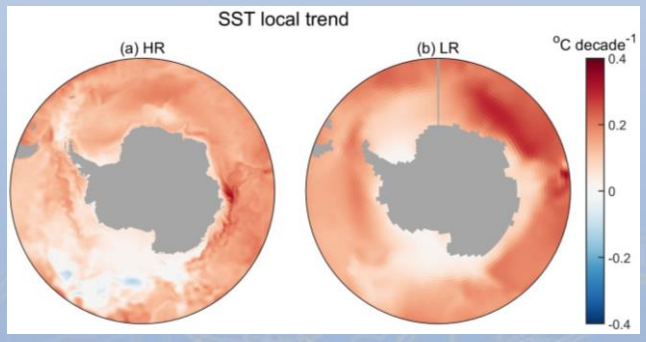


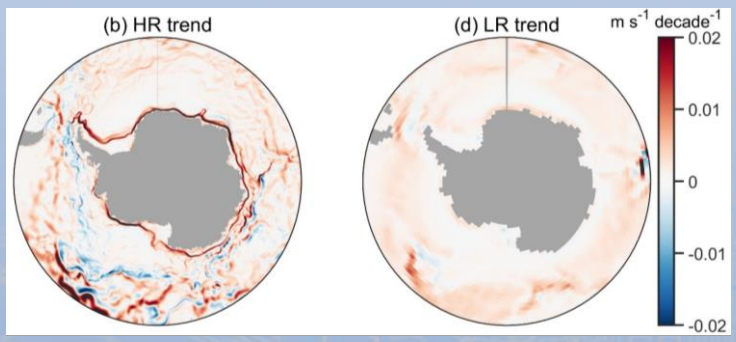




2. Emerging trend and extremes of Southern Ocean cooling in a warming climate

Cooling corresponds to the northward shift of ACC (reason?)





SAIL

Subarctic–Arctic Interest League

SAIL is a research interest league working on the climate and ecological impacts from (sub)Arctic mesoscales and extremes

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