

Explaining the

# Impact of ocean heat transport on sea ice

using a simple energy-balance model

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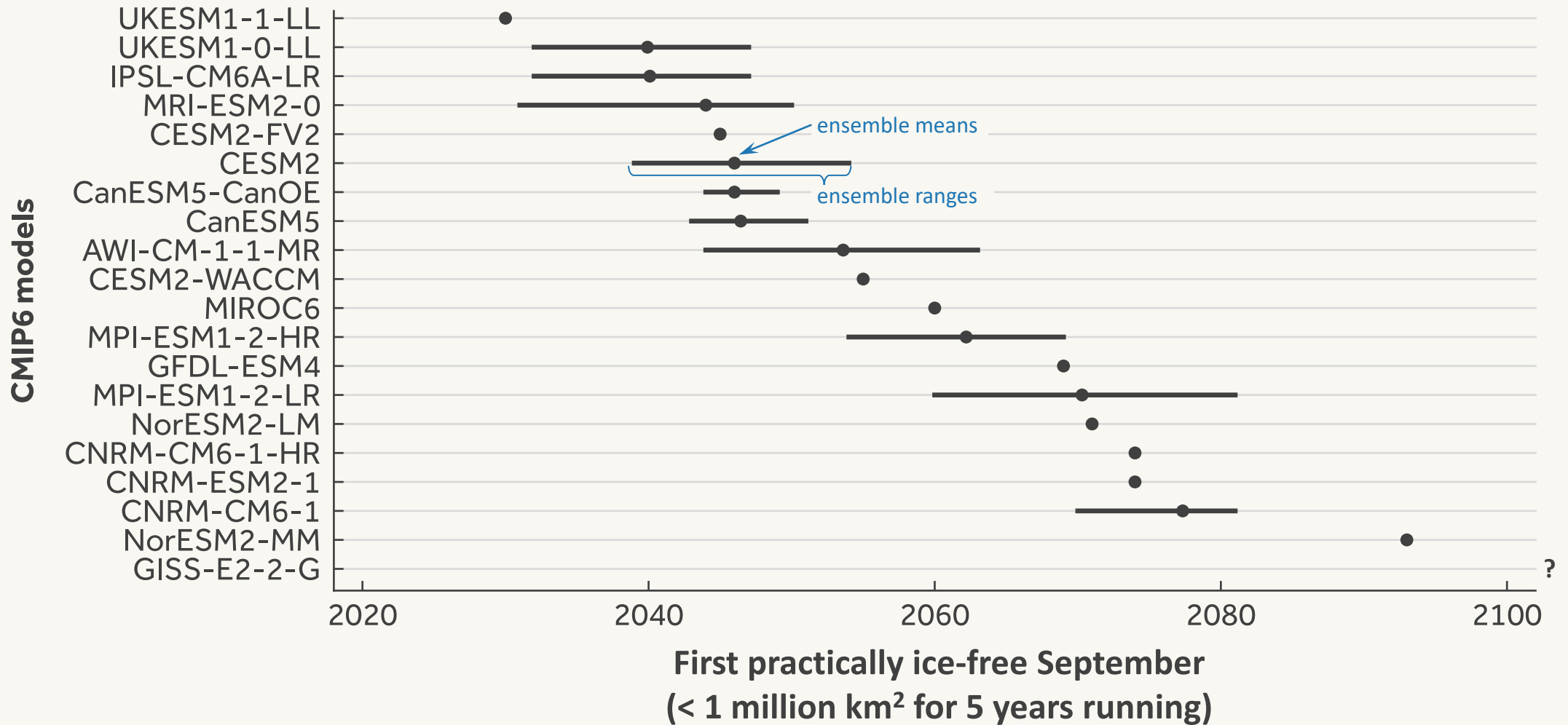
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## Background

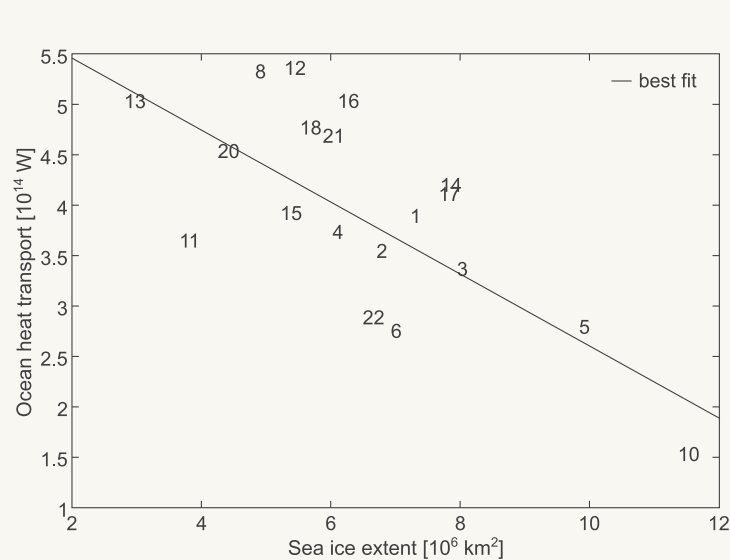
# The uncertain future of Arctic sea ice



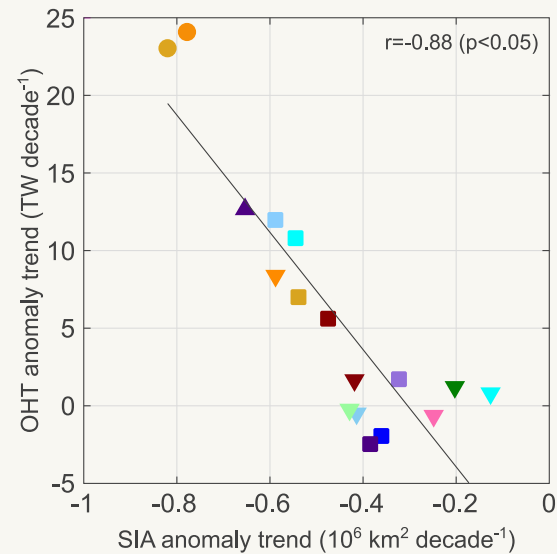
## Background

# Multi-model relationships

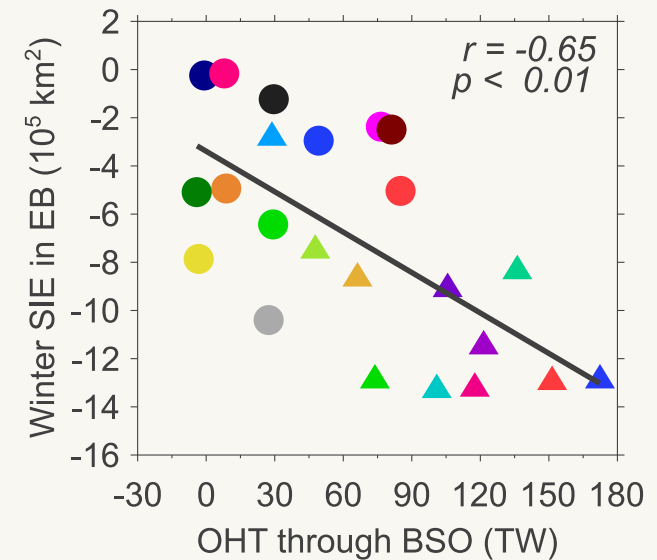
- Many studies find **correlation** between Arctic sea ice and OHT across CMIP models/simulations:



Mahlstein and Knutti (2011, *J. Clim.*)



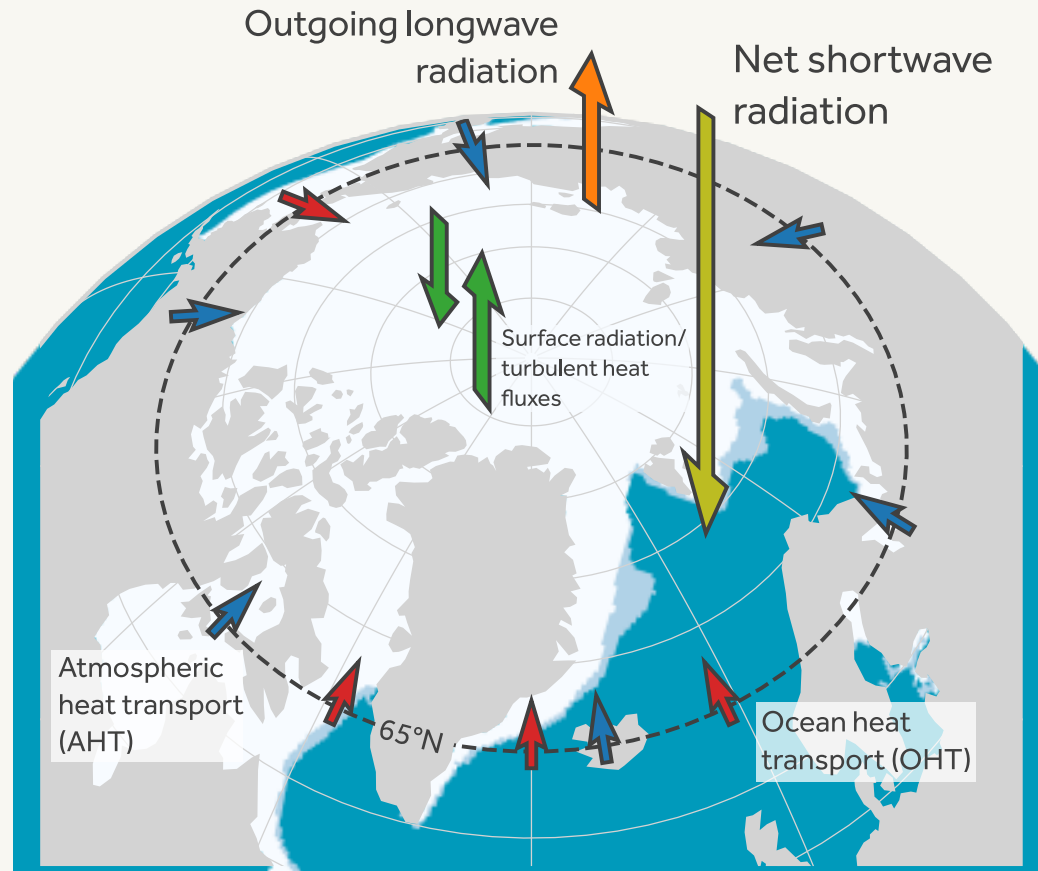
Lee et al. (2023, *J. Clim.*)



Pan et al. (2023, *GRL*)

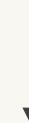
- But none provide an **explanation** – e.g., what sets the sensitivity?

# Energy balance model (EBM)



(see Aylmer et al., 2020, *J. Clim.*)

1. Use energy conservation to relate large-scale heat fluxes
2. Account for physical processes in a simple manner



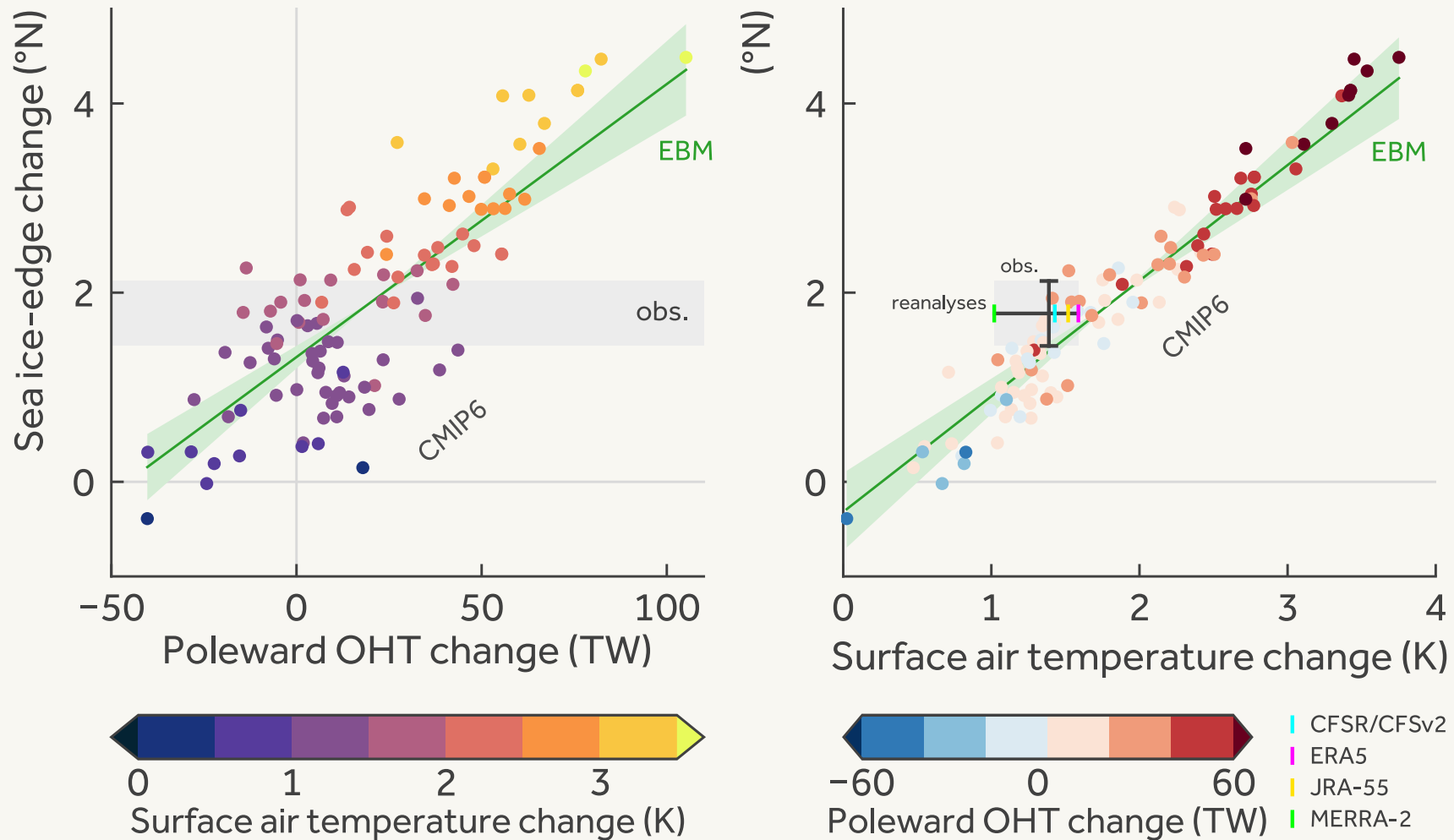
$$S\Delta\phi_i = R\Delta T - C\Delta OHT$$

*radiation/geometric parameters (constants)*

*accounts for AHT and heat uptake*

## Results

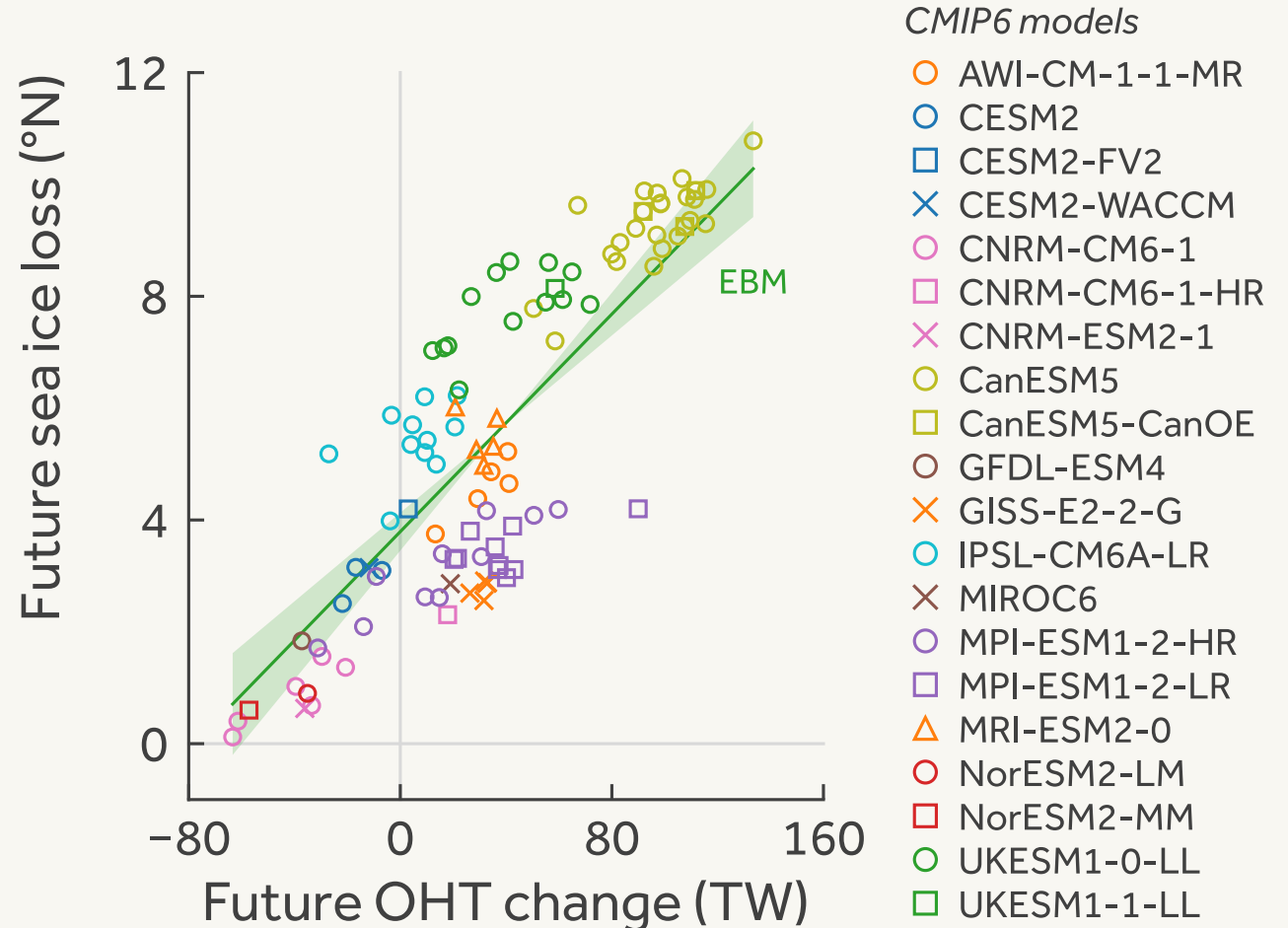
# CMIP6 simulations: 1980–2021



## Results

# CMIP6 future projections (1980–2050)

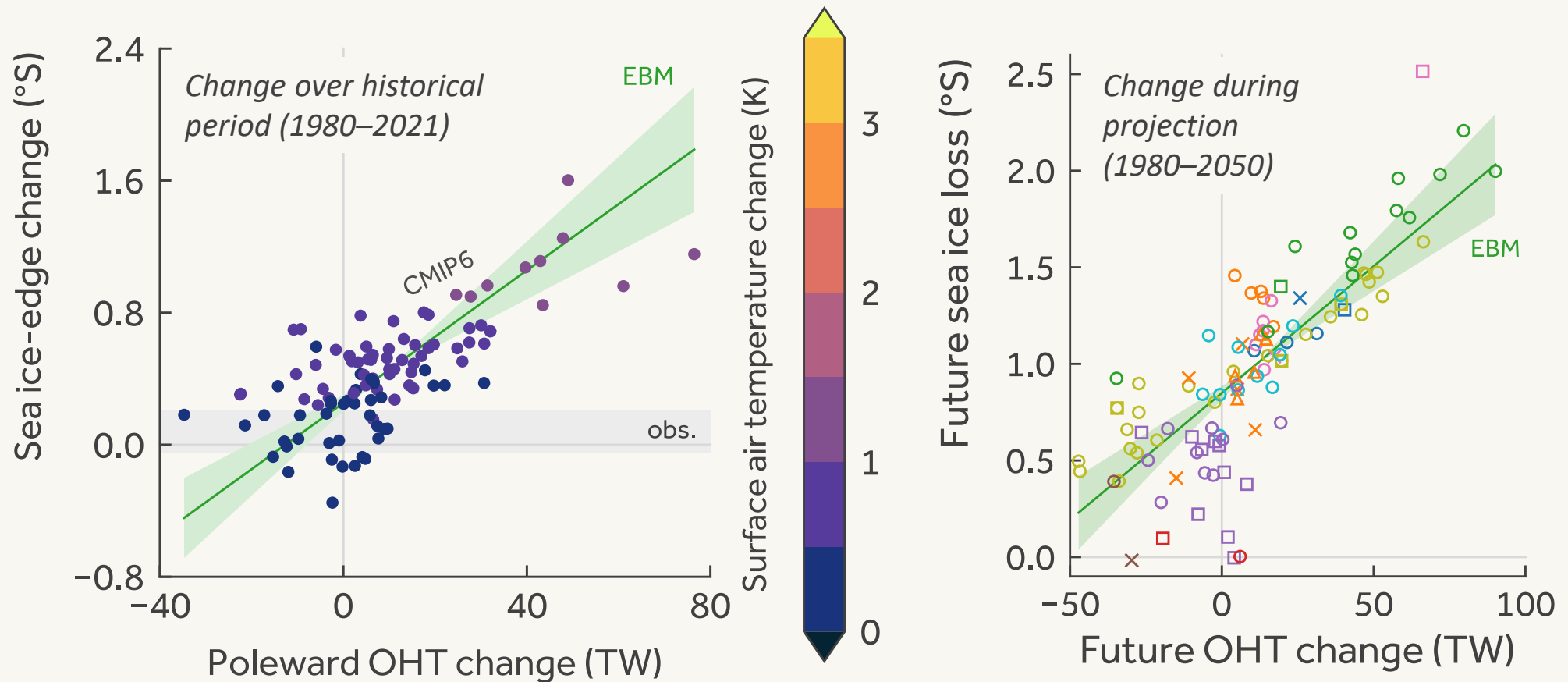
- Striking range of sea ice changes
- Possible link with seasonal ice loss? E.g., CanESM5 ( ) becomes seasonal ~30 years earlier than CNRM-CM6-1 ( )
- Model biases > internal variability



\* 2030–2050 minus 1980–2000 means

# What about the Southern Ocean?

- Weaker relationship and internal variability outweighs model biases



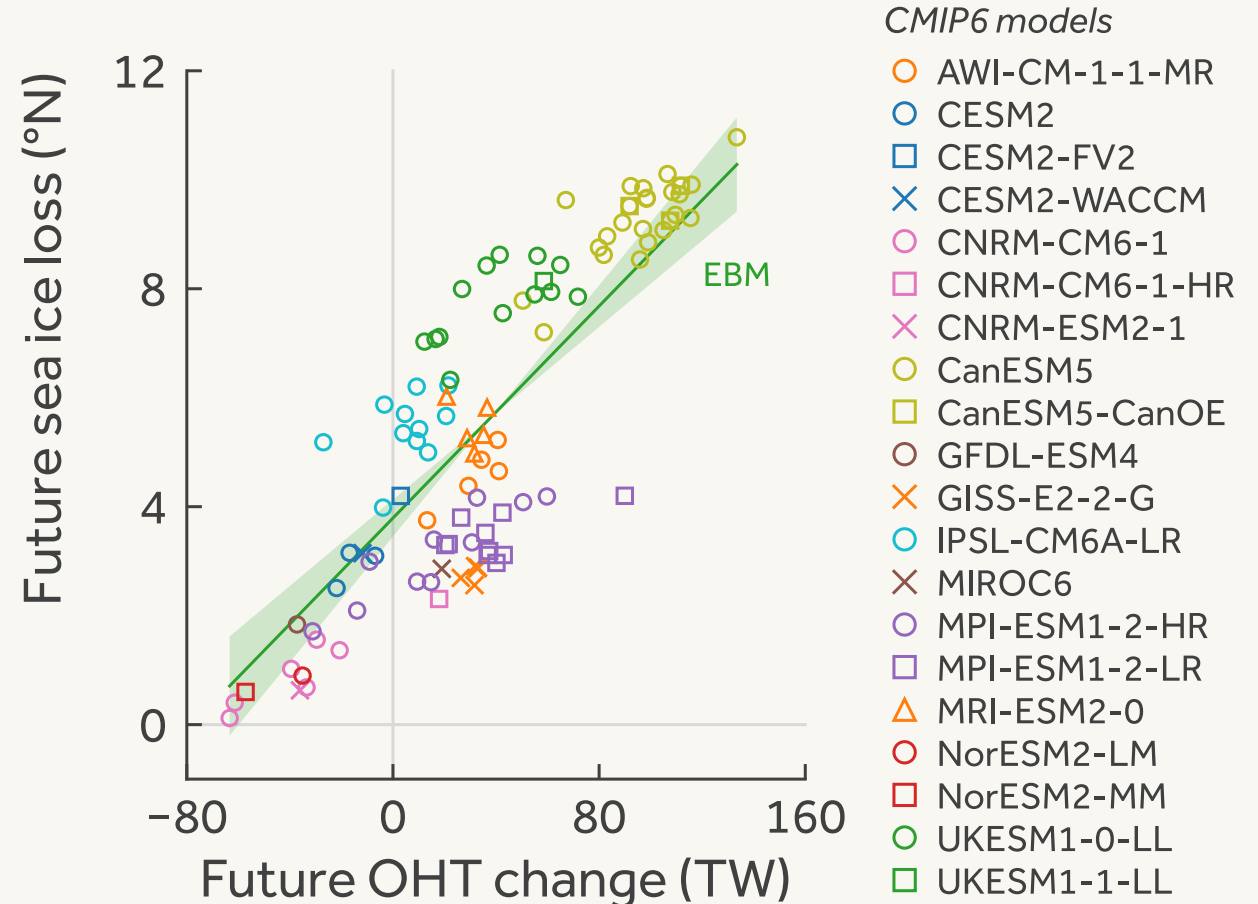
# Summary



- Simulated changes in sea ice are strongly correlated with ocean heat transport (OHT)
- Multi-model relationships captured by a simple **energy balance model**
- Systematic contribution of ocean biases to **uncertainty in future projections** of Arctic sea ice

Preprint

Aylmer, Ferreira, and Feltham





# References

Aylmer, J. R., D. G. Ferreira, and D. L. Feltham, 2020: Impacts of oceanic and atmospheric heat transports on sea ice extent, *J. Clim.*, **33**, 7197–7215, doi:[10.1175/JCLI-D-19-0761.1](https://doi.org/10.1175/JCLI-D-19-0761.1)

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Lee, Y. J., M. Watts, W. Maslowski, J. C. Kinney, and R. Osinski, 2023: Assessment of the pan-Arctic accelerated rate of sea ice decline in CMIP6 historical simulations, *J. Clim.*, **36**, 6069–6089, doi:[10.1175/JCLI-D-21-0539.1](https://doi.org/10.1175/JCLI-D-21-0539.1)

Mahlstein, I. and R. Knutti, 2011: Ocean heat transport as a cause for model uncertainty in projected Arctic warming, *J. Clim.*, **24**, 1451–1460, doi:[10.1175/2010JCLI3713.1](https://doi.org/10.1175/2010JCLI3713.1)

Pan, R., Q. Shu, Q. Wang, S. Wang, Z. Song, Y. He, and F. Qiao, 2023: Future Arctic climate change in CMIP6 strikingly intensified by NEMO-family climate models, *Geophys. Res. Lett.*, **50**, e2022GL102077, doi:[10.1029/2022GL102077](https://doi.org/10.1029/2022GL102077)