Large-scale wind-driven Greenland melt influences sea-level rise projection uncertainties

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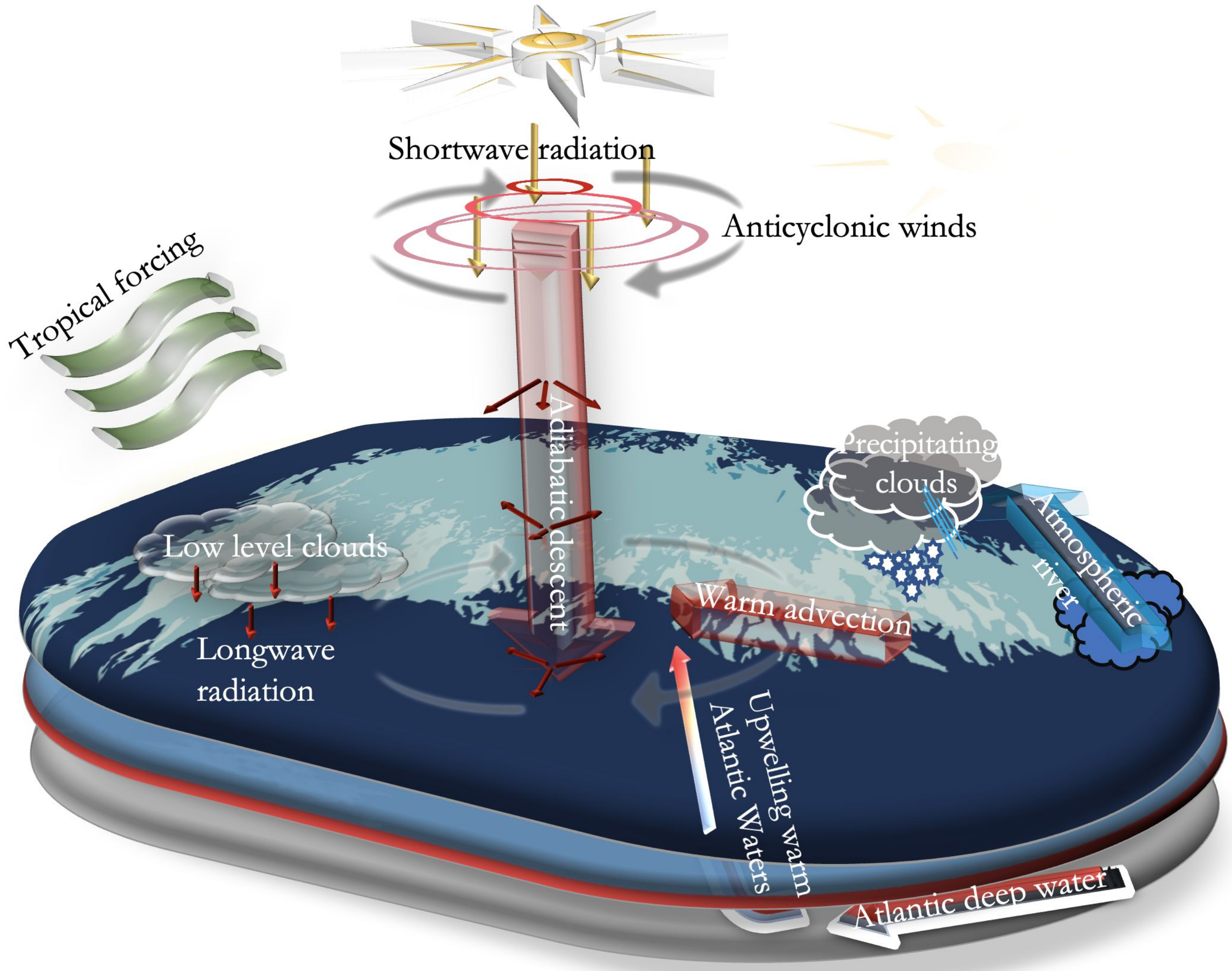
Outline

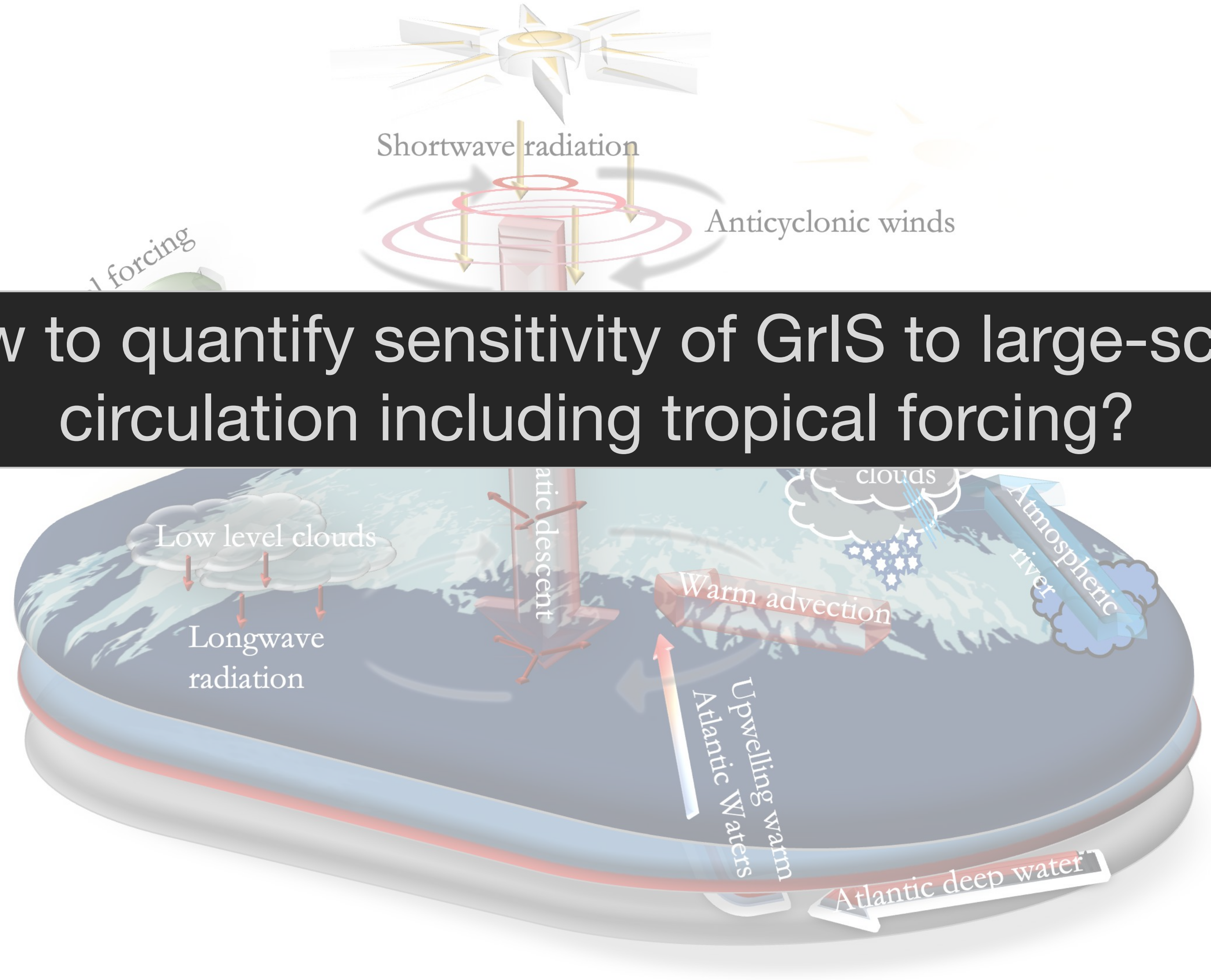
1. Model- versus reanalysis-derived sensitivity of Greenland to atmospheric circulation
2. Wind-nudging experiments with CESM2
3. Wind-driven SLR contribution from Greenland
4. Possible sources of model sensitivity issues

Atmospheric circulation impact on the ice sheet



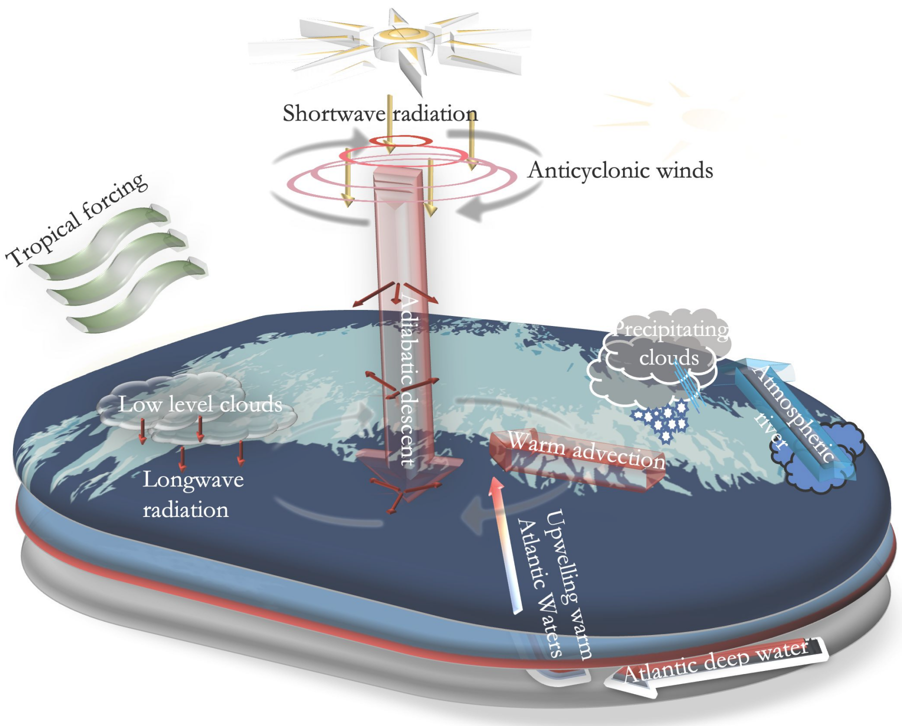
Hanna et al, in prep

Atmospheric circulation impact on the ice sheet



How to quantify sensitivity of GrIS to large-scale circulation including tropical forcing?

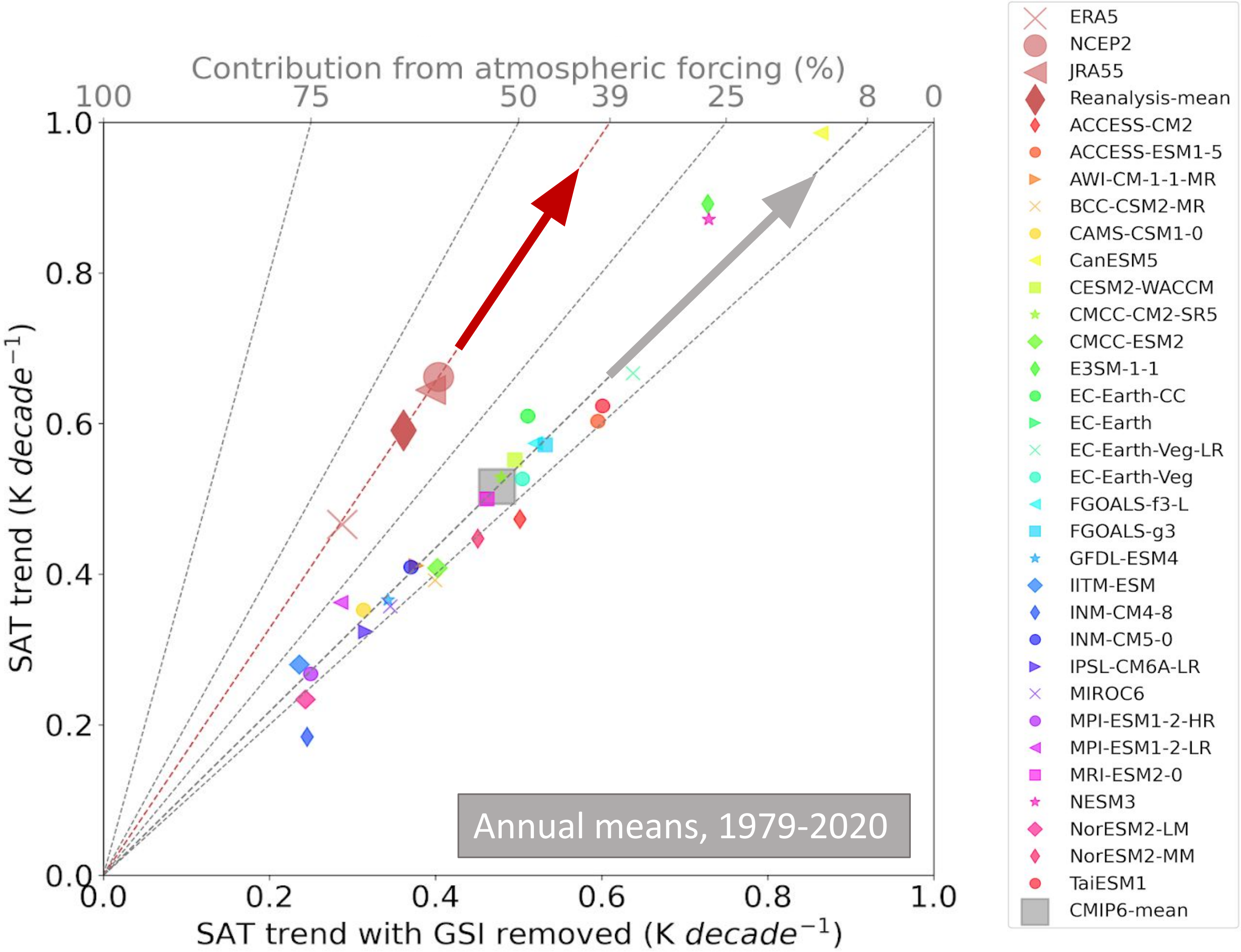
Quantifing sensitivity of GrIS to large-scale circulation



- Calculate streamfunction (Ψ) from global horizontal wind field at 500hPa
- Spatial-average streamfunction field over the GrIS = **G**reenland **S**treamfunction **I**ndex
- Remove GSI from surface temperature index via linear regression
  - compare the *raw* SAT versus *residual* SAT

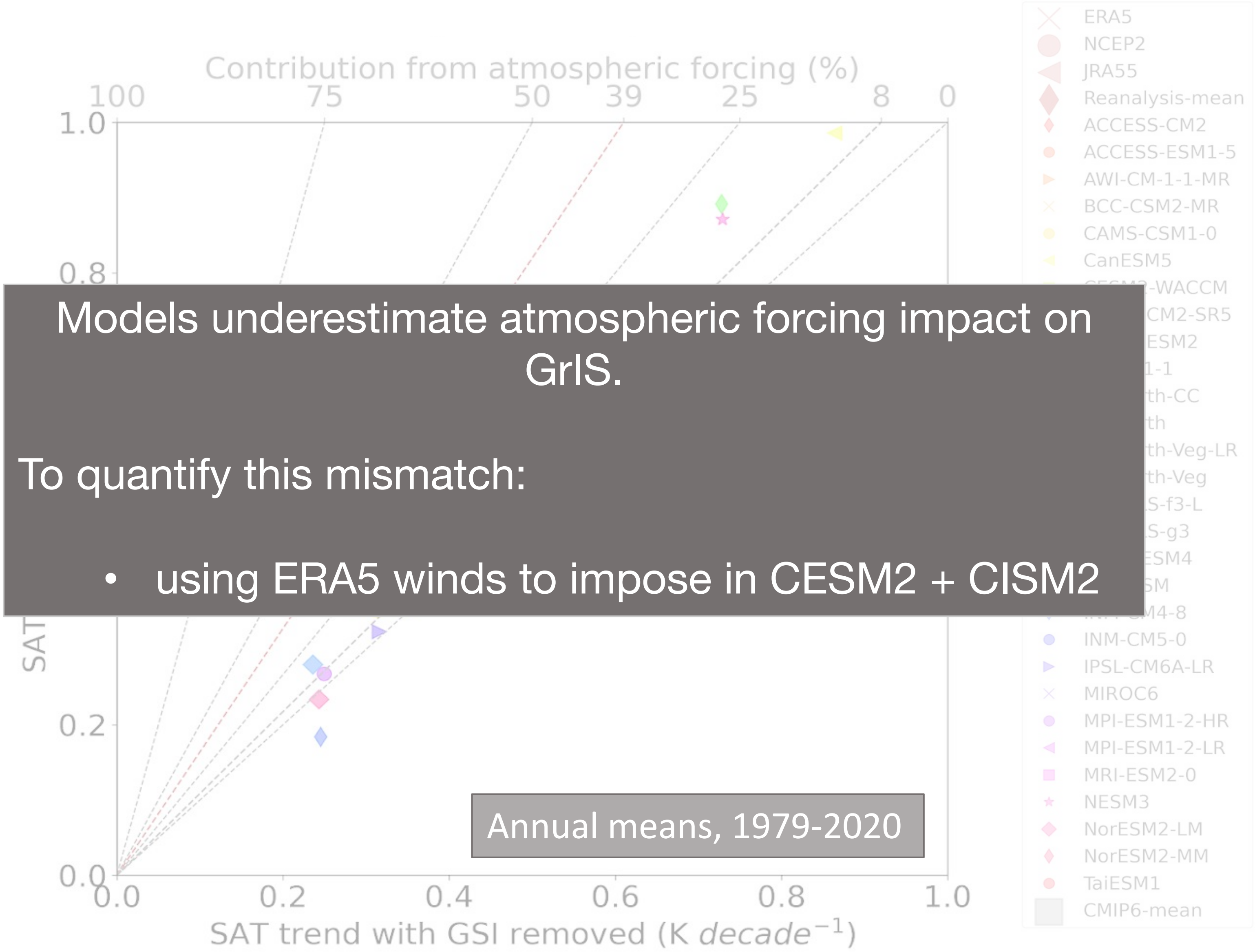
(Secular trends are removed from SAT and GSI, respectively, before constructing the regression model)

Quantifing sensitivity of GrIS to large-scale circulation



Topál and Ding, in review

Quantifing sensitivity of GrIS to large-scale circulation



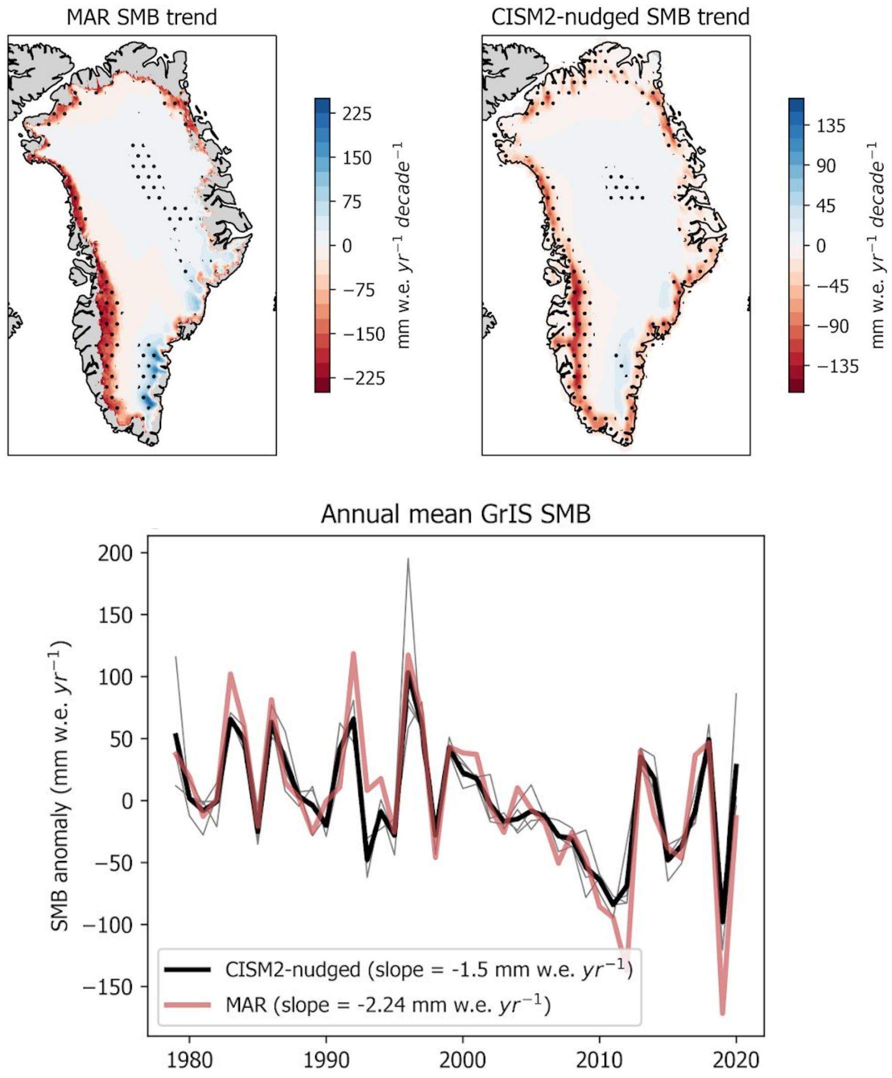
Models underestimate atmospheric forcing impact on GrIS.

To quantify this mismatch:

- using ERA5 winds to impose in CESM2 + CISM2

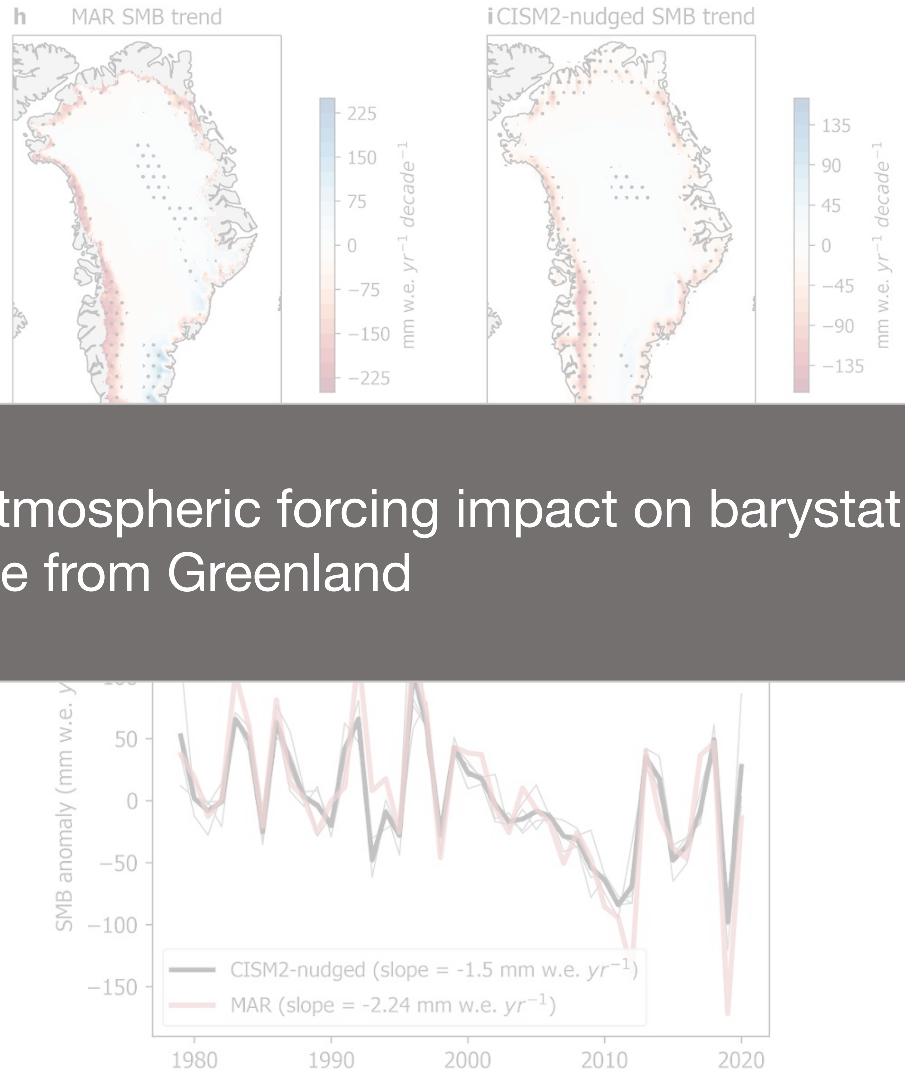
CESM2 + CISM2 experiments with ERA5 winds nudged

- ERA5 horizontal winds (u,v) are imposed in the CESM2
- external forcing is kept constant



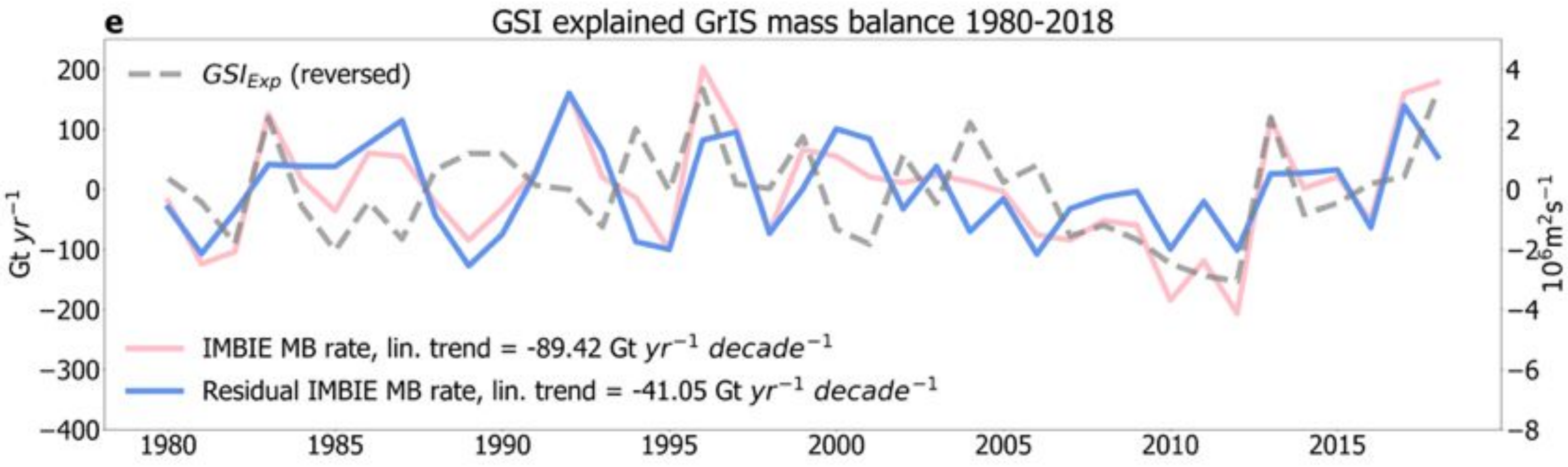
Topál and Ding (in review)

CESM2 + CISM2 experiments with ERA5 winds nudged



We may use the GSI to estimate atmospheric forcing impact on barystatic sea-level rise from Greenland

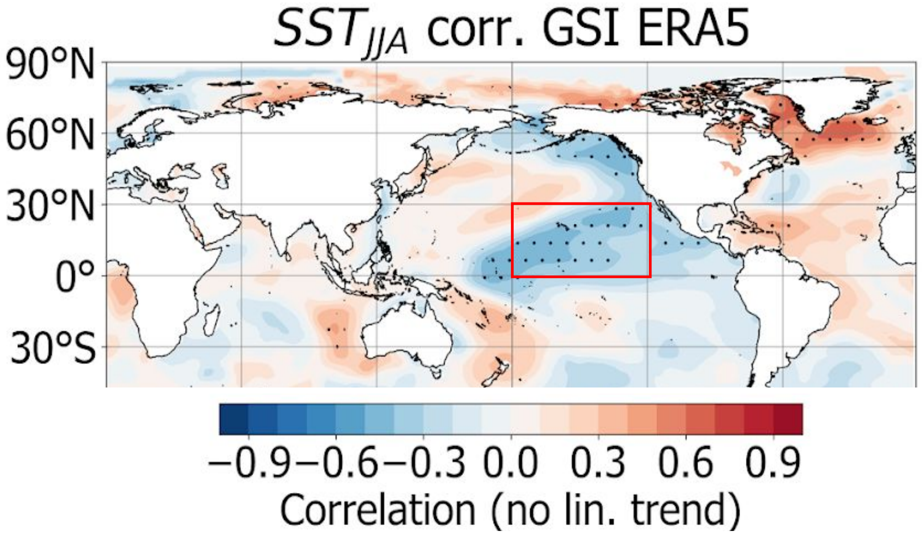
Atmospheric contribution to sea-level rise through the GrIS



- ~45% of the acceleration between 1990-2012 is explained by GSI

Topál et al. (2022) Nat Commun 13, 6833

Sources of differences between observed and modelled sensitivity



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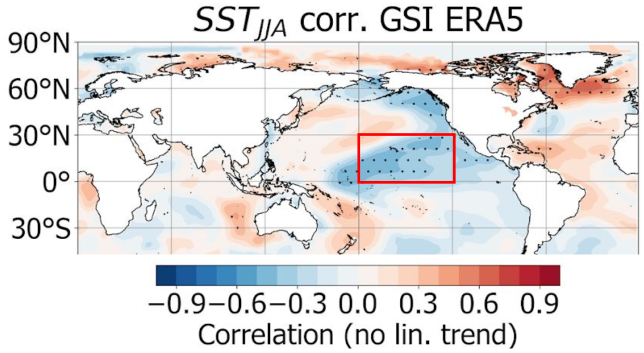
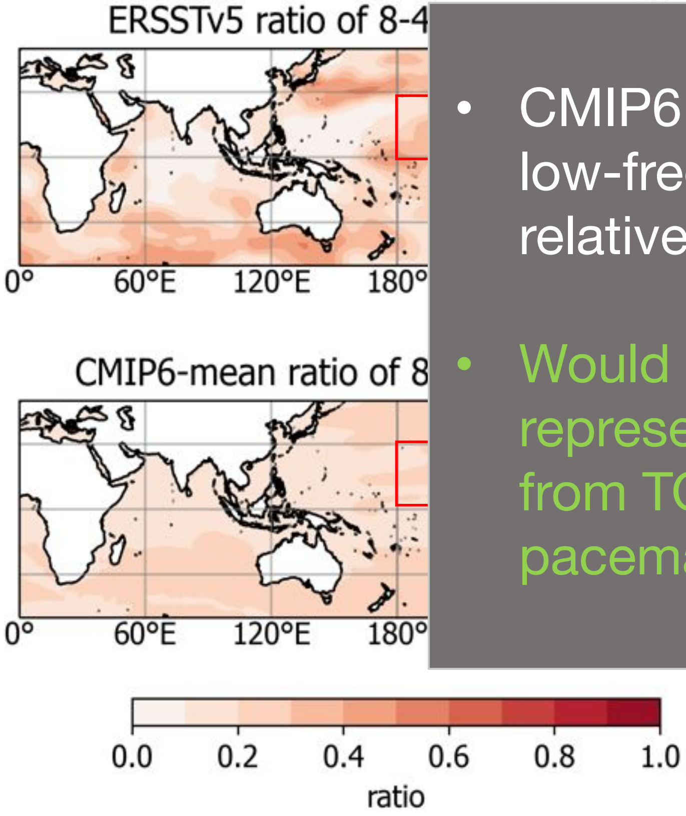
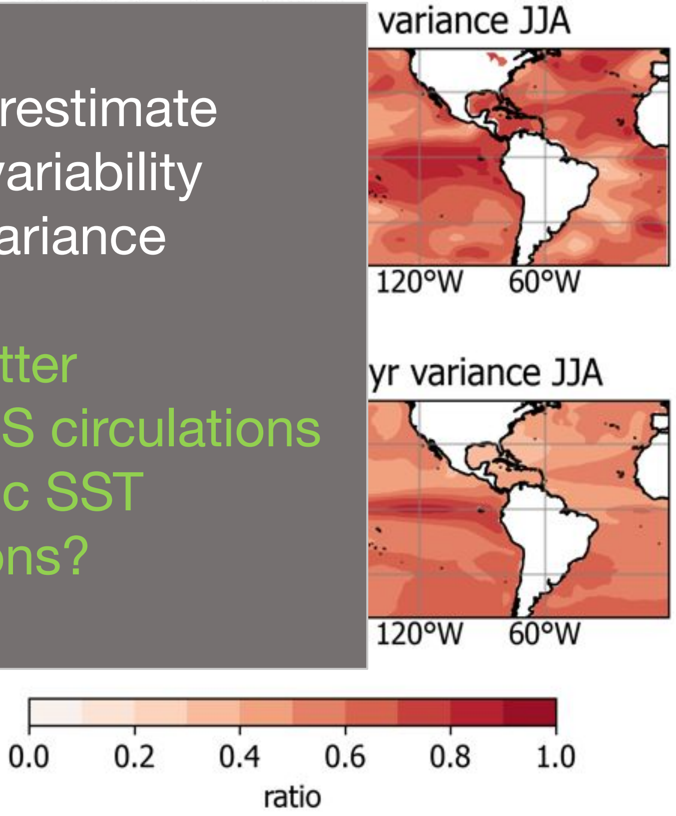
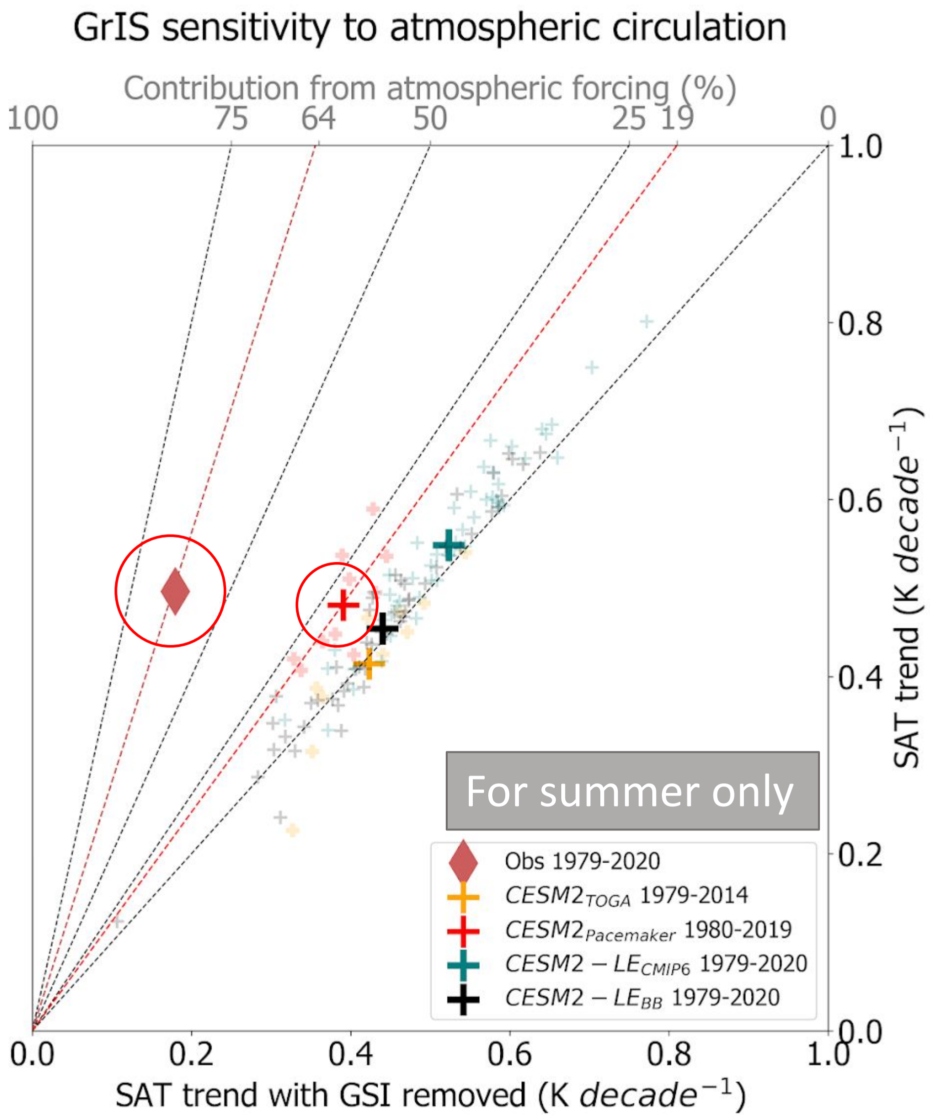




- CMIP6 models underestimate low-frequency SST variability relative to the total variance
- Would we expect better representation of GrIS circulations from TOGA, or Pacific SST pacemaker simulations?



Sources of differences between observed and modelled sensitivity



Summary

Findings

- Summer and annual mean SAT response to atmospheric forcing over the GrIS is ~30-50% underestimated in CMIP6
- Nudging experiments to quantify the SMB response too to winds

Potential causes

- Low-frequency SST variability
- The forced response in atmospheric circulation can also be biased

Potential consequences

- e.g., projected SLR uncertainties from Greenland

More details in

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Discrepancies between observations and climate models of large-scale wind-driven Greenland melt influence sea-level rise projections

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Abstract

While climate models project that Greenland ice sheet (GrIS) melt will continue to accelerate with climate change, models exhibit limitations in capturing observed connections between GrIS melt and changes in high-latitude atmospheric circulation. Here we impose observed Arctic winds in a fully-coupled climate model with fixed anthropogenic forcing to quantify the influence of the rotational component of large-scale atmospheric circulation variability over the Arctic on the temperature field and the surface mass/energy balances through adiabatic processes. We show that recent changes involving mid-to-upper-tropospheric anticyclonic wind anomalies – linked with tropical forcing – explain half of the observed Greenland surface warming and ice loss acceleration since 1990, suggesting a pathway for large-scale winds to potentially enhance sea-level rise by ~0.2 mm/year per decade. We further reveal fingerprints of this observed teleconnection in paleo-reanalyses spanning the past 400 years, which heightens concern about model limitations to capture wind-driven adiabatic processes associated with GrIS melt.