Enhanced Early 21st Century Arctic Sea Ice Loss due to CMIP6 Biomass Burning Emissions

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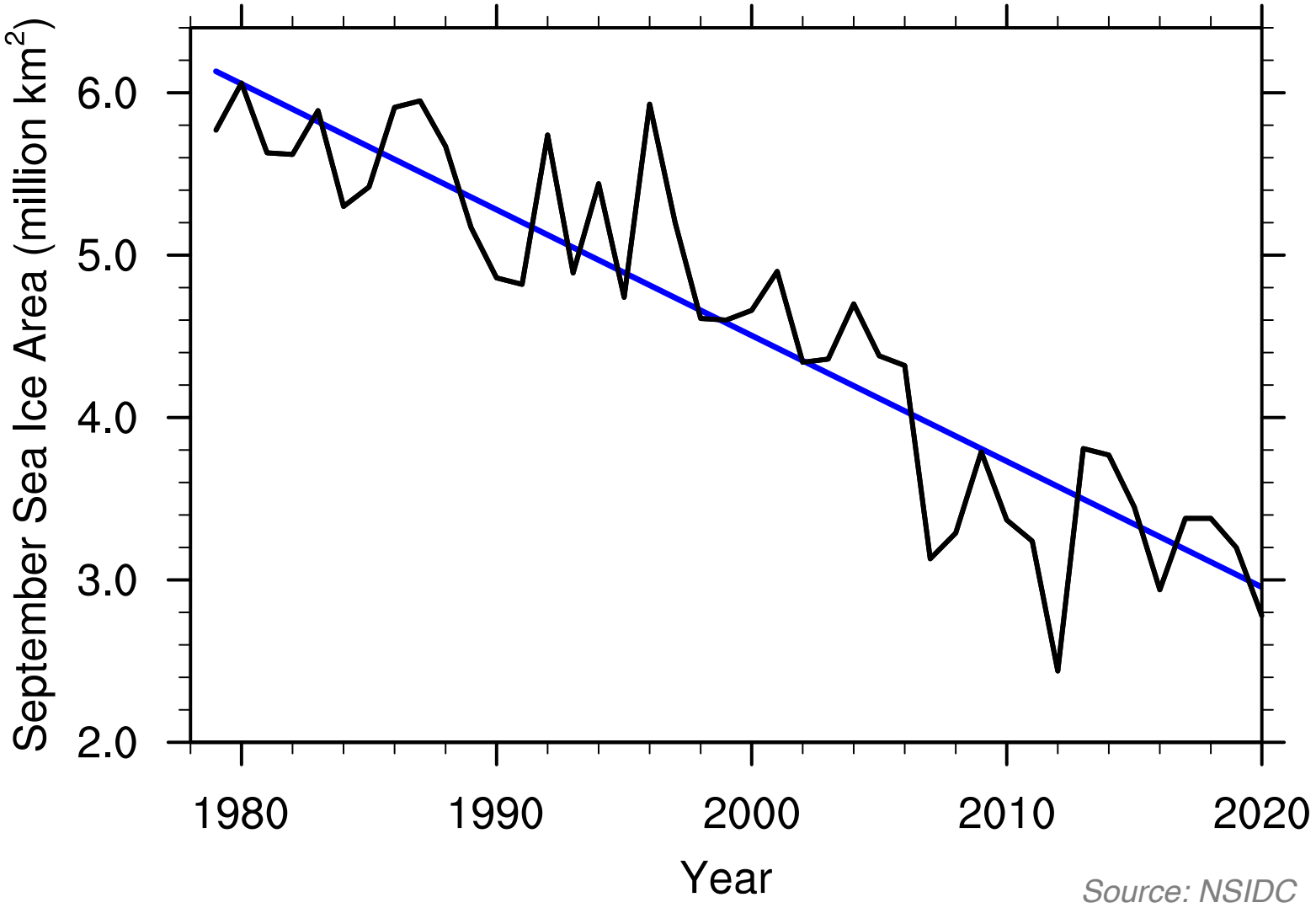
DeRepentigny et al., under review at Nature Climate Change.

Evolution of observed Arctic sea ice in September



Source: NSIDC

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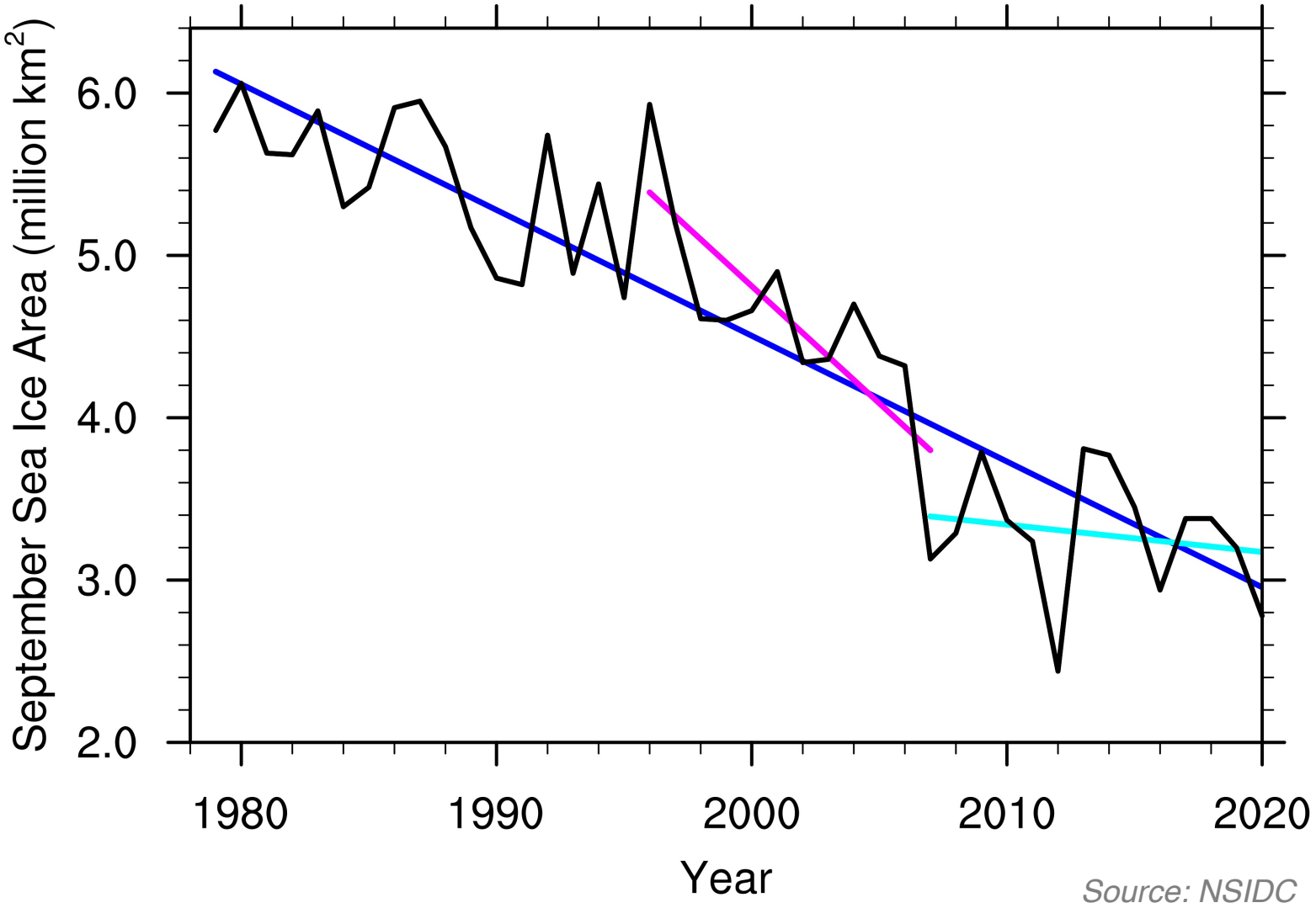
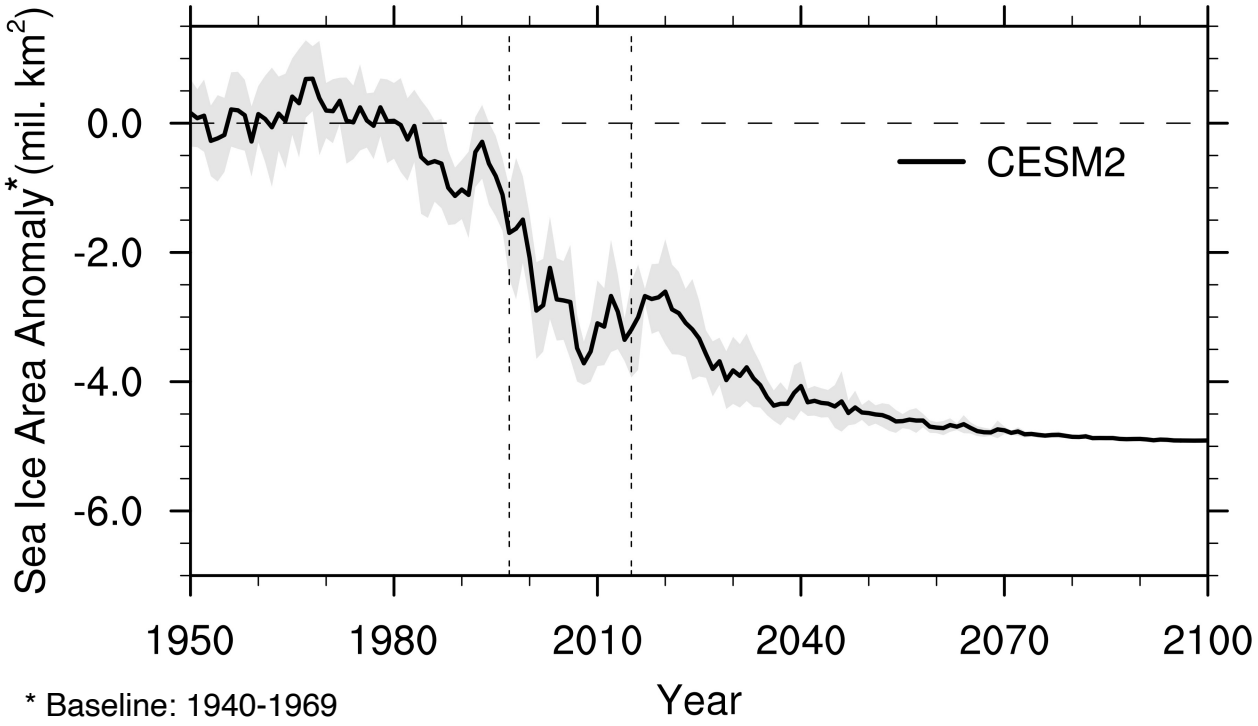


Source: NSIDC

Reported by:

- Swart et al., 2015
- Baxter et al., 2019

Different sea ice evolution between CESM2 and CESM1-LE



* Baseline: 1940-1969

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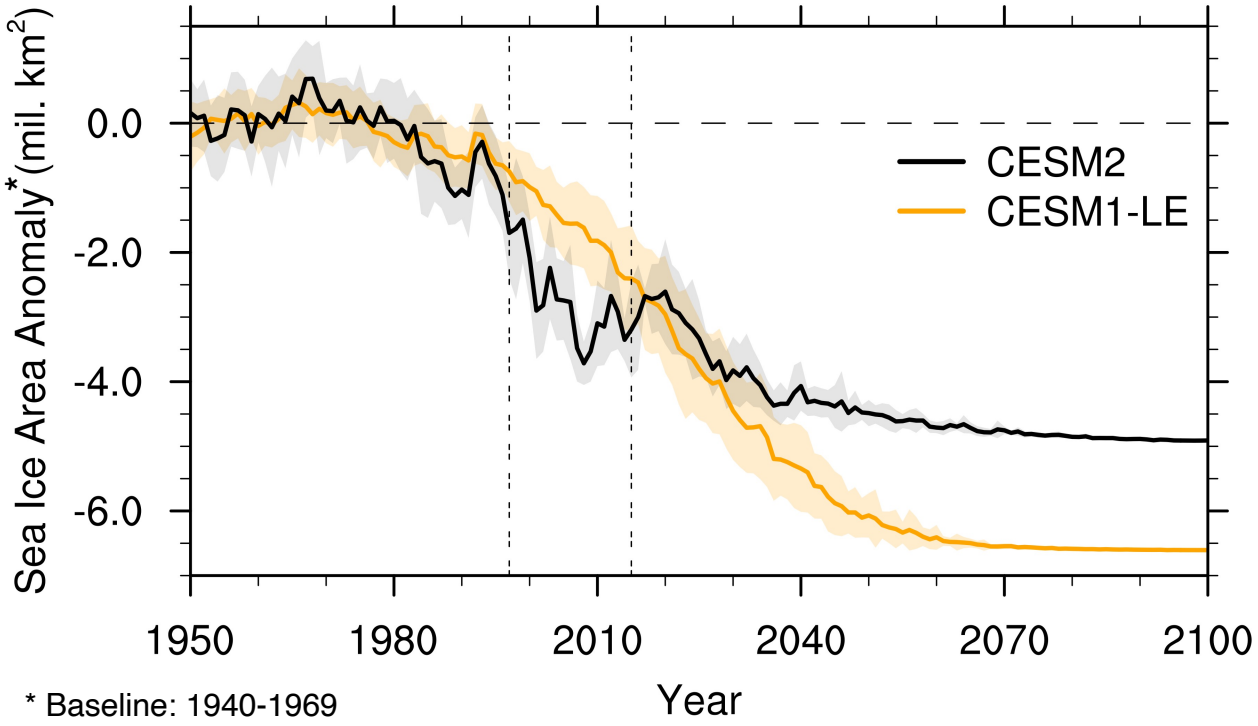

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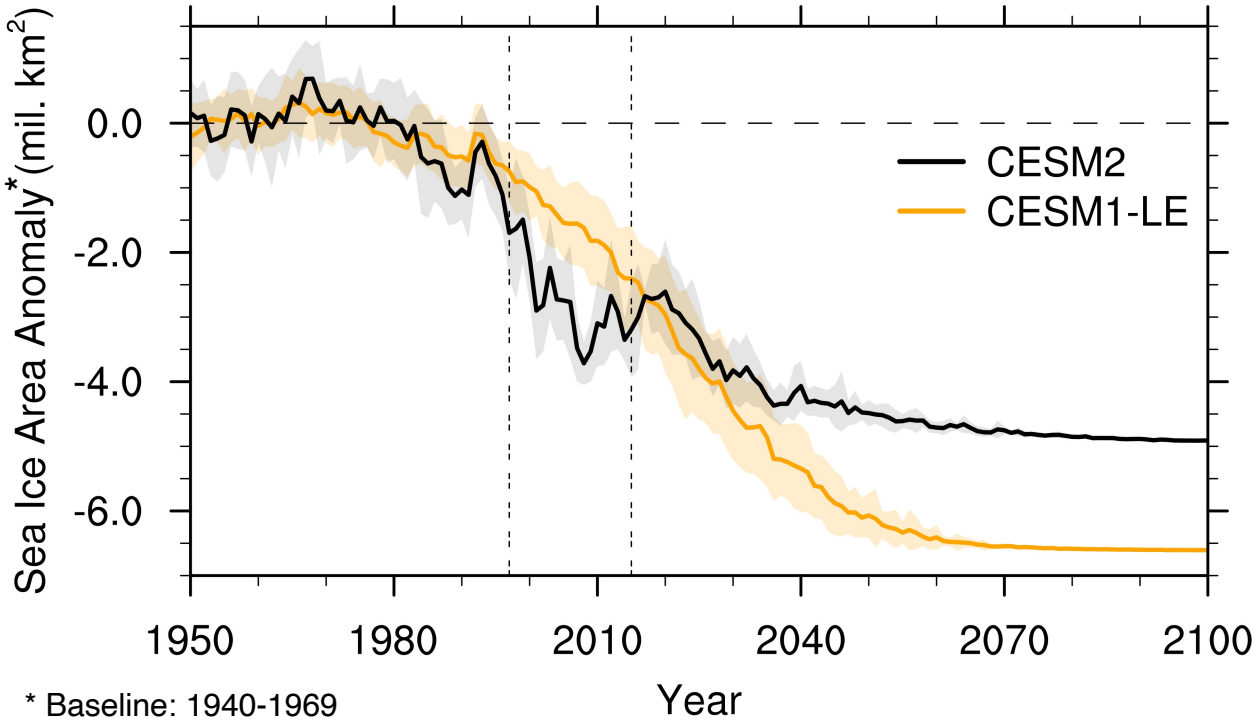

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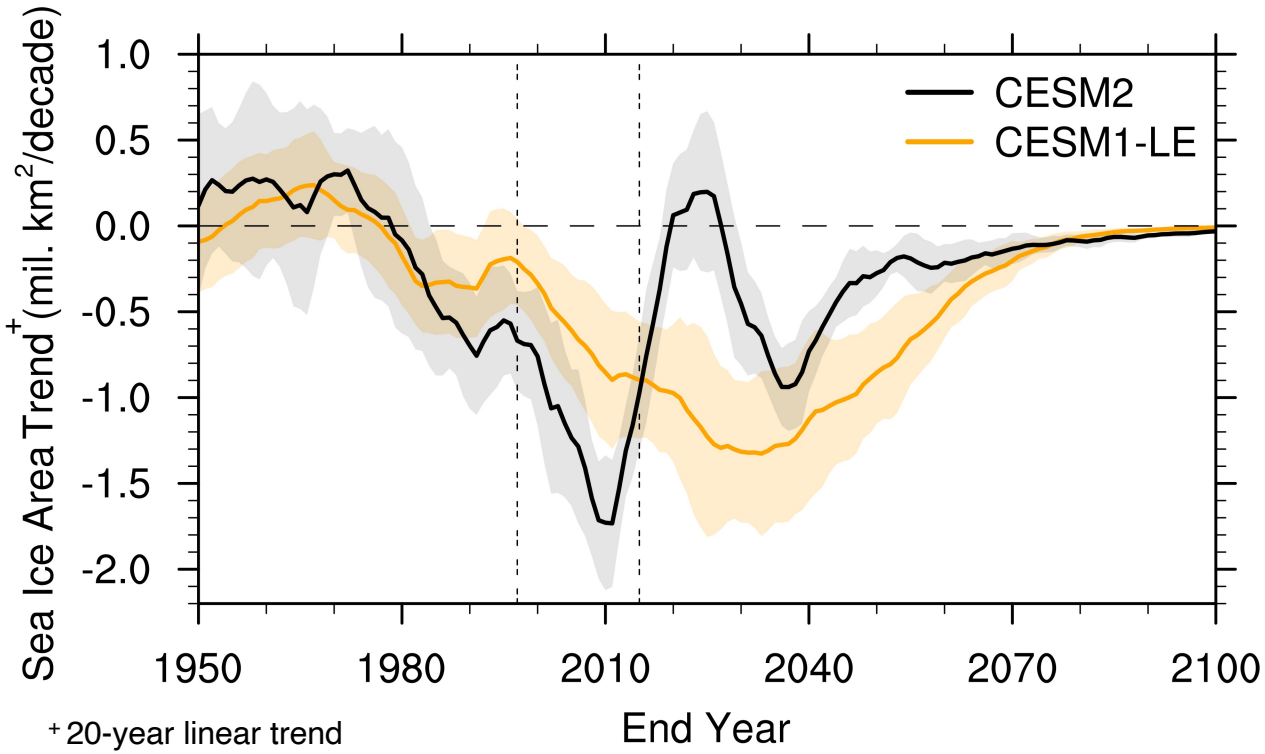
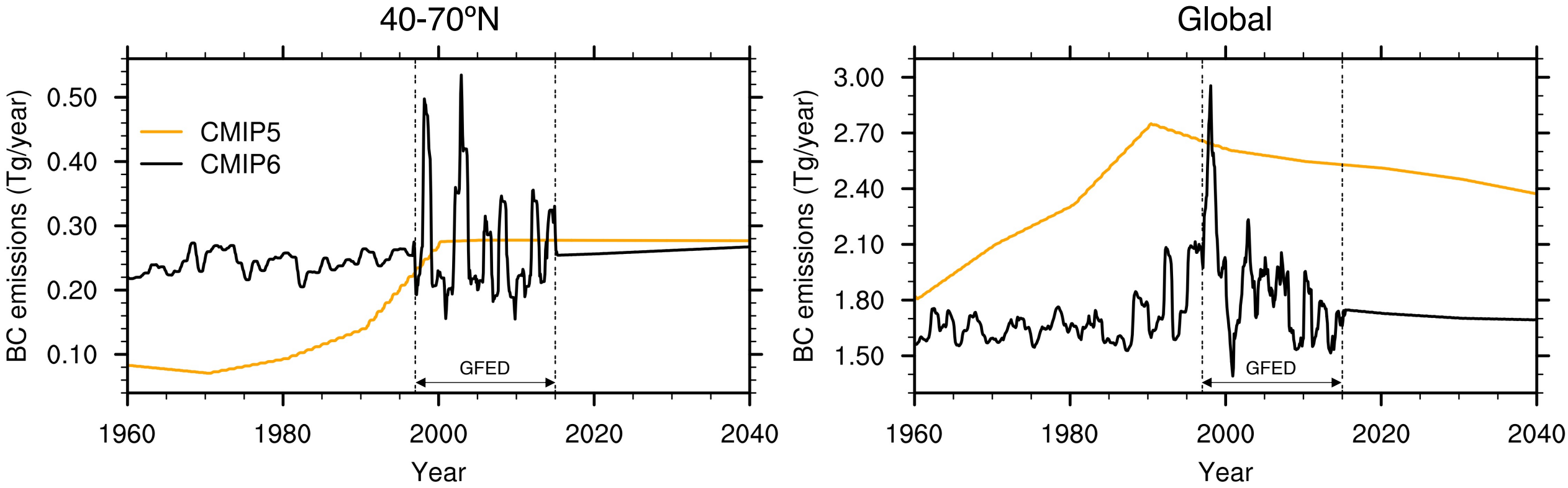


+ 20-year linear trend

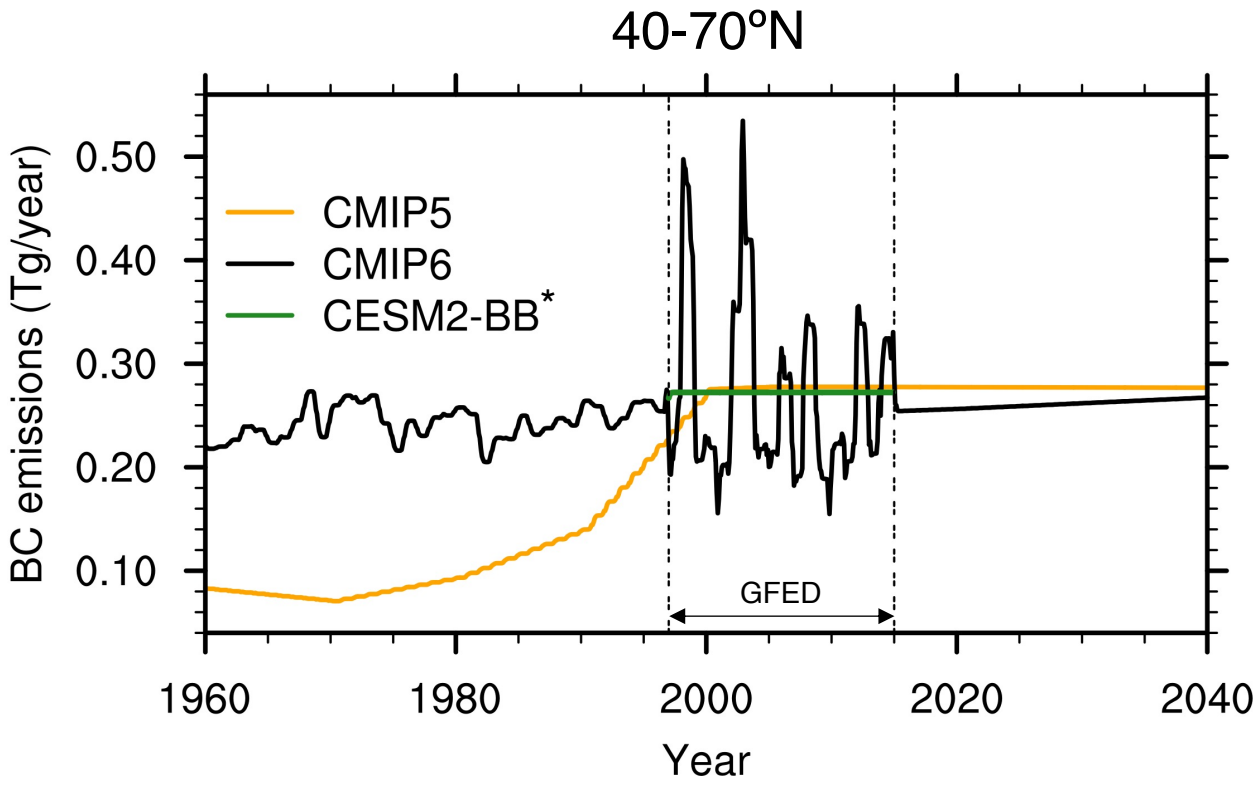
CMIP6 BB emissions include inter-annual variability

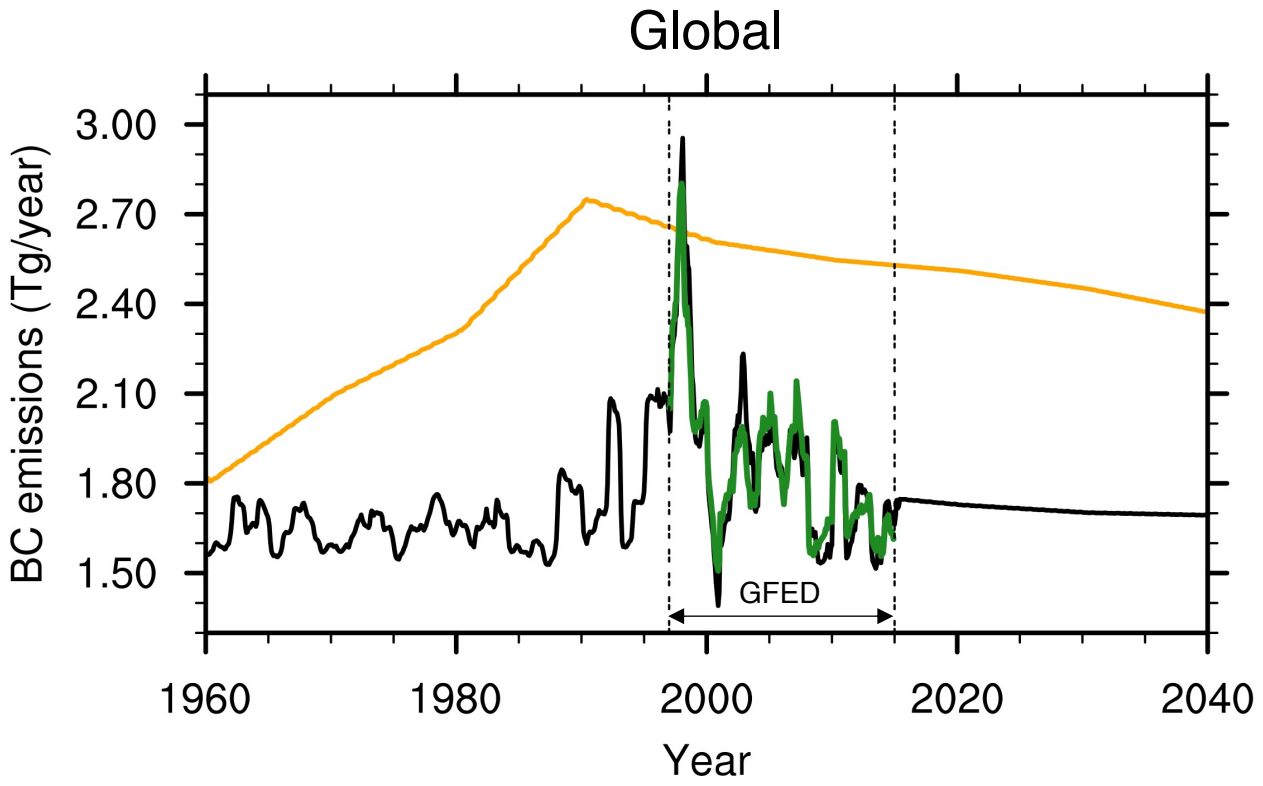


- From 1997-2014, estimates of BB emissions are based on the Global Fire Emissions Database (GFED), which combines newly available satellite information on fire activity and vegetation productivity.

- In CMIP6, biomass burning (BB) emissions were updated to include inter-annual variability rather than using decadal means as was done in CMIP5.

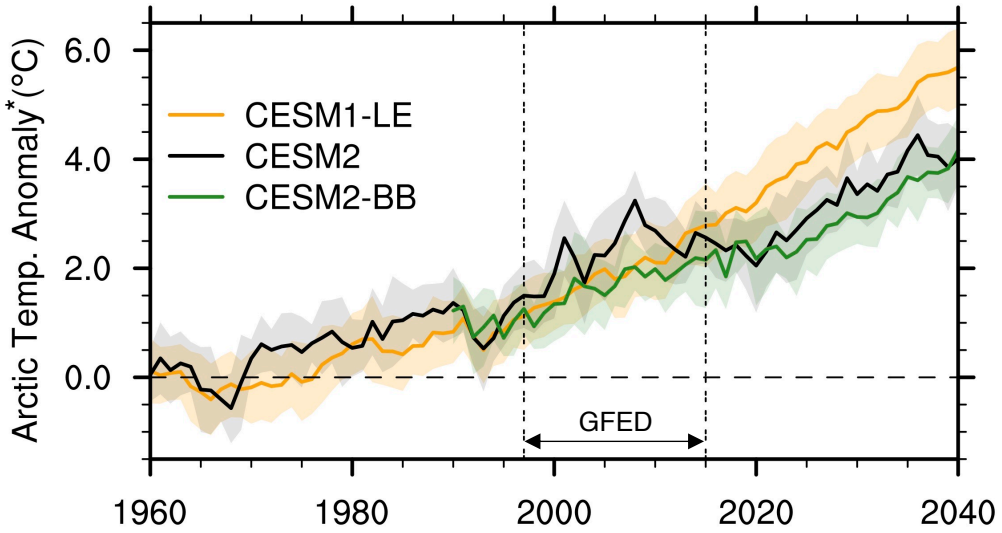
Sensitivity experiments with homogenized BB emissions





*CESM2-BB is a 10-member ensemble, branched from the first 10 members of the CESM2 in 1990.

Arctic temperature and sea ice response to BB emissions



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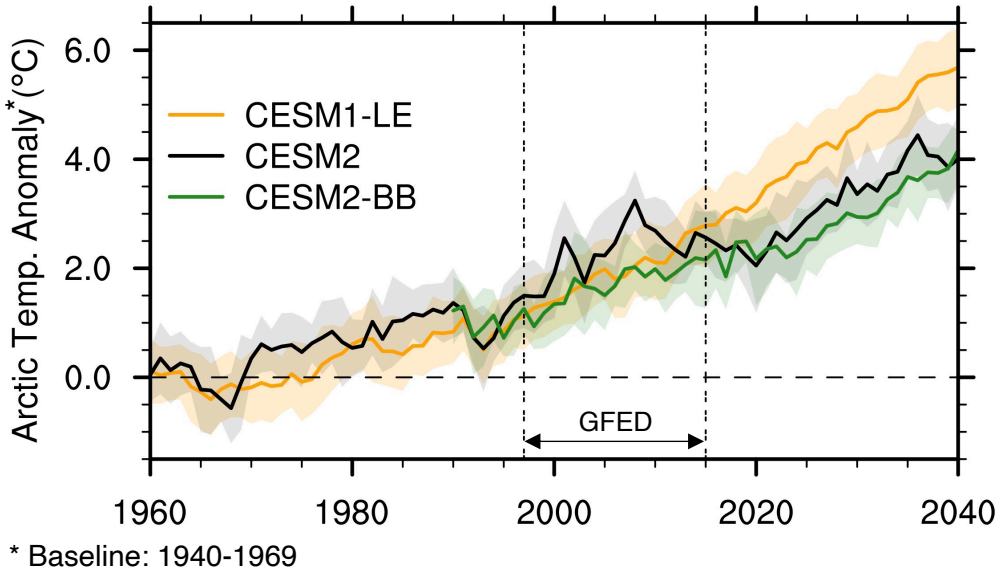

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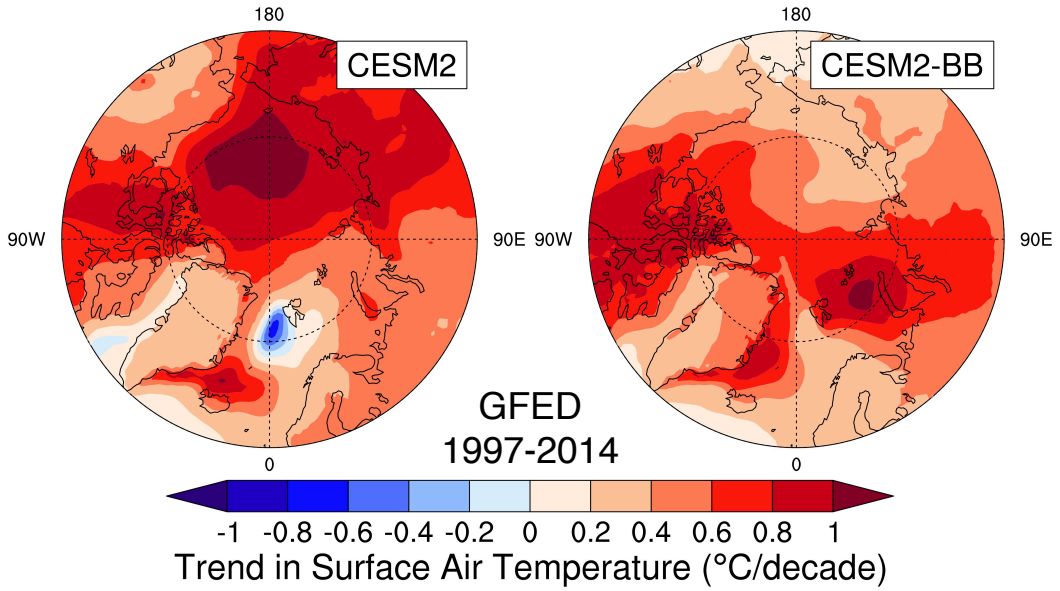

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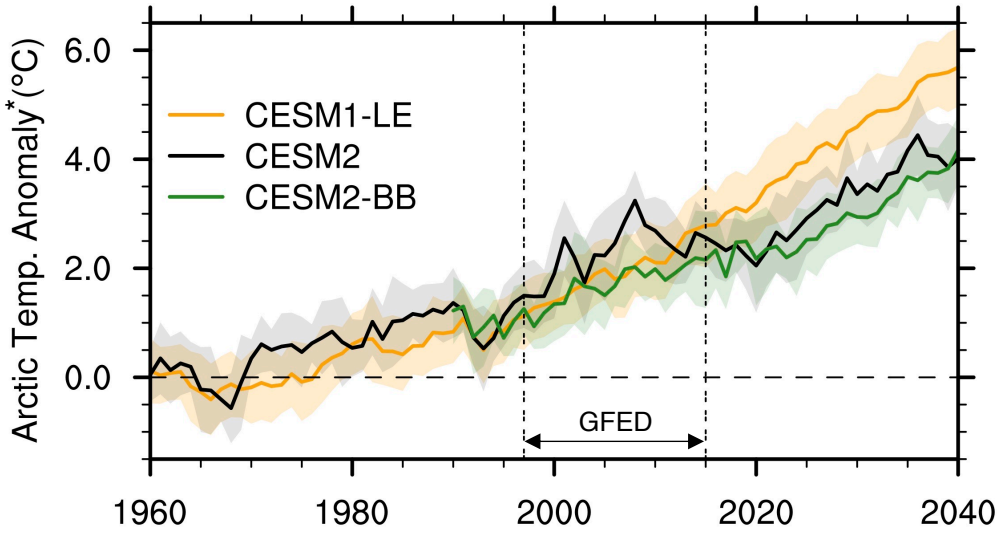

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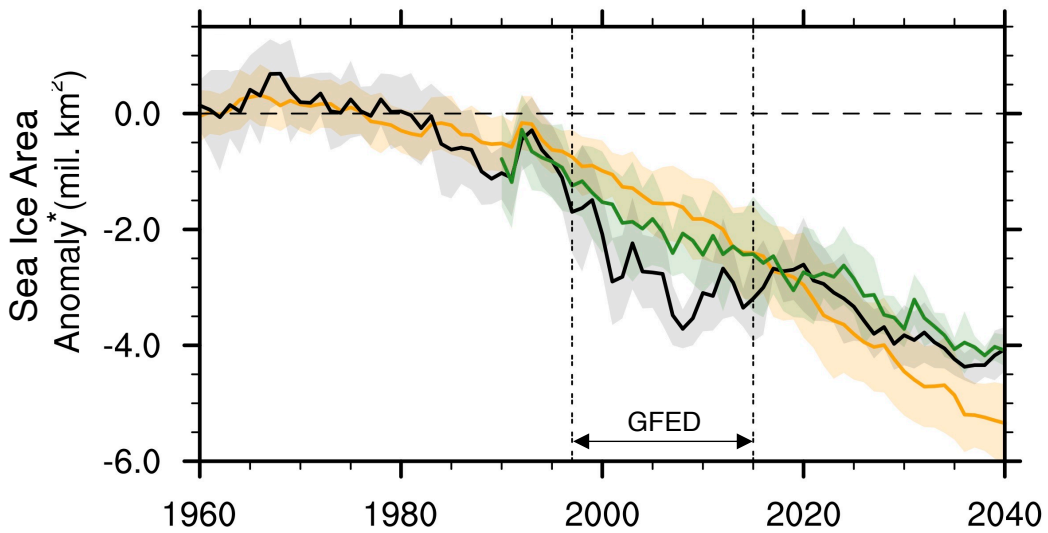

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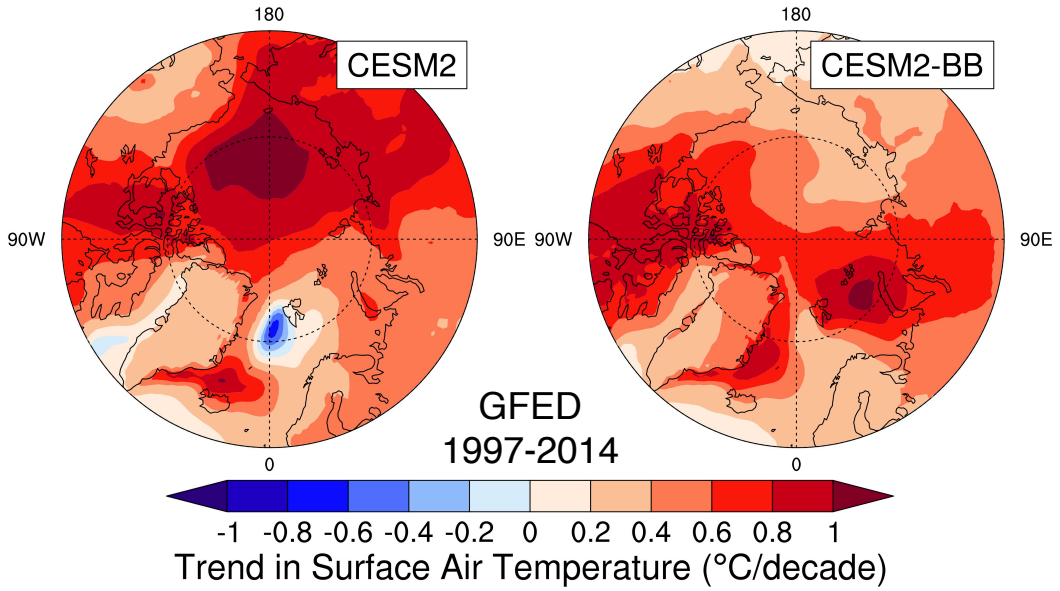

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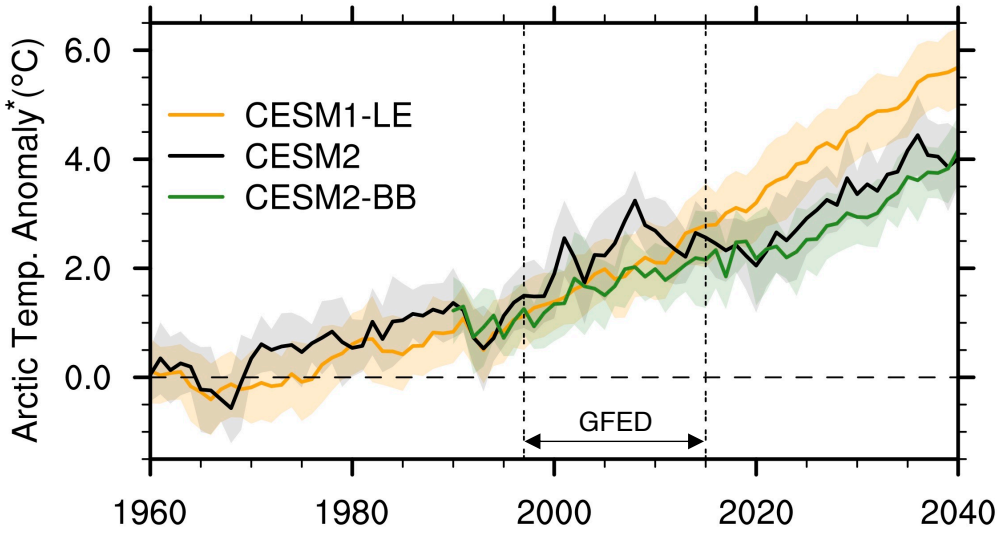

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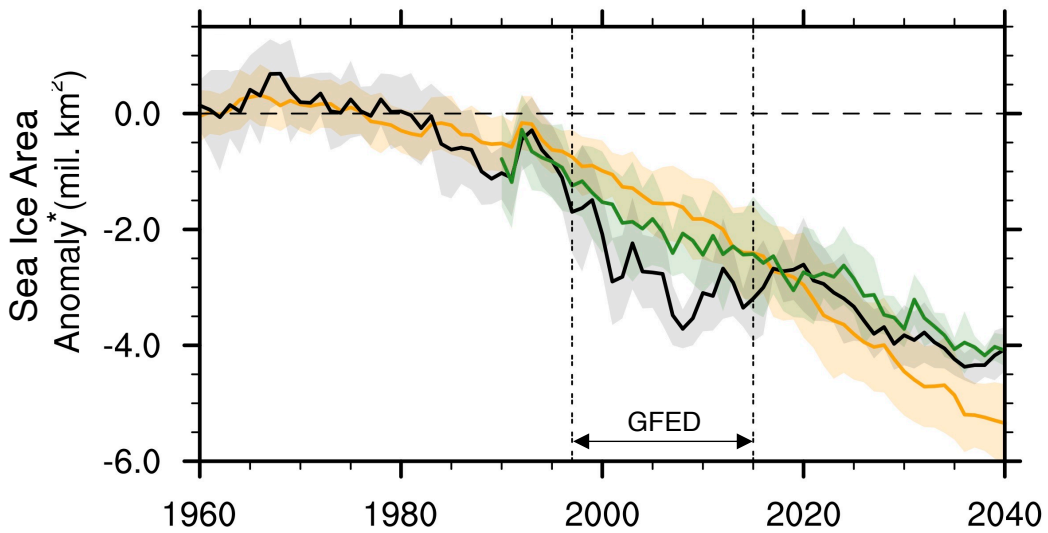

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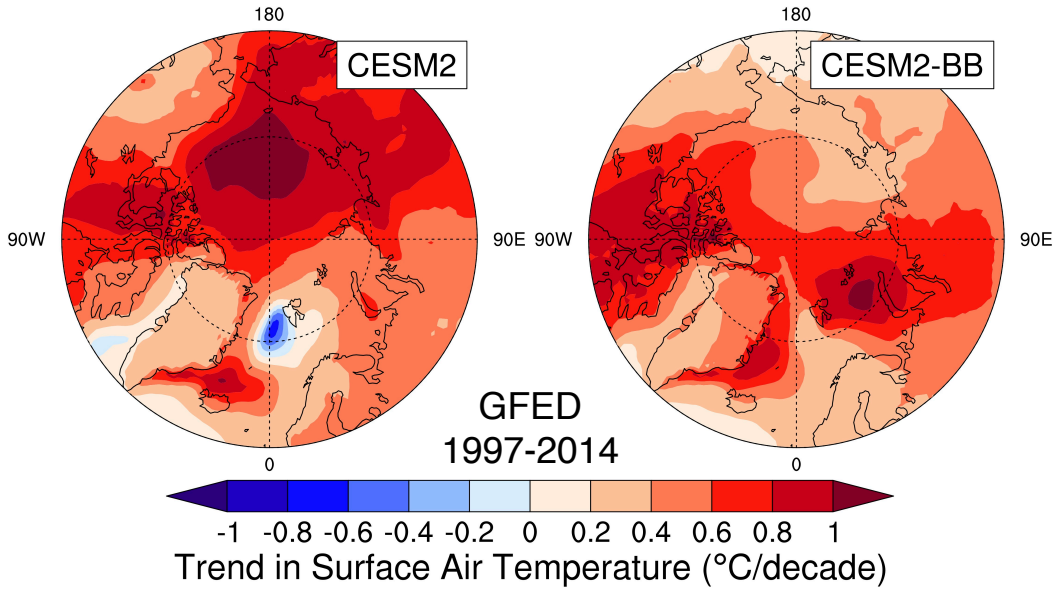
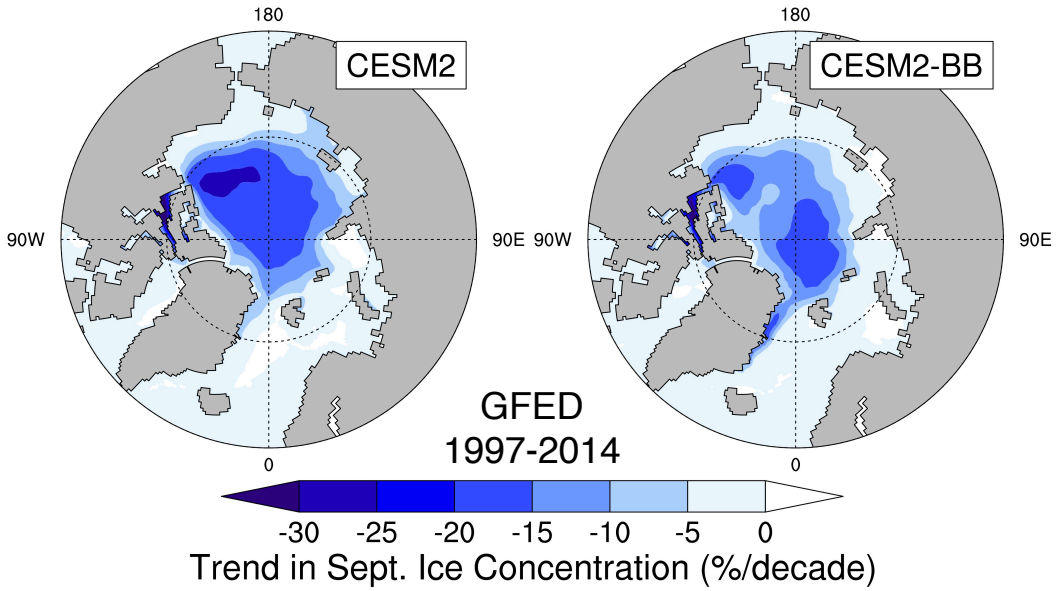




Atmospheric and radiative response to BB emissions

CESM2-BB – CESM2

Vertically integrated cloud droplet number (10^9 m^{-2})

Net surface shortwave flux (W m^{-2})

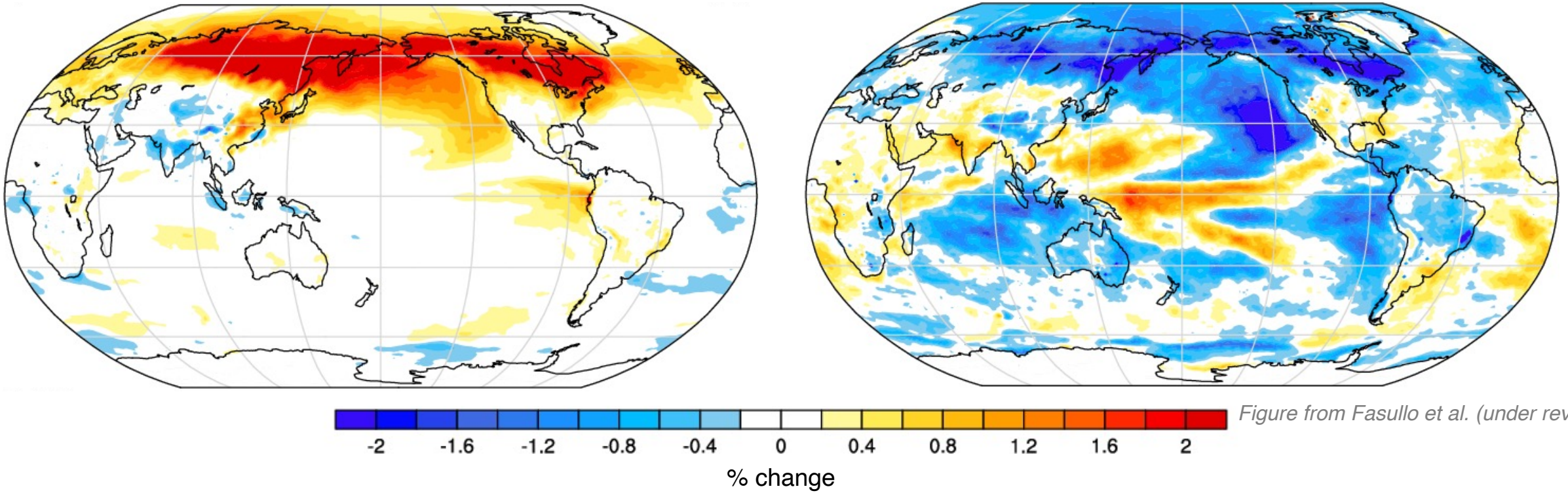
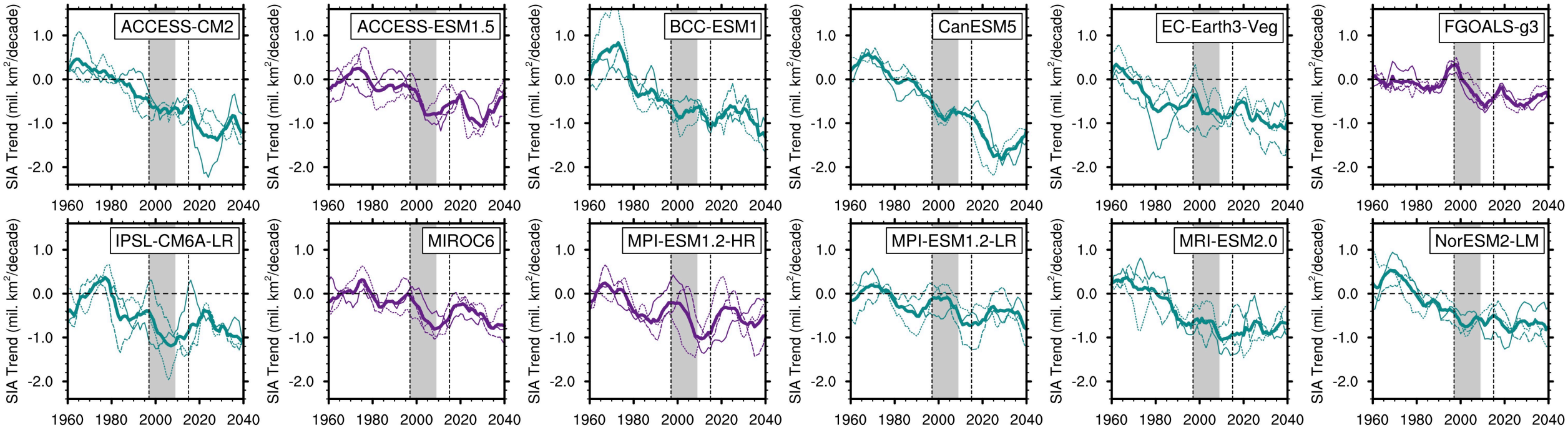


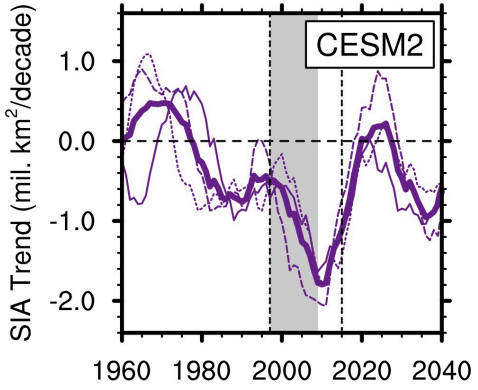
Figure from Fasullo et al. (under review)

Indications of similar behavior in other CMIP6 models



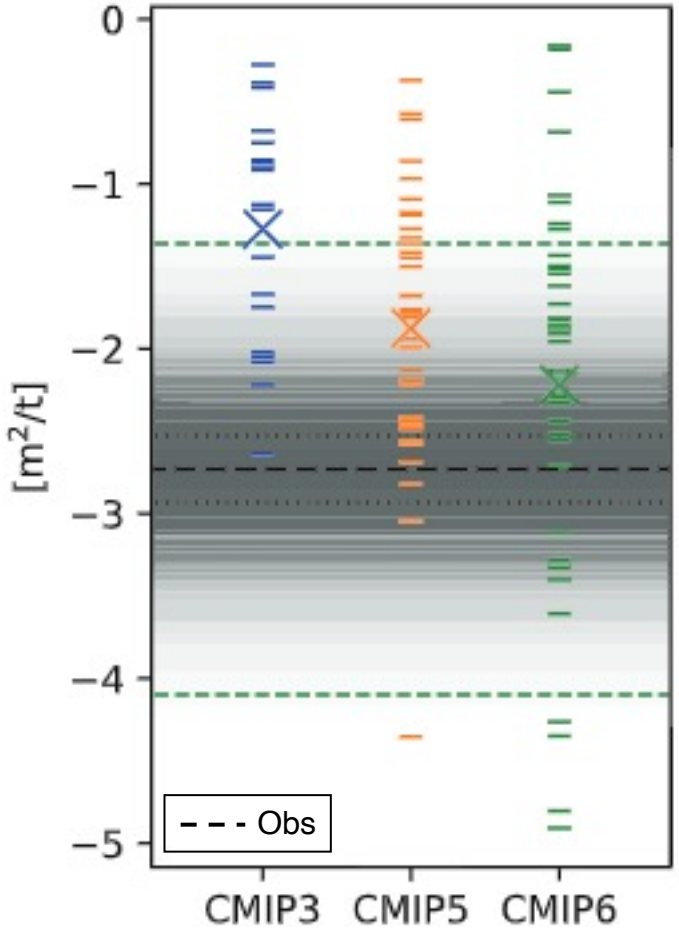
Sensitive

Not sensitive

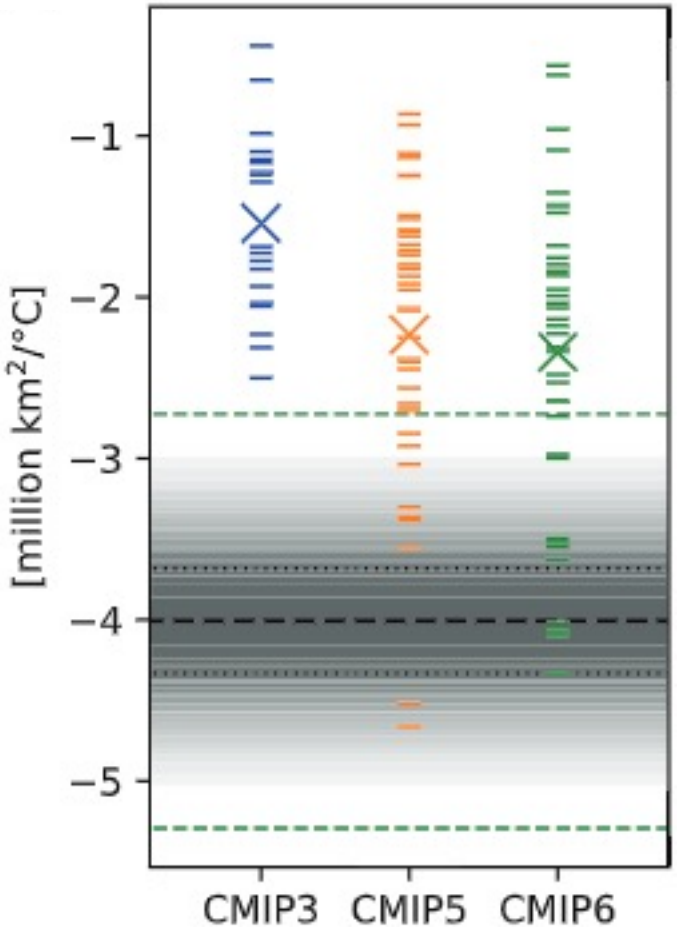


Reported improvement in sea ice sensitivity in CMIP6

Sea ice sensitivity to cumulative anthropogenic CO_2 emissions (1979-2014)

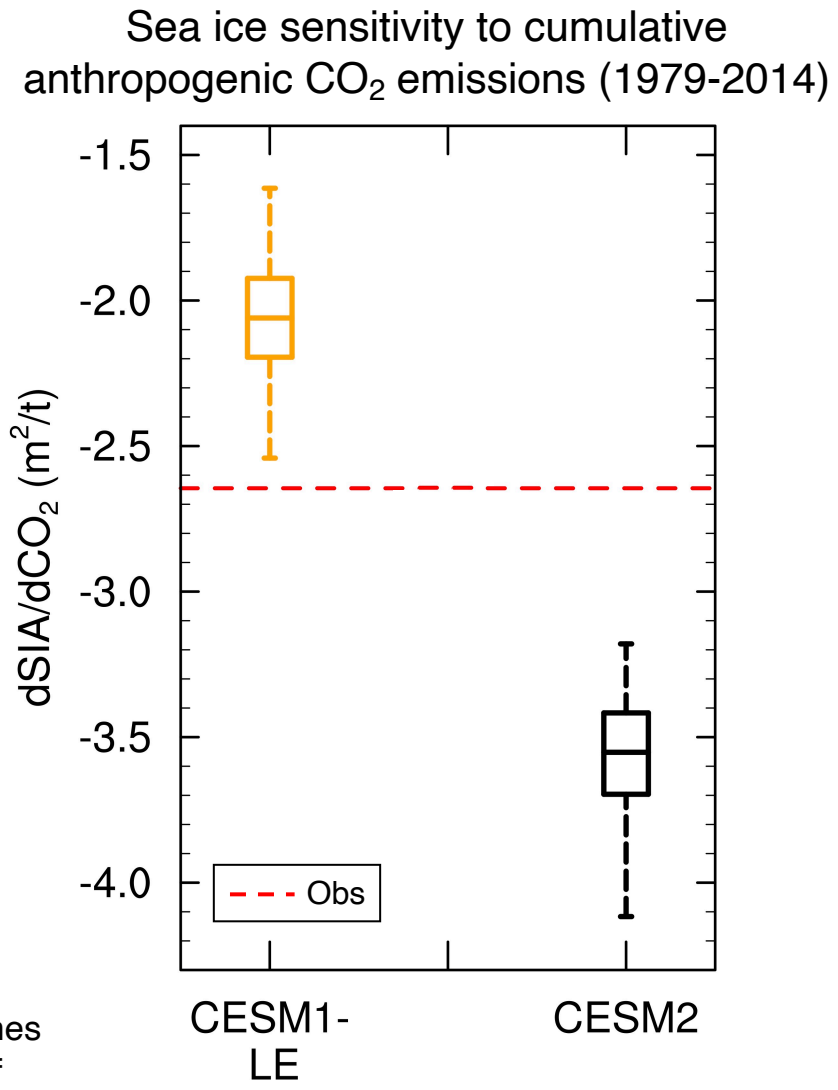


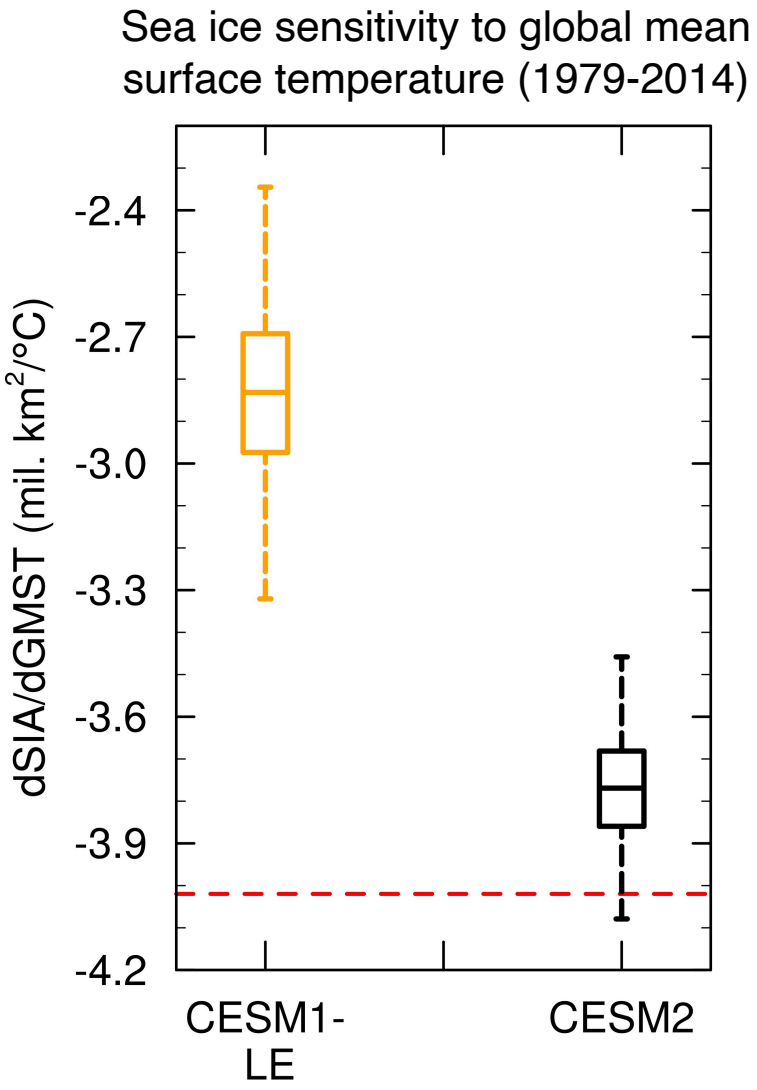
Sea ice sensitivity to global mean surface temperature (1979-2014)



SIMIP Community (2020)

BB emissions explain ½ of the increased sea ice sensitivity





*Bootstrapped 10,000 times with a sub-sample size of n=10 to account for the different ensemble size.

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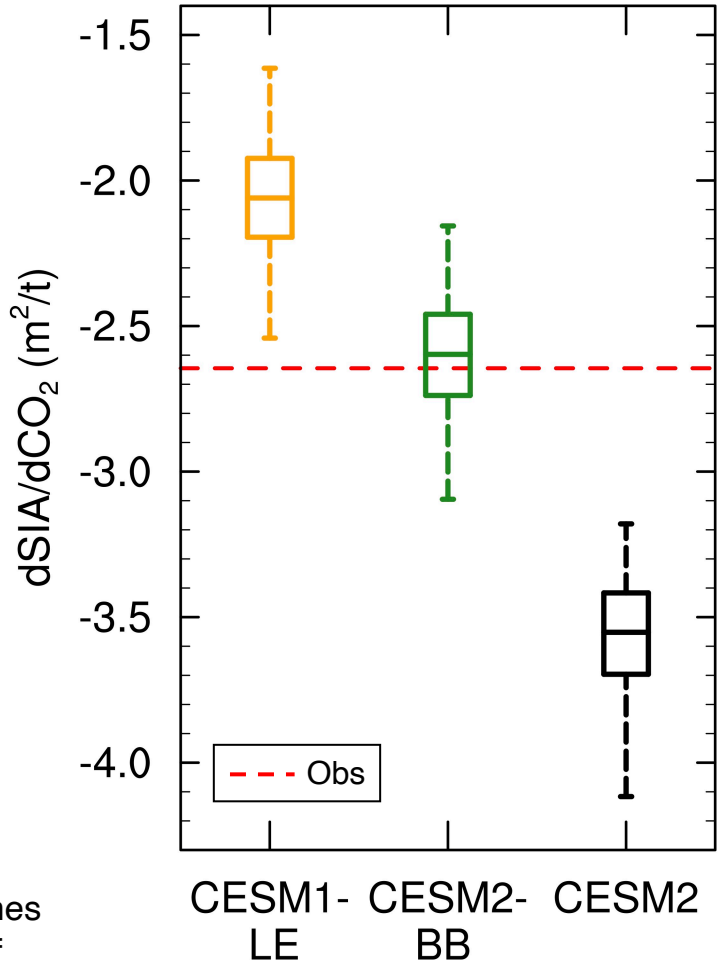

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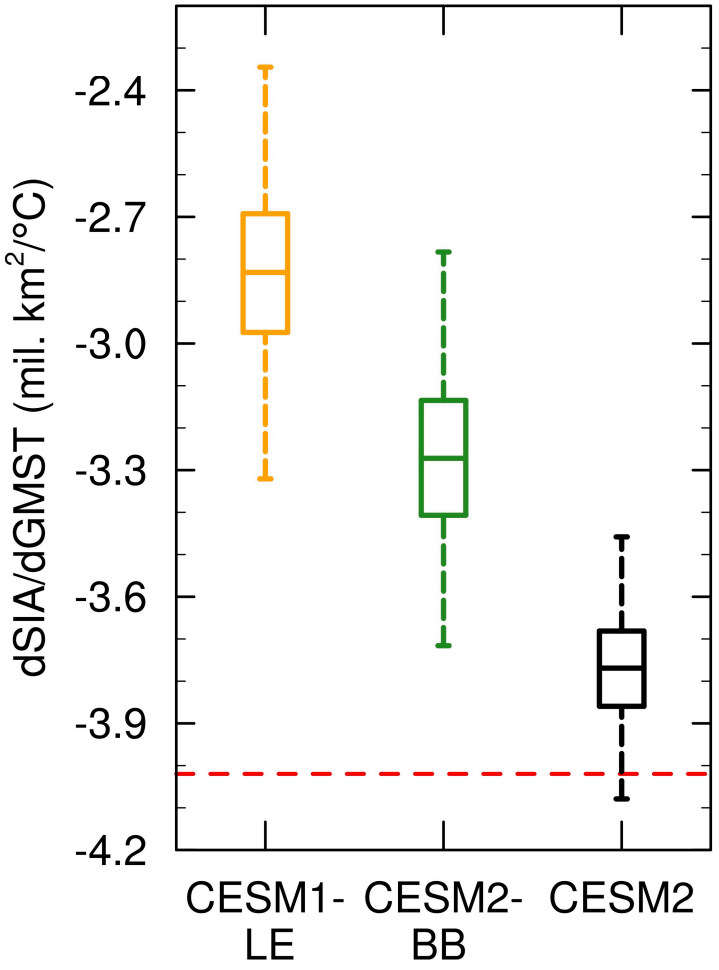

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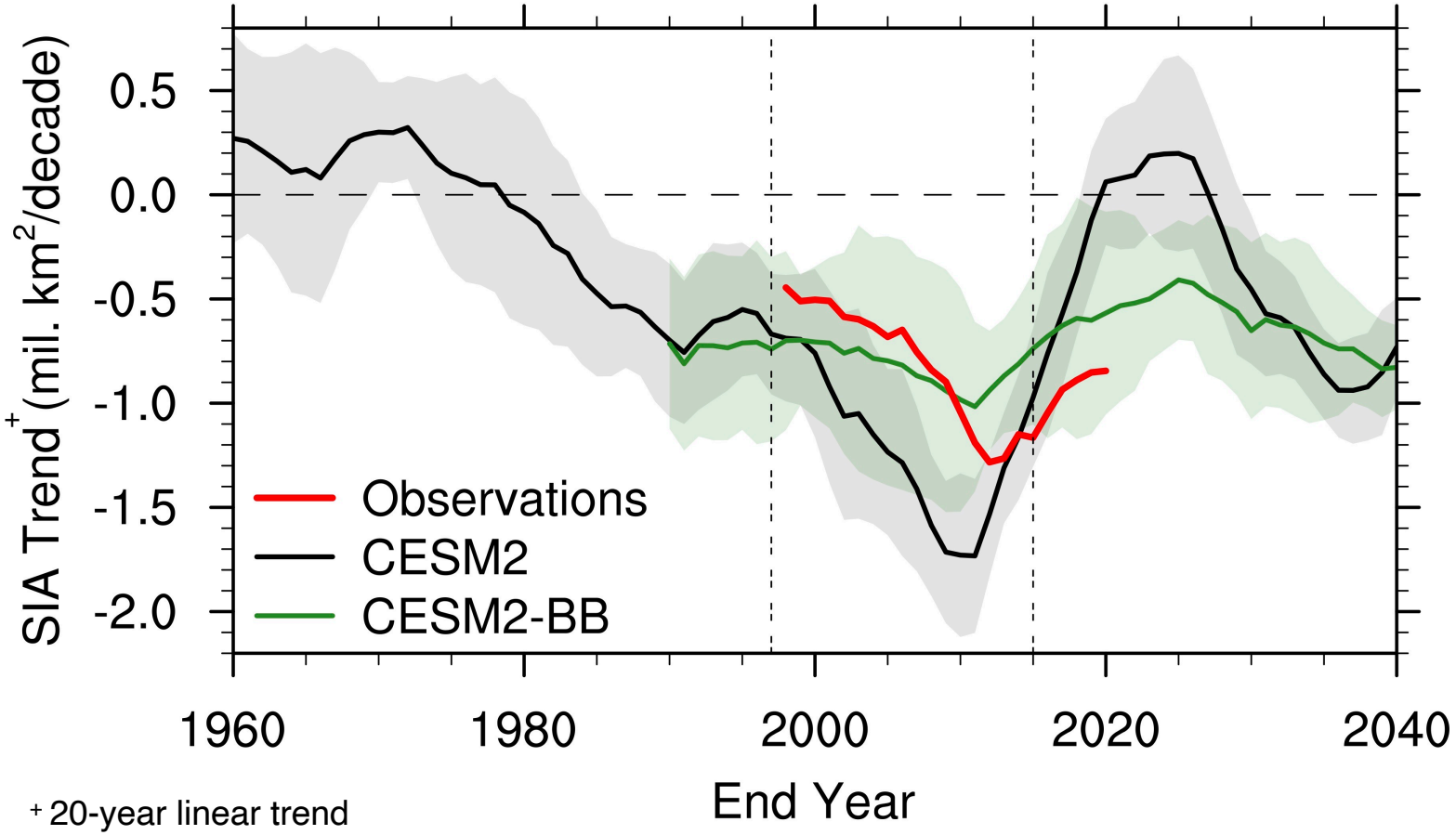
Good qualitative match between CESM2 and observations



+ 20-year linear trend

Conclusions

- The CESM2, as well as other CMIP6 models, simulates an acceleration in sea ice decline that coincides with the start of the GFED period, followed by a recovery until the start of the 2020s.
- We conducted a sensitivity experiment in which we removed the inter-annual variability in BB emissions over the GFED period.
- The sensitivity runs show reduced Arctic warming and sea ice decline compared to the CESM2 when the BB variability is removed.
- Half of the increase in sea ice sensitivity from CMIP5 to CMIP6 in the CESM can be attributed to the increased variability in BB emissions during the GFED period.
- There is indication of a BB-forced signal in the observed early 21st century accelerated rate of Arctic sea ice loss.

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