Emergent constraint on future Arctic amplification

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Motivation

- Arctic amplification (AA) is a robust feature of climate change, and is expected to continue in the 21st century [1,2].
- CMIP6 models project a large spread in the magnitude of future AA:

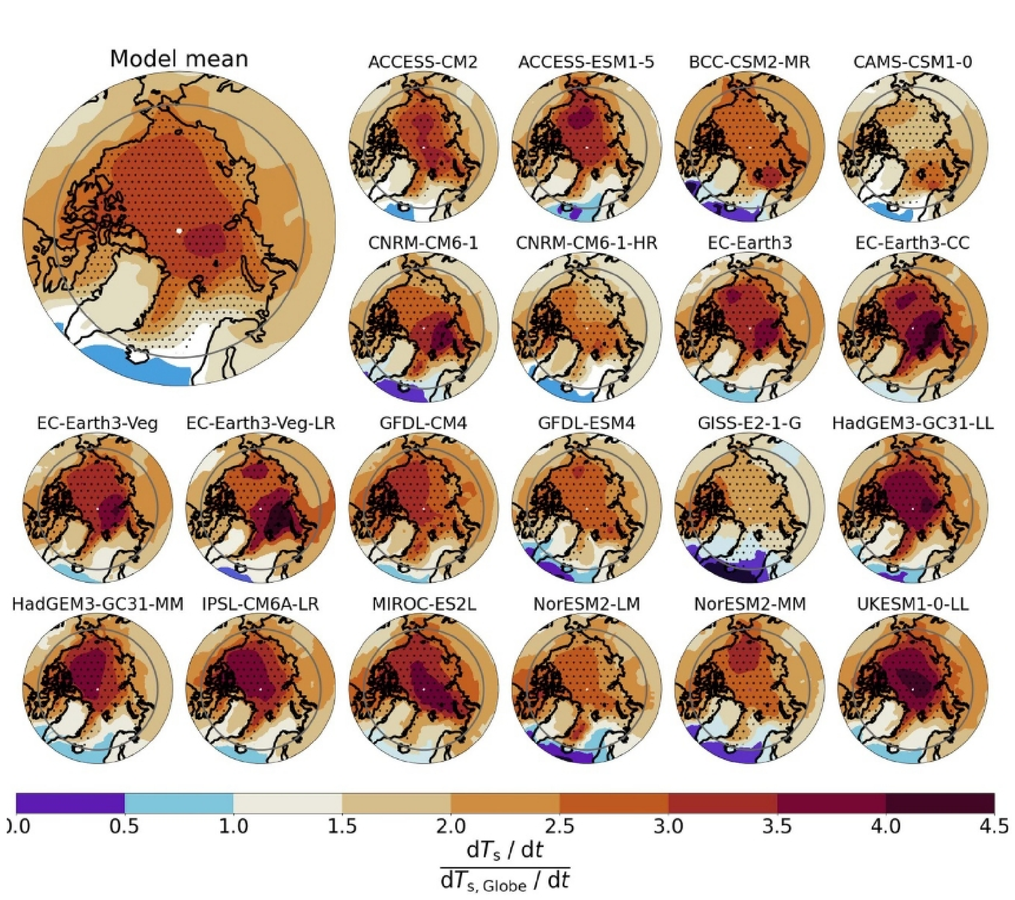


Figure 1. 21st-century Arctic warming, as local amplification factor: Ratio of local and global-mean warming trend 2005–2099. Dotted areas: Ice covered ocean in the current climate (2005-2034).

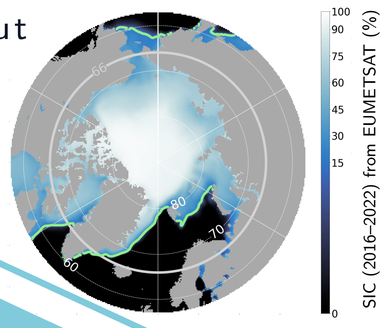
- The magnitude of AA relates to the strength of long-term sea ice loss across climate models [3,4].

Hypothesis: The current-climate sea ice amount sets the stage for climatological sea ice loss in the future, which mediates the magnitude of AA.

Methods and Data

Emergent constraint (EC) on future AA based on current sea ice climatology in CMIP6 [5] in conjunction with satellite observations (OBS) [6].

- 20 CMIP6 climate models using the highest emission scenario [7]
- Satellite data from EUMETSAT:
  - SIC output



- Time period: 2005-2099
- AA magnitude:

$$\mathrm{AA} = \frac{\mathrm{d}T_{s,\mathrm{Arctic}} / \mathrm{d}t}{\mathrm{d}T_{s,\mathrm{Globe}} / \mathrm{d}t}$$

=Ratio of linear temperature trends [8]

ABBREVIATIONS

AA – Arctic amplification
EC – Emergent constraint
OBS – Observations
SIC, SIE – Sea ice concentration, - extent
ES – Emission scenario
SIAF – Sea-ice albedo feedback
LRF – Lapse-rate feedback
PR' – Planck response

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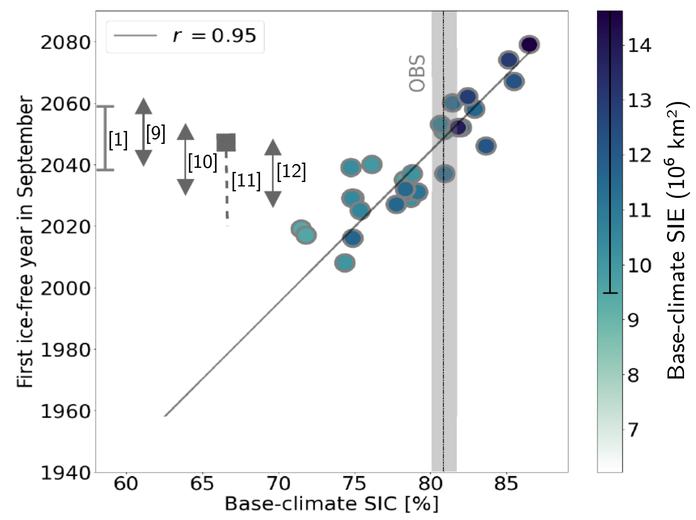
Results



Ice-free Arctic by mid-century?

Presented study: [1], CMIP6 high emission scenario (ES)

Prediction: 2038–2059

Previous studies:

[9] CMIP5 high ES

[10], [11], [12] CMIP6 irrespective of ES

Figure 2. Relationship between current sea ice amount and timing of an ice-free Arctic: Inter-model relationship between SIC and first year with ice-free September across CMIP6 models. Color coding by current sea ice extent (SIE). OBS - Mean observational estimate (2016–2022). Bars along the y-axis give the prediction range per study.

Future AA and role of climate feedbacks?

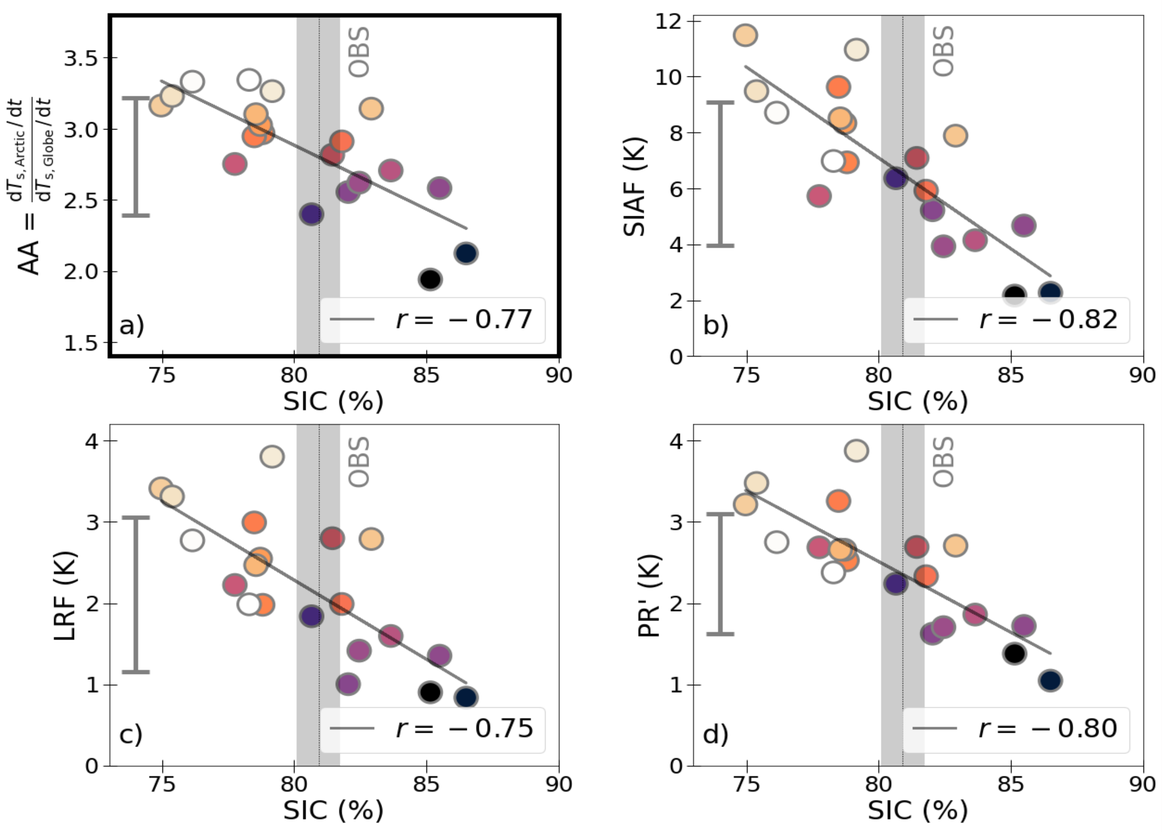


Figure 3. Relationship between current-climate SIC and future AA and amplifying climate feedbacks: Relationship between **a)** SIC and AA, **b)** SIC and sea-ice albedo feedback (SIAF), **c)** SIC and lapse-rate feedback (LRF) and d) SIC and Planck response (PR'). Color coding by magnitude of AA. OBS - Mean observational estimate (2016–2022). Bars along the y-axis give the 95 % prediction ranges.

Conclusion – EC on future AA

Across CMIP6 models, a **lower current sea ice amount** links to **stronger future ice loss [1]** and **larger feedback warming** contributions, thereby mediating a **stronger AA.**

21st-century predictions:

- SIAF 4.0–9.1 K
- LRF 1.2–3.1 K
- PR' 1.6–3.1 K
- **AA 2.5–3.3**

REFERENCES

[1] Linke et al. 2023, *ERCL*, 10.1088/2752-5295/acf4b7

[2] Davy & Griewank 2023. *ERL*, 10.1088/1748-9326/ace273

[3] Screen & Simmonds 2010, *NPG*, 10.1038/nature09051.

[4] Dai et al. 2019, *Nat. Commun.* 10.1038/s41467-018-07954-9.

[5] Eyring et al. 2016, *GMD*, 10.5194/gmd-9-1937-2016.

[6] Lavergne et al. 2019, *The Cryosphere*, 10.5194/tc-13-49-2019

[7] O'Neill et al. 2016, *GMD*, 10.5194/gmd-9-3461-2016., [8] Smith et al. 2020 *GMD*, 10.5194/gmd-12-1139-2019.

[9] Massonnet et al. 2012, *The Cryosphere*, 10.5194/tc-6-1383-2012., [10] Bonan et al. 2021, *GRL*, 10.1029/2021GL094309.

[11] Notz & SIMIP Community 2020, *GRL*, 10.1029/2019GL086749., [12] Kim et al. 2023, *Nat Commun.*, 10.1038/s41467-023-38511-8

Link to paper