Local and remote controls of changes to Arctic precipitation under global warming

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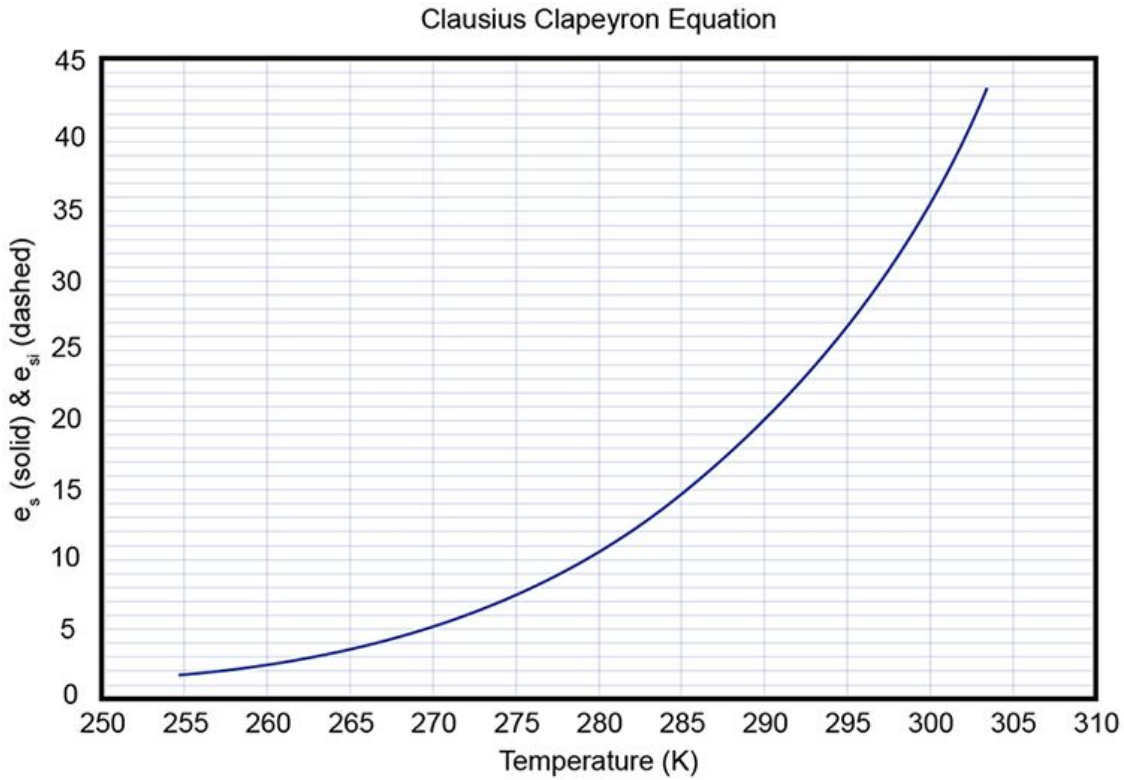
Arctic Amplification ⟷ ↑Arctic Precipitation



Sources of moisture:

Local: Evaporation

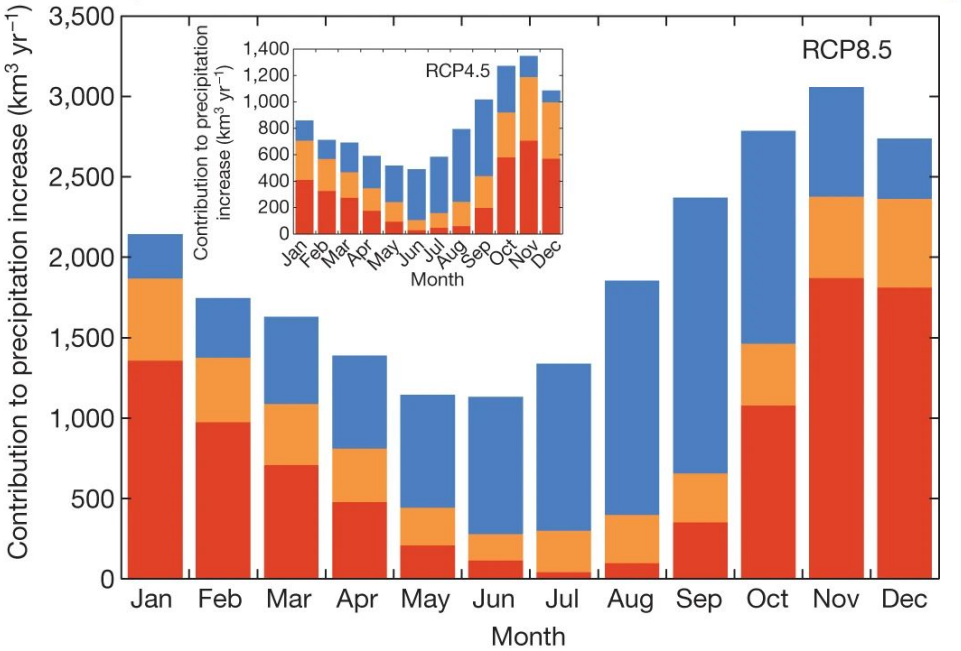
Remote: Moisture intrusion from lower latitude

Arctic Precipitation (Local vs Remote)

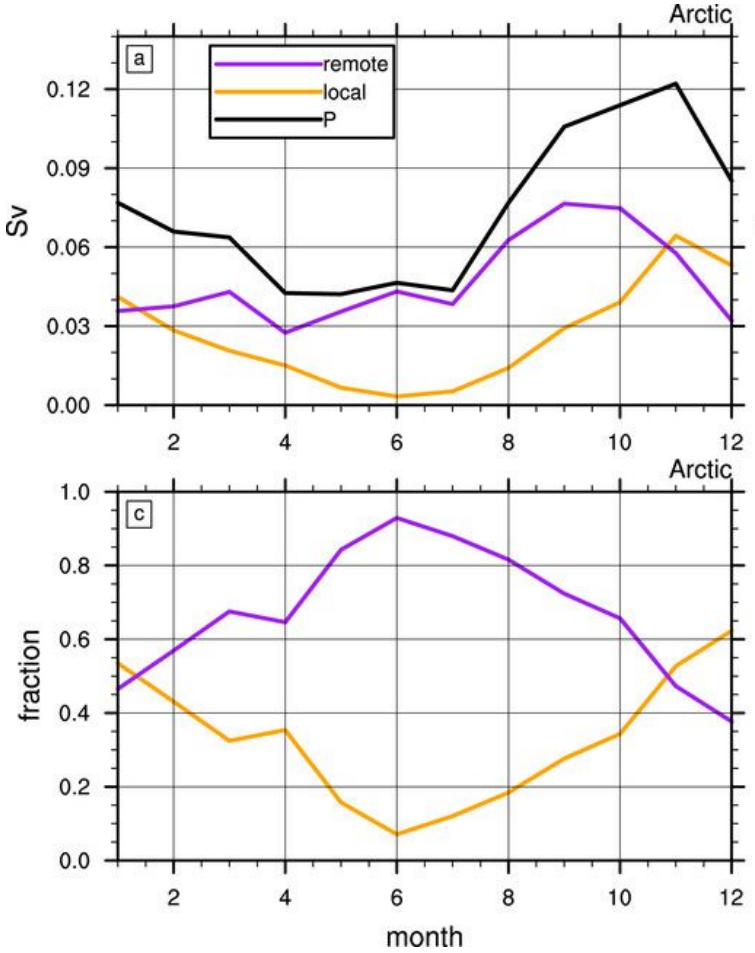
Transport (remote origin)

Evaporation unrelated to sea ice (local origin)

Evaporation due to sea-ice retreat (local origin)



Bintanja, et.al (2014)



Singh, et.al (2017)

How does sea ice loss and doubling of CO2 affect the local and remote controls of Arctic precipitation?
Is the effect additive?

Model Simulations and Methodology

——— Last 50 years of multi-centennial simulation from PAMIP (CESM with WACCM4)

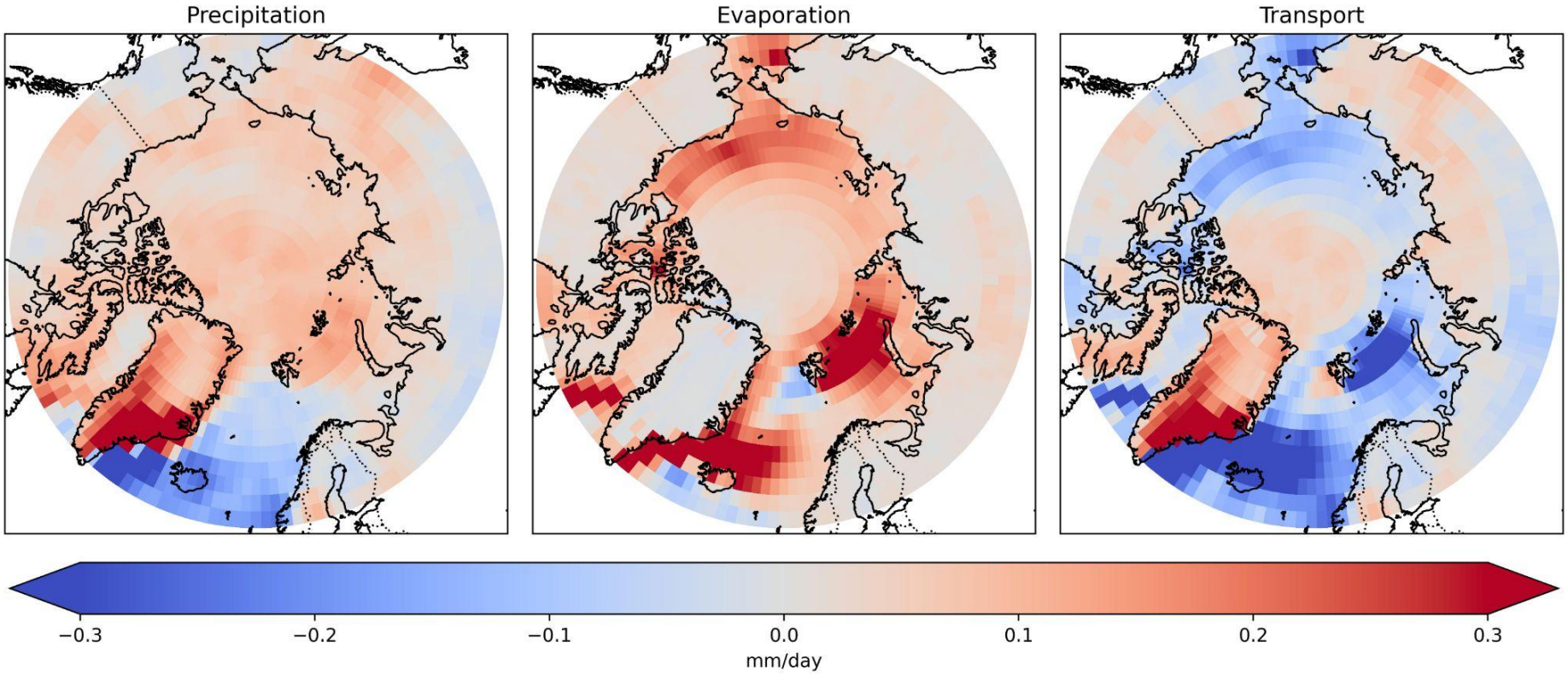
Scenarios	Description
pa-pdSIC-ext	Present Day Sea Ice Concentration (SIC)
pa-futArcSIC-ext	Future Arctic Sea Ice Concentration
pa-pdSIC-2XCO2-ext	Present Day SIC with Doubling C02
pa-futSIC-2XCO2-ext	Future SIC with Doubling CO2

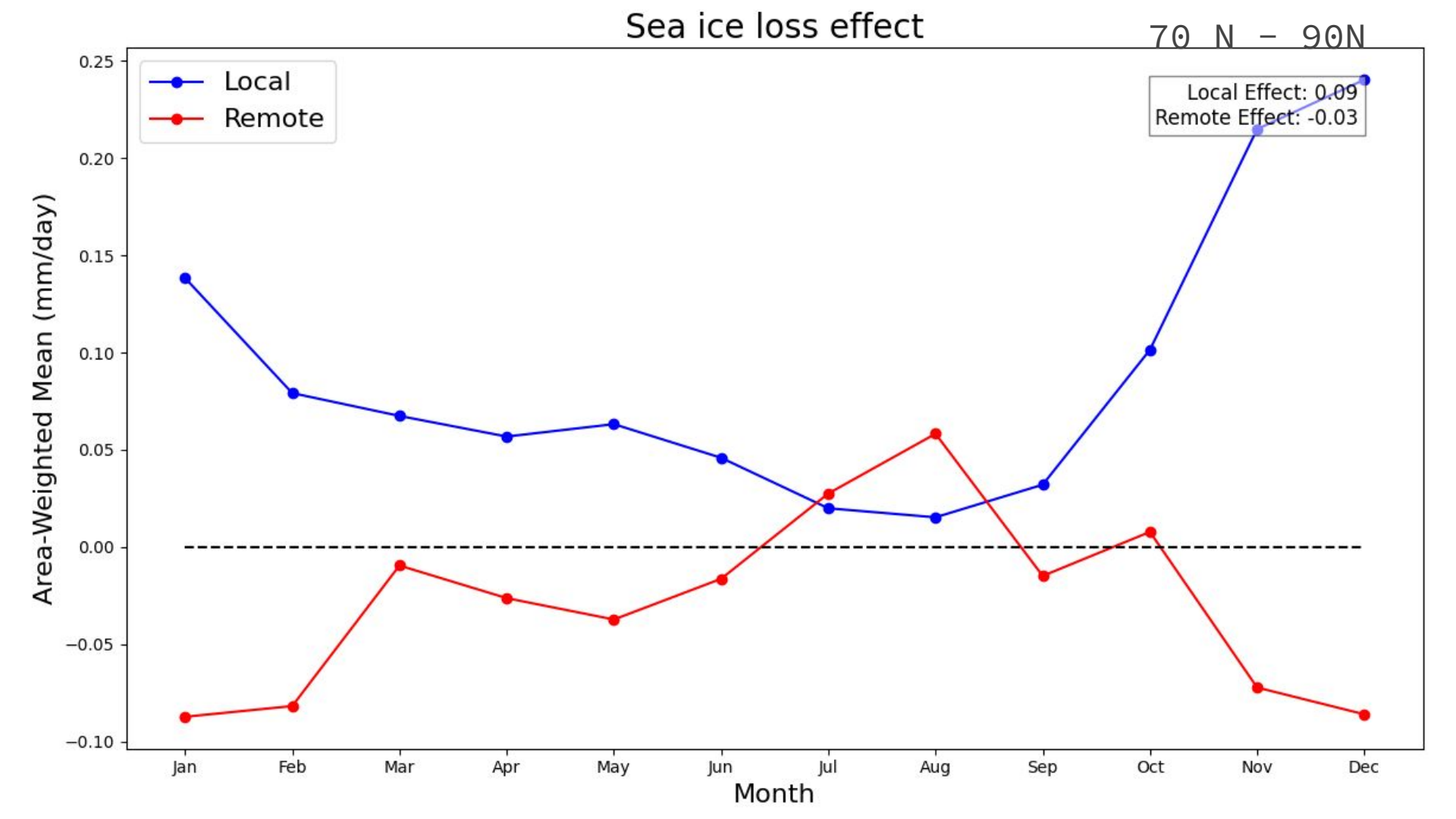
Budget method to analyze the controls

Precipitation (P) - Evaporation (E) = Transport

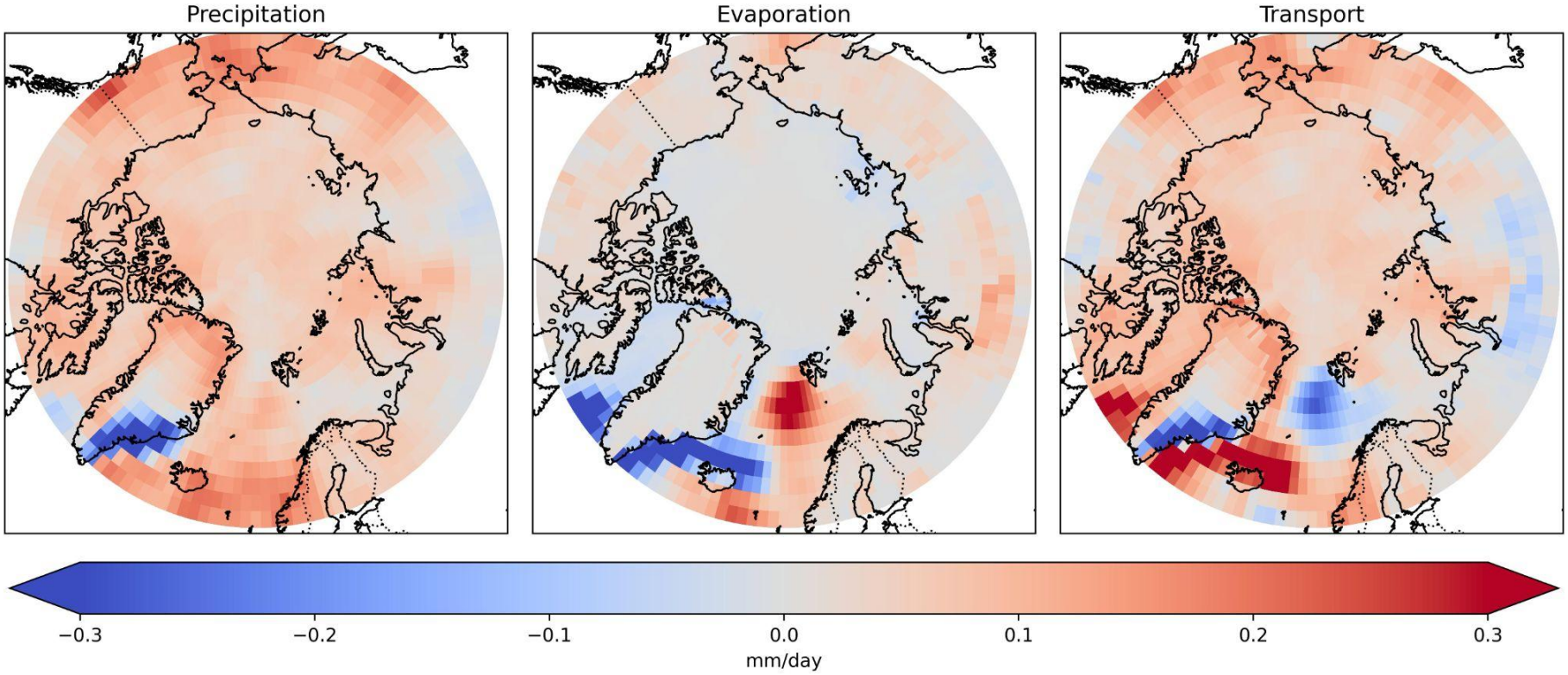
Results

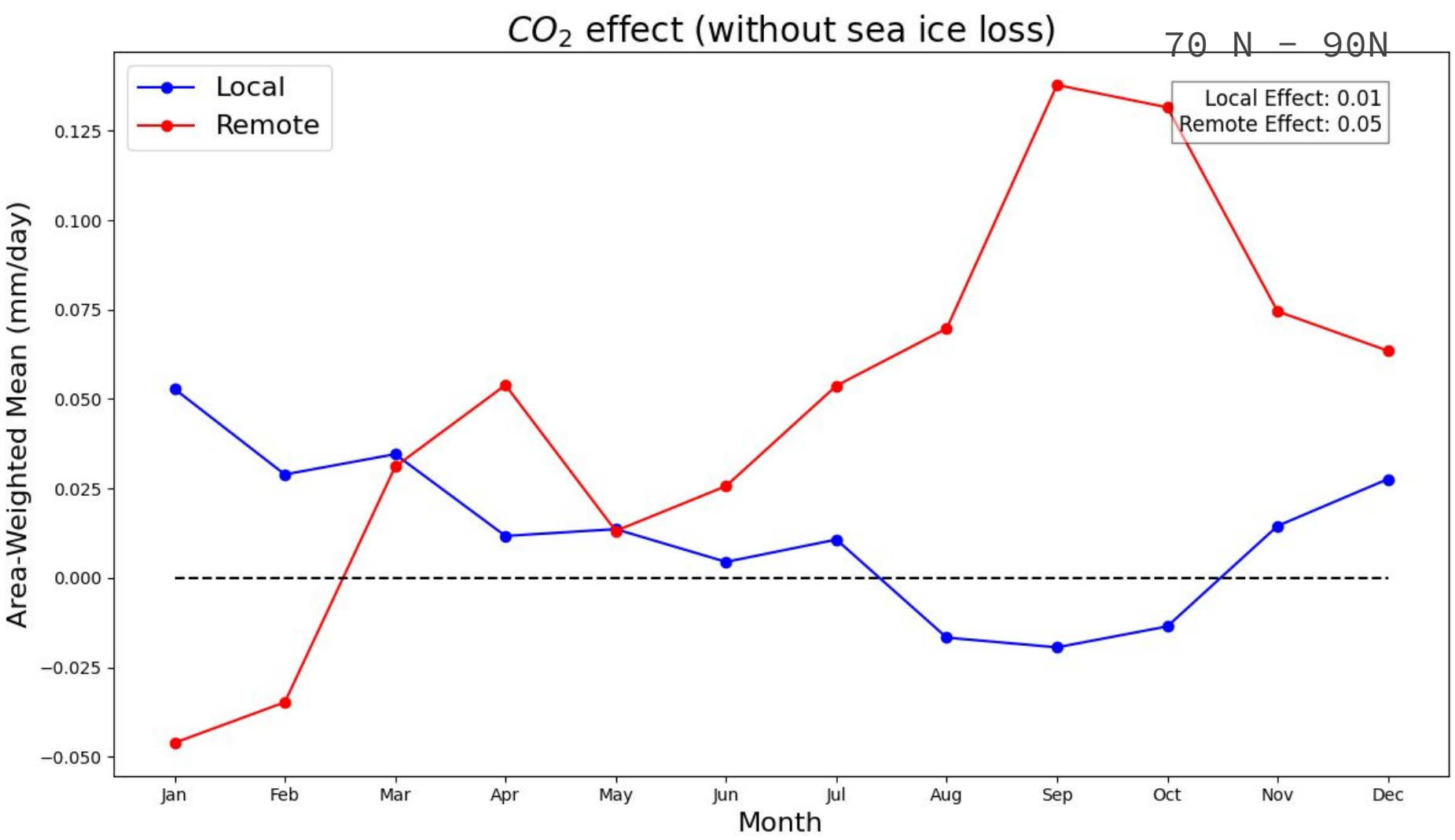
Sea Ice Loss Effect



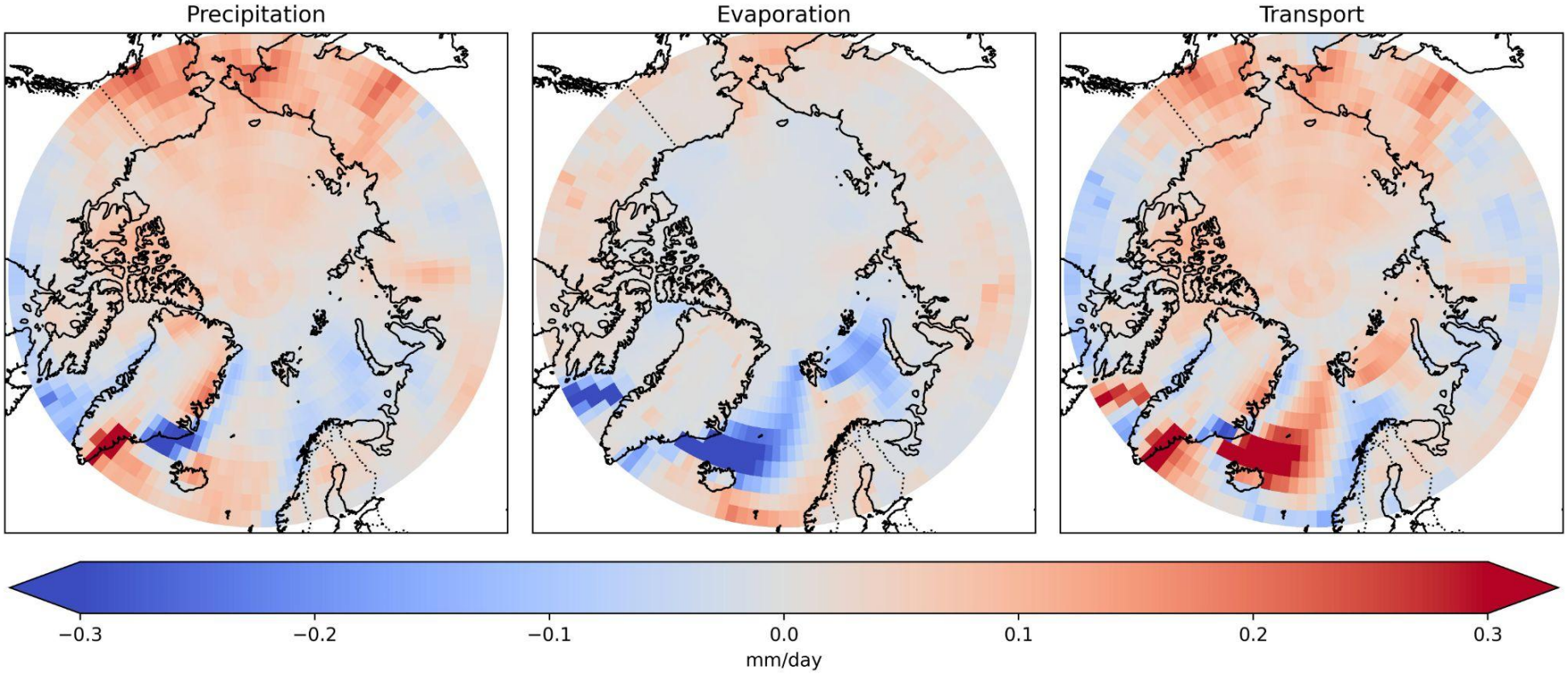

Sea ice loss effect
70 N – 90N
Local
Remote
Local Effect: 0.09
Remote Effect: -0.03
Area-Weighted Mean (mm/day)
0.25
0.20
0.15
0.10
0.05
0.00
−0.05
−0.10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

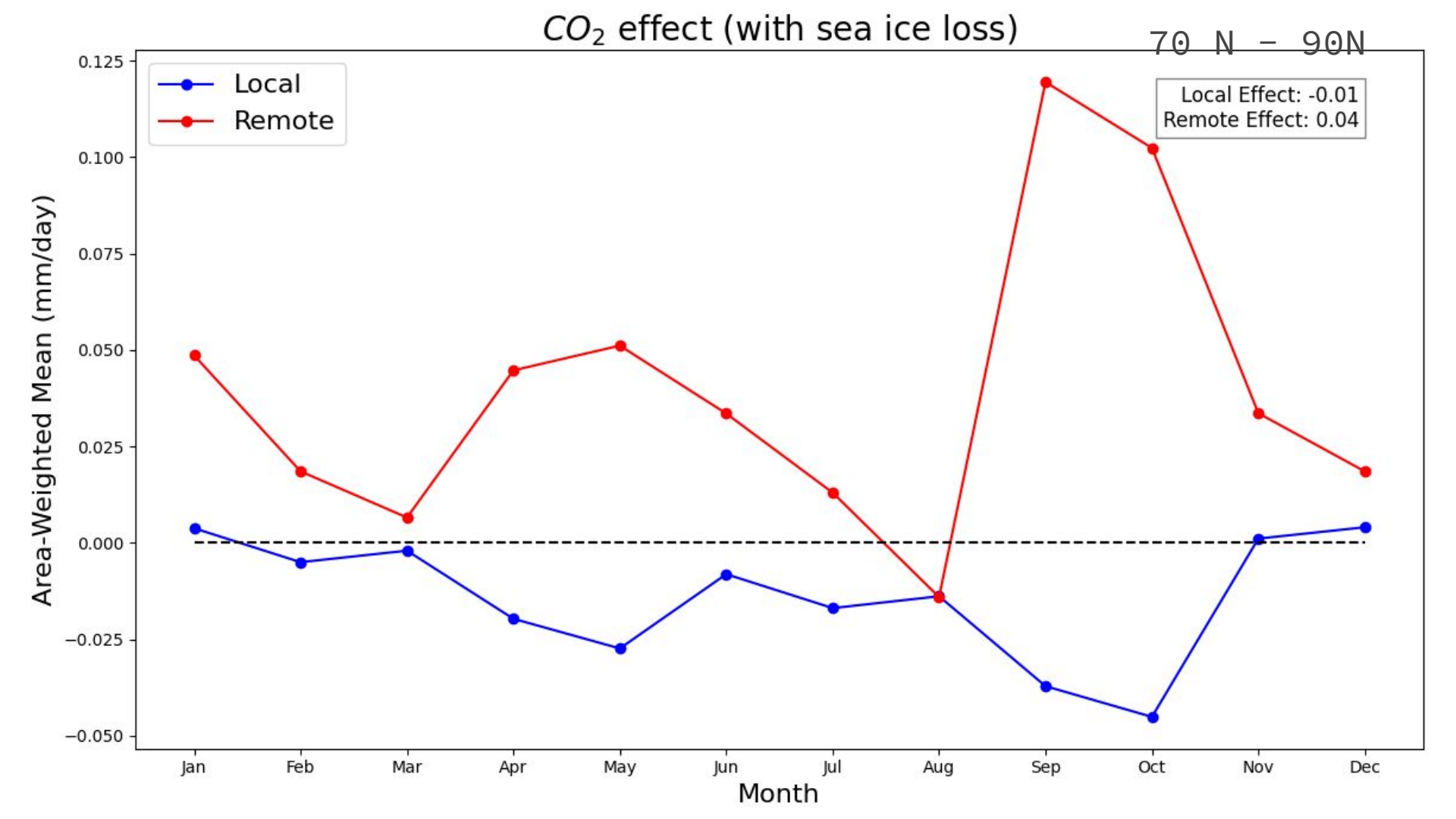
CO2 Effect - No Sea Ice Loss




CO_2 effect (without sea ice loss)
70 N - 90N
Local
Remote
Local Effect: 0.01
Remote Effect: 0.05
Area-Weighted Mean (mm/day)
0.125
0.100
0.075
0.050
0.025
0.000
−0.025
−0.050
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Combined Effect: CO2 Effect - With Sea Ice Loss




CO_2 effect (with sea ice loss)
70 N – 90N
Local
Remote
Local Effect: -0.01
Remote Effect: 0.04
Area-Weighted Mean (mm/day)
0.125
0.100
0.075
0.050
0.025
0.000
−0.025
−0.050
Jan
Feb
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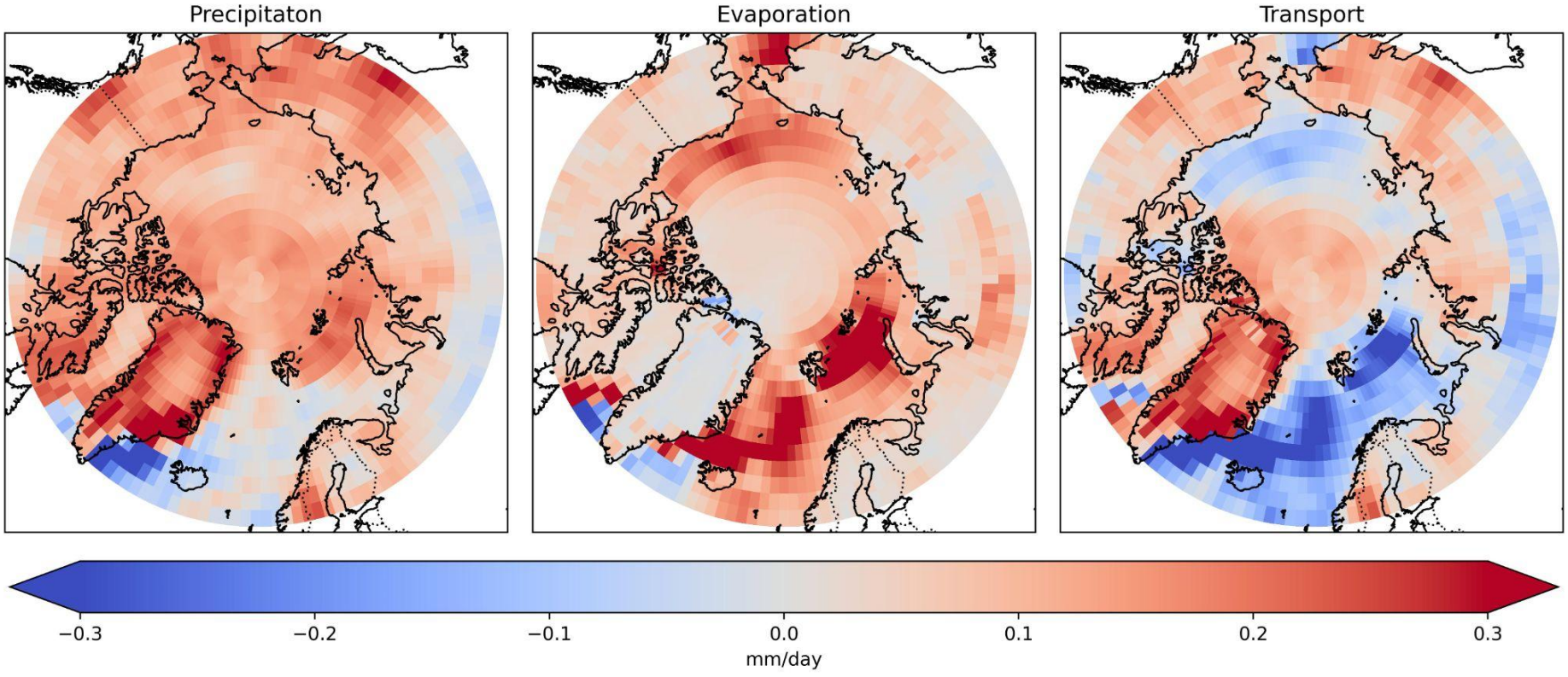
Nov
Dec
Month

Combined Individual effects = Sea Ice Loss Effect + CO2 Effect



Summary

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1. Sea ice loss enhances evaporation, while CO2 doubling strengthens moisture transport, with both effects exhibiting strong seasonal variability.

2. The individual effects of sea ice loss and CO2 on the controls are not additive; instead, they interact and modulate each other’s impact on Arctic precipitation.

Future Plan

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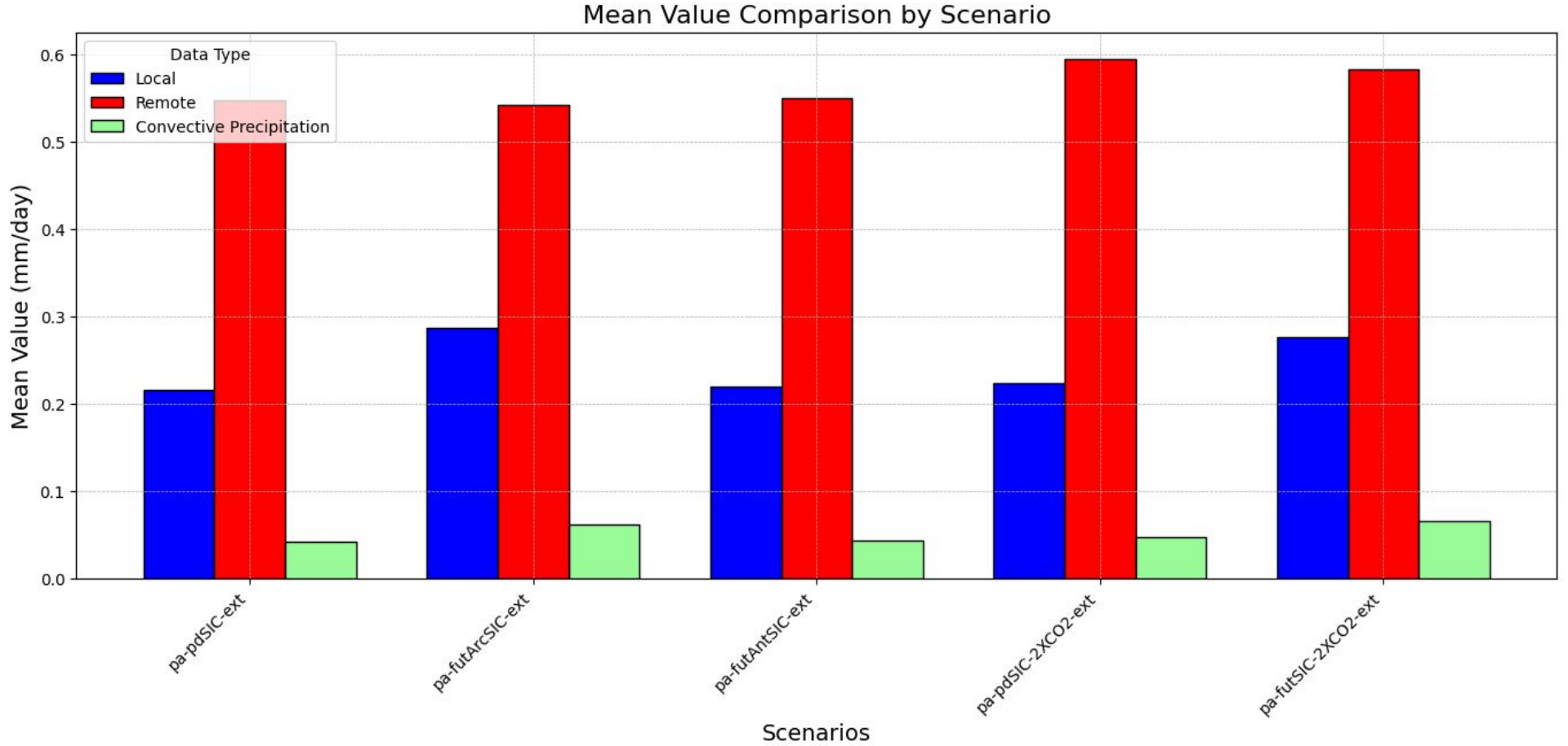
1. Investigate and quantify the strength of CO2 and sea ice effect and its relation to the changes on controls.
2. How will convective precipitation be affected under these scenarios?
3. What are the notable effects of sea ice loss in Antarctica?
4. What do other model simulations predict about these changes?


Mean Value Comparison by Scenario
Data Type
Local
Remote
Convective Precipitation
Mean Value (mm/day)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
pa-pdSIC-ext
pa-futArcSIC-ext
pa-futAntSIC-ext
pa-pdSIC-2XCO2-ext
pa-futSIC-2XCO2-ext
Scenarios

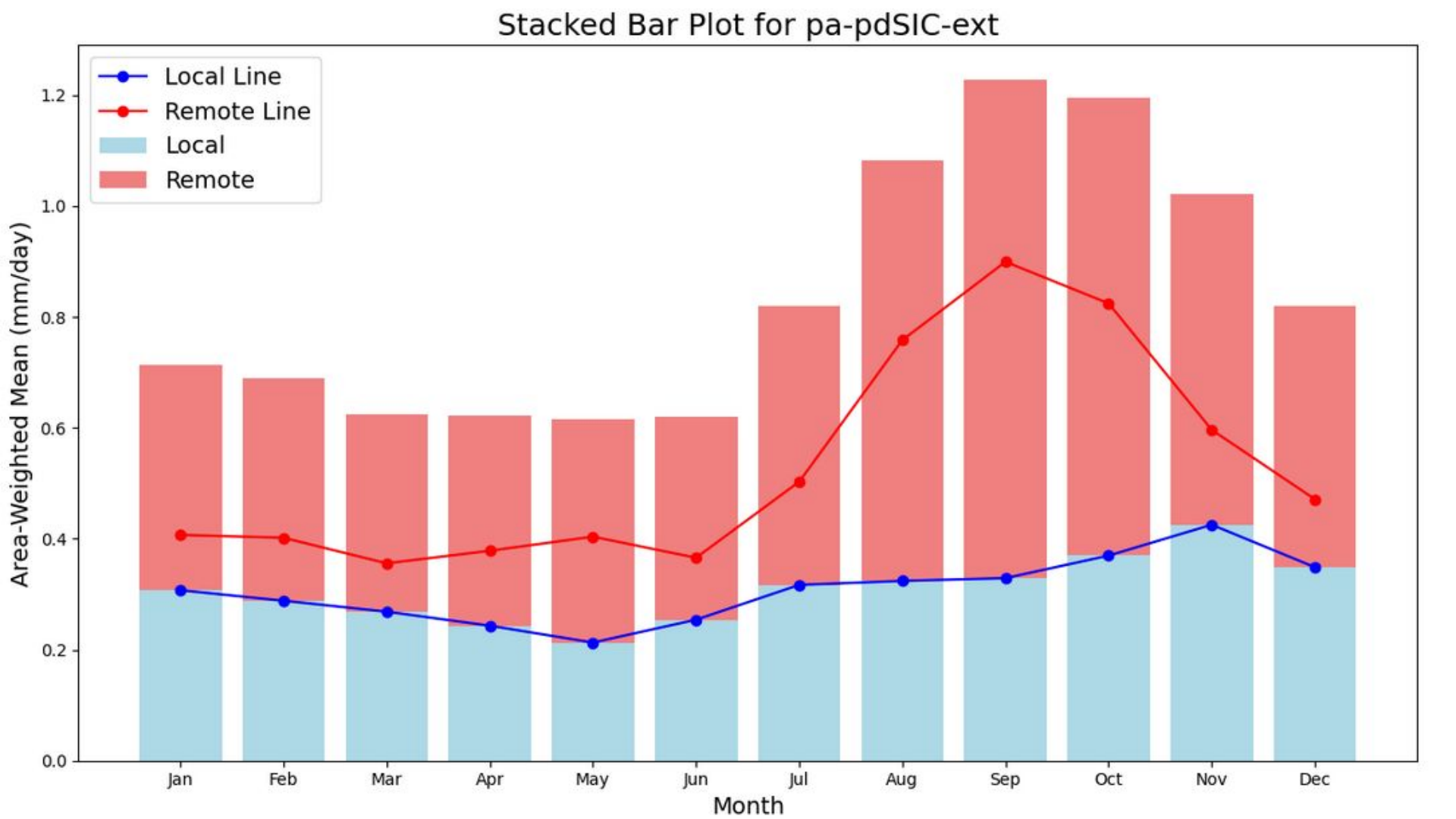
THANK YOU!

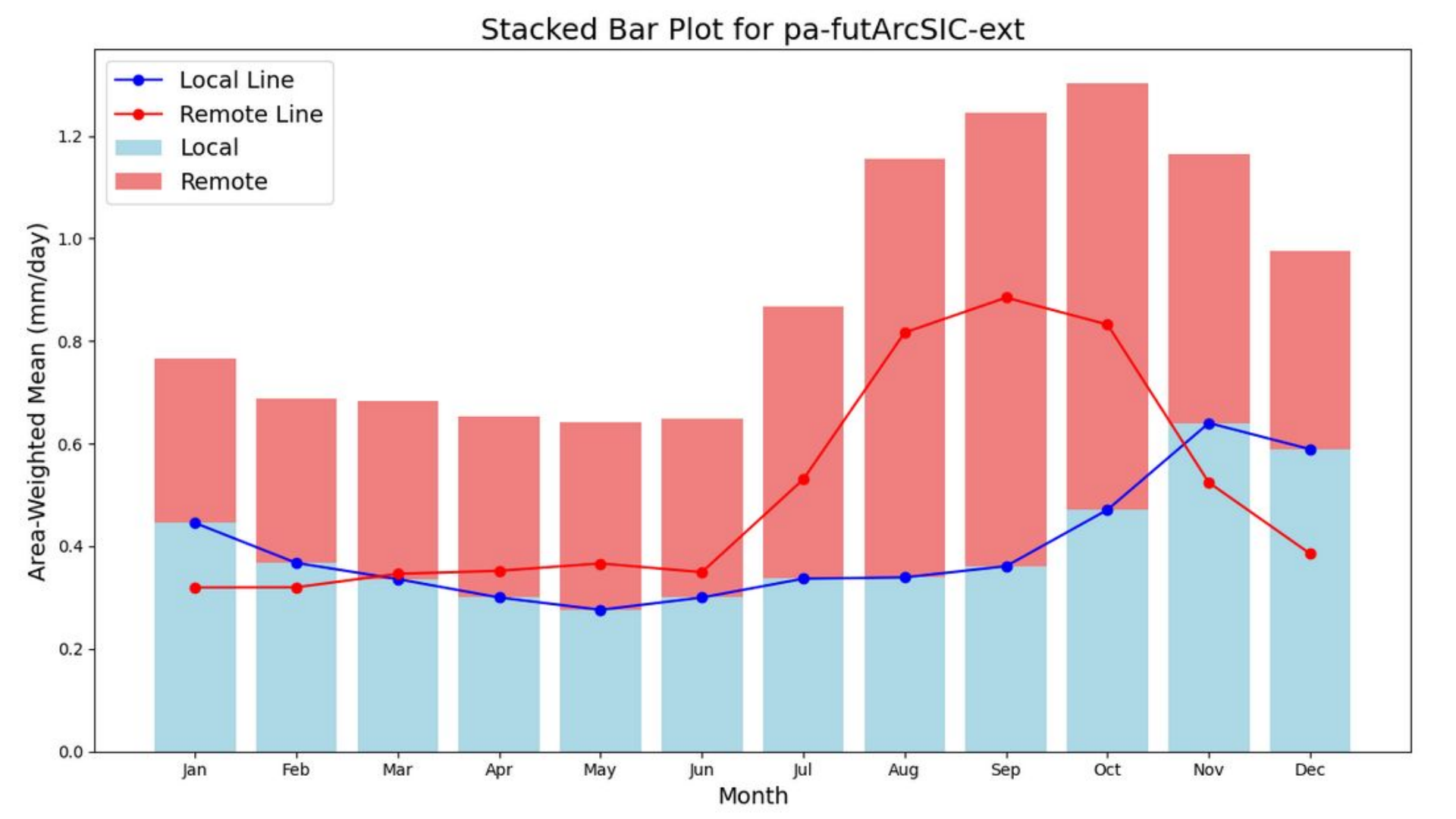
Reference

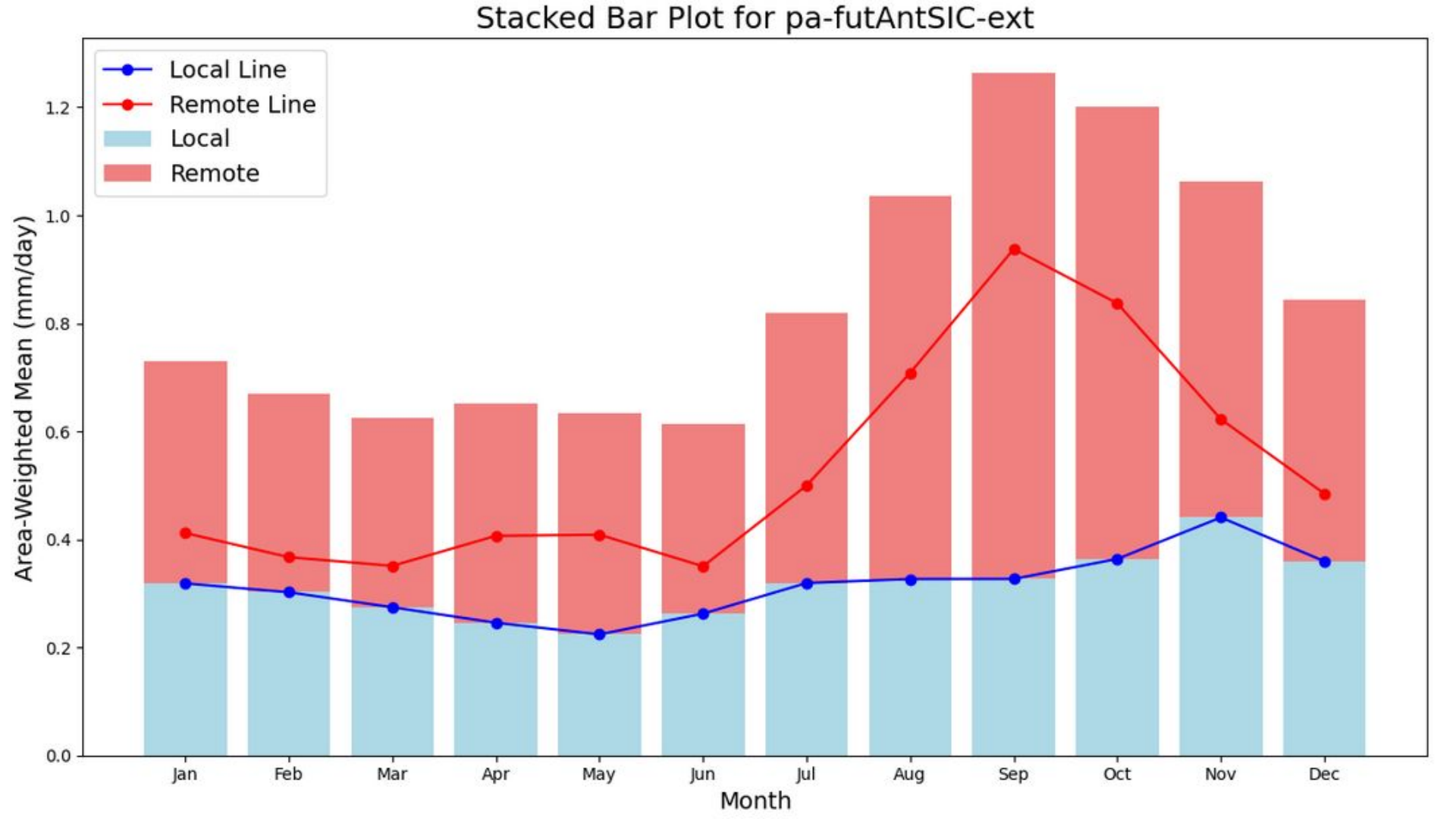
Bintanja, R., Selten, F. Future increases in Arctic precipitation linked to local evaporation and sea-ice retreat. *Nature* **509**, 479–482 (2014). https://doi.org/10.1038/nature13259

Singh, H. K., Bitz, C. M., Donohoe, A., & Rasch, P. J. (2017). A source–receptor perspective on the polar hydrologic cycle: Sources, seasonality, and Arctic–Antarctic parity in the hydrologic cycle response to CO2 doubling. Journal of Climate, 30(24), 9999-10017

Supplementary plot


Stacked Bar Plot for pa-pdSIC-ext
Local Line
Remote Line
Local
Remote
Area-Weighted Mean (mm/day)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Stacked Bar Plot for pa-futArcSIC-ext
Local Line
Remote Line
Local
Remote
Area-Weighted Mean (mm/day)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Stacked Bar Plot for pa-futAntSIC-ext
Local Line
Remote Line
Local
Remote
Area-Weighted Mean (mm/day)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Jan
Feb
Mar
Apr
May
Jun
Jul
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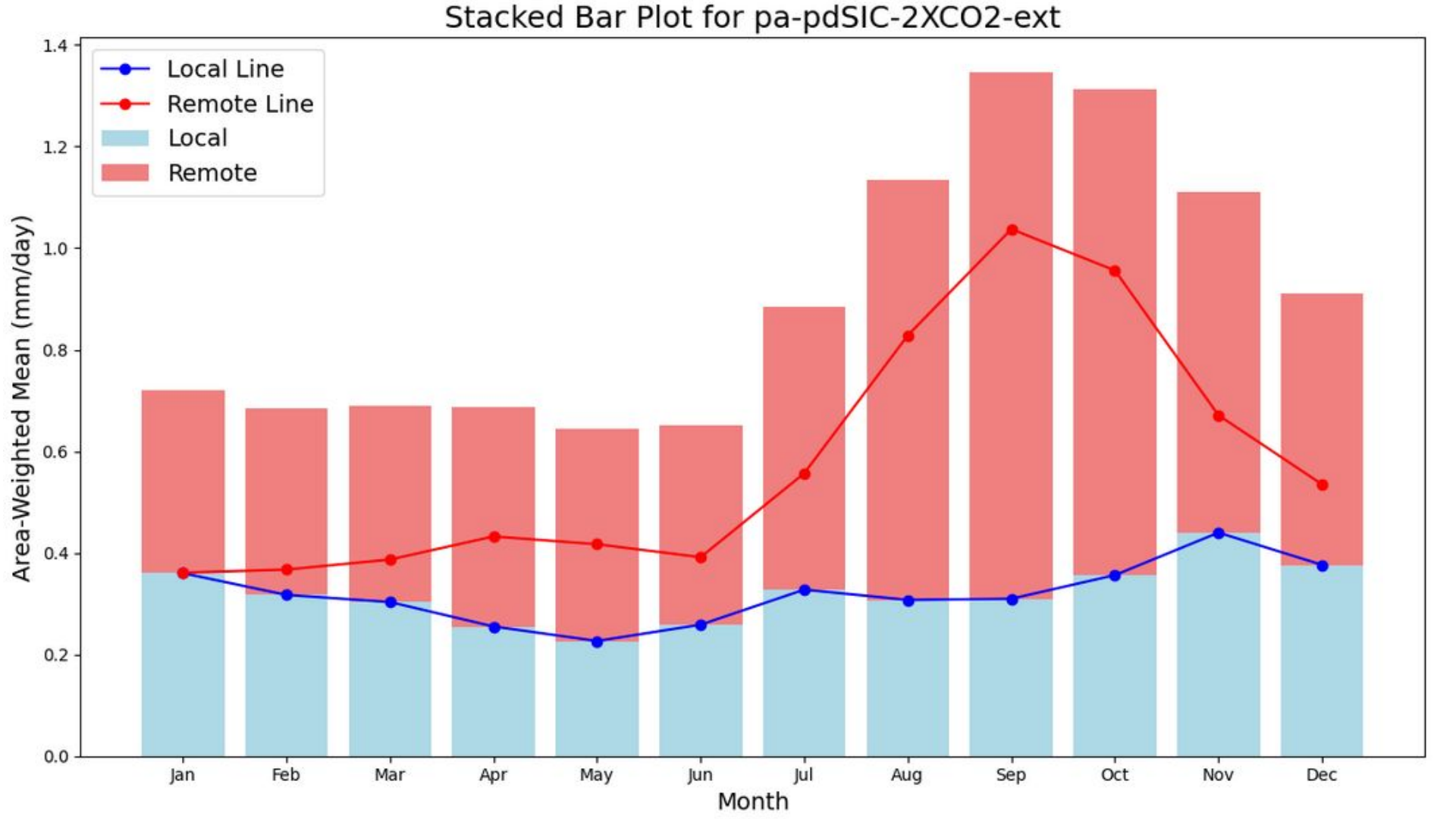
Sep
Oct
Nov
Dec
Month


Stacked Bar Plot for pa-pdSIC-2XCO2-ext
Local Line
Remote Line
Local
Remote
Area-Weighted Mean (mm/day)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Jan
Feb
Mar
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May
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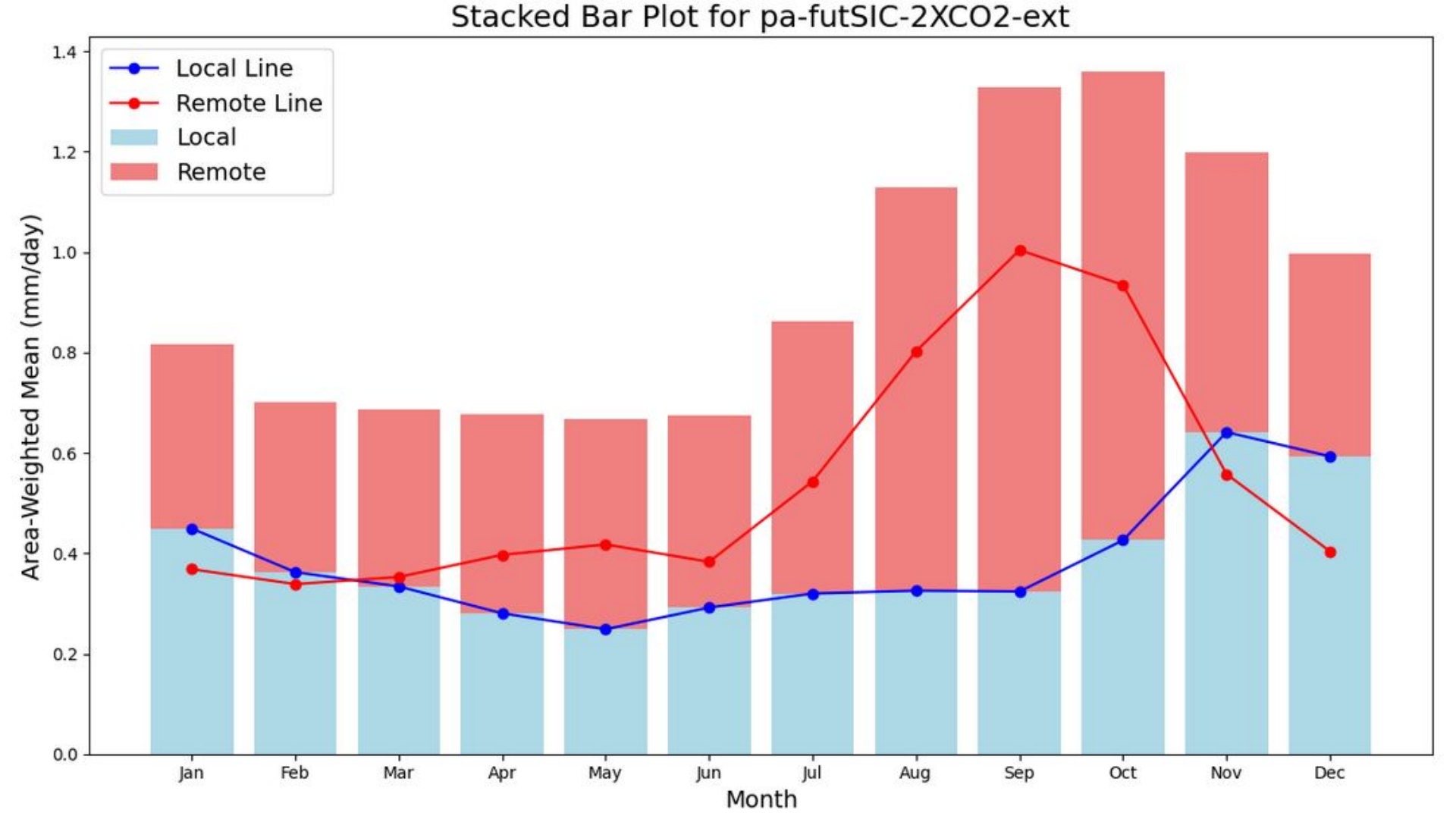
Month


Stacked Bar Plot for pa-futSIC-2XCO2-ext
Local Line
Remote Line
Local
Remote
Area-Weighted Mean (mm/day)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Jan
Feb
Mar
Apr
May
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Jul
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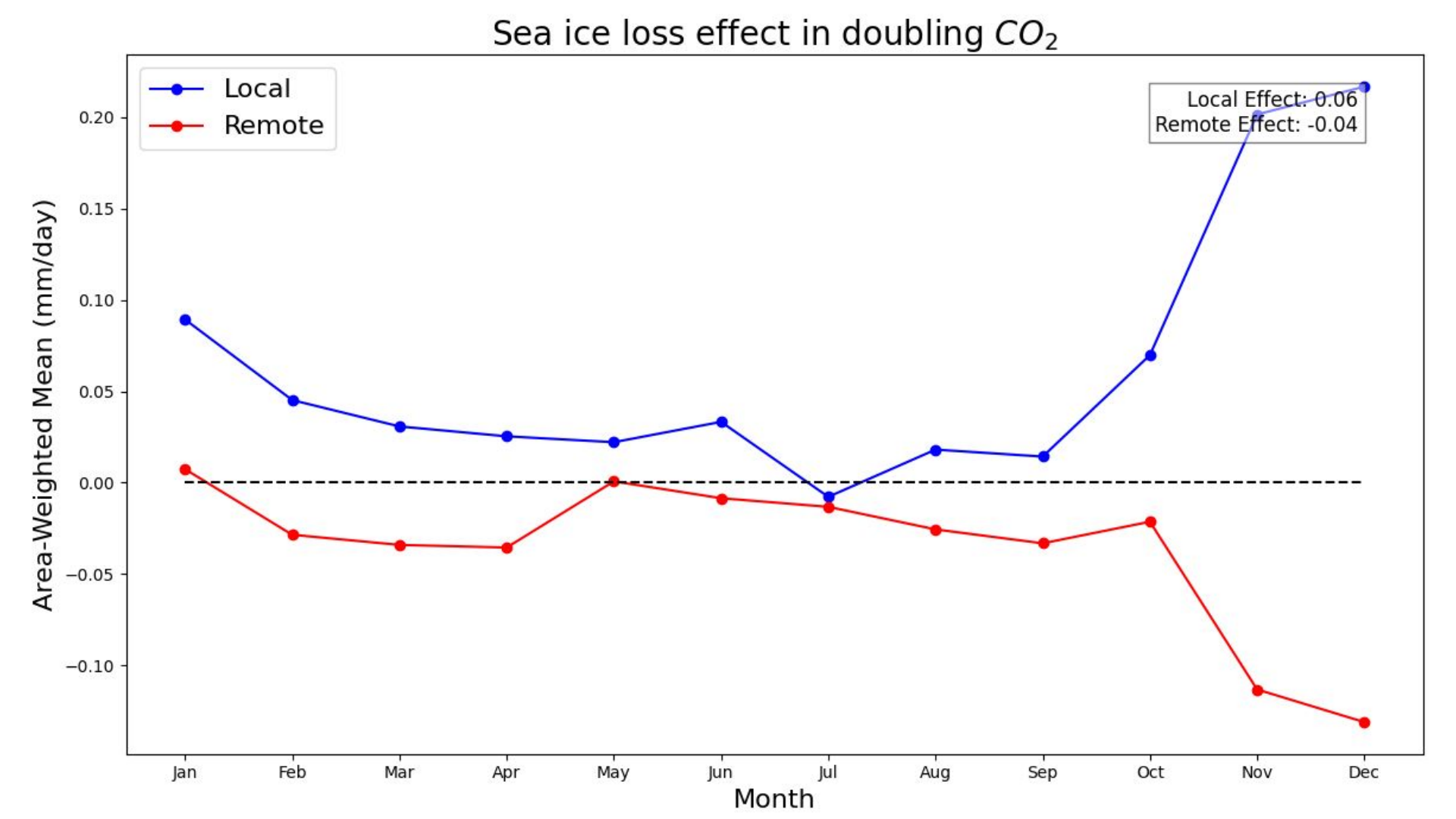
Sep
Oct
Nov
Dec
Month


Sea ice loss effect in doubling CO_2
Local
Remote
Local Effect: 0.06
Remote Effect: -0.04
Area-Weighted Mean (mm/day)
0.20
0.15
0.10
0.05
0.00
−0.05
−0.10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month