Potential Impacts of Marine Cloud Brightening in the Arctic System and Beyond

CAMAS Workshop

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Boulder | Colorado Springs | Denver | Anschutz Medical Campus
Grantham Foundation
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NSF
NCAR
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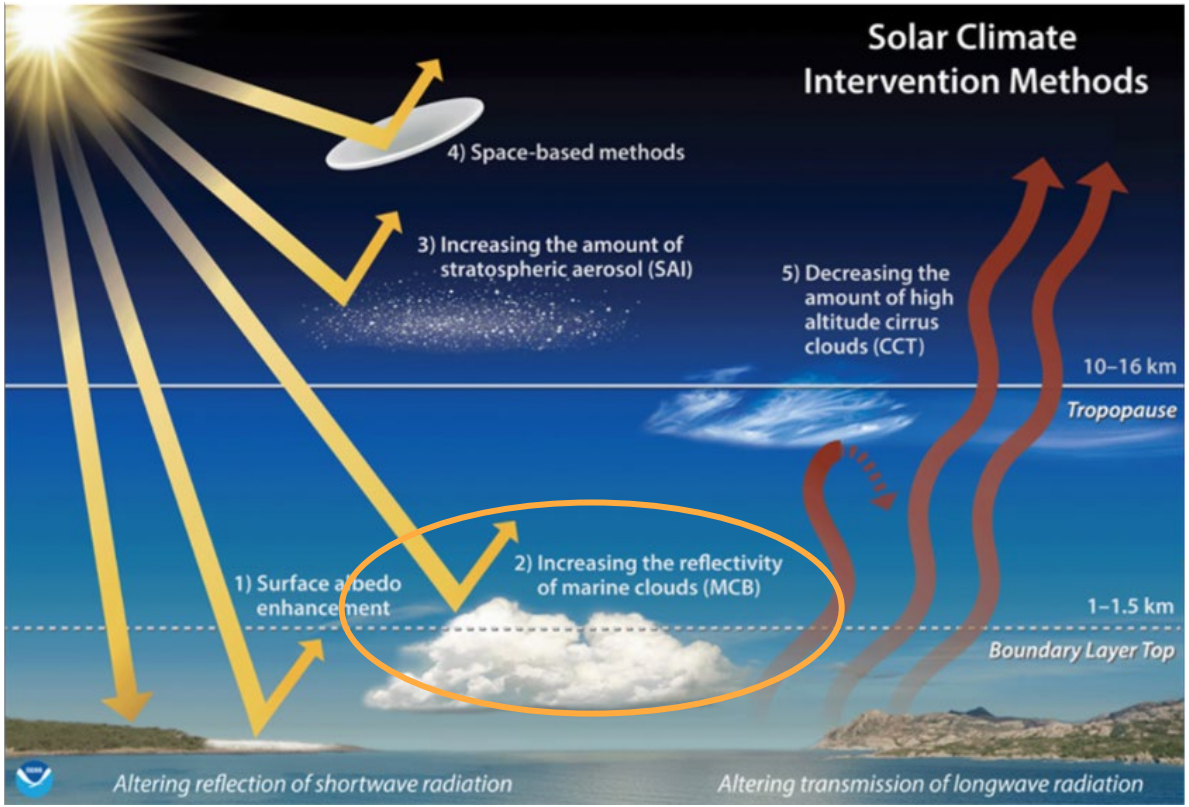
Climate Intervention

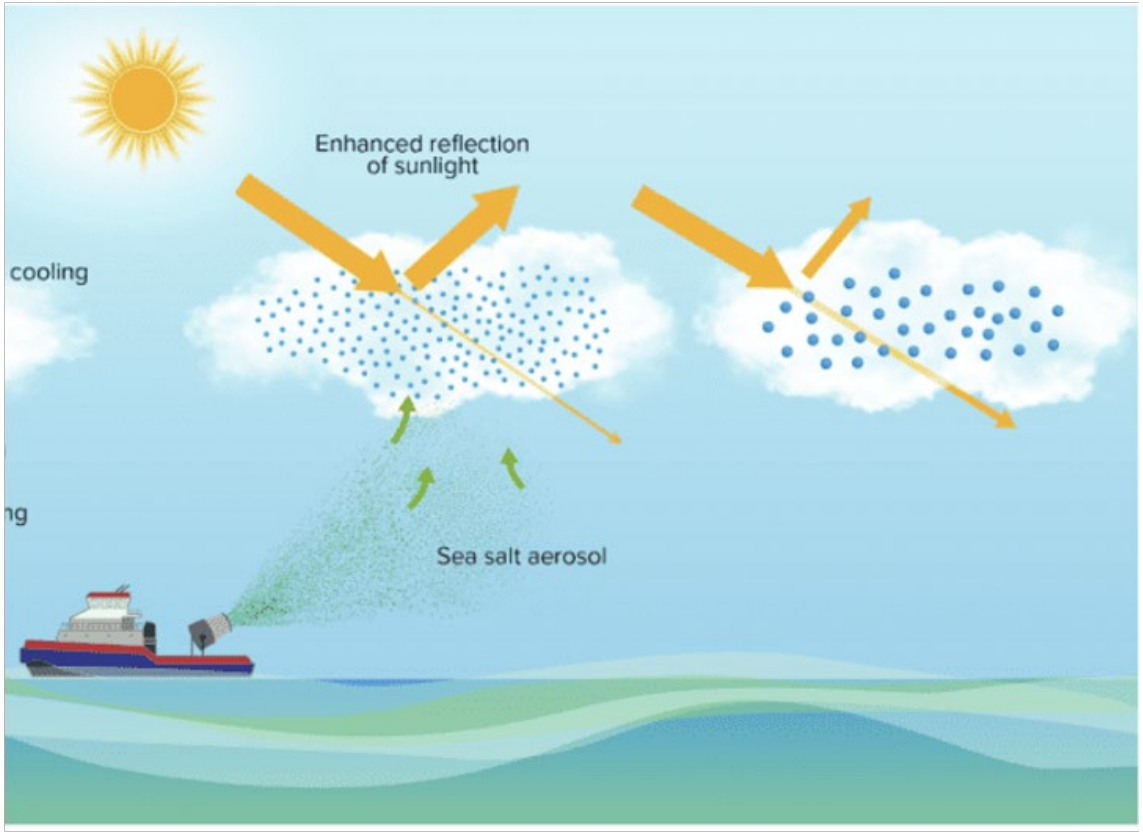
“Solar radiation modification”

“Solar geoengineering”



NOAA, Dr. Chelsea Thompson

Marine Cloud Brightening



NOAA

NASA

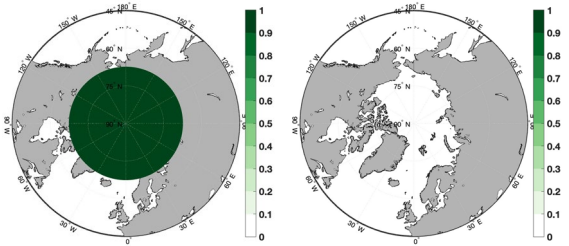
Experimental Setup

- Community Earth System Model version 2 (CESM2) simulations under moderate warming (SSP3-7.0) scenario
  - “less-melt” parameterization, improving the representation of Arctic sea ice
  - 4 phytoplankton and 2 zooplankton functional types (but no sea ice algae)
  - Offline fish model FEISTY
- 5 baseline simulations, evaluated from 1920-2070
- 6 marine cloud brightening perturbations for 2035-2070
  - Strategy
  - Magnitude

Cloud seeding strategies

“Summer”

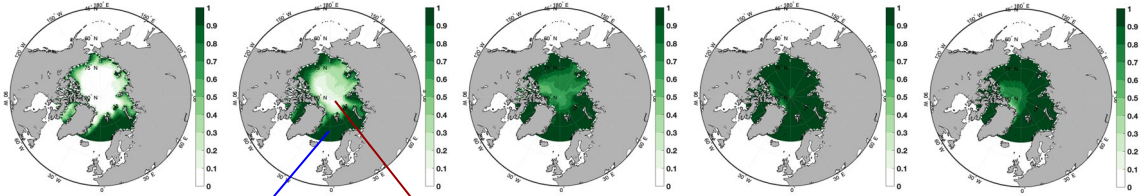
Summer-only seeding
All grid cells >67°N



May-Sept Oct-Apr

“Dynamic Mask”

Summer-only seeding, >67°N;
exclude SIC ≥ 90%, land ≥ 50%
Change mask each timestep

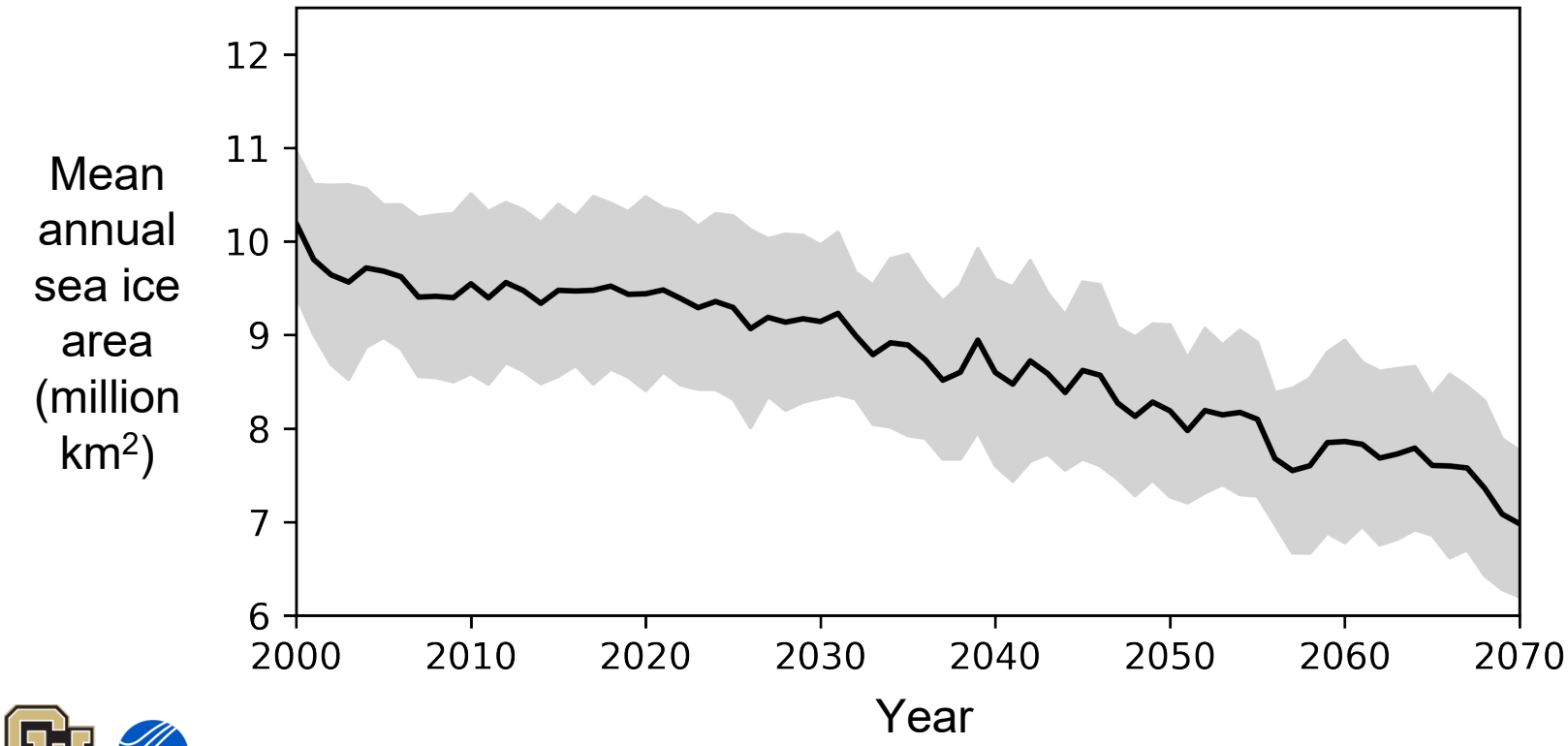


May June July Aug Sept

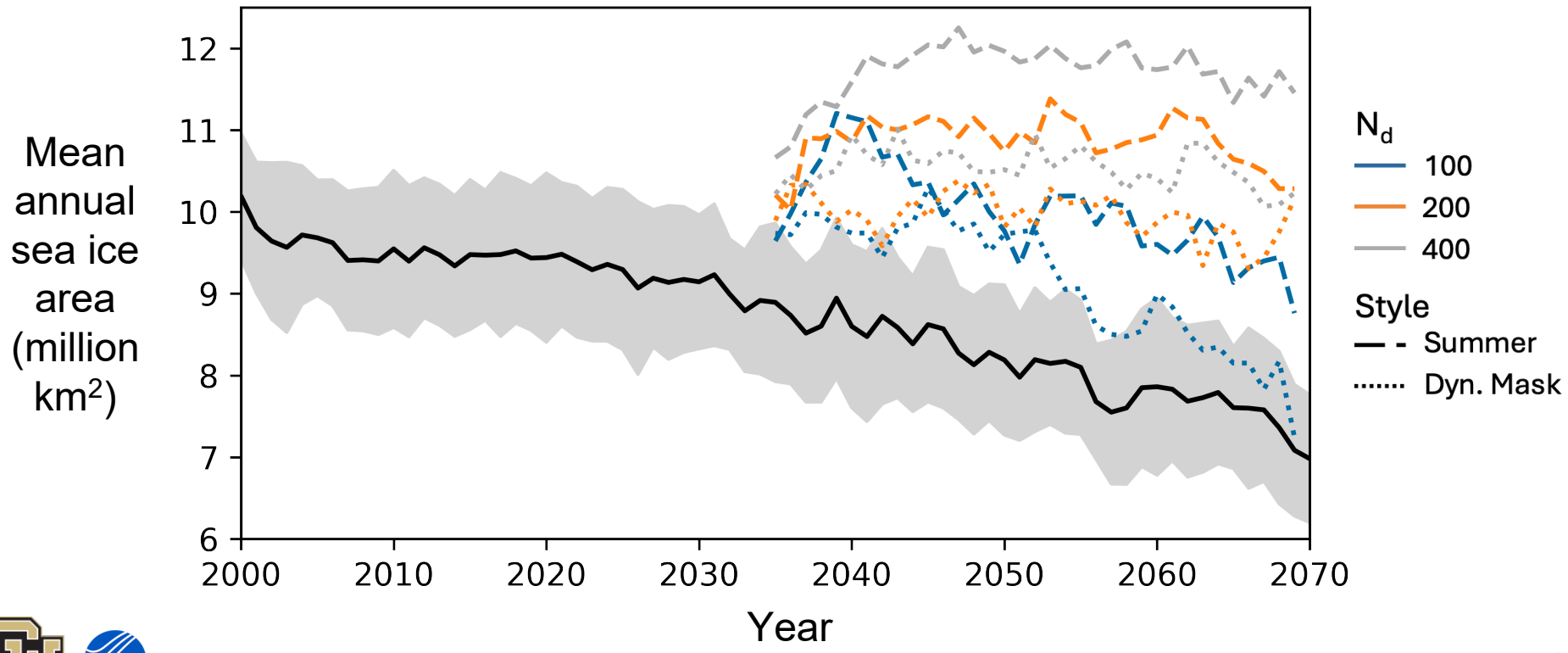
Dark green: seeded most/all of the time

Light green/white: seeded less often

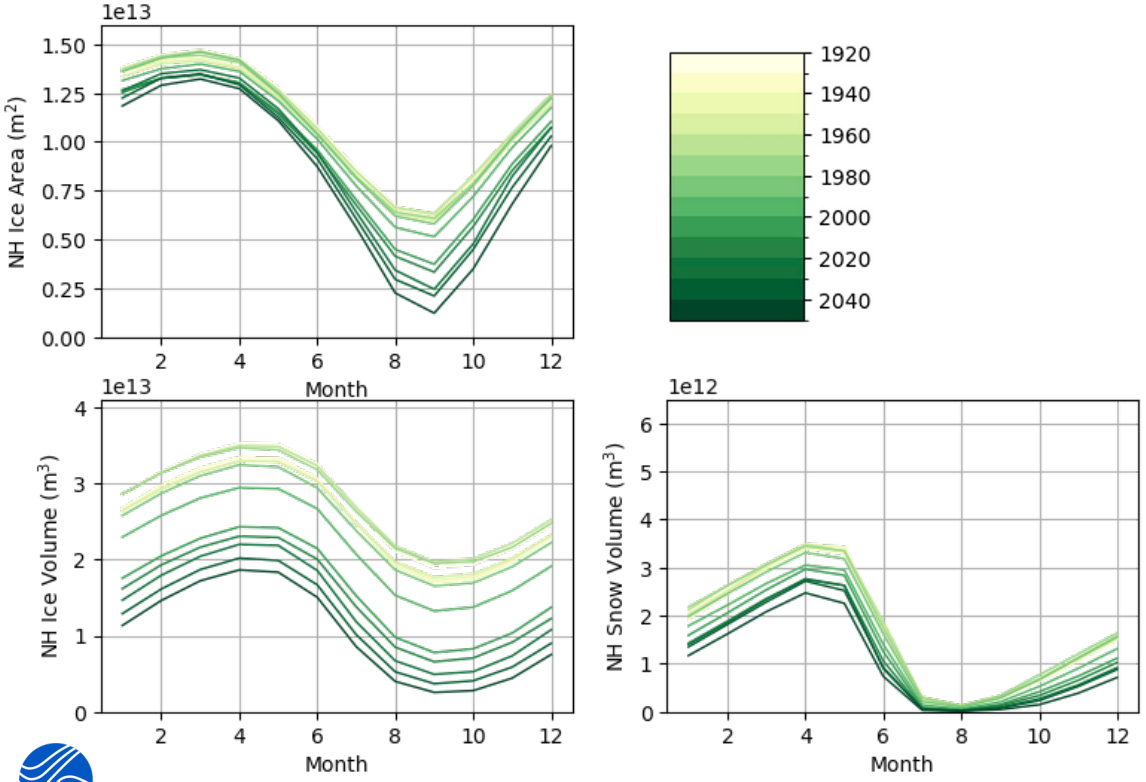
Magnitude: $N_d \rightarrow$ 100, 200, 400 # cm^{-3} simulations


Mean annual sea ice area (million km^2)
12
11
10
9
8
7
6
2000
2010
2020
2030
2040
2050
2060
2070
Year

Sea ice area increases under all perturbations



Annual cycle of Northern Hemisphere snow and sea ice



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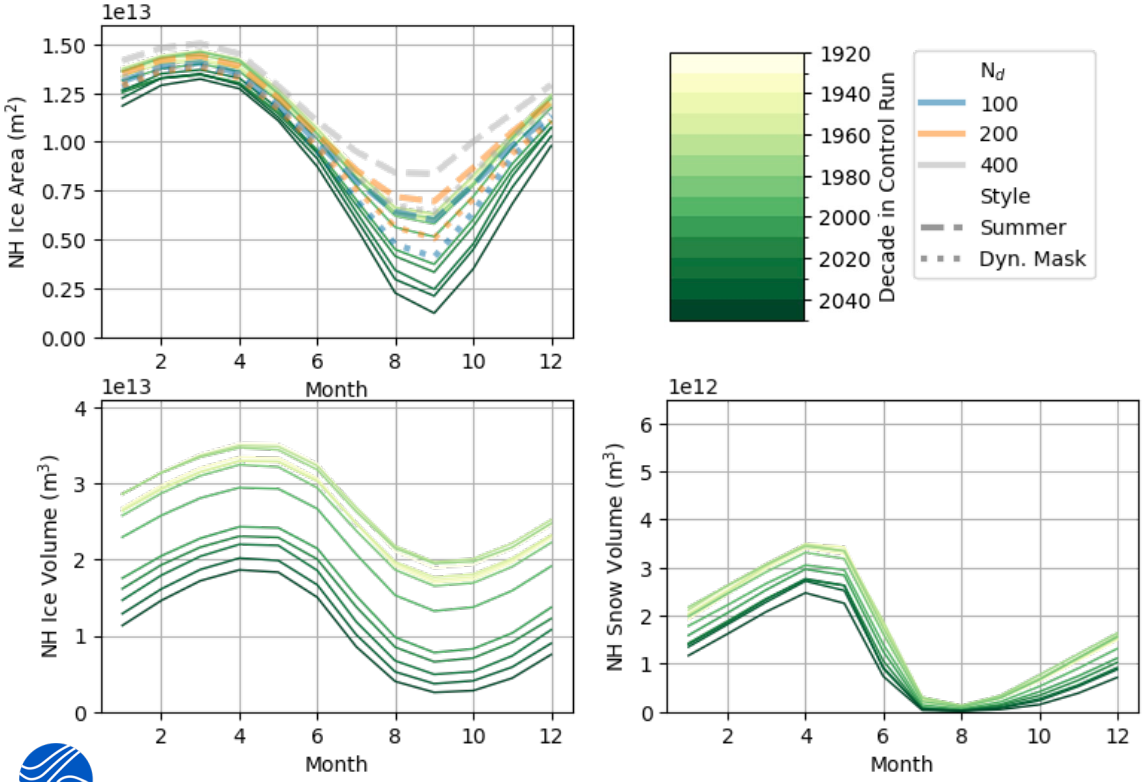
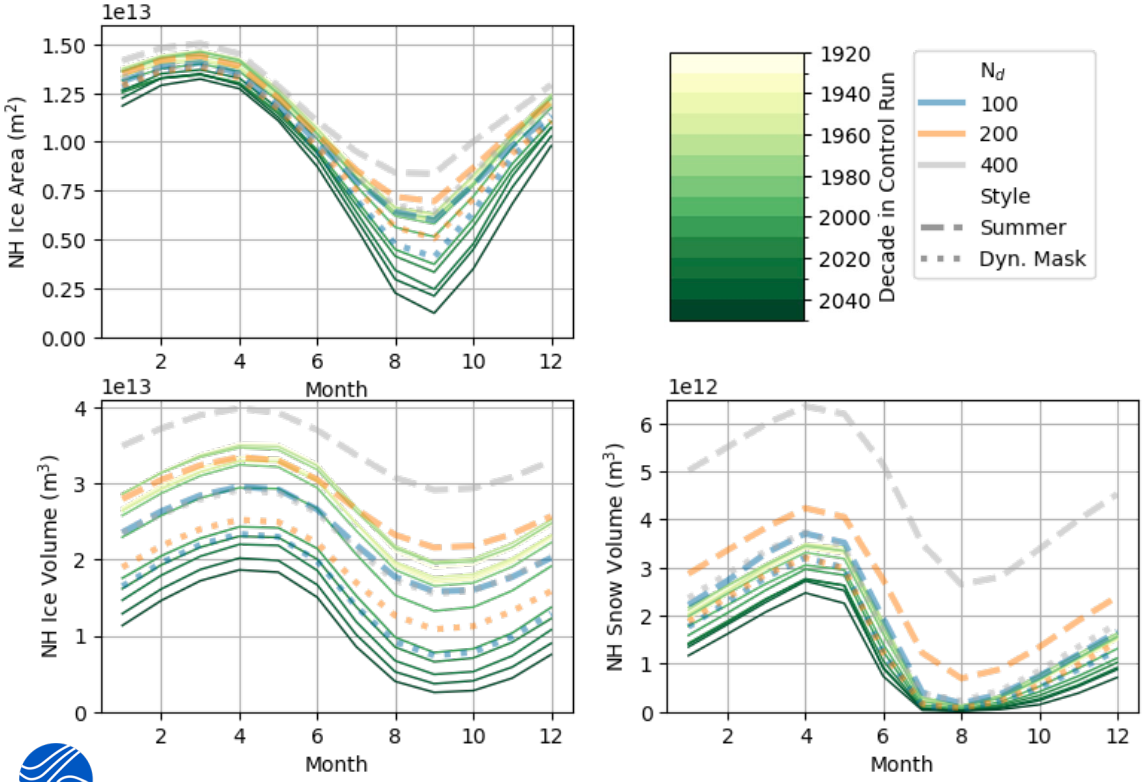


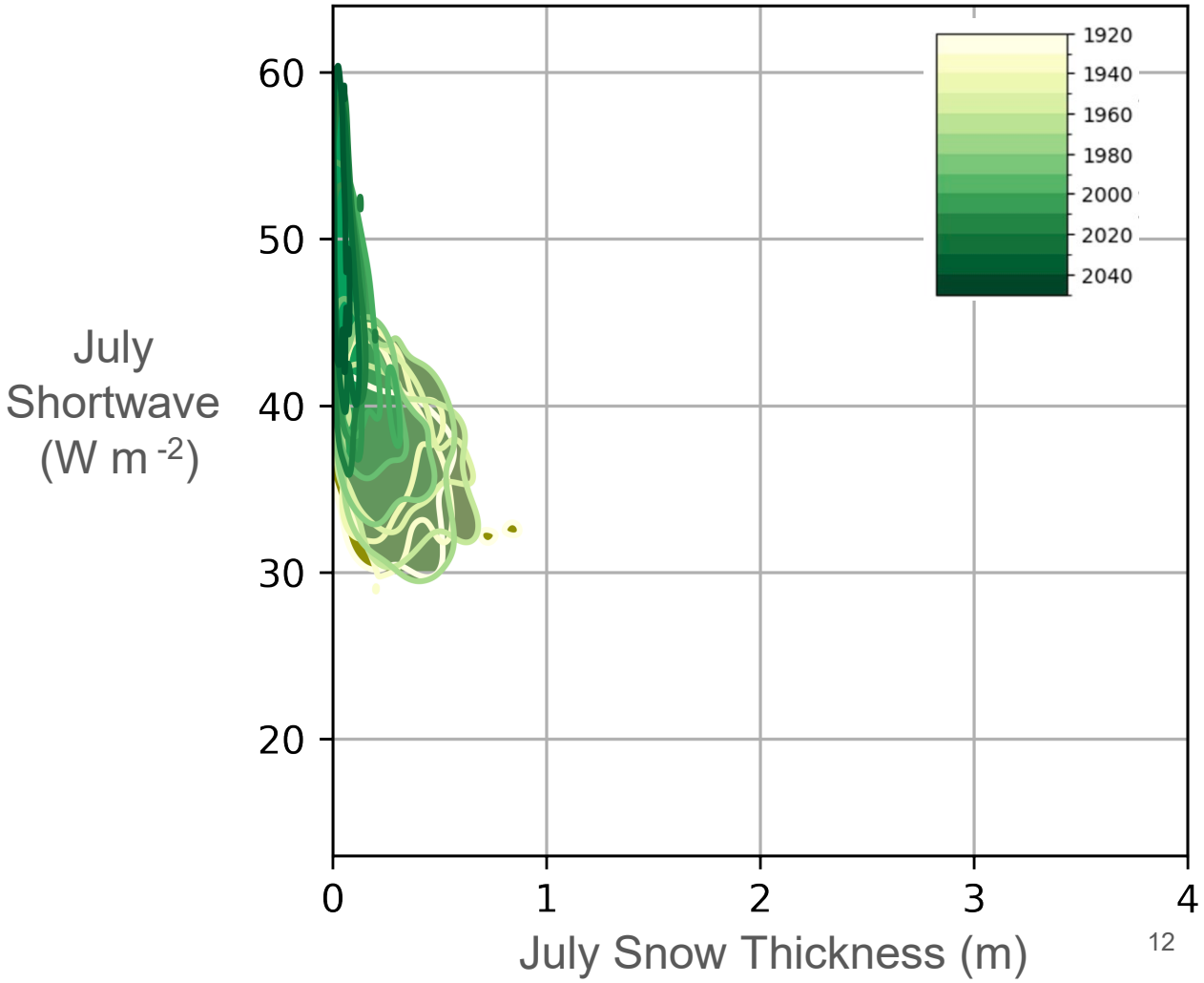
Lower-magnitude perturbations return ice state to historical conditions

Annual cycle of Northern Hemisphere snow and sea ice

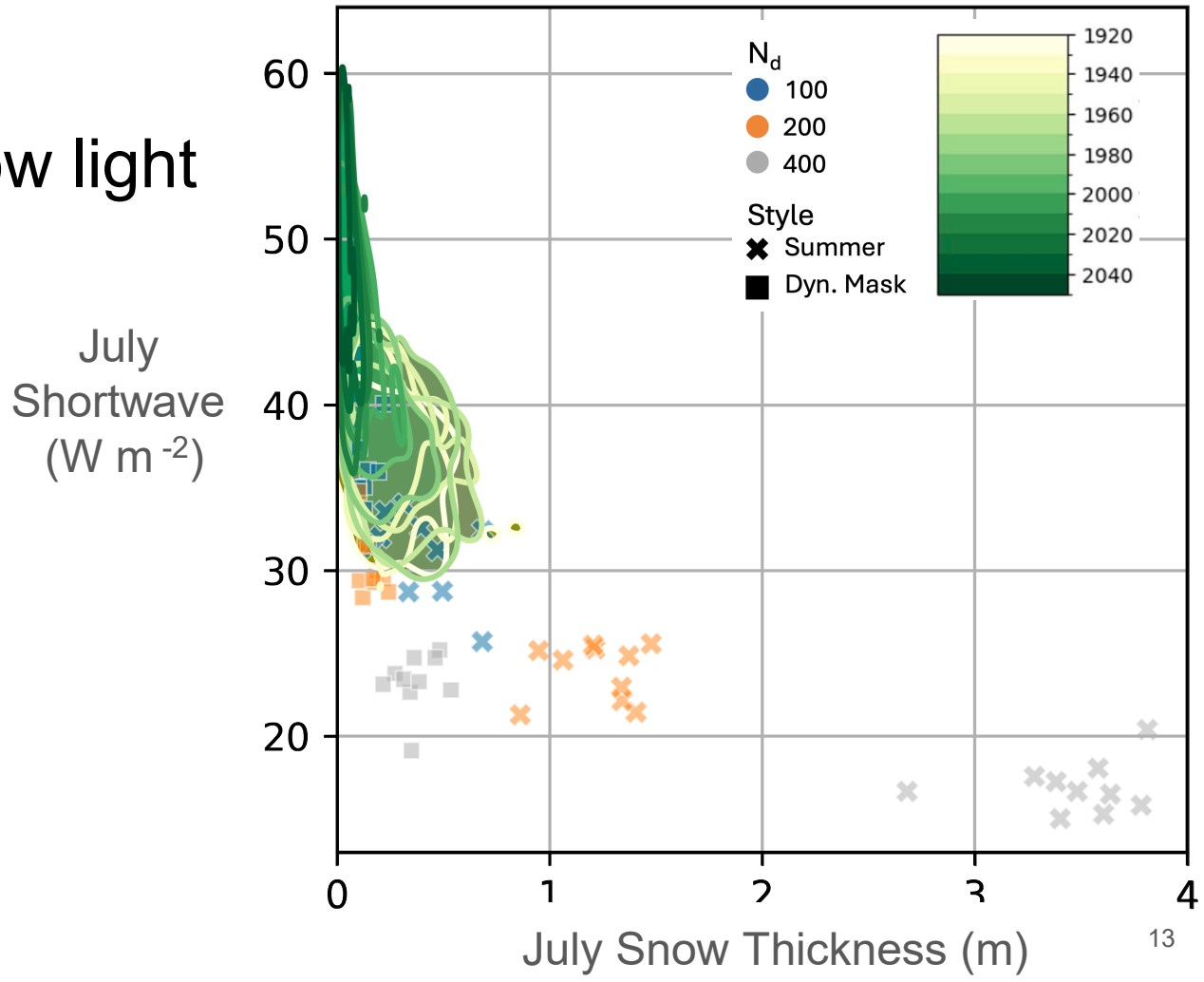


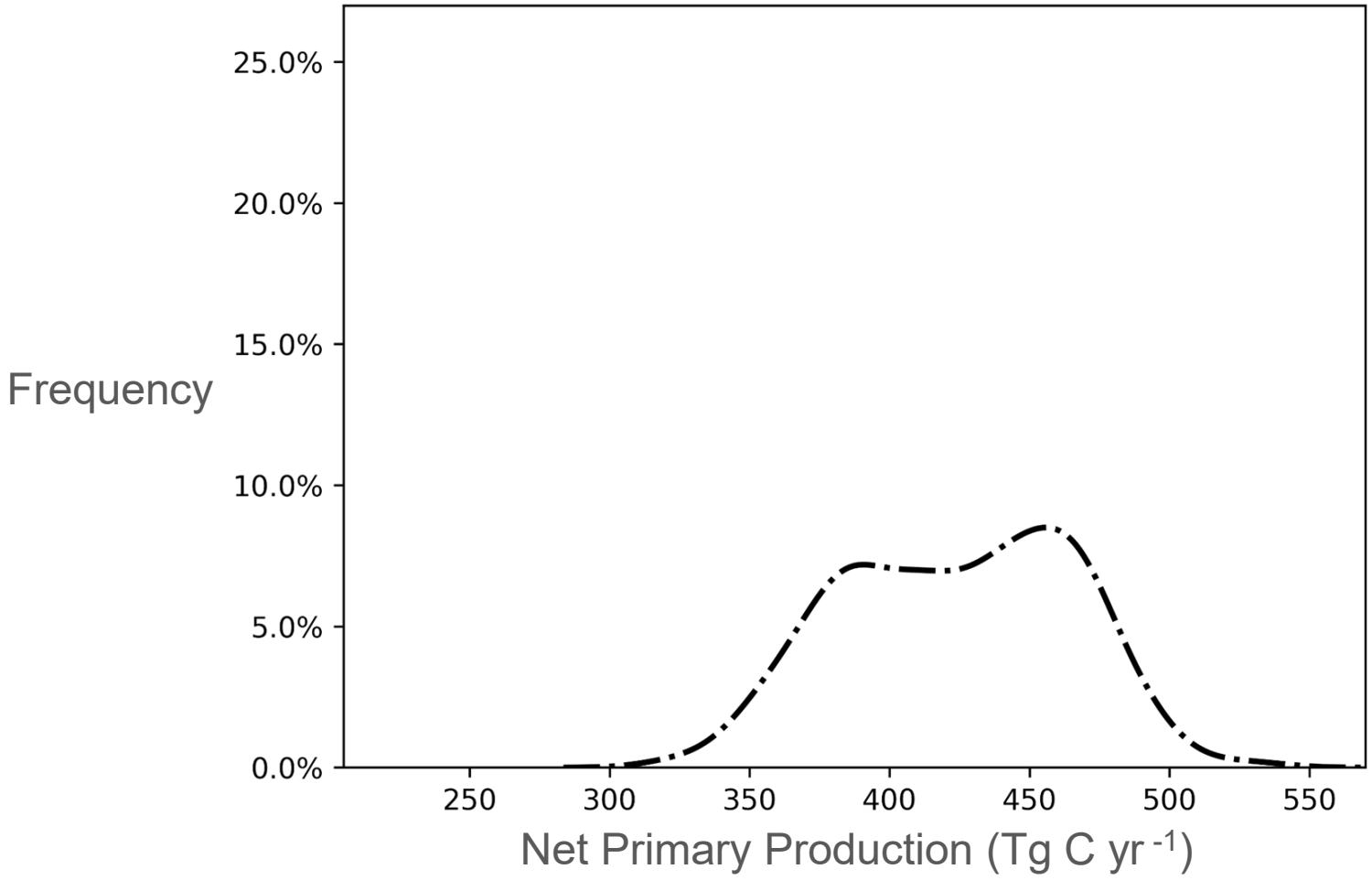
Lower-magnitude perturbations return ice state to historical conditions

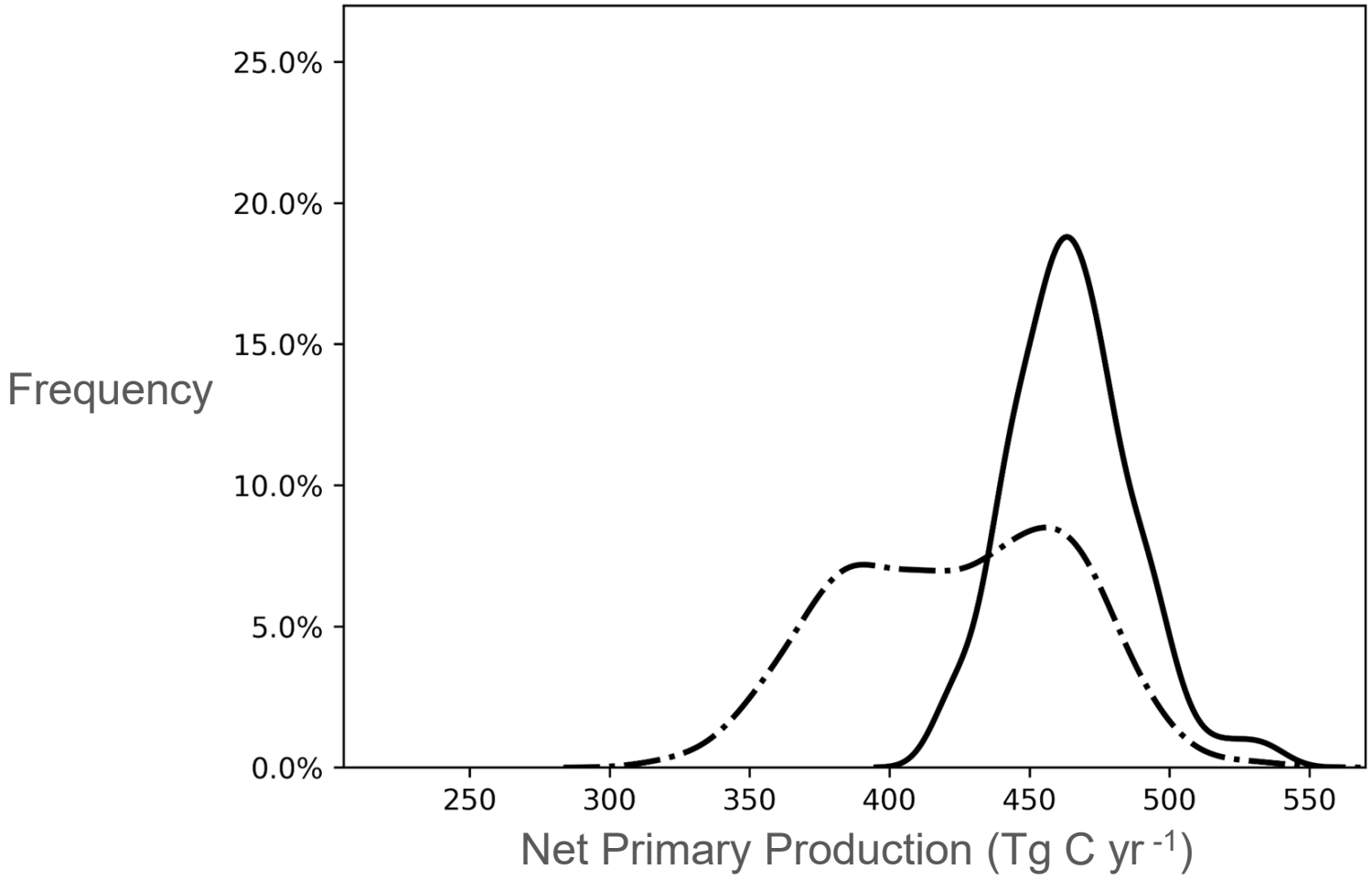
Higher-magnitude perturbations shift snow and ice state to conditions unprecedented in recent history.


July
Shortwave
(W m -2)
60
50
40
30
20
0
1
2
3
4
July Snow Thickness (m)
1920
1940
1960
1980
2000
2020
2040

Historically unprecedented low light in upper ocean




Frequency
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
250
300
350
400
450
500
550
Net Primary Production (Tg C yr -1)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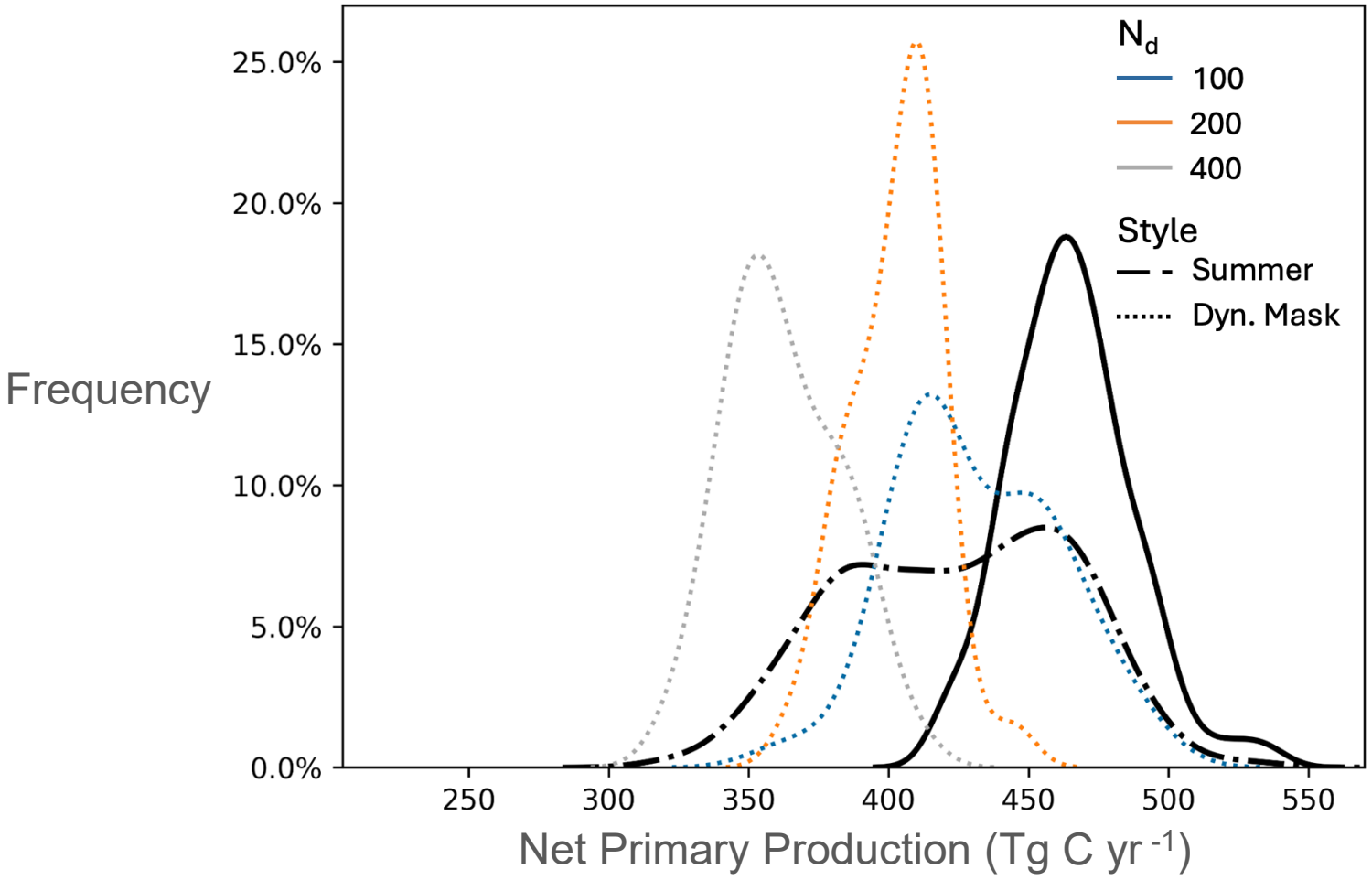
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15.0%
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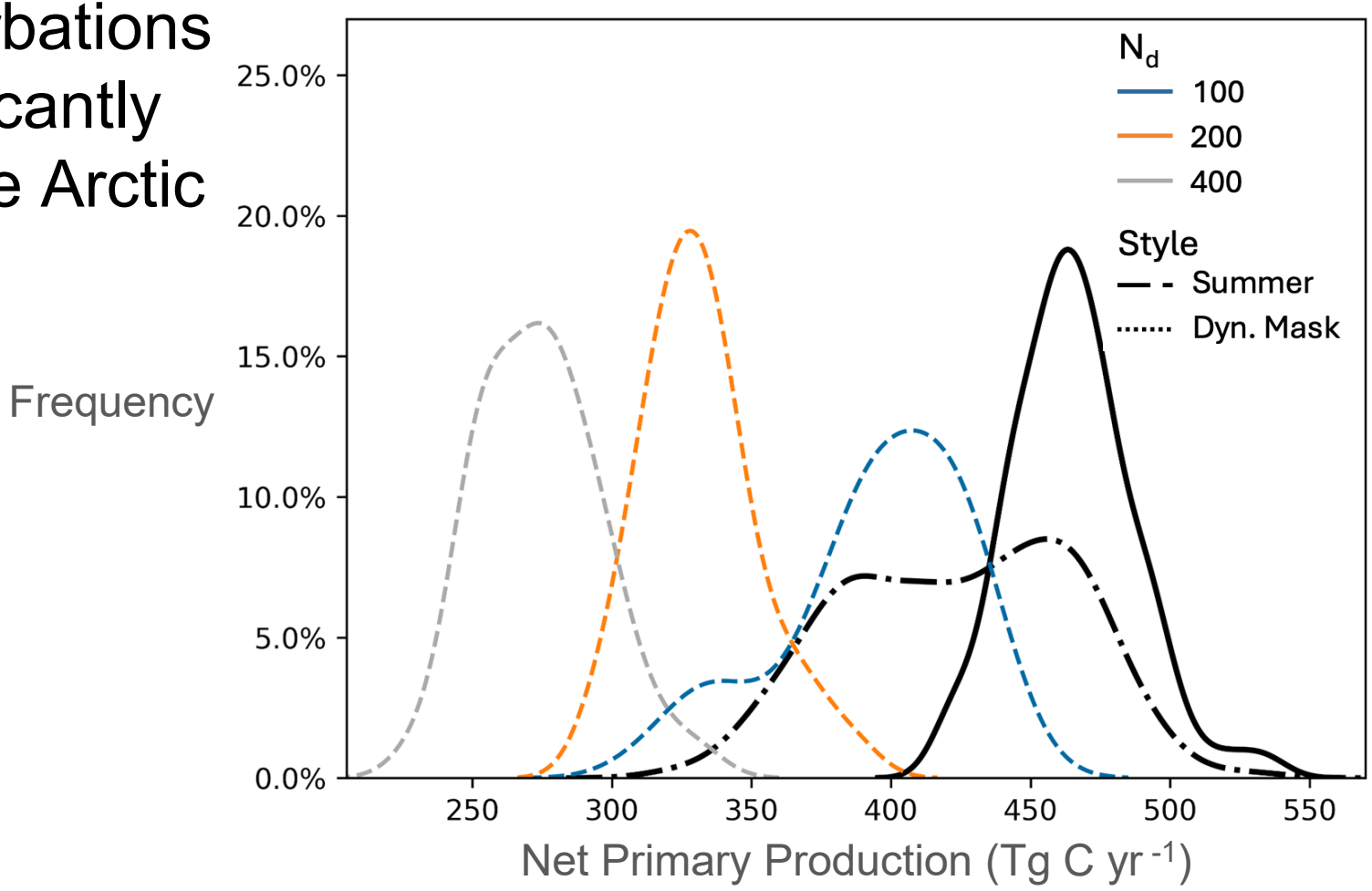
5.0%
0.0%
250
300
350
400
450
500
550
Net Primary Production (Tg C yr -1)
N_d
100
200
400
Style
Summer
Dyn. Mask

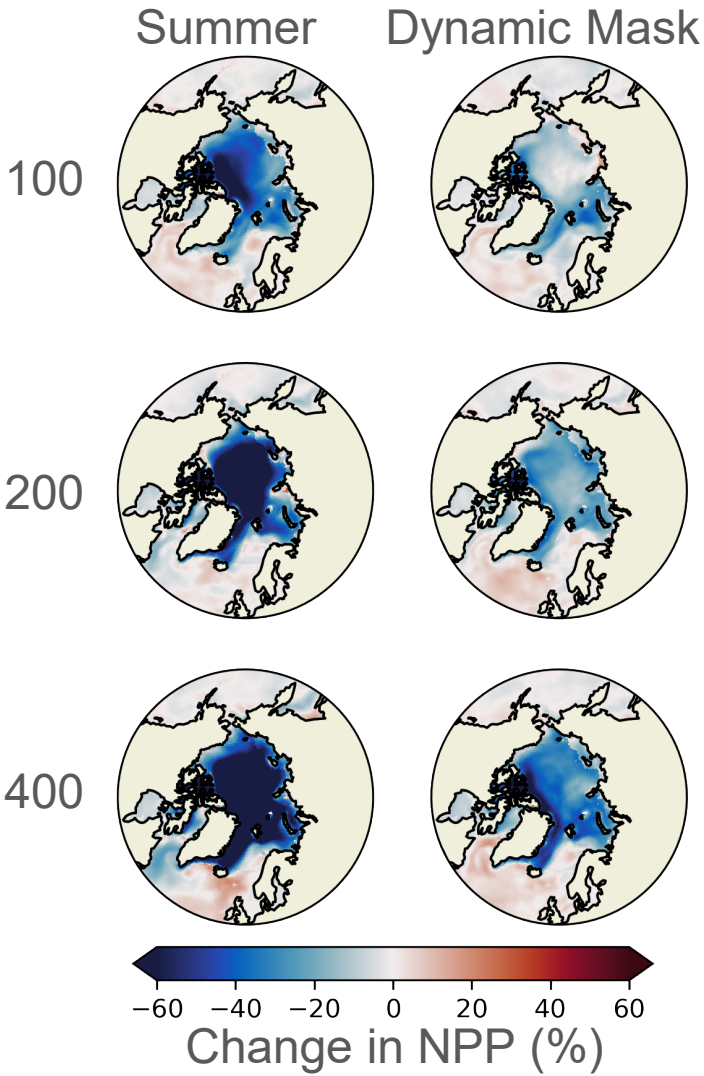
Perturbations significantly reduce Arctic NPP



Decline is focused in the central Arctic

15 – 82% decline in phytoplankton NPP north of 80°N relative to unperturbed simulations.

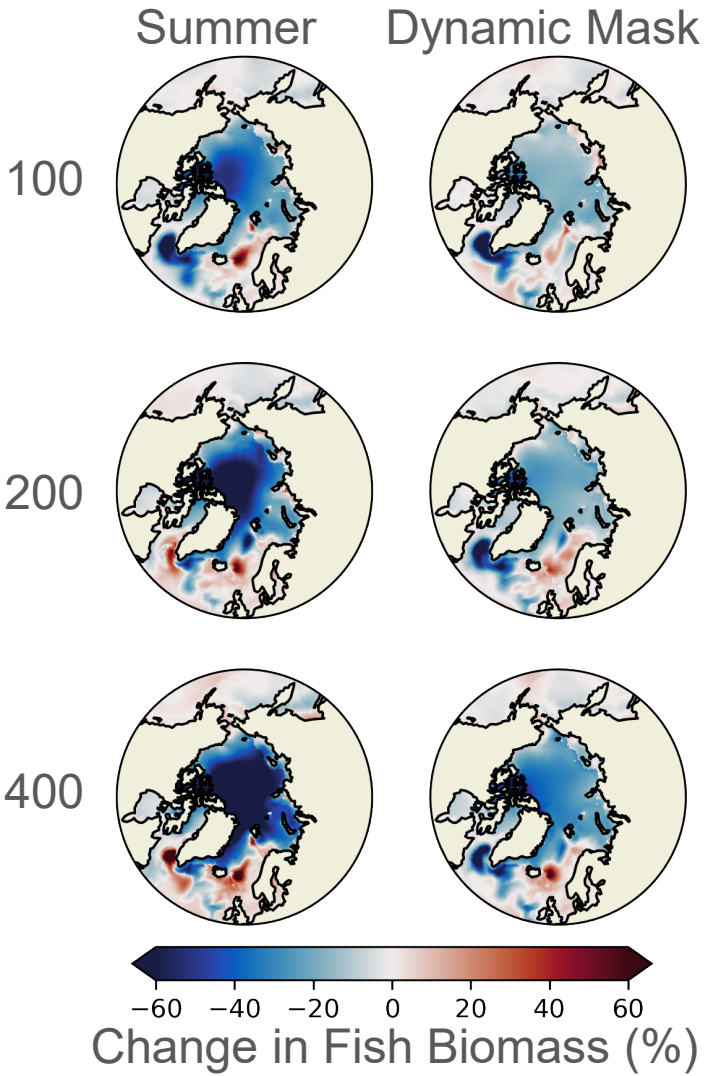
3 – 9% decline in NPP over the Arctic Ocean and sub-Arctic seas (>50°N)



Reduction in phytoplankton NPP reduces fish biomass

17 – 72% decline in total fish biomass north of 80°N relative to unperturbed simulations

4 - 12% decline in fish biomass over the Arctic Ocean and sub-Arctic seas (>50°N)



Summary

- Arctic marine cloud brightening can result in increased sea ice area.
- Higher-magnitude perturbations can result in sea ice and snow states unprecedented in the 20th century, reducing light in the upper ocean.
- Large declines in Arctic phytoplankton NPP, particularly in the central Arctic, yield large reductions in fish biomass in the Arctic and sub-Arctic.