A story about summer onset over the central Arctic as seen from the A-Train era

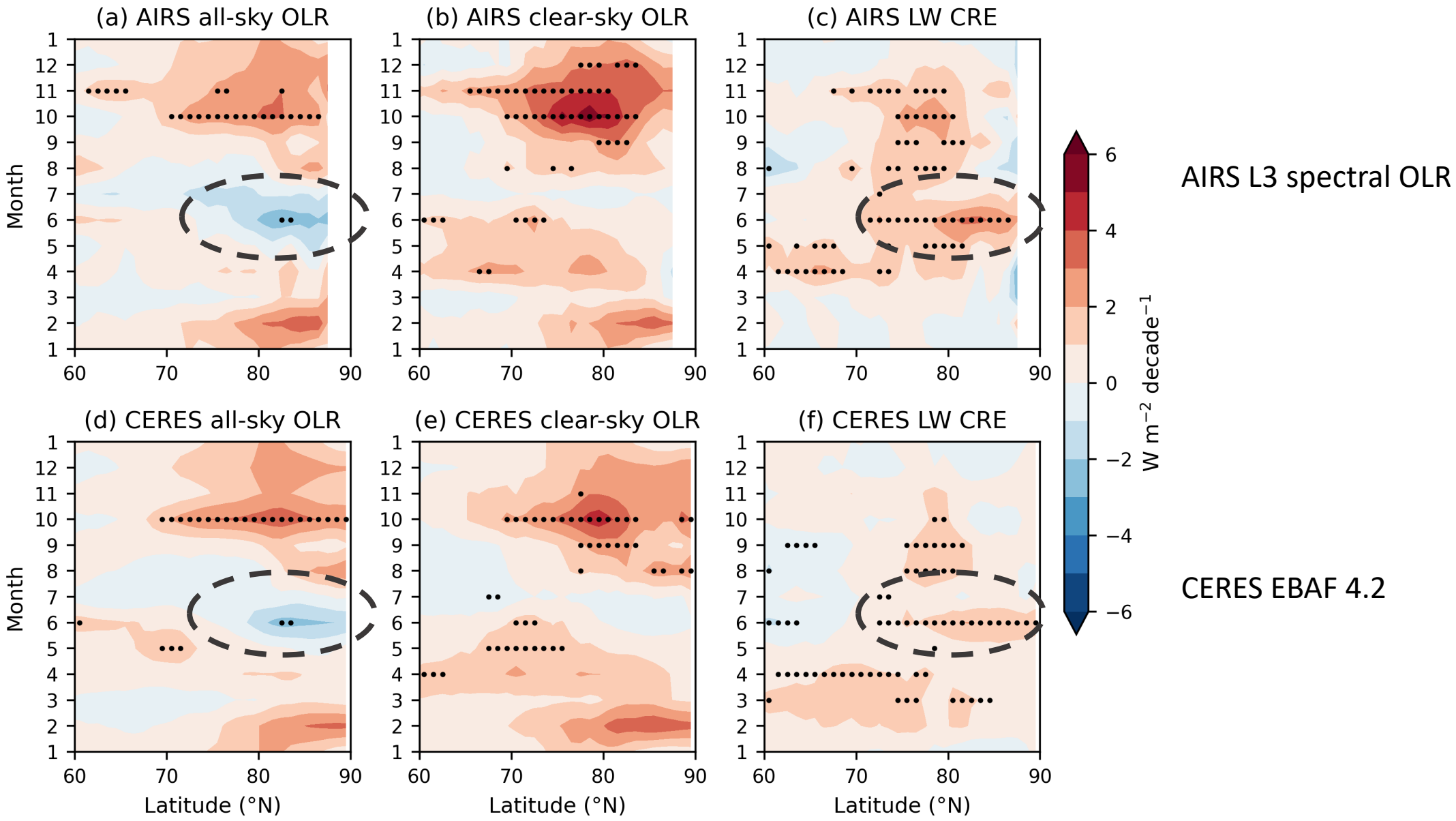
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CERES 2026 Fall STM
Hampton, VA
November 27, 2026

Acknowledgments: NASA CERES project/PREFIRE mission and DoE RGMA program
Based on a manuscript under review

Zonal-mean, monthly trend in the Arctic (2003-2021)

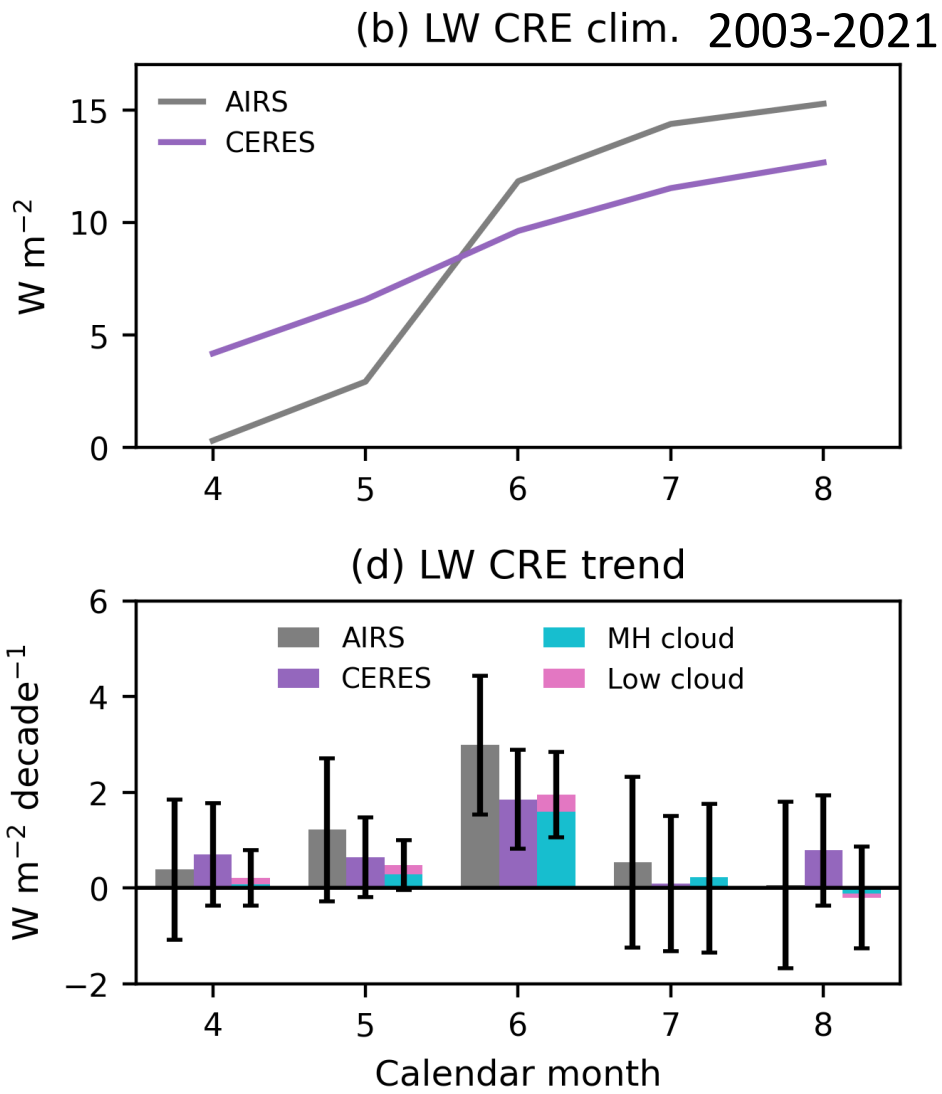


AIRS L3 spectral OLR

CERES EBAF 4.2

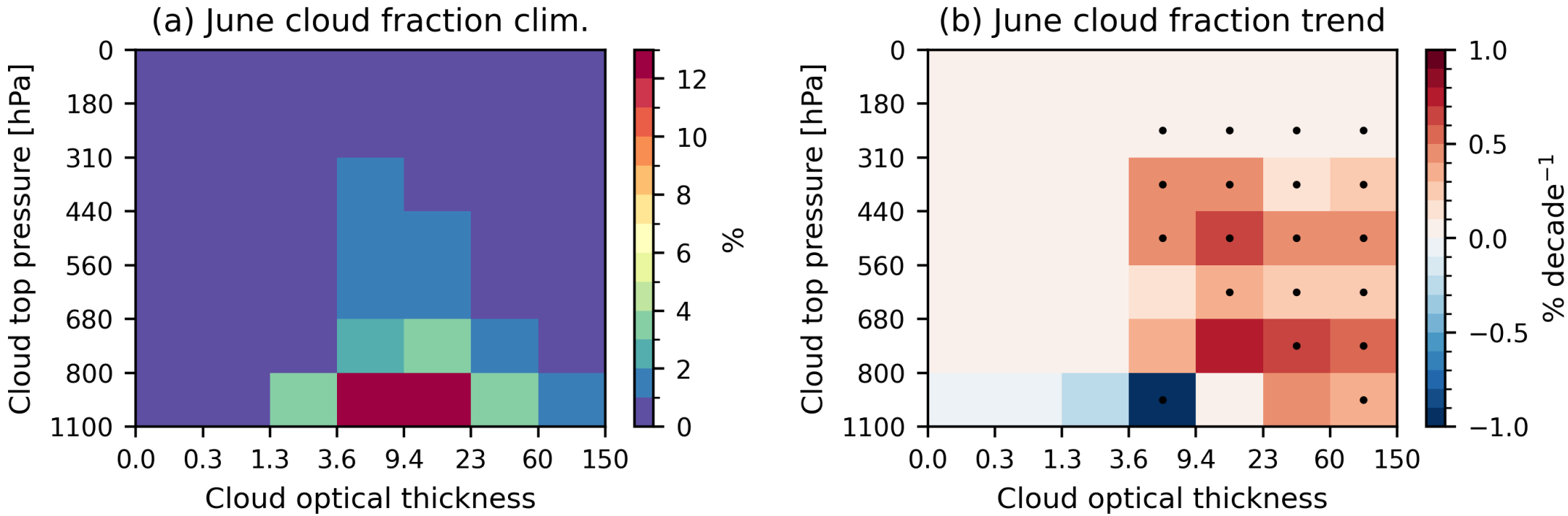
Central Arctic (80-90˚ N): ¼ of the Arctic Ocean

The trend is not small, but only significant in June



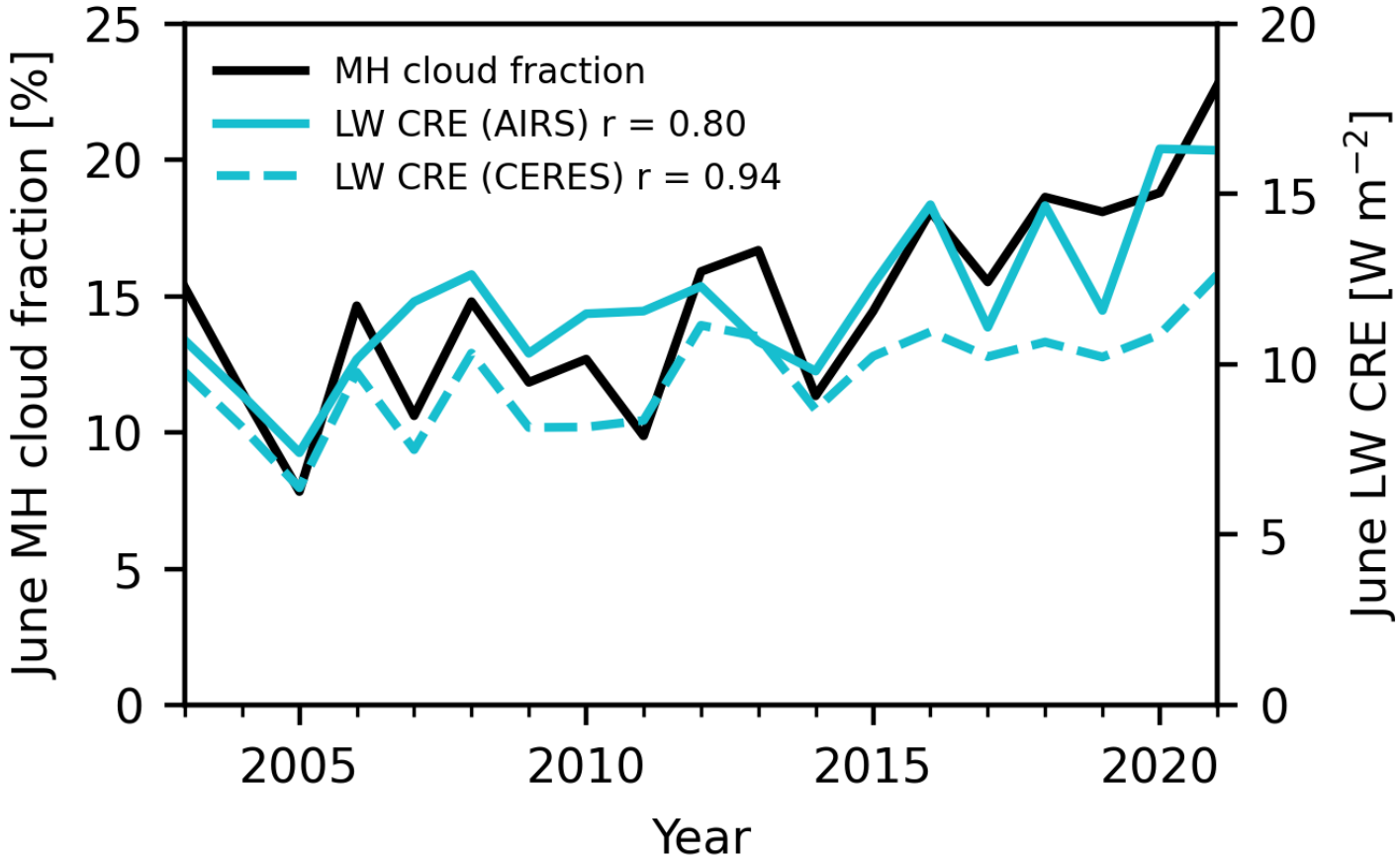
Central Arctic Average

Central Arctic average

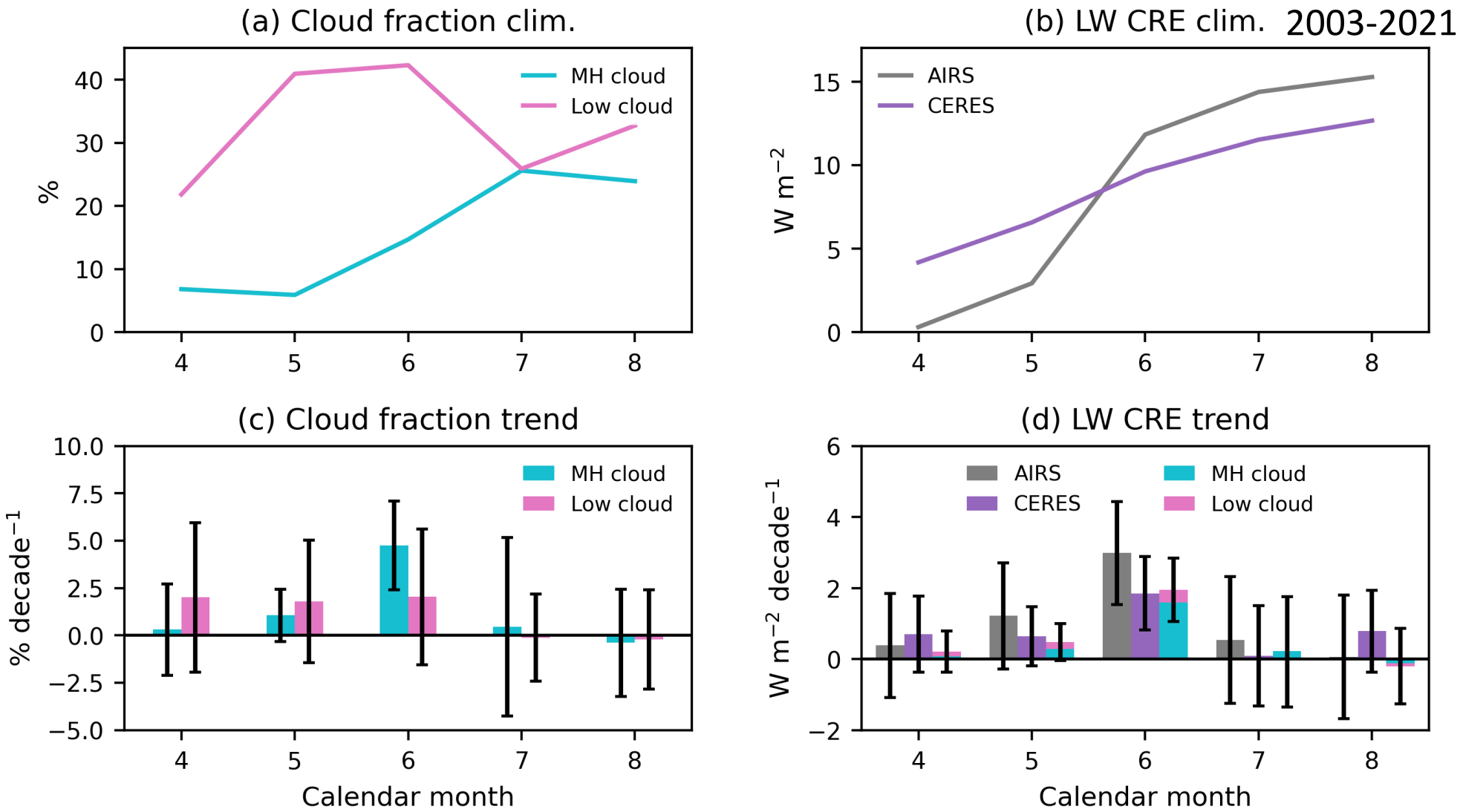


(Pincus et al., 2022, ESSD)
MODIS MC06COSP: Merges pixel-scale cloud observations from both the Terra (MOD06_L2) and Aqua (MYD06_L2)

Note: MODIS tends to detect less cloud than CALIPSO over this region, but CALIPSO has little coverage beyond 80˚N

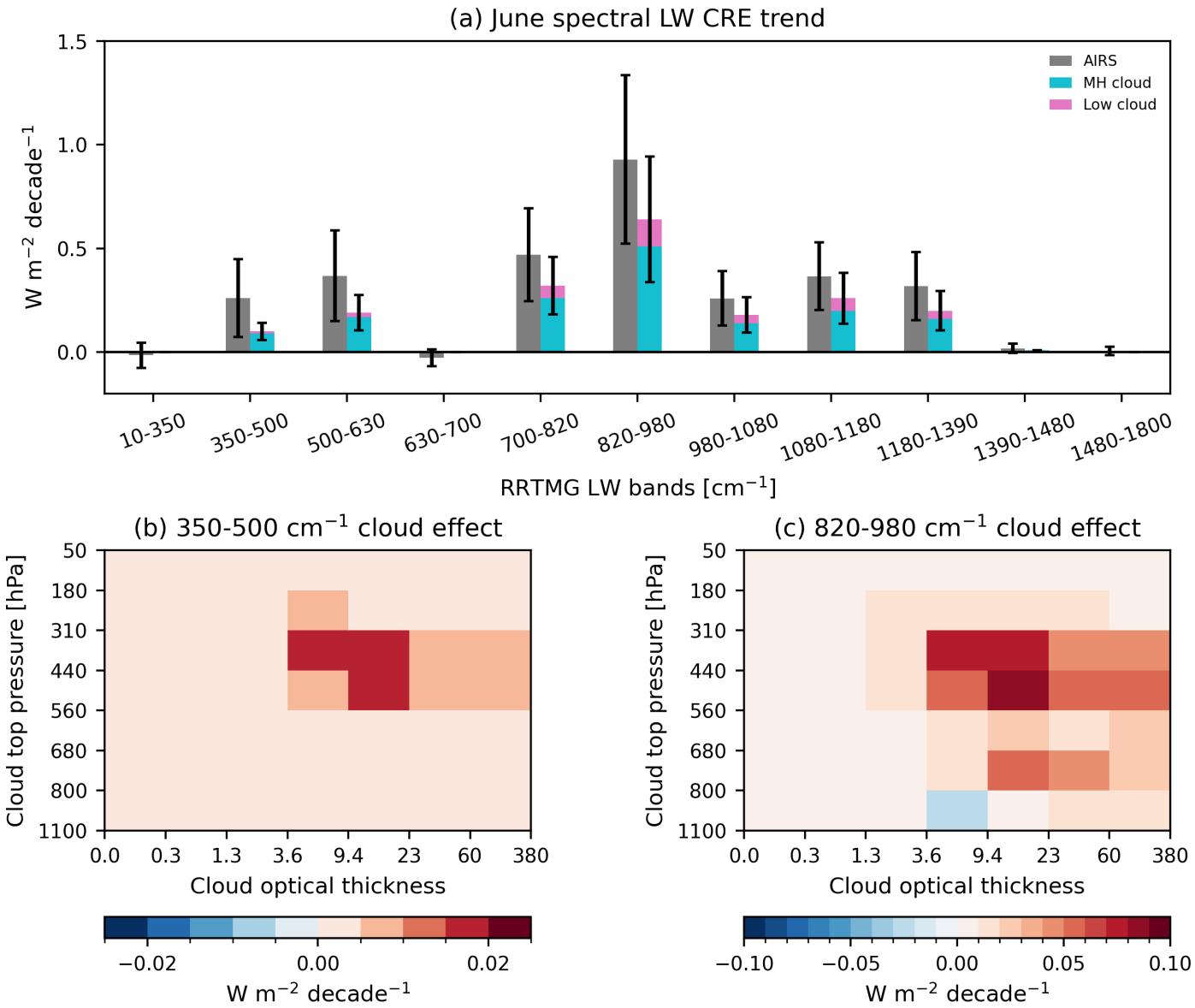

MH cloud fraction
LW CRE (AIRS) r = 0.80
LW CRE (CERES) r = 0.94
June MH cloud fraction [%]
June LW CRE [W m^{-2}]
Year
0
5
10
15
20
25
2005
2010
2015
2020

The trend is not small, but only significant in June



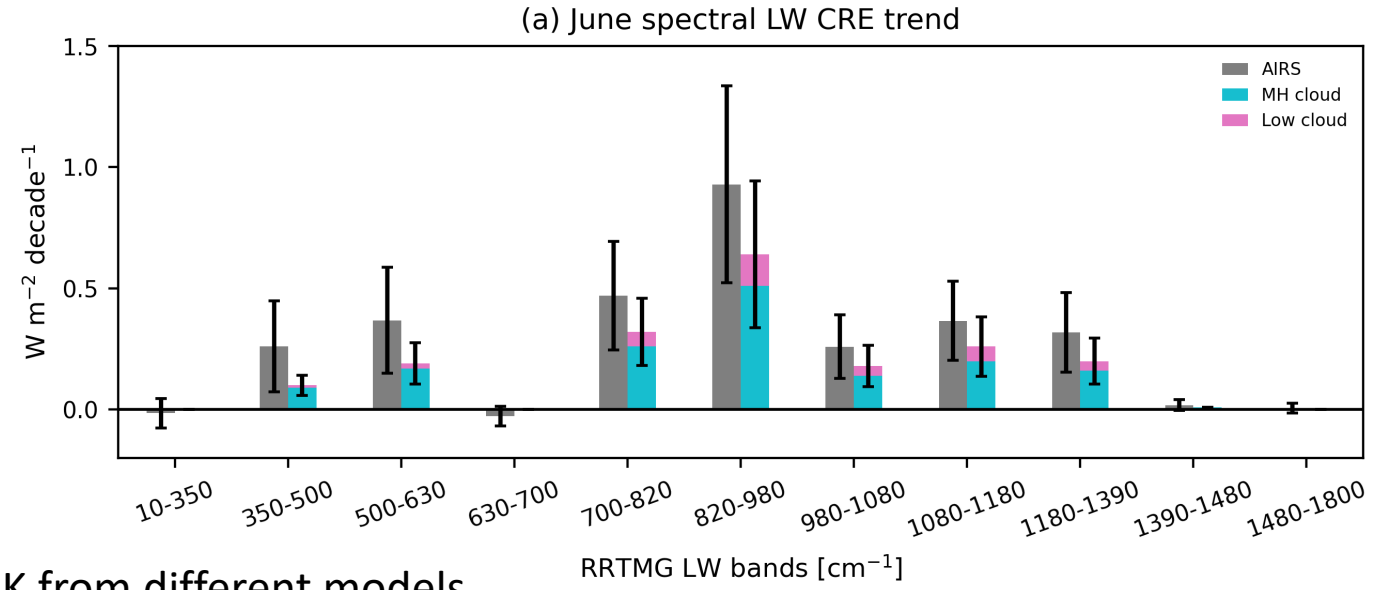
Central Arctic Average

Observation-based Spectra Cloud Radiative Kernel (Huang et al., 2019) can confirm the contributions of middle and high clouds



Central Arctic average

Different spectral cloud radiative kernel can give similar results



June LW CRE trend

+1.9 ± 1.0 (CERES)

+3.0 ± 1.5 (AIRS)

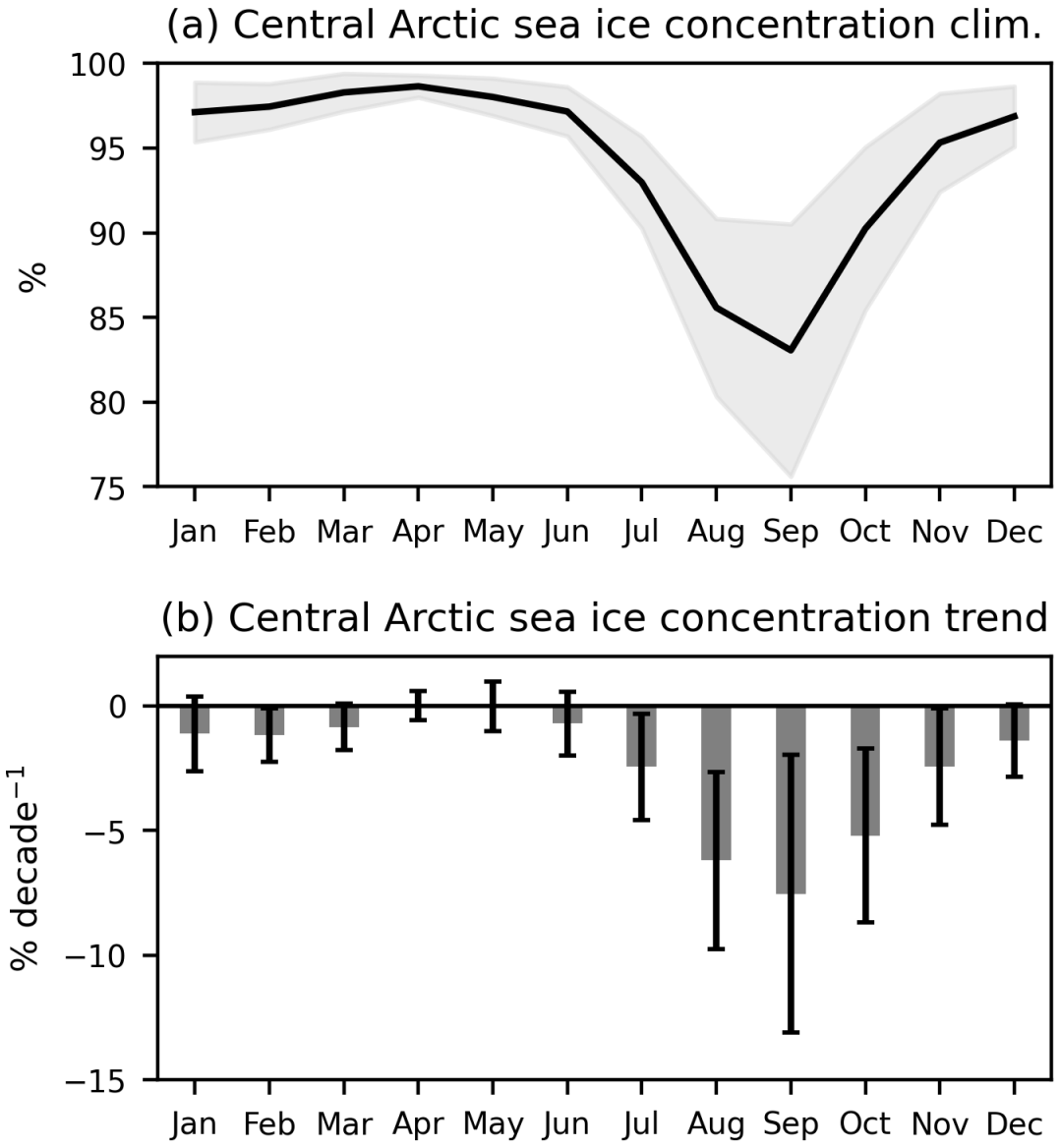
W m^{-2} per decade

CRK from different models

	MHC contribution to the LW CRE trend (Wm^{-2} decade^{-1})	Low cloud contribution to the LW CRE trend (Wm^{-2} decade^{-1})	Relative contribution from MHC	Total cloud contribution to the LW CRE trend (Wm^{-2} decade^{-1})
CESM1.1.1	1.07±0.60	0.22±0.36	82.9%	1.29±0.70
CESM2	1.59±0.76	0.36±0.46	81.5%	1.95±0.89
E3SM v2	1.82±0.86	0.34±0.45	84.2%	2.16±0.97
E3SM v3	1.10±0.59	0.11±0.34	90.9%	1.21±0.68

What drives the increase in mid- and high-level clouds over the central Arctic in June? Why not in other sunlit months?

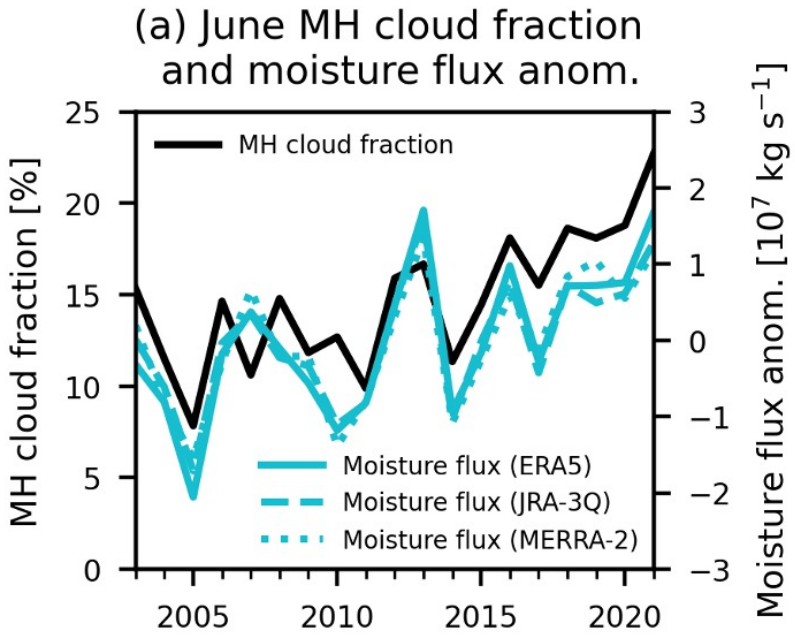
Local sea ice change is not a factor

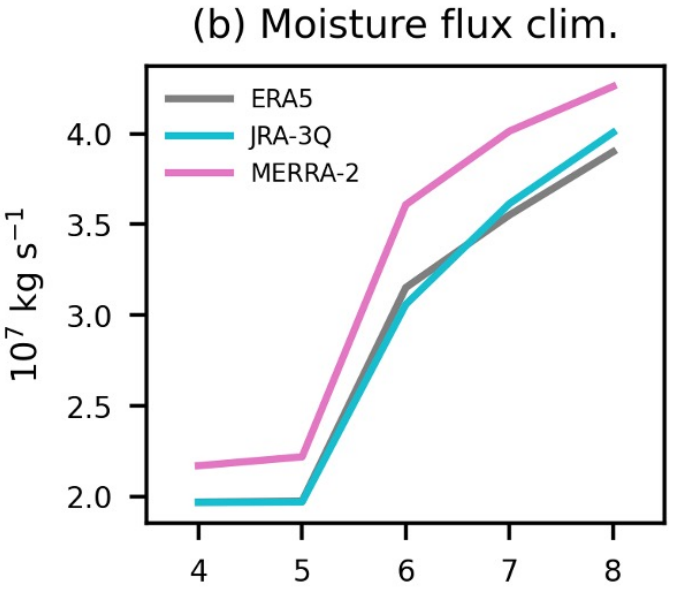


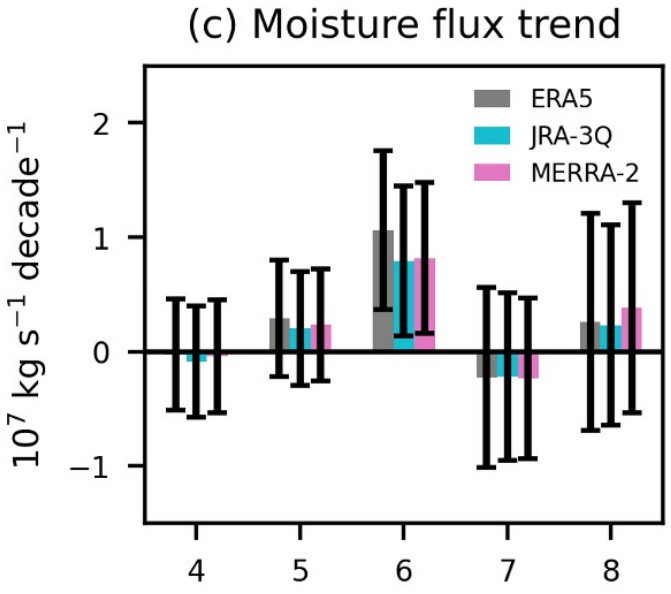
June: largely covered by sea ice, so near-surface inversion still prevails, which caps the vertical moisture movements.

If it is not local, then it must be remote

Moisture flux into the central Arctic



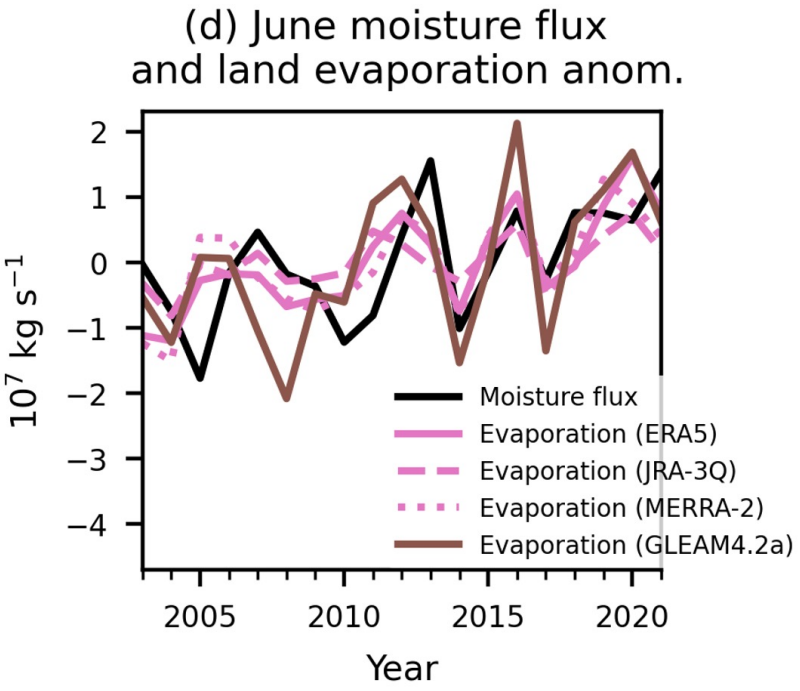


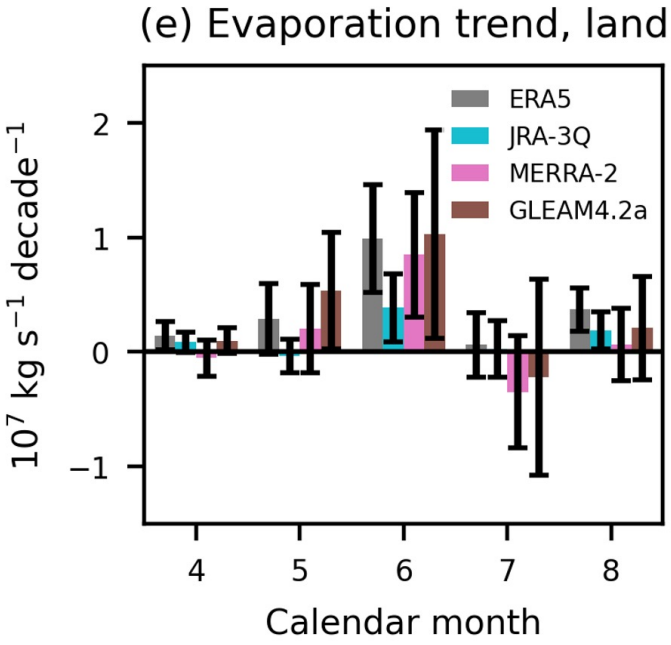


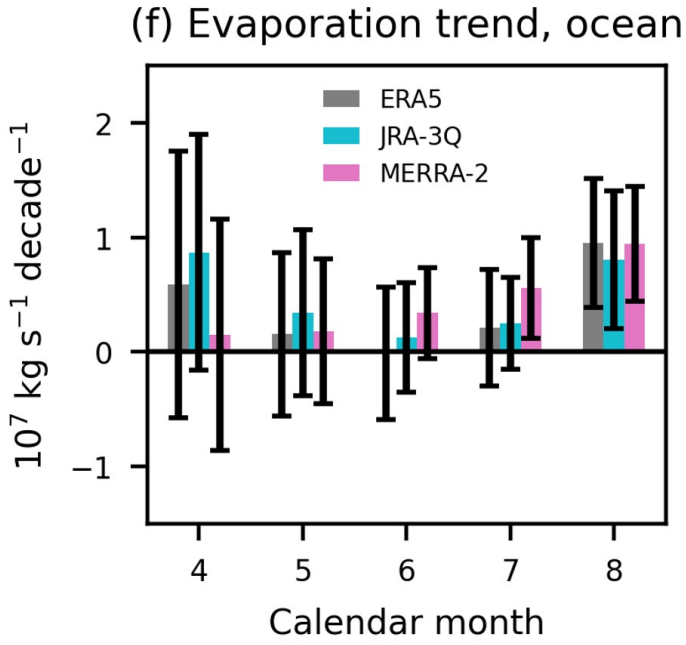
The trend is only significant in June, too

What drives the moisture flux trend in June?

Land vs. ocean evaporation in the subarctic



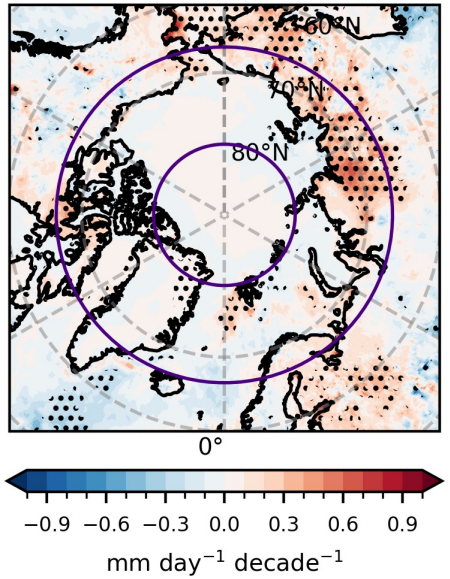




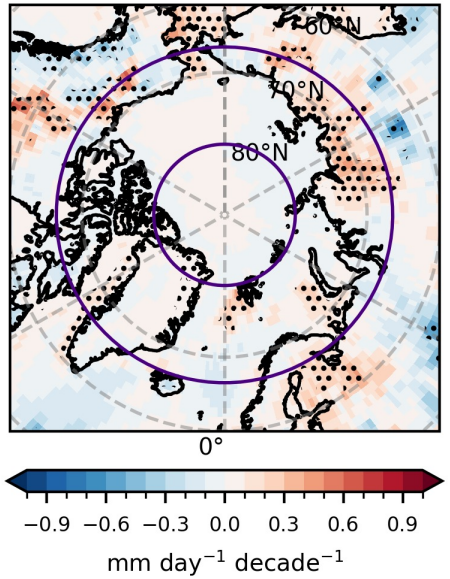
GLEAM 4.2a: a satellite/observation-based land evaporation dataset

Greening in Eurasia and North America vs. summer polar circulation

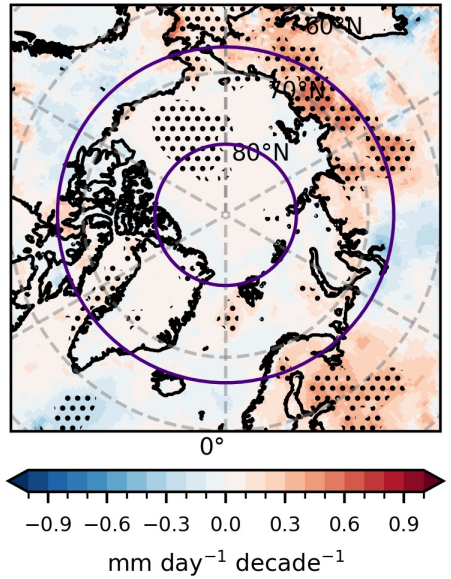
(a) June evaporation trend (ERA5)



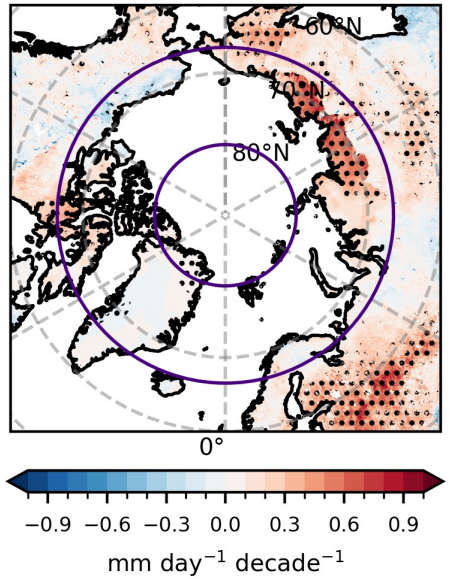
(b) June evaporation trend (JRA-3Q)



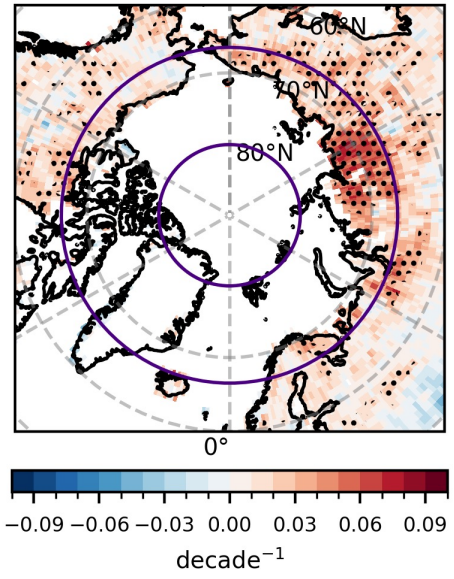
(c) June evaporation trend (MERRA-2)



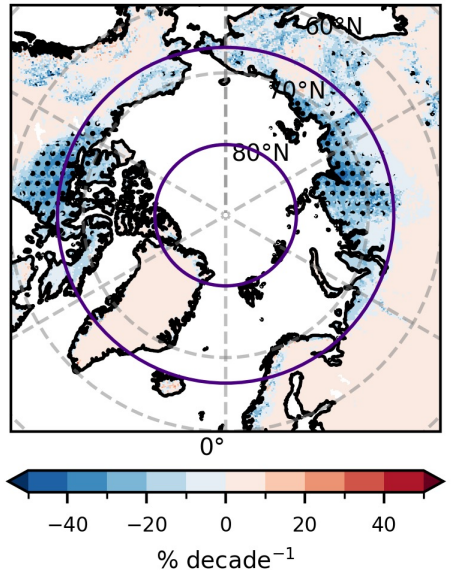
(d) June evaporation trend (GLEAM4.2a)



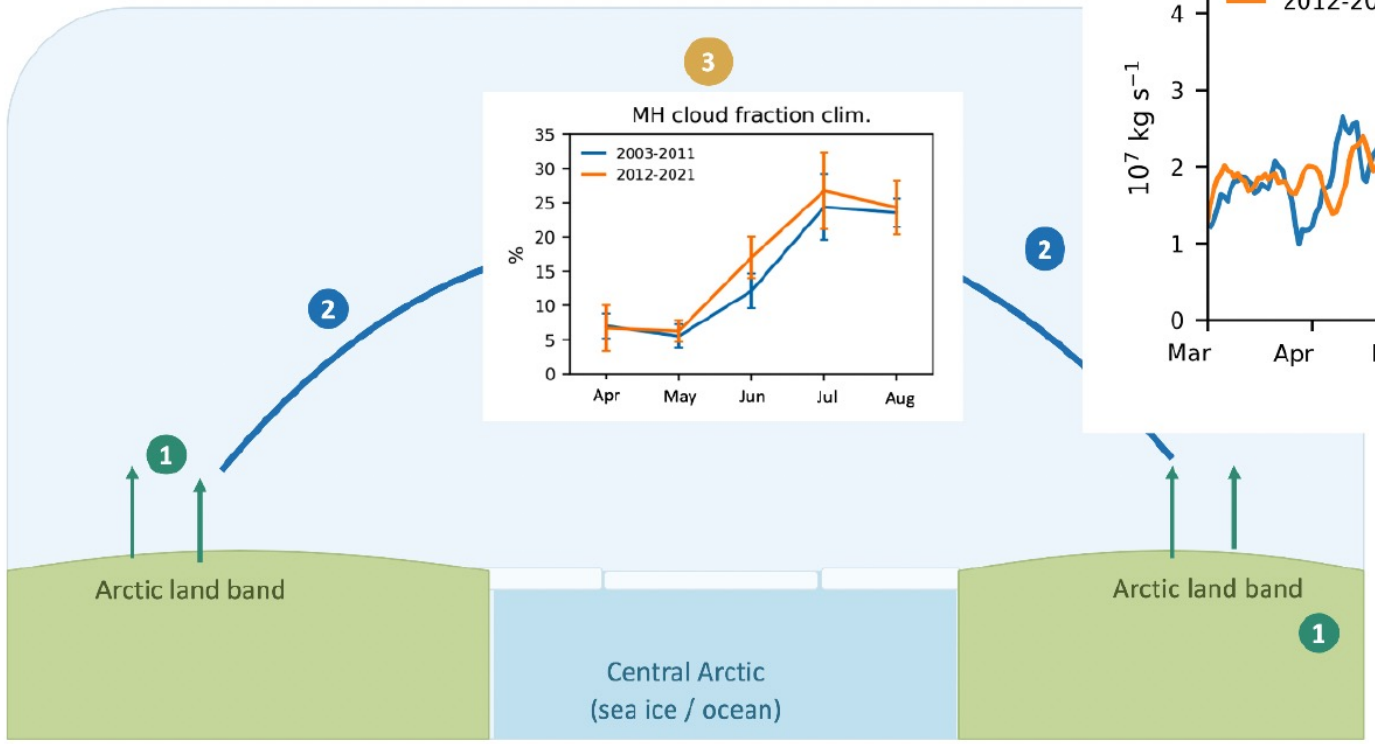
(e) June NDVI trend (good)

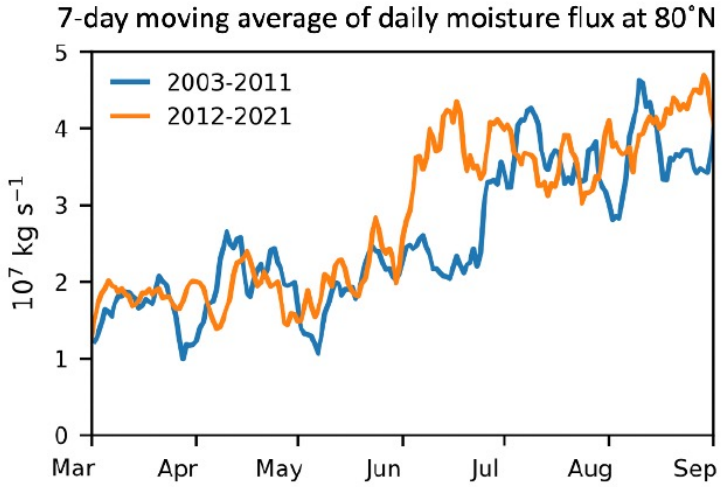


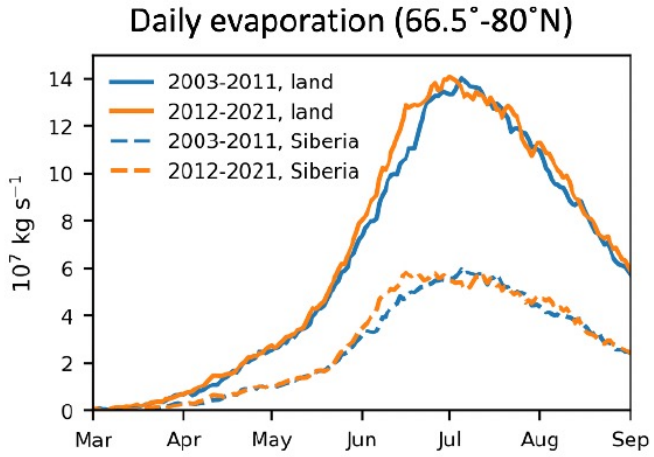
(f) June snow cover extent trend



Why June? Summer comes early?







1 Increased evaporation over the Arctic land in June

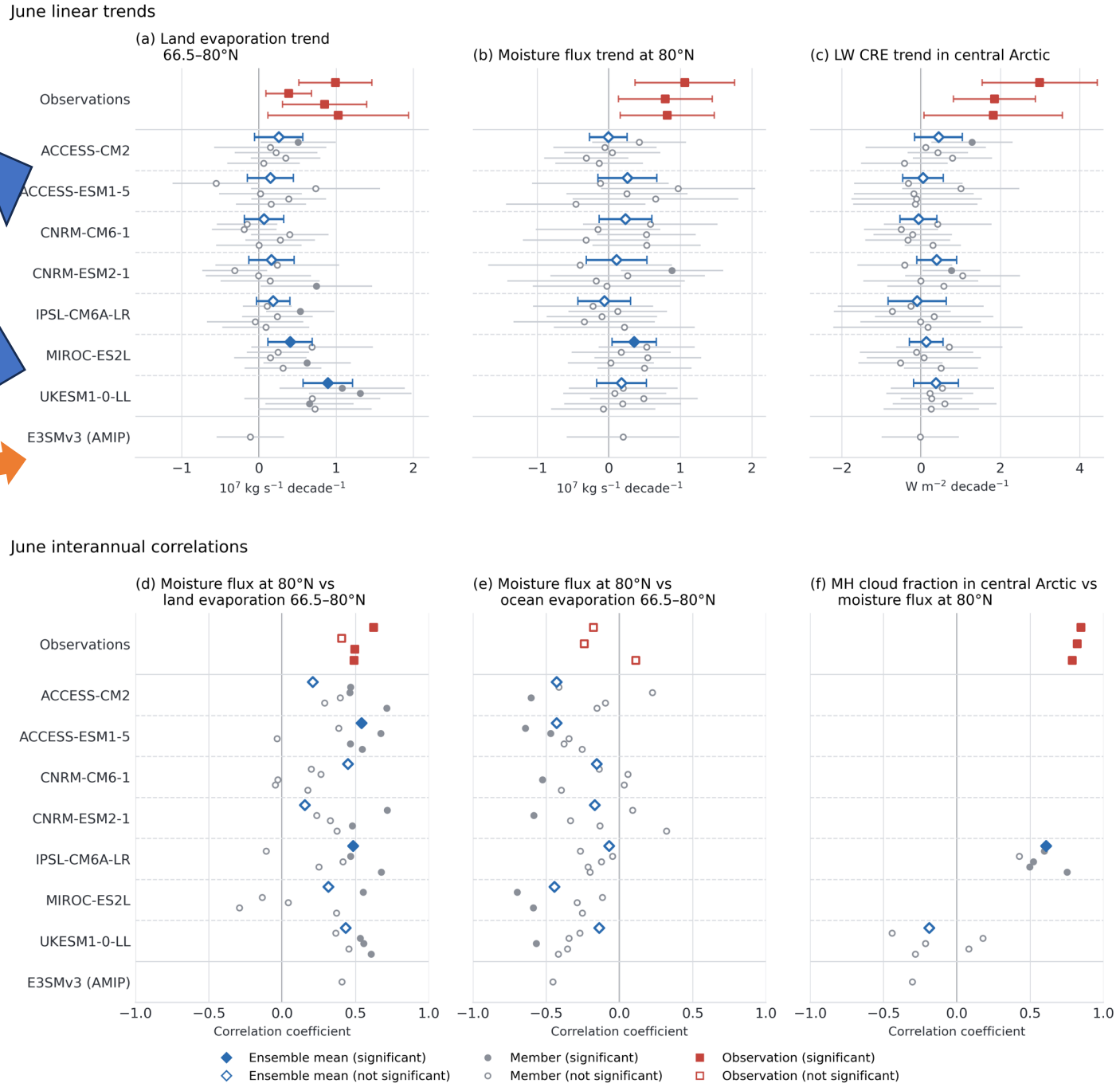
2 Enhanced moisture transport into the central Arctic in June

3 Increased middle and high cloud fraction over the central Arctic

How well can models capture such relations?

With CMIP6 forcing to 2014 and then SSP4.5 to 2021

With the most recent CMIP7 forcing 2003-2021 and observed SST/sea ice

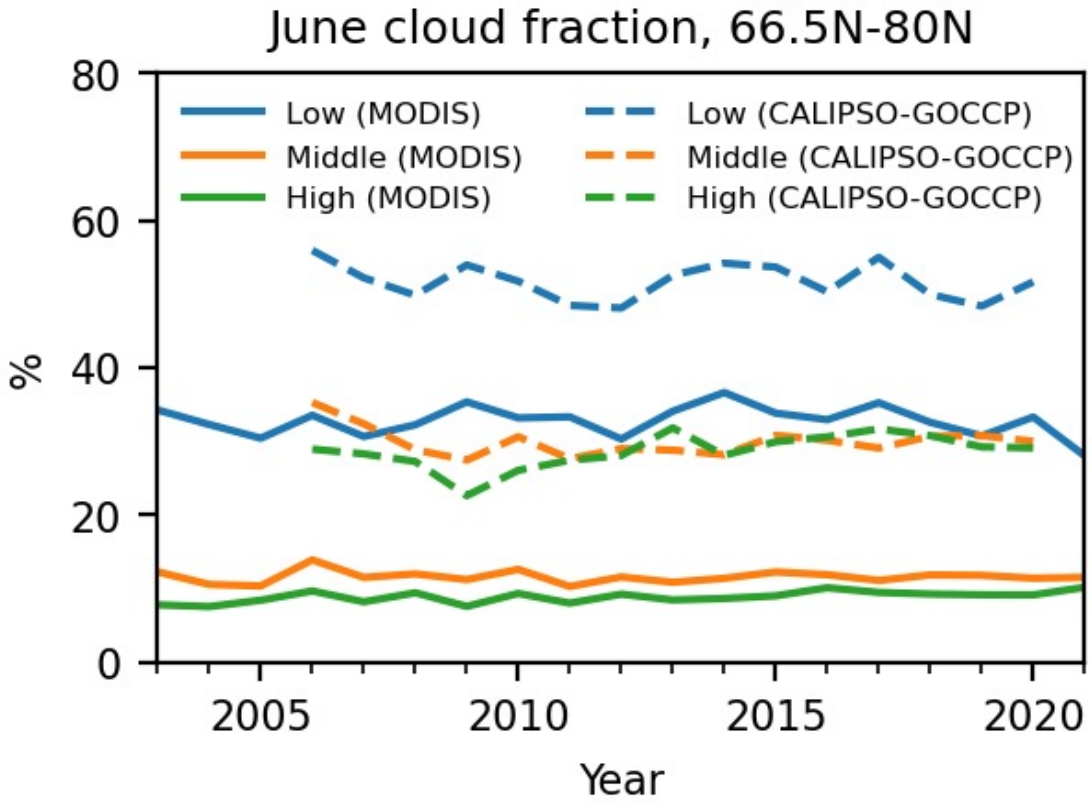


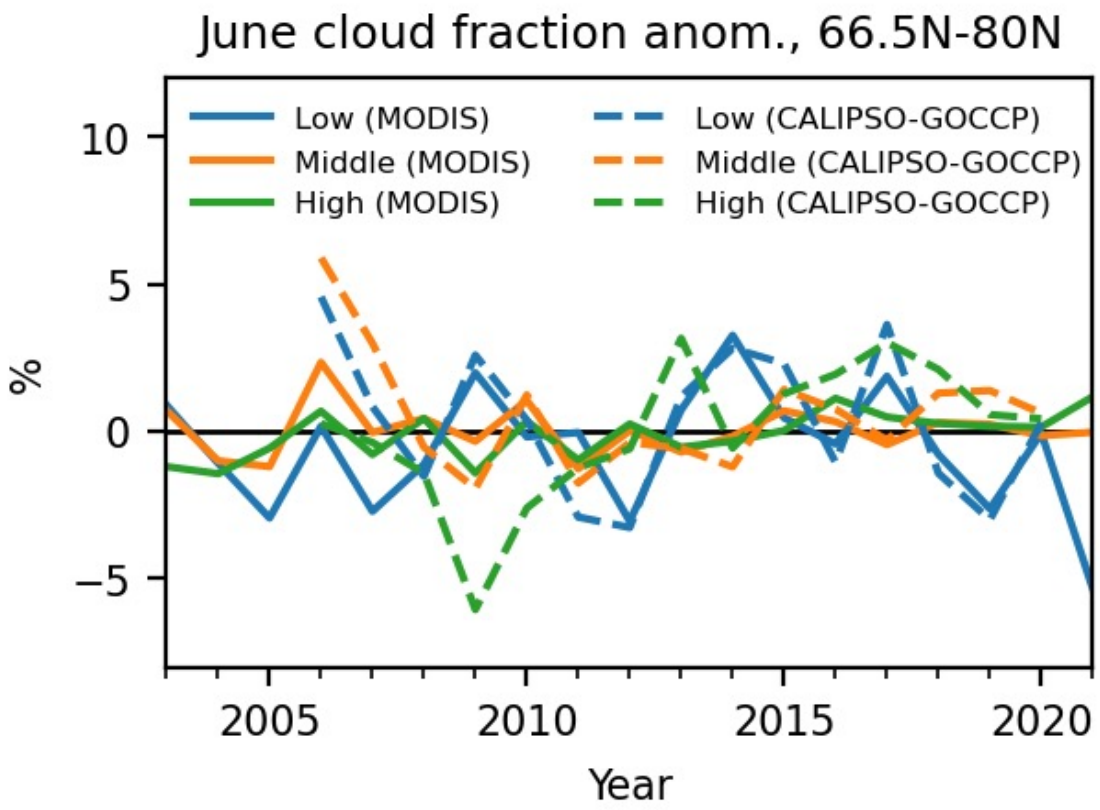
Summaries

- From 2003 to 2021, June is the only sunlit month with significant trends in central-Arctic middle and high clouds (+4.7% per decade) and LW CRE (+1.9 to +3.0 W m^{-2} per decade).
- The driver is moisture transported across 80°N, fed by evaporation from Arctic land — not sea ice, not the ocean.
- This concerted chain of changes in June is consistent with the greening of Arctic land
  - Not only does the growing season becomes longer, summer arrives earlier
- This chain of changes is a fidelity test for Earth system models
  - Model can capture the relation between land evaporation and moisture flux, but not the land evaporation

Thank You!

June cloud fraction, 66.5N-80N





CALIPSO-GOCCP (2deg avg)
Anomaly: Relative to 2008-2020 climatology

June cloud fraction trend, 66.5N-80N

	2003-2021 (MODIS)	2008-2020 (MODIS)	2008-2020 (CALIPSO)
Low	-0.4 ± 1.9	-0.5 ± 3.0	0.0 ± 4.1
Middle	-0.1 ± 0.8	0.0 ± 1.0	1.8* ± 1.7
High	0.9* ± 0.6	0.7 ± 1.0	4.3* ± 3.2

Unit: %/decade