A comparison of CERES Surface albedo in the Arctic with AMIP and CMIP6 model output

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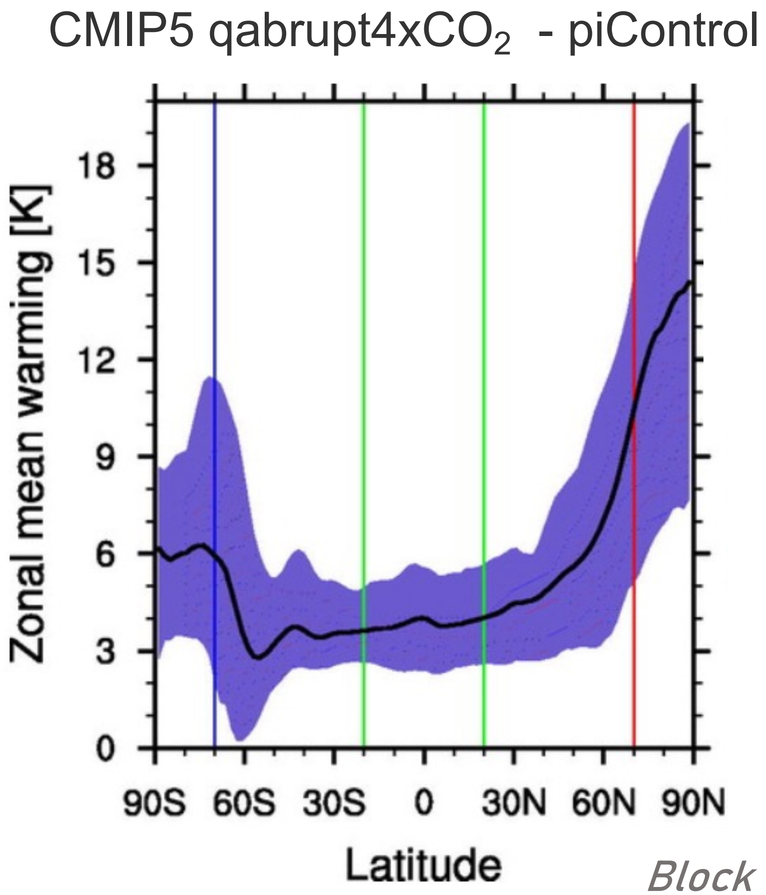
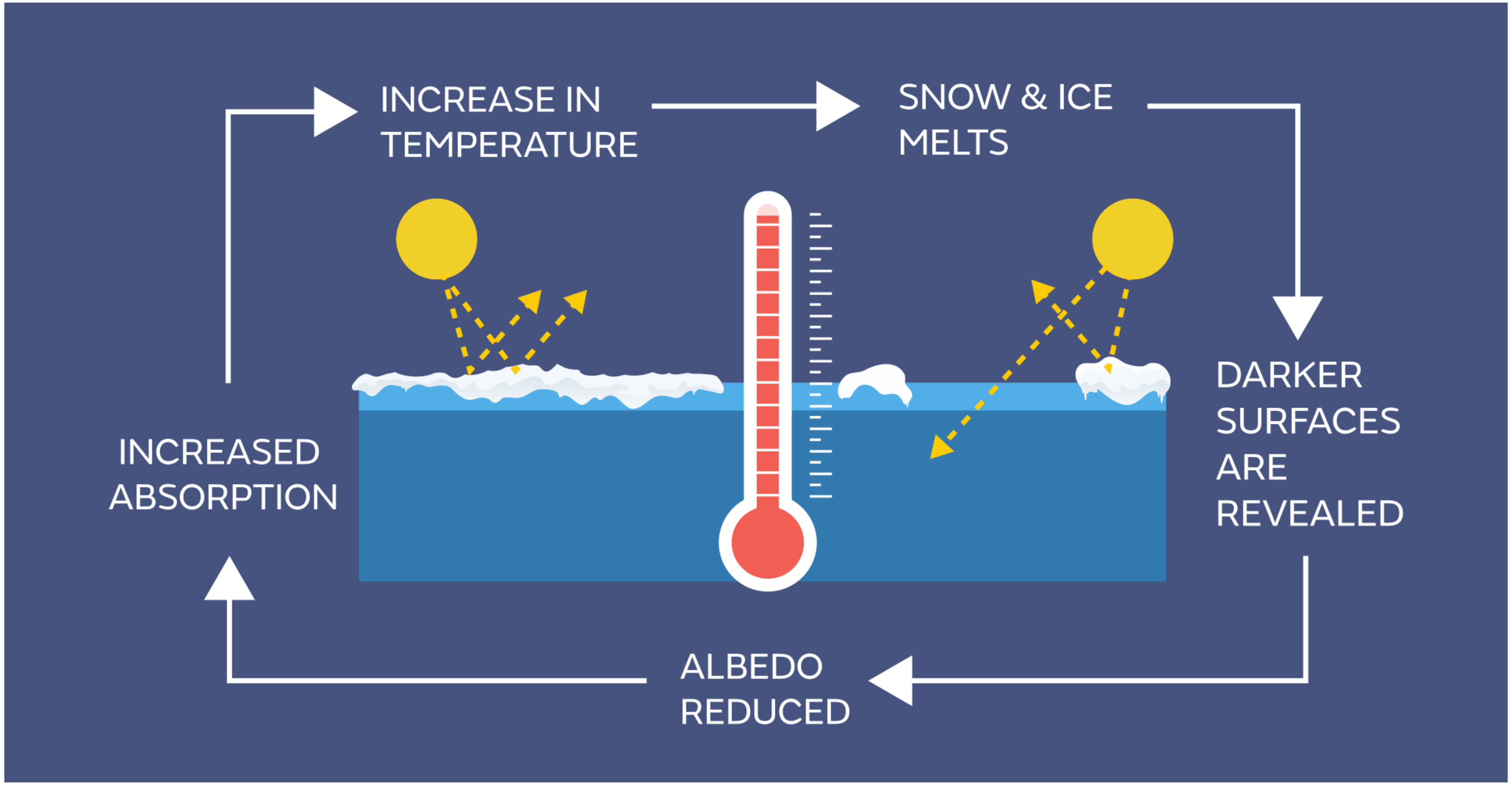
“Arctic amplification”

The Arctic is warming about twice as fast as the rest of the planet



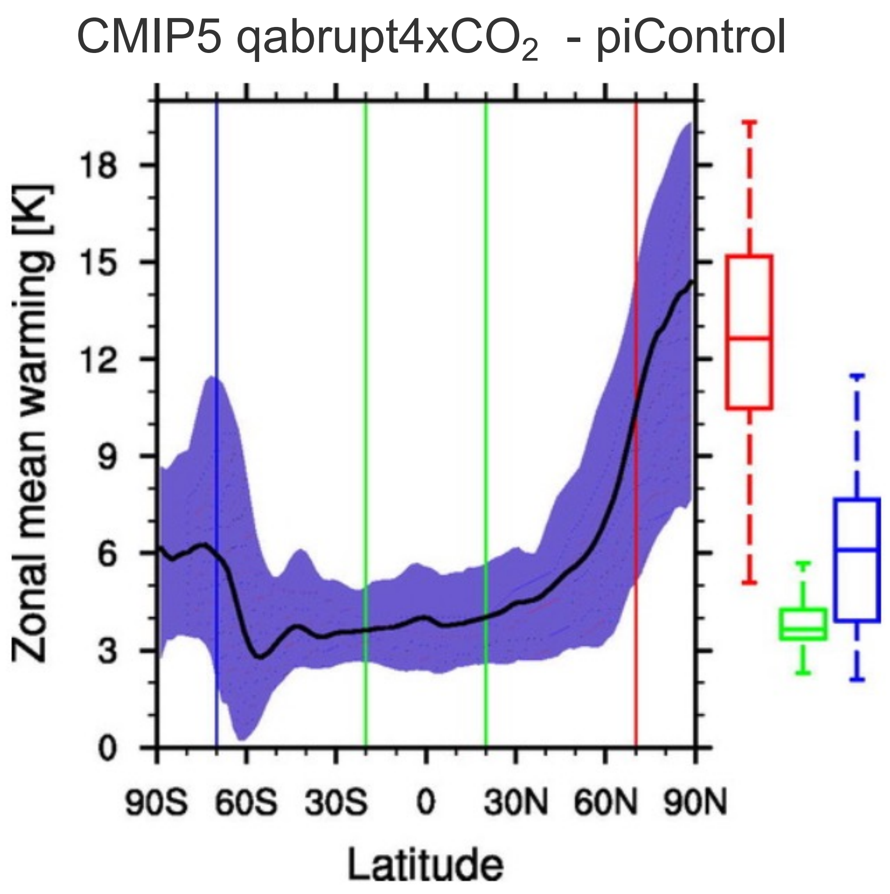
Block et al. 2019

The surface ice-albedo feedback is widely accepted to play a leading role on Arctic amplification



Schematic from Met Office

CMIP models exhibit **large intermodel spread in Arctic amplification**

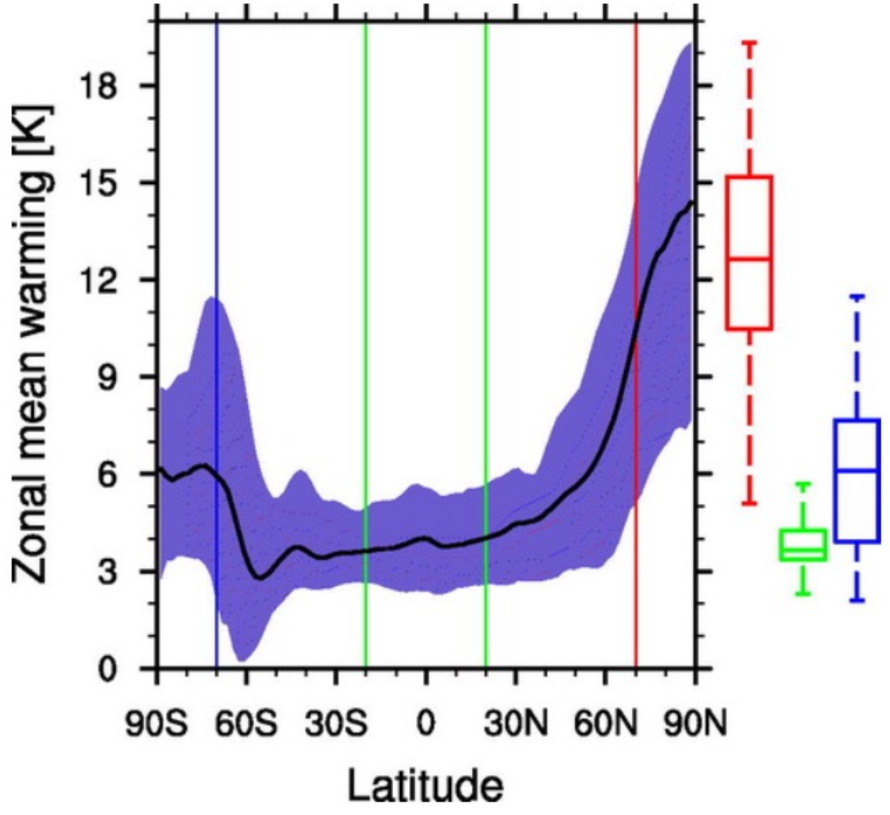


Block et al. 2019

Large intermodel difference in Arctic amplification

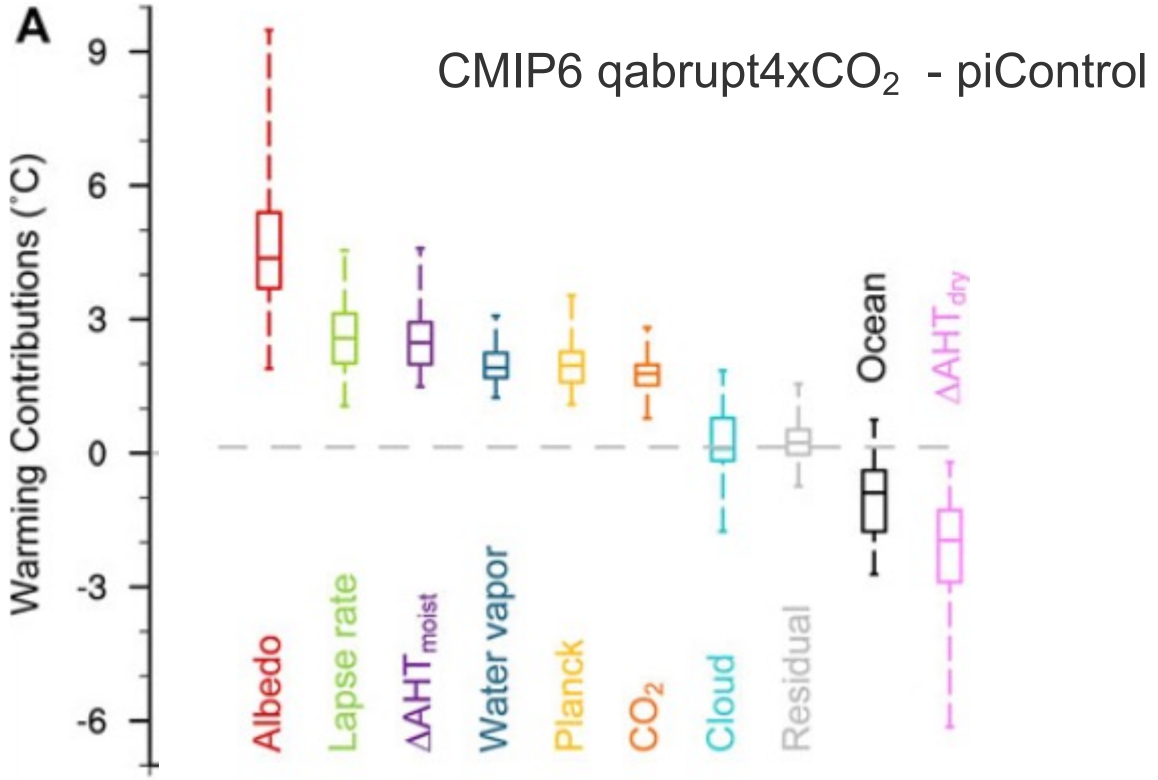
is highly related to **differences in albedo** among the models

CMIP5 qabrupt4xCO_2 - piControl



Block et al. 2019

Intermodel spread of polar warming contributions



Hahn et al. 2021

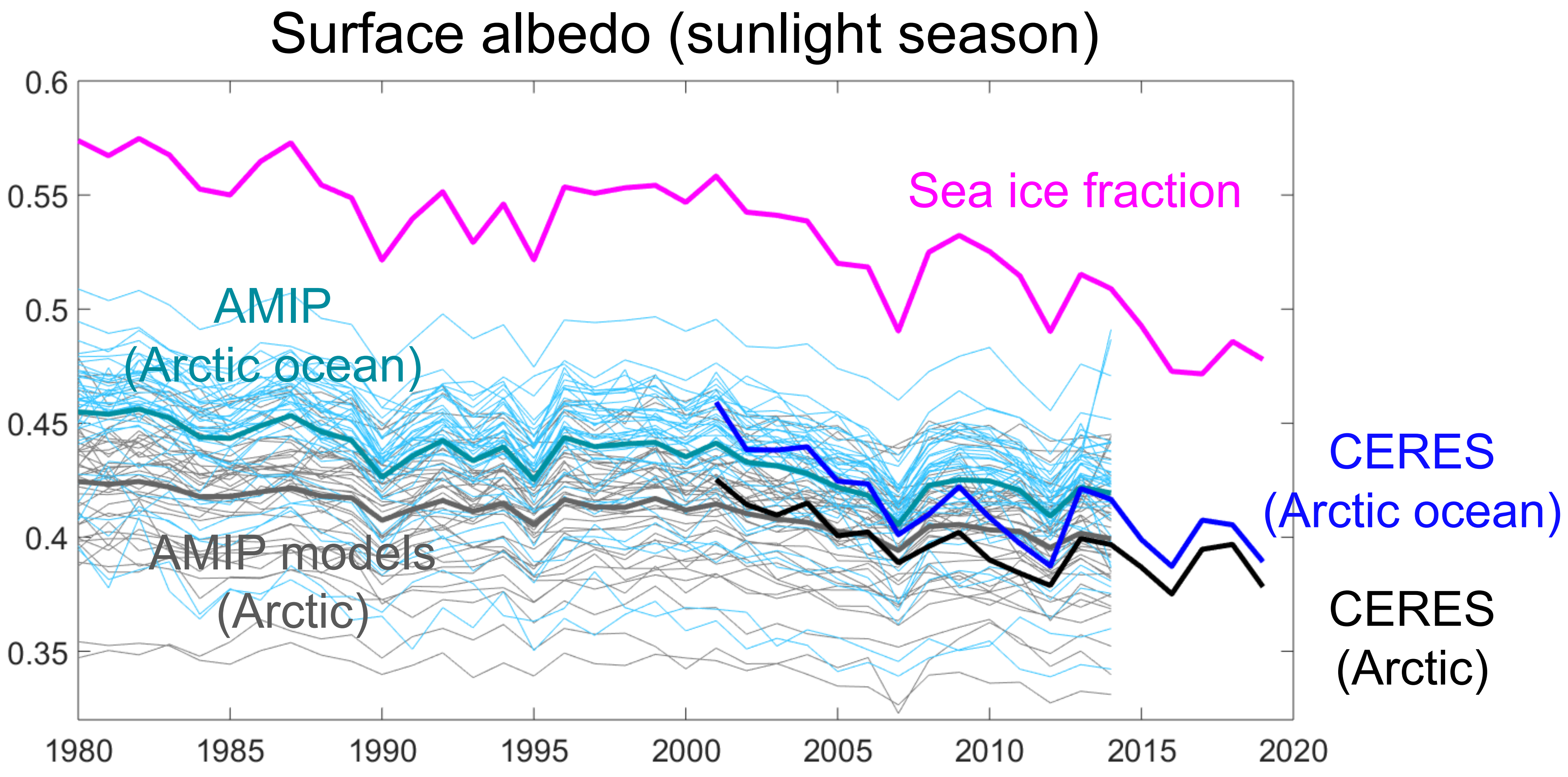
A comparison of CERES Surface albedo in the Arctic with AMIP and CMIP6 model output

- AMIP 32 models: historical run, 1980-2014 (SST & SIC fixed)
- CMIP 32 models: historical run, 1980-2014 (Full coupled models)
- CERES: 2001-2019
- Hurrell SST/sea ice consistency criteria applied to merged HadISST (1870-01 1981-10) & NCEP-0I2 (1981-11 to 2016-12)

Surface albedo : $\alpha_s = \frac{F_{\uparrow}^{SFC}}{F_{\downarrow}^{SFC}}$

averaged over 65°N,
sunlight season (Mar through Sep)

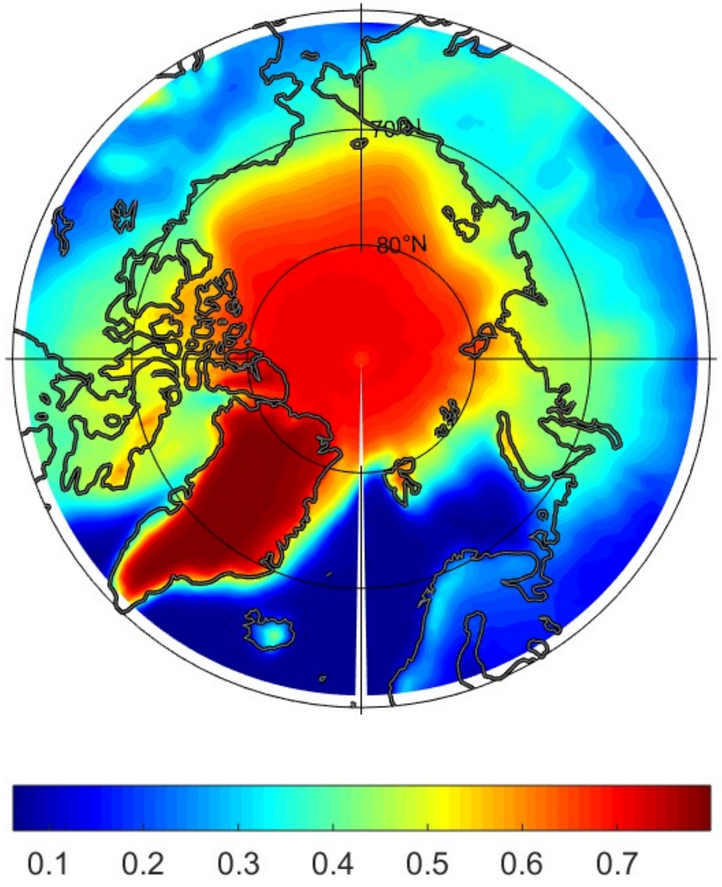
Simulated Arctic surface albedo exhibits a large inter-model spread



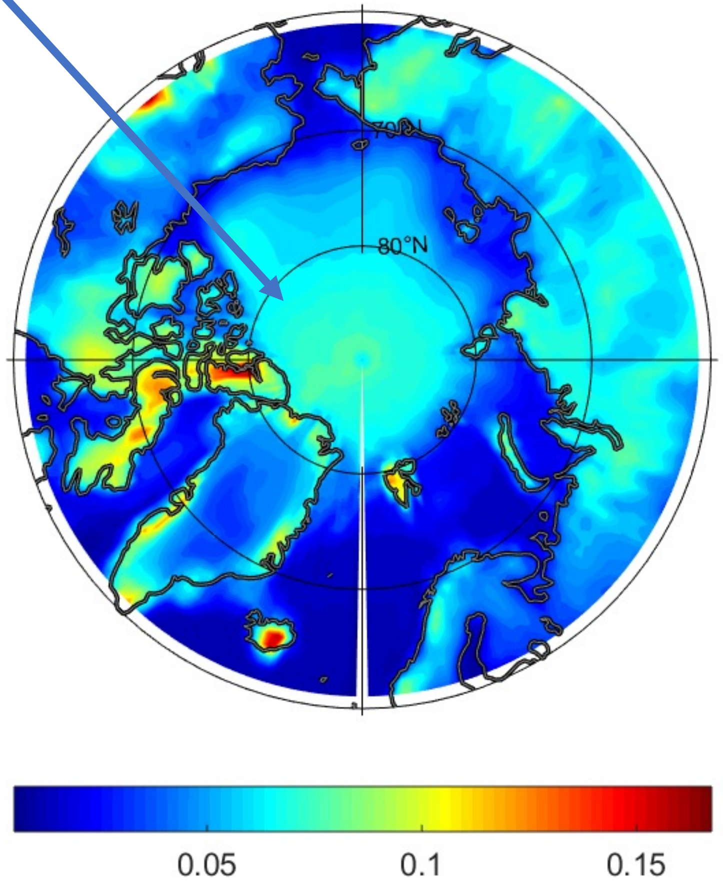
AMIP: SST and Sea Ice concentration is prescribed

0.07:10%p, if 250W/m^2=250x0.07=17.5W/m^2

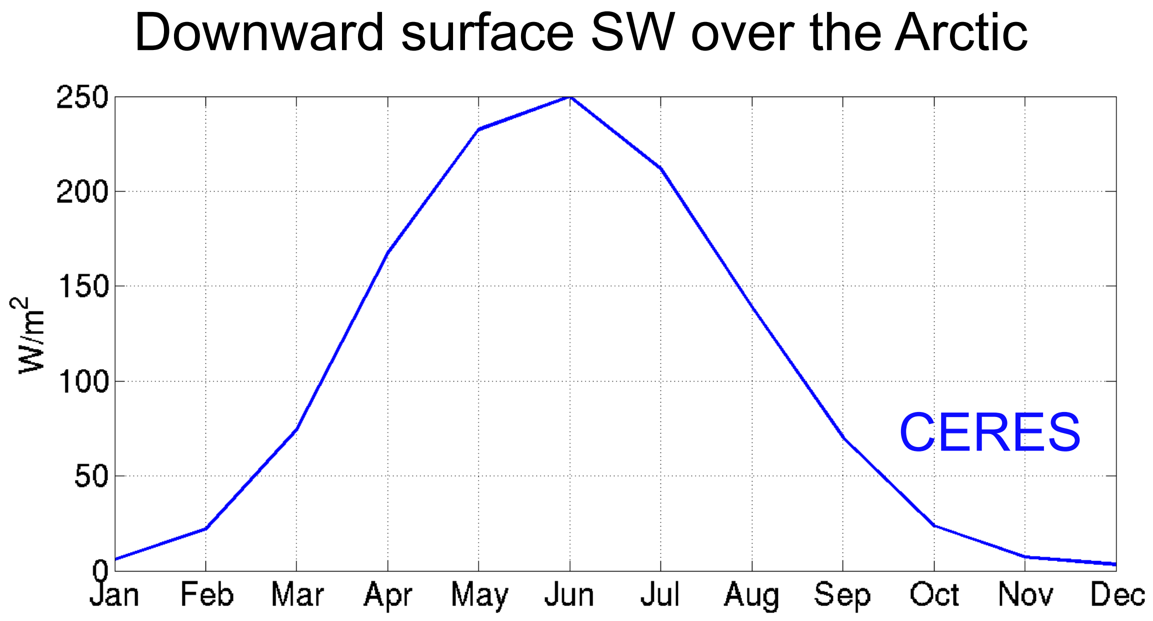
Surface albedo
(AMIP MMM sunlight season)



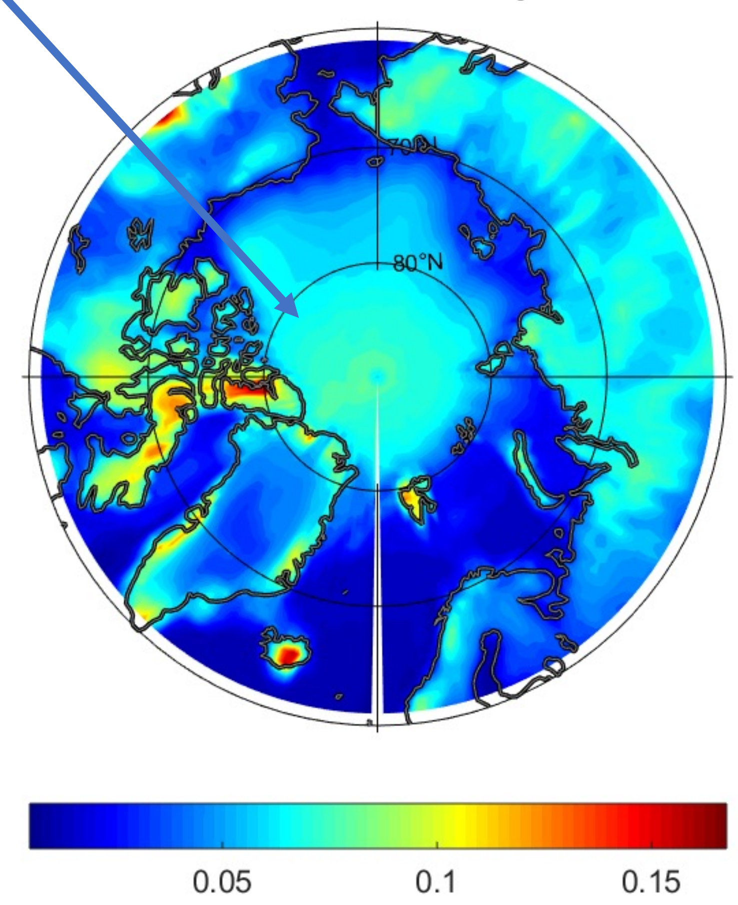
Surface albedo
(AMIP STD sunlight season)



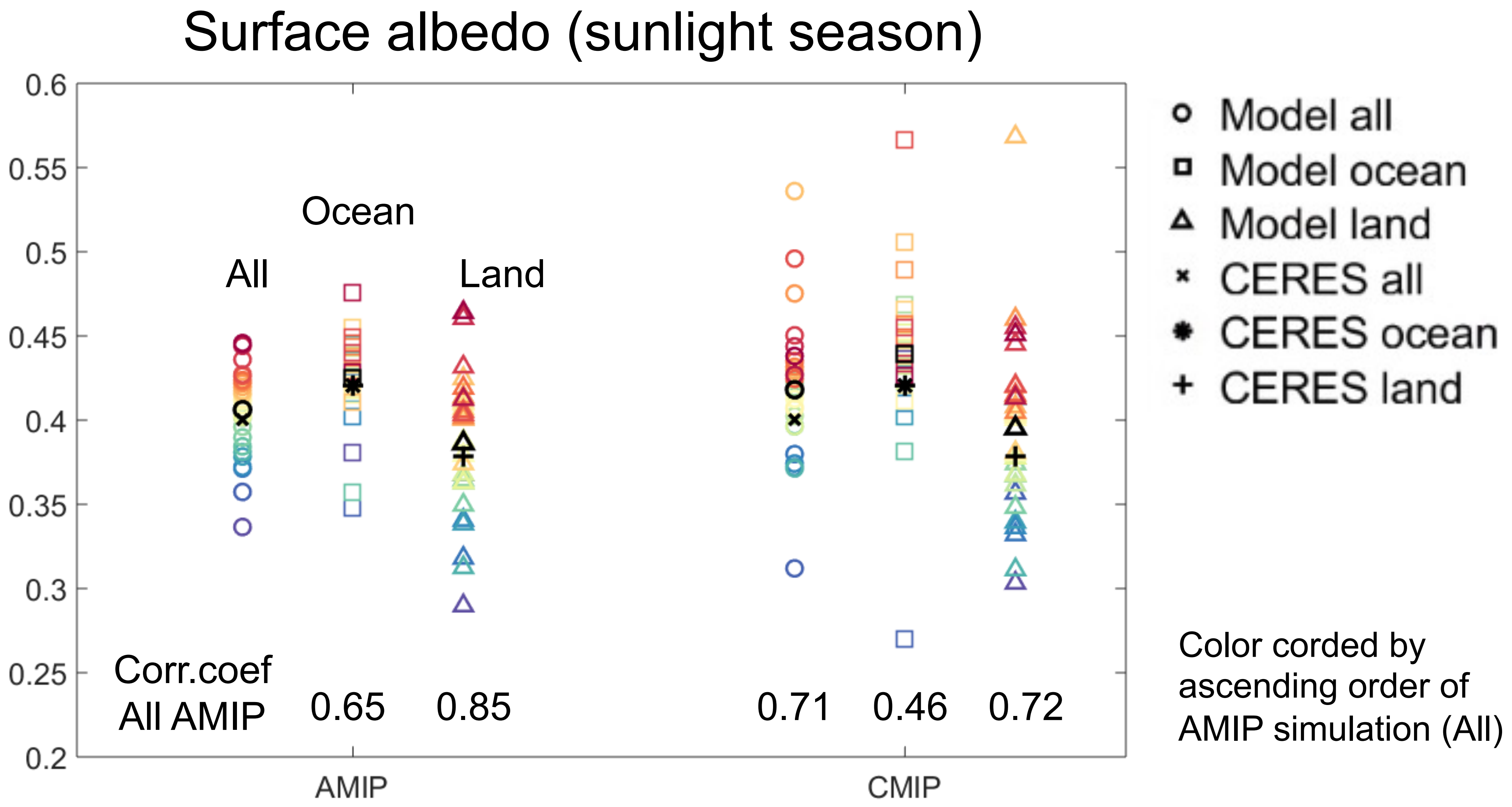
0.07:10%p, if 250W/m^2=250x0.07=17.5W/m^2



Surface albedo
(AMIP STD sunlight season)



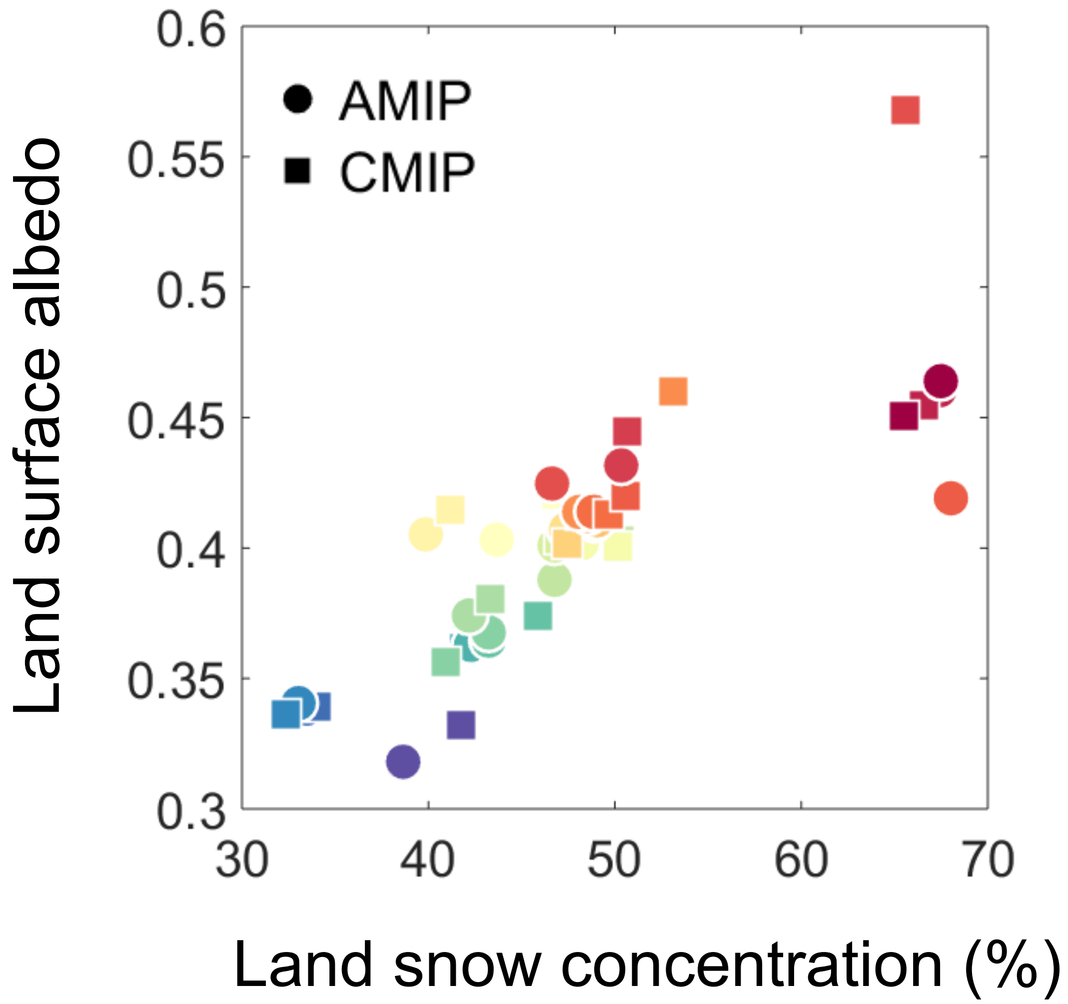
Sea ice concentration is not a main driver for spreads in surface albedo?



Color corded by ascending order of AMIP simulation (All)

Most intermodel spreads in CMIP models are originated from AMIP simulations

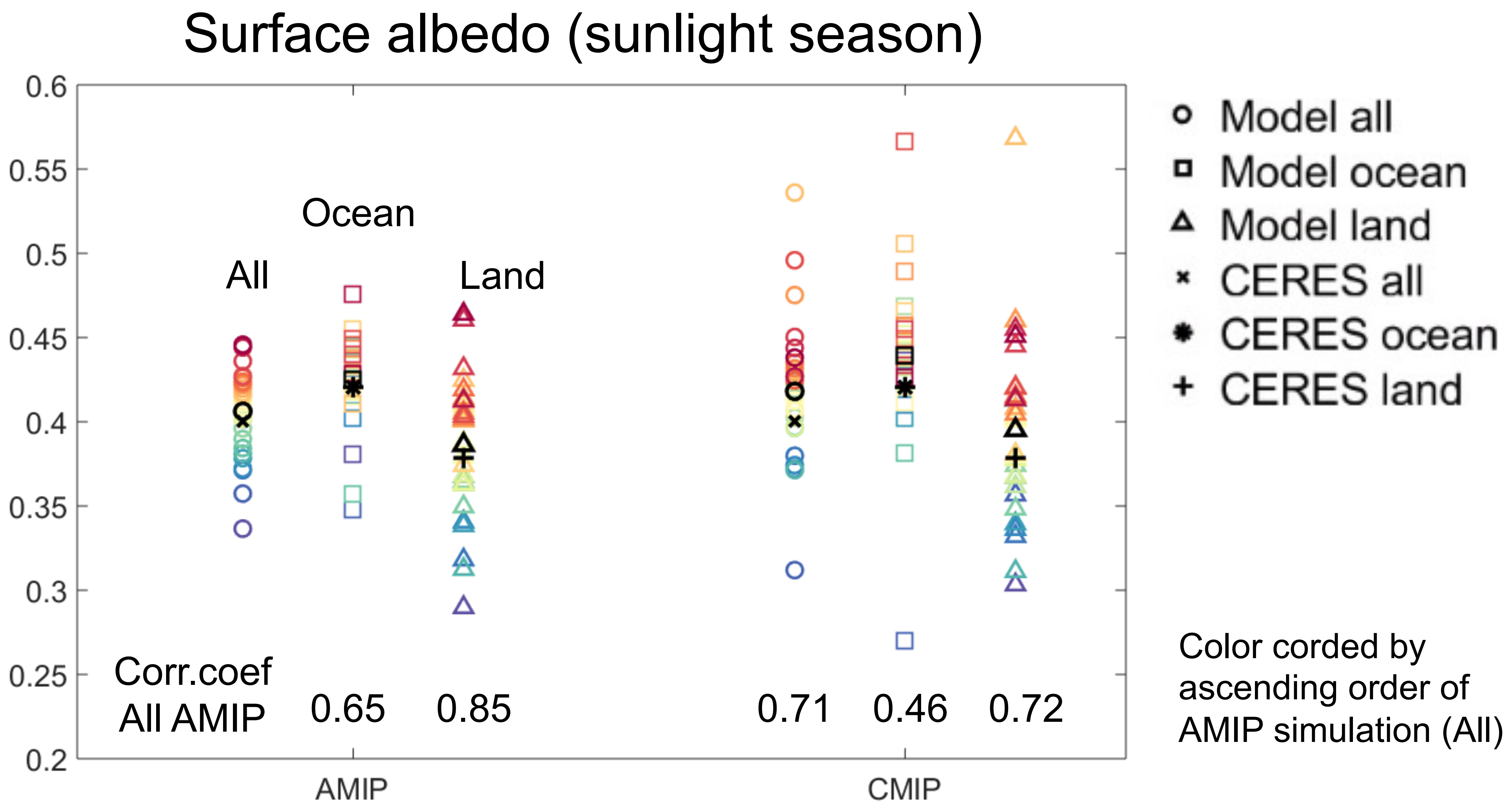
Models with **a larger land snow concentration** exhibit the **higher surface albedo**



Correlations

land snow & land albedo	0.82 (AMIP) 0.85 (CMIP)
land albedo AMIP& CMIP	0.80
land snow AMIP&CMIP	0.80

The large differences in ocean albedo in AMIP simulation while SST and SIC are prescribed

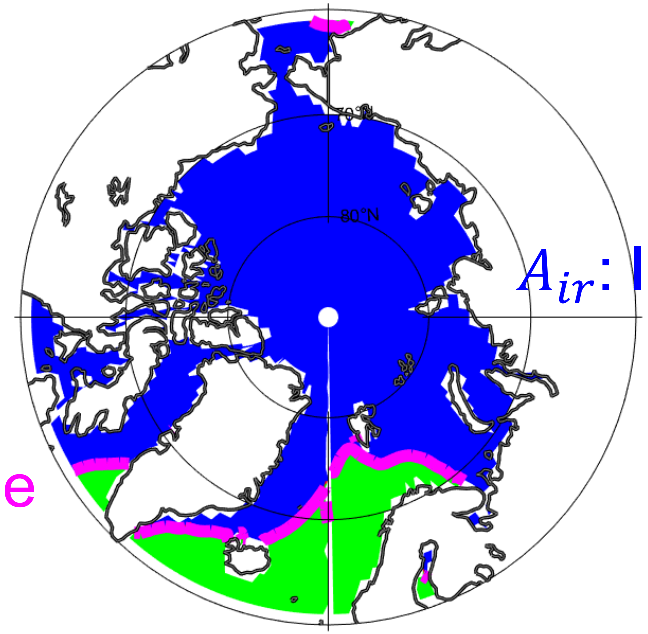


Breaking down albedo: a new definition for ice albedo difference and sea ice concentration difference

$$\alpha = \alpha_{ir}A_{ir} + \alpha_{or}(1 - A_{ir})$$

$$\alpha_{ir} = \alpha_{i_{ir}}c_{ir} + \alpha_{o_{ir}}(1 - c_{ir})$$

: ocean albedo is calculated by averaging the surface albedo where sea ice concentration is less than 15%



A_{ir}: Ice region

15% sea ice concentration line

$(1 - A_{ir})$: Ocean region

α: surface albedo

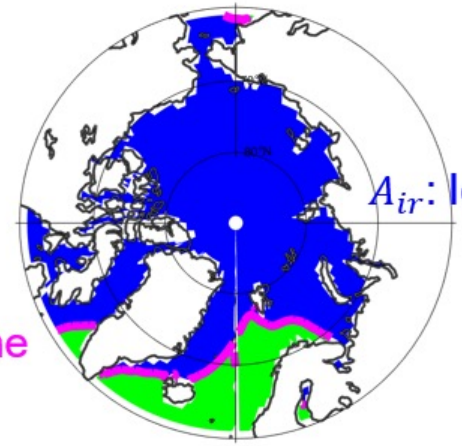
c: sea ice concentration

Breaking down albedo: a new definition for ice albedo difference and sea ice concentration difference

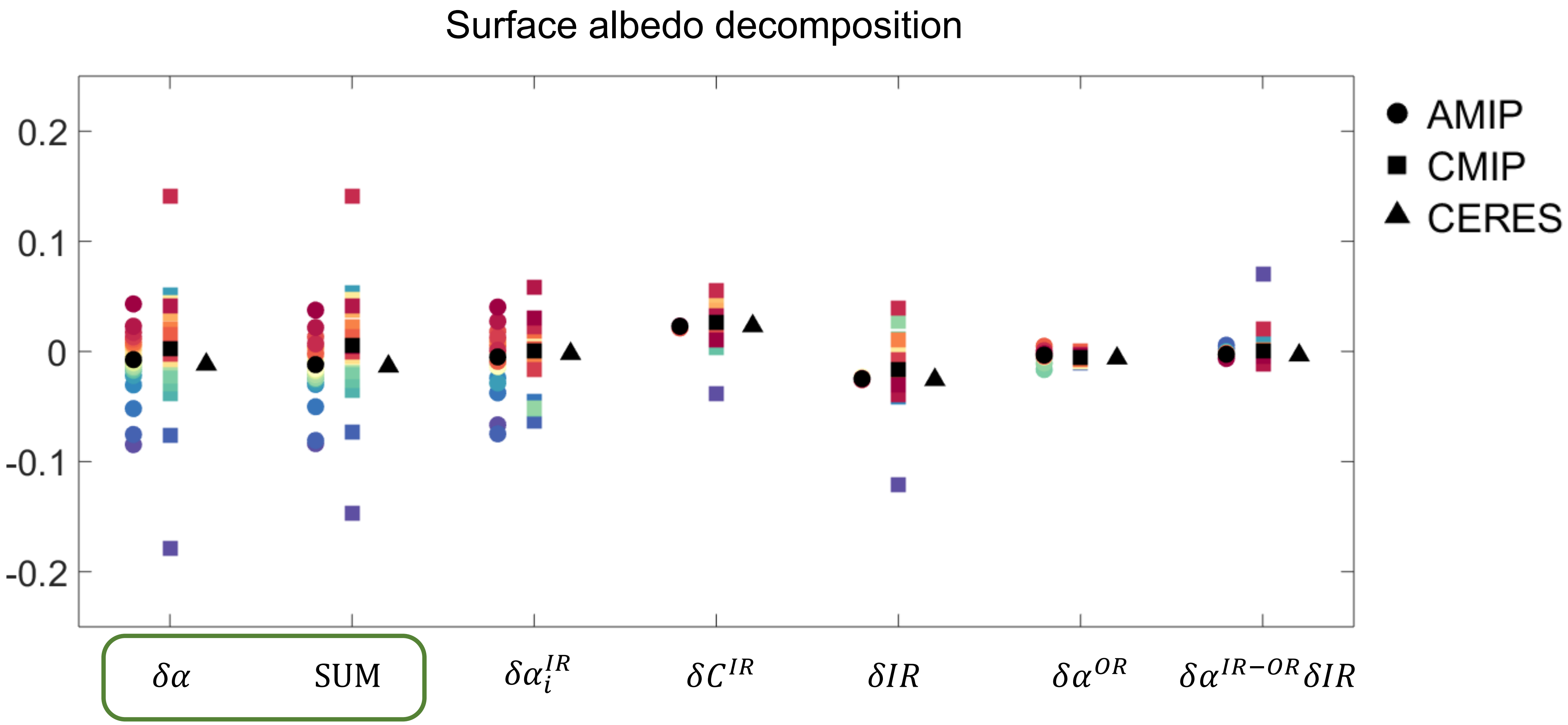
$$\delta\alpha = \delta\alpha_i^{IR} + \delta C^{IR} + \delta\alpha_o^{IR} + \delta IR + \delta\alpha^{OR} + \delta(\alpha^{IR} - \alpha^{OR})\delta IR + \delta(\alpha_i^{IR} - \alpha_o^{IR})\delta c + \delta\overline{\alpha_i' c'}$$

① ② ③ ④ ⑤ ⑥

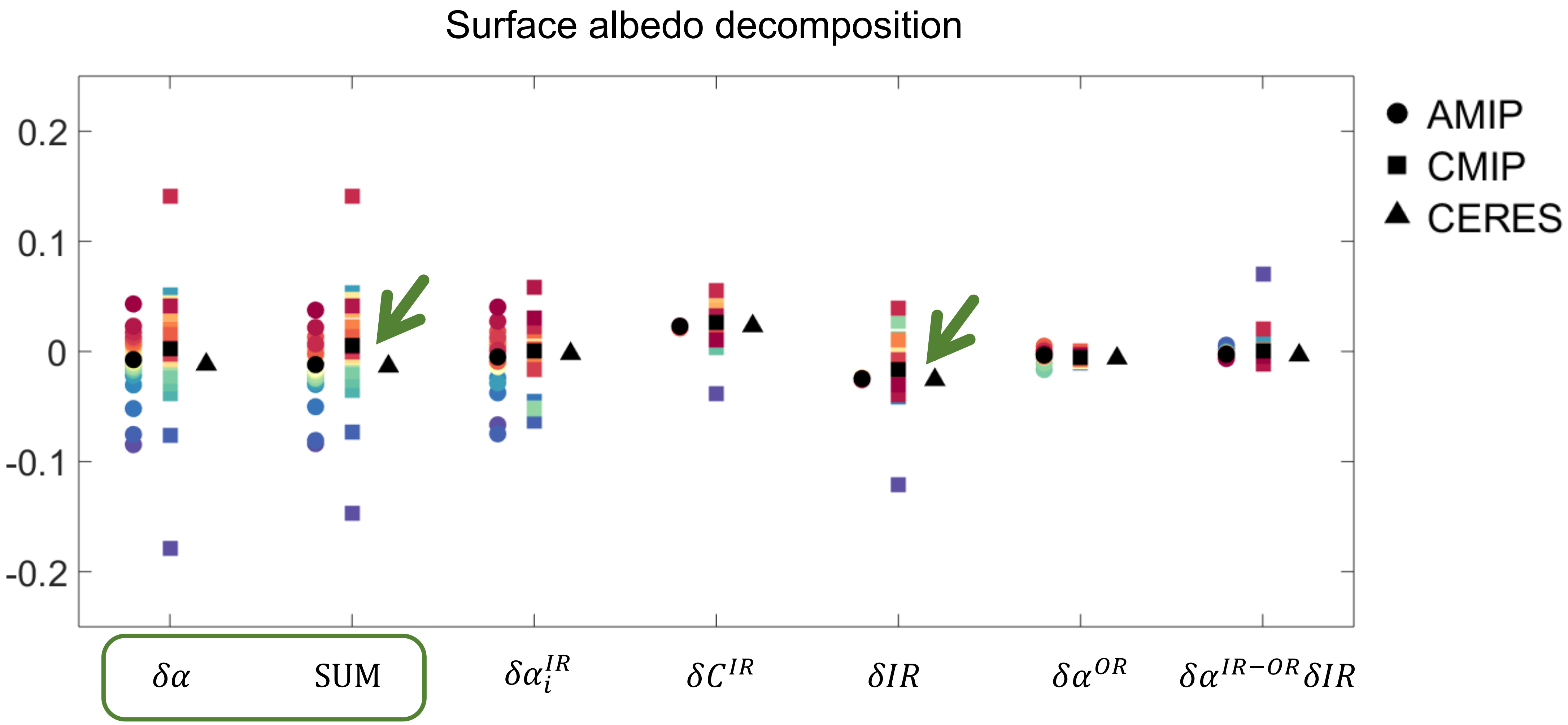
① Sea ice albedo in ice region
② Sea ice concentration in ice region
③ Ocean albedo in ice region
④ Ice region term
⑤ Albedo in ocean region
⑥ Albedo difference with ice region difference



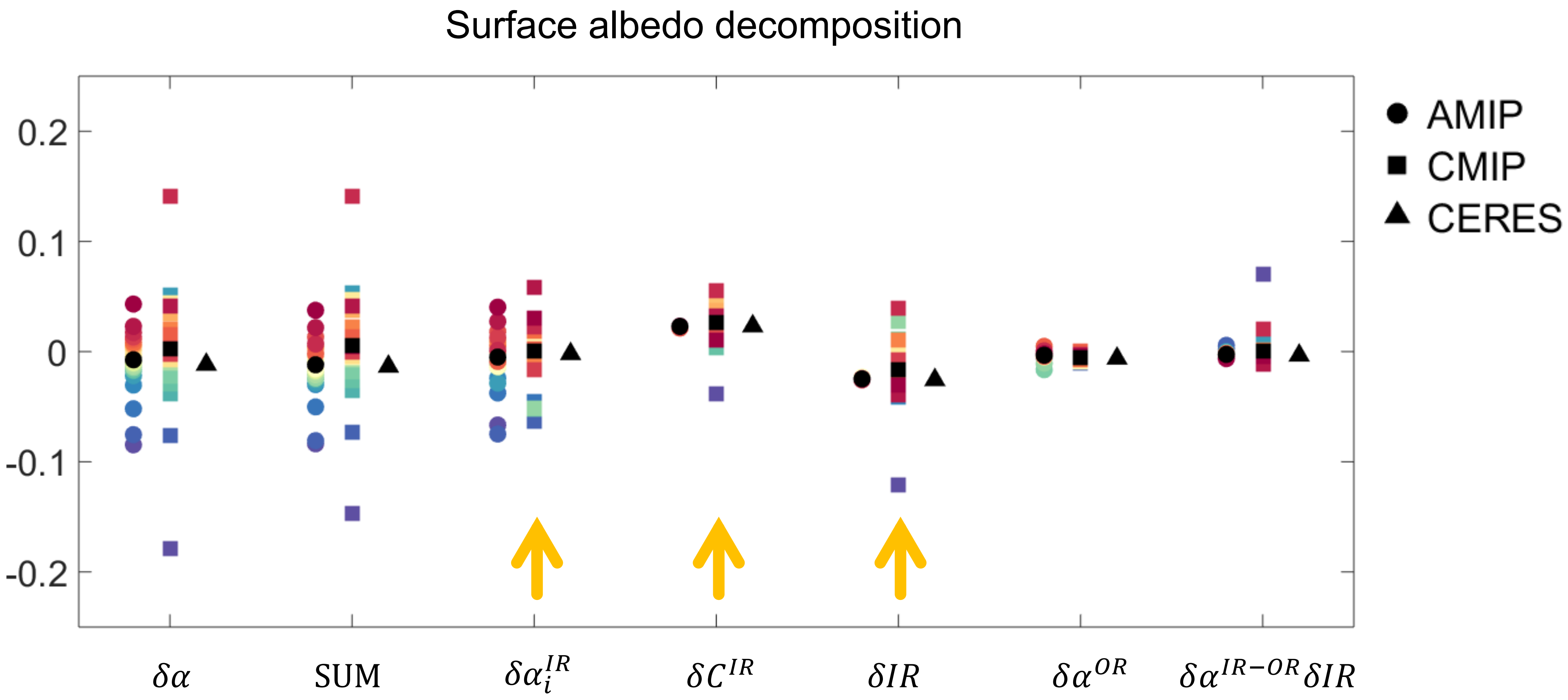
When we add up the decomposition, it matches pretty well with the outputs from models



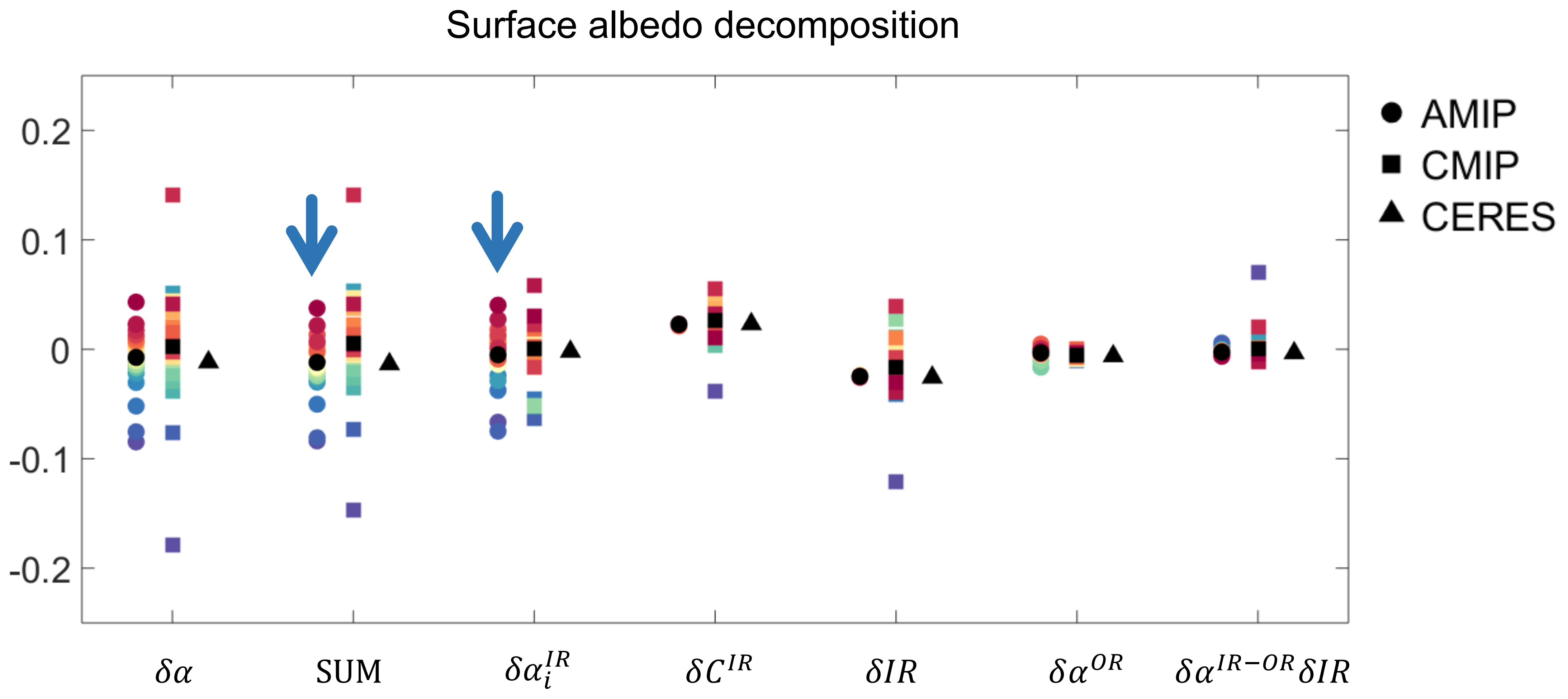
CMIP model mean is a little higher compared to CERES, and that is because of the **difference in sea ice edge area**

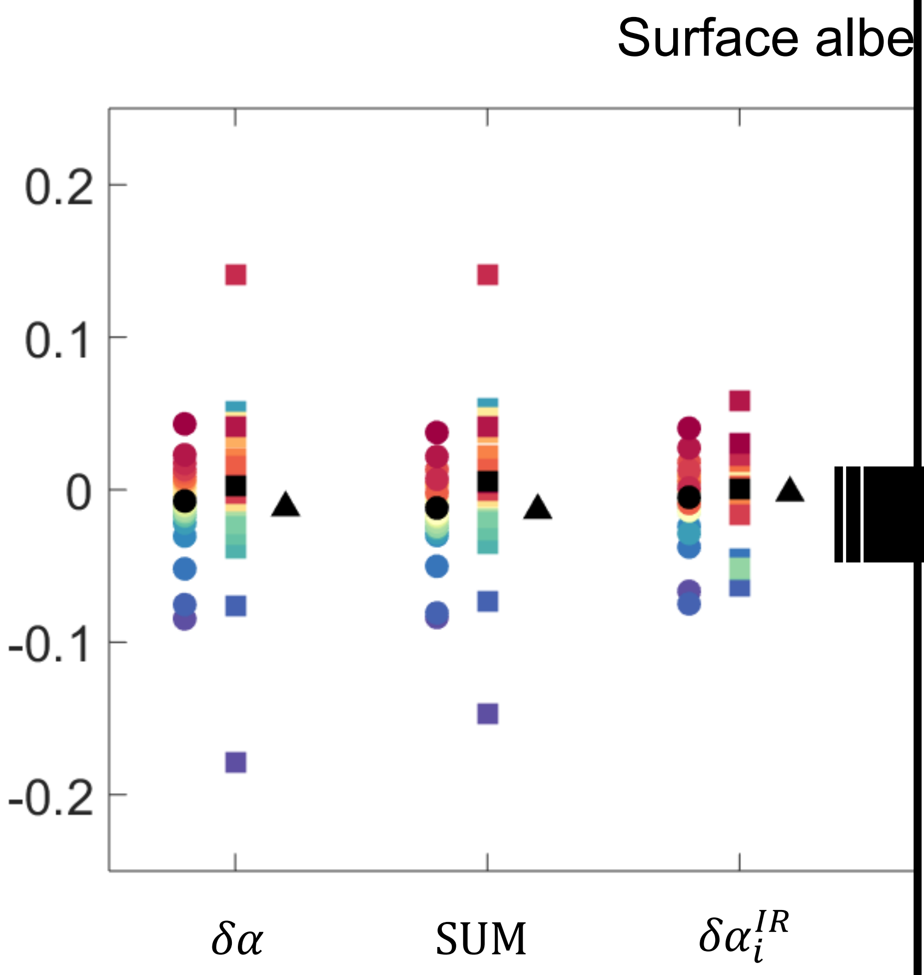


For CMIP models, the difference in sea ice albedo, concentration and ice region are main factors that explain the spread in model results

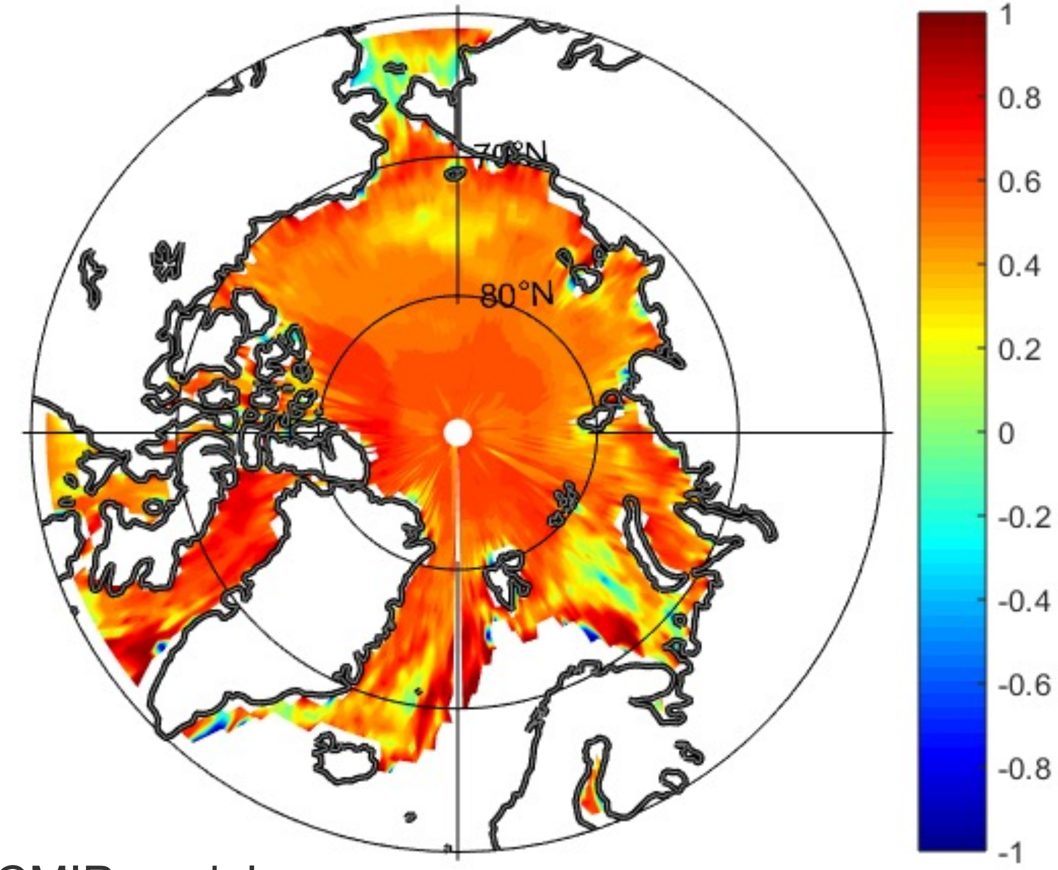


For AMIP simulations, a large variation in surface albedo is due to the difference in ice albedo with same sea ice concentration



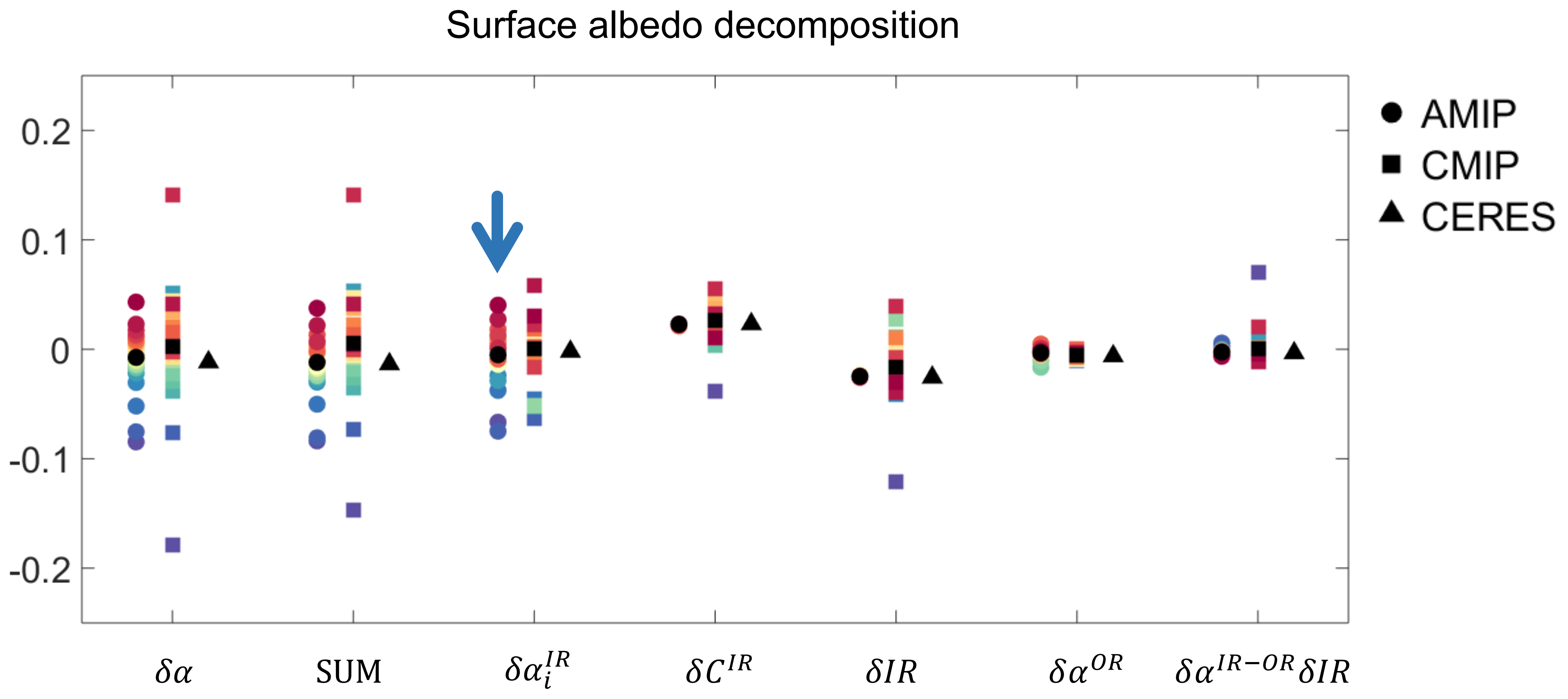


Correlations:
sea ice albedo (eq) vs.
snow cover over sea ice

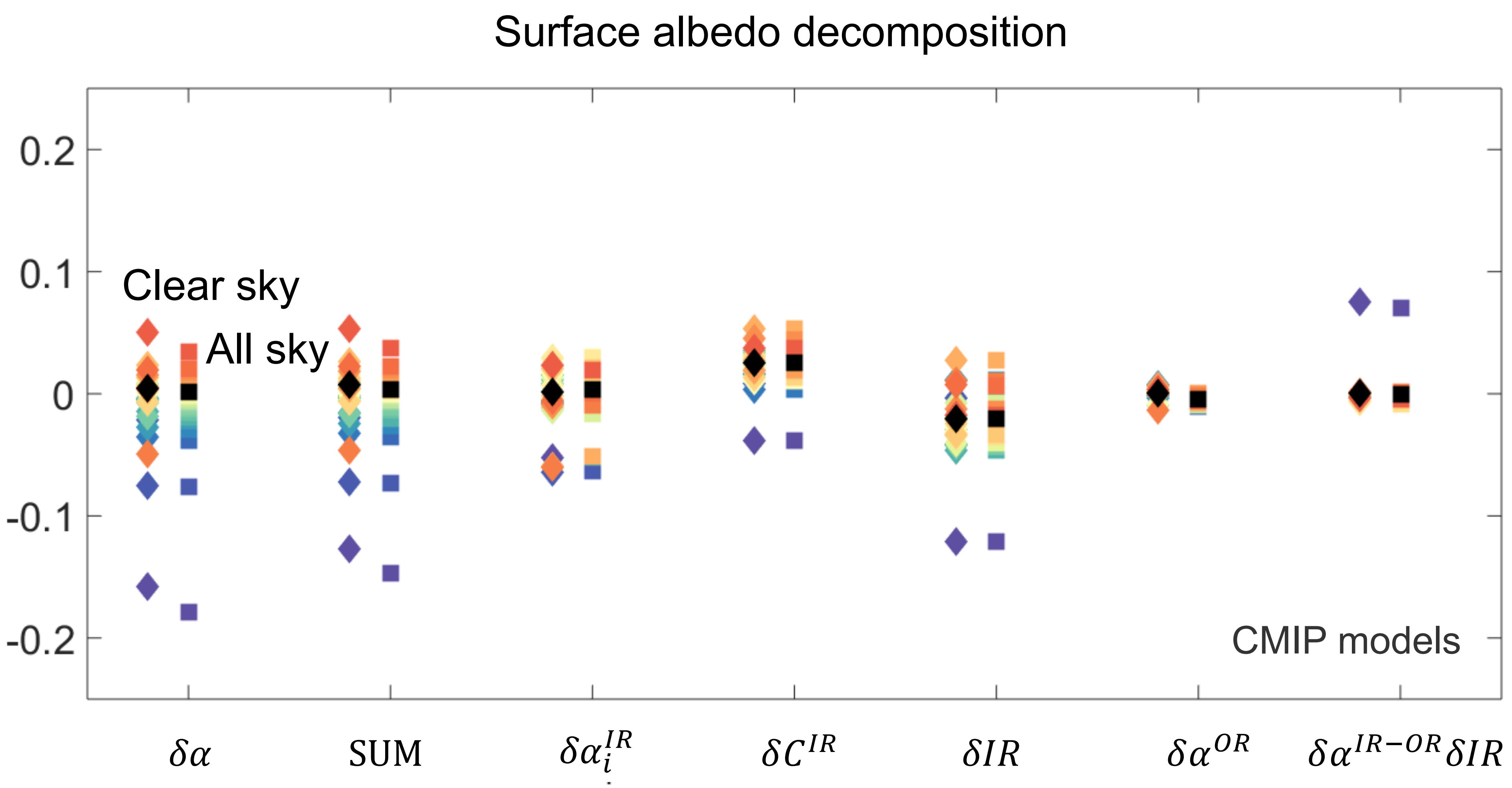


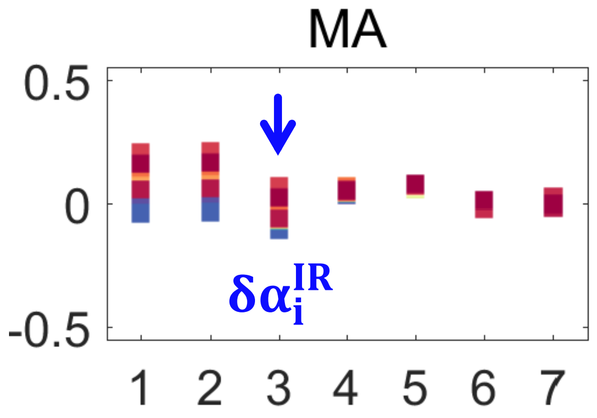
23 CMIP models

Consideration of **surface ice albedo with snow cover** is a key component in modeling spread of surface albedo

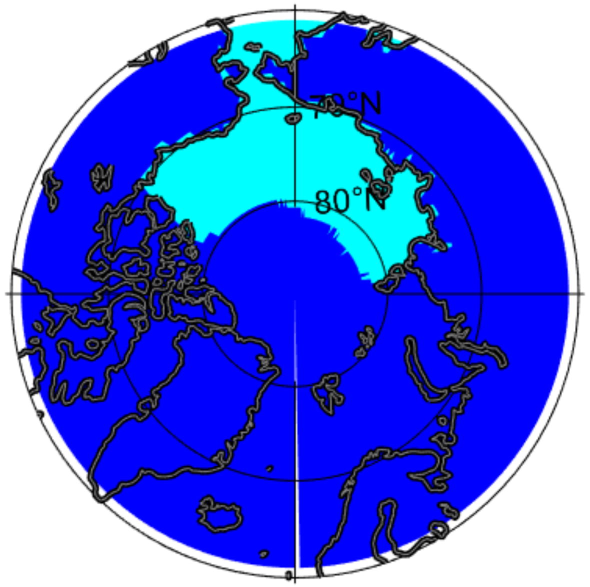


Negligible effect of cloud on inter-model spread of surface albedo



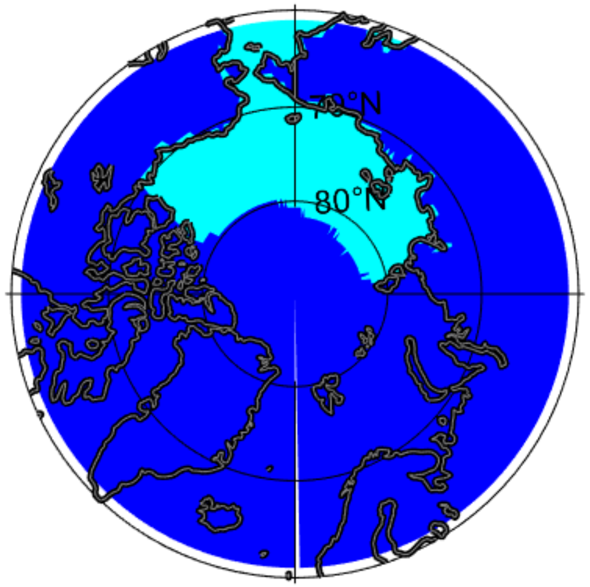


East Siberian, Chukchi, & Beaufort



1. $\delta\alpha$
2. SUM
3. $\delta\alpha_i^{IR}$
4. δC^{IR}
5. δIR
6. $\delta\alpha^{OR}$
7. $\delta\alpha^{IR-OR}\delta IR$

East Siberian, Chukchi, & Beaufort



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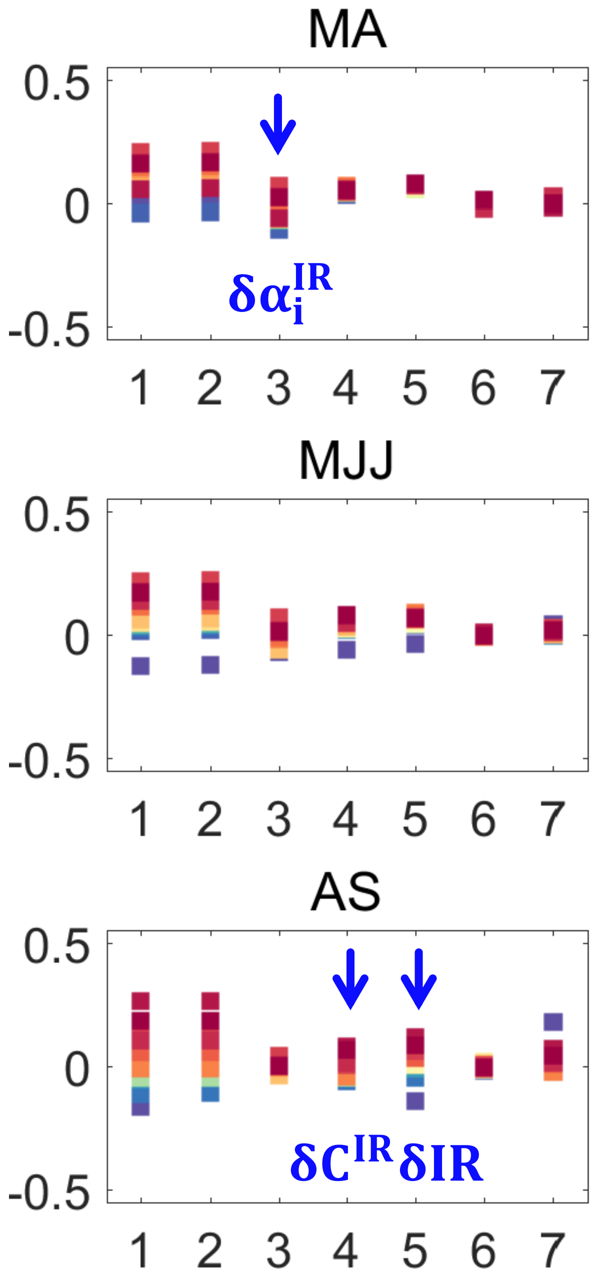
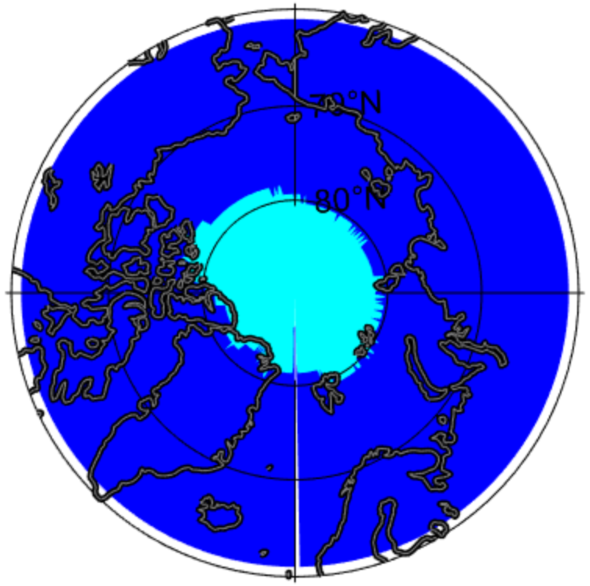


East Siberian, Chukchi, & Beaufort

Central Arctic



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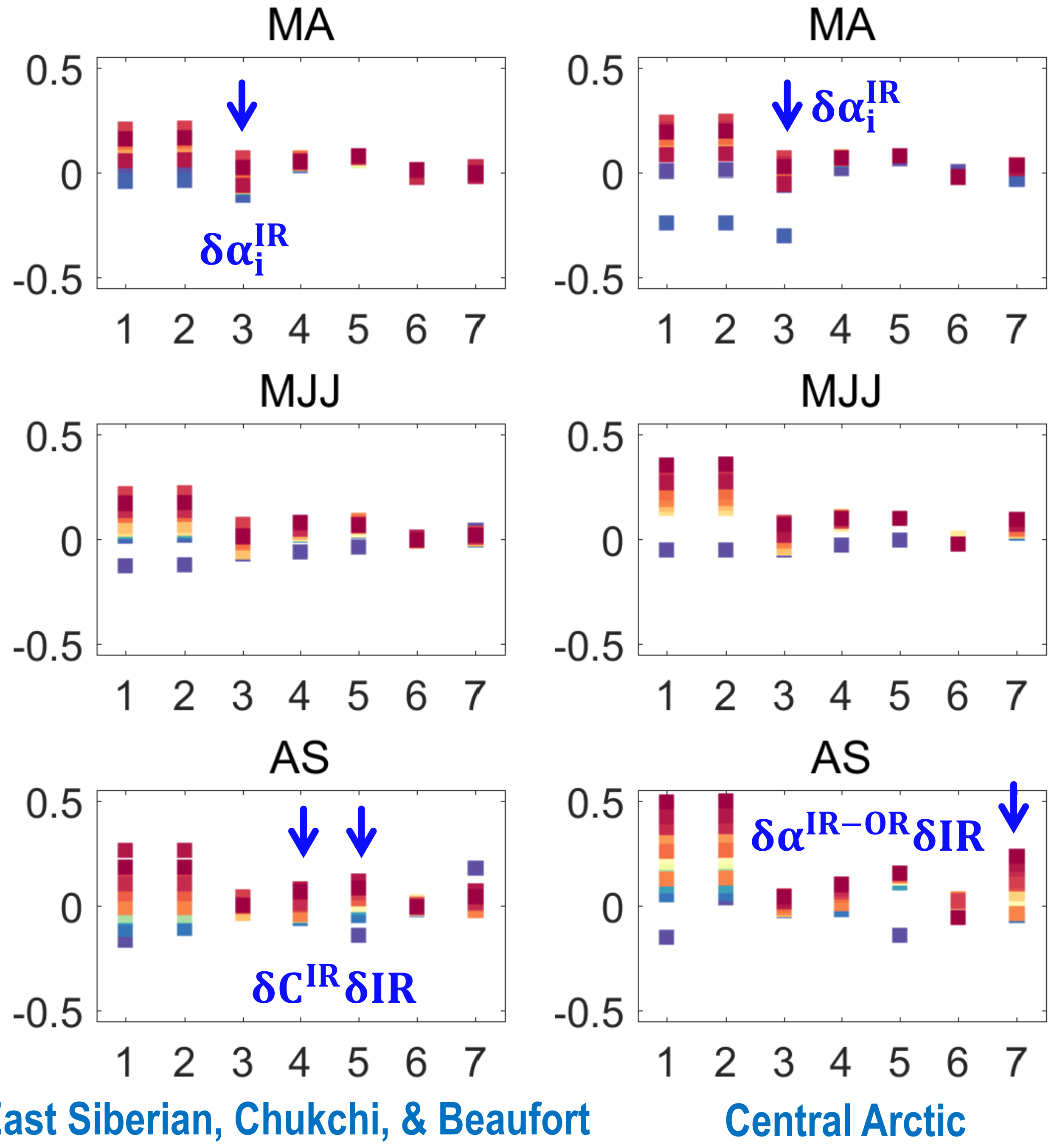
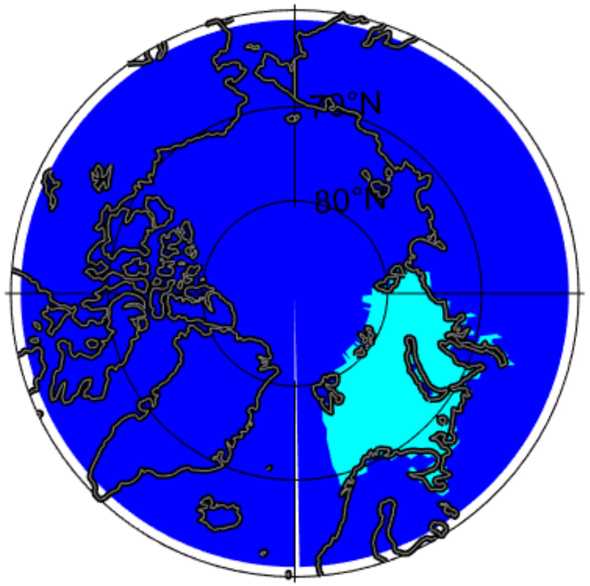


Barents, Kara, & Laptev



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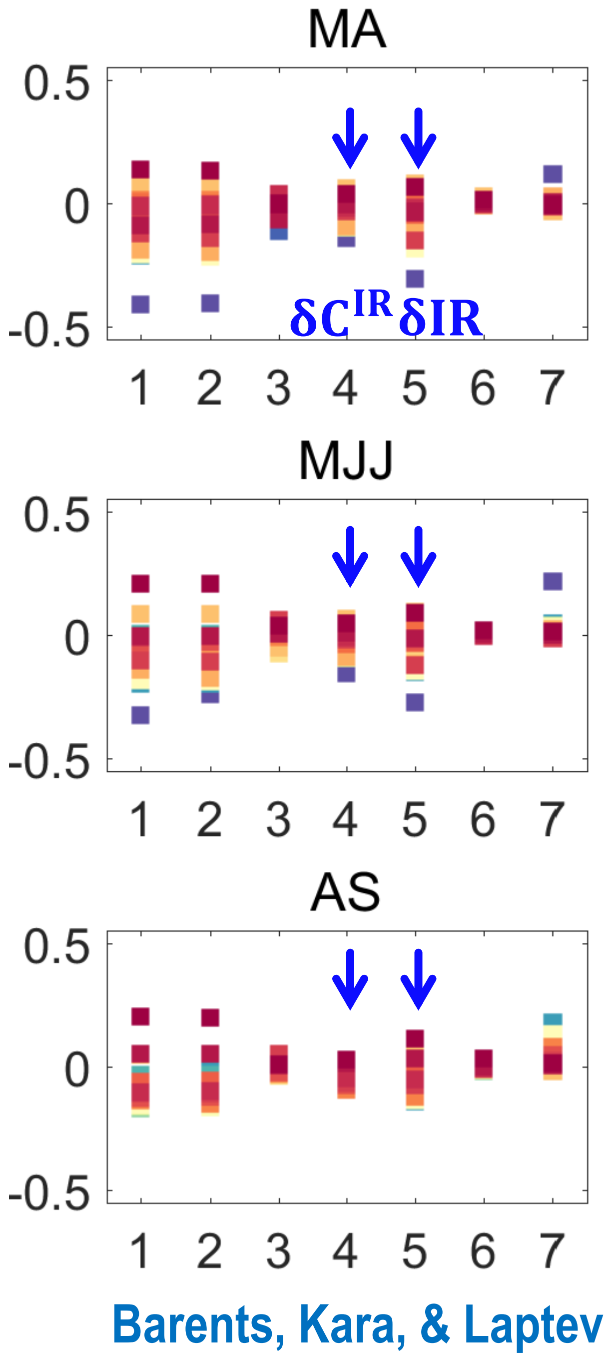
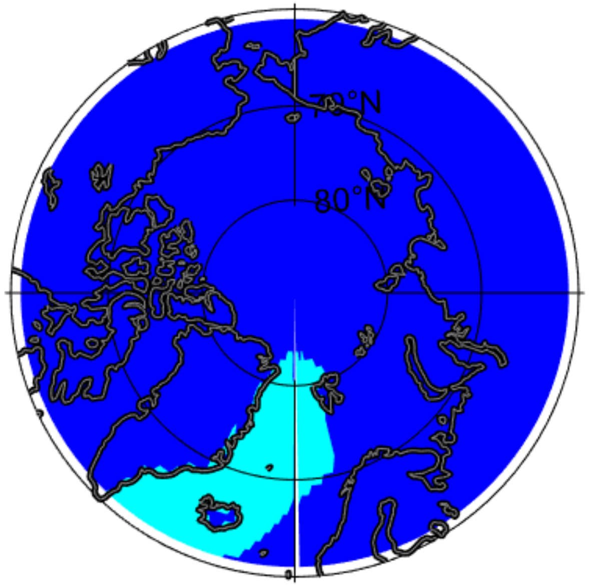


Greenland sea



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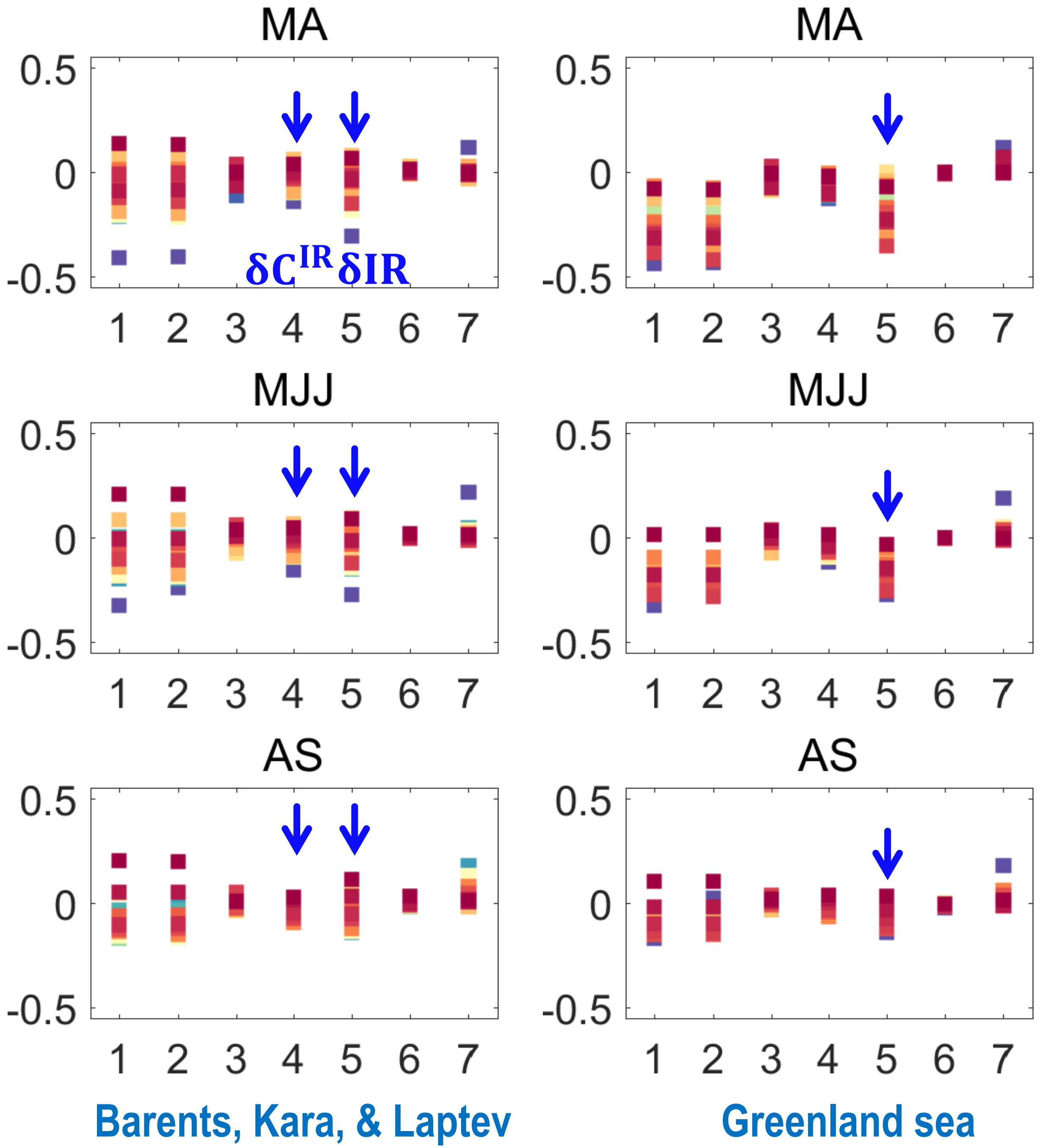

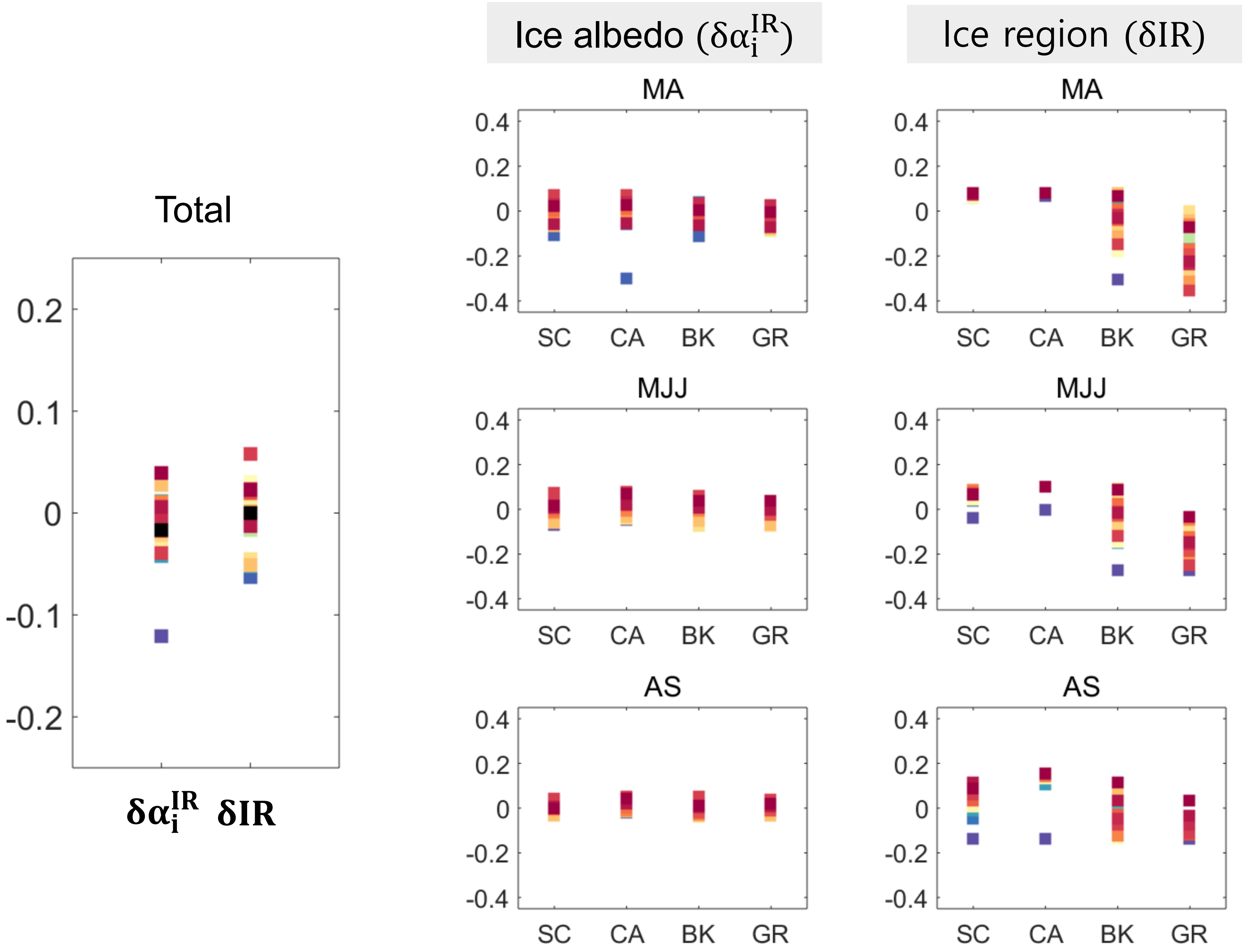

SC: Siberian&Chukchi
CA: Central Arctic
BK: Barents& Kara
GR: Greenland sea

Summary

- While the **model mean of Arctic surface albedo agreeing with CERES,** the Arctic albedo exhibits a **significant intermodel spread**, even when sea ice is held constant in AMIP simulations

- Variations in **land snow cover** can account for the differences observed in land surface albedo in both CMIP and AMIP models

- Our analysis with a new albedo decomposition revealed that not only the ice fraction differences but **the ice albedo differences** has a substantial effect on the model spread in surface albedo

- The correlation between **the spread of ice albedo and snow cover over sea ice** highlights the need to study snow fraction to minimize inter-model differences in surface albedo

We need AMIP diagnostics for snow cover over sea ice !!