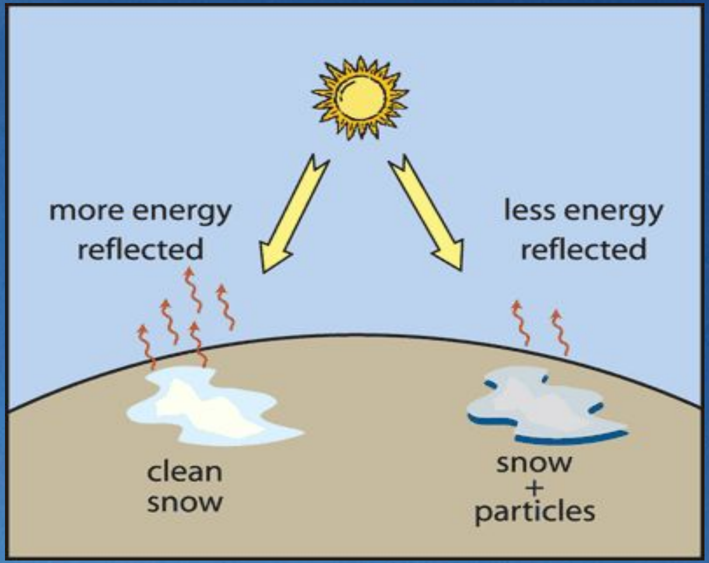
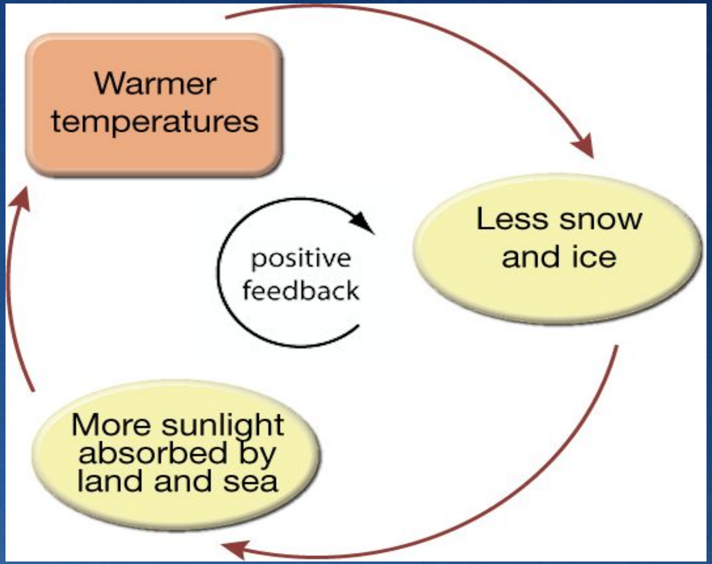
New features and enhancements in CESM/CLM snow albedo scheme:

Towards more physical and realistic representations of snow-radiation-aerosol interactions



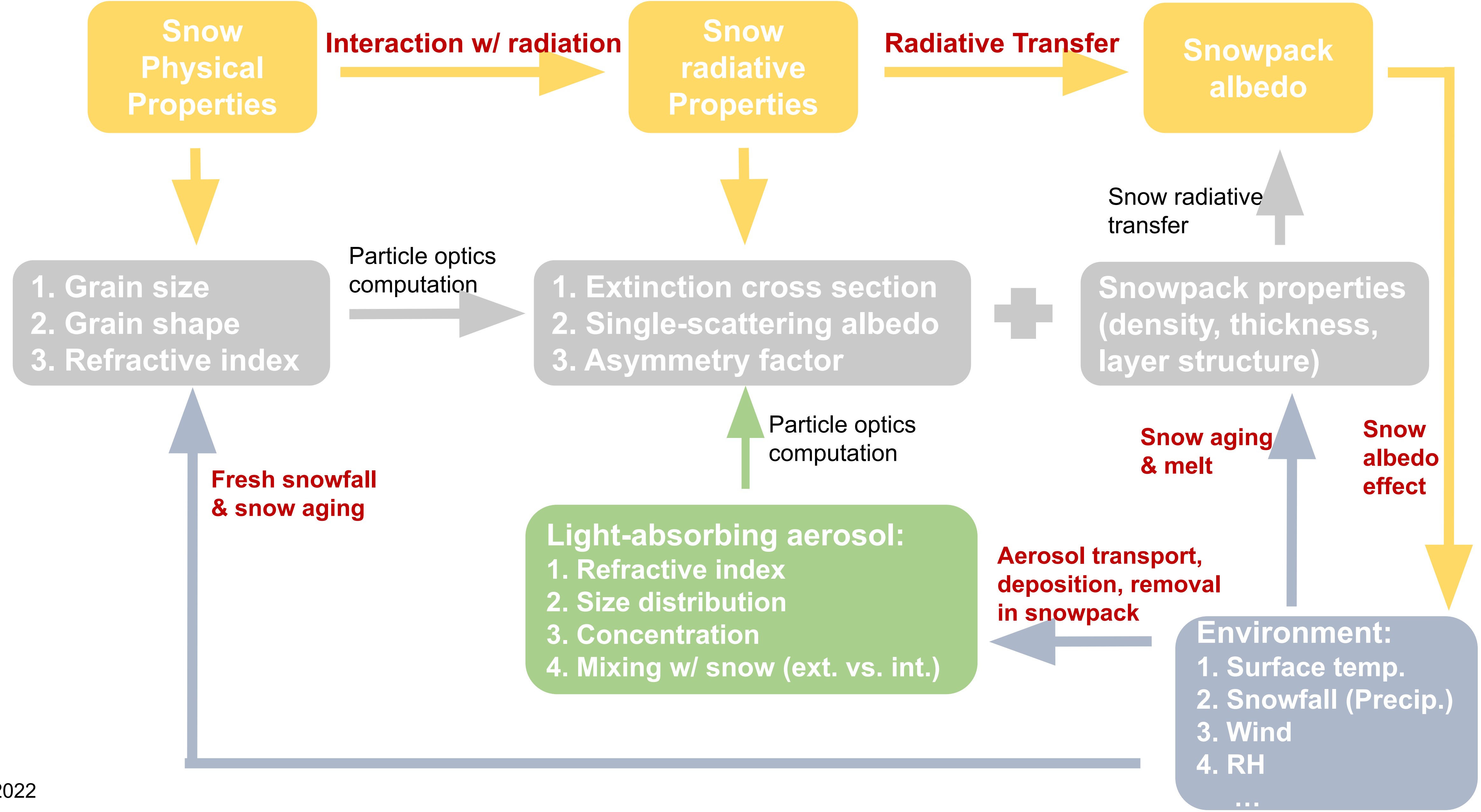


Cenlin He (NCAR)

Mark Flanner (UMich), David Lawrence (NCAR), Yu Gu (UCLA)

Funding source: NOAA's Climate Process Teams (CPT)

Model physics: snow-radiation-aerosol interaction and feedback

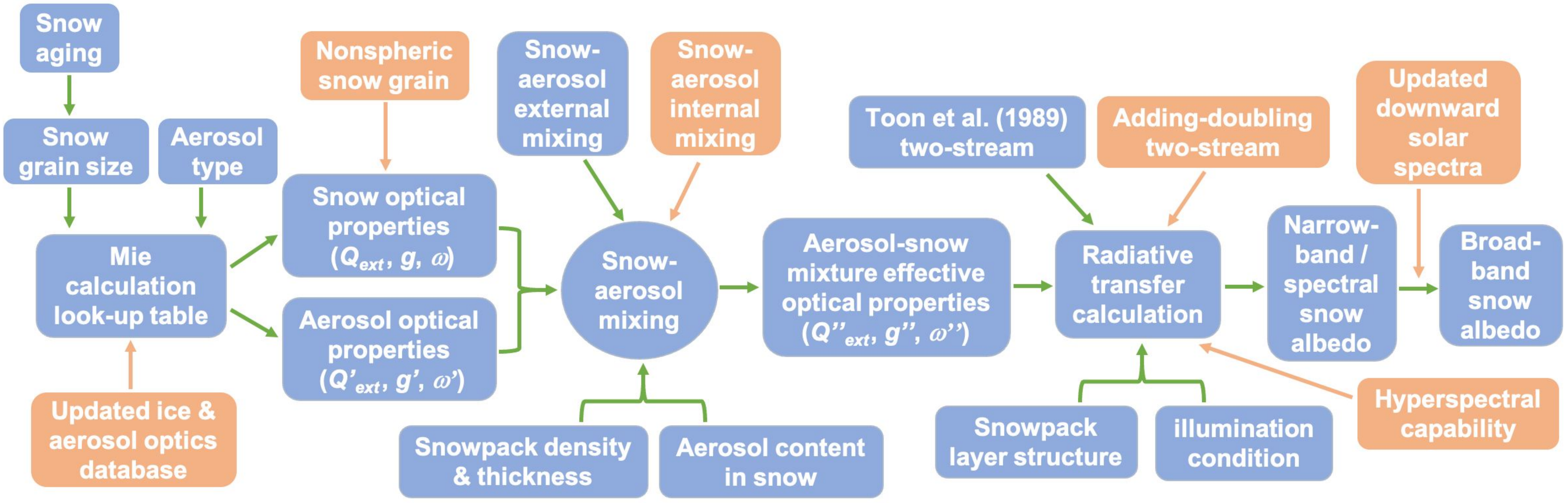


He, 2022

Workflow for CTSM/CLM-SNICAR

Orange box: new elements added in this study

Blue box: default CLM-SNICAR elements



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CTSM/CLM-SNICAR new features and enhancement lists

	SNCIAR New features or enhancements	New SNICAR namelist controls (bold: new default)	Original SNICAR
1	Updated ice optical properties from Flanner et al. (2021), with multiple types for ice refractive indices	snicar_snw_optics = 1 (Warren84), 2 (Warren08), **3 (Picard16)**	Warren84
2	Updated aerosol optical properties from Flanner et al. (2021) with multiple dust types & new BC and OC optics	snicar_dust_optics = **1 (Sahara median)**, 2 (Colorado), 3 (Greenland)	Dust: Sahara old (Zender2006) BC/OC: Flanner2007
3	Updated downward solar spectra from Flanner et al. (2021) for multiple condition types	snicar_solarspec = **1 (mid-latitude winter)**, 2 (mid-latitude summer), 3 (sub-Arctic winter), 4 (sub-Arctic summer), 5 (Greenland summer), 6 (high mountain summer)	Old mid-latitude winter
4	More accurate radiative transfer solver (adding-doubling) from Dang et al. (2019)	snicar_rt_solver = 1 (Toon1989), **2 (Adding-Doubling)**	Toon1989 two-stream
5	Nonspherical snow grain scheme from He et al. (2017)	snicar_snw_shape = 1 (sphere), 2 (spheroid), **3 (hexagonal)**, 4 (snowflake)	sphere
6	BC-snow internal mixing scheme from He et al. (2017)	snicar_snobc_intmix = true, **false**	BC-snow external mixing
7	Dust-snow internal mixing scheme from He et al. (2019)	snicar_snodst_intmix = true, **false**	Dust-snow external mixing
8	Hyperspectral (480-band, 10-nm spectral res) capability with all the above features	snicar_numrad_snw = **5**, 480 fsnowoptics, fsnowoptics480,	5-band fsnowoptics
9	Add new namelist controls for aerosol in snow	snicar_use_aerosol = **true**, false DO_SNO_OC = true, **false**	No control on use_aerosol hard-coded DO_SNO_OC

New SNICAR input datasets: snicar_optics_5bnd_c013122.nc, snicar_optics_480bnd_c012422.nc

Global CTSM/CLM offline simulation setup

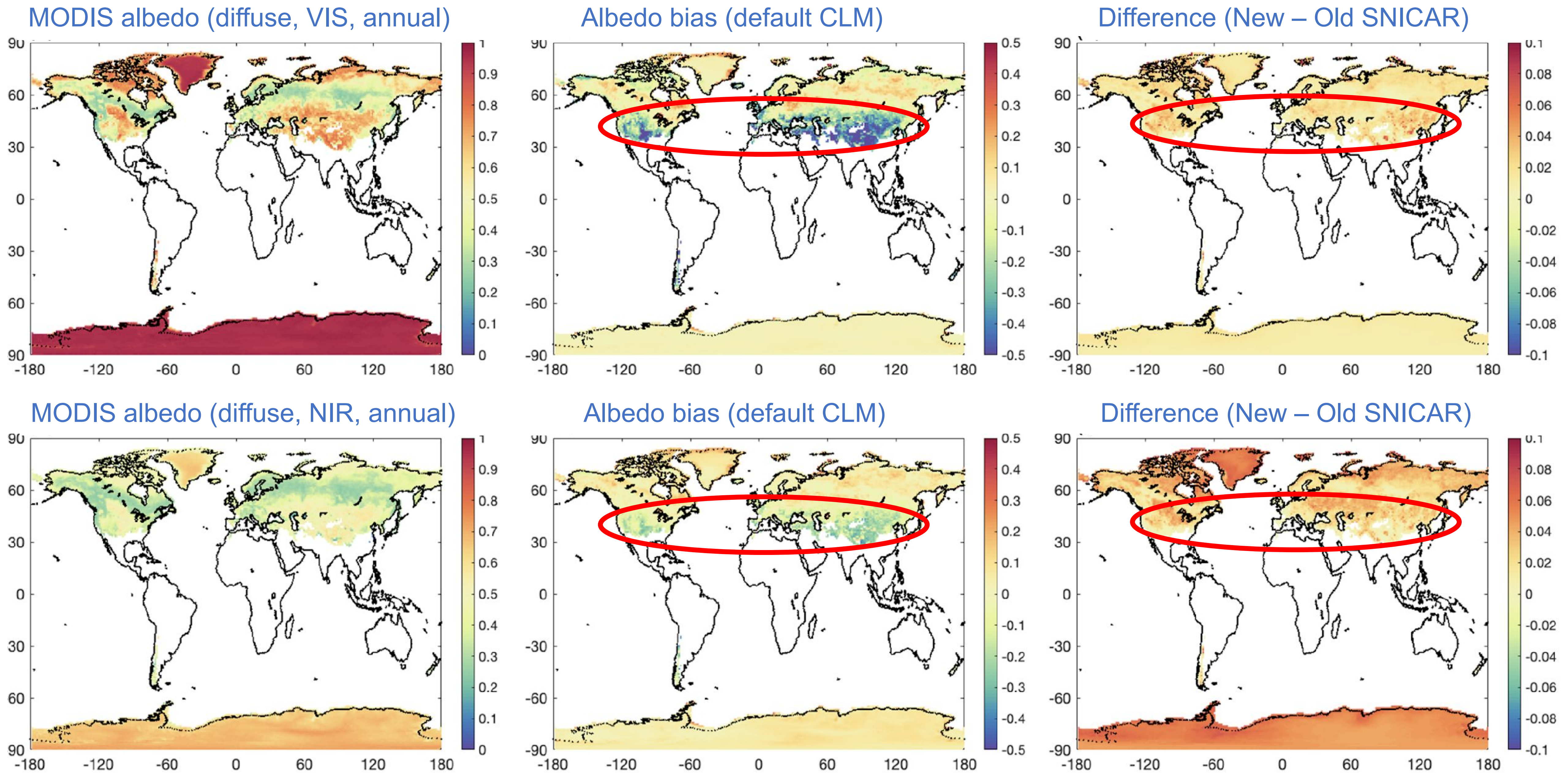
- **Compset:** I2000Clm51Sp (2000_DATM%GSWP3v1_CLM50%SP_SICE_SOCN_MOSART_SGLC_SWAV)

- **Resolution**: ~ 1 deg (f09_g17)

- **Atmospheric forcing**: GSWA v3

- **Simulation period**: 2000-2005 for spin-up, 2006-2010 for analysis

Surface albedo evaluation:
Reduced negative bias in mid-latitudes but slightly increased positive NIR albedo bias in polar regions



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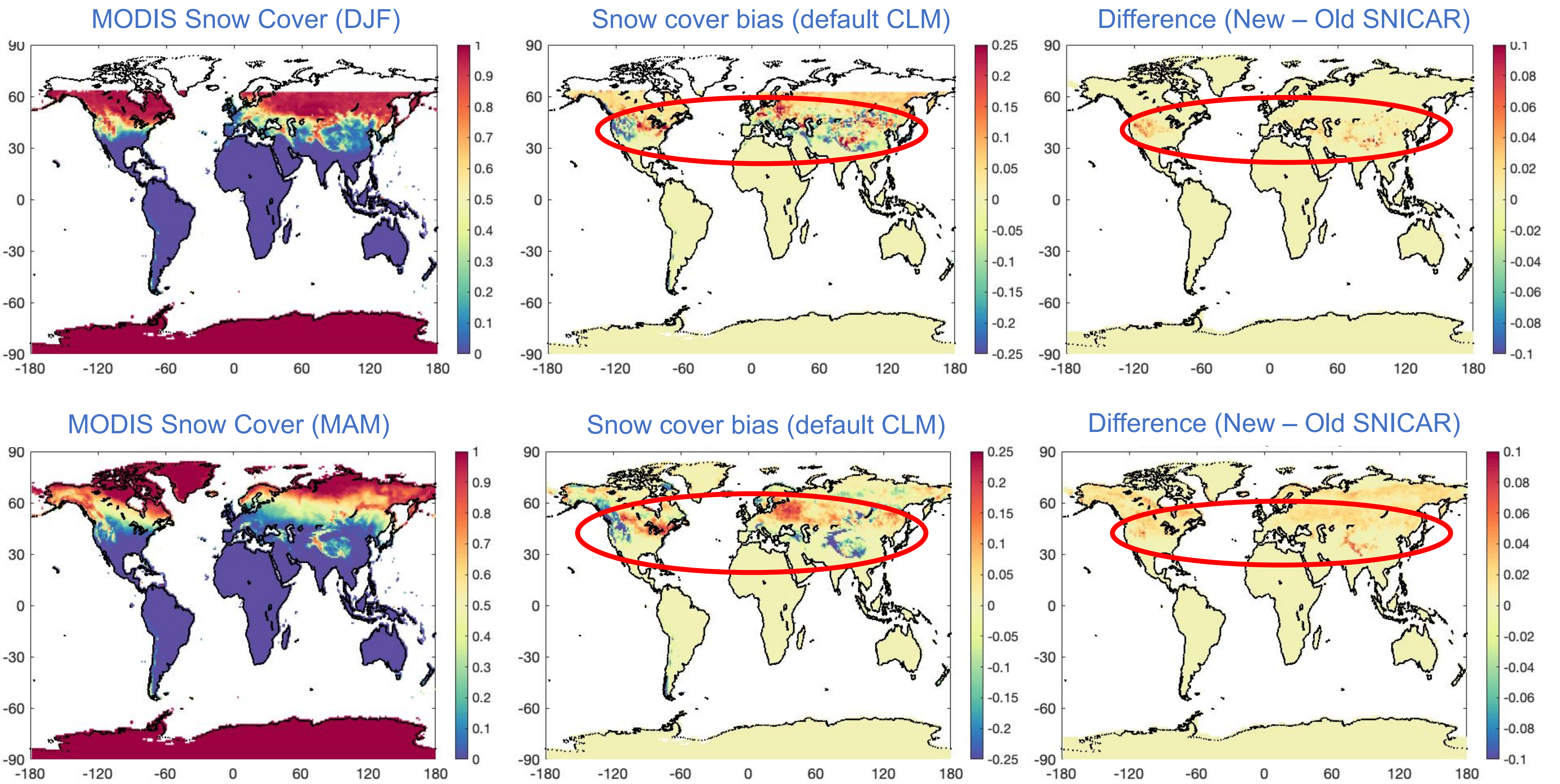
Snow cover evaluation:
Reduced negative bias in mid-latitudes and negligible impacts in polar regions



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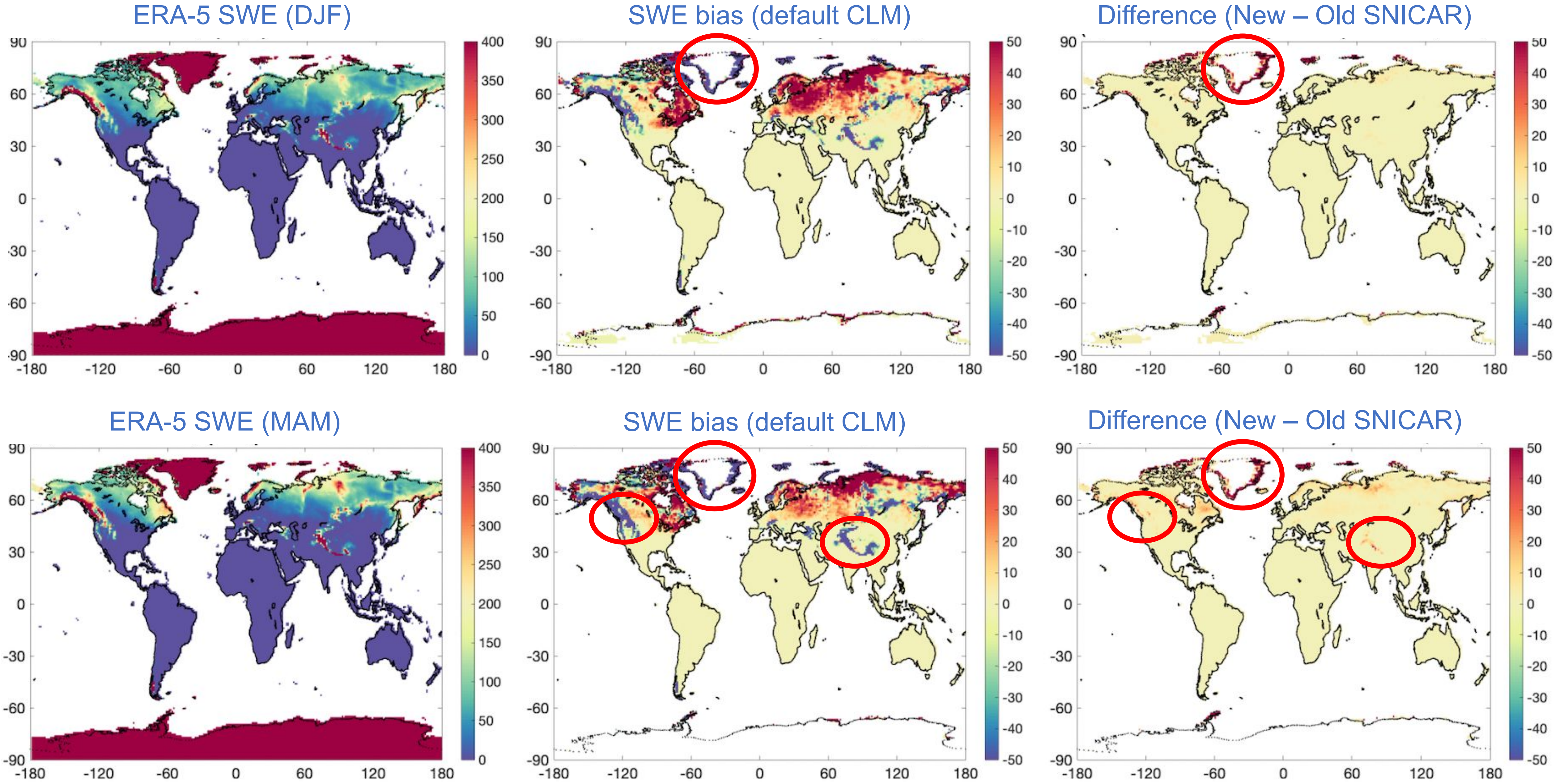
SWE evaluation:
Reduced negative bias in Greenland coasts & some mid-latitude mountains in spring



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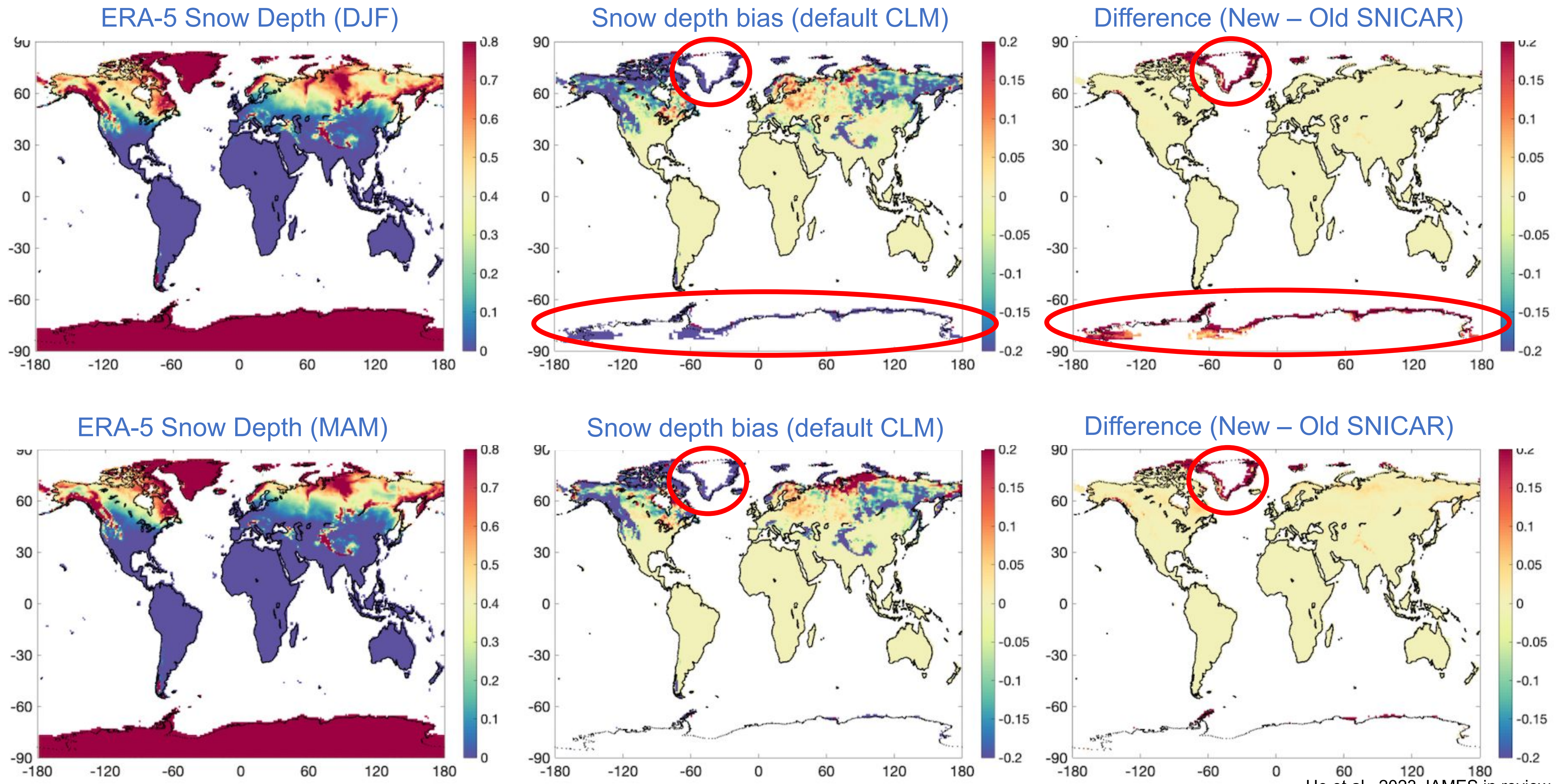
Snow depth evaluation: Reduced negative bias in polar regions



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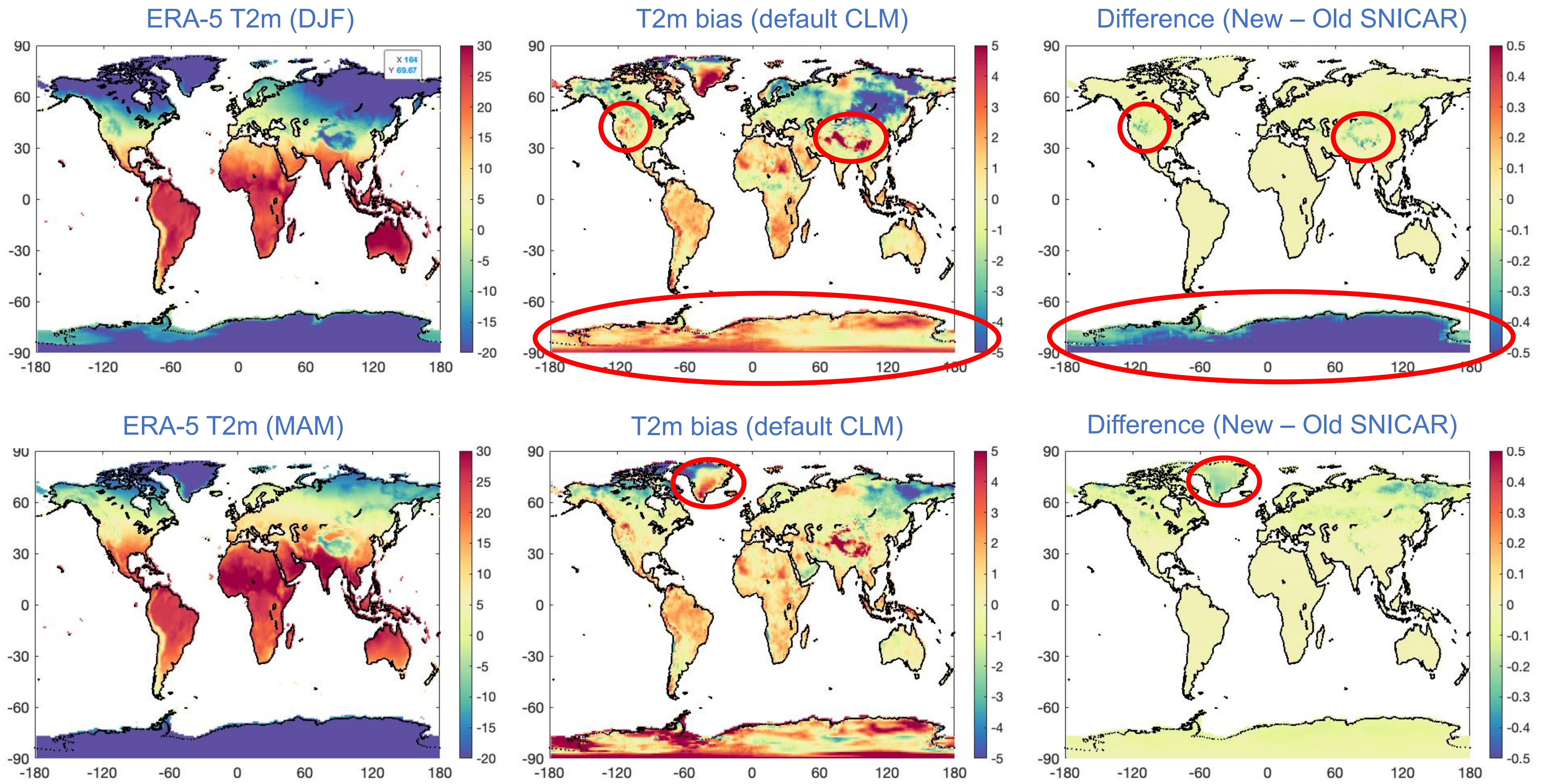
2-m temperature evaluation:
Reduced positive bias in mid-latitude mountains & polar regions



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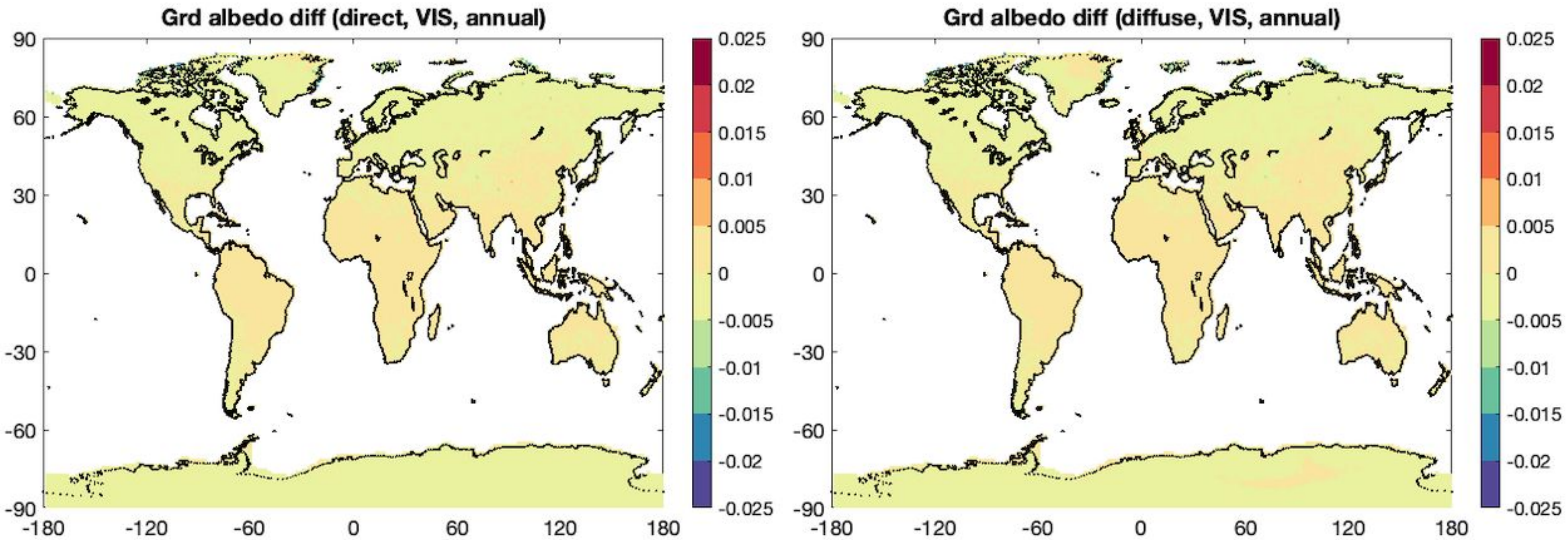
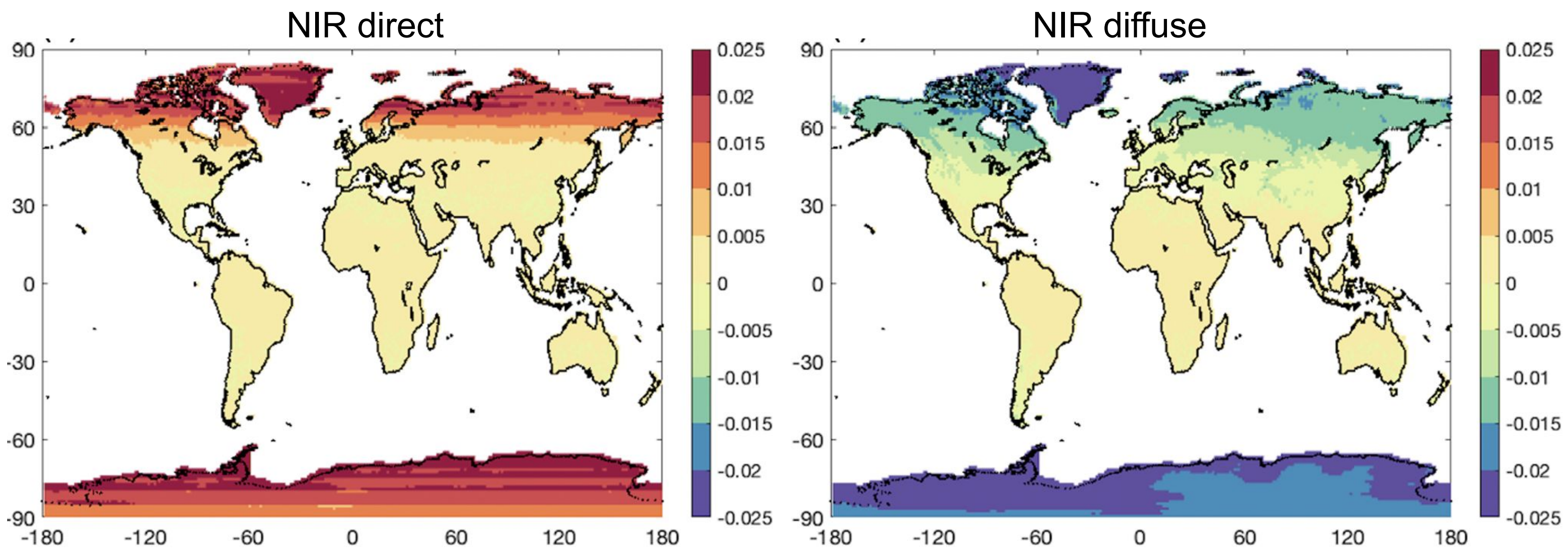
Sensitivities to some key new features

Effect of more accurate radiative transfer solver (Adding-doubling)

Visible snow albedo reduction annual difference (New - Old)



NIR snow albedo reduction annual difference (New - Old)



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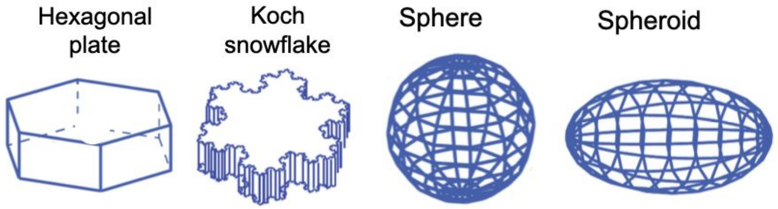
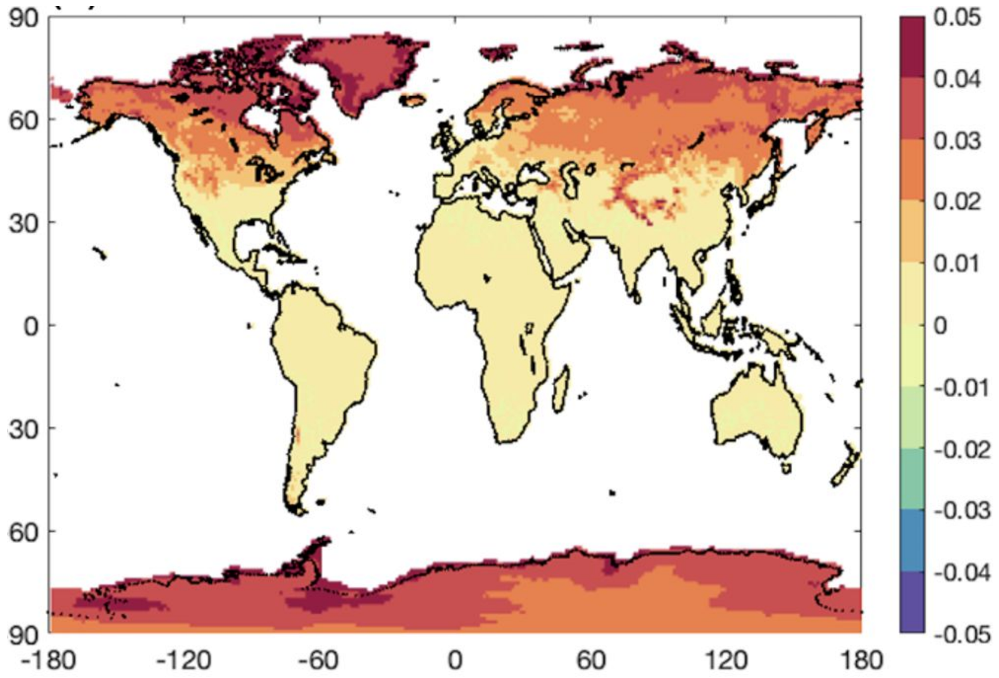
Effect of nonspherical snow grain shape

Higher snow albedo for nonspherical snow

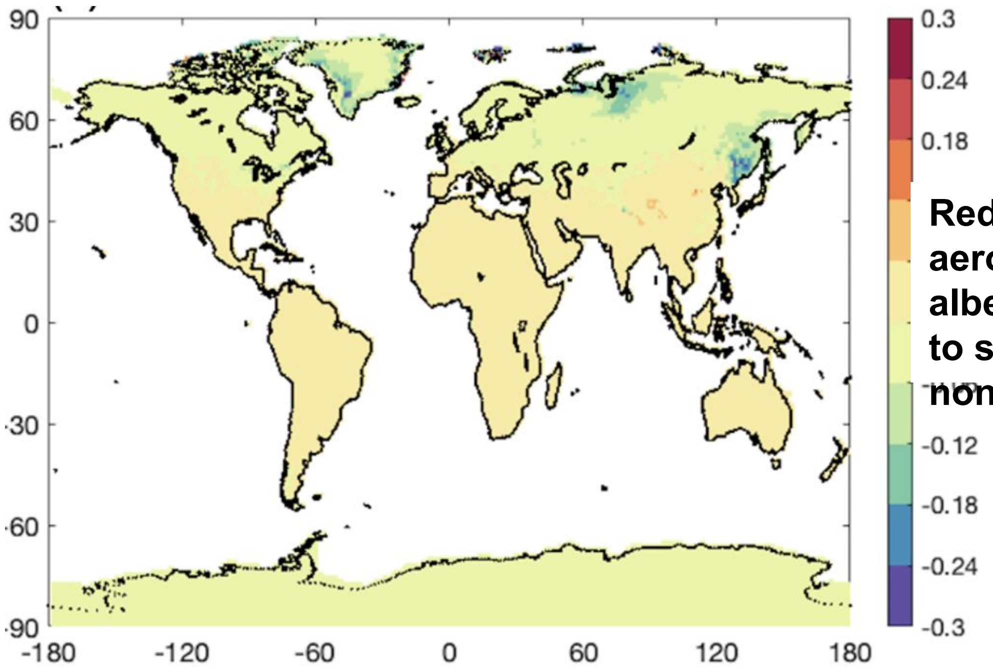


Annual all-sky differences (Snowflake - Sphere)

Snow albedo difference



BC-induced surface radiative effect difference



Reduced aerosol-snow albedo effects due to snow nonsphericity

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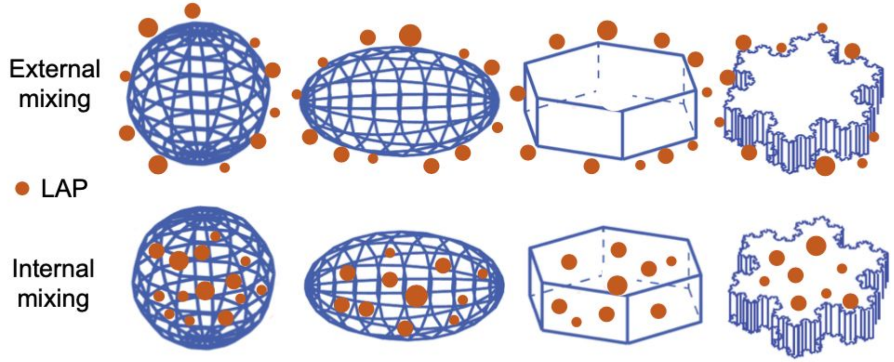
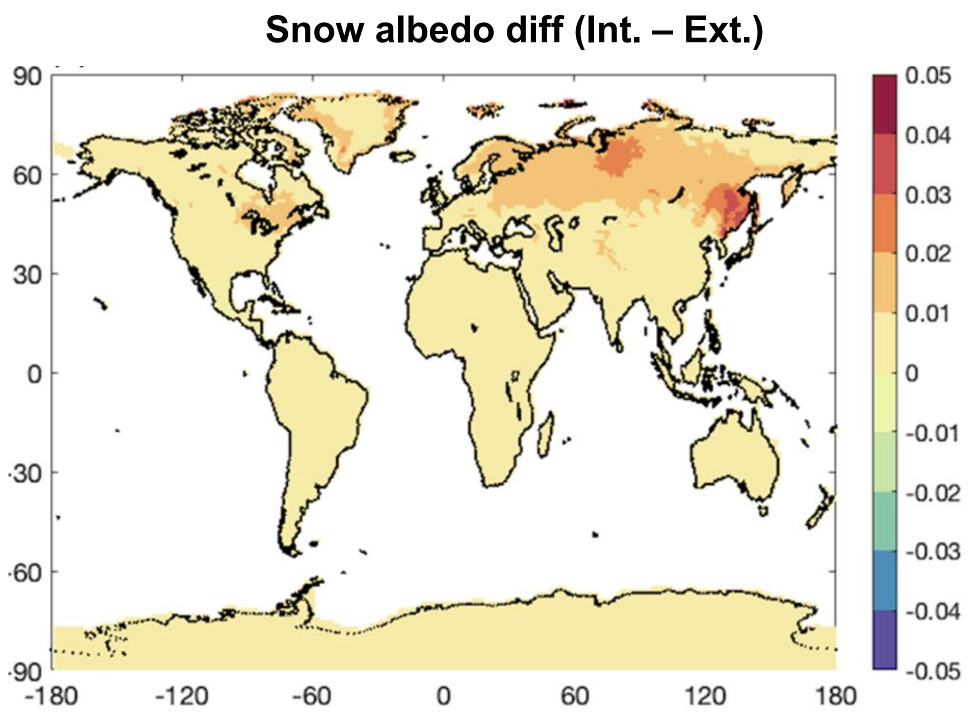
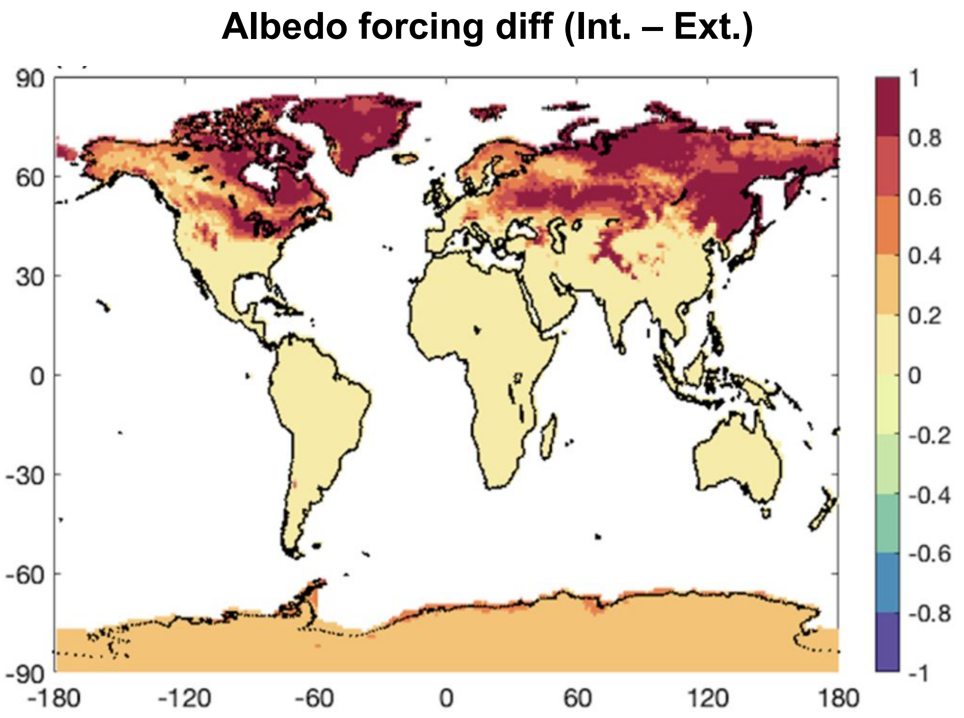
Effect of BC/dust-snow internal mixing (using BC as an example)



He et al., 2018





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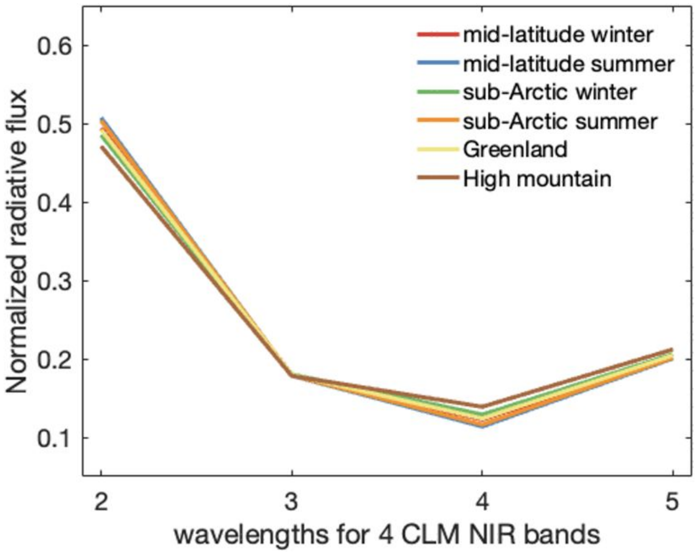
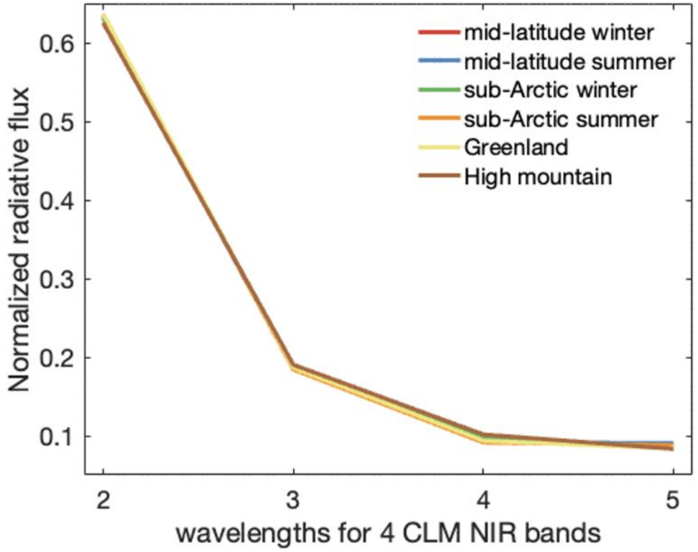
Effects of downward solar spectrum

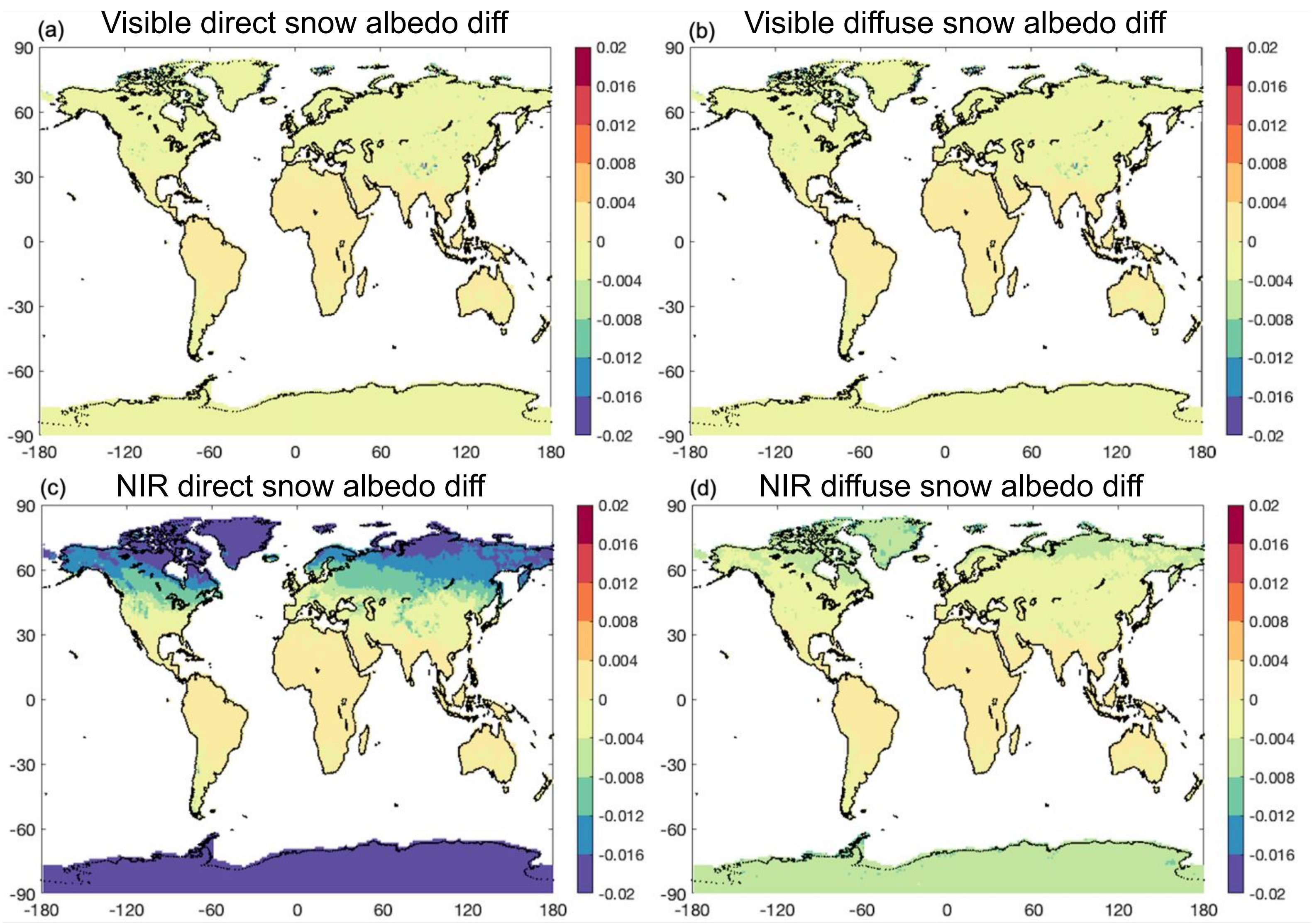
Direct downward solar spectra



Diffuse downward solar spectra



High mountain spec – Mid-latitude summer



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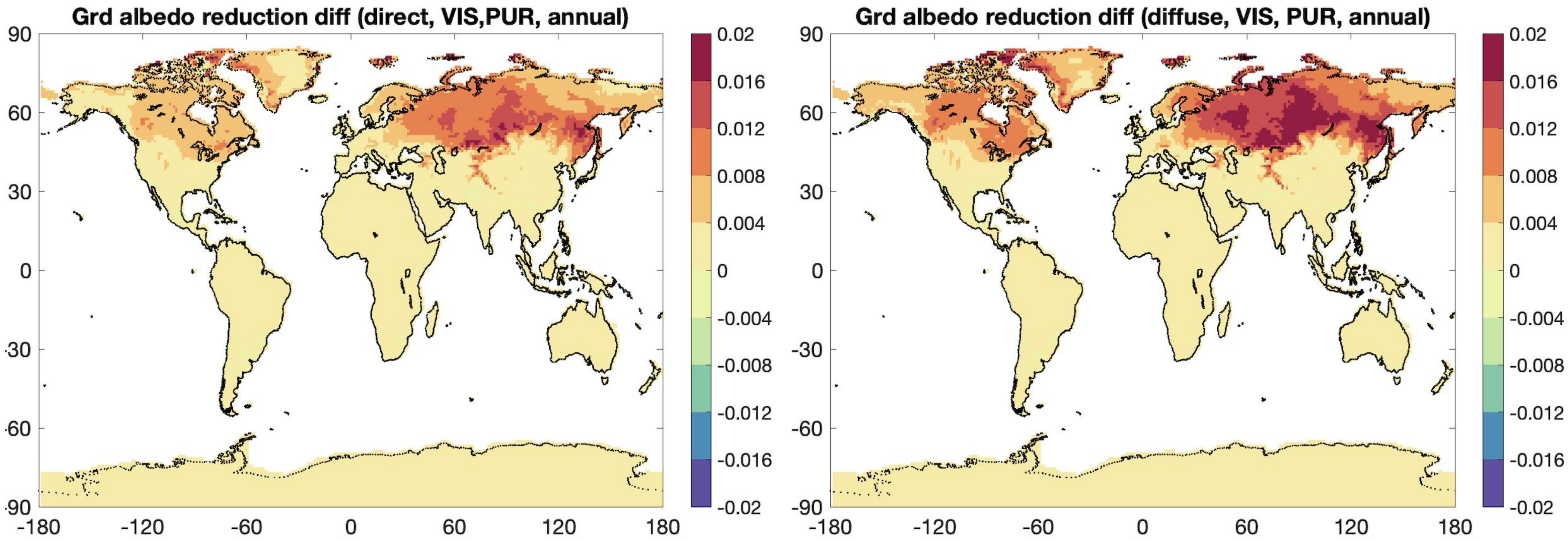
Thank you!

If you are interested in our work, please email me cenlinhe@ucar.edu

Effect of updated aerosol optics

Aerosol-induced annual snow-covered ground albedo reduction difference (Flanner21 optics – Flanner07 optics)



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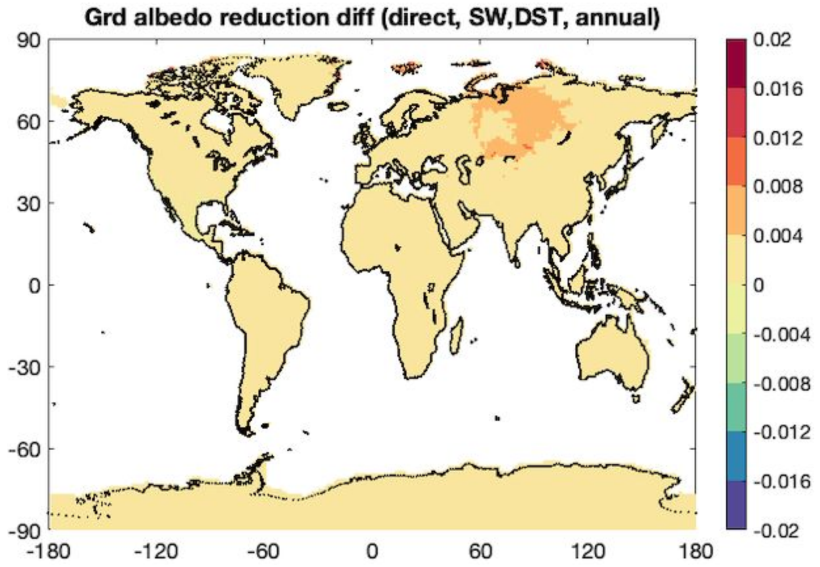
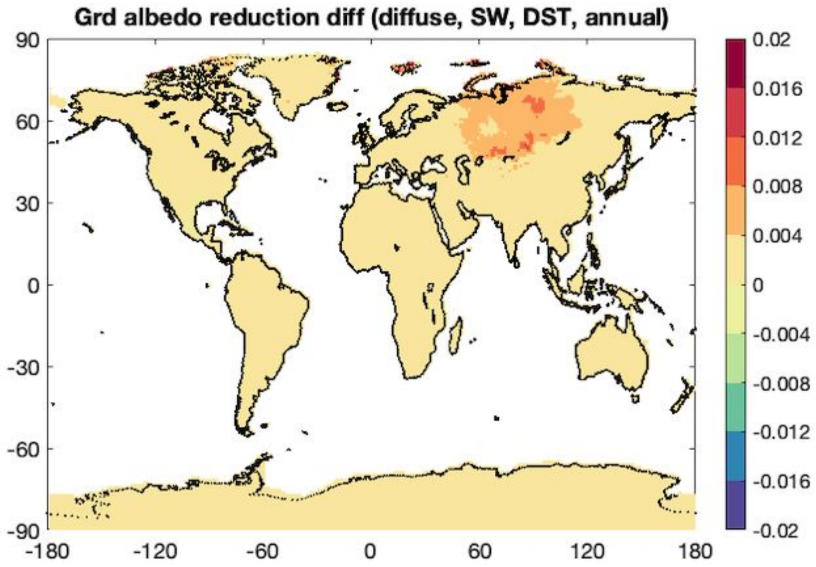
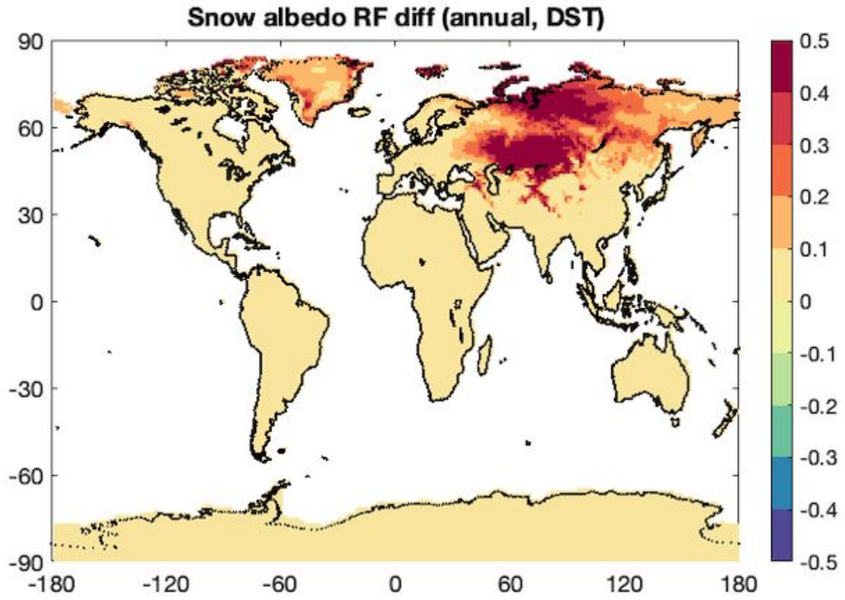
Effects of multiple dust types

Dust-induced annual snow-covered ground albedo reduction difference (Greenland dust – Colorado dust)





Dust-induced annual snow albedo radiative forcing difference (Greenland dust – Colorado dust)



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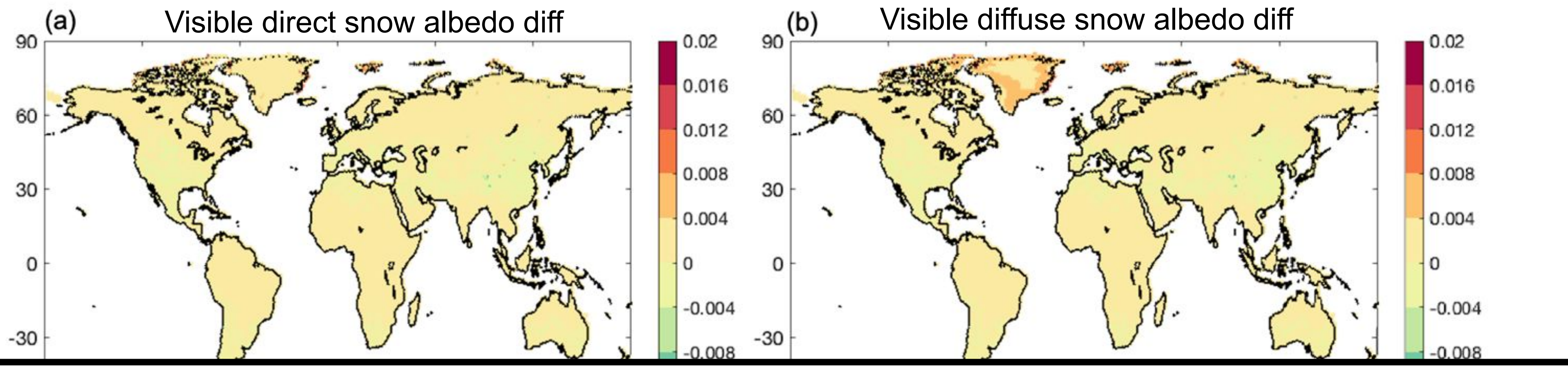
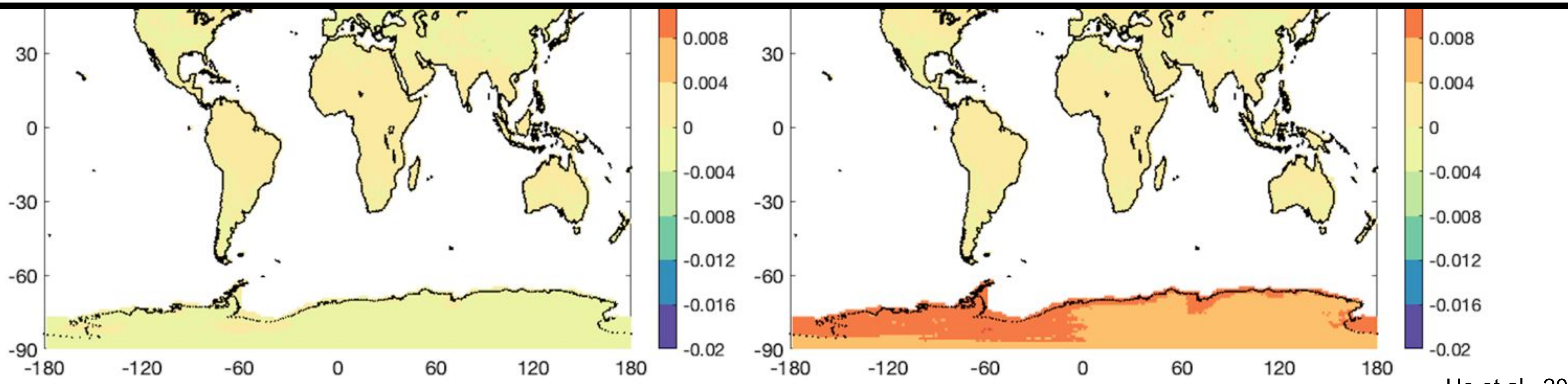
Effect of 480-band hyperspectral calculation



Why do we need 480-band hyperspectral capability although it is much slower than 5-band?

- More accurate due to nonlinearity of radiative transfer and the way of averaging snow & aerosol optics to 5-bands before radiative transfer (Wang et al. 2022)
- Make noticeable differences in high-latitude regions and aerosol effects on snow albedo
- Benefit point-scale and regional process-level study and spectral snow albedo DA



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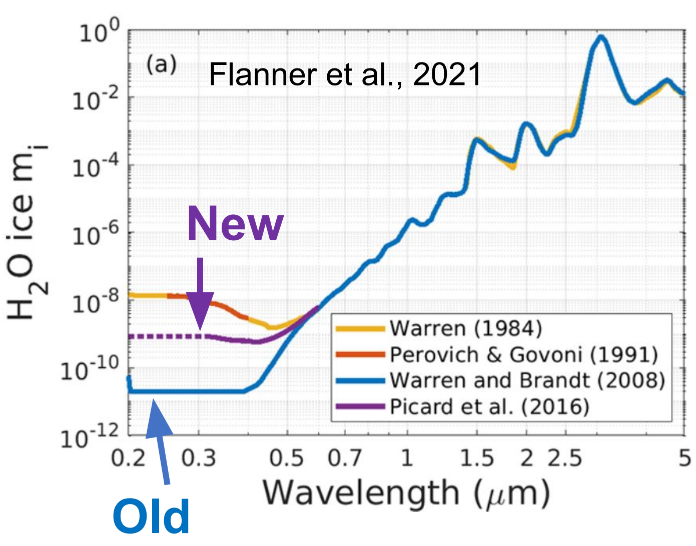
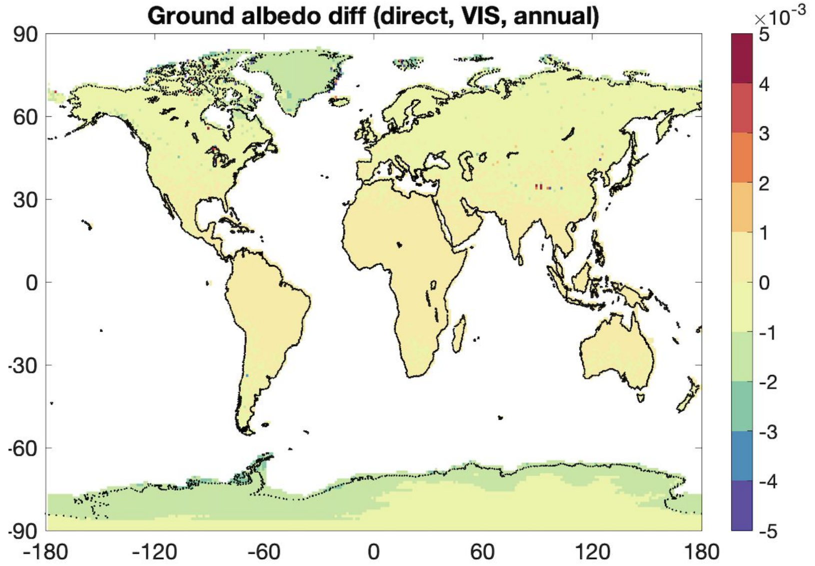
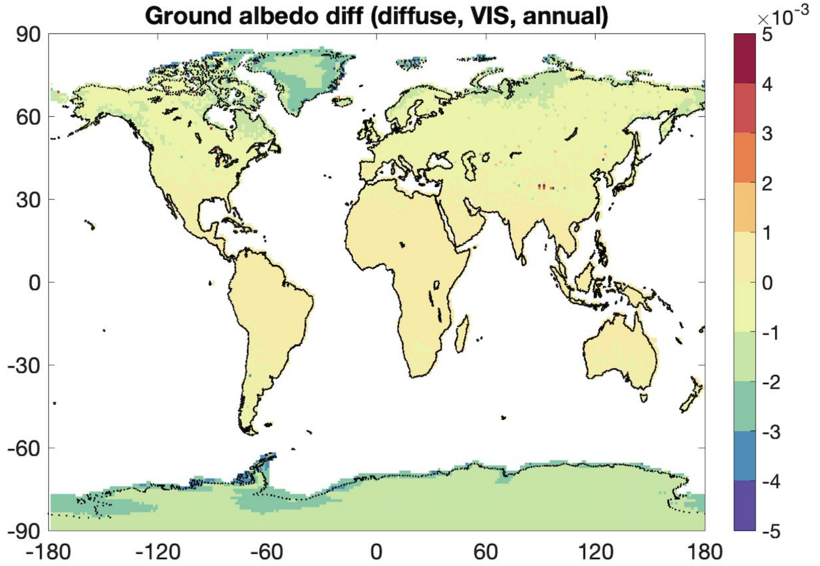
Effects of updated ice optics

Visible snow albedo annual difference (Flanner21 optics – Flanner07 optics)







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