Microphysical influence on anvil cloud albedo during New Mexico deep convective cloud cases

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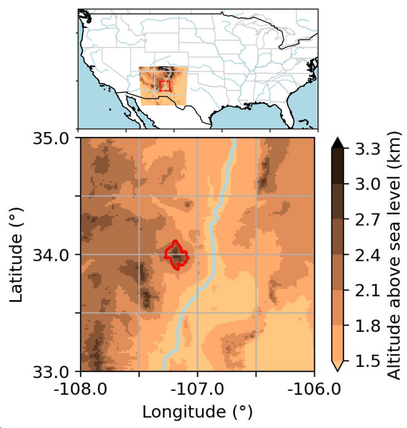
Motivation

Anvil cloud feedbacks represent a large uncertainty in Equilibrium Climate Sensitivity (i.e. warming response to CO_2). Recent studies have highlighted that the role of microphysics and anvil albedo feedback are not well constrained/understood[1,2].

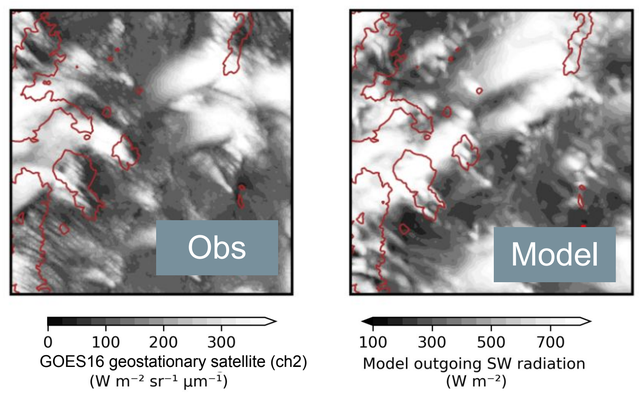
Method

Observation-informed[3] microphysics experiments are generated with the UK Met Office Unified Model and new CASIM microphysics component[4] (1.5 km grid). 13 cases with similar timing of model convection are usedl. Each case averages anvil albedo for the 6 hours over the peak of the solar irradiance (18-0 UTC).

Model domain



Example case (27th July 2022)



Microphysics experiments

ctl (control) - Fixed cloud droplet number concentration (CDNC) vertical profile (panel A: solid purple) ; Ice nucleating particle (INP) temperature dependence (panel B: solid purple) ; Secondary ice production (SIP) is governed by the Hallet-Mossop process with a splintering rate of 350 x 10^6 splinters kg^{-1}(rime).

drop125 - half CDNC (panel A: dashed orange)

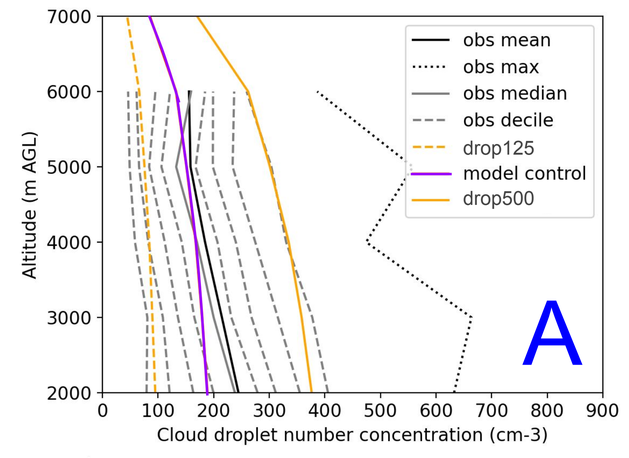
drop500 - double CDNC (panel A: solid orange)

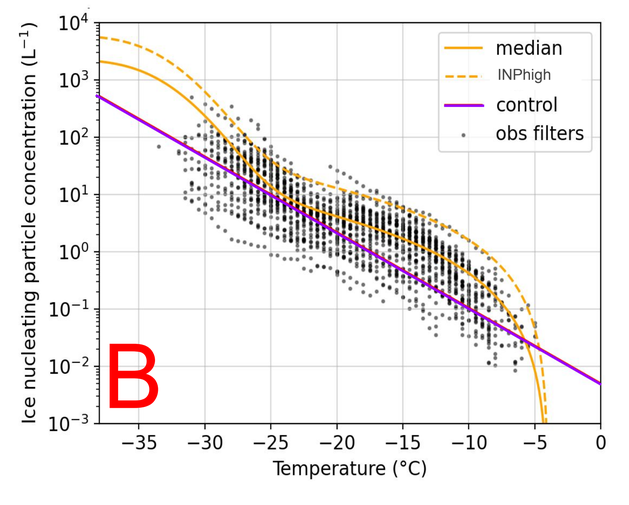
INPmedian - median observed INP (panel B: solid orange)

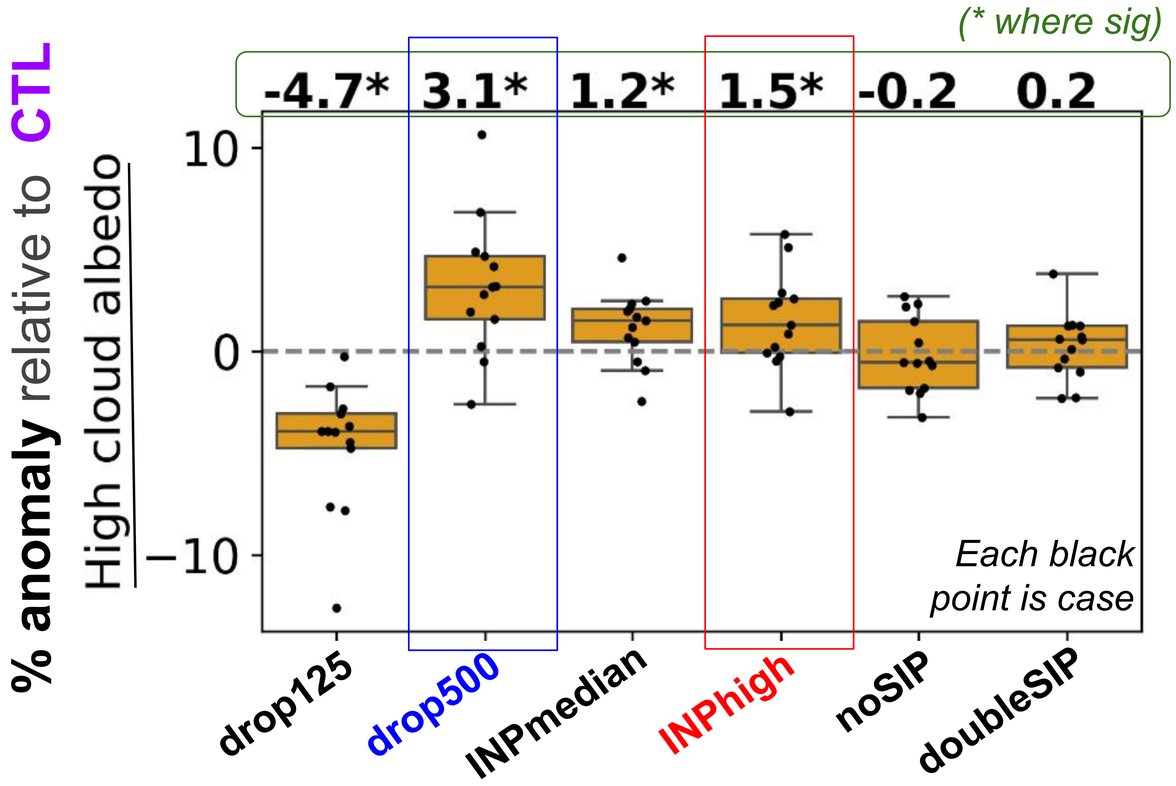
INPhigh - high observed INP (panel B: dashed orange)

noSIP - zero SIP rate

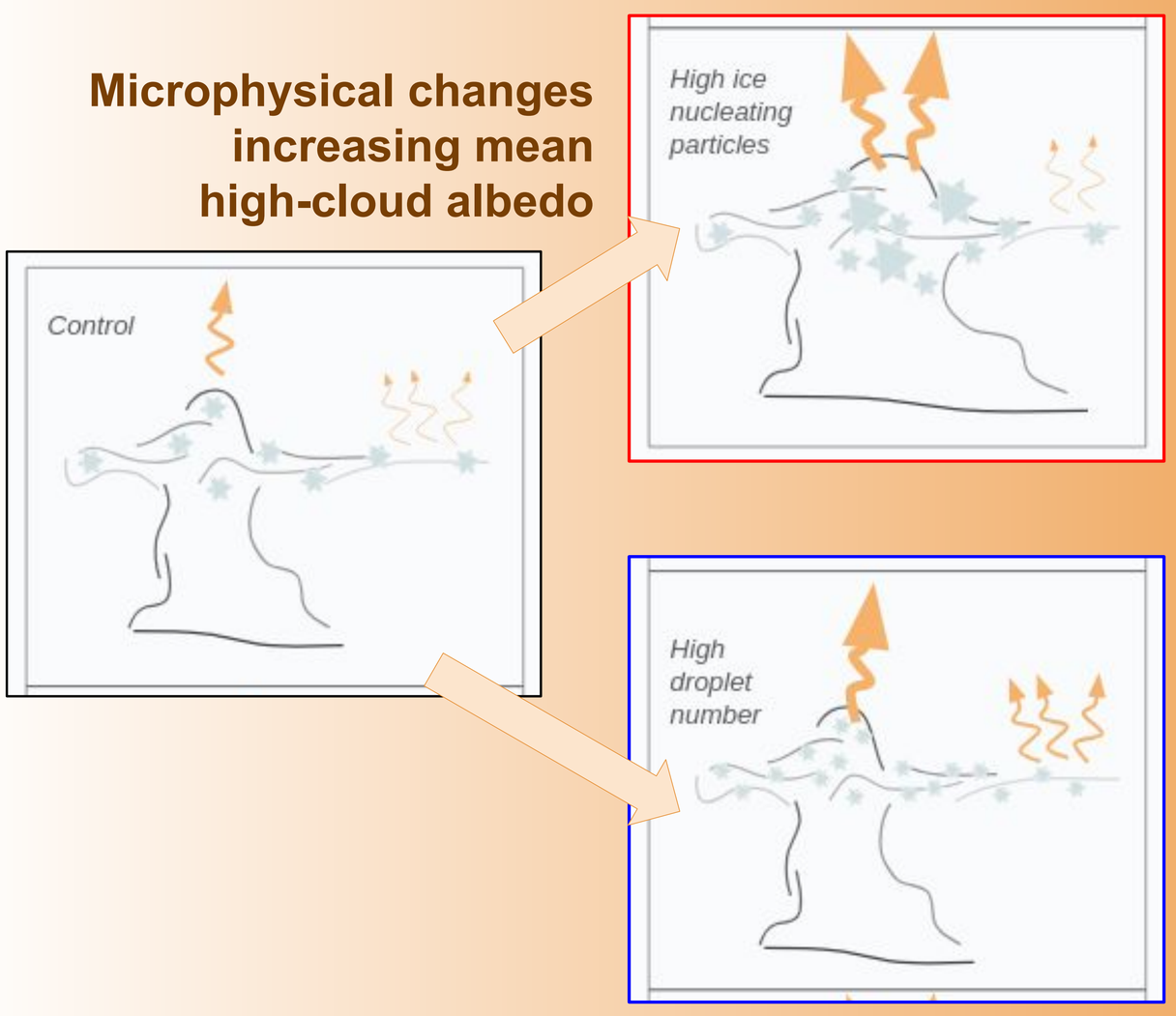
doubleSIP - double SIP rate







Microphysical changes increasing mean high-cloud albedo

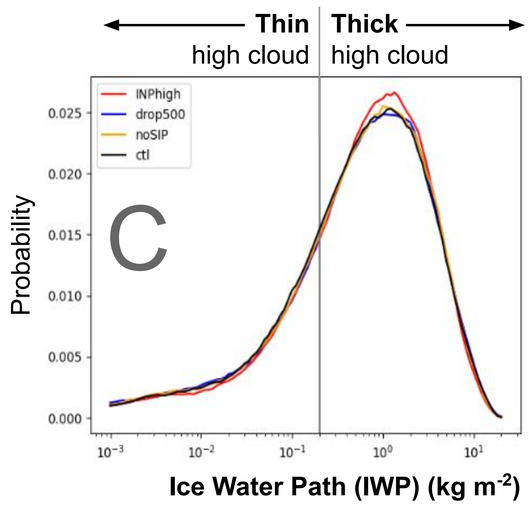


Increase in "thick" (high IWP) cloud area relative to "thin" cloud area - as seen by the shift in the high cloud IWP PDF (panel C: red line)

Results in: A shift of albedo PDF to higher values as albedo is closely related to IWP

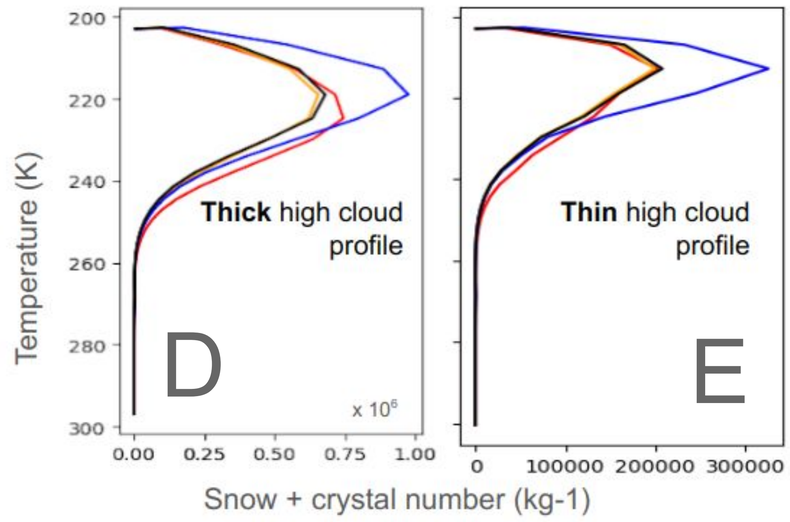
Increased snow number in the *thick* cloud (panel D, red line)

Results in: Increased mean albedo of *thick* high cloud, independent of IWP change



Increased crystal number in all high cloud (panels D/E, blue line)

Results in: Higher mean albedo across all high cloud types, despite negligible change in IWP PDF



Conclusions…

Doubling droplet number increases anvil albedo by 3% on average, as a result of increased crystal number throughout the anvil

Maximum measured INP-temp dependence (~1 order of magnitude larger than control) increased anvil albedo by 1.5% on average, as a result of relatively more thick cloud, and increased snow number and therefore albedo of thick cloud

(Not shown) Considering the control simulation across cases: 40% of model, and 58% of observed, variability in anvil albedo can be explained by variability in daily mean relative humidity at 700hPa. The model and observations differ in whether 200hPa wind speed or CAPE are beneficial explanatory variables.

References

1. McKim et al. (2024) Nat. Geosci. https://doi.org/10.1038/s41561-024-01414-4
2. Sokol et al. (2024) Nat. Geosci. https://doi.org/10.1038/s41561-024-01420-6
3. Finney et al (2024) ESSD https://doi.org/10.5194/essd-16-2141-2024
4. Field et al. (2023) QJRMS https://doi.org/10.1002/qj.4414

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