Evaluating the effect of coupled-to-decoupled transition of the atmospheric boundary layer on the phase partitioning in the mixed-phase stratiform clouds

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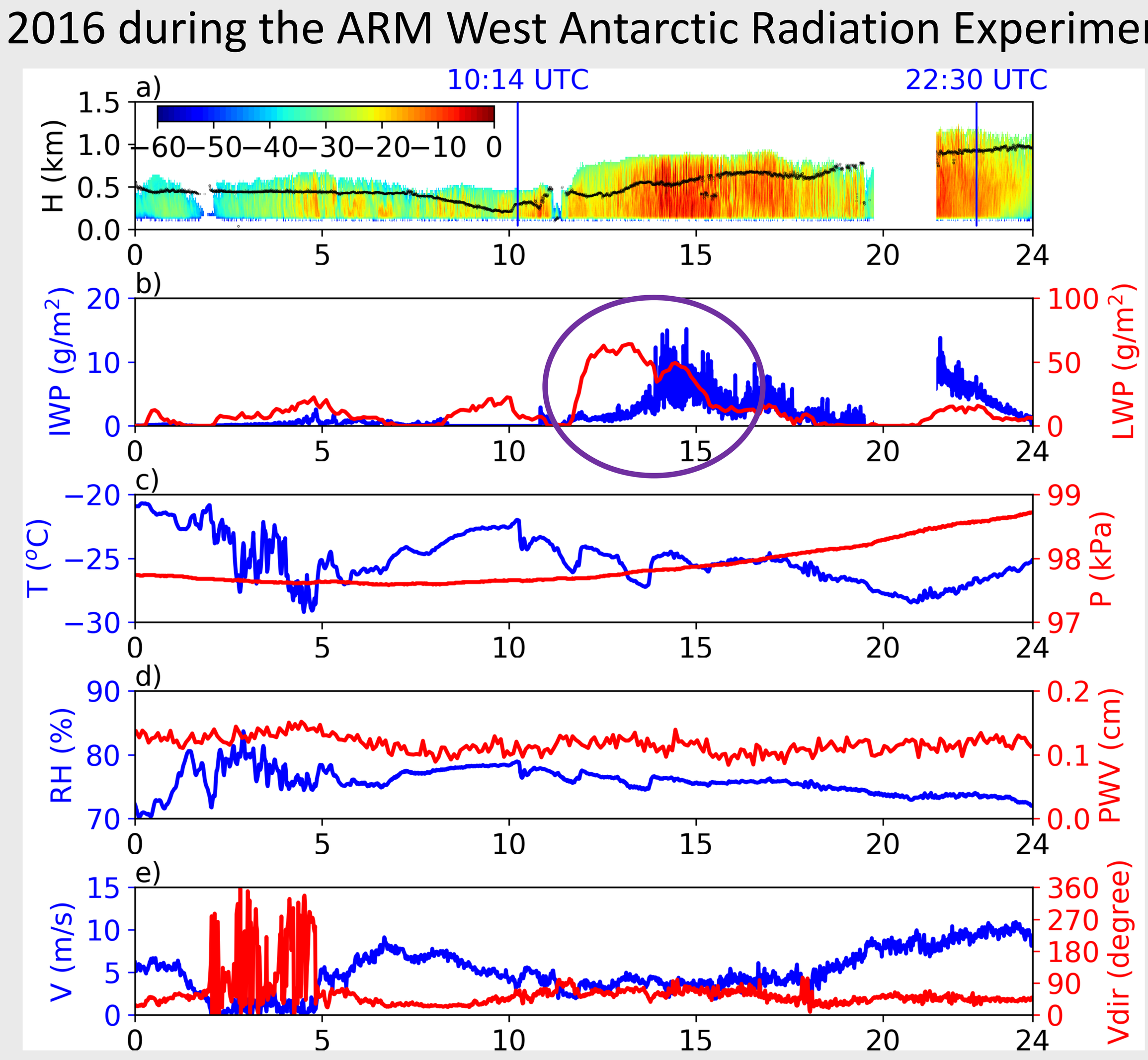
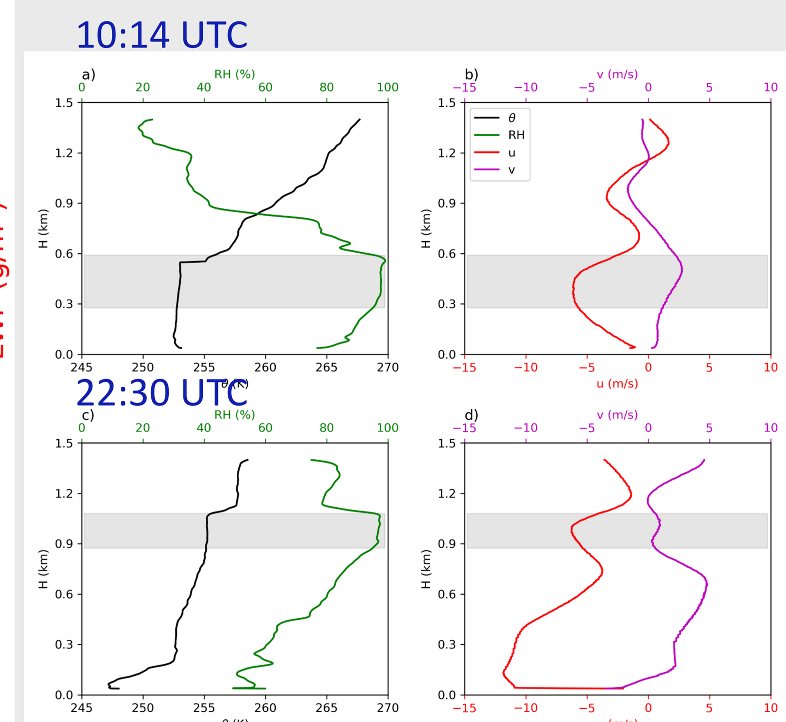
Fast Change of Phase Partitioning in the Mixed-Phase Stratiform Clouds

was observed at McMurdo Station (77°51'S, 166°40'E) on Ross Island, Antarctica, on 31 March 2016 during the ARM West Antarctic Radiation Experiment (AWARE).





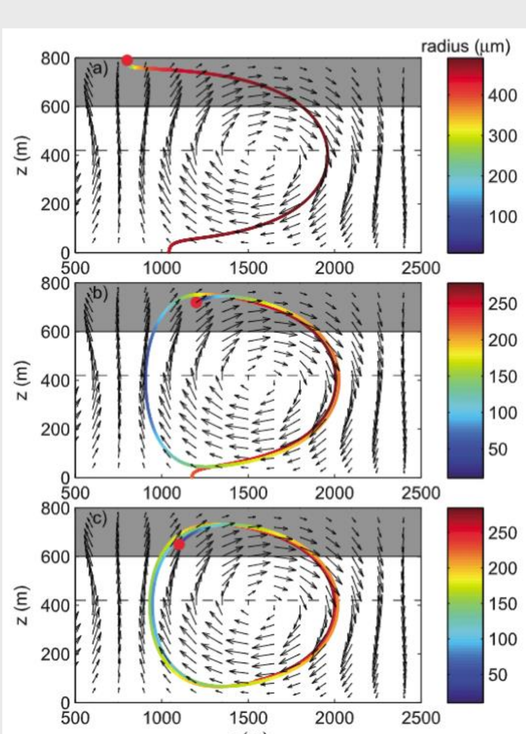
Cloud layer is coupled with surface at 10:14 UTC and is decoupled with surface at 22:30 UTC.

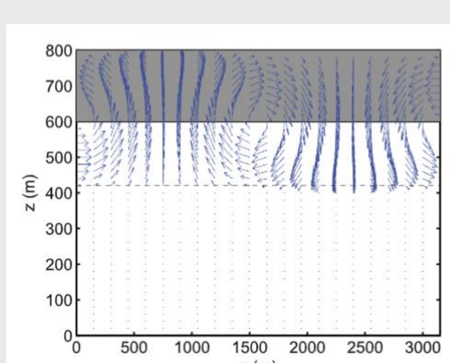
Ice nucleation
Bergeron process
Riming

→ Phase partitioning in the mixed-phase stratiform clouds →

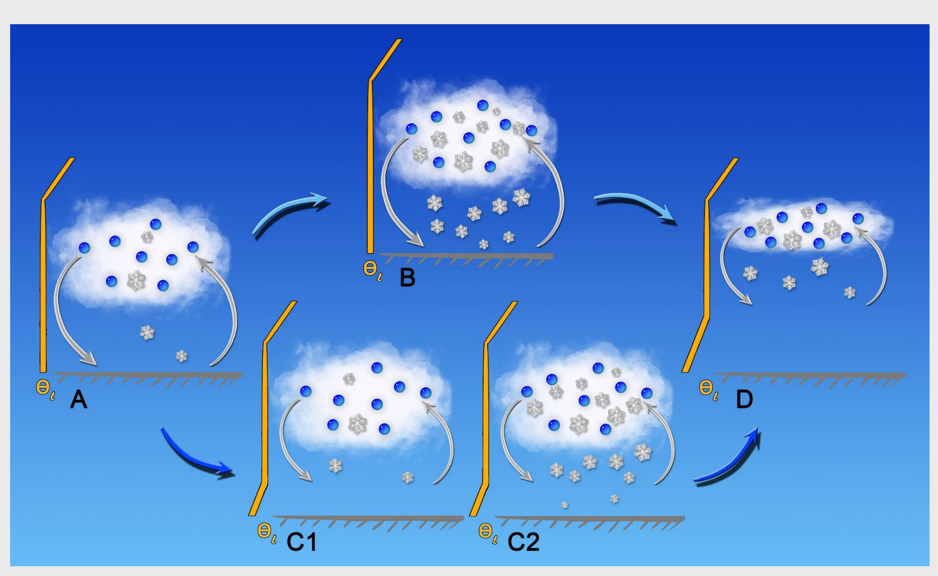
Radiation
Precipitation
Cloud lifetime

Possible mechanisms





Yang et al. (2015) suggested that IWP in a decoupled field is larger than that in a coupled field with the same mixed-phase cloud thickness and ice nucleation rate[1].



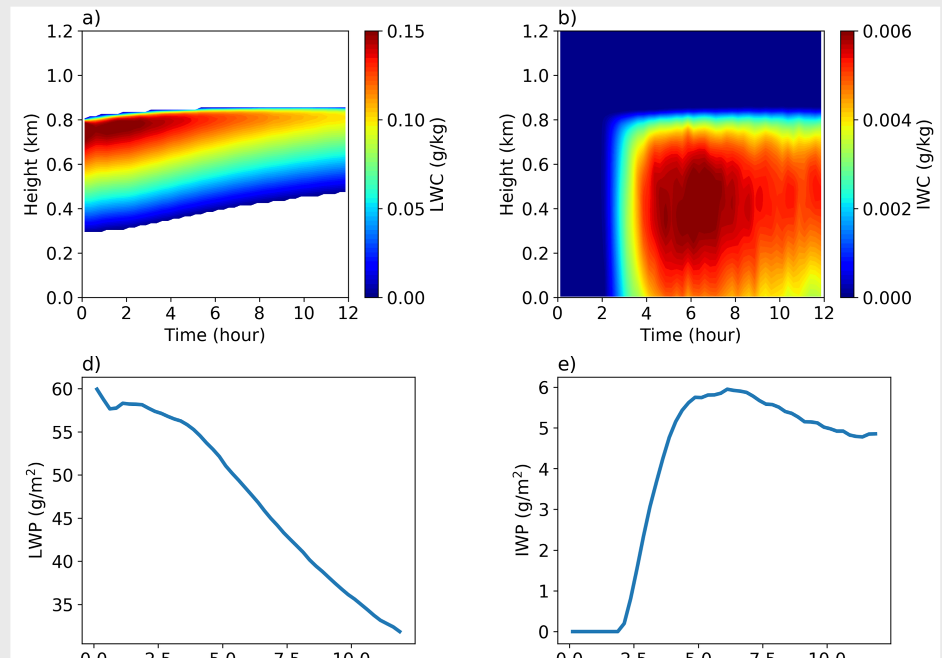
Motivation:

Is the coupled-to-decoupled transition of the atmospheric boundary layer the cause or the result of the fast change of phase partitioning in the mixed-phase stratiform clouds?

Model setup

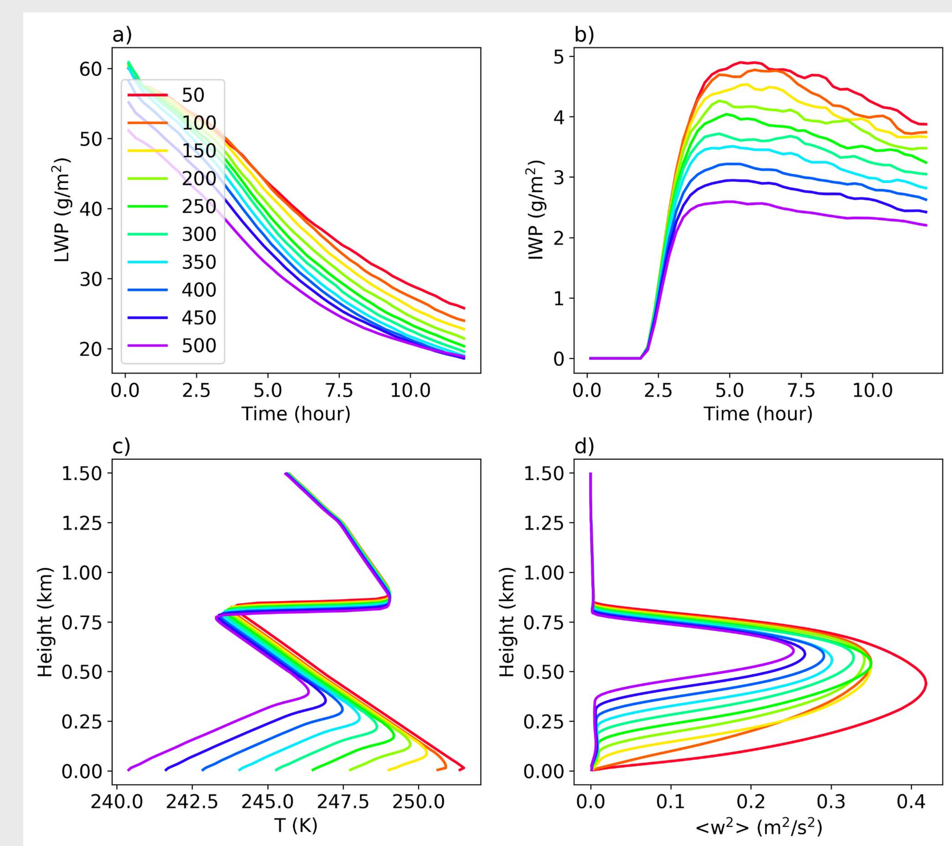
The simulation is similar to ISDAC case (Ovchinnikov et al., 2014) with some modifications.

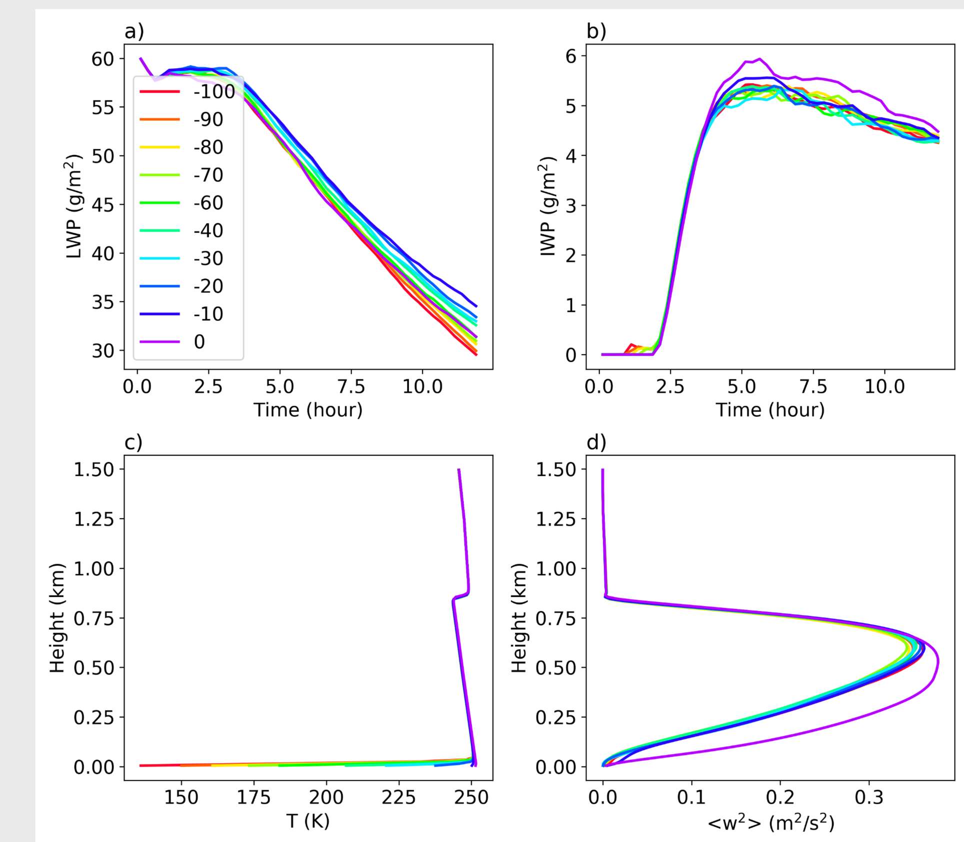
Model: SAM 6.11.2
Resolution: 50 m x 50 m x 10 m
Domain: 3.2 km x 3.2 km x 1.5 km
Total time: 12 hours
Initial profiles: Sounding at 10:14 UTC
Radiation: longwave from NCAR CAM3 model
Microphysics: Morrison et al. (2009)
Forcing: large-scale subsidence
Nudging: u, v
Surface:
(1) Control run: no surface flux
(2) Three ways to generate surface inversion:
* nudging
* negative sensible heat flux
* Monin-Obukhov + surface T forcing

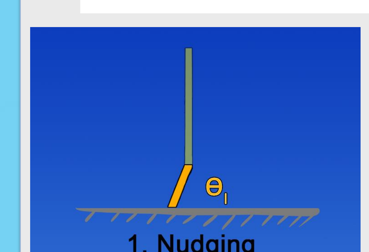


For control run, we do not see
(a) fast change of phase partitioning or
(b) surface inversion

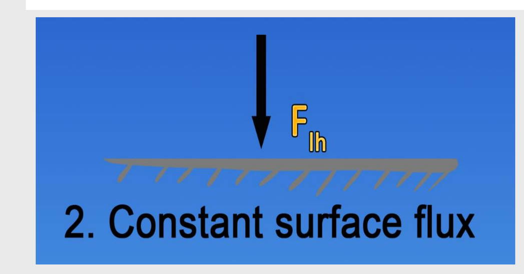
Effect of boundary layer structure on the phase partitioning



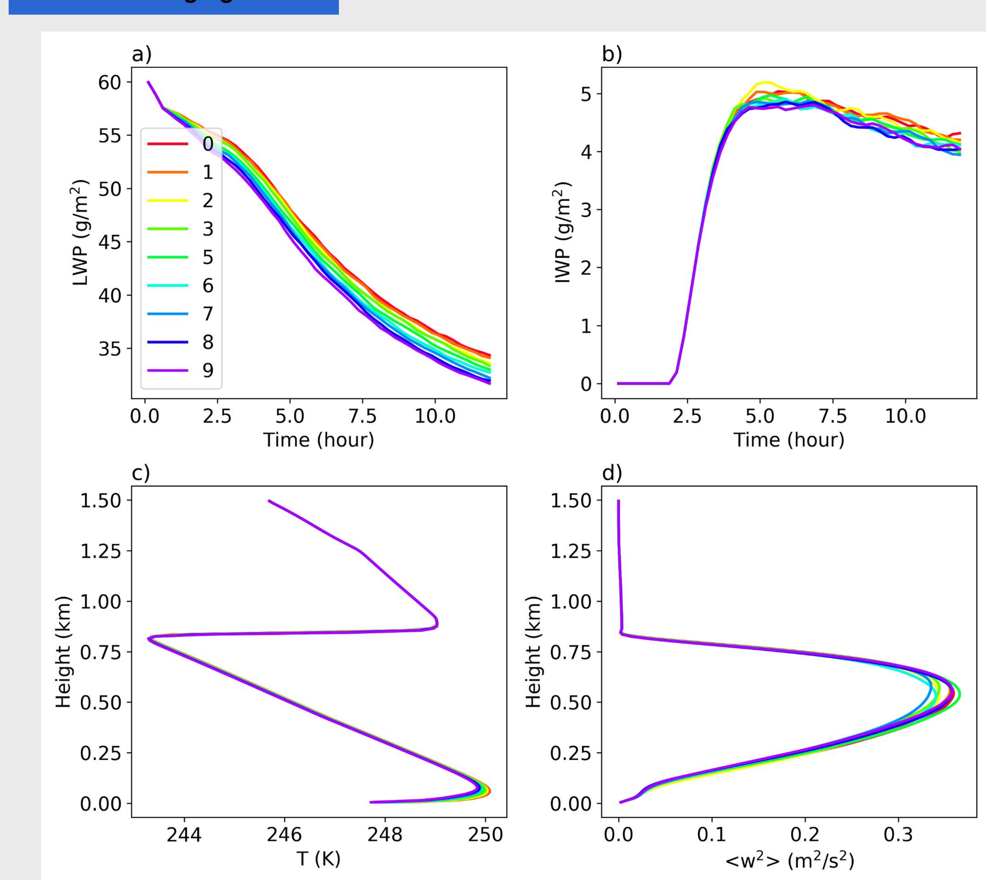


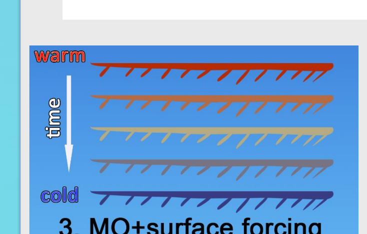


Lines in the figure represent different thicknesses of the nudged-inversion layers above the surface.



Lines represent different values of sensible heat flux at the surface.

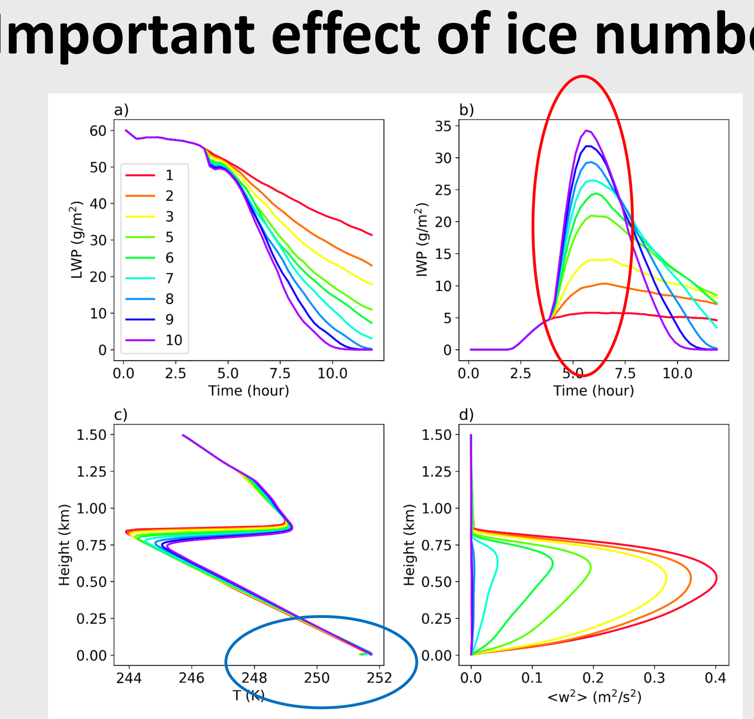




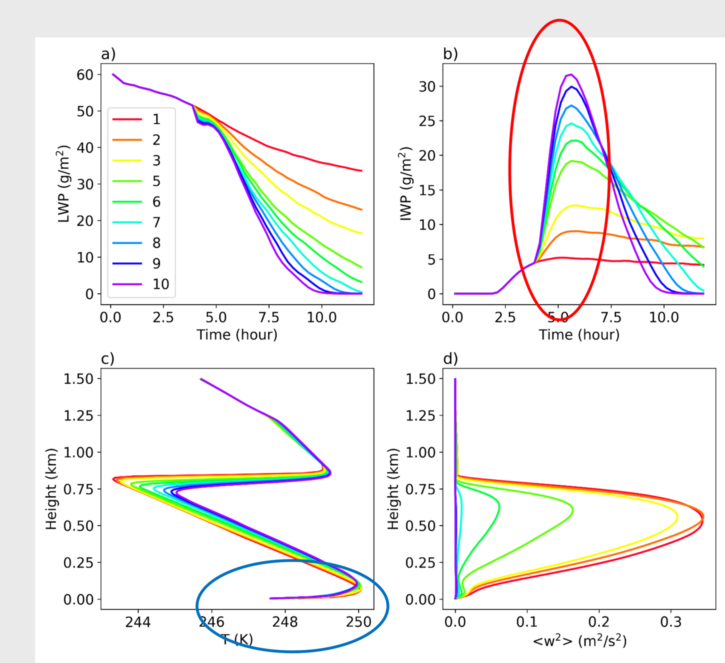
Lines represent different values of surface roughness $z_0 = 2^n \times 10^{-4}$ at the surface.

For all cases, we do not see fast change of phase partitioning. Increasing the thickness of surface inversion layer will decrease the thickness of the mixing layer, thus weaken the turbulent strength in the mixing layer, and lose the ability to recycle large ice particles, which compensates the thermodynamic benefit of IWP enhancement for a decoupled boundary layer as proposed in Yang et al. (2015). **The coupled-to-decoupled transition of the atmospheric boundary layer is unlikely to be the main cause of the observed fast change of phase partitioning.**

Important effect of ice number concentration



Ice number concentration effect without surface flux



Ice number concentration effect with surface flux

Reference:

Yang, Fan, Mikhail Ovchinnikov, and Raymond A. Shaw. "Long-lifetime ice particles in mixed-phase stratiform clouds: Quasi-steady and recycled growth." Journal of Geophysical Research: Atmospheres 120, no. 22 (2015): 11-617.

Ovchinnikov, Mikhail, Andrew S. Ackerman, Alexander Avramov, Anning Cheng, Jiwen Fan, Ann M. Fridlind, Steven Ghan et al. "Intercomparison of large-eddy simulations of Arctic mixed-phase clouds: Importance of ice size distribution assumptions." Journal of Advances in Modeling Earth Systems 6, no. 1 (2014): 223-248.