Motivation

Observations indicate that the processes that maintain subtropical and Arctic stratocumulus (Sc) differ, due to the different environments in which they occur. For example, specific humidity inversions (specific humidity increasing with height) are frequently observed to occur coincident with temperature inversions in the Arctic (e.g., Curry et al. 1996, Tjemström et al. 2000, Stull and Tjemström 2009). In a recent study, Stull et al. 2010 analyzed data from SHEBA, ASCOS, and Barrow, Alaska, to find that specific humidity inversions occurred 75-80% of the time when low-level clouds were present. In addition, this study found a significant relationship between the existence of specific humidity inversions and Arctic Mixed-Phase Stratocumulus (AMPS) that extended into the temperature inversion, highlighting the difference between AMPS and subtropical Sc. Specifically, we use nested LES simulations to quantify the role of humidity inversions at cloud top in the persistence of AMPS.

In this study we focus on a decoupled AMPS in order to focus on the conditions that make AMPS distinct from subtropical Sc. Specifically, we use nested LES simulations to quantify the role of humidity inversions at cloud top in the persistence of AMPS.

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Boundary Layer Structure Along Mean Mixed Layer Winds

- Vertical structure at 20Z along mean cloud layer wind from 50 m nest.
- A) Cloud water, in units of g kg$^{-1}$.
- B) Cloud ice, in units of kg m$^{-2}$.
- C) Subgrid W, in units of cm s$^{-1}$.
- D) Equivalent potential temperature, in units of K.
- E) Horizontal winds, in units of m s$^{-1}$.
- F) Vertical velocity, in units of m s$^{-1}$.
- G) Temperature, in units of K.
- H) Specific humidity, in units of g kg$^{-1}$.
- I) Cloud liquid water and cloud ice water, and water content, respectively.
- J) Total water, in units of g kg$^{-1}$.

Phases Stratocumulus (AMPS) that extended into the temperature inversion, highlighting the difference between warm Sc and AMPS are more effective cloud top radiative cooling aloft prevents cloud liquid water from forming in the temperature inversion. Other important differences between warm Sc and AMPS are more effective cloud top radiative cooling because of the cold, dry overlying Arctic free troposphere, and the vapor diffusion onto ice (Bergeron process) which acts as a potentially large sink of water vapor for AMPS even when there is limited liquid water. In warm Sc drizzle grows by collision-coalescence of droplets, so as liquid water in warm Sc decreases, drizzle will shut off.

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Domain Average Water Tendencies and Mean Fields

Tendencies averaged over total cloud domain calculated from 15 minutes averages.

A) Cloud water, vapor, ice, and total water tendencies, in units of g kg$^{-1}$ day$^{-1}$. Gray dash lines denote boundaries of cloud top entrainment zones, mixed layer, and lower entrainment zones. Positive (negative) indicates water gained (lost) by the layer.

B) Mean vertical velocity. Blue, dash lines are +/- one standard deviation and equivalent potential temperature in black, in units of K m$^{-1}$ and K, respectively.

C) Mean total water, cloud liquid water, cloud ice water, and water vapor, in units of g kg$^{-1}$. Gray shading indicates entrainment zones.

Processes that contribute to 15-minute averaged water content tendencies above the surface layer for the total cloud domain, in units of g m$^{-2}$ day$^{-1}$. The residual is equal to subgrid scale mixing plus diffusion. Mean advection terms (denoted with VM, LVM) are calculated by horizontally averaging tendencies. Horizontal eddy advection (LVM) is calculated as the divergence of fluxes across the domain. Vertical eddy advection (VWM) is the divergence of the vertical eddy flux.

AMPS Conceptual Model

Schematic of AMPS from model results.

A) Evolution from initial cloud-free environment (gray profile) to a decoupled AMPS topped boundary layer (black profile). Red arrows indicate net effect of dynamical mixing and sedimentation.

B) Evolution of detached AMPS topped boundary layer over one hour.