Episodes of *warm-air advection* causing cloud-surface *decoupling* during the MARCUS

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What is the definition of “decoupling” of a cloud-topped boundary layer (CTBL)?

• Definition # 1 (commonly used):
  Thermodynamically stratified (poorly mixing).  

  [Nicholls 1984]

• Definition # 2 (more intuitive):
  A shut-off of exchanges between cloud-containing layers and the surface.
Cumulus-fed stratocumulus: coupled or decoupled?

Wood 2012
Cumulus-fed stratocumulus: coupled or decoupled?

Wood 2012
What is the key influential factor that modulates the cloud-surface interactions?

Wood 2012
Importance of low-level temperature advection

Low-level cold air advection (CAA)

“Deepening warming” decoupling
(Bretherton and Wyant, 1997)
Importance of low-level temperature advection

Low-level cold air advection (CAA)

Low-level warm air advection (WAA)

“Deepening warming” decoupling (Bretherton and Wyant, 1997)

Zheng et al., 2018b, JGR
Zheng and Li, 2019, submitted to JGR
Measurements of Aerosols, Radiation, and Clouds over the Southern Ocean (MARCUS)

- U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM)
- Sep 2017 – April 2018
- PI: Greg McFarquhar
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Wall et al., 2017
An example of CTBL under LLWAA influence during MARCUS

- Ship location
- 36-h back trajectory

Feb 28 – Mar 3, 2018
An example of CTBL under LLWAA influence during MARCUS

Black = cloud base height
Red = LCL
Yellow = $\theta$ profile
Common characteristics of CTBL under WAA:

• The MBLs are highly stratified to the extent that the penetration of cumulus into the inversion, which is common for subtropical decoupled MBLs, is non-existent.

• Sea surface temperature (SST) lower than the near-surface air temperature, indicating a negative surface fluxes.

• Decoupled clouds manifest stratiform with lifetime as long as several tens of hours.

• They locate in warm sectors of middle-latitude cyclones where the lack of strong large-scale subsidence is favorable for their maintenance (lack of subsidence-induced drying).
Himawari-8 RGB imagery

-24hr, 2018-01-08T12:00:00Z
Take-home message:

• The conventional definition of “decoupling” (Nicholls, 1984) fails to reveal the “coupled” nature of cumulus-fed stratocumulus regime over subtropics.

• The decoupled MBL caused by the “deepening warming” mechanism is less stratified/decoupled than that in warm air advection (WAA). The latter has been receiving less attention.

• The WAA-induced decoupled clouds can be quite persistent with lifetime as long as several tens of hours.

• The WAA-induced decoupled clouds may influence the pathway through which surface-generated aerosols affect the clouds.
Supplementary slides
Importance of low-level temperature advection

Low-level cold air advection (CAA)

“Deepening warming” decoupling (Bretherton and Wyant, 1997)

Zheng et al., 2018a, GRL
An example under LLWAA influence during MARCUS