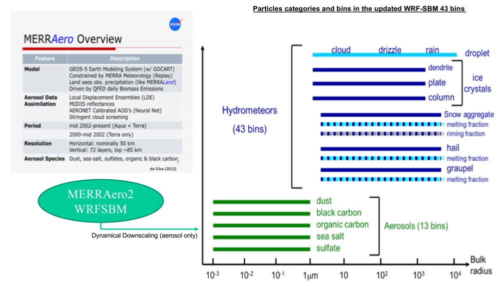
Investigating the Sensitivity of Tropical and Mid-latitude Deep Convection to CAPE and CCN Changes

S. A. Rutledge[1], T. Iguchi[2], T. Matsui[2], J. Barnum[1], W.-K. Tao[2], B. Dolan[1] and S. Lang[2]
[1]Department of Atmospheric Science, Colorado State University, Fort Collins, CO
[2]NASA Goddard Space Flight Center, Greenbelt, MD

Introduction

WRF-SBM simulations are used to investigate how changes in CAPE and CCN concentrations impact convection. Cases are selected from both the tropics (from the TWP-ICE field campaign) and the mid-latitudes (from the MC3E field campaign). Representative CCN concentrations are dynamically downscaled from the NASA MERRA Aerosol Reanalysis to arrive at base CCN concentration inputs for the WRF model. CCN sensitivity tests are performed via interchanging the tropical and mid-latitude CCN concentrations (i.e., feeding the TWP-ICE case with the mid-latitude CCN profile, and vice versa). CAPE is perturbed by modifying water vapor profiles.

For TWP-ICE, with higher CCN concentrations, a 10% increase in the areal-averaged convective rain rate is found. The convective component is characterized by larger graupel volumes in the "polluted" simulation compared to the base case, consistent with previous studies on convective invigoration by CCN. Convective rain rates are reduced in the MC3E simulation with lower CCN concentrations. CAPE and CCN are also simultaneously modified. The POLARRIS framework we previously developed is utilized to compare polarimetric fields produced by the model for the base and CCN sensitivity simulations.



Experimental Design

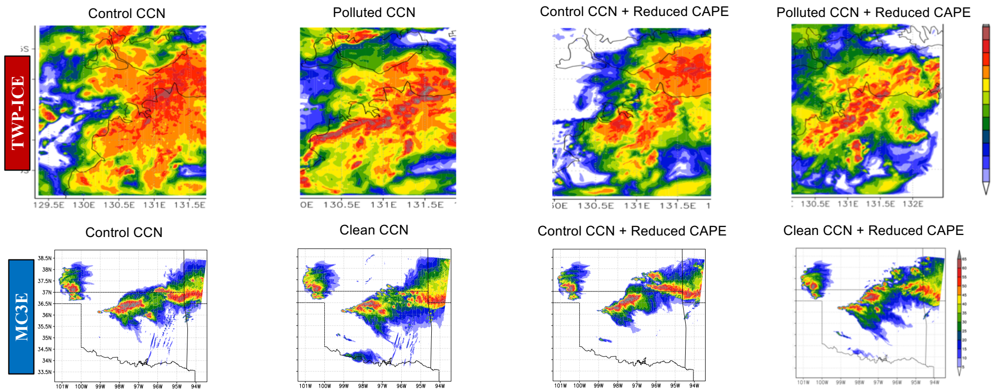
Model Description:

The WRF-SBM is the WRF-ARW version 3.6.1 coupled with Hebrew University Cloud Model (HUCM) Spectral Bin Microphysics (SBM) 43-bin version. We updated SBM to include the typical five aerosol types (which for cloud interactions currently serve as cloud condensation nuclei). In addition, we developed a framework of dynamical downscaling of aerosols from the NASA Modern Era Retrospective analysis for Research and Applications Aerosol Reanalysis (MERRA Aerosol) into the WRF-SBM.

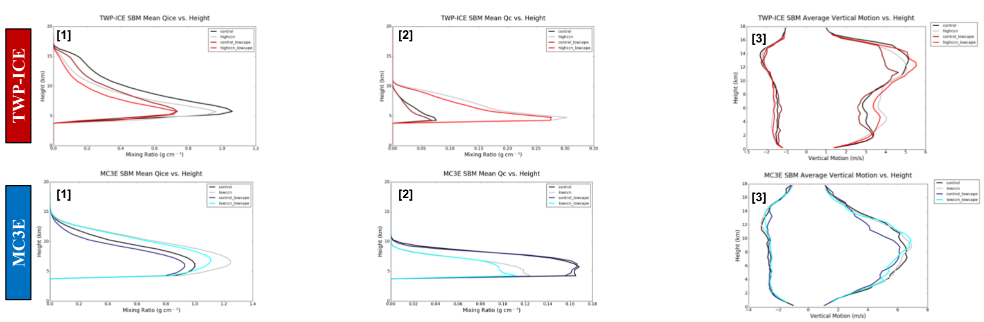
TWP-ICE Jan 23 (experiments used HUCM SBM)		Aerosols	
		Control Runs (CCN 77 cm^{-3})	Polluted Runs (CCN 1399 cm^{3})
Thermo	Dry Max CAPE: 1401	Dry Control	Dry Polluted
	Control Max CAPE: 2247	Control	Control Polluted

MC3E May 23 (experiments used HUCM SBM)		Aerosols	
		Control Runs (1399 cm^{-3})	Clean Runs (77 cm^{-3})
Thermo	Dry Max CAPE: 3764	Dry Control	Dry Clean
	Control Max CAPE: 4167	Control	Control Clean

Preliminary Results

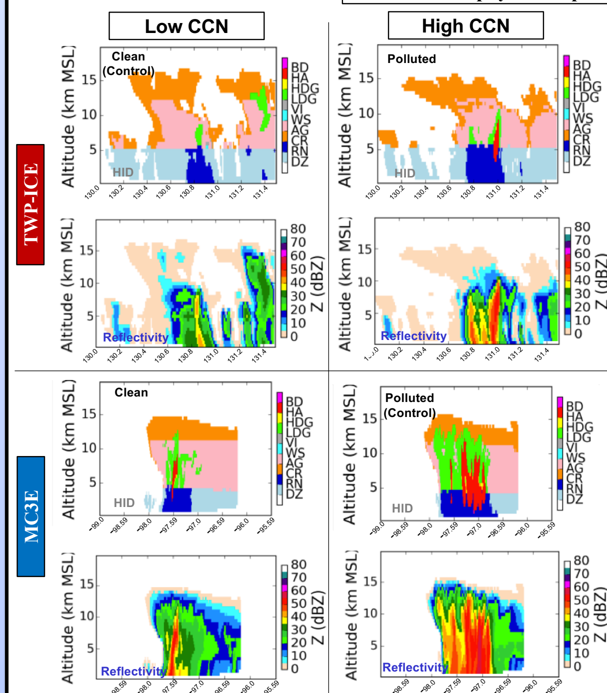


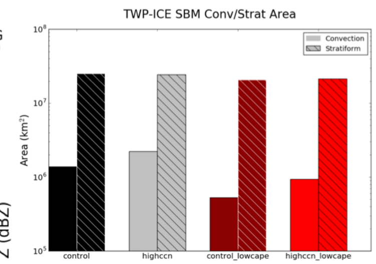
- TWP-ICE: Increased CCN results in more intense and isolated convection.
  - Reduced CAPE yields significantly reduced precipitation coverage.
- MC3E: Decreased CCN results in slightly weaker convection and a slight increase in stratiform precipitation.
  - Reduced CAPE yields slightly smaller precipitation coverage without much change to intensity.

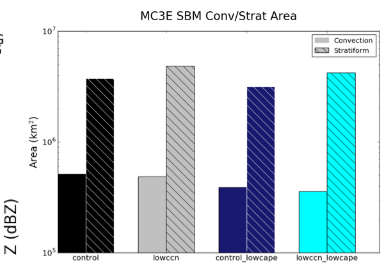


- All results shown here are for "convective" areas only.
- [1] TWP-ICE: more sensitivity to CAPE changes compared to CCN changes.
  - Base CAPE simulations yield larger mean ice mass mixing ratios (regardless of CCN profile) for TWP-ICE. [2] Increased CCN (regardless of CAPE) yields an increase in mean supercooled liquid water mixing ratio (q_c) for both locations.
  - ~ 0.2 g cm^{-3} difference in q_c for TWP-ICE, only ~0.05 g cm^{-3} for MC3E.
- [3] Downdraft profiles between TWP-ICE and MC3E are similar, but the TWP-ICE updraft profile has a double-peak structure and MC3E does not.
  - TWP-ICE updraft values are highest for high CCN concentrations suggesting convective invigoration. MC3E updraft values are somewhat larger for low CCN concentrations. This behavior was not expected.

Microphysical impacts







- Higher CCN results in more significant hail and graupel production aloft, as well as more intense, and vertically-extensive, reflectivities.
  - This agrees with TWP-ICE mean updraft results, but differs from MC3E mean updrafts (which are shown to be slightly smaller for increased CCN concentrations).
- In TWP-ICE, higher CCN results in increased (slightly decreased) convective (stratiform) area regardless of CAPE
- In MC3E, higher CCN results in a decrease in stratiform area, but a minimal change in convective area
- Regardless of CCN, decreased CAPE reduces convective area, with more significant effect in TWP-ICE. Stratiform area is also slightly decreased.

Discussion

- In general, increasing aerosols results in:
  - More intense, compact convective cores
  - Increased graupel and hail mass
- Reduced CAPE reduces rain rates, rain area, convective intensity and hail and graupel production aloft.
- We are currently conducting the same set of simulations using "bulk" microphysics. We are interested to see if the sensitivities to CCN and CAPE are preserved when bin microphysics and replaced by "bulk" microphysics.

Acknowledgements

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