Impacts of Varying Model Physics on Simulated Structures in a Cold Air Outbreak Cloud System

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ABSTRACT

Put in an abstract.

1. Introduction

Turbulence parameterization methodology has had an important role in model handling of clouds. Early versions of turbulence parameterizations used a diagnostic equation to solve for K, the eddy viscosity (Pielke 1974). Other methods sought a prognostic turbulent kinetic energy (TKE) equation though even second-moment schemes at times had difficulty with vertical transport of TKE (Yamada and Mellor 1975). Third-moment turbulent closure schemes have been used to better capture TKE in the boundary layer and in-cloud (Krueger 1988).

2. Model Background

3. CONSTRAIN Model Setup

The grey zone is the range of grid sizes in atmospheric model simulations that are between high resolution scales which can adequately resolve turbulence (< 1 km) to low resolution scales which require convective parameterization (> 10 km). This range is critical in handling modeling questions from topics as diverse as the Madden-Julian Oscillation (MJO) (Wang et al. 2015), tropical cyclones (Sun et al. 2014), stratocumulus (Boutle et al. 2014), and the convective boundary layer (Shin and Hong 2015).

The Grey Zone Project was designed to explore model behavior with and without convective parameterization at grid sizes throughout the grey zone in order to better understand model performance. A case study selected for intercomparison is from CONSTRAIN, a Met Office field campaign in January 2010 over the North Atlantic ocean. The specific day selected is a cold-air outbreak event on 31 January 2010. Cold-air outbreak cases have been shown to have convection morph from organized rolls to open cellular convection, which can have significant impacts on transport of heat and moisture (Brümmer 1999; Brümmer and Pohlmann 2000). The case is

14.5 hours in duration with initial conditions and forcings generated from high resolution limited area model simulations performed by Paul Field on the Met Office Unified Model (UM) (Field et al. 2014). Model simulations for this event have been compared to aircraft, satellite, and radar observations (Field et al. 2014; McBeath et al. 2014).

For the CONSTRAIN case, SAM runs without SHOC at .1 km were used as the LES baseline run for each set of model physics. From there, many other runs were performed, outlined in Table 1. Sets of runs at varying grid resolution for NOSHOC were run for full physics, no radiation, and no ice configurations. Sets of runs for SHOC were performed for full physics, no radiation, no ice, ice only, no ice sedimentation, and no ice/sedimentation/precipitation configurations. Additional runs were performed for no precipitation, and no radiation/precipitation configurations. Peter Bogenschutz also ran LES and 3 km SHOC and NOSHOC simulations using the Morrison M2005 double-moment microphysics scheme.

4. Results

Model profiles were made by averaging the last hour of model output. The profiles for total cloud water are shown in Figure 1. For most of the runs, the NOSHOC and SHOC runs are fairly representative of the LES runs with slight differences in maximum total cloud water elevation and total cloud water amount. For no sedimentation runs, the maximum total cloud water amount is underestimated in the SHOC runs. The lower resolution no ice runs (8 km for SHOC, 3 km for NOSHOC) have slightly larger differences from the LES baseline than the higher resolution no ice runs. Since most of the TKE is resolved at grid sizes up to 3 km, the differences between SHOC and NOSHOC remain small.

Time series for LES runs of surface precipitation rate, cloud water path (CWP) + ice water path (IWP), and cloud shield fraction are shown in Figure 2. Precipitation rates are higher in the full physics run than the no radiation run; however, the difference in CWP + IWP and cloud shield fraction is very small in the precipitation allowing runs for full physics vs no radiation. Cloud fraction is larger in no precipitation runs and much larger for the full physics run without precipitation than the no radiation run without precipitation.

Effects of cloud ice and ice sedimentation for LES runs are shown in Figure 3. The full physics run has a higher cloud fraction than the ice only run at a higher level, just over 1 km for full physics compared to just over 0.5 km for ice only. The runs without ice sedimentation had much higher cloud fractions with a maximum at roughly 2.25 km. Total TKE was higher throughout the entire profile for the no ice sedimentation runs which shows these runs have higher entrainment than the runs that allow for ice sedimentation.

The effects of the microphysics scheme selection along with additional no ice and no ice sedimentation choices on LES runs is shown in Figure 4. Surface precipitation rate increases faster in the full physics and no ice sedimentation runs; however, the double-moment (M2005) microphysics run has the highest surface precipitation rate of the four at around 14 hours. The no ice run is the slowest to develop precipitation. CWP + IWP stays lower for the runs with higher precipitation and highest for the no ice run. The microphysics scheme makes a significant difference in IWP as the M2005 run only develops a minute fraction of IWP relative to the single-moment full physics run. Inversion height generally trends upward over time though is much slower for the full physics run which decreases slightly in inversion height the first five hours.

5. Conclusions

Add in conclusions.

Acknowledgments. CONSTRAIN runs using the M2005 microphysics were run by Peter Bogenschutz. This research was supported by the Office of Science (BER), U. S. Department of

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TABLE 1. Model simulations performed for the CONSTRAIN case study.

	SHOC						NOSHOC				
Grid Spacing	30 km	8 km	4 km	3 km	1 km	.5 km	30 km	3 km	1 km	.5 km	.1 km
Full Physics	x			x	x	x	x	x	x	x	x
No Precipitation					x	x					x
No Rad.	x			x	x	x	x	x	x	x	x
No Rad./Prec.											x
No Ice	x	x		x	x	x		x	x	x	x
Ice Only	x			x	x	x					x
No Sed.				x	x	x					x
No Ice/Sed./Prec.		x	x		x						x
M2005				x				x			x

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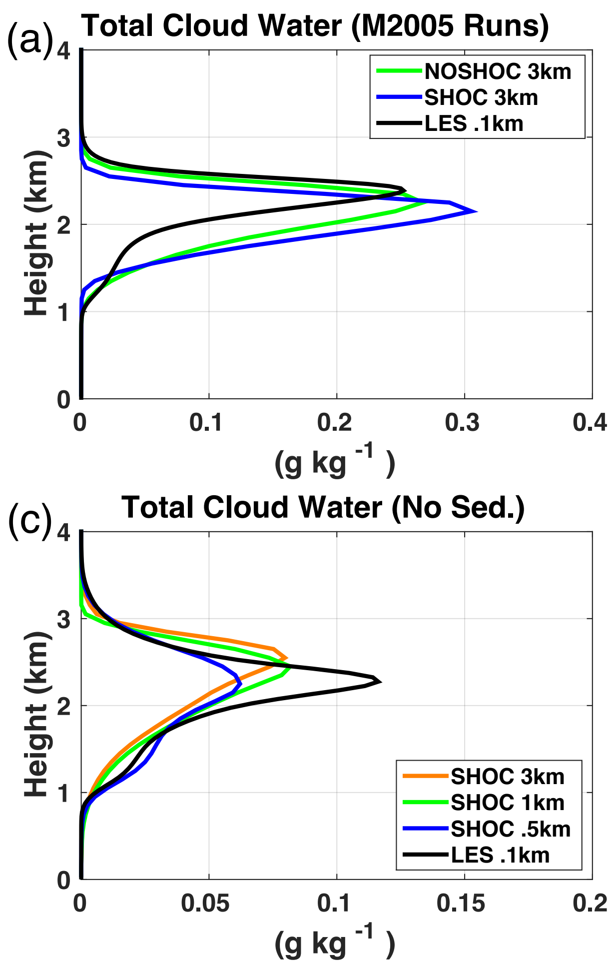
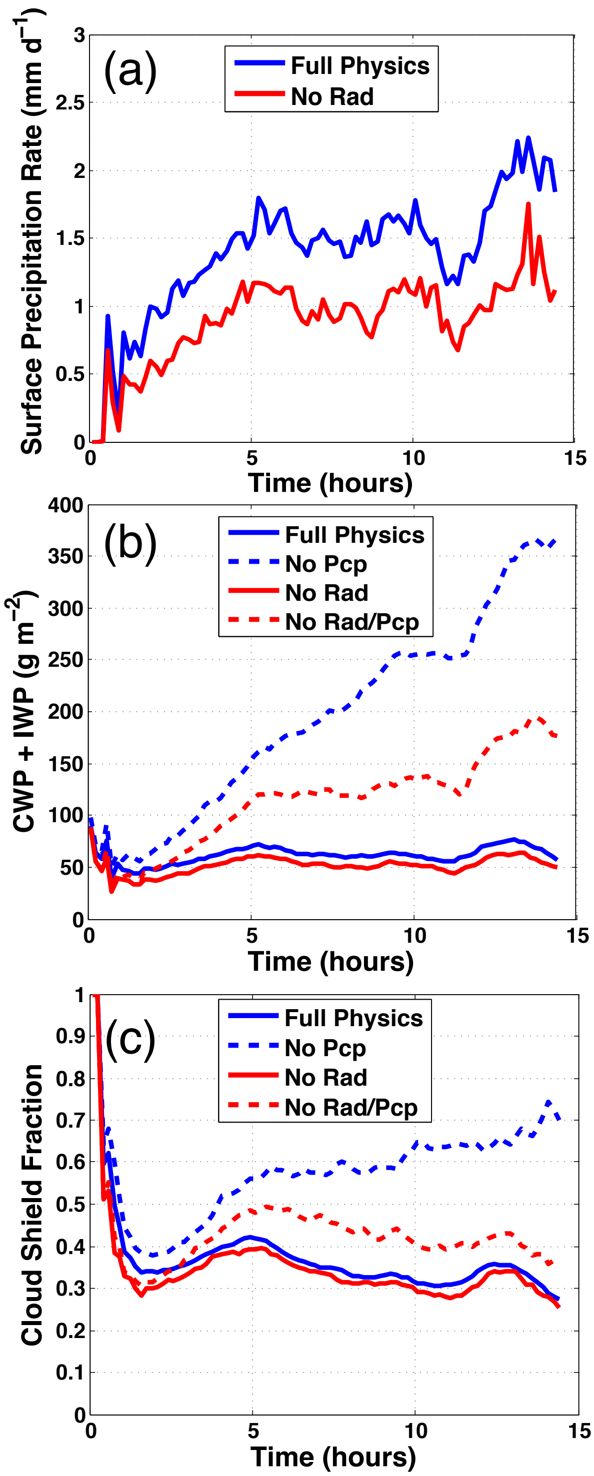


126 FIG. 1. Final-hour averaged total cloud water profiles of CONSTRAIN simulations for: a) double-moment microphysics runs, b) no ice runs with SHOC, c) no ice sedimentation runs, and d) no ice runs without SHOC. LES runs in each plot panel are high resolution runs used as benchmarks. Note: x-axis scales are different among the panels.



130 FIG. 2. CONSTRAIN LES time series of full physics, no precipitation, no radiation, and no radiation or
131 precipitation runs for a) surface precipitation rate, b) cloud water path + ice water path, and c) cloud shield
132 fraction.

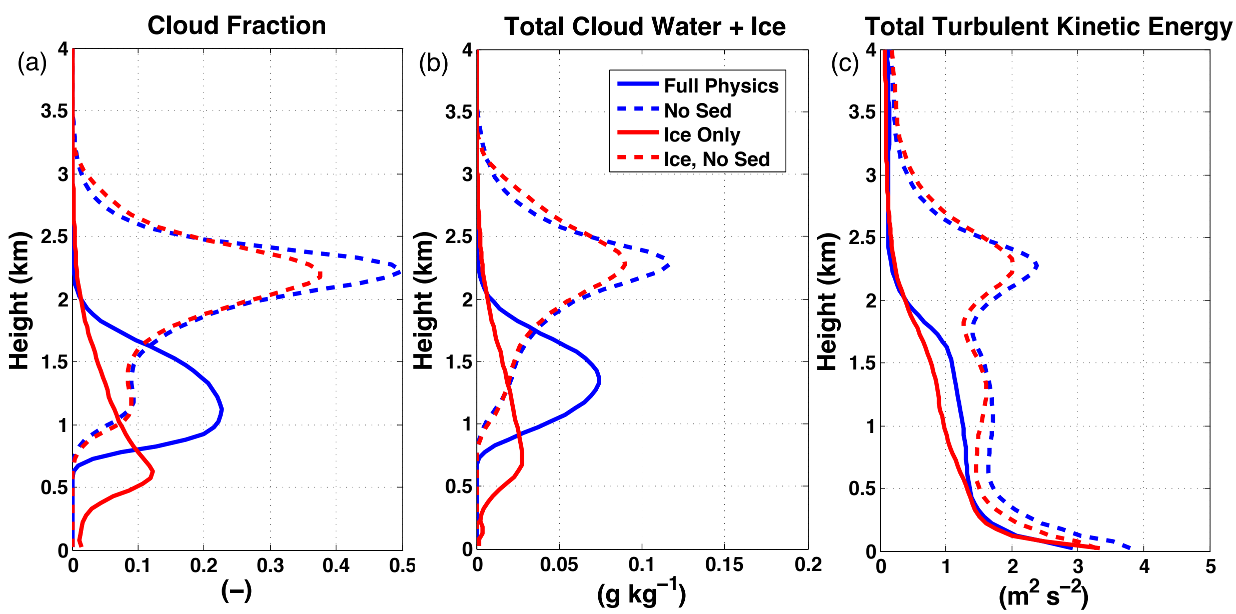
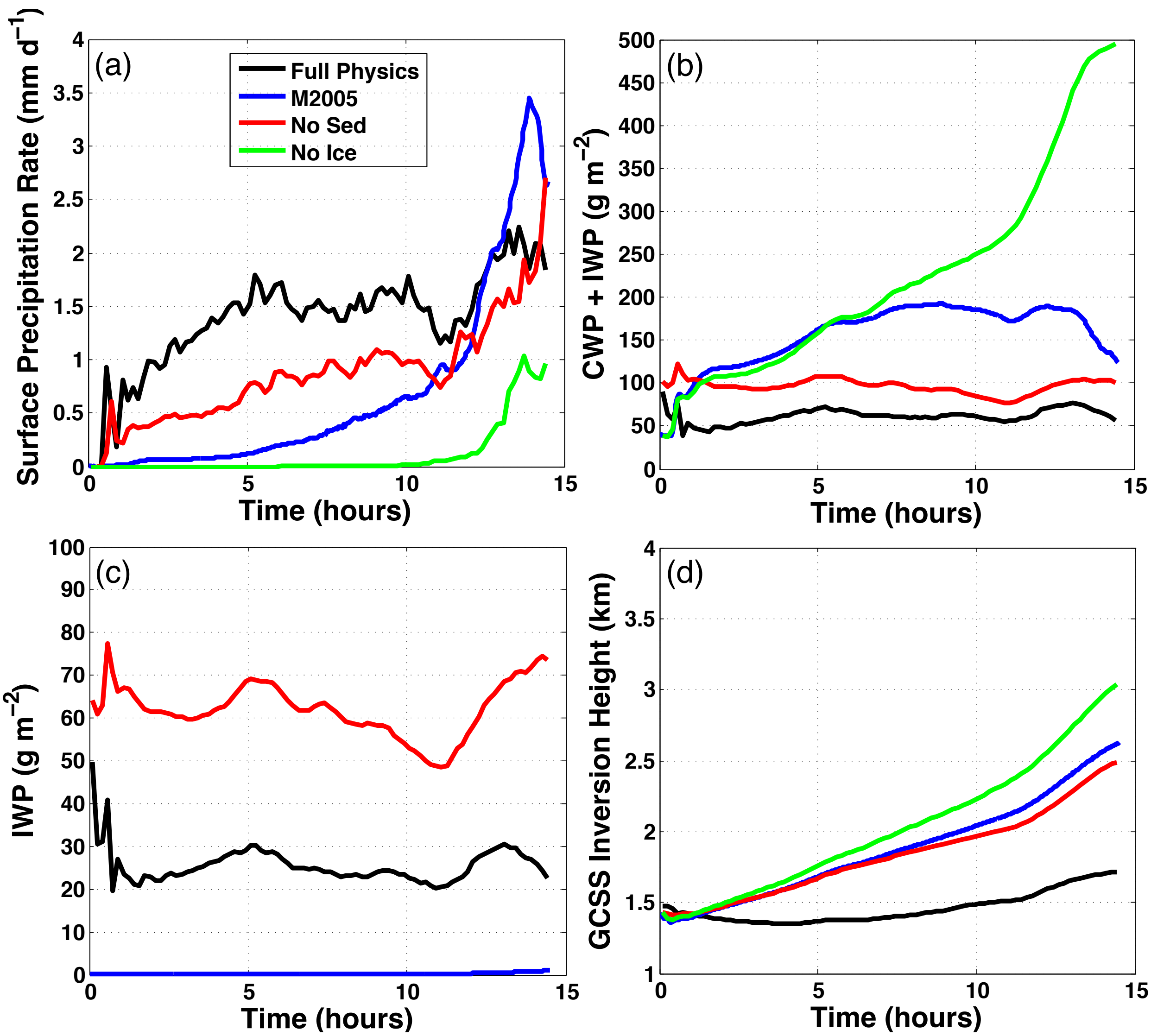


FIG. 3. Final-hour averaged CONSTRAIN LES profiles of a) cloud fraction, b) total cloud water and ice, and c) total turbulent kinetic energy for full physics, no ice sedimentation, ice only, and ice only + no ice sedimentation runs.



136 FIG. 4. CONSTRAIN LES time series of full physics, Morrison (2005) double-moment microphysics, no ice sedimentation, and no ice runs for a) surface precipitation rate, b) cloud water path + ice water path, c) ice water path, and d) inversion height.