Evaluation of drizzle representation in LES models with bin microphysics

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Case study: 2009-11-22

MODIS image from AQUA overpasses

Storm influence from reanalysis
Case study: 2009-11-22
Case study: 2009-11-22
Motivation

1. Found no “easy” constraint of LES drizzle formation owing to large spread in observed variables over very wide range of \((all?)\) spatiotemporal scales

   - Drizzle strongly dependent on LWP (among other parameters)
   - No clear approach to reproduce observed frequencies (of LWP or other parameters) in LES
   - No clear approach (yet in hand) to robustly evaluate single LES case study with observations variably sampled over wide and multivariate parameter space

*Time series from ground instruments (MWR, MFRSR, TSI)*
*Black symbols from VISST (courtesy of Kirk Ayers / NASA Langley)*
Motivation

2. Found motivation to work harder owing to large differences in the number of drops produced by two LES for a given CCN [*due to differences in vertical velocity variance for same cloud-top entrainment!*]
   - Drizzle strongly dependent on the number of drops
   - Updated SAM dynamics agree closely with DHARMA, but observational verification required
   - No clear approach yet in hand to well constrain the LES vertical velocity variance
Motivation
Differences in the dynamics
Two LES models with bin microphysics

- idealized initial sounding (11Z), fixed subsidence profile and SST, periodic boundaries, fixed/similarity surface fluxes, nudged horizontal winds, diagnostic ammonium bisulfate aerosol PSD [Clarke et al. 1974]

<table>
<thead>
<tr>
<th>DHARMA</th>
<th>SAMEX</th>
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<tbody>
<tr>
<td>finite-difference dynamics scheme [Stevens et al. 2002]</td>
<td>finite-difference dynamics scheme [Khairoutdinov and Kogan 2003]</td>
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<tr>
<td>dynamic Smagorinsky sub-grid scale scheme [Kirkpatrick et al. 2006]</td>
<td>prognostic TKE sub-grid scale scheme [Deardorff 1980]</td>
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<tr>
<td>one-moment bin scheme</td>
<td>one-moment bin scheme</td>
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<tr>
<td>3rd-order advection scheme</td>
<td>2nd-order advection scheme</td>
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<td>Beard and Ochs [1984, 1995] or coalescence efficiency = 1</td>
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Approach

• Observed drizzle moments and spectral properties exhibit robust relationships: do LES reproduce these?

→ Use the McGill radar Doppler spectra simulator to emulate radar spectra and moments from results of both LES models
Z–MDV relationship

Within cloud

Wiggles
Z, MDV, W near CT
Z–MDV relationship

Wiggles in Z-MDV space appear to be caused by limitations in LES representation of cloud-top dynamics: strong LES downdrafts near cloud top are not observed, presumably owing to limitations of LES dynamics here.
Z–Skewness relationship

Most pronounced: excessively negative spectral skewness in LES everywhere (DHARMA) or below cloud base (SAMEX)
Further look

- Forward simulations from a 1D model and in situ observations are consistent with a sharp decrease in N(D) at largest D more closer to SAMEX
- Motivation for follow-on study with DHARMA and McGill in 1D framework (DSDs realistic enough)
Ultimate goals

- Improve ability of LES with bin microphysics to faithfully represent radar observables without sacrifice to performance (analogous to three-moment CRM schemes)
- Use radar observables to do the “hard” constraint of LES drizzle formation
Approach

- Observed drizzle moments and spectral properties exhibit robust relationships: do LES reproduce these?
DHARMA – 130cc

[Graphs showing data with axes for Height [km], Restored time [hr], Reflectivity [dBZ], MDV [m s⁻¹], Width [m s⁻¹], with legend indicating color scales for each variable.}

NB: Velocity +ve upward
DHARMA – 130cc – 60 bins

NB: Velocity +ve upward
DHARMA – 65cc – 60 bins

NB: Velocity +ve upward
SAMEX – 130cc

Reflectivity [dBZ]

MDV [m s⁻¹]

Width [m s⁻¹]

Height [km]  Restored time [hr]

NB: Velocity +ve upward