LES/SCM based on well-observed case studies + evaluation of ESM physics using long-term ARM data = A good pairing for community participation?

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• Thanks for attending!
  – First hour presentations and questions, second hour open discussion
  – Type in your question to chat or raise your hand (from phone toggle *9)
  – Video welcomed during open discussion
  – Please keep questions and comments as brief as possible
  – This session will be recorded
Where is this coming from?

- **ARM Cloud and Precipitation Measurements and Science Group**
  - “how resources can best be applied ... to increase the scientific impact of these measurements” (charter)
  - “are there subtopics where ARM has strong potential to contribute but is not reaching that potential for various possible reasons?”
  - a draft recommendation: *seek and support frameworks that bring individuals and groups together for limited joint exercises*

- **Examples**
  - GCSS model intercomparison studies (cases still widely used)
  - GASS Diurnal Cycle of Precipitation Project (*next talk*)
  - general pairing: LES/SCM cases + ESM evaluation with long-term obs?
    - latter may usually require forward simulator approach (*last talk*)
ModelE3 development approach

Field campaigns → LES → SCM

ACTIVATE Flight RF13
1 March 2020
mixed-phase cold-air outbreak
(Tornow et al., in prep)

Global data → GCM tuning

From https://satcorps.larc.nasa.gov

Pseudo-Albedo -- time: 9h
highsub_4x (mean=0.62)

GMAO/cubed-sphere

CALIPSO
### ModelE3 development approach

**Field campaigns → LES → SCM**

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Case study</th>
</tr>
</thead>
<tbody>
<tr>
<td>dry convective boundary layer</td>
<td>idealized [Bretherton and Park 2009]</td>
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<tr>
<td>dry stable boundary layer</td>
<td>GABLS1 [Cuxart et al. 2006]</td>
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<tr>
<td>marine stratocumulus</td>
<td>DYCOMS-II RF02 [Ackerman et al. 2009]</td>
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<tr>
<td>marine trade cumulus (shallow)</td>
<td>BOMEX [Siebesma et al. 2003]</td>
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<tr>
<td>marine trade cumulus (deep, raining)</td>
<td>RICO [van Zanten et al. 2011]</td>
</tr>
<tr>
<td>marine stratocumulus to cumulus transition</td>
<td>SCT [Sandu and Stevens 2011]</td>
</tr>
<tr>
<td>continental cumulus</td>
<td>RACORO [Vogelmann et al. 2015]</td>
</tr>
<tr>
<td>Arctic mixed-phase stratus</td>
<td>M-PACE [Klein et al. 2009]</td>
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<tr>
<td>Antarctic mixed-phase stratus</td>
<td>AWARE [Silber et al. 2019]</td>
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<tr>
<td>tropical deep convection</td>
<td>TWP-ICE [Fridlind et al. 2012]</td>
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<tr>
<td>mid-latitude synoptic cirrus</td>
<td>SPARTICUS [Mühlbauer et al. 2014]</td>
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</table>
M-PACE to ISDAC progress

Klein et al. (2009)

Ovchinnikov et al. (2009)

see also Fridling and Ackerman (2018)
M-PACE LES vs ModelE3 SCM

**M-PACE, 012.0 h**

- **t (K)**: 250 to 270
- **e_turb (m²/s²)**: 0.0 to 1.2
- **qcl (g/kg)**: 0.0 to 0.4
- **qpl (g/kg)**: 0.00 to 0.04
- **qcpi (g/kg)**: 0.00 to 0.05
- **ncl (cm⁻³)**: 0 to 80
- **ncpi (L⁻¹)**: 0 to 10

**Z (m)**: 0 to 3000

**PBL height (m)**: 0 to 3000

**Time (hours since 2004-10-09 17:00 UTC)**: 0 to 10

**Stratiform Cloud Cover (%)**

- 0% to 100%

**Convective Cloud Cover (%)**

- 0% to 100%

**Liquid Water Path (kg/m²)**

- 0.00 to 0.20

**Ice Water Path (kg/m²)**

- 0.00 to 0.08

**LES_MPACE**

- SCM_MPACE_Ni0p1
- SCM_MPACE_Ni1
- SCM_MPACE_Ni10
Decoupled Antarctic stratus (Lagrangian LES)

- stable initial profile
- supercooled liquid promotes LW cooling, ice formation
- turbulent layer from \( \sim 10 \) h
  - deepens downward
  - fails to couple (cf. ISDAC)
- possible \( N_d \) control by gravity waves (cf. Silber et al. GRL 2020)
- moisture inversion (cf. ISDAC, SHEBA)

AWARE campaign case study (Silber et al. JGR 2019)
AWARE LES vs ModelE3 SCM

- AWARE, 009.0 h
- e_turb (m^2/s^2)
- qcl (g/kg)
- qpl (g/kg)
- qcip (g/kg)
- ncl (cm^-3)
- ncpi (L^-1)

Liquid Water Path (kg/m^2)

Ice Water Path (kg/m^2)
LES/SCM case studies

• pros
  – basic tests of ESM column physics
  – convenient framework for model development
  – can be used to tune model parameters (e.g., Williamson et al. 2013)
  – observation-derived cases highlight fundamental knowledge gaps (e.g., ice multiplication, mesoscale structure, CCN and INP budgets)

• cons
  – how to choose? (statistically representative? extremes? ensemble?)
  – are improvements borne out in free-running ESM?
  – useful but not sufficient
Ground-based long-term observations

- great majority of supercooled polar clouds precipitating at cloud base
- poorly observed from space, without ancillary data (LWP, soundings, etc.)

Silber et al. (submitted)
Putting parts together

• A polar cloud pairing
  – Arctic and Antarctic LES/SCM basic tests of supercooled cloud persistence (M-PACE CAO) and formation (AWARE decoupled stratus)
  – evaluation of ESM supercooled cloud occurrence frequency, cloud base precipitation rate vs long-term NSA and McMurdo obs
  – expect that SCM and ESM performance will be related

• Other pairings or additions?
  – warm cloud precipitation statistics at ENA (e.g., Lamer et al. 2019), ...
  – additional relationship of LES/SCM and ESM performance to ECS, MJO or other metrics
Group activities on the GCSS model

• Pros
  – reduced duplication of effort in setting up cases
  – valuable consensus-building & knowledge-sharing re cases & setup (e.g. MPACE to ISDAC)
  – can motivate and efficiently use dedicated efforts from observationalists

• Cons
  – major effort from a lead organizer who is not specifically funded
  – overhead on every group to report specified results & file formats (e.g. TWP-ICE)

• Possible changes
  – introduce community code development (e.g., to convert outputs to unified format, apply forward simulators with assumptions matched to ESM physics, plot results from multiple models vs obs)
    • use DEPHY input/output community standards for LES/SCM component (https://www.lmd.jussieu.fr/~hourdin/Workshop1Dstd.html)
  – introduce use of ARM computing resources
  – emphasize a bare minimum package of runs & diagnostics (low-overhead participation option)
  – decrease emphasis on omnibus manuscripts?

• More opening a discussion than proposing a solution
Discussion

• Need for more organized modeling activities within ASR?
  – reinstitute a model-centric focus group?
  – expand focus beyond IOPs to explicitly harness long-term (and AMF) statistics?
  – could support multiple, diverse group activities with any number of participants

• Overall approach
  – one possibility: pairing LES/SCM cases with ESM evaluation using long-term obs (diverge from relying primarily on airborne field campaigns)
    • start by identifying key uncertainties/biases in climate model physics that attract wide community interest (e.g., cloud phase)
    • then develop SCM/LES tests and use of long-term obs that target the relevant cloud types & physical processes
    • NSA and AWARE AMF? extension to COMBLE AMF? ORACES+LASIC? PBL at SGP?
  – reusable elements to lower overhead on participation

• Elements
  – LES/SCM unified framework
  – open source ground-based forward simulator codes
  – use of ARM computational resources to support model-obs evaluations