THE EAM SINGLE COLUMN MODEL

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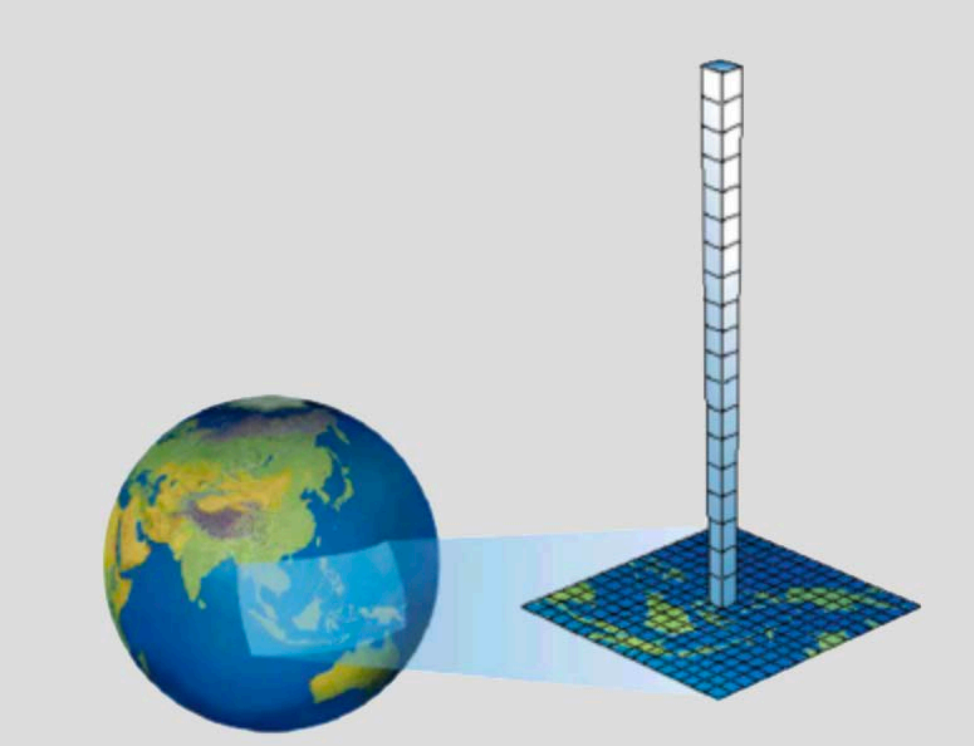
SUMMARY:

1. A fully-functional and scientifically validated SCM was included in the E3SM v1 release (available now for all E3SM scientists)
2. We have created an online library including many SCM cases and validation data
3. We are now collaborating with ARM (Shaocheng Xie + Jim Mather) to add new case studies
4. A SE-dycore version of the EAM SCM will be on master soon
5. Soon, you will be able to exactly "replay" a column from your GCM run in the SCM

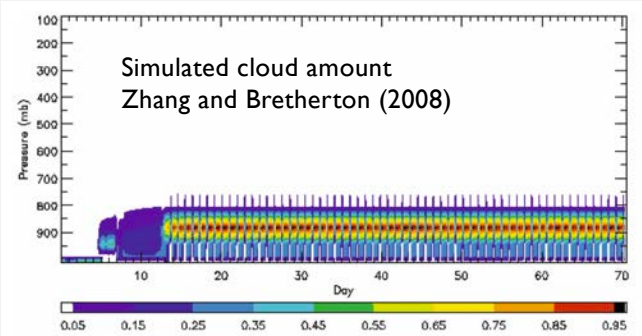
SINGLE COLUMN MODEL (SCM)

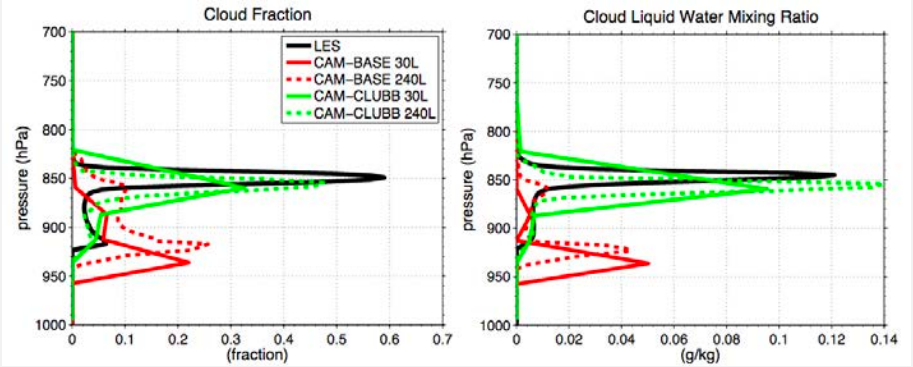
- The SCM is a mode of the EAM model where a single column of the atmosphere is run in isolation with prescribed atmospheric dynamics. Land fluxes can be prescribed or the land model can be run in this configuration
- The SCM is a very important tool for **development of model parameterizations** and can also be useful for **model assessment and tuning**
  - It allows developers to easily test a wide variety of model changes
  - Large number of SCM/GCSS/ARM cases exist that span a wide range of climate regimes



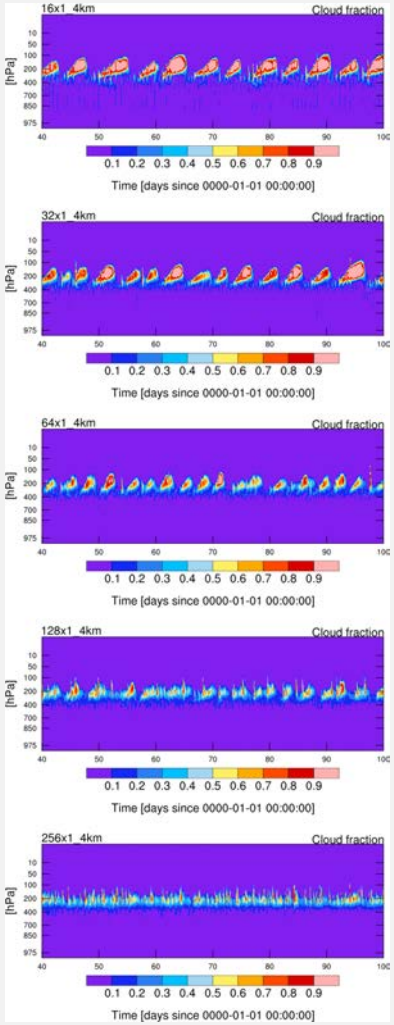
EXAMPLES OF SCM USEFULNESS

- Zhang and Bretheron (2008) used the SCM to show that cloud feedbacks in CAM3 were controlled by unphysical oscillations caused by interactions between convection and resolved-scale processes





Bogenschutz et al. (2012) used SCM to perform vertical resolution sensitivity tests with CAM with a new parameterization (CLUBB)



EXAMPLE OF E3SM SCM USEFULNESS

- Walter Hannah (LLNL) has been using the SCM for experimentation with the super-parameterized version of the E3SM
  - SCM is helping spin-up RCE initial conditions for RCEMIP. This would be a pain without the SCM, but using SCM for spinup is part of the RCEMIP protocol, so SCM is essential
  - Testing large CRM domains is suddenly super cheap! This is really helpful for the planned GPU experiments, which will require more CRM columns than we normally run in order to fill the machine use requirements
  - Continuing to add new features to the SP-E3SM as well as explore various sensitivities, and up until now progress has been slow. But the SCM is really speeding up development and testing work!

Slide courtesy Walter Hannah

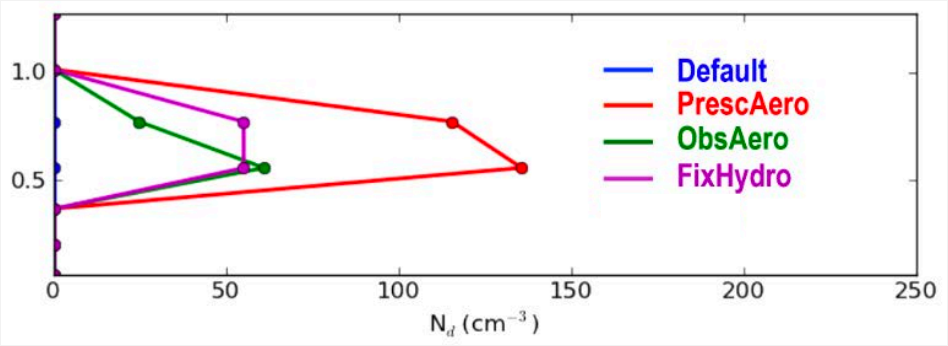
SCM WOES

- Though a useful tool, the SCM has had several shortcomings, which we have addressed or are currently addressing:
  - The SCM has received minimal support. Often times, this results in a broken version of the model, which can be time consuming to sort out. ✔
  - Scripts to run the SCM are often passed from user-to-user. Can result in improper case setups and unscientific solutions. ✔
  - With the upgrade to a modal aerosol model, aerosols by default are initialized to zero. This can significantly effect the SCM solution. ✔
  - Lack of "idealizations" required for apples-to-apples comparison with select large eddy simulation (LES) intercomparison studies. ✔
  - The EAM SCM runs with a dynamical core (Eulerian) which is not the same as the full model (Spectral Element)

✔ = task complete and incorporated into EAM SCM v1 release

E3SM SCM AEROSOL SPECIFICATION

Nd from DYCOMS-RF02 (drizzling marine stratocumulus)



From Lebassi-Habtezion and Caldwell (2014)

- E3SM SCM initializes all aerosol mass mixing ratios to zero
- This results in unrealistically low aerosol concentrations until surface emissions loft sufficient aerosol (process can take several days)
- Most GCSS boundary layer cloud cases are hours in length
- In addition, with E3SMv1 shallow convective clouds are tied to the MG microphysics
- SOLUTION: We implemented the modifications presented in Lebassi-Habtezion and Caldwell (2014)

E3SM SCM AEROSOL SPECIFICATION OPTIONS

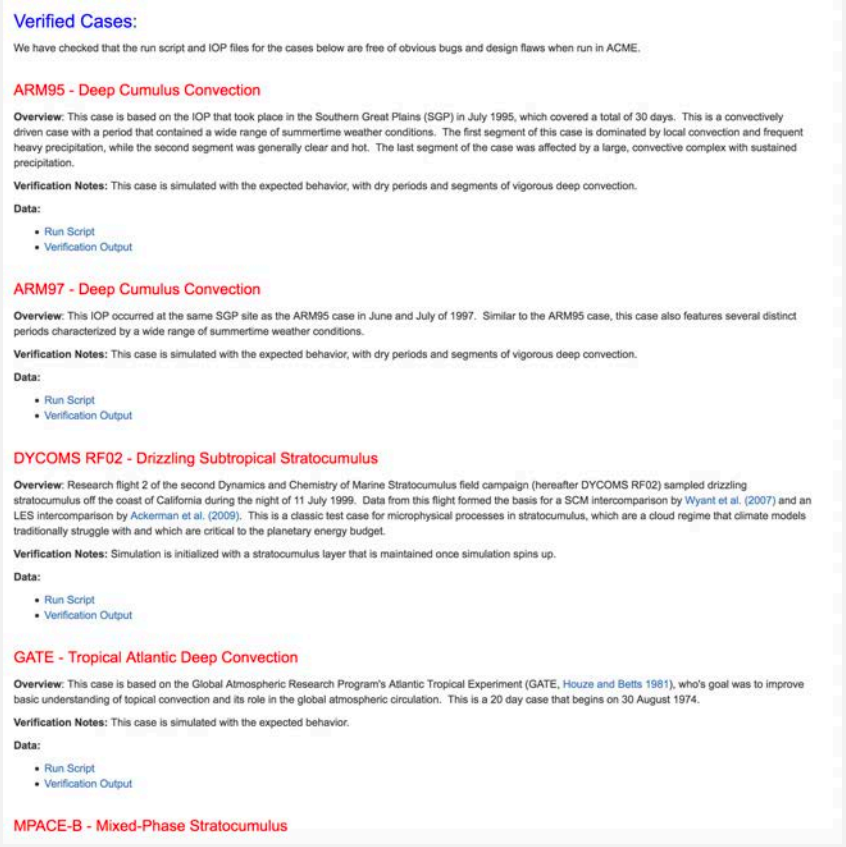
- Aerosol specification may be accomplished via one of three methods as documented in BLP2014:
  - Fix cloud-droplet (Nd) and ice crystal (Ni) number concentration
  - Prescribed aerosols
    - Prescribes mass mixing ratios of aerosol species based on climatologies
    - Derived from a long prognostic-aerosol run
  - Observed mixing ratios
    - Apply the observed mixing ratios and size distributions to the aerosols (where available)
- IT IS IMPORTANT to run with one of these three options for scientifically credible solution. EAM SCM scripts FORCES the user to run with one of these options.
- When in doubt, run with prescribed aerosols.

I WANT TO RUN THE EAM SCM!

WHAT DO I DO?!

E3SM SCM PAGE & CASE LIBRARY

- Confluence How-To page documents the SCM cases library, in addition to obtaining relevant scripts to run them
- All cases should run out-of-the-box on E3SM supported machines
- https://acme-climate.atlassian.net/wiki/display/Docs/ACME+Single-Column+Model+Case+Library
  - VERIFIED CASES: ARM95, ARM97, DYCOMS2-RF02, MPACE-B, RICO, TOGA-COARE, TWP-ICE, GATE, ARM-GCSS, ATEX, BOMEX, DYCOMS-RF01
  - UNVERIFIED CASES: SPARTICUS, RACORO
  - Working with Shaocheng Xie, Shuaiqi Tang, and Jim Mather to add many more ARM cases (ie DYNAMO, GoAmazon, LASSO, ISDAC, etc.)
- Verified Case = We have checked that the run script and IOP files for the cases below are free of obvious bugs and design flaws when run in ACME.



Verified Cases:

We have checked that the run script and IOP files for the cases below are free of obvious bugs and design flaws when run in ACME.

ARM95 - Deep Cumulus Convection

Overview: This case is based on the IOP that took place in the Southern Great Plains (SGP) in July 1995, which covered a total of 30 days. This is a convectively driven case with a period that contained a wide range of summertime weather conditions. The first segment of this case is dominated by local convection and frequent heavy precipitation, while the second segment was generally clear and hot. The last segment of the case was affected by a large, convective complex with sustained precipitation.

Verification Notes: This case is simulated with the expected behavior, with dry periods and segments of vigorous deep convection.

Data:

- Run Script
- Verification Output

ARM97 - Deep Cumulus Convection

Overview: This IOP occurred at the same SGP site as the ARM95 case in June and July of 1997. Similar to the ARM95 case, this case also features several distinct periods characterized by a wide range of summertime weather conditions.

Verification Notes: This case is simulated with the expected behavior, with dry periods and segments of vigorous deep convection.

Data:

- Run Script
- Verification Output

DYCOMS RF02 - Drizzling Subtropical Stratocumulus

Overview: Research flight 2 of the second Dynamics and Chemistry of Marine Stratocumulus field campaign (hereafter DYCOMS RF02) sampled drizzling stratocumulus off the coast of California during the night of 11 July 1999. Data from this flight formed the basis for a SCM intercomparison by Wyant et al. (2007) and an LES intercomparison by Ackerman et al. (2009). This is a classic test case for microphysical processes in stratocumulus, which are a cloud regime that climate models traditionally struggle with and which are critical to the planetary energy budget.

Verification Notes: Simulation is initialized with a stratocumulus layer that is maintained once simulation spins up.

Data:

- Run Script
- Verification Output

GATE - Tropical Atlantic Deep Convection

Overview: This case is based on the Global Atmospheric Research Program's Atlantic Tropical Experiment (GATE, Houze and Betts 1981), who's goal was to improve basic understanding of topical convection and its role in the global atmospheric circulation. This is a 20 day case that begins on 30 August 1974.

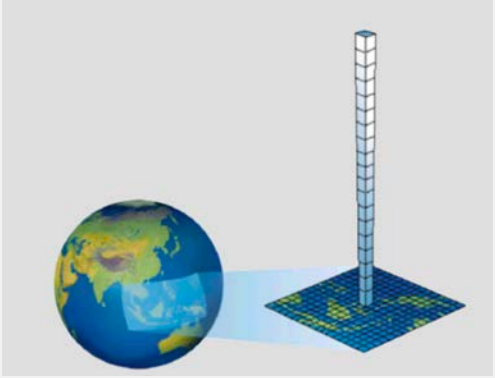
Verification Notes: This case is simulated with the expected behavior.

Data:

- Run Script
- Verification Output

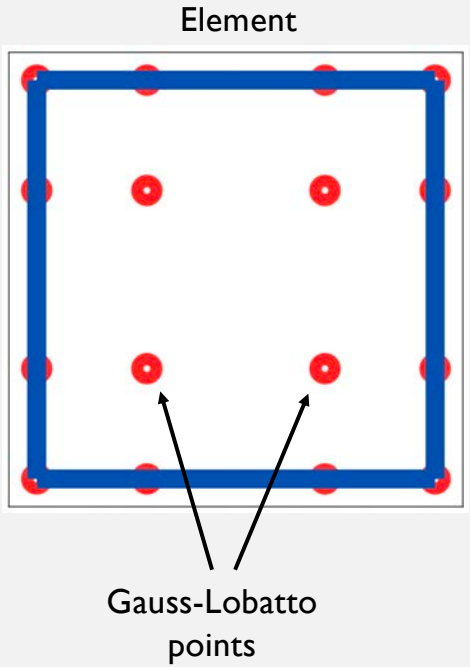
MPACE-B - Mixed-Phase Stratocumulus

SCM AND DY-CORE



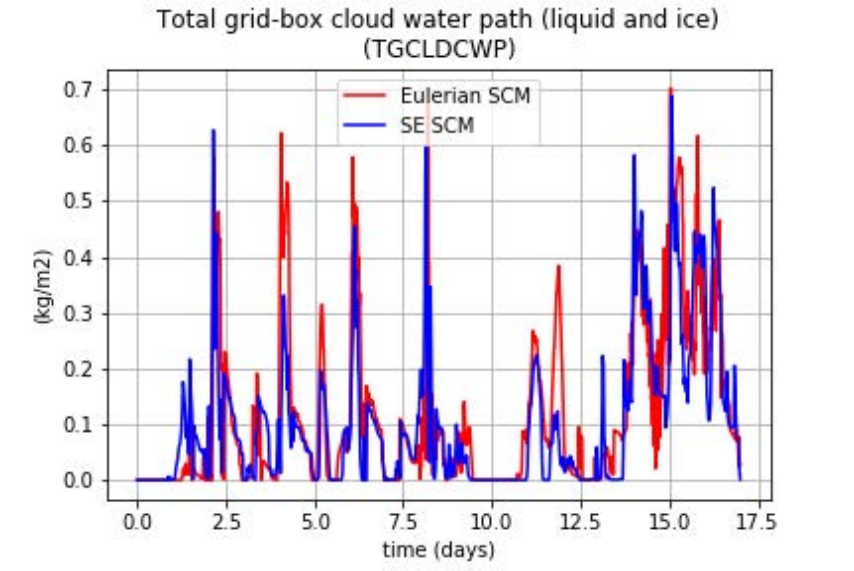
- The default E3SM and CAM SCM must be run with the Eulerian dynamical core, which is inconsistent with the dynamical core used in the full model
  - Inconsistencies with vertical advection
  - Inconsistent time stepping and numerics
  - Inconsistencies with the "replay" option
- Towards removing the ties with the Eulerian dynamical core we explored two options:
  - Enabling the SCM to run with the SE dynamical core
  - "Small planet" of several identically forced columns with forcing driven through nudging routines

SPECTRAL ELEMENT SCM



- SE infrastructure makes it impossible to initialize one column (i.e. one Gauss-Lobatto point)
- The least invasive way to get around this is to initialize the entire ne4 grid, while initializing physics grid with only one column
- The only portion of the dynamics code called is SCM forecast routine and vertical advection (one column)
- All code that is shared between SE and Eulerian SCM (i.e. IOP reading routines, forecast routine, etc.) has been put into a shared directory
- SCM routines that are dy-core specific are put into a module that can be used as a template for introducing the SCM to new dy-cores

SE SCM

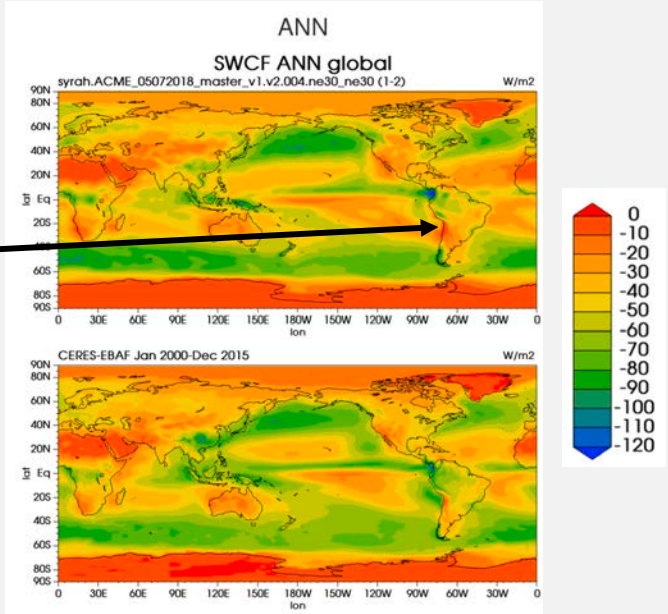


ARM97 case

- The SE E3SM SCM shows qualitatively similar to results to the Eulerian SCM
  - B4B answers will never be expected due to differences in time stepping, numerics, and vertical advection
- SE SCM uses Lagrangian vertical advection for all tracers, temperature, and mass (more consistent than Eulerian core)
- SE SCM will soon be on E3SM master for beta testing before being switched as the default SCM

THE SCM REPLAY OPTION

- The ”replay” option will allow users to reproduce a column from the full model in SCM mode
- This is a powerful tool that can be used to:
  - Diagnose model crashes
  - Investigate and improve poorly simulated features (i.e. marine Sc)
- Functionality has always been in place for CESM/E3SM SCM, but has been impractical/difficult to use since it required running the full model with the Eulerian core to generate the forcing
- Since the SCM and full model dycores will be consistent, this feature can finally be easily utilized



THE SCM REPLAY OPTION

- Full documentation and scripts will be provided on the SCM website to instruct the user how to utilize this feature:
  - Run the full model and generate appropriate forcings (controlled by switching on a configure flag)
    - These forcings can be generated over the entire globe or for a regional subdomain (the smarter choice)
    - Likely this will involve the user having to do a "branch" run, so the forcing is generated from a spun-up state
  - Use the SCM "replay" script that will be provided to select the latitude and longitude the user would like to simulate
- This feature is in the final stages of development and will appear in a PR in the coming months

WHERE ARE WE GOING?

- Working on two features to put on master:
  - Produce finalized version of E3SM SE SCM
  - Ability to extract boundary conditions from a GCM run and use it to exactly reproduce the behavior of a single column in SCM mode (a.k.a. "global-IOPs" or "replay" option)
- New cases!
  - Work with ARM scientists to include a more comprehensive case library of recent field campaigns
  - Develop a process/protocol for making adding new cases as simple as possible
- As time allows:
  - Design official SCM diagnostics package