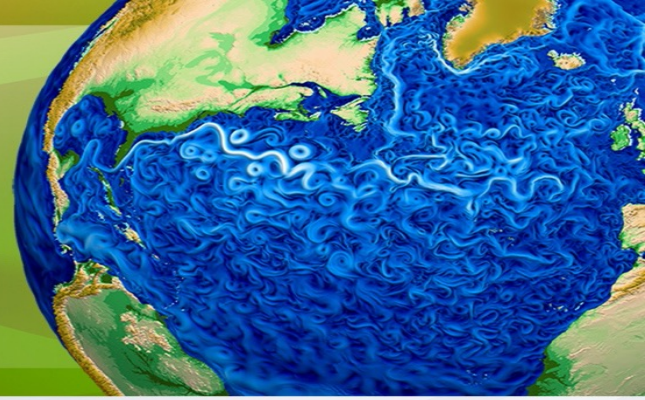

The Doubly Periodic SCREAM Configuration

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* Special thanks to: Noel Keen, Chris Terai, and Hassan Beydoun

E3SM All Hands, February 3rd, 2022

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Outline

- Introduction to Doubly-Periodic SCREAM (DP-SCREAM)
  - Motivation
  - Summary of development
  - DP-SCREAM case library
  - Availability and how to use
- An example of a scientific application of DP-SCREAM
  - Assessment of the horizontal resolution sensitivity of SCREAM

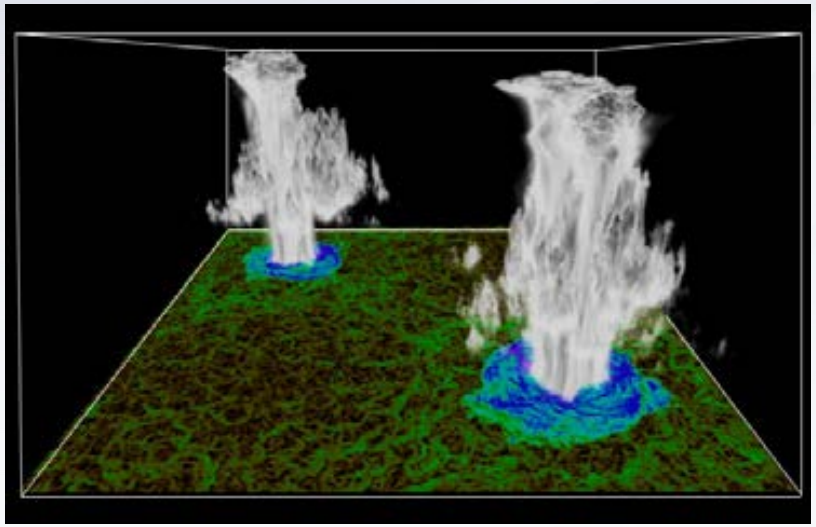


Figure courtesy Jungmin Lee

SCREAM

- SCREAM = Simple Cloud-Resolving E3SM Atmosphere Model (Caldwell et al. 2021)
- Target dx = 3 km globally, 128 vertical layers with a top at 40 km
- Contributed to DYAMOND2
- Moving to high resolution solves many long-standing problems with E3SM…

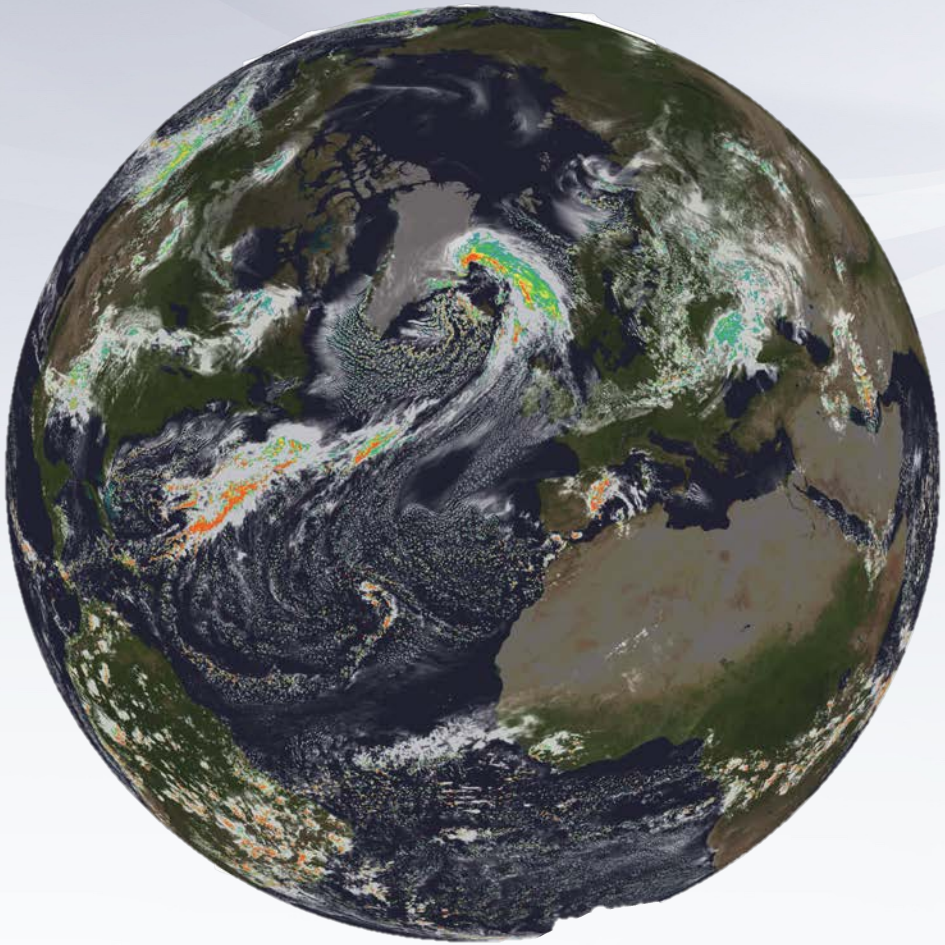
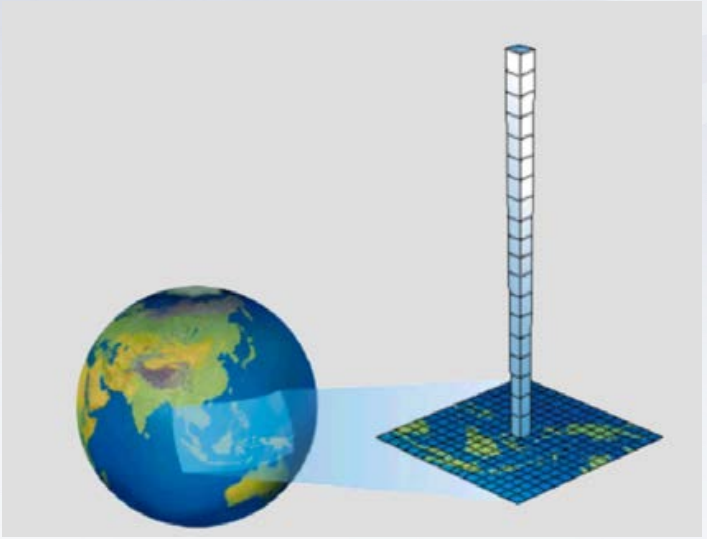


Figure courtesy Chris Terai. SCREAM DYAMOND2. White: liq+ice cloud water path. Colors: precip rate.

“Efficient Configurations” in GCMs

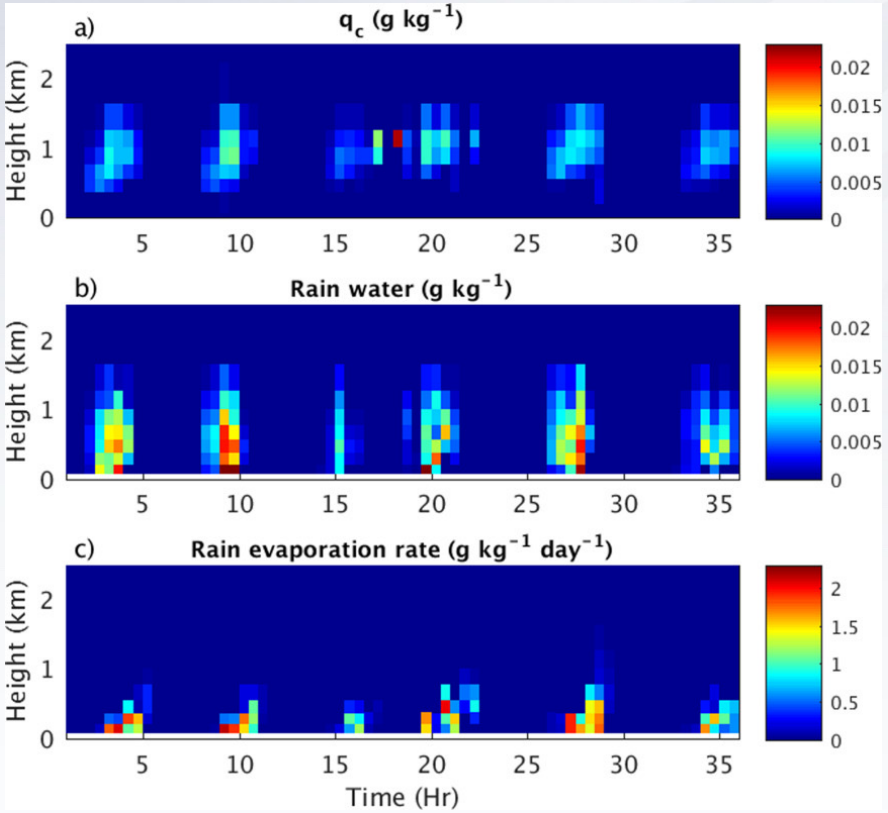
- Global cloud resolving models (GCRMs) (i.e. SCREAM) are far more computationally expensive than “conventional” ~100 km GCMs (i.e. E3SM).
- Even these relatively cheap conventional GCMs usually have a “single column model” (SCM) functionality.
- Isolates a single column on the globe (driven by “Intensive Observation Period” forcing).
- Energy Exascale Earth System Model (E3SM) SCM (Bogenschutz et al. 2020)



Depiction of traditional SCM from a conventional GCM

Single Column Models in GCMs

- Runs in a matter of minutes on a single node to enable fast feedback of GCM physics.
- SCMs insanely useful for:
  - Efficiently debugging the model.
  - Parameterization implementation/development (Bogenschutz et al. 2012; Park et al. 2014).
  - Elucidating parameterization biases/deficiencies (Zheng et al. 2017).
  - Performing perturbed parameter /ML applications.



Global Cloud Resolving Models

- SCREAM is "convection permitting", meaning that clouds/convection are resolved over several columns.
- Thus, a SCM is not valid for GCRMs.
- However, SCREAM is a wildly expensive model so an "efficient" configuration to obtain fast feedback is necessary…

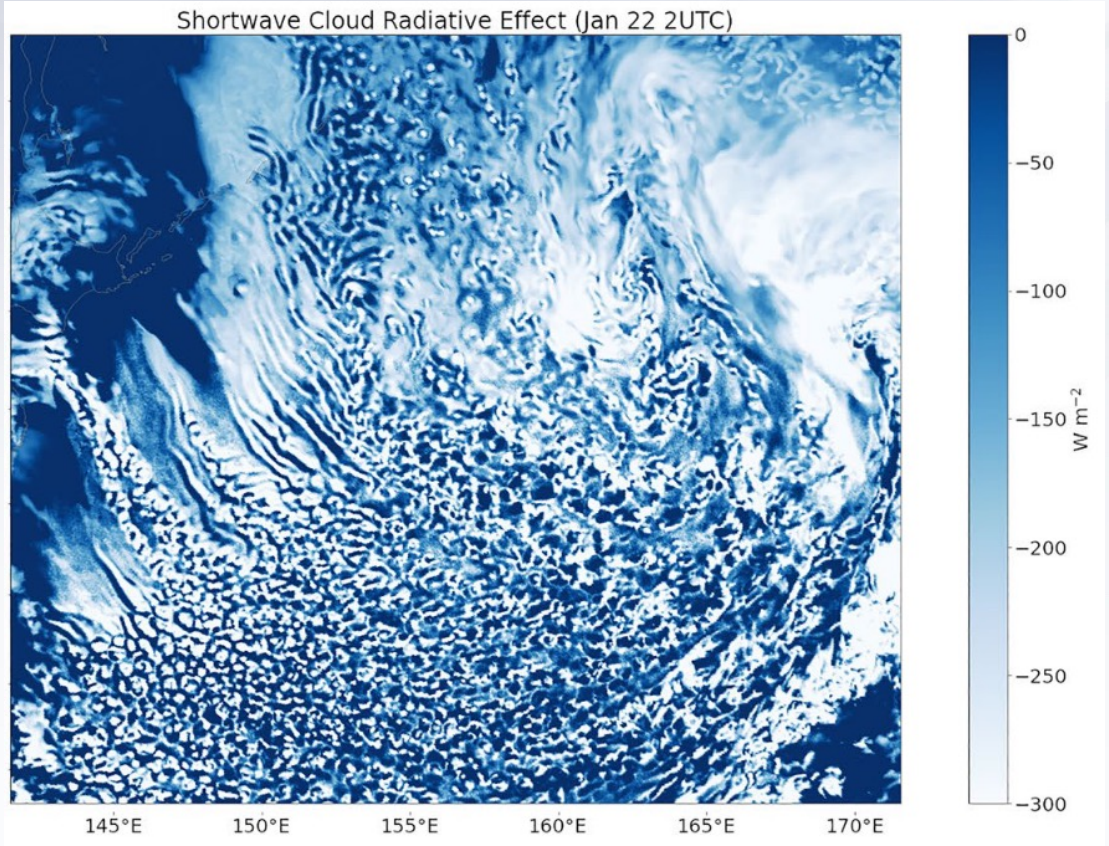
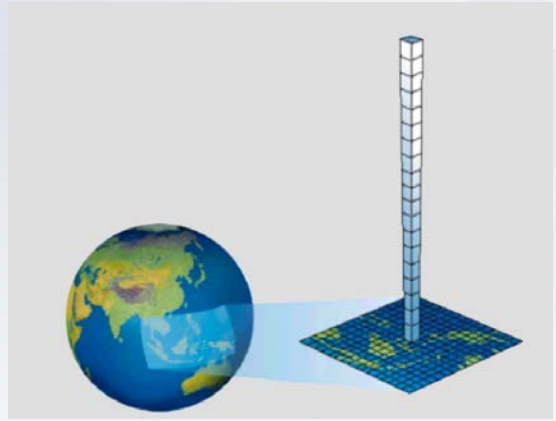


Figure from Caldwell et al. (2021)

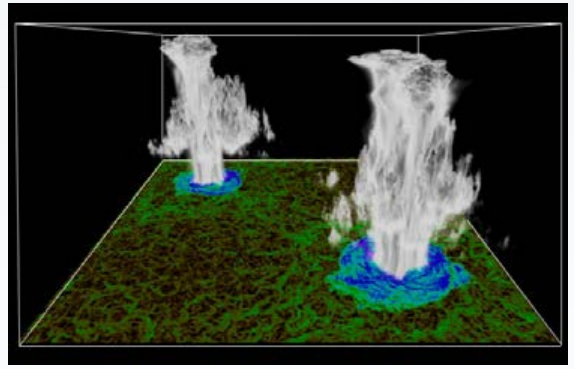
Doubly-Periodic SCREAM (DP-SCREAM)

- DP-SCREAM represents a “single-point” three-dimensional cloud resolving model.
  - Size of domain and resolution determined by user.
  - Location and surface (i.e. land/ocean; radiation) determined from lat/lon of IOP case being used and ne30 grid.
  - Initialized as a collection of identical columns on a planar grid.
  - Random temperature perturbations applied to initial condition.
  - Boundary conditions are periodic in x & y.
- DP-SCREAM is NOT a true “limited area” model.
- Unlike SCM, DP-SCREAM “exercises” the entire model (i.e. physics AND dynamics).

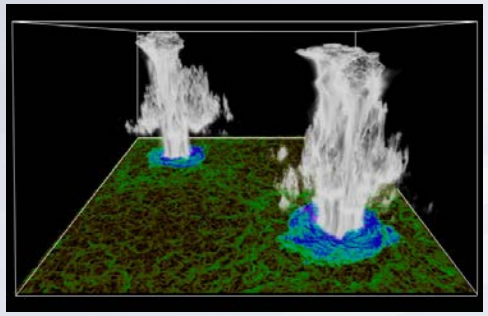
E3SM SCM view



DP-SCREAM view



DP-SCREAM Development

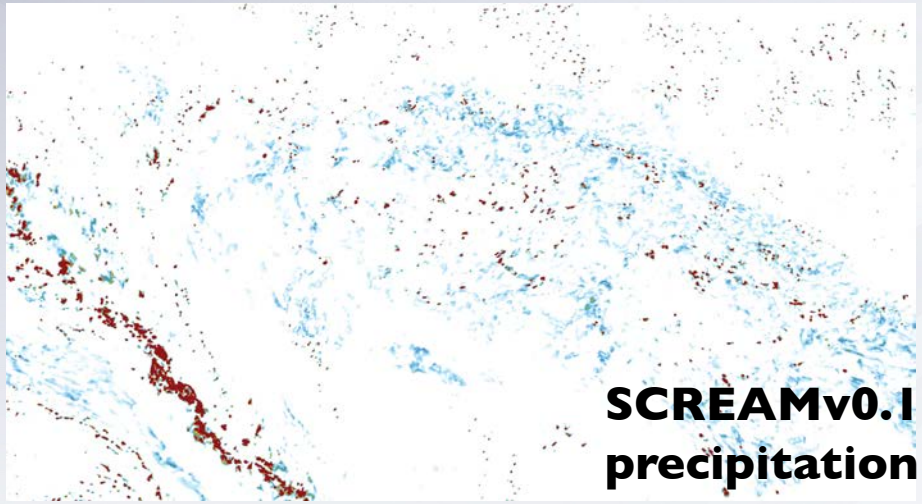


- A two-step parallel effort:
  - Infrastructure (Bogenschutz):
    - Modifications to the SCM infrastructure to enable its use across multiple columns.
    - Use the lat/lon of the desired case for the entire domain.
  - Planar HOMME (Eldred):
    - Ability to run standalone HOMME dynamical core on doubly-periodic planar grids.
    - Uses shallow water (sweqx) and hydrostatic/non-hydrostatic primitive equations (preqx and theta-l) models.
- Final step of stitching these two aspects together and providing resources to make DP-SCREAM accessible to use.

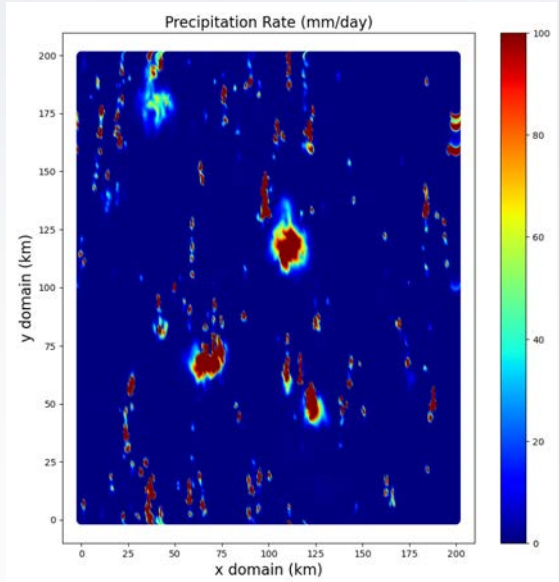
DP-SCREAM Status

- DP-SCREAM development is complete and has been in “beta” testing mode for several months.
  - DP-SCREAM currently only available in SCREAM F90
  - C++ conversion will take place in 2022
- Official F90 “release” will occur in spring 2022.
- SCREAM evaluation team uses DP-SCREAM to efficiently replicate biases we see in the global model (i.e. “popcorn convection”).

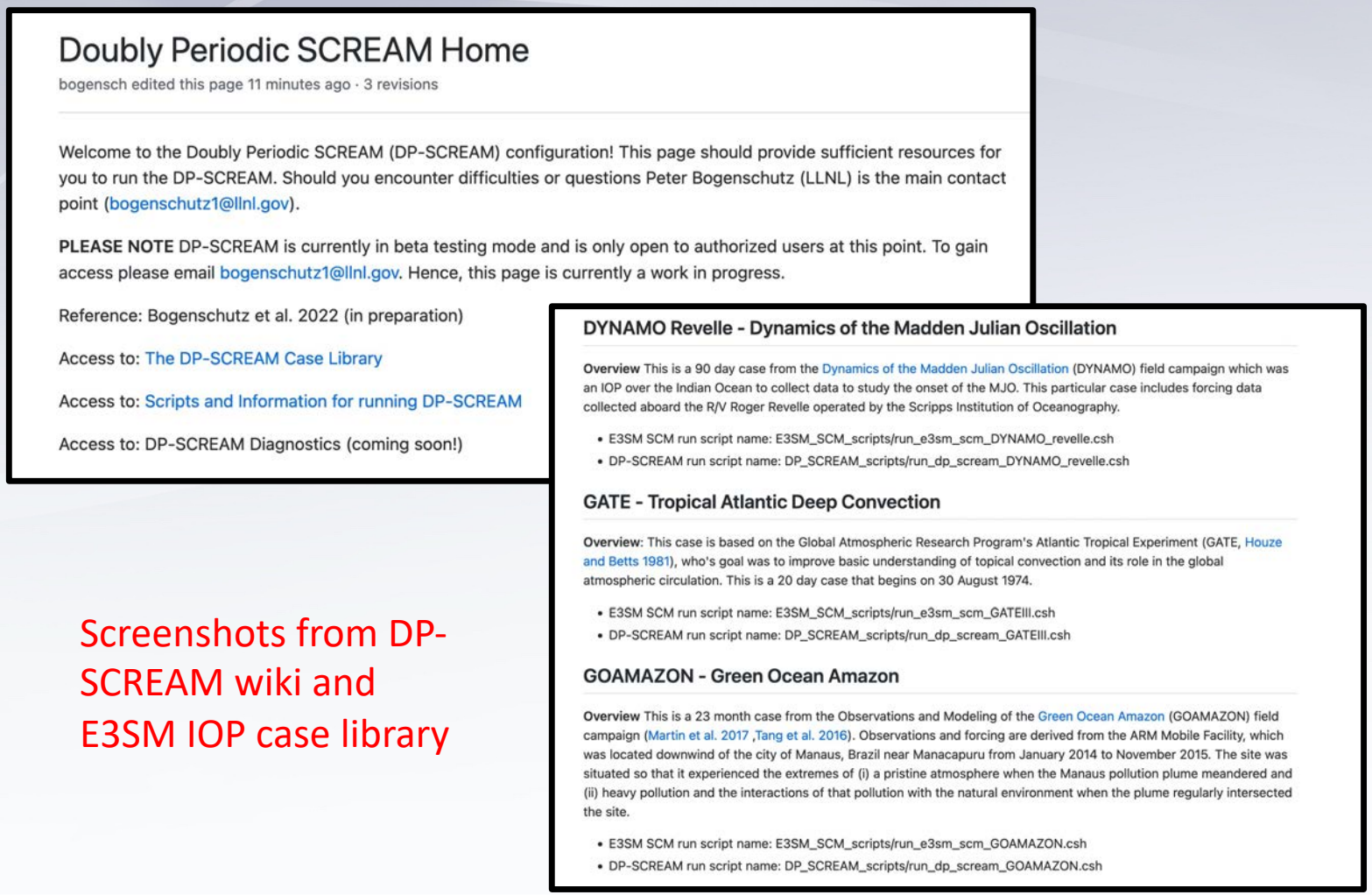
Top figure courtesy Chris Terai



DP-SCREAM



Running DP-SCREAM



Doubly Periodic SCREAM Home

bogensch edited this page 11 minutes ago · 3 revisions

Welcome to the Doubly Periodic SCREAM (DP-SCREAM) configuration! This page should provide sufficient resources for you to run the DP-SCREAM. Should you encounter difficulties or questions Peter Bogenschutz (LLNL) is the main contact point (bogenschutz1@llnl.gov).

PLEASE NOTE DP-SCREAM is currently in beta testing mode and is only open to authorized users at this point. To gain access please email bogenschutz1@llnl.gov. Hence, this page is currently a work in progress.

Reference: Bogenschutz et al. 2022 (in preparation)

Access to: The DP-SCREAM Case Library

Access to: Scripts and Information for running DP-SCREAM

Access to: DP-SCREAM Diagnostics (coming soon!)

DYNAMO Revelle - Dynamics of the Madden Julian Oscillation

Overview This is a 90 day case from the Dynamics of the Madden Julian Oscillation (DYNAMO) field campaign which was an IOP over the Indian Ocean to collect data to study the onset of the MJO. This particular case includes forcing data collected aboard the R/V Roger Revelle operated by the Scripps Institution of Oceanography.

- E3SM SCM run script name: E3SM_SCM_scripts/run_e3sm_scm_DYNAMO_revelle.csh
- DP-SCREAM run script name: DP_SCREAM_scripts/run_dp_scream_DYNAMO_revelle.csh

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.

- E3SM SCM run script name: E3SM_SCM_scripts/run_e3sm_scm_GATEIII.csh
- DP-SCREAM run script name: DP_SCREAM_scripts/run_dp_scream_GATEIII.csh

GOAMAZON - Green Ocean Amazon

Overview This is a 23 month case from the Observations and Modeling of the Green Ocean Amazon (GOAMAZON) field campaign (Martin et al. 2017 ,Tang et al. 2016). Observations and forcing are derived from the ARM Mobile Facility, which was located downwind of the city of Manaus, Brazil near Manacapuru from January 2014 to November 2015. The site was situated so that it experienced the extremes of (i) a pristine atmosphere when the Manaus pollution plume meandered and (ii) heavy pollution and the interactions of that pollution with the natural environment when the plume regularly intersected the site.

- E3SM SCM run script name: E3SM_SCM_scripts/run_e3sm_scm_GOAMAZON.csh
- DP-SCREAM run script name: DP_SCREAM_scripts/run_dp_scream_GOAMAZON.csh

Screenshots from DP-SCREAM wiki and E3SM IOP case library

To get started go to: https://github.com/E3SM-Project/scmlib/wiki/

E3SM SCM wiki on Github (publicly viewable) is now supporting both E3SM SCM and DP-SCREAM.

Includes instructions on how to run DP-SCREAM and documents the case library.

Currently we provide support for 27+ cases that will run out of the box with E3SM SCM and DP-SCREAM.

Each case has short description and run script (checked out from repo).

Running DP-SCREAM

- 1) Users need the most up-to-date SCREAM repo
- 2) Users will checkout the SCM/DP-SCREAM script repo from Github
  - Each case will have a script
  - Each case set up to run dx=dy=3.3 km by default

    User has complete freedom to modify this!

```
#!/bin/csh -fe

#########################################################################
#########################################################################
#######  Script to run SCREAM in doubly periodic (DP) mode
#######  ARM97
#######  Deep convection over ARM SGP site
#######
#######  Script Author: P. Bogenschutz (bogenschutz1@llnl.gov)

########################################################
#######  BEGIN USER DEFINED SETTINGS

  # Set the name of your case here
  setenv casename scream_dp_ARM97

  # Set the case directory here
  setenv casedirectory /p/lustre2/bogensch/ACME_simulations

  # Directory where code lives
  setenv code_dir /g/g19/bogensch/code

  # Code tag name
  setenv code_tag SCREAM_DP

  # Name of machine you are running on (i.e. cori, anvil, etc)
  setenv machine quartz

  # Name of project to run on, if submitting to queue
  setenv projectname cbronze


  # Set to debug queue?
  # - Some cases are small enough to run on debug queues
  # - Setting to true only supported for NERSC and Livermore Computing,
  #   else user will need to modify script to submit to debug queue
  setenv debug_queue false

  # Set number of processors to use
  set num_procs = 256

  # set walltime
  set walltime = '05:00:00'

  ## SET DOMAIN SIZE AND RESOLUTION:
  # - Note that these scripts are set to run with dx=dy=3.33 km
  # which is the default SCREAM resolution.

  # To estimate dx (analogous for dy):
  # dx = domain_size_x / (num_ne_x * 3)
  # (there are 3x3 unique columns per element, hence the "3" factor)

  # Set number of elements in the x&y directions
  set num_ne_x = 20
  set num_ne_y = 20

  # Set domain length [m] in x&y direction
  set domain_size_x = 200000
  set domain_size_y = 200000

  # BELOW SETS RESOLUTION DEPENDENT SETTINGS
  # (Note that all default values below are appropriate for dx=dy=3.33 km and do not
  #  need to be modified if you are not changing the resolution)
```

User/machine specific information

Processor and wall time settings

Setting domain and resolution

What kind of cases can I run?!

Continuous forcing:
- **ARM SGP** site from 2004-2015
- **Darwin**, Australia: summer seasons 2004-2007
- **GOAMAZON**: 2014-2015

Deep Convection Cases:
- **GATE, GATE-IDEAL, TOGA-COARE, DYNAMO (AMIE, Revelle, North Sounding), TWP-ICE** (maritime deep convection)
- **ARM97, ARM95, MC3E** (continental deep convection)
- **LBA** (shallow to deep transition, continental)
- **SPARTICUS** (cirrus cloud)
- **Radiative Convective Equilibrium (RCE)**

Boundary Layer Cases:
- **DYCOMS-RF01 and RF02** (marine Sc)
- **BOMEX and RICO** (marine trade Cu)
- **ATEX** (Cu under Sc)
- **ARM shallow Cu** (continental Cu)
- **RACORO** (continental low clouds)
- **MPACE, MPACE-B, ISDAC** (mixed phase arctic clouds)
- **GABLS** (stable boundary layer)

Coming Soon:
- Cold air outbreak (COMBLE)
- Southern ocean clouds (SOCRATES)
- Others needed? Let me know!

*Case contributors: Shuaiqi Tang, Shaocheng Xie, Cheng Tao, Yunyan Zhang, Peter Bogenschutz

Rapid Feedback by DP-SCREAM

- Cost of a boundary layer cloud case
  - 50 km x 50 km horizontal domain size
    - At dx=dy=3.3 km to run for one simulated day: 4 minutes on ONE node
    - Compared to E3SM SCM cost of: 2 minutes on ONE node

- Cost of a deep convection case
  - Generally requires larger domain size (200 km x 200 km)
    - At dx=dy=3.3 km to run for one simulated day: 4 minutes on 6 nodes

- Cost of one simulated day of SCREAMv0:
  - One simulated day: ~ 5 hours on 1536 nodes

*machine used is cori-knl for all timings

DP-SCREAM Scientific Application

- DP-SCREAM allows the user to determine the domain size and resolution on the fly
  - Changing resolution in global models requires time consuming generation of many input files
- Thus, we can use DP-SCREAM to assess the horizontal resolution sensitivity of SCREAM
  - Is SCREAM scale aware (i.e. is it theoretically valid to run SCREAM at resolutions other than ~3 km)?
  - Is SCREAM scale insensitive (i.e. does the answer change when resolution changes)?

DP-SCREAM Horizontal Resolution Experiments

CASE	Regime	Run Duration	Horizontal domain size
GATE	Deep Cu	20 d	200 x 200 km
ARM97	Deep Cu	8 d	200 x 200 km
DYCOMS-RF01	Marine Sc	6 hr	50 x 50 km
MPACE-B	Mixed-phase	12 hr	50 x 50 km
RICO	Shallow Cu	24 hr	50 x 50 km

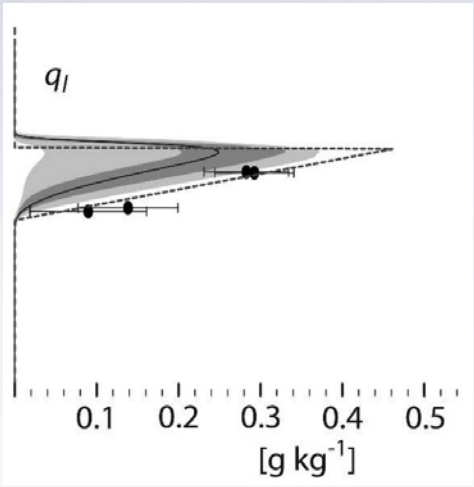
* In the interest of time, will focus on results from DYCOMS-RF01 and ARM97 today

RED cases run with dx = dy = 500 m, 1.5 km, 3 km, 5 km
GREEN cases run with dx = dy = 100 m, 500 m, 1.5 km, 3 km, 5 km

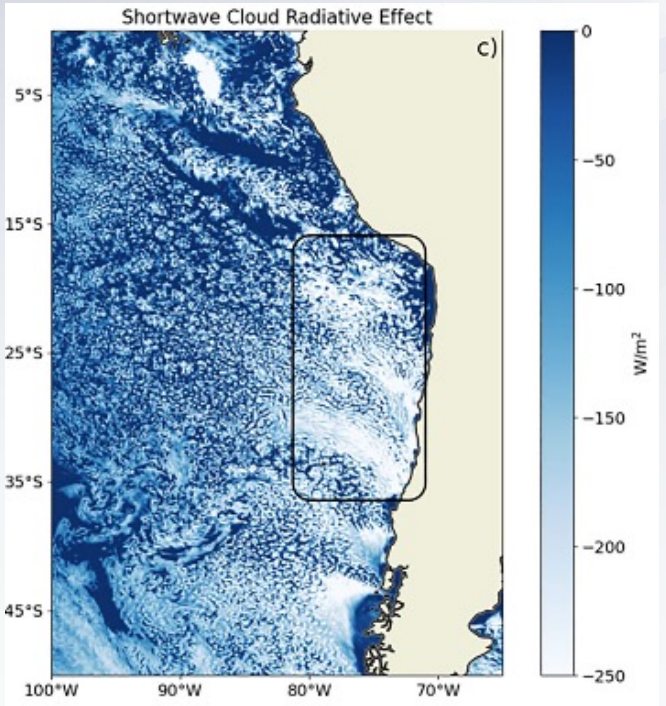
All cases and resolutions are all run with the **EXACT SAME** code and tunable parameters.

Marine Stratocumulus Case

- DYCOMS-RF01: Marine stratocumulus capped by a particularly strong inversion.
- LES intercomparison: Stevens et al. (2005)
- SCREAMv0 does a particularly good job with marine Sc.
  - These clouds are primarily SGS at 3km
- What about when resolution changes?

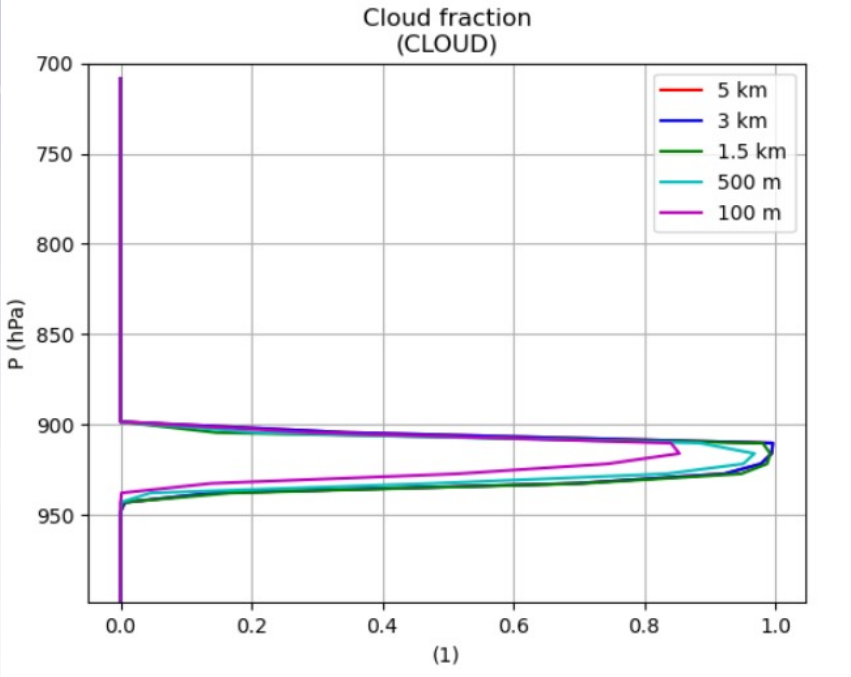


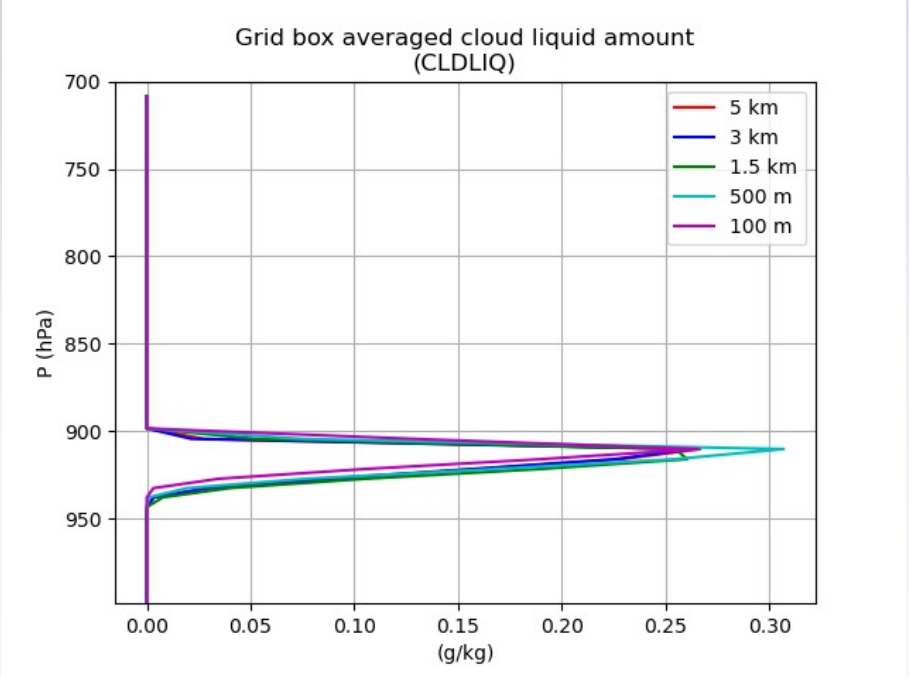
Stevens et al. (2005) LES intercomparison

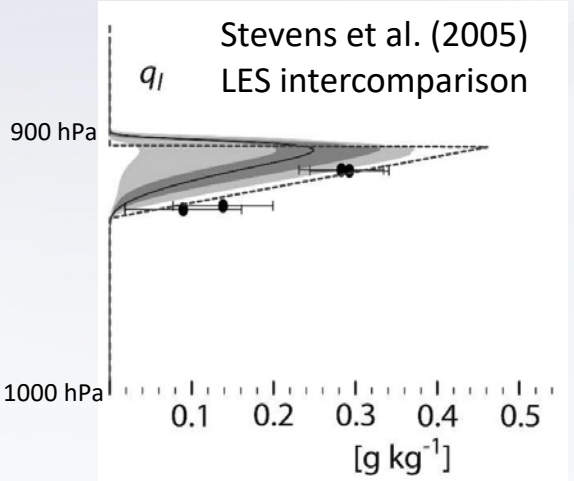


SCREAMv0 (Caldwell et al. 2021)

DYCOMS-RF01: Marine Stratocumulus
Example of Scale Sensitivity

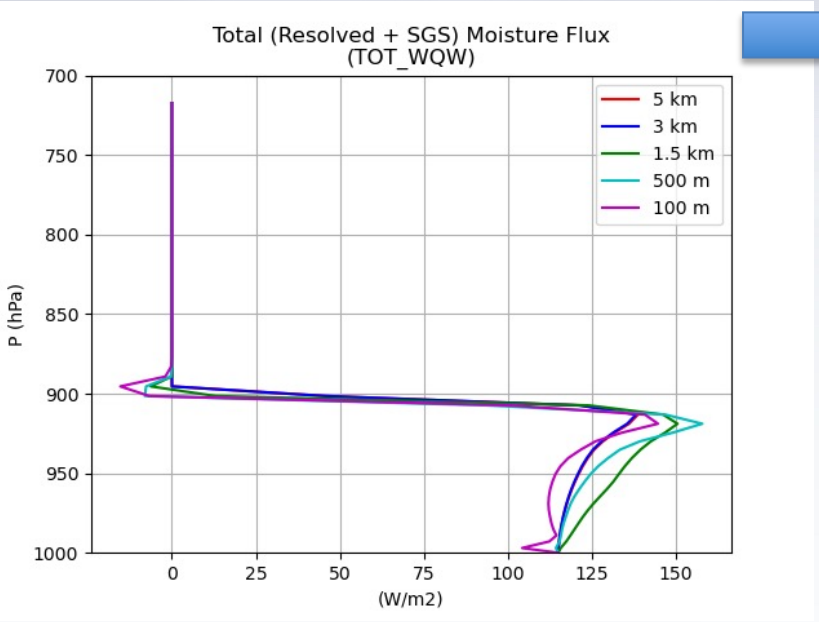






Running with SCREAM's 128 vertical layers, which is still considered too coarse for marine Sc clouds (Bogenschutz et al. 2021; Lee et al. 2021).

DYCOMS-RF01: Turbulence Across Scales
Example of Scale Awareness



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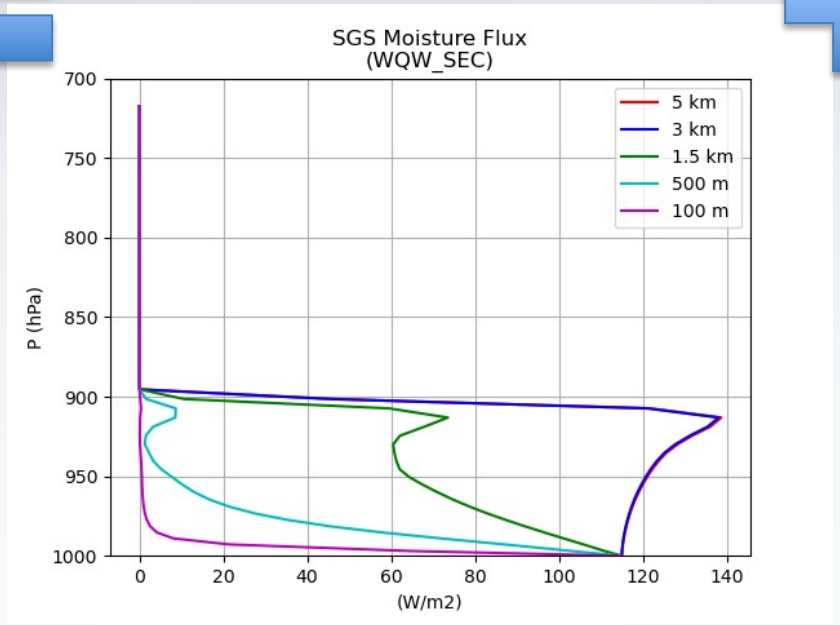
Parameterized from SHOC



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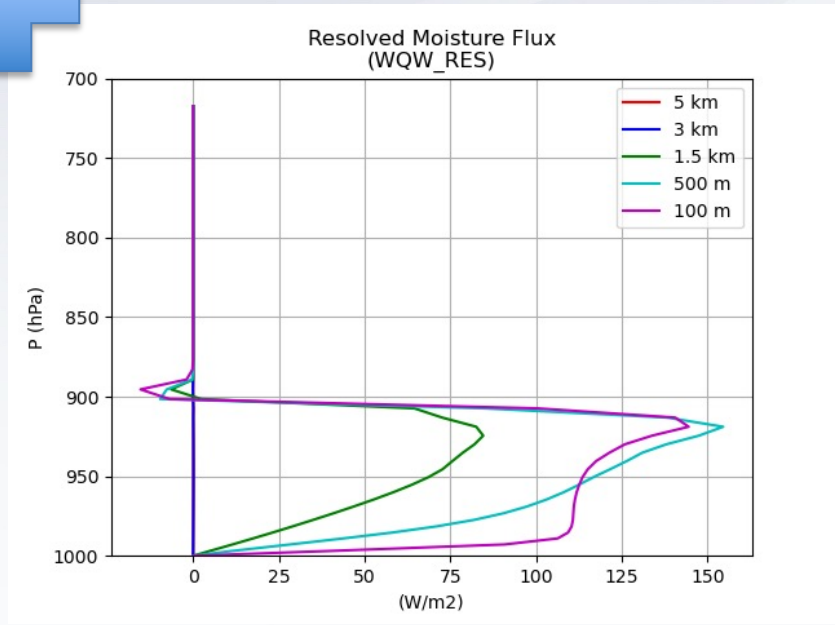
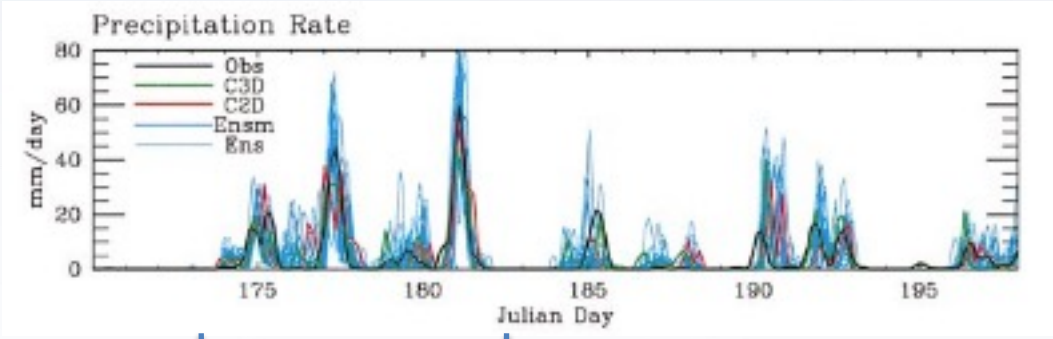
Resolved by dynamics



Continental Deep Convective Case

- ARM97 case
- Deep convection over land as observed at the ARM Southern Great Plains (SGP) Site
- 27 day case widely used for SCMs and CRMs
- Here we focus on an 8 day subset from an active period
- Run with prescribed surface fluxes (could be interactive)

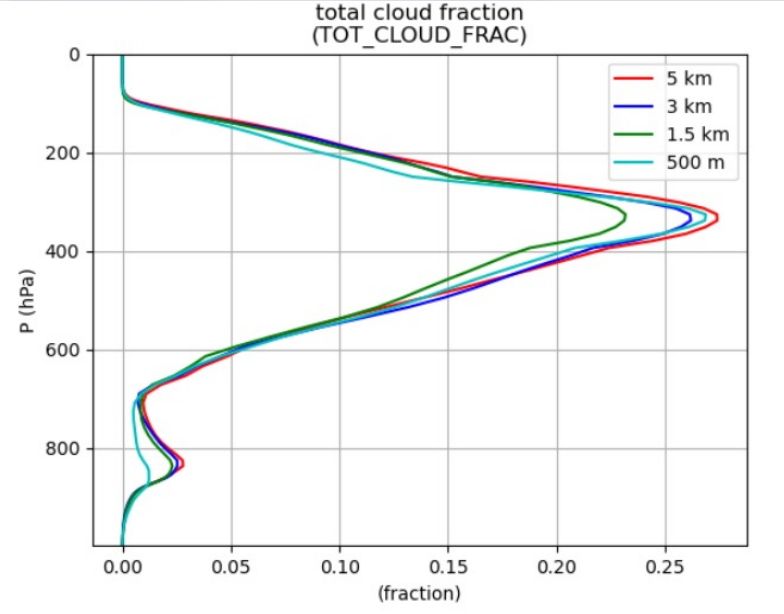


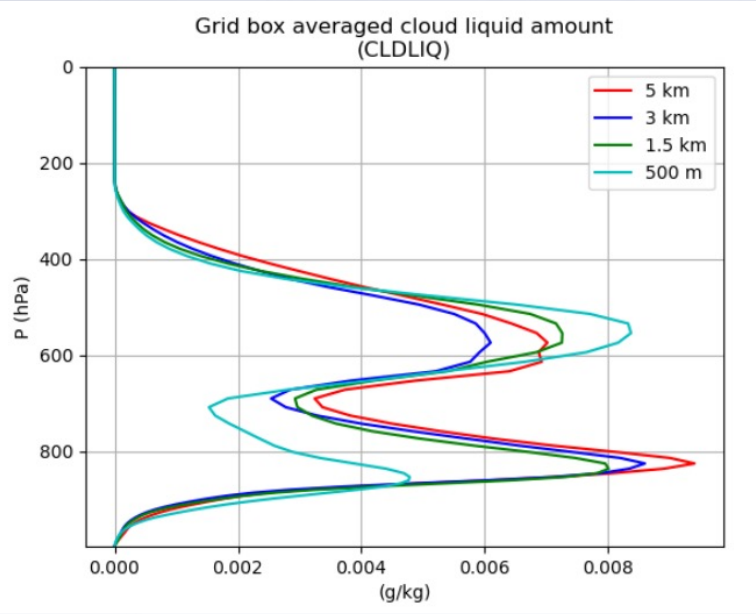
Khairoutdinov and Randall (2003)

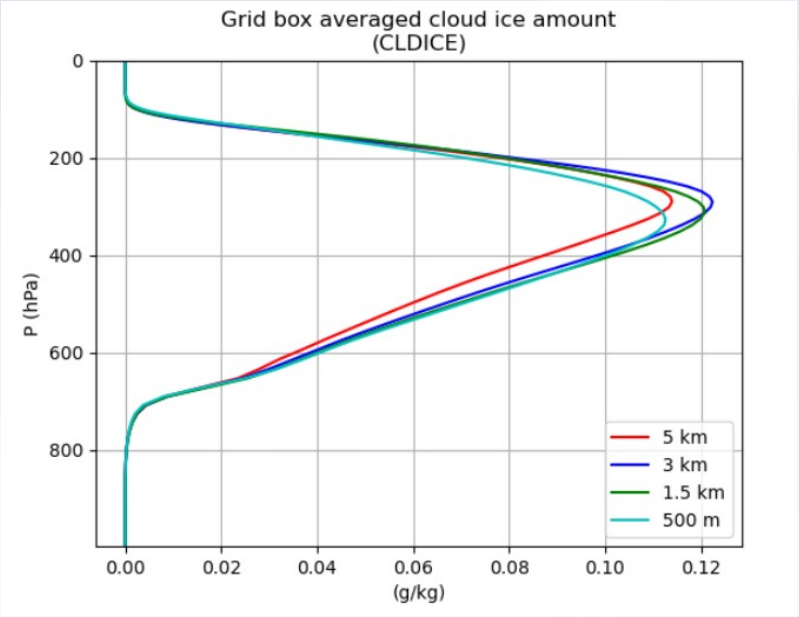
Period of focus

ARM97: Continental Deep Convection

Cloud Profiles

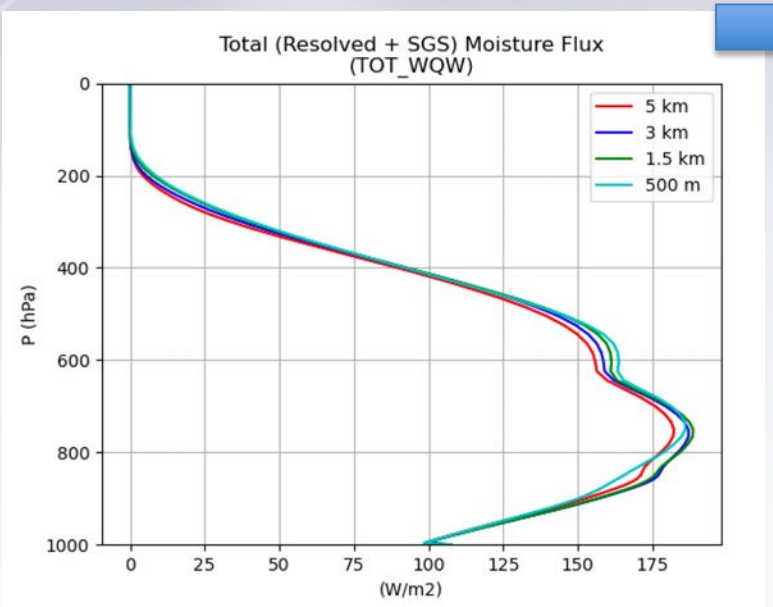




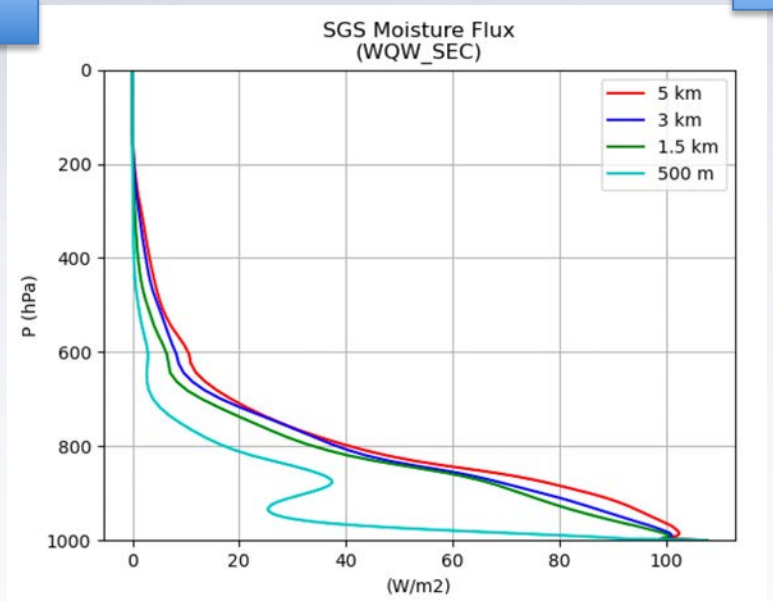


Result averaged from an 8-day active period starting on June 23, 1997

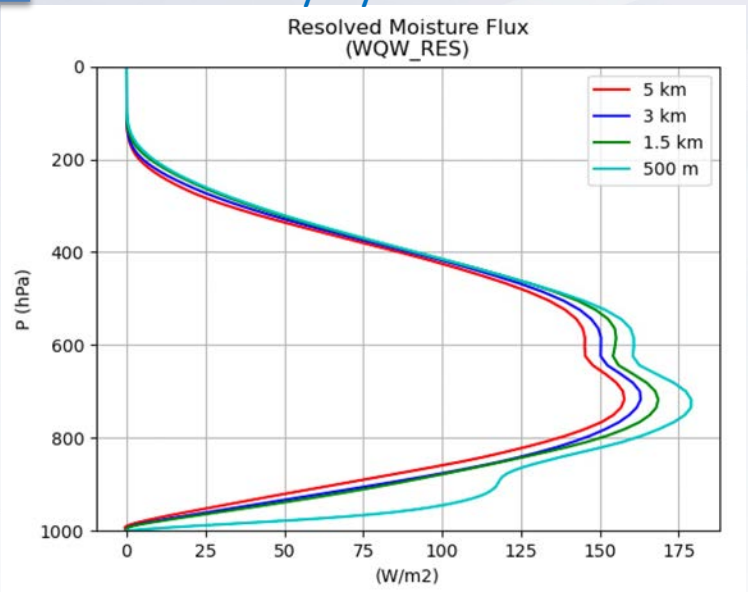
ARM97: Continental Deep Convection



Parameterized from SHOC



Resolved by dynamics



Result averaged from an 8-day active period starting on June 23, 1997

Summary

- DP-SCREAM represents an “efficient” configuration of SCREAM that can be used for model development, debugging, and analysis.
- Using DP-SCREAM we determine that SCREAM is a scale aware model
  - We can run SCREAM at fine resolutions without the need of making structural changes (or “swapping” out parameterization).
- SCREAM is reasonably scale insensitive at the kilometer scale, but exhibits sensitivity outside of these bounds
  - Tuning may be required for very high resolution runs.