Overview of the CESM2/CESM2.1 Simpler Model Framework

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In collaboration with the Simpler Model Initiative by Lorenzo Polvani (Columbia U.), Amy Clement & James Benedict (U. Miami)
A comprehensive simulation-to-science infrastructure that tackles the needs of next-generation, high-resolution, data intensive climate modeling activities.

CESM Simpler Model Webpage (in development)

http://www.cesm.ucar.edu/models/simpler-models/

Simpler Models

This webpage documents simpler model configurations that are released and supported by the CESM project. As part of CESM2.0, several dynamical core and aquaplanet configurations have been made available. The documentation on these web pages provides information on how to use these configurations and applies to CESM2.0 or later releases. In order to make use of these configurations, users must download CESM2.0 or subsequent releases and guidance on doing that can be found here.

For questions about the aquaplanet configuration, please contact Brian Medeiros (brianpm@ucar.edu) and for questions about the dry dynamical core configuration, please contact Isla Simpson (islas@ucar.edu). If you would like to contribute to the development of other configurations, please contact Lorenzo Polvani (Imp@columbia.edu) or Amy Clement (aclement@rsmas.miami.edu).

Currently available simpler models

Atmosphere (CAM)

- Dry Dynamical Core
- Aquaplanet
- Moist baroclinic wave with Kessler microphysics
- Toy Terminator Chemistry

In development simpler models

Atmosphere (CAM)

- Moist Held-Suarez
- Single Column Atmospheric Model

Newly available with CESM2.0 and CESM2.1

CESM Project

CESM is a fully-coupled, community, global climate model that provides state-of-the-art computer simulations of the Earth’s past, present, and future climate states.

CESM is sponsored by the National Science Foundation (NSF) and the U.S. Department of Energy (DOE). Administration of the CESM is maintained by the Climate and Global Dynamics Laboratory (CGD) at the National Center for Atmospheric Research (NCAR).
Background: Simpler Model Stakeholders

Traditionally, there have been two different communities

Model Development Community
- Primarily interested in inter-comparisons and the design aspects of weather and climate models

User Community
- Primarily interested in the general circulation (climate) of the atmosphere

Examples:
- Dynamical Core Model Intercomparison Project (DCMIP)
- Aqua-Planet Experiment (APE)
- Held-Suarez test (original intent)

Both approaches also serve as teaching tools
Simpler Models & Model Hierarchies

- Over the last 15 years there has been increased recognition (including a Model Hierarchies Workshop at GFDL in 2016) that a model hierarchy promotes our understanding of model designs and the general circulation of the atmosphere.

- Example publications include:
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Model Hierarchies

- **Isolated Dynamics:**
  - Deterministic dry dynamical core tests

- **Isolated Physics:**
  - Single Column Modeling

- Deterministic moist dynamical core tests

- **Dry dynamical core (climate)**

- **Models with simplified physics (climate)**

- **Radiative Convective Equilibrium (RCE) Models**

- **Full-physics Aqua Planet Models**

- **Atmosphere models with prescribed ocean/ice data (AMIP, CAPT)**

- **Coupled Earth System Models**
In-Depth Look at Model Hierarchies

- **Isolated Dynamics:** Deterministic dry dynamical core tests
- **Isolated Physics:** Single Column Modeling (NCAR contact: Andrew Gettelman and John Truesdale)
- **Deterministic moist dynamical core tests**
- **Dry dynamical core (climate)**
- **Models with simplified physics (climate)**
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**CESM configuration:** --compset FSCAM
A Closer Look at the Pyramid: Deterministic Dry Dynamical Core Hierarchy

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DCMIP-2012 tests with optional reduced-size Earth

Analytic initial conditions are implemented for JW06 and UMJS14

CESM configuration:
Adiabatic: --compset FADIAB
P04: --compset FDABIP04

Dry dycore

Nonrotating planet

Rotating planet

Topography

No topography

Mountain wave tests

Advection tests

Gravity waves

Fixed dissipation

Scaled dissipation

JW06 baroclinic wave

UMJS14 baroclinic wave

P04 baroclinic wave (EUL)

optional toy chemistry

optional deep-atmosphere

dcimip
Snapshots of the dry UMJS14 baroclinic wave

Surface pressure at day 10 ($\Delta x=110$ km): overall patterns similar, details differ

- Some Gibb’s ringing in E3SM (ACME)
- Some grid imprinting (wave 4 and wave 5 signals) in CSU_LZ, DYNAMICO, FV3, ICON, NICAM, apparent in the Southern Hemispheres

Examples from DCMIP-2016

Design Considerations: Simplified Moist Physics

Large-scale condensation or Kessler-type warm rain

PBL Mixing of pot. T, q, u, v

Surface fluxes of sensible & latent heat, and momentum

Simple-Physics (Reed and Jablonowski, 2012; Klemp et al., 2015)
A Closer Look at the Pyramid: Simplified Moist Dynamical Cores (deterministic)

- **Moist dycore**
  - Precipitation only: Kessler physics
  - Precipitation (large-scale condensation), PBL mixing and surface fluxes

CESM configuration: --compset FKESSLER

- **Moist UMJS14 baroclinic wave (DCMIP-2016 configuration with analytic initial data)**
  - Supercell (on a small planet)

Today: Use IC data files

- **CESM configuration:** --compset FTJ16 but with modifications

- **Moist JW06 baroclinic wave (DCMIP-2012 configuration, analytic IC)**

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Precipitation rates at day 10 ($\Delta x=110$ km): overall patterns similar, details differ

- At day 10 precipitation bands become very narrow, tend to break up in some models (with very strong grid-point scale precipitation)
- Differing levels of ‘noise’ and diffusion
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**In-Depth Look at Model Hierarchies**

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  - Dry dynamical core (climate)
  - Models with simplified physics (climate)
  - Radiative Convective Equilibrium (RCE) Models
- **Isolated Physics:**
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A Closer Look at the Pyramid: Dry Dynamical Core (Climate) Hierarchy

 CESM configuration: --compset FHS94

Based on Held-Suarez (1994) forcing

Boer and Denis (1997) forcing

Dry dycore

with stratospheric modifications

Original Held and Suarez (1994) test

Held-Suarez test with topography

Williamson et al. (1998)

Polvani and Kushner (2002)

Jucker (2016)

Gerber and Polvani (2009), Gerber (2012)

Available, but requires code changes described here:
http://www.cesm.ucar.edu/models/simpler-models/changetrefana.html

optional topography

optional Age-of-Air tracers
Examples of Held-Suarez simulations with high top

Intercomparisons of the monthly-mean zonal-mean zonal wind of four CAM dynamical cores with 200 km grid spacing, 55 levels and a model top at 0.1 hPa

Exposes QBO-like oscillations in the stratosphere

Zonal-mean monthly-mean zonal wind

Examples of Held-Suarez simulations with stratospheric modifications by Williamson et al. (1998)

Exposes Sudden Stratospheric Warming (SSW) signals in CAM-SLD

Time series of the potential vorticity on the 840K isentrope shows break up of the polar vortex (SSW) at the North Pole

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A Closer Look at the Pyramid: Simplified Moist Models (Climate) Hierarchy

Moist dycore with large-scale precipitation, PBL mixing, and surface fluxes

CESM configuration: --compset FTJ16

Prescribed SST

Thatcher and Jablonowski (2016): moist version of the Held-Suarez test

Frierson et al. (2006)

O’Gorman and Schneider (2008)

Merlis et al. (2013)

Gray radiation

modified Frierson et al. (2006) with SBM convection

Complex radiation

modified Merlis et al. (2013)

simplified Betts-Miller (SBM) convection scheme (Frierson 2007) can be added

with prescribed ocean heat fluxes and SBM convection

Jucker and Gerber (2017)
Comparison of TJ16 (‘moist Held-Suarez’) and Aqua-Planet

CAM5-SE 1° L30: Moist Held-Suarez mimics Aqua-Planet simulations

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CAM5-SE 1° L30: Moist Held-Suarez mimics Aqua-Planet simulations

Moist Held-Suarez(TJ16) vs. Aqua-Planet with complex CAM5 physics

Specific humidity

Less efficient upward moisture transport in PBL, but distributions are similar

Relative Humidity

Lack of deep convection leads to dryer areas near the tropopause
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**In-Depth Look at Model Hierarchies**

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Examples of RCE simulations with CAM5-SE

RCE Hierarchy

RCE setup

Prescribed STT  Slab ocean (SOM)

RCE setup includes:
no rotation, fixed insulation, full-physics package, water-covered Earth (aqua-planet)


Fig. 1. Monthly-averaged (left) cloud fraction (contours) and lowermost-model-level winds (vectors) and (right) total precipitation for the RCE simulations for a randomly selected month. Results are shown for each resolution and surface boundary condition (see labels).
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**A Closer Look at the Pyramid: Aqua-Planet Hierarchy (Climate)**

- **Aqua-planet configuration (full physics)**
  - Prescribed SSTs
    - QOBS SST
    - Other prescribed aqua-planet SSTs
  - Slab ocean

- CESM configurations:
  - --compset QPC4
  - --compset QPC5
  - --compset QPC6

- Neale and Hoskins (2000)

- CAM4 physics
- CAM5 physics
- CAM6 physics

- CAM4 physics
- CAM5 physics
- CAM6 physics

- CESM configurations:
  - --compset QSC4
  - --compset QSC5
  - --compset QSC6
CESM2/CESM2.1 Simpler Model Status

• The currently available idealized (simpler) model configurations can be run out-of-the-box via the create_newcase (compset) and xmlchange commands.

• Several analytic initial conditions are available via namelist settings for e.g. dry and moist dynamical core tests:
  - `analytic_ic_type = 'dry_baroclinic_wave_dcmip2016'`
  - `analytic_ic_type = 'moist_baroclinic_wave_dcmip2016'`
  - `analytic_ic_type = 'dry_baroclinic_wave_jw2006'`
  - `analytic_ic_type = 'held_suarez_1994'`

• Alternatively: Initial conditions can also be read from an initial data file (relevant for many other adiabatic tests).

• Several setups are currently in progress: simplified-physics gray-radiation, RCE.
Conclusions

• Efforts are under way to build up a CAM Simpler Model Framework that supports the broader community
• Supports the standardization of the model configurations
• Framework supports (1) model intercomparisons with CAM dycores and various CAM physics packages, (2) investigation of the general circulation, and (3) education (Simpler Models are a teaching tool)
• The idea is that the available idealized (simpler) model configurations can be run either out-of-the-box or with a few added settings (e.g. via the namelist or xmlchange)
• The Simpler Model webpage documentation will soon be updated to reflect the current status
• As demonstrated the Simpler Model Framework only captures fragments of the possible model hierarchies (indicated by the compsets names in the presentation)
• Up for discussions: Which additions to the framework are desired by the community? Which ones are useful?
All References (1)


All References (2)


All References (3)


All References (4)


All References (5)


DCMIP-2016 project page and documentation of the DCMIP-2016 test cases: https://www.earthsystemcog.org/projects/dcmip-2016/testcases

DCMIP-2012 test cases (including the moist JW06 baroclinic wave & other dycore tests): https://www.earthsystemcog.org/projects/dcmip-2012/test_cases